Triterpenoids. Part VIII.[1] Allylic Oxidation by *N*-Bromosuccinimide

By **B. W. Finucane** and **J. B. Thomson,*** Department of Chemistry, University College, Dublin 4, Ireland

Treatment of β-amyrin acetate with *N*-bromosuccinimide in aqueous dioxan gives variable amounts of 3β-acetoxyolean-12-ene-11-one as the major product, together with 3β-acetoxyolean-12-en-11α-ol, 3β-acetoxy-12-bromoolean-12-en-11α-ol, and 12α-bromo-16-oxotaraxeryl acetate. 3β-Acetoxyolean-12-en-11-one is the sole product, obtained in essentially quantitative yield, when the reaction mixture is irradiated with visible light. Similar photo-oxidations afford high yields of the corresponding αβ-unsaturated ketones from α-amyrin acetate, taraxeryl acetate, α- and β-amyrin and their benzoates, olean-12-ene, urs-12-ene, olean-12-en-3-one, urs-12-en-3-one, and cholesteryl acetate.

THE preparation of αβ-unsaturated 11-oxotriterpenes by oxidation of the corresponding 12-enes with chromic acid is unsatisfactory in that the conditions are too vigorous for some functional groups to remain intact and the yields, which are seldom better than moderate, vary widely even in the most favourable cases.† The reported [3] formation of 3β-acetoxyurs-12-en-11-one (2) in *ca.* 80% yield (crude) by treatment of α-amyrin acetate (1) with *N*-bromosuccinimide (NBS) in aqueous dioxan seemed to offer an attractive alternative. However, in our hands, the reaction as described [3] gave 3β-acetoxyolean-12-en-11-one (6) from β-amyrin acetate (5) in yields that fluctuated between 20 and 60%, together with a number of by-products, separation of which required careful chromatography. We have since found [4] that when the reaction mixture is irradiated with visible light, αβ-unsaturated ketones are formed in near quantitative yields from a number of trisubstituted olefins containing an allylic methylene group. A related, more widely applicable, allylic photo-oxidation was described recently.[5]

In a typical ambient-light experiment (see Experi-

† *E.g.* Karliner and Djerassi [2a] report 68% 11-ketone from olean-12-ene, whereas, under the same conditions, only 26% 11-ketone is obtained from 18α-olean-12-ene.[2b]

[1] Part VII, B. W. Finucane and J. B. Thomson, *J. Chem. Soc.* (*C*), 1971, 1569.

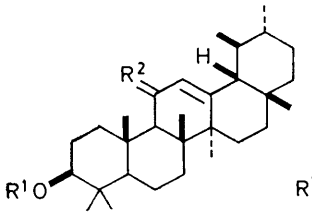
[2] (*a*) J. Karliner and C. Djerassi, *J. Org. Chem.*, 1966, **31**, 1054; (*b*) D. H. R. Barton, E. F. Lieu, and J. F. McGhie, *J. Chem. Soc.* (*C*), 1968, 1035.

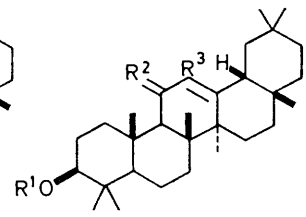
[3] S. Corsano and G. Piancatelli, *Ann. Chim.* (*Italy*), 1965, **55**, 742.

[4] B. W. Finucane and J. B. Thomson, *Chem. Comm.*, 1969, 1220.

[5] N. Friedman, M. Gorodetsky, and Y. Mazur, *Chem. Comm.*, 1971, 874.

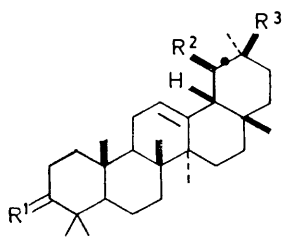
mental section), β-amyrin acetate (5) was treated with NBS in aqueous dioxan, as described by Corsano and Piancatelli,[3] to give a mixture of starting material (*ca.* 50%), 3β-acetoxyolean-12-en-11-one (6) (*ca.* 40%),





(1) R^1 = Ac, R^2 = H_2
(2) R^1 = Ac, R^2 = O
(3) R^1 = Bz, R^2 = H_2
(4) R^1 = H, R^2 = H_2

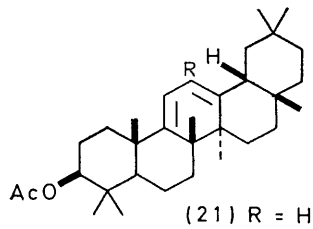
(5) R^1 = Ac, R^2 = H_2, R^3 = H
(6) R^1 = Ac, R^2 = O, R^3 = H
(7) R^1 = Ac, R^2 = α-OH,H, R^3 = H
(8) R^1 = Ac, R^2 = α-OMe,H, R^3 = H
(9) R^1 = Ac, R^2 = α-OAc,H, R^3 = H
(10) R^1 = Ac, R^2 = α-OH,H, R^3 = Br
(11) R^1 = Ac, R^2 = β-OH,H, R^3 = H
(12) R^1 = Ac, R^2 = O, R^3 = Br
(13) R^1 = Ac, R^2 = H_2, R^3 = Br
(14) R^1 = Ac, R^2 = α-Br,H, R^3 = H
(15) R^1 = Bz, R^2 = H_2, R^3 = H
(16) R^1 = R^3 = H, R^2 = H_2



