Enantioselective Addition of 2-Hydroxy-2-Methyl-3-butyne, to Aldehydes: Preparation of 3-Hydroxy-1-Butynes

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Supplementary Material

General Procedures: All reactions were performed using oven dried glassware under an atmosphere of dry nitrogen. Toluene was distilled and dried before use (≤ 20 ppm H_2O as determined by Karl Fischer titration). Reagents were purchased from either Aldrich or Fluka chemical companies and used without prior purification except aldehydes which were distilled before use. $Zn(OTf)_2$ was purchased from Fluka chemical company (purity ≥ 98%). Chromatographic purification of products was accomplished using forced flow chromatography on Fluka Silica Gel 60 according to the method of Still.[1] NMR spectra were recorded on a Varian Mercury 300 operating at 300 MHz and 75 MHz for ^1H and ^{13}C, respectively, and referenced to the internal solvent signals. IR spectra were recorded on a Perkin Elmer Spectrum RX I FT-IR spectrometer as thin film unless otherwise noted. Optical rotations were measured on a JASCO DID-1000 digital polarimeter. Thin layer chromatography was performed using Merck Silica Gel 60 F_{254} TLC plates and visualized either with ultraviolet light or stained with CAM-Stain or $KMnO_4$-Stain. HPLC analysis were carried out on a Merck Hitachi D-7000 system. Combustion analysis was performed by the Mikroelementaranalytisches Laboratorium at the ETH, Zürich.

General procedure for the Nucleophilic Addition of 2-Methyl-3-butyn-2-ol to α-Branched-aldehydes (Entries 1–3, Table 1).[2] A 10 mL flask was charged with $Zn(OTf)_2$ (200 mg, 0.55 mmol, 1.1 eq) and (-)-*N*-Methylephedrine (108 mg, 0.60 mmol, 1.2 eq) and purged with nitrogen for 15 min. To the flask was added toluene (1.5 mL) and triethylamine (61 mg, 0.60 mmol, 1.2 eq). The resulting mixture was vigorously stirred at 23ºC for 2 h before the alkyne (50 mg, 0.60 mmol, 1.2 eq) was added by syringe in one portion. After 15 min of stirring the aldehyde (0.50 mmol, 1.0 eq) was added in one portion by syringe. The reaction was quenched by the addition of saturated aqueous NH_4Cl solution (3 mL). The reaction mixture was poured into a separatory funnel containing diethyl ether (10 mL). The layers were separated and the aqueous layer was extracted with diethyl ether (3 x 10

[1] W. C. Still, H. L. Ammon, P. DeShong, P. *J. Am. Chem. Soc.* **1995**, *117*, 5166.
[2] Frantz, D. E.; Fässler, R.; Carreira, E.M. *J. Am. Chem. Soc*. **2000**, *122*, 1806.

mL). The combined organic layers were washed with brine (10 mL), dried over anhydrous $MgSO_4$ and concentrated in vacuo.
Purification of the material by chromatography on silica gel using a 20 to 35% mixture of ethyl acetate / hexanes afforded the secondary propargylic alcohol.

Procedure for the Nucleophilic Addition of 2-Methyl-3-butyn-2-ol to α-Unbranched-aldehydes (Entries 4-6 and 10 in Table 1). A 10 mL flask was charged with $Zn(OTf)_2$ (300 mg, 0.83 mmol, 2.0 eq) and (-)-*N*-Methylephedrine (156 mg, 0.87 mmol, 2.1 eq) and purged with nitrogen for 15 min. To the flask was added toluene (0.7 mL) and triethylamine (88 mg, 0.87 mmol, 2.1 eq). The resulting mixture was vigorously stirred at 23ºC for 2 h before the alkyne (73 mg, 0.87 mmol, 2.1 eq) was added by syringe in one portion. After 15 min of stirring a solution of the aldehyde (0.41 mmol, 1.0 eq) in toluene (1 ml) was slowly added dropwise. The reaction was quenched by the addition of saturated aqueous NH_4Cl solution (3 mL). The reaction mixture was poured into a separatory funnel containing diethyl ether (10 mL). The layers were separated and the aqueous layer was extracted with diethyl ether (3 x 10 mL). The combined organic layers were washed with brine (10 mL), dried over anhydrous $MgSO_4$ and concentrated in vacuo.
Purification of the material by chromatography on silica gel using a 10 to 30% mixture of ethyl acetate / hexanes afforded the secondary propargylic alcohol.

Procedure for the Nucleophilic Addition of 2-Methyl-3-butyn-2-ol to aromatic aldehydes (Entries 7, 8, and 9 in Table 1). A 20 mL flask was charged with $Zn(OTf)_2$ (800 mg, 2.2 mmol, 3.0 eq) and (-)-*N*-Methylephedrine (408 mg, 2.3 mmol, 3.1 eq) and purged with nitrogen for 15 min. To the flask was added toluene (6 mL) and triethylamine (230 mg, 2.3 mmol, 3.1 eq). The resulting mixture was vigorously stirred at 23ºC for 2 h before the alkyne (192 mg, 2.3 mmol, 3.1 eq) was added by syringe in one portion. After 15 min of stirring a solution of the aldehyde (0.74 mmol, 1.0 eq) was added in one portion. After stirring for 8 h at 23°C the reaction was quenched by the addition of saturated aqueous NH_4Cl solution (5 mL). The reaction mixture was poured into a separatory funnel containing diethyl ether (15 mL). The layers were separated and the aqueous layer was extracted with diethyl ether (3 x 10 mL). The combined organic layers were washed with brine (15 mL), dried over anhydrous $MgSO_4$ and concentrated in vacuo.
Purification of the material by chromatography on silica gel using a 15 to 35% mixture of ethyl acetate / hexanes afforded the secondary propargylic alcohol.

