(20 mL) was refluxed for 45 h. The reaction mixture was cooled to room temperature, and the resulting precipitate was filtered off, washed with water, and dried over P_2O_5 to afford 167 mg (59%) of **3d** as white solid; mp 250–254 °C. Crystallization from chloroform and recrystallization from chloroform–petroleum ether gave the analytical sample as white needles: mp 254–255 °C; IR (KBr) 3350 and 1650 cm^{-1}.

Acidification of the filtrate with dilute HCl precipitated a white solid, which was filtered, washed with water, and dried over P_2O_5 to yield **3e** (106 mg, 37%); mp 234–236 °C. Crystallization from benzene–hexane gave pure **3e** as light yellow prisms: mp 236 °C; NMR (acetone-d_6) δ 4.20 (s, 2, CH_2), 7.12–7.43 and 7.51–7.82 (m, 8, aromatic), 8.26–8.58 (m, 3, H_4, H_{10}, and H_{11}); IR (KBr) 1680 cm^{-1} (C=O).

A solution of **3c** (110 mg, 0.412 mmol) and NaOH (2 g) in ethylene glycol (20 mL), diglyme (10 mL), and water (10 mL) was refluxed for 40 h. Addition of ice–water and acidification with dilute HCl precipitated **3e** (65 mg, 55%) accompanied by an insoluble polymeric residue.

Hydrolysis of 3d. A suspension of **3d** (65 mg, 0.228 mmol) in a solution of NaOH (100 mg) in ethylene glycol (10 mL) and water (4 mL) was heated at reflux for 86 h. The product was filtered to remove a small amount of an insoluble material and acidified with HCl. Conventional workup furnished **3e** (55 mg, 85%).

4-Hydroxybenzo[*a*]pyrene (1a). A solution of **3e** (83 mg, 0.29 mmol) in anhydrous HF (20 mL) in a Teflon bottle was stirred under N_2 for 15 h. Evaporation of the HF in a stream of N_2 required 2 h. To the resulting greenish yellow residue was added a solution of $NaHCO_3$ (100 mg) in 40 mL of water. This was stirred together for 30 min, then extracted with ether, and worked up in a conventional manner. The crude product was triturated with two 3-mL portions of hexane and then purified by vacuum sublimation at 160–200 °C (0.03 mmHg) to afford pure **1a** (65 mg, 84%) as a yellow solid: mp 225–227 °C dec (lit.[2] mp 195–196 °C); NMR (acetone-d_6) δ 7.46 (s, 1, H_5), 7.73–7.84 (m, 2, $H_{8,9}$), 8.09 (t, 1, J = 8 Hz, H_2), 8.24–8.30 (m, 1, H_3), 8.34–8.46 (m, 3, $H_{6,7,12}$), 8.59 (d, 1, J = 8 Hz, H_1), 9.08–9.20 (m, 1, H_{10}), 9.16 (d, 1, J = 9 Hz, H_{11}), 9.58–9.68 (m, 1, OH); the OH absorption vanished when D_2O was added.

4-Acetoxybenzo[*a*]pyrene (1b). Acetylation of **1a** (53 mg, 0.24 mmol) with acetic anhydride (20 mL) and pyridine (2 mL) at room temperature for 5 h gave after workup and chromatography on Florisil (eluted with benzene) 62 mg (92%) of **1b** as a yellow solid: mp 170–172 °C; NMR δ 2.48 (s, 3, CH_3), 7.77 (s, 1, H_5), 7.79–7.83 (m, 2, $H_{8,9}$), 7.89 (t, 1, J = 8 Hz, H_2), 8.02 (d, 1, J = 8 Hz, H_3), 8.14 (d, 1, J = 8 Hz, H_1), 8.20–8.28 (m, 1, H_7), 8.21 (d, 1, J = 9 Hz, H_{12}), 8.47 (s, 1, H_6), 8.89–8.99 (m, 1, H_{10}), 8.92 (d, 1, J = 9 Hz, H_{11}).

4- and 5-Acetoxybenzo[*a*]pyrene. *cis*-4,5-Diacetoxy-4,5-dihydrobenzo[*a*]pyrene[4] (2.60 g, 7 mmol) was refluxed with *p*-toluenesulfonic acid monohydrate (260 mg) in 100 mL of dry benzene for 4 h under nitrogen. Conventional workup afforded 2.2 g of a foam, which was chromatographed under N_2 on a short column of Florisil. Elution with benzene gave 1.99 g (91%) of 4- and 5-acetoxybenzo[*a*]pyrenes in 3:2 ratio (by NMR). Crystallization from benzene–hexane gave **1b** (264 mg), which recrystallized from CH_2Cl_2–hexane as pale yellow needles: mp 170–172 °C; its NMR spectrum matched that of an authentic sample.

