Chiral Recognition of Binaphthyls by Permethylated β-Cyclodextrin

Koji Kano,* Kazuhiro Yoshiyasu, and Shizunobu Hashimoto

Department of Applied Chemistry, Faculty of Engineering, Doshisha University, Kyoto 602, Japan

The (*S*)-enantiomers of binaphthyl derivatives such as 1,1′-bi-2-naphthol, 2,2′-dimethoxy-1,1′-binaphthyl, and 1,1′-binaphthyl-2,2′-diyl hydrogen phosphate are more preferable guests for permethylated β-cyclodextrin compared with the (*R*)-enantiomers.

One of the current reseach topics of host–guest chemistry is chiral recognition by cyclodextrins (CDx).[1] Recently, aspects derived from studies on chiral recognition in solutions have been developed into chromatographic analyses of chiral compounds, where α- and β-CDx were used as the functional hosts attached to the stationary phases for liquid chromatography and/or coexisted in the mobile phases for t.l.c. and h.p.l.c.[2] A three-point attachment model[3] explains the chiral recognition by CDx.[4] According to this model, the guest molecule should be included into a hydrophobic cavity of CDx and, at least, two sites of the guest molecule need to interact with two parts of CDx *via* attractive and/or repulsive forces to achieve enantioselective complexation with CDx. In most cases, hydrogen bonds have been utilized to realize such interaction between guest and host molecules. We present here an amplified chiral recognition of binaphthyl derivatives, such as 1,1′-bi-2-naphthol (BNOH), 2,2′-dimethoxy-1,1′-binaphthyl (BNOMe), and 1,1′-binaphthyl-2,2′-diyl hydrogen phosphate (BNP), by heptakis-(2,3,6-tri-*O*-methyl)-β-CDx (TMe-β-CDx). Our present results may be the first examples where enantioselective complexation can be performed in solutions by using permethylated β-CDx without the aid of hydrogen bonding.

Figure 1 shows the effects of added TMe-β-CDx (Tohsin Chem., Tokyo, m.p. 156—158 °C) on the fluorescence intensities of (*S*)- and (*R*)-BNOH in water. A very low fluorescence yield of BNOH in water should be ascribed to the rotation along the intra-annular bond[5] and the proton dissociation of photoexcited BNOH.[6] Inclusion of the BNOH molecule into the TMe-β-CDx cavity may restrict both photoinduced rotation and H^+-dissociation leading to an increase in the fluorescence yield. As Figure 1 clearly shows, the effect of TMe-β-CDx for (*S*)-BNOH is much more remarkable than that for (*R*)-BNOH. The fluorescence behaviour in the (*S*)-BNOH-TMe-β-CDx system could be analysed by a Benesi–Hildebrand equation for the formation of the 2:1 complex of TMe-β-CDx and BNOH [equation (1)]. A plot of

$$\Delta I_f^{-1} = (aK_1K_2)^{-1}([CDx]_0)^{-2} + a^{-1} \quad (1)$$

ΔI_f^{-1} *vs.* $[CDx]_0^{-2}$ provides K_1K_2 of 3.5×10^4 dm^6 mol^{-2}. Meanwhile the Benesi–Hildebrand equation for the 1:1 complex formation was applied for the (*R*)-BNOH-TMe-β-CDx system giving K of 20 dm^3 mol^{-1}. Another marked difference between (*S*)- and (*R*)-BNOH arose in fluorescence lifetimes (τ_f) from complexation with TMe-β-CDx. (*S*)-BNOH (1×10^{-5} M) in the aqueous TMe-β-CDx (1×10^{-2} M) showed a single exponential fluorescence decay with τ_f of 6.6 ns, while the fluorescence decay curve of (*R*)-BNOH consisted of the two-exponential factors [2.9 ns (95%) and *ca.* 23 ns (5%)]. β-CDx formed the 1:1 complexes with both (*S*)- and (*R*)-BNOH, the K values being 280 dm^3 mol^{-1} for (*S*)-BNOH and 230 dm^3 mol^{-1} for (*R*)-BNOH. β-CDx is not a good host for enantioselective complexation with BNOH.

In analogy with the case of BNOH, TMe-β-CDx binds preferentially with the (*S*)-enantiomer of BNP. The Benesi–Hildebrand plots for the fluorescence intensities clearly indicate the formation of the 1:1 complexes of the (*S*)- and (*R*)-enantiomers and TMe-β-CDx, having the K values of 400 and 50 dm^3 mol^{-1}, respectively. The 2:1 complexes of β-CDx and (*S*)- and (*R*)-BNP were formed. β-CDx also shows the lower ability to recognize the chirality of BNP, the K_1K_2 values being 1×10^6 dm^6 mol^{-2} for (*S*)-BNP and 0.5×10^6 dm^6 mol^{-2} for (*R*)-BNP.

A solution of racemic BNOMe (2×10^{-5} M) in aqueous TMe-β-CDx (1×10^{-2} M, 10 ml) was turbid because free BNOMe is completely insoluble in water. The solution was filtered (Millex-SR filter, 0.5 μm) and the residue was extracted by acetonitrile. The circular dichroism (c.d.) spectra of the resulting aqueous filtrate (solution I) and acetonitrile solutions (solution II) were measured. The oppositely signed bisignated c.d. spectra were obtained for these two solutions. An exciton-coupling theory indicates that the (*S*)-enantiomer of BNOMe is the predominant solute in solution I and the (*R*)-enantiomer precipitates preferentially in aqueous TMe-β-CDx. Although the results for BNOMe are qualitative, it is clear that the (*S*)-enantiomer of BNOMe is the preferable guest to TMe-β-CDx and the hydrogen bonding does not contribute to the chiral recognition. Judging from the intensities of the bisignated c.d. signals, it can be concluded that β-CDx also shows a relatively weak ability to recognize the chirality of BNOMe compared with TMe-β-CDx.

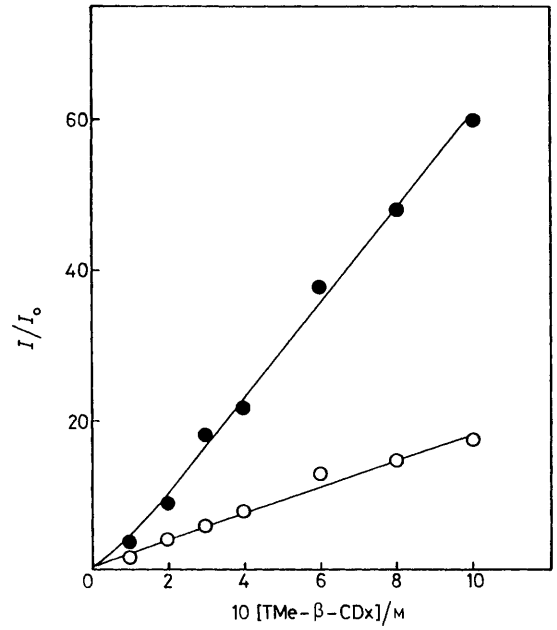

Figure 1. Changes in the fluorescence intensities of (*S*)- (●) and (*R*)-BNOH (○) as a function of the TMe-β-CDx concentration. Each enantiomer of BNOH (1×10^{-5} M) in water was excited at 293 nm. I_0 and I represent the fluorescence intensities at 358 nm in the absence and the presence of TMe-β-CDx, respectively.

The present study reveals that the permethylation of β-CDx enhances the enantioselective complexation with the binaphthyl derivatives. The multi-point attachment model seems to be applied to the present system while the hydrogen bonding does not play an important role. Formation of the chiral pyrene dimer in the γ-CDx cavity[7] and enantiomer separation by capillary gas chromatography on a perpentylated α-CDx stationary phase[8] fall under the same category. The asymmetric nature of the β-CDx cavity may be amplified by permethylation.

Received, 15th March 1989; Com. 9/01141B

References

1 For example: H. P. Benschop and G. R. Van den Berg, *J. Chem. Soc., Chem. Commun.*, 1970, **1431**; J. A. Hamilton and L. Chen, *J. Am. Chem. Soc.*, 1988, **110**, 5833.

2 For example: A. Harada, M. Furue, and S. Nozakura, *J. Polym. Sci., Polym. Chem. Ed.*, 1978, **16**, 189; D. W. Armstrong, T. J. Ward, A. Czech, B. P. Czech, and R. A. Bartsch, *J. Org. Chem.*, 1985, **50**, 5556.

3 V. Daffe and J. Fastrez, *J. Chem. Soc., Perkin Trans. 2*, 1983, 789; W. H. Pirkle, M. H. Hyun, and B. Bank, *J. Chromatogr.*, 1984, **316**, 585.

4 M. Mikolajczyk and J. Drabowicz, *J. Am. Chem. Soc.*, 1978, **100**, 2510; W. L. Hinze, T. E. Riehl, D. W. Armstrong, M. DeMond, A. Alak, and T. Ward, *Anal. Chem.*, 1985, **57**, 237.

5 M. Irie, K. Yoshida, and K. Hayashi, *J. Phys. Chem.*, 1977, **81**, 969.

6 M. Ofran and J. Feitelson, *Chem. Phys. Lett.*, 1973, **19**, 427; K. K. Smith, K. J. Kaufmann, D. Huppert, and M. Gutman, *ibid.*, 1979, **64**, 522; J. Lee, R. D. Griffin, and G. W. Robinson, *J. Chem. Phys.*, 1985, **82**, 4920.

7 K. Kano, H. Matsumoto, S. Hashimoto, M. Sisido, and Y. Imanishi, *J. Am. Chem. Soc.*, 1985, **107**, 6117; K. Kano, H. Matsumoto, Y. Yoshimura, and S. Hashimoto, *ibid.*, 1988, **110**, 204.

8 W. A. König, S. Lutz, and G. Wenz, *Angew. Chem.*, 1988, **100**, 989.