Supporting Information

Design of Axially Chiral Dicarboxylic Acid for Asymmetric Mannich Reaction of Arylaldehyde *N*-Boc Imines and Diazo Compounds

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General Information. Infrared (IR) spectra were recorded on a Shimadzu IRPrestige-21 spectrometer. ^1H NMR spectra were measured on a JEOL JNM-FX400 (400 MHz) spectrometer. Data were reported as follows: chemical shifts in ppm from tetramethylsilane as an internal standard in CDCl_3 or CD_2HOD ($\delta = 3.30$) in CD_3OD , integration, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, dd = double-doublet, m = multiplet, br = broad, app = apparent), coupling constants (Hz), and assignment. ^{13}C NMR spectra were measured on a JEOL JNM-FX400 (100 MHz) spectrometer with complete proton decoupling. Chemical shifts were reported in ppm from the residual solvent as an internal standard. High performance liquid chromatography (HPLC) was performed on Shimadzu 10A instruments at 220 nm using 4.6 nm x 25 cm Daicel Chiralpak and Chiralcel. High-resolution mass spectra (HRMS) were performed on Bruker microTOF. Optical rotations were measured on a JASCO DIP-1000 digital polarimeter. For thin layer chromatography (TLC) analysis throughout this work, Merck precoated TLC plates (silica gel 60 GF₂₅₄, 0.25 mm) were used. The products were purified by flash column chromatography silica gel 60 (Merck, 230-400 mesh).

In experiments requiring dry solvent, CH_2Cl_2 , toluene and THF were purchased from Kanto Chemical Co. Inc. as “Dehydrated” and further purified by passing through neutral alumina under nitrogen atmosphere. *N*-Boc arylimines were prepared according to the literature procedure.¹ *tert*-Butyl diazoacetate² and dimethyl diazomethylphosphonate³ was prepared according to the literature procedure and used after purification by column chromatography. Commercially obtained reagents were used as received.

•Synthesis of the dicarboxylic acid (4f).

Bis(2-(trimethylsilyl)ethyl) (*R*)-1,1'-binaphthyl-2,2'-dicarboxylate.

To the flask containing (*R*)-1,1'-binaphthyl-2,2'-dicarboxylic acid (6.7 mmol, 2.29 g) was added SOCl₂ (40 mmol, 2.92 mL). After stirring for 2 h at 80 °C, residual SOCl₂ was removed by evaporation to give the acid chloride as a white solid. The solid thus obtained was then diluted with THF (15 mL) and cooled to 0 °C. To the solution were added 2-(trimethylsilyl)ethanol (16.8 mmol, 2.40 mL) and pyridine (20 mmol, 1.62 mL). After stirring for 12 h at room temperature, the reaction solution was treated with saturated aqueous NH₄Cl and extracted with ethyl acetate. The combined organic layers were dried over Na₂SO₄ and concentrated. The residue was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 15:1) to give the title compound as a colorless oil [97% (3.54 g)].

¹H NMR (400 MHz, CDCl₃) δ 8.17 (2H, d, *J* = 8.8 Hz, ArH), 7.99 (2H, d, *J* = 8.6 Hz, ArH), 7.92 (2H, d, *J* = 8.3 Hz, ArH), 7.50 (2H, m, ArH), 7.23 (2H, m, ArH), 7.11 (2H, d, *J* = 8.6 Hz, ArH), 3.90 (4H, m, CH₂CH₂TMS), 0.44 (4H, m, CH₂CH₂TMS), −0.10 (18H, s, TMS); ¹³C NMR (100 MHz, CDCl₃) δ 167.1, 140.0, 134.8, 133.1, 127.9, 127.8, 127.7, 127.5, 127.4, 126.6, 126.0, 62.8, 16.6, 1.7; IR (neat) 3061, 2953, 2897, 1721, 1325, 1277, 1244, 1130, 1061, 1040 cm^{−1}; HRMS (ESI) exact mass calcd. for C₃₂H₃₈O₄Si₂: *m/z* 565.2201 ([M + Na]⁺), found: *m/z* 565.2208 ([M + Na]⁺); [α]_D²⁸ = +38.8 (*c* = 1.0, CHCl₃).

Bis(2-(trimethylsilyl)ethyl) (*R*)-3,3'-dibromo-1,1'-binaphthyl-2,2'-dicarboxylate.

To a THF solution (0.4 M, 30 mmol, 75 mL) of Mg(TMP)₂ prepared according to the literature⁴ was added bis(2-(trimethylsilyl)ethyl) (*R*)-1,1'-binaphthyl-2,2'-dicarboxylate (6.5 mmol, 3.54 g) in THF (20 mL) dropwise at −78 °C under argon atmosphere. The mixture was then allowed to warm to room temperature and stirred for 2 h. After being

cooled to $-78\text{ }^{\circ}\text{C}$, Br_2 (72 mmol, 3.69 mL) was added and stirring was continued for 2 h at room temperature. This mixture was then poured into cooled 1 N HCl, washed with saturated Na_2SO_3 , and extracted with EtOAc. The organic layer was dried over Na_2SO_4 and concentrated. Purification of the residue by column chromatography on silica gel (eluting with $\text{CH}_2\text{Cl}_2/\text{EtOAc}/\text{hexane}$ 1:1:20) gave the title compound as a white solid [ca. 44% (2.0 g), some impurities included]. Analytical sample was prepared by carefully washing this material with hexane.

^1H NMR (400 MHz, CDCl_3) δ 8.23 (2H, s, ArH), 7.82 (2H, d, $J = 8.0$ Hz, ArH), 7.53 (2H, m, ArH), 7.35 (2H, m, ArH), 7.18 (2H, d, $J = 8.6$ Hz, ArH), 3.87 (4H, m, $\text{CH}_2\text{CH}_2\text{TMS}$), 0.34 (4H, m, $\text{CH}_2\text{CH}_2\text{TMS}$), -0.11 (18H, s, TMS); ^{13}C NMR (100 MHz, CDCl_3) δ 166.2, 134.6, 134.02, 133.95, 132.2, 131.5, 128.0, 127.6, 127.3, 126.9, 115.9, 63.7, 16.5, -1.7 ; IR (neat) 3061, 2953, 2895, 1726, 1275, 1248, 1157, 1132, 1063, 1042 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{32}\text{H}_{36}\text{Br}_2\text{O}_4\text{Si}_2$: m/z 721.0411 ($[\text{M} + \text{Na}]^+$), found: m/z 721.0426 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{28} = +38.6$ ($c = 1.0$, CHCl_3).

Bis(2-(trimethylsilyl)ethyl) (R)-3,3'-bis(4-tert-butyl-2,6-dimethylphenyl)-1,1'-binaphthyl-2,2'-dicarboxylate.

