Students of the Brigham Young University are gratefully acknowledged.

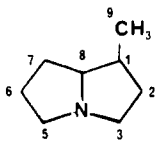
Registry No. 1, 19172-47-5; 2, 84877-69-0; 3, 54129-84-9; $PhC(O)OCH_2CH_2OPh$, 4173-59-5; $Cl(CH_2)_3C(O)OEt$, 3153-36-4; PhCH=CHC(O)OEt, 103-36-6; $PhC(S)OCH_2CH_2OPh$, 52772-15-3; PhCH=CHC(S)OEt, 73818-80-1; $PhCH_2OCH_2CH_2OPh$, 84877-70-3; $PhCH_2CH_2CH_2OEt$, 5848-56-6; $EtOCH_2CH_2OEt$, 629-14-1; methyl thionobenzoate, 5873-86-9; toluene, 108-88-3; benzyl mercaptan, 100-53-8; 1,2-diphenylethane, 103-29-7; stilbene, 588-59-0; coumarin, 91-64-5; 2-cumaranone, 553-86-6; 2-thiocoumarin, 3986-98-9; 2(3*H*)-benzofuranthione, 84877-71-4; chroman, 493-08-3; 2,3-dihydrobenzofuran, 496-16-2; 2,6-bis(methoxymethyl)pyridine, 64726-18-7.

Communications

Pyrrolizidine Alkaloid Synthesis. (±)-Supinidine

Summary: Synthesis of the $\Delta^{1,2}$-unsaturated pyrrolizidine alkaloid supinidine proceeding via regioselective N1–C2 vicinal annulation of a 1,3-dihaloalkane onto a 3-(hydroxymethyl)-3-pyrroline system is described.

Sir: The pyrrolizidine alkaloids have a broad distribution within the plant kingdom.[1] The over 100 constituents of this alkaloid class, which possesses the 1-azabicyclo[3.3.0]bicyclooctane skeleton 1 often functionalized by



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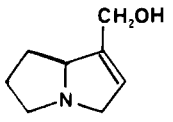
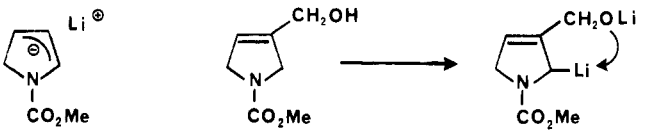


2

hydroxyl or carboxylic ester moieties at a variety of structural sites, demonstrate a broad range of pharmacological activities. The $\Delta^{1,2}$-unsaturated subgroup of the pyrrolizidine alkaloids has been associated with severe pneumovascular- and hepatotoxicities and with carcinogenic, mutagenic, and teratogenic activities at sublethal doses.[1,2] In addition, $\Delta^{1,2}$-unsaturated pyrrolizidine alkaloids have been examined by the National Cancer Institute as potential agents against neoplastic diseases.[3] Due to their intriguing chemical structures and their pharmacological activities, the pyrrolizidine alkaloids have witnessed considerable synthetic attention.[4,5] Our laboratory has been engaged in developing synthetic entries into the pyrrolizidine and the structurally homologous indolizidine ring systems, which proceed via 1,2-vicinal annulation of an appropriate three-carbon (pyrrolizidine) or four-carbon (indolizidine) unit onto a suitably substituted five-membered 1-azaheterocyclic ring.[6] We describe here the utility of this strategy in a direct entry into the $\Delta^{1,2}$-unsaturated pyrrolizidine alkaloids as illustrated by the synthesis of supinidine **2**.[5]

Our initial studies on the viability of this strategy in the synthesis of fused pyrrolidine systems employed α-alkylation of the dipole-stabilized pyrroline anion **3** in the



