CHAPTER 2

Synthesis and Characterization of Chromogenic Calixarenes
ABSTRACT

Nitrocalix[4]arene was synthesized and the corresponding calix(4)arene hydroxamic acid was prepared by coupling the partially reduced nitrocalix[4]arene with anthraquinone carbonyl chloride at a very low temperature [0-(-5)°C] in dioxane medium with an aqueous suspension of sodium bicarbonate.


Calix[6]arene substituted at the methylene group by benzaldehyde was synthesized for the first time by acid catalyzed reaction from p-cresol and benzaldehyde in high yields, by using a simple, single step, condensation procedure.

The synthesized calixarenes and their chromogenic derivatives were characterized by mp, elemental analysis and spectral techniques viz. FT – IR, 1H-NMR, 13C-NMR and FAB-MS.
INTRODUCTION

Molecular recognition is the fundament of supramolecular chemistry. The topical problems of supramolecular chemistry are the molecular design and synthesis of partially preorganized molecules capable of molecular recognizing and multicenter binding, those results in the host-guest complexes and in self-organizing supramolecular groups and devices. From this viewpoint, very promising compounds are calix-[n]arenes (n usually equals 4, 6, or 8) which have been extensively studied in the last two decades. Valuable properties of calixarenes originate from the presence of a hydrophobic aromatic cavity and the possibility for both upper- and lower-rim modification by appropriate functional groups. They also can serve as suitable molecular platforms for constructing the three-dimensional structures on them with a wide range of cavity sizes, different number and type of binding centres, and spatial arrangement of the binding groups. These structures can differ in possibilities of forming the asymmetric cavities and of changing the balance between the rigidity and flexibility of a receptor. As a result, these compounds can be widely used as models for molecular recognition, membrane transport, etc. In this connection, important problems are both synthesis of new types of calixarenes and development of procedures for their selective functionalization.

Our synthetic studies are aimed at preparation of preorganized structures with the rigid and deep cavities. The choice of the basic structures for the production of three-dimensional receptors can be explained as follows. For a substrate to recognize the receptor most efficiently, the surface area of the contact (interaction) between them should be the maximum. This condition can be achieved when the receptor “embraces” the substrate thus binding it through many intermolecular interactions and determining its molecular size, form, and structure. The cuplike structure of calixarenes fully meets these
requirements. Therefore, basic “blocks” chosen for constructing the host molecules were calix[4]arene and calix[6]arene.

Chemical sensing, which is accompanied by combining a recognition element with an optical or electronic transduction element, has received much attention as an efficient analytical technique for the detection of particular species. Among these sensing systems, chromogenic receptors give rise to a specific color change upon selective complexation with guest species, which are not only used as spectrophotometric analytical reagents but also as the tools for the detailed understanding of receptor–substrate interaction because that molecular recognition process could be efficiently amplified as an optical signal. Therefore, the design of new and highly efficient chromogenic receptors is always a challenge for supramolecular chemistry and analytical techniques.

Calixarenes can be ideal frameworks or building blocks for the development of chromogenic receptors in molecular recognition since the incorporation of an appropriate sensory group into the calixarene having a preorganized substrate binding site results in a tailored chromogenic receptor. A variety of chromogenic calixarenes bearing quinone, nitrophenol, nitrophenylazophenol, indoaniline, indophenol and azophenol have been synthesized which show high selectivity in recognition for cations and organic molecules.1-3

In the present investigation new chromogenic calix(4)arene and calix(6)arene have been synthesised by anchoring anthraquinone and styrene groups to the calixarene backbone through hydroxamic acid linkage to exploit the potentialities of hydroxamic acid as efficient metal complexing chelates. These molecular edifices combine the best features of the sub-units and the parent macrocycle; namely the selectivity of calixarenes, the sensitivity of styrene and anthraquinone moiety and the complexing ability of hydroxamic group. Another new calix(6)arene was also prepared by substituting phenyl
group on methylene bridge to get a hexaphenyl methyl calix(6)arene which showed good interaction with drug molecules.

