traction into ether, pure 2-phenylpiperidine was isolated by preparative VPC: NMR ($CDCl_3$) δ 7.35 (s, 5, aromatic), 3.8–2.5 (m, 3), 2.05–1.25 (m, 7); IR (neat) 3350 (w), 2950, 1440, 1100, 750, 695; mass spectrum, *m/e* 161.120 (M^+, calcd for $C_{11}H_{15}N$, 161.120).

Solutions of 1-Pyrroline (2). Solutions of 1-pyrroline were prepared by reacting freshly distilled pyrrolidine (2.84 g, 40 mmol) with *tert*-butyl hypochlorite in ether (100 mL) by the method of Bachmann et al. as detailed elsewhere by us.[2] *N*-Chloropyrrolidine was not isolated, but its ether solution was slurried with potassium superoxide (6.25 g, 88 mmol) and 18-crown-6 ether (80 mg) for 9 h. The solution was filtered before addition to the appropriate organolithium.

2-*n*-Butylpyrrolidine (3). A solution of *n*-butyllithium (53 mL of a 1.5 M solution, 80 mmol) was introduced into a flask fitted as described in the synthesis of **4**. A solution of 1-pyrroline prepared as described above was added dropwise with stirring at ambient temperature over 30 min. The reaction was treated as in the usual manner, and 1.41 g of 2-butylpyrrolidine was distilled at 65–72 °C (18 mm) VPC analysis showed that it contained 10% hexane (25% yield of pure material). Preparative VPC provided pure sample: NMR ($CDCl_3$) δ 3.2–2.6 (m, 3), 2.1–1.7 (complex m, 14); IR (neat) 3300, 2900, 1460, 1400; mass spectrum, *m/e* 127.137 (M^+, calcd for $C_8H_{17}N$, 127.136).

2-Phenylpyrrolidine (5). Phenyllithium (60 mmol) was prepared from bromobenzene and lithium metal in ether at reflux in a flask fitted as described in the synthesis of **4**. After the solution of phenyllithium was cooled, a solution of 1-pyrroline (prepared as above from 30 mmol of pyrrolidine) was added in the usual manner. The reaction mixture was treated as in the synthesis of **4** to yield 2.22 g of 2-phenylpyrrolidine (58% pure by NMR, contained biphenyl as the impurity): bp 98–100 °C (2.5 mm); 29% yield of pure material. Preparative VPC provided a pure sample: NMR ($CDCl_3$) δ 7.35 (m, 5), 4.12 (t, 1), 3.40–2.73 (m, 2), 2.40–1.42 (m, 5); IR (neat) 3300, 2950, 1600, 1480, 1440, 1060, 1020, 750, 695; mass spectrum, *m/e* 147.105 (M^+, calcd for $C_{10}H_{13}N$, 147.105); picrate, mp 150–151 °C (lit.[11] mp 148–149 °C).

***dl*-Anabasine (7).** 3-Pyridyllithium was prepared by the dropwise addition over 1 h of 3-bromopyridine (12.6 g, 80 mmol) in ether (100 mL) to *tert*-butyllithium (66 mL of a 1.2 M solution in pentane, 80 mmol) in ether (100 mL) under a nitrogen atmosphere in a −120 °C bath [pentane–2-propanol–acetone (4:1:1), liquid N_2]. The resulting yellow slurry was stirred an additional 0.5 h before a solution of piperideine (40 mmol) in ether (125 mL) was added dropwise over 1 h at −100 °C. The mixture was stirred an additional 0.5 h before warming over 1 h to −40 °C. Water (15 mL) was added dropwise with stirring, and the reaction mixture warmed rapidly to room temperature with a warm-water bath. The ether was decanted, and 2 mL of a 50% aqueous KOH solution was added to the residue which was then extracted with ether (20 mL, three times). After the ether extracts were combined with the product mixture and the ether dried over anhydrous sodium sulfate and concentrated, the residue was distilled, and 2.96 g of 97% pure *dl*-anabasine was collected at 100–112 °C (2 mm) (44% yield of pure material by NMR). Preparative VPC provided a pure sample: NMR ($CDCl_3$) δ 8.51 (m, 2), 7.73 (dt, 1), 7.22 (dd, 1) 3.62 (m, 1), 3.42–2.46 (m, 2), 2.12–1.0 (m, 7); IR (neat) 3300, 2940, 1570, 1420, 1310, 1100, 1020, 710; mass spectrum, *m/e* 162.115 (M^+, calcd for $C_{10}H_{14}N_2$, 162.115).[12]

