moiety.[21] The 8(14),15-pimaradiene diterpenes (β axial vinylidene) have strongly positive contributions[21] and if present in **2**, in conjunction with the above mentioned positive allylic alcohol effects, would presumably result in a $\Delta\epsilon$ considerably higher (20–25) than the one observed. Thus we assign the stereochemistry at C_{13} in **1** and **2** as shown.

(21) C. R. Enzell and S. R. Wallis, *Tetrahedron Lett.*, 243 (1966); the reported ORD values are plain curves measured and calculated to *ca.* 225 nm with ϕ ~5000 for 8(14),15-isopimaradienes and ~+29,000 for the epimeric 8(14),15-pimaradienes.

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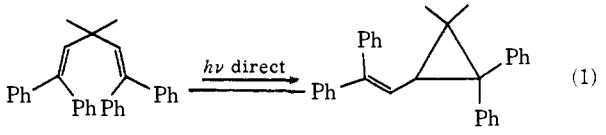
An Unexpected $\sigma + \pi$ Rearrangement of a Di-π-methane Reactant. Inhibition of the Di-π-methane Rearrangement. Mechanistic and Exploratory Organic Photochemistry. LXX[1]

Sir:

In previous reports we have noted the ubiquity and mechanism of the di-π-methane rearrangement.[2] Typifying acyclic examples is the very facile rearrangement of dimethyltetraphenyldiene **1**.[2b,c] In contrast, preliminary evidence suggested that analogs lacking central methyl and terminal phenyl substitution rearrange at best with reluctance.[3] To determine the role of central methyl substitution we investigated the photochemistry of 1,1,5,5-tetraphenyl-1,4-pentadiene[4] (**3**).

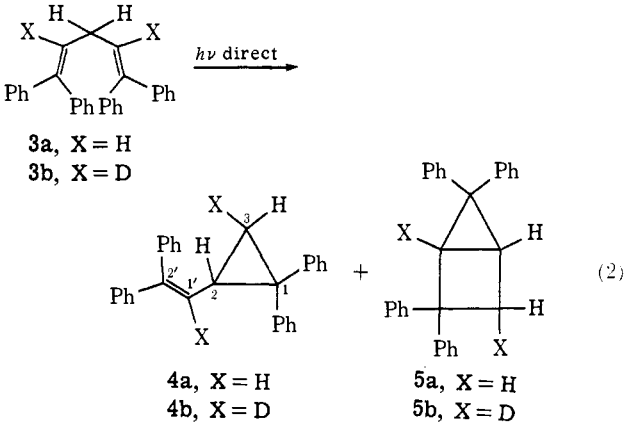


(1)

1 **2**

Presently, we report: (a) a requirement of central methyl substitution for facile di-π-methane rearrangement; (b) the observation of the expected di-π-methane product **4**, however *via* an alternative C–H $\sigma + \pi$ mechanism; (c) demonstration that the low reactivity of tetraphenyldiene **3** derives from an inherently low excited state reactivity and not just from rapid competitive decay; (d) formation of a housane product arising not from simple 2 + 2 addition but rather from diversion of a diradical species of the $\sigma + \pi$ route; (e) singlet reaction multiplicity.

Preparative photolysis of tetraphenyldiene **3**[5] for 24 hr in *tert*-butyl alcohol gave 12% of 1,1-diphenyl-2-(2,-2-diphenylvinyl)cyclopropane (**4a**), mp 101–102°, 11% of 2,2,5,5-tetraphenylbicyclo[2.1.0]pentane (**5a**), mp



(2)

