2-Methyl-1-(2′-deoxy-β-D-ribofuranosyl)benzimidazole. A mixture of 2-methylbenzimidazole[24] (4.88 g., 0.04 mole) and 1,3,5-tri-*O*-acetyl-2-deoxy-D-ribofuranose[17] (13.0 g., 0.05 mole) was fused at 160° to obtain a clear melt after 4 min. Chloracetic acid (0.15 g.) was added and the mixture was heated for 20 min. *in vacuo*. The cold reaction mixture was dissolved in benzene (200 ml.) and filtered to remove 0.065 g. of insoluble material. The filtrate was evaporated to a clear sirup, treated with methanol saturated with ammonia (250 ml.), and allowed to stand at room temperature for 48 hr. Methanol was removed from the mixture and the residue partially crystallized on trituration with ethanol. The solid was collected by filtration and recrystallized from ethanol to obtain 2-methyl-1-(2′-deoxy-β-D-ribofuranosyl)benzimidazole (2.29 g.) as a colorless, crystalline compound, m.p. 206–207°.

Anal. Calcd. for $C_{13}H_{16}N_2O_3$: C, 62.9; H, 6.5; N, 11.3. Found: C, 62.9; H, 6.5; N, 11.4.

After isolation of the β-anomer, the combined filtrates were dissolved in ethanol and placed on a column of alumina (4.5 × 21 cm.). The column was eluted with ethanol and 25-ml. fractions were collected. The fractions (3–5) contained glycoside (5.07 g.) together with a little acetamide which was removed by sublimation at 50° (0.1 mm.). Recrystallization of the crude glycoside mixture provided an additional 0.7 g. of the pure β-anomer, but the α-anomer could not be separated from the β-anomer successfully by fractional crystallization. The total yield of crystalline anomeric nucleosides was 7.36. g. (80%).

5,6-Dimethoxy-1-(2′-deoxy-α-D-ribofuranosyl)benzimidazole (XII). A mixture of 5,6-dimethoxybenzimidazole[19] (3.56 g., 0.02 mole) and 1,3,5-tri-*O*-acetyl-2-deoxy-D-ribofuranose[17] (6.0 g., 0.023 mole) was fused to a clear melt at 160° (bath temperature). Chloracetic acid (0.01 g.) was added and the mixture was heated *in vacuo* for 20 min., until rapid evolution of acetic acid had ceased. The mixture was cooled and treated with benzene as usual; the benzene filtrate was evaporated to dryness. The residual sirup was treated with methanol saturated with ammonia (150 ml.) and allowed to stand at room temperature for 24 hr. The methanol was removed and remaining sirup was treated with ethanol–ether and scratched with a glass rod to obtain a crystalline product (4.66 g., 79%, m.p. 153.5–165°). This crude glycoside was fractionally recrystallized from methanol–ethyl acetate to obtain 5,6-dimethoxy-1-(2′-deoxy-α-D-ribofuranosyl)benzimidazole (XII) (0.8 g.) as colorless needles, m.p. 190–191°.

Anal. Calcd. for $C_{14}H_{18}N_2O_5$: C, 57.1; H, 6.2; N, 9.5. Found: C, 57.4; H, 6.4; N, 9.6.

The mother liquors after isolation of pure XII yielded material, m.p. 162.5–172.5°. This material, however, could not be obtained free of contaminating α-anomer by fractional crystallization.

(24) K. Hofmann, "Imidazole and Derivatives," Interscience Publishers, New York, N. Y., 1953, p. 381.

10,22-Dioxokopsane, N_a-Methyl-10,22-dioxokopsane, and N_a-Carbomethoxy-10,22-dioxokopsane. Three New Alkaloids of *Pleiocarpa mutica* Benth.[1]

H. Achenbach and K. Biemann

Contribution from the Department of Chemistry, Massachusetts Institute of Technology, Cambridge, Massachusetts. *Received July 16, 1965*

Careful chromatography of the extract of the stem bark of Pleiocarpa mutica Benth. yielded three weakly basic dihydroindole alkaloids. On the basis of spectral data, mainly conventional and high-resolution mass spectrometry, they were shown to be 10,22-dioxokopsane (IC), its N_a-methyl and N_a-carbomethoxy derivatives IB and IA, respectively. These structural assignments were confirmed by direct chemical correlation of IA with IC and IB and conversion of the latter to pleiocarpinilam, an alkaloid of known structure.

In continuation of the investigation[2,3] of the minor alkaloids from the stem bark of *Pleiocarpa mutica* Benth., we have isolated three additional new weakly basic alkaloids A, B, and C by very careful repeated chromatography of the crude extract on alumina and silica gel.

The similarity of their mass spectra, which exhibited an analogous pattern and molecular weights of 378, 334, and 320, suggested that all three alkaloids contain the same carbon skeleton. The high-resolution mass spectrum revealed the elemental composition to be $C_{22}H_{22}N_2O_4$, $C_{21}H_{22}N_2O_2$, and $C_{20}H_{20}N_2O_2$, respectively, differences which suggest that alkaloid A contains a carbomethoxy group and alkaloid B a methyl group more than alkaloid C. As a typical example the spectrum of B is shown in Figure 1 in the form of a conventional, low-resolution spectrum,[4] and in Figure 2

(1) Part XXXII of the series Application of Mass Spectrometry to Structure Problems. For part XXXI see ref. 2.

(2) H. Achenbach and K. Biemann, *Tetrahedron Letters*, in press.

(3) H. Achenbach and K. Biemann, *J. Am. Chem. Soc.*, 87, 4177 (1965).

