BASE-CATALYZED AUTOXIDATION OF 3α,5-CYCLO-5α-CHOLESTAN-6-ONE AND 3α,5-CYCLO-5α-CHOLESTAN-7-ONE*

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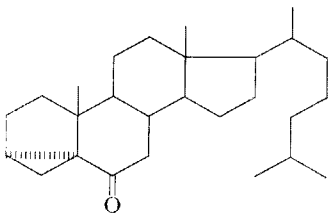
Autoxidation of 3α,5-cyclo-5α-cholestan-6-one (*I*) and of 3α,5-cyclo-5α-cholestan-7-one (*II*) in tert-butyl alcohol in the presence of potassium tert-butoxide yields 7-hydroxy-3α,5-cyclo-5α-cholest-7-en-6-one (*V*), 6α-hydroxy-3α,5-cyclo-5α-cholestan-7-one (*IV*), 6α-hydroxy-3α,5-cyclo-6,7-seco-5α-cholestan-6,7-dioic acid (*IIIa*), 8-oxo-3α,5-cyclo-B-nor-6,8-seco-5α,14β-cholestan-6-oic acid (*VIa*), 7β-hydroxy-3α,5-cyclo-B-nor-5α-cholestan-7α-carboxylic acid (*VIIIa*) and 9α,14α-epoxy-8-oxo-3α,5-cyclo-B-nor-6,8-seco-5α-cholestan-6-oic acid (*VIIa*). Ketol *IV* is a precursor of *IIIa*, *V*, *VIa*, *VIIa* and *VIIIa*, diosphenol *V* is a precursor of *VIa* but not of *VIIIa*. Ketoester *VIa* gives rise to *VIIa*.

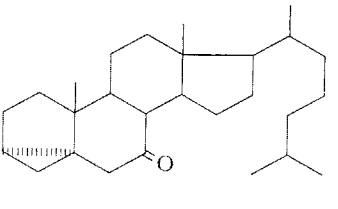
Autoxidation of ketones in a basic medium has found broad application in the chemistry of natural products. Particularly, diosphenols[1-6], α-hydroxy or α-hydroperoxy ketones[4,7-11], hydroxynaphtoquinones from 1-tetralones[12] or derivatives of carboxylic acids[5,13-17] can be obtained depending on structural factors and reaction conditions. The reaction proved to be a simple method for the preparation of compounds not readily accessible by other synthetic routes.

In the course of our synthetic work we became interested in the autoxidation of 3α,5-cyclo-5α-cholestan-6-one (*I*) under alkaline conditions. In our approach, *a*) a detailed product analysis was undertaken, *b*) the products were individually subjected to reaction conditions and their behavior investigated, *c*) the same reaction was applied to the isomeric 3α,5-cyclo-5α-cholestan-7-one (*II*) and the products compared with those obtained from the 6-ketone. The reaction was carried out in tert-butyl alcohol in the presence of potassium tert-butoxide in an oxygen atmosphere. The reaction mixture was separated into neutral and acidic components and the acidic compounds were converted into methyl esters with diazomethane before chromatographic separation. Both preparative adsorption chromatography and analytical gas chromatography were used for separation of the reaction mixtures and product identification.

* Part CLXXXVI in the series On Steroids; Part CLXXXV: This Journal *41*, 2630 (1976).

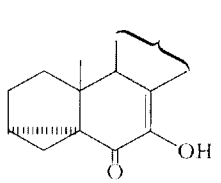


I

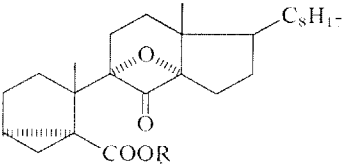


II

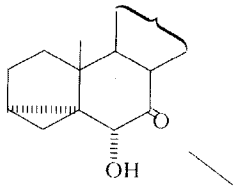
It was found that both the 6- and 7-ketone gave mixtures of identical products: neutral substances were diosphenol *V* and α-hydroxy ketone *IV*. Acidic products were isolated as methyl esters *IIIb*, *VIb*, *VIIb* and *VIIIb*.



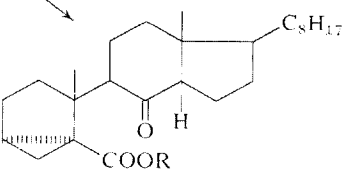
V



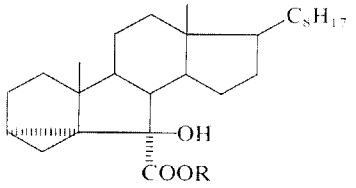
VIIa, R = H
VIIb, R = CH_3



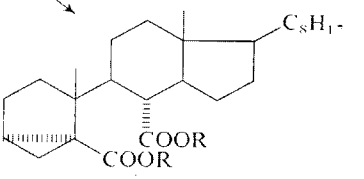
IV



VIa, R = H
VIb, R = CH_3

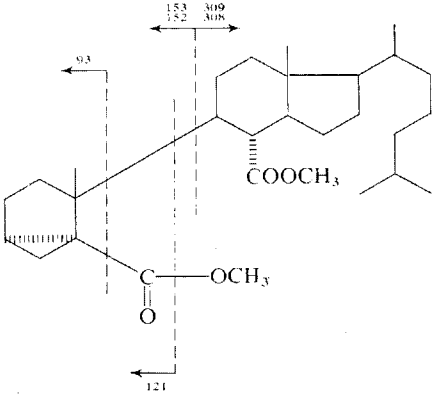


VIIIa, R = H
VIIIb, R = CH_3

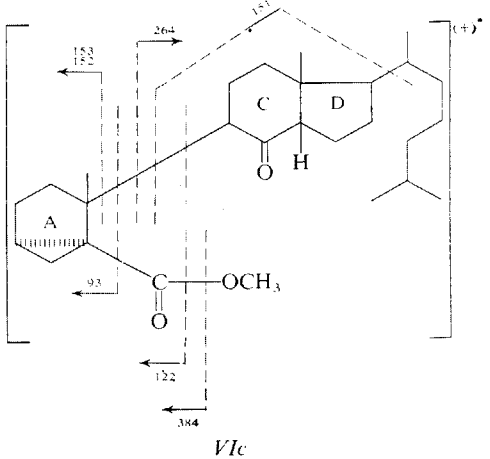


IIIa, R = H
IIIb, R = CH_3

After 24 hours, the neutral portion of the reaction mixture consists, mainly, of diosphenol *V*. Its structure follows from the positive ferric chloride reaction, from the presence of one intramolecularly hydrogen-bonded hydroxyl group and one keto group conjugated with one double bond (IR- and UV-spectra). Reduction of diosphenol *V* with lithium aluminum hydride gives ketol *IV* which is also one of the products of autoxidation as a minor component of the neutral portion. In *IV*, presence of a cyclopropane ring is proved by the ^{1}H-NMR spectrum. The keto group (ν(CO) 1709) is located at $C_{(7)}$ since the 6-ketones with keto group in α-position to a cyclopropane ring absorb at 1 695 cm^{-1}. Location of the hydroxyl at $C_{(6)}$ is corroborated by the ^{1}H-NMR spectrum where the doublet of the —CH—O— proton collapses to a singlet after addition of CD_3COOD. Conformation of the 6-hydroxyl group in hydroxy ketone *IV* follows from IR- and ^{1}H-NMR data. In the region of OH-stretching vibrations, the IR-spectrum exhibits two bands; a weaker band of a free hydroxyl at 3640 cm^{-1} and a stronger band (persisting at the concentration of $5\cdot10^{-4}$M in tetrachloromethane) at 3488 cm^{-1} due to an intramolecularly bonded OH group. The difference in values of the wave numbers for the free and bonded hydroxyl group ($\Delta\nu$ 152 cm^{-1}) is larger than in, *e.g.*, cerine ($\Delta\nu$ 124 cm^{-1})[18]; the latter has an equatorial hydroxyl which is hydrogen-bonded to the adjacent keto group. Measurement of 5-hydroxy-5β-cholestan-6-one as a rigid model with coplanar orientation of the equatorial hydroxyl and keto group showed the presence of only an intramolecularly bonded hydroxyl (ν(OH) 3485 cm^{-1}); on the other hand, the axial hydroxyl in 5-hydroxy-5α-cholestan-6-one is present only in the free form (ν(OH) 3605 cm^{-1}). All these data demonstrate the coplanar orientation of the hydroxyl and the keto group in *IV*. The relatively high wave number of the free hydroxyl is close to values found for equatorial hydroxyl adjacent to a cyclopropane ring[19].



