Electronic Supplementary Material (ESI) for Organic & Biomolecular Chemistry

Supporting Information-I

Direct Catalytic Asymmetric Synthesis of Highly Functionalized (2-Ethynylphenyl)alcohols *via* Barbas-List Aldol Reaction: Scope and Synthetic Applications

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General Methods: The ^{1}H NMR and ^{13}C NMR spectra were recorded at 400 MHz and 100 MHz, respectively. The chemical shifts are reported in ppm downfield to TMS ($\delta = 0$) for ^{1}H NMR and relative to the central $CDCl_3$ resonance ($\delta = 77.0$) for ^{13}C NMR. *In the ^{13}C NMR spectra, the nature of the carbons (C, CH, CH_2 or CH_3) was determined by recording the DEPT-135 experiment, and is given in parentheses.* The coupling constants *J* are given in Hz. Column chromatography was performed using Acme's silica gel (particle size 0.063-0.200 mm). High-resolution mass spectra were recorded on micromass ESI-TOF MS. GCMS mass spectrometry was performed on Shimadzu GCMS-QP2010 mass spectrometer. IR spectra were recorded on JASCO FT/IR-5300. Elemental analyses were recorded on a Thermo Finnigan Flash EA 1112 analyzer. Mass spectra were recorded on either VG7070H mass spectrometer using EI technique or Shimadzu-LCMS-2010 A mass spectrometer. The X-ray diffraction measurements were carried out at 298 K on an automated Enraf-Nonious MACH 3 diffractometer using graphite monochromated, Mo-Kα ($\lambda = 0.71073$ Å) radiation with CAD4 software or the X-ray intensity data were measured at 298 K on a Bruker SMART APEX CCD area detector system equipped with a graphite monochromator and a Mo-Kα fine-focus sealed tube ($\lambda = 0.71073$ Å). For thin-layer chromatography (TLC), silica gel plates Merck 60 F254

were used and compounds were visualized by irradiation with UV light and/or by treatment with a solution of *p*-anisaldehyde (23 mL), conc. H_2SO_4 (35 mL), acetic acid (10 mL), and ethanol (900 mL) followed by heating.

The enantiomeric excess (*ee*) of the *BLA* products was determined by chiral stationary phase HPLC using a Daicel Chiralcel OD-H, Chiralcel OJ-H, Chiralpak AD-H, Chiralpak AS-H or Lux 5u Amylose-2 columns and hexane/2-propanol as the eluent. Retention times and solvent ratios are indicated in the respective entries.

Materials: All solvents and commercially available chemicals were used as received.

General Experimental Procedures for the Asymmetric *BLA* Reactions:

Prolinamide 3 catalyzed BLA reaction of 2-alkynylbenzaldehydes 1 with ketone 2 (Method A): In a 10 mL round bottomed flask equipped with a magnetic stirring bar, to the prolinamide catalyst **3h** or **3i** (10 mol%) was added $PhCO_2H$ (10 mol%). The flask was cooled to –35 °C and then ketone **2** (1 ml, 0.3 M) was added to it. After stirring the reaction mixture at –35 °C for 0.5 h, 2-ethynylbenzaldehyde **1** (0.3 mmol) was added to it and stirring was continued at the same temperature for 24–60 h. The crude reaction mixture was worked up with aqueous NH_4Cl solution and the aqueous layer was extracted with ethyl acetate (2 x 20 mL). The combined organic layers were dried (Na_2SO_4), filtered and concentrated. Pure BLA products **5** and double-aldol addition products **6** were obtained by column chromatography (silica gel, mixture of hexane/ ethylacetate).

***trans*-4-*OH*-L-Proline catalyzed BLA reaction of 2-alkynylbenzaldehydes with ketones (Method B):** In an ordinary glass vial equipped with a magnetic stirring bar, to 0.3 mmol of 2-ethynylbenzaldehyde **1** was added 2.4 mL of solvent, followed by the addition of the catalyst *trans*-4-*OH*-L-proline **3d** (0.06 mmol, 20 mol%, 6.9 mg). After stirring the reaction mixture at 25 °C for 2–3 min, ketone **2** was added and the reaction mixture was allowed to stir at the same temperature for 24–72 h. The crude reaction mixture was worked up with aqueous NH_4Cl solution and the aqueous layer was

extracted with ethyl acetate (2 x 20 mL). The combined organic layers were dried (Na_2SO_4), filtered and concentrated. Pure BLA products **5** were obtained by column chromatography (silica gel, mixture of hexane/ethyl acetate).

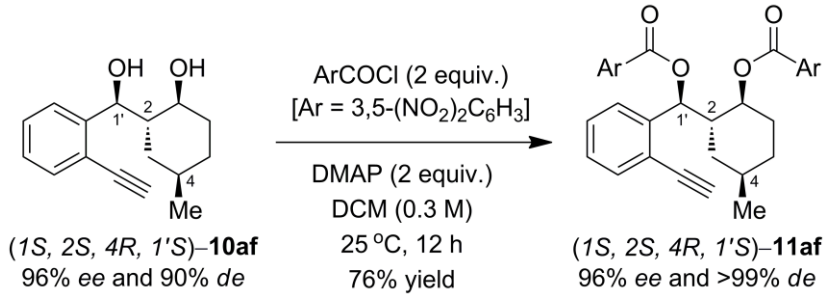
$CuSO_4$/Na-(+)-Ascorbate-Catalyzed Click Reaction (**Method C**)**:** Compound **5aa** (0.3 mmol) and aryl azide **7** (0.5 equiv.) was dissolved in *t*-BuOH/H_2O (2 mL, 1:1 ratio) in a 10 mL round bottomed flask equipped with a magnetic stirring bar, to that 40 mol% of $CuSO_4$, 20 mol% of Na-(+)-Ascorbate were added and the reaction mixture was stirred at the room temperature for 8-12 h. The crude reaction mixture was worked up with aqueous NH_4Cl solution and the aqueous layer was extracted with ethyl acetate (2 x 20 mL). The combined organic layers were dried (Na_2SO_4), filtered and concentrated. Pure click products **10** were obtained by column chromatography (silica gel, mixture of hexane/ethyl acetate).

$CuSO_4$/Cu-Catalyzed Click Reaction (**Method D**)**:** Compound **6aa** (0.3 mmol) and aryl azide **7b** (0.6 mmol) was dissolved in EtOH (2 mL) in a 10 mL round bottomed flask equipped with a magnetic stirring bar, to that 1.0 equiv. of $CuSO_4$, 5 mol% of Cu powder were added and the reaction mixture was stirred at the room temperature for 12 h. The crude reaction mixture was worked up with H_2O and the aqueous layer was extracted with ethyl acetate (2 x 20 mL). The combined organic layers were dried (Na_2SO_4), filtered and concentrated. Pure cyclic click product **9aab** was obtained by column chromatography (silica gel, mixture of hexane/ethyl acetate).

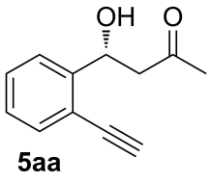
General Procedure for the Reduction of BLA Products 5 (**Method E**)**:** In a 10 mL round bottomed flask equipped with a magnetic stirring bar, compound **5aa-5bf** (0.2 mmol) was dissolved in dry MeOH (0.25 M) and then cooled to ice salt temperature, $NaBH_4$ (2 equiv.) was added to it under nitrogen atmosphere. After stirring the reaction mixture at same temperature for 0.5 h, the crude reaction mixture was worked up with aqueous NH_4Cl solution and the aqueous layer was extracted with ethyl acetate (2 x 20 mL). The combined organic layers were dried (Na_2SO_4), filtered and concentrated. Pure products **10** were obtained by column chromatography (silica gel, mixture of hexane/ethyl acetate).

Lewis acid Mediated *syn*-Selective *Reduction of BLA Products 5* (**Method F**)**:** In a 10 mL round bottomed flask equipped with a magnetic stirring bar, compound **5aa-5bf** (0.2 mmol) was dissolved in dry THF : MeOH (4:1, 0.2 M) and then cooled to –75 °C temperature, $BEt_2(OMe)$ (1.1 equiv.), and $NaBH_4$ (1.1 equiv.) was added to it under nitrogen atmosphere. After stirring the reaction mixture at same temperature for 4 h, the crude reaction mixture was worked up with aqueous NH_4Cl solution and the aqueous layer was extracted with ethyl acetate (2 x 20 mL). The combined organic layers were dried (Na_2SO_4), filtered and concentrated. Pure products *syn*-**10** was obtained by column chromatography (silica gel, mixture of hexane/ethyl acetate).

Double Protection of BLA-Reduction Product syn-10af (**Method G**)**:** In a 10 mL round bottomed flask compound *syn*-**10af** (189 mg, 0.3 mmol) was dissolved in 1 mL of dry DCM, to that 2.0 equiv. of 3,5-dinitrobenzoyl chloride and 2.0 equiv. of DMAP were added. After stirring the reaction mixture at 25 °C for 12 h, the crude reaction mixture was worked up with aqueous NH_4Cl solution and the aqueous layer was extracted with DCM (2 x 20 mL). The combined organic layers were dried (Na_2SO_4), filtered and concentrated. Pure product **11af** was obtained by column chromatography (silica gel, mixture of hexane/ethyl acetate).

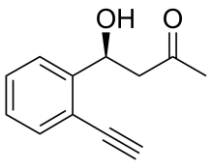


Scheme S1: Double protection on BLA-reduction product *syn*-**10af**.