The mother liquor was concentrated to dryness in vacuo, taken up in benzene (25 mL), and chromatographed on a short column of Florisil under N_2. Elution with hexane gave a trace amount of benzo[*a*]pyrene. Elution with hexane–benzene (1:1) gave 62 mg of an unidentified yellow solid followed by 140 mg of 5-acetoxybenzo[*a*]pyrene: NMR δ 2.52 (s, 3, CH_3), 7.72–7.86 (m, 2, $H_{8,9}$), 7.79 (s, 1, H_4), 7.99 (t, 1, J = 8 Hz, H_2), 8.10 (d, 1, J = 8 Hz, H_3), 8.20–8.28 (m, 2, $H_{1,7}$), 8.28 (d, 1, J = 9 Hz, H_{12}), 8.45 (s, 1, H_6), 8.98 (m, 1, H_{10}), 8.99 (d, 1, J = 9 Hz, H_{11}).

Further elution with increasing proportions of benzene in hexane gave fractions rich in the 4-isomer, which were recrystallized to afford an additional 68 mg of **1b**. The overall purification procedure afforded 332 mg (15%) of pure **1b**, 140 mg (6.4%) of the pure 5-isomer, and 1.18 g (54%) of recovered mixed isomers. Repetition of the procedure twice more furnished overall yields of 30% and 11% of the 4- and 5-isomers, respectively.

Hydrolysis of 1b. A solution of **1b** (267 mg, 0.86 mmol) was heated at reflux in glacial acetic acid (15 mL) and concentrated HCl (3 mL) for 100 min. Addition of ice–water followed by extraction with ether and conventional workup furnished crude **1a** (242 mg). Trituration with hexane (5 mL) gave 210 mg (91%) of essentially pure **1a**; the NMR spectrum matched that of the authentic compound. The color and appearance of this compound was dependent upon the mode of purification. While sublimed **1a** was yellow, the recrystallized compound appeared black, but afforded yellow solutions.

Acknowledgment. The 270-MHz NMR spectrometer was funded in part through the University of Chicago Research Center Grant No. CA 14599.

Registry No. **1a**, 37574-48-4; **1b**, 56182-98-0; **2**, 34908-52-6; **3a**, 3697-24-3; **3b**, 85083-61-0; **3c**, 85083-62-1; **3d**, 85083-63-2; **3e**, 85083-64-3; 5-acetoxybenzo[*a*]pyrene, 24027-82-5; *cis*-4,5-diacetoxy-4,5-dihydrobenzo[*a*]pyrene, 56182-92-4.

Calixarenes. 10. Oxacalixarenes

Balram Dhawan and C. David Gutsche*

Department of Chemistry, Washington University, St. Louis, Missouri 63130

Received July 26, 1982

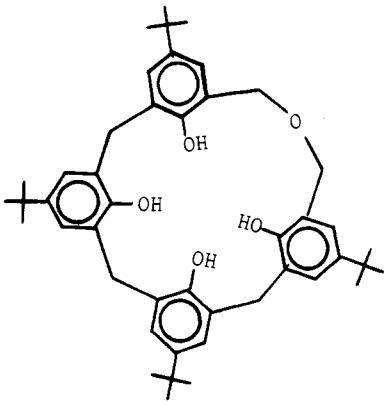
The base-catalyzed condensation of *p-tert*-butylphenol and paraformaldehyde yields a series of cyclic oligomers[1,2] for which the name "calixarene" has been suggested.[3] Under certain conditions a homologue containing an extra oxygen in the macrocyclic ring, designated as a dihomooxacalix[4]arene (**1**),[1,4] can also be isolated (Chart I). Although ^1H NMR analysis of the crude mixture indicates **1** to be present in significant quantities, its isolation in good yield in pure form is difficult. This note is concerned with an alternate route to **1** as well as the related oxacalixarenes *p-tert*-butyltetrahomodioxacalix[4]arene (**2**) and *p-tert*-butylhexahomotrioxacalix[3]arene (**3**).

The action of aqueous formaldehyde on *p-tert*-butylphenol in the presence of base is reported to yield the bis(hydroxymethyl) monomer **4** under mild conditions and the bis(hydroxymethyl) dimer **5** under more strenuous conditions.[5] When the published details were followed, a difficultly separable mixture of **4** and **5** was produced, but by extending the reaction time to 7 days, **5** could be isolated in pure form (Scheme I). Although **5** is obtained in only ca. 30% yield, the simplicity of the procedure makes it a readily available material. Alternatively, we have prepared **5** by debromination of the previously described *o*-bromo-*o'*-hydroxymethyl dimer **8**[1] followed by hydroxymethylation with aqueous formaldehyde and base. Condensation of **5** with *p-tert*-butylphenol in the presence of a catalytic amount of *p*-toluenesulfonic acid produces the linear tetramer **6** in 82.5% yield. An interesting property of **6** is its propensity to form a 1:2 complex with cyclohexane. The complex, which melts at 105 °C, is stable to heating for 24 h at 55 °C under vacuum but loses cyclohexane at its melting point to give solvent-free **6** melting at 212–213 °C. Treatment of **6** with excess aqueous

