The Chemistry of the Triterpenes and Related Compounds. Part XXIII. The Structure of Taraxasterol, ψ-Taraxasterol (Heterolupeol), and Lupenol-I.*

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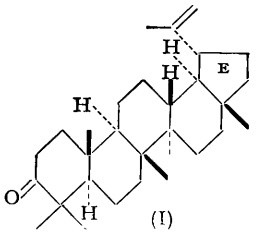
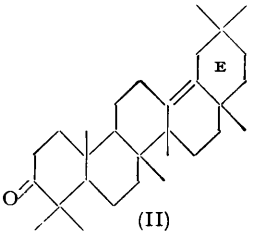
The elucidation of the structures of the pentacyclic triterpenes, taraxasterol, ψ-taraxasterol (heterolupeol), and lupenol-I has been completed. Acidic isomerisation of lupeol and its derivatives has given, under various conditions, compounds of the lupenol-I, ψ-taraxasterol, germanicol, and δ-amyrin types. It is now possible to interpret all of these reactions in a rational manner.

Some reactions of lupene-I and the corresponding alcohol and ketone are described.

THE pentacyclic triterpene, lupenone (I), is isomerised by 15% sulphuric acid in acetic acid to δ-amyrenone (II) and by 6% sulphuric acid in the same solvent to lupenone-I. This is also converted into δ-amyrenone under more strongly acidic conditions (Ames, Halsall, and Jones, *J.*, 1951, 450).



(I)



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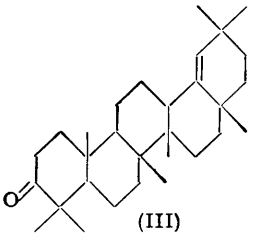


(III)

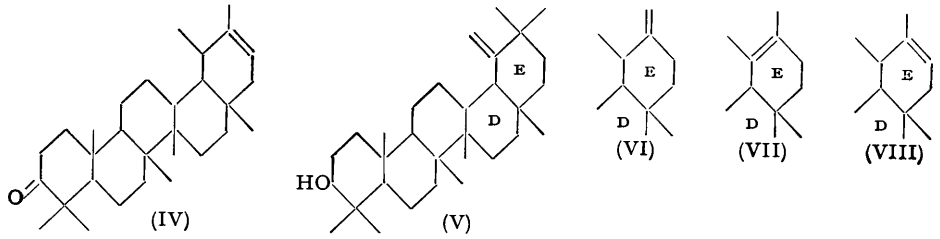
Lupenone-I has a trisubstituted double bond (Ames *et al.*, *loc. cit.*) but the obvious structure which accommodates this fact and the isomerisation to δ-amyrenone is that of germanicone (III) (Barton and Brooks, *J.*, 1951, 257), which is not identical with lupenone-I. It is necessary, however, to consider for lupenone-I a structure with a six-membered ring E since ring enlargement is known to occur even when lupenone is treated with very mild acidic reagents. For example formic acid–benzene at 20° gave 19α-formyloxy-18α-oleanan-3-one (Ames, Davy, Halsall, and Jones, *J.*, 1952, 2868). The most probable structure was (IV) and in the light of the suggested structures for taraxasterol (V or VI) and ψ-taraxasterol (heterolupeol) (VII or VIII) (Dietrich and Jeger, *Helv. Chim. Acta*, 1950, **33**, 711; cf. " Elsevier's Encyclopaedia of Organic Chemistry," Vol. 14 S, pp. 1157 S *et seq.*) it appeared possible directly to correlate lupenone-I and its derivatives with the corresponding compounds of the taraxasterol and ψ-taraxasterol series. This possibility was emphasised when it was found that some ψ-taraxasterol was formed on boiling lupeol in formic acid (Halsall, Jones, and Swayne, preceding paper).

It has been shown that taraxasteryl acetate can be isomerised to lupenyl-I acetate

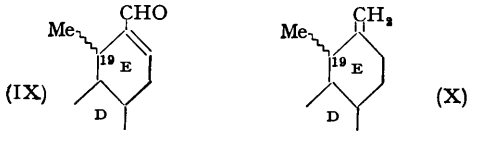
* Part XXII, preceding paper.

(cf. Barton and Bruun, *J.*, 1952, 1683) by using more vigorous conditions (6% sulphuric acid in acetic acid) than those (10% ethanolic sulphuric acid in benzene) already known to isomerise taraxasteryl acetate to ψ-taraxasteryl acetate (Lardelli, Krüsi, Jeger, and Ruzicka, *Helv. Chim. Acta*, 1948, **31**, 1815). The latter acetate, as well as the corresponding benzoate and hydrocarbon, have also been converted by *ca.* 6% sulphuric acid in acetic acid into lupenol-I derivatives.

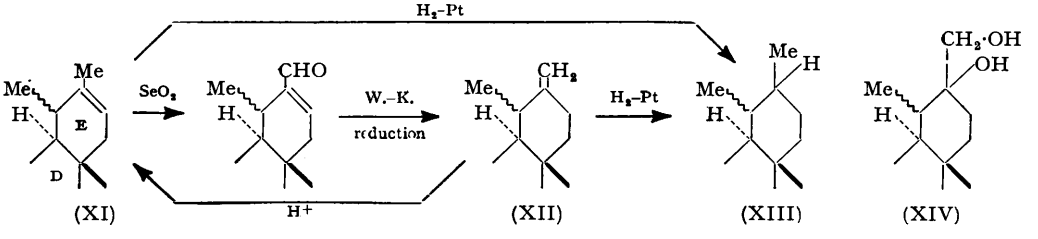
Oxidation of both taraxastene and ψ-taraxastene with selenium dioxide leads to the same αβ-unsaturated aldehyde, heterolupenal (Lardelli *et al.*, *loc. cit.*), which has maximum light absorption in *cyclo*hexane at 2300 Å ($\varepsilon = 13{,}900$) and in ethanol at 2340 Å. Lupene-I underwent a similar oxidation to give a different αβ-unsaturated aldehyde (lupenal-I) with a maximum in *cyclo*hexane at 2285 Å ($\varepsilon = 12{,}300$). These values are in accord with



those expected for an αβ-disubstituted αβ-unsaturated aldehyde, but they preclude the possibility of the ethylenic linkage being tetrasubstituted. Thus, *cyclo*hexenealdehyde shows maximum absorption in ethanol at 2290 Å whilst 2-methyl*cyclo*hexenealdehyde and β-*cyclo*citraldehyde absorb at much longer wave-lengths, *viz.*, 2420 and 2490 Å, respectively (Braude, Jones, Koch, Richardson, Sondheimer, and Toogood, *J.*, 1949, 1890). The structures for heterolupenal and lupenal-I consistent with these results are the two stereoisomers of (IX), differing in the configuration of the $C_{(19)}$-methyl group. If this deduction is correct then taraxastene, obtained from heterolupenal by Wolff–Kishner reduction (Lardelli *et al.*, *loc. cit.*), should be one of the two isomers of structure (X), and its $C_{(19)}$-epimer should be obtainable from lupenal-I by similar reduction.



Lupenal-I was subjected to the Wolff–Kishner reaction, and an amorphous hydrocarbon $C_{30}H_{50}$ was obtained which had an infra-red spectrum in "Nujol" with bands at 886, 1647, and 3075 cm.$^{-1}$ characteristic of a vinylidene group ($>C{=}CH_2$). It appeared, therefore, that this hydrocarbon was indeed the $C_{(19)}$-epimer of taraxastene (*iso*lupene-I). On hydrogenation it gave lupane-I in *good* yield, and it afforded lupene-I on isomerisation with acid. These results are consistent with partial structures (XI), (XII), and (XIII) for lupene-I, *iso*lupene-I, and lupane-I.

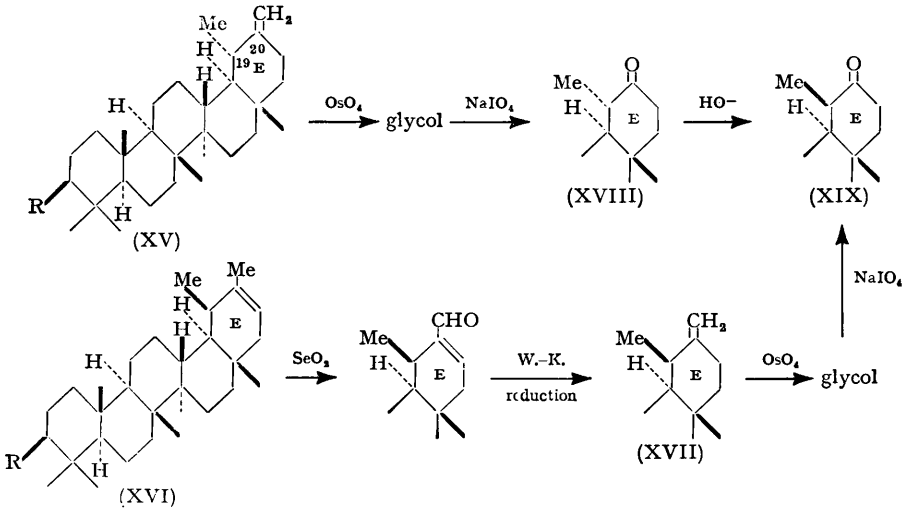


When, however, the Wolff–Kishner reduction product was treated with osmium tetroxide, some lupane-I was isolated (20% yield), in addition to the expected glycol (XIV), which was obtained in 75% yield. The reduction product is therefore a mixture

of *iso*lupene-I and the corresponding saturated hydrocarbon, lupane-I. Although the reduction was not investigated in great detail it appeared that the amount of lupane-I formed was dependent on the temperature of the reduction. Other examples are known of the complete reduction of an αβ-unsaturated carbonyl system. For instance, cholest-5-en-7-one is reduced to a mixture of cholest-6-ene and cholestane (*ca.* 45%) (Fischer, Lardelli, and Jeger, *Helv. Chim. Acta*, 1951, **34**, 1577).

