Supporting Information

Synthesis of (–)-Tetracycline.

Mark G. Charest, Dionicio R. Siegel, and Andrew G. Myers*

Department of Chemistry and Chemical Biology, Harvard University, Cambridge, Massachusetts 02138

myers@chemistry.harvard.edu

Index

1. Experimental

General Procedures. All reactions were performed in oven- or flame-dried round bottomed or modified Schlenk (Kjeldahl shape) flasks fitted with rubber septa under a positive pressure of argon, unless otherwise noted. Air- and moisture-sensitive liquids and solutions were transferred via syringe or stainless steel cannula. Organic solutions were concentrated by rotary evaporation (house vacuum, ~25 Torr) at 23–30 °C. Flash column chromatography was performed as described by Still et al. (Still, W. C.; Kahn, M.; Mitra, A. *J. Org. Chem.* **1978**, *43*, 2923-2925.) employing silica gel (60 Å pore size, 230–400 mesh, Merck KGA; or 60 Å pore size, 32–63 μm, standard grade, Sorbent Technologies). Analytical thin-layer chromatography (TLC) was performed using glass plates pre-coated with silica gel (0.25 mm, 60 Å pore size, 230-400 mesh, Merck KGA) impregnated with a fluorescent indicator (254 nm). TLC plates were visualized by exposure to ultraviolet light (UV) and/or exposure to ceric ammonium molybdate solution (CAM) or an acidic solution of *p*-anisaldehyde (anisaldehyde) followed by brief heating on a hot plate (~200 °C, 10–15 s).

Materials. Commercial reagents and solvents were used as received with the following exceptions. Dichloromethane, tetrahydrofuran, and *N*,*N*-dimethylformamide were purified by the method of Pangborn et al. (Pangborn, A. B.; Giardello, M. A.; Grubbs, R. H.; Rosen, R. K.; Timmers, F. J. *Organometallics* **1996**, *15*, 1518-1520.). *o*-Iodoxybenzoic acid (IBX), was prepared as reported by Frigerio et al. (Frigerio, M.; Santagostino, M.; Sputore, S. *J. Org. Chem.* **1999**, *64*, 4537-4538.). Commercial *m*-chloroperoxybenzoic acid (*m*-CPBA) was purified as follows: A solution of *m*-CPBA (100 g, 77% Aldrich) in benzene (1 L) was washed with an aqueous sodium phosphate

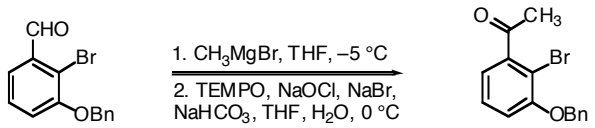
buffer solution (pH 7.4, 3 × 1 L) and dried over anhydrous sodium sulfate for 3 h. The dried solution was concentrated (<40 °C, thermal detonation hazard), providing pure *m*-CPBA as a white solid (~60 g).

Instrumentation. Proton nuclear magnetic resonance (^{1}H NMR) spectra and carbon nuclear magnetic resonance (^{13}C NMR) were recorded with Varian Unity/Inova 600 (600 MHz), Varian Unity/Inova 500 (500 MHz/125 MHz), Varian Mercury 400 (400 MHz/100 MHz), or Varian Mercury 300 (300 MHz/75 MHz) NMR spectrometers. Chemical shifts for protons are reported in parts per million scale (δ scale) downfield from tetramethylsilane and are referenced to residual protium in the NMR solvents ($CHCl_3$: δ 7.26, C_6D_5H: δ 7.15, D_2HCOD: δ 3.31). Chemical shifts for carbon are reported in parts per million (δ scale) downfield from tetramethylsilane and are referenced to the carbon resonances of the solvent ($CDCl_3$: δ 77.0, C_6D_6: δ 128.0, D_3COD: δ 44.9). Data are represented as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad), integration, coupling constant in Hz, and assignment. Infrared (IR) spectra were obtained using a Perkin-Elmer 1600 FT-IR spectrophotometer referenced to a polystyrene standard. Data are represented as follows: frequency of the absorption (cm^{-1}), intensity of absorption (s = strong, sb = strong broad, m = medium, w = weak, br = broad), and assignment (where appropriate). Optical rotations were determined on a JASCO DIP-370 digital polarimeter equipped with a sodium lamp source using a 200-μL or 2-mL solution cell. Reported readings are the average of ten measurements for each sample. High resolution mass spectra were obtained at the Harvard University Mass Spectrometry Facilities.

2. Procedures

Route to triethylsilyloxybenzocyclobutene **4**:

Ketone **4b**:



4a 80% (2 steps) **4b**

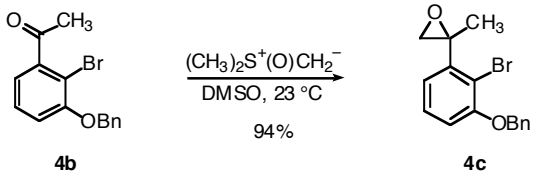
A solution of methylmagnesium bromide in ether (3.15 M, 11.6 mL, 36.7 mmol, 1.07 equiv) was added to a solution of the aldehyde **4a** (Prepared in 2 steps from commercially available 3-benzyloxy benzyl alcohol. Hollinshed, S. P.; Nichols, J. B.; Wilson, J. W. *J. Org. Chem.* **1994**, *59*, 6703.) (10.0 g, 34.3 mmol, 1.0 equiv) in tetrahydrofuran (90 mL) at –5 °C (NaCl/ice bath). The light brown solution was stirred at –5 °C for 60 min, then was partitioned between saturated aqueous ammonium chloride solution (400 mL) and ethyl acetate (400 mL). The organic phase was separated and dried over anhydrous sodium sulfate. The dried solution was filtered and the filtrate was concentrated, providing a light yellow oil (10.1 g, 95% crude). The product was used without further purification.

Sodium bromide (846 mg, 8.22 mmol, 0.25 equiv) and 2,2,6,6-tetramethyl-1-piperidinyloxyl (51.0 mg, 0.329 mmol, 0.01 equiv) were added in sequence to a solution of the light yellow oil prepared above (10.1 g, 32.8 mmol, 1.0 equiv) in tetrahydrofuran (30 mL) at 0 °C. A freshly prepared solution of sodium bicarbonate (690 mg, 8.22 mmol, 0.25 equiv) in commercial Clorox bleach (90 mL) was cooled to 0 °C and was added in one portion to the mixture prepared above at 0 °C. The resulting bright yellow mixture was stirred vigorously at 0 °C for 1.5 h whereupon sodium sulfite (1.0 g) was added. The

resulting mixture was stirred for 15 min at 23 °C, then was partitioned between water (400 mL) and ethyl acetate (400 mL). The organic phase was separated and dried over anhydrous sodium sulfate. The dried solution was filtered and the filtrate was concentrated, providing a light brown oil. The product was crystallized from ethanol, furnishing the ketone **4b** as a white solid (8.08 g, 80% over 2 steps).

R_f 0.80 (3:7 ethyl acetate-hexanes); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.26-7.48 (m, 6H, Ar**H**), 6.98 (m, 2H, Ar**H**), 5.19 (s, 2H, OC$\mathbf{H}_2$Ph), 2.62 (s, 3H, C(=O)C$\mathbf{H}_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ 202.4, 155.5, 144.4, 136.3, 128.9, 128.7, 128.3, 127.2, 120.3, 115.2, 109.1, 71.3, 30.9; FTIR (neat), cm $^{-1}$ 3065 (w), 3032 (w), 2918 (m), 1701 (s, C=O), 1565 (m), 1426 (m), 1300 (s), 1271 (s), 1028 (m); HRMS (ES) *m/z* calcd for $(C_{15}H_{13}O_2Br+H)^+$ 304.0099, found 304.0105.

Epoxide **4c**:



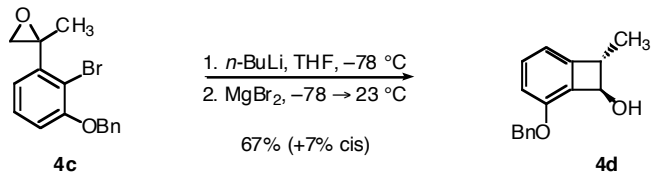
4b **4c**

Dimethylsulfoxide (90 mL) was added dropwise via syringe to a mixture of solid trimethylsulfoxonium iodide (694 mg, 3.15 mmol, 1.3 equiv) and solid sodium hydride (60% in oil, 126 mg, 3.15 mmol, 1.3 equiv, washed with three 2-mL portions of *n*-hexane) at 23 °C. Vigorous gas evolution was observed upon addition. The resulting cloudy gray mixture was stirred at 23 °C for 40 min, then a solution of the ketone **4b** (8.08 g, 26.5 mmol, 1.0 equiv) in dimethylsulfoxide (30 mL) was added dropwise via cannula. The transfer was quantitated with a 2-mL portion of dimethylsulfoxide. The resulting orange mixture was stirred at 23 °C for 35 h, then was partitioned between brine (1 L) and ether (500 mL). The organic phase was separated and the aqueous phase was further extracted with one 500-mL portion of ether. The organic phases were combined and dried over anhydrous sodium sulfate. The dried solution was filtered and the filtrate was concentrated, providing a yellow oil. The product was purified by flash column chromatography (5:95 ethyl acetate-hexanes), affording the epoxide **4c** as a clear oil (7.94 g, 94%).

R_f 0.90 (3:7 ethyl acetate-hexanes); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.20-7.52 (m, 6H, Ar**H**), 7.10 (dd, 1H, *J* = 7.5, 1.2 Hz, *o*-Ar**H**), 6.88 (dd, 1H, *J* = 8.1, 1.2 Hz, *o*-Ar**H**), 5.16 (s, 2H, OC**H**$_2$Ph), 3.03 (d, 1H, *J* = 4.8 Hz, C**H**H´OCCH$_3$), 2.87 (d, 1H, *J* = 4.8 Hz, CH**H**´OCCH$_3$), 1.67 (s, 3H, COC**H**$_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.0, 143.4, 136.7, 128.8, 128.4, 128.2, 127.2, 121.2, 112.8, 112.3, 71.2, 59.7, 55.9, 22.9; FTIR (neat), cm $^{-1}$

3034 (w), 2981 (w), 2925 (w), 1595 (w), 1567 (s), 1469 (s), 1423 (s), 1354 (s), 1300 (s), 1266 (s), 1028 (s); HRMS (ES) m/z calcd for $(C_{16}H_{15}O_2Br+H)^+$ 318.0255, found 318.0254.