**EXPERIMENTAL**

**Instruments and measurements**

Melting points are taken in a sealed capillary tube using a Toshniwal (India) melting point apparatus and are uncorrected. Infrared spectra are obtained on Brucker Tensor 27. The $^1$H NMR spectra are recorded on DRX 300 spectrophotometer operating at 300 MHz for proton in DMSO – $d_6$ with TMS as internal standard. The FAB mass spectra are recorded on a JEOL SX 102 / DA – 6000 mass spectrometer / data system using argon / xenon (6KV, 10mA) as the FAB gas. The accelerating voltage is 10 KV and the spectra are recorded at room temperature. M-nitro benzyl alcohol (NBA) is used as the matrix and the matrix peaks appeared at m/z 136, 137, 154, 289, 307.

**Chemicals and Reagents**

All reagents and solvents used are of AR grade of BDH and E-Merck unless otherwise specified.

**Preparation of nitro calix[4]arene**

Nitro calixarene was synthesized as described in literature.4-5,8 m. p. > 300°C (decomp.)

**Partial reduction of nitrocalix[4]arene**

In a 100-mL three neck round bottom flask equipped with condenser and a mechanical stirrer 20 g (0.03 mol) of nitrocalix[4]arene is taken in 50 mL DMF and is stirred till the temperature of reaction mixture reached 0°C - (-5°C). Then 4 - 5 g of Raney - Ni (W - 2) is added followed by 20 mL (0.41 mol)
of hydrazine hydrate (80%) which is added drop wise. The reaction mixture is stirred below 0°C for 1h. After an hour, the calix[4]arene hydroxylamine is filtered and the filtrate, insitu, is directly used for coupling considering its yield 60% i.e. 12 g.

**Preparation of Anthraquinone Calix(4)arene Hydroxamic Acid (ACHA)**

In a 100-ml conical flask fitted with dropping funnel, freshly prepared, in-situ, 12 g (0.02 mol) calix[4]arene hydroxylamine is placed. An aqueous suspension of 4.87 g (0.058 mol) sodium bicarbonate in 10 ml of water is added and stirred. After the mixture is cooled to 0°C – (- 5°C), 10.12 g (0.04 mol) anthraquinone – 2 – carbonyl chloride in 25 ml dioxan is added dropwise during a period of 45 min and stirring is continued for another 15 min. almost the entire amount of hydroxamic acid formed is precipitated as an orange granular solid. It is filtered off, washed with water and the solid product thus obtained is twice re-crystallized from chloroform - toluene mixture (1:1) and gives a pale orange compound, mp 265 ⁰C, yield 7.2 g (60%). This synthesis is shown in Scheme 1.
Synthesis of MethylCalix[6]arene

A 23.6 mL (0.2185 mol) p-cresol is treated with 33.0 mL (1.10 mol) 35 % formaldehyde in presence of 75 mL of p-xylene and 23.6 mL conc. HCl and refluxed for 8 h at a temperature of 80-90 °C. The product obtained is resinous in nature. The crude product is washed with different solvents and the product is passed through a column packed with Silica 60 using chloroform and toluene in 9:1 ratio. The elution sequence having cyclic hexamer > cyclic tetramer > linear compounds which was analyzed
and confirmed by osmometric and spectral studies. Yield of cyclic hexamer 90% (21.2 g), m.p. > 370°C.

**Synthesis of ester of Methyl calix[6]arene**

Methyl calix[6]arene 0.72 g (1 mmol) was suspended in dry DMF (20 ml) in a flask equipped with a CaCl₂ drying tube and then treated with NaH (4 mmol). Ethyl bromoacetate 0.45 ml (5 mmol) was added and the mixture was stirred at 80°C. After about 2h the reaction mixture was cooled and treated with a second portion of NaH (2 mmol). Ethylbromoacetate 0.22 ml (2.4 mmol) was then added. The mixture was stirred again at 80°C for a further 2h. This operation was repeated until no phenolic OH was detectable by u.v. spectroscopy. The reaction was also followed by T.L.C. The solvent was evaporated under reduced pressure and the residue was washed with water and the product extracted with chloroform. The chloroform was evaporated to give the solid product. Yield 60% (0.42 g), m.p. 340°C

**Hydrolysis of ester of Methyl Calix[6]arene**

The ester 0.92 g (1mmol) in THF (50ml) was added to 10% aqueous tetramethylammonium hydroxide (50 ml) and heated under reflux for 24 hours. After cooling, the reaction mixture was acidified with concentrated HCl and stirred overnight. The resulting precipitate was filtered off, washed thoroughly with water, and dried in an air oven. Yield 65% (0.55 g), m.p. 320°C
Synthesis of acid chloride of substituted Calix[6]arene

Into a 100 ml round bottom flask 0.86 g (1 mmol) of hexamethylenecarboxylic acid [6]arene was refluxed with 9 ml of thionyl chloride on a water bath with occasional stirring for 6 hours. The reaction mixture was allowed to cool and excess of thionyl chloride was removed under vacuum and finally distilled under reduced pressure.

