Friedel–Crafts Reactions. A mixture of 1.0 g (6.8 mmol) of 1-*1*-^{13}*C*-2-*Ph*-d_5 and 1.5 g (11 mmol) of $AlCl_3$ in 5.0 mL of benzene or a mixture of 1.0 g (7.0 mmol) of 1-*1*-^{13}*C* and 1.5 g (11 mmol) of $AlCl_3$ in 5.0 mL of [$^2H_6$]benzene was heated under relux for 1 h. These conditions were chosen after preliminary trials which showed that longer reaction times at reflux temperature did not significantly improve the yields while reactions at room temperature failed to give appreciable yields of the product. The reaction mixture was worked up as previously described[1a] to give about 500 mg (about 40%) of 1,2-diphenylethane (**2**) which, after crystallization from 95% ethanol, melted at 52 °C (lit.[5] mp 52 °C). The mass spectra of samples of **2** were obtained with a Finnigan Model 3000 GC-MS instrument. Oxidation of **2** from the reaction of 1-*1*-^{13}*C*-2-*Ph*-d_5 with benzene in alkaline $KMnO_4$[1a] gave benzoic acid whose mass spectrum was also recorded.

Acknowledgment. The financial support given by the Natural Sciences and Engineering Research Council of Canada is sincerely acknowledged.

Registry No. 1-*1*-^{13}*C*, 35462-97-6; 1-*1*-^{13}*C*-2-*Ph*-d_5, 94371-69-4; **2**, 103-29-7; **2**-d_1, 94371-77-4; **2**-d_2, 94371-78-5; **2**-d_3, 94371-79-6; **2**-d_4, 94371-80-9; **2**-d_5, 94404-10-1; **2**-d_6, 94371-81-0; **2**-d_7, 94371-82-1; **2**-d_8, 94371-83-2; **2**-d_9, 94371-84-3; **2**-d_{10}, 94371-85-4; **2**-d_{11}, 94371-86-5; **2**-d_{12}, 94371-87-6; **2**-d_{13}, 94371-88-7; **2**-d_{14}, 94371-89-8; **2**-^{13}*C*, 61829-72-9; **2**-^{13}*C*-d_1, 94371-91-2; **2**-^{13}*C*-d_2, 94371-92-3; **2**-^{13}*C*-d_3, 94371-93-4; **2**-^{13}*C*-d_4, 94371-94-5; **2**-^{13}*C*-d_5, 94371-95-6; **2**-^{13}*C*-d_6, 94371-96-7; **2**-^{13}C-d_7, 94371-97-8; **2**-^{13}*C*-d_8, 94371-98-9; **2**-^{13}*C*-d_9, 94371-99-0; **2**-^{13}*C*-d_{10}, 94404-11-2; **2**-^{13}*C*-d_{11}, 94372-00-6; **2**-^{13}*C*-d_{12}, 94372-01-7; **2**-^{13}*C*-d_{13}, 94372-02-8; **2**-^{13}*C*-d_{14}, 94371-90-1; **3**, 65-85-0; **3**-d_1, 94371-70-7; **3**-d_2, 94371-71-8; **3**-d_3, 94371-72-9; **3**-d_4, 94371-73-0; **3**-^{13}*C*, 3880-99-7; **3**-^{13}*C*-d_1, 94371-74-1; **3**-^{13}*C*-d_2, 94371-75-2; **3**-^{13}*C*-d_3, 94371-76-3; H_2, 1333-74-0; $AlCl_3$, 7446-70-0; [^{13}C]CO_2, 1111-72-4; benzene, 71-43-2; [$^2H_6$]benzene, 1076-43-3; benzylmagnesium chloride, 6921-34-2; phenyl[1-^{13}C]acetic acid, 1563-79-7; 2-phenyl[1-^{13}C]ethanol, 35462-98-7; [$^2H_5$]bromobenzene, 4165-57-5; benzyl chloride, 100-44-7; benzyl alcohol, 100-51-6.

(5) "Dictionary of Organic Compounds", 5th ed.; Chapman and Hall: New York, 1982; p 2314.