2-*tert*-Butylpiperidine (8). A 0.36 M solution of **1** in ether prepared from *N*-chloropiperidine (4.84 g, 40 mmol) was added dropwise to a solution of *tert*-butyllithium in pentane (1.2 M, 80 mmol) at −80 °C. After the mixture was stirred for 1 h, water (10 mL) was added dropwise over 10 min and the mixture warmed to room temperature with a warm-water bath. The product mixture was filtered and dried over anhydrous sodium sulfate. After filtration the solution was concentrated at atmospheric pressure through a 6-in. Vigreaux column. When the head temperature reached 160 °C, the Vigreaux head was removed, and the product (3.74 g) was distilled with a microcondenser and collected from 168 to 175 °C (lit.[13] bp 173–174 °C). VPC analysis showed it to be 95% pure (63% yield). Preparative VPC provided a pure sample. The spectra were identical with those of 2-*tert*-butylpiperidine prepared by the method of Grundon and Reynolds:[13] NMR (CCl_4) δ 3.40–0.94 (m, 10), 0.86 (s, 9); IR (neat) 3350 (w), 2950, 1470, 1430, 1350, 1320, 1190, 1110, 1050, 857, 842, 747; mass spectrum, *m/e* 141.154 (M^+, calcd for $C_9H_{19}N$, 141.152); hydrochloride, mp 257–259 °C.[14]

Acknowledgment is made to the donors of the Petroleum Research Fund, administered by the American Chemical Society, and the Research Corp. for the support of this research. We are grateful to Professor R. Graham Cooks and the Mass Spectroscopy Center of the Chemistry Department, Purdue University, for providing us with high- and low-resolution mass spectra of the compounds described here and to Dr. Michael Lusch of Polaroid Corp. for many helpful discussions.

Registry No. 1, 505-18-0; 2, 5724-81-2; 3, 3446-98-8; 4, 72939-22-1; 4·HCl, 72939-23-2; 5, 1006-64-0; 5 picrate, 1689-55-0; 6, 3466-80-6; 7, 13078-04-1; 8, 72939-24-3; 8·HCl, 72939-25-4; *N*-chloropiperidine, 2156-71-0; bromobenzene, 108-86-1; pyrrolidine, 123-75-1; 3-bromopyridine, 626-55-1.

(11) S. Gabriel and J. Colman, *Chem. Ber.*, **41**, 513 (1908).

(12) NMR and IR spectra were identical with those of an authenic sample. We are grateful to Dr. Edward Sanders of the Philip Morris Research Center for providing us with spectra for comparison.

(13) M. F. Grundon and B. E. Reynolds, *J. Chem. Soc.*, 2445 (1964).

(14) The melting point of the hydrochloride reported by Grundon and Reynolds[13] is 229–232 °C. We have repeated their synthesis and found a melting point for the hydrochloride (acetone) of 257–259 °C.

New Synthesis of (±)-Menthofuran[1]

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Received September 13, 1979

Syntheses of menthofuran, one of the important aromatics, have been carried out by many groups.[2a-k] They mostly used naturally occuring pulegone or isopulegone as a starting material. Wenkert et at.[2j] synthesized (±)-menthofuran in about 18% overall yield in five steps from ethyl 4-methyl-2-oxo-1-cyclohexanecarboxylate (**1**),[3] via the thermal interaction of dimethyl diazomalonate with 1-methoxy-5-methyl-1-cyclohexene, which was derived from **1** as a key intermediate. Overall yields of menthofuran in these procedures appear to be no higher than 20%. For example, Zalkow et al.[2g] prepared optically pure (+)-menthofuran from pulegone by a two-step sequence in about 20% yield. Bedoukian [2b] also obtained (+)-menthofuran via pulegenol sulfonic ester[2a] in 20% yield. In this paper, we wish to report a new synthesis of (±)-menthofuran, in about 45% overall yield in a three-step sequence from **1**, via the direct C-alkylation with ethyl 2-iodopropionate. The reaction sequence of the present

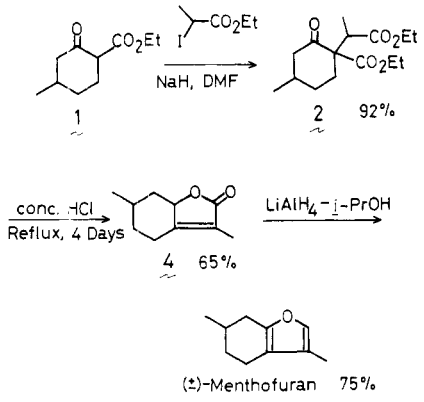
(1) Presented in part at the 22nd Symposium on the Chemistry of Terpenes, Essential Oils, and Aromatics, the Chemical Society of Japan, Yokohama, Oct 1978.

