conditions used, gave 2,2-dimethyl-4-pentenal when treated with methyl tosylate followed by hydrolysis.

When *N,N*-dimethylisobutenylamine was treated with benzyl bromide in acetonitrile,[1] an exothermic reaction occurred. Hydrolysis of the reaction mixture as soon as the exothermic reaction was over and after six and one-half and twenty-four hours of refluxing gave, respectively, 0, 26, and 37% yields of α,α-dimethylhydrocinnamaldehyde. These results also suggested the probability of initial nitrogen-alkylation followed by N-to-C migration of the benzyl group. This was shown to be feasible by treatment of *N*-isobutenyl-*N*-methylbenzylamine in acetonitrile with methyl iodide. Hydrolysis of the reaction mixture after thirteen hours of refluxing gave α,α-dimethylhydrocinnamaldehyde in 47% yield.[3]

EXPERIMENTAL[4]

The enamines used were prepared as follows:

N,N-Dimethylisobutenylamine. A chilled mixture of isobutyraldehyde (288 g., 4 moles), potassium carbonate (150 g.), and xylene (500 ml.) was charged to an autoclave. Dimethylamine (200 g., 4.4 moles) was added and the autoclave was then sealed and rocked for 4 hr. at 100°. The bomb was cooled, the product discharged, and the liquid decanted. Distillation through an efficient column gave 122 g. of forerun, b.p. 53–87°, and 216 g. (55%) of *N,N*-dimethylisobutenylamine, b.p. 87–88°, n_D^{20} 1.4221. Gas chromatographic analysis indicated the product to be about 97.5% pure.

Anal. Calcd. for $C_6H_{13}N$: C, 72.7; H, 13.2. Found: C, 73.0; H, 13.7.

Similar runs in which less potassium carbonate or less xylene was used gave poor results, as did allowing the crude reaction mixture to stand several hours before decantation and distillation. *N*-Allyl-*N*-methylisobutenylamine, b.p. 130–131° at atm. press., n_D^{20} 1.4434, was prepared according to the method of Benzing.[5]

Anal. Calcd. for $C_8H_{15}N$: C, 76.7; H, 12.1. Found: C, 77.0; H, 11.9.

N-Isobutenyl-*N*-methylbenzylamine, b.p. 50–54° at *ca.* 1 mm, n_D^{20} 1.5123, was prepared according to Benzing.[5]

Anal. Calcd. for $C_{12}H_{17}N$; C, 82.2; H, 9.8. Found: C, 82.3; H, 10.0.

Technical grade crotyl bromide (Aldrich Chemical Co.) was used without purification. Gas chromatographic analysis indicated that two major components were present in a ratio of 85:15. Winstein and Young[6] found the equilibrium mixture to contain 87% 1-bromo-2-butene and 13% 1-bromo-2-methylpropene.

Reaction of N,N-dimethylisobutenylamine with crotyl bromide. Crotyl bromide (100 g., 0.74 mole) was added all at once to *N,N*-dimethylisobutenylamine (75 g., 0.76 mole) in 250 ml. of acetonitrile. The temperature rose to 79° over a 5-min. period and the mixture refluxed gently for about 10 min.

The reaction mixture was allowed to cool slowly to room temperature and then stirred for a total of 5 hr. Water (250 ml.) was added and the mixture was allowed to stand overnight. The oil layer was dissolved in ether, washed with water, and distilled to give, after removal of ether and a small amount of acetonitrile, 46 g. (49%) of 2,2,3-trimethyl-4-pentenal, b.p. 145–146°, n_D^{20} 1.4307. A similar experiment in which the reaction mixture was refluxed for 6.5 hr. after the initial exothermic reaction gave 2,2,3-trimethyl-4-pentenal in 67% yield.

Anal. Calcd. for $C_8H_{14}O$: C, 76.1; H, 11.2. Found: C, 75.8; H, 11.1.

The product had an infrared spectrum identical with that of a sample (b.p. 145.5–146°, n_D^{20} 1.4313) prepared from crotyl alcohol and isobutyraldehyde.[7]

The 2,4-dinitrophenylhydrazone from the crotyl bromide-enamine product melted at 129–130°.

Anal. Calcd. for $C_{14}H_{18}N_4O_4$: C, 54.9; H, 5.9. Found: C, 55.0; H, 5.9.

