PHOTOLYSIS OF 19β,28-EPOXY-18α-OLEANAN-2β-OL NITRITES: FUNCTIONALIZATION OF 10β- AND 8β-METHYL GROUPS*

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On photolysis, 19β,28-epoxy-18α-oleanan-2β-ol nitrite (*I*) undergoes functionalization of the 10β-methyl group (formation of oxime *II*) as well as of the rather distant 8β-methyl group (leading to oxime *III*). No products of attack at the 4β-methyl group have been found. The 2β-nitrosyloxy-3β-acetoxy derivative *XX* reacts similarly whereas its 2β-nitrosyloxy-3α-acetoxy isomer *XIII* is photolyzed to give diol *XI*. Oximes *II* and *III* were converted into two series of nitriles (*a* and *b*) with various functional groups on the ring A. Structure of all compounds was derived from their spectral data. Double radical transfer has been proposed for functionalization of the 8β-methyl group (position 26).

Reactions based on short-distance radical transfer (the so-called directed functionalizations) are very useful in preparation of compounds with functionalities in positions accessible by other methods only with difficulty. Such reactions are, for example, the decomposition of haloamines, acyl azides, azidoformates, or hypohalites, reaction of alcohols with lead tetraacetate, cyclopalladation of oximes and photolysis of nitrites (Barton reaction)[1-5]. Directed functionalizations proved to be useful in the steroid chemistry and in several cases they were also used for introduction of functional groups into usually unsubstituted positions in triterpenoids. Thus, for example, position 12 in lupane derivatives was functionalized from position 20 (refs[6,7]), position 13 from position 28 (refs[8,9]), and positions 18 and 21 from position 29 (ref.[10]). Starting from position 3, the 4α-methyl group in lupane[5], lanostane[11], and cycloartane[12] derivatives was functionalized using various methods. In ursane derivatives, the 10β-methyl group was functionalized[13] from position 24, in lanostane derivatives the 14α-methyl[14] and in hopane derivatives the 14α- and 18α-methyl groups[15] from position 7α and in the latter compounds also the 8β-methyl group[15] from position 15β. The 5β- and 9β-methyl groups in friedelane were functionalized from position 3β in the hypoiodite reaction[16], the Barton reaction introduced functionality into the 5β-methyl from position 3β in friedelane and shionane[17].

Our present paper describes the photolysis of several 2β-nitrosyloxy-19β,28--epoxy-18α-oleanane derivatives. As known from steroid chemistry, in photolysis

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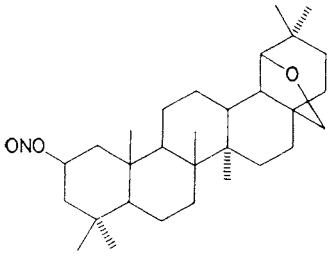
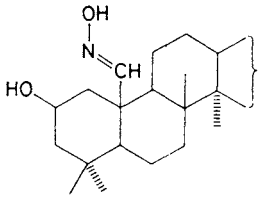
of axial nitrites the 1,3-*syn*-axial methyl groups are easily functionalized. Thus, for example, in 2β- and 6β-nitrites the 10β-methyl group is functionalized[18,19], in 4,4--dimethyl steroidal 6β-nitrites the 4β- and 10β-methyl groups are attacked[20] in a ratio of about 1 : 4.

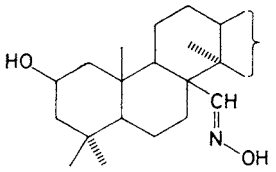
Since triterpenoids contain two axial methyl groups (4β and 10β) close to the 2β-nitrosyloxy group, it was of interest which of them will be attacked and how the functionalization will be influenced by further substituents on the ring A. We studied three derivatives of 19β,28-epoxy-18α-oleanane: 2β-nitrosyloxy derivative *I*, 2β--nitrosyloxy-3β-acetoxy derivative *XX* and 2β-nitrosyloxy-3α-acetoxy derivative *XIII*. They were prepared by reaction of the corresponding alcohols *XV*, *XIX*, and *XII* (see refs[21,22]) with nitrosyl chloride in pyridine under conditions chosen according to stability of the desired nitrite. Nitrite *I* was completely stable in the crystalline state and did not decompose in chloroform solution even after several weeks, nitrite *XX* was of limited stability in the crystalline state and in chloroform solution it decomposed in several days; nitrite *XIII* decomposed in solution in several hours.



I



II

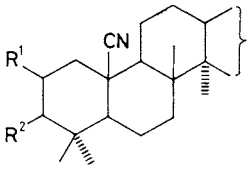


III

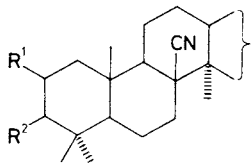
All the three nitrites were irradiated in benzene solution with a 125 W mercury lamp for 30 min. After this time the reaction mixtures contained no starting nitrites. Nitrite *I* afforded a mixture of oximes *II* and *III*, along with minor quantities of 2β--hydroxy derivative *XV* and 2-oxo derivative *IX*. Proton NMR spectra of both oximes exhibit six methyl signals, i.e. one less than in the starting nitrite *I*. The singlets due to —CH=N protons in *II* (δ 7·92) and *III* (δ 7·76) show that the functionalization took place at methyl groups bonded to quaternary carbon atoms. In both cases, the chemical shift corresponds to *E*-aldoximes because signals of *Z*-aldoximes occur[23] in the region δ 6·4–6·9.