The Stereospecific Total Synthesis of (±)-*cis*-Chrysanthemic Acid via the Alicyclic Claisen Rearrangement

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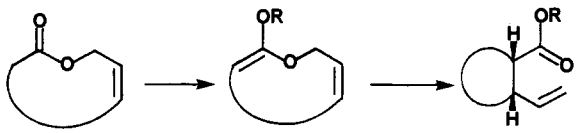
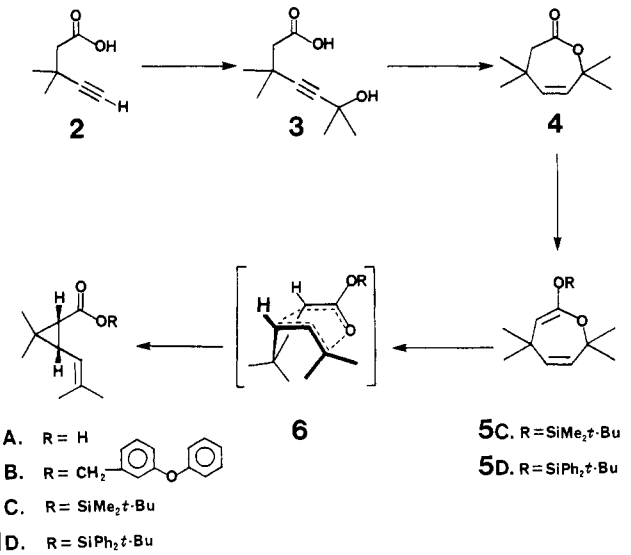
Pyrethroids are a class of powerful insecticides structurally related to the naturally occurring chrysanthemates.[1] The high insecticidal activity of the pyrethroids coupled with their low mammalian toxicity[2] has stimulated considerable synthetic activity in this area. Most of this effort has been directed toward the pyrethrins and cinerins, which are esters of *trans*-chrysanthemic acid or *trans*-pyrethric acid,[1] respectively. It has been discovered[3] that certain esters of *cis*-chrysanthemic acid possess superior activity relative to the *trans*-chrysanthemates, e.g., **1b**. Nevertheless, relatively few stereospecific total syntheses of the unnatural *cis*-chrysanthemic acid (**1a**) have been published.[4–6] Obviously, the major obstacle inherent in this synthetic problem is the cis relationship of the carboxy and alkenyl substituents on the cyclopropane ring.

Scheme I



Scheme II



We have recently reported a general, stereospecific synthesis of *cis*-2-alkenylcycloalkanecarboxylic acids via Claisen rearrangement mediated ring contraction of macrocyclic ketene acetals (Scheme I).[7] We now report the application of this methodology in a short, stereospecific synthesis of *cis*-chrysanthemic acid (**1a**).

The dianion of the readily available 3,3-dimethyl-4-pentynoic acid[8] (1 equiv of **2**, 2.1 equiv of *n*-BuLi, THF, −41 °C) was treated sequentially with lithium bromide[9] (0.5 equiv, THF, −41 °C) and dry acetone (1.1 equiv, −41 → 25 °C) to give the crystalline hydroxy acid **3** (mp 78–79 °C) in 65% yield (Scheme II). Catalytic semihydrogenation[10] of **3** ($Pd/BaSO_4$, quinoline, MeOH) gave a hydroxy acid which spontaneously lactonized to afford the desired Claisen rearrangement precursor, lactone **4** (mp

