

Polymeric Calixarenes. Synthesis, Polymerisation and Na⁺ Complexation of a Calix[4]arene Methacrylate

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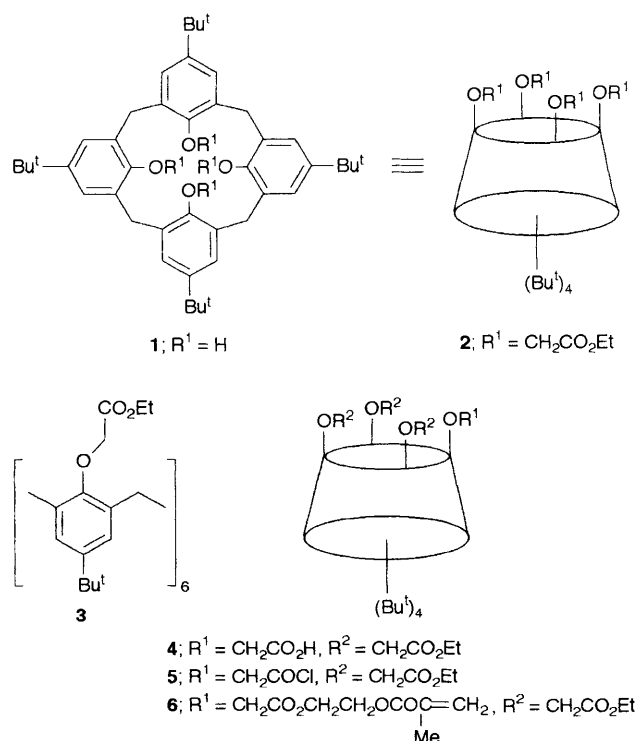
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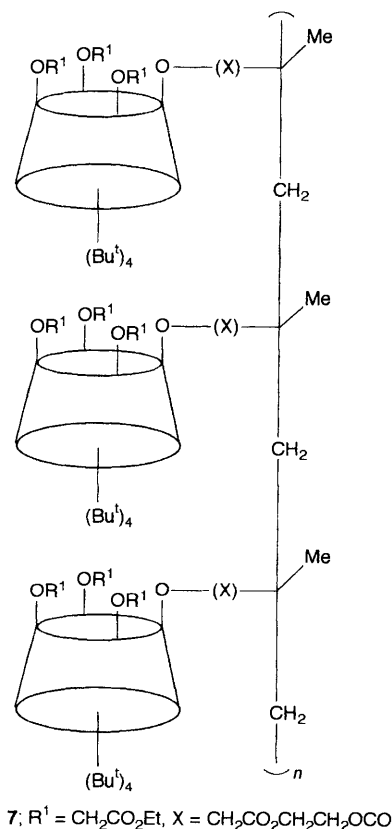
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A calix[4]arene methacrylate has been prepared from *p*-*tert*-butylcalix[4]arene and polymerised under free radical conditions: both monomer and polymer form stable complexes with sodium thiocyanate.

The calixarenes are phenolic metacyclophanes which offer novel possibilities as building blocks for synthetic receptors and enzyme mimics.^{1,2} A part of their popular appeal lies in the high degree of preorganisation associated with the cone conformation of the tetramer **1** allied to the ease with which chemical modification can be brought about at either the upper or lower rim of the macrocyclic array. The oxygen functions of the latter offer many possibilities for manipulation of potential binding sites and several groups have demonstrated how functional groups such as ester,^{3,4,5} ketone,³ ether,⁶ amide,^{7,8,9} thioamide¹⁰ and carboxylic acid¹¹ can be assembled as ligating side arms or podands for the reception of guest species, notably alkali,³⁻⁶ alkaline earth^{8,9} and some transition metal cations.¹² For example, tetraester **2**¹³ and hexaester **3**¹⁴ are sufficiently selective for Na⁺ and Cs⁺ respectively to enable their exploitation in ion-selective electrodes. The efficacy of the Na⁺ electrode has been demonstrated in extensive clinical trials for Na⁺ analysis in blood.¹⁵ Until now all these complexation studies have been conducted with monomeric calixarenes. Polymeric calixarenes are a much more recent innovation. One of us has recently described the attachment of calix[4]arenes to a polymer support¹⁶ and Shinkai has prepared a calix[6]arene fixed to polystyrene.¹⁷ We now report the first preparation of a calix[4]arene methacrylate, its polymerisation and Na⁺ complexation.