2a: (*S*)-2,6-Dimethyl-hept-3-yne-2,5-diol:[2] Isolated in 97% yield and 98% ee as determined by HPLC analysis of the corresponding 3,5-dinitrobenzoate ester (Chiralcel OD-H, 10% *i*-PrOH in hexane, 254 nm), t_r 43.4 (minor), 53.9 (major); colourless oil; $[\alpha]_D^{23}$ –1.5° (c = 1.0, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.18 (d, 1H, *J* = 6.7 Hz), 2.85 (bs, 2H), 1.92-1.80 (m, 1H), 1.52 (s, 6H), 0.99 (d, 3H, *J* = 6.7 Hz), 0.97 (d, 3H, *J* = 6.7 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 90.4 (C), 81.8 (C), 67.7 (CH), 65.1 (C), 34.4 (CH), 31.4 (CH_3), 18.2 (CH_3), 17.5 (CH_3); FTIR ($CHCl_3$) 3338, 2980, 2932, 2874, 2342, 1654, 1459, 1365, 1236, 1166, 1021, 952, 861 cm^{-1}; Anal. Calcd. For $C_9H_{16}O_2$: C, 69.19%; H, 10.32%. Found: C, 69.24%; H, 10.21%.

2b: (*S*)-1-Cyclohexyl-4-methyl-pent-2-yne-1,4-diol: Isolated in 89% yield and 99% ee as determined by HPLC analysis of the corresponding 3,5-dinitrobenzoate ester (Chiralcel OD-H, 15% *i*-PrOH in hexane, 254 nm), t_r 14.1 (minor); 16.3 (major); white solid, mp 74°C; $[\alpha]_D^{23}$ –5.7° (c = 0.95, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.14 (d, 1H, *J* = 6.0 Hz), 2.45 (bs, 2H), 1.91-1.62 (m, 5H), 1.51 (s, 6H), 1.45 (m, 1H) 1.33-0.98 (m, 5H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 90.4 (C), 82.1(C), 66.9 (CH), 65.1 (C), 44.0 (CH), 31.4 (CH_3), 28.7 (CH_2), 28.1 (CH_2), 26.4 (CH_2), 25.9 (CH_2); FTIR

[2] Frantz, D. E.; Fässler, R.; Carreira, E.M. *J. Am. Chem. Soc*. **2000**, *122*, 1806.

($CHCl_3$) 3608, 3400, 3021, 2930, 2856, 2400. 1521, 1451, 1225, 1214, 1207, 930 cm^{-1}; Anal. Calcd. For $C_{12}H_{20}O_2$: C, 73.43%; H, 10.27%. Found: C, 73.50%; H, 10.14%.

2c: (*S*)-2,6,6-Trimethyl-hept-3-yne-2,5-diol: Isolated in 82% yield and 98% ee as determined by HPLC analysis of the corresponding 3,5-dinitrobenzoate ester (Chiralcel OD-H, 10% *i*-PrOH in hexane, 254 nm), t_r 26.1 (minor), 33.3 (major); white solid, mp 74°C; $[\alpha]_D^{23}$ –1.3° (c = 0.80, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.02 (s, 1H), 2.18 (bs, 2H), 1.51 (s, 6H), 0.98 (s, 9H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 90.5 (C), 81.8 (C), 71.2 (CH), 65.2 (C), 35.8 (C), 31.4 (CH_3), 25.3 (CH_3); FTIR ($CHCl_3$) 3601, 3400, 3019, 2968, 1366, 1223, 1208, 1164, 1002 cm^{-1}; Anal. Calcd. For $C_{10}H_{18}O_2$: C, 70.55%; H, 10.66 %. Found: C, 70.56%; H, 10.73%.

2d: (*S*)-2-Methyl-dec-3-yne-2,5-diol:[3] Isolated in 81% yield and 98% ee as determined by HPLC analysis of the corresponding 3,5-dinitrobenzoate ester (Chiralcel OD-H, 10% *i*-PrOH in hexane, 254 nm), t_r 20.5 (minor), 24.0 (major); colourless oil; $[\alpha]_D^{23}$ –0.3° (c = 3.20, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.38 (t, 1H, *J* = 6.6 Hz), 2.21 (bs, 2H), 1.68 (m, 2H), 1.51 (s, 6H), 1.42 (m, 2H), 1.36-1.25 (4H, m), 0.89 (t, 3H, *J* = 6.6 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 89.5 (C), 83.2 (C), 65.1 (C), 62.4 (CH), 37.7 (CH_2), 31.4 (CH_3), 31.4 (CH_2), 24.8 (CH_2), 22.5 (CH_2), 14.0 (CH_3); FTIR ($CHCl_3$) 3600, 3400, 2932, 2862, 1458, 1366. 1329, 1219, 1164, 943 cm^{-1}; Anal. Calcd. For $C_{11}H_{20}O_2$: C, 71.70%; H, 10.94 %. Found: C, 71.75%; H, 10.64%.