The glycol (XIV) from *iso*lupene-I was oxidised with sodium periodate and gave a nor-ketone, the infra-red spectrum of which exhibited a band at 1710 cm.$^{-1}$ in both carbon tetrachloride and carbon disulphide, characteristic of a keto-group in a six-membered ring. This proves that the vinylidene group in *iso*lupene-I is also in the same-sized ring, and as *iso*lupene-I gives lupane-I on hydrogenation it follows that the latter and lupene-I both have a six-membered ring E. Treatment of the nor-ketone with methylmagnesium iodide and decomposition of the complex with sulphuric acid gave back lupene-I.

Taraxastene is oxidised by osmium tetroxide to a glycol (Lardelli *et al.*, *loc. cit.*) which is different from that from *iso*lupene-I. Fission of this second glycol with sodium periodate gave a different nor-ketone. Its infra-red spectrum exhibited bands at 1703 and 1706 cm.$^{-1}$ in carbon tetrachloride and carbon disulphide, respectively. When, however, it was adsorbed from benzene on to " neutralised " alumina (of activity I; pH 7—8) it epimerised to the nor-ketone already obtained from *iso*lupene-I. The sequence of reactions leading from taraxastene (XV; R = H) and lupene-I (XVI; R = H) to the

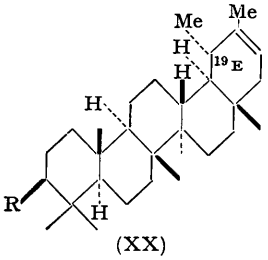


same ketone (XIX; R = H) is summarised in the scheme. It makes it clear that one carbon atom of ring E of the basic ring system must be common to the double bonds of taraxastene and lupene-I and, since the lupene-I double bond is trisubstituted, this common atom is $C_{(20)}$ and not $C_{(19)}$. Further, taraxastene and lupene-I must differ at $C_{(19)}$, having the methyl groups in the epimeric positions. Since the nor-ketone (XVIII) from taraxastene isomerises to that (XIX; R = H) from *iso*lupene-I (XVII), the $C_{(19)}$-methyl group in taraxastene may be regarded as being in the less stable conformation. At first this was assumed to be the axial (polar) conformation (cf. Beton, Bowers, Halsall, and Jones, *Chem. and Ind.*, 1953, 847), but in the light of arguments put forward by Professor D. H. R. Barton and Dr. W. Klyne (cf. *Chem. and Ind.*, 1953, 1386) and discussed later in this paper, we now believe that the weight of evidence and opinion points to the less stable conformation being equatorial, leading to (XV; R = H) for taraxastene and (XVI; R = H) for lupene-I.

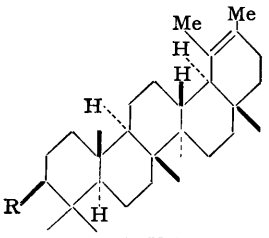
For ψ-taraxasterol the results so far described do not distinguish conclusively between structures (XX; R = OH) and (XXI; R = OH), containing tri- and tetra-substituted double bonds, respectively. However, with heterolupenal established as one of the

stereoisomers of (IX), (XX; R = OH) was strongly favoured for ψ-taraxasterol and final proof was obtained as follows.

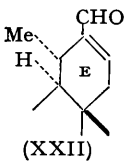
The infra-red spectra of ψ-taraxastene (in "Nujol"), ψ-taraxasterol, ψ-taraxasteryl acetate, and ψ-taraxasteryl formate (all in carbon disulphide) and of heterolupenal (XXII) exhibit bands at 779, 778, 780, 779, and 782 cm.$^{-1}$ respectively, indicative of a trisubstituted double bond. Further the short wave-length ultra-violet spectra of ψ-taraxastene and of lupene-I, which has a trisubstituted double bond, are very similar, both showing a rapid falling off in intensity between 2150 and 2250 Å. This is to be contrasted with the much more gradual intensity decrease for 1 : 2-dimethyl*cyclo*hexene (detailed values are given in the experimental section). Finally ψ-taraxastene was oxidised with osmium tetroxide to a diol (heterolupanediol; Jeger, Krüsi, and Ruzicka, *Helv. Chim. Acta*, 1947,



(XX)



(XXI)



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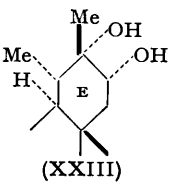


(XXIII)

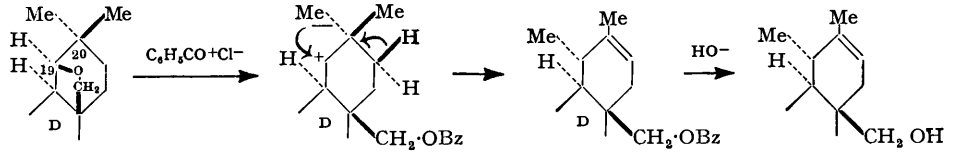
30, 1048). If ψ-taraxasterol is (XX) then the diol would be taraxastane-20α : 21α-diol (XXIII), α-attack of the reagent being assumed. A compound with this structure should form a monoacetate easily, having a secondary equatorial hydroxyl group, and be oxidised under mild conditions to a hydroxy-ketone. On the other hand, if (XXI) were correct then the resulting diol would have two tertiary hydroxyl groups which would be very difficult to acetylate. Further, oxidation would not give a hydroxy-ketone. In fact the diol formed a monoacetate and on oxidation with chromic acid under mild conditions gave a hydroxy-ketone. ψ-Taraxasterol is therefore (XX; R = OH), the $C_{(19)}$-methyl group being assumed to be in the equatorial conformation.

A decision concerning the conformation of the $C_{(19)}$-methyl group in ψ-taraxastene and in lupene-I is not easy to make. Evidence on this point was sought from a consideration of the relative stabilities of the nor-ketones (XVIII) and (XIX) derived from, and corresponding stereochemically to, ψ-taraxastene and lupene-I, respectively. Normally in α-substituted *cyclo*hexanone derivatives the more stable structure is that with the substituent equatorial, but exceptions to this generalisation occur. For instance, in the case of 2-bromo*cyclo*hexanone interaction between the C–Br and C=O dipoles in the equatorial conformation makes this the less stable system (Corey, *J. Amer. Chem. Soc.*, 1953, **75**, 2301). Again Barton (*Chem. and Ind.*, 1953, 664) has discussed the stability of a number of polyalkylated *cyclo*hexanes and has shown that in certain cases a substituent may be more stable in the axial (polar) than in the equatorial conformation. In the two nor-ketones, whilst the axial (polar) conformation involves a non-bonded interaction between the $C_{(19)}$ and $C_{(17)}$ axial (polar) methyl groups, the equatorial conformation (cf. XVIII) involves *similar* interaction, probably of the same order of magnitude, between the $C_{(19)}$-methyl and the $C_{(12)}$-methylene groups. This suggests that the difference in stability between the two conformations may be small and that any prediction on these grounds concerning the conformation of the more stable isomer is not justified.

More definite evidence is provided by a consideration of the mechanism of formation from *allo*betulin (XXIV) (Davy, Halsall, Jones, and Meakins, *J.*, 1951, 2702) of heterobetulin (Dischendorfer and Grillmayer, *Monatsh.*, 1926, **47**, 419), the 28-hydroxy-derivative of ψ-taraxasterol (Lardelli, Krüsi, Jeger, and Ruzicka, *Helv. Chim. Acta*, 1948, **31**, 1159). The most plausible mechanism appears to be that indicated, initiated by attack on the ether-oxygen atom by benzoyl chloride ($PhCO^+$ ion). The benzoate is formed by fission of the $C_{(19)}$–O bond and simultaneously a replacement reaction (S_N2) occurs at $C_{(19)}$ with the $C_{(20)}$ axial (α) methyl group becoming attached to $C_{(19)}$ in the *equatorial* conformation.

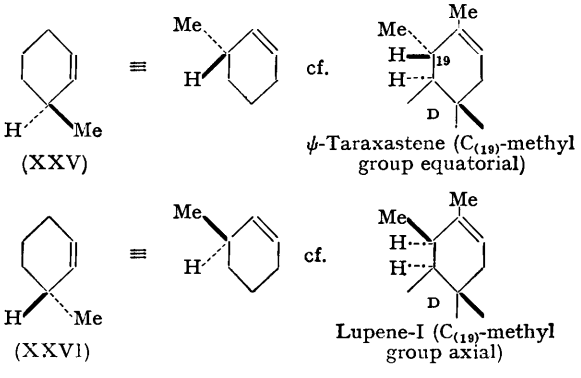
A proton is then expelled from $C_{(21)}$. Now since heterobetulin has been simply converted into ψ-taraxasterol (Lardelli *et al.*, *loc. cit.*) these considerations strongly suggest that the $C_{(19)}$-methyl group in ψ-taraxasterol, and hence in taraxasterol and the nor-ketone from taraxastene, is in the equatorial conformation (cf. XV and XVIII). In turn it follows that the $C_{(19)}$-methyl group in lupene-I, and in the more stable nor-ketone (XIX), is in the axial (polar) conformation.

