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Tetrahedron
Tetrahedron 64 (2008) 1983–1997
www.elsevier.com/locate/tet

Aminolysis of *p-tert*-butyltetrathiacalix[4]arene tetraethylacetates in cone, partial cone and 1,3-alternate conformation: synthesis of amide based receptors for oxyanions

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Received 2 June 2007; received in revised form 16 October 2007; accepted 1 November 2007
Available online 7 November 2007

Abstract

Cone, partial cone and 1,3-alternate conformers of tetrathiacalix[4]arene tetraethylacetate were synthesized and subjected to aminolysis with alkyl amines [$CH_3(CH_2)_nNH_2$; n=2, 3, 5] to yield mono-, di-, tri- or tetrasubstituted *p-tert*-butyltetrathiacalix[4]arene amides which were characterized by detailed analysis of their NMR spectral and single crystal X-ray crystallography. It has been observed that while the 1,3-alternate and cone conformers of the tetrathiacalix[4]arene tetraethylacetate gave corresponding tetrathiacalix[4]arene tetraamides under different experimental conditions, the corresponding partial cone conformer undergoes a cascade of regioselective reactions with the same amines. Variable temperature ^{1}H NMR experiments allowed the determination of relative stability of different conformers within the temperature range of 298–333 K. The synthesized derivatives were evaluated as molecular extractants for cations and anions and were determined to facilitate extraction of oxyanions (CrO_4^{2-} and $Cr_2O_7^{2-}$) from aqueous to the organic phase. The studies have a significance in the design of tetrathiacalix[n]arene based molecular receptors for innovative applications.

Keywords: Tetrathiacalix[4]arenes; Aminolysis; Amidocrowns

1. Introduction

Tetrathiacalix[4]arenes constitute an important class of molecular scaffolds that are akin to calix[4]arenes with their methylene bridges replaced by epithio groups.[1] Tetrathiacalix[4]arenes are conformationally mobile and are also known to exist in their cone, partial cone, 1,3-alternate and 1,2-alternate conformations.[2] In general, they exhibit higher architectural flexibility in solution and are known to adopt different conformational preferences in the solid state[2,3] in comparison to their calix[4]arene analogues. They also promise additional possibilities for further derivatization to design organized molecular assemblies for novel applications.[1c,d,4] It was envisaged that the tetrathiacalix[4]arene architecture embedded with amide functions[5] would generate useful molecular receptors for anions since the amidic protons can in principle form hydrogen bonds with anions. Recent reports on suitably modified calix[4]arene amides in their 1,3-alternate and partial cone conformations to provide regulatory control systems for ion transport across membranes through symport or antiport mechanisms strengthen this view.[6] In this paper, we report the synthesis of cone, partial cone and 1,3-alternate conformers of tetrathiacalix[4]arene esters and have examined their reaction with various alkyl amines with a view to understand the stereochemistry of the aminolysis reaction in tetrathiacalixarenes which hopefully would help obtain novel molecular receptors for practical applications. During preliminary studies, it has been observed that some of the synthesized tetrathiacalix[4]arene amides can act as effective transporters for oxyanions (chromate and dichromate) which represent just one example of hitherto unexplored oxyanion recognition by tetrathiacalix[4]arenes.

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0040-4020/$ - see front matter © 2007 Published by Elsevier Ltd.
doi:10.1016/j.tet.2007.11.018

2. Results and discussion

2.1. Synthesis

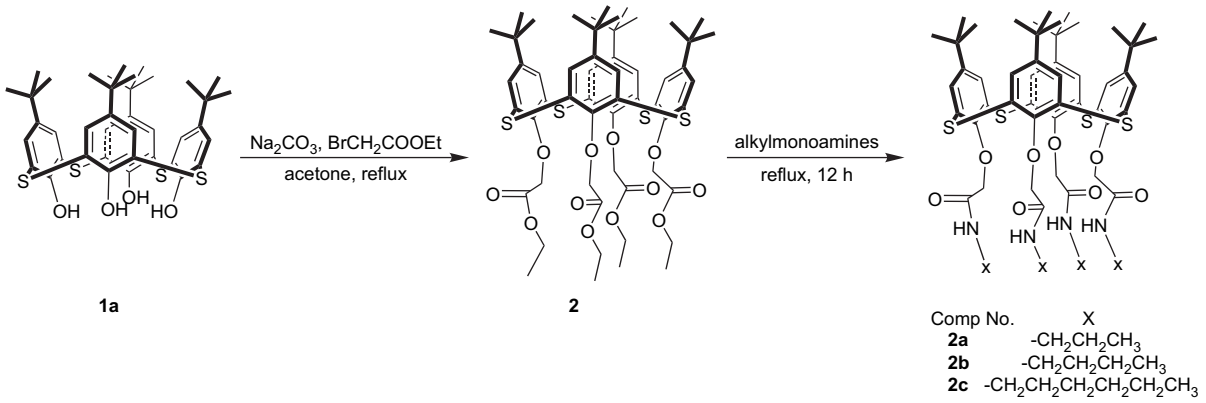
Parent *p-tert*-butyltetrathiacalix[4]arene **1a** was obtained by the base catalyzed condensation of *p-tert*-butylphenol and sulfur.[1a] It was subjected to reverse Friedel–Crafts reaction in the presence of $AlCl_3$ and phenol in toluene to give tetrathiacalix[4]arene **1b** as reported previously.[1b] Compound **1a** could be esterified by reaction with bromoethylacetate in the presence of different metal carbonates (Na_2CO_3, Cs_2CO_3 or K_2CO_3) to yield the *p-tert*-butyltetrathiacalix[4]arene tetraethylacetates in cone (**2**), 1,3-alternate (**3a**) and partial cone (**5**) conformations, respectively. The conformational outcome of the reaction could be confirmed by comparison of observed spectral data with that documented earlier.[7] It was, however, observed that **1b** yielded the 1,3-alternate conformer of tetrathiacalix[4]arene tetraethylacetate (**3b**) when the above mentioned bases were used for esterification.[2] The obtained ester conformers when reacted with alkyl monoamines [$CH_3(CH_2)_nNH_2$, n=2, 3, 5] under reaction conditions given in Schemes 1–3 provided the tetrathiacalix[4]arene amides which were characterized as described later in this paper.

2.2. Results

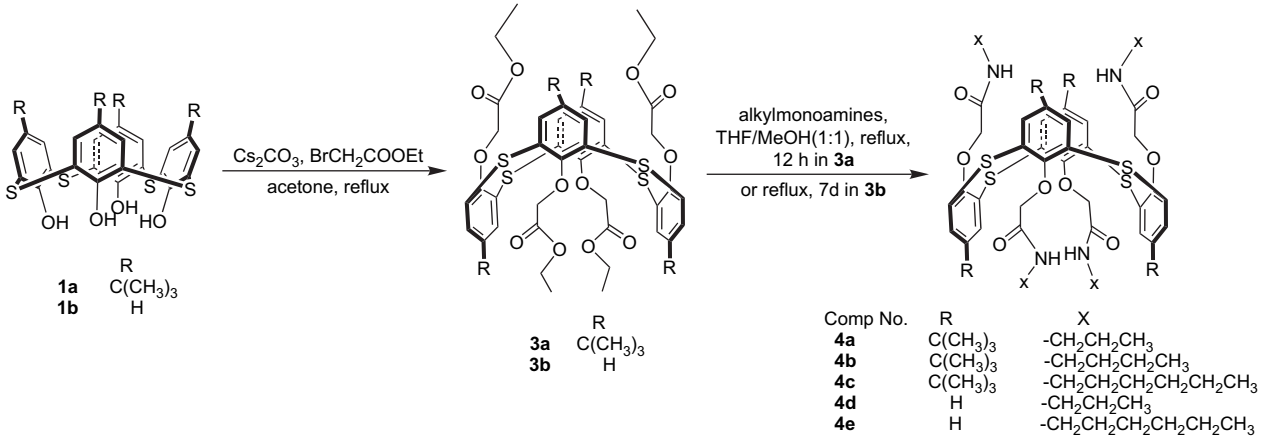
The reaction of the cone conformer of *p-tert*-butyltetrathiacalix[4]arene tetraethylacetate **2** with neat alkyl amines (Scheme 1) gave tetraamide derivatives with retention of their cone conformation.

When the reaction was repeated with the 1,3-alternate conformer of *p-tert*-butyltetrathiacalix[4]arene tetraethylacetate under identical conditions, no reaction was noticed despite the fact that nucleophilic attack in the 1,3-alternate conformation of the substrate would be facilitated from stereochemical considerations. Surprisingly, when **3a** was refluxed with alkyl monoamines (propylamine, butylamine and hexylamine) in THF/methanol (1:1), the reaction proceeded smoothly to give the tetrasubstituted products (**4a–c**) (Scheme 2). Interestingly, the reaction took a long time when the 1,3-alternate conformer of the corresponding debutylated analogue, **3b**, was used as the substrate.

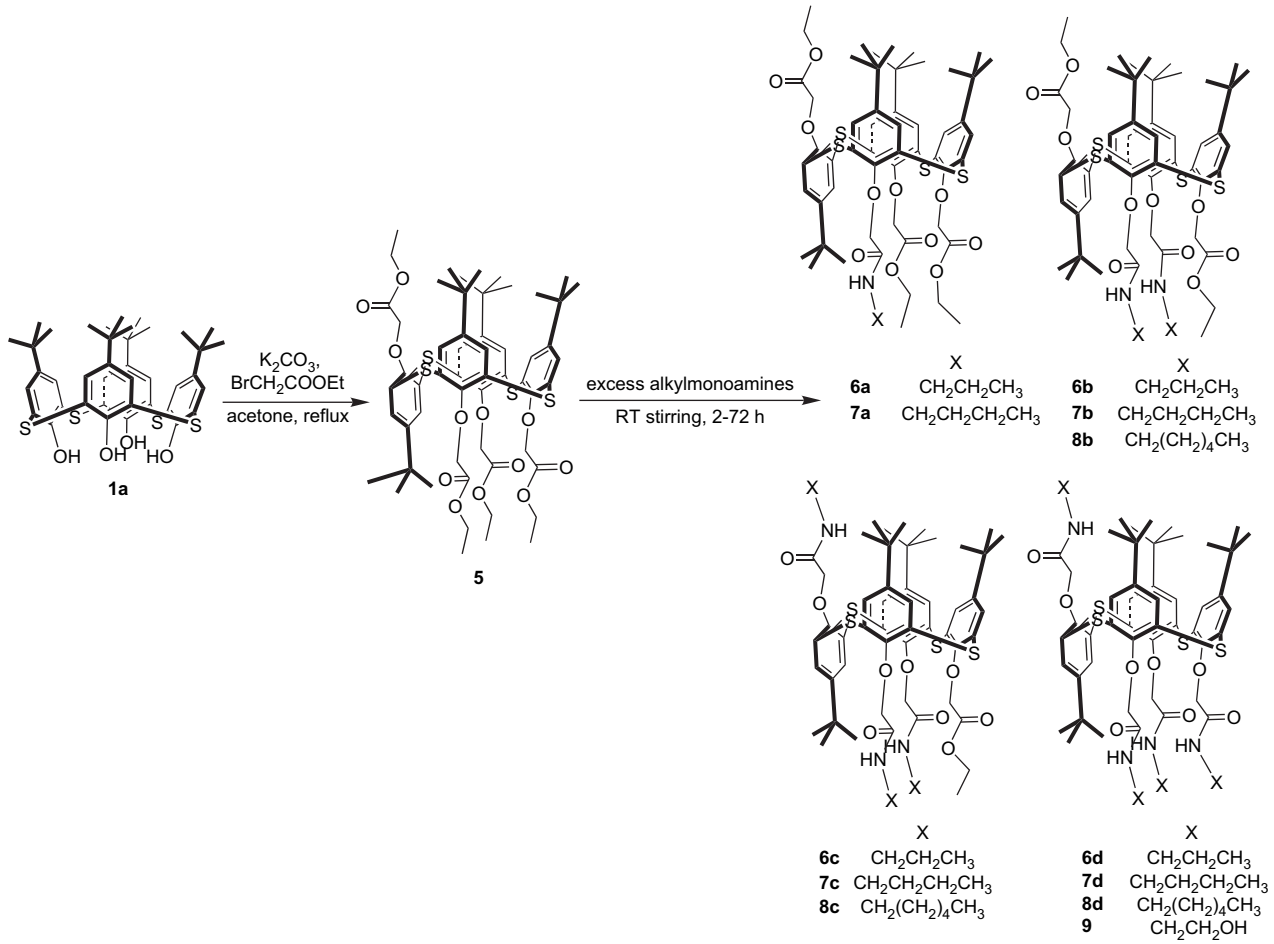
When the partial cone conformer of the *p-tert*-butyltetrathiacalix[4]arene tetraethylacetate, **5**, was reacted with the alkylmonoamines, the reaction failed even when the reactants in toluene/methanol (1:1) were refluxed. However, the reaction proceeded smoothly at room temperature when respective



Scheme 1. Reaction of alkyl monoamines with cone conformer of tetrathiacalix[4]arene tetraethylacetate.