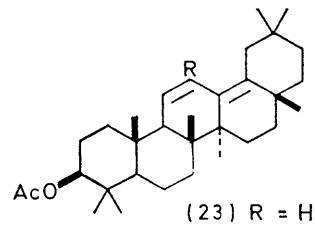
(17) R^1 = H_2, R^2 = H, R^3 = Me
(18) R^1 = H_2, R^2 = Me, R^3 = H
(19) R^1 = O, R^2 = Me, R^3 = H
(20) R^1 = O, R^2 = H, R^3 = Me

bromo-compounds (*ca.* 8%), and 3β-acetoxyolean-12-en-11α-ol [6] (7) (*ca.* 2%), which was separated by chromatography on silica. Oxidation of the 11α-ol (7) with chromic acid in acetone [7] afforded 3β-acetoxyolean-12-en-11-one (6). In another experiment, when the reaction mixture was chromatographed on alumina, the products consisted of β-amyrin acetate (5) (*ca.* 35%), 3β-acetoxyolean-12-en-11-one (6) (*ca.* 40%), bromo-compounds (*ca.* 10%), and polar material (*ca.* 10%). The last was eluted with methanol, acetylated, and rechromatographed to give 11α-methoxyolean-12-en-3β-yl acetate (8), together with smaller amounts of the 11α-ol (7) and oleana-9(11),12-dien-3β-yl acetate [8] (21), and a trace of the 3β,11α-diacetate [6] (9). The methoxy-acetate (8) was the major product when a methanolic solution of the 11α-ol (7) was stirred with alumina. Treatment of the methoxy-acetate (8) with toluene-*p*-sulphonic acid in acetic anhydride afforded 3β-acetoxyoleana-11,13(18)-diene (23) in essentially quantitative yield. The 11α-configuration of the methoxy-group was assigned on the basis of the magnitude of the 9α-H,11-H coupling constant [3,6,9] (9 Hz).

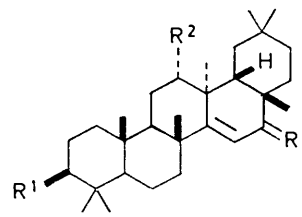
The fraction containing the bromo-compounds was resolved, by chromatography on alumina and fractional crystallisation, into two components, the major of which ($C_{32}H_{51}BrO_3$) was a diol monoacetate (i.r. spectrum). Although the free hydroxy-group is secondary [τ 5·6 (*H*C·OH)], the monoacetate resisted further acetylation with acetic anhydride in hot pyridine. The compound gave a yellow colour with tetranitromethane in chloroform and showed end-absorption in the u.v. but no olefinic proton or *H*CBr signal in its n.m.r. spectrum. These data suggested that the bromo-compound was 3β-acetoxy-12-bromo-olean-12-en-11-ol (10). In accord with this structure, the compound resisted attempted dehydrobromination, although prolonged treatment with lithium chloride in hot dimethylformamide resulted in dehydration with formation of 12-bromo-oleana-9(11),12-dien-3β-yl acetate [8] (22). It is noteworthy that acid-catalysed dehydration of the 12-bromo-11-ol (10) also yields the homoannular diene (22) and not the heteroannular isomer (24). In the absence of the 12-bromine



(21) R = H
(22) R = Br



(23) R = H
(24) R = Br



(25) R^1 = OAc, R^2 = Br, R^3 = O
(26) R^1 = OAc, R^2 = H, R^3 = H_2
(27) R^1 = H, R^2 = Br, R^3 = O
(28) R^1 = OAc, R^2 = H, R^3 = O
(29) R^1 = OAc, R^2 = H, R^3 = β-OH,H

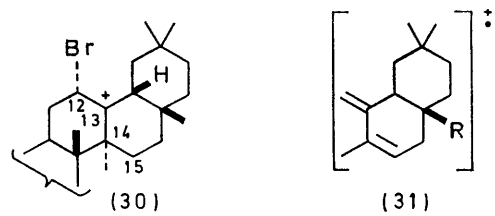
atom, the heteroannular diene (23) (the thermodynamically more stable isomer [10]) is the only product [from either the 11α-ol (7) or the 11β-ol (11)]. Models of the 12-bromo-11,13(18)-diene (24) show a severe non-bonding interaction between the bromine atom and the 19-protons, irrespective of the conformation of ring E.

[6] S. Corsano and G. Piancatelli, *Ann. Chim.* (*Italy*), 1965, **55**, 730.
[7] K. Bowden, I. M. Heilbron, E. R. H. Jones, and B. C. L. Weedon, *J. Chem. Soc.*, 1946, 39.
[8] O. P. Arya and R. C. Cookson, *J. Chem. Soc.*, 1957, 972.
[9] S. Corsano and G. Piancatelli, *Gazzetta*, 1964, **94**, 1378.
[10] (*a*) J. M. Beaton, J. D. Johnston, L. C. McKean, and F. S. Spring, *J. Chem. Soc.*, 1953, 3660; G. G. Allan, J. D. Johnston, and F. S. Spring, *ibid.*, 1954, 1546; J. I. Shaw, F. S. Spring, and R. Stevenson, *ibid.*, 1956, 465; (*b*) J. M. Beaton, F. S. Spring, R. Stevenson, and W. S. Strachan, *ibid.*, 1955, 2610.

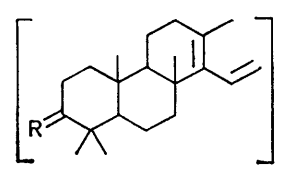
This interaction is absent in the 12-bromo-9(11),12-diene (22). Confirmation of the presence of the 11-hydroxy-group in the bromo-compound (10) was obtained by mild oxidation to yield 3β-acetoxy-12-bromo-olean-12-en-11-one [8] (12). The large negative difference in molecular rotation (—266°) between the bromo-alcohol (10) and 12-bromo-olean-12-en-3β-yl acetate [8] (13) suggested [6,9] the 11α-configuration for the hydroxy-group, an assignment which is supported [3,6,9] by the magnitude of the 9α-H,11-H coupling constant (7·8 Hz) for the 11-ol (10).

The minor component of the mixture of bromo-compounds is an αβ-unsaturated ketone ($C_{32}H_{49}BrO_3$), $\lambda_{max.}$ 244 nm, the n.m.r. spectrum of which shows that the double bond is trisubstituted [τ 4·10 (1H, s)] and that the bromine atom is secondary [τ 5·3 (*H*CBr)]. Dehydrobromination readily yielded a dienone in which the new double bond is not conjugated, nor is it brought into conjugation by treatment with base. The n.m.r. spectrum of this dienone showed that the isolated double bond is disubstituted [τ 4·14 (2H, m)]. Such a dienone system cannot be located in an unrearranged oleanane skeleton but is most plausibly accommodated in 3β-acetoxytaraxera-11,14-diene-16-one (33), in which case the bromo-ketone must be 12α-bromo-16-oxo-taraxeryl acetate (25). These structures are consistent with the observed spectroscopic properties and are mechanistically acceptable. Thus, initial α-face attack on β-amyrin acetate (5) at C-12 would lead to the carbonium ion (30). Elimination of a proton from C-12, followed by allylic hydroxylation, would then lead to 3β-acetoxy-12-bromo-olean-12-en-11α-ol (10). Alternatively, migration of the 14α-methyl group to C-13, elimination of a proton from C-15, and subsequent allylic oxidation [*cf.* allylic oxidation of taraxeryl acetate (26); see later] would afford the 12α-bromo-16-one (25). In the n.m.r. spectrum of the bromo-ketone (25) the *H*CBr signal overlaps the 3α-H multiplet. However, in the spectrum of 12α-bromotaraxer-14-en-16-one (27), which was obtained from olean-12-ene (17) in a reaction similar to that already described for β-amyrin acetate (5), the *H*CBr signal is a triplet (*J* 8·1 Hz). While this does not unambiguously establish either the position or the stereochemistry of the proton in question, it is compatible with the proposed 12β-H configuration in the ring-C boat of the taraxerene skeleton when the effect of the substituent on the vicinal coupling constants is considered.[11]

