Calixarenehydroxamic acid : synthesis and characterization

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Manuscript received 3 June 2002, revised 30 December 2002, accepted 21 January 2003

Calix[4]arenes are synthesised by the acid catalyzed reaction of *p*-hydroxybenzoic acid with bezaldehyde. The corresponding calixarenehydroxamic acids are prepared by converting the calixarene to acid chloride and then coupling it with *N*-arylhydroxylamines at low temperature in diethyl ether containing aqueous suspension of sodium bicarbonate.

The calixarenes are a group of phenolic macrocycles that have become significant in supramolecular chemistry during the past decade¹. Hydroxamic acids are bidentate ligands having remarkable versatility for the organic and inorganic analysis².

In the present investigation, the synthesis of calixarene hydroxamic acids (1–5) (Fig. 1) is described.

Results and discussion

The method adopted here for the synthesis of calixarene hydroxamic acid is very simple and of general applicability. It gives pure acids with improved yields. It has been reported

that the use of equimolar proportion of hydroxylamines and acid chlorides³ gives higher yield of monoacylated derivative. The excess of acid chloride results in increasing amounts of di-derivatives. Similarly, the excess of *N*-arylhydroxylamines gives impure products, possibly due to decomposition of hydroxylamine or acid catalyzed rearrangement of hydroxylamines and its decomposition to a complex product⁴. However, since there are four carboxyl groups in one molecule of calixarene, the quantity of hydroxylamine is taken four time that of acid chloride. The phenyl and methyl substituted calixarenes are white solids while others are yellowish in colour. In the ultraviolet region, the calixarene hydroxamic acids have two strong bands around 260 ± 4 and 315 ± 5 nm which are the characteristics bands of benzene I and II, respectively. In the IR spectra only those bands which are associated with hydroxamic acid functional group $-N(OH)-CO-$ have been assigned. The presence of OH group is observed at $3250-3180\text{ cm}^{-1}$. The C=O and N=O bands are observed at $1680-1665\text{ cm}^{-1}$. The NMR spectra show signals at δ 10.9, 10.8, 10.7, 10.8 and 10.6, which disappear on deuterium exchange and correspond to O–H of the hydroxamate functional grouping. The signal around δ 7.9 corresponds to O–H group of the phenol (inside the ring). The aromatic protons show signal around δ 6.8.

1 R = phenyl	4 R = <i>p</i> -iodophenyl
2 R = <i>p</i> -chlorophenyl	5 R = <i>p</i> -methylphenyl
3 R = <i>p</i> -bromophenyl	

Fig. 1. Substituted calix[4]arenehydroxamic acids.

Experimental

All chemicals used were of G.R. grades (E. Merck) unless otherwise specified.

IR spectra (KBr) were recorded on a Jasco FT-IR 410 spectrophotometer, UV spectra on a Hitachi 3210 spectrophotometer and ¹H NMR spectra (CDCl₃) on a Varian T-60 spectrometer (60 MHz) using tetramethylsilane as internal standard.

5, 11, 17, 23-*p*-Tetracarboxy-*C*-phenyl-25, 26, 27, 28-tetrahydroxycalix[4]arene : A mixture of *p*-hydroxybenzoic

acid (69 g, 0.5 mol) dissolved in water (125 ml), ethanol (125 ml) and 37% HCl (72.5 ml) was stirred and benzaldehyde (53 g, 0.5 mol) was slowly added to it. The mixture was refluxed at 80° for 16 h. The excess of solvent was then distilled off and resulting white solid was crystallized from ethanol-water (60 : 40), (yield 60%), m.p. 86°.

The acid chloride: A mixture of the above calix[4]arene (45.2 g, 0.05 mol), toluene (15 ml) and thionyl chloride (14.5 ml, 0.2 mol) was refluxed on a water-bath for 6 h. It was then allowed to cool and the excess thionyl chloride was removed under reduced pressure to give yellowish brown coloured product (44 g, 90%).

Arylhydroxylamines: These were prepared by reduction of the respective nitrobenzene with zinc dust and ammonium chloride from alcohol-water by reported method^{3,4}.

