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LETTERS

Synthesis of new phenylazocalix[*n*]arenes (*n*=4, 5)

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Abstract

Four new double calix[*n*]arenes (*n*=4, 5) **2a**, **2b**, **3a** and **3b** have been synthesized by coupling reaction of tetrazonium salts **1a** and **1b** on calix[*n*]arenes (*n*=4, 5). The conformation of **2a** was studied in solution and in the solid state. © 2000 Elsevier Science Ltd. All rights reserved.

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Double calixarenes can be divided into three groups: lower rim–lower rim, upper rim–upper rim, upper rim–lower rim.[1] Double calix[4]arenes upper rim–upper rim connected have been reported by many chemists.[2–11] Chawla and Srinivas[12] have tried to synthesize a double calix[4]arene linked by four molecules of benzidine, but they have produced a bisazobiphenyl bridged calix[4]arene with transannular (1,3) bisazobiphenyl linkages. Recently, double calix[5]arenes have been synthesized by Fukazawa et al.:[13] these new host molecules have been used for the inclusion of fullerenes. Recently, Luzikov et al.[14] have synthesized a new type of double calix[4]arene in which two trisadamantylcalix[4]arene units are bound by the bifunctionnal electrophilic agents (benzidine) obtained in azo-coupling.

In this work we report the synthesis of four new potential receptors made of calix[*n*]arene (*n*=4, 5) moities (upper rim–upper rim connected by one bisazobiphenyl linkage). At first, we synthesized the tetrazonium salts **1** according to Saunders and Allen;[15] then we employed 0.5 equivalent of these salts in 5:1 THF:pyridine mixture with 1 equivalent of calix[4]arene or calix[5]arene to obtain the corresponding double calix[*n*]arenes **2** and **3**. The general reaction is described in Scheme 1.

The diazonium salts were excellent electrophiles and would attack any available position on the calix[*n*]arenes to yield a complex mixture. Workup of the reaction mixtures and column chromatography of the crude products afforded the corresponding bisazobiphenyl double calix[*n*]arenes **2** and **3** in 8–15% yields.[16] In the case of R=OCH_3, monoazobiphenyl calix[*n*]arenes **4a** and **5a** were isolated as

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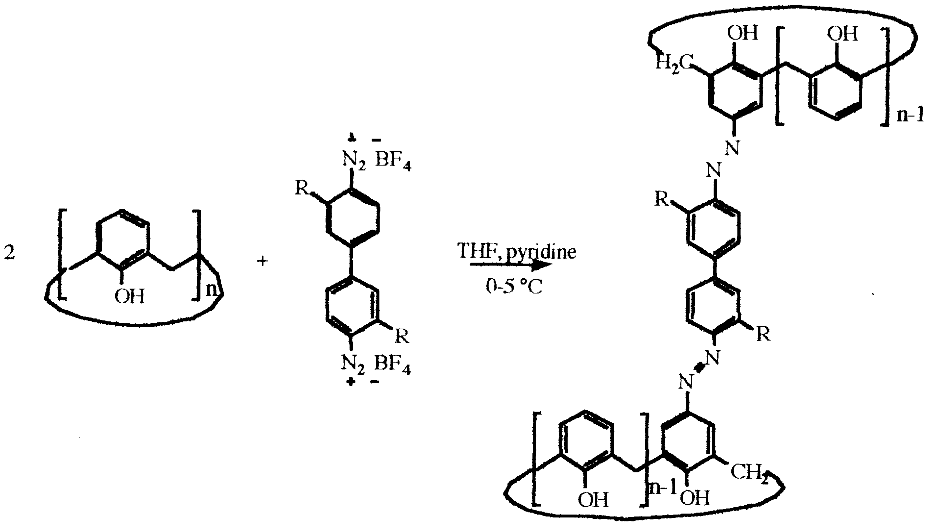
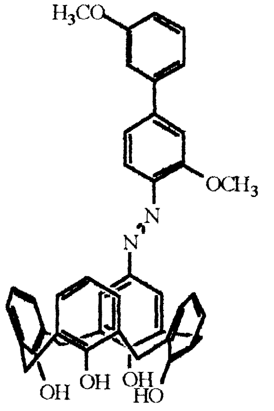