IIIc



VIc

Further conclusions can be drawn from comparison of the ^{1}H-NMR spectrum of the compound *IV* with the spectra of suitable models. Introduction of 6α- or 6β-hydroxyl or a 6-keto group into the molecule of 3α,5-cyclo-5α-cholestane (*XXXI*) is accompanied by characteristic changes in chemical shifts of protons at $C_{(4)}$ and $C_{(19)}$ (Tables I and

TABLE I

Characteristic Parameters of ^{1}H-NMR Spectra of 3α,5-Cyclo-5α-cholestanes

Compound	Solvent	$C_{(4)}$—H		$C_{(6)}$—H	19-CH_3	18-CH_3	21-CH_3	26,27-CH_3
		H^a	H^b					
XXXI	$CDCl_3$	0·32	−0·02	[c]	0·89	0·68	0·90	0·86
XXXII	$CDCl_3$	0·24	0·60	3·87[d]	0·90	0·68	0·90	0·86
	$CDCl_3$ + TAI[e]	0·31	0·42	5·19[d]	0·95	0·68	0·89	0·85
XXXIII	$CDCl_3$	0·49	0·26	3·21[f]	1·03	0·70	0·89	0·84
	$CDCl_3$ + TAI	0·55	0·55	4·49[f]	1·00	0·72	0·89	0·83
II	$CDCl_3$	0·46	0·10	1·59 2·88[g]	1·12	0·66	0·89	0·84
IV	$CDCl_3$	0·36	0·70	4·34	1·17	0·68	0·90	0·85
	$CDCl_3$ + TAI	0·48	0·59	5·44	1·22	0·69	0·90	0·85
XIII	$CDCl_3$	0·42	[c]	3·58[h]	0·95	0·71	0·92	0·86
	$CDCl_3$ + TAI	0·46	[c]	4·93[h]	0·96	0·69	0·92	0·86
VIIIb	$CDCl_3$	0·55	0·48	—	0·93	0·67	0·92	0·86
	$CDCl_3$ + TAI	0·65	[c]	—	0·94	0·65	0·92	0·86

[a] H-endo triplet, $J_{4,4} = J_{4,3} = 4-5$ Hz; [b] H-exo doublet of doublets, $J_{4,4} = 4-5$ Hz, $J_{4,3} = 8-9$ Hz; [c] the proton is overlapped in the methylene envelope; [d] doublet of doublets, $J_{6,7} = 11·5$ and 4·5 Hz; [e] trichloroacetyl isocyanate; [f] triplet, $J_{6,7} = 2·5$ and 2·5 Hz; [g] two doublets, $J_{6,6} = 13$ Hz; [h] doublet, $J_{6,8} = 5·5$ Hz.

TABLE II

Effects of Substituents on Chemical Shifts of Cyclopropane and Angular Methyl Protons in 3α,5-Cyclo-5α-cholestane Derivatives

Substituent	$C_{(4)}$—H		19-CH_3	18-CH_3
	H_{endo}	H_{exo}		
6α-OH	−0·08	0·62	0·01	0
6β-OH	0·17	0·28	0·14	0·02
7-Oxo	0·14	0·12	0·23	−0·02

II). The chemical shifts calculated on the basis of such contributions indicate clearly the α-configuration of the 6-hydroxyl as expressed in the formula *IV* (Table III). The same result is achieved when *IV* is treated with trichloroacetyl isocyanate and the values of induced chemical shifts of protons at $C_{(4)}$ and $C_{(19)}$ are compared with those in models *XXXII* and *XXXIII* after the same treatment (Table IV).

The acid portion of the reaction mixture was methylated with diazomethane and the components were separated by adsorption chromatography on silica gel. The major component was identical with the known[20,21] diester *IIIb*. Its mass spectrum is characterized by intense peaks that correspond to ions arising by cleavage of the $C_{(9)}$—$C_{(10)}$ linkage (*cf. IIIc*). The structure *VIIIb* for the less abundant ester is based on physico-chemical data proving its composition ($C_{28}H_{46}O_3$; mass spectrum) and presence of the functional groups. It was proved by chemical degradation: The ester *VIIIb* was reduced with lithium aluminum hydride to give a diol *X* which, on periodic

TABLE III

The Calculated and Found Values of Chemical Shifts of Cyclopropane and Angular Methyl Protons for Hydroxy Ketone *IV*

Value	$C_{(4)}$—H		19-CH_3	18-CH_3
	H_{endo}	H_{exo}		
Calculated for 6α-OH,7-oxo	0·38	0·72	1·13	0·66
Calculated for 6β-OH,7-oxo	0·63	0·38	1·26	0·68
Found for *IV*	0·36	0·70	1·17	0·68

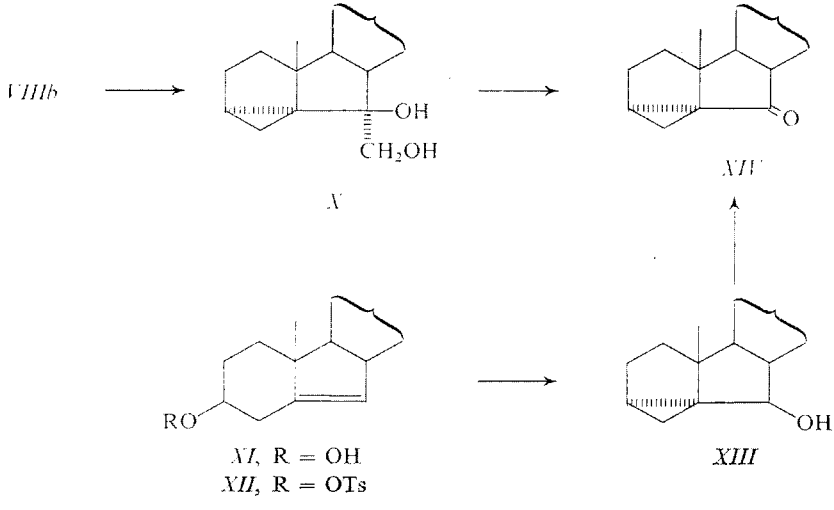
TABLE IV

Changes of Proton Chemical Shifts of Hydroxysteroids Induced after Reaction with Trichloroacetyl Isocyanate

Compound	H_{endo}[a]	H_{exo}[a]	19-CH_3	18-CH_3
XXXII	0·07	−0·18	0·05	0·00
XXXIII	0·06	0·29	−0·03	0·02
IV	0·12	−0·11	0·05	0·01
XIII	0·04	[b]	0·01	−0·02
VIIIb	0·10	[b]	0·01	−0·02

[a] Methylene group in cyclopropane, [b] indeterminable value.

acid oxidation, yielded the ketone *XIV*. The IR spectrum of the latter showed the expected maxima of a cyclopropane ring (3060, 3020 cm^{-1}) and of a keto group (1721 cm^{-1}); this value is consistent with the presence of a keto group in a five-membered cycle adjacent to a cyclopropane ring. Its $[\alpha]_D$ +8° (ethanol), however, differed from that ($[\alpha]_D$ +26·7° (ethanol)) reported by Zorbach and coworkers[22] for this compound obtained in a different manner. This discrepancy prompted us to prepare the compound by an independent and unequivocal procedure. B-Norcholesterol (*XI*) was converted to its tosylate *XII* and to the 3,5-cyclosteroid *XIII*.



Oxidation of the latter compound gave the ketone *XIV*, m.p. 81–82°C, $[\alpha]_D$ +11° (ethanol) the IR-spectrum of which was identical with that of the ketone prepared from diol *X*. Obviously, Zorbach's $[\alpha]_D$ value is either erroneous or their procedure furnished an impure product. For reasons discussed later, the configuration of the acid is assumed to be as shown in *VIIIa*.

The remaining minor compounds, *VIb* and *VIIb*, both contained a ketonic function. The ketone *VIb* was shown to have the composition $C_{27}H_{44}O_3$ (mass spectrometry) and to contain a methoxycarbonyl group conjugated with a cyclopropane ring (IR-spectrum). The formula *VIb* was corroborated by the mass spectrometric fragmentation pattern as summarized in formula *VIc*. The linkage between rings A and C is the most readily cleaved, such fission being involved in the most frequent fragmentation processes. The base peak of the spectrum at *m/e* 93 (C_7H_9) is due to an ion representing the ring A after elimination of the methoxycarbonyl radical. Ions of *m/e* 153 and 152 correspond to a part of the molecule containing the ring A and the methoxycarbonyl group. They arise by a simple cleavage of the linkage connecting the rings

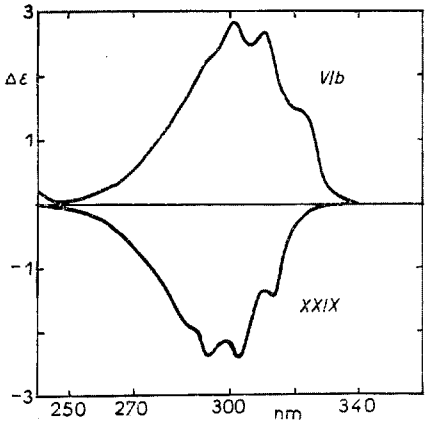


FIG. 1

CD Curve of Windaus' Ketone *XXIX* and 8-Oxo-3α,5-cyclo-B-nor-6,8-seco-5α,14β--cholestan-6-oic Acid Methyl Ester (*VIb*)