Evidence in favour of this conclusion has been provided by Dr. W. Klyne from the molecular-rotation differences between ψ-taraxasterol and lupenol-I derivatives. If ψ-taraxastene is (XX; R = H) and lupene-I is (XVI; R = H) with the $C_{(19)}$-methyl group in the axial conformation, then ψ-taraxastene can be regarded as a derivative of



*allo*betulin (XXIV) heterobetulin

lævo-3-methyl*cyclo*hexene (XXV) and lupene-I as a derivative of *dextro*-3-methyl*cyclo*hexene (XXVI). Mills (*J.*, 1952, 4976) has shown that derivatives of type (XXVI) are more dextrorotatory than those of type (XXV) and that the difference ($\Delta[M_D]$ + 200°) is approximately independent of the presence of additional substituents in the *cyclo*hexene



ring, provided that they have the same configuration in any pair of 3-methyl*cyclo*hexenes which are compared. As indicated in the Table, lupene-I and its derivatives are more dextrorotatory ($\Delta[M_D]$ + *ca.* 200°) than the corresponding ψ-taraxastene derivatives. This is in agreement with lupene-I being of type (XXVI) rather than of type (XXV) and hence with the axial (β) conformation of the $C_{(19)}$-methyl group.

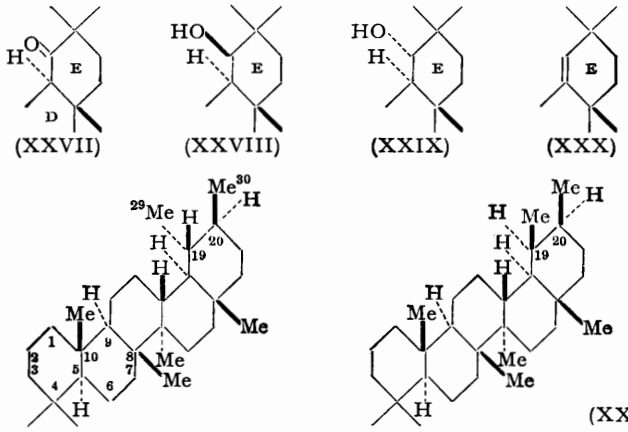
Molecular-rotation differences.

Derivative	$[M]_D$, lupene-I series	$[M_D]$, ψ-taraxastene series	Δ
Hydrocarbon	+418°	+205°	+213°
3β-Hydroxy-	+413	+211	+202
3β-Acetoxy-	+454	+262	+192
3-Oxo-	+534	+344	+190

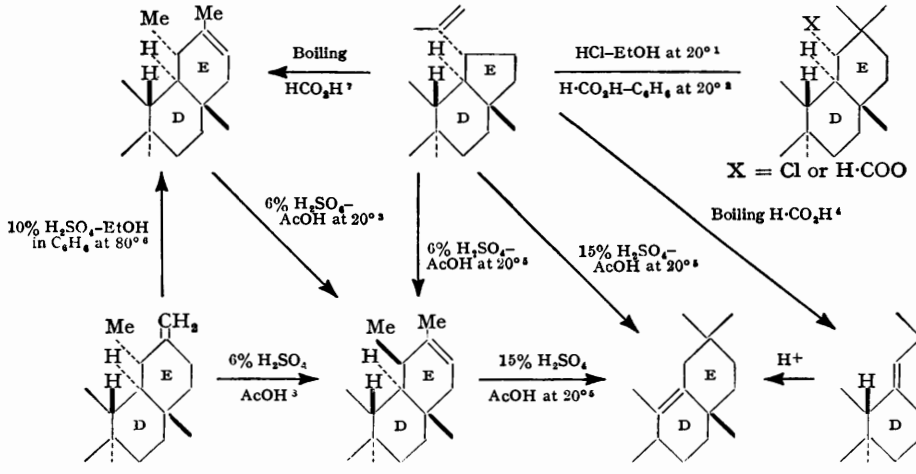
On the basis of the above arguments we incline to the view that lupene-I is correctly represented by (XVI; R = H) and taraxastene by (XV; R = H). Further support for this conclusion is provided by a study of the reduction of 18α-oleanan-19-one (XXVII) with sodium and amyl alcohol when the thermodynamically more stable product should result. From this reduction 18α-oleanan-19β-ol (XXVIII) was obtained in *ca.* 70% yield. It was also formed on reduction of 18α-oleanan-19-one with lithium aluminium hydride. On dehydration with phosphoryl chloride in pyridine it gave germanicene (XXX), elimination occurring between the two *trans* axial groups. In contrast, the isomeric

19α-alcohol (XXIX), prepared by Wolff–Kishner reduction of 19α-hydroxy-18α-oleanan-3-one (Ames, Davy, Halsall, and Jones, *J.*, 1952, 2868), gave α-lupene on similar dehydration. The formation of 18α-oleanan-19β-ol on sodium–alcohol reduction of the keto-compound shows that in *the case of* 18α-*oleanane* a substituent at $C_{(19)}$ is more stable in the *axial* conformation.

With the elucidation of the structures of taraxastene and lupene-I a system of nomenclature for these compounds and their derivatives is proposed based on (XXXI), the structure of taraxastane. This is obtained by hydrogenation of both taraxastene and ψ-taraxastene (see later) and it is reasonable to assume that the hydrogen introduced at $C_{(20)}$ attaches itself to the α-face of the planar molecule, the axial β $C_{(17)}$-methyl group preventing hydrogenation from the β-side. Taraxastene thus becomes taraxast-20(30)-ene, and lupene-I (XVI; R = H) 19α(H)-taraxast-20-ene, *iso*lupene-I (XVII) 19α(H)-taraxast-20(30)-ene, and lupane-I (XXXII), α-hydrogenation of lupene-I being assumed, 19α(H)-taraxastane. Other examples of the application of this system of nomenclature are to be found in the experimental section.

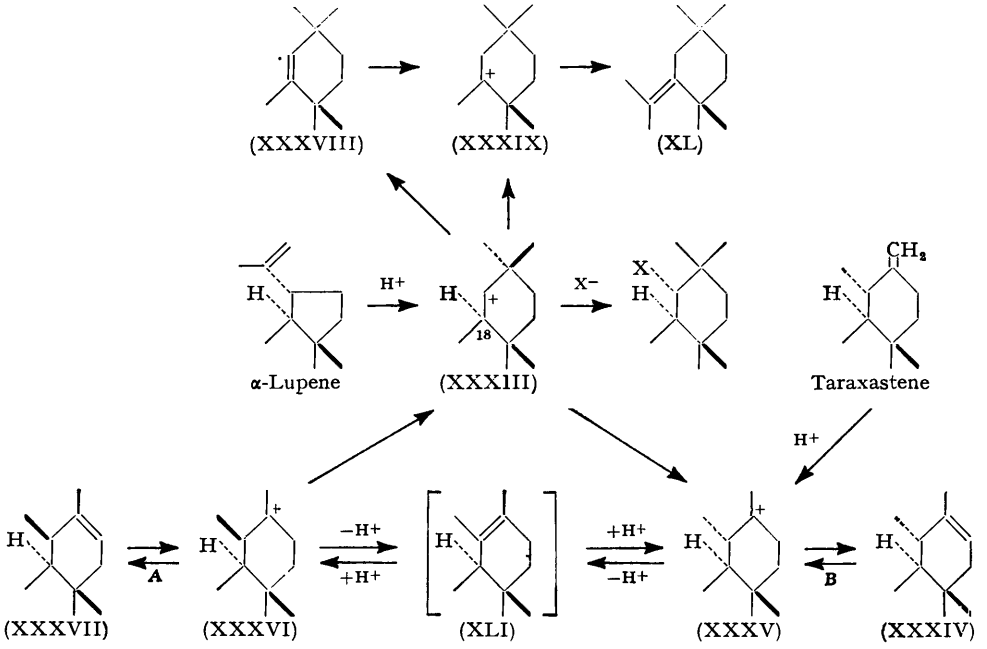


It is now possible to attempt a rational discussion of the isomerisation of lupenol and its derivatives. The products obtained, with their now known structures and the various reaction conditions employed in their formation, are summarised schematically below.



[1] Halsall, Jones, and Meakins, *J.*, 1952, 2862. [2] Ames, Davy, Halsall, and Jones, *ibid.*, p. 2868. [3] This paper. [4] Biedebach, *Arch. Pharm.*, 1943, **281**, 49. [5] Ames, Halsall, and Jones, *J.*, 1951, 450. [6] Lardelli, Krüsi, Jeger, and Ruzicka, *Helv. Chim. Acta*, 1948, **31**, 1815. [7] Halsall, Jones, and Swayne, preceding paper.

The first stage is ring enlargement to the carbonium ion (XXXIII). In the presence of a large excess of a reactive anion, and under relatively weak acidic conditions, the ring enlargement is accompanied by a concerted stereospecific addition of the anion with the formation of 19α-substituted 18α-oleanane derivatives (cf. Halsall, Jones, and Meakins, *J.*, 1952, 2862; Ames, Davy, Halsall, and Jones, *loc. cit.*). Under more acidic conditions the axial $\alpha C_{(20)}$-methyl group takes the place of the entering anion and participates in a concerted stereospecific rearrangement leading to a 19α-methyl derivative (ψ-taraxastene derivative, XXXIV). This rearrangement involves the formation of the ion (XXXV) and the setting up of the equilibrium *A*. The ψ-taraxastene structure (XXXIV) is thermodynamically less stable than that of lupene-I (XXXVII) to which it isomerises. The isomerisation probably involves (XLI) as a transitory intermediate as indicated. The path proposed involves neither the formation of a secondary carbonium ion nor a carbon–carbon bond fission. Since the lupene-I structure is more stable than that of ψ-taraxastene, lupene-I derivatives will normally be formed, unless the ψ-taraxastene derivative is effectively removed from equilibrium *A*. Two factors may bring this about: insolubility of the ψ-taraxastene compound in the reaction medium and insufficient acid strength to effect proton addition to the double bond of (XXXIV). It is possible that the first factor operates in the formation of ψ-taraxasterol in small yield from lupeol in boiling formic acid and that the second is responsible for the isolation of heterobetulin from *allo*betulin.