3 4 5

central carbon–carbon bond-forming step of a synthesis of the indolizidine gephyrotoxin 223AB.[6] Adaptation of this strategy to the synthesis of the eight carbon-containing $\Delta^{1,2}$-unsaturated pyrrolizidine alkaloid skeleton required the use of an unsymmetrical 3-alkyl-substituted pyrroline anion precursor. 3-(Hydroxymethyl)-3-pyrroline (**4**) was selected as the pyrroline synthon because of the common presence of a C-1 hydroxymethyl substituent or a derived carboxylate ester in these alkaloids and the capability of the hydroxyl function to assist in regioselective pyrroline deprotonation. In an unsymmetrical 3-pyrroline system, pyrroline anion formation might be anticipated to occur a priori at either or both the C-2 and C-5 positions. We envisioned that regiospecific 2-pyrroline anion formation would occur in pyrroline **4** as a consequence of two possible and nonexclusive factors, which are a function of complexation with the proximate pro-C-9 hydroxyl (or alkoxide) function. Thus, complexation of the pro-C-9 alkoxide moiety with the metalation base prior to ring-proton removal might act to direct pyrroline deprotonation to the proximate C-2 position via a seven-membered transition state (e.g., primarily an entropic effect). An additional feature of pyrroline **4** that might act to reinforce regioselective pyrroline deprotonation was postulated to be alkoxide complexation of the incipient C-2 organolithio derivative via a five-membered internal chelate as illustrated in **5** (e.g., primarily an enthalpic effect). Regioselective alkylation of the derived allylic organometallic (e.g., **5**) at the C-2 (rather than the C-4) position was anticipated on the basis of our and Lapierre Armande and Pandit's[7]

(1) For reviews of the pyrrolizidine alkaloids, see: (a) Robins, D. J. *Adv. Heterocycl. Chem.* **1979**, *24*, 247. (b) Klasek, A.; Weinbergova, O. *Recent Dev. Chem. Nat. Carbon Compd.* **1975**, *6*, 35. (c) Warren, F. L. *Alkaloids (N.Y.)* **1970**, *12*, 245. (d) Culvenor, C. C. J.; Bull, L. B.; Dick, A. T. "The Pyrrolizidine Alkaloids"; North Holland: Amsterdam, 1968.

(2) (a) Smith, L. W.; Culvenor, C. C. J. *J. Nat. prod.* **1981**, *44*, 129. (b) Atal, C. K. *Lloydia* **1978**, *41*, 313. (c) Matlocks, A. R.; White, I. N. H. *Chem.-Biol. Interact.* **1976**, *15*, 173. (d) Matlocks, A. R. In "Phytochemical Ecology"; Harborne, J. B., Ed.; Academic Press: London, 1972; p 179.

(3) (a) Letendre, L.; Smithson, W. A.; Gilchrist, G. S.; Bergert, E. O.; Hoagland, C. H.; Ames, M. M.; Powis, G.; Korach, J. S. *Cancer* **1981**, *47*, 437 and references therein. (b) Hartwell, J. *Cancer Treat. Rep.* **1976**, *60*, 1031.

(4) For recent synthetic studies of the $\Delta^{1,2}$-unsaturated pyrrolizidine alkaloids, see: (a) Vedejs, E.; Martinez, G. R. *J. Am. Chem. Soc.* **1980**, *102*, 7993. (b) Keck, G. E.; Nickell, D. G. *Ibid.* **1980**, *102*, 3632. (c) Tufariello, J. J.; Lee, G. E. *Ibid.* **1980**, *102*, 373.

(5) For total syntheses of supinidine, see: (a) Tufariello, J. J.; Tette, J. P. *J. Org. Chem.* **1975**, *40*, 3866. (b) Robins, D. J.; Sakdarat, S. *J. Chem. Soc., Perkin Trans. 1* **1979**, 1734. (c) Chamberlin, A. R.; Chung, J. Y. L. *Tetrahedron Lett.* **1982**, *23*, 2619. (d) Hart, D. J.; Yang, T.-K. *Ibid.* **1982**, *23*, 2761.

(6) (a) Macdonald, T. L. *J. Org. Chem.* **1980**, *45*, 193. (b) Spande, T. F.; Daly, J. W.; Hart, D. J.; Tsai, Y.-M.; Macdonald, T. L. *Experentia* **1981**, *37*, 1242.

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earlier studies. These expectations have been realized.