Scheme 2. Reaction of alkyl monoamines with 1,3-alternate conformer of tetrathiacalix[4]arene tetraethylacetate.



Scheme 3. Reaction of alkyl monoamines with partial cone conformer of tetrathiacalix[4]arene tetraethylacetate.

amines were employed as the solvent (Scheme 3). The extent of substitution in the products was found to be time dependant and it was determined that during the initial period of the reaction (2–6 h), di-amido substituted products were the major products with minor quantities of the mono- and trisubstituted derivatives. *p-tert*-Butyltetrathiacalix[4]arene tetraamides could, however, be obtained only after 3 days of stirring at room temperature. Analysis of the intermediate products observed in the reaction revealed that the partial cone conformation was retained in each of these products during the aminolysis.

2.3. Characterization of products

All the products (mono-, di-, tri- and tetraamido substituted *p-tert*-butyltetrathiacalix[4]arenes) were identified by their IR, ^{1}H and ^{13}C NMR, FAB mass spectral and elemental analysis. The IR spectra of the synthesized amides showed characteristic absorptions for −C(=O)−N− (1650−1675 cm^{-1}) and −N−H (3310−3360 cm^{-1}) groups. The carbonyl stretching frequency for the ester group of the partially substituted *p-tert*-butyltetrathiacalix[4]arene amides appeared at ∼1755 cm^{-1}, which was absent in the case of the completely substituted products. In the case of mono-, di- or trisubstituted products, carbonyl stretching absorptions for both the amidic as well as the ester moieties appeared in the expected IR spectral regions.

NMR spectroscopy was found to be more useful in determining the exact substitution pattern as well as the conformation of the products. For instance, **2b** exhibited signals at δ 7.78 (br t, 4H), 7.34 (s, 8H) and 4.81 (s, 8H) for amidic, aromatic and ArOCH_2− protons, respectively, while protons for the butyl chain and the *tert*-butyl group could be observed at δ 3.37 (m, 8H), 1.57 (t, 8H), 1.25 (m, 8H), 0.94 (t, 8H) and 1.11 (s, 36H), respectively, in the ^{1}H NMR spectrum (Fig. 1a) suggesting it to be a tetrasubstituted compound with a symmetric structure. A very similar ^{1}H NMR spectral pattern was observed for **4b** which showed prominent signals as per their assignment given in the parentheses, at δ 7.75 (br t, 4H, amidic), 7.54 (s, 8H, aromatic) and 4.10 (s, 8H, ArOCH_2−), 3.28 (t, 8H, butyl chain), 1.60 (t, 8H, butyl chain), 1.35 (m, 8H, butyl chain), 0.95 (t, 8H, butyl chain) and 1.22 (s, 36H, *tert*-butyl) (Fig. 1b). It was also observed that the ArOCH_2− protons in **4b** appeared at a considerably higher field in comparison to **2b** due to the shielding effect of the neighbouring phenyl groups in the case of the 1,3-alternate conformation.

The debutylated tetrathiacalix[4]arene tetraamides also exhibited similar ^{1}H NMR spectral patterns. For instance, **4d** exhibited a broad signal at δ 6.38 for the amidic protons, a characteristic doublet and a triplet for the aromatic protons at 7.53 and 6.92, a singlet for the ArOCH_2 protons at 4.63 and signals at 3.28, 1.60 and 0.99 ppm for the protons of the

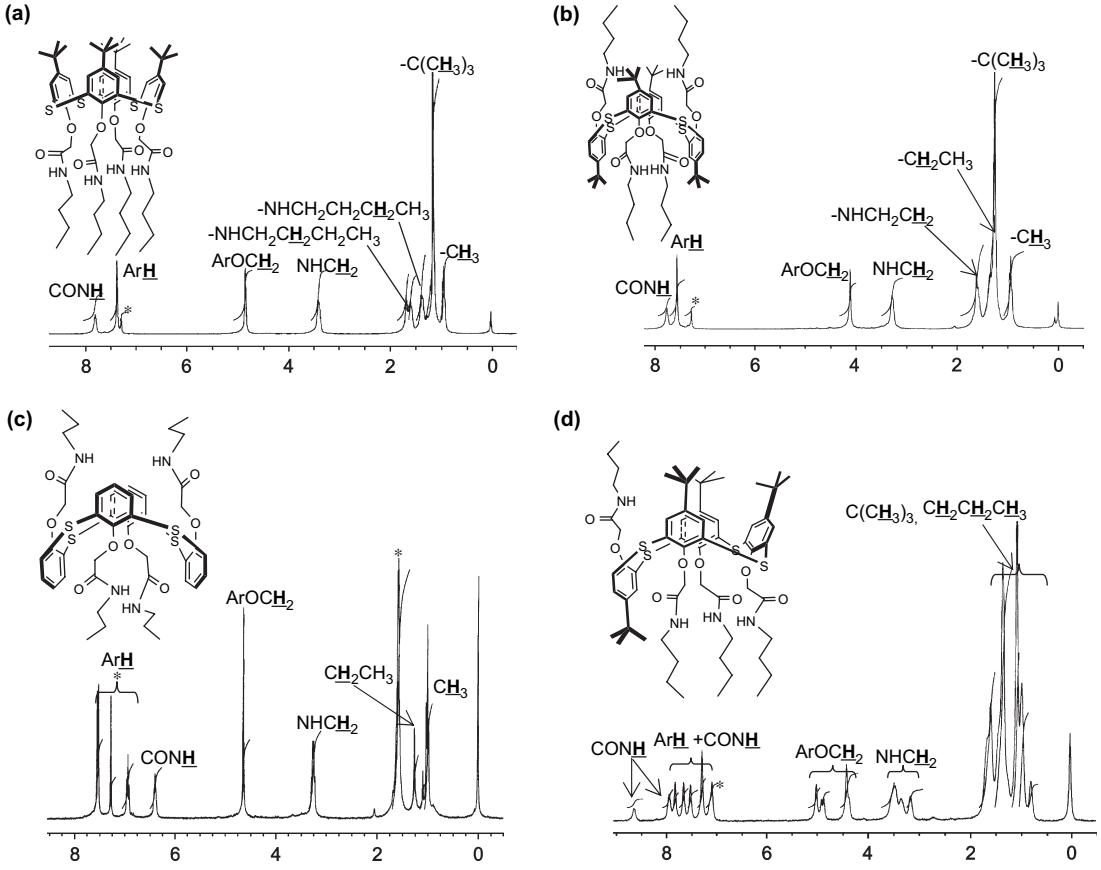


Figure 1. Comparison of the ^{1}H NMR spectral patterns of (a) **2b**, (b) **4b**, (c) **4d** and (d) **7d**.

propyl chain. It is noteworthy that the OCH_2–C(O)NHCH_2 protons in the case of **4b** and **4d** along with the *tert*-butyl protons in the case of **4b** appeared considerably upfield in comparison to **2b**. This could be attributed to the shielding effect of neighbouring phenyl groups, which seems to be of use only in the case of the 1,3-alternate conformation. Other tetrathiacalix[4]arene tetraamide derivatives in the cone and 1,3-alternate conformation could be similarly characterized.

The tetrasubstituted products obtained from the partial cone conformers of *p-tert*-butyltetrathiacalix[4]arene esters exhibited a complicated spectral pattern which prominently exhibited three singlets for the *tert*-butyl groups (ratio 1:2:1), four singlets for aromatic protons (1:1:1:1) and three deuterium exchangeable broad singlets for the NH protons in the ratio 1:2:1. This pattern could be attributed to their partial cone conformation. For instance, **7d** exhibited prominent signals at δ 0.94, 1.05 and 1.33 for *tert*-butyl groups while its NH protons appeared at δ 7.06, 7.91 and 8.62 and the aromatic protons appeared at δ 7.06, 7.49, 7.63 and 7.79 (Fig. 1d). Further proof of exact structure of tetrasubstituted products was provided by single crystal X-ray analyses of **7d** and **8d** (discussed later).

The characterization of the partially substituted amides obtained by the aminolysis of the partial cone conformer of the *p-tert*-butyltetrathiacalix[4]arene tetraethylacetate proved to be more difficult due to the different possibilities of substitution and complex spectral patterns observed. FAB-MS analysis helped to ascertain the extent of substitution in this case. For example, the molecular ion peak at 1078 (M^++1) in the FAB-MS spectrum of **6a** suggested that it is a monoamide derivative. A deuterable triplet at δ 8.38 (^{1}H NMR) for the amidic protons integrating for only one proton confirmed monosubstitution in the product. Since **6a** exhibited four singlets for the $(CH_3)_3C$– protons at δ 1.43, 1.33, 1.06 and 1.04 (ratio 1:1:1:1) in its ^{1}H NMR spectrum (Fig. 2), the possibility of structures **B** and **C** could be ruled out, which would be expected to give three singlets (ratio 1:2:1). Compound **7a** also exhibited a similar ^{1}H NMR spectral pattern.

Likewise, the integration of the ^{1}H NMR signals in the case of **6b** indicated that only two of the ester moieties had reacted with the amines to give a disubstituted amide derivative which was further confirmed by the molecular ion peak at 1091 (M^++1) in its FAB mass spectrum giving four possibilities as shown in Figure 3a for disubstituted products in partial cone conformation. The appearance of three singlets for the aromatic protons at 7.77, 7.58 and 7.02 ppm (ratio 1:2:1) and three singlets for the *tert*-butyl protons at 1.35, 1.33 and 1.05 ppm (ratio 1:1:2) in its ^{1}H NMR allowed us to exclude the possibility of structures **B** and **C**. A deuterium exchangeable broad signal for the –CONH– proton at δ 8.34 integrating for two protons suggested that both these protons had similar environments which would only be possible if **A** was the correct structure for **6b** (Fig. 3). Other disubstituted derivatives (**7b** and **8b**) also showed similar ^{1}H NMR spectral patterns and were therefore characterized in a similar fashion.

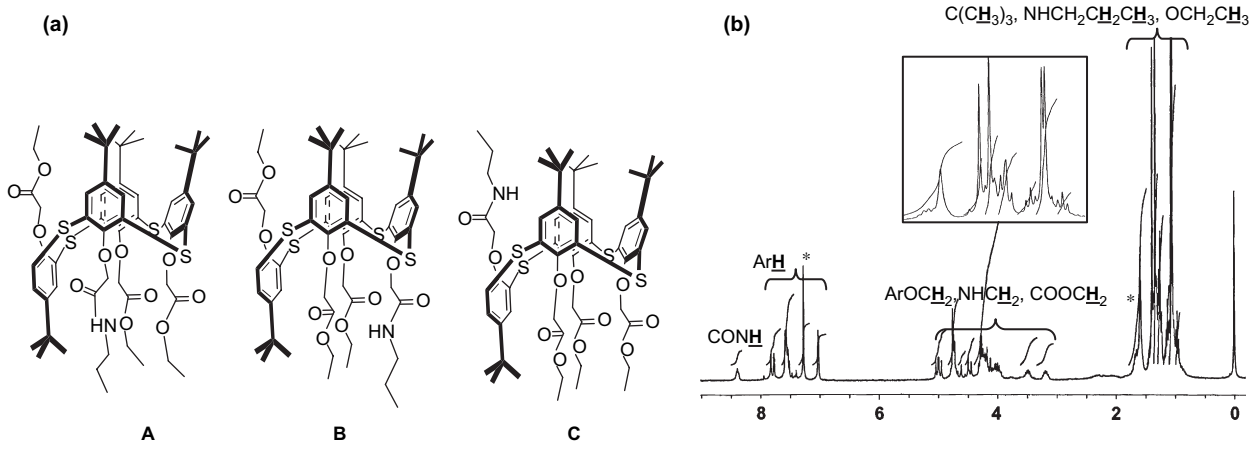


Figure 2. (a) Possible structures of the partial cone monoamide derivative, **6a** and (b) its ^{1}H NMR spectrum.

The exact structure of the diamide **7b** could be deduced from its single crystal X-ray analysis (Fig. 6a), which allowed us to conclude that aminolysis takes place at the ester functions on the distal aromatic rings.

Trisubstitution in **6c**, **7c** and **8c** obtained from the aminolysis of the partial cone conformer of the *p-tert*-butyltetrathiacalix[4]arene tetraethylacetate was revealed by the analysis of their FAB mass spectra. Out of the three possible structures for the trisubstituted product (as shown in Fig. 4a), the correct structures of the products were assigned on the basis of their ^{1}H NMR spectra which exhibited three singlets for the *tert*-butyl protons (1:2:1), four singlets for the aromatic protons (1:1:1:1) and two triplets for −CONH− protons (1:2).

