troscopy to still contain starting material. The mixture was again dissolved in acetone (6.0 mL), a 15% aqueous solution of trifluoroacetic acid (2.6 mL) was added, and the reaction mixture was stirred for an additional 2 days. The reaction was worked up as above and chromatographed (4:1 petroleum ether–ethyl acetate) to afford 0.95 g (86%) of **8** as an oil: R_f 0.47 (2:1 petroleum ether–ethyl acetate); IR (film) ν 2953, 2938, 2877, 2725, 1724, 1699, 1455, 1105, 1023 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.96 (d, J = 6.0 Hz, 3 H), 1.57 (m, 1 H), 1.95 (m, 2 H), 2.05 (m, 1 H), 2.26 (m, 2 H), 2.41 (m, 1 H), 2.58 (m, 2 H), 3.16 (m, 1 H), 3.38 (s, 3 H), 3.55 (br t, J = 4.5 Hz, 2 H), 3.75 (dd, J = 8.4, 4.1 Hz, 2 H), 3.95 (d, J = 5.8 Hz, 1 H), 4.74 (d, J = 7.1 Hz, 1 H), 4.83 (d, J = 7.1 Hz, 1 H), 5.34 (d, J = 11.4 Hz, 1 H), 5.61 (dd, J = 11.6, 5.8 Hz, 1 H), 5.85 (ddd, J = 11.6, 6.7, 1.5 Hz, 1 H), 5.95 (dd, J = 11.5, 6.8 Hz, 1 H), 9.77 (s, 1 H); ^{13}C NMR ($CDCl_3$) δ 23.72, 26.81, 36.49, 38.71, 43.35, 50.01, 58.89, 62.47, 68.12, 71.62, 79.25, 95.83, 125.37, 127.36, 131.37, 133.15, 201.43, 210.30; mass spectrum, m/e (%) 336 (0.6), 247 (69), 231 (16), 147 (47), 105 (17), 91 (23), 89 (64), 59 (100.0); high-resolution mass spectrum calcd for $C_{19}H_{28}O_5$ 336.1936, [exp – MEM] 247.1334, found 247.1338.

12-(2-Methoxyethoxy)-2,3,8,9,10,11-hexahydro-10-methyl-3a,8-methano-3a*H*-cyclopentacyclodecene-1,11a-diol (9). The air-sensitive cyclopentadienyltitanium trichloride (Aldrich) and lithium aluminum hydride (Aldrich) were weighed and transferred, under N_2, in a glovebag. To a solution of cyclopentadienyltitanium trichloride (0.20 g, 9 mmol) in freshly distilled tetrahydrofuran (4.0 mL) was cautiously added lithium aluminum hydride (0.027 g, 0.675 mmol). The resultant black mixture was stirred at 50 °C for 1 h, and then a solution of the keto aldehyde **8** (0.05 g, 0.15 mmol) in tetrahydrofuran (2 mL) was introduced. The black mixture was stirred for 9 h at 50 °C, cooled to room temperature, treated with a saturated aqueous solution of potassium carbonate (0.5 mL), and stirred for an additional 0.25 h. The resultant dark blue mixture was filtered through Celite with a 1:1 mixture of diethyl ether and ethyl acetate. The filtrate was washed with brine, dried, and concentrated in vacuo to give a yellow oil. Flash chromatography (4:1 petroleum ether–ethyl acetate) afforded 0.024 g (48%) of diol **9**: R_f 0.24 (2:1 hexane–ethyl acetate); IR (film) ν 3447, 3021, 2951, 2929, 2887, 1457, 1368, 1219, 1202, 1128, 1106, 1090, 1020, 962 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.94 (d, J = 6.6 Hz, 3 H), 1.56 (m, 1 H), 1.66 (m, 4 H), 1.81 (m, 1 H), 2.01 (m, 1 H), 2.12 (m, 2 H), 2.36 (m, 1 H), 3.14 (m, 1 H), 3.18 (m, 1 H), 3.38 (s, 3 H), 3.55 (br t, J = 4.7 Hz, 2 H), 3.68 (m, 1 H), 3.78 (m, 2 H), 3.89 (d, J = 5.0 Hz, 1 H), 4.78 (d, J = 7.1 Hz, 1 H), 4.91 (d, J = 7.1 Hz, 1 H), 5.40 (m, 1 H), 5.56 (m, 1 H), 5.76 (m, 2 H); ^{13}C NMR ($CDCl_3$) δ 25.33, 30.67, 38.40, 39.13, 43.75, 44.10, 59.04, 60.09, 68.56, 71.71, 81.80, 83.26, 96.60, 122.72, 122.92, 134.74, 134.91. Anal. Calcd for $C_{19}H_{30}O_5$: C, 67.42; H, 8.94. Found: C, 67.34; H, 8.80.