180–181°, and 71% of recovered reactant **3**. The structure of **4a** is that expected for simple di-π-methane rearrangement, and the nmr was consistent with this formulation. Thus on-line graphic computer simulation[7]—choosing chemical shifts as τ_2 7.64, τ_{3c} 8.50 (note subscript 3c refers to cis configuration relative to H at C-2), τ_{3t} 8.46, and τ_1' 4.84, and selecting coupling constants as $J_{23c} = 9$, $J_{23t} = 5.5$, $J_{33} = -6$, and $J_{21'} = 10$ Hz—gave perfect agreement with observation. Absolute structural confirmation derived from the synthesis of **4a** from the reaction of diphenyldiazomethane with 1,1-diphenyl-1,3-butadiene. The gross structure of housane **5a** was initially suggested by the lack of vinyl proton absorption in the nmr (two multiplets at τ 7.50 (3 H) and 6.97 (1 H) plus an aromatic multiplet (20 H) at 3.0) and the ultraviolet spectrum with weak peaks at 263 (1080) and 273 (760) nm characteristic of an unconjugated phenyl-substituted product. That the actual structure was that of **5a** and not the simple 2 + 2 adduct of tetraphenyldiene **3** was established by Pd/C hydrogenation to give the known 1,1,3,3-tetraphenylcyclopentane.[8]

The quantum yield of formation of **4a** on direct irradiation was found to be $\phi = 0.0024$ and that for **5a** was 0.0020. In contrast, acetophenone sensitization gave no detectible reaction (*i.e.*, $\phi < 0.00002$).

The low efficiency in the formation of **4a** on direct irradiation contrasts with the 0.082 efficiency[2b] of the dimethyltetraphenyldiene **1**. That this is an inherent difference in reactivity and not just due to differences in rates of excited state decay was ascertained by assessment of the reaction rates using the method described by us previously[2c] and also by Dalton and Turro.[9] Thus, k_r for singlet excited state formation of vinylcyclopropane **4a** is 1.2×10^{10} sec^{-1} contrasting with $k_r = 7.8 \times 10^{11}$ sec^{-1} [2c] for dimethyltetraphenyldiene **1**.[10]

(1) For the previous paper in this series see H. E. Zimmerman, P. Baeckstrom, T. Johnson, and D. Kurtz, *J. Amer. Chem. Soc.*, **94**, 5504 (1972).

(2) (a) H. E. Zimmerman, R. W. Binkley, R. S. Givens, and M. A. Sherwin, *ibid.*, **89**, 3932 (1967); (b) H. E. Zimmerman and P. S. Mariano, *ibid.*, **91**, 1718 (1969); (c) H. E. Zimmerman and A. A. Baum, *ibid.*, **93**, 3646 (1971); (d) H. E. Zimmerman and A. C. Pratt, *ibid.*, **92**, 6259, 6267 (1970).

(3) In the gas phase with 112 kcal/mol of mercury sensitization simple di-π-methane systems lacking central substitution do rearrange. For example note: J. Meinwald and G. W. Smith, *ibid.*, **89**, 4923 (1967); R. Srinivasan and K. H. Carlough, *ibid.*, **89**, 4932 (1967).

(4) G. Wittig and B. Obermann, *Chem. Ber.*, **67**, 2053 (1934); **68**, 2214 (1935).

(5) All compounds analyzed properly. Full experimental details will appear in our full paper. Photolyses were run preparatively with a 450-Watt apparatus and quantitative runs were on our Black Box apparatus.[6]

(6) H. E. Zimmerman, *Mol. Photochem.*, 3, 281 (1971).

(7) (a) D. Juers, R. Boettcher, V. J. Hull, and H. E. Zimmerman, Digital Equipment Users Society Program No. 8-194; (b) D. Juers, Ph.D. Thesis, University of Wisconsin, 1971.

(8) D. H. Richards and N. F. Scilly, *J. Chem. Soc. C*, 2661 (1969).

(9) J. C. Dalton and N. J. Turro, *J. Amer. Chem. Soc.*, **93**, 3569 (1971).

