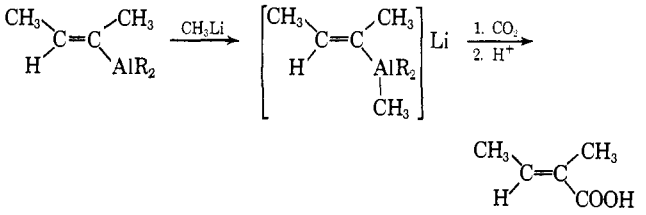
Table I. Products from *cis*- and *trans*-Vinylalanates with Various Reagents

Alkyne	Vinylalanate	Reagent	Product[c]	Yield, %
2-Butyne	*cis*[a]	CO_2	Tiglic acid	76
	trans[b]	CO_2	Angelic acid	72
3-Hexyne	*cis*[a]	H_2O	*cis*-3-Hexene	90[d]
		CO_2	*trans*-2-Ethyl-2-pentenoic acid	78
		HCHO	*trans*-2-Ethyl-2-penten-1-ol	73
		I_2	*cis*-3-Iodo-3-hexene	57
	trans[b]	H_2O	*trans*-3-Hexene	88[d]
		CO_2	*cis*-2-Ethyl-2-pentenoic acid	67
		HCHO	*cis*-2-Ethyl-2-penten-1-ol	68
		I_2	*trans*-3-Iodo-3-hexene	60

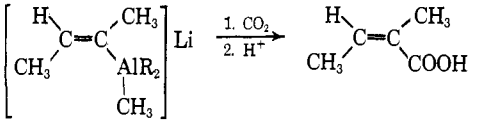
[a] From diisobutylaluminum hydride followed by treatment of the vinylalane with methyllithium. [b] From hydroalumination with lithium diisobutylmethylaluminum hydride. [c] All products gave satisfactory elemental analyses and infrared and pmr spectra in agreement with the assigned structures. [d] Yield by glpc analysis.

drolysis of the reaction mixture with dilute sulfuric acid yielded only *cis*-3-hexene, indicating that the *cis*-vinylalanate had not isomerized. Thus, in contrast to the observed *cis* addition of the aluminum–hydrogen bond in the hydroalumination of alkynes with diisobutylaluminum hydride, lithium diisobutylmethylaluminum hydride must directly add *trans*.[7]

We have recently shown that *cis*-vinylalanes, derived from the hydroalumination of alkynes with diisobutylaluminum hydride, upon treatment with methyllithium yield the corresponding ate complexes, which react readily with a variety of Grignard coreagents to give isomerically pure *trans*-α,β-unsaturated derivatives.[3,8] This is shown as follows.



Correspondingly, carbonation of the *trans*-vinylalanates derived from the hydroalumination of alkynes with lithium diisobutylmethylaluminum hydride yields *cis*-α,β-unsaturated acids in high yields.



Paraformaldehyde reacts with the *trans*-vinylalanates to produce *cis*-α,β-unsaturated alcohols, and iodination of the *trans*-vinylalanates affords the *trans*-vinyl iodides.[9] Since vinylaluminum compounds are readily hydrolyzed to olefins when treated with diluted acid, it is also now possible to convert disubstituted acetylenes *via* hydroalumination into either *cis*- or *trans*-olefins, depending on the nature of the hydroaluminating agent used. These reactions are essentially free from side products, since the alkyl moieties on aluminum are converted to the volatile hydrocarbons methane and/or isobutane in the hydrolysis step. A summary of the experimental results of these reactions is given in Table I.

It is evident that the feasibility for preparing both *cis*- and *trans*-vinylaluminum compounds from disubstituted alkynes should greatly increase the synthetic versatility of the hydroalumination reaction. The general procedure for the preparation of *trans*-α,β-unsaturated derivatives from *cis*-vinylalanates was reported earlier.[3] The simplicity of the present procedure for the conversion of alkynes into *cis*-α,β-unsaturated compounds *via trans*-hydroalumination with lithium diisobutylmethylaluminum hydride is illustrated by the following example.

To 0.10 mole of diisobutylaluminum hydride in 30 ml of monoglyme was added 0.10 mole of methyllithium in ether while maintaining the temperature below 25°. The diethyl ether was then removed under reduced pressure and 0.05 mole of 3-hexyne was added.[10] The reaction mixture was heated at 100–130° for 6 hr and cooled to 60° and 0.10 mole of paraformaldehyde was added at a rate such that the temperature was maintained between 60 and 70°. After standing for an additional hour at 65° the reaction mixture was poured slowly into a mixture of ice and concentrated hydrochloric acid, and the alcohol produced was extracted with ether. The ether extract was washed with sodium carbonate and distilled to give 3.9 g of *cis*-2-ethyl-2-penten-1-ol (68%), bp 40° (1 mm), $n^{22}D$ 1.4467.

