

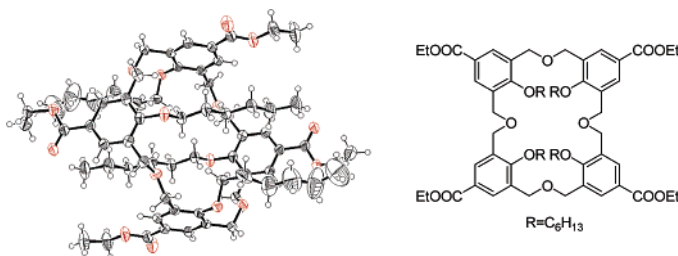
## Liquid Crystal and Crystal Structure of Octahomotetraoxacalix[4]arenes

Shigeo Kohmoto,<sup>\*,†</sup> Yasunobu Someya,<sup>†</sup> Hyuma Masu,<sup>‡</sup> Kentaro Yamaguchi,<sup>‡</sup> and Keiki Kishikawa<sup>†</sup>

Department of Applied Chemistry and Biotechnology, Faculty of Engineering, Chiba University, 1-33, Yayoi-cho, Inage-ku, Chiba 263-8522, Japan, and Faculty of Pharmaceutical Sciences at Kagawa Campus, Tokushima Bunri University, 1314-1, Shido, Sanuki-city, Kagawa 769-2193, Japan

kohmoto@faculty.chiba-u.jp

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Octahomotetraoxacalix[4]arenes bearing long alkyl chains on their lower rim were prepared. Ester **4a** existed in a 1,2-alternate conformation in its crystal structure, which was examined by single-crystal X-ray diffraction analysis. To prepare liquid crystalline materials possessing calixarene moieties by self-assembling, carboxylic acid derivatives **5** were synthesized. Among them, **5c**, the octadecyloxy derivative, showed smectic liquid crystal phase. Homooxacalixarenes **5** also formed liquid crystal phases with longer layer distances when two equivalent moles of 1,2-ethylenediamine were added as a linker. These phases were investigated with X-ray diffraction, differential scanning calorimetry, and polarized optical microscopy.

### Introduction

Calixarenes and their derivatives are attractive compounds for host–guest chemistry and supramolecular chemistry. An easy access to their functionalizations at the upper and lower rims provides them suitable binding sites for guest encapsulation and molecular assembly.<sup>1</sup> Recent studies have shown the calixarene's specific self-assembling character<sup>2–5</sup> by means of

intermolecular forces, such as coordination bonds,<sup>2</sup> hydrogen bonds,<sup>3</sup> and ionic bonds.<sup>4</sup> Various types of superstructures based on calixarenes were reported, such as fibers,<sup>5</sup> micelles,<sup>6</sup> films,<sup>7</sup> and liquid crystals.<sup>5,8–12</sup>

<sup>‡</sup> Tokushima Bunri University.

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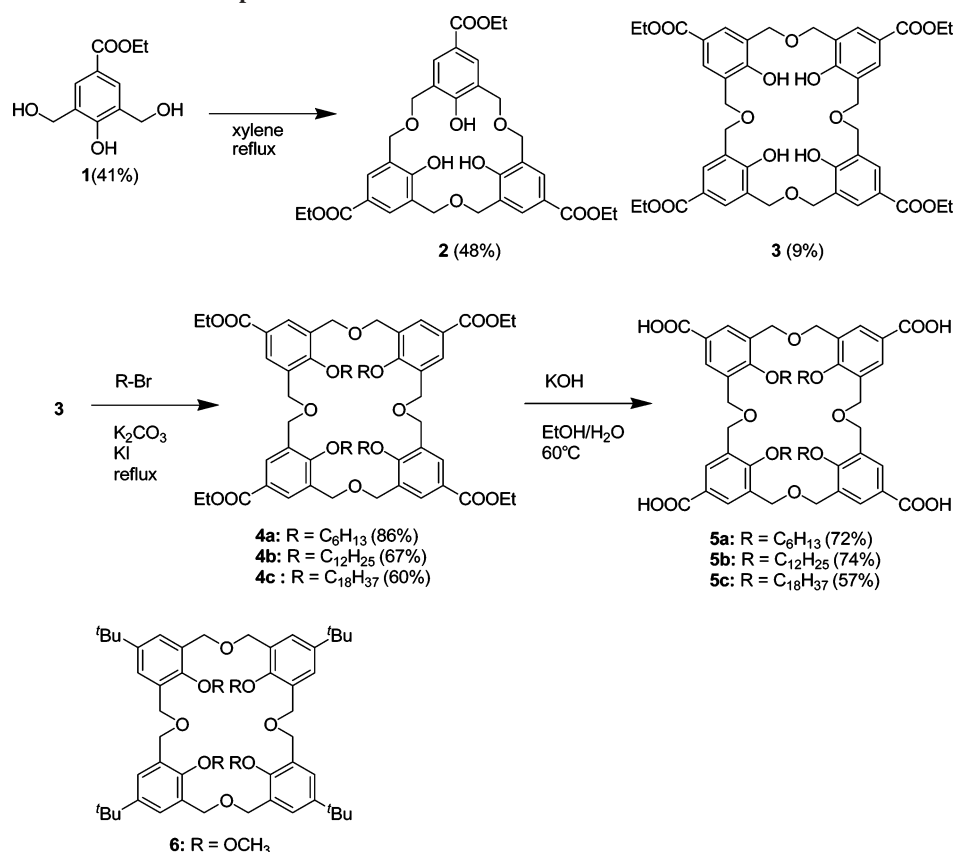
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## SCHEME 1. Synthetic Scheme for Compounds 5



Homooxacalixarenes are latent hosts since they have larger cavities and more conformational flexibility than ordinary calixarenes.<sup>2,13</sup> This conformational flexibility is useful to induce supramolecular system responding to stimulus. For example, Shinkai et al. reported that hexahomotrioxacalix[3]arenes were capable of encapsulating and releasing C<sub>60</sub> depending on the size of alkaline metal cations to be bound in their complexes.<sup>2</sup> In particular, octahomotetraoxacalix[4]arenes seem to be promising hosts since they have a large inner space for encapsulation of large guest molecules. However, their structures and properties were poorly studied due to their synthetic difficulties.<sup>14</sup>

In this paper, we report the synthesis of novel octahomotetraoxacalixarenes and investigation of the crystal structure and liquid crystallinity of them.