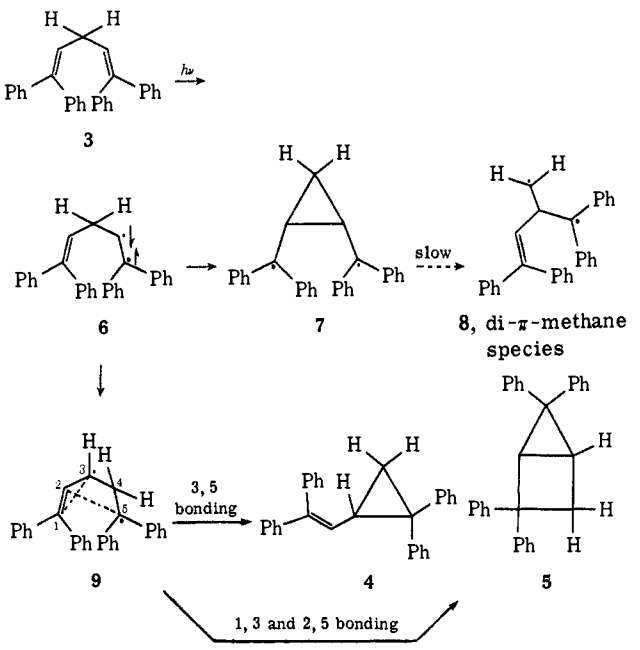
(10) These rates as determined by the indirect method described[2c,9] are best considered as relative to one another. Unpublished results from our laboratories obviate dependence on literature fluorescence quantum yields used for reference and give directly measured values. However, for consistency and comparison with reported values the indirect method is preferable here.

That the situation was more complex became apparent from irradiation of the dideuterio derivative **3b**[5] of the tetraphenyldiene **3a**. A simple di-π-methane mechanism of **3b** would afford vinylcyclopropane product **4** with deuteriums at C-2 and C-1′ and the two aliphatic hydrogens at C-3. Instead, nmr analysis indicated minimally the product consisted of 90% **4b** with single hydrogens at C-2 and C-3, a product not expected from the di-π-methane rearrangement of **3**. This means that, to the extent that an undetected di-π-methane process occurs at all, its efficiency of formation from the excited singlet must be even lower than that for **4** and is estimated as $\phi \leq 0.0002$ corresponding to $k_r \leq 1.2 \times 10^9$ sec^{-1}.

Thus, the central substitution of the dimethyltetraphenyldiene **1** seems essential for an efficient di-π-methane rearrangement.

It is seen that vinylcyclopropane **4b** arises from 1,2-excited state sigmatropic rearrangement of a central hydrogen atom as depicted in Chart I. The normal

Chart I. Mechanisms of Rearrangement of the Tetraphenyldiene **3**



di-π-methane route involves putting odd electron density on a primary carbon (note species **8**) and is inhibited,[11] accounting for its low rate. The inhibition of the usually facile di-π-methane rearrangement by diminished central substitution suggests that ring opening of species **7** plays a role in determining the excited state rate.[12] The reaction which does occur is the 1,2-hydrogen sigmatropic shift[13] leading to species **9**. 3,5-Bonding then leads directly to vinylcyclopropane product **4** while a unique 2,5- plus 1,3-bonding process affords housane **5**.[14] Overall this is $2_\sigma + 2_\pi + 2_\pi$ and could be concerted. Hence, one mechanism accounts for both unexpected products.

Acknowledgment. Support of this research by National Institutes of Health Grant No. GM 07487 and a NRC of Canada Postdoctoral Fellowship to J. A. P. is gratefully acknowledged.

(11) Di-π-methane systems involving phenyl migrations seem able to overcome this inhibition because of regeneration of aromaticity in this step. For examples note: (a) G. W. Griffin, A. F. Marcantonio, H. Kristinsson, R. C. Peterson, and C. S. Irving, *Tetrahedron Lett.*, 2951 (1965); (b) S. Hixson, *J. Amer. Chem. Soc.*, **94**, 2507 (1972).

(12) A conformational contribution to the central methyl effect is a possibility presently under study.