(4) Figure 1 represents a computer-compiled presentation of the high-resolution spectrum (Figure 2), by summing the abundance of all species of the same nominal mass and plotting these summed intensities *vs.* that of the most abundant ion.[5] Because of its high intensity, the largest peak (the molecular ion) is displayed as one-half its relative size. The resulting "bar graph" has the appearance of conventional mass spectra. It is practically identical with the spectrum obtained with a single-focusing mass spectrometer (CEC 21-103C) except that that instru-

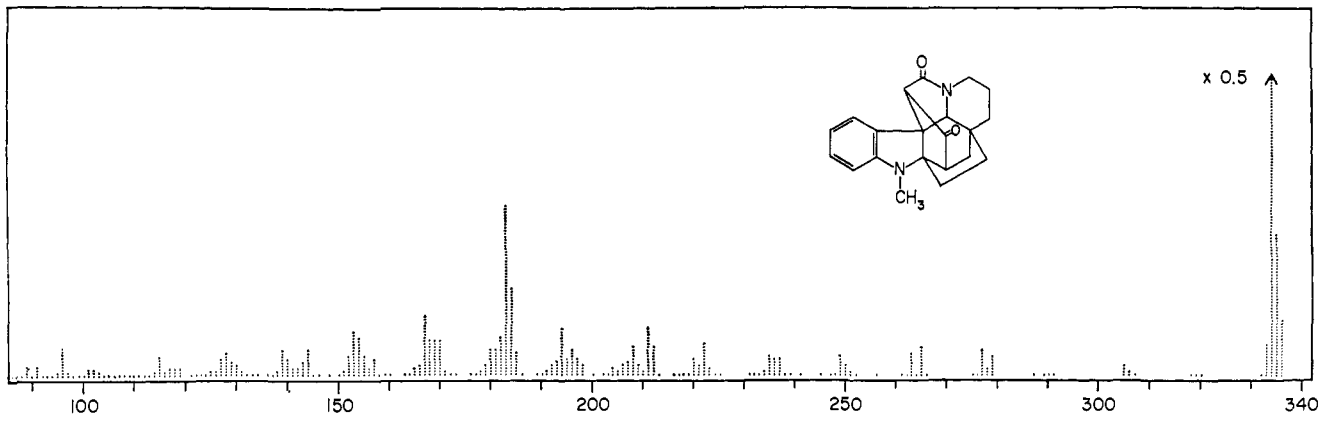
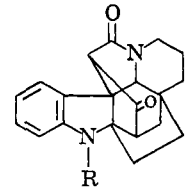


Figure 1. Conventional mass spectrum of alkaloid B.

as an element map.[6] The high-resolution mass spectra of alkaloids A, B, and C indicate that these substituents must be in the aromatic portion of the molecule because they are retained in one of the most characteristic fragment peaks at *m/e* 227, 183, and 169, respectively. This is deduced from their elemental composition ($C_{14}H_{13}NO_2$, $C_{13}H_{13}N$, and $C_{12}H_{11}N$) which not only reflects the same differences as the molecules themselves but also requires that these ions contain the aromatic ring because of the low hydrogen-to-carbon ratio. For biogenetic reasons, the most plausible position for such substituents would be the indole nitrogen.

The presence of such a system is indicated by the dihydroindole-like ultraviolet spectrum as well as a band at 1605 cm.$^{-1}$ in the infrared spectrum. Further confirmation of the presence of these functional groups is obtained from the n.m.r. and infrared spectra which showed a methoxyl group at 3.85 p.p.m. in alkaloid A and an N-methyl group at 2.60 p.p.m. in alkaloid B while the infrared spectrum of alkaloid C had a band at 3380 cm.$^{-1}$ indicative of an NH grouping. These assignments, as well as the hypothesis of a common carbon skeleton for all three alkaloids, were corroborated by chemical interconversion when it was found that reduction of alkaloid A with lithium aluminum hydride gave a mixture of two compounds of molecular weight 322 and 308, identical with the products obtained by lithium aluminum hydride reduction of alkaloids B and C, respectively. Since the mass difference between these products and the starting material corresponds to 70 and 56 mass units, respectively, reduction of CO to CH_2 and CO to CHOH must have taken place in addition to the conversion of the carbomethoxy group to NCH_3 and NH, respectively. The difference in elemental composition between alkaloid A and the reduction product of alkaloid B, namely loss of one carbon and three oxygen atoms with gain of four hydrogen atoms ($C_{22}H_{22}N_2O_4 \rightarrow C_{21}H_{26}N_2O$) as deduced from the high-resolution mass spectra, clearly substantiates these conclusions.

The above-mentioned data require that the basic structure, as represented by alkaloid C and common to all three compounds, must be a heptacyclic C_{20}-dihydroindole alkaloid containing one tertiary nitrogen as part of a lactam grouping and one additional carbonyl group. On the basis of further physical data, particularly of the mass spectra of chemical degradation and conversion products, we propose structures IA, IB, and IC for alkaloids A, B, and C, which thus represent N_a-substituted derivatives of 10,22-dioxokopsane (I).



alkaloid A: IA, R = $COOCH_3$
alkaloid B: IB, R = CH_3
alkaloid C: IC, R = H

The relevant data and their interpretation which led to this hypothesis and its final proof shall be discussed below. Because of the intercorrelation of the three alkaloids mentioned above, it sufficed to prove the structure of only one of them. Alkaloid B was chosen for this purpose because in contrast to the simpler representative (C) it was available in reasonable amounts and the N-carbomethoxy group present in the even more abundant alkaloid A would have led to complications in the degradation and conversion reactions.

