Supplementary Material (ESI) for Chemical Communications

Direct Asymmetric Aldol-Tishchenko Reaction of Aliphatic Ketones Catalyzed by *syn*-Aminoalcohol-Yb(III)-Complexes

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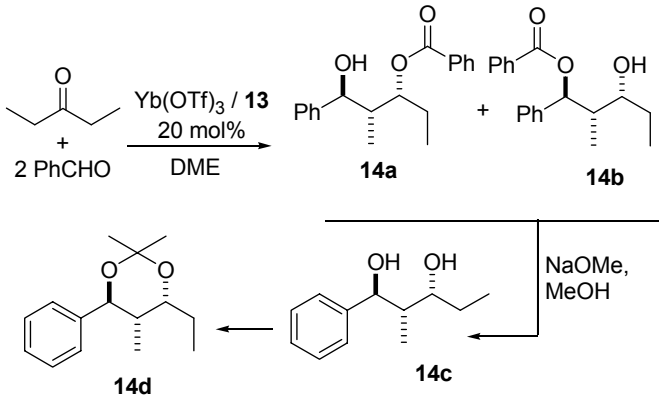
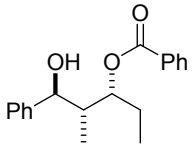
General: Ytterbium (III) triflate prepared from ytterbium(III) oxide (Aldrich) and trifluoromethanesulfonic acid (Fluka) was dried 24 hours at 200 °C under vacuum. All reactions were carried out under argon. Optical rotations were measured with a JASCO Dip-360 Digital Polarimeter at room temperature. ^{1}H NMR spectra were recorded on Varian-400 and Bruker-500 spectrometers in $CDCl_3$ with Me_4Si as internal standard. High resolution mass spectra were taken on a Mariner PerSeptive Biosystems mass spectrometer with time-of-flight (TOF) detector. IR spectra were taken with a Perkin Elmer FT-IR-1600 spectrophotometer. Reactions were controlled using TLC on silica [Merck alu-plates (0.2 mm)]. All reagents and solvents were purified and dried according to common methods. All organic solutions were dried over Na_2SO_4. Reaction products were purified by flash chromatography using Merck's Kieselgel 60 (240-400 mesh). HPLC analysis were performed on Knauer-HPLC system equipped with Daicel columns with chiral stationary phase, detection at 254 nm.



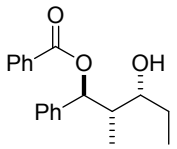
Scheme 1.

Typical procedure for the aldol-Tishchenko condensation of aldehydes with 3-pentanone
Ytterbium (III) triflate (125 mg 0.20 mmol) was placed in an oven-dried flask with a magnetic stirring bar and the flask was heated at 200 °C for 10 min in *vacuo* and then flushed with argon. After the flask was cooled down to rt a solution of ligand **13** (164 mg, 0.80 mmol) in DME (2 mL) was added. The resulting solution was stirred for 30 min at rt under argon atmosphere. To a solution of the catalyst 3-pentanone (100 μL, 0.95 mmol) and benzaldehyde (101 μL, 1.00 mmol) were added successively. The resulting solution was stirred for 20 h at rt, then dissolved with MTBE and washed with water and brine. Organic layer was dried over Na_2SO_4, concentrated and submitted to column chromatography (hexane-ethyl acetate, 9:1).

1-Hydroxy-2-methyl-1-phenylpentyl benzoate (14a) and 3-hydroxy-2-methyl-1-phenylpentyl benzoate (14b)[1,2]



