Synthesis of Both Antipodal Forms of 7,7-Dimethylbicyclo[2.2.2]oct-2-en-5-one by Enantiomer Interconversion

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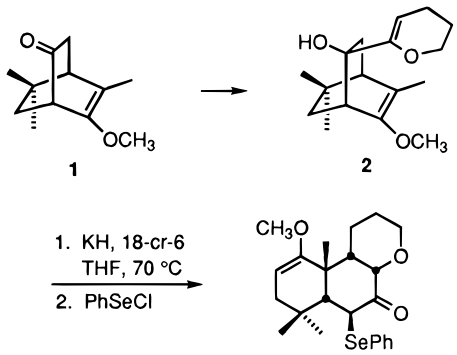
An enantioselective synthesis of both enantiomers of the title ketone **5** from a common achiral β-diketone is reported. Bakers' yeast reduction of **6** cleanly differentiates between the two carbonyl groups to deliver (+)-**9** in >90% yield, and with an ee exceeding 98%. Direct xanthate elimination leads to (+)-**5**. To arrive at the levorotatory antipode, the OH group in the β-hydroxy ketone is transformed into the tetrahydropyranyl ether and the carbonyl group is subsequently reduced in advance of formal dehydration. Oxidation of the deprotected alcohol ultimately reestablishes the carbonyl functionality and delivers (−)-**5** of equally high optical purity.

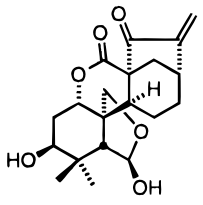
The anionic oxy-Cope rearrangement[1−3] constitutes a powerful and definitive means for constructing polycyclic ring systems with complete control over the several stereogenic centers resident in the framework. The outstanding stereoselectivity and utmost brevity provided by this central reaction emerge in notably serviceable fashion when the electrophilic reaction partner is a bicyclic β,γ-unsaturated ketone. In the illustrated example, the addition of lithiated dihydropyran to **1**, subsequent generation of the potassium salt of **2**, and direct trapping of the regiospecifically generated enolate anion with benzeneselenenyl chloride provides direct entry to a forskolin prototype.[4]

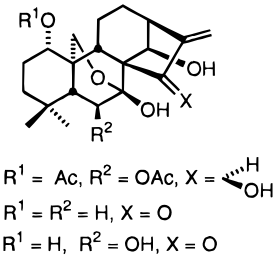
Other important examples of the strategic adaptation of this tactic can be found in the syntheses of coronafacic acid,[5] cannivonine,[6] (+)-ikarugamycin,[7] dimethyl secologanoside *O*-methyl ether,[8a] 9-isocyanopupukeanane,[8b] reserpine intermediates,[9] and ambergris-type odorants.[10]



The bicyclic ketones may possess internal double bonds as in **1** or carry an exocyclic β,γ-olefinic substituent. The latter variant provides considerable added versatility.[11−13]

In such isomerization reactions, the emerging interrelationship of the stereogenic centers is controlled by the particular transition state that is adopted. Beyond this, absolute configuration can be traced directly to the dissymmetric elements present in the ketone reactant. Insofar as these considerations apply to projected enantioselective syntheses of enmein (**3**)[14,15] and other kaurane-related diterpenoid targets such as rabdokaurin C (**4a**),[16] megathyrin A (**4b**),[17] and oridorin (**4c**),[18] the sigmatropic mechanistic model contemplates initial condensation of an appropriate cyclohexenyl anion with the (1*S*,4*S*) enantiomer of 7,7-dimethylbicyclo[2.2.2]oct-2-en-5-one, *viz.* **5**. This paper describes experiments which





cleanly deliver both **5** and its enantiomer **5′** from the common 1,3-diketone precursor **6**. Since the reduction

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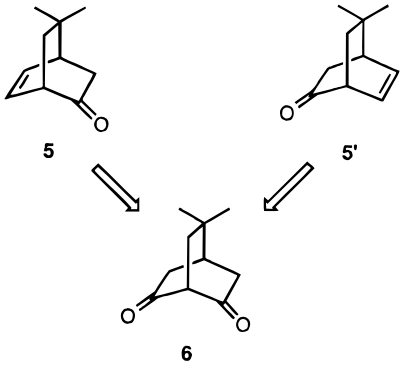
of prochiral **6** with bakers' yeast is amenable to producing only one highly optically enriched keto alcohol, reliance had necessarily to be placed as well on chemical means for distinguishing between the two oxidized ethano bridges in this intermediate.

