J. Am. Chem. Soc. 1987, 109, 2212-2213

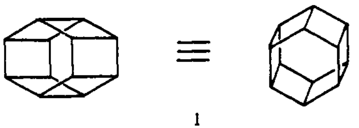
Secohexaprismane

Goverdhan Mehta* and S. Padma

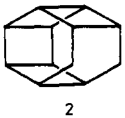
School of Chemistry, University of Hyderabad
Hyderabad 500 134, India

Received October 17, 1986

Prismanes are a fascinating class of $(CH)_n$ polyhedranes, whose synthetic appeal has been sustained through the prediction and expectancy of novel structural characteristics and unusual chemical reactivity.[1] The synthetic conquest of triprismane (Ladenburg's benzene),[2] tetraprismane (cubane),[3] and pentaprismane (housane)[1d,4] has now shifted the focus on higher prismanes.[1] The next in line, hexaprismane (**1**), formally a face-to-face dimer of benzene,



1



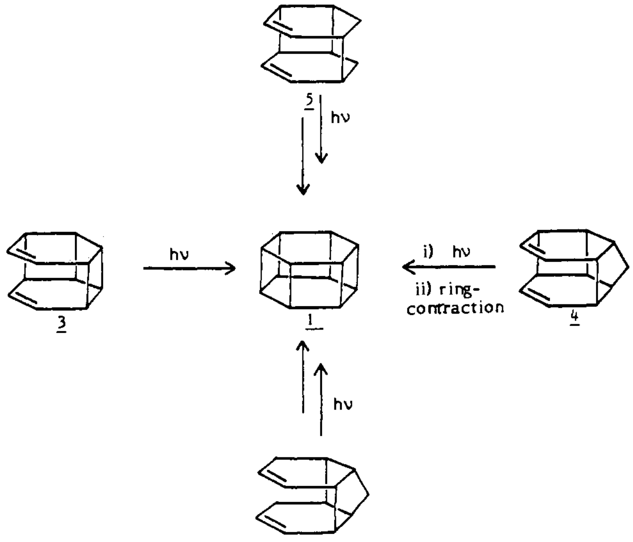
2

of static D_{6h} symmetry has been predicted to possess interesting geometry[1c] and has high strain energy of about 160 kcal mol,$^{-1}$ midway between tetra- and pentaprismane.[1f,g] The heptacyclic, $C_{12}H_{12}$ hydrocarbon **1** poses a formidable synthetic challenge that has enticed many groups into the synthetic act but only very limited progress toward its synthesis has been forthcoming.[5] In this paper, we wish to disclose our synthetic strategy aimed at **1**, which has resulted in the synthesis of secohexaprismane **2**, the closest, one-bond-away, secologue of **1**.

In our scheme of things, suitably functionalized pentacyclic cages **3** and **4** appeared to be the pivotal precursors of **1**. While **3** could directly give **1** on photoclosure, **4** required an additional ring contraction protocol after the initial (2 + 2) photocycloaddition. As backup alternatives to **3** and **4**, we identified derivatized tetracyclics **5** and **6** which could eventuate to **1** through photoclosure and a few additional maneuvers (Scheme I). Since carbocyclic structures related to **3**–**6** are formidable in their own right and synthetic routes to them remain unknown in literature, their synthesis by a common, flexible route became our first objective.

The readily available Diels–Alder adduct **7**[6] of 1,5-cyclooctadiene and 5,5-dimethoxy-1,2,3,4-tetrachlorocyclopentadiene on allylic bromination and carefully controlled dehydrobromination furnished the symmetrical 1,3-diene **8**. 1,4-Oxygen functionalization of the diene moiety in **8** was achieved through stereoselective (4 + 2) addition of singlet oxygen to give the cyclic peroxide **9**, mp 170 °C.[7] LAH reduction and acetylation furnished the diacetate **10**, which underwent smooth intramolecular (2 + 2) cycloaddition on acetophenone-sensitized irradiation to deliver the caged pentacyclic *endo,endo*-diacetate **11**, mp 175 °C. The diacetate was routinely transformed to the dimesylate **13** via the diol **12**. Direct 1,2-elimination of the *endo*-mesylate groups with base in **13** presented difficulties but treatment with NaI in hexamethylphosphoric triamide (HMPA) at 130 °C led to simultaneous substitution and elimination to yield the key diene **14**, mp 236 °C.[7] Ketal group deprotection in **14** set the stage for the Favorskii contraction, and the novel pentacyclic dibenzene derivative **15**[8,9] as well as the competing Haller–Bauer cleavage product **16**[8] were obtained in a 1:1 ratio (Scheme II). With the successful attainment of **14**, **15**, and **16**, three of the precursors of hexaprismane, enumerated in Scheme I, were in hand and their photochemical ring closure was promptly investigated. Disappointment struck immediately, as none of the three, not even **14** whose X-ray crystal structure[7] had revealed the two double bonds to be within range (2.92 Å) with favorable spatial orientation, could be induced toward a (2 + 2) cycloaddition under a variety of irradiation regimens.[10] We therefore turned to the last option of Scheme I and a derivative of **6**.

