in 8 drops of methanol was heated to boiling and 1 ml of ethyl acetate was added. After standing in the refrigerator for 1 day, this gave 25 mg of crystals: mp 133–137°. This was recrystallized four times to give 9.5 mg of constant mp 136–138° (no depression in melting point when admixed with the cinchonidine salt prepared from senecic acid: mp 136–138°). The infrared (KBr) spectra of the two samples were identical. The synthetic cinchonidine salt was dissolved in dilute hydrochloric acid and extracted with ether. Evaporation of the extract and crystallization from ether–petroleum ether gave crystals, mp 146–148°, and no depression resulted when admixed with senecic acid. The infrared (KBr) spectra of the synthetic sample and senecic acid were identical in every respect.

Acknowledgment.—The authors gratefully acknowledge support of this work by a grant from the Robert A. Welch Foundation. We are indebted to Dr. C. C. J. Culvenor, C.S.I.R.O., Melbourne, Australia, for a sample of seneciomine.

Indole-3-alkylamine Bases of *Desmodium pulchellum*

S. GHOSAL AND B. MUKHERJEE[1]

Department of Chemistry, University of Kalyani, Kalyani, Nadia, West Bengal, India

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The isolation and identification of seven indole-3-alkylamine bases derived from tryptophan in *Desmodium pulchellum* are described. Rearrangement of N,N-dimethyl tryptamine oxide and 5-methoxy-N,N-dimethyltryptamine oxide, obtained from this species, has been studied and its implication in the light of alkaloid biosynthesis is appraised.

Previously, the occurrence of seven indolealkylamine bases in *Desmodium pulchellum* Benth *ex* Baker (family *Leguminosae*) has been reported.[2] The present paper describes the experimental details of the isolation and identification of these compounds. In addition, the results of rearrangement of two tertiary amine oxides, *viz.*, N,N-dimethyltryptamine oxide and its 5-methoxy analog, isolated from this plant, are now reported. These results indicate the pathway of tryptophan metabolism and support a recent suggestion[3] that the formation of amine oxides and their rearrangement to carbinol amine bases may be important stages in the biosynthesis of certain group of alkaloids.

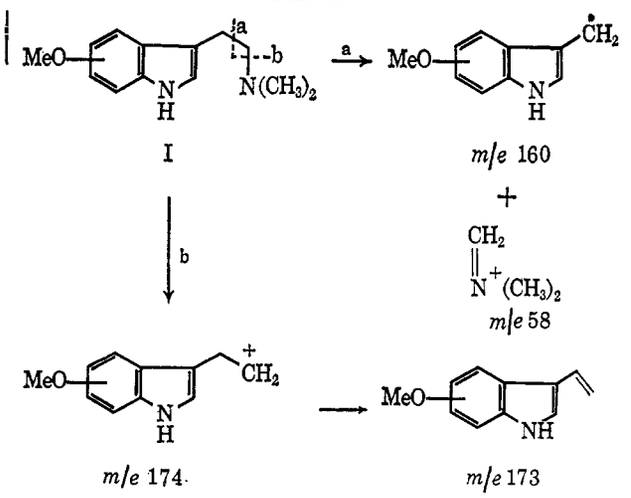
The alkaloids were extracted from the defatted plant material with alcohol containing acetic acid and the mixture of crude bases obtained in the usual way was separated into the following three main components by column chromatography on Brockmann alumina. Elution with benzene gave the major base while the minor components, less and more polar, migrated out as brown gum upon washing of the column with ether–methyl alcohol and methyl alcohol, respectively. The more polar compounds were finally purified by column chromatography on cellulose powder.

The total alkaloids from the plant showed with *p*-dimethylaminobenzaldehyde or with vanillin in presence of concentrated hydrochloric acid purple and blue colors and exhibited ultraviolet absorption characteristic of 3-alkyl indoles. Four of the seven compounds mentioned here were isolated in quantities sufficient for complete characterization, and for the remaining three minor bases the general procedure for identification involved paper and thin layer chromatographic determinations. The mixture of minor components was submitted to preparative paper chromatography and the distinct zones obtained were eluted with ethyl alcohol. The ethyl alcohol eluates were chromatographed separately and in mixture with a reference compound. The pure components from separate chromatographic runs were used for ultraviolet absorption spectra determinations and for preparation of picrates.