To a Schlenk tube equipped with a rubber septum and a magnetic stir bar were added $\text{Pd}(\text{OAc})_2$ (0.025 mmol, 5.6 mg), 2-(2',6'-dimethoxybiphenyl)dicyclohexylphosphine⁵ (0.050 mmol, 20.5 mg), 4-tert-butyl-2,6-dimethylphenylboronic acid (2.5 mmol, 515 mg), anhydrous K_3PO_4 (4.0 mmol, 850 mg) and bis(2-(trimethylsilyl)ethyl) (R)-3,3'-dibromo-1,1'-binaphthyl-2,2'-dicarboxylate (0.5 mmol, 350 mg). The Schlenk tube was then evacuated and backfilled with argon. After adding toluene (2.0 mL) to the Schlenk tube, the rubber septum was replaced by a glass stopper and the reaction was stirred for 10 h at $100\text{ }^{\circ}\text{C}$. The mixture was then allowed to room temperature and diluted with ethyl acetate. The solution was passed through short pad of silica gel and concentrated *in vacuo*. The residue was then purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 30:1) to give the title compound as a colorless oil [62% (262 mg)].

^1H NMR (400 MHz, CDCl_3) δ 7.86 (2H, d, $J = 8.3$ Hz, ArH), 7.74 (2H, s, ArH), 7.50

(2H, m, ArH), 7.34 (4H, m, ArH), 7.08 (2H, s, ArH), 7.06 (2H, s, ArH), 3.54 (2H, m, CHHCH₂TMS), 3.40 (2H, m, CHHCH₂TMS), 2.11 (6H, s, ArCH₃), 2.09 (6H, s, ArCH₃), 1.32 (18H, s, *t*-Bu), 0.09 (4H, m, CH₂CH₂TMS), -0.21 (18H, s, TMS); ¹³C NMR (100 MHz, CDCl₃) δ 167.6, 150.0, 136.9, 136.7, 136.1, 135.8, 134.5, 133.48, 133.45, 132.3, 128.8, 127.69, 127.66, 126.9, 126.4, 123.8, 123.7, 62.3, 34.3, 31.5, 21.2, 21.0, 16.1, -1.8; IR (neat) 3057, 2955, 2868, 1728, 1265, 1258, 1134, 1098, 1038 cm⁻¹; HRMS (ESI) exact mass calcd. for C₅₆H₇₀O₄Si₂: *m/z* 885.4705 ([M + Na]⁺), found: *m/z* 885.4715 ([M + Na]⁺); [α]_D²⁵ = +50.6 (*c* = 1.0, CHCl₃).

(*R*)-3,3'-Bis(4-*tert*-butyl-2,6-dimethylphenyl)-1,1'-binaphthyl-2,2'-dicarboxylic acid (4f).

To a stirred solution of the ester (0.31 mmol, 262 mg) in THF (1.0 mL) was added a 1 M solution of tetrabutylammonium fluoride in THF (3.1 mmol, 3.1 mL) and the reaction was warmed to 60 °C. After stirring for 24 h at the same temperature, the mixture was treated with 1N HCl and the organic layer was extracted with ethyl acetate. The combined organic layers were dried over Na₂SO₄ and concentrated. The residue was then purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 2:1 to 1:1) to give the title compound as a white solid [74% (157 mg)].

¹H NMR (400 MHz, CD₃OD) δ 7.92 (2H, d, *J* = 8.3 Hz, ArH), 7.73 (2H, s, ArH), 7.50 (2H, m, ArH), 7.32 (2H, m, ArH), 7.18 (2H, d, *J* = 8.6 Hz, ArH), 7.12 (2H, s, ArH), 7.09 (2H, s, ArH), 2.23 (6H, s, ArCH₃), 2.05 (6H, s, ArCH₃), 1.32 (18H, s, *t*-Bu); ¹³C NMR (100 MHz, CD₃OD) δ 173.9, 151.1, 138.3, 138.0, 137.1, 137.0, 135.1, 133.7, 132.9, 130.6, 128.9, 128.0, 127.8, 127.7, 125.0, 35.1, 31.9, 21.8, 21.3; IR (neat) 3055, 2959, 2866, 1749, 1690, 1452, 1360, 1269, 1233 cm⁻¹; HRMS (ESI) exact mass calcd. for C₄₆H₄₆O₄: *m/z* 685.3288 ([M + Na]⁺), found: *m/z* 685.3312 ([M + Na]⁺); [α]_D²⁶ = +78.2 (*c* = 0.5, CH₃OH).

(*R*)-3,3'-Diphenyl-1,1'-binaphthyl-2,2'-dicarboxylic acid (4b).

¹H NMR (400 MHz, CD₃OD) δ 8.02 (2H, s, ArH), 7.96 (2H, d, *J* = 8.3 Hz, ArH), 7.67 (4H, d, *J* = 7.1 Hz, ArH), 7.42-7.49 (6H, m, ArH), 7.36 (2H, t, *J* = 7.3 Hz, ArH), 7.26

(2H, m, ArH), 7.06 (2H, d, $J = 8.8$ Hz, ArH); ^{13}C NMR (100 MHz, CD_3OD) δ 175.7, 142.4, 137.8, 134.6, 133.5, 132.9, 130.8, 129.9, 129.4, 129.2, 128.4, 128.1, 128.0, 127.8; HRMS (ESI) exact mass calcd. for $\text{C}_{34}\text{H}_{22}\text{O}_4$: m/z 517.1410 ($[\text{M} + \text{Na}]^+$), found: m/z 517.1419 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{23} = +16.8$ ($c = 0.5$, CH_3OH).

(*R*)-3,3'-Bis(3,5-bis(trifluoromethyl)phenyl)-1,1'-binaphthyl-2,2'-dicarboxylic acid (4c).

^1H NMR (400 MHz, CD_3OD) δ 8.15 (4H, s, ArH), 8.05 (2H, s, ArH), 7.95 (2H, d, $J = 8.3$ Hz, ArH), 7.89 (2H, s, ArH), 7.43 (2H, m, ArH), 7.23 (2H, m, ArH), 6.98 (2H, d, $J = 8.6$ Hz, ArH); ^{13}C NMR (100 MHz, CD_3OD) δ 175.0, 144.9, 137.6, 134.7, 134.5, 133.54, 133.47, 132.7 (q, $^2J(^{13}\text{C}, ^{19}\text{F}) = 32.9$ Hz), 131.5, 130.4 (m), 129.6, 129.0, 128.5, 127.7, 124.9 (q, $^1J(^{13}\text{C}, ^{19}\text{F}) = 273.4$ Hz), 122.1 (m); HRMS (ESI) exact mass calcd. for $\text{C}_{38}\text{H}_{18}\text{F}_{12}\text{O}_4$: m/z 789.0906 ($[\text{M} + \text{Na}]^+$), found: m/z 789.0922 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{25} = +32.1$ ($c = 0.5$, CH_3OH).

(*R*)-3,3'-Bis(4-*tert*-butylphenyl)-1,1'-binaphthyl-2,2'-dicarboxylic acid (4d).

^1H NMR (400 MHz, CD_3OD) δ 7.98 (2H, s, ArH), 7.93 (2H, d, $J = 8.1$ Hz, ArH), 7.62 (4H, d, $J = 8.6$ Hz, ArH), 7.48 (4H, d, $J = 8.6$ Hz, ArH), 7.44 (2H, m, ArH), 7.23 (2H, m, ArH), 7.04 (2H, d, $J = 8.3$ Hz, ArH), 1.36 (18H, s, *t*-Bu); ^{13}C NMR (100 MHz, CD_3OD) δ 176.2, 151.4, 139.5, 137.6, 134.6, 133.3, 132.9, 130.6, 129.6, 129.1, 127.9, 127.8, 126.3, 35.4, 31.8; HRMS (ESI) exact mass calcd. for $\text{C}_{42}\text{H}_{38}\text{O}_4$: m/z 629.2662 ($[\text{M} + \text{Na}]^+$), found: m/z 629.2643 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{29} = -26.3$ ($c = 0.5$, CH_3OH).

