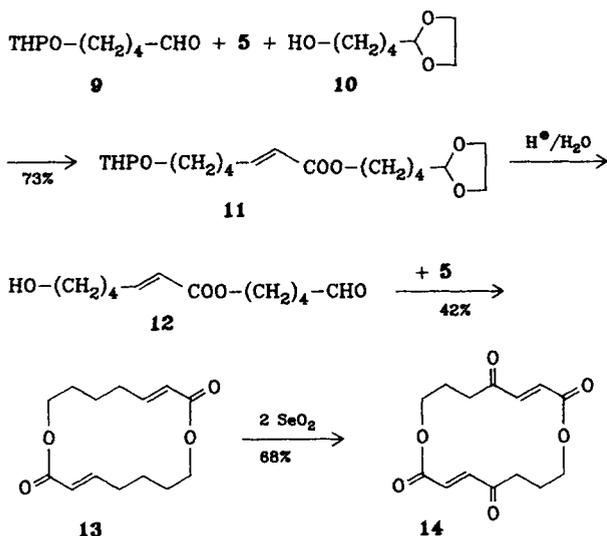


cleaved in acid. The ω -hydroxy aldehyde **12** so formed is not isolated but rather cyclized to the diolide **13** by addition of a ca. 0.1 M solution of **12** in xylene to the molar equivalent amount of **5** in refluxing xylene (high-dilution conditions).^[1] The subsequent oxidation of **13** with two



equivalents of selenium dioxide affords norpyrenophorin **14**^[11] (**11**: b.p. = 125–128 °C/0.05 torr (Kugelrohr, air-bath heating); **13**: m.p. = 55 °C (hexane), b.p. = 127 °C/0.01 torr; **14**: m.p. = 131 °C).

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1 (R¹ = *n*-C₃H₇, R² = *n*-C₄H₉), 97827-33-3; **1** (R¹ = *n*-C₃H₇, R² = *n*-C₄H₉), 97827-34-4; **1** (R¹ = C₂H₅, R² = (–)-menthyl), 97827-35-5; **1** (R¹ = C₂H₅, R² = CH(*n*-C₃H₇)₂), 97827-36-6; **1** (R¹ = CH₃, R² = (–)-menthyl), 57564-56-4; **2a**, 97827-37-7; **2b**, 97827-38-8; **2c**, 97827-39-9; **3a**, 97827-40-2; **3b**, 97827-41-3; **3c**, 97827-42-4; (±)-**4**, 97827-43-5; **5**, 15596-07-3; (±)-**6**, 97827-44-6; (±)-**7**, 77413-26-4; (±)-**8**, 56448-20-5; **9**, 14194-86-6; **10**, 83516-55-6; **11**, 97827-45-7; **12**, 97827-46-8; **13**, 97827-47-9; **14**, 69604-23-5.

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Chiral Poly(9,9'-spirobifluorene) Crown Ethers

By Max Dobler, Miljenko Dumić, Martin Egli, and Vladimir Prelog*

The first two members of the poly(9,9'-spirobifluorene) crown ether series, bis(9,9'-spirobifluorene)-[26]crown-4 **4** and bis(9,9'-spirobifluorene)-[32]crown-6 **5**, were initially obtained as side products in the preparation of the corresponding mono(9,9'-spirobifluorene) crown ethers from 2,2'-bis(bromomethyl)-9,9'-spirobifluorene **1** and the alkoxides of ethylene glycol and diethylene glycol, respectively.^[1] Direct synthesis via condensation of **1** with alkoxides of the two dihydroxy ethers **2** and **3** in the presence of potassium *tert*-butoxide affords the cyclic products only in moderate, nonreproducible yields.