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Registry No. (±)-**2**, 125902-33-2; (±)-**2**(dioxolanylethyl derivative), 125902-41-2; (±)-**3**, 125902-34-3; (±)-**4**, 125902-35-4; (±)-**5**, 125902-36-5; (±)-**5**(trimethylsilyl enol ether), 125902-42-3; (±)-**6**, 125902-37-6; (±)-**7**, 125902-38-7; (±)-**8**, 125902-39-8; (±)-**9**, 125902-40-1; $BrCH_2CO_2Bu$-*t*, 5292-43-3; $BrCH_2CO_2Et$, 105-36-2; 2-(2-iodoethyl)-1,3-dioxolane, 83665-55-8.

Unexpected Cis Openings of Cyclopentadiene Monoepoxide with Lithium Acetylides and Dialkylalkynylalanes[1a]

Andrew J. Briggs[1b] and Keith A. M. Walker*

Institute of Organic Chemistry, Syntex Research, Palo Alto, California 94304

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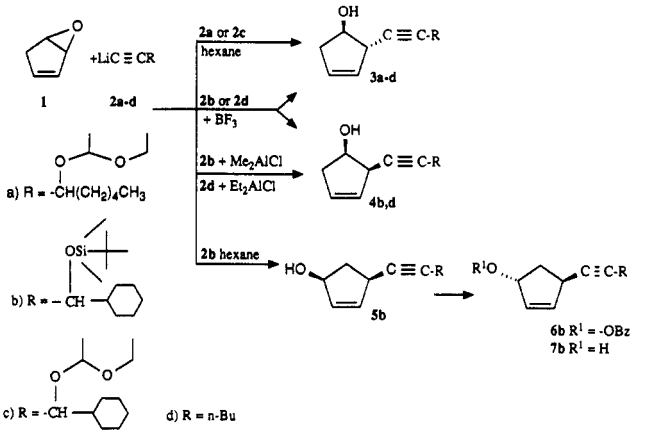
The reactions of vinyloxiranes with organometallic compounds have received considerable attention recently, with reliable methods now having been developed for syn-1,4 and anti-1,4 addition.[2] However, the reaction of alkynyl anions has been largely overlooked, there being only two applications in the literature.[3,4] We have previously applied the work of Stork[3] to prepare trans-cyclopentenol **3a**[5] by coupling the lithium acetylide **2a** with cyclopentadiene monoepoxide (**1**) for the preparation of prostacyclin analogues.[6] In an attempt to apply the same



conditions (*n*-BuLi/hexane) to the silyl-protected acetylide **2b**, we were surprised to obtain exclusively the cis-1,4-opening product **5b** (in 25% yield)[7] rather than the expected trans-1,2-opening product **3b**.

The 1,4-relationship in **5b** was readily ascertained from ^1H NMR decoupling experiments that showed the ring propargylic proton coupled to the downfield methylene proton but not the carbinol proton. The cis relationship of the substituents was initially deduced from the large chemical shift difference (0.9 ppm) of the two ring methylene protons arising from the cumulative shielding of one of these by the hydroxyl and acetylene moieties. To strengthen this assignment however, the trans isomer was needed for direct comparison. The presumed cis alcohol **5b** was therefore epimerized[9] by using the Mitsunobu reaction[10] to give the inverted benzoate **6b** (88%), followed by cleavage of the unstable benzoate with lithium aluminum hydride to give **7b** (92%). The much closer separation of the ring methylene proton resonances (0.1 ppm) in this epimer (trans) vindicated the original assignment.

