intermediate in the reaction leading to 10-dicyanomethyleneanthrone.

The mechanism and the scope of the above reaction are currently under investigation. Although both anthrone and malononitrile contain extremely reactive methylene groups, the former compound is a tautomer of 9-anthrol. The facile interconversion of anthrone and 9-anthrol would indicate that the reaction path may proceed through either structure. While there are papers pertaining to reactions of thionyl chloride with hydroxy aromatic[5,6] and active methylene compounds,[7] their direct applicability to the present reaction is not obvious. Although further work on this system is necessary before a logical mechanism can be advanced, it appears that the reaction is not proceeding *via* anthraquinone or dichloroanthrone. Furthermore, there is no evidence to indicate that I results from the chlorination of malononitrile by thionyl chloride, followed by alkylation of anthrone.

Experimental[8,9]

10-Dicyanomethyleneanthrone.—A mixture of 4 g. of anthrone and 25 g. (15 ml.) of thionyl chloride was refluxed 3 hr. To the refluxing mixture, a solution of 6 g. of malononitrile in 60 ml. of dioxane was added. The resulting solution was heated and approximately 30 ml. of distillate was removed from the system under reduced pressure. The remaining solution was refluxed for an additional 2 hr. The remaining thionyl chloride and dioxane were then removed under reduced pressure leaving a brown solid. The solid was triturated twice with 75 ml. of acetonitrile, and once with acetone leaving a green solid. This solid was then placed in a Soxhlet extraction apparatus and extracted with toluene for 24 hr. The toluene was concentrated to approximately 150 ml. and allowed to cool. The yellow crystals were collected and dried, yielding 4.65 g. (88%) of 10-dicyanomethyleneanthrone, m.p. 289°.

Anal. Calcd. for $C_{17}H_8N_2O$: C, 79.68; H, 3.15; N, 10.93. Found: C, 80.00; H, 3.17; N, 10.81.

10-(Cyanocarbonamidomethylene)anthrone.—A solution of 6 g. of 10-dicyanomethyleneanthrone, 20 ml. of concentrated sulfuric acid and 2 ml. of water was heated to 100°. The resulting red solution was poured onto 300 g. of crushed ice. The yellow precipitate was collected, taken up in 200 ml. of hot ethanol, and filtered. The filtrate was poured into 500 ml. of cold water and the crystals collected. These yellow crystals were recrystallized from ethyl acetate yielding 2.7 g. (42%) of 10-(cyanocarbonamidomethylene)-anthrone, m.p. 246°.

Anal. Calcd. for $C_{17}H_{10}N_2O_2$: C, 74.44; H, 3.66; N, 10.21. Found: C, 74.53; H, 3.80; N, 10.25.

10-Dicyanomethylanthrone.—A mixture of 3 g. of 10-dicyanomethyleneanthrone and 200 ml. of toluene was catalytically hydrogenated with 0.3 g. of Adams catalyst on a Parr apparatus for 1 hr. The contents were then removed from the Parr shaker, heated to near boiling, and filtered free of catalyst while hot. The toluene was concentrated, cooled, and the crystals collected, yielding 2.4 g. (80%) of 10-dicyanomethylanthrone, m.p. 220–225°. Recrystallizations from toluene yielded an analytical sample of white crystals, m.p. 225°.

Anal. Calcd. for $C_{17}H_{10}N_2O$: C, 79.06; H, 3.91; N, 10.85. Found: C, 79.13; H, 3.70; N, 10.80.

10-(Cyanocarbonamidomethyl)anthrone.—A mixture of 2.7 g. of 10-(cyanocarbonamidomethylene)anthrone and 300 ml. of ethanol was catalytically hydrogenated with 0.5 g. of 5% palladium on charcoal on a Parr shaker. The mixture was removed from the Parr apparatus and heated to effect solution. The hot solution was filtered free of catalyst. The alcohol solution was concentrated and allowed to cool Upon cooling 1.6 g. (60%) of 10-(cyanocarbonamidomethyl)-anthrone, m.p. 205–210°, crystallized. An analytical sample was recrystallized from ethanol, yielding white needles, m.p. 213–115°.