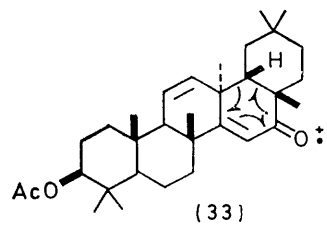
The most characteristic features of the mass spectra of taraxer-14-enes are the D/E-ring fragments (31) and retro-Diels–Alder fragments (32).[12] The presence of an 11,12-double bond in the dehydrobromination product (33) was expected to prevent formation of the former and, together with the 16-oxo-function, enhance the abundance of the latter fragment. This was found to be the case: the mass spectrum of the dienone (33) showed no fragment corresponding to the D/E-ring species (31) and only two abundant ions of *m/e* >50, *viz.* *m/e* 356 [$C_{22}H_{32}O_3$ (34)] and 148. A metastable ion, *m/e* 264·2 (calc. 264·0), was observed corresponding to direct formation of the former from the molecular ion. High resolution measurements confirmed the constitution of the *m/e* 356 fragment and showed that the species of



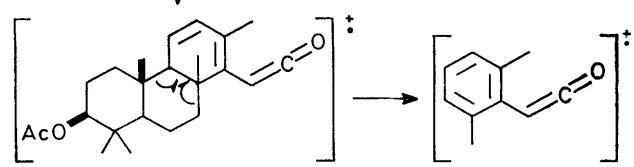
(30) (31)



(32)

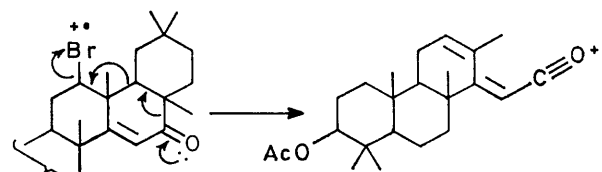


(33)



(34) (35)

m/e 148, of equal abundance, was $C_{10}H_{10}O$, to which might be plausibly ascribed the aromatic keten structure (35). In the spectrum of the bromo-ketone (25) a D/E-ring fragment was again absent and the expected even-electron species (36) was the most abundant ion.



(25) (36)

When the oxidation of β-amyrin acetate (5) with NBS was carried out at 50° the reagent was quickly consumed but the yield of αβ-unsaturated ketone (6) was less (*ca.* 10%). In addition to a considerable amount (*ca.* 60%) of starting material, the reaction mixture

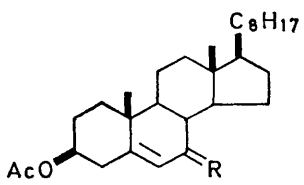
[11] H. Booth, *Tetrahedron Letters*, 1965, 411.
[12] H. Budzikiewicz, J. M. Wilson, and C. Djerassi, *J. Amer Chem. Soc.*, 1963, **85**, 3691.

contained the 12-bromo-11α-ol (10) (*ca.* 10%) and an unstable substance (*ca.* 10%) containing bromine. Crystallisation of the latter from methanol gave a high yield of 11α-methoxyolean-12-en-3β-yl acetate (8) and the bromo-compound is possibly 11-bromo-olean-12-en-3β-yl acetate (14). However, attempts to purify this compound were unsuccessful.

In the dark, at room temperature, β-amyrin acetate (5) was consumed slowly and gave only *ca.* 4% of 3β-acetoxyolean-12-en-11-one (6). The major products were 3β-acetoxy-12-bromo-olean-12-en-11α-ol (10) (*ca.* 30%) and the corresponding ketone (12) (*ca.* 20%).

Oxidation of taraxeryl acetate (26) by the method of Corsano and Piancatelli [3] yielded two major products, *viz.* 16-oxotaraxeryl acetate (28) (*ca.* 30%) and 16β-hydroxytaraxeryl acetate (29) (*ca.* 30%). Treatment of the latter with chromic acid in acetone [7] furnished the unsaturated ketone (28). The 16β-configuration for the hydroxy-group is favoured since a Dreiding model of the taraxer-14-ene skeleton with a trigonal C-16 shows that the β-face is less hindered than the α-face. The 15-H signal in the n.m.r. spectrum of taraxeryl acetate (26) is a quartet (J_1 4, J_2 8 Hz) whereas that in the alcohol (29) is a doublet (J 4 Hz). A Dreiding model of taraxer-14-ene shows the 15-H,16-H dihedral angles to be *ca.* 90° (16α-H) and *ca.* 30° (16β-H); thus the expected [13a] vicinal coupling constants are ' very small ' and *ca.* 8 Hz, respectively. The increased magnitude of the smaller coupling constant may be attributed to efficient overlap of the π-orbital with the axial 16α-H bond. Also consistent with the α-axial configuration for the 16-H is the appearance of the 17β-methyl signal as a doublet (J 1 Hz).[13b]

When solutions of α- (1) or β- (5) amyrin acetate in aqueous dioxan containing NBS were irradiated with visible light the corresponding 11-ketones [(2) or (6)] were formed in essentially quantitative yields. Similar high yields of αβ-unsaturated ketones were obtained from olean-12-ene (17), urs-12-ene (18), their benzoyloxy-derivatives [(15) and (3)], and taraxeryl acetate (26). Although NBS oxidises alcohols to ketones [14] and rapidly α-brominates ketones,[15] α- (4) and β- (16) amyrin, olean-12-en-3-one (20), and urs-12-en-3-one (19) also afforded the corresponding 11-ketones in high yields under the conditions described. The oxidation of



(37) R = H_2
(38) R = O

cholesteryl acetate (37) is less clean but, nevertheless, 7-oxocholesteryl acetate (38) is obtained in *ca.* 80% yield.

