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STUDIES ON THE POTENTIAL INTERMEDIATES FOR THE SYNTHESES OF ROSANE TYPE DITERPENOIDS

PREPARATION OF 8β-ACETOXYMETHYL-2β-ACETOXY-4aβ,8-DIMETHYL-1,2,3,4,4a,4bα,5,6,7,8,10,10aα-DODECAHYDROPHENANTHRENE AND 8β-CARBOXY-2β-BENZOYLOXY-4aβ,8-DIMETHYL-9-KETO-*TRANS, ANTI, TRANS*-PERHYDROPHENANTHRENE

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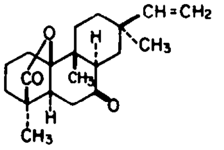
Abstract—Some attempts to functionalize the 8β-methyl group in the rosane skeleton were made and the syntheses of the titled compounds were described.

EXTENSIVE investigations[1] have been made towards the functionalization of abietic and podocarpic acids with a view to preparing valuable intermediates for the syntheses of naturally occurring diterpenoids, such as the gibberellin and the aconitum and garrya alkaloid types. However, similar functionalization of the C-8* methyl groups in the compounds possessing a rosane skeleton[2] has not yet been investigated although recently some attempts have been made by Ireland and Mander[3] to oxidise the C-8β methyl group in a *cis*-fused B/C structure for the purpose of constructing the lactone ring of rosenonolactone (I).[4] We have studied such modification[5] of the C-8β methyl group in the rosane system in order to prepare intermediates which may be utilized for the syntheses of natural diterpenoids, such as erythroxydiol X (II) and its related compounds.[6]



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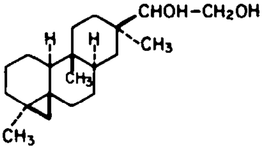

II

CHART 1

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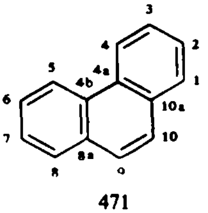
* The phenanthrene numbering system is used throughout the subsequent discussion.



Our first attempt towards the syntheses of such intermediates was to prepare ketone Vb and then photolyze[7] it to obtain a cyclobutane derivative (VII) which in turn would be converted by lead tetraacetate oxidation into a keto alcohol (VIII). Keto alcohol VIII might be expected to be a promising intermediate for the synthesis of erythroxydiol X (II) since on mesylation it would yield a 9-oxo-12-mesyloxy derivative, which, on treatment with NaOMe, would be readily transformed to a 9-oxo-8aβ,12-cyclopropyl compound.[7]

2β-Hydroxy-4aβ,8,8-trimethyl-1,2,3,4,4a,4bα,5,6,7,8,10,10aα-dodecahydrophenanthrene* (IIIa) was prepared according to the method of Ireland and Mander.[8] On treatment with dihydropyran in the presence of *p*-TsOH it yielded a noncrystalline tetrahydropyranyl ether (IIIb). Hydroboration of this by the standard procedure[9] afforded the 9β-hydroxy ether (IVb) as revealed by its NMR [δ 3·21–4·20 (3H, m, H at C-2′ and C-9), 4·76 (1H, m, H at C-6′), and no olefinic proton] as well as IR spectrum [3280 cm^{-1} (OH)]. On acid hydrolysis IVb yielded a diol (IVa). The assignment of the β-configuration to the C-9 OH group was made on the following basis. Inspection of a molecular model of the olefin (IIIb) shows that the α-side of the molecule is encumbered by the axial 8α-Me group. Its β-face is partially shielded by the axial 4aβ-Me group, which however is in a 1,4-relationship with the C-9 position. Thus the approach to the β-side of the 8a,9-double bond should be less sterically hindered and be favoured for the production of the desired 9β-alcohol. On oxidation with Sarett reagent[10] hydroxy ether IVb afforded ketone Vb† which exhibited an intense carbonyl band at 1700 cm^{-1} in its IR spectrum. On acid hydrolysis ketone Vb yielded a hydroxy ketone (Va), which was benzoylated with benzoyl chloride in pyridine. Reduction of the benzoate (Vc) with $NaBH_4$ yielded a product which gave two spots of equal intensity on the TLC. Chromatographic separation of the product on alumina afforded two alcohols, one of which showed m.p. 143–145° (from ether–hexane) and the other, m.p. 147–149° (from ether–hexane). In the NMR spectrum of the alcohol, m.p. 143–145°, the proton at C-9 occurred at δ 3·58 ppm as a broad multiplet (half-width, *ca.* 25 cps), which is characteristic of the axial proton. On the other hand, the corresponding proton of the alcohol, m.p. 147–149°, exhibited a multiplet (half-width, *ca.* 6 cps) at δ 4·30 ppm which indicated the equatorial nature of this proton.[11] Thus the alcohol, m.p. 143–145°, has structure VIa‡ and the other alcohol, m.p. 147–149°, structure VIb.‡ On alkaline hydrolysis alcohol VIa afforded a diol which is identical with the diol (IVa) obtained from the acid hydrolysis of the tetrahydropyranyl ether (IVb). Thus the axial nature of the proton at C-9 (hence the equatorial nature of the C-9β OH) in the alcohols IVa and IVb has also been established.