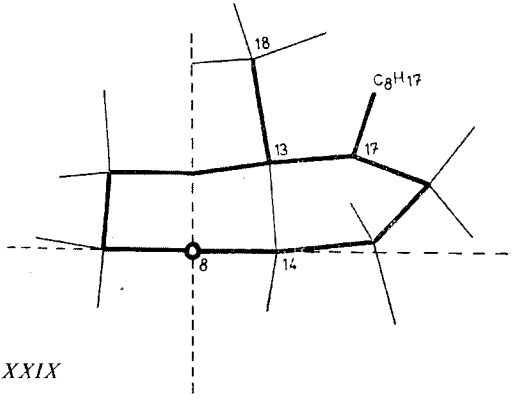


FIG. 2

Octant Projection of the Windaus' Ketone *XXIX*

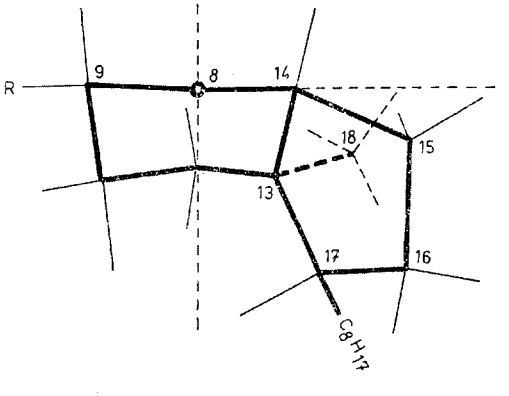
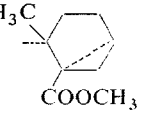
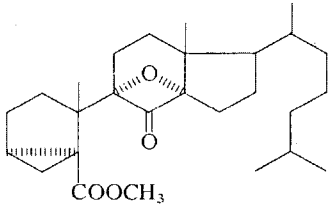


FIG. 3

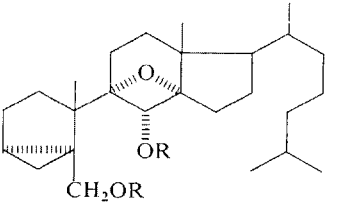
Octant Projection of 8-Oxo-3α,5-cyclo-B--nor-6,8-seco-5α,14β-cholestan-6-oic Acid Methyl Ester (*VIb*) R =



A and C (ion at *m/e* 153) or by cleavage with hydrogen transfer to the eliminated species (ion at *m/e* 152). Finally, the configuration at $C_{(14)}$ had to be established since epimerization at this center was well possible. In order to obtain the necessary information, the CD curve (Fig. 1) of the ketone *VIb* was compared with that of the Windaus' ketone *XXIX*. The latter compound was prepared some forty years ago by Windaus and coworkers[23,24]. We prepared the same compound by permanganate oxidation of vitamin D_3 in a manner analogous to that applied to vitamin D_2 by Windaus and Grundmann[25]. The identity was proved by elemental analysis, m.p. of the semicarbazone[24], IR and UV spectra and mass spectrometric fragmentation pattern. The Windaus' ketone should exhibit a negative Cotton effect owing to the presence of the D ring in the back upper right octant (Fig. 2). This was indeed found to be so. On the other hand, the compound *VIb* showed a CD curve which is practically a mirror image of the CD curve of the Windaus' ketone. This behavior is expected of *VIb* with 14β configuration since the D ring is located in the back lower right octant (Fig. 3). It should be pointed out that the ring A may be disregarded in these considerations. The bulky A ring must assume equatorial conformation at $C_{(9)}$ and, lying in a nodal plane, does not contribute to the Cotton effect of the molecule. Besides, the chiral centers in the A ring have no individual effect; this follows from the fact that the diester *IIIb* exhibits only a plain ORD curve.

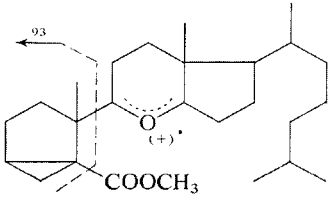


VIIb



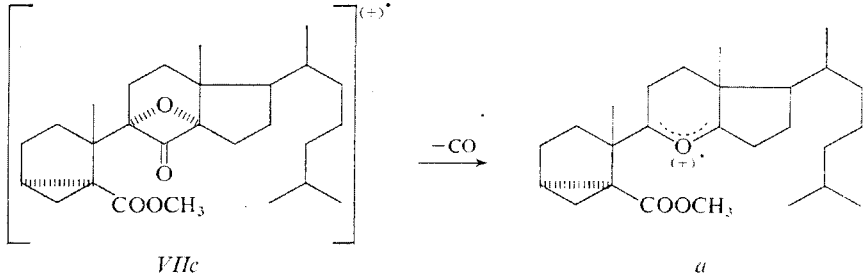
IXa, R = H
IXb, R = Ac

−CO

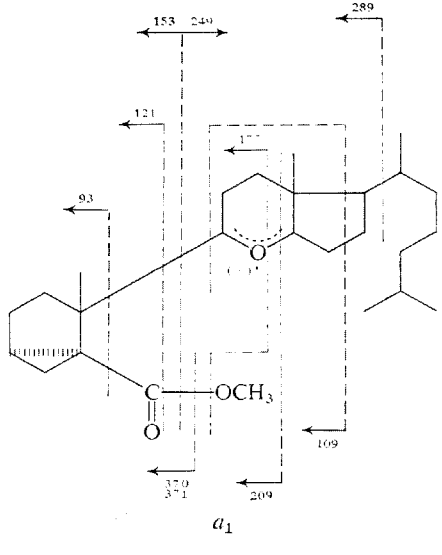


The molecular formula of the last compound isolated, $C_{27}H_{42}O_4$, reveals a surprisingly low hydrogen content. No double bond could be detected by ^{1}H-NMR and IR spectroscopy. The spectral evidence demonstrated the presence of a carbonyl

group and of a cyclopropane ring conjugated with a methoxycarbonyl group; the molecule contains no hydroxyl. All these data indicate that the fourth oxygen is a part of a cyclic ether and the whole molecule constitutes a five-ring system. Attachment of the ether oxygen to $C_{(9)}$ and $C_{(14)}$ is indicated by the following findings. Reduction of the compounds with lithium aluminum hydride gave a diol $C_{26}H_{44}O_3$ (*IXa*) exhibiting no carbonyl absorption and containing a cyclopropane ring, one primary and one secondary hydroxyl group, both acetylable by the pyridine method. The singlet character of the signal for the proton at the carbon atom to which the secondary hydroxyl is attached demonstrates full substitution of the adjacent carbon atoms and permits formulation of the starting keto ester as *VIIb*. The presence



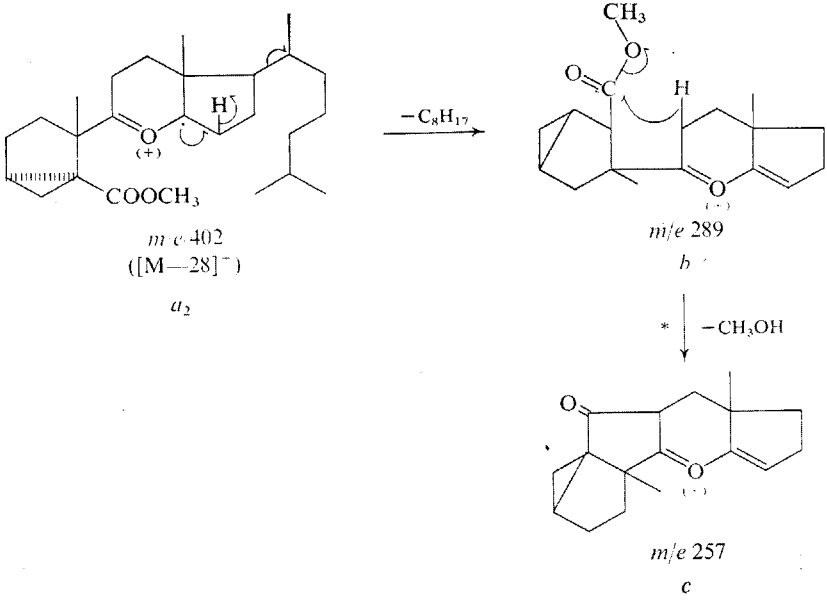
VIIc *a*



a_1

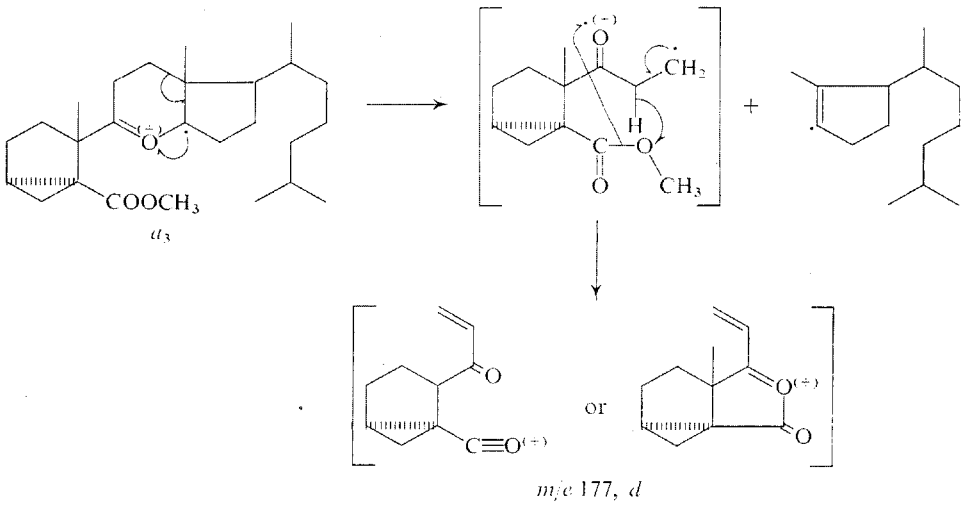
of an oxetanone system is also in conformity with the absorption[26] of the carbonyl group in the infrared region at 1800 cm^{-1}. This assumption is fully confirmed by mass spectrometric evidence. The mass spectrum of this compound contains a small

