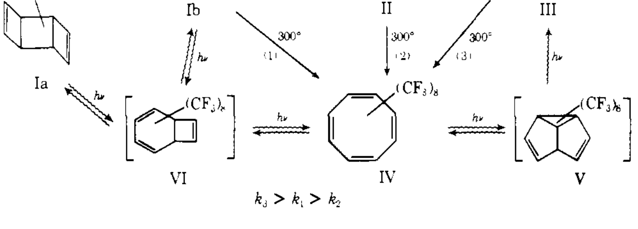
Communications to the Editor

Syntheses from Perfluoro-2-Butyne. 2.[1] Perfluorooctamethylcubane, Perfluorooctamethylcuneane, and Perfluorooctamethylcyclooctatetraene

Sir:

We believe that the continuing comparison of the physical and chemical properties of highly fluorinated carbon compounds with those of the highly hydrogenated compounds, on which present theories of organic chemistry are largely based, will be productive of increased understanding not achievable by other routes.[2] Such a comparison is possible over a uniquely wide range of carbon structures but its broad realization is dependent upon the development of applicable synthetic methods for carbon-fluorine compounds. As new results in this area we wish to report the preparation of perfluorooctamethylcubane (II) and perfluorooctamethylcuneane (III) by the ultraviolet irradiation of either *syn*- or *anti*-perfluorooctamethyltricyclo[4.2.0.0^{2,5}]-3,7-octadiene (I), the dimers of perfluorotetramethylcyclobutadiene. These substances are stable easily sublimable solids which yield perfluorooctamethylcyclooctatetraene (IV) on heating. They are derived from perfluoro-2-butyne[1] and comprise the first fully fluorinated examples of their respective types. The preparation of II also appears to be the first conversion of a cyclobutadiene dimer into a cubane. Attempts to prepare the hydrocarbon octamethylcubane from the syn dimer of tetramethylcyclobutadiene have been unsuccessful.[3] On the other hand, octamethylcuneane has been obtained by the irradiation of its stable isomer, octamethylsemibullvalene.[4] Interconversions of $C_6(CF_3)_6$ valence bond isomers have also been shown to take place[5] which are of interest for comparison with those of the $C_8(CF_3)_8$ isomers reported here.

Irradiation of Ia,[6] mp 104-105°, preferably in fluorocarbon solution,[10] yielded II, mp 253-254°,[11] and III, mp 186-187°,[14] in order of elution from a 20% squalane on Chromosorb P GLC column at 80°. Interconversions between Ia, Ib, and IV took place during irradiation and Ib and IV also yielded II and III as major final products. Conversion of IV into Ib was carried out in high yield with limited irradiation. As shown below, we postulate that II was formed from the syn isomer of I and III from perfluorooctamethylsemibullvalene (V) with perfluorooctamethylbicyclo[4.2.0]octa-2,4,7-triene (VI), the intermediate between IV and Ia and Ib.[15] Compounds V and VI have not been isolated. However, their formation was consistent with GLC traces and ir spectra. A well-resolved low yield intermediate product eluted between II and III.



On heating in sealed tubes Ia, Ib, II, and III yielded IV[16] quantitatively.[17] The cubane II was found to be more stable than either I or the cuneane, III. At 300° after 4 h II was only about 30% converted into IV while III was completely converted after 1 h. After 16 h II was completely converted. At 300° IV was unchanged during 48 h and only slight decomposition could be detected after 1 h at 400°. The great thermal stability of IV was in marked contrast to its photochemical lability. The corresponding $C_8(CH_3)_8$ hydrocarbons have a very different thermal chemistry. The most stable isomer was found to be octamethylsemibullvalene (V_H).[4]

