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STEROIDS—CCCXV[1]

DEHYDROGENATION STUDIES WITH STEROIDAL LACTONES—THE SYNTHESIS OF 4-OXA-$\Delta^{1,5(10)}$-3-KETONES[2]

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Abstract -Various steroidal δ-lactones were dehydrogenated by 2,3-dichloro-5,6-dicyanobenzoquinone to the corresponding α,β-unsaturated -δ-lactones in 25–75% yield. The synthesis of steroidal ring A α-pyrones from 19-norsteroid lactone precursors is also described.

REPLACEMENT of carbon atom 2 of the steroid nucleus by oxygen has been achieved in the androstane, pregnane and corticoid series and many of the lactones so obtained have biological properties similar to the parent hormones.[3,4] Saturated steroidal lactones bearing the ring oxygen at the 4-position have also been known for some time[5,6] but the synthesis of the corresponding 1,2-dehydro-4-oxa-3-ketones has not been investigated extensively.

A useful route to unsaturated lactones evolved from a recent investigation concerned with the synthesis of steroidal tricycles lacking the A ring. Since substantial quantities of 17β-hydroxy-4-oxa-5α-androst-1-en-3-one acetate (**1b**) were required for degradation experiments a one-step dehydrogenation of the readily available 17β-hydroxy-4-oxa-5α-androstan-3-one acetate (**1a**) was attempted in order to circumvent an earlier synthesis based on the selective oxidation of the 4,5-double bond of 17β-hydroxy-androsta-1,4-dien-3-one. Accordingly, treatment of the saturated lactone (**1a**) with 2,3-dichloro-5,6-dicyanobenzoquinone (DDQ)[7] afforded in moderate yield a new substance readily identified as the requisite 1,2-dehydrolactone (**1b**).

The practical significance of this finding prompted a search for additional examples of this reaction. The effect of DDQ on 19-nor-4-oxa-3-ketosteroids was viewed with particular interest since in principle, these substances could afford the hitherto unreported 4-oxa-$\Delta^{1,5(10)}$-3-ketosteroids (ring A α-pyrones) on exposure to the quinone. Eight steroidal lactones were synthesized according to standard methods[5,6,8] (Experimental) and allowed to react with DDQ in boiling dioxan solution. The results of the successful experiments are summarized in Table 1. The saturated δ-lactones were less reactive towards DDQ than Δ^4-3-ketones which usually are dehydrogenated by 1·1·5 molar equivs of the quinone after 18 hr in boiling dioxan.[9] In general, moderate yields of the unsaturated lactones were attained after exposure to 2 molar equivs of DDQ for 96 hr in dioxan at reflux. The ring D lactone (**5a**) was particularly unreactive and required 240 hr after which time the 15-dehydro lactone (**5b**) was

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TABLE 1. REACTION CONDITIONS FOR α,β-UNSATURATED LACTONE SYNTHESIS

Dehydrogenation product	Molar equiv DDQ	Reaction time (Hr)	Yield (%)
1. 17β-Hydroxy-4-oxa-5α-estr-1-en-3-one acetate (**2a**)[a]	2	96	50
2. 17β-Hydroxy-4-oxa-5β-estr-1-en-3-one acetate (**2b**)[a]	2	96	50
3. 17β-Hydroxy-4-oxa-5α-androst-1-en-3-one acetate (**1b**)[a]	1·5	96	60
4. 3β-Hydroxy-17a-oxa-D-homo-5α-androst-15-en-17-one acetate (**5b**)[b]	3	240	25
5. 20β-Hydroxy-4-oxa-5α-19-norpregn-1-en-3-one acetate (**3b**)[a]	2	130	40
6. 20β-Hydroxy-4-oxa-5α-pregn-1-en-3-one acetate (**1d**)[a]	2	93	75

For preparation of starting material see [a] Experimental; [b] Ref. 10.

