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Heterocalixarenes. Part 4. Synthesis of oxocalix[1]heterocycle[2]-arenes: a unique H-bonding network in calix[1]benzimidazol-2-one[2]arene·½ H_2O †

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Received (in Cambridge, UK) 31st January 2000, Accepted 2nd May 2000
Published on the Web 3rd July 2000

The Friedel–Crafts aroylation of 2-methylanisole with 3-methylbenzoyl chloride followed by NBS bromination and cyclizations with 1,3-dihydrobenzimidazol-2-one, 1,3-dihydro-5,6-dinitrobenzimidazol-2-one, uracil, 6-methyluracil and quinazoline-2,4(1*H*,3*H*)-dione provide respective oxocalix[1]heterocycle[2]arenes **5**–**9**. The X-ray crystal structure (solid) and ^{1}H NMR spectral (solution) studies show them to have by and large inwardly flattened partial cone conformations which vary in torsion angles between the rings. The calix[1]benzimidazol-2-one[2]arene·½ H_2O complex shows a unique array of H-bonds in which three of the four CH and the imide oxygen of the benzimidazol-2-one unit, carbonyl oxygen and water molecule are involved in H-bonding with surrounding calixarene molecules. This heterocalixarene, in contrast to earlier reported benzimidazol-2-one-based calixarenes, does not show heterocyclic π–π stacking.

Calix[*n*]arenes – which structurally constitute a cyclic array of 1,3-phenylene rings joined by methylene bridges – adopt varied conformations depending upon the number of 1,3-phenylene rings[2] and the nature of substituents present on these rings[2]/methylene bridges.[3] The tetra-O-substituted calix[4]arenes have a rigid structure and may adopt cone, partial cone, 1,2-alternate or 1,3-alternate conformations. The higher homologues of calix[4]arenes, due to their increased structural flexibility, display numerous conformations. The replacement of arene ring(s) with heterocyclic ring(s) influences the π-electron density in the cavities and also provides alternative sites for binding.[4]

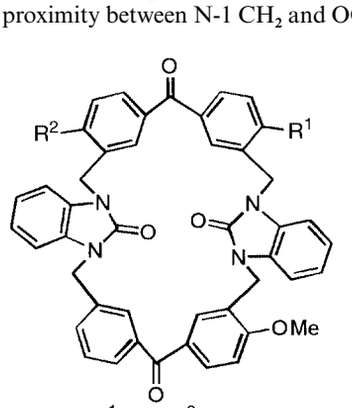
The calixarenes with less than four rings have attracted scant attention. The only known *p*-halogenocalix[3]arenes[5] have been assigned a cone conformation by ^{1}H NMR and IR spectral data but, due to the non-availability of any X-ray structure, it is not confirmed. Recently, three-fold and two-fold symmetric conformations of carbotrianions of calix[3]arenes[6] have been revealed. To the best of our knowledge, no other report on calix[3]arenes is available in the literature. Now, in the present investigation, a simple three-step methodology for the synthesis of oxo-bridged calix[1]heterocycle[2]arenes (**5**–**9**), a previously unknown class of heterocalix[3]arenes, is reported. The X-ray crystal structures of heterocalix[3]arenes **5** and **7** show them to have inwardly flattened partial cone conformations. The calix[1]dihydrobenzimidazol-2-one[2]arene **5**, which crystallizes as a 2 : 1 complex with water, shows a unique array of H-bonds in which three of the four CH and the imide oxygen of the 1,3-dihydrobenzimidazol-2-one unit, the carbonyl oxygen and a water molecule are involved in H-bonds with surrounding calixarene molecules.

Results and discussion

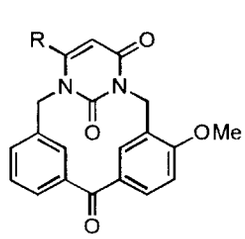
Synthesis

The Friedel–Crafts aroylation of 2-methylanisole **1** with 3-methylbenzoyl chloride **2** in dry chloroform in the presence of $AlCl_3$ (anhydrous) provides **3** (95%). The bromination of **3** with NBS in CCl_4 provides the dibromide **4** (70%). The intermolecular cyclization of **4** with 1,3-dihydrobenzimidazol-2-one under phase-transfer catalytic conditions provides monooxoheterocalix[3]arene **5** (40%) (Scheme 1) and isomeric dioxoheterocalix[6]arene **10a** or **10b** (< 2%).

The reaction of **4** with 1,3-dihydro-5,6-dinitrobenzimidazol-2-one provides only **6** (28%). The cyclocondensation of **4** with uracil/6-methyluracil, due to non-equivalence of N-1 and N-3, could form isomeric products **7**/**8** and **7a**/**8a**. However, in each case a single isomer (TLC, ^{1}H NMR) was formed. So, NOE experiments were performed to determine their structures. In the NOE spectrum of **7**, irradiation of the U-6H doublet enhanced the intensities of one doublet (δ 4.59) of an AB quartet (δ 4.59, 5.48) and of the U-5H doublet and OCH_3 singlet. This observation shows that N^1-CH_2 is placed close to the OCH_3 group. Therefore, the cyclization of **4** with uracil provides exclusively **7** and not the isomeric **7a**. Structure **7** has been confirmed by single-crystal X-ray structure analysis. In the NOE spectrum of **8**, irradiation of the U^6-CH_3 group enhanced the intensity of U-5H (singlet) and one doublet (δ 4.89) of an AB quartet (δ 4.89, 5.40). Irradiation of the proton C^3-H marked with an asterisk (structure **11**) enhanced the intensity of a second AB quartet (δ 5.20, 5.46). These results point to the proximity between N-1 CH_2 and OCH_3 groups. So, the reaction



10a R^1 = H, R^2 = OMe
10b R^1 = OMe, R^2 = H



7a R = H
8a R = Me

† ^{1}H–^{1}H COSY spectra of compounds **7**–**9** are available as supplementary data from BLDSC (SUPPL. NO. 57709, pp. 4) or the RSC Library. See Instructions for Authors available *via* the RSC web page (http://www.rsc.org/authors).