(1) Elliot, M.; James, N. J. "Pyrethrum, the Natural Insecticide"; Casida, J. E., Ed.; Academic Press: New York–London, 1973; pp 55–100.
(2) Elliot, M. *ACS Symp. Ser.* **1977**, *42*, 1 and references cited therein.
(3) Okuno, Y.; Masachika, T.; Takeda, H.; Itaya, N. Jpn. Pat. **1975**, DOS 2 439 251; Sumitomo Chem. Co.
(4) Arlt, D.; Jautelat, M.; Lantzsch, R. *Angew. Chem., Int. Ed. Engl.* **1981**, *20*, 703 and references therein.
(5) (a) Sevrin, M.; Hevesi, L.; Krief, A. *Tetrahedron Lett.* **1976**, 3915. (b) Franck-Neumann, M.; Dietrich-Buchecker, C. *Tetrahedron Lett.* **1980**, *21*, 671. (c) Franck-Neumann, M.; Miesch, M. *Tetrahedron Lett.* **1982**, *23*, 1409. (d) Lehmkuhl, H.; Mehler, K. *Liebigs Ann. Chem.* **1978**, 1841; **1982**, 2244. (e) Ganet, J. P.; Piau, F.; Ficini, J. *Tetrahedron Lett.* **1980**, 3183. (f) Torii, S., Inokuchi, T., Oi, R. *J. Org. Chem.* **1983**, *48*, 1944. (g) Nesmeyanova, O. A.; Rudashevskaya, T. Y.; Dyachenko, A. I.; Savilova, S. F.; Nefedov, O. M. *Synthesis* **1982**, 296.
(6) For the total syntheses of *cis*-2,2-dimethyl-3-(2,2-dihalovinyl)-cyclopropanecarboxylic acids, see the following: (a) Martin, P. *Helv. Chim. Acta* **1983**, *66*, 1189. (b) Martin, P.; Greuter, H.; Bellus, D. *J. Am. Chem. Soc.* **1979**, *101*, 5855. (c) DeVos, M. J.; Krief, A. *Tetrahedron Lett.* **1983**, 103. (d) DeVos, M. J. Krief, A. *J. Am. Chem. Soc.* **1982**, *104*, 4282. (e) Koudo, K.; Takashima, T.; Negishi, A.; Matsui, K.; Fujimoto, T.; Sugimoto, K.; Hatch, C. E., III; Baum, J. S. *Pestic. Sci.* **1980**, *11*, 180. (f) Itaya, N.; Matsuo, T.; Ohno, N.; Mizutani, T.; Fijita, F.; Yoshioka, H. *ACS Symp. Ser.* **1977**, *42*, 51.
(7) Abelman, M. M.; Funk, R. L.; Munger, J. D., Jr. *J. Am. Chem. Soc.* **1982**, *104*, 4030. We have coined the term "alicyclic Claisen rearrangement" to describe this methodology.
(8) Smith, A. B., III; Guaciaro, M. A.; Schow, S. R.; Workulich, P. M.; Toder, B. H.; Hall, T. W. *J. Am. Chem. Soc.* **1981**, *103*, 219.
(9) Brandsma, L.; Verkruijsse, H. D. "Synthesis of Acetylenes, Allenes, and Cumulenes. A Laboratory Manual"; Elsevier: Amsterdam–Oxford–New York, 1981; p 76. The yield without the addition of lithium bromide is ca. 20%.
(10) Cram, D. J.; Allinger, N. L. *J. Am. Chem. Soc.* **1956**, *78*, 2522.

0022-3263/85/1950-0707$01.50/0

40–41 °C) in 90% yield from **3**.

Based on previous studies,[7] we anticipated that the Claisen rearrangement of the (*E*)-silyl ketene acetal **5** would proceed through a boat-like transition state to give exclusively the *cis*-chrysanthemic ester (Scheme II, **6**).

Indeed, subjection of lactone **4** to standard silylation conditions[7] (LDA, *t*-BuMe$_2$SiCl, THF, −70 °C) gave the (*E*)-silyl ketene acetal **5c** in 97% isolated yield. Rearrangement of **5c** in chloroform (65 °C, $t_{1/2}$ = 58 min) smoothly produced *cis*-chrysanthemic ester **1c**. The ester **1c** was hydrolyzed with HF (2 equiv) in acetonitrile affording **1a** (mp 115–116 °C) in 94% yield from **5c**.[11] Comparison of the ^{1}H NMR spectrum of **1a** obtained by this synthetic sequence with the published spectrum[13] of authentic **1a** clearly establishes the product's stereochemical integrity and purity. The overall yield for this sequence based on **2** is 53%, which compares quite favorably with published syntheses[5] of *cis*-chrysanthemic acid (**1a**).

Experimental Section

The 90-MHz ^{1}H NMR spectra were recorded on a Varian EM 390 spectrometer, and the data are reported as follows: chemical shifts, in parts per million downfield of internal tetramethylsilane, (number of protons, multiplicity, coupling constant(s)). The IR spectra were obtained on a Perkin-Elmer Model 283 spectrometer and were referenced to polystyrene (1601 cm^{-1}). High-resolution mass spectra were provided by the Midwest Center for Mass Spectrometry of the University of Nebraska–Lincoln. Elemental analyses were provided by Galbraith Laboratories, Inc. of Knoxville, TN. Melting points were determined on a Thomas-Hoover Unimelt apparatus and are uncorrected. All chromatography was carried out on E. M. Reagents silica gel (400–230 mesh) according to the method of Still.[14] Tetrahydrofuran (THF) was dried by distallation from lithium aluminum hydride prior to use. All reactions were conducted in flame-dried glassware under a dry N_2 atmosphere unless otherwise indicated.