Scheme I



Access to the ring system **6** required regioselective removal of one of the cyclobutane bonds in the pentacyclic system **13**. Toward this objective, **13** was subjected to a controlled NaI–HMPA

---

(1) (a) Greenberg, A.; Liebman, J. F. *Strained Organic Molecules*; Academic: New York, 1978. (b) Minkin, V. I.; Minyaev, R. M. *Zh. Org. Khim.* **1981**, *17*, 221. (c) Allinger, N. L.; Eaton, P. E. *Tetrahedron Lett.* **1983**, 3697. (d) Eaton, P. E.; Or, Y. S.; Branca, S. J.; Shankar, B. K. R. *Tetrahedron* **1986**, *42*, 1621. (e) Martin, R. M., unpublished results quoted in ref 1d. (f) Reddy, V. P.; Jemmis, E. D. *Tetrahedron Lett.* **1986**, 3771. (g) Ōsawa, E., private communication.

(2) Katz, T. J.; Acton, N. *J. Am. Chem. Soc.* **1973**, *95*, 2738.

(3) Eaton, P. E.; Cole, T. R. *Ibid.* **1964**, *86*, 3157.

(4) Eaton, P. E.; Or, Y. S.; Branca, S. J. *Ibid.* **1981**, *103*, 2134.

(5) (a) Eaton, P. E.; Chakraborty, U. R. *J. Am. Chem. Soc.* **1978**, *100*, 3634. (b) Mehta, G.; Srikrishna, A.; Nair, M. S.; Cameron, T. S.; Tacreiter, W. *Ind. J. Chem.* **1983**, *22B*, 621. (c) Higuchi, H.; Takatsu, K.; Otsubo, T.; Sakata, Y.; Misumi, S. *Tetrahedron Lett.* **1982**, 671. (d) Yang, N. C.; Horner, M. G. *Ibid.* **1986**, 543.

(6) Aktar, I. A.; Fray, G. I.; Yarrow, J. M. *J. Chem. Soc. C* **1968**, 812.

(7) X-ray crystal structure was kindly determined by Professor T. S. Cameron and W. Tacreiter, Dalhousie University, Canada. These results will be reported in due course.