The corresponding derivative from the crotyl alcohol–isobutyraldehyde product melted at 130–131°. The mixture of the two derivatives melted at 129–131°, which indicates the possible presence of a small amount of 2,2-dimethyl-4-hexenal in the crotyl bromide–enamine product. The assigned structures were fully confirmed by NMR and infrared spectra, although the NMR spectrum of the crotyl bromide–enamine product indicated <5% of an impurity.

Reaction of N-allyl-N-methylisobutenylamine with methyl tosylate. Methyl tosylate (112 g., 0.6 mole) was added to a solution of *N*-allyl-*N*-methylisobutenylamine (85 g., 0.58 mole) in 250 ml. of acetonitrile. There was no evidence of reaction. The mixture was refluxed for 3 hr., then hydrolyzed with 500 ml. of water. Treatment as described in the preceding example gave 30 g. (46%) of 2,2-dimethyl-4-pentenal, b.p. 124–125°, n_D^{20} 1.4195 (reported[7] b.p. 124–125°, n_D^{20} 1.4200).

Reaction of N-isobutenyl-N-methylbenzylamine with methyl iodide. Methyl iodide (14.1 g., 0.1 mole) was added to *N*-isobutenyl-*N*-methylbenzylamine (17.5 g., 0.1 mole) in 30 ml. of acetonitrile. There was a very slight evolution of heat. After 1.5 hr. the mixture was refluxed for 13 hr. Hydrolysis and subsequent treatment as in the preceding examples gave 7.6 g. (47%) of α,α-dimethylhydrocinnamaldehyde, b.p. 57–58° at 1 mm. (reported b.p. 98–101° at 10 mm.[1]), n_D^{20} 1.5097. The infrared spectrum of the product was identical with that obtained from *N,N*-dimethylisobutenylamine and benzyl bromide, as described by Opitz.[1] Its structure was fully confirmed by its NMR spectrum.

Acknowledgment. We are grateful to Dr. Günter Opitz for providing us with unpublished information and experimental data and for his helpful discussions and suggestions.

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(3) We do not wish to imply that the mechanisms proposed in this paper are general, as Dr. Opitz has informed us of several cases in which no rearrangement occurred in the reaction of crotyl bromide with other enamines.

(4) Boiling points and melting points are uncorrected. The latter were determined using a Fisher-Johns melting-point apparatus.

(5) E. Benzing, *Angew. Chem.*, **71**, 521 (1959).

(6) S. Winstein and W. G. Young, *J. Am. Chem. Soc.*, **58**, 104 (1936).

(7) K. C. Brannock, *J. Am. Chem. Soc.*, **81**, 3379 (1959).

Synthesis of 17-Desoxyrauwolscine (17-Desoxy-α-yohimbine)

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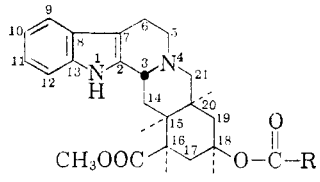
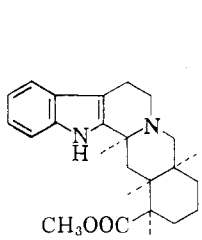
In the course of the total synthesis of 17-desmethoxydeserpidine (I) carried out in these laboratories[1] it became necessary to correlate one of the

(1) F. L. Weisenborn, *J. Am. Chem. Soc.*, **79**, 4818 (1957).

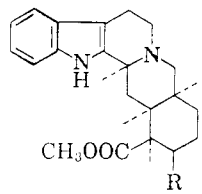
intermediates of the synthesis with authentic 17-desoxyrauwolscine (17-desoxy-α-yohimbine) (II). In this paper we wish to report the synthesis of the latter from the naturally occurring alkaloids rauwolscine (α-yohimbine) (III) and alloyohimbine (IV).[2]

