Tetrahedron. Vol. 32, pp. 2945 to 2948. Pergamon Press 1976. Printed in Great Britain

SYNTHESIS AND STRUCTURES OF DIHYDROEDULAN I AND II TRACE COMPONENTS FROM THE JUICE OF *PASSIFLORA EDULIS* SIMS

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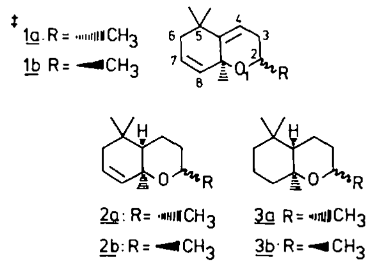
(*Received in the UK 26 April 1976; Accepted for publication 15 June 1976*)

Abstract—Dihydroedulan I and II, two trace components of the juice of the passionfruit *Passiflora edulis* Sims, have been shown by synthesis to be the epimeric 2,3,4,4a,5,6-hexahydro-2,5,5,8a-tetramethyl-(8aH)-1-benzopyrans **2b** and **2a**.

In a continuing investigation of the components responsible for the unique flavour of the juice of the purple-skinned passionfruit *Passiflora edulis* Sims,[1] two trace components, structurally related to the edulans **1a** and **1b**,[2-4] have been characterised and synthesised.

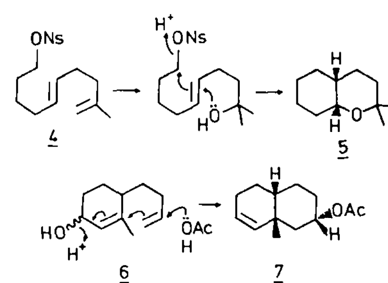
The compounds were initially detected by their characteristic camphoraceous aromas during an olfactory screening of the GLC effluent of the volatile components of the juice. Subsequent GLC investigations using (a) Carbowax 20 M and (b) Silicone OV-101 phases showed that these compounds, Compound A, linear retention indexes[5] (LRI) (a) 1519, (b) 1291 and Compound B, (a) 1543, (b) 1294 were present in fresh juice at concentrations of 1 and 6 ppb respectively. For characterisation the compounds were isolated by the sampling of headspace volatiles of fresh juice by absorption on Chromosorb 105 porous polymer resin,[6] followed by successive fractionation of the extract on two high resolution GLC columns of different polarity. Their MS showed identical fragmentation patterns with a weak M^+ at *m/e* 194 and a base peak at *m/e* 179. High resolution MS confirmed a molecular formula of $C_{13}H_{22}O$ for Compound B. Microhydrogenation of the compounds by reaction GLC (PTO_2 at 160°) gave in each case single compounds, M^+ at *m/e* 196 corresponding to a molecular formula of $C_{13}H_{24}O$. The MS and LRI on two columns of the reduction products of Compounds A and B were identical with those of the known[2,7] epimeric *cis*-fused 2,3,4,4a,5,6,7,8 - octahydro - 2,5,5,8a - tetramethyl - (8aH) - 1 - benzopyrans **3a** and **3b** respectively. Compounds A and B were thus structurally related to the edulans **1a** and **1b**.

During the course of the structural investigation of the edulans by microhydrogenation,[2] two minor products named dihydroedulan I and II, had been detected and these compounds had MS and LRI identical with those of Compounds B and A respectively. Subsequent reinvestigation of the microhydrogenation of the edulans led to the isolation of these minor reduction preducts. Microhydrogenation by reaction GLC (PtO_2 at 160°) of dihydroedulan I and II gave the epimeric octahydrobenzopyrans **3b** and **3a**. Based on this information compounds A and B were renamed dihydroedulan II and I and were tentatively assigned the epimeric *cis*-fused 2,3,4,4a,5,6 - hexahydro - 2,5,5,8a - tetramethyl - (8aH) - 1 - benzopyran structures **2a** and **2b** respectively.



‡As the absolute stereochemistry is unknown, only relative stereochemistry is indicated.