(2) (a) W. Treibs, *Chem. Ber.*, **70**, 85 (1937); (b) P. Z. Bedoukian, *J. Am. Chem. Soc.*, **70**, 621 (1948); (c) W. Treibs, G. Jucivs, H. Kogler, and H. Breslander, *Justus Liebigs Ann. Chem.*, **581**, 59 (1953); (d) H. Fritel and P. Baranger, *C. R. Hebd. Seances Acad. Sci.*, **241**, 674 (1955); (e) H. Fritel and M. Fetizon, *J. Org. Chem.*, **23**, 481 (1958); (f) H. Stetter and R. Lauterbach, *Chem. Ber.*, **93**, 603 (1960); (g) L. H. Zalkow, J. W. Ellis, and S. M. R. Brennan, *J. Org. Chem.*, **28**, 1705 (1963); (h) L. H. Zalkow and J. W. Ellis, *ibid.*, **29**, 2626 (1964); (i) K. Ohkata, T. Sakai, Y. Kubo, and T. Hanafusa, *J. Chem. Soc., Chem. Commun.*, 581 (1974); (j) E. Wenkert, M. E. Alonso, B. L. Buckwalter, and K. J. Chou, *J. Am. Chem. Soc.*, **99**, 4778 (1977); (k) B. Harirchian and P. D. Magnus, *Synth. Commun.*, **7**, 119 (1977).

(3) C. Djerassi, J. Burakevich, J. W. Chamberlin, D. Elad, T. Toda, and G. Stork, *J. Am. Chem. Soc.*, **86**, 465 (1964).

0022-3263/80/1945-1517$01.00/0

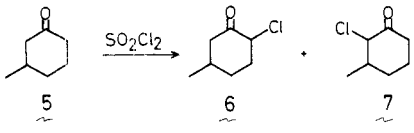
Scheme I



synthesis is shown in Scheme I.

Alkylation of β-keto esters with alkyl halides is well investigated.[4,5] Pond and Cargill[5] have reported that the reaction of the potassium salt of ethyl 2-oxo-1-cyclopentanecarboxylate with isopropyl iodide in dimethyl sulfoxide at room temperature provides exclusively C-alkylated product. We have found that the sodium salt of **1** reacts with ethyl 2-iodopropionate in dimethylformamide (DMF) at 100 °C to give C-alkylated product **2** in almost quantitative yield. On the other hand, the reaction of **1** with ethyl 2-bromopropionate in ethanol in the presence of sodium ethoxide only resulted in a ring cleavage of **1** to give diethyl 3-methyl-1,7-heptanedioate (**3**). Hydrolysis of the diester **2** with concentrated HCl afforded 3,6-dimethyl-2,4,5,6,7,7a-hexahydrobenzofuran-2-one (**4**) in 65% yield. Its IR spectrum showed a strong peak at 1755 cm^{-1} due to lactone carbonyl stretching. Both ^1H and ^{13}C NMR spectra also supported the structure of **4**.

Attempts to introduce propionic ester moiety at the C-6 position of 3-methylcyclohexanone (**5**) by S_N2 reaction of



6-chloro-3-methylcyclohexanone (**6**)[6] with diethyl sodiomethylmalonate, however, led to unsatisfactory results since the chlorination[6-8] of **5** with sulfuryl chloride afforded a mixture of **6** (65%) and 2-chloro-3-methylcyclohexanone (**7**, 29%), which could not be separated by fractional distillation.

The interconversion between the furan ring and the α,β-unsaturated γ-lactone ring by oxidation or reduction is well-known.[9] Minato and Nagasaki[9] have reported that the reduction of α,β-unsaturated γ-lactones with diisobutylaluminum hydride (DIBAL) gave furan rings in good yields. We investigated the reduction of unsaturated lactone **4** with lithium aluminum hydride (LAH) partially quenched by alcohols. The results of reductions of **4** under various conditions are tabulated in Table I. When LAH quenched by an equimolar amount of 2-propanol was used

Table I. Reduction of 4 with $LiAlH_4$-*i*-PrOH

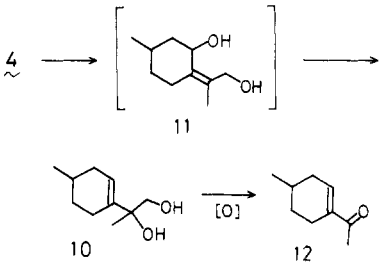
ratio[b]	T, °C	time, h	product (yield, %)
4	−60 to −50	3	menthofuran (75)
0.5	−60 to −50	0.5	menthofuran (9, 29[a]), lactone **4** (70)
4	−76	2.5	menthofuran (25, 51[a]), lactone **4** (52)
1.5	(1) −60 to −50, (2) room temp	0.5 1	diol **10** (79)