(*R*)-3,3'-Dimesityl-1,1'-binaphthyl-2,2'-dicarboxylic acid (4e).

^1H NMR (400 MHz, CD_3OD) δ 7.94 (2H, d, $J = 8.3$ Hz, ArH), 7.74 (2H, s, ArH), 7.52 (2H, m, ArH), 7.33 (2H, m, ArH), 7.19 (2H, d, 8.5 Hz, ArH), 6.91 (2H, s, ArH), 6.88 (2H, s, ArH), 2.28 (6H, s, ArCH₃), 2.18 (6H, s, ArCH₃), 2.00 (6H, s, ArCH₃); ^{13}C NMR (100 MHz, CD_3OD) δ 173.4, 138.3, 138.03, 138.00, 137.4, 136.9, 136.3, 135.2, 134.0, 132.9, 130.7, 129.0, 128.8, 128.7, 128.2, 127.9, 127.7, 21.4, 21.2, 20.9; HRMS (ESI) exact mass calcd. for $\text{C}_{40}\text{H}_{34}\text{O}_4$: m/z 601.2349 ($[\text{M} + \text{Na}]^+$), found: m/z 601.2347 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{26} = +102.7$ ($c = 0.5$, CH_3OH).

•General procedure for the Mannich reaction of *N*-Boc imines and *tert*-butyl diazoacetate.

The reaction flask containing powdered molecular sieves 4 Å (100 mg) was flame-dried

under vacuum. To the flask were added catalyst **4f** (0.005 mmol, 3.3 mg) and CH₂Cl₂ (1.0 mL) and the solution was cooled to 0 °C. To the mixture were then added the corresponding imine (0.10 mmol) and *tert*-butyl diazoacetate (0.15 mmol, 21.3 mg). After the completion of the reaction, the solution was directly charged to column chromatography on silica gel to give the adduct.

***tert*-Butyl (R)-3-(*tert*-butoxycarbonylamino)-2-diazo-3-phenylpropanoate (Table 2, entry 1).**

Prepared according to the general procedure with benzaldehyde *N*-(*tert*-butoxycarbonyl)imine (0.10 mmol, 20.5 mg) and *tert*-butyl diazoacetate (0.15 mmol, 21.3 mg) over the course of 24 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/diethyl ether = 4:1) to give the title compound as a yellow oil [80% yield (27.8 mg), 95% ee].

Enantiomeric purity was determined by HPLC analysis (Daicel Chiralpak AD-H, hexane/2-propanol = 30:1, flow rate = 0.5 mL/min, retention time; 22.7 min (major) and 24.9 min (minor)).

¹H NMR (400 MHz, CDCl₃) δ 7.27-7.38 (5H, m, ArH), 5.62 (1H, d, *J* = 6.4 Hz, CHNH₂Boc), 5.37 (1H, br, CHNH₂Boc), 1.45 (9H, s, *t*-Bu), 1.44 (9H, s, *t*-Bu); ¹³C NMR (100 MHz, CDCl₃) δ 165.3, 154.9, 139.4, 128.8, 127.9, 126.2, 82.0, 80.3, 61.1, 51.1, 28.34, 28.61; IR (neat) 3341, 2978, 2932, 2091, 1692, 1495, 1368, 1250, 1165 cm⁻¹; HRMS (ESI) exact mass calcd. for C₁₈H₂₅N₃O₄: *m/z* 370.1737 ([M + Na]⁺), found: *m/z* 370.1741 ([M + Na]⁺); [α]_D²⁶ = +27.6 (*c* = 1.0, CHCl₃; 95% ee).

***tert*-Butyl (R)-3-(*tert*-butoxycarbonylamino)-2-diazo-3-(2-tolyl)propanoate (Table 2, entry 2).**

Prepared according to the general procedure with *o*-tolualdehyde *N*-(*tert*-butoxycarbonyl)imine (0.10 mmol, 21.9 mg) and *tert*-butyl diazoacetate (0.15 mmol, 21.3 mg) over the course of 72 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/diethyl ether = 4:1) to give the title compound as a yellow oil [53% yield (19.2 mg), 91% ee].

Enantiomeric purity was determined by HPLC analysis (Daicel Chiralpak AD-H, hexane/2-propanol = 30:1, flow rate = 0.5 mL/min, retention time; 19.6 min (major) and 26.8 min (minor)).

¹H NMR (400 MHz, CDCl₃) δ 7.31 (1H, m, ArH), 7.16-7.22 (3H, m, ArH), 5.76 (1H, d, *J* = 6.6 Hz, CHNH₂Boc), 5.10 (1H, br, CHNH₂Boc), 2.37 (3H, s, ArCH₃), 1.44 (9H, s, *t*-Bu), 1.43 (9H, s, *t*-Bu); ¹³C NMR (100 MHz, CDCl₃) δ 165.1, 154.7, 137.3, 135.4,

130.9, 128.0, 126.3, 125.5, 81.9, 80.2, 61.1, 48.0, 28.33, 28.28; IR (neat) 3350, 3260, 2978, 2932, 2091, 1692, 1487, 1368, 1341, 1294, 1250, 1161, 1098, 1044 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{19}\text{H}_{27}\text{N}_3\text{O}_4$: m/z 384.1894 ($[\text{M} + \text{Na}]^+$), found: m/z 384.1889 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{28} = +46.8$ ($c = 1.0$, CHCl_3 ; 90% ee).

tert-Butyl (R)-3-(tert-butoxycarbonylamino)-2-diazo-3-(3-tolyl)propanoate (Table 2, entry 3).

Prepared according to the general procedure with *m*-tolualdehyde *N*-(tert-butoxycarbonyl)imine (0.10 mmol, 21.9 mg) and *tert*-butyl diazoacetate (0.15 mmol, 21.3 mg) over the course of 20 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/diethyl ether = 5:1) to give the title compound as a yellow oil [74% yield (26.7 mg), 92% ee].

Enantiomeric purity was determined by HPLC analysis (Daicel Chiralpak AD-H, hexane/2-propanol = 30:1, flow rate = 0.5 mL/min, retention time; 20.1 min (major) and 23.4 min (minor)).

^1H NMR (400 MHz, CDCl_3) δ 7.23 (1H, d, $J = 7.8$ Hz, ArH), 7.09-7.14 (3H, m, ArH), 5.57 (1H, d, $J = 7.3$ Hz, CHNH_{Boc}), 5.32 (1H, br, CHNH_{Boc}), 2.35 (3H, s, ArCH₃), 1.45 (9H, s, *t*-Bu), 1.44 (9H, s, *t*-Bu); ^{13}C NMR (100 MHz, CDCl_3) δ 165.3, 154.9, 139.3, 138.5, 128.7, 126.9, 123.2, 81.9, 80.2, 61.2, 51.1, 28.34, 28.31, 21.5; IR (neat) 3352, 2974, 2932, 2091, 1695, 1489, 1368, 1231, 1163 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{19}\text{H}_{27}\text{N}_3\text{O}_4$: m/z 384.1894 ($[\text{M} + \text{Na}]^+$), found: m/z 384.1900 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{28} = +23.5$ ($c = 1.0$, CHCl_3 ; 92% ee).

tert-Butyl (R)-3-(tert-butoxycarbonylamino)-2-diazo-3-(4-tolyl)propanoate (Table 2, entry 4).