The ion (XXXIII), besides undergoing a carbon–carbon rearrangement, can also lose a proton from $C_{(18)}$ to give the germanicol structure (XXXVIII) or rearrange to (XXXIX) which then gives the δ-amyrin skeleton (XL). The formation of δ-amyrin derivatives usually requires strongly acidic conditions (*e.g.*, 15% sulphuric acid in acetic acid). In the case of the conversion of lupene-I derivatives into those of δ-amyrin, the vigorous conditions may be necessary to convert the tertiary ion (XXXVI) into the secondary ion (XXXIII). In this conversion the methyl group which moves is again in the axial conformation.

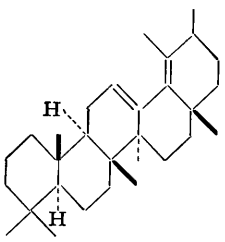
The absence of appreciable amounts of germanicol derivatives in most isomerisations may be due either to the rapid conversion of (XXXVIII) into (XXXIX) or to the direct formation of (XXXIX) from (XXXIII), (XXXVIII) being by-passed. In this connection

it may be of significance that the $C_{(18)}$-hydrogen atom is in the (α)-configuration and so can become attached to $C_{(19)}$ in the α (equatorial) position. This is analogous to the formation of 19α-chloro-18α-oleanan-3β-ol from lupeol.

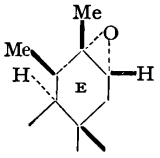
It is of interest that the ion (XXXIII) is postulated by Ruzicka, Eschenmoser, and Heusser as a key intermediate in their scheme for the biogenesis of pentacyclic triterpenes (*Experientia*, 1953, **9**, 357).

So far compounds with the tetrasubstituted double bond structure (XLI) have not been isolated from acidic isomerisations. This is probably due to the instability of this system. Inspection of models of structure (XLI) indicates very great interference between the $C_{(19)}$-methyl group and the $C_{(12)}$-methylene group of ring C. Attention may be drawn to the fact that the isomer of lupeol with the three-carbon side-chain present as an *iso*-propylidene group is unknown, and to the lack of reactivity of the keto-group in trisnorlupanone (Davy, Jones, and Halsall, *Rec. Trav. chim.*, 1950, **69**, 368). Both the *iso*propylidene group of the isomer and the keto-group of trisnorlupanone interfere with the $C_{(12)}$-methylene group. Similar interference would be expected between the $C_{(19)}$-methyl and the $C_{(12)}$-methylene group in derivatives of α-amyra-12 : 18-diene (ursa-12 : 18-diene) (XLII?), and it is probably this factor which has prevented the formation so far of such a diene system in the α-amyrin series, although the corresponding system in the β-amyrin series is well known.

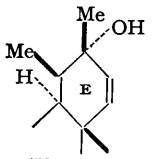
It is now appropriate to describe a number of reactions of lupene-I and its derivatives. Both lupenyl-I acetate and lupenone-I form epoxides when treated with perbenzoic acid. In view of the hindrance to β-attack afforded by the $C_{(17)}$-methyl group it is probable that the oxidation products are α-epoxides (partial structure XLIII). Reduction of each epoxide with lithium aluminium hydride yielded the same diol which formed a monoacetate. Axial opening of the epoxide being assumed, the diol can be formulated as 19α(H)-taraxastane-3β : 20α-diol (partial structure XLIV). Treatment of the epoxide from lupenyl-I acetate with sulphuric acid afforded two products, a monohydroxy conjugated diene and a triol, which was characterised as a monoacetate. The diene showed maximum absorption at 2300—2360 Å (ε = 13,400) and its infra-red spectrum in " Nujol " exhibited a band at 884 $cm.^{-1}$, characteristic of a vinylidene group. The diene is formulated as 19α(H)-taraxasta-20(30) : 21-dien-3β-ol (partial structure XLV). The calculated position of maximum absorption of this structure in the ultra-violet region is 2320 Å. Partial hydrogenation of the diene gave lupenol-I and complete hydrogenation lupanol-I, showing that the carbon skeleton is unchanged on formation of the diene.



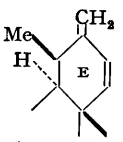
(XLII)



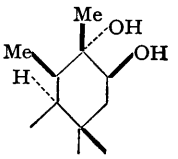
(XLIII)



(XLIV)



(XLV)



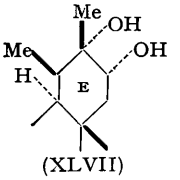
(XLVI)

Acidic fission of an epoxide of a cyclic compound gives a diaxial diol (Barton, *J.*, 1953, 1033). The triol described above is therefore 19α(H)-taraxastane-3β : 20α : 21β-triol (partial structure XLVI). Only the 3β(equatorial)-hydroxyl group should acetylate readily. The formation of a monoacetate is in agreement with this conclusion. The triol is different from that prepared by the action of osmium tetroxide on lupenol-I. This should be the 3β : 20α : 21α-triol and should have two equatorial hydroxyl groups which can be readily acetylated. On acetylation a diacetate was in fact obtained.

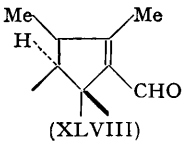
The α-glycol grouping introduced when osmium tetroxide reacts with lupene-I to give a diol (Ames, Halsall, and Jones, *loc. cit.*) should be *cis* (cf. XLVII), and should have one axial and one equatorial hydroxyl group. α-Attack of the reagent again being assumed, the diol should be 19α(H)-taraxastane-20α : 21α-diol (partial structure XLVII). The

21α-hydroxyl group, being secondary and equatorial, should acetylate readily; on acetylation of the diol a monoacetate is formed. Oxidation of the diol with lead tetra-acetate gave a product, $C_{30}H_{48}O$, which formed a 2 : 4-dinitrophenylhydrazone. The formula corresponds to the fission of the glycol to a dicarbonyl derivative followed by cyclisation with elimination of one molecule of water. The most likely cyclisation would appear to lead to (XLVIII).

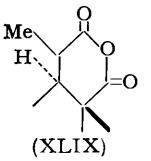
The ultra-violet spectrum of the lead tetra-acetate product shows maximum absorption at 2560—2580 Å and 3200—3400 Å (ε = 13,100 and 150, respectively). The position of maximum absorption is at a somewhat longer wave-length than that calculated by adding, to allow for an additional β-methyl substituent, an increment of 120 Å to the value 2360—2380 Å, which is the wave-length at which *cyclo*pent-1-enealdehyde ($\varepsilon_{max.}$ = 13,500) shows maximum absorption (Brown, Henbest, and Jones, *J.*, 1950, 3624). The *cyclo*pentene



(XLVII)



(XLVIII)



(XLIX)

ring, however, in the lead tetra-acetate fission product is very much more heavily substituted than that of *cyclo*pent-1-enealdehyde. Proof of the presence of an aldehyde group was obtained by further oxidation of the lead tetra-acetate product with chromic acid. A neutral and an acidic fraction were obtained. The latter was methylated with diazomethane to a methyl ester, $C_{31}H_{50}O_2$, with an ultra-violet spectrum characteristic of an αβ-unsaturated ester ($\lambda_{max.}$ 2270—2290 Å, ε = 8800). The neutral fraction did not absorb in the ultra-violet above 2150 Å and gave an analysis in agreement with $C_{28}H_{41}O_3$. One possible structure is the anhydride (XLIX). The investigation of the nature of this compound was not pursued further.

Experimental

Rotations were determined in chloroform at room temperature unless otherwise stated. M. p.s were determined on a Kofler block and are corrected. The alumina used for chromatography had an activity I—II. Light petroleum refers to the fraction with b. p. 60—80° unless otherwise stated.

Isolation of Taraxasterol [*Taraxast*-20(30)-*en*-3β-*ol*].—Extraction of chamomile flowers (Belgium first picking) (2·25 kg.) with ether (12 l.) at 20° for 3 days afforded a green oil (75 g.) which was heated under reflux for 4 hr. with potassium hydroxide (60 g.), ethanol (400 c.c.), benzene (200 c.c.), and water (100 c.c.). Extraction of the reaction mixture with ether yielded a yellow solid (20 g.) which was adsorbed from benzene on alumina (activity II; 600 g.). Elution with benzene gave a pale yellow wax (4·12 g.), m. p. 30—40°. Further elution with ether–methanol (4 : 1) yielded a pale yellow amorphous solid (16·1 g.), acetylation of which afforded taraxasteryl acetate [taraxast-20(30)-en-3β-yl acetate] (3·7 g.) as plates (from chloroform–methanol), m. p. 246—248°, $[\alpha]_D$ +100° (*c*, 0·97). Hydrolysis of the acetate with methanolic potassium hydroxide gave taraxasterol as needles (from chloroform–methanol), m. p. 217—220°, $[\alpha]_D$ +92·5° (*c*, 1·4). Benzoylation of taraxasterol with benzoyl chloride and pyridine at 100° gave taraxasteryl benzoate [taraxast-20(30)-en-3β-yl benzoate] as plates (from ethyl acetate–ethanol), m. p. 241—243°, $[\alpha]_D$ +106° (*c*, 0·35).

