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THE SYNTHESIS OF PENTACYCLO[6.4.0.$0^{2,7}$.$0^{3,12}$.$0^{6,9}$]DODECA-4,10-DIENE A PENTACYCLIC DIMER OF BENZENE

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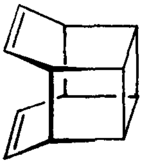
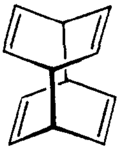
Summary: The synthesis of the title compound is described. The key synthetic step is the pericyclic photochemical addition to benzene of a substituted cyclohexadiene.

The study of arene dimers has provided important information about the nature of pericyclic reaction mechanisms.[1-3] In an effort to produce energy-rich dimers, we have been interested in the synthesis of stable benzene dimers.[4-6] We would like to report the synthesis of a pentacyclic dibenzene, 1, which may be a useful precursor to both p,p'-dibenzene (2) and hexaprismane (3). The synthesis is outlined in the Scheme.


1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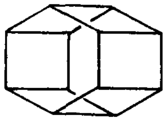
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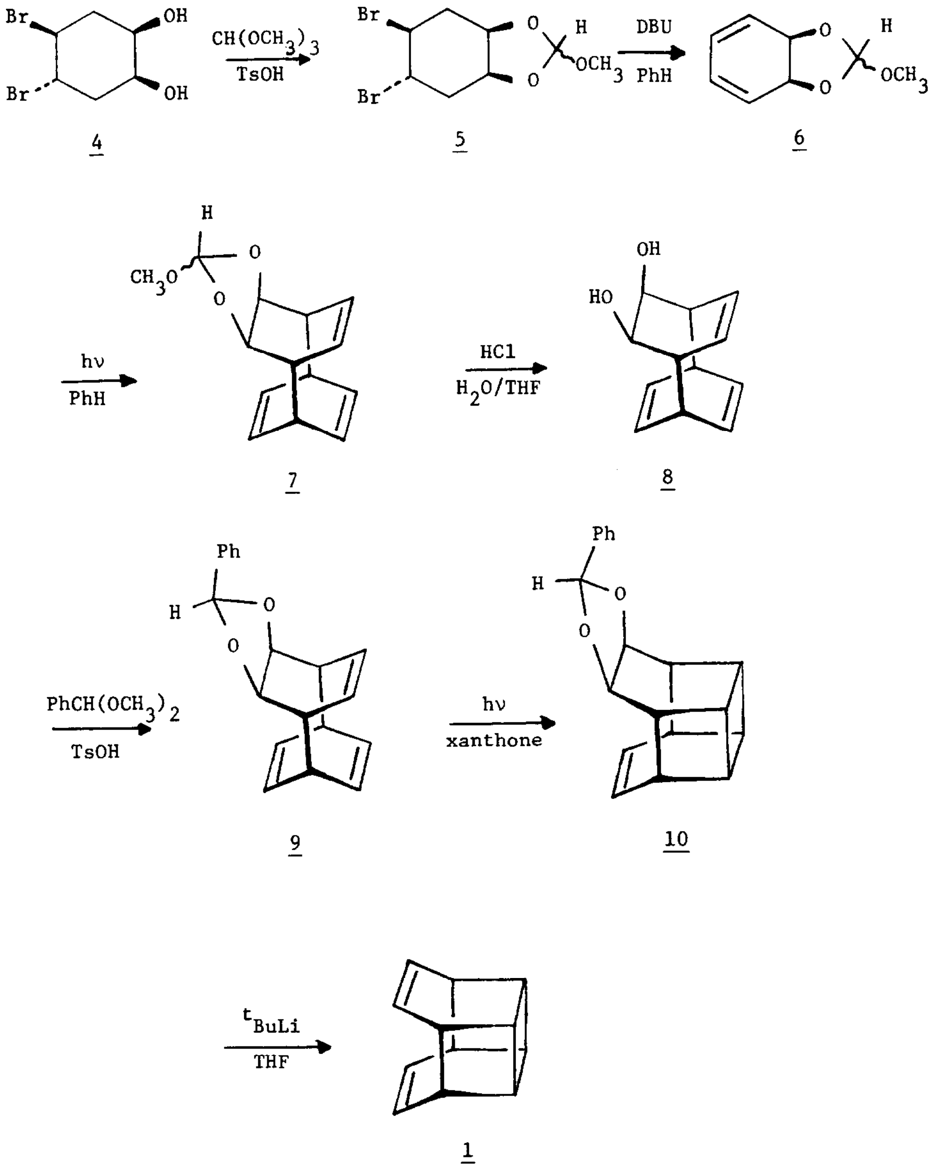
The photochemical addition of cyclohexadiene to arenes has proven to be an effective route to $[\pi_{4s}+\pi_{4s}]$ adducts similar in structure to dimer 2.[7] The use of properly substituted cyclohexadienes leads to adducts which may be converted to interesting benzene-arene adducts.[4,8]

