beyond the range of the existence of chemical compounds, *i.e.*, $\simeq$ 5000°K.

The problem arises, can substances be contained at high temperatures in liquid containers? This problem was solved[5,6] in principle in 1950, when liquid aluminum metal was boiled, at $\simeq$ 2700°K., in a container of liquid alumina (melting point 2320°K.). A centrifugal chemical reactor was used and it consisted essentially of a large steel pipe, lined with Al_2O_3 bricks, which was rotated horizontally at a few hundred r.p.m. In the free cylindrical volume aluminum metal was combusted in O_2 to Al_2O_3, at an average temperature of 3800°K. The prerequisite for successful operation of a centrifugal reactor is that the density of the liquid reactant *be less* than that of the liquid container.

A limiting disadvantage of a chemical centrifugal furnace is that it must be coupled to an exothermic chemical reaction. Thus no other chemical reactions can be studied except the one actually taking place.

It occurred to us to utilize a high temperature plasma jet[7,8,9] with a noble gas such as helium or argon in the temperature range of 5000 to 15,000°K. as a source of heat for a centrifugal furnace. Such a centrifugal plasma jet furnace now has been operated successfully.

The centrifugal furnace consists of a steel cylinder approximately 12 cm. in diameter surrounded by a water jacket. The unit is rotated in ball bearings by a one horsepower variable drive unit. The r.p.m. range of this unit extends from 500 to 1500. The interior of the steel pipe can be filled with any desired insulating material such as alumina bubbles or Thermofax carbon. The reaction section of the furnace consists of a number of coaxial tubes of any oxide or graphite, depending upon the substance to be contained.

Since the inside diameter of the inner containing tube can vary from 1 to 2.5 cm., a fairly wide range of speeds is necessary to rim[10] the contained material.

The power consumed operating this type furnace varied from 8 to 15 k.w.; voltage was approximately 25 to 30; amperage was approximately 350 to 500. The helium flow was 15 to 30 liters (at N.T.P.)/min. The average temperature of the plasma was 10,000 to 17,500 °K.

An example of the use of the furnace (at 1 atm.) is given. An Al_2O_3 tube was first melted, by heating it for about 5 minutes in the plasma jet; the liquid Al_2O_3 could be observed readily through the exit port, by means of dark glasses. A solid rod of aluminum of known weight was then introduced through the exit port, at a slight angle; it melted in a few seconds and floated on the liquid Al_2O_3 container and came to a boil in about 3 minutes, distilling out through the exit port and burning in air with the usual brilliant flame.

The density of liquid Al_2O_3[11] is 3.053 g./cm.^{3} at the melting point (2288°K.) and 2.569 at 2720°K.; the density of (Al)liq. can be estimated, as has been done for Mg,[12] to be equal to 2.050 at 2720°K., *i.e.*, the N.B.P. of Al.

On letting the rotating furnace cool it was found that the innermost Al_2O_3 tube melted over a length $\simeq$ 10 cm. and the remaining aluminum metal formed a sharp cylindrical band, about 3 cm. wide and $\simeq$ 3 mm. thick, ON the Al_2O_3, the two phases being perfectly defined and separate.

A ThO_2 tube also has been melted in the plasma jet.

The extended range of use of liquid oxide containers is, on the average

Al_2O_3	2288°K. (m.p.) to $\simeq$ 3800°K.
ZrO_2	3000°K. (m.p.) to $\simeq$ 4600°K.
ThO_2	3300°K. (m.p.) to $\simeq$ 4700°K.

The ratio of the vapor pressure of the container to the total pressure can be adjusted, as desired, by operating the plasma jet and furnace at a higher total pressure.

Thus a way is now open to extend research, particularly on chemical reactions in liquid phase, (for example, between the container and any added substance, lighter than the container) to a much higher temperature range. A full report will be published later.

The above method is not well suited for physical measurements (such as density, electrical resistivity, etc.) because of imperfect geometry. This can be accomplished by the use of centrifugal furnaces heated by ohmic resistance. This type of furnace will be described shortly.

(5) A. V. Grosse, "High Temperature Symposium Proceedings," June 25–27, 1956, Berkeley, California, pp. 59–68, see Fig. 7 and 8, p. 63.

(6) A. V. Grosse and J. B. Conway, *Ind. Eng. Chem.*, **50**, 663 (1958), see Fig. 5 and 6.

(7) C. S. Stokes, W. W. Knipe and L. A. Streng, *J. Electrochem.*, **107**, 35 (1960).

(8) C. S. Stokes and W. W. Knipe, *Ind. Eng. Chem.*, **52**, 287 (1960).

(9) H. W. Leutner and C. S. Stokes, *ibid.*, **53**, 341 (1961).

(10) R. E. White and T. W. Higgins, *Tappi*, **41**, 71 (1958).

