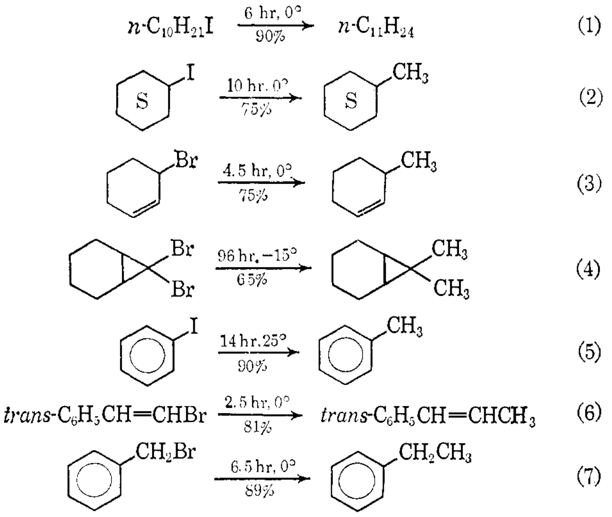
Gilman and co-workers[2] have previously prepared two methylcopper derivatives, one an insoluble, probably polymeric reagent, $(CH_3Cu)_n$, from equimolar amounts of methyllithium (or methyl Grignard reagent) and cuprous halide in ether, and the other an ether-soluble complex from 2 mole equiv of methyllithium to 1 of cuprous halide, perhaps representable as $Li^+(CH_3)_2Cu^-$, in which the anion is isoelectronic with dimethylzinc.[3] Our studies indicate that the latter complex, referred to herein as lithium dimethylcopper, is an excellent reagent for the selective replacement of iodine or bromine in a wide variety of substrates by methyl. In general, ethereal solutions of the reagent were prepared from the reaction of ethereal methyllithium (from lithium and methyl bromide) with cuprous iodide (molar ratio 2:1) at 0° under nitrogen, and most of the methylations were performed at 0° [4] with 5 moles of the copper reagent (concentration *ca.* 0.5 *M*) per mole of halide. In all cases products were analyzed by vapor phase chromatography, isolated, and characterized by comparison with authentic samples.[5] Equations 1–7 typify the transformations which have been observed with the lithium dimethylcopper reagent in ether solution.



Appreciable amounts of by-products were observed in some instances, specifically *exo*-7-methylnorcarane[6] (25%) in reaction 4 and *trans,trans*-1,4-diphenylbutadiene (12%) in the case of reaction 6.

Reaction 6 occurs *stereospecifically* and, in addition, *cis*-1-bromo-2-phenylethylene is stereospecifically converted to *cis*-1-phenylpropene. In contrast, however, *cis*-1-bromo-4-*t*-butylcyclohexane[7] reacts with lithium dimethylcopper *nonstereospecifically* to give a mixture of 45% *trans*-1-methyl-4-*t*-butylcyclohexane and 10% *cis*-1-methyl-4-*t*-butylcyclohexane, in addition to some *t*-butylcyclohexane and 4-*t*-butylcyclohexene. Further study is required before the stereochemical and mechanistic details of these methylation reactions can be understood. However, the broad scope and utility of the method are apparent.[8,9] It should be noted that methyllithium itself is a totally unsatisfactory reagent for the majority of the transformations 1–7. For example, the reaction of methyllithium with 7,7-dibromonorcarane affords little if any 7,7-dimethylnorcarane,[10,11] and the reaction of methyllithium with the 1-bromo-2-phenylethylenes produces mainly phenylacetylene.

A number of previous studies are clearly relevant to the presently reported results. These include observations on the intermediacy of arylcopper compounds in the Ullmann synthesis of biphenyls,[12–14] the coupling of cuprous acetylides with aryl iodides,[15] and the well-known substitution reactions of cuprous cyanide and cuprous mercaptides with aromatic halides.[16]

Investigations are continuing on the extension, refinement, and application of the cross-coupling method reported here.

Acknowledgment. We thank the National Institutes of Health and the National Science Foundation for support of this work.

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[2] H. Gilman, R. G. Jones, and L. A. Woods, *J. Org. Chem.*, 17, 1630 (1952); also see H. Gilman and J. M. Straley, *Rec. Trav. Chim.*, **55**, 821 (1936).

[3] See H. O. House, W. L. Respess, and G. M. Whitesides, *J. Org. Chem.*, 31, 3128 (1966).