The 3β-acetoxy nitrite *XX* was photolyzed to give a complex, unseparable mixture of products, containing (according to thin-layer chromatography) 2β-hydroxy--3β-acetoxy derivative *XIX*, the isomeric 2β-acetoxy-3β-hydroxy compound *XXI* arising by migration of the acetyl group in *XIX* (see ref.[22]), and several oximes. The mixture was acetylated with hot acetic anhydride to give a mixture of diacetate

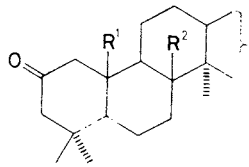
XVIII and nitrile-diacetates *VIIIa* and *VIIIb*. At this stage it was possible to separate compound *XVIII*; both nitriles were separated only after hydrolysis to diols *VIIa* and *VIIb*. The formation of two nitriles indicates that also in this case two different methyl groups were functionalized.



IVa, $R^1 = R^2 = H$
Va, $R^1 = OH$; $R^2 = H$
VIa, $R^1 = OCOCH_3$; $R^2 = H$
VIIa, $R^1 = R^2 = OH$
VIIIa, $R^1 = R^2 = OCOCH_3$

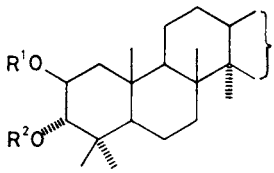


IVb, $R^1 = R^2 = H$
Vb, $R^1 = OH$; $R^2 = H$
VIb, $R^1 = OCOCH_3$; $R^2 = H$
VIIb, $R^1 = R^2 = OH$
VIIIb, $R^1 = R^2 = OCOCH_3$

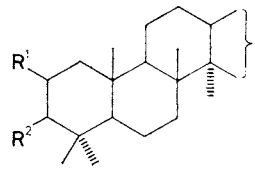


IX, $R^1 = R^2 = CH_3$
Xa, $R^1 = CN$; $R^2 = CH_3$
Xb, $R^1 = CH_3$; $R^2 = CN$

Contrary to the nitrites *I* and *XX*, the 3α-acetoxy nitrite *XIII* underwent no functionalization, affording the diol *XI* as the sole reaction product. The reason may be either low stability of *XIII* in solution or a spatial arrangement different from that of *I* and *XX*, caused by the 3α-axial functional group.



XI, $R^1 = R^2 = H$
XII, $R^1 = H$; $R^2 = COCH_3$
XIII, $R^1 = NO$; $R^2 = COCH_3$



XIV, $R^1 = R^2 = H$
XV, $R^1 = OH$; $R^2 = H$
XVI, $R^1 = OCOCH_3$; $R^2 = H$
XVII, $R^1 = R^2 = OH$
XVIII, $R^1 = R^2 = OCOCH_3$
XIX, $R^1 = OH$; $R^2 = OCOCH_3$
XX, $R^1 = ONO$; $R^2 = OCOCH_3$
XXI, $R^1 = OCOCH_3$; $R^2 = OH$

The oximes *II* and *III* were converted into 2β-acetoxynitriles *VIa* and *VIb*. Transformation of the functionalities in position 2 gave 2β-hydroxynitriles *Va* and *Vb*, 2-oxonitriles *Xa* and *Xb* and deoxy derivatives *IVa* and *IVb*. These two series (*a* and *b*) of nitriles were supplemented by 2β,3β-disubstituted nitriles *VII* and *VIII* which were assigned structure *a* or *b* by comparison of the following physical properties: *a*) When chromatographed on silica gel, compounds *a* are somewhat more polar

than their counterparts *b*; *b*) their melting points are lower by 20–50°C; *c*) in their mass spectra the M – 71 ion (arising by fragmentation of the E-ring[24]) is the most abundant one whereas in spectra of compounds *b* this ion is less abundant than the dominant molecular ion; *d*) their C≡N stretching vibration is by 2–5 cm^{-1} higher; *e*) in the ^1H NMR spectra (Table I) their H-28 (*endo*) signal is shifted about 0·10 ppm upfield and the H-28 (*exo*) and H-19α signals are shifted slightly upfield (0·01 to 0·02 ppm).

Originally, we assumed that the attack takes place on the 4β- and 10β-methyl groups that are close to the 2β-nitrosyloxy group, and ascribed provisionally the 4β-cyano (24-nitriles) and 10β-cyano (25-nitriles) structures to compounds of the series *a* and *b* (or vice versa). However, interpretation of the spectral data encountered serious complications: E.g. in the ^1H NMR spectra of nitriles of the series *b* only one methyl signal is markedly shifted downfield whereas (because of magnetic anisotropy of the C≡N group and also analogically to steroid compounds[25,26]) one should expect a downfield shift of two axial methyl signals (4β- and 8β-methyl) by 0·25–0·35 ppm. For the 24-nitriles a similar shift of the 10β--methyl signal can be expected, together with a downfield shift of the 4α-methyl group of about 0·4–0·6 ppm (by analogy with aliphatic compounds). Also, the assignment of methyl signals in nitriles of the series *b* was difficult, as well as an explanation of the downfield shift of the H-28 (*endo*) proton etc. Moreover, both 2-oxonitriles *Xa* and *Xb* exhibit the same Cotton effect in the CD spectra (Δε + 1·2 at 299 nm), somewhat different from that of the 2-oxo derivative *IX* with a methyl instead of nitrile group (Δε + 2·2, see ref.[27]) which is not compatible with the symmetrical arrangement of the 4β- and 10β-cyano groups relative to the carbonyl group.

