Supporting Information for

Highly stereoselective approach to alk-2-yne-1,4-diols by oxazaborolidine-mediated reduction of alk-2-yne-1,4-diones

Xavier Ariza, Jordi Bach, Ramon Berenguer, Jaume Farràs, Montserrat Fontes, Jordi Garcia,* Marta López, and Jordi Ortiz*

Departament de Química Orgànica, Universitat de Barcelona, C/ Martí i Franquès 1-11, E-08028 Barcelona, Catalonia, Spain

Contents

General. All the solvents were distilled from an appropriate drying agent and stored under nitrogen atmosphere. The crude products were purified by column chromatography on silica gel of 230-400 mesh (flash chromatography). Thin-layer chromatograms were performed on HF 254 silica gel plates (using CH_2Cl_2, CH_2Cl_2/MeOH, or CH_2Cl_2/hexane as the eluents, as indicated after the R_f values). Melting points are uncorrected. ^1H, ^{13}C, and ^{19}F NMR spectra were obtained in $CDCl_3$ at 200 MHz or 300 MHz, 50.3 MHz, and 282.2 MHz, respectively; chemical shifts are given in ppm with respect to internal TMS, and *J* values are quoted in Hz. FT-IR spectra were measured on NaCl plates (film) or in KBr; only the most significant absorptions, in cm^{-1}, are indicated. Chemical ionization mass spectra (NH_3) are given in *m*/*z*. HRMS values were measured by electronic impact (EI). Propargylic diol **1g**,[1] diketone **5a**[2] and **5f**,[3] as well as oxazaborolidines (R)-**6**[4] and (4*R*,5*S*)-**7**[5] were prepared according to published procedures. Diol **1a** is commercially available.

1. Preparation of diols 1b–e (mixture of stereoisomers)

1.1. Oct-4-yne-3,6-diol (1b). A solution of *t*-butyl hydroperoxide (TBHP) in CH_2Cl_2 was obtained by swirling 12.5 mL (90.0 mmol) of commercial aqueous TBHP (70 % w/w in water) with 20 mL of CH_2Cl_2 in a separatory funnel. The milky mixture was allowed to stand until complete separation of the layers had occurred. The organic layer was separated and dried (Na_2SO_4). To this solution of TBHP in CH_2Cl_2, SeO_2 (2.40 g, 21.62 mmol) was added. The mixture was magnetically stirred for 15 min at room temperature and oct-4-yne (3.3 mL, 22.5 mmol) was added dropwise. The reaction mixture was stirred for 24 h at room temperature. Then, 125 mL of 5% aq KOH and 200 mL of CH_2Cl_2 were slowly added to the reaction mixture (cooled in an ice bath). After 30 min, the organic layer, cooled in an ice bath, was stirred with 100 mL of saturated $NaHSO_3$ for 30 min to destroy excess of TBHP. The organic layer was separated, dried (Na_2SO_4) and concentrated in vacuo to a pale-yellow oil. This oil was dissolved in 50 mL of MeOH, and the resulting solution was cooled in an ice bath. Then, $NaBH_4$ (2.0 g, 52.9 mmol) was cautiously added over a period of 5–10 min. After 15 min, the reaction mixture was poured into a cold mixture of pH 7 phosphate buffer (100 mL) and CH_2Cl_2 (100 mL). The aqueous layer was decanted and extracted with CH_2Cl_2. The combined organic phases were washed with brine, dried (Na_2SO_4) and concentrated in vacuo. The residue was purified by flash chromatography (CH_2Cl_2/MeOH 98:2) to give oct-4-yne-3,6-diol 1b (1.28 g, 40%) as a mixture of stereoisomers besides oct-4-yne-3-ol (1.32 g, 47%) which was amenable to suffer a further oxidation with SeO_2.

1.2. Dec-5-yne-4,7-diol (1c). To a magnetically stirred solution of hex-1-yne (4.0 mL, 34.8 mmol) in dry THF (40 mL), BuLi in hexanes (19.6 mL, 31.34 mmol) were added dropwise at -78 ºC under Ar. After 30 min, butanal (2.83 mL, 31.40 mmol) was added and the resulting solution was stirred for 5 min at 0 ºC and 30 min at room temperature. Then, the reaction was poured into CH_2Cl_2 (40 mL) and pH 7 phosphate buffer (40 mL). The aqueous phase was separated and extracted with CH_2Cl_2. The combined organic phases were washed with brine, dried (Na_2SO_4) and concentrated in vacuo to give 4.68 g