[4] All reactions involving organocopper reagents were carried out with the usual precautions for rigorous exclusion of air and moisture. The insoluble methylcopper is inferior to lithium dimethylcopper as a nucleophilic methylating reagent, since the reactions of the former are inordinately slow.

[5] Using infrared, nuclear magnetic resonance, and in some cases mass spectroscopy in addition to vapor chromatographic data.

[6] G. Wittig and M. Jautelat, *Ann.*, 702, 24 (1967); M. Jautelat, Ph.D. Thesis, Heidelberg, 1966; H. E. Simmons, E. P. Blanchard, and R. D. Smith, *J. Am. Chem. Soc.*, **86**, 1347 (1964). For the previously described several-step synthesis of 7,7-dimethylnorcarane see E. D. Andrews and W. E. Harvey, *J. Chem. Soc.*, 4636 (1964).

[7] E. L. Eliel and R. G. Haber, *J. Org. Chem.*, **24**, 143 (1959).

[8] For the application of organocopper reagents in conjugate addition to α,β-unsaturated ketones which originates from the work of Kharasch, see ref 3 and literature cited therein.

[9] For recent studies on the formation of symmetrical coupling products by thermal decomposition of vinylcopper compounds (and vinylsilver compound), see (a) G. M. Whitesides and C. P. Casey, *J. Am. Chem. Soc.*, **88**, 4541 (1966); (b) T. Kauffmann and W. Sahm, *Angew. Chem. Intern. Ed. Engl.*, **6**, 85 (1967); (c) G. Köbrich, H. Fröhlich, and W. Drischel, *J. Organometal. Chem.* (Amsterdam), **6**, 194 (1966).

[10] (a) W. R. Moore and H. R. Ward, *J. Org. Chem.*, **25**, 2073 (1960); (b) *ibid.*, 27, 4179 (1962); (c) W. R. Moore, H. R. Ward, and R. F. Merritt, *J. Am. Chem. Soc.*, **83**, 2019 (1961).

[11] E. T. Marquis and P. D. Gardner, *Tetrahedron Letters*, 2793 (1966).

[12] R. G. R. Bacon and H. A. O. Hill, *Quart. Rev.* (London), **19**, 95 (1965).

[13] A. H. Lewin and T. Cohen, *Tetrahedron Letters*, 4531 (1965).

[14] M. Nilsson, *ibid.*, 679 (1966).

[15] C. E. Castro, E. J. Gaughan, and D. C. Owsley, *J. Org. Chem.*, 31, 4071 (1966), and earlier papers cited therein.

[16] See, for example, R. Adams, W. Reifschneider, and A. Ferretti, *Org. Syn.*, **42**, 22 (1962).

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Construction of Ring Systems Containing the *gem*-Dimethylcyclopropane Unit Using Diphenylsulfonium Isopropylide

Sir:

The generation of the highly reactive sulfur ylide diphenylsulfonium isopropylide (I) and the interaction of this reagent with *nonconjugated* aldehydes and ketones to form oxiranes have recently been described.[1–3]

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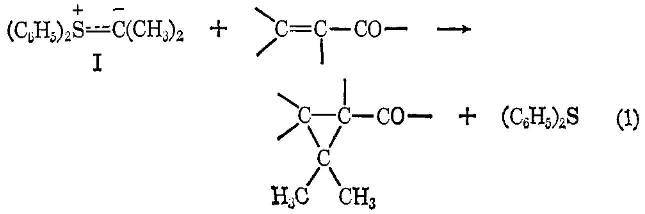
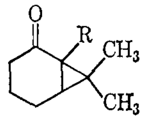
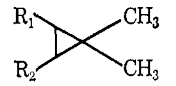
[1] E. J. Corey, M. Jautelat, and W. Oppolzer, *Tetrahedron Letters*, 2325 (1967).

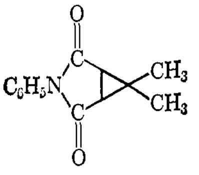
[2] Diphenylsulfonium isopropylide can be generated by two different procedures:[1] (a) from diphenylethylsulfonium fluoroborate in dimethoxyethane by the sequence ylide formation (dichloromethyllithium, produced *in situ* from lithium diisopropylamide and methylene chloride, as base at −70°), methylation (methyl iodide), and ylide formation (dichloromethyllithium at −70°); (b) from diphenylisopropylsulfonium fluoroborate in tetrahydrofuran at −70° using *t*-butyllithium as base.

