ethers, and *tert*-butyldimethylsilyl ethers.[8b] The major limitation is that sterically accessible olefins are likely to be saturated under these conditions.

Experimental Section

General Methods. W-2 Raney nickel was prepared according to the standard procedure.[10] The catalyst was stored at −20 °C under methanol. In several cases, freshly prepared (i.e., less than 24-h old) catalyst was found to be too active and caused overreduction. To avoid this, the catalyst was routinely stored for 2 weeks at −20 °C prior to first use. Activity was maintained up to 4–6 months. Overreduction was also effected by excess amounts of catalyst.

General Reduction Procedure. A spatula tip of Raney nickel under methanol (estimated 50–100 mg) was added to a mixture of boric acid (359 mg, 5.8 mmol) and acetone[11] (156 mg, 2.7 mmol) in THF:MeOH:H_2O (7:7:1; 4 mL) or MeOH:H_2O (5:1). After stirring for 1 h at room temperature, the oxime (1 mmol) was added and the reaction was placed under an atmosphere of hydrogen (balloon) by repeated evacuation and flushing (~5 times). The reaction mixture was vigorously stirred for the indicated time (monitored by TLC), filtered through Celite, and diluted with water (30 mL). The aqueous phase was extracted with CH_2Cl_2 (3 × 25 mL). The organic phase was washed with water (2 × 25 mL) and brine (1 × 25 mL), dried over Na_2SO_4, and concentrated in vacuo. The crude ketone (>90%) was usually obtained in a good state of purity. Occasionally, trace amounts of amine (<5%) were detected. Isolated yields were determined by 2,4-dinitrophenylhydrazone formation.

Acknowledgment is made to the National Institutes of Health (GM-31678) and the Health Research and Services Foundation for partial support of this work.

Registry No. Ra-Ni, 7440-02-0; $B(OH)_3$, 10043-35-3; 4-*tert*-butylcyclohexanone oxime, 4701-98-8; 4-*tert*-butylcyclohexanone oxime methyl ether, 61580-74-3; 4-*tert*-butylcyclohexanone oxime benzyl ether, 89231-89-0; 4-*tert*-butylcyclohexanone 2,4-dinitrophenylhydrazone, 54532-12-6; 4-*tert*-butylcyclohexanone, 98-53-3; cyclohexanone oxime, 100-64-1; cyclohexanone 2,4-dinitrophenylhydrazone, 1589-62-4; acetophenone oxime, 613-91-2; acetophenone 2,4-dinitrophenylhydrazone, 1677-87-8; norcamphor oxime, 4576-48-1; norcamphor 2,4-dinitrophenylhydrazone, 3281-03-6; cyclododecanone oxime, 946-89-4; cyclododecanone 2,4-dinitrophenylhydrazone, 907-99-3; cycloheptanone oxime, 2158-31-8; cycloheptanone 2,4-dinitrophenylhydrazone, 3349-73-3; 2-octanone oxime, 7207-49-0; 2-octanone 2,4-dinitrophenylhydrazone, 2074-06-8; 3-octanone oxime, 7207-50-3; 3-octanone 2,4-dinitrophenylhydrazone, 14129-50-1; androstanolone oxime, 2436-48-8; androstanolone, 521-18-6; acetone, 67-64-1.

(10) Mozingo, R. "Organic Syntheses"; Wiley: New York, 1955; Collect. Vol. III, p 181.

(11) For deactivation of Raney-Nickel with acetone, see: Spero, G. B., McIntosh, A. V., Jr.; Levin, R. H. *J. Am. Chem. Soc.* **1948**, *70*, 1907. Rosenkranz, G.; Kaufmann, S.; Romo, J. *Ibid.* **1949**, *71*, 3689. Barkley, L. B.; Farrar, M. W.; Knowles, W. S.; Raffelson, H. *Ibid.* **1954**, *76*, 5017.