(8) All new compounds reported here were fully characterized on the basis of their IR, ^{1}H NMR, and ^{13}C NMR spectral data and elemental analyses. Selected spectral data for some of the important compounds are given below. Compound **15**: mp 135 °C; IR (KBr) 1730 cm^{-1}, ^{1}H NMR (100 MHz, $CDCl_3$) δ 6.28–6.0 (4 H, m), 3.79 (3 H, s), 3.74–3.36 (4 H, m); ^{13}C NMR (25.0 MHz, $CDCl_3$) δ 167.4, 128.2 (2 C), 127.5 (2 C), 71.9, 67.4, 65.7, 59.3, 52.2, 50.8, 49.9, 49.6, 41.4. **16**: mp 138 °C; IR (KBr) 1740 cm^{-1}; ^{1}H NMR (100 MHz, $CDCl_3$) δ 6.36–6.08 (2 H, m), 5.74–5.44 (2 H, m), 4.34 (1 H, d, $J = 4$ Hz), 3.9 (3 H, s), 3.88–3.04 (4 H, series of m); ^{13}C NMR (25.0 MHz, $CDCl_3$) δ 169.1, 132.4, 131.5, 126.9, 126.6, 73.6, 72.4, 69.9, 58.8, 54.0, 53.2, 48.9, 44.8, 42.1. **18**: mp 164–165 °C. ^{1}H NMR (100 MHz, $CDCl_3$) δ 5.8–5.56 (2 H, ddd, $J_1 = 10$, $J_2 = J_3 = 4$ Hz), 5.52–5.28 (2 H, ddd, $J_1 = 10$, $J_2 = J_3 = 2$ Hz), 3.74 (3 H, s), 3.68 (3 H, s), 3.0 (2 H, m), 2.5–1.78 (4 H, AB q with st $J_1 = 38$ Hz, $J_2 = J_3 = 20$ Hz); ^{13}C NMR (25.0 MHz, $CDCl_3$) δ 130.8, 120.0, 104.5, 72.5 (2 C), 52.0, 50.8, 40.4, 20.7. **19**: mp 236–7 °C; ^{1}H NMR (100 MHz, $CDCl_3$) δ 3.66 (3 H, s), 3.62 (3 H, s), 3.0–2.84 (4 H, m), 2.8–2.6 (2 H, m), 1.7–1.56 (4 H, br s); ^{13}C NMR (25.0 MHz, $CDCl_3$) δ 106.5, 75.6, 73.0, 51.7, 51.0, 43.4, 39.6, 28.1, 16.2. **21**: mp 159 °C; IR (KBr) 1740 cm^{-1}; ^{1}H NMR (100 MHz, $CDCl_3$) δ 3.76 (3 H, s), 3.3–2.8 (6 H, series of m), 2.8–2.5 (4 H, m); ^{13}C NMR (25.0 MHz, $CDCl_3$) δ 168.5, 74.8, 68.6, 66.9, 59.1, 51.9, 44.4, 43.4, 40.0, 31.1, 28.6, 28.2, 17.5, 16.8.

(9) While our preparation of the pentacyclo[6.4.0.0^{2,7}.0^{3,10}.0^{6,9}]dodeca-4,10-diene ring system **15** was realized quite some time back, Yang and Horner[5d] have recently reported the preparation of the corresponding hydrocarbon following a different approach.

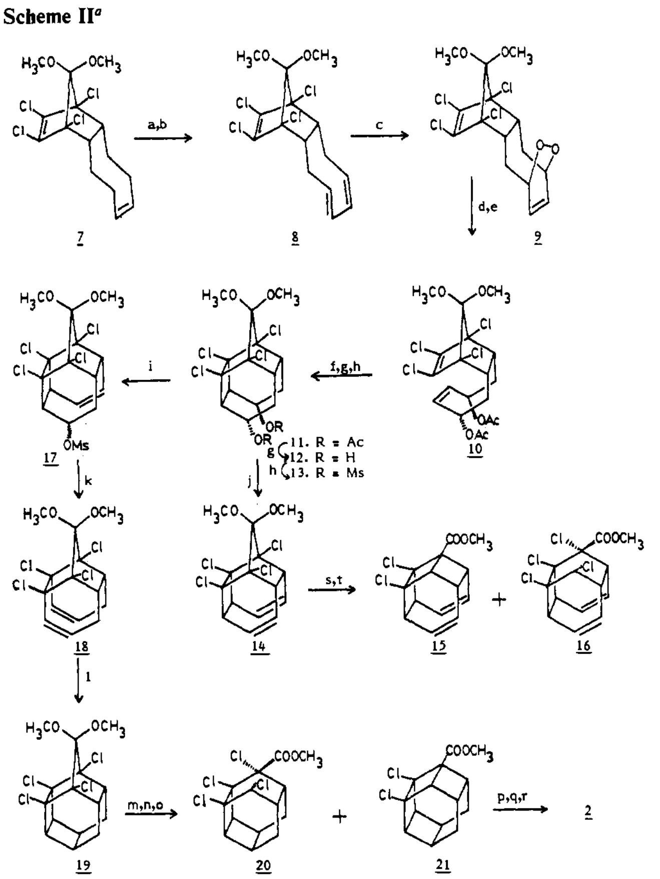
(10) Detailed MM2′ calculations on the photoclosure reactions that could lead to hexaprismane from a variety of precursors, including **3**–**6**, have been carried out in collaboration with Professor E. Ōsawa of Hokkaido University. The results indicate that strain energy buildup during the photoclosure reaction seems to play a dominant role in the outcome of the reaction.[11] In the photocycloaddition steps involving **3** and **4** about 75 kcal mol^{-1} strain energy climb is involved, which seems prohibitive with a threshold >65 kcal mol^{-1}.[12] On the other hand, the successful photoclosure of system **6** (see, **18** → **19**) involves ~56 kcal mol^{-1} strain energy increase. Ōsawa, E.; Mehta, G. et al., manuscript under preparation.

