10 times with chloroform. The latter was washed with a small volume of saturated sodium chloride solution, then cleared with sodium sulfate and concentrated finally *in vacuo*. The resin (1.57 g.) was dissolved in a small volume of methanol and induced to crystallize as small short prisms by careful dilution; 0.33 g. was collected with water, in which it was appreciably soluble. It consisted of germine contaminated with the isomer.

The mother liquor was concentrated *in vacuo* to remove methanol and the aqueous mixture when heated deposited a resin which redissolved on cooling. Soon micro needles or rods began to separate and gradually increased on standing. This fraction was collected with water and amounted to 0.46 g. It consisted largely of pseudogermine contaminated with germine. On careful dilution of the solution in a small volume of methanol, an initial fraction of 62 mg. of germine separated. The mother liquor was concentrated finally to dryness *in vacuo*. A solution of the residue in the minimum of methanol crystallized on addition of ether as small four-sided micro crystals; 0.3 g., m.p. 173–174°, $[\alpha]^{25}D$ +11.4° (*c* 1.05 in abs. EtOH). Contrary to germine this substance did not crystallize from chloroform.

Anal. Calcd. for $C_{27}H_{43}NO_8$: C, 63.63; H, 8.51. Found (dried at 100° *in vacuo*): C, 63.63; H, 8.48.

The above fractions of germine were dissolved in about 10 ml. of warm chloroform and after partial concentration allowed to crystallize as needles of the germine–chloroform adduct. The collected substance when recrystallized by concentration of the methanol solution was found to be unchanged germine; $[\alpha]^{28}D$ +5° (*c* 1.03 in abs. EtOH).

The residue obtained from the chloroform mother liquor yielded from methanol–ether 0.125 g. of pseudogermine; $[\alpha]^{8}D$ +12° (*c* 1.00 in abs. EtOH).

Anal. Found (dried at 100° *in vacuo*): C, 63.58; H, 8.49.

The original mother liquors gave additional fractions of germine and pseudogermine and contained appreciable amounts of unidentified material. No isogermine was isolated.

Infrared Spectra.—Samples were prepared as Nujol mulls and their spectra determined from 2 to 14.5 μ without compensation on a Perkin–Elmer model 21 double beam spectrometer with sodium chloride optics, set at resolution 5, response 3, gain 8, suppression 1 and a scanning speed of 0.12 μ per minute on a chart scale of 2 inches for 1 μ.

We wish to acknowledge the generous coöperation of Dr. T. F. Gallagher of the Sloan–Kettering Institute and of Dr. H. Jaffe of The Rockefeller Institute in obtaining the infrared data. All analytical results have been obtained by Mr. D. Rigakos of this Laboratory.

NOTE ADDED IN PROOF.—D. H. R. Barton and J. F. Eastham (*J. Chem. Soc.*, 424 (1953)) recently reported on the basis of ultraviolet absorption studies that cevine possesses an oxidic structure in place of a double bond and a hydroxyl group. Such a possibility could also be considered for veracevine, germine, pseudogermine and protoverine. However, the correctness of this conclusion is under further study in this Laboratory. They have also shown that so called β-cevine is cevine contaminated with an oxidation product which may possess a strongly absorbing diosphenol chromophore.

NEW YORK 21, N. Y.

[CONTRIBUTION FROM THE RESEARCH LABORATORIES OF MERCK & CO., INC.]

The Conversion of Hecogenin to $\Delta^{7,9(11)}$-22-isoallospirostadiene-3β-ol[1]

BY RALPH HIRSCHMANN, C. STEWART SNODDY, JR., AND N. L. WENDLER

RECEIVED JANUARY 28, 1953

Hecogenin has been transformed to $\Delta^{9(11)}$-dehydrotigogenin and thence *via* 22-isoallospirostane-3(β),9(α),11(α)-triol to $\Delta^{7,9}$-22-isoallospirostadiene-3β-ol in good over-all yield.