The major alkaloid, mp 69°, which crystallizes from ether–petroleum ether is a tertiary base as it readily forms a methiodide and an N-oxide. Elemental analysis of the alkaloid and its derivatives are consistent with the molecular formula $C_{13}H_{18}N_2O$ for the parent base.

The molecular formula of the base was further verified with the help of mass spectrometry (M = 218). Aside from the molecular ion peak, there are certain important peaks at *m/e* 174, 173, 160, 159, 158, 145,and 58 (strongest) in the mass spectrum of this alkaloid. The two peaks at *m/e* 160 and 174 seem to represent a methoxy indole grouping with one and two CH_2 groups, respectively, attached to the β position of the indole. The peaks at *m/e* 145 and 159 presumably arise from the loss of a methyl group (−15) from *m/e* 160 and 174, respectively. The genesis of the strongest peak at *m/e* 58 and other significant peaks can be best explained by assuming a skeleton (I) present in this alkaloid (see Scheme I).

SCHEME I



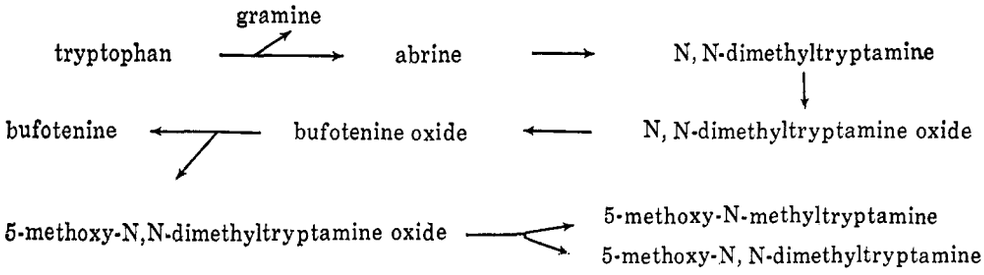
The above evidences together with the pmr spectral data of the alkaloid in $CDCl_3$ [one-proton singlet at τ 1.58 (NH), three-proton singlet at τ 6.08 (OCH_3), and

(1) Department of Pure Chemistry, University College of Science, Calcutta, India.

(2) S. Ghosal and B. Mukherjee, *Chem. Ind.* (London), 794 (1965).

(3) A. Chatterjee and S. Ghosal, *J. Indian Chem. Soc.*, **42**, 123 (1965), and references cited therein.

SCHEME II



a six-proton singlet at 7.62 τ ($2N_b\,CH_3$)] suggest strongly its identity with the O-methyl ether of bufotenine.[4,5] The O-demethyl compound obtained upon treatment of the base with anhydrous aluminum chloride in benzene was found to be identical with bufotenine in all respects.

The minor bases obtained from the ether–methyl alcohol eluates were characterized by paper chromatography as 5-methoxy-N-methyltryptamine,[6] bufotenine,[7] N,N-dimethyltryptamine,[7] and N,N-dimethyltryptamine oxide.[7]

The mixture of bases obtained upon washing the alumina column with methyl alcohol was eventually separated into pure components by rechromatography on cellulose powder and on Brockmann alumina. The less polar compounds eluted out of the cellulose column with ethyl acetate afforded an oil, which was separated into 5-methoxy-N-methyltryptamine[6] and gramine[4] through the formation of their picrates and fractional crystallization of these derivatives from acetone. Gramine picrate obtained from the acetone mother liquor was recrystallized from ethyl alcohol and the corresponding base was regenerated by passing the picrate solution through a weakly basic alumina column and eluting with benzene–ether.

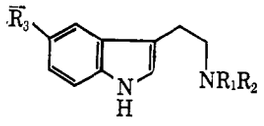
The more polar and more abundant fraction, a viscous, brown oil, from the acetone–water eluates of the cellulose powder chromatographic run, gave an orange-red picrate, mp 153–159° with prior shrinkage at 138–143°. The base was purified by treatment with water which removed the major portion of the gum. The remaining portion was further purified by column chromatography on Brockmann alumina and the resulting base was found to be identical with gramine.

