957. *Studies in the Synthesis of Terpenes. Part V.* Some Bicyclic Intermediates for Triterpene Synthesis.*

By T. G. Halsall and M. Moyle.

The preparation of a number of compounds of potential use as intermediates for the construction of rings D and E of the δ-amyrin carbon skeleton has been investigated.

A possible route for the synthesis of pentacyclic triterpenes with the oleanane skeleton involves the cyclisation of a tetracyclic intermediate such as (I) (cf. refs. 1—3). As

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* Part IV, *J.*, 1959, 2798.

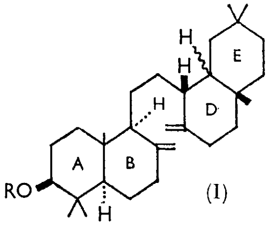
[1] Halsall and Thomas, *J.*, 1956, 2431.

[2] Sondheimer and Wolfe, *Canad. J. Chem.*, 1959, **37**, 1870.

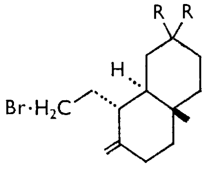
[3] Corey, Hess, and Proskow, *J. Amer. Chem. Soc.*, 1959, **81**, 5259; Stork, Davies, and Meisels, *ibid.*, p. 5516; Corey and Sauers, *ibid.*, 1957, **79**, 3925; 1959, **81**, 1739; Romann, Frey, Stadler, and Eschenmoser, *Helv. Chim. Acta*, 1957, **40**, 1900; Sondheimer and Elad, *Proc. Chem. Soc.*, 1957, 206; *J. Amer. Chem. Soc.*, 1959, **81**, 4429; King, Ritchie, and Timmons, *Chem. and Ind.*, 1956, 1230.

precursors of the D/E half of such an intermediate the bromide (II), the acids (IV) and (V), and related compounds are of potential interest.

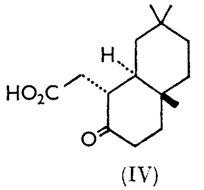
The preparation of the octalone (VI) has already been described [1] but its direct reduction to the decalone (VIII) with lithium in liquid ammonia in the absence of a proton source could not be brought about. Reduction in the presence of ethanol gave, as well as the diol (X), some of the decalone (VIII), treatment of which with methylmagnesium iodide gave the two diols (XI and XII).



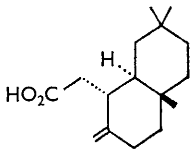
(I)



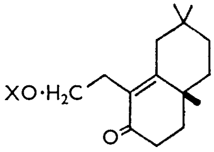
(II) R = Me
(III) R = H



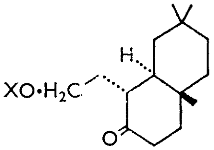
(IV)



(V)

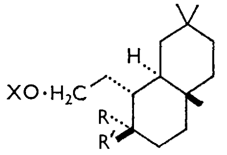


(VI) X = H
(VII) X = THP

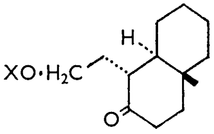


(VIII) X = H
(IX) X = THP

THP = tetrahydro-2-pyranyl



(X) X=H, R=H, R′= OH
(XI) X=H, R=Me, R′=OH
(XII) X=H, R = OH, R′=Me
(XIII) X= THP, R=H, R′= OH



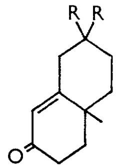
(XIV) X = THP

The tetrahydropyranyl ether (IX) of the trimethyldecalone (VIII) has now been prepared from the octalone (VI) by conversion of the latter into its tetrahydropyranyl ether (VII), reduction with lithium in liquid ammonia to the decalol (XIII), and oxidation with chromic acid in pyridine. The corresponding methyldecalone ether (XIV) has also been prepared.

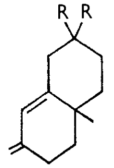
By use of the Wittig–Sköllkopf procedure [4] the oxygen atom of a carbonyl group can be replaced by methylene. Sondheimer and Wolfe [2] have already converted the octalone (XV) into the trimethylmethyleneoctalin (XVII) by means of methylenetriphenylphosphorane. They stated [2] that their product was unstable. We have repeated their procedure and find that our product is stable over a period of six months. The monomethyloctalone (XVI) has also been converted into the methylene derivative (XVIII). When this method was applied to the tetrahydropyranyl ether (VII) of the octalone (VI) no reaction occurred. On the other hand the decalone ethers (IX) and (XIV) gave, after removal of the ether group, the methylene derivatives (XIX) and (XX). The Wittig reaction must therefore be subject to steric interference. Attempts were made to convert these hydroxyethylmethylenedecalins into the corresponding bromides (II) and (III) by formation of the toluene-*p*-sulphonates followed by treatment with calcium bromide in ethanol.[5] Bromine-containing products were obtained but their infrared spectra had no band indicative of a methylene group or a trisubstituted double bond. It appears likely that the double bond has moved to the tetrasubstituted 1,2-position during the treatment with calcium bromide as the toluene-*p*-sulphonates still had bands at 1640 and 895 cm.$^{-1}$, but the mechanism of such a change is not clear. Subsequently the bromide (III) was prepared by another route.

[4] Wittig and Sköllkopf, *Chem. Ber.*, 1954, **87**, 1318.
[5] Eglinton and Whiting, *J.*, 1950, 3650.

