catalyst by filtration the solution was evaporated to afford 17α-ethyl-19-norandrostane-17β-ol-3-one (X) (1.56 g.), m.p. 195–200°, raised by several crystallizations from acetone-hexane to 211–213°, identical in all respects with the sample prepared as in method a.

(c) **By the Hydrogenation of 17α-Ethynyl-19-norandrostane-17β-ol-3-one (VIII).**—As described in the previous experiment the 17α-ethynyl compound VII was hydrogenated to yield 17α-ethyl-19-norandrostane-17β-ol-3-one (X) (63% yield), identical in every respect with the products obtained in the two preceding experiments.

17α-Ethyl-19-norandrostane-3β,17β-diol (XIII).—Reduction of 17α-ethyl-19-norandrostane-17β-ol-3-one (X) (1.0 g.) with sodium borohydride using the method described above afforded 17α-ethyl-19-norandrostane-3β,17β-diol (XIII) (670 mg.), m.p. 174–180°, raised by crystallizations from acetone–hexane to 181–183°, $[\alpha]_D$ + 2°.

Anal. Calcd. for $C_{20}H_{34}O_2$: C, 78.38 H, 11.18. Found: C, 78.20 H, 11.03.

APARTADO POSTAL 2679
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[CONTRIBUTION FROM THE RESEARCH LABORATORIES OF SYNTEX, S.A.]

Steroids. CII.[1] Synthesis of 19-Norprogesterone from Estrone[2]

BY J. S. MILLS, H. J. RINGOLD AND CARL DJERASSI

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17α-Ethinylestradiol methyl ether 17-acetate (IId), obtainable in three steps from estrone, was converted by means of hypobromous acid followed by zinc treatment into 17α-acetylestradiol 3-methyl ether 17β-acetate (IVb). Removal of the 17α-acetyl group was accomplished concurrently with Birch reduction of the aromatic ring and 19-norprogesterone (VIII) was prepared without isolation of intermediates by acid hydrolysis of the dihydroanisole and oxidation at C-20, the over-all yield from 17α-ethinylestradiol 3-methyl ether (IIc) being 30%. Alternatively, this reaction sequence could also be applied to 17α-ethinylestradiol diacetate (IIb), whereupon 3-hydroxy-17β-acetyl-1,3,5-estratriene (Va) was obtained in 62% overall yield, all of the intermediates having been characterized. Finally, 19-nor-17α-ethinyltestosterone (XIa) also has been converted into 19-norprogesterone (VIII), the key step being calcium–ammonia reduction of the 3-enol ether XIII of 17β-acetoxy-17-iso-19-norprogesterone.

19-Norprogesterone (VIII) was the first 19-nor steroid in which removal of the angular methyl group was shown to be accompanied by a remarkable increase in biological activity.[3,4] This prompted the synthesis of a large number of 19-nor analogs of steroid hormones[5b] and the first to find clinical application has been 19-nor-17α-ethinyltestosterone (Norlutin), a substance readily obtainable[5a,6] from estrone (I). On the other hand, 19-norprogesterone (VIII) so far has been prepared[4] only by Birch reduction[7] of 3-methoxy-17β-acetyl-1,3,5-estratriene (Vb) and the latter's synthesis[8,9] is cumbersome and unattractive for large scale work. Since considerable amounts of the aromatic precursor Va as well as of 19-norprogesterone (VIII) were required for extensive biological and chemical experimentation, alternative synthetic routes were examined and the present paper deals with several successful approaches.