1a R = OCH_3 **2a** R = OCH_3 n = 4 **3a** R = OCH_3 n = 5

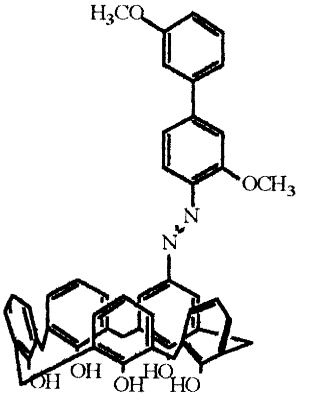
1b R = H **2b** R = H n = 4 **3b** R = H n = 5

Scheme 1. Coupling reaction between tetrazonium salts and calix[*n*]arenes (*n*=4, 5)

by-products. These compounds were probably produced by reduction of diazonium group by THF, as described by some authors.[17]



4a



5a

Conformational study has been realized by ^1H NMR spectra at different temperatures. Thus, at 25°C the $ArCH_2Ar$ methylene protons display two broad singlets for **2a** and **2b** which split into two pairs of doublets (3.57–4.30 ppm J=13.9 Hz and 3.72–4.28 ppm J=13.9 Hz) when the temperature was lowered (Fig. 1). At room temperature the singlets indicate that the calixarenes are conformationally mobile. On the contrary, at low temperature the two pairs of doublets indicate a cone conformation.[18,19] In the case of **3** the phenomenon is the same, but at room temperature, there is only one broad singlet showing a better mobility than in **2**. Indeed, in a calix[5]arene mobility is more easy than in a calix[4]arene in relation with difference of size and a less strong hydrogen bond stabilization.[19]

Suitable single crystals for **2a** could be obtained from CD_2Cl_2.[20] Compound **2a** crystallized in a monoclinic form, space group C2/c. X-Ray studies of **2a** have showed that the two calixarenes were

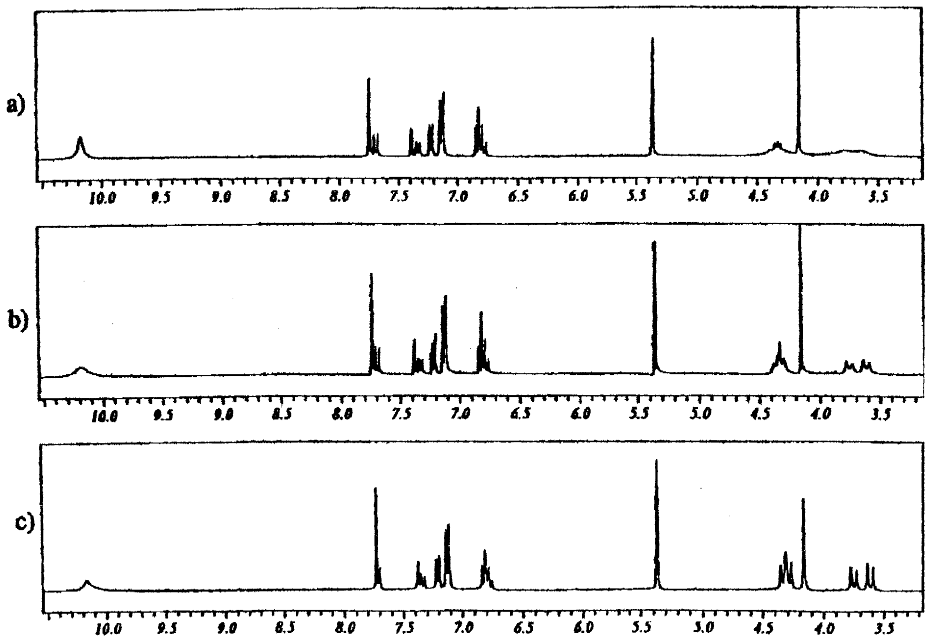


Fig. 1. ^{1}H NMR spectra of **2a** in CD_2Cl_2 at (a) 25°C, (b) 5°C, (c) −40°C

in cone conformation and in *anti*-position (Fig. 2). The solid state conformation of **2a** is in agreement with its solution conformation at low temperature.