of crude. The NMR spectra of the crude product revealed that it was constituted mainly of dec-5-yne-4-ol, **10** (4.68 g, 30.34 mmol, 97%) and it was used without further purification. Dec-5-yne-4-ol, (**10**): colorless oil; R_f 0.60 (CH_2Cl_2); ^{1}H NMR ($CDCl_3$, 200 MHz) 0.94 (m, 6H, CH_3), 1.45 (m, 4H, CH_2), 1.53 (m, 4H, CH_2), 2.21 (m, 2H, $CH_2C{\equiv}C$), 4.36 (t, 1H, J = 6.0 Hz, C<u>H</u>OH); ^{13}C NMR ($CDCl_3$) 13.6 and 13.7 (CH_3), 18.2, 18.5, 21.9, 30.7 and 40.3 (CH_2), 62.7 (CHOH), 81.3 and 85.3 (C≡C). Allylic oxidation of the crude propargylic alcohol **10** (4.68 g, 30.34 mmol) was performed with TBHP (obtained from 16.5 mL of 70 wt. % aqueous TBHP) and SeO_2 (1.68 g, 15.15 mmol) in CH_2Cl_2 (30 mL) according to the procedure described in **1.1.** The treatment of the crude product with an excess of $NaBH_4$ (1.15 g, 30.4 mmol) in MeOH (100 mL) afforded a crude product which was separated by flash chromatography (CH_2Cl_2/MeOH 98:2) to give dec-5-yne-4,7-diol **1c** (2.49 g, 47% overall yield) as a mixture of stereoisomers along with starting alkynol **10** (0.706 g, 15%).

1.3. 1,4-Dicyclohexylbut-2-yne-1,4-diol (1d). This compound was prepared according to a literature procedure.[6] Purified acetylene[7] was bubbled for 30 min through a stirred mixture of 1.6M commercial hexane solution of BuLi (40.0 mL, 64.0 mmol), anhydrous THF (20 mL) and anhydrous diethyl ether (40 mL) at 4 ºC. Additional ether was added to compensate evaporation losses. During this time the solution turned a milky white. The mixture was stirred at 4 ºC for two additional hours to complete reaction and to allow for disproportionation of any monolithium acetylide. Then, a stream of dry nitrogen was passed through to remove the excess acetylene before the dropwise addition of cyclohexancarbaldehyde (3.86 mL, 31.9 mmol). Further addition of aldehyde (0.5 mL, 4.13 mmol) were performed every 10 min until an overall amount of 7.75 mL (64.0 mmol) of aldehyde. The suspension was stirred for 24 h at room temperature. Hydrolysis was accomplished by cooling at 4 ºC and stirring with 30 mL of saturated aqueous NH_4Cl for a few minutes. The aqueous layer was extracted with Et_2O and the combined organic phases were dried over $MgSO_4$. The solvent was removed and the residue was purified by flash chromatography (CH_2Cl_2/MeOH 95:5) to give 1,4-dicyclohexylbut-2-yne-1,4-diol, **1d**, (6.11 g, 76%).

1.4. 2,2,7,7-Tetramethyloct-4-yne-3,6-diol (1e). Addition of dilithium acetylide to dimethylpropanal (7.04 mL, 64.0 mmol) according to the procedure described in **1.3.** cleanly afforded 2,2,7,7-tetramethyloct-4-yne-3,6-diol, **1e**, (6.22 g, 98%).

2. Preparation of diketones

2.1. **Dec-5-yne-4,7-dione (5c).**[8] Yield 73%; yellow oil [lit.[8] bp 74–75 ºC/0.4 mm]; R_f 0.72 (CH_2Cl_2); ^{1}H NMR ($CDCl_3$, 200 MHz) 0.93 (t, 6H, J = 7.5 Hz), 1.68 (m, 4H), 2.58 (t, 4H, J = 7.2 Hz); ^{13}C NMR 13.2, 16.9, 46.9, 84.0 (C≡C), 186.2 (CO); IR (neat) 2950, 1680, 1455; Anal. Calcd for $C_{10}H_{14}O_2$: C, 72.26; H, 8.49. Found: C, 71.98; H, 8.27.

