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Synthesis of (1*R*) -[1-D]-α-Fenchocamphoronequinone[1,2]

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The title compound (**6b**) was prepared from (1*R*)-[1-D]-α-fenchocamphorone (**5b**), which was obtained from (+)-camphor (**1**) *via* ketopinic acid (**2**). Introduction of deuterium was achieved by $LiAlD_4$ reduction of 1-bromo-α-fenchocamphorone (**3**), a degradation product of ketopinic acid (**2**). (1*R*)-[1-D]-α-Fenchocamphoronequinone, a diketone whose chirality is due only to deuterium substitution, showed a small but measurable effect in CD of both low-intensity absorption bands in the region of 250–520 nm.

In the recent literature several authors have published results[3] of calculations on the optical activity of the twisted α-dicarbonyl chromophore. Glyoxal was used as a model compound for these calculations. It was found that when in *cis*-glyoxal the formyl groups are slightly rotated with respect to each other around the C–C bond, the Cotton effects associated with the two low-intensity absorption bands at longest wavelength should have an opposite sign. As it is known that the Cotton effects in camphorquinone at about 300 and 480 nm have an opposite sign, these authors[3] felt that the CD of camphorquinone corroborated their predictions and they assumed twist to be present in its -dicarbonyl chromophore.

In view of the successful synthesis of (1*R*)-[2-^{18}O]-α-fenchocamphoronequinone[4] and of the measurement of its CD[4,5] it seemed worthwhile to synthesize a similar compound with chirality due only to deuterium substitution in the hope that this compound would also show a measurable effect in CD. Such a CD curve might contribute to the knowledge of the electronic and geometrical structure of the α-dicarbonyl group in norcamphorquinones.

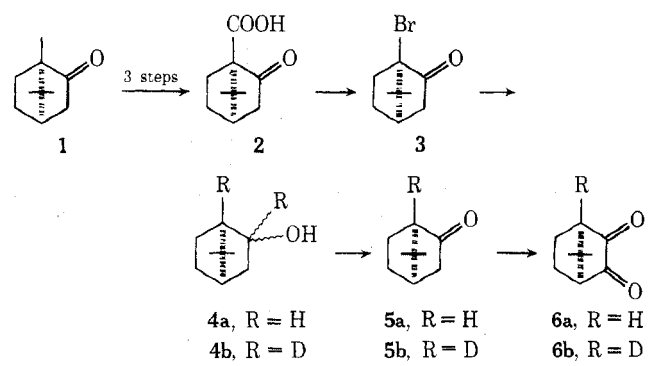
We were successful in synthesizing (1*R*)-[1-D]-α-fenchocamphoronequinone (**6b**), which showed a CD spectrum (Figure 1[6])) differing in many respects from the CD spectrum of (1*R*)-[2-^{18}O]-α-fenchocamphoronequinone.[2,4,5] This result suggests that in general optical activity due to isotopic substitution may provide new information about the structure of chromophores.

Details of the Synthesis. The route we followed to (1*R*)-[1-D]-α-fenchocamphoronequinone (**6b**, Scheme I) is obvious once one knows that the bridgehead methyl group in camphor (**1**) can be converted into a carboxyl group in three steps.

For the replacement of the bridgehead halogen in **3** by hydrogen we chose $LiAlH_4$. The halogen was rather unreactive toward this reducing agent: when *N*-methylmorpholine[12] (bp 115–116°) was used as a solvent a large excess of $LiAlH_4$ and a reaction time of several days were necessary to achieve complete reduction.

After it was verified that α-fenchocamphorone (**5a**) did not contain annoying impurities [it could be oxidized to give α-fenchocamphoronequinone (**6a**) which was inactive in CD], the desired deuterium-containing diketone (**6b**) was synthesized following the same route.

Scheme I[a]



[a] Absolute configurations of the compounds are depicted.[11]

Experimental Section

Melting points are not corrected; angles of rotation were measured with a Perkin-Elmer polarimeter (Model 131) at room temperature; concentrations (*c*) are given in grams of solute per 100 ml of solution; labels were calculated from peak intensities of mass spectra obtained with a MS-9 mass spectrometer; nmr spectra were recorded at room temperature using a Jeol 100-MHz nmr spectrometer; nmr shifts (both ^{1}H, ^{2}H and ^{18}C shifts) are with respect to TMS; new compounds gave satisfactory elemental analyses.

