Pergamon

Tetrahedron Letters, Vol. 38, No. 9, pp. 1603-1606, 1997

0040-4039/97 $17.00 + 0.00

PII: S0040-4039(97)00123-8

Molecular Recognition of α,ω-Diamines by Metalloporphyrin Dimer

Takashi Hayashi,* Masanori Nonoguchi, Toshihiro Aya and Hisanobu Ogoshi*

Department of Synthetic Chemistry and Biological Chemistry, Faculty of Engineering,
Kyoto University, Kyoto 606-01, Japan

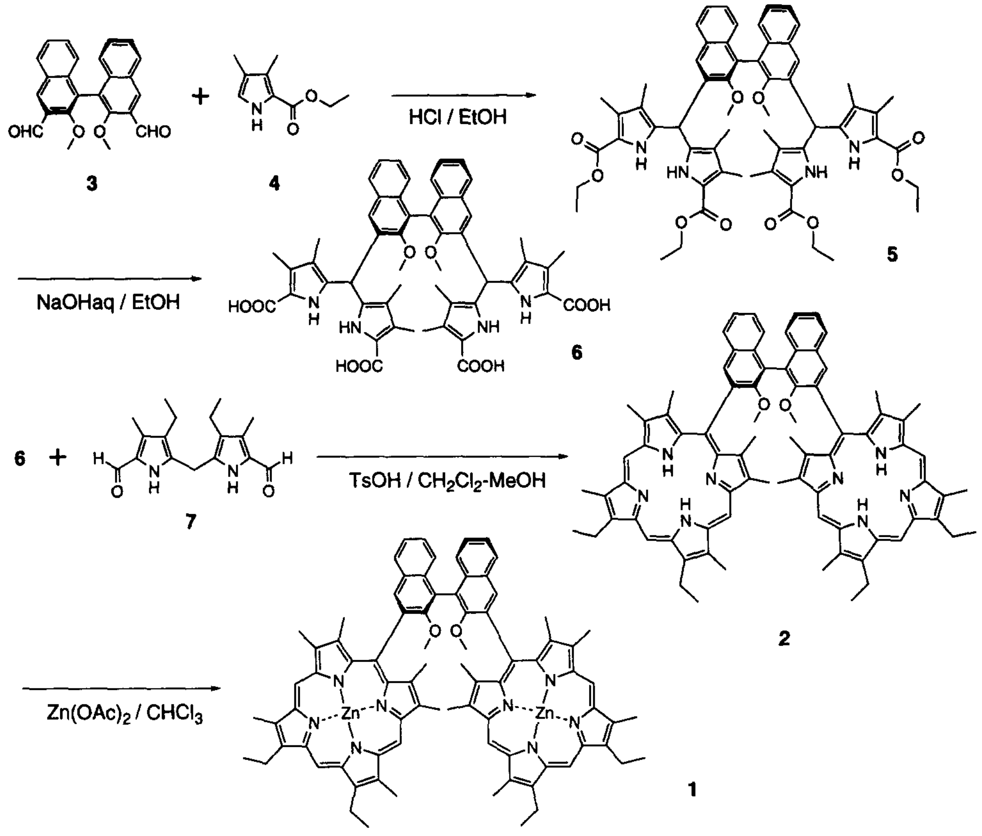
Abstract: Porphyrin dimer linked with chiral binaphthyl derivative was prepared as a ditopic coreceptor for a series of diamines. Its zinc complex shows the good affinity for α,ω-diamines $H_2N(CH_2)_nNH_2$ (n = 6, 8, 10, 12; $K_a = 10^5 - 10^6$ M^{-1} in CH_2Cl_2 at 15 °C). These complexes gave the significant bisignate CD spectra due to the exciton coupling between two zinc porphyrins and its intensity depends on the length of diamine. The CD spectrum in the complex reflects angle and flexibility of the chiral twist between two zinc porphyrin units.

