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OXIDATION OF STEROID α-DIKETONES BY THALLIUM(III) ACETATE

CRYSTAL AND MOLECULAR STRUCTURE OF A SPIRO-CYCLOPENTAN-a,s-INDACENO DERIVATIVE OBTAINED FROM 3,4-DIKETO STEROIDS

(Dedicated to Prof. LUIGI PANIZZI on the occasion of his 70th birthday)

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Abstract—Treatment of 2,3-diketo-cholestane (**1**) with thallium triacetate in acetic acid afforded mainly 3α-carbomethoxy-A-nor-5α-cholestan-2-one (**2**). Under similar conditions, the 3,4-diketo steroids (**3** and **4**) underwent extensive rearrangement affording spiro-lactones (**9** and **10**), in low yields. The structural assignment of the spiro-cholestane derivative was supported by crystallographic X-ray analysis. This product was the result of A and B-ring contractions followed by acid-catalysed cyclization of an unsaturated carboxy intermediate.

There has been little detailed work on oxy-thallations of α-diketones and only the 1,2-cyclohexandione reaction, in aqueous perchloric acid, leading to the 3-hydroxy derivative has been reported.[1] A few papers deal with oxy-thallation of cyclic ketones[2] and steroid ketones[3] reporting acetoxylation, dehydrogenation products, and rearrangement reactions leading to ring contractions.

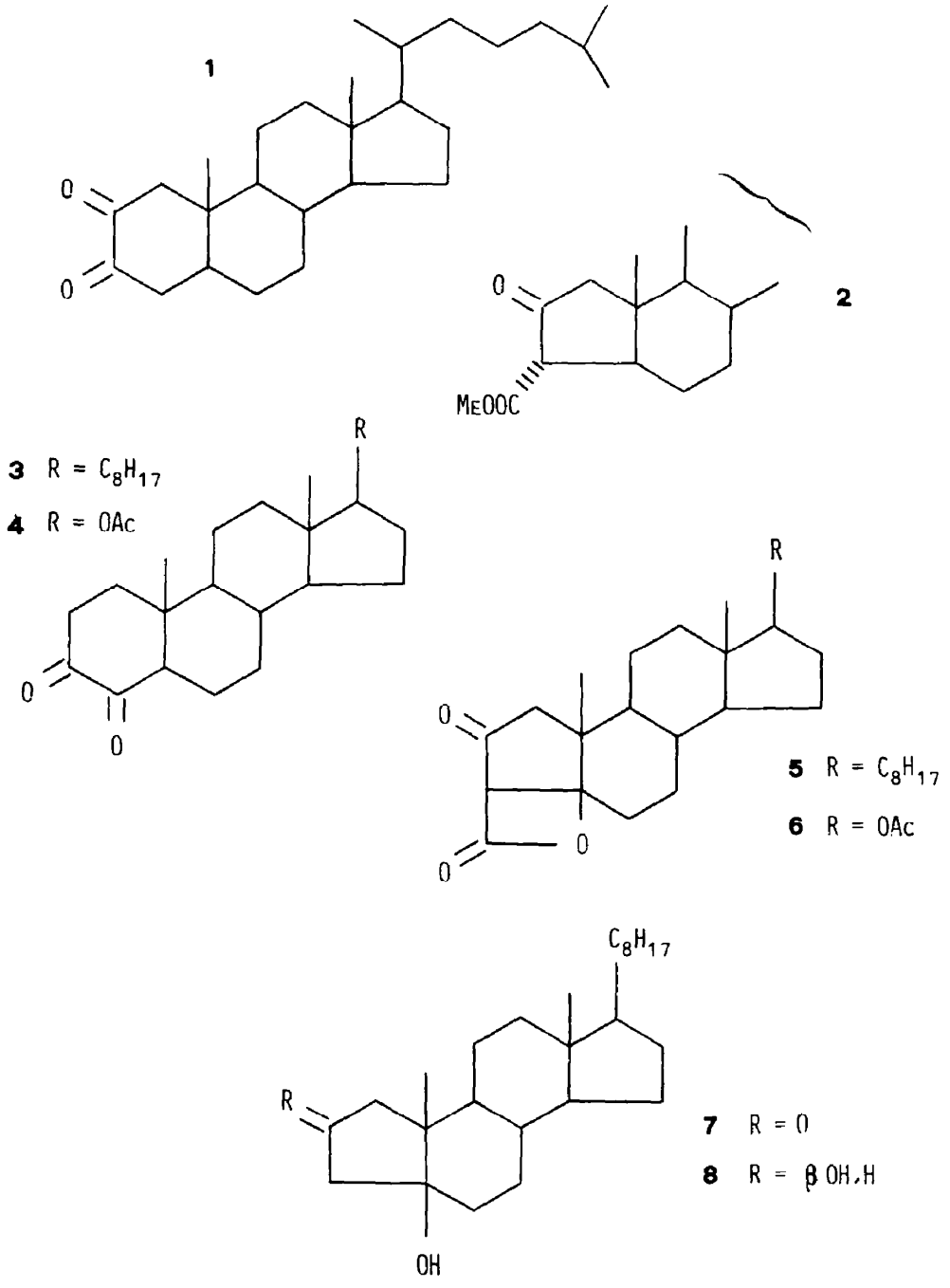
The steroid diosphenols have been found to undergo ready ring contraction under benzilic-acid conditions[4] and therefore we were interested in investigating the oxy-thallation behaviour of steroid α-diketones.