On the other hand, all the spectral data can be plausibly interpreted if we assume that compounds of series *a* contain a 10β-cyano group (25-nitriles) and derivatives *b* are 8β-cyano derivatives (26-nitriles). For these structures the assignment of the methyl proton signals makes no difficulties: The pertinent NMR data, together with those for derivatives containing a methyl instead of carbonitrile group, are given in Table I. The assignment is based on the known position[28,29] of methyl signals in 19β,28-epoxy-18α-oleanane (*XIV*). The mean values of substituent effects (Δδ) on the chemical shift of methyl protons and the 19α- and 28-protons are given in Table II. The values agree well and mostly the differences are not higher than 0·01 ppm. Somewhat higher differences, observed (footnote *b* in Table II) for the 4β- and 8β-methyl groups in the 25-nitriles with a 2-oxo or 2β-hydroxy group, may be due to a slight skeletal deformation caused by an interaction between the spatially close polar groups. No such agreement has been achieved if the 24-nitrile structure was considered for either of the series *a* or *b*. Further, it should be noted that effects of substituents in position 2 and 3 on the chemical shift of the 4α, 4β-, and 14α--methyl groups (Δδ) is in accord with those found with 4,4-dimethyl steroids[30] or derivatives of 8-lanostene[31] or steroids[32].

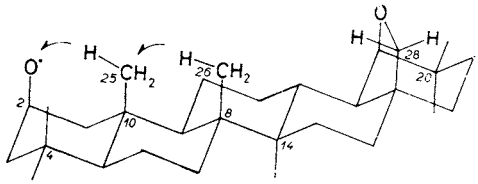
TABLE I

Chemical shifts of some protons in 25-nitriles, 26-nitriles and analogous compounds without nitrile group

Compound[a]	Substituents	CH_3[b]							H-19[c]	H-28[d] (*exo*)	H-28[d] (*endo*)
		4α	4β	10β	8β	14α	20a	20b			
IVa	—	0·888	1·098	—	1·262	0·911	0·936	0·798	3·54	3·45	3·78
Va	2β-OH	0·939	1·319	—	1·295	0·889	0·939	0·800	3·54	3·45	3·80
VIa	2β-$OCOCH_3$	0·948	1·278	—	1·278	0·889	0·948	0·801	3·53	3·45	3·79
Xa	2-oxo	1·057	1·170	—	1·276	0·913	0·939	0·802	3·53	3·46	3·79
VIIa	2β,3β-$(OH)_2$	1·039	1·268	—	1·292	0·889	0·939	0·804	3·54	3·46	3·81
VIIIa	2β,3β-$(OCOCH_3)_2$	0·937	1·327	—	1·289	0·889	0·937	0·799	3·53	3·45	3·78
IVb	—	0·870	0·845	1·094	—	0·944	0·944	0·802	3·55	3·46	3·89
Vb	2β-OH	0·944	1·026	1·340	—	0·944	0·944	0·804	3·56	3·46	3·89
VIb	2β-$OCOCH_3$	0·942	1·006	1·307	—	0·942	0·942	0·801	3·55	3·46	3·89
Xb	2-oxo	1·072	0·923	1·099	—	0·973	0·945	0·800	3·55	3·47	3·88
VIIb	2β,3β-$(OH)_2$	1·021	1·021	1·397	—	0·941	0·941	0·801	3·56	3·47	3·89
VIIIb	2β,3β-$(OCOCH_3)_2$	0·917	1·075	1·374	—	0·941	0·941	0·801	3·55	3·47	3·89
XIV	—	0·850	0·800	0·850	0·982	0·929	0·929	0·800	3·53	3·43	3·77
XV	2β-OH	0·914	0·976	1·103	0·976	0·933	0·933	0·801	3·54	3·44	3·78
XVI	2β-$OCOCH_3$	0·915	0·964	1·074	0·984	0·931	0·931	0·798	3·53	3·43	3·78
IX	2-oxo	1·052	0·880	0·868	0·987	0·955	0·934	0·800	3·53	3·44	3·77
XVII	2β,3β-$(OH)_2$	0·995	0·995	1·175	0·995	0·912	0·930	0·799	3·54	3·45	3·79
XVIII	2β,3β-$(OCOCH_3)_2$	0·897	1·031	1·133	0·999	0·913	0·925	0·801	3·53	3·44	3·77

[a] For other signals see Table III and Experimental; [b] singlets, chemical shifts were obtained from expanded scale (1 Hz/1 cm); [c] singlets; [d] doublets, $J(28, 28) = 8$ Hz.

Replacement of the 10β-methyl by a carbonitrile group resulted in a downfield shift of signals of both *syn*-axial methyl groups (4β, 8β) by about 0·30 ppm. The same change in the position 8β leads to a shift of the 10β-methyl signal downfield by 0·23 ppm; the other signals are affected only little, except that of the 28 (*endo*)-proton (downfield shift 0·11 ppm) which is close to the nitrile group in 26-nitriles (see also formula *XXII*). The H-28(*exo*) signal is less shifted. In the 25-nitriles both the protons on C-28 are influenced only negligibly. A similar situation also exists with the corresponding oximes: compared with compound *XV*, the H-28(*endo*) signal in the 26-oximino derivative *III* is shifted upfield by 0·09 ppm and the H-28(*exo*) one only by 0·06 ppm; for the 25-oximino derivative *II* these upfield shifts are smaller (−0·03 and −0·01 ppm, respectively).