To confirm that the origin of this effect (cis-1,4 versus trans-1,2 opening) lay in the nature of the protecting group

(1) (a) Contribution No. 743 from the Institute of Organic Chemistry, Syntex Research, 3401 Hillview Ave., Palo Alto, CA 94304. (b) Syntex Postdoctoral Fellow 1984–1986.

(2) See: Marshall, J. A.; Trometer, J. D.; Blough, B. E.; Crute, T. D. *J. Org. Chem.* **1988**, *53*, 4274. Marshall, J. A.; Trometer, J. D.; Cleary, D. G. *Tetrahedron* **1989**, *45*, 391. Larock, R. C.; Ilkka, S. J. *Tetrahedron Lett.* **1986**, *27*, 2211. Tueting, D. R.; Echavarren, A. M.; Stille, J. K. *Tetrahedron* **1989**, *45*, 979. Marshall, J. A.; Trometer, J. D.; Blough, B. E.; Crute, T. D. *Tetrahedron Lett.* **1988**, *29*, 913. Marino, J. P.; Farina, J. S. *J. Org. Chem.* **1976**, *41*, 3213 and references therein.

(3) Stork, G.; Isobe, M. *J. Am. Chem. Soc.* **1975**, *97*, 4745.

(4) Crosby, G. A.; Stephenson, R. A. *J. Chem. Soc., Chem. Commun.* **1975**, 287.

(5) For clarity, only one enantiomer or pair of diastereomers (for propargylic alcohols) are depicted. All compounds are racemic or mixtures of diastereomeric racemates.

(6) Bradbury, R. H.; Walker, K. A. M. *J. Org. Chem.* **1983**, *48*, 1741.

(7) Although the unoptimized yields in the reactions described are modest, no other significant products are obtained. The low yields probably reflect the known reluctance of acetylenes to add to epoxides[8] and loss or incomplete reaction of the sensitive epoxide **1**.

(8) Inhotten, H. H.; Weissermel, K.; Quinkert, G.; Bartling, D. *Chem. Ber.* **1956**, *89*, 853. Arnold, R. T.; Smelinsky, G. *J. Am. Chem. Soc.* **1960**, *82*, 4918

(9) Bose, A. K.; Lal, B.; Hoffman, W. A., III; Manhas, M. S. *Tetrahedron Lett.* **1973**, 1619.

(10) Mitsunobu, O. *Synthesis* **1981**, 1.

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(rather than the alkyl chain), the reaction was repeated with the ethoxyethyl-protected acetylide **2c**, giving now the expected trans-1,2-opening product **3c** exclusively (38%). Apparently, replacement of the chelating ethoxyethyl protecting group by a silyl ether is responsible for this dramatic redirection of the reaction pathway.

Since we required the silyl-protected compound **3b**, other reaction conditions were investigated for the silyloxy acetylene **2b** in the hope of obtaining trans-1,2 opening. Crosby[4] has previously reported trans-1,2 opening of cyclopentadiene monoepoxide by the alane reagent prepared from 1-hexyne in an ethereal solvent system. In an attempt to apply these findings, Me_2AlCl was added to the lithium salt of **2b** in hexane/THF, followed by the epoxide **1**. The reaction did indeed provide a cyclopentenol arising from 1,2-opening as the major product **4b** (20%); however, although the chemical shifts of the cyclopentene ring protons corresponded to those reported by Crosby[4] for the hexynyl derivative, they were quite different from the shifts observed for the trans-1,2-opening[11] products **3a**[6] and **3c**.

Several other additives were examined, including $BF_3{\cdot}Et_2O$, a reagent that has found increasingly wide use in epoxide cleavage.[12] When the lithium salt of the silyl-protected alkyne **2b** was treated with cyclopentadiene monoepoxide (**1**) and then $BF_3{\cdot}Et_2O$ at −78 °C, 1,2-opening again predominated, furnishing in this instance two cyclopentenols. One was identical with that derived from the alane reagent above; the other had chemical shifts for the cyclopentenyl ring protons almost identical with those observed for the trans diols **3a** and **3c**. The regiochemistry of the epoxide opening was unequivocally established by ^1H NMR decoupling experiments for both isomers. ^{13}C NMR spectra and NOE experiments fully supported the assignment of these as the cis **4b** (24%) and trans **3b** (25%) isomers, respectively.[13]