The reaction between thallium triacetate and 2,3-diketo cholestane (**1**) proceeded slowly at room temperature, in 96% acetic acid, to afford, in 48% yield, a carboxylic acid, identified as 3α-carbomethoxy-A-nor-5α-cholestan-2-one (**2**), a known compound.[5] Whilst the oxy-thallation of 2,3-diketo-cholestane showed normal behaviour, the reaction of 3,4-diketo-cholestane (**3**), under similar conditions, was more complicated, affording a mixture formed by a main product (in 20% yield), whose spectroscopic data fitted the lactone structure suggested (**5**), together with a certain amount of unchanged α-diketone. In fact, the IR spectrum immediately suggested the presence of β-lactone (ν_{max} 1790 cm^{-1}) and cyclopentanone (ν_{max} 1745 cm^{-1}) systems. Moreover, elemental analysis, mass spectrum (m/z 414, M^+) and NMR at 100 MHz, were also in accord with the structure **5**. At 0.65 and 1.65 ppm, the NMR spectrum of this compound showed the 18 and 19 Me signals, a two-proton singlet at 2.53 and a one-proton singlet at 3.36 ppm.

These results prompted us to investigate the behaviour with thallium(III) salts of 3,4-diketo-androstane derivatives and the reaction with 17β-acetoxy-3,4-diketo-androstane (**4**) showed a similar behaviour, leading to a lactone (**6**). On varying the nature of the associated anion of the Tl(III) salt, no changes in yields or in the number of the obtainable products from 3,4-diketo compounds were noted. Thus, the Tl(III) nitrate, which is almost completely ionic, afforded the lactone (**5**) with the same yield (20%).

The reaction between Tl(III) salts and 3,4-diketo steroids gave low yields of only one product but showed a peculiar behaviour, which we brought to light when we attempted the conversion of the suggested lactone **5** into the known ketol **7**.[6] In fact the lactone, after hydrolysis and decarboxylation under sublimation, afforded a ketol, which, whilst still showing the presence of a tertiary OH group in the NMR spectrum,[a] was distinctly different from 5β-hydroxy-A-norcholestan-2-one (**7**).[6] Moreover, the diol **8** obtained by reduction of the suggested ketol showed physical data which were different from those

[a]On treatment with trichloroacetylisocyanate (TAI), the NMR spectrum of the ketol showed a one-proton singlet at 8.53 ppm, which was due to a carbamate proton (Ref. 7).



Scheme 1.

of the known A-nor-cholestan-2,5-diols.[6] Because physical, chemical and spectroscopic data were, at this point, insufficient to clarify the lactone structure, we decided to submit this compound to crystallographic X-ray analysis.

X-ray data revealed an unusual and unexpected structure, derived by extensive rearrangement of the α-diketone (3). Figure 1 shows a general view of the molecular structure of compound **9** together with the crystallographic numbering scheme adopted for the non-H- atoms and the rings.[b] The H- atoms have been omitted for clarity. The spirocyclopentan-a,s-indaceno structure is the result of the A and B ring contractions of the original steroidal system, followed by acid-catalysed cyclization of an unsaturated carboxy intermediate. The C and D rings together with the side chain are recognized as a steroid fragment while B ring has been reduced from 6- to a 5-membered ring.

Bond distances and valency angles are given in Tables 1 and 2 respectively. The large discrepancies of the bonds C(25)–C(26) and C(25)–C(27) can essentially be ascribed to high thermal motion of the two Me groups. The oxa-bicyclo-heptandione system

[b]The crystallographic numbering scheme shown in Fig. 1 is adopted throughout the work.

Table 1. Bond lengths (Å) with standard deviations in parentheses.