The conversion of hecogenin (I) to $\Delta^{9(11)}$-dehydrohecogenin (V) *via* the 11,23-dibromide II has been reported recently[2]; reduction of V to $\Delta^{9(11)}$-dehydrotigogenin (VIIa) was accomplished[3] by the Wolff–Kishner reduction, a method which has been observed to give mixtures of $\Delta^{9(11)}$- and Δ^{11}-olefins in the bile acid series.[3,4] We have found that the conversion of I to V may be alternatively effected by the action of selenium dioxide on the 23-monobromide III,[5] derived from hecogenin, followed by reductive debromination of the intermediate 23-bromo-$\Delta^{9(11)}$-dehydrohecogenin acetate (IV). The conversion of $\Delta^{9(11)}$-dehydrohecogenin (V) to $\Delta^{9(11)}$-dehydrotigogenin (VIIa) was accomplished by Raney nickel hydrogenolysis of the crystalline ethylene dithioketal derivative VI to give VII in excellent yield.[6] The value M_D (VII) − M_D (VIIa) of −45° is in good agreement with the average value of −52° for $\Delta^{9(11)}$-steroid olefins (*trans* A/B).[7] Furthermore the infrared spectrum of $\Delta^{9(11)}$-dehydrotigogenin (VIIa) exhibited a well-defined band at 1647 cm.$^{-1}$ (6.06 μ)[8] and at 821 cm.$^{-1}$, characteristic of trisubstituted olefins.[9]

Attempts to dehydrogenate the $\Delta^{9(11)}$-olefin VII with mercuric acetate[3] or by low temperature bromination–dehydrobromination[10] were unsuccessful; the product in each instance was essentially unchanged starting material. Treatment of the $\Delta^{9(11)}$-olefin VII with osmium tetroxide, however, converted it smoothly and in good yield to

(1) Presented at the Meeting-in-Miniature of the North Jersey Section of the American Chemical Society on January 26, 1953, at Newark, N. J.

(2) C. Djerassi, H. Martinez and G. Rosenkranz, *J. Org. Chem.*, **16**, 303 (1951).

(3) C. Djerassi, H. Martinez and G. Rosenkranz, *ibid.*, **16**, 1278 (1951).

(4) H. B. Alther and T. Reichstein, *Helv. Chim. Acta*, **26**, 492 (1943); E. Seebeck and T. Reichstein, *ibid.*, **26**, 536 (1943); L. F. Fieser and S. Rajagopalan, THIS JOURNAL, **73**, 118 (1951); similar observations have been made in this Laboratory by Dr. Evelyn Wilson.

(5) R. E. Marker, R. B. Wagner, P. R. Ulshafer, E. L. Wittbecker, D. P. J. Goldsmith and C. H. Ruof, *ibid.*, **69**, 2167 (1947).