The cubane structure for II, $C_{16}F_{24}$,[11] was concluded from the absence of unsaturation as shown by its infrared and Raman spectra, the presence of only NMR equivalent fluorines with a single absorption attributable to the $-CF_3$ group,[18] and its method of preparation and conversion into IV. The observed lack of overlap between ir and Raman bands was consistent with a centrosymmetric structure.[19] Similarly, III was shown to be a saturated $C_{16}F_{24}$ isomer with three different type fluorines in the ratio of 1:2:1.[14] Of the three possible saturated $C_8(CF_3)_8$ isomers, II, III, and perfluorooctamethylpentacyclo[5,1.0.0^{2,4}.0^{3,5}.0^{6,8}]octane,[20] only the cuneane has three different type fluorines. Compound IV[16] was not oxidied by $KMnO_4$ in acetone and could not be chlorinated at temperatures up to 200°. However, the presence of unsaturation was shown by its Raman spectrum and photochemistry. Only NMR equivalent fluorines were present. Its very great stability and quantitative production by pyrolysis of its valence bond isomers taken with the above observations were considered to be consistent only with the cyclooctatetraene structure.[21]

Acknowledgment. This work was supported by grants from the National Science Foundation and from the Army Office of Research-Durham. We also wish to express our appreciation to Dr. W. M. Koppes for valuable experimental help.

References and Notes

(1) For the first paper in this series see W. T. Miller, R. J. Hummel, and L. F. Pelosi, *J. Am. Chem. Soc.*, **95**, 6850 (1973).
(2) An objective of major importance is to provide an expanded experimental basis for chemical bonding theory.
(3) R. Criegee et al., unpublished work. Cited by D. Seebach, *Angew Chem., Int. Ed. Engl.*, 4, 131 (1965).
(4) R. Criegee and R. Askani, *Angew. Chem., Int. Ed. Engl.*, 7, 537 (1968).
(5) M. G. Barlow, R. N. Haszeldine, and R. Hubbard, *J. Chem. Soc. C*, 1232 (1970); *Chem. Commun.*, 202 (1969); D. M. Lemal, J. V. Stavos, and V. Austel, *J. Am. Chem. Soc.*, **91**, 3373 (1969).

(6) We have prepared the two isomers of perfluorooctamethyltricyclo[4.2.0.0^{2,5}]-3,7-octadiene, Ia, mp 104–105°, and Ib, mp 207–208°.[7] Isomer Ia was first prepared by treatment of *trans*-3-bromoperfluoro-1,2,3,4-tetramethylcyclobutene[1] with MeLi in ethyl ether at −125° and was postulated to be the syn isomer.[7] However, Kobayashi et al. have concluded recently on the basis of preliminary x-ray structural data that isomer Ib (mp 204–205°) has the syn configuration.[6] We have also obtained experimental results on the fluoride ion promoted equilibration of Ia and Ib, which support this assignment, i.e., that Ia is in fact the more stable and presumably anti isomer.[9]

(7) W. T. Miller, R. J. ND L. F. Pelosi, pred in part at the 6th International Symposium on Fluorine Chemistry, Durham, England, July 1971; L. F. Pelosi, Ph.D. Thesis, Cornell University, 1973.

(8) Y. Kobayashi, I. Kumadaki, A. Ohsawa, Y. Hanzawa, and M. Honda, *Tetrahedron Lett.*, 3001 (1975).

(9) Unpublished work with W. M. Koppes.

(10) A Hanovia 450-W high pressure quartz mercury vapor lamp was utilized. II and III were first isolated from cyclohexane and characterized but the major reaction involved the solvent. Good yields of $C_6(CF_3)_6$ isomers were recovered after irradiation in a mixture of 1,3- and 1,4-c-$C_6F_{10}(CF_3)_2$; ~20% II and 15% III were isolated after 36 h irradiation. In addition to being highly inert the fluorocarbon solvent readily dissolved both reactants and products.

(11) Perfluorooctamethylpentacyclo[4.2.0.0^{2,5}.0^{3,6}.0^{4,7}]octane (II): mp 253–254° (sealed tube); ir (gas) 135 (w), 1330 (vw), 1249 (w,sh), 1237 (vs), 1115 (vw) cm^{-1} with no other appreciable absorption within the region of 3500–660 cm^{-1};[12] laser Raman[13] (solid microsample) 1427 (m), 1256 (s), 1062 (m), 749 (vs), 560 (s), 324 (m), 303 (m), 261 (s), 230 (m) cm^{-1}; NMR ^{19}F (c-C_6F_{10}) 64.4 (sharp singlet) ppm upfield from external CCl_3F; MS (70 eV) *m/e* 648 (very weak, $C_{16}F_{24}^+$), 629 (15, $C_{16}F_{23}^+$), 579 (15, $C_{15}F_{21}^+$), ...69 (100, CF_3^+).

