Synthesis of *rctt*, *rccc*, and *rcct* diastereomers of calix[4]methylresorcinarenes based on *p*-tolualdehyde. X-ray diffraction study of the *rcct* isomer. Formation of *rctt* and *rccc* cavitands in a cone conformation

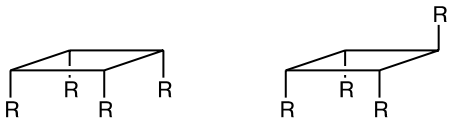
A. V. Prosvirkin,[a] E. Kh. Kazakova,[a]★ A. T. Gubaidullin,[a] I. A. Litvinov,[a] M. Gruner,[b] W. D. Habicher,[b]★ and A. I. Konovalov[a]

[a]A. E. Arbuzov Institute of Organic and Physical Chemistry, Kazan Research Center of the Russian Academy of Sciences, 8 ul. Akad. Arbuzova, 420088 Kazan, Russian Federation. Fax: +7 (843 2) 75 2253. E-mail: ella@iopc.knc.ru
[b]Dresden University of Technology, Institute of Organic Chemistry, Mommsenstrasse 13, D-01062 Dresden, Germany Fax: (+351) 3463 4093. E-mail: Wolf.Habicher@chemie.tu-dresden.de

The reaction of 2-methylresorcinol with *p*-tolualdehyde afforded *rctt* and *rccc* diastereomers of calix[4]methylresorcinarene and an insignificant amount of the *rcct* isomer. The structure of the latter was established by X-ray diffraction analysis. The macrocycle in the *rcct* isomer adopts a 1,2-diplanar conformation, in which one pair of adjacent resorcinol fragments is nearly orthogonal to another pair of resorcinol fragments. The supramolecular organization of the diastereomer in the crystal was studied. The tolyl fragments form the outer surface of the layers composed of the macrocycles, which are separated by "interlayers" of solvent molecules. Cavitands adopting a cone conformation were prepared from the *rctt* and *rccc* diastereomers by linking the adjacent phenoxy groups through methylene bridges. The structure of the *rctt* cavitand was confirmed by 2D NMR spectroscopy.

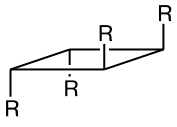
Key words: calixarene, calix[4]methylresorcinarenes, cavitands, supramolecular structure, stereo- and regioselectivity, isomerization, hydrogen bond.

Macrocyclic condensation products of resorcinol with aldehydes are known as calix[4]resorcinarenes, which can exist as four diastereomers. If all four substituents in the calixarene fragment are mutually *cis*, this compound (according to Hoegberg[1]) is defined as the *rccc* isomer. Other diastereomers are *rcct*, *rctt*, and *rtct* isomers.

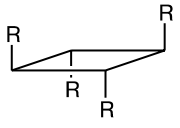


rccc

rcct



rctt



rtct

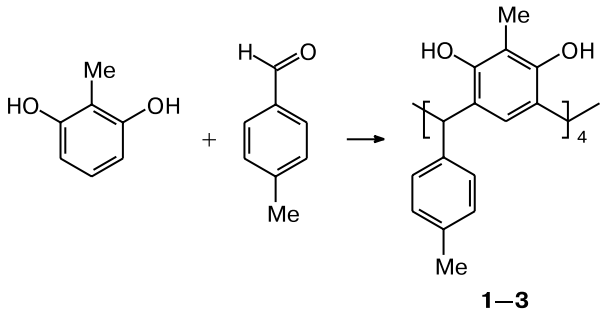
Studies of the diastereomeric compositions of acetyl derivatives of calix[4]resorcinarenes[1] showed that the condensation affords *rccc* and *rctt* diastereomers (1 : 4). The ratio of diastereomers usually depends on the structure of the aldehyde. The condensation with long-chain aliphatic aldehydes gives predominantly the *rccc* isomer (60—80%),[2] that with aromatic aldehydes yields a mixture of the *rccc* and *rctt* isomers,[2,3] whereas the condensation of aromatic aldehydes with 2-methylresorcinol affords exclusively the *rctt* isomer.[4] In the present study, we examined the structure and isomeric composition of a new calix[4]methylresorcinarene derived from 2-methylresorcinol and *p*-tolualdehyde.

Results and Discussion

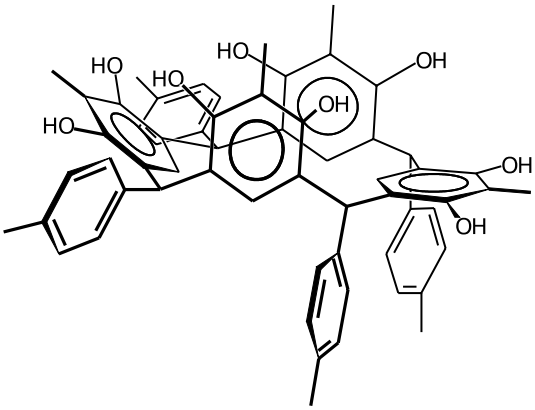
We synthesized and characterized new isomers of calix[4]methylresorcinarenes based on 2-methylresorcinol and *p*-tolualdehyde (Scheme 1). The reaction afforded two main products in a ratio of 6 : 1, whose molecular mass (M = 904) corresponds to that for the tetramer. The resulting isomers differ in solubilities. The *rctt* diastereomer (**1**) precipitates from the reaction mixture and is par-

Published in Russian in *Izvestiya Akademii Nauk. Seriya Khimicheskaya,* No. 11, pp. 2470—2477, November, 2005.