Since our findings are at odds with those of Crosby, we repeated the reaction of epoxide **1** with the diethylhexynylalkane according to the published procedure.[4] The major product was indeed the cis isomer **4d** (33%), having chemical shift values similar to those of the product previously reported by Crosby, who had assumed a trans relationship based on the normal behavior of simpler epoxides. As would be anticipated, reaction of epoxide **1** with (1-hexynyl)lithium in the presence of $BF_3{\cdot}Et_2O$ gave a mixture of the cis-1,2-opening product **4d** (16%) described above and the trans-1,2 product **3d** (12%). The chemical shifts of the ring protons in the latter correspond closely to those of the trans compounds **3a** and **3c** and also match closely those described by Crosby[4] for a "regioisomer". Clearly, caution needs to be exercised in assigning structures to the products of opening of cyclopentadiene monoepoxide.

We have thus shown that the reported trans-1,2 opening of cyclopentadiene monoepoxide by alkynyllithiums requires the presence of a chelating group in the side chain; otherwise cis-1,4 opening occurs. The complementary trans-1,4 opening using vinylcyanocuprates[14] and cis-1,4 opening using stabilized anions (palladium catalysis)[15] are not applicable to acetylenes. Modifications developed to facilitate epoxide opening by acetylenes do not improve this reaction but do change the course. Significantly, and contrary to a previous report,[4] the alane modification gives cis-1,2 opening, a mode of reaction rarely observed with carbanions,[16] and should make the cis-1,2 vinyl analogues accessible. The BF_3 modification reduces selectivity, in contrast to reactions of saturated epoxides.

Experimental Section

General details are as described previously.[6] ^1H NMR and ^{13}C NMR spectra were measured on a Bruker WM-300 spectrometer as solutions in $CDCl_3$ with Me_4Si as internal standard. Radial chromatography was performed with a Harrison Research Model 7924 chromatotron, and flash chromatography according to the procedure of Still, Kahn, and Mitra.[17] Tetrahydrofuran (THF, Mallinckrodt reagent grade) was dried by distillation from sodium/benzophenone ketyl. All reactions were carried out under a nitrogen atmosphere.

***cis*-4-(3-((*tert*-Butyldimethylsilyl)oxy)-3-cyclohexyl-1-propynyl)-2-cyclopenten-1-ol (5b).** To a solution of 3-((*tert*-butyldimethylsilyl)oxy)-3-cyclohexyl-1-propyne (**2b**)[18] (0.833 g, 3.30 mmol) in hexane (3 mL) was added *n*-BuLi (2.4 mL of a 1.28 M solution in hexane; 3.1 mmol) dropwise at 0 °C. After stirring for 15 min, the mixture was cooled to −78 °C, and a suspension of 3,4-epoxycyclopentene[19] (**1**) (0.140 g, 1.70 mmol) in hexane (0.5 mL) was added dropwise. The reaction was slowly warmed to room temperature and stirred overnight. After dilution with saturated aqueous NH_4Cl the mixture was extracted with ether (3 × 25 mL). The extracts were dried ($MgSO_4$), evaporated, and chromatographed on silica gel (90 g), eluting with 20% ether in hexane to give **5b** (0.140 g, 25%): IR ($CHCl_3$) 3610, 2240 cm^{-1}; ^1H NMR (300 MHz) δ 0.08 (3 H, s), 0.11 (3 H, s), 0.90 (9 H, s), 0.87–1.32 (5 H, m), 1.45 (1 H, m), 1.51 (1 H, d, J = 9 Hz, exchanges with D_2O), 1.55–1.90 (6 H, m), 2.66 (1 H, dt, J = 14, 8 Hz), 3.40 (1 H, m), 4.06 (1 H, dd, J = 6, 2 Hz), 4.78 (1 H, m), 5.88 (2 H, s); mass spectrum (CI), m/z 352 [$(M + NH_4)^+$], 317 ($MH^+ - H_2O$), 220, 203, 185. Anal. Calcd for $C_{20}H_{34}O_2Si$: C, 71.80; H, 10.24. Found: C, 71.67; H, 10.58.