DOI: 10.1039/b000832j

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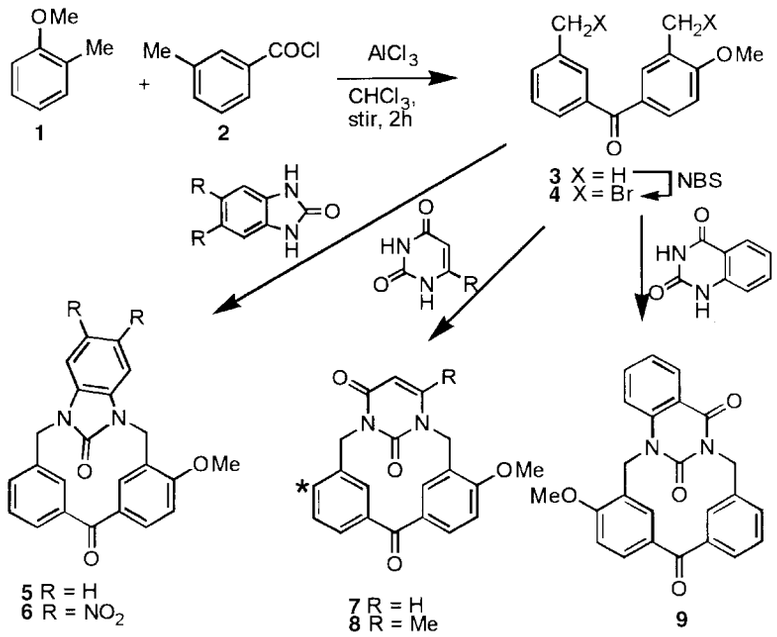


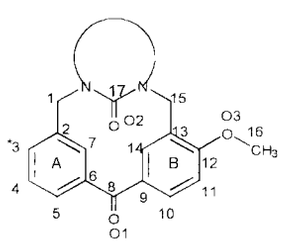
Scheme 1

of **4** with 6-methyluracil provides exclusively one isomer **8**, out of the two possible isomers **8** and **8a**.

In case of the condensation product of **4** and quinazoline-2,4(1*H*,3*H*)-dione, the signals of various protons in the aromatic region are so closely placed that irradiation of a selected signal in the NOE experiment is not possible. So, it was not possible to experimentally define the structure but, in analogy with **7** and **8**, the structure **9** has been assigned to the product.

Conformational analysis

The heterocalix[3]arenes can adopt either cone or partial cone conformations. The inward or outward flattening of one of the rings can lead to additional inwardly flattened or outwardly flattened cone or partial cone conformations (Fig. 1). The conformational analysis of these heterocalix[3]arenes has been carried out by using X-ray (solid state), ^{1}H NMR, ^{1}H–^{1}H COSY (solution state) and force-field energy-minimization studies. The heterocalixarenes **5**–**9** have two arylene rings as a common structural feature and differ in the nature of the heterocyclic rings which are invariably elaborate urea spacers, and so can be collectively represented in structure **11**.



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(a) Solid phase: X-ray. The X-ray crystal structures of heterocalix[3]arenes **5** and **7** (Figs. 2 and 3) show them to attain by and large similar conformations, which have been analysed as inwardly flattened partial cone conformations. The small differences in torsion angles (Fig. 4, Table 1) arising in **5** and **7** may be due to the presence of different heterocyclic rings, and a water molecule in the case of **5**.

The torsion angles about C1, C8 and C15 vary as − +, + +, − −, in both the heterocalix[3]arenes (Table 1). In **5** and **7** with

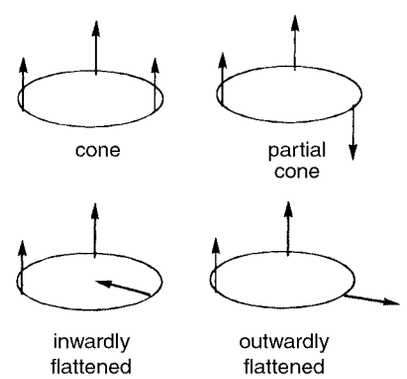

Fig. 1 Iconographic representations of possible conformations in calix[3]arenes.

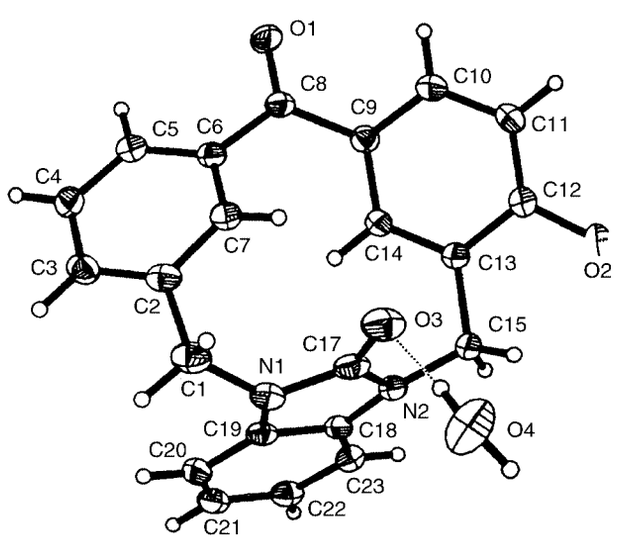

Fig. 2 ORTEP view of heterocalix[3]arene **5**. Thermal ellipsoids are drawn with 50% probability and hydrogen atoms are drawn with arbitrary small isotropic thermal parameters for the sake of clarity.

respect to the mean plane constituted by bridging carbons C1, C8 and C15, the heterocyclic rings are nearly perpendicular [81.1(1)° in **5**, 108.7(1)° in **7**], the phenylene rings 'B' are in an

Table 1 Important torsion angles (°) in heterocalixarenes **5** and **7**

	5	**7**
C7–C2–C1–N1	−53.6(3)	−66.3(3)
C2–C1–N1–C17	81.0(3)	85.4(3)
C14–C13–C15–N2	−17.5(4)	−14.4(4)
C13–C15–N2–C17	−59.7(3)	−59.7(3)
C7–C6–C8–C9	25.2(4)	28.7(3)
C6–C8–C9–C14	23.3(4)	25.7(4)

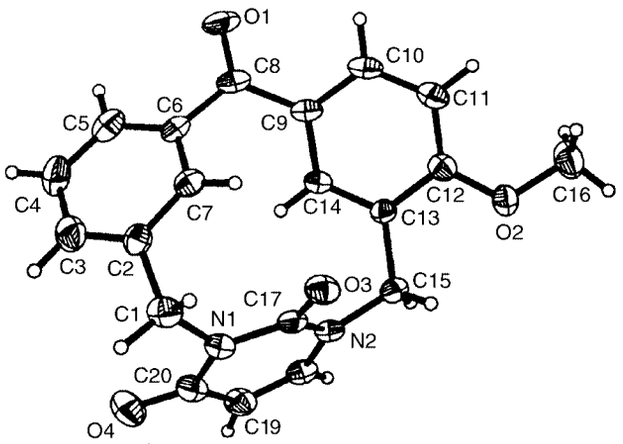

Fig. 3 ORTEP view of heterocalix[3]arene **7**. Thermal ellipsoids are drawn with 50% probability and hydrogen atoms are drawn with arbitrary small isotropic thermal parameters for the sake of clarity.