Prepared according to the general procedure with *p*-tolualdehyde *N*-(tert-butoxycarbonyl)imine (0.10 mmol, 21.9 mg) and *tert*-butyl diazoacetate (0.15 mmol, 21.3 mg) over the course of 18 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/diethyl ether = 5:1) to give the title compound as a yellow solid [79% yield (28.7 mg), 95% ee].

Enantiomeric purity was determined by HPLC analysis (Daicel Chiralpak AD-H, hexane/2-propanol = 30:1, flow rate = 0.5 mL/min, retention time; 23.0 min (major) and 25.6 min (minor)).

^1H NMR (400 MHz, CDCl_3) δ 7.22 (2H, d, $J = 8.3$ Hz, ArH), 7.12 (2H, d, $J = 8.3$ Hz, ArH), 5.58 (1H, d, $J = 6.1$ Hz, CHNH Boc), 5.33 (1H, br, CHNH Boc), 2.33 (3H, s, ArCH $_3$), 1.45 (9H, s, $t\text{-Bu}$), 1.44 (9H, s, $t\text{-Bu}$); ^{13}C NMR (100 MHz, CDCl_3) δ 165.3, 154.9, 137.6, 136.3, 129.5, 126.1, 81.9, 80.2, 61.2, 51.0, 28.35, 28.32, 21.1; IR (neat) 3350, 2978, 2930, 2091, 1692, 1512, 1368, 1250, 1165 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{19}\text{H}_{27}\text{N}_3\text{O}_4$: m/z 384.1894 ($[\text{M} + \text{Na}]^+$), found: m/z 384.1899 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{27} = +24.1$ ($c = 1.0$, CHCl_3 ; 95% ee).

***tert*-Butyl (R)-3-(*tert*-butoxycarbonylamino)-2-diazo-3-(2-naphthyl)propanoate (Table 2, entry 5).**

Prepared according to the general procedure with 2-naphthaldehyde N -(*tert*-butoxycarbonyl)imine (0.10 mmol, 25.5 mg) and *tert*-butyl diazoacetate (0.15 mmol, 21.3 mg) over the course of 17 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/diethyl ether = 5:1) to give the title compound as a yellow solid [77% yield (30.7 mg), 94% ee].

Enantiomeric purity was determined by HPLC analysis (Daicel Chiralpak AD-H, hexane/2-propanol = 30:1, flow rate = 0.5 mL/min, retention time; 28.8 min (major) and 34.2 min (minor)).

^1H NMR (400 MHz, CDCl_3) δ 7.79-7.85 (4H, m, ArH), 7.44-7.50 (3H, m, ArH), 5.79 (1H, d, $J = 6.6$ Hz, CHNH Boc), 5.50 (1H, br, CHNH Boc), 1.47 (9H, s, $t\text{-Bu}$), 1.44 (9H, s, $t\text{-Bu}$); ^{13}C NMR (100 MHz, CDCl_3) δ 165.3, 155.0, 136.7, 133.3, 133.0, 128.8, 128.1, 127.6, 126.4, 126.2, 125.0, 124.3, 82.0, 80.4, 61.2, 51.5, 28.36, 28.34; IR (neat) 3348, 2976, 2932, 2091, 1692, 1506, 1368, 1341, 1250, 1163 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{22}\text{H}_{27}\text{N}_3\text{O}_4$: m/z 420.1894 ($[\text{M} + \text{Na}]^+$), found: m/z 420.1900 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{30} = +28.4$ ($c = 1.0$, CHCl_3 ; 94% ee).

***tert*-Butyl (R)-3-(*tert*-butoxycarbonylamino)-2-diazo-3-(4-fluorophenyl)propanoate (Table 2, entry 6).**

Prepared according to the general procedure with *p*-fluorobenzaldehyde N -(*tert*-butoxycarbonyl)imine (0.10 mmol, 22.3 mg) and *tert*-butyl diazoacetate (0.15 mmol, 21.3 mg) over the course of 20 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/diethyl ether = 4:1, further purification was performed eluting with CH_2Cl_2) to give the title compound as a yellow solid [83% yield (30.2 mg), 95% ee].

Enantiomeric purity was determined by HPLC analysis (Daicel Chiralpak AD-H, hexane/2-propanol = 30:1, flow rate = 0.5 mL/min, retention time; 22.5 min (major) and 27.9 min (minor)).

^1H NMR (400 MHz, CDCl_3) δ 7.32 (2H, dd, $J = 8.8$ Hz, $^4J(^1\text{H}, ^{19}\text{F}) = 5.4$ Hz, ArH), 7.04 (2H, app t, $J = 8.8$ Hz, ArH), 5.59 (1H, d, $J = 7.1$ Hz, CHNHBoc), 5.37 (1H, br, CHNHBoc), 1.45 (9H, s, *t*-Bu), 1.44 (9H, s, *t*-Bu); ^{13}C NMR (100 MHz, CDCl_3) δ 165.1, 162.3 (d, $^1J(^{13}\text{C}, ^{19}\text{F}) = 247.7$ Hz), 135.2, 127.9 (d, $^3J(^{13}\text{C}, ^{19}\text{F}) = 8.2$ Hz), 115.6 (d, $^2J(^{13}\text{C}, ^{19}\text{F}) = 21.4$ Hz), 82.1, 80.4, 60.9, 50.8, 28.34, 28.30; IR (neat) 3341, 2978, 2934, 2091, 1688, 1508, 1368, 1341, 1298, 1227, 1157, 1098 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{18}\text{H}_{24}\text{FN}_3\text{O}_4$: m/z 388.1643 ($[\text{M} + \text{Na}]^+$), found: m/z 388.1634 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{28} = +39.2$ ($c = 1.0$, CHCl_3 ; 95% ee).

***tert*-Butyl (R)-3-(*tert*-butoxycarbonylamino)-2-diazo-3-(4-chlorophenyl)propanoate (Table 2, entry 7).**

Prepared according to the general procedure with *p*-chlorobenzaldehyde *N*-(*tert*-butoxycarbonyl)imine (0.10 mmol, 24.0 mg) and *tert*-butyl diazoacetate (0.15 mmol, 21.3 mg) over the course of 26 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/diethyl ether = 4:1) to give the title compound as a yellow solid [89% yield (33.8 mg), 95% ee].

Enantiomeric purity was determined by HPLC analysis (Daicel Chiralpak AD-H, hexane/2-propanol = 30:1, flow rate = 0.5 mL/min, retention time; 24.2 min (major) and 29.1 min (minor)).