***trans*-4-(3-((*tert*-Butyldimethylsilyl)oxy)-3-cyclohexyl-1-propynyl)-2-cyclopentenyl Benzoate (6b).** To a solution of **5b** (0.200 g, 0.60 mmol), Ph_3P (0.235 g, 0.90 mmol), and benzoic acid (0.073 g, 0.60 mmol) in THF (5 mL) was added diethyl azodicarboxylate (0.157 g, 142 μL, 0.90 mmol) dropwise. The mixture was stirred overnight at room temperature, concentrated, and chromatographed on silica gel (65 g), eluting with 2% ether in hexane to give **6b** (0.23 g, 88%): IR ($CHCl_3$) 1700, 1600, 1580 cm^{-1}; ^1H NMR (300 MHz) δ 0.09, 0.12 (6 H, 2 s), 0.92 (9 H, s), 0.85–1.33 (5 H, m), 1.46 (1 H, m), 1.62–1.92 (5 H, m), 2.38 (2 H, m), 3.82 (1 H, m), 4.07 (1 H, dd, J = 6, 2 Hz), 5.97 (1 H, m), 6.01 (1 H, m), 6.07 (1 H, m), 7.42 (2 H, t, J = 7 Hz), 7.55 (1 H, t, J = 7 Hz), 8.00 (2 H, d, J = 7 Hz); mass spectrum (CI), m/z 456 [$(M + NH_4)^+$], 334, 324, 317, 307. Exact mass (EI), m/z 381.1884 ($M^+ - C_4H_9$), calcd for $C_{23}H_{29}O_3Si$ 381.1886.

***trans*-4-(3-((*tert*-Butyldimethylsilyl)oxy)-3-cyclohexyl-1-propynyl)-2-cyclopenten-1-ol (7b).** To a solution of **6b** (0.095 g, 0.22 mmol) in ether (1.5 mL) was added $LiAlH_4$ (0.018 g, 0.47 mmol) portionwise at 0 °C. After 30 min of stirring, wet Na_2SO_4

(11) The trans stereochemistry of **3a** was confirmed by its ultimate conversion to (±)-$PgF_{1\alpha}$.[3]

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(13) A large positive NOE was observed between the two methine protons on the cyclopentene ring of the cis isomer **4b** and none in the trans isomer **3b**. In the ^{13}C NMR the resonances for the carbon atoms attached to these protons in **4b** are upfield of those in **3b**, in agreement with well-established shifts observed in *cis*- and *trans*-2-methylcyclopentanols: Christi, M.; Reich, H. J.; Roberts, J. D. *J. Am. Chem. Soc.* **1971**, *93*, 3463. Similar shifts have been observed in prostaglandins; see: Cooper, G. F.; Fried, J. *Proc. Natl. Acad. Sci. U.S.A.* **1973**, *70*, 1579. Mizsak, S. A.; Slomp, G. *Prostaglandins* **1975**, *10*, 807. Arroniz, C. E.; Gallina, J.; Martinez, E.; Muchowski, J. M.; Velarde, E.; Rooks, W. H. *Prostaglandins* **1978**, *16*, 47. We thank Dr. M. Maddox, Syntex Research, for interpretation of the ^{13}C NMR data.

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(19) Korach, M.; Nielsen, D. R.; Rideout, W. H. *Organic Synthesis*; Wiley: New York, 1973; Collect. Vol. V, p 414.

was added, and the mixture was stirred for 5 min. The precipitate was removed and washed with ether, and the filtrate was evaporated. Radial chromatography, eluting with 5% and then 10% acetone in cyclohexane, gave **7b** (0.067 g, 92%): IR ($CHCl_3$) 3610, 3450 cm^{-1}; ^1H NMR (300 MHz) δ 0.07 (3 H, s), 0.08 (3 H, s), 0.89 (9 H, s), 0.85–1.32 (5 H, m), 1.44 (1 H, m), 1.50–1.90 (6 H, m), 2.12 (1 H, ddd, J = 14, 9, 2 Hz), 2.24 (1 H, dm, J = 14 Hz), 3.73 (1 H, m), 4.04 (1 H, dd, J = 6, 2 Hz), 4.96 (1 H, m), 5.90 (2 H, m); mass spectrum (EI), m/z 352 [$(M + NH_4)^+$], 334 [$(M + NH_4)^+ - H_2O$], 317 ($MH^+ - H_2O$), 220, 203, 185. Anal. Calcd for $C_{20}H_{34}O_2Si$: C, 71.80; H, 10.24. Found: C, 71.67; H, 9.95.