Structure **B** was ruled out as it would exhibit four singlets for the *tert*-butyl protons (ratio 1:1:1:1), eight singlets for the aromatic protons and three triplets for the −CONH− protons (1:1:1). The appearance of two deuterium exchangeable signals in a 1:2 ratio for the −CONH− protons between δ 8.00−8.80 suggested the existence of two different types of −CONH− protons in different environments. Two protons existed in the same environment while the third was found to exist in a different environment. Detailed NMR experiments established that the signal for this −CONH− proton correlated well with aromatic protons in the NOESY spectrum of **6c** (Fig. 5) indicating that **6c** had structure **C**. Final proof for the exact structure of the trisubstituted products was obtained from the single crystal X-ray analysis of **6c** and **8c** (discussed later).

2.4. X-ray crystallographic analysis

The structures of the above described partial cone *p-tert*-butyltetrathiacalix[4]arene derivatives **7b**, **6c**, **7d**, **8c** and **8d** were unequivocally proved by their single crystal X-ray analysis (Fig. 6). Suitable single crystals of these compounds were grown from a mixture of CH_2Cl_2/CH_3CN. All of them were found to adopt a partial cone conformation as revealed by the +−, +−, ++, −− sequence of the torsion angles at their sulfur bridges. While **7b**, **6c** and **8c** crystallized in a monoclinic system with $P2_1/c$, $C2/c$ and $P2_1/n$ space groups, respectively, **7d** and **8d** existed in a triclinic system having P-1 space group. The carbonyl groups of both the amide functions in **7b** are directed away from the tetrathiacalix[4]arene cavity. The carbonyl group of the ester function on the inverted arene ring is orientated in an *endo* fashion while that of the other ester function in **7b** is directed *exo* to the tetrathiacalix[4]arene cavity. This is probably due to relatively strong intramolecular

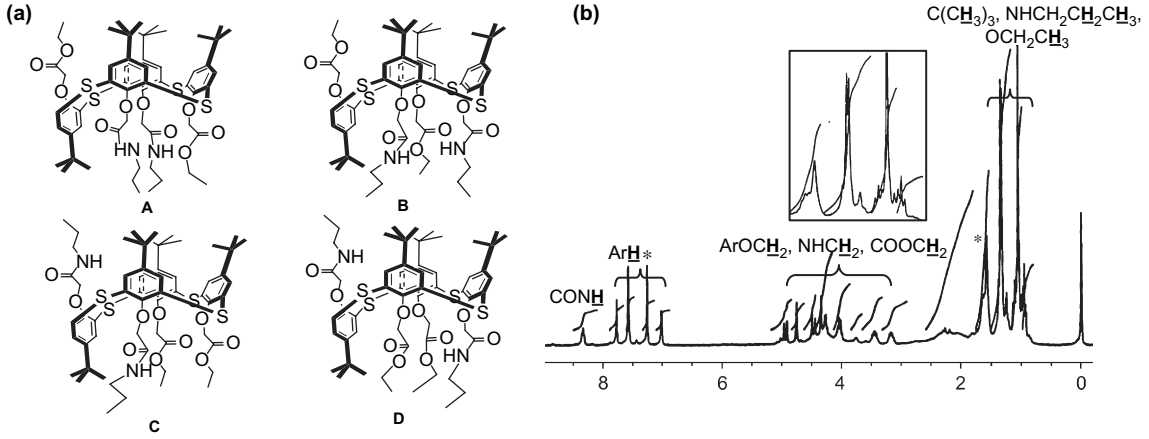


Figure 3. (a) Possible structures of partial cone diamide derivative, **6b** and (b) its ^{1}H NMR spectrum.

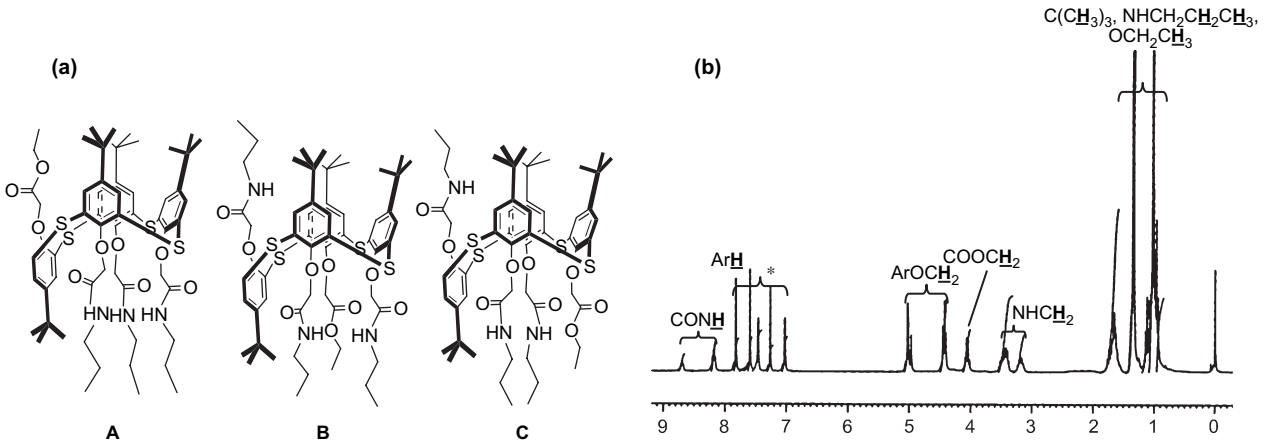


Figure 4. (a) Possible structures of partial cone triamide derivative, **6c** and (b) its ^{1}H NMR spectrum.

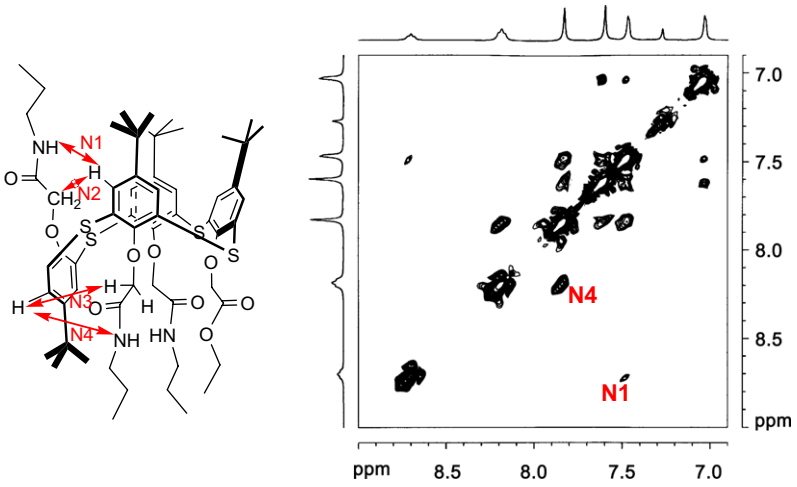


Figure 5. Exact structure of **6c** showing some of the important NOESY correlations (N=NOESY correlations) and part of its NOESY spectrum.

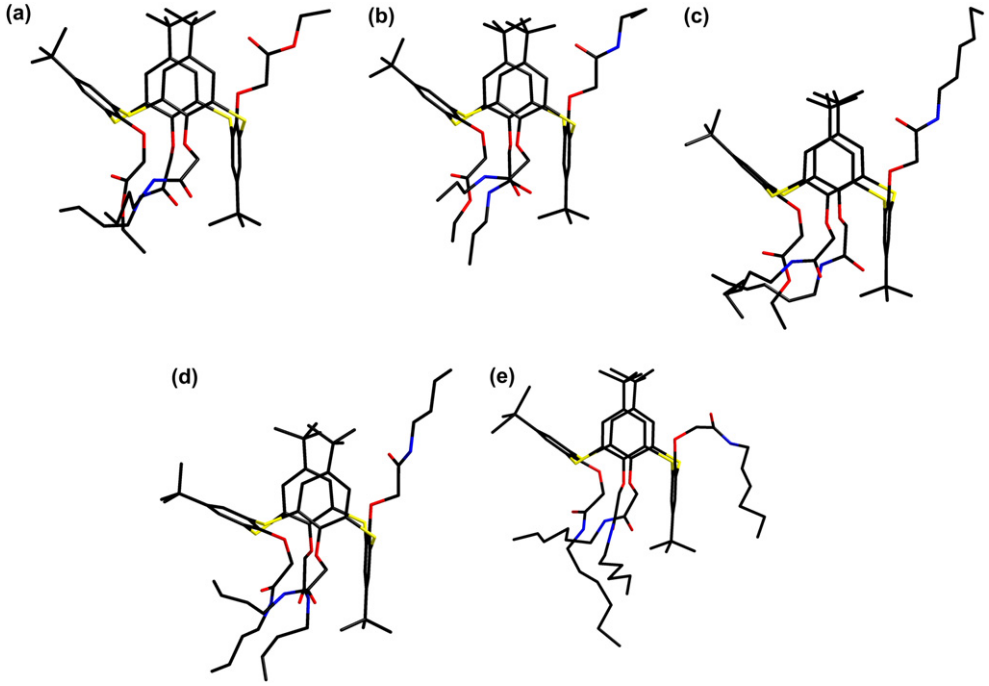


Figure 6. X-ray crystal structures of **7b**, **6c**, **8c**, **7d** and **8d**.

hydrogen bonding between this carbonyl oxygen and the amide group on the adjacent arene ring with O···H–N distance being 2.66 Å. Moreover, the molecule is also involved in hydrogen bond interactions with the amide functions on the two adjacent tetrathiacalix[4]arene molecules with the O···H–N distance being 1.94 Å (Fig. 7a). In the case of **6c** and **8c** too, the carbonyl groups of the distal amide functions as well as the carbonyl group of the ester function are orientated *exo* with respect to the tetrathiacalix[4]arene cavity, while the carbonyl group of the amide function on the inverted arene part seems to be orientated towards the cavity in an *endo* fashion. In **6c**, there is only one intramolecular hydrogen bond interaction between the carbonyl oxygen of the ester moiety and the amide nitrogen on one of the adjacent distally positioned tetrathiacalix[4]arene rings (O6···H2–N2 distance being 2.72 Å). Also the carbonyl oxygens of the two distal amidic functions in **6c** seem to be involved in strong intermolecular hydrogen bonding with two adjacent tetrathiacalix[4]arene molecules (O···H–N distances 2.13 and 2.14 Å). The NH on one of the distal amide moieties is also involved in hydrogen bonding with a neighbouring tetrathiacalix[4]arene molecule with the N–H···O distance being 2.13 Å. The NH on the inverted arene of the same molecule forms a hydrogen bond with another adjacent tetrathiacalix[4]-arene molecule with a N–H···O bond distance of 2.14 Å (Fig. 7b). Both **6c** and **8c** are involved in similar intermolecular hydrogen bonding interactions forming supramolecular arrays.

The nature of hydrogen bond interactions in **7d** and **8d** is somewhat different from that observed in the above cases in that both intermolecular as well as intramolecular hydrogen bonds are present. It was determined that only one of the double bonded oxygen atoms is orientated in an *endo* fashion while all of the carbonyl groups are directed out of the macrocyclic molecular cavity. It was observed that the three amide bridging units on the same side of the tetrathiacalix[4]arene framework in the case of **7c** are held by strong intramolecular hydrogen bond interactions [O7···H2–N2 (2.12 Å) and O6···H1–N1 (2.21 Å)]. The same molecule is also involved in four intermolecular [N3′–H3′···O8 and N3–H3···O8′ (2.01 Å), O6″···H4–N4 and O6···H4″–N4″ (2.04 Å)] hydrogen bond interactions to provide infinite supramolecular channels throughout the crystal lattice (Fig. 7c).