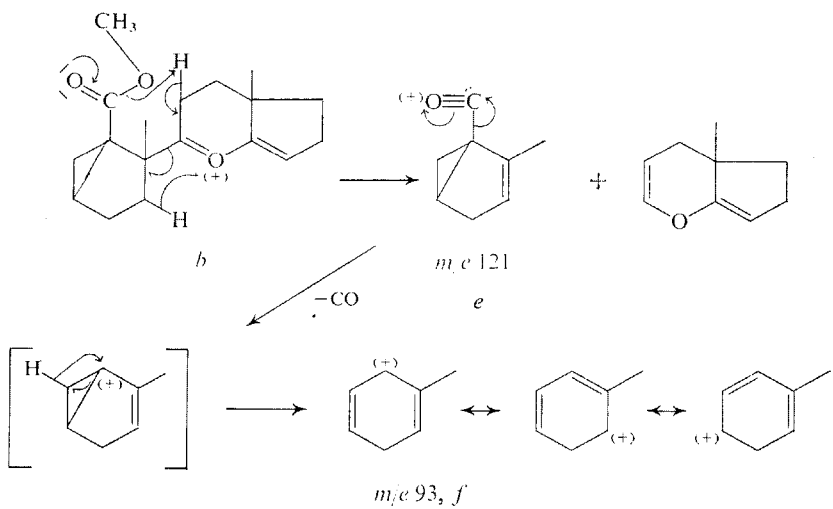
molecular peak at M^+ 430 with accurate mass corresponding to the empirical formula $C_{27}H_{42}O_4$ and a very intense (65%) peak at *m/e* 402 corresponding to the ion C_{26} . . $H_{42}O_3$. Expulsion of carbon monoxide is thus one of the most preferred fragmentation processes of the molecular ion. This fact is in agreement with the structure *VIIc* which eliminates carbon monoxide from the strained oxetanone ring. The oxonium ion *a* thus formed is stabilized by delocalization of the conjugated unshared electron (*VIIc* → *a*). All important ions of the spectrum can be derived from the ion *a* by its decomposition (a_1). Elimination of a molecule of methanol from the ion at *m/e* 289 ($m^*_{289\to257}$ = 228·8, found 228·8) gives rise to a highly unsaturated ion at *m/e* 257 ($C_{17}H_{21}O_2$). This process is assumed to occur as shown by the sequence $a_2 \to b \to c$. The proposed structure *d* of the *m/e* 177 ion ($C_{11}H_{13}O_2$) contains a system of conjugated multiple bonds which rationalizes the intensity of the corresponding peak. The formation of the ion *d* is assumed to occur as shown ($a_3 \to d$).



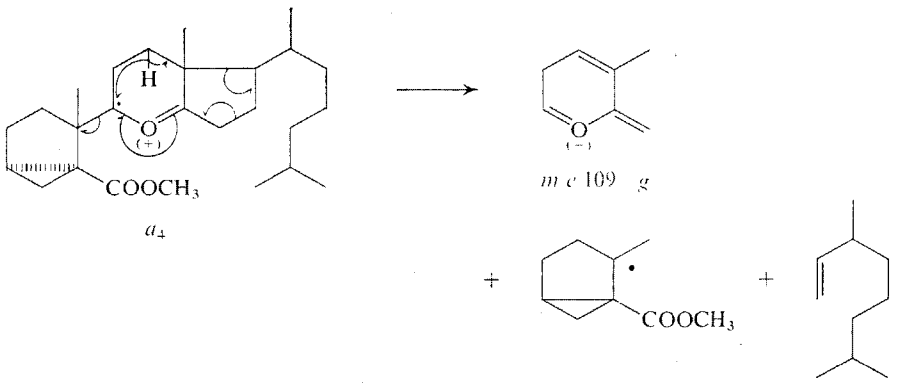
Formation of the species *e*(*m/e* 121) and *f*(*m/e* 93, base peak) is due to successive degradation of the ion *b* (*b* → *e* → *f*). High intensity of the peak at *m/e* 109 (C_7H_9O, 85% of the base peak) is due to the stable ion *g* containing a system of conjugated double bonds. The ion *g* is assumed to arise by the splitting off of peripheral parts from ring C of the ion *a*. This process occurs by a cyclic mechanism involving the shift of one hydrogen atom ($a_4 \to g$).

The 9α,14α-stereochemistry in *VIIb* is based on the negative Cotton effect[27] of this compound.



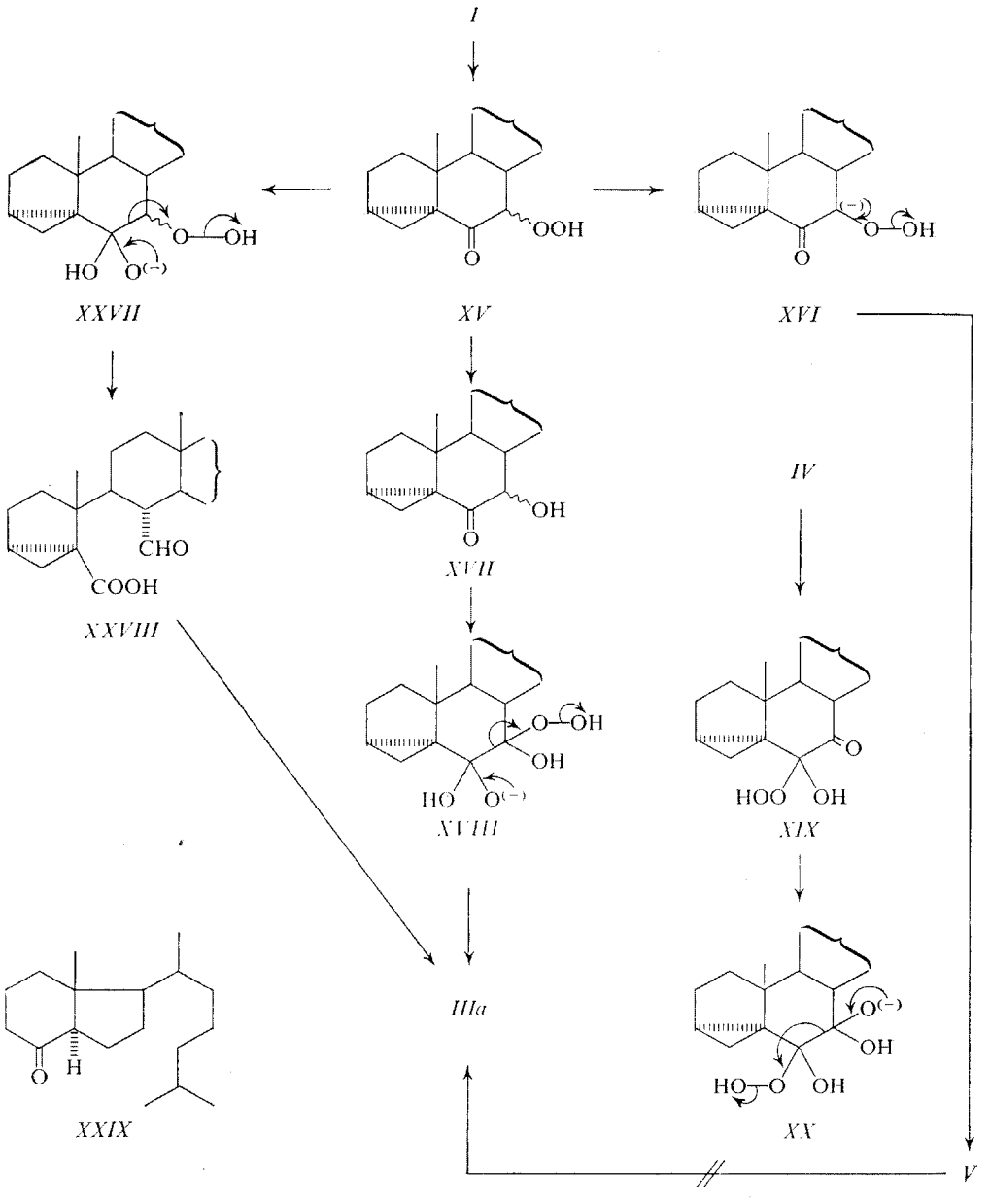


Concerning the mode of the formation of compounds *III* – *VII*, important information could be obtained by subjecting each of these compounds individually to autoxidation conditions. It appeared that the compounds *IIIa* and *VIIa* are end products undergoing no more change. On the other hand, the α-ketol *IV* gives rise to all reaction products and the keto acid *VIa* is a precursor of the oxetanone *VIIa*.



