followed by stirring at room temperature for 2 h. The workup procedure included the bubbling of a stream of air through an acidic aqueous suspension of the reaction mixture, giving the crystalline tetracyclic acid VII, which was converted into the methyl ester VIII[23a] (mp 197.5–198.5 °C) in 42% yield for the two steps. Epoxidation of ester VIII with *m*-chloroperbenzoic acid gave epoxide IX (mp 233–234.5 °C), isolated in 85.8% yield.[14,23a] When a solution of the epoxide IX in acetonitrile was treated with sodium bromide and *p*-toluenesulfonic acid at room temperature, a single bromohydrin (X) (mp 192–194 °C) was obtained (87.6%). Examination of a Dreiding model reveals that trans-diaxial displacement on the epoxide ring[15] is favored from the C-8 direction. Removal of the bromide was accomplished by hydrogenolysis over palladium on charcoal in methanol in the presence of ammonium acetate and acetic acid,[16] giving the alcohol (XI)[23b] (mp 234–235 °C) in 53% yield. Demethylation of the 4-methoxy group proceeded smoothly with aluminum chloride in methylene chloride[17] at room temperature, and racemic 7-deoxyaklavinone[18] (XII) (mp 214–216 °C) was obtained in 81% yield. Radical initiated bromination gave the 7-bromo derivative[19] XIII, which was solvolyzed on a preparative silica gel thick layer chromatography plate during purification, giving racemic aklavinone (I)[20] (mp 207–209 °C) in 30% yield. When the solvolysis reaction was carried out in aqueous dioxane in the presence of calcium carbonate, the overall yield was improved to 54%.[21] The synthetic material was identical with a sample of the natural product[22] in terms of chromatographic properties and mass, infrared, ultraviolet, and nuclear magnetic resonance spectra.

We have achieved a regio- and stereospecific total synthesis of racemic aklavinone in 12 steps, in 1.7% yield, from readily available starting materials.

Acknowledgment. We thank Dr. L. Tökés, Dr. I. Massey, D. Cho, J. Smith, L. Lightman, Dr. M. Maddox, J. Nelson, L. Kurz, and the Syntex Analytical Department for their expert help in obtaining the analytical data and Drs. J. Edwards, J. G. Moffatt, J. Muchowski, and M. Marx for their encouragement throughout the course of this research effort. Yu Lin Wu thanks Dr. J. G. Moffatt for his support and encouragement.

Supplementary Material Available: Spectroscopic data (NMR, IR, MS, UV) and elemental analysis for compounds V and VIII–XII (3 pages). Ordering information is given on any current masthead page.

(14) Lin, H.-j.; Kumar, V.; Remers, W. A. *J. Med. Chem.* **1980**, *23*, 1242. In this publication, Remers reported that epoxidation of 8,9-dehydro-5-rhodomycinone obtained from degradation of a natural product gave a 6:4 mixture of α- and β-epoxides. Our epoxidation result was much more stereoselective. Examination of the thin-layer chromatogram showed that the β-epoxide (IX′) could not be as much as 10% of the crude product and was isolated in 2% yield. The C_{10} carbomethoxy group for the β isomer (IX′) has a chemical shift of δ 3.87, and the corresponding peak for the α-isomer (IX) is δ 3.69 in the NMR spectrum.

(15) See, for example: Eliel, E. L.; Allinger, N. L.; Angyal, S. J.; Morrison, G. A. "Conformational Analysis"; Wiley: New York, 1965; p 296. [The NMR spectrum of the bromohydrin X has a one-proton peak at δ 4.49 for C_8-H which appears as a d x d coupled to C_7-H_2 with J = 6, 9 Hz.]

(16) Ringold, H. J.; Löken, B.; Rosenkranz, G.; Sondheimer, F., *J. Am. Chem. Soc.* **1956**, *78*, 816. In this publication, the hydrogenation reaction was carried out in the presence of ammonium acetate with palladium–charcoal as the catalyst. We added acetic acid to the reaction mixture, since the original reaction conditions gave mainly the epoxide VIII, apparently the result of base-promoted cyclization.

(17) (a) Li, T.-t.; Ellison, R. H. *J. Am. Chem. Soc.* **1978**, *100*, 6263. (b) Kende, A. S.; Rizzi, J. P. *Tetrahedron Lett.* **1981**, 1779.