(7) It has been reported that lithium aluminum hydride is a catalyst for the selective *trans*-hydrogenation of 2-pentyne: L. H. Slaugh, *Tetrahedron*, 22, 1741 (1966).

(8) Direct carbonation of *cis*-vinylalanes gives lower yields (50–60%) of the corresponding carboxylic acids.

(9) G. Zweifel and C. C. Whitney, *J. Am. Chem. Soc.*, **89**, 2753 (1967).

(10) A lower ratio of lithium diisobutylmethylaluminum hydride to alkyne may be used; however, longer reaction times or higher temperatures are required to achieve high yields of products.

(11) National Institutes of Health Predoctoral Fellow, 1965–1967.

George Zweifel, Roger B. Steele[11]
Department of Chemistry, University of California
Davis, California 95616
Received June 28, 1967

α-Halovinylboranes. Their Preparation and Conversion into *cis*-Vinyl Halides, *trans*-Olefins, Ketones, and *trans*-Vinylboranes[1]

Sir:

The hydroboration of 1-bromo- and 1-iodo-1-alkenes with dicyclohexylborane results in the formation of α-haloboranes which undergo migration of one alkyl group from boron to the adjacent carbon atom. Oxidation of the reaction mixture with alkaline hydrogen peroxide

(1) This research was supported by the National Science Foundation Grant No. GP-6633.

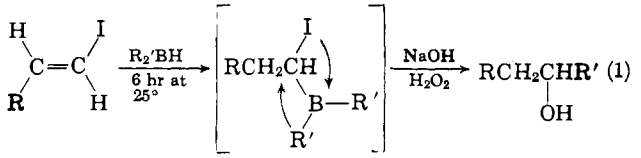
Table I. Products from *trans*-Halovinylboranes with Various Reagents

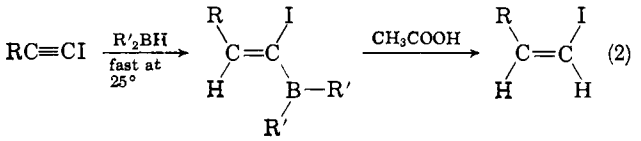
Halovinylborane	Reagent	Product and isomeric purity	Yield, %[a]
trans-1-Iodo-1-hexenyl-dicyclohexylborane	CH_3COOH	*cis*-1-Iodo-1-hexene (99)	95
	$NaOCH_3$–CH_3COOH	*trans*-1-Cyclohexyl-1-hexene (93)	82
	$NaOH$–H_2O_2	Cyclohexyl pentyl ketone	87
trans-1-Bromo-1-hexenyl-dicyclohexylborane	CH_3COOH	*cis*-1-Bromo-1-hexene (99)	85
	$NaOCH_3$–CH_3COOH	*trans*-1-Cyclohexyl-1-hexene (99)	90
	$NaOH$–H_2O_2	Cyclohexyl pentyl ketone	85

[a] By glpc analysis.

gives the corresponding secondary alcohols in 70–80% yields, indicating that the initial attachment of boron occurs predominantly to the carbon bearing the halogen (1).[2,3]

We wish now to report that the addition of dicylohexylborane to 1-bromo- and 1-iodo-1-alkynes in tetrahydrofuran solvent affords the corresponding *trans*-α-halovinylboranes (I), a new, previously unreported class of stable organoboranes. These derivatives do not undergo alkyl group rearrangement in tetrahydrofuran as evidenced by their conversion into *cis*-vinyl halides upon protonolysis with acetic acid (2).



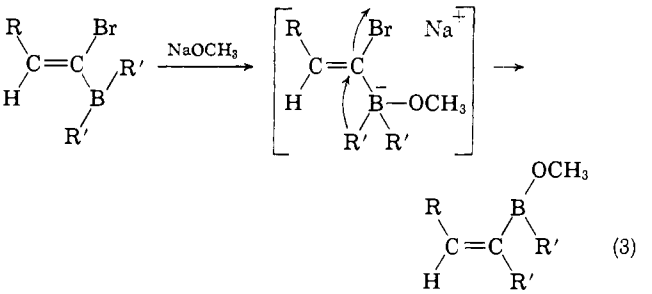


I

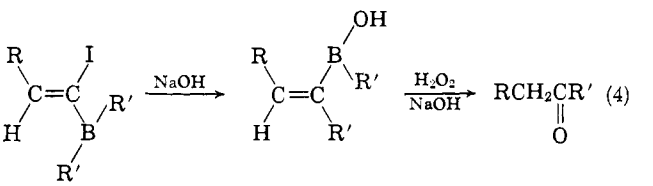
The fact that protonolysis of the α-iodovinylborane derived from deuterioboration (R'_2BD) of 1-iodo-1-hexyne with acetic acid gives a 85% yield of *cis*-1-iodo-1-hexene with better than 95% deuterium substitution at the 2 position indicates the preferential addition of boron to the α-carbon atom. The observed stability of the α-halovinylboranes toward rearrangement can be attributed to the strength of the vinyl–halogen bonds which opposes the alkyl group transfer reaction.