3-Cyclohexyl-3-(1-ethoxyethoxy)-1-propyne (2c). To a solution of 1-cyclohexyl-2-propyn-1-ol[18] (13.8 g, 100 mmol) and naphthalenesulfonic acid (50 mg, 0.24 mmol) in ether (50 mL) was added ethyl vinyl ether (10.8 g, 14.3 mL, 150 mmol) dropwise at 0 °C. The mixture was warmed to room temperature, stirred overnight, and then diluted with $NaHCO_3$ solution (100 mL) and ether (75 mL). The aqueous phase was separated and extracted with ether (75 mL), and the extracts were dried ($MgSO_4/K_2CO_3$) and evaporated. Kugelrohr distillation (80 °C, ca. 0.1 mmHg) gave **2c** (17.78 g, 85%): IR (liquid film) 3330 cm^{-1}; ^1H NMR (300 MHz) δ 1.00–1.35 (5 H, m), 1.20 and 1.21 (3 H, 2 t, J = 7 Hz), 1.33 and 1.34 (3 H, 2 d, J = 5 Hz), 1.55–1.95 (6 H, m), 2.38 and 2.40 (1 H, 2 d, J = 2 Hz), 3.45–3.85 (2 H, m), 3.94 and 4.15 (1 H, 2 dd, J = 6, 2 Hz), 4.82 and 4.99 (1 H, 2 q, J = 5 Hz). Anal. Calcd for $C_{13}H_{22}O_2$: C, 74.24; H, 10.55. Found: C, 74.10; H, 10.59.

***trans*-2-(3-Cyclohexyl-3-(1-ethoxyethoxy)-1-propynyl)-3-cyclopenten-1-ol (3c).** To a solution of **2c** (0.210 g, 1.00 mmol) in hexane (1 mL) was added n-BuLi (0.69 mL of a 1.6 M solution in hexane; 1.1 mmol) dropwise at 0 °C. After 15 min the mixture was cooled to −78 °C and a suspension of **1** (0.205 g, 2.50 mmol) in hexane (0.5 mL) was added dropwise. The mixture was warmed to room temperature, stirred overnight, and diluted with aqueous NaCl (25 mL). The product was extracted with ether, dried ($MgSO_4/K_2CO_3$), concentrated, and chromatographed on silica gel (40 g), eluting with 50% ether in hexane to give **3c** (0.110 g, 38%): ^1H NMR (300 MHz) δ 1.00–1.95 (17 H, m), 2.03 (1 H, br), 2.31 (1 H, m), 2.78 (1 H, m), 3.42 (1 H, m), 3.45–3.80 (2 H, m), 3.92 and 4.12 (1 H, dd, J = 6, 2 Hz), 4.47 (1 H, m), 4.79 and 4.95 (1 H, q, J = 6 Hz), 5.65 (1 H, m), 5.75 (1 H, m).