## Results and Discussion

**Synthesis.** Octahomotetraoxacalix[4]arenes **5a–c** were synthesized as shown in Scheme 1. Refluxing of **1**<sup>15</sup> in xylene, the

reported method for the preparation of hexahomotrioxacalix[3]arene **2**,<sup>16</sup> afforded the known **2** and the unknown octahomotetraoxacalix[4]arene **3** as a mixture. In their <sup>1</sup>H NMR spectra, the phenolic protons were observed at 9.1 and 8.9 ppm for **2** and **3**, respectively. Other protons appeared as almost identical patterns. Their mass spectra showed that the former was a trimer and the latter was a tetramer. Since some homoaxacalixarenes were reported to have slightly different solubility depending on their ring sizes,<sup>17</sup> we carried out the separation of **3** from **2** using the Soxhlet extractor with toluene. Flexible long-chain parts were introduced to **3** on its lower rim by O-alkylation. However, homoaxacalix[3]arene **2** was not O-alkylated because of its steric hindrance at the lower rim. Hydrolysis of O-alkylated compounds **4a–c** derived from **3** was carried out with KOH in EtOH/H<sub>2</sub>O solution at 60 °C to yield the corresponding tetraacids **5a–c**, respectively.

**Crystal Structure of Ester 4a.** To investigate the conformation of octahomotetraoxacalix[4]arene, we performed single-crystal X-ray diffraction analysis on ester **4a**. It was found that **4a** possessed the 1,2-alternate conformation in its crystal state (Figure 1). Only a few reports mentioned on the single-crystal X-ray structure of homodioxacalix[4]arene<sup>18</sup> and homotetraoxacalix[4]arenes.<sup>19</sup> Multiple weak intermolecular interactions, such as CH/π<sup>20</sup> and CH⋯O interactions,<sup>21</sup> operate to create the crystal packing. The molecules packed with a tilt angle of 19°

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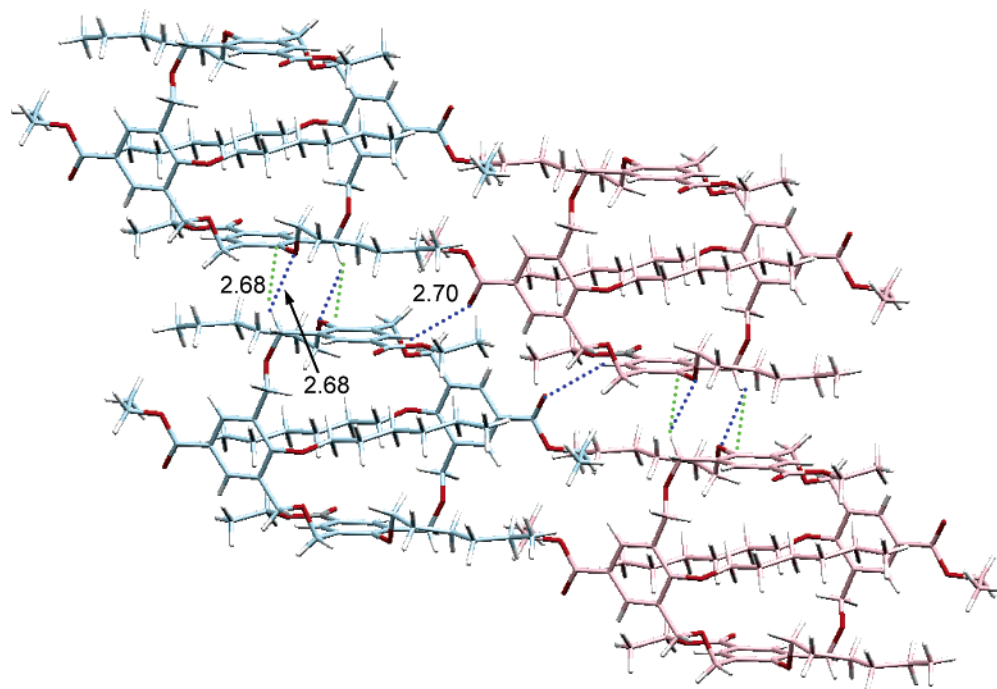
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**FIGURE 1.** Single-crystal X-ray structure of **4a**. Packing structure showing the intermolecular interactions within the layer (the molecules with the same color) and between layers (the molecules with different colors). Green and blue dotted lines indicate intermolecular CH/ $\pi$  and CH $\cdots$ O interactions, respectively. Distances are indicated in Å.

within the layers. Intermolecular CH/ $\pi$  interactions were also found between the layers (Figure 1). The distance of 2.68 Å was observed between the adjacent carbon atom of phenyl ring and one of the benzylic hydrogen atoms. The CH $\cdots$ O interaction (2.70 Å) was operated between the oxygen atom of ester carbonyl and one of the phenyl hydrogen atoms. As a whole, a cylindrical molecule packed in a layer owing to these intermolecular interactions. The molecules are packed in the direction of the *b*-axis creating layers. Intermolecular CH $\cdots$ O interactions (2.68 Å) were also observed between the benzylic hydrogen atoms and the phenoxy oxygen atom.

