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SOME OXIDATION PRODUCTS OF 7-HYDROXYKAURENOLIDE

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Abstract—The oxidation of the Δ^{16}-terminal methylene group of 7-hydroxykaurenolide by a number of reagents is described. Structures are proposed for some by-products from the ozonolysis of 7-hydroxykaurenolide. The alkaline isomerization of the 16 → 13-δ-lactone to a 16 → 7-γ-lactone is noted. Lactonols have been isolated from the oxidation of the 6α,7β diols (XIV; R = CH_3 and R = O respectively).

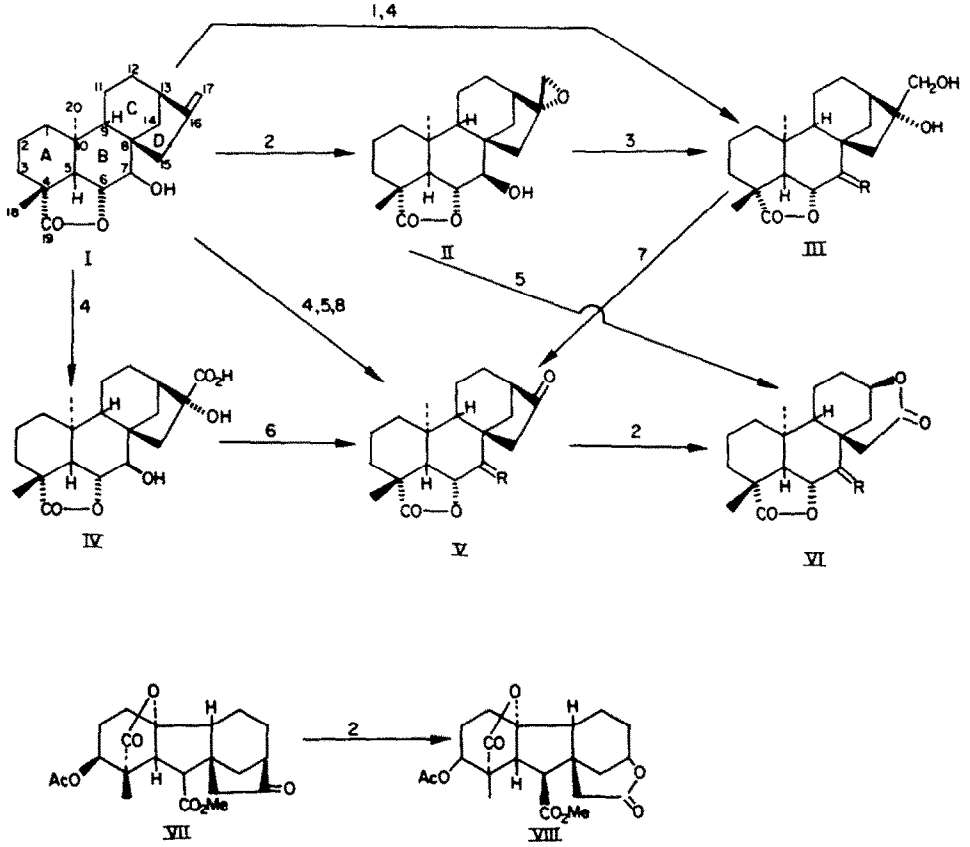
7-HYDROXYKAURENOLIDE has been shown[1,2] to have the structure and stereochemistry I. Its oxidative degradation led to a number of compounds which, although not contributing to the proof[3,4] of the structure of the kaurenolides, nevertheless shed some light on the reactivity of the ring system. Their properties form the subject of this paper.

On treatment with perbenzoic acid, 7-hydroxykaurenolide (I) formed[2] a single epoxide (II) which, in turn gave a triol (III; R = β-OH, α-H) [ν_{max} 3340 (br), 1761 cm^{-1}] on treatment with mineral acid. This triol was also obtained, together with the corresponding dihydroxy-7-ketone (III; R = O), by hydroxylation of 7-hydroxykaurenolide with osmium tetroxide. Both these 16,17-glycols were cleaved with sodium periodate in aqueous methanol to form their corresponding 16-ketones[2] (V; R = β-OH, α-H and V; R = O respectively) which, in the case of the latter, served to define the position of the carbonyl group at C(7). Although these two steps could be combined to form the 16-ketones by making use of the Rudloff-Lemieux procedure,[4] oxidation of 7-hydroxykaurenolide with excess neutral potassium permanganate led,[cf.5] not only to the formation of the 16-ketone (V; R = β-OH, α-H) but also to the triol (III; R = β-OH, α-H) and the corresponding α-hydroxyl-acid [ν_{max} 3486 (OH), 2480 and 1980 (carboxyl OH), 1750 and 1690 cm^{-1}]. The acid, in support of its formulation as IV, was oxidized with sodium bismuthate to the 16-ketone (V; R = β-OH, α-H). The configuration with an 16α-hydroxyl group is preferred for this series of compounds in view of the well-known propensity of the reagents used for attacking the less hindered face of a molecule.