Our next step was to subject ketone Vb to photochemical reaction[7] with the hope of obtaining a cyclobutane derivative (VII) which on ring cleavage would produce keto alcohol VIII. Photolysis of ketone Vb with a 200 W Hanovia high pressure mercury lamp with a Pyrex filter under oxygen-free N_2 gave a product which failed

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* All compounds described here are racemic modifications although only one enantiomer is depicted in the drawings.

† The A/B ring fusion of this ketone is assumed to be in the more stable *trans* configuration. For a similar case, see ref. 3.

‡ The rings A, B, and C are expected to be in a chair form[3].

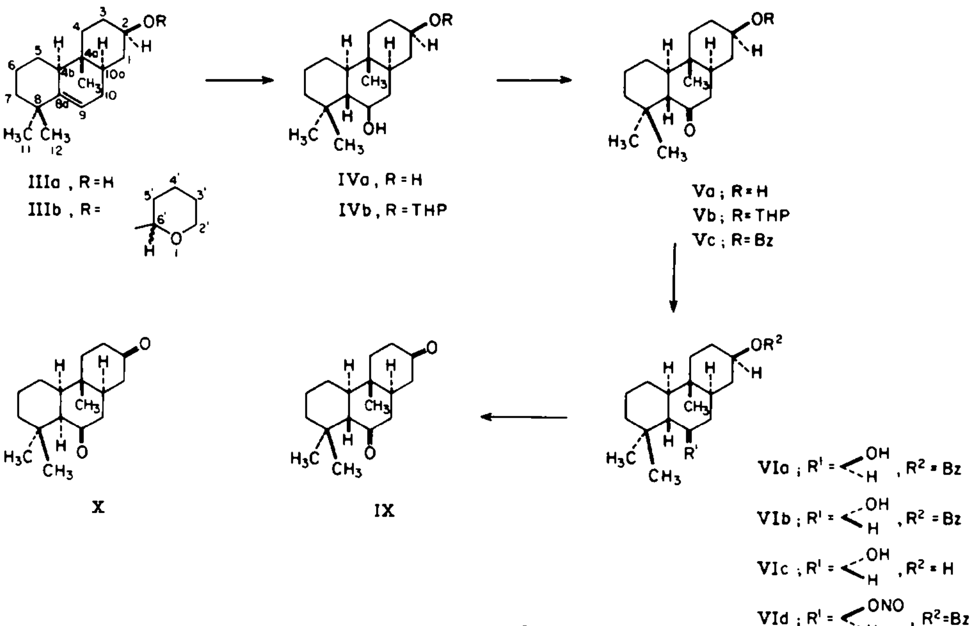

CHART 2

to crystallize. Hydrolysis of the product with AcOH yielded a semi-solid material which was chromatographed on alumina. Elution with hexane–ether (1:1) gave a solid, m.p. 206–208°, which exhibited no carbonyl band but an intense OH band at 3320 cm^{-1} in its IR spectrum. This compound gave a molecular ion peak at *m/e* 266 and was shown by direct comparison to be identical with diol IVa. Oxidation of this diol with Jones reagent[12] yielded diketone IX, m.p. 173–175°, which formed a mono-2,4-dinitrophenylhydrazone, m.p. 238–239°. Further elution with C_6H_6–ether (1:9) yielded a product, m.p. 150–151°, which also exhibited an intense OH band at 3310 cm^{-1} but lacked a carbonyl band in its IR spectrum. The elemental analysis of this compound corresponded to a formula, $C_{17}H_{30}O_2$ [*m/e* 266 (M^+)], but it* was shown to be different from either diol IVa or the isomeric alcohol VIc obtained from the alkaline hydrolysis of the benzoate (VIb). Oxidation of this diol with Jones reagent[12] afforded a diketone which could not be crystallized, but formed a crystalline di-2,4-dinitrophenylhydrazone, m.p. 246–248°. This diketone apparently does not possess a structure such as X in which the A/B ring junction is *cis* since it did not isomerize to the A/B ring *trans* diketone (IX) under either acidic or basic condition.

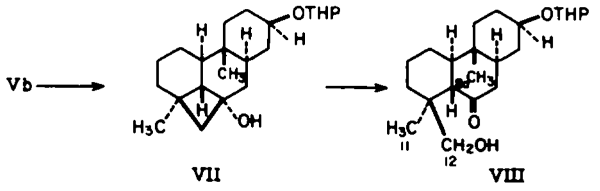

CHART 3

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* The structure of this diol is now being determined by X-ray crystallographic analysis.

In connection with the photolysis of ketone Va, we have also studied the photolysis of the nitrite (VId)[13a,b,c] in order to functionalize the C-8β Me group and then cyclize the resulting iodomethyl group to a cyclopropane derivative. On being treated with nitrosyl chloride in dry pyridine the alcohol (VIa) afforded a crystalline nitrite (VId) which showed characteristic nitrite bands at 1630 and 1590 cm^{-1} in its IR spectrum. This nitrite was irradiated in C_6H_6 containing iodine under oxygen-free N_2 with a 200 W high pressure mercury lamp with a Pyrex filter. The progress of the reaction was monitored by the TLC. The resulting product was immediately oxidized with Jones reagent[12] and then treated with alumina (Merck, standardized, activity II–III) in dry C_6H_6. Subsequent chromatography of the product* over alumina and elution with C_6H_6 yielded a solid, m.p. 162–163°, identified as the reformed ketone (Vc). Further elution with C_6H_6–ether (2%) afforded in 24% yield a crystalline solid, m.p. 177–178°, identified as ether derivative XIc (see below) by direct comparison. Alkaline hydrolysis of XIc gave the hydroxy ether (XIa). Further elution with C_6H_6–ether (30%) afforded a very small amount of semi-solid material. It gave a positive halogen reaction with a copper wire, but because of its small amount, was not investigated further.