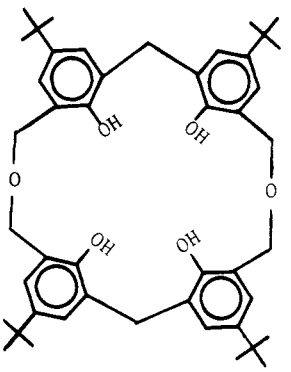
(1) Gutsche, C. D.; Dhawan, B.; No, K. H.; Muthukrishnan, R. *J. Am. Chem. Soc.* **1981**, *103*, 3782.
(2) Ninagawa, A.; Matsuda, H. *Makromol. Chem. Rapid Commun.* **1982**, *3*, 65.
(3) Gutsche, C. D.; Muthukrishnan, R. *J. Org. Chem.* **1978**, *43*, 4905.
(4) Mukoyama, Y.; Tanno, T. *Org. Coat. Plast. Chem.* **1979**, *40*, 894.
(5) Zinke, A.; Kretz, R.; Leggewie, R.; Hössinger, K. *Monatsh. Chem.* **1952**, *83*, 1213.

0022-3263/83/1948-1536$01.50/0

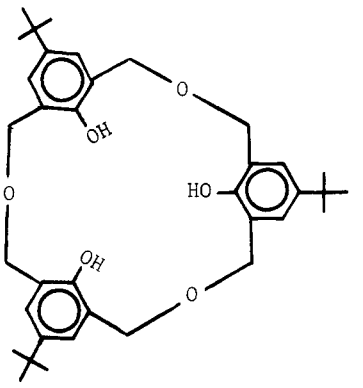
Chart I



1



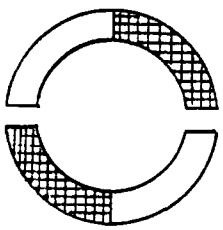
2



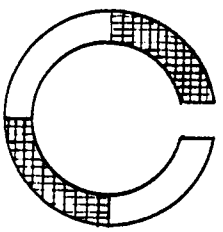
3

formaldehyde in the presence of base[6] affords the bis(hydroxymethyl) tetramer **7** in 50% yield after purification. When **7** is dissolved in xylene and heated to reflux, it is converted in almost quantitative yield to *p-tert*-butyldihomooxacalix[4]arene (**1**), identical with the product isolated from the condensation of *p-tert*-butylphenol and paraformaldehyde.

Cairns and Eglinton[7] observed stretching bands near 3200 cm^{-1} in the IR spectra of compounds similar to **4**, **5**, and **7**, indicative of very strong hydrogen bonding. Molecular models suggest that with **4** and **5** the hydrogen bonding is probably intermolecular (to give species for which we suggest the name "hemicalixarene") but that with



hemicalix[4]arene



pseudocalix[4]arene

7 it can be intramolecular (to give a species for which we suggest the name "pseudocalixarene"). Thus oriented by hydrogen bonding, it follows that **4** and **5** undergo fairly facile intermolecular dehydration to yield **3**[8] and **2**,[9] respectively, and **7** undergoes extremely facile intramolecular dehydration to form **1**. Falling between the dimer **5** and the tetramer **7** is the bis(hydroxymethyl) trimer **10**, and it would be of interest to know whether its thermally induced dehydration follows an intermolecular or intramolecular route. Space-filling molecular models indicate that *p-tert*-butyldihomooxacalix[3]arene is not too strained to be capable of formation. Unfortunately, however, the dehydration product from **10** is so refractory that it has not yet been possible to characterize it, suggesting that it may be a product of intermolecular dehydration.

Compounds **1** and **2** differ with respect to their stability to base and with respect to their tendency to form molecular complexes. Compound **1** undergoes little or no change when treated with base in refluxing xlyene (i.e., the conditions under which calixarenes are formed), whereas compound **2** is converted to the same mixture of calixarenes that is obtained directly from *p-tert*-butylphenol and formaldehyde. As reported previously,[10] compound **1** forms a strong molecular complex with methylene chloride, whereas compound **2** appears to lack strong complexing properties. All of the oxacalixarenes are potentially interesting candidates for complexation studies, however, for their similarity to the calixarenes extends the family of calixarene-like molecules containing macrocyclic rings of various diameters, depths, and polarity.

Experimental Section[11]

3-(5-*tert*-Butylsalicyl)-5-*tert*-butyl-2-hydroxybenzyl alcohol (9) was prepared by Pd/C-catalyzed hydrogenolysis of 3-(3-bromo-5-*tert*-butylsalicyl)-5-*tert*-butyl-2-hydroxybenzyl alcohol (**8**)[1] and obtained as a colorless crystalline solid after recrystallization from $CHCl_3$–petroleum ether (bp 35–60 °C): mp 157–158 °C (lit.[12] mp 155 °C); IR (KBr) 3390 and 3200 (OH stretching), 875 (1,2,3,5-tetrasubstituted Ar), 820 cm^{-1} (1,2,4-trisubstituted Ar); ^1H NMR ($CDCl_3$) δ 6.65–7.35 (m, 8, Ar H and OH), 4.80 (s, 2, CH_2OH), 3.88 (s, 2, $ArCH_2Ar$), 1.26 (s, 18, $C(CH_3)_3$).

