powder from ether, $C_{21}H_{28}O_2N_2$, mol. wt. 340 by mass spectrometry, exhibited spectral properties consistent with structure IV (λ_{max}^{MeOH} 244 and 299 mμ; 5.80 μ). Final confirmation of structure IV was obtained from the mass spectrum. The most intense peak in the mass spectrum occurred at m/e = 124 whereas the second most intense peak was present at m/e = 254 (M − 86) due to the loss of the elements of methyl acrylate. Indeed, comparison of the above spectrum with a mass spectrum of authentic dihydrovincadifformine,[1,13] kindly provided by Professor Djerassi, indicated that both spectra were *identical*.[14] Further chemical verification was provided by heating III with 2 *N* hydrochloric acid[1] to yield a gum which showed the expected spectral properties of an indolenine system[1,15] (λ_{max}^{MeOH} 221, 227 (inflection), 250 mμ (very broad), no infrared carbonyl absorption). This latter substance, on reduction with lithium aluminum hydride, afforded a crystalline product, m.p. 89–90° (from acetone), $[\alpha]^{26}D$ −60° ($CHCl_3$). The cyclic structure V was assigned to this product on the basis of the following evidence. $C_{19}H_{26}N_2$, mol. wt. 282 by mass spectrometry; λ_{max}^{MeOH} 243 and 295 mμ (log ϵ 3.81 and 3.45); n.m.r. signals 6.4–7.3 p.p.m., area = 4H; mass spectrum showed significant peaks at m/e = 282 (M^+), 281 (M − 1), 254 (M − 28), 190, 152, 144, 138, 130, and a very strong peak at 124. Indeed, the mass spectrum of V was identical with the mass spectrum of a previously established substance possessing the aspidosperma skeleton.[6,16] Finally, more evidence for the Aspidosperma system in V was obtained from the N-acetyl derivative VI, $C_{21}H_{28}N_2O$, m.p. 107.5–109° (from petroleum ether). The spectral properties were in excellent agreement with demethoxypalosine[17] (λ_{max}^{MeOH} 253, 279, and 289 mμ (log ϵ 4.13, 3.58, and 3.51); λ_{min} 226, 276, and 287 mμ (log ϵ 3.51, 3.56, and 3.45)); n.m.r. signals 7.15 p.p.m., broad, area = 3H; 8.13 p.p.m. (C-17–H). The spectral data were generally in very good agreement with our previous work.[6,18]

The stereochemistry of this transannular cyclization (see VII) is presently being considered by X-ray methods since a convenient correlation to a known alkaloid is not possible at this time. However, we do feel that the demonstration of this type of reaction will open interesting avenues to the synthesis of several alkaloid systems. For example, the obvious extension of this reaction to an alkaloid such as vincadine[19] should provide a direct route to vincadifformine (I) and its relatives.

(13) See also C. Djerassi, *Pure Appl. Chem.*, **6**, 575 (1963).

(14) This evidence indicates that the mass spectrometric method cannot distinguish in the region normally considered (above m/e = 120) between an Aspidosperma skeleton possessing an ethyl group at C-5 and one at C-7.

(15) K. Biemann, M. Spiteller-Friedmann, and G. Spiteller, *J. Am. Chem. Soc.*, **85**, 631 (1963).

(16) The peak at m/e = 190 which was also present in the previously reported spectrum[6] was disregarded since there was good reason at that time to believe that it was due to an impurity in the mass spectrometer. We have recently established that this peak is characteristic of this system and may represent an interesting variation in the fragmentation process normally postulated for the Aspidosperma alkaloids.

(17) B. Gilbert, J. A. Brissolese, J. M. Wilson, H. Budzikiewicz, L. J. Durham, and C. Djerassi, *Chem. Ind.* (London), 1949 (1962).

(18) Since it is known that the starting material, II, has a different stereochemistry at the asymmetric center bearing the ethyl group from that present in dihydrocleavamine, the compound assigned structure V will possess a different stereochemistry at least at this center from the previously described substance.[6]

(19) J. Mokry, I. Kompis, L. Dubravkova, and P. Sefcovic, *Tetrahedron Letters*, 1185 (1962).

It will be of considerable interest to observe whether alkaloids possessing the system III will be found in nature.

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The Synthesis of Iboga Alkaloids *via* a Novel Transannular Cyclization Reaction

Sir:

In connection with the chemistry of the known Vinca alkaloid catharanthine,[1] we were able to establish the structure of cleavamine (I),[2] one of the acid-rearrangement products of this Iboga-type alkaloid. Consideration of the mechanistic aspects of this rearrangement process led us in turn to consider some of the biosynthetic hypotheses which have been proposed for the Iboga alkaloids. Wenkert[3] introduced an attractive scheme wherein he visualized the cyclization of an ionic intermediate such as II to provide a pathway to the Iboga alkaloid system. It is immediately apparent that this latter intermediate possesses a cleavamine-like skeleton and it was, therefore, of considerable interest to evaluate the feasibility of such a cyclization process. We now wish to report the first synthesis of several Iboga alkaloids *via* a transannular cyclization of the type mentioned above.

