ORGANIC
LETTERS

2003
Vol. 5, No. 14
2547−2549

Synthesis of Novel Phenylazomethine Dendrimers Having a Cyclam Core and Their Zinc Complex

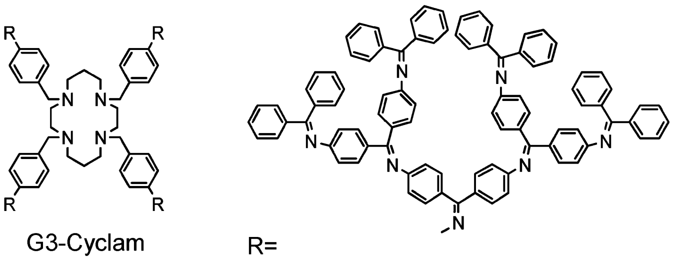
Osamu Enoki, Takane Imaoka, and Kimihisa Yamamoto*

*Department of Chemistry, Faculty of Science & Technology, Keio University,
Yokohama 223-8522, Japan*

yamamoto@chem.keio.ac.jp

Received May 13, 2003

ABSTRACT



Novel phenylazomethine dendrimers having a cyclam core were synthesized by the convergent method. The dendrimers showed selective coordination with zinc chloride on the cyclam ring and with tin chloride on the imine groups. The metal cyclam exhibits a metal-assembling function to provide a multinuclear hetero metal complex.

The metallodendrimer is an attractive material for catalysts[1] and optic/electronic/magnetic devices[2] as a result of total control of its properties through modification of the chemical structure. We found that phenylazomethine dendrimers have the special property of performing a stepwise radial complexation,[3] layer-selective complexation between a tin(II) chloride and the imine group from the core to periphery. Recently, we reported that these metal-coordinated dendrons cause an interesting effect on the core molecule and drastically change its function.[3b]

Cyclam (1,4,8,11-tetraazacyclotetradecane, **1**) is a macrocyclic polyamine ligand for various metal salts and forms a stable 1:1 complex. The cyclam and its complex are interesting materials because some of them exhibit extraordinary properties for catalysis or medical use.[4] In this Letter, we report the synthesis of novel phenylazomethine dendrimers having a cyclam core and their metal complexes, which are expected to provide a new structure for metal-organic hybrid nanomaterials.

The dendrimer core **2** was obtained in good yield from **1** by simple reduction of the nitro groups after reaction with α-bromo-*p*-nitrotoluene (Scheme 1). The phenylazomethine dendrons were synthesized by the convergent method,[5] repeating the dehydration between the amino and ketone group using titanium(IV) chloride as a dehydrating agent.

---

[1] (a) Astruc, D.; Chardac F. *Chem. Rev.* **2001**, *101*, 2991. (b) van Heerbeek, R.; Kamer, P. C. J.; van Leeuwen, P. W. N. M.; Reek, J. N. H. *Chem. Rev.* **2002**, *102*, 3717. (c) Oosterom, G. E.; Reek, J. N. H.; Kamer, P. C. J.; van Leeuwen, P. W. N. M. *Angew. Chem., Int. Ed.* **2001**, *40*, 1828.