(13) Similar 1,2-hydrogen shifts have been observed in other systems.[11a]

(14) Previous studies[15] have indicated that vinylcyclopropane to housane interconversions do occur; this would fit the observed labeling. However, housane **5** is a primary photoproduct of the photolysis of tetraphenyldiene **3** since its quantum yield of formation is constant in runs varying from 2 to 8% conversion.

(15) H. Kristinsson and G. S. Hammond, *J. Amer. Chem. Soc.*, **89**, 5970 (1967).

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Bridging of Peptides to Solid Supports through the Dinitrophenylene Moiety. Bidirectional Extension of Peptide Chains[1-3]

Sir:

We wish to report on a method of peptide synthesis which permits the bidirectional (NH_2 and COOH directed) elaboration of a peptide chain starting with an amino acid anchored by its side chain *via* a thiol-labile linkage[4] to a solid support.[5]

The principle of the method is illustrated in Scheme I by the synthesis of thyrotropin-releasing hormone (TRH).[6-8] In brief, the histidine residue, bound to a solid support through an N^{im}-dinitrophenylene bridge, served as a point of departure from which the peptide chain was extended in the COOH and NH_2 terminal directions to yield resin-bound TRH. The hormone was liberated from the resin by treatment in DMF solution with 2-mercaptoethanol—an unusually mild treatment for the removal of a peptide from its polymeric support.

Boc-Glycine, esterified with chloromethylpolystyrene–2% divinylbenzene resin (5 g, 0.28 mequiv of glycine/g of esterified resin),[9] was converted to the free base. The esterified resin was washed with $CHCl_3$ and then suspended in 25 ml of $CHCl_3$ containing a large molar excess (5 g) of 1,5-difluoro-2,4-dinitrobenzene (FFDNB).[10] During the next 5 hr, a total of 0.2 ml of Et_3N was added in three portions to the agitated suspension; 2 hr later the yellow, ninhydrin-negative[12]

(1) Supported in part by U. S. Public Health Service Grants AM-10080 and AM-13567 and by the Atomic Energy Commission.

(2) Abbreviations follow the rules of the IUPAC-IUB Commission on Biochemical Nomenclature in *Biochem. J.*, **126**, 773 (1972).

(3) Analytical grade solvents were further purified prior to use: DMF was distilled *in vacuo*, stirred for 24 hr at 23° with (*Z*)-Leu-ONp, redistilled *in vacuo* under nitrogen, and stored over Linde 4A Molecular Sieve. Pyridine was distilled from NaOH pellets and triethylamine from ninhydrin. In addition, $CHCl_3$ and MeOH were distilled. Each "washing" procedure entailed the use of three 25-ml portions of the solvents in question; the solvents are cited in the order they were used.

(4) S. Shaltiel, *Biochem. Biophys. Res. Commun.*, **29**, 178 (1967).

(5) R. B. Merrifield, *J. Amer. Chem. Soc.*, **85**, 2149 (1963); *Science*, **150**, 178 (1965).

(6) A. V. Schally, T. W. Redding, C. Y. Bowers, and J. F. Barrett, *J. Biol. Chem.*, **244**, 4077 (1969).

(7) J. Bøler, F. Enzmann, K. Folkers, C. Y. Bowers, and A. V. Schally, *Biochem. Biophys. Res. Commun.*, 37, 705 (1969).

(8) R. Burgus, T. F. Dunn, D. Desiderio, and R. Guillemin, *C. R. Acad. Sci.*, **269**, 1870 (1969).

(9) R. B. Merrifield, *Biochemistry*, 3, 1385 (1964).

(10) The use of appropriate concentrations of FFDNB in the reaction mixture was successfully applied by Zahn and Meienhofer[11] in the selective preparation of monofunctional, bifunctional, or mixed bifunctional amino acid derivatives.

(11) H. Zahn and J. Meienhofer, *J. Makromol. Chem.*, **26**, 126 (1958).

(12) E. Kaiser, R. L. Colescott, C. D. Bossinger, and P. I. Cook, *Anal. Biochem.*, **34**, 595 (1970).