

UNSATURATED CROWN ETHERS : STILBENO-CROWN ETHERS<sup>1)</sup>

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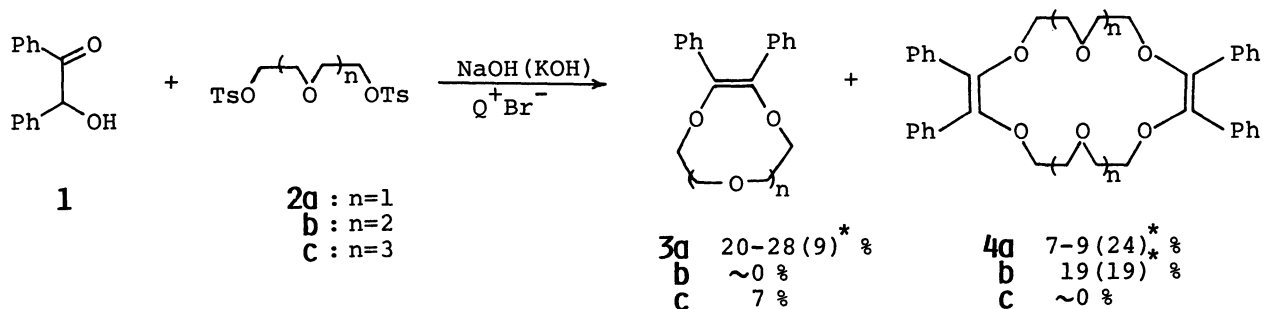
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Stilbenocrown ethers **3a,c** and **4a,b** were synthesized in a cyclization reaction of benzoin with oligoethylene glycol ditosylates (**2a-c**) under a phase-transfer condition. Extractions of aqueous alkali picrates ( $\text{Na}^+$ - $\text{Cs}^+$ ) were examined with the distilbenocrown ethers **4a,b**, the partially-hydrogenated tetraphenylcrown ethers **6a,b**, and the fully-hydrogenated tetracyclohexylcrown ethers **7a,b**.

Recent trends are the syntheses of highly functionalized crown ethers. Of these, unsaturated crown ethers containing C=C double bond(s) in the ring are of our special interest in view of the coexistence of a soft  $\pi$ -bond and a hard O atom, the increased rigidity due to the fixed O-C=C-O linkage, and the presence of the prochiral and UV-absorbing double bond. In spite of the versatile synthesis of some unsaturated crown ethers carrying a stilbene chromophore by Merz,<sup>2)</sup> further applications of the method to higher homologs have not been reported so far.<sup>3)</sup>

In the present communication, we wish to report extended syntheses of some new stilbenocrown ethers and the corresponding saturated crown ethers, and comparative extraction studies on both the unsaturated and the saturated crown ethers.

Syntheses of Stilbenocrown Ethers. Stilbeno-9-crown-3 (**3a**), stilbeno-15-crown-5 (**3c**), distilbeno-18-crown-6 (**4a**), and distilbeno-24-crown-8 (**4b**) were synthesized from benzoin (**1**) and di-, tri-, or tetraethylene glycol ditosylate (**2a-c**) under similar phase-transfer conditions described by Merz.<sup>2)</sup> To a benzene solution (600 ml) of equimolar amounts of benzoin **1** (0.08 mol) and the ditosylate **2** (0.08 mol) containing tetrabutyl- or hexadecyltrimethylammonium bromide (400 mg) was added a 50% aqueous sodium or potassium hydroxide solution (80 ml).<sup>4)</sup> The mixture was stirred at 70-78°C for ca. 15 h, cooled, poured into water, and extracted twice with benzene.