3,3,6-Trimethyl-6-hydroxy-4-heptynoic Acid (3). To a 100-mL, three-necked, round-bottomed flask equipped with a magnetic stir bar and a low-temperature thermometer charged with THF (40 mL) was added 3,3-dimethyl-4-pentynoic acid[8] (1.209 g, 9.59 mmol) and cooled to −41 °C. To this solution was added *n*-butyllithium (1.6 M in hexane, 12.6 mL, 20.16 mmol) dropwise via syringe such as the temperature of the reaction mixture was maintained below −35 °C, and the resulting opaque white suspension was stirred at −41 °C for 1 h. A solution of lithium bromide (417 mg, 4.80 mmol) in THF (17 mL) was added dropwise to the reaction mixture at −41 °C and stirred for 5 min, resulting in a clear, pale yellow solution. Acetone (0.70 mL, 10.56 mmol), which was previously distilled and dried over 4-Å sieves for 4 h, was added in one portion to this solution, and the solution was stirred for 1 h at −41 °C, followed by warming to ambient temperature. The resultant clear, colorless solution was allowed to stir for 18 h at 25 °C and then partitioned between ether and water. The separated ether layer was extracted with saturated $NaHCO_3$ (2 × 10 mL), and the combined aqueous layers were neutralized with concentrated hydrochloric acid and extracted with ether (3 × 25 mL). The combined organics were dried over $MgSO_4$ and solvents were removed in vacuo to give the crude product as an oil (1.60 g). Crystallization from ethyl acetate–hexanes gave 650 mg of a white solid. Concentration of the mother liquor gave 760 mg of a light yellow oil, which was chromatographed on 100 g of silica gel and eluted with isopropyl alcohol–hexanes (15:85) to yield 550 mg of a white solid. The combined solids were recrystallized from methyl acetate–petroleum ether to yield 1.142 g (65%) of **3** as fine white crystals: mp 78–79 °C; ^{1}H NMR ($CDCl_3$) δ 6.71 (2 H, br s), 2.43 (2 H, s), 1.49 (6 H, s), 1.34 (6 H, s); IR (NaCl, $CHCl_3$) ν_{max} 3500–2800, 2975, 2930, 2230, 1714, 1387, 1370, 1329, 1239, 1167 cm^{-1}; MS, ($M^{+\cdot} - H_2O$) 166.0999 (calcd for $C_{10}H_{14}O_2$, 166.0990). Anal. Calcd for $C_{10}H_{16}O_3$: C, 65.19; H, 8.75. Found: C, 64.91; H, 8.99.

(*Z*)-3,3,6-Trimethyl-6-hydroxy-4-heptenoic Acid Lactone (4). To a solution of hydroxy acid **3** (551.6 mg, 2.99 mmol) in methanol (20 mL) was added 5% palladium on barium sulfate (190 mg) and freshly distilled quinoline (190 mg, 0.17 mL). The resulting suspension was subjected to atmospheric hydrogenation with vigorous agitation. After hydrogen uptake had ceased (61 mL), the suspension was filtered and the filtrate evaporated in vacuo. The residue was partitioned between ether (100 mL) and 3 N aqueous hydrochloric acid (20 mL), and the organic layer was separated, washed with brine, and dried over $MgSO_4$. The solvents were removed in vacuo and the crude product was chromatographed on 35 g of silica gel using ethyl acetate–hexanes (1:4) to yield 450.6 mg (90%) of lactone **4** as large, clear prisms: mp 40–41 °C; ^{1}H NMR ($CDCl_3$) δ 5.37 (2 H, s), 2.76 (2 H, s), 1.58 (6 H, s), 1.17 (6 H, s); IR (NaCl, film) ν_{max} 2960, 2915, 1726, 1468, 1376, 1364, 1312, 1290, 1255, 1205, 1135, 1110, 1010, 995, 802, 745 cm^{-1}; MS ($M^{+\cdot}$) 168.1151 (calcd for $C_{10}H_{16}O_2$, 168.1146). Anal. Calcd for $C_{10}H_{16}O_2$: C, 71.39; H, 9.59. Found: C, 71.19; H, 9.73.

