the resulting precipitate washed twice with 10 ml portions of ether and dried overnight *in vacuo* over phosphorus pentoxide. Yield 16 mg (89%), $[\alpha]_D^{23}$ 23.6° (*c*, 0.50, water), mol. wt. 8000, determined by sedimentation equilibrium. The i.r. spectrum showed characteristic peaks at 6.06 and 6.45 μ.

Anal. Calcd. for $(C_5H_7NO_3 \cdot 1/4H_2O)_\infty$: C, 44.94; H, 5.66; N, 10.48. Found: C, 44.69; H, 5.56; N, 10.25.

*Optical Purity of Poly-γ-*D*-glutamic Acid*

It was determined by hydrolyzing 40.0 mg of a polymer sample, $[\alpha]_D^{22}$ 23.4° (*c*, 0.70, water), for 24 h under reflux in 1 ml of 6 *N* hydrochloric acid and 1 ml of glacial acetic acid. The hydrolysate was diluted to 3 ml with glacial acetic acid, giving α_D^{23} −0.441 ± 0.01°. A control sample consisting of 44.0 mg of D-glutamic acid of 100% optical purity, $[\alpha]_D^{23}$ −32.0° (*c*, 1.84, 6 *N* hydrochloric acid), was treated under the same conditions, giving α_D^{23} −0.441 ± 0.01°. This would indicate that the polymer is optically pure.

*Poly-γ-*L*-glutamic Acid*

It was prepared similarly in an 89% yield, $[\alpha]_D^{23}$ −23.3° (*c*, 0.58, water) mol. wt. 9000 as determined by sedimentation equilibrium. The i.r. spectrum showed characteristic peaks at 6.06 and 6.44 μ.

Anal. Found: C, 44.59; H, 5.20.

Weight average molecular weights were determined in a Spinco Model E analytical ultracentrifuge by the sedimentation equilibrium method in 0.1 *M* aqueous KCl. The calculations used were those given by Schachman. Measurements were made on concentrations in the range of 0.2–0.5% at 25–30°, using a rotor speed of 25 980 r.p.m. and a schlieren angle of 80°. The charge effect, which can lead to low mol. wt. values in water, was assumed to be minimized by using 0.1 *M* aqueous KCl as the solvent.

Acknowledgments

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A steroidal 14β-hydroperoxide

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Air oxidation of Δ^{14}-androsten-3β-ol-17-one acetate (**1**) was found to afford stereospecifically 14β-hydroperoxy-Δ^{15}-androsten-3β-ol-17-one 3-acetate (**2***a*).

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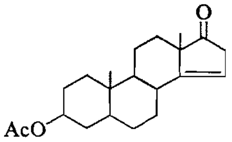
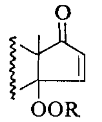
A common structural feature of most of the naturally-occurring cardiac-active steroidal lactones is the presence of a 14β-hydroxy substituent (1). The stereospecific introduction of a 14β-hydroxy group into the steroidal nucleus is therefore of interest in synthetic and biosynthetic studies of this class of compounds. A few methods for 14β-hydroxylation of steroids have been described in the literature (2), and in this note we report a new method which makes use of the susceptibility of β,γ-unsaturated ketone systems to undergo oxygenation at the γ-position with simultaneous reconjugation (3).

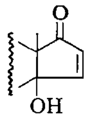
The oxygenation substrate used in our work was Δ^{14}-androsten-3β-ol-17-one acetate (**1**) (2*b*, 4, 5). This compound has been prepared in less than 5% yield by the dehydrobromination of 16-bromo epiandrosterone acetate with collidine (5);



1



2*a*, R = H
b, R = OAc



3

we obtained higher yields of **1** (42%) by carrying out the dehydrobromination of the same compound with lithium bromide – lithium carbonate in dimethylformamide (6). Exposure of **1** to oxygen led to the formation of a polar product in 82% yield, λ_{max} 212 mμ, which was characterized as 14β-hydroperoxy-Δ^{15}-androsten-3β-ol-17-one 3-acetate (2*a*). Its acetylation product **2*b*** exhibits the acetoxyperoxide absorption at 5.60 μ (3*b*). Reduction of **2*a*** with triethylphosphite in pyridine (8) afforded a product which was identical in all respects with Δ^{15}-androsten-3β,14β-diol-17-one 3-acetate (**3**) prepared by the published procedure (2*b*).[1]

In view of the mild conditions under which **1** undergoes stereospecific oxygenation at C-14, a biogenetic origin for the 14β-hydroxy group of cardenolides and bufadienolides may be suggested. Recently it has been demonstrated that C_{21}-steroids are involved in the biogenesis of cardiac active glycosides (9). However, in the alternative C_{19}–C_4 hypothesis (10), the C_{19}-steroidal fragment could be envisioned to acquire the 14β-hydroxy group in a manner analogous to the one described herein.

