[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE 39, MASS.]

Application of Mass Spectrometry to Structure Problems. IV.[1] The Carbon Skeleton of Sarpagine[2]

BY K. BIEMANN

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It is demonstrated that the mass spectra of indole alkaloids are characteristic of the particular alicyclic carbon skeleton present and that this fact can be used to compare such compounds even if they differ in the substituents attached to the aromatic part and are, therefore, not suitable for a direct comparison by the use of physical constants. This is demonstrated by the correlation of the carbon skeleton of sarpagine with a derivative of ajmaline. The spectra of IV (from ajmaline) and V (from sarpagine) are almost identical with the exception of a shift of 16 mass units because the over-all difference in their substituents is one oxygen atom. The two functional groups present in the alicyclic system of sarpagine were replaced by deuterium atoms and their positions located on the basis of mass spectra. A detailed discussion of the spectra is presented.

In the elucidation of the structure of an alkaloid, the presence of an aromatic system—its type and frequently also the position of substituents—is commonly deduced from its ultraviolet spectrum, or from the products formed in drastic degradations. The aliphatic part of the molecule is in general more reluctant to a speedy elucidation, and lengthy chemical degradation or conversion to a known compound is necessary. This approach not only is often very time-consuming but also requires a considerable amount of material, which is not always available. While infrared spectra provide an indication of the presence or absence of functional groups, conclusive information regarding the carbon skeleton cannot be obtained in this way.

Mass spectrometry, on the other hand, promises to be a valuable method for the characterization and identification of the aliphatic or alicyclic part of such molecules. While in simpler cases the mass spectrum can be unequivocally interpreted in terms of the structure of the side chain, this is at present not possible with the high confidence required for structure determination if the molecule in question is a rather complex one. Model compounds considerably aid in such situations and the comparison of two possibly related compounds is a special case of this type. The following investigation will illustrate this point.

A molecule consisting of an aromatic and an aliphatic or alicyclic part will on electron impact[3] undergo fragmentation mainly at bonds which are part of the saturated moiety of the molecule, while the aromatic part is much more resistant to fragmentation. The probability of cleavage of a given bond is dependent upon the bond energy, the stability of the positively charged fragment and also of the neutral one formed. The fragmentation pattern of two indole alkaloids, for example, which—except for differences in small substituents in the aromatic part—have the same alicyclic system, will be very similar with the exception of certain constant differences in the mass of the fragments because the above-mentioned factors governing the fragmentations are almost the same in both molecules. As only the positively charged fragments appear as peaks in the spectra, we will in general find two groups of peaks. Those fragments retaining the positive charge on a part of the molecule not bearing the groups responsible for the difference between the two compounds will give rise to peaks of the same mass in both spectra. Another set of peaks, due to positively charged fragments retaining these groups, will appear at masses shifted in one compound for the net difference in the mass of the additional substituents.

Before discussing the application of this principle on a specific example, it should be pointed out that a close similarity of the spectra with respect to intensity ratios can be expected only if the change in substitution of the aromatic ring does not appreciably influence the stabilization of the positive charge in certain fragments. An increase in stabilization would, of course, increase the intensity of the corresponding peak and *vice versa*. This effect is, however, not pronounced in the case of indole derivatives in which these additional substituents, if strongly electron-donating or electron-withdrawing, are in the benzene ring, while the alicyclic system is attached to the pyrrole ring. A methyl group on the indole nitrogen is also not expected to alter significantly the mode of fragmentation of a molecule containing a number of bonds more easily cleaved because the loss of this methyl group would lead to a rather unfavorable ion with an electron deficient pyrrole nitrogen.

The successful application of the principle stated above is illustrated in the correlation of the alicyclic carbon skeleton of sarpagine with the one of ajmaline.

In 1953, Stoll and Hofmann[4] reported the isolation of sarpagine from *Rauwolfia serpentina* Benth. and the same alkaloid has been found also in other Rauwolfia species. A few years later several groups[5-8] simultaneously suggested structure Ia for

(1) Part III, K. Biemann, C. Lioret, J. Asselineau, E. Lederer and J. Polonsky, *Biochem. Biophys. Acta*, **40**, 369 (1960).

(2) Presented at the International Symposium on the Chemistry of Natural Products, Melbourne, Australia, August, 1960. Part of this work was the subject of a preliminary Communication: K. Biemann, *Tetrahedron Letters*, **15**, 9 (1960).