Anal. Calcd for $C_{22}H_{30}O_3$: C, 77.19; H, 8.77. Found: C, 77.10; H, 8.84.

3-[3-(Hydroxymethyl)-5-*tert*-butylsalicyl]-5-*tert*-butyl-2-hydroxybenzyl Alcohol (5). A. Via Hydroxymethylation of 9. A mixture of 1.1 g of **9**, 2.2 mL of 25% NaOH, 2 mL of CH_3OH, and 4.4 mL of 37% HCHO solution was heated at 50 °C for 24 h in an atmosphere of N_2. The mixture was cooled, poured into 100 mL of cold water, acidified with 35 mL of 0.5

(6) This procedure is in contrast with that described by No and Gutsche (No, K. H.; Gutsche, C. D. *J. Org. Chem.* **1982**, *47*, 2713) in which a limited amount of formaldehyde was used to maximize the amount of mono(hydroxymethyl) tetramer formed.

(7) Cairns, E.; Eglinton, G. *Nature (London)* **1962**, *196*, 535.

(8) Compound **3** was isolated by Hultzsch (Hultzsch, K. *Kunststoffe* **1962**, *52*, 19) in less than 1% yield by heating compound **5**, and it has recently been well characterized by Mukoyama and Tanno.[4]

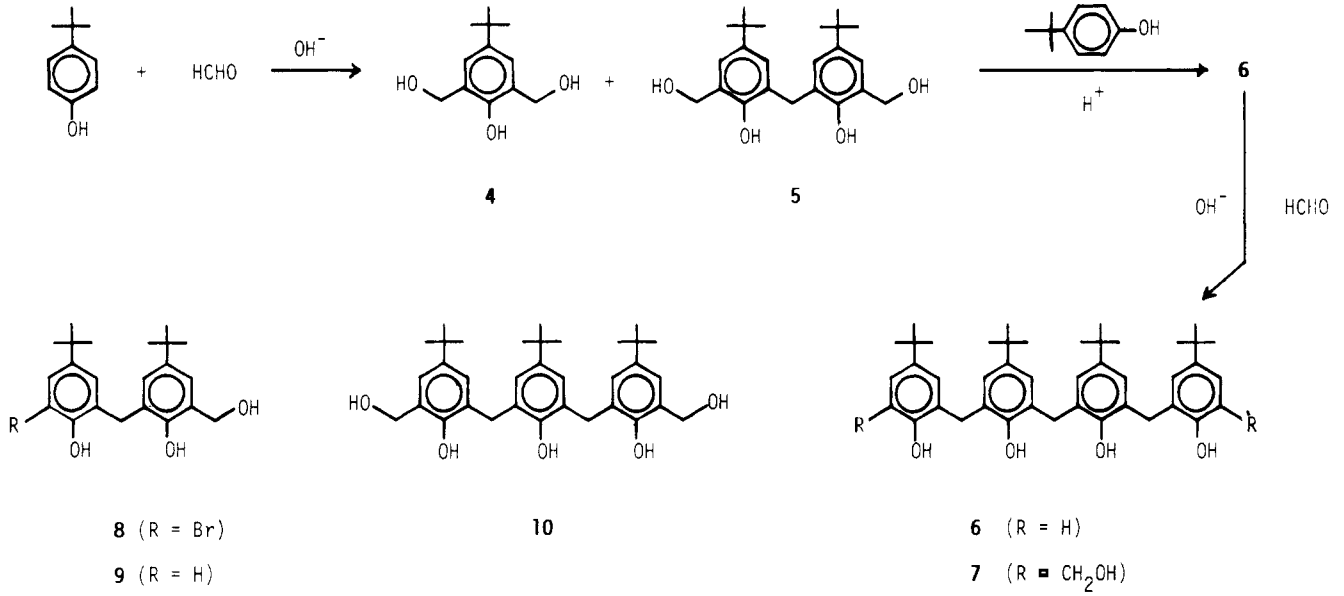
(9) The *p*-methyl analogue of compound **2** was prepared in very low yield by von Euler et al. (von Euler, H.; Adler, E.; Bergstrom, B. *Ark. Kemi, Mineral. Geol.* **1941**, *14B*, Nr. 30) by heating a neat sample. In the present work good yields (65%) of **2** were obtained by heating **5** in refluxing xylene solution.

(10) Gutsche, C. D.; Muthukrishnan, R.; No, K. H. *Tetrahedron Lett.* **1979**, 2213.