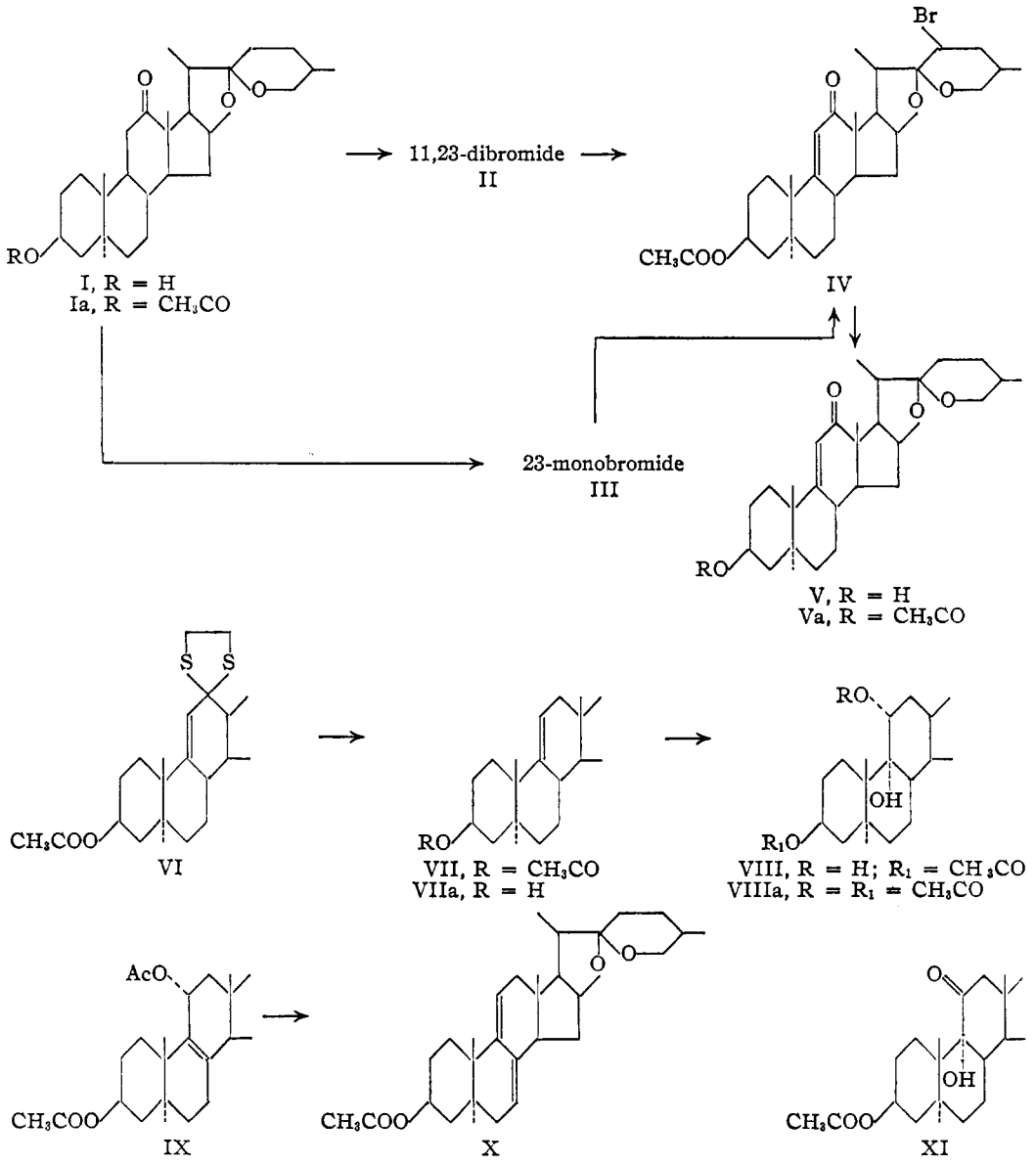
(6) It is interesting to note that M. Mujovic, W. Voser, H. Heusser and O. Jeger, (*Helv. Chim. Acta*, **35**, 964 (1952)) have recently observed retro-migration of the double bond during reduction of the monoethylenedithioketal derivative of acetoxylanostendione.

(7) D. H. R. Barton, *J. Chem. Soc.*, 813 (1945).

(8) We are indebted to Dr. K. Dobriner of the Sloan-Kettering Institute for Cancer Research, N. Y., for the determination of this spectrum.

(9) P. Bladon, J. Fabian, H. Henbest, H. Koch and G. Wood, *J. Chem. Soc.*, 2402 (1951); also H. Hirschmann, THIS JOURNAL, **74**, 5357 (1952).