Isomerisation of Taraxasteryl Acetate to Lupenyl-I Acetate [19α(*H*)-*Taraxast*-20-*en*-3β-*yl Acetate*].—Taraxasteryl acetate (500 mg.) was dissolved in benzene (5 c.c.) and acetic acid (20 c.c.), and sulphuric acid (1·25 c.c.; *d* 1·84) in acetic acid (5 c.c.) was added. The solution became brown and developed a green fluorescence. After 3 days at 18° a white solid (310 mg.) had crystallised and was filtered off. Several crystallisations from chloroform–methanol afforded lupenyl-I acetate as plates, $[\alpha]_D$ +97° (*c*, 0·64), m. p. 241·5—243° undepressed on admixture with an authentic sample (Found: C, 82·1; H, 11·3. Calc. for $C_{32}H_{52}O_2$: C, 82·0, H, 11·2%). The infra-red spectra, determined in "Nujol" suspension, of the crystals and of lupenyl-I acetate were identical. The acetate was further identified by hydrolysis to lupenol-I [19α(H)-taraxast-20-en-3β-ol], $[\alpha]_D$ +96·5° (*c*, 0·54), m. p. 252—253° undepressed on admixture

with an authentic sample. Benzoylation gave lupenyl-I benzoate [19α(H)-taraxast-20-en-3β-yl benzoate], $[\alpha]_D$ +108° (*c*, 0·082), m. p. 273—275° undepressed on admixture with an authentic sample.

Preparation of ψ-Taraxasterol (*Heterolupeol*) (*Taraxast-20-en-3β-ol*).—Taraxasteryl acetate (1·9 g.), benzene (100 c.c.), and ethanol (200 c.c.) were heated under reflux for 5 hr. with concentrated sulphuric acid (20 c.c.). After dilution with water, ethereal extraction yielded a product which was purified by chromatography on alumina and then crystallised from chloroform–methanol, giving ψ-taraxasterol as needles, m. p. 214—216° raised by sublimation to 219—221°, $[\alpha]_D$ +45° (*c*, 1·22) (Found: C 84·55; H 11·8. Calc. for $C_{30}H_{50}O$: C 84·45; H 11·8%). Acetylation of the ψ-taraxasterol in the usual manner afforded ψ-taraxasteryl acetate (taraxast-20-en-3β-yl acetate) as plates m. p. 238—240° (from chloroform–methanol), $[\alpha]_D$ +56° (*c*, 1·24). Benzoylation gave ψ-taraxasteryl benzoate (taraxast-20-en-3β-yl benzoate) as needles, m. p. 273—275° (from ethyl acetate–ethanol), $[\alpha]_D$ +75° (*c*, 1·2).

Preparation of ψ-Taraxastenone (*Taraxast-20-en-3-one*).—ψ-Taraxasterol (1·0 g.) was dissolved in dioxan (50 c.c.) and acetone (100 c.c.) and an 8N-solution of chromic acid in sulphuric acid (3·4 c.c.; 2 mol.) was added. After dilution with water, ethereal extraction yielded a product which was purified by chromatography on alumina and then crystallised from chloroform–methanol, giving ψ-*taraxastenone* (*taraxast-20-en-3-one*) as needles, m. p. 174—175°, $[\alpha]_D$ +81·5° (*c*, 4·4) (Found: C, 85·0; H, 11·4. $C_{30}H_{48}O$ requires C, 84·85; H, 11·4%).

Wolff–Kishner Reduction of ψ-Taraxastenone.—ψ-Taraxastenone (7·5 g.), hydrazine hydrate (100 c.c.; 60%), ethanol (400 c.c.), and sodium (20 g.) were heated in an autoclave at 200—240° for 5 hr. under 100 atm. pressure. After dilution with water, ethereal extraction yielded a product which was purified by chromatography on alumina and then crystallised from chloroform–methanol, giving ψ-taraxastene (heterolupene) (taraxast-20-ene) as needles (5 g.), m. p. 182—184°, $[\alpha]_D$ +50° (*c*, 1·37).

Isomerisation of ψ-Taraxasteryl Acetate to Lupenyl-I Acetate.—ψ-Taraxasteryl acetate (1 g.) was dissolved in benzene (10 c.c.) and acetic acid (40 c.c.), and sulphuric acid (3 c.c.; *d* 1·84) in acetic acid (5 c.c.) was added. The mixture was kept at 20° for 60 hr. The crystalline material which had separated was filtered off, washed several times with ethanol, and dried (weight, 680 mg.; m. p. 230—240°). Crystallisation of this product from chloroform–methanol afforded lupenyl-I acetate as plates, m. p. 244—246° undepressed on admixture with an authentic sample, $[\alpha]_D$ +99° (*c*, 1·34). The acetate was further identified by hydrolysis to lupenol-I, m. p. 251—252° undepressed on admixture with an authentic sample, $[\alpha]_D$ +93·5° (*c*, 1·36). Benzoylation of the lupenol-I gave lupenyl-I benzoate, m. p. 273—275° undepressed on admixture with an authentic sample, $[\alpha]_D$ +114° (*c*, 0·58).

Isomerisation of ψ-Taraxasteryl Benzoate to Lupenyl-I Benzoate.—ψ-Taraxasteryl benzoate (120 mg.) was dissolved in benzene (3 c.c.) and acetic acid (5 c.c.), and sulphuric acid (0·25 c.c.; *d* 1·84) in acetic acid (5 c.c.) was added. The mixture was heated to 110°, allowed to cool, and kept at 15° for 45 hr. The white crystalline solid (80 mg.) which separated was filtered off and crystallised from chloroform–methanol, giving lupenyl-I benzoate as plates, m. p. 265—271° undepressed on admixture with an authentic sample, $[\alpha]_D$ +110° (*c*, 1·2).

Isomerisation of ψ-Taraxastene (*Taraxast-20-ene*) *to Lupene-I* [19α(*H*)-*Taraxast-20-ene*].—ψ-Taraxastene (1·2 g.) was dissolved in benzene (60 c.c.) and acetic acid (120 c.c.), and sulphuric acid (16 c.c.; *d* 1·84) in acetic acid (20 c.c.) was added. After 50 hr. at 20° the crystalline material (660 mg.) which had separated was filtered off, washed with ethanol, and crystallised from ethyl acetate, giving lupene-I as plates, m. p. 223—225° undepressed on admixture with an authentic sample, $[\alpha]_D$ +102° (*c*, 1·39).

Preparation of Taraxast-20(30)-ene.—Taraxast-20(30)-en-3β-one (1·32 g.) [m. p. 182—183·5°, $[\alpha]_D$ +127° (*c*, 0·59)], prepared by oxidising taraxasterol in benzene with a solution of potassium dichromate in dilute sulphuric acid, was heated in an autoclave at 200—240° for 6 hr. with hydrazine hydrate (25 c.c.; 60%) and sodium ethoxide [from sodium (5·4 g.)] in ethanol (100 c.c.). Extraction with benzene yielded a product which was adsorbed from light petroleum on alumina (50 g.; activity II). Elution with light petroleum (750 c.c.) afforded taraxast-20(30)-ene (935 mg.) as needles (several recrystallisations from ethyl acetate), m. p. 209—211°, $[\alpha]_D$ +99° (*c*, 0·3) (Found: C, 87·5; H, 12·4. Calc. for $C_{30}H_{50}$: C, 87·75; H, 12·25%).

Oxidation of 19α(*H*)-*Taraxast-20-ene* (*Lupene-I*) *with Selenium Dioxide.*—Lupene-I (560 mg.) in acetic acid–dioxan (1 : 1; 120 c.c.) was heated under reflux with selenium dioxide (600 mg.) for 1 hr. After dilution with water, extraction with benzene afforded a solid (500 mg.) which was adsorbed from light petroleum on alumina (100 g.). Elution with benzene yielded a fraction (220 mg.) which was crystallised from chloroform–methanol giving 30-*oxo*-19α(*H*)-*taraxast-*

20-*ene* (lupenal-I) as plates, m. p. 277—278°, $[\alpha]_D$ +90° (*c*, 0·51) (Found: C, 84·75; H, 11·7. $C_{30}H_{48}O$ requires C, 84·85; H, 11·4%). Light absorption in *cyclo*hexane: Max. 2285 and 3175—3250 Å; $\varepsilon = 12{,}300$ and 38. In another preparation 30-oxo-19α(H)-taraxast-20-ene was obtained as plates (from ethyl acetate), m. p. 279—281°, $[\alpha]_D$ +95° (*c*, 1·09).

Wolff–Kishner Reduction of 30-*Oxo*-19α(H)-*taraxast*-20-*ene*.—30-Oxo-19α(H)-taraxast-20-ene (1 g.) in diethylene glycol (200 c.c.) was heated under reflux for 1 hr. with hydrazine hydrate (60%; 5 c.c.). Potassium hydroxide (0·8 g.) was added to the cooled mixture, and heating was then continued for a further 6 hr. After dilution with water, extraction with benzene yielded a solid which was adsorbed from light petroleum (200 c.c.) on alumina (50 g.). Elution with light petroleum gave a non-crystalline solid (730 mg.), m. p. 196—206° (from ethyl acetate) raised by many crystallisations from ethyl acetate, chloroform–methanol, and chloroform–acetone to 208—210°, $[\alpha]_D$ −12° (*c*, 1·04). The final product was a mixture of 19α(H)-taraxast-20(30)-ene (*iso*lupene-I) and 19α(H)-taraxastane (lupane-I). The melting point fluctuated slightly on repeated crystallisation (Found, in a typical sample: C, 87·55; H, 12·3. Calc. for $C_{30}H_{50}$: C, 87·75; H, 12·25%. Calc. for $C_{30}H_{52}$: C, 87·3; H, 12·7%). The infra-red spectrum in "Nujol" suspension had bands at 886, 1647, and 3075 cm.$^{-1}$.

Hydrogenation of the Wolff–Kishner Reduction Product from 30-*Oxo*-19α(*H*)-*taraxast*-20-*ene*.—The product (100 mg.) in ethyl acetate (50 c.c.) was shaken with hydrogen for 48 hr. in the presence of Adams platinum catalyst. The resulting product was crystallised from ethyl acetate, giving 19α(H)-taraxastane as plates (70 mg.), m. p. 231—233° undepressed on admixture with an authentic sample, $[\alpha]_D$ +22° (*c*, 0·35).