The water-soluble base could be recovered only partially from the aqueous solution by repeated extraction with chloroform. The chloroform extract gave a pale violet oil upon removal of the solvent. The residue formed a crimson red picrate, mp 158°, and showed only one spot on the paper chromatogram (R_f 0.56; isopropyl alcohol–ammonia–water, 9:1:1). An aliquot of the aqueous solution was acidified with acetic acid and then reduced with zinc dust, and the solution was brought to pH 9 with ammonia and then extracted with chloroform when almost quantitative recovery of the base in the form of 5-methoxy-N,N-dimethyltryptamine was effected. The remaining aqueous portion containing the water-soluble base when treated with ferrous sulfate yielded formaldehyde, identified as the dimedone derivative, and a mixture of 5-methoxy-N,N-dimethyltryptamine, 5-methoxy-N-methyltryptamine, and 6-methoxy-2-methyl-1,2,3,4-tetrahydro-β-carboline. The origin of C_3 of the β-carboline obviously lies in one of the two $N_{(b)}$ methyl groups of the tryptamine moiety. This rearrangement was repeated with authentic 5-methoxy-N,N-dimethyltryptamine oxide prepared from the corresponding tertiary base by treatment with hydrogen peroxide and gave identical results.

The foregoing results indicate that the water-soluble alkaloid from *D. pulchellum* is the tertiary amine oxide, 5-methoxy-N,N-dimethyltryptamine oxide. The formation of this amine oxide from 5-methoxy-N,N-dimethyltryptamine was never observed in absence of a specific oxidizing agent and suggests that it is not an artifact and exists as such in the plant.

The occurrence of several tertiary amine oxides in a single plant species is of considerable biogenetic interest because the amine oxides are probably the key intermediates in certain alkaloid biosyntheses.[8]

Of the series of nine tryptamines having the general formula II, all except 5-methoxytryptamine are known



II, R_1 = H or CH_3
R_2 = H or CH_3
R_3 = H, OH or OCH_3

to occur in nature. These observations together with the present isolation of two tertiary amine oxides, gramine, and four other secondary and tertiary bases from a single natural source are consistent with the pathway of tryptophan metabolism shown in Scheme II.

It is pertinent to mention in this connection the recent paper[9] by Ferris and Gerwe. They have shown that the following are the stages in the iron-catalyzed demethylation of trimethylamine oxide. Stages 2 and

$$(CH_3)_3\overset{+}{N}OH + Fe(II) + H^+ \longrightarrow (CH_3)_3\overset{+}{N}\cdot + Fe(III) + H_2O \quad (1)$$

$$(CH_3)_3\overset{+}{N}\cdot + Fe(II) + H^+ \longrightarrow (CH_3)_3\overset{+}{N}H + Fe(III) \quad (2)$$

$$(CH_3)_3\overset{+}{N}\cdot \longrightarrow (CH_3)_2\overset{+}{N}HCH_2\cdot \quad (3)$$

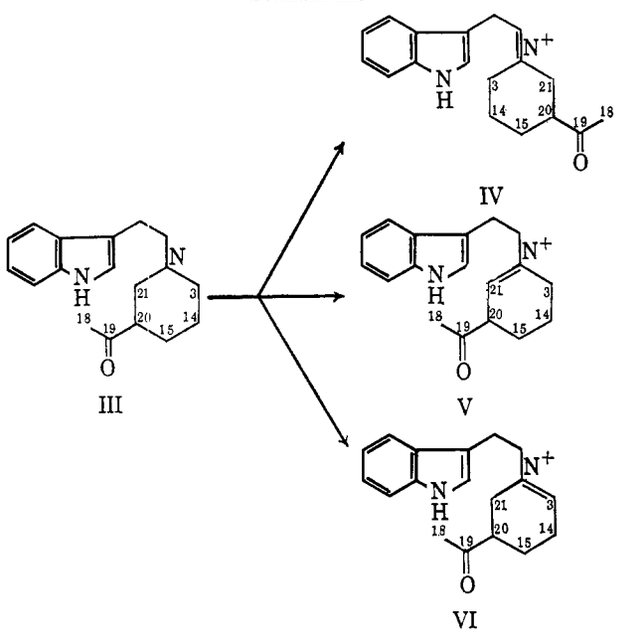
$$(CH_3)_2\overset{+}{N}HCH_2\cdot + (CH_3)_3\overset{+}{N}OH \longrightarrow (CH_3)_2\overset{+}{N}HCH_2OH + (CH_3)_3\overset{+}{N}\cdot \quad (4)$$

(4) I. J. Pachter, D. E. Zacharias, and O. Ribeiro, *J. Org. Chem.*, **24**, 1285 (1959).
(5) G. Legler and R. Tschesche, *Naturwiss.*, **50**, 94 (1963).
(6) S. Wilkinson, *J. Chem. Soc.*, 2079 (1958).
(7) M. S. Fish, N. M. Johnson, and E. C. Horning, *J. Am. Chem. Soc.*, **77**, 5892 (1955); **78**, 3670 (1956).
(8) J. C. Craig, F. P. Dwyer, A. N. Glazer, and E. C. Horning, *ibid.*, **83**, 1871 (1961).
(9) J. P. Ferris and R. Gerwe, *Tetrahedron Letters*, **No. 24**, 1613 (1964).