A stereospecific synthesis of the hexahydrobenzopyran system **2a** and **2b** was suggested by the observation[8,9] that the *trans*-fused octahydrobenzopyran **5** was the major product of the formic acid solvolysis of the methyl-decadienyl derivative **4**. A *cis*-fused system could be predicted if a cyclohexenol type initiator, as in the conversion **6** to **7**, was employed.[10] This approach was used in the following synthesis of the epimeric *cis*-fused hexahydrotetramethylbenzopyrans **2a** and **2b**.



The synthesis of the epimeric *cis*-fused 2,3,4,4a,5,6 - hexahydro - 2,5,5,8a - tetramethyl - (8aH) - 1 - benzopyrans **2a** and **2b** is outlined in Scheme 1. Reaction

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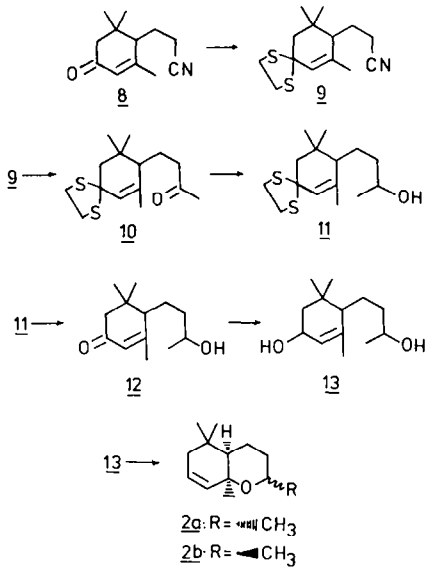
of 3 - (4 - oxo - 2,2,6 - trimethylcyclohex - 5 - enyl) propanenitrile **8**[11] with ethanedithiol gave the thioketal **9** (93%). Addition of methyllithium to the nitrile **9** followed by acid hydrolysis of the resultant salt afforded the methyl ketone **10** (52%) which on reduction with sodium bis-(2-methoxyethoxy) aluminium hydride gave a racemic mixture of the alcohols **11** (98%). Treatment of the thioketal **11** with aqueous acetonitrile–iodomethane[12] yielded the cyclic ketone **12** (60%) which on reduction, with the above complex hydride, afforded the isomeric 4 - (4 - hydroxy - 2,2,6 - trimethylcyclohex - 5 - enyl)butan - 2 - ols **13** (95%). Acid cyclization of these diols **13** in a two-phase system of formic acid and olefin-free pentane



Scheme 1. (Formulae depict only one enantiomer of a racemic pair).

gave a mixture of four cyclic ethers (70%) in a ratio of 1:15:15:1 after the removal of polar reaction products by silica gel chromatography. Further silica gel chromatography followed by preparative GLC eventually gave as the major products the epimeric hexahydrobenzopyrans **2a** and **2b**. The structures **2a** and **2b** were fully supported by their spectral characteristics: IR (μm), **2a** and **2b**, *cis* C=C–H, 3.30 (sh), 6.05, 13.8; C–O–C, 9.1, 9.2, 9.25, 9.55: NMR (δ): **2a**, gem dimethyl, 0.96, 3H, s, and 1.07, 3H, s: C_2 methyl, 1.12, 3H, d, J = 7 Hz; allylic methyl, 1.38, 3H, s; C_2H, 3.38, 1H, m and vinyl H, 5.52, 2H, m; **2b**, gem dimethyl, 0.97, 3H, s, and 1.08, 3H, s; C_2 methyl, 1.12, 3H, d, J = 8 Hz; allylic methyl, 1.33, 3H, s; C_2H, 3.78, 1H, q, J = 8 Hz; and vinyl H, 5.62, 2H, m. The relative stereochemistry of the synthetic hexahyrobenzopyrans **2a** and **2b** was confirmed by microhydrogenation using reaction gas chromatography (PtO_2 at 160°). In each case single compounds were obtained and had MS and LRI identical with those of the epimeric *cis*-fused octahydrobenzopyrans **3a** and **3b**. The high yield of the *cis*-fused benzopyrans **2a** and **2b** from the cyclization step, > 94% of the cyclic ethers detected, confirmed the earlier prediction of a stereospecific cyclization and has demonstrated a general approach to the synthesis of *cis*-fused benzopyrans.