(11) Melting points of all compounds melting above 250 °C were taken in sealed and evacuated capillary tubes on a Mel-Temp apparatus (Laboratory Devices, Cambridge, MA) using a 500 °C thermometer calibrated against a thermocouple (accuracy ±1 °C). Infrared (IR) spectra were determined on a Perkin-Elmer 283B spectrometer. Proton nuclear magnetic resonance (^1H NMR) spectra were recorded on a Hitachi-Perkin-Elmer 24B spectrometer, and carbon nuclear magnetic resonance (^{13}C NMR) spectra were recorded on a JEOL FX-100 spectrometer. Chemical shifts are reported as δ values in parts per million relative to tetramethylsilane (δ 0.0) as an internal standard. Mass spectra were obtained on a Varian MAT 311A instrument. Osmometric molecular weight determinations were made on a Wescan Model 232A apparatus using concentrations of ca. 10^{-3} M in $CHCl_3$. Microanalyses were carried out by Industrial Testing Laboratories, St Louis, MO.

(12) Kämmerer, H.; Happel, G.; Böhmer, V. *Org. Prep. Proced. Int.* **1976**, *8*, 245.

Scheme I



N HCl, and the precipitated white solid extracted into ether. The ether extract was dried over anhydrous Na_2SO_4, and the solvent was removed by evaporation to leave a solid residue that was crystallized from benzene–cyclohexane to give 0.86 g (71%) of white plates: mp 115–116 °C (lit.[5] mp 117–118 °C); IR (KBr) 3420 and 3210 (OH stretching), 875 cm^{-1} (1,2,3,5-tetrasubstituted Ar); ^1H NMR ($CDCl_3$) δ 7.26 (d, 2, J = 2 Hz, Ar H), 6.94 (d, 2, J = 2 Hz, Ar H), 4.70 (s, 4, CH_2OH), 3.88 (s, 2, $ArCH_2Ar$), 1.26 (s, 18, $C(CH_3)_3$).

B. Via Action of HCHO on *p*-*tert*-Butylphenol. A mixture of 45 g of *p*-*tert*-butylphenol, 60 mL of 37% HCHO solution, and 140 mL of 10% NaOH was placed in a 500-mL round-bottomed flask fitted with a reflux condenser. The mixture was heated at 50 ± 5 °C for 7 days in an atmosphere of N_2. It was then cooled, and the resinous precipitate was collected by filtration, dissolved in 50 mL of acetone, and then acidified with 200 mL of cold 50% aqueous acetic acid. The oil that separated was washed with 100 mL of water and extracted into ether that was dried over anhydrous Na_2SO_4, and the solvent was removed to give a reddish oil. This was dissolved in 60–80 mL of benzene to which petroleum ether (bp 35–60 °C) was added to turbidity. A white, crystalline solid eventually separated, which was removed by filtration and crystallized from $CHCl_3$–petroleum ether (bp 35–60 °C) to give 16 g (29%) of white plates, mp 116–117 °C, identical in all respects with the material described above.

3-[3-[3-(Hydroxymethyl)-5-*tert*-butylsalicyl]-5-*tert*-butylsalicyl]-5-*tert*-butyl-2-hydroxybenzyl Alcohol (10). A 150-g (1.0 mol) sample of *p*-*tert*-butylphenol was dissolved in 300 mL of benzene, treated with 100 mg of *p*-toluenesulfonic acid, and brought to reflux. To the boiling mixture was added a solution of 42 g (0.2 mol) of 2,6-bis(hydroxymethyl)-4-*tert*-butylphenol (**4**) in 100 mL of benzene over a period of 1.5 h. The mixture was refluxed for an additional 12 h, cooled, and filtered to remove a white solid, which was recrystallized from benzene to yield 57.5 g (61%) of colorless 2-[3-(5-*tert*-butylsalicyl)-5-*tert*-butylsalicyl]-4-*tert*-butylphenol: mp 219–221 °C (lit.[13] mp 217–220 °C); ^1H NMR ($CDCl_3$) δ 6.65–7.40 (m, 10, Ar H and OH), 3.9 (s, 4, CH_2), 1.26 (2 s, 27, $C(CH_3)_3$); TLC on 250-μm Silica Gel G (ether–petroleum ether (5:3)) R_f 0.61. A mixture of 10.0 g of this material, 44 mL of 37% HCHO, 11 mL of 25% NaOH, and 20 mL of methanol was heated at 50 ± 3 °C for 24 h in an atmosphere of N_2. After cooling and diluting with 300 mL of water, the mixture was acidified with 500 mL of cold 1 N HCl, and a white solid was removed by filtration. This was dissolved in $CHCl_3$ and stirred with 100 mL of 1 N HCl, and the organic layer was separated, dried over anhydrous Na_2SO_4, and evaporated to give a sticky mass, which, when triturated with petroleum ether (bp 35–60 °C), gave 7.5 g (67%) of a white solid, mp 140–142.5 °C. Recrystallization from benzene–petroleum ether (bp 35–60 °C) afforded an analytical sample: mp 143–145 °C dec (lit.[13] mp 140–145 °C); IR (KBr) 3285 (br, OH stretching), 875 cm^{-1} (1,2,3,5-tetrasubstituted Ar); ^1H NMR ($CDCl_3$) δ 6.86–7.30 (m, 6, Ar H), 4.74 (s, 4, CH_2OH), 3.88 (s, 4, CH_2), 1.26 (s, 27, $C(CH_3)_3$), osmometric M_r ($CHCl_3$, 37 °C). 545 (calcd 534).