(11) A. D. Kirshenbaum and J. A. Cahill, *J. Inorg. Nucl. Chem.*, **14**, 285–287 (1960).

(12) P. J. McGonigal, A. D. Kirshenbaum and A. V. Grosse, *J. Phys. Chem.*, **66**, 737 (1962).

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ALKALOID STUDIES. XXXVIII.[1] PILOCEREINE—A TRIMERIC CACTUS ALKALOID[2]

Sir:

With the exception of pilocereine[3] and its isomer, piloceredine,[4] all of the naturally occurring cactus alkaloids[5] are based on a simple β-phenylethylamine or tetrahydroisoquinoline nucleus. Pilocereine had been assigned[3,6] the empirical formula $C_{30}H_{44}N_2O_4$ (496) on the basis of numerous analyses

(1) Paper XXXVII. C. Djerassi, R. J. Owellen, J. M. Ferreira and L. D. Antonaccio, *Experientia*, **18**, September (1962).

(2) Supported by grant No. 2G-682 from the National Heart Institute of the National Institutes of Health, U. S. Public Health Service.

(3) G. Heyl, *Arch. Pharm.*, **239**, 451 (1901).

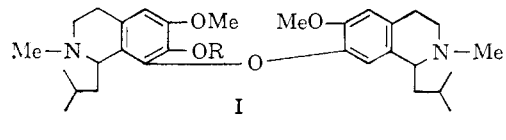
(4) C. Djerassi, T. Nakano and I. M. Bobbitt, *Tetrahedron*, **2**, 58 (1958).

(5) For review see L. Reti in R. H. F. Manske and H. L. Holmes "The Alkaloids," Academic Press, Inc., New York, 1954, Vol. IV, pp. 7–28.

(6) C. Djerassi, S. K. Figdor, J. M. Bobbitt and F. X. Markley, *J. Am. Chem. Soc.*, **79**, 2203 (1957).

and Rast molecular weight determination (found[7]: 532). Since potassium–liquid ammonia cleavage of the methyl or ethyl ethers of pilocereine[6] and piloceredine[4] provided the tetrahydroisoquinolines III-VIII, the structures of which were established by synthesis,[8] pilocereine and piloceredine were considered to be stereoisomers of the "dimer" Ia.

Recently, we had occasion to examine the n.m.r. spectra of pilocereine and some of its derivatives and found them to be incompatible with the molecular weight implicit in structure Ia. A particularly striking example is afforded by pilocereine acetate (old structure[6] Id; now shown to be IId), where integration required a ratio of four aromatic hydrogens: three methoxyl, three N-methyl, one acetate, three isobutyl groups. These results suggested an unprecedented "trimeric" structure (*e.g.*, II, XI, etc.) and this was confirmed fully by determination of the molecular weight (calcd. for $C_{31}H_{46}N_2O_4$ (Ib): 510; calcd. for $C_{46}H_{67}N_3O_6$(IIb): 757) of pilocereine methyl ether by the thermistor method (found: 735, 743) and especially by mass spectrometry (found: 757). While all of the earlier recorded carbon, hydrogen and nitrogen analyses are, of course, equally compatible with either a dimeric or trimeric formula, a new acetyl determination (found: 5.4) on pilocereine acetate (calcd. for Id: 8.0; calcd. for IId: 5.5) serves as a further criterion of differentiation.



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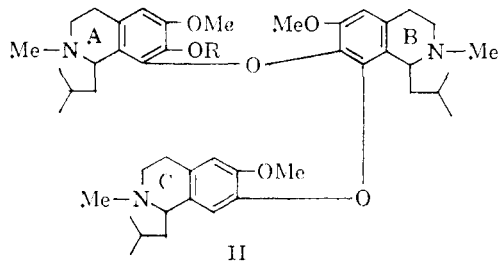
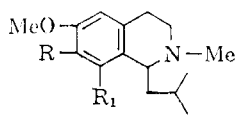


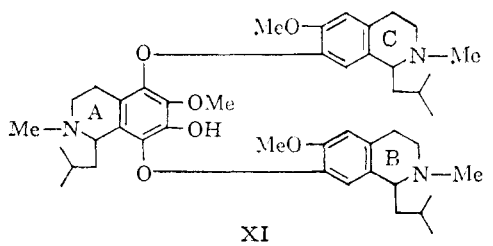
II

Ia, R = H
b, R = Me
c, R = Et
d, R = Ac

IIa, R = H
b, R = Me
c, R = Et
d, R = Ac



III, R = R = H
IV, R = OH, R_1 = H
V, R = OMe, R_1 = H
VI, R = OEt, R_1 = H
VII, R = OMe, R_1 = OH
VIII, R = OEt R_1 = OH
IX, R = H, R_1 = OH
X, R = H, R_1 = OMe



XI

The originally assigned[6] expression Ia for pilocereine can now be attributed to "isopilocereine," one of the kryptophenolic fragments encountered[6] in the potassium–ammonia cleavage of pilocereine (Ia) and which had earlier[6] been assumed to represent a rearrangement product of no structurally diagnostic value. The correctness of the "dimeric" structure Ia for "isopilocereine" could be established by n.m.r. and mass spectral measurements (mol. wt. found, 510) of its crystalline methyl ether Ib (m.p. 88–90°)[9] and by potassium–ammonia cleavage to III (trace), IV and V.