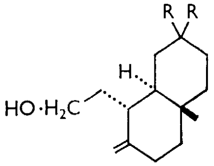
Attention was next turned to the synthesis of the acids (IV) and (V) from the trimethyloctalone (XV). Because of its greater availability model experiments were first carried out with the methyloctalone (XVI). With ethyl bromoacetate in benzene in the presence of sodium t-pentyl oxide [6] this gave the substituted octalone (XXI).* It showed maximal light absorption at the unusually low wavelength of 2440 Å, as compared with a calculated value of 2520 Å. The octalone ester (XXI) was hydrolysed to the acid (XXII) which was reduced with lithium in liquid ammonia, the formation of a *trans*-decalin and an equatorially disposed 1-side-chain being expected. The crude product was methylated and oxidised to the keto-ester (XXIII) and thence gave the acid (XXIV). The keto-ester (XXIII) was converted into its ethylenedioxy-derivative which was reduced with lithium aluminium hydride to the hydroxy-ketal (XXV). Hydrolysis of this did not give a keto-alcohol. Instead two crystalline fractions, both melting over a range of temperature, were obtained and neither had an infrared band indicative of a carbonyl group. Bands indicative of a hydroxyl group and an ether linkage were found. The two fractions are therefore mixtures of the hemiketals (XXVI) and (XXVII). Hydrolysis of the hydroxyethyldecalone tetrahydropyranyl ether (XIV) gave the same mixture.



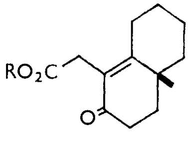
(XV) R = Me
(XVI) R = H



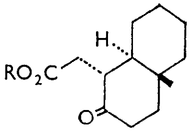
(XVII) R = Me
(XVIII) R = H



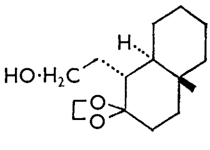
(XIX) R = Me
(XX) R = H



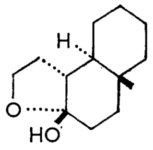
(XXI) R = Et
(XXII) R = H



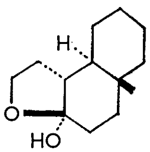
(XXIII) R = Me
(XXIV) R = H



(XXV)



(XXVI)



(XXVII)

The keto-acid (XXIV), with methylmagnesium iodide, gave a mixture from which a neutral and an acidic compound were isolated. The former had the formula $C_{14}H_{22}O_2$ and possessed a lactone group ($\nu_{max.}$ 1765 cm.$^{-1}$). It is formulated as the lactone (XXIX) of the hydroxy-acid (XXVIII) with the axial hydroxyl group, attack by the Grignard reagent having occurred from the side of the ring opposite to that occupied by the side-chain. The ring fusion of the lactone is therefore *cis*. Reduction of the lactone gave the diol (XXX). With phosphoryl chloride this gave a product containing only one oxygen atom and no chlorine. Its infrared spectrum indicated the presence of an ether linkage but no hydroxyl group, and indicates that the product is the cyclic ether (XXXI).

The acidic compound is the hydroxy-acid (XXXII) with an equatorial hydroxyl group. Reduction of its methyl ester with lithium aluminium hydride gave a second diol (XXXIII). The equatorial nature of its tertiary hydroxyl group, and hence of that of the hydroxy-acid, was confirmed by treatment of the diol with phosphoryl bromide in

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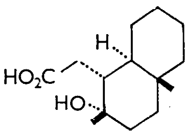
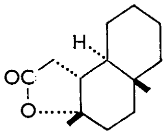
* The initial work on this reaction was carried out by O. M. N. Behr to whom we express our thanks (cf. Behr, B.Sc. Thesis, Oxford, 1958).

[6] Cf. Conia, *Bull. Soc. chim. France*, 1954, 690.

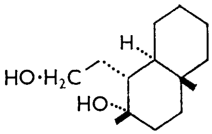
pyridine. The product contained a methylene group arising from the dehydration of an equatorial tertiary hydroxy-group and had the formula $C_{14}H_{23}Br$. It therefore had structure (III). Dehydration of the methyl ester of the hydroxy-acid (XXXII) with phosphoryl chloride in pyridine gave the corresponding methylene derivative (XXXIV).



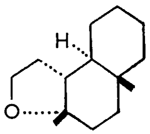
(XXVIII)



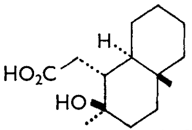
(XXIX)



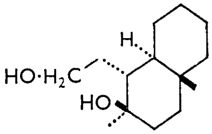
(XXX)



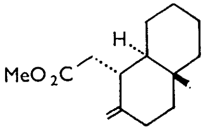
(XXXI)



(XXXII)

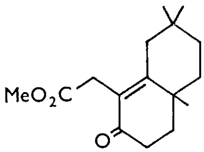


(XXXIII)

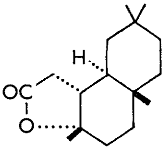


(XXXIV)

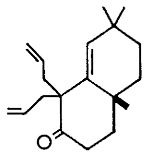
After the sequence of reactions described above had been elucidated, the trimethyloctalone (XV) was converted into the ester (XXXV) by treatment with ethyl bromoacetate and base, followed by hydrolysis of the product and subsequent methylation. The reaction did not go as well as in the monomethyloctalone case. The ester (XXXV) also had maximal light absorption at 2440 Å. The ester (XXXV) was converted into the



(XXXV)



(XXXVI)



(XXXVII)

acid which was reduced with lithium in ammonia, and the product was subjected to the same sequence of reactions as described above; the decalone-acid (IV) was thus obtained. When this was treated with methylmagnesium iodide only the lactone (XXXVI), with the tertiary oxygen atom in the less useful axial configuration, was isolated. Reduction of the lactone gave the diol (XII) already prepared by Halsall and Thomas.[1] Because of the configuration of the tertiary hydroxyl group dehydration of the diol will not give a methylene group.

When the trimethyloctalone was treated with the more reactive allyl bromide only the disubstituted product (XXXVII) was obtained.