Salamon and Reichstein[10] were the first to observe that Faworsky bromination[11] of 17α-ethinyl-17β-acetoxy steroids followed by debromination leads to the corresponding 17α-acetoxy-20-ketopregnane derivatives (IX). We decided to examine this reaction in the estrogen series in order to obtain a substrate suitable for Birch reduction and the first studies were conducted with the previously unknown 17α-ethinylestradiol 3,17-diacetate (IIb), prepared by acid-catalyzed acetylation of 17α-ethinylestradiol (IIa).[12] Treatment of the diacetate IIb with N-bromoacetamide in buffered aqueous acetic acid furnished in 96% yield, the dibromo ketone IIIa, which could be debrominated with zinc dust to 17α-acetylestradiol 3,17β-diacetate (IVa). The problem resolved itself now largely to developing conditions for the deacetoxylation of IVa without producing a D-homo rearrangement.[13] Rosenfeld[14] reported recently that allopregnane-3β,17β-diol-20-one diacetate (IX) could be deacetoxylated in 46% yield to allopregnan-3β-ol-20-one acetate (X) by employing a large excess of zinc in glacial acetic acid. These conditions did not appear suitable for large scale work nor applicable to a Δ^4-3-keto-19-nor steroid (XIII) and attention was directed, therefore, at the calcium–liquid ammonia reaction.[15] The Glaxo group[15] de-

(1) Paper CI, A. Bowers, H. J. Ringold and E. Denot, THIS JOURNAL, **80**, 6115 (1958).

(2) Presented at the 6th National Medicinal Chemistry Symposium, Madison, Wisc., June 25, 1958.

(3) M. Ehrenstein, *J. Org. Chem.*, **9**, 435 (1944), first prepared an amorphous 19-norprogesterone from strophanthidine and found it to be at least as active as progesterone (see W. M. Allen and M. Ehrenstein, *Science*, **100**, 251 (1944)). Subsequently, this substance was obtained in crystalline form (G. W. Barber and M. Ehrenstein, *Ann.*, **603**, 89 (1957)) and shown to possess the 14-iso-17-iso orientation with the 10β-configuration (C. Djerassi, M. Ehrenstein and G. W. Barber, *ibid.*, **612**, 93 (1958)). The crystalline isomer exhibited eight times the biological activity of progesterone.

(4) C. Djerassi, L. Miramontes and G. Rosenkranz, THIS JOURNAL, **75**, 4440 (1953), first described (for preliminary communication see *ibid.*, **73**, 3540 (1951)) 19-norprogesterone (VIII) with the correct stereochemistry at all asymmetric centers (see C. Djerassi, R. Riniker and B. Riniker, *ibid.*, **78**, 6377 (1956)).

(5) (a) C. Djerassi, L. Miramontes, G. Rosenkranz and F. Sondheimer, *ibid.*, **76**, 4089 (1954); (b) additional biological data as well as references to the preparation of other 19-nor steroids are given by D. A. McGinty and C. Djerassi, *Ann. N. Y. Acad. Sci.*, **71**, 500 (1958).

(6) H. J. Ringold, G. Rosenkranz and F. Sondheimer, THIS JOURNAL, **78**, 2477 (1956).

(7) A. J. Birch and H. Smith, *Quart. Revs.*, **12**, 17 (1958).

(8) L. Velluz and G. Muller, *Bull. soc. chim. France*, 166 (1950).

(9) C. Djerassi, G. Rosenkranz, J. Iriarte, J. Romo and J. Berlin, THIS JOURNAL, **73**, 1523 (1951).

(10) I. Salamon and T. Reichstein, *Helv. Chim. Acta*, **30**, 1616 (1947).