The MS, LRI and hydrogenation products of the synthetic hexahydrobenzopyrans **2a** and **2b** are identical to those of the dihydroedulans: dihydroedulan I and II therefore are the epimeric *cis*-fused 2,3,4,4a,5,6 - hexahydro - 2,5,5,8a - tetramethyl - (8aH) - 1 - benzopyrans **2a** and **2b**.

With the inclusion of the dihydroedulans, nine C_{13} compounds, which may be considered as being related to carotenoids via trimethylcyclohexanylbutane derivatives of the type **12** and **13**, have now been detected in the juice of *P. edulis* Sims. This juice is well known for its relatively high concentration of carotenoid pigments[13] and it would therefore appear likely that the biosynthesis of the above compounds is connected with the production and/or decomposition of these terpenoids.

EXPERIMENTAL

Traps designed for the collection of (a) headspace volatiles and (b) GLC fractions were made of stainless steel tubing (90 mm, 2.4 mm i.d.) and were packed (a) with 100 mg of 50/60 mesh Chromosorb 105 (Johns–Manville, USA)[6] and (b) with 40 mg of 30/40 mesh HMDS silanized Chromosorb A (Johns–Manville, USA) coated with 10% Silicone SF96.[1] High resolution GLC was performed in a laboratory-designed gas chromatograph featuring valve introduction by which the above traps can be inserted into a heated introducer and the trapped material transferred to the GLC column.[1] A similar gas chromatograph is connected to an Atlas CH4 mass spectrometer. The GLC columns were of stainless steel capillary (150 m, 0.75 mm i.d.) and were coated with (a) Carbowax 20 M and (b) Silicone OV-101 containing 10% Igepal 880.[1] An identical Carbowax column was coupled to the mass spectrometer. Estimations of the amounts of natural products isolated were determined by GLC comparisons with standard solutions of the corresponding synthetic compounds. Routine GLC monitoring of the synthetic intermediates and preparative GLC of the ethers **2a** and **2b** were performed using a Hewlett–Packard HP402 gas chromatograph using glass columns (c) (2 m, 3 mm i.d.) packed with 3% Silicone OV-17 on 80/100 Gas Chrom Q and (d) (3 m, 3 mm i.d.) packed with 10% QF-1 coated on 80/100 Gas Chrom Q. TLC was performed using 0.25 mm thick Merck Silica Gel GF_{254}. NMR spectra were recorded in $CDCl_3$ solution with TMS as an internal standard using a Varian Associates T-60 NMR spectrometer. IR spectra were determined as liquid films on a Perkin–Elmer 137 spectrophotometer. MS were recorded in an Atlas CH4 spectrometer fitted with a ratio recorder,[14] while the high resolution MS was recorded on an AEI MS902. Microanalyses were performed by Messrs Meier and Consul of the Department of Chemistry, Stanford University, Stanford, California, USA. Unless otherwise specified, all synthetic reactions were conducted under a slight positive pressure of nitrogen.

Headspace collection of volatiles from the juice of Passiflora edulis *Sims.* Five mature fruit were halved, the pulp carefully removed and the juice (~25 g) separated from the seeds by pressure filtration through a 100-mesh stainless steel sieve. The juice (25 g) was immediately saturated with analytical grade NaCl (~6.5 g) and transferred to a 100 ml conical flask fitted with a system of collection traps[6] packed with Chromosorb 105, and the whole heated to 40°. The volatiles were then collected, as previously described[6] for 1 h, by the downward passage of clean O_2-free N_2 (flow-rate 40 ml/min) into the flask, over the surface of the gently stirred juice and through the collection traps situated 2 cm above the liquid surface. The traps were then transferred to a dry flask, heated to 28°, and purged with dry N_2 (flow-rate 40 ml/min) for 2 min to remove residual H_2O from the Chromosorb 105. The collection traps were then sealed with PTFE end caps and stored under solid CO_2.