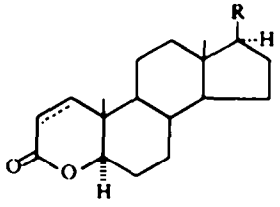
obtained in only 25% yield. The dehydrogenation of 17α,20:20,21-bismethylenedioxy-11β-hydroxy-4-oxa-5α-pregnan-3-one (**4**) by DDQ was accompanied by extensive decomposition, and no identifiable products were isolated from this experiment. The dehydrogenation of the 19-norlactones (**2a, b**; **3a**) stopped at the unsaturated lactone stage. Indeed, prolonged treatment of **2a, b** and **3a** with a large excess of DDQ failed to yield either an α-pyrone derivative or products of extended conjugation as judged by careful chromatographic and spectroscopic analysis of the reaction mixtures.

Also noteworthy is the observation that the γ-lactone ring of 3-(17β-hydroxy-5α-androst-2-en-17α-yl)-propanoic acid lactone[11] (**6**) is resistant to attack by DDQ under the usual dehydrogenation conditions. However, the lack of reactivity of **6** may be due to the rigid nature of the spirolactone system rather than ring size.

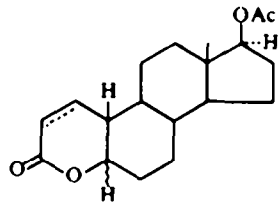
The synthesis of the ring A α-pyrones was accomplished by two routes. Initial success was achieved by allylic bromination of 17β-acetoxy-4-oxa-5α-estr-1-en-3-one (**2c**) with N-bromosuccinimide[12] in carbon tetrachloride to the 10ξ-bromo compound which was dehydrobrominated by calcium carbonate in boiling dimethylformamide.[13] This afforded 17β-hydroxy-4-oxaestra-1,5(10)-dien-3-one acetate (**7a**) which exhibited a typical α-pyrone absorption maximum at 309 mμ in the UV.[14] The overall yield of **7a** from the starting lactone (**2c**) was 67%.

The bromination-dehydrobromination method proved inoperable with 20β-hydroxy-4-oxa-5α-19-norpregn-1-en-3-one acetate (**3b**) and the following sequence was adopted for obtaining the corresponding pyrone. A mixture of the 5α and 5β isomers of 20β-hydroxy-4-oxa-19-norpregn-1-en-3-one acetate was first converted to the sodium salt of the 5(α,β), 20β-dihydroxyseco acid by treatment with dilute sodium hydroxide in aqueous dioxan solution. The resulting salt was next esterified with methyl iodide and the crude dihydroxy ester oxidized with 8N chromium trioxide-sulfuric acid reagent in acetone solution. Purification by preparative TLC afforded 5,20-dioxo-3,5-seco-19-norpregn-1-en-3-oic acid methyl ester (**8**) which cyclized to the α-pyrone (**7b**) (λ_{max} 310 mμ)[14] upon treatment with *p*-toluenesulfonic acid in boiling benzene.

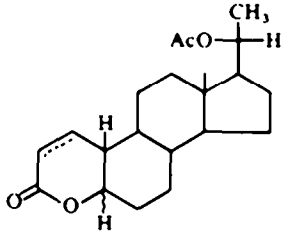
The configuration at C-5 of the starting lactones as well as the structures of the various dehydrogenation products were confirmed in all cases by NMR spectroscopy (Table 2). The former problem has already been studied with steroidal ring A lactones by Edward and Ferland[15] and the present assignments are in harmony with the published work. Thus the C-5 axial protons of the saturated A/B-*trans* lactones



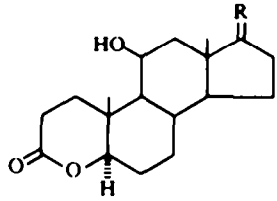
1a: R = $OCOCH_3$; 1,2-dihydro
b: R = $OCOCH_3$; 1,2-double bond
c: R = $CH_3CHOCOCH_3$; 1,2-dihydro
d: R = $CH_3CHOCOCH_3$; 1,2-double bond



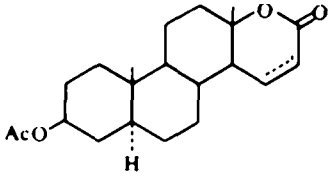
2a: 5α-H; 1,2-dihydro
b: 5β-H; 1,2-dihydro
c: 5α-H; 1,2-double bond
d: 5β-H; 1,2-double bond



