SYNTHESIS AND X-RAY CRYSTAL STRUCTURE OF A (C_2)-DIOXATRISECODODECAHEDRANE‡

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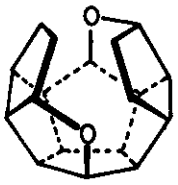
A trisecododecahedrane in which two oxygen atoms have replaced a pair of methylene groups at sites of high steric congestion has been prepared with crystalline features suitable for x-ray analysis. The complete structure of the molecule which reveals its topology is reported.

Quite recently, an efficient synthesis of the axially symmetric heterocyclic trisecododecahedrane 1 was reported by one of our groups.[2] The preparation of 1 was undertaken to gain some appreciation of the conformational changes which materialize when a pair of the highly congested methylene groups in hydrocarbon 2 are replaced by oxygen atoms. Unfortunately, 1 was found not to crystallize in a form suitable for x-ray crystal structure analysis. In the



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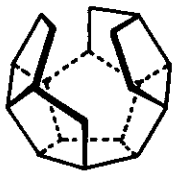

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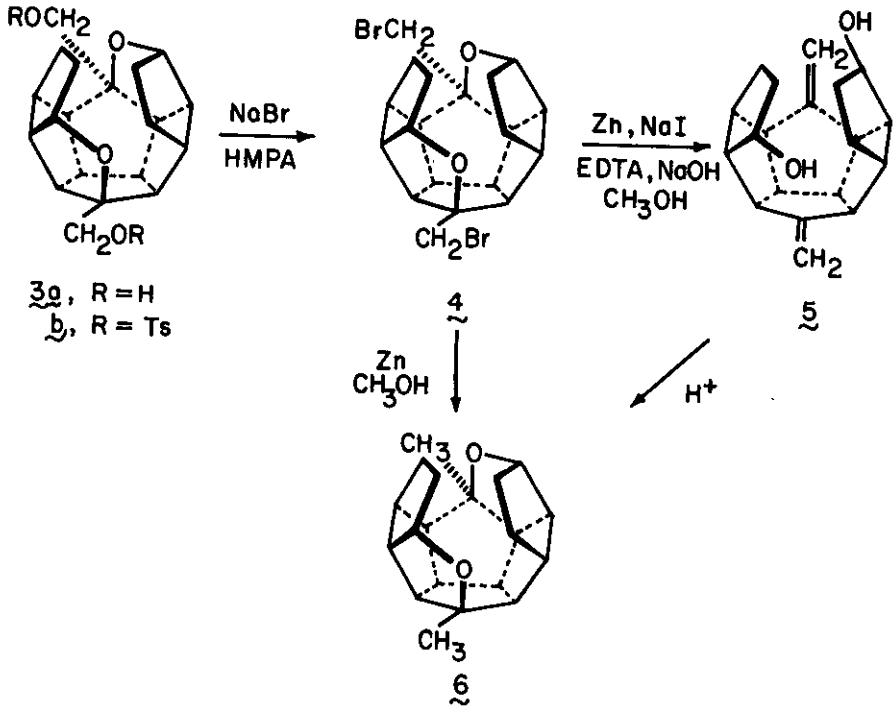
course of related work on dodecahedrane, we noted that hemispherical and almost totally spherical compounds symmetrically substituted with a pair of methyl groups are almost always more crystalline and higher melting than their unsubstituted analogues. Consequently, our attention turned to 6, molecular models of which clearly show that no significant framework perturbation is introduced by the pendant alkyl spacers.

To arrive at 6, use was made of alcohol 3a which was available from the earlier work.[2] Treatment of 3a with p-toluenesulfonyl chloride in pyridine at 0°C, followed by S_N2 displacement at the two functionalized neopentyl centers with sodium bromide in anhydrous hexamethylphosphoramide at 80°C led efficiently to dibromide 4. Although the reduction of 4 with activated

‡Dedicated to Professor Tetsuji Kametani on the occasion of his retirement from a most active and stellar career at Tohoku University.