Our synthesis of supinidine **2** proceeded by selective reduction of *N*-(methoxycarbonyl)-4-(ethoxycarbonyl)-3-pyrrolidone (**6**)[8] with sodium cyanoborohydride in methanol to afford a mixture of epimeric alcohols **7** (~85:15) [sodium cyanoborohydride (1.2 equiv), MeOH, pH 3, 20 °C; 77%].[9a] Epimeric alcohols **7** were benzoylated [benzoyl chloride (1.2 equiv), pyridine, (dimethylamino)-pyridine (catalytic), 20 °C; 65%],[9b] and the derived benzoates were β-eliminated with diazabicycloundecene (DBU) in refluxing benzene to afford crystalline *N*-methoxycarbonyl pyrroline **9**[9c] [DBU (1.5 equiv), benzene, reflux; 67%; mp 75–77 °C]. The ester moiety in pyrroline **9** was selectively reduced with lithium aluminum hydride in ether to afford the desired 3-hydroxymethyl pyrroline intermediate **4** as colorless crystals[9d] [lithium aluminum hydride (1.0 equiv), ether, –78 °C; mp 81–83 °C, 75%]. Treatment of hydroxymethyl pyrroline **4** with a slight excess of lithiotetramethylpiperidide in tetrahydrofuran generated a deep red species postulated to be dianion **5** [LiTMP (2.2 equiv), THF, –78 °C, 15 min], which was immediately quenched by alkylation adjacent to the nitrogen dipole in high regioselectivity (≥97%) with a variety of agents [RCH_2X (5.0 equiv), THF, –78 °C; 30–82%]. However, unambiguous establishment of the site of alkylation (either C-2 or C-5) in these structurally homogenous adducts by spectroscopic methods proved difficult. Proton NMR spectroscopy indicated that both the pyrroline methine hydrogen (J = 1.5 Hz) and the pyrroline methylene hydrogens (J = 2.0 Hz) were coupled to the pyrroline vinyl hydrogen; little long-range coupling of either pyrroline alkane protons to the hydroxymethylene protons ($J \lesssim 1.0$ Hz) was observed. Analysis of ^{13}C NMR spectra of alkylated products of pyrroline **4** supported the proposed C-2-alkylation regiochemistry, although this analysis rested upon correct assignment of the carbon resonances in **4**. The postulated C-2 regiochemistry of the alkylation was confirmed by conversion of the 3-chloropropyl alkylation adduct (**10**) into supinidine **2**. Thus, in situ generation of the dianion of pyrroline **5** followed by alkylation with 1-bromo-3-chloropropane gave 2-(3′-chloropropyl)-3-(hydroxymethyl)-3-pyrroline (**10**) as a light yellow oil[9e] [1-bromo-3-chloropropane (5.0 equiv), THF, –78 °C; 48%]. Subsequent N-decarbomethoxylation of pyrroline **10** by treatment with methyllithium in tetrahydrofuran and spontaneous cyclization of the released lithioamide by nucleophilic displacement at the internal alkyl chloride site afforded supinidine **2**, which was identical by spectroscopic analysis with authentic supinidine [MeLi (4.2 equiv), THF, 0 °C; 91%].[9f,10] N-Decarbomethoxylation with methyllithium, while enabling direct in situ cyclization in high yield, was, in addition, the only successful method examined for N-decarbomethoxylation. Alternate methods for urethane removal [trimethylsilyl iodide, thiophenoxide, methanolic hydroxide] proved to be incompatible with the additional functional groups in **10**. Interestingly, methanolic hydroxide treatment of chloropropyl pyrroline **10** afforded the cyclic ethers **11** or **12**, depending upon the extent of base treatment.

This entry into $\Delta^{1,2}$-unsaturated pyrrolizidine alkaloid construction can be conceptually viewed as proceeding via vicinal annulation of a bifunctional alkylating agent at the nitrogen and α-nitrogen molecular sites in a preformed pyrroline system. The approach possesses synthetic flexibility to generate a variety of natural and analogue pyrrolizidines via substitution of a suitably adjusted bifunctional electrophilic component into the convergent scheme. We are currently examining the implementation of this approach to the construction of more structurally complex fused pyrroline and pyrrolidine ring systems.

Acknowledgment is made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, and to the National Institutes of Health (ES00267) for support of this research. Timothy L. Macdonald is a Research Fellow of the Alfred P. Sloan Foundation.