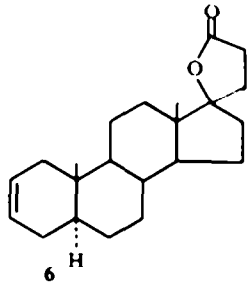
3a: 5α-H; 1,2-dihydro
b: 5α-H; 1,2-double bond
c: 5β-H; 1,2-double bond



4: R = bismethylenedioxy



5a: 15,16-dihydro
b: 15,16-double bond



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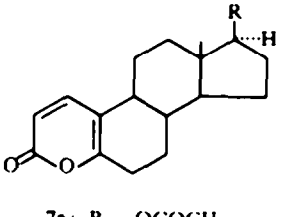
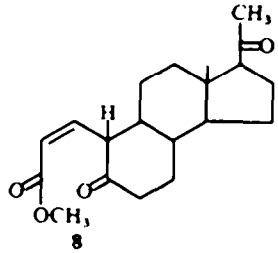


7a: R = $OCOCH_3$
b: R = CH_3CO



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(**1a**, **c**; **2a**; **3a**) appear as broad multiplets (half-band width ca. 15·0 c/s) whereas the C-5 equatorial proton of the *cis* compound **2b** is observed as a narrower multiplet (half-band width 7·0 c/s) downfield by 0·56 ppm relative to the corresponding 5-H resonance of the *trans* epimer **2a**.

The olefinic proton resonances of the Δ^1-3-keto-4-oxa steroids bearing a C-19 angular Me group and of the pyrones (**7a, b**) appear as pairs of doublets $J_{1,2}$ 10·0 c/s. In the NMR spectra of the Δ^1-5β-19-norlactones (**2d**; **3c**) the C-2 proton resonances occur as doublets $J_{1,2}$ 9·5–10·0 c/s, whereas the C-1 proton resonances are observed as quartets, $J_{1,2}$ 9·5–10·0 c/s, $J_{1,10}$ 6·0–6·5 c/s, owing to vicinal coupling with the C-2 and C-10 protons. Absence of measurable allylic coupling between the C-2 and C-10 protons in the 5β-series concurs with the small dihedral angle (ca. 10°) subtended by the C_2-H and C_{10}-H bonds as revealed by inspection of the relevant Dreiding molecular models.[16*] The C-1 and C-2 protons of the unsaturated *trans*-19-norlactones (**2c**; **3b**) exhibit vicinal ($J_{1,10}$ 1·0–2·0 c/s) and allylic ($J_{2,10}$ 2·5–3·0 c/s) coupling, respectively, to the C-10 proton as well as 1,2 coupling and therefore appear as the A and B quartets of an ABX system.† In these examples the value of the allylic coupling is maximal in agreement with the observed dihedral angle which approximates to 110°.[16] The same splitting pattern is also exhibited by the 15 and 16 protons of the Δ^{15}-lactone (**5b**).

TABLE 2. OLEFINIC PROTON RESONANCES OF α,β-UNSATURATED LACTONES AND PYRONES

Steroid	2-H ppm	1-H ppm	Coupling constants c/s
17β-Hydroxy-4-oxa-5α-androst-1-en-3-one acetate (**1b**)	5·88 (d)	7·02 (d)	$J_{1,2}$ 10·0
20β-Hydroxy-4-oxa-5α-pregn-1-en-3-one acetate (**1d**)	5·92 (d)	7·08 (d)	$J_{1,2}$ 10·0
17β-Hydroxy-4-oxaestra-1,5(10)-dien-3-one acetate (**7a**)	6·15 (d)	7·35 (d)	$J_{1,2}$ 10·0
4-Oxa-19-norpregna-1,5(10)-diene-3,20-dione (**7b**)	6·13 (d)	7·39 (d)	$J_{1,2}$ 10·0
17β-Hydroxy-4-oxa-5α-estr-1-en-3-one acetate (**2c**)	5·89 (d), 6·05 (d)	6·88 (d), 7·03 (d)	$J_{1,2}$ 10·0, $J_{1,10}$ 2·0, $J_{2,10}$ 3·0
17β-Hydroxy-4-oxa-5β-estr-1-en-3-one acetate (**2d**)	6·00 (d)	7·05 (d), 7·21 (d)	$J_{1,2}$ 9·5, $J_{1,10}$ 6·5
20β-Hydroxy-4-oxa-5α,19-norpregn-1-en-3-one acetate (**3b**)	5·92 (d), 6·08 (d)	6·88 (d), 7·04 (d)	$J_{1,2}$ 9·5, $J_{1,10}$ ~1·0, $J_{2,10}$ 2·5
20β-Hydroxy-4-oxa-5β,19-norpregn-1-en-3-one acetate (**3c**)	6·00 (d)	7·04 (d), 7·21 (d)	$J_{1,2}$ 10·0, $J_{1,10}$ 6·0
	16-H	**15-H**	
17β-Hydroxy-17a-oxa-D-homo-5α-androst-15-en-17-one acetate (**5b**)	5·93 (d), 6·09 (d)	6·75 (d), 6·91 (d)	$J_{15,16}$ 10·0, $J_{15,14}$ 2·0, $J_{14,16}$ 3·0

