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APPROACHES TO THE SYNTHESIS OF TRITERPENOIDS—VII[a-c]

THE SYNTHESIS OF SOME REDUCED CHRYSENE DERIVATIVES AS SUITABLE INTERMEDIATES FOR PENTACYCLIC TRITERPENES. SYNTHESIS VIA BCDE RING CONSTRUCTION

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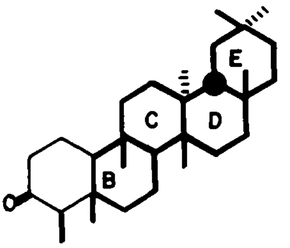
Abstract—The synthesis and X-ray crystal structure determination of 8-methoxy-3,3,10bα, 12aβ-tetramethyl-1,2,5,6,10b,11,12,12a-octahydro-4(3H)-chrysenone is described. This and related compounds represent useful intermediates for pentacyclic triterpene synthesis.

As part of our continuing studies in the area of pentacyclic triterpene synthesis[1-3] we have examined a pathway based on construction of the BCDE rings of target molecules such as friedelin **1** and β amyrin **2** as illustrated by the thickened bonds in the structures. Our synthetic subgoals were reduced chrysenes such as **3** and **4**, and although our studies towards this end have not been completely successful, our observations are now presented.

The basic strategy of this work parallelled our recently reported route to the pentacyclic compound **5** using an intramolecular aldol condensation as shown.[3] Thus, we reasoned that a precursor such as **6** might exhibit preferential cyclisation of one of its constituent racemates,[e] a tactic that had previously been used to advantage by us.[3].

Alkylation of the methoxy tetralone **7**[4] with the tosylate **8**[3] yielded the mixture of diastereomers **6a** and **6b** after deketalization of the reaction products. Reaction of this mixture in dimethoxyethane with a tetrahydrofuran solution of t-butylmagnesium chloride[3,5] led to the formation of three compounds, **9**



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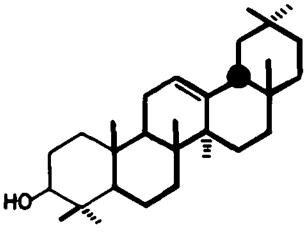

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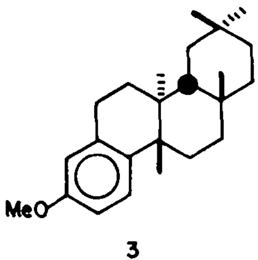

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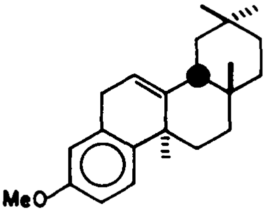

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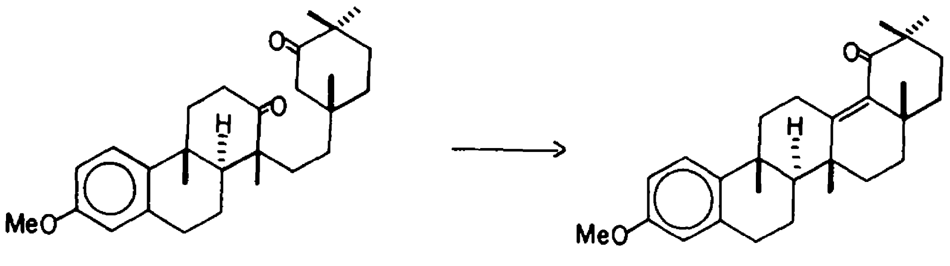
[a] Dedicated to the memory of R. B. Woodward.

[b] For part VI see J. W. ApSimon and K. Yamasaki, *Can. J. Chem.* In press.

[c] NRCC No. 18726.

[d] Portions of this work are described in the Ph.D. thesis of AMG (Carleton University 1980) and the M.Sc. thesis of N.D.T. (1978).

[e] With the exception of structures **1** and **2**, which represent natural products, all structures used in this paper represent racemates. Only that enantiomer bearing a direct relationship to the natural series is shown for convenience. It is to be noted that condensation of **7** and **8** (Scheme 1) leads to a mixture of diastereoisomers represented as **6a** and **6b**.