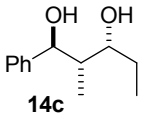
14a



14b

First fraction contained ester **14a**: yield 42 %; oil; $[\alpha]_D$ +3.3 (*c* 1.00 in CH_2Cl_2, 72 %ee); ^{1}H NMR (400 MHz) δ: 0.75 (d, 3H, *J* 6.9 Hz), 0.99 (t, 3H, *J* 7.4 Hz), 1.55-1.76 (m, 1H), 1.81-2.12 (m, 2H), 3.71 (d, 1H, *J* 3.8 Hz, OH), 4.19 (dd, 1H, *J* 3.6, 9.8 Hz), 5.62 (ddd, 1H, *J* 1.5, 5.6, 8.7 Hz), 7.20-7.64 (m, 8H, Ar), 8.10 (d, 2H, Ar); ^{13}C NMR (100 MHz) δ: 9.9, 10.5, 25.7, 44.3, 75.7, 75.8, 127.0, 127.6, 128.3, 128.4, 129.7, 130.2, 133.2, 142.8, 167.6.
Detection of enantiomers ratio: HPLC on Chiralpak AD-H column: hexane-^{i}PrOH (9:1), 1 mL/min; t_1 = 12.3 min, t_2 = 21.6 min (major).
Second fraction contained ester **14b**: yield 39 %; $[\alpha]_D$ –8.5 (*c* 0.75 in CH_2Cl_2, 73 %ee); ^{1}H NMR (400 MHz) δ: 0.75 (d, 3H, *J* 6.9 Hz), 0.94 (t, 3H, *J* 7.3 Hz), 1.24-1.69 (m, 2H), 2.02-2.20 (m, 1H), 2.52 (brs, 1H, OH), 3.75 (t, 1H, *J* 6.5 Hz), 5.95 (d, 1H, *J* 9.8 Hz), 7.20-7.68 (m, 8H, Ar), 8.10 (d, 2H, Ar); ^{13}C NMR (100 MHz) δ: 8.9, 10.8, 27.3, 43.0, 71.2, 78.8, 127.4, 128.1, 128.3, 128.4, 129.7, 129.9, 133.1, 139.4, 166.5.
Detection of enantiomers ratio: HPLC on Chiralpak AD-H column: hexane-^{i}PrOH (97:3), 1 mL/min; t_1 = 23.2 min (major), t_2 = 24.3 min; Chiralpak OD-H column: hexane-^{i}PrOH (97:3), 1 mL/min; t_1 = 8.1 min, t_2 = 8.7 min (major).

2-Methyl-1-phenylpentane-1,3-diol (14c)[1]



14c

A solution of monoester **14a/b** (150 mg, 0.5 mmol) in MeOH (3 mL) was treated with catalytic amount of sodium. The mixture was stirred overnight, then evaporated with silica gel and purified on silica gel column (hexane-ethyl acetate, 3:2) to yield diol **14c** as an oil in quantitative yield: $[\alpha]_D$ –36.2 (*c* 0.60 in CH_2Cl_2, 75 %ee); ^{1}H NMR (500 MHz) δ: 0.87 (d, 3H, *J* 7.1 Hz), 0.91 (t, 3H, *J* 7.4 Hz), 1.39-1.48 (m, 1H), 1.51-1.60 (m, 1H), 1.94 (dq, 1H, *J* 2.1, 7.0 Hz), 2.46 (d, 1H, *J* 4.9 Hz, OH), 3.09 (d, 1H, *J* 4.1 Hz, OH), 3.70-3.75 (m, 1H), 4.72 (dd, 1H, *J* 4.1, 6.6 Hz), 7.25-7.30 (m, 1H, Ar), 7.35 (d, 4H, Ar); ^{13}C NMR (125 MHz) δ: 10.6, 11.3, 26.7, 43.4, 74.0, 78.3, 126.3, 127.4, 128.4, 143.9.
Detection of enantiomers ratio: HPLC on Chiralpak AD-H column: hexane-^{i}PrOH (9:1), 1 mL/min; t_1 = 7.8 min, t_2 = 10.1 min (major).

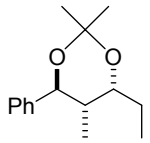
Discussion on diol stereochemistry

To double check the structure of compounds **14a** and **14b** its deprotected forms were prepared by ester saponification. Structure of prepared diol **14c** was confirmed by comparison with known NMR data.[1,2] Chemical shift of H-1 (4.72 ppm) as well as $J_{1,2}$ coupling constant (6.6 Hz) are characteristic values for 1,2-*anti*-1,3-*anti* configuration of tree continuous stereocenters in this system. ^{13}C NMR data are in good agreement with those published by Mahrwald[1] and Fang[2] (in this paper, however, one carbon signal was missed (78.3 ppm) and replaced by one from $CDCl_3$ triplet (76.6 ppm). In two papers all sets of signals published for compound **14c** seems to be not correct.[3,4] This concerns ^{1}H NMR data published by Hayashi[4] (reverse sequence of doublet and triplet of both CH_3 groups and large coupling constant $J_{1,2}$ suggest rather 1,2-*anti*-1,3-*syn* configuration)[8] and ^{1}H and ^{13}C NMR presented by Badia.[3] In the latter, presented spectra do not fit the postulated 1,2-*anti*-1,3-*anti* configuration. Published $J_{1,2}$ value (2.2 Hz) is obviously too small for 1,2-*anti* relationship and presented ^{13}C NMR includes signal at 3.8 ppm which is not characteristic for discussed structures (see ref. [1] and [2]).