2.2 1,4-Dicyclohexylbut-2-yne-1,4-dione (5d). Yield 87%; yellowish oil; R_f 0.70 (CH_2Cl_2); ^{1}H NMR ($CDCl_3$, 200 MHz) 1.00–1.55 (m, 10H, CH_2), 1.60–2.20 (m, 10H, CH_2), 2.35–2.60 (m, 2H, CH); ^{13}C NMR 25.1, 25.5, 27.7, 52.0 (CH), 84.9 (C≡C), 189.7 (CO); IR (neat) 2920, 2840, 1720, 1675, 1495; Anal. Calcd for $C_{16}H_{22}O_2$: C, 78.01; H,

9.00. Found: C, 77.81; H, 9.12; HRMS (EI) calcd for $C_{16}H_{22}O_2(M^+)$ 246.1620, found 246.1620.

2.3. 2,2,7,7-Tetramethyloct-4-yne-3,6-dione (5e). Yield 93%; mp 47–8 °C; R_f 0.88 (CH_2Cl_2/MeOH 95:5); ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.24 (s, 18H, CH_3); ^{13}C NMR δ 25.6 (CH_3), 45.0 ($\underline{C}(CH_3)_3$), 85.1 (C≡C), 192.4 (CO); IR (KBr) 2975, 1676; MS (NH_3/CI) m/z (rel. int.) 212 (100, [M + NH_4^+]); Anal. Calcd for $C_{12}H_{18}O_2$: C, 74.19; H, 9.34. Found: C, 73.95; H, 9.15.

3. Reduction of diketones

3.1. (*S,S*)-Oct-4-yne-3,6-diol [(*S,S*)-**1b**]. Reduction of **5b** (138 mg, 1 mmol) was performed with oxazaborolidine (*R*)-**6** (2 mmol) and BH_3:SMe_2 (222 μL, 2.2 mmol) according to the procedure employed for **5a**, to yield enantioenriched (*R,R*)-**1b** in 85% yield. An analytical sample of the crude product was treated with an excess of (*S*)-Mosher acid chloride (derived from (*R*)-acid) to give a mixture of Mosher diesters. The analysis by HPLC (Tracer Spherisorb S3W column, 0.5 mL/min, hexane/THF 99:1, t_R (*R,R*) = 12.3 min, t_R (*R,S*) = 14.8 min, t_R (*S,S*) = 17.4 min) revealed a 87:13 *dl*/*meso* ratio and 98% e.e. A similar reduction using a molar ratio (*R*)-**6**/diketone = 0.2 led to (*R,R*)-**1b** in 81% yield, with a *dl*/*meso* ratio of 72:18 and 96% e.e.
Alternatively, to a solution of of $Co_2(CO)_8$ (376 mg, 1.1 mmol) in anhyd pentane (5 mL) under Ar at rt., a solution of diketone **5b** (138 mg, 1.0 mmol) in anhyd pentane (3 mL) and CH_2Cl_2 (0.5 mL) was added via cannula. The dark red solution was stirred at rt. After 1 h, TLC revealed the disappearance of the starting ketone. The solution was filtered through silica gel (CH_2Cl_2). The solvent was removed *in vacuo* to yield the crude hexacarbonyldicobalt complex **8b** as a brown oil: R_f 0.55 (CH_2Cl_2); ^{1}H NMR ($CDCl_3$, 200 MHz) δ 1.10 (t, 6H, *J* = 7.2 Hz), 2.79 (m, 4H); ^{13}C NMR δ 8.4 (CH_3), 37.1 (CH_2), 85.2 (C≡C), 189.8 (CO), 197.1 (CO). The crude complex **8b** was then transformed into (*S,S*)-**1b** as described for (*S,S*)-**1a** in 96% yield. The analysis by HPLC of the corresponding Mosher's diesters revealed a 98.6:1.4 *dl*/*meso* ratio and 98% e.e. (*S,S*)-Oct-4-yne-3,6-diol, (*S,S*)-**1b**: colorless oil [lit.[9] bp 92–95 °C/1 mmHg for a mixture of stereoisomers]; R_f 0.10 (CH_2Cl_2/MeOH 96:4); $[\alpha]_D^{20}$ –10.8 (*c* = 0.5, $CHCl_3$). ^{1}H NMR ($CDCl_3$, 200 MHz) δ 1.00 (t, 6H, *J* = 6.9 Hz), 1.65–1.80 (m, 4H, CH_2), 2.50 (bs, 2H, OH), 4.34 (t, 2H, *J* = 7.1 Hz, C$\underline{H}$OH); ^{13}C NMR δ 9.5 (CH_3), 30.6 (CH_2), 63.3 (CHOH), 85.6 (C≡C); IR (neat) 3250, 2940, 1950, 960. HRMS (EI) calcd for $C_8H_{14}O_2$ (M^+) 142.0994, found 142.0999.