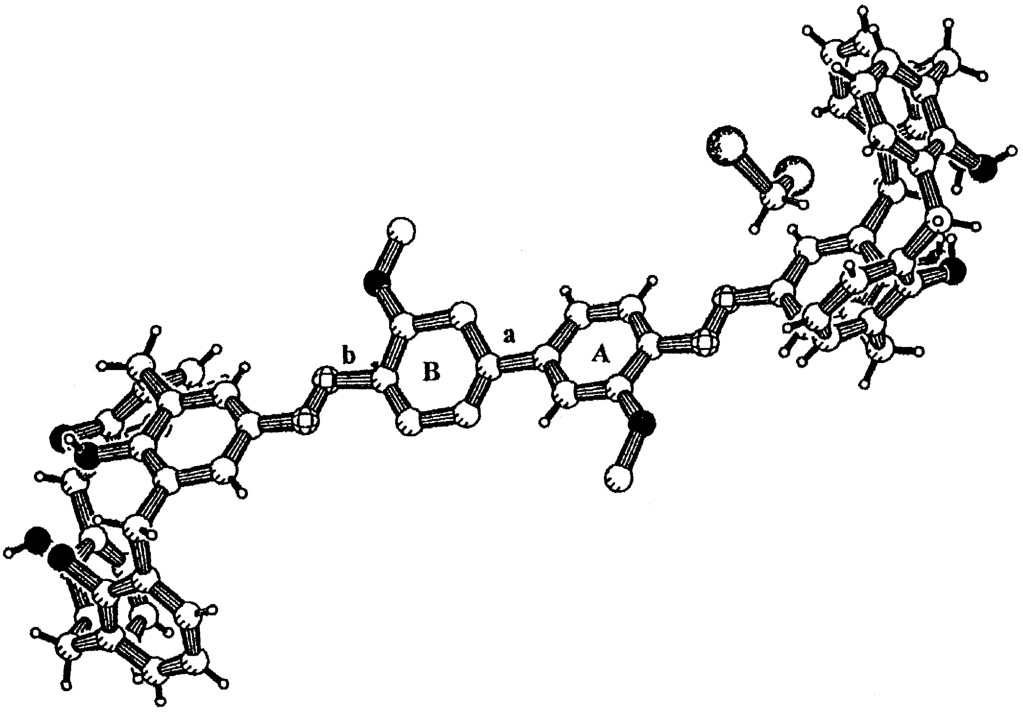


Fig. 2. X-Ray structure of the compound **2a** with one dichloromethane molecule

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16. Experimental: melting points (°C, uncorrected) were determined on an Electrothermal 9100 capilliary apparatus. Elemental analyses were performed at S.C.A., CNRS, Solaize, France. Mass spectra were obtained by electrospray technique, negative or positive mode (HP 5989/MS engine, S.C.A., CNRS, Solaize, France).^{1}H and ^{13}C NMR spectra were recorded on a Bruker AM 300. H aromatic of calixarenes are noted H_{ar} and H aromatic of biphenyl moities are noted H_{biph}. Tetrazonium salts (**1a**) and (**1b**) were synthesized according to literature procedure.[15] 4,4′-Bis[25,26,27,28-tetrahydroxycalix[4]aren-5-ylazo]3,3′-dimethoxybiphenyl (**2a**): Calix[4]arene (0.30 g, 0.71 mmol) and tetrazonium salt **1a** (0.16 g, 0.36 mmol) were dissolved in THF (15 mL). The reaction was initiated by the addition of pyridine (3 mL) to the cooled THF solution. After stirring for 22 h, the reaction was stopped by addition of water. A precipitate was recovered by filtration and washed with water and diethylether. Then the crude product was further purified by column chromatography (silica, 70:30 CH_2Cl_2:petroleum ether as eluent) to give 15% of pure **2a**. M.p.: 320°C (dec.). ES-MS (neg. mode): 1113 $[M-H]^-$. Anal. calcd for $(C_{70}H_{58}N_4O_{10})\cdot 1.5\ H_2O\cdot 0.5\ CH_2Cl_2$: C 71.5; H 5.27; N 4.73; O 15.53; found: C 71.99; H 5.29; N 4.77; O 15.33; ^{1}H NMR (300 MHz, $CDCl_3$, 25°C): δ (ppm): 3.70 (bs, 8H, $ArCH_2$); 4.10 (s, 6H, OCH_3); 4.28 (bs, 8H, $ArCH_2$); 6.75 (t, 6H, H_{ar}, J=7.8); 7.06 (d, 8H, H_{ar}, J=7.8); 7.17 (d, 4H, H_{ar}, J=7.8); 7.22–7.27 (m, 4H, H_{biph}); 7.60 (d, 2H, H_{biph}, J=8.5); 7.71 (s, 4H, H_{ar}); 10.22 (s, 8H, OH). ^{13}C NMR (75.5 MHz, DMSO-d_6, 25°C): δ (ppm): 56.31 (OCH_3); 30.65 (CH_2); 111.64, 116.89, 119.27, 120.97, 121.08, 123.64, 128.63, 128.80 (CH); 128.51, 128.57, 128.69, 129.54, 141.21, 142.59, 146.28, 149.63, 149.71, 156.29 (Car). 