**Conformation of Ester Derivatives in Solution.** It is known that the nature of conformational isomerism for homooxalixarenes is more complicated than for calixarenes.<sup>22</sup> Generally, as the size of their annuli becomes larger, their conformational mobility increases. Unlike calix[4]arenes whose conformations can be deduced on the basis of their <sup>13</sup>C NMR chemical shifts,<sup>23</sup> no such a general rule has been reported for octahomotetraoxalix[4]arenes. Four main conformations, cone, partial cone, 1,2-alternate, and 1,3-alternate, were known for them. It was reported that the cone conformation was disfavored in

octahomotetraoxalix[4]arenes **6** based on the upfield shift of its OCH<sub>3</sub> signal in its <sup>1</sup>H NMR.<sup>24</sup> No direct information on the actually existing conformations has been available. Similarly, upfield shifts of the protons, OCH<sub>2</sub>R, of alkoxy groups were observed in our homooxalixarenes. These protons appeared at  $\delta$  3.49, 3.49, and 3.52 for **4a**, **4b**, and **4c**, respectively, in CDCl<sub>3</sub> at ambient temperature, which were about 0.4 ppm upfield with respect to the calculated standard value ( $\delta$  3.9). The results indicate that the cone conformations were also disfavored in our homooxalixarenes in solution at ambient temperature. The magnitude of the upfield shift is similar to that of **6**. The shielding of the alkoxy protons OCH<sub>2</sub>R could be caused by the adjacent phenyl rings in cylindrical 1,2- or 1,3-alternate conformations. As the length of the alkoxy chains becomes longer, broader proton signals were observed. Relatively sharp proton signals were observed for that of **4a** in CDCl<sub>3</sub> at ambient temperature. In contrast, those of **4b** and **4c** appeared as broad signals even at ambient temperature. Long alkoxy chains disturb the conformational mobility of them.

To survey further the conformations of octahomotetraoxalix[4]arenes in solution, we carried out a variable-temperature (VT) NMR study of them in CDCl<sub>3</sub>. Due to insolubility at low temperature, it was difficult to carry out a VT study of acid derivatives. Figure 2 shows the VT <sup>1</sup>H NMR spectra of the annulus (CH<sub>2</sub>OCH<sub>2</sub>), ester (COOCH<sub>2</sub>CH<sub>3</sub>), and alkoxy (OCH<sub>2</sub>-C<sub>5</sub>H<sub>11</sub>) methylene protons of **4a** in the temperature range from 295 to 223 K. All of these proton signals gradually became broad as the temperature went down. The annulus and alkoxy-methylene proton signals were split into two peaks at 223 K. The results clearly indicate that two conformations exist at this temperature. From the chemical shift of the splitting alkoxy-methylene protons which still appeared at upfield region, it is

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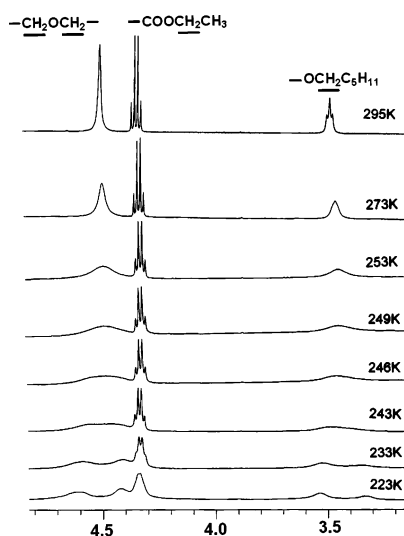
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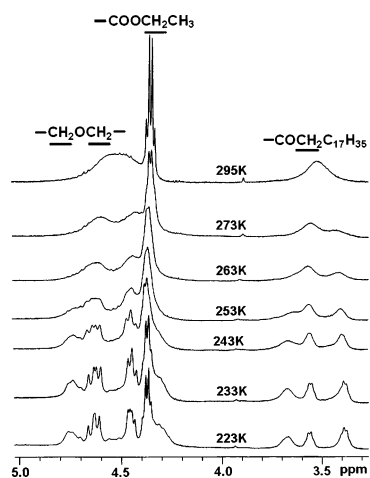
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**FIGURE 2.** Variable-temperature  $^1\text{H}$  NMR spectra of **4a** in  $\text{CDCl}_3$ . Parts of the spectra are presented.



**FIGURE 3.** Variable-temperature  $^1\text{H}$  NMR spectra of **4c** in  $\text{CDCl}_3$ . Parts of the spectra are presented.

reasonable to assume that these two conformations could be 1,2- and 1,3-alternate conformations. The coalescence temperature was ca. 246 K. Although we could not obtain sharp signals at low temperature, we roughly estimated that the free energy of activation for their conformational equilibrium was ca. 18.7 kcal/mol. To confirm the existence of two conformations at low temperature,  $^{13}\text{C}$  NMR of **4a** was recorded at 223K in  $\text{CDCl}_3$ . The annulus methylene carbon appeared at  $\delta$  66.49 at 293K were split into two broad peaks at 67.07 and 65.30. The results also showed the existence of two conformations and agreed with that of  $^1\text{H}$  NMR study.