Registry No. (±)-**2**, 23185-51-5; **4**, 84731-29-3; **5**, 84731-30-6; (±)-**6**, 80616-42-8; (±)-**7** (isomer 1), 84731-31-7; (±)-**7** (isomer 2),

(7) (a) Lapierre Armande, J. C.; Pandit, V. K. *Recl. Trav. Chim. Pays-Bas* **1980**, *99*, 87. (b) Lapierre Armande, J. C.; Pandit, V. K. *Tetrahedron Lett.* **1977**, 897.

(8) Kuhn, R. *Chem. Ber.* **1956**, *89*, 1423.

(9) (a) IR 3400 (m), 1717 (s), 1650 (w) cm^{-1}; ^1H NMR ($CDCl_3$) δ 4.00–4.55 (br m, 8 H), 3.75 (s, 3 H), 2.60 (m, 1 H), 1.28 (t, J = 8.0 Hz, 3 H). (b) Major isomer (purified by chromatography on silica gel with 20:80 ethyl acetate–petroleum ether): IR 2910 (s), 1725 (s), 1710 (s), 1680 (s) cm^{-1}; ^1H NMR ($CDCl_3$) δ 8.00–8.25 (m, 2 H, 7.45–7.75 (m, 3 H), 5.80 (t, d, J = 6.0, 3.0 Hz, 1 H), 4.32 (q, J = 8.0 Hz, 2 H), 3.85–4.00 (br m, 4 H), 3.70 (s, 3 H), 3.32 (t, d, J = 6.0, 3.0 Hz), 1 .30 (t, J = 8.0 Hz, 3 H); ^{13}C NMR ($CDCl_3$) 170.4, 165.2, 155.0, 133.1, 129.4, 128.1, 74.5, 61.2, 52.3, 50.7, 48.1, 46.8, 13.7 ppm; MS (70 eV), m/e 321 (8%), 200 (21%), 126 (100). Anal. Calcd for $C_{16}H_{19}NO_6$: C, 59.82; H, 5.96. Found: C, 59.56; H, 6.01. (c) IR 1710 (s), 1690 (s), 1620 (m) cm^{-1}; ^1H NMR ($CDCl_3$) δ 6.70 (s, 1 H), 4.35 (s, 4 H), 4.25 (q, J = 8.0 Hz, 2 H), 3.70 (s, 3 H), 1.35 (t, J = 8.0 Hz, 3 H); ^{13}C NMR ($CDCl_3$) 162.4, 155.0, 136.1, 132.3, 60.6, 54.03, 52.4, 52.4, 51.8, 14.08 ppm; MS (70 eV), m/e 199 (26)), 171 (54), 126 (100). Anal. Calcd for $C_9H_{13}NO_4$: C, 54.27; H, 6.58. Found: C, 54.41; H, 6.74. (d) IR 3450 (s), 1705 (s), 1660 (m) cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.80 (s, 1 H), 4.28 (s, 4 H), 3.84 (s, 3 H), 2.28 (s, 1 H, OH); ^{13}C NMR ($CDCl_3$) 155.2, 139.5, 119.9, 59.5, 53.3, 52.9, 52.3 ppm; MS (70 eV), m/e 157 (13), 126 (100). Anal. Calcd for $C_7H_9NO_3$: C, 53.50; H, 7.06. Found: C, 53.49; H, 7.06. (e) IR 3400 (m), 1700 (s), 1660 (m) cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.80 (br s, 1 H), 4.82 (br d, J = 1.5 Hz, 1 H), 4.28 (br d, J = 2.0 Hz, 2 H), 4.20 (br s, 2 H) 3.82 (s, 3 H), 3.60 (t, J = 6.0 Hz, 2 H), 2.10–1.75 (m, 5 H including OH); ^{13}C NMR ($CDCl_3$) 155.4, 141.7, 120.7, 63.5, 59.1, 53.3, 52.3, 45.0, 28.2, 14.7 ppm; MS (70 eV), m/e 233 (12), 202 (100), 156 (85). Anal. Calcd for $C_{10}H_{16}ClNO_3$: C, 51.38; H, 6.89. Found: C, 50,99; H, 6.96. (f) IR 3310 (m), 1595 (m) cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.82 (br s, 1 H), 4.24 (br s., 2 H), 4.10–3.00 (m, 5H including OH), 2.5 (m, 1 H), 1.20–2.20 (m, 4 H); ^{13}H NMR ($CDCl_3$) 144.1, 120.5, 71.2, 61.8, 59.5, 56.6, 30.2, 25.8 ppm; MS (70 eV), m/e 139 (65), 80 (100).

