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Amine selective coloration with chromoacerands

Soichi Misumi

The Institute of Scientific and industrial Research, Osaka University, Mihogaoka 8-1, Ibaraki, Osaka 567, Japan

Abstract-Amine selective complexation of some azophenol-dyed crowns with concurrent coloration and molecular structures of two sec. amine-dyed crown complexes are reported as well as selective colorations of enantiomeric amines with chiral azophenol crowns and of diamines with bisazophenol crown.

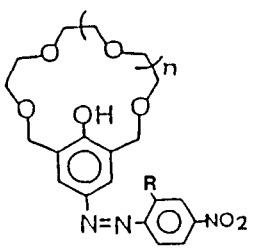
INTRODUCTION

A variety of complexes and inclusion compounds between cationic or neutral guest and neutral host, e.g. crowns, cryptands, cyclodextrins, and antibiotics has been studied to develop the phase-transfer catalysis and to elucidate the mechanism of enzyme/substrate and naturally occurring ionophore /metal cation interactions so far. On the other hand, studies on complexation involving the coulombic attractive force between oppositely charged hosts and guests have been expected to draw a new trend in molecular recognition, since this additional binding force will affect the stability and selectivity of the complex other than ion-dipole interaction and/or hydrogen bonding.

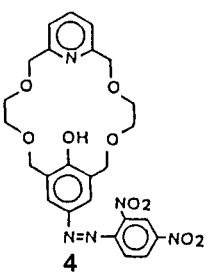
Previously we reported design and syntheses of a series of ligands which can selectively bind a given metal ion and undergo concurrently color change,[1] e.g. lithium ion selective coloration with azophenol-dyed crowns,[2] and azophenol spherand-like cyclophane[3], lithium ion specific fluorescent emission with benzothiazolylphenol crowns,[4] and their application to lithium ion analyses.

AMINE SELECTIVE COMPLEXATION-COLORATION[5]

Now we wish to report selective complexation of protonated amines by the use of azophenol crowns **1**-**6** and podand **7** which have a phenol group in the cavity to yield the corresponding ammonium phenolate complex **10** (Scheme 1). The colored complex **10** must be differentiated from simple ion-dipole type complexes by an additional binding force, that is, coulombic interaction between the host phenolate anion and the guest ammonium cation. We recently observed such a perching type complexation of protonated amines by the phenolate anion and ether oxygens of the azophenol crowns.



1:R=NO2; 2:R=H



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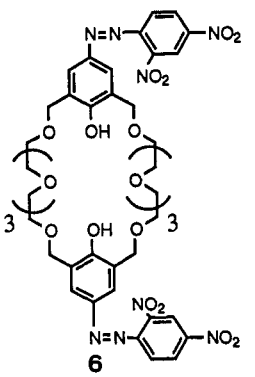

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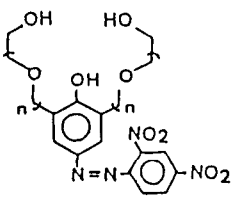

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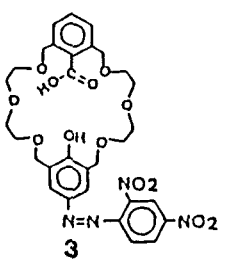

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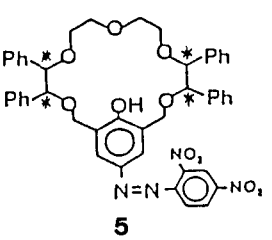