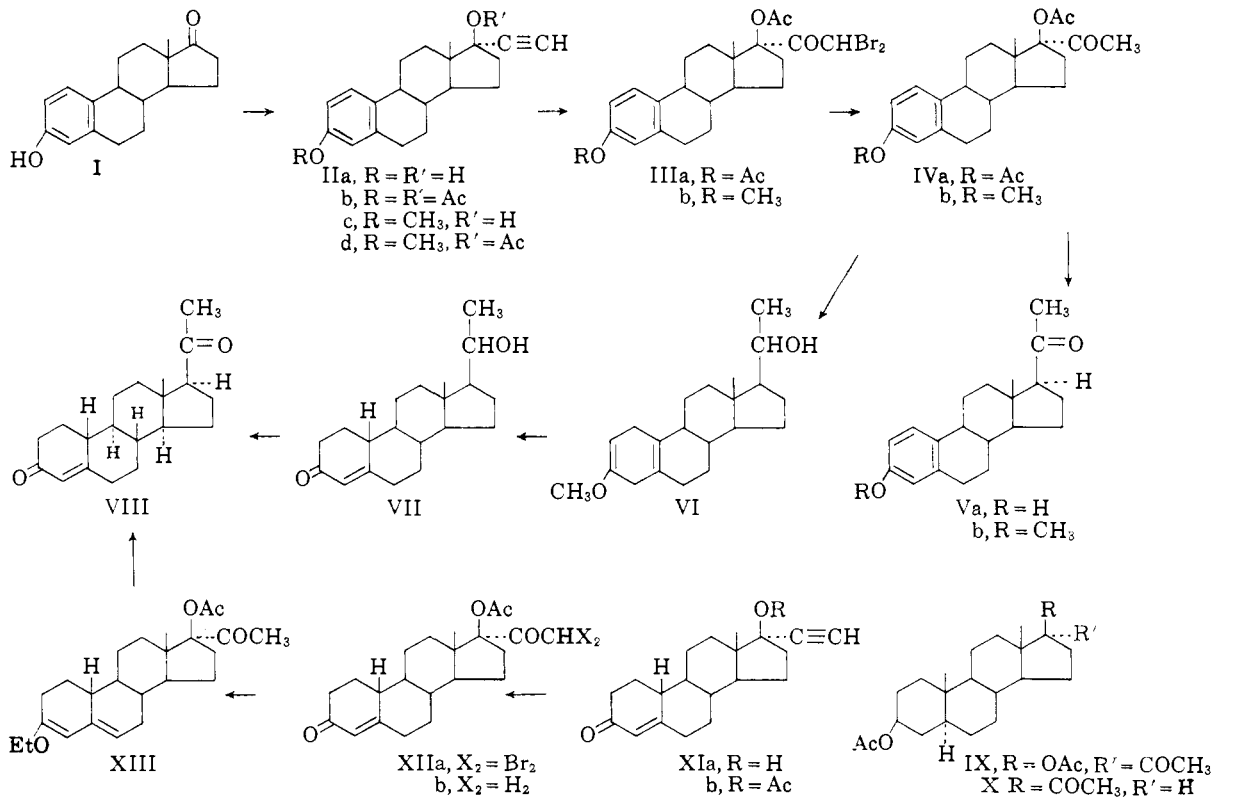
(11) A. Faworsky, *J. prakt. Chem.*, [2] **51**, 533 (1895).

(12) The ethinylation of estrone (I) in 90% yield was first described by H. H. Inhoffen, W. Logemann, W. Hohlweg and A. Serini, *Ber.*, **71**, 1024 (1938).

(13) 17β-Hydroxy-17-isopregnan-20-ones readily undergo D-homo rearrangement with a variety of reagents; for mechanism and leading references see R. B. Turner, M. Perelman and K. T. Park, THIS JOURNAL, **79**, 1108 (1957).

(14) R. S. Rosenfeld, *ibid.*, **79**, 5540 (1957).

(15) J. H. Chapman, J. Elks, G. H. Phillipps and L. J. Wyman, *J. Chem. Soc.*, 4344 (1956).



veloped this elegant reagent for the removal of the acetoxy function in ring C ketols of the steroidal sapogenin series, but mechanistically[7,15] this should be equally applicable to other ketol acetates. Indeed when the calcium–ammonia reaction was applied to the diacetate IVa, deacetoxylation (as well as cleavage of the acetate function at C-3) could be effected in 76% yield to furnish the desired 3-hydroxy-17β-acetyl-1,3,5-estratriene (Va).[8,9] In fact, when the purification of intermediates was omitted and the reaction sequence conducted on a 200-g. scale, a 62% over-all yield of Va could be realized based on 17α-ethinylestradiol (IIa). As pointed out above, the starting material IIa is available in 90% yield[12] from estrone (I) and since the latter is now prepared on an industrial scale by partial aromatization of androgen precursors,[16,17] the above reaction path represents by far the most convenient synthesis of 3-hydroxy-17β-acetyl-1,3,5-estratriene (Va) and thence, by Birch reduction[4] of its methyl ether Vb, of 19-norprogesterone (VIII).