***tert*-Butyldimethylsilyl *cis*-Chrysanthemate (1c).** To a 25-mL, three-necked, round-bottomed flask equipped with a low-temperature thermometer and a magnetic stir bar was added THF (7 mL), and this was cooled to 0 °C. To this was added freshly distilled diisopropylamine (0.20 mL, 1.43 mmol) in one portion followed by dropwise addition of *n*-butyllithium (2.6 M in hexane, 0.83 mL, 1.32 mmol) via syringe such that the temperature of the reaction was maintained below 5 °C. The resulting solution was stirred 10 min at 0 °C and then cooled to −70 °C (internal temperature). To this solution was added dropwise via syringe a solution of lactone **4** (184 mg, 1.10 mmol) in THF (2 mL), and the solution was stirred for 20 min at −70 °C. The reaction mixture was warmed briefly to −50 °C and recooled to −70 °C over a period of 15 min. A solution of *tert*-butyldimethylsilyl chloride (199 mg, 1.32 mmol) in THF (2 mL) was then added dropwise immediately followed by addition of HMPA (0.38 mL, 2.20 mmol). The bright yellow reaction mixture was allowed to warm slowly to room temperature over ca. 2 h and was partitioned between hexanes (70 mL) and water. The aqueous layer was extracted with hexanes and the combined organics were washed with water (4 × 10 mL) and brine and dried over Na_2SO_4. Removal of the solvent under vacuum gave 280 mg (97%) of (*E*)-silyl ketene acetal **5c** as a light yellow oil: ^{1}H NMR ($CDCl_3$) δ 5.20 (2 H, s), 4.05 (1 H, s), 1.38 (6 H, s), 1.11 (6 H, s), 0.92 (9 H, s), 0.16 (6 H, s). Ketene acetal **5c** was immediately azeotroped with dry benzene under reduced pressure and ca. 30 mg placed in an NMR tube with dry, degassed $CDCl_3$ (0.4 mL). The remaining ketene acetal was diluted with dry, degassed chloroform (4.5 mL) and placed in a 10-mL, round-bottomed flask sealed with a standard taper stopper. Both samples were placed in an oil bath set at 65 °C, and the progress was monitored by obtaining NMR spectra at regular intervals. The peak at 0.16 (assigned to the CH_3Si of the ketene acetal) was observed to disappear with the concommitant appearance of a new peak at 0.24 (assigned to the CH_3Si of the silyl ester). The half-life of the rearrangement (observance of equal heights of the δ 0.16 and 0.24 peaks) was found to be 58 ± 1 min. Further heating of the sample (7 h) gave silyl ester **1c** in quantitative yield: ^{1}H NMR ($CDCl_3$) δ 5.28 (1 H, dm, $J \simeq 8$, 1.5 Hz), 1.88 (1 H, dd, $J \simeq 8$, 6 Hz), 1.72 (3 H, s), 1.67 (3 H, s), 1.52 (1 H, d, $J \simeq 6$ Hz), 1.23 (3 H, s), 1.17 (3 H, s)), 0.93 (9 H, s), 0.24 (6 H, s).

***tert*-Butyldiphenylsilyl *cis*-Chrysanthemate (1d).** Treatment of lactone **4** (95.6 mg, 0.56 mmol) to similar silylation conditions using *tert*-butyldiphenylsilyl chloride (0.18 mL, 0.68 mmol) gave (*E*)-silyl ketene acetal **5d** (263.4 mg) as an oil: ^{1}H NMR ($CDCl_3$) δ 7.67 (4 H, m), 7.29 (6 H, m), 5.12 (2 H, s), 3.96 (1 H, s), 1.24 (6 H, s), 1.10 (9 H, s), 0.97 (6 H, s). Rearrangement of **5d** at 65 °C ($t_{1/2}$ = 60 min) gave silyl ester **1d**, which was chromatographed on 20 g of silica gel using ethyl acetate–hexanes

(11) In a similar manner, the (*E*)-silyl ketene acetal **5d** was prepared by using *t*-BuPh$_2$SiCl as the silylating agent. In contrast to previous reports,[12] no C-silylation was observed, possibly due to the steric congestion at the α-carbon of lactone **4**. Rearrangement of **5d** produced **1d**, which was isolated in 77% yield from **4** after column chromatography (silica gel). Silyl ester **1c** could not be chromatographed in this manner due to its instability on silica gel.