4 are consistent with the formation of both tertiary and secondary amines (the latter is presumably formed *via* the carbinol amine base) from tertiary amine oxides and has been further tested in the present study with other amine oxides. When treated with aqueous ferrous sulfate at ordinary temperatures, N,N-dimethyltryptamine oxide was rearranged to give a mixture of formaldehyde, N-methyltryptamine, and indole-3-acetaldehyde.[10] This determination lends further credence to the metabolic sequence of tryptophan envisaged in the above scheme.

The significance of the foregoing results lies further in the mode of formation of certain complex alkaloid patterns. Our recent paper may be cited[3] in this connection. While suggesting a hypothetical biogenetic route common to all indole bases, we contended that entities (IV to VI), formed from III, *via* the corresponding N-oxide, are presumably the branch points enroute to different indole structure patterns. The present and previous[11,12] laboratory analogies amply support this scheme and advocate it as a working hypothesis for further biochemical testing. (See Scheme III.)

SCHEME III



Experimental Section

All melting points were uncorrected and determined in open capillary. Infrared spectra were taken in a Perkin-Elmer double-beam spectrophotometer and ultraviolet spectra were recorded in a Beckman DU spectrophotometer. Microanalyses were performed by Dr. Alfred Bernhardt, Mikroanalytisches Laboratorium im Max-Planck-Institut für Kohlenforschung, Mülheim (Ruhr).

Isolation of the Alkaloids.—Dried and finely ground whole plant (4 kg) of *D. pulchellum* was treated with benzene under reflux in a Soxhlet apparatus for 8 hr. The benzene extract was kept aside for further examination for alkaloids and neutral components. The defatted plant material was extracted with alcohol (95%) containing acetic acid (2%) in a percolator at room temperature for 4 weeks. The alcoholic solution was concentrated under reduced pressure to give a viscous brown slurry (170 g) which was poured into aqueous acetic acid (2%, 200 ml) with stirring and the mixture kept overnight at ordinary temperature. Suspended impurities were filtered off and the filtrate shaken with chloroform (three 500-ml portions) which removed 1.7 g of the material. The pH of the aqueous solution was brought to 9 with ammonia and the liberated bases were extracted with chloroform. The chloroform solution was washed with water and dried ($CaCl_2$); solvent was removed under reduced pressure giving a thick slurry (*ca.* 18 g).

Chromatographic Resolution of the Bases on Alumina.—The total basic extractable was dissolved in methanol (10 ml) and chromatographed on Brockmann alumina (35 × 4 cm). The results are presented in Table I. Elution was carried out with 100-ml portions of petroleum ether (bp 40–60°), petroleum ether–benzene (90:10, 80:20, 50:50), benzene, benzene–ether (95:5, 90:10, 80:20, 50:50, 20:80), and methanol; 40-ml fractions were collected. The course of separation was followed by paper chromatography (ascending type) using isopropyl alcohol–ammonia–water (9:1:1) as the solvent system and 0.5% solution of *p*-dimethylaminobenzaldehyde in 1 *N* hydrochloric acid as the spraying reagent.

TABLE I

COLUMN CHROMATOGRAPHIC DATA

Fraction	Residue, g	R_f values and color developed
2–3	4.62	0.97 blue
6–8	3.00	0.96 blue, 0.92 red
9–11	0.74	0.97 blue, 0.916 blue
20–25	0.016	0.92 blue, 0.82 red
27–33	0.472	Four spots: 0.92 blue, 0.86 blue, 0.82 red, 0.62 red
37–40	0.322	0.86 blue, 0.56 red

5-Methoxy-N,N-dimethyltryptamine.—Fractions 2–11 were combined and concentrated under reduced pressure. The residue (8.36 g) upon crystallization from ether–light petroleum ether (1:1) gave colorless plates: mp 69° (lit.[4] mp 69°); infrared, λ_{max}^{KBr} 2.93 (NH), 3.55 (NMe), 6.19 μ (aromatic OMe); ultraviolet, λ_{max}^{EtOH} 224, 277, and 296 mμ (log ϵ 4.46, 3.84, and 3.76, respectively).