Although the 16-ketones were more conveniently prepared[2] by ozonolysis of

[1] B. E. Cross, R. H. B. Galt, J. R. Hanson and W. Klyne, *Tetrahedron Letters* 145 (1962).
[2] B. E. Cross, R. H. B. Galt, and J. R. Hanson, *J. Chem. Soc.* 2944 (1963).
[3] B. E. Cross, R. H. B. Galt, and J. R. Hanson, *J. Chem. Soc.* 3783 (1963).
[4] E. von Rudloff and R. V. Lemieux, *Canad. J. Chem.* **33**, 1701 (1955).
[5] L. H. Briggs, B. F. Cain, R. C. Cambie and B. R. Davis, *J. Chem. Soc.* 1840 (1962).
[6] R. A. Finnagan, *J. Org. Chem.* **26**, 3057 (1961).

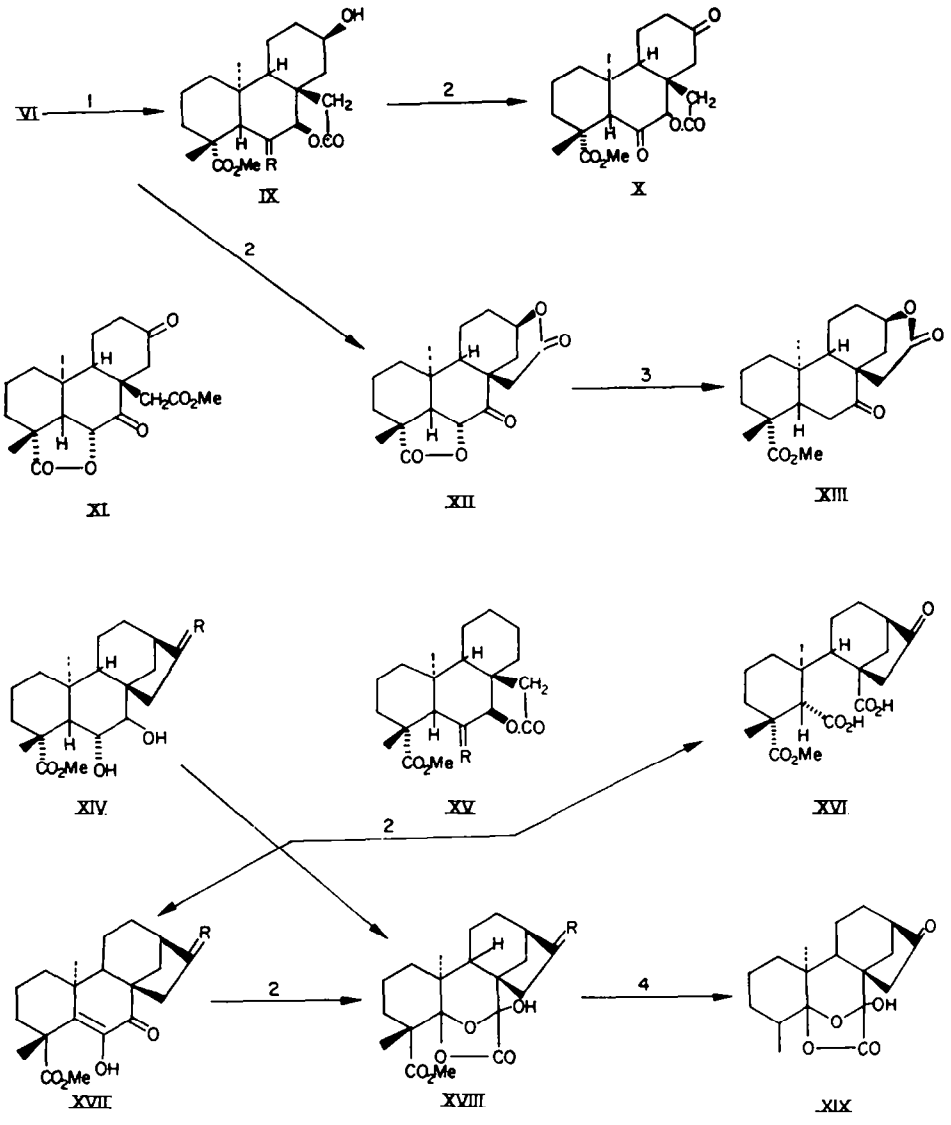
7-hydroxykaurenolide in glacial acetic acid, this led to the isolation of several by-products which included the δ-lactone (VI; R = β-OH, α-H) (ν_{max} 3450, 1761 and 1695 cm^{-1}). This lactone was also prepared by Baeyer-Villiger oxidation of the 16-ketone (V; R = β-OH, α-H) with perbenzoic acid. In the analogous oxidation of the gibberellin A_4 8-ketone (VII), the orientation of the corresponding δ-lactone as VIII has been unambiguously established[7] by interrelationship with gibberellic acid.



