7.25–8.11 (4 H, multiplet). The analytical sample was purified by chromatography on silicic acid using 8:2 benzene–ether as the eluent.

Anal. Calcd for $C_{10}H_{11}NO_3$: C, 62.20; H, 5.74; N, 7.24. Found: C, 62.42; H, 5.87; N, 6.88.

trans-α-**Methyl**-*o*-**nitrocinnamyl Bromide**-d_1 (**12**).—Phosphorus tribromide (1.98 g, 0.0073 mol) in dry ether (25 ml) was added dropwise to deuterated **11** (3.7 g, 0.019 mol) in dry ether (42 ml) at −10°. After addition of phosphorus tribromide was complete, the solution was stirred at room temperature for 7 hr. The reaction mixture was poured onto ice and extracted with ether. The ether was washed with aqueous sodium carbonate, dried over magnesium sulfate, and concentrated. The residual oil was distilled, giving a yellow oil (4.3 g, 0.017 mol, 87%): bp 111–113° (0.1 mm); ν_{NO_2} 1520, 1340 cm^{-1}.

An undeuterated sample was prepared by an identical procedure from unlabeled **11**: nmr peaks ($CDCl_3$) at δ 1.87 (3 H, d), 4.17 (2 H, d), 6.96 (1 H, broad singlet) and 7.30–8.20 (4 H, multiplet).

Anal. Calcd for $C_{10}H_{10}NO_2Br$: C, 46.90; H, 4.21; N, 5.46. Found: C, 47.00; H, 3.97; N, 5.50.

trans-**2-Methyl-1-**(*o*-**nitrophenyl**)-**1-propene-3**-d_2.—A solution of deuterated **11** (5.0 g, 0.019 mol) in dry ether (70 ml) was added dropwise to lithium aluminum deuteride (0.412 g, 0.0098 mol) in dry ether (75 ml). After addition was complete, the reaction mixture was refluxed for 2.5 hr. Excess lithium aluminum deuteride was destroyed with moist ether and water and the reaction mixture was hydrolyzed with 10% sulfuric acid. The ether layer was washed with water, dried, and evaporated. Chromatography of the residual oil on silicic acid gave **3** (1.07 g, 0.0060 mol, 30%): ν_{NO_2} 1520, 1340 cm^{-1}; nmr peaks ($CDCl_3$) at δ 1.69 (3 H, d), 1.91 (1 H, d), 6.48 (1 H, broad singlet), and 7.1–8.0 (4 H, multiplet). Except for the diminished intensity of the signal at δ 1.91, the nmr spectrum is identical with an unlabeled sample of **3** from unlabeled **12** and with a sample previously prepared by an independent procedure.[3]

Standard Deoxygenation Procedure.—The nitrostyrene was refluxed with a 6 *M* ratio of triethyl phosphite under a nitrogen atmosphere for 6 hr. The solution was cooled and triethyl phosphite [bp ~25° (0.1 mm)] and triethyl phosphite [bp 43–46° (0.2 mm)] were removed by vacuum distillation. The residue was dissolved in ether, washed with water, dried, and concentrated. The residue was chromatographed on silicic acid (60–70 g, packed as a slurry in hexane). The solvent sequence was hexane, 9:1 hexane–benzene, 4:1 hexane–benzene, 1:1 hexane–benzene, and 9:1 benzene–ether. The course of the chromatography was followed by tlc.

Deoxygenation of *trans*-α-**Methyl-2′-nitrostilbene** (**1**).—Deoxygenation of **1** (3.1 g, 0.013 mol) gave an oil (0.016 g) eluted by hexane and tentatively identified as **16** on the basis of an nmr spectrum: nmr peaks at δ 1.2 (t), 2.3 (s), 4.2 (q) 7.0–7.8 (multiplet). Hexane–benzene (9:1) eluted **14** as an oil (0.28 g, 0.0012 mol, 9%) which was identified by spectral comparison with an authentic sample.[3] Hexane–benzene (1:1) eluted **13** (1.43 g, 0.0069 mol, 53%) containing **15** as a contaminant as shown by tlc comparison with authentic **15**. The methyl signal of **15** at δ 2.34 was not discernible in the nmr spectrum (<2% yield). The infrared and nmr spectrum of the product were identical with an authentic sample of **13**.[11]

Deoxygenation of *cis*-α-**Methyl-2′-nitrostilbene** (**2**).—Deoxygenation of **2** (2.5 g, 0.010 mol) gave **14** (0.39 g, 0.0012 mol, 12%), **13** (1.13 g, 0.0055 mol, 54%), and a 1:1 mixture of **14** and **15** (0.035 g, 0.8% yield of each) as identified by tlc and nmr spectral data.

Deoxygenation of β,β-**Dimethyl**-*o*-**nitrostyrene**-d_2 (**3**).—Deoxygenation of **3** (1.50 g, 0.0084 mol) gave **17** (0.28 g, 0.0019 mol, 22%) which was eluted with 1:1 hexane–benzene and identified by tlc and nmr comparison with unlabeled **17**. The integrated intensity of the peaks at δ 1.80 and 2.10 in benzene-d_6 were identical. Benzene–ether (9:1) eluted 2,2-dimethyl-3-indolinone (0.30 g, 0.0018 mol, 22%) which was identified by tlc and infrared data. A deoxygenation of unlabeled **3** gave similar product yields.

Control Experiment.—Partial deoxygenation of *cis*-α-methyl-2′-nitrostilbene (1 hr) permitted recovery of 10% of the nitrostilbene shown by nmr to be an 83:17 mixture of **2** and **1**, indicating that thermal isomerization of **2** to **1** is slow relative to deoxygenation.

Partial deoxygenation of **3** (1 hr) permitted recovery of 5.5% of unreacted **3**. The nmr spectrum of **3** showed a 1:3 integration ratio for the peaks at δ 1.9 and 1.7 indicating no interchange of the methyl and methyl-d_2 groups.

Registry No.—**2**, 20072-75-7; **3**, 20072-76-8; **6**, 20072-77-9; **7**, 20072-78-0; **8**, 20072-79-1; **9**, 20072-83-7; **10**, 20072-80-4; **11**, 20072-81-5; **12**, 20072-82-6; **11** (undeuterated), 20073-27-2; **12** (undeuterated, 20073-28-3; 2,2′-azo-α-phenylcinnamyl alcohol, 20072-84-8.

(11) E. W. Ockenden and K. Schofield, *J. Chem. Soc.*, 612 (1953).

The Enol Acetylation of Alkylated Δ^4-3-Oxo Steroids. A Novel Enone–Phenol Transformation

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The perchloric acid catalyzed acetic anhydride acylation of a number of mono- and dialkylated steroids at the C-2 and C-6 positions has been investigated. In those cases where $\Delta^{2,4}$-dienol acetate formation is favored a novel hydride abstraction reaction is described which leads to intermediates which undergo dienone–phenol rearrangement. In contrast, the isopropenyl acetate enol acetylation of these compounds invariably led to the exclusive formation of $\Delta^{3,5}$-dienol acetate except in the one instance where the presence of a 6β substituent resulted in a 1:1 mixture of $\Delta^{2,4}$- and $\Delta^{3,5}$-dienol acetates.

As part of a program to examine the influence of remote substituents on the enolization properties of Δ^4-3-oxo steroids, we have been studying the perchloric acid catalyzed acetic anhydride enol acetylation of steroids. The enol acetylating conditions chosen are known to reflect the enolization properties of saturated keto steroids.[1] However, in a previous study[2] with conjugated ketones it was demonstrated that under these conditions the enol acetylation reaction leads to mixtures of O- and C-acylated products. The major products from the reaction of 17β-hydroxyandrost-4-en-3-one (**1a**) were 3,17β-diacetoxy-2-acetylandrosta-2,4-diene and 3,17β-diacetoxy-6-acetylandrosta-3,5-diene. The C-acylation reaction was shown to proceed *via* the intermediate $\Delta^{3,5}$- and $\Delta^{2,4}$-dienol diacetates. The subsequent acetylium ion[3] attack on the isomeric

(1) A. J. Liston, *J. Org. Chem.*, **31**, 2105 (1966).

(2) A. J. Liston and P. Toft, *ibid.*, **33**, 3109 (1968).

(3) The identity of the acetylating species in perchloric acid catalyzed enol acetylations has not been unequivocally established. However, there is increasing evidence that this ion must play a significant role [*cf.* D. P. N. Satchell, *Quart. Rev.* (London), **17**, 196 (1963)].

dienol diacetates effectively prevented any study of the equilibrium between the isomeric enolic forms.

To eliminate the foregoing difficulties alkylated Δ⁴-3-oxo steroids were studied. The incorporation of alkyl groups at the C-2 and C-6 positions of the steroid nucleus would be expected to render the dienol acetates impervious to acetylium ion attack since it has been shown by Gorodetsky[4] that tetrasubstituted double bonds are not susceptible to attack by this ion.

For this study a series of alkylated steroids was prepared. They are 17β-acetoxy-2α-methylandrost-4-en-3-one (**1c**), 17β-acetoxy-2α-ethylandrost-4-en-3-one (**1d**), 2α,6β-dimethyl-17β-hydroxyandrost-4-en-3-one (**1h**), and 6α-methylandrost-4-en-3-one (**1e**). The first compound, **1c**, was prepared in 65% yield by methylation of the ethoxyoxalate derivative of testosterone (**1a**) with methyl iodide.[5] Elimination of the oxalyl moiety was carried out with sodium ethoxide in ethanol and the product, 2α-methyltestosterone (**1f**), was acetylated with pyridine–acetic anhydride mixture to yield compound **1c**. The 2α-ethyl analog **1g** was prepared by the same method using ethyl iodide as alkylating agent.[6] The product **1g** was treated as before to yield the corresponding acetate **1d**.