4-[25,26,27,28-Tetrahydroxycalix[4]aren-5-ylazo]3,3′-dimethoxybiphenyl (**4a**) (8%): M.p.: 140°C. ES-MS (pos. mode): 665.3 $[M+H]^+$, 687.3 $[M+Na]^+$. ^{1}H NMR (300 MHz, $CDCl_3$, 25°C): δ (ppm): 3.65 (bs, 4H, $ArCH_2$); 3.89 (s, 3H, OCH_3); 4.07 (s, 3H, OCH_3); 4.30 (bs, 4H, $ArCH_2$); 6.76 (t, 3H, H_{ar}, J=7.5); 7.05–7.35 (m, 11H, H_{ar}, H_{biph}); 7.37 (d, 1H, $H_{biph,}$ J=8.4); 7.58 (d, 1H, H_{biph}, J=8.4); 7.70 (s, 2H, H_{ar}); 10.22 (s, 4H, OH). ^{13}C NMR (75.5 MHz, $CDCl_3$, 25°C): δ (ppm): 55.83, 56.46 (OCH_3); 31.70 (CH_2); 111.46, 113.09, 117.44, 119.70, 122.30, 124.17, 129.00, 129.20, 129.87, 130.34 (CH); 127.69, 128.10, 128.31, 128.98, 141.75, 142.02, 144.65, 148.70, 151.71, 156.62, 159.97 (Car). 4,4′-Bis[31,32,33,34,35-pentahydroxycalix[5]aren-5-ylazo]3,3′-dimethoxybiphenyl (**3a**): The same manipulative process was repeated with calix[5]arene (0.22 g, 0.42 mmol) and tetrazonium salt **1a** (0.09 g, 0.21 mmol) to give 8% of pure **3a**. M.p.: 250°C (dec.). ES-MS (neg. mode): 1325.5 $[M-H]^-$. ^{1}H NMR (300 MHz, $CDCl_3$, 25°C): δ (ppm): 3.86 (bs, 20H, $ArCH_2$); 4.15 (s, 6H, OCH_3); 6.86 (t, 8H, H_{ar}, J=7.5); 7.22 (d, 12H, H_{ar}, J=7.5); 7.24 (d, 4H, H_{ar}, J=7.5); 7.30 (d, 2H, H_{biph}, J=8.1); 7.33 (s, 2H, H_{biph}); 7.75 (d, 2H, H_{biph}, J=8.1); 7.89 (s, 4H, H_{ar}); 8.92 (bs, 8H, OH); 9.40 (bs, 2H, OH). 4-[31,32,33,34,35-Pentahydroxycalix[5]aren-5-ylazo]3,3′-dimethoxybiphenyl (**5a**) (5%): M.p.: 125°C. ES-MS (pos. mode): 771.3 $[M+H]^+$, 793.3 $[M+Na]^+$. ^{1}H NMR (300 MHz, $CDCl_3$, 25°C): δ (ppm): 3.89 (bs and s, 13H, $ArCH_2$ and OCH_3); 4.11 (s, 3H, OCH_3); 6.90 (m, 4H, H_{ar}); 7.18–7.42 (m, 14H, H_{ar},H_{biph}); 7.78 (d, 1H, H_{biph}); 7.89 (s, 2H, H_{ar}), 8.93 (s, 5H, OH). 4,4′-Bis[25,26,27,28-tetrahydroxycalix[4]aren-5-ylazo]biphenyl (**2b**): The same manipulative process was repeated with calix[4]arene (0.22 g, 0.52 mmol) and tetrazonium salt **1b** (0.10 g, 0.26 mmol) to give 10% of pure **2b**. M.p.: 330°C (dec). ES-MS (neg. mode) 1053.6 $[M-H]^-$, 526.2 $[M-2H]^{2-}/2$. ^{1}H NMR (300 MHz, $CDCl_3$, 25°C): δ (ppm): 3.58 and 4.31 (2 bs, 16H, $ArCH_2$); 6.76 (t, 6H, H_{ar}, J=7.5); 7.05 (d, 8H, H_{ar}, J=7.5); 7.18 (d, 4H, H_{ar}, J=7.5); 7.72 (s, 4H, H_{ar}); 7.76 (d, 4H, H_{biph}, J=8.2); 7.91 (d, 4H, H_{biph}, J=8.2); 10.20 (s, 8H, OH). 4,4′-Bis[31,32,33,34,35-pentahydroxycalix[5]aren-5-ylazo]biphenyl (**3b**): The same manipulative process was repeated with calix[5]arene (0.30 g; 0.56 mmol) and tetrazonium salt **1b** (0.11 g; 0.28 mmol) to give 10% of pure **3b**. M.p.: 270°C (dec.). ES-MS (neg. mode) 1265.6 $[M-H]^-$, 632.4 $[M-2H]^{2-}/2$. ^{1}H NMR