[13] N. S. Bhacca and D. H. Williams, ' Applications of NMR Spectroscopy in Organic Chemistry,' Holden-Day, San Francisco, 1964, (*a*) pp. 49—52; (*b*) pp. 115—121.

EXPERIMENTAL

Optical rotations were determined for *ca.* 1% solutions in chloroform at 30° with a Perkin-Elmer 141 automatic polarimeter. T.l.c. was carried out with Merck silica $HF_{254+366}$. Petroleum refers to light petroleum (b.p. 60—80°). U.v. spectra were determined with a Bausch and Lomb 505 spectrophotometer, i.r. spectra (KBr discs) with a Beckman IR-5, and n.m.r. spectra ($CDCl_3$) with Varian HR-60A and Perkin-Elmer R12 instruments. Dioxan was refluxed over, and distilled from, potassium hydroxide pellets. The NBS was purified by rapid crystallisation from a ten-fold excess of boiling water. The ambient light experiments were carried out in a well-lit (daylight) laboratory but direct sunlight was avoided.

Oxidation of β-Amyrin Acetate in Ambient Light.—(a) *At room temperature; with chromatography on silica* (cf. *ref.* 3). NBS (5 g) was added to a suspension of calcium carbonate (5 g) in a solution of β-amyrin acetate (5 g) in dioxan (850 ml) containing water (65 ml), and the mixture was stirred (8 h). *N*-Ethylmorpholine (3 ml) was added, and the mixture was filtered and poured into water (*ca.* 2 l). The crude product was isolated with chloroform in the conventional manner, dissolved in benzene containing petroleum (10%), and chromatographed on silica (210 g). Elution with the same solvent mixture gave β-amyrin acetate (2·48 g, 50%) and 3β-acetoxyolean-12-en-11-one (6) (2·06 g, 40%), m.p. 268—269° (from chloroform–methanol), $[\alpha]_D$ +102° (lit.,[3] m.p. 264—266°, $[\alpha]_D$ +100°); $\lambda_{max.}$ (MeOH) 252 nm (ε 12,000); $\nu_{max.}$ 1735, 1660, and 1245 cm^{-1}; τ 9·12 (s, Me), 9·09 (s, Me), 9·08 (s, 3 × Me), 8·84 (s, Me), 8·83 (s, Me), 8·63 (s, Me), 7·95 (s, Ac), 7·62 (s, 9α-H), 5·48 (m, 3α-H), and 4·41 (s, 12-H) (Found: C, 79·7; H, 10·4. Calc. for $C_{32}H_{50}O_3$: C, 79·6; H, 10·4%). Elution with benzene yielded a mixture (420 mg, 8%) of bromo-compounds [see (c)] and elution with 10% ethyl acetate in benzene afforded 3β-acetoxyolean-12-en-11α-ol (7) (110 mg, 2%), m.p. 232—235° (from chloroform–methanol), $[\alpha]_D$ +47° (lit.,[6] m.p. 228—233°, $[\alpha]_D$ +50°); $\nu_{max.}$ 3430, 1735, and 1245 cm^{-1}; τ 9·14 (s, Me), 9·10 (s, 4 × Me), 8·97 (s, Me), 8·89 (s, Me), 8·77 (s, Me), 7·93 (s, Ac), 5·76 (q, J_1 3·5, J_2 8 Hz, 11β-H), 5·42 (m, 3α-H), and 4 71 (d, J 3 5 Hz, 12-H) [Found: C, 79·0; H, 10·7%; *M* (mass spectrum), 484. Calc. for $C_{32}H_{52}O_3$: C, 79·3; H, 10·8%; *M*, 484]. Treatment of the 11α-ol (100 mg) in acetone (10 ml) with 8N-chromic acid [7] yielded 3β-acetoxyolean-12-en-11-one (85 mg), m.p. 268—269°, $[\alpha]_D$ +102°.

(b) *At room temperature; with chromatography on alumina.* A solution of β-amyrin acetate (5 g) in aqueous dioxan was treated with NBS, as in (a), and the product was chromatographed on alumina (250 g). Elution with benzene gave β-amyrin acetate (1·79 g, 35%), 3β-acetoxyolean-12-en-11-one (2·05 g, 40%), and a mixture (500 mg) of bromo-compounds [see (c)]. The residual material (660 mg) was eluted with methanol and acetylated with acetic anhydride in pyridine at 80°. The mixed acetates were chromatographed on silica (100 g). Elution with 5% petroleum in benzene yielded oleana-9(11),12-dien-3β-yl acetate (21) (50 mg), m.p. 218—219° (from chloroform–methanol), $[\alpha]_D$ +330° (lit.,[8] m.p. 216—217°, $[\alpha]_D$ +335°); $\lambda_{max.}$ (iso-octane) 282 nm (ε 9600); τ 9·09 (s, 5 × Me), 9·00 (s, Me), 8·83 (s, Me), 8·76 (s, Me), 7·91 (s, Ac), 5·41 (m, 3α-H), and 4·39 (s, 11-H and 12-H) (Found: C, 82·1; H, 10·7. Calc. for

[14] R. Filler, *Chem. Rev.*, 1963, **63**, 21.
[15] H. Schmid and P. Karrer, *Helv. Chim. Acta*, 1946, **29**, 573; C. Djerassi and C. Scholz, *Experientia*, 1947, **3**, 107.

