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(11) In compound **13**, where C-3 hybridization is now sp^3, the coupling constant for the protons on C-4–C-5 is slightly reduced to 5 Hz, again supporting the sterochemical assignment. Cf. O. Ben-Ishai and E. Goldstein, *Tetrahedron*, 3119 (1971), for coupling constants in a similar system.
(12) Compounds **12** and **13** each exist with a single, but unknown, stereochemistry at C-3.
(13) Fellow of the Alfred P. Sloan Foundation, 1975–1977; National Institutes of Health Research Career Development Awardee, 1975–1980.

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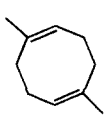
Transannular Cyclizations. A Stereoselective Synthesis of the Cyclopentanoid Monoterpenes

Summary: A highly stereoselective method of cyclopentanoid ring formation by transannular cyclization of cyclooctane systems is described. Its utility is illustrated by a total synthesis of the monoterpene iridomyrmecin.

Sir: We wish to report an approach to the synthesis of the cyclopentanoid class of monoterpenes which commences with the novel head-to-tail isoprene dimer 1,5-dimethyl-1,5-cyclooctadiene[1] (1) and which makes use of a transannular cyclization[2] to construct the carbon framework of a key intermediate in a stereoselective manner. The route, illustrated by the total synthesis of the naturally occurring insecticide iridomyrmecin, isolated from the Argentine and *Iridomyrmex humilis*, could potentially be diverted at suitable points to synthesize many of the cyclopentanoid monoterpenes.[3]

The diene **1**[4] was converted into alcohol **2a**[5] (75% yield)



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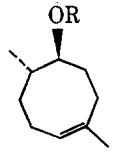
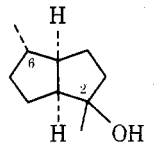


2a, R = H
b, R = SO_2CH_3

by a selective monohydroboration–oxidation sequence employing 9-borabicyclo[3.3.1]nonane,[6] and thence to the sulfonate ester **2b** with methanesulfonyl chloride and triethylamine in methylene chloride.[7] Without purification, this ester was subjected to solvolysis for 12 hr at 60° in aqueous dioxane in the presence of an excess of sodium carbonate. The alcohol **3** (60% yield overall from **2a**) thereby produced has the indicated orientation of the C-6 methyl group (exo- to the cis-fused bicyclo[3.3.0]octane system) that both follows from and is required for a successful synthesis of iridomyrmecin. The stereochemical control observed in this cyclization is the result of π-electron participation in the solvolytic removal of the sulfonyloxy group and thus the exo orientation at C-6 can be attributed directly to the trans relationship of the methyl group and the sulfonate moiety in **2b**. Though the reaction could have alternatively occurred without assistance while still generating the product of transannular cyclization, consideration of molecular models indicates that the C-6 epimer would be expected to be the predominent product of such a process.[8] Alcohol **3** was transformed into olefin **4** (70% yield) by a *p*-



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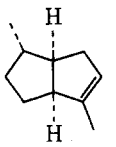
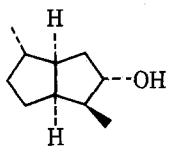


4

toluenesulfonic acid catalyzed dehydration in pentane at reflux to effect azeotropic removal of water. A second hydroboration–oxidation sequence using diborane served to convert olefin **4** into alcohol **5** (60% yield) containing a small amount of a second alcohol, possibly that resulting from attack by diborane on the endo face of olefin **4**. Alcohol **5** was converted into the corresponding ketone (**6**, 90%



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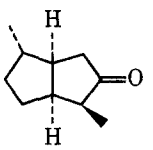
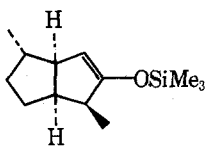


6

yield) by Jones oxidation.[9] The kinetic enolate of this ketone was generated with lithium diisopropylamide in tetrahydrofuran solution and then trapped by trimethylsilyl chloride to form the unstable enolsilyl ether **7**. Without isolation of intermediates, the enol ether **7** was cleaved with



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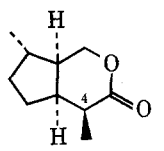

iridomyrmecin

ozone in methanol–methylene chloride solution,[10] the resulting acid–aldehyde was reduced with sodium borohydride, and the hydroxy acid was subjected to aqueous hydrochloric acid to effect lactonization. The crude material thus formed (40% overall yield from ketone **6**) crystallized spontaneously and could be recrystallized from pentane to afford needles with mp 57–58° (lit. 59° for racemic iridomyrmecin).[11,12] Further confirmation of the structure was provided by the conversion of iridomyrmecin into the more stable C-4 epimer, isoiridomyrmecin, by the known procedure.[11,12]

Acknowledgment is gratefully made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, for financial support of this research.