The 2α,6β-dimethyl steroid **1h** was prepared from 17β-hydroxy-2α-methylandrost-4-en-3-one (**1f**). Ketalization of **1f** gave only one product, the 3,3-ethylenedioxy derivative **2**, in which the location of the double bond was established by nmr spectroscopy.[7-10] The ketal **2** was treated with *m*-chloroperbenzoic acid to form a mixture of epoxides which were identified by their rotations. It has been established[11] that the epoxidation of Δ⁵-3,3-ethylenedioxy compounds gives predominantly the α-epoxide. Glpc analysis of the crude reaction product demonstrated two products, the less polar β-epoxide **4** (30%) and the more polar α-epoxide **3** (70%), the more levorotatory compound **3** being assigned the α configuration. These assignments were confirmed by nmr spectroscopy. The 6β-proton signal of the α-epoxide **3** was located at δ 2.78 in the nmr spectrum; the doublet had the characteristic coupling constant, $J = 4$ Hz, whereas the doublet due to the 6α proton of the β-epoxide **2** was situated at δ 3.03 with the characteristic coupling constant, $J = 2$ Hz.[12] The α-epoxide **3** was treated with methylmagnesium iodide to yield 3,3-ethylenedioxy-2α,6β-dimethylandrosta-5α,17β-diol (**5a**). The stereochemistry of the product was assigned by analogy with previous work on similar compounds.[13] The ketal group was removed by hydrolysis with acetic acid to yield the ketodiol **5b** which was dehydrated with dilute aqueous methanolic sodium hydroxide.[13a]

In view of the strong C-6–C-10 diaxial methyl interaction it had been expected that prolonged base treatment such as employed in the dehydration reaction would effect concomitant epimerization of the C-6 methyl substituent.[14] The nmr spectrum of the product suggested that the stereochemistry at C-6 was not altered. The location of the C-19 methyl signal at δ 1.28 was in agreement with the calculated value for a 6β-methyl substituent.[15a] Further, the lack of allylic coupling between the C-4 vinylic proton and the α proton at C-6 corroborated the assignment.[15b] Under acidic conditions the compound underwent facile isomerization to yield the 2α,6α-dimethyl product **1j**. These equilibration results are in agreement with those of Malhotra and Ringold[16] in which enolization toward the Δ³,⁵ position is disfavored under basic conditions.

The model compound **1e** was prepared from 3β,17α-dihydroxy-6-methylpregn-5-en-20-one (**6**) by treatment with sodium borohydride to form an epimeric mixture of C-20 alcohols which was cleaved with sodium periodate (Scheme I).[17] The product, 3β-hydroxy-6-methylandrost-5-en-17-one (**7**), was converted into 6-methylandrost-5-en-3β-ol (**8**) by Wolff–Kishner reduction. Oppenauer oxidation of **8** with aluminum *t*-butoxide afforded 6α-methylandrost-4-en-3-one (**1e**).[18,19]

The enol acetylation of 17β-acetoxy-2α-methylandrost-4-en-3-one (**1c**) using isopropenyl acetate–sulfuric acid catalyst gave an excellent yield of 3,17β-diacetoxy-2α-methylandrosta-3,5-diene (**10a**) (Scheme II). The compound was identified by comparison of the uv spectrum with that of 3,17β-diacetoxyandrosta-3,5-diene.[20] The identity of compound **10a** was confirmed by nmr spectroscopy which demonstrated signals due to the two vinylic protons at C-4 and C-6. Compound **10a** was treated under equilibrating conditions using a solution of acetic anhydride in benzene–carbon tetrachloride containing a trace of perchloric acid catalyst.[2] After 6 hr glpc analysis demonstrated the formation of two major components in a ratio of 23% (**14a**) and 77% (**13a**). Treatment of 2α-methyltestosterone (**1f**) with acetic anhydride–perchloric acid reagent gave essentially the same results. Glpc analysis indicated that the starting material **1f** was rapidly converted (10 min) into 3,17β-diacetoxy-2α-methylandrosta-3,5-diene (**10a**) and then followed the same reaction pathway leading to the two major products previously detected.

(4) M. Gorodetsky, E. Levy, R. D. Youssefyeh, and Y. Mazur, *Tetrahedron*, **22**, 2039 (1966).

(5) (a) H. J. Ringold, E. Batres, O. Halpern, and E. Necoechea, *J. Amer. Chem. Soc.*, **81**, 427 (1959); (b) H. J. Ringold and G. Rosenkranz, *J. Org. Chem.*, **21**, 1333 (1956).

(6) A similar low yield in preparing a 2α-ethyl derivative was reported by J. A. Hogg, F. H. Lincoln, R. W. Jackson, and W. P. Schneider, *J. Amer. Chem. Soc.*, **77**, 6401 (1955).

(7) The fact that no Δ⁴-3-ketal was obtained from the 2α-methyl compound **1f** suggests that the Δ²,⁴-dienol ether[8] is not an intermediate of the ketalization reaction, and rather supports the mechanism proposed by Djerassi[9] and Christiansen.[10]

(8) J. J. Brown, R. H. Lenhard, and S. Bernstein, *J. Amer. Chem. Soc.*, **86**, 2183 (1964).

(9) C. Djerassi and M. Gorman, *ibid.*, **75**, 3704 (1953).

(10) J. W. Dean and R. G. Christiansen, *J. Org. Chem.*, **28**, 2110 (1963).

(11) A. Bowers, L. C. Ibanez, and J. J. Ringold, *Tetrahedron*, **7**, 138 (1959).

(12) A. D. Cross, *J. Amer. Chem. Soc.*, **84**, 3206 (1962).

(13) (a) S. Bernstein and R. Littell, *ibid.*, **82**, 1235 (1960); (b) G. Cooley, B. Ellis, D. N. Kirk, and V. Petrow, *J. Chem. Soc.*, 4112 (1957).

(14) *Cf.* J. A. Campbell, J. C. Babcock, and J. A. Hogg, *J. Amer. Chem. Soc.*, **80**, 4717 (1958).

(15) N. S. Bhacca and D. H. Williams, "Applications of NMR Spectroscopy in Organic Chemistry," Holden-Day, Inc., San Francisco, Calif., 1966: (a) p 14; (b) p 109.

(16) S. K. Malhotra and H. J. Ringold, *J. Amer. Chem. Soc.*, **86**, 1997 (1964).

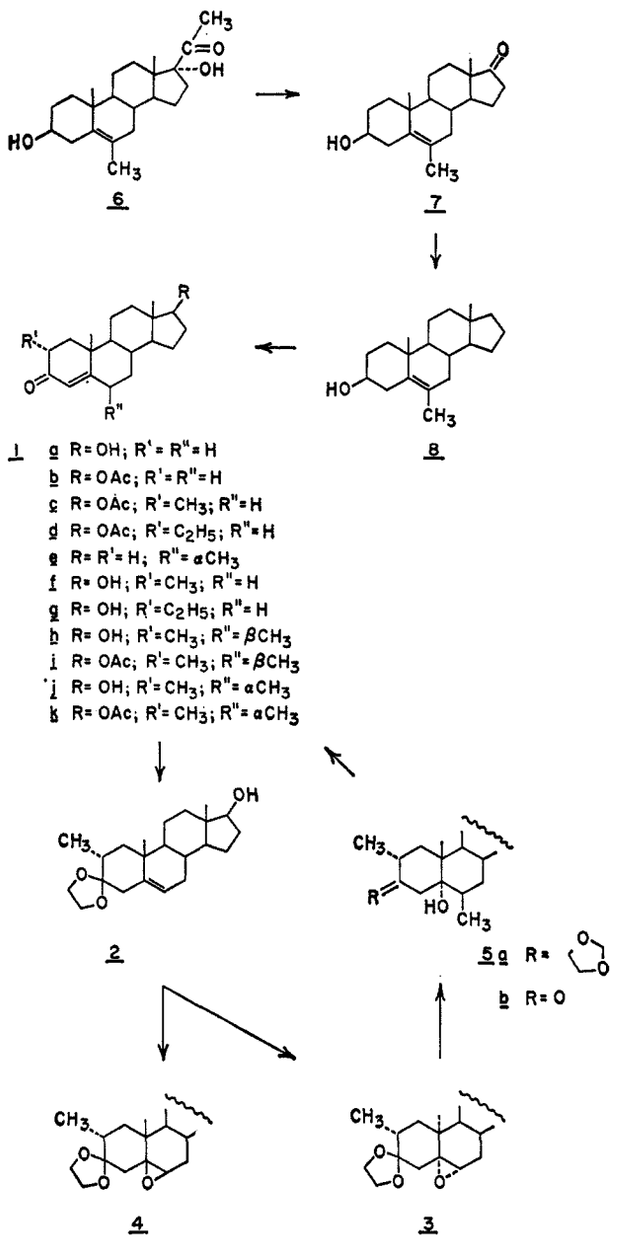
(17) A. J. Liston and M. Howarth, *J. Org. Chem.*, **32**, 1034 (1967).

(18) The oxidation of 3-hydroxy Δ⁵-steroids by chromic acid or chromium trioxide is known to give erratic results;[19] however, the milder pyridine–chromium trioxide reagent was used in an attempt to prepare the Δ⁴-3-ketone **1e**. By allowing compound **8** to stand at room temperature in the presence of an excess of oxidizing agent for 40 hr, a 20% yield of 6β-hydroxy-6α-methylandrost-4-en-3-one (**16**) was isolated. The stereochemistry at C-6 was assigned on the basis of the nmr spectrum. The location of the C-19 angular methyl signal at 85 Hz was in agreement with the calculated value whereas the epimeric compound would be expected to have the C-19 signal at 75 Hz.[15a]

(19) L. F. Fieser and M. Fieser, "Steroids," Reinhold Publishing Corp., New York, N. Y., 1959, p 202.

(20) (a) R. H. Cox and E. Y. Spencer, *Can. J. Chem.*, **29**, 398 (1951); (b) U. Westphal, *Naturwissenschaften*, **24**, 696 (1936); (c) U. Westphal, *Ber.*, **70**, 2128 (1937).

SCHEME I



The major constituent **13a** of the reaction mixture was isolated by column chromatography. The mass spectrum of the product demonstrated a molecular ion peak at *m/e* 470 and the uv spectrum with a maximum at 288 mμ suggested a complex polyacetylation product. The salient features of the nmr spectrum were a vinylic one-proton singlet, a one-proton multiplet due to a hydrogen geminal with an acetate function,[21] five methyl signals between 98 and 130 Hz, and two angular methyl signals. The lack of the 2α-methyl doublet at δ 0.98, observed in spectrum of compound **10a**, indicated a $\Delta^{2,4}$-dienic structure. The 6-(1′-acetoxyethylidene)-3,17β-diacetoxy-2α-methylandrosta-2,4-diene (**13a**) structure was assigned to the compound. The assignment was verified by mild saponification with aqueous sodium acetate[4] which yielded a mixture of epimeric C-6 methyl ketones of which 6β-acetyl-17β-acetoxy-2α-methylandrost-4-en-3-one (**15a**) was the major constituent. The compounds were separated by column chromatography and the major constituent **15a** had a uv maximum (246 mμ) which shifted (to 428 mμ) in ethanolic potassium hydroxide. The bathochromic shift in base and the location of these maxima is characteristic for the 6-acetyl-Δ^4-3-ketone chromophore.[2,4] The nmr spectrum of the compound was consistent with structure **15a**, the signals due to the methyl ketone appearing at δ 2.12 and the 6α hydrogen as a doublet centered at δ 3.24 with J = 4.5 Hz. These features of the spectrum were identical with those of 6β-acetyl-17β-acetoxyandrost-4-en-3-one previously prepared.[2,4] The minor constituent of the mixture, the 6α-acetyl derivative was isolated and demonstrated a uv spectrum (240 mμ) which underwent a bathochromic shift under alkaline conditions (to 428 mμ). Insufficient material was available to characterize the product completely.