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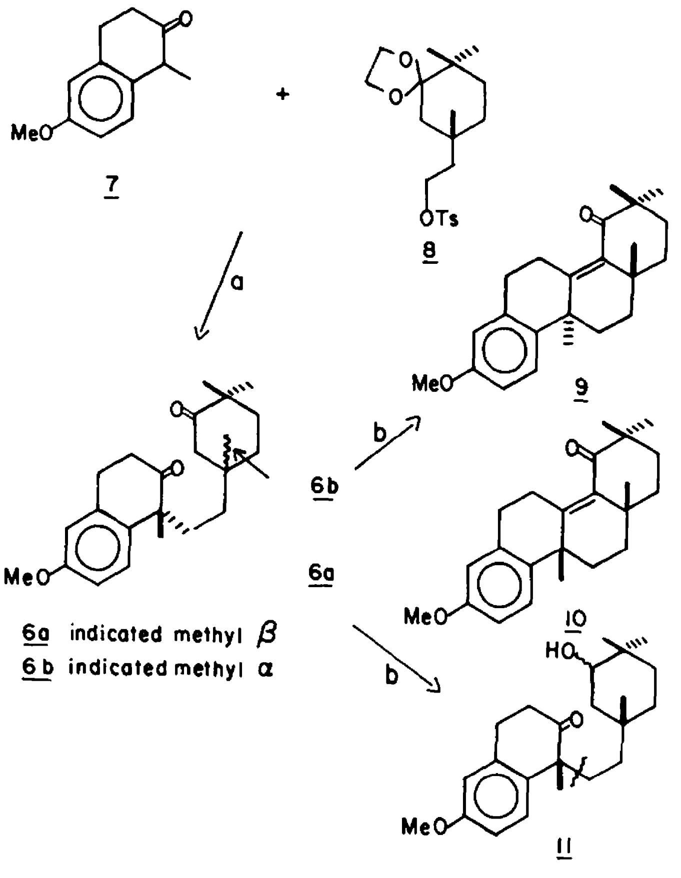

Reagents: a. i KOtAm / benzene, i aq oxalic acid; b- t-BuMgCl.

Scheme 1.

(45%), **10** (<3%) and **11** (30%) separated by column chromatography.[†] The major cyclised product, **9** was subjected to a single crystal X-ray structure determination and a stereoscopic view of the molecule produced by ORTEP II[12] is provided in Fig. 1. The final atomic parameters are listed with their e.s.d.'s in Table 1.

The anisotropic thermal parameters were analysed for rigid-body motion using the MGTLS program of Schomaker and Trueblood[6]. The rigid-body approximation was found not to apply to the molecule as a whole, but is appropriate for two portions, one consisting of atoms C(1), C(2)...C(10) and the other comprising C(8), C(9), C(11)...C(18). The r.m.s. differences between the observed and calculated U_{ij}'s are 0.0021 and 0.0029 Å^2 for the first and second groups respectively. Rotational oscillation (libration) for the first group is very anisotropic, with principal

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[†] For brevity we choose to describe unexceptional spectroscopic properties in the experimental section only. All data is in accord with structures depicted herein.

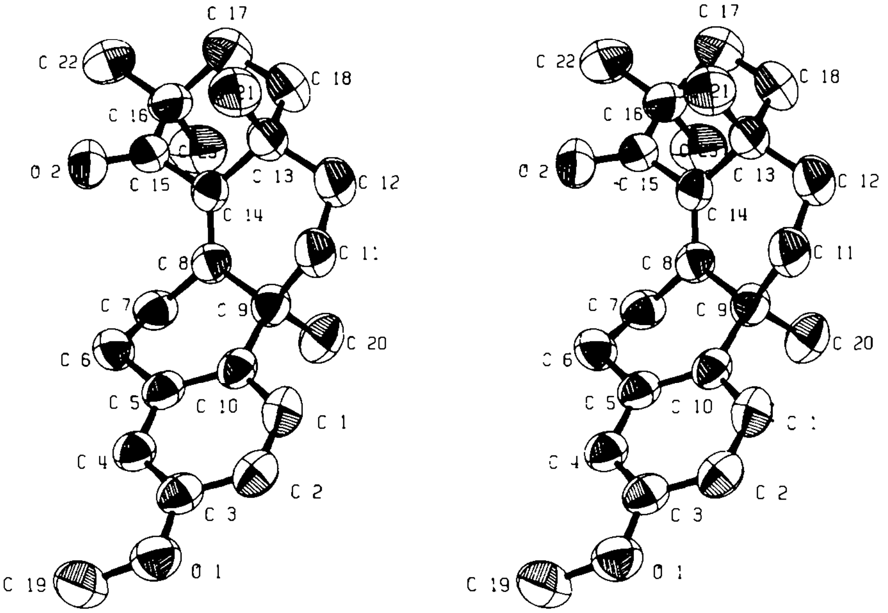


Fig. 1. A stereoscopic view of the molecule showing the numbering scheme used in the analysis. The thermal ellipsoids enclose 50% probability.

axis values corresponding to 6.1, 2.3 and 1.4°. The largest libration is about an axis nearly parallel to the C(3)...C(8) direction. For the second group the principal libration axes correspond to 4.9, 3.5 and 2.4°. Translational vibration for both groups is more nearly isotropic, with r.m.s. displacements varying between 0.20 and 0.29 Å. The bond length corrections calculated from the two libration tensors vary from 0.002 to 0.008 Å (up to twice the corresponding e.s.d.'s) and are included in the bond lengths presented in Fig. 2 except for C(19)-O(1), O(1)-C(3), O(2)-C(15), C(20)-C(9), C(21)-C(13), C(22)-C(16) and C(23)-C(16), which include "riding-motion" corrections[7] instead.

The bond lengths in this structure are very similar to those observed in the related pentacyclic compound **5**[3] and require no special comments. C-H bond lengths in the present compound vary from 0.91 to 1.08 Å, with mean 1.00 Å.