(10) R. C. Anderson, R. Budziarek, G. T. Newbold, R. Stevenson and F. S. Spring, *Chemistry and Industry*, 1035 (1951).



the triol monoacetate VIII.[11] The ease of this hydroxylation with osmium tetroxide is noteworthy in view of the non-reactivity toward this reagent by $\Delta^{9(11)}$-double bonds in the cholic acid (*cis* A/B) series.[12]

The triol monoacetate VIII exhibited an amazing stability and all attempts to effect its rearrangement to 11-ketotigogenin thermally or under a variety of acidic conditions were without substantial success; in the majority of instances triol monoacetate VIII was recovered essentially unchanged from such treatments. Chromic acid oxidation of VIII, on the other hand, afforded the ketol XI in low yield, whereas N-bromacetamide produced no appreciable oxidation. The triol monoacetate VIII on standing at room temperature with pyridine and acetic anhydride was converted in high yield to the triol diacetate VIIIa. The latter, quite surprisingly, was found to be very stable to refluxing phosphorus oxychloride in pyridine or collidine and could be recovered after such treatment largely unchanged. In contrast to its stability to phosphorus oxychloride, however, the triol diacetate VIIIa was smoothly converted to $\Delta^{7,9(11)}$-22-isoallospirostadiene-3β-ol acetate (X) by treatment with thionyl chloride in pyridine at room temperature. When allowed to react with thionyl chloride in pyridine at 0–5°, on the other hand, VIIIa yielded the unstable intermediate IX, exhibiting a strong tetranitromethane test for unsaturation but negligible absorption in the ultraviolet. Passage of a petroleum ether–benzene solution of IX through a column of acid-washed alumina resulted in its smooth conversion to the diene X.

The importance of $\Delta^{7,9(11)}$-22-isoallospirostadiene-3β-ol acetate (X) in connection with its conversion to adrenal cortical substances has already

(11) The 9(α),11(α)-orientation of hydroxyl groups in VIII follows, *inter alia*, from the known *cis*-hydroxylation of olefins by osmium tetroxide and the ability of VIII to form a diacetate VIIIa.

(12) L. F. Fieser and S. Rajagopalan, THIS JOURNAL, **73**, 118 (1951); see also L. F. Fieser and M. Fieser, "Natural Products Related to Phenanthrene," 3rd Edition, Reinhold Publ. Corp., New York, N. Y., 1949, p. 227.

been demonstrated.[13] In view thereof, the work reported herein constitutes a route from hecogenin to these hormone substances.[14]

Experimental[15]

$\Delta^{9(11)}$-Dehydrohecogenin Acetate (Va). (Method A).—Prepared by a modification of the procedure reported by Djerassi, Martinez and Rosenkranz[2] employing chloroform instead of acetic acid as solvent. An **11,23-dibromide II** was obtained as needles from ether–petroleum ether, m.p. 185–186° (dec.) (reported as a mixture m.p. *ca.* 140–150° (dec.)[2]; also 173° (dec.).[16]

Anal. Calcd. for $C_{29}H_{42}O_5Br_2$: C, 55.24; H, 6.72. Found: C, 55.35; H, 6.62.

II was converted in refluxing collidine to **$\Delta^{9(11)}$-dehydro-23-bromohecogenin acetate (IV)**, obtained as crystals from ether–petroleum ether, m.p. 218–219° (dec.); $\lambda_{max}^{CH_3OH}$ 238 mμ, log ε 4.1 (reported m.p. 209–213° (dec.); λ_{max} 238 mμ, log ε 4.12).

Anal. Calcd. for $C_{29}H_{41}O_5Br$: C, 63.38; H, 7.52; Br, 14.54. Found: C, 63.81; H, 7.48; Br, 14.90.

IV was obtained in 65% over-all yield from hecogenin acetate in a sufficient state of purity for the succeeding step.

Debromination of IV with zinc dust in refluxing acetic acid for 40 minutes gave $\Delta^{9(11)}$-dehydrohecogenin acetate Va as crystals from acetone, m.p. 219.5–221.5°, $\lambda_{max}^{CH_3OH}$ 238 mμ, log ε 4.1 (reported[2] 218–220°, λ_{max} 238 mμ, log ε 4.17).

Anal. Calcd. for $C_{29}H_{42}O_5$: C, 74.00; H, 9.00. Found: C, 73.94; H, 8.93.

Yields of Va from IV averaged between 85–95% depending on the quality of IV.