The high-resolution mass spectrum of alkaloid B, shown in Figure 2 in the form of an element map, is typical for an indole alkaloid: it is rather bare of C,H ions and those present are all aromatic and contain only a maximum of 14 carbon atoms while the majority of all ions are found in the C,H,N group and indicate alicyclic (low C/H ratio) and aromatic (high C/H ratio) compositions up to C_8 but only aromatic compositions up to C_{18}. Somewhat unusual for a dihydroindole alkaloid with a total of two oxygen atoms is the relatively high abundance of ions containing both

ment favors low masses at the expense of high masses (in comparison with Figure 1) because it employs electrical scanning.

(5) D. Desiderio, Massachusetts Institute of Technology, unpublished work.

(6) (a) K. Biemann, P. Bommer, and D. Desiderio, *Tetrahedron Letters*, **No. 26**, 1725 (1964). (b) In each column the values listed represent the number of carbon and hydrogen atoms, and the difference in millimass units between the mass measured and that calculated for this combination of C, H, N, and O. In contrast to earlier approximations,[6a] the number of asterisks equals 2.7 × log *I*, where *I* is the abundance (determined from the blackening of the photographic emulsion) of the ion, relative to the most abundant ion in the spectrum which is assigned an abundance of 2000.[5] For the sake of brevity, ions of abundance below 4 have been omitted.

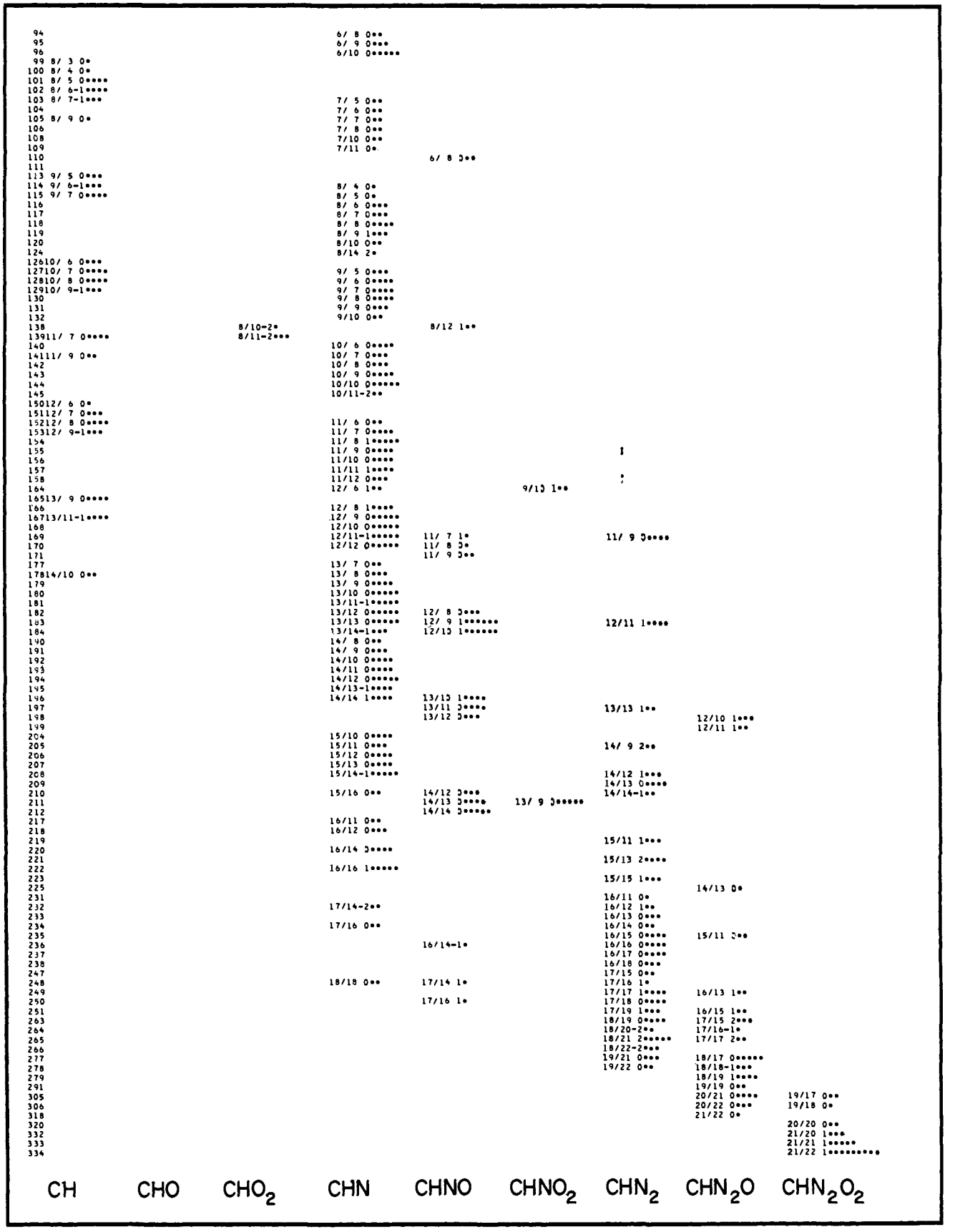


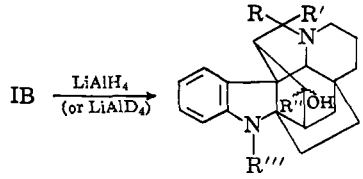
Figure 2. High-resolution mass spectrum of alkaloid B.

nitrogens but no oxygen which are found up to C_{19} requiring the loss of two oxygen atoms with only two carbon atoms (formation of $C_{19}H_{22}N_2$ from $C_{21}H_{22}N_2O_2$). This makes the suggested presence of two carbonyl groups again highly plausible. Furthermore, the preponderance of ions which have lost only one oxygen

and are thus found in the C,H,N_2,O group would imply that they are not adjacent to each other as it was the case in another alkaloid found in this plant, 10,11-dioxopleiocarpine.[2] The presence of quite abundant C,H,N,O ions with as few as 12 carbon atoms and 8 to 10 hydrogens requires that one of the two carbonyl groups is within 11 carbon atoms of the indole system, and the fragment $C_{13}H_9NO_2$ requires that the second carbonyl group is directly connected to this moiety.