EXPERIMENTAL

M. p.s were determined on a Kofler block and are corrected. The alumina used for chromatography (unless otherwise stated) was alumina of activity I—II which had been deactivated with 5% of 10% aqueous acetic acid. Light petroleum refers to the fraction with b. p. 60—80°. Unless otherwise stated, ultraviolet spectra were determined for EtOH solutions and infrared spectra on natural films.

All the compounds being racemic, (±)-prefixes are omitted.

1-2′-Hydroxyethyl-10-methyl-$\Delta^{1(9)}$*-octal-2-one.*—This octalone was prepared by the method of Halsall and Thomas.[1] The *semicarbazone* was obtained as needles, m. p. 208° (decomp.), from ethanol (Found: C, 63·6; H, 8·75. $C_{14}H_{23}N_3O_2$ requires C, 63·35; H, 8·75%). The octalone (10·1 g.) was converted into its tetrahydropyranyl ether by treatment with 2,3-dihydropyran (35 c.c.) and 10N-hydrochloric acid (0·25 c.c.) at 20° for 7 days. Ether was added and the solution washed with potassium carbonate solution. Removal of the solvent gave the tetrahydropyranyl ether (13·2 g.) as an oil, n_D^{22} 1·5220, $\nu_{max.}$ 1665, 1080, 1070, and 1033 cm.$^{-1}$, which was used for subsequent transformations without further purification.

10-*Methyl*-1-2′-*tetrahydropyranyloxyethyl*-trans-*decal*-2-*one* (XIV).—10-Methyl-1-2′-tetrahydropyranyloxyethyl-$\Delta^{1(9)}$-octal-2-one (10·4 g.) in ether (160 c.c.) was added during 15 min. to a stirred solution of lithium (2 g.) in ammonia (500 c.c.). After a further 45 min. ethanol was slowly added. After evaporation of the ammonia water was added and the product isolated with ether. The resulting viscous oil ($\nu_{max.}$ 3400, 1710, 1080, 1070, and 1033 cm.$^{-1}$; no band at 1665 cm.$^{-1}$) (9 g.) in pyridine (100 c.c.) was added to chromic oxide (10 g.) in pyridine (100 c.c.) and the mixture kept at 20° for 20 hr. After dilution with water the product was isolated by continuous ether-extraction. Evaporation of the extract gave an oil (7·2 g.) which was adsorbed from light petroleum on alumina (350 g.). Elution with light petroleum (500 c.c.) gave an oil (2·8 g.), the infrared spectrum of which indicated that it was non-ketonic. Further elution with benzene–light petroleum (1 : 4; 500 c.c.) gave 10-*methyl*-1-2′-*tetrahydropyranyloxyethyl*-trans-*decal*-2-*one* (2·95 g.), b. p. 170—180° (bath)/0·1 mm., n_D^{20} 1·5000 (Found: C, 73·55; H, 10·05. $C_{18}H_{30}O_3$ requires C, 73·45; H, 10·25%), $\nu_{max.}$ 1710, 1080, 1070, and 1033 cm.$^{-1}$.

1-2′-*Hydroxyethyl*-7,7,10-*trimethyl*-$\Delta^{1(9)}$-*octal*-2-*one*.—This octalone was prepared by the method of Halsall and Thomas.[1] The octalone (3·5 g.) was converted into its tetrahydropyranyl ether by treatment with 2,3-dihydropyran (10 c.c.) and 10N-hydrochloric acid (0·1 c.c.) at 20° for 7 days. Ether was added and the solution washed with potassium hydrogen carbonate solution. Removal of the solvent gave the ether as an oil (4·6 g.), n_D^{20} 1·5185, $\lambda_{max.}$ 2520 Å (ε 12,500), $\nu_{max.}$ 1665, 1610, 1080, 1070, and 1032 cm.$^{-1}$. The ether was used for subsequent transformations without further purification.

7,7,10-*Trimethyl*-1-2′-*tetrahydropyranyloxyethyl*-trans-*decal*-2-*one* (IX).—7,7,10-Trimethyl-1-2′-tetrahydropyranyloxyethyl-$\Delta^{1(9)}$-octal-2-one (8·8 g.) in ether (150 c.c.) was added during 15 min. to a stirred solution of lithium (2·0 g.) in ammonia (500 c.c.). After a further 45 min. ethanol was added. The ammonia was allowed to evaporate. Water was added and the product was isolated with ether as a viscous oil (7·9 g.), $\nu_{max.}$ 3400, 1710w, 1080, 1070, and 1033 cm.$^{-1}$ (no band at 1665 cm.$^{-1}$). The total product was oxidised without further purification in pyridine (80 c.c.) with chromic oxide (8 g.) in pyridine (80 c.c.) for 20 hr. at 20°. After addition of water the product was isolated by continuous ether-extraction. Evaporation of the extract afforded an oil (6·8 g.) which was adsorbed from light petroleum on alumina (350 g.). After elution of a non-ketonic fraction (2·4 g.) with light petroleum (500 c.c.), elution with benzene–light petroleum (500 c.c.; 1 : 4) afforded 7,7,10-*trimethyl*-1-2′-*tetrahydropyranyloxyethyl*-trans-*decal*-2-*one* (2·45 g.), b. p. 175—180° (bath)/0·1 mm., n_D^{20} 1·4980 (Found: C, 74·2; H, 10·8. $C_{20}H_{34}O_3$ requires C, 74·5; H, 10·65%), $\nu_{max.}$ 1710, 1080, 1070, and 1033 cm.$^{-1}$.