(12) Cubane is similarly transparent in the infrared with absorption bands only at 3000, 1231, and 851 cm^{-1}. P. E. Eaton and T. W. Cole, Jr., *J. Am. Chem. Soc.*, **86**, 3157 (1964).

(13) Determined in the laboratories of the E. I. du Pont de Nemours & Co. by J. J. Jack through the courtesy of P. R. Resnick.

(14) Perfluorooctamethylpentacyclo[5.1.0.0^{2,6}.0^{3,5}.0^{4,8}]octane (III): mp 186–187° (sealed tube, unchanged after 4 h at 200°); ir (gas) 1426 (vw), 1302 (w), 1261 (m), 1246 (m, sh), 1236 (vs), 1070 (vw) cm^{-1}; laser Raman[13] (solid microsample) 1425 (vw), 970 (vw), 749 (s). 559 (w), 499 (vw), 312 (m), 259 (m), 233 (w) cm^{-1}; NMR ^{19}F (C_6F_6) 53.1 (s), 57.2 (s), 60.9 (s) ppm upfield from external CCl_3F with areas of 1:2:1; MS (70 eV) *m/e* 648 (very weak, $C_{16}F_{24}^+$), 629 (20, $C_{16}F_{23}^+$), 579 (19, $C_{15}F_{21}^+$), ... 69 (100, CF_3^+).

(15) For a review of analogous interconversions of carbon–hydrogen compounds see L. T. Scott and M. Jones, Jr., *Chem. Rev.*, **72**, 181 (1972).

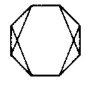
(16) Perfluorooctamethylcyclooctatetraene (IV): mp 160–161°; ir (gas) 1310 (m), 1260 (vs), 1220 (vs), 729 (w) cm^{-1}; laser Raman[13] (solid microsample) 1653 (s), 1214 (w), 1175 (vw), 1064 (m), 925 (vw), 905 (w), 771 (vw), 750 (vs), 619 (vw), 543 (vw), 336 (m), 260 (vs), 248 (m,sh), 169 (m) cm^{-1}; NMR ^{19}F (C_6F_6) 59.7 (complex singlet) ppm upfield from external CCl_3F; MS (70 eV) *m/e* 647.9604 (5, $C_{16}F_{24}^+$), 629 (37, $C_{16}F_{23}^+$), 579 (26, $C_{15}F_{21}^+$) . . . . 69 (100, CF_3^+).

(17) The thermal conversions of II and III into IV appear to be the first such transitions to be established with a cubane and a cuneane.

(18) J. W. Emsley, J. Feeney, and L. Y. Sutcliffe, "High Resolution Nuclear Magnetic Resonance Spectroscopy", Vol. II. Pergamon Press, New York, N.Y., 1966.

(19) G. W. King, "Spectroscopy and Molecular Structure", Rhinehart and Wilson, New York, N.Y., 1964, p 366.

(20) An unknown structure,



(21) An early report that IV was obtained as a thermal reaction product of perfluoro-2-butyne[a] has been shown to be incorrect.[b] (a) B. Ekstrom, *Chem. Ber.*, **92**, 749 (1959); (b) H. C. Brown, H. L. Gewanter, D. M. White and W. G. Woods, *J. Org. Chem.*, **25**, 634 (1960).