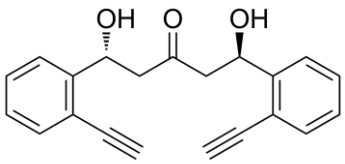
5aa

(*R*)-4-(2-Ethynylphenyl)-4-hydroxy-butan-2-one (5aa): Prepared following the Method-**A**; and purified by column chromatography using EtOAc/hexane and isolated as liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralcel OD-H column (hexane/2-propanol = 92:8, flow rate 1.0 mL/min, λ= 254 nm), t_R = 8.56 min (minor), t_R = 9.71 min (major). **$[\alpha]_D^{25}$ = +62.1°** (*c* = 0.27 g/100 mL, $CHCl_3$, **93% *ee***); IR (Neat): ν_{max} 3448, 3286 (O-H), 2925, 1709 (*C*=O), 1447, 1362, 1264, 1165, 1105, 1065, 763, 666, 651 and 625 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.58 (1H, d, *J* = 8.0 Hz), 7.46 (1H, dd, *J* = 7.6, 1.2 Hz), 7.37 (1H, dt, *J* = 7.6, 1.2 Hz), 7.22 (1H, dt, *J* = 7.6, 1.2 Hz)[Ar-*H*]; 5.57 (1H, dd, *J* = 9.6, 2.0 Hz, C*H*OH), 3.61 (1H, br s, O*H*), 3.34 (1H, s, C≡C*H*), 3.00 (1H, dd, *J* = 17.2, 2.4 Hz, COCH_2), 2.72 (1H, dd, *J* =17.6, 9.6 Hz, COCH_2), 2.19 (3H, s, COCH_3); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 209.1 (C, *C*=O), 145.1 (C), 132.7 (CH), 129.3 (CH), 127.1 (CH), 125.2 (CH), 118.8 (C), 82.6 (CH, Ar-C≡*C*H), 81.0 (C, Ar-*C*≡CH), 67.6 (CH, *C*HOH), 50.8 (CH_2, CO*C*H_2), 30.4 (CH_3, CO*C*H_3); LRMS m/z 189.10 (M+1), calcd. for $C_{12}H_{12}O_2$ 188.0837; Anal. calcd. for $C_{12}H_{12}O_2$ (188.0837); C, 76.57; H, 6.43. Found: C, 76.48; H, 6.51%.



(*S*)-**5aa**

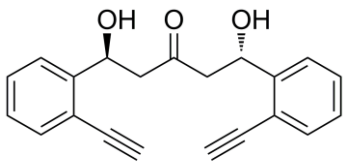
(*S*)-4-(2-Ethynylphenyl)-4-hydroxy-butan-2-one (5aa): Prepared following the Method-**A**; and purified by column chromatography using EtOAc/hexane and isolated as liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralcel OD-H column (hexane/2-propanol = 92:8, flow rate 1.0 mL/min, λ= 254 nm), t_R = 8.56 min (major), t_R = 9.71 min (minor). **$[\alpha]_D^{25}$ = –56.2°** (*c* = 0.42 g/100 mL, $CHCl_3$, **95% *ee***); IR (Neat): ν_{max} 3448, 3286 (O-H), 2925, 1709 (*C*=O), 1447, 1362, 1264, 1165, 1105, 1065, 763, 666, 651 and 625 cm^{-1}.



(*R*,*R*)-(+)-**6aa**

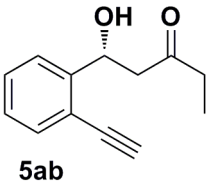
(*R*,*R*)-1,5-Bis-(2-ethynylphenyl)-1,5-dihydroxy-pentan-3-one (**6aa**): Prepared following Method-**A**, purified by column chromatography using EtOAc/hexane and isolated as gummy liquid. The enantiomeric excess (ee) was

determined by chiral stationary phase HPLC using a Daicel Chiralcel OD-H column (hexane/2-propanol = 92:8, flow rate 1.0 mL/min, λ= 254 nm), t_R = 20.10 min (minor), t_R = 22.95 min (major). **$[\alpha]_D^{25}$ = +122.0°** (*c* = 0.81 g/100 mL, $CHCl_3$, **>99% *ee***); IR (Neat): ν_{max} 3285 (O-H), 1708 (*C*=O), 1479, 1363, 1316, 1204, 1105, 1059, 763, 685, 650 and 612 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.59 (2H, d, *J* = 8.0 Hz), 7.47 (2H, d, *J* = 7.2 Hz), 7.39 (2H, t, *J* = 7.6 Hz), 7.24 (2H, t, *J* = 7.6 Hz)[Ar-*H*]; 5.64 (2H, d, *J* = 9.2 Hz, 2 x C*H*OH), 3.42 (2H, br s, 2 x O*H*), 3.34 (2H, s, 2 x C≡C*H*), 3.02 (2H, dd, *J* = 16.8, 2.0 Hz, 2 x COCH_2), 2.82 (2H, dd, *J* =17.2, 10.0 Hz, 2 x COCH_2); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 211.0 (C, *C*=O), 145.0 (2 x C), 132.9 (2 x CH), 129.4 (2 x CH), 127.3 (2 x CH), 125.2 (2 x CH), 118.9 (2 x C), 82.9 (2 x CH, 2 x Ar-C≡*C*H), 81.0 (2 x C, 2 x Ar-*C*≡CH), 67.8 (2 x CH, 2 x *C*HOH), 50.6 (2 x CH_2, 2 x CO*C*H_2); LRMS m/z 317.00 (M^+-1), calcd. for $C_{21}H_{18}O_3$ 318.1256; Anal. calcd. for $C_{21}H_{18}O_3$ (318.1256); C, 79.22; H, 5.70. Found: C, 79.32; H, 5.65%.



(*S*,*S*)-(–)-**6aa**

(*S*,*S*)-1,5-Bis-(2-ethynylphenyl)-1,5-dihydroxy-pentan-3-one (**6aa**): Prepared following Method-**A**, purified by column chromatography using EtOAc/hexane and isolated as gummy liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralcel OD-H column (hexane/2-propanol = 92:8, flow rate 1.0 mL/min, λ= 254 nm), t_R = 20.10 min (major), t_R = 22.95 min (minor). **$[\alpha]_D^{25}$ = –112.4°** (*c* = 0.27 g/100 mL, $CHCl_3$, **>99% *ee***); IR (Neat): ν_{max} 3285 (O-H), 1708 (*C*=O), 1479, 1363, 1316, 1204, 1105, 1059, 763, 685, 650 and 612 cm^{-1}.

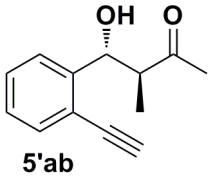


5ab

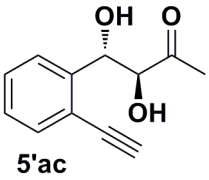
(*R*)-1-(2-Ethynylphenyl)-1-hydroxy-pentan-3-one (5ab): Prepared following the Method-**A**; purified by column chromatography using EtOAc/hexane and isolated as liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralpak AD-H column (hexane/2-propanol = 94:6, flow rate 1.0 mL/min, λ= 254 nm), t_R = 9.22 min (major), t_R = 10.44 min (minor). **$[\alpha]_D^{25}$ = +109.7°** (*c* = 0.43 g/100 mL,

$CHCl_3$, **99% *ee***); IR (Neat): ν_{max} 3449, 3291 (O-H), 3069, 2978, 2939, 2102, 1712 (*C*=O), 1448, 1408, 1373, 1311, 1203, 1113, 1070 and 761 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.59 (1H, br dd, *J* = 8.0, 0.5 Hz), 7.47 (1H, dd, *J* = 7.6, 1.2 Hz), 7.39 (1H, dt, *J* = 7.6, 1.3 Hz), 7.23 (1H, dt, *J* = 7.5, 1.3 Hz)[Ar-*H*]; 5.58 (1H, d, *J* = 9.2 Hz, C*H*OH), 3.63 (1H, br s, O*H*), 3.33 (1H, s, Ar-C≡C*H*), 3.00 (1H, dd, *J* = 17.4, 2.0 Hz, COCH_2), 2.69 (1H, dd, *J* =17.6, 10.0 Hz, COCH_2), 2.56–2.40 (2H, m, COC$H_2$$CH_3$), 1.08 (3H, t, *J* = 7.3 Hz, $COCH_2CH_3$); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 212.2 (C, *C*=O), 145.2 (C), 132.8 (CH), 129.4 (CH), 127.1 (CH), 125.2 (CH), 118.8 (C), 82.6 (CH, Ar-C≡*C*H), 81.1 (C, Ar-*C*≡CH), 67.9 (CH, *C*HOH), 49.4 (CH_2, CO*C*H_2), 36.6 (CH_2, CO*C*H_2CH_3), 7.5 (CH_3, $COCH_2CH_3$); LRMS m/z 203.00 (M+1), calcd. for $C_{13}H_{14}O_2$ 202.0994; Anal. calcd. for $C_{13}H_{14}O_2$ (202.0994); C, 77.20, H, 6.98; Found: C, 77.35; H, 6.87%.

(*3S,4R*)-4-(2-Ethynylphenyl)-4-hydroxy-3-methyl-butan-2-one (5'ab): Prepared following Method-**A**, purified by column chromatography using EtOAc/hexane and isolated as liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralpak AD-H column (hexane/2-propanol = 94:6, flow rate 1.0 mL/min, λ= 254 nm), t_R = 10.91 min (major), t_R = 12.43 min (minor). **$[\alpha]_D^{25}$ = +30.9°** (*c* = 0.13 g/100 mL, $CHCl_3$, **>99% *ee*** and **>99% *de***); IR (Neat): ν_{max} 3430, 3295 (O-H), 3065, 2975, 2934, 2104, 1707 (C=O), 1481, 1456, 1360, 1242, 1170, 1100, 1051, 1019, 955, 912, 833 and 764 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.49 (1H, dd, *J* = 8.0, 1.2 Hz), 7.47–7.45 (1H, m), 7.39 (1H, dt, *J* = 8.0, 1.2 Hz), 7.25 (1H, dt, *J* = 7.6, 1.2 Hz)[Ar-*H*]; 5.29 (1H, dd, *J* = 7.2, 3.4 Hz, C*H*OH), 3.35 (1H, s, Ar-C≡C*H*), 3.30 (1H, br s, O*H*), 3.09 (1H, quintet, *J* = 7.6 Hz, COC*H*CH_3), 2.16 (3H, s, COCH_3), 1.06 (3H, d, *J* = 7.2 Hz, COCHCH_3); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 213.6 (C, *C*=O), 144.4 (C), 132.9 (CH), 129.3 (CH), 127.5 (CH), 126.2 (CH), 120.3 (C), 82.4 (CH, Ar-C≡*C*H), 81.5 (C, Ar-*C*≡CH), 73.7 (CH, *C*HOH), 53.0 (CH, CO*C*HCH_3), 30.0 (CH_3, CO*C*H_3), 14.0 (CH_3, COCH*C*H_3); LRMS m/z 203.05 (M+1), calcd. for $C_{13}H_{14}O_2$ 202.0994; Anal. calcd. for $C_{13}H_{14}O_2$ (202.0994); C, 77.20, H, 6.98; Found: C, 77.38; H, 7.05%.