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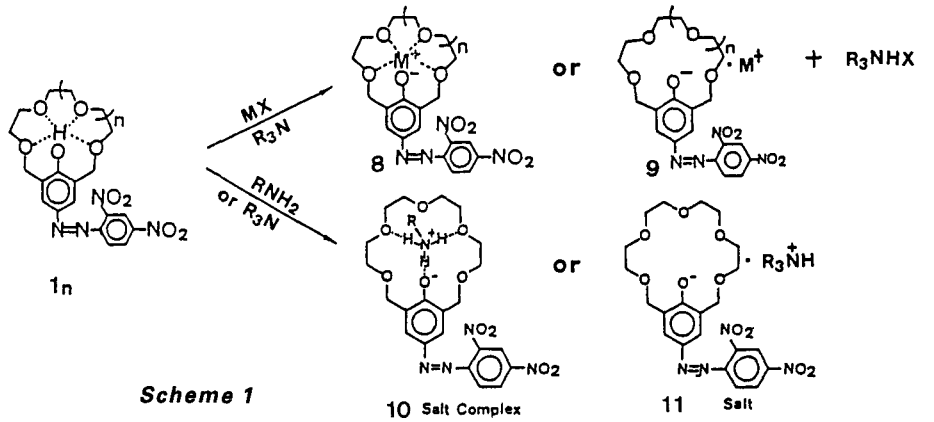


Scheme 1

The azophenol crown **1** does not dissociate in chloroform, but shows the formation of phenolate-ammonium complex in the presence of amines in their absorption spectra. Thus the formation of the salt complex **10** with amine is strongly depend upon the structure of amines but not their basicity. For example, absorption maxima of **1** (n=1-3)-amine complexes appear in shorter wavelength region compared to those of acyclic reference azophenols like A and B in Fig. 1.[6] The figure shows that acyclic hosts reveal nearly constant

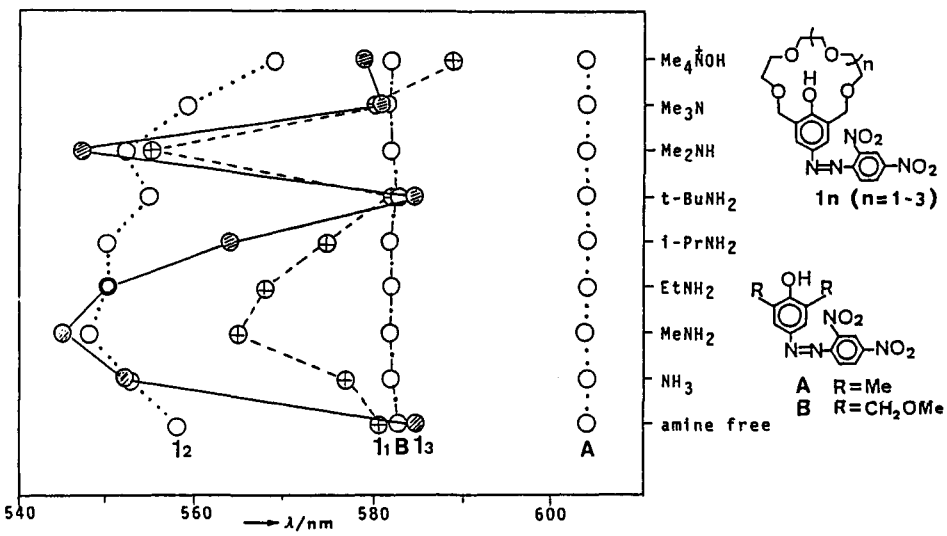


Fig.1.Absorption maxima of azophenol dye-amine systems in EtOH.

value of the maxima regardless of the amine species. The complexes of dimethylamine show, in general, blue shifts of their maxima in any solvent. On the other hand, 1_1 shows larger absorbances of the salt complexes with relatively less bulky amines compared to those of bulky amines. The 1_1-piperidine (1:1) complex was purified and determined by X-ray analysis to be a typical perching type structure where the whole chromophore except ortho nitro group is coplanar and nearly perpendicular to the crown ring (fig. 2).[6]