We anticipated that a monomeric calix[4]arene incorporating an acrylate or methacrylate would be amenable to





polymerisation through the alkenic moiety. Such a monomer could be synthesised by taking advantage of an earlier discovery that treatment of tetraester **2** with trifluoroacetic acid results in the clean removal of a single ester group to afford triester-monoacid **4**.¹⁸ This monoacid readily furnished the acyl chloride **5** on exposure to thionyl chloride. A methacrylate group was then introduced by combining the acyl chloride with 2-hydroxyethyl methacrylate, whereupon the triethyl monomethacrylate ester **6**, m.p. 63–65 °C, was obtained in good yield. The ¹H NMR spectrum of **6** was fully consistent with the presence of a stable cone conformation, exhibiting, *inter alia*, two *tert*-butyl signals at δ 1.05 and 1.10 (1:3 ratio) and two aromatic signals at δ 6.74 and 6.80 (1:3 ratio). Treatment of **6** with sodium thiocyanate produced the crystalline NaSCN complex **6a** whose NMR spectrum displayed all the chemical shift changes characteristic of cation binding by ester groups^{3,4} in a calix[4]arene receptor.

Polymerisation was achieved by heating **6** with azobisisobutyronitrile in toluene for *ca.* 17 h. Dilution of the reaction mixture with methanol precipitated the polymer **7** as a white solid (50% yield) which was soluble in chloroform, dichloromethane and acetone. Treatment of the polymer with sodium thiocyanate produced the Na⁺ complex as a stable white powder. That the product **7** was polymethacrylate was confirmed by the absence of vinylic absorptions in both the IR and NMR spectra and by the molecular weight of 6745.[†] Thus the average chain length is *ca.* 6 calixarene units. The ¹H NMR spectrum of the polymer exhibited rather broad signals for all protons with two singlets each for the *tert*-butyl (δ 1.04 and 1.13) and aromatic (δ 6.71 and 6.85) residues. The H_A proton of the AB system, characteristic of the bridging methylene protons in tetramers in the cone conformation, was partly obscured at δ 4.82. The spectrum of the Na⁺-complexed

polymer, in contrast, showed sharp singlets at δ 1.07 and 7.05 for the *tert*-butyl and aromatic protons, respectively, with the H_A chemical shift at δ 4.30. These chemical shift changes on complexation, particularly those associated with the aromatic and H_A protons, are very similar to those observed with monomer methacrylate **6** and the tetraethyl ester **2** on complexation with sodium thiocyanate,^{3,4} and confirm that each calixarene receptor unit of the polymer was occupied by a guest cation. The methylene signals of the polymer backbone in the ¹H NMR spectra of both the free and complexed material were broadened to such an extent that a stereochemical assignment of the stereogenic centres was not possible. The rather short chain length of **7** may result from severe steric congestion as bulky calixarene pendant units are added to every second carbon atom of the growing polymer. Phase transfer studies using alkali picrates in water–dichloromethane confirmed that polymer **7** is sodium selective as is its monomer. In an alternative approach to the sodium-complexed polymer an attempt was made to polymerise the sodium-complexed monomer. No reaction was observed; apparently, thiocyanate ion is an inhibitor of free radical polymerisation.¹⁹

The possibility that linear polyreceptors such as **7** could act as cation 'stepping stones' for sodium ions in transmembranes channels is under study.

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[†] The molecular weight was determined by gel permeation chromatography on a commercial HPLC instrument; narrow molecular weight-distribution polystyrenes, supplied by Polymer Laboratories, UK, Ltd., were used as standards.