Supporting Information

Tandem Anionic 5-Exo Dig Cyclization/ Claisen Rearrangement as an Efficient Route to Fused Polycyclic Ring Systems

Timo V. Ovaska,* and Jonathan B. Roses

Department of Chemistry, Connecticut College, 270 Mohegan Avenue, New London, CT 06320

tvova@conncoll.edu

Experimental Section

NMR spectra were recorded at 250 MHz (^{1}H) or at 63 MHz (^{13}C) with a Bruker AC-250 NMR spectrometer as solutions in $CDCl_3$. All chemical shifts are reported relative to tetramethylsilane at $\delta = 0.00$. Product mixtures were analyzed by GC on a 25 m HP-1 cross linked methyl silicone fused-silica capillary column (0.32 mm × 1.05 μm film thickness) and by GC-MS on a on a 25 m HP-1 cross linked methyl silicone fused-silica capillary column (0.32 mm × 1.05 μm film thickness). All operations involving organolithiums were performed in flame-dried glassware using standard syringe/cannula techniques under an atmosphere of dry nitrogen or argon. The concentration of commercial solutions of alkyllithium solutions was determined prior to use by titration with standard 2-butanol in xylene using 1,10-phenanthroline as indicator following the method of Watson and Eastham.[1] Diethyl ether and THF were distilled from dark-purple solutions of sodium/benzophenone. Diphenyl ether was distilled over sodium and stored over activated molecular sieves. All glassware used for the tandem

[1] Watson, S. C.; Eastham, J. F. *J. Organomet. Chem.* **1967**, *9*, 165.

cyclization/Claisen rearrangement reaction was base-washed (aq. NaOH) prior to use. Dilute solutions (~0.1 M) of the MeLi catalyst used for these reactions were prepared by dissolving commercially available MeLi in diethyl ether in anhydrous phenetole. Melting points are uncorrected.

(1S*, 2S*)-1-Cyclohex-1-enyl-2-(2-propynyl)cyclopentanol (4a) To a –78°C solution of 1.20 g (7.45 mmol) of 1-bromocyclohexene[2] in 21 mL of diethyl ether at under argon was added 8.40 mL of *t*-butyllithium in pentane (1.22 M, 10.2 mmol) dropwise. The resulting solution was allowed to stir at this temperature for 5 min. The cooling bath was then removed and the mixture was allowed to warm to 0 °C. After recooling to –78 °C, the cold mixture was rapidly transferred via cannula to a slurry of 1.85 g (7.51 mmol) of anhydrous $CeCl_3$ in 10 mL of THF (this mixture had been allowed to stir at room temperature for 1 hour under argon prior to cooling) at –78 °C. After 1 h, 414 mg (3.39 mmol) of 2-(2-propynyl)cyclopentanone in 10 mL of THF was added dropwise. The resulting mixture was stirred at –78 °C overnight and the reaction was then quenched by the addition of water (1 mL). The mixture was then concentrated in vacuo, diluted with ether (60 mL) and water (50 mL) and the layers were separated. The aqueous layer was extracted with diethyl ether (3 x 50 mL) and the combined organic layers were dried over magnesium sulfate. Filtration, followed by solvent removal gave a yellow oil that consisted mainly of **4a** and its (1S*, 2R*) diastereomer (4:1 ratio). The crude product was purified by column chromatography on silica gel (10% ethyl acetate/hexanes) to yield 429 mg (62%) of **4a** as a clear viscous oil: ^{1}H NMR δ 5.77-5.73 (m, 1H), 2.10-2.26 (m, 2H), 1.94–2.10 (m, 4H), 1.84–1.94 (m, 3H), 1.65 –1.84 (m, 3H), 1.37 –1.65 (m, 7H); ^{13}C NMR δ 139.7, 120.7, 107.0, 85.1, 84.1, 44.9, 39.0, 29.2, 25.1, 23.0, 22.3, 21.1, 20.4, 18.6; IR (KBr) 758.4, 838.6, 1020, 1248, 2174, 2934, 3399 cm^{-1}.