The second constituent **14a** of the reaction product was isolated by column chromatography and its nmr spectrum indicated one angular methyl signal (C-18), four methyl signals at lower field (δ 2.25–2.05), and a single olefinic proton signal. The molecular weight determined by mass spectrometry was 384 which suggested the molecular formula $C_{24}H_{37}O_4$. The ir and uv spectra were consistent with a phenolic steroid in which migration of the angular methyl group *via* dienone–phenol rearrangement had occurred. If the transformation follows the conventional dienone–phenol type of rearrangement the product could have the aromatic methyl substituents at positions 1 and 2, 2 and 3, or 2 and 4.[22,23] It was not possible to predict the mechanistic pathway since previous examples of this rearrangement were limited to steroids having three or more double bonds in the ring A and B portion of the steroid[24] and hence did not involve an oxidative step.

Proof that the compound was in fact 1,17β-diacetoxy-2,4-dimethylestra-1,3,5(10)-triene (**14a**) was obtained by independent synthesis. The compound was prepared from **1f** by selenium dioxide dehydrogenation[25] to yield the dienone **11a**. Dienone–phenol rearrangement was carried out in acetic anhydride–*p*-toluenesulfonic acid.[24] The product was identical with the compound isolated in the enol acetylation of **1c**. The identity was further confirmed by saponification of the acetate functions and by comparing the 2,4-dimethylestra-1,3,5(10)-triene-1,17β-diol (**14c**) with authentic material.

The enol acetylation of 17β-acetoxy-2α-ethylandrost-4-en-3-one (**1d**) was studied using identical conditions. The $\Delta^{3,5}$-dienol diacetate **10b** was prepared by the isopropenyl acetate method and identified by comparison of its spectral properties with those of the corresponding 2α-methyl derivative **10a**. Treatment of the dienol diacetate **10b** with perchloric acid–acetic anhydride mixture gave similar results. Two major products were detected by glpc analysis and separated by column chromatography. The major constituent (90%) was 6-(1′-acetoxyethylidene)-3,17β-diacetoxy-2-ethylandrosta-2,4-diene (**13b**). The compound was identified by mass spectrometry and by comparison of its

(21) S. G. Levine, N. H. Eudy, and C. F. Leffler, *J. Org. Chem.*, **31**, 3995 (1966).

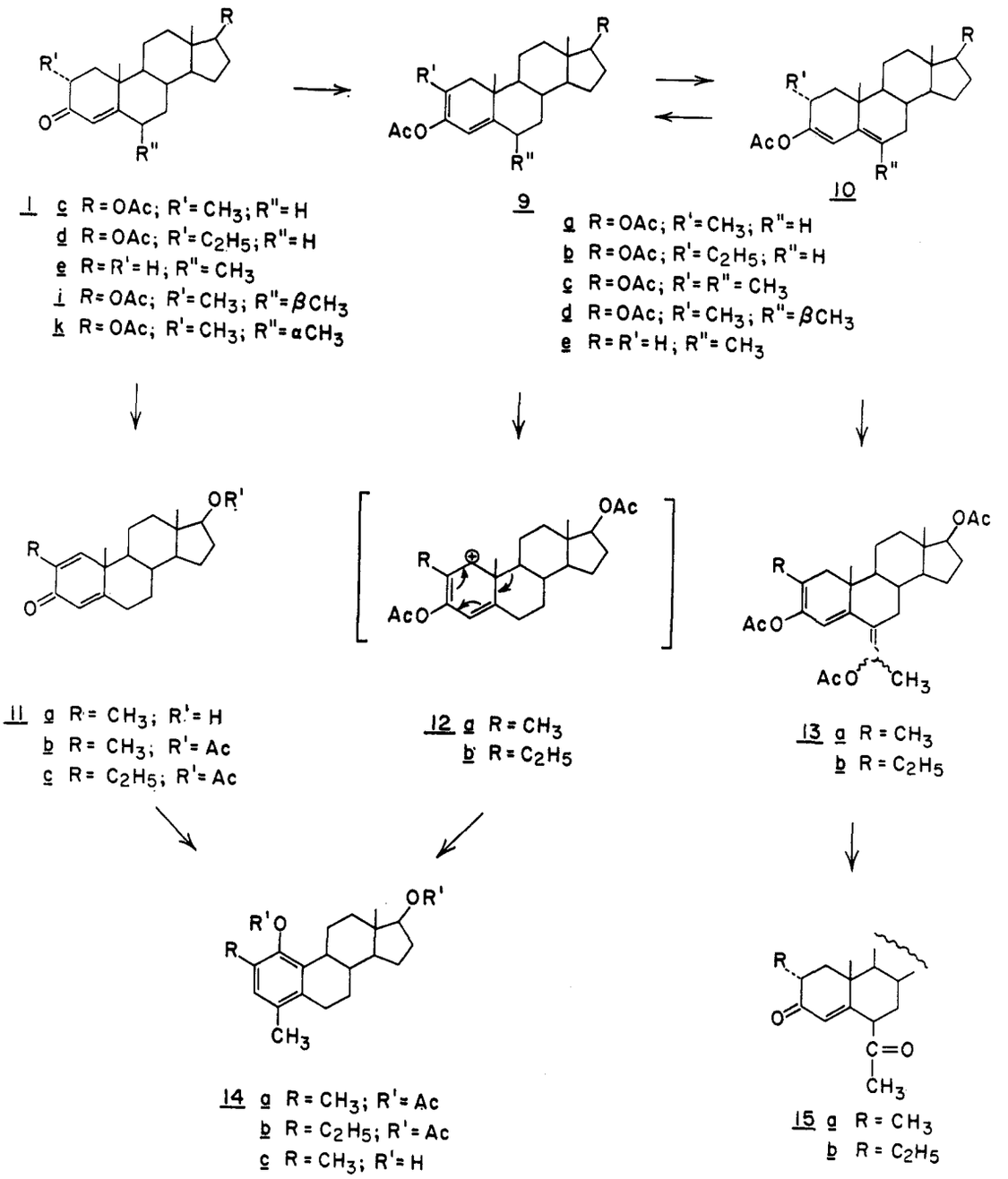
(22) R. B. Woodward and T. Singh, *J. Amer. Chem. Soc.*, **72**, 429 (1950).

(23) W. H. Hopff and A. S. Dreiding, *Angew. Chem. Intern. Ed. Eng.*, **4**, 690 (1965).

(24) C. Djerassi, "Steroid Reactions," Holden-Day Inc., San Francisco, Calif., 1963, p 373.

(25) J. Iriarte and H. J. Ringold, *Tetrahedron*, **3**, 28 (1958).

SCHEME II



spectral properties with those of the 2α analog **13a**. The structure **13b** was confirmed by saponification with aqueous sodium acetate to yield a mixture of C-6 epimers of 17β-acetoxy-6-acetyl-2α-ethylandrost-4-en-3-one (**15b**). The minor constituent of the reaction (10%) was 1,17β-diacetoxy-2-ethyl-4-methylestra-1,3,5(10)-triene (**14b**).[26] The compound demonstrated the necessary spectral properties for the assigned structure. The proof of structure was obtained by independent synthesis of the compound *via* the intermediate 17β-acetoxy-2-ethylandrost-1,4-dien-3-one (**11c**) which was subjected to the dienone–phenol rearrangement.

(26) The content of transformation product **14b** was difficult to assess accurately by glpc analysis because the peak was coincident with that of the $\Delta^{3,5}$-dienol diacetate **10b**. The estimate was made at that point when there was no further variation in the peak height relative to that of the major product **13b**.

Treatment of 2α,6β-dimethyl-17β-hydroxyandrost-4-en-3-one (**1h**) with isopropenyl acetate gave a mixture of enol acetates which varied with the catalyst used in the reaction. Using sulfuric acid catalyst the ratio of $\Delta^{3,5}$- (**10c**) to $\Delta^{2,4}$-dienol acetate (**9d**) was 85:15. When *p*-toluenesulfonic acid was used as catalyst the ratio of products formed was 50:50. The compounds were separated by column chromatography using 10% silver nitrate on Florisil. The $\Delta^{3,5}$-dienol acetate **10c** was identified by comparison of its spectral properties with those of the previously prepared 2α-methyl analog (**10a**). The $\Delta^{2,4}$-dienol diacetate **9d** structure was assigned on the basis of its uv spectrum (269 mμ which is characteristic for a homoannular diene. Proof that the compound was isomeric with **10c** was obtained by treating the dienol diacetate **9d** with the perchloric acid–acetic anhydride mixture. The com-

pound was completely isomerized to the $\Delta^{3,5}$-dienol diacetate **10c** at room temperature within 30 min. The *p*-toluenesulfonic acid catalyzed isopropenyl acetate enol acetylation of the epimeric 2α,6α-dimethyl steroid **1k** yielded a single $\Delta^{3,5}$-dienol diacetate **10c**.

Isopropenyl acetate enol acetylation of 6α-methylandrost-4-en-3-one (**1e**) gave a single enol acetate, 3-acetoxy-6-methylandrosta-3,5-diene (**10e**), which was stable to the perchloric acid–acetic anhydride equilibrating conditions. The structural assignment was made on the basis of the nmr and uv spectra.

Traces of phenolic products (3%) have previously been detected in the perchloric acid catalyzed enol acetylation of Δ^1-3-oxo-5α steroids.[27] The formation of such compounds was ascribed to dienone–phenol rearrangement of an intermediate 1,4-dien-3-one which arose from perchloric acid oxidation of the starting Δ^1-3-ketone. This hypothesis was tested by treating compound **1f** under the perchloric acid conditions except that acetic acid was substituted for the anhydride. Careful glpc analysis of the mixture at 24 hr revealed no trace of secondary products. Similarly glpc analysis of the crude acetylation product of **1c** was devoid of a signal which corresponded to the proposed intermediate **11a**.[28] These results signify that the transformation of the 2α-methyl steroid **10a** does not occur by the intermediacy of an oxidation product formed directly by the action of perchloric acid to give a dienone which subsequently undergoes conventional dienone–phenol rearrangement.