(3) It should be recalled that in the rather complex over-all process, an electron is first removed from the molecule, M, to form a positive molecular ion M^+. The latter may decompose into a positive and a neutral fragment, a step which can also occur repeatedly leading to a stepwise multi-fragmentation.

$$M. \xrightarrow{-e^-} M^+ \longrightarrow F^+ + F^0 \text{ (radical or molecule)}$$

(4) A. Stoll and A. Hofmann, *Helv. Chim. Acta*, **36**, 1143 (1953).

(5) D. Stauffacher, A. Hofmann and E. Seebeck, *Helv. Chim. Acta*, **40**, 508 (1957).

(6) J. Poisson, J. LeMen and M.-M. Janot, *Bull. Soc. Chim. France*, 610 (1957).

(7) S. K. Talapatra and A. Chatterjee, *Science and Culture (Calcutta)*, **22**, 692 (1957).

(8) W. Arnold, W. von Philipsborn, H. Schmid and P. Karrer, *Helv. Chim. Acta*, **40**, 705 (1957).

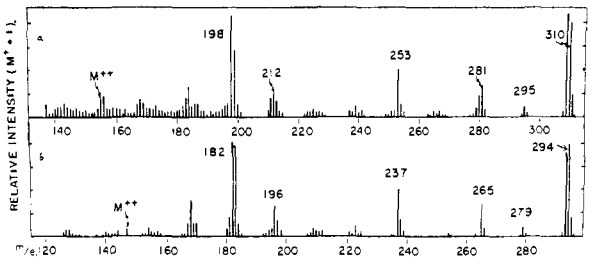
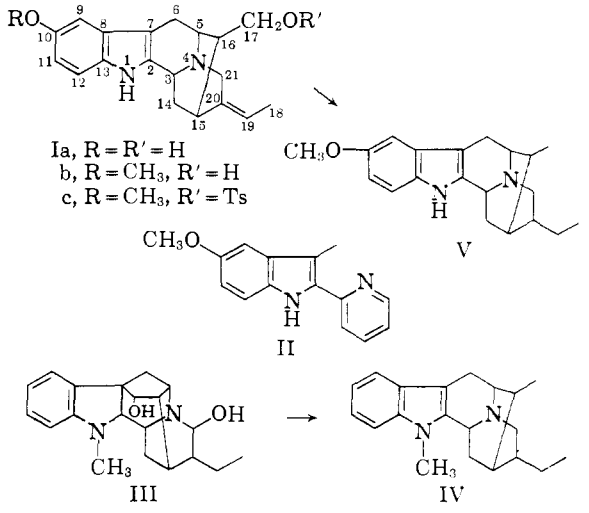


Fig. 1.—Mass spectra of compound V (a) derived from sarpagine and of compound IV (b) derived from ajmaline. All peaks $\geq 2\%$ of the intensity of the peak of the molecular ion are shown in the mass region indicated on the abscissa. The peak at m/e 182 in (b) is 1.45 times as intense as the peak at m/e 294.

sarpagine on the basis of ultraviolet and infrared data which revealed a 5-hydroxyindole moiety unsubstituted on nitrogen and a free alcoholic hydroxyl group. Chemical reactions suggested the presence of a tertiary nitrogen, a C-methyl and a >C=CH—CH_3 group and that the alcoholic hydroxyl is very probably —CH_2OH attached to a highly substituted carbon atom. The alicyclic carbon skeleton in structure Ia was, however, based



entirely on biogenetic considerations and only the French group had isolated in a selenium dehydrogenation a trace of a product,[6] the ultraviolet spectrum of which suggested the chromophore II. The close relationship of structure Ia to ajmaline (III)[9] was generally recognized, but none of the investigators reported a successful interconversion of sarpagine into a derivative of ajmaline, which would have shed some light on the soundness of the structural proposal discussed above.

Such a correlation was, however, expected to be a simple task employing the mass spectrometric principle outlined earlier in this paper. The availability of a degradation product (IV)[10] of ajmaline required, for such a comparison, O-methyldeoxydihydrosarpagine(V) because both these compounds should have the same alicyclic carbon skeleton if structure Ia for sarpagine were correct. The net mass difference between the substituents on the indole nucleus (methoxyl in V *vs.* methyl in IV) is due to one oxygen, *i.e.*, 16 mass units. The peaks in the mass spectrum of V should thus be found 16 mass units higher than in the spectrum of IV.