Diene 6 was conveniently prepared in two steps from dibromodiol 4. The synthesis of 4 has been previously reported.[5] Treatment of 4 with trimethyl orthoformate and p-toluenesulfonic acid yields the cyclic orthoformate 5, which can be immediately dehydrobrominated with DBU in refluxing benzene to give the desired diene 6 in 45% yield from 4, bp 53-55° (1 torr).

When a benzene solution of diene 6 is irradiated at 3° with a 450 watt Hanovia medium pressure mercury lamp through a Vycor filter, a complex reaction mixture is produced. Column Chromatography (silica gel, Activity III) of the reaction mixture gives the desired [4+4] adduct of diene 6 to benzene as a crude waxy solid in 2% yield. The crude product can be hydrolyzed to the more stable diol 8 in 75% yield.

Scheme

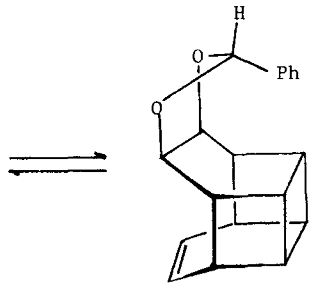

Br
Br
OH
OH
4
CH(OCH3)3
TsOH
Br
Br
O
O
H
OCH3
5
DBU
PhH
O
O
H
OCH3
6
hν
PhH
H
O
CH3O
O
7
HCl
H2O/THF
OH
HO
8
PhCH(OCH3)2
TsOH
Ph
H
O
O
9
hν
xanthone
Ph
H
O
O
10
tBuLi
THF
1

The structure of diol 8, mp 124-125° (CH_2Cl_2-hexane), is established by its elemental analysis and nmr spectra. The ^1H nmr spectra consists of seven resonances. Multiplets at δ6.40, 6.26, and 5.97 ppm, each possessing an AA'XX' structure, are indicative of three types of olefinic protons. Complex multiplets at δ3.20 and 3.05 ppm are identified with two types of bridgehead positions, while broad doublets at δ4.55 and 2.28 ppm belong to a methine proton on a carbon bearing hydroxyl substituent and the hydroxyl proton, respectively. The ^{13}C nmr spectrum possesses only six resonances, identifying three types of olefinic carbons (δ139.0, 136.8 and 134.6 ppm), two types of allylic positions (δ52.6 and 40.3 ppm) and one type of carbon bearing a heteroatom (δ70.2 ppm).

The base-induced fragmentation of cyclic acetals to yield unstable olefins[9] has proven to be a useful procedure for the production of unusual arene heterodimers.[4,6] When a diol 8 is treated with benzaldehyde dimethyl acetal in chloroform solution with dilute acid as a catalyst, a cyclic acetal is produced which is believed to possess the structure shown in 9, mp 143-143.5° (CH_2Cl_2-hexane). This structure is expected on the basis of the preference of a phenyl substituent for a pseudoequatorial position on a puckered five-membered ring, and the ^1H nmr spectrum has been correlated with this isomer by comparison with the spectra of analogous isomers of [4+4] adducts to anthracene.[4,6] When acetal 9 is treated with t-butyl lithium in THF at 22°, no reaction is observed. This result is in agreement with an earlier report of a diastereo-selectivity in the fragmentation of similar cyclic phenyl acetals.[4,6] In both cases, π-orbital repulsion between the phenyl group and the sterically close olefin prevent the five-membered ring from attaining a geometry in which the acetal hydrogen occupies an axial position with its C-H bond parallel to the C-O bonds being cleaved.