(12) Larson, G.; Fuentes, L. M. *J. Am. Chem. Soc.* **1981**, *103*, 2418.

(13) Bramwell, A. F.; Crombie, L.; Hemesley, P.; Pattenden, G.; Elliott, M.; Janes, N. F. *Tetrahedron* **1969**, *25*, 1727.

(14) Still, W. C.; Kahn, M. Mitra, A. *J. Org. Chem.* **1978**, *43*, 2923.

(15) Maude Hammond Fling Fellow, 1982–84, from University of Nebraska.

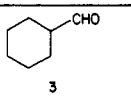
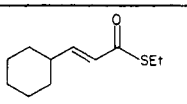
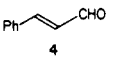
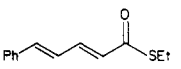
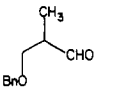
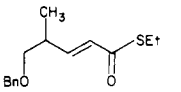
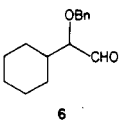
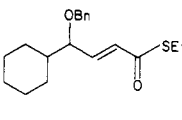
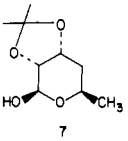
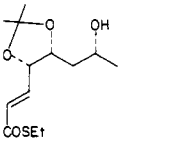
(1:9) to afford 177.1 mg (77%) of pure **1d** as an oil: ^{1}H NMR ($CDCl_3$) δ 7.61 (4 H, m), 7.31 (6 H, m), 5.25 (1 H, dm, $J \simeq 8$, 1.5 Hz), 1.89 (1 H, dd, $J \simeq 8$, 6 Hz), 1.83 (1 H, br s), 1.69 and 1.67 (3 H and 3 H, overlapping s), 1.24 (3 H, s), 1.21 (3 H, s), 1.12 (9 H, s); IR (NaCl, film) ν_{max} 3068, 3048, 2955, 2925, 2885, 1718, 1473, 1465, 1430, 1392, 1379, 1365, 1175, 1146, 1118, 1080, 824, 742, 699 cm^{-1}.

(±)-*cis*-Chrysanthemic Acid (1a). A solution of silyl ester **1c** (50.3 mg, 0.17 mmol) in acetonitrile (4 mL) was cooled to 0 °C, and to this was added a solution of hydrofluoric acid in acetonitrile (0.12 mL of a 3 M solution in acetonitrile, prepared from 48% aqueous HF, 0.35 mmol). After 0.5 h at 0 °C, aqueous K_2CO_3 (1.5 mL, 3 M) was added to the reaction mixture, and the solution was stirred for 5 min followed by addition of ether (5 mL). The aqueous layer was separated and washed with ether (5 mL), neutralized with concentrated hydrochloric acid, and extracted with ether (4 × 10 mL). The combined organics were washed with brine and dried over $MgSO_4$. Removal of the solvents gave 28 mg (94%) of **1a** as white prisms, mp 115–116 °C (lit.[5g] mp 115–116 °C), whose ^{1}H NMR spectra were identical with that in ref 13.

Acknowledgment. We appreciate the financial and material support provided by the National Institutes of Health (Grant No. GM2866301). Mass spectra were obtained through the National Science Foundation Regional Mass Spectrometry Center at the University of Nebraska (Grant CHE-82-11164).

Registry No. (±)-**1a**, 2935-23-1; (±)-**1c**, 94500-32-0; (±)-**1d**, 94500-33-1; **2**, 67099-40-5; **3**, 94500-34-2; **4**, 94500-35-3; **5c**, 94500-36-4; **5d**, 94500-37-5; acetone, 67-64-1.

Table I

aldehyde	product	yield,[a,b] %	trans/cis ratio[a,c]
 3		91 (93)	96:4 (95:5)
 4		87 (84)	96:4 (86:14)
 5		80 (89)	97:3 (97:3)
 6		78 (81)	91:9 (75:25)
 7		79 (71)	80:20 (56:44)

[a] Values in parentheses refer to results obtained for preparation of the corresponding methyl esters using carbomethoxymethylenetriphenylphosphorane under identical conditions. [b] All yields are isolated yields of cis-trans mixtures. Satisfactory C, H combustion analyses were obtained on the trans thiol ester products derived from aldehydes **3**, **4**, and **5**. [c] Trans-cis ratios were determined by capillary VPC analysis except with substrate **7**, where these ratios were determined by isolation.