Of the various alternatives for a trimeric constitution, expression IIa appeared the most likely one on the basis of structure Ia for the dimeric cleavage product "isopilocereine" and the earlier[6] isolation of fragments III–VIII. However, in the strictest sense, the "monomers" III–VIII could all have arisen from components A and B or components A and C (see II) and it was necessary to isolate a fragment which would be derived unambiguously from the third ring and thus exclude less likely alternatives for pilocereine, such as XI.

We have now repeated the earlier described[6] potassium–liquid ammonia fission of pilocereine *ethyl* ether (IIc), with the modification that, in addition to column chromatography coupled with picrate formation,[6] gas phase chromatography together with n.m.r. and mass spectral measurements were also employed to search for the missing fragment. Indeed, in addition[6] to III, VI and VIII. there was obtained in the "non-phenolic" fraction oily 1-isobutyl-2-methyl-6-methoxy-8-hydroxy-1,2,3,4-tetrahydroisoquinoline (IX) (calcd. for $C_{15}H_{23}NO_2$: mol. wt. 249; found (mass spec.) 249), the n.m.r. spectrum of which exhibited signals corresponding to one phenolic (8.02δ), two aromatic (6.15δ; *meta* coupling J = 2.5 c.p.s.) three methoxyl (3.68δ) and three N-methyl (2.43δ) protons. Diazomethane methylation of IX provided the known[8b] 1-isobutyl-2-methyl-6,8-dimethoxy-1,2,3,4-tetrahydroisoquinoline (X) picrate (m.p. 147–149°) which had to be derived from moiety B in structure IIc.

The biogenetically very intriguing structure IIa for pilocereine—arising from trimerization of the "monomer" lophocereine (IV)[4]—is thus proved. Experiments are currently in progress to determine whether piloceredine,[4] also shown to be trimeric by n.m.r. and mass spectral measurements, is a diastereoisomer of IIa or actually a structural isomer.

Acknowledgment.—We are indebted to Drs. H. Budzikiewicz and J. M. Wilson for the mass spectra and to Mr. E. Meier for the careful micro-

(7) C. Djerassi, N. Frick and L. E. Geller, *J. Am. Chem. Soc.*, **75**, 3632 (1953).

(8) (a) C. Djerassi, J. J. Beereboom, S. P. Marfey and S. K. Figdor, *J. Am. Chem. Soc.*, **77**, 484 (1955); (b) C. Djerassi, F. X. Markley and R. Ehrlich, *J. Org. Chem.*, **21**, 975 (1956); (c) J. M. Bobbitt and T. T. Chou, *ibid.*, **25**, 560 (1960).

(9) This sample was identical with a synthetic specimen obtained in the laboratory of Prof. M. Tomita of the University of Kyoto, to whom we are indebted for performing the direct comparison.

analyses and thermistor molecular weight determinations.

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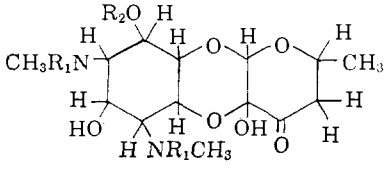
CHEMISTRY OF ACTINOSPECTACIN. II. THE STRUCTURE OF ACTINOSPECTACIN

Sir:

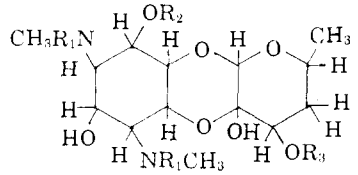
The previous communication[1] in this series described the structure of actinamine, the basic moiety of actinospectacin.[2-5] In this paper Ia is presented as the actinospectacin structure exclusive of stereo-



Ia, $R_1 = R_2 = H$
Ib, R_1 = acetyl, $R_2 = H$
Ic, $R_1 = R_2$ = acetyl
Id, $R_1 = H$, R_2 = acetyl
Ie, R_1 = ethylcarbamoyl, $R_2 = H$

chemistry. Crystalline actinospectacin hexahydrate, m.p. 65–72°, $[\alpha]D$ 7.6° (*c*, 1, water), has the molecular formula $C_{14}H_{24}N_2O_7 \cdot 6H_2O$,[6,7] and contains two N–CH_3, one C–CH_3 and two basic groups, p*K*a's of 6.95 and 8.70. Besides infrared bands ascribed to hydroxyl and amino hydrogen at 3200–3500 cm.$^{-1}$, Ia exhibits a carbonyl band at 1735 cm.$^{-1}$, present only in mulls of rigorously dried samples and absent in crystalline hydrates.