***cis*-2-(3-((*tert*-Butyldimethylsilyl)oxy)-3-cyclohexyl-1-propynyl)-3-cyclopenten-1-ol (4b).** To a solution of **2b** (0.833 g, 3.30 mmol) in THF (6.0 mL) was added n-BuLi (2.0 mL of a 1.6 M solution in hexane; 3.2 mmol) dropwise at 0 °C. After 15 min Me_2AlCl (3.3 mL of a 1.0 M solution in hexane; 3.3 mmol) was added dropwise, and the mixture was stirred at 0 °C for 50 min and cooled to −20 °C. Epoxide **1** (0.100 g, 1.2 mmol) in THF (0.5 mL) was added dropwise, and the reaction was maintained at this temperature for 2 h and allowed to warm to room temperature overnight. After dilution with saturated NH_4Cl (25 mL), the mixture was filtered through Celite and the residue washed with ether (25 mL). The aqueous phase was extracted with ether (25 mL), and the extracts were dried ($MgSO_4$), concentrated, and chromatographed on silica gel (90 g), eluting with 20% ether in hexane to give **4b** (0.081 g, 20%): IR ($CHCl_3$) 3570 cm^{-1}; ^1H NMR (300 MHz) δ 0.09 (3 H, s), 0.12 (3 H, 2 s), 0.90 (9 H, s), 0.85–1.32 (5 H, m), 1.49 (1 H, m), 1.56–1.91 (5 H, m), 2.19 (1 H, br s, exchanges with D_2O), 2.43 (1 H, dm, J = 15 Hz), 2.58 (1 H, dm, J = 15 Hz), 3.64 (1 H, m), 4.13 (1 H, d, J = 6 Hz), 4.38 (1 H, m), 5.63 (1 H, m), 5.80 (1 H, m); ^{13}C NMR ($CDCl_3$) δ 130.1 (d), 129.1 (d), 87.3 (s), 80.6 (s), 71.5 (d), 67.9 (d), 45.0 (d), 43.6 (d), 40.7 (t), 28.7 (t), 26.6 (t), 26.0 (t), 25.9 (q), 18.2 (s), 4.4 (q), −5.0 (q); mass spectrum (CI), m/z 352 [$(M + NH_4)^+$], 335 (MH^+), 220, 204, 203, 185. Anal. Calcd for $C_{20}H_{34}O_2Si$: C, 71.80; H, 10.24. Found: C, 71.60; H, 10.04.

***cis*-2-(1-Hexynyl)-3-cyclopenten-1-ol (4d).** The reaction was carried out as above using 1-hexyne (1.00 g, 1.40 mL, 12.2 mmol) with Et_2AlCl (6.77 mL of a 1.8 M solution in toluene; 12.2 mmol) added dropwise followed by toluene (9.5 mL). The mixture was warmed to room temperature, stirred for 1.5 h, and cooled to −20 °C, and **1** (0.492 g, 0.49 mL, 6.0 mmol) was added dropwise. Workup as above and chromatography on silica gel (100 g), eluting with 10% ether in hexane, gave **4d** (0.325 g, 33%): IR ($CHCl_3$) 3550 cm^{-1}; ^1H NMR (300 MHz) δ 0.91 (3 H, t), 1.35–1.56 (4 H, m), 2.23 (2 H, dt, J = 2, 7 Hz), 2.29 (1 H, d, J = 4 Hz, exchanges with D_2O, 2.42 (1 H, dm, J = 15 Hz), 2.58 (1 H, dm, J = 15 Hz), 3.60 (1 H, m), 4.35 (1 H, m), 5.62 (1 H, m), 5.78 (1 H, m); mass spectrum (CI), m/z 182 [$(M + NH_4)^+$], 165 (MH^+). Exact mass (EI), m/z 149.0968 ($M^+ - CH_3$), calcd for $C_{10}H_{13}O$ 149.0966.

***cis*- (4d) and *trans*-2-(1-Hexynyl)-3-cyclopenten-1-ol (3d).** To 1-hexyne (0.688 g, 0.96 mL, 8.4 mmol) in THF (20 mL) was added n-BuLi (4.88 mL of a 1.6 M solution in hexane; 7.8 mmol) at 0 °C. After 15 min the mixture was cooled to −78 °C and **1** (0.492 g, 0.49 mL, 6.0 mmol) was added dropwise over 5 min followed immediately by dropwise addition of $BF_3{\cdot}Et_2O$ (0.852 g, 0.76 mL, 6.0 mmol). After 30 min of stirring at −78 °C, saturated NH_4Cl (50 mL) was added and the mixture was warmed to room temperature. After addition of water to solubilize undissolved salts, the mixture was extracted with ether (3 × 50 mL), and the extracts were dried ($MgSO_4$), evaporated, and chromatographed on silica gel (100 g), eluting with 20% ether in hexane to give **4d** (0.160 g, 16%). Further elution gave **3d** (0.117 g, 12%): IR ($CHCl_3$) 3650, 3470 cm^{-1}; ^1H NMR (300 MHz) δ 0.90 (3 H, t, J = 7 Hz), 1.33–1.53 (4 H, m), 1.96 (1 H, br s, exchanges with D_2O), 2.16 (2 H, dt, J = 2, 7 Hz), 2.29 (1 H, dm, J = 15 Hz), 2.78 (1 H, dm, J = 15 Hz), 3.35 (1 H, m), 4.43 (1 H, m), 5.64 (1 H, m), 5.73 (1 H, m); mass spectrum, m/z 164 (M^+), 146 ($M^+ - H_2O$) 135 ($M^+ - C_2H_5$), 121, 117 ($M^+ - C_2H_5 - H_2O$), 107; exact mass, m/z 164.1180, calcd for $C_{11}H_{16}O$ 164.1201.