Additional prove for structure of obtained diol **14c** was analysis of its rigid di-*O*-isopropylidene derivative **14d**. Large $J_{1,2}$ value (8.3 Hz) confirms 1,2-*anti* relationship. Characteristic signals of isopropylidene ring in ^{13}C NMR (23.6, 24.8 and 100.9 ppm) are in full agreement with rules presented by Rychnowski[5] for 1,3-*anti* diols.[5]

We have not detected the formation of 1,2-*anti*-1,3-*syn* co-products in the reaction mixture as it took place in the case of reaction promoted by titanium complexes.[1] Instead, some traces of 1,2-*syn*-1,3-*anti* analogues were detected in the reaction mixtures (2-5 %). Its structure was confirmed after ester saponification as 1,3-diol by comparison with known NMR data.[6,8] The same 1,2-*syn*-1,3-*anti* diol – analogue of **14c** was detected as admixture in the racemic sample prepared according to literature procedure.[2]

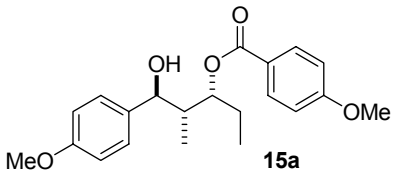
1,3-*O*-isopropylidene-2-methyl-1-phenylpentane-1,3-diol (14d)



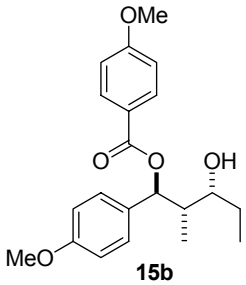
14d

The 1,3-diol **14c** (97 mg, 0.5 mmol) was dissolved in 5 mL of a (4:1) mixture of acetone and 2,2-dimethoxypropane. To the solution was added camphorosulfonic acid (small crystal) at rt. The mixture was stirred at ambient temperature for 1 h, then quenched with one drop of Et_3N, concentrated under reduced pressure and purified by flash chromatography (hexane-ethyl acetate, 9:1) to yield diacetonide **14d** as an oil: (113 mg, 93 %); $[\alpha]_D$ –40.1 (*c* 0.65 in CH_2Cl_2, 43 %ee); ^{1}H NMR (500 MHz) δ: 0.88 (d, 3H, *J* 6.8 Hz), 0.97 (t, 3H, *J* 7.3 Hz), 1.43 and 1.45 (2s, 2×3H, O^{i}Pr), 1.39-1.46 (m, 1H), 1.49-1.58 (m, 1H), 2.00-2.07 (m, 1H), 3.73 (ddd, 1H, *J* 2.1, 4.6, 6.8 Hz), 3.95 (m, 1H), 4.24 (d, 1H, *J* 8.3 Hz), 7.26-7.42 (m, 5H, Ar); ^{13}C NMR (125 MHz) δ: 10.6, 11.3, 23.6, 24.0, 24.8, 41.7, 71.1, 77.6, 100.9, 126.9, 127.6, 128.4, 142.0; IR (film): 2984, 2966, 2937, 2878, 1496, 1455, 1378, 1223 cm^{-1}; HRMS (EI) calcd for $C_{15}H_{22}O_2$ $[M]^+$ 234.1619, found 234.1618. Detection of enantiomers ratio: HPLC on Chiralpak AS-H column: hexane-^{i}PrOH (99:1), 1 mL/min; t_1 = 3.3 min (major), t_2 = 3.6 min.

