major reaction products from dimethylformamide and $(H_3O)_2B_{10}H_{10}$ are $B_{10}H_9OCHO^=$ and $B_{10}H_9N(CH_3)_2H^-$. The latter is isolated from aqueous solution as an acid salt because of its exceedingly weak acidity. $B_{10}H_9N(CH_3)_2H^-$ is such a weak acid that OH^- does not remove the proton from the quaternary nitrogen. This proton, however, undergoes exchange with deuterium in deuterium oxide, thus demonstrating its lability.

Anal. Calcd. for $(CH_3)_3SB_{10}H_9N(CH_3)_2H$: C, 25.1; H, 10.5; B, 45.2; N, 5.8; S, 13.4. Found: C, 25.3; H, 10.3; B, 45.1; N, 5.6; S, 13.3. Calcd. for $Cs_2B_{10}H_9OCHO$: C, 2.8; H, 2.3; B, 25.0; Cs, 62.1. Found: C, 2.7; H, 2.6; B, 25.5; Cs, 62.0.

$(H_3O)_2B_{10}H_{10}$ and $(H_3O)_2B_{12}H_{12}$ react with donor oxygen and sulfur functions in organic compounds to give a variety of derivatives, *e.g.*

$$B_{12}H_{11}OCH_3^= + B_{12}H_{11}OH^=$$
$$\uparrow CH_3OH$$
$$B_{12}H_{12}^= \xrightarrow{CH_3OCH_2CH_2OCH_3} B_{12}H_{10}(OCH_2CH_2OCH_3)_2$$
$$\downarrow CH_3COOH$$
$$B_{12}H_{11}OH^= + B_{12}H_{11}OCH_2CH_3^= + B_{12}H_{11}OCOCH_3^=$$

Disulfides give thioether derivatives, *e.g.*, $B_{10}H_8(SCH_3)_2^=$. Hydrogen halides also react with the B_{10} and B_{12} acids; $B_{12}H_8F_4^=$ and $B_{12}H_{11}Cl^=$ have been obtained in this fashion. Olefins also add readily to $(H_3O)_2B_{10}H_{10}$ and $(H_3O)_2B_{12}H_{12}$. Styrene and propylene, for example, have given $B_{12}H_{11}CH(CH_3)C_6H_5^=$ and $B_{12}H_{11}C_3H_7^=$.

Anal. Calcd. for $Cs_2B_{12}Br_{11}OH$ (*ex* bromination of $B_{12}H_{11}OH^=$): Cs, 20.6; B, 10.1; Br, 68.0. Found: Cs, 20.3; B, 9.8; Br, 68.4. Calcd. for $Cs_2B_{12}H_8F_4$: B, 27.0; F, 15.7. Found: B, 27.0; F, 15.7. Calcd. for $Cs_2B_{12}H_{11}CH(CH_3)C_6H_5$: C, 31.3; H, 4.6; B, 21.1. Found: C, 32.5; H, 5.1; B, 21.1.

It is also possible to attach dimethyl sulfide to these boron cages, the charge on the resulting species being dependent on the number of such ligands attached. An example is $B_{10}H_8[S(CH_3)_2]_2$, which can be prepared by the reaction of $B_{10}H_{10}^=$ with dimethyl sulfoxide under acidic conditions. This reaction also gives $B_{10}H_9S(CH_3)_2^-$.

Anal. Calcd. for $B_{10}H_8[S(CH_3)_2]_2$: C, 20.0; H, 8.4; B, 45.0; S, 26.6; mol. wt., 240. Found: C, 20.1; H, 8.3; B, 44.4; S, 26.7; mol. wt., 230.

As would be expected, the order of reactivity toward electrophilic reagents is $B_{10}H_{10}^= > B_{10}H_9S(CH_3)_2^- > B_{10}H_8[S(CH_3)_2]_2$.

The mechanisms of some of these reactions are obscure but most of them seem to be electrophilic. Stereochemical and mechanism studies have been initiated to learn more of this aspect. In preliminary work it has been shown that deuteration of $B_{10}H_{10}^=$ under acid conditions occurs most rapidly at the two apical boron[5] atoms and presumably they would be the initial site of electrophilic attack. In agreement with this, boron resonance studies show that $B_{10}H_8[S(CH_3)_2]_2$ is apically substituted.

(5) The term "apical boron" refers to the $B_{10}H_{10}^-$ structure postulated by W. N. Lipscomb, A. R. Pitochelli and M. F. Hawthorne, *J. Am. Chem. Soc.*, **81**, 5833 (1959).