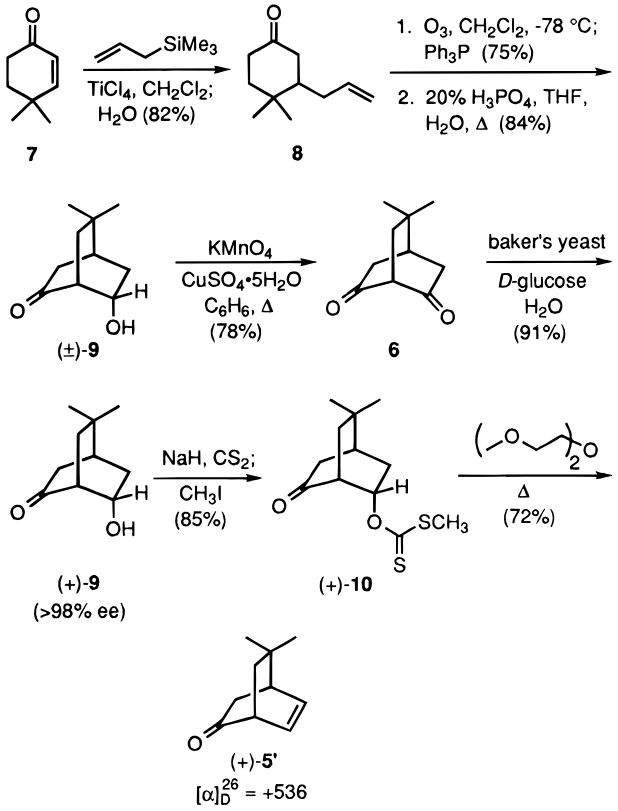


Results and Discussion

The simplest approach to **6** consisted of adapting the Sakurai reaction[19] to readily available 4,4-dimethyl-2-cyclohexenone (**7**).[20] The titanium tetrachloride-promoted conjugate allylation[21] afforded **8** (82%), thereby setting the stage for ozonolytic cleavage of the double bond and intramolecular aldolization to give **9** under catalysis by 20% phosphoric acid in THF[22] (Scheme 1). The racemic hydroxy ketone was obtained as colorless needles in 84% yield. The most reproducible and effective means uncovered for the oxidation of this aldol to **6** involved the solid oxidant $KMnO_4 \cdot CuSO_4(H_2O)_5$ developed by Menger and Lee.[23] The mildness of this reagent appears to obviate the substantive fluctuations in yield noted with chromium-based oxidants.

As noted above, the role of **6** was to serve as a substrate for asymmetric reduction by fermenting bakers' yeast.[24] Several substituted bicyclo[2.2.2]octane-2,6-diones had previously been subjected to comparable biocatalytic reduction, most notably in the laboratories of Mori[25] and Frejd.[26] In all instances, the endo hydroxy ketone predominated heavily and the optical purity of this product was very high. In line with these prior developments, **6** was transformed within 24 h in water into (+)-**9**, which was isolated in 91% yield and shown to be >98% ee by Mosher ester analysis.[27]

Scheme 1



The regioselectivity associated with the conversion of **6** into (+)-**9** was initially assigned by analogy.[25,26] Derivatization of this keto alcohol as its xanthate and thermal elimination in refluxing 2-methoxyethyl ether for 2 days gave rise to the powerfully dextrorotatory product **5′**. Comparison with closely related bicyclo[2.2.2]-octenones[10b] was reason to believe **5′** to be the (1*R*,4*R*) form.

From among a variety of options available for the transformation of (+)-**9** into (−)-**5**, the decision was made to pursue in Scheme 2 a reaction sequence closely related to that which worked so well in Scheme 1. Thus, the hydroxyl group was protected as its tetrahydropyranyl ether derivative in advance of 1,2-reduction of the ketone with sodium borohydride, formation of the xanthate, and pyrolysis of the latter intermediate. Adherence to this route delivered **12** in very good overall yield. The deprotection and oxidation of **12** proceeded smoothly to make (−)-**5** available without event. This enone proved to be strongly levorotatory and was characterized by a large Cotton effect with the following circular dichroic characteristics: $[\varphi]_{295}$ −3611°, $[\theta]_{max}$ −5420° and $[\varphi]_{305}$ -3578°, $[\theta]_{max}$ −5371°. The octant rule for such systems[28] is uniquely consistent with formulation of this ketone as the (1*S*,4*S*) enantiomer.