1-Hydroxy-2-methyl-1-(4-methoxyphenyl)pentyl 4-methoxybenzoate (15a) and 3-hydroxy-2-methyl-1-(4-methoxyphenyl)pentyl 4-methoxybenzoate (15b)



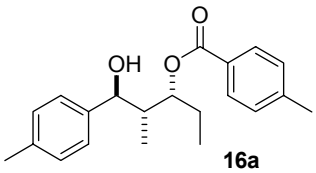
15a



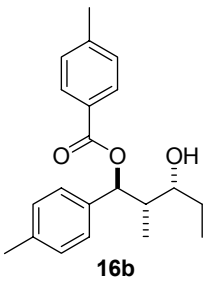
15b

Based on the general procedure of aldol-Tishchenko reaction *p*-anizaldehyde was reacted with 3-pentanone in 1 mmol scale to yield after column chromatography (hexane-ethyl acetate, 4:1) two esters. First fraction contained ester **15a**: oil; yield 9%; ^{1}H NMR (400 MHz) δ: 0.72 (d, 3H, *J* 7.0 Hz), 0.98 (t, 3H, *J* 7.5 Hz), 1.60-1.69 (m, 1H), 1.85-1.96 (m, 1H), 1.96-2.00 (m, 1H), 3.79 (s, 3H, OMe), 3.81 (d, 1H, OH, *J* 3.7 Hz), 3.88 (s, 3H, OMe), 4.13 (dd, 1H, *J* 3.7, 9.8 Hz), 5.57 (ddd, 1H, *J* 1.7, 4.9, 8.8 Hz), 6.85 (d, 2H Ar), 6.97 (d, 2H, Ar), 7.22 (d, 2H Ar), 8.05 (d, 2H Ar); ^{13}C NMR (100 MHz) δ: 9.9, 10.6, 25.7, 44.4, 55.2, 55.5, 75.2, 75.5, 77.3, 113.6, 113.7, 122.3, 128.1, 131.8, 135.0, 159.0, 163.6, 167.5; IR (film): 2491, 2965, 2937, 2838, 1710, 1607, 1513, 1254 cm^{-1}; HRMS (ESI) calcd for $C_{21}H_{26}O_5$ $[M+Na]^+$ 381.1672 found, 381.1674.
Detection of enantiomers ratio: HPLC on Chiralpak AD-H column: hexane-^{i}PrOH (4:1), 1 mL/min; t_1 = 14.0 min, t_2 = 24.1 min (major).
Second fraction contained ester **15b**: yield 49%; oil; ^{1}H NMR (400 MHz) δ: 0.73 (d, 3H, *J* 7.0 Hz), 0.94 (t, 3H, *J* 7.4 Hz), 1.31-1.50 (m, 1H), 1.51-1.72 (m, 1H), 2.00-2.17 (m, 1H), 3.67-3.73 (m, 1H), 3.79 (s, 3H, OMe), 3.83 (s, 3H, OMe), 5.87 (d, 1H, *J* 10.2 Hz), 6.90 (d, 4H Ar), 7.35 (d, 2H Ar), 8.00 (d, 2H Ar); ^{13}C NMR (100 MHz) δ: 8.9, 10.9, 27.2, 43.0, 55.1, 55.3, 71.2, 78.2, 113.6, 113.8, 122.3, 128.6, 131.7, 159.3, 163.5, 166.5; IR (film): 3491, 3965, 2937, 1710, 1607, 1168 cm^{-1}; HRMS (ESI) calcd for $C_{21}H_{26}O_5$ $[M+Na]^+$ 381.1674 found, 381.1672.
Detection of enantiomers ratio: HPLC on Chiralpak AD-H column: hexane-^{i}PrOH (4:1), 1 mL/min; t_1 = 17.7 min, t_2 = 23.7 min (major).

1-Hydroxy-2-methyl-1-(4-methylphenyl)pentyl 4-methylbenzoate (16a) and 3-hydroxy-2-methyl-1-(4-methylphenyl)pentyl 4-methylbenzoate (16b)



16a

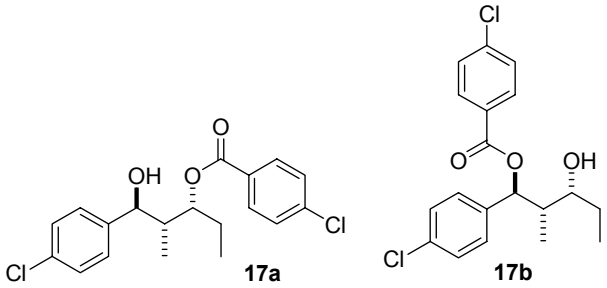


16b

First fraction contained ester **16a**: yield 25 %; oil; ^{1}H NMR (400 MHz) δ: 0.73 (d, 3H, *J* 7.0 Hz), 0.98 (t, 3H, *J* 7.4 Hz), 1.59-70 (m, 1H), 1.86-1.95 (m, 1H), 1.98-2.06 (m, 1H), 2.32 (s, 3H), 2.44 (s, 3H), 4.14 (d, 1H, *J* 9.7 Hz), 5.59 (ddd, 1H, *J* 1.6, 4.8, 8.8 Hz), 7.11-7.19 (m, 4H,