Isolation of the dihydroedulans and of the edulans. The volatile components contained in the Chromosorb 105 traps were transferred, as previously described,[6] to the Carbowax 20 M column of the gas chromatograph at an introducer temp. of 160°. The column was then temp.-programmed: 32 min at 69° followed by 0.75°/min rise to 160° and then isothermal at 160° for 1 h (flow-rate 3 ml/min of N_2). Fractions covering the following LRI ranges were collected in traps packed with 10% SF96 on Chromosorb A:[1] edulan II, 1485–1495; dihydroedulan II, 1515–1525; Dihydroedulan I, 1538–1548; edulan I, 1630–1645. These

fractions were then individually introduced (160°), as previously described[1] to the silicone OV-101 columns with the column temperature isothermal at 128° (flow-rate 3.5 ml/min N_2). Single component fractions were then re-collected at the following LRI (yield per 25 g juice): edulan II, 1258 (~2.5 μg); dihydroedulan II, 1291 (~0.03 μg); dihydroedulan I, 1294 (~0.15 μg); edulan I, 1309 (~25 μg). Accurate LRI on the polar phase were determined on the Carbowax 20 M column coupled to the mass spectrometer, the column operating at 128° isothermal (flow-rate 3 ml/min He): edulan II 1490; dihydroedulan II, 1519; dihydroedulan I, 1543; edulan I 1638. MS: major fragments (relative intensity), dihydroedulan II, *m/e* 194 (M^+, 19), 179 (100), 69 (91), 43 (74), 41 (66), 107 (46), 84 (43), 55 (40), 67 (28), 95 (27), 91 (20); dihydroedulan I, *m/e* 194 (M^+, 4), 179 (100), 69 (38), 43 (34), 41 (31), 55 (29), 107 (17), 29 (14), 180 (13), 39 (13), 111 (12). High resolution MS: dihydroedulan I, 194.1667; Calcd for $C_{13}H_{22}O$, 194.1661.

Microhydrogenation of dihydroedulan I and II. Dihydroedulan I (~0.6 μg) from four collections was trapped from the silicone column on a small layer of Adams catalyst (~1 mg) contained in a 100 μl glass microcap (Drummond Scientific Co) the area about the catalyst being cooled in solid CO_2. After trapping, the capillary was removed from the GLC and a stream of H_2 (flow-rate 2 ml/min) was passed over the catalyst for 2 min with the cold trap in position.[15] The capillary was then sealed at both ends and transferred to a capillary crushing probe[15] which was then positioned in the GLC introducer, previously heated to 160°. After 3 min the capillary was crushed and the reaction products swept into the silicone column operating isothermally at 128° (flow-rate 3.5 ml/min of N_2). The single reduction product 2,3,4,4a,5,6,7,8 - octahydro - 2,5,5,8a - tetramethyl - (8aH) - 1 - benzopyran **3b** (~0.4 μg) LRI, 1313 was trapped and transferred to the Carbowax 20 M column coupled to the mass spectrometer and operating at 128° isothermal (flow-rate 3 ml/min He) LRI 1502. MS: major fragments (relative intensity) *m/e* 196 (M^+, 3), 181 (100), 153 (31), 109 (34), 81 (29), 69 (63), 67 (20), 55 (45), 43 (88), 41 (65), 29 (22). Dihydroedulan II (~0.34 μg) from eleven collections was collected and hydrogenated as previously described and gave a single product 2,3,4,4a,5,6,7,8 - octahydro - 2,5,5,8a - tetramethyl - (8aH) - 1 - benzopyran **3a** (~0.24 μg) LRI (a) 1549, (b) 1335. MS: *m/e* 196 (M^+, 7), 181 (30), 153 (98), 109 (24), 71 (23), 69 (40), 67 (20), 55 (38), 43 (100), 41 (59), 29 (21).