Benzocyclobutene **4d**:



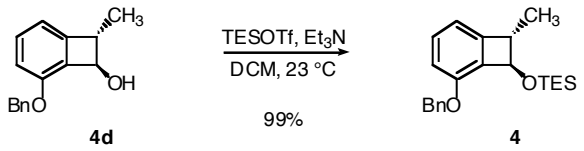
4c **4d**

A solution of *n*-butyllithium in hexanes (1.60 M, 8.25 mL, 13.6 mmol, 1.4 equiv) was added dropwise via syringe down the side of a reaction vessel containing a solution of the epoxide **4c** (3.11 g, 9.74 mmol, 1.0 equiv) in tetrahydrofuran (90 mL) at –78 °C. The resulting yellow solution was stirred at –78 °C for 20 min whereupon a suspension of magnesium bromide (3.95 g, 21.4 mmol, 2.2 equiv) in tetrahydrofuran (25 mL) was added dropwise via cannula. The transfer was quantitated with two 2.5-mL portions of tetrahydrofuran. The resulting cloudy mixture was stirred at –78 °C for 60 min, then the cooling bath was removed and the reaction mixture was allowed to warm to 23 °C. The mixture became clear upon warming and was stirred at 23 °C for 1 h. The reaction mixture was poured into aqueous Rochelle's salt solution (10% wt/wt, 1 L) and the resulting mixture was extracted with ethyl acetate (2 × 400 mL). The organic phases were combined and dried over anhydrous sodium sulfate. The dried solution was filtered and the filtrate was concentrated, providing an off-white solid. The product was purified by flash column chromatography (1:9 to 2:9 ethyl acetate-hexanes), affording the *trans*-benzocyclobutene **4d** as a white solid (1.57 g, 67%).

R_f 0.50 (3:7 ethyl acetate-hexanes); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.44 (br d, 2H, *J* = 7.5 Hz, Ar**H**), 7.38 (br dd, 2H, *J* = 7.5, 7.5 Hz, Ar**H**), 7.22-7.34 (m, 2H, Ar**H**), 6.82 (d, 1H, *J* = 8.5 Hz, *o*-Ar**H**), 6.75 (d, 1H, *J* = 7.5 Hz, *o*-Ar**H**), 5.35 (d, 1H, *J* = 12.0 Hz, OC**H**H´Ph), 5.25 (d, 1H, *J* = 12.0 Hz, OCH**H**´Ph),), 4.71 (br d, 1H, *J* = 5.5 Hz, C**H**OH), 3.31 (br q, 1H, *J* = 7.0 Hz, C**H**CH_3), 2.21 (br d, 1H, *J* = 7.0 Hz, O**H**), 1.38 (d, 3H, *J* = 7.0 Hz,

CHC**H**$_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.0, 148.9, 137.4, 131.5, 128.5, 128.4, 127.8, 127.3, 115.2, 114.6, 77.6, 71.2, 50.6, 16.5; FTIR (neat), cm $^{-1}$ 3249 (m, OH), 2958 (w), 1602 (m), 1580 (s), 1453 (s), 1261 (s), 1039 (s); HRMS (ES) *m*/*z* calcd for $(C_{16}H_{16}O_2+H)^+$ 240.1150, found 240.1154.

Triethylsilyloxybenzocyclobutene **4**:

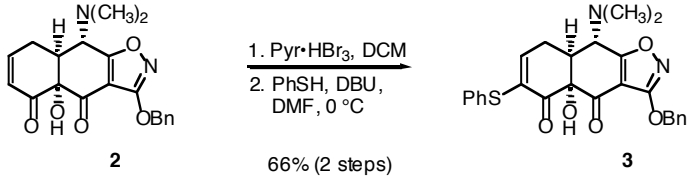


4d **4**

Triethylamine (336 μL, 2.41 mmol, 1.4 equiv) and triethylsilyl trifluoromethanesulfonate (468 μL, 2.07 mmol, 1.2 equiv) were added in sequence to a solution of the benzocyclobutene **4d** (500 mg, 1.72 mmol, 1.0 equiv) in dichloromethane (10 mL) at 23 °C. The light yellow solution was stirred at 23 °C for 15 min, then was partitioned between water (30 mL) and dichloromethane (30 mL). The organic phase was separated and dried over anhydrous sodium sulfate. The dried solution was filtered and the filtrate was concentrated, providing a yellow oil. The product was purified by flash column chromatography (5:95 ethyl acetate-hexanes), affording the triethylsilyloxybenzocyclobutene **4** as a clear oil (609 mg, 99%).

R_f 0.85 (1:4 ethyl acetate-hexanes); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48-7.32 (m, 5H, Ar**H**), 7.24 (m, 2H, Ar**H**), 6.82 (d, 1H, *J* = 8.4 Hz, *o*-Ar**H**), 6.74 (d, 1H, *J* = 7.2 Hz, *o*-Ar**H**), 5.37 (d, 1H, *J* = 11.2 Hz, C**H**H´Ph),), 5.20 (d, 1H, *J* = 11.2 Hz, CH**H**´Ph),), 4.87 (d, 1H, *J* = 1.6 Hz, C**H**OTES), 3.45 (dq, 1H, *J* = 7.2, 1.6 Hz, C**H**CH_3), 1.42 (d, 3H, *J* = 7.2 Hz, CHC**H**$_3$), 0.98 (t, 9H, *J* = 7.6 Hz, Si(CH_2C**H**$_3$)$_3$), 0.56 (q, 6H, *J* = 7.6 Hz, Si(C**H**$_2$$CH_3$)$_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.2, 148.8, 137.6, 131.3, 129.0, 128.7, 128.1, 127.8, 115.1, 114.7, 71.7, 49.9, 16.9, 7.1, 5.2, 5.1; FTIR (neat), cm $^{-1}$ 2952 (w), 2923 (w), 2854 (w), 1606 (w), 1469 (w), 1371 (m), 1265 (s), 1086 (s), 1057 (s), 1048 (s); HRMS (ES) *m/z* calcd for ($C_{22}H_{30}O_2Si$+H)$^+$ 354.2015, found 354.2006.

Vinyl Sulfide **3**:



Solid pyridinium hydrobromide perbromide (293 mg, 0.917 mmol, 2.5 equiv) was added to a solution of the enone **2** (135 mg, 0.367 mmol, 1.0 equiv) in dichloromethane (4 mL) at 23 °C. The brown solution was stirred vigorously at 23 °C for 17 h whereupon sodium sulfite (150 mg, 1.19 mmol, 3.25 equiv) was added. The resulting mixture was partitioned between an aqueous potassium phosphate buffer solution (pH 7.0, 0.2 M, 30 mL) and dichloromethane (30 mL). The organic phase was separated and dried over anhydrous sodium sulfate. The dried solution was filtered and the filtrate was concentrated, providing a light brown foamy solid. The product (α-bromide) was used immediately without further purification.

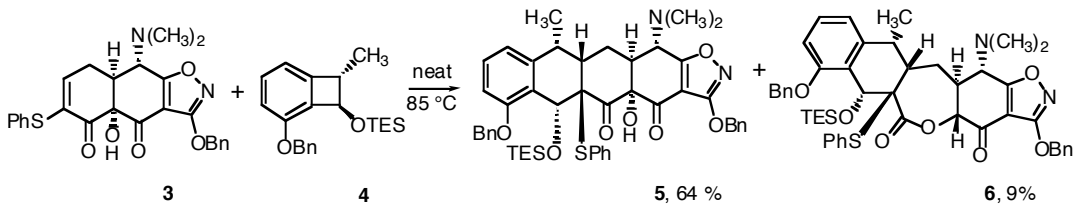
R_f 0.45 (2:3 ethyl acetate-hexanes); ^{1}H NMR (500 MHz, C_6D_6) δ 7.24 (d, 2H, *J* = 7.0 Hz, *o*-Ar**H**), 7.02 (t, 2H, *J* = 7.0 Hz, *m*-Ar**H**), 6.99 (d, 1H, *J* = 7.0 Hz, *p*-Ar**H**), 6.42 (ddd, 1H, *J* = 6.0, 3.5, 2.0 Hz, C**H**=CBr), 5.12 (d, 1H, *J* = 12.5 Hz, C**H**H´Ph),), 5.03 (d, 1H, *J* = 12.5 Hz, CH**H**´Ph),), 4.00 (br s, 1H, O**H**), 3.25 (d, 1H, *J* = 11.0 Hz, C**H**N$(CH_3)_2$), 2.28-2.22 (m, 2H, C**H**H´CH, CH_2C**H**), 2.16 (dd, 1H, *J* = 18.0, 6.0 Hz, CH**H**´CH), 1.83 (s, 6H, N$(CH_3)_2$); FTIR (neat), cm^{-1} 3397 (m, OH), 3063 (m), 2943 (m), 1714 (s, C=O), 1606 (s), 1514 (s), 1477 (s), 1371 (m), 1022 (m); HRMS (ES) *m*/*z* calcd for $(C_{20}H_{19}O_5BrN_2)^+$ 447.0555, found 447.0545.

Benzenethiol (39.0 μL, 0.378 mmol, 1.03 equiv) and 1,8-diazabicyclo[5,4,0]undec-7-ene (56.0 μL, 0.378 mmol, 1.03 equiv) were added in

sequence to a solution of the product prepared above (164 mg, 0.367 mmol, 1.0 equiv) in *N*,*N*-dimethylformamide (4 mL) at 0 °C. The resulting dark brown mixture was stirred vigorously at 0 °C for 25 min, then was partitioned between ethyl acetate-hexanes (1:1, 30 mL) and an aqueous potassium phosphate buffer solution (pH 7.0, 0.2 M, 30 mL). The organic phase was separated and the aqueous phase was further extracted with two 15-mL portions of ethyl acetate-hexanes (1:1). The organic phases were combined and dried over anhydrous sodium sulfate. The dried solution was filtered and the filtrate was concentrated, providing a brown oil. The product was purified by flash column chromatography (15:85 to 1:4 ethyl acetate-hexanes), furnishing the vinyl sulfide **3** as a white foam (116 mg, 66% over two steps).

R_f 0.47 (2:3 ethyl acetate-hexanes); ^{1}H NMR (500 MHz, C_6D_6) δ 7.34 (dd, 2H, *J* = 7.0, 1.0 Hz, *o*-Ar**H**), 7.23 (d, 2H, *J* = 6.5 Hz, *o*-Ar**H**), 6.85-7.04 (m, 6H, Ar**H**), 6.27 (ddd, 1H, *J* = 6.0, 3.0, 1.0 Hz, C**H**=CSPh), 5.11 (d, 1H, *J* = 12.0 Hz, OC**H**H´Ph), 5.02 (d, 1H, *J* = 12.0 Hz, OCH**H**´Ph), 4.62 (br s, 1H, O**H**), 3.42 (d, 1H, *J* = 10.5 Hz, C**H**N$(CH_3)_2$), 2.44 (ddd, 1H, *J* = 20.0, 5.5, 3.0 Hz, C**H**H´CH), 2.27-2.34 (m, 2H, CH**H**´CH, CH_2C**H**), 1.87 (s, 6H, N(C**H**$_3)_2$); ^{13}C NMR (100 MHz, $CDCl_3$) δ 188.9, 187.4, 182.5, 167.6, 145.4, 135.3, 135.2, 132.8, 132.6, 129.5, 128.6, 128.4, 128.3, 128.0, 127.8, 108.1, 80.3, 72.5, 59.8, 45.7, 41.4, 25.9; FTIR (neat), cm^{-1} 3445 (w, OH), 3056 (w), 2943 (m), 2800 (w), 1711 (s, C=O), 1682 (s), 1600 (m), 1507 (s), 1471 (s), 1451 (m), 1333 (m), 1020 (m); HRMS (ES) *m*/*z* calcd for $(C_{26}H_{24}O_5N_2S+H)^+$ 477.1484, found 447.1465.