$C_{32}H_{50}O_2$: C, 82·35; H, 10·8%). Elution with benzene gave olean-12-ene-3β,11α-diyl diacetate (9) (3 mg), m.p. 206—208° (from methanol), $[\alpha]_D$ −35° (lit.,[6] m.p. 204—208°, $[\alpha]_D$ −37°) (Found: C, 77·7; H, 10·4. Calc. for $C_{34}H_{54}O_4$: C, 77·5; H, 10·3%), identical (mixed m.p. and i.r. spectrum) with a sample prepared by acetylation [6] of the 11α-ol (7); a small amount of homoannular diene (21) was formed in this acetylation. Elution of the column with 5% chloroform in benzene yielded *11α-methoxyolean-12-en-3β-yl acetate* (8) (360 mg), m.p. 183—184° (from chloroform–methanol), $[\alpha]_D$ +22°; $\nu_{max.}$ 2817, 1735, and 1245 cm^{-1}; τ 9·15 (s, Me), 9·10 (s, 3 × Me), 9·05 (s, Me), 8·97 (s, Me), 8·91 (s, Me), 8·77 (s, Me), 7·93 (s, Ac), 6·77 (s, OMe), 6·09 (q, J_1 3·6, J_2 9·0 Hz, 11β-H), 5·45 (m, 3α-H), and 4·66 (d, J 3·6 Hz, 12-H) [Found: C, 79·8; H, 11·1%; M (mass spectrum), 498. $C_{33}H_{54}O_3$ requires C, 79·5; H, 10·9%; M, 498]. Continued elution with the same solvent mixture afforded the 11α-alcohol (7) (110 mg), m.p. 232—234°, $[\alpha]_D$ +47°.

A solution of the 11α-ol (7) in methanol stirred overnight at room temperature with alumina yielded mainly the methoxy-acetate (8), together with starting material and the homoannular diene (21) in varying amounts, depending upon the activity of the alumina.

A solution of the methoxy-acetate (8) (100 mg) in acetic anhydride (5 ml) containing toluene-*p*-sulphonic acid (50 mg) was heated (3 h) at 120—135° and the product was isolated in the conventional manner with ether to give oleana-11,13(18)-dien-3β-yl acetate (23) (92 mg), m.p. 233—234° (from chloroform–methanol), $[\alpha]_D$ −59° (lit.,[16] m.p. 227—228°, $[\alpha]_D$ −63°); $\lambda_{max.}$ (iso-octane) 242, 250, and 260 nm (ε 26,900, 28,800, and 19,800).

(c) *Separation of the bromo-compounds.* The mixture of bromo-compounds (500 mg) was dissolved in benzene and chromatographed on alumina (50 g). Elution with benzene yielded *3β-acetoxy-12-bromo-olean-12-en-11α-ol* (10) (220 mg), m.p. 221—222° (from chloroform–methanol), $[\alpha]_D$ −4·5°; $\lambda_{max.}$ (iso-octane) 210 nm (ε 12,200); $\nu_{max.}$ 3400, 1730, and 1250 cm^{-1}: τ 9·14 (s, Me), 9·11 (s, 3 × Me), 9·03 (s, Me), 8·96 (s, Me), 8·92 (s, Me), 8·75 (s, Me), 7·93 (s, Ac), 5·83 (d, J 7·8 Hz, 11β-H), and 5·42 (m, 3α-H) [Found: C, 68·0; H, 9·35; Br, 14·8%; M (mass spectrum), 562, 564. $C_{32}H_{51}BrO_3$ requires C, 68·2; H, 9·1; Br, 14·2%; M,.562, 564]. The bromohydrin (10) (100 mg) with 3% potassium hydroxide in methanol (75 ml) was refluxed (2 h) and the product was isolated with chloroform to give *12-bromo-olean-12-ene-3β,11α-diol* (75 mg), m.p. 199—200° (from chloroform–methanol), $[\alpha]_D$ −5°; $\nu_{max.}$ 3410 cm^{-1} (Found: C, 68·8; H, 9·2; Br, 15·8. $C_{30}H_{49}BrO_2$ requires C, 69·1; H, 9·5; Br, 15·3%). When this diol was heated on a steam-bath with acetic anhydride in pyridine the product was the 3-monoacetate (10); no trace of diacetate was detected by t.l.c.

Further elution of the column with benzene afforded a mixture, fractional crystallisation (triangulation) of which from chloroform–methanol gave the 12-bromo-11α-ol (10) (175 mg) and *12α-bromo-16-oxotaraxeryl acetate* (25) (70 mg), m.p. 239—240°, $[\alpha]_D$ −20°; $\lambda_{max.}$ (iso-octane) 244 nm (ε 10,300); $\nu_{max.}$ 1730, 1669, and 1245 cm^{-1}; τ 9·15 (s, Me), 9·13 (s, 2 × Me), 9·10 (s, Me), 9·04 (s, Me), 8·88 (s, Me), 8·79 (s, Me), 8·76 (s, Me), 7·96 (s, Ac), 5·5 (m, 3α-H), 5·3 (m, 12β-H), and 4·10 (s, 15-H); *m/e* 560 (11%) and 562 (11%) (M^+), 545 (5%), and 547 (5%) [$(M - Me)^+$], 481 [67% $(M - Br)^+$], 480 [33% $(M - HBr)^+$], and 357 [100% (36)] (Found: C, 68·7; H, 8·6; Br, 13·8. $C_{32}H_{49}BrO_3$ requires C, 68·4; H, 8·8; Br, 14·2%).

(d) *At* 50°. NBS (1 g) was added to a suspension of calcium carbonate (850 mg) in a solution of β-amyrin acetate (1 g) in dioxan (170 ml) containing water (12 ml) and the mixture was stirred (1 h) at 50°. After dilution with water (500 ml) the product was isolated with chloroform and chromatographed on silica (30 g). Elution of the column with benzene gave β-amyrin acetate (560 mg, 56%), *3β-acetoxyolean-12-en-11-one* (6) (114 mg, 11%), the 12-bromo-11α-ol (10) (120 mg, 10%), and a fraction (100 mg) which gave a positive copper-wire test for halogen and which decomposed during attempted purification by further chromatography or by crystallisation. Crystallisation of this bromo-compound (60 mg) from methanol afforded 11α-methoxyolean-12-en-3β-yl acetate (8) (50 mg), m.p. 183—186°, $[\alpha]_D$ +20°, identical (mixed m.p.; i.r. and n.m.r. spectra) with a sample prepared from the 11α-alcohol (7).