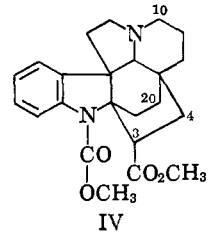
Further aspects of the environment of the two carbonyl oxygens may be deduced from the infrared spectrum which shows bands at 1760 and 1685 $cm.^{-1}$ which may be assigned to a five-membered ring ketone and a five-membered lactam.

The above-mentioned chemical evidence (lithium aluminum hydride reduction) for the presence of a lactam and a ketone grouping is further confirmed by reduction of alkaloid B with lithium aluminum deuteride which gave a product (III) of molecular weight 325, requiring the incorporation of three deuterium atoms during this reduction. The mass spectrum of the



IIB (R = R′ = R″ = H; R‴ = CH_3)
III (R = R′ = R″ = D; R‴ = CH_3)
IIC (R = R′ = R″ = R‴ = H)

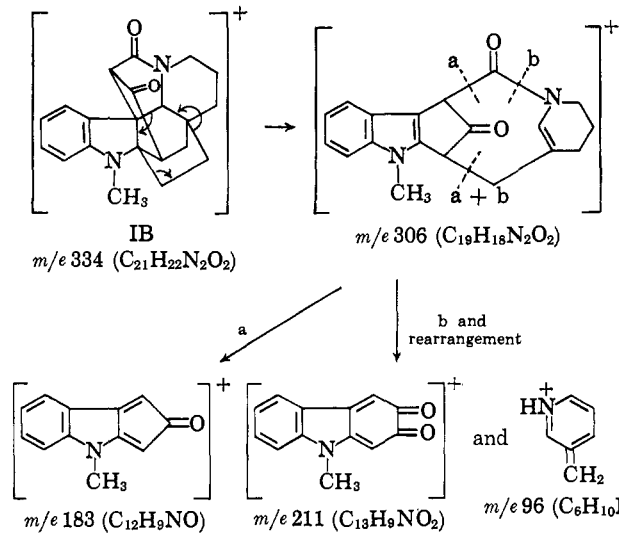
undeuterated reduction product (IIB; mol. wt., 322) contained a rather abundant peak at mass 109 ($C_7H_{11}N$) which is characteristic of compounds of the pleiocarpine (IV) type and assumed to contain the piperidine ring, C-10 and C-4 or C-20.[7] It is found at mass



IV

111 in the product obtained with lithium aluminum deuteride supporting the lactam hypothesis and indicating that the other carbonyl group cannot be on the piperidine ring or one of the carbon atoms directly connected to it. While the infrared spectrum of the alkaloid already favors a C-10 lactam rather than the 8-isomer one can deduce further evidence to this effect from the mass spectra of the three alkaloids, all of which contain a characteristic peak of mass 96 which the high-resolution spectrum shows to be $C_6H_{10}N$. Its composition requires that this ion represents the piperidine ring plus one additional carbon atom and the absence of oxygen in this fragment implies that neither the lactam oxygen nor the keto oxygen is attached to that ring. In a formal sense some of the fragmentation processes implied above may be pictured as follows.

(7) C. Djerassi, H. Budzikiewicz, R. J. Owellen, J. M. Wilson, W. G. Kump, D. J. LeCount, A. R. Battersby, and H. Schmid, *Helv. Chim. Acta*, **46**, 742 (1963).



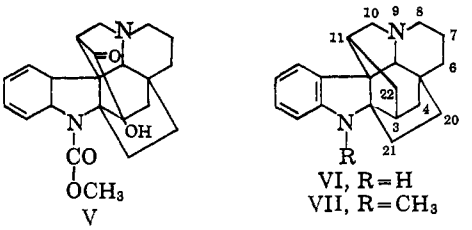
Cleavage along b with retention of the positive charge on the piperidine moiety and transfer of a hydrogen (from C-11 to N-9?) can lead to the $C_6H_{10}N$ ion. The fragmentation processes suggested above are supported by the mass spectrum of the ketone VIII (see below) which contained peaks at *m/e* 169 ($C_{12}H_{11}N$) and 197 ($C_{13}H_{11}NO$), as well as *m/e* 96 ($C_6H_{10}N$).

The n.m.r. spectrum of alkaloid B is also in agreement with the proposed structure IB. A broad doublet at 4.24 p.p.m. (1 H) can be attributed to one of the hydrogens at C-8 (J = 12 c.p.s.). The singlet at 3.73 p.p.m. (1 H) represents the hydrogen at C-11 while another singlet at 2.79 p.p.m. (1 H) is attributed to the hydrogen at C-19. This signal corresponding to the NCH_3 group at 2.60 p.p.m. has already been mentioned and 11 additional hydrogens appear unresolved in the region of 1.0–2.2 p.p.m.