2e: (*S*)-2-Methyl-oct-3-yne-2,5-diol: Isolated in 77% yield and 99% ee as determined by HPLC analysis of the corresponding 3,5-dinitrobenzoate ester (Chiralcel OD-H, 10% *i*-PrOH in hexane, 254 nm), t_r 15.4 (minor), 33.1 (major); colourless oil; $[\alpha]_D^{24}$ -5.45° (c= 2.0, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.36 (t, 1H, *J* = 6.3 Hz), 3.28 (bs, 2H), 1.65 (m, 2H), 1.49 (s, 6H), 1.45 (m, 2H), 0.92 (t, 3H, *J* = 7.0 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 89.5 (C), 83.2 (C), 65.0 (C), 62.0 (CH), 39.7 (CH_2), 31.3 (CH_3), 18.5 (CH_2), 13.7 (CH_3); FTIR ($CHCl_3$) 3600, 3401, 2963, 2935, 2875, 1458, 1366. 1329, 1233, 1222, 1218, 1164, 1117, 1019, 934 cm^{-1}; Anal. Calcd. For $C_9H_{16}O_2$: C, 69.19%; H, 10.32 %. Found: C, 68.91%; H, 10.44%.

2f: (*S*)- 4-Methyl-1-phenyl-pent-2-yne-1,4-diol:[3] Isolated in 96% yield and 98% ee as determined by HPLC analysis (Chiralcel OD-H, 3% *i*-PrOH / hexane, 254 nm), t_r 21.8 (major), 27.5 (minor); white solid, mp 66°C; $[\alpha]_D^{23}$ –15.2° (c= 1.57, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.52 (m, 2H), 7.34 (m, 3H), 5.46 (s,1H), 2.22 (bs, 2H), 1.54 (s, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 140.5 (C), 128.6 (CH), 128.4 (CH), 126.7 (CH) 91.4 (C), 82.8 (C), 65.3(C), 64.5 (CH), 31.3 (CH_3); FTIR ($CHCl_3$) 3675, 3594, 3383, 3066, 3031, 3013, 2986, 2934, 1603, 1493, 1455, 1366, 1329, 1232, 1212, 1166, 1058, 984, 945, 863 cm^{-1}; Anal. Calcd. For $C_{12}H_{14}O_2$: C, 75.76%; H, 7.42 %. Found: C, 75.57%; H, 7.53%.

2g: (*S*)-2-Methyl-7-phenyl-hept-6-en-3-yne-2,5-diol: Isolated in 99% yield and 88% ee as determined by HPLC analysis (Chiralcel OD-H, 2-7% *i*-PrOH in hexane, 254 nm), t_r 35.9 (major), 39.8 (minor); pale yellow solid, mp 80°C; $[\alpha]_D^{23}$ –1.3° (c = 0.77, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.41 (m, 2H), 7.32 (m, 3H), 6.73 (d, 1H, *J* = 15.6 Hz), 6.28 (dd, 1H, J_1 = 15.6 Hz and J_2 = 6.1 Hz), 5.07 (d, 1H, *J* = 6.2 Hz), 2.67 (bs, 2H), 1.55 (s, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 136.0 (C), 132.0 (CH), 128.7 (CH), 128.2 (CH), 128.0 (CH), 126.8 (CH), 91.1 (C), 81.0 (C), 65.3 (C), 62.9 (CH), 31.4 (CH_3); FTIR ($CHCl_3$) 3596, 3400, 3013, 1710, 1366, 1222, 1215, 1210, 1165, 964 cm^{-1}; Anal. Calcd. For $C_{14}H_{16}O_2$: C, 77.75%; H, 7.46 %. Found: C, 77.81%; H, 7.48%.

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[3] a) Saimoto, H.; Yasui, M.; Ohrai, S.; Oikawa, H.; Yokoyama, K.; Shigemasa, Y. *Bull. Chem. Soc. Jpn*., **1999**, *72*, 279.
b) Parker, W.; Raphael, R.A.; Wilkinson, D.I.; *J. Chem. Soc*., **1958**, 3871.

2h: (*S*)-2-Methyl-7-(triisopropyl-silanyloxy)-hept-3-yne-2,5-diol: Isolated in 82% yield and 97% ee as determined by ^{19}F NMR of the corresponding Mosher esters[4] (δ –71.40 (minor), -71.72 (major)); colourless oil; $[\alpha]_D^{26}$ –11.4° (c = 0.98, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 4.67 (m, 1H), 4.12 (m, 1H), 3.90 (m, 1H), 3.72 (sb, 1H), 2.14 (sb, 1H), 2.00 (m, 1H), 1.88 (m, 1H), 1.51 (s, 6H), 1.10-0.97 (m, 21H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 89.5 (C), 82.5 (C), 65.1 (C), 62.1 (CH), 61.8 (CH_2), 38.5 (CH_2), 31.4 (CH_3), 18.0 (CH_3), 11.7 (CH); FTIR ($CHCl_3$) 3599, 3446, 3020, 2946, 2868, 2385, 1731, 1631, 1460, 1384, 1238, 1210, 1095, 1058, 921, 882 cm^{-1}; Anal. Calcd. For $C_{17}H_{34}O_3Si$: C, 64.92%; H, 10.89 %. Found: C, 64.74%; H, 10.70%.