^1H NMR (400 MHz, CDCl_3) δ 7.33 (2H, d, $J = 8.8$ Hz, ArH), 7.28 (2H, d, $J = 9.0$ Hz, ArH), 5.59 (1H, d, $J = 6.4$ Hz, CHNHBoc), 5.42 (1H, br, CHNHBoc), 1.45 (9H, s, *t*-Bu), 1.44 (9H, s, *t*-Bu); ^{13}C NMR (100 MHz, CDCl_3) δ 165.1, 154.9, 138.0, 133.7, 128.9, 127.6, 82.2, 80.4, 60.7, 50.8, 28.34, 28.30; IR (neat) 3341, 2978, 2932, 2091, 1688, 1491, 1368, 1341, 1298, 1248, 1161, 1092 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{18}\text{H}_{24}\text{ClN}_3\text{O}_4$: m/z 404.1348 ($[\text{M} + \text{Na}]^+$), found: m/z 404.1344 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{28} = +41.0$ ($c = 1.0$, CHCl_3 ; 95% ee).

***tert*-Butyl (R)-3-(*tert*-butoxycarbonylamino)-2-diazo-3-(4-nitrophenyl)propanoate (Table 2, entry 8).**

Prepared according to the general procedure with *p*-nitrobenzaldehyde *N*-(*tert*-butoxycarbonyl)imine (0.10 mmol, 25.0 mg) and *tert*-butyl diazoacetate (0.15 mmol, 21.3 mg) over the course of 72

h. The crude material was purified by column chromatography on silica gel (eluting with hexane/diethyl ether = 5:1) to give the title compound as a yellow oil [37% yield (14.7 mg), 95% ee].

Enantiomeric purity was determined by HPLC analysis (Daicel Chiralpak AD-H, hexane/2-propanol = 10:1, flow rate = 0.5 mL/min, retention time; 24.9 min (minor) and 29.0 min (major)).

^1H NMR (400 MHz, CDCl_3) δ 8.23 (2H, d, J = 8.8 Hz, ArH), 7.54 (2H, d, J = 8.8 Hz, ArH), 5.70 (1H, d, J = 6.8 Hz, CHNHBoc), 5.60 (1H, br, CHNHBoc), 1.46 (9H, s, t -Bu), 1.45 (9H, s, t -Bu); ^{13}C NMR (100 MHz, CDCl_3) δ 164.8, 154.9, 147.5, 146.9, 82.7, 80.9, 60.3, 51.2, 28.34, 28.29; IR (neat) 3339, 2978, 2932, 2093, 1688, 1522, 1493, 1368, 1346, 1250, 1161 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{18}\text{H}_{24}\text{N}_4\text{O}_6$: m/z 415.1588 ($[\text{M} + \text{Na}]^+$), found: m/z 415.1590 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{27} = +66.6$ (c = 1.0, CHCl_3 ; 95% ee).

***tert*-Butyl (*R*)-3-(*tert*-butoxycarbonylamino)-2-diazo-3-(4-methoxyphenyl) propanoate (Table 2, entry 9).**

Prepared according to the general procedure with *p*-anisaldehyde *N*-(*tert*-butoxycarbonyl)imine (0.10 mmol, 23.5 mg) and *tert*-butyl diazoacetate (0.15 mmol, 21.3 mg) over the course of 20 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/diethyl ether = 3:1) to give the title compound as a yellow oil [72% yield (27.2 mg), 95% ee].

Enantiomeric purity was determined by HPLC analysis (Daicel Chiralpak AD-H, hexane/2-propanol = 20:1, flow rate = 0.5 mL/min, retention time; 25.4 min (major) and 30.1 min (minor)).

^1H NMR (400 MHz, CDCl_3) δ 7.26 (2H, d, J = 9.0 Hz, ArH), 6.88 (2H, d, J = 8.8 Hz, ArH), 5.56 (1H, d, J = 6.8 Hz, CHNHBoc), 5.31 (1H, br, CHNHBoc), 3.80 (3H, s, OCH_3), 1.449 (9H, s, t -Bu), 1.443 (9H, s, t -Bu); ^{13}C NMR (100 MHz, CDCl_3) δ 165.3, 159.2, 154.9, 131.4, 127.4, 114.1, 81.9, 80.2, 61.2, 55.3, 50.7, 28.36, 28.32; IR (neat) 3347, 2976, 2930, 2091, 1694, 1512, 1368, 1339, 1300, 1250, 1163, 1036 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{19}\text{H}_{27}\text{N}_3\text{O}_5$: m/z 400.1843 ($[\text{M} + \text{Na}]^+$), found: m/z 400.1844 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{27} = +16.8$ (c = 1.0, CHCl_3 ; 95% ee).

***tert*-Butyl (*S*)-3-(*tert*-butoxycarbonylamino)-2-diazo-3-(2-furyl)propanoate (Table 2, entry 10).**

Prepared according to the general procedure with furfural *N*-(*tert*-butoxycarbonyl)imine (0.10 mmol, 19.5 mg) and *tert*-butyl diazoacetate (0.15 mmol, 21.3 mg) over the course of 5 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/diethyl ether = 4:1) to give the title compound as a yellow oil [84% yield (28.5 mg), 85% ee].

Enantiomeric purity was determined by HPLC analysis (Daicel Chiralpak AD-H, hexane/ethanol = 100:1, flow rate = 0.5 mL/min, retention time; 23.4 min (minor) and 28.1 min (major)).

¹H NMR (400 MHz, CDCl₃) δ 7.36 (1H, d, *J* = 1.0 Hz, ArH), 6.33 (1H, dd, *J* = 3.2, 1.7 Hz, ArH), 6.27 (1H, d, *J* = 3.2 Hz, ArH), 5.65 (1H, d, *J* = 6.6 Hz, CHNH₂Boc), 5.39 (1H, br, CHNH₂Boc), 1.46 (18H, app s, *t*-Bu); ¹³C NMR (100 MHz, CDCl₃) δ 164.9, 154.7, 151.4, 142.3, 110.5, 106.9, 82.0, 80.4, 60.0, 46.1, 28.33, 28.29; IR (neat) 3341, 2978, 2934, 2093, 1690, 1503, 1368, 1298, 1250, 1157, 1011 cm⁻¹; HRMS (ESI) exact mass calcd. for C₁₆H₂₃N₃O₅: *m/z* 360.1530 ([M + Na]⁺), found: *m/z* 360.1516 ([M + Na]⁺); [α]_D²⁷ = +17.1 (*c* = 1.0, CHCl₃; 85% ee).

•General procedure for the Mannich reaction of *N*-Boc imines and dimethyl diazomethylphosphonate.

The reaction flask containing powdered molecular sieves 4 Å (100 mg) was flame-dried under vacuum. To the flask were added catalyst **4f** (0.005 mmol, 3.3 mg) and CH₂Cl₂ (1.0 mL) and the solution was cooled to 0 °C. To the mixture were then added the corresponding imine (0.10 mmol) and dimethyl diazomethylphosphonate (0.15 mmol, 22.5 mg). After the completion of the reaction, the solution was directly charged to column chromatography on silica gel to give the adduct.

Dimethyl (R)-2-(*tert*-butoxycarbonylamino)-1-diazo-2-phenylethylphosphonate (Table 3, entry 1).

Prepared according to the general procedure with benzaldehyde *N*-(*tert*-butoxycarbonyl)imine (0.10 mmol, 20.5 mg) and dimethyl diazomethylphosphonate (0.15 mmol, 22.5 mg) over the course of 85 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:1) to give the title compound as a yellow oil [68% yield (24.3 mg), 96% ee].