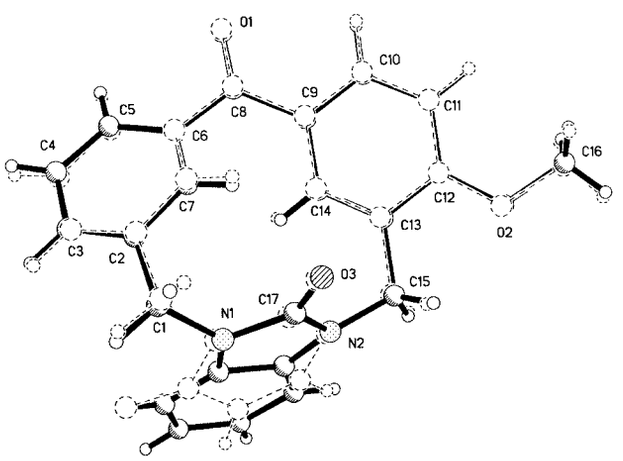

Fig. 4 Superimposition of X-ray structures of **5** (bold) and **7** (dotted).

anti position [141.7(1)° in **5**, 134.8(1)° in **7**] and phenylene rings 'A' are in nearly a *gauche* [38.5(1)° in **5**, 42.9(1)° in **7**] conformation. The phenylene rings 'A' and 'B' (see structure **11**) are placed at an angle of 79.6(1)°, 65.29(1)° in **5** and 96.8(1)°, 56.6(1)° in **7** with respect to the heterocyclic rings, but are in nearly a *gauche* [55.4(1)° in **5**, 40.8(1)° in **7**] conformation with respect to each other. Consequently, 7-H and 14-H are oriented above and below the plane of the bridging carbons, respectively. The 7-H lies in the direction of O3, and 14-H faces the other side, giving rise to an inwardly flattened partial cone conformation, where ring 'B' is placed in an inwardly flattened conformation. It may be seen that, in **5** and **7**, 7-H shows unique short intramolecular contacts with O3 and that 14-H lies under the influence of the π-cloud of the respective heterocyclic rings. There is a strong ArCH···π interaction between 14-H···1,3-dihydrobenzimidazol-2-one ring [2.7(1) Å, 122(1)°] in **5**. These distances and angles are found to be quite comparable with those reported earlier.[4d,7] A similar CH···π interaction in **7** [ArH···π = 2.9(1) Å] may be considered, but is quite weak.

Table 2 The four distinct H-bonding distances (Å) and angles (°) in **5**

X···O	Å	H···O	Å	∠X–H–O
O4···O3′	2.85(1)	H41···O3^{i}	1.93(4)	174(1)
C23···O4^{ii}	3.47(1)	H23···O4^{ii}	2.5(1)	173(3)
C21···O1^{iv}	3.42(1)	H21···O1^{iv}	2.5(5)	155(3)
C22···O1^{v}	3.35(1)	H22···O1^{v}	2.5(4)	145(3)

i = $-x$, $+y$, $-z+\frac{3}{2}$; ii = x, $y+1$, z; iv = x, $-y+1$, $z+\frac{1}{2}$; v = $-x+\frac{1}{2}$, $-y+\frac{1}{2}$, $z+\frac{1}{2}$.

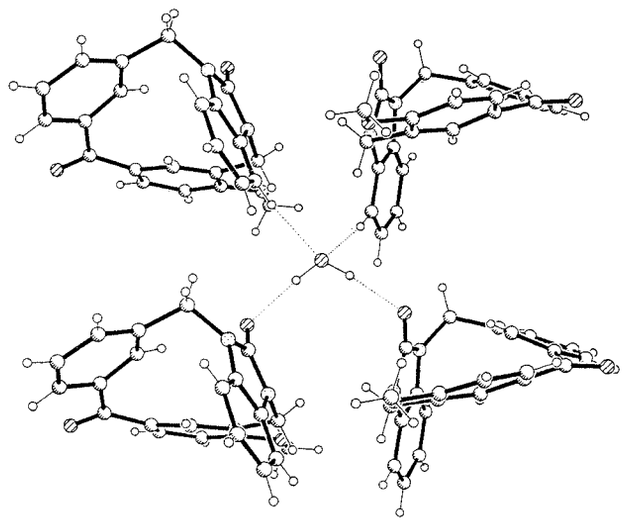

Fig. 5 Diagram showing H-bonding of H_2O with four molecules of heterocalix[3]arene **5** in tetrahedral geometry.

The heterocalixarenes **5** and **7** show quite different crystal packings. **5** Crystallizes as **5**·½ H_2O complex and shows a strong H-bonding network. Each molecule acts three times as an acceptor and three times as a donor, making six contacts per molecule with four distinct distances (Table 2). As a result each molecule of **5** is connected to five other symmetry-related molecules through CH···O interactions, and with three symmetry-related molecules through H_2O H-bonding interactions. Each water molecule is strongly H-bonded to four molecules of **5** placed in a tetrahedral geometry (Fig. 5). Water behaves both as H-bond donor and acceptor. Water O4 donates through both its hydrogens, which are bonded to O3 of two symmetry-related molecules. Water behaves as an H-bond acceptor through 23-H···O4 (Table 2). The oxygen of oxo bridge O1 is also involved in CH···O-type H-bonding interactions with an aromatic CH of the benzimidazol-2-one unit of two adjacent molecules of **5** (Table 2). The packing of **5** (Fig. 6) shows stacking of the molecule down the '*b*'-axis. This packing gives rise to face-to-face π–π interactions[8] [4.0(1) Å] between the rings 'B' of the two heterocalix[3]arene molecules related by a glide plane perpendicular to the '*b*'-axis. In contrast to benzimidazol-2-one-based calix[8/9]arenes,[4c,4d] where side-on-side stacking of heterocyclic units is an important motif contributing to crystal formation, here in calix[1]-1,3-dihydrobenzimidazol-2-one[2]arenes such heterocyclic π stacking is not observed.