Synthesis of β - nitro Styrene

In a three necked flask with a thermometer, mechanical stirrer and a dropping funnel, 27 ml (0.52 mol) of nitromethane, 50.5 ml (0.5 mol) of purified benzaldehyde and 100 ml (2.45 mol) of methanol is added and cooled to about -10°C. To this, 21 g (0.525 mol) of NaOH in 50 ml of ice cold water is added dropwise through the dropping funnel with vigorous stirring. Temperature is maintained at 10-15°C. A bulky white precipitate is formed, to this 350 ml of ice cold water along with crushed ice is added. The resulting cold solution is immediately run into 250 mL of dil. hydrochloric acid contained in a 2 liter flask with stirring. The pale yellow crystals of nitrostyrene thus precipitated are crystallized from hot ethanol. The pale yellow crystals of nitrostyrene thus precipitated are crystallized from hot ethanol. The yield of pure nitrostyrene is 125 g (mp. 58°C)
Synthesis of hydroxylamine derivative of the nitro Styrene

β - Styrene hydroxylamine was prepared by the reduction of β - nitro Styrene with ammonium hydrosulphide. β - nitro styrene (10 g) was taken 250 ml ethanol, cooled externally in freezing mixture and saturated with 50 ml of liq. NH₄OH and H₂S was passed for half an hour. After keeping the mixture for 24 h, the reaction mixture was added to 250 ml ice cold water with vigorous stirring. Yellow crystals of β - styrene hydroxylamine were precipitated out which were filtered and washed with water.

Synthesis of Styrene Calix[6]arene Hydroxamic Acid (SCHA)

In a 100-ml conical flask fitted with dropping funnel, freshly prepared, in-situ, 0.26 g (2.0 mmol) styrene hydroxylamine is placed. An aqueous suspension of (5.8 mmol) sodium bicarbonate in 10 ml of water is added and stirred. After the mixture is cooled to 0°C (-5°C), 3.47 g (4.0 mmol) calix[6]arene carbonyl chloride dissolved in 25 ml dioxan is added dropwise during a period of 45 min and stirring is continued for another 15 min., almost the entire amount of hydroxamic acid formed is precipitated as a yellow granular solid. It is filtered off, washed with water and the solid product thus obtained is twice re-crystallized from chloroform-toluene mixture (1:1) and gives a pale yellow compound, m. p. 210°C decomp., yield 2.0 g (60%).

This synthesis is shown in Scheme 2.
Scheme 2

In a three necked one liter flask fitted with a stirrer and condenser, 5.0 mL (0.0462 mol) p-cresol is treated with 4.70 mL (0.0462 mol) benzaldehyde in presence of 5.0 mL of p-xylene and 6 mL conc. HCl and refluxed for 16 h at a temperature of 80-90°C. The product obtained is resinous in nature. The crude product is washed with hot water and recrystallized from ethanol-water (60:40) mixture. The pale yellow crystals of calix(6)arene were obtained having m. p. 200°C (Yield 82 %). The synthesis is shown in Scheme 3.

\[
\begin{align*}
\text{p - Cresol} & \quad + \quad \text{Benzaldehyde} \\
& \xrightarrow{\text{p xylene, Reflux 16 hours, Conc. HCl, 80-90°C}} \\
& \quad 5,11,17,23-p\text{-phenyl-} \\
& \quad -25,26,27,28\text{-tetrahydroxy Calix(6)arene}
\end{align*}
\]
RESULTS AND DISCUSSION:

Synthesis of Anthraquinone Calix[4]arene Hydroxamic Acid

Nitration of calix[4]arenes has been attempted by a number of workers using direct and indirect methods. There seems to be no reported general methodology to obtain p-nitrocalix[n]arenes. Some methods are limited to calix[n]arene ethers while others are suitable only for calix[n]arenes. The reported methods are limited by low yields, multiplicity of steps or over oxidation of starting calixarenes by the nitrating mixture.