* Dihedral angle measurements were recorded for ring A half-chair conformation. The same conclusions also obtain for the less-stable ring A flexible conformation.

† In a comparative study of the olefinic proton resonance of various 5α and 5β-19-nor-Δ^1-3-ketones measurable allylic (H_2–H_{10}) coupling was observed only in the A/B trans series.[17]

EXPERIMENTAL*

17β-Hydroxy-4-oxa-5α-androstan-3-one acetate (**1a**). A stirred soln of testosterone acetate (25 g) in 1 l. t-butanol was treated successively with 1·5% K_2CO_3 aq (400 ml), 1% $KMnO_4$ aq (250 ml) and a soln of sodium metaperiodate (100 g) in water (1·25 l.). This mixture was kept at ice-bath temp for 3 hr after which time solid $NaHSO_3$ was added to destroy the excess $KMnO_4$. The greater part of the t-butanol was removed by distillation and the product isolated by extraction with EtOAc. This afforded 26 g of 17β-hydroxy-5-oxo-3,5-secoandrostan-3-oic acid acetate[18] as an oil which slowly crystallized. An analytical sample prepared from acetone–hexane exhibited m.p. 137–139°; $[\alpha]_D$ +26°; ν_{max} 3100, 1740, 1730, 1690, 1240 cm^{-1}. (Found: C, 68·94; H, 8·65; O, 22·94. $C_{20}H_{30}O_5$ requires: C, 68·54; H, 8·63; O, 22·83%).

A soln of the foregoing acid (25 g) in dioxan (150 ml) was cooled in ice to 10° and reduced with a soln of $NaBH_4$ (8 g) in water (60 ml) for 20 min. The reaction mixture was diluted with water (750 ml) and excess 1N HCl and the resulting ppt was collected, dried, and crystallized from acetone–heptane to afford 16·2 g of **1a**, m.p. 180–183°. An analytically pure sample showed m.p. 186–188°; $[\alpha]_D$ +65°; ν_{max} 1740, 1250 cm^{-1}; NMR 0·81 (s, 18-H), 0·94 (s, 19-H), 2·03 (s, 17-acetoxy-H), 3·95 ppm (q, 5α-H, $J_{5\alpha,6\alpha}$ 4·8 c/s, $J_{5\alpha,6\beta}$ 11·7 c/s). (Found: C, 72·12; H, 9·02; O, 19·00. $C_{20}H_{30}O_4$ requires: C, 71·82; H, 9·04; O, 19·14%).

17β-Hydroxy-4-oxa-5α-estran-3-one acetate (**2a**) *and 17β-hydroxy-4-oxa-5β-estran-3-one acetate* (**2b**). Sodium borohydride (3 g) in water (30 ml) was added dropwise with stirring during 15 min to a cooled soln of 17β-acetoxy-5-oxo-3,5-secoestran-3-oic acid[19] (10 g) dissolved in dioxan (40 ml). The resulting soln was diluted with water (200 ml), filtered through charcoal and acidified with 6N HCl. The filtered ppt was dried and twice crystallized from $CHCl_3$–heptane to yield 3·5 g of **2a**, m.p. 210–212°; $[\alpha]_D$ +49°; ν_{max} 1730, 1240 cm^{-1}; NMR 0·83 (s, 18-H), 2·02 (s, 17-acetoxy-H), 3·95 ppm (m, 5α-H, $W_{\frac{1}{2}}$ = 15 c/s). (Found: C, 71·19; H, 8·94; O, 19·92. $C_{19}H_{28}O_4$ requires: C, 71·22; H, 8·81; O, 19·97%).