The best means of effecting[4] the Birch reduction of 3-methoxy-17β-acetyl-1,3,5-estratriene proved to be the lithium–ammonia system[18] and while this reagent was not found to be particularly suitable for deacetoxylations in the sapogenin series,[15] it appeared very attractive to investigate the combination of both steps—deacetoxylation and Birch reduction—by means of one reagent.

For this purpose, 17α-ethinylestradiol methyl ether (IIc)[19] was transformed into the corresponding 17-acetate IId, treated with N-bromoacetamide and the resulting dibromo ketone IIIb reduced with zinc to 17α-acetylestradiol 3-methyl ether 17β-acetate (IVb). This substance now had the requisite functional groups (aromatic methyl ether as well as ketol acetate) for simultaneous Birch reduction and deacetoxylation and when the reaction was conducted with lithium in liquid ammonia in the presence of methanol, reduction at both centers could be effected. The crude dihydroanisole derivative VI[4] was directly cleaved with acid to the α,β-unsaturated ketone VII[4] and the latter was oxidized to afford 19-norprogesterone (VIII) in 51% yield (30% over-all based on IIc). In our hands, this has proved to be the method of choice for the large scale synthesis of this important progestational steroid.

Finally, it was also of interest to examine the feasibility of synthesizing 19-norprogesterone (VIII) from 19-nor-17α-ethinyltestosterone (XIa),[5] since this substance is now available in industrial quantities. Its 17-acetate XIb[20] was again subjected to Faworsky bromination[10,11] and debromination to afford 17β-acetoxy-17-iso-19-norprogesterone (XIIb). Since a preliminary experiment demonstrated the loss of the Δ^4-3-keto chromophore upon exposure to the calcium–ammonia reagent, the substance first was transformed into its enol ether XIII and then deacetoxylated with calcium in liquid ammonia; acid cleavage of the reduction product furnished 19-norprogesterone

(16) H. H. Inhoffen, *Angew. Chem.*, **59**, 207 (1947); E. B. Hershberg, M. Rubin and E. Schwenk, *J. Org. Chem.*, **15**, 292 (1950).

(17) C. Djerassi, G. Rosenkranz, R. Romo, S. Kaufmann and J. Pataki, THIS JOURNAL, **72**, 4534 (1950).

(18) A. L. Wilds and N. A. Nelson, *ibid.*, **75**, 5360, 5366 (1953).

(19) F. B. Colton, L. N. Nysted, B. Riegel and A. L. Raymond, *ibid.*, **79**, 1123 (1957).

(20) See O. Engelfried, E. Kaspar, A. Popper and M. Schenck, German Patent 1,017,166.

(VIII) in moderate yield, but no attempt was made to develop optimum conditions for this reaction sequence.

Experimental[21]

17α-Ethinylestradiol Diacetate (IIb).—A solution of 10.0 g. of 17α-ethinylestradiol and 3.0 g. of *p*-toluenesulfonic acid monohydrate in 100 cc. of acetic acid was left overnight at room temperature, poured into water and filtered after 1 hr. One crystallization from methanol furnished 11.0 g. of the diacetate IIb, m.p. 138–140° suitable for subsequent transformations. The analytical sample crystallized as colorless plates, m.p. 143–144°, $[\alpha]D \pm 0°$.

Anal. Calcd. for $C_{24}H_{28}O_4$: C, 75.76; H, 7.42; O, 16.82. Found: C, 75.72; H, 7.60; O, 17.01.