Next, the complexation of azophenol crown **3** containing a benzoic acid moiety was studied. The dye **3** is also yellow (λmax 400 nm) in chloroform and shows color change to blue by the addition of monoamines while to pink by diamines, indicating a remarkably different color developing based on the two ionic sites, carboxylate and phenolate anions, in the crown cavity(Fig. 3).
Such a coloration (λmax 538-580 nm) of dye crown **3**-amine complexes is related to the structure of complex and not strongly to relative basicity of the amines. From the study of the relationship between the positions of absorption maxima and the concentrations of amines, it was observed that the dye **3** forms a 1:1 complex with some equivalents of diamine (0.5-500 eq. in the case of piperazine) and 1:2 complex with large excess of diamine (more than 10^3 eq. for piperazine)(Fig. 4). Especially, piperazine forms a 1:1 complex in quantitative yield.[7]

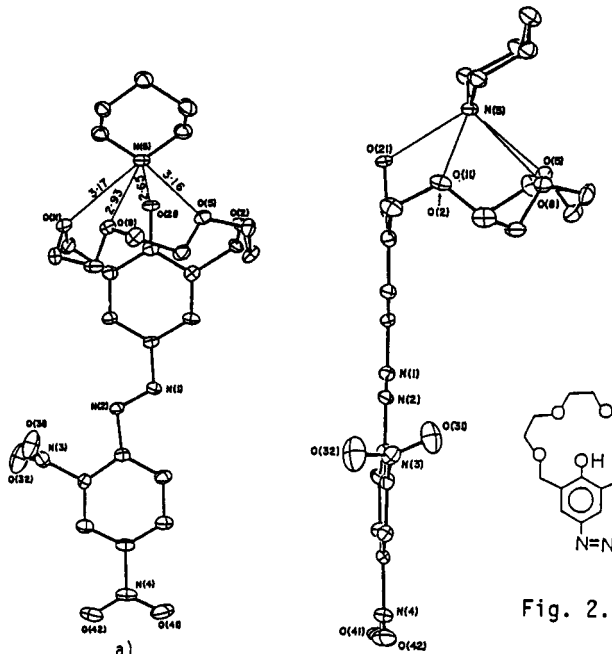


Fig. 2. ORTEP views of 1_1-piperidine 1:1 complex.

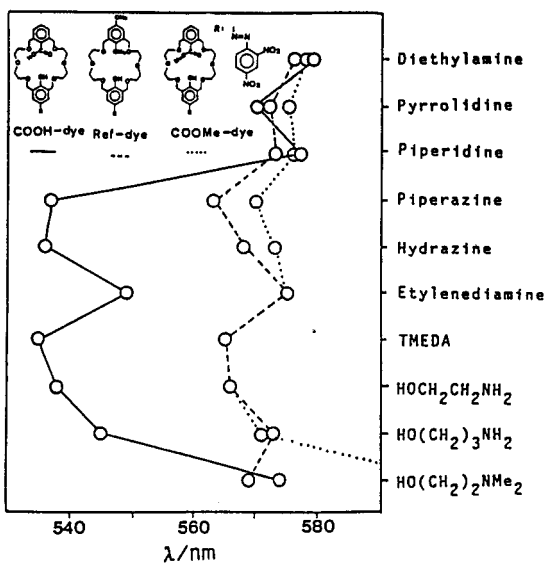


Fig. 3. Absorption Maxima (in nm) of Visible Spectra for Dye-Amine Systems in $CHCl_3$

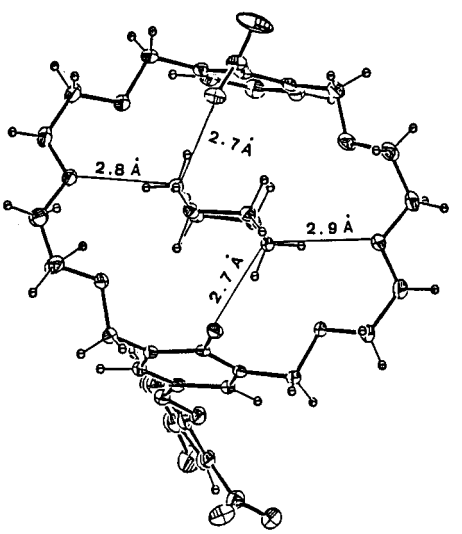


Fig. 5. ORTEP view of COOH-dye: piperazine (1:1) complex.