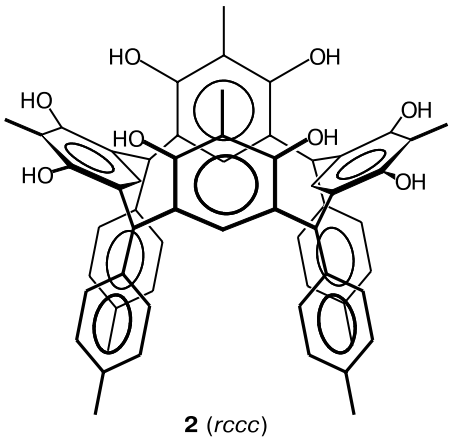
Scheme 1



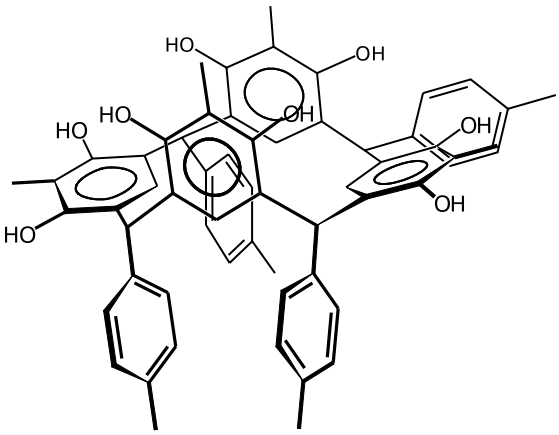
1—3



1 (*rctt*)



2 (*rccc*)



3 (*rcct*)

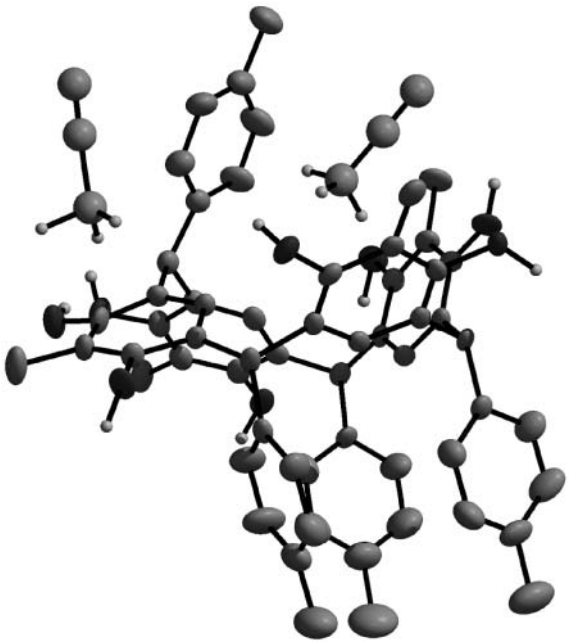


Fig. 1. Mutual arrangement of molecule **3** and two acetonitrile solvate molecules. Hydrogen atoms are ignored, except for the hydrogen atoms of the hydroxy and methyl groups of the acetonitrile molecules.

tially soluble on heating only in DMSO, whereas the *rccc* diastereomer (**2**) remains in the filtrate and, after isolation in pure form, is readily soluble in ethanol and acetone.

In addition, several crystals of *rcct* isomer **3** were isolated from the reaction mixture. Its structure was established by X-ray diffraction. Earlier, this isomer has not been observed in analogous reactions. In this connection, we report the results of X-ray diffraction study of this compound.

In the crystal structure of **3**, there are one resorcinarene molecule and two solvate molecules of acetonitrile per asymmetric unit (Fig. 1)

The conformation of the macrocycle in the crystal can be described as 1,2-alternate or chair (two adjacent resorcinol groups are in opposite orientation relative to two other resorcinol groups) (Fig. 2).

Let us take the plane passing through the bridging C(1), C(8), C(15), and C(22) atoms as the arbitrary basis plane. Then the dihedral angles between the benzene rings $\overline{C(2)—C(7)}$, $\overline{C(9)—C(14)}$, $\overline{C(16)—C(21)}$ and $\overline{C(23)—C(28)}$ and the above plane are 34.0(1), 49.3(1), 79.6(1), and 32.7(1)°, respectively (see Fig. 2). This molecular geometry is favorable for the formation of numerous intramolecular hydrogen bonds in the macrocyclic core.

A system of weak directed interactions in the crystal involves both classical O—H...O and O—H...N hydrogen

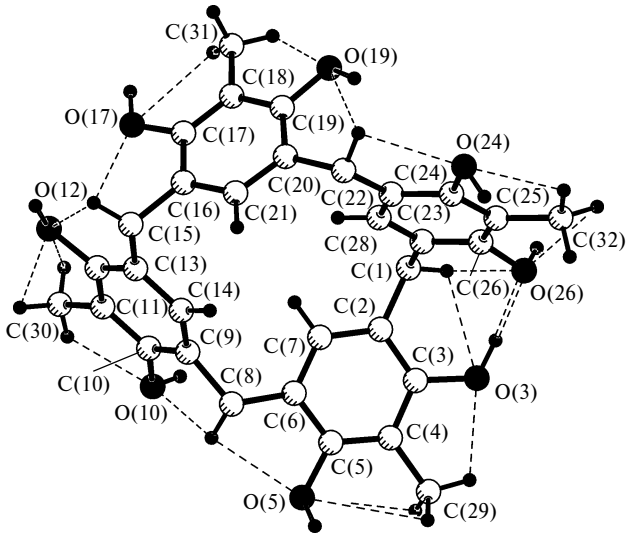


Fig. 2. Atomic numbering scheme and intramolecular hydrogen bonds in molecule **3**. Hydrogen atoms are ignored, except for the hydrogen atoms involved in hydrogen bonding.

bonds and weaker C—H...O hydrogen bonds, as well as C—H...π and π...π interactions (Table 1). Many of these interactions are bi- and trifurcate.

All other hydroxy groups are involved in intermolecular contacts corresponding to hydrogen bonds. The macrocycles are linked to each other through the O(5)—H(5)...O(24) and O(19)—H(19)...O(5) hydrogen bonds to form chains along the [100] crystallographic direction. The chains, in turn, are linked to each other along the [011] direction through the bifurcate O(24)—H(24)...O(3) and O(17)—H(17)...O(12) hydrogen bonds. These weak interactions are responsible for the formation of a supramolecular structure as a layer parallel to the [011] crystallographic plane (Fig. 3).

