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Concave Reagents - 23. Synthesis of a Calix[6]arene Bridged by a 1,10-Phenanthroline[1]

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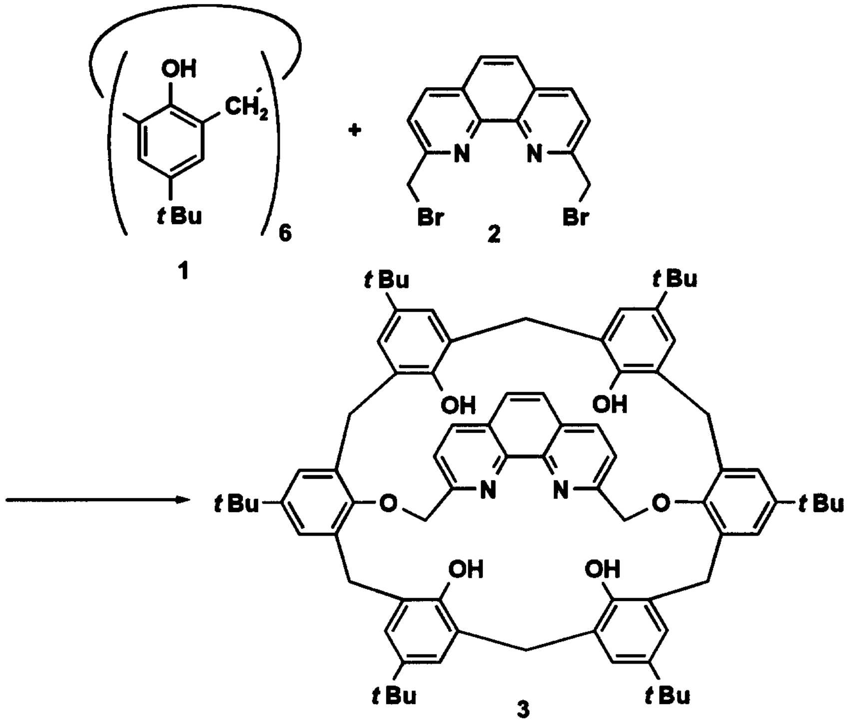
Abstract: **3**, the first calix[6]arene A,D-bridged by a 1,10-phenanthroline, was synthesized by reaction of *p-tert*-butylcalix[6]arene (**1**) with 2,9-bis(bromomethyl)-1,10-phenanthroline (**2**). The basicity of **3** was investigated qualitatively and quantitatively. Preliminary complexation studies indicate that **3** is a suitable ligand for Cu^+. © 1997 Elsevier Science Ltd.

In accordance with the concept of concave reagents, a variety of bimacrocyclic concave bases and acids such as pyridines, 1,10-phenanthrolines, anilines, carboxylic acids, sulfinic acids and thiols have been synthesized by incorporation of an appropriate functional group into a concave environment.[2] Several of these concave reagents have been employed in model reactions with improved selectivities due to the concave shielding of the functional group. In order to obtain concave reagents, different synthetic strategies have been applied. One of these strategies consists in the reaction of *p-tert*-butylcalix[6]arene[3] (**1**) with bifunctional molecules which contain the desired functional group thus providing A,D-bridged calix[6]arenes.[4,5] Similar A,D-bridged calix[6]arenes containing functional groups in the bridge were also described by Okazaki and co-workers.[6] 2-Substituted 1,3-bis(bromomethyl)benzenes and 2,6-bis(bromomethyl)pyridines, respectively, were used as bridging reagents. In comparison to these compounds the distance between the two bromomethyl groups in 2,9-bis(bromomethyl)-1,10-phenanthroline (**2**) is increased by ca. 2 Å.[7] Nevertheless bridging of *p-tert*-butylcalix[6]arene (**1**) with 2,9-bis(bromomethyl)-1,10-phenanthroline (**2**) is possible as well and furnishes the calixarene **3** in 38 % yield. Like most A,D-bridged tetrahydroxycalix[6]arenes, compound **3** adopts a (**u**,u,u,u,u,u) conformation.[8] No other regioisomers could be isolated. Calix[4]arenes with 1,10-phenanthroline units attached to the oxygen atoms have been described in the recent literature,[9] but **3** is the first calixarene bridged by a 1,10-phenanthroline.