Conformation. The aromatic ring (A) is planar within experimental error ($\chi^2 = 2.28$), and the OMe group is approximately coplanar with it. The C(19)-O(1)-C(3)-C(4) torsional angle is 4.4°. (E.s.d.'s of the torsional angles are about 0.3°.) Both rings B

Table 1(a). Fractional coordinates, vibration tensor components (Å^2) for the expression $T = \exp[-2\pi^2(U_{11}a^{*2}h^2 + \ldots\ldots + 2U_{23}b^*c^*kl + \ldots\ldots)]$, and their e.s.d.'s for the carbon and oxygen atoms. All quantities $\times 10^4$

	X	Y	Z	U_{11}	U_{22}	U_{33}	$2U_{23}$	$2U_{13}$	$2U_{12}$
O(1)	8198(1)	-5061(3)	3890(1)	821(13)	777(13)	703(12)	241(21)	311(20)	-108(21)
O(2)	8999(1)	2669(3)	930(1)	650(12)	998(16)	966(15)	331(26)	528(22)	319(23)
C(1)	6593(2)	-1906(4)	2909(2)	570(16)	740(19)	769(18)	-116(31)	413(28)	-117(28)
C(2)	6934(2)	-3330(4)	3311(2)	702(17)	697(19)	705(18)	- 33(31)	495(29)	-259(30)
C(3)	7913(2)	-3620(4)	3479(1)	715(17)	691(18)	487(15)	-118(27)	272(25)	-134(30)
C(4)	8540(2)	-2455(4)	3241(1)	602(16)	719(18)	490(15)	- 51(27)	199(24)	-150(28)
C(5)	8188(2)	-1010(4)	2832(1)	622(16)	703(18)	450(13)	- 76(26)	227(24)	-185(28)
C(6)	8907(2)	225(4)	2597(2)	539(15)	818(21)	671(16)	263(31)	52(25)	-157(29)
C(7)	8479(2)	1991(4)	2433(1)	689(17)	746(20)	557(15)	- 38(29)	146(27)	-273(30)
C(8)	7549(2)	1839(3)	1903(1)	585(15)	589(16)	539(15)	-129(26)	202(24)	30(26)
C(9)	6770(2)	878(4)	2220(1)	583(16)	675(18)	610(16)	-127(28)	282(25)	16(28)
C(10)	7204(2)	- 700(4)	2654(1)	576(15)	666(17)	498(15)	-178(26)	291(23)	- 95(27)
C(11)	5968(2)	318(4)	1586(2)	550(16)	905(22)	776(20)	- 52(35)	152(28)	- 25(31)
C(12)	5662(2)	1782(5)	1044(2)	571(17)	1048(25)	819(20)	- 66(38)	58(29)	85(34)
C(13)	6480(2)	2394(4)	662(2)	617(16)	860(21)	588(16)	- 74(31)	113(27)	267(31)
C(14)	7416(2)	2457(4)	1210(1)	558(15)	641(17)	585(15)	- 90(27)	262(24)	206(27)
C(15)	8223(2)	3359(4)	913(1)	635(16)	753(19)	498(15)	9(28)	237(24)	200(30)
C(16)	8016(2)	5133(4)	587(2)	835(19)	805(21)	615(16)	241(31)	367(29)	236(33)
C(17)	7063(3)	5070(5)	36(2)	965(23)	985(25)	845(23)	424(40)	253(38)	372(42)
C(18)	6254(2)	4219(5)	345(2)	699(19)	1100(28)	879(23)	256(42)	4(33)	460(39)
C(19)	9188(2)	-5324(4)	4128(2)	841(20)	863(23)	766(20)	259(36)	- 10(33)	-124(36)
C(20)	6344(2)	2072(4)	2761(2)	849(20)	797(22)	840(21)	-186(36)	687(34)	104(34)
C(21)	6610(2)	1156(5)	27(2)	923(22)	1195(29)	657(20)	-407(41)	82(34)	133(44)
C(22)	8820(3)	5746(6)	195(2)	1100(27)	1337(34)	924(25)	885(50)	642(43)	- 5(51)
C(23)	7946(3)	6331(4)	1244(2)	1439(32)	704(23)	919(25)	26(40)	434(46)	289(45)

Table 1(b). Fractional coordinates ($\times 10^3$), isotropic temperature factors (Å^2) for the expression T = exp ($-$B $\sin^2\theta/\lambda^2$), and their e.s.d.'s for the hydrogen atoms