1. OsO_4; 2. $C_6H_5 \cdot CO_3H$, toluene-*p*-sulphonic acid; 3. H^+; 4. $KMnO_4$; 5. O_3; 6. $NaBiO_3$; 7. $NaIO_4$; 8. $KMnO_4$: $NaIO_4$.

Hydrolysis of the δ-lactone (VI; R = β-OH, α-H) with N-sodium hydroxide for 2 hr followed by methylation, gave a γ-lactone-methyl ester, $C_{20}H_{30}O_6$, [ν_{max} 3500, 3339, 1748 and 1704 cm^{-1}, (in $CHCl_3$) 3620, 3590, 3380, 1771 and 1699 cm^{-1}]. On oxidation with chromium trioxide, this formed a diketone, $C_{20}H_{26}O_6$ (ν_{max} 1785, 1730 and 1710 cm^{-1}), with the loss of four hydrogen atoms and hence the parent ester was a diol. The diketone showed no UV absorption typical of a conjugated system whilst products characteristic of the oxidation of an unprotected vicinal glycol[2] were absent from the oxidation of the diol. Hence we conclude that either the 6- or 7-hydroxyl participates in the lactone ring. The NMR spectrum of the diketone, apart from containing resonances from the two tertiary methyl groups (τ = 8·6 and

[7] B. E. Cross, R. H. B. Galt and J. R. Hanson, *Tetrahedron* **18**, 451 (1962).



1. OH′ then CH_2N_2; 2. 8N-CrO_3/H_2SO_4; 3. $Zn/(CH_3CO)_2O$; 4. OH′ then H^+.

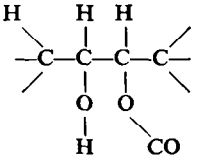
8·9) and a methyl ester (τ = 6·3), showed a one-proton singlet at τ = 4·9 and seven proton resonances between 7·4 and 7·97. Whilst this is not consistent with structure XI for the diketone, which, *inter alia*, would be expected[8] to show a doublet τ = 5·1; J = c/s) from a 6-proton and a resonance at τ = 9·1–9·2 due to the $C_{(20)}$ protons, these features may be accommodated by structure X for the diketone and hence IX (R = α-OH, β-H) for the dihydroxy-ester in which isomerization of the 16 → 13-δ-lactone to a 16 → 7-γ-lactone has occurred.

Although Baeyer-Villiger oxidation of the 7-epihydroxy-16-ketone (V, R = α-OH

[8] J. R. Hanson, unpublished work.

β-H) gave intractable products, oxidation of the corresponding acetate (V, R = α-O·CO·CH_3, β-H) gave a δ-lactone (VI; R = α-$OCOCH_3$, β-H). However, hydrolysis of this led to the formation of δ-lactonic methyl ester (ν_{max} 1706 cm^{-1}) showing the characteristic hydrogen-bonded hydroxyl absorption of a 6α,7α-diol at 3450 cm^{-1}. Oxidation of the δ-lactone (VI; R = β-OH, α-H) with chromium trioxide gave the 7-ketone (XII; ν_{max} 1777, 1738 and 1730 cm^{-1}) which, on hydrogenolysis with zinc dust in acetic anhydride followed by methylation, formed the corresponding 6-deoxy-7-ketone (XIII). A broad single-proton resonance in the NMR spectra of VI and XII at 5·15 and 5·25 respectively which is absent from the spectrum of 7-hydroxy kaurenolide, may be associated with the proton at C-13 thus providing some further evidence for the orientation of the lactone ring.

