

Acknowledgment.—We are indebted to Mr. Clayton Mabuni for technical assistance. This investigation was supported by a PHS Grant GM-10413 from the Institute of General Medical Sciences, Public Health Service.

(13) N.D.E.A. Fellow, 1960–1963; NIH Predoctoral Fellow, 1963–1964.

DEPARTMENT OF CHEMISTRY
UNIVERSITY OF HAWAII
HONOLULU, HAWAII

CLIFFORD W. J. CHANG¹³
RICHARD E. MOORE
PAUL J. SCHEUER

RECEIVED MAY 26, 1964

Hydroboration of Ureido-Substituted Olefins¹

Sir:

A research program leading to the synthesis of boron compounds for neutron capture therapy^{2,3} has prompted attempts directed toward the synthesis of nucleic acid bases containing boron as a ring hetero atom. This has resulted in the preparation of several ureidoalkylboronic acids inaccessible by any previously known methods. The synthesis of functionally substituted aliphatic boronic acids has been effected primarily by radical additions of vinylboronic acid derivatives.⁴ The scope of the hydroboration reaction for the synthesis of such compounds is indicated in the work of Brown,⁵ and some examples are realized in this report.

Diborane normally reacts with unhindered olefins to produce trialkylboranes.⁶ However, when *N*-vinylurea⁷ (1 mole) was treated with diborane (1.5 moles as BH_3) in tetrahydrofuran at 0° and followed by decomposition of the excess diborane and the intermediate alkylborane with excess methanol, **dimethyl β -ureidoethylboronate** (Ia), m.p. 65–68°, was formed in 80% yield. *Anal.* Calcd. for $\text{C}_5\text{H}_{13}\text{BN}_2\text{O}_3$: C, 37.54; H, 8.19; B, 6.76; N, 17.52. Found: C, 37.81; H, 8.20; B, 6.85; N, 17.72. This hygroscopic ester afforded the corresponding **boronic acid** (Ib), m.p. 102–104°, on treatment with water. *Anal.* Calcd. for $\text{C}_3\text{H}_9\text{BN}_2\text{O}_3$: C, 27.30; H, 6.88; B, 7.64; N, 21.25. Found: C, 27.35; H, 6.92; B, 7.84; N, 21.30. The n.m.r. spectrum of this acid in D_2O showed five exchangeable protons and two triplets (each of two protons, 0.96 and 3.50, $J = 15$ c.p.s.), thus establishing the 1:2-disubstituted ethane structure. Both the ester Ia and the acid Ib gave the same derivative II, m.p. 237–238°, when treated with diethanolamine. *Anal.* Calcd. for $\text{C}_7\text{H}_{16}\text{BN}_3\text{O}_3$: C, 41.82; H, 8.02; B, 5.38; N, 20.89. Found: C, 42.10; H, 8.14; B, 5.71; N, 21.10.

(1) This investigation was supported by grants from the John A. Hartford Foundation, Inc., the U. S. Atomic Energy Commission (AT(30-1)3287), and the U. S. Public Health Service (CA 07368).

(2) A. H. Soloway, "Boron Compounds in Cancer Therapy," in "Progress in Boron Chemistry," Vol. 1, Pergamon Press, New York, N. Y., 1964, pp. 203–234.

(3) T. K. Liao, E. G. Podrebarac, and C. C. Cheng, *J. Am. Chem. Soc.*, **86**, 1869 (1964), and references cited therein.

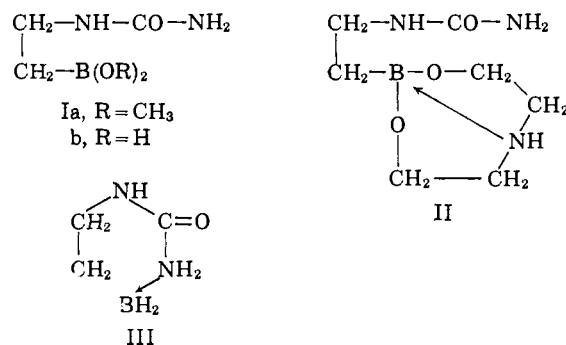
(4) D. S. Matteson and W. H. Mah, *ibid.*, **85**, 2599 (1963).

(5) (a) H. C. Brown, "Hydroboration," W. A. Benjamin, Inc., New York, N. Y., 1962, Chapter 19; (b) H. C. Brown and K. A. Kebly, *J. Am. Chem. Soc.*, **86**, 1791 (1964); (c) H. C. Brown and K. A. Kebly, *ibid.*, **86**, 1795 (1964); (d) H. C. Brown and O. J. Cope, *ibid.*, **86**, 1801 (1964).

(6) See ref. 5a, chapter 6.

(7) R. Hart, *Bull. soc. chim. Belges*, **66**, 229 (1957).

Using the same conditions, analogous compounds have been obtained from *N*-propenyl-,⁸ *N*-cyclohexenyl-,⁸ and *N*-allylurea, in yields ranging from 30 to 90% of theory.



The formation of these monoalkylboronic acid derivatives in such high yields rather than the usual trialkylboron compounds points to the probability of an internally stabilized intermediate such as III being involved. This type of coordination would decrease the reactivity of the monoalkylborane to further hydroboration of unsaturated centers. Thus, the reaction would terminate at this stage. The utilization of one mole of "hydride"^{5b,c} per mole of olefin in the hydroboration of certain unsaturated chlorides and tosylates^{5b} and the facile reduction of unsaturated esters^{5c} where such cyclic entities can occur lend support to this type of coordinated monoalkylborane intermediate.

The extension of this work to other functionally substituted olefins bearing atoms which can coordinate with the introduced borane moiety in five-, six- or seven-membered intermediates is underway in these laboratories. In this manner, it is expected that the reaction will terminate at the monoalkylborane stage, thus permitting the synthesis of other substituted alkylboronic derivatives. The further interaction of the boronic acid moiety with the functional group may permit the synthesis of new boron heterocycles of potential pharmacological interest.

Acknowledgment.—The authors wish to thank William H. Sweet, M.D., Chief of the Neurosurgical Services at the Massachusetts General Hospital, for his interest and encouragement.

(8) D. N. Butler and A. H. Soloway, unpublished work. These ureas were prepared by the method used by Hart (see ref. 7) for the synthesis of *N*-vinylurea and satisfactory analytical data have been obtained for these compounds.

NEUROSURGICAL SERVICE
MASSACHUSETTS GENERAL HOSPITAL
BOSTON, MASSACHUSETTS

D. N. BUTLER
A. H. SOLOWAY

RECEIVED MAY 18, 1964

Dihalomethylenation of Protonic Acids with Phenyl(trihalomethyl)mercury Compounds

Sir:

The dihalomethylenation by phenyl(trihalomethyl)mercury compounds of C–H, Si–H, and Ge–H bonds,¹ as well as the halogenation of Sn–H bonds by such mercurials,² have been reported. We have extended our studies of the reactions of phenyl(trihalomethyl)-

(1) D. Seyferth and J. M. Burlitch, *J. Am. Chem. Soc.*, **85**, 2667 (1963).

(2) D. Seyferth, H. D. Simmons, Jr., and L. J. Todd, *J. Organometal. Chem.*, in press.