Anal. Calcd for $C_{34}H_{46}O_5$: C, 76.40; H, 8.61. Found: C, 76.43; H, 8.84.

2-[3-[3-(5-*tert*-Butylsalicyl)-5-*tert*-butylsalicyl]-5-*tert*-butylsalicyl]-4-*tert*-butylphenol (6). A solution of 7.44 g (0.02 mol) of **5** in 50 mL of benzene was added dropwise to a refluxing solution of 30 g (0.2 mol) of *p*-*tert*-butylphenol in 100 mL of benzene containing 50 mg of *p*-toluenesulfonic acid. The mixture was refluxed for 24 h, the benzene was removed by evaporation, and the excess *p*-*tert*-butylphenol was removed by steam distillation. The crude product was separated by filtration and crystallized from cyclohexane to give 13.26 g (82.5%) of a cyclohexane complex of **6** as a colorless solid: mp 105 °C (resolidification and remelting at 212–213 °C); IR (KBr) 3260 (OH stretching), 1450 (CH_2 of cyclohexane), 875 (1,2,3,5-tetrasubstituted Ar), 815 cm^{-1} (1,2,4-trisubstituted Ar); ^1H NMR ($CDCl_3$) δ 6.68–7.40 (m, 10, Ar H), 3.83 (s, 6, CH_2), 1.42 (s, 24, cyclohexane), 1.22 and 1.25 (2 s, 36, $C(CH_3)_3$). An analytical sample was obtained by drying at 55 °C for 24 h at less than 1 mm of pressure.

Anal. Calcd for $C_{43}H_{56}O_4 \cdot 2C_6H_{12}$: C, 82.08; H, 9.95. Found: C, 82.30; H, 9.96.

A 0.1365-g sample of this compound was heated at 105–110 °C for 30 min, losing 0.0325 g in weight (corresponding to slightly more than 2 molar equiv of cyclohexane) as well as the δ 1.42 resonance in the NMR. A 10.6-g sample of the cyclohexane complex of **6** was dissolved in petroleum ether (bp 35–60 °C) and warmed, whereupon the uncomplexed tetramer **6** precipitated as fine, colorless neeldes in 95% yield: mp 212–213 °C (lit.[14] mp 211 °C); IR (KBr) 3250 (OH stretching), 875 (1,2,3,5-tetrasubstituted Ar), 820 cm^{-1} (1,2,4-trisubstituted Ar); ^1H NMR ($CDCl_3$) δ 6.72–7.38 (m, 10, Ar H), 3.88 (s, 6, CH_2), 1.25 and 1.28 (2 s, 36, $C(CH_3)_3$).

3-[3-[3-[3-(Hydroxymethyl)-5-*tert*-butylsalicyl]-5-*tert*-butylsalicyl]-5-*tert*-butylsalicyl]-5-*tert*-butyl-2-hydroxybenzyl Alcohol (7). A mixture of 5 g of **6**, 22 mL of 37% HCHO, 5.5 mL of 25% NaOH, 15 mL of dioxane, and 30 mL of CH_3OH was heated at 55 ± 5 °C for 48 h. It was cooled, diluted with 100 mL of water, and acidified with 250 mL of cold 1 N HCl. The precipitate was collected by filtration, dissolved in $CHCl_3$, and shaken with 100 mL of 1 N HCl. The organic layer was separated, washed with water, and dried over anhydrous Na_2SO_4, and the solvent was removed to leave a pasty mass, which was triturated with petroleum ether (bp 35–60 °C) and recrystallized from

(13) British Patent 882 855; *Chem. Abstr.* **1962**, *56*, 7482c.

(14) Kämmerer, H.; Haberer, K., *Monatsh. Chem.* **1964**, *95*, 1589.

$CHCl_3$–C_5H_{12} to give 2.85 g (48.5%) of **7** as a colorless solid: mp 139–140 °C; IR (KBr) 3300 (OH stretching), 875 cm^{-1} (1,2,3,5-tetrasubstituted Ar); ^1H NMR ($CDCl_3$) δ 7.0–7.40 (m, 8, Ar H), 4.62 (s, 4, CH_2OH), 3.80 (s, 6, $ArCH_2Ar$), 1.20 (s, 36, $C(CH_3)_3$).

Anal. Calcd for $C_{45}H_{60}O_6$: C, 77.58; H, 8.62. Found: C, 77.10; H, 8.68.