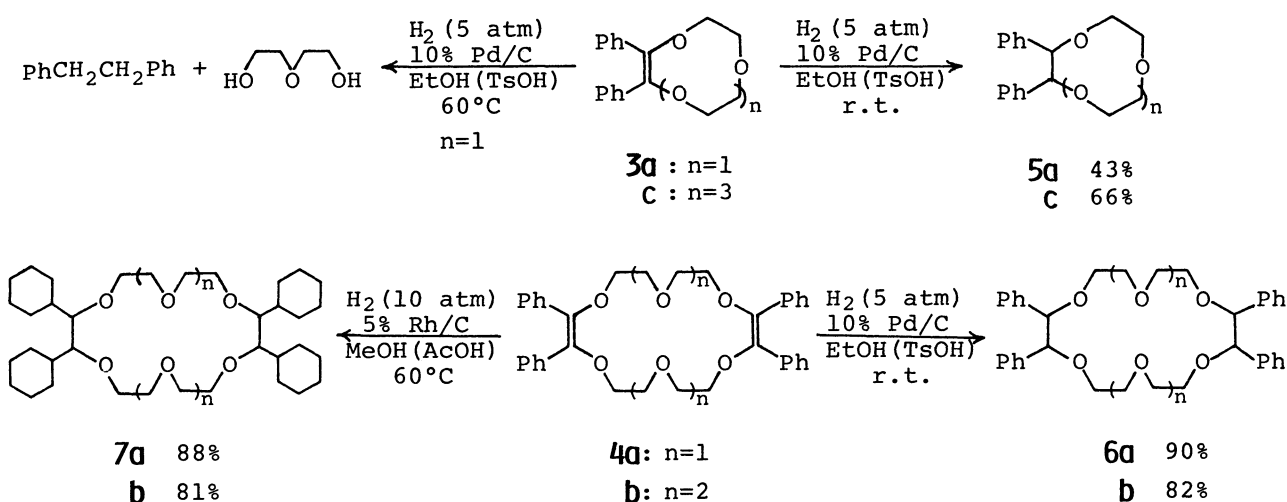


\*Yields for reaction with KOH as a base.

A yellow oil obtained after work-up was subjected to column chromatography over silica gel to give pure crown ether(s). Isolated yields were relatively low.

The structures of the crown ethers rest on the following data. Stilbeno-9-crown-3 (**3a**): mp 84.0-84.5°C (lit. 78°C<sup>2</sup>); m/z (70 ev) 282 (M<sup>+</sup>); IR (KBr) 1630 (C=C), 1260 (=C-O-C), 1110 (C-O-C) cm<sup>-1</sup>; UV (⊙<sub>H</sub>, log ε) 305 (4.01), 245 (sh. 3.87) nm; <sup>1</sup>H NMR (CDCl<sub>3</sub>, TMS) δ 6.97 (br. s, 10H, Ph), 4.20 (t, 4H, OCH<sub>2</sub>), 3.87 (t, 4H, OCH<sub>2</sub>); <sup>13</sup>C NMR (CDCl<sub>3</sub>, TMS) δ 142.0 (s, PhC=), 137.8 (s), 131.1 (d), 129.0 (d), 128.5 (d), 73.2 (t), 72.0 (t). Stilbeno-15-crown-5 (**3c**): mp 75.5-76.5°C; m/z 370 (M<sup>+</sup>); IR 1640 (C=C), 1260 (=C-O-C), 1140 (C-O-C) cm<sup>-1</sup>; UV (CH<sub>3</sub>CN) 298 (3.99), 243 (sh., 4.07) nm; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.17 (s, 10H, Ph), 3.82, 3.78 (s, 16H); <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 144.0 (s, PhC=), 136.2 (s), 131.1 (d), 129.2 (d), 128.8 (d), 72.3 (t), 71.7 (t), 71.2 (t). Distilbeno-18-crown-6 (**4a**): mp 174-176°C (lit. 173-175°C<sup>2</sup>); m/z 564 (M<sup>+</sup>); IR 1625 (C=C), 1270 (=C-O-C), 1100 (C-O-C) cm<sup>-1</sup>; UV (CH<sub>2</sub>Cl<sub>2</sub>) 297 (4.34), 245 (sh., 4.24) nm; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.00 (br. s, 20H, Ph), 3.84 (br. s, 16H, OCH<sub>2</sub>); <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 143.6 (s, PhC=), 136.3 (s), 131.1 (d), 129.0 (d), 128.7 (d), 71.3 (t). Distilbeno-24-crown-8 (**4b**): mp 133.5-134.5°C; m/z 652 (M<sup>+</sup>); IR 1620 (C=C), 1260 (=C-O-C), 1100 (C-O-C) cm<sup>-1</sup>; UV (CH<sub>3</sub>CN) 297 (4.29), 243 (sh., 4.13) nm; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.00 (br. s, 20H, Ph), 3.83 (br. s, 24H, OCH<sub>2</sub>); <sup>13</sup>C NMR (CDCl<sub>3</sub>) δ 143.6 (s, PhC=), 136.5 (s), 131.0 (d), 129.0 (d), 128.6 (d), 72.0 (t), 71.8 (t), 71.3 (t).

Hydrogenation of Stilbenocrown Ethers. Hydrogenation over Pd/C was first examined. After several attempted hydrogenations under various conditions, double bond of the stilbenocrown ethers **3a**, **3c**, **4a**, and **4b** was selectively hydrogenated over 10% Pd/C in ethanol or ethanol-benzene solution containing a trace amount of p-toluenesulfonic acid at room temperature at a hydrogen pressure of 5 atm to yield 2,3-diphenyl-9-crown-3 (**5a**), 2,3-diphenyl-15-crown-5 (**5c**), 2,3,11,12-tetraphenyl-18-crown-6 (**6a**), and 2,3,14,15-tetraphenyl-24-crown-8 (**6b**), respectively.<sup>5</sup> A similar hydrogenation of **3a** at 60°C merely gave the hydrogenolysis products, i.e. 1,2-diphenylethane and diethylene glycol.