Preparation of compound **3**. The synthesis of the A,D-bridged calix[6]arene **3** is illustrated in scheme 1. *p-tert*-Butylcalix[6]arene (**1**) in THF is reacted under nitrogen with 6 equiv. of *t*BuOK and 1.2 equiv. of 2,9-bis(bromomethyl)-1,10-phenanthroline[10] (**2**). After stirring for 24 h at rt, the mixture is treated with dilute HCl. The crude product is purified by chromatography on silica eluting with cyclohexane-ethyl acetate (4:1) followed by recrystallization from dichloromethane-methanol to yield the product **3** as a colorless solid.[11]



Scheme 1. Reagents and conditions: **1** (ca. 8 mM in THF), *t*BuOK (6 equiv.), **2** (1.2 equiv.), rt.

Basicity of compound **3**. The ^{1}H NMR signals belonging to the 1,10-phenanthroline moiety of **3** are shifted to lower magnetic field upon the addition of picric acid as a result of *N*-protonation. At the same time these signals are distinctly broadened while the signals of the calixarene framework are not affected significantly. The basicity of **3** has been determined quantitatively by a photometrical titration against the indicator thymol blue in ethanol.[7] This method has been applied in the case of numerous concave bases including pyridine and aniline bridged calix[6]arenes[4b,c] and furnishes equilibrium constants K for the reaction of **3** with thymol blue in ethanol instead of pK_a values in water.

$$\mathbf{3} + \text{thymol blue} \overset{K}{\rightleftharpoons} \mathbf{3}\cdot\text{H}^{\oplus} + \text{thymol blue anion}^{\ominus}$$

The log K scale is parallel to the pK_a scale and has thymol blue as origin. On the thymol blue scale, log K values of 1,10-phenanthroline and 2,9-dimethyl-1,10-phenanthroline are 0.0 and 0.8 - 1.0, respectively.[7] log K of the bridged calixarene **3** is 0.5. This value indicates an increased basicity of **3** since the 2,9-bis-(aryloxymethylene) substitution should cause a lower basicity than found for 1,10-phenanthroline.[12] A similar enhancement of basicity has been observed previously in the case of pyridine bridged calix[6]arenes and can be explained by a stabilization of **3**·H^+ by intramolecular hydrogen bonds to the oxygen atoms of the lateral hydroxy groups.[4b]

Compound **3** *as ligand*. The complexation ability of 1,10-phenanthrolines can be regarded as more important than their basicity. Complexation of transition metal ions by concave 1,10-phenanthrolines has been established qualitatively by ^{1}H NMR and quantitatively by UV titrations.[7,13] Here we present preliminary ^{1}H NMR complexation studies of the A,D-bridged calix[6]arene **3**.

When $[Cu(CH_3CN)_4]BF_4$ is added to a solution of **3** in $CDCl_3$, signal shifts of the 1,10-phenanthroline moiety are observed suggesting complexation of Cu^+. These shifts are similar to the shifts resulting from protonation. On the other side, addition of lanthanum triflate does not give rise to significant NMR shifts. Addition of silver trifluoroacetate to a solution of **3** in C_6D_6 results in immense line broadenings which are somewhat reduced upon heating (C_6D_6 was used for solubility reasons). However, signal shifts of the 1,10-phenanthroline moiety are negligible and complexation of Ag^+ is not evident. As there are no paramagnetic ions present in solution, two other reasons for the line broadening might be considered: (i) Ag^+ is bound unspecifically by the aromatic rings of the calixarene framework and there is a fast exchange on the NMR time scale. (ii) The 1,10-phenanthroline bridge is swinging from one side to the other. This motion which has been established in the case of other A,D-bridged calix[6]arenes[4c,6c] is decelerated in the presence of Ag^+.

These results show that calixarene **3** is in principle suitable as a complex ligand. For future investigations, alkylation of the four hydroxy groups of **3** might be necessary in order to improve the solubility and complexation ability. Besides applications of calixarene-phenanthroline metal complexes as catalysts their luminescence properties might be of interest.[14]

REFERENCES AND NOTES

1. Concave Reagents 22: Hagen, M.; Lüning, U. *Chem. Ber./Recueil* **1997**, *130*, 231-234.
2. a) Lüning, U. *Liebigs Ann. Chem.* **1987**, 949-955. - b) Lüning, U. *Top. Curr. Chem.* **1995**, *175*, 57-99. - c) Lüning, U. *J. Inclusion Phenom. Mol. Recognit. Chem.* **1996**, *24*, 43-60. - d) Lüning, U. *J. Mater. Chem.* **1997**, *7*, 175-182.
3. a) Gutsche, C. D.; Dhawan, B.; Leonis, M.; Stewart, D. *Org. Synth.* **1990**, *68*, 238-242. - On calixarenes in general see: b) Gutsche, C. D. *Calixarenes*; The Royal Society of Chemistry: Cambridge, 1989. -

c) Vicens, J.; Böhmer, V., Eds. *Calixarenes, a Versatile Class of Macrocyclic Compounds*; Kluwer Academic Publishers: Dordrecht, 1991. - d) Böhmer, V. *Angew. Chem.* **1995**, *107*, 785-818; *Angew. Chem. Int. Ed. Engl.* **1995**, *34*, 713-745.