Anal. Calcd. for $C_{17}H_{12}N_2O_2$: C, 73.90; H, 4.38; N, 10.14. Found: C, 73.88; H, 4.35; N, 10.10.

Acknowledgment.—The authors are indebted to Dr. L. Schieler for the helpful interest in this work and to Mr. G. B. Charlan for infrared measurements.

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[5] V. J. Dalvi and G. V. Jadhav, *J. Ind. Chem. Soc.*, **34**, 324 (1957) and references cited therein.

[6] W. E. Bissinger and F. E. Kung, *J. Am. Chem. Soc.*, **70**, 2664 (1948).

[7] K. G. Naik and S. A. Vaishnav, *J. Ind. Chem. Soc.*, **13**, 28 (1936) and references cited therein.

[8] All melting points are uncorrected.

[9] All analyses were performed by Spang Microanalytical Laboratory, Ann Arbor, Mich.

Anodic Decarboxylation of Isostevic Acid

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Received August 8, 1962

Evidence has been recently presented supporting structures I and II for steviol and isosteviol, respectively.[1] [2] Prior to these communications, work in this laboratory had been directed toward decarboxylation of the steviol–isosteviol system to ascertain whether the carboxyl group was at position 4 or 10. If the carboxyl were at C-4, decarboxylation should lead to a compound having a methyl resonance split by spin coupling to a lone proton on an adjacent carbon atom.

To achieve decarboxylation, chemical procedures were initially investigated. Hunsdiecker reaction[3] was found inapplicable because I and II failed to give silver salts. In the hope of replacing the carboxyl group by an acetoxy group which might subsequently be removed, isostevic acid (III)[4] was converted *via* the acid chloride to the methyl ketone.[5] The latter, however, failed to undergo Baeyer–Villiger oxidation in trifluoroperacetic acid.[6]

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[1] E. Mosettig, P. Quitt, U. Beglinger, J. A. Waters, H. Vorbrueggen, and C. Djerassi, *J. Am. Chem. Soc.*, **83**, 3163 (1961).

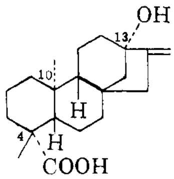
[2] C. Djerassi, P. Quitt, E. Mosettig, R. C. Cambie, P. S. Rutledge, and L. H. Briggs, *ibid.*, **83**, 3720 (1961).

[3] C. F. H. Allen and C. V. Wilson, "Organic Syntheses," Coll. Vol. III, John Wiley & Sons, Inc., New York, N. Y., 1955, p. 578.

[4] E. Mosettig and W. R. Nes, *J. Org. Chem.*, **20**, 884 (1955).

[5] W. Cole and P. L. Julian, *J. Am. Chem. Soc.*, **67**, 1369 (1945).

[6] J. W. Wilt and A. Danielzadeh, *J. Org. Chem.*, **23**, 920 (1958).



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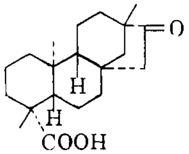
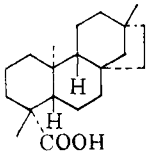
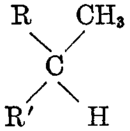


II



III

This led us to experiment with electrolytic decarboxylation.[7] In preliminary experiments, dihydrosteviol A[8] was electrolyzed in methanol containing sodium methoxide to give 4-normethoxy-13-hydroxystevane A. Dihydrosteviol A, however, contains the following group in ring D.

