3,3-dimethyl-2-oxobutanoate (2, R = *t*-Bu) is representative. An oven-dried, 50-mL long-necked round-bottomed flask equipped with a septum-capped side arm, magnetic stirring bar, and stopcock adaptor connected to a mercury bubbler was assembled while hot and flushed with a stream of nitrogen. The flask was charged with the THF solution (0.43 M, 26 mL) of the reagent 1 (11 mmol) and cooled to −78 °C. Into the flask was added 1.44 g of methyl 3,3-dimethyl-2-oxobutanoate (10 mmol) in 7 mL of THF precooled to −78 °C via a double-ended needle.[9] After the reaction mixture was stirred, the mixture was maintained at −78 °C for 10 h. The excess of hydride was then destroyed by an addition of 2 mL of methanol precooled to −78 °C. After the volatiles were pumped off at aspirator pressure, the residue was dissolved in 25 mL of ethyl ether. The mixture was cooled to 0 °C and oxidized with 3 mL of 30% hydrogen peroxide in 4 mL of pH 7 phosphate buffer solution at 0 °C for 3 h. The ether layer was separated and the aqueous layer was extracted with 3 × 25 mL portions of ethyl ether. The combined extract was washed once with saturated brine solution (15 mL), dried over anhydrous magnesium sulfate, and filtered. The filtrate was concentrated. Distillation of the residue provided 1.11 g of methyl 3,3-dimethyl-2-hydroxybutanoate (3, R = *t*-Bu) (76%, bp 77–80 °C/18 mmHg, GC yield 85%) containing a small amount of impurities. The alcohol was further purified by preparative GC (20% Carbowax 20M, 6 ft × $^1/_2$ in. column, 100 °C) and the rotation was measured: $[\alpha]^{22}_D$ +40.37° (*c* 3.22, $CHCl_3$), 113% based on the maximum reported rotation $[\alpha]^{20}_D$ −35.8° (*c* 3.16, $CHCl_3$).[10] Capillary GC analysis (Supelcowax, 15 M) of MTPA esters[11] of the product alcohol revealed a composition of 98.5% *S* + 1.5% *R* (i.e., 97% ee).

In conclusion, the present study provides a new, highly efficient method for the chiral synthesis of optically active α-hydroxy esters in optical purities approaching 100% ee by reduction of α-keto esters with the new chiral reducing agent, K 9-*O*-DIPGF-9-BBNH, 1. The reagent affords α-hydroxy esters consistently enriched in their *S* enantiomers.

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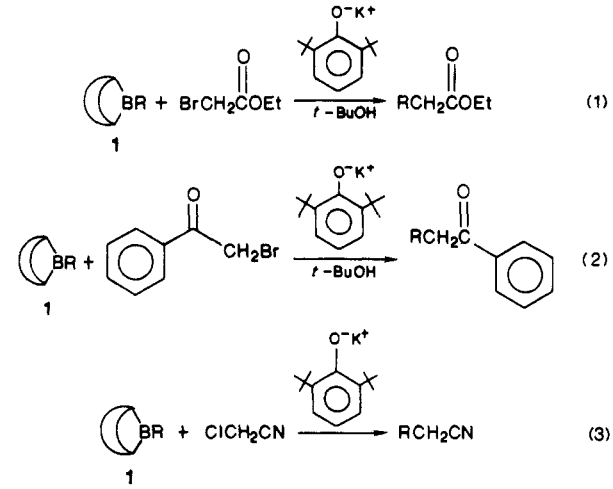
Base-Induced α-Alkenylation of Ethyl Bromoacetate, Phenacyl Bromide, and Chloroacetonitrile via *B*-*trans*-1-Alkenyl-9-borabicyclo[3.3.1]nonanes

Summary: *B*-*trans*-1-Alkenyl-9-borabicyclo[3.3.1]nonanes, easily and quantitatively prepared by the reaction of 9-BBN with various 1-alkynes in tetrahydrofuran, undergo facile reaction with α-halo carbanions generated from ethyl bromoacetate, phenacyl bromide, and chloroacetonitrile in the presence of potassium 2,6-di-*tert*-butylphenoxide, providing the corresponding β,γ-unsaturated esters, ketones, and nitriles in good yield.