17α-Dibromoacetylestradiol 3,17β-Diacetate (IIIa).—A mixture of 1.9 g. of 17α-ethinylestradiol diacetate (IIb), 2.1 g. of N-bromoacetamide, 2.0 g. of anhydrous sodium acetate, 10 cc. of water and 100 cc. of acetic acid was left at room temperature for 2 hr., then diluted with 200 cc. of water and the colorless crystals (2.7 g., m.p. 185–190°) were collected. This material was used in the next step, while an analytical sample was prepared from methanol–chloroform, m.p. 196–198°, $[\alpha]D -13.4°$, ν_{max}^{KBr} 1755 and 1727 cm.$^{-1}$.

Anal. Calcd. for $C_{24}H_{28}Br_2O_5$: C, 51.44; H, 5.11; Br, 28.95; O, 14.49. Found: C, 51.06; H, 4.92; Br, 29.00; O, 14.92.

17α-Acetylestradiol 3,17β-Diacetate (IVa).—The preceding dibromo ketone IIIa (2.7 g.), dissolved in 100 cc. of acetic acid containing 2.5 g. of anhydrous sodium acetate and 10 cc. of water, was stirred for 15 min. on the steam-bath with 3.5 g. of zinc dust. After filtering the zinc, the product was precipitated by the addition of water, collected and crystallized from methanol–ethyl acetate to give 1.47 g. (76%) of colorless plates, m.p. 172–174°. The analytical sample was obtained on further recrystallization from the same solvent pair, m.p. 178–180°, $[\alpha]D +47°$; ν_{max}^{KBr} 1760, 1736 and 1713 cm.$^{-1}$.

Anal. Calcd. for $C_{24}H_{30}O_5$: C, 72.33; H, 7.59. Found: C, 72.31; H, 7.23.

3-Hydroxy-17β-acetyl-1,3,5-estratriene (Va).—A solution of 2.0 g. of 17α-acetylestradiol 3,17β-diacetate (IVa) (m.p. 172–174°) in 20 cc. of dry dioxane was added to 1.0 g. of calcium metal dissolved in 300 cc. of liquid ammonia (directly from cylinder) and the mixture was stirred without external cooling for 1 hr. Methanol (5 cc.) then was added rapidly followed, after a further 30 min., by 5.0 g. of ammonium chloride. After evaporation of the ammonia, dilution with water and filtration gave 1.5 g. of solid which was crystallized from ethyl acetate to yield 1.14 g. (76%) of **3-hydroxy-17β-acetyl-1,3,5-estratriene (Va)**, m.p. 244–247°. One further recrystallization gave material of m.p. 247–249°, undepressed upon admixture with an authentic specimen,[9] $[\alpha]D +164°$. Identity was confirmed further by infrared spectral comparison.

From a practical standpoint, it was desirable to conduct the entire reaction sequence without purification of intermediates in the following manner. 17α-Ethinylestradiol (IIa) (200 g.) was acetylated with 1.5 l. of acetic anhydride and 50 g. of *p*-toluenesulfonic acid and the crude product, obtained upon precipitation with water, was dissolved in 16 l. of acetic acid containing 280 g. of sodium acetate and 1.2 l. of water and treated with stirring for 3 hr. with 360 g. of N-bromoacetamide. The dibromo ketone IIIa was precipitated with water, filtered and debrominated directly in 10 l. of acetic acid (containing 300 g. of sodium acetate) with 480 g. of zinc dust. The product (IVa) was crystallized from ethanol to give 236 g. of material, m.p. 171–175°, which was reduced with 100 g. of calcium in 15 l. of liquid ammonia, methanol (1.25 l.) being added after 1 hr. followed by 500 g. of ammonium chloride. Isolation as described above and recrystallization from ethyl acetate yielded 124.5 g. of 3-hydroxy-17β-acetyl-1,3,5-estratriene (Va), m.p. 245–248°.