[a] Based on consumed lactone **4**. [b] Molar ratio of LAH-*i*-PrOH to **4**.

at −60 to −50 °C, (±)-menthofuran was obtained in a satisfactory yield. For an examination of the applicability of the present method, a few examples were investigated under the same condition as described above. The reduction of 3-methyl-2,4,5,6,7,7a-hexahydrobenzofuran-2-one (**8**) gave 3-methyl-4,5,6,7-tetrahydrobenzofuran (**9**) in 57% yield. However, the reduction of γ-alkyl-substituted

α,β-unsaturated γ-lactones gave an unsatisfactory result. For example, the reduction of 5-*n*-octyl-2(5*H*)-furanone afforded an unidentified mixture, whose IR spectrum showed a strong absorption band at 3400 cm^{-1} due to OH groups. Therefore, this procedure seems to be useful only for the reduction of unsaturated cyclic γ-lactones to fused furans.

Prolonged treatment of **4** with the reducing reagent at room temperature gave 2-(4-methyl-1-cyclohexenyl)-1,2-propanediol (**10**) in 79% yield. The formation of **10** can



be explained by the allylic rearrangement of the reduction product **11**. The structure of **10** was further confirmed by the fact that the oxidation of **10** provided methyl 4-methyl-1-cyclohexenyl ketone (**12**) quantitatively. The melting point of the 2,4-dinitrophenylhydrazone of **12** was identical with that of the authentic sample.[10]

The present synthesis readily provides (±)-menthofuran in a reasonable overall yield by brief and experimentally simple procedures.

Experimental Section

The melting points and boiling points are uncorrected. Elemental analyses were carried out by Mr. Eiichiro Amano of our laboratory. Analytical determinations by GLC were performed on a Hitachi Model K-53 gas chromatograph fitted with 10% Apiezon L grease on Chromosorb W (3 mm o.d. × 1 m). Mass spectra were obtained with a Hitachi Model RMS-4 mass spectrometer. ^1H NMR spectra (60 MHz) were recorded with a Hitachi Model R-24 apparatus. ^{13}C NMR spectra were obtained with a JEOL JNM-FX100. Chemical shifts were measured by

(4) For example, H. O. House, "Modern Synthetic Reactions", 2nd ed., W. A. Benjamin, New York, 1972, Chapter 9.
(5) D. M. Pond and R. L. Cargill, *J. Org. Chem.*, **32** 4064 (1967).
(6) R. N. McDonald and T. E. Tabor, *J. Am. Chem. Soc.*, **89**, 6573 (1967). These authors have reported that the chlorination of **5** with sulfuryl chloride gave only **6**.
(7) The ratio of **6** and **7** was determined by comparison of the ^1H NMR data with those[8] of authentic samples.
(8) F. M. Laskovics and M. M. Schulman, *J. Am. Chem. Soc.*, **99**, 6672 (1977).
(9) H. Minato and T. Nagasaki, *J. Chem. Soc. C*, 377 (1966).
(10) O. P. Vig, A. Lal, G. Singh, and K. L. Matta, *Indian J. Chem.*, **6**, 431 (1968).

using Me_4Si as an internal standard and were given in terms of δ (ppm).

Ethyl 4-methyl-2-oxo-1-cyclohexanecarboxylate (1) was prepared from **5** by the method described in the literature:[9] bp 75–80 °C (2 mm) [lit.[3] bp 100–120 °C (5 mm)]; 57% yield (lit.[3] 75%).

Ethyl 2-[1-(Ethoxycarbonyl)-4-methyl-2-oxocyclohexyl]-propionate (2). A solution of **1** (2.62 g, 14.2 mmol) in dry DMF (2 mL) was added to a mixture of 641 mg of a 61% dispersion of sodium hydride in mineral oil (16.3 mmol of NaH) and 26 mL of dry DMF. The mixed solution was stirred at room temperature for 2 h. A solution of ethyl 2-iodopropionate (3.72 g, 16.3 mmol) in 2 mL of dry DMF was added slowly, and the mixture was stirred at 100–110 °C (oil-bath temperature) under an atmosphere of dry nitrogen for 2.5 h. The resulting mixture was poured into water. The organic layer was extracted with ether, washed with water, and dried over $MgSO_4$. Removal of the solvent gave an oil of crude **2** (3.93 g, 92% yield by GLC analysis). It was distilled to give 3.16 g (78%) of pure **2**: bp 129–130 °C (2 mm); IR (neat) 1720, 1735 cm^{-1}; NMR (CCl_4) δ 1.02 (d, 3 H, J = 5 Hz, ring methyl), 1.21 (d, 3 H, J = 5 Hz, $CH(CH_3)CO_2Et$), 1.29 (t, 6 H, J = 7 Hz, 2 $CO_2CH_2CH_3$), 1.5–2.7 (m, 7 H, ring protons), 3.1 (m, 1 H, $CH(CH_3)CO_2Et$), 4.15 (dq, 4 H, J = 7 Hz, 2 $CO_2CH_2CH_3$).