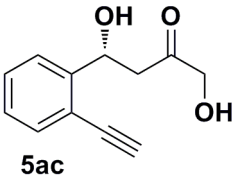


5'ab



5'ac

(*3S,4R*)-4-(2-Ethynylphenyl)-3,4-dihydroxy-butan-2-one (5'ac): Prepared following Method-**B**, purified by column chromatography using EtOAc/hexane and isolated as liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralpak AD-H column (hexane/2-propanol = 94:6, flow rate 1.0 mL/min, λ= 254 nm), t_R(*syn*) = 18.46 min (major), t_R(*syn*) = 23.66 min (minor); t_R(*anti*) = 26.86 min (major), t_R(*anti*) = 29.22 min (minor). **$[\alpha]_D^{25}$ = +72.1°** (*c* = 0.47 g/100 mL, $CHCl_3$, **93% *ee*** for major *anti*-isomer and **26% *ee*** for minor *syn*-isomer; and **50% *de***); IR (Neat): ν_{max} 3418, 3283 (O-H), 3067, 2926, 2099, 1960, 1715 (C=O), 1622, 1399, 1360, 1254, 1096, 1053 and 762 cm^{-1}; **^{1}H NMR ($CDCl_3$, 3:1 mixture of *anti:syn* diastereomers)** δ 7.59 (1H, d, *J* = 8.0 Hz), 7.54–7.50 (3H, m), 7.44–7.38 (2H, m), 7.31–7.26 (2H, m)[Ar-*H*]; 5.60 (1H, s, ArC*H*OH), 5.42 (1H, d, *J* = 4.0 Hz, ArC*H*OH), 4.75 (1H, d, *J* = 3.2 Hz, COC*H*OH), 4.52 (1H, s, COC*H*OH), 3.89 (1H, br s, OH), 3.74 (1H, br. s, OH), 3.45 (1H, s, Ar-C≡C*H*), 3.42 (1H, s, Ar-C≡C*H*), 3.16 (1H, br s, OH), 3.00 (1H, br s, OH), 2.37 (3H, s, COCH_3), 1.88 (3H, s, COCH_3); **^{13}C NMR ($CDCl_3$, DEPT-135, 3:1 mixture of *anti:syn* diastereomers)** δ 208.1 (C, *C*=O), 207.4 (C, C=O), 142.8 (C), 141.3 (C), 133.2 (CH), 132.9 (CH), 129.3 (2 x CH), 127.9 (CH), 127.6 (CH), 126.3 (CH), 126.0 (CH), 119.9 (C), 119.0 (C), 83.3 (CH, Ar-C≡*C*H), 83.2 (CH, Ar-C≡*C*H), 81.5 (C, Ar-*C*≡CH), 81.1 (C, Ar-*C*≡CH), 79.7 (CH, Ar*C*HOH), 79.4 (CH, Ar*C*HOH), 73.2 (CH, CO*C*HOH), 71.1 (CH, CO*C*HOH), 27.9 (CH_3, CO*C*H_3), 25.3 (CH_3, CO*C*H_3); LRMS m/z 205.20 (M+1), calcd. for $C_{12}H_{12}O_3$ 204.0786; Anal. calcd. for $C_{12}H_{12}O_3$ (204.0786); C, 70.57, H, 5.92; Found: C, 70.42; H, 5.85%.

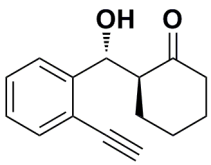


5ac

(*R*)-4-(2-Ethynylphenyl)-1,4-dihydroxy-butan-2-one (5ac): Prepared following Method-**A**, purified by column chromatography using EtOAc/hexane and isolated as liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralpak AD-H column (hexane/2-propanol = 90:10, flow rate 1.0 mL/min, λ= 254 nm), t_R = 16.11 min (major), t_R = 19.56 min (minor). **$[\alpha]_D^{25}$ = +35.2°** (*c* = 0.18 g/100 mL, $CHCl_3$, **90% *ee***); IR (Neat): ν_{max} 3397 (O-H), 3283, 3073, 2926, 2859, 1715

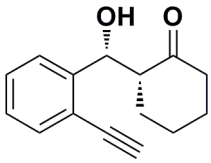
(C=O), 1622, 1449, 1389, 1263, 1161, 1069 and 762 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 7.56 (1H, d, *J* = 7.6 Hz), 7.47 (1H, d, *J* = 7.6 Hz), 7.40 (1H, t, *J* = 7.6 Hz), 7.24 (1H, t, *J* = 7.6 Hz) [Ar-*H*]; 5.62 (1H, dd, *J* = 9.6, 2.4 Hz), 4.28 (2H, ABq, *J* = 19.2 Hz), 3.38 (1H, s, Ar-C≡C*H*), 3.40-3.20 (2H, br s, 2 x OH), 2.90 (1H, dd, *J* = 16.4, 2.8 Hz), 2.76 (1H, dd, *J* = 16.4, 9.6 Hz); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 209.3 (C, *C*=O), 144.9 (C), 133.0 (CH), 129.5 (CH), 127.5 (CH), 125.1 (CH), 118.9 (C), 83.1 (CH, Ar-C≡*C*H), 80.9 (C, Ar-*C*≡CH), 68.8 (CH_2, CO*C*H_2OH), 67.9 (CH, Ar*C*HOH), 46.2 (CH_2, CO*C*H_2); LRMS m/z 205.20 (M+1), calcd. for $C_{12}H_{12}O_3$ 204.0786; Anal. calcd. for $C_{12}H_{12}O_3$ (204.0786); C, 70.57, H, 5.92; Found: C, 70.45; H, 5.86%.

(*2S,1'R*)-2-[(2-Ethynylphenyl)-hydroxymethyl]-cyclohexanone (*anti*–5ad): Prepared following Method-**A**, purified by column chromatography using EtOAc/hexane and isolated as liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralcel OD-H column (hexane/2-propanol = 92:8, flow rate 1.0 mL/min, λ= 254 nm), t_R = 8.42 min (major), t_R = 9.87 min (minor). **$[\alpha]_D^{25}$ = +41.6°** (*c* = 0.14 g/100 mL, $CHCl_3$, **96% *ee***); IR (Neat): ν_{max} 3520, 3442, 3285 (O-H), 2940, 2868, 1694 (C=O), 1445, 1409, 1311, 1230, 1128, 1037, 1017, 763, 652 and 625 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 7.52 (1H, d, *J* = 8.0 Hz), 7.47 (1H, d, *J* = 8.0 Hz), 7.39 (1H, t, *J* = 7.6 Hz), 7.24 (1H, t, *J* = 7.6 Hz)[Ar-*H*]; 5.39 (1H, d, *J* = 8.4 Hz, C*H*OH), 4.04 (1H, br s, O*H*), 3.27 (1H, s, Ar-C≡C*H*), 2.73–2.66 (1H, m), 2.46 (1H, d, *J* = 13.2 Hz), 2.34 (1H, dt, *J* = 13.2, 6.0 Hz), 2.09–2.04 (1H, m), 1.82–1.79 (1H, m), 1.74–1.66 (1H, m), 1.61–1.51 (3H, m); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 215.4 (C, *C*=O), 143.7 (C), 132.5 (CH), 129.3 (CH), 127.3 (CH), 126.4 (CH), 120.9 (C), 81.8 (CH, Ar-C≡*C*H), 81.7 (C, Ar-*C*≡CH), 71.6 (CH, *C*HOH), 57.7 (CH, CO*C*H-), 42.6 (CH_2), 30.4 (CH_2), 27.7 (CH_2), 24.8 (CH_2); LRMS m/z 228.20 (M^+), calcd. for $C_{15}H_{16}O_2$ 228.1150; Anal. calcd. for $C_{15}H_{16}O_2$ (228.1150); C, 78.92, H, 7.06; Found: C, 78.81; H, 7.15%.



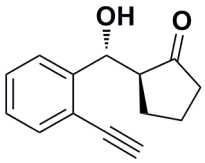
anti–**5ad**

(*2R,1'R*)-2-[(2-Ethynylphenyl)-hydroxymethyl]-cyclohexanone (*syn*–5ad): Prepared following Method-**A**, purified by column chromatography using EtOAc/hexane and isolated as liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralpak AS-H column (hexane/2-propanol = 94:6, flow rate 1.0 mL/min, λ= 254 nm), t_R = 10.65 min (minor), t_R = 11.98 min (major). **$[\alpha]_D^{25}$ = +108.8°** (*c* = 0.06 g/100 mL, $CHCl_3$, **91% *ee***); IR (Neat): ν_{max} 3459, 3291 (O-H), 3061, 2940, 2866, 1703 (C=O), 1605, 1449, 1308, 1235, 1130, 1065, 1032, 978, 887 and 762 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.55 (1H, d, *J* = 7.8 Hz), 7.46 (1H, d, *J* = 7.6 Hz), 7.37 (1H, t, *J* = 7.6 Hz), 7.22 (1H, t, *J* = 7.5 Hz)[Ar-*H*]; 5.80 (1H, br s, C*H*OH), 3.29 (1H, s, Ar-C≡C*H*), 3.19 (1H, br s, O*H*), 2.88 (1H, dd, *J* = 12.6, 5.2 Hz), 2.47–2.35 (2H, m), 2.10–2.04 (1H, m), 1.84–1.49 (5H, m); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 214.8 (C, *C*=O), 143.8 (C), 132.7 (CH), 128.7 (CH), 126.7 (CH), 126.5 (CH), 118.5 (C), 82.6 (CH, Ar-C≡*C*H), 81.2 (C, Ar-*C*≡CH), 68.7 (CH, *C*HOH), 54.6 (CH, CO*C*H), 42.5 (CH_2), 27.9 (CH_2), 25.9 (CH_2), 24.8 (CH_2); LRMS m/z 228.70 (M+1), calcd. for $C_{15}H_{16}O_2$ 228.1150; Anal. calcd. for $C_{15}H_{16}O_2$ (228.1150); C, 78.92, H, 7.06; Found: C, 78.82; H, 6.95%.