Procedure for the "*in situ*" protection of the generated secondary propargylic alcohols, (Entries 1-3, Table 2). A 10 mL flask was charged with $Zn(OTf)_2$ (200 mg, 0.55 mmol, 1.1 eq) and (-)-*N*-Methylephedrine (108 mg, 0.60 mmol, 1.2 eq) and purged with nitrogen for 15 min. To the flask was added toluene (1.5 mL) and triethylamine (61 mg, 0.60 mmol, 1.2 eq). The resulting mixture was vigorously stirred at 23ºC for 2 h before the alkyne (50 mg, 0.60 mmol, 1.2 eq) was added by syringe in one portion. After 15 min of stirring the aldehyde (0.50 mmol, 1.0 eq) was added in one portion by syringe. After the addition is completed, (see table 1 for times) CH_2Cl_2 (1.5 ml) was added and the reaction was cooled to 0°C. Then, benzoyl chloride (194 mg, 1.38 mmol, 2.75 eq), triethylamine (140 mg, 1.38 mmol, 2.75 eq), and DMAP (0.3 eq.) were sequentially added at 0°C. The reaction was quenched by the addition of saturated aqueous NH_4Cl solution (4 mL). The reaction mixture was poured into a separatory funnel containing CH_2Cl_2 (10 mL). The layers were separated and the aqueous layer was extracted with CH_2Cl_2 (3 x 10 mL). The combined organic layers were washed with brine (10 mL), dried over anhydrous $MgSO_4$ and concentrated in vacuo.
Purification of the material by chromatography on silica gel using a 5 to 20% mixture of ethyl acetate / hexanes afforded the secondary benzoylated propargylic alcohol.

Procedure for the silylation of the generated secondary propargylic alcohols, (Entries 4-8, Table 2). The crude reaction mixture obtained from the nucleophilic addition without further purification was dissolved in CH_2Cl_2 (4 ml) and 2,6-lutidine (102 mg, 0.95 mmol, 1.3 eq) and TIPSOTf (291 mg, 0.95 mmol, 1.3 eq) were sequentially added at 0°C. After stirring for 10 min the reaction was quenched by addition of saturated aqueous NH_4Cl solution (4 mL). The reaction mixture was poured in a separatory funnel containing CH_2Cl_2 (10 mL). The layers were separated and the aqueous layer was extracted with CH_2Cl_2 (3 x 10 mL). The organic layer were washed with brine (10 ml), dried over anhydrous $MgSO_4$ and concentrated in vacuo.
Purification of the material by chromatography on silica gel using a 5 to 15% mixture of ethyl acetate / hexanes afforded the siloxy propargylic alcohol

4a: (*S*)-Benzoic acid 4-hydroxy-1-isopropyl-4-methyl-pent-2-ynyl ester: Isolated in 91% yield; colourless oil; $[\alpha]_D^{24}$ –9.5° (c = 11.6, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 8.05 (d, 2H, *J* = 10.5 Hz), 7.55 (m, 1H), 7.44 (m, 2H), 5.44 (d, 1H, *J* = 8.1 Hz), 2.80 (bs, 1H), 2.10 (m, 1H), 1.51 (s, 6H), 1.07 (m, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.2 (C), 132.7 (CH), 129.7 (C), 129.3 (CH), 128.0 (CH), 90.7 (C), 77.6 (C), 69.1 (CH), 64.5 (C), 32.7 (CH), 30.9 (CH_3), 17.8 (CH_3), 17.3 (CH_3); FTIR ($CHCl_3$) 3597, 3028, 2973, 2933, 2876, 1718, 1602, 1452, 1367, 1336, 1316, 1267, 1212, 1166, 1112, 1070, 1026, 975, 914 cm^{-1}; Anal. Calcd. For $C_{16}H_{20}O_3$: C, 73.82%; H, 7.74%. Found: C, 73.84%; H, 7.76%.

[4] Dale, J.A.; Dull, D. L.; Mosher, H.S. *J. Org. Chem*. **1969**, *34*, 2543.

4b: (*S*)-Benzoic acid 1-cyclohexyl-4-hydroxy-4-methyl-pent-2-ynyl ester: Isolated in 81% yield; colourless oil; $[\alpha]_D^{25}$ –19.1° (c= 0.90, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.05 (d, 2H, *J* = 10.5 Hz), 7.53 (m, 1H), 7.42 (m, 2H), 5.44 (d, 1H, *J* = 8.7 Hz), 2.80 (bs, 1H), 1.78 (m, 6H), 1.51 (s, 6H), 1.24 (m, 5H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.3 (C), 132.7 (CH), 129.5 (C), 129.4 (CH), 128.0 (CH), 90.7 (C), 77.9 (C), 68.4 (CH), 64.5 (C), 41.5 (CH), 30.9 (CH_3), 28.2 (CH_2), 27.9 (CH_2), 25.8 (CH_2), 25.3 (CH_2); FTIR ($CHCl_3$) 3601, 3019, 2933, 2857, 2400, 1717, 1521, 1452, 1316, 1269, 1212, 1111, 1069, 1026, 971, 929 cm^{-1}; Anal. Calcd. For $C_{19}H_{24}O_3$: C, 75.97%; H, 8.05%. Found: C, 75.79%; H, 8.04%.