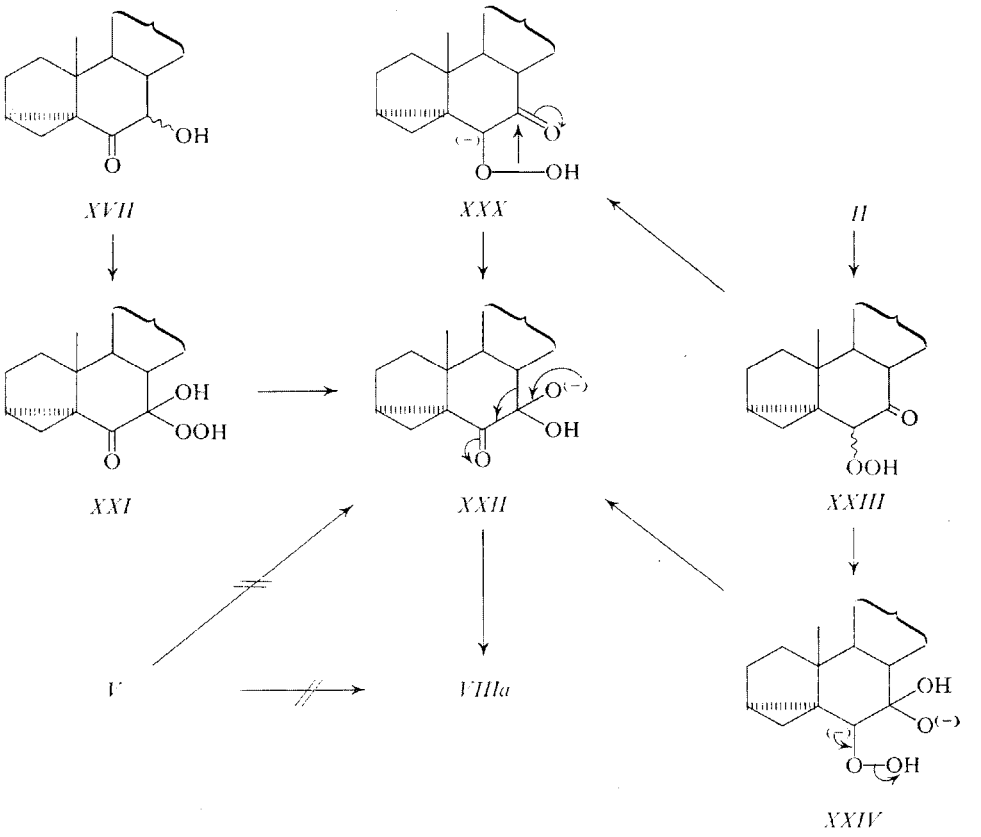
a

Diosphenol *V* is converted to *VIa* and *VIIa*. It is well known that the first step in the autoxidation of ketones is an α-hydroperoxy ketone. Formation of 1,2-diketones (or diosphenols from cyclic ketones) *via* an α-hydroperoxy ketonic intermediate follows a known mechanism[28,29] an example of which is represented in the sequence $I-XV$ to $XVI-V$. Action of oxygen upon the diosphenol *V* in the presence of potassium tert-butoxide does not yield the acid *IIIa*. This fact is not surprising since it has been established[30] that cleavage of 1,2-diketones to the corresponding diacids in an alkaline medium does not proceed by oxidation with elemental oxygen but is due to the presence of hydrogen peroxide. Now, there is an important difference between the model experiment with pure diosphenol where no hydrogen peroxide is present, and between autoxidation of 3α,5-cyclo-5α-cholestan-6-one where the complex reaction mixture may contain hydrogen peroxide liberated by alkaline hydrolysis from some α-hydroperoxy ketone. Therefore, we compared autoxidation of the ketone *I* both in the presence and absence of manganese dioxide; the latter would decompose any free hydrogen peroxide. If the main pathway to the diacid *IIIa* were its formation from the diosphenol by oxidation with hydrogen peroxide, addition of manganese dioxide should suppress formation of the acid significantly. However, there was no significant difference between experiments with and without manganese dioxide. Therefore, we conclude that diosphenol *V* is indeed no intermediate in the formation of the acid *IIIa*. One pathway to the diacid *IIIa* is oxidation of the α-hydroxy ketone *IV*. Autoxidation of α-hydroxy ketones to dicarboxylic acids in a basic medium is a well-known reaction[31]; we could indeed demonstrate that *IV* yields *IIIa*. Formation of the ketol *IV* from the ketone *I* is plausibly rationalized by hydrolysis of the hydroperoxide *XV* to the non-isolated α-hydroxy ketone *XVII* and base-catalyzed isomerization of the latter to *IV*. There is a possibility that the ketol *XVII* may partially escape isomerization and undergo direct oxidation to *IIIa*. The third possible pathway to *IIIa* may be the oxidative cleavage of *XV* to the aldehyde *XXVIII* followed by further oxidation (the sequence $I-XV-XXVII-XXVIII-IIIa$). There is no direct experimental



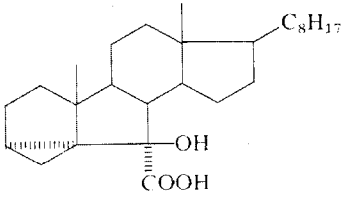
evidence in favor of this possibility but cleavage of ketones to aldehydo acids is a common autoxidation process[29,32].

Since many examples of benzilic acid rearrangement of diosphenols have been reported[33,34], it could be expected that the compound *VIIIa* is a product of such

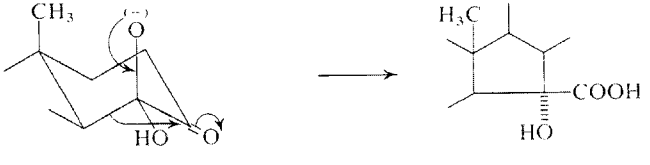


a rearrangement of the diosphenol *V*. However, this was found not to be the case; under reaction conditions applied in the autoxidation, no *VIIIa* is formed from *V*. Evidently, the anionic precursor *XXII* of the rearranged product *VIIIa* is formed in a pathway not involving *V*. The possibility that in base catalyzed autoxidations of ketones the rearranged products of benzilic acid type are not formed *via* the 1,2-diketone was already suggested by Doering[29], and our finding provides experimental confirmation of this. Since both ketones *I* and *II* give the same acid, the anion that is postulated as an intermediate in the rearrangement must be the same in both cases, either *A* or *B*. It is well known from many examples of benzilic acid rearrangements that the reacting species is the less sterically hindered one[35,36]. Although the mode of formation of this species differs from that occuring in the benzilic acid rearrangement of 1,2-diketones, the fact that an identical product is formed from both *I* and *II* permits the assumption of similar preference. The alternative *A* involves an 1,3-diaxial interaction of 6β-hydroxyl and 19-methyl whereas no such interaction is

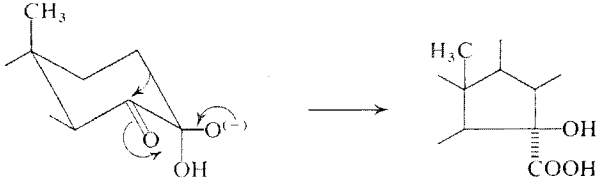
present in the intermediate *B*. Therefore, the pathway $B-D$ is assumed to be preferred. The pathway $B-D$ and the stereochemistry of the product *VIIIb* is supported by ^{1}H-NMR evidence: When the ester *VIIIb* was treated with trichloroacetyl isocyanate, a small but significant downfield shift ($\Delta\delta = +0{\cdot}01$ p.p.m) of the 19-methyl signal and an upfield shift ($\Delta\delta = -0{\cdot}02$ p.p.m.) of the 18-methyl signal were observed.



VIIIa



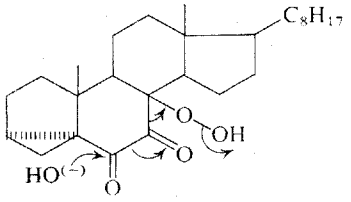
A *C*



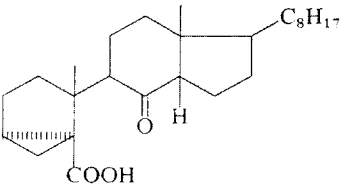
B *D*

Shifts of the same sense and magnitude were observed when the model 6β-hydroxy derivative *XIII* was treated with the same reagent (Table IV). The exact way how the intermediate *XXII* arises from *I* and *II* remains unestablished. Possible pathways are represented by sequences $I-XVII-XXI-XXII$ and $II-XXIII-XXIV-XXII$ or $II-XXIII-XXX-XXII$.

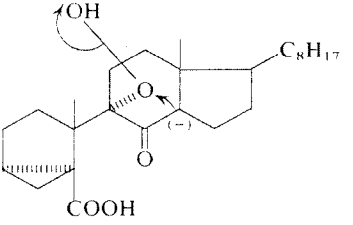
Formation of the keto acid *VIa* from the diosphenol V ($V-XXV-VIa$) is a cleavage well known from analogous cases[5,37,38]. Formation of the 3-oxetanone *XXVI* from the keto acid *VIa* is assumed to proceed *via* the α-hydroperoxy ketone giving an enolate anion (here represented as the carbanion *XXVI*) which cyclizes with the



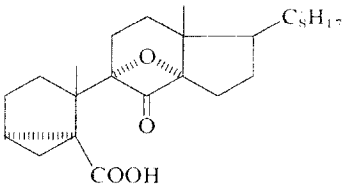
XXV



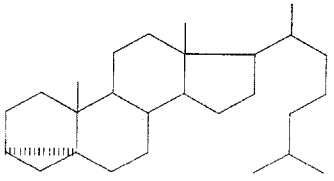
VIa



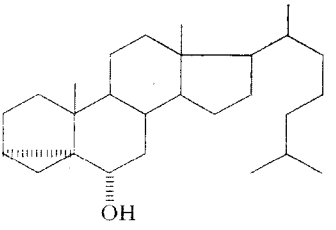
XXVI



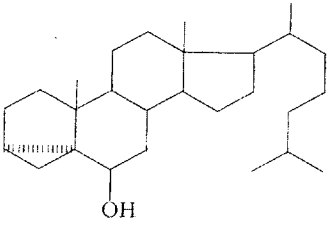
VIIa



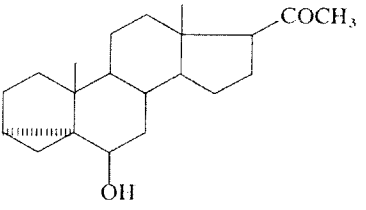
XXXI



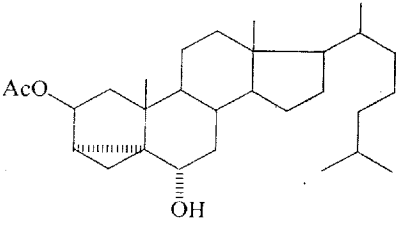
XXXII



XXXIII



XXXIV



XXXV

elimination of a hydroxyl ion. Generation of a 3-oxetanone in the course of an autoxidation process in a strongly alkaline medium has not yet been observed. To our knowledge, only one paper reports on autoxidative formation of a 3-oxetanone from a ketone. The reported reaction, however, proceeds in the presence of an organic acid or of a weak organic base whereas autoxidation in a strong base takes a different course[39].

