carboxypeptidase; MSH activity 1.1 × 10^8 U./g.[15]) were isolated from the partial hydrolysate by chromatography on carboxymethylcellulose,[17] cellulose-block electrophoresis at pH 7.0 and then c.m.c. chromatography.

Repeated assays of various batches of our preparation of the eicosapeptide amide by the rat adrenal ascorbic acid depletion method gave an average value of 111.0 ± 18.0 U./mg. For determination of the ability of the material to bring about steroidogenesis in man the preparation was infused over a 15 minute period and plasma 17-hydroxysteroid levels were determined at 0, 15, 30 and 60 minutes. The material was administered to 22 patients, and at all levels above 5 units there was a significant rise in plasma 17-hydroxysteroids which occurred maximally at 30 minutes but persisted into the 60 minute period.[18]

In conjunction with previous observations these findings indicate that the structural elements which are essential for full adrenocorticotropic activity reside in that portion of the ACTH molecule which corresponds to the first twenty residues from the amino end. It is of interest that the addition of the valine amide moiety to the C-terminus of the nonadecapeptide (II) brings about such a remarkable increase in biological potency. We have no explanation for the discrepancy between our results and those of Boissonnas, *et al.*[4]

---

(17) E. A. Peterson and H. A. Sober, *J. Am. Chem. Soc.*, **78**, 751 (1956).

(18) We wish to express our sincere thanks to Dr. H. S. Lipscomb, Department of Physiology, Baylor University College of Medicine for the results with human patients which will be presented in a separate publication.

KLAUS HOFMANN
BIOCHEMISTRY DEPARTMENT — TEH-YUNG LIU
UNIVERSITY OF PITTSBURGH — HARUAKI YAJIMA
SCHOOL OF MEDICINE — NOBORU YANAIHARA
PITTSBURGH, PENNSYLVANIA — CHIZUKO YANAIHARA
JOHN L. HUMES

RECEIVED JANUARY 18, 1962

DERIVATIVE CHEMISTRY OF $B_{10}H_{10}^{=}$ AND $B_{12}H_{12}^{=}$

Sir:

We wish to report a derivative chemistry of such scope and diversity as to presage a new major area of inorganic chemistry. This chemistry is based on reactions of the polyhedral borane anions $B_{10}H_{10}^{=}$ and $B_{12}H_{12}^{=}$.[1,2] The stability of these anions to strong base, strong acids and oxidizing agents is unique for boron hydride structures. For example, they are inert to hot sodium hydroxide or sodium methoxide solutions and can be converted to the stable acids $(H_3O)_2B_{10}H_{10}\cdot xH_2O$ and $(H_3O)_2B_{12}H_{12}\cdot xH_2O$. These acids are slightly stronger than sulfuric acid.[3] The anions form insoluble, apparently covalent silver salts with no reduction to silver metal. However, the anions react smoothly with certain reagents, particularly electrophilic species, to give stable derivatives in which hydrogen atoms are replaced by the attacking group.

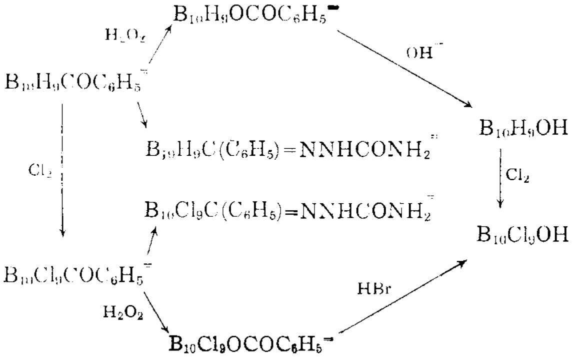
All of the halogens react smoothly with aqueous or alcoholic solutions of $B_{10}H_{10}^{=}$ and $B_{12}H_{12}^{=}$ to give a series of haloborates. Examples of some of the anions we have isolated in the form of salts and crystalline hydrated acids[4] are $B_{10}Cl_{10}^{=}$, $B_{12}H_3Br_6Cl_3^{=}$, $B_{12}F_{12}^{=}$, $B_{12}I_{12}^{=}$, $B_{10}H_3Br_7^{=}$, $B_{10}H_6I_4^{=}$, $B_{12}H_{11}I^{=}$, $B_{12}Cl_{10}H_2^{=}$, $B_{12}Br_{12}^{=}$ and $B_{10}I_{10}^{=}$. The halogenated salts have excellent chemical and thermal stabilities. For example, differential thermal analysis studies have shown that $Cs_2B_{10}Cl_{10}$ is stable to at least 400° in the presence of air. The halogen–boron bonds are inert to nucleophiles such as hydroxide or methoxide in refluxing water or methanol.