syn–**5ad**

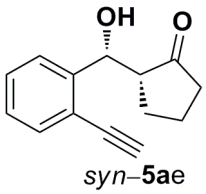
(*2S,1'R*)-2-[(2-Ethynylphenyl)-hydroxymethyl]-cyclopentanone (*anti*–5ae): Prepared following Method-**A**, purified by column chromatography using EtOAc/hexane and isolated as liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralpak AD-H column (hexane/2-propanol = 90:10, flow rate 1.0 mL/min, λ= 254 nm), t_R = 10.51 min (major), t_R = 12.42 min (minor). **$[\alpha]_D^{25}$ = –23.8°** (*c* = 0.71g/100 mL, $CHCl_3$, **95% *ee***); IR (Neat): ν_{max} 3281 (O-H), 3065, 2967, 2882, 2102, 1937, 1728 (C=O), 1622, 1402, 1159, 1026, 841 and 766 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.56 (1H, dd, *J* = 8.0, 0.8 Hz), 7.48 (1H, dd, *J* = 8.0, 1.2 Hz), 7.41 (1H, dt, *J* = 8.0, 1.2 Hz), 7.25 (1H, dt, *J* = 7.6, 1.2 Hz)[Ar-*H*]; 5.33 (1H, d, *J* = 9.6 Hz, C*H*OH), 4.58 (1H, br s, O*H*), 3.27 (1H, s, Ar-C≡C*H*), 2.50–2.40 (2H, m), 2.36–2.26 (1H, m), 2.05–1.95 (1H, m), 1.80–1.65 (3H, m); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 223.2 (C, *C*=O), 143.8 (C),



anti–**5ae**

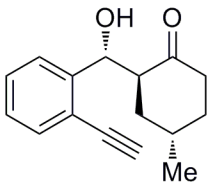
132.8 (CH), 129.5 (CH), 127.6 (CH), 126.5 (CH), 120.4 (C), 81.9 (C, Ar-*C*≡CH), 81.8 (CH, Ar-C≡*C*H), 71.8 (CH, *C*HOH), 55.7 (CH), 38.7 (CH_2), 26.4 (CH_2), 20.5 (CH_2); LRMS m/z 213.10 (M-1), calcd. for $C_{14}H_{14}O_2$ 214.0994; Anal. calcd. for $C_{14}H_{14}O_2$ (214.0994); C, 78.48, H, 6.59; Found: C, 78.32; H, 6.65%.

(*2R,1'R*)-2-[(2-Ethynylphenyl)-hydroxymethyl]-cyclopentanone (*syn*–5ae): Prepared following Method-**B,** purified by column chromatography using EtOAc/hexane and isolated as liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralpak AS-H column (hexane/2-propanol = 90:10, flow rate 1.0 mL/min, λ= 254 nm), t_R = 11.52 min. , t_R = 14.61 min., **0% *ee***; IR (Neat): ν_{max} 3443, 3291 (O-H), 3065, 2965, 2882, 1736 (C=O), 1622, 1478, 1449, 1402, 1337, 1269, 1204, 1157, 1107, 1026, 968, 883, 841 and 762 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.57 (1H, d, *J* = 7.6 Hz), 7.47 (1H, dd, *J* = 7.6, 1.2 Hz), 7.39 (1H, dt, *J* = 7.6, 0.8 Hz), 7.24 (1H, dt, *J* = 7.6, 1.2 Hz)[Ar-*H*]; 5.78 (1H, s, C*H*OH), 3.36 (1H, s, Ar-C≡C*H*), 2.77–2.72 (1H, m), 2.41–2.33 (2H, m), 2.20–2.10 (1H, m), 2.03–1.95 (2H, m), 1.76–1.65 (2H, m); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 220.1 (C, *C*=O), 145.0 (C), 132.7 (CH), 129.0 (CH), 127.0 (CH), 125.5 (CH), 118.8 (C), 83.0 (CH, Ar-C≡*C*H), 80.9 (C, Ar-*C*≡CH), 69.2 (CH, *C*HOH), 54.3 (CH), 39.0 (CH_2), 22.6 (CH_2), 20.3 (CH_2); LRMS m/z 213.10 (M-1), calcd. for $C_{14}H_{14}O_2$ 214.0994; Anal. calcd. for $C_{14}H_{14}O_2$ (214.0994); C, 78.48, H, 6.59; Found: C, 78.36; H, 6.51%.



syn–**5ae**

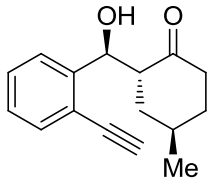
(2S,4S,1'R)*-2-[(2-Ethynylphenyl)-hydroxymethyl]-4-methyl-cyclohexanone [*(2S,4S,1'R)*–5af]:** Prepared following Method-**A**, purified by column chromatography using EtOAc/hexane and isolated as a yellow liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralcel OJ-H column (hexane/2-propanol = 96:4, flow rate 1.0 mL/min, λ= 254 nm), t_R = 17.37 min (minor), t_R = 18.55 min (major). **$[\alpha]_D^{25}$ = –8.1°** (*c* = 0.15 g/100 mL, $CHCl_3$, **>99% *de and **96% *ee***); IR (Neat): ν_{max} 3443, 3267 (O-H), 2961, 2876, 2830, 1708 (C=O),



(2*S*, 4*S*, 1'*R*)–**5af**

1452, 1379, 1327, 1187, 1125, 1099, 1038, 951 and 763 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 7.51–7.47 (2H, m), 7.39 (1H, t, *J* = 7.6 Hz), 7.27–7.23 (1H, m)[Ar-*H*]; 5.40 (1H, d, *J* = 8.4 Hz, C*H*OH), 3.71 (1H, br s, OH), 3.30 (1H, s, Ar-C≡C*H*), 2.86 (1H, dd, *J* = 8.8, 2.8 Hz), 2.53–2.40 (2H, m), 2.17–2.10 (1H, m), 2.00–1.92 (1H, m), 1.76–1.64 (2H, m), 1.40–1.34 (1H, m), 1.01 (3H, d, *J* = 6.8 Hz, C*H*$_3$); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 215.3 (C, *C*=O), 144.0 (C), 132.7 (CH), 129.4 (CH), 127.5 (CH), 126.4 (CH), 120.7 (C), 81.9 (CH, Ar-C≡*C*H), 81.7 (C, Ar-*C*≡CH), 72.0 (CH, *C*HOH), 54.0 (CH), 38.4 (CH_2), 36.1 (CH_2), 33.6 (CH_2), 26.9 (CH), 18.7 (CH_3); LRMS m/z 243.10 (M+1), calcd. for $C_{16}H_{18}O_2$ 242.1307; Anal. calcd. for $C_{16}H_{18}O_2$ (242.1307); C, 79.31, H, 7.49; Found: C, 79.45; H, 7.41%.

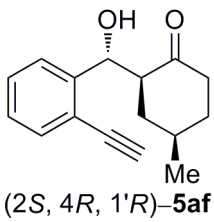
(2*R*,4*R*)-2-((*S*)-(2-ethynylphenyl)(hydroxy)methyl)-4-methylcyclohexanone (5af):



(2*R*, 4*R*, 1'*S*)–**5af**

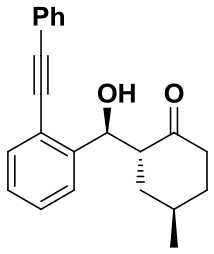
Prepared following Method-**A**, purified by column chromatography using EtOAc/hexane and isolated as liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralpak OJ-H column (hexane/2-propanol = 96:4, flow rate 1.0 mL/min, λ= 254 nm), t_R = 15.38 min (major), t_R = 16.96 min (minor). **$[\alpha]_D^{25}$ = +3.3° (*c* = 0.67 g/100 mL, $CHCl_3$, >99% *de* and 96% *ee*)**; IR (Neat): λ_{max} 3499 (O-H), 2951, 1707 (C=O), 1493, 1443, 1035, 757, 664 and 647 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 7.47 (1H, d, *J* = 7.6 Hz), 7.46 (1H, d, *J* = 7.2 Hz), 7.36 (1H, t, *J* = 7.6 Hz), 7.22 (1H, t, *J* = 7.6 Hz), 5.40 (1H, d, *J* = 8.8 Hz), 3.76 (1H, br s), 3.30 (1H, s, Ar-C≡C*H*), 2.84 (1H, q, *J* = 8.8 Hz), 2.47–2.42 (2H, m), 2.15–2.12 (1H, m), 1.97–1.91 (1H, m), 1.73–1.62 (2H, m), 1.37–1.31 (1H, m), 1.00 (3H, d, *J* = 6.8 Hz, C*H*$_3$); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 215.2 (C, *C*=O), 144.0 (C), 132.7 (CH), 129.4 (CH), 127.4 (CH), 126.3 (CH), 120.7 (C), 81.9 (CH, Ar-C≡*C*H), 81.6 (C, Ar-*C*≡C*H*), 71.9 (CH, *C*HOH), 54.1 (CH), 38.4 (CH_2), 36.1 (CH_2), 33.6 (CH_2), 26.9 (CH), 18.7 (CH_3); LRMS m/z 243.10 (M+1), calcd. for $C_{16}H_{18}O_2$ 242.1307; Anal. calcd. for $C_{16}H_{18}O_2$ (242.1307); C, 79.31, H, 7.49; Found: C, 79.26; H, 7.55%.