*2.5. Hydrogen bonds (H–N···H) and the stability of the different conformers of tetrathiacalix[4]arene amides: variable temperature ^{1}H NMR study of **2b** (cone), **4b** (1,3-alternate) and **7d** (partial cone)*

The stability of different conformations of the *p-tert*-butyltetrathiacalix[4]arene amide derivatives synthesized in this work was analyzed by means of variable temperature ^{1}H NMR experiments using some of the representative derivatives [**2b** (cone), **4b** (1,3-alternate) and **7d** (partial cone)]. Though details of the conformational isomerism in calix[4]arenes due to rotation of Ar–CH_2–Ar bonds or molecular rotation through the annulus are now known[8,9] the same cannot be stated with certainty about conformer stability of

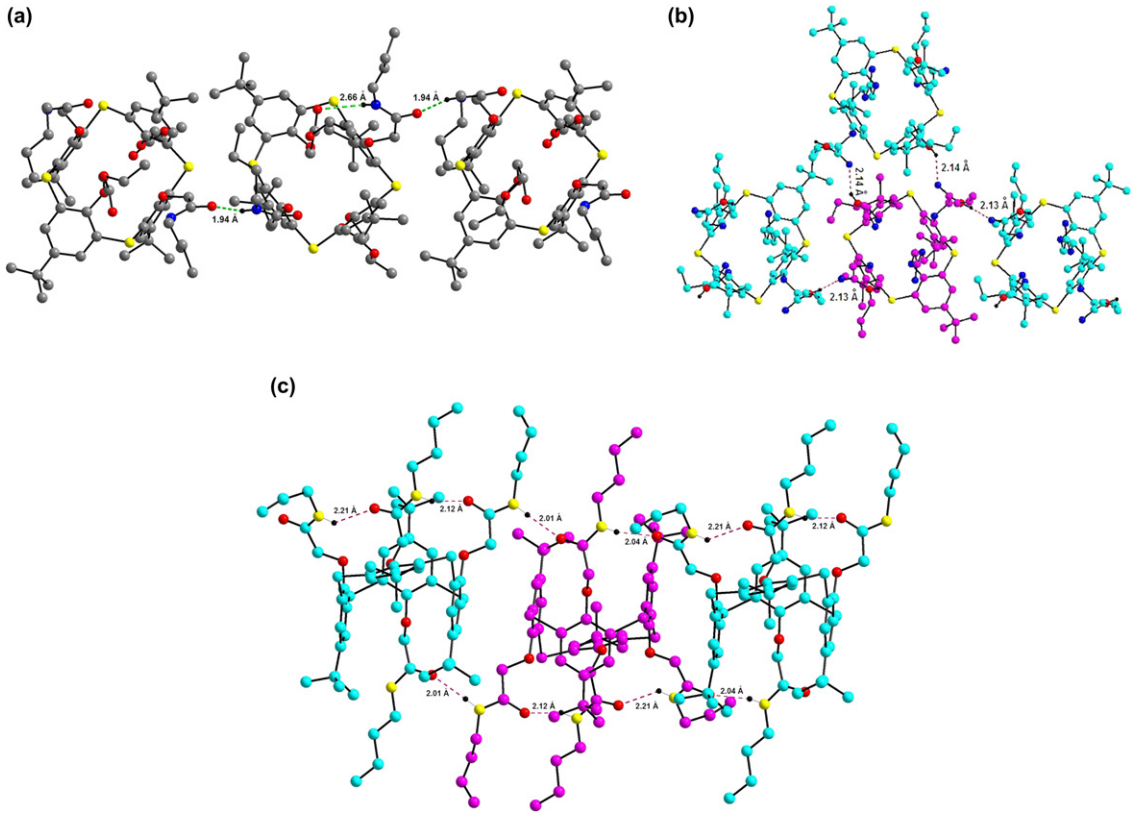


Figure 7. Intramolecular and intermolecular hydrogen bonding interactions in (a) **7b**, (b) **6c** and (c) **7d**.

tetrathiacalix[4]arenes which still require in-depth theoretical and experimental studies. Since tetrathiacalix[4]arenes have a larger cavity size, their conformational behaviour is expected to be different.

A variable temperature ^{1}H NMR study on *p-tert*-butyltetrathiacalix[4]arenes in the 298–333 K range revealed insignificant change in their ^{1}H NMR in this temperature range. However, the amide protons of **2b**, **4b** and **7d** were found to shift upfield with increase in temperature of NMR measurements. For example, the amide protons of **2b** shifted from δ 7.76 at 298 K to δ 7.64 at 333 K while the amide protons of **4b** appeared at δ 7.74 at 298 K and at δ 7.55 (merged with aromatic signals) at 333 K. Similarly, the amide protons of **7d** at δ 8.60, 7.91 and 7.12 at 298 K shifted to δ 8.38, 7.73 and 6.99, respectively, at 333 K. These changes in the position of amide protons at higher temperature could be ascribed to the change in strength of hydrogen bonds associated with amidic protons in solution.[10] The signals for the $ArOCH_2-$ protons in **7d** were found to become clearer with increase in temperature with insignificant shift in their position (Fig. 8). Since all these changes are small in comparison to those expected for any major conformational rearrangement, it was concluded that the conformational framework of tetrathiacalix[4]arene is rigid enough to withstand increase in temperature in the 298–333 K range.

2.6. Liquid–liquid extraction studies

The relative capabilities of different conformers of the *p-tert*-butyltetrathiacalix[4]arene amides for extraction of alkali (Li^+, Na^+, K^+, Rb^+ and Cs^+), alkaline earth (Mg^{2+} and Ba^{2+}) and transition (Co^{2+}, Ni^{2+}, Pb^{2+} and Ag^+) metal ions were examined by solvent extraction protocols.[11] It was determined that the metal picrates were extracted into the organic phase by complex formation with the *p-tert*-butyltetrathiacalix[4]arene amides (**2b**, **4b**, **7d**) and the decrease in the absorbance of the picrate in the aqueous phase was then followed by UV spectroscopy. It was observed that none of the alkali, alkaline or transition metal ions were significantly extracted by any of the *p-tert*-butyltetrathiacalix[4]arene amide derivatives examined in the present study though the tetrabutyl derivatives (**2b**, **7d**, **4b**) showed some affinity towards sodium and potassium ions. The percentage limits of extraction are given in Table 1.

It was, however, observed that *p-tert*-butyltetrathiacalix[4]-arene amide derivatives exhibited better extraction abilities towards potassium dichromate (Table 2). For instance, the cone conformer of the *p-tert*-butyltetrathiacalix[4]arene tetrabutylamide derivative **2b** was found to be effective for the extraction of dichromate anion (50%). The *p-tert*-butyltetrathiacalix[4]-arene amide derivatives with a long hexyl chain showed a relatively lower percentage of extraction towards dichromate

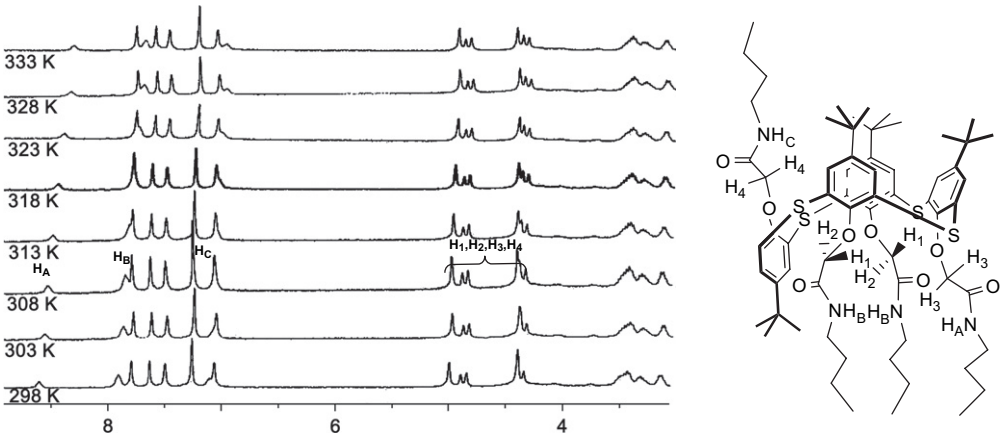


Figure 8. Partial ^{1}H NMR spectrum of **7d** at variable temperature.

Table 1
Extraction (%) of alkali (Li^+, Na^+, K^+, Rb^+ and Cs^+), alkaline earth (Mg^{2+} and Ba^{2+}) and transition (Co^{2+}, Ni^{2+}, Pb^{2+} and Ag^+) metal ions by synthesized tetrathiacalix[4]arene amides

Compd no.	Metal picrate										
	Li^+	Na^+	K^+	Rb^+	Cs^+	Mg^{2+}	Ba^{2+}	Co^{2+}	Ni^{2+}	Pb^{2+}	Ag^+
2b (Cone)	[a]	6.7	5.8	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]
7d (Partial cone)	[a]	8.1	5.9	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]
4b (1,3-Alternate)	[a]	5.0	5.9	[a]	[a]	[a]	[a]	5.0	[a]	[a]	[a]
2c (Cone)	[a]	[a]	[a]	[a]	[a]	[a]	3.2	[a]	[a]	[a]	2.5
8d (Partial cone)	[a]	[a]	[a]	[a]	[a]	[a]	1.4	[a]	[a]	[a]	1.3
4c (1,3-Alternate)	[a]	[a]	[a]	[a]	[a]	[a]	1.6	[a]	[a]	[a]	7.6

[a] Less than 1% extraction.

Table 2
% Extraction of oxyanions

Compd no.	Salts used			
	$(Na^+)_2$ (CrO_4^{2-})	$(K^+)_2$ (CrO_4^{2-})	$(Na^+)_2$ $(Cr_2O_7^{2-})$	$(K^+)_2$ $(Cr_2O_7^{2-})$
2b	4.5	6.0	38.8	50.0
7d	4.3	4.8	10.4	12.3
4b	14.3	17.6	8.7	10.8
2c	[a]	[a]	18.2	13.3
8d	8.2	6.7	15.6	22.7
4c	32.3	24.6	11.3	9.2

[a] Less than 1% extraction.

anion as compared to their shorter chain analogues. Better anion extraction capability of the *p-tert*-butyltetrathiacalix[4]-arene amide derivatives is probably due to greater affinity for oxyanions as compared to the corresponding metal cations since these changes were observed only when chromate or dichromate ions were employed as counteranions in place of picrate as the counter ion.

The observed oxoanion selectivity appeared to relate to the size of the cavity, length of the alkyl chain and specific arrangement of the amidic function, probably functioning through the hydrogen bonding between the anion and amidic protons. Since the protonated form of *p-tert*-butyltetrathiacalix[4]arene amide will not be present in significant concentrations in aqueous solutions at neutral pH, the protonated amide functions do not appear to be involved to a significant extent (The pK_a of the protonated amide is approximately −1).

2.7. Discussion

2.7.1. Plausible mechanism of aminolysis of tetrathiacalix[4]arene tetraethylacetates

All the ester groups on each of the cone, 1,2-alternate and 1,3-alternate conformers are equivalent and there is no preference for the first site of action by nucleophilic amine. However, in the partial cone conformer (Fig. 9), the esters are spatially disposed differentially as shown by three different colours, i.e., green (E1, E3), blue (E2) and red (E4). As analyzed earlier, it was determined that out of three possibilities for the monosubstituted products, only one product was obtained (Fig. 2, structure **A**).

The same is the case for di- and trisubstituted products whereby only single product is obtained [Fig. 3 (structure **A**) and Fig. 4 (structure **C**)].

Thus, during aminolysis reaction, it appears that the nucleophile first attacks at E1 or E3 ester functions (equivalent) followed by a quick distal substitution analogous to the case of cone conformers of calixarene derivatives.[9c] Further reaction might take place at E2 (Fig. 9, blue coloured ester group) or E4 (Fig. 9, red coloured ester group) but it seems that both these ester positions are hindered to some extent due to the steric crowding of neighbouring *tert*-butyl- or alkylamide groups. It is felt that nucleophilic attack at E4 (inverted) would be favoured to avoid steric crowding of the three amide functions on the same side of the macrocyclic framework. This conclusion is supported by the fact that the aminolysis reaction on this ester group occurs only if the reaction is continued for a longer period and trisubstituted compound with three amide groups on the same side (Fig. 4, structure **A**) could not be observed in the reaction mixture. Thus, it is evident that the aminolysis reaction of monoamines with the partial cone conformer of *p-tert*-butyltetrathiacalix[4]arene tetraethylacetate is time dependant and proceeds in a very selective and stepwise manner as shown in Figure 9. It is significant to note that this is the first study on distal substitution in the partial cone conformation of calix[4]arene or tetrathiacalix[4]arene derivatives.

2.7.2. Two-phase extraction

For a molecule to be effective as a preorganized host, it is necessary that it does not undergo significant conformational reorganization and its structural features remain compatible with those of the target guest. It is evident from the variable temperature ^{1}H NMR study reported above that the tetrathiacalixarene amide derivatives do not undergo any conformational reorganization and therefore are not interconvertible.

Thus these compounds may be expected to act as preorganized hosts for anionic guests through their amidic arm which offers immense possibilities of hydrogen bonding with the anionic guest molecules. Nevertheless, since the periphery of oxyanions has oxygen functions, they represent potential sites for hydrogen bonding to the host amido tetrathiacalix[4]-arenes. The percentage of selective extraction of oxyanions appears to indicate that more sophisticated amidic tetrathiacalix[4]arenes can recognize the oxyanions.

3. Conclusion

A number of tetrathiacalix[4]arene amide derivatives in cone, partial cone and 1,3-alternate conformations have been synthesized. The present work reveals that the partial cone conformer of *p-tert*-butyltetrathiacalix[4]arene tetraethylacetate undergoes aminolysis with alkyl monoamines through a regioselective route to yield the *p-tert*-butyltetrathiacalix[4]-arene amide derivatives. The synthesized amide derivatives in different conformations are capable of extraction of toxic anions (through amidic protons) and can function as model molecular hosts for oxyanions.