(10) We have been unable to obtain a sample of authentic supinidine. Our synthetic material has ^1H NMR, IR, and mass spectra identical with spectra of authentic supinidine kindly provided by Dr. J. J. Tufariello of SUNY Buffalo. The ^{13}C NMR spectrum of our synthetic material was in accord with the reported spectrum of supinine,[11] the 2,3-dihydroxy-2-isopropyl butyrate ester of supinidine.

(11) Mody, N. V.; Sawhney, R. S.; Delletier, S. W. *J. Nat. Prod.* **1979**, *42*, 417.

(12) Address correspondence to Timothy L. Macdonald at Department of Chemistry, University of Virginia, Charlottesville, VA, 22901.

80633-42-7; (±)-7 (R = C_6H_5CO) (isomer 1), 84731-32-8; (±)-7 (R = C_6H_5CO) (isomer 2), 84731-33-9; 9, 84731-34-0; (±)-10, 84731-35-1.

Supplementary Material Available: Full experimental details and spectral data for the synthesis of supinidine 2 from pyrrolidone 6 are available (5 pages). Ordering information is given on any current masthead page.

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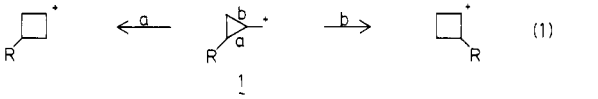
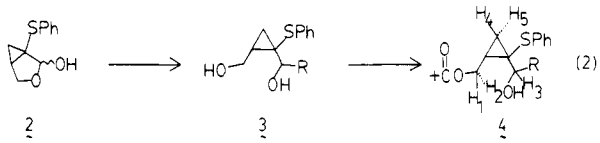
An Unusual Migratory Aptitude in a Cyclopropylcarbinyl–Cyclobutyl Rearrangement. Synthesis of 2,4-Disubstituted Cyclobutanones

Summary: The inductive effect of an (acyloxy)methyl substituent encourages migration of the *less* substituted carbon in the Grignard adducts of (*E*)-2-(hydroxymethyl)-1-(phenylthio)cyclopropane-1-carboxaldehyde.

Sir: The utility of cyclobutanones as synthetic intermediates surges as their accessibility increases.[1,2] [2 + 2] Cycloadditions of ketenes[2,3] and ketene iminium salts[4] provide ready access to 2,3-disubstituted cyclobutanones.[5] Sprioannulation with diphenylsulfonium cyclopropylide[6] and 1-lithiocyclopropyl phenyl sulfide[7] as well as the oxygen[8] and selenium[9] analogues of the latter generates 1,1-disubstituted cyclobutanones. We record a facile approach to 2,4-disubstituted cyclobutanones that derives from an unusual migratory aptitude in a cyclopropylcarbinyl–cyclobutyl rearrangement in which a remote substituent diverts the normally preferred migration of the more substituted carbon in 1 (i.e., bond a)[10] to the less substituted carbon (i.e., bond b) (see eq 1). The magnitude as well as the direction of this reversal is particularly surprising considering the normal migratory aptitudes reported for such reactions.[10]



Addition of Grignard reagents to the lactol 2[11] in THF at 0 °C provides the diol 3 in virtually quantitative yield. Chemoselective acylation of the primary alcohol occurs smoothly with pivaloyl chloride (DMAP, C_5H_5N, CH_2Cl_2, 0 °C) to give the hydroxypivalates 4 in 70–82% overall yield from 2 (see Table I and eq 2). The IR spectra



showed characteristic absorptions at 3580 ± 20 cm^{-1} for the hydroxyl group and 1725 ± 5 cm^{-1} for the ester carbonyl group. The 270-MHz NMR spectra showed H_1 and H_2 as doublet of doublets at δ 4.48 ± 0.12 (J = 12.1, 5.5 ± 0.25) and δ 4.00 ± 0.25 (J = 12.1, 9.9 ± 0.6 Hz), H_3 as a multiplet at δ 3.64 ± 0.36 (except for 4, R = Ph, at δ 4.71), H_4 as a multiplet or doublet of doublets at δ 1.30 ± 0.06 (J = 9.4 ± 0.2, 5.4 ± 0.3 Hz), and H_5 as a triplet at δ 0.94 ± 0.18 (J = 5.8 ± 0.4 Hz). In each case 4 existed as a 1:1 to 2:1 diastereomeric mixture, which normally was not separated.