Cycloadduct **5** and Lactone **6**:



A reaction vessel containing a mixture of the vinylsulfide **3** (131 mg, 0.275 mmol, 1.0 equiv) and the triethylsilyloxybenzocyclobutene **4** (750 mg, 2.11 mmol, 7.7 equiv) was placed in an oil bath preheated to 85 °C. The light yellow solution was stirred at 85 °C for 48 h, then was allowed to cool to 23 °C. The cooled mixture was purified by flash column chromatography (1:19 to 1:4 ethyl acetate-hexanes), affording the cycloadduct product **5** as an off-white foamy solid (145 mg, 64%), the lactone **6** as a clear oil (20.0 mg, 9%), and the recovered triethylsilyloxybenzocyclobutenol **4** as a clear oil (650 mg).

Cycloadduct **5**:

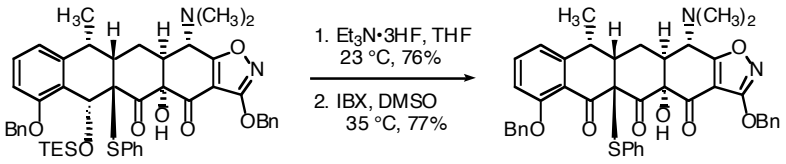
mp 178-179 °C; R_f 0.55 (2:3 ethyl acetate-hexanes); ^{1}H NMR (600 MHz, C_6D_6) δ 7.27 (d, 2H, *J* = 7.2 Hz, *o*-Ar**H**), 7.06-7.22 (m, 8H, Ar**H**), 6.92-6.96 (m, 3H, Ar**H**), 6.85 (d, 1H, *J* = 7.2 Hz, Ar**H**), 6.70-6.75 (m, 3H, Ar**H**), 6.55 (d, 1H, *J* = 8.4 Hz, *o*-Ar**H**), 5.75 (s, 1H, C**H**OTES), 5.29 (br s, 1H, O**H**), 5.16 (d, 1H, *J* = 12.0 Hz, OC**H**H´Ph), 5.10 (d, 1H, *J* = 12.0 Hz, OCH**H**´Ph), 4.66 (d, 1H, *J* = 10.8 Hz, OC**H**H´Ph´), 4.63 (d, 1H, *J* = 10.8 Hz, OCH**H**´Ph´), 4.36 (d, 1H, *J* = 6.6 Hz, C**H**N$(CH_3)_2$), 3.02 (dq, 1H, *J* = 7.8, 6.0 Hz, CH_3C**H**), 2.77 (ddd, 1H, *J* = 6.6, 6.0, 4.2 Hz, C**H**CHN$(CH_3)_2$), 2.41-2.52 (m, 2H, CHC**H**H´CH, CH_3CHC**H**CH_2), 2.08 (s, 6H, N(C**H**$_3)_2$), 1.83 (ddd, 1H, *J* = 13.2, 4.2, 4.2 Hz, CHCH**H**´CH), 1.34 (d, 3H, *J* = 7.8 Hz, C**H**$_3$CH), 0.70 (t, 9H, *J* = 7.8 Hz, Si(CH_2C**H**$_3)_3$), 0.48 (d, 6H, *J* = 7.8 Hz, Si(C**H**$_2$$CH_3)_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.3, 186.1, 181.4, 168.3, 156.3, 143.9, 137.6, 136.6, 135.4, 130.6, 129.8, 129.3, 128.6,

128.5, 128.4, 128.2, 128.0, 127.8, 125.4, 121.1, 109.3, 108.4, 80.6, 72.4, 70.2, 66.0, 62.5, 61.7, 43.2, 42.0, 38.1, 37.2, 27.4, 20.5, 6.9, 4.9; FTIR (neat), cm^{-1} 3490 (w, OH), 3063 (w), 3023 (w), 2951 (m), 2871 (m), 1715 (s, C=O), 1602 (m), 1589 (m), 1513 (s), 1457 (s), 1366 (m), 1260 (s), 1065 (s), 1012 (s); HRMS (FAB) *m*/*z* calcd for $(C_{48}H_{54}O_7N_2SSi+Na)^+$ 853.3318, found 853.3314.

Lactone **6**:

R_f 0.55 (3:7 ethyl acetate-hexanes); ^1H NMR (600 MHz, C_6D_6) δ 7.34 (d, 2H, *J* = 7.2 Hz, *o*-Ar**H**), 7.02-7.18 (m, 11H, Ar**H**), 6.72-6.84 (m, 4H, Ar**H**), 6.54 (d, 1H, *J* = 7.8 Hz, *o*-Ar**H**), 5.73 (s, 1H, C**H**OTES), 5.49 (d, 1H, *J* = 6.6 Hz, (C=O)OC**H**C=O), 5.20 (s, 2H, OC$\mathbf{H}_2$Ph), 4.60 (d, 1H, *J* = 11.4 Hz, OC**H**H´Ph´), 4.57 (d, 1H, *J* = 11.4 Hz, OCH**H**´Ph´), 3.49 (d, 1H, *J* = 11.4 Hz, C**H**N$(CH_3)_2$), 3.23 (dq, 1H, *J* = 9.0, 7.2 Hz, CH_3C**H**), 2.49 (m, 1H, CH_3CHCHC**H**H´), 2.30-2.40 (m, 2H, C**H**CHN$(CH_3)_2$, CH_3CHC**H**CH_2), 2.16 (dd, 1H, *J* = 12.0, 0.6 Hz, CH_3CHCHCH**H**´), 1.96 (s, 6H, N(C$\mathbf{H}_3)_2$), 1.33 (d, 3H, *J* = 7.2 Hz, C$\mathbf{H}_3$CH), 0.73 (t, 9H, *J* = 7.8 Hz, Si(CH_2C$\mathbf{H}_3)_3$), 0.46-0.62 (m, 6H, Si(C$\mathbf{H}_2CH_3)_3$); ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.4, 176.0, 170.0, 157.9, 156.0, 144.0, 136.6, 136.5, 135.6, 129.8, 129.7, 129.4, 128.9, 128.6, 128.4, 128.3, 128.2, 128.1, 127.8, 125.1, 121.2, 108.8, 101.9, 75.9, 72.1, 70.1, 64.7, 64.6, 62.9, 41.4, 36.7, 35.6, 27.7, 21.7, 6.9, 4.9; FTIR (neat), cm^{-1} 3062 (w), 3033 (w), 2950 (m), 2874 (m), 1731 (s, C=O), 1599 (m), 1590 (m), 1514 (s), 1453 (s), 1365 (m), 1259 (s), 1120 (s), 1059 (s), 1010 (s); HRMS (ES) *m*/*z* calcd for $(C_{48}H_{54}O_7N_2SSi+H)^+$ 831.3499, found 831.3509.

Alcohol **7**:



5 **7**

Triethylamine trihydrofluoride (200 μL, 1.23 mmol, 8.5 equiv) was added to a solution of the cycloadduct **5** (120 mg, 0.144 mmol, 1.0 equiv) in tetrahydrofuran (6 mL) at 23 °C. The mixture was stirred vigorously at 23 °C for 12 h, then was partitioned between an aqueous potassium phosphate buffer solution (pH 7.0, 0.2 M, 30 mL) and ethyl acetate (30 mL). The organic phase was separated and dried over anhydrous sodium sulfate. The dried solution was filtered and the filtrate was concentrated, providing a light brown solid. The product was purified by flash column chromatography (1:4 to 1:1 ethyl acetate-hexanes), affording the alcohol **7a** (structure not shown) as a colorless oil (78.3 mg, 76%).

R_f 0.20 (2:3 ethyl acetate-hexanes); ^{1}H NMR (600 MHz, C_6D_6) δ 7.69 (dd, 2H, J = 7.2, 0.6 Hz, *o*-Ar**H**), 7.24 (d, 2H, J = 7.2 Hz, Ar**H**), 6.92-7.06 (m, 12H, Ar**H**), 6.76 (d, 1H, J = 7.8 Hz, Ar**H**), 6.47 (d, 1H, J = 8.4 Hz, *o*-Ar**H**), 5.44 (br s, 1H, C**H**OH), 5.18 (d, 1H, J = 12.0 Hz, OC**H**H´Ph), 5.16 (d, 1H, J = 12.0 Hz, OCH**H**´Ph), 4.57 (d, 1H, J = 12.6 Hz, OC**H**H´Ph´), 4.52 (d, 1H, J = 12.6 Hz, OCH**H**´Ph´), 3.44 (dq, 1H, J = 6.6, 5.4 Hz, CH_3C**H**), 2.98 (d, 1H, J = 3.0 Hz, CHC**H**N$(CH_3)_2$), 2.90 (m, 1H, C**H**CHN$(CH_3)_2$), 2.76 (br s, 1H, O**H**), 2.32 (m, 1H, CH_3CHC**H**CH_2), 1.94 (m, 1H, CH_3CHCHC**H**H´), 1.79 (s, 6H, N(C**H**$_3)_2$), 1.07 (m, 1H, CH_3CHCHCH**H**´), 0.84 (d, 3H, J = 6.6 Hz, C**H**$_3$CH); ^{13}C NMR (100 MHz, $CDCl_3$) δ 202.5, 185.6, 179.2, 168.9, 156.9, 139.4, 139.1, 137.1, 136.5, 135.3, 130.5, 129.6, 128.8, 128.7, 128.6, 128.5, 128.4, 128.3, 127.8, 126.9, 124.7, 119.3,

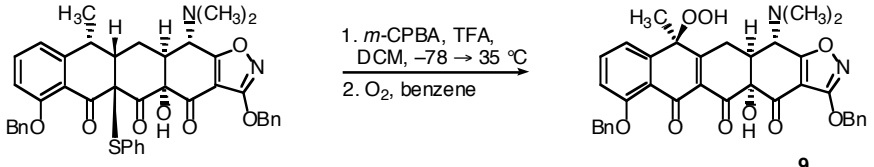
110.0, 106.8, 82.3, 72.5, 69.9, 66.4, 64.2, 59.3, 43.0, 39.1, 37.8, 32.6, 25.3, 16.8; FTIR (neat), cm^{-1} 3435 (w, OH), 3066 (w), 2964 (w), 2933 (w), 2871 (w), 1738 (s, C=O), 1698 (s, C=O), 1614 (m), 1583 (m), 1513 (s), 1471 (s), 1453 (s), 1369 (m), 1263 (m), 1035 (m), 1014 (m); HRMS (ES) *m/z* calcd for $(C_{42}H_{40}O_7N_2S+H)^+$ 717.2634, found 717.2631.

Solid *o*-iodoxybenzoic acid (459 mg, 1.64 mmol, 15.0 equiv) was added in one portion to a solution of the alcohol **7a** (78.3 mg, 0.109 mmol, 1.0 equiv) in dimethylsulfoxide (3.0 mL) at 23 °C. The resulting heterogeneous mixture was stirred for 5 min whereupon it became homogeneous. The reaction vessel was protected from light and was placed in an oil bath preheated to 35 °C. The brown solution was stirred vigorously at 35 °C for 18 h, then was partitioned between saturated aqueous sodium bicarbonate solution-brine-water (2:1:1, 75 mL) and ethyl acetate-ether (1:2, 35 mL). The organic phase was separated and the aqueous phase was further extracted with two 25-mL portions ethyl acetate-ether (1:2). The organic phases were combined and dried over anhydrous sodium sulfate. The dried solution was filtered and the filtrate was concentrated, providing a yellow oil. The product was purified by flash column chromatography (1:2 ethyl acetate-hexanes), affording the ketone **7** as a yellow oil (61.5 mg, 77%).