Thermally Induced Dehydration of 2,6-Bis(hydroxymethyl)-4-*tert*-butylphenol (4). A solution of 5.0 g of **4** in 25 mL of xylene was refluxed for 4 h in an atmosphere of N_2. The xylene was removed by evaporation under reduced pressure, and the sticky residue was triturated with 30 mL of CH_3OH to leave 1.35 g (29.5%) of a colorless solid. Recrystallization from $CHCl_3$–CH_3OH yielded 7,15,23-tri-*tert*-butyl-2,3,10,11,18,19-hexahomo-3,11,19-trioxacalix[3]arene (**3**) as glistening, very fine blades: mp 220–221 °C (lit[2] mp, 245 °C); ^1H NMR ($CDCl_3$) δ 8.50 (s, 1, OH), 7.05 (s, 2, ArH), 4.68 (s, 4, CH_2), 1.25 (s, 9, $C(CH_3)_3$); osmometric M_r ($CHCl_3$, 37 °C), 619 (calcd for 4·1/2 CH_3OH, 592); mass spectrum (EI, 90 eV), *m/e* 576 (calcd for *3*, 576).

Anal. Calcd for $C_{36}H_{48}O_6 \cdot 0.5CH_3OH$: C, 73.98; H, 8.39. Found: C, 74.12; H, 8.33.

The CH_3OH triturate deposited a white solid upon standing at room temperature, the ^1H NMR of which was similar to that of **3** except for the absence of the resonance at δ 8.50 arising from the OH groups. The osmometric M_r of this material was 1023, corresponding to ca. 5.5 monomeric units in what is presumed to be a linear oligomer.

Thermally Induced Dehydration of 3-[3-(Hydroxymethyl)-5-*tert*-butylsalicyl]-5-*tert*-butyl-2-hydroxybenzyl Alcohol (5). A 2-g sample of **5** was dissolved in 10 mL of xylene and refluxed for 4 h. From the cooled reaction mixture, 0.85 g of a white solid was separated by filtration and crystallized from $CHCl_3$–CH_3OH to yield 7,13,21,27-tetra-*tert*-butyl-29,30,31,32-tetrahydroxy-2,3,16,17-tetrahomo-3,17-dioxacalix[4]arene (**2**) as glistening, very small blades: mp 245 °C; IR (KBr) 3370 (OH stretching), 1075 (CO stretching), 875 cm^{-1} (1,2,3,5-tetrasubstituted Ar); ^1H NMR ($CDCl_3$) δ 8.96 (s, 4, OH), 7.31 (d, 4, J = 2.4 Hz, Ar H), 6.95 (d, 4, J = 2.4 Hz, Ar H), 4.63 (s, 8, CH_2OCH_2), 3.93 (s, 4, CH_2), 1.27 (s, 36, $C(CH_3)_3$); ^{13}C NMR ($CDCl_3$) δ 150.4 (Ar), 143.0 (Ar), 127.6 (Ar), 127.4 (Ar), 124.8 (Ar), 122.4 (Ar), 71.9 (CH_2OCH_2), 33.92 (CH_2), 31.48 ($C(CH_3)_3$); osmometric M_r ($CHCl_3$, 37 °C), 721 (calcd, 708).

Anal. Calcd for $C_{46}H_{60}O_6$: C, 77.97; H, 8.47. Found: C, 77.69; H, 8.56.

Removal of the xylene from the filtrate described above left 1.0 g of a glassy residue, which was indicated by TLC to be a mixture of the dihomooxa compound **1**, the tetrahomobisoxa compound **2**, and polymeric material in the approximate ratio of 2:5:6.

Thermally Induced Dehydration of 3-[3-[3-[3-(Hydroxymethyl)-5-*tert*-butylsalicyl]-5-*tert*-butylsalicyl]-5-*tert*-butylsalicyl]-5-*tert*-butyl-2-hydroxybenzyl Alcohol (7). A 0.75-g sample of **7** was dissolved in 4 mL of xylene and refluxed for 4 h. Upon cooling, 0.7 g of a white crystalline solid precipitated, which was removed by filtration and recrystallized from CH_2Cl_2–CH_3OH to afford 0.70 g (96%) of 7,13,19,25-tetra-*tert*-butyl-27,28,29,30-tetrahydroxy-2,3-dihomo-3-oxacalix[4]arene (**1**) as colorless needles, identical in all respects with the material previously described.[1]

Action of Base on 7,13,21,27-Tetra-*tert*-butyl-29,30,31,32-tetrahydroxy-2,3,16,17-tetrahomo-3,17-dioxacalix[4]arene (2). A mixture of 0.5 g of **2**, 0.008 mL of 10 N KOH, and 3 mL of xylene was heated at reflux for 4 h. From the cooled mixture, 0.22 g of a white solid was removed by filtration and shown by TLC to be mainly *p-tert*-butylcalix[8]arene. Recrystallization from $CHCl_3$ afforded a pure sample, mp 408–410 °C. Evaporation of the xylene filtrate left a solid residue, which was shown by TLC to contain *p-tert*-butylcalix[6]arene, *p-tert*-butylcalix[4]arene, the dihomooxa compound **1**, and polymeric material in the ratio of ca. 1:1:4:2. On the basis of these data, the yields of products are estimated to be cyclic octamer (48%), cyclic hexamer (5%), cyclic tetramer (5%), and dihomooxa compound (20.5%).