(11) Alternate explanations based on extensive thorough-bond coupling overriding the spatial proximity have been offered for failure of some intramolecular (2 + 2) photocycloadditions; see: Schmidt, W.; Wilkins, B. T. *Tetrahedron* **1972**, *28*, 5649.

(12) Ōsawa, E.; Aigami, K.; Inamoto, Y. *J. Org. Chem.* **1977**, *48*, 2621.

0002-7863/87/1509-2212$01.50/0

Scheme II[a]



[a] Reagents and yields: (a) *N*-bromosuccinamide–CCl_4, AIBN, reflux, 4 h, 100%; (b) DBU–Me_2SO, room temperature, 8 h, 70%; (c) O_2–CH_2Cl_2, methylene blue, 500-W tungsten lamp, 15 °C, 7 days, 70%; (d) $LiAlH_4$–Et_2O, room temperature, 3 h; (e) Ac_2O–Py, room temperature, 4 h, 75% from **9**; (f) $h\nu$, acetophenone–benzene, 20 °C, 8 h, 73%; (g) aqueous KOH–MeOH, room temperature, 2 h, 100%; (h) CH_3SO_2Cl–Py, room temperature, 5 h, 85%; (i) NaI–HMPA, 100 °C, 60 h, 55%; (j) NaI–HMPA, 130 °C, 72 h, 73%; (k) B_2H_6–THF, room temperature, 2 h, aqueous NaOH, reflux, 1.5 h, 74%; (l) $h\nu$, acetone, 20 °C, 14 h, 60%; (m) 90% H_2SO_4–CH_2Cl_2, 0 °C → room temperature, 10 h, 85%; (n) NaOH–toluene, reflux, 10 min; (o) CH_2N_2–MeOH, 0 °C, 15 min, 60% **21** and 25% **20**; (p) aqueous KOH–MeOH, reflux, 2 h; (q) HgO–CH_2Cl_2, reflux, 1 h, Br_2, reflux, 2 h, 82% from **21**; (r) Li–THF-*t*-BuOH, reflux, 3 h, 32%; (s) 90% H_2SO_4–CH_2Cl_2 0 °C → room temperature, 12 h, 85%; (t) NaOH–toluene, reflux, 10 min, CH_2N_2–MeOH, 0 °C, 15 min, 46% **15** and 46% **16**.

substitution–elimination reaction and the olefinic monomesylate **17** could be readily obtained. Diborane-induced fragmentation[13] of **17** took the projected course and the tetracyclic diene **18**[8] was delivered in just two steps from **13**. Irradiation of **18** with acetone as sensitizer led to the (2 + 2) ring closure and the now much sought hexacyclic compound **19**[8] was realized quite uneventfully. Unmasking of the carbonyl group in **19** set up the Favorskii ring contraction and a 2:5 ratio of the secohexaprismane ester **21**[8] and the Haller–Bauer ester **20** was obtained. Finally, a three-step sequence consisting of alkaline hydrolysis, Hunsdiecker reaction, and reductive dehalogenation (Scheme II) furnished the hexacyclic hydrocarbon secohexaprismane **2**, a highly volatile waxy solid, sublimed at 80 °C, mp > 250 °C. The EI and CI mass spectrum of **2** did not show a molecular ion but a base peak at *m/e* 79.0559 corresponding to $M^+/2$ ($C_6H_7^+$; calcd for C_6H_7, 79.0548) was observed. The 300-MHz ^1H NMR spectrum had four resonances at δ 3.12–3.06 (m), 2.90–2.79 (m), 1.78 (d with st, J = 14 Hz), and 1.30 (d, J = 14 Hz) in a ratio of 1:4:1:1 and the ^{13}C NMR spectrum exhibited four resonances at δ 35.0, 33.8, 29.2, and 20.5 in accordance with its symmetry. With the attainment of secohexaprismane (**2**), we are now pursuing the general synthetic strategy outlined here toward hexa and higher prismanes with tactical adjustments.