12-Bromo-oleana-9(11),12-dien-3β-yl Acetate (22).—(*a*) The 12-bromo-11α-ol (10) (100 mg) in dry dimethylformamide (20 ml) was heated (5 days) at 100° with anhydrous lithium chloride in an inert atmosphere. The product, isolated with ether in the conventional manner, was subjected to preparative t.l.c. (silica–benzene) to give starting material (8 mg) and the bromo-diene (22) (68 mg), m.p. 218—219° (from methanol), $[\alpha]_D$ +202° (lit.,[8] m.p. 213—214°, $[\alpha]_D$ +206°); $\lambda_{max.}$ (iso-octane) 284 nm (ε 9500); τ 9·09br (s, 4 × Me), 9·04 (s, Me), 8·98 (s, Me), 8·82 (s, Me), 8·75 (s, Me), 7·94 (s, Ac), 5·43 (m, 3α-H), and 4·25 (s, 11-H) [Found: C, 70·4; H, 9·2; Br, 14·3%; M (mass spectrum), 544 and 546. Calc. for $C_{32}H_{49}BrO_2$: C, 70·4; H, 9·05; Br, 14·6%; M, 544 and 546].

(*b*) A solution of the 12-bromo-11α-ol (10) (80 mg) in acetic anhydride (10 ml) was refluxed (3 h) under nitrogen with toluene-*p*-sulphonic acid (40 mg). The product was isolated with ether and crystallised from methanol to yield the 12-bromo-homoannular diene (22) (60 mg), m.p. 218—219°, $[\alpha]_D$ +204°. Under the same conditions, 11α- (7) and 11β- (11) hydroxy-β-amyrin acetates gave the hetero-annular diene (23).

3β-Acetoxy-12-bromo-olean-12-en-11-one (12).—To a solution of the 12-bromo-11α-ol (10) (50 mg) in acetone (8 ml), 8N-chromic acid [7] was added dropwise until the orange colour persisted. After 3 min the product was isolated with ether in the conventional manner to yield 3β-acetoxy-12-bromo-olean-12-en-11-one (12) (40 mg), m.p. 278—279° (from chloroform–methanol), $[\alpha]_D$ +49° (lit.,[8] 276—277°, $[\alpha]_D$ +50°); $\lambda_{max.}$ (methanol) 270 nm (ε 10,000); $\nu_{max.}$ 1725, 1680, and 1245 cm^{-1}; τ 9·14 (s, Me), 9·11 (s, 3 × Me), 9·07 (s, Me), 9·02 (s, Me), 8·85 (s, Me), 8·63 (s, Me), 7·95 (s, Ac), 7·51 (s, 9α-H), and 5·47 (m, 3α-H) (Found: C, 68·55; H, 8·9; Br, 14·7. Calc. for $C_{32}H_{49}BrO_3$: C, 68·4; H, 8·8; Br, 14·2%).

3β-Acetoxytaraxera-11,14-dien-16-one (33).—The bromo-ketone (25) (20 mg) was heated (1·5 h) with 5% potassium hydroxide in refluxing methanol (10 ml). The product was isolated with chloroform and heated (2 h) on a steam-bath with acetic anhydride in pyridine to yield the *dienone* (33) (11 mg), m.p. 232—234° (from methanol); $\lambda_{max.}$ (iso-octane) 236 nm (ε 11,500); $\nu_{max.}$ 1734, 1662, and 1245 cm^{-1}; τ 9·10 (s, 2 × Me), 9·01 (s, Me), 8·97 (s, 2 × Me), 8·89 (s, Me), 8·75 (s, 2 × Me), 7·94 (s, Ac), 5·48 (m, 3α-H), 4·14 (s, 15-H), and 4·14 (m, 11-H and 12-H); *m/e* 480 [11%, $(M)^+$], 356 [100%, (34)], and 148 [100%, (35)] (Found: C, 79·7; H, 9·9. $C_{32}H_{48}O_3$ requires C, 79·95; H, 10·1%).

[16] G. G. Allan and F. S. Spring, *J. Chem. Soc.*, 1955, 2125.

Oxidation of β-Amyrin Acetate in the Dark.—NBS (500 mg) was added to a suspension of calcium carbonate (500 mg) in a solution of β-amyrin acetate (500 mg) in dioxan (85 ml) containing water (65 ml), and the mixture was stirred (36 h) at room temperature in the dark. After addition of *N*-ethylmorpholine (1 ml), the mixture was poured into excess of water and the product isolated with chloroform. Chromatography on silica (30 g) and elution with benzene gave β-amyrin acetate (25 mg, 5%) and 3β-acetoxyolean-12-en-11-one (6) (22·5 mg, 4·4%). Elution with 5% chloroform in benzene furnished the 12-bromo-11-ketone (12) (130 mg, 22%) and the 12-bromo-11α-ol (10) (205 mg, 34%). Elution with more polar solvents gave complex mixtures which were not investigated.

Oxidation of Olean-12-ene in Ambient Light.—A solution of olean-12-ene (17) (1 g) in dioxan (150 ml) containing water (14 ml) was stirred (4 h) at room temperature with calcium carbonate (1 g) and NBS (1 g). The mixture was filtered into excess of water; the product was isolated with chloroform and chromatographed on silica (30 g). Elution with 10% petroleum in benzene gave olean-12-ene (600 mg) and olean-12-en-11-one (250 mg), m.p. 215—216° (from methanol), $[\alpha]_D$ +110° (lit.,[2a] m.p. 214—216°); $\lambda_{max.}$ (MeOH) 250 nm (ε 11,500); $\nu_{max.}$ 1660 and 1620 cm^{-1} (Found: C, 84·5; H, 11·2. Calc. for $C_{30}H_{48}O$: C, 84·8; H, 11·4%). The material from the mother liquors, from crystallisation of the 11-ketone, was subjected to preparative t.l.c. (silica; 10% petroleum in benzene) to give more olean-12-en-11-one (80 mg) and 12α-*bromotaraxer*-14-*en*-16-*one* (27) (32 mg), m.p. 152—155° (from methanol), $[\alpha]_D$ −10°; $\lambda_{max.}$ (MeOH) 254 nm (ε 11,100); $\nu_{max.}$ 1672 cm^{-1}; τ 9·14 (s, Me), 9·11 (s, Me), 9·06 (s, Me), 9·04 (s, Me), 9·01 (s, Me), 8·84 (s, Me), 8·75 (s, Me), 8·72 (s, Me), 5·25 (t, *J* 8·1 Hz, 12β-H), and 4·05 (s, 15-H) (Found: C, 71·8; H, 9·6; Br, 15·4. $C_{30}H_{47}BrO$ requires C, 71·55; H, 9·4; Br, 15·9%).