(Method B).—Hecogenin acetate (Ia) was converted to the **23-bromo derivative III** with one mole of bromine in chloroform solution and crystallized from ether, m.p. 231–232° (dec.) (reported[5] m.p. 234° dec.).

Anal. Calcd. for $C_{29}H_{43}O_5Br$: C, 63.15; H, 7.86; Br, 14.49. Found: C, 63.17; H, 8.02; Br, 14.30.

III was dehydrogenated with selenium dioxide in chlorobenzene[17] to afford $\Delta^{9(11)}$-dehydro-23-bromohecogenin acetate (IV), crystallized from ether–petroleum ether, m.p. 212–218° (dec.), $\lambda_{max}^{CH_3OH}$ 238 mμ, log ε 4.1, m.m.p. with IV obtained by method A was not depressed.

Ethylene Dithioketal Derivative of $\Delta^{9(11)}$-Dehydrohecogenin Acetate (VI).—A solution of 3.51 g. of $\Delta^{9(11)}$-dehydrohecogenin acetate (Va) (m.p. 214–218°, log ε 4.30 at 238 mμ) in 11 cc. of ethandithiol-1,2 was cooled to −5° and anhydrous hydrogen chloride gas bubbled into the mixture at this temperature for one hour. Stirring with cooling was continued for one hour after discontinuing the introduction of hydrogen chloride. Solid potassium carbonate was added to the reaction mixture until evolution of carbon dioxide had ceased. The reaction product was distributed between ether and water, and the ether extract washed with 5% aqueous sodium hydroxide until the aqueous washings were colorless. The ether solution was finally washed with water, saturated salt solution and dried over anhydrous sodium sulfate. Evaporation of the solvent gave 4.96 g. of oily product. The latter was chromatographed on 69 g. of acid-washed alumina using 1:1 benzene–petroleum ether for elution. Trituration of the eluates with methanol yielded a total of 3.37 g. (83%) of VI wherein the m.p. of the various fractions varied from *ca.* 140–150°. Material of this purity was satisfactory for the next step. Additional fractions afforded 0.24 g. of material, m.p. 137–141°. A sample was recrystallized several times from methanol for analysis, m.p. 180–182°, $[\alpha]^{23}D$ −5.8° (chloroform), $\lambda_{max}^{CH_3OH}$ 218 mμ, log ε 3.93.

Anal. Calcd. for $C_{31}H_{46}O_4S_2$: S, 11.71. Found: S, 11.81.

$\Delta^{9(11)}$-Dehydrotigogenin (VIIa).—The above crude thioketal, 3.37 g., was dissolved in 700 cc. of ethanol and refluxed with stirring with 25 g. of Raney nickel for six hours. The filtered solution was concentrated to yield 2.2 g. (78%) of VII, m.p. 198–205°. A second crop, wt. 0.3 g., m.p. 185–193°, raised the yield to 88.5%. A solution of this material in 2:5 benzene–petroleum ether was passed through a column of alumina and the first fraction on recrystallization from methanol and acetone gave pure VII as prisms, m.p. 205–208°, $[\alpha]^{23}D$ −61.6° (chloroform) (reported[3] m.p. 197–199°, $[\alpha]^{20}D$ −53°).

Anal. Calcd. for $C_{29}H_{44}O_4$: C, 76.27; H, 9.71. Found: C, 76.51; H, 9.56.

Hydrolysis of VII with sodium hydroxide in methanolic tetrahydrofuran afforded VIIa, m.p. 180–193°. Since the m.p. of this substance did not improve materially on recrystallization it was passed through acid-washed alumina to provide material which gave VIIa as beautiful needles from methanol, m.p. 190–192.5°, $[\alpha]^{23}D$ −56.2° (chloroform) (reported[3] m.p. 190–191°, $[\alpha]^{20}D$ −57°).

Anal. Calcd. for $C_{27}H_{42}O_3$: C, 78.21; H, 10.21. Found: C, 78.43; H, 10.26.