(2S,4R,1'R)*-2-[(2-Ethynylphenyl)-hydroxymethyl]-4-methyl-cyclohexanone [*(2S,4R,1'R)*–5af]:** Prepared following Method-**B**, purified by column chromatography using EtOAc/hexane and isolated as liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralpak AD-H column (hexane/2-propanol = 94:6, flow rate 1.0 mL/min, λ= 254 nm), t_R = 8.67 min (minor), t_R = 11.43 min (major). **$[\alpha]_D^{25}$ = –172.7°** (*c* = 0.14 g/100 mL, $CHCl_3$, **77% *ee); IR (Neat): ν_{max} 3415, 3298 (O-H), 3279, 2955, 2874, 1704 (C=O), 1451, 1306, 1258, 1220, 1198, 1121 1077, 1021 and 763 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.53 (1H, d, *J* = 7.6 Hz), 7.47 (1H, dd, *J* = 7.6, 1.2 Hz), 7.38 (1H, dt, *J* = 7.6, 1.2 Hz), 7.23 (1H, dt, *J* = 7.6, 1.2 Hz)[Ar-*H*]; 5.79 (1H, s, C*H*OH), 3.31 (1H, s, Ar-C≡C*H*), 3.14–3.09 (1H, m), 3.03 (1H, d, *J* = 2.4 Hz), 2.59–2.51 (1H, m), 2.38–2.31 (1H, m), 2.13–2.01 (2H, m), 1.95–1.88 (1H, m), 1.79–1.74 (1H, m), 1.35–1.29 (1H, m), 1.03 (3H, d, *J* = 6.8 Hz, C*H*$_3$); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 215.3 (C, *C*=O), 143.7 (C), 132.9 (CH), 128.9 (CH), 126.8 (CH), 126.6 (CH), 118.6 (C), 82.6 (CH, Ar-C≡*C*H), 81.3 (C, Ar-*C*≡CH), 69.2 (CH, *C*HOH), 50.2 (CH), 38.3 (CH_2), 33.1 (CH_2), 31.7 (CH_2), 26.7 (CH), 18.3 (CH_3); LRMS m/z 243.10 (M+1), calcd. for $C_{16}H_{18}O_2$ 242.1307; Anal. calcd. for $C_{16}H_{18}O_2$ (242.1307); C, 79.31, H, 7.49; Found: C, 79.45; H, 7.53%.



(2*S*, 4*R*, 1'*R*)–**5af**

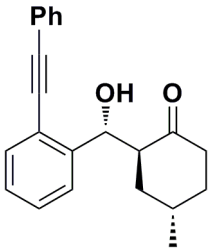
(2*R*, 4*R*)-2-[(*S*)-Hydroxy-(2-(phenylethynyl)phenyl)methyl]-4-methylcyclohexanone (5bf): Prepared following Method-**A**, purified by column chromatography using EtOAc/hexane and isolated as liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralpak AD-H column (hexane/2-propanol = 94:6, flow rate 1.0 mL/min, λ= 254 nm), t_R = 18.33 min (major), t_R = 22.77 min (minor). **$[\alpha]_D^{25}$ = +109.2° (*c* = 0.26 g/100 mL, $CHCl_3$, >99% *de* and 90% *ee*);** IR (Neat): λ_{max} 3353 (O-H), 2929, 1711 (C=O), 1493, 1038, 757, 686 and 633 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.56-7.54 (4H, m), 7.41-7.38 (4H, m), 7.29 (1H, t, *J* = 6.0 Hz), 5.53-5.51 (1H, m), 2.96 (1H, q, *J* = 6.4 Hz), 2.50 (2H, t, *J* = 5.2 Hz), 2.22–2.18 (1H, m), 1.98–1.95 (1H, m), 1.81–1.76 (1H, m), 1.68–1.66 (1H, m), 1.47-



(2*R*, 4*R*, 1'*S*)-**5bf**

1.45 (1H, m) 1.00-0.98 (3H, br s, CH_3); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 215.1 (C, *C*=O), 143.6 (C), 132.2 (CH), 131.5 (2 x CH), 129.0 (CH), 128.5 (CH), 128.5 (2 x CH), 127.6 (CH), 126.6 (CH), 123.0 (C), 121.8 (C), 94.1 (CH, Ar-C≡*C*H), 87.5 (C, Ar-*C*≡CH), 72.4 (CH, *C*HOH), 54.4 (CH), 38.6 (CH_2), 36.6 (CH_2), 33.9 (CH_2), 27.1 (CH), 19.0 (CH_3); LRMS m/z 319.20 (M+1), calcd. for $C_{22}H_{22}O_2$ 318.1620; Anal. calcd. for $C_{22}H_{22}O_2$ (318.1620); C, 82.99, H, 6.96; Found: C, 82.85; H, 6.88%.

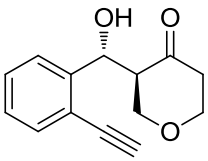
(2*S*,4*S*)-2-[(*R*)-Hydroxy-(2-(phenylethynyl)phenyl)methyl]-4-methylcyclohexanone



(*2S, 4S, 1'R*)-**5bf**

(5bf): Prepared following Method-**A**, purified by column chromatography using EtOAc/hexane and isolated as liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralpak AD-H column (hexane/2-propanol = 94:6, flow rate 1.0 mL/min, λ= 254 nm), t_R = 18.33 min (minor), t_R = 22.77 min (major). **$[\alpha]_D^{25}$ = –89.2° (*c* = 0.37 g/100 mL, $CHCl_3$, >99% *de* and 86% *ee*);** IR (Neat): λ_{max} 3353 (O-H), 2929, 1711 (C=O), 1493, 1038, 757, 686 and 633 cm^{-1}.

(*S*)-3-((*R*)-(2-ethynylphenyl)(hydroxy)methyl)dihydro-2*H*-pyran-4(3*H*)-one (5ag):

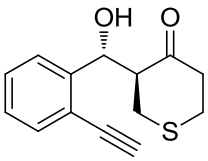


anti-5ag

Prepared following Method-**A**, purified by column chromatography using EtOAc/hexane and isolated as liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralpak AD-H column (hexane/2-propanol = 90:10, flow rate 1.0 mL/min, λ= 254 nm), t_R(*syn*) = 9.31 min (major), t_R(*syn*) = 10.84 min (minor); t_R(*anti*) = 13.79 min (minor), t_R(*anti*) = 15.17 min (major). **$[\alpha]_D^{25}$ = +206.3° (*c* = 0.06 g/100 mL, $CHCl_3$, 93% *ee*);** IR (Neat): λ_{max} 3423 (O-H), 1708 (C=O), 1208, 760, 684, 666, 648 and 635 cm^{-1}; ^{1}H NMR ($CDCl_3$, **8.2:1 mixture of *anti:syn* diastereomers**) δ 7.54 (1H, d, *J* = 8.0 Hz), 7.50 (1H, d, *J* = 7.6 Hz), 7.47 (2H, d, *J* = 7.6 Hz), 7.42-7.35 (2H, m), 7.27-7.21 (2H, m) [Ar-*H*], 5.84 (1H, br s), 5.39 (1H, br d, *J* = 7.2 Hz), 4.22-4.16 (2H, m), 3.91 (1H, br s), 3.82 (2H, d, *J* = 8.4 Hz), 3.79-3.68 (3H, m), 3.60 (1H, dd, *J* = 11.2, 10.0 Hz), 3.33 (1H, s, Ar-C≡C*H*), 3.32 (1H, s, Ar-C≡C*H*), 3.19–3.14 (1H, m), 3.04–2.99 (2H, m), 2.71–2.62 (2H, m), 2.48 (2H, tt, *J* = 15.2, 3.2 Hz); ^{13}C NMR ($CDCl_3$,

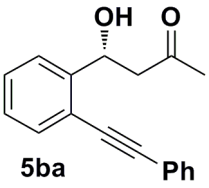
DEPT-135, **8.2:1 mixture of *anti:syn* diastereomers**) δ 210.1 (C, *C*=O), 209.0 (C), 142.9 (C), 142.8 (C), 133.0 (CH), 132.9 (CH), 129.6 (CH), 129.1 (CH), 127.8 (CH), 127.2 (CH), 126.5 (CH), 125.9 (CH), 120.2 (C), 118.8 (C), 83.1 (CH, Ar-C≡*CH*), 82.5 (CH, Ar-C≡*CH*), 81.3 (C, Ar-*C*≡C*H*), 81.0 (C, Ar-*C*≡C*H*), 70.0 (CH_2), 69.4 (CH), 68.4 (CH_2), 68.3 (CH_2), 67.9 (CH_2), 67.8 (CH), 58.2 (CH), 55.3 (CH), 43.1 (CH_2), 43.0 (CH_2); LRMS m/z 231.10 (M+1), calcd. for $C_{14}H_{14}O_3$ 230.0943; Anal. calcd. for $C_{14}H_{14}O_3$ (230.0943); C, 73.03, H, 6.13; Found: C, 73.21; H, 6.18%.

(*S*)-3-((*R*)-(2-ethynylphenyl)(hydroxy)methyl)dihydro-2*H*-thiopyran-4(3*H*)-one



***anti*-5ah**

(5ah): Prepared following method **A** in THF, purified by column chromatography using EtOAc/hexane and isolated as liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralpak AD-H column (hexane/2-propanol = 90:10, flow rate 1.0 mL/min, λ= 254 nm), t_R = 14.74 min (minor), t_R = 16.44 min (major); **$[\alpha]_D^{25}$ = +26.2° (*c* = 0.16 g/100 mL, $CHCl_3$, 99% *de*, 88% *ee*);** IR (Neat): λ_{max} 3428 (O-H), 2924, 1703 (C=O), 1425, 1287, 1107, 1018 and 762 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.54 (1H, d, *J* = 7.5 Hz), 7.49 (1H, d, *J* = 8.0 Hz), 7.41 (1H, t, *J* = 7.5 Hz), 7.27 (1H, t, *J* = 7.5 Hz) [Ar-*H*]; 5.48 (1H, dd, *J* = 8.0, 3.5 Hz), 3.75-3.71 (1H, m, *OH*), 3.32 (1H, s, Ar-C≡C*H*), 3.12-3.08 (1H, m), 3.02-2.94 (2H, m), 2.85-2.78 (3H, m), 2.53-2.49 (1H, m); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 212.0 (C, *C*=O), 142.8 (C), 132.8 (CH), 129.6 (CH), 127.8 (CH), 126.6 (CH), 120.7 (C), 82.5 (CH, Ar-C≡*CH*), 81.5 (C, Ar-*C*≡C*H*), 71.3 (CH), 59.9 (CH), 45.0 (CH_2), 32.8 (CH_2), 30.9 (CH_2); LRMS m/z 247.20 (M+1), calcd. for $C_{14}H_{14}O_2S$ 246.0715; Anal. calcd. for $C_{14}H_{14}O_2S$ (246.0715); C, 68.26, H, 5.73; Found: C, 68.15; H, 5.78%.