(1S*, 2S*)-1-Cyclohex-1-enyl-2-(2-butynyl)cyclopentanol (4d) To a –78°C solution of 812 mg (5.04 mmol) of 1-bromocyclohexene in 14 mL of diethyl ether at under argon was added 4.91 mL of *t*-butyllithium in pentane (2.06 M, 10.1 mmol) dropwise. The resulting solution was allowed to stir at this temperature for 5 min. The cooling bath was then removed and the mixture was allowed to warm to 0 °C. After recooling to –78 °C, the cold mixture was rapidly transferred via cannula to a slurry of 1.24 g (5.04 mmol) of anhydrous $CeCl_3$ in 7 mL of THF (this mixture had been allowed to stir at room temperature under argon for 1 hour prior to cooling) at –78 °C.

After 1 h, 343 mg (2.52 mmol) of 2-(2-butynyl)cyclopentanone in 8 mL of THF was added dropwise. The resulting mixture was stirred at –78 °C for 3.5 h and the reaction was then quenched by the addition of water (1 mL). The mixture was then concentrated in vacuo, diluted with ether (40 mL) and water (30 mL), and the layers were separated. The aqueous layer was extracted with diethyl ether (3 x 50 mL) and the combined organic layers were dried over magnesium sulfate. Filtration, followed by solvent removal gave a yellow oil that consisted mainly of **4d** and its (1S*, 2R*) diastereomer (9:1 ratio). The crude product was purified by column chromatography on silica gel (10% ethyl acetate/hexanes) to yield 450 mg (82 %) of **4d** as a clear oil: ^{1}H NMR δ 5.73-5.76 (m, 1H), 1.98-2.15 (m, 5H), 1.76-1.94 (m, 5H), 1.69-1.73 (m, 4H), 1.43-1.63 (m, 7H); ^{13}C NMR δ 139.9, 120.5, 84.3, 78.3, 76.3, 44.7, 38.9, 29.2, 25.1, 25.0, 23.0, 22.3, 21.1, 17.4, 3.4 ppm. IR (neat, cm^{-1}) 838, 920, 1016, 1138, 1335, 1446, 1741, 2927, 3498 cm^{-1}. Mass spectroscopic molecular weight calculated for $C_{15}H_{22}O$ 218.1671, found 218.1666.

(1S*, 2S*)-1-cyclopent-1-enyl-2-(2-propynyl)cyclohexanol (5a). To a –78°C solution of 1.30 g (8.84 mmol) 1-bromocyclopentene[2] in 20 mL of diethyl ether at under argon was added 9.11 mL of *t*-butyllithium in pentane (1.74 M, 15.9 mmol) dropwise. The resulting solution was allowed to stir at this temperature for 5 min. The cooling bath was then removed and the mixture was allowed to warm to 0 °C. After recooling to –78 °C, the cold mixture was rapidly transferred via cannula to a slurry of 2.17 g (8.80 mmol) of anhydrous $CeCl_3$ in 14 mL of THF (this mixture had been allowed to stir at room temperature under argon for 1 hour prior to cooling) at –78 °C. After 1 h, 0.801 g (5.87 mmol) of 2-(2-propynyl)cyclohexanone in 8 mL of THF was added dropwise. The resulting mixture was stirred at –78 °C for 3.5 h and the reaction was then quenched by the addition of water (1 mL). The mixture was then concentrated in vacuo, diluted with ether (40 mL) and water (30 mL), and the layers were separated. The aqueous layer was extracted with diethyl ether (3 x 50 mL) and the combined organic layers were dried over magnesium sulfate. Filtration followed by solvent removal yielded a yellow oil which was further purified by column chromatography over silica gel (10% ethyl acetate/hexanes) to yield 756 mg (63 %) of the desired product as a clear oil: ^{1}H NMR δ 5.58–5.63 (m, 1H), 2.18–2.35 (m, 4 H), 2.15 (dd, J = 3.61 Hz, 2.70 Hz, 1 H), 2. 04 (dd, *J* = 8.66 Hz, 2.70 Hz, 1H), 1.95 (t, *J* = 2.70

[2] Roman, U. Von; Ruhdorfer, J.; Knorr, R.; *Synthesis* **1993**, 985-992.