EXPERIMENTAL

Melting points were determined on a Kofler block and are uncorrected. Unless stated otherwise, optical rotations were measured in chloroform. The IR spectra were recorded on a Zeiss UR 10 spectrophotometer in tetrachloromethane, ORD measurements on a JASCO model ORD/UV-5 and CD measurements on a Roussel Jouan dichrograph II. The ^{1}H-NMR spectra were measured in deuteriochloroform on a Varian HA-100 instrument using tetramethylsilane as internal standard. Chemical shifts are given in δ-scale and coupling constants in Hz. The mass spectra were measured on a mass spectrometer AEI MS-902; the temperature of the direct inlet and of the ionic source was about 160°C, the energy of electrons was 70 eV. The high resolution measurements were carried out with a resolution of 10000 and all accurate masses were within 3 p.p.m. of the theoretical value. Gas chromatography was carried out on a Perkin-Elmer F 11 chromatograph with flame ionization detector and dual system of glass columns. The carrier gas was nitrogen, flow rate 50 ml/min. Columns: *A*. 3% G. C. GRADE GE-SE-30 on 80/100 mesh GAS CHROM Q (0·4 . 180 cm), temperature 225°C. B. 3% FS-I on 100/120 mesh Diatomite CQ (0·4 . 130 cm), temperature 210°C. Identity of the samples prepared by different routes was checked by mixture m.p. determinations, thin layer chromatography and by IR spectra. The statement "worked up as usual" stands for: The solution was washed with 5% hydrochloric acid, water, 5% potassium hydrogen carbonate, water, dried over sodium sulfate and the solvent evaporated *in vacuo*.

Autoxidation of 3α,5-Cyclo-5α-cholestan-6-one (*I*)

3α,5-Cyclo-5α-cholestan-6-one (*I*, 20 g) was suspended in a solution of potassium (24 g) in tert-butyl alcohol (800 ml) and shaken in an oxygen atmosphere for 24 h. The mixture was poured on ice–water, acidified with dilute hydrochloric acid and taken up in ether. The organic layer was washed with water five times, then with aqueous potassium hydroxide (5%) three times. The ethereal and alkaline aqueous portions were worked up as followed. The ethereal layer was washed with water, dried and the solvent was removed under reduced pressure. The residue (6·57 g) was chromatographed over silica gel (300 g) in light petroleum–ether (99 : 1). The less polar fraction (5·28 g) was crystallized from ether–methanol to give 4·15 g of 7-hydroxy-3α,5-cyclo-5α-cholest-7-en-6-one (*V*), m.p. 89—92°C, $[\alpha]_D^{20}$ +142° (*c* 1·42). The ferric chloride test (ethanol) gave an intense greenblue coloration. UV spectrum (ethanol): λ_{max_1} 235 nm, log ε 3·54; λ_{min} 254 nm, log ε 3·37; λ_{max_2} 292 nm, log ε 3·97. IR spectrum: 3400, 1634, 1659 cm^{-1} [C=C(OH)CO]. ^{1}H-NMR spectrum: 0·785 s, 3 H (18-CH_3); 0·88 d, 6 H (26 + 27-CH_3) s, J = 6; 0·955 d, 3 H (21-CH_3), J = 6; 1·105 s, 3 H (19-CH_3); 6·24 s, 1 H (OH). For $C_{27}H_{42}O_2$ (398·6) calculated: 81·35% C, 10·62% H; found: 81·18% C, 10·46% H.

The more polar fraction (246 mg) was crystallized from methanol to give the starting compound (168 mg), m.p. and mixture m.p. 96—98°C; the IR spectrum was identical with that of the authentic sample.

The alkaline extract was acidified with dilute hydrochloric acid (ice) and the precipitated material was taken up in ether. After washing with water and drying, the solvent was evaporated under reduced pressure at room temperature, the residue treated with diazomethane, excess reagent removed with a drop of acetic acid and the solvent evaporated under reduced pressure. The residue (13·4 g) was chromatographed on silica gel (300 g) in light petroleum–ether (99 : 1) and the intermediate fractions rechromatographed under the same conditions. The least polar fraction was oily 7β-hydroxy-3α,5-cyclo-B-nor-5α-cholestan-7α-carboxylic acid methyl ester (*VIIIb*, 3·15 g), $[\alpha]_D^{20}$ +15° (*c* 1·28). IR spectrum: 3528 (OH in CO···HO—), 3604 (OH in —COO···H—O—), 1723, 1742, 1250, 1160 ($COOCH_3$); 3004 cm^{-1} (cyclopropane); mass spectrum (all peaks from the upper part of the spectrum starting with *m/e* 299 with intensity of the least 2% of the base peak are given (with elemental composition in parentheses, if measured)): M^+ 430, 4% ($C_{28}H_{46}O_3$); 413, 4·6%; 412, 14·6%; 399, 2·9%; 398, 9·7%; 397, 5·9%; 373, 4·3%; 372, 28·6%; 371, 100% ($C_{26}H_{43}O$); 370, 4·6%; 354, 4·3%; 353, 14·9%; 352, 3·7%; 342, 2·6%; 299, 7·7%. ^{1}H-NMR spectrum: 0·40—0·56 mt, 2 H (cyclopropane); 0·67 s, 3 H (18-CH_3); 0·86 d, 6 H (26 + 27-CH_3) s, J = 6; 0·92 d, 3 H (21-CH_3), J = 6; 0·93 s, 3 H (19-CH_3); 3·77 s, 3 H ($COOCH_3$) (see also Table I). For $C_{28}H_{46}O_3$ (430·6) calculated: 78·09% C, 10·77% H; found: 77·74% C, 10·77% H.

The next more polar compound was 8-oxo-3α,5-cyclo-B-nor-6,8-seco-5α,14β-cholestan-6-oic acid methyl ester (*VIb*, 300 mg), an oil, $[\alpha]_D^{20}$ +75° (*c* 0·98). CD spectrum (cyclohexane): λ 301 nm, Δε +2·84; λ 306 nm, Δε +2·46; λ 311 nm, Δε +2·68. IR spectrum: 1720, 1437, 1158 ($COOCH_3$ conjugated with cyclopropane ring), 1708 (CO); 3060 cm^{-1} (cyclopropane). ^{1}H-NMR spectrum: 0·86 d, 9 H (21,26,27-CH_3), J = 6; 1·03 s, 3 H (18-CH_3); 1·36 s, 3 H (19-CH_3); 3·62 s, 3 H ($COOCH_3$); no olefinic proton up to 7·00 p.p.m. Partial mass spectrum (given *m/e*, intensity in % of the base peak and elemental composition (with multiplets followed by % of entire peak intensity in parentheses)): M^+ 416, 55·4%, $C_{27}H_{44}O_3$; 401, 13·9%; 384, 46·7%, $C_{26}H_{40}O_2$; 369, 36·5%, $C_{25}H_{37}O_2$; 361, 8·1%, $C_{23}H_{37}O_3$; 360, 11·5%, $C_{23}H_{36}O_3$; 356, 12·6%, $C_{25}H_{40}O$ (85%); 343, 14%, $C_{23}H_{35}O_2$; 264, 31%, $C_{18}H_{32}O$; 247, 14%, $C_{15}H_{19}O_3$ (50%), $C_{18}H_{31}$ (50%); 180, 13·2%, $C_{12}H_{20}O$; 153, 30·2%, $C_9H_{13}O_2$; 152, 38·7%, $C_9H_{12}O_2$ (85%), $C_{10}H_{16}O$ (15%); 151, 39·1%, $C_{10}H_{15}O$; 121, 52%, C_8H_9O (75%), C_9H_{13} (25%); 93, 100%, C_7H_9. For $C_{27}H_{44}O_3$ (461·6) calculated: 77·83% C, 10·65% H; found: 77·79% C, 10·65% H. The next fractions contained 9α,14α-epoxy-8-oxo-3α,5-cyclo-B-nor-6,8-seco-5α-cholestan-6-oic acid methyl ester (*VIIb*, 230 mg), an oil, $[\alpha]_D^{20}$ −70° (*c* 1·11). CD spectrum (cyclohexane): λ297 nm, Δε −2·83. IR spectrum: 1720, 1433, 1158 ($COOCH_3$ conjugated with a cyclopropane ring); 1800 cm^{-1} (CO). ^{1}H-NMR spectrum: 0·78 s, 3 H (18-CH_3); 0·86 d, 9 H (21,26,27-CH_3), J = 6; 1·31 s, 3 H (19-CH_3); 3·64 s, 3 H ($COOCH_3$). Mass spectrum (given *m/e*, intensity in % of base peak and elemental composition (with multiplets followed by % of entire peak intensity in parentheses)): M^+ 430, 0·46%, C_{27} . . $H_{42}O_4$; 402, 65%, $C_{26}H_{42}O_3$; 387, 7·8%, $C_{25}H_{39}O_3$; 370, 7·6%, $C_{25}H_{38}O_2$; 355, 3·7%, $C_{24}H_{35}O_2$; 343, 8·7%, $C_{24}H_{39}O$; 289, 40·7%, $C_{18}H_{25}O_3$; 257, 24%, $C_{17}H_{21}O_2$; 249, 20%, $C_{17}H_{29}O$; 221, 21·8%, $C_{15}H_{25}O$ (90%); 209, 15·8%, $C_{12}H_{17}O_3$ (80%), $C_{14}H_{25}O$ (20%); 206, 13·5%, $C_{15}H_{26}$; 177, 29·6%, $C_{11}H_{13}O_2$; 153, 44%, $C_9H_{13}O_2$; 121, 39%, C_8H_9O (60%), C_9H_{13} (40%); 109, 65%, C_7H_9O (80%); 93, 100%, C_7H_9. For $C_{27}H_{42}O_4$ (430·6) calculated: 75·30% C, 9·83% H; found: 75·60% C, 10·04% H.