In summary, the synthetic undertaking described herein was quite successful in that reasonable quantities of either antipode of **5** can be obtained in high optical

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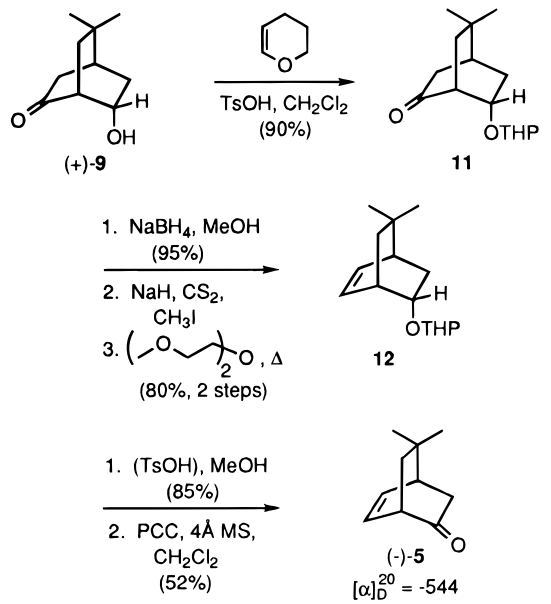
Scheme 2



purity within a relatively short time frame. The synthetic regimen is such that several consecutive steps can easily be dovetailed without need for the isolation or purification of reaction intermediates. This merging of steps, in combination with the exceptional efficacy of the biosynthetic transformation, allows for rewarding utilization of **5** and **5′** as key reactants in various extensions of oxy-Cope chemistry. The progress made along these lines will be recorded in due course.

Experimental Section

Melting points are uncorrected. ^{1}H and ^{13}C NMR spectra were recorded at the indicated field strengths. High-resolution mass spectra were recorded at The Ohio State University Chemical Instrumentation Center. Elemental analyses were performed at the Scandinavian Microanalytical Laboratory, Herlev, Denmark. All separations were effected under flash chromatography conditions on Merck silica gel HG_{254}. The organic extracts were dried over anhydrous magnesium sulfate. Solvents were reagent grade and in many cases dried before use.

3-Allyl-4,4-dimethylcyclohexanone (8).[29] 4,4-Dimethylcyclohexenone (20.0 g, 0.16 mol) in CH_2Cl_2 (100 mL) was added dropwise to a cold (−78 °C), magnetically stirred solution of titanium tetrachloride (26.3 mL, 0.24 mol) in CH_2Cl_2 (240 mL) under N_2. After 15 min, allyltrimethylsilane (28 mL, 0.18 mol) was introduced, and the mixture was stirred a further 3 h prior to quenching the reaction mixture with water (150 mL). The mixture was allowed to warm to rt, and the separated aqueous phase was extracted with CH_2Cl_2 (50 mL). The combined organic layers were dried, filtered, and evaporated to leave an oil which upon distillation afforded 22.0 g (82%) of **8** as a colorless liquid: IR (neat, cm^{-1}) 1714, 1640; ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.68−5.54 (m, 1 H), 4.97 (s, 1 H), 4.94−4.90 (m, 1 H), 2.41−2.28 (m, 3 H), 2.25−2.16 (m, 1 H), 1.98 (ddd, J = 14.9, 11.9, 0.9 Hz, 1 H), 1.73−1.49 (m, 4 H), 1.00 (s, 3 H), 0.96 (s, 3 H); ^{13}C NMR (75 MHz, $CDCl_3$) ppm 211.6, 136.6, 116.4, 46.2, 42.4, 40.2, 38.1, 35.2, 32.6, 28.6, 19.4; MS m/z (M^+) calcd 166.1358, obsd 166.1356.