XXII

TABLE II

Effect of substituents (Δδ) on chemical shifts in the ^{1}H NMR spectra

Signal[a]	10β-CN	8β-CN	2β-OH	2β-OCOCH$_3$	2-oxo	2β,3β-(OH)$_2$	2β,3β-(OCOCH$_3$)$_2$
4α-CH$_3$	0·03[b]	0·02	0·06	0·07	0·19[b]	0·15	0·05
4β-CH$_3$	0·30[b]	0·04	0·19[b]	0·17	0·08	0·18	0·23
10β-CH$_3$	—	0·23	0·25	0·22	0·01	0·31	0·28
8β-CH$_3$	0·29[b]	—	0·01[b]	0·01	0·01	0·02	0·02
14α-CH$_3$	−0·03	0·02	−0·01	−0·01	0·02	−0·01	−0·01
20a-CH$_3$	0·01	0·01	0·00	0·00	0·00	0·00	0·00
20b-CH$_3$	0·00	0·00	0·00	0·00	0·00	0·00	0·00
19α-H	0·00	0·02	0·01	0·00	0·00	0·01	0·00
28-H(*exo*)	0·01	0·03	0·00	0·00	0·01	0·01	0·01
28-H(*endo*)	0·02	0·11	0·01	0·01	0·00	0·02	0·00

[a] Positive Δδ denotes a downfield shift; for CN Δδ = δ (compound with nitrile group) − δ(compound with methyl group), for other substituents Δδ = δ(substituted compound) − δ(unsubstituted compound), mean Δδ values are rounded to 0·01 ppm; unless stated otherwise (see footnote *b*), maximum difference from the mean value is 0·01 ppm. [b] One or two values differ from the mean one by 0·02−0·04 ppm.

In the 2-ketones the remote 8β-carbonitrile group practically does not alter the chemical shifts of protons in positions 1 and 3 whereas the 10β-carbonitrile group has a marked effect (see Table III). The 3α-H doublet in the 2β,3β-diacetoxy-26--nitrile *VIIIb* occurs at the same position (δ 4·62) as that of the diacetate *XVIII* with a methyl instead of carbonitrile group[22], in the 2β,3β-diacetoxy-25-nitrile *VIIIa* this doublet is shifted slightly upfield (δ 4·58). If some of the nitriles *VIII* had the 24-nitrile structure, the 3α-H signal should be shifted substantially downfield.

All the above-mentioned data confirm the suggested structures of the *a* and *b* series of nitriles and the corresponding oximes. In accord with the assignment are also the O—H stretching frequencies in the infrared spectra of 2β-hydroxy derivatives (see Table IV). Hydrogen bond is present in the 25-substituted compounds but not in the 26-substituted analogues: whereas IR spectrum of the 26-oxime *III* exhibits bands of the free 2β-hydroxyl and of the free oxime group only, no free 2β--hydroxyl is present in the 25-oxime *II*; instead, its spectrum displays a broad band at 3 260 cm^{-1} corresponding to a strong intramolecular bond[6,35] to nitrogen *n*--electrons in the (*E*)-25-oximino group. The weak band at 3 604 cm^{-1} in the spectrum of 2β-hydroxy-25-nitrile *Va* can be ascribed[36,37] to intramolecular hydrogen bond of the hydroxyl to π-electrons of the C≡N triple bond; no such band is present in the spectrum of *Vb*. The relatively strong broad band at about 3 430 cm^{-1} in the spectra of both the 25-nitriles *Va* and *VIIa* is evidently due to an intermolecular hydrogen bond. Interestingly, these compounds associate in concentrations as low as 10^{-3}mol. $.l^{-1}$ whereas the corresponding 26-nitriles *Vb* and *VIIb* do not form associates even in concentrations one order of magnitude higher. The facile association in 2β--hydroxy-25-nitriles may be connected with the 1,3-*syn*-axial arrangement of the functional groups (possible formation of cyclic dimers).

TABLE III

Chemical shifts and coupling constants of protons on the ring A in 2-ketones

Compound	Position of CN	δ[a]				J(1, 1)	J(3,3)
		H-1α	H-1β	H-3α	H-3β		
IX[b]	—	1·93	2·42	2·26	2·17	12·6	13·9
Xb	26	1·94	2·44	≧2·23[c]	≦2·23[c]	13·0	*d*
Xa[e]	25	2·11	2·92	2·24	2·51	15·5	14·1

[a] Obtained by analysis of AB systems; [b] see ref.[33], assignment based on the long-range coupling between H-1α and 10β-CH_3 and between H-1β and H-3β; [c] degenerate AB system, actual values can be up to 0·03 higher or up to 0·03 lower; [d] value not determined; [e] tentative assignment, signals may be interchanged.

The functionalization of the rather distant 8β-methyl group in the photolysis of 2β-nitrites *I* and *XX* is unusual. It can be explained by two consecutive 1,5-hydrogen shifts between the 1,3-*syn*-axial groups: The first consists in H$^{\bullet}$ radical transfer from the 10β-methyl group to the oxygen radical generated by homolytic cleavage of the 2β-nitrite, the second is a transfer from the 8β-methyl group to the radical at C-25 (see formula *XXII*). Finally, recombination with the NO$^{\bullet}$ radical gives the 26-oximino group. Similar consecutive 1,5-transfers of an H$^{\bullet}$ radical have been observed in reactions of lead tetraacetate and iodine with some diterpenoid and triterpenoid axial alcohols having an analogous 1,3-syn-axial arrangement of two methyl groups and hydroxyl. However, contrary to photolysis of nitrites *I* and *XX*, these hypoiodite reactions afford compounds functionalized simultaneously on both the near and the distant axial methyl group, e.g. 7α-hopanol yields 7α,27-epoxy-28--iodohopane[15]. Even with very small amounts of the reagent, no product functionalized solely on the more distant methyl group has been observed[16]. A comparison of the photolysis of 2β-nitrites *I* and *XX* with the hypoiodite reaction of 15β-hopanol and 21α*H*-hopan-5β-ol (see ref.[15]) is also interesting. If the alkoxyl radical is generated in position 2β by photolysis of the nitrite, the second hydrogen transfer (from C-26 to C-25) takes place whereas if it is generated in position 15β by hypoiodite reaction[15], the second H$^{\bullet}$ transfer (from C-25 to C-26) is not observed and the reaction affords products of attack at the less distant methyl group (15β,26-epoxyhopanes). On the other hand, hypoiodite reaction proceeded with double hydrogen transfer even in cases where nitrite photolysis led only to attack of the nearer methyl group, e.g. in isopimaran-8β-ol[15] or 3β-friedelanol[16,17].