10-*Methyl*-2-*methylene*-$\Delta^{1(9)}$-*octalin* (XVIII).—Ethereal butyl-lithium (1 equiv.) was added under nitrogen to a stirred suspension of methyltriphenylphosphonium iodide (4·1 g., 0·01 mol.) in tetrahydrofuran (125 c.c.). Stirring was continued a further 2 hr. after which a few crystals of the iodide still remained. 10-Methyl-$\Delta^{1(9)}$-octal-2-one [7] (1·64 g., 0·01 mol.) in tetrahydrofuran (10 c.c.) was added, a precipitate being immediately formed. The mixture was kept under nitrogen at 20° overnight, then acetone was added dropwise to destroy any unchanged methylenetriphenylphosphorane. The solvents were removed and the residue was partitioned between 50% aqueous methanol (80 c.c.) and light petroleum (250 c.c.). After further extraction of the aqueous phase the light petroleum extracts afforded a residue to which light petroleum (50 c.c.) was added. The solution was decanted from triphenylphosphine oxide and adsorbed on alumina (75 g.). Elution with light petroleum (250 c.c.) afforded 10-*methyl*-2-*methylene*-$\Delta^{1(9)}$-*octalin* (1·55 g.), b. p. 106—108°/20 mm., n_D^{20} 1·5260 (Found: C, 89·0; H, 11·1. $C_{12}H_{18}$ requires C, 88·8; H, 11·2%), $\lambda_{max.}$ 2390 Å (ε 17,000), $\nu_{max.}$ 3080w, 1640, and 890 cm.$^{-1}$.

7,7,10-*Trimethyl*-2-*methylene*-$\Delta^{1(9)}$-*octalin* (XVII).—This was prepared by the procedure described above. 7,7,10-Trimethyl-$\Delta^{1(9)}$-octal-2-one [1,8] (1·92 g.) afforded 7,7,10-trimethyl-2-methylene-$\Delta^{1(9)}$-octalin (1·50 g.), b. p. 107—109°/20 mm., n_D^{18} 1·5185 (Found: C, 88·45; H, 11·25. Calc. for $C_{14}H_{22}$: C, 88·35; H, 11·65%), $\lambda_{max.}$ 2390 Å (ε 17,000), $\nu_{max.}$ 1620, 1385, 1365, and 895 cm.$^{-1}$ [lit.,[2] b. p. (bath) 130—140°/23 mm., n_D^{24} 1·5100].

[7] Gaspert, Halsall, and Willis, *J.*, 1958, 624.

[8] Eschenmoser, personal communication.

Attempted Preparation of 7,7,10-*Trimethyl*-2-*methylene*-1-2′-*tetrahydropyranyloxyethyl*-$\Delta^{1(9)}$-*octalin*.—A suspension of methyltriphenylphosphonium iodide (10·25 g., 0·025 mol.) in tetrahydrofuran (150 c.c.) was treated with ethereal phenyl-lithium in the manner described above. 7,7,10-Trimethyl-1-2′-tetrahydropyranyloxyethyl-$\Delta^{1(9)}$-octal-2-one (VII) (1·6 g., 0·005 mol.) was added to the resulting methylene triphenylphosphorane, and the mixture was heated under reflux under nitrogen for 36 hr. Acetone was added to destroy the excess of reagent, and the solvent evaporated, to give a residue which was worked up as described above. The resulting light petroleum solution was adsorbed on alumina (100 g.). Elution with light petroleum (350 c.c.) gave an oil (0·65 g.), the infrared spectrum of which had aromatic bands but no band at 890 cm.$^{-1}$ indicative of $=CH_2$. Further elution with benzene–light petroleum (1 : 2; 350 c.c.) afforded an oil (1·3 g.), the infrared spectrum of which was identical with that of 1-2′-tetrahydropyranyloxyethyl-7,7,10-trimethyl-$\Delta^{1(9)}$-octal-2-one.

1-2′-*Hydroxyethyl*-10-*methyl*-2-*methylene*-trans-*decalin* (XX).—A suspension of methyltriphenylphosphonium iodide (6 g.) in tetrahydrofuran (150 c.c.) was treated with ethereal phenyl-lithium (1 equiv.), and 10-methyl-1-2′-tetrahydropyranyloxy-*trans*-decal-2-one (1·73 g.) added to the derived methylene triphenylphosphorane. The mixture was kept under nitrogen at 20° overnight, during which a white precipitate separated. Acetone was added and the solvent then removed to give a residue which was worked up as described above. The resulting light petroleum solution was adsorbed on alumina (150 g.). Elution with light petroleum (400 c.c.) gave an oil (1580 mg.), $\nu_{max.}$ 1640, 895 ($=CH_2$), 1080, 1070, and 1033 cm.$^{-1}$ (no band at 1710 cm.$^{-1}$).

The total product in methanol (25 c.c.) and 0·1N-hydrochloric acid (10 c.c.) was shaken overnight. After dilution with water ether-extraction afforded a product which was adsorbed from light petroleum on alumina (100 g.). Elution with light petroleum (300 c.c.) gave an oil, the infrared spectrum of which indicated that it was aromatic. Further elution with benzene–light petroleum (400 c.c.; 1 : 1) gave 1-2′-*hydroxyethyl*-10-*methyl*-2-*methylene*-trans-*decalin* (750 mg.), b. p. 140° (bath)/0·1 mm., n_D^{23} 1·5140 (Found: C, 80·5; H, 11·5. $C_{14}H_{24}O$ requires C, 80·7; H, 11·6%), $\nu_{max.}$ 3400, 1640, 890 cm.$^{-1}$.