Isomerisation of the Wolff–Kishner Reduction Product from 30-*Oxo*-19α(H)-*taraxast*-20-*ene*.—The product (103 mg.) in benzene (20 c.c.) was heated under reflux for 5 hr. with ethanolic sulphuric acid (10%; 45 c.c.). After dilution with water, extraction with benzene afforded a crystalline solid which was adsorbed from light petroleum on alumina (25 g.). Elution with light petroleum yielded a fraction (90 mg.) which was crystallised several times from ethyl acetate giving lupene-I, m. p. 223—225° undepressed on admixture with an authentic sample, $[\alpha]_D$ +104° (*c*, 0·75).

Hydroxylation of the Wolff–Kishner Reduction Product from 30-*Oxo*-19α(*H*)-*taraxast*-20-*ene*.—The hydrocarbon mixture (617 mg.) in pyridine–chloroform (1 : 1; 40 c.c.) was treated with osmium tetroxide (400 mg.) and the solution kept at 20° for 7 days. Evaporation of the solvent under reduced pressure gave a dark residue which was heated under reflux for 3 hr. with benzene (13 c.c.), methanol (13 c.c.), and a mixture of potassium hydroxide (3 g.) and mannitol (3 g.) in ethanol (13 c.c.) and water (8 c.c.). After dilution with water, extraction with ether gave a product which was adsorbed from benzene on alumina (50 g.) deactivated by shaking a suspension in benzene with water (5 c.c.). Elution with benzene gave 19α(H)-taraxastane as plates (125 mg.) (from ethyl acetate), m. p. 220—224°, raised by several crystallisations from ethyl acetate to 229—230° undepressed on admixture with an authentic specimen; $[\alpha]_D$ +21°. Elution with benzene–ether (3 : 1; 600 c.c.) gave 19α(*H*)-*taraxastane*-20α : 30-*diol* as plates (500 mg.) (from ethyl acetate), m. p. 257—262° raised by several crystallisations from ethyl acetate to 261—264°, $[\alpha]_D$ +16° (*c*, 1·01) (Found: C, 80·8; H, 11·9. $C_{30}H_{52}O_2$ requires C, 81·0; H, 11·8%).

Oxidative Fission of 19α(*H*)-*Taraxastane*-20α : 30-*diol*.—19α(H)-Taraxastane-20α : 30-diol (319 mg.) in ethanol (100 c.c.) was treated with sodium metaperiodate (300 mg.) in water (5 c.c.) and the solution was kept at 20° for 48 hr. After dilution with water, extraction with ether gave 30-*nor*-19α(H)-*taraxastan*-20-*one* * as needles (250 mg.) (from ethyl acetate), m. p. 225—245° raised by several crystallisations from ethyl acetate to 251—253°, $[\alpha]_D$ +14° (*c*, 1·09) (Found: C, 84·4; H, 11·5. $C_{29}H_{48}O$ requires C, 84·4; H, 11·7%). The infra-red spectra in carbon disulphide and carbon tetrachloride both exhibited a strong band at 1710 cm.$^{-1}$. 30-*Nor*-19α(H)-*taraxastan*-20-*one oxime* crystallised as flat needles (from ethyl acetate), m. p. 250—252° (Found: N, 3·15. $C_{29}H_{49}ON$ requires N, 3·3%).

Action of Methylmagnesium Iodide on 30-*Nor*-19α(*H*)-*taraxastan*-20-*one*.—30-Nor-19α(H)-taraxastan-20-one (35 mg.) in ether (50 c.c.) was heated under reflux with excess of methylmagnesium iodide for 30 min. and then kept at 20° for 16 hr. Dilute sulphuric acid was then added (2N; 50 c.c.), and the product was extracted with ether and adsorbed from light petroleum (10 c.c.) on alumina (3 g.). Elution with light petroleum gave 19α(H)-taraxast-20-ene (34 mg.) as plates (from ethyl acetate), m. p. 217—221° raised by several crystallisations from ethyl acetate to 221—223° and then undepressed on admixture with an authentic sample, $[\alpha]_D$ +107° (*c*, 0·95).

* The number prefixing "nor" is that of the carbon atom removed.

Taraxastane-20α : 30-*diol*.—Taraxast-20(30)-ene (2·2 g.) in pyridine–chloroform (1 : 1; 100 c.c.) was treated with osmium tetroxide (1·3 g.), and the solution kept at 20° for 7 days. Evaporation of the solvent under reduced pressure gave a dark residue which was heated under reflux for 3 hr. with benzene (45 c.c.), methanol (45 c.c.), and a mixture of potassium hydroxide (10·5 g.) and mannitol (10·5 g.) in ethanol (45 c.c.) and water (28 c.c.). After dilution with water, extraction with ether yielded a product which was adsorbed from benzene (150 c.c.) on alumina (40 g.). Elution with benzene (500 c.c.) gave taraxast-20(30)-ene (650 mg.). Elution with ether yielded a fraction which was crystallised from ethyl acetate, giving taraxastane-20α : 30-diol as needles (900 mg.), m. p. 233—236° raised by several crystallisations from ethyl acetate to 235—237°, $[\alpha]_D$ +13° (*c*, 0·89). Lardelli *et al.* (*Helv. Chim. Acta*, 1948, **31**, 1815) give m. p. 236—238°, $[\alpha]_D$ +10·5°.

Oxidative Fission of Taraxastane-20α : 30-*diol*.—The diol (360 mg.) in ethanol (175 c.c.) was treated with a solution of sodium metaperiodate (280 mg.) in water (2·5 c.c.), and the solution was kept at 20° for 16 hr. After dilution with water, extraction with ether gave 30-*nortaraxastan*-20-*one* as needles (290 mg.) (from ethyl acetate), m. p. 195—211° raised by several crystallisations from ethyl acetate to 210—213°, $[\alpha]_D$ +65° (*c*, 1·27) (Found: C, 84·3; H, 11·65. $C_{29}H_{48}O$ requires C, 84·4; H, 11·7%). The infra-red spectrum in carbon tetrachloride exhibited a strong band at 1703 cm.$^{-1}$, and in carbon disulphide at 1706 cm.$^{-1}$. 30-*Nortaraxastan*-20-*one oxime* crystallised as fine needles, m. p. 217—219°, from ethyl acetate (Found: N, 3·5. $C_{29}H_{49}ON$ requires N, 3·3%).

Epimerisation of 30-*Nortaraxastan*-20-*one to* 30-*Nor*-19α(H)-*taraxastan*-20-*one*.—30-Nortaraxastan-20-one (400 mg.) in benzene (50 c.c.) was adsorbed on alumina (30 g.; activity I; pH 7·5—8·0). Elution with benzene–ether (120 : 1; 700 c.c.) gave a fraction (390 mg.) which was crystallised several times from ethyl acetate, giving 30-nor-19α(H)-taraxastan-20-one as needles, m. p. 252—254° undepressed on admixture with an authentic sample; $[\alpha]_D$ +15° (*c*, 1·19). The infra-red spectrum in carbon disulphide was identical with that of an authentic specimen.

Oxidation of Taraxast-20-*ene* (ψ-*Taraxastene*) *with Selenium Dioxide*.—Taraxast-20-ene (750 mg.) in acetic acid–dioxan (1 : 1; 150 c.c.) was heated under reflux for 2 hr. with a solution of selenium dioxide (750 mg.) in water (5 c.c.) and acetic acid (20 c.c.). After dilution with water, extraction with ether afforded a solid (750 mg.) which was adsorbed from light petroleum on alumina (40 g.; deactivated by addition of 4 c.c. of 10% aqueous acetic acid). Elution with light petroleum yielded a fraction which was crystallised from chloroform–methanol, giving 30-oxotaraxast-20-ene (heterolupenal) as plates (535 mg.), m. p. 226—228°, $[\alpha]_D$ +89° (*c*, 6·88) (Found: C, 84·7; H, 11·45. Calc. for $C_{30}H_{48}O$: C, 84·85; H, 11·4%). Light absorption in *cyclo*hexane: Max. 2300 and 3200—3250 Å; ε = 13,900 and 63·5. Light absorption in ethanol: Max. 2340 Å; ε = 12,500.

Acetylation of Taraxastane-20α : 21α-*diol* (*Heterolupanediol*).—The diol (150 mg.) (m. p. 254—258°; $[\alpha]_D$ +30°), prepared according to Jeger, Krüsi, and Ruzicka's method (*Helv. Chim. Acta*, 1947, **30**, 1048), was dissolved in pyridine (10 c.c.) and heated with acetic anhydride (1 c.c.) at 100° for 2 hr. After dilution with water, extraction with ether yielded a product which was adsorbed from benzene (10 c.c.) on alumina (10 g.). Elution with benzene–ether (4 : 1; 300 c.c.) gave a *monoacetate* which crystallised from methanol as needles, m. p. 204—206°, $[\alpha]_D$ +63° (*c*, 0·54) (Found: C, 79·2; H, 11·35. $C_{32}H_{54}O_3$ requires C, 78·95; H, 11·2%). The monoacetate was converted back to the original diol, m. p. 256—258° undepressed on admixture with an authentic sample, $[\alpha]_D$ +30° (*c*, 1·06), by treatment with ethereal lithium aluminium hydride.

Oxidation of Taraxastane-20α : 21α-*diol* (*Heterolupanediol*).—The diol (150 mg.) in acetone (150 c.c.) was treated with 8N-chromic acid according to the method of Bowers *et al.* (*J.*, 1953, 2555). After dilution with water, extraction with ether yielded a product which was adsorbed from benzene (15 c.c.) on alumina (15 g.; pH 7·5). Elution with benzene–ether (9 : 1; 400 c.c.) gave 20α-*hydroxy*-21-*oxotaraxastane* (90 mg.) as plates (from methanol), m. p. 212—220° raised by several recrystallisations from methanol–chloroform to 221—224°, $[\alpha]_D$ +6° (*c*, 0·57) (Found: C, 81·25; H, 11·45. $C_{30}H_{50}O_2$ requires C, 81·4; H, 11·4%). The infra-red spectrum in carbon tetrachloride exhibited bands at 1698 and 3510 cm.$^{-1}$.