(18) Ollis, W. D.; Sutherland, I. O.; Veal, P. L. *Proc. Chem. Soc. (London)* **1960**, 349. The published mass spectrum of this material from the natural source (see: Brockmann, H., Jr.; Budzikiewicz, H.; Djerassi, C.; Brockmann, H.; Niemeyer, J. *Chem. Ber.* **1965**, *98*, 1260) is in agreement with that of our synthetic material.

(19) Kende, A. S.; Tsay, Y. G.; Mills, J. E. *J. Am. Chem. Soc.* **1976**, *98*, 1967.

(20) The solvolysis of 7-deoxy-7-bromodaunomycinone gave 7-*epi*-daunomycinone; however, 7-deoxy-7-bromoaklavinone solvolysis led directly to the desired configuration at C-7. This is in agreement with the result reported in a similar reaction (see: Kende, A. S.; Rizzi, J. P. *Tetrahedron Lett.* **1981**, 1779).

(21) Shanghai Institute of Organic Chemistry: *Hua Hsueh Hsueh Pao* **1978**, *36* (2), 155; *Chem. Abstr.* **1978**, *89*, 214953z.

(22) We are grateful to Dr. T. Oki and Dr. T. Takita of Tokyo Microbial Institute for a generous gift of an authentic sample of this natural product.

(23) (a) Spectroscopic data (NMR, IR, MS, UV) and elemental analysis for this compound are in accordance with the assigned structure. (b) Spectroscopic data (NMR, IR, MS, UV) and high-resolution MS for this compound are in accordance with the assigned structure. Melting points are measured in a Fisher–Jones hot plate and are uncorrected.

Unusual Sesterterpenoids from the Secretion of *Ceroplastes floridensis* (Coccidae), an Orchard Pest. Application of the Allylic Benzoate Method for Determination of Absolute Configuration

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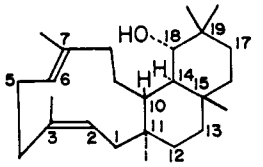
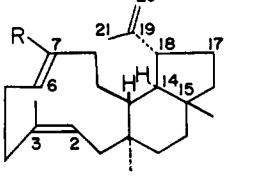
Received August 30, 1981

We report the structures of floridenol (**1**), 5α-hydroxyfloridenol (**2**), flocerol (**3**), and floceric acid (**4**), which represent two new skeletal classes of sesterterpenes, and the first actual application of a nonempirical method for determination of absolute configurations.

In recent years we have isolated numerous terpenoids and waxes including 12 new 14-membered-ring sesterterpenes from the secretion of the scale insect *Ceroplastes ceriferus* Anderson.[1-4] The present series **1–4** was isolated from *C. floridensis* (*japonicus*) Comstock (collected in Osaka Prefecture, March, 1979), a pest insect which infests persimmon, tangerine, and other orchards. The planar structure and relative configurations were determined by X-ray crystallographic studies of floridenone **5** (derived from floridenol **1**), NMR studies, and chemical correlations, whereas the absolute configuration rests on application of the recently developed allylic and homoallylic benzoate chirality method[5] to **2**. The compounds **1–4** were isolated by chloroform extraction of the insects, filtration of insect debris, concentration, addition of acetone,[2,4] and successive silica gel chromatography of the acetone-soluble fraction.





1 floridenol
2 5α-OH-floridenol(see 2a)
5 floridenone, 18-one
3 flocerol, R:CH_2OH
4 floceric acid, R:COOH
6 flocerene, R: Me

Floridenol (**1**), $C_{25}H_{42}O$ (EI–MS, m/z 358.322, calcd 358.323, M^+), mp 62–63 °C (from AcOH), $[\alpha]^{27}_D$ –81.2° (c 1.0, $CHCl_3$), has an IR (neat) band assignable to an OH at 3550 cm^{-1} which resisted acetylation. The ^1H NMR spectrum[6] of **1** showed the

(1) Naya, Y.; Miyamoto, F.; Takemoto, T. *Experientia* **1978**, *34*, 984.
(2) Miyamoto, F.; Naoki, H.; Takemoto, T.; Naya, Y. *Tetrahedron* **1979**, *35*, 1913.
(3) Naya, Y.; Miyamoto, F.; Kishida, K.; Kusumi, T.; Kakisawa, H.; Nakanishi, K., *Chem. Lett.* **1980**, 883.
(4) Miyamoto, F.; Naoki, H.; Naya, Y.; Nakanishi, K. *Tetrahedron* **1980**, *36*, 3481.
(5) Harada, N.; Iwabuchi, J.; Yokota, Y.; Uda, H.; Nakanishi, K. *J. Am. Chem. Soc.* **1981**, *103*, 5590.