O(1)–C(1)	1.49(1)
O(1)–C(4)	1.35(1)
O(2)–C(4)	1.21(1)
O(3)–C(5)	1.20(1)
C(1)–C(2)	1.51(2)
C(1)–C(10)	1.54(1)
C(1)–C(19)	1.51(1)
C(2)–C(3)	1.51(2)
C(3)–C(4)	1.51(1)
C(3)–C(5)	1.51(1)
C(5)–C(10)	1.52(1)
C(6)–C(7)	1.54(1)
C(6)–C(10)	1.55(1)
C(7)–C(8)	1.53(1)
C(8)–C(9)	1.49(1)
C(8)–C(14)	1.52(1)
C(9)–C(10)	1.56(1)
C(9)–C(11)	1.55(1)
C(11)–C(12)	1.53(1)
C(12)–C(13)	1.51(1)
C(13)–C(14)	1.54(1)
C(13)–C(17)	1.55(1)
C(13)–C(18)	1.57(1)
C(14)–C(15)	1.51(1)
C(15)–C(16)	1.55(1)
C(16)–C(17)	1.56(1)
C(17)–C(20)	1.53(1)
C(20)–C(21)	1.54(1)
C(20)–C(22)	1.51(1)
C(22)–C(23)	1.53(1)
C(23)–C(24)	1.49(1)
C(24)–C(25)	1.60(2)
C(25)–C(26)	1.62(3)
C(25)–C(27)	1.47(3)

Table 2. Bond angles (°) with standard deviations in parentheses.

C(1)–O(1)–C(4)	107.4(7)
O(1)–C(1)–C(2)	99.1(7)
O(1)–C(1)–C(10)	104.7(7)
O(1)–C(1)–C(19)	105.4(7)
C(2)–C(1)–C(10)	103.4(7)
C(2)–C(1)–C(19)	121.8(11)
C(10)–C(1)–C(19)	119.4(9)
C(1)–C(2)–C(3)	95.6(9)
C(2)–C(3)–C(4)	97.7(8)
C(2)–C(3)–C(5)	99.4(8)
C(4)–C(3)–C(5)	104.9(9)
O(1)–C(4)–O(2)	123.6(9)
O(1)–C(4)–C(3)	106.8(8)
O(2)–C(4)–C(3)	129.6(10)
O(3)–C(5)–C(3)	125.0(9)
O(3)–C(5)–C(10)	126.9(9)
C(3)–C(5)–C(10)	108.1(7)
C(7)–C(6)–C(10)	107.6(8)
C(6)–C(7)–C(8)	103.7(7)
C(7)–C(8)–C(9)	102.4(6)
C(7)–C(8)–C(14)	117.6(7)
C(9)–C(8)–C(14)	109.8(6)
C(8)–C(9)–C(10)	105.2(6)
C(8)–C(9)–C(11)	114.1(6)
C(10)–C(9)–C(11)	121.7(6)
C(1)–C(10)–C(5)	99.3(7)
C(1)–C(10)–C(6)	113.6(7)
C(1)–C(10)–C(9)	118.2(7)
C(5)–C(10)–C(6)	113.3(8)
C(5)–C(10)–C(9)	110.7(6)
C(6)–C(10)–C(9)	102.3(7)
C(9)–C(11)–C(12)	110.7(6)
C(11)–C(12)–C(13)	115.4(6)
C(12)–C(13)–C(14)	108.7(6)
C(12)–C(13)–C(17)	117.7(5)
C(12)–C(13)–C(18)	110.0(6)
C(14)–C(13)–C(17)	100.7(6)
C(14)–C(13)–C(18)	111.4(6)
C(17)–C(13)–C(18)	108.0(6)
C(8)–C(14)–C(13)	112.7(6)
C(8)–C(14)–C(15)	122.4(7)
C(13)–C(14)–C(15)	105.6(6)
C(14)–C(15)–C(16)	105.2(7)
C(15)–C(16)–C(17)	105.8(7)
C(13)–C(17)–C(16)	104.6(6)
C(13)–C(17)–C(20)	121.6(6)
C(16)–C(17)–C(20)	111.3(6)
C(17)–C(20)–C(21)	113.7(7)
C(17)–C(20)–C(22)	110.0(6)
C(20)–C(22)–C(23)	115.5(7)
C(22)–C(23)–C(24)	113.0(8)
C(23)–C(24)–C(25)	114.4(10)
C(24)–C(25)–C(26)	102.2(14)
C(24)–C(25)–C(27)	113.8(15)
C(26)–C(25)–C(27)	112.9(12)

(A_1,A_2 ring system) is fairly strained, as can be deduced from the valency angles of the sp^3 hybridized C atoms which are significantly different from the expected tetrahedral values. A_1 ring is in envelope conformation, with an approximate mirror plane through atom C(2) which deviates from the plane of the other four ring atoms of 0.83 Å on the same side of the C(19) Me group (plane(a), Table 3). The envelope conformation of the A_2 ring has an approximate mirror plane through atom C(2) which deviates from the plane of the other four ring atoms of 0.83 Å on the same side of the C(19) Me group (plane(b), Table 3).