The VT  $^1\text{H}$  NMR of **4c** showed rather complicated spectra (Figure 3). The broad signal of alkoxymethylene protons at 295 K split into two broad peaks and then became three peaks with decreasing temperature. The annulus methylene protons showed a complicated pattern. Several AB patterns could be seen which indicated the existence of the 1,2-alternate, cone, or partial cone conformations. The involvement of the 1,3-alternate conformation whose annulus methylene protons will appear as a singlet cannot be excluded due to the complexity of the spectra. The broad singlet of phenyl protons ( $\delta$  8.07 at 295 K) appeared as

**TABLE 1.** Phase Transition Behaviors of **5a** ( $^\circ\text{C}$ )

<b>5a</b>	Cr	$\xrightarrow{>200}$	decomp
<b>5b</b>	Cr	$\xrightarrow{>200}$	decomp
<b>5c</b>	Cr1	$\xrightarrow{106}$	SmX(1) <i>Form1</i>
		$\xleftarrow{99}$	
		$\xrightarrow{>100}$	
	Cr2	$\xrightarrow{101}$	SmX(2) <i>Form2</i>
		$\xleftarrow{92}$	
		$\xrightarrow{>200}$	decomp

<sup>a</sup> Key: Cr, crystalline state; SmX, smectic X phase, decomp, decomposition.

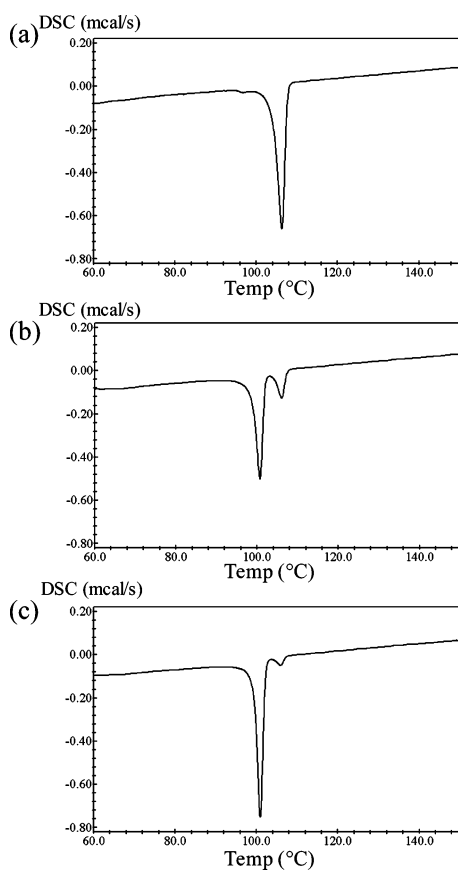
three broad signals at  $\delta$  8.16, 8.10, and 8.08 at 223 K, which indicated the existence of three conformers at this temperature.

**Liquid Crystallinity.** Liquid crystals were attractive materials from the viewpoint of controlling the orientation of molecules. Until now, only a few attempts were made to prepare arrays of calixarenes by applying liquid crystals.<sup>8–12</sup> In those cases, cone-shaped calixarenes piled up to create a columnar structure. Based on this X-ray crystallographic analysis of **4a**, we considered that the introduction of long alkyl chains on both sides of the calixarenes with 1,2-alternate structures might create cylindrical liquid crystalline molecules. For this purpose, we examined the properties of **4b** (R = dodecyl) and **4c** (R = octadecyl). However, they did not show liquid crystallinity. Therefore, we tried the second approach, creation of supramolecular liquid crystals with hydrogen bonding using tetraacids derivatives **5a–c**.<sup>25</sup> Since the two protons of  $\text{ArCH}_2\text{O}$  of ester **4** were observed equivalently in their  $^1\text{H}$  NMR spectra in  $\text{CDCl}_3$ , ester **4** was conformationally flexible in  $\text{CDCl}_3$ . During the equilibrium, two molecules of cone-shaped **5a–c** were expected to be assembled to create capsular molecules with hydrogen bondings among carboxylic groups.<sup>26</sup> Since these calixarenes had a rigid core and flexible alkoxy chains, liquid crystal phases could be formed.

From polarized optical microscopy (POM) observations, **5a** and **5b** did not show liquid crystal phases. In contrast, octadecyloxy derivative **5c** showed smectic liquid crystal phases (Table 1). To investigate the phase transition behavior, differential scanning calorimetry (DSC) was performed (Figure 4). Since **5c** decomposed over 200  $^\circ\text{C}$ , DSC was performed below 150  $^\circ\text{C}$ . On the first heating, an endothermic peak was observed at 106  $^\circ\text{C}$  for the phase transition from crystal to a smectic liquid crystal. In contrast to the first heating, a new endothermic peak appeared at 101  $^\circ\text{C}$  together with the peak of 106  $^\circ\text{C}$  on the second heating. The peak at 106  $^\circ\text{C}$  became significantly smaller than the corresponding one observed on the first heating. On the third heating, the peak at 106  $^\circ\text{C}$  was almost converted to the one at 101  $^\circ\text{C}$ . These results indicate that two forms of structures exist in **5c**. One form (Form 1) showed the phase transition at 106  $^\circ\text{C}$  on heating. The phase

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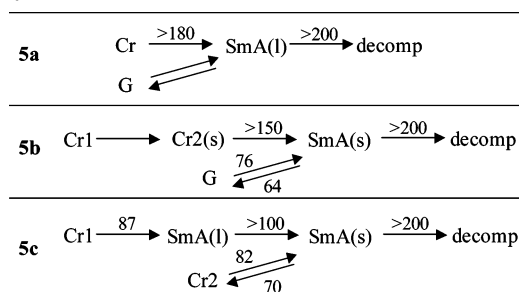


**FIGURE 4.** DSC behaviors of **5c** on (a) the first heating, (b) the second heating, and (c) the third heating (heating and cooling rates: 5 °C/min).

transition occurred at 101 °C in the other form (Form 2). Form 1 slowly converted to the thermodynamically stable Form 2 in a liquid crystal phase. After the fourth heating, Form 1 was completely converted to Form 2. Since this conversion was irreversible, it might be originated in the structural change occurred in **5c**.

