**Tetrahedron Letters No.9, pp. 951-956, 1966. Pergamon Press Ltd.
Printed in Great Britain.**

HYDROBORATION OF 2,3-DICARBOMETHOXY-2,3-DIAZABICYCLO[2.2.1]HEPT-5-ENE. THE ELIMINATION MECHANISM OF THE ORGANOBORANE INTERMEDIATE.

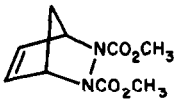
Evan L. Allred, Clyde L. Anderson, and Richard L. Smith
Department of Chemistry, University of Utah
Salt Lake City, Utah 84112

(Received 21 December 1965)

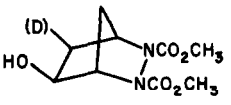
Recent reports show that hydroboration of several different allyl derivatives results in β-elimination of the organoborane intermediate (1-3). A problem still largely unsolved is that of the intimate details of the elimination mechanism. A trans elimination and two varieties of cis eliminations have been postulated, with the suggestion that much more work needs to be done (2b). In the only other study, evidence has been cited for a cis elimination and a boron trifluoride catalyzed trans elimination of β-ethoxyorganoboranes (4). We now report the β-elimination of yet another functional group, definitive evidence for a trans mechanism in this case, and a cursory survey of nucleophiles which effect the elimination.

Hydroboration of I (5) in tetrahydrofuran at 0°, followed by oxidation, gives II and the partially fragmented products III and IV. The structure of II, m.p. 113-114°, was assigned on the basis of the following spectral data:* infrared (Nujol), 3450 $cm.^{-1}$ (O-H) and a doublet at 1750 and 1700 $cm.^{-1}$ (C=O); n.m.r. ($CDCl_3$), τ 5.45 (singlet, 1 H), 5.64 (sirglet, 1 H), 5.9 (doublet, J~7 c.p.s., 1 H), 6.23 (singlet,

* All compounds reported have excellent carbon, hydrogen, and nitrogen analyses.



I



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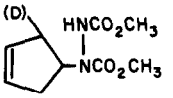

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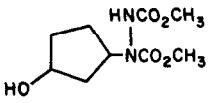

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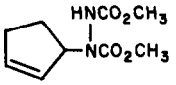

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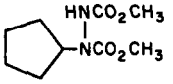


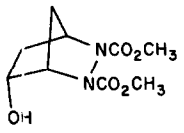
VI

6 H), 6.35 (broad singlet, 1 H), 7.9 (multiplet, 2 H), and 8.3 (multiplet, 2 H). Structure III, m.p. 117.5-118°, follows from the infrared spectrum (Nujol), 3250 cm.$^{-1}$ (N-H), 1720 cm.$^{-1}$ (C=O), and 1525 cm.$^{-1}$ (-CO-NH-); and the n.m.r. spectrum ($CDCl_3$), τ 2.62 (broad singlet, 1 H), 4.35 (singlet, 2 H), 5.06 (quintet, J~7 c.p.s., 1 H), 6.23 (singlet, 6 H), and 7.50 (doublet, J~7 c.p.s., 4 H). As additional confirmation, the 3-substituted isomer V, m.p. 127-128°, was synthesized from cyclopentene and dimethyl azodicarboxylate by the method of Huisgen and Jacob (6). Hydrogenation of III and V gave the same cyclopentane derivative VI, m.p. 98-98.5°. The structure of IV, m.p. 146-147.5°, is based on the infrared spectrum (Nujol), 3450 cm.$^{-1}$ (O-H), 3250 cm.$^{-1}$ (N-H), 1718 and 1689 cm.$^{-1}$ (C=O), and 1525 cm.$^{-1}$ (-CO-NH-); and the fact that hydroboration of III gives IV in high yield.

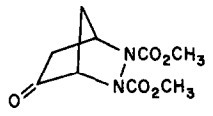
Treatment of I with deuterodiborane, followed by oxidation, results in at least 90-95% incorporation of one deuterium atom at the ring position C-6 for II and C-3 for III. For this experiment, the deuterodiborane reaction product was divided in half and worked up as in experiments 1 and 5 of Table I to give II and III, respectively. The n.m.r. spectra show the disappearance of one proton at τ 8.3 and 7.50

for II and III, respectively.

Oxidation of the organoborane from I appears to provide only the exo isomer II. This is based on the O-H stretching absorption in the infrared first overtone region. In dilute carbon tetrachloride solution II shows only a single band at 1.414μ. This is entirely analogous to the free O-H absorption found for exo-norborneol (7). For additional confirmation, the endo isomer VII was synthesized. Oxidation of II with chromium trioxide in pyridine gives a ketone VIII, m.p. 87-88°. Reduction of VIII with sodium borohydride in methanol affords the endo alcohol VII, m.p. 135-136°. The infrared and n.m.r. spectra are in complete accord with these structures. As expected, VII exhibits the free O-H band at 1.410μ and another band at 1.456μ which is due to intramolecular hydrogen bonding.