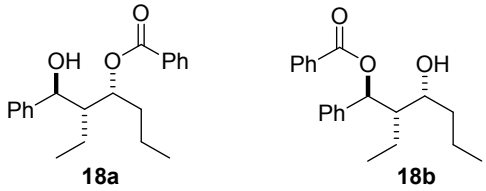
Ar), 7.28 (d, 2H, *J* 7.9 Hz, Ar), 7.99 (d, 2H, *J* 8.2 Hz, Ar); ^{13}C NMR (100 MHz) δ: 9.9, 10.6, 21.1, 21.6, 25.7, 44.3, 75.5, 75.6, 126.9, 127.2, 129.0, 129.1, 129.8, 137.2, 139.8, 143.9, 167.7; IR (film): 3475, 2971, 2923, 1714, 1694, 1278, 1109 cm^{-1}; HRMS (ESI) calcd for $C_{21}H_{26}O_3$ $[M+Na]^+$ 349.1765, found 349.1774.
Detection of enantiomers ratio: HPLC on Chiralpak AD-H column: hexane-^{i}PrOH (9:1), 1 mL/min; t_1 = 14.1 min., t_2 = 21.1 min.
Second fraction contained ester **16b**: yield 51 %; oil; ^{1}H NMR (400 MHz) δ: 0.74 (d, 3H, *J* 6.8 Hz), 0.94 (t, 3H, *J* 7.3 Hz), 1.36-1.47 (m, 1H), 1.55-1.66 (m, 1H), 2.04-2.13 (m, 1H), 2.34 (s, 3H), 2.40 (s, 3H), 3.71 (ddd, 1H, *J* 1.8, 5.1, 8.3 Hz), 5.89 (d, 1H, *J* 9.9 Hz), 7.16-7.24 (m, 4H, Ar), 7.32 (d, 2H, *J* 8.0 Hz, Ar), 7.93 (d, 2H, *J* 8.2 Hz, Ar); ^{13}C NMR (100 MHz) δ: 9.0, 10.9, 21.1, 21.6, 27.2, 43.0, 71.2, 78.6, 127.2, 127.3, 129.1, 129.2, 129.8, 136.6, 137.8, 143.9, 166.7; IR (film): 3509, 2972, 2937, 1718, 1701, 1274, 1107 cm^{-1}; HRMS (ESI) calcd for $C_{21}H_{26}O_3$ $[M+Na]^+$ 349.1793, found 349.1774.
Detection of enantiomers ratio: HPLC on Chiralpak AD-H column: hexane-^{i}PrOH (9:1), 1 mL/min; t_1 = 18.0 min., t_2 = 21.0 min.

1-Hydroxy-2-methyl-1-(4-chlororphenyl)pentyl 4-chlorobenzoate (17a) and 3-hydroxy-2-methyl-1-(4-chlorophenyl)pentyl 4-chlorobenzoate (17b)