***cis*- (4b) and *trans*-2-(3-((*tert*-Butyldimethylsilyl)oxy)-3-cyclohexyl-1-propynyl)-3-cyclopenten-1-ol (3b).** Treatment of **2b** as above furnished **4b** (24%) and **3b** (0.100 g, 25%): IR ($CHCl_3$) 3620 cm^{-1}; ^1H NMR (300 MHz) δ 0.07 (3 H, s), 0.10 (3 H, s), 0.89 (9 H, s), 0.85–1.30 (5 H, m), 1.44 (1 H, m), 1.55–1.95 (6 H, m), 2.30 (1 H, dm, J = 15 Hz), 2.78 (1 H, dm, J = 15 Hz), 3.39 (1 H, m), 4.06 (1 H, dd, J = 6, 2 Hz), 4.47 (1 H, m), 5.65 (1 H, m), 5.74 (1 H, m); ^{13}C NMR δ 129.6 (d), 129.1 (d), 84.2 (s), 83.3 (s), 78.9 (d), 67.9 (d), 45.9 (d), 45.0 (d), 41.0 (t), 28.7 (t), 26.6 (t), 26.1 (t), 25.9 (q), 18.3 (s), −4.4 (q), −5.0 (q); mass spectrum (CI), m/z 352 [$(M + NH_4)^+$], 335 (MH^+), 220, 203, 202, 185. Anal. Calcd for $C_{20}H_{34}O_2Si$: C, 71.80; H, 10.24. Found: C, 71.84; H, 10.49.

Registry No. 1, 7129-41-1; **2b**, 91098-88-3; **2c**, 125974-16-5; **3b**, 125974-19-8; **3c**, 125974-17-6; **3d**, 56268-11-2; **4b**, 125974-12-1; **4d**, 125974-18-7; **5b**, 125974-13-2; **6b**, 125974-14-3; **7b**, 125974-15-4; 1-cyclohexyl-2-propyn-1-ol, 4187-88-6; ethyl vinyl ether, 109-92-2; 1-hexene, 592-41-6.

Synthesis of 2,4-Dialkoxy-6-(trifluoromethyl)-3,5-pyridinedicarboxylates via a Novel Cyclocondensation of Dialkyl 3-Oxopentanedioates with Trifluoroacetonitrile

Len F. Lee* and Jean E. Normansell

Technology Division, Monsanto, Agricultural Company, A Unit of Monsanto Company, St. Louis, Missouri 63167

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Although 4-alkyl- and 4-aryl-3,5-pyridinedicarboxylates are well-known,[1] the corresponding 2,4-dialkoxy analogues have not been reported. In a continuing effort to synthesize 2-(trifluoromethyl)-3,5-pyridinedicarboxylates as herbicides,[2,3] we decided to prepare 2,4-dialkoxy-6-(trifluoromethyl)-3,5-pyridinedicarboxylates to study the

(1) For a review, see: Pollak, P. I.; Windholz, M. In *Pyridine and Its Derivatives*; Abramovitch, R. A., Ed.; *The Chemistry of Heterocyclic Compounds*; Wiley: New York, 1974; Vol. 14, Supplement Part Three, Chapter X.

(2) Lee, L. F. Eur. Pat. Appl. EP 133 612, 1985; U.S. Patent 4 692 184, 1987; *Chem. Abstr.* **1986**, *104*, 19514.

(3) Lee, L. F.; Stikes, G. L.; Normansell, J. E.; Molyneaux, J. M.; Sing, Y. L.; Chupp, J. P.; Woodard, S. S., manuscript submitted for publication in *J. Org. Chem.*

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