Enantiomeric purity was determined by HPLC analysis (Daicel Chiralcel OD-H, hexane/2-propanol = 20:1, flow rate = 0.5 mL/min, retention time; 18.7 min (minor) and 21.7 min (major)).

^1H NMR (400 MHz, CDCl_3) δ 7.28-7.38 (5H, m, ArH), 5.46 (2H, br, CHNH₂Boc), 3.74 (3H, d, $^2J(^1\text{H}, ^{31}\text{P}) = 12.0$, P(OMe)), 3.62 (3H, d, $^2J(^1\text{H}, ^{31}\text{P}) = 12.0$, P(OMe)), 1.45 (9H, s, *t*-Bu); ^{13}C NMR (100 MHz, CDCl_3) δ 154.7, 139.0 ($^3J(^{13}\text{C}, ^{31}\text{P}) = 2.4$ Hz), 128.9, 128.2, 126.2, 80.3, 53.01 (d, $^2J(^{13}\text{C}, ^{31}\text{P}) = 5.4$ Hz), 52.96 (d, $^2J(^{13}\text{C}, ^{31}\text{P}) = 5.8$ Hz), 52.0 (br), 45.9 ($^1J(^{13}\text{C}, ^{31}\text{P}) = 231.2$ Hz), 28.2; IR (neat) 3279, 2978, 2089, 1711, 1520, 1454, 1366, 1248, 1167, 1022 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{15}\text{H}_{22}\text{N}_3\text{O}_5\text{P}$: m/z 378.1189 ($[\text{M} + \text{Na}]^+$), found: m/z 378.1179 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{27} = +73.2$ ($c = 1.0$, CHCl_3 ; 96% ee).

Dimethyl (R)-2-(tert-butoxycarbonylamino)-1-diazo-2-(4-tolyl)ethylphosphonate (Table 3, entry 2).

Prepared according to the general procedure with *p*-tolualdehyde *N*-(tert-butoxycarbonyl)imine (0.10 mmol, 21.9 mg) and dimethyl diazomethylphosphonate (0.15 mmol, 22.5 mg) over the course of 68 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:1) to give the title compound as a yellow solid [68% yield (25.1 mg), 96% ee].

Enantiomeric purity was determined by HPLC analysis (Daicel Chiralcel OD-H, hexane/2-propanol = 20:1, flow rate = 0.5 mL/min, retention time; 18.2 min (minor) and 22.7 min (major)).

^1H NMR (400 MHz, CDCl_3) δ 7.25 (2H, d, $J = 8.3$ Hz, ArH), 7.17 (2H, d, $J = 8.1$ Hz, ArH), 5.42 (1H, app d, $J = 5.4$ Hz, CHNH₂Boc), 5.38 (1H, br, CHNH₂Boc), 3.75 (3H, d, $^2J(^1\text{H}, ^{31}\text{P}) = 11.7$ Hz, P(OMe)), 3.63 (3H, d, $^2J(^1\text{H}, ^{31}\text{P}) = 12.0$ Hz, P(OMe)), 2.34 (3H, s, ArCH₃), 1.45 (9H, s, *t*-Bu); ^{13}C NMR (100 MHz, CDCl_3) δ 154.7, 138.0, 136.0 ($^3J(^{13}\text{C}, ^{31}\text{P}) = 3.3$ Hz), 80.3, 53.1 (d, $^2J(^{13}\text{C}, ^{31}\text{P}) = 4.9$ Hz), 53.0 (d, $^2J(^{13}\text{C}, ^{31}\text{P}) = 4.9$ Hz), 51.8 (br), 46.0 ($^1J(^{13}\text{C}, ^{31}\text{P}) = 231.2$ Hz), 28.3, 21.1; IR (neat) 3279, 2976, 2855, 2089, 1711, 1514, 1454, 1368, 1248, 1169, 1024 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{16}\text{H}_{24}\text{N}_3\text{O}_5\text{P}$: m/z 392.1346 ($[\text{M} + \text{Na}]^+$), found: m/z 392.1352 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{28} = +61.6$ ($c = 1.0$, CHCl_3 ; 96% ee).

Dimethyl (R)-2-(tert-butoxycarbonylamino)-1-diazo-2-(4-fluorophenyl)ethylphosphonate (Table 3, entry 3).

Prepared according to the general procedure with

p-fluorobenzaldehyde *N*-(*tert*-butoxycarbonyl)imine (0.10 mmol, 22.3 mg) and dimethyl diazomethylphosphonate (0.15 mmol, 22.5 mg) over the course of 52 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:1) to give the title compound as a yellow oil [85% yield (31.6 mg), 96% ee].

Enantiomeric purity was determined by HPLC analysis (Daicel Chiralcel OD-H, hexane/2-propanol = 20:1, flow rate = 0.5 mL/min, retention time; 19.5 min (minor) and 24.5 min (major)).

¹H NMR (400 MHz, CDCl₃) δ 7.36 (2H, dd, *J* = 8.8 Hz, ⁴*J*(¹H, ¹⁹F) = 5.4 Hz, ArH), 7.04 (2H, app t, *J* = 8.6 Hz, ArH), 5.48 (2H, br, CHNH*Boc*), 3.75 (3H, d, ²*J*(¹H, ³¹P) = 12.0 Hz, P(OMe)), 3.65 (3H, d, ²*J*(¹H, ³¹P) = 12.0 Hz, P(OMe)), 1.45 (9H, s, *t*-Bu); ¹³C NMR (100 MHz, CDCl₃) δ 162.4 (d, ¹*J*(¹³C, ¹⁹F) = 248.5 Hz), 154.7, 135.0 (app t, *J* = 3.3 Hz), 128.1 (d, ³*J*(¹³C, ¹⁹F) = 8.2 Hz), 115.8 (d, ²*J*(¹³C, ¹⁹F) = 22.2 Hz), 80.5, 53.11 (d, ²*J*(¹³C, ³¹P) = 5.8 Hz), 53.09 (d, ²*J*(¹³C, ³¹P) = 5.8 Hz), 51.6 (br), 45.9 (¹*J*(¹³C, ³¹P) = 231.2 Hz), 28.3; IR (neat) 3277, 2978, 2089, 1709, 1605, 1508, 1456, 1368, 1246, 1159, 1024 cm⁻¹; HRMS (ESI) exact mass calcd. for C₁₅H₂₁FN₃O₅P: *m/z* 396.1095 ([M + Na]⁺), found: *m/z* 396.1086 ([M + Na]⁺); [α]_D²⁹ = +75.8 (*c* = 1.0, CHCl₃; 96% ee).

Dimethyl (R)-2-(*tert*-butoxycarbonylamino)-1-diazo-2-(4-chlorophenyl)ethylphosphonate (Table 3, entry 4).

Prepared according to the general procedure with *p*-chlorobenzaldehyde *N*-(*tert*-butoxycarbonyl)imine (0.10 mmol, 24.0 mg) and dimethyl diazomethylphosphonate (0.15 mmol, 22.5 mg) over the course of 68 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:1) to give the title compound as a yellow oil [81% yield (31.7 mg), 96% ee].