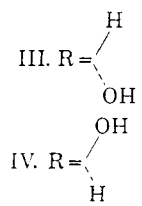


I. R = $-C_6H_2(OCH_3)_3$

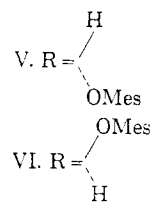


II





III. R = H, OH

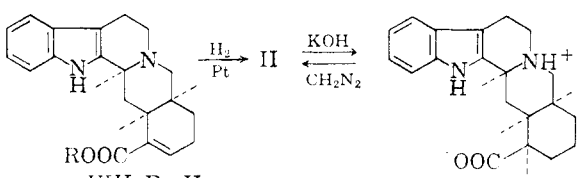


V. R = H, OMes

IV. R = OH, H

VI. R = OMes, H

Reaction of rauwolscine and alloyohimbine with methanesulfonyl chloride in pyridine at room temperature gave rauwolscine *O*-mesylate (V) and alloyohimbine *O*-mesylate (VI) respectively. Reaction of these compounds with alkali converted them to aporauwolscic acid (VIII). Esterification by diazomethane gave aporauwolscine[3] (IX) which on catalytic hydrogenation at room temperature gave the desired 17-desoxyrauwolscine.



VIII. R = H
IX. R = CH_3

X

As the hydrogenation created a new asymmetric center at position 16, it was necessary to determine the configuration of the carbomethoxyl group. From steric considerations it was likely that the *alpha* side of IX would be more available for absorption on the catalyst in the hydrogenation step and II should therefore have the carbomethoxyl group in the *beta* and equatorial conformation. This was ascertained by alkaline hydrolysis of II to the corresponding amino acid (X), under conditions which would cause epimerization of an axial carboxyl group in the yohimbe' alkaloids,[4] and re-esterification by diazomethane back to II.

EXPERIMENTAL

Rauwolscine O-mesylate (V). A solution of 1.99 g. (5.61 mmoles) of rauwolscine in 60 ml. of dry pyridine was cooled in an ice bath and to this was added slowly a solution of 1.67 g. (14.59 moles) of methanesulfonyl chloride in 24 ml. of dry pyridine. The reaction was protected from moisture, the ice bath removed and the mixture left at room temperature overnight. The solution was then concentrated to dryness *in vacuo* and the residue distributed between chloroform and 10% ammonium hydroxide. The chloroform extract was washed twice with water, dried over sodium sulfate and concentrated to dryness, *in vacuo*, yielding 2.81 g. of a dark amorphous powder. Crystallization of this powder from methanol gave 1.85 g. of rauwolscine *O*-mesylate, m.p. 189–190°, $[\alpha]_D^{29}$ + 14.6° (chloroform); λ_{max}^{Nujol} 2.97 μ, 5.77 μ, 7.48–7.60 μ, 8.60–8.70 μ.

Anal. Calcd. for $C_{22}H_{28}O_5N_2S$ (432.53): C, 61.09; H, 6.52; N, 6.48. Found: C, 61.22; H, 6.33; N, 6.22. Neut. Eq. ($HClO_4$), 433.

Alloyohimbine O-mesylate (VI). A solution of 171 mg. (0.48 mmole) of alloyohimbine in 7 ml. of dry pyridine was treated with 0.19 g. (1.7 mmoles) of methane sulfonyl chloride and the solution left overnight at room temperature. The pyridine was then removed *in vacuo*, and 15 ml. of chloroform were added. The chloroform solution was then washed successively with 10% ammonium hydroxide and twice with water. It was dried over sodium sulfate and evaporated to dryness. Crystallization from methanol gave alloyohimbine *O*-mesylate (68 mg.) $[\alpha]_D^{25}$ −16° (pyridine). λ_{max}^{Nujol} 2.97 μ, 5.78 μ, 7.46 μ, 8.56 μ.

Anal. Calcd. for $C_{22}H_{28}O_5N_2S$ (432.53) C, 61.09; H, 6.52; N, 6.48. Found: C, 61.36; H, 6.83; N, 6.28.

Aporauwolscic acid (VIII). A suspension of 359 mg. of rauwolscine *O*-mesylate in 10 ml. of 2*N* potassium hydroxide in 50% aqueous methanol was refluxed on a steam bath for 3 hr. during which time the compound slowly dissolved. The reflux condenser was then removed and the heating continued for an additional half hour to remove most of the methanol. After cooling, the *p*H was adjusted to 6.0 with acetic acid whereupon the aporauwolscic acid precipitated. It was filtered, washed with a little water and dried to give 210 mg., m.p. 302–304° λ_{max}^{Nujol} 3.10–3.17 μ, 6.06 μ, 6.42 μ.

Anal. Calcd. for $C_{20}H_{22}O_2N_2 \cdot {}^1/_2H_2O$: C, 72.47; H, 6.99; N, 8.45. Found: C, 72.50; H, 6.91; N, 8.20.