Synthesis of Dialkylamines via the Reaction of Organoboranes with *N*-Chloroalkylamines

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Organoboranes react with chloramine[1,2] and hydroxylamine-*O*-sulfonic acid[3,4] derivatives to produce the corresponding alkylamines in good yields.

$$R_3B + NH_2X \rightarrow RNH_2$$

where X = Cl or OSO_3H

The reaction has been extended to the preparation of alkyldimethylamines but is complicated by a free-radical side reaction that leads to the formation of chloroalkanes.[5,6]

$$R_3B + (CH_3)_2NCl \rightarrow RN(CH_3)_2 + RCl$$

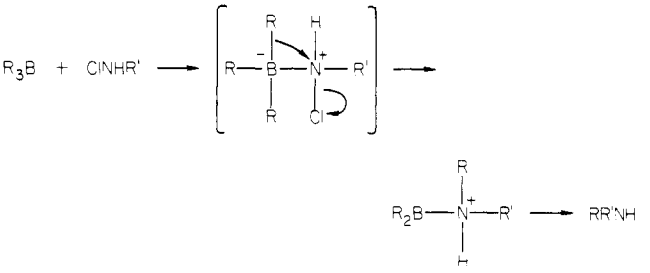
The successful reaction of *N*-chloroalkylamines with trialkylboranes has never been reported, but there are related reactions that would indicate that the reaction would be successful. For example, the reactions of trialkylboranes with *N*-chlorosulfonamides[7] and *N*-chloro-*O*-dinitrophenylhydroxylamine[8] are known.

$$R_3B + C_6H_6SO_2NHClNa \rightarrow RNHSO_2C_6H_5$$

We report that the reaction of trialkylboranes with *N*-chloroalkylamines can be utilized to synthesize a wide variety of functionally substituted dialkylamines in good yield. The reaction complements the synthesis of dialkylamines via the reaction of trialkylboranes with organic azides.[9] Our results are summarized in Tables I and II.

$$R_3B + R'NHCl \rightarrow RR'NH$$

The reaction is analogous to the reaction of chloramine with organoboranes and presumably occurs via an anionotropic migration of an alkyl group from boron to nitrogen.



The formation of alkyl chlorides as byproducts is often noted in the reactions, indicating that a competitive free-radical reaction can occur.[6] As an example, the reaction of tri-*n*-octylborane with *N*-chloro-1-octylamine yields both di-*n*-octylamine in 70% yield (isolated) and 1-chlorooctane in 20% yield. The yields of dialkylamines generally decrease as the steric bulk of either the *N*-chloroalkylamine or the organoborane increase. Thus, tricyclohexylborane reacts with *N*-chloro-1-octylamine to yield the corresponding dialkylamine in 60% yield, but the reaction of tricyclohexylborane with *N*-chloro-2-octylamine produces only trace amounts of the desired product. In an analogous fashion, *N*-chloro-*tert*-butylamine failed to produce the desired *tert*-butylalkylamines when it was allowed to react with a variety of trialkylboranes.[10]

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(3) Rathke, M. W.; Inoue, N.; Varma, K. R.; Brown, H. C. *J. Am. Chem. Soc.* **1966**, *88*, 2870.

(4) Tamura, Y.; Minamikawa, J.; Fujii, S.; Ikeda, M. *Synthesis* **1974**, 196.

(5) Davies, A. G.; Hook, S. C. W.; Roberts, B. P. *J. Organomet. Chem.* **1970**, *23*, C11.

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(7) Jigajinni, V. B.; Pelter, A.; Smith, K. *Tetrahedron Lett.* **1978**, 181.

(8) Mueller, R. H. *Tetrahedron Lett.* **1976**, 2925.

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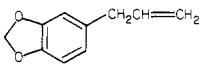
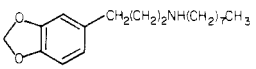
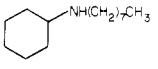
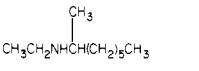
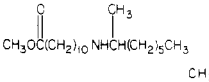
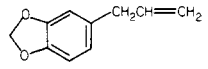
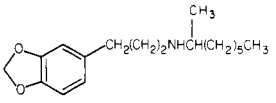
0022-3263/84/1949-1656$01.50/0

Table I. Reaction of *N*-Chloro-1-octylamine with Trialkylborane

alkene[a]	product	yield,[b] %
$CH_2{=}CH_2$	$CH_3CH_2NH(CH_2)_7CH_3$	90
$CH_3O\overset{O}{\overset{\|}{C}}(CH_2)_8CH{=}CH_2$	$CH_3O\overset{O}{\overset{\|}{C}}(CH_2)_{10}NH(CH_2)_7CH_3$	77
		65
		60

[a] The alkenes were converted into the corresponding trialkylboranes via hydroboration with BH_3·THF. [b] Isolated yields based on *N*-chloro-1-octylamine.