Microhydrogenation of edulan I and II. Edulan I (~50 μg) recovered from the silicone column was hydrogenated over Adams catalyst (~1 mg) by reaction GLC at 160° as previously described. Fractionation of the reaction products on the same column gave four major compounds having the same LRI as dihydroedulan I (~10 μg),† edulan I (~10 μg), the octahydrobenzopyran **3b** (~15 μg) and dihydroedulan III (~5 μg),† LRI 1319. The first peak was trapped and transferred to the Carbowax 20 M column where further fractionation gave dihydroedulan I (~5 μg). The dihydroedulan was trapped on Adams catalyst and hydrogenated as previously described at 160° for 3 min and gave a single product the octahydrobenzopyran **3b** (~3 μg) identical in LRI and MS with an authentic sample.[2,6] Edulan II (~25 μg) was hydrogenated over Adams catalyst (~1 mg) and the products fractionated on the silicone column. Four major products were resolved, dihydroedulan II (~2 μg),† dihydroedulan IV (~1 μg),† LRI 1299, the octahydrobenzopyran **3a** (~10 μg) and a *trans*-fused octahydrobenzopyran (~3 μg).[2,6] The first peak was collected on Adams catalyst (~1 mg) and hydrogenated as previously described. A single product, the octahydrobenzopyran **3a** (~2 μg), was obtained, identical in LRI and MS with an authentic sample.[2,6]

3 - (4 - *Ethanedithio* - 2,2,6 - *trimethylcyclohex* - 5 - *enyl)propanenitrile* **9**

To a solution of 3 - (4 - oxo - 2,2,6 - trimethylcyclohex - 5 - enyl)propanenitrile **8**[11] (6.37 g, 33.4 mmole) in $CHCl_3$ (350 ml) was added ethanedithiol (30 ml) followed by BF_3–etherate (3 ml). The reaction mixture was stirred at 25° and gradually became cloudy (separation of H_2O) and reddish-orange in colour. Examination of the mixture by TLC indicated the reaction was complete after 36 h. The mixture was treated with $NaHCO_3$ soln (~2 ml) and then diluted with ether (500 ml). The organic layer was washed with 2N NaOH (4 × 150 ml) and brine (2 × 150 ml), dried ($MgSO_4$) and concentrated *in vacuo* to give the crude thioketal **9** (8.81 g). This material was purified by bulb-to-bulb distillation (160°/0.04 mm) to give **9** (8.31 g, 93%) as an orange oil which was homogeneous by TLC (R_f 0.45, 30% ethyl acetate–hexane) and by GLC (3% OV-17, 200°, R_t 5.8 min); IR (μm), 4.42 (CN), 6.05 (C=C); NMR (δ), 0.97 (s, 3H, methyl), 1.09 (s, 3H, methyl), 1.76 (d, J = 1 Hz, 3H, allylic methyl), 3.35 (s, 4H, $-SCH_2CH_2S-$), 5.58 (broad s, 1H, vinyl H) (Found: C, 63.16; H, 8.05; N, 5.24; S. 24.09. Calc. for $C_{14}H_{21}NS_2$: C, 62.90; H, 7.92; N, 5.24; S, 23.94%).

4 - (4 - *Ethanedithio* - 2,2,6 - *trimethylcyclohex* - 5 - *enyl)butan* - 2 - *one* **10**

To a stirred solution of methyl lithium (50.5 mmole) in dry ether (40 ml) at 0° was added the thioketal **9** (8.31 g) in dry ether (80 ml). The mixture was stirred for 2 h at 0° and then for 2 h at 25°. The reaction mixture was then treated cautiously with 20% H_2SO_4 (50 ml) in dioxane (100 ml). The solution was stirred at 60–65° for 2 h and then at 25° overnight. The cooled mixture was extracted with ether, the aqueous layer neutralized with 2N NaOH and then extracted with two further portions of ether. The combined organic layers were washed (H_2O, brine), dried ($MgSO_4$) filtered through Florisil, concentrated *in vacuo* and then evaporatively distilled (175°/0.01 mm) to give the crude ketone **10** (6.59 g). Chromatography of this material on silica gel (200 g) with 10% ethyl acetate–hexane gave **10** (4.60 g, 52%) which was homogeneous by TLC (R_f 0.36, 30% ethyl acetate–hexane) and by GLC (OV-17, 200°, R_t 4.7 min); IR (μm), 5.85 (C=O); NMR (δ), 0.97 (s, 3H, methyl), 1.04 (s, 3H, methyl), 1.71 (d, J = 1 Hz, 3H, allylic methyl), 2.12 (s, 3H, acetyl methyl), 3.32 (s, 4H, $-SCH_2CH_2S-$), 5.52 (s, 1H, vinyl H). (Found: C, 63.48; H, 8.48; S, 22.59. Calc. for $C_{15}H_{24}S_2O$: C, 63.36; H, 8.51; S, 22.50%).