Hz, 1 H), 1.91–1.75 (m, 3H), 1.45–1.70 (m, 8H), 1.15–1.30 (m, 1H); ^{13}C NMR δ 150.4, 124.2, 84.2, 74.8, 69.3, 41.7, 37.8, 32.2, 32.1, 26.4, 25.7, 23.9, 21.2, 19.8; IR (neat) 3609, 3306, 2933, 2115, 1641, 1447, 1366, 1325, 1137, 1048, 989, 949, 803 cm^{-1}.

(1S*, 2S*)-1-cyclopent-1-enyl-2-(3-trimethylsilyl-2-propynyl)cyclohexanol (5b). To a –78°C solution of 1.06 g (7.21 mmol) 1-bromocyclopentene[3] in 16 mL of diethyl ether at under argon was added 7.41 mL of *t*-butyllithium in pentane (1.75 M, 13.0 mmol) dropwise. The resulting solution was allowed to stir at this temperature for 5 min. The cooling bath was then removed and the mixture was allowed to warm to 0 °C. After recooling to –78 °C, the cold mixture was rapidly transferred via cannula to a slurry of 1.78 g (7.22 mmol) of anhydrous $CeCl_3$ in 12 mL of THF (this mixture had been allowed to stir at room temperature under argon for 1 hour prior to cooling) at –78 °C. After 1 h, 0.914 g (4.80 mmol) of 2-(3-trimethylsilyl-2-propynyl)cyclohexanone in 10 mL of THF was added dropwise (45 min). The resulting mixture was stirred at –78 °C for 1 h and the reaction was then quenched by the addition of water (1 mL). The mixture was then concentrated in vacuo, diluted with ether (30 mL) and water (30 mL), and the layers were separated. The aqueous layer was extracted with diethyl ether (3 x 40 mL) and the combined organic layers were dried over magnesium sulfate. Filtration followed by solvent removal yielded a yellow oil which was further purified by column chromatography over silica gel (10% ethyl acetate/hexanes) to yield 1.13 g (85 %) of the desired product as pale yellow crystals: mp 48–51 °C; ^{1}H NMR δ 5.58–5.65 (m, 1H), 2.20–2.35 (m, 4H), 2.08–2.18 (m, 2H), 2.00 (br s, 1H), 1.82–1.92 (m, 2 H), 1.67–1.80 (m, 2H), 1.56–1.65 (m 2 H), 1.45–1.54 (m, 3H), 1.18–1.32 (m, 2H), 0.12 (s, 9 H); ^{13}C NMR 150.4, 124.1, 106.9, 86.3, 75.0, 41.6, 37.7, 32.2, 32.1, 26.4, 25.9, 23.9, 21.3, 21.2, 0.09; IR (KBr) 3402, 2934, 2171, 1446, 1248, 1019, 840 cm^{-1}.

General Procedure for Tandem 5-Exo-dig Cyclization/Claisen Rearrangement. A 0.2 – 0.3 M solution of the appropriate 4-alkyn-1-ol in anhydrous diphenyl ether under nitrogen was heated to the temperature indicated in Table 1. To this was then added a solution of MeLi in phenetole (~10 mol %) in a dropwise fashion and the resulting mixture was stirred until the reaction was judged complete either by TLC or GC. The rate studies were conducted by removing aliquots of the reaction mixtures at frequent intervals (every 30 min), and the samples were analyzed by a gas chromatograph equipped with a flame-ionization detector. For product

isolation, the following procedure was followed. Most of the solvent was first removed by Kugelrohr distillation under reduced pressure and the residue was subjected to purification by column chromatography on silica gel. Alternatively, the reaction mixture could be chromatographed directly on silica gel, the relatively non-polar solvent being the first fraction to elute from the column followed the reaction products.