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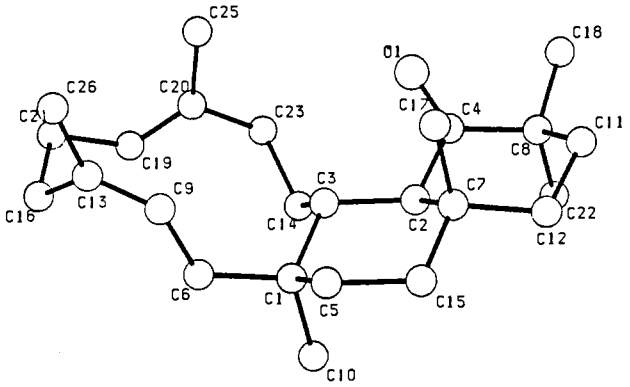
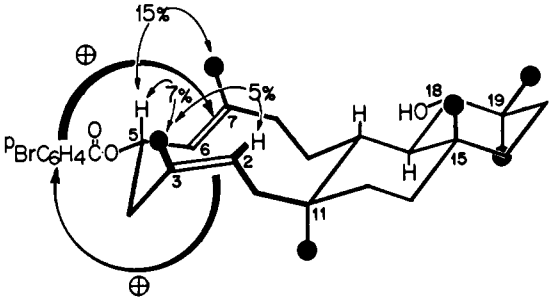


Figure 1.

presence of four quaternary Me's (0.79, 0.86, 0.92, and 1.01 ppm), two vinyl Me's (1.60, 1.73; both br s), a carbinyl proton attached to an equatorial OH (3.35, br d, J = 10 Hz, 18-H[7]), and two vinyl H's at 5.18 (br t, J = 8 Hz, 6-H[7]) and 5.40 ppm (br d, J = 10 Hz, 2-H[7]), the latter being coupled to one of the methylene H's at 2.36 ppm (dd, J = 16 and 10 Hz). The ^{13}C NMR[6] spectrum clarified the following carbons: six Me's [17.5, 19.5, 20.2 (7, γ-high field shift[2]), 22.2 (19 ax), 24.2 (3), 30.1 (19 eq)], nine CH_2's [25.6 (C-5), 31.6 (C-4), 31.7, 31.7, 34.8, 37.6, 38.2, 38.5, 39.0], three CH's [39.6, 47.3, 78.0 (C-18)], three quaternary carbons [36.5, 37.6, and 38.7], and four vinyl carbons [122.7 (C-6), 123.8 (C-2), 133.4 (C-3), 137.0 (C-7)].

Jones oxidation of floridenol gave the corresponding ketone, floridenone (**5**), $C_{25}H_{40}O$ (m/z 356.309, calcd 356.308), mp 95–96 °C (from EtOH), $[\alpha]^{24}_D$ −103.7° (c 0.98, $CHCl_3$); IR (Nujol) 1700 cm^{-1}. A single crystal of **5** with approximate dimensions 0.59 × 0.34 × 0.21 mm was submitted to X-ray analysis. The cell dimensions and intensity data were measured on an automatic Rigaku four-circle diffractometer by using Ni-filtered Cu Kα radiation (λ = 1.5418 Å). Intensity data of 1964 reflections with $2\theta \leq 120.0°$ were collected by the θ–2θ scan method. No absorption correction was applied. The structure was solved by direct methods with the program MULTAN78.[8] The positional and thermal parameters were refined by block-diagonal least-squares techniques with HBLS-5.[9] The final R value was 0.103 for 1685 nonzero reflections. Crystal data: $C_{25}H_{40}O$; M_r 356.59; orthorhombic; space group $p2_12_12_1$; a = 19.544 (6), b = 16.974 (5), c = 6.760 (1) Å; V = 2242.6 Å^3; D_c = 1.056 Mg m^{-3} for Z = 4; μ(Cu Kα) = 0.469 mm^{-1}.