While at this point structures IA, IB, and IC represent very plausible working hypotheses which are in agreement with all experimental data, it remained to prove the correctness of these proposals by correlations with known structures. Since the carbon skeleton of I is also present in kopsine (V),[8,9] correlation with this alkaloid or better with one of the less substituted key degradation products, kopsane (VI),[8] was thought to constitute a reliable structure proof. For this purpose alcohol IIB was oxidized with cyclohexylcarbodiimide in dimethyl sulfoxide[10] to give the corresponding ketone VIII as evidenced by an infrared band at 1750 $cm.^{-1}$. Removal of the carbonyl function by Wolff–Kishner reduction gave an oxygen-free substance which proved to be identical (mass spectra and R_f values) with N_a-methylkopsane obtained by pyrolysis of N_a-methylkopsinyl iodide (IX) in addition to N_a-methylkopsinylene (XII). This reaction is identical with that which led to kopsane (VI) from pleiocarpine (IV).[8] It should be noted that the same cyclization occurs also upon heating of N_a-methylkopsinyl tosylate (X) which makes the previously suggested[8] radical character of this pyrolysis reaction somewhat doubtful. At the same time it seems that the production of this compound from

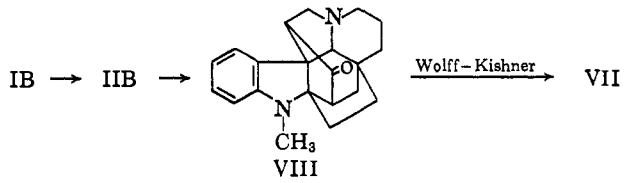
(8) T. R. Govindachari, B. R. Pai, S. Rajappa, N. Viswanathan, W. G. Kump, K. Nagarajan, and H. Schmid, *ibid.*, **45**, 1146 (1962).
(9) G. Spiteller, A. Chatterjee, A. Bhattacharya, and A. Deb, *Monatsh.*, **93**, 1220 (1962).
(10) K. E. Pfitzner and J. G. Moffatt, *J. Am. Chem. Soc.*, **85**, 3027 (1963).

alkaloid B by much milder and much more straight-forward reactions (lithium aluminum hydride reduction, oxidation, and Wolff–Kishner reduction) than the drastic conditions used in the degradation of kopsine (hydrogen iodide and phosphorus)[8] strengthens the structure (VI) proposed[8] for kopsane.

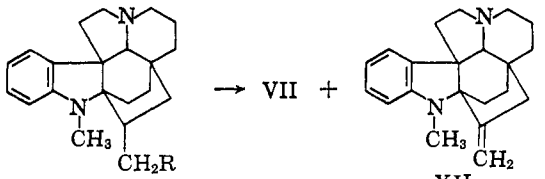


V

VI, R=H
VII, R=CH_3



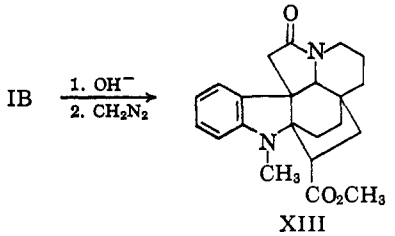
VIII



IX, R=I
X, R=Ts
XI, R=OH

XII

The proposed 1,3-dicarbonyl system in itself suggests a reaction which could prove its presence as well as the correctness of structures IA, IB, and IC for these alkaloids, as attack of the 22-carbonyl group by base should lead to cleavage of the cyclopentanone ring. Heating of alkaloid B with methanolic potassium hydroxide followed by esterification of the crude reaction products yielded, in fact, a lactam ester which on the basis of its mass spectrum, infrared spectrum, and R_f value was shown to be identical with pleiocarpinilam for which structure XIII had recently been established.[11] This interconversion thus represents conclusive proof for the correctness of structure IB for alkaloid B and thus also of alkaloids A and C. As a corollary it provides further proof for the *cis* relationship of C-3 and C-11 in pleiocarpine (IV).



XIII

It would seem that alkaloid C is identical with Schmid's "lactam alkaloid 3" (melting point, ultraviolet, infrared, R_f) which was occasionally mentioned but not further investigated.[11]

In the past it has been the custom to invent nonchemical names for newly isolated alkaloids mainly because years or decades (even centuries) elapsed before their structure was elucidated. This led to the accumulation of the present maze of meaningless, not infrequently confusing, names of alkaloids. The rapid advances in recent years of the techniques used for the determination of the structure of organic molecules in many instances obviate the necessity of reporting the isolation of a new alkaloid, and thus naming it, before its structure has been determined. For this reason we refrained, as we did previously,[2] from the construction of a trivial name for the alkaloids reported in this paper in preference to the chemical names mentioned in the title, based on the term "kopsane" for the heptacyclic system VI.

(11) C. Kump and H. Schmid, *Helv. Chim. Acta*, **45**, 1090 (1962).

Experimental Section

Melting points are uncorrected and were taken on a Kofler micro hot stage. Optical rotations were measured in chloroform solution. Unless stated otherwise, spectra were determined as follows: ultraviolet spectra in methanol using a Cary Model 14 recording spectrophotometer; infrared spectra in chloroform solution using a Perkin-Elmer Model 337 spectrophotometer; nuclear magnetic resonance spectra in deuteriochloroform with tetramethylsilane as an internal standard, using a Varian A 60 spectrometer; low-resolution mass spectra with a CEC Model 21-103C mass spectrometer using a direct inlet system; high-resolution mass spectra with a double-focusing mass spectrometer (CEC 21-110) using a photographic plate for recording.[12]

All solutions were dried with anhydrous sodium sulfate and evaporated on a rotary evaporator at 50° (aspirator vacuum). All R_f values refer to thin layer chromatography performed on silica gel G using methanol–chloroform (1:9). Unless stated otherwise, a solution of 2% ceric sulfate in 2 *N* sulfuric acid was used as color reagent (see Table I).