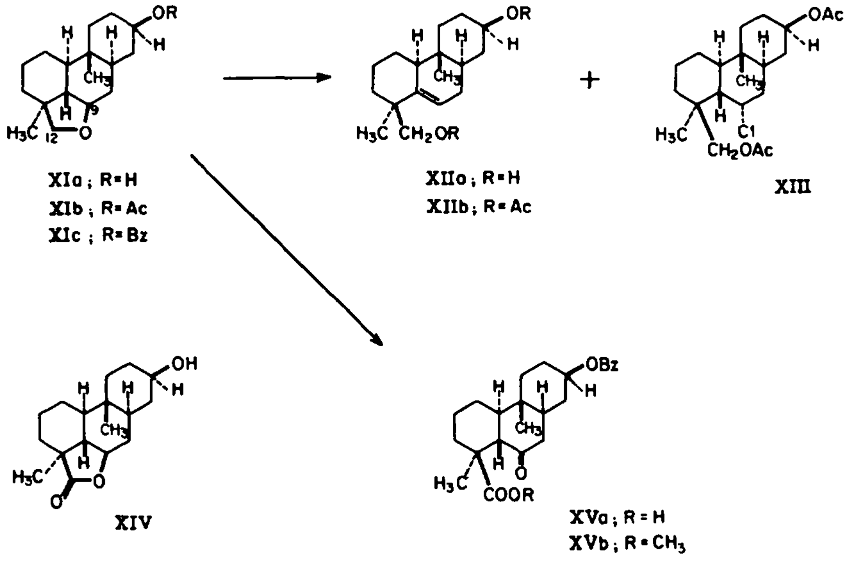

CHART 4

Having had no success in the foregoing approach, we have turned back to the $Pb(OAc)_4$ oxidation of the 9β-alcohol (IVa). The tetrahydropyranyl ether (IVb) was oxidized in cyclohexane with $Pb(OAc)_4$ in the presence of I_2. The resulting product, after acid hydrolysis, afforded a gummy material, which was chromatographed on alumina to yield the hydroxy ether (XIa) in a 30% yield. The formation of the 9β → 12 cyclic ether was confirmed by the appearance of an AB quartet (δ 3·66, $J = 8$ cps, 2H at C-12) and a multiplet (δ 3·50, 1H at C-9) and the disappearance of one of the

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* The NMR and IR spectra of the crude product did not indicate the formation of a cyclopropane derivative (see ref 13b and 13c).

C-8 Me groups in its NMR spectrum. The lactone such as XIV could not be isolated in this reaction, although Ireland and Mander[3] obtained a γ-lactone as a major product in a similar oxidation of a B/C ring *cis*-fused system. Similar oxidation of the pyranyl ether (IVb) with $Pb(OAc)_4$ in C_6H_6 in the absence of I_2 and subsequent acid hydrolysis of the product afforded the same hydroxy ether (XIa), the yield being almost the same in both cases. On acetylation with Ac_2O-py the hydroxy ether (XIa) gave the acetoxy ether (XIb). Treatment of XIb with pyridine hydrochloride and Ac_2O at reflux yielded a gummy mass, which on chromatography on alumina and elution with hexane, afforded a product in poor yield which was homogeneous on the TLC. This compound is formulated as the olefin XIIb since it exhibited IR bands at 1735 (acetate C=O) and 1245 (C—O—) cm^{-1} and NMR signals at δ 2·06 (3H, s, OAc), 2·10 (3H, s, OAc), 4·18 (2H, AB q, J = 12 cps, $C\underline{H}_2OAc$), 4·83 (1H, broad multiplet, $C\underline{H}OAc$), and 5·55 (1H, m, olefinic proton at C-9) ppm. Hydrolysis of this compound with 3% methanolic KOH gave an alcohol (XIIa), the NMR spectrum of which showed peaks at δ 0·75 (3H, singlet, quaternary Me), 0·98 (3H, singlet, quaternary Me), 3·61 (1H, m, $C\underline{H}OH$), 3·63 (2H, AB q, J = 11 cps, $C\underline{H}_2OH$), and 5·63 (1H, m, olefinic proton at C-9) ppm.

Further elution with hexane–C_6H_6 (1 : 1) afforded a chlorine-containing compound. It exhibited NMR peaks at δ 0·88 (3H, s, quaternary Me), 0·98 (3H, s, quaternary Me), 2·05 (3H, s, OAc), 2·08 (3H, s, OAc), 3·53 (2H, AB q, J = 11 cps, $C\underline{H}_2OAc$), and 4·41–5·16 (2H, multiplets, $C\underline{H}Cl$ and $C\underline{H}OAc$) ppm, and was assigned the structure XIII. Refluxing of this chloro compound with 5% methanolic K_2CO_3 solution gave back the hydroxy ether (XIa).