(±)-(1*R*,4S*,7S)-7-Hydroxy-5,5-dimethylbicyclo[2.2.2]-octan-2-one (9).** A solution of **8** (22.0 g, 0.13 mol) in CH_2Cl_2 (250 mL) was ozonolyzed at −78 °C until a blue color persisted. After the introduction of triphenylphosphine (51 g), the reaction mixture was allowed to stir at rt for 30 min and concentrated in vacuo. The white precipitate was separated by filtration and washed with ether. The combined filtrates were evaporated, and the residue was purified by chromatography on silica gel (elution with 3:1 petroleum ether−ether) to give the keto aldehyde as a colorless oil (17.0 g, 75%): ^{1}H NMR (300 MHz, $CDCl_3$) δ 9.71 (dd, J = 2.1, 1.1 Hz, 1 H), 2.60 (dt, J = 14.7, 1.1 Hz, 1 H), 2.44−2.06 (m, 6 H), 1.77−1.60 (m, 2 H), 1.02 (s, 3 H), 0.99 (s, 3 H); ^{13}CNMR (75 MHz, $CDCl_3$) ppm 210.2, 201.0, 45.5, 43.5, 41.4, 39.6, 38.0, 32.3, 28.5, 19.9; MS m/z (M^+) calcd 168.1150, obsd 168.1152.

A solution of the above product (2.5 g, 0.015 mol) in THF (20 mL) was treated with 20% phosphoric acid in water (20 mL) and heated at reflux overnight. The cooled reaction mixture was extracted with ether (1 × 50 mL, 2 × 25 mL), and the combined organic phases were dried and concentrated. The residue was purified by chromatography on silica gel (elution with 2:1 ether−petroleum ether) and recrystallization from this solvent system. There was obtained 2.1 g (84%) of **9** as colorless needles: mp 112−113 °C; IR (KBr, cm^{-1}) 3416, 1724; ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.14 (dt, J = 8.8, 3.3 Hz, 1 H), 3.66 (s, 1 H), 2.50−2.39 (m, 3 H), 2.31 (dd, J = 6.4, 3.3 Hz, 1 H), 2.08 (dd, J = 19.1, 2.4 Hz, 1 H), 1.49−1.34 (m, 3 H), 0.99 (s, 3 H), 0.91 (s, 3 H); ^{13}C NMR (75 MHz, $CDCl_3$) ppm 216.9, 67.8, 52.4, 41.4, 38.9, 36.9, 33.0, 29.8, 29.7, 29.2; MS m/z (M^+) calcd 168.1150, obsd 168.1149. Anal. Calcd for $C_{10}H_{16}O_2$: C, 71.38; H, 9.59. Found: C, 71.49; H, 9.56.

8,8-Dimethylbicyclo[2.2.2]octane-2,6-dione (6). A solution of (±)-**9** (15.0 g, 0.089 mol) in benzene (300 mL) was treated with $KMnO_4$·$CuSO_4(H_2O)_5$[23] (105 g, 2:1 w/w), and the suspension was heated to reflux overnight. After being cooled, the solid was removed by filtration through a pad of silica gel and rinsed thoroughly with ether. Following concentation of the filtrate, the residue was chromatographed on silica gel (elution with 2:1 petroleum ether−ether) to provide 11.6 g (78%) of **6** as colorless needles, mp 153−155 °C; IR (KBr, cm^{-1}) 1716; ^{1}H NMR (300 MHz, $CDCl_3$) δ 3.09 (t, J = 3.0 Hz, 1 H), 2.84 (ddd, J = 21.2, 3.2, 2.8 Hz, 2 H), 2.28−2.10 (m, 3 H), 1.88 (d, J = 3.0 Hz, 2 H), 1.15 (s, 6 H); ^{13}C NMR (75 MHz, $CDCl_3$) ppm 207.0, 65.3, 41.6, 39.5, 39.1, 31.2, 29.5; MS m/z (M^+) calcd 166.0994, obsd 166.0993. Anal. Calcd for $C_{10}H_{14}O_2$: C, 72.25; H, 8.49. Found: C, 71.95; H, 8.44.

(+)-(1*R*,4*S*,7*S*)-7-Hydroxy-5,5-dimethylbicyclo[2.2.2]-octan-2-one (9). A mixture of **6** (3.0 g, 0.018 mol), D-glucose (46 g), and bakers' yeast (type II, 46 g) in water (30 mL) was rapidly stirred at rt for 24 h. Following extraction with ethyl acetate (6 × 100 mL), the combined organics were dried, filtered, and evaporated. Chromatography of the residue on silica gel (elution with 2:1 ether−petroleum ether) gave (+)-**9** as colorless needles: mp 112−113 °C (2.5 g, 82%). The spectra for (+)-**9** were identical to those of the racemate: $[\alpha]^{23}_D$ + 17.5 (*c* 0.69, $CHCl_3$).