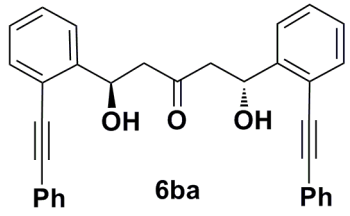


5ba

(*R*)-4-Hydroxy-4-(2-phenylethynylphenyl)-butan-2-one (5ba): Prepared following Method-**B,** purified by column chromatography using EtOAc/hexane and isolated as white solid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralcel AD-H column (hexane/2-propanol = 94:6, flow rate 1.0 mL/min, λ= 254 nm), t_R = 13.52 min (major), t_R = 15.56 min (minor). **$[\alpha]_D^{25}$ = +52.2°** (*c* = 0.54

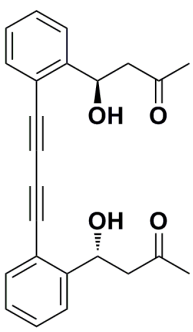
g/100 mL, $CHCl_3$, **76% *ee***); IR (Neat): ν_{max} 3352 (O-H), 2929, 1706 (*C*=O), 1494, 1406, 1365, 1260, 1186, 1164, 1102, 1064, 756, 690 and 664 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.61 (1H, d, *J* = 8.0 Hz), 7.51–7.47 (3H, m), 7.40–7.34 (4H, m), 7.26 (1H, t, *J* = 8.0 Hz)[Ar-*H*]; 5.69 (1H, d, *J* = 8.0 Hz, C*H*OH), 3.48 (1H, br s, O*H*), 3.07 (1H, dd, *J* = 17.6, 1.6 Hz, COCH_2), 2.77 (1H, dd, *J* =17.6, 9.6 Hz, COCH_2), 2.19 (3H, s, COCH_3); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 209.2 (C, *C*=O), 144.5 (C), 132.0 (CH), 131.4 (2 x CH), 128.9 (CH), 128.51 (CH), 128.45 (2 x CH), 127.2 (CH), 125.1 (CH), 122.8 (C), 119.9 (C), 94.9 (C, Ar-C≡*C*Ph), 86.6 (C, Ar-C≡*C*Ph), 68.0 (CH, *C*HOH), 50.9 (CH_2, CO*C*H_2), 30.7 (CH_3, CO*C*H_3); LRMS m/z 263.00 (M-1), calcd. for $C_{18}H_{16}O_2$ 264.1150; Anal. calcd. for $C_{18}H_{16}O_2$ (264.1150); C, 81.79; H, 6.10. Found: C, 81.65; H, 6.22%.

(*R*,*R*)-1,5-Dihydroxy-1,5-bis-(2-phenylethynylphenyl)-pentan-3-one (6ba): Prepared following Method-**A,** purified by column chromatography using EtOAc/hexane and isolated as yellow gummy liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralpak AD-H column (hexane/2-propanol = 94:6, flow rate 1.0 mL/min, λ= 254 nm), t_R = 56.27 min (minor), t_R = 61.58 min (major), **>99.9% *ee***. IR (Neat): ν_{max} 3410 (O-H), 3059, 2926, 2216, 1960, 1713 (C=O), 1597, 1493, 1447, 1389, 1267, 1063, 756 and 691 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.58 (4H, d, *J* = 7.0 Hz), 7.51–7.48 (8H, m), 7.34–7.32 (6H, m)[Ar-*H*]; 5.78 (2H, dd, *J* = 9.9, 2.1 Hz, 2 x C*H*OH), 3.20 (2H, br s, O*H*), 3.09 (2H, dd, *J* = 16.8, 2.4 Hz, COCH_2), 2.86 (2H, dd, *J* =16.8, 9.8 Hz, COCH_2); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 210.8 (C, *C*=O), 144.4 (2 x C), 132.1 (2 x CH), 131.5 (4 x CH), 128.9 (2 x CH), 128.6 (2 x CH), 128.5 (4 x CH), 127.3 (2 x CH), 125.1 (2 x CH), 122.8 (2 x C), 120.0 (2 x C), 95.2 (2 x C, 2 x Ar-*C*≡CPh), 86.5 (2 x C, 2 x Ar-C≡*C*Ph), 68.1 (2 x CH, 2 x *C*HOH), 51.1 (2 x CH_2, 2 x CO*C*H_2); LRMS m/z 471.30 (M^+ +1), calcd. for $C_{33}H_{26}O_3$ 470.1882; Anal. calcd. for $C_{33}H_{26}O_3$ (470.1882); C, 84.23; H, 5.57. Found: C, 84.15; H, 5.63%.

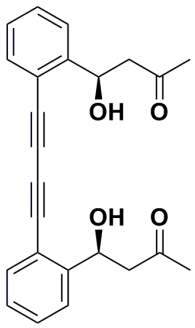


6ba

(*R*,*R*)-4-Hydroxy-4-(2-{4-[2-(1-hydroxy-3-oxobutyl)phenyl]buta-1,3-diynyl}-phenyl)butan-2-one (5ca, major) and (*R*,*S*)-4-Hydroxy-4-(2-{4-[2-(1-hydroxy-3-oxobutyl)phenyl]buta-1,3-diynyl}-phenyl)butan-2-one (5ca, minor): Prepared following Method-**A**, purified by column chromatography using EtOAc/hexane and isolated as yellow liquid. The enantiomeric excess (ee) was determined by chiral stationary phase HPLC using a Daicel Chiralcel OJ-H column (hexane/2-propanol = 94:6, flow rate 1.0 mL/min, λ= 254 nm), t_R = 44.46 min (minor), t_R = 57.34 min (major). **$[\alpha]_D^{25}$ = +69.5°** (*c* = 0.27 g/100 mL, $CHCl_3$, **21:1 *dr*** and **>99% *ee***); IR (Neat): ν_{max} 3432 (O-H), 3065, 2920, 2213, 2143, 1715 (C=O), 1711 (C=O), 1476, 1447, 1362, 1233, 1163, 1107, 1067, 955, 887, 818 and 762 cm^{-1}; ^1H NMR ($CDCl_3$, **major isomer**) δ 7.61 (2H, d, *J* = 7.8 Hz), 7.51 (2H, d, *J* = 7.2 Hz), 7.41 (2H, dt, *J* = 7.6, 1.0 Hz), 7.25 (2H, dt, *J* = 7.6, 1.2 Hz)[Ar-*H*]; 5.56 (2H, dd, *J* = 9.6, 2.0 Hz, 2 x C*H*OH), 3.69 (2H, br s, 2 x O*H*), 2.99 (2H, dd, *J* = 17.4, 2.4 Hz, COCH_2), 2.76 (2H, dd, *J* =17.4, 9.6 Hz, COCH_2), 2.24 (6H, s, 2 x COCH_3); ^{13}C NMR ($CDCl_3$, DEPT-135, **major isomer**) δ 209.15 (2 x C, 2 x *C*=O), 146.0 (2 x C), 133.23 (2 x CH), 129.9 (2 x CH), 127.3 (2 x CH), 125.5 (2 x CH), 118.42 (2 x C), 80.2 (2 x C), 78.5 (2 x C), 67.8 (2 x CH, 2 x *C*HOH), 50.9 (2 x CH_2, 2 x CO*C*H_2), 30.6 (2 x CH_3, 2 x CO*C*H_3); LRMS m/z 375.30 (M+1), calcd. for $C_{24}H_{22}O_4$ 374.1518; Anal. calcd. for $C_{24}H_{22}O_4$ (374.1518); C, 76.99; H, 5.92. Found: C, 76.85; H, 5.98%.

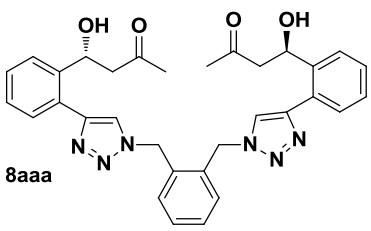


(*R*,*R*)-**5ca**



(*R*,*S*)-**5ca**

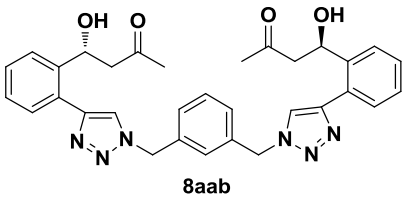
(4*R*,4'*R*)-4,4'-((1,1'-(1,2-phenylenebis(methylene))bis(1*H*-1,2,3-triazole-4,1-diyl))bis(2,1-phenylene))bis(4-hydroxybutan-2-one) (8aaa): Prepared following Method-**C**, purified by column chromatography using EtOAc/hexane and isolated as liquid. **$[\alpha]_D^{25}$ = +60.5° (*c* = 0.385 g/100 mL, $CHCl_3$, 95% *ee*);** IR (Neat): λ_{max} 3464 (O-H), 2359, 1708 (C=O), 1361, 1075, 911, 733, 681 and 673 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.72 (1H, s),



8aaa

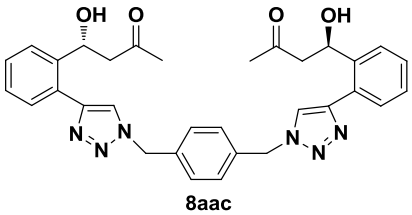
7.53 (1H, d, *J* = 7.6 Hz), 7.41-7.38 (1H, m), 7.34-7.29 (3H, m), 7.19 (1H, t, *J* = 7.6 Hz), 5.68 (2H, ABq, *J* = 15.2 Hz, NC*H*$_2$Ar), 5.31 (1H, t, *J* = 5.6 Hz, C*H*OH), 2.89 (2H, d, *J* = 6.0 Hz), 2.11 (3H, s, C*H*$_3$CO); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 208.7 (C, *C*=O), 147.3 (C), 140.8 (C), 133.1 (C), 130.6 (CH), 129.9 (CH), 129.4 (CH), 128.8 (CH), 127.9 (C), 127.6 (CH), 126.6 (CH), 122.4 (CH), 67.2 (CH), 51.2 (CH_2), 50.3 (CH_2), 30.6 (CH_3); HRMS m/z 587.2383 (M+Na), calcd. for $C_{32}H_{32}N_6O_4Na$ 587.2383; Anal. calcd. for $C_{32}H_{32}N_6O_4$ (564.2485); C, 68.07; H, 5.71; N, 14.88; Found: C, 67.95; H, 5.69; N, 14.92%.