Acknowledgment. We thank UGC for a Special Assistance Programme in Organic Chemistry and for COSIST support in Organic Synthesis. S.P. thanks CSIR for a Junior Research Fellowship.

Registry No. 2, 106880-88-0; **2** (dichloride), 106880-90-4; **7**, 67335-74-4; **8**, 106880-92-6; **9**, 106880-93-7; **10**, 106880-94-8; **11**, 106880-95-9; **12**, 106880-96-0; **13**, 106880-97-1; **14**, 106880-98-2; **14** (ketone), 106880-91-5; **15**, 106880-99-3; **16**, 106881-00-9; **17**, 106881-01-0; **18**, 106881-02-1; **19**, 106881-03-2; **19** (ketone), 106880-89-1; **20**, 106881-04-3; **21**, 106905-23-1.

Supplementary Material Available: 300 MHz ^1H NMR spectrum of secohexaprismane (1 page). Ordering information is given on any current masthead page.

---

[13] Marshall, J. A.; Bundy, G. L. *J. Am. Chem. Soc.* **1966**, *88*, 4291.

Stereochemical Consequences of Thermal Fluorine-for-Chlorine Atomic Substitution with 2(*S*)-(+)-Chloropropionyl Chloride

Mahmoud L. Firouzbakht, Richard A. Ferrieri,* and Alfred P. Wolf

Chemistry Department, Brookhaven National Laboratory
Upton, New York 11973

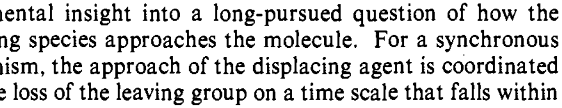
Edward P. Rack

Chemistry Department, University of Nebraska—Lincoln
Lincoln, Nebraska 68588-0304

Received August 29, 1986

Considerable interest exists in understanding the fundamental aspects of homolytic bimolecular substitution (S_H2) reactions at sp^3 hybridized carbon atoms[1] perhaps because of the practical implications to understanding radical substitution reactions in organic synthesis. Over the years, particular attention has been given to the halogen atom substitution reactions.[2-4] Ingold and Roberts pointed out in an early monograph that available data could not provide unequivocal evidence for the existence of thermoneutral substitution reactions at thermal energies. However, it was suggested that highly exothermic substitutions might be more probable. A recent study by Rowland and Subramonia demonstrated this point where thermal F-for-X substitutions were observed with CH_3X (X = Cl, Br, I).[5] The rate constants for reaction were found to be somewhat slow, ranging between 8×10^{-13} and 3.7×10^{-14} cm^3 molecule^{-1} s^{-1}, compared to H-abstraction, but increased as the reaction exothermicity increased.

A second point made by Ingold and Roberts[1] is that substitution of an atom or radical at an asymmetric carbon atom could provide fundamental insight into a long-pursued question of how the attacking species approaches the molecule. For a synchronous mechanism, the approach of the displacing agent is coordinated with the loss of the leaving group on a time scale that falls within the period for a single vibration. Under these circumstances, the stereochemical configuration of the substrate should be preserved if attack occurs on the front or side of the molecule.



$$X\cdot + abcCB \longrightarrow [X\cdots C(a)(b)(c)\cdots B] \longrightarrow XCabc + B\cdot \qquad (1)$$

---

* Address correspondence to this author.

[1] Ingold, K. U.; Roberts, B. P. *Free Radical Substitution Reactions*; Wiley: New York, **1971**.

[2] Ogg, R. A., Jr.; Polanyi, M. *Trans. Faraday Soc.* **1935**, *31*, 482–495.

[3] Avonda, F. P.; Gervasi, J. A.; Bigelow, L. A. *J. Am. Chem. Soc.* **1956**, *78*, 2798–2800.

[4] Tedder, J. M. *Adv. Fluorine Chem.* **1961**, *2*, 104–137.

[5] Subramonia, I.; Rowland, F. S. *J. Phys. Chem.* **1981**, *85*, 2488–2492.

0002-7863/87/1509-2213$01.50/0