Anal. Calcd. for $[(CH_3)_4N]_2B_{12}Br_{12}$: C, 7.8; H, 2.0; B, 10.5; Br, 77.6. Found: C, 8.3; H, 2.3; B, 10.6; Br, 77.7. Calcd. for $(H_3O)_2B_{10}I_{10}\cdot 6H_2O$: B, 7.1; I, 83.5; neut. equiv., 760. Found: B, 7.0; I, 83.5; neut. equiv., 754.

$B_{12}H_{12}^{=}$ has been nitrated with nitric acid under carefully controlled conditions to give $B_{12}H_{11}NO_2^{=}$.

Anal. Calcd. for $Cs_2B_{12}H_{11}NO_2$: B, 28.7; H, 3.4; N, 3.1. Found: B, 28.3; H, 3.1; N, 3.4. The presence of the nitro group is confirmed by infrared absorption bands at 6.35 μ and 7.7 μ.

Benzoyl chloride reacts with $(H_3O)_2B_{10}H_{10}$ to give $B_{10}H_9COC_6H_5^{=}$ which can undergo further reactions at either the B–H or the carbonyl functionalities.



Anal. Calcd. for $[(CH_3)_3S]_2B_{10}Cl_9C(C_6H_5){=\!=}NNHCONH_2$: C, 22.5; H, 3.5; B, 14.5; N, 5.6; Cl, 43.0. Found: C, 21.7; H, 3.4; B, 15.0; N, 4.9; Cl, 44.2. Calcd. for $[(CH_3)_4N]_2B_{10}Cl_9OH$: C, 16.2; H, 4.2; B, 18.3; Cl, 53.9. Found: C, 16.8; H, 4.7; B, 18.3; Cl, 53.2.

The carbonyl absorption in the infrared spectra of $B_{10}H_9COC_6H_5^{=}$ and $B_{10}Cl_9COC_6H_5^{=}$ is shifted to about 6.4 μ and its intensity decreased so that it is difficult to distinguish from the phenyl bands. The preparation of semicarbazones demonstrates that carbonyl reactivity persists, however. Oxidation with hydrogen peroxide to $B_{10}H_9OCOC_6H_5^{=}$ and $B_{10}Cl_9OCOC_6H_5^{=}$ restores normal carbonyl intensity and the position of the carbonyl band drops back to 6.0 μ.

Amides also react with concentrated aqueous solutions of $B_{10}H_{10}^{=}$ under acid conditions. The

---

(1) These anions may be called decahydrodecaborate(-2) and dodecahydrododecaborate(-2) following proposals made by the Committee on Nomenclature of the American Chemical Society, Division of Inorganic Chemistry; *cf.* paper by K. L. Loening to the Division of Chemical Literature, 134th American Chemical Society Meeting, Chicago, Illinois, September, 1958, abstracts, p. 1-G.

(2) M. F. Hawthorne and A. R. Pitochelli, *J. Am. Chem. Soc.*, **81**, 5519 (1959); M. F. Hawthorne and A. R. Pitochelli, *ibid.*, **82**, 3228 (1960).

(3) Y. T. Chia, to be published.

(4) These are strong acids; in general comparable to sulfuric acid.

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.*

$$\begin{tikzcd}
B_{12}H_{11}OCH_3^= + B_{12}H_{11}OH^= & \\
B_{12}H_{12}^= \arrow[u, "CH_3OH"] \arrow[r, "CH_3OCH_2CH_2OCH_3"] \arrow[d, "CH_3COOH"] & B_{12}H_{10}(OCH_2CH_2OCH_3)_2 \\
B_{12}H_{11}OH^= + B_{12}H_{11}OCH_2CH_3^= + B_{12}H_{11}OCOCH_3^= &
\end{tikzcd}$$

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.

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

W. H. KNOTH
H. C. MILLER
D. C. ENGLAND
G. W. PARSHALL
E. L. MUETTERTIES

RECEIVED DECEMBER 14, 1961

---

[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).

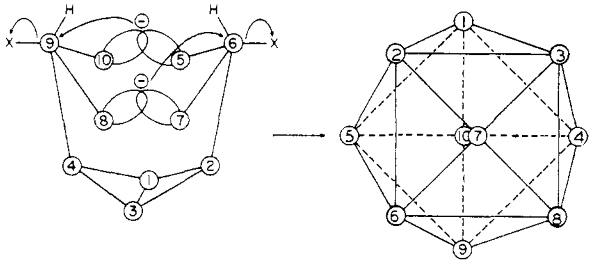
OBSERVATIONS ON THE MECHANISM OF $B_{10}H_{10}^{-2}$ FORMATION

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.