Compound V was prepared from sarpagine by O-methylation, tosylation of the alcoholic hydroxyl and reduction with lithium aluminum hydride to phenol-O-methyl-deoxysarpagine, which had been prepared previously from C-Alkaloid T lochnerine, O-methylsarpagine (Ib).[8] For the methylation of sarpagine we found trimethylanilinium hydroxide[6] to be superior to dimethyl sulfate.[5] The O-methylsarpagine obtained in this experiment, 29.3 milligrams, was tosylated and half of the crude product (Ic) reduced to O-methyldeoxysarpagine.[8] Hydrogenation of 2 milligrams of this product yielded O-methyldeoxydihydrosarpagine (V), m.p. 237–240°.

The mass spectrum of this compound is shown in Fig. 1 along with the spectrum of compound IV. Both spectra are, in fact, very similar but exhibit a shift of 16 mass units. On the basis of the arguments advanced earlier in this paper, we conclude that compound IV and O-methyldeoxydihydrosarpagine must have the same carbon skeleton attached to the α- and β-positions of the indole nucleus and the latter of the two substances is therefore correctly represented by structure V (stereochemistry at C_{16} and C_{20} unspecified; see discussion below).

A number of points deserve further comment here. The many additional small peaks in Fig. 1a compared with 1b are due to more pronounced contributions of the background (traces of grease?) because of the lower volatility of the sarpagine derivative leading to a lower absolute intensity of the spectrum. The peaks at mass 279 and 280 in Fig. 1a, whose counterparts at mass 263 and 264 are absent in Fig. 1b, are due to loss of the methoxyl group (masss 31) as such and as CH_2O (mass 30). The doubly charged molecular ions (M^{++}) differ, of course, by 8 mass units. While the spectra were obtained from mass 24 to mass 400, only the part from about mass 140 to the molecular weight is shown in Fig. 1. The peaks at lower masses are of relatively low intensity and not characteristic.

The location of the two functional groups which were removed in the preparation of V remained now to be determined. For this purpose another part of the tosylate of O-methylsarpagine was treated with lithium aluminum deuteride to mark the original position of the hydroxyl group, followed by hydrogenation of the double bond as before. The mass spectrum of monodeuterio-V is shown in Fig. 2b. The molecular weight of 311 indicates that one atom of deuterium was incorporated, as expected. Part of the peak originally at mass 295 due to the loss of a methyl group has now shifted to 296. This finding implies that methyl groups are lost as CH_3 or CH_2D and that the hydroxyl was therefore located on a terminal CH_3-group. It is not, however, part of the two carbon chain (C_{18}, C_{19}) because the latter is still lost as 29 mass units giving rise to a peak at mass 282 instead of 281 in the non-deuterated molecule. The position of the hydroxyl group on C_{17} is thus corroborated.

(9) R. B. Woodward, *Angew. Chem.*, **68**, 13 (1956).

(10) Obtained from deoxyajmalal[9] by Wolff–Kishner reduction; R. B. Woodward and K. Schenker, unpublished.

The double bond was located by a similar deuteration experiment. O-Methyldeoxysarpagine was catalytically deuterated using D_2–Pt–CH_3OD. The product was then treated with H_2–Pt–CH_3OH to exchange the labile deuterium atoms at the indole nitrogen and possibly in the aromatic system. The mass spectrum of "dideuterio"-O-methyldeoxysarpagine (Fig. 2c) indicates the presence of up to six deuterium atoms, two of which were introduced by addition of deuterium to the double bond and the other four by exchange on the neighboring saturated carbon atoms. All, but one, deuterium atoms are located in the ethyl group because the fragment due to loss of that group is now found at mass 282. The series of peaks beyond 282 are due to the fragments formed by loss of the methoxyl group (mass 279 and 280 in V), therefore containing all the deuterium atoms. While this finding permits us only to place the double bond in sarpagine either at C_{19}–C_{20}, or C_{18}–C_{19}, the former position is preferred because the incorporation of one full atom of deuterium at C_{20} (retained in the fragment of mass 282) is more probable by addition rather than exchange. In view of the fact that the exchange of hydrogen for deuterium on saturated carbon atoms is very facile in aliphatic molecules, as dramatically shown by the incorporation of up to 18 deuterium atoms into methyl stearate during catalytic deuteration of methyl oleate,[11] our results indicate that the steric arrangement around the carbon–carbon double bond has considerable influence on the extent of such an exchange. Catalytic deuteration of the double bond may thus serve as a tool for the elucidation of its environment.