Discussion

Examination of the perchloric acid catalyzed enol acetylation results indicates that only two model compounds formed phenolic products; the 2α-methyl steroid **1c** formed 22.8% **14a** and the 2α-ethyl compound **1d** formed 10% **14b**. These results suggest that in compounds such as **1b**, **1e**, and **1i** where the $\Delta^{3,5}$-dienol acetate structure **10** would be expected to be more stable there is no formation of phenolic products. However, in those compounds where the 2-alkyl substituent stabilizes the $\Delta^{2,4}$-dienol acetate structure **9** phenolic products are formed. Since the 2-methyl substituent has a greater hyperconjugative effect than the 2-ethyl substituent it is consistent that more phenol is formed in the methyl series if the transformation is dependent on $\Delta^{2,4}$-dienol acetate formation.

It has been suggested that acetylium ion can cause hydride abstraction to produce acetaldehyde but the latter was neither isolated nor identified.[29] To determine if hydride abstraction was in fact the oxidative step, the crude reaction mixture was treated with dinitrophenylhydrazine reagent and the product examined by tlc. Acetaldehyde dinitrophenylhydrazone was isolated and its identity was established by mixture melting point with authentic material.

From previous work it has been shown that in an unsubstituted Δ^4-3-ketone such as **1a** there is formation of an intermediate $\Delta^{2,4}$-dienol acetate which is C acylated at the 2 position.[2] When a 2-alkyl substituent is present the formation of $\Delta^{2,4}$-dienol acetate is favored[30,31] but the C-acylation reaction is prohibited.[4] Under these conditions hydride abstraction plays a significant role. The allylically activated hydrogens at C-1 are the most likely candidates for abstraction. Delocalization of the charge in **12** results in an intermediate which is capable of undergoing a dienone–phenol type of rearrangement to give structure **14**.

Further evidence for the stability of the $\Delta^{2,4}$-dienic system in the 2-alkylated steroids may be derived from the arrangement of double bonds in the C-6 acylated products that are formed. In compound **13a** the precursor is probably a methyl ketone **15a** which results from acetylium ion attack on the $\Delta^{3,5}$-dienol acetate **10a**. Enol acetylation of the C-6 acyl compound would be expected to yield 6-acetyl-3,17β-diacetoxyandrosta-3,5-diene.[2] In contrast, the stability of the $\Delta^{2,4}$-diene system is such that the compound undergoes further O acylation to yield the $\Delta^{2,4}$-ethylidene derivative **13a**.[32]

The lack of C-acylation products in the perchloric acid catalyzed enol acetylation of **1i** is in accord with the results obtained by Gorodetsky with similar compounds.[4] In this case, the hyperconjugative effects cancel each other and the $\Delta^{3,5}$-diene **10c** is the most stable product.

The isopropenyl acetate enol acetylation of **1i** is surprising in view of previous results.[2] The Δ^4-3-ketone group usually forms the $\Delta^{3,5}$-dienol acetate; however, with the 2α and 6β substituents a 1:1 mixture of dienol acetates **9d** and **10c** was obtained. When the reaction was carried out with the C-6 epimer **1k** only a single enol acetate **10c** was formed. These results indicate that under the isopropenyl acetate enol acetylation conditions the 6β axial proton is lost more readily than the 6α equatorial proton.[16,33]

Further insight into the behavior of these steroids toward O and C acylation can be derived from the perchloric acid catalyzed enol acetylation of **1e**. In this structure the hyperconjugative effect stabilizes the $\Delta^{3,5}$-dienol acetate **10e** to such an extent that the transient formation of **9e** is forbidden and C-2 acylation does not occur. This contrasts sharply with the behavior of testosterone which under these conditions forms predominantly the C-2 acylation product.[2]

Experimental Section

General.—Melting points were determined on an Electrothermal apparatus by the capillary method and are corrected. Rotations were measured in chloroform solution. The ir spectra were recorded on a Perkin-Elmer Model 237B double-beam spectrophotometer. The uv spectra were determined in ethanol solution using a Bausch and Lomb Spectronic 502 recording spectrophotometer. The nmr spectra were determined on a Varian A-60A spectrometer in deuteriochloroform with tetramethylsilane as an internal standard. Hydroxyl proton signals were detected by hydrogen–deuterium exchange with D_2O. The mass spectra were determined on a Hitachi–Perkin-Elmer

(27) O. R. Rodig and G. Zanati, *J. Org. Chem.*, **32**, 1423 (1967).

(28) Under the reaction conditions used the dienone–phenol rearrangement of **11a** was complete in approximately 10 min. The glpc conditions used were such that approximately 0.25% **11a** would have been detected.

(29) (a) G. Baddeley and E. Wrench, *J. Chem. Soc.*, 1324 (1959); (b) G. Baddeley, B. G. Heaton, and J. W. Rasburn, *ibid.*, 4713 (1960).

(30) The hyperconjugative effect is known to be the dominant factor in determining the direction in which an unsymmetrical ketone will enolize under acid conditions.[31]

(31) (a) W. D. Emmons and M. F. Hawthorne, *J. Amer. Chem. Soc.*, **78**, 5593 (1956); (b) H. M. E. Cardwell and A. E. H. Kilmer, *J. Chem. Soc.*, 2430 (1951).

(32) There are two possible geometrical isomers for compound **13**, but only a single product could be detected. An examination of Dreiding models suggested that the isomer with the acetoxyl group on the same side as the C-4 vinylic proton is the more probable.

(33) E. J. Corey and R. A. Sneen, *J. Amer. Chem. Soc.*, **78**, 6269 (1956).

RMU-6D spectrometer. Gas chromatography was carried out on a Model 810 F & M gas chromatograph equipped with dual flame detectors. The columns were 5% fluorosilicone FS-1265 (QF-1) on 60–80 mesh Diatoport S, 8 ft × 4 mm o.d. The carrier gas was helium at a flow rate of 60 ml/min and the column temperature was 230°. Quantitative estimation of components was made by triangulation of the signals.

17β-Hydroxy-2α-methylandrost-4-en-3-one (1f).—Testosterone (**1a**, 10 g) was dissolved in absolute ethanol (50 ml) and treated with a solution of sodium (2 g) and ethyl oxalate (10 ml) in absolute ethanol (50 ml). The reaction mixture was cooled to 0° and left overnight. The solution was brought to pH 3 with 3 *N* sulfuric acid and the mixture was partitioned between ether (500 ml) and water (1 l.). The organic layer was washed with saturated sodium bicarbonate solution, salt solution, and dried ($MgSO_4$). The crude ethoxyoxalyl derivative (12.6 g) was analyzed by tlc using benzene–ethanol 8:1 and was found to be free of starting material. The oxalyl derivative in acetone (350 ml) was refluxed (24 hr) with a mixture of methyl iodide (50 ml) and anhydrous potassium carbonate (25 g). The solvent was evaporated and the residue partitioned between ether (500 ml) and water (500 ml). The organic layer was dried ($MgSO_4$) and the solvent was evaporated leaving crude 2-methyl-2-ethoxyoxalyl derivative (12.0 g). The product was dissolved in methanol (150 ml) and treated with sodium methoxide (3.5 g) in methanol (65 ml) for 1 hr. The reaction mixture was acidified (pH 5) with acetic acid and the solvent was evaporated to dryness. The residue was crystallized from acetone–ether yielding 17β-hydroxy-2α-methylandrost-4-en-3-one (**1f**, 8.3 g): mp 155–158°; $[\alpha]^{26}D$ +108° (*c* 1.0) (lit.[5] mp 149–153°).

17β-Acetoxy-2α-methylandrost-4-en-3-one (1c).—Acetylation of 17β-hydroxy-2α-methylandrost-4-en-3-one (**1f**, 1 g) by the usual method using pyridine–acetic anhydride afforded the 17β-acetate **1c** which was crystallized from acetone–hexane (860 mg): mp 179–180°; $[\alpha]^{26}D$ +96.5° (*c* 1.0); uv max 240 mμ (ε 14,500); ir (CCl_4) 1675 (C=O), 1623 (C=C), 1740 cm^{-1} (ester C=O).

Anal.[34] Calcd for $C_{22}H_{32}O_3$: C, 76.64; H, 9.50. Found: C, 76.36; H, 9.34.

17β-Hydroxy-2α-ethylandrost-4-en-3-one (1g).—The ethoxalylation of testosterone (**1a**, 10 g) was carried out as previously described. The alkylation procedure was carried out with ethyl iodide (80 ml) using an extended reflux of 80 hr. The crude product **1g** (2.3 g) was purified by column chromatography over Florisil (120 g) and the product was eluted with benzene–hexane 19:1. Crystallization from acetone–hexane gave **1g** (960 mg): mp 112–113°; $[\alpha]^{26}D$ +118° (*c* 1.0); uv max 241 mμ (ε 14,800); ir (CCl_4) 1675 (C=O), 1625 cm^{-1} (C=C); nmr δ 0.80 (s, 3, 18-H_3), 1.21 (s, 3, 19-H_3), 1.03 (t, 3, *J* = 6.5 Hz, 2-CH_2CH_3), 5.70 (s, 1, 4-H).

Anal. Calcd for $C_{21}H_{32}O_2$: C, 79.70; H, 10.19. Found: C, 79.59; H, 10.38.

17β-Acetoxy-2α-ethylandrost-4-en-3-one (1d).—Acetylation of 17β-hydroxy-2α-ethylandrost-4-en-3-one (**1g**, 900 mg) using pyridine–acetic anhydride gave the corresponding 17β-acetate **1d**, which crystallized from acetone–hexane (800 mg): mp 135–137°; $[\alpha]^{26}D$ +76.5 (*c* 1.1); uv max 240 mμ (ε 14,500); ir (CCl_4) 1740 (ester C=O), 1680 (C=O), 1627 cm^{-1} (C=C).

Anal. Calcd for $C_{23}H_{34}O_3$: C, 77.05; H, 9.56. Found: C, 77.01; H, 9.68.

3,3-Ethylenedioxy-2α-methylandrost-5-en-17β-ol (2).—A solution of 17β-hydroxy-2α-methylandrost-4-en-3-one (**1f**, 4.25 g) in ethylene glycol (215 ml) containing *p*-toluenesulfonic acid (425 mg) was distilled slowly (4 hr) *in vacuo* to half-volume, the bath temperature being kept below 90°. The reaction mixture was cooled and poured into 1% aqueous pyridine (1 l.) and stirred for 15 min. The suspension was filtered and the solid was washed with water. The crude product **2** (3.6 g) was dried under vacuum and recrystallized from acetone–hexane (3 g): mp 176–178°; $[\alpha]^{29}D$ −8.3° (*c* 1.0); ir (CCl_4) 3500 and 3625 (OH), 1668 (C=C), 1090 and 1046 cm^{-1} (ketal); nmr δ 0.76 (s, 3, 18-H_3), 1.06 (s, 3, 19-H_3), 0.86 (d, 3, *J* = 6.5 Hz, 2-CH_3), 3.65 (m, 1, 17-**H**), 3.95 [s, 4, $(CH_2)_2O_2C$-3], 5.26 (m, 1, 6-H).