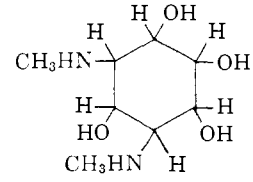
The facile reduction, either with sodium borohydride or catalytic (Pt) hydrogen, of Ia to yield dihydroactinospectacin base, IIa, melting at 83–84°, was further evidence for this carbonyl function.



IIa, $R_1 = R_2 = R_3 = H$
IIb, R_1 = acetyl, $R_2 = R_3 = H$
IIc, $R_1 = R_2 = R_3$ = acetyl

Dihydroactinospectacin contains all the functional groups of its parent antibiotic except the carbonyl function as evidenced by the permanent disappearance of the 1735 cm.$^{-1}$ band in the infrared. Both Ia and IIa readily form a series of acetyl derivatives, Ib,c,d and IIb,c, isolated as amorphous solids after countercurrent distribution. The monoacetate, Id, consumes 3 moles of periodate, showing that the acetoxy group cannot be located between the two nitrogen-bearing carbons. Actinospectacin reacts with ethyl isocyanate to produce N,N′-bis-(ethylcarbamoyl)-actinospectacin (Ie) $[\alpha]D$ −8° (*c*, 0.84, water), which consumes one mole of periodate.

Methanolic hydrogen chloride fails to cleave actinospectacin or dihydroactinospectacin appreciably. Various acid hydrolyses and mercaptolyses gave actinamine, III, but the remaining six carbons ($C_6H_{6-8}O_3$) were isolated as intractable mixtures



III

suggesting degradation. Periodate (4 moles) reacts with actinospectacin to give two moles of formic acid and two moles of methylamine. This indication that only three adjacent bonds in the actinamine moiety are available for oxidation was confirmed when N,N′-diacetylactinospectacin, Ib, consumed 1 mole, liberating after hydrolysis actinamine, III, and glyoxylic acid. Two adjacent oxygens, then, are involved in linkages to the remaining fragment(s) totaling six carbons.

From preceding and subsequent data, actinospectacin can be considered to be a glycoside of a relatively unstable, six-carbon, sugar-like substance, designated actinospectose. This moiety as contained in actinospectacin has one C–CH_3, one carbonyl, and at least one non-acylable hydroxyl.

Dihydroactinospectacin took up four moles of periodate, the diacetyl derivative IIb, one, and the tetraacetyl IIc (in contrast to triacetyl actinospectacin (Ic) which consumes one mole) none. In tetraacetyldihydroactinospectacin the fourth acetate must have been formed at the former carbonyl position. Since this now blocks the periodate reaction, the original carbonyl function must have been adjacent to a hydroxyl. Because the bismuth oxide test for acyloins[8] is negative for actinospectacin, it must be tertiary.

As in the case of the corresponding derivative from actinospectacin, Ib, both actinamine and glyoxylic[9] acid were isolated from periodate oxidation of IIb. The remaining four carbons were found in the third compound isolated from IIb, crotonaldehyde.[9] Similarly, crotonic acid was isolated as its *p*-bromophenacyl ester, after periodate oxidation of the actinospectacin derivative, Ie. The new unsaturation must arise from elimination of hydroxyl from a *beta*-carbon. This could not have been a free hydroxyl in actinospectacin as evidenced by a negative iodoform test and failure to acetylate. Partial structure IV for the actinospectose glycoside, linked to actin-

(1) P. F. Wiley, *J. Am. Chem. Soc.*, **84**, 1514 (1962).

(2) A. C. Sinclair and A. F. Winfield, First Interscience Conference on Antimicrobial Agents and Chemotherapy, Oct. 31–Nov. 2, 1961, New York, N. Y.

(3) The trade name of The Upjohn Company for actinospectacin is Trobicin.

(4) D. J. Mason, A. Dietz and R. M. Smith, *Antibiotics and Chemotherapy*, **11**, 118 (1961).

(5) M. E. Bergy, T. E. Eble and R. R. Herr, *ibid.*, **11**, 661 (1961).

(6) Analytical values for all the compounds described in this paper were consistent with the indicated formulas.

(7) Erroneously reported as $C_{14}H_{26-28}N_2O_7$ in earlier papers.[2,5]

(8) W. Rigby, *J. Chem. Soc.*, 793 (1951).

(9) Isolated as the 2,4-dinitrophenylhydrazone.