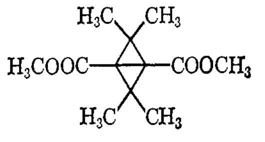
We report here a novel and direct approach to the *gem*-dimethylcyclopropane system using the reaction of I with *conjugated* carbonyl compounds as described by eq 1. The isopropylidene transfer reaction can be carried out generally using equivalent amounts of the ylide I and the unsaturated carbonyl compound at temperatures in the range −70 to −20° under nitrogen.[4] The following cyclopropane derivatives were obtained cleanly from the ylide I:[5] II (from 2-cyclohexenone at −60°, 1.5 hr, liquid, 74% yield); III (from 2-methyl-2-cyclohexenone, −70 to −30°, 3 hr, liquid, 86% yield); IV (from methyl acrylate at −70 to −50°, 1.5 hr, liquid, 71% yield); *trans*-V (stereospecifically from dimethyl fumarate at −70°, 1.5 hr, liquid, 82% yield); *cis*-V (along with some *trans*-V, *cis*:*trans* ratio 7:1, from dimethyl maleate, −70°, 1.5 hr, liquid, 75% yield of *cis*-V); *cis*-VI (from N-phenylmaleimide, −70 to −50°, 2 hr, 84%, mp 142–144° (lit.[5] mp 143°)); VII[6,7] (from dimethyl acetylenedicarboxylate, −70 to −50°, 2 hr, liquid, 16% yield).




II, R = H
III, R = CH₃

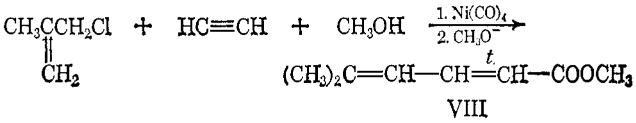

IV, $R_1 = H$; $R_2 = COOCH_3$
V, $R_1 = R_2 = COOCH_3$

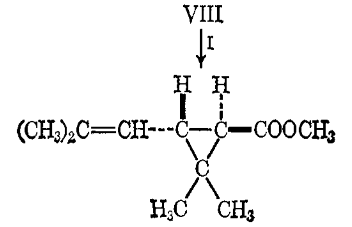

VI


VII

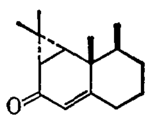
The reaction of the isopropylide I with 2-cyclohexenone reveals a much greater tendency of this ylide to form a cyclopropane by α,β addition rather than an oxirane by carbonyl addition, and a sharp contrast with dimethylsulfonium methylide[3a] which affords only oxirane with 2-cyclohexenone.[8] Even with the isopropylide I, it is apparent that the balance between ethylenic and carbonyl addition possibilities is strongly influenced by structural features of the enone system, particularly with regard to the substituents at the carbonyl carbon and the β-carbon. For example, 3-methyl-2-cyclohexenone reacts with I to form mainly unsaturated oxirane.

The availability of the isopropylidene transfer reagent I has made possible a new synthesis of the important insecticidal natural product chrysanthemic acid by a particularly simple, stereospecific route. Methyl 5-methyl-*trans*-2,4-hexadienoate (VIII), which is readily available from the reaction of methallyl chloride, acetylene, and methanol in the presence of nickel carbonyl[9] followed by treatment with sodium methoxide, affords cleanly (±)-methyl *trans*-chrysanthemate (IX) by reaction with 1 equiv of the isopropylide I; the experimental procedure for this synthesis is typical:[10]


$$\underset{\underset{CH_2}{\|}}{CH_3C}CH_2Cl + HC{\equiv}CH + CH_3OH \xrightarrow[2.\ CH_3O^-]{1.\ Ni(CO)_4} \underset{t}{(CH_3)_2C{=}CH{-}CH{=}CH{-}COOCH_3}$$
VIII