Anal. Calcd for $C_{13}H_{18}N_2O$: C, 71.55; H, 8.25; 1-OMe, 14.22; $1H^+$, 0.46. Found: C, 70.47; H, 8.29; -OMe, 14.22; H^+, 0.46.

The base gave a methiodide which crystallized from acetone–methyl alcohol (9:1): mp 181–182°.

Anal. Calcd for $C_{14}H_{21}N_2OI$: C, 46.66; H, 5.83; N, 7.77; I, 35.28. Found: C, 46.55; H, 5.88; N, 7.65; I, 35.35.

The base picrate was crystallized from methyl alcohol in orange-yellow needles, mp 172°.

Anal. Calcd for $C_{13}H_{18}N_2O \cdot C_6H_3N_3O_7$: N, 15.66. Found: N, 15.80.

5-Methoxy-N-methyltryptamine.—Fractions 27–33 were combined, the solvent was removed under reduced pressure, and the crude mixture of bases obtained was divided into few small portions. To one of these portions in dry ether, hydrogen chloride gas was passed, and the crude hydrochloride which separated was crystallized from methyl alcohol in needles: mp 167° (lit.[6] mp 165–166°); ultraviolet, λ_{max}^{EtOH} 223, 276, and 292 mμ.

Anal. Calcd for $C_{12}H_{17}N_2OCl$: C, 59.99; H, 7.08; N, 11.68. Found: C, 59.72; H, 7.13; N, 11.24.

To another portion in acetone, picric acid solution in the same solvent was added. The orange-red picrate which separated was crystallized from methyl alcohol: mp 222°.

Anal. Calcd for $C_{12}H_{16}N_2O \cdot C_6H_3N_3O_7$: N, 16.16. Found: N, 15.98.

Bufotenine, N,N-Dimethyltryptamine, and N,N-Dimethyltryptamine Oxide.—A sample from fractions 27–33 was subjected to paper chromatography on Whatman No. 1 paper and an isopropyl alcohol–ammonia–water (9:1:1) system was used for development. The entire width of the paper was utilized. Three zones were cut at R_f values (0.91, 0.82, 0.63) determined with marker strips. Each zone was eluted with ethyl alcohol. The three solutions obtained this way were used for final paper chromatographic determinations. Tentative identification of these bases was substantiated by chromatography with authentic samples.

The R_f values of the seven alkaloids isolated so far were de-

(10) A. Chatterjee, S. Ghosal, and S. Ghosh Majumdar, *Chem. Ind.* (London), 265 (1960).

(11) D. Schumann and H. Schmid, *Helv. Chim. Acta*, **46**, 1996 (1963).

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

termined separately after purification. The results are presented in Table II. The following abbreviations for the solvent system are used: IPAW, isopropyl alcohol–ammonia–water (9:1:1); BAW, *n*-butyl alcohol–acetic acid (10:4), saturated with water. A 0.5% *p*-dimethylaminobenzaldehyde in 1 *N* aqueous hydrochloric acid was used as the spraying reagent.

TABLE II

PAPER CHROMATOGRAPHIC DATA OF *D. pulchellum* ALKALOIDS

Compd	—R_f values— IPAW	BAW	Color developed
N,N-Dimethyltryptamine	0.91	0.74	Blue
N,N-Dimethyltryptamine oxide	0.63	0.81	Mauve to blue
Gramine	0.95	0.73	No immediate color with Ehrlich reagent; with Dragendorff reagent, orange
Bufotenine	0.82	0.63	Blue
5-Methoxy-N-methyltryptamine	0.86	0.70	Blue
5-Methoxy-N,N-dimethyltryptamine	0.97	0.72	Blue
5-Methoxy-N,N-dimethyltryptamine oxide	0.56	0.89	Cherry red to blue

Gramine.—Fractions 37–40 (Table I) were combined and concentrated under reduced pressure; the residue (0.322 g) was dissolved in methyl alcohol (2 ml) and chromatographed on cellulose powder. Whatman ashless standard grade cellulose powder (*ca.* 30 g) was used. The column was prepared according to the procedure reported by Taylor, *et al.*[13] The flow rate was adjusted to 2–3 ml/min and 40-ml fractions were collected. The results are presented in Table III.