Crystallization of the mother liquors from EtOH afforded a second crop of impure **2a**. Compound **2b** (810 mg) was obtained from the remaining mother liquors by crystallization from $CHCl_3$–heptane. The analytical sample of **2b** exhibited m.p. 169–171°; $[\alpha]_D$ ±0°; ν_{max} 1730, 1250 cm^{-1}; NMR 0·83 (s, 18-H), 2·04 (s, 17-acetoxy-H), 4·52 ppm (m, 5β-H, $W_{\frac{1}{2}}$ = 7 c/s). (Found: C, 71·15; H, 8·98; O, 20·20. $C_{19}H_{28}O_4$ requires: C, 71·22; H, 8·81; O, 19·97%).

20β-Hydroxy-4-oxa-5α-pregnan-20-one acetate (**1c**). 5,20-Dioxo-3,5-secopregnan-3-oic acid[20] (30 g) dissolved in dioxan (300 ml) was reduced with $NaBH_4$ (10 g) in water (100 ml) as described previously. The crude product was crystallized from toluene to furnish 10·8 g of 20β-hydroxy-4-oxa-5α-pregnan-20-one m.p. 225 228° and raised to 239–241° after several additional crystallizations, $[\alpha]_D$ +70°; ν_{max} 3450, 1730 cm^{-1}. (Found: C, 74·44; H, 9·95; O, 14·99. $C_{20}H_{32}O_3$ requires: C, 74·96; H, 10·06; O, 14·98%). The corresponding **1c** prepared by Ac_2O–pyridine treatment showed m.p. 209–212° (from $CHCl_3$–heptane); $[\alpha]_D$ +96°; ν_{max} 1740, 1725, 1250 cm^{-1}; NMR 0·65 (s, 18-H), 0·92 (s, 19-H), 1·04 (d, 21-H, J = 7 c/s), 1·99 (s, 20-acetoxy-H), 3·95 (m, 5α-H, $W_{\frac{1}{2}}$ = 13 c/s), 4·83 ppm (m, 20-H $W_{\frac{1}{2}}$ = 15 c/s). (Found: C, 72·70; H, 9·41; O, 17·79. $C_{23}H_{34}O_4$ requires: C, 72·89; H, 9·45; O, 17·66%).

20β-Hydroxy-4-oxa-5α,19-norpregnan-20-one acetate (**3a**). A soln of 19-norprogesterone (10 g) in EtOAc (600 ml) was treated at −70° with an excess O_3 and then 30% H_2O_2 (15 ml) was added. After being allowed to stand at room temp for 17 hr, the reaction mixture was washed successively with water, 5% NaI and 5% $Na_2S_2O_3$ solns and water, dried (Na_2SO_4) and evaporated. Chromatography of the resulting oil over silica gel (300 g) using hexane–EtOAc (7:3) as eluant furnished 7 g of 5,20-dioxo-3,5-seco-19-norpregnan-3-oic acid; m.p. 130–131° (from acetone heptane); $[\alpha]_D$ +89°; ν_{max} 3200, 1740, 1710, 1690 cm^{-1}. (Found: C, 71·42; H, 8·86. $C_{19}H_{28}O_4$ requires: C, 71·22; H, 8·81%).

A soln of the foregoing seco-acid (6 g) in dioxan (60 ml) was reduced at 10° with a soln of $NaBH_4$ (3·3 g) in water (18 ml). The reaction mixture was processed as described previously to yield 2·9 g of 20β-hydroxy-4-oxa-5α,19-norpregnan-3-one; m.p. 200 202 (from acetone hexane); $[\alpha]_D$ +54°; ν_{max} 3450, 1730 cm^{-1}. (Found: C, 74·66; H, 9·96; O, 15·61. $C_{19}H_{30}O_3$ requires: C, 74·47; H, 9·87; O, 15·66%). Ac_2O–pyridine treatment of the latter product provided the corresponding **1c** m.p. 147 149° (from CH_2Cl_2–hexane); $[\alpha]_D$ +44°; ν_{max} 1730, 1240 cm^{-1}; NMR 0·68 (s, 18-H), 1·17 (s, 21-H, J = 6 c/s), 2·02 (s, 20-acetoxy-H), 3·93 ppm (m, 5α-H, $W_{\frac{1}{2}}$ = 17 c/s). (Found: C, 72·47; H, 9·49; O, 18·05. $C_{21}H_{32}O_4$ requires: C, 72·38; H, 9·27; O, 18·37%).