During the preparation of a quantity of methyl 6α,7β-dihydroxy-16-oxo-17-norkauran-19-oate (XIV), 7-hydroxykaurenolide was ozonized[2] in glacial acetic acid and the acidic solution made alkaline with sodium hydroxide and hydrolysed overnight. After recovery and methylation the resulting mixture was chromatographed on alumina. This led to the isolation of, not only the expected diol (XIV)[2] as the major product but also, as minor products, an isomeric methyl ester $C_{20}H_{30}O_5$, and a third methyl ester $C_{20}H_{30}O_6$. Although the methyl ester $C_{20}H_{30}O_5$ (ν_{max} 1749 and 1719 cm^{-1}) showed hydroxy absorption in the IR (ν_{max} 3455 cm^{-1}), it did not form an acetyl derivative under conditions of mild acetylation in which the 6α,7β-diol (XIV) gave a 7-monoacetate.[8] The ester was inert to microhydrogenation and since it showed no significant end-absorption in the UV, it must be tricarbocyclic. Furthermore it was oxidized (by chromium trioxide), with the loss of only two hydrogen atoms, to form a hydroxyl-free ketone, $C_{20}H_{28}O_5$ (ν_{max} 1785, 1718 and 1704 cm^{-1}), again showing no significant absorption in the UV. Clearly this ester cannot possess the free 6,7-disecondary-α-glycol present in the diol (XIV). The NMR spectrum of the keto-ester, $C_{20}H_{28}O_5$, showed resonances indicative of two tertiary methyl groups (τ = 8·82 and 8·6), a methyl ester (τ = 6·3), and three protons adjacent to carbonyl groups (τ = 7·5, 7·65 and 7·9) together with a sharp singlet at τ = 5·2 ascribed to a proton attached to a carbon atom bearing oxygen and not coupled to any adjacent protons. The spectrum of the parent alcohol lacked the one-proton singlet at τ = 7·9 and contained a two-proton multiplet between τ = 5·3 and 5·4 in place of the one proton singlet at τ = 5·2. These results led to the partial structure



and hence to the over-all structure XV (R = H, OH) for the methyl ester $C_{20}H_{28}O_5$. Some support is given to this by the change[9] in lactone carbonyl frequency on oxidation of the 6-hydroxyl group. The third methyl ester $C_{20}H_{30}O_6$, [ν_{max} 3500, 1753 and 1696 cm^{-1}, (in $CHCl_3$) 3615, 3591, 1772 and 1701 cm^{-1}] was isomeric with the hydrolysis product (IX; R = β-H, α-OH) of the δ-lactone (XI) and yet on

[9] R. N. Jones, P. Humphries, F. Herling and K. Dobriner, *J. Amer. Chem. Soc.* **74**, 2822 (1952).
[10] D. G. Hardy, W. Rigby and D. P. Moody, *J. Chem. Soc.* 2955 (1957).

oxidation it gave the same diketo-ester (X). The IR spectrum of the ester lacked absorption at 3400 cm^{-1} accorded[2] to the 6 (ax) hydroxyl group bonded to the 19-methyl ester whilst on pyrolysis at 285° it did not undergo the facile relactonization characteristic[2] of the 6 (ax)-hydroxy-19-methyl esters but was recovered unchanged. Hence, bearing in mind the formation of this ester under prolonged alkaline conditions, we are led to propose epimerization of the 6-hydroxyl group to the 6β-(eq) isomer (IX; R = β-OH, α-H).

Hydrolysis of 7-hydroxykaurenolide led to a 6α,7β-diol (XIV; R = CH_2) which on oxidation with chromium trioxide in sulphuric acid formed a crystalline diosphenol (XVII; R = CH_2) (λ_{max} 281 mμ) and a lactonol $C_{21}H_{28}O_6$. Further oxidation of this lactonol gave the 16-norketone (XVII, R = O). Similarly oxidation of the diol[2] (XIV; R = O), with chromium trioxide gave in addition to the compounds XVI and XVII described previously, the lactonol, $C_{20}H_{26}O_7$ (ν_{max} 3415, 1801 and 1727 cm^{-1}; XVIII; R = O). On one occasion a second lactonol, $C_{19}H_{26}O_6$, was also isolated. The C(20)-lactonol which was also obtained by oxidation of the diosphenol[2] (XVI; R = O), consumed one mole of alkali on microtitration. After refluxing the lactonol with alkali, acidification of the solution gave one mole of carbon dioxide and a second lactonol, $C_{18}H_{24}O_5$ (XIX) (ν_{max} 3393, 1788 and 1744 cm^{-1}). The latter, whilst retaining the high frequency IR absorption of the γ-lactone, no longer contained a methoxyl group and hence the parent lactonol must have contained a potential β-keto-ester. It was therefore tentatively assigned the structure XVIII (R = O) although it was not possible to exclude structures based on a ring–ring tautomerization reaction (cf 11).