Chawla et al. have carried out a comparative study of nitration of calixarene methyl ethers by (i) HNO₃/CH₃ COOH, (ii) HNO₃/AC₂O, (iii) KNO₃/AlCl₃ in CH₂Cl₂ and (iv) cerium(IV) ammonium nitrate as against the reported method of using fuming nitric acid. Comparative analysis of nitro products obtained under a variety of conditions revealed that pure nitric acid in acetic acid is the best reagent for obtaining nitrocalixarenes in 70–79% yield. This method can only be applied to calix[n]arene ethers and is not suitable for calix[n]arenes.

In the present investigation nitro calix[4]arene was synthesized following Shinkai’s method modified by Huang et al. The complete reduction of substituted nitrocalix[4]arene is reported by Arduini et al. using Pd/C catalyst and by Shinkai et al. using N₂H₄/FeCl₃ on activated charcoal. In the present investigation the nitrocalix[4]arene is partially reduced by Raney nickel catalyst (W – 4), using hydrazine hydrate (80%) in ethanol below 0°C.

Since calix[4]arene hydroxylamine is found to be unstable, the coupling reaction with the acid chloride of anthraquinone is carried out in in-situ. The coupling of calix[4]arene hydroxylamine with anthraquinone acid chloride is very simple, quick and the reaction product obtained is in pure crystalline form.
During the partial reduction and coupling only two of the four nitro groups on alternate benzene rings undergo substitution. The IR spectra of the compound show the presence of $-\text{NO}_2$ groups; the elemental analysis and mass spectra confirm the presence of two such groups. The $^1\text{H}$ – NMR spectra of the compound for the methylene bridge protons indicated the cone confirmation. The possibility of substitution on adjacent phenyl rings was ruled out on steric considerations favouring the functionalisation on 1,3 positions.

Properties

The synthesized compounds N,N'-(2-carboxo-anthraquinone)-7,19-dinitro-25,26,27,28-tertahydroxy-1,13-calix[4]aryl hydroxamic acid is light orange crystalline solid. It is insoluble in water and soluble in organic solvents like chloroform, dioxan and DMF with molecular weight 1044 corresponding to the molecular formula C$_{58}$H$_{36}$N$_4$O$_{16}$ with a sharp m. p. 265$^\circ$C. Anal. calcd C: 66.6, H: 3.4, N: 5.3, O: 24.5 % and Found: C: 66.2, H: 3.8, N: 5.0 O: 24.8 %.

Spectral Interpretation of ACHA

Infrared Spectra

O-H Stretching Vibrations

The IR spectra of chromogenic calix[4]arenes show broad and short bands which appears at around 3527 cm$^{-1}$ and 3435 cm$^{-1}$. The first band is assigned to phenolic – OH of calixarenes at 3527 cm$^{-1}$ while second band is of $v_{\text{OH}}$ of the hydroxamic functional group ($-\text{N}-\text{OH}$). It is well known that absorption due to $v_{\text{OH}}$ stretching vibrations, when free appear around 3650 cm$^{-1}$; however hydrogen bonding shifts these bands to lower frequencies.$^{13-17}$

In the present case the shifting of (phenolic – OH) bands of calixarenes to lower frequency may be attributed to the intramolecular hydrogen bonding
between the lower rim hydroxyl groups of the calixarene. The same can be explained for the lower frequency band of (O - H) group of the hydroxamic acid group. The acidic (- OH) is placed at very close proximity to the polar carbonyl group (C = O) which is highly favorable condition for the formation of the intramolecular hydrogen bonding. This causes a large shift in the absorption band to lower frequencies and may be ascribed to resonance stabilization which lowers the force constant of (C - O) bond and increases the contribution of single bond form.

C=O Stretching Vibrations

The stretching vibration due to C = O of anthraquinone group appears at 1676 cm\(^{-1}\) in ACHA. But due to the substitution in the fused ring system the band shift to lower wavelength. The conjugation also shifts the band of carbonyl to the lower frequency.\(^{18}\)

The band at 1590 cm\(^{-1}\) is assigned to the C = O of hydroxamic group in anthraquinone calix[4]arene. Mathis has assigned this band in benzo, propiono and substituted benzo hydroxamic acid at 1640 ± 30 cm\(^{-1}\).\(^{19}\)

- The H- bonding lower the (C = O) by 10 - 50 cm\(^{-1}\). The conjugation of C = O with C = C lower the absorption band by about 50 cm\(^{-1}\).