The most polar fraction was 3α,5-cyclo-6,7-seco-5α-cholestan-6,7-dioic acid dimethyl ester (*IIIb*, 5 g), an oil, $[\alpha]_D^{20}$ +6° (*c* 1·23). IR spectrum: 1725, 1435, 1150 ($COOCH_3$);3070 cm^{-1} (cyclopropane). Identical with that of the authentic sample[20,21]. ^{1}H-NMR spectrum: 0·685 s, 3 H (18-CH_3); 0·87 d, 6 H (26,27-CH_3), J = 6; 0·90 d, 3 H (21-CH_3), J = 6; 1·10 s, 3 H (19-CH_3); 2·27 t, 1 H ($C_{(8)}$—H), $J_{8,9} = J_{8,14}$ = 10·5; 3·63 s, 3 H ($COOCH_3$); 3·65 s, 3 H ($COOCH_3$). Partial mass spectrum (all peaks of the upper part of the spectrum (up to *m/e* 150) with intensity

of at least 2% of base peak are given): M^+ 460, 10%; 461, 3·3%; 429, 4%; 428, 3%, 400, 2%; 396, 5·2%; 309, 7·4%; 308, 6%; 153, 90·5%; 152, 100%; 121, 36·2%; 93, 65·5%. For $C_{29}H_{48}O_4$ (460·7) calculated: 75·61% C, 10·50% H; found: 75·21% C, 10·76% H.

Hydride Reduction of *VIIb*

The oxetanone *VIIb* (75 mg) and lithium aluminum hydride (110 mg) in ether (10 ml) was refluxed for two hours. The mixture was then poured on ice–hydrochloric acid and extracted with ether. After the usual work-up the crystalline residue (70 mg) was repeatedly crystallized from ether–light petroleum to give 9α,14α-epoxy-3α,5-cyclo-B-nor-6,8-seco-5α-cholestan-6,8α-diol (*IXa*, 32 mg), m.p. 164–167°C, $[\alpha]_D^{20}$ +2° (*c* 1·12). IR spectrum: 3640 (free OH), 3555, 3472 (OH intramol. H-bonded), 3065 cm^{-1} (cyclopropane). ^{1}H-NMR spectrum: 0·33 mt, 2H (cyclopropane); 0·86 d, 6 H (26, 27-CH_3), J = 6; 0·87 d, 3 H (21-CH_3), J = 6; 1·02 s, 3 H (18-CH_3); 1·21 s, 3 H (19-CH_3); 3·40 d, 3·66 d, 2 H ($C_{(6)}$—H_2), $J_{6,6}$ = 13; 4·46 s, 1 H ($C_{(8)}$—H). For $C_{26}H_{44}O_3$ (404·6) calculated: 77·18% C, 10·96% H; found: 77·06% C, 11·16% H.

9α,14α-Epoxy-3α,5-cyclo-B-nor-6,8-seco-5α-cholestan-6,8α-diol Diacetate (*IXb*)

The diol *IXa* (210 mg) was acetylated in pyridine with acetic anhydride at 32°C for 40 h. After the usual work-up crystallization from ether–methanol gave the diacetate *IXb* (190 mg), m.p. 96–98°C, $[\alpha]_D^{21}$ −15° (*c* 1·3). IR spectrum: 1747, 1235 ($OCOCH_3$); 3075 cm^{-1} (cyclopropane); ^{1}H-NMR spectrum: 0·51 dd, 1 H (cyclopropane H), J = 8·5 and 5; 0·86 d, 6 H (26,27-CH_3), J = 6; 0·86 s, 3 H (18-CH_3); 1·23 s, 3 H (19-CH_3); 2·01 s, 3 H ($OCOCH_3$); 2·05 s, 3 H ($OCOCH_3$); 3·96 d, 4·40 d, 2 H ($C_{(6)}$—H_2), $J_{6,6}$ = 12; 5·27 s, 1 H ($C_{(8)}$—H). For $C_{30}H_{48}O_5$ (488·7) calculated: 73·73% C, 9·90% H; found: 73·97% C, 9·99% H.

3α,5-Cyclo-B-nor-5α-cholestan-7α-hydroxymethyl-7β-ol (*X*)

The methyl ester *VIIIb* (200 mg) in ether (20 ml) was treated with lithium aluminum hydride (220 mg) at reflux temperature for 2 h. The mixture was poured on hydrochloric acid–ice, extracted with ether and worked up. The residue (185 mg) was filtered through a layer of silica gel in benzene solution, the solvent evaporated and the residue (160 mg) crystallized from light petroleum at −60°C to give the diol *X* (60 mg), m.p. 92–93°C, $[\alpha]_D^{20}$ +25° (*c* 1·60). IR spectrum: 3615, 3645, 1024, 1075 (OH); 3055 cm^{-1} (cyclopropane). For $C_{27}H_{46}O_2$ (402·6) calculated: 80·54% C, 11·52% H; found: 80·66% C, 11·29% H.

3α,5-Cyclo-B-nor-5α-cholestan-6-one (*XIV*)

a) The diol *X* (132 mg) was dissolved in dioxane (8 ml), treated with a solution of periodic acid (220 mg) in water (1·5 ml), kept at room temperature for 6 h, the solution concentrated under reduced pressure, diluted with water and extracted with ether. The organic layer was washed with water and sodium carbonate solution, dried with magnesium sulfate and the solvent evaporated under reduced pressure. The residue was crystallized from methanol to give the product (55 mg), m.p. 80–82°C, $[\alpha]_D^{20}$ +8° (ethanol, *c* 1·14), −15° (chloroform, *c* 1·06). Literature[22] reports m.p. 77–79°C, $[\alpha]_D^{20}$ +26·7° (ethanol). IR spectrum: 1721 (CO), 3060, 3020 cm^{-1} (cyclopropane). For $C_{26}H_{42}O$ (370·6) calculated: 84·26% C, 11·42% H; found: 83·88% C, 11·65% H.

b) The i-steroid *XIII* (550 mg) was oxidized in pyridine (350 ml) with chromium trioxide (4·7 g)–pyridine complex at 0°C, then at room temperature for four days. After the usual work-up the product was crystallized from methanol to give *XIV* (313 mg), m.p. 81–82°C, undepressed on admixture with the above sample, $[\alpha]_D^{20}$ +11° (ethanol, *c* 1·1). For $C_{26}H_{42}O$ (370·6) found: 84·33% C, 11·61% H. The IR spectrum is identical with that of the product prepared under *a*).

3α,5-Cyclo-B-nor-5α-cholestan-6β-ol (*XIII*)

The tosylate[40] *XII* (1·16 g) was dissolved in acetone (110 ml), potassium hydrogen carbonate (100 mg) and potassium acetate (2·5 g) in water (30 ml) was added and the mixture heated at reflux temperature with stirring. After 45 h, the solution was concentrated to a small volume under reduced pressure and the product isolated with ether. Chromatography on silica gel (40 g, pretreated 30 minutes with gaseous ammonia) in benzene–light petroleum (1 : 1) separated the less polar impurity (150 mg) and afforded pure 3,5-cyclosteroid, oil, $[\alpha]_D^{20}$ +5° (*c* 0·795). IR spectrum: 3622, 1068, 1030 (OH); 3055, 3015 cm^{-1} (cyclopropane). ^{1}H-NMR spectrum: Tables I and IV. For $C_{26}H_{44}O$ (372·6) calculated: 83·80% C, 11·90% H; found: 83·88% C, 12·02% H.