R_f 0.45 (2:3 ethyl acetate-hexanes); ^{1}H NMR (600 MHz, C_6D_6) δ 7.57 (d, 2H, *J* = 7.2 Hz, *o*-Ar**H**), 7.40 (d, 2H, *J* = 7.2 Hz, Ar**H**), 7.18-7.23 (m, 3H, Ar**H**), 6.94-7.06 (m, 6H, Ar**H**), 6.76-6.84 (m, 3H, Ar**H**), 6.59 (d, 1H, *J* = 7.8 Hz, Ar**H**), 6.53 (d, 1H, *J* = 8.4 Hz, *o*-Ar**H**), 5.09 (d, 1H, *J* = 12.6 Hz, OC**H**H´Ph), 4.96 (d, 1H, *J* = 12.6 Hz, OCH**H**´Ph), 4.77 (d, 1H, *J* = 12.0 Hz, OC**H**H´Ph´), 4.72 (d, 1H, *J* = 12.0 Hz, OCH**H**´Ph´), 4.48 (br s, 1H, O**H**),

4.06 (dq, 1H, *J* = 7.2, 3.0 Hz, $CH_3C\mathbf{H}$), 3.15 (d, 1H, *J* = 12.0 Hz, $CHC\mathbf{H}N(CH_3)_2$), 2.20 (ddd, 1H, *J* = 12.6, 5.4, 3.0 Hz, $CH_3CHC\mathbf{H}CH_2$), 2.13 (ddd, 1H, *J* = 12.0, 3.0, 0.6 Hz, $C\mathbf{H}CHN(CH_3)_2$), 1.81-1.88 (m, 7H, $N(C\mathbf{H}_3)_2$, $CH_3CHCHC\mathbf{H}H´$), 1.78 (ddd, 1H, *J* = 13.8, 5.4, 0.6 Hz, $CH_3CHCHCH\mathbf{H}´$), 1.01 (d, 3H, *J* = 7.2 Hz, $C\mathbf{H_3}CH$); ^{13}C NMR (100 MHz, $CDCl_3$) δ 200.3, 187.5, 183.1, 167.8, 160.6, 146.4, 138.2, 137.1, 135.3, 134.3, 131.7, 129.6, 128.9, 128.6, 128.5, 128.4, 128.3, 127.7, 126.7, 121.3, 118.0, 112.8, 108.3, 82.9, 77.5, 72.4, 70.3, 58.1, 47.0, 44.1, 32.4, 18.7, 18.0, 16.3; FTIR (neat), cm^{-1} 3457 (w, OH), 3063 (w), 2939 (w), 2878 (w), 2795 (w), 1727 (s, C=O), 1704 (s, C=O), 1667 (m, C=O), 1593 (s), 1513 (s), 1471 (s), 1453 (s), 1371 (m), 1276 (m), 1044 (m); HRMS (ES) *m/z* calcd for $(C_{42}H_{38}O_7N_2S+H)^+$ 715.2478, found 715.2483.

Hydroperoxide **9**:

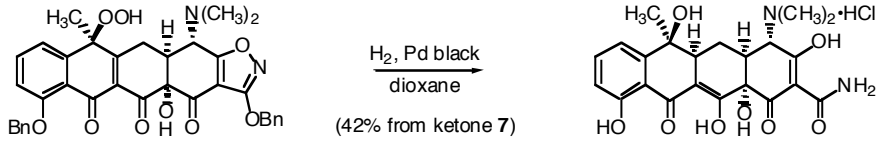


7 **9**

A solution of trifluoroacetic acid in dichloromethane (1.0 M, 0.189 mL, 0.189 mmol, 2.5 equiv) and a solution of *m*-chloroperoxybenzoic acid in dichloromethane (0.5 M, 0.228 mL, 0.114 mmol, 1.5 equiv) were added in sequence to a solution of the ketone **7** (54.2 mg, 0.0758 mmol, 1.0 equiv) in dichloromethane (4.0 mL) at –78 °C. The resulting cloudy mixture was stirred at –78 °C for 10 min, then the –78 °C bath was replaced with a 0 °C bath. The mixture became homogeneous upon warming. The solution was stirred at 0 °C for 30 min, then was partitioned between an aqueous potassium phosphate buffer solution (pH 7.0, 0.2 M, 10 mL) and dichloromethane (10 mL). The organic phase was separated and dried over anhydrous sodium sulfate. The dried solution was filtered and the filtrate was concentrated, providing a bright yellow oil. The oil was taken up in toluene (1 mL) and dried by azeotropic distillation at 40 °C under high vacuum. The resulting yellow oil was dissolved in chloroform (2 mL) and the reaction vessel was exposed to atmospheric oxygen. The mixture was allowed to stand until oxidation was complete as evidenced by ^{1}H NMR spectroscopy (24-36 h). The mixture was filtered and the filtrate was concentrated, providing the hydroperoxide **9** as a brown oil. The product was reduced immediately to tetracycline.

R_f 0.10 (2:3 ethyl acetate-hexanes); ^{1}H NMR (500 MHz, C_6D_6, keto tautomer reported) δ 8.95 (br s, 1H, OO**H**), 7.48 (d, 2H, *J* = 7.0 Hz, *o*-Ar**H**), 7.28 (d, 2H, *J* = 7.0 Hz, Ar**H**), 6.96-7.16 (m, 8H, Ar**H**), 6.53 (d, 1H, *J* = 8.0 Hz, Ar**H**), 5.14 (d, 1H, *J* = 12.0 Hz, OC**H**H´Ph), 5.03 (d, 1H, *J* = 12.0 Hz, OCH**H**´Ph), 4.83 (d, 1H, *J* = 12.5 Hz, OC**H**H´Ph´), 4.74 (d, 1H, *J* = 12.5 Hz, OCH**H**´Ph´), 4.60 (br s, 1H, O**H**), 3.54 (d, 1H, *J* = 11.0 Hz, CHC**H**N$(CH_3)_2$), 3.12 (dd, 1H, *J* = 18.0, 0.5 Hz, CHC**H**H´CH), 2.82 (dd, 1H, *J* = 18.0, 4.5 Hz, CHCH**H**´CH), 2.44 (ddd, 1H, *J* = 11.0, 4.5, 0.5 Hz, C**H**CHN$(CH_3)_2$), 1.86 (s, 6H, N(C**H**$_3)_2$), 1.01 (s, 3H, C**H**$_3$); ^{13}C NMR (100 MHz, C_6D_6, enol and keto tautomers reported) δ 194.4, 188.6, 187.8, 187.2, 182.3, 178.4, 171.9, 167.7, 165.6, 159.5, 158.4, 147.9, 145.9, 137.0, 136.8, 136.6, 135.4, 135.3, 134.5, 134.3, 133.5, 133.4, 133.1, 132.9, 131.0, 130.8, 130.2, 129.9, 129.7, 129.2, 128.9, 126.8, 126.7, 124.5, 124.3, 122.2, 118.6, 116.9, 116.5, 113.4, 113.3, 113.2, 108.2, 107.9, 103.3, 83.7, 81.7, 80.1, 79.1, 72.4, 70.7, 70.4, 63.9, 59.1, 46.1, 44.9, 41.4, 40.8, 31.5, 30.0, 26.8, 22.9, 21.4; FTIR (neat film), cm^{-1} 3035 (w), 2946 (w), 1907 (w), 1731 (s, C=O), 1410 (s), 1379 (m), 1235 (m), 1170 (m), 1136 (m); HRMS (ES) *m*/*z* calcd for $(C_{36}H_{32}O_9N_2+H)^+$ 637.2186, found 637.2190.

(–)-Tetracycline (**1**) Hydrochloride:

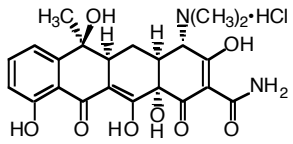


9 (–)-tetracycline (**1**) hydrochloride

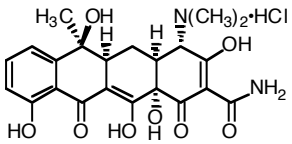
Pd black (14.1 mg, 0.133 mmol, 1.75 equiv) was added in one portion to a solution of the hydroperoxide **9** (48.2 mg, 0.0758 mmol, 1.0 equiv) in dioxane (3 mL) at 23 °C. An atmosphere of hydrogen was introduced by briefly evacuating the flask, then flushing with pure hydrogen (1 atm). The Pd catalyst was initially present as a fine dispersion, but aggregated into clumps within 5 min. The yellow heterogeneous mixture was stirred at 23 °C for 2 h, then was filtered through a plug of cotton. The filtrate was concentrated, affording a yellow solid. The product was purified by preparatory HPLC on a Phenomenex Polymerx DVB column (10 μM, 250 x 10 mm, flow rate 4.0 mL/min, Solvent A: methanol-0.005 N aq. HCl (1:4), Solvent B: acetonitrile) using an injection volume of solvent A (500 μL) containing oxalic acid (10 mg) and an isochratic elution of 5% B for 2 min, then a gradient elution of 5-50% B for 20 min. The peak eluting at 11-16 min was collected and concentrated, affording (–)-tetracycline hydrochloride as a yellow powder (16.0 mg, 42% from the ketone **7**), which was identical with natural (–)-tetracycline hydrochloride in all respects.

^{1}H NMR (600 MHz, CD_3OD, hydrochloride) δ 7.50 (dd, 1H, J = 8.4, 7.8 Hz, Ar**H**), 7.13 (d, 1H, J = 7.8 Hz, Ar**H**), 6.91 (d, 1H, J = 8.4 Hz, Ar**H**), 4.03 (s, 1H, C**H**N$(CH_3)_2$), 2.96-3.04 (m, 7H, HOC(CH_3)C**H**, N$(C\mathbf{H}_3)_2$), 2.91 (br dd, 1H, J = 12.6, 2.4 Hz, C**H**CHN$(CH_3)_2$), 2.18 (ddd, 1H, J = 12.6, 6.0, 2.4 Hz, CHC**H**H´CH), 1.90 (ddd, 1H, J = 12.6, 12.6, 12.0 Hz, CHCH**H**´CH), 1.60 (s, 3H, C$\mathbf{H}_3$); ^{13}C NMR (100 MHz, CD_3OD) δ

195.4, 174.5, 163.8, 148.3, 137.8, 118.7, 116.4, 116.0, 107.5, 96.5, 74.7, 71.2, 70.1, 43.5, 43.0, 35.9, 27.8, 22.9; UV max (0.1 N HCl), nm 217, 269, 356; $[\alpha]_D$ = –251° (c = 0.12 in 0.1 M HCl); lit. (*The Merck Index: An Encyclopedia of Chemicals, Drugs, and Biologicals*, 12th ed. Budavari, S.; O'Neal, M. J.; Smith, A.; Heckelman, P. E.; Kinneary, J. F., Eds.; Merck & Co.: Whitehouse Station, NJ, 1996; entry 9337.) UV max (0.1 N HCl), nm 220, 268, 355; $[\alpha]_D$ = –257.9° (c = 0.5 in 0.1 M HCl); HRMS (ES) *m*/*z* calcd for $(C_{22}H_{24}O_8N_2+H)^+$ 445.1611, found 445.1608.



synthetic (–)-tetracycline (**1**) hydrochloride



natural (–)-tetracycline (**1**) hydrochloride

3. X-ray Crystal Structure Data for the Cycloadduct 5

Data were collected using a Bruker SMART CCD (charge coupled device) based diffractometer equipped with an Oxford Cryostream low-temperature apparatus operating at 193 K. A suitable crystal was chosen and mounted on a glass fiber using grease. Data were measured using omega scans of 0.3° per frame for 30 seconds, such that a hemisphere was collected. A total of 1271 frames were collected with a maximum resolution of 0.76 Å. The first 50 frames were recollected at the end of data collection to monitor for decay. Cell parameters were retrieved using SMART[1] software and refined using SAINT on all observed reflections. Data reduction was performed using the SAINT software[2] which corrects for Lp and decay. The structures were solved by the direct method using the SHELXS-97[3] program and refined by least squares method on F^2, SHELXL-97,[4] incorporated in SHELXTL-PC V 6.10.[5]

The structure was solved in the space group $P2_12_12_1$ (# 19) by analysis of systematic absences. All non-hydrogen atoms were refined anisotropically. Hydrogens were calculated by geometrical methods and refined as a riding model. The crystal used for the diffraction study showed no decomposition during data collection. Drawings depict 50% thermal ellipsoids.