The packing of **7** (Fig. 7) shows C-10···O1^{vi} H-bond interactions between two symmetry-related molecules of **7** [C10···O1^{vi} 3.25(1) Å, 10-H···O1^{vi} 2.4(1) Å, 153(1)°, vi = $-x+1$, $-y+2$, $-z+1$], giving rise to dimers. This packing results in a strong face-to-face π–π interaction[8] [3.5(1) Å] between two symmetry-related rings 'B' of **7**, down the '*b*' axis.

(b) Solution phase: ^{1}H NMR. The rationalization of multiplicities and chemical shifts of various proton signals in the ^{1}H NMR spectra, and comparison with their acyclic precursors,

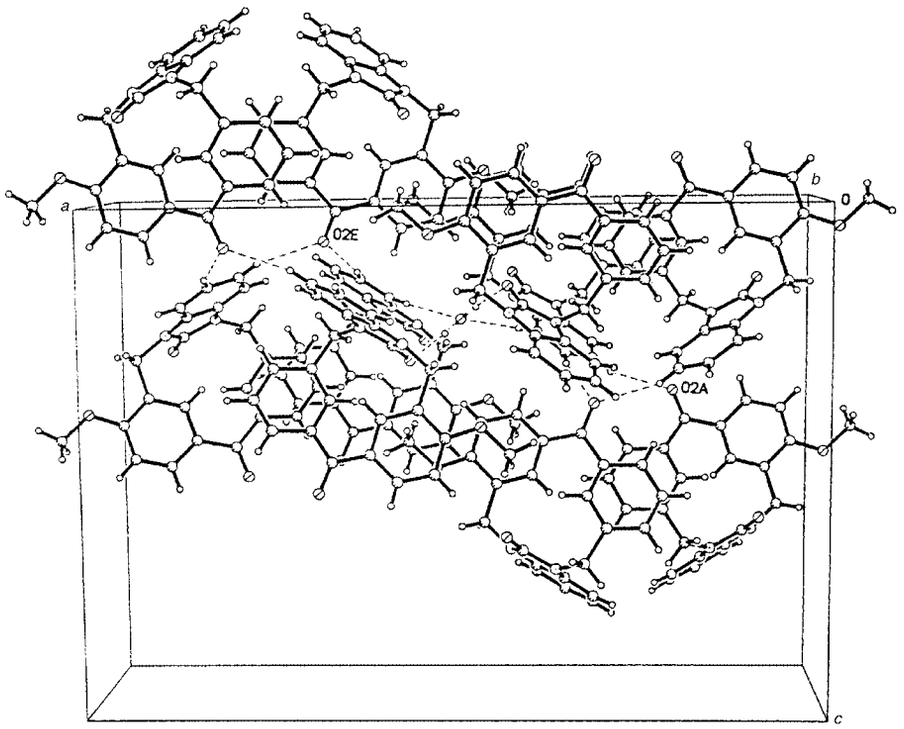

Fig. 6 Packing diagram of $5\cdot\frac{1}{2}H_2O$ showing H-bonding network.

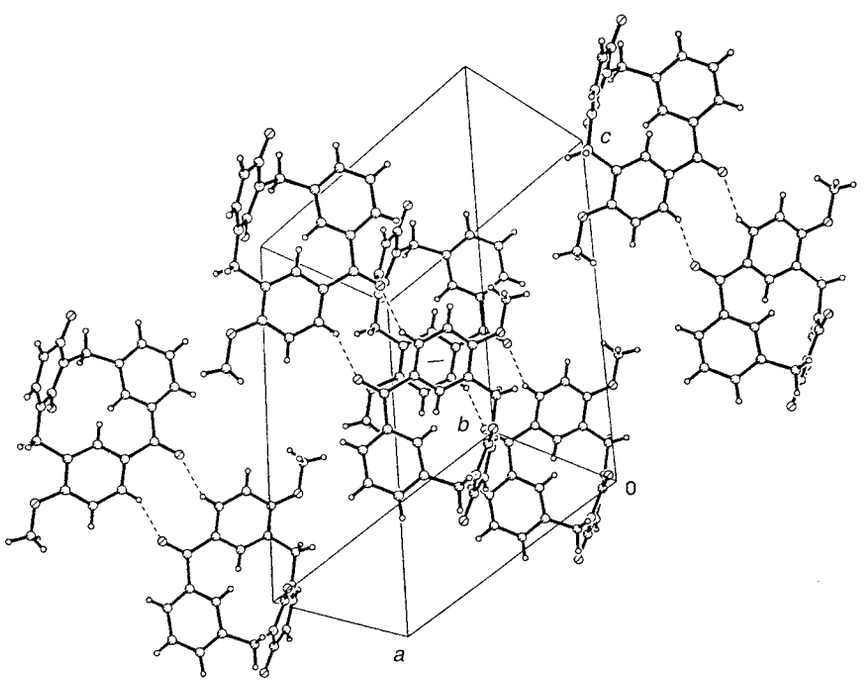

Fig. 7 Packing diagram of **7** showing H-bonding and π–π interactions.

provides a useful tool for assigning the geometries of calixarenes. The heterocalix[3]arenes **5**–**9**, show well defined ^{1}H NMR spectra but the presence of a number of doublets makes it impossible to assign chemical shifts to various protons. So, in order to assign the chemical shifts of the various protons, the ^{1}H–^{1}H COSY spectra of heterocalix[3]arenes **5**–**9** have been recorded.