1,2,3a,4,6,6a,7,8,9,10-Decahydro-3H-benzo[e]azulen-5-one (**8a**). ^{1}H NMR δ 3.43 (dd, *J*=4.4 Hz, 12.6 Hz, 1H), 2.90-3.10 (m, 1H), 2.60 (ddd, *J*=0.9 Hz, 2.0 Hz, 18.5 Hz, 1H), 2.24-2.64 (m, 4H), 2.18 (ddd, *J*=1.2 Hz, 3.6 Hz, 12.5 Hz, 1H), 1.70-2.05 (m, 1H), 1.65-1.85 (m, 5H), 1.05-1.55 (m, 6H); ^{13}C NMR δ 213.2, 136.4, 133.2, 50.1, 47.5, 41.4, 38.0, 35.6, 35.6, 33.7, 32.7, 27.9, 26.9, 24.9; IR (neat) 2927, 2852, 1706, 1258, 1034, 626 cm^{-1}. Mass spectroscopic molecular weight calculated for $C_{14}H_{20}O$ 204.1514, found 204.1514.

6-Methyl-1,2,3a,4,6,6a,7,8,9,10-decahydro-3H-benzo[e]azulen-5-one (**8d**). Major isomer: ^{1}H NMR δ 3.53 (dq, *J*=3.35 Hz, 6.72 Hz, 1H), 2.91-3.08 (m, 1H), 2.61 (dd, *J*=2.75 Hz, 18.8 Hz, 1H), 2.03-2.50 (m, 5H), 1.86-1.98 (m, 1H), 1.60-1.83 (m, 5H), 1.08-1.54 (m, 5H), 1.00 (d, *J*=6.74 Hz, 3H) ppm; ^{13}C NMR δ 213.8, 135.6, 134.5, 49.4. 48.7, 45.7, 38.4, 35.7, 34.3, 32.6, 30.3, 28.5. 27.2, 24.8, 13.6 ppm; IR (neat) 2931, 2853, 2251, 1705, 1447, 1378, 1187, 1162, 918, 845, 732 cm^{-1}. Mass spectroscopic molecular weight calculated for $C_{15}H_{22}O$ 218.1671, found 218.1670.

4,4-Dimethyl-1,2,3a,4,6,6a,7,8,9,10-decahydro-3H-benzo[e]azulen-5-one (**8e**). ^{1}H NMR δ 3.72 (dd, *J*=11.3 Hz, 5.34 Hz, 1H), 3.19-3.28 (m, 1H), 2.32-2.56 (m, 3H), 1.98-2.18 (m, 1H), 2.02 (dd, *J*=11.3 Hz, 3.66 Hz, 1H), 1.51-1.85 (m, 6H), 1.26-1.50 (m, 3H), 1.05-1.23 (m, 1H), 1.11 (dd, *J*=12.7 Hz, 3.56Hz, 1 H), 1.00 (s, 3H), 0.98 (s, 3H); ^{13}C NMR δ 217.9, 135.0, 132.0, 52.2, 47.0, 44.9, 41.8, 33.8, 33.6, 29.2, 27.0, 26.3, 26.0, 24.9, 18.5, 18.2 ppm. IR (KBr) 2929, 2853, 1699, 1446, 1258, 1241, 1019, 916, 733 cm $^{-1}$. Mass spectroscopic molecular weight calculated for $C_{16}H_{24}O$: 232.1827, found 232.1831.