Since the yield of the desired olefinic compound (XIIa), which may be utilized for the construction of a cyclopropane ring* as shown in the structure II, was poor, we turned our attention to the possibility of the oxidation† of the hydroxy ether XIa with CrO_3 to the lactone (XIV). On benzoylation with benzoyl chloride in pyridine the hydroxy ether (XIa) gave the corresponding benzoate (XIc). Treatment of this benzoate with CrO_3 in AcOH at room temperature afforded a nicely crystalline product in 53% yield. That the cleavage of the 9β → 12 ether linkage had occurred was evidenced by the absence of the AB quartet due to the C-12 oxymethylene protons in its NMR spectrum. The possibility of the formation of a γ-lactone such as XIV was excluded since this product gave an unresolved carbonyl band of high intensity at 1701 cm^{-1} but lacked a lactonic carbonyl band in its IR spectrum. Its molecular weight as determined by mass spectrometry was found to be 398 which corresponded to the keto acid (XVa). On methylation with CH_2N_2 it gave the methyl ester (XVb), ν_{max} 1720 (six-membered C=O), 1710 (ester C=O), and 1700 (benzoate C=O) and 1270 (benzoate C—O—), *m/e* 412 (M^+), δ 1·03 (3H) and 1·16 (3H) (singlets, two quaternary Me), 3·63 (3H, s, $COOC\underline{H}_3$), 4·90 (1H, broad multiplet, H at C-2), and 7·20–8·20 (5H, multiplets, benzenoid protons). Further work on the conversion of keto acid XVa into keto alcohol VIII for the construction of a cyclopropane ring with the same stereochemistry as in erythroxydiol X (II) is in progress.

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* Mesylation of XIIa and subsequent reduction of the resulting mesylate with LAH would produce a 8aβ,12-cyclopropyl derivative (J. A. Marshall, H. Fauble and T. M. Warne, jun., *Chem. Comm.*, 753 (1967): for a similar case, W. Herz, R. N. Mirrington and H. Young, *Tetrahedron Letters* 405 (1968).

† Note that Ireland and Mander did not succeed in oxidizing the corresponding ether derivative with a B/C *cis*-fused ring[3].

EXPERIMENTAL

M.ps were determined on a Kofler hot-stage and are uncorrected. Unless otherwise specified, IR spectra were taken on a Perkin-Elmer 337 spectrometer for KBr discs or liquid films and UV spectra were measured with a Cary Model 15 spectrometer for EtOH soln. NMR spectra were obtained for soln in $CDCl_3$ with a Varian A-60 spectrometer. Chemical shifts are reported as δ units using TMS as an internal standard. Mass spectra were recorded on a Hitachi Perkin-Elmer RMU 6E at 70 eV using a direct inlet system. Merck standardized alumina, activity II-III was used for column chromatography. For TLC, Merck silica gel G was used and the spots were identified by exposure to I_2 vapour. All organic extracts were dried over anhyd $MgSO_4$ and evaporated under reduced pressure below 40°. Microanalyses were carried out by Dr A. Bernhardt, Microanalytical Laboratory, 5251 Elbach über Engelskirchen, West Germany.

2β-*Tetrahydropyranyl* 4aβ,8,8-*trimethyl*-1,2,3,4,4a,4bα,5,6,7,8,10,10aα-*dodecahydrophenanthrene* (IIIb). The hydroxy olefin (IIIa: 2·2 g) was stirred with dihydropyran (30 ml) with *p*-TsOH (5 mg) for 35 min. Anhyd K_2CO_3 (1 g) was added and the mixture stirred for 2 min. H_2O (100 ml) was then added and the product extracted with ether. The residual liquid (2·9 g) left after removal of solvent was chromatographed over alumina. On elution with hexane the tetrahydropyranyl ether (IIIb; 2·74 g) was obtained as a colourless oil homogeneous in TLC (hexane: C_6H_6 2:1). It could not be induced to crystallize, but showed no OH absorption in the IR spectrum: NMR signals at 0·71 (3H, s), 1·01 (3H, s), and 1·08 (3H, s) ($C\underline{H}_3$ on C-4a and C-8), 3·33–4·16 (3H, m, $\underline{H}$ on C-2 and C-2′), 4·83 (1H, m, $\underline{H}$ on C-6′), and 5·60 (1H, m, $\underline{H}$ on C-9).

Tetrahydropyranyl 9β-*hydroxy*-4aβ,8,8-*trimethyl*-trans,anti,trans-*perhydro*-2β-*phenanthryl ether* (IVb). A soln of B_2H_6 in THF was prepared under N_2-stream at 0° by the addition of BF_3-Et_2O (7 g) to a suspension of $NaBH_4$ (1·5 g) in dry THF (50 ml). After 5 min a soln of the pyranyl ether (2·75 g) in dry THF (50 ml) was added and the mixture stirred for 20 hr at 0–5°. The mixture was allowed to warm at room temp for 1 hr. Then 10% NaOH aq (30 ml) was cautiously added, followed immediately by 30% H_2O_2 (30 ml). The mixture was refluxed for 1 hr, cooled and diluted with C_6H_6. The organic layer was separated and the aq layer extracted with ether. The combined organic extract was washed with H_2O and evaporated to give a gummy mass which on trituration with ether-hexane afforded a white solid (2·5 g). After crystallization from hexane it melted at 119–121°: ν_{max} 3280 (OH) cm^{-1}; NMR signals at 1·00 (3H, s), 1·06 (3H, s), and 1·15 (3H, s) ($C\underline{H}_3$ on C-4a and C-8), 3·21–4·20 (3H, m) ($\underline{H}$ on C-2′ and C-9), 4·76 (1H, m) ($\underline{H}$ on C-6′), and no vinyl proton. (Found: C, 74·89; H, 10·90. $C_{22}H_{38}O_3$ requires: C, 75·38; H, 10·93%).