(21) Melting points are uncorrected. We are indebted to Dr. L. Throop and staff for all rotation (chloroform solution) and spectral measurements.

17α-Dibromoacetylestradiol 3-Methyl Ether 17β-Acetate (IIIb).—Acetylation of 20 g. of 17α-ethinylestradiol methyl ether (IIIc) with 200 cc. of acetic anhydride and 6.0 g. of *p*-toluenesulfonic acid followed by recrystallization from methanol–ethyl acetate furnished 18.6 g. of **17α-ethinylestradiol 3-methyl ether 17-acetate (IId)**, m.p. 162–164°, $[\alpha]D \pm 0°$.

Anal. Calcd. for $C_{23}H_{28}O_3$: C, 78.37; H, 8.01; O, 13.62. Found: C, 78.00; H, 7.88; O, 13.83.

The foregoing compound (1.75 g.) was dissolved in 75 cc. of *t*-butyl alcohol containing 1 cc. of water and treated with 1.6 g. of N-bromoacetamide. Crystallization of the dibromo ketone commenced after stirring for a few minutes and after 1 hr., 25 cc. of water was added, the mixture cooled in ice and the product collected. Washing with methanol provided 2.27 g. of colorless crystals, m.p. 204–208°, suitable for the next step; the analytical sample was recrystallized from methylene chloride–methanol, m.p. 212–214°, $[\alpha]D -16°$.

Anal. Calcd. for $C_{23}H_{28}Br_2O_4$: C, 52.27; H, 5.34; Br, 30.27; O, 12.12. Found: C, 52.30; H, 5.38; Br, 30.83; O, 12.40.

17α-Acetylestradiol 3-Methyl Ether 17β-Acetate (IVb).—The debromination of 8.67 g. of the dibromo ketone IIIb was performed with 11 g. of zinc dust, 300 cc. of acetic acid, 8 g. of sodium acetate and 30 cc. of water exactly as described for the acetate IIIa and after crystallization from methanol–ethyl acetate yielded 4.67 g. (81%) of the ketone IVb, m.p. 156–160°. The analytical sample exhibited m.p. 159–161°, $[\alpha]D +53°$, ν_{max}^{KBr} 1740 and 1713 cm.$^{-1}$.

Anal. Calcd. for $C_{23}H_{30}O_4$: C, 74.56; H, 8.16; O, 17.28. Found: C, 74.89; H, 7.88; O, 17.03.

19-Norprogesterone (VIII). (a) **From 17α-Acetylestradiol 3-Methyl Ether 17β-Acetate (IVb).**—A solution of 2.0 g. of the above ketone IVb in 20 cc. of dry dioxane was added to 1.0 g. of lithium in 500 cc. of liquid ammonia without external cooling. After stirring for 1 hr. 50 cc. of methanol was added dropwise over a period of 15 min. followed by 4.0 g. of lithium in small pieces. Evaporation of the ammonia and precipitation with water gave a solid (VI)[4] which was hydrolyzed directly by heating under reflux for 1 hr. with 30 cc. of 4 *N* hydrochloric acid and 50 cc. of methanol. Isolation with ethyl acetate gave the crude keto alcohol VII[4] which was oxidized in 80 cc. of acetone with 8 *N* chromium trioxide–sulfuric acid reagent.[22] Dilution with water gave a crystalline precipitate which after filtration in benzene solution through a short column of alumina and one recrystallization from acetone–hexane afforded 0.83 g. of **19-norprogesterone (VIII)**, m.p. 141–144°, undepressed when mixed with an authentic[4] specimen, $[\alpha]D +154°$, λ_{max}^{EtOH} 240 mμ, log ε 4.25. The infrared spectra of the two samples were identical.