Functional porphyrins are particularly suitable for the host molecules to investigate the behavior of molecular recognition, since large aromatic framework of porphyrin ring enables us to monitor the chemical change upon host-guest complexation by many kinds of spectroscopic measurements in high sensitivity. In the last decade, we have demonstrated the synthetic porphyrins as host molecules which have convergent functional groups upon the porphyrin ring to efficiently interact with a variety of biomolecules as guests.[1] Furthermore, we have prepared an intrinsic chiral porphyrin and discussed the mechanism of induced circular dichroism (CD) upon binding of guest molecules.[2] One of our next aims is to control the selectivity of recognition behavior by an extrinsic chiral porphyrin dimer as a ditopic coreceptor.[3] Recently, we have prepared the porphyrin dimer and its zinc complex **1** linked with chiral binaphthyl derivative and determined the affinities of α,ω-diamines.[4] In this paper, we wish to report the size-specific interaction behavior of diamines for semiflexible porphyrin dimers **1** by use of NMR and CD studies.

The synthetic route to the porphyrin dimer is shown in Scheme 1. The condensation of (*S*)-1,1'-bi-2-naphthol derivative **3** and pyrrole **4** led to the precursor of porphyrin dimer **5** in quantitative yield. After the hydrolysis of **5**, the addition of 5,5'-diformyldipyrrole **7** to the solution of **6** in the presence of *p*-toluenesulfonic acid gave porphyrin dimer **2** in 30% yield. The free base porphyrin **2** was converted into zinc complex **1** by metallation with zinc acetate.[5] Two enantiomeric porphyrin dimers, **1** and its enantiomer, were obtained from (*S*)- and (*R*)-1,1'-bi-2-naphthols, respectively,[6] and exhibited symmetric Cotton effects toward each other at their Soret bands of CD spectra.[7,8] The electronic absorption spectrum of **1** in CH_2Cl_2 suggests no remarkable interaction between the two zinc porphyrin units, compared with that of octaethylporphyrin zinc complex (**8**).

Interaction between **1** and diamines was examined by ^1H NMR, electronic absorption and CD spectroscopic methods. ^1H NMR spectrum of 1,8-diaminooctane (**9**) in the presence of **1** exhibited the marked

Scheme 1



upfield shift ($\Delta\delta$ = -7.7 ppm) of amino protons due to the ring current of porphyrin dimer. Furthermore, several methyl protons at β-position of pyrrole also slightly shifted to upfield ($\Delta\delta$ = -0.15 ppm).[9] The Soret band of **1** shifted to 423 nm with clear isosbestic points by titrimetic measurement, which suggests the complexation of 1:1 stoichiometry. Figure 1(a) shows that the porphyrin dimer **1** in the presence of **9** gives the large exciton split coupling CD with amplitude A = +1788. Compared to **1•9** system, the complex formation of **1** with monoamine, *n*-octylamine (**10**), exhibited the weaker coupling CD. This result demonstrates that the dihedral angle of two naphthyl groups is fixed by coordination of the α and ω NH_2 of **9** to each zinc atom of **1** resulted in large increase of A. These spectroscopic results clearly indicate that diamine **9** interacts with two zinc atoms within the porphyrin cave of **1** as shown in Figure 2.

The binding constants determined by UV-vis study are shown in Table 1. The affinity of α,ω-diamine with porphyrin dimer **1** clearly depends on its length, particularly, diamine **9** has suitable length to form a bridge between two zinc porphyrins of **1** via coordination (K_a = 2.1 x 10^6 M^{-1} in CH_2Cl_2 at 288 K). In contrast, the binding constant of porphyrin dimer-monoamine (**1•11**) and porphyrin monomer-diamine (**8•12**) complexes are almost similar to K_a for simple porphyrin monomer-monoamine (**8•11**) complex. Thus, the ditopic interaction of diamines enhances affinity by a factor of ca 10^3 in K_a.[10] Furthermore, the determined affinities for a series of diamines indicate that the ditopic interaction inside the cave of **1** requires longer spacer than hexamethylene in the α,ω-diamines.[11]