3a, R = H
b, R = Ts

4

5

6

zinc in methanol did provide 6, mechanistic considerations led us to examine the possibility that dienediol 5 serves as an intermediate in this transformation. In practice, the isolation of 5 could be successfully achieved only in the presence of a vast excess of ethylenediaminetetraacetic acid tetrasodium salt which chelates the Zn^{+2} as it is formed. The proximity of the functional groups in 5 is such that this substance is extremely sensitive to all electrophiles, quantitative cyclization to 6 occurring even in the presence of noble metal hydrogenation catalysts.

The (C_2)-dioxatrisecodocecahedrane 6 ($C_{20}H_{28}O_2$) crystallizes in the space group Aba2 with lattice parameters a=20.638(6), b=11.079(2), and c=13.181(5)Å (CuK_α radiation, $\sin\theta/\lambda$ max=0.61). Eight molecules were observed per unit cell (d=1.33 g cm^{-3}). The fractional coordinates and bond lengths are given in Tables I and II, respectively. Although R=0.09, the latter values should not be regarded as strictly reliable because of a disorder in the crystal. Two different three-dimensional representations of 6 appear in Figure 1.

Two molecules are statistically distributed in the asymmetric unit with the result that a pseudo mirror plane is generated across the molecule. Separate refinement of each molecule in the non-centrosymmetric space group always have the same mean structure with a pseudo mirror plane. As a consequence, the results are not highly accurate. Nonetheless, the shape of the molecule can clearly be seen (Figure 1). All of the bond lengths are normal and compare well

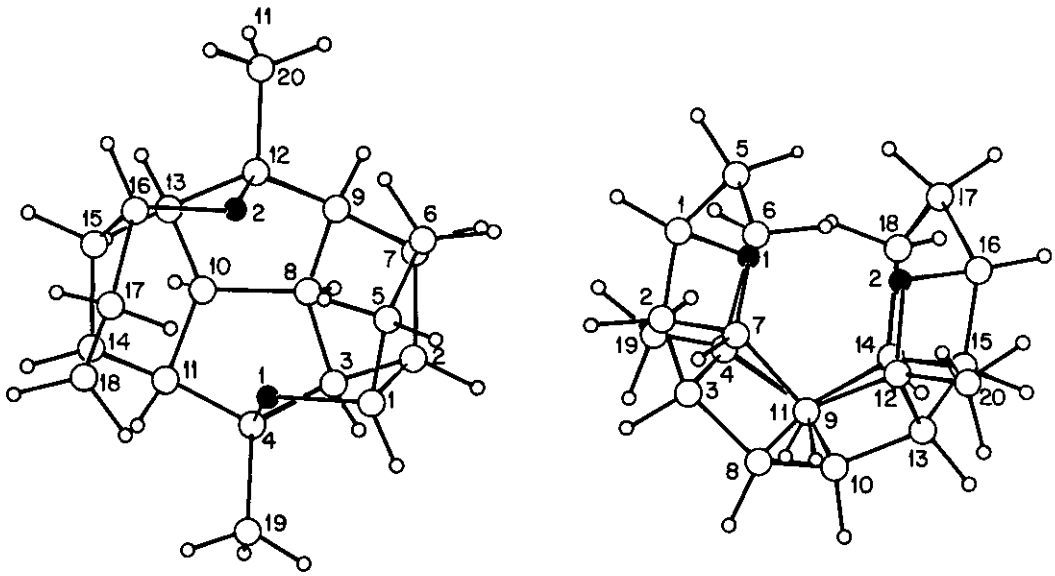


Figure 1. A pair of three-dimensional views of 6 as determined by x-ray analysis.

with those of (±)-and meso-bivalvane,[3] C_{16}-hexaquinacene,[4] tetrahydro-C_{16}-hexaquinacene-1,4-dione,[5] and a dilactone homolog of 1.[6] Most striking is the conformation adopted by 6 which perspicuously projects its two oxygen atoms to the inner regions of the sphere. In this manner, the methylene carbons at C(5), C(6), C(17), and C(18) find it possible to tilt outward from the cavity, these deformations from a more symmetric shape serving to release significant nonbonded

Table I. Fractional Coordinates of 6.