6α-Hydroxy-3α,5-cyclo-5α-cholestan-7-one (*IV*)

a) The diosphenol *V* (150 mg) was treated in ethereal (30 ml) solution with lithium aluminum hydride (170 mg) and refluxed for 1·5 h. The mixture was poured upon an ice–potassium hydroxide solution, the solution washed with potassium hydroxide and water, dried, and the solvent evaporated. The residue was chromatographed on silica gel (15 g) in light petroleum–ether (1%) to give the product *IV* (65 mg), m.p. 117–119°C, after recrystallization from methanol, $[\alpha]_D^{20}$ +16° (*c* 2·5). IR spectrum: 1709 (CO); 3488 (OH); 3075 cm^{-1} (cyclopropane) (Table V). ^{1}H-NMR spectrum: 0·36 t, 1 H (cycloprop. H), $J = 4$ and 4·5; 0·70 dd, 1 H (cycloprop. H), $J = 4$ and 8; 0·68 s, 3 H (18-CH_3); 0·85 d, 6 H (25,27-CH_3), $J = 6$; 1·17 s, 3 H (19-CH_3); 2·50 t, 1 H ($C_{(8)}$–H), $J_{8,9} = J_{8,14} = 11$; 3·19 broad d, 1 H (OH), $J_{OH,6} = 5$ (disappears after addition of CD_3COOD); 4·37 broad signal, 1 H ($C_{(6)}$–H, gives a singlet after addition of CD_3COOD). See also Tables I, III and IV. For $C_{27}H_{44}O_2$ (400·6) calculated: 80·94% C, 11·07% H; found: 80·79% C, 10·84% H.

b) Autoxidation was carried out with 1 g of *II* and potassium tert-butoxide from potassium (1·2 g) in tert-butyl alcohol (40 ml) in an oxygen atmosphere for two hours. The mixture was worked up as described above in the large autoxidation experiment and the neutral portion (750 mg) was chromatographed in light petroleum–ether (1%). After separating the ketone *II* and diosphenol *V*, the more polar fraction (15 mg) was crystallized repeatedly from light petroleum to give the product (8 mg), m.p. 115–117°C, undepressed on admixture with *IV* obtained on hydride reduction of *V*. Thin layer chromatographic migration rate in benzene (silica gel) and IR spectra of both compounds were identical.

c) The same autoxidation yielded 5 mg of *IV*, m.p. 114–117°C, identical (mixture m.p., infrared spectrum, thin-layer chromatographic migration rate, gas chromatography) with the product obtained from *II*.

1-(1,5-Dimethylhexyl)-7a-methylhexahydroindan-4-one (Windaus' Ketone *XXIX*)

A procedure reported[25] for oxidation of vitamin D_2 was applied to vitamin D_3. The product was separated with Girard T reagent and purified by chromatography on silica gel in light petroleum–ether (99 : 1). UV spectrum (ethanol): λ_{max} 283 nm, log ε 1·46; IR spectrum: 1716 cm^{-1} (CO).

TABLE V

IR Spectroscopic Data of 3α,5-Cyclo-5α-cholestanes

Compound	Conformation	Solvent	ν(OH) cm^{-1}	ν(C—OH) cm^{-1}	Cyclopropane ν(CH) cm^{-1}
XXXIII	ax	CCl_4	3 618[a]	1 052, 1 037, 1 020[b]	3 060, 3 018[a]
		$CHCl_3$		1 052, 1 033, 1 019[b]	
XXXII	eq	CCl_4	3 633[a], 3 615[c]	1 052, 1 043, 1 039, 1 023 1 004[b]	3 072, 3 035, (3 003)[a]
		$CHCl_3$		1 050, 1 042, 1 038, 1 021, 1 002[b]	
XXXIV	ax	CCl_4	3 618[a]	1 052[c], 1 030, 1 021[d]	3 060, 3 018[a]
		$CHCl_3$		1 056, 1 050, 1 028, 1 021[f]	
XXXV	eq	$CHCl_3$	3 630 3 615[cf]	overlapped by the acetate band 994[f]	3 080[f] overlapped by $CHCl_3$
IV	eq	CCl_4	3 640, 3 488[gh]	1 048, 1 029, 1 022, 1 005[f]	3 075, 3 035[h]

[a] Wave numbers of ν(OH) (free) and ν(CH) cyclopropane, concentration $\sim 5 \cdot 10^{-3}$M; cell 1 cm. [b] Concentration 7%; cell 0·1 mm. [c] Side band. [d] Saturated solution; cell 0·1 mm. [e] Asymmetry of the band at the higher wave number. [f] Concentration 6%; cell 0·1 mm. [g] Intramolecularly bonded. [h] Wave numbers of ν(OH) (free and intramolecularly bonded) and of ν(CH) cyclopropane, concentration $\sim 5 \cdot 10^{-4}$M; cell 10 cm.

Mass spectrum: M^+ 264, *m/e* 111 (C-ring fragment), *m/e* 151 (M-113; loss of the side chain), *m/e* 124 and 125 (fragments arising by loss of the D ring by cleavage between $C_{(13)}$—$C_{(17)}$ and $C_{(15)}$—$C_{(16)}$. CD spectrum (cyclohexane): λ 293 nm, $\Delta\varepsilon$ −2·38; λ 297 nm, $\Delta\varepsilon$ −2·12; λ 303 nm, $\Delta\varepsilon$ −2·46. The ketone was characterized as semicarbazone, m.p. 213–214°C (literature[24] reports m.p. 214°C). For $C_{19}H_{35}N_3O$ (321·5) calculated: 70·98% C, 10·97% H, 13·07% N; found: 70·68% C, 11·06% H, 13·23% N.

Behavior of Individual Reaction Products Under Autoxidation Conditions

Unless mentioned otherwise, autoxidations were carried out for 24 h in potassium tert-butoxide solution in tert-butyl alcohol and separated preparatively as given above. Gas chromatography was carried out after separating the reaction mixture into a neutral and an acidic portion and remethylation of the latter with diazomethane. The conditions of gas chromatographic separation are defined above.

a) *Behavior of diosphenol* V: Diosphenol *V* (1g) was dissolved in a potassium tert-butoxide solution prepared from potassium (1·2 g) and tert-butyl alcohol (40 ml) and shaken under oxygen for 20 h. The acidic portion after methylation with diazomethane and chromatography gave a complex mixture of less polar compounds (166 mg) followed by oxetanone *VIIb* (0·6 g), $[\alpha]_D^{20}$ −65°, identical by thin-layer chromatography and IR spectrum with the authentic sample. For $C_{27}H_{42}$ . . O_4 (430·6) calculated: 75·30% C, 9·83% H; found: 75·26% C, 9·83% H. Gas chromatography both on phase A and B showed the presence of the oxetanone *VIIb*, a small quantity of the keto ester *VIb*, no *IIIb* and no *VIIIb*.

b) *Behavior of the hydroxy ketone* IV: Gas chromatography (column A) showed the presence of all reaction products: *IIIb*, *V*, *VIb*, *VIIb* and *VIIIb*. The same compounds were detected by thin layer chromatography (silica gel, benzene).

c) *Behavior of the keto ester* VIb: Gas chromatography (column A) of the samples taken after 0·5, 1·2 and 4 h showed an increasing amount of the oxetanone *VIIb*, the sample taken after 24 h consisted exclusively of *VIIb*.

d, e, f) *Behavior of the oxetanone* VIIb, *diester* IIIb *and norester* VIIIb: Gas chromatography (column A) showed only the presence of the unchanged starting compounds in all three instances. g, h) *Behavior of* 3α,5-*cyclo*-5α-*cholestan*-6-*one* (I) *in the presence* (g) *and absence* (h) *of* MnO_2: Both experiments (100 mg, 24 h) led to practically identical results: neutral portion — 24% and 28%, acidic portion — 76% and 68%, respectively. Gas chromatography showed the presence of all components with prevaling diester (86% and 83%, respectively) in practically identical relations.

Autoxidation of 3α,5-cyclo-5α-cholestan-7-one (*II*)

The reaction was carried out with 5 g of *II* in a manner analogous to that described above for *I*. The following compounds were isolated: *1*) The norester *VIIIb* (283 mg) identified by thin-layer chromatography and infrared spectrum, $[\alpha]_D^{21}$ +15° (*c* 0·78). For $C_{28}H_{46}O_3$ (430·6) calculated: 70·09% C, 10·77% H; found: 78·28% C, 10·81% H. *2*) The oxetanone *VIIb* (178 mg), $[\alpha]_D^{20}$ −66° (*c* 1·8), identified by thin-layer chromatography, infrared, ^{1}H-NMR and mass spectrum. For $C_{27}H_{42}O_4$ (430·6) calculated: 75·30% C, 9·83% H; found: 75·26% C, 9·83% H. *3*) The diester *IIIb* (1·85 g), $[\alpha]_D^{20}$ +9° (*c* 2·0), identified by thin-layer chromatography and infrared spectrum. For $C_{29}H_{48}O_4$ (460·7) calculated: 75·61% C, 10·50% H; found: 76·04% C, 10·29% H. *4*) The

diosphenol *V* (190 mg), m.p. 87—89°C, undepressed on admixture with authentic sample, identified by thin-layer chromatography and infrared spectrum. Both acidic (methylated) and neutral portions were analyzed by gas chromatography (column A). In addition to compounds isolated on the preparative scale, chromatography proved the presence of small quantities of *IV* (~2·5% to 1·2%—0%) and *VIb* (~1·1%—4·8%—4·8%) after 30 min —2 h—24 h, respectively.

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