N - O Stretching Vibration

A sharp band at 933 cm\(^{-1}\) in ACHA may be attributed to N - O stretching vibration in calix(4)arene anthraquinone hydroxamic acid. The assignment is supported by Pilipenko\(^{20}\) Agrawal\(^{21-26}\) and Hadzi.\(^{27}\)

The presence of sharp bands at 1329 cm\(^{-1}\) and 1552 cm\(^{-1}\) similar to those observed in nitrocalix(4)arene, suggests the presence of – NO\(_2\) group in the compound.
\textbf{\textsuperscript{1}H NMR Spectra}

The \textsuperscript{1}H NMR spectra of the synthesized chromogenic calix[4]arene is discussed here. The \textsuperscript{1}H NMR spectra are recorded in the range of 0-11 ppm in CDCl\textsubscript{3} using TMS as internal standard. Chemical shifts are expressed in ppm scale. The \textsuperscript{1}H NMR spectra of chromogenic calix[4]arene shows a doublet at 4.96 ppm in ACHA due to the $-$CH\textsubscript{2} proton indicating the cone conformation. The multiplets due to aromatic protons appears at 7.97 – 8.45 ppm in ACHA. The singlet of hydroxyl protons on the calix[4]arene lower rim appears at 10.62 and 10.50 ppm in ACHA and due to the hydroxamic group appears at 10.28 ppm in ACHA. In ACHA the presence of $-$NO\textsubscript{2} group was found at 7.57 and 7.52 ppm.

\textbf{\textsuperscript{13}C – NMR}

In the \textsuperscript{13}C – NMR spectra, carbon atoms in the chromogenic calix[4]arene is denoted as shown in Fig. 1. The chemical shifts calculated and observed are also tabulated in Table 1.

Since the observed $^{13}$C – NMR matches with the calculated $^{13}$C – NMR based on the assumption that functionalization takes place on 1,3 position, therefore it confirms that functionalization takes place on 1,3 position.
Fig 1: Carbon numbered in Anthraquinone Calix[4]arene

Hydroxamic acid
Table 1: $^{13}$C-NMR of Anthraquinone Calix[4]arene Hydroxamic acid (ACHA)

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<th>δ ppm</th>
<th>Number of Carbon</th>
<th>δ ppm</th>
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<td>C2</td>
<td>140.1</td>
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<tr>
<td>C14</td>
<td>127.2</td>
<td>C28</td>
<td>-</td>
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N.B: The values given inside the parenthesis are the theoretical values
Mass Spectra

The FAB-MS spectra of ACHA showed molecular ion peak at 1086 (M + 2H₂O)⁺. Its fragmentation pattern is shown in Fig. 4.

Synthesis of Styrene Calix[6]arene Hydroxamic Acid

Methyl calix[6]arene is synthesized for the first time in single step using an acid catalyst by our group. Different methods were used for the synthesis of p-methyl calix[6]arene. The p-cresol derived p-methyl calixarene was synthesized by Hayes et al. using step wise synthesis, which involved 14 steps. This stepwise method is long and tedious. However, Kammer improved the synthetic route by reducing the number of steps involved during the synthesis. However still, the methyl calix[6]arene could not be synthesized in a single step.

In the present method methyl calix[6]arene was synthesized by reacting p-cresol with formaldehyde in presence of conc. HCl and p-xylene for 8-9 h. The crude product obtained is greenish white and resinous in nature. The FAB-MS and ¹H-NMR of the product indicated the presence of cyclic hexamer, tetramer and linear oligomers and it is then passed through SI 60 silica column and eluted with the mixture of chloroform and toluene in the ratio of 9:1 giving the elution sequence: cyclic hexamer > cyclic tetramer (8%) > linear compounds (2%); their presence being confirmed by osmometric determination.


Ester derivative of Methyl calix[6]arene was converted to its acid derivative by 10% aqueous tetramethylammonium hydroxide in THF. Acid
derivative was finally precipitated using dil. HCl. The product is also yellowish in colour.