(300 MHz, $CDCl_3$, 25°C): δ (ppm): 3.88 (bs, 20H, $ArCH_2$); 6.87 (t, 8H, H_{ar}); 7.24 (d, 12H, H_{ar}); 7.33 (d, 4H, H_{ar}) 7.80 (d, 4H, H_{biph}, J=8.7); 7.90 (s, 4H, H_{ar}); 7.98 (d, 4H, H_{biph}, J=8.7); 8.90 (bs, 8H, OH); 9.44 (bs, 2H, OH).

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20. X-Ray data for **2a**: monoclinic, a=45.939(9), b=19.099(4), c=19.862(4) Å, β=109.58(3), U=16419(7) Å^3, space group C2/c, Z=8. Data were mesured on an Enraf–Nonius Kappa-CCD diffractometer. Crystals of double calix[4]arene were of very poor quality and lost solvent molecules very quickly. However, due to the interest of the compound, the determination of the crystal structure was performed. The refinement leads to an *R* value of 0.16 with some large *B* values due to a disorder for the ring B and its substituent OCH_3. Some attempts were made to resolve the disorder but the results were not good probably because the two ring positions are very near; the two positions result by a rotation around a···b. The conformation shows the *anti*-position of the two macrocycles. The calixarene molecules are in cone conformation. The OH bonds lengths and the inclination of the phenolic rings versus plane of oxygen atoms have usual values (2.59–2.74 Å and 118.2–127.1°). The angle between the two benzene ring planes A and B is 185°. The length of the molecule is approximatively 27 Å. The double calixarene crystallizes with a dichloromethane molecule; this one is inside one of the macrocycle and gives some interactions with two benzene rings. Fig. 2 shows the conformation of such a double calix[4]arene.