	X	Y	Z	B
H(11)	590(2)	-180(3)	280(1)	5.0(0.6)
H(21)	651(2)	-415(4)	348(1)	5.7(0.6)
H(41)	925(1)	-255(3)	338(1)	3.9(0.5)
H(61)	915(2)	- 23(4)	213(2)	8.0(0.8)
H(62)	948(2)	27(3)	295(1)	5.2(0.6)
H(71)	896(2)	282(3)	227(1)	4.5(0.5)
H(72)	836(2)	247(3)	286(1)	4.1(0.5)
H(111)	541(2)	- 13(3)	175(1)	5.5(0.6)
H(112)	623(2)	- 74(4)	133(2)	7.0(0.7)
H(121)	542(2)	278(4)	130(2)	6.4(0.7)
H(122)	510(2)	136(4)	71(2)	6.7(0.7)
H(171)	721(2)	425(4)	- 41(2)	9.4(0.9)
H(172)	693(3)	641(5)	- 9(2)	10.5(1.1)
H(181)	567(2)	407(4)	0(2)	7.6(0.8)
H(182)	608(2)	491(4)	77(2)	8.2(0.8)
H(191)	928(2)	-642(5)	444(2)	10.2(1.0)
H(192)	953(2)	-440(4)	440(2)	7.8(0.8)
H(193)	954(2)	-549(4)	371(2)	8.2(0.8)
H(201)	606(2)	316(4)	252(2)	7.7(0.8)
H(202)	690(2)	245(4)	318(2)	6.9(0.7)
H(203)	578(2)	142(4)	292(2)	7.3(0.8)
H(211)	665(2)	- 7(4)	22(2)	8.3(0.8)
H(212)	603(2)	132(4)	- 39(2)	7.9(0.8)
H(213)	718(2)	143(4)	- 21(2)	8.8(0.9)
H(221)	864(3)	699(6)	- 1(2)	12.4(1.3)
H(222)	941(2)	573(4)	55(2)	8.8(0.9)
H(223)	888(3)	503(5)	- 25(2)	11.7(1.2)
H(231)	778(2)	745(5)	106(2)	9.9(1.0)
H(232)	734(3)	598(6)	151(2)	12.3(1.2)
H(233)	859(2)	629(5)	164(2)	9.3(0.9)

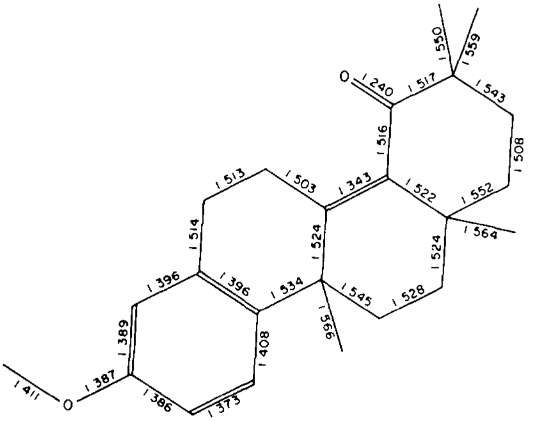


Fig. 2. Final bond lengths. The bonds comprising the ring skeleton have been corrected for rigid-body motion, while bonds involving substituents have been corrected for "riding" motion.

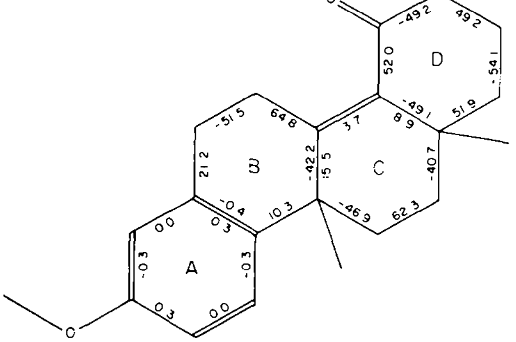


Fig. 3. Endocyclic torsional angles.

and C have slightly distorted half-chair forms, the distortion in ring C being mainly a flattening of the ring at C(13). Ring D has the chair form, somewhat flattened at C(16) because of the two Me groups, and also at the quaternary C(13). Endocyclic torsional angles are shown in Fig. 3. Me groups C(20) and C(21) are *trans* across the ring skeleton.

As in the related pentacyclic compound **5**[3], there appears to be no conjugation between the C(8) C(14) double bond and the C(15) O(2) CO group. The C(8) C(14)–C(15)–O(2) torsional angle is 54.3° and the C(14) C(15) bond length, 1.516 Å, is about 0.08 longer than expected in a conjugated system. The twist of C(15)–O(2) out of the C(7) C(8) C(14) plane is necessary to avoid very short H(71)...O(2) and C(7)...O(2) non-bonded contact distances. In the crystal structure these are 2.45 and 3.00 Å respectively. The C(7)...O(2) and H(71)...O(2) non-bonded repulsion is probably also responsible for the extra puckering of ring B at C(7); the displacements of C(7) and C(8) from the mean plane through C(6), C(5), C(10), C(9) are −0.50 and 0.25 Å respectively, whereas in an ideal half-chair, the displacements would be equal in magnitude.