The conformation of the B ring may be described as C_S C_2 intermediate conformation: the envelope has the C(8) atom 0.63 Å out of the plane of the other four ring atoms on the same side of the C(1) atom, while the half-chair presents the C(8) and C(9) atoms out of the plane of the other three ring atoms 0.50 and −0.17 Å respectively on opposite sides (planes(c) and (d), Table 3). The degree of departure from ideal C_S symmetry and C_2 symmetry can be evaluated according to the proposal of Duax, Weeks and Rohrer.[8] The asymmetry parameters for the B ring are: $C_S^8 = 8.8°$ and $C_2^6 = 11.0°$.

Also the conformation of the D ring may be described as a C_S–C_2 intermediate conformation: the envelope has the C(13) atom 0.63 Å out of the plane of the other four ring atoms on the same side of the C(18) Me group, while the half-chair has the C(13) and C(14) atoms out of the plane of the other three ring atoms 0.50 and −0.17 Å respectively on opposite sides (plane(e) and (f), Table 3). Steroid D rings assume many intermediate conformations between the half-chair and the C(13) envelope. The description of the conformation of the D ring may also be given in terms of the maximum angle of torsion and the phase angle of pseudorotation according to Altona, Geise and Romers:[9] their values are $\phi_m = 43.0°$, $\Delta = 16.4$ respectively. Ring C is in chair conformation with the atoms C(9) and C(13) deviating −0.61 and 0.66 Å on either side of the least-squares plane through the other four ring atoms (plane(g), Table 3). Both the B/C and C/D junctions are trans. The sum of the absolute values of the torsion angles of junction[10] are 98.3 and 99.7° for the C(8)–C(9) and C(13)–C(14) bonds respectively.

Table 3. Equations of least-squares planes in the form Ax + By + Cz = D where x, y and z are gractional coordinates. Deviations (Å) of atoms from the plane are given in square brackets.

Plane(a): O(1), C(1), C(3), C(4)
3.2603x+5.9735y+7.6984z = 5.3357

[O(1)-0.016, C(1) 0.010, C(3)- 0.010, C(4)0.016,C(2)0.834, C(19) 0.512]

Plane(b): C(1), C(3), C(5), C(10)
3.1747x + 5.4915y - 10.4054z = -1.6121

[C(1)0.003, C(3)-0.003, C(5)0.004, C(10)-0.004, C(2)0.832, C(19)0.154]

Plane(c): C(6), C(7), C(9), C(10)
9.1380x + 0.8032y + 5.7321z = 1.7018

[C(6)-0.038, C(7)0.025, C(9)-0.024, C(10)0.037, C(8)0.627, C(1)1.215]

Plane(d): C(6), C(7), C(10)
8.8409x + 0.4856y + 6.6824z = 1.9386

[C(8)0.499, C(9)-0.166, C(1)1.196]

Plane(e): C(14), C(15), C(16), C(17)
8.0165x + 2.1164y + 7.6018z = 2.3649

[C(14)-0.027, C(15)0.041, C(16)-0.040, C(17)0.026, C(13)0.633, C(18)2.185]

Plane(f): C(15), C(16), C(17)
8.5120x + 1.8532y + 6.6862z = 2.4411

[C(13)0.499, C(14)-0.173, C(18)2.060]

Plane (g): C(8), C(11), C(12), C(14)
9.5512x + 1.1922y + 4.0641z = 2.0627

[C(8)0.035, C(11)-0.035, C(12)0.036, C(14)-0.036C(9)-0.607, C(13)0.662, C(18)2.202]

The side-chain is in extended conformation as can be deduced from the torsion angles.[11] (The two terminal methyl groups denoted by C(26) and C(27) give rise to trans and gauche* conformation respectively. The distance between the atoms C(17) and C(25) is a measure of the extension of the chain: in a fully extended conformation this distance is 6.9 Å,[12] in our structure this value is 6.4 Å.

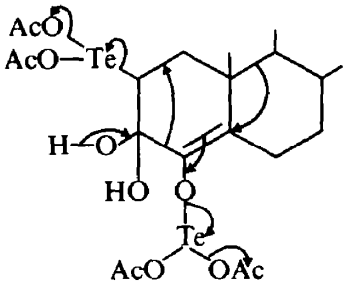
Figure 2 shows a packing diagram of the crystal viewed down the b axis. No significant short intermolecular contact is present in the packing.