Ketopinic acid (2) can be prepared in three steps from camphor[13] *via* camphor-10-sulfonic acid and camphor-10-sulfonyl chloride. Some labor can be saved if one starts with (+)-(1*S*)-camphor-10-sulfonic acid, which is commercially available. Oxidation[13] of (1*S*)-camphor-10-sulfonyl chloride and recrystallization of the crude product from water gave (1*S*)-**2** in 20.9–24.5% yield, mp 226–228°, $[\alpha]_D$ +25.8° (*c* 0.65, MeOH). This low yield is in disagreement with the yield claimed in the procedure followed (38–42%). We obtained a by-product in this reaction: a white compound sublimed on the flat flange lid of the reaction vessel. It was identified as (1*S*)-10-chlorocamphor by comparison of its spectra with those of an authentic sample of this compound, yield 2.7–2.9% after resublimation, mp 130–131°, $[\alpha]_D$ +39.75° (*c* 0.79, $CHCl_3$), $[\alpha]_D$ +41.7° (*c* 0.85, absolute EtOH). This chlorocamphor was formed not only when crude sulfonyl chloride was used for the preparation of **2**, but also when pure recrystallized (from benzene–hexane) sulfonyl chloride was used in this reaction. Thus the assumption that the isolation of 10-chlorocamphor is a consequence of overheating during the preparation of the sulfonyl chloride is not justified.

(1*S*)-10-Chlorocamphor has been reported by Forster,[14] but in Beilstein[15] an alternative structure (6-chlorocamphor) is proposed

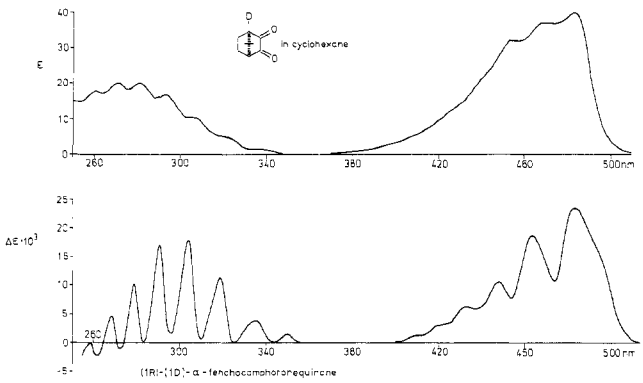


Figure 1.

for Forster's compound as well. We decided to prepare 10-chlorocamphor for use as a reference in such a way that no doubt can be thrown upon its structure. (1*S*)-10-Bromocamphor[16] (1.0 g) was heated with lithium chloride[17] (1.0 g) in DMF (10 ml) for 20 hr at 155°. The mixture was poured into water. Ether extraction, washing of the extract with water, and evaporation of the ether gave the crystalline chloro ketone (0.78 g), which was shown by glc (SE-30 column) to be almost pure, the impurity being <2% of 10-bromocamphor. (1*S*)-10-Chlorocamphor showed mp 131–132° after two recrystallizations from isooctane (the crystals were removed by filtration at −15° after every recrystallization), $[\alpha]_D$ +41.8° (*c* 0.96, absolute EtOH) [lit.[14] mp 132.5°, $[\alpha]_D$ +40.7° (*c* 2.0, absolute EtOH)]. Nmr data of 10-chlorocamphor ($CDCl_3$) include singlets at δ 0.97 and 1.11 ppm (methyl groups) and a quartet at δ 3.69 ppm (J_1 = 22.4, J_2 = 12.2 Hz, hydrogens attached to C_{10}).

(1*S*)-10-Chlorocamphor oxime showed mp 131–132° after recrystallization from isooctane–toluene (3:1), $[\alpha]_D$ −54.8° (*c* 0.94, $CHCl_3$) [lit.[14] mp 134°, $[\alpha]_D$ −58.1° (*c* 2.0, $CHCl_3$). Nmr data of this oxime ($CDCl_3$) include singlets at δ 0.95 and 1.09 ppm (methyl groups) and a quartet at δ 3.91 ppm (J_1 = 15.7, J_2 = 11.1 Hz, hydrogens attached to C_{10}).