Acknowledgement. The CCD based x-ray diffractometer at Harvard University was purchased through NIH grant (1S10RR11937-01).

References

1. SMART V 5.625 (NT) *Software for the CCD Detector System*; Bruker Analytical X-ray Systems, Madison, WI (2001).

2. SAINT V 6.22 (NT) *Software for the CCD Detector System* Bruker Analytical X-ray Systems, Madison, WI (2001).

3. Sheldrick, G. M. SHELXS-90, *Program for the Solution of Crystal Structure*, University of Göttingen, Germany, 1990.

4. Sheldrick, G. M. SHELXL-97, *Program for the Refinement of Crystal Structure,* University of Göttingen, Germany, 1997.

5. SHELXTL 6.1 (PC-Version), *Program library for Structure Solution and Molecular Graphics*; Bruker Analytical X-ray Systems, Madison, WI (2000).

[a] Obtained with graphite monochromated Mo Kα ($\lambda = 0.71073$ Å) radiation. [b]$R1 = \sum||F_o| - |F_c||/\sum|F_o|$. [c]$wR_2 = \{\sum[w(F_o^2 - F_c^2)^2/\{\sum[w(F_o^2)^2]\}^{1/2}$.

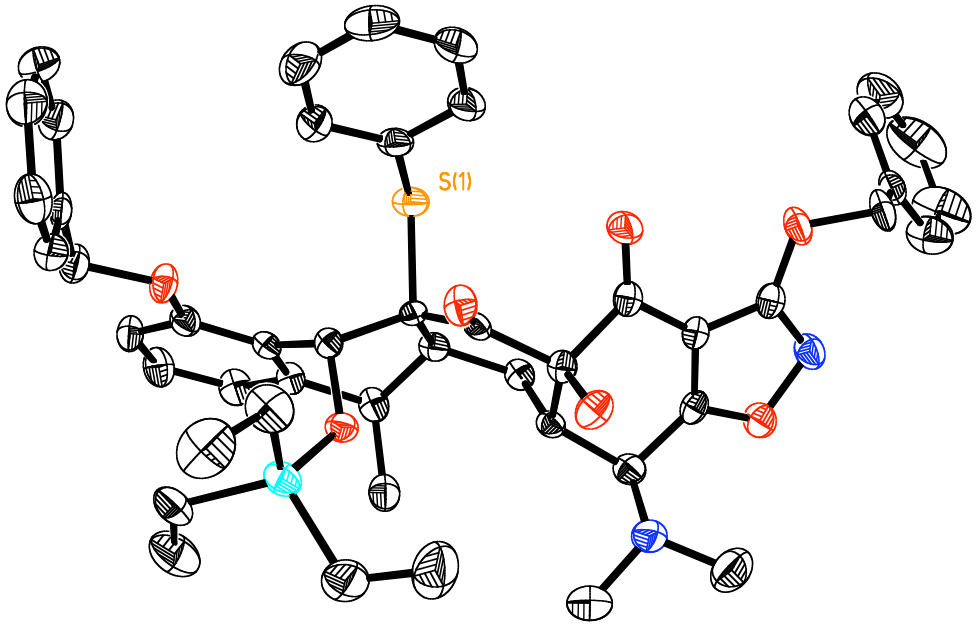


Table 1. Crystal data and structure refinement for the cycloadduct **5**.

Identification code	agm30t	
Empirical formula	$C_{48}H_{54}N_2O_7SSi$	
Formula weight	831.08	
Temperature	193(2) K	
Wavelength	0.71073 Å	
Crystal system	Orthorhombic	
Space group	P2(1)2(1)2(1)	
Unit cell dimensions	a = 8.8381(10) Å	α= 90°.
	b = 18.5394(19) Å	β= 90°.
	c = 26.865(3) Å	γ = 90°.
Volume	4401.9(8) Å ^{3}	
Z	4	
Density (calculated)	1.254 Mg/m^3	
Absorption coefficient	0.154 mm^{-1}	
F(000)	1768	
Crystal size	0.14 x 0.08 x 0.08 mm^3	
Theta range for data collection	1.33 to 27.92°.	
Index ranges	-11<=h<=11, -24<=k<=12, -35<=l<=33	
Reflections collected	31299	
Independent reflections	10538 [R(int) = 0.0787]	
Completeness to theta = 27.92°	99.8%	
Absorption correction	None	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	10538 / 0 / 539	
Goodness-of-fit on F^2	0.976	
Final R indices [I>2sigma(I)]	R1 = 0.0648, wR2 = 0.0726	
R indices (all data)	R1 = 0.0988, wR2 = 0.0792	
Absolute structure parameter	-0.04(7)	
Largest diff. peak and hole	0.670 and -0.437 e. $Å^{-3}$	

Table 2. Atomic coordinates (x 10^4) and equivalent isotropic displacement parameters ($Å^2$x 10^3) for the cycloadduct **5**. U(eq) is defined as one third of the trace of the orthogonalized U^{ij} tensor.

	x	y	z	U(eq)
S(1)	9838(1)	247(1)	2323(1)	31(1)
Si(1)	9369(1)	2832(1)	1371(1)	32(1)
O(1)	7520(2)	-2149(1)	802(1)	35(1)
O(2)	10046(2)	2006(1)	1433(1)	27(1)
O(3)	10325(2)	2491(1)	2736(1)	30(1)
O(4)	9922(2)	-1316(1)	-35(1)	35(1)
O(5)	7460(2)	-698(1)	1397(1)	37(1)
O(6)	7497(2)	1001(1)	1568(1)	31(1)
O(7)	7558(2)	560(1)	634(1)	34(1)
N(1)	9108(3)	-1940(1)	129(1)	34(1)
N(2)	9556(3)	373(1)	-175(1)	36(1)
C(1)	8411(3)	-1722(1)	531(1)	27(1)
C(2)	8703(3)	-984(1)	645(1)	25(1)
C(3)	8221(3)	-508(1)	1050(1)	25(1)
C(4)	8701(3)	283(1)	954(1)	25(1)
C(5)	8667(3)	718(1)	1440(1)	24(1)
C(6)	10106(3)	812(1)	1756(1)	21(1)
C(7)	10186(3)	1615(1)	1895(1)	22(1)
C(8)	11655(3)	1811(1)	2142(1)	23(1)
C(9)	11712(3)	2285(1)	2543(1)	27(1)
C(10)	13090(3)	2535(1)	2724(1)	30(1)
C(11)	14412(3)	2281(1)	2506(1)	35(1)
C(12)	14378(3)	1794(1)	2123(1)	33(1)
C(13)	13001(3)	1556(1)	1930(1)	27(1)
C(14)	12960(3)	1055(1)	1493(1)	29(1)
C(15)	11632(3)	503(1)	1548(1)	25(1)
C(16)	11429(3)	21(1)	1092(1)	26(1)
C(17)	10287(3)	329(1)	721(1)	23(1)
C(18)	10354(3)	-52(1)	210(1)	29(1)
C(19)	9640(3)	-773(1)	280(1)	26(1)
C(20)	7062(3)	-2827(1)	572(1)	37(1)

C(21)	8161(3)	-3435(1)	650(1)	34(1)
C(22)	8951(4)	-3723(2)	259(1)	53(1)
C(23)	9871(5)	-4322(2)	333(2)	81(1)
C(24)	9999(5)	-4613(2)	799(2)	86(2)
C(25)	9230(5)	-4327(2)	1190(2)	76(1)
C(26)	8309(4)	-3739(2)	1116(1)	54(1)
C(27)	8047(3)	454(1)	2593(1)	30(1)
C(28)	7903(4)	999(2)	2933(1)	38(1)
C(29)	6539(4)	1094(2)	3182(1)	48(1)
C(30)	5339(4)	645(2)	3088(1)	49(1)
C(31)	5478(4)	108(2)	2745(1)	49(1)
C(32)	6823(4)	-1(2)	2498(1)	42(1)
C(33)	7521(3)	2899(2)	1693(1)	46(1)
C(34)	6791(4)	3644(2)	1687(1)	62(1)
C(35)	10674(3)	3530(1)	1627(1)	41(1)
C(36)	12286(4)	3523(2)	1425(1)	63(1)
C(37)	9194(4)	2944(2)	689(1)	51(1)
C(38)	7980(5)	2482(2)	438(1)	77(1)
C(39)	10354(3)	3031(1)	3118(1)	34(1)
C(40)	8777(3)	3120(1)	3318(1)	26(1)
C(41)	8341(3)	2769(2)	3748(1)	35(1)
C(42)	6921(4)	2869(2)	3946(1)	41(1)
C(43)	5909(3)	3323(2)	3710(1)	41(1)
C(44)	6317(3)	3665(2)	3281(1)	39(1)
C(45)	7741(4)	3567(1)	3080(1)	34(1)
C(46)	13098(3)	1457(1)	998(1)	37(1)
C(47)	10410(4)	1029(2)	-290(1)	59(1)
C(48)	9350(4)	-29(2)	-638(1)	59(1)

Table 3. Bond lengths [Å] and angles [°] for the cycloadduct **5**.