Experimental

Melting points are uncorrected. Specific rotations were determined on 0.3% solutions in dioxane. Nuclear magnetic resonance spectra in $CDCl_3$ using TMS as the internal standard were determined on a Varian A-60A spectrometer. The author thanks Mr. M. Yudis and his staff for these physical measurements.

Δ^{14}-Androstene-3β-ol-17-one Acetate (1)

A mixture of 16-bromo epiandrosterone acetate (9.9 g) (5), lithium bromide (10 g), and lithium carbonate (10 g) in dimethylformamide (100 ml) was stirred and heated at 180° under argon for 3 h. The reaction mixture was cooled to room temperature, diluted with ice-water, acidified with dilute hydrochloric acid and extracted with ethyl acetate. The organic extracts were washed with water, dried, and evaporated under reduced pressure. The residue was crystallized twice from ether–hexane to afford colorless needles of **1** (3.3 g, 42%), m.p. 152–155°; $[\alpha]_D$ +110° (chloroform) [reported (2*b*): m.p. 154–156°; $[\alpha]_D$ +112°].

14β-Hydroperoxy-Δ^{15}-androstene-3β-ol-17-one 3-Monoacetate (2a)

A solution of Δ^{14}-androstene-3β-ol-17-one acetate (**1**, 1 g) in the minimum amount of chloroform was distributed as a film on the inside walls of a 4-l conical flask which was then filled with oxygen and allowed to stand at room temperature. The disappearance of **1** was followed by thin-layer chromatography and after 5 days the reaction was complete. During this reaction period additional amounts of chloroform were added as required in order to prevent **1** from crystallizing out. The product was transferred to a smaller flask and triturated with ether to afford 2*a* (502 mg). The filtrate was evaporated and the residue was applied on a 20 × 20 × 0.1 cm silica gel plate which was then developed in 10% ethyl acetate–chloroform. The material from the band corresponding to 2*a* was isolated and crystallized from ether (393 mg, 82% total yield). Recrystallization from ethyl acetate–ether afforded 2*a* as colorless needles, m.p. 175–180° (decomp.); λ_{max}(Nujol) 3.08, 5.79, 5.86 μ; λ_{max} (MeOH) 212 mμ (ε 8800); $[\alpha]_D{}^{26}$ +43.2°; n.m.r. ($CDCl_3$, 60 Mc.p.s.), δ 0.82, 1.22, 2.01 (singlets, 3H each, $19\text{-C}H_3$, $18\text{-C}H_3$ and $C_3\text{-O}\overset{\overset{\text{O}}{\|}}{\text{C}}\text{C}H_3$), δ 6.39, 7.34 (doublets, 1H each, J = 6.5 c.p.s., C-16 and $C_{15}\text{-}H$), δ 7.84 (singlet, 1H, 14-OO*H*, exchangeable with D_2O); positive starch iodide test.

Anal. Calcd. for $C_{21}H_{30}O_5$: C, 69.58; H, 8.34. Found: C, 69.62; H, 8.42.

14β-Hydroperoxy-Δ^{15}-androstene-3β-ol-17-one 3,14-Diacetate (2b)

Acetic anhydride (0.7 ml) was added to a cold (0°) solution of **1** (0.34 g) in pyridine (1.5 ml). After 1 h at 0° the solution was allowed to stand at room temperature for 15 min and then diluted with ice-water. The insoluble product was filtered out, washed with water, and dried. The product was crystallized from hexane as colorless needles (2*c*, 0.232 g), m.p. 125–131° (decomp.); λ_{max}(Nujol) 5.59, 5.79, 5.82 μ; λ_{max}(EtOH) 212 mμ (ε 8300); $[\alpha]_D{}^{26}$ −98.1°; n.m.r., δ 0.83, 1.20, 1.90, 2.01 (singlets, 3H each, $19\text{-C}H_3$, $18\text{-C}H_3$, $C_{14}\text{-OO}\overset{\overset{\text{O}}{\|}}{\text{C}}\text{C}H_3$ and $C_3\text{-O}\overset{\overset{\text{O}}{\|}}{\text{C}}\text{C}H_3$), δ 6.33, 7.40 (doublets, 1H each, J = 6.5 c.p.s., C-16 and $C_{15}\text{-}H$).