(1*S*)-10-Chlorocamphor semicarbazone had mp 215–216° after recrystallization from alcohol, but this melting point was dependent on the rate of heating of the melting point apparatus. Nmr data (CF_3COOH) include singlets at δ 1.14 and 1.26 ppm (methyl groups) and a quartet at δ 4.15 ppm (J_1 = 18.0, J_2 = 12.0 Hz, hydrogens at C_{10}).

(1*S*)-1-Bromo-α-fenchocamphorone (3). Degradation of **2** with bromine and mercuric oxide in dichloromethane has been reported.[18] We followed this procedure.[18] Because decarboxylation reactions such as this one are radical reactions, usually the desired product is not the only product; *e.g.*, it is known that when a Hunsdiecker reaction is carried out in carbon tetrachloride also chlorinated product is to be expected.[19] Analysis of the reaction mixture after the degradation of **2** showed that a by-product was formed (20%) which was identified by glc as α-fenchocamphorone (**5a**). Formation of **5a** was not reported in ref 18. No chlorine-containing product could be detected.

The solvent was removed and the crude product was dissolved in an equal volume of MeOH; (1*S*)-1-bromo-α-fenchocamphorone (**3**) was then removed by filtration at −15°, yield 50–51%. This product, once recrystallized, was used for further reactions. Part of it was further purified by recrystallization from heptane. Then it showed $[\alpha]_D$ +73.5° (*c* 0.61, MeOH), mp 190–191°. Nmr data ($CDCl_3$) include two singlets at δ 0.95 and 1.09 ppm (methyl groups).[18]

The semicarbazone of 3, fine needles from alcohol, seems not very suitable for the characterization of **3** because its low solubility does not permit measurement of the angle of rotation. It is soluble in CF_3COOH, but we did not want to expose the polarimeter cell to this solvent. The semicarbazone has no sharp melting point: decomposition starts at 230°; the compound is a liquid at 245°. Nmr data (CF_3COOH) include singlets at δ 1.08 and 1.29 ppm (methyl groups).

(1*S*)-1-Bromo-α-fenchocamphoronequinone. 3 was oxidized with selenium dioxide in acetic anhydride[20] to give 1-bromo-α-fenchocamphoronequinone, $[\alpha]_D$ −366° (*c* 0.38, $CHCl_3$), mp 201.5–202.0°, in 31.2% yield after six recrystallizations from heptane. Nmr data of this diketone ($CDCl_3$) include a quartet at δ 2.85 ppm (J_1 = 4.5, J_2 = 1.5 Hz, bridgehead proton), a complex multiplet at δ 1.5–2.5 ppm (4 protons), and singlets at δ 1.03 and 1.19 ppm (methyl groups). Absorption band in the visible region: ϵ_{max} (460.0 nm) 54.0; $\Delta\epsilon_{min}$ (457.0 nm) −2.97 ($CHCl_3$). Absorption band at about 300 nm: in $CHCl_3$ this second absorption band is not isolated from the third band (which has a high intensity), but gives rise to a number of shoulders on the longest wavelength side of this band; $\Delta\epsilon_{max}$ (295.0 nm) +1.14.

$LiAlH_4$ Reduction of Bromo Ketones. General Procedure. A solution of the compound to be reduced was added without stirring to a boiling mixture of $LiAlH_4$ and solvent heated on an oil bath. The product was always isolated by steam distillation after water had been added to destroy the excess of unreacted $LiAlH_4$ and sufficient hydrochloric acid had been added to acidify the mixture. When the condenser got clogged during the steam distillation it was cleaned with dichloromethane.

Reduction of 3.[21] A mixture of **3** (35 g), $LiAlH_4$ (19 g, 529% excess), and *N*-methylmorpholine (200 ml) was refluxed for 6 days. Then reduction was complete. Yield was 80%. It followed from glc measurements (DEGA column) that we had obtained a mixture of *exo*-**4a** (87.1%) and *endo*-**4a** (12.9%). The exo configuration is assigned to the main product[22] because this alcohol is formed as the minor product of the reduction of **5a** with sodium and ethanol (see below).