A similar spiro ring fusion with an indaceno-structure is reported[13] for 6β,19-oxido-2,17-dihydroxy-androst-1,4-dien-3-one in benzilic-acid rearrangement conditions. The spiro lactone (**9**), derived by the A and B ring contractions and lactonisation of a carboxy intermediate may arise from the following thallium adduct:

A matter of particular interest is the β-configuration of the carboxylic group of the acidic intermediate, since the oxy-thallation rearrangements, reported to date, lead always to α-carboxy groups in ring-contracted derivatives for both cyclic[2] and steroid ketones.[3]

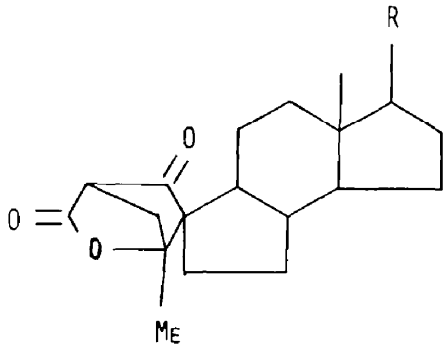
We could also observe the usual α-configuration of the carboxy group in the above-reported oxy-thallation of 2,3-diketocholestane, which led to the 3α-carbomethoxy derivative (**2**). The lactone with β-configuration, obtained from the 3,4-diketo steroids, derived by an extensive rearrangement of the A and B rings, could arise from a particular conformation of the intermediate, which leads to the unsaturated carboxylic acid, or from an epimerisation,[14] which is unlikely because of the mild reaction conditions and the formation of only one product.

Another possibility is that the lactonisation may derive from some reaction-accompanying the ring contractions, but is not induced by an acetoxy-thallation process, as instead occurs in the case of 2-*endo*-norbornene carboxylic acids.[15]



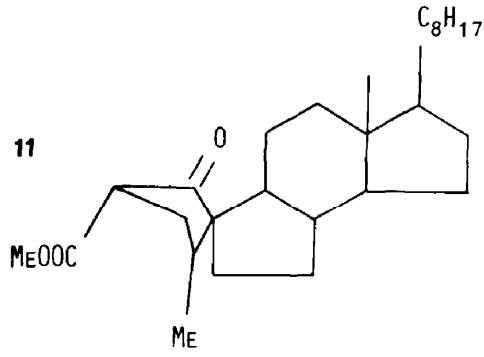
EXPERIMENTAL

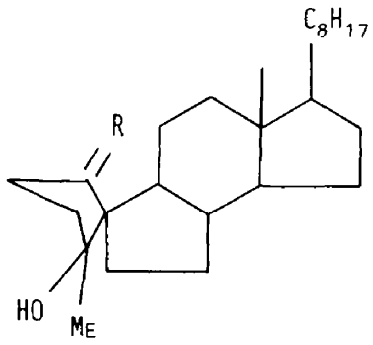
Thallium triacetate and thallium nitrate were prepared by lit. procedures.[16,17] M.ps were determined with a Köfler hot-stage apparatus and were uncorrected. Optical rotations were taken at 20° with a Schimdt-Haensch polarimeter (1 dm cell). UV and IR spectra were recorded on Cary Model 14 and Perkin-Elmer 521 spectrophotometers respectively. ^{1}H NMR spectra were measured in $CDCl_3$ solns with a Jeol C60 and Varian XL 100 spectrometers and chemical shifts are measured in ppm downfield from internal TMS. Mass spectra were run in a 5980A Hewlett-Packard mass spectrometer.



9 R = C_8H_{17}

10 R = OAc





12 R = O

13 R = ξ OH,H

Scheme 2.