The ^{1}H NMR spectrum of **5** exhibits four doublets (two pairs) with geminal coupling (δ 4.98, 5.34; 4.82, 5.53; J = 16.6 Hz), due to two NCH_2 units and well defined but complex multiplets in the aromatic region. In the ^{1}H–^{1}H COSY spectrum of **5** (Fig. 8), the triplet (δ 7.37 (of C4-H shows cross-peaks at δ 7.53 (d, C3-H/C5-H) and 7.68 (d, C5-H/C3-H). Since C5-H is *ortho* to the carbonyl group, it could be assigned the downfield signal at δ 7.68. The doublets at δ 7.53, 7.68 also show cross-peaks at δ 7.17 (s, C7-H) due to *meta*-couplings. The double doublet of C10-H at δ 7.87 (J_1 8.6 Hz, J_2 2.2 Hz) shows two cross-peaks, at δ 6.94 (d, J 8.6 Hz, C11-H) and 6.62 (d, J 2.2 Hz, C14-H). This assignment is based on the doublet at δ 6.94, which could easily be assigned to C11-H, placed *ortho* to the OMe unit. ^{1}H NMR spectra of the heterocalixarenes **6**–**9** similarly exhibit NCH_2 units as AB quartets and well resolved aromatic H signals, which could be assigned to specific protons from their ^{1}H–^{1}H COSY spectra (see supplementary data for spectra of compounds **7**–**9**).

The comparison of ^{1}H NMR chemical shifts of heterocalix[3]arenes **5**–**9** with **4** shows that the signals due to C7-H and C14-H of rings 'A' and 'B', respectively, depending upon the

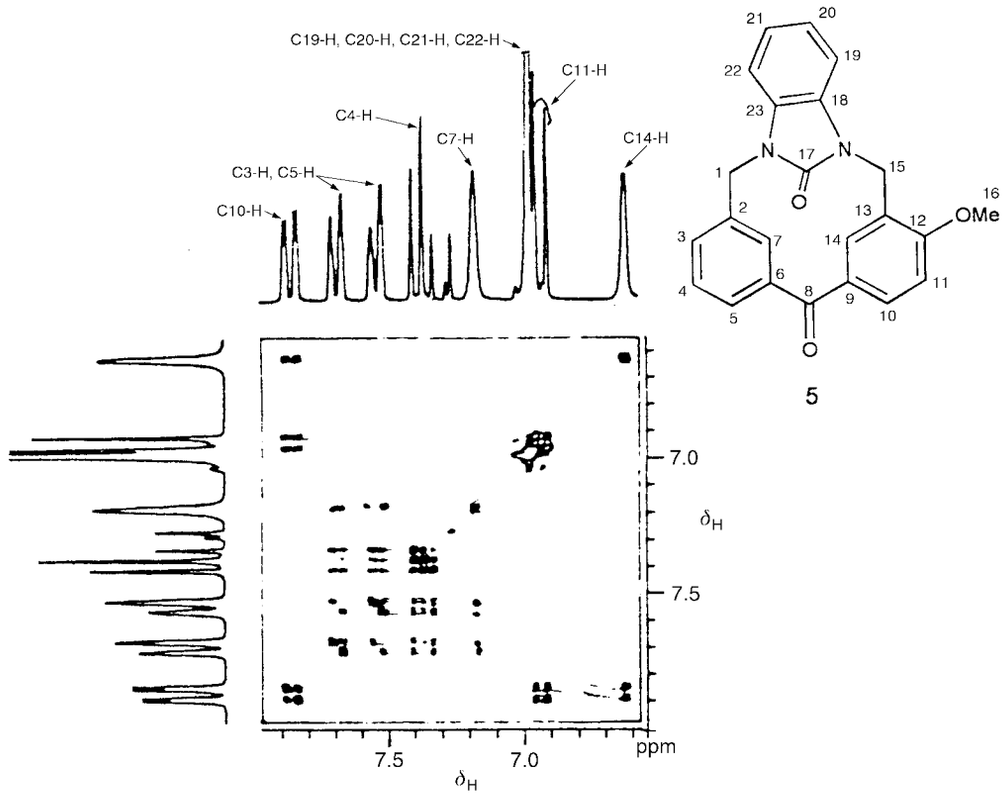

Fig. 8 ^{1}H–^{1}H COSY spectrum of heterocalix[3]arene **5**.

Table 3 Change in chemical shifts ($\Delta\delta$) of C7-H and C14-H in **5**–**9** in comparison with **4**

	Heterocalix[3]arene				
	5	**6**	**7**	**8**	**9**
C7-H	−0.62	−1.13	−0.42	−0.25	−0.43
C14-H	−1.25	−1.08	−0.83	−0.84	−0.43

nature of the heterocyclic moiety, are shifted upfield by 0.25–1.13 and 0.43–1.25 ppm (Table 3). The other signals remain by and large unaffected. Therefore, C7-H and C14-H protons have been placed in geometrical positions where they either interact with the imide O or face the aryl rings. Since these heterocalix[3]arenes exhibit AB quartets due to NCH_2 protons, these are considered to have rigid structures and might have similar conformations in both the solid and solution phases. In analogy with X-ray crystal-structure analysis, C14-H in **5** is placed close to the π-cloud of the heterocyclic ring and is shifted more upfield than it is in **7**. Similarly, C7-H forms a better contact with imide C=O in **5** and is shifted more upfield than is observed in **7**. So, the ^{1}H NMR spectra show that the heterocalix[3]arenes **5**–**9** have, by and large, inwardly flattened partial cone conformations, but, depending upon the nature of heterocyclic ring, the torsion angles between the rings vary.

Therefore, a simple three-step methodology involving Friedel–Crafts aroylation as the key step provides mono-oxocalix[1]heterocycle[2]arenes. The calix[1]dihydrobenzimidazol-2-one[2]arene·$\frac{1}{2}$ H_2O complex shows a strong H-bonding network but, in contrast to earlier reported benzimidazol-2-one-based calixarenes, does not show heterocyclic π-stacking.

Experimental

For experimental details, see ref. 9. In ^{13}C NMR spectral data, the +ve and −ve signals correspond to the DEPT-135 spectrum and 'ab' corresponds to quaternary C signals, which are absent in DEPT-135 but are observed in the normal ^{13}C spectrum.

