SUPPORTING INFORMATION

Catalytic Enantioselective Addition of Dialkylzinc to *N*-Diphenylphosphinoylimines. A Practical Synthesis of α -Chiral Amines.

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General experimental procedure. HPLC traces and conditions for the separation of 1:1 mixture and enantioenriched compounds.

General: All non-aqueous reactions were run under an inert atmosphere (nitrogen or argon) with rigid exclusion of moisture from reagents and glassware using standard techniques for manipulating air-sensitive compounds.¹ All glassware was stored in the oven and/or was flame-dried prior to use under an inert atmosphere of gas. Anhydrous solvents were obtained either by filtration through drying columns (THF, ether, CH₂Cl₂, benzene, toluene, hexane) on a GlassContour system (Irvine, CA), by distillation over calcium hydride Et₃N or by distillation over sodium/benzophenone (DME). Analytical thin-layer chromatography (TLC) was performed on precoated, glass-backed silica gel (Merck 60 F254). Visualization of the developed chromatogram was performed by UV absorbance, aqueous cerium molybdate, ethanolic phosphomolybdic acid, iodine, aqueous potassium permanganate, or ninhydrin. Flash column chromatography was performed using 230-400 mesh silica (EM Science or Silicycle) of the indicated solvent system according to standard technique.² Melting points were obtained on a Buchi melting point apparatus and are uncorrected. Infrared spectra were taken on a Perkin Elmer Spectrum One FTIR and are reported in reciprocal centimeters (cm⁻¹). Nuclear magnetic resonance spectra (¹H, ¹³C) were recorded either on a Bruker AMX 300 or 400 spectrometer. Optical rotations were determined with a Perkin-Elmer 341 polarimeter at 589 or 546 nm. Data are reported as follows: [α]_D^{temp}, concentration (*c* in g/100 mL), and solvent.

Analytical HPLC was performed on a HP 1100 Analytical Instrument equipped with a diode array UV detector. Data are reported as follows: column type, eluent, flow rate, and retention time (*t*_r). Analytical Supercritical Fluid Chromatography was performed on a Berger SFC Analytical Instrument equipped with a diode array UV detector. Data are reported as follows: column type, eluent, flow rate, and retention time (*t*_r).

Materials: The (*R,R*)-Me-DUPHOS, Me₂Zn, and the Cu(OTf)₂ were purchased from Strem Chemicals. The Et₂Zn was purchased from Akzo Nobel Chemicals. All starting materials were purchased from Aldrich Chemical Company and used directly. The *N*-diphenylphosphinoylimines **14a**³⁻²¹, **14b**^{8,10-12,14,15,18-20}, **14c**^{11,18}, **14d**^{5-7,10,12-14,18}, **14e**^{4,5,9,14,18}, **14f**^{6,7,9-11,14,18}, **14g**^{11,18}, **14h**^{5-7,10,13-17,19}, **14i**^{4-9,15,17,19-21}, **14j**^{9,10,12,14,17} were prepared according to literature procedure. The resulting *N*-diphenylphosphinoylamides **15a**^{8,11,13-21}, **15b**^{8,11,14,15,18-20}, **15c**^{11,18}, **15d**^{13,14,18}, **15e**^{14,18}, **15f**^{11,14,18}, **15g**^{11,18}, **15h**^{13,17,19}, **15i**^{8,15,17,19-21}, **15j**^{14,17}, **15k**^{8,13,16}, **15m**⁸ were compared to authentic samples. Racemic samples for HPLC comparison were prepared by addition of EtMgBr in THF to *N*-diphenylphosphinoylimines. Dibutylzinc was prepared according to Noller's procedure.²²

Typical Experimental Procedure for the Catalytic Enantioselective Addition of Diethylzinc to *N*-Diphenylphosphinoylimines:

In the same flask (*R,R*)-Me-DUPHOS (30.1 mg, 0.098 mmol, 0.05 equiv) and Cu(OTf)₂ (71.0 mg, 0.196 mmol, 0.10 equiv) were dissolved in toluene (6 mL). The resulting heterogenous purple solution was stirred for 1 h at rt. Neat diethylzinc (411 μL, 3.93 mmol, 2.00 equiv) was added at rt, and the resulting brown suspension was stirred for an additional 20 min before cooling to 0 °C. After 10 min, a cooled solution (0 °C) of a fine suspension of *P,P*-diphenyl-*N*-[(1*E*)-1-phenylmethylene]phosphinic amide (**14a**) (599 mg, 1.96 mmol, 1.00 equiv) in PhMe (11 mL + 3 mL for washing) was cannulated (teflon cannula) to the catalyst solution. After stirring for 48 h at 0 °C, the reaction was quenched with saturated NH₄Cl and the aqueous phase was washed rapidly 3 with CH₂Cl₂ (3x). The combined organic layers were dried over Na₂SO₄. Concentration and purification by silica gel column chromatography gave *P,P*-diphenyl-*N*-[(1*S*)-1-phenylpropyl]phosphinic amide (**15a**) (618.6 mg, 94%) as a white solid. The enantiomeric ratio was determined to be 51:1 (96% *ee*) by HPLC analysis (*vide infra*).