4. Experimental section

4.1. General

All the reagents used in the study were purchased from Sigma–Aldrich or Merck and were considered chemically pure to be used without further purification. The solvents used were distilled and purified as recommended in the literature.[12] Chromatographic separations were performed on silica gel (60–120 mesh, Merck). Melting points were recorded on an electric melting point apparatus (Toshniwal, India) and are uncorrected. IR spectra were recorded on a Nicolet Protégé 460 spectrometer in KBr discs while CHN analyses were obtained using a Perkin–Elmer 240C elemental analyzer. ^{1}H NMR spectra were recorded on a 300 MHz Bruker DPX 300

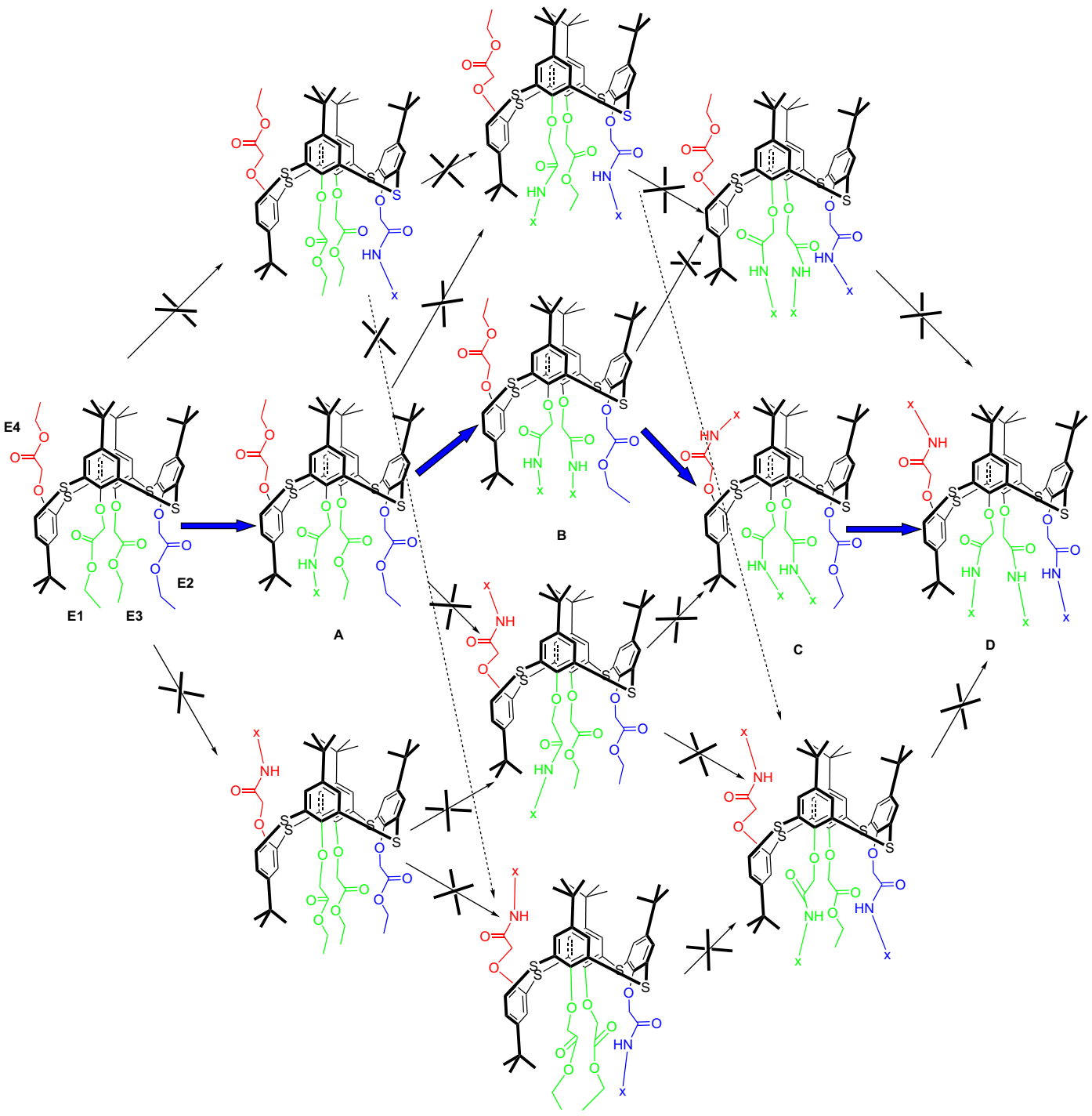


Figure 9. Stepwise regioselective aminolysis of the partial cone conformer of the tetrathiacalix[4]arene tetraester (the blue block arrows represent the actual route and the line and dotted arrows represent the possible routes).

instrument at room temperature using tetramethylsilane (TMS) as an internal standard. The FAB mass spectra were recorded on a JEOL SX 102/DA-6000 Mass spectrometer/Data System using Argon/Xenon (6 kV, 10 mA) as the FAB gas.

4.2. Preparation of the starting materials

p-tert-Butyltetrathiacalix[4]arene[1a] (**1a**) and tetrathiacalix[4]arene[1b,c] (**1b**) were synthesized by methods reported earlier. The tetraacetates were synthesized by the treatment of **1a** and **1b** with ethylbromoacetate using M_2CO_3 (M=Na, K or Cs) as the base in refluxing acetone.[7]

4.3. General procedure for aminolysis

The aminolysis reaction was carried out using two different methods represented by methods A and B.

Method A: a mixture of tetrathiacalix[4]arene tetraethylacetate (1 g, 1.88 mmol) and alkyl monoamine (20 equiv) was refluxed in (a) THF/methanol (1:1) (30 mL) or (b) toluene/methanol (1:1) (30 mL). After removing the solvent by distillation under reduced pressure, the crude mixture was precipitated with water or methanol to provide compounds which were purified either by recrystallization from appropriate solvents or by column chromatography as mentioned under each compound given below.

Method B: a mixture of tetrathiacalix[4]arene tetraethylacetate (1 g, 1.88 mmol) was treated with excess of the alkyl amines (20 mL) and (a) stirred for 2–72 h at room temperature or (b) refluxed. The alkyl monoamine was evaporated and the remaining white solid was dried under vacuum or water (40 mL) was added to the reaction mixture and the insoluble precipitate was filtered and washed with water to give a dull white crude product which was purified by either recrystallization or chromatographic separation as stated in the description given later.

4.3.1. Compound **2a** (cone)[5d]

Method B (b), reaction time: 12 h, white solid (0.86 g, 82%). Mp 150 °C. IR (KBr, ν/cm^{-1}): 3340, 1662. Anal. Calcd for $C_{60}H_{84}N_4O_8S_4$: C, 64.48; H, 7.58; N, 5.01. Found: C, 64.35; H, 7.59; N, 5.03. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H 7.82 (br s, 4H, CON*H*), 7.34 (s, 8H, Ar*H*), 4.82 (s, 8H, ArOCH_2), 3.34 (m, 8H, CONHCH_2), 1.63–1.58 (m, 8H, −NHCH$_2$CH_2), 1.11 (s, 36H, −C(CH_3)$_3$), 0.95 (t, J=7.2 Hz, 12H, CH_3); ^{13}C-DEPT 135 NMR (75 MHz, $CDCl_3$) δ (ppm): 134.9 (aromatic *C*H), 75.5 (ArO*C*H$_2$), 41.2 (NH*C*H$_2$), 31.2 (C(*C*H$_3$)$_3$), 23.1 (*C*H$_2$CH$_3$), 11.5 (*C*H$_3$). FAB-MS: m/z=1116 [M$^+$, 100%].

4.3.2. Compound **2b** (cone)[5d]

Method B (b), reaction time: 12 h, white solid (0.85 g, 78%). Mp 135 °C. IR (KBr, ν/cm^{-1}): 3343, 1664. Anal. Calcd for $C_{64}H_{92}N_4O_8S_4$: C, 65.49; H, 7.90; N, 4.77. Found: C, 65.66; H, 7.89; N, 4.77. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H 7.78 (br s, 4H, CON*H*), 7.34 (s, 8H, Ar*H*), 4.81 (s, 8H, ArOCH_2), 3.37–3.35 (br m, 8H, CONHCH_2), 1.60–1.56 (m, 8H, −NHCH$_2$CH_2), 1.35–1.31 (m, 8H, −NHCH$_2$CH$_2$CH_2CH$_3$), 1.11 (s, 36H, −C(CH_3)$_3$), 0.94 (t, J=6.8 Hz, 12H, CH_3); ^{13}C-DEPT 135 NMR (75 MHz, $CDCl_3$) δ (ppm): 134.8 (aromatic *C*H), 74.6 (ArO*C*H$_2$), 39.2 (NH*C*H$_2$), 31.8 (NHCH$_2$*C*H$_2$), 31.1 (C(*C*H$_3$)$_3$), 20.2 (*C*H$_2$CH$_3$), 13.7 (*C*H$_3$). FAB-MS: m/z= 1172 [M$^+$, 100%].

4.3.3. Compound **2c** (cone)

Method B (b), reaction time: 12 h, white solid (0.87 g, 72%). Mp 125 °C. IR (KBr, ν/cm^{-1}): 3360, 1664. Anal. Calcd for $C_{72}H_{108}N_4O_8S_4$: C, 67.25; H, 8.47; N, 4.36. Found: C, 67.38; H, 8.47; N, 4.37. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H 7.78 (br s, 4H, CON*H*), 7.34 (s, 8H, Ar*H*), 4.81 (s, 8H, ArOCH_2), 3.37–3.33 (br m, 8H, CONHCH_2), 1.62–1.59 (m, 8H, −NHCH$_2$CH_2), 1.29 (br s, 24H, −NHCH$_2$CH$_2$(CH_2)$_3$CH$_3$), 1.11 (s, 36H, −C(CH_3)$_3$), 0.87 (br s, 12H, CH_3); ^{13}C-DEPT 135 NMR (75 MHz, $CDCl_3$) δ (ppm): 134.8 (aromatic *C*H), 74.6 (ArO*C*H$_2$), 39.5 (NH*C*H$_2$), 31.5 (NHCH$_2$*C*H$_2$), 31.1 (C(*C*H$_3$)$_3$), 29.7 (NHCH$_2$CH$_2$*C*H$_2$), 26.8 (*C*H$_2$CH$_2$CH$_3$), 22.6 (*C*H$_2$CH$_3$), 13.7 (*C*H$_3$). FAB-MS: m/z=1286 [M$^+$, 100%].

4.3.4. Compound **4a** (1,3-alternate)[5d]

Method A (a), reaction time: 12 h, white solid (0.75 g, 72%). Mp 123 °C. IR (KBr, ν/cm^{-1}): 3322, 1651. Anal. Calcd for $C_{60}H_{84}N_4O_8S_4$: C, 64.48; H, 7.58; N, 5.01. Found: C, 64.29; H, 7.60; N, 4.99. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H 7.78 (br s, 4H, CON*H*), 7.54 (s, 8H, Ar*H*), 4.09 (s, 8H, ArOCH_2), 3.27–3.25 (m, 8H, CONHCH_2), 1.60–1.58 (m, 8H, −NHCH$_2$CH_2), 1.24 (s, 36H, −C(CH_3)$_3$), 0.88 (br s, 12H, CH_3); ^{13}C-DEPT 135 NMR (75 MHz, $CDCl_3$) δ (ppm): 132.9 (aromatic *C*H), 71.1 (ArO*C*H$_2$), 41.2 (NH*C*H$_2$), 31.0 (C(*C*H$_3$)$_3$), 23.5 (*C*H$_2$CH$_3$), 11.5 (*C*H$_3$). FAB-MS: m/z=1118 [M$^+$, 100%].

4.3.5. Compound **4b** (1,3-alternate)

Method A (a), reaction time: 12 h, white solid (0.77 g, 70%). Mp 135 °C. IR (KBr, ν/cm^{-1}): 3319, 1653. Anal. Calcd for $C_{64}H_{92}N_4O_8S_4$: C, 65.49; H, 7.90; N, 4.77. Found: C, 65.31; H, 7.91; N, 4.75. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H 7.75 (br s, 4H, CON*H*), 7.54 (s, 8H, Ar*H*), 4.10 (s, 8H, ArOCH_2), 3.29–3.26 (m, 8H, CONHCH_2), 1.60–1.57 (m, 8H, −NHCH$_2$CH_2), 1.35–1.32 (m, 8H, −CH_2CH$_3$), 1.22 (s, 36H, −C(CH_3)$_3$), 0.95 (t, J=6.9 Hz, 12H, CH_3); ^{13}C-DEPT 135 NMR (75 MHz, $CDCl_3$) δ (ppm): 133.2 (aromatic *C*H), 71.02 (ArO*C*H$_2$), 39.1 (NH*C*H$_2$), 31.5 (NHCH$_2$*C*H$_2$), 31.02 (C(*C*H$_3$)$_3$), 20.2 (*C*H$_2$CH$_3$), 13.6 (*C*H$_3$). FAB-MS: m/z=1172 [M$^+$, 100%].