Carbomethoxydihydrocleavamine (III)[4,5] on reaction with mercuric acetate would be expected to generate an intermediate with the iminium group ($>C{=}\overset{+}{N}<$) involving C-19 and/or C-5. The intermediate with the C-19 $=\overset{+}{N}<$ group could, by the appropriate transannular cyclization process, provide a vincadifformine-type system,[6] whereas the substance with the C-5 $=\overset{+}{N}<$ group could, by a different transannular cyclization scheme (see IV), provide entry into the Iboga alkaloid system. Indeed, we have now been able to show that both processes are feasible—the formation of the vincadifformine-type skeleton is presented in the accompanying communication[7] whereas the generation of the Iboga system is described here.

Carbomethoxydihydrocleavamine (III), on reaction with mercuric acetate in acetic acid at room temperature followed by reflux, provided a crude mixture which was then subjected to chromatography on alumina.

(1) N. Neuss and M. Gorman, *Tetrahedron Letters*, 206 (1961).

(2) J. P. Kutney, J. Trotter, T. Tabata, A. Kerigan, and N. Camerman, *Chem. Ind.* (London), 648 (1963).

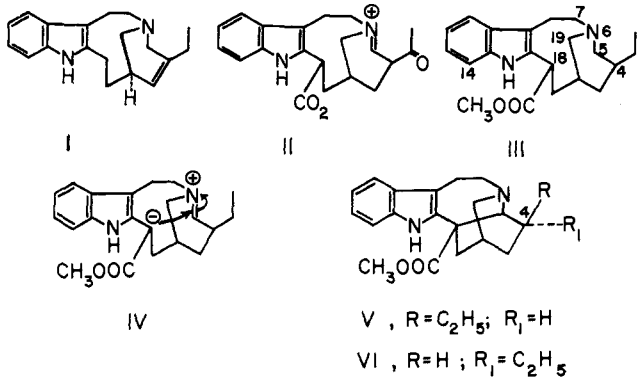
(3) E. Wenkert, *J. Am. Chem. Soc.*, **84**, 98 (1962).

(4) We are very grateful to Dr. M. Gorman and Dr. N. Neuss, Eli Lilly laboratories, for providing the experimental procedure for preparing this compound prior to publication. This compound was first prepared by Professor G. Büchi, Massachusetts Institute of Technology.

(5) The numbering system used here is that normally used in the Iboga alkaloid series.

(6) C. Djerassi, H. Budzikiewicz, J. M. Wilson, J. Gosset, J. Le Men, and M. M. Janot, *Tetrahedron Letters*, 235 (1962).

(7) J. P. Kutney, R. T. Brown, and E. Piers, *J. Am. Chem. Soc.*, **86**, 2286 (1964).



I II III

IV

V , $R=C_2H_5$; $R_1=H$

VI , $R=H$; $R_1=C_2H_5$

This chromatographic separation allowed the isolation of three main components. The major product[7] was obtained as an amorphous powder in the initial fractions (benzene elution) whereas the remaining two alkaloids were isolated from the later fractions (benzene and benzene–ether elutions, respectively). The alkaloid isolated from the later benzene fractions was amorphous and showed an indole chromophore in the ultraviolet spectrum (λ_{max}^{MeOH} 226, 285, and 293 mμ). The presence of an ester carbonyl infrared absorption ($\lambda_{max}^{CCl_4}$ 5.85 μ) and the stability of this ester group to acidic hydrolysis[8] suggested that this alkaloid was probably a member of the Iboga series. Indeed, comparison (infrared and thin layer chromatography) of this amorphous alkaloid with an authentic sample of coronaridine (V)[9,10] showed these to be identical. A further comparison (mixture melting point and infrared spectrum) of the crystalline hydrochlorides completely established the identity. The alkaloid isolated from the benzene–ether elution was crystalline, m.p. 143–145.5° (from petroleum ether, b.p. 60–80°), $[\alpha]^{23}D$ +49° ($CHCl_3$), and its spectral properties (indole absorption in the ultraviolet and ester carbonyl absorption in the infrared) indicated another possible relative of the Iboga series, namely dihydrocatharanthine (VI). We prepared an authentic sample of dihydrocatharanthine by catalytic reduction of catharanthine[1,11] and were able to confirm (mixture melting point, infrared spectrum, and thin layer chromatography) that the above mentioned product was indeed dihydrocatharanthine (VI).