Table II. Reaction of *N*-Chloro-2-octylamine with Trialkylborane

alkene[a]	product	yield,[b] %
$CH_2{=}CH_2$		85
$CH_3O\overset{O}{\overset{\|}{C}}(CH_2)_8CH{=}CH_2$		50
		70

[a] The alkenes were converted into the corresponding trialkylboranes via hydroboration with BH_3·THF. [b] Isolated yields based on *N*-chloro-2-octylamine.

Experimental Section

Triethylborane was obtained from Callery Chem. Co and was used without further purification. Commercially available samples (Aldrich) of cyclohexene, methyl 10-undecenoate, safrole, and 1-amino- and 2-aminooctane were distilled prior to use. *N*-Chlorosuccinimide was used without further purification. Melting points and boiling points are uncorrected. NMR spectra were recorded on a Varian T-60 spectrophotometer. All chemical shifts are reported in parts per million downfield from Me_4Si. Mass spectra were recorded on a HP-5982-A GC–mass spectrometer. The elemental analyses were performed at Galbraith Laboratories, Knoxville, TN.

Preparation of *N*-Chloramines. General Procedure. N-chlorosuccinimide (NCS) (1.34 g, 10 mmol) was dissolved in 100 mL of methylene chloride. The alkylamine (10 mmol) was rapidly added, dropwise, to the stirred NCS solution at room temperature, and the mixture was stirred for 10 min. The reaction mixture was filtered and the filtrate washed with 2 × 25 mL of 0.4 M sodium bicarbonate to remove succinimide. The organic layer was dried over anhydrous sodium sulfate, filtered, and concentrated to yield the *N*-chloroalkylamine in essentially quantitative yield.

Hydroborations. General Procedure.[11] The alkene (30 mmol) in 10 mL of dry THF was placed in a dry, 100-mL, nitrogen-flushed flask fitted with a septum inlet and cooled to 0 °C. BH_3·THF (10 mmol, 5 mL of a 2 M solution) was added over a period of 2 min. The solution was allowed to warm to room temperature and stirred for 1 h.

Synthesis of Dialkylamines. General Procedure. The organoborane (10 mmol in 10 mL of THF) was cooled to 0 °C while maintaining a nitrogen atmosphere, aqueous sodium bicarbonate (10 mL of a 0.4 M solution) was added, and then *N*-chloroalkylamine (10 mmol) in THF (5 mL) was added dropwise.[12] The reaction mixture was stirred for 5 min. The mixture was acidified with 10% HCl (5 mL) and the product isolated as the hydrochloride. The free amine was obtained via the addition of sodium hydroxide (3 N) and extraction of the product amine into ether.

1-(Ethylamino)octane. Triethylborane (10 mmol, 1.4 mL) was allowed to react with *N*-chloro-1-aminooctane (10 mmol) as outlined in the general procedure. The isolated yield was 1.41 g (90%): MS, *m/e* 157 (calcd 157); ^1H NMR ($CDCl_3$) δ 0.8–1.0 (m, 6 H, CH_3), 1.00–1.25 (m, 12 H, aliphatic), 1.9 (br s, 1 H, NH), 2.4–2.8 (m, 4 H, CH_2NHCH_2).

Methyl 11-(1-Octylamino)undecanoate. Methyl 10-undecenoate (30 mmol, 5.95 g) was hydroborated with BH_3·THF (10 mmol) for 1 h. *N*-Chloro-1-aminooctane was added as described in the general procedure to yield 2.79 g (77%) of methyl 11-(1-octylamino)undecanoate as the hydrochloride: mp 181–183 °C; MS, *m/e* 327 (calcd 327); ^1H NMR ($CDCl_3$) δ 0.9 (t, 3 H, CH_3), 1.2–1.5 (envelope, 28 H, aliphatic), 1.9–2.0 (m, 2 H, CH_2CO), 2.39 (s, 1 H, NH), 2.5–2.8 (m, 4 H, CH_2NHCH_2), 3.6 (s, 3 H, OCH_3). Anal. Calcd for $C_{20}H_{42}NO_2Cl$: C, 65.97; H, 11.64; N, 3.85. Found: C, 66.02; H, 11.71; N, 3.73.