IX


X

(±)-**Methyl** ***trans*****-Chrysanthemate**. A solution of 3.0 g (0.01 mole) of diphenylethylsulfonium fluoroborate[11] and 0.85 g (0.01 mole) of methylene chloride in 100 ml of dry dimethoxyethane (distilled from lithium aluminum hydride) under nitrogen was cooled to −70° and treated with 0.011 mole of a cold solution of lithium diisopropylamide (reagent prepared freshly by the addition of 7.0 ml of 1.6 *M* *n*-butyllithium in hexane to 1.12 g of diisopropylamine in 10 ml of dimethoxyethane at −70°). The yellow-green solution which resulted became cloudy after 10 min. After 30 min at −70° the solution was treated with 1.50 g (0.0105 mole) of methyl iodide and the reaction mixture was maintained at −70 to −50° for 2 hr, at the end of which time 0.011 mole of lithium diisopropylamide solution was again added at −70°; an orange color

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(3) For similar examples of oxirane formation from less substituted sulfonium ylides see (a) E. J. Corey and M. Chaykovsky, *J. Am. Chem. Soc.*, **87**, 1353 (1965), and earlier papers therein cited; (b) E. J. Corey and W. Oppolzer, *ibid.*, **86**, 1899 (1964); (c) V. Franzen and H.-E. Driessen, *Chem. Ber.*, **96**, 1881 (1963); (d) A. W. Johnson, V. J. Hruby, and J. L. Williams, *J. Am. Chem. Soc.*, **86**, 918 (1964).

(4) All reactions involving the ylide I must be conducted with rigorous exclusion of air and moisture. In addition, because of the thermal unstability of I, the safe upper limit of temperature for its reactions is −20°. The initial temperature for the reactions described herein was −70°, and reactions which proceeded within a few hours at −70 to −50° (as judged by the fading of the orange color due to I) were conducted in this range; with relatively unreactive carbonyl compounds a reaction temperature of −30 to −20° is recommended.

(5) The yields reported are for isolated products, purification (from the co-product diphenyl sulfide) being accomplished simply by distillation, except for VI (previously reported by M. R. Loquin, *Bull. Soc. Chim. France*, [4] 15, 747 (1914)) which was obtained by chromatography and recrystallization and VII which was separated by thin layer chromatography on silica gel. All new compounds were identified unambiguously by elemental analysis and by nuclear magnetic resonance, infrared, and mass spectroscopy. The peaks due to *gem*-dimethyl appear in the nmr spectra in the range 1.1–1.4 ppm (downfield from internal tetramethylsilane) as follows: II, 1.05, 1.15; III, 1.11, 1.27; IV, 1.15, 1.20; *trans*-V, 1.28; *cis*-V, 1.15, 1.40; VI, 1.25, 1.38; VII, 1.43, 1.46.

(6) The bicyclo[1.1.1]butane VII has recently been reported as one of three products of photodecomposition of the pyrazolopyrazole from 2-diazopropane and dimethyl acetylenedicarboxylate: M. Franck-Neumann, *Angew. Chem. Intern. Ed. Engl.*, **6**, 79 (1967). The nmr data reported are in agreement with those found for VII in the present work.

(7) The major product of this reaction is dimethyl 2,3-diisopropylidenesuccinate (70% yield); see ref 6.

(8) Dimethyloxosulfonium methylide, however, transfers methylene to the ethylenic linkage of 2-cyclohexenone; see ref 3a.

(9) See G. P. Chiusoli and S. Merzoni, *Angew. Chem. Intern. Ed. Engl.*, **6**, 124 (1967).

(10) For another recent synthesis of chrysanthemic acid see (a) M. Julia and A. Guy-Rouault, *Bull. Soc. Chim. France*, 1411 (1967). (b) A general review appears in L. Crombie and M. Elliott, *Fortsch. Chem. Org. Naturstoffe*, **19**, 120 (1961). It is noteworthy that the cyclopropane ring of chrysanthemic acid has now been accomplished by each of the three possible ways involving attachment of a disubstituted carbon unit to an olefinic unit.

(11) From diphenyl sulfide and triethyloxonium fluoroborate (H. Meerivein, *Org. Syn.* **46**, 113 (1966)).

was produced rapidly. After 1 hr at $-70°$, 1.40 g (0.01 mole) of VIII[9] was added, and the orange solution was allowed to warm over 3 hr to $-20°$ and then stored at that temperature for 12 hr. Addition of water, extraction with pentane, and distillation afforded 1.32 g (72.5%) of pure methyl *trans*-chrysanthemate, bp 90–92° (12 mm), infrared absorption at 1720 cm^{-1} (C=O), nmr peaks at 1.11 and 1.25 ppm due to *gem*-dimethyl groups attached to the cyclopropane ring, 1.69 and 1.71 ppm (6 H) due to the isopropylidene protons, 1.38 (doublet, $J = 5$ cps) and 2.05 ppm (multiplet) (1 H each) due respectively to the protons α and β to the carbomethoxy group, 3.65 ppm (COOCH$_3$), and 4.89 ppm (1 H, olefinic proton). Hydrolysis of the methyl ester with alkali afforded ($\pm$)-*trans*-chrysanthemic acid, mp 46–47° (lit.[10a] 46–48°).