Atom	x	y	z
O(1)	0.44251	0.34488	0.21320
O(2)	0.31267	0.36433	0.25467
C(1)	0.44306	0.36778	0.10026
C(2)	0.41155	0.25616	0.05430
C(3)	0.43033	0.16406	0.14167
C(4)	0.46099	0.22199	0.22995
C(5)	0.38466	0.45965	0.08417
C(6)	0.32971	0.39619	0.04722
C(7)	0.33592	0.26299	0.05406
C(8)	0.36831	0.09571	0.17401
C(9)	0.30857	0.18001	0.14396
C(10)	0.36754	0.10223	0.29022
C(11)	0.43188	0.15871	0.32786
C(12)	0.28442	0.24697	0.23244
C(13)	0.31208	0.17395	0.32959
C(14)	0.41111	0.24317	0.40940
C(15)	0.33795	0.25894	0.41015
C(16)	0.31211	0.39036	0.36640
C(17)	0.38089	0.46775	0.39013
C(18)	0.43116	0.38243	0.41808
C(19)	0.53571	0.21586	0.23160
C(20)	0.21128	0.25960	0.23019

steric interactions. The extent to which crystal packing forces contribute to this geometry remains unknown, as usual. Nonetheless, this heterocyclic trisecododecahedrane is expected to serve as a useful reference point in the assessment of strain in more sterically congested hydrocarbon analogues and homologues.

Table II. Bond lengths in 6.

O(1)-C(4)	1.431Å	C(10)-C(13)	1.487Å
-C(1)	1.510	-C(8)	1.534
O(2)-C(12)	1.455	-C(11)	1.550
-C(16)	1.501	C(11)-C(14)	1.488
C(1)-O(1)	1.510	-C(10)	1.550
-C(2)	1.523	-C(4)	1.587
-C(5)	1.592	C(12)-O(2)	1.455
C(2)-C(1)	1.523	-C(9)	1.569
-C(7)	1.563	-C(20)	1.519
-C(3)	1.587	-C(13)	1.619
C(3)-C(4)	1.472	C(13)-C(10)	1.487
-C(8)	1.547	-C(15)	1.516
-C(2)	1.587	-C(12)	1.619
C(4)-O(1)	1.431	C(14)-C(11)	1.488
-C(3)	1.472	-C(15)	1.520
-C(19)	1.544	-C(18)	1.602
-C(11)	1.587	C(15)-C(13)	1.516
C(5)-C(6)	1.420	-C(14)	1.520
-C(1)	1.592	-C(16)	1.654
C(6)-C(5)	1.420	C(16)-O(2)	1.501
-C(7)	1.484	-C(15)	1.654
C(7)-C(6)	1.484	-C(17)	1.688
-C(2)	1.563	C(17)-C(18)	1.541
-C(9)	1.603	-C(16)	1.688
C(8)-C(10)	1.534	C(18)-C(17)	1.451
-C(3)	1.547	-C(14)	1.602
-C(9)	1.597	C(19)-C(4)	1.544
C(9)-C(12)	1.469	C(20)-C(12)	1.516
-C(8)	1.597		
-C(7)	1.603		

Experimental Section

3a,6a-Bis(p-toluenesulfonyloxymethyl)hexadecahydro-3,6-dioxadicyclopenta[3,4]pentaleno-[2,1,6-cde:2',1',6'-gh'a]pentalene (3b). p-Toluenesulfonyl chloride (500 mg, 2.62 mmol) was added slowly to a cold (0°C) solution of 3a[2] (185 mg, 0.56 mmol) in 10 ml of pyridine under a nitrogen atmosphere. The mixture was stored overnight at 0°C, at which time a few ice chips were added and the mixture was poured into ice water (50 ml). The product was extracted into dichloromethane (4x20 ml) and the combined organic layers were washed with water (2x) and brine prior to drying. Removal of solvent left a solid residue, recrystallization of which from benzene gave pure 3b (225 mg, 70%) which decomposes at 129.5-136°C; IR (KBr, cm^{-1}) 1362, 1172, 968, 662, and 557; ^1H NMR (δ, $CDCl_3$) 7.68 and 7.26 (AA'BB'q, $J_{AB}=J'_{AB}=7.7$Hz, $\Delta\nu_{AB}=28$ Hz, 8H), 4.49 (br s, 2H), 3.77 (s,4H), 3.4-1.5 (series of m, 18H), and 2.41 (s, 6H).

Anal. Calcd for $C_{34}H_{38}O_8S_2$: C, 63.95; H, 5.96 Found: C, 63.73; H, 5.94.