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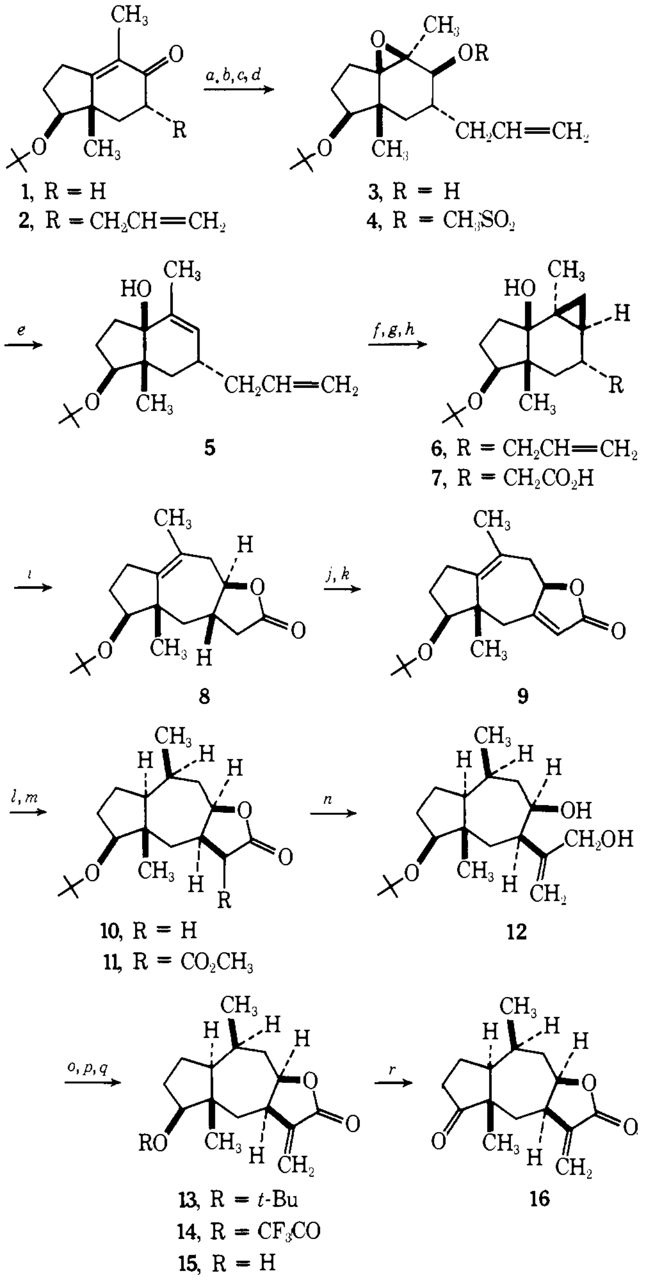
The Stereoselective Total Synthesis of Pseudoguaianolides: Confertin

Sir:

The pseudoguaianolide family of sesquiterpenes is a widely distributed class of natural products whose diverse structures and medicinal properties have been of increasing interest in recent years.[1] A major problem in the synthesis of representative members of this structural class has been rigid control of stereochemistry in flexible hydroazulene ring systems.[2] In this report we describe a highly stereoselective synthesis of confertin (**16**) by an approach which should be applicable to other pseudoguaianolides as well.



[a] $LiN(i\text{-}Pr)_2$, $CH_2{=}CHCH_2Br$. [b] $LiAlH_4$. [c] *m*-$ClC_6H_4CO_3H$. [d] CH_3SO_2Cl. [e] Li, NH_3. [f] CH_2I_2, Zn(Cu). [g] O_3. [h] Ag_2O. [i] H_3O^+. [j] $LiN(i\text{-}Pr)_2$, $(PhSe)_2$. [k] H_2O_2. [l] H_2/Pd–C, EtOAc. [m] KH, $CH_3OCO_2CH_3$. [n] KH, $LiAlH_4$. [o] MnO_2, C_6H_6. [p] CF_3CO_2H. [q] *i*-PrOH, NaOH. [r] $CrO_3(C_5H_5N)_2$, CH_2Cl_2.

Keto ether **1** obtained in 75% overall yield from 2-methyl-1,3-cyclopentanedione[3,4] was alkylated with allyl bromide using lithium diisopropylamide in tetrahydrofuran (THF)–hexamethylphosphoric triamide (HMPA) to give the dienone **2**. Attempts at reduction-elimination of the corresponding α,β-epoxy ketone to alcohol **5** via the Wharton method[5] were totally unsuccessful. Therefore the alternative sequence of lithium aluminum hydride reduction and epoxidation to epoxy alcohol **3** followed by lithium-ammonia reduction of the mesylate derivative **4** was developed to circumvent this problem. The overall yield of this modified sequence was 75%.