CONTRIBUTION NO. 733 FROM THE CENTRAL RESEARCH DEPARTMENT EXPERIMENTAL STATION E. I. DU PONT DE NEMOURS AND CO. WILMINGTON 98, DELAWARE

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RECEIVED DECEMBER 14, 1961

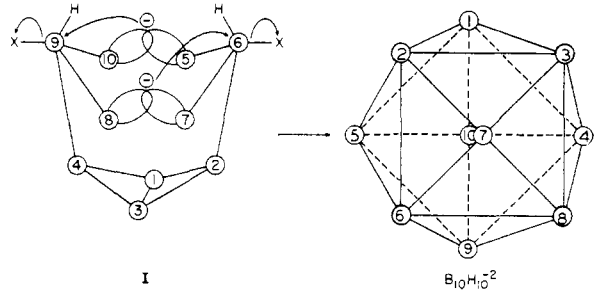
OBSERVATIONS ON THE MECHANISM OF $B_{10}H_{10}^{-2}$ FORMATION

Sir:

The recent preparation[1] and the proposal of the probable structure[2] of the $B_{10}H_{10}^{-2}$ ion has led to a study of the mechanism of $B_{10}H_{10}^{-2}$ ion formation. As previously described,[1] the $B_{10}H_{10}^{-2}$ ion is formed when members of the $B_{10}H_{12}X_2$ (X = ligand) series are treated with base. An example of this interconversion is shown in (1). The

$$B_{10}H_{12}(CH_3CN)_2 + 2Et_3N \longrightarrow 2Et_3NH^+ + B_{10}H_{10}^{-2} + 2CH_3CN \quad (1)$$

proposed structure of the $B_{10}H_{10}^{-2}$ ion[2] requires a subtle rearrangement of the boron atom configuration present in $B_{10}H_{12}X_2$ compounds.[3] It was observed[4] that the attachment of a 5(7)-boron atom to the 9-boron atom of decaborane and then a similar attachment of the 8(10)-boron atom to the 6-position results in the unique formation of the proposed $B_{10}H_{10}^{-2}$ configuration. The two ligand molecules and the two bridge hydrogen atoms present in the reactant $B_{10}H_{12}X_2$ molecule are expelled during this reaction. In mechanistic terms, the bridge hydrogen atoms present in $B_{10}H_{12}X_2$ may be removed as protons to produce an intermediate (I) which contains filled 2-center orbitals between edge neighbors. These two filled 2-center orbitals may then serve as novel intramolecular nucleophiles for the displacement of the ligands, X, from the 6 and 9 positions.



I $B_{10}H_{10}^{-2}$

The over-all transformation of $B_{10}H_{12}(CH_3CN)_2$ to $B_{10}H_{10}^{-2}$ outlined above requires that the two apices of the proposed D_{4d} polyhedron[2] be derived from the 5 and 8 or the 7 and 10 boron atoms of the decaborane molecule. A sample of tetradeuteriodecaborane, deuterated at the 2,4 and 1, 3 boron positions was available from another

(1) M. F. Hawthorne and A. R. Pitochelli, *J. Am. Chem. Soc.*, **81**, 5519 (1959).

(2) W. N. Lipscomb, Anthony R. Pitochelli and M. F. Hawthorne, *ibid.*, **81**, 5833 (1959).

(3) J. Reddy and W. N. Lipscomb, *J. Chem. Phys.*, **31**, 610 (1959), report the boron atom configuration of $B_{10}H_{12}(CH_3CN)_2$ to be essentially that present in the decaborane-14 molecule.

(4) Also proposed by W. N. Lipscomb, private communication, September, 1960.

study,[5] and was converted with triethylamine[1] to the $B_{10}H_6D_4^{-2}$ ion. The B^{11} n.m.r. spectrum of the latter was compared with that of $(Et_3NH)_2$-$B_{10}H_{10}$ in acetonitrile

	δ (in p.p.m. ± 0.5 relative to $B(OCH_3)_3$)	J_{BH} (in c./s. ± 5)
$(Et_3NH)_2B_{10}H_{10}$ axial	18.8	138
$(Et_3NH)_2B_{10}H_{10}$ equatorial	47.0	125
$(Et_3NH)_2B_{10}H_6D_4$ axial	19.0	143
$(Et_3NH)_2B_{10}H_6D_4$ equatorial	48.1	Broad singlet

No change was apparent in the low field doublet ascribed to apical BH units, while appreciable collapse was observed in the high field doublet attributed to the equatorial belt of eight equivalent BH units. Because of the inherent line widths of B^{11} resonances, line shapes are only moderately sensitive indices of deuteration. At present, we can conclude that at least 90% of the apical positions of $B_{10}H_6D_4^{-2}$ contained BH bonds, whereas random distribution of deuteriums would predict 60%. Thus, the available data are consistent with the proposed structure[2] and the mechanism of ion formation outlined here.

It might further be mentioned that infrared studies show $B_{10}H_{10}^{-2}$ does not undergo deuterium exchange with D_2O or $(Et_3ND)^+$.

(5) J. A. Dupont and M. F. Hawthorne, Meeting Abstracts, p. 47-N, 138th Meeting of the American Chemical Society, New York, New York, September 11–16, 1960.