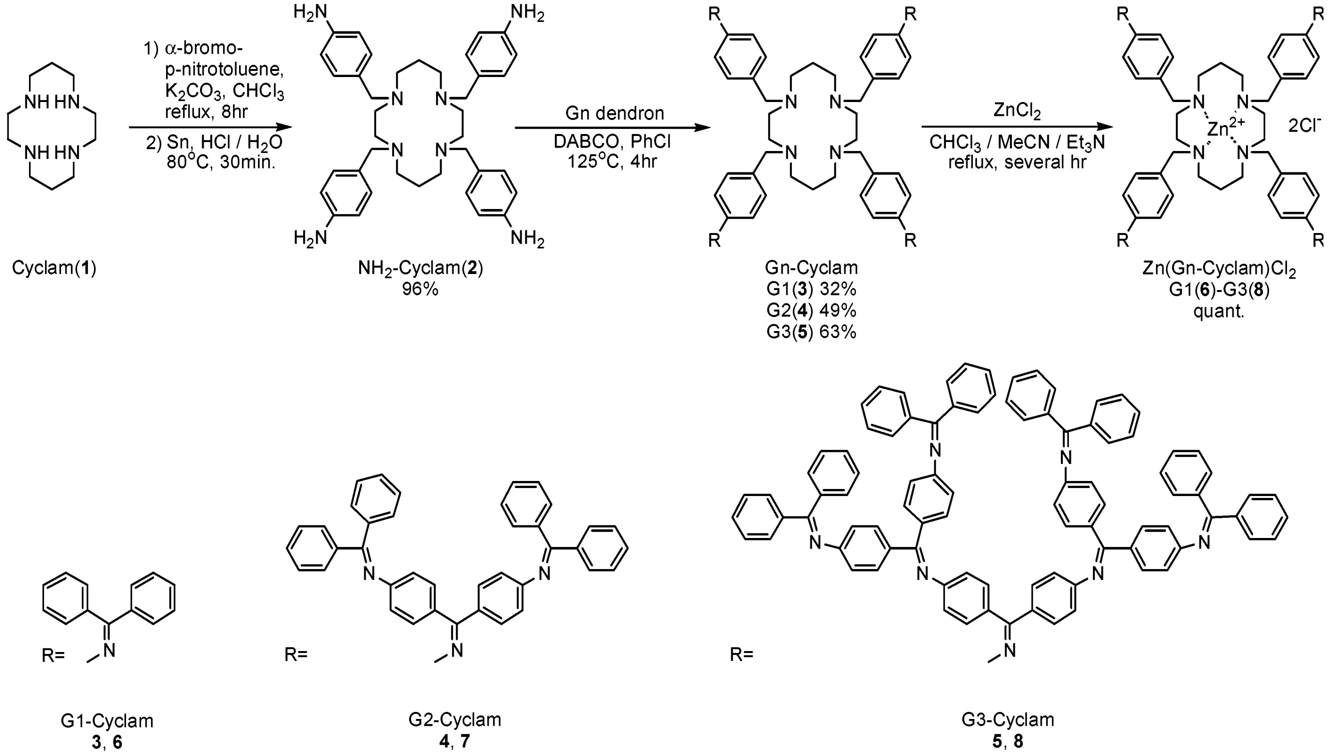
[2] (a) Nishide, H.; Ozawa, T.; Miyasaka, M.; Tsuchida, E. *J. Am. Chem. Soc.* **2001**, *123*, 5949. (b) Nishide, H.; Miyasaka, M.; Tsuchida, E. *J. Org. Chem.* **1998**, *63*, 7399. (c) Balzani, V.; Ceroni, P.; Juris, A.; Venturi, M.; Campagna, S.; Puntoriero, F.; Serroni, S. *Coord. Chem. Rev.* **2001**, *219−221*, 545. (d) Campagna, S.; Di Pietro, C.; Loiseau, F.; Maubert, B.; McClenaghan, N.; Passalacqua, R.; Puntoriero, F.; Ricevuto, V.; Serroni, S. *Coord. Chem. Rev.* **2002**, *229*, 67. (e) Kawa, M.; Fréchet, J. M. J. *Chem. Mater.* **1998**, *10*, 286. (f) Adronov, A.; Fréchet, J. M. J. *Chem. Commun.* **2000**, 1701. (g) Ma, H.; Jen, A. K.-Y. *Adv. Mater.* **2001**, *13*, 1201.

[3] (a) Yamamoto, K.; Higuchi, M.; Shiki, S.; Tsuruta, M.; Chiba, H. *Nature* **2002**, *415*, 509. (b) Imaoka, T.; Horiguchi, H.; Yamamoto, K. *J. Am. Chem. Soc.* **2003**, *125*, 340.