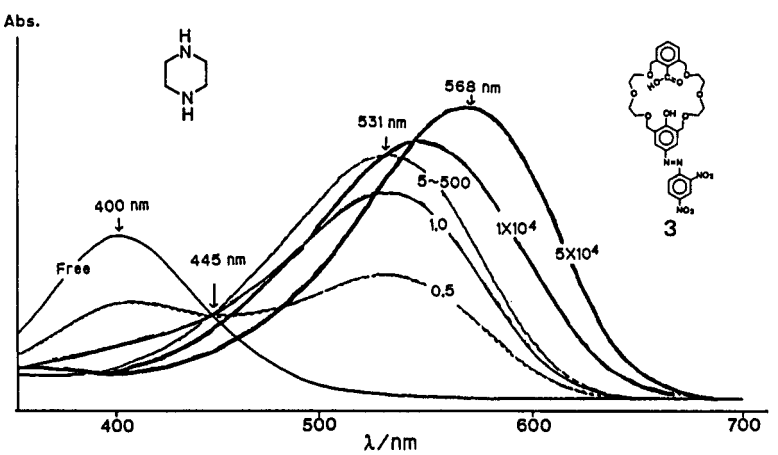


Fig. 4. Visible Spectra of "COOH-dye"-Piperazine Systems in $CHCl_3$

The molecular structure of the complex was determined by X-ray crystallography.[7] As shown in Fig. 5, the diprotonated piperazine is sandwiched between phenolate and benzoate planes in chair form, and is bound by marked short hydrogen bond. This is the first example of X-ray analysis of crown ether-sec. amine complex, to our knowledge, and the figure indicates an intercharge hydrogen bonding ($O^-\cdots H-N^+$) to be useful to bind the guest ion as well as ion-dipole interaction and hydrogen bonding.

As an application of amine selective complexation-coloration, it was observed that the substitution pattern of amines, i.e. primary, secondary, and tertiary, is able to discriminate by combined use of two azophenol hosts, pyridine-crown **4** and podand **7** (n=1).
Dye crown **4** reacts with all kinds of amines in acetonitrile to form ammonium phenolates. The absorption maxima of **4**-prim. amine systems appear in a region of 574-586 nm, which is definitely distinct from those of sec. and tert. amine systems (λmax 602-606 nm except for dimethylamine 592 nm) as shown in Fig. 6.