(+)-(1*R*,4*R*)-8,8-Dimethylbicyclo[2.2.2]oct-5-en-2-one (5′). A solution of (+)-**9** (610 mg, 3.63 mmol) in carbon disulfide (5 mL) was added to a stirred suspension of sodium hydride (871 mg, 36.3 mmol) in CS_2 (15 mL) at rt. The suspension was refluxed overnight, cooled to rt, and treated dropwise with methyl iodide (2.3 mL, 36.3 mmol). After 15 min, the mixture was poured into iced water (100 mL) and extracted with ether (1 × 50 mL, 1 × 20 mL). The combined organics were dried and concentrated to leave xanthate (+)-**10** (769 mg, 85%), which was obtained as white needles, mp 70−71 °C, upon recrystallization from petroleum ether−ether: IR (KBr, cm^{-1}) 1731; ^{1}H NMR (300 MHz, $CDCl_3$) δ 5.86 (dt, J = 9.0, 3.3 Hz, 1 H), 2.75−2.60 (m, 3 H), 2.47 (s, 3 H), 2.19 (dd, J = 19.0, 2.4 Hz, 1 H), 1.84 (t, J = 2.9 Hz, 1 H), 1.71−1.55 (m, 3 H), 1.11 (s, 3 H), 1.03 (s, 3 H); ^{13}C NMR (75 MHz, $CDCl_3$) ppm 214.4, 212.6, 79.5, 48.4, 41.6, 39.1, 36.9, 31.2, 30.1, 29.9, 29.2, 18.7; MS m/z (M^+) calcd 258.0748, obsd 258.0747; $[\alpha]^{25}_D$ + 4.6 (*c* 0.35, $CHCl_3$). Anal. Calcd for $C_{12}H_{18}O_2S_2$: C, 55.80; H, 7.03. Found: C, 55.95; H, 7.06. Racemic **10** exhibits a melting point of 52−53 °C.

A solution of (+)-**10** (621 mg, 2.41 mmol) in 2-methoxyethyl ether (10 mL) was refluxed under N_2 for 15 h, cooled to rt, and diluted with water (100 mL) and petroleum ether (100 mL). The separated organic phase was washed further with water (5 × 20 mL), dried, and concentrated by bulb-to-bulb

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distillation. The concentrate was passed through a column of silica gel (elution with 8:1 petroleum ether−ether) to give 260 mg (72%) of (+)- **5′** as a waxy white solid which was further purified by sublimation, mp 98−99 °C; IR (KBr, cm^{-1}) 1722; ^1H NMR (300 MHz, $CDCl_3$) δ 6.51 (t, J = 7.2 Hz, 1 H), 6.10 (t, J = 7.2 Hz, 1 H), 2.95 (t, J = 3.1 Hz, 1 H), 2.42−2.40 (m, 1 H), 2.30 (dd, J = 11.7, 2.2 Hz, 1 H), 1.86 (dd, J = 18.7, 3.0 Hz, 1 H), 1.57 (dd, J = 13.2, 2.1 Hz, 1 H), 1.40 (dd, J = 13.2, 3.4 Hz, 1 H), 1.05 (s, 3 H), 0.94 (s, 3 H); ^{13}C NMR (75 MHz, $CDCl_3$) ppm 212.9, 138.5, 126.8, 50.0, 44.3, 39.0, 36.5, 33.7, 31.6, 28.6; MS m/z (M^+) calcd 150.1044, obsd 150.1033; $[\alpha]^{26}_D$ + 536 (c 0.46, $CHCl_3$). The racemic ketone, accessed in a very different manner, has been reported previously.[30]