Anal. Calcd for $C_{15}H_{24}O_5$: C, 63.36; H, 8.51. Found: C, 63.22; H, 8.41.

Reaction of Ethyl 2-Bromopropionate with 1. To a solution of sodium ethoxide prepared by dissolving sodium (57 mg, 2.5 mmol) in dry ethanol (5 mL) was added 500 mg (2.72 mmol) of **1**. After the mixture was stirred for 15 min, ethyl 2-bromopropionate (447 mg, 2.47 mmol) was added dropwise. The mixture was heated under reflux for 40 h. After the mixture cooled, the precipitated sodium bromide was removed by filtration. The filtrate, after being condensed in vacuo, was poured into water. The organic material was extracted with ether, and the ethereal layer was washed with saturated aqueous NaCl solution and then with water and dried over $MgSO_4$. Removal of the solvent gave 536 mg of a light brown oil, which was distilled to give 260 mg (46%) of **3**: bp 140 °C (2 mm) [lit.[11] bp 139–140 °C (7 mm)]; IR (neat) 1735 (ester C=O); ^1H NMR (CCl_4) δ 0.92 (d, 3 H, J = 7 Hz, $>CHCH_3$), 1.21 (t, 6 H, J = 7 Hz, 2 $CO_2CH_2CH_3$), 1.3–2.6 (m, 9 H, $-(CH_2)_4-$ and $>CHCH_3$), 4.11 (q, 4 H, J = 7 Hz, 2 $CO_2CH_2CH_3$); ^{13}C NMR ($CDCl_3$) δ 14.3 ($CO_2CH_2CH_3$), 19.6 ($CH_3CH<$), 22.4 (C-5), 30.2 ($CH_3CH<$), 34.4 (C-4), 36.2 (C-2), 41.7 (C-6), 60.1 ($COCH_2CH_3$), 173.1 (C=O), 173.6 (C=O).

3,6-Dimethyl-2,4,5,6,7,7α-hexahydrobenzofuran-2-one (4). The diester **2** (0.395 g, 1.39 mmol) was heated under reflux with 5.5 mL of concentrated HCl for 4 days. The organic layer was extracted with ether, and the combined ethereal layer was washed with aqueous $NaHCO_3$ solution and dried over $MgSO_4$. Removal of the solvent gave 0.15 g (65%) of a light brown oil of crude **4**. IR and NMR data were identical with those of the authentic sample.[12] Bulb-to-bulb distillation (140 °C, 2 mm) gave 0.116 g (50%) of **4** as a clean oil: ^{13}C NMR ($CDCl_3$) δ 8.2 ($CH_3C=$), 21.2 ($CH_3CH<$), 25.5 (C-4), 29.7 (C-6), 34.6 (C-5), 42.1 (C-7), 80.0 (C-7a), 119.6 (C-3), 162.8 (C-3a), 175.1 (C=O).

(±)-Menthofuran. After a solution of 2-propanol (1.01 g, 16.9 mmol) in dry ether (5 mL) was added to a suspension of LAH (642 mg, 16.9 mmol) in dry ether (30 mL), the mixture was stirred at −60 to −50 °C for 15 min. A solution of **4** (700 mg, 4.22 mmol) in dry ether (5 mL) was slowly added to the mixture under an atmosphere of nitrogen. After being stirred for 3 h, the mixture was poured into ice–water and then acidified with 10% HCl. The organic layer, extracted with ether, was washed with water and dried over $MgSO_4$. Removal of the solvent gave 473 mg (75%) of (±)-menthofuran. The ^1H NMR spectrum of the product was identical with that of the authentic sample.[13] Further purification of the product by preparative TLC resulted in the formation of a number of minor components which appear to occur by oxidative decomposition.