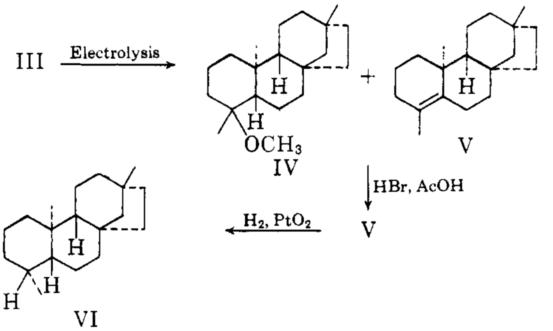


To facilitate interpretation of n.m.r. spectrum of a decarboxylated compound, isostevic acid (III), which lacks the above-mentioned grouping, was selected for subsequent work.

The anodic reaction of III in methanol gave a neutral product in 70–85% yield. A positive Zeisel test for alkoxyl and an infrared band at 1065–1100 cm.$^{-1}$, as well as a positive tetranitromethane test, suggested that the product was a mixture. This was confirmed by vapor phase chromatographic analysis (IV in 65% and V in 25% yield).[9] Column chromatography did not separate the components. However, treatment of the anodic mixture IV + V with 1% aqueous hydrobromic acid in refluxing glacial acetic acid gave a single olefin shown by vapor phase chromatography to be identical with V.

The n.m.r. spectrum[10] of V established the position of the double bond at 4 as well as the position of the original carboxyl group (C-4). It showed the absence of olefinic protons and the presence of a methyl group (94 c.p.s.) attached to a double bonded carbon. The product arising from decarboxylation of a C-10 acid would be expected to show methyl proton absorption only in the 55–65 c.p.s. region.

Hydrogenation of 4-nor-Δ^4-isostevene (V) with platinum oxide in glacial acetic acid–ethyl acetate under a pressure of 20 p.s.i. yielded the saturated hydrocarbon 4-norisostevane (VI). A frontal attack of hydrogen is proposed, thereby yielding the C-4 axial methyl compound (ring A in chair form). A rear attack is unlikely because of steric interference to the double bond on the back side by the C-10 methyl group.



The n.m.r. spectrum of VI also confirmed the position of the carboxyl group in isostevic acid (III). An asymmetric doublet at 49.5 and 54 c.p.s. was shown, the typical absorption of a methyl coupled to an adjacent proton (A_3B coupling). This can occur for the C-4 methyl if the carboxyl were originally at C-4 but not at C-10. A strong line at 56 c.p.s. was ascribed to the other two methyls at C-10 and C-13.

Experimental[11]

Description of the Electrolysis Apparatus.—The apparatus consisted of two smooth platinum electrodes (sheet), 9 mm. wide and 40 mm. long. The electrodes, placed parallel to each other 3–4 mm. apart, were immersed 20–25 mm. into the magnetically stirred solutions. Glass beakers (20 and 30 ml.) were used as electrolysis vessels.

Anodic Reaction of Dihydrosteviol A.—To a solution of 671 mg. of dihydrosteviol A in 32 ml. of absolute methanol was added 58 mg. of metallic sodium. The solution was electrolyzed at 100 mamperes and 10–13 volts for 7 hr. 20 min. Methanol was added periodically during this period to maintain the original volume. The temperature of the solution was maintained at 18–20° by use of an evaporating acetone bath. On completion of the electrolysis period, the solvent was removed under reduced pressure and the residue dissolved in chloroform and extracted several times with 5% sodium carbonate. The chloroform layer was dried and concentrated under reduced pressure to give 389 mg. of a thick oil which was chromatographed on 11.7 g. of grade III alumina. Elution with benzene–petroleum ether (b.p. 30–60°) (1:1) gave 139 mg. of product. Sublimation at 3.5–4.0 × 10^{-4} mm. gave a colorless, tacky solid. The infrared spectrum showed a broad band at 1065–1100 cm.$^{-1}$ (methoxyl). Analysis of the product indicated 4-normethoxy-13-hydroxystevane A; $[\alpha]^{20}\text{D}$ $-29.3 \pm 2.5°$ (*c*, 0.785, $CHCl_3$).