The solvate molecules of acetonitrile are linked to the calixarene molecules through the O(12)—H(12)...N(66) and O(26)—H(26)...N(63) hydrogen bonds. In addition, these molecules are probably involved in weak C—H...π interactions. However, the main function of these molecules is to fill the cavities in the crystal packing, thus decreasing the unit-cell volume, which is potentially accessible to the solvent, to the minimum value of 16 Å^3 (the volume of the water molecule is 40 Å^3).

It should be noted that analysis of intermolecular contacts (which was carried out with the use of the PLATON program[5]) based on the formal criteria for hydrogen bonding in a donor—hydrogen...acceptor (D—H...A) system, *viz.*, d(D...A) < R(D) + R(A) + 0.50 Å, d(H...A) < R(H) + R(A) − 0.12 Å, and ∠D—H...A > 100.0° (where R are the van der Waals radii of the corresponding atoms), revealed no involvement of the H(10) atom of one of the hydroxy group in contacts of any type. This may be attributed only to the steric factor. This fact is additional evidence that the principle of the maximum saturation of hydrogen bonds in the crystal formation is not always completely satisfied.

Table 1. Hydrogen bonds and angles in the crystal structure of compound **3**

Bond type[a]	D—H...A triad	H...A/Å [D...A]/Å	Angle D—H...A /deg
IntraHB	O(3)—H(3)...O(26)	1.96 [2.858(4)]	156.6
IntraHB	C(1)—H(1)...O(3)	2.53 [2.907(4)]	102.8
IntraHB	C(1)—H(1)...O(26)	2.32 [2.817(4)]	110.8
IntraHB	C(8)—H(8)...O(10)	2.48 [2.921(4)]	104.7
IntraHB	C(15)—H(15)...O(12)	2.48 [2.933(5)]	108.4
IntraHB	C(29)—H(291)...O(3)	2.34 [2.784(6)]	107.6
IntraHB	C(30)—H(301)...O(10)	2.33 [2.790(5)]	108.9
IntraHB	C(31)—H(313)...O(19)	2.33 [2.770(5)]	106.8
IntraHB	C(32)—H(322)...O(24)	2.45 [2.916(5)]	109.5
InterHB	O(26)—H(26)...N(63)	1.92 [2.809(11)]	160.4
InterHB[b]	O(5)—H(5)...O(24)	1.97 [2.748(3)]	138.5
InterHB[c]	O(12)—H(12)...N(66)	1.97 [2.933(7)]	141.4
InterHB[c]	O(17)—H(17)...O(12)	1.96 [2.833(3)]	149.2
InterHB[d]	O(19)—H(19)...O(5)	2.02 [2.937(3)]	134.1
InterHB[e]	O(24)—H(24)...O(3)	1.89 [2.862(3)]	161.1
InterHB[d]	C(22)—H(22)...O(5)	2.51 [3.330(4)]	143.5
InterHB[f]	C(61)—H(613)...O(19)	2.57 [3.44(2)]	152.9

[a] IntraHB and InterHB are intra- and intermolecular hydrogen bonds, respectively. The molecules are related by the symmetry operations: [b] 1 + x, y, z; [c] 1 − x, 1 − y, −z; [d] −1 + x, y, z; [e] 1 − x, −y, 1 − z; [f] −x, 1 − y, 1 − z.

In the crystal structure, π...π interactions occur between pairs of the resorcinol fragments C(23)—C(28) of the adjacent molecules related by the symmetry operation (1 − x, −y, 1 − z) (the shortest distance between the planes of the rings is 3.64 Å and the dihedral angle is 0°). The *p*-tolyl fragments belonging both to the same molecule and to adjacent molecules are coplanar with each other (in the former case, the interplanar distance is 4.60 Å; in the latter case, the interplanar distance is smaller (3.34 Å), but the distance between the centers of the rings is larger (5.77 Å)).

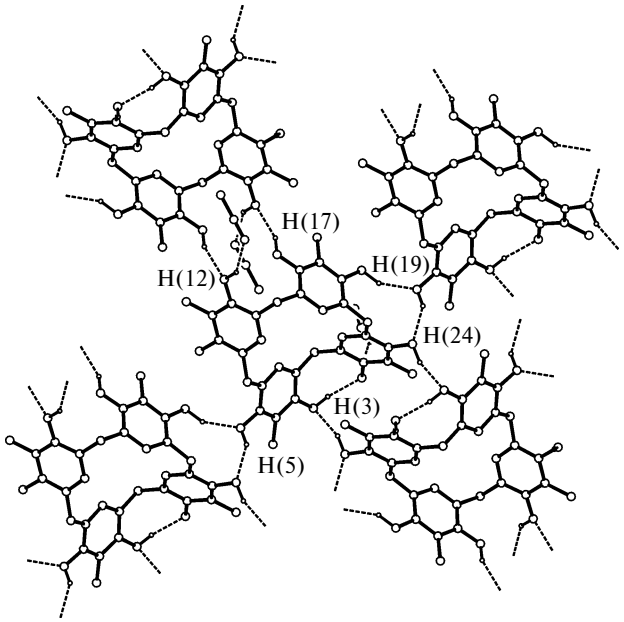


Fig. 3. Formation of infinite layers of hydrogen-bonded molecules in the crystal of **3**.

The environment of two solvent molecules differs. Two resorcinol fragments of the macrocycle and the *p*-tolyl fragment form a pseudoplane, and one of the acetonitrile solvate molecules lies in this plane. The methyl group of this solvent molecule is directed inside the cavity. The hydrogen atoms of this group are directed toward three benzene rings, which is favorable for the formation of three C—H...π interactions. The distances between the hydrogen atoms and the centers of the rings are in the range of 2.35—3.01 Å, and the angles vary from 101° to 170°. The second solvent molecule is involved only in one C—H...π interaction with the resorcinol fragment of molecule **3** (the distance is 2.86 Å and the angle is 166°).