3-Methyl-2,4,5,6,7,7a-hexahydrobenzofuran-2-one (8) was prepared in the same way as for the preparation of **4**. Condensation of ethyl 2-oxo-1-cyclohexanecarboxylate (**1**) (3.4 g, 0.02 mol) with ethyl 2-iodopropionate (5.02 g, 0.022 mol) in the presence of NaH (0.53 g, 0.022 mol) gave 4.5 g (83%) of ethyl 2-[1-(ethoxycarbonyl)-2-oxocyclohexyl]propionate (**13**): bp 110–130 °C (bath temperature) (0.05 mm); IR (neat) 1730 (ester C=O), 1710 (ketone C=O); NMR ($CDCl_3$) δ 1.27 (t, 6 H, J = 7 Hz, 2 $CO_2CH_2CH_3$), 0.9–2.6 (m, 11 H), 3.1 (m, $>CH(CH_3)CO_2Et$), 4.15 (m, 4 H, J = 7 Hz, 2 $CO_2CH_2CH_3$). Hydrolysis of **13** (2.1 g, 7.8 mmol) with concentrated HCl (30 mL) gave 0.66 g (56%) of crude **8**, from which short-path distillation afforded 0.53 g (44%) of **8**: bp 130–135 °C (bath temperature) (3 mm) [lit.[14] bp 133–134 °C (3 mm)]; IR (neat) 1760 (lactone C=O), 1685 (C=C); NMR ($CDCl_3$) δ 1.0–3.0 (m, 8 H, methylene protons of C-4, C-5, C-6, and C-7), 1.8 (t, J = 1.5 Hz, CH_3), 4.52 (m, >CHO).

3-Methyl-4,5,6,7-tetrahydrobenzofuran (9). An ethereal solution of **8** (0.15 g, 1.0 mmol) was treated with LAH (0.15 g, 4 mmol) quenched by 2-propanol (0.24 g, 4 mmol) at −60 to −50 °C. The mixture was worked up as described in the section on (±)-menthofuran. Short-path distillation of the crude product gave 77 mg (57%) of **9** as a clean oil: bp 110 °C (bath temperature) (13 mm) [lit.[9] bp 55 °C (bath temperature) (8 mm)]; NMR ($CDCl_3$) δ 1.4–2.0 (m, 4 H, methylene protons of C-5 and C-6), 1.85 (d, J = 1.5 Hz, CH_3), 2.0–2.6 (m, 4 H, methylene protons of C-4 and C-7), 6.94 (s, CH=); IR spectrum identical with that of the authentic sample.[9]

2-(4-Methyl-1-cyclohexenyl)-1,2-propanediol (10). A solution of 2-propanol (272 mg, 4.52 mmol) in dry ether (2 mL) was added to a dispersion of LAH (172 mg, 4.52 mmol) in dry ether (20 mL) at −60 to −50 °C. After the mixture was stirred for 15 min, a solution of the lactone **4** (500 mg, 3.01 mmol) in dry ether (3 mL) was added. The mixture was further stirred for 30 min at −60 to −50 °C and then for 1 h at room temperature. It was poured into water and acidified with 10% HCl. The organic layer was extracted several times with ether. The combined ethereal layer was washed with water and dried over $MgSO_4$. Removal of the solvent gave clean oil **10** (405 mg, 79%): mp 49–51 °C (from hexane); IR (neat) 3280, 3390 cm^{-1} (OH); ^1H NMR (CCl_4) δ 0.95 (d, 3 H, J = 5 Hz, ring CH_3), 1.16 (s, 3 H, $CH_3C(OH)CH_2OH$), 1.2–2.4 (m, 7 H, ring methin and methylene), 3.1–3.7 (m, 4 H, $>C(OH)CH_2OH$), 5.6–5.9 (m, 1 H, CH=C); ^{13}C NMR[15] ($CDCl_3$) δ 21.6 (ring CH_3), 23.4 and 23.6 (CH_3COH), 24.7 and 24.9 (ring C-5), 28.1 (ring C-4), 31.1 (ring C-3 or C-6), 33.6 (ring C-6 or C-3), 68.3 (CH_2OH), 75.3 ($COHCH_3$), 121.0 and 121.3 (ring C-2), 139.6 and 139.8 (ring C-1); mass spectrum, (70 eV) m/e (relative intensity) 152 (M − H_2O, 11).

Anal. Calcd for $C_{10}H_{18}O_2$: C, 70.55; H, 10.65. Found: C, 70.63; H, 10.76.