Sir: Alkylations α to a carbonyl group still present a major challenge to the synthetic organic chemist.[1] A variety of ingenious methods have, however, been developed to achieve such transformations. Reaction of trialkylboranes with α-diazo ketones,[2] nitriles,[3] and aldehydes[4] provides good yields of the α-alkylated products. Use of dialkylchloroboranes[3,5] in a modified procedure allows an exceptionally facile α-alkylation of ethyl diazoacetates. We previously reported the base-induced α-alkylation of α-halo esters,[6] ketones,[7] and nitriles.[8] α-Alkylation of α-phenoxyacetic acid[9] under the influence of a base represents another approach. In all of these reactions, only one of the three groups of trialkylborane is utilized. This limitation could constitute a major difficulty in cases where it is desired to apply these homologation reactions to valuable intermediates. Fortunately, the use of *B*-alkyl-9-BBN derivatives 1 circumvented this difficulty for the base-induced synthesis of esters,[10] ketones,[11] and nitriles[9] (eq 1–3). In these reactions the alkyl group migrates preferentially over the cyclooctyl ring.



Since nucleophilic displacements on sp^2 hybridized carbons are achieved only with great difficulty, alkenyla-

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Table I. β,γ-Unsaturated Esters from a Base-Promoted α-Alkenylation of Ethyl Bromoacetate with *B-trans*-1-Alkenyl-9-BBN Derivatives

B-alkenyl-9-BBN	β,γ-unsaturated ester[a]	product no.	yield,[b] %	bp (°C)/torr	isomeric purity,[c] %	n^{20}_D
B-1-hexenyl-9-BBN (**2a**)	ethyl (3*E*)-3-octenoate	**3a**	63	93–95/10	96	1.4362
B-3,3-Dimethyl-1-butenyl-9-BBN (**2b**)	ethyl (3*E*)-5,5-dimethyl-3-hexenoate	**3b**	(57)		98	1.4307
B-2-cyclohexyl-1-ethenyl-9-BBN (**2c**)	ethyl (3*E*)-4-cyclohexyl-3-butenoate	**3c**	65	80–82/0.20	98	1.4615
B-1-octenyl-9-BBN (**2d**)	ethyl (3*E*)-3-decenoate	**3d**	65	78–80/0.60	95	1.4372

[a] All structures were confirmed by IR, ^{1}H NMR, ^{13}C NMR and mass spectral data. [b] Yields of pure products isolated (from 10-mmol-scale reactions) by distillation; based on the *B-trans*-1-alkenyl-9-BBN used. Values in parentheses indicate the yields obtained by preparative gas chromatography. [c] Isomeric purities[14] were determined by analyzing samples on 5890A capillary GC.

Table II. β,γ-Unsaturated Ketones from the Reaction of *B-trans*-Alkenyl-9-BBN Derivatives with Phenacyl Bromide under the Influence of 2,6-Di-*tert*-butylphenoxide

B-alkenyl-9-BBN	β,γ-unsaturated ketone[a]	product no.	yield,[b] %	bp (°C)/torr	isomeric purity,[c] %	n^{20}_D
B-1-hexenyl-9-BBN (**2a**)	(3*E*)-1-phenyl-3-octen-1-one	**4a**	(61)		96	1.5220
B-3,3-dimethyl-1-butenyl-9-BBN (**2b**)	(3*E*)-5,5-dimethyl-1-phenyl-3-hexen-1-one	**4b**	(71)		98	1.5235
B-2-cyclohexyl-1-ethenyl-9-BBN (**2c**)	(3*E*)-4-cyclohexyl-1-phenyl-3-buten-1-one	**4c**	60	120–122/0.01	98	1.5425

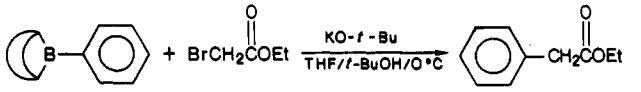
[a] All structures were confirmed by IR, ^{1}H NMR, ^{13}C NMR and mass spectral data. [b] Yields of pure products isolated (from 10-mmol-scale reactions) by distillation; based on the *B-trans*-1-alkenyl-9-BBN used. Values in parentheses indicate the yields obtained by preparative gas chromatography. [c] Isomeric purities[14] were determined by analyzing samples on 5890A capillary GC.