4.3.6. Compound **4c** (1,3-alternate)

Method A (a), reaction time: 12 h, white solid (0.78 g, 65%). Mp 207 °C. IR (KBr, ν/cm^{-1}): 3328, 1657. Anal. Calcd for $C_{72}H_{108}N_4O_8S_4$: C, 67.25; H, 8.47; N, 4.36. Found: C, 67.37; H, 8.45; N, 4.37. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H 7.82 (br s, 4H, CON*H*), 7.53 (s, 8H, Ar*H*), 4.14 (s, 8H, ArOCH_2), 3.22 (br m, 8H, CONHCH_2), 1.62–1.59 (m, 8H, −NHCH$_2$CH_2), 1.33–1.31 (m, 16H, −NHCH$_2$CH$_2$CH_2CH_2), 1.22 (br s, 36H, −C(CH_3)$_3$ and 8H, −CH_2CH$_3$), 0.94 (t, J=6.9 Hz, 12H, CH_3); ^{13}C-DEPT 135 NMR (75 MHz, $CDCl_3$) δ (ppm): 133.4 (aromatic *C*H), 71.7 (ArO*C*H$_2$), 39.5 (NH*C*H$_2$), 31.6 (NHCH$_2$*C*H$_2$), 31.09 (C(*C*H$_3$)$_3$), 26.8, 22.5, 20.2 ((*C*H$_2$)$_3$CH$_3$), 13.7 (*C*H$_3$). FAB-MS: m/z=1286 [M$^+$, 100%].

4.3.7. Compound **4d** (1,3-alternate)

Method B (b), reaction time: 7 days, white solid (0.72 g, 32%) recrystallized from $CHCl_3$/acetonitrile. Mp 235 °C (decomp.). IR (KBr, ν/cm^{-1}): 3317, 1651. Anal. Calcd for $C_{44}H_{52}N_4O_8S_4$: C, 59.17; H, 5.87; N, 6.27. Found: C, 59.23; H, 5.87; N, 6.28. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H 7.53 (d, J=7.6 Hz, 8H, Ar*H*), 6.92 (t, J=15.2 Hz, 4H, Ar*H*), 6.38 (br s, 4H, CON*H*), 4.63 (s, 8H, ArOCH_2), 3.28 (m, 8H, NHCH_2), 1.60–1.56 (m, 8H, NHCH$_2$CH_2), 0.99 (t, J=14.6 Hz, 12H, CH_3); ^{13}C NMR (75 MHz, $CDCl_3$) δ (ppm): 167.5 (*C*=O), 159.5, 135.7, 128.5, 124.0 (aromatic

C and aromatic *C*H), 69.9 (ArO*C*H$_2$), 40.9 (NH*C*H$_2$), 23.2 (NHCH$_2$*C*H$_2$), 11.5 (*C*H$_3$). FAB-MS: *m*/*z*=892 [M$^+$, 100%].

*4.3.8. Compound **4e** (1,3-alternate)*

Method B (b), reaction time: 7 days, white solid (0.69 g, 55%) recrystallized from CHCl$_3$/acetonitrile. Mp 146 °C. IR (KBr, ν/cm^{-1}): 3298, 1653. Anal. Calcd for $C_{56}H_{76}N_4O_8S_4$: C, 63.36; H, 7.22; N, 5.28. Found: C, 62.91; H, 6.72; N, 5.48. ^{1}H NMR (300 MHz, CDCl$_3$) δ_H 7.53 (d, *J*=7.6 Hz, 8H, Ar*H*), 6.90 (t, *J*=15.2 Hz, 4H, Ar*H*), 6.41 (br s, 4H, CON*H*), 4.60 (s, 8H, ArOC*H*$_2$), 3.27 (m, 8H, NHC*H*$_2$), 1.64–1.55 (m, 8H, NHCH$_2$C*H*$_2$C*H*$_2$), 1.36 (m, 24H, C*H*$_2$C*H*$_2$CH$_3$), 0.93 (br s, 12H, C*H*$_3$); ^{13}C NMR (75 MHz, CDCl$_3$) δ (ppm): 167.5 (*C*=O), 159.0, 135.7, 128.4, 124.0 (aromatic *C* and aromatic *C*H), 69.9 (ArO*C*H$_2$), 39.3 (NH*C*H$_2$), 31.5, 30.0, 26.8, 22.6 (NHCH$_2$(*C*H$_2$)$_4$), 14.0 (*C*H$_3$). FAB-MS: *m*/*z*=1062 [M$^+$, 100%].

*4.3.9. Compound **6a** (partial cone)*

Method B (a), reaction time: 2 h, white solid (0.14 g, 14%) purified by column chromatography (chloroform/ethyl acetate 9.6:0.4), R_f=0.78. Mp 207 °C (decomp.). IR (KBr, ν/cm^{-1}): 3343, 1757, 1674. Anal. Calcd for $C_{57}H_{75}NO_{11}S_4$: C, 63.48; H, 7.01; N, 1.30. Found: C, 63.29; H, 6.99; N, 1.30. ^{1}H NMR (300 MHz, CDCl$_3$) δ_H 8.38 (br s, 1H, CON*H*), 7.81 (s, 1H, Ar*H*), 7.76 (s, 1H, Ar*H*), 7.57–7.52 (m, 4H, Ar*H*), 7.01 (br s, 2H, Ar*H*), 5.03 (d, *J*=12.5 Hz, 1H, ArOC*H*$_2$), 4.98 (d, *J*=14.0 Hz, 1H, ArOC*H*$_2$), 4.74 (s, 2H, ArOC*H*$_2$), 4.72 (d, *J*=4.4 Hz, 2H, ArOC*H*$_2$), 4.48 (d, *J*=15.5 Hz, 2H, ArOC*H*$_2$), 4.30–3.96 (m, 6H, OCH$_2$CH$_3$), 3.53–3.45 (m, 1H, NHC*H*$_2$), 3.23–3.16 (m, 1H, NHC*H*$_2$), 1.66–1.64 (m, 2H, NHCH$_2$C*H*$_2$CH$_3$), 1.43 (s, 9H, C(C*H*$_3$)$_3$), 1.33 (s, 9H, C(C*H*$_3$)$_3$), 1.24 (t, *J*=16.7 Hz, 6H, C*H*$_3$), 1.12 (t, *J*=14.3 Hz, 3H, C*H*$_3$), 1.06 (s, 9H, C(C*H*$_3$)$_3$), 1.04 (s, 9H, C(C*H*$_3$)$_3$), 0.95 (t, *J*=14.6 Hz, 3H, C*H*$_3$); ^{13}C-DEPT 135 NMR (75 MHz, CDCl$_3$) δ (ppm): 135.5, 134.9, 134.6, 134.5, 134.4, 133.8, 133.06 (aromatic *C*), 74.1, 70.5, 69.3, 65.9, 60.7, 60.6, 60.0 (ArO*C*H$_2$), 40.9 (NH*C*H$_2$), 31.3, 31.1, 31.04, 31.02 (C(*C*H$_3$)$_3$), 22.7 (NHCH$_2$*C*H$_2$), 14.2, 14.1, 13.9, 11.5 (CH$_2$*C*H$_3$). FAB-MS: *m*/*z*=1076 [M$^+$–1, 100%].

*4.3.10. Compound **6b** (partial cone)*

Method B (a), reaction time: 2 h, white solid (0.57 g, 56%) purified by column chromatography (chloroform/ethyl acetate 9.6:0.4), R_f=0.71. Mp 222 °C (decomp.). IR (KBr, ν/cm^{-1}): 3319, 1755, 1660. Anal. Calcd for $C_{58}H_{78}N_2O_{10}S_4$: C, 63.82; H, 7.20; N, 2.57. Found: C, 63.91; H, 7.21; N, 2.56. ^{1}H NMR (300 MHz, CDCl$_3$) δ_H 8.35 (br s, 2H, CON*H*), 7.77 (s, 2H, Ar*H*), 7.58 (s, 4H, Ar*H*), 7.02 (s, 2H, Ar*H*), 4.97 (d, *J*=15.2 Hz, 2H, ArOC*H*$_2$), 4.76 (s, 2H, ArOC*H*$_2$), 4.50 (d, *J*=15.3 Hz, 2H, ArOC*H*$_2$), 4.35 (s, 2H, ArOC*H*$_2$), 4.31 (q, *J*=7.2 Hz, 2H, OC*H*$_2$CH$_3$), 4.05 (q, *J*=7.1 Hz, 2H, OC*H*$_2$CH$_3$), 3.49 (m, 2H, NHC*H*$_2$), 3.18 (m, 2H, NHC*H*$_2$), 1.64 (m, 4H, NHCH$_2$C*H*$_2$CH$_3$), 1.35 (s, 9H, C(C*H*$_3$)$_3$), 1.33 (s, 9H, C(C*H*$_3$)$_3$), 1.12 (t, *J*=7.0 Hz, 6H, C*H*$_3$), 1.05 (s, 18H, C(C*H*$_3$)$_3$), 0.96 (t, *J*=7.0 Hz, 6H, C*H*$_3$); ^{13}C-DEPT 135 NMR (75 MHz, CDCl$_3$) δ (ppm): 134.9, 134.6, 134.4, 134.01 (aromatic *C*H), 74.01, 69.3, 65.3, 60.5, 60.6 (ArO*C*H$_2$ and O*C*H$_2$CH$_3$), 40.8 (NH*C*H$_2$), 31.2, 31.1, 30.9 (C(*C*H$_3$)$_3$), 22.9 (NHCH$_2$*C*H$_2$), 14.2, 14.01, 11.5 (CH$_2$*C*H$_3$). FAB-MS: *m*/*z*=1089 [M$^+$–1, 100%].

*4.3.11. Compound **6c** (partial cone)*

Method B (a), reaction time: 2–16 h, white solid (0.20 g, 20%) purified by column chromatography (chloroform/ethyl acetate 9.6:0.4), R_f=0.63. Mp 243 °C (decomp.). IR (KBr, ν/cm^{-1}): 3323, 1752, 1667. Anal. Calcd for $C_{59}H_{81}N_3O_9S_4$: C, 64.16; H, 7.39; N, 3.80. Found: C, 64.27; H, 7.37; N, 3.80. ^{1}H NMR (300 MHz, CDCl$_3$) δ_H 8.69 (t, *J*=5.7 Hz, 1H, CON*H*), 8.18 (t, *J*=5.4 Hz, 2H, CON*H*), 7.82 (s, 2H, Ar*H*), 7.59 (s, 2H, Ar*H*), 7.46 (d, *J*=2.4 Hz, 2H, Ar*H*), 7.03 (d, *J*=2.4 Hz, 2H, Ar*H*), 5.026 (s, 2H, ArOC*H*$_2$), 5.020 (d, *J*=15.3 Hz, 2H, ArOC*H*$_2$), 4.44 (d, *J*=15.2 Hz, 2H, ArOC*H*$_2$), 4.42 (s, 2H, ArOC*H*$_2$), 4.06 (q, *J*=7.2 Hz, 2H, OC*H*$_2$CH$_3$), 3.53–3.37 (m, 4H, NHC*H*$_2$), 3.21–3.17 (m, 2H, NHC*H*$_2$), 1.73–1.65 (m, 6H, CONHCH$_2$C*H*$_2$), 1.35 (s, 9H, C(C*H*$_3$)$_3$), 1.33 (s, 9H, C(C*H*$_3$)$_3$), 1.12 (t, 6H, *J*=7.2 Hz, C*H*$_3$), 1.02 (s, 18H, C(C*H*$_3$)$_3$), 0.96 (t, *J*=7.5 Hz, 6H, C*H*$_3$); ^{13}C-DEPT 135 NMR (75 MHz, CDCl$_3$) δ (ppm): 136.2, 135.1, 134.1, 133.2 (aromatic *C*H), 74.5, 74.0, 66.1, 60.9 (ArO*C*H$_2$ and O*C*H$_2$CH$_3$), 40.0, 39.9 (NH*C*H$_2$), 31.3, 31.1, 31.1 (C(*C*H$_3$)$_3$), 23.1, 22.9 (NHCH$_2$*C*H$_2$), 14.2, 11.3, 11.5 (CH$_2$*C*H$_3$). FAB-MS: *m*/*z*=1103 [M$^+$, 100%].