The mass spectra discussed in the preceding section represent conclusive evidence for structure Ia for sarpagine with the exception of the stereochemistry at C_{16} and the *cis* or *trans* relationship of C_{18} and C_{21}. Mass spectra are, in general, rather insensitive toward such differences except if they would lead to differences in the stability of the molecular ion or of certain fragment ions as will be shown in a forthcoming paper on the boga alkaloids. Though this is a certain disadvantage of such mass spectrometric correlations, it may frequently turn into an advantage because compounds of different stereochemistry but otherwise identical structure may be compared in this way. It would not be possible, however, by other means like melting points or infrared spectra.

While the arguments advanced for the structure of sarpagine (Ia) are of a novel type but nevertheless compelling, it is gratifying to note that almost simultaneously with our preliminary communication on this subject[2] there appeared another one[12] reporting the chemical conversion of a derivatives of sarpagine into an identical one from ajmaline. Though the sequence of reactions employed was more laborious and probably required much more material than ours, it led to compounds identical in every respect, which in addition permitted the assignment of the absolute stereochemistry, except

(11) Ng. Dinh-Nguyen and R. Ryhage, *Acta Chem. Scand.*, **13**, 1032 (1959); *J. Research Inst. Catalysis, Hokkaido Univ.*, **8**, 73 (1960).

(12) M. F. Bartlett, R. Sklar and W. I. Taylor, *J. Am. Chem. Soc.*, **82**, 3790 (1960).

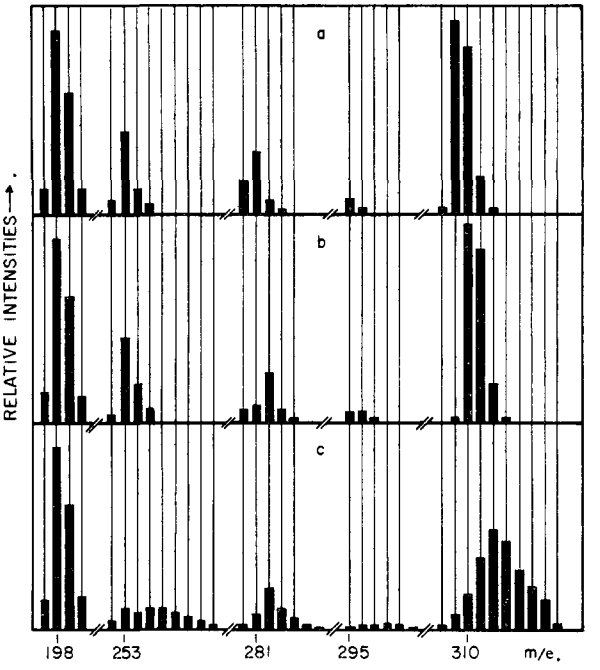
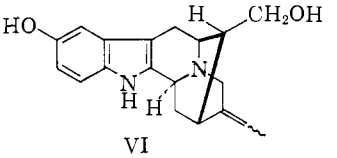


Fig. 2.—Partial mass spectra of O-methyldeoxydihydrosarpagine (V): (a) undeuterated, (b) monodeuterated at C_{17}, (c) containing up to six atoms of deuterium at C_{18}, C_{19} and C_{20}

the steric relationship of C_{21} with regard to C_{18}, as shown in VI.