First fraction contained ester **17a**: yield 37 %; oil; ^{1}H NMR (400 MHz) δ: 0.73 (d, 3H, *J* 7.0 Hz), 0.98 (t, 3H, *J* 7.2 Hz), 1.60-1.70 (m, 1H), 1.85-2.01 (m, 2H), 4.14 (d, 1H, *J* 9.6 Hz), 5.57 (ddd, 1H, *J* 1.6, 5.0, 8.9 Hz), 7.21-7.24 (m, 2H, Ar), 7.28-7.31 (m, 2H, Ar), 7.44-7.47 (m, 2H, Ar), 8.00-8.03 (m, 2H, Ar); ^{13}C NMR (100 MHz) δ: 9.8, 10.5, 25.6, 44.4, 75.1, 76.1, 128.2, 128.3, 128.5, 128.8, 131.1, 133.3, 139.8, 141.2, 166.8; IR (film): 3485, 2973, 2938, 1715, 1700, 1275 cm^{-1}; HRMS (ESI) calcd for $C_{19}H_{20}Cl_2O_3$ $[M+Na]^+$ 389.0692, found 389.0682.
Detection of enantiomers ratio: HPLC on Chiralpak AD-H column: hexane-^{i}PrOH (9:1), 1 mL/min; t_1 = 13.2 min., t_2 = 19.8 min.
Second fraction contained ester **17b**: yield 39 %; oil; ^{1}H NMR (400 MHz) δ: 0.72 (d, 3H, *J* 7.2 Hz), 0.96 (t, 3H, *J* 7.6 Hz), 1.39–1.49 (m, 1H), 1.55–1.66 (m, 1H), 2.06–2.12 (m, 1H), 3.70–3.74 (m, 1H), 5.89 (d, 1H, *J* 10.0 Hz), 7.32-7.37 (m, 2H, Ar), 7.40-7.43 (m, 2H, Ar), 7.94–7.98 (m, 2H, Ar); ^{13}C NMR (100 MHz) δ: 8.8, 10.8, 27.4, 42.8, 71.2, 78.3, 128.2, 128.7, 128.8 (2C), 131.0, 134.0, 137.9, 139.8, 165.5; IR (film): 3513, 2968, 2938, 1720, 1594, 1270, 1092 cm^{-1}; HRMS (ESI) calcd for $C_{19}H_{20}Cl_2O_3$ $[M+Na]^+$ 389.0698 found 389.0682.
Detection of enantiomers ratio: HPLC on Chiralpak AD-H column: hexane-^{i}PrOH (9:1), 1 mL/min; t_1 = 15.5 min., t_2 = 19.0 min.

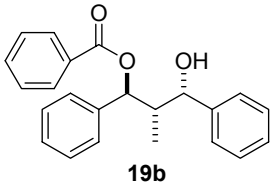
1-Hydroxy-2-ethyl-1-phenylhexyl benzoate (18a) and 3-hydroxy-2-ethyl-1-phenylhexyl benzoate (18b)



18a **18b**

First fraction contained ester **18a**: colorless oil; yield 23 %; oil; ^{1}H NMR (400 MHz) δ: 0.77 (t, 3H, *J* 7.5 Hz), 0.91 (t, 3H, *J* 7.3 Hz), 1.23-1.61 (m, 6H), 1.84-1.97 (m, 2H), 3.59 (d, 1H, *J* 4.4 Hz, OH), 4.50 (dd, 1H, *J* 4.4, 8.5 Hz), 5.60 (ddd, 1H, *J* 1.8, 4.5, 9.2 Hz), 7.26-7.35 (m, 5H, Ar), 7.46-7.50 (m, 2H, Ar), 7.58-7.62 (m, 1H, Ar), 8.07-8.10 (d, 2H, Ar); ^{13}C NMR (100 MHz) δ: 12.9, 13.8, 19.0, 19.3, 30.0, 50.9, 74.4, 74.6, 77.3, 126.9, 127.5, 128.3, 128.5, 129.7, 130.0, 133.2, 142.8, 167.4; IR (film): 3479, 2961, 2874, 1715, 1695, 1278 cm^{-1}; HRMS (ESI) calcd for $C_{21}H_{26}O_3$ $[M+Na]^+$ 349.1774 found 349.1775.
Detection of enantiomers ratio: HPLC on Chiralpak AD-H column: hexane-^{i}PrOH (9:1), 1 mL/min; t_1 = 10.2 min, t_2 = 21.1 min (major).
Second fraction contained ester **18b**: colorless oil; yield 54 %, ^{1}H NMR (400 MHz) δ: 0.84 (t, 3H, *J* 7.4 Hz), 0.97 (t, 3H, *J* 7.1 Hz), 1.25-1.61 (m, 7H), 1.86-1.91 (m, 1H), 3.87 (ddd, 1H, *J* 2.7, 4.4, 8.7 Hz), 6.15 (d, 1H, *J* 7.8 Hz), 7.30-7.48 (m, 7H, Ar), 7.55-7.61 (m, 1H, Ar), 8.03-8.09 (d, 2H, Ar); ^{13}C NMR (100 MHz) δ: 13.0, 13.9, 17.9, 19.6, 36.6, 50.2, 70.3, 77.8, 126.9, 128.0, 128.4, 128.5, 129.6, 129.8, 133.2, 139.4, 166.0; IR (film): 3500, 2961, 2874, 1720, 1704, 1273 cm^{-1}; HRMS (ESI) calcd for $C_{21}H_{26}O_3$ $[M+Na]^+$ 349.1774 found 349.1798.
Detection of enantiomers ratio: HPLC on Chiralpak AD-H column: hexane-^{i}PrOH (9:1), 1 mL/min; t_1 = 10.7 min (major), t_2 = 11.6 min.