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[7] For discussions of organic electrolytic processes, see B. C. L. Weedon, "Advances in Organic Chemistry, Methods and Results," Vol. I, Interscience Publishers, Inc., New York, N. Y., 1960; C. Walling, "Free Radicals in Solution," John Wiley & Sons, Inc., New York, N. Y., 1957.

[8] F. Dolder, H. Lichti, E. Mosettig, and P. Quitt, *J. Am. Chem. Soc.*, **82**, 246 (1960).

[9] The reaction appears to involve decarboxylation of the acid to a free radical which subsequently undergoes anodic oxidation to give a carbonium ion from which either IV (attack by solvent) or V (β-elimination) may result. See W. B. Smith and H.-G. Gilde, *ibid.*, **83**, 1355 (1961) and ref. 10 cited therein.

[10] N.m.r. spectra were obtained with a Varian HR-60 spectrometer. Deuteriochloroform was used as solvent and data are reported in c.p.s. referred to tetramethylsilane as an internal reference.

[11] Analyses and rotations were performed by the Analytical Services Unit, NIAMD, under the direction of Mr. H. G. McCann. Infrared spectra were obtained on a Perkin–Elmer Model 21 spectrophotometer. Vapor phase chromatograms were obtained on a Barber-Coleman Model 15 gas chromatograph, using a 9-ft. column (4-mm. i.d.) of 3/4% SE-30 on Gaschrom P (110–120 mesh) at 210° and 14 p.s.i.

Anal. Calcd. for $C_{20}H_{34}O_2$: C, 78.38; H, 11.18; OCH_3, 10.12. Found: C, 78.60; H, 11.16; OCH_3, 10.19.

Anodic Reaction of Isostevic Acid (III).—To a solution of 284 mg. of isostevic acid in 17 ml. of methanol was added 75 mg. of metallic sodium. The solution was electrolyzed at 100 mamperes and 10 volts for 4.5 hr. During the electrolysis methanol was added periodically to maintain the original volume. The solution temperature was maintained at 25° by use of an evaporating acetone bath. On completion of electrolysis, the solvent was removed under reduced pressure. To the residue was added 35 ml. of ether and the resulting mixture was washed four times with 5-ml. portions of sodium hydroxide (5%) and then with water. The ether solution was dried over sodium sulfate and evaporated to give 254 mg. of a neutral product which was chromatographed on 7.5 g. of grade III alumina. Elution with petroleum ether (b.p. 30–60°) gave 151 mg. of an oil which was distilled at 0.6–0.8 × 10^{-4} mm. The colorless oil gave positive Zeisel and tetranitromethane tests and showed an infrared band at 1065–1100 cm.$^{-1}$ (methoxyl). Vapor phase chromatographic analysis indicated two major components, 65% 4-normethoxyisostevane (IV) and 25% 4-nor-Δ^4-isostevene (V). Two minor components (10%) were removed by the subsequent step. Repeated column chromatography failed to separate the two major components.

4-Nor-Δ^4-isostevene.—To a solution of 214 mg. of a mixture of 4-normethoxyisostevene and 4-nor-Δ^4-isostevane (obtained from the electrolysis experiment) in 20 ml. of glacial acetic acid was added 12 ml. of 1% aqueous hydrobromic acid solution. The mixture was refluxed in an oil bath (120–130°) for 1 hr. and then allowed to stand overnight at room temperature. After addition of 50 ml. of water, the mixture was extracted four times with 20-ml. portions of ether. The combined ether extracts were washed several times with 5-ml. portions of sodium hydroxide (5%), followed by water, and dried over sodium sulfate. Evaporation of the solvent under reduced pressure gave 172 mg. of pale yellow oil which was chromatographed on grade III alumina (5 g.). Elution with petroleum ether (b.p. 30–60°) gave 132 mg. of colorless oil (positive tetranitromethane test). Distillation at 5.3–5.8 × 10^{-4} mm. gave a clear, colorless oil; $[\alpha]^{20}D$ −118° ± 1.0 (*c*, 1.15, $CHCl_3$). Vapor phase chromatographic analysis indicated one major component (98%).