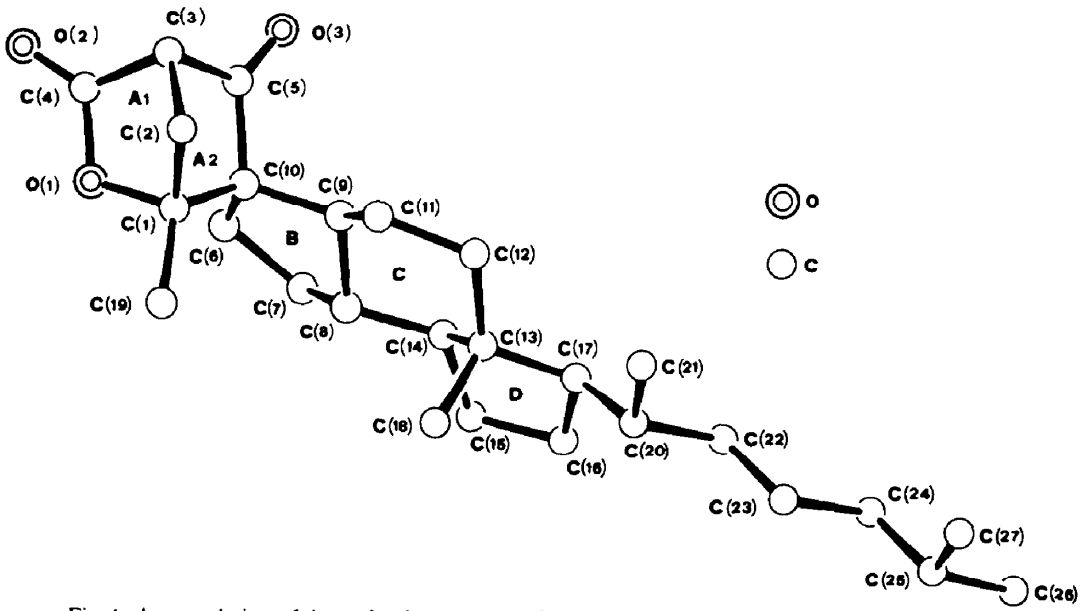


Fig. 1. A general view of the molecular structure of compound (**9**) together with the numbering scheme adopted for the crystallographic analysis.

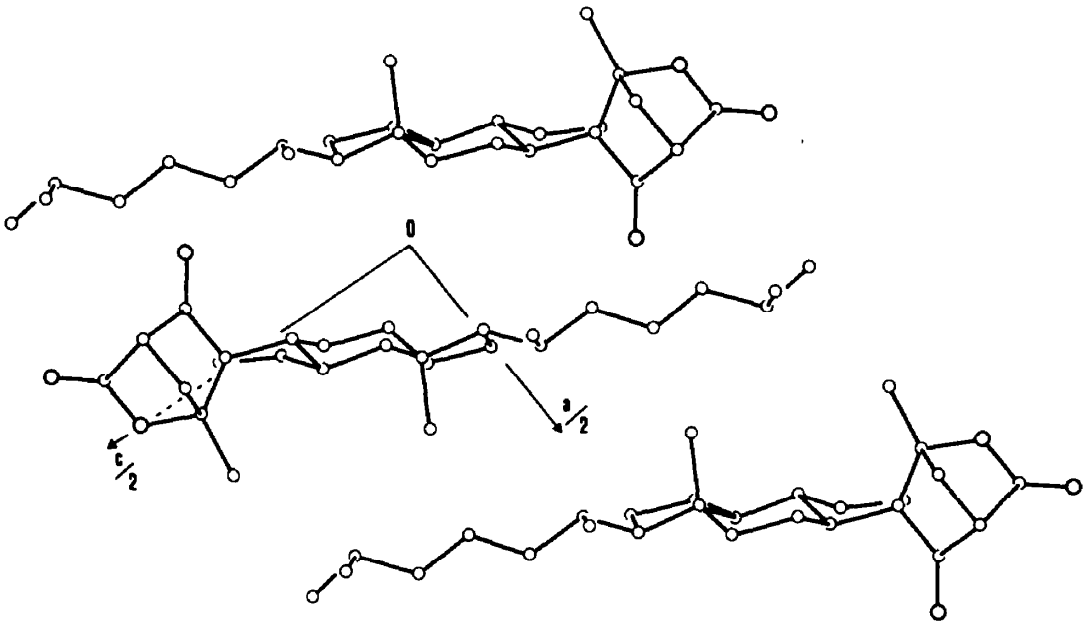


Fig. 2. The packing diagram viewed down the b axis.

Preparative layer chromatography was carried out with Merck HF_{254} silica gel (layers 0.5 mm thick). Steroidal α-diketones were prepared following literature procedures (Refs. 18–20).

General procedure for oxidation of steroidal α-diketones with Tl(III) salts. A soln of the diketo steroid (1 mmol) and Tl(III) salt (6 mmol) in 96% AcOH (1 ml for every 0.03 g of thallium salt) was stirred at room temp. The oxidation was followed by tlc. The mixture was diluted with water, and extracted three times with ether, and the ether layers were washed to neutrality, dried and evaporated.