Anal. Calcd for $C_{22}H_{34}O_3$: C, 76.26; H, 9.89. Found: C, 75.82; H, 9.93.

3,3-Ethylenedioxy-5α,6α-epoxy-2α-methylandrostan-17β-ol (3).—To a chilled solution of 3,3-ethylenedioxy-2α-methylandrost-5-en-17β-ol (**2**, 23 g) in anhydrous benzene (890 ml) was added a chilled solution of *m*-chloroperbenzoic acid (13.2 g) in chloroform (50 ml). The solution was stored at 8° and the crude product monitored by glpc analysis. The latter demonstrated that 50 hr was the optimum reaction time. The analysis indicated that there was formed 30% 5β,6β-epoxide **4** and 70% 5α,6α-epoxide **3**. The reaction mixture was washed with bicarbonate solution (150 ml) and sodium chloride solution until neutral and dried (Na_2SO_4). The solvent was removed and the product chromatographed over Florisil (250 g). Elution with benzene removed the 5β,6β-epoxide along with some hydrolyzed ketal. Further elution of the column with benzene–ether 9:1 gave 3,3-ethylenedioxy-5α,6α-epoxy-2α-methylandrostan-17β-ol (**3**, 5.7 g): mp 224–226°; $[\alpha]^{28}D$ −20.3° (*c* 1.1); ir (CCl_4) 3620 (OH), 1090, 1045 and 1023 cm^{-1} (ketal); nmr δ 0.72 (s, 3, 18-H_3), 0.94 (d, 3, *J* = 6.5 Hz, 2-CH_3), 1.11 (s, 3, 19-H_3), 2.78 (d, 1, *J* = 4 Hz, 6-H).

Anal. Calcd for $C_{22}H_{34}O_4$: C, 72.89; H, 9.45. Found: C, 73.22; H, 9.23.

3,3-Ethylenedioxy-5β,6β-epoxy-2α-methylandrostan-17β-ol (4).—The crude mixture of epoxide **4** and hydrolyzed starting material **1f** isolated from the above column was crystallized from acetone–1% pyridine. The analytical specimen of **4** had mp 216–217.5°; $[\alpha]^{28}D$ −1.4° (*c* 1.1); ir (CCl_4) 3620 (OH), 1090 and 1050 cm^{-1} (ketal); nmr δ 0.73 (s, 3, 18-H_3), 0.87 (d, 3, *J* = 6 Hz, 2-CH_3), 1.06 (s, 3, 19-H_3), 3.03 (d, 1, *J* = 2.5 Hz, 6-H), 3.92 [s, 4, $(CH_2)_2O_2C$-3].

Anal. Calcd for $C_{22}H_{34}O_4$: C, 72.89; H, 9.45. Found: C, 73.18; H, 9.61.

3,3-Ethylenedioxy-2α,6β-dimethylandrostane-5α,17β-diol (5a).—To anhydrous ether (10 ml) was added ether-washed magnesium turnings (470 mg) and methyl iodide (1.3 ml). The mixture was refluxed under nitrogen until dissolution of the metal was complete. A solution of 3,3-ethylenedioxy-5α,6α-epoxy-2α-methylandrostan-17β-ol (**3**, 1.04 g) in tetrahydrofuran (100 ml) was added and refluxed for 78 hr. The reaction was quenched by addition of saturated NH_4Cl solution until all of the salts dissolved. The supernatant liquid was decanted and the aqueous portion washed with dichloromethane (200 ml). The organic portions were combined, and evaporated to dryness. The residue was partitioned between methylene chloride (100 ml) and brine (100 ml), dried (Na_2SO_4), and the solvent evaporated leaving crude material (940 mg). Recrystallization from acetone–hexane gave **5a** (835 mg): mp 225–226°; $[\alpha]^{28}D$ −15.2° (*c* 0.98); ir (CCl_4) 3630, 3520 (OH), 1090, and 1048 cm^{-1} (ketal). The compound was homogeneous by glpc analysis.

Anal. Calcd for $C_{23}H_{38}O_4$: C, 72.97; H, 10.11. Found: C, 72.04; H, 10.07.

5α,17β-Dihydroxy-2α,6β-dimethylandrostan-3-one (5b).—A solution of 3,3-ethylenedioxy-2α,6β-dimethylandrostane-5α,17β-diol (56 mg) in 75% acetic acid (6 ml) was heated on a steam bath for 45 min and the solvents removed under vacuum. The residue was dissolved in ether (25 ml) and washed with sodium bicarbonate solution and brine. The solution was dried (Na_2SO_4), the solvent removed, and the residue crystallized from acetone–hexane to yield **5b** (33 mg): mp 112–114° (with decomposition); $[\alpha]^{27}D$ −7.9° (*c* 0.7); ir (CCl_4) 3640 (OH), 1715 cm^{-1} (C=O); nmr δ 0.78 (s, 3, 18-H_3), 1.30 (d, 3, *J* = 6.5 Hz, $CHCH_3$), and 1.07 (d, 3, *J* = 7 Hz, $CHCH_3$).

Anal. Calcd for $C_{21}H_{34}O_3$: C, 75.40; H, 10.25. Found: C, 75.32; H, 10.42.

17β-Hydroxy-2α,6β-dimethylandrost-4-en-3-one (1h).—A solution of 5α,17β-dihydroxy-2α,6β-dimethylandrostan-3-one (400 mg) in 50% aqueous methanolic sodium hydroxide solution (76 ml of 0.05 *N*) was stirred at room temperature under nitrogen for 17 hr. Acetic acid (4 ml) was then added and the mixture concentrated to half-volume. The reaction product was extracted with ether (150 ml), washed with brine, and dried (Na_2SO_4). The solvent was removed and the residue was crystallized from acetone–hexane to yield **1h** (200 mg): mp 190–191°; $[\alpha]^{28}D$ 56.8° (*c* 1.0); uv max 241 mμ (ε 15,500); ir (CCl_4) 3620 (OH), 1680 (C=O) 1615 cm^{-1} (C=C); nmr δ 0.81 (s, 3, 18-H_3), 1.09 (d, 3, *J* = 7 Hz, $CHCH_3$), 1.21 (d, 3, *J* = 8 Hz, $CHCH_3$), 1.28 (s, 3, 19-H_3), and 4.75 (s, 1, 4-H).

Anal. Calcd for $C_{21}H_{32}O_2$: C, 79.69; H, 10.19. Found: C, 79.62; H, 10.32.

17β-Acetoxy-2α,6α-dimethylandrost-4-en-3-one (1k).—To a solution of 17β-hydroxy-2α,6β-dimethylandrost-4-en-3-one (**1h**, 64 mg) in benzene (10 ml) was added *p*-toluenesulfonic acid (15 mg) and the solution was refluxed until glpc analysis indicated

(34) Microanalyses were performed by Schwarzkopf Microanalytical Laboratories, Woodside, N. Y.

complete conversion (3.5 hr) to the isomeric 17β-hydroxy-2α,6α-dimethylandrost-4-en-3-one (**1j**). The solution was poured into sodium bicarbonate solution (20 ml) and the organic layer was washed with brine, dried (Na_2SO_4), and the solvent was evaporated. The residual oil (54 mg), homogeneous by glpc and tlc, failed to crystallize. The nmr spectrum ($CDCl_3$) showed δ 0.80 (s, 3, 18-H_3), 1.05, 1.12, 1.16, 1.23, and 1.26 (a series of methyl signals in which assignments could not be made), 5.80 (d, 1, J = 2 Hz, 4-H). The compound was acetylated using pyridine–acetic anhydride reagent and the corresponding acetate **1k** failed to crystallize from the usual solvents: $[\alpha]^{28}D$ +62.5° (*c* 0.5); ir (CCl_4) 1731 (ester), 1668 (C=O), and 1618 cm^{-1} (C=C).

6-Methylpregn-5-ene-3β,17α,20ξ-triol.—3β,17α-Dihydroxy-6-methylpregn-5-en-20-one (**6**, 10.046 g) in absolute ethanol (500 ml) was treated with sodium borohydride (12.2 g), and the reactants were refluxed with stirring for 3.5 hr. The mixture was evaporated to dryness under reduced pressure, and the residue was extracted with dichloromethane. The organic solution was washed with brine and dried (Na_2SO_4), and the solvent was evaporated. The residue (9.7 g), a mixture of C-20 epimeric compounds, had no absorption in the carbonyl region of the infrared spectrum, and was not purified further but used directly in the next experiment.

3β-Hydroxy-6-methylandrost-5-en-17-one (**7**).—Sodium periodate (11.3 g) in water (100 ml) was added dropwise with stirring to an ice-cold solution of 6-methylpregn-5-ene-3β,17α,20ξ-triol (9.7 g) in ethanol (300 ml). When the addition was complete the ice bath was removed and the mixture was stirred at room temperature for 6 hr. The mixture was poured into ice–water (2 l.) and refrigerated overnight to crystallize. The product (**7**, 5.15 g) was collected by filtration and recrystallized from acetone: mp 146.5–148°; $[\alpha]^{28}D$ +5.6° (*c* 1.2); ir (CCl_4) 3625 (OH), 1740 (C=O) and 1045 cm^{-1}.

Anal. Calcd for $C_{20}H_{30}O_2 \cdot 0.5(CH_3)_2CO$: C, 77.90; H, 10.03. Found: C, 78.07; H, 10.03.

6-Methylandrost-5-en-3β-ol (**8**).—3-Hydroxy-6-methylandrost-5-en-17-one (6.4 g) in diethylene glycol (250 mg) was treated with 95% anhydrous hydrazine (50 ml) and potassium hydroxide (20 g). The reactants were refluxed (reflux temperature 155°) for 1.5 hr, and then hydrazine and water were distilled off until the temperature reached 203°. The reaction mixture was refluxed for a further 6 hr at 203°, then cooled to room temperature, and water (1.5 l.) was added. The resulting crystals were filtered off, washed with water, dried at 60°, and recrystallized from acetone–hexane to yield 6-methylandrost-5-en-3β-ol (**8**, 4.96 g): mp 138–139°; $[\alpha]^{29}D$ −34.6° (*c* 1.0); ir (CCl_4) 3625, 1374, 1055 and 1045 cm^{-1}; nmr δ 0.74 (s, 3, 18-H_3), 1.01 (s, 3, 19-H_3), 1.63 (s, 3, 6-CH_3), and 3.70 (s, 1, OH).