The partial reduction of the nitro styrene was carried out using liq. NH₄OH and H₂S below 0 °C. Since hydroxylamines are unstable it was quickly used for coupling with the acid chlorides of calix(6)arene carbonyl chloride. Since β - styrene hydroxylamine is unstable, the coupling reaction with the acid chloride of calix[6]arene is carried out in in-situ. The coupling of β - styrene hydroxylamine with calix[6]arene acid chloride is very simple, quick and the reaction product obtained is in pure crystalline form.

During the esterification of calix[6]arene all of the six - OH groups undergo substitution. The IR spectrum of the substituted derivative shows the presence of ester groups; the elemental analysis and mass spectra confirms the presence of four such groups. The ¹H – NMR spectra of the compound for the methylene bridge protons indicated the cone confirmation. The possibility of substitution on adjacent phenyl rings was ruled out on steric considerations favouring the functionalization on 1, 4 positions.

Properties

The synthesized compound obtained after coupling of hydroxyl amine of β - Styrene and acid chloride of calix[6]arene carboxylic acid i.e. (SCHA) is light yellow crystalline solid. It is insoluble in water and soluble in organic solvents like chloroform, dioxan and DMF with molecular weigh 1351 corresponding to the molecular formula C₆₈H₆₆O₂₂N₂ with a sharp m. p. 210 °C. It is purified by petroleum ether and toluene. Anal. calcd C: 64.6, H: 5.2, N: 2.2, O: 27.8 % and found: C: 65.0, H: 4.8, N: 2.0 O: 28.0 %.
Spectral Interpretation of SCHA

IR Spectra

O-H Stretching Vibrations

The IR spectra of the calix[6]arene shows a broad band around 3265 cm\(^{-1}\), the band assigned is of \(v_{\text{OH}}\) of the hydroxamic functional group (-N-OH). This is in conjugation with the carbonyl group and hence it lowers the absorption band by 10-15 cm\(^{-1}\). Since the acidic O-H is placed in close proximity to the polar carbonyl group, which is highly favourable condition for the formation of the intramolecular hydrogen bonding\(^{33}\), it causes a large shift in the absorption band to lower frequencies and may be ascribed to resonance stabilization which lowers the force constant of C = O bond and increases the contribution of single bond form.

>C=O Stretching Vibrations

The band at 1600 cm\(^{-1}\) is assigned to \(v_{\text{C=O}}\) of hydroxamic group. The >C=O stretching vibrations of hydroxamic acid is assigned in the region of 1640 cm\(^{-1}\).\(^{34}\)

The H- bonding lower the (C = O) by 10 - 50 cm\(^{-1}\). The conjugation of C = O with C = C lower the absorption band by about 50 cm\(^{-1}\).

The band at 1690cm\(^{-1}\) is assigned to \(v_{\text{C=O}}\) of the ester group.

N-O Stretching Vibration

A sharp band at 913 cm\(^{-1}\) in SCHA may be attributed to N-O stretching vibration in styrene calixarene hydroxamic acid. The assignment is supported by Pilipenko,\(^{20}\) Agrawal\(^{21-26}\) and Hadzi.\(^{27}\)
**$^1$H NMR**

The $^1$H NMR was recorded in the range of 0-11 ppm using TMS as the internal standard. Chemical shifts were expressed in ppm scale.

The $^1$H-NMR spectra of the SCHA showed a sharp singlet at $\delta$ 9.25 indicating the presence of the protons of hydroxamic group (N-OH). A doublet at $\delta$ 3.86 - 3.90 ppm indicates the presence of methylene protons. The aromatic protons are found in the range of $\delta$ 6.35 - 7.57.

**$^{13}$C - NMR**

In the $^{13}$C -NMR spectra, carbon atoms in the SCHA are denoted as shown in Fig. 2. The chemical shifts calculated and observed are also tabulated in Table 2.

![Carbon numbered in Styrene Calix[6]arene Hydroxamic acid (SCHA)](image)

**Fig. 2 : Carbon numbered in Styrene Calix[6]arene Hydroxamic acid (SCHA)**
Since the observed $^{13}$C – NMR matches with the calculated $^{13}$C – NMR based on the assumption that functionalization takes place on 1,4 position, therefore it confirms that functionalization takes place on 1,4 position.