3.2. (*S,S*)-Dec-5-yne-4,7-diol [(*S,S*)-**1c**]. Reduction of **5c** (166 mg, 1 mmol) was performed with oxazaborolidine (*R*)-**6** (2 mmol) and BH_3:SMe_2 (222 μL, 2.2 mmol) according to the procedure employed for **5a**, to yield enantioenriched (*R,R*)-**1c** in 86% yield. An analytical sample of the crude product was treated with an excess of (*S*)-Mosher acid chloride (derived from (*R*)-acid) to give a mixture of Mosher diesters. A careful analysis by ^{19}F NMR revealed a 90:10 *dl*/*meso* ratio and 99% e.e. When the same reaction was carried out using a molar ratio of (*R*)-**6**/diketone = 0.2 the compound (*R,R*)-**1c** was obtained in 77% yield, with a *dl*/*meso* ratio of 75:25 and 98% e.e.
Alternatively, a sample of **5c** was treated with $Co_2(CO)_8$ in pentane according to the procedure described in **3.1**, to yield the crude hexacarbonyldicobalt complex **8c** as a

brown oil: R_f 0.60 (CH_2Cl_2); ^{1}H NMR ($CDCl_3$, 300 MHz) δ 0.98 (t, 6H, J = 7.4 Hz), 1.79 (qt, 4H, J = 7.4, 7.2 Hz), 2.73 (t, 4H, J = 7.2 Hz); ^{13}C NMR δ 13.6 (CH_3), 17.9 and 45.6 (CH_2), 84.2 (C≡C), 186.4 (CO), 198.0 (CO). The crude complex **8c** was then transformed into (*S*,*S*)-**1c** as described for (*S*,*S*)-**1a** in 95% yield. The analysis by ^{19}F NMR of the corresponding Mosher's diesters revealed a 92:8 *dl*/*meso* ratio and 98% e.e. (*S,S*)-Dec-5-yne-4,7-diol, (*S*,*S*)-**1c**: Colorless oil [lit.[1] bp 112-115 ºC/1 mmHg for a mixture of stereoisomers]; R_f 0.18 (CH_2Cl_2/MeOH 95:5); $[\alpha]_D^{20}$ –11.8 (c = 0.96, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 200 MHz) δ 0.95 (t, 6H, J = 7.2 Hz), 1.52 (m, 4H, CH_2), 1.65 (m, 4H, CH_2), 2.93 (bs, 2H, OH), 4.41 (t, 2H, J = 6.6 Hz, C<u>H</u>OH); ^{13}C NMR δ 13.4 (CH_3), 18.5 and 39.97 (CH_2), 62.1 (CHOH), 85.8 (C≡C); IR (neat) 3300, 2950, 1455, 1020. HRMS (EI) calcd for $C_{10}H_{18}O_2$ (M^+) 170.1307, found 170.1301. Anal. Calcd for $C_{10}H_{18}O_2$: C, 70.55; H, 10.66. Found: C, 70.82; H, 10.62.

3.3. (*S,S*)-Dicyclohexylbut-2-yne-1,4-diol [(*S,S*)-**1d**]. Reduction of **5d** (250 mg, 1 mmol) was performed with oxazaborolidine (*R*)-**6** (2 mmol) and BH_3:SMe_2 (222 μL, 2.2 mmol) according to the procedure employed for **5a**, to yield enantioenriched (*R,R*)-**1d** in 90% yield. An analytical sample of the crude product was treated with an excess of (*S*)-Mosher acid chloride (derived from (*R*)-acid) to give a mixture of Mosher diesters. The analysis by HPLC (Tracer Spherisorb S3W column, 0.9 mL/min, hexane/THF 99:1, t_R (*R*,*R*) = 8.9 min, t_R (*R*,*S*) = 9.8 min, t_R (*S*,*S*) = 12.1 min) revealed a 88:12 *dl*/*meso* ratio and 97% e.e. When the same reaction was carried out using a molar ratio of (*R*)-**6**/diketone = 0.2 the compound (*R*,*R*)-**1d** was obtained in 90% yield, with a *dl*/*meso* ratio of 84:16 and 96% e.e.
Alternatively, a sample of **5d** was treated with $Co_2(CO)_8$ in pentane according to the procedure described in **3.1**, to yield the crude hexacarbonyldicobalt complex **8d** as a brown oil: R_f 0.30 (CH_2Cl_2/hexane 1:1); ^{1}H NMR ($CDCl_3$, 200 MHz) δ 0.88–1.90 (m, 20H, CH_2), 2.68 (m, 2H, CH); ^{13}C NMR δ 25.6 and 29.7 (CH_2), 52.3 (CH), 88.0 (C≡C), 192.8 (CO), 204.2 (CO). The crude complex **8d** (1 mmol) was then transformed into (*S*,*S*)-**1d** as described for (*S*,*S*)-**1a** in 71% overall yield by using excesses of BH_3:SMe_2 (3 mmol) and (4*R*,5*S*)-**7** (4 mmol) to complete the reduction. The analysis by HPLC of the corresponding Mosher's diesters revealed a 95:5 *dl*/*meso* ratio and 96% e.e. (*S,S*)-dicyclohexylbut-2-yne-1,4-diol, (*S*,*S*)-**1d**.