TABLE IV
Infrared O—H stretching frequencies in 2β-hydroxy derivatives

Compound[a]	Substituents	ν(OH), cm^{-1}	
		free	bonded
XV	2β-OH	3 622 s[b]	—
II	2β-OH, 25-HON=	—, 3 592 s[c]	3 260 m,b
III	2β-OH, 26-HON=	3 620 m, 3 598 s[c]	—
Va	2β-OH, 25-CN	3 623 s	3 604 sh,w, 3 440 m,b
Vb	2β-OH, 26-CN	3 624 s	—
XVII	2β,3β-$(OH)_2$	3 635 s	3 583 s
VIIa	2β,3β-$(OH)_2$, 25-CN	3 623 s	3 576 s, 3 430 m,b
VIIb	2β,3β-$(OH)_2$, 26-CN	3 631 s	3 581 s

[a] Measured in tetrachloromethane on a Unicam SP 700 spectrometer, concentration 1—2 . . 10^{-3} mol l^{-1}; [b] taken from ref.[34]; [c] oxime OH.

The results of this work show that in the photolysis of triterpenoid 2β-nitrites the hydrogen is primarily transferred only from the 10β-methyl but not from the 4β--methyl group. Products of functionalization in the 4β-position have not been detected at all. This might indicate that the distance between the hydrogen atom of the 10β--methyl group and the 2β-oxygen atom is shorter than in the case of the 4β-methyl group.

The prepared 26-nitriles and the 26-oximino derivative belong to the small number of the hitherto known 26-substituted triterpenoids of oleanane, ursane, hopane, lupane or similar skeleton. Only recently[38], derivatives of 20(29)-lupen-26-oic acid were isolated as the first natural triterpenoids with a substituent in position 26.

EXPERIMENTAL

Melting points were determined on a Kofler block and are uncorrected. Optical rotations were measured on an automatic polarimeter ETL-NPL (Bendix–Ericsson) in chloroform (*c* 0·5—1·0), accuracy ±2°. Infrared spectra were recorded in chloroform on a PE 684 (Perkin–Elmer) spectrometer. ^{1}H NMR spectra were taken with a Tesla BS 487A instrument (80 MHz) in deuteriochloroform with hexamethyldisiloxane (HMDS) as internal standard. Chemical shifts are given in the δ-scale with tetramethylsilane (TMS) as reference (δ(TMS) = δ(HMDS) + 0·063). Mass spectra were measured on a Varian MAT 311 spectrometer, ionizing electron energy 70 eV, direct inlet temperature 130—150°C. Identity of samples prepared by different procedures was confirmed by thin-layer chromatography (TLC) and IR and ^{1}H NMR spectra. TLC was done on silica gel G (Merck), detection with 10% sulfuric acid and heating, or on Silufol foils (Kavalier, Votice, Czechoslovakia), detection with 5% ethanolic phosphomolybdic acid and heating. Column chromatography was performed on silica gel Silpearl (Kavalier, Votice). Analytical samples were dried over phosphorus pentoxide under diminished pressure at 100°C. The starting 2β-hydroxy derivative *XV* was prepared by the described[21] reduction of the 2-oxo derivative *IX*, obtained according to ref.[33]. Monoacetates *XII* and *XIX* were prepared as described[22]. The photolyses were carried out with a 125 W mercury lamp RKW (Tesla).

The "usual work-up procedure" means pouring the reaction mixture into water, taking the products up in ether, successive washing the ethereal layer with water, saturated sodium hydrogen carbonate solution, again with water, drying over sodium sulfate and evaporation of the solvents.

19β,28-Epoxy-18α-oleanan-2β-ol Nitrite (*I*)

Nitrosyl chloride was introduced at −20°C into a stirred solution of *XV* (0·8 g) in pyridine (50 ml) until the orange colour persisted. The solution was warmed to room temperature and water (20 ml) was added dropwise under stirring. The separated crystalline *I* (0·79 g; 93%) was used directly in further reaction. An analytical sample was obtained by crystallization from chloroform–methanol; m.p. 154—155°C (dec.), $[\alpha]_D$ +51°. IR spectrum: 1 632 (ONO); 1 031 (C—O—C) cm^{-1}. For $C_{30}H_{49}NO_3$ (471·7) calculated: 76·39% C, 10·47% H, 2·97% N; found: 76·21% C, 10·43% H, 2·83% N.