S(1)-C(27)	1.783(3)
S(1)-C(6)	1.864(2)
Si(1)-O(2)	1.6525(17)
Si(1)-C(37)	1.848(3)
Si(1)-C(33)	1.852(3)
Si(1)-C(35)	1.865(3)
O(1)-C(1)	1.333(3)
O(1)-C(20)	1.459(3)
O(2)-C(7)	1.444(3)
O(3)-C(9)	1.385(3)
O(3)-C(39)	1.433(3)
O(4)-C(19)	1.340(3)
O(4)-N(1)	1.431(3)
O(5)-C(3)	1.202(3)
O(6)-C(5)	1.209(3)
O(7)-C(4)	1.422(3)
O(7)-H(7)	0.8400
N(1)-C(1)	1.307(3)
N(2)-C(48)	1.460(3)
N(2)-C(47)	1.465(3)
N(2)-C(18)	1.479(3)
C(1)-C(2)	1.426(3)
C(2)-C(19)	1.342(3)
C(2)-C(3)	1.462(4)
C(3)-C(4)	1.548(3)
C(4)-C(5)	1.537(4)
C(4)-C(17)	1.538(3)
C(5)-C(6)	1.539(4)
C(6)-C(7)	1.535(3)
C(6)-C(15)	1.568(3)
C(7)-C(8)	1.503(4)
C(7)-H(7A)	1.0000
C(8)-C(9)	1.392(3)
C(8)-C(13)	1.401(4)

C(9)-C(10)	1.391(4)
C(10)-C(11)	1.389(4)
C(10)-H(10)	0.9500
C(11)-C(12)	1.368(4)
C(11)-H(11)	0.9500
C(12)-C(13)	1.394(4)
C(12)-H(12)	0.9500
C(13)-C(14)	1.499(4)
C(14)-C(46)	1.530(4)
C(14)-C(15)	1.564(3)
C(14)-H(14)	1.0000
C(15)-C(16)	1.526(3)
C(15)-H(15)	1.0000
C(16)-C(17)	1.529(3)
C(16)-H(16A)	0.9900
C(16)-H(16B)	0.9900
C(17)-C(18)	1.545(3)
C(17)-H(17)	1.0000
C(18)-C(19)	1.490(3)
C(18)-H(18)	1.0000
C(20)-C(21)	1.502(4)
C(20)-H(20A)	0.9900
C(20)-H(20B)	0.9900
C(21)-C(22)	1.369(4)
C(21)-C(26)	1.381(4)
C(22)-C(23)	1.390(4)
C(22)-H(22)	0.9500
C(23)-C(24)	1.366(5)
C(23)-H(23)	0.9500
C(24)-C(25)	1.359(5)
C(24)-H(24)	0.9500
C(25)-C(26)	1.375(5)
C(25)-H(25)	0.9500
C(26)-H(26)	0.9500
C(27)-C(28)	1.367(4)
C(27)-C(32)	1.395(4)

C(28)-C(29)	1.390(4)
C(28)-H(28)	0.9500
C(29)-C(30)	1.372(4)
C(29)-H(29)	0.9500
C(30)-C(31)	1.362(4)
C(30)-H(30)	0.9500
C(31)-C(32)	1.376(4)
C(31)-H(31)	0.9500
C(32)-H(32)	0.9500
C(33)-C(34)	1.525(4)
C(33)-H(33A)	0.9900
C(33)-H(33B)	0.9900
C(34)-H(34A)	0.9800
C(34)-H(34B)	0.9800
C(34)-H(34C)	0.9800
C(35)-C(36)	1.524(4)
C(35)-H(35A)	0.9900
C(35)-H(35B)	0.9900
C(36)-H(36A)	0.9800
C(36)-H(36B)	0.9800
C(36)-H(36C)	0.9800
C(37)-C(38)	1.529(4)
C(37)-H(37A)	0.9900
C(37)-H(37B)	0.9900
C(38)-H(38A)	0.9800
C(38)-H(38B)	0.9800
C(38)-H(38C)	0.9800
C(39)-C(40)	1.503(4)
C(39)-H(39A)	0.9900
C(39)-H(39B)	0.9900
C(40)-C(41)	1.380(4)
C(40)-C(45)	1.391(4)
C(41)-C(42)	1.375(4)
C(41)-H(41)	0.9500
C(42)-C(43)	1.383(4)
C(42)-H(42)	0.9500

C(43)-C(44)	1.364(4)
C(43)-H(43)	0.9500
C(44)-C(45)	1.382(4)
C(44)-H(44)	0.9500
C(45)-H(45)	0.9500
C(46)-H(46A)	0.9800
C(46)-H(46B)	0.9800
C(46)-H(46C)	0.9800
C(47)-H(47A)	0.9800
C(47)-H(47B)	0.9800
C(47)-H(47C)	0.9800
C(48)-H(48A)	0.9800
C(48)-H(48B)	0.9800
C(48)-H(48C)	0.9800

C(27)-S(1)-C(6)	108.86(12)
O(2)-Si(1)-C(37)	103.55(12)
O(2)-Si(1)-C(33)	109.53(12)
C(37)-Si(1)-C(33)	112.41(15)
O(2)-Si(1)-C(35)	112.41(12)
C(37)-Si(1)-C(35)	109.84(15)
C(33)-Si(1)-C(35)	109.06(14)
C(1)-O(1)-C(20)	116.4(2)
C(7)-O(2)-Si(1)	125.72(15)
C(9)-O(3)-C(39)	116.4(2)
C(19)-O(4)-N(1)	108.6(2)
C(4)-O(7)-H(7)	109.5
C(1)-N(1)-O(4)	104.0(2)
C(48)-N(2)-C(47)	108.0(2)
C(48)-N(2)-C(18)	112.5(2)
C(47)-N(2)-C(18)	110.1(2)
N(1)-C(1)-O(1)	123.1(2)
N(1)-C(1)-C(2)	112.9(3)
O(1)-C(1)-C(2)	124.0(3)
C(19)-C(2)-C(1)	103.6(2)
C(19)-C(2)-C(3)	123.1(3)

C(1)-C(2)-C(3)	133.3(3)
O(5)-C(3)-C(2)	124.3(3)
O(5)-C(3)-C(4)	124.0(2)
C(2)-C(3)-C(4)	111.6(2)
O(7)-C(4)-C(5)	108.1(2)
O(7)-C(4)-C(17)	112.4(2)
C(5)-C(4)-C(17)	109.6(2)
O(7)-C(4)-C(3)	104.4(2)
C(5)-C(4)-C(3)	110.5(2)
C(17)-C(4)-C(3)	111.7(2)
O(6)-C(5)-C(4)	119.1(3)
O(6)-C(5)-C(6)	120.1(2)
C(4)-C(5)-C(6)	120.8(2)
C(7)-C(6)-C(5)	106.3(2)
C(7)-C(6)-C(15)	113.6(2)
C(5)-C(6)-C(15)	118.2(2)
C(7)-C(6)-S(1)	110.67(17)
C(5)-C(6)-S(1)	106.38(17)
C(15)-C(6)-S(1)	101.23(17)
O(2)-C(7)-C(8)	109.4(2)
O(2)-C(7)-C(6)	105.99(19)
C(8)-C(7)-C(6)	112.5(2)
O(2)-C(7)-H(7A)	109.6
C(8)-C(7)-H(7A)	109.6
C(6)-C(7)-H(7A)	109.6
C(9)-C(8)-C(13)	119.8(3)
C(9)-C(8)-C(7)	121.8(2)
C(13)-C(8)-C(7)	118.2(2)
O(3)-C(9)-C(10)	123.5(2)
O(3)-C(9)-C(8)	115.6(2)
C(10)-C(9)-C(8)	120.9(3)
C(11)-C(10)-C(9)	118.4(3)
C(11)-C(10)-H(10)	120.8
C(9)-C(10)-H(10)	120.8
C(12)-C(11)-C(10)	121.5(3)
C(12)-C(11)-H(11)	119.3

C(10)-C(11)-H(11)	119.3
C(11)-C(12)-C(13)	120.5(3)
C(11)-C(12)-H(12)	119.7
C(13)-C(12)-H(12)	119.7
C(12)-C(13)-C(8)	118.9(2)
C(12)-C(13)-C(14)	120.6(2)
C(8)-C(13)-C(14)	120.5(2)
C(13)-C(14)-C(46)	112.1(2)
C(13)-C(14)-C(15)	110.5(2)
C(46)-C(14)-C(15)	117.5(2)
C(13)-C(14)-H(14)	105.2
C(46)-C(14)-H(14)	105.2
C(15)-C(14)-H(14)	105.2
C(16)-C(15)-C(14)	113.2(2)
C(16)-C(15)-C(6)	113.5(2)
C(14)-C(15)-C(6)	116.08(19)
C(16)-C(15)-H(15)	104.1
C(14)-C(15)-H(15)	104.1
C(6)-C(15)-H(15)	104.1
C(15)-C(16)-C(17)	112.5(2)
C(15)-C(16)-H(16A)	109.1
C(17)-C(16)-H(16A)	109.1
C(15)-C(16)-H(16B)	109.1
C(17)-C(16)-H(16B)	109.1
H(16A)-C(16)-H(16B)	107.8
C(16)-C(17)-C(4)	108.4(2)
C(16)-C(17)-C(18)	112.6(2)
C(4)-C(17)-C(18)	111.8(2)
C(16)-C(17)-H(17)	108.0
C(4)-C(17)-H(17)	108.0
C(18)-C(17)-H(17)	108.0
N(2)-C(18)-C(19)	111.4(2)
N(2)-C(18)-C(17)	111.1(2)
C(19)-C(18)-C(17)	106.3(2)
N(2)-C(18)-H(18)	109.3
C(19)-C(18)-H(18)	109.3

C(17)-C(18)-H(18)	109.3
O(4)-C(19)-C(2)	111.0(2)
O(4)-C(19)-C(18)	121.0(2)
C(2)-C(19)-C(18)	128.0(2)
O(1)-C(20)-C(21)	114.0(2)
O(1)-C(20)-H(20A)	108.7
C(21)-C(20)-H(20A)	108.7
O(1)-C(20)-H(20B)	108.7
C(21)-C(20)-H(20B)	108.7
H(20A)-C(20)-H(20B)	107.6
C(22)-C(21)-C(26)	119.2(3)
C(22)-C(21)-C(20)	121.1(3)
C(26)-C(21)-C(20)	119.6(3)
C(21)-C(22)-C(23)	120.0(4)
C(21)-C(22)-H(22)	120.0
C(23)-C(22)-H(22)	120.0
C(24)-C(23)-C(22)	119.7(4)
C(24)-C(23)-H(23)	120.2
C(22)-C(23)-H(23)	120.2
C(25)-C(24)-C(23)	120.8(4)
C(25)-C(24)-H(24)	119.6
C(23)-C(24)-H(24)	119.6
C(24)-C(25)-C(26)	119.6(4)
C(24)-C(25)-H(25)	120.2
C(26)-C(25)-H(25)	120.2
C(25)-C(26)-C(21)	120.7(4)
C(25)-C(26)-H(26)	119.7
C(21)-C(26)-H(26)	119.7
C(28)-C(27)-C(32)	119.8(3)
C(28)-C(27)-S(1)	120.9(2)
C(32)-C(27)-S(1)	118.9(2)
C(27)-C(28)-C(29)	119.7(3)
C(27)-C(28)-H(28)	120.2
C(29)-C(28)-H(28)	120.2
C(30)-C(29)-C(28)	120.4(3)
C(30)-C(29)-H(29)	119.8