We recently reported a method for the preparation of *trans*-1-halo-1-alkenes from vinylalanes and halogens.[4] The hydroboration of 1-halo-1-alkynes[5] followed by protonolysis with acetic acid now affords a synthesis of the corresponding *cis*-1-halo-1-alkenes. It is especially gratifying that both the *cis*- and *trans*-1-iodo-1-alkenes, which were hitherto accessible only with difficulty, may readily be prepared in high isomeric purity using these new procedures.

Although the α-halovinylboranes are stable toward alkyl group migration in tetrahydrofuran solvent, they readily undergo anionotropic rearrangement when converted to the corresponding boronate complexes (3). Thus, the reaction of sodium methoxide with the α-halovinylboranes followed by treatment of the reaction mixtures with acetic acid produces *trans* olefins. Since protonolysis proceeds with retention of configuration,[6] it follows that the rearrangement must have occurred with inversion by backside attack of the alkyl group at the carbon atom bearing the halogen substituent.[7] The synthesis of *trans*-olefins by this novel reaction complements our procedure reported earlier for the preparation of the corresponding *cis*-olefins.[8]



Finally, treatment of the α-halovinylboranes with sodium hydroxide gives the rearranged 1,2-disubstituted vinylboranes which, on treatment with hydrogen peroxide, yield the corresponding ketones (4). A summary of the yields observed in each of these reactions is given in Table I.



It is obvious that the α-halovinylboranes should be exceedingly useful as intermediates for organic synthesis, since they may readily be converted into a great variety of functional derivatives. Moreover, they represent convenient starting materials for the preparation of unsymmetrical *trans*-1,2-disubstituted vinylboranes which were not readily available previously. It should be noted that the monohydroboration of unsymetrical substituted alkynes gives only mixtures of *cis*-vinylboranes.

(2) G. Zweifel and H. Arzoumanian, to be published.

(3) Migrations of alkyl substituents from boron to the α-carbon in α-haloorganoboranes have also been reported by D. J. Pasto and J. L. Miesel, *J. Am. Chem. Soc.*, **85**, 2118 (1963); D. S. Matteson and R. W. H. Mah, *ibid.*, **85**, 2599 (1963).

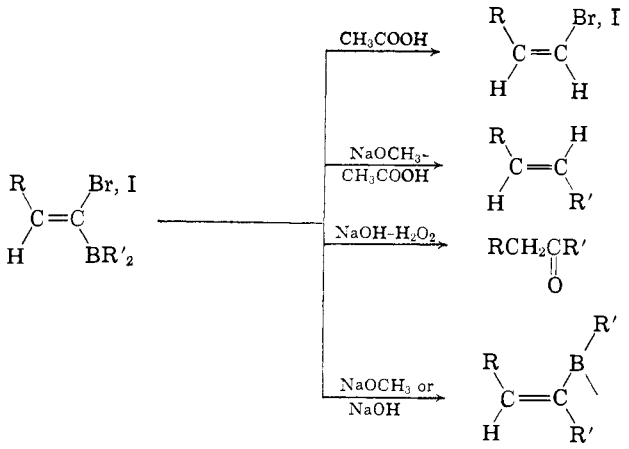
(4) G. Zweifel and C. C. Whitney, *ibid.*, **89**, 2753 (1967).

(5) 1-Iodo- and 1-bromo-1-alkynes are readily available by the halogenation of the corresponding lithium alkynes at low temperature.

(6) H. C. Brown, "Hydroboration," W. A. Benjamin, Inc., New York, N. Y., 1962.

(7) G. Köbrich and H. R. Merkle, *Angew. Chem. Intern. Ed. Engl.*, **6**, 74 (1967), have shown that the boron *ate* complexes derived from α-chlorovinyllithium compounds and triphenylboron undergo phenyl group migration.

(8) G. Zweifel, H. Arzoumanian, and C. C. Whitney, *J. Am. Chem. Soc.*, **89**, 3652 (1967).



A representative procedure for the preparation of ketones from α-halovinylorganoboranes is given as follows. To a suspension of 30 mmoles of dicyclohexylborane[9] in tetrahydrofuran at 0° was added 30 mmoles of 1-bromo-1-hexyne. After maintaining the reaction mixture for an additional 30 min at 20–30°, 15 ml of 3 *N* sodium hydroxide was slowly added while keeping the temperature at 20–30°. The resulting organoborane was then oxidized at 30–40° by adding 15 ml of 30% hydrogen peroxide. The ketone formed was extracted into ether and the combined extracts were washed with saturated sodium chloride solution. Distillation gave 4.33 g of cyclohexyl pentyl ketone (79%), bp 99–100° (3 mm), n^{22}D 1.4545.