2β,9β-*Dihydroxy*-4aβ,8,8-*trimethyl*-trans,anti,trans-*perhydrophenanthrene* (IVa). The hydroborated product (0·15 g) in acetone (15 ml) was treated with 3N HCl (5 ml) with stirring at room temp for 3 hr. The soln was diluted with H_2O and extracted with ether. The ether extract was washed with H_2O and evaporated to give a crystalline diol (IVa; 0·1 g), which after recrystallization from ether showed m.p. 206–208°. (Found: C, 76·30; H, 11·19. $C_{17}H_{30}O_2$ requires: C, 76·64; H, 11·35%).

Tetrahydropyranyl 9-*keto*-4aβ,8,8-*trimethyl*-trans,anti,trans-*perhydro*-2β-*phenanthryl ether* (Vb). A soln of the pyranyl ether (IVb: 4 g) in dry pyridine (10 ml) was added to the Sarett reagent prepared from CrO_3 (4 g) and pyridine (40 ml) at 0–5°. The mixture was left to stand at room temp for 20 hr, diluted with water and extracted with ether. The ether extract was evaporated to give the ketone (Vb; 3·1 g), m.p. 132–136°. After recrystallization from ether-hexane it showed m.p. 149–150°; ν_{max} 1700 (C=O) cm^{-1}; NMR signals at 1·03 (3H, s), 1·10 (3H, s), and 1·16 (3H, s) ($C\underline{H}_3$ on C-4a and C-8), 3·33–4·30 (3H, m) ($\underline{H}$ on C-2′ and C-2), and 4·86 (1H, m) ($\underline{H}$ on C-6′). (Found: C, 75·92; H, 10·42. $C_{22}H_{36}O_3$ requires: C, 75·81; H, 10·41%).

2β-*Hydroxy*-9-*keto*-4aβ,8,8-*trimethyl*-trans,anti,trans-*perhydrophenanthrene* (Va). A soln of the keto tetrahydropyranyl ether (Vb; 5·8 g) in acetone (60 ml) was stirred with 3N HCl (40 ml) for 3 hr at room temp. The acidic soln was diluted with H_2O and extracted with ether. The ether extract was washed with water and evaporated to give a solid (4·5 g) which on recrystallization from ether-hexane showed m.p. 120–122°; ν_{max} 3400 (OH) and 1690 (C=O) cm^{-1}: NMR signals at 1·00 (3H, s), 1·06 (3H, s), and 1·13 (CH, s) (Me on C-4a and C-8), 3·63 (1H, broad m) (H on C-2). (Found: C, 76·88; H, 10·61. $C_{17}H_{28}O_2$ requires: C, 77·22; H, 10·67%).

2β-*Benzoyloxy*-9-*keto*-4aβ,8,8-*trimethyl*-trans,anti,trans-*perhydrophenanthrene* (Vc). The hydroxy compound (Va; 4·5 g) in pyridine (25 ml) was treated with benzoyl chloride (3·5 g) and the mixture left at room temp overnight. After dilution with H_2O, the product was extracted with ether and the ether extract washed successively with H_2O, dil HCl, and H_2O. After evaporation of the ether a solid (4·62 g) was obtained which after recrystallization from ether-hexane showed m.p. 162–164°; ν_{max} 1700 (benzoate C=O) and 1275 (benzoate —O—C) and 1690 (C=O) cm^{-1}. (Found: C, 77·92; H, 8·62. $C_{24}H_{32}O_3$ requires: C, 78·22; H, 8·75%).

2β-*Benzoyloxy*-9β-*hydroxy*-4aβ,8,8-*trimethyl*-trans,anti,trans-*perhydrophenanthrene* (VIa) *and* 2β-*benz-*

*oyloxy-9α-hydroxy-*4aβ,8,8-*trimethyl-*trans,anti,trans-*perhydrophenanthrene* (VIb). The keto benzoate (Vc: 2·4 g) was dissolved in a mixture of MeOH (60 ml) and dioxane (30 ml). $NaBH_4$ (1 g) was then added and the mixture stirred at room temp for 20 hr. After acidification with dil HCl, the product was extracted with $CHCl_3$. Washing of the organic extract with water and evaporation yielded a solid (2·5 g) which gave two spots on TLC (hexane: ether 1:1). This was chromatographed over alumina to give the following two fractions:

(i) Hexane: C_6H_6 (65:35)—A white solid (VIa: 1·01 g) was obtained which after crystallization from ether–hexane showed m.p. 143–145°: ν_{max} 3555 (OH), and 1694 (benzoate C=O) and 1275 (benzoate —O—C) cm^{-1}: NMR signals at 0·85 (3H, s), 0·96 (3H, s), and 1·21 (3H, s) ($C\underline{H}_3$ on C-4a and C-8), 3·58 (1H, broad m) ($\underline{H}$ at C-9), 4·95 (1H, broad m) ($\underline{H}$ at C-2), and 7·25–8·25 (5H, m) (benzenoid H). (Found: C, 77·56; H, 9·15. $C_{24}H_{34}O_3$ requires: C, 77·80; H, 9·25%). The alcohol (VIa; 0·08 g) on hydrolysis with a soln of KOH (0·08 g) in EtOH (95%) at refluxing temp for 2 hr afforded a diol which after crystallization from ether–hexane melted at 206–208° and was found identical with the diol (IVa).