(1-Octylamino)-3-[3,4-(methylenedioxy)phenyl]propane. Safrole (30 mmol, 4.87 g) was hydroborated with BH_3·THF (10 mmol) for 1 h. *N*-Chloro-1-aminooctane was added as described in the general procedure to yield 2.12 g (65%) of the desired product as the hydrochloride: mp 221–223 °C; MS, *m/e* 291 (calcd 291); ^1H NMR ($CDCl_3$) δ 0.9–1.1 (m, 3 H, CH_3), 1.2–1.5 (br s, 12 H, aliphatic), 1.5–2.1 (m, 3 H, CH_2CH_2NH), 2.7 (m, 6 H, CH_2NH, Ar CH_2), 5.8 (s, 2 H, OCH_2O), 6.6 (s, 3 H, Ar H). Anal. Calcd for $C_{18}H_{30}NO_2Cl$: C, 65.94; H, 9.22; N, 4.27. Found: C, 65.74; H, 9.37; N, 4.01.

(1-Octylamino)cyclohexane. Cyclohexene (30 mmol, 2.46 g) was hydroborated with BH_3·THF (10 mmol) for 3 h. *N*-Chloro-1-aminooctane was added as described in the general procedure to yield 1.48 g (60%) of the desired product as the hydrochloride: mp 214 °C (lit.[14] mp 212 °C); MS, *m/e* 211 (calcd 211); ^1H NMR ($CDCl_3$) δ 0.8–1.8 (br, 26 H, aliphatic), 2.5 (m, 3 H, CH_2NCH).

2-(Ethylamino)octane. Triethylborane (10 mmol, 1.4 mL) was allowed to react with *N*-chloro-2-aminooctane (10 mmol) as outlined in the general procedure to yield 1.33 g (85%) of the desired product: MS, *m/e* 157 (calcd 157); ^1H NMR ($CDCl_3$) δ 0.85–1.2 (m, 9 H, CH_3), 1.2–1.4 (br s, 10 H, aliphatic), 2.0 (s, 1 H, NH), 2.4–2.8 (m, 3 H, $CHNHCH_2$). Anal. Calcd for $C_{16}H_{27}NSO_2$ (benzenesulfonamide): C, 64.61; H, 9.15; N, 4.71. Found: C, 64.60; H, 9.13; N, 4.67.

Methyl 11-(2-Octylamino)undecanoate. Methyl 10-undecenoate (30 mmol, 5.95 g) was hydroborated with BH_3·THF (10 mmol) for 1 h. *N*-Chloro-2-aminooctane was added as described in the general procedure to yield 1.8 g (50%) of the desired product as the hydrochloride: mp 89–91 °C; MS, *m/e* 327 (calcd 327); ^1H NMR ($CDCl_3$) δ 0.8–1.0 (m, 6 H, CH_3), 1.0–1.5 (br s, 26 H, aliphatic), 1.9–2.0 (m, 2 H, CH_2CO), 2.0 (s, 1 H, NH), 2.2–2.5 (m, 3 H, $CHNHCH_2$), 3.7 (s, 3 H, OCH_3). Anal. Calcd for $C_{20}H_{42}NO_2Cl$: C, 65.97; H, 11.64; H, 3.85. Found: C, 66.28; H, 11.79; N, 3.64.

1-(2-Octylamino)-3-[3,4-(methylenedioxy)phenyl]propane. Safrole (30 mmol, 4.87 g) was hydroborated with BH_3·THF (10 mmol) for 1 h. *N*-Chloro-2-aminooctane was added as described in the general procedure to yield 2.28 g (70%) of the desired product as the hydrochloride: mp 123–124 °C: MS, *m/e* 291 (calcd 291); ^1H NMR ($CDCl_3$) δ 0.85–1.0 (m, 6 H, CH_3), 1.2–1.45 (br s, 10 H, aliphatic), 1.6–2.1 (m, 3 H, NH, Ar CH_2CH_2), 2.5–2.8 (m, 5 H, $ArCH_2CH_2NHCH$), 5.8 (s, 2 H, OCH_2O), 6.6 (s, 3 H, Ar H). Anal. Calcd for $C_{18}H_{30}NO_2Cl$: C, 65.94; H, 9.22; N, 4.27. Found: C, 66.07; H, 9.24; N, 4.20.

Acknowledgment. We thank the Department of Energy (DE-AS05-90EV10363) for support of this research.