4c: (*S*)-Benzoic acid 1-*tert*-butyl-4-hydroxy-4-methyl-pent-2-ynyl ester: Isolated in 76% yield; colourless oil; $[\alpha]_D^{26}$ – 41.63° (c = 2.4, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.06 (d, 2H, *J* = 8.7 Hz), 7.57 (m, 1H), 7.44 (m, 2H), 5.33 (s, 1H), 2.36 (bs, 1H), 1.50 (s, 6H), 1.09 (s, 9H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.7 (C), 133.1 (CH), 130.1(C), 129.8 (CH), 128.4 (CH), 90.8 (C), 78.2 (C), 72.4 (CH), 65.1 (C), 35.5 (C), 31.3 (CH_3), 25.7 (CH_3); FTIR ($CHCl_3$) 3597, 2974, 1718, 1452, 1367, 1316, 1270, 1220, 1211, 1112, 1070, 1025, 959 cm^{-1}; Anal. Calcd. For $C_{17}H_{22}O_3$: C, 74.42%; H, 8.08 %. Found: C, 74.14%; H, 7.83%.

4d: (*S*)-Benzoic acid 4-hydroxy-4-methyl-1-pentyl-pent-2-ynyl ester: Isolated in 78% yield; colourless oil; $[\alpha]_D^{24}$ –19.9° (c = 2.35, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.06 (d, 2H, *J* = 8.7 Hz), 7.57 (m, 1H), 7.44 (m, 2H), 5.62 (t, 1H, *J* = 6.6 Hz), 2.27 (bs, 1H),1.88 (m, 2H), 1.51 (s, 6H), 1.49 (m, 2H), 1.32 (m, 4H), 0.90 (m, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.6 (C), 133.1 (CH), 130.1(C), 129.8 (CH), 128.4 (CH), 90.2 (C), 79.6 (C), 65.1 (C), 64.6 (CH), 34.9 (CH_2), 31.3 (CH_3), 31.3 (CH_2), 24.7 (CH_2), 22.5 (CH_2), 14.0 (CH_3); FTIR ($CHCl_3$) 3596, 2933, 1717, 1452, 1316, 1271, 1211, 1176, 1111, 1070, 1026. 945 cm^{-1}; Anal. Calcd. For $C_{18}H_{24}O_3$: C, 74.97%; H, 8.39 %. Found: C, 74.98%; H, 8.40%.

4e: (*S*)-Benzoic acid 4-hydroxy-4-methyl-1-propyl-pent-2-ynyl ester: Isolated in 77%; colourless oil; $[\alpha]_D^{26}$ –27.4° (c = 1.05, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.06 (d, 2H *J* = 8.4 Hz), 7.56 (m, 1H), 7.44 (m, 2H), 5.63 (t, 1H, *J* = 6.6 Hz), 2.35 (bs, 1H),1.86 (m, 2H), 1.52 (m, 2H), 1.51 (s, 6H), 0.97 (t, 3H, *J* = 7.7 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.6 (C), 133.1 (CH), 130.4 (C), 129.8 (CH), 128.4 (CH), 90.2 (C), 79.6 (C), 65.1 (C), 64.4 (CH), 37.0 (CH_2), 31.3 (CH_3), 18.4 (CH_2), 13.7 (CH_3); FTIR ($CHCl_3$) 3597, 2964, 2936, 2876, 1717, 1602, 1452, 1366, 1317, 1274, 1166, 1110, 1070, 1026, 992, 947 cm^{-1}; Anal. Calcd. For $C_{16}H_{20}O_3$: C, 73.82%; H, 7.74%. Found: C, 73.95%; H, 7.82%.

4f: (*S*)-Benzoic acid 4-hydroxy-4-methyl-1-[2-(triisopropyl-silanyloxy)-ethyl]-pent-2-ynyl ester: Isolated in 82% yield; colourless oil; $[\alpha]_D^{26}$ –17.5° (c = 1.27 , $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.05 (m, 2H), 7.54 (m, 1H), 7.43 (m, 2H), 5.80 (t, 1H, *J* = 7.2 Hz), 3.89 (t, 2H, *J* = 6Hz), 2.80 (bs, 1H), 2.14 (m, 2H), 1.49 (s, 6H), 1.06 (m, 21H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.5 (C), 133.1 (CH), 130.0 (C), 129.8 (CH), 128.4 (CH), 90.4 (C), 79.5 (C), 65.1 (C), 62.0 (CH), 59.2 (CH_2), 38.1 (CH_2), 31.3 (CH_3), 17.1 (CH_3), 11.9 (CH); FTIR ($CHCl_3$) 3598, 3019, 2945, 2868, 1722, 1602, 1459, 1316, 1270, 1221, 1108, 1070, 1026, 949, 883 cm^{-1}; Anal. Calcd. For $C_{24}H_{38}O_4Si$: C, 68.86%; H, 9.15%. Found: C, 68.95%; H, 9.16%.