4. a) Ross, H.; Lüning, U. *Angew. Chem.* **1995**, *107*, 2723-2725; *Angew. Chem. Int. Ed. Engl.* **1995**, *34*, 2555-2557. - b) Ross, H.; Lüning, U. *Liebigs Ann.* **1996**, 1367-1373. - c) Ross, H.; Lüning, U. *Tetrahedron* **1996**, *52*, 10879-10882.
5. A,D-bridging is defined as the connection of two opposite phenol rings of a calix[6]arene. The alternative term 1,4-bridging does not correspond to the numbering of the calix[6]arene oxygene atoms (37-42).
6. a) Tokitoh, N.; Saiki, T.; Okazaki, R. *J. Chem. Soc. Chem. Commun.* **1995**, 1899-1900. - b) Saiki, T.; Goto, K.; Tokitoh, N.; Okazaki, R. *J. Org. Chem.* **1996**, *61*, 2924-2925. - c) Saiki, T.; Goto, K.; Tokitoh, N.; Goto, M.; Okazaki, R. *Tetrahedron Lett.* **1996**, *37*, 4039-4042. - d) Saiki, T.; Goto, K.; Okazaki, R. *Chem. Lett.* **1996**, 993-994.
7. Lüning, U.; Müller, M. *Liebigs Ann. Chem.* **1989**, 367-374.
8. Kanamathareddy, S.; Gutsche, C. D. *J. Am. Chem. Soc.* **1993**, *115*, 6572-6579.
9. Casnati, A.; Fischer, C.; Guardigli, M.; Isernia, A.; Manet, I.; Sabbatini, N.; Ungaro, R. *J. Chem. Soc. Perkin Trans. 2* **1996**, 395-399.
10. Masood, M. A.; Hodgson, D. J. *Inorg. Chem.* **1993**, *32*, 4839-4844.
11. *Analytical data of compound* **3**: mp 259-262 °C (dec.). - ^{1}H NMR (500 MHz, $CDCl_3$, D_2O): $\delta = 1.11$ (s, 36 H, CH_3), 1.15 (s, 18 H, CH_3), 3.54 (d, $J = 15.4$ Hz, 4 H, ArCH_2Ar), 3.59 (d, $J = 14.7$ Hz, 2 H, ArCH_2Ar), 3.82 (d, $J = 14.7$ Hz, 2 H, ArCH_2Ar), 4.50 (d, $J = 15.4$ Hz, 4 H, ArCH_2Ar), 5.30 (s, ca. 1 H, CH_2Cl$_2$), 5.52 (s, 4 H, OCH_2), 6.87 (d, $J = 2.2$ Hz, 4 H, Ar*H*-calix), 6.95 (s, 4 H, Ar*H*-calix), 6.98 (d, $J = 2.2$ Hz, 4 H, Ar*H*-calix), 7.76 (s, 2 H, Ar*H*-phen), 7.83 (d, $J = 8.3$ Hz, 2 H, Ar*H*-phen), 8.27 (d, $J = 8.3$ Hz, Ar*H*-phen). In the absence of D_2O signals for H_2O and ArO*H* are observed as broad singlets at δ 2.1-2.2 and δ 7.6-7.9, respectively. - MS (EI, 70 eV); *m/z* (%): 1177 (100) [M$^+$]. - A satisfactory elemental analysis was found for **3**·0.5 CH_2Cl_2·1.0 H_2O.
12. On prediction of basicities of heterocyclic bases with the aid of Hammett parameters: Clark, J.; Perrin, D. D. *Q. Revs. Chem. Soc.* **1964**, *18*, 295-320.
13. a) Lüning, U.; Müller, M.; Gelbert, M.; von Schnering, H. G.; Keller, M. *Chem. Ber.* **1994**, *127*, 2297-2306. - b) Körber, C. *Diploma Thesis*, University of Kiel, 1996.
14. a) Alpha, B.; Lehn, J.-M.; Mathis, G. *Angew. Chem.* **1987**, *99*, 259-261; *Angew. Chem. Int. Ed. Engl.* **1987**, *26*, 266. b) Ulrich, G.; Ziessel, R. *Tetrahedron Lett.* **1994**, *35*, 6299-6302.

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