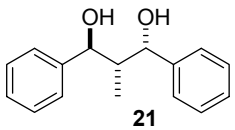
(1*S*,2*S*,3*S*)-3-Hydroxy-2-methyl-1,3-diphenylpropyl benzoate (19b)[2]



19b

Colorless oil; yield 85 %, ^{1}H NMR (400 MHz) δ: 0.62 (d, 3H, *J* 6.9 Hz), 2.41 (m, 1H), 2.80 (d, 1H, *J* 4.0 Hz, OH), 5.10 (dd, 1H, *J* 2.2, 3.9 Hz), 6.08 (d, 1H, *J* 9.9 Hz), 7.20-7.25 (m, 1H, Ar), 7.29-7.40 (m, 7H, Ar), 7.43-7.49 (m, 4H, Ar), 7.55-7.62 (m, 1H, Ar), 8.08-8.11 (m, 2H, Ar); ^{13}C NMR (100 MHz) δ: 8.9, 45.9, 71.4, 78.9, 125.6, 126.8, 127.4, 128.1, 128.2, 128.4, 128.5, 129.7, 129.9, 133.3, 139.2, 142.8, 166.6; IR (film): 3498, 1719, 1703, 1451, 1272 cm^{-1}; HRMS (ESI) calcd for $C_{23}H_{22}O_3$ $[M+Na]^+$ 369.1461 found 369.1466.
Detection of enantiomers ratio: HPLC on Chiralpak AD-H column: hexane-^{i}PrOH (9:1), 1 mL/min; t_1 = 10.5 min, t_2 = 16.8 min (major).

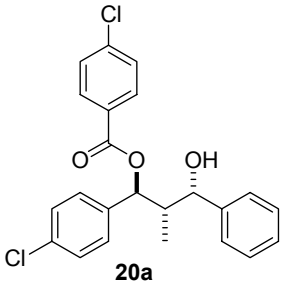
(1*S*,3*S*)-2-Methyl-1,3-diphenyl-propane-1,3-diol (21)[8,9]



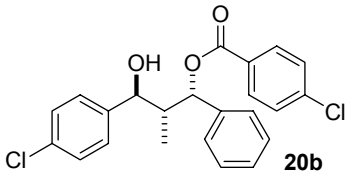
21

A solution of monoester **19b** (100 mg) in MeOH (3 mL) was treated with catalytic amount of sodium. The mixture was stirred overnight, then evaporated with silica gel and purified on silica gel column (hexane-ethyl acetate, 3:2) to yield diol **21** as an oil in quantitative yield: $[\alpha]_D$ –13.0 (*c* 0.60 in CH_2Cl_2, 75 %ee), lit.[9]: $[\alpha]_D$ –12.1 (*c* 1.0 in CH_2Cl_2, 84% ee); ^{1}H NMR (400 MHz) δ: 0.71 (d, 3H, *J* 7.1 Hz), 2.14 (dq, 1H, *J* 2.5, 7.14 Hz), 3.45 (m, 2H, OH), 4.64 (dd, 1H, *J* 3.6, 6.6 Hz), 4.96 (t, 1H, *J* 3.18 Hz), 7.20-7.40 (m, 10H, Ar); ^{13}C NMR (100 MHz) δ: 11.2, 45.7, 74.3, 77.7, 125.9, 126.2, 126.9, 127.5, 127.9, 128.3, 142.5, 143.4.
Detection of enantiomers ratio: HPLC on Chiralpak AD-H column: hexane-^{i}PrOH (9:1), 1 mL/min; t_1 = 11.3 min, t_2 = 14.5 min (major).