Action of Base on 7,13,19,25-Tetra-*tert*-butyl-27,28,29,30-tetrahydroxy-2,3-dihomo-3-oxacalix[4]arene (1). A mixture of 0.100 g of **1**, 0.03 mL of 10 N KOH, and 2 mL of xylene was heated at reflux for 4 h. The xylene was removed by evaporation under vacuum, and the residue was examined by TLC, which showed that no conversion to cyclic oligomers had occurred. Recrystallization of the residue from CH_2Cl_2–CH_3OH gave starting material, **1**. A similar reaction carried out with 0.6 mL of 10 N KOH (a 20-fold increase over the previous experiment) gave a crude product in which no cyclic oligomers could be detected by TLC analysis, although what are assumed to be linear oligomers appeared to be present.

Acknowledgment. We are indebted to the National Institutes of Health (Grant GM-23534) for financial support of this work.

Registry No. **1**, 72251-68-4; **2**, 85097-23-0; **3**, 76543-12-9; **4**, 2203-14-7; **5**, 2467-07-4; **6**, 992-52-9; **7**, 85097-22-9; **8**, 78077-41-5; **9**, 35851-06-0; **10**, 65566-87-2; 2-[3-(5-*tert*-butylsalicyl)-5-*tert*-butylsalicyl]-4-*tert*-butylphenol, 810-52-6; *p-tert*-butylcalix[6]arene, 78092-53-2; *p-tert*-butylcalix[4]arene, 60705-62-6; *p-tert*-butylcalix[8]arene, 68971-82-4; *p-tert*-butylphenol, 98-54-4.

N^{ω}-Alkoxycarbonylation of α,ω-Diamino Acids with 2-(Trimethylsilyl)ethyl 4-Nitrophenyl Carbonate

Andre Rosowsky* and Joel E. Wright

Sidney Farber Cancer Institute and Harvard Medical School, Boston, Massachusetts 02115

Received October 22, 1982

In connection with a larger project in peptide synthesis, we had a need for N^{ω}-protected derivatives of α,ω-diamino acids from which the protecting group could be cleaved under mild neutral conditions. A further requirement was that the protecting group had to be compatible with both benzyloxycarbonyl (Z) and *tert*-butyloxycarbonyl (Boc) groups. The [2-(trimethylsilyl)ethoxy]carbonyl (Teoc) group,[1-5] which is easily cleaved at room temperature with tetrabutylammonium fluoride and is stable to hydrogenolysis,[1] was considered attractive, provided that a method could be found to selectively remove not only the Cbz group but also the Boc group while keeping the Teoc group intact. Until now this goal has been elusive, inasmuch as Teoc was found to be labile under a variety of conventional Boc acidolysis conditions.[1] We sought to solve the problem of orthogonal Boc/Teoc deprotection by the application of selective methods of Boc cleavage similar to those that spare *tert*-butyl esters.[6]

In this note we report the synthesis of the N^{ω}-Teoc derivatives of lysine, ornithine, and 2,4-diaminobutyric acid from their copper complexes. The reagent, 2-(trimethylsilyl)ethyl 4-nitrophenyl carbonate was prepared from 2-(trimethylsilyl)ethanol and *p*-nitrophenyl chloroformate. The literature synthesis of 2-(trimethylsilyl)ethanol by $LiAlH_4$ reduction of ethyl 2-(trimethylsilyl)acetate[7] was found to be difficult and gave unsatisfactory yields, due in part to the formation of an insoluble complex during the reaction. In addition, problems were encountered when

(1) Carpino, L.; Tsao, J.-H.; Ringsdorf, H.; Fell, E.; Hettrich, G. *J. Chem. Soc., Chem. Commun.* **1978**, 358.
(2) Gioeli, C.; Balgobin, N.; Josephson, S.; Chattopadhyaya, J. *Tetrahedron Lett.* **1981**, 969.
(3) Kita, Y.; Haruta, J.; Yasuda, H.; Fukunaga, K.; Shirouchi, H.; Tamura, Y. *J. Org. Chem.* **1982**, *47*, 2697.
(4) Kozyukov, V. P.; Sheludyakov, V. D.; Miranov, V. F. *Zh. Obshch. Khim.* **1968**, *38*, 1179.
(5) Wünsch, E.; Moroder, L.; Keller, O. *Hoppe-Seyler's Z. Physiol. Chem.* **1981**, *362*, 1289.
(6) Roeske, R. W. In "The Peptides: Analysis, Synthesis, Biology;" Gross, E., Meienhofer, J., Eds.; Academic Press: New York, 1981; Vol. III, p 107.
(7) Jarvie, A. W. P.; Holt, A.; Thompson, J. *J. Chem. Soc* **1969**, 852.

0022-3263/83/1948-1539$01.50/0