(1S*, 2S*)-1-(1,4-Dioxaspiro[4.5]dec-7-en-7-yl)-2-(3-trimethylsilyl-2-propynyl)-cyclopentanol (**11**). To a –78°C solution of 674 mg (3.08 mmol) of 7-bromo-1,4-dioxa-spiro[4.5]dec-

7-ene[3] in 10 mL of diethyl ether under argon was added 5.00 mL of *t*-butyllithium in pentane (1.23 M, 6.16 mmol) dropwise. The resulting solution was allowed to stir at this temperature for 5 min. The cooling bath was then removed and the mixture was allowed to warm to 0 °C. After recooling to –78 °C, the cold mixture was rapidly transferred via cannula to a slurry of 758 mg (3.08 mmol) of anhydrous $CeCl_3$ in 7 mL of THF (this mixture had been allowed to stir at room temperature under argon for 1 hour prior to cooling) at –78 °C. After 1 h, 598 mg (3.08 mmol) of 2-(3-trimethylsilyl-2-propynyl)cyclopentanone in 7 mL of THF was added dropwise and the resulting mixture was stirred at –78 °C overnight. The reaction was quenched by the addition of water (1 mL). The mixture was then concentrated in vacuo, diluted with ether (40 mL) and water (30 mL), and the layers were separated. The aqueous layer was extracted with diethyl ether (3 x 40 mL) and the combined organic layers were dried over magnesium sulfate. Filtration followed by solvent removal yielded a yellow oil which was further purified by column chromatography over silica gel (10% ethyl acetate/CH_2Cl_2) to yield 465 mg (45 %) of the desired isomer as a viscous clear oil: ^{1}H NMR δ 5.76-5.81 (m, 1H), 3.98 (s, 4 H), 2.22-2.37 (m, 5 H), 1.86–2.10 (m, 2 H), 1.75–1.84 (m, 2 H), 1.58–1.72 (m, 6H), 1.23–1.3 (m, 1 H), 0.11 (s, 9 H); ^{13}C NMR δ 138.1, 119.8, 108.5, 106.6, 85.7, 83.8, 54.4 (two peaks), 44.7, 39.2, 35.4, 30.5, 29.1, 24.2, 21.1,18.7, 0.08. IR (neat) 3478, 2957, 2173, 1660, 1435, 1367, 1249, 1060, 842 cm^{-1}. Mass spectroscopic molecular weight calculated for $C_{19}H_{30}O_3Si$ 334.1964, found 334.1959.

Tandem 5-exo dig cyclization/Claisen rearrangement of 11. Following the general procedure outlined above, 140 mg (0.418 mmol) of 11 was dissolved in 1.7 mL of anhydrous diphenyl ether under nitrogen, and the resulting solution was heated to 185 °C. To this was then added 0.210 mL of MeLi in phenetol (0.192 M, 0.0403 mmol) in a dropwise fashion and the resulting mixture was allowed to stir at this temperature for 3 h. The solvents were then removed under reduced pressure by Kugelrohr distillation and the residue was dissolved in 7 mL of diethyl ether. A solution of 1M tetrabutylammonium fluoride (0.80 mL, 0.80 mmol) in THF was then added and the solution was stirred at room temperature for 15 min. The reaction mixture was then transferred to a separatory funnel and washed with 3 mL of H_2O. Drying ($MgSO_4$), filtration and solvent evaporation under reduced pressure, followed by purification by column chromatography on silica gel (10 % EtOAc in CH_2Cl_2) afforded 81.0 mg (74 %) of **12** as pale

[3] Swenton, J. S.; Shih, C. *J. Org. Chem.* **1982**, *47*, 2825.