The following data confirm the structures of the hydrogenated products.

2,3-Diphenyl-9-crown-3 (**5a**): mp 100-102°C; m/z 284 (M<sup>+</sup>); IR 1100 (C-O-C) cm<sup>-1</sup>; UV (CHCl<sub>3</sub>) 257 (2.66) nm; <sup>1</sup>H NMR (CDCl<sub>3</sub>) δ 7.07 (br. s, 10H, Ph), 4.97 (s, 2H, PhCH), 3.94 (br. s, 8H, OCH<sub>2</sub>);

$^{13}\text{C}$  NMR( $\text{CDCl}_3$ )  $\delta$  139.6(s), 128.6(d), 86.2(d, PhCH), 77.3(t), 72.6(t). 2,3-Diphenyl-15-crown-5 (5c):  $m/z$  372( $\text{M}^+$ ); IR 1110(C-O-C)  $\text{cm}^{-1}$ ; UV( $\text{CHCl}_3$ ) 257(2.60)nm;  $^1\text{H}$  NMR( $\text{CDCl}_3$ )  $\delta$  7.27(br.s, 10H), 4.77(s, 2H, PhCH), 3.5-3.8(m, 16H);  $^{13}\text{C}$  NMR( $\text{CDCl}_3$ )  $\delta$  138.4(s), 129.6(d), 128.7(d), 84.6(d, PhCH), 71.7(t), 69.8(t). 2,3,11,12-Tetraphenyl-18-crown-6 (6a): mp 177.5-178.0°C;  $m/z$  568( $\text{M}^+$ ); IR 1100(C-O-C)  $\text{cm}^{-1}$ ; UV( $\text{CHCl}_3$ ) 258(2.96)nm;  $^1\text{H}$  NMR( $\text{CDCl}_3$ )  $\delta$  7.00(br.s, 20H), 4.65(s, 4H, PhCH), 3.54(br.s, 16H);  $^{13}\text{C}$  NMR( $\text{CDCl}_3$ )  $\delta$  138.7(s), 129.7(d), 128.8(d), 86.3(d, PhCH), 71.6(t), 69.7(t). 2,3,14,15-Tetraphenyl-24-crown-8 (6b): mp 102-104.5°C;  $m/z$  656( $\text{M}^+$ ); IR 1100(C-O-C)  $\text{cm}^{-1}$ ; UV( $\text{CHCl}_3$ ) 258(2.90)nm;  $^1\text{H}$  NMR( $\text{CDCl}_3$ )  $\delta$  7.00(br.s, 20H), 4.47(s, 4H, PhCH), 3.43(br.s, 24H);  $^{13}\text{C}$  NMR( $\text{CDCl}_3$ )  $\delta$  139.8(s), 130.9(d), 129.3(d), 128.7(d), 86.5(d, PhCH), 71.7(t), 70.0(t).

Simultaneous double-bond and nuclear hydrogenations of 4 were successfully performed over Rh/C catalyst(Engelhard Inc.).<sup>6)</sup> The distilbenocrown ethers 4a and 4b were fully hydrogenated over 5% Rh/C in methanol containing 10% acetic acid at 60°C at a hydrogen pressure of 10 atm to give 2,3,11,12-tetracyclohexyl-18-crown-6 (7a) and 2,3,14,15-tetracyclohexyl-24-crown-8 (7b), respectively.

The saturated crown ethers 7 were identified on the basis of the following spectral data. 2,3,11,12-Tetracyclohexyl-18-crown-6 (7a):<sup>7)</sup> mp 82-85°C;  $m/z$  592( $\text{M}^+$ ); IR 1120(C-O-C)  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR( $\text{CDCl}_3$ )  $\delta$  3.68(br.s, 16H), 3.17(d, 4H), 2.1(m, 4H), 0.6-1.9(m, 40H);  $^{13}\text{C}$  NMR( $\text{CDCl}_3$ )  $\delta$  87.1(d), 72.1(t), 41.1(d), 32.2(t), 30.9(t), 27.8(t). 2,3,14,15-Tetracyclohexyl-24-crown-8 (7b):<sup>7)</sup> mp 67-70°C;  $m/z$  680( $\text{M}^+$ ); IR 1110(C-O-C)  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR( $\text{CDCl}_3$ )  $\delta$  3.67(br.s, 24H), 3.17(d, 4H), 2.1(m, 4H), 0.6-1.9(m, 40H);  $^{13}\text{C}$  NMR( $\text{CDCl}_3$ )  $\delta$  87.2(d), 72.1(t), 40.9(d), 32.2(t), 30.5(t), 27.8(t). Both the saturated crown ethers did not show any absorptions at wavelengths >220 nm.