Enantiomeric purity was determined by HPLC analysis (Daicel Chiralcel OD-H, hexane/2-propanol = 20:1, flow rate = 0.5 mL/min, retention time; 19.2 min (minor) and 25.2 min (major)).

¹H NMR (400 MHz, CDCl₃) δ 7.35 (2H, d, *J* = 8.8 Hz, ArH), 7.32 (2H, d, *J* = 8.8 Hz, ArH), 5.52 (1H, app d, *J* = 7.6 Hz, CHNH*Boc*), 5.47 (1H, br, CHNH*Boc*), 3.75 (3H, d, ²*J*(¹H, ³¹P) = 12.0 Hz, P(OMe)), 3.65 (3H, d, ²*J*(¹H, ³¹P) = 12.0 Hz, P(OMe)), 1.45 (9H, s, *t*-Bu); ¹³C NMR (100 MHz, CDCl₃) δ 154.7, 137.7 (³*J*(¹³C, ³¹P) = 2.5 Hz), 134.0, 129.1, 127.7, 80.5, 53.1 (app d, *J* = 49.4 Hz), 46.9 (br), 45.8 (¹*J*(¹³C, ³¹P) = 231.3 Hz), 28.3; IR (neat) 3275, 2978, 2089, 1711, 1520, 1493, 1366, 1248, 1167, 1090, 1022 cm⁻¹;

HRMS (ESI) exact mass calcd. for C₁₅H₂₁ClN₃O₅P: *m/z* 412.0800 ([M + Na]⁺), found: *m/z* 412.0801 ([M + Na]⁺); [α]_D²⁸ = +70.9 (*c* = 1.0, CHCl₃; 96% ee).

Dimethyl (R)-2-(tert-butoxycarbonylamino)-1-diazo-2-(4-methoxyphenyl)ethylphosphonate (Table 3, entry 5).

Prepared according to the general procedure with *p*-anisaldehyde *N*-(tert-butoxycarbonyl)imine (0.10 mmol, 23.5 mg) and dimethyl diazomethylphosphonate (0.15 mmol, 22.5 mg) over the course of 50 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:1) to give the title compound as a yellow oil [40% yield (15.5 mg), 95% ee].

Enantiomeric purity was determined by HPLC analysis (Daicel Chiralcel OD-H, hexane/2-propanol = 20:1, flow rate = 0.5 mL/min, retention time; 28.1 min (minor) and 36.7 min (major)).

¹H NMR (400 MHz, CDCl₃) δ 7.29 (2H, d, *J* = 8.8 Hz, ArH), 6.90 (2H, d, *J* = 8.8 Hz, ArH), 5.43 (1H, br, CHNH₂Boc), 5.33 (1H, br, CHNH₂Boc), 3.81 (3H, s, ArOCH₃), 3.75 (3H, d, ²*J*(¹H, ³¹P) = 11.7 Hz, P(OMe)), 3.63 (3H, d, ²*J*(¹H, ³¹P) = 12.0 Hz, P(OMe)), 1.45 (9H, s, *t*-Bu); ¹³C NMR (100 MHz, CDCl₃) δ 159.4, 154.7, 131.1 (³*J*(¹³C, ³¹P) = 3.3 Hz), 127.5, 114.2, 80.3, 55.3, 53.07 (²*J*(¹³C, ³¹P) = 5.8 Hz), 53.03 (²*J*(¹³C, ³¹P) = 4.9 Hz), 51.5 (br), 46.0 (¹*J*(¹³C, ³¹P) = 231.3 Hz), 28.3; IR (neat) 3277, 2974, 2847, 2087, 1707, 1612, 1510, 1458, 1364, 1246, 1169, 1024 cm⁻¹; HRMS (ESI) exact mass calcd. for C₁₆H₂₄N₃O₆P: *m/z* 408.1295 ([M + Na]⁺), found: *m/z* 408.1299 ([M + Na]⁺); [α]_D³⁰ = +60.8 (*c* = 1.0, CHCl₃; 95% ee).

Dimethyl (R)-2-(tert-butoxycarbonylamino)-1-diazo-2-(2-furyl)ethylphosphonate (Table 3, entry 6).

Prepared according to the general procedure with 2-furaldehyde *N*-(tert-butoxycarbonyl)imine (0.10 mmol, 19.5 mg) and dimethyl diazomethylphosphonate (0.15 mmol, 22.5 mg) over the course of 46 h. The crude material was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:1) to give the title compound as a yellow oil [89% yield (30.6 mg), 92% ee].

Enantiomeric purity was determined by HPLC analysis (Daicel Chiralcel OD-H, hexane/2-propanol = 20:1, flow rate = 0.5 mL/min, retention time; 20.6 min (minor) and 23.1 min (major)).

^1H NMR (400 MHz, CDCl_3) δ 7.39 (1H, d, J = 2.0 Hz, ArH), 6.37 (1H, dd, J = 2.0, 3.4 Hz, ArH), 6.32 (1H, d, J = 3.2 Hz, ArH), 5.52 (1H, app t, J = 9.0 Hz, CHNHBoc), 5.44 (1H, br, CHNHBoc), 3.75 (3H, d, $^2J(^1\text{H}, ^{31}\text{P})$ = 12.0 Hz, P(OMe)), 3.68 (3H, d, $^2J(^1\text{H}, ^{31}\text{P})$ = 12.0 Hz, P(OMe)), 1.46 (9H, s, *t*-Bu); ^{13}C NMR (100 MHz, CDCl_3) δ 154.5, 151.3 ($^3J(^{13}\text{C}, ^{31}\text{P})$ = 3.3 Hz), 142.6, 110.6, 107.2, 80.5, 53.05 ($^2J(^{13}\text{C}, ^{31}\text{P})$ = 5.8 Hz), 53.03 ($^2J(^{13}\text{C}, ^{31}\text{P})$ = 5.8 Hz), 46.9 (br), 44.6 ($^1J(^{13}\text{C}, ^{31}\text{P})$ = 230.0 Hz), 28.3; IR (neat) 3267, 2978, 2955, 2093, 1711, 1522, 1456, 1310, 1250, 1169, 1022 cm^{-1} ; HRMS (ESI) exact mass calcd. for $\text{C}_{13}\text{H}_{20}\text{N}_3\text{O}_6\text{P}$: m/z 368.0982 ($[\text{M} + \text{Na}]^+$), found: m/z 368.0984 ($[\text{M} + \text{Na}]^+$); $[\alpha]_{\text{D}}^{28}$ = +61.2 (c = 1.0, CHCl_3 ; 92% ee).

•Synthesis of Dimethyl (*R*)-2-(*tert*-butoxycarbonylamino)-2-phenylethylphosphonate 6.

To a stirred solution of Dimethyl (*R*)-2-(*tert*-butoxycarbonylamino)-1-diazo-2-phenylethylphosphonate (0.068 mmol, 24.3 mg) in MeOH (2 mL) was added 10% palladium on activated charcoal (15 mg). The reaction flask was then charged with hydrogen gas (balloon) and stirred for 2 h at room temperature. After the completion of the reaction (yellow color of the diazo compound disappeared), the mixture was filtered off. The filtrate was concentrated *in vacuo* and the residue was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 1:3) to give the title compound **6** as a colorless oil [90% yield (20.2 mg), 96% ee].