Table I. R_f Values of the Alkaloids and Their Derivatives

Compd.	R_f[a]	Color[b]
N_a-Carbomethoxy-11,22-dioxokopsane (alkaloid A) (IA)	0.70	Violet[c]
N_a-Methyl-11,22-dioxokopsane (alkaloid B) (IB)	0.17	Red
10,22-Dioxokopsane (alkaloid C) (IC)	0.62	Orange
N_a-Methyl-22-hydroxykopsane (IIB)	0.09	Red
	0.45	Red-orange
22-Hydroxykopsane (IIC)	0.09	Orange
	0.27	Red-orange
N_a-Methylkopsane (VII)	0.20	Red-orange
N_a-Methyl-22-oxokopsane (VIII)	0.68	Red
N_a-Methylkopsinyl iodide (IX)	0.51	Red
N_a-Methylkopsinyl tosylate (X)	0.56	Red
N_a-Methylkopsinylene (XII)	0.32	Red

[a] Thin layer chromatogram on silica gel G.: eluent, methanol–chloroform (1:9). Pleiocarpine (IV), R_f 0.64. [b] Color with ceric sulfate. [c] Ceric sulfate in concentrated sulfuric acid.

Isolation of Alkaloids. The separation procedure has been described in detail previously.[3] Combined fractions A1–A3 and B4–B20 were separated on silicic acid (1500 g., 100 mesh); elution with chloroform in 225 fractions (chromatogram C), each of either 500-ml. volume (Cl to C100) or 850-ml. volume (C101 to C225).

(12) Twelfth Annual Conference on Mass Spectrometry and Allied Topics, Montreal, June 1964: (a) P. Bommer, W. McMurray, and K. Biemann, and (b) D. Desiderio and K. Biemann.

Alkaloid B (IB). Fractions C114 to C128 yielded 433 mg. of crystalline material (from methanol). Recrystallization from methanol gave white cubes: m.p. 269°; $[\alpha]^{29}D$ +74° (*c* 0.61); $C_{21}H_{22}N_2O_2$ (M^+: found, 334.169; calcd., 334.1681); infrared ν_{max} 2950 (s), 1760 (s), 1685 (s), and 1608 (m) $cm.^{-1}$; ultraviolet λ_{max} 250 mμ (log ε 3.96) and 298 mμ (log ε 3.56); λ_{min} 233 mμ (log ε 3.75) and 274 mμ (log ε 3.31); n.m.r. 7.4–6.4 (4 H, four aromatic protons), 4.24 (1 H, broad doublet, J = 12 c.p.s.), 3.73 (1 H, singlet), 2.91 (1 H, broad doublet, J = 12 c.p.s.), 2.79 (1 H, singlet), 2.60 (3 H, singlet, NCH_3), and 2.2–1.0 p.p.m. (11 H, methylenic protons). For mass spectra see Figures 1 and 2.

Alkaloid A (IA). Combined fractions C130 to C149 were evaporated and crystallized from methanol to yield 1.05 g. of material. Recrystallization from methanol (twice) and finally from chloroform–petroleum ether (b.p. 40–50°) gave white needles: m.p. 264–265°; $[\alpha]^{30}D$ +110° (*c* 1.31); $C_{22}H_{22}N_2O_4$ (M^+: found, 378.159; calcd., 378.1579); infrared ν_{max} 2950 (s), 1760 (s), 1710 (sh), 1690 (vs), and 1605 (m) $cm.^{-1}$; ultraviolet λ_{max} 240 mμ (log ε 4.09) and 279 mμ (log ε 3.33); λ_{min} 221 mμ (log ε 3.82) and 263 mμ (log ε 3.06); λ_{infl} 285 mμ (log ε 3.30); mass spectrum *m/e* 378.159 (M^+), 350.163, 347.138, 319.146, 282.139, 263.155, 227.093, 227.060, 206.096, 194.095, 167.073, 154.066, 115.053, and 96.081; n.m.r. 3.85 p.p.m. (3 H, singlet, OCH_3).

Alkaloid C (IC). The combined fractions C164 to C174 (inclusively) were evaporated and dissolved in acetone. Addition of petroleum ether precipitated alkaloid C as white needles (58 mg.) which on recrystallization from methanol had m.p. 298°; $[\alpha]^{28}D$ +156° (*c* 0.32); $C_{20}H_{20}N_2O_2$ (M^+: found, 320.155; calcd., 320.1525); infrared ν_{max} 3380 (m), 2950 (m), 1760 (s), 1690 (s), and 1605 (m) $cm.^{-1}$; ultraviolet λ_{max} 242 mμ (log ε 3.90) and 294 mμ (log ε 3.53); λ_{min} 226 mμ (log ε 3.82) and 266 mμ (log ε 3.21); mass spectrum *m/e* 320.155 (M^+), 292, 291, 265, 263, 197, 180, 170, 169, 154, 140, 128, 115, and 96.