Since these smectic phases were difficult to be identified by POM, we assigned them SmX(1) and SmX(2). The conversion from SmX(1) to SmX(2) was not obvious enough to be determined by POM. In order to investigate the structure of these forms, X-ray diffraction was performed. In the crystal phase, the peaks corresponding to the layer distances of 31 Å were observed in Form 1. On the other hand, the layer distances became 35 Å after several thermal cycles (Form 2). In the liquid crystal phase, both forms showed peaks corresponding to the smectic phase with layer distances of 34 and 37 Å for Form 1 and Form 2, respectively (Figure 4a,c). The mixture of Form 1 and Form 2 showed layer distances of both 34 and 38 Å (Figure 4b). The peaks corresponding to the molecular widths were observed at 10.7 and 9.5 Å in Form 1 and Form 2, respectively. These results of XRD analysis indicated that two forms certainly existed in **5c**. Out of four possible conformations; cone, partial cone, 1,2-alternate, and 1,3-alternate conformations, a partial cone could be eliminated since it has undesirable shape as a mesogen. Although it is hard to assign the conformations of these two forms at the moment, we postulate that the thermodynamically favorable Form 2 might be the hydrogen bonded dimer of cone based on the results of the experiment in the next section with 1,2-ethylenediamine additive. The layer

**TABLE 2.** Phase Transition Behaviors of **5** with 1,2-Ethylenediamine<sup>a</sup> (°C)



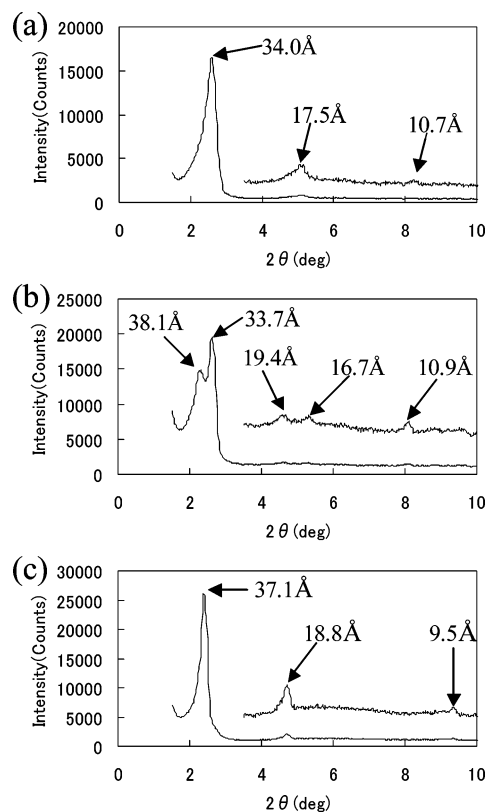
<sup>a</sup> Key: Cr, crystalline state; Cr(s), crystalline state with a shorter layer distance; SmA(l), smectic A phase with a longer layer distance; SmA(s), smectic A phase with a shorter layer distance; decomp, decomposition.

distance observed for Form 2 was similar to that obtained after elimination of 1,2-ethylenediamine by heating from the supramolecular liquid crystal of **5c** with 1,2-ethylenediamine (see the next section).

**Effect of 1,2-Ethylenediamine Additive as a Linker on Liquid Crystallinity.** We were also interested in their assemblies with the aid of flexible alkylidenediamine linkers. Since a carboxyl–amino ionic interaction is stronger than that of carboxyl–carboxyl,<sup>25</sup> **5a–c** are liable to be assembled with alkylidenediamines.<sup>27</sup> The phase transition behaviors of **5** with two equivalent moles of 1,2-ethylenediamine were shown in Table 2. In the case of **5c**, two types of smectic A phases were observed. The addition of the flexible diamine linker lowered the phase transition temperature. In XRD, the mixed sample of **5c** with two equivalent moles of 1,2-ethylenediamine showed the peaks corresponding to the layer distances of 51 Å (100) and 25 Å (200), respectively (Figure 6a). Peaks corresponding to shorter layer distances were observed at higher temperature (Figure 6b,c). These results can be interpreted in terms of the vaporization of 1,2-ethylenediamine at high temperature, which results in the formation of a new smectic A phase. These two types of smectic phases have broad peaks of ca. 9.7 Å corresponding to the molecular width. This molecular width was nearly equal to the one of Form 2 in absence of 1,2-ethylenediamine. This result indicated the phase similar to the one observed in Form 2 of neat **5c** was generated after the evaporation of 1,2-ethylenediamine from the originally formed 1,2-ethylenediamine-incorporated phase. However, the addition of longer alkylidenediamines, such as 1,3-diaminopropane and 1,4-diaminobutane, did not trigger a liquid crystal phase below 200 °C. Since alkylidenediamines with longer chain lengths decrease an intermolecular core–core interaction, homoacalixarene was not aligned.