Anal. Calcd for $C_{20}H_{32}O$: C, 83.27; H, 11.18. Found: C, 83.49; H, 11.34.

Oxidation of 6-Methylandrost-5-en-3β-ol (**8**) **with Chromic Oxide–Pyridine Reagent.**—6-Methylandrost-5-en-3β-ol (4.8 g) was added with stirring to a slurry of chromic oxide (7 g) and pyridine (150 ml). The reactants were kept at room temperature overnight, and more chromic oxide (3 g) in pyridine (40 ml) was added. After 40 hr of reaction ether (500 ml) was added and the mixture was filtered through Celite. The residue was washed with ether, and the filtrate and washings were washed with saturated sodium bicarbonate solution, water, 2 *N* hydrochloric acid, brine, and dried (Na_2SO_4). The solvent was evaporated and the residue (3.5 g) was taken up in benzene and adsorbed on to a column of Florisil (200 g). Elution with benzene–ether (9:1) and crystallization of the product from acetone–hexane afforded 6β-hydroxy-6α-methylandrost-4-en-3-one (**16**, 923 mg): mp 211–213.5°; $[\alpha]^{28}D$ +3.3° (*c* 1.2); uv max 239 mμ (ε 8900); ir (CCl_4) 3600 (OH), 1675 cm^{-1} (C=C—C=O); nmr δ 0.80 (s, 3, C_{18}-H_3), 1.42 and shoulder at 1.41 (s, 6, 19-H_3 and 6-$OHCH_3$), 1.60 (s, 1, OH), and 6.01 (s, 1, 4-H); mass spectrum *m/e* (relative intensity) 302 (9), 260 (100), 149 (15), and 135 (16).

Anal. Calcd for $C_{20}H_{30}O_2$: C, 79.42; H, 10.00. Found: C, 79.51; H, 10.19.

6α-Methylandrost-4-en-3-one (**1e**).—6-Methylandrost-5-en-3β-ol (**8**, 4.16 g) in dry benzene (100 ml) was treated with aluminum *t*-butoxide (5.5 g) and cyclohexanone (12 ml). The mixture was refluxed for 18 hr and then cooled to room temperature. The reaction mixture was diluted with ether and washed with dilute sulfuric acid, sodium bicarbonate solution, and brine, and then dried (Na_2SO_4). The solvent was evaporated and the residual oil was taken up in hexane and adsorbed onto a column of Florisil (200 g). Elution with hexane removed cyclohexanone and cyclohexanol. Further elution with benzene afforded 6α-methylandrost-4-en-3-one (**1e**, 1.628 g): mp 117–118°; $[\alpha]^{28}D$ +95.5° (*c* 1.1); uv max 241 mμ (ε 14,500); ir (CCl_4) 1675, shoulder at 1680 (C=C–C=O), 1610 (C=C), 1375, and 1265 cm^{-1}; nmr δ 0.77 (s, 3, 18-H_3), and 5.82 (d, 1, J = 1.6 Hz, 4-H).

Anal. Calcd for $C_{20}H_{30}O$: C, 83.86; H, 10.56. Found: C, 83.94; H, 10.76.

3,17β-Diacetoxy-2α-methylandrosta-3,5-diene (**10a**).—17β-Hydroxy-2α-methylandrost-4-en-3-one (**1f**, 5 g) was suspended in isopropenyl acetate (50 ml) and treated with sulfuric acid (0.02 ml). The solution was refluxed under nitrogen for 2 hr, and then cooled and diluted with ether (200 ml). The ether solution was washed with saturated aqueous sodium bicarbonate and brine, dried (Na_2SO_4), and the solvent was evaporated. The residue was taken up in benzene and filtered through a short column of Florisil to remove coloration. The filtrate was evaporated and the residue was crystallized from ethanol–1% pyridine to yield 3,17β-diacetoxy-2α-methylandrosta-3,5-diene (**10a**, 3.3 g): mp 169–171°; $[\alpha]^{31}D$ −30° (*c* 1.0); uv max 237 mμ (ε 17,050); ir (CCl_4) 1748 (C=COCOCH$_3$), 1723 (-OCOCH$_3$), 1659 and 1632 cm^{-1} (C=C); nmr δ 0.83 (s, 3, 18-H_3), 0.96 (d, 3, J = 4.5 Hz, 2-CH_3), 1.06 (s, 3, 19-H_3), 2.03 (s, 3, 17-OCOCH$_3$), 2.12 (s, 3, 3-OCOCH$_3$), 5.36 (m, 1, 6-H), and 5.64 (d, 1, J = 2.0 Hz, 4-H).

Anal. Calcd for $C_{24}H_{34}O_4$: C, 74.56; H, 8.87. Found: C, 74.76; H, 9.04.

3,17β-Diacetoxy-2α-ethylandrosta-3,5-diene (**10b**).—17β-Hydroxy-2α-ethylandrost-4-en-3-one (**1g**, 883 mg) was treated with isopropenyl acetate (10 ml) and sulfuric acid (0.02 ml) as described for the synthesis of compound **10a**. The product was crystallized from acetone–hexane to give 3,17β-diacetoxy-2α-ethylandrosta-3,5-diene (**10b**, 652 mg): mp 219–221°; $[\alpha]^{28}D$ −29.5° (*c* 1.0); uv max 238 mμ (ε 20,250); ir (CCl_4) 1755 and 1220 (C=COCOCH$_3$), 1735 and 1240 (-OCOCH$_3$), and 1175 cm^{-1}; nmr δ 0.83 (s, 3, 18-H_3), 1.03 (s, 3, 19-H_3), 2.02 (s, 3, 17-OCOCH$_3$), 2.12 (s, 3, 3-OCOCH$_3$), 4.63 (m, 1, 17-H), 5.39 (m, 1, 6-H), and 5.67 (d, 1, J = 2.5 Hz, 4-H); mass spectrum *m/e* (relative intensity) 400 (8), 360 (5), 359 (35), 358 (100), 344 (6), 343 (4), and 147 (6).

Anal. Calcd for $C_{25}H_{36}O_4$: C, 74.96; H, 9.06. Found: C, 75.20; H, 9.05.

Enol Acetylation of 2α,6β-Dimethyl-17β-hydroxyandrost-4-en-3-one (**1h**) **Using Isopropenyl Acetate. A. *p*-Toluenesulfonic Acid Catalyst.**—2α,6β-Dimethyl-17β-hydroxyandrost-4-en-3-one (**1h**, 187 mg) was treated with isopropenyl acetate (10 ml) and *p*-toluenesulfonic acid (23 mg) and the solution was refluxed under nitrogen. Glpc analysis of aliquots of the reaction mixture indicated that the reaction was complete after 3 hr and that two products were formed in approximately equal amounts with retention times of 6.8 and 7.2 min. The reaction was quenched by partitioning between saturated aqueous sodium bicarbonate and ether. The ether layer was washed with brine, dried (Na_2SO_4), and the solvent was evaporated. The residue was taken up in benzene–hexane (1:1) and adsorbed on to a column of Florisil impregnated with 10% silver nitrate. Elution with benzene–hexane (1:1) afforded 3,17β-diacetoxy-2α,6-dimethylandrosta-3,5-diene (**10c**, 51 mg), which crystallized from aqueous methanol: mp 142–144°; $[\alpha]^{27.5}D$ −64.5° (*c* 0.5); uv max 247 mμ (ε 21,467); ir (CCl_4) 1760 and 1225 (>C=COCOCH$_3$), 1740 and 1245 (-OCOCH$_3$), 1660 and 1630 (diene), and 1195 cm^{-1}; nmr δ 0.83 (s, 3, 18-H_3), 0.97 (d, 3, J = 6.4 Hz, 2-CH_3), 1.03 (s, 3, 19-H_3), 1.62 (s, 3, 6-CH_3), 2.04 (s, 3, 17-OCOCH$_3$), 2.16 (s, 3, 3-OCOCH$_3$), 4.65 (m, 1, 17-H), and 6.04 (d, 1, J = 2 Hz, 4-H).

Anal. Calcd for $C_{25}H_{36}O_4$: C, 74.96; H, 9.06. Found: C, 74.85; H, 9.07.

Further elution with benzene yielded 3,17β-diacetoxy-2,6β-dimethylandrosta-2,4-diene (**9d**, 48 mg) which was crystallized from acetone–hexane: mp 154–156°; $[\alpha]^{28.5}D$ +167.3° (*c* 1.0); uv max 269 mμ (ε 10,760); ir (CCl_4) 1760 and 1230 (C=COCOCH$_3$), 1740 and 1245 (-OCOCH$_3$), 1680 (C=C), 1375 and 1124 cm^{-1}; nmr δ 0.83 (s, 3, 18-H_3), 1.03 (s, 3, 19-H_3), 1.15 (d, 3, J = 7.5 Hz, 6-CH_3), 1.60 (s, 3, 2-CH_3), 2.03 (s, 3, 17-OCOCH$_3$), 2.15 (s, 3, 3-OCOCH$_3$), 4.61 (m, 1, 17-H), and 5.38 (s, 1, 4-H).

Anal. Calcd for $C_{25}H_{36}O_4$: C, 74.96; H, 9.06. Found: C, 74.64; H, 8.91.

B. Sulfuric Acid Catalyst.—2α,6β-Dimethyl-17β-hydroxyandrost-4-en-3-one (**1h**, 80 mg) in isopropenyl acetate (15 ml) was treated with sulfuric acid (2 drops), and the mixture was refluxed under nitrogen for 2.5 hr. Glpc analysis of aliquots of

the reaction mixture showed that the reaction was complete after 1 hr and that the reaction mixture consisted of 3,17β-diacetoxy-2α,6-dimethylandrosta-3,5-diene (**10c**) and 3,17β-diacetoxy-2,6β-dimethylandrosta-2,4-dinee (**9d**) in the ratio 85:15.

Enol Acetylation of 17β-Acetoxy-2α,6α-dimethylandrost-4-en-3-one (1k).—To a solution of the title compound **1k** (30 mg) in isopropenyl acetate (3 ml) was added *p*-toluenesulfonic acid (5 mg) and the mixture was refluxed under nitrogen until glpc analysis indicated the reaction was complete (3 hr). A single product could be detected by glpc analysis. The product was isolated as previously described. The crude product was filtered through Florisil and eluted with benzene. The product, 3,17β-diacetoxy-2α,6-dimethylandrosta-3,5-diene (**10c**), was crystallized from aqueous methanol (5 mg): mp 136–141°; mixture melting point with authentic material previously prepared was undepressed.