1-2′-*Hydroxyethyl*-7,7,10-*trimethyl*-2-*methylene*-trans-*decalin* (XIX).—7,7,10-Trimethyl-1-2′-tetrahydropyranyloxyethyl-*trans*-decal-2-one (1·85 g.) was added to a solution of methylenetriphenylphosphorane [from methyltriphenylphosphonium iodide (6 g.)] in tetrahydrofuran (150 c.c.) under nitrogen. The mixture was kept overnight at 20°. Acetone was then added and the solvent removed under reduced pressure, to give a residue which was partitioned between 50% aqueous methanol (100 c.c.) and light petroleum (250 c.c.). The aqueous phase was extracted with light petroleum (2 × 75 c.c.), and the combined light petroleum solutions were then worked up to give a residue which was extracted with light petroleum (75 c.c.). The solution was placed on alumina (150 g.). Elution with light petroleum (450 c.c.) gave an oil (1·35 g.), $\nu_{max.}$ 1640, 895 ($C=CH_2$), 1080, 1070, and 1033 cm.$^{-1}$ (no band at 1710 cm.$^{-1}$). This was shaken in methanol (25 c.c.) with 0·3N-hydrochloric acid (5 c.c.) for 16 hr. After addition of water ether-extraction afforded a product which was adsorbed from light petroleum on alumina (100 g.). Elution with light petroleum (300 c.c.) gave an oil (520 mg.), the infrared spectrum of which indicated that it contained aromatic material. Further elution with benzene–light petroleum (400 c.c.; 1 : 1) gave 1-2′-*hydroxyethyl*-7,7,10-*trimethyl*-2-*methylene*-trans-*decalin* (530 mg.), b. p. 140—145° (bath)/0·1 mm., n_D^{20} 1·5065 (Found: C, 81·2; H, 11·8. $C_{16}H_{28}O$ requires C, 81·3; H, 11·95%), $\nu_{max.}$ 3400, 1640, and 895 cm.$^{-1}$.

Ethyl 10-*methyl*-2-*oxo*-1-$\Delta^{1(9)}$-*octalylacetate* (XXI).—10-Methyl-$\Delta^{1(9)}$-octal-2-one (33 g.) in benzene (150 c.c.) was added to a solution of sodium t-pentyloxide [from sodium (8 g.)] in benzene (150 c.c.) under nitrogen. Ethyl bromoacetate (39 g., 1·2 mol.) in ether (150 c.c.) was added with stirring during 2 hr. The mixture was then stirred overnight at 20°. Water (250 c.c.) was added and the organic phase was separated and combined with an ethereal extract of the aqueous layer. After the solvents had been removed, distillation under reduced pressure yielded (i) a fore-run (7 g.), b. p. below 120° (bath)/0·2 mm., consisting mainly of unchanged 10-methyl-$\Delta^{1(9)}$-octal-2-one, and (ii) a fraction, b. p. 120—140°/0·2 mm. Redistillation of the latter fraction afforded the *ester* (24 g.), b. p. 126—128°/0·2 mm., n_D^{25} 1·5085 (Found: C, 71·75; H, 8·95. $C_{15}H_{22}O_3$ requires C, 71·97; H, 8·85%), $\lambda_{max.}$ 2440 Å (ε 13,500) $\nu_{max.}$ 1738, 1665, and 1620 cm.$^{-1}$. The 2,4-*dinitrophenylhydrazone* was obtained as leaflets, m. p. 128—130° (from ethanol) (Found: C, 58·75; H, 5·95. $C_{21}H_{26}O_6N_4$ requires C, 58·6; H, 6·1%), $\lambda_{max.}$ 3840 Å (ε 30,000 in $CHCl_3$).

The ester (7 g.), methanol (75 c.c.), and 2N-aqueous potassium hydroxide solution (50 c.c.)

were heated under reflux under nitrogen for 1·5 hr. After acidification the product was isolated and characterised as the *cyclohexylamine salt*, which crystallised from ethyl acetate as needles, m. p. 132° (rapid heating) (Found: C, 70·75; H, 9·65. $C_{19}H_{31}O_3N$ requires C, 71·0; H, 9·7%), $\lambda_{max.}$ 2440 Å (ε 12,500). Regeneration of the acid from the salt gave a gum.

10-*Methyl*-2-*oxo*-trans-1-*decalylacetic Acid* (XXIV).—The acid (XXII) [5·8 g., from the cyclohexylamine salt (9·0 g.)] in ether (150 c.c.) was added during 15 min. to a stirred solution of lithium (1·5 g.) in liquid ammonia (600 c.c.). After a further 45 min. ethanol was slowly added to discharge the blue colour and then the ammonia was evaporated. The residue was acidified and the product isolated with ether. The acidic material was separated from a small quantity of neutral material (0·5 g.) (possibly lactone) by extraction with potassium hydrogen carbonate followed by acidification and ether-extraction. It was methylated with diazomethane, and the resulting methyl ester ($\nu_{max.}$ 3400w, 1735s, and 1710s; no band at 1665 cm.$^{-1}$) was oxidised with an 8N-solution of chromic acid in acetone. The resulting keto-ester was hydrolysed with methanolic potassium hydroxide, to give the *acid* (XXIV) which crystallised from light petroleum—benzene as needles (3·1 g.), m. p. 117—119° (Found: C, 69·95; H, 9·05. $C_{13}H_{20}O_3$ requires C, 69·6; H, 9·0%). The mother-liquors were evaporated and the residue was treated with cyclohexylamine in ethyl acetate, to give the *cyclohexylamine salt* as needles, m. p. 128° (rapid heating) (from ethyl acetate) (Found: C, 70·4; H, 10·3. $C_{19}H_{39}O_3N$ requires C, 70·55; H, 10·3%). Decomposition of the salt afforded a further yield of acid (0·7 g.), m. p. 117—119°.