Interestingly, an addition of 1,2-ethylenediamine to **5a** and **5b** resulted in the formation of liquid crystalline state with layer distances 28 and 31 Å, respectively, although neat **5a** and **5b** did not show liquid crystal phases. In the case of **5a**, smectic A phase with the long layer distance was observed without evaporation of 1,2-ethylenediamine. In the case of **5b**, a crystal phase (Cr1) with a longer layer distance (39 Å at 120 °C) slowly changed into another crystal phase (Cr2(s)) with a shorter layer distance (32 Å at 150 °C) due to the vaporization of 1,2-ethylenediamine from the mixture. The remaining **5b** showed smectic A phases with a shorter layer distance (31 Å at 180

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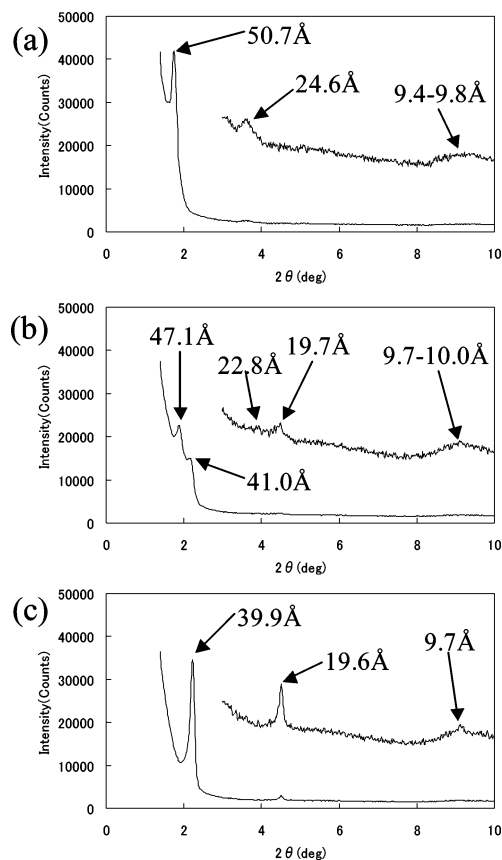
**FIGURE 5.** X-ray diffractions of **5c** of (a) Form 1 at 110 °C on the first heating, (b) the mixture of Form 1 and Form 2 at 100 °C, and (c) Form 2 at 103 °C.

°C). In these cases, 1,2-ethylenediamine plays a catalytic role to form the smectic liquid crystal phase. An addition of 1,2-ethylenediamine might assist the conformational fixation of cone conformation via the salt formation during equilibrium. The cone conformation thus formed was stable and did not revert to other conformations. These are schematically represented in Figure 7.

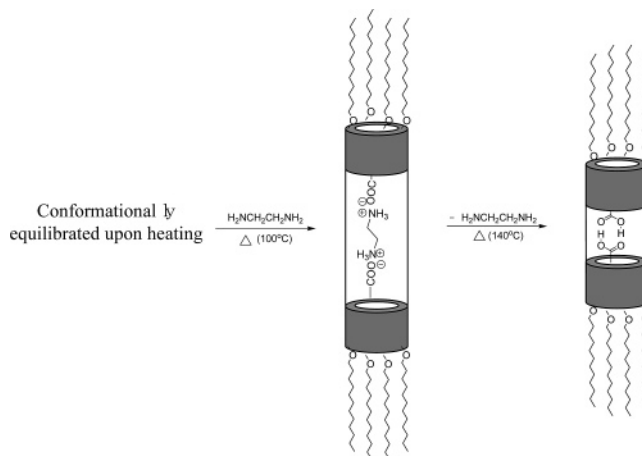
**Conclusion.** Octahomotetraoxacalix[4]arene tetraester **4a** existed in a 1,2-alternate conformation in its crystal. Its cone conformation was disfavored in solution. Calixarene tetraacid **5c** with a long alkyl chain ( $C_{18}H_{37}$ ) on its lower rim showed two types of smectic liquid crystal phases. The mixture of **5a–c** and 1,2-ethylenediamine showed smectic A phases via self-assembly. Investigation on inclusion of guest molecular in liquid crystal phases using homooxacalixarene is currently in progress in our laboratory. Encapsulation of functional guests by assembling may lead to the novel function reflecting the nature of inner guests.

## Experimental Section

**Synthesis of 2 and 3.** Compound **1** (3.93 g, 17.4 mmol) was refluxed in xylene (140 mL) for 1 day. The column packed with Molecular Sieves 4A was placed beneath a condenser to ensure dryness of the solvent. After cooling to room temperature, white powders of hexahomotrioxacalix[3]arene **2** and octahomotetraoxacalix[4]arene **3** were precipitated together. After the precipitate was washed with methanol, **2** and **3** were separated by extraction using Soxhlet extractor with toluene. Calixarene **2** (1.75 g) was obtained as a toluene extract, and **3** (0.356 g) was obtained as a remaining powder. **7,15,23-Tri(ethoxycarbonyl)-25,26,27-trihydroxy-2,3,10,11,18,19-hexahomo-3,11,19-trioxacalix[3]arene (2):**



**FIGURE 6.** XRD charts of **5c** with 1 equiv of 1,2-ethylenediamine at (a) 100 °C (b) 120 °C, and (c) 140 °C.



**FIGURE 7.** Schematic representation of the proposed conformational change of **5** with 1,2-ethylenediamine.

yield 48%; mp 225–226 °C;  $^1H$  NMR (500 MHz,  $CDCl_3$ )  $\delta$  1.37 (t, 9H), 4.35 (q, 6H), 4.76 (s, 12H), 7.86 (s, 6H), 9.19 (s, 3H); MS (FAB)  $m/z$  625 ( $MH^+$ ); IR (KBr)  $\nu$  3325, 2983, 2895, 1720, 1615, 1319, 1203, 1082, 1038, 765  $cm^{-1}$ . **7,15,23,31-Tetra(ethoxycarbonyl)-33,34,35,36-tetrahydroxy-2,3,10,11,18,19,26,27-octahomo-3,11,19,27-tetraoxacalix[4]arene (3):** yield 10%; mp 270 °C dec;  $^1H$  NMR (500 MHz,  $CDCl_3$ )  $\delta$  1.37 (t,  $J = 7.1$  Hz, 12H), 4.33 (q,  $J = 7.1$  Hz, 8H), 4.78 (s, 16H), 7.87 (s, 8H), 8.84 (s, 4H);  $^{13}C$  NMR (125.65 MHz,  $CDCl_3$ )  $\delta$  14.4, 60.8, 71.1, 122.0, 123.8, 131.8, 160.0, 166.0; MS (FAB)  $m/z$  833 [ $MH^+$ ]; IR (KBr)  $\nu$  3357, 2923, 1719, 1611, 1316, 1211, 1079, 1032, 767  $cm^{-1}$ . Anal. Calcd for  $C_{44}H_{48}O_{16}$ : C, 63.45; H, 5.81. Found: C, 63.47; H, 5.76.