VII



VIII

The product distribution from the hydroboration-oxidation of I proved to be very sensitive to reaction conditions. In Table I are summarized the effect of nucleophiles and temperature on the product ratio. This study was conducted with 0.6 M or 1.0 M borane in tetrahydrofuran. Care was taken to exclude boron trifluoride or dissolved salts from these solutions by using diborane which had been generated from sodium borohydride and boron trifluoride and then passed through a diglyme solution of sodium borohydride (8). It is apparent that boron-carbon cleavage of the organoborane intermediate and the resulting β-elimination are a consequence of nucleophilic attack on boron. This data provides the first evidence of a correspondence between the elimination and the nucleophilicity of the group attacking the boron atom.

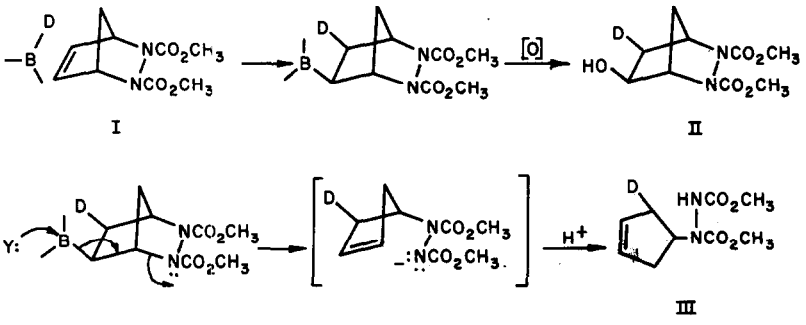
TABLE I

Expt.[a]	Time hours	Temp. °C	Added nucleophile	% Composition of the product[b] II	III	IV
1	-	0	---	94	<3	<3
2[c]	8	60	THF	>90	<5	--
3[d]	3	0	OH^-	95	<3	<3
4[d]	1	60	OH^-	45	50	<5
5[d]	3	60	OH^-	8	86	--
6[e]	3	60	H_2O	65	31	<3
7[f]	3	0	BH_4^-	65	<5	30

[a]A 1:1 ratio of BH_3 to I was used for all hydroborations. Hydroboration was conducted at 0° for 3 hours. The standard oxidation work up consisted of rapid addition of a 2 fold excess of aqueous $NaOH-H_2O_2$ at 0°. [b]The products II, III, and IV were separated by careful chromatography on a Florisil column using as eluant solvents dichloromethane, dichloromethane-ether, and ether-methanol, respectively. The course of separation was followed by infrared spectra. In all cases the recovered total product (II, III, and IV) yield was greater than 90%. The product compositions are believed to be reliable to ca. ± 3%. [c]The excess BH_3 was removed under vacuum and fresh, dry THF was added. [d]Enough 3 M NaOH was added to give a 1:1 mole ratio of OH^- to I. The standard oxidation work up was used at 0°. [e]A 9:1 mole ratio of H_2O to I was used. The standard oxidation work up was used. [f]A 0.5:1 mole ratio of $NaBH_4$ to I was added at the start of the hydroboration. This result was checked with duplicate experiments.

Brown has accumulated convincing evidence that hydroboration involves cis addition of the B-H bond, and that oxidation to the alcohol proceeds with retention of configuration (9). On this basis, the labelling, stereochemical, and nucleophilic results are accommodated readily by the

trans elimination mechanism in the following scheme where Y: represents the nucleophile.



To the best of our knowledge, experiment 7 represents the first recognition that sodium borohydride causes elimination of β-hetero-substituted organoboranes. The effectiveness of this reagent is indicated by the efficiency of elimination at 0°. This is all the more impressive because elimination of the organoborane from I is much slower than with the boron derivative of allyl ethyl ether (2b). These observations make it clear that for most synthetic applications in situ hydroboration is not the procedure of choice with heterosubstituted alkenes.

Acknowledgement. This study was supported by the National Science Foundation, Grant No. GP-3534.

REFERENCES

1. P. Binger and R. Koster, Tetrahedron Letters, No. 4, 156 (1961).

2. (a) H. C. Brown and K. A. Keblys, J. Am. Chem. Soc., 86, 1791 (1964).

   (b) H. C. Brown and O. J. Cope, J. Am. Chem. Soc., 86, 1801 (1964).

3. J. G. Sharefkin and S. H. Pohl, J. Org. Chem., 29, 2050 (1964).

4. D. J. Pasto and C. C. Cumbo, J. Am. Chem. Soc., 86, 4343 (1964).

5. J. C. J. MacKenzie, A. Rodgman, and G. F. Wright, J. Org. Chem., 17, 1666 (1952).

6. R. Huisgen and F. Jacob, Ann., 590, 37 (1954).

7. R. Piccolini and S. Winstein, Tetrahedron Letters, No. 13, 4 (1959).

8. G. Zweifel, K. Nagase, and H. C. Brown, J. Am. Chem. Soc., 84, 188 (1962).

9. H. C. Brown, Hydroboration, pp. 12-16, 71-72, and c. 8. W. A. Benjamin, Inc., New York, N. Y. (1962).