In the meantime, it has been found that the two bis(9,9'-spirobifluorene) crown ethers **4** and **5** exhibit, as ionophores, high enantioselectivity for salts of biologically active α -amino alcohols (e.g., ephedrine),^[2] thus enhancing their interest. We have attempted to improve the second procedure of preparation of the compounds **4** and **5** by modifying the reaction conditions. It was finally possible to obtain **4** and **5** reproducibly in 40–50% yield by reaction of **1** with the dihydroxy ethers **2** and **3**, which may be prepared quantitatively, under the conditions of phase-transfer catalysis.^[3]

Upon investigation of the crude products by thin layer chromatography, the two bis(9,9'-spirobifluorene) crown ethers **4** and **5** were found to be accompanied by several closely related compounds, which could be separated by chromatography on silica gel. These compounds were identified as poly(9,9'-spirobifluorene) crown ethers **6** to **9** on the basis of their UV, CD, NMR, and, in particular, mass spectra^[4] and are summarized in Table I.

The crown ethers **6** to **9**^[5] are striking in several respects. They are well-defined cyclic compounds with a large number of ring members (52 to 104). They belong to the class of chiral yet highly symmetrical compounds (point group symmetry C_n, n = 4, 6, 8), for which only a few examples are known.^[6] As crown ethers, they are potential host molecules. On account of their chirality, they are expected to be enantioselective, like the compounds **4** and **5**.^[2] It is therefore advantageous that their sense of chirality, or absolute configuration, is known.

Characteristic of the poly(9,9'-spirobifluorene) crown ethers is the strong binding of solvent and crystallization

* Prof. Dr. V. Prelog, Priv.-Doz. Dr. M. Dobler, Dr. M. Dumić, Dipl.-Chem. M. Egli
 Laboratorium für Organische Chemie
 der Eidgenössischen Technischen Hochschule
 ETH-Zentrum, Universitätstrasse 16, CH-8092 Zürich (Switzerland)