***P,P*-diphenyl-*N*-[(1*S*)-1-phenylpropyl]phosphinic amide (**15a**).** The general procedure was followed. Yield 94%, enantiomeric ratio (51:1) (96% *ee*) was determined by HPLC analysis (Chiralpak AD, 80:20 hexanes:*i*-PrOH, 1.0 mL/min: (*R*)-**15a** *t*_r, 8.7 min, (*S*)-**15a** *t*_r, 11.4 min) or by SFC analysis (Chiralcel OD, 40°C, 200 bar, 10% MeOH in CO₂, 1.1 mL/min): (*R*)-**15a** *t*_r, 9.2 min, (*S*)-**15a** *t*_r, 10.8 min)

***N*-[*(1S)*-1-(4-methylphenyl)propyl]-*P,P*-diphenylphosphinic amide (**15b**).** The general procedure was followed. Yield 91 %, enantiomeric ratio (36:1) (95% *ee*) was determined by HPLC analysis (Chiralpak AD, 80:20 hexanes:*i*-PrOH, 1.0 mL/min: (*R*)-**15b** *t_r*, 8.7 min, (*S*)-**15b** *t_r*, 10.4 min).

***N*-[*(1S)*-1-(3-methylphenyl)propyl]-*P,P*-diphenylphosphinic amide (**15c**).** The general procedure was followed. Yield 93 %, enantiomeric ratio (32:1) (94% *ee*) was determined by HPLC analysis (Chiralpak AD, 80:20 hexanes:*i*-PrOH, 1.0 mL/min: (*R*)-**15c** *t_r*, 6.5 min, (*S*)-**15c** *t_r*, 10.2 min).

***N*-[*(1S)*-1-(4-chlorophenyl)propyl]-*P,P*-diphenylphosphinic amide (**15d**).** The general procedure was followed. Yield 95 %, enantiomeric ratio (19:1) (90% *ee*) was determined by HPLC analysis (Chiralpak AD, 80:20 hexanes:*i*-PrOH, 1.0 mL/min: (*R*)-**15d** *t_r*, 11.1 min, (*S*)-**15d** *t_r*, 12.8 min).

***N*–[(1*S*)-1-(4-bromophenyl)propyl]-*P,P*-diphenylphosphinic amide (15e).** The general procedure was followed. Yield 96 %, enantiomeric ratio (25:1) (92% *ee*) was determined by HPLC analysis (Chiralpak AD, 80:20 hexanes:*i*-PrOH, 1.0 mL/min: (*R*)-15e *t_r*, 11.3 min, (*R*)-15e *t_r*, 12.9 min).

***N*–[(1*S*)-1-(4-methoxyphenyl)propyl]-*P,P*-diphenylphosphinic amide (15f).** The general procedure was followed. Yield 74 %, enantiomeric ratio (42:1) (95% *ee*) was determined by HPLC analysis (Chiralpak AD, 80:20 hexanes:*i*-PrOH, 1.0 mL/min: (*R*)-15f *t_r*, 11.4 min, (*S*)-15f *t_r*, 14.0 min).

***N*–[(1*S*)-1-(1,3-benzodioxol-5-yl)propyl]-*P,P*-diphenylphosphinic amide (15g).** The general procedure was followed. Yield 81 %, enantiomeric ratio (37:1) (95% *ee*) was determined by HPLC

analysis (Chiralpak AD, 80:20 hexanes:*i*-PrOH, 1.0 mL/min: (*R*)-**15g** t_r , 11.3 min, (*S*)-**15g** t_r , 17.3 min).

***N*[(1*S*)-1-(1-naphthyl)propyl]-*P,P*-diphenylphosphinic amide (**15h**).** The general procedure was followed. Yield 93 %, enantiomeric ratio (24:1) (92% *ee*) was determined by HPLC analysis (Chiralpak AD, 90:10 hexanes:*i*-PrOH, 1.3 mL/min: (*R*)-**15h** t_r , 14.8 min, (*S*)-**15h** t_r , 25.1 min).