EXPERIMENTAL

M.ps were determined on a Kofler block and were corrected. IR spectra were determined as Nujol mulls on a Perkin–Elmer 221 spectrometer unless otherwise stated, whilst UV spectra were determined in EtOH solution. NMR spectra were determined on a Varian Associates A60 spectrometer in $CDCl_3$ solution with tetramethylsilane as an internal reference. Alumina for chromatography was Woelm grade II acid washed. Light petroleum refers to the fraction b.p. 60–80°.

Hydrolysis of the epoxide (II) *with mineral acid.* The epoxide[2] II (101 mg) in MeOH (5 ml) was heated under reflux with dil HCl (50 ml) for 3 hr. The solution was left overnight during which time it deposited needles (64 mg) of *6α,7β,16α,17-tetrahydroxy-(−)-kauran-19-oic acid* 19 → *6α-lactone* (III; R = β-OH, α-H) which crystallized from aqueous MeOH, m.p. 239–242°. (Found C, 69·0; H, 8·2. $C_{20}H_{30}O_5$ requires: C, 68·5; H, 8·6%) ν_{max} 3540 (br), 1761, 1739 (sh) cm^{-1}.

Hydroxylation of 7-hydroxykaurenolide. 7-Hydroxykaurenolide (254 mg) suspended in ether (10 ml) was treated with osmium tetroxide (500 mg) in pyridine (5 ml) at room temp overnight. The suspension was heated for 1 hr with KOH (2·5 g), mannitol (5 g) and water (100 ml) and then acidified. Recovery with ethyl acetate gave a crystalline residue which was chromatographed on silica. Elution with ethyl acetate gave *6α,16α,17-trihydroxy-7-oxo-(−)-kauran-19-oic acid* 19 → *6α-lactone* (III; R = O; 75 mg) which crystallized from acetone–light petroleum as needles, m.p. 248–250°. (Found: C, 69·05; H, 8·2. $C_{20}H_{28}O_5$ requires: C, 68·9; H, 8·1%) ν_{max} 3535, 3475, 3414, 1786 and 1699 cm^{-1}. Further elution with ethyl acetate and 5% MeOH in ethyl acetate gave the triol described above (109 mg) which crystallized from aqueous MeOH, m.p. 239–244°.

Oxidation of the α-glycol (III; R = β-OH, α-H). The glycol (84 mg) in MeOH (10 ml) was treated at room temp with a solution of sodium periodate (390 mg) in water (2 ml) for 18 hr. The solution was concentrated, diluted with water and the organic material recovered with ethyl acetate. Crystallization of the residue from acetone–light petroleum gave V[2] (R = β-OH, α-H; 26 mg), m.p. 303–306°, which was identified by its IR spectrum.

Oxidation of the α-glycol (III; R = O). The glycol (6 mg) in MeOH (0·5 ml) was treated with a solution of sodium periodate (24 mg) in water (0·5 ml) at room temp overnight. The solution was diluted with water and the organic material recovered with ethyl acetate. On crystallization from

acetone–light petroleum it gave V (R = O; 3 mg) as needles, m.p. 289–292°, identified by its IR spectrum.

Rudloff-Lemieux oxidation of 7-hydroxykaurenolide (I). 7-Hydroxykaurenolide (306 mg) in fresh dioxan (3 ml) was added to a solution of $KMuO_4$ (79 mg), K_2CO_3 (0·5 g) and sodium periodate (1·05 g) in water (25 ml) and allowed to stand at room temp for 18 hr. The suspension was diluted with water, sodium metabisulphite added and the organic material recovered with ethyl acetate. On crystallization from acetone–light petroleum it gave V[2] (R = β-OH, α-H; 210 mg), m.p. 305–307°, identified by its IR spectrum.

Oxidation of 7-hydroxykaurenolide with potassium permanganate. Potassium permanganate (1 g) was added to a solution of 7-hydroxykaurenolide (750 mg) in purified acetone (20 ml). After 6 hr the precipitated MnO_2 was filtered off and thoroughly washed with acetone. The solutions were combined and decolourized with H_2SO_3, concentrated and diluted with water. The solution was extracted with ethyl acetate and the extract separated into acidic and neutral fractions with $NaHCO_3$aq. The neutral fraction (0·49 g) was chromatographed on alumina. Elution with 50% ethyl acetate–light petroleum gave V (R = β-OH, α-H; 210 mg) m.p. 304–306°, identified by its IR spectrum. Elution with ethyl acetate and 5% MeOH in ethyl acetate gave III (R = β-OH, α-H; 130 mg), m.p. 239–241°, which was identified by its IR spectrum. The acid fraction gave *6α,7β,16α-trihydroxy-(−)-kauran-17,19-dioic acid* 19 → *6α-lactone* (IV; 57 mg) which crystallized from acetone–light petroleum as prisms, m.p. 148–150° with dec. (Found: C, 62·9; H, 7·8. $C_{20}H_{32}O_6 \cdot H_2O$ requires: C, 62·8; H, 7·9%) ν_{max} 3406 (hydroxyl), 2480, 1980 (carboxyl OH), 1750 (γ-lactone), 1690 (carboxyl) cm^{-1}.