5a: (*R*)-2-Methyl-5-phenyl-5-(triisopropyl-silanyloxy)-pent-3-yn-2-ol: Isolated in 96% yield; colourless oil; $[\alpha]_D^{28}$ –14.5° (c = 1.00 $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.50 (d, 2H, *J* = 7.2 Hz), 7.31 (m, 3H), 5.60 (s, 1H), 2.05 (bs, 1H), 1.50 (s, 6H), 1.21 (m, 3H), 1.10 (m, 18H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 142.1(C), 128.4 (CH), 127.5 (CH), 126.0 (CH), 89.6 (C), 83.5 (C), 65.3 (C), 64.3 (CH), 31.2 (CH_3), 18.1 (CH_3), 12.3 (CH); FTIR ($CHCl_3$) 3668, 3599, 3429, 2945, 2892, 2867, 2360, 1731, 1602, 1493, 1464, 1384, 1366, 1328, 1246, 1164, 1095, 1065, 1040, 997, 918, 883 cm^{-1}; Anal. Calcd. For $C_{21}H_{34}O_2Si$: C, 72.78%; H, 9.89 %. Found: C, 72.93%; H, 9.78%.

5b: (*S*)-2-Methyl-5-(triisopropyl-silanyloxy)-7-phenyl-hept-6-en-3-yn-2-ol: Isolated in 92% yield; colourless oil; $[\alpha]_D^{26}$ –3.5° (c = 1.50, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.42-7.23 (m, 5H), 6.79 (d, 1H, *J* = 15.8 Hz), 6.25 (dd, 1H, J_1 = 15.7 Hz and J_2 = 5.3 Hz), 5.17 (d, 1H, *J* = 5.2 Hz), 2.04 (bs, 1H), 1.53 (s, 6H), 1.23-1.06 (m, 21H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 136.6 (C),129.9 (CH), 129.4 (CH), 128.6 (CH), 127.8 (CH), 126.7 (CH), 89.8 (C), 82.1 (C), 65.2 (C), 63.3 (CH), 31.3 (CH_3), 18.0 (CH_3),12.3 (CH); FTIR ($CHCl_3$) 3666, 3598, 3155, 2946, 2893, 2868, 2359, 2254, 1794, 1647, 1600, 1464, 1383, 1366, 1328, 1165, 1112, 1064, 964, 913 cm^{-1}; Anal. Calcd. For $C_{23}H_{37}O_2Si$: C, 73.94%; H, 9.98%. Found: C, 73.98%; H, 9.93%.

Fragmentation of 2j: (*S*)-2,6-Dimethyl-5-(triisopropyl-silanoxy)-hept-3-yn-2-ol. Isolated in 93% yield as a colourless oil; $[\alpha]_D^{23}$ –18.5° (c = 0.96, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.30 (d, 1H, *J* = 5.4), 1.95-1.79 (m, 2H), 1.50 (s, 6H), 1.10-1.05 (m, 21H), 0.98 (d, 3H, *J* = 6.6), 0.94 (d, 3H, *J* = 6.9); ^{13}C NMR (75 MHz, $CDCl_3$) δ 89.1 (C), 82.6 (C), 68.2 (CH), 65.2 (C), 35.5 (CH), 31.4 (CH_3), 31.3 (CH_3), 18.1 (CH_3), 17.7 (CH_3), 12.3 (CH); FTIR ($CHCl_3$) 3672, 3601, 2945, 2893, 2867, 1602, 1464, 1384, 1366, 1328, 1237, 1220, 1211, 1163, 1101, 1066, 1014 cm^{-1}; Anal. Calcd. For $C_{18}H_{36}O_2Si$: C, 69.17%; H, 11.61%. Found: C 69.21%; H, 11.50%.

General procedure for the pyrolysis of aliphatic alkynes (Entries 1–6, and 8, Table 3). A 25 mL flask was charged with ground potassium carbonate (531 mg, 3.84 mmol) and 18-crown-6 (203 mg, 0.77 mmol) and then purged with nitrogen. To the flask was added the alkyne (1.00 g, 3.84 mmol) in toluene (8 mL + 2 mL wash) and the suspension was heated to 120°C. The mixture was vigorously stirred under a stream of nitrogen until completion. Water (20 mL) was added and the mixture poured into a separatory funnel containing ethyl acetate (10 mL). The layers were seperated and the aqueous layer was extracted with ethyl acetate (2 x 10 mL). The combined organic layers were dried over Na_2SO_4 and concentrated *in vacuo*.
Purification of the material by column chromatography on silica gel using a 10% mixture of ethyl acetate / hexanes afforded the terminal alkyne.

General procedure for the pyrolysis of aromatic alkynes (Entries 7-8, Table 3). A 10 mL flask was charged with ground potassium carbonate (120 mg, 0.868 mmol) and 18-crown-6 (92 mg, 0.35 mmol) and then purged with nitrogen. To the flask was added the alkyne (300 mg, 0.87 mmol) in toluene (1.2 mL + 1 mL wash) and the suspension was heated to 120°C. The mixture was vigorously stirred under a stream of nitrogen until completion. Water (5 mL) was added and the mixture poured into a separatory funnel containing ethyl acetate (5 mL). The layers were seperated and the aqueous layer was extracted with ethyl acetate (2 x 5 mL). The combined organic layers were dried over Na_2SO_4 and concentrated *in vacuo*.
Purification of the material by column chromatography on silica gel using a 1% mixture of ethyl acetate / hexanes afforded the terminal alkyne.