The absolute configuration of floridenol **1** was determined from circular dichroic (CD) studies of the minor congener 5-hydroxyfloridenol (**2**), $C_{25}H_{42}O_2$ (m/z 374.319, calcd 374.319). A comparison of the ^{13}C NMR data of floridenol **1** with **2** established that the extra OH function in the latter was attached to C-5. Relative to **1**, the NMR peaks of **2** showed the following downfield shifts (in ppm): C-5, 43.0; C-4, 5.7; C-6, 5.7; C-7, 1.4; 7-Me, 2.6; 3-Me, 1.1. The C-3 peak was shifted 2.1 ppm upfield, whereas the shifts for all other carbons were less than 0.5 ppm. The 5α configuration was evident from ^{1}H NMR data of **2** and NOE data of 2-*p*-bromobenzoate. Approximately 1 mg of **2** was converted into its mono-*p*-bromobenzoate (as in **1** the 18-OH resisted benzoylation); the ^{1}H NMR data, in particular the NOE values,[10] indicate that the 11-membered ring adopts the conformation depicted in **2a** which is similar to that of floridenone **5** (Figure 1).[11] The CD of the bromobenzoate, UV (isooctane) 244 nm, had a positive Cotton effect at 242 nm (isooctane) with $\Delta\epsilon$ +12.[12] We have recently shown that in allylic benzoate systems, the double bond $\pi\pi^*$ transition at 195 nm and the benzoate ^1L_a transition constitute a coupled oscillator and that the signs of CD Cotton effects arising from the ^1L_a benzoate transition represent the chirality between the double bond and allylic C–O bond.[5] The positive sign of the 242-nm Cotton effect thus leads to the absolute configuration shown in **2a**. The absolute value of $\Delta\epsilon$ (+12) is considerably larger than that of cholest-4-en-3β-(*p*-bromobenzoate) ($\Delta\epsilon$ −7.00),[5,13] a typical allylic benzoate; this fact is attributed to the presence of *two positive chiralities*, i.e., the homoallylic 2-ene/5-benzoate system *and* the allylic 5-benzoate/6-ene system (see **2a**) which exert their effects in an additive manner.[14]



2a Methyl groups are indicated by black circles. Thin arrows denote NOE. Thick arrows show the chirality of the 2-ene/5-benzoate system and that of the 5-benzoate/6-ene system.

Flocerol (**3**), oil, $C_{25}H_{40}O$ (m/z 356.305, calcd 356.308, M$^+$), $[\alpha]^{24}_D$ −130.9° (c 2.33, $CHCl_3$), IR (neat) 3400 cm^{-1} (OH), 1635 and 880 (=CH_2), showed the following ^{1}H NMR peaks: 0.78 and 0.80 (quaternary Me's), 1.74 (s, 6 H, 2 vinyl Me's), 2.68 (18-H, dt, J = 10, 4 Hz), 3.93 (7-CH_2O, br s), 4.64 and 4.80 (20-H's, d, J = 2 Hz), 5.36 (6-H, deformed t, J = 8 Hz), and 5.48 (2-H, d, J = 10 Hz). The ^{13}C NMR spectrum showed peaks corresponding to the various carbons expected for structure **3**, the pertinent peaks being the following: 21.4 (q, 21-), 109.9 (t, 20-), 62.1 (t, 7-CH_2O). The structure of flocerol (**3**) was established as follows.

Catalytic hydrogenation of **3** on Pd/$BaSO_4$ in ethanol–ether resulted in hydrogenolysis to give a hydrocarbon flocerene (**6**), $C_{25}H_{40}$ (m/z 340), $[\alpha]^{26}_D$ −88.5° (c 0.9, $CHCl_3$), in which the hydroxymethylene NMR signals of **3** at 3.93 (^{1}H) and 61.2 ppm (^{13}C) has been replaced by vinyl Me signals at 1.58 and 20.4 ppm. The fact that this newly formed Me signal absorbed at the high field of 20.4 ppm showed that it was subject to a γ effect and hence is attached to C-7; i.e., the hydroxymethyl group in flocerol (**3**) should be linked to C-7. The same hydrocarbon flocerone **6** was also produced from floridenol **1** by skeletal rearrangement upon treatment with mesyl chloride/triethylamine in dichloromethane at 0 °C. Thus floridenol **1** and flocerol **3** have identical configurations at ring junctions, and the isopropenyl configuration in

(6) All ^{1}H and ^{13}C NMR spectra were taken in $CDCl_3$; 100-MHz and/or 360-MHz spectrometers (ppm), Me_4Si as internal standard.

(7) The numbering system is based on that of the presumed biogenetic precursor geranylfarnesyl cation.