Table I. Synthesis of 2,4-Disubstituted Cyclobutanones

entry	Grignard reagent	4,[a] R, yield, %	5,[a] yield, %
1	CH_3MgBr	CH_3, 76	48
2	n-C_4H_9MgBr	n-C_4H_9, 77	59
3	i-C_3H_7MgBr	i-C_3H_7, 70	46
4	CH_2=$CHCH_2CH_2MgBr$	CH_2=$CHCH_2CH_2$, 75	38
5	$PhCH_2CH_2MgBr$	$PhCH_2CH_2$, 82	55
6	CH_2=$CHMgBr$	CH_2=CH, 70	ND[b]
7	PhMgBr	Ph, 74	ND[b]

[a] All new compounds have been fully characterized by spectral means and elemental composition determined by high-resolution mass spectroscopy and/or combustion analysis. [b] ND = not determined.

(1) For selected recent references, see: Cadogan, J. E. G.; Buchan, C. M.; Gosney, I.; Hamill, B. J.; McLaughlin, L. M. *J. Chem. Soc., Chem. Commun.* **1982**, 325. Liu, H. J.; Dieck-Abularach, T. *Tetrahedron Lett.* **1982**, *23*, 295. Goldstein, S.; Vannes, P.; Honge, C.; Frisque-Hesbain, A. M.; Wiaux-Zamar, C.; Ghosez, L. *J. Am. Chem. Soc.* **1981**, *103*, 4616. Howard, C.; Newton, R. F.; Roberts, S. M. *J. Chem. Soc., Perkin Trans. 1* **1981**, 2049. Sano, T.; Toda, J.; Horiguchi, Y.; Imafuku, K.; Tsuda, Y. *Heterocycles* **1981**, *16*, 1463. Huet, F.; Lechevallier, A.; Conia, J. M. *Chem. Lett.* **1981**, 1515. Huston, R.; Rey, M.; Dreiding, A. S. *Helv. Chim. Acta* **1982**, *65*, 451. Ogura, K.; Yamashita, M.; Suzuki, M.; Tsuchihashi, G. *Chem. Lett.* **1982**, 93. Duc, D. K. M.; Fetizon, M.; Hanna, I.; Olesker, A. *Tetrahedron Lett.* **1981**, *22*, 3847. Le-Ruff, E.; Hopinkson, A. C.; Kazarians-Moghaddam, H.; Duperrazel, P.; Gupta, B.; Katz, M. *Ibid.* **1981**, *22*, 4917. Schumacher, W.; Hanack, M. *Synthesis* **1981**, 490. White, J. D.; Matsui, T.; Thomas, J. A. *J. Org. Chem.* **1981**, *46*, 3378. Greenlee, M. L. *J. Am. Chem. Soc.* **1981**, *103*, 2425. Levine, S. G.; McDaniel, R. L., Jr. *J. Org. Chem.* **1981**, *46*, 2199. Bertrand, M.; Gil, G.; Junio, A.; Maurin, R. *J. Chem. Res., Miniprint* **1980**, 1551. Ghatak, U. R.; Ghosh, S.; Sanyal, B. *J. Chem. Soc., Perkin Trans. 1* **1980**, 2881. Yanaguja, M.; Tomita, T.; Matsumoto, T. *Bull. Chem. Soc. Jpn.* **1980**, *53*, 1177. Michel, P.; O'Donnell, M.; Biname, R.; Hesbain-Frisque, A. M.; Ghosez, L.; DeClercq, J. P.; Germain, G.; Arte, E.; Van Meerssche, *Ibid.* M. *Tetrahedron Lett.* **1980**, *21*, 2577. Miller, R. D.; McKean, D. R. *Ibid.* **1980**, *21*, 2639. Kahn, M. *Ibid.* **1980**, *21*, 4547. Depres, J. P.; Greene, A. E. *J. Org. Chem.* **1980**, *45*, 2036. Halazy, S.; Krief, A. *Tetrahedron Lett.* **1980**, *21*, 1997. Wender, P. A.; Hubbs, J. C. *J. Org. Chem.* **1980**, *45*, 365. Wender, P. A. Letendre, L. J. *Ibid.* **1980**, *45*, 367. Knapp, S. *Tetrahedron Lett.* **1980**, *21*, 4301, 4557. Greene, A. E. *Tetrahedron Lett.* **1980**, *21*, 3059. Grieco, P. A.; Oguri, T.; Gilman, S. *J. Am. Chem. Soc.* **1980**, *102*, 5886.