(1*R*)-*exo*-α-Fenchocamphorol (*exo*-4a). A solution of crude **4** in dichloromethane (prepared from **3** as indicated above) was cooled to −15°. The crystals (needles) were than removed by filtration. Pure *exo*-**4a** could be obtained by four recrystallizations of these needles from pentane–dichloromethane (4:1); the crystals were removed by filtration at −15° after every recrystallization. Pure *exo*-**4a** has mp 140–141°, $[\alpha]_D$ −15.45° (*c* 0.93; $CHCl_3$). Nmr data ($CDCl_3$) include singlets at δ 0.95 and 1.22 ppm (methyl groups) and a quartet at δ 3.84 ppm (J_1 = 7.3, J_2 = 4.0 Hz, H attached to C_2).

(1*R*)-α-Fenchocamphorone (5a) was prepared from **4a** by ruthenium tetroxide oxidation. We preferred this method of oxidation to Jones oxidation, because Jones oxidation of norbornanols can give rise to (partial) racemization.[10] Ruthenium tetroxide oxidation of alcohols is so fast that racemization of norbornanols during this oxidation seems unlikely.[28]

Ruthenium tetroxide was prepared by oxidation of potassium ruthenate with chlorine following the procedure of Gutbier.[29] The crystals of RuO_4 obtained in this manner were not resublimed in a current of an inert gas, as proposed by Gutbier,[29] but were dissolved in dichloromethane (RuO_4 from 10 g of Ru in 100 ml of CH_2Cl_2). To remove traces of chlorine the first 10% (by volume) of this solution was removed by distillation (from a water bath at 45–50°) and discarded. The remaining solution in the distillation flask was stored at −15° until needed.

Oxidation Procedure. 4a (3.0 g) [which had been purified by preparative glc (SE-30 column) under the same conditions as used for the purification of its deuterium-containing analog **4b** (see below)] was dissolved in CH_2Cl_2 (60 ml), and with magnetic stirring the calculated quantity[30] of RuO_4 solution was added dropwise. The temperature of the mixture was kept at −25 to −30° during the addition. After the addition stirring was continued at −15° for 30 min. Then it was verified by glc (Carbowax column) that no starting material (**4a**) was left. To destroy a possible small excess of RuO_4 some ether was carefully added. When the reaction mixture had reached room temperature, water was added; methylene chloride was then removed by distillation. The remaining **5a** in the distillation flask was freed from RuO_2 by steam distillation; the product crystallized in the condenser from which it was isolated using methylene chloride. Evaporation of the CH_2Cl_2 afforded crude **5a** in ~80% yield.

Glc measurements of crude **5a** indicated the presence of two impurities. For optical measurements **5a** was purified by preparative glc (Carbowax column). The most abundant impurity (2.0%) with a retention time shorter than that of **5a** could be completely removed, whereas the other impurity (0.2%) with a retention time longer than that of **5a** could be partially removed. Purified (1*R*)-**5a** had mp 100–105°, $[\alpha]_D$ +66.5° (*c* 0.68, absolute EtOH); in nmr ($CDCl_3$) the two methyl peaks coincided at δ 1.04 ppm [lit.[8] $[\alpha]_D$ +73.94° (EtOH), mp 113.0–3.5°]. The spectra of **5a** were of course identical with those recorded during our work on [^{16}O–^{18}O]-**6a**.[4]

α-Fenchocamphoronequinone (6a). To show that **5a** did not contain annoying impurities, crude **5a** (2.0 g) was oxidized[20] with selenium dioxide in acetic anhydride. To the product was added dichloromethane, and it was filtered, washed free from acid, and distilled. The distillate was purified by preparative glc in order to remove unreacted **5a**. Yield of **6a** after sublimation was 1.5 g (68%), mp 138.5–139.5°. Fortunately no CD of **6a** could be detect-

ed, indicating the absence of annoying impurities. Nmr data of **6a** ($CDCl_3$) include a triplet at δ 2.59 ppm ($J_1 = J_2 = 2.8$ Hz, bridgehead protons), complex multiplets at δ 2.1–2.4 and 1.5–1.8 ppm (each multiplet corresponds to 2 protons), and singlets at δ 1.09 and 1.14 ppm (methyl groups). We also recorded the ^{13}C nmr spectrum (in $CDCl_3$): singlets at δ_C 19.8, 22.9, 23.1, 41.1, 57.7, and 202.6 ppm.