Anal. Calcd. for $C_{23}H_{32}O_6$: C, 68.29; H, 7.97. Found: C, 68.58; H, 7.85.

Δ^{15}-Androstene-3β,14β-diol-17-one 3-Monoacetate (3)

a) From Δ^{14}-Androsten-3β-ol-17-one Acetate (1)

The procedure described in the literature (2*b*) was followed. The product was crystallized from acetone–hexane as colorless plates, m.p. 162–163°; λ_{max}(Nujol) 2.90, 5.78, 5.82 μ; λ_{max}(MeOH) 212 mμ (ε 8000); $[\alpha]_D{}^{26}$ +103.6°; optical rotatory dispersion in dioxane[2] (*c*, 0.07):

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[1] The physical constants reported (2*b*) for **3** are not in complete agreement with those found by us on chromatographically pure **3**. Low values, like ours, for extinction coefficients have been observed in other 14β-hydroxy-Δ^{15}-17-ketones (7). The identity of our **3** was confirmed from its optical rotatory dispersion curve which shows a positive cotton effect and is identical in shape with the published (2*b*) curve.

[2] The author thanks Dr. M. Tanabe of Stanford Research Institute for determining the optical rotatory dispersion curve.

$[\alpha]_{700}$ +77°; $[\alpha]_{589}$ +103°; $[\alpha]_{375}$ +1048°; $[\alpha]_{365}$ +976°; $[\alpha]_{330}$ −827°; $[\alpha]_{300}$ −1254° [reported (2*b*): m.p. 153–155°; λ_{max}(KBr) 2.90, 5.78, 5.85 μ; λ_{max}(EtOH) 213 mμ (ε 13 000); o.r.d.: $[\alpha]_{700}$ +37°; $[\alpha]_{589}$ +69°; $[\alpha]_{375}$ +1100°; $[\alpha]_{365}$ +1000°; $[\alpha]_{330}$ −948°; $[\alpha]_{300}$ −1545°].

b) From 14β-Hydroperoxy-Δ^{15}-androstene-3β-ol-17-one 3-Monoacetate (2a)

A solution of **2*a*** (100 mg) in pyridine (1.0 ml) containing triethylphosphite (0.5 ml) was heated on the steam bath for 15 mins and then evaporated under an air draft. The residue was crystallized twice from acetone–hexane as colorless plates, m.p. 162–163°; undepressed on admixture with **3** described under (*a*); λ_{max}(EtOH) 212 mμ (ε 8000); $[\alpha]_D^{26}$ +104.2°. The mobility on thin-layer chromatography and the infrared spectrum of the product were identical with that of **3** prepared by the literature procedure (2*b*).

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Reductions with sulfurated borohydrides. III. Borohydrides incorporating selenium and tellurium

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The reactions of selenium and tellurium with lithium, sodium, potassium, and tetramethylammonium borohydrides have been examined, using the hydrogen evolution as a measurement of the replacement of hydrogen by the chalcogen on the borohydride anion. Of all the possible reactions, only the combination of sodium borohydride with tellurium led to a stable compound, easily isolated and of definite stoichiometry. This new borohydride, $NaBH_2Te_3$ offers interesting possibilities as a reducer.

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We have reported the sulfuration of sodium borohydride by elemental sulfur, in the presence of organic solvents (1). This reaction gave a new reducer (2, 3), incorporating sulfur, according to eq. [1].

$$[1] \qquad NaBH_4 + 3S \xrightarrow[25°]{THF} H_2 + NaBH_2S_3$$

We had noted from qualitative tests that similar reactions could be obtained with selenium and tellurium. This paper describes the reaction of lower chalcogens with various borohydrides.

Experimental

The reactions were performed with hydrides (British Drug Houses Reagent grade) without purification. Diglyme was used as solvent, after overnight reflux and distillation over sodium. Selenium and tellurium (Fisher Reagent grade) were used in the form of a fine powder, dried in a dessicator under vacuum in the presence of sulfuric acid.

In a typical experiment, a mixture of 0.10 mole (3.78g) of $NaBH_4$ and 0.30 mole (38.4g) of tellurium was placed in a 500 ml, three-neck flask bearing a condenser and an adding funnel. The flask was kept at 40° in a water bath and after flushing with dry nitrogen, 100 ml of dry diglyme was added to the mixture of solids, with stirring. The hydrogen evolved from the system was collected on top of the condenser and measured over water previously saturated with that gas. A drying tube between the gas-collection apparatus and the reacting flask prevented diffusion of water vapors into the reacting vessel.

The infrared (i.r.) spectrum of the borohydride incorporating tellurium was measured in Nujol suspen-