(b) **From 19-Nor-17α-ethinyltestosterone (XIa).**—The acetate (10.0 g.) XIb[20] of 19-nor-17α-ethinyltestosterone (XIa)[5a] in 250 cc. of *t*-butyl alcohol and 10 cc. of water was brominated (2 hr., 25°) with 8.8 g. of N-bromoacetamide and the total, crude dibromo ketone XIIa, obtained by precipitation with water, was debrominated in the above-described manner with 17 g. of zinc dust, 570 cc. of acetic acid and 14 g. of sodium acetate. Crystallization from aqueous methanol provided 7.34 g. of **17β-acetoxy-17-iso-19-norprogesterone (XIIb)**, m.p. 162–165°, which was used in the next step without further purification. The analytical sample had m.p. 173–174°, $[\alpha]D +30°$, λ_{max}^{EtOH} 240 mμ, log ε 4.23; ν_{max}^{KBr} 1740, 1720, 1660 and 1615 cm.$^{-1}$.

Anal. Calcd. for $C_{22}H_{30}O_4$: C, 73.71; H, 8.44; O, 17.85. Found: C, 73.79; H, 8.32; O, 18.11.

To 5.5 g. of the above ketone XIIb in 95 cc. of dioxane was added 12.6 g. of ethyl orthoformate and 190 mg. of *p*-toluenesulfonic acid monohydrate and after standing for 40 min., 6.5 cc. of pyridine was added and the product was precipitated with water. **3-Ethoxy-17β-acetoxy-19-nor-Δ^{3,5}-pregnadien-20-one (XIII)** was isolated with ethyl acetate and recrystallized from aqueous methanol containing one drop of pyridine; yield 2.0 g., m.p. 135–138°, $[\alpha]D -125°$, λ_{max}^{EtOH} 242 mμ, log ε 4.16.

(22) See K. Bowden, I. M. Heilbron, E. R. H. Jones and B. C. L. Weedon, *J. Chem. Soc.*, 39 (1946).

Anal. Calcd. for $C_{24}H_{34}O_4$: C, 74.58; H, 8.87; O, 16.55. Found: C, 74.28; H, 8.89; O, 17.04.

The above enol ether XIII (1.0 g.) in 25 cc. of dioxane was added to 0.5 g. of calcium in 250 cc. of liquid ammonia and after stirring for 30 min., 4.0 g. of ammonium chloride was added and the product isolated in the usual manner. After heating under reflux for 1 hr. with 5 cc. of concd. hydrochloric acid, 10 cc. of water and 25 cc. of methanol, 19-norprogesterone (VIII) (0.27 g., m.p. 140–142°) was obtained after passage through a short column of alumina and recrystallization from acetone–hexane.

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[CONTRIBUTION FROM THE SLOAN-KETTERING INSTITUTE FOR CANCER RESEARCH AND THE DIVISION OF PURE CHEMISTRY OF THE NATIONAL RESEARCH COUNCIL OF CANADA][1]

The Infrared Spectra of Hydroxysteroids below 1350 Cm.$^{-1}$

BY R. NORMAN JONES AND GLYN ROBERTS

RECEIVED JUNE 17, 1958

Characteristic absorption bands in the range 1350–650 cm.$^{-1}$ are reported for steroids hydroxylated at C(3), C(17) and C(20). The bands are observed in the monohydroxy compounds and in steroids containing additional hydroxy, acetoxy and ketonic groups, provided the functional groups are well separated. The general implications of these and similar bands in the spectra of ketones and acetates also are considered.

In preceding papers[2,3] it has been shown that many of the prominent bands occurring between 1350 and 650 cm.$^{-1}$ in the infrared spectra of steroid ketones and acetates depend specifically on the position and stereochemical arrangement of the functional group. Where the steroid contains two or more functional groups it is often possible to distinguish bands characteristic of each group. This applies most generally where the functional groups are well separated so that interaction effects are reduced. Examples have been given where one functional group is at C(3) and the other at C(17) or C(20).

The spectra of a large number of steroid alcohols have now been surveyed in a similar fashion, and for these compounds also many of the infrared absorption bands in the 1350–650 cm.$^{-1}$ range are observed to fall within narrow frequency ranges for steroids containing the same hydroxy substituent.