Anal. Calcd. for $C_{19}H_{30}$: C, 88.30; H, 11.70. Found: C, 88.14; H, 11.64.

4-Norisostevane (VI).—To a solution of 158 mg. of 4-nor-Δ^4-isostevene in 6 ml. of glacial acetic acid and 8 ml. of ethyl acetate was added 73 mg. of platinum oxide. The mixture was hydrogenated for 5.5 hr. at room temperature and under pressure of 20 p.s.i., using the Parr apparatus. Removal of the catalyst by filtration and evaporation of the solvent under reduced pressure gave 156 mg. of pale yellow oil (negative tetranitromethane test). The product was chromatographed on grade III alumina (4.5 g.). Elution with petroleum ether (b.p. 30–60°) gave 133 mg. (83.5%) of colorless oil. The product was distilled at 0.2–0.3 × 10^{-4} mm. Vapor phase chromatographic analysis indicated one major component (95%), two trace components (5%). $[\alpha]^{20}D$ −17.5 ± 1.0° (*c*, 0.916, $CHCl_3$).

Anal. Calcd. for $C_{19}H_{32}$: C, 87.62; H, 12.38. Found: C, 87.70; H, 12.42.

Acknowledgment.—The authors are grateful to U. Beglinger for assistance in the preparation of starting materials, to H. M. Fales for valuable discussion concerning the anodic reaction, to H. K. Miller for assembling the electrolysis apparatus, and to H. Ziffer and R. B. Bradley for collaboration in the n.m.r. study.

The Synthesis of Some Heterocyclic Compounds Derived from Guanidines

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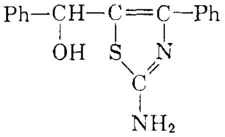
Received July 12, 1962

Earlier workers[2] have shown that thiourea reacts with 1-benzoyl-2-phenylethylene oxide to give 2-amino-4α hydroxybenzyl-5-phenylthiazole (I). Because of the structural similarity between thiourea and guanidine, it was of interest to examine the reaction of the latter and some of its homologs with 1-benzoyl-2-phenylethylene oxide. A series of compounds thus was prepared to which the general structure II was assigned.



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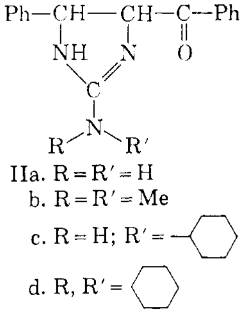

IIa. R = R′ = H
b. R = R′ = Me
c. R = H; R′ =
d. R, R′ =

None of these compounds have been reported previously in the literature. They are crystalline solids of high melting point and are best purified by recrystallization from aqueous acetic acid. Dissolution in mineral acid followed by dilution with water causes separation of the free base. All compounds in this series are formed in high yield (lowest 81%) in ethanolic solution, separation of the solid product occurring within a few minutes. The parent 2-amino-4-benzoyl-5-phenylimidazoline-2 (IIa) furnishes diacetyl, monoacetyl, and monopropionyl derivatives, although the more heavily substituted analogs are less reactive, but readily yield crystalline picrates. Failure of IIb, c, and d to furnish acetyl derivatives may be due to hydrolysis during the work-up procedure, particularly if acetylation of ring nitrogen atoms is involved.

Possible alternative structures for these compounds may be ruled out from the chemical and physical evidence. Each compound displays a stretching frequency in the carbonyl region which probably excludes structures such as 2-amino (or alkylamino)4α-hydroxybenzyl-5-phenylimidazole. However, the carbonyl function does not form the

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[1] Present address: Andrews Laboratories, Rosebery, N.S.W., Australia.

[2] C. C. J. Culvenor, W. Davies, J. A. Maclaren, P. F. Nelson, and W. E. Savige, *J. Chem. Soc.*, 2573 (1949).