Oxidation of cholestane-2,3-dione (1). The α-diketone[18] (1.06 g) and Tl(III) acetate (6.06 g) (molar ratio 1:6) in 96% AcOH (202 ml) reacted for 120 hr. The residue from the ethereal extract gave a crude acid (1.1 g) which was directly esterified with ethereal diazomethane. Preparative layer chromatography of the crude ester (benzene as eluant, two runs) gave *3α-carbomethoxy-A-nor-5α-cholestan-2-one* (2) (520 mg) (48%), m.p. 107–108 (from MeOH); α_D + 106° (c = 1, $CHCl_3$); IR (KBr): ν_{max} 3700–3200, 1765, 1730 cm^{-1}; NMR: δ 0.66 (3H, s, 18-Me), 0.86 (3H, s, 19-Me), 3.73 (3H, s, Me ester), 3.05 (1H, d, J = 13 Hz, 3-H); MS: m/z (430, M^+). The spectral data were identical with the authentic data.[5]

Oxidation of cholestane-3,4-dione (3). The α-diketone[19] (1.3 g) and Tl(III) acetate (7.44 g) in 96% AcOH (250 ml) reacted for 120 hr at room temp. The usual work-up gave a residue (1.32 g), which was chromatographed on silica (plc) (elution with benzene, three runs) giving unchanged starting material (300 mg) and the *compound* 9 (350 mg), m.p. 162–163° (from n-hexane); α_D − 10.8° (c = 1, $CHCl_3$); UV (EtOH): λ_{max} 285 nm (1 g ε 2.335); IR (KBr): ν_{max} 1790, 1745 cm^{-1}; NMR: δ 0.65 (3H, s, 18-Me), 1.65 (3H, s, 19-Me), 2.53 (2H, s, 2-H), 3.36 (1H, s, 3-H); MS: m/z 414, 396, 386, 370, 355. (Found: C, 78.06; H, 10.17; M^+ 414. $C_{27}H_{42}O_3$ requires: C, 78.21; H, 10.21%; M, 414.6).

Crystallographic analysis of 9. Suitable single crystals of 9 were obtained as colourless needles by evaporation of a isopropyl ether soln at low temperature. Space group and preliminary cell dimensions were determined from oscillation and Weissenberg photographs. Accurate lattice constants and intensities were measured on an automatic SYNTEX $P2_1$ diffractometer with MoK_α radiation (0.71069 Å) monochromatized by a graphite crystal. Refined cell parameters were calculated by a least-squares fit of the θ angles of 15 high-order reflexions.

The crystal data are: $C_{27}H_{42}O_3$, M = 414.6, space group $P2_1$, a = 10.451(3), b = 7.536(3), c = 16.063(4) Å; β 97.40(2)°; V = 1255 $Å^3$, Z = 2, D_c = 1.10 g cm^{-3}.

The intensities were collected within the range $2.4 \leqslant 2\theta \leqslant 50.0°$ by the ω-scan technique with a scan speed in the interval 0.5 ÷ 29.3 min^{-1} over a range of 0.8°. Reflexions with larger 2θ values could not be detected owing to the low scattering power of the crystal. Background counts were taken for half time of the scan. Of the 2391 reflexions measured the intensities of 1667 were considered observed [$I > 2\sigma(I)$]. Three standard reflexions monitored after every 100 remained essentially constant, showing no X-ray damage. Lorentz and polarization factors, but no absorption corrections were applied $\mu(MoK_\alpha) = 0.75\,cm^{-1}$.

Structure solution and refinement. The absolute scale factor and the overall B were derived by the Wilson method, normalized structure amplitudes were calculated and 300 reflexions with $|E| > 1.5$ were used for phase determination. The structure was solved by MULTAN.[21] An E map computed with the phases of one of the sets having the highest figures of merit revealed only a molecular fragment chemically significant. The rest of the molecule was recognized from successive structure factors and Fourier syntheses calculations. The structure was refined by block-diagonal least-squares method, isotropically and anisotropically except for the two carbon atoms C(26) and C(27) of the Me groups, which showed large isotropic temp factors: disorder for these two atoms was checked, but no other peaks in bonding positions could be detected from the final Fourier difference. The function minimized was $\Sigma w(|F_o| - |F_c|)^2$ where $w = (a + |F_o| + b|F_o|^2)^{-1}$ with a and b of the order of $2F_{o(min)}$ and $2/F_{o(max)}$ respectively. Scattering factors were taken from International Tables for X-ray Crystallography.[22] A difference synthesis showed 16 peaks larger than $\sigma(\rho)$ in positions stereochemically feasible with H atoms. These were included in the refinement with an isotropic B value equal to that of the carrier carbon atom before the anisotropic refinement, keeping fixed their parameters. Refinement was stopped when the parameter shifts were $< 0.1\sigma$. The adequacy of the weighting scheme was checked by inspection of the mean of $\omega|\Delta F^2|$ as a function of the $|F_o|$ and $\sin\theta/\lambda$ ranges: in both cases the function was nearly constant. The final R and R_w are 0.090 and 0.125 respectively for all observed reflexions. All the calculations were carried out on the HP21MX minicomputer[23] of the CNR Research Area and

on the UNIVAC 1110 computer[24] of the University of Rome. A list of observed and calculated structure factors is available on request from the authors.