N-Aryl-25,26,27,28-tetrahydroxy-5,11,17,23-tetrakis-calix[4]arenehydroxamic acid: A mixture of freshly crystallized *N*-arylhydroxylamine (0.2 mol) dissolved in diethyl ether (75 ml) and sodium bicarbonate (0.25–0.3 mol) suspended in water (40 ml) was stirred and cooled considerably to keep at 0° or below. To it an ethereal solution (50 ml) of the acid chloride (0.05 mol) was added dropwise during 30–40 min. This solid mass was filtered, the ether layer separated and ether was removed under vacuum. The solid mass was titrated with saturated sodium bicarbonate solution to remove the acidic impurities. The solid products (yields 63–73%) were washed with distilled water and crystallized from the mixture of toluene and petroleum ether.

N-Phenyl-25,26,27,28-tetrahydroxy-5,11,17,23-tetrakis-calixarene hydroxamic acid (1), white, 72%, m.p. 91–92° (Found : C, 75.58; H, 4.79; N, 4.72. $C_{80}H_{60}O_{12}N_4O$ requires : C, 75.70; H, 4.76; N, 4.41%); $\lambda_{\max}$ (ϵ , dm^3 mol cm^{-1}) 264 (1.1×10^4), 350 nm (1×10^3); λ_{II}/λ_I 1.1; $\nu_{\max}$ (KBr) 3250, 1675, 1375, 965 cm^{-1} ; δ 6.8, 7.98, 10.9.

N-p-Chlorophenylcalixarenehydroxamic acid (2), yellow, 73%, m.p. 114–116° (Found : C, 68.30; H, 3.98; N, 3.95; Cl, 10.80. $C_{80}H_{56}O_{12}N_4Cl_4$ requires : C, 68.28; H, 4.01; N, 3.95; Cl, 10.08%); $\lambda_{\max}$ (ϵ , dm^3 mol cm^{-1}) 257 (2.4×10^4); 300 nm (6.0×10^4); λ_{II}/λ_I 1.2; $\nu_{\max}$ (KBr)

3280, 1670, 1370, 950 cm^{-1} ; δ 6.6, 7.94, 10.8.

N-p-Bromophenylcalixarenehydroxamic acid (3), yellow, m.p. 119–120° (Found : C, 60.68; H, 3.52; N, 3.50; Br, 20.20. $C_{80}H_{56}O_{12}N_4Br_4$ requires : C, 60.62; H, 3.56; N, 3.53; Br, 20.16%); $\lambda_{\max}$ (ϵ , dm^3 mol cm^{-1}) 258 (2.9×10^4), 304 nm (2.4×10^3); λ_{II}/λ_I 1.2; $\nu_{\max}$ (KBr) 3270, 1680, 1380, 960 cm^{-1} ; δ 6.9, 7.97, 10.7.

N-p-Iodophenylcalixarenehydroxamic acid (4), yellow, m.p. 156–161° (Found : C, 54.50; H, 3.05; N, 3.20; I, 18.70. $C_{80}H_{56}O_{12}N_4I_4$ requires : C, 54.20; H, 3.05; N, 3.20; I, 28.70%); $\lambda_{\max}$ (ϵ , dm^3 mol cm^{-1}) 258 (3.4×10^4), 304 nm (5.1×10^3); λ_{II}/λ_I 1.2; $\nu_{\max}$ (KBr), 3180, 1675, 1375, 935 cm^{-1} ; δ 6.8, 7.93, 10.8.

N-p-Methylphenylcalixarenehydroxamic acid (5), yellow, m.p. 104–106° (Found : C, 76.00; H, 5.20, N, 4.30. $C_{84}H_{68}O_{12}N_4$ requires : C, 76.12; H, 5.17; N, 4.22%); $\lambda_{\max}$ (ϵ , dm^3 mol cm^{-1}) 260 (2.5×10^4), 301 nm (1.1×10^3); $\nu_{\max}$ (KBr) 3230, 1665, 1380, 965 cm^{-1} ; δ 6.8, 7.84, 10.6.

Acknowledgement

Financial assistance by D.S.T., New Delhi, is gratefully acknowledged. One of the authors (M.S.) is grateful to C.S.I.R., New Delhi, for awarding Research Assistance.

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