20α : 21α-*Epoxy*-19α(*H*)-*taraxastan*-3β-*yl Acetate*.—Lupenyl-I acetate (8·0 g.) in chloroform (140 c.c.) was kept at 6° with perbenzoic acid (1·2 mol.) in chloroform (75 c.c.) for 65 hr. The product, isolated in the usual manner, was adsorbed from benzene (60 c.c.) on alumina (400 g.). Elution with light petroleum–benzene (2 : 3; 400 c.c.), benzene (200 c.c. and 1100 c.c.), benzene–ether (1 : 1; 500 c.c.), and ether (400 c.c.) yielded fractions: (i) (40 mg.), (ii) (0·78 g.), (iii) (4·24 g.), (iv) 0·98 g., and (v) 0·39 g. Fractions (i) and (ii) were unchanged lupenyl-I acetate.

Crystallisation of fractions (iii), (iv), and (v) from chloroform–methanol gave 20α : 21α-*epoxy*-19α(*H*)-*taraxastan*-3β-*yl acetate* as thick platelets (4·16 g.), m. p. 279—281°, $[\alpha]_D^{20}$ +57° (*c*, 1·18) (Found : C, 79·1; H, 10·9. $C_{32}H_{52}O_3$ requires C, 79·3; H, 10·8%).

20α : 21α-*Epoxy*-19α(*H*)-*taraxastan*-3-*one*.—Lupenone-I (4·0 g.) was treated with perbenzoic acid as in the preceding experiment. The product was isolated in the usual manner and adsorbed from benzene on alumina (150 g.). Elution with light petroleum–benzene (3 : 7; 800 c.c.) yielded a fraction which crystallised from chloroform–methanol to give 20α : 21α-*epoxy*-19α(*H*)-*taraxastan*-3-*one* as prisms (2·05 g.), m. p. 242—248°, $[\alpha]_D$ +86° (*c*, 2·1) (Found : C, 81·9; H, 10·8. $C_{30}H_{48}O_2$ requires C, 81·75; H, 11·0%).

Reduction of 20α : 21α-*Epoxy*-19α(*H*)-*taraxastane*-3-*one with Lithium Aluminium Hydride*.—20α : 21α-Epoxy-19α(H)-taraxastan-3-one (2·05 g.) in ether (600 c.c.) containing sodium methoxide [from sodium (0·05 g.) in methanol (1 c.c.)] was treated with lithium aluminium hydride (0·5 g.) in ether (100 c.c.). After the mixture had been kept at 20° for 30 min., sulphuric acid (2N; 100 c.c.) was carefully added with cooling. The product was isolated in the usual manner and adsorbed from benzene (60 c.c.) on alumina (120 g.). Elution with benzene–ether (1 : 1; 1120 c.c.) afforded a solid which was crystallised several times from dioxan–methanol, giving 19α(*H*)-*taraxastane*-3β : 20α-*diol* as prisms (960 mg.), m. p. 302·5—304°, $[\alpha]_D$ +49° (*c*, 2·2) (Found : C, 81·35; H, 11·6. $C_{30}H_{52}O_2$ requires C, 81·0; H, 11·8%). When this reaction was carried out in the absence of sodium methoxide, chromatographic separation afforded small and variable quantities of a compound which crystallised from chloroform–methanol as felted needles, m. p. 267—268°, $[\alpha]_D$ +20° (*c*, 0·75) (Found : C, 80·1; H, 11·9%).

The diol (1·05 g.) was acetylated in pyridine (20 c.c.) at 90° with acetic anhydride (10 c.c.) for 2 hr. The product after chromatographic purification (900 mg.) gave, on crystallisation from chloroform–methanol, platelets of 20α-*hydroxy*-19α(*H*)-*taraxastan*-3β-*yl acetate*, m. p. 279—280°, $[\alpha]_D$ +55·5° (*c*, 1·37) (Found : C, 78·8; H, 11·2. $C_{32}H_{54}O_3$ requires C, 78·95; H, 11·2%).

Reduction of 20α : 21α-*Epoxy*-19α(*H*)-*taraxastan*-3β-*yl Acetate with Lithium Aluminium Hydride*.—20α : 21α-Epoxy-19α(H)-taraxastan-3β-yl acetate was reduced with lithium aluminium hydride in the absence of sodium methoxide under similar conditions to those used for the reduction of lupenone-I epoxide. The main product was 19α(H)-taraxastan-3β : 20α-diol together with small quantities (*ca.* 5%) of the compound, m. p. 267—268°, described above.

Acidic Fission of 20α : 21α-*Epoxy*-19α(*H*)-*taraxastan*-3β-*yl Acetate*.—The epoxide (5·5 g.) in ethanol (95%; 960 c.c.) was heated under reflux for 24 hr. with sulphuric acid (2N; 103 c.c.). After dilution with water, extraction with chloroform yielded a solid (5·46 g.) which was adsorbed from benzene (50 c.c.) on alumina (500 g.). Two main fractions were eluted with benzene–ether (7 : 3; 2100 c.c.) (2·82 g.) and ether (1600 c.c.) (2·50 g.). The first crystallised from chloroform–methanol to give 19α(*H*)-*taraxasta*-20(30) : 21-*dien*-3β-*ol* (dehydrolupenol-I) as needles, m. p. 246·5—248°, $[\alpha]_D$ +249° (*c*, 1·65) (Found : C, 84·5; H, 11·4. $C_{30}H_{48}O$ requires C, 84·8; H, 11·4%). Light absorption in *n*-hexane : Max. 2300—2360 Å; ε = 13,400. Acetylation with pyridine–acetic anhydride, in the usual manner, gave the *acetate* which crystallised from chloroform–methanol as platelets, m. p. 247—249°, $[\alpha]_D$ +230° (*c*, 1·42) (Found : C, 82·35; H, 10·75. $C_{32}H_{50}O_2$ requires C, 82·3; H, 10·8%). The infra-red spectrum in " Nujol " had a band at 884 cm.$^{-1}$.

The second fraction did not crystallise satisfactorily. Accordingly a portion (817 mg.) in pyridine (8 c.c.) was kept at *ca.* 90° with acetic anhydride (4 c.c.) for 2 hr. Dilution with water and extraction with chloroform yielded a product which was purified by chromatography on alumina and crystallised from chloroform–methanol, giving 20α : 21β-*dihydroxy*-19α(*H*)-*taraxastan*-3β-*yl acetate* as platelets, m. p. 306—306·5°, $[\alpha]_D$ +47° (*c*, 0·95) (Found : C, 76·4; H, 11·0. $C_{32}H_{54}O_4$ requires C, 76·45; H, 10·85%). The monoacetate did not absorb ultra-violet light above 2150 Å.

Action of Osmium Tetroxide on Lupenol-I.—Lupenol-I (1 g.) in pyridine–chloroform (1 : 1; 50 c.c.) was treated with osmium tetroxide (1 g.), and the solution kept at 20° for 14 days. Evaporation of the solvent under reduced pressure gave a dark residue which was heated under reflux for 3 hr. with benzene (30 c.c.), methanol (30 c.c.), and a mixture of potassium hydroxide (6 g.) and mannitol (6 g.) in ethanol (30 c.c.) and water (15 c.c.). Sodium sulphite (1 g.) was then added and the mixture refluxed for a further hour. After evaporation of the solvents under reduced pressure, extraction with ether yielded a product which was purified by chromatography on alumina to give a white solid (1 g.). This was crystallised from ethyl acetate to give 19α(*H*)-*taraxastane*-3β : 20α : 21α-*triol* as needles, m. p. 280—282°, $[\alpha]_D$ −6° (*c*, 1·0 in C_5H_5N) (Found : C, 78·45; H, 11·35. $C_{30}H_{52}O_3$ requires C, 78·2; H, 11·4%). The triol (130 mg.)

was acetylated in pyridine (5 c.c.) at 20° with acetic anhydride (2 c.c.) for 20 hr. The product crystallised from methanol to give 3β : 21α-*diacetoxy*-20α-*hydroxy*-19α(*H*)-*taraxastane*, m. p. 281—282°, $[\alpha]_D$ +2° (*c*, 0·9) (Found: C, 74·85; H, 10·3. $C_{34}H_{56}O_5$ requires C, 74·95; H, 10·35%).

Hydrogenation of 19α(*H*)-*Taraxastan*-3-*one* (*Lupenone-I*).—Lupenone-I (650 mg.) in acetic acid (120 c.c.) was shaken with Adams catalyst (325 mg.) and hydrogen at 20° for 18 hr. After filtration and evaporation, crystallisation of the residue from chloroform–methanol gave 19α(*H*)-*taraxastan*-3β-*ol* (lupanol-I) as platelets (560 mg.), m. p. 260—260·5°, $[\alpha]_D$ +12° (*c*, 0·92) (Found: C, 82·6; H, 12·4. $C_{30}H_{52}O,\frac{1}{2}CH_3{\cdot}OH$ requires C, 82·4; H, 12·3%).

Acetylation with pyridine–acetic anhydride in the usual manner gave 19α(*H*)-*taraxastan*-3β-*yl acetate* as platelets (from chloroform–methanol), m. p. 252·5—253°, $[\alpha]_D$ +21° (*c*, 1·68) (Found: C, 81·7; H, 11·4. $C_{32}H_{54}O_2$ requires C, 81·6; H, 11·6%). Benzoylation with benzoyl chloride in pyridine at 20° for 24 hr. gave 19α(*H*)-*taraxastan*-3β-*yl benzoate* as platelets (from chloroform–methanol), m. p. 238—240°, $[\alpha]_D$ +41° (*c*, 0·89) (Found: C, 83·3; H, 10·7. $C_{37}H_{56}O_2$ requires C, 83·4; H, 10·6%).