(1R)-*endo*-α-Fenchocamphorol (*endo*-4a). Reduction of **5a** with sodium and ethanol, following a procedure for the reduction of camphor,[31] gave a mixture of *endo*-**4a** (75%) and *exo*-**4a** (25%). The relative configuration at C_2 of these alcohols follows from the known stereochemistry of the reduction of norbornanones with sodium and ethanol.[28,26] The mixture of alcohols was separated by preparative glc (DEGS column) to give (1*R*)-*endo*-**4a**, mp 115–123°, $[\alpha]_D$ +7.05° (*c* 1.46, $CHCl_3$), after recrystallization from dichloromethane and hexane. (The crystals were removed by filtration at −15° after every recrystallization.) Nmr data of *endo*-**4a** ($CDCl_3$) include singlets at δ 0.99 and 1.01 ppm (methyl groups) and a multiplet at δ 4.48 ppm (H attached to C_2).

Characterization of 11. Mattinen[8] purified **5a** as the semicarbazone. We found that this semicarbazone could only be recrystallized with considerable loss of material from benzene or water-ethanol (1:1). We prepared[32] the 2,4-dinitrophenylhydrazone of **5a**, mp 141–142°, $[\alpha]_D$ −79.9° (*c* 0.81, $CHCl_3$), in about 50% yield after four recrystallizations from ethanol. Nmr data of this 2,4-dinitrophenylhydrazone ($CDCl_3$) include singlets at δ 9.1 (H attached to N), 1.10, and 1.02 ppm (2 methyl groups), and two doublets and a quartet at δ 6.3–8.0 ppm (3 aromatic protons).

Experiments with Deuterated Compounds. Note: **3** necessary for the synthesis of both **6a** and **6b** was obtained in the same preparation.

A mixture of **3** (20 g), $LiAlD_4$ [98% D; a fresh 10-g package (Merck), 420% excess], and *N*-methylmorpholine (110 ml) was refluxed for 6 days. Then reduction was incomplete:[33] 41.4% of the mixture was deuterated α-fenchocamphorol (**4b**); 58.6% was 1-bromo-α-fenchocamphorol. The two alcohols were separated by preparative glc (SE-30 column), yield of bromo alcohol 8.7 g (73.6%; yield based on **3** and on the composition of the mixture of reduction products). Nmr data of this bromo alcohol ($CDCl_3$) include singlets at δ 0.97 and 1.13 ppm (methyl groups); as a consequence of the high deuterium content of the $LiAlD_4$ used, H attached to C_2 could not be detected by nmr.

4b was oxidized with RuO_4 in CH_2Cl_2 to give **5** (3.4 g, 64.6%; yield based on **3** and on the composition of the mixture of reduction products). Only 33.60% of **5b** was labeled with one deuterium and 1.77% was doubly labeled with deuterium.

5b (2.0 g) was oxidized as indicated above, and gave after purification by preparative glc **6b** (1.4 g, 64%), mp 137.5–139.0°; 30.08% of **6b** was labeled with one D and 0.53% was doubly labeled. This **6b** was used for the measurement of CD.[34]

The observed CD was not caused by impurities because (1) undeuterated diketone **6a**, prepared in the same manner as **6b** from **3**, was inactive in CD; (2) recrystallization of **6b** (from heptane) did not affect the effect in CD; (3) if the observed effect in CD were due only to an impurity having $\Delta\epsilon$ 2 (*i.e.*, a much larger effect in CD than camphorquinone), this impurity should be present in the mixture for about 0.4%. Careful examination of **5b** with capillary columns (SE-30, DEGA) indicated that in **5b** only the same harmless impurities were present as in **5a** and in about the same concentration.