6a: (*S*)-benzoic acid 1-isopropyl-prop-2-ynyl ester: [4] Isolated in 91% yield as a colourless oil; $[\alpha]_D^{26}$ –35.7° (c = 1.55, $CHCl_3$); ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.10-8.06 (m, 2H), 7.61-7.55 (m, 1H), 7.48-7.43 (m, 2H), 5.45 (dd, 1H, *J* = 5.6, 2.1), 2.47 (d, 1H, *J* = 2.1), 2.22-2.11 (m, 1H), 1.13 (d, 3H, *J* = 6.6), 1.10 (d, 3H, *J* = 6.9); ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.5 (C), 133.2 (CH), 129.9 (C), 129.8 (CH), 128.4 (CH), 79.9 (C), 74.2 (CH), 69.2 (CH), 32.5 (CH), 18.1 (CH_3), 17.6 (CH_3); FTIR ($CHCl_3$) 3307, 3065, 3030, 3013, 2971, 2943, 2877, 2124, 1721, 1602, 1585, 1492, 1470, 1452,

[4] Trahanovsky, W. S.; Eweis, S. L. *J. Am. Chem. Soc.*, **1975**, 3773.

1390, 1371, 1337, 1316, 1265, 1178, 1110, 1070, 1026 cm^{-1}; Anal. Calcd. For $C_{13}H_{14}O_2$: C, 77.20%; H, 6.98%. Found: C 77.23%; H, 7.08%.

6b: (*S*)-benzoic acid 1-cyclohexyl-prop-2-ynyl ester: [5] Isolated in 90% yield as a colourless oil; $[\alpha]_D^{26}$ –10.0° (c = 0.88, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 8.10-8.06 (m, 2H), 7.60-7.54 (m, 1H), 7.48-7.43 (m, 2H), 5.45 (dd, 1H, *J* = 5.4, 2.1), 2.48 (d, 1H, *J* = 2.1), 1.98-1.68 (m, 6H), 1.33-1.19 (m, 5H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.6 (C), 133.2 (CH), 129.9 (C), 129.8 (CH), 128.4 (CH), 80.3 (C), 74.3 (CH), 68.5 (CH), 41.9 (CH), 28.5 (CH_2), 28.2 (CH_2), 26.2 (CH_2), 25.8 (CH_2), 25.7 (CH_2); FTIR ($CHCl_3$) 3307, 2903, 2857, 1720, 1602, 1452, 1316, 1265, 1222, 1210, 1178, 1110, 1070, 1026 cm^{-1}; Anal. Calcd. For $C_{16}H_{18}O_2$: C, 79.31%; H, 7.49%. Found: C 79.37%; H, 7.44%.

6c: (*S*)-benzoic acid 1-*tert*-butyl-prop-2-ynyl ester: Isolated in 81% yield as a colourless oil; $[\alpha]_D^{25}$ –51.9° (c = 1.03, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 8.10-8.07 (m, 2H), 7.61-7.55 (m, 1H), 7.49-7.43 (m, 2H), 5.33 (dd, 1H, *J* = 2.4), 2.45 (d, 1H, *J* = 2.4), 1.12 (s, 9H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.6 (C), 133.2 (CH), 130.0 (C), 129.8 (CH), 128.5 (CH), 79.9 (C), 74.2 (CH), 72.2 (CH), 35.3 (C), 25.6 (CH_3); FTIR ($CHCl_3$) 3307, 3030, 2974, 2873, 1720, 1602, 1586, 1479, 1465, 1452, 1398, 1368, 1339, 1316, 1269, 1193, 1178, 1110, 1070, 1048, 1026 cm^{-1}; Anal. Calcd. For $C_{14}H_{16}O_2$: C, 77.75%; H, 7.46%. Found: C 77.83%; H, 7.46%.

6d: (*S*)-benzoic acid 1-pentyl-prop-2-ynyl ester: Isolated in 91% yield as a colourless oil; $[\alpha]_D^{24}$ –37.6° (c = 1.01, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 8.10-8.06 (m, 2H), 7.60-7.54 (m, 1H), 7.48-7.42 (m, 2H), 5.60 (td, 1H, *J* = 6.9, 2.4), 2.49 (d, 1H, *J* = 2.4), 1.96-1.88 (m, 2H), 1.59-1.49 (m, 2H), 1.40-1.32 (m, 4H), 0.93-0.88 (m, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.5 (C), 133.2 (CH), 129.9 (C), 129.8 (CH), 128.4 (CH), 81.4 (C), 73.6 (CH), 64.4 (CH), 34.7 (CH_2), 31.3 (CH_2), 24.7 (CH_2), 22.5 (CH_2), 14.0 (CH_3); FTIR ($CHCl_3$) 3307, 3031, 2954, 2933, 2863, 1719, 1602, 1492, 1452, 1316, 1270, 1210, 1178, 1109, 1070, 1026 cm^{-1}; Anal. Calcd. For $C_{15}H_{18}O_2$: C, 78.23%; H, 7.88%. Found: C 78.30%; H, 8.01%.