3.4. (*R,R*)-2,2,7,7-Tetramethyloct-4-yne-3,6-diol [(*R,R*)-**1e**]. Reduction of **5e** (250 mg, 1 mmol) was performed with oxazaborolidine (*R*)-**6** (2 mmol) and BH_3:SMe_2 (222 μL, 2.2 mmol) according to the procedure employed for **5a**, to yield enantioenriched (*R,R*)-**1e** in 98% yield. An analytical sample of the crude product was treated with an excess of (*S*)-Mosher acid chloride (derived from (*R*)-acid) to give a mixture of Mosher diesters. A careful analysis by ^{19}F NMR revealed a 99.9:0.1 *dl*/*meso* ratio and 99.9% e.e. When the same reaction was carried out using a molar ratio of (*R*)-**6**/diketone = 0.2 the compound (*R*,*R*)-**1e** was obtained in 95% yield, with a *dl*/*meso* ratio of 97:3 and 99% e.e. (*R*,*R*)-2,2,7,7-Tetramethyloct-4-yne-3,6-diol, (*R*,*R*)-**1e**: mp 145-147 ºC [lit.[6] mp 129–131 ºC for a racemic mixture]; R_f 0.30 (CH_2Cl_2/MeOH 95:5); $[\alpha]_D^{20}$ +46.4 (c = 1.4, MeOH); ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.00 (s, 18H, CH_3), 2.23 (bs, 2H, OH), 4.07 (s, 2H, C<u>H</u>OH); ^{13}C NMR δ 25.7 (CH_3), 36.2 (<u>C</u>(CH_3)$_3$), 71.4 (CHOH), 85.1 (C≡C); IR (KBr) 3200, 2910,

2050, 1445. MS (NH_3/CI) *m/z* (rel. int.) 216 (100, [M + NH_4^+]); HRMS (EI) calcd for $C_{12}H_{23}O_2$ (M^++H) 199.1698, found 199.1699. Anal. Calcd for $C_{12}H_{22}O_2$: C, 72.68; H, 11.18. Found: C, 72.89; H, 11.11.

3.5. (*R,R*)-Diphenylbut-2-yne-1,4-diol [(*R,R*)-**1f**].[10] Reduction of **5f** (188 mg, 1 mmol) was performed with oxazaborolidine (*R*)-**6** (2 mmol) and BH_3:SMe_2 (222 μL, 2.2 mmol) according to the procedure employed for **5a**, to yield enantioenriched (*R,R*)-**1f** in 75% yield. An analytical sample of the crude product was treated with an excess of (*S*)-Mosher acid chloride (derived from (*R*)-acid) to give a mixture of Mosher diesters. The analysis by HPLC (Chiracel OD-H, 0.5 mL/min, hexane/*i*-PrOH 99.5:0.5, t_R (*R,R*) = 29.8 min, t_R (*R,S*) = 25.0 min, t_R (*S,S*) = 27.0 min) revealed a 91:9 *dl*/*meso* ratio and 98% e.e. When the same reaction was carried out using a molar ratio of (*R*)-**6**/diketone = 0.2 a complex crude mixture was obtained from which the compound (*R,R*)-**1f** was obtained in 23% yield, with a *dl*/*meso* ratio of 86:14 and 98% e.e. (*R,R*)-Diphenylbut-2-yne-1,4-diol**,** (*R,R*)-**1f**: mp 106-7 ºC [lit.[10] mp 110 ºC]; R_f 0.22 (CH_2Cl_2/MeOH 95:5); $[\alpha]_D^{20}$ +29.0 (*c* = 1.4, EtOH) [lit.[10] $[\alpha]_D^{20}$ +34.7, *c* = 6.1, EtOH)]; ^{1}H NMR ($CDCl_3$, 300 MHz) δ 2.06 (bs, 2H, OH), 5.56 (s, 2H, C<u>H</u>OH), 7.25–7.60 (m, 10H, Ar); ^{13}C NMR δ 64.7 (CHOH), 86.3 (C≡C), 126.6, 128.5, 128.6 and 140.1; IR (KBr) 3225, 2910, 1451, 1040, 697. Anal. Calcd for $C_{16}H_{14}O_2$: C, 80.65; H, 5.92. Found: C, 80.38; H, 6.00.