TABLE III

COLUMN CHROMATOGRAPHY ON CELLULOSE POWDER

Eluents	Fractions	Residue
Ethyl acetate	2–5	Brown oil (81 mg) R_f 0.69, 0.73, BAW
Ethyl acetate–acetone (95:5)	6–8	Negligible R_f 0.68, 0.74, BAW
Acetone–water (90:10)	11–15	Brown oil (142 mg) R_f 0.69, 0.85, BAW

The residue from fractions 2–5 was dissolved in acetone (5 ml) and picric acid solution in the same solvent (5 ml) was added to it. Orange-red crystals separated almost immediately. The crude picrate was recrystallized from methyl alcohol in fine needles, mp 220°, and was found to be identical in all respects with the picrate of 5-methoxy-N-methyltryptamine.[6] The yellow acetone mother liquor was evaporated to dryness and the residue was crystallized from ethyl alcohol in yellow needles, mp 144–145°.

Anal. Calcd for $C_{11}H_{14}N_2 \cdot C_6H_3N_3O_7$: C, 50.62; H, 4.21; N, 6.94. Found: C, 50.21; H, 4.05; N, 6.34.

The parent base (gramine) was subsequently obtained by passing the picrate solution through a Brockmann alumina column (18 × 1 cm) and eluting with benzene–ether. The crude base was crystallized from benzene in flakes, mp 133–135°. Mixture melting point with an authentic sample remained undepressed.

5-Methoxy-N,N-dimethyltryptamine Oxide.—The water-soluble portion from fractions 11–15 (Table III) was exhaustively extracted with chloroform and the chloroform layer gave a pale violet oil (17 mg) upon removal of the solvent. The residue in alcohol formed a crimson red picrate, mp 157–158°, and gave two spots, R_f 0.53 (faint spot, gramine), 0.91 (5-methoxy-N,N-dimethyltryptamine oxide) on the thin layer chromatogram using alumina as the adsorbent and chloroform–methyl alcohol (90:10) as the developer. The red picrate was recrystallized from ethyl alcohol in needles, mp 158°.

Anal. $C_{13}H_{18}N_2O_2$, $C_6H_3N_3O_7$ requires: C, 49.24; H, 4.53; N, 15.33. Found: C, 49.54; H, 4.33; N, 15.08.

Demethylation of 5-Methoxy-N,N-dimethyltryptamine.—5-Methoxy-N,N-dimethyltryptamine (200 mg) was dissolved in dry benzene (20 ml) to which anhydrous aluminium chloride (1.1 g) was added. The mixture was refluxed on a water bath for 6 hr and cooled in ice; aluminum chloride was decomposed with water. The benzene layer was washed with water and dried (Na_2SO_4); solvent was removed under reduced pressure. The residue, a brown gum (177 mg), R_f 0.82 (IPAW), gave a picrate which was crystallized from methanol in yellow needles, mp 177–178°, identical in all respects with bufotenine dipicrate.[7]

Preparation of 5-Methoxy-N,N-dimethyltryptamine Oxide.—A solution of 5-methoxy-N,N-dimethyltryptamine (50 mg) in ethyl alcohol (2 ml) was treated with a solution (3 ml) of 30% hydrogen peroxide in ethyl alcohol (2 ml in 8 ml). The mixture was kept at room temperature for 2 hr, then diluted with ether when flocculent solid separated. The hygroscopic amine oxide (R_f 0.89; BAW) yielded a red picrate from ethyl alcohol: mp 158–159°.

Anal. Calcd for $C_{13}H_{18}N_2O_2$, $C_6H_3N_3O_7$: N, 15.33. Found: N, 14.93.

Rearrangement[14] of 5-Methoxy-N,N-dimethyltryptamine Oxide with Ferrous Sulfate.—A solution of the amine oxide (64 mg) in aqueous acetic acid (5 ml) and ferrous sulfate heptahydrate (198 mg) in water (10 ml) was kept for 40 min over a steam bath (60–65°) after which the mixture was cooled in ice.

Detection of Formaldehyde.—To an aliquot of the above solution an aqueous solution of dimedone (0.5%, 50 ml) was added; the mixture was vigorously shaken and kept at room temperature overnight. The formaldehyde dimedone which precipitated was filtered, washed with water, and dried *in vacuo:* mp 187–188°. The melting point of this compound remained undepressed on admixture with authentic formaldehyde dimedone, mp 188°.