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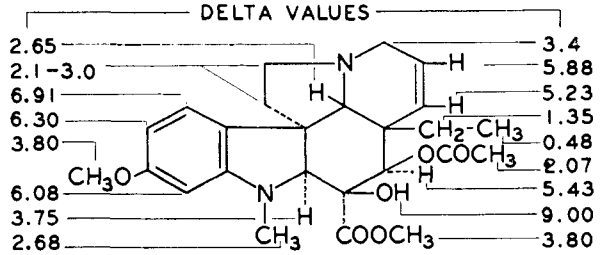
RECEIVED DECEMBER 26, 1961

VINCA ALKALOIDS. X[1]. THE STRUCTURE OF VINDOLINE

Sir:

Vindoline,[2,3] $C_{25}H_{32}O_6N_2$, is the major alkaloid in the leaves of *Vinca rosea* Linn. It occurs not only as the free base which possesses little biological activity, but combined with various indolic moieties[4] it is ubiquitous in the dimeric *Vinca* alkaloids such as vinblastine[5] (VLB) and leurocristine,[1] which are potent oncolytic agents.[6]



I

(1) Paper IX, G. H. Svoboda, *Lloydia*, **24**, 173 (1961).

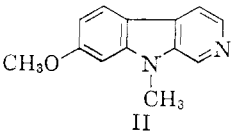
(2) M. Gorman, N. Neuss, G. H. Svoboda, A. J. Barnes, Jr., and N. J. Cone, *J. Am. Pharm. Assoc., Sci. Ed.*, **48**, 256 (1959).

(3) G. H. Svoboda, N. Neuss, and M. Gorman, *ibid.*, **48**, 659 (1959).

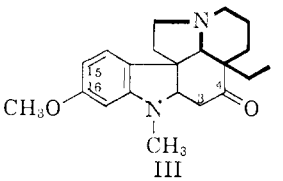
(4) M. Gorman, N. Neuss, and G. H. Svoboda, *J. Am. Chem. Soc.*, **81**, 4745 (1959).

(5) Previously called vincaleukoblastne: N. Neuss, M. Gorman, G. H. Svoboda, G. M. Maciak, and C. T. Beer, *ibid.*, **81**, 4754 (1959).

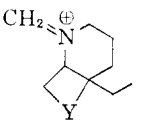
The base was previously shown[2] to be pentacyclic and to contain an isolated double bond. Five of the oxygens were found to be present as hydroxyl, carbomethoxyl and acetoxyl functions.



II



III



IV, Y = C=O
V, Y = CH_2

Structure I has been found to be consonant with all observed spectral and chemical data for vindoline. The stereochemical implications are quite tentative and rest on evidence which will be presented in the full paper. Examination of the n.m.r. spectrum[7] of vindoline allows the assignment of each proton as shown. The assignments, however, deserve some comment. The unsplit peak of the proton on the carbon bearing the acetoxyl moiety shifts to 4.07δ in desacetylvindoline. The protons of the methylene portion of the C-ethyl group are not equivalent and are found as a 12-band multiplet centered at 1.35δ (J = 7.5 c.p.s.). The methyl triplet, however, is almost symmetrical in vindoline, being found at an exceptionally high field (0.48δ, J = 7.5 c.p.s.) for a grouping of this type. This high field appears to be the result of increased shielding by ring currents from the aromatic ring. The coupling constant of the two *cis* vinyl protons is J = 10 c.p.s., and one of these (5.88δ) is further split by two non-equivalent adjacent protons (δ = 3.4) with coupling constants J = 5 and 2 c.p.s.

The position of the aromatic methoxyl is shown to be at either C-15 or C-16[8] by examination of the typical 1,2,4 aromatic proton pattern (*ortho* splitting J = 8 c.p.s., *meta* splitting J = 2.5 c.p.s.). The final selection of C-16 is based on the comparison of the infrared and ultraviolet spectra of vindoline with 6-methoxy-N-methyldihydroindole[9] and by the isolation of *ind*-N-methylnorharmine (II); m.p. 112–114°, hydrochloride m.p. 232–236°, molecular weight (M) 212 (by mass spectrometry), λ_{max}^{EtOH} 243 (37,500), 303 (15,100), 336 (4,300), from a soda lime distillation of vindoline at 325°. This derivative also indicates the position of the N-CH_3 as being on the anilino nitrogen.[10] A

(6) I. S. Johnson, H. F. Wright, and G. H. Svoboda, *Abstract of the Proc. Am. Assoc. for Cancer Research*, Vol. 3, No. 4 (1962) (in press) and references cited therein.

(7) Spectra recorded on Varian HR-60 in $CDCl_3$ with tetramethylsilane as internal standard: Values δ(PPM), TMS = 0.

(8) For numbering system see C. Djerassi, *et al.*, *Proc. Natl. Acad. Sci. U.S.*, **48**, 113 (1962).

(9) Kindly supplied by Dr. A. Hofmann, Sandoz A. G., Basel, Switzerland.

(10) The presence of the dimethylene "tryptophan" bridge is also strongly supported by the isolation of *ind*-N-methylnorharmine and the finding that tryptophan is an excellent *in vivo* precursor for vindoline (private communication, R. McMahon and M. Gorman, Eli Lilly and Company).