22-Isoallospirostane-3β,9α,11α-triol 3-Monoacetate (VIII).—A solution of 0.86 g. of $\Delta^{9(11)}$-dehydrotigogenin acetate (VII) (m.p. 197–207°) and 0.54 g. of osmium tetroxide in 0.65 cc. of pyridine and 11 cc. of benzene was allowed to stand at room temperature for 92 hours. The dark solution of the osmate ester was decomposed by addition of 37 cc. of water, 11 cc. of benzene, 25 cc. of methanol and 3.84 g. each of sodium sulfite and potassium bicarbonate. The mixture was stirred at room temperature for five hours, 80 cc. of chloroform was then added and the suspension filtered. The solid residue from the filtration was thoroughly washed with *ca.* 120 cc. of hot chloroform and the combined chloroform extracts in turn were washed with saturated salt solution and dried over anhydrous sodium sulfate. The residue obtained upon removal of the chloroform was dissolved in benzene–petroleum ether and chromatographed on acid-washed alumina. Recrystallization of the ethyl acetate fraction from acetone–petroleum ether provided 0.41 g. of VIII, m.p. 224–229°. The mother liquors were rechromatographed and recrystallized to afford an additional 0.27 g. of VIII giving a total yield of 74%. An analytical sample was prepared by crystallization from methanol–water to give VIII as needles, m.p. 224–227°, $[\alpha]^{23}D$ −68.4° (chloroform).

Anal. Calcd. for $C_{29}H_{46}O_6$: C, 70.98; H, 9.45. Found: C, 70.80; H, 9.45.

22-Isoallospirostane-3β,9α,11α-triol 3,11-Diacetate (VIIIa).—A solution of 0.74 g. of VIII in 12 cc. of anhydrous pyridine was treated with 6 cc. of acetic anhydride and allowed to stand at room temperature for 12 hours. The reaction mixture was worked up in the usual fashion and the product crystallized from methanol to give 0.53 g. of VIIIa as elongated prisms, m.p. 179–180.5°. A second crop, m.p. 176–180°, amounted to 0.182 g. giving a total yield of 89–90%. An analytical sample prepared by recrystallization from methanol melted at 181°.

Anal. Calcd. for $C_{31}H_{48}O_7$: C, 69.89; H, 9.08. Found: C, 69.71; H, 8.81.

22-Isoallospirostane-3β,9α-diol-11-one 3-Monoacetate (XI).—A chilled solution of 0.548 g. of VIII in 15 cc. of acetic acid was treated with 0.085 g. of chromic anhydride and allowed to stand at room temperature for 12 hours. At the end of this time the excess chromic acid was reduced with methanol and the solvents evaporated *in vacuo*. The residue was dissolved in ether and washed successively with 2 *N* aqueous sulfuric acid and cold aqueous sodium carbonate solution. Evaporation of the solvent and crystallization of the residue from acetone–petroleum ether afforded XI as prisms, m.p. 280–285°.

Anal. Calcd. for $C_{29}H_{44}O_6$: C, 71.28; H, 9.10. Found: C, 71.08; H, 8.90.

The major share of the products of this oxidation consisted of acidic material.

(13) E. M. Chamberlin, W. V. Ruyle, A. E. Erickson, J. M. Chemerda, L. M. Aliminosa, R. L. Erickson, G. E. Sita and M. Tishler, THIS JOURNAL, **73**, 2396 (1951); G. Stork, J. Romo, G. Rosenkranz and C. Djerassi, *ibid.*, **73**, 3546 (1951), and cross ref. therein.

(14) An alternate route has been reported recently by C. Djerassi, H. J. Ringold and G. Rosenkranz, *ibid.*, **73**, 5513 (1951).

(15) All melting points were taken on a micro hot-stage unless otherwise indicated and are corrected. Microanalyses by Mr. Richard Boos and his associates.

(16) G. P. Mueller, R. E. Stobaugh and R. S. Winiford, THIS JOURNAL, **73**, 2400 (1951).