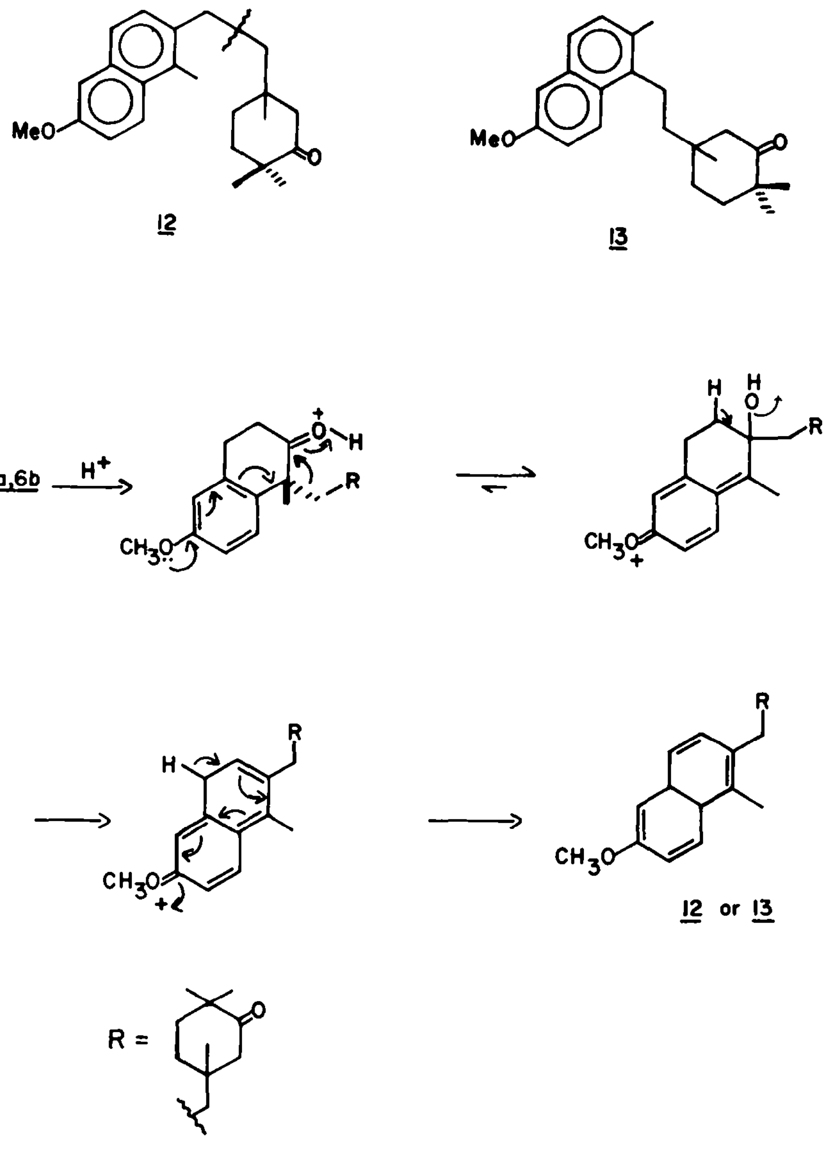
There are no intermolecular contacts shorter than the corresponding van der Waals distances.

With structure **9** secure it is a simple matter to assign structure **10**. Compound **11** exhibited, besides the expected spectroscopic properties, a peak at *m/e* 189 in its mass spectrum indicative of cleavage as indicated in structure **11** and confirming the site of the OH group in this compound.

These observations provide direct evidence that our original surmise concerning the different reactivities of **6a** and **6b** towards cyclisation was correct. Thus, **9** arises from **6b** while **10** and **11** are derived from **6a**. The stereoelectronic requirements of the aldol process presumably dictate this selectivity. Apparently, the cyclisation of **6b** is very efficient (45% of **9** is equivalent to 90% cyclisation of one component of the mixture) whilst **6a** is relatively unreactive to cyclisation, preferring a hydride transfer route in the reaction with Grignard reagent.[3,8] Confirmation of these cyclisation routes was obtained by separation of **6a** and **6b** initially by column chromatography and later by high performance liquid chromatography (hplc) and exposure of both compounds to the cyclisation conditions. Further, compound **11** could be converted to **6a** on mild oxidation.

Whilst it is gratifying that the conceptual basis of the selective cyclisation approach has been demonstrated, it was disappointing to us that **6b** rather than **6a** underwent this cyclisation especially as we had predicted the reverse selectivity from an inspection of molecular models! Nevertheless, compound **9** is now available to us in gram amounts and although of no use in a friedelin (**1**) synthesis it is a promising precursor for approaches to the *β*-amyrin (**2**) nucleus. We hope to be able to report on our work to this end in subsequent papers in this series.

While one synthetic subgoal is complete, the obtention of larger amounts of **10** would be of particular interest for our other goals. In a large series of base-catalysed reactions both in the presence and absence of bivalent metal ions we have been unable to detect any enhanced yield of this material. Bearing in mind our previous success[3] with acid catalysis in the aldol process we therefore examined the reaction of **6a** and **6b**, either as a mixture or separately with *p*-toluenesulfonic acid in *p*-xylene. Whilst both materials underwent cyclisation to **10** and **9** respectively, the yields were low (~20%). In both cases we isolated



Scheme 2.

another transformation product in 30–40% yield. The same material was isolated from both **6a** and **6b** and has been assigned structure **12** or **13** based on spectroscopic data and our previous experience.[9] In particular the mass spectrum of this material indicated at intense fragment at *m/e* 185, resulting from benzylic cleavage as indicated in **12**. The origin of this species can best be accounted for by the route outlined in Scheme 2, although doubt still exists as to which group has migrated. For convenience we have depicted only side chain migration in Scheme 2. Thus, acid-catalysed cyclisation has proved to be of no utility for triterpene synthesis.