(1*S*,2*S*,3*S*)-3-Hydroxy-2-methyl-3-phenyl-1-(4-chlorophenyl)propyl 4-chlorobenzoate (20a) and (1*S*,2*S*,3*S*)-1-Hydroxy-2-methyl-3-phenyl-1-(4-chlorophenyl)propyl 4-chlorobenzoate (20b)



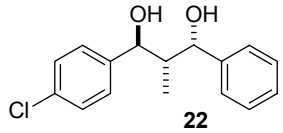
20a



20b

First fraction contained ester **20a**: colorless oil; yield 40 %; oil; ^{1}H NMR (400 MHz) δ: 0.61 (t, 3H, *J* 7.0 Hz), 2.25-2.48 (m, 1H), 2.57 (d, 1H, *J* 4.1 Hz, OH), 5.07 (dd, 1H, *J* 2.6, 3.9 Hz), 6.00 (d, 1H, *J* 9.9 Hz), 7.20-7.43 (m, 11H, Ar), 8.00 (d, 2H, Ar); ^{13}C NMR (100 MHz) δ: 8.9, 45.6, 71.5, 78.3, 125.6, 127.0, 128.2, 128.7, 128.8, 131.0, 134.1, 137.6, 139.8, 142.6, 165.4; IR (film): 3500, 2978, 1720, 1594, 1490, 1270 cm^{-1}; HRMS (ESI) calcd for $C_{23}H_{20}Cl_2O_3$ $[M+Na]^+$ 437.0687 found 437.0689.
Detection of enantiomers ratio: HPLC on Chiralpak AD-H column: hexane-^{i}PrOH (4:1), 1 mL/min; t_1 = 21.0 min, t_2 = 29.9 min (major).
Second fraction contained ester **20b**: colorless oil; yield 29 %, ^{1}H NMR (400 MHz) δ: 0.67 (t, 3H, *J* 7.0 Hz), 2.15-2.33 (m, 1H), 3.15 (brs, 1H, OH), 4.39 (dd, 1H, *J* 3.3, 9.3 Hz), 6.70 (d, 1H, *J* 2.4 Hz), 7.20-7.50 (m, 11H, Ar), 8.10 (d, 2H, Ar); ^{13}C NMR (100 MHz) δ: 9.8, 47.3, 75.1, 75.3, 125.6, 127.4, 128.2, 128.3, 128.5, 128.7, 128.9, 131.1, 133.5, 139.3, 140.0, 141.0, 165.5; IR (film): 3486, 1723, 1595, 1488, 1272 cm^{-1}; HRMS (ESI) calcd for $C_{23}H_{20}Cl_2O_3$ $[M+Na]^+$ 437.0687 found 437.0690.
Detection of enantiomers ratio: HPLC on Chiralpak AD-H column: hexane-^{i}PrOH (4:1), 1 mL/min; t_1 = 15.2 min, t_2 = 16.4 min (major).

(1*S*,2*S*,3*S*)-1-(4-Chlorophenyl)-2-methyl-3-phenylpropane-1,3-diol (22)[9]



22

A solution of monoester **20a/b** (100 mg) in MeOH (3 mL) was treated with catalytic amount of sodium. The mixture was stirred overnight, then evaporated with silica gel and purified on silica gel column (hexane-ethyl acetate, 3:2) to yield diol **22** as an oil in quantitative yield: $[\alpha]_D$ +1.1 (*c* 0.50 in CH_2Cl_2, 70 %ee), lit.[9]: $[\alpha]_D$ +1.3 (*c* 1.75 in CH_2Cl_2, 95% ee); ^{1}H NMR (400 MHz) δ: 0.75 (d, 3H, *J* 7.1 Hz), 2.18 (dq, 1H, *J* 2.7, 6.7 Hz), 3.00 (d, 1H, *J* 3.6 Hz, OH), 3.30 (d, 1H, *J* 4.1 Hz, OH), 4.67 (dd, 1H, *J* 4.3, 6.6 Hz), 5.00 (t, 1H, *J* 2.9 Hz), 7.12-7.40 (m, 9H, Ar); ^{13}C NMR (100 MHz) δ: 11.3, 45.5, 74.4, 77.0, 125.9, 127.1, 127.5, 128.0, 128.4, 133.0, 141.9, 142.1.
Detection of enantiomers ratio: HPLC on Chiralpak AD-H column: hexane-^{i}PrOH (95:5), 1 mL/min; t_1 = 22.8 min, t_2 = 28.8 min (major).

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