The acid with ethereal diazomethane gave its *methyl ester* (XXIII), b. p. 104—106°/0·1 mm., n_D^{25} 1·4915 (Found: C, 70·75; H, 9·5. $C_{14}H_{22}O_3$ requires C, 70·55; H, 9·3%), $\nu_{max.}$ 1735 and 1710 cm.$^{-1}$.

Methyl 2-*Ethylenedioxy*-10-*methyl*-trans-1-*decalylacetate*.—The preceding ester (XXIII) (2·4g.), ethylene glycol (3·0 c.c.), and toluene-*p*-sulphonic acid (100 mg.) in benzene (100 c.c.) were heated under a Dean and Stark apparatus. The benzene solution was washed with potassium hydrogen carbonate solution, and the solvent was then evaporated, to give the *ketal* (2·6 g.), b. p. 106—108°/0·1 mm., n_D^{25} 1·4945 (Found: C, 68·3; H, 9·45. $C_{16}H_{26}O_4$ requires C, 68·05; H, 9·3%), $\nu_{max.}$ 1110, 1060, 1040, and 1020 cm.$^{-1}$ (no band at 1710 cm.$^{-1}$).

2-*Ethylenedioxy*-1-2′-*hydroxyethyl*-10-*methyl*-trans-*decalin* (XXV).—The ketal ester last mentioned (2·0 g.) and lithium aluminium hydride (250 mg.) in ether (75 c.c.) were heated under reflux for 3 hr. The excess of hydride was decomposed with ethyl acetate and then water, and the product was isolated with ether. Crystallisation from light petroleum (b. p. 40—60°) gave 2-*ethylenedioxy*-1-2′-*hydroxyethyl*-10-*methyl*-trans-*decalin* as needles (1·6 g.), m. p. 70—71° (Found: C, 70·55; H, 10·1. $C_{15}H_{26}O_3$ requires C, 70·85; H, 10·3%), $\nu_{max.}$ (melt) 3400, 1100, 1070, and 1050 cm.$^{-1}$ (no band at 1738 cm.$^{-1}$).

Hydrolysis of the Ketal (XXV).—The ketal (800 mg.), methanol (20 c.c.), and 5N-hydrochloric acid (6 c.c.) were heated under reflux for 1 hr. Water was added and the product ($\nu_{max.}$ 3450, 1095, 1065, 1025 cm.$^{-1}$; no band at 1710 cm.$^{-1}$) isolated with ether. The total product was adsorbed from light petroleum on alumina (80 g.). Elution with light petroleum–benzene (2 : 1) gave a gum which crystallised. Recrystallisation from a small volume of light petroleum gave prisms, m. p. 88—110°, a mixture of the hemiketals (XXVI) and (XXVII) (Found: C, 74·45; H, 10·45. Calc. for $C_{13}H_{22}O_2$: C, 74·25; H, 10·55%), $\nu_{max.}$ 3450, 1095, and 1065 cm.$^{-1}$. Further elution with benzene–light petroleum afforded a similar mixture which crystallised from a small volume of light petroleum (b. p. 40—60°) as needles, m. p. 90—114° (Found: C, 74·5; H, 10·7%), $\nu_{max.}$ 3450, 1095, and 1065 cm.$^{-1}$ (no band at 1710 cm.$^{-1}$).

Hydrolysis of 10-*Methyl*-1-2′-*tetrahydropyranyloxyethyl*-trans-*decal*-2-*one* (XIV).—The tetrahydropyranyl ether (270 mg.) was kept overnight at 20° in methanol (10 c.c.) containing 10N-hydrochloric acid (0·15 c.c.); after dilution with water, ether-extraction afforded a product which crystallised from a small volume of light petroleum (b. p. 40—60°) as a mixture of needles and prisms (110 mg.), m. p. 88—114° (Found: C, 74·35; H, 10·25%), $\nu_{max.}$ 3450 and 1095 cm.$^{-1}$. No band at 1710 cm.$^{-1}$.

Reaction of the Acid (XXIV) *with Methylmagnesium Iodide*.—The keto-acid (3·0 g.) in dioxan (50 c.c.) was added to a solution of methylmagnesium iodide [from magnesium (3·0 g.) and methyl iodide (10 c.c.)] in ether (100 c.c.), and the mixture was heated under reflux for 4 hr. Solid ammonium chloride was then added, followed by dilute hydrochloric acid. The crude product was isolated with ether and the acidic fraction separated from the neutral fraction by extraction with potassium hydrogen carbonate solution. Crystallisation of the neutral fraction from light petroleum gave the *lactone* of 2α-*hydroxy*-2β,10β-*dimethyl*-trans-1α-*decalylacetic acid lactone* (XXIX) as leaflets (1·54 g.), m. p. 98—99° (Found: C, 75·85; H, 9·89. $C_{14}H_{22}O_2$ requires C, 75·65; H, 9·95%), $\nu_{max.}$ (Nujol) 1765 cm.$^{-1}$.

Crystallisation of the acidic fraction from benzene gave 2β-*hydroxy*-2α,10β-*dimethyl*-trans-1α-*decalylacetic acid* (XXXII) as needles (540 mg.), m. p. 155—157° (softening at ~150°) (Found: C, 69·8; H, 9·7. $C_{14}H_{24}O_3$ requires C, 69·95; H, 10·05%). Methylation of the acid with ethereal diazomethane gave the methyl ester as a viscous oil, n_D^{20} 1·4970 (Found: C, 70·65; H, 10·15. $C_{15}H_{26}O_3$ requires C, 70·85; H, 10·3%), $\nu_{max.}$ 3400 and 1738 cm.$^{-1}$ (no band at 1710 cm.$^{-1}$).