4. *vic*-Dibromodiols

4.1. (2*S*,3*E*,5*S*)-3,4-Dibromohex-3-ene-2,5-diol[11] [(*S,S*)-**9a**]: mp 119–120 ºC [lit.[12] mp 118-119 ºC for a racemic mixture]; R_f 0.13 (CH_2Cl_2/MeOH 98:2); $[\alpha]_D^{20}$ –17.2 (*c* = 0.3, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 200 MHz) δ 1.13 (d, 6H, *J* = 6.4 Hz, CH_3), 4.93 (q, 2H, *J* = 6.4 Hz, C<u>H</u>OH); ^{13}C NMR δ 19.8 (CH_3), 68.4 (CHOH), 125.9 (CBr=); IR (KBr) 3347, 2925, 2856, 1457, 1372, 1131, 1071, 700. MS (NH_3/CI) *m/z* (rel. int.) 292 (100, $^{79}Br^{81}Br$, [M + NH_4^+]).

4.2. (2R,3E,5S)-3,4-Dibromohex-3-ene-2,5-diol[11] (meso-**9a**): mp 214–215 ºC [lit.[12] mp 217–218 ºC]; R_f 0.20 (CH_2Cl_2/MeOH 98:2); ^{1}H NMR ($CDCl_3$, 200 MHz) δ 1.17 (d, 6H, *J* = 6.4 Hz, CH_3), 4.96 (q, 2H, *J* = 6.4 Hz, CHOH); ^{13}C NMR δ 19.9 (CH_3), 68.8 (CHOH), 126.2 (CBr=); IR (KBr) 3260, 2928, 2863, 1450, 1366, 1079, 704; MS (NH_3/CI) *m/z* (rel. int.) 292 (100, $^{79}Br^{81}Br$, [M + NH_4^+]).

4.3. (3S,4E,6S)-4,5-Dibromooct-4-ene-3,6-diol [(*S,S*)-**9b**]: mp 70–72 ºC; R_f 0.16 (CH_2Cl_2/MeOH 98:2); $[\alpha]_D^{20}$ –1.6 (*c* = 1.2, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 200 MHz) δ 0.94 (t, 6H, *J* = 7.4 Hz, CH_3), 1.66 (m, 4H, CH_2), 2.07 (bs, 2H, OH), 4.82 (t, 2H, *J* = 6.8 Hz, C<u>H</u>OH); ^{13}C NMR δ 9.4 (CH_3), 28.3 (CH_2), 74.9 (CHOH), 127.0 (CBr=); IR (KBr) 3250, 2950, 1080, 700. MS (NH_3/CI) *m/z* (rel. int.) 320 (100, $^{79}Br^{81}Br$, [M + NH_4^+]); HRMS (EI) calcd for $C_8H_{14}O_2{}^{79}Br^{81}Br$ (M^+) 301.9336, found 301.9340. Anal. Calcd for $C_8H_{14}O_2Br_2$: C, 31.82; H, 4.67; Br, 52.92. Found: C, 32.00; H, 4.77; Br, 53.10.

4.4. (3*R*,4*E*,6*S*)-4,5-Dibromooct-4-ene-3,6-diol (*meso*-**9b**): mp 170–172 ºC; R_f 0.46 (CH_2Cl_2/MeOH 95:5); ^{1}H NMR ($CDCl_3$, 200 MHz) δ 0.96 (t, 6H, J = 7.4 Hz, CH_3), 1.71 (m, 4H, CH_2), 2.20 (bs, 2H, OH), 4.82 (t, 2H, J = 4.0 Hz, C<u>H</u>OH); ^{13}C NMR δ 9.4 (CH_3), 28.2 (CH_2), 74.7 (CHOH), 127.0 (CBr=); IR (KBr) 3800, 2950, 1701, 1506, 700. MS (NH_3/CI) m/z (rel. int.) 320 (100, $^{79}Br^{81}Br$, [M + NH_4^+]). HRMS (EI) calcd for $C_8H_{14}O_2{}^{79}Br^{81}Br$ (M^+) 301.9336, found 301.9338.

4.5. (4S,5E,7S)-4,5-Dibromodec-5-ene-4,7-diol [(*S,S*)-**9c**]: mp 89–90 ºC; R_f 0.11 (CH_2Cl_2/MeOH 97:3); $[\alpha]_D^{20}$ –20.6 (c = 2.3, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 200 MHz) δ 0.97 (t, 6H, J = 7.2 Hz, CH_3), 1.15–1.85 (m, 8H, CH_2), 1.88 (d, 2H, J = 7.4 Hz, OH), 4.87 (dt, 2H, J = 7.4, 6.8 Hz, C<u>H</u>OH); ^{13}C NMR δ 14.0 (CH_3), 18.3 and 37.9 (CH_2), 73.3 (CHOH), 126.8 (CBr=); IR (KBr) 3350, 2960, 1435, 685. MS (NH_3/CI) m/z (rel. int.) 348 (100, $^{79}Br^{81}Br$, [M+ NH_4^+]); HRMS (EI) calcd for $C_{10}H_{18}O_2{}^{79}Br^{81}Br$ (M^+) 329.9653, found 329.9650. Anal. Calcd for $C_{10}H_{18}O_2Br_2$: C, 36.39; H, 5.50. Found: C, 36.31; H, 5.41.