Identification of the Basic Fragments.—To the major portion of the ferrous sulfate treated solution, solid sodium hydroxide was added (pH brought to 12) and the liberated bases were extracted with chloroform. The chloroform solution was washed with little cold water and dried and then solvent was removed. The viscous brown mass left (27 mg) was chromatographed on Brockmann alumina (18 × 1 cm). From the benzene–chloroform (80:20) eluates was obtained the least polar component (*ca.* 7 mg), as an oil (R_f 0.97; IPAW), which did not respond to Ehrlich color reaction but showed an intense blue color with Hopkin-Cole's glyoxalic reagent: ultraviolet,[15] λ_{max}^{EtOH} 228, 282 mμ with inflection at 291 mμ; λ_{min}^{EtOH} 247, 288 mμ. It formed a yellow picrate which crystallized from ethanol: mp 182–191°.

Anal. Calcd for $C_{13}H_{16}N_2O \cdot C_6H_3N_3O_7$: C, 51.23; H, 4.27; N, 15.73. Found: C, 50.89; H, 4.19; N, 15.80. All the aforementioned properties indicate that it is 6-methoxy-2-methyl-1,2,3,4-tetrahydro-β-carboline.

The more polar components were obtained by washing the alumina column with ether–methyl alcohol (90:10) and identified as 5-methoxy-N,N-dimethyltryptamine and 5-methoxy-N-methyltryptamine (R_f 0.86, 0.97; IPAW). The corresponding picrates were separated by fractional crystallization from methyl alcohol in which the picrate of the latter compound was more soluble.

Rearrangement of N,N-Dimethyltryptamine Oxide[7] with Ferrous Sulfate.—The preceding experiment was repeated with N,N-dimethyltryptamine oxide (140 mg) and ferrous sulfate (212 mg); the aldehyde compounds formed were found to be a mixture of formaldehyde and indole-3-acetaldehyde.[10] The latter was identified as the 2,4-dinitrophenylhydrazone derivative. The DNP reagent was prepared by dissolving 2,4-DNP (2 g) in aqueous hydrochloric acid (2 *N*, 500 ml). The ferrous sulfate rearranged solution was shaken vigorously with the above DNP reagent and kept for 4 hr at room temperature; the mix-

(13) M. F. Bartlett, B. Korzun, R. Sklar, A. F. Smith, and W. I. Taylor, *J. Org. Chem.*, **28**, 1445 (1963).

(14) Rearrangement of this type was first investigated by Horning *et al.*; *cf.* ref 7.

(15) The ultraviolet absorption maxima and minima are comparable with those of 10-methoxy-3,4,5,6-tetrahydroharman: λ_{max}^{EtOH} 227, 282, 290 mμ; λ_{min}^{EtOH} 247, 288 mμ. *Cf.* also M. M. Janot and R. Goutarel, *Compt. Rend.*, **234**, 850 (1952).

ture of products (formaldehyde 2,4-dinitrophenylhydrazone and indole-3-acetaldehyde 2,4-dinitrophenylhydrazone) was filtered, washed with water, and dried. They were separated into pure components by fractional crystallization from light petroleum ether–benzene in which the latter was insoluble.

Acknowledgement.—The junior author (B. M.) is grateful to East India Pharmaceutical Works Ltd., Calcutta, for financial assistance during the tenure of this work.

Intramolecular Hydrogen Bonding in *cis*-2-Phenylmercaptoindanol

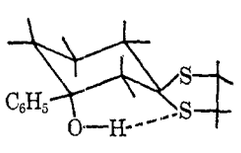
H. HARRY SZMANT AND JUAN J. RIGAU[1]

Puerto Rico Nuclear Center and the Department of Chemistry, University of Puerto Rico, Rio Piedras, Puerto Rico

Received November 19, 1965

The *cis*- and *trans*-2-phenylmercaptoindanols exhibit some interesting differences in their physical and chemical properties which can be attributed to the existence of an intramolecular hydrogen bond in the *cis* isomer.

The participation of a sulfide function in intramolecular hydrogen bonding has been demonstrated in a relatively small number of situations and apparently it is very sensitive to structural factors. Thus, while compound I is known[2] to give a strong intramolecular hydrogen bond, none is reported,[3,4] for example, in the structures IIa and IIb. On the other hand, intramolecular hydrogen bonding is known to affect conformational equilibria in 1,3-dithianes.[5] In connection with the determination of the structures of the four isomeric 2-phenylsulfinylindanols[6] we had occasion to prepare the corresponding *cis* and *trans* sulfides as well as the sulfones, and, in view of the clear-cut demonstration of an intramolecular hydrogen bond in the *cis* compounds, we have at hand an opportunity to compare the behavior of the sulfide, sulfoxide, and sulfone groups in a related family of structures.