(4*R*,4'*R*)-4,4'-((1,1'-(1,3-phenylenebis(methylene))bis(1*H*-1,2,3-triazole-4,1-diyl))bis(2,1-phenylene))bis(4-hydroxybutan-2-one) (8aab): Prepared following



8aab

Method-**C**, purified by column chromatography using EtOAc/hexane and isolated as solid. **$[\alpha]_D^{25}$ = +48.5° (*c* = 1.714 g/100 mL, $CHCl_3$, 95% *ee*);** IR (Neat): λ_{max} 3446 (O-H), 2929, 1709 (C=O), 1357, 1218, 1075, 760, 659 and 652 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 7.78 (1H, s), 7.52 (1H, d, *J* = 7.2 Hz), 7.35-7.30 (2H, m), 7.28-7.25 (2H, m), 7.20-7.19 (2H, m), 5.51 (2H, s, NC*H*$_2$Ar), 5.32-5.30 (1H, m, C*H*OH), 4.80 (1H, br s, OH), 2.89-2.87 (2H, m), 2.10 (3H, s, COC*H*$_3$); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 208.7 (C, *C*=O), 147.2 (C), 140.8 (C), 135.6 (C), 129.7 (CH), 129.3 (CH), 128.7 (CH), 128.1 (CH), 128.0 (C), 127.5 (CH), 127.2 (CH), 126.5 (CH), 122.3 (CH), 67.1 (CH), 53.5 (CH_2), 50.3 (CH_2), 30.6 (CH_3); HRMS m/z 587.2383 (M+Na), calcd. for $C_{32}H_{32}N_6O_4Na$ 587.2383; Anal. calcd. for $C_{32}H_{32}N_6O_4$ (564.2485); C, 68.07; H, 5.71; N, 14.88; Found: C, 68.12; H, 5.75; N, 14.78%.

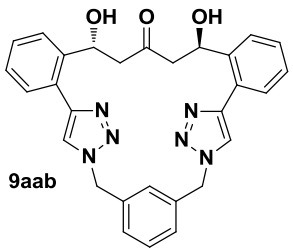


8aac

(4*R*,4'*R*)-4,4'-((1,1'-(1,4-phenylenebis(methylene))bis(1*H*-1,2,3-triazole-4,1-diyl))bis(2,1-phenylene))bis(4-hydroxybutan-2-one) (8aac): Prepared following Method-**C**, purified by column chromatography using EtOAc/hexane and isolated as liquid. **$[\alpha]_D^{25}$ = +47.4° (*c* = 0.80 g/100 mL, $CHCl_3$, 95% *ee*);** IR (Neat): λ_{max} 3421 (O-H), 2928, 1710 (C=O),

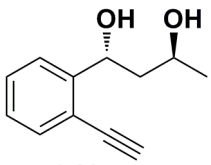
1356, 1109, 1077, 764, 642 and 611 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.74 (1H, s), 7.52 (1H, d, *J* = 8.0 Hz), 7.36-7.30 (2H, m), 7.28 (2H, m), 7.21 (1H, t, *J* = 7.2 Hz), 5.51 (2H, s, NC*H*$_2$Ar), 5.31 (1H, t, *J* = 6.4 Hz, C*H*OH), 2.91 (2H, d, *J* = 6.4 Hz), 2.11 (3H, s, COC*H*$_3$); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 208.7 (C, *C*=O), 147.4 (C), 140.8 (C), 135.1 (C), 129.3 (CH), 128.7 (3 x CH), 128.0 (C), 127.5 (CH), 126.5 (CH), 122.1 (CH), 67.2 (CH), 53.5 (CH_2), 50.1 (CH_2), 30.6 (CH_3); HRMS m/z 587.2383 (M+Na), calcd. for $C_{32}H_{32}N_6O_4Na$ 587.2383; Anal. calcd. for $C_{32}H_{32}N_6O_4$ (564.2485); C, 68.07, H, 5.71; N, 14.88; Found: C, 68.15; H, 5.75; N, 14.76%.

***(R, R)*-Cyclic double click product (9aab):** Prepared following Method-**D**, purified by column chromatography using EtOAc/hexane and isolated as white solid. **$[\alpha]_D^{25}$ = +3.0° (*c* = 0.42 g/100 mL, $CHCl_3$, 99% *ee*);** IR (Neat): λ_{max} 3430, 2360, 1654 (C=O), 907, 731, 659 and 650 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.78 (1H, s), 7.63 (1H, d, *J* = 7.6 Hz), 7.51 (1H, d, *J* = 7.2 Hz), 7.49-7.38 (2H, m), 7.32 (1H, t, *J* = 7.2 Hz), 7.28 (1H, s), 5.64-5.51 (2H, m), 5.37-5.29 (1H, m), 4.86 (1H, brs), 3.09-2.89 (2H, m); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 210.2 (C, *C*=O), 147.4 (C), 141.6 (C), 136.0 (C), 129.7 (CH), 129.5 (CH), 129.1 (CH), 128.2 (CH), 127.7 (CH), 127.4 (C), 127.4 (CH), 126.0 (CH), 122.4 (CH), 68.8 (CH), 53.7 (CH_2), 51.8 (CH_2); HRMS m/z 529.1957 (M+Na), calcd. for $C_{29}H_{26}O_3Na$ 529.1964.



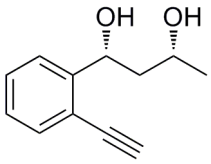
9aab

(*R,S*)-1-(2-Ethynylphenyl)-butane-1,3-diol (*anti*–10aa): Prepared following Method-**E,** purified by column chromatography using EtOAc/hexane and isolated as liquid. **$[\alpha]_D^{25}$ = +58.6°** (*c* = 0.27 g/100 mL, $CHCl_3$, **93% *ee***); IR (Neat): ν_{max} 3293 (O-H), 3063, 2973, 2903, 2103, 1698, 1447, 1373, 1318, 1208, 1130, 1069, 932, 847 and 763 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.57 (1H, d, *J* = 8.4 Hz), 7.46 (1H, d, *J* = 7.2 Hz), 7.38 (1H, t, *J* = 7.2 Hz), 7.22 (1H, t, *J* = 7.2 Hz)[Ar-*H*]; 5.38 (1H, d, *J* = 10.0 Hz, C*H*OH), 4.21–4.11 (1H, m), 3.79 (1H, br s, O*H*), 3.43 (1H, br s, OH), 3.32 (1H, s, Ar-C≡C*H*), 1.92–1.85 (1H, m), 1.76–1.70 (1H, m), 1.21 (3H, d, *J* = 6.0 Hz); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 146.8 (C), 132.7 (CH), 129.4 (CH), 127.0 (CH), 125.2 (CH), 118.9 (C), 82.2 (CH, Ar-C≡*C*H), 81.3



***anti*-10aa**

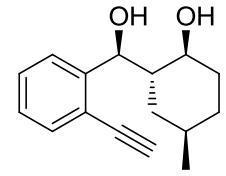
(C, Ar-*C*≡CH), 72.7 (CH, *C*HOH), 69.0 (CH, *C*HOH), 45.9 (CH_2), 23.9 (CH_3); LRMS m/z 188.95 (M-1), calcd. for $C_{12}H_{14}O_2$ 190.0994; Anal. calcd. for $C_{12}H_{14}O_2$ (190.0994); C, 76.57; H, 6.43. Found: C, 75.68; H, 7.51%.



syn-**10aa**

(*R*,*R*)-1-(2-Ethynylphenyl)-butane-1,3-diol (*syn*–10aa): Prepared following Method-**F,** purified by column chromatography using EtOAc/hexane and isolated as liquid. **$[\alpha]_D^{25}$ = –43.2°** (*c* = 0.21 g/100 mL, $CHCl_3$, 95% ee); IR (Neat): ν_{max} 3293 (O-H), 3065, 2971, 2917, 2103, 1644, 1447, 1420, 1377, 1335, 1109, 1071, 974, 937, 866, 814 and 760 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.61 (1H, d, *J* = 7.2 Hz), 7.47 (1H, d, *J* = 7.6 Hz), 7.39 (1H, t, *J* = 7.2 Hz), 7.23 (1H, t, *J* = 7.2 Hz)[Ar-*H*]; 5.52 (1H, s, C*H*OH), 4.07 (1H, s), 3.43 (1H, br s, O*H*), 3.33 (1H, s, Ar-C≡C*H*), 2.53 (1H, br. s, OH), 2.00–1.90 (2H, m), 1.27 (3H, d, *J* = 6.0 Hz); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 146.8 (C), 132.9 (CH), 129.2 (CH), 126.9 (CH), 125.4 (CH), 118.9 (C), 82.4 (CH, Ar-C≡*C*H), 81.3 (C, Ar-*C*≡CH), 69.9 (CH, *C*HOH), 65.9 (CH, *C*HOH), 44.2 (CH_2), 23.3 (CH_3); LRMS m/z 191.15 (M +1), calcd. for $C_{12}H_{14}O_2$ 190.0994; Anal. calcd. for $C_{12}H_{14}O_2$ (190.0994); C, 76.57; H, 6.43. Found: C, 75.61; H, 7.52%.