The synthetic method described herein provides a simple route to many substances hitherto accessible only by lengthy or complicated syntheses. It should be especially useful in the field of isoprenoid synthesis; for example, it provides a simple approach to the structure proposed for the sesquiterpenoid ketone aristolone (X).[12] The other known direct approaches to *gem*-dimethylcyclopropane structures appear to be complementary to the route *via* I; these include the use of the reagent from chromous salts and 2,2-dibromopropane[13] and the replacement of bromine in *gem*-dibromocyclopropanes by methyl using lithium dimethylcopper complex.[14]

Acknowledgment. This work was supported by the National Science Foundation and the National Institutes of Health.

(12) S. Furukawa and N. Soma, *J. Pharm. Soc. Japan*, **81**, 559 (1961).
(13) C. E. Castro and W. C. Kray, Jr., *J. Am. Chem. Soc.*, **88**, 4447 (1966).
(14) E. J. Corey and G. H. Posner, *ibid.*, **89**, 3911 (1967).

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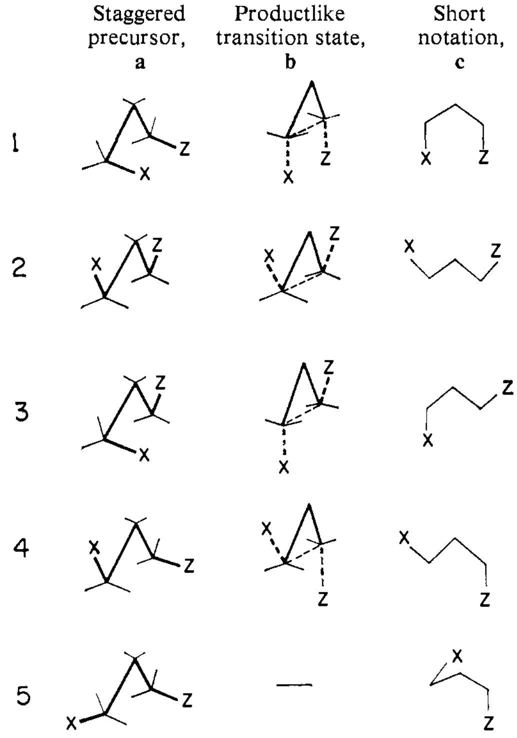
1,3 Eliminations. I. Stereochemical Considerations and Terminology[1]

Sir:

Three-membered rings are formed by net 1,3 eliminations under a variety of circumstances.[2] In a five-atom system X–A–B–C–Z, independent rotation about the A–B and B–C bonds gives rise to numerous conformations, and for concerted loss of X and Z to form a three-membered ring it has not been established whether any of these conformations are favored over others.[3]

If we consider only staggered conformations for the precursor (or for a transition state that resembles precursor) five distinct arrangements (**1a**–**5a**, Chart I) of X and Z exist, whereas four arrangements (**1b**–**4b**) are possible for a transition state that resembles the cyclopropyl ring. The simple nonperspective notation **1c**–**5c** delineates adequately the five relevant atoms of the precursor or of its corresponding transition state. We propose the following terminology for concerted 1,3 eliminations, to be used whether the transition state resembles staggered precursor or cyclopropyl product: **1** = U; **2** = W; **3** = *exo*-Sickle; **4** = *endo*-Sickle; **5** = *apo*-Sickle.[4] The same nomenclature can be used for cyclopropyl ring cleavages that are the microscopic reverse of 1,3 eliminations. In the present context *exo* and *endo* refer to Z, which is defined to be of greater electronegativity than X. Commonly X is hydrogen,

Chart I. Concerted 1,3 Eliminations and Cyclopropane Ring Cleavages



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[1] Supported by the National Science Foundation and the Petroleum Research Fund (administered by the American Chemical Society).