(9) Prepared by hydroboration of cyclohexene with borane in tetrahydrofuran in a 2:1 ratio of 0°.

George Zweifel, Henri Arzoumanian
Department of Chemistry, University of California
Davis, California 95616
Received July 7, 1967

Book Reviews

Peptide Synthesis. By MIKLOS BODANSZKY and MIGUEL A. ONDETTI, The Squibb Institute for Medical Research, New Brunswick, N. J. Interscience Publishers, John Wiley and Sons, Inc., 605 Third Ave., New York, N. Y. 1966. x + 294 pp. 16 × 23.5 cm. $9.50.

In 1949, the extant information on the synthesis of peptides was critically reviewed by J. S. Fruton in 82 pages in Volume 5 of *Advances in Protein Chemistry*. Fruton's article not only reported in tabular form all of the known peptides, but also included a critique of the various methods of peptide synthesis. This article set the style for a number of reviews which have appeared periodically since that time, the most recent being the two-volume treatise on "The Peptides" by E. Schröder and K. Lübke.[1] The present book represents a departure from these earlier works in that no attempt is made to catalog the properties of the various peptides. Rather, the authors have concentrated on a delineation of the merits and limitations of the methods involved in peptide synthesis. After short introductory chapters on the historical aspects and on the over-all problems of peptide synthesis, the book takes up seriatim the topics of protective groups, peptide bond formation, racemization, and strategy. In each topic the advantages and disadvantages of the methods are thoroughly discussed and documented. Few if any of the myriad pitfalls present in peptide synthesis have been omitted. The authors through their wide experience have a fine appreciation for the unexpected side reaction which may be overlooked by the novice (and often by the experienced investigator) and which may defeat an otherwise perfect synthesis. Their thoughtful discussion of these problems is alone a sufficient reason for reading this book. The book ends with a chapter outlining the synthesis of a number of biologically active peptides. These schemes not only illustrate the historical developments of peptide synthesis but serve as useful guides for charting the synthesis of new peptides.

This book will be most useful to the novice in peptide synthesis. Its readable and clear exposition will be much appreciated by the graduate student as well as by the experienced investigator who is suddenly immersed in a problem involving peptide synthesis. The reactions are amply illustrated by structural formulas which are presented with surprisingly few errors. The book does not attempt to catalog the various peptides, and in this sense will not be useful as a source book to the established investigator. Understandably emphasis is placed on the contributions of the senior author to peptide chemistry, but with few exceptions other contributors are dealt with quite fairly. To this reviewer, more discussion should have been placed on Merrifields' "solid-phase" synthesis. In part, this deficiency may be due to the problem of timeliness. Even though the authors have made a few citations to the literature in 1965, this book is based largely on the information available through 1964. Much new material has appeared since 1964, and, although in most cases it is supplementary rather than contradictory to the themes espoused in this book, the "solid-phase" technique has had some successes which were not foreshadowed in this writing. This minor criticism on timeliness should not deter the potential purchaser. The authors have carefully illuminated the problems involved in peptide synthesis. These *problems* are timeless. It is the *solutions* which, hopefully, will yield to the passage of time and require a revision of the text.

(1) For a review see G. W. Anderson, *J. Am. Chem. Soc.*, **89**, 2510 (1967).

Frederick H. Carpenter
Department of Biochemistry, University of California
Berkeley, California 94720

The Analytical Chemistry of Cobalt. By ROLAND S. YOUNG, Department of Mines and Petroleum Resources, Victoria, B. C., Canada. Pergamon Press Inc., 44-01 21st St., Long Island City, N. Y. 1966. vii + 170 pp. 15 × 22 cm. $7.00.

Until recent years, a relatively neglected sector of the analytical chemical literature has been the analytical chemistry of individual elements. This lack is now being filled by monographs appearing as members of major series or singly. Thus, the V. I. Vernadskii Institute of Geochemistry and Analytical Chemistry of the Academy of Sciences of the USSR is publishing a series of some 50 volumes on the analytical chemistry of individual elements, which are being translated into English. Young's "Analytical Chemistry of Cobalt" is an independent monograph. It deals as comprehensively as most analysts might wish with chemical, physicochemical, and physical methods for the determination of the element. In addition, sampling, separation methods, and some other topics are treated. Detailed procedures are presented for a considerable number of chemical methods. Because of his experience in the field, the author is able to make helpful recommendations.

The author has conscientiously listed hundreds of references on the determination of cobalt. In the chapter of colorimetric methods,