The postulated structure (**6b**) *of the deuterated diketone is based only on synthetic evidence,* but contamination of **6b** with deuterated isomers is very unlikely since there is no evidence for such isomerizations in the literature on $LiAlD_4$ reductions. One might suppose that physical evidence for the structure of **6b** can be obtained from nmr. In ^1H nmr the triplet of **6b** at δ 2.59 ppm should have a relative intensity only 15% lower than the relative intensity of the corresponding triplet in the spectrum of **6a**. Unfortunately, integration of nmr spectra is not very accurate. Use of ^{13}C nmr seemed to be a better approach to the problem. A deuterium atom attached to ^{13}C splits the ^{13}C line into a triplet (three lines of equal intensity, splitting constant ~50 Hz). Thus in the ^{13}C spectrum of **6b** the bridgehead atoms should give rise to a triplet with relative intensities of the lines 5:90:5 (this intensity distribution holds only if the influence of the NOE effect on the component of the central line due to undeuterated diketone is neglected). Unfortunately, no satellites of any line in this spectrum could be separated from the noise. We also recorded the ^2H nmr spectrum of **6b** (in $CDCl_3$). This consisted of only one line at δ_D 3.00 ppm. However, as a consequence of isotope effects in nmr ($\delta_H \neq \delta_D$) and of the unavailability of the ^2H nmr spectrum of perdeuterio-**6a**, this ^2H nmr spectrum of **6b** cannot be used as a proof of its structure.

Acknowledgment. The authors are indebted to Professor L. J. Oosterhoff for his interest in this work, and to Professor H. Wynberg (Groningen) for reading the manuscript. The CD measurements were carried out with a sensitive instrument build by Mr. H. P. J. M. Dekkers in this department.

Registry No.—**2**, 464-78-8; **3**, 51057-34-2; **3** semicarbazone, 51057-35-3; *exo*-**4a**, 51153-09-4; *endo*-**4a**, 51153-10-7; **5a**, 40550-41-2; **5a** 2,4-dinitrophenylhydrazone, 51057-36-4; **6a**, 4183-87-3; **6b**, 50764-42-6; **6** (R = Br), 51057-37-5; (1*S*)-10-chlorocamphor, 51057-38-6; (1*S*)-10-chlorocamphor oxime, 51057-39-7; (1*S*)-10-chlorocamphor semicarbazone, 51057-40-0

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(22) Because the stereochemistry of $LiAlH_4$ reduction of norbornanones is rather complicated, a reliable assignment of the configuration at C_2 of norbornanols, prepared by $LiAlH_4$ reduction of the corresponding ketone, cannot be based on the stereochemistry of this reduction. For example, camphor[23-26] and epicamphor[23] can be reduced by $LiAlH_4$ to give mainly the exo alcohols, but mainly the endo alcohols are obtained on $LiAlH_4$ reduction of fenchone[24-27] and isofenchone.[25-27]
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(30) We determined the RuO_4 concentration of our stock solution by adding a sample of it to an excess of some secondary alcohol (e.g., borneol) in methylene chloride under conditions similar to those described in the oxidation procedure. After the oxidation the mixture was left to stand till it had reached room temperature, and then it was filtered. The RuO_4 concentration was easily calculated from the ketone:alcohol ratio in the filtrate (glc, Carbowax column). For alternative procedures for the quantitative determination of RuO_4, cf. C. Djerassi and R. R. Engle, J. Amer. Chem. Soc., 75, 3838 (1953); W. R. Crowell and D. M. Yost, ibid., 50, 374 (1928).
(31) O. Wallach, Justus Liebigs Ann. Chem., 230, 225 (1885).
(32) O. L. Brady, J. Chem. Soc., 756 (1931).
(33) There seemed to be a large isotope effect in the reduction of 3: under conditions where $LiAlH_4$ reduction of 3 was complete. $LiAlD_4$ gave a mixture of the desired alcohol 4b (minor product) and 1-bromo-α-fenchocamphorol. However, we have not investigated whether this result of $LiAlD_4$ reduction is reproducible.
(34) We have not investigated why the deuterium content of 5b and 6b was much lower than was expected.