Partial Hydrogenation of 19α(*H*)-*Taraxasta*-20(30) : 21-*dien*-3β-*ol*.—19α(H)-Taraxasta-20(30) : 21-dien-3β-ol (80 mg.) in acetic acid (100 c.c.) was shaken with 5% palladised charcoal (100 mg.) and hydrogen at 20° for 4 hr. After filtration and evaporation, elution of the residue with benzene–ether (2 : 3; 700 c.c.) from alumina (30 g.) yielded a fraction which crystallised from chloroform–methanol, giving 19α(H)-taraxast-20-en-3β-ol (lupenol-I) as platelets (49 mg.), m. p. 252—254° undepressed on admixture with an authentic sample, $[\alpha]_D$ +86° (*c*, 1·02).

Complete Hydrogenation of 19α(*H*)-*Taraxasta*-20(30) : 21-*dien*-3β-*ol*.—19α(H)-Taraxasta-20(30) : 21-dien-3β-ol (150 mg.) in chloroform (10 c.c.) and acetic acid (40 c.c.) was shaken with Adams catalyst (50 mg.) and hydrogen for 18 hr. at 20°. After filtration and evaporation, crystallisation of the residue from chloroform–methanol gave 19α(H)-taraxastan-3β-ol as platelets (126 mg.), m. p. 261·5—262° undepressed on admixture with an authentic sample prepared by hydrogenation of 19α(H)-taraxast-20-en-3β-ol, $[\alpha]_D$ +13° (*c*, 1·79).

Oxidation of 19α(*H*)-*Taraxastane*-20α : 21α-*diol with Lead Tetra-acetate*.—19α(H)-Taraxastane-20α : 21α-diol (1·34 g.) in chloroform (100 c.c.) and acetic acid (300 c.c.) was treated at 20° with a solution of lead tetra-acetate (1·50 g.; 1·2 mol.) in chloroform (20 c.c.) and acetic acid (70 c.c.). The mixture was warmed to 45° and then, after 15 min. at this temperature, was kept at 20° for 14 hr. After dilution with water, extraction with chloroform afforded a resin which was adsorbed from benzene (30 c.c.) on alumina (200 g.). After development of the chromatogram with benzene (500 c.c.), elution with benzene–ether (7 : 3; 800 c.c.) yielded a solid *product* which crystallised from ethyl acetate–methanol as platelets (960 mg.), m. p. 264—298° (decomp. over range), $[\alpha]_D$ +50° (*c*, 1·19) (Found: C, 84·5; H, 11·2. $C_{30}H_{48}O$ requires C, 84·8; H, 11·4%). Light absorption in chloroform: Max. 2560—2580 and 3200—3400 Å; ε = 13,100 and 150.

The 2 : 4-*dinitrophenylhydrazone* of the oxidation product crystallised from chloroform–methanol as red needles, m. p. 274·5—278° (decomp.) (Found: N, 9·3. $C_{36}H_{54}O_4N_4$ requires N, 9·3%).

Oxidation of the Product of the Reaction between 19α(*H*)-*Taraxastane*-20α : 21α-*diol and Lead Tetra-acetate*.—The product (300 mg.) in chloroform (30 c.c.) and acetic acid (150 c.c.) was treated with chromic acid (90 mg.) in 95% acetic acid (11 c.c.) and kept at 20° for 15 hr. After destruction of the excess of oxidising agent with methanol, dilution with water and extraction with chloroform gave a gummy solid which was divided into an acidic and a neutral fraction. The neutral fraction (178 mg.) was adsorbed on alumina. Elution with light petroleum (b. p. 40—60°)–benzene (1 : 9; 600 c.c.) gave starting material (89 mg.). Further elution with benzene–ether (1 : 1) (600 c.c.) gave a fraction (84 mg.) which crystallised from chloroform–methanol to give platelets, m. p. 267·5—268°, $[\alpha]_D$ +30° (*c*, 0·49) (Found: C, 78·9; H, 10·4. $C_{28}H_{44}O_3$ requires C, 78·45; H, 10·35%. $C_{30}H_{46}O_3$ requires C, 79·2; H, 10·2%). The platelets in chloroform gave a pale yellow colour with tetranitromethane. Light absorption in ethanol: ε at 2100 Å = 640, ε at 2150 Å = 430, ε at 2200 Å = 325, and ε at 2250 Å = 275.

The acidic fraction (103 mg.) was treated with ethereal diazomethane, and the product was adsorbed on alumina (30 g.). The fraction (80 mg.) eluted with light petroleum (b. p. 40—60°)–benzene (7 : 3; 400 c.c.) was crystallised from chloroform–methanol, giving platelets, m. p. 237·5—238·5° (Found: C, 81·4; H, 11·0. $C_{31}H_{50}O_2$ requires C, 81·85; H, 11·1%). Light absorption in hexane: Max. 2270—2290 Å; ε = 8800.

The 1 : 2-dimethyl*cyclo*hexene had b. p. 136—138°, n_D^{20} 1·4590, and was prepared by Signaigo and Cramer's method (*J. Amer. Chem. Soc.*, 1933, **55**, 3326).

Reduction of 18α-*Oleanan*-19-*one with Sodium in Amyl Alcohol.*—18α-Oleanan-19-one (380 mg.), prepared by the Clemmensen reduction of 18(α)-oleanane-3 : 19-dione (cf. Ames, Davy, Halsall, and Jones, *J.*, 1952, 2872), was heated under reflux with sodium (10 g.) in boiling amyl alcohol (100 c.c.) for 4 hr. After removal of excess of sodium by addition of

Ultra-violet light absorption in cyclo*hexane of taraxast*-20-*ene*, 19α(*H*)-*taraxast*-20-*ene* (*lupene-I*), *and* 1 : 2-*dimethyl*cyclo*hexene*.

	ε values at					
	2050	2100	2150	2200	2230	2250 Å
Taraxast-20-ene	3800	1600	450	70	20	15
19β(H)-Taraxast-20-ene	4700	2600	1030	140	30	20
1 : 2-Dimethyl*cyclo*hexene	4100	2550	1360	750	540	420

methanol and dilution with water, extraction with ether yielded a product which was adsorbed from light petroleum on alumina (50 g.). After elution with light petroleum (300 c.c.), elution with benzene (200 c.c.) afforded a fraction (300 mg.) which was crystallised from chloroform–methanol, giving 18α-*oleanan*-19β-*ol* as prisms (250 mg.), m. p. 236—237°, $[\alpha]_D$ +31° (*c*, 0·46) (Found : C, 84·3; H, 12·25. $C_{30}H_{52}O_2$ requires C, 84·05; H, 12·25%). On further crystallisation of the compound from the same solvent, platelets, m. p. 229—230°, $[\alpha]_D$ +31·5° (*c*, 0·9), were obtained. The m. p. of a mixture of the two forms was 229—230°.

Dehydration of 18α-*Oleanan*-19β-*ol with Phosphoryl Chloride in Pyridine.*—18α-Oleanan-19β-ol (55 mg.) in pyridine (15 c.c.) was heated under reflux with phosphoryl chloride (2·5 c.c.) for 1 hr. After careful addition of water extraction with ether yielded a product (needles; 50 mg.) which was adsorbed from light petroleum on alumina (20 g.). Elution with light petroleum afforded a fraction (40 mg.) which was crystallised from chloroform–methanol, giving olean-18-ene (germanicene) as fine needles, m. p. 174—174·5° undepressed on admixture with an authentic sample of germanicene kindly supplied by Professor D. H. R. Barton.

Reduction of 18α-*Oleanan*-19-*one with Lithium Aluminium Hydride.*—18α-Oleanan-19-one (162 mg.) in dry ether (70 c.c.) was treated with lithium aluminium hydride (100 mg.) at 20° for 2 hr. After careful addition of water, ethereal extraction yielded a product which was crystallised from chloroform–methanol, giving 18α-oleanan-19β-ol as rhombs (120 mg.), m. p. 231—232° undepressed on admixture with the sample prepared by reduction with sodium in amyl alcohol; $[\alpha]_D$ +29·5° (*c*, 1·22).

Preparation of 18α-*Oleanan*-19α-*ol.*—19α-Hydroxy-18α-oleanan-3-one (Ames, Davy, *et al.*, *loc. cit.*) (0·65 g.), hydrazine hydrate (90%; 2·5 c.c.), and a solution of sodium in ethanol (20 c.c.) were heated in an autoclave for 5 hr. After dilution with water, the product was isolated by filtration and adsorbed from benzene on alumina (50 g.). Elution with benzene–ether (1 : 1; 250 c.c.) gave a fraction (505 mg.), m. p. 222·5—223·5°, which was crystallised from ethanol–chloroform, giving 18α-*oleanan*-19α-*ol* as plates, m. p. 223·5—225°, $[\alpha]_D$ −3° (*c*, 1·6) (Found : C, 83·85; H, 12·05. $C_{30}H_{52}O_2$ requires C, 84·05; H, 12·25%).

Dehydration of 18α-*Oleanan*-19α-*ol with Phosphoryl Chloride in Pyridine.*—18α-Oleanan-19α-ol (130 mg.) in pyridine (5 c.c.) was heated under reflux with phosphoryl chloride (0·5 c.c.) for 2 hr. After careful addition of water, extraction with ether yielded a product (110 mg.) which was crystallised from chloroform–methanol giving α-lupene as needles (80 mg.), m. p. 163—165° undepressed on admixture with an authentic sample, $[\alpha]_D$ +29° (*c*, 0·45).

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