3a,6a-Bis(bromomethyl)hexadecahydro-3,6-dioxadicyclopenta[3,4]pentaleno[2,1,6-cde:2',1',6'-gh'a]pentalene (4). To a solution of 3b (150 mg, 0.235 mmol) in 6 ml of anhydrous hexamethylphosphoramide was added sodium bromide (250 mg, 2.35 mmol) and the mixture was heated to 80°C with stirring for 15 hr. The cooled reaction mixture was added to ether (40 ml) and the ether layer was washed with water (4x10 ml), dried, and evaporated. The resulting semi-solid was triturated with pentane to give 100 mg (90%) of 4, mp 158.5-160°C (from hexane); IR (KBr, cm^{-1}) 2938, 1033, 1014, 990, and 652; ^1H NMR (δ, $CDCl_3$) 4.8-4.5 (br t, 2H), 3.40 (s, 4H), and 3.4-1.3 (series of m, 18H); ^{13}C NMR (ppm, $CDCl_3$) 99.46, 91.15, 63.96, 62.45 (2C), 56.01, 50.01, 39.32, 33.92, and 28.28; m/e calcd 454.0144, obs 454.0153.

Anal. Calcd for $C_{20}H_{24}Br_2$: C, 52.63; H, 5.26. Found: C, 52.89; H, 5.32.

Ring Cleavage of 4. A suspension of zinc and ethylenediaminetetraacetic acid was prepared by adding sodium hydroxide (200 mg, 4.9 mmol) to 4 ml of methanol followed by EDTA disodium salt (923 mg, 2.5 mmol). Subsequently, sodium iodide (30 mg, 0.25 mmol) and zinc dust (216 mg, 3.3 mg-at) were introduced. This slurry was added to a solution of 4 (40 mg, 0.09 mmol) in 10 ml of benzene and 2 ml of methanol and the mixture was heated at the reflux temperature under nitrogen for 30 hr, cooled, and filtered through Celite. The filtrate was added to dichloromethane (50 ml) and washed with water, saturated sodium bicarbonate solution, water, and brine before drying. Solvent evaporation left 25 mg (92%) of 5 as a colorless crystalline solid; IR (KBr, cm^{-1}) 3360, 1632, 1093, and 903; ^1H NMR (δ, $CDCl_3$) 5.25 (br s, 2H), 4.9 (br s, 2H), 4.25 (br s, 2H), and 3.6-1.0 (series of m, 20H); m/e calcd 298.1933, obs 298.1940.

3a,6a-Dimethylhexadecahydro-3,6-dioxadicyclopenta[3,4]pentaleno[2,1,6-cde:2',1',6',-gh'a]-pentalene (6). A. Direct Reduction of 4. Activated zinc (240 mg, 3.55 mg-at) was added under nitrogen to a solution of 4 (40 mg, 0.088 mmol) in 10 ml of methanol and 1 ml of tetrahydrofuran. The mixture was heated at the reflux temperature for 20 hr, cooled, and filtered through Celite. The filtrate was added to water (10 ml) and extracted with dichloromethane (5x15 ml). The combined organic phases were washed with water and brine, dried, and evaporated. Preparative layer chromatography of the residue on silica gel (elution with 10% ether in hexane) gave two major bands. The band with R_f=0.75 proved to be 6 (12 mg, 46%). The second band, R_f=0.2 (9 mg), was not identified.

B. Acid-Promoted Cyclization of 5. To a solution of 5 (30 mg) in methanol (5 ml) was added one drop of 1 N methanolic hydrogen chloride and the mixture was stirred at 25°C for 12 hr. Evaporation of solvent left a yellowish oil which was purified as above to give 25 mg (83%) of 6. Recrystallization from hexane afforded colorless prisms, mp 210-215°C; IR (KBr, cm^{-1}) 2920, 1055, and 1031; ^1H NMR (δ, $CDCl_3$) 4.65 (m 2H), 3.8-1.0 (series of m, 18H), and 1.23

(s, 6H); m/e calcd 298.1933, obs 298.1940.

Anal. Calcd for $C_{20}H_{26}O_2$: C, 80.49; H, 8.78. Found: C, 80.06; H, 8.63.

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