Our continuing studies are presently directed towards other modes of cyclisation of species such as **6**.

EXPERIMENTAL

General. All mps were determined on a Fisher–Johns apparatus and are uncorrected. IR spectra were recorded on a Perkin–Elmer Model 237B IR spectrometer, UV spectra on a Perkin Elmer 202 UV-Visible Spectrophotometer. Mass spectra were obtained on an AEI MS12 Instrument at Trent University. NMR spectra were measured on a Varian T-60 (^1H) or Varian HA-100 (^1H and ^{13}C), using TMS as an internal standard. Chemical shifts are expressed in the δ scale with the following designations; s, singlet; d, doublet; t, triplet; m, multiplet. Combustion analyses were performed by the Spang Microanalytical Laboratory, Ann Arbor, Michigan, and Guelph Chemical Labs. Ltd. Guelph, Ontario.

All reactions and chromatograms were routinely monitored by analytical tlc (Merck 60 PF-254 plates, 0.25 mm). Spots were developed by exposing to I_2 vapour, or by spraying with ceric sulfate and heating. Preparative tlc was carried out on Merck 60 F-254 precoated silica gel plates of 2.0 mm thickness. Bands were visualized by viewing under an UV source or by staining one edge with ceric sulfate/heating. Silica gel (Davison Chemical Co., grade 923 (100–200 mesh) was used for column chromatography. Flash chromatography refers to elution of material on a silica gel pad (silica gel 60H-E.M. Reagents, sintered glass funnel) using water aspirator suction, with collection and analysis of 50–150 ml fractions. HPLC was performed using a Waters Prep 500 High Performance Liquid Chromatograph.

The term "dry benzene" and "dry toluene" refer to benzene or toluene which was distilled and stored over Na. Dry THF and dry dimethoxyethane were obtained by distillation from LAH. "Anhydrous ether" was available from Mallinckrodt Canada Ltd. Petroleum ether refers to the fraction boiling at 30–60°.

1-*Methyl*-1 [2-(3-keto-1,4,4-trimethylcyclohexyl)ethyl]-6-*methoxy*-3,4-*dihydro*-2(1H)-*naphthalenones* **6a** and **6b**

K metal (1.5 g, 38 mmol) t-amyl alcohol (6 g, 68 mmol) and dry benzene (200 mL) were refluxed for 2 hr, (until all K dissolved), the soln was cooled to room temp, then **7**[4] (6.3 g; 33.5 mmol) in benzene (25 ml) was added dropwise. Benzene/t-amyl alcohol were then removed by azeotroping whilst the solvent level was kept constant by addition of fresh benzene over a 1–2.5 hr period. The mixture was then recooled to room temp and **8**[3] (12 g, 31.4 mmol) in benzene (30 ml) was added slowly, and the reaction stirred overnight at room temp and then refluxed for 25 hr. The cooled mixture was poured into ice/water and extracted with ether (× 2). The cold yellow aqueous layer was then acidified carefully with a few drops of conc H_2SO_4 and immediately extracted with ether (× 3). The combined organic layers were washed with satd. $NaHCO_3$ aq; satd. NaCl aq and dried ($MgSO_4$). Concentration yielded 17.5 g of an oil which was dissolved in EtOH (250 ml). Satd aqueous oxalic acid (250 ml) was added and the mixture refluxed for 1.5 hr. Water and EtOH were removed under reduced pressure and ether and water were added. The layers were separated and the aqueous layer was extracted with ether (× 3). The combined organic layers were washed with satd. $NaHCO_3$ aq; water and satd. NaCl aq, then dried ($MgSO_4$). In earlier experiments column chromatography of this mixture (silica gel/petroleum ether–ether) afforded unreacted starting materials plus **6a** and **6b** (54%) as a colorless oil. In this case, repetitive HPLC of the concentrated material gave (a) 2.6 g of **7** (b) 1.8 g of **6b** (c) 3.2 g of a mixture of **6a** and **6b** (d) 1.4 g of **6a** contaminated with a trace of **6b**. The yield of **6a** and **6b** was 59%. Analytical data of the mixture: IR (neat) ν_{max} 1700, 1705 cm^{-1} (2 C = 0). NMR ($CDCl_3$) δ ppm: 1.0 (2s. 6H gem di-C$\underline{H}_3$) 1.4 (s. 3H C-1′CH_3) 1.5 (s. 3H C-1 CH_3) 2.0 (s. 2H. CH_2CO) 4.0 (s. 3H OCH_3) 6.6–7.2 (m. 3H. ArH). Mass Spec. *m/e* (r.i.) 356 (M^+, 15) 203 (100), 175 (33). (Found: C: 77.25, H: 9.11. Calc: for $C_{23}H_{32}O_3$: C: 77.52; H: 8.98.