4.6. (4*R*,5*E*,7*S*)-4,5-Dibromodec-5-ene-4,7-diol (*meso*-**9c**): mp 113–115 ºC; R_f 0.31 (CH_2Cl_2/MeOH 97:3); ^{1}H NMR ($CDCl_3$, 200 MHz) δ 0.97 (t, 6H, J = 7.2 Hz, CH_3), 1.15–1.82 (m, 8H, CH_2), 1.82 (d, 2H, J = 8.0 Hz, OH), 4.87 (dt, 2H, J = 8.0, 7.0 Hz, C<u>H</u>OH); ^{13}C NMR δ 14.0 (CH_3), 18.4 and 37.5 (CH_2), 73.5 (CHOH), 126.8 (CBr=); IR (KBr) 3310, 2965, 1470, 695. MS (NH_3/CI) m/z (rel. int.) 348 (100, $^{79}Br^{81}Br$, [M + NH_4^+]); HRMS (EI) calcd for $C_{10}H_{18}O_2{}^{79}Br^{81}Br$ (M^+) 329.9653, found 329.9655. Anal. Calcd for $C_{10}H_{18}O_2Br_2$: C, 36.39; H, 5.50. Found: C, 36.41; H, 5.51.

4.7. (4*R*,5*E*,7*R*)-4,5-Dibromo-2,2,7,7-tetramethyloct-4-ene-3,6-diol [(*R,R*)-**9e**]: In a well ventilated hood, a ~3M solution of bromine in CH_2Cl_2 was slowly added to a solution of (*R,R*)-2,2,7,7-tetramethyloct-4-yne-3,6-diol, (*R,R*)-**1e**, (500 mg, 2.52 mmol) in 10 mL of CH_2Cl_2 at 0 ºC until brown colour persisted and then the solution was stirred at rt. The progress of the reaction was monitored by TLC. After 1 h, the reaction was cautiously quenched by addition of sat. aqueous $NaHSO_3$ (10 mL) and the aqueous layer was extracted with more CH_2Cl_2. The combined organic layers were dried ($MgSO_4$) and the solvent was eliminated *in vacuo*. The residue was purified by flash chromatography (CH_2Cl_2 and then CH_2Cl_2/MeOH 99:1) to give (*R,R*)-**9e** (266 mg, 0.74 mmol) along with *meso*-**9e** (14 mg, 0.04 mmol) (31 % overall yield), recovering 149 mg (30%) of starting propargylic diol **1e**. (4*R*,5*E*,7*R*)-4,5-Dibromo-2,2,7,7-tetramethyloct-4-ene-3,6-diol, (*R,R*)-**9e**: mp 119–120 ºC; R_f 0.21 (CH_2Cl_2/MeOH 95:5); $[\alpha]_D^{20}$ +12.8 (c = 1.9, $CHCl_3$); ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.07 (s, 18H, CH_3), 2.20 (bs, 2H, OH), 4.80 (d, 2H, J = 4.6 Hz, CHOH); ^{13}C NMR δ 26.9 (CH_3), 37.3 (<u>C</u>(CH_3)$_3$), 79.2 (CHOH), 126.7 (CBr=); IR (KBr) 3448, 2965, 1478, 775. MS (NH_3/CI) m/z (rel. int.) 376 (100, $^{79}Br^{81}Br$, [M + NH_4^+]); HRMS (EI) calcd for $C_8H_{12}O^{79}Br^{81}Br$ (M^+–*t*-BuOH) 283.9234, found 283.9231. Anal. Calcd for $C_{12}H_{22}O_2Br_2$: C, 40.25; H, 6.19; Br, 44.63. Found: C, 39.97; H, 6.19; Br, 44.21.