Oxidation of 10. To a solution of chromium(VI) oxide–pyridine (1:2)[16] (220 mg, 1.23 mmol) in anhydrous dichloromethane (1.5 mL) was added a solution of **10** (34 mg, 0.20 mmol) under an atmosphere of nitrogen with cooling. The mixture was stirred for 18 h at room temperature. The precipitate was washed with ether three times. After the combined ethereal layer was washed with 5% NaOH, 5% HCl, 5% $NaHCO_3$, and finally with saturated aqueous NaCl solution, it was dried over $MgSO_4$. Removal of the solvent gave clean oil **12** (28 mg, 100% yield). Column chromatography [silica gel, hexane–acetone (10:1)] gave the analytical sample of **12**: IR (neat) 1640, 1665 cm^{-1}; ^1H NMR (CCl_4) δ 0.98 (d, 3 H, J = 5 Hz, ring CH_3), 2.18 (s, 3 H, $COCH_3$), 1.1–2.6 (m, 7 H, ring protons), 6.6–6.9 (m, 1 H, CH=C); ^{13}C NMR ($CDCl_3$) δ 21.5 (ring CH_3), 23.0 (C_5), 25.3 (C_4), 27.7 (CH_3CO) 30.2 (C-3 or C-6), 34.5 (C-6 or C-3), 139.6 (C-1), 140.7 (C-2), 199.6 (C=O); 2,4-dinitrophenylhydrazone, mp 212–215 °C (lit.[10] mp 210 °C).

Acknowledgment. We thank Dr. Nobuo Iwata of Nippon Terpene Chemical Co., Ltd., for supplying a sample of menthofuran. We also thank Dr. E. M. Schulman of State University College at Buffalo for donation of NMR spectra of α- and α'-chloro-3-methylcyclohexanones. The

(11) G. R. Delpierre, F. W. Eastwood, G. E. Gream, D. G. I. Kingston, P. S. Sarin, Lord Todd, and D. H. Williams, *J. Chem. Soc. C*, 1666 (1966).
(12) C. S. Foote, M. T. Wuesthoff, S. Wexler, I. G. Burstain, R. Denny, G. O. Schenck, and K. H. Schulte-Elte, *Tetrahedron*, **23**, 2583 (1967).
(13) Commercial menthofuran was supplyed by Nippon Terpene Chemical Co., Ltd.
(14) W. Cocker and S. Hornsby, *J. Chem. Soc.*, 1157 (1947).
(15) This shows compound **10** contains two diastereomers.
(16) J. C. Collins and W. W. Hess, *Org. Synth.*, **52**, 5 (1972).

present work was partially supported by a Grant-in-Aid for Scientific Research from the Ministry of Education.

Registry No. 1, 13537-82-1; 2, 72952-61-5; 3, 13357-88-5; 4, 13341-72-5; 5, 591-24-2; 8, 15174-78-4; 9, 1919-00-2; 10, 13674-37-8; 12, 22273-97-8; 12 2,4-DNP, 22273-98-9; 13, 72952-62-6; ethyl 2-iodopropionate, 31253-08-4; ethyl 2-bromopropionate, 535-11-5; (±)-menthofuran, 59553-66-1; 2-propanol, 67-63-0.

The Stereochemistry of Thioxanthenium Methylides. Use of 1,4-Dimethylthioxanthenium Methylides as Model Compounds

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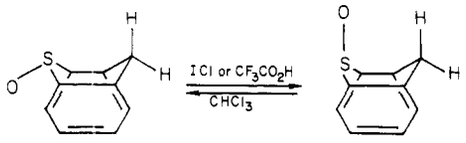
Received September 17, 1979

We previously have shown[1] that the preferred conformation of the sulfinyl oxygen in thioxanthene 10-oxide (1)

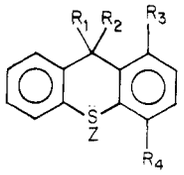


1e′ 1a′

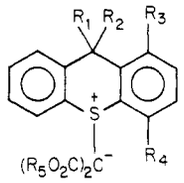
and related thioxanthene 10-oxides (e.g., *cis*- and *trans*-9-methylthioxanthene 10-oxides (*cis*- and *trans*-**2**)) is one in which the sulfinyl oxygen occupies the pseudoequatorial position (e′). More recently, we have demonstrated that complexation of the sulfinyl oxygen of **1** with iodine monochloride[2] or trifluoracetic acid[3] increases the amount of the pseudoaxial conformer (a′).

Since X-ray data[4] suggest that the a′ position is less hindered than the e′ position and since we recently have demonstrated[5] that phenoxathiin sulfoxide (**3**) exists in the a′ array, we now have determined the conformational preference of several ylides derived from thioxanthene in order to assess the effect of increased bulk (i.e., O^- to CR_2^-) upon the stereochemistry about sulfur in these systems.