Synthesis of benzophenone derivative 3

To a suspension of $AlCl_3$ (anhydrous) (13.5 g, 0.1 mol) in dry chloroform (100 ml) was added 3-methylbenzoyl chloride **2** (15.0 g, 0.095 mol) with stirring during 5 min. The stirring was continued to dissolve $AlCl_3$ completely and the temperature of the reaction mixture was lowered to 5 °C by immersing the flask in an ice-bath. A solution of 2-methylanisole **1** (14.6 g, 0.12 mol) in dry chloroform (50 ml) was added dropwise during 30 min and stirring was continued at room temperature for 1 h. The reaction mixture was cooled to 0 °C and treated with methanol and then with water. It was extracted with chloroform, the organic layer was dried with Na_2SO_4 (anhyd.), and solvents were removed and the residue was fractionally distilled under vacuum to give pure **3** (95%), bp 194–198 °C (20 mmHg), mp 64–66 °C; *m/z* 240 (M^+); ^{1}H NMR ($CDCl_3$) δ 2.26 (3H, s, CH_3), 2.42 (3H, s, CH_3), 3.91 (3H, s, OCH_3), 6.86 (1H, d, *J* 9.0 Hz, ArH), 7.34–7.69 (6H, m, 6 × ArH); ^{13}C NMR (normal/DEPT-135) ($CDCl_3$) δ_C 15.65 (+ve, CH_3), 20.72 (+ve, CH_3), 54.84 (+ve, OCH_3), 106.44 (+ve, ArCH), 126.04 (ab, ArC), 126.39 (+ve, ArCH), 127.41 (+ve, ArCH), 129.19 (ab, ArC), 129.56 (+ve, ARCH), 130.06 (+ve, ArCH), 131.96 (+ve, ArCH), 137.36 (ab, ArC), 137.99 (ab, ArCH), 160.91 (ab, ArC), 195.08 (ab, C=O); ν_{max}(KBr)/cm^{-1} 1667 (Calc. for $C_{16}H_{16}O_2$: C, 80.00; H, 6.67. Found: C, 79.3; H, 6.9%).

Synthesis of dibromide 4

A solution of ketone **3** (24.0 g, 0.1 mol) in CCl_4 (200 ml) containing a suspension of NBS (37.2 g, 0.21 mol) and benzoyl peroxide (100 mg) was refluxed for 4 h. The solid formed was filtered off and the solvent was removed under vacuum. The solid residue was crystallized from methanol–dichloromethane mixture (70%), mp 100–102 °C; *m/z* 396, 398, 400 (1 : 2 : 1, M^+);

^{1}H NMR ($CDCl_3$) δ 4.00 (3H, s, OCH_3), 4.54 (2H, s, CH_2), 4.57 (2H, s, CH_2), 6.97 (1H, d, *J* 8.6 Hz, ArH), 7.47 (1H, t, *J* 6.8 Hz, ArH), 7.60–7.70 (2H, m, 2 × ArH), 7.79 (1H, s, ArH), 7.81 (1H, dd, J_1 8.6 Hz, J_2 2.0 Hz, ArH), 7.87 (1H, d, *J* 2.0 Hz, ArH); ^{13}C NMR (normal/DEPT-135) ($CDCl_3$) δ_C 27.81 (−ve, CH_2), 32.48 (−ve, CH_2), 55.93 (+ve, OCH_3), 110.34 (+ve, ArCH), 126.30 (ab, ArC), 128.69 (+ve, ArCH), 129.49 (+ve, ArCH), 129.67 (ab, ArC), 130.07 (+ve, ArCH), 133.41 (+ve, ArCH), 133.02 (+ve, ArCH), 133.06 (+ve, ArCH), 138.05 (ab, ArC), 138.40 (ab, ArC), 160.96 (ab, ArC), 194.13 (ab, C=O); ν_{max}(KBr)/cm^{-1} 1660 (Calc. for $C_{16}H_{14}Br_2O_2$: C, 48.24; H, 3.52. Found: C, 48.8; H, 4.0%).

General procedure for the synthesis of 5–9

A suspension of dibromide **4** (3.98 g, 0.01 mol) and 1,3-dihydrobenzimidazol-2-one (1.34 g, 0.01 mol) in acetonitrile (700 ml) containing K_2CO_3 (12 g) and tetrabutylammonium hydrogen sulfate (TBA·HSO_4) (50 mg) was heated to reflux and the progress of reaction was monitored by TLC. After the completion of reaction, suspended solid was filtered off and the filtrate was concentrated under vacuum and the residue was subjected to column chromatography to afford pure product **5**. Similarly, the reactions of dibromide **4** with 1,3-dihydro-5,6-dinitrobenzimidazol-2-one,[10] uracil, 6-methyluracil and quinazoline-2,4(1*H*,3*H*)-dione gave the respective calixarenes **6**–**9**.

Compound 5. (40%), mp 201–203 °C (from MeOH + $CHCl_3$); *m*/*z* 370 (M^+); ^{1}H NMR ($CDCl_3$) δ 4.01 (3H, s, OCH_3), 4.82, 5.53 (2H, two doublets, *J* 16.6 Hz, NCH_2), 4.98, 5.34 (2H, two doublets, *J* 16.6 Hz, NCH_2), 6.62 (1H, s, C14-H), 6.94 (1H, d, *J* 8.6 Hz, C11-H), 6.96 (4H, br s, benzim, ArH), 7.17 (1H, s, C7-H), 7.37 (1H, t, *J* 6.6 Hz, C4-H), 7.53 (1H, d, *J* 7.6 Hz, C3-H), 7.68 (1H, d, *J* 7.6 Hz, C5-H), 7.87 (1H, dd, J_1 8.6 Hz, J_2 2.2 Hz, C10-H); ^{13}C NMR (normal/DEPT-135) ($CDCl_3$) δ_C 40.51 (−ve, CH_2), 46.27 (−ve, CH_2), 55.76 (+ve, OCH_3), 108.94 (+ve, ArCH), 109.46 (+ve, ArCH), 110.22 (+ve, ArCH), 121.90 (+ve, ArCH), 122.09 (+ve, ArCH), 123.78 (ab, ArC), 127.79 (+ve, ArCH), 128.16 (+ve, ArCH), 129.51 (ab, ArC), 130.18 (+ve, ArCH), 130.96 (ab, ArC), 131.16 (+ve, ArCH), 133.45 (+ve, ArCH), 134.82 (+ve, ArCH), 136.70 (ab, ArC), 137.64 (ab, ArC), 158.11 (ab, C), 160.45 (ab, C), 193.55 (ab, C=O); ν_{max}(KBr)/cm^{-1} 1656, 1678 (Calc. for $C_{23}H_{18}N_2O_3$: C, 74.59; H, 4.86; N, 7.56. Found: C, 74.1; H, 4.2; N, 8.0%).