10,11-Dioxopleiocarpine.[2] Fractions C190 to C194 (inclusively) were evaporated and dissolved in methanol. On standing for some days yellow crystals (15 mg.) appeared, which were recrystallized from methanol, yielding yellow cubes, m.p. 285–287°. The characterization and determination of the structure of this alkaloid has been described elsewhere.[2]

Lithium Aluminum Hydride Reduction of Alkaloid B (IB) to N_a-Methyl-22-hydroxykopsane (IIB). Alkaloid B (50 mg.) was dissolved in dry tetrahydrofuran (3 ml.). After addition of lithium aluminum hydride (50 mg.) the mixture was refluxed for 3 hr. and evaporated to dryness. A concentrated solution of potassium sodium tartrate was added and the alkaloid was extracted with chloroform. Upon concentration of the chloroform solution the reduction product (IIB) crystallized as white needles (29 mg.): m.p. 239–241°; $C_{21}H_{26}N_2O$ (M^+: found, 322.203; calcd., 322.2045); infrared ν_{max} 2935 (s), 1608 (m), and 1485 (s) $cm.^{-1}$ (in KBr); ultraviolet λ_{max} 256 mμ (log ε 4.02) and 303 mμ (log ε 3.57); λ_{min} 232 mμ (log ε 3.58) and 277 mμ (log ε 3.16) (in ethanol); mass spectrum *m/e* 322.203 (M^+), 321.196, 305.202, 304.194, 265.170, 265.144, 238.146, 221.118, 208.010, 194.096, 182.096, 170.096, 161.103, 152.064, 152.107, 144.081, 115.054, 109.089, and 96.081. Thin layer chromatography of the mother liquors showed that in addition to the above-mentioned crystalline major product (R_f 0.09) there was obtained also a minor product (R_f 0.4) which exhibited almost the same mass spectrum as IIB.

Lithium Aluminum Deuteride Reduction of Alkaloid B (IB) to III. The same procedure was followed for the lithium aluminum deuteride reduction of 10 mg. of IB. The product was crystallized from chloroform to give white needles: m.p. 239–240°; R_f 0.09; mass spectrum *m/e* 325 (M^+), 324, 323, 308, 306, 265, 238, 221, 208, 194, 183, 170, 162.5, 162, 153, 144, 115, 111, and 96.

Lithium Aluminum Hydride Reduction of Alkaloid A (IA) to N_a-Methyl-22-hydroxykopsane (IIB) and 22-Hydroxykopsane (IIC). Alkaloid A (*ca.* 5 mg.) was dissolved in tetrahydrofuran and reduced with lithium aluminum hydride as described above. The reaction product was purified and separated into two compounds by thin layer chromatography. The major product had R_f 0.09; infrared ν_{max} 2935 (s), 1608 (m), and 1485 (s) $cm.^{-1}$ (in KBr); mass spectrum *m/e* 322 (M^+), 321, 305, 304, 265, 238, 221, 208, 194, 182, 170, 161, 160.5, 152, 144, 115, 109, and 96. The minor product had R_f 0.27, mass spectrum *m/e* 308 (M^+).

Lithium Aluminum Hydride Reduction of Alkaloid C (IC) to 22-Hydroxykopsane (IIC). Alkaloid C (*ca.* 5 mg.) was dissolved in tetrahydrofuran and reduced with lithium aluminum hydride as described above. The reaction product was separated and purified by thin layer chromatography giving two compounds. The major product had R_f 0.27; mass spectrum *m/e* 308 (M^+), 289, 251, 224, 209, 194, 180, 197, 154, 115, 110, and 109. The minor product had R_f 0.1, mass spectrum *m/e* 308 (M^+).

Oxidation of IIB to N_a-Methyl-22-oxokopsane (VIII). The alcohol (IIB, 25 mg.) was dissolved in dry dimethyl sulfoxide (2.5 ml.) and trifluoroacetic acid (10 μl.), and N,N′-dicyclohexylcarbodiimide (95 mg.) was added.[10] After standing at room temperature for 15 hr., water (10 ml.) was added and the solution was adjusted to pH 10 with sodium carbonate. The basic material was extracted five times with ethyl acetate. The combined ethyl acetate phases were extracted with hydrochloric acid (0.2 *N*). The acid extracts were neutralized, adjusted to pH 10 with sodium carbonate, and extracted with chloroform. Evaporation to dryness yielded the crude reaction product (14 mg., R_f 0.68) which was purified by chromatography on silicic acid (1.0 g., 100 mesh) using chloroform as eluent. The product was distilled (130° at 0.01 mm.) and gave 8 mg. of crystals (VIII): m.p. 127° upon addition of acetone; infrared ν_{max} 2950 (s), 1750 (s), and 1606 (m) $cm.^{-1}$; ultraviolet λ_{max} 253 mμ (log ε 3.93) and 298 mμ (log ε 3.57); λ_{min} 230 mμ (log ε 3.56) and 276 mμ (log ε 3.33); mass spectrum *m/e* 320 (M^+), 305, 290, 291, 265, 238, 222, 209, 197, 183, 169, 160, 159.5, 144, 115, 109, and 96.

Wolff–Kishner Reduction of VIII to N_a-Methylkopsane (VII). The ketone (5 mg.) was dissolved in dry ethanol (3 ml.) and hydrazine hydrate (0.5 ml.) was added. After refluxing for 3 hr., the ethanol was evaporated,

water (15 ml.) was added, and the hydrazone was extracted with chloroform. This chloroform extract was evaporated to dryness and the residue was dissolved in diethylene glycol (3 ml.). After addition of sodium hydroxide (*ca.* 50 mg.) the solution was heated in an oil bath (220°) for 3.5 hr. Water was added and the basic material was extracted with chloroform. After evaporation and sublimation (100° at 0.01 mm.) of the crude extract white crystals (VII, *ca.* 0.5 mg.) were obtained: R_f 0.20; mass spectrum *m/e* 306 (M^+), 291, 265, 238, 223, 209, 194, 182, 169, 153, 152.5, 144, 138, 109, and 96.