1α-2′-*Hydroxyethyl*-2β,10β-*dimethyl*-trans-*decal*-2α-*ol* (XXX).—A cooled solution of the lactone (XXIX) (1200 mg.) in ether (60 c.c.) was treated with lithium aluminium hydride (350 mg.), and then the mixture was heated under reflux for 1 hr. After decomposition of the excess of reagent with ethyl acetate and dilute sulphuric acid the product was isolated with ether and crystallised from benzene–light petroleum to give 1α-2′-*hydroxyethyl*-2β,10β-*dimethyl*-trans-*decal*-2α-*ol* (1030 mg.) as prisms, m. p. 116—118° (Found: C, 74·5; H, 11·3. $C_{14}H_{26}O_2$ requires C, 74·3; H, 11·6%).

1α-2′-*Hydroxyethyl*-2α,10β-*dimethyl*-trans-*decal*-2β-*ol* (XXXIII).—The ester (450 mg.) of the acid (XXXII) was treated with lithium aluminium hydride as described above; the resulting 1α-2′-*hydroxyethyl*-2α,10β-*dimethyl*-trans-*decal*-2β-*ol* crystallised from benzene–light petroleum as needles (350 mg.), m. p. 141° (softening at ~133°) (Found: C, 74·0; H, 11·4. $C_{14}H_{26}O_2$ requires C, 74·3; H, 11·6%).

Reaction of 1α-2′-*Hydroxyethyl*-2β,10β-*dimethyl*-trans-*decal*-2α-*ol with Phosphoryl Chloride.*—The diol (500 mg.) in pyridine (10 c.c.) was treated at 0° with phosphoryl chloride (1·0 c.c.) and kept overnight at 20°. Ice was added and the product was isolated with ether and adsorbed from light petroleum on alumina (50 g.). Elution with light petroleum (150 c.c.) afforded *perhydro*-2,10-*dimethylnaphtho*(2′,1′-2,3)*furan* (XXXI) (420 mg.), b. p. 105—110° (bath)/0·2 mm., n_D^{18} 1·5010 (Found: C, 81·1; H, 11·4. $C_{14}H_{24}O$ requires C, 80·7; H, 11·6%), $\nu_{max.}$ 1040s and 1070m cm.$^{-1}$.

1-2′-*Bromoethyl*-10-*methyl*-2-*methylene*-trans-*decalin* (III).—A cooled solution of 1α-2′-hydroxyethyl-2α,10β-dimethyl-*trans*-decal-2β-ol (350 mg.) in pyridine (8 c.c.) was treated with phosphoryl bromide (1·2 g.) and was kept overnight at 20°. Ice was added and the product was isolated with ether and adsorbed from light petroleum on alumina (35 g.). Elution with light petroleum (100 c.c.) afforded 1-2′-*bromoethyl*-10-*methyl*-2-*methylene*-trans-*decalin* (290 mg.), b. p. 110—115° (bath)/0·1 mm., n_D^{20} 1·5305 (Found: C, 61·95; H, 8·5. $C_{14}H_{23}Br$ requires C, 62·0; H, 8·55%), $\nu_{max.}$ 3085w, 1645, and 895 cm.$^{-1}$.

10β-*Methyl*-2-*methylene*-trans-1α-*decalylacetic Acid* (cf. XXXIV).—A cooled solution of the ester (400 mg.) of the hydroxy-acid (XXXI) in pyridine (5 c.c.) was treated with phosphoryl chloride (1 c.c.) and kept at 20° overnight. Ice was added and the product was isolated with ether and adsorbed from light petroleum on alumina (40 g.). Elution with light petroleum (150 c.c.) gave the *ester* (XXXIV) (350 mg.), b. p. 130—135° (bath)/0·1 mm., n_D^{20} 1·4975 (Found: C, 76·25; H, 10·05. $C_{15}H_{24}O_2$ requires C, 76·25; H, 10·25%), $\nu_{max.}$ 1738, 1640, 890 cm.$^{-1}$.

Hydrolysis afforded the acid, which was characterised as its *cyclohexylamine salt*, needles (from ethyl acetate), m. p. 138° (rapid heating) (Found: C, 74·9; H, 10·95. $C_{20}H_{35}NO_2$ requires C, 74·7; H, 10·95%). Regeneration of the *acid* from the salt gave needles [from light petroleum (b. p. 40—60°)], m. p. 97—99° (Found: C, 75·55; H, 10·15. $C_{14}H_{22}O_2$ requires C, 75·65; H, 9·95%).

Reaction of 7,7,10-*Trimethyl*-$\Delta^{1(9)}$-*octal*-2-*one with Ethyl Bromoacetate.*—(*a*) The octalone (5·8 g.) was added to a solution of potassium (3·0 g.) in t-butyl alcohol (100 c.c.) under nitrogen. The solution was heated under reflux and ethyl bromoacetate (14·0 g.) in t-butyl alcohol (50 c.c.) was added during 1 hr. After a further 2 hours' heating the solvent was removed under reduced pressure, water was added, and the product isolated with ether.

The crude product was hydrolysed under nitrogen with 2N-methanolic potassium hydroxide, and the acidic fraction separated from the neutral fraction. The latter was distilled under reduced pressure to give oily starting material (1·8 g.). The acidic fraction was methylated with ethereal diazomethane and adsorbed from light petroleum on alumina (300 g.). Elution with 1 : 2 benzene–light petroleum (1200 c.c.) afforded *methyl* 7,7,10-*trimethyl*-2-*oxo*-1-$\Delta^{1(9)}$-*octalylacetate* (XXXV) (1·2 g.), b. p. 145—150° (bath)/0·1 mm., n_D^{25} 1·5055 (Found: C, 72·8; H, 9·25. $C_{16}H_{24}O_3$ requires C, 72·7; H, 9·15%), $\lambda_{max.}$ 2440 Å (ε 12,600), $\nu_{max.}$ 1738, 1665, and 1620 cm.$^{-1}$. The 2,4-*dinitrophenylhydrazone* was obtained as needles, m. p. 168—170° (from ethanol) (Found: C, 59·75; H, 6·55. $C_{22}H_{28}N_4O_6$ requires C, 59·45; H, 6·35%).