Registry No. $H_2N(CH_2)_7CH_3$, 111-86-4; $ClNH(CH_2)_7CH_3$, 89231-76-5; $CH_3CH(NH_2)(CH_2)_5CH_3$, 693-16-3; $CH_3CH(NH$-

(10) The procedure is not successful for the preparation of phenylalkylamines due to the instability of *N*-chlorophenylamine.
(11) Brown, H. C. "Organic Synthesis Via Boranes"; Wiley: New York, 1975.
(12) The use of a glass pipette is recommended due to the corrosive nature of the *N*-chloramines.
(13) Klamann, D.; Hofbauer, G. *Chem. Ber.* **1953**, 1246.
(14) Burrows, E. T.; Hargreaves, B. M. C.; Page, J. E.; Resuggan, J. C. L.; Robinson, F. A. *J. Chem. Soc.* **1974**, 197.

Cl)$(CH_2)_5CH_3$, 89231-77-6; $CH_2{=}CH_2$, 74-85-1; $(CH_3CH_2)_3B$, 97-94-9; $CH_3OCO(CH_2)_8CH{=}CH_2$, 111-81-9; $(CH_3OCO(CH_2)_{10})_3B$, 63399-92-8; $CH_3CH_2NH(CH_2)_7CH_3$, 4088-36-2; $CH_3OCO(CH_2)_{10}NH(CH_2)_7CH_3$·HCl, 89231-71-0; $CH_3CH_2N(SO_2C_6H_5)CHCH_3(CH_2)_5CH_3$, 89231-73-2; $CH_3OCO(CH_2)_{10}NHCHCH_3(CH_2)_5CH_3$·HCl, 89231-74-3; safrole, 94-59-7; tri[3-[3,4-(methylenedioxy)phenyl]propyl]borane, 78498-54-1; cyclohexene, 110-83-8; tricyclohexylborane, 1088-01-3; 1-(1-octylamino)-3-[3,4-(methylenedioxy)phenyl]propane hydrochloride, 89231-72-1; (1-octylamino)cyclohexane hydrochloride, 4922-19-4; 1-(2-octylamino)-3-[3,4-(methylenedioxy)phenyl]propane hydrochloride, 89231-75-4.

Synthesis of the Simple Flavonoid Broussonin A

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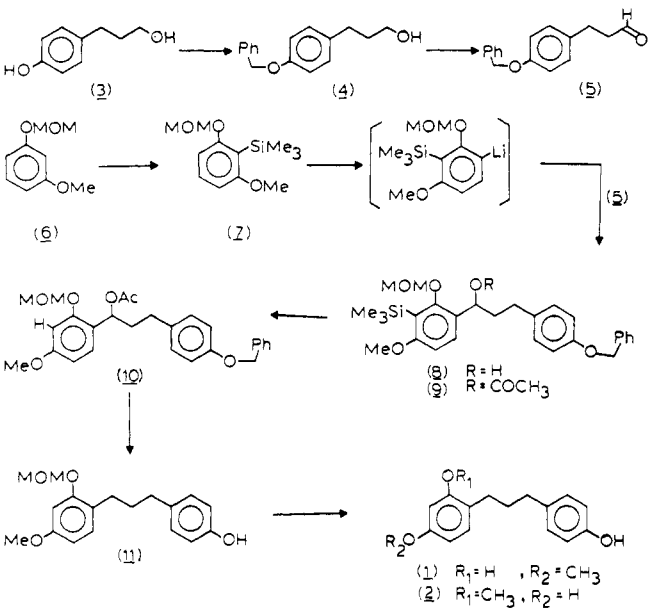
In 1980, Takasugi and co-workers reported the isolation and activities of several antifungal metabolites from the tissues of the paper mullberry (*Broussoneutra papyifera* Vent.) subsequent to infection with *Fusarium solani* f. sp. *mori*.[1] The structures of two previously unreported compounds were deduced by a combination of spectral and chemical degradation evidence and were assigned as broussonins A and B (**1** and **2**), respectively (Scheme I). The broussonins constitute a new type of phytoalexins, as they possess a 1,3-diarylpropane carbon skeleton. This structural feature also allows them to be classified as flavonoids and as such are among the simplest of that class of natural products to be found in nature.[2] Though syntheses have been reported for naturally occurring 1,3-diarylpropanoids lacking oxygenation on the propyl bridge,[2] they have not appeared in print to date. The synthesis of broussonin A (**1**) is the topic of this report.