(2) For a review, see: Seebach, D.; Beckmann, S.; Geiger, H. In "Methoden der Organischen Chemie"; Muller, E., Ed.; George Thieme: Stuttgart, 1971. Trost, B. M. *Acc. Chem. Res.* **1974**, *7*, 85. Trost, B. M. *Pure Appl. Chem.* **1975**, *43*, 563. Conia, J. M.; Robson, M. J. *Angew. Chem., Int. Ed. Engl.* **1975**, *14*, 473. Ghosez, L.; Marchand-Brynaert, *J. Adv. Org. Chem.* **1976**, *9*, 421.

(3) Brady, W. T.; Lloyd, R. M. *J. Org. Chem.* **1980**, *45*, 2025. Hassner, A.; Krepski, L. R. *Ibid.* **1979**, *44*, 1376. Bak, D. A.; Brady, W. T. *Ibid.* **1979**, *44*, 107. Jeanne-Carlier, R.; Bourelle-Wargnier, F. *Bull. Soc. Chim. Fr.* **1976**, 297. Rey, M.; Robert, S.; Dieffenbacher, A.; Dreiding, A. S. *Helv. Chim. Acta* **1970**, *53*, 417.

(4) Falmagne, J.-B.; Escudero, J.; Taleb-Sahraoui, S.; Ghosez, L. *Angew. Chem., Int. Ed. Engl.* **1981**, *20*, 879. Heiner, H. G.; Hartmann, W. *Ibid.* **1981**, *20*, 782 and references cited therein.

(5) Cf. Braun, M.; Dammann, R.; Seebach, D. *Chem. Ber.* **1975**, *108*, 2368.

(6) Trost, B. M.; Bogdanowicz, M. J. *J. Am. Chem. Soc.* **1973**, *95*, 5321. Trost, B. M.; Scudder, P. H. *Ibid.* **1977**, *99*, 7601.

(7) Trost, B. M.; Keeley, D. E.; Arndt, H. C.; Bogdanowicz, M. J. *J. Am. Chem. Soc.* **1977**, *99*, 3088. Also see: Cohen, T.; Matz, J. R. *Synth. Commun.* **1980**, *10*, 311. Tanaka, K.; Uneme, H.; Matsui, S.; Tanikaga, R.; Kaji, A. *Chem. Lett.* **1980**, 287.

(8) Cohen, T.; Matz, J. R. *Tetrahedron Lett.* **1981**, *22*, 2455.

(9) Halazy, S.; Krief, A. *Tetrahedron Lett.* **1981**, *22*, 4341.

(10) (a) Schleyer, P. V. R.; Van Dine, G. W. *J. Am. Chem. Soc.* **1966**, *88*, 2321. Julia, M.; Noel, Y. *Bull Soc. Chim. Fr.* **1968**, 3756. Roberts, J. D.; Watson, T. M. *J. Org. Chem.* **1970**, *35*, 978. Shono, T.; Nishiguchi, I.; Oda, R. *Ibid.* **1970**, *35*, 42. Also see: Wiberg, K. B.; Hess, B. A., Jr.; Ashe, A. J. In "Carbonium Ions"; Olah, G. A., Schleyer, P. v. R., Eds.; Wiley-Interscience: New York, 1972; Vol III, Chapter 26. (b) Poulter, C. D.; Spillner, C. J. *J. Am. Chem. Soc.* **1974**, *96*, 7591.

(11) Trost, B. M.; Ornstein. P. L. *J. Org. Chem.* **1982**, *47*, 748.

0022-3263/83/1948-1131$01.50/0