(8) Main, P.; Hull, S. E.; Lessinger, L.; Germain, G.; Declercq, J. P.; Woolfson, M. M. MULTAN78, 1978. A system of Computer Programs for the Automatic Solution of Crystal Structures from X-ray Diffraction Data, University of York, England.

(9) Ashida, T. The Universal Crystallographic Computing System—Osaka; The Computing Center: Osaka University, Japan, 1973; pp. 55–61.

(10) The NOE values were obtained from difference spectra.

(11) Computer analysis carried out by Professor W. C. Still, Columbia University, using the Allinger MM2 force field program (obtained from Quantum Chemistry Exchange, QCPE Program No. 395), also showed that the 11-membered-ring conformation depicted in **2a** and Figure 1 is favored by 3 kcal over the next stablest conformation.

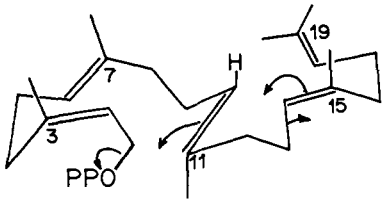
(12) The concentration of the CD solution was estimated from the absorbance of the UV of *p*-bromobenzoates, the ϵ of which have a value of ca. 21 300 (Ref. 13).

(13) The $\Delta\epsilon$ of coupled CD Cotton effects are dependent on the interchromophoric angles, but the $\Delta\epsilon$ +12 value is too large for a single interaction between the double bond and a p-bromobenzoate (calculation by Dr. N. Harada).

(14) The amplitude of the exciton-split CD curve of a system consisting of multiple interacting chromophores can be approximated by the sum of each interacting chromophoric pair. For example, the CD amplitude of a system with three interacting chromophores I, II, and III can be represented by the sum of component amplitudes I/II plus II/III plus III/I; Liu, H. W.; Nakanishi, K. *J. Am. Chem. Soc.* **1981**, *103*, 5591.

3 is the same as that of 18-OH in **1**, i.e., α.

Floceric acid **4** was obtained as needles, mp 149.5–151 °C (from petroleum ether), $C_{25}H_{38}O_2$ (*m/z* 370.287, calcd 370.287 M^+), $[\alpha]^{22}_D$ −203° (*c* 2.3, $CHCl_3$), IR (neat) 1680 and 1635 cm^{-1} (α,β-unsaturated COOH). LAH reduction of the acid yielded flocerol (**3**), and this establishes its structure as **4**.



7

These unprecedented sesterterpenoid skeletons may biogenetically be derived from a head-to-tail cyclization of 2-(*Z*)-geranylfarnesyl pyrophosphate involving migration as shown in **7**. The biological role of these sesterterpenoids remains to be clarified.

Supplementary Material Available: Physical properties (IR, MS, ^1H and ^{13}C NMR spectra) of the compounds **1–6** and tables of fractional coordinates, thermal parameters, bond distances, and bond angles of compound **5** (42 pages). Ordering information is given on any current masthead page.

Thermal Rearrangement of an Allenic Diazoalkane and Intermolecular Capture of a Diazoethene by a Cyclopropene To Give a Common Dihydropyridazine Product

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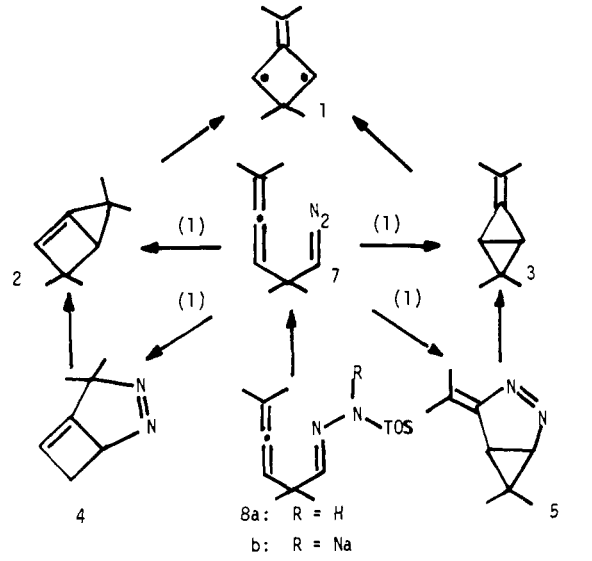
Received June 22, 1981

In an exploration of synthetic pathways to a 2-alkylidenecyclobutane-1,3-diyl (**1**) and some of its potential precursors (Scheme I, hydrocarbons **2** and **3**, diazenes **4** and **5**), we have discovered two novel rearrangements which surprisingly give the identical product from two apparently unrelated reactions. The observations bear on the credibility of the previously postulated[2,3] but so far elusive diazoethenes (e.g., **6**).