For the synthesis of **1**, the primary consideration was the regiospecific introduction of the propyl chain with respect to the oxygenation patterns of both aryl rings. Conceptually, commercially available 3-(*p*-hydroxyphenyl)-1-propanol (**3**) provided a monooxygenated phenyl ring attached correctly to a propyl chain which contained latent electrophilic activation at the requisite position for subsequent anionic coupling. In practice, monobenzylation of **3**, followed by selective oxidation, provided aldehyde **5** as a suitable substrate for this type of reaction.

The work of Winkle[3] documented that metallation of methoxymethyl (MOM) protected phenols provide specific α lithiation with excellent regioselectivity in many cases when the α positions are nonequivalent. Unfortunately, with 3-(methoxymethoxy)anisole (**6**) only the 2-lithio species was available regioselectively, the 6-lithio derivative being formed only statistically with the 2-substituted isomer under altered conditions. It was reasonable to presume that selective protection of the 2 position would provide a substrate that would lithiate specifically at the 6-position and as such generate the desired nucleophile for coupling with **5**. In order to accomplish this, **6** was selectively metallated with *tert*-butyllithium, and the lithioarene was silylated with trimethylsilyl chloride to produce **7**.[4] Lithiation of **7** with *tert*-butyllithium apparently

Scheme I



provided the 6-lithiospecies, since treatment with aldehyde **5** provided the coupling product **8**. In addition to providing the desired carbon framework of the natural product with the correct arene oxygenation and substitution patterns, this coupling demonstrated the effective protection of a metallation active aryl C–H bond, thus allowing specific access to a less active metallation site.

To complete the systhesis, dihydrogenolysis of both the alcohol **8**, and the derived acetate **9** were attempted. Only debenzylated material was isolated, presumably due to inefficient catalyst contact caused by proximal steric congestion.[5] In order to circumvent this problem, mild protodesilylation of **9** provided **10**, which underwent the desired dihydrogenolysis to give **11**. Standard acidic removal of the MOM group[6] produced the synthetic natural product. Though this material would not crystallize in our hands, (lit.[1] mp 101–101.5 °C), spectral and chromatographic data have established its identity with the reported natural product,[7] thereby confirming its proposed structure and providing a viable route for its synthesis.

Experimental Section

Melting point determinations were made in open capillaries with a Thomas-Hoover Unimelt apparatus and are uncorrected. Boiling points were determined at atmospheric pressure unless noted otherwise and are uncorrected. Proton nuclear magnetic resonance (^{1}H NMR) spectra were recorded on a Varian Associates EM-360 or Nicolet Technologies Corp. NT-200 spectrophotometer using tetramethylsilane as an internal standard and are reported as δ values in parts per million relative to tetramethylsilane, which equals 0. Infrared (IR) spectra were recorded on a Beckman Acculab 1 spectrophotometer and are reported in reciprocal centimeters. Gas chromatography (GLC) was performed with

(1) Takasugi, M.; Anetai, M.; Masamune, T.; Shirata, A.; Takahashi, K. *Chem. Lett.* **1980**, 339–340.
(2) Gottlieb, O. R. *Isr. J. Chem.* **1977**, *16*, 45–51, and references therein.
(3) Winkle, M.; Ronald, R. C. *J. Org. Chem.* **1982**, *47*, 2102–2108.
(4) The rate of this reaction is noteworthy in that some 20 h are required for the reaction to reach stasis as opposed to the short (less than 1 h) reaction times usually encountered in reactions of aryllithiums. See ref 3, and references therein for typical short reactions.
(5) This hypothesis was supported by the subsequent reactions of the protodesilylated material and is consistent with the diasteromeric signals of the MOM methylene protons by ^{1}H NMR at 60 or 200 MHz in **8** and **9** but not in **10**. This observation indicates a relatively close juxtaposition of the MOM group and the optical center in the two former unreactive compounds but not in the latter reactive substrate.
(6) Yardley, J. P.; Fletcher III, H. *Synthesis* **1976**, 244.
(7) The direct comparison of synthetic and naturally occuring broussonin A by 200-MHz ^{1}H NMR, IR, and TLC employing a variety of solvent systems showed identical chemical shifts and integrated intensities, absorbances, and R_f values, respectively.

0022-3263/84/1949-1658$01.50/0