Photolysis of Nitrite *I*

Compound *I* (4 g) in benzene (100 ml) was irradiated in a Sial glass flask for 30 min with an externally placed 125 W mercury lamp, nitrogen being introduced into the solution before and

during the irradiation. The solvent was evaporated and the residue chromatographed on a column of silica gel (100 g) in light petroleum–ether (15 : 1), affording 0·21 g (6%) of *IX*, 0·38 g (10%) of *XV*, 0·24 g (6%) of amorphous (*E*)-19β,28-epoxy-2β-hydroxy-18α-oleanane 25-aldoxime (*II*), m.p. 263–266°C (sublimes at 210° as needles), $[\alpha]_D$ +26°. IR spectrum: 3 585, 3 229 (OH); 1 033 (C—O—C) cm^{-1}. ^1H NMR spectrum: 0·79 s, 3 H (CH_3); 0·89 s, 3 H (CH_3); 0·94 s, 12 H (4 × CH_3); 2·86 bd, 1 H (H-1ξ, J = 15 Hz); 3·50 s, 1 H (H-19α); 3·43 d, 1 H and 3·75 d, 1 H (H_2-28, J = 8 Hz); 4·10 m, 1 H (H-2α, $W_{1/2}$ = 14 Hz); 7·92 s, 1 H (H-25). Mass spectrum, *m/z* (%): 471 (M^+, 19), 453 (56), 451 (28), 438 (35), 410 (37), 408 (23), 382 (100), 380 (84), 364 (35), 339 (33), 245 (28), 224 (58). For $C_{30}H_{49}NO_3$ (471·7) calculated: 76·39% C, 10·47% H, 2·97% N; found: 76·42% C, 10·63% H, 3·15% N.

Further elution with the same solvent mixture gave 2·6 g (65%) of *II* and *III* (1 : 1, according to ^1H NMR spectrum) and 0·21 g (5%) of (*E*)-19β,28-epoxy-2β-hydroxy-18α-oleanane 26-aldoxime (*III*), m.p. 278–280°C (chloroform–methanol), $[\alpha]_D$ +27°. IR spectrum: 3 583, 3 336 (OH); 1 031 (C—O—C) cm^{-1}. ^1H NMR spectrum: 0·80 s, 3 H (CH_3); 0·91 s, 3 H (CH_3); 0·94 s, 6 H (2 × CH_3); 0·96 s, 6 H (2 × CH_3); 2·14 bd, 1 H (J = 12 Hz); 3·56 s, 1 H (H-19α); 3·38 d, 1 H and 3·69 d, 1 H (H_2-28, J = 8 Hz); 4·05 m, 1 H (H-2α, $W_{1/2}$ = 15 Hz); 7·76 s, 1 H (H-26). Mass spectrum, *m/z* (%): 471 (M^+, 20), 453 (100), 451 (40), 382 (42), 380 (30), 300, (22), 288 (23), 286 (26). For $C_{30}H_{49}NO_3$ (471·7) calculated: 76·39% C, 10·47% H, 2·97% N; found: 76·51% C, 10·59% H, 3·28% N.

19β,28-Epoxy-18α-oleanane-2β,3β-diol 3-Acetate, 2-Nitrite (*XX*)

Nitrosyl chloride was introduced at −10°C into a solution of *XIX* (850 mg) in pyridine (15 ml) until the orange colour persisted. After standing at −10°C for 2 h, the mixture was poured on ice, the product taken up in ether, the ethereal layer washed with dilute hydrochloric acid and worked up in the usual manner. Crystallization from benzene–ethanol afforded 750 mg (83%) of *XX*, m.p. 205–208°C, $[\alpha]_D$ +37°. IR spectrum: 1 731, 1 247 ($OCOCH_3$); 1 680, 1 651 (ONO); 1 030 (C—O—C) cm^{-1}. For $C_{32}H_{51}NO_5$ (529·8) calculated: 72·55% C, 9·70% H, 2·64% N; found: 72·36% C, 9·81% H, 2·83% N. On standing in chloroform, the product decomposed to give a mixture of *XIX* and *XXI* (according to TLC).

Photolysis of Nitrite *XX*

The compound *XX* (730 mg) was photolysed as described for *I* to give an unseparable mixture of compounds (TLC). The mixture was refluxed with acetic anhydride (10 ml) for 10 min and then the acetic anhydride was distilled off under reduced pressure. According to TLC, the residue contained *XVIII*, *VIIIa*, and *VIIIb*. Attempted separation by crystallization from methanol gave a 1 : 1 mixture of *VIIIa* and *VIIIb* (^1H NMR spectra), m.p. 287–288°C. Thin-layer chromatography of the mother liquors (15 g of silica gel, eluent light petroleum–ether 3 : 1) afforded 140 mg (18%) of *XVIII*, identical with the compound described in ref.[22]. The mixture of *VIIIa* and *VIIIb* was unseparable by chromatography, and its composition did not alter by repeated crystallizations. It was therefore hydrolyzed by boiling with 5% sodium hydroxide in ethanol (30 ml) for 2 h, worked up as usual and chromatographed on a column of silica gel (50 g) in light petroleum–ether (15 : 1). The elution gave: 210 mg (32%) of 19β,28-epoxy-2β,3β-dihydroxy-18α-oleanane-26-nitrile (*VIIb*), m.p. 327–329°C (chloroform–methanol), $[\alpha]_D$ + 51°. IR spectrum: 3 624, 3 583, 3 571, 3 400 (OH); 2 225 (CN); 1 034 (C—O—C) cm^{-1}. For $C_{30}H_{47}NO_3$ (469·7) calculated: 76·71% C, 10·09% H, 2·98% N; found: 76·59% C, 9·85% H, 2·72% N. Further elution afforded 220 mg (34%) of 19β,28-epoxy-2β,3β-dihydroxy-18α-oleanane-25-nitrile (*VIIa*), m.p. 310–320°C (dec.), (chloroform–methanol), $[\alpha]_D$ + 55°. IR spectrum: 3 619, 3 576, 3 561,

3 400 (OH); 2 228 (CN); 1 032 (C—O—C) cm^{-1}. ^1H NMR spectrum: 2·66 m, 1 H (H-1ξ). For $C_{30}H_{47}NO_3$ (469·7) calculated: 76·71% C, 10·09% H, 2·98% N; found: 76·65% C, 10·15% H, 2·69% N.