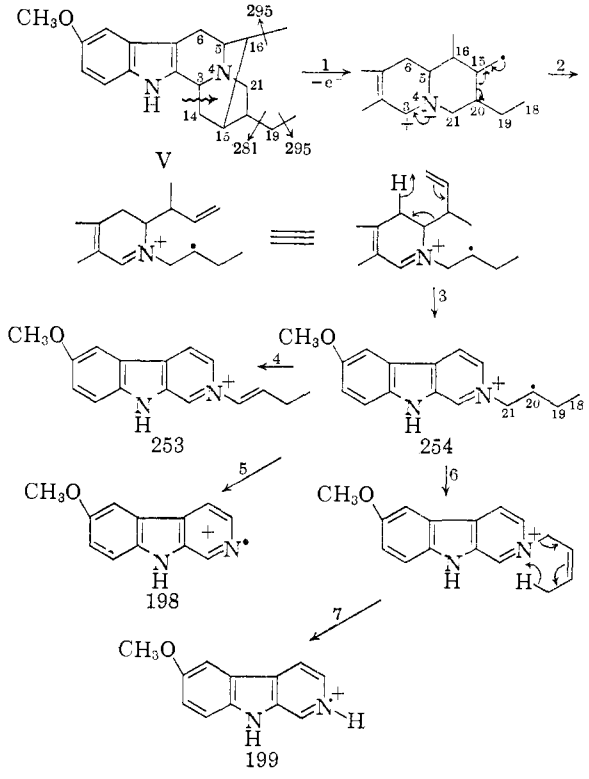
VI

Discussion of the Mass Spectra.—A detailed discussion of these mass spectra is now in order for two reasons. First, we have not yet presented any evidence that only indole alkaloids with such a carbon skeleton give this type of mass spectrum and, secondly, a wider knowledge about the fragmentation of such molecules may make it possible to deduce the structure of an alkaloid with a closely related but not identical alicyclic carbon skeleton.

The molecular weight is clearly indicated by the peak at mass 310, which is due to the monisotopic species, while the peaks at masses 311 and 312 are due to the molecules containing C^{13}, N^{15}, H^2 and O^{18}. Unless stated otherwise, the mass numbers used here and in the following discussion refer to the spectrum of V (Fig. 1a).

The fragments of mass 295 and 281 have been already discussed and found to be due to the loss of one of the two methyl groups (C_{17} or C_{18}) and to loss of the ethyl group ($C_{18,19}$). The strong peak at mass 309 indicates the preferred loss of one hydrogen atom, which is in contrast to all other indole alkaloids that we have thus far examined. It implies that there is no other bond cleaved with particular ease. Loss of hydrogen from C_6 or, less likely, from C_{20} seems to be the only possibility for the formation of an ion of mass 309 in which the positive

charge would be well stabilized and where the resonance form would not involve a double bond on a bridge-head. The latter would be the case in an ion arising from the loss of hydrogen from C_3, C_5 or C_{21}. Removal of the tertiary hydrogen at C_{15} would create a bridgehead carbonium ion which is also unfavorable.



In the formation of the other important fragments (mass 198, 199, 253) more than one bond has to be broken. This has to occur in a manner which leads to stable positive ions and avoids the accumulation of unpaired electrons since the over-all process must be an energetically favorable one to give rise to rather intense peaks. Scheme I illustrates a plausible mechanism fulfilling these requirements and is also in agreement with the spectra of the two deuterated species of V (Fig. 2). The latter indicate that C_{20} is lost in the formation of the fragments of mass 253, 199 and 198 and also that the two last-mentioned fragments do not contain C_{18}, C_{19} and C_{20}.

The initial removal of one electron, to give the molecular ion, is followed by cleavage (wiggled arrow) of the C_3–C_{14} bond in such a manner as to retain one electron on C_{14} while the positive charge at C_3 is particularly stabilized, not only by the free electron pair of N_4, but also of N_1 by participation of the π-electron system of the pyrrole ring (step 1). A shift of electrons (step 2) simultaneously breaks a single bond, forms a double bond, and converts a primary radical to a secondary one. Concerted rearrangement of a hydrogen and elimination of butylene (step 3) gives rise to an ion-radical of mass 254. This process is analogous to the behavior of simple, aliphatic olefins, in which such eliminations have been observed.[13] Formation of a double bond by loss of a hydrogen radical from C_{21} forms the fragment of mass 253 in step 4. The intense peak at mass 198 arises by loss of butylene from the fragment of mass 254 *via* homolytic cleavage of the N_4–C_{21} bond (step 5) and represents the molecular ion of methoxy-β-carboline. As such it is in agreement with the high intensity of this peak indicating a very stable structure which also does not fragment further. The particle of mass 199 is the corresponding protonated form derived from mass 254, which is able to eliminate first a hydrogen atom from C_{19} (step 6) and then a molecule of butadiene (step 7).