(ii) C_6H_6: hexane (60:40)—A white solid (VIb: 1·12 g) was obtained which after recrystallization from ether–hexane, had m.p. 147–149°: ν_{max} 3500 (OH) and 1694 (benzoate C=O) and 1285 (benzoate —O—C) Cm^{-1}; NMR signals at 0·83 (3H, s), 1·03 (3H, s), and 1·10 (3H, s) ($C\underline{H}_3$ on C-4a, and C-8), 4·30 (1H, m) ($\underline{H}$ at C-9), 5·00 (1H, broad m) ($\underline{H}$ at C-2), and 7·25–8·26 (5H, m) (benzenoid H). (Found: C, 77·58: H, 9·18. $C_{24}H_{34}O_3$ requires: C, 77·80: H, 9·25%). The alcohol (VIb; 50 mg) on hydrolysis with a soln of KOH (40 mg) in EtOH (95%) at refluxing temp for 2 hr afforded diol VIc which after crystallization from ether–hexane melted at 210–212^c. (Found: C, 76·29: H, 11·18. $C_{17}H_{30}O_2$ requires: C, 76·24, H, 11·35%).

Photolysis of the ketone (Vb). The ketone (Vb: 1·1 g) in 95% EtOH (850 ml) saturated with anhyd K_2CO_3 was irradiated for 25 hr with a 200 W Hanovia high pressure lamp with a Pyrex filter under O_2 free N_2. On removal of the EtOH a liquid (1·1 g) was obtained, which was chromatographed over alumina (20 g). Elution with hexane: ether (60:40) yielded a colourless liquid (0·73 g) which was homogeneous to TLC (ether: hexane 1:1). In the same way another lot of the ketone (Vb) was subjected to the same photochemical reaction as above and after chromatography a colourless liquid (0·801 g) was obtained. The combined irradiated product (1·504 g) was refluxed with a mixture of AcOH (45 ml), MeOH (100 ml), and water (20 ml) for 2 hr. The crude product (1·2 g) obtained after the usual work-up was passed over a column of alumina (20 g) in C_6H_6 and on elution the following fractions were obtained:

(i) C_6H_6—A yellowish liquid (0·462 g) was obtained which was not further investigated.

(ii) C_6H_6: ether (4:6). A crystalline solid (0·292 g) was obtained which after recrystallization from ether showed m.p. 206–208°. This compound exhibited a strong OH absorption at 3320 cm^{-1}, but no carbonyl band in the IR spectrum. It gave a molecular ion peak at *m/e* 266. It was shown to be identical with diol IVa by m.m.p. determination.

Jones chromic acid reagent (1 ml) was added to an ice-cooled soln of this diol (0·12 g) in acetone (3 ml) and the mixture left at room temp for 10 min. Isopropanol was added to destroy excess oxidant and after the usual work-up the diketone (IX: 0·08 g) was obtained as a solid, which after recrystallization from ether showed m.p. 173–175^c; ν_{max} 1690 (C=O) cm^{-1}. (Found: C, 77·76: H, 9·92. $C_{17}H_{26}O_2$ requires: C, 77·82: H, 9·99%). It formed a yellow mono-2,4-dinitrophenylhydrazone, m.p. 238–239° (from $CHCl_3$–EtOH), ν_{max} 1700 (C=O) cm^{-1}. (Found: C, 61·69: H, 6·52: N, 12·47. $C_{23}H_{30}O_5N_4$ requires: C, 62·42: H, 6·83: N, 12·06%).

(iii) C_6H_6: ether (1:9)—A crystalline solid (0·212 g) was obtained which was recrystallized from ether, m.p. 150–151°. It exhibited a very broad OH band at 3310 cm^{-1} but no carbonyl band in the IR spectrum: *m/e* 266 (M^+). (Found: C, 76·31: H, 11·18. $C_{17}H_{30}O_2$ requires: C, 76·64: H, 11·35%).

Oxidation of this diol (0·11 g) with Jones chromic acid reagent gave a diketone which could not be induced to crystallize: ν_{max} 1705 (C=O) cm^{-1}. It afforded a yellow di-2,4-dinitrophenylhydrazone, m.p. 246–248° (from $CHCl_3$–EtOH). (Found: C, 55·75: H, 5·60: N, 17·89. $C_{29}H_{34}O_8N_8$ requires: C, 55·94: H, 5·46: N, 18·00%).

Attempted isomerization of the above unknown ketone. (a) The diketone from the alcohol, m.p. 150–151°, was refluxed with 5% methanolic KOH (30 ml) for 4 hr. After the usual work-up the starting material was recovered, identified by TLC [hexane: ether (2:1)] and m.m.p. determination of its 2,4-dinitrophenylhydrazone derivative. In the next experiment refluxing was continued for 10 hr and the soln was left overnight at room temp. After work-up as usual starting material was recovered unchanged.