3-Acetoxy-6-methylandrosta-3,5-diene (10e).—6α-Methylandrost-4-en-3-one (**1e**, 263 mg) was treated with isopropenyl acetate (10 ml) and sulfuric acid (0.01 ml) as described for the synthesis of compound **10a**. The product was crystallized from aqueous methanol to yield 3-acetoxy-6-methylandrosta-3,5-diene (**10e**, 185 mg): mp 86–88°; $[\alpha]^{28}D$ −165.6° (*c* 1.2); uv max 245 mμ (ε 15,200); ir (CCl_4) 1755 and 1225 (C=COCOCH₃), 1660 and 1630 cm^{-1} (diene); nmr δ 0.75 (s, 3, 18-H₃), 0.99 (s, 3, 19-H₃), 1.66 (d, 3, *J* = 0.5 Hz, 6-CH₃), 2.16 (s, 3, 3-OCOCH₃), and 6.13 (d, 1, *J* = 2.0 Hz, 4-H).

Anal. Calcd for $C_{22}H_{32}O_2$: C, 80.44; H, 9.82. Found: C, 80.62; H, 9.99.

Treatment of 3,17β-Diacetoxy-2α-methylandrosta-3,5-diene (10a) with Perchloric Acid–Acetic Anhydride Reagent.—3,17β-Diacetoxy-2α-methylandrosta-3,5-diene (**10a**, 1.25 g) in benzene (200 ml) and carbon tetrachloride (80 ml) was treated with a solution (50 ml) of 70% perchloric acid (0.5 ml) in acetic anhydride (249.5 ml) at room temperature. Glpc analysis of aliquots of the reaction mixture indicated that the reaction was complete after 6 hr, and showed that the products were **14a** (22%, retention time 10.5 min) and **13a** (77.2%, retention time 26.0 min). The reaction was quenched by dilution with sodium bicarbonate solution (100 ml) and ether (100 ml). The organic layer was washed with bicarbonate solution and brine, dried (Na_2SO_4), and the solvent was evaporated. The residue (2.3 g of dark material) was taken up in benzene–hexane (4:1) and adsorbed on to a column of Florisil (200 g). Elution with benzene–ether (200:1) yielded 1,17β-diacetoxy-2,4-dimethylestra-1,3,5(10)-triene (**14a**, 29 mg): mp 184–185.5°; the mixture melting point with authentic compound was undepressed. The mass spectrum had a molecular ion peak at *m/e* 384. Saponification of the acetate groups with alcoholic potassium hydroxide by the usual method yielded 2,4-dimethylestra-1,3,5(10)-triene-1,17β-diol (**14c**): mp 164–166°; the mixture melting point with authentic material was undepressed.

Further elution of the column with benzene–ether (50:1) afforded 6-(1′-acetoxyethylidene)-3,17β-diacetoxy-2-methylandrosta-2,4-diene (**13a**, 120 mg) which was crystallized from ethanol: mp 167–168°; $[\alpha]^{28}D$ +446° (*c* 1.0); uv max 288 mμ (ε 9400); ir (CCl_4) 1750 (C=COCOCH₃), 1735 (-OCOCH₃) and 1680 cm^{-1} (C=C); nmr δ 0.8 (s, 3, 18-H₃), 0.95 (s, 3, 19-H₃), 1.64 (s, 3, 2-CH₃), 2.00 (s, 3), 2.02 (s, 3), 2.12 (s, 3), 2.15 (s, 3), 4.63 (m, 1, 17-H), and 5.42 (s, 1, 4-H); molecular weight by mass spectrometry 470.

Anal. Calcd for $C_{28}H_{38}O_6$: C, 71.46; H, 8.14. Found: C, 71.37; H, 8.09.

6-(1′-Acetoxyethylidene)-3,17β-diacetoxy-2-ethylandrosta-2,4-diene (13b). **A.**—To a stirred solution of 3,17β-diacetoxy-2α-ethylandrosta-3,5-diene (190 mg) in dry benzene (25 ml) and carbon tetrachloride (10 ml) was added a solution (6.4 ml) prepared from acetic anhydride (249.5 ml) and 70% perchloric acid (0.5 ml). Glpc analysis of aliquots of reaction mixture indicated that the reaction was complete after 75 min and that two products were formed. The major constituent (90%) was 6-(1′-acetoxyethylidene)-3,17β-diacetoxy-2-ethylandrosta-2,4-diene (**13b**) and the minor component (10%) was 1,17β-diacetoxy-2-ethyl-4-methylestra-1,3,5(10)-triene (**14b**) whose isolation is described subsequently. The reaction mixture was diluted with ether and washed with saturated sodium bicarbonate solution and water, dried (Na_2SO_4), and the solvent was evaporated. The residue was taken up in benzene–hexane (1:1) and adsorbed on to a column of Florisil (20 g). Elution with benzene–ether (19:1) afforded **13b** (84 mg), which was crystallized from acetone–hexane: mp 184–187°; $[\alpha]^{27.5}D$ +321.3° (*c* 0.3); uv max 293 mμ (ε 10,920); ir (CCl_4) 1755 and 1220 (C=COCOCH₃), 1740 and 1240 cm^{-1} (-OCOCH₃); nmr δ 0.80 (s, 3, 18-H₃), 0.95 (s, 3, 19-H₃), 0.96 (t, 3, *J* = 7 Hz, 2-CH_2CH_3),[35] 1.98 (s, 3), 2.01 (s, 3), 2.12 (s, 3), 2.15 (s, 3), 4.60 (m, 1, 17-H), and 5.42 (s, 1, 4-H); mass spectrum *m/e* (relative intensity) 484 (11), 443 (31), 442 (100), 401 (19), 400 (68) and 121 (31).

Anal. Calcd for $C_{29}H_{40}O_6$: C, 71.87; H, 8.32. Found: C, 71.91; H, 7.98.

B.—2α-Ethyltestosterone (**1g**, 582 mg) was treated in a manner analogous to the above, and after crystallization from acetone–hexane 226 mg of compound **13b** was obtained, identical in every respect with the material obtained from the above experiment.

Isolation of 1,17β-Diacetoxy-2-ethyl-4-methylestra-1,3,5(10)-triene (14b) from the Reaction of 2α-Ethyltestosterone with Perchloric Acid–Acetic Anhydride Reagent.—2α-Ethyltestosterone (**1b**, 367 mg) in benzene (50 ml) and carbon tetrachloride (20 ml) was treated with a solution (5 ml) prepared from 70% perchloric acid (5 ml) and acetic anhydride (245 mg). The mixture was stirred at room temperature for 3 hr. Glpc analysis of aliquots of reaction mixture indicated that reaction was complete, and that two products were formed in approximately a 9:1 ratio. The isolation of the major constituent, compound **13b**, is described above. The isolation of the minor component was achieved by dilution with ether, washing with saturated sodium bicarbonate solution and brine, and drying (Na_2SO_4). The solvent was evaporated, and the residue was taken up in methanol (100 ml) and treated with saturated aqueous sodium acetate (20 ml). The solution was refluxed for 3 hr and then evaporated to dryness. The solid material was extracted with ether, and the solvent was evaporated. The residue was taken up in benzene and adsorbed onto a column of Florisil (30 g). Elution with benzene gave 1,17β-diacetoxy-2-ethyl-4-methylestra-1,3,5(10)-triene (**14b**, 27 mg) which crystallized from acetone–hexane, mp 183–186°. Admixture with authentic material gave no depression of the melting point.

Treatment of 2α,6β-Dimethyl-17β-hydroxyandrost-4-en-3-one (1h) with Perchloric Acid–Acetic Anhydride Reagent.—2α,6β-Dimethyl-17β-hydroxyandrost-4-en-3-one (**1h**, 5 mg) in dry benzene (0.5 ml) and carbon tetrachloride (0.2 ml) was treated with a solution (0.05 ml) prepared from 70% perchloric acid (5 ml) and acetic anhydride (245 ml). The solution was stirred at room temperature, and the reaction was monitored by glpc which demonstrated that only one product was formed. The reaction was complete after 1 min and there was no change after a further 3 hr. The mixture was diluted with ether, washed with aqueous sodium bicarbonate and brine, and dried (Na_2SO_4). The ether was evaporated and the product had ir and uv spectra and glpc retention time identical with those of authentic 3,17β-diacetoxy-2α,6-dimethylandrosta-3,5-diene (**10c**).

Treatment of 6α-Methylandrost-4-en-3-one (1e) with Perchloric Acid–Acetic Anhydride Reagent.—6α-Methylandrost-4-en-3-one (**1e**, 196 mg) in dry benzene (25 ml) and carbon tetrachloride (10 ml) was treated with a solution (7 ml) prepared from acetic anhydride (250 ml) and 70% perchloric acid (0.5 ml) at room temperature. Glpc analysis of aliquots of the reaction mixture indicated that the reaction was complete after 15 min and that there was no further change after 5 hr when the reaction was quenched by partitioning between saturated aqueous sodium bicarbonate and ether. The ether layer was washed with brine, dried (Na_2SO_4), and the solvent was evaporated. The residue was taken up in benzene and filtered through a short column of Florisil to remove coloration. The solvent was evaporated and the residue was crystallized from aqueous methanol to yield 3-acetoxy-6-methylandrosta-3,5-diene (**10e**, 102 mg): mp 86–88°; mixture melting point with authentic material previously prepared was undepressed, and their ir spectra were also identical.

Hydrolysis of 6-(1′-Acetoxyethylidene)-3,17β-diacetoxy-2-methylandrosta-2,4-diene (13a).—The title compound (100 mg) in ethanol (25 ml) was treated with saturated aqueous sodium acetate (5 ml). The mixture was refluxed for 2 hr, and evaporated to dryness. The residue was partitioned between ether (50 ml) and water (50 ml). The ether layer was dried (Na_2SO_4) and the solvent was evaporated. The residue was taken up in benzene and adsorbed onto a column of Florisil (15 g). Elution with benzene gave a mixture with 17β-acetoxy-6β-acetyl-2α-methyl-

(35) The assignment of this signal was verified by spin-decoupling experiments.

androst-4-en-3-one (**15a**) as the major component. Crystallization from acetone–hexane afforded **15a** (8 mg): mp 189–190°; uv max 246 mμ (ε 12,300); uv max (EtOH–5% KOH) 428 mμ (ε 10,800); ir (KBr) 1738 (–OCOCH$_3$), 1725 (C=O), 1685 (C=C–C=O) and 1610 cm^{-1} (C=C);

Anal. Calcd for $C_{24}H_{34}O_4$: C, 74.58; H, 8.87. Found: C, 74.24; H, 8.69.