**Table 2: $^{13}$C-NMR of Styrene Calix[6]arene Hydroxamic acid (SCHA)**

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<th>( \delta ) ppm</th>
<th>Number of Carbon</th>
<th>( \delta ) ppm</th>
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</table>

N.B: The values given inside the parenthesis are the theoretical values.

**Mass Spectra**

The FAB-MS spectra of SCHA showed molecular ion peak at 1351. Its fragmentation pattern is shown in Fig. 5.

Substitution at the methylene bridges has been used to attach various additional functionalities to calixarene skeleton, thus extending its utility as a building block for the construction of larger molecular assemblies and polymers. Calixarene derivatives with two distal methylene groups substituted in a trans fashion by phenyl or mesityl groups have been synthesized.35

There are no reports of substitution at methylene bridges by phenyl groups till now. Methyl calix[6]arene substituted at all the six methylene bridges is synthesized for the first time in single step using an acid catalyst.

Properties

The synthesized compound is light yellow crystalline solid. It is insoluble in water and soluble in organic solvents like methanol, ethanol, chloroform, dioxan and DMF with the molecular weight 1176 corresponding to the molecular formula C₈₄H₇₂O₆ with m. p. < 200°C decomp. It is purified by chloroform and toluene. Anal. Calcd C: 85.7, H: 6.1, O: 8.16 % and found: C: 86.0, H: 5.8, O: 8.0 %.

Spectral Interpretation of Hexaphenyl methyl Calix(6)arene

IR Spectra

O-H Stretching Vibrations

The IR spectra of the calix[6]arene shows a broad band between 3409 - 2860cm⁻¹ which indicates the presence of the intramolecular hydrogen bonding.
**1H NMR**

The 1H NMR was recorded in the range of 0-11 ppm using TMS as the internal standard. Chemical shifts were expressed in ppm scale.

The 1H-NMR spectra of the Hexaphenyl methyl Calix(6)arene showed a sharp singlet δ 7.62 which indicated the presence of phenolic proton, a doublet at 3.66 - 3.52 ppm indicates the presence of methyne protons. The aromatic protons are found in the range of 6.56 - 7.61 ppm.

**13C NMR**

In the 13C-NMR spectra, carbon atoms in the Hexaphenyl methyl Calix(6)arene are denoted as shown in Fig. 3. The chemical shifts calculated and observed are also tabulated in Table 3.

![Diagram of Hexaphenyl methyl Calix(6)arene](image-url)

**Fig 3: Carbon numbered in Hexaphenyl methyl Calix(6)arene.**
Table 3: $^{13}$C-NMR of Hexaphenyl methyl Calix(6)arene.

<table>
<thead>
<tr>
<th>Number of Carbon</th>
<th>$\delta$ ppm</th>
<th>Number of Carbon</th>
<th>$\delta$ ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>20.7(20.7)</td>
<td>C7</td>
<td>1261(126.6)</td>
</tr>
<tr>
<td>C2</td>
<td>129.9(130.5)</td>
<td>C8</td>
<td>128.9(128.7)</td>
</tr>
<tr>
<td>C3</td>
<td>129.2(130.8)</td>
<td>C9</td>
<td>128.4(128.0)</td>
</tr>
<tr>
<td>C4</td>
<td>116.0(115.0)</td>
<td>C10</td>
<td>44.4(42.3)</td>
</tr>
<tr>
<td>C5</td>
<td>151.3(152.2)</td>
<td>C11</td>
<td>141.7(136.5)</td>
</tr>
<tr>
<td>C6</td>
<td>21.0(21.0)</td>
<td>C12</td>
<td>130.5(130.6)</td>
</tr>
</tbody>
</table>

N.B: The values given inside the parenthesis are the theoretical values

Mass Spectra

The FAB-MS spectra of Hexaphenyl methyl Calix(6)arene showed molecular ion peak at 1177 (M $^+$) Its fragmentation pattern is shown in Fig. 6.
Fig. 4: Mass fragmentation of ACHA

![Mass fragmentation diagram with molecular structures and m/z values]
Fig. 5: Mass fragmentation of SCHA
Fig. 6: Mass fragmentation of Hexaphenyl methyl Calix(6)arene
References