Acetylation of *VIIb* with acetic anhydride in pyridine (24 h), decomposition with ice and hydrochloric acid, usual work-up and crystallization from acetone afforded 78% of *VIIIb*, m.p. 328—329°C (sublimes at about 300°C), $[\alpha]_D$ +61°. IR spectrum: 2 226 (CN); 1 737, 1 261 and 1 255 ($OCOCH_3$); 1 035 (C—O—C) cm^{-1}. ^1H NMR spectrum: 2·03 s, 3 H and 2·05 s, 3 H (2 × $OCOCH_3$); 2·09 m, 1 H (H-1ξ); 4·62 d, 1 H, (H-3α, J = 3·4 Hz); 5·26 m, 1 H (H-2α, $W_{1/2}$ = 12 Hz). Mass spectrum, m/z (%): 553 (M^+, 100), 538 (16), 535 (15), 482 (69), 187 (42). For $C_{34}H_{51}NO_5$ (553·8) calculated: 73·74% C, 9·28% H, 2·53% N; found: 73·85% C, 9·39% H, 2·68% N.

Diol *VIIa* was acetylated in the same manner to give diacetate *VIIIa* in 82% yield, m.p. 292 to 293°C (methanol). $[\alpha]_D$ +87°. IR spectrum 2 231 (CN); 1 738, 1 253, and 1 241 ($OCOCH_3$); 1 033 (C—O—C) cm^{-1}. ^1H NMR spectrum: 2·06 s, 3 H and 2·11 s, 3 H (2 × $OCOCH_3$); 2·61 m, 1 H (H-1ξ); 4·58 d, 1 H (H-3α, J = 3·4 Hz); 5·28 m, 1 H (H-2α, $W_{1/2}$ = 10 Hz). Mass spectrum, m/z (%): 553 (M^+, 23), 523 (8), 494 (14), 482 (100), 422 (11), 380 (12), 273 (10), 245 (12). For $C_{34}H_{51}NO_5$ (553·8) calculated: 73·74% C, 9·28% H, 2·53% N; found: 73·91% C, 9·43% H, 2·72% N.

19β,28-Epoxy-18α-oleanane-2β,3α-diol 3-Acetate, 2-Nitrite (*XIII*) and Its Photolysis

Gaseous nitrosyl chloride was introduced at −20°C into a stirred solution of *XII* (150 mg) in pyridine (10 ml) until the orange colour persisted. After standing at −20°C for 4 h, the solution was poured on ice (5 g) and the separated product was collected on filter; yield 110 mg (80%) of *XIII* which melted with decomposition at 112—115°C, resolidified and melted again at 248 to 253°C; $[\alpha]_D$ +62°. Crystalline *XIII* decomposed within several days, in chloroform solution in several hours. It could not be crystallized from chloroform–methanol mixture. In all cases the decomposition product was *XI*. Photolysis of freshly prepared *XIII*, performed as described for *I*, led to a single product (TLC) which was isolated by crystallization from methanol in 83% yield and identified as *XI* by comparison with an authentic sample[27].

19β,28-Epoxy-2β-hydroxy-18α-oleanane-25-nitrile Acetate (*VIa*) and 19β,28-Epoxy-2β--hydroxy-18α-oleanane-26-nitrile Acetate (*VIb*)

A mixture of *II* (100 mg) and acetic anhydride (1 ml) was refluxed for 30 min. Most of the acetic anhydride was distilled off under reduced pressure and the residue was crystallized from chloroform–methanol to give 95 mg (90%) of *VIa*, m.p. 255—257°C (sublimes at 220°C from platelets to form needles), $[\alpha]_D$ +58°. IR spectrum: 2 228 (CN); 1 730, 1 250 ($OCOCH_3$); 1 034 (C—O—C) cm^{-1}. ^1H NMR spectrum: 2·08 s, 3 H ($OCOCH_3$); 2·57 m, 1 H (H-1ξ, $W_{1/2}$ = 15 Hz); 5·08 m, 1 H (H-2α, $W_{1/2}$ = 16 Hz). Mass spectrum, m/z (%): 495 (M^+, 51), 480 (6), 477 (5), 436 (12), 435 (13), 424 (100), 366 (13), 364 (18), 273 (11). For $C_{32}H_{49}NO_3$ (495·7) calculated: 77·53% C, 9·96% H, 2·83% N; found: 77·38% C, 10·04% H, 2·77% N.

A mixture of *III* (200 mg) and acetic anhydride (1 ml) was refluxed for 30 min. After cooling to room temperature the reaction mixture afforded crystals of *VIb* (190 mg, 95%), m.p. 283 to 285°C, $[\alpha]_D$ +54°. IR spectrum: 2 224 (CN); 1 728, 1 257 ($OCOCH_3$); 1 035 (C—O—C) cm^{-1}. ^1H NMR spectrum: 2·02 s, 3 H ($OCOCH_3$); 5·07 m, 1 H (H-2α, $W_{1/2}$ = 18 Hz). Mass spectrum, m/z (%): 495 (M^+, 100), 480 (6), 477 (7), 435 (45), 424 (53), 405 (47), 300 (15). For $C_{32}H_{49}NO_3$ (495·7) calculated: 77·53% C, 9·96% H, 2·83% N; found: 77·36% C, 10·16% H, 2·96% N.