Hydrolysis of 6-(1′-Acetoxyethylidene)-3,17β-diacetoxy-2-ethylandrosta-2,4-diene (13b).—Compound **13b** (199 mg) in methanol (55 ml) was treated with saturated aqueous sodium acetate (10 ml) and the solution was refluxed for 3 hr. The mixture was evaporated to small volume and extracted with dichloromethane. The organic solution was washed with brine, dried (Na_2SO_4), and the solvent was evaporated. The residue was crystallized from acetone–hexane giving a mixture of C-6 epimers of 17β-acetoxy-6ξ-acetyl-2α-ethylandrost-4-en-3-one (29 mg): uv max 241 mμ (ε 13,500); uv max (EtOH–5% KOH) 425 mμ; ir (CCl_4) 1740 and 1240 (–OCOCH$_3$), 1718 (–COCH$_3$), 1680 and 1612 (O=C–C=C), and 1040 cm^{-1}; nmr δ 0.83 (s, 3, 19-H$_3$), 1.06 and 1.28 (two s, 3, 19-**H**$_3$ in the two epimers), 2.02 (s, 3, –OCOCH$_3$), 2.12 and 2.18 (two s, 3, epimeric 6-COCH$_3$), 3.23 (d, 1, J = 5 Hz, 6-H), 5.43 (d, 1, J = 1.6 Hz, 4-H in 6α epimer), and 6.03 (s, 1, 4-H in 6β epimer).

Anal. Calcd for $C_{25}H_{36}O_4$: C, 74.96; H, 9.06. Found: C, 75.23; H, 9.20.

17β-Hydroxy-2-methylandrosta-1,4-dien-3-one (11a).—A solution of 17β-hydroxy-2α-methylandrost-4-en-3-one (**1f**, 3.07 g) in *t*-butyl alcohol (100 ml) was added to a solution of selenium dioxide (3.07 g) in acetic acid (2.7 ml) and the reaction mixture was refluxed under nitrogen for 75 hr. The mixture was cooled, diluted with ethyl acetate (200 ml), and filtered through Celite. The solvent was evaporated to dryness and the residue was taken up in ethyl acetate (100 ml). The organic solution was washed with three successive portions of water (100 ml), aqueous sodium bicarbonate, cold ammonium sulfide solution (100 ml), cold 3 *N* ammonium hydroxide (100 ml), 3 *N* hydrochloric acid (100 ml), and brine until neutral. The organic layer was dried (Na_2SO_4) and the solvent was evaporated. The residue (2 g) was chromatographed on Florisil (60 g) and eluted with benzene. The product was crystallized from acetone–hexane to yield 17β-hydroxy-2-methylandrosta-1,4-dien-3-one (**11a**, 1.2 g): mp 208–211°; $[\alpha]^{27}D$ +5.8° (*c* 1.0) (lit.[25] mp 210–211°; $[\alpha]D$ +6°).

17β-Acetoxy-2-methylandrosta-1,4-dien-3-one (11b).—17β-Hydroxy-2-methylandrosta-1,4-dien-3-one (**11a**, 500 mg) was acetylated by the usual method using acetic anhydride and pyridine. The product was crystallized from acetone–hexane to yield 17β-acetoxy-2-methylandrosta-1,4-dien-3-one (**11b**, 480 mg): mp 180–182°; $[\alpha]^{26}D$ +7.6° (*c* 1.0); uv max 247 mμ (ε 16,300); ir (CCl_4) 1741 and 1247 (OCOCH$_3$), 1670 (C=C–C=O), 1646, 1633 cm^{-1} (C=C).

Anal. Calcd for $C_{22}H_{30}O_3$: C, 77.16; H, 8.83. Found: C, 77.01; H, 8.96.

17β-Acetoxy-2-ethylandrosta-1,4-dien-3-one (11c).—17β-Hydroxy-2α-ethylandrost-4-en-3-one (**1g**, 1.052 g) in *t*-butyl alcohol (30 ml) was treated with selenium dioxide (1.2 g) in acetic acid (10 ml), and the mixture was refluxed under nitrogen for 72 hr. The product was isolated in a manner analogous to that used for compound **11a** and there was obtained by crystallization from acetone–hexane 17β-acetoxy-2-ethylandrosta-1,4-dien-3-one (**11c**, 228 mg): mp 153–154°; $[\alpha]^{29}D$ +9.2° (*c* 1.0); uv max 248 mμ (ε 15,300); ir (KBr) 1735 and 1245 (–OCOCH$_3$), 1665 (C=C–C=O), and 1630 cm^{-1} (C=C); nmr δ 0.87 (s, 3, 18-H$_3$), 1.19 (s, 3, 19-H$_3$), 1.05 (t, 3, J = 7 Hz, 2-CH$_2$**CH**$_3$), 2.01 (s, 3, 17-OCOCH$_3$), 4.60 (m, 1, 17-H), 6.04 (s, 1, 4-H), and 6.73 (t, 1, J = 1.3 Hz, 1-H).

Anal. Calcd for $C_{23}H_{32}O_3$: C, 77.49; H, 9.05. Found: C, 77.57; H, 9.22.

1,17β-Diacetoxy-2,4-dimethylestra-1,3,5(10)-triene (14a).—17β-Acetoxy-2-methylandrosta-1,4-dien-3-one (**11b**, 314 mg) in acetic anhydride (6.0 ml) was treated with *p*-toluenesulfonic acid (120 mg) and the mixture was heated at 90° for 6 hr under nitrogen. The solution was cooled and partitioned between ether (100 ml) and water (50 ml). The organic layer was washed with saturated aqueous sodium bicarbonate and brine, dried (Na_2SO_4), and the solvent was evaporated. The residue was sublimed at 90° *in vacuo* yielding 1,17β-diacetoxy-2,4-dimethylestra-1,3,5-(10)-triene (**14a**, 195 mg): mp 185–187°; $[\alpha]^{27}D$ +142.5° (*c* 1.0); uv max 272 mμ (ε 4600); ir (CCl_4) 1755 (C=COCOCH$_3$) and 1736 cm^{-1} (–OCOCH$_3$); nmr δ 0.87 (s, 3, 18-H$_3$), 2.04 (s, 3), 2.07 (s, 3) and 2.16 (s, 3) (two aromatic methyl signals and 17-OCOCH$_3$), 2.26 (s, 3, 1-OCOCH$_3$), 4.73 (m, 1, 17-H), and 6.86 (m, 1, aromatic H).

Anal. Calcd for $C_{24}H_{32}O_4$: C, 74.94; H, 8.39. Found: C, 74.74; H, 8.30.

1,17β-Diacetoxy-2-ethyl-4-methylestra-1,3,5(10)-triene (14b).—To a solution of 17β-acetoxy-2-ethylandrosta-1,4-dien-3-one (**11c**, 68 mg) in dry benzene (10 ml) and carbon tetrachloride (4 ml) was added a solution (2.4 ml) prepared from acetic anhydride (36 ml) and 70% perchloric acid (0.12 ml). The mixture was stirred at room temperature for 40 min and then diluted with ether. The ether solution was washed with saturated sodium bicarbonate solution and brine, dried (Na_2SO_4), and the solvent was evaporated. The residual oil was crystallized from acetone–hexane and afforded 1,17β-diacetoxy-2-ethyl-4-methylestra-1,3,5(10)-triene (**14b**, 45 mg): mp 181–184°; $[\alpha]^{28}D$ +116° (*c* 1.0); ir (CCl_4) 1760 and 1190 (C=COCOCH$_3$), 1735 and 1240 cm^{-1} (OCOCH$_3$); nmr δ 0.85 (s, 3, 18-H$_3$), 1.15 (t, 3, J = 7.8 Hz, 2-CH$_2$**CH**$_3$), 2.03 (s, 3, 17-OCOCH$_3$), 2.18 (d, 3, J = 1.5 Hz, 4-CH$_3$), 2.27 (s, 3, 1-OCOCH$_3$), 2.48 (q, 2, J = 7.5 Hz, 2-C**H**$_2$CH$_3$), 4.7 (m, 1, 17-H) and 6.91 (m, 1, 3-H).

Anal. Calcd for $C_{25}H_{34}O_4$: C, 75.34; H, 8.60. Found: C, 75.06; H, 8.59.

Detection of Acetaldehyde as a Product of the Reaction of 2α-Methyltestosterone with Perchloric Acid–Acetic Anhydride Reagent.—2α-Methyltestosterone (1.0 g) dissolved in anhydrous benzene (100 ml) and carbon tetrachloride (40 ml) was treated with a solution (10 ml) prepared from acetic anhydride (245 ml) and 70% perchloric acid (5 ml). The mixture was stirred at room temperature for 4 hr and then cooled. A 30-ml sample of the reaction mixture was added to a solution of 2,4-dinitrophenylhydrazine (1.0 g) in methanol (30 ml) containing sulfuric acid (1 ml), and the resulting solution was allowed to stand for 0.5 hr. It was then diluted with chloroform (100 ml), washed with saturated aqueous sodium bicarbonate and brine, and dried (Na_2SO_4). The solvent was evaporated and the residue was taken up in benzene and adsorbed onto a column of neutral alumina (25 g). The column was eluted with benzene, and the orange product was further purified by tlc on silica gel plates (0.5 mm) using benzene as solvent. The band at R_f 0.35 was removed and extracted with dichloromethane. The solvent was evaporated leaving acetaldehyde 2,4-dinitrophenylhydrazone (10 mg) which crystallized from ethanol: mp 147–148°; and the mixture melting point with authentic substance was undepressed.

A "blank" reaction was carried out in the same manner as described above except that the steroid was not included, and no acetaldehyde could be detected.

Registry No.—**1c**, 19990-39-7; **1d**, 19990-40-0; **1e**, 19990-41-1; **1g**, 19990-42-2; **1h**, 19990-43-3; **1k**, 19990-44-4; **2**, 19990-45-5; **3**, 19990-46-6; **4**, 19990-47-7; **5a**, 19990-48-8; **5b**, 19990-49-9; **7**, 298-66-8; **8**, 19990-51-3; **9d**, 19990-52-4; **10a**, 19990-53-5; **10b**, 19990-54-6; **10c**, 19990-55-7; **10e**, 19990-56-8; **11b**, 6223-99-0; **11c**, 19990-58-0; **13a**, 20013-28-9; **13b**, 19990-59-1; **14a**, 6224-21-1; **14b**, 19990-60-4; **15a**, 19990-61-5; **16**, 19990-62-6.

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