Oxidation of Taraxeryl Acetate in Ambient Light.—NBS (300 mg) was added to a solution of taraxeryl acetate (26) (51 mg) in dioxan (100 ml) containing water (5 ml) and calcium carbonate (250 mg) and the mixture was stirred (5·5 h) at room temperature. *N*-Ethylmorpholine (1 ml) was added, the mixture was filtered, the filtrate was concentrated (to *ca.* 10 ml) under reduced pressure at room temperature, and the residual solution was diluted with water (50 ml). The product was isolated in the conventional manner with ether and subjected to preparative t.l.c. (silica; 5% ethyl acetate in benzene) to give (i) an unidentified compound, R_F 0·7 (5 mg), m.p. 175—177° (from methanol), $[\alpha]_D$ +94°; $\nu_{max.}$ 1735, 1245, and 680 cm^{-1}; yellow colour with tetranitromethane in chloroform; negative copper-wire test for halogen; (ii) an unidentified compound, R_F 0·25 (4 mg), m.p. 301—302° (from chloroform–methanol), $[\alpha]_D$ −60°; $\nu_{max.}$ 1730, 1678, and 1245 cm^{-1}; no colour with tetranitromethane in chloroform; (iii) 16-*oxotaraxeryl acetate* (28) (15 mg, 29%), R_F 0·5, m.p. 251—252° (decomp.) (from chloroform–methanol), $[\alpha]_D$ +92°; $\lambda_{max.}$ (MeOH) 250 nm (ε 10,200); $\nu_{max.}$ 1725, 1650, and 1242 cm^{-1}; τ 9·11 (s, 6 × Me), 9·07 (s, Me), 8·43 (s, Me), 7·97 (s, Ac), 5·35 (m, 3α-H), and 4·37 (s, 15-H) (Found: C, 79·5; H, 10·4. $C_{32}H_{50}O_3$ requires C, 79·6; H, 10·4%); and (iv) 16β-*hydroxytaraxeryl acetate* (29) (16 mg, 30%), R_F 0·2, m.p. 177—179° (decomp.) (from chloroform–methanol), $[\alpha]_D$ +38°; $\nu_{max.}$ 3410, 1735, and 1245 cm^{-1}; τ 9·10br [s (shoulders at 9·11, 9·08, and 9·07), 7 × Me], 8·90 (d, *J* 1 Hz, 17β-Me), 7·95 (s, Ac), 5·85 (m, 16α-H), 5·43 (m, 3α-H), and 4·66 (d, *J* 4 Hz, 15-H) (Found: C, 79·0; H, 10·7%. $C_{32}H_{52}O_3$ requires C, 79·3; H, 10·8%).

A solution of the alcohol (29) (10 mg) in acetone was treated[7] with 8N-chromic acid; the product was isolated by preparative t.l.c. to give the 16-ketone (28) (9 mg).

Photo-oxidations.—Unless otherwise indicated, the following experiments were carried out with equal weights of the olefin, NBS, and calcium carbonate, and the reaction mixtures were irradiated for 1 h with fluorescent (conveniently 2 × 35 W circular tubes) or tungsten-filament (2 × 60 W) lamps. A yellow colour developed 1—3 min after addition of the NBS. The detailed procedure described for 3β-acetoxyolean-12-en-11-one was used throughout.

3β-*Acetoxyolean*-12-*en*-11-*one* (6).—A suspension of calcium carbonate (5 g) in a solution of β-amyrin acetate (5) (5 g) in dioxan (850 ml) containing water (65 ml) was irradiated at room temperature and NBS (5 g) was added in a single batch. After 1 h, *N*-ethylmorpholine or triethylamine (*ca.* 2 ml) was added to decolourise the mixture, which was then filtered into water (*ca.* 2 l). The product was isolated with chloroform in the conventional manner to yield 3β-acetoxyolean-12-en-11-one (4·94 g, 96%), m.p. 268—269° (from chloroform–methanol), $[\alpha]_D$ +102°. Concentration of the mother liquor from the crystallisation gave a second crop (200 mg), m.p. 264—266°, $[\alpha]_D$ +101°.

3β-*Acetoxyurs*-12-*en*-11-*one* (2).—α-Amyrin acetate (1) (1 g) in dioxan (150 ml) and water (15 ml) gave 3β-acetoxyurs-12-en-11-one (1 g, 98%), m.p. 289—290° (from chloroform–methanol), $[\alpha]_D$ +98° (lit.,[10b] m.p. 283—286°, $[\alpha]_D$ +98°); $\lambda_{max.}$ (MeOH) 252 nm (ε 11,500); $\nu_{max.}$ 1735, 1662, and 1245 cm^{-1}; τ 9·16 (Me), 9·10 (3 × Me), 9·01 (Me), 8·79 (2 × Me), 8·68 (Me), 7·93 (s, Ac), 7·62 (s, 9α-H), 5·45 (m, 3α-H), and 4·42 (s, 12-H) (Found: C, 79·4; H, 10·3. Calc. for $C_{32}H_{50}O_3$: C, 79·6; H, 10·4%).

Olean-12-*en*-11-*one*.—Olean-12-ene (17) (250 mg) in dioxan (60 ml) and water (5 ml) gave olean-12-en-11-one (230 mg), m.p. 215—216° (from methanol), $[\alpha]_D$ +112°.

Urs-12-*en*-11-*one*.—Urs-12-ene (18) (250 mg) in dioxan (50 ml) and water (6 ml) yielded urs-12-en-11-one (238 mg), m.p. 166—167° (from methanol), $[\alpha]_D$ +190° (lit.,[17] m.p. 165—166°, $[\alpha]_D$ +207°); $\lambda_{max.}$ (MeOH) 250 nm (ε 11,000); $\nu_{max.}$ 1667 cm^{-1} (Found: C, 84·7; H, 11·4. Calc. for $C_{30}H_{48}O$: C, 84·8; H, 11·4%).