4 - (4 - *Ethanedithio* - 2,2,6 - *trimethylcyclohex* - 5 - *enyl)butan* - 2 - *ol* **11**

To a stirred solution of the ketone **10** (4.59 g, 16.2 mmole) in dry THF (250 ml) at 0° was added a 70% soln of $NaAlH_2(OCH_2CH_2OCH_3)_2$ in benzene (6 ml). The mixture was stirred during 1 h at 0° and then treated cautiously with 2N NaOH soln. Ether (100 ml) was then added and the organic layer was washed (H_2O, brine), dried ($MgSO_4$), concentrated *in vacuo* and evaporatively distilled (150°/0.01 mm) to give **11** (4.58 g, 98%) which was homogeneous by TLC (R_f 0.24, 30% ethyl acetate–hexane) and by GLC (OV-17, 200°, R, 4.2 min); IR (μm), 2.93 (O–H), 6.03 (C=C); NMR (δ), 0.96 (s, 3H, methyl), 1.03 (s, 3H, methyl), 1.15 (d, J = 6 Hz, 3H, carbinol methyl), 1.72 (d, J = 1 Hz, 3H, allylic methyl), 3.31 (s, 4H, $-SCH_2CH_2S-$), 3.72 (m, 1H, carbinol methine), 5.50 (s, 1H, vinyl H). (Found: C, 62.78; H, 9.06; S, 22.13. Calc. for $C_{15}H_{26}S_2O$: C, 62.91; H, 9.15; S, 22.34%).

4 - (4 - *Oxo* - 2,2,6 - *trimethylcyclohex* - 5 - *enyl)butan* - 2 - *ol* **12**

A solution of the alcohol **11** (4.58 g, 16 mmole) in acetonitrile (300 ml) containing iodomethane (35 ml) and H_2O (60 ml) was refluxed for 6 h (bath temp. 60–70°). Monitoring of the reaction progress by TLC indicated the alcohol **11** (R_f 0.45, 50% ethyl acetate–hexane) was completely consumed and that two new products had appeared at R_f 0.39 (non-UV-active) and R_f 0.17 (UV-active). The cooled reaction mixture was poured into H_2O (500 ml) and extracted with ether (3 × 100 ml). The combined organics were washed (saturated $Na_2S_2O_5$ soln, H_2O and three portions of brine) dried ($MgSO_4$) and concentrated *in vacuo* to give the crude hydroxy–enone **12** (2.9 g). Chromatography on Florisil (150 g) with 20%, 40% and 60% ethyl acetate–hexane mixtures gave **12** (2.03 g, 60.4%) homogeneous by TLC and >92% pure by GLC (OV-17, 150°, R_t 4.5 min); IR (μm), 2.92 (O–H), 6.02 (C=O); NMR (δ), 1.01 (s, 3H, methyl), 1.04 (s, 3H, methyl), 1.17 (d,

†The yields and the ratios of the dihydroedulans are variable. Hydrogenations of less than 5 μg of edulan do not yield detectable amounts of the dihydro-compounds. Dihydroedulan III and IV are believed to be epimeric 2,3,5,6,7,8 - hexahydro - 2,5,5,8a - tetramethyl - (8aH) - 1 - benzopyrans.

J = 6 Hz, 3H, carbinol methyl), 1.98 (d, J = 1 Hz, 3H, allylic methyl), 3.73 (m, 1H, carbinol methine), 5.82 (s, 1H, vinyl H).