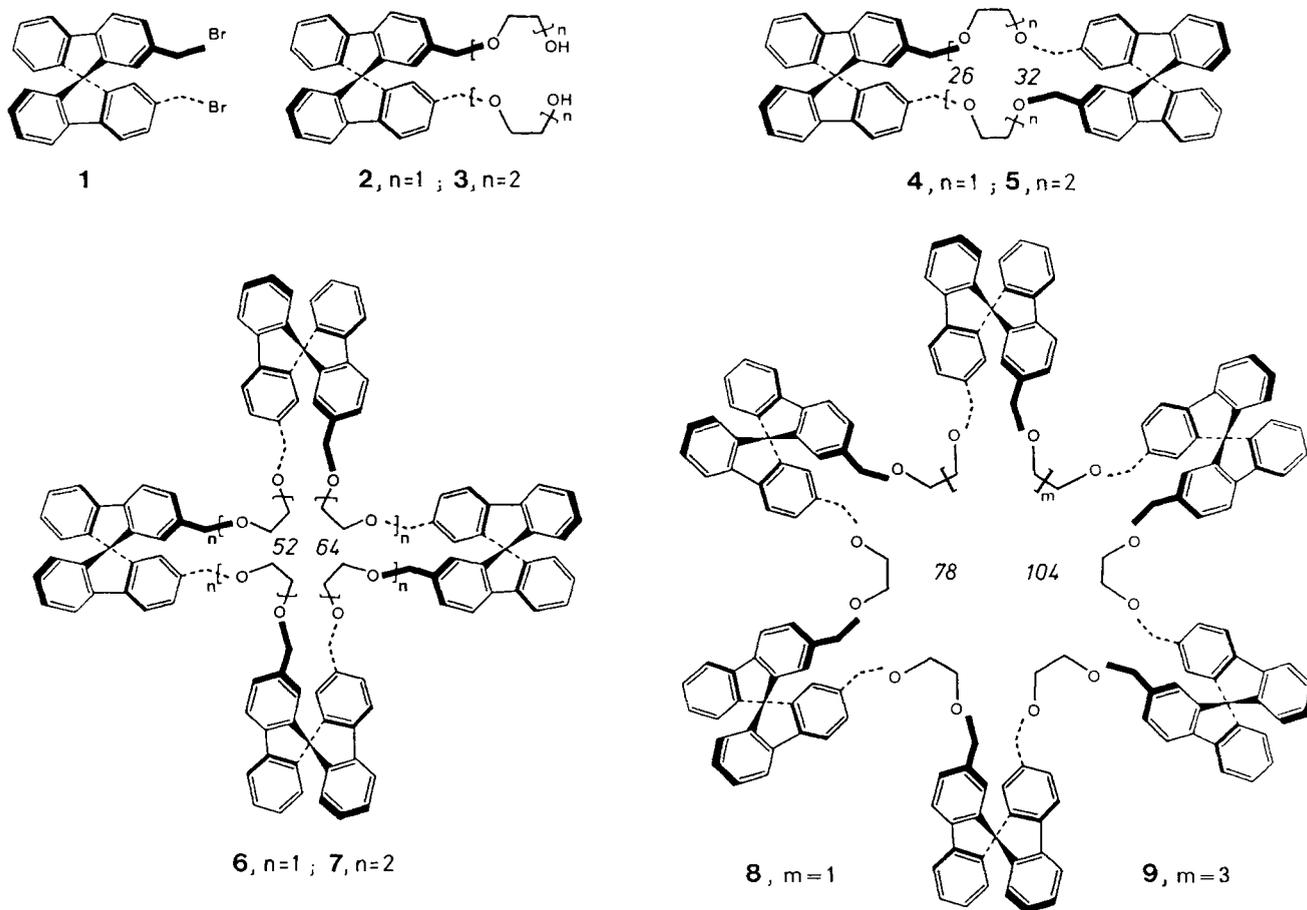


Table 1. Poly(9,9'-spirobifluorene) crown ethers [4].

	Ring members	Empirical formula	M_r , calcd	M_r , found (MS)	Yield [%]	R_f	$[\alpha]_D^{25}$ [a] [°]		
4	Bis	26	$C_{58}H_{44}O_4$	805.0 + 2 C_6H_6	961.2	M^+ 804 [b]	42	0.48 [c]	+ 138
6	Tetra	52	$C_{116}H_{88}O_8$	1610.0	$[M + Na]^+$ 1631 [d]	10.5	0.37 [c]	- 12	
8	Hexa	78	$C_{174}H_{132}O_{12}$	2415.0	$[M + K]^+$ 2451 [d]	2	0.28 [c]	- 41	
9	Okta	104	$C_{232}H_{176}O_{16}$	3220.0	$[M + Na]^+$ 3243.4 [e]	0.1	0.20 [c]	-	
5	Bis	32	$C_{62}H_{52}O_6$	893.1 + CH_2Cl_2	978.0	M^+ 892 [b]	45	0.56 [f]	+ 29
7	Tetra	64	$C_{124}H_{104}O_{12}$	1786.2	$[M + K]^+$ 1823 [d]	7	0.37 [f]	- 13	

[a] $CHCl_3$, $c \approx 1$. [b] Recorded on a Hitachi-Perkin Elmer RMU-6M; direct injection, EI, 70 eV. [c] Benzene/ethyl acetate (9 : 1). [d] Recorded on a KRATOS MS 50; FAB, matrix 3-nitrobenzyl alcohol + KI, Xe 6 kV. [e] Recorded by Dr. F. Raschdorf, Ciba-Geigy, Basel, on a VG Micromass ZAB with high-field magnet; FAB, matrix 3-nitrobenzyl alcohol, Xe 7 kV. [f] Benzene/ethyl acetate (7 : 3).

with solvent molecules. Thus, **4** crystallizes with two molecules of benzene (m.p. = 122–124°C) and **5** with one molecule of dichloromethane (m.p. = 153–156°C). The results of the X-ray analyses^[7] are presented in Figures 1 and 2.

The 26-membered compound **4** has a structure similar to those of other crown ethers having the same ring size.^[8] The shape and size of its chiral cavity account for its complexing abilities and the observed enantioselectivity. The structure of the 32-membered compound **5** differs: the 9,9'-spirobifluorene moieties are closer to each other (separation of the two spiro atoms in **4**, 11.09 Å; in **5**, 6.65 Å) and the two oxygen-containing chains lie to the side so that no cavity for a guest molecule is present. The host molecule must first adapt itself to the guest by a significant conformational change. Such an "induced fit" has often been observed for natural as well as for synthetic ionophores.^[9]