Oxidation of 17β-acetoxy-androstane-3,4-dione (**4**). The α-diketone[20] (1.1 g) and thallium triacetate (7.45 g) in 96% AcOH (250 ml) reacted for 120 hr at room temp. The usual work-up gave a residue (1.1 g) which was chromatographed on silica (plc) (elution with benzene–ether 95:5, two runs) leading to starting material (250 mg) and to *lactone* (10) (180 mg), m.p. 167–168° (from ether–hexane); α_D − 28.4 (c = 1, $CHCl_3$); IR (KBr): ν_{max} 1790, 1748, 1730 cm^{-1}; NMR: δ 0.80 (3H, s, 18-Me), 1.66 (3H, s, 19-Me), 2.02 (3H, s, 17-OAc), 2.52 (2H, s, 2-H), 3.36 (1H, s, 3-H). (Found: C, 69.90; H, 7.86; M, 360. $C_{21}H_{28}O_5$ requires: C, 69.97; H, 7.83%; M, 360.4).

Oxidation of cholestane-3,4-dione with Tl(III) *nitrate*. The α-diketone (210 mg) and Tl(III) nitrate (1.38 g) in 96% AcOH (46 ml) reacted for 78 hr at room temp. The usual work-up and purification by plc (benzene as eluant) gave the *spiro-lactone* **9** (40 mg).

Methyl ester derivative (**11**). Compound **9** (160 mg) was treated with 5% methanolic KOH aq (MeOH–H_2O 1:1) (2.5 ml) for 8 hr at 45°. The separation of the acidic fraction gave a crude product (140 mg) which was directly esterified with ethereal diazomethane. Chromatography of the crude ester on silica (plc) (benzene–ether 7:3, as eluant) and extraction of the major band gave the *spiro-methyl ester* **11** (120 mg) (oil); α_D − 45.2 (c = 1, $CHCl_3$); IR ($CHCl_3$): ν_{max} 1740, 1715 cm^{-1}; NMR: δ 0.64 (3H, s, 18-Me), 1.49 (3H, s, 19-Me), 3.5 (1H, apparent d, J = 9 Hz, 3-H), 3.74 (3H, s, Me ester) (Found: C, 74.94; H, 10.37; M, 446. $C_{28}H_{46}O_4$ requires: C, 75.29; H, 10.38%; M, 446.4).

Decarboxylation of carboxy derivative obtained from spiro-lactone (**9**). Hydrolysis of **9** (180 mg) was carried out in the usual manner. The acidic fraction (150 mg) was sublimated *in vacuo* (0.05 mmHg) at 140° to the *spiro-ketol* **12** (130 mg), m.p. 154–155° (from n-hexane); α_D − 70.2 (c = 1, $CHCl_3$); UV (EtOH): λ_{max} 275–280 nm (lg ε 2.79); IR (KBr): ν_{max} 3420, 1722, 1710 cm^{-1}; NMR: δ 0.64 (3H, s, 18-Me), 1.43 (3H, s, 19-Me); NMR ($CDCl_3$ + TAI): δ 8.53 (1H, s, N-H carbamate):[7] MS: m/z 388 (M^+), 373, 370, 287, 275, 247. (Found: C, 80.31; H, 11.46; M, 388. $C_{26}H_{44}O_2$ requires: C, 80.35; H, 11.41%; M, 388.6).

Reduction of ketol (**12**). Ketol **12** (100 mg) in dry Et_2O (8 ml) was added under stirring to LAH (24 mg) in dry ether (4 ml). The mixture was kept at room temperature for 90 min. After usual work-up the residue was purified by plc (benzene–ether 1:1, as eluant) giving the *spiro-diol* **13**, m.p. 158–163° (from MeOH); α_D − 11.7 (c = 0.62, $CHCl_3$); IR ($CHCl_3$): ν_{max} 3580–3430 cm^{-1}; NMR: δ 0.66 (3H, s, 18-Me), 1.33 (3H, s, 19-Me), 4.46 (1H, t, J = 8 Hz, 5-H); MS: m/z 390 (M^+), 372, 339, 331, 330. (Found: C, 79.91; H, 11.82; M, 390. $C_{26}H_{46}O_2$ requires: C, 79.94; H, 11.87%; M, 390.65).

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