C(28)-C(29)-H(29)	119.8
C(31)-C(30)-C(29)	119.9(3)
C(31)-C(30)-H(30)	120.1
C(29)-C(30)-H(30)	120.1
C(30)-C(31)-C(32)	120.7(3)
C(30)-C(31)-H(31)	119.6
C(32)-C(31)-H(31)	119.6
C(31)-C(32)-C(27)	119.5(3)
C(31)-C(32)-H(32)	120.2
C(27)-C(32)-H(32)	120.2
C(34)-C(33)-Si(1)	115.4(2)
C(34)-C(33)-H(33A)	108.4
Si(1)-C(33)-H(33A)	108.4
C(34)-C(33)-H(33B)	108.4
Si(1)-C(33)-H(33B)	108.4
H(33A)-C(33)-H(33B)	107.5
C(33)-C(34)-H(34A)	109.5
C(33)-C(34)-H(34B)	109.5
H(34A)-C(34)-H(34B)	109.5
C(33)-C(34)-H(34C)	109.5
H(34A)-C(34)-H(34C)	109.5
H(34B)-C(34)-H(34C)	109.5
C(36)-C(35)-Si(1)	116.2(2)
C(36)-C(35)-H(35A)	108.2
Si(1)-C(35)-H(35A)	108.2
C(36)-C(35)-H(35B)	108.2
Si(1)-C(35)-H(35B)	108.2
H(35A)-C(35)-H(35B)	107.4
C(35)-C(36)-H(36A)	109.5
C(35)-C(36)-H(36B)	109.5
H(36A)-C(36)-H(36B)	109.5
C(35)-C(36)-H(36C)	109.5
H(36A)-C(36)-H(36C)	109.5
H(36B)-C(36)-H(36C)	109.5
C(38)-C(37)-Si(1)	115.6(2)
C(38)-C(37)-H(37A)	108.4

Si(1)-C(37)-H(37A)	108.4
C(38)-C(37)-H(37B)	108.4
Si(1)-C(37)-H(37B)	108.4
H(37A)-C(37)-H(37B)	107.4
C(37)-C(38)-H(38A)	109.5
C(37)-C(38)-H(38B)	109.5
H(38A)-C(38)-H(38B)	109.5
C(37)-C(38)-H(38C)	109.5
H(38A)-C(38)-H(38C)	109.5
H(38B)-C(38)-H(38C)	109.5
O(3)-C(39)-C(40)	108.4(2)
O(3)-C(39)-H(39A)	110.0
C(40)-C(39)-H(39A)	110.0
O(3)-C(39)-H(39B)	110.0
C(40)-C(39)-H(39B)	110.0
H(39A)-C(39)-H(39B)	108.4
C(41)-C(40)-C(45)	118.8(3)
C(41)-C(40)-C(39)	120.4(3)
C(45)-C(40)-C(39)	120.8(3)
C(42)-C(41)-C(40)	121.0(3)
C(42)-C(41)-H(41)	119.5
C(40)-C(41)-H(41)	119.5
C(41)-C(42)-C(43)	119.7(3)
C(41)-C(42)-H(42)	120.2
C(43)-C(42)-H(42)	120.2
C(44)-C(43)-C(42)	120.0(3)
C(44)-C(43)-H(43)	120.0
C(42)-C(43)-H(43)	120.0
C(43)-C(44)-C(45)	120.7(3)
C(43)-C(44)-H(44)	119.6
C(45)-C(44)-H(44)	119.6
C(44)-C(45)-C(40)	119.8(3)
C(44)-C(45)-H(45)	120.1
C(40)-C(45)-H(45)	120.1
C(14)-C(46)-H(46A)	109.5
C(14)-C(46)-H(46B)	109.5

H(46A)-C(46)-H(46B)	109.5
C(14)-C(46)-H(46C)	109.5
H(46A)-C(46)-H(46C)	109.5
H(46B)-C(46)-H(46C)	109.5
N(2)-C(47)-H(47A)	109.5
N(2)-C(47)-H(47B)	109.5
H(47A)-C(47)-H(47B)	109.5
N(2)-C(47)-H(47C)	109.5
H(47A)-C(47)-H(47C)	109.5
H(47B)-C(47)-H(47C)	109.5
N(2)-C(48)-H(48A)	109.5
N(2)-C(48)-H(48B)	109.5
H(48A)-C(48)-H(48B)	109.5
N(2)-C(48)-H(48C)	109.5
H(48A)-C(48)-H(48C)	109.5
H(48B)-C(48)-H(48C)	109.5

Symmetry transformations used to generate equivalent atoms:

Table 4. Anisotropic displacement parameters ($Å^2 \times 10^3$) for the cycloadduct **5**. The anisotropic displacement factor exponent takes the form: $-2\pi^2[h^2 a^{*2}U^{11} + ... + 2 h k a^* b^* U^{12}]$.

	U^{11}	U^{22}	U^{33}	U^{23}	U^{13}	U^{12}
S(1)	34(1)	29(1)	31(1)	5(1)	8(1)	3(1)
Si(1)	32(1)	26(1)	38(1)	4(1)	2(1)	2(1)
O(1)	36(1)	27(1)	43(1)	-11(1)	7(1)	-11(1)
O(2)	30(1)	24(1)	26(1)	3(1)	2(1)	1(1)
O(3)	24(1)	34(1)	32(1)	-14(1)	4(1)	-1(1)
O(4)	42(1)	29(1)	35(1)	-8(1)	11(1)	0(1)
O(5)	39(1)	35(1)	37(1)	-4(1)	15(1)	-9(1)
O(6)	23(1)	30(1)	38(1)	-11(1)	6(1)	4(1)
O(7)	31(1)	41(1)	29(1)	-2(1)	-4(1)	8(1)
N(1)	37(2)	26(2)	40(2)	-7(1)	6(1)	-4(1)
N(2)	47(2)	30(2)	31(2)	3(1)	1(1)	0(1)
C(1)	22(2)	30(2)	29(2)	-4(1)	-5(1)	3(1)
C(2)	25(2)	26(2)	24(2)	-5(1)	-2(1)	0(1)
C(3)	17(2)	30(2)	28(2)	-4(1)	-5(1)	1(1)
C(4)	24(2)	23(2)	27(2)	-2(1)	-1(1)	3(1)
C(5)	30(2)	15(2)	27(2)	1(1)	5(1)	-2(1)
C(6)	24(2)	22(2)	17(1)	-1(1)	5(1)	-2(1)
C(7)	21(2)	20(2)	25(2)	-3(1)	5(1)	3(1)
C(8)	22(2)	20(2)	27(2)	2(1)	2(1)	-2(1)
C(9)	26(2)	24(2)	31(2)	-1(1)	5(1)	-2(1)
C(10)	30(2)	30(2)	31(2)	-9(1)	-1(2)	-3(1)
C(11)	24(2)	36(2)	46(2)	-7(2)	-5(2)	-4(1)
C(12)	19(2)	35(2)	44(2)	-6(1)	8(2)	3(1)
C(13)	26(2)	24(2)	31(2)	-2(1)	-1(1)	-1(1)
C(14)	21(2)	27(2)	38(2)	-6(1)	6(1)	2(1)
C(15)	25(2)	21(2)	28(2)	1(1)	4(1)	5(1)
C(16)	22(2)	24(2)	32(2)	-3(1)	6(1)	2(1)
C(17)	26(2)	18(2)	25(2)	1(1)	5(1)	0(1)
C(18)	29(2)	27(2)	30(2)	-2(1)	9(1)	1(1)
C(19)	27(2)	26(2)	23(2)	-7(1)	0(1)	7(1)
C(20)	33(2)	28(2)	50(2)	-13(2)	-1(2)	-12(1)

C(21)	34(2)	27(2)	40(2)	0(2)	-7(2)	-10(1)
C(22)	57(3)	39(2)	61(3)	6(2)	15(2)	10(2)
C(23)	80(3)	52(3)	111(4)	7(2)	33(3)	22(2)
C(24)	63(3)	57(3)	140(5)	38(3)	-5(3)	15(2)
C(25)	85(4)	62(3)	82(4)	29(2)	-29(3)	-18(3)
C(26)	64(3)	45(2)	53(3)	2(2)	-4(2)	-18(2)
C(27)	35(2)	25(2)	28(2)	3(1)	11(2)	3(1)
C(28)	41(2)	37(2)	35(2)	-5(2)	5(2)	-4(2)
C(29)	57(2)	48(2)	39(2)	-10(2)	13(2)	8(2)
C(30)	41(2)	62(2)	43(2)	9(2)	20(2)	5(2)
C(31)	48(2)	50(2)	47(2)	-1(2)	16(2)	-20(2)
C(32)	51(2)	34(2)	40(2)	-4(1)	19(2)	-10(2)
C(33)	32(2)	45(2)	61(2)	-2(2)	10(2)	7(2)
C(34)	53(2)	70(3)	64(3)	-3(2)	-4(2)	31(2)
C(35)	46(2)	26(2)	51(2)	6(2)	-2(2)	-5(2)
C(36)	54(2)	56(2)	80(3)	11(2)	4(2)	-19(2)
C(37)	66(3)	40(2)	46(2)	9(2)	-7(2)	13(2)
C(38)	120(4)	52(3)	60(3)	-3(2)	-37(3)	12(2)
C(39)	34(2)	35(2)	35(2)	-11(1)	5(2)	-4(1)
C(40)	31(2)	23(2)	26(2)	-13(1)	2(1)	-5(1)
C(41)	40(2)	33(2)	32(2)	-4(1)	-2(2)	4(2)
C(42)	46(2)	45(2)	33(2)	-3(2)	12(2)	-7(2)
C(43)	28(2)	46(2)	49(2)	-13(2)	11(2)	-5(2)
C(44)	38(2)	29(2)	49(2)	-6(2)	-7(2)	4(2)
C(45)	42(2)	33(2)	28(2)	-4(1)	2(2)	-8(2)
C(46)	31(2)	40(2)	39(2)	-11(1)	12(2)	-10(1)
C(47)	84(3)	51(2)	42(2)	13(2)	-2(2)	-11(2)
C(48)	81(3)	56(2)	40(2)	-1(2)	-15(2)	4(2)

Table 5. Hydrogen coordinates (x 10^4) and isotropic displacement parameters ($Å^2$x 10^3) for the cycloadduct **5**.

	x	y	z	U(eq)
H(7)	7891	580	341	50
H(7A)	9323	1740	2119	26
H(10)	13127	2872	2990	36
H(11)	15361	2448	2626	42
H(12)	15299	1618	1988	39
H(14)	13904	760	1520	34
H(15)	11985	165	1814	30
H(16A)	11083	-461	1201	31
H(16B)	12418	-38	924	31
H(17)	10533	850	669	28
H(18)	11435	-117	109	34
H(20A)	6934	-2748	210	44
H(20B)	6066	-2971	709	44
H(22)	8871	-3514	-63	63
H(23)	10409	-4527	62	97
H(24)	10632	-5021	849	104
H(25)	9329	-4532	1512	91
H(26)	7768	-3540	1389	65
H(28)	8732	1311	2999	45
H(29)	6436	1473	3417	57
H(30)	4413	708	3262	58
H(31)	4637	-195	2675	58
H(32)	6919	-383	2265	50
H(33A)	6813	2553	1536	55
H(33B)	7661	2749	2043	55
H(34A)	7434	3985	1869	94
H(34B)	5795	3619	1847	94
H(34C)	6674	3808	1343	94
H(35A)	10231	4011	1560	49
H(35B)	10720	3469	1993	49

H(36A)	12805	3086	1539	95
H(36B)	12829	3949	1546	95
H(36C)	12260	3529	1061	95
H(37A)	8973	3458	618	61
H(37B)	10183	2830	535	61
H(38A)	8180	1972	505	116
H(38B)	8000	2567	78	116
H(38C)	6983	2612	570	116
H(39A)	10720	3494	2979	41
H(39B)	11048	2883	3388	41
H(41)	9032	2454	3909	42
H(42)	6638	2627	4243	50
H(43)	4929	3396	3847	49
H(44)	5615	3975	3120	46
H(45)	8011	3805	2779	41
H(46A)	12212	1768	951	55
H(46B)	13156	1108	725	55
H(46C)	14016	1754	1001	55
H(47A)	11417	898	-413	89
H(47B)	10510	1322	12	89
H(47C)	9874	1306	-546	89
H(48A)	8877	284	-887	88
H(48B)	8699	-448	-576	88
H(48C)	10336	-193	-760	88

Table 6. Torsion angles [°] for the cycloadduct **5**.