The tolyl fragments form the outer surface of the above-considered layers (Fig. 4). Hence, these fragments and the solvate molecules located in these layers form "interlayers" between the adjacent layers packed in the crystal structure. Thus, the alternating spatial separation of the regions having predominantly hydrophilic and hydrophobic properties is observed in the crystal packing of **3**, as in other structures studied earlier.[6,7]

The minor condensation product of 2-methylresorcinol with *p*-tolualdehyde was identified as *rccc* isomer **2** by ^{1}H and ^{13}C NMR spectroscopy and mass spectrometry as well as by analogy with the published data.[2—5]

The ^{1}H NMR spectra of isomeric calixarenes **1** and **2** are similar to the spectra of analogous isomers described earlier,[2—4] but differ substantially from each other. In the spectrum of product **2**, the signals for the protons of the tolyl residues at δ 7.01 and 6.85 are observed as two doublets, the integrated intensity of each signal corresponding to eight protons. The methine protons are represented by one resonance singlet at δ 5.78 with an integrated intensity corresponding to four protons. Two groups of signals each corresponding to 12 protons at δ 2.42 and 2.20 are assigned to the methyl groups of the tolyl and resorcinol fragments, respectively. This simple spectral pattern is indicative of high symmetry of the structure and is completely analogous to that usually observed for *rccc* isomers.

The spectrum of the major condensation product **1** is totally different. All protons of the tolyl substituents are represented by double sets of signals. Two low-field doublets at δ 7.40 and 7.17 with integrated intensities of 4 H each were assigned (according to the published data[2—5]) to protons of two tolyl fragments that are orthogonal to

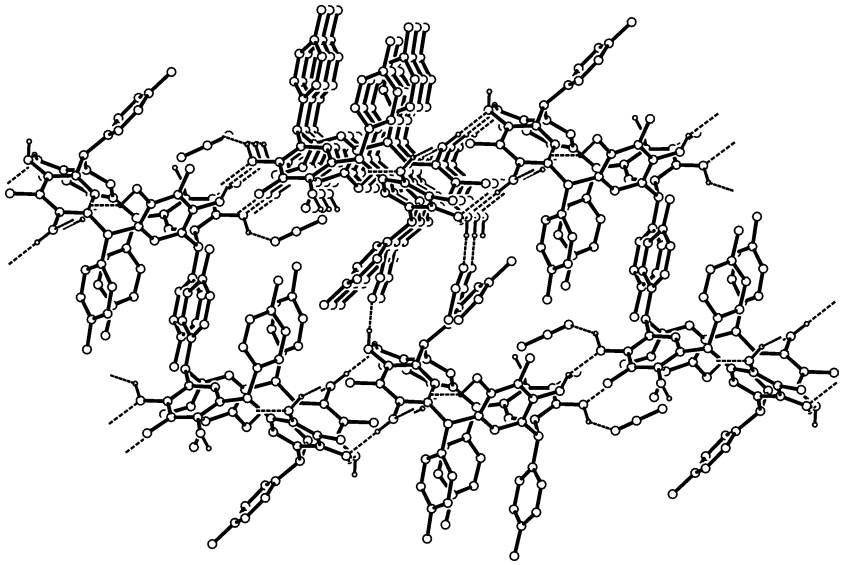


Fig. 4. Molecular packing in the crystal of **3** projected along the *a* axis.

the arbitrary plane of the macrocycle passing through the bridging carbon atoms. Another pair of doublets at higher field (at δ 7.13 and 7.07) with the same integrated intensity belongs to another pair of protons of the tolyl groups arranged parallel to the arbitrary plane of the macrocycle. The spectrum shows two sets of signals for the methine protons at δ 6.40 and 5.00 with the intensity of 2 H, which does not contradict the proposed mutual *trans* orientation of the substituents and is convincingly confirmed by the fact that the protons of the methyl groups of the tolyl fragments are also observed as two sets of signals at δ 2.40 and 2.30.

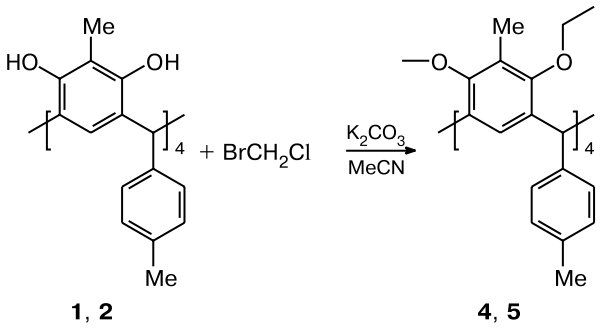
The signals for the protons of the methyl groups and the aromatic *para*-protons of the resorcinol fragments are grouped in a different way. They give three groups of signals, one of which has a double intensity. The methyl groups give signals at δ 2.13 (3 H), 1.93 (3 H), and 2.03 (6 H). The first two signals each have an intensity of 3 H, and their chemical shifts are most different. The signal with an intermediate chemical shift has an intensity of 6 H. Three signals for the protons of the resorcinol fragments at δ 7.20 (s, 1 H), 7.02 (s, 2 H), and 6.90 (s, 1 H) are characterized by the same intensity ratio. The double intensities of the signals of the resorcinol fragments with intermediate chemical shifts indicate that two resorcinol rings have an equivalent environment.

This spectral pattern agrees well with the structure of *rctt* isomer **1**. This isomer is presented in Scheme 1 as a molecular model constructed with the use of the HyperChem program. Two opposite resorcinol rings are nearly orthogonal to the arbitrary plane of the macrocycle passing through the bridging carbon atoms. This is consistent with the noticeable difference in the chemical shifts of the protons bound to these carbon atoms.

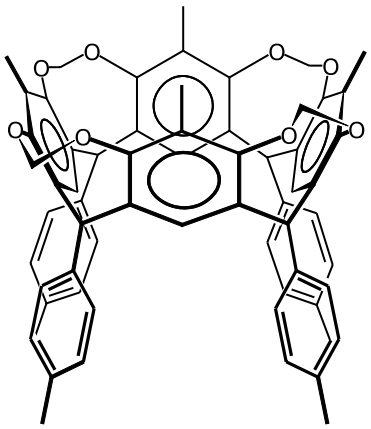
Cavitands based on calixarenes are readily formed by linking the adjacent hydroxy groups only from structures, in which these groups are spatially close to each other. In most cases, these calixarenes adopt a cone conformation.[8] However, it has been demonstrated[4] that *rctt* isomers also form cavitands.