*4.3.12. Compound **6d** (partial cone)*

Method B (a), reaction time: 3 days, white solid (0.80 g, 77%) recrystallized from CHCl$_3$/MeOH. Mp 239 °C. IR (KBr, ν/cm^{-1}): 3287, 1674. Anal. Calcd for $C_{60}H_{84}N_4O_8S_4$: C, 64.48; H, 7.58; N, 5.01. Found: C, 64.55; H, 7.58; N, 5.02. ^{1}H NMR (300 MHz, CDCl$_3$) δ_H 8.47 (br s, 1H, CON*H*), 7.83 (br s, 2H, CON*H*), 7.72 (s, 2H, Ar*H*), 7.56 (s, 2H, Ar*H*), 7.42 (s, 2H, Ar*H*), 7.00 (s, 3H, Ar*H* and CON*H*), 4.90 (s, 2H, ArOC*H*$_2$), 4.82 (d, *J*=14.5 Hz, 2H, ArOC*H*$_2$), 4.35 (br s, 4H, ArOC*H*$_2$), 3.31–3.27 (m, 4H, CONHC*H*$_2$), 3.21 (br s, 2H, CONHC*H*$_2$), 3.04 (br s, 2H, CONHC*H*$_2$), 1.57–1.50 (m, 8H, C*H*$_2$CH$_3$), 1.51 (s, 18H, C(C*H*$_3$)$_3$), 1.26 (s, 9H, C(C*H*$_3$)$_3$), 1.24 (br s, 4H, C*H*$_2$CH$_3$), 0.98 (s, 9H, C(C*H*$_3$)$_3$), 0.92 (m, 9H, C*H*$_3$), 0.58 (m, 3H, C*H*$_3$); ^{13}C-DEPT 135 NMR (75 MHz, CDCl$_3$) δ (ppm): 136.3, 135.1, 134.8, 133.3 (aromatic *C*H), 74.4, 73.6, 69.7 (ArO*C*H$_2$), 39.3, 39.1, 38.7 (NH*C*H$_2$), 31.4, 31.2, 30.9 (C(*C*H$_3$)$_3$), 20.2, 19.7, 19.5 (NHCH$_2$*C*H$_2$), 13.7, 13.3, 12.9 (CH$_2$*C*H$_3$). FAB-MS: calcd for $C_{60}H_{84}N_4O_8S_4$: *m*/*z*=1116.51 [M$^+$]; found: *m*/*z*=1116 [M$^+$, 100%].

*4.3.13. Compound **7a** (partial cone)*

Method B (a), reaction time: 4.5 h, white solid (0.11 g, 11%) purified by column chromatography (chloroform/ethyl acetate 9.6:0.4), R_f=0.76. Mp 186 °C (decomp.). IR (KBr, ν/cm^{-1}): 3340, 1757, 1672. Anal. Calcd for $C_{58}H_{77}NO_{11}S_4$: C, 63.76; H, 7.10; N, 1.28. Found: C, 63.81; H, 7.12; N, 1.27. ^{1}H NMR (300 MHz, CDCl$_3$) δ_H 8.37 (t, *J*=5.1 Hz, 1H, CON*H*), 7.82 (d, *J*=2.4 Hz, 1H, Ar*H*), 7.76 (d, *J*=2.7 Hz, 1H, Ar*H*), 7.58–7.51 (m, 4H, Ar*H*), 7.02 (t, *J*=2.4 Hz, 2H,

Ar*H*), 5.00 (d, *J*=4.8 Hz, 1H, ArOC*H*$_2$), 4.95 (d, *J*=6.3 Hz, 1H, ArOC*H*$_2$), 4.74 (s, 2H, ArOC*H*$_2$), 4.72 (d, *J*=5.1 Hz, 2H, ArOC*H*$_2$), 4.50 (d, *J*=15.6 Hz, 2H, ArOC*H*$_2$), 4.30–3.92 (m, 6H, OCH$_2$CH$_3$), 3.55–3.48 (m, 1H, NHC*H*$_2$), 3.24–3.18 (m, 1H, NHC*H*$_2$), 1.67–1.57 (m, 2H, NHCH$_2$C*H*$_2$), 1.38 (s, 9H, C(C*H*$_3$)$_3$), 1.33 (s, 9H, C(C*H*$_3$)$_3$), 1.31–1.27 (m, 4H, CH$_2$C*H*$_2$CH$_3$), 1.25 (t, *J*=7.5 Hz, 6H, C*H*$_3$), 1.14 (t, *J*=7.2 Hz, 3H, C*H*$_3$), 1.06 (s, 9H, C(C*H*$_3$)$_3$), 1.04 (s, 9H, C(C*H*$_3$)$_3$), 0.92 (t, *J*=7.2 Hz, 3H, C*H*$_3$); ^{13}C-DEPT 135 NMR (75 MHz, CDCl$_3$) δ (ppm): 135.6, 135.0, 134.7, 134.59, 134.51, 133.9, 133.1 (aromatic *C*), 74.2, 70.5, 69.4, 66.0, 60.8, 60.7, 60.0 (ArO*C*H$_2$ and O*C*H$_2$CH$_3$), 39.0 (NH*C*H$_2$), 31.7 (NHCH$_2$*C*H$_2$), 31.3, 31.2, 31.06, 31.05 (C(*C*H$_3$)$_3$), 29.6 (NHCH$_2$*C*H$_2$), 20.2 (NHCH$_2$CH$_2$*C*H$_2$), 14.28, 14.21, 14.0, 13.8 (CH$_2$*C*H$_3$). FAB-MS: *m*/*z*=1091 [M$^+$, 100%].

*4.3.14. Compound **7b** (partial cone)*

Method B (a), reaction time: 4.5 h, white solid (0.47 g, 45%) purified by column chromatography (chloroform/ethyl acetate 9.6:0.4), R_f=0.72. Mp 203 °C (decomp.). IR (KBr, ν/cm^{-1}): 3328, 1757, 1663. Anal. Calcd for $C_{60}H_{82}NO_{10}S_4$: C, 64.37; H, 7.38; N, 2.50. Found: C, 64.47; H, 7.40; N, 2.49. ^{1}H NMR (300 MHz, CDCl$_3$) δ_H 8.35 (t, *J*=11.7 Hz, 2H, CON*H*), 7.77 (s, 2H, Ar*H*), 7.588 (s, 2H, Ar*H*), 7.582 (s, 2H, Ar*H*), 7.03 (s, 2H, Ar*H*), 4.95 (d, *J*=15.3 Hz, 2H, ArOC*H*$_2$), 4.76 (s, 2H, ArOC*H*$_2$), 4.51 (d, *J*=15.6 Hz, 2H, ArOC*H*$_2$), 4.33 (s, 2H, ArOC*H*$_2$), 4.25 (q, *J*=6.9 Hz, 2H, OC*H*$_2$CH$_3$), 4.08 (q, *J*=7.2 Hz, 2H, OC*H*$_2$CH$_3$), 3.54–3.43 (m, 2H, CONHC*H*$_2$), 3.26–3.15 (m, 2H, CONHC*H*$_2$), 1.57–1.52 (m, 4H, NHCH$_2$C*H*$_2$CH$_2$), 1.43–1.36 (m, 4H, NHCH$_2$CH$_2$C*H*$_2$), 1.35 (s, 9H, C(C*H*$_3$)$_3$), 1.33 (s, 9H, C(C*H*$_3$)$_3$), 1.12 (t, *J*=7.2 Hz, 6H, C*H*$_3$), 1.05 (s, 18H, C(C*H*$_3$)$_3$), 0.92 (t, *J*=7.2 Hz, 6H, C*H*$_3$); ^{13}C-DEPT 135 NMR (75 MHz, CDCl$_3$) δ (ppm): 135.4, 135.1, 134.9, 134.4 (aromatic *C*H), 74.7, 69.8, 65.8, 61.2, 61.0 (ArO*C*H$_2$ and O*C*H$_2$CH$_3$), 39.4 (NH*C*H$_2$), 32.1 (NHCH$_2$*C*H$_2$), 31.7, 31.5, 31.4 (C(*C*H$_3$)$_3$), 20.6 (*C*H$_2$CH$_3$), 14.7, 14.4, 14.1 (CH$_2$*C*H$_3$). FAB-MS: *m*/*z*=1117 [M$^+$–1, 100%].

*4.3.15. Compound **7c** (partial cone)*

Method B (a), reaction time: 4.5 h, white solid (0.22 g, 21%) puirified by column chromatography (chloroform/ethyl acetate 9.6:0.4), R_f=0.56. Mp 224 °C (decomp.). IR (KBr, ν/cm^{-1}): 3327, 1753, 1663. Anal. Calcd for $C_{62}H_{87}N_3O_9S_4$: C, 64.94; H, 7.65; N, 3.66. Found: C, 65.08; H, 7.66; N, 3.66. ^{1}H NMR (300 MHz, CDCl$_3$) δ_H 8.69 (t, *J*=5.7 Hz, 1H, CON*H*), 8.17 (t, *J*=5.4 Hz, 2H, CON*H*), 7.83 (s, 2H, Ar*H*), 7.59 (s, 2H, Ar*H*), 7.47 (d, 2H, Ar*H*), 7.03 (d, 2H, Ar*H*), 5.03 (s, 2H, ArOC*H*$_2$), 4.99 (d, *J*=15.3 Hz, 2H, ArOC*H*$_2$), 4.46 (d, *J*=15.3 Hz, 2H, ArOC*H*$_2$), 4.41 (s, 2H, ArOC*H*$_2$), 4.09 (q, *J*=7.2 Hz, 2H, OC*H*$_2$CH$_3$), 3.56–3.41 (m, 4H, NHC*H*$_2$), 3.27–3.16 (m, 2H, NHC*H*$_2$), 1.74–1.61 (m, 6H, NHCH$_2$C*H*$_2$), 1.45–1.38 (m, 6H, NHCH$_2$CH$_2$C*H*$_2$), 1.35 (s, 9H, C(C*H*$_3$)$_3$), 1.34 (s, 9H, C(C*H*$_3$)$_3$), 1.12 (t, *J*=6.9 Hz, 3H, C*H*$_3$), 1.03 (s, 18H, C(C*H*$_3$)$_3$), 0.93 (t, *J*=7.2 Hz, 9H, C*H*$_3$); ^{13}C-DEPT 135 NMR (75 MHz, CDCl$_3$) δ (ppm): 136.2, 135.2, 134.1, 133.2 (aromatic *C*H), 74.2, 73.8, 66.1, 60.8 (ArO*C*H$_2$ and O*C*H$_2$CH$_3$), 39.0, 38.8 (NH*C*H$_2$), 32.0, 31.8 (NHCH$_2$C*H*$_2$), 31.3, 31.1, 31.0 (C(*C*H$_3$)$_3$), 20.5, 20.4 (NHCH$_2$CH$_2$C*H*$_2$), 14.2, 11.3, 11.5 (CH$_2$*C*H$_3$). FAB-MS: *m*/*z*=1144 [M$^+$–1, 100%].

*4.3.16. Compound **7d** (partial cone)*

Method B (a), reaction time: 3 days, white solid (0.89 g, 81%) recrystallized from CHCl$_3$/MeOH. Mp 218 °C (decomp.). IR (KBr, ν/cm^{-1}): 3288, 1669. Anal. Calcd for $C_{64}H_{92}N_4O_8S_4$: C, 65.49; H, 7.90; N, 4.77. Found: C, 65.57; H, 7.88; N, 4.78. ^{1}H NMR (300 MHz, CDCl$_3$) δ_H 8.62 (br s, 1H, CON*H*), 7.91 (br s, 2H, CON*H*), 7.79 (s, 2H, Ar*H*), 7.63 (s, 2H, Ar*H*), 7.49 (s, 2H, Ar*H*), 7.06 (s, 3H, Ar*H* and CON*H*), 4.99 (s, 2H, ArOC*H*$_2$), 4.89 (d, *J*=13.2 Hz, 2H, ArOC*H*$_2$), 4.39 (br s, 4H, ArOC*H*$_2$), 3.45–3.41 (m, 4H, NHC*H*$_2$), 3.35–3.31 (m, 2H, NHC*H*$_2$), 3.14 (br s, 2H, NHC*H*$_2$), 1.62–1.58 (m, 8H, C*H*$_2$CH$_2$CH$_3$), 1.33 (br s, 18H, C(C*H*$_3$)$_3$ and 8H, C*H*$_2$CH$_3$), 1.05 (s, 18H, C(C*H*$_3$)$_3$), 0.94 (br s, 9H, C*H*$_3$), 0.77 (br s, 3H, C*H*$_3$). FAB-MS: *m*/*z*=1171 [M$^+$+1, 100%].