Table III. β,γ-Unsaturated Nitriles from a Base-Promoted α-Alkenylation of Chloroacetonitrile with *B-trans*-1-Alkenyl-9-BBN Derivatives

B-alkenyl-9-BBN	β,γ-unsaturated ketone[a]	product no.	yield,[b] %	bp (°C)/torr	isomeric purity,[c] %	n^{20}_D
B-1-hexenyl-9-BBN (**2a**)	(2*E*)-1-cyano-2-heptene	**5a**	70	68–70/3.0	99	1.4345
B-3,3-dimethyl-1-butenyl-9-BBN (**2b**)	(2*E*)-1-cyano-4,4-dimethyl-2-pentene	**5b**	69	88–90/16.0	98	1.4315
B-2-cyclohexyl-1-ethenyl-9-BBN (**2c**)	(2*E*)-1-cyano-3-cyclohexyl-2-propene	**5c**	65	56–58/0.03	96	1.4732

[a] All structures were confirmed by IR, ^{1}H NMR, ^{13}C NMR, and mass spectral data. [b] Yields of pure products isolated (from 10-mmol-scale reactions) by distillation; based on the *B-trans*-1-alkenyl-9-BBN used. Values in parentheses indicate the yields obtained by preparative gas chromatography. [c] Isomeric purities[14] were determined by analyzing samples on 5890A capillary GC.

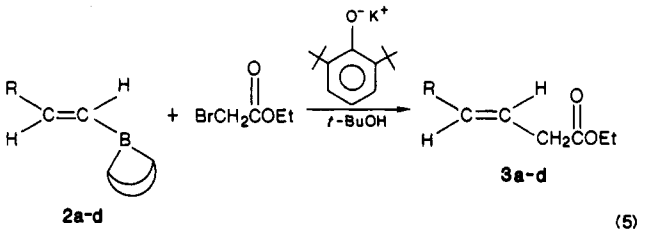
tions α to a carbonyl group have been essentially nonexistent. In fact, the success achieved in applying *B*-aryl-9-BBN compounds to arylate ethyl bromoacetate[12] (eq 4) led us to consider the possibility of extending the reaction to achieve comparable alkenylations.



(4)

Hence, an investigation was undertaken to examine the practicality of extending the well-established carbonyl α-alkylation reaction of alkyl- and arylboranes to alkenylboranes. The emphasis was directed toward development of the reaction as a practical synthetic route to stereodefined homoconjugated carbonyl and nitrile compounds. Indeed, we found that *B-trans*-1-alkenyl-9-BBN derivatives **2** react with α-halo carbanions generated from ethyl bromoacetate, phenacyl bromide, and chloroacetonitrile under the influence of 2,6-di-*tert*-butylphenoxide, providing the corresponding β,γ-unsaturated esters, ketones, and nitriles in good yields (eq 5–7).

The reactions are very simple. The base, potassium 2,6-di-*tert*-butylphenoxide, was generated by using potassium *tert*-butoxide and the phenol in tetrahydrofuran at 0 °C. *B-trans*-1-Alkenyl-9-BBN derivatives[13] were then



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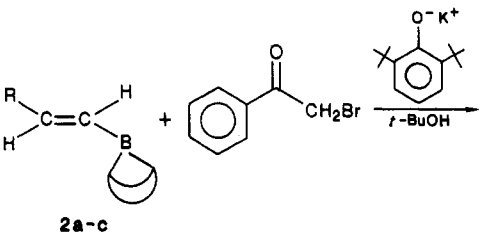