* M.ps are uncorrected. Unless specified otherwise rotations are recorded in $CHCl_3$, UV spectra in EtOH and IR spectra in KBr discs. NMR spectra are recorded on a Varian A-60 spectrometer in 5–10% $CDCl_3$ soln containing TMS as internal reference. Chemical shifts are reported as ppm on the δ scale. We thank J. Murphy and J. Tremble for these determinations. In the presentation of data s = singlet, d = doublet, q = quartet, m = multiplet.

17α,20:20,21-*Bismethylenedioxy*-11β-*hydroxy*-4-*oxa*-5α-*pregnan*-3-*one* (4). A soln of 17α,20:20,21-bismethylenedioxy-11β-hydroxy-5-oxo-3,5-secopregnan-3-oic acid[21] (1·75 g) in dioxan (40 ml) was reduced as before with $NaBH_4$ (1 g) in water (3 ml) for 30 min. Acidification with 8N HCl precipitated 0·8 g of 4; m.p. 254–256° (from acetone–hexane); $[\alpha]_D$ −34°; ν_{max} 3400, 1720 cm^{-1}; NMR 1·10 (s, 18-H), 1·18 (s, 19-H), 3·66–4·00 (m, 5α-H, resonance partially obscured by 21-H signal), 4·02 (s, 21-H), 5·06, 5·33 ppm (2 × s, bismethylenedioxy-H). (Found: C, 65·01; H, 8·00; O, 27·52. $C_{22}H_{32}O_7$ requires: C, 64·68; H, 7·90; O, 27·42%).

General procedure for DDQ dehydrogenation of saturated lactones. Relevant experimental conditions are summarized in Table 1. All dehydrogenations were performed in boiling dioxan. Products were isolated by dilution of the reaction mixture with several volumes of CH_2Cl_2 followed by filtration through a column of neutral alumina (30 g Al_2O_3/1 g of starting lactone). Removal of the solvent yielded the crude unsaturated lactone which was purified further by crystallization. Physical constants and analytical data are recorded in Table 3.

For the synthesis of 7b the dehydrogenation was conducted with a mixture of C-5 epimers of 20β-hydroxy-4-oxa-19-norpregnan-3-one acetate (see above) as follows. A soln of the mixed lactones (10 g) in 150 ml dioxan containing 20 g DDQ was boiled for 113 hr. The reaction mixture was diluted with 500 ml CH_2Cl_2 and filtered through a column of 300 g neutral alumina. Removal of the solvent gave 6·2 g of a mixture of C-5 epimeric unsaturated lactones which was utilized directly for the next reaction. Purification of a 500 mg sample of this mixture by preparative TLC* (EtOAc–hexane (1:1) as the solvent system) afforded pure samples of 3b; m.p. 190–191° and its 5β-epimer 3c; m.p. 186–187° (see Table 3 for additional data).

17β-*Hydroxy*-4-*oxaestra*-1,5(10)-*dien*-3-*one acetate* (7a). Benzoyl peroxide (10 mg) and N-bromosuccinimide (605 mg) were added to a suspension of 2c (1·1 g) in CCl_4 (34 ml) and the resulting mixture was heated under reflux for 55 min. The cooled reaction mixture was diluted with an equal volume of $CHCl_3$ washed with water, dried (Na_2SO_4) and evaporated *in vacuo* at 30–40°. A soln of the crude 10-bromo compound in dimethylformamide (10 ml) containing Li_2CO_3 (1·1 g) was boiled for 2 hr and then partitioned between water and EtOAc. The organic phase was washed with water, dried (Na_2SO_4) and evaporated to yield 740 mg of 7a m.p. 181–182° (from MeOH); $[\alpha]_D$ +35°; λ_{max} 309 mμ (log ε 3·73); ν_{max} 1730, 1640, 1550, 1240 cm^{-1}; NMR 0·85 (s, 18-H), 2·05 (s, 17-acetoxy-H), 4·67 ppm (m, 17α-H); for olefinic-H, see Table 2. (Found: C, 71·91; H, 7·69; O, 20·01. $C_{19}H_{24}O_4$ requires: C, 72·12; H, 7·65; O, 20·23%).