[4] (a) Beley, M.; Collin, J.-P.; Ruppert, R.; Sauvage, J.-P. *J. Chem. Soc., Chem. Commun.* **1984**, 1315. (b) Beley, M.; Collin, J.-P.; Ruppert, R.; Sauvage, J.-P. *J. Am. Chem. Soc.* **1986**, *108*, 7461. (c) Collin, J.-P.; Sauvage, J.-P. *Coord. Chem. Rev.* **1989**, *93*, 245. (d) De Clercq, E.; Yamamoto, N., Pauwel, R.; Baba, M.; Schols, D.; Nakashima, H.; Balzarini, J.; Debyser, Z.; Murrer, B. A.; Schwartz, D.; Thoronton, D.; Bridger, G.; Fricker, S.; Henson, G.; Abrams, M.; Picker, D. *Proc. Natl. Acad. Sci. U.S.A.* **1992**, *89*, 5286. (e) Bridger, G.; Skerlj, R. T.; Padmanabhan, S.; Thornton, D. *J. Org. Chem.* **1996**, *61*, 1519.

10.1021/ol034817j CCC: $25.00

Scheme 1. Synthesis of Phenylazomethine Cyclam Dendrimers and Their Zinc Complexes



The phenylazomethine cyclam dendrimers **3**−**5** were synthesized via the same reaction for the dendrons, the dehydration between the amino groups of **2** and the ketone groups of the dendrons. The raw product was purified by silica gel column chromatography; however, the isolation of the dendrimer was difficult because the R_f value of the dendron and that of the dendrimer were so similar at the higher generation. To employ preparative scale gel permeation chromatography (GPC), the dendron and the dendrimer were perfectly separated by the distinction in molecular size.

The ^{1}H NMR spectra of the dendrimer showed two regions of signals, around 1.5−3.5 ppm for the core and around 6−8 ppm for the dendron. The core signals were broader at higher generations, because the molecular vibration of the cyclam ring was prevented by the steric hindrance of the bulky dendrons. The MALDI-TOF MS of each dendrimer showed the molecular ion $[M]^+$ and a fragment ion $[\text{dendron} + 90]^+$, which was generated by the cleavage of the benzylamine C−N bond at the cyclam core. The fragment ion was more intense at the higher generation compared with the molecular ion, suggesting that the charge of the fragment cation was stabilized by the electronic and/or steric effect of the dendron.

The ^{1}H NMR signals of the cyclam ring were shifted and very broad as a result of the complexation; meanwhile, those of the dendron were not (Figure 1). This result indicates that $ZnCl_2$ selectively coordinates on the cyclam ring, never on the imines group. $ZnCl_2$ may coordinate on the imine groups, but those on the imine groups were entirely removed through the isolation process with GPC. $ZnCl_2$ on the cyclam ring merely remained, which was stabilized by the chelating effect.

The ^{13}C NMR signals of the cyclam ring became split and much less intense by complexation. This suggested that the

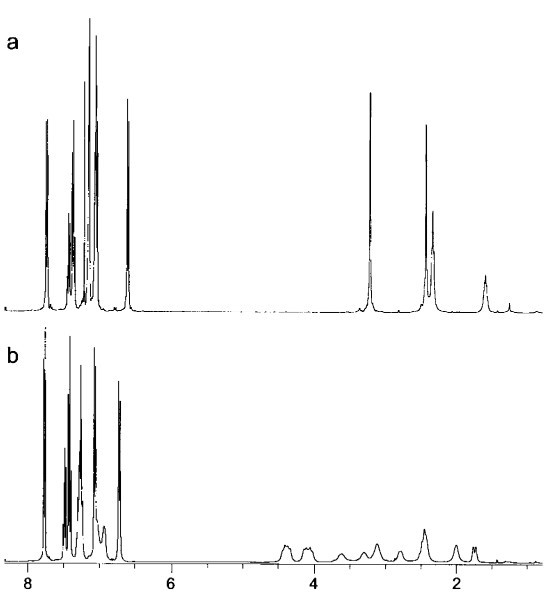


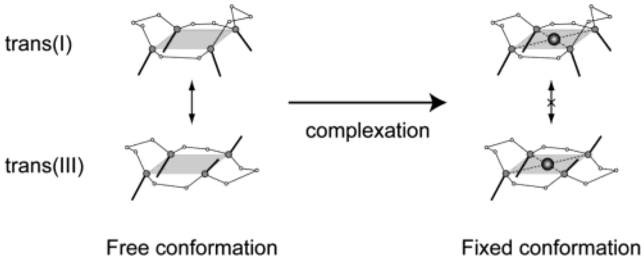
Figure 1. ^{1}H NMR spectra of (a) G1 cyclam dendrimer and (b) its zinc complex in $CDCl_3$.