References and Notes

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routes, see G. W. K. Cavill in "Cyclopentanoid Terpene Derivatives", W. I. Taylor and A. R. Battersby, Ed., Marcel Dekker, New York, N.Y., 1969, Chapter 3; and G. W. K. Cavill and D. V. Clark in "Naturally Occurring Insecticides", M. Jacobson and D. J. Grosby, Ed., Marcel Dekker, New York, N.Y., 1971, Chapter 7.
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(5) Proton and ^{13}C magnetic resonance, infrared, and low resolution mass spectral data as well as either elemental analytical or high resolution mass spectral data consistent with the proposed structures of all intermediates were obtained. All of the intermediates were obtained as oils.
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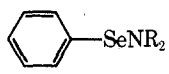
Organoselenium Chemistry. Preparation and Reactions of Benzeneselenenamides

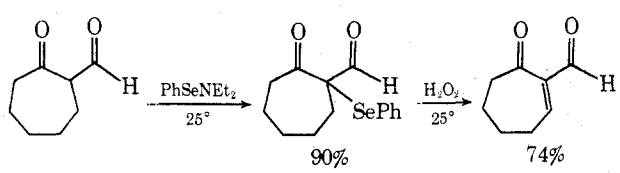
Summary: *N,N*-Dialkylbenzeneselenenamides react with β-dicarbonyl compounds to give β-dicarbonyl selenides, with acetic anhydride to give benzeneselenenyl acetate, and with some enones to give α-phenylseleno-β-dialkylamino ketones.

Sir: The chemistry of the amides of selenenic acids (selenenamides) has been little studied.[1] We have prepared several simple *N,N*-dialkylbenzeneselenenamides (**1a–c**) by reaction of secondary amines with PhSeCl, PhSeBr, or PhSeOH (generated in situ by selenoxide syn elimination) and examined their chemistry.[2] Compound **1a**[3a] is rather easily hydrolyzed and should be handled with appropriate care. The more hindered diethyl (**1b**)[3b] and diisopropyl (**1c**)[3b] derivatives are substantially more resistant to hydrolysis.

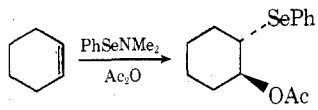


1a, R = CH_3
b, R = CH_2CH_3
c, R = $CH(CH_3)_2$

Selenenamides undergo a number of reactions similar to those of the analogous sulfenamides. For example, 2-formylcycloheptanone is selenenylated cleanly and rapidly by reaction with **1b** or **1c**.[3c,d] Careful oxidation of the selenide with hydrogen peroxide (2 equiv) then leads to β-dicarbonyl enone.[4,5a–c]

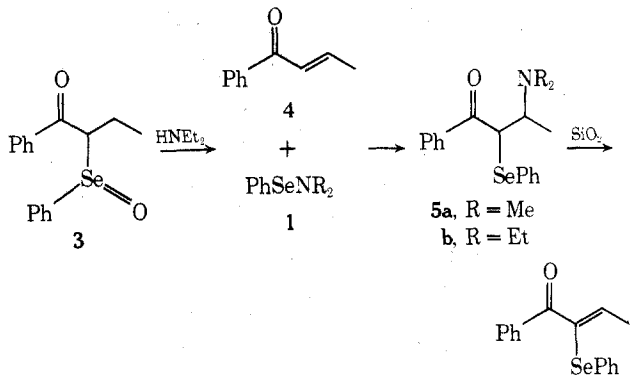


Compound **1a** reacts with acetic anhydride in the presence of cyclohexene to give the adduct **2**. Apparently benzeneselenenyl acetate ($PhSeO_2CCH_3$)[5d,6,7] is formed under these conditions.



2 (80%)

A reaction of selenenamides which appears to have no parallel in sulfur chemistry[8] is the addition to electron-deficient olefins. This reaction was discovered when **3** was warmed in the presence of diethylamine. Selenoxide syn elimination gives a mixture of enone **4** and selenenamide[9] **1b**. These compounds then react with each other slowly at 25° to give a new product identified from its spectral data as **5b**.[10] Similar results were obtained when pure **1a** or **1b** and **4** were allowed to react. Attempted purification of **5** by chromatography on silica gel resulted in elimination of dialkylamine giving **6** (88% yield using **1a**).

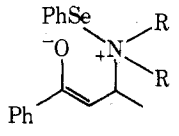


3 **1** **5a**, R = Me; **b**, R = Et

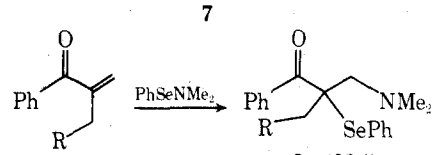
6

The formation of **5** probably occurs by a Michael addition leading to **7**, followed by an intramolecular selenenylation. Indirect evidence for a long-lived reversibly formed intermediate is provided by the observation that the cis isomer of **4** is isomerized to **4** in the presence of **1b**.[11]

The addition of selenenamides to α,β-unsaturated carbonyl compounds is successful only with some of the more reactive Michael acceptors,[12] and **1a** is significantly more reactive than **1b** or **1c**. Benzene and chloroform are the preferred solvents for the addition. Addition of **1a** in chloroform to compound **8a** is complete in 18 hr, **8b** requires 3 days, while 2-ethyl-1-phenyl-2-buten-1-one is incomplete after several weeks.



7



8a, R = H
b, R = CH_3

9a (93%)
b (94%)

Of several possible transformations of the adducts **9** we have examined oxidation and subsequent selenoxide elimination. Oxidation of **9a** with *m*-chloroperbenzoic acid at −40° followed by warming to room temperature leads to **10a** in good yield. Only trace amounts of the products **11a** and **12a** resulting from elimination toward the dimethylamino group are formed. The additional substituent in **9b** almost equalizes the ratio of elimination directions. The product **12b** is apparently formed by reaction of **11b** with an active selenenylating reagent (PhSeOH or a dispropor-