The complex mechanism suggested may seem to be mere speculation. However, it is proposed not only because it fulfills the requirements noted earlier but is in some phases in agreement with the known behavior of much simpler molecules. Strong support is derived also from the fact that the spectrum of the ajmaline derivative IV, when obtained with bombarding electrons of low energy (9–10 eV.), indicates that the formation of the fragments of mass 182 and particularly 238 (corresponding to 198 and 254 in V) require the least energy for their formation from the molecular ion, while the peaks at mass 183 and 237 (corresponding to 199 and 253 in V) disappear almost completely. This is in agreement with the suggestion that in the formation of mass 198 and 254 only neutral molecules are eliminated while steps 4 and 6 both involve the additional rupture of a bond with the formation of a hydrogen radical. Finally, steps 3, 4 and 5 are supported by the presence of metastable peaks[14] in the spectrum of IV: 294 → 238, calcd. 192.7, found 193.5; 238 → 237, calcd. 236.0, found 236; 238 → 182, calcd. 139.2, found 140. The lower intensity of the spectrum of V, caused by the much lower vapor pressure of this substance, prohibited these determinations for V.

It is of interest to note that there are no peaks of appreciable intensity present which could be due to fragments representing parts of the alicyclic system of the molecule after loss of the aromatic moiety. Such peaks are quite abundant in the spectra of other indole alkaloids, such as ibogaine and its congeners and also dihydroindoles of the aspidospermine type which will be discussed in following papers of this series. In the sarpagine skeleton the highly stabilized β-carboline system is already preformed and we believe it is for this reason that this ring system is present in all the more important fragments observed.

In that respect there is a certain analogy to be noted between the behavior of these molecules and their thermal degradation. Both ibogaine[15] and aspidospermine[16] yield in considerable amounts, on heating with potassium hydroxide, zinc dust or selenium, pyridine derivatives while sarpagine does not.

(13) F. W. McLafferty, *Anal. Chem.*, **31**, 2072 (1959).

(14) For the origin of metastable peaks see J. A. Hipple and E. U. Condon, *Phys. Rev.*, **68**, 54 (1945). Its significance for the interpretation has been discussed recently (K. Biemann, J. Seibl and F. Gapp, *J. Am. Chem. Soc.*, **83**, 3795 (1961)).

(15) R. Goutarel, M.-M. Janot, F. Mathys and V. Prelog, *Compt. rend.*, **237**, 1718 (1953); R. Goutarel, F. Percheron, J. Wohlfahrt and M.-M. Janot, *Ann. pharm. franc.*, **15**, 353 (1957).

(16) B. Witkop, *J. Am. Chem. Soc.*, **70**, 3712 (1948).

Experimental[17]

O-Methylsarpagine (Ib).—Trimethylanilinium iodide (0.40 g.) in 10 ml. of hot ethanol was stirred with excess silver oxide for a few minutes, centrifuged and the supernatant evaporated. To the sirupy residue was added 200 mg. of sarpagine (Ia) and 0.45 ml. of dimethylaniline. After heating this mixture to 165° for 1.5 hours, it was poured into dilute acetic acid and extracted with ether. The aqueous layer was then made alkaline with sodium hydroxide and extracted with dichloromethane–ether. The residue of the organic layer was chromatographed on alumina (neutral, II); chloroform eluted 49 mg.; after recrystallization from ethanol–water 32.6 mg. of O-methylsarpagine, m.p. 201–203° (lit.[3] 202–202.5°), was obtained.

O-Methyldeoxysarpagine.—O-Methylsarpagine (29.3 mg.) was tosylated[3] using 25 mg. of toluolsulfochloride in 0.5 ml. of pyridine. The crude amorphous product (Ic) was divided into several parts and reduced: (a) With lithium aluminum hydride.—Half of the above product Ic was reduced with 32 mg. of $LiAlH_4$ in 2 ml. of tetrahydrofuran yielding 7.8 mg. of O-methyldeoxysarpagine, m.p. 248–250° (lit.[3] 248–250°), mol. wt. 308 (by mass spectrometry). (b) With lithium aluminum deuteride.—One-quarter of the crude tosylate Ic was reduced in the same way, using 18 mg. of $LiAlD_4$. The crude product 5.4 mg. was recrystallized, giving 2.0 mg. of O-methyldeoxysarpagine-d_1, m.p. 247–249°, mol. wt. 309 (by mass spectrometry).

O-Methyldeoxydihydrosarpagine (V).—Two milligrams of O-methyldeoxysarpagine were hydrogenated in ethanol, using platinum as a catalyst. After 20 min. the product was isolated and sublimed at 0.1 mm. and 200° (bath); m.p. 237–240°. The mol. wt. of 310 (by mass spectrometry, see Fig. 1a) indicated the formation of a dihydro derivative.