Enantiomeric purity was determined by HPLC analysis (Daicel Chiralcel OD-H, hexane/2-propanol = 10:1, flow rate = 0.5 mL/min, retention time; 20.0 min (minor) and 23.1 min (major)).

^1H NMR (400 MHz, CDCl_3) δ 7.24-7.37 (5H, m, ArH), 5.78 (1H, br, CHNHBoc), 5.07 (1H, br, CHNHBoc), 3.66 (3H, d, $^2J(^1\text{H}, ^{31}\text{P})$ = 11.0 Hz, P(OMe)), 3.44 (3H, d, $^2J(^1\text{H}, ^{31}\text{P})$ = 9.0 Hz, P(OMe)), 2.33 (2H, m, CH_2P), 1.42 (9H, s, *t*-Bu); ^{13}C NMR (100 MHz, CDCl_3) δ 155.0, 141.8, 128.6, 127.5, 126.0, 79.7, 52.3 ($^2J(^{13}\text{C}, ^{31}\text{P})$ = 7.4 Hz), 52.2 ($^2J(^{13}\text{C}, ^{31}\text{P})$ = 6.6 Hz), 49.9 (br), 32.3 ($^1J(^{13}\text{C}, ^{31}\text{P})$ = 139.1 Hz), 28.3; IR (neat) 3291, 2976, 1711, 1522, 1454, 1366, 1248, 1171, 1036 cm^{-1} ; HRMS (ESI) exact mass calcd.

for C₁₅H₂₄NO₃P: m/z 352.1284 ([M + Na]⁺), found: m/z 352.1295 ([M + Na]⁺); [α]_D²⁶ = -17.4 (c = 1.0, CHCl₃; 96% ee).

•Synthesis of Dimethyl (*R*)-2-amio-2-phenylethylphosphonate 7 and the determination of the absolute configuration.

To a stirred solution of dimethyl (*R*)-2-(*tert*-butoxycarbonylamino)-2-phenylethylphosphonate **6** (0.61 mmol, 20.2 mg) in CH₂Cl₂ (1.0 mL) was added trifluoroacetic acid (0.10 mL) and the mixture was stirred for 1 h at room temperature. The reaction solution was then quenched with saturated aqueous NaHCO₃ and extracted with CH₂Cl₂. The combined organic layers were dried over Na₂SO₄ and evaporated *in vacuo* to give the title compound **7** as a pale yellow oil [91% yield (12.7 mg)].

¹H NMR (400 MHz, CDCl₃) δ 7.32-7.40 (4H, m, ArH), 7.26 (1H, m, ArH), 4.42 (1H, br, CHNH₂), 3.73 (3H, d, J = 5.1 Hz, P(OMe)), 3.70 (3H, d, J = 5.2 Hz, P(OMe)), 2.17 (2H, m, CH₂P); ¹³C NMR (100 MHz, CDCl₃) δ 145.3 (³ J (¹³C, ³¹P) = 16.5 Hz), 128.7, 127.6, 126.1, 52.4 (² J (¹³C, ³¹P) = 6.6 Hz), 52.3 (² J (¹³C, ³¹P) = 6.6 Hz), 35.1 (¹ J (¹³C, ³¹P) = 137.4 Hz); IR (neat) 3375, 2953, 2851, 1238, 1184, 1028 cm⁻¹; HRMS (ESI) exact mass calcd. for C₁₀H₁₆NO₃P: m/z 252.0760 ([M + Na]⁺), found: m/z 252.0751 ([M + Na]⁺); [α]_D²⁸ = -18.3 (c = 1.0, CHCl₃; 96% ee; lit.⁶ [α]_D²⁰ = -15.3 for (*R*)).

•Synthesis of *tert*-butyl (*S*)-3-(*tert*-butoxycarbonylamino)-3-phenylpropanoate 8 and the determination of the absolute configuration of 2.

To a stirred solution of *tert*-butyl (*R*)-3-(*tert*-butoxycarbonylamino)-2-diazo-3-phenylpropanoate **2** (0.038 mmol, 13.3 mg) in ethyl acetate (1 mL)/acetic acid (0.1 mL) was added PtO₂ (0.0038 mmol, 0.9 mg). The reaction flask was then charged with hydrogen gas (balloon) and stirred for 2 h at room temperature. After the completion of the reaction (yellow color of diazo compound disappeared), the mixture was filtered off and washed with saturated aqueous NaHCO₃. The organic layer was collected, dried

over Na₂SO₄ and concentrated *in vacuo*. The residue was purified by column chromatography on silica gel (eluting with hexane/ethyl acetate = 7:1) to give the title compound **8** with *S* configuration as a white solid [87% yield (10.7 mg), 94% ee].

Enantiomeric purity was determined by HPLC analysis (Daicel Chiralpak AD-H, hexane/2-propanol = 20:1, flow rate = 0.5 mL/min, retention time; 30.2 min (major) and 34.2 min (minor)).

¹H NMR (400 MHz, CDCl₃) δ 7.22-7.34 (5H, m, ArH), 5.46 (1H, br, CHNH₂Boc), 5.07 (1H, br, CHNH₂Boc), 2.73 (2H, m, CH₂CO₂*t*-Bu), 1.42 (9H, s, *t*-Bu), 1.34 (9H, s, *t*-Bu); ¹³C NMR (100 MHz, CDCl₃) δ 170.2, 155.0, 141.4, 128.5, 127.4, 126.2, 81.1, 79.5, 51.4, 42.2, 28.4, 27.9; IR (neat) 3347, 2978, 2932, 1713, 1497, 1366, 1288, 1248, 1159, 1045, 1022 cm⁻¹; HRMS (ESI) exact mass calcd. for C₁₈H₂₇NO₄: *m/z* 344.1832 ([M + Na]⁺), found: *m/z* 344.1841 ([M + Na]⁺); [α]_D²⁸ = -26.1 (*c* = 1.0, CHCl₃; 94% ee; lit.⁷ [α]_D²⁵ = +21.0 for (*R*)).

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Daicel Chiralpak AD-H
hexane/2-propanol = 30:1
flow rate = 0.5 mL/min

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hexane/2-propanol = 30:1
flow rate = 0.5 mL/min

Daicel Chiralpak AD-H
hexane/2-propanol = 30:1
flow rate = 0.5 mL/min

Daicel Chiralpak AD-H
hexane/ethanol = 100:1
flow rate = 0.5 mL/min

Daicel Chiralcel OD-H
hexane/2-propanol = 20:1
flow rate = 0.5 mL/min

Daicel Chiralcel OD-H
hexane/2-propanol = 20:1
flow rate = 0.5 mL/min

Daicel Chiralcel OD-H
hexane/2-propanol = 20:1
flow rate = 0.5 mL/min

Daicel Chiralcel OD-H
hexane/2-propanol = 20:1
flow rate = 0.5 mL/min

Daicel Chiralcel OD-H
hexane/2-propanol = 20:1
flow rate = 0.5 mL/min

Daicel Chiralcel OD-H
hexane/2-propanol = 20:1
flow rate = 0.5 mL/min

Daicel Chiralcel OD-H
hexane/2-propanol = 10:1
flow rate = 0.5 mL/min

Daicel Chiralpak AD-H
hexane/2-propanol = 20:1
flow rate = 0.5 mL/min