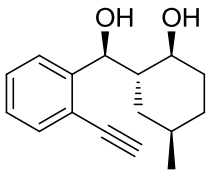
(1*S*,2*S*,4*R*)-2-((*S*)-(2-ethynylphenyl)(hydroxy)methyl)-4-methylcyclohexanol (10af):



(1S, 2S, 4R, 1'S)-**10af**

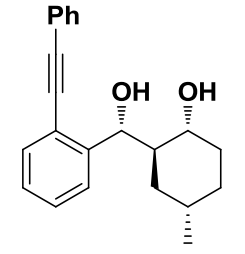
Prepared following Method-**F** and purified by column chromatography using EtOAc/hexane and isolated as liquid. **$[\alpha]_D^{25}$ = +29.6° (*c* = 0.071 g/100 mL, $CHCl_3$, 96% *ee* and >99% *de*);** IR (Neat): λ_{max} 3300 (O-H), 2929, 1084, 756, 613, 566 and 538 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.48 (2H, d, *J* = 7.2 Hz), 7.40 (1H, t, *J* = 7.6 Hz), 7.24 (1H, t, *J* = 7.2 Hz), 5.18 (1H, d, *J* = 9.2 Hz, C*H*OH), 4.00-3.80 (2H, br s, OH), 3.80-3.72 (1H, m, C*H*OH), 3.29 (1H, s, Ar-C≡C*H*), 2.03–1.99 (1H, m), 1.84–1.76 (2H, m), 1.68–1.49 (3H, m), 1.25–1.15 (1H, m), 0.90–0.80 (1H, m), 0.84 (3H, d, *J* = 7.2 Hz); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 145.0 (C), 132.8 (CH), 129.6 (CH), 127.5 (CH), 126.8 (CH), 120.8 (C), 81.9 (C, Ar-*C*≡CH), 81.8 (*CH*, Ar-C≡*CH*), 78.3 (CH, *C*HOH), 76.6 (CH, *C*HOH), 44.7 (CH), 32.4 (CH_2), 29.7 (CH_2), 29.3 (CH_2), 26.4 (CH), 17.7 (CH_3); LRMS m/z 245.25 (M+1), calcd. for $C_{16}H_{20}O_2$ 244.1463.

(1*S*,2*S*,4*R*)-2-((*S*)-(2-ethynylphenyl)(hydroxy)methyl)-4-methylcyclohexanol (10af):



(*1S, 2S, 4R, 1'S*)-**10af**

Prepared following Method-**E**, purified by column chromatography using EtOAc/hexane and isolated as liquid. **$[\alpha]_D^{25}$ = +2.2° (*c* = 0.67 g/100 mL, $CHCl_3$, 96% *ee* and 90% *de*);** IR (Neat): λ_{max} 3415 (O-H), 1395, 1324, 1135, 755, 703, 658 and 646 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.47 (1H, d, *J* = 6.8 Hz), 7.45 (1H, d, *J* = 6.8 Hz), 7.38 (1H, t, *J* = 7.6 Hz), 7.22 (1H, t, *J* = 7.6 Hz), 5.16 (1H, d, *J* = 9.2 Hz, C*H*OH), 4.38 (1H, br s, OH), 4.20 (1H, br s, OH), 3.71-3.68 (1H, m, C*H*OH), 3.28 (1H, s, Ar-C≡C*H*), 1.97–1.93 (1H, m), 1.89–1.80 (1H, m), 1.75–1.72 (1H, m), 1.58–1.46 (3H, m), 1.22–1.15 (1H, m), 0.90–0.80 (1H, m), 0.82 (3H, d, *J* = 7.2 Hz); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 145.2 (C), 132.7 (CH), 129.6 (CH), 127.4 (CH), 126.8 (CH), 120.9 (C), 82.0 (C, Ar-*C*≡CH), 81.7 (CH, Ar-C≡*C*H), 78.1 (CH, *C*HOH), 76.5 (CH, *C*HOH), 44.7 (CH), 32.4 (CH_2), 29.7 (CH_2), 29.3 (CH_2), 26.5 (CH), 17.7 (CH_3); LRMS m/z 245.25 (M+1), calcd. for $C_{16}H_{20}O_2$ 244.1463; Anal. calcd. for $C_{16}H_{20}O_2$ (244.1463); C, 78.65, H, 8.25; Found: C, 78.53; H, 8.16%.

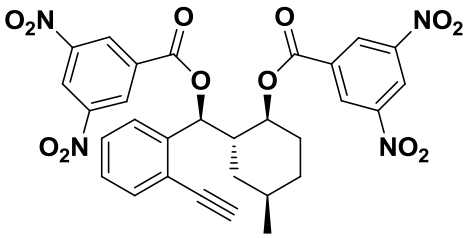


(1*R*, 2*R*, 4*S*, 1'*R*)-**10bf**

(1*R*,2*R*,4*S*)-2-((*R*)-hydroxy(2-(phenylethynyl)phenyl)methyl)-4-methylcyclohexanol (10bf): Prepared following Method-**E**, purified by column chromatography using EtOAc/hexane and isolated as liquid. **$[\alpha]_D^{25}$ = –98.2° (*c* = 0.26 g/100 mL, $CHCl_3$, 86% *ee* and 80% *de*);** IR (Neat): ν_{max} 3401 (O-H), 2970, 1458, 1383, 1307, 1104, 910, 881, 763, 748 and 645 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.47-7.42 (4H, m), 7.32-7.29 (4H, m), 7.19 (1H, t, *J* = 8.0 Hz), 5.18 (1H, d, *J* = 9.2 Hz, C*H*OH), 4.60-4.00 (2H, br s, OH), 3.72-3.63 (1H, m, C*H*OH), 2.04-1.95 (1H, m), 1.84-1.64 (2H, m), 1.57-1.31 (3H, m), 1.20–1.06 (1H, m), 0.82–0.78 (1H, m), 0.75 (3H, d, *J* = 10.0 Hz); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 144.5 (C), 132.1 (CH), 131.4 (2 x CH), 129.1 (CH), 128.5 (3 x CH), 127.5 (CH), 126.9 (CH), 123.1 (C), 121.9 (C), 93.9 (C), 87.6 (C), 78.6 (CH, *C*HOH), 76.5 (CH, *C*HOH), 44.8 (CH), 32.6 (CH_2), 29.7 (CH_2), 29.4 (CH_2), 26.5 (CH), 17.8 (CH_3); LRMS m/z 321.25 (M+1), calcd. for

$C_{22}H_{24}O_2$ 320.1776; Anal. calcd. for $C_{22}H_{24}O_2$ (320.1776); C, 82.46, H, 7.55; Found: C, 82.15; H, 7.49%.

(1*S*,2*S*,4*R*)-2-((*S*)-((3,5-dinitrobenzoyl)oxy)(2-ethynylphenyl)methyl)-4-methylcyclohexyl 3,5-dinitrobenzoate (11af): Prepared following Method-**G**, purified by column chromatography using EtOAc/hexane and isolated as solid. **$[\alpha]_D^{25}$ = +1.9° (*c* = 0.38 g/100 mL, $CHCl_3$, 96% *ee* and 90% *de*);** IR (Neat): λ_{max} 2955, 1728 (C=O), 1543 (NO_2), 1343 (NO_2), 1275, 1167, 730, 719 and 661 cm^{-1}; ^1H NMR ($CDCl_3$) δ 9.28-9.27 (2H, m), 9.24-9.23 (1H, m), 9.21-9.19 (1H, m), 9.02-9.01 (2H, m), 7.59-7.57 (1H, m), 7.37-7.34 (1H, m), 7.25-7.22 (2H, m), 6.58 (1H, d, *J* = 8.8 Hz, C*H*OBz), 5.57 (1H, q, *J* = 4.4 Hz, C*H*OBz), 3.54 (1H, s, Ar-C≡C*H*), 3.08 (1H, m), 2.05-2.00 (2H, m), 1.76-1.72 (1H, m), 1.58-1.50 (1H, m), 1.48-1.42 (1H, m), 1.35–1.24 (2H, m), 0.98 (3H, d, *J* = 6.4 Hz), 0.90-0.80 (1H, m); ^{13}C NMR ($CDCl_3$, DEPT-135) δ 161.8 (C), 161.7 (C), 148.8 (2 x C), 148.6 (2 x C), 140.3 (C), 134.1 (C), 134.0 (CH), 133.5 (C), 129.7 (2 x CH), 129.3 (3 x CH), 128.4 (CH), 126.4 (CH), 122.6 (CH), 122.4 (CH), 121.2 (C), 83.1 (CH, Ar-C≡*C*H), 81.3 (C, Ar-*C*≡CH), 77.3 (CH), 73.7 (CH), 42.0 (CH), 32.4 (CH_2), 29.2 (CH_2), 27.0 (CH), 26.4 (CH_2), 20.8 (CH_3); LRMS m/z 632.55 (M+1), calcd. for $C_{30}H_{24}N_4O_{12}$ 632.1391; Anal. calcd. for $C_{30}H_{24}N_4O_{12}$ (632.1391); C, 56.96, H, 3.82, N, 8.86; Found: C, 56.85; H, 3.76; N, 8.45%.



(1*S*, 2*S*, 4*R*, 1'*S*)–**11af**

Datablock: (*R*,*R*)-(+)-6aa

Bond precision: C-C = 0.0037 A Wavelength=0.71073

Cell: a=5.7710(11) b=10.930(2) c=28.102(6)

alpha=90 beta=90 gamma=90

Temperature: 273 K

	Calculated	Reported
Volume	1772.6(6)	1772.7(6)
Space group	P 21 21 21	P212121
Hall group	P 2ac 2ab	?
Moiety formula	C21 H18 O3	?
Sum formula	C21 H18 O3	C1.62 H1.38 O0.23
Mr	318.35	24.49
Dx,g cm-3	1.193	1.193
Z	4	52
Mu (mm-1)	0.079	0.079
F000	672.0	672.0
F000'	672.33	
h,k,lmax	7,13,34	7,13,34
Nref	2056[3501]	3480
Tmin,Tmax	0.970,0.978	0.971,0.978
Tmin'	0.970	

Correction method= MULTI-SCAN

Data completeness= 1.69/0.99 Theta(max)= 26.050

R(reflections)= 0.0556(2978) wR2(reflections)= 0.1295(3480)

S = 1.116 Npar= 223

Datablock (*R*,*R*)-(+)-6aa - ellipsoid plot