(b) The diketone in C_6H_6 (30 ml) was refluxed for 3 hr with a catalytic amount of *p*-TsOH. After the usual work-up, the starting material was recovered unchanged, identified by TLC and m.m.p. determination of its 2,4-dinitrophenylhydrazone derivative.

*2β-Benzoyloxy-4aβ,8,8-trimethyl-*trans,anti,trans-*perhydrophenanthryl-*9β-yl *nitrite* (VId). The hydroxy compound (VIa; 0·5 g) was dissolved in dry pyridine (30 ml) and the soln cooled below 0° and treated with dry gaseous nitrosyl chloride. The soln developed a blue colour and then turned deep orange. The mixture was poured into H_2O and extracted with $CHCl_3$. The organic extract was washed with H_2O and evaporated to afford a solid (0·523 g) which after recrystallization from ether–hexane had m.p. 128–130°: ν_{max} 1630 and 1590 (—ONO) and 1710 (benzoate C═O) and 1273 (benzoate —O—C) cm^{-1}. (Found: C, 71·83; H, 8·25; N, 3·17. $C_{24}H_{33}O_4N$ requires: C, 72·15; H, 8·33; N, 3·51%).

Photolysis of the nitrite (VId). The nitrite (VId; 0·523 g) was dissolved in dry C_6H_6 (400 ml), followed by I_2 (0·521 g). The brown coloured solution was irradiated by a 200 W Hanovia high mercury pressure lamp with a Pyrex filter under dry O_2 free N_2 and the reaction followed by TLC. After 1 hr, all nitrite had disappeared and the C_6H_6 soln was shaken with solid $NaHSO_3$ to discharge the colour of I_2. After filtration the solvent was removed under reduced pressure at room temp. The residue was treated with acetone and oxidised with Jones reagent. After the usual work-up a deep grown product (0·543 g) was obtained, which gave a green colour with a copper wire. This was dissolved in dry C_6H_6 (30 ml) and treated with Al_2O_3 (20 g) at room temp for 15 hr. The mixture was poured into an Al_2O_3 column containing C_6H_6 and elution with C_6H_6 afforded the ketone (Vc; 0·41 g) which after crystallization from ether–hexane showed m.p. 162–163°, identical with an authentic sample by m.p. and m.m.p. determination. Elution with C_6H_6–ether (98:2) gave the ether (XIc; 0·117 g) which after recrystallization from ether–hexane melted at 177–178°. The ether (XIc) on alkaline hydrolysis afforded a hydroxy ether (XIa), m.p. 138–139° (from ether–hexane). The ether (XIc) and the hydroxy ether (XIa) were identified by direct comparison (m.m.p.) with their corresponding products from $Pb(OAc)_4$ oxidation (see below). Elution with benzene–ether (30:70) afforded a semi-solid (0·03 g) which gave a green colour with a copper wire.

*Lead tetraacetate oxidation of tetrahydropyranyl 9β-hydroxy-4aβ,8,8-trimethyl-*trans,anti,trans-*prehydro-2β-phenanthryl ether* (IVb). A mixture of $Pb(OAc)_4$ (5 g) and anhyd $CaCO_3$ (5 g) was dried under reduced pressure and then heated with cyclohexane (250 ml) under reflux for 30 min with stirring. Then a soln of the pyranyl ether (IVb; 1·2 g) in cyclohexane (50 ml) was added to the above suspension, followed immediately by I_2 (1·27 g). The mixture was heated under reflux for 1 hr with two Philips 500-W photolamps. The cooled mixture was filtered and the filtered cake was washed thoroughly with ether. The combined organic solvents were washed with 1% NaOH aq and the colour of the I_2 was removed by washing with $NaHSO_3$ soln. Subsequent washing with H_2O and evaporation under reduced pressure afforded a yellowish liquid (1·5 g). The same experiment was repeated twice. The total product (4·5 g) in acetone (80 ml) was treated with 3N HCl (50 ml) and the soln was stirred at room temp for 3 hr. The mixture was diluted with H_2O and extracted with ether. The ether extract after washing with H_2O was evaporated to yield a dark brown oily liquid (3·9 g). This was chromatographed on alumina (80 g) and the following three fractions were obtained.

(i) Hexane:ether (9:1)—A yellowish liquid (1·4 g) was obtained which was not further investigated.

(ii) Hexane:ether (6:4)—A white solid (XIa; 0·872 g) was obtained which after recrystallization from ether–hexane showed m.p. 137–139°: ν_{max} 3360 (OH) cm^{-1}; NMR signals at 0·83 (3H, s) and 1·00 (3H, s) ($C\underline{H}_3$ on C-4a and C-8), 3·43–4·00 (4H, m) ($\underline{H}$ on C-2, C-9, and C-12). (Found: C, 76·78; H, 10·65. $C_{17}H_{28}O_2$ requires: C, 77·22; H, 10·67%).

(iii) Ether—A liquid (0·256 g) was obtained which was not further examined.