6e: (*S*)-benzoic acid 1-propyl-prop-2-ynyl ester:[1] Isolated in 89% yield as a colourless oil; $[\alpha]_D^{23}$ –34.8° (c = 0.58, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 8.09-8.06 (m, 2H), 7.60-7.54 (m, 1H), 7.48-7.42 (m, 2H), 5.61 (td, 1H, *J* = 6.8, 2.4), 2.49 (d, 1H, *J* = 2.4), 1.96-1.87 (m, 2H), 1.64-1.51 (m, 2H), 0.99 (t, 3H, *J* = 7.5); ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.5 (C), 133.2 (CH), 129.9 (C), 129.8 (CH), 128.4 (CH), 81.3 (C), 73.6 (CH), 64.2 (CH), 36.8 (CH_2), 18.3 (CH_2), 13.7 (CH_3); FTIR ($CHCl_3$) 3308, 3033, 2964, 2937, 2876, 1720, 1602, 1585, 1492, 1452, 1346, 1316, 1273, 1211, 1178, 1109, 1070, 1026 cm^{-1}; Anal. Calcd. For $C_{13}H_{14}O_2$: C, 77.20%; H, 6.98%. Found: C 77.15%; H, 6.98%.

6f: (*S*)-benzoic acid 1-(triisopropyl-silanyloxymethyl)-prop-2-ynyl ester: Isolated in 88% yield as a colourless oil; $[\alpha]_D^{22}$ –29.7° (c = 1.03, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 8.09-8.05 (m, 2H), 7.60-7.54 (m, 1H), 7.47-7.41 (m, 2H), 5.78 (td, 1H, *J* = 6.9, 2.1), 3.96-3.88 (m, 2H), 2.50 (d, 1H, *J* = 2.1), 2.29-2.08 (m, 2H), 1.15-0.99 (m, 21H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 165.4 (C), 133.2 (CH), 129.9 (C), 129.8 (CH), 128.4 (CH), 81.3 (C), 73.8 (CH), 61.7 (CH), 59.0 (CH_2), 38.0 (CH_2), 18.0 (CH), 11.9 (CH_3); FTIR ($CHCl_3$) 3308, 3032, 2945, 2867, 2125, 1723, 1602, 1585, 1493, 1464, 1452, 1384, 1345, 1316, 1304, 1270, 1217, 1178, 1106, 1070, 1026, 1014 cm^{-1}; Anal. Calcd. For $C_{21}H_{32}O_3Si$: C, 69.95%; H, 8.95%. Found: C 70.13%; H, 8.85%.

6g: (*R*)-Triisopropyl-(1-phenyl-prop-2-ynyloxy)-silane: Isolated in 83% yield as a colourless oil; $[\alpha]_D^{24}$ –5.7° (c = 0.71, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.53-7.49 (m, 2H), 7.40-7.26 (m, 3H), 5.57 (d, 1H, *J* = 2.1), 2.54 (d, 1H, *J* = 2.1), 1.27-1.07 (m, 21H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 141.9

[5] Wolf, Still. *Arzneim forsch.*, **1957**, *7*, 85, 87, 90.

(C), 128.4 (CH), 127.8 (CH), 125.9 (CH), 85.2 (C), 73.4 (CH), 64.7 (CH), 18.0 (CH), 12.3 (CH_3); FTIR ($CHCl_3$) 3307, 2946, 2867, 1693, 1658, 1589, 1493, 1464, 1384, 1347, 1317, 1290, 1097, 1067 cm^{-1}; Anal. Calcd. For $C_{18}H_{28}OSi$: C, 74.94%; H, 9.78%. Found: C 74.96%; H, 9.73%.

6h: (*S*)-(*E*)-(1-Ethynyl-3-phenyl-allyloxy)-triisopropyl-silane: Isolated in 70% yield as a colourless oil; $[\alpha]_D^{28}$ +3.53° (c = 0.91, $CHCl_3$); ^1H NMR (300 MHz, $CDCl_3$) δ 7.43-7.40 (m, 2H), 7.36-7.23 (m, 3H), 6.74 (dd, 1H, *J* = 15.8, 1.5), 6.27 (dd, 1H, *J* = 15.8, 5.7), 5.16 (ddd, 1H, *J* = 5.7, 2.1, 1.5) 2.56 (d, 1H, *J* = 2.1), 1.13-1.03 (m, 21H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 136.5 (C), 130.3 (CH), 129.1 (CH), 128.6 (CH), 127.8 (C), 126.8 (C), 83.8 (C), 73.4 (CH), 63.3 (CH), 18.0 (CH), 12.2 (CH_3); FTIR ($CHCl_3$) 3306, 3011, 2946, 2893, 2868, 1600, 1495, 1464, 1257, 1222, 1211, 1110, 1061, 1014 cm^{-1}; Anal. Calcd. For $C_{20}H_{30}OSi$: C, 76.37%; H, 9.61%. Found: C 76.44%; H, 9.61%.