(1*R*,4*S*,7*S*)-5,5-Dimethyl-7-[(tetrahydro-2*H*-pyran-2-yl)-oxy]bicyclo[2.2.2]octan-2-one (11). A solution of (+)-**9** (21.6 g, 0.13 mol), *p*-toluenesulfonic acid monohydrate (20 mg), and dihydropyran (78 mL, 0.19 mol) in CH_2Cl_2 (200 mL) was stirred at rt for 2 h, filtered through a short pad of silica gel, and freed of solvent. Chromatography of the residue on silica gel (elution with 3:1 petroleum ether−ether) gave **11** as a colorless oil (29.0 g, 90%): IR (neat, cm^{-1}) 1730; ^1H NMR (300 MHz, $CDCl_3$) δ 4.66 (br d, J = 23.0 Hz, 1 H), 4.12 (dm, J = 23.0 Hz, 1 H), 3.82−3.75 (m, 1 H), 3.46−3.43 (m, 1 H), 2.53−2.37 (m, 3 H), 2.13 (br d, J = 18.7 Hz, 1 H), 1.79−1.37 (m, 10 H), 1.04−1.02 (m, 3 H), 0.96 (s, 3 H); ^{13}H MR (75 MHz, $CDCl_3$) ppm 215.0, (96.6, 95.8), (72.3, 71.0), (62.7, 61.6), (50.6, 48.2), (41.6, 41.5), (39.1, 39.0), (37.5, 37.0), (31.8, 31.4), (30.8, 30.7), (30.3, 30.1), 29.9, (29.2, 29.0), (25.4, 25.3), (19.5, 18.7); MS m/z (M^+) calcd 252.1726, obsd 252.1734. Anal. Calcd for $C_{15}H_{24}O_3$: C, 71.38; H, 9.59. Found: C, 70.97; H, 9.61.

Sodium Borohydride Reduction of 11. A cold (0 °C), magnetically stirred solution of **11** (29.0 g, 0.12 mol) in methanol (200 mL) was treated in small portions with sodium borohydride (4.4 g, 0.12 mol). The reaction mixture was stirred at 0 °C for 1 h and diluted with CH_2Cl_2 (200 mL) and water (200 mL). The separated aqueous phase was extracted with CH_2Cl_2 (2 × 100 mL), and the combined organic layers were dried and evaporated. Purification of the residue by chromatography on silica gel (elution with 1:1 ether−petroleum ether) gave the alcohol as a colorless oil (27.0 g, 95%): IR (neat, cm^{-1}) 3534; ^1H NMR (300 MHz, $CDCl_3$) δ 4.73−4.71 (m, 1 H), 4.12−4.01 (m, 1 H), 3.91−3.81 (m, 2 H), 3.65−3.58 (br s, 1 H), 3.53−3.45 (m, 2 H), 2.49−2.20 (m, 2 H), 2.08−2.01 (m, 1 H), 1.83−1.34 (series of m, 8 H), 1.31−1.11 (m, 3 H), 0.93−0.90 (m, 6 H); ^{13}C NMR (75 MHz, $CDCl_3$) ppm (97.3, 95.7), (74.6, 73.0), (69.2, 68.9), (62.5, 62.0), 38.31, (38.26, 38.1), (36.5, 36.1), (36.4, 36.3), 33.0, 32.0, (30.9, 30.8), 30.2, 29.2, 25.3, (19.3, 19.1); MS m/z (M^+) calcd 254.1882, obsd 254.1909. Anal. Calcd for $C_{15}H_{26}O_3$: C, 70.81; H, 10.31. Found: C, 70.87; H, 10.36.

2-[[(1*S*,2*S*,4*S*)-8,8-Dimethylbicyclo[2.2.2]oct-5-en-2-yl]-oxy]tetrahydro-2*H*-pyran (12). A solution of the preceding alcohol (27.0 g, 0.11 mol) in carbon disulfide (50 mL) was added to a stirred suspension of sodium hydride (29.0 g, 1.2 mol) in CS_2 at rt, and the mixture was heated at reflux overnight, cooled to rt, and treated dropwise with methyl iodide (2.3 mL, 36.3 mmol). After 15 min, the workup described above was implemented to give the xanthate (33 g, 90%) as white needles: mp 82−83 °C (from ether−petroleum ether); ^1H NMR (300 MHz, $CDCl_3$) δ 5.68−5.60 (m, 1 H), 4.68 and 4.59 (t, J = 3.4 and 2.4 Hz, respectively, 1 H), 4.06−3.90 (m, 1 H), 3.89−3.79 (m, 1 H), 3.48−3.39 (m, 1 H), 2.53 (s, 3 H), 2.51−2.29 (m, 3 H), 1.90−1.24 (series of m, 11 H), 0.99 (s, 6 H); ^{13}C NMR (75 MHz, $CDCl_3$) ppm (214.9, 214.7), (96.5, 96.4), (81.9, 81.2), (71.0, 70.6), (62.7, 61.9), (38.3, 37.9), (36.4, 36.1), 33.0, (32.6, 32.1), (31.6, 31.3), (31.2, 30.9), 30.3, 30.2, (29.9, 29.8), (25.6, 25.5), (19.9, 19.2), (18.5, 18.3); MS m/z (M^+) calcd 344.1480, obsd 344.1499. Anal. Calcd for $C_{17}H_{28}O_3S_2$: C, 59.28; H, 8.20. Found: C, 59.26; H, 8.20.