[2] (a) Solvolyses: S. Winstein, E. Clippinger, R. Howe, and E. Vogelfanger, *J. Am. Chem. Soc.*, **87**, 376 (1965); (b) deaminations: G. J. Karabatsos, R. A. Mount, D. O. Rickter, and S. Meyerson, *ibid.*, **88**, 5651 (1966); A. T. Jurewicz and L. Friedman, *ibid.*, **89**, 149 (1967); A. A. Aboderin and R. L. Baird, *ibid.*, **86**, 2300 (1964); P. S. Skell and I. Starer, *ibid.*, **82**, 2971 (1960); M. S. Silver, *ibid.*, **82**, 2971 (1960); (c) Bamford–Stevens reactions: F. Cook, H. Schechter, J. Bayless, L. Friedman, R. L. Folz, and R. Randall, *ibid.*, **88**, 3870 (1966); A. Nickon and N. H. Werstiuk, *ibid.*, **88**, 4543 (1966); K. B. Wiberg and J. M. Lavanish, *ibid.*, **88**, 5272 (1966); (d) deoxideations: P. S. Skell and I. Starer, *ibid.*, **81**, 4117 (1959); P. S. Skell and R. J. Maxwell, *ibid.*, **84**, 3963 (1962); (e) pyrolyses: R. C. Bicknell and A. Maccoll, *Chem. Ind.* (London), 1912 (1961); W. Huckel and H.-J. Kern, *Ann.*, **687**, 40 (1965); G. Komppa and R. H. Roschier, *ibid.*, **429**, 175 (1922); J. McKenna and J. B. Slinger, *J. Chem. Soc.*, 2759 (1958); F. M. Sonnenberg and J. K. Stille, *J. Org. Chem.*, **31**, 3441 (1966); (f) Favorskii reactions: G. Stork and I. J. Borowitz, *J. Am. Chem. Soc.*, **82**, 4307 (1960); H. O. House and W. F. Gilmore, *ibid.*, **83**, 3980 (1961); H. O. House and H. W. Thompson, *ibid.*, **28**, 164 (1963); H. O. House and G. A. Frank, *J. Org. Chem.*, **30**, 2948 (1965); N. J. Turro and W. B. Hammond, *J. Am. Chem. Soc.*, **87**, 3258, (1965); E. E. Smissman, T. L. Lemke, and O. Kristiansen, *ibid.*, **88**, 334 (1966); (g) Ramberg-Bäckland reaction: N. P. Neureiter and F. G. Bordwell, *ibid.*, **85**, 1209 (1963); (h) reactions of sulfoxides: R. Baker and M. J. Spillett, *Chem. Commun.*, 757 (1966); (i) heterogeneous reactions: H. Pines and C. N. Pillai, *J. Am. Chem. Soc.*, **82**, 2921 (1960); (j) quaternary ammonium compounds: C. L. Bumgardner, *J. Org. Chem.*, **29**, 767 (1964); ref 3a; (k) α-lactams: H. E. Baumgartner, J. F. Fuerholzer, R. D. Clark, and R. D. Thompson, *J. Am. Chem. Soc.*, **85**, 3303 (1963).

[3] For E1cB processes see: (a) C. L. Bumgardner and H. Iwerks, *ibid.*, **88**, 5518 (1966); (b) S. J. Cristol and B. B. Jarvis, *ibid.*, **89**, 401 (1967; S. J. Cristol, J. K. Harrington, and M. S. Singer, *ibid.*, **88**, 1529 (1966); S. J. Cristol and B. B. Jarvis, *ibid.*, **88**, 3095 (1966); (c) J. Meinwald, C. Swithenbank, and A. Lewis, *ibid.*, **85**, 1880 (1963); J. Meinwald and J. K. Crandall, *ibid.*, **88**, 1292 (1966); (d) H. O. House and co-workers.[2f]

[4] This nomenclature preserves terms (U, W, Sickle) and their geometric significance already used in the chemical literature in various connections: R. B. Bates, R. H. Carnighan, and C. E. Stables, *J. Am. Chem. Soc.*, **85**, 3031 (1963); R. B. Bates, D. W. Gosselink, and J. A. Kaczynski, *Tetrahedron Letters*, 199, 205 (1967); A. Rassat, C. W. Jefford, J. M. Lehn, and B. Waegell, *ibid.*, 233 (1964); R. Hoffman, *Trans. N. Y. Acad. Sci.*, [II], **28**, 475 (1966).