(17) E. Schwenk and E. Stahl, *Arch. Biochem.*, **14**, 124 (1947).

$\Delta^{7,9(11)}$-22-Isoallospirostadiene-3β-ol Acetate (X).—A thoroughly dried sample of VIIIa (262 mg.) was dissolved in 1.9 cc. of anhydrous pyridine, chilled to 0°, and treated with 0.2 cc. of redistilled thionyl chloride. The reaction mixture was allowed to stand at 0–5° for 16 hours. At the end of this period the reaction mixture was allowed to come to room temperature and then rechilled and decomposed with ice-water. The decomposed reaction mixture was extracted with ether and the ether solution of the product washed successively with dilute hydrochloric acid, 5% aqueous sodium bicarbonate and water. Evaporation of the dried ether solution gave 0.280 g. of amorphous solid which gave a strong test for unsaturation (yellow color) with tetranitromethane and showed only very weak absorption in the 240–250 mμ region. This material was dissolved in petroleum ether–benzene (7:1) and passed through a short column of alumina to give after recrystallization from ethyl acetate 0.076 g. of X, m.p. 205–213.5°, λ_{max} 2350 Å., log ϵ 4.14, λ_{max} 2420 Å., log ϵ 4.19, and λ_{max} 2500 Å., log ϵ 4.0 (methanol).

Anal. Calcd. for $C_{29}H_{42}O_4$: C, 76.61; H, 9.31. Found: C, 77.00; H, 9.40.

A mixed melting point of this material with an authentic sample of X[13] showed no depression and the infrared spectra of the two samples were identical.

A second crop of X amounting to 0.056 g., m.p. 203–210°, brought the over-all yield on the conversion VIII → X to 60%.

RAHWAY, N. J.

[JOINT CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE UNIVERSITY OF CALIFORNIA, AND THE RESEARCH LABORATORIES OF MERCK AND CO., INC.]

The Preparation of $\Delta^{5,7}$-Steroidal Dienes[1]

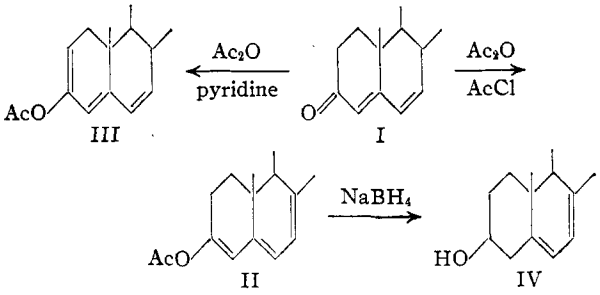
BY W. G. DAUBEN, J. F. EASTHAM, R. A. MICHELI, K. H. TAKEMURA, L. MANDELL AND J. M. CHEMERDA

RECEIVED DECEMBER 17, 1952

When $\Delta^{4,6}$-cholestadiene-3-one or $\Delta^{4,6}$-22-isospirostadiene-3-one was allowed to react with acetyl chloride and acetic anhydride, the 3-acetoxy-$\Delta^{3,5,7}$-trienes were formed. If the isospirostadienone reaction was conducted in the presence of one equivalent of pyridine, the side chain was opened and 3,26-diacetoxy-$\Delta^{3,5,7,20(22)}$-furostetraene was obtained. When the acetylation of either ketone was performed in the presence of excess pyridine and acetic anhydride or with isopropenyl acetate and acid, the isomeric 3-acetoxy-$\Delta^{2,4,6}$-trienes were formed. Reduction of the 3-acetoxy-$\Delta^{3,5,7}$-trienes with sodium borohydride yielded the $\Delta^{5,7}$-diene-3-ols. A discussion of the possible mechanisms of these enolizations is given. Comparison of the molecular rotations in these series suggest a vicinal effect.