Product **4** was prepared in 36.8% yield by linking *rccc* isomer **2** with $BrCH_2Cl$ (Scheme 2). This product was isolated in pure form by chromatography and was characterized by ^1H and ^{13}C NMR spectroscopy and mass spectrometry. The elucidation of the structures of cavitands synthesized from *rccc* isomers presents no difficulty because these compounds are symmetrical and have been well characterized. The structure is confirmed by the absence of a broad signal of hydroxy groups in the ^1H NMR spectrum of the product, which was observed in the spectrum of starting calixarene **2** (δ 3.06). The spectrum contained two new doublets (δ 5.90 and 4.34) for the protons of the methylene bridge formed as a result of linking.

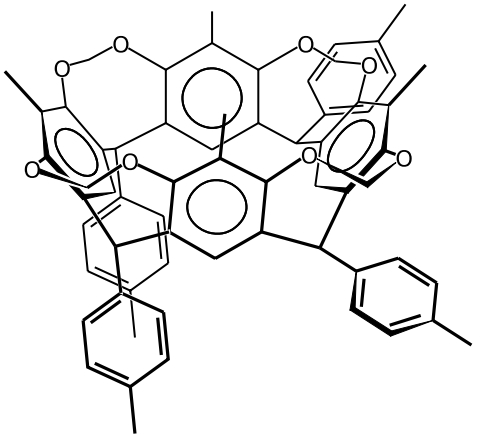
Scheme 2



1, **2** **4**, **5**



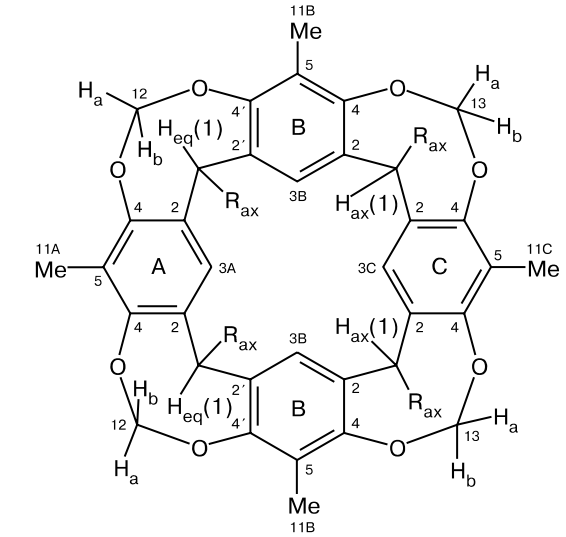
4 (*rccc*)



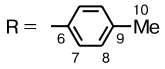
5 (*rctt*)

Product **5** was synthesized analogously from *rctt* isomer **1** in lower yield (14.3%) (see Scheme 2). After chromatographic purification, the product with M = 952 was isolated. Its structure was established by 2D NMR spectroscopy, because the closure of *rctt* isomer **1** by a methylene bridge to form a cavitand could not be expected *a priori* since it was not evident whether steric conditions are sufficient for the complete linking of all hydroxy groups giving rise to a cavitand.

The structure of cavitand **5** was confirmed by analysis of its 2D COSY (Fig. 5), HSQC, and ROESY spectra, which allowed us to identify signals for the protons of the Me group (the atomic numbering scheme corresponds to that used for cavitand systems) of the tolyl substituent, which appear as two singlets (δ 2.38 and 2.33). The protons of the methylene bridge, H(12) and H(13), are observed as four doublets (δ 6.01, 5.67, 4.47, and 4.37), and the methine protons are nonequivalent and appear as two singlets (δ 6.46 and 5.00) denoted as $H_{eq}(1)$ and $H_{ax}(1)$. The mutual *trans* arrangement of pairs of the aromatic substituents with respect to the arbitrary plane of the macrocycle is confirmed by the fact that the ROESY spectrum has signals attributed to exchange interactions in the oxygen-containing rings of the cavitand between the mutually *cis* methine protons $H_{eq}(1)$ and the protons of the methylene bridge, $H_a(12)$ and $H_b(12,)$ which links the resorcinol oxygen atoms. This is evidence that these groups are closely spaced. The absence of analogous interactions in two other oxygen-containing rings between the mutu-