***N*[(1*S*)-1-(2-naphthyl)propyl]-*P,P*-diphenylphosphinic amide (**15i**).** The general procedure was followed. Yield 94 %, enantiomeric ratio (29:1) (93% *ee*) was determined by HPLC analysis (Chiralpak AD, 80:20 hexanes:*i*-PrOH, 1.0 mL/min: (*R*)-**15i** t_r , 9.4 min, (*S*)-**15i** t_r , 12.9 min). mp 125-126 °C; $[\alpha]_D^{20} +28.4^\circ$ (c 3.84, MeOH); ^1H NMR (400 MHz, C_6D_6) δ 8.11-7.96 (m, 4H), 7.08-6.97 (m, 6H), 2.70 (t, $J = 8.4$ Hz, 1H), 2.41-2.29 (m, 1H), 1.49 (qn, $J = 6.9$ Hz, 2H), 0.85 (t, $J = 7.6$ Hz, 3H), 0.58-0.45 (m, 1H), 0.43-0.34 (m, 1H), 0.34-0.17 (m, 2H), 0.05-0.00 (m, 1H); ^{13}C NMR (100 MHz, C_6D_6) 133.2, 133.1, 133.1, 133.0, 131.7, 128.9, 128.8, 128.7, 58.1, 31.4 ($J_{\text{C-P}} = 4.8$ Hz), 18.2 ($J_{\text{C-P}} = 5.3$ Hz), 10.8, 4.9, 4.6; ^{31}P NMR (122 MHz, C_6D_6) 19.3; IR (neat) 3191 (br), 1435 (m), 1184 (s), 1121 (s), 1011 (s), 750 (m), 723 (s), 693 (s) cm^{-1} .

***N*–[(1*S*)-1-(2-furyl)propyl]-*P,P*-diphenylphosphinic amide (15j).** The general procedure was used except that 0.055 equiv of (*R,R*)-Me-DuPhos and 0.050 equiv Cu(OTf)₂ were used. The reaction was stirred at -10 °C for 24 h. Yield 97 %, enantiomeric ratio (16:1) (89% *ee*) was determined by HPLC analysis (Chiralpak AS, 95:5 hexanes:*i*-PrOH, 1.0 mL/min: (*R*)-**15j** *t*_r 31.0 min, (*S*)-**15j** *t*_r 36.5 min).

***N*–[1-cyclopropylpropyl]-*P,P*-diphenylphosphinic amide (15k).** The general procedure was followed. Yield 82 %, enantiomeric ratio (12:1) (85% *ee*) was determined by HPLC analysis (Chiralpak AD, 80:20 hexanes:*i*-PrOH, 1.0 mL/min: (+)-**15k** *t*_r 8.3 min, (-)-**15k** *t*_r 10.0 min).

***P,P*-diphenyl-*N*–[(1*S*)-1-phenylethyl]phosphinic amide (15l).** The general procedure was used except that the reaction was run in ether and 0.10 equiv of (*R,R*)-Me-DuPhos and 0.095 equiv of (CuOTf)₂•PhMe were used. The reaction was stirred at room temperature for 24 h. Yield: 51%,

enantiomeric ratio (19:1) (90% *ee*) was determined by HPLC analysis (Chiralpak AD, 92:8 hexanes:*i*-PrOH, 1.0 mL/min: (*R*)-**15l** *t_r*, 29.1 min, (*S*)-**15l** *t_r*, 34.8 min).

***P,P*-diphenyl-*N*[(1*S*)-1-phenylpentyl]phosphinic amide (15m).** The general procedure was followed. Yield 71 %, enantiomeric ratio (22:1) (91% *ee*) was determined by HPLC analysis (Chiralpak AD, 80:20 hexanes:*i*-PrOH, 1.0 mL/min: (*R*)-**15m** *t_r*, 7.5 min, (*S*)-**15m** *t_r*, 10.0 min).

(1*S*)-1-phenylpropan-1-aminium chloride (16a). To a solution of (*S*)-*P,P*-diphenyl-*N*-(1-phenylpropyl)phosphinic amide **16a** (90.6 mg, 0.270 mmol, 1.00 equiv) in MeOH 2M HCl (2.7 mL). After stirring for 4 h at room temperature, the reaction was concentrated and purified by silica gel column chromatography giving **16a** (>95 %) as a white solid. The enantiomeric ratio (53:1) (96% *ee*) was determined by SFC analysis of the benzamide derivative (Chiralcel OD, 40°C, 200 bar, 5% MeOH in CO₂, 2.0 mL/min): (*R*)-**16a** *t_r*, 9.0 min, (*S*)-**16a** *t_r*, 11.0 min).

References and Notes

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