---

(5) (a) Higuchi, M.; Shiki, S.; Ariga, K.; Yamamoto, K. *J. Am. Chem. Soc.* **2001**, *123*, 4414. (b) Higuchi, M.; Shiki, S.; Yamamoto, K. *Org. Lett.* **2000**, *2*, 3079.

conformation of the cyclam ring was completely fixed in two forms, trans(III) and trans(I), the form that the cyclam complex usually takes[6] (Scheme 2).

Scheme 2. Change of Conformation State of Cyclam Core by Complexation



Coordination of the dendrimer complex with a tin chloride was confirmed by the titration method. With the addition of a tin chloride to the dendrimer complex in solution, the UV−vis spectrum gradually changed with the isosbestic point (Figure 2). This change continued until the molecular amount of the added tin chloride was equal to the stoichiometry of the imine groups. This result indicated that the dendrimer complex was capable of assembling the very same number of tin chlorides as the imine groups.

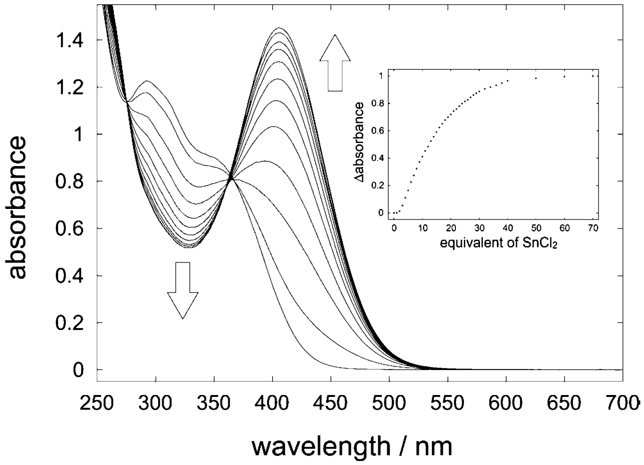


Figure 2. UV−vis spectra change of Zn(G3-cyclam)Cl_2 on addition of tin chloride.

In conclusion, we synthesized novel dendrimers having a cyclam core. The dendrimer selectively coordinated a $ZnCl_2$ on the cyclam ring, never on the dendron imines, and formed a stable 1:1 complex that was soluble in an organic solvent. The structure of the dendrimer was investigated by NMR and showed that the steric property of the core was affected by the generation of the dendrimer and coordinated metal. The dendrimer complex was capable of assembling the very same number of tin chlorides as the imine groups. As a consequence, a dendrimer is able to possess two kinds of metal salts in its structure, and these dendrimers are expected to be used as novel organic−inorganic hybrid materials.

Acknowledgment. This work was partially supported by the 21st COE program (Keio-LCC) and for Scientific Research (15655019, 15350073, 15036262) from MEXT, Japan, and KAST Research Grant (Project 23).

Supporting Information Available: Detailed experimental procedures and characterization data of phenylazomethine cyclam dendrimers and their zinc complexes. This material is available free of charge via the Internet at http://pubs.acs.org.

OL034817J

---

[6] (a) Bosnich, B.; Poon, C. K.; Tobe, M. L. *Inorg. Chem.* **1965**, *4*, 1102. (b) Bosnich, B.; Tobe, M. L.; Webb, G. A. *Inorg. Chem.* **1965**, *4*, 1109. (c) Oberholzer, M. R.; Neuburger, M.; Zehnder, M.; Kaden, T. A. *Helv. Chim. Acta* **1995**, *78*, 505. (d) Alcock, N. W.; Benniston, A. C.; Grant, S. J.; Omar, H. A. A.; Moore, P. *J. Chem. Soc., Chem. Commun.* **1991**, 1573. (e) Blake, A. J.; Gould, R. O.; Hyde, T. I.; Schröder, M. *J. Chem. Soc., Chem. Commun.* **1987**, 1730. (f) Pierce D. V.; Hatfield T. L.; Billo E. J.; Ping Y. *Inorg. Chem.* **1997**, *36*, 2950.