Spectral data for **6a** and **6b** were indistinguishable except for the relative chemical shifts of the Me and OMe group protons in the presence of Euroshift reagent which was used to monitor the isomeric purity of **6a** and **6b**.

Reaction of diastereoisomeric **6a** *and* **6b** *with t-butylmagnesium chloride.*

Synthesis of 8-methoxy-3,3,10bα,12aβ-tetramethyl-1,2,5,6,10b,11,12,12a-octahydro-4(3H)-chrysenone **9**. A mixture of Mg metal (36 g dried in an oven at 160°) freshly distilled THF (30 mL), dried over Na metal and a few crystals of I_2 was refluxed for 15 min. To initiate the reaction, 40 drops of freshly distilled t-BuCl were added. The soln was refluxed for 30 min at which time the I_2 colour had disappeared. A soln of t-BuCl (7.5 g) in THF (40 ml) was added dropwise and the mixture was refluxed for another 30 min. The soln was cooled to room temp and a titration showed the molarity to be 1 M.

The diastereoisomeric mixture **6a** and **6b** (1 50 g, 4.35×10^{-3} moles) dissolved in dimethoxyethane (150 mL) (DME) at −78° under N_2. After 10 min, t-BuMgCl (1.74×10^{-2} moles) was added and a pale yellow ppt appeared after 3 min. The mixture was kept stirring for 30 min longer then refluxed for 24 hr. After cooling, ether (100 ml) was added and the mixture was poured into a mixture of ice and ammonium chloride. Work-up in the usual manner afforded 1.50 g crude product. Column chromatography (silica gel–petroleum-ether afforded 0.70 g pure **9** that was recrystallized from pet. ether to give colorless blocks m.p.: 87–88°; IR (CH_2Cl_2); ν_{max} 1660 (α,β-unsaturated C = 0), 1635 cm^{-1} (C = C); NMR ($CDCl_3$): δ 0.89 (s, 3, CH_3 at C_{12}), 1.12 (s, 3, $-OCH_3$): mass spectrum: *m/e* (relative intensity): 338 (36) (M^+), 324 (23); 323 (100). UV (CH_3OH): λ_{max}: 285 ($\varepsilon = 2460$), 250 ($\varepsilon = 5450$). (Found: C: 81.71; H: 9.07. Calc. for $C_{23}H_{30}O_2$: C: 81.67; H. 8.87).

Later fractions from this column provided trace amounts (15 mg) of **10** as colorless needles, m.p.: 125–126°; IR (CH_2Cl_2): 1665 (α,β-unsaturated C = O); 1635 cm^{-1} (C = C). NMR ($CDCl_3$): δ 1.00 (s, 3, CH_3 at C_{12}); 1.06 and 1.12 (s, 6, *gem*-dimethyl); 1.43 (s, 3, CH_3 at C_{10b}); 3 73 (s, 3-0-CH_3). Mass spectrum: *m/e* (relative intensity): 338 (35) (M^+) 324 (23), 320 (100). UV (CH_3OH): λ_{max}: 2870 ($\varepsilon = 2470$); 250 ($\varepsilon = 5470$). (Found: C: 81.61; H: 9.05. Calc. for $C_{23}H_{30}O_2$: C: 81.67; H: 8.87).

Finally **11** (0.45 g, 30%) was obtained, IR (neat). 3450 (OH); 1710 cm^{-1} (C = 0). NMR ($CDCl_3$): δ 0.73 and 0.8 (s, 6, gem-dimethyl); 0.96 (s, 3, CH_3 at C_1); 1.30 (s, 3, CH_3 at C_1); 3.76 (s, 3, O-CH_3). Mass spectrum: *m/e* (relative intensity): 356 (11) (M^+); 189 (100). (Found: C: 76.92; H: 9.52 Calc. for $C_{23}H_{32}O_3$: C: 77 48: H: 9.05.)

1-[2-(3-*Keto*-]-1,4,4-*trimethylcyclohexyl*)*ethyl*]-2-*methyl*-6-*methoxynaphthalene* **12**

A mixture of **6a** and **6b** (3.9 g, 11 mmol) *p*-toluenesulfonic acid (14 g) in *p*-xylene (300 m) were refluxed for 6 hr. Water (100 ml) was added to the cooled soln. The aqueous layer was extracted with ether (× 2) and the combined organic extracts washed with satd. $NaHCO_3$ aq, water and satd NaCl aq; then dried ($MgSO_4$). Concentration and chromatography (silica gel) gave 260 mg of **9** (spectral data identical to authentic sample), and 1.56 g (42%) of **12** m.p. 109–110° IR (KBr) ν_{max} 1710 (C = 0) 1610, 1625 cm^{-1} (C = C) UV λ_{max} 273, 285 ($\varepsilon = 8.1 \times 10^3$), 290. NMR ($CDCl_3$) δ: 1.03 (S. CH_3), 1.10 (s, 6, 2 × CH_3), 2.6 (s, 3, Aromatic CH_3), 3.9 (s, 3, OCH_3); 7.2–8.0 (1 m, 5, naphthalenic H's). Mass spec: *m/e* (r.i.) 338 (M^+ 100) 185 (98) 199 (12) 139 (28). (Found: C: 81.38; H: 9.17 Calc. for: $C_{23}H_{30}O_2$: C: 81.67, H: 8.87).