When a solution of acetal 9 and xanthone is irradiated at -20° through a Pyrex filter, the cage acetal 10 is produced in 80% yield, mp 173-174° (CH_2Cl_2-hexane). The product is characterized by the presence of only one olefinic resonance (δ6.30 ppm) in the ^1H nmr spectrum and the appearance of three complex multiplets at δ3.49, 3.07 and 2.85 ppm with intensities in the ratio of 2:1:1 for the cyclobutyl protons. When this cage acetal is treated with t-butyl lithium in THF at 0°, elimination proceeds rapidly and in good yield to give diene 1 (75%). The reactivity of cage acetal 10 contrasts sharply with the inert behavior of acetal 9 under the same conditions. Molecular models support the idea that cage acetal 10 can adopt a conformation with the acetal C-H bond in a pseudoequatorial position, such as might be required for a concerted elimination of the acetal. Such a geometry is accessible in acetal 10 since there no longer exists a strongly destabilizing steric repulsion as is present in a similar conformation of acetal 9.

10



The title compound exhibits a characteristic camphene-like odor, mp 73-75° (methanol). It exhibits a parent peak at m/e 156.0942 (calcd for $C_{12}H_{12}$, 156.0938; rel. int., 11.5) as well as peaks corresponding to $C_{12}H_{11}^+$ (66.8), $C_7H_7^+$ (84.9), $C_6H_7^+$ (100) and $C_6H_6^+$ (100) in its mass spectrum (CI, isobutane), and peaks at 3024, 2954, 2931, 2852, 873 and 804 cm^{-1} in its ir spectrum (KBr). Diene 1 is identified by only three resonances in the ^1H nmr, at δ6.17, 3.38 and 2.90 ppm, indicative of the olefinic, allylic, and cyclobutyl protons. The ^{13}C nmr spectrum consists of three resonances, at δ130.88, 41.07 and 32.90 ppm, confirming the existence of two symmetry planes in the molecule. When the C-H coupling constants of the olefin and allylic resonances (J_{CH} = 157.5 and 138.0 Hz) are not appreciably different from normal values, cyclobutyl resonance at δ32.90 ppm has a large coupling constant, J_{CH} = 148.9 Hz, which is indicative of 29.8% s-character in the C-H bond.[10]

The investigation in this area is being continued in our laboratory.

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References

1. H. Rotelle, W. Martin, J. F. M. Oth and G. Schröder, Chem. Ber., 1969, 102, 3985-3995, and references cited therein.
2. J. A. Berson and R. F. Davis, J. Am. Chem. Soc., 1972, 94, 3658-3659.
3. W. Grimme and H. G. Kosner, Angew. Chem. Int. Ed. Engl., 1980, 19, 307-308.
4. N. C. Yang, M. J. Chen, P. Chen and K. T. Mak, J. Am. Chem. Soc., 1982, 104, 853-855.
5. N. C. Yang, M. J. Chen and P. Chen, J. Am. Chem. Soc., 1984, 106, 7310-7315.
6. M. J. Chen, Ph.D. Thesis, University of Chicago, 1982.
7. N. C. Yang and J. Libman, J. Am. Chem. Soc., 1972, 94, 1405-1406; ibid., 9228-9229.
8. K. T. Mak, K. Srinivasachar and N. C. Yang, J. Chem. Soc. Chem. Commun., 1979, 1038-1039.
9. J. N. Hines, M. J. Peagram, E. J. Thomas and D. H. Whitham, J. Chem. Soc. Perkin Trans. I, 1973, 2332-2337.
10. N. Muller and D. E. Pritchard, J. Chem. Phys., 1959, 31, 768-771.

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