Experimental Procedure

Poly(9,9'-spirobifluorene) crown ethers **4**, **6**, **8**, and **9**: (S)-(-)-2,2'-bis(bromomethyl)-9,9'-spirobifluorene **1** (502 mg) in 5 mL of toluene was added over 2 h with vigorous stirring to a solution of KOtBu (447 mg) and CsI (259 mg) in 25 mL of ethylene glycol at 70°C. The reaction mixture was then heated for an additional 13 h. After dilution with water and acidification, it was extracted with 500 mL of benzene. The washed benzene extracts, containing the dihydroxy ether **2** in practically quantitative yield, were concentrated to 200 mL, treated with an additional 478 mg of **1** as well as with tetrabutylammonium hydrogen sulfate (97 mg), acetonitrile (100 mL), and 200 mL of 50% sodium hydroxide solution, and vigorously stirred for 20 h at room temperature. The reaction mixture was diluted with water and acidified. The benzene layer was separated, washed, dried with $MgSO_4$, and evaporated. The residue (840 mg) afforded $4 \cdot 2 C_6H_6$ (323 mg) after recrystallization from benzene. By flash chromatography [10] of the mother liquor on silica gel 60 (Merck) with benzene/ethyl acetate (9.5 : 0.5) and (9 : 1) and recrystallization, an additional 70 mg of $4 \cdot 2 C_6H_6$ was obtained from the first fractions. The later fractions were rechromatographed and gave **6** (82.5 mg), **8** (14.1 mg), and **9** (1.0 mg). The final fractions contained the dihydroxy ethers with five (74.5 mg; $C_{145}H_{116}O_{12}$; $[M + K]^+ = 2111$) and with three (91.5 mg; $C_{88}H_{72}O_8$;

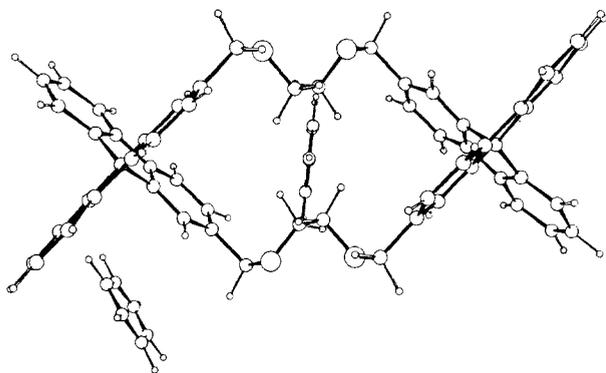


Fig. 1. Crystal structure of $4 \cdot 2C_6H_6$ along the crystallographic two-fold axis. The benzene molecule drawn in the center lies 5.7 \AA below the crown ether ring. Important bond distances, bond angles, and torsion angles: spirobifluorene, six-membered ring $1.348 \dots 1.435$, average 1.387 \AA ; $117.0 \dots 123.2^\circ$, average 120.0° . Five-membered ring, single bonds $1.443 \dots 1.556$, average 1.513 \AA , angles (without angles at spiro atom) $106.5 \dots 111.6^\circ$, average 109.7° , at spiro atom $100.2, 101.8^\circ$. Angle between the best planes 91.3° . 26-membered ring, values for the asymmetric moiety, beginning at the spiro atom: distances $1.542, 1.348, 1.385, 1.540, 1.443, 1.407, 1.518, 1.438, 1.425, 1.506, 1.409, 1.384, 1.509 \text{ \AA}$; angles $113.0, 126.7, 119.4, 120.2, 111.5, 111.6, 107.8, 108.1, 111.9, 114.9, 120.4, 117.8, 126.9^\circ$; torsion angles $59.7, -172.9, 179.9, -45.6, -70.5, 176.1, 70.5, -177.7, -71.4, -32.1, -178.4, -178.3, 56.8^\circ$.