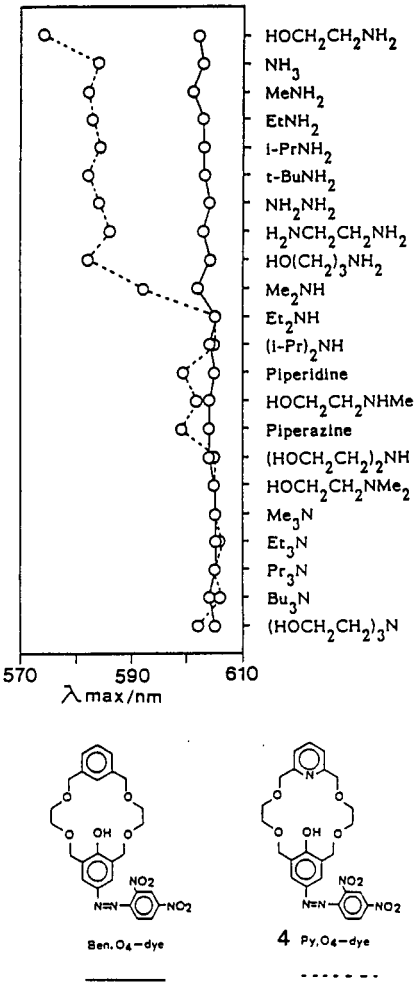


Fig. 6. Absorption maxima of dye-amine systems in acetinitrile

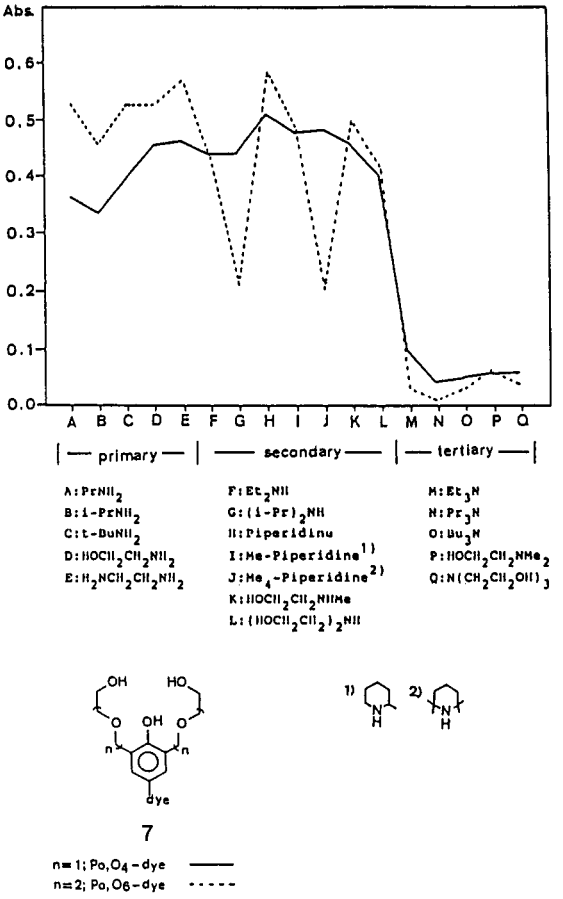
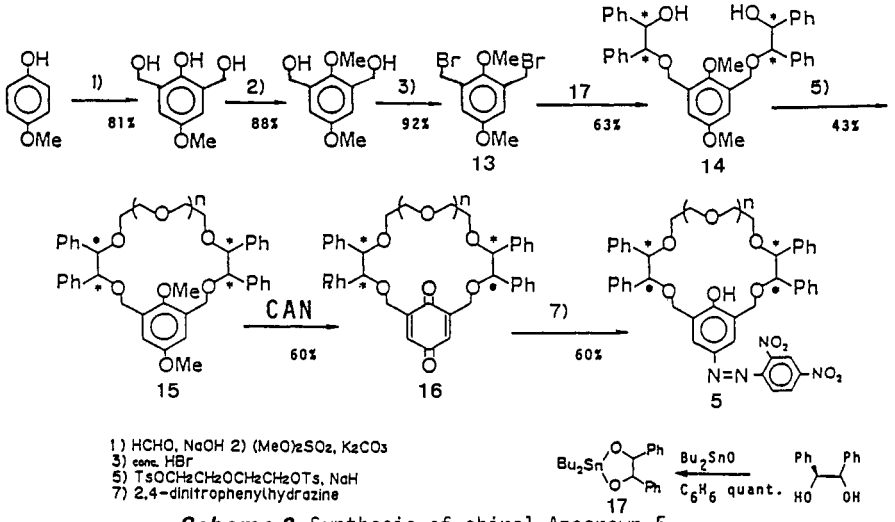


Fig. 7. Absorbance at absorption maxima of dye-amine systems in chloroform

On the other hand, azophenol podand **7** (n=1) shows the complexation-coloration with all of prim. and sec. amines, included sterically bulky amines such as t-$BuNH_2$, $(i\text{-}Pr)_2NH$, and 2,2,6,6-tetramethylpiperidine, but not for tert. amines (Fig. 7). Consequently, the combined use of two types of azophenol hosts, **4** and **7**, is highly useful to discriminate the substitution pattern of amines by means of coloration. The two end hydroxyl groups in the dyed podand **7** are required for such discrimination of amine pattern because no complexation-coloration is observed by addition of various amines when the hydroxyl groups are substituted with methoxyl groups.