The ylides used in this study are derived from thioxanthene (**4**), 9,9-dideuteriothioxanthene (**5**), 1,4-dimethylthioxanthene (**6**), and 9,9-dideuterio-1,4-dimethylthioxanthene (**7**). We have already shown that a methyl group peri to sulfur (i.e., C4-CH_3) forces a proximal sulfinyl to adopt the a′ conformation in various thioxanthene sulfoxides[1b] and that peri methyl groups force C9 alkyl groups into the a′ array in thioxanthenes[6] and 9,10-dihydroanthracenes.[7] The same steric repulsions will be present in ylides derived from **6** and **7** and will permit them to be used as models for ylides having an a′ array. In turn, their spectral parameters can be used to deduce



	R_1	R_2	R_3	R_4	Z
1	H	H	H	H	O
2	CH_3	H	H	H	O
4	H	H	H	H	··
5	D	D	H	H	··
6	H	H	CH_3	CH_3	··
7	D	D	CH_3	CH_3	··



	R_1	R_2	R_3	R_4	R_5
8	H	H	CH_3	CH_3	CH_3
9	D	D	CH_3	CH_3	C_2H_5
10	H	H	H	H	CH_3
11	D	D	H	H	C_2H_5

the conformation of "uncongested" ylides derived from **4** and **5**.

1,4-Dimethylthioxanthenium bis(carbomethoxy)-methylide (**8**) and 9,9-dideuterio-1,4-dimethylthioxanthenium bis(carbethoxy)methylide (**9**) must, by virtue of their C4-CH_3 groups, be constrained to the a′ conformation. This view is supported by the ^1H NMR spectra of the C9-CH_2 group of **8**. Thus, the a′ proton[8] occurs downfield of the e′ proton (see Table I). This is similar to what is observed when the corresponding sulfinyl group is a′.[1b,3]

Study of **9** permitted analysis of the methylene region of the ethoxy group which might have otherwise been confounded by overlap with the C9-CH_2 region. This a′ ethoxy group is characterized by a triplet centered at δ 1.20 (J = 7 Hz) and a quartet centered at δ 4.08 (J = 7 Hz). Deuteration prevented observation of the C9-methylene group; however, it is assumed to be similar to that of **8**.

Thioxanthenium bis(carbomethoxy)methylide (**10**) exhibits a pair of AB doublets for its methylene group which is strikingly different from that of **8**. Thus, the broadened wing of the "AB quartet" (C9-Ha′) is found upfield of the sharper (e′) wing. This argues that the malonyl residue in **10** does not have the same conformation as in **8** and is, therefore, e′. 9,9-Dideuteriothioxanthenium bis(carbethoxy)methylide (**11**) also was prepared and its methyl resonance was observed to be different from that of **9**. This is consistent with the view that **9** and **11** have different geometries.

We conclude that, like the corresponding sulfoxides, ylides **10** and **11** exist in the e′ conformation. Moreover, we have shown that ylides **8** and **9** serve as models for the a′ array, much as do the corresponding sulfoxides. Since hydrogen bonding increases the amount of a′ conformer present in **1**, and since these ylides (**10** and **11**) exist in the e′ array, our current results are consistent with the view that the "effective size" of the hydrogen-bonded sulfinyl

(1) (a) Ternay, A. L., Jr.; Chasar, D. W. *J. Org. Chem.* **1968**, *33*, 2237. (b) Ternay, A. L., Jr.; Ens, L.; Herrmann, J.; Evans, S. *Ibid.* **1969**, *34*, 940. (c) Evans, S.; Ternay, A. L., Jr. *Ibid.* **1975**, *40*, 2993.

(2) Ternay, A. L., Jr.; Herrmann, J.; Harris, M.; Hayes, B. R. *J. Org. Chem.* **1977**, *42*, 2010.

(3) Ternay, A. L., Jr.; Herrmann, J.; Hayes, B. A.; Joseph-Nathan, P. *J. Org. Chem.* **1980**, *45*, 189.

(4) Ternay, A. L., Jr.; Chasar, D. W.; Sax, M. *J. Org. Chem.* **1967**, *32*, 2465. (b) Chu, S. S. C. *Acta Crystallogr., Sect. B* **1975**, *31*, 1975; and related publications.

(5) Chen, J. S.; Watson, W. H.; Austin, D.; Ternay, A. L., Jr. *J. Org. Chem.* **1979**, *44*, 1989.

(6) Ternay, A. L., Jr.; Evans, S. A. *J. Org. Chem.* **1974**, *39*, 2941 and references cited therein.

(7) Ternay, A. L., Jr.; Brinkmann, A. W.; Evans, S.; Herrmann, J. *J. Chem. Soc. D* **1969**, 654.

(8) Identified by its relative broadness.[1] (The bandwidth at half-height of the more intense peak of the downfield portion of the AB quartet was approximately 1.5 times as large as the comparable peak of the upfield portion.) Long-range coupling to the aryl protons broadens the C9-Ha′.

0022-3263/80/1945-1520$01.00/0