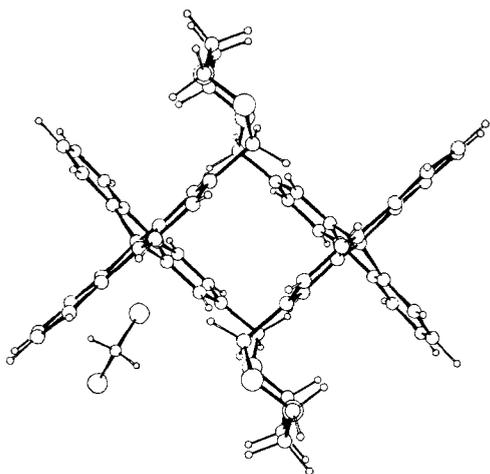


Fig. 2. Crystal structure of $5 \cdot CH_2Cl_2$ along the crystallographic two-fold axis. Important bond distances, bond angles, and torsion angles: spirobifluorene, six-membered ring $1.354 \dots 1.420$, average 1.385 \AA ; $116.3 \dots 123.4^\circ$, average 120.0° . Five-membered ring, single bonds $1.500 \dots 1.552$, average 1.522 \AA , angles (without angles at spiro atom) average 109.6° , at spiro atom $101.1, 101.4^\circ$. Angle between the best planes 92.2° . 32-membered ring, values for the asymmetric moiety, beginning at the spiro atom: distances $1.552, 1.371, 1.398, 1.518, 1.402, 1.426, 1.486, 1.405, 1.443, 1.492, 1.414, 1.418, 1.569, 1.389, 1.373, 1.511 \text{ \AA}$; angles $117.4, 128.5, 118.5, 120.2, 109.7, 110.4, 107.5, 108.7, 114.2, 107.8, 115.2, 115.8, 111.7, 118.0, 117.4, 128.3^\circ$; torsion angles $45.5, -178.8, 176.5, 36.2, 179.6, 172.3, -72.0, 174.3, -173.8, 80.7, -69.6, -64.2, 131.5, 176.7, 177.6, 59.3^\circ$.

$[M+K]^+ = 1307$) 9,9'-spirobifluorene residues as intermediate or side products along with 27 mg of unreacted **2**.

Poly(9,9'-spirobifluorene) crown ethers **5** and **7**: Analogously, $5 \cdot CH_2Cl_2$ (439 mg) and **7** (62.5 mg) were obtained from a total of 1004 mg of **1** with diethylene glycol.

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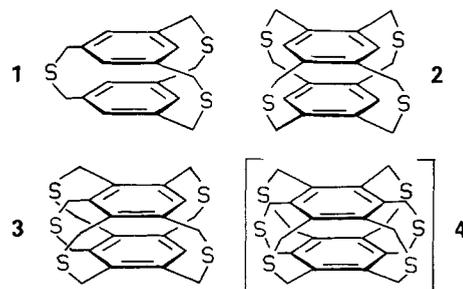
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First Sixfold Bridge-Formation in One Step**

By Wolfram Kissener and Fritz Vögtle*

While threefold,^[1] fourfold,^[2] and fivefold^[2] bridging between two benzene rings in one step have all been successfully demonstrated in the past 15 years in the synthesis of thephanes **1–3**, the realization of a sixfold bridging, e.g. to give the ten-membered "superphane hexasulfide" **4**, in one step has not proven possible, despite numerous efforts.^[1–4]



We assume that all previous attempts at achieving this aim have remained unsuccessful, not because of the number of bridges involved, but primarily because of the steric strain. Working on this basis we have now found that even six bridges can indeed be coupled intermolecularly if sterically less demanding starting materials are allowed to react with each other using the cesium effect^[5] and dilution principle. An example is the reaction of hexakis[3-(bromomethyl)phenyl]benzene **5**^[6] with the corresponding hexathioli **6**^[7] to give **7**.

Using a general procedure previously optimized by us in earlier work,^[2,3] this reaction resulted in precipitation of the 22-membered polycyclic hexasulfide **7** as pale yellow crystals (m.p. $> 320^\circ\text{C}$) in ca. 0.1% yield. The mass spec-

[*] Prof. Dr. F. Vögtle, Dipl.-Chem. W. Kissener
Institut für Organische Chemie und Biochemie der Universität
Gerhard-Domagk-Strasse 1, D-5300 Bonn 1 (FRG)

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