*4.3.17. Compound **8b** (partial cone)*

Method B (a), reaction time: 4.5 h, white solid (0.46 g, 42%) purified by column chromatography (chloroform/ethyl acetate 9.8:0.2), R_f=0.70. Mp 130 °C. IR (KBr, ν/cm^{-1}): 3332, 1759, 1668. Anal. Calcd for $C_{64}H_{90}N_2O_{10}S_4$: C, 65.38; H, 7.72; N, 2.38. Found: C, 65.54; H, 7.73; N, 2.38. ^{1}H NMR (300 MHz, CDCl$_3$) δ_H 8.32 (br t, 2H, CON*H*), 7.78 (s, 2H, Ar*H*), 7.57 (s, 2H, Ar*H*), 7.56 (s, 2H, Ar*H*), 7.03 (s, 2H, Ar*H*), 4.95 (d, *J*=15.3 Hz, 2H, ArOC*H*$_2$), 4.76 (s, 2H, ArOC*H*$_2$), 4.50 (d, *J*=15.3 Hz, 2H, ArOC*H*$_2$), 4.33 (s, 2H, ArOC*H*$_2$), 4.29 (q, *J*=7.2 Hz, 2H, OC*H*$_2$CH$_3$), 4.07 (q, *J*=7.0 Hz, 2H, OC*H*$_2$CH$_3$), 3.51–3.45 (m, 2H, NHC*H*$_2$), 3.22–3.15 (m, 2H, NHC*H*$_2$), 1.64–1.60 (m, 8H, NHCH$_2$(C*H*$_2$)$_2$), 1.34 (s, 9H, C(C*H*$_3$)$_3$), 1.33 (s, 9H, C(C*H*$_3$)$_3$), 1.31–1.24 (m, 8H, (C*H*$_2$)$_2$CH$_3$ and 3H, –C*H*$_3$), 1.11 (t, *J*=7.0 Hz, 3H, C*H*$_3$), 1.05 (s, 18H, C(C*H*$_3$)$_3$), 0.86 (br t, 6H, C*H*$_3$); ^{13}C-DEPT 135 NMR (75 MHz, CDCl$_3$) δ (ppm): 135.0, 134.8, 134.5, 133.9 (aromatic *C*H), 74.3, 69.4, 65.4, 60.7, 60.5 (ArO*C*H$_2$ and O*C*H$_2$CH$_3$), 39.2 (NH*C*H$_2$), 31.5 (NHCH$_2$*C*H$_2$), 31.3, 31.2, 31.0 (C(*C*H$_3$)$_3$), 29.6, 26.7, 22.5 (*C*H$_2$CH$_2$CH$_2$CH$_3$), 14.2, 14.0, 13.9 (CH$_2$*C*H$_3$). FAB-MS: *m*/*z*=1174 [M$^+$, 100%].

*4.3.18. Compound **8c** (partial cone)*

Method B (a), reaction time: 6 h, white solid (0.18 g, 16%) purified by column chromatography (chloroform/ethyl acetate 9.6:0.4), R_f=0.53. Mp 169 °C (decomp.). IR (KBr, ν/cm^{-1}): 3324, 1753, 1661. Anal. Calcd for $C_{68}H_{99}N_3O_9S_4$: C, 66.36; H, 8.11; N, 3.41. Found: C, 66.51; H, 8.10; N, 3.43. ^{1}H NMR (300 MHz, CDCl$_3$) δ_H 8.67 (br s, 1H, CON*H*), 8.16 (br s, 2H, CON*H*), 7.82 (s, 2H, Ar*H*), 7.58 (s, 2H, Ar*H*), 7.46 (s, 2H, Ar*H*), 7.03 (br s, 2H, Ar*H*), 5.02 (s, 2H, ArOC*H*$_2$), 4.99 (d, *J*=15.2 Hz, 2H, ArOC*H*$_2$), 4.46 (d, *J*=15.2 Hz, 2H, ArOC*H*$_2$), 4.33 (s, 2H, ArOC*H*$_2$), 4.06 (q, *J*=7.0 Hz, 2H, OC*H*$_2$CH$_3$), 3.51–3.44 (m, 4H, NHC*H*$_2$),

3.23–3.19 (m, 2H, NHCH_2), 1.70–1.65 (m, 12H, NHCH$_2$(CH_2)$_2$), 1.34 (br s, 18H, C(CH_3)$_3$ and 12H, (CH_2)$_2$CH$_3$), 1.13 (t, J=7.0 Hz, 3H, CH_3), 1.03 (s, 18H, C(CH_3)$_3$), 0.86 (br s, 9H, CH_3). FAB-MS: m/z=1231 [M$^+$, 100%].

*4.3.19. Compound **8d** (partial cone)*

Method B (a), reaction time: 3 days, white solid (1.01 g, 84%) recrystallized from $CHCl_3$: MeOH. Mp 188 °C. IR (KBr, ν/cm^{-1}): 3296, 1656. Anal. Calcd for $C_{72}H_{108}N_4O_8S_4$: C, 67.25; H, 8.47; N, 4.36. Found: C, 67.42; H, 8.47; N, 4.37. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H 8.62 (br s, 1H, CONH), 7.91 (br s, 2H, CONH), 7.79 (s, 2H, ArH), 7.62 (s, 2H, ArH), 7.49 (s, 2H, ArH), 7.13 (br s, 1H, CONH), 7.05 (s, 2H, ArH), 4.99 (s, 2H, ArOCH_2), 4.89 (d, J=14.8 Hz, 2H, ArOCH_2), 4.39 (s, 2H, ArOCH_2), 4.34 (d, J=14.6 Hz, 2H, ArOCH_2), 3.48–3.43 (m, 4H, NHCH_2), 3.33–3.28 (m, 2H, NHCH_2), 3.16–3.12 (m, 2H, NHCH_2), 1.70–1.63 (m, 8H, NHCH$_2$CH_2), 1.33 (s, 9H, C(CH_3)$_3$), 1.31 (s, 9H, C(CH_3)$_3$), 1.30–1.25 (m, 24H, (CH_2)$_3$CH$_3$), 1.04 (s, 18H, C(CH_3)$_3$), 0.89–0.79 (m, 12H, CH_3); ^{13}C-DEPT 135 NMR (75 MHz, $CDCl_3$) δ (ppm): 136.8, 135.5, 135.2, 133.8 (aromatic CH), 75.1, 74.2, 70.01 (ArOCH$_2$), 39.9, 39.7, 39.3 (NHCH$_2$), 31.9, 31.8, 31.7 (NHCH$_2$$CH_2$), 31.6, 31.5, 31.4 (C($CH_3$)$_3$), 30.2, 30.1, 29.8, 27.3, 27.2, 26.8, 22.9 (NHCH$_2$(CH$_2$)$_4$), 14.4 (CH$_2$$CH_3$). FAB-MS: m/z=1286 [M$^+$, 100%].

*4.3.20. Compound **9** (partial cone)*

Method A (b), reaction time: 5 days, white solid (0.35 g, 68%) recrystallized from $CHCl_3$/MeOH. Mp 162 °C (decomp.). IR (KBr, ν/cm^{-1}): 3312, 1658. Anal. Calcd for $C_{56}H_{76}N_4O_{12}S_4$: C, 59.76; H, 6.81; N, 4.98. Found: C, 59.91; H, 6.79; N, 4.98. ^{1}H NMR (300 MHz, $CDCl_3$) δ_H 8.16 (br s, 1H, CONH), 8.00 (br s, 2H, CONH), 7.70 (s, 2H, ArH), 7.55 (s, 2H, ArH), 7.52 (s, 2H, ArH), 7.20 (br s, 2H, ArH and 1H, CONH), 4.91 (d, J=14.6 Hz, 2H, ArOCH_2), 4.74 (d, 2H, ArOCH_2), 4.46 (d, J=14.7 Hz, 2H, ArOCH_2), 4.16 (s, 2H, ArOCH_2), 3.75–3.71 (m, 4H, NHCH_2CH_2OH), 3.60 (br s, 4H, CH_2OH), 3.52 (br s, 2H, NHCH_2), 3.42 (br s, 2H, NHCH_2), 3.23 (br s, 2H, CH_2OH), 3.05 (br s, 2H, NHCH_2), 1.33 (s, 9H, C(CH_3)$_3$), 1.24 (s, 18H, C(CH_3)$_3$), 1.09 (s, 9H, C(CH_3)$_3$). FAB-MS: m/z=1125 [M$^+$+1, 100%].

4.4. X-ray crystallographic data

Diffraction data were collected at 298 K on a CCD area detector diffractometer on a fine focus sealed tube (Mo Ka=0.71073 Å). All structures were solved using direct methods (SHELXS-97) and refined on F^2 (SHELXL-97). The structures contained a number of disordered moieties that could be satisfactorily described with two-site disorder models: *tert*-butyl groups and alkyl chains. Non-hydrogen atoms were refined with anisotropic displacement parameters. Hydrogen atoms were included on calculated positions riding on their carrier. The apparently high R values are possibly due to the disorder found in *p-tert*-butyl groups, ester groups and the alkylamide chains. The poor quality and sensitivity of the crystals also posed difficulties in data collection and resulted in high R values during structure refinement. The details of the crystal data of **7b**, **6c**, **8c**, **7d** and **8d** are given below.

*4.4.1. Compound **7b***

$C_{60}H_{81}N_2O_{10}S_4$, M_r=1118.55, monoclinic, $P2_1/c$ with a=14.919(4) Å, b=20.916(5) Å, c=21.771(5) Å, α=90.00°, β=100.288(4)°, γ=90.00°, V=6684(3) Å^3, Z=4, $R1$[5705I>2$\sigma(I)$]=0.0743, $wR2$ (7166 refl)=0.2359. Crystallographic data for the structure have been deposited with Cambridge Crystallographic Database as supplementary publication number CCDC 639698.

*4.4.2. Compound **6c***

$C_{59}H_{81}N_3O_9S_4$, M_r=1104.55, monoclinic, $C2/c$ with a=31.310(4) Å, b=21.062(3) Å, c=21.817(3) Å, α=90.00°, β=118.632(2)°, γ=90.00°, V=12,628(3) Å^3, Z=8, $R1$[5599I>2$\sigma(I)$]=0.0806, $wR2$ (6781 refl)=0.2225. Crystallographic data for the structure have been deposited with Cambridge Crystallographic Database as supplementary publication number CCDC 639700.

*4.4.3. Compound **8c***

$C_{68}H_{71}N_3O_9S_4$, M_r=1202.56, monoclinic, $P2_1/n$ with a=17.680(4) Å, b=21.407(5) Å, c=20.337(5) Å, α=90.00°, β=110.957(6)°, γ=90.00°, V=7188(3) Å^3, Z=4, $R1$[5352I>2$\sigma(I)$]=0.1051, $wR2$ (7701 refl)=0.2605. Crystallographic data for the structure have been deposited with Cambridge Crystallographic Database as supplementary publication number CCDC 639699.

*4.4.4. Compound **7d***

$C_{64}H_{78}N_4O_8S_4$, M_r=1159.59, triclinic, P-1 with a=14.009(3) Å, b=14.575(3) Å, c=18.252(4) Å, α=81.998(5)°, β=84.215(5)°, γ=70.699(4)°, V=3477.0(13) Å^3, Z=2, $R1$[4969I>2$\sigma(I)$]=0.0754, $wR2$ (9092 refl)=0.2014. Crystallographic data for the structure have been deposited with Cambridge Crystallographic Database as supplementary publication number CCDC 620313.

*4.4.5. Compound **8d***

$C_{144}H_{133}N_8O_{16}S_8$, M_r=2488.15, triclinic, P-1 with a=15.245(4) Å, b=16.265(4) Å, c=17.083(4) Å, α=95.015(5)°, β=107.938(5)°, γ=100.446(5)°, V=3916.6(16) Å^3, Z=1, $R1$[5755I>2$\sigma(I)$]=0.0920, $wR2$ (8435 refl)=0.2584. Crystallographic data for the structure have been deposited with Cambridge Crystallographic Database as supplementary publication number CCDC 619665.

4.5. Liquid–liquid extraction

Metal picrates (Li^+, Na^+, K^+, Rb^+, Cs^+, Mg^{2+}, Ba^{2+}, Co^{2+}, Ni^{2+}, Pb^{2+} and Ag^+) were prepared by the reaction of picric acid with the appropriate metal carbonate.[13] To determine the extractability of the ligand for a metal picrate, an aqueous solution (5.0 mL) containing 2.5×10^{-5} M metal picrate and an ethanol free chloroform solution (5.0 mL) of the extractant (2.5×10^{-5} M) were shaken for 3 h at 25 °C (±2).

The concentration of the picrate anion extracted from the aqueous phase into the organic phase was determined by UV spectrophotometry (λ_{max}=355 nm). Three independant experiments were carried out for each combination of molecular host and the metal picrate. The extraction percentages listed in Table 1 are the average of three determinations. The extraction of the oxyanions by molecular receptors was also followed by UV–visible spectroscopy in a similar fashion by stirring a solution of the tetrathiacalix[4]arene amides (5.0 mL, 2.5×10^{-5} M) and the metal oxyanions (Na_2CrO_4, K_2CrO_4, $Na_2Cr_2O_7$ and $K_2Cr_2O_7$) (5.0 mL, 2.5×10^{-5} M) for 3 h at 25 °C(±2). The decrease in the absorbance of the respective oxyanions in the aqueous phase was then followed by UV spectroscopy and the percentage extraction calculated (Table 2) according to the formula: % Extraction=$[(A_{blank}-A_{extracted})/A_{blank}]\times100$.[14]

Acknowledgements

We thank the CSIR for a senior research fellowship (to S.P.S.) and UGC for a senior research fellowship (to A.C.). We also thank D.S.T., M.F.P.I., M.R.D., M.O.E.F. and D.B.T., Government of India for financial assistance, Sophisticated Analytical Instrumentation Facility, Central Drug Research Institute, Lucknow for the mass spectra reported in this paper and DST-FIST grant for single crystal CCD X-ray facility at Indian Institute of Technology, New Delhi.

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