yellow crystals: mp 73-76 °C, ^{1}H NMR δ 3.88-3.94 (m, 4 H), 3.37 (dd, *J*=12.5 Hz, 4.07 Hz, 1 H), 2.90–3.06 (m, 1 H), 2.56–2.63 (m, 1 H), 2.55 (dd, *J*=13.3 Hz, 2.5 Hz, 1 H), 2.30–2.41 (m, 4 H), 2.24 (dd, *J*=12.5 Hz, 4.1 Hz, 1 H), 2.09 (d, *J*=13.3 Hz, 1 H), 1.86–2.00 (m, 1 H), 1.58–1.85 (m, 4 H), 1.17–1.53 (m, 3 H); ^{13}C NMR δ 212.3, 140.1, 128.1, 109.6, 64.5, 64.3, 49.8, 46.9, 42.1, 40.1, 38.1, 35.5, 35.3, 33.0, 31.1, 24.9. IR (KBr) 2948, 1703, 1439, 1357, 1247, 1109, 918, 731 cm^{-1}. Mass spectroscopic molecular weight calculated for $C_{16}H_{22}O_3$ 262.1569, found 262.1574.

7-(3-Trimethylsilyl-2-propynyl)-1,4-dioxaspiro[4.5]decan-8-one (**13**). A solution of 1.00 g (6.40 mmol) of 1,4-cyclohexanedione monoethylene ketal in 10 mL of THF was added dropwise to a –78 °C solution of 7.80 mmol of sodium hexamethyldisilazide (3.90 mL, 2.0 M in THF) in 8.0 mL of THF. The resulting mixture was allowed to stir at this temperature for 30 min followed by rapid addition of 2.28 g (9.57 mmol) of trimethyl 3-iodo-1-propynylsilane.[4]. The mixture was then allowed to warm to 0 °C and water (5.0 mL) was added. Most of the solvent was removed under reduced pressure and 15 mL of diethyl ether was added. The layers were separated and the aqueous layer was extracted with diethyl ether (2 × 10 mL). The combined ethereal layers were dried over $MgSO_4$. Filtration and solvent evaporation under reduced pressure followed by purification by column chromatography (20 % EtOAc/hexanes) gave 1.28 g (75 %) of **13** as a pale yellow oil: ^{1}H NMR δ 3.98–4.05 (m, 4 H), 2.63–2.84 (m, 1 H), 2.54–2.64 (m, 2 H), 2.28–2.41 (m, 2 H), 2.22 (dd, *J*=17.3 Hz, 8.7 Hz, 1 H), 1.92–2.2 (m, 2 H), 1.74 (app. t, *J*=13.3 Hz, 1 H), 0.10 (s, 9 H); ^{13}C NMR δ 209.3, 107.3, 104.5, 86.3, 64.7, 64.6, 45.4, 39.3, 37.9, 34.5, 19.7, 0.1; IR (neat) 2959, 2896, 2176, 1716, 1438, 1366, 1250, 1123, 1052, 1003, 842, 760 cm^{-1}. Mass spectroscopic molecular weight calculated for $C_{14}H_{22}O_3Si$ 266.1338, found 266.1340.

(7S*, 8R*)-Cyclopent-1-enyl-7-(3-trimethylsilyl-2-propynyl)-1,4-dioxaspiro[4.5]decan-8-ol (**14**). To a –78°C solution of 553 mg (3.76 mmol) 1-bromocyclopentene[2] in 10 mL of diethyl ether at under argon was added 3.65 mL of *t*-butyllithium in pentane (2.06 M, 7.52 mmol) dropwise. The resulting solution was allowed to stir at this temperature for 5 min. The cooling bath was then removed and the mixture was allowed to warm to 0 °C. After recooling to –78 °C, the cold mixture was rapidly transferred via cannula to a slurry of 925 mg (3.76 mmol) of