The conversion of Δ^5-steroids to $\Delta^{5,7}$-steroid dienes has become of importance due to the recent work which has shown that such dienes are useful starting substances for the introduction of an 11-oxygen function into the steroid nucleus.[2] Several methods are available for the introduction of such unsaturation and all involve the preparation of a 7-substituted-Δ^5-sterol with subsequent elimination of the elements of water or acid from the 7,8-position.[3] A synthetic sequence not involving the preparation of a 7-substituted steroid appeared to warrant investigation.

It has previously been reported[4] that when the enol acetate of cholestenone (3-acetoxy-$\Delta^{3,5}$-cholestadiene) is allowed to react with sodium borohydride, the product is the β,γ-unsaturated alcohol, cholesterol. The mechanism of such a reduction has been shown to proceed through the 3-keto-Δ^5-steroid,[4,5] reduction occurring prior to the migration of the unsaturated center to a position of conjugation. Thus, if the enol acetate of a steroid containing the desired $\Delta^{5,7}$-system could be prepared from the easily available intermediate, $\Delta^{4,6}$-3-keto steroid, it should serve as a source of the $\Delta^{5,7}$-steroidal dienes. Such an enol acetate has been prepared in the ergosterol series by Heilbron and his co-workers[6] and in the sapogenin series by Yashin, Rosenkranz and Djerassi[7] but in both cases the source of their enol esters was the desired 3-hydroxy-$\Delta^{5,7}$-compound itself.



It has now been found that when $\Delta^{4,6}$-cholestadien-3-one (I), easily prepared from cholesterol[8] using the Wettstein modification[9] of the Oppenauer oxidation employing quinone and aluminum isopropoxide, is allowed to react with a mixture of acetyl chloride and acetic anhydride, 3-acetoxy-$\Delta^{3,5,7}$-cholestatriene (II) is the sole product obtained in pure form. The spectroscopic properties of the product were in good agreement with those

(1) A preliminary announcement of part of this work was reported in THIS JOURNAL, **73**, 4496 (1951).

(2) E. M. Chamberlin, W. V. Ruyle, A. E. Erickson, J. M. Chemerda, L. M. Aliminosa, R. L. Erickson, G. E. Sita and M. Tishler, THIS JOURNAL, **73**, 2396 (1951); L. F. Fieser, J. E. Herz and Wei-Yuan Huang, *ibid.*, **73**, 2397 (1951); H. Heusser, K. Eichenberger, P. Kurath, H. R. Dallenbach and O. Jeger, *Helv. Chim. Acta*, **34**, 2106 (1951); R. C. Anderson, R. Budziarck, G. T. Newbold, R. Stevenson and F. S. Spring, *Chemistry and Industry*, 1035 (1950); G. Stork, J. Romo, G. Rosenkranz and C. Djerassi, THIS JOURNAL, **73**, 3456 (1951).

(3) For leading references see v. J. Schmutz, H. Schaltegger and M. Sanz, *Helv. Chim. Acta*, **34**, 1111 (1951); and L. F. Fieser and M. Fieser, "Natural Products Related to Phenanthrene," Reinhold Publ. Corp., New York, N. Y., 1949, pp. 179–182.

(4) E. Schwenk, M. Gutand and J. Belisle, *Arch. Biochem. Biophys.*, **31**, 456 (1951); T. F. Gallagher and B. Belleau, THIS JOURNAL, **73**, 4458 (1951); W. G. Dauben and J. F. Eastham, *ibid.*, **73**, 4463 (1951).

(5) W. G. Dauben, R. A. Micheli and J. F. Eastham, *ibid.*, **74**, 3582 (1952).

(6) I. M. Heilbron, T. Kennedy, F. S. Spring and G. Swain, *J. Chem. Soc.*, 869 (1938).

(7) R. Yashin, G. Rosenkranz and C. Djerassi, THIS JOURNAL, **73**, 4654 (1951).

(8) A. L. Wilds and C. Djerassi, *ibid.*, **68**, 1712 (1946), and earlier references.

(9) A. Wettstein, *Helv. Chim. Acta*, **23**, 388 (1940).