3β-*Benzoyloxyolean*-12-*en*-11-*one*.—β-Amyrin benzoate (15) (500 mg) in dioxan (150 ml) and water (15 ml) gave 3β-benzoyloxyolean-12-en-11-one (503 mg), m.p. 265—266° (from chloroform–methanol), $[\alpha]_D$ +113° (lit.,[18] m.p. 263—264°, $[\alpha]_D$ +112°); $\nu_{max.}$ 1710, 1656, and 1277 cm^{-1}; τ 9·06 (s, 3 × Me), 9·04 (s, Me), 8·95 (s, Me), 8·83 (s, Me), 8·81 (s, Me), 8·62 (s, Me), 7·66 (s, 9α-H), 5·25 (m, 3α-H), 4·45 (s, 12-H), 2·55 (3H, m, aromatic), and 2·00 (2H, m, aromatic) (Found: C, 81·3; H, 9·55. Calc. for $C_{37}H_{52}O_3$: C, 81·6; H, 9·6%).

3β-*Benzoyloxyurs*-12-*en*-11-*one*.—α-Amyrin benzoate (3) (500 mg) in dioxan (130 ml) and water (12 ml) gave 3β-benzoyloxyurs-12-en-11-one (470 mg), m.p. 275—276° (from chloroform–methanol), $[\alpha]_D$ +105° (lit.,[19] m.p. 275—276°, $[\alpha]_D$ +107°); $\nu_{max.}$ 1712, 1660, and 1277 cm^{-1}; τ 9·14 (Me), 9·03 (3 × Me), 8·95 (Me), 8·79 (2 × Me), 8·68 (Me), 7·69 (s, 9α-H), 5·25 (m, 3α-H), 4·53 (s, 12-H), 2·55 (3H, m,

[17] J. A. Bosson, M. N. Galbraith, E. Ritchie, and W. C. Taylor, *Austral. J. Chem.*, 1963, **16**, 491.
[18] J. Simpson, *J. Chem. Soc.*, 1940, 230.
[19] J. McLean, S. U. Ruff, and F. S. Spring, *J. Chem. Soc.*, 1951, 1093.

aromatic), and 1·98 (2H, m, aromatic) (Found: C, 81·5; H, 9·6. Calc. for $C_{37}H_{52}O_3$: C, 81·6; H, 9·6%).

Olean-12-*ene*-3,11-*dione*.—Olean-12-en-3-one (20) (200 mg) in dioxan (40 ml) and water (4 ml) gave the 3,11-dione (171 mg), m.p. 237—238° (from methanol), $[\alpha]_D$ +141° (lit.,[20] m.p. 235°, $[\alpha]_D$ +144°); $\lambda_{max.}$ (MeOH) 252 nm (ε 10,800); $\nu_{max.}$ 1712 and 1655 cm^{-1} (Found: C, 81·95; H, 10·4. Calc. for $C_{30}H_{46}O_2$: C, 82·1; H, 10·6%).

Urs-12-*ene*-3,11-*dione*.—Urs-12-en-3-one (19) (50 mg) in dioxan (20 ml) and water (1 ml) irradiated for 30 min gave the 3,11-dione (44 mg), m.p. 201—202° (from methanol), $[\alpha]_D$ +131° (lit.,[21] m.p. 193°, $[\alpha]_D$ +141°); $\lambda_{max.}$ (MeOH) 252 nm (ε 10,400); $\nu_{max.}$ 1710 and 1660 cm^{-1} (Found: C, 82·0; H, 10·6. Calc. for $C_{30}H_{46}O_2$: C, 82·1; H, 10·6%).

3β-*Hydroxyolean*-12-*en*-11-*one*.—β-Amyrin (16) (100 mg) in dioxan (20 ml) and water (2 ml) irradiated for 5 min gave 3β-hydroxyolean-12-en-11-one (92 mg), m.p. 231—233° (from methanol), $[\alpha]_D$ +103° (lit.,[18] m.p. 233—234°, $[\alpha]_D$ +104°); $\lambda_{max.}$ (MeOH) 252 nm (ε 10,500); $\nu_{max.}$ 3420 and 1665 cm^{-1} (Found: C, 81·4; H, 10·8. Calc. for $C_{30}H_{48}O_2$: C, 81·8; H, 11·0%).

3β-*Hydroxyurs*-12-*en*-11-*one*.—α-Amyrin (4) (100 mg) in dioxan (15 ml) and water (1 ml) irradiated (5 min) gave 3β-hydroxyurs-12-en-11-one (87 mg), m.p. 207·5—208·5° (from methanol), $[\alpha]_D$ +100° (lit.,[22] m.p. 205—206°, $[\alpha]_D$ +99°); $\lambda_{max.}$ (MeOH) 252 nm (ε 10,500); $\nu_{max.}$ 3450 and 1665 cm^{-1} (Found: C, 81·55; H, 10·75. Calc. for $C_{30}H_{48}O_2$: C, 81·8; H, 11·0%).

16-*Oxotaraxeryl Acetate* (28).—Taraxeryl acetate (26) (50 mg) in dioxan (100 ml) and water (8 ml) with calcium carbonate (200 mg) and NBS (250 mg) gave the 16-ketone (49 mg), m.p. 251—252°, $[\alpha]_D$ +92°. In this experiment the filtered reaction mixture was concentrated (to *ca.* 10 ml) under reduced pressure at room temperature before dilution with water.

7-*Oxocholesteryl Acetate* (38).—Cholesteryl acetate (37) (300 mg) in dioxan (300 ml) and water (20 ml) irradiated for 2 h at *ca.* 45° gave, after chromatography on silica (30 g) the 7-ketone (251 mg), m.p. 159—160° (from chloroform–methanol), $[\alpha]_D$ −98° (lit.,[23] m.p. 155—163°, $[\alpha]_D$ −100 ± 3°); $\lambda_{max.}$ (MeOH) 236 nm (ε 10,100); $\nu_{max.}$ 1735, 1670, and 1245 cm^{-1} (Found: C, 78·7; H, 10·35. Calc. for $C_{29}H_{46}O_3$: C, 78·7; H, 10·5%).

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[20] C. W. Picard and F. S. Spring, *J. Chem. Soc.*, 1940, 1198.
[21] F. S. Spring and T. Vickerstaff, *J. Chem. Soc.*, 1934, 650.
[22] K. Yagishita and M. Nishinura, *Agric. and Biol. Chem.* (*Japan*), 1961, **25**, 517; 844 (*Chem. Abs.*, 1961, **55**, 22,367; 1962, **56**, 8758).
[23] 'Tables of Constants and Mumerical Data. 14. Optical Rotatory Power. 1a. Steroids,' Pergamon, London, 1965, p. 560.