The isolation of both coronaridine and dihydrocatharanthine from this transannular cyclization process indicates that isomerization at C-4 takes place during this reaction. This is not entirely unexpected since the iminium intermediate, assigned structure IV, could isomerize to an enamine bearing a double bond at the C-4–C-5 position. The mobility of the enamine–iminium system is well known.[12,13]

We feel that the synthesis of these alkaloids provides an interesting synthetic approach to the Iboga alkaloids. Since the decarboxylation of the C-18 carbomethoxy function is also well known,[9,14] it is obvious that this sequence provides a synthesis of ibogamine[15] and epiibogamine[1] as well.

Apart from its chemical interest, the above synthesis establishes the fact that the type of transannular cyclization reaction originally postulated in Wenkert's biosynthetic hypothesis[3] can be realized in the laboratory. It will be of interest to determine whether nature follows this course as well.

Acknowledgment.—Financial aid from the National Cancer Institute of Canada and the National Research Council of Canada is gratefully acknowledged.

(8) This ester group was found to survive the acidic conditions normally used for the removal of the carbomethoxy group in vincadifformine.[7]

(9) M. Gorman, N. Neuss, N. J. Cone, and J. A. Deyrup, *J. Am. Chem. Soc.*, **82**, 1142 (1960).

(10) We are very grateful to Dr. M. Gorman for providing us with an authentic sample of coronaridine.

(11) The sample of catharanthine (as its hydrochloride) was kindly supplied by Dr. M. Gorman, Eli Lilly Laboratories. We cannot reconcile the difference in our melting point and rotation values with the reported[1] ones (m.p. 63–65°, $[\alpha]^{22}D$ +33° ($CHCl_3$)) except to say that all our data are completely consistent with that expected for dihydrocatharanthine.

(12) N. J. Leonard, A. S. Hay, R. W. Fulmer, and V. W. Gash, *J. Am. Chem. Soc.*, **77**, 439 (1955).

(13) N. J. Leonard, W. J. Middleton, P. D. Thomas, and D. Choudhury, *J. Org. Chem.*, **21**, 344 (1956).

(14) V. Renner, D. A. Prins, and W. G. Stoll, *Helv. Chim. Acta*, **42**, 1572 (1959).

(15) M. F. Bartlett, D. F. Dickel, and W. I. Taylor, *J. Am. Chem. Soc.*, **80**, 126 (1958).

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The Geometry of Manganese Pentacarbonyl Hydride. An X-Ray Diffraction Study[1]

Sir:

The geometry and the nature of the metal–hydrogen bond in the hydride complexes of the transition metals have been the subjects of intense study in recent years.[2] We report here the results of an X-ray diffraction study of the crystal structure of manganese pentacarbonyl hydride, $Mn(CO)_5H$, which was undertaken preparatory to a neutron diffraction study intended to determine a precise value for the Mn—H bond length. Inasmuch as this represents the first crystallographic study of a typical, simple, transition metal carbonyl hydride, and because the results will help to clarify or nullify a great deal of the speculation which has appeared in the literature regarding the geometry of these compounds, we feel that a communication at this time is warranted.

Manganese pentacarbonyl hydride[3] is typical of a group of compounds ML_nH_x, where M is a transition metal, the ligand L is usually cyclopentadienyl, carbonyl, or cyano, and x is usually 1 or 2. The electron diffraction investigation[4] of $Fe(CO)_4H_2$ and $Co(CO)_4H$, the classic compounds of this type, seemed to indicate that the carbonyls are disposed in a tetrahedral arrangement about the metal atom; the hydrogen atoms were not located, although Ewens and Lister assumed that the hydrogen atoms must be attached *via* C=O—H bonds. High resolution nuclear magnetic resonance studies of this group of compounds[5] indicate that the hydrogen atom is always highly shielded and hence in a region of high electron density. It thus seems certain that a metal–hydrogen bond is involved, and some investigators[6] have proposed an abnormally short length (1.2 Å. or less) for this bond. Lohr and Lipscomb[5] have shown, however, that a simple molecular orbital description of the bond-

(1) Research performed under the auspices of the U. S. Atomic Energy Commission.

(2) J. Chatt, *Proc. Chem. Soc.*, 318 (1962).

(3) W. Hieber and G. Wagner, *Z. Naturforsch.*, **13b**, 339 (1958).

(4) R. V. G. Ewens and M. W. Lister, *Trans. Faraday Soc.*, **35**, 681 (1939).

(5) L. L. Lohr and W. N. Lipscomb, *Inorg. Chem.*, **3**, 22 (1964), and references quoted therein.

(6) F. A. Cotton, *J. Am. Chem. Soc.*, **80**, 4425 (1958).