Oxidation of the hydroxy-acid (IV) *with sodium bismuthate.* The hydroxy-acid (24 mg) in 80% acetic acid (2 ml) was treated with Analar sodium bismuthate (26 mg) for 4 hr. The solution was made alkaline with 3N NaOH, diluted with water and extracted with ethyl acetate. The extract was washed with $NaHCO_3$aq, water and dried. The solvent was evaporated and the residue crystallized from acetone–light petroleum to give V (R = β-OH, α-H; 10 mg), m.p. 304–306°, identified by its IR spectrum.

Isolation of the δ-lactone (VI; R = β-OH, α-H). 7-Hydroxykaurenolide (1·5 g) in glacial acetic acid (75 ml) was treated with a stream of ozonized O_2 (17 mg/min) for 15 min. The acetic acid was neutralized with Na_2CO_3 carbonate, diluted with water and the product recovered in ethyl acetate. It crystallized from acetone–light petroleum to give V (R = β-OH, α-H; 905 mg) as needles, m.p. 304–307°, Chromatography of the mother liquors on alumina gave, in the fractions eluted with 75% ethyl acetate–light petroleum, the *δ-lactone* (VI; R = β-OH, α-H; 148 mg) which crystallized from acetone–light petroleum as prisms, m.p. 284–285°. (Found: C, 68·0; H, 8·0. $C_{19}H_{28}O_5$ requires: C, 68·2; H, 7·8%) ν_{max} 3450, 1761 and 1695 cm^{-1}.

Baeyer-Villiger oxidation of the 16-ketone (V; R = β-OH, α-H). The ketone (150 mg) and toluene-*p*-sulphonic acid (26 mg) were dissolved in a 1·3N-solution of perbenzoic acid in chloroform (10 ml) and stood at 0° for 17 hr. The solution was diluted with chloroform, washed with $NaHCO_3$aq, $FeSO_4$aq, water and dried. The solvent was evaporated and the residual gum chromatographed on alumina. Elution with 50% ethyl acetate–light petroleum gave the starting material (24 mg) whilst elution with 75% ethyl acetate–light petroleum gave the δ-lactone (94 mg) which crystallized from acetone–light petroleum as needles, m.p. 284–285°, identical with the sample prepared above.

Hydrolysis of the δ-lactone (VI; R = β-OH, α-H). The lactone (53 mg) in MeOH (5 ml) was heated under reflux with 1N NaOH (10 ml) for 2 hr. The solution was cooled, diluted with water, cautiously acidified and extracted with ethyl acetate. The extract was washed with water, dried and evaporated to give a gum which was methylated with diazomethane. The residue was filtered through alumina to give the *Methyl ester* (IX; R = α-OH, β-H; 41 mg) as needles, m.p. 216–218°. (Found: C, 65·6; H, 8·45. $C_{20}H_{30}O_6$ requires: C, 65·6; H, 8·25%) ν_{max} 3500, 3339, 1748 and 1704 cm^{-1}, (in $CHCl_3$) 3620, 3590, 3380, 1771 and 1699 cm^{-1}.

Oxidation of the lactone (IX; R = α-OH, β-H). The lactone (19 mg) in acetone (2 ml) was treated with the 8N-chromium trioxide reagent[9,11] (0·13 ml) for 1 hr. MeOH was added and the solution poured into water and extracted with ethyl acetate. The extract was separated into acidic and neutral fractions with $NaHCO_3$. The neutral fraction (15 mg) gave the *diketone* (X) which crystallized from acetone–light petroleum as needles (12 mg), m.p. 214–215°. (Found: C, 66·3; H, 7·4. $C_{20}H_{26}O_6$ requires: C, 66·3; H, 7·2%) ν_{max} 1785, 1730, 1710 cm^{-1} τ = 8·8, 8·6, 7·97, 7·67, 7·4, 6·28 and 4·83.

[11] R. G. Curtis, E. R. H. Jones, Sir I. Heilbron and G. F. Woods, *J. Chem. Soc.* 457 (1953).