O-Methyldeoxydihydrosarpagine-d_1 was prepared in the same manner by catalytic hydrogenation of O-methyldeoxysarpagine-d_1; mol. wt. 311 (by mass spectrometry, see Fig. 2b).

O-Methyldeoxydihydrosarpagine-d_0-d_6.—When O-methyldeoxysarpagine (1.5 mg.) was catalytically deuterated, using D_2–MeOD–Pt and worked up as described for the hydrogenations above including repeated evaporation with ethanol, the mass spectrum indicated a mixture of species containing up to seven deuterium atoms per molecule, the major component having a mol. wt. of 313 (-trideuterio derivative). Equilibration of this "mixture" with H_2–EtOH–Pt gave rise to the apparent loss of one deuterium atom. The mass spectrum of this material is shown in Fig. 2c.

Acknowledgments.—The author is greatly indebted to Prof. R. B. Woodward for a sample of compound IV, to Dr. A. Hofmann for sarpagine, and to the National Science Foundation for financial support (Grant G5051).

(17) The spectra were determined with a CEC 21-103C mass spectrometer, equipped with heated inlet system, operated at 140°. Samples of 50–250 micrograms were employed. Melting points were determined on a Kofler micro-hot-stage.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE 39, MASS.]

Application of Mass Spectrometry to Structure Problems. V.[1] Iboga Alkaloids[2]

BY K. BIEMANN AND MARGOT FRIEDMANN-SPITELLER

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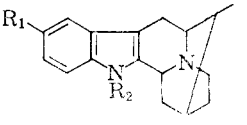
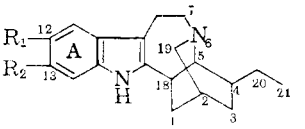
The mass spectra of the indole alkaloids ibogamine (III), ibogaine (IV) and tabernanthine (V) have been determined and are discussed in detail. The usefulness of mass spectrometry for the determination of the structure of such compounds is illustrated by two examples. Ibogaline was shown to have structure VI and iboxygaine to have structure VIII. The replacement of a hydroxyl group by deuterium and locating its position in the molecule by mass spectrometry proved useful for deciding between two previously proposed structures.

In a previous paper[1] we have correlated a degradation product of sarpagine with one of ajmaline (I and II) on the basis of their characteristic mass spectra, which exhibited almost identical peaks shifted 16 mass numbers, the difference between CH_3O and CH_3. It was concluded that both compounds must have the same carbon skeleton, the fragmentation of which gives rise to these characteristic peaks in the spectrum.

To provide experimental proof for the validity of such arguments, we have determined the spectra of two indole alkaloids of unambiguously proven structure[3]—ibogamine (III) and ibogaine (IV). Both contain the same carbon skeleton and differ merely in the presence of a methoxy group in ring A in IV, which is absent in III. These spectra, shown in Fig. 1, permit a number of important conclusions to be drawn. First of all, the spectrum (Fig. 1b) of ibogaine (IV) is very different from the one[1] of the isomeric compound I obtained from sarpagine (VII) and verifies our conclusion that compounds of different carbon skeleton, in fact, give different mass spectra. Secondly, a comparison of the spectra (Figs. 1a and 1b) of ibogamine (III) and ibogaine (IV) reveals the presence of two groups of peaks: one set which is of identical mass number and comparable intensity in both spectra (for example, mass 122



I, $R_1 = CH_3O$, $R_2 = H$
II, $R_1 = H$, $R_2 = CH_3$



III, $R_1 = R_2 = H$
IV, $R_1 = CH_3O$, $R_2 = H$
V, $R_1 = H$, $R_2 = CH_3O$
VI, $R_1 = R_2 = CH_3O$

124, 135, 136, 149) and must therefore arise from the isoquinuclidine moiety in the molecules, identical in both compounds. The peaks of the second group are also comparable in intensity in both spectra but appear in the spectrum of IV 30 units higher than in the one of III (mass 156, 195, 251, 265, 280 in III). These fragments must, therefore, contain the indole nucleus. The mass of these fragments alone is already an indication of their origin as the first group fits best the type of

(1) Part IV, K. Biemann, *J. Am. Chem. Soc.*, **83**, 4801 (1961).

(2) Presented in part at the 138th Meeting of the American Chemical Society, New York, N. Y., September, 1960. Another part was the subject of a preliminary communication: K. Biemann and Margot Friedmann-Spiteller, *Tetrahedron Letters*, No. 2, 68 (1961).

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