5



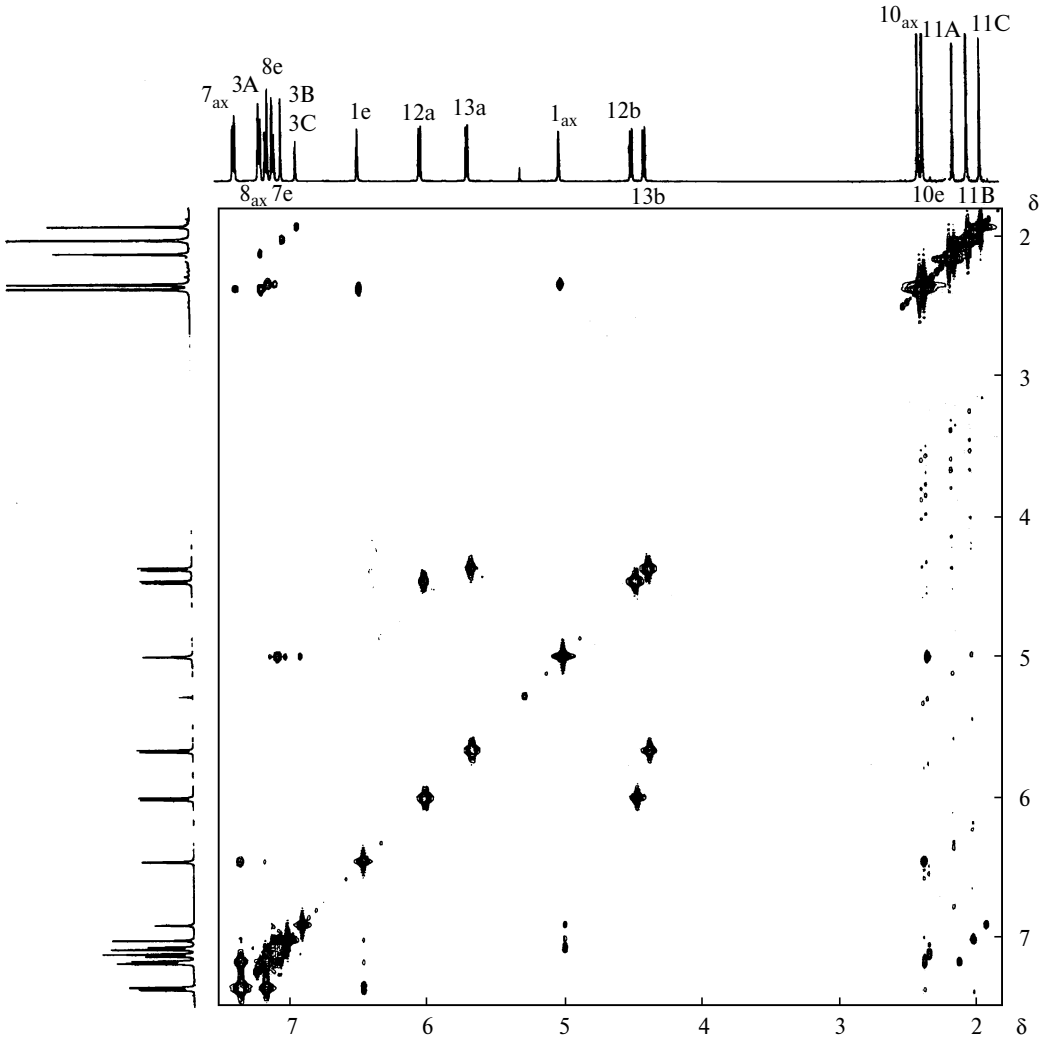


Fig. 5. COSY $^1H—^1H$ spectrum of cavitand **5**.

ally *trans* protons $H_{ax}(1)$ and the corresponding protons of the methylene bridge, $H_a(13)$ and $H_b(13)$, is evidence that these fragments are far apart.

Thus, the reaction of 2-methylresorcinol with *p*-tolualdehyde, unlike analogous reactions with other aromatic aldehydes, afforded two main diastereomers (*rctt* and *rccc*) rather than one *rctt* isomer. In addition, we demonstrated that not only the *rccc* isomer but also the *rctt* isomer can be linked to form cavitands adopting a cone conformation in spite of the fact that the latter isomer adopts a chair conformation containing two differently oriented aryl substituents.

Experimental

The ^1H and ^{13}C NMR spectra were recorded on a Bruker AC-300 spectrophotometer (300.1 MHz for ^1H and 75 MHz for ^{13}C). The 2D NMR spectra were measured on a Bruker DRX-500 instrument operating at 500.1 and 125.7 MHz, respectively; Me_4Si was used as the internal standard. The mass spectra were obtained on a MALDI-TOF Kratos Kompact MALDI II mass spectrometer (Shimadzu Europa GmbH, Duisburg, Germany), N2-Laserquelle (λ = 337 nm), with the use of 1,8,9-trihydroxyanthracene and *p*-nitroaniline as the matrices. The melting points were determined on a Boetius hot-stage apparatus. Elemental analysis was carried out in microanalytical laboratories at the A. E. Arbuzov Institute of Organic and Physical Chemistry of the Kazan Research Center of the Russian Academy of Sciences and the Institute of Organic Chemistry of the Dresden University of Technology.

X-ray diffraction analysis of compound 3 was carried out on an automated four-circle Enraf-Nonius CAD-4 diffractometer. Crystals of **3**, $C_{60}H_{56}O_8 \cdot 2C_2H_3N$, are triclinic. At 20 °C, a = 11.217(4), b = 13.567(3), c = 19.09(1) Å, α = 83.28(4), β = 78.39(3), γ = 69.33(3)°, V = 2660.5(4) Å^3, Z = 2, d_{calc} = 1.23 g cm^{-3}, space group $P\bar{1}$.

The unit cell parameters and intensities of 7682 reflections, of which 5071 reflections were with $I \geq 3\sigma$, were measured at 20 °C (λ(Cu-Kα) = 1.5418 Å, graphite monochromator, $\omega/2\theta$ scanning technique, $\theta \leq 57.22°$). The intensities of three check reflections showed no decrease in the course of X-ray data collection. The absorption correction was ignored because of the small absorption coefficient (μCu = 6.09 cm^{-1}). The structure was solved by direct methods using the SIR program[9] and refined first isotropically and then anisotropically, except for the atoms of two solvate molecules, which were refined isotropically. Subsequently, all hydrogen atoms were located from difference electron density maps. The contributions of the hydrogen atoms to the structure amplitudes were taken into account with fixed positional and thermal parameters in the final steps of the least-squares refinement. The final reliability factors were as follows: R = 0.062, R_w = 0.076 using 5071 independent reflections with $F^2 \geq 3\sigma$. All calculations were carried out using the MolEN program package[10] on an AlphaStation 200 computer. The atomic coordinates and displacement parameters were deposited with the Cambridge Structural Database. Selected geomet-