Experimental Methods and Results

The spectra were measured on Perkin–Elmer model 112 and model 21 spectrometers using sodium chloride prisms. The bands common to the various compounds of the same type are listed in Table I and the frequency ranges of the bands common to the compounds of the same type are summarized in Table II. A representative spectrum of each type of steroid alcohol is illustrated in Figs. 1–11. The common bands are cross-referenced between figures and tables by the letters A, B, etc., but it must be emphasized that these letters are assigned for identification purposes only, and no relationship is implied between bands carrying the same letter on different figures.

The bands are classified in Tables I and II into categories I, II and III. The basis of this classification was discussed in connection with ketone spectra.[2] Category I bands provide the main functional group identification; category II bands usually stand out in the spectra and are useful for secondary confirmation of the structure. The category III bands are generally weaker and tend to be obscured by other absorption in the spectra of steroids containing more than one functional group.

Most of the spectra were measured in carbon disulfide solution, but, because of the low solubility of many hydroxy steroids in this solvent, data for chloroform solutions at 1 mm. path length and for potassium bromide dispersions also are included in Table I. The spectra of some hydroxysteroids in potassium bromide disks have been shown to be sensitive to the conditions under which the disk is prepared[4]; therefore the frequency ranges given in Table II are based only on measurements in carbon disulfide solution.

The majority of the spectra discussed in this paper have been published in an atlas[5,6] and in the right hand column of Table I references are given to the corresponding atlas chart numbers. In some instances the band positions given in Table I are taken from measurements made with the model 112 spectrometer under higher resolution than the curves published in the atlas; this accounts for small frequency differences of the order of ±3 cm.$^{-1}$ between the band positions listed in Table I and those which would be interpolated from the atlas charts for the same compounds.

Discussion

3-Hydroxysteroids.—The most prominent band in the spectra of 3-hydroxysteroids occurs between 1056 and 999 cm.$^{-1}$. This band is outstandingly intense with $\epsilon^{(a)}_{max}$ in the range 160–220. The corresponding bands in steroids hydroxylated at C(17) or C(20) have $\epsilon^{(a)}_{max}$ in the range 60–120.

This band is presumed to involve principally a C–O stretching motion, and, in accordance with this, it is observed that the band position is affected only slightly by replacement of the hydroxy hydrogen atom with deuterium.[7] The position of the band within the range depends on the stereochemistry at C(3) and C(5).[8–10] The ranges previously assigned to this band in the various conformational isomers of 3-hydroxy steroids have been revised slightly as a result of the present investigation, and the new values are summarized in the second column of Table III.

3-Hydroxysteroids also exhibit several bands between 1015 and 890 cm.$^{-1}$; these, though weak, are usually sharp and can be useful as confirmatory

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(2) R. N. Jones, F. Herling and E. R. Katzenellenbogen, THIS JOURNAL, **77**, 651 (1955).

(3) R. N. Jones and F. Herling, *ibid.*, **78**, 1152 (1956).

(4) G. Roberts, *Anal. Chem.*, **29**, 911 (1957).

(5) K. Dobriner, E. R. Katzenellenbogen and R. N. Jones, "Infrared Absorption Spectra of Steroids—An Atlas," Interscience Publishers, Inc., New York, N. Y., 1953.

(6) G. Roberts, B. Gallagher and R. N. Jones, "Infrared Absorption Spectra of Steroids—An Atlas, Volume II," Interscience Publishers, Inc., New York, N. Y., 1958.

(7) R. N. Jones, H. E. Hallam and J. Mateos, unpublished observation.

(8) A. R. H. Cole, R. N. Jones and K. Dobriner, THIS JOURNAL, **74**, 5571 (1952).

(9) H. Rosenkrantz and I. Zablow, *ibid.*, **75**, 903 (1953).

(10) H. Rosenkrantz and P. Skogstrom, *ibid.*, **77**, 2237 (1955).