Enantiomer selective coloration of optically active amines, our important project, was realized by chiral azophenol crown **5** incorporated with two units of opt. active hydrobenzoin. The synthetic route is shown in Scheme 2. Reaction of 2,6-bis(bromomethyl)-1,4-dimethoxybenzene **13**, which is derived from hydroquinone-monomethylether by three-step procedure, with dibutyltin derivative **17** of opt. active dihydrobenzoin gives opt. active podand **14** in 63% yield. Cyclization of **14** with ditosylate of polyethylene glycol, followed by oxidation with ceric ammonium nitrate (CAN) and treatment with dinitrophenylhydrazine, affords the desired chiral azophenol crowns **5**.



Scheme 2 Synthesis of chiral Azocrown 5.

Of several active monoalkylamines and ethanolamines, a selective coloration with norpseudoephedrine, $Ph(OH)CH\text{-}CH(NH_2)CH_3$, is described as a typical example. The examination with CPK molecular model shows that norpseudoephedrine **18** having R,R-configuration may form more stable complex with (SSSS)-dye **5**, compared to that with (RRRR)-dye **5**. In fact, (RRRR)-**5**, in chloroform was kept yellow by addition of the amine in a range of concentration, 4.8×10^{-7} to 1.2×10^{-6} M, whereas (SSSS)-**5** revealed color change of the solution from yellow to reddish violet with the same concentration of the amine (Fig. 8).[8]

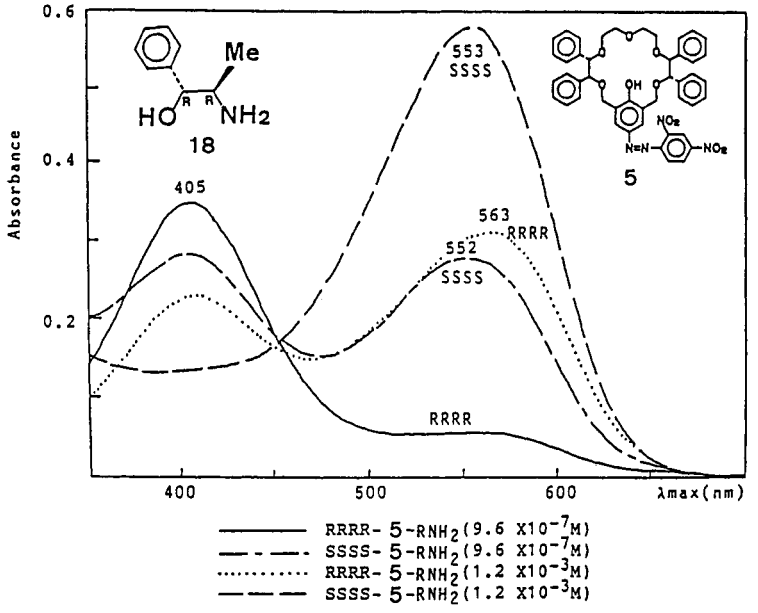


Fig. 8. Absorption Spectra of 5- Norpseudoephedrine 18 System in Chloroform

For further study on the selective binding of amines, a bisazophenolic crown **6** which has a thirty-six membered ring and two units of azophenol was synthesized from dibromide **13** according to the usual method. The pale green solution of the crown in alcohol is changed to pink to blue color by addition of a series of amines, e.g. 20 alkylamines, 12 diamines, and 5 aminoalcohols.