4-*Oxa*-19-*norpregna*-1,5(10)-*diene*-3,20-*dione* (7b). A mixture of C-5 epimers of 20β-hydroxy-4-oxa-19-norpregn-1-en-3-one acetate (3·1 g, see above) was dissolved in 30 ml dioxan and added to 50 ml 1% KOH aq. This mixture was kept at 90° for ½ hr and thereafter diluted with 100 ml water, 100 ml dioxan, and 30 ml MeI. The resulting soln was heated under reflux for 2 hr, then cooled and extracted with EtOAc. The organic layers were combined, washed with water, and concentrated to dryness to afford an oil which was oxidized with 4·5 ml 8N CrO_3 in acetone soln at 0°. Addition of water afforded an oil which was isolated by extraction with EtOAc and purified by preparative TLC* (EtOAc:hexane, 1:4). This yielded 0·8 g of 8 m.p. 104–105·5° (from acetone heptane); $[\alpha]_D$ +3°; ν_{max} 1725, 1705, 1655 cm^{-1}. (Found: C, 72·08; H, 8·66; O, 19·10. $C_{20}H_{28}O_4$ requires: C, 72·26; H, 8·49; O, 19·25%).

A soln of 0·6 g of the foregoing seco-ester in 30 ml benzene containing 25 mg *p*-toluenesulfonic acid was slowly distilled for 6½ hr, the original volume of the mixture being maintained by the periodic addition of solvent. The reaction mixture was washed with 1% $NaHCO_3$ aq and water, dried (Na_2SO_4) and evaporated to afford an oil which was purified by preparative TLC* (EtOAc hexane 7:13). This furnished 0·3 g of 7b m.p. 131–133° (from CH_2Cl_2 hexane); $[\alpha]_D$ +136°; λ_{max} 310 mμ (log ε 3·83); ν_{max} 1735, 1705, 1635, 1555 cm^{-1}; NMR 0·68 (s, 18-H), 2·13 ppm (s, 21-H); for olefinic-H, see Table 2. (Found: C, 75·29; H, 7·92. $C_{19}H_{24}O_3$ requires: C, 75·97; H, 8·05%).

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* Preparative TLC was conducted using silica gels GF and HF (from Brinkmann Instruments Inc., N.Y.) at thicknesses of 0·25 and 1·3 mm and steroid loadings of 1 mg and 6 mg per cm respectively.

TABLE 3. PHYSICAL CONSTANTS OF α,β-UNSATURATED LACTONES

Compound	m.p.	$[\alpha]_D$	λ_{max} (iso-octane) mμ (log ε)	ν_{max} cm^{-1}	δ ppm 18-H	19-H	Formula	Found (%) C	H	Required (%) C	H
1b	162 164	−13	205 (4·05)	1730, 1260	0·81	1·02	$C_{20}H_{28}O_4$	72·44	8·54	72·26	8·49
1d	184 186	+22	205 (4·09)	1735, 1724 1250	0·66	1·01	$C_{22}H_{32}O_4$	73·28	8·95	73·30	8·95
2c	193–194	+32	205 (4·08)	1725, 1240	0·84		$C_{19}H_{26}O_4$	71·60	8·30	71·67	8·23
2d	172–173	+247	< 200	1730, 1255	0·83		$C_{19}H_{26}O_4$	71·97	8·32	71·67	8·23
3b	190 191	+50	203 (4·07)	1730, 1240	0·68		$C_{21}H_{30}O_4$	73·01	8·64	72·80	8·73
3c	186–187	+252	202 (4·06)	1735, 1715, 1250	0·68		$C_{21}H_{30}O_4$	72·49	8·47	72·80	8·73
5b	149–150	−52	208 (4·0)	1750, 1240	0·82	1·32	$C_{21}H_{30}O_4$	73·08	8·80	72·80	8·73

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