In order to evaluate the cation-binding abilities of the unsaturated and saturated crown ethers synthesized, extractions of aqueous alkali picrates were carried out<sup>8)</sup> with chloroform solutions of the distilbeno-, tetraphenyl-, and tetracyclohexyl crown ethers 4, 6, and 7 along with their parent or analogous crown ethers,

Table Extraction of some alkali picrates<sup>a)</sup>

Crown ether	Extractability (%) <sup>b)</sup>			
	$\text{Na}^+$	$\text{K}^+$	$\text{Rb}^+$	$\text{Cs}^+$
18-Crown-6	3.9	22.5	13.6	6.0
Dibenzo-18-crown-6	0.4	0.8	0.8	0.1
Distilbeno-18-crown-6 ( <u>4a</u> )	1.5	2.4	1.3	0.2
Tetraphenyl-18-crown-6 ( <u>6a</u> )	1.5	4.3	1.7	1.0
Tetracyclohexyl-18-crown-6 ( <u>7a</u> )	0.6	1.5	0.9	0.7
Distilbeno-24-crown-8 ( <u>4b</u> )	1.2	0.4	1.4	1.0
Tetraphenyl-24-crown-8 ( <u>6b</u> )	0.5	0.7	1.7	1.2
Tetracyclohexyl-24-crown-8 ( <u>7b</u> )	0.8	0.5	0.1	0.1

a) Temperature  $25.0 \pm 0.1^\circ\text{C}$ ; aqueous phase(10 ml): [picrate] =  $7.0 \times 10^{-4}\text{M}$ ; organic phase( $\text{CHCl}_3$ , 10ml): [crown ether] =  $7.0 \times 10^{-4}\text{M}$ .

b) % Picrate extracted into the organic phase.

where available. As can be seen from Table, the distilbeno- and tetraphenylcrown ethers 4 and 6 showed quite low extractabilities under the conditions employed,<sup>8)</sup> where the parent 18-crown-6 gave a moderate extractability. It should be noted however that the extractability of dibenzo-18-crown-6, with which 4a and 6a may be compared, is much lower. This is most probably due to the low lipophilicity of these crown ethers. Since the tetraphenylcrown ethers 6 showed somewhat improved extractabilities, the low values for the dibenzo- and distilbenocrown ethers may be further attributable to the rigid O=C=C-O linkages, which makes difficult to arrange oxygen atoms in a favorable conformation for complexation.

The most surprising finding is the extremely low extractabilities of the tetra-cyclohexylcrown ethers 7. One would anticipate much higher extractabilities for these saturated crown ethers 7 from the absence of rigid double bonds and the increased lipophilicity. An examination of molecular models entirely dissolves the discrepancy. Since a cyclohexyl group is much more bulky than a phenyl, the two adjacent cyclohexyl groups of 7 go staggered and break the binding arrangement of oxygen atoms to give poor extractabilities.

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#### References

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- 2) A. Merz, *Angew. Chem.*, 89, 484(1977); *Angew. Chem. Int. Ed. Engl.*, 16, 467(1977).
- 3) Recently, Merz et al. have reported the synthesis, photochemistry, and partial hydrogenation of mono- or distilbeno-18-crown-6: a) M. Eichner and A. Merz, *Tetrahedron Lett.*, 22, 1315(1981); b) A. Merz, M. Eichner, and R. Tomahogh, *ibid.*, 22, 1319(1981); c) *idem.*, *Liebigs Ann. Chem.*, 1774(1981). No further examples have not been reported yet.
- 4) Hexadecyltrimethylammonium bromide as a catalyst generally gave better yields.
- 5) Two adjacent phenyl groups of 5a, 5c, 6a, and 6b are inferred to be *cis* each other, while it is not known whether the two transannular diphenylethylene groups of 6 are in *syn*- and/or *anti*-form. In the course of our study, Merz et al. have revealed that catalytic hydrogenation of 4a in dimethylformamide gave *syn*- and *anti*-6a in a ratio of ca. 3:1.<sup>3c)</sup> Judging from their mp(*syn*:110-111°C, *anti*: 214-216°C), our tetraphenyl-18-crown-6 6a(mp 177.5-180°C) must be a *syn*-*anti* mixture.
- 6) J.H. Stocker, *J. Org. Chem.*, 27, 2288(1962).
- 7) LC analysis on a  $\mu$ -Bondapak C<sub>18</sub> column with 5% hexane-methanol eluent revealed that 7a contained two components of similar amounts. They are probably *syn*- and *anti*-stereoisomers. Quite surprisingly, 7b contained only one isomer, although the stereochemistry is not known.
- 8) Because of the low solubilities of the crown ethers 4a and 6a in most organic solvents, extractions were run at relatively low concentration of crown ethers.

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