Baeyer-Villiger oxidation of the ketone (V; R = α-O·CO·CH_3, β-H). Acetylation of 6α,7α-dihydroxy-16-oxo-(−)-17-norkauran-19-oic acid 19 → 6α lactone with acetic anhydride–pyridine gave the *acetyl derivative* which crystallized from acetone–light petroleum as needles, m.p. 178–180°. (Found: C, 70·0; H, 8·1. $C_{21}H_{28}O_6$ requires: C, 70·0; H, 7·8%) ν_{max} 1769, 1739 and 1720 cm^{-1}.

The acetyl derivative (103 mg) in chloroform (5 ml) was treated with 1·3N perbenzoic acid (4 ml) and toluene-*p*-sulphonic acid (10 mg) at 0° for 48 hr. The solution was diluted with ethyl acetate, extracted with $NaHCO_3$aq and washed with water. Evaporation of the solvent and chromatography of the residual gum on silica gel gave the *δ-lactone* (VI, R = α-OCOCH_3, β-H; 56 mg) which crystallized from acetone–light petroleum as needles m.p. 290–291°. (Found: C, 67·5; H, 7·3. $C_{21}H_{28}O_6$ requires: C, 67·0; H, 7·5%) ν_{max} 1770, 1735, 1721 cm^{-1}.

Hydrolysis with refluxing 3N NaOH followed by acidification, recovery of the product in ether and methylation with diazomethane gave a low yield of a diol which crystallized from acetone–light petroleum as prisms, m.p. 230–231° ν_{max} 3580, 3450, 1721 and 1695 cm^{-1}.

Oxidation of the lactone (VI; R = β-OH, α-H). The lactone (84 mg) in acetone (5 ml) was treated with the above chromium trioxide reagent (0·13 ml) at room temp for 1 hr. MeOH was added and the solution concentrated, diluted with water and extracted with ethyl acetate. The extract was washed with dil HCl, water and dried. The solvent was evaporated and the residue crystallized from acetone–light petroleum to give the *keto-lactone* (XII; 58 mg) as prisms, m.p. 275–279°. (Found: C, 68·7; H, 7·4. $C_{19}H_{24}O_5$ requires: C, 68·65, H, 7·3%) ν_{max} 1777, 1738 and 1730 cm^{-1}.

Hydrogenolysis of the keto-lactone (XII). The keto-lactone (43 mg) in acetic anhydride (5 ml) was heated under reflux with Zn dust (1 g) overnight. More Zn dust (1 g) was then added and the solution refluxed for a further 2 hr. The acetic anhydride was evaporated and the residue extracted with ethyl acetate. The extract was washed with water, dil HCl, dried and evaporated to give a residue which was methylated with diazomethane. On crystallization from acetone–light petroleum it gave the *keto-lactone* (XIII) as prisms (31 mg), m.p. 184–186°. (Found: C, 69·2; H, 7·3. $C_{20}H_{28}O_5$ requires: C, 68·9; H, 8·1%) ν_{max} 1724, 1716 and 1704 cm^{-1}.

Isolation of the esters (IX; R = β-OH, α-H) and (XV; R = OH, H). Ozonized O_2 (5·6 mg/min) was passed through a solution of 7-hydroxykaurenolide (2·5 g) in acetic acid (45 ml) for 90 min. 3N NaOH (500 ml) was added and the solution refluxed overnight. The solution was cooled and carefully acidified and extracted with ethyl acetate. The extract was washed with water, dried and evaporated to give a gum which was methylated with diazomethane. Methyl 6α,7β-dihydroxy-16-oxo-17-nor-(−)-kauran-10-oate (0·5 g) was removed by direct crystallization from acetone–light petroleum and the residue was chromatographed on alumina (grade I, 150 g). Elution with 10% ethyl acetate–light petroleum gave the *mono-ol* (XV; R = OH, H; 210 mg) which crystallized from acetone–light petroleum as needles, m.p. 179–180°. (Found: C, 69·0; H, 8·5. $C_{20}H_{30}O_5$ requires: C, 68·5; H, 8·6%) ν_{max} 3455, 1749, 1719 cm^{-1}, τ = 9·1; 8·55; 7·61; 7·12, (J = 17 c/s), 6·2, 5·45 and 5·3. Further elution with 15% ethyl acetate–light petroleum gave the above diol (560 mg) identified by its IR spectrum. Elution with 20% ethyl acetate–light petroleum gave the *diol* (IX; R = β-OH, α-H; 304 mg) which crystallized from acetone–light petroleum as needles, m.p. 217–218°. (Found: C, 65·95; H, 8·45. $C_{20}H_{30}O_6$ requires: C, 65·55; H, 8·25%) ν_{max} 3500, 1753 and 1696 cm^{-1} (in $CHCl_3$) 3615, 3591, 1772 and 1701 cm^{-1}.