Pyrolysis of N_a-Methylkopsinyl Tosylate (X) to N_a-Methylkopsinylene (XII) and N_a-Methylkopsane (VII). N_a-Methylkopsinyl alcohol (10 mg.) was dissolved in pyridine (5 ml.) and *p*-toluenesulfonic anhydride (80 mg.) was added. After standing at room temperature for 18 hr., water was added, and the reaction mixture was evaporated (at 90°) and extracted several times with chloroform. The combined extracts were washed and purified by chromatography on silicic acid (1 g., 100 mesh) using chloroform as eluent, R_f 0.56. Kept at 100° (1 hr., 2×10^{-6} mm.) the tosylate decomposed giving N_a-methylkopsinylene[13] (XII, *ca.* 10–20% yield, R_f 0.32) and N_a-methylkopsane (VII, *ca.* 10–20% yield, R_f 0.20) in addition to starting material (*ca.* 50–70%). N_a-Methylkopsinyl tosylate decomposed in the mass spectrometer (at 90°) giving a spectrum being almost identical with that of N_a-methylkopsane (some contamination with N_a-methylkopsinylene).

Pyrolysis of N_a-Methylkopsinyl Iodide (IX) to N_a-Methylkopsinylene (XII) and N_a-Methylkopsane (VII). N_a-Methylkopsinyl alcohol (XI, 50 mg.) was dissolved in freshly distilled hydriodic acid (5 ml.) and red phosphorus (250 mg.) was added. This mixture was kept under nitrogen in an oil bath at 140° for 30 hr. The solution was neutralized with sodium carbonate and adjusted to pH 10. After extraction with chloroform and evaporation, the reaction product was separated from starting material by chromatography on silicic acid (2 g., 100 mesh) using methanol–chloroform (1:99) as eluent to give N_a-methylkopsinyl iodide (IX, 20 mg., R_f 0.51), mass spectrum *m/e* 434 (M^+). The iodide was pyrolized at 90° (1.5 hr., 0.01 mm.). The reaction product was separated by thin layer chromatography yielding undecomposed starting material (70–80% yield, R_f 0.51), N_a-methylkopsinylene (XII, 10–15% yield, R_f 0.32), and N_a-methylkopsane (VII, 10–15% yield), R_f 0.20); mass spectrum 306 (M^+), 291, 238, 223, 209, 194, 182, 169, 153, 152.5, 144, 138, 109, and 96; infrared 2940 (s), 1605 (m), and 1490 (m) $cm.^{-1}$; ultraviolet λ_{max} 255 and 303 mμ; λ_{min} 231 and 277 mμ.

Cleavage of Alkaloid B (IB) by Alkali to Pleiocarpinilam (XIII). Alkaloid B (10 mg.) was refluxed for 2 hr. with 4 ml. of methanolic sodium hydroxide. After evaporation to dryness the residue was suspended in water and extracted with chloroform. The aqueous layer was evaporated to dryness, methanol (10 ml.) was added, and gaseous hydrochloric acid was bubbled through this solution for 2.5 hr. while it was heated to reflux. The methanol was removed by evaporation, water (10 ml.) was added, and the pH was adjusted to 10 with sodium carbonate. The basic material was extracted with chloroform and purified by thin layer chromatography. It was found to be identical with pleiocarpinilam (XIII)[11] on the basis of infrared and mass spectra and mobility on t.l.c.

Acknowledgment. We are indebted to Dr. Frank A. Hochstein (Charles Pfizer) for the crude bark extract. This work was supported by a research grant from the National Science Foundation (GP 3734).

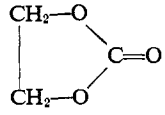
(13) Mass spectrum and R_f value identical with an authentic sample kindly supplied by Professor G. Büchi.

Communications to the Editor

The Planarity of the Ring Atoms in Ethylene Carbonate

Sir:

An X-ray diffraction study[1] of ethylene carbonate



has shown the molecule in the solid state to have C_2 symmetry, with the CO_3 moiety forming a plane and the C–C bond in the ethylenic part of the molecule at an angle of about 20° to the CO_3 plane. Angell[2] has made a very interesting suggestion, based on the infrared spectrum of the molecule, that the symmetry changes to C_{2v} when the solid is melted, dissolved, or vaporized, and that the entire molecule with the exception of the hydrogen atoms becomes coplanar. His evidence comes from the disappearance of bands at 1008, 1225, and 3030 $cm.^{-1}$ in the gas, liquid, and solution spectra, these bands being allowed for C_2 symmetry but infrared inactive for C_{2v}. Simon and Heintz[3] have also investigated the infrared and Raman spectra of ethylene carbonate and come to the same conclusion. The reported change of symmetry between the solid and other phases is quite unusual and seemed to warrant further study.

Microwave spectroscopic techniques provide a very sensitive test for strict planarity. If the molecule is not planar, the potential function for the ring-puckering vibration has a double minimum. Provided the barrier at the planar configuration is sufficiently low, tunneling through the barrier causes the energy levels to be split with a consequent doubling of the observed

(1) C. J. Brown, *Acta Cryst.*, 7, 92 (1954).
(2) C. L. Angell, *Trans. Faraday Soc.*, 52, 1178 (1956).
(3) A. Simon and G. Heintz, *Chem. Ber.*, 95, 2333 (1962).