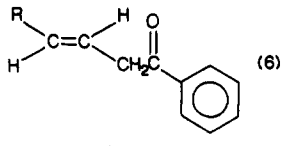

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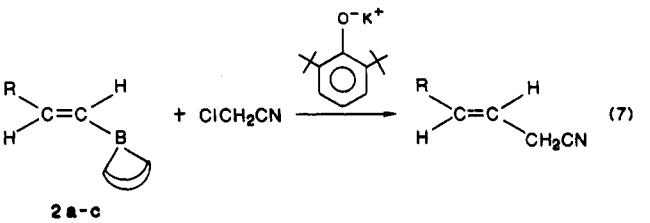

(7)

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added. After adding excess *tert*-butyl alcohol, the ethyl bromoacetate was slowly added to initiate the reaction at 0 °C. The reactions are complete after 0.5 h at 0 °C and 2 h at room temperature. The products and yields obtained of the resulting β,γ-unsaturated esters are presented in Table I. Similarly, β,γ-unsaturated ketones and β,γ-unsaturated nitriles were prepared in good yields (Tables II and III).

Thus, this α-alkenylation reaction does provide a direct route to highly stereoselective syntheses of β,γ-unsaturated esters, ketones, and nitriles. Stereochemically pure[14] (≥95%) products are obtained from *B-trans*-1-alkenyl-9-BBN derivatives. An exploratory experiment under the same conditions attempting to utilize the organoborane from an internal alkyne and 9-BBN with ethyl bromoacetate under the influence of 2,6-di-*tert*-butylphenoxide gave a mixture of cis and trans isomers (50:50). The nonstereospecificity exhibited by internal alkenyl-9-BBN compounds renders the reaction much less useful in these cases.

The following procedure for the preparation of ethyl (3*E*)-3-decenoate (**3**) is representative. To an ice-cooled solution of 2,6-di-*tert*-butylphenol in THF (10 mmol, 6.94 mL of 1.44 M solution) was added slowly 5.6 mL of a 1.78 M solution of potassium *tert*-butoxide in THF. After stirring for 0.5 h at 0 °C, neat *B*-1-octenyl-9-BBN (2.7 mL, 10 mmol) was added, followed by 10 mL of *tert*-butyl alcohol. Immediately following was added 1.10 mL (10 mmol) of neat ethyl bromoacetate dropwise. The reaction was stirred for 0.5 h at 0 °C and 2 h at 25 °C to ensure complete reaction. The residual organoborane was oxidized with $NaOAc/H_2O_2$ and stirred 3 h at 25 °C. The reaction mixture was extracted with pentane and the extract dried over anhydrous $MgSO_4$. The crude product was purified by chromatography over silicic acid. It was further purified by high vacuum distillation to yield pure ethyl (3*E*)-3-decenoate (**3d**; 1.30 g, 65%): bp 78–80 °C (0.60 mm); n^{20}_D 1.4372. GC analysis indicated 95% isomeric purity. **3d**: IR (neat) ν 1735 (ester carbonyl), 1654, 967 (C=C) cm^{-1}; ^1H NMR ($CDCl_3$, Me_4Si) δ 0.6–1.0 (t, 3 H), 1.33 (m, 11 H), 2.06 (m, 2 H), 3.0 (d, J = 4 Hz, 2 H), 4.13 (m, 2 H), 5.53 ppm (m, 2 H); ^{13}C NMR[15] ($CDCl_3$, Me_4Si) δ 171.52, 134.34, 121.72, 60.07, 37.91, 32.35, 31.62, 29.66, 28.65, 22.47, 13.99, 13.81 ppm; mass spectrum, M^+ 198.

The same procedures were employed for preparing β,γ-unsaturated ketones **4a–c** and β,γ-unsaturated nitriles **5a–c**.

Acknowledgment. We express our deep appreciation to the National Science Foundation (Grant CHE 8414171) for the support which made this research possible.