19β,28-Epoxy-2β-hydroxy-18α-oleanane-25-nitrile (*Va*) and
19β,28-Epoxy-2β-hydroxy-18α-oleanane-26-nitrile (*Vb*)

A solution of sodium hydroxide (100 mg) in ethanol (5 ml) was added to a solution of *VIa* (200 mg) in benzene (5 ml). The mixture was refluxed for 3 h, poured into water, the benzene layer was separated, the aqueous one was extracted with ether and the combined organic phases were washed with dilute hydrochloric acid and processed as usual. Crystallization of the residue from acetone furnished 165 mg (90%) of *Va*, m.p. 283–284°C (at 250°C change from needles to prisms), $[\alpha]_D$ +50°. IR spectrum: 3 607, 3 401 (OH); 2 227 (CN); 1 032 (C—O—C) cm^{-1}. ^1H NMR spectrum: 2·41 m, 1 H (H-1ξ, $W_{1/2}$ = 15 Hz); 4·16 m, 1 H (H-2α, $W_{1/2}$ = 16 Hz). For $C_{30}H_{47}NO_2$ (453·7) calculated: 79·42% C, 10·44% H, 3·09% N; found: 79·28% C, 10·31% H, 2·87% N.

Compound *VIb* was prepared from *Vb* in the same way; yield 95%, m.p. 318–320°C (dec.) (sublimes at 250–300°C), $[\alpha]_D$ +57°. IR spectrum: 3 610 (OH); 2 225 (CN); 1 034 and 1 007 (C—O—C) cm^{-1}. ^1H NMR spectrum: 2·04 m, 1 H (H-1ξ, $W_{1/2}$ = 14 Hz); 4·06 m, 1 H (H-2α, $W_{1/2}$ = 19 Hz). For $C_{30}H_{47}NO_2$ (453·7) calculated: 79·42% C, 10·44% H, 3·09% N; found: 79·16% C, 10·31% H, 3·28% N.

19β,28-Epoxy-2-oxo-18α-oleanane-25-nitrile (*Xa*) and
19β,28-Epoxy-2-oxo-18α-oleanane-26-nitrile (*Xb*)

Compound *Va* (100 mg) was added to a solution of sodium acetate (150 mg) and sodium dichromate (50 mg) in acetic acid (10 ml). The suspension was stirred to homogeneity (3 h) and set aside at room temperature overnight. Methanol (1 ml) was added and the mixture was worked up in the usual manner. Crystallization of the residue from ethanol afforded 105 mg (87%) of *Xa*, m.p. 316–318°C (at 300°C change from needles to platelets), $[\alpha]_D$ +69°. IR spectrum: 2 229 (CN); 1 713 (CO); 1 032 and 1 005 (C—O—C) cm^{-1}. CD spectrum (dioxane): λ_{max} 299 nm, $\Delta\varepsilon$ +1·2. For $C_{30}H_{45}NO_2$ (451·7) calculated: 79·77% C, 10·04% H, 3·10% N; found: 79·61% C, 10·21% H, 3·16% N.

Compound *Vb* was oxidized in the same manner. Crystallization from acetone afforded 95% of *Xb*, m.p. 361–363°C (sublimes at about 280°C), $[\alpha]_D$ +56°. IR spectrum: 2 226 (CN); 1 703 (CO); 1 035 and 1 007 (C—O—C) cm^{-1}. CD spectrum (dioxane): λ_{max} 299 nm, $\Delta\varepsilon$ +1·2. For $C_{30}H_{45}NO_2$ (451·7) calculated: 79·77% C, 10·04% H, 3·10% N; found: 79·99% C, 9·88% H, 3·21% N.

19β,28-Epoxy-18α-oleanane-25-nitrile (*IVa*) and 19β,28-Epoxy-18α-oleanane-26-nitrile (*IVb*)

Compound *Xa* (50 mg) was heated to 150°C with a mixture of diethylene glycol (3 ml) and hydrazine hydrate (0·2 ml) until water vapours no longer escaped (about 40 min). After cooling and addition of solid potassium hydroxide (100 mg), the mixture was heated to 210°C for 2 h, cooled and poured into water. The separated product was collected on filter, dissolved in ether and the ethereal solution was worked up in the usual manner. Crystallization from chloroform–methanol gave 35 mg (73%) of *IVa*, m.p. 298–300°C (dec.) (sublimation from 220°C), $[\alpha]_D$ +57°. IR spectrum: 2 225 (CN); 1 032 and 1 004 (C—O—C) cm^{-1}. ^1H NMR spectrum: 2·24 m, 1 H (H-1ξ, $W_{1/2}$ = 14 Hz). For $C_{30}H_{47}NO$ (437·7) calculated: 82·32% C, 10·82% H, 3·20% N; found: 82·04% C, 10·91% H, 3·33% N.

The same procedure was applied to *Xb* which was converted into *IVb* in 81% yield (after crystallization from chloroform–acetone); m.p. 320–321°C (at about 270°C sublimes from prisms to form platelets), $[\alpha]_D$ +33°. IR spectrum: 2 223 (CN); 1 034 and 1 007 (C—O—C) cm^{-1}.

For $C_{30}H_{47}NO$ (437·7) calculated: 82·32% C, 10·82% H, 3·20% N; found: 82·47% C, 10·69% H, 3·23% N.

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