Table 2. Selected geometric parameters of molecule **3**

Bond	d/Å	Bond angle	ω/deg	Torsion angle	τ/deg
O(3)—C(3)	1.379(4)	C(2)—C(1)—C(27)	111.1(3)	H(3)—O(3)—C(3)—C(2)	−5.5(5)
O(5)—C(5)	1.392(4)	C(2)—C(1)—C(33)	113.8(3)	H(5)—O(5)—C(5)—C(4)	−60.8(4)
O(10)—C(10)	1.377(5)	C(2)—C(1)—H(1)	110.2(3)	H(10)—O(10)—C(10)—C(9)	78.8(4)
O(12)—C(12)	1.396(4)	C(27)—C(1)—C(33)	116.2(3)	H(12)—O(12)—C(12)—C(11)	−163.2(2)
O(17)—C(17)	1.381(4)	C(27)—C(1)—H(1)	105.4(3)	H(17)—O(17)—C(17)—C(16)	179.1(3)
O(19)—C(19)	1.390(4)	C(33)—C(1)—H(1)	99.0(3)	H(19)—O(19)—C(19)—C(18)	−160.9(2)
O(24)—C(24)	1.398(5)	C(9)—C(8)—H(8)	103.5(3)	H(24)—O(24)—C(24)—C(23)	−122.7(3)
O(26)—C(26)	1.386(5)	C(6)—C(8)—C(9)	116.5(2)	H(26)—O(26)—C(26)—C(25)	105.3(3)
N(63)—C(62)	1.05(2)	C(6)—C(8)—C(40)	110.9(3)	C(27)—C(1)—C(2)—C(3)	96.6(3)
N(66)—C(65)	1.141(7)	C(6)—C(8)—H(8)	110.7(3)	C(2)—C(1)—C(33)—C(34)	41.6(4)
C(1)—C(2)	1.520(5)	C(9)—C(8)—C(40)	109.6(3)	C(27)—C(1)—C(33)—C(34)	172.5(3)
C(1)—C(27)	1.521(6)	C(40)—C(8)—H(8)	104.8(3)	C(6)—C(8)—C(9)—C(10)	−95.9(4)
C(1)—C(33)	1.542(5)	C(13)—C(15)—C(16)	109.0(3)	C(6)—C(8)—C(40)—C(45)	−25.8(5)
C(4)—C(29)	1.517(6)	C(13)—C(15)—C(47)	115.8(3)	C(9)—C(8)—C(40)—C(45)	104.2(4)
C(6)—C(8)	1.514(4)	C(13)—C(15)—H(15)	108.3(3)	C(13)—C(15)—C(47)—C(48)	−12.3(5)
C(8)—C(9)	1.534(5)	C(16)—C(15)—C(47)	112.6(3)	C(16)—C(15)—C(47)—C(48)	114.0(4)
C(8)—C(40)	1.532(5)	C(16)—C(15)—H(15)	110.9(3)	C(14)—C(13)—C(15)—C(16)	−66.6(4)
C(11)—C(30)	1.495(6)	C(47)—C(15)—H(15)	99.9(3)	C(19)—C(20)—C(22)—C(23)	71.4(4)
C(13)—C(15)	1.520(6)	C(23)—C(22)—H(22)	106.8(3)	C(20)—C(22)—C(54)—C(55)	−106.3(4)
C(15)—C(16)	1.514(4)	C(20)—C(22)—C(23)	111.3(3)	C(23)—C(22)—C(54)—C(55)	19.6(5)
C(15)—C(47)	1.517(5)	C(20)—C(22)—C(54)	111.7(2)		
C(18)—C(31)	1.503(4)	C(20)—C(22)—H(22)	106.9(3)		
C(20)—C(22)	1.542(5)	C(23)—C(22)—C(54)	112.4(3)		
C(22)—C(23)	1.524(5)	C(54)—C(22)—H(22)	107.4(4)		
C(22)—C(54)	1.516(4)	N(63)—C(62)—C(61)	167.0(2)		
C(25)—C(32)	1.516(5)	N(66)—C(65)—C(64)	179.3(6)		

ric parameters are given in Table 2. The molecular structures were drawn and intermolecular interactions were calculated using the PLATON program.[5]

Calix[4]methylresorcinarenes 1 (*rctt*) and 2 (*rccc*). Concentrated HCl (25 mL) was added with stirring and cooling (ice—water) to a solution of 2-methylresorcinol (13.8 g, 0.112 mol) and *p*-tolualdehyde (12.25 g, 0.100 mol) in ethanol (200 mL). The reaction mixture was stirred at room temperature for 3 days. The white precipitate that formed was filtered off and washed with ethanol (3×50 mL). Compound **1** was obtained in a yield of 20.2 g (80.3%), m.p. 360 °C (decomp.). Water (300 mL) was added to the filtrate. The yellow precipitate was filtered off and washed with water. Compound **2** was obtained in a yield of 3.12 g (12.4%), m.p. 360 °C (decomp.).

Compound 1. Found (%): C, 79.10; H, 6.00. $C_{60}H_{56}O_8$. Calculated (%): C, 79.62; H, 6.23. ^{1}H NMR (DMSO-d_6), δ: 7.40 (d, 4 H, J = 7.4 Hz); 7.20 (s, 1 H); 7.17 (d, 4 H, J = 7.4 Hz); 7.13 (d, 4 H, J = 8.2 Hz); 7.07 (d, 4 H, J = 8.2 Hz); 7.02 (s, 2 H); 6.90 (s, 1 H); 6.40 (s, 2 H); 5.00 (s, 2 H); 2.40 (s, 6 H); 2.30 (s, 6 H); 2.13 (s, 3 H); 2.03 (s, 6 H); 1.93 (s, 3 H). ^{13}C NMR (DMSO-d_6), δ: 155.1, 154.9, 153.8, 153.0, 137.9, 137.5, 137.4, 136.2, 136.0, 135.5, 135.2, 131.1, 129.1, 128.7, 128.5, 127.2, 126.9, 126.7, 125.4, 124.2, 123.9, 56.1, 42.0, 21.1, 20.8, 10.6, 10.5, 10.4. MS, m/z (I_{rel} (%)): 904 $[M - 1]^+$ (100), calcd. M = 905.