**Typical Procedure for Synthesis of 4.** A suspension of **3** (0.105 g, 0.126 mmol), potassium carbonate (0.187 g, 1.35 mmol), and potassium iodide (0.241 g, 1.45 mmol) in acetone (25 mL) was stirred under reflux for 2 h. Then, 1-bromohexane (0.308 g, 1.86 mmol) was added to the resulting mixture and stirred for an additional 20 h under reflux. After the formed precipitate was filtered off, the filtrate was evaporated. The residue was purified by column chromatography on silica gel (*n*-hexane/ethyl acetate = 4:1) to afford **4a** as a white powder.

**7,15,23,31-Tetra(ethoxycarbonyl)-33,34,35,36-tetrahexyloxy-2,3,10,11,18,19,26,27-octahomo-3,11,19,27-tetraoxacalix[4]arene (4a):** yield 86%; mp 100–101 °C; <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 0.80 (t, *J* = 7.2 Hz, 12H), 1.05 (m, 16H), 1.12 (quin, *J* = 6.6 Hz, 8H), 1.33 (m, 8H), 1.39 (t, *J* = 7.0 Hz, 12H), 3.50 (t, *J* = 6.6 Hz, 8H), 4.36 (q, *J* = 7.2 Hz, 8H), 4.52 (s, 16H), 8.08 (s, 8H); <sup>13</sup>C NMR (125.65 MHz, CDCl<sub>3</sub>) δ 14.0, 14.3, 22.4, 25.4, 30.0, 31.6, 60.9, 66.6, 75.8, 126.0, 131.4, 132.0, 160.3, 166.0; MS (FAB) *m/z* 1191 [M + Na]<sup>+</sup>; IR (KBr) ν 2932, 1716, 1607, 1459, 1365, 1306, 1195, 1075, 1037 cm<sup>-1</sup>. Anal. Calcd for C<sub>68</sub>H<sub>96</sub>O<sub>16</sub>: C, 69.84; H, 8.27. Found: C, 69.92; H, 8.37.

**Crystallographic Data for 4a.** X-ray data were collected on a CCD detector by using MoKα radiation (λ = 0.71073 Å). The crystal structure was solved by direct methods SHELXS-97 and refined by full-matrix least-squares SHELXL-97.<sup>28</sup> All non-hydrogen atoms were refined anisotropically. All hydrogen atoms were included as their calculated positions: C<sub>68</sub>H<sub>96</sub>O<sub>16</sub>, *M* = 1169.45 g mol<sup>-1</sup>, triclinic, *P*-1, *a* = 9.7628(9) Å, *b* = 12.5244(11) Å, *c* = 13.9344(12) Å, α = 102.227(2)°, β = 94.988(2)°, γ = 99.295(2)°, *V* = 1630.3(3) Å<sup>3</sup>, *Z* = 1, *D*<sub>calcd</sub> = 1.191 Mg m<sup>-3</sup>, *T* = 150 K, μ = 0.084 mm<sup>-1</sup>, GOF on *F*<sup>2</sup> = 1.073, *R*<sub>1</sub> = 0.0715, w*R*<sub>2</sub> = 0.1973 (*I* > 2σ(*I*)).

**7,15,23,31-Tetra(ethoxycarbonyl)-33,34,35,36-tetradodecyloxy-2,3,10,11,18,19,26,27-octahomo-3,11,19,27-tetraoxacalix[4]arene (4b):** yield 67%; mp 48–50 °C; <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 0.89 (t, *J* = 7.0 Hz, 12H), 1.09–1.32 (m, 80H), 1.40 (t, *J* = 7.2 Hz, 12H), 3.49 (br, 8H), 4.35 (q, *J* = 7.2 Hz, 8H), 4.52 (br, 16H), 8.07 (s, 8H); <sup>13</sup>C NMR (125.65 MHz, CDCl<sub>3</sub>) δ 14.2, 14.5, 22.8, 25.9, 29.5, 29.6, 29.7, 29.8, 30.2, 32.1, 61.0, 66.7, 75.9, 126.1, 131.5, 132.2, 160.4, 166.1; MS (FAB) *m/z* 1528 [M + Na]<sup>+</sup>; IR (KBr) ν 2921, 2853, 1719, 1606, 1467, 1367, 1310, 1195, 1099, 1073, 1035 cm<sup>-1</sup>. Anal. Calcd for C<sub>92</sub>H<sub>144</sub>O<sub>16</sub>: C, 73.37; H, 9.64. Found: C, 73.30; H, 9.69. **7,15,23,31-tetra(ethoxycarbonyl)-33,34,35,36-tetra(octadecyloxy)-2,3,10,11,18,19,26,27-octahomo-3,11,19,27-tetraoxacalix[4]arene (4c):** yield 60%; mp. 48–49 °C; <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 0.88 (t, *J* = 6.9 Hz, 12H), 1.17–1.26 (m, 128H), 1.39 (t, *J* = 6.9 Hz, 12H), 2.85 (br, 8H), 4.35 (q, *J* = 6.8 Hz, 8H), 4.53 (br, 16H), 8.07 (s, 8H); <sup>13</sup>C NMR (125.65

MHz, CDCl<sub>3</sub>) δ 14.1, 14.4, 22.7, 25.9, 29.4, 29.5, 29.6, 29.70, 29.77, 29.82, 30.1, 31.9, 60.9, 66.7, 75.9, 126.1, 131.4, 132.1, 160.3, 166.0; MS (FAB) *m/z* 1864 [M+Na]<sup>+</sup>; IR (KBr) ν 2919, 2851, 1720, 1607, 1466, 1366, 1309, 1198, 1074, 1033, 771 cm<sup>-1</sup>; Anal. Calcd for C<sub>116</sub>H<sub>192</sub>O<sub>16</sub>: C, 75.61; H, 10.50. Found: C, 75.53; H, 10.17.

**Typical Procedure for Synthesis of 5.** An ethanol solution (15 mL) of **4a** (0.0526 g, 45.0 μmol) was heated at 60 °C. To this solution, aqueous solution (2 mL) of KOH (14%) was added and stirred at 60 °C for 7 h. After being cooled to room temperature, the reaction mixture was neutralized with 1 N HCl aqueous solution. The white powder precipitated was purified by reprecipitation with THF/hexane. **7,15,23,31-Tetra(hydroxycarbonyl)-33,34,35,36-tetrahexyloxy-2,3,10,11,18,19,26,27-octahomo-3,11,19,27-tetraoxacalix[4]arene (5a):** yield 72%; mp >200 °C dec; <sup>1</sup>H NMR (500 MHz, DMSO-*d*<sub>6</sub>) δ 0.80 (t, *J* = 7.3 Hz, 12H), 1.01 (m, 16H), 1.09 (quin, *J* = 6.9 Hz, 8H), 1.29 (m, 8H), 3.49 (br, 8H), 4.54 (s, 16H), 8.02 (s, 8H), 12.86 (br); <sup>13</sup>C NMR (125.65 MHz, DMSO-*d*<sub>6</sub>) δ 13.9, 21.9, 24.9, 29.5, 31.1, 65.7, 75.1, 126.2, 131.3, 131.5, 159.5, 166.7; MS (FAB) *m/z* 1079 [M + Na]<sup>+</sup>; IR (KBr) ν 3447, 2931, 2860, 1690, 1607, 1430, 1377, 1303, 1211, 1078 cm<sup>-1</sup>. Anal. Calcd for C<sub>60</sub>H<sub>80</sub>O<sub>16</sub>: C, 68.16; H, 7.63. Found: C, 68.16; H, 7.47. **7,15,23,31-Tetra(hydroxycarbonyl)-33,34,35,36-tetradodecyloxy-2,3,10,11,18,19,26,27-octahomo-3,11,19,27-tetraoxacalix[4]arene (5b):** yield 74%; mp >200 °C dec; <sup>1</sup>H NMR (500 MHz, DMSO-*d*<sub>6</sub>) δ 0.91 (t, *J* = 7.0 Hz, 12H), 1.06–1.34 (m, 80H), 3.52 (br, 8H), 4.53 (s, 16H), 8.00 (s, 8H); <sup>13</sup>C NMR (125.65 MHz, DMSO-*d*<sub>6</sub>) δ 13.9, 22.1, 25.2, 28.7, 28.9, 29.0, 29.6, 31.3, 65.7, 75.0, 126.4, 131.1, 131.5, 159.4, 166.7; MS (FAB) *m/z* 1416 [M + Na]<sup>+</sup>; IR (KBr) ν 3449, 2924, 2853, 1689, 1607, 1430, 1378, 1304, 1208 1078 cm<sup>-1</sup>. Anal. Calcd for C<sub>84</sub>H<sub>128</sub>O<sub>16</sub>: C, 72.38; H, 9.26. Found: C, 72.06; H, 9.24. **7,15,23,31-Tetra(hydroxycarbonyl)-33,34,35,36-tetra(octadecyloxy)-2,3,10,11,18,19,26,27-octahomo-3,11,19,27-tetraoxacalix[4]arene (5c):** yield 57%; mp >200 °C dec; <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 0.88 (t, *J* = 7.0 Hz, 12H), 1.27–1.35 (m, 112H), 1.54 (quin, *J* = 7.3 Hz, 8H), 1.82 (quin, *J* = 7.0 Hz, 8H), 3.78 (t, *J* = 6.4 Hz, 8H), 4.41 (d, *J* = 12.8 Hz, 8H), 4.50 (d, *J* = 12.8 Hz, 8H), 7.89 (s, 8H); <sup>13</sup>C NMR (125.65 MHz, CDCl<sub>3</sub>) δ 14.4, 23.0, 26.5, 29.6, 29.95, 29.99, 30.01, 30.04, 30.06, 30.07, 30.10, 30.12, 30.7, 32.2, 67.5, 75.7, 125.2, 131.6, 132.4, 159.7, 172.2; MS (ESI) *m/z* 1731 [MH]<sup>+</sup>; IR (KBr) ν 3450, 2917, 2851, 1690, 1607, 1467, 1430, 1377, 1304, 1210, 1079 cm<sup>-1</sup>. Anal. Calcd for C<sub>108</sub>H<sub>176</sub>O<sub>16</sub>: C, 74.96; H, 10.25. Found: C, 75.05; H, 10.17.

**Supporting Information Available:** Copies of <sup>1</sup>H NMR and <sup>13</sup>C NMR spectroscopic data of **3**, **4a–c**, and **5a–c**, ORTEP diagram of **4a**, and crystallographic data of **4a** (CIF). This material is available free of charge via the Internet at <http://pubs.acs.org>.

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