A solution of this xanthate (33.0 g, 0.096 mol) in 2-methoxyethyl ether (100 mL) was heated to reflux under N_2 for 2 days and processed in the predescribed manner. Chromatography on silica gel (elution with 7:1 petroleum ether−ether) gave 20.0 g (80%) of **12** as a colorless oil: IR (neat, cm^{-1}) 1465, 1452; ^1H NMR (300 MHz, $CDCl_3$) δ 6.49−6.41 (m, 1 H), 6.13−5.99 (m, 1 H), 4.70−4.58 (m, 1 H), 4.03−3.83 (m, 2 H), 3.51−3.44 (m, 1 H), 2.76−2.70 (m, 1 H), 2.37−2.27 (m, 1 H), 2.05−2.02 (m, 1 H) 1.82−1.43 (m, 6 H), 1.26−1.00 (m, 3 H), 0.99 (s, 3 H), 0.82 (s, 3 H); ^{13}C NMR (75 MHz, $CDCl_3$) ppm (136.7, 136.1), (129.1, 128.3), 99.7, (97.7, 96.6), (74.9, 73.1), 62.9, (42.3, 42.2), (39.7, 39.4), (38.0, 35.4), (32.6, 32.3), 31.6, (31.3, 31.1), (29.7, 29.6), 25.5, 20.1; MS m/z (M^+) calcd 236.1777, obsd 236.1773. Anal. Calcd for $C_{15}H_{24}O_2$: C, 76.21; H, 10.24. Found: C, 76.24; H, 10.33.

(−)-(1*S*,4*S*)-8,8-Dimethylbicyclo[2.2.2]oct-5-en-2-one (5). A solution of **12** (20.0 g, 0.085 mol) in methanol (50 mL) was treated with a catalytic amount of *p*-toluenesulfonic acid, stirred at rt for 1 h, and filtered through a pad of silica gel. Solvent evaporation followed by chromatography on silica gel (elution with 1:1 ether−petroleum ether) gave the alcohol as a white solid: mp 61−61.5 °C, after sublimation at 65 °C and 0.5 Torr (11.0 g, 85%); IR (film, cm^{-1}) 3300, 1445; ^1H NMR (300 MHz, $CDCl_3$) δ 6.50 (dt, J = 6.9, 1.1 Hz, 1 H), 6.06 (dt, J = 6.2, 0.9 Hz, 1 H) 3.92 (ddt, J = 8.3, 3.1, 1.0 Hz, 1 H), 2.65−2.60 (m, 1 H), 2.39 (ddd, J = 8.3, 4.0, 2.7 Hz, 1 H), 2.07−2.03 (m, 1 H), 1.38 (s, 1 H), 1.19 (ABX, J_{AB} = 13.0 Hz, J_{AX} = 2.4 Hz, 1 H), 1.14 (ABX, J_{AB} = 13.0 Hz, J_{BX} = 3.6 Hz, 1 H), 0.97 (s, 3 H), 0.90 (dt, J = 14.0, 3.1 Hz, 1 H), 0.83 (s, 3 H); ^{13}C NMR (75 MHz, $CDCl_3$) ppm 138.0, 127.9, 69.6, 42.5, 40.0, 39.2, 35.2, 32.2, 31.5, 29.5; MS m/z (M^+) calcd 152.1200, obsd 152.1206; $[\alpha]^{23}_D$ −77.6 (c 0.62, $CHCl_3$).

The above alcohol was dissolved in CH_2Cl_2 (10 mL), treated with 4 Å molecular sieves (500 mg) and pyridinium chlorochromate (134 mg, 0.62 mmol), and stirred at rt for 2 h. After petroleum ether (20 mL) was introduced, the solid was separated by filtration and the filtrate was concentrated. The residue was purified by chromatography on silica gel and sublimation as before (24 mg, 52%). The colorless solid exhibited mp 95−98 °C and $[\alpha]^{25}_D$ −544 (c 0.33, $CHCl_3$).

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