Compound 2. Found (%): C, 78.90; H, 6.20. $C_{60}H_{56}O_8$. Calculated (%): C, 79.62; H, 6.23. ^{1}H NMR (acetone-d_6), δ: 7.01 (d, 8 H, J = 8.0 Hz); 6.85 (d, 8 H, J = 8.0 Hz); 6.08 (s, 4 H); 5.78 (s, 4 H); 3.06 (br.s, 8 OH); 2.42 (s, 12 H); 2.20 (s, 12 H). ^{13}C NMR (acetone-d_6), δ: 154.9, 137.5, 137.0, 135.4, 131.2, 129.6, 128.1, 125.4, 55.6, 21.9, 9.1. MS, m/z (I_{rel} (%)): 904 $[M - 1]^+$ (100), calcd. M = 905.

Calix[4]methylresorcinarene-based cavitand (4, *rccc*). A solution of calix[4]methylresorcinarene **2** (3.1 g, 3.4 mmol) and $BrCH_2Cl$ (4 mL, 61.25 mmol) in DMF (150 mL) and K_2CO_3 (11 g, 80 mmol) were stirred at 70 °C for 4 days. After removal of the solvent *in vacuo*, CH_2Cl_2 (60 mL) was added, and the solution was washed with 2 *M* HCl (3×25 mL). After silica gel column chromatography (CH_2Cl_2 as the eluent), a pale-pink powder of **4** was isolated in a yield of 1.2 g (36.8%), m.p. 360 °C (decomp.). Found (%): C, 80.10; H, 5.90. $C_{64}H_{56}O_8$. Calculated (%): C, 80.64; H, 5.92. ^{1}H NMR ($CDCl_3$), δ: 7.11 and 6.97 (both d, 8 H each, J = 8.0 Hz); 6.73 and 6.29 (both s, 4 H each); 5.90 and 4.34 (both d, 4 H each, J = 6.9 Hz); 2.22 and 2.01 (both s, 12 H each). ^{13}C NMR ($CDCl_3$), δ: 154.8, 137.5, 137.1, 135.4, 131.2, 129.6, 128.1, 125.4, 96.9, 55.4, 22.1, 10.4. MS, m/z (I_{rel} (%)): 952 $[M - 1]^+$ (100), calcd. M = 953.

Calix[4]methylresorcinarene-based cavitand (5, *rctt*) was prepared analogously from calix[4]methylresorcinarene **1** in 14.3% yield, m.p. 360 °C (decomp.). Found (%): C, 79.80; H, 5.80. $C_{64}H_{56}O_8$. Calculated (%): C, 80.64; H, 5.92. ^{1}H NMR ($CDCl_3$), δ: 7.38 (d, 4 H, J = 7.4 Hz); 7.19 (s, 1 H); 7.17 (d, 4 H, J = 7.4 Hz); 7.13 and 7.07 (both d, 4 H each, J = 8.2 Hz); 7.02 (s, 2 H); 6.92 and 6.46 (both s, 2 H each); 6.01 (d, 2 H, J = 6.9 Hz); 5.67 (d, 2 H, J = 6.96 Hz); 5.00 (s, 2 H); 4.47 (d, 2 H, J = 6.9 Hz); 4.37 (d, 2 H, J = 6.96 Hz); 2.38 and 2.33 (both s, 6 H each); 2.13 (s, 3 H); 2.03 (s, 6 H); 1.93 (s, 3 H). ^{13}C NMR ($CDCl_3$), δ: 155.2, 154.4, 153.8, 153.1, 137.5, 137.4, 137.3, 137.0, 136.2, 135.9, 135.7, 135.2, 131.1, 129.0, 128.7, 128.5, 127.1, 126.8, 125.5, 124.2, 123.97, 98.5, 97.7, 56.3, 41.9, 21.07, 20.98, 10.6, 10.5, 10.4. MS, m/z (I_{rel} (%)): 952 $[M - 1]^+$ (100), calcd. M = 953.

We thank Professor V. Boehmer (Johannes Gutenberg University of Mainz, Germany) for help in interpreting 2D NMR spectra.

This study was financially supported by the Russian Foundation for Basic Research (Project Nos 03-03-96258 and 02-03-32280) and the Academy of Sciences of Tatarstan (Grant 07-7.4-207).

References

1. A. G. S. Hoegberg, *J. Org. Chem.*, 1980, **45**, 4498.
2. L. M. Tunstad, J. A. Tucker, E. Dalcanale, J. Weiser, J. A. Bryant, J. C. Sherman, R. C. Helgeson, C. B. Knobler, and D. J. Cram, *J. Org. Chem.*, 1989, **54**, 1305.
3. Y. Yamakawa, M. Ueda, R. Nagahata, K. Takeuchi, and M. Asai, *J. Chem. Soc., Perkin Trans. 1*, 1998, 4135.
4. O. Middel, W. Verboom, R. Hulst, H. Kooijman, A. L. Spek, and D. N. Reinhoudt, *J. Org. Chem.*, 1998, **63**, 8259.
5. A. L. Spek, *Acta Crystallogr., Sect. A, Fund. Crystallogr.*, 1990, **46**, 34.
6. A. T. Gubaidullin, *Intern. Union of Crystallography XVIII Congress and General Assembly (Glasgow, August 4—13, 1999), Collected Abstract*, Glasgow (Scotland, UK), 1999, 393.
7. V. F. Mironov, A. T. Gubaidullin, A. A. Shtyrlina, I. A. Litvinov, R. R. Petrov, A. I. Konovalov, T. A. Zyablikova, R. Z. Musin, and E. N. Varaksina, *Zh. Org. Khim.*, 2002, **72**, 1868 [*Russ. J. Org. Chem.*, 2002, **72** (Engl. Transl.)].
8. H. Boerrigter, W. Verboom, and D. N. Reinhoudt, *J. Org. Chem.*, 1997, **62**, 7148.
9. A. Altomare, G. Cascarano, C. Giacovazzo, and D. Viterbo, *Acta Crystallogr., Sect. A*, 1991, **47**, 744.
10. L. H. Straver and A. J. Schierbeek, *MolEN. Structure Determination System. Vol. 1. Program Description*, Nonius B. V., 1994, 180 p.

Received January 10, 2003;
in revised form September 22, 2005