Total Stereoselective Synthesis of α-Atlantone

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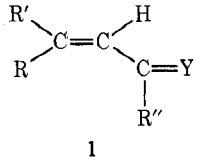
A stereoselective synthesis of α-atlantone (13) has been achieved, the key step involving the allylic rearrangement of tertiary vinyl carbinol 6 to primary allylic acetate 7. Saponification of the latter followed by oxidation using the chromium trioxide–pyridine complex afforded α,β-unsaturated aldehyde 9 of very high stereochemical purity. The synthesis was completed by addition of methallylmagnesium chloride (11) to aldehyde 9 to yield alcohol 12, which upon mild oxidation followed by base-catalyzed isomerization yielded α-atlantone (13), identical in physical and spectral properties with those of the authentic natural product. An alternate route to α,β-unsaturated aldehyde 9 involved preparation of nitrile 10 from ketone 5 *via* a modified Wittig reaction using diethyl cyanomethylphosphonate. Subsequent reduction of nitrile 10 with diisobutylaluminum hydride followed by hydrolysis afforded the desired aldehyde (9).

Until recently atlantones, the major ketones of the essential oil from *Cedrus libanotica* Link., *C. atlantica* Manet, and *C. deodara* Loud. (the "true" cedars), had not been obtained in pure form and were considered to be an inseparable mixture of isomers. In 1971, however, the essential oil from *Cedrus deodara* was found[1] to contain essentially one member of this group, α-atlantone (13). The assigned structure and stereochemistry of this ketone was subsequently confirmed by a total synthesis[2] of α-atlantone by a route that also led to the synthesis of other bisabolane sesquiterpenes.[3]

Since α-atlantone can be viewed as a functionalized trisubstituted olefin of structural type 1, we decided to investigate its possible synthesis *via* a route which we have recently developed[4] for the bishomologation of ketones to such derivatives.



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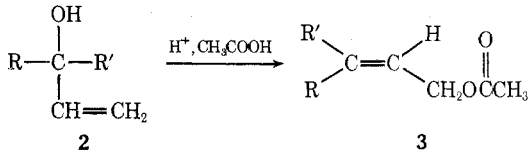
R′ > R in size

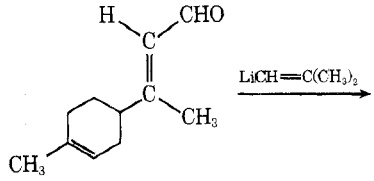
The key step in the synthesis of these functionalized olefins (1) involves the acid-catalyzed rearrangement of a tertiary vinyl carbinol (2) in acetic acid to afford in high yield the primary allylic acetate (3). The starting alcohols (2) for the process are readily obtained *via* addition of vinylmagnesium chloride to an appropriate ketone.



2 3

The tertiary vinyl carbinol required for a synthesis of α-atlantone utilizing the above rearrangement is alcohol 6, obtained in high yield by addition of vinyllithium to the previously reported[5] ketone 5. Diels–Alder reaction of isoprene with methyl vinyl ketone afforded the latter compound (5) as the major product. As expected, the allylic rearrangement of alcohol 6 proceeded smoothly to give the desired primary allylic acetate (7) in approximately 70% yield. Furthermore, as indicated by vpc and nmr analysis of acetate 7 as well as the corresponding alcohol 8 and aldehyde 9, the product appeared to consist predominantly (>90%) of the *E* stereoisomer, the one vital in a stereoselective synthesis of α-atlantone.

Encouraged by the success of the allylic rearrangement, we continued the total synthesis as outlined in Chart I. Saponification of allylic acetate 7 followed by mild oxidation of the corresponding alcohol 8 with the chromium trioxide–pyridine complex[6] proceeded without complications to afford aldehyde 9 in high yield. Initially we had planned to add isobutenyllithium to aldehyde 9 to obtain alcohol 4, which could subsequently be oxidized directly to α-atlantone (13). However, we were unable to obtain



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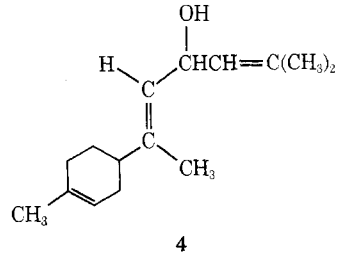

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this organolithium derivative in satisfactory yield following the literature procedure[7] for its preparation. We found it more convenient to prepare methallylmagnesium chloride (11), which reacted with aldehyde 9 to yield the unsaturated alcohol 12. Oxidation of the alcohol moiety followed by a facile base-catalyzed isomerization (*via* eno-