4.8. (4*R*,5*E*,7*S*)-4,5-Dibromo-2,2,7,7-tetramethyloct-4-ene-3,6-diol (*meso*-**9e**): mp 174–175 ºC; R_f 0.36 (CH_2Cl_2/MeOH 95:5); ^{1}H NMR ($CDCl_3$, 300 MHz) δ 1.07 (s, 18H, CH_3), 2.10 (d, 2H, J = 9.0 Hz, OH), 4.85 (d, 2H, J = 9.0 Hz, C<u>H</u>OH); ^{13}C NMR δ 26.9 (CH_3), 37.3 (<u>C</u>(CH_3)$_3$), 79.4 (CHOH), 126.8 (CBr=); IR (KBr) 3338, 2963, 1480, 775.

MS (NH_3/CI) *m*/*z* (rel. int.) 376 ($^{79}Br^{81}Br$) (100, [M + NH_4^+]); Anal. Calcd for $C_{12}H_{22}O_2Br_2$: C, 40.25; H, 6.19; Br, 44.63. Found: C, 40.07; H, 6.22; Br, 44.87.

4.9. (1*S*,2*E*,4*S*)-2,3-Dibromo-1,4-diphenybut-2-ene-1,4-diol [(*S,S*)-**9f**]: mp 172-3 ºC ; R_f 0.28 (CH_2Cl_2/MeOH 95:5); $[\alpha]_D^{20}$ +269.0 (*c* = 1.8, MeOH); ^{1}H NMR (CD_3OD, 300 MHz) δ 4.83 (bs, 2H, OH), 6.20 (s, 2H, C<u>H</u>OH), 7.25–7.45 (m, 10H, Ar); ^{13}C NMR (CD_3OD) δ 75.0 (CHOH), 126.8 (CBr=), 128.5, 128.7, 129.1 and 142.0 (Ar); IR (KBr) 3303, 2925, 1717, 1449, 1059, 745, 693. Anal. Calcd for $C_{16}H_{14}O_2Br_2$: C, 48.27; H, 3.54; Br, 40.14. Found: C, 47.96; H, 3.49; Br, 40.37.

4.10. (1*R*,2*E*,4*S*)-2,3-Dibromo-1,4-diphenybut-2-ene-1,4-diol (*meso*-**9f**): mp 176-7 ºC ; R_f 0.60 (CH_2Cl_2/MeOH 95:5); ^{1}H NMR (CD_3OD, 300 MHz) δ 4.93 (bs, 2H, OH), 6.19 (s, 2H, C<u>H</u>OH), 7.25–7.45 (m, 10H, Ar); ^{13}C NMR (CD_3OD) δ 75.1 (CHOH), 127.1 (CBr=), 128.6, 128.7, 129.1 and 141.6 (Ar); IR (KBr) 3525, 2925, 1653, 1449, 1061, 746, 693. Anal. Calcd for $C_{16}H_{14}O_2Br_2$: C, 48.27; H, 3.54; Br, 40.14. Found: C, 48.17; H, 3.43; Br, 40.40.

References:

1. Chabaud, B.; Sharpless, K. B. *J. Org. Chem.* **1979**, *44***,** 4202–4204.
2. (a) Acheson, R. M.; Bite, M. G.; Cooper, M. W. *J. Chem. Soc., Perkin I* **1976**, 1908–1911. See also: (b) Dunn, P. J.; Rees, C. W. *J. Chem. Soc., Perkin I* **1987**, 1579–1584.
3. Bowden, K.; Heilbron, I. M.; Jones, E. R. H.; Weedon, B. C. L. *J. Chem. Soc.* **1946**, 39–45.
4. Bach, J.; Berenguer, R.; Garcia, J.; Loscertales, T.; Vilarrasa, *J. Org. Chem.* **1996**, *61*, 9021–9025.
5. Quallich, G. J.; Blake, J. F.; Woodall, T. M. *J. Am. Chem. Soc.* **1994**, *116*, 8516–8525.
6. Sudweeks, W. B.; Broadbent, H. S. *J. Org. Chem.* **1975**, *40***,** 1131–1136.
7. Acetylene was purified by passing through concd H_2SO_4 and then through two dry ice-acetone cooled traps.
8. Bowden, K.; Heilbron, I. M.; Jones, E. R. H.; Weedon, B. C. L. *J. Chem. Soc.,* **1946**, 39–45.
9. Lu, X.; Ji, J.; Ma, D.; Shen, W. *J. Org. Chem.* **1991**, *56***,** 5774–5778.
10. Iwai, I.; Tomika, K. *Chem. Pharm. Bull.* **1963**, 524-528.
11. Dupont, M. G. *C. R. Acad. Sci.* **1909**, *149*, 1381–1383.
12. Hill, R. K.; Pendalwar, S. L.; Kielbasinski, K.; Baevsky, M. F.; Nugara, P. N. *Synthetic Commun.* **1990**, *20*, 1877–1884.