As seen in Fig. 9, some diamines showed significant blue shift of maxima of complexes compared to those of the other amines. In particular, ethylenediamine shows the most remarkable shift of absorption maximum at 530 nm, indicating the formation of stable salt complex coinciding with CPK molecular model examination.[9]

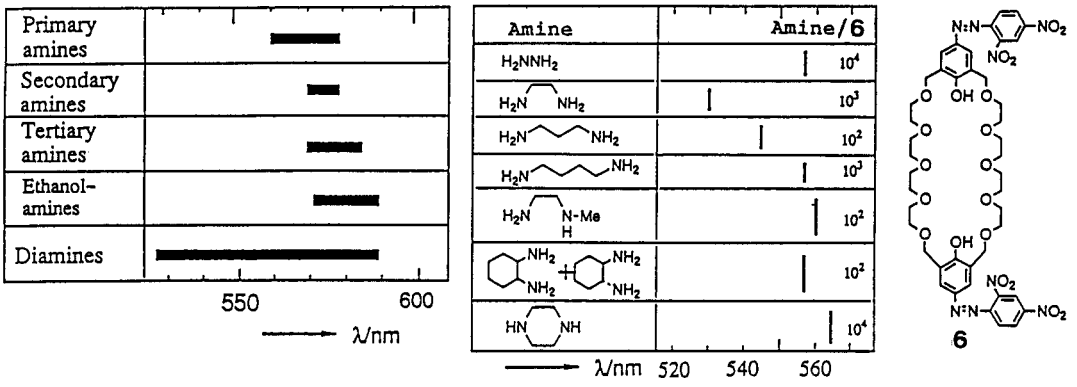


Fig. 9. Absorption Maximum wavelengths of acerand 19-amine complexes (in EtOH).

REFERENCES

1) For review: S. Misumi and T. Kaneda, Mem. Inst. Sci. Ind. Res., Osaka Univ., 44, 29 (1987).
2) T. Kaneda, K. Sugihara, H. Kamiya, and S. Misumi, Tetrahedron Lett., 22, 4407 (1981); K. Sugihara, T. Kaneda, and S. Misumi, Heterocycles, 18, 57 (1982); K. Nakashima, S. Nakatsuji, S. Akiyama, T. Kaneda, and S. Misumi, Chem. Lett., 1781 (1982); Chem. Pharm. Bull., 34, 168 (1986).
3) T. Kaneda, S. Umeda, H. Tanigawa, S. Misumi, Y. Kai, H. Horii, K. Miki, and N. Kasai, J. Am. Chem. Soc., 107, 4802 (1985).
4) I. Tanigawa, K. Tsuemoto, T. Kaneda, and S. Misumi, Tetrahedron Lett., 25, 5327 (1984); K. Nakashima, S. Nakatsuji, S. Akiyama,m I. Tanigawa, T. Kaneda, and S. Misumi, Talanta, 31, 749 (1984); K. Nakashima, Y. Nagaoka, S. Nakatsuji, T. Kaneda, I. Tanigawa, K. Hirose, S. Misumi, and S. Akiyama, Bull. Chem. Soc. Jpn., 60, 3219 (1987).
5) S. Misumi and T. Kaneda, Mem. Inst. Sci. Ind. Res., Osaka Univ., 46, (1989); J. Inclusion Phenom., 7, 73 (1989).
6) T. Kaneda, S. Umeda, Y. Ishizaki, H.-S. Kuo, and S. Misumi, J. Am. Chem. Soc., 111, 1881 (1989).
7) T. Kaneda, Y. Ishizaki, S. Misumi, Y. Kai, G. Hirano, and N. Kasai, J. Am. Chem. Soc., 110, 2970(1988).
8) T. Kaneda, K. Hirose, and S. Misumi, J. Am. Chem. Soc., 111, 742 (1989).
9) M. Fukuhara, Y. Ishizaki, T. Kaneda, and S. Misumi, Abstract of 58th Annual Meeting of Jpn. Chem. Soc. Tokyo (1989), II, p.1359.