Oxidation of the ester (XV; R = β-OH, α-H). The mono-ol (95 mg) in acetone (5 ml) was treated with the above chromium trioxide reagent (0·2 ml) for 2 hr at room temp. MeOH was added, the solution concentrated and diluted with water and extracted with ethyl acetate. The extract was washed with $NaHCO_3$aq, water and dried. Evaporation of the solvent and crystallization of the residue from acetone–light petroleum gave the *ketone* (XV; R = 0; 53 mg), m.p. 174–176°. (Found: C, 68·95; H, 8·2. $C_{20}H_{28}O_5$ requires: C, 68·9; H, 8·1%) ν_{max} 1785, 1718 and 1704 cm^{-1} τ = 8·82, 8·61, 8·3, 7·9, 7·62, 7·37 (J = 17 c/s) 6·3 and 5·21.

Oxidation of the ester (IX; R = β-OH, α-H). The diol (73 mg) in acetone (5 ml) was treated with the above chromium trioxide reagent (0·2 ml) for 2·5 hr at room temp. MeOH was added and the solution concentrated diluted with water and extracted with ethyl acetate. The extract was washed with $NaHCO_3$aq, dil HCl, water and dried. Evaporation of the solvent and crystallization of the residue from acetone–light petroleum gave X (36 mg) as needles, m.p. 213–215°, identified by its IR spectrum.

Oxidation of the diol (XIV; R = O). The diol (2 g) in acetone (50 ml) was treated, with cooling, with the above chromium trioxide reagent (6 ml) and allowed to stand at room temp for 16 hr. It was

treated with MeOH (1 ml) and then concentrated at 30°. The concentrate (10 ml) was diluted with water and extracted with ethyl acetate. The extract was separated into acidic and neutral fractions with $NaHCO_3$. The acidic fraction crystallized from acetone–light petroleum to give XVII[2] (450 mg) as needles, m.p. 169–171° and 202–204°. The neutral fraction was chromatographed on silica gel (25 × 2 cm). Elution with 15% ethyl acetate–light petroleum gave XVI[2] (500 mg) as a gum (λ_{max} 281 mμ log ε 3·9) identified by its IR spectrum. Elution with 20–25% ethyl acetate–light petroleum gave the *lactonol* (XVIII; 400 mg) which crystallized from acetone–light petroleum as prisms, m.p. 242–243° with dec. (Found: C, 63·7, 63·8; H, 7·0, 7·05; OMe 8·25; equiv., 334. $C_{20}H_{26}O_7$ requires: C, 63·5; H, 6·9; OMe 8·2%; M, 350) ν_{max} 3415, 1801 and 1727 cm^{-1}. The lactonol was recovered unchanged from standing overnight in acetone solution with excess chromium trioxide reagent. On one occasion a *compound* m.p. 210–215°. (Found: C, 64·9; H, 7·1. $C_{19}H_{26}O_6$ requires: C, 65·1; H, 7·5%) was also isolated from this reaction.

Oxidation of methyl 6α,7β-dihydroxykaur-16-en-19-oate (by Dr. R. H. B. Galt) under similar conditions gave, *inter alia*, XVII (R = CH_3), m.p. 65–68°. (Found: C, 70·05; H, 8·5. $C_{21}H_{28}O_4 \cdot CH_3OH$ requires: C, 70·2; H, 8·6%) ν_{max} 3417, 1740, 1661, 1635, 875 cm^{-1} and a *lactonol* (XVIII; R = CH_3), m.p. 205–210°. (Found: C, 67·1; H, 7·5. $C_{21}H_{28}O_6$ requires: C, 67·0; H, 7·5%) ν_{max} 3350, 1790, 1721 cm^{-1}. The lactonol (17 mg) in acetone (5 ml) was treated with the 8N chromium trioxide reagent (0·1 ml) overnight gave XVIII (R = O; 5 mg) identified by its IR spectrum.

Alkaline hydrolysis of the lactonol (XVIII). The lactonol (200 mg) in EtOH (5 ml) was refluxed with 0·5N NaOH (5 ml) under N_2 for 1 hr. The solution was then acidified with dil HCl. There was a copious evolution of CO_2 (Baryta trap). The solution was diluted with water and extracted with ethyl acetate and the extract separated into acidic and neutral fractions with $NaHCO_3$. The neutral fraction was chromatographed on silica gel in 20% ethyl acetate–light petroleum to give the *lactonol* XI; 40 mg) which crystallized from acetone–light petroleum as needles, m.p. 246–251°. (Found: C, 67·6; H, 7·8. $C_{18}H_{24}O_5$ requires: C, 67·5; H, 7·55%) ν_{max} 3393, 1788 and 1744 cm^{-1}.

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