A Useful Wittig Reagent for the Stereoselective Synthesis of Trans α,β-Unsaturated Thiol Esters

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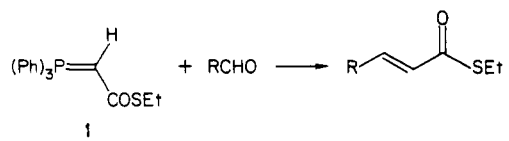
The reaction of aldehydes with Wittig reagents of the general structure $(Ph)_3PCHCO_2R$ constitutes an extremely powerful method for two-carbon chain extension which has seen wide application. The corresponding phosphonates, $(RO)_2P(O)CH_2CO_2R'$, are also very useful reagents in the same context. However, several problems can arise upon application of the above reagents to complex systems. For instance, the phosphoranes often exhibit low trans selectivity, particularly with α-alkoxy aldehydes, where trans–cis ratios of ca. 1:1 are not uncommon.[2] Moreover, the lithio or sodio derivatives of the corresponding phosphonates are generally not useful with base-sensitive substrates.[3] Finally, if the corresponding carboxylic acids are the ultimate goal of such Wittig processes, rather harsh hydrolytic conditions may be required to accomplish the requisite hydrolysis. We record here the preparation and reactions of a Wittig reagent (compound **1**) which has proven very useful in our laboratories. This material serves to allow for two-carbon chain extension resulting in the production of a latent "active" ester, from which either carboxylic acids or simple esters are readily accessible under mild and specific conditions.[4] Moreover, the application of such thiol esters to macrocyclic lactonization, as espoused by Masamune,[5] may further contribute to the utility of the reagent.



1

Reagent **1** is readily available in 78% overall yield from bromoacetic acid by the sequence: (1) thiol ester formation (ethanethiol) using dicyclohexylcarbodiimide (DCC) and catalytic 4-(dimethylamino)pyridine (4-DMAP) as described by Steglich;[6] (2) treatment with triphenylphosphine in benzene; and (3) exposure of the phosphonium salt so produced to aqueous sodium carbonate.

We summarize in Table I the Wittig reactions of **1** with five representative aldehydes. It should be noted that the higher trans selectivity exhibited by **1** as compared to, e.g., carbomethoxymethylenetriphenylphosphorane (**2**) *can be increased even further by exposure of the product to catalytic amounts of 4-(dimethylamino)pyridine (4-DMAP)*. For instance, substrate **7** yields a 60:40 mixture of unsaturated esters upon reaction with carbomethoxymethylenetriphenylphosphorane while **1** gives an 80:20 mixture of unsaturated thiol esters. Exposure of the isolated cis thiol ester product to 4-DMAP in CH_2Cl_2 at room temperature results in essentially quantitative isomerization to the trans thiol ester isomer; the cis unsaturated methyl ester obtained from carbomethoxymethylenetri-

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(2) For a recent example, note: Roush, W. R.; Lesur, B. M. *Tetrahedron Lett.* **1983**, *24*, 2231–2234.
(3) For a very recent solution to this problem, note: Blanchette, M. A.; Choy, W.; Davis, J. T.; Essenfeld, A. P.; Masamune, S.; Roush, W. R.; Sakai, T. *Tetrahedron Lett.* **1984**, *25*, 2183–2186.
(4) (a) Masamune, S.; Lu, L. D.-L.; Jackson, W. P.; Kaiho, T.; Toyoda, T. *J. Am. Chem. Soc.* **1982**, *104*, 5523–5526. (b) Masamune, S. *Aldrichimica Acta* **1978**, *11*, 23–32. (c) Masamune, S.; Hayase, Y.; Schilling, W.; Chan, W. K.; Bates, G. S. *J. Am. Chem. Soc.* **1977**, *99*, 6756–6758.
(5) Masamune, S.; Kamata, S.; Schilling, W. *J. Am. Chem. Soc.* **1975**, *97*, 3515–3516. Note also ref 4b and 4c.
(6) Steglich, W.; Neises, B. *Angew. Chem., Int. Ed. Engl.* **1978**, *17*, 522–524.

0022-3263/85/1950-0709$01.50/0