anhydrous $CeCl_3$ in 9 mL of THF (this mixture had been allowed to stir at room temperature under argon for 1 hour prior to cooling) at –78 °C. After 1 h, 500 mg (1.88 mmol) of **13** in 10 mL of THF was added dropwise (60 min). The resulting mixture was stirred at –78 °C for 1 h and the reaction was then quenched by the addition of water (1 mL). The mixture was then concentrated in vacuo, diluted with ether (20 mL) and water (25 mL), and the layers were separated. The aqueous layer was extracted with diethyl ether (3 x 20 mL) and the combined organic layers were dried over magnesium sulfate. Filtration followed by solvent removal yielded a yellow oil which was further purified by column chromatography over silica gel (5% ethyl acetate/CH_2Cl_2) to yield 453 mg (72 %) of the desired product as white crystals: mp 90–92 °C; ^{1}H NMR δ 5.64–5.69 (m, 1 H), 3.80–4.00 (m, 4 H), 2.27–2.37 (m, 3 H), 2.19–2.26 (m, 1 H) 2.13–2.19 (m, 2H), 1.92–2.04 (m, 3 H), 1.81–1.91 (m, 2 H), 1.68–1.79 (m, 2 H), 1.45–1.62 (m, 1 H), 0.11 (s, 9 H); ^{13}C NMR δ 149.7, 124.8, 109.0, 105.8, 87.5, 74.4, 64.3, 64.2, 39.0, 35.0, 32.2, 32.1, 30.1, 23.9, 21.0, 0.01. 2.08–2.18 (m, 2 H), 2.00 (br s, 1 H), 1.82–1.92 (m, 2 H), 1.67–1.80 (m, 2 H), 1.56–1.65 (m 2 H), 1.45–1.54 (m, 3 H), 1.18–1.32 (m, 2 H), 0.12 (s, 9 H); 150.4, 124.1, 106.9, 86.3, 75.0, 41.6, 37.7, 32.2, 32.1, 26.4, 25.9, 23.9, 21.3, 21.2, 0.09; IR (KBr) 3479, 2956, 2172, 1662, 1447, 1367,1249, 1059, 841, 760 cm^{-1}.

Tandem 5-exo dig cyclization/Claisen rearrangement of 14. Following the general procedure outlined above, 70.0 mg (0.209 mmol) of **14** was dissolved in 1.0 mL of anhydrous diphenyl ether under nitrogen, and the resulting solution was heated to 185 °C. To this was then added 0.127 mL of MeLi in phenetol (0.165 M, 0.0209 mmol) in a dropwise fashion and the resulting mixture was allowed to stir at this temperature for 3 h. The solvents were then removed under reduced pressure by Kugelrohr distillation and the residue was dissolved in 5 mL of diethyl ether. A solution of 1M tetrabutylammonium fluoride (0.25 mL, 0.25 mmol) in THF was then added and the solution was stirred at room temperature for 10 min. The reaction mixture was then transferred to a separatory funnel and washed with 3 mL of H_2O. Drying ($MgSO_4$), filtration and solvent evaporation under reduced pressure, followed by purification by column chromatography on silica gel (10 % EtOAc in CH_2Cl_2) afforded 35.0 mg (64 %) of **15** as white crystals: mp 49-52 °C; ^{1}H NMR δ 3.85-3.95 (m, 4 H), 3.42 (dd, *J*=12.7 Hz, 4.70 Hz, 1 H), 2.92–3.09 (m, 1 H), 2.62–2.70 (m, 1 H), 2.60 (dd, *J*=18.5 Hz, 2.5 Hz, 1 H), 2.18–2.43

[4] Ovaska, T. V.; Roark, J. L.; Shoemaker, C. M. *Tetrahedron Lett.* **1998**, 39, 5705.

(overlapping patterns, 5 H), 2.13 (dd, *J*=12.7 Hz, 4.2 Hz, 1 H), 1.88–2.03 (m, 1 H), 1.65–1.78 (m, 3 H), 1.31–1.56 (overlaping patterns, 3 H), 1.15–1.28 (m, 1 H); ^{13}C NMR δ 212.4, 138.2, 130.8, 108.8, 64.4 (two overlapping signals), 50.0, 46.7, 43.0, 37.9, 37.4, 36.1, 35.4, 32.9, 29.8, 24.9; IR (KBr) 2946, 1705, 1448, 1356, 1232, 1118, 1073, 905, 800 cm^{-1}. Mass spectroscopic molecular weight calculated for $C_{16}H_{22}O_3$ 262.1569, found 262.1570.