C(37)-Si(1)-O(2)-C(7)	-170.5(2)
C(33)-Si(1)-O(2)-C(7)	-50.4(2)
C(35)-Si(1)-O(2)-C(7)	71.0(2)
C(19)-O(4)-N(1)-C(1)	-0.4(3)
O(4)-N(1)-C(1)-O(1)	-179.8(2)
O(4)-N(1)-C(1)-C(2)	0.4(3)
C(20)-O(1)-C(1)-N(1)	-13.9(4)
C(20)-O(1)-C(1)-C(2)	165.8(2)
N(1)-C(1)-C(2)-C(19)	-0.3(3)
O(1)-C(1)-C(2)-C(19)	180.0(3)
N(1)-C(1)-C(2)-C(3)	-178.7(3)
O(1)-C(1)-C(2)-C(3)	1.5(5)
C(19)-C(2)-C(3)-O(5)	-175.1(3)
C(1)-C(2)-C(3)-O(5)	3.0(5)
C(19)-C(2)-C(3)-C(4)	9.5(4)
C(1)-C(2)-C(3)-C(4)	-172.3(3)
O(5)-C(3)-C(4)-O(7)	-92.7(3)
C(2)-C(3)-C(4)-O(7)	82.6(3)
O(5)-C(3)-C(4)-C(5)	23.3(4)
C(2)-C(3)-C(4)-C(5)	-161.4(2)
O(5)-C(3)-C(4)-C(17)	145.5(3)
C(2)-C(3)-C(4)-C(17)	-39.1(3)
O(7)-C(4)-C(5)-O(6)	26.5(3)
C(17)-C(4)-C(5)-O(6)	149.3(2)
C(3)-C(4)-C(5)-O(6)	-87.1(3)
O(7)-C(4)-C(5)-C(6)	-151.9(2)
C(17)-C(4)-C(5)-C(6)	-29.1(3)
C(3)-C(4)-C(5)-C(6)	94.4(3)
O(6)-C(5)-C(6)-C(7)	-44.6(3)
C(4)-C(5)-C(6)-C(7)	133.8(2)
O(6)-C(5)-C(6)-C(15)	-173.8(2)
C(4)-C(5)-C(6)-C(15)	4.6(3)
O(6)-C(5)-C(6)-S(1)	73.4(3)
C(4)-C(5)-C(6)-S(1)	-108.2(2)

C(27)-S(1)-C(6)-C(7)	64.5(2)
C(27)-S(1)-C(6)-C(5)	-50.57(19)
C(27)-S(1)-C(6)-C(15)	-174.68(16)
Si(1)-O(2)-C(7)-C(8)	-85.4(2)
Si(1)-O(2)-C(7)-C(6)	153.10(17)
C(5)-C(6)-C(7)-O(2)	-52.2(2)
C(15)-C(6)-C(7)-O(2)	79.6(3)
S(1)-C(6)-C(7)-O(2)	-167.33(16)
C(5)-C(6)-C(7)-C(8)	-171.7(2)
C(15)-C(6)-C(7)-C(8)	-39.9(3)
S(1)-C(6)-C(7)-C(8)	73.2(2)
O(2)-C(7)-C(8)-C(9)	102.7(3)
C(6)-C(7)-C(8)-C(9)	-139.8(2)
O(2)-C(7)-C(8)-C(13)	-71.5(3)
C(6)-C(7)-C(8)-C(13)	45.9(3)
C(39)-O(3)-C(9)-C(10)	4.7(4)
C(39)-O(3)-C(9)-C(8)	-174.2(2)
C(13)-C(8)-C(9)-O(3)	-178.2(2)
C(7)-C(8)-C(9)-O(3)	7.6(4)
C(13)-C(8)-C(9)-C(10)	2.8(4)
C(7)-C(8)-C(9)-C(10)	-171.3(2)
O(3)-C(9)-C(10)-C(11)	178.9(3)
C(8)-C(9)-C(10)-C(11)	-2.2(4)
C(9)-C(10)-C(11)-C(12)	-0.2(4)
C(10)-C(11)-C(12)-C(13)	2.0(4)
C(11)-C(12)-C(13)-C(8)	-1.4(4)
C(11)-C(12)-C(13)-C(14)	176.6(3)
C(9)-C(8)-C(13)-C(12)	-1.0(4)
C(7)-C(8)-C(13)-C(12)	173.4(2)
C(9)-C(8)-C(13)-C(14)	-179.0(2)
C(7)-C(8)-C(13)-C(14)	-4.6(4)
C(12)-C(13)-C(14)-C(46)	-83.3(3)
C(8)-C(13)-C(14)-C(46)	94.7(3)
C(12)-C(13)-C(14)-C(15)	143.6(3)
C(8)-C(13)-C(14)-C(15)	-38.5(4)
C(13)-C(14)-C(15)-C(16)	174.5(2)

C(46)-C(14)-C(15)-C(16)	44.1(3)
C(13)-C(14)-C(15)-C(6)	40.6(3)
C(46)-C(14)-C(15)-C(6)	-89.8(3)
C(7)-C(6)-C(15)-C(16)	-136.2(2)
C(5)-C(6)-C(15)-C(16)	-10.5(3)
S(1)-C(6)-C(15)-C(16)	105.1(2)
C(7)-C(6)-C(15)-C(14)	-2.4(3)
C(5)-C(6)-C(15)-C(14)	123.3(2)
S(1)-C(6)-C(15)-C(14)	-121.1(2)
C(14)-C(15)-C(16)-C(17)	-92.6(3)
C(6)-C(15)-C(16)-C(17)	42.5(3)
C(15)-C(16)-C(17)-C(4)	-69.5(3)
C(15)-C(16)-C(17)-C(18)	166.4(2)
O(7)-C(4)-C(17)-C(16)	179.9(2)
C(5)-C(4)-C(17)-C(16)	59.7(3)
C(3)-C(4)-C(17)-C(16)	-63.2(3)
O(7)-C(4)-C(17)-C(18)	-55.5(3)
C(5)-C(4)-C(17)-C(18)	-175.7(2)
C(3)-C(4)-C(17)-C(18)	61.5(3)
C(48)-N(2)-C(18)-C(19)	-51.0(3)
C(47)-N(2)-C(18)-C(19)	-171.5(2)
C(48)-N(2)-C(18)-C(17)	-169.3(2)
C(47)-N(2)-C(18)-C(17)	70.2(3)
C(16)-C(17)-C(18)-N(2)	-164.8(2)
C(4)-C(17)-C(18)-N(2)	73.0(3)
C(16)-C(17)-C(18)-C(19)	73.9(3)
C(4)-C(17)-C(18)-C(19)	-48.4(3)
N(1)-O(4)-C(19)-C(2)	0.3(3)
N(1)-O(4)-C(19)-C(18)	179.0(2)
C(1)-C(2)-C(19)-O(4)	0.0(3)
C(3)-C(2)-C(19)-O(4)	178.6(2)
C(1)-C(2)-C(19)-C(18)	-178.7(3)
C(3)-C(2)-C(19)-C(18)	0.0(5)
N(2)-C(18)-C(19)-O(4)	79.8(3)
C(17)-C(18)-C(19)-O(4)	-159.0(2)
N(2)-C(18)-C(19)-C(2)	-101.6(3)

C(17)-C(18)-C(19)-C(2)	19.6(4)
C(1)-O(1)-C(20)-C(21)	87.0(3)
O(1)-C(20)-C(21)-C(22)	-113.4(3)
O(1)-C(20)-C(21)-C(26)	70.9(3)
C(26)-C(21)-C(22)-C(23)	0.9(5)
C(20)-C(21)-C(22)-C(23)	-174.9(3)
C(21)-C(22)-C(23)-C(24)	-0.9(6)
C(22)-C(23)-C(24)-C(25)	0.3(7)
C(23)-C(24)-C(25)-C(26)	0.3(7)
C(24)-C(25)-C(26)-C(21)	-0.3(6)
C(22)-C(21)-C(26)-C(25)	-0.3(5)
C(20)-C(21)-C(26)-C(25)	175.5(3)
C(6)-S(1)-C(27)-C(28)	-88.3(3)
C(6)-S(1)-C(27)-C(32)	99.2(2)
C(32)-C(27)-C(28)-C(29)	0.0(5)
S(1)-C(27)-C(28)-C(29)	-172.3(2)
C(27)-C(28)-C(29)-C(30)	0.1(5)
C(28)-C(29)-C(30)-C(31)	-0.9(5)
C(29)-C(30)-C(31)-C(32)	1.5(5)
C(30)-C(31)-C(32)-C(27)	-1.4(5)
C(28)-C(27)-C(32)-C(31)	0.6(5)
S(1)-C(27)-C(32)-C(31)	173.1(2)
O(2)-Si(1)-C(33)-C(34)	177.3(2)
C(37)-Si(1)-C(33)-C(34)	-68.2(3)
C(35)-Si(1)-C(33)-C(34)	53.9(3)
O(2)-Si(1)-C(35)-C(36)	54.7(3)
C(37)-Si(1)-C(35)-C(36)	-60.0(3)
C(33)-Si(1)-C(35)-C(36)	176.4(2)
O(2)-Si(1)-C(37)-C(38)	68.5(3)
C(33)-Si(1)-C(37)-C(38)	-49.7(3)
C(35)-Si(1)-C(37)-C(38)	-171.3(2)
C(9)-O(3)-C(39)-C(40)	-173.7(2)
O(3)-C(39)-C(40)-C(41)	97.3(3)
O(3)-C(39)-C(40)-C(45)	-84.0(3)
C(45)-C(40)-C(41)-C(42)	-1.4(4)
C(39)-C(40)-C(41)-C(42)	177.3(3)

C(40)-C(41)-C(42)-C(43)	0.5(5)
C(41)-C(42)-C(43)-C(44)	0.5(5)
C(42)-C(43)-C(44)-C(45)	-0.4(5)
C(43)-C(44)-C(45)-C(40)	-0.6(4)
C(41)-C(40)-C(45)-C(44)	1.5(4)
C(39)-C(40)-C(45)-C(44)	-177.2(2)

Symmetry transformations used to generate equivalent atoms:

Table 7. Hydrogen bonds for the cycloadduct **5** [Å and °].

D-H...A	d(D-H)	d(H...A)	d(D...A)	<(DHA)
O(7)-H(7)...N(2)	0.84	2.06	2.822(3)	150.7

Symmetry transformations used to generate equivalent atoms: