

SYNTHESIS OF CROWNOPHANE POSSESSING PYRIDINE MOIETIES ON THE AROMATIC NUCLEI (PYRIDINE-LARIAT CROWNOPHANE): A CROWNOPHANE EXHIBITING PERFECT SELECTIVITY TOWARD Ag<sup>+</sup>

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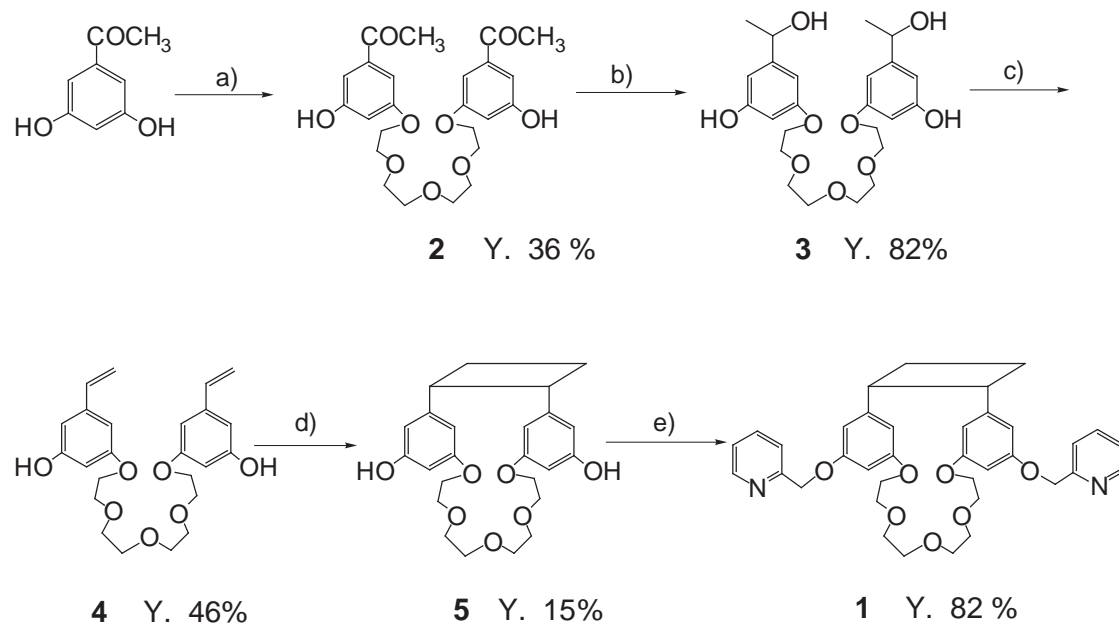
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**Abstract**-A novel crown compound with two hydroxy groups on the aromatic nuclei was conveniently prepared by means of intramolecular [2 + 2] photocycloaddition of styrene derivatives. It was readily converted to the title compound (**1**). In the liquid-liquid extraction of heavy metal cations, **1** showed perfect selectivity and high efficiency toward Ag<sup>+</sup>. From ESI-MS analysis, the compound was found to form a 1:1 with Ag<sup>+</sup> ion in MeCN-H<sub>2</sub>O homogeneous system.

It has been clarified that conventional crownphanes show unique characteristics on host-guest interaction with many kinds of metal cations and organic compounds in organic media.<sup>1</sup> We have prepared prototypical crownphanes conveniently and efficiently by the intramolecular [2 + 2] photocycloaddition of styrene derivatives possessing oligo(oxyethylene) linkage.<sup>2</sup> This cyclization method has been applied to synthesis of thia-<sup>3</sup> and aza-crown compounds.<sup>4</sup> Pyridine rings arranged in an appropriate position of host molecules have been found to exhibit interesting complexing behavior.<sup>5-9</sup> We have found that crownphanes with a pyridine moiety in the polyether linkages showed high affinity toward heavy metal cations such as Ag<sup>+</sup> and Pb<sup>2+</sup> ions.<sup>10</sup> We have also found that lariat crownphanes having pyridine residues on the polyether side chains showed the specific affinity toward heavy metal cations.<sup>11,12</sup> In this communication, we describe the synthesis and complexing properties of crownphane possessing pyridine moieties on the aromatic nuclei (pyridine-lariat crownphane).

Pyridine-lariat crownphane (**1**) was prepared by the sequence shown in Scheme 1. Thus, compound (**2**) was obtained from etherification of 3',5'-dihydroxyacetophenone with tetraethylene glycol ditosylate in moderate yield. Compound (**3**) was prepared by reduction of **2** and then converted to **4** by using acid catalyst (KHSO<sub>4</sub>) in DMSO. Crownphane possessing two hydroxyl groups (**5**) was synthesized by the

photoreaction.<sup>2</sup> By conventional reaction with picolyl chloride in the presence of NaH, **5** was converted to the target ionophore (**1**) in good yield. Analytical data of new compounds prepared are given.<sup>13</sup>



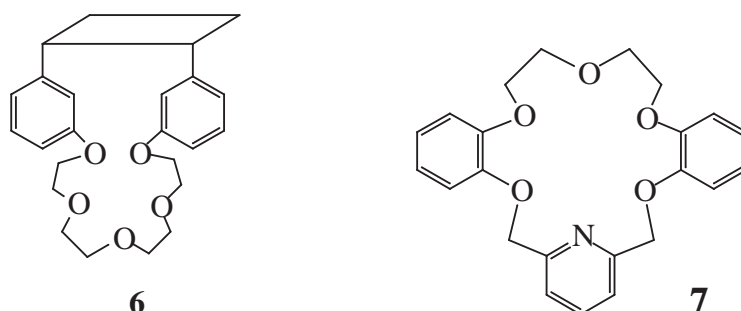
a)  $\text{Ts}(\text{C}_2\text{H}_4\text{O})_4\text{Ts}$ ,  $\text{K}_2\text{CO}_3/\text{DMF}$ . b)  $\text{NaBH}_4/\text{EtOH}$ . c)  $\text{KHSO}_4/\text{DMSO}$ . d)  $h\nu (>280 \text{ nm})/\text{MeCN}$ . e) 2-chloromethylpyridine hydrochloride,  $\text{NaH}/\text{THF-DMF}$ .

Scheme 1. Preparation of pyridine lariat crownophane (**1**).

Table 1. Extraction of heavy metal cations with ligands

Ligand	Extractability (%) <sup>a</sup>							
	$\text{Ag}^+$	$\text{Pb}^{2+}$	$\text{Cu}^{2+}$	$\text{Mn}^{2+}$	$\text{Zn}^{2+}$	$\text{Ni}^{2+}$	$\text{Co}^{2+}$	$\text{Fe}^{3+}$
<b>1</b>	78(4.2)	0(5.0)	0(4.2)	0(6.1)	0(5.3)	0(6.9)	0(7.1)	0(1.7)
<b>5</b>	2(4.1)	0(4.9)	0(4.3)	0(6.2)	0(5.4)	0(6.8)	0(7.1)	0(1.7)
<b>6</b>	0(4.1)	0(5.0)	0(4.2)	0(6.3)	0(5.5)	0(6.9)	0(7.0)	0(1.7)
<b>7</b>	59(5.5)	10(5.6)	0(4.1)	0(6.3)	2(6.2)	0(6.7)	0(6.9)	0(1.6)

a) Extraction conditions: Aq. phase (5 mL),  $[\text{metal nitrate}] = 1.0 \times 10^{-1} \text{ mol dm}^{-3}$ ; Org. phase,  $\text{CH}_2\text{Cl}_2$  (5 mL),  $[\text{ligand}] = 1.0 \times 10^{-4} \text{ mol dm}^{-3}$ ; at *ca.* 20 °C, shaken for 1 h. The values were based on the concentration of the crown compounds. Values in parentheses were equilibrium pH of aqueous phase. Reproducibility was  $\pm 15\%$  which was the average value obtained from three independent runs.



Pyridine-lariat ether (**1**) obtained were used as a extractant for heavy metal cations in a liquid-liquid system. Results are summarized in Table 1 with reference metacrownphanes (**4** and **6**) and dibenzopyridino-18-crown-6 (**7**). Both **4** and **6** hardly extracted any heavy metal cations examined. Pyridine-lariat crownophane (**1**) exclusively extracted  $\text{Ag}^+$  ion with high efficiency, which was higher than that of **7**.

From the frame work investigation using space-filling model, the cavity of the crownophane is just fitted to the cation and the side arms are thought to be able to act cooperatively for incorporating the metal cation into the cavity.

This cooperation was clarified by  $^{13}\text{C}$  NMR measurement. As shown in Figure 1, the chemical shift of pyridine  $\alpha$ -carbon and that of methylene carbon attached to the phenolic oxygen considerably changed with increasing the amount of  $\text{AgClO}_4$  added to the host solution, but the titration curve was not reached to a plateau within the observation, indicating a difficulty in determining exact stoichiometric relationships between the host compound and  $\text{Ag}^+$  ion in the complexation by this method.

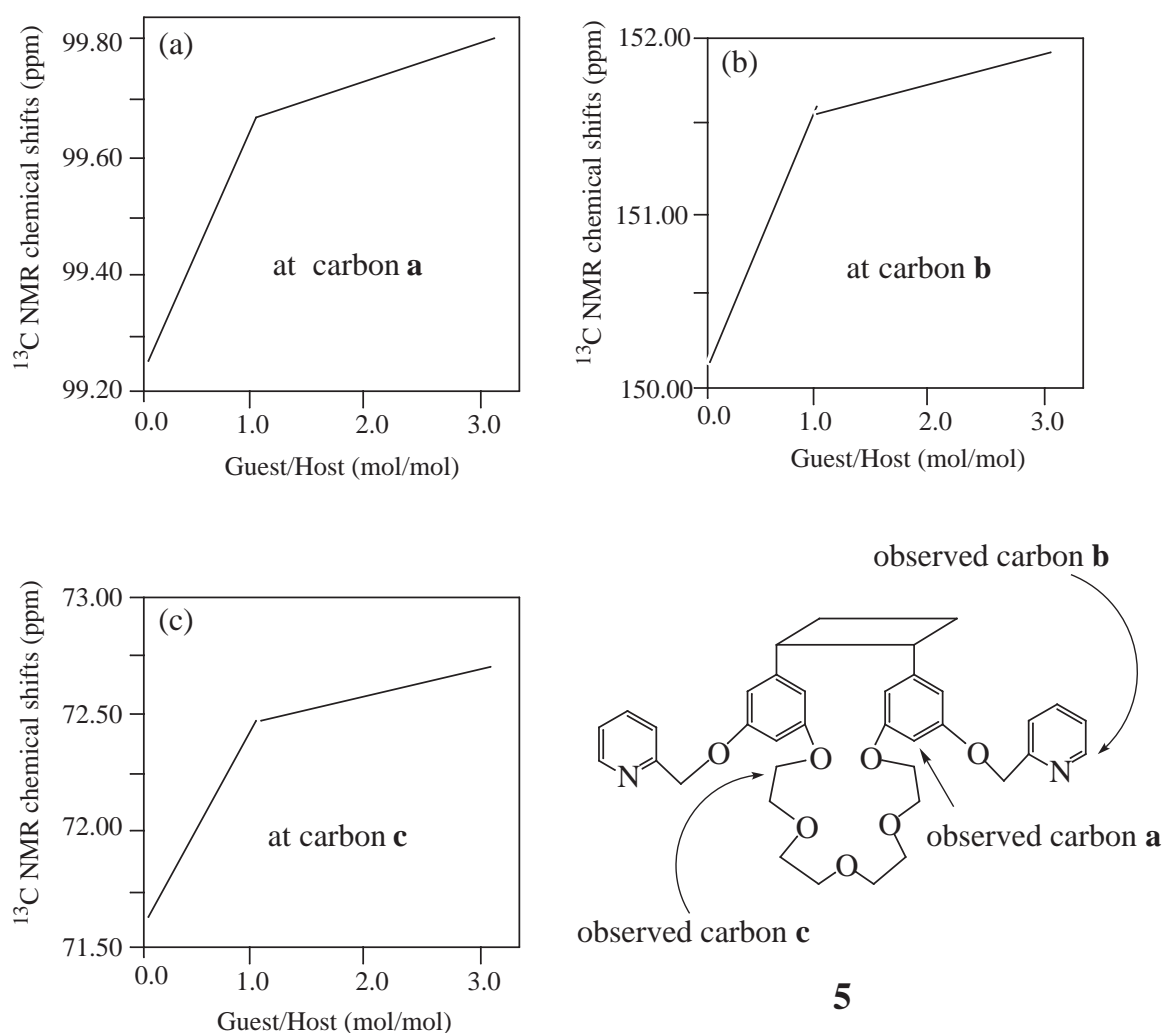


Figure 1.  $\text{Ag}^+$ -induced changes of  $^{13}\text{C}$  NMR chemical shifts at aromatic carbons indicated. Observed in  $\text{MeCN-}d_3$ .

In order to make the complexing behavior of **5** to  $\text{Ag}^+$  more clear, we investigated the interaction between **5** and  $\text{Ag}^+$  ion in MeCN- $\text{H}_2\text{O}$  (1:1) by employing ESI-MS (Figure 2). It was clarified that **5** almost quantitatively formed 1:1 (host/guest) complexes with  $\text{Ag}^+$  ion, because no peak was observed at  $\text{M}^+$  mass number.

In conclusion, we found that the crownphane lariat ether showed extraordinarily high efficiency and selectivity toward  $\text{Ag}^+$  ion. The complex from the host compound and  $\text{Ag}^+$  ion seemed to form quantitatively in homogeneous solution.

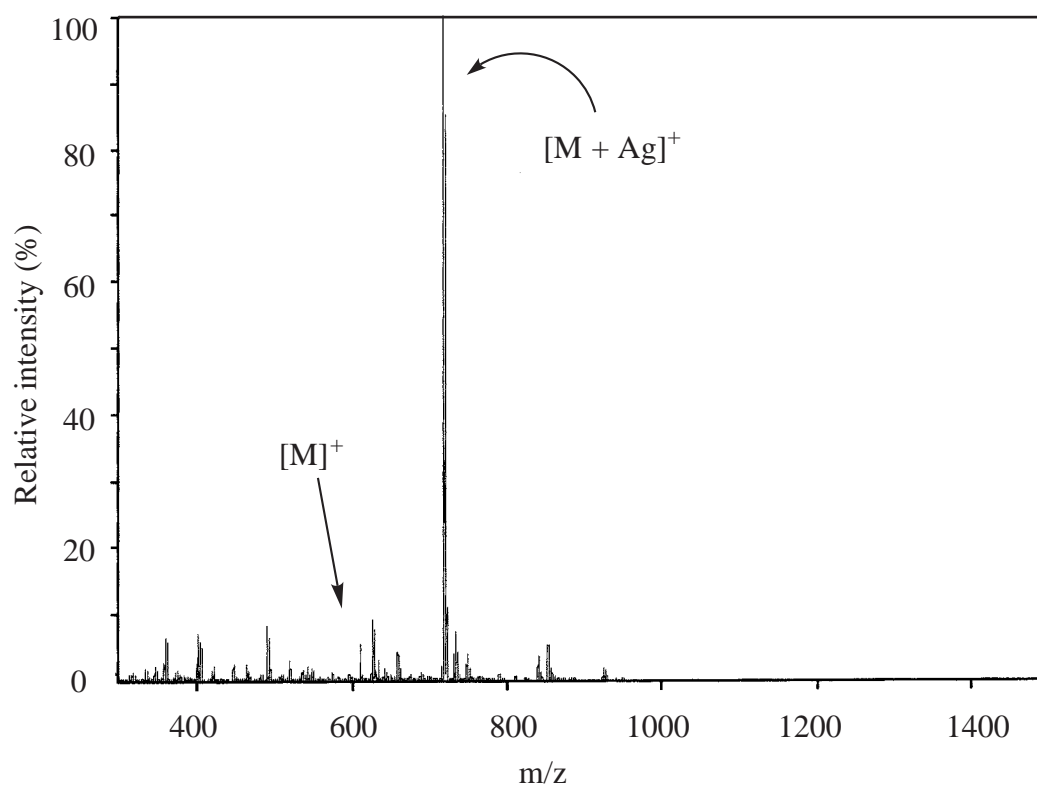


Figure 2. ESI-MS spectrum of **5** in 1:1 (v/v) MeCN- $\text{H}_2\text{O}$  containing  $\text{AgClO}_4$ .

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13. Analytical and spectroscopic data are shown in the following. **2**: white solid (mp 36.5-37.5 °C, hexane-ethanol); <sup>1</sup>H NMR (CDCl<sub>3</sub>, 500 MHz) δ=6.11 (6H, s), 5.73 (s, 2H), 3.88 (6H, s), 3.78 (4H, m), 3.67 (8H, m), 2.36 (4H, m); ESI-MS m/z 431.4 ([M + H]<sup>+</sup>). **3**: transparent liquid; <sup>1</sup>H NMR (DMSO-*d*<sub>6</sub>, 500 MHz) δ=9.24 (2H, s), 6.31 (4H, d, J=12.5), 6.14 (2H, s), 5.00 (2H, s), 4.52 (2H, m), 3.97 (4H, m), 3.68 (4H, m), 3.56 (8H, m). **4**: white solid (mp 94.5-95.5 °C, hexane-ethanol); <sup>1</sup>H NMR (CDCl<sub>3</sub>, 500 MHz) δ=7.26 (2H, s), 6.57 (2H, dd, J=16.6 and 10.8), 6.52 (4H, m), 6.41 (2H, s), 5.67 (2H, d, J=16.6), 5.21 (2H, d, J=10.8), 4.09 (4H, m), 3.80 (4H, m), 3.71 (4H, m), 3.67 (4H, m). **5**: white solid (mp 36.5-37.5 °C, hexane-ethanol); <sup>1</sup>H NMR (CDCl<sub>3</sub>, 500 MHz) δ=6.11 (6H, s), 5.73 (s, 2H), 3.88 (6H, s), 3.78 (4H, m), 3.67 (8H, m), 2.36 (4H, m); ESI-MS m/z 431.4 ([M + H]<sup>+</sup>). **1**: pale yellow transparent liquid; <sup>1</sup>H NMR (CDCl<sub>3</sub>, 500 MHz) δ=8.56 (2H, d, J=4.6), 7.65 (2H, t, J=7.6), 7.38 (2H, d, J=7.7), 7.17 (2H, m), 6.27 (4H, d, J=6.7), 5.06 (4H, s), 3.86 (6H, m), 3.78 (4H, m), 3.66 (8H, m), 2.37 (4H, m); ESI-MS m/z 612.3 (M<sup>+</sup>).