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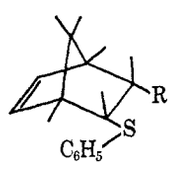

IIa, R = CO_2H
IIb, R = CH_2OH

Experimental Section

Determination of Infrared Spectra.—The infrared spectra of the *cis*- and *trans*-2-phenylmercaptoindanols,[6] mp 71.5 and 101°, respectively, were determined in a variable-path cell by means of a Perkin-Elmer Model 237 spectrophotometer. Carbon tetrachloride was employed as solvent and the concentrations were varied between 0.00625 and 0.100 *M*. The temperature range of the measurements was 25 ± 2°. The absorbances of the "free" O–H stretching frequency were measured at 3600 cm^{-1} in the case of both isomers. As will be shown below, the "free" OH band is actually believed to be a "π-bonded" OH association. The absorbances of the "sulfide-bound" OH were determined at 3470 cm^{-1} in the case of the rather simple band of the *cis* compound, and at 3510 cm^{-1} for the *trans* isomer. The results of these measurements are listed in Table I. The infrared spectra of the two isomers were also examined at a single concentration of 0.005 *M* in carbon tetrachloride using a 1-cm cell and a Perkin-Elmer Model 521 spectrophotometer,[7] and the bands, together with those of the corresponding sulfoxides and sulfones, are listed in Table II.

TABLE I

CONCENTRATION DEPENDENCE OF THE ABSORBANCE OF THE OH BANDS IN *cis*- AND *trans*-2-PHENYLMERCAPTOINDANOLS

	Cell	Absorbance of OH			
	path,	*cis* isomer		*trans* isomer	
Concn, *M*	mm	π bonded	S bonded	π bonded	S bonded
0.00384	5.00	0.013	0.067	...	...
0.00625	3.20	0.022	0.070	0.120	0.002
0.0125	1.600	...	...	0.144	0.009
0.025	0.800	...	...	0.135	0.014
0.050	0.400	0.017	0.070	0.120	0.015
0.100	0.200	0.016	0.076	0.110	0.041
0.800	0.025	...	0.067	...	...

TABLE II

HIGH-RESOLUTION H–O STRETCHING FREQUENCIES (cm^{-1}) OF *cis*- AND *trans*-2-PHENYLMERCAPTOINDANOLS AND RELATED COMPOUNDS

	Band Assignment of OH	
Compd	π bonded	S bonded
cis sulfide	3596	3500
trans sulfide	3607	...
cis–anti sulfoxide[6]	3564	3334
cis sulfone	3559	3494
trans sulfone	3587	...

Determination of Ultraviolet Spectra.—The ultraviolet spectra were determined by means of a Zeiss PMQ II spectrophotometer using 1-cm cells, and spectroquality cyclohexane and purified 95% ethanol as solvents. The spectra exhibited one strong band at 253–258 mμ, and peaks of a weaker and partially hidden band at 272 mμ. These results are summarized in Table III.

Spontaneous Decomposition of *cis*-2-Phenylmercaptoindanol.—On several occasions it was noted that a sample of *cis*-2-phenylmercaptoindanol, purified satisfactorily by crystallization from ethanol or hexane, decomposed upon standing with the production of a strong thiophenol-like odor. In order to ascertain the nature of this decomposition a 0.292-g sample of pure compound was kept for 2 months in a closed container. At the end of this period the crystals became oily and there was noted a strong thiophenol-like odor. The mixture was carefully chromatographed on a silica gel column using chloroform as eluent. The eluted material consisted of at least two components, approximately 180 mg of unchanged starting material, and approximately 90 mg of a material, the infrared spectrum of which showed an absence of the hydroxyl function and strong absorption at 1700 cm^{-1} characteristic of a ketone. The material also showed other bands at 1605 and 1585 cm^{-1} characteristic of the 1-indanone spectrum. The material gave a 2,4-dinitrophenylhydrazone of mp 255–258° which did not depress the melting point of an

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(7) We thank the Department of Chemistry of the University of Pennsylvania for this courtesy, and Mr. E. J. Leopold for technical assistance.