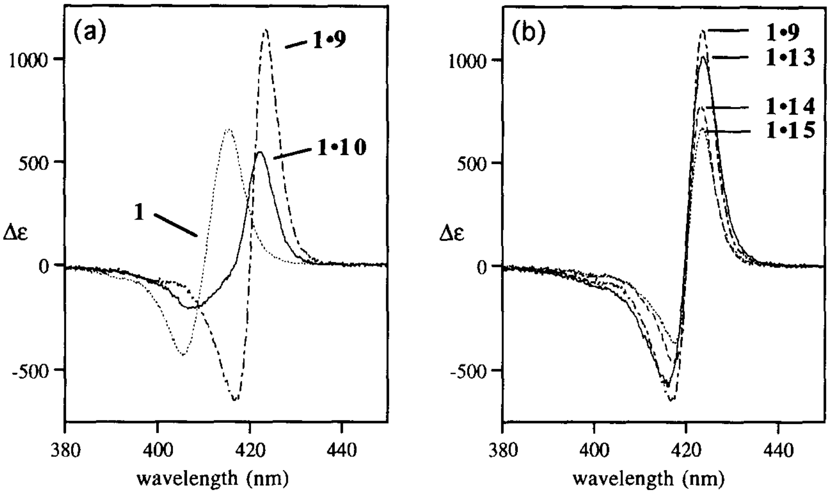


Figure 1. CD spectra of zinc porphyrin dimer **1** in CH_2Cl_2 at 288 K. $[\mathbf{1}]_0 = 2.0 \times 10^{-6}$ M. $[\mathbf{9}]_0 = 4.0 \times 10^{-5}$ M. $[\mathbf{10}]_0 = 6.0 \times 10^{-4}$ M. $[\mathbf{13}]_0 = [\mathbf{14}]_0 = 6.0 \times 10^{-5}$ M. $[\mathbf{15}]_0 = 8.0 \times 10^{-5}$ M.

Table 1. Binding Constants (K_a) for Porphyrin-Amine Complexation in CH_2Cl_2 at 288 K.

Host	Guest	K_a (M^{-1})[a]
1	1,6-diaminohexane (**13**)	$(9.4 \pm 0.2) \times 10^5$
1	1,8-diaminooctane (**9**)	$(2.1 \pm 0.3) \times 10^6$
1	1,10-diaminodecane (**14**)	$(1.7 \pm 0.2) \times 10^6$
1	1,12-diaminododecane (**15**)	$(5.5 \pm 0.2) \times 10^5$
1	*n*-butylamine (**11**)	$(2.7 \pm 0.1) \times 10^3$
8	ethylenediamine (**12**)	$(2.9 \pm 0.1) \times 10^3$
8	*n*-butylamine (**11**)	$(2.2 \pm 0.1) \times 10^3$

[a] Binding constants were calculated from non-linear curve fitting analysis of 1 : 1 complexation.

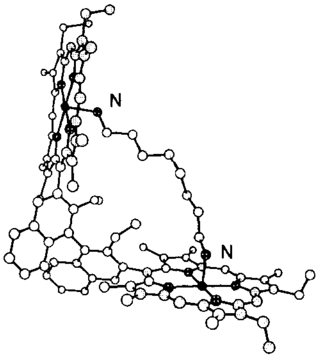


Figure 2. Proposed structure of **1•9** complex. All protons are omitted.

Figure 1(b) shows the split type CD spectra in the Soret region upon binding between **1** and diamine, $H_2N(CH_2)_nNH_2$ (**13**: n = 6, **9**: n = 8, **14**: n = 10, **15**: n = 12). These sharp CD spectra were obtained by use of several diamines; $6 \leq n \leq 12$, whereas the CD spectra obtained from **1** and shorter ($n < 6$) diamines were similar to that in **1•10** complex.[12] Figure 1b reveals the good relationship between binding constants and the intensity of CD. It is likely that the decrease of *A* value in **1•14** or **1•15** derives from the flexibility induced by longer carbon chain of **14** or **15**. Thus, the *A* value seems to relevant to the degree of the chiral twist of two zinc porphyrins. The exciton coupled CD of the chiral porphyrin dimer **1** gives us the interesting information about the structural feature of the complexation.

REFERENCES AND NOTES

1. Ogoshi, H.; Kuroda, Y.; Mizutani, T.; Hayashi, T. *Pure Appl. Chem.* **1996**, *68*, 1411-1415.
2. Mizutani, T.; Ema, T.; Yoshida, T.; Renné, T.; Ogoshi, H. *Inorg. Chem.* **1994**, *33*, 3558-3566.
3. Lehn, J.-M. In *Biomimetic Chemistry*; Yoshida, Z.-I.; Ise, N., Eds.; Studies in Organic Chemistry 13; Kodansha: Tokyo, 1983; pp 163-187.
4. Crossley and his co-workers have reported the bisporphyrin as a host molecule for diamine and amino acid, in which two zinc porphyrins were linked with a rigid spacer by Tröger's base. a) Crossley, M. J.; Hambley, T. W.; Mackay, L. G.; Try, A. C.; Walton, R. *J. Chem. Soc., Chem. Commun.* **1995**, 1077-1079. b) Crossley, M. J.; Mackay, L. G.; Try, A. C. *J. Chem. Soc., Chem. Commun.* **1995**, 1925-1927.
5. ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 10.20 (s, 2H), 10.00 (s, 4H), 8.67 (s, 2H), 8.09 (d, J = 8.0 Hz, 2H), 8.01 (d, J = 8.6 Hz, 2H), 7.71 (dd, J = 8.6, 7.0 Hz, 2H), 6.66 (dd, J = 8.0, 7.0 Hz, 2H), 4.05 (m, 8H), 3.66 (s, 6H), 3.63 (s, 6H), 3.52 (s, 6H), 3.17 (s, 6H), 2.92 (s, 6H), 2.73 (s, 6H), 2.45 (s, 6H), 1.87 (t, J = 7.9 Hz, 6H), 1.84 (t, J = 8.1 Hz, 6H); HRMS(FAB) Calcd. for $C_{82}H_{78}N_8O_2Zn_2$ (M^+) 1334.4829: Found 1334.4871; UV-visible (CH_2Cl_2) λ_{abs} (ε) 410 (5.68 x 10^5), 538 (3.60 x 10^3), 573 (2.70 x 10^4) nm.
6. The porphyrin dimer of (*R*)-configuration was prepared by same procedure presented in Scheme 1. The enantiomeric mixture of the porphyrin dimer obtained from racemic 1,1'-bi-2-naphthol was resolved on chiral HPLC column and first fraction was assign to **1** derived from (*S*)-1,1'-bi-2-naphthol. The HPLC analysis further showed that each product prepared from (*S*)- or (*R*)-binaphthol, respectively, did not contain the alternate enantiomer: column, CHIRALCEL OD (0.46 x 25 cm); eluent, hexane/2-propanol = 25 : 1.
7. Harada, N; Nakanishi, K. *Circular Dichroic Spectroscopy-Exciton Coupling in Organic Stereochemistry*; University Science Books: Mill Valley, CA, 1983.
8. (a) Ema, T.; Nemugaki, S.; Tsuboi, S.; Utaka, M. *Tetrahedron Lett.* **1995**, *36*, 5905-5908. (b) Matile, S.; Berova, I.; Nakanishi, K.; Novkova, S.; Philipova, I.; Blagoev, B. *J. Am. Chem. Soc.* **1995**, *117*, 7021-7022. (c) Mihara, H.; Haruta, Y.; Sakamoto, S.; Nishino, N.; Aoyagi, H. *Chem. Lett.* **1996**, 1-2. (d) Takeuchi, M.; Chin, Y.; Imada, T.; Shinkai, S. *J. Chem. Soc., Chem. Commun.* **1996**, 1867-1868.
9. This shift could be caused by the overlap of two porphyrin rings due to the complexation of **1** and **9**.
10. (a) Hunter, C. A.; Meah, M. N.; Sanders, J. K. M. *J. Am. Chem. Soc.* **1990**, *112*, 5773-5780. (b) Anderson, H. L.; Hunter, C. A.; Meah, M. N.; Sanders, J. K. M. *J. Am. Chem. Soc.* **1990**, *112*, 5780-5789. (c) Danks, I. P.; Lane, T. G.; Sutherland, I. O.; Yap, M. *Tetrahedron* **1992**, *48*, 7679-7688.
11. The binding constants for ethylene diamine and 1,3-diaminopropane are 4.7 x 10^3 M^{-1} and 6.6 x 10^3 M^{-1}, respectively, which are twice that for binding of monoamine to porphyrin dimer **1**.
12. These spectra were obtained with 2.0 x 10^{-6} M of **1** and < 1 x 10^{-4} M of diamine. Under these conditions, almost complexes could be formed by simple monotopic interaction and one zinc atom of **1** and one NH_2 of diamine could be free.

(*Received in Japan* 11 *December* 1996; *revised* 10 *January* 1997; *accepted* 16 *January* 1997)