4 - (4 - Hydroxy - 2,2,6 - trimethylcyclohex - 5 - enyl)butan - 2 - ol **13**

To a stirred solution of the hydroxy–enone **12** (455 mg, 2.18 mmole) in dry THF (60 ml) at 0° was added with stirring a 70% soln of $NaAlH_2(OCH_2CH_2OCH_3)_2$ in benzene (1.5 ml). The mixture was then warmed to 25° and held at this temp. for 13 h. After cooling, the mixture was treated cautiously with 2N NaOH (5 ml), and the product extracted with ether (50 ml). The organic layer was washed (H_2O, brine) dried ($MgSO_4$) and concentrated *in vacuo* to give a mixture of epimeric diols **13** (435 mg) which appeared as two spots on TLC (R_f 0.10 (major), 0.19 (minor), 50% ethyl acetate–benzene); IR (μm), 2.95–3.05 (O–H); NMR (δ), 0.88 (s, 3H, methyl), 0.94, 1.04 (s, s, total of 3H, methyls of two epimers), 1.20 (d, J = 6 Hz, 3H, carbinol methyl), 1.76 (d, J = 1 Hz, 3H, allylic carbinol methine), 5.38 (broad s, 1H, vinylic H) (Found: C, 73.24; H, 11.15. Calc. for $C_{13}H_{24}O_2$: C, 73.54; H, 11.39%).

2,3,4,4a,5,6 - Hexahydro - 2,5,5,8a - tetramethyl - (8aH) - 1 - benzopyrans **2a** *and* **2b**

To a stirred suspension of the crude diols **13** (420 mg) in olefin-free pentane† (80 ml), held at 0°, was slowly added over a period of 5 min 97% formic acid (1.4 ml). As the reaction proceeded stirring became easier and the temp. was increased to 25° and held there for 2 h. The mixture was then poured into a saturated soln of $NaHCO_3$ and the products isolated by ether extraction. Concentration *in vacuo* gave a mixture of crude cyclic ethers which appeared as two spots on TLC (R_f 0.43 and 0.48, 10% ethyl acetate–hexane). Rapid chromatography on silica gel (15 g) with 10% ether–pentane removed the polar impurities to give a mixture of cyclic ethers (266 mg, 70%). Examination by GLC (10% QF-1, 120°, R_t 6.0, 8.0, 9.2 and 12.4 min) indicated the presence of four components in a ratio of 1:15:15:1. The two major isomers partially resolved by careful chromatography on silica gel with 2% ether–hexane were further fractionated by preparative GLC (10% QF-1, 120°) and gave the hexahydrobenzopyrans **2a** and **2b**.

†Olefin-free pentane was prepared as follows: technical grade solvent was washed with 30% fuming H_2SO_4, conc. H_2SO_4, H_2O, 10% $NaHCO_3$ and dried over Na_2SO_4, and distilled over phosphorus pentoxide.

Examination of the ethers **2a** and **2b** by high resolution GLC and by combined GLC–MS indicated that the isomers were essentially free from other compounds and had the same LRI and MS as dihydroedulan II and I respectively. Spectral data are presented in the text. Microhydrogenation of the epimer **2a** (~ 2 μg) by reaction GLC as previously described gave a single compound (~ 1.2 μg) identical in LRI and MS with an authentic sample of the octahydrobenzopyran **3a**. Similarly microhydrogenation of the epimer **2b** gave the octahydrobenzopyran **3b**.

Acknowledgements—The authors are indebted to Mr C. MacDonald (CSIRO Division of Entomology) for the high resolution mass spectrum, and to Dr. J. C. Leffingwell (R. C. Reynolds Tobacco Co.) for a generous sample of cyanoketone **8**. One of us (G.D.P.) expresses his gratitude to Professors W. S. Johnson (Stanford University) and Jerrold Meinwald (Cornell University) and the National Institutes of Health for financial support and laboratory facilities during the course of the synthetic work. In addition, G.D.P. acknowledges NIAID fellowship No. AI 05076 for support during the preparation of this manuscript.

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