A soln of 230 mg (6.4×10^{-4} mole) of **6a**, 836 mg (4.4×10^{-3} mole) *p*-toluenesulfonic acid in 25 ml of *p*-xylene under an N_2 was refluxed for 6 hr. Water was added and the xylene layer separated. The aqueous layer was extracted (× 3) with ether. The combined extracts were washed with a 5% $NaHCO_3$ aq, water and sat brine soln and dried over Na_2SO_4. Evaporation of the solvent gave an oil (230 mg) which was chromatographed on silica gel using a mixture of petroleum-ether and ether as eluent to afford 42 mg of **10** and 80 mg of **12**. Total yield: 56%.

A soln of 430 mg of **6b**, 1.60 g *p*-toluenesulfonic acid in 50 mL *p*-xylene under N_2 was refluxed for 6 hr. Work-up in the usual manner afforded 425 mg crude product (oil) which was chromatographed on silica gel when a mixture of petroleum ether and ether as eluent afforded 143 mg of **9** and 197 mg of **12**, total yield: 83%.

*X-ray data collection.** Compound **9** crystallized from petroleum ether containing a few drops of ether as large colourless blocks elongated along c*. Preliminary photography showed monoclinic symmetry and systematic extinctions OkO with k odd and h0l with l odd. For data collection a specimen was cut to approximate dimensions 0.20 × 0.30 × 0.35 mm and was mounted with b as rotation axis. Crystal data are as follows: $C_{23}H_{30}O_2$, Mol. wt. = 338.5. Monoclinic, **a** = 14.066 (2), **b** = 7.781 (3), **c** = 18.271(3) Å, $\beta = 99.65(5)°$ (based on λ ($CuK\alpha_1$) = 1.54051 and λ ($CuK\alpha_2$) = 1.54433 Å), V = 1971.4 $Å^3$, z = 4, $d_x = 1.14\,g\,cm^{-3}$. Space group: $P2_1/c$. μ ($CuK\alpha$) = 5.56 cm^{-1}. Cell dimensions and relative intensities were measured at room temp with Ni-filtered Cu radiation on a Picker diffractometer equipped with a scintillation counter and pulse-height analyser. The $\theta/2\theta$ scan mode was used, with scan ranges from 2.0 to 4.0° and a 2θ scan speed of 2°/min. A 10 sec, background count was taken at the end of each scan. Two octants (hkl and hk$\bar{l}$) were surveyed to a $\sin\theta/\lambda$ limit of 0.575 $Å^{-1}$. The intensities of two standard reflections were measured at intervals of approximately 30 reflections throughout the data collection, and were used to scale all the data. Fluctuations in the standard counts appeared to be random. Of the 3134 independent reflections measured, 961 were classified as 'unobserved', having net counts less than 10 decacounts or less than 10% of the total background count. These were assigned zero weight in subsequent least-squares calculations. No absorption corrections were applied.

The structure was solved by the symbolic addition procedure and refined by block-diagonal least-squares, minimizing $\Sigma\omega(|F_0| - |F_c|)^2$. All H atoms were located on a different map and were refined isotropically while the C and O atoms were refined anisotropically. Scattering factors for C and O were those of Hanson, Herman, Lea and Skillmann[10] and bonded H scattering values were taken from Stewart, Davidson and Simpson.[11] The weighting scheme used for the later cycles of refinement was

$$\omega = 1/[1.0 + \{(|F_o| - 6.0)/10.0\}^2]: 1.6 < F_o < 106.4$$

and

$$\omega = \omega \times (0.45/\sin^2\theta) \text{ if } \sin^2\theta > 0.45.$$

This reduced the dependence of $\langle\omega\Delta^2\rangle$ on $|F_o|$ and on $\sin^2\theta$. It was noted that some of the strongest reflections appeared to be unaffected by secondary extinction. The ten reflections with highest net counts were therefore excluded from the final least-squares cycles, as was one other reflection (1 0 0) which showed poor agreement. In the final least-squares cycle the average (shift/e.s.d.) was 0.08 and the largest (Δ/σ) was 0.43. For all (2173) observed reflections the final conventional R value ($= \Sigma||F_o| - |F_c||/\Sigma|F_o|$) is 0.062. A difference map computed from the final structure factors* showed no density outside the range −0.16 to +0.15 e $Å^{-3}$.

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*Copies of tables of observed and calculated structure factors and of uncorrected bond lengths and angles are available, at a nominal charge, from the Depository of Unpublished Data, CISTI, National Research Council of Canada, Ottawa, Canada K1A 0S2.