We examined two alternative synthetic approaches: In Scheme I, generation of the allenic diazo compound **7** from the *p*-toluenesulfonylhydrazonate **8b** followed by intramolecular 1,3-cycloaddition of **7** would give the diazenes **4** and/or **5**, which might serve as sources of **2** and **3**, or deazetation of **7** followed by cyclization of the resulting carbene would give **2** and/or **3** directly. In Scheme II, generation of a dimethylvinylidene equivalent **9** via **6**, formed from the reaction of acetone with the diazophosphonate **10** and (a) KO-*t*-Bu[2] or (b) BuLi[3] followed by cycloaddition to 3,3-dimethylcyclopropene (**16**), would give **3**. The carbenoid **9** or a closely related species also could be formed by (c) α elimination from 1,1-dibromo-2-methylpropene (**11**) by treatment with BuLi.[4]

Pyrolysis of **8b** in boiling benzene for 3 h (see Scheme I) gives no volatile hydrocarbons but instead gives a 48% yield of 4,4-dimethyl-6-isopropenyl-1,4-dihydropyridazine (**12**, Scheme III), colorless prisms, mp 62–64 °C, from CH_2Cl_2/petroleum ether. The structure of **12** is deduced from its spectroscopic properties,[5] its smooth reduction to the dihydro derivative **13**,[5] and a crystal X-ray diffraction analysis.[5] In boiling CCl_4, the same reaction

Scheme I



Scheme II

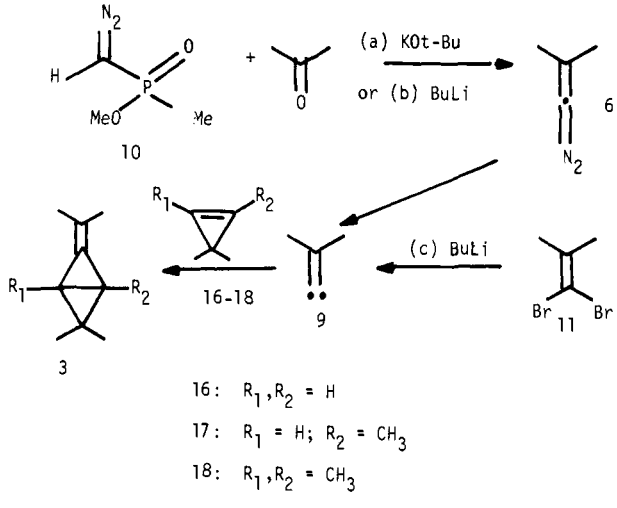
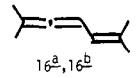
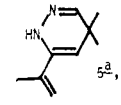
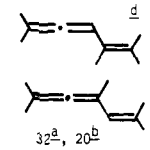


Table I. Products from the Reactions of Dimethyl Diazomethylphosphonate (**10**), Acetone, and Cyclopropenes

	products, % yield[c]	
cyclopropene	allenes	nitrogenous compd
 16	 16[a],16[b]	 5[a],10[b]
 17	 32[a], 20[b]	none
 18	none[e]	none

[a] Method a, Scheme II. [b] Method b, Scheme II. [c] Isolated by GC. [d] Unstable. Not obtained pure but identified spectroscopically (see supplementary material) in the reaction mixture from method c, Scheme II. [e] Major hydrocarbon products are 2,5-dimethylhexa-2,3,4-triene (carbene dimer) and 1-isopropylidene-3,4,4-trimethylspiro[2.2]pentane from method c.

(1) National Science Foundation Graduate Fellow, 1979–1981.
(2) (a) Gilbert, J. C.; Weerasooriya, U.; Giamalva, D. *Tetrahedron Lett.* **1979**, 4619; (b) Gilbert, J. C.; Weerasooriya, U. *J. Org. Chem.* **1979**, *44*, 4997.
(3) Colvin, E. W.; Hamill, B. J. *J. Chem. Soc., Perkin Trans. 1* **1977**, 869.
(4) Hartzler, H. D. *J. Am. Chem. Soc.* **1964**, *86*, 526.
(5) Described in supplementary material.

0002-7863/81/1503-7011$01.25/0