Similar treatment of alloyohimbine-*O*-mesylate gave material which was identical with the aporauwolscic acid.

Aporauwolscine (IX). Aporauwolscic acid (89.1 mg.) was suspended in 10 ml. methanol and an ethereal solution of diazomethane was added dropwise until the amino acid dissolved and a yellow color persisted. After standing at room temperature for 30 min. the solution was evaporated to dryness and the residue crystallized from methanol-water to give 70 mg. aporauwolscine, m.p. 171–172°,[5] $[\alpha]_D$ −127° (pyridine). λ_{max}^{Nujol} 2.96 μ, 5.85 μ, 6.11 μ.

Anal. Calcd. for $C_{21}H_{24}O_2N_2$(336.42): C, 74.97; H, 7.19; N, 8.33. Found: C, 75.00; H, 7.01; N, 8.22.

17-Desoxyrauwolscine (II). A solution of 84 mg. of aporauwolscine in 20 ml. of absolute ethanol was hydrogenated at room temperature and atmospheric pressure using 53 mg. of platinum oxide catlayst. After 18 hr. the catalyst was

(2) The alloyohimbine was kindly supplied by Dr. B. Witkop, National Institutes of Health, NIAMD, Bethesda, Md.

(3) P. E. Aldrich *et al.*, *J. Am. Chem. Soc.*, **81**, 2481 (1959).

(4) M. M. Janot and R. Goutarel, *Bull. soc. chim., France*, **16**, 509 (1949).

(5) If aporauwolscine was recrystallized from methanol, *cf.* ref. 3, a polymorphic modification melting at 204–207° was obtained. This form had the same specific rotation and infrared spectrum as the lower melting compound.

filtered off, the solution evaporated to dryness *in vacuo* and the residue crystallized from methanol-water to give 60 mg. of 17-desoxyrauwolscine, m.p. 210–212° $[\alpha]_D^{25}$ −12.2° (pyridine). λ_{max}^{Nujol} 2.93 μ, 5.82 μ.

Anal. Calcd. for $C_{21}H_{26}O_2N_2$ (338.43): C, 74.52; H, 7.74. Found: C, 74.49; H, 7.74; N.E. ($HClO_4$) 337.

Hydrolysis of 17-desoxyrauwolscine to X and regeneration by esterification. A suspension of 89 mg. 17-desoxyrauwolscine in 15 ml. of 2*N* potassium hydroxide in 50% aqueous methanol was refluxed for 3 hr. during which time the alkaloid dissolved completely. After cooling, the solution was acidified with hydrochloric acid whereupon precipitation occurred. The precipitate was filtered and recrystallized from dilute hydrochloric acid to give 50 mg. of 17-desoxyrauwolscic acid hydrochloride (X), m.p. 300–302°, $[\alpha]_D^{24}$ +39.3° (pyridine). λ_{max}^{Nujol} 3.20 μ, 5.82 μ.

Anal. Calcd. for $C_{20}H_{24}O_2N_2$.HCl (360.88): C, 66.56; H, 6.98. Found: C, 66.51; H, 6.97.

Re-esterification of X with diazomethane converted it to 17-desoxyrauwolscine, identical in all respects with the starting material.

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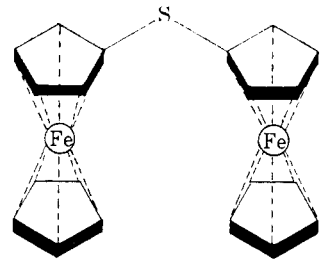
Convenient Synthesis of Ferrocenyl Aryl Sulfides[1]

M. D. RAUSCH

Received February 2, 1961

The discovery by three independent groups of investigators that ferrocene can readily be sulfonated has been followed by the preparation of a number of sulfur-containing ferrocene derivatives.[2–7] Knox and Pauson reported that ferrocenethiol can be formed by reduction of ferrocenesulfonyl chloride and have converted the sodium salt of ferrocenethiol to methyl and allyl ferrocenyl sulfides by reaction with dimethyl sulfate and allyl bromide, respectively.[7] Ferrocenyl methyl sulfide has also been subjected to the aminomethylation reaction.[8] Ferrocenyl aryl sulfides, however, have not previously been described in the literature.

