Supporting information

Efficient recycling of a chiral palladium catalytic system for asymmetric allylic substitutions in ionic liquid

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Experimental section

General

All compounds were prepared under a purified argon atmosphere using standard Schlenk and vacuum-line techniques. The organic solvents were purified on MBraun solvent purification system – 800 series. Ionic liquids IL1(1-butyl-3-methyl-imidazolium hexafluorophosphate) and IL2 (N-butyl-N-methyl pyrrolidinium bis-trifluoromethylsulfonylamide) were supplied by Solvionic and treated under vacuum at 60 °C overnight prior use. Other chemicals were used as purchased. The chiral carbohydrate-based diphosphite ligands (L1 and L2) were prepared following previously described methodology (for ligand L1, see: G. J. H. Buisman, M. E. Martin, E. J. Vos, A. Klootwijk, P. C. J. Kamer, P. W. N. M. van Leeuwen, *Tetrahedron: Asymmetry,* 1995, 6, 719; for L2, see: M. R. Axet, J. B. Benett-Buchholz, C. Claver, S. Castillon, *Adv. Synth. Cat*., 2007, 349, 1983). NMR spectra were recorded on a Bruker Avance 300 MHz for ^{1}H NMR and 121 MHz for ^{31}P NMR. Enantiomeric excess were determined by HPLC at 25 °C on a Waters Alliance 2695 HPLC separation module with a Waters 996 PDA Detector for allylic alkylation and amination. Enantiomeric excess were determined for allylic phosphination on PIC solution Supercritical fluid chromatography SFC with a UV PDA detector at 35 °C. ICP-MS were done by an independant analytical laboratory (Antellis) from Toulouse (France).

General procedure for palladium-catalysed allylic alkylation

The catalytic precursor was generated in situ from $[Pd(\eta^3\text{-}C_3H_5)Cl]_2$ and the appropriate ligand (for 1 mol%: 0.01 mmol of Pd and 0.0125 mmol of chiral ligand) dissolved in 1 cm^3 of

IL or CH_2Cl_2 for 30 minutes before adding the substrate *rac*-3-acetoxy-1,3-diphenyl-1-propene (252 mg, 1 mmol), dimethyl malonate (396 mg, 3 mmol), BSA (610 mg, 3 mmol), and a catalytic amount of KOAc. The mixture was stirred at 40 °C. At the end of the reaction, in the case of IL, the products were first recovered with pentane.

Then in both case (IL or CH_2Cl_2) the organic phase was washed with saturated ammonium chloride solution (4 x 10 cm^3) and water (4 x 10 cm^3). The organic phase was dried over anhydrous Na_2SO_4, filtered off, and solvent removed under reduced pressure. Conversions were determined by ^1H NMR and enantiomeric excesses determined by HPLC on a Chiralcel OJ-H chiral column, using heptane/isopropanol 80/20 as eluent, and on Chiralcel OD chiral column using heptane/isopropanol =98/2 as eluent, with 1 cm^3/min flow.

General procedure for palladium-catalysed allylic amination

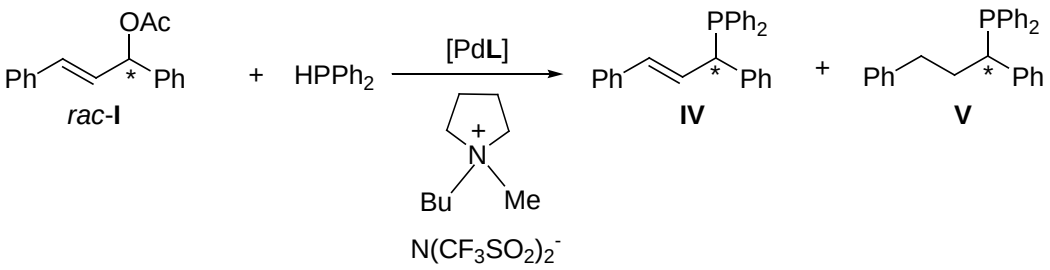
The catalytic precursor was generated in situ from $[Pd(\eta^3\text{-}C_3H_5)Cl]_2$ and the appropriate ligand (for 1 mol% of catalyst: 0.01 mmol of Pd and 0.0125 mmol of the corresponding chiral ligand) dissolved in 1 cm^3 of IL or CH_2Cl_2 for 30 minutes before adding the substrate *rac*-3-acetoxy-1,3-diphenyl-1-propene (252 mg, 1 mmol) and benzylamine (107 mg, 1 mmol). The mixture was stirred at 40 °C. At the end of the reaction, the products were extracted with pentane and filtered over celite. Then the solvent removed under reduced pressure. Conversions were determined by ^1H