Acetylation of the hydroxy ether (XIa). The ether (XIa; 0·86 g) was dissolved in pyridine (5 ml) and treated with Ac_2O (5 ml). The resulting soln was refluxed for 50 min, diluted with H_2O, and extracted with ether. After washing with 1% Na_2CO_3 aq and H_2O, the ether extract was evaporated to give the acetoxy ether (XIb; 0·935 g) which after crystallization from ether–hexane had m.p. 110–112°; NMR signals at 0·86 (3H, s) and 1·00 (3H, s) ($C\underline{H}_3$ on C-4a and C-8), 2·06 (3H, s) ($OCOC\underline{H}_3$ on C-2), 3·50 (1H, m) ($\underline{H}$ at C-9), 3·66 (2H, AB q, $J = 8$ cps) (2 $\underline{H}$ on C-12), and 4·80 (1H broad m) ($\underline{H}$ on C-2). (Found: C, 74·03; H, 9·81. $C_{19}H_{30}O_3$ requires: C, 74·47; H, 9·87%).

Hydrolysis of the acetoxy ether (XIb). The acetate (XIb; 0·1 g) was refluxed for 2 hr with 3% methanolic KOH (10 ml). After the usual work-up the hydroxy ether (XIa; 0·05 g) was obtained, m.p. 138–139°.

*8β-Acetoxymethyl-2β-acetoxy-4aβ,8-dimethyl-*1,2,3,4,4a,4bα,5,6,7,8,10,10aα-*dodecahydrophenanthrene* (XIIb). The acetoxy compound (XIb; 0·935 g) was heated under reflux with Ac_2O (25 ml) and pyridine-HCl (0·06 g) for 5 hr. The mixture was treated with cold H_2O and extracted with ether. The ether extract was washed successively with H_2O, 1% K_2CO_3 aq and H_2O, and evaporated to yield a yellow liquid (1·12 g) which gave a positive halogen test with a copper wire. The liquid was chromatographed on alumina to give the following fractions:

(i) Hexane. This gave olefinic compound XIIb as a liquid (0·201 g) which was found to be homogeneous on TLC (hexane:C_6H_6 8:2). It gave a negative halogen test. The compound (b.p. 110–115°/0·15 mm) (bath temp) could not be induced to crystallize. (Found: C, 72·46; H, 9·28. $C_{21}H_{32}O_4$ requires: C, 72·38; H, 9·26%). Hydrolysis of the product (XIIb) with 3% methanolic KOH (20 ml) afforded the alcohol (XIIa) as a yellowish liquid (b.p. 125–138°/0·15 mm) (bath temp) which could not be induced to crystallize. (Found: C, 77·28; H, 10·61. $C_{17}H_{28}O_2$ requires: C, 77·22; H, 10·67%).

(ii) Hexane:C_6H_6 (1:1)--The chloro compound (XIII) was obtained as a semi-solid (0·801 g) which gave a positive halogen test. Refluxing of this chloro compound with 5% methanolic K_2CO_3 soln for 40 min yielded the ether (XIa) identified by direct comparison with an authentic sample.

Benzoylation of the ether (XIa). The hydroxy ether (XIa: 0·2 g) in pyridine (10 ml) was treated with benzoyl chloride (0·21 g) and the mixture was kept overnight at room temp. On working up as usual, the benzoate (XIc) was obtained as a crystalline solid (0·205 g) which on crystallization from ether had m.p. 179–181°: ν_{max} 1705 (benzoate C=O and 1275 (benzoate --O—C) cm^{-1}: NMR signals 0·88 (3H, s) and 1·00 (3H, s) ($C\underline{H}_3$ on C-4a and C-8), 3·36 (1H, m) ($\underline{H}$ on C-9), 3·63 (2$\underline{H}$, AB q, J = 7 cps) (2$\underline{H}$ on C-12), 5·00 (1$\underline{H}$, broad m) ($\underline{H}$ at C-2), and 7·21–8·35 (5H, m) (benzenoid $\underline{H}$). (Found: C, 77·79; H, 8·70. $C_{24}H_{32}O_3$ requires: C, 78·22; H, 8·75%).

8β-*Carboxy*-2β-*benzoyloxy*-4aβ.8-*dimethyl*-9-*keto*-trans,anti,trans-*perhydrophenanthrene* (XVa). To the ether (XIc: 0·2 g) in AcOH (4 ml, 99%) was added a soln of CrO_3 (0·18 g) in AcOH (1 ml, 80%) and the mixture was kept at room temp for 60 hr. After the usual work-up, the product (XVa) was isolated as a white solid (0·11 g) which on crystallization from $CHCl_3$:hexane had m.p. 280–282°; *m/e* 398 (M^+): 353 (M^+—COOH) and 276 (M^+—C_6H_5COOH): ν_{max} 1701 (unresolved benzoate, acid, and ketonic C=O) and 1270 (benzoate --O—C) cm^{-1}: NMR signals at 1·08 (3H, s) and 1·23 (3H, s) ($C\underline{H}_3$ on C-4a and C-8), 5·00 (1H, broad m) ($\underline{H}$ on C-2), and 7·25–8·20 (5H, m) (benzenoid $\underline{H}$). (Found: C, 71·91: H, 7·56. $C_{24}H_{30}O_5$ requires: C, 72·33: H, 7·59%).

8β-*Carboxymethyl*-2β-*benzoyloxy*-4aβ,8-*dimethyl*-9-keto-trans,anti,trans-*perhydrophenanthrene* (XVb). The keto acid (XVa) on esterification with ethereal CH_2N_2 gave a solid which on recrystallization from ether showed m.p. 184–185°: *m/e* 412 (M^+), and 290 (M^+—C_6H_5COOH). (Found: C, 72·31: H, 7·66. $C_{25}H_{32}O_5$ requires: C, 72·79: H, 7·82%).

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