In conjunction with our studies involving the haloferrocenes,[9,10] we wish to report a procedure by which ferrocenyl aryl sulfides can be readily prepared. Mauthner observed many years ago that aryl iodides reacted with various sodium arenethiolates in the presence of catalytic amounts of copper to yield diaryl sulfides.[11] We have found that iodoferrocene and sodium benzenethiolate react similarly to produce ferrocenyl phenyl sulfide in 76% yield. Phenyl-substituted sulfides such as ferrocenyl *p*-tolyl sulfide can likewise be readily prepared starting with the appropriate thiol. Of particular utility is the facile reaction of iodoferrocene and sodium ferrocenethiolate to produce diferrocenyl sulfide (I). Mauthner's procedure can therefore be used as a convenient and general synthesis of ferrocenyl aryl sulfides.



I

Several attempts to obtain diferrocenyl sulfide from diferrocenylmercury and sulfur were not successful. The only isolable products were ferrocene and a small amount of diferrocenyl disulfide.

EXPERIMENTAL[12]

Materials. Iodoferrocene was prepared in 60–70% yield by reaction of chloromercuriferrocene and iodine in xylene solution at 75–80°.[13] Copper bronze was obtained from B. F. Drakenfield and Co., Inc., New York, and was activated according to the procedure of Vogel.[14] Benzenethiol was obtained from Distillation Products Industries and *p*-toluenethiol from The Matheson Co., Inc. Ferrocenethiol was prepared according to the procedure of Knox and Pauson.[7] Diferrocenylmercury was obtained from chloromercuriferrocene according to published procedures.[15,16] Chromatographic alumina was obtained from Merck & Co., Inc. G.E. lamp-grade nitrogen was used throughout this investigation.

Diferrocenyl sulfide (I). To 5 ml. of absolute ethanol in a Schlenk tube under nitrogen was added 0.19 g. (0.0084 g.-atom) of sodium. Ferrocenethiol, prepared by the reduction of 2.40 g. (0.0084 mole) of ferrocenesulfonyl chloride by lithium aluminum hydride (1.28 g.) in 50 ml. of anhydrous

(1) Part V of a series: "Ferrocene and Related Organometallic π-Complexes." Part IV, see Ref. 10.

(2) V. Weinmayr, *J. Am. Chem. Soc.*, **77**, 3009 (1955).

(3) A. N. Nesmeyanov, E. G. Perevalova, and S. S. Churanov, *Doklady Akad. Nauk S.S.S.R.*, **114**, 335 (1957).

(4) A. N. Nesmeyanov, E. G. Perevalova, S. S. Churanov, and O. A. Nesmeyanova, *Doklady Akad. Nauk S.S.S.R.*, **119**, 949 (1958).

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(6) E. G. Perevalova, O. A. Nesmeyanova, and I. G. Lukyanova, *Doklady Akad. Nauk S.S.S.R.*, **132**, 853 (1960).

(7) G. R. Knox and P. L. Pauson, *J. Chem. Soc.*, 692 (1958).

(8) G. R. Knox, P. L. Pauson, and G. V. D. Tiers, *Chem. & Ind. (London)*, 1046 (1959).

(9) M. D. Rausch, *J. Am. Chem. Soc.*, **82**, 2080 (1960).

(10) M. D. Rausch, *J. Org. Chem.*, **26**, 1802 (1961).

(11) F. Mauthner, *Ber.*, **39**, 1347, 3593 (1906).

(12) All melting points are uncorrected. Elemental analyses and molecular weight determinations (cryoscopic in camphor) were performed by Mr. J. Edwards of this laboratory and by Schwarzkopf Microanalytical Laboratory, Woodside 77, N. Y.

(13) A. N. Nesmeyanov, E. G. Perevalova, and O. A. Nesmeyanova, *Doklady Akad. Nauk S.S.S.R.*, **100**, 1099 (1955).

(14) A. I. Vogel, *A Textbook of Practical Organic Chemistry*, Longmans, Green and Company, London, 1954, p. 88.

(15) A. N. Nesmeyanov, E. G. Perevalova, R. V. Golovnya, and O. A. Nesmeyanova, *Doklady Akad. Nauk. S.S.S.R.*, **97**, 459 (1954).

(16) M. D. Rausch, M. Vogel, and H. Rosenberg, *J. Org. Chem.*, **22**, 900 (1957).