The ester was hydrolysed under nitrogen with 2N-methanolic potassium hydroxide, and the resulting acid was characterised as, and purified through, its *cyclohexylamine salt*, needles, m. p. 138° (rapid heating) (from ethyl acetate) (Found: C, 71·9; H, 10·25. $C_{21}H_{35}NO_3$ requires C, 72·15; H, 10·1%). Regeneration of the acid from the salt gave only a gum.

(*b*) The octalone (0·96 g.) was added to a solution of sodium t-pentyl oxide [from sodium (0·23 g.)] in toluene (25 c.c.) under nitrogen. Ethyl bromoacetate (1·67 g.) was added, and the mixture was heated under reflux for 14 hr. Working up as in (*a*) gave an acidic fraction which was methylated with diazomethane. Chromatography on alumina gave the octahydronaphthylacetate (120 mg.), characterised as its 2,4-dinitrophenylhydrazone, m. p. and mixed m. p. 167—169°.

7,7,10β-*Trimethyl*-2-*oxo*-trans-1α-*decalylacetic Acid* (IV).—A solution of the acid derived from (XXXV) (from 2·0 g. of the cyclohexylamine salt) in dioxan (45 c.c.) was added during 15 min. to a stirred solution of lithium (0·5 g.) in ammonia (200 c.c.). The mixture was stirred for a further 45 min., then the lithium complex was decomposed with ammonium chloride and the ammonia evaporated. The residue was acidified with dilute sulphuric acid, the product isolated with ether, and the acidic fraction separated from a small amount of lactone by extraction with potassium hydrogen carbonate solution. The acidic fraction was treated with ethereal diazomethane and then an 8N-solution of chromic acid in acetone,[9] and the resulting keto-ester was adsorbed from light petroleum on alumina (100 g.). Elution with 1 : 3 benzene–light petroleum (500 c.c.) gave a decahydro-ester (850 mg.), $\nu_{max.}$ 1738 and 1710 cm.$^{-1}$ (no bands at 3400 or 1665 cm.$^{-1}$) whose 2,4-*dinitrophenylhydrazone* was obtained as needles (from ethanol–benzene), m. p. 187—189° (Found: C, 59·35; H, 6·7. $C_{22}H_{30}N_4O_6$ requires C, 59·2; H, 6·65%).

Hydrolysis of this ester gave the *acid* (IV) as needles (from light petroleum), m. p. 92—94° (Found: C, 71·05; H, 9·5. $C_{15}H_{24}O_3$ requires C, 71·4; H, 9·6%).

Reaction of the Acid (IV) *with Methylmagnesium Iodide*.—The acid (IV) (1·0 g.) in dioxan (25 c.c.) was added to a solution of methylmagnesium iodide [from magnesium (1·0 g.)] in ether (25 c.c.) and heated under reflux for 4 hr. Solid ammonium chloride was added, followed by dilute sulphuric acid. The product was isolated with ether, and the acidic fraction separated from the neutral fraction with potassium hydrogen carbonate solution. Crystallisation of the neutral fraction from light petroleum (b. p. 40—60°) gave 2α-*hydroxy*-2β,7,7,10β-*tetramethyl*-trans-1α-*decalylacetic acid lactone* (XXXVI) as needles (600 mg.), m. p. 99—100° (Found: C, 77·05; H, 10·45. $C_{16}H_{26}O_2$ requires C, 76·75; H, 10·45%), $\nu_{max.}$ 1765 cm.$^{-1}$.

1α-2′-*Hydroxyethyl*-2β,7,7,10β-*tetramethyl*-trans-*decal*-2α-*ol* (XII).—The lactone (XXXVI) (408 mg.) in ether (40 c.c.) was treated at 0° with lithium aluminium hydride (100 mg.) and heated under reflux for 1 hr. The excess of hydride was destroyed with ethyl acetate and then dilute sulphuric acid, and the product was isolated with ether. Crystallisation from light petroleum gave the diol (XII) as prisms (310 mg.), m. p. and mixed m. p. 116—118°.

Reaction of 7,7,10-*Trimethyl*-$\Delta^{1(9)}$-*octal*-2-*one with Allyl Bromide*.—The octalone (0·96 g.) was added to a solution of potassium (0·39 g.) in t-butyl alcohol (30 c.c.) under nitrogen. Allyl bromide (1·2 g.) in t-butyl alcohol (5 c.c.) was added and the mixture heated under reflux for 2 hr. The solvent was removed under reduced pressure, water was added to the residue; the product, isolated with ether, had no absorption above 2300 Å. The product was adsorbed from light petroleum on alumina (65 g.). Elution with light petroleum (200 c.c.) gave 1,1-*diallyl*-7,7,10-*trimethyl*-Δ^8-*octal*-2-*one* (XXXVII) (1·20 g.), b. p. 125—130° (bath)/0·1 mm., n_D^{20} 1·5050 (Found: C, 83·45; H, 10·2. $C_{19}H_{28}O$ requires C, 83·75; H, 10·35%), $\nu_{max.}$ 1710, 3080, 1625, and 910 cm.$^{-1}$. The *semicarbazone* was obtained as needles (from methanol), m. p. 185—187° (Found: C, 72·75; H, 9·5. $C_{20}H_{31}N_3O$ requires C, 72·9; H, 9·5%).

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[9] Bowers, Halsall, Jones, and Lemin, *J.*, 1953, 2555.