(14) Stereochemistry of the double bond was established by analyzing the samples on a 5890A capillary GC. Both cis and trans isomers separate cleanly on Supelcowax 10, 15 M, 0.25 in. I.D. column. Reference for the preparation of cis isomers: Brown, H. C.; Bhat, N. G., unpublished results.

(15) In a mixture of isomers, the vinylic carbons of cis isomers can be distinguished from the corresponding carbons of trans isomers. Reference: Dorman, D. E.; Jautelat, M.; Roberts, J. D. *J. Org. Chem.* **1971**, *36*, 2757.

(16) Postdoctoral research associate on Grant CHE 8414171 provided by the National Science Foundation.

(17) Graduate research assistant on Grant 76-20846 provided by the National Science Foundation.

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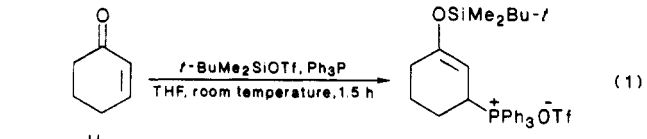
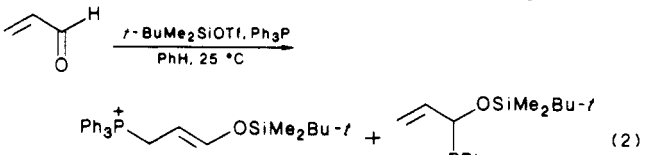
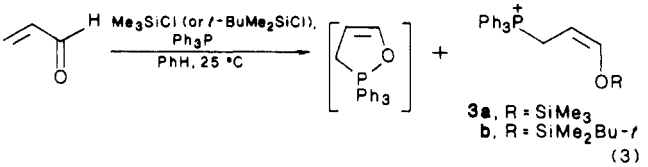
Phosphoniosilylation: An Efficient and Practical Method for the β-Functionalization of Enones

Summary: A useful procedure for the β-functionalization of enones is described in which the Wittig reaction is combined with an initial phosphoniosilylation process.

Sir: During studies related to the construction of the adenylate cyclase activator forskolin,[1] we needed to construct variously substituted dienes[2] as key starting materials. This need led us to investigate the reactions of an array of enones with triphenylphosphine in the presence of reactive silylating agents, a reaction type studied in some detail (especially for the silicon phosphite esters) previously by Evans and co-workers.[3] In contrast to this earlier report of Evans, we have now found that one can react cyclic enones, such as cyclohexenone, with *t*-Bu-$(Me)_2SiOTf/Ph_3P$ to generate products formed by the addition of Ph_3P to the β-position of the enone with silylation of the ketone oxygen (eq 1). The success of the







present study is in part a consequence of the present day availability of these more reactive silylating agents.[4a] Since the acyclic enone acrolein gave rise to the (*E*)-silyl enol ether (300-MHz ^1H NMR analysis) together with some of the 1,2-addition product under our reaction conditions (eq 2), while Evans conditions (Ph_3P, Me_3SiCl, PhH, 25 °C) led exclusively to the (*Z*)-olefin isomer (eq 3), we suggest that with the more reactive silyl triflate reagents the reaction pathway may be quite different from that proposed by Evans.

It would appear likely that with the more reactive silyl

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(2) For an excellent review of hetero-substituted 1,3-dienes, see: Petrzilka, M.; Grayson, J. I. *Synthesis* **1981**, 753. Also, see: Makin, S. M. *Russ. Chem. Rev. (Engl. Transl.)* **1969**, *38*, 237.

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(5) Brunn, J.; Peust, S. *Z. Chem.* **1976**, *16*, 154. Also, see: Oppolzer, W. *Angew. Chem., Int. Ed. Engl.* **1984**, *23*, 876. Abraham, R. J.; Siverns, T. M. *Tetrahedron* **1972**, *28*, 3015. Carreira, L. A. *J. Chem. Phys.* **1975**, *62*, 3851. Wyn-Jones, E.; Pethrick, R. A. In *Topics in Stereochemistry*; Eliel, E. L., Allinger, N. L., Eds.; Wiley: New York; 1969; Vol. 5, pp 205–274.

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