Compound 6. (28%), mp 296–298 °C (from MeOH + $CHCl_3$); *m*/*z* 460 (M^+); ^{1}H NMR ($CDCl_3$) δ 4.13 (3H, s, OCH_3), 5.15, 5.62 (2H, two doublets, *J* 16.6 Hz, NCH_2), 5.24, 5.49 (2H, two doublets, *J* 16.6 Hz, NCH_2), 6.66 (1H, br s, C7-H), 6.79 (1H, br s, C14-H), 7.09 (1H, d, *J* 8.6 Hz, C11-H), 7.57 (1H, t, *J* 7.6 Hz, C4-H), 7.66 (1H, d, *J* 7.6 Hz, benzim, ArH), 7.70 (1H, d, *J* 7.6 Hz, C3-H), 7.72 (1H, s, benzim. ArH), 7.86 (1H, d, *J* 7.6 Hz, C5-H), 7.98 (1H, dd, J_1 8.6 Hz, J_2 2.0 Hz, C10-H); ^{13}C NMR (normal/DEPT-135) ($CDCl_3$) δ_C 41.52 (−ve, CH_2), 47.54 (−ve, CH_2), 56.21 (+ve, OCH_3), 106.33 (+ve, ArCH), 107.70 (+ve, ArCH), 111.18 (+ve, ArCH), 122.61 (ab, ArC), 129.00 (+ve, ArCH), 129.43 (+ve, ArCH), 132.14 (+ve, ArCH), 132.33 (+ve, ArCH), 132.61 (ab, ArC), 132.79 (+ve, ArCH), 134.69 (ab, ArC), 135.63 (+ve, ArCH), 137.22 (ab, ArC), 138.92 (ab, ArC), 139.11 (ab, ArC), 158.33 (ab, C), 161.15 (ab, C), 196.77 (ab, C=O); ν_{max}(KBr)/cm^{-1} 1661, 1730 (Calc. for $C_{23}H_{16}N_4O_7$: C, 60.00; H, 3.48; N, 12.17. Found: C, 60.1; H, 3.2; N, 11.8%).

Compound 10. (< 2%), mp 279–283 °C (from $CHCl_3$); *m*/*z* 740 (M^+); ^{1}H NMR ($CDCl_3$) δ 4.67 (6H, s, 2 × OCH_3), 5.08 (4H, s, NCH_2), 5.16 (4H, s, NCH_2), 6.53 (4H, d, *J* 8.0 Hz, ArH), 6.79–6.93 (4H, m, ArH), 6.97–7.24 (4H, m, ArH), 7.26 (2H, d, *J* 7.8 Hz, ArH), 7.36 (2H, d, *J* 7.8 Hz, ArH), 7.50 (2H, dd, J_1 7.8 Hz, J_2 1.8 Hz, ArH), 7.58 (2H, s, ArH), 7.66 (2H, s, ArH); ^{13}C NMR (normal/DEPT-135) ($CDCl_3$) δ_C 40.71 (−ve, NCH_2), 44.60 (−ve, NCH_2), 55.50 (+ve, OCH_3), 110.00 (+ve, ArCH), 112.04 (+ve, ArCH), 121.32 (+ve, ArCH), 121.77 (+ve, ArCH), 123.70 (+ve, ArCH), 128.26 (+ve, ArCH), 128.67 (ab, ArC), 128.78 (+ve, ArCH), 129.03 (ab, ArC), 129.21 (ab, ArC), 129.53 (+ve, ArCH), 130.74 (+ve, ArCH), 131.09 (+ve, ArCH), 132.58 (+ve, ArCH), 135.91 (ab, ArC), 137.18 (ab, ArC), 154.05 (ab, C=O), 155.54 (ab, C=O), 161.10 (ab, ArC), 192.91 (ab, C=O); ν_{max}(KBr)/cm^{-1} 1669, 1718.

Compound 7. (60%), mp 230 °C (from MeOH + $CHCl_3$); *m*/*z* 348 (M^+); ^{1}H NMR ($CDCl_3$) δ 3.97 (3H, s, OCH_3), 4.59, 5.48 (2H, two doublets, *J* 16.0 Hz, N3-CH_2), 5.16, 5.49 (2H, two doublets, *J* 14.2 Hz, N1-CH_2), 5.66 (1H, d, *J* 7.8 Hz, U5′-H), 7.00 (1H, d, *J* 8.6 Hz, C11-H), 7.04 (1H, br s, C14-H), 7.11 (1H, d, *J* 7.8 Hz, U6′-H), 7.37 (1H, br s, C7-H), 7.44 (1H, t, *J* 7.6 Hz, C4-H), 7.59 (1H, d, *J* 7.6 Hz, C3-H), 7.80 (1H, d, *J* 7.6 Hz, C5-H), 7.96 (1H, dd, J_1 8.4 Hz, J_2 2.0 Hz, C10-H); ^{13}C NMR (normal/DEPT-135) ($CDCl_3$) δ 44.37 (−ve, CH_2), 49.58 (−ve, CH_2), 55.87 (+ve, OCH_3), 102.56 (+ve, U5-CH), 110.53 (+ve, ArCH), 122.87 (ab, ArC), 127.75 (+ve, ArCH), 128.65 (ab, ArCH), 130.47 (ab, ArC), 130.79 (+ve, ArCH), 131.87 (+ve, ArCH), 132.54 (+ve, ArCH), 133.99 (+ve, ArCH), 136.74 (ab, ArC), 137.76 (ab, ArC), 142.94 (+ve, U6-CH), 152.60 (ab, ArC), 159.43 (ab, C=O), 162.29 (ab, C=O), 194.14 (ab, C=O); ν_{max}(KBr)/cm^{-1} 1660, 1725 (Calc. for $C_{20}H_{16}N_2O_4$: C, 68.69; H, 4.60; N, 8.05. Found: C, 69.0; H, 4.76; N, 7.5%).

Compound 8. (65%), mp 242 °C (from MeOH + $CHCl_3$); *m*/*z* 362 (M^+); ^{1}H NMR ($CDCl_3$) δ 2.21 (3H, s, U6′-CH_3), 3.98 (3H, s, OCH_3), 4.89, 5.40 (2H, two doublets, *J* 16.6 Hz, N^3-CH_2), 5.20, 5.46 (2H, two doublets, *J* 14.0 Hz, N^1-CH_2), 5.54 (1H, s, U5′-H), 7.01 (1H, d, *J* 8.8 Hz, C11-H), 7.03 (1H, s, C14-H), 7.44 (1H, t, *J* 7.6 Hz, C4-H), 7.54 (1H, s, C7-H), 7.60 (1H, d, *J* 7.6 Hz, C3-H), 7.80 (1H, d, *J* 7.6 Hz, C5-H), 8.00 (1H, dd, J_1 8.6 Hz, J_2 1.6 Hz, C10-H); ^{13}C NMR ($CDCl_3$) δ_C 19.87 (+ve, CH_3), 44.12 (−ve, NCH_2), 44.48 (−ve, NCH_2), 55.71 (+ve, OCH_3), 102.23 (+ve, U5-CH), 110.47 (+ve, ArCH), 122.52 (ab, ArC), 127.72 (+ve, ArCH), 128.51 (+ve, ArCH), 130.05 (ab, ArC), 130.53 (+ve, ArCH), 131.94 (+ve, ArCH), 132.81 (+ve, ArCH), 133.88 (+ve, ArCH), 136.90 (ab, ArC), 137.49 (ab, ArC), 151.53 (ab, ArC), 153.31 (ab, ArC), 159.44 (ab, C=O), 161.239 (ab, C=O), 193.80 (ab, C=O); ν_{max}(KBr)/cm^{-1} 1658, 1716 (Calc. for $C_{21}H_{18}N_2O_4$: C, 69.61; H, 4.97; N, 7.73. Found: C, 69.4; H, 4.6; N, 7.5%).

Compound 9. (42%), mp 222 °C (from MeOH + $CHCl_3$); *m*/*z* 398 (M^+); ^{1}H NMR ($CDCl_3$) δ 4.01 (3H, s, OCH_3), 5.25, 5.80 (2H, two doublets, *J* 14.6 Hz, NCH_2), 5.30, 5.65 (2H, two doublets, *J* 16.2 Hz, NCH_2), 6.96 (1H, d, *J* 8.6 Hz, C11-H), 7.22 (1H, t, *J* 7.4 Hz, quinaz. 7′-H), 7.36 (2H, br s, C7-, C14-H), 7.46 (1H, t, *J* 7.4 Hz, C4-H), 7.48 (1H, d, *J* 7.8 Hz, quinaz. 8′-H), 7.58–7.66 (2H, m, C3- and quinaz. 6′-H), 7.78 (1H, d, *J* 7.6 Hz, C5-H), 7.93 (1H, dd, J_1 8.4 Hz, J_2 2.2 Hz, C10-H), 8.18 (1H, dd, J_1 7.8 Hz, J_2 1.2 Hz, quinaz. 5′-H); ^{13}C NMR (normal/DEPT-135) ($CDCl_3$) δ_C 42.88 (−ve, NCH_2), 45.96 (−ve, NCH_2), 55.76 (+ve, OCH_3), 111.07 (+ve, ArCH), 114.43 (+ve, ArCH), 114.92 (ab, ArC), 124.92 (+ve, ArCH), 128.64 (+ve, ArCH), 128.80 (ab, ArC), 129.24 (+ve, ArCH), 129.45 (+ve, ArCH), 131.98 (+ve, ArCH), 133.24 (+ve, ArCH), 135.46 (ab, ArC), 136.20 (+ve, ArCH), 136.61 (+ve, ArCH), 136.76 (+ve, ArCH), 139.22 (ab, ArC), 152.81 (ab, ArC), 161.63 (ab, C=O), 163.40 (ab, C=O), 199.15 (ab, C=O); ν_{max}(KBr)/cm^{-1} 1662 (C=O), 1716 (C=O) (Calc. for

Table 4 Crystal data collection and refinement parameters for heterocalix[3]arenes **5** and **7**

	5·½ H_2O	**7**
Empirical formula	$C_{23}H_{18}N_2O_3$·½ H_2O	$C_{20}H_{16}N_2O_4$
M	379.40	348.35
Crystal system	Orthorhombic	Monoclinic
Space group	*Pbcn*	$P2_1/n$
a/Å	25.868(2)	12.259(2)
b/Å	7.826(1)	8.865(1)
c/Å	18.105(2)	15.943(2)
β/°		110.46(1)
V/Å^{-3}	3665.2(7)	1623.3(4)
Z	8	4
No. of measured/unique reflections	3233/3232	2178/2036
No. of observed reflections $[I_o \geqslant 2\sigma(I_o)]$	2221	1513
Residual *R* (observed data)	0.0473	0.0423

$C_{24}H_{18}N_2O_4$: C, 72.36; H, 4.52; N, 7.04. Found: C, 71.7; H, 4.8; N, 7.5%).

X-Ray crystal structure analysis of heterocalix[3]arenes 5 and 7‡

The crystals of **5** and **7** suitable for X-ray diffraction work were obtained by recrystallization from chloroform–methanol (1 : 1). All intensity data measurements were carried out on a Siemens P4 four-circle diffractometer with graphite monochromatic Mo-*Kα* radiation ($\lambda = 0.71069$ Å) at room temperature up to $\theta_{max} = 25$ °C. Both structures were solved and refined using SHELXTL software[11] package on a Siemens Nixdorf computer. The data were corrected for Lorentz and polarization effects but not for absorption effects. The structures were solved by direct methods. Full matrix least-squares refinement was employed with anisotropic thermal parameters for the non-hydrogen atoms. The hydrogen atoms attached to the water molecules were located by difference Fourier synthesis and the rest were fixed geometrically. The crystal data and parameters for data collection and refinement are summarized in Table 4.

‡ CCDC reference number 207/429. See http://www.rsc.org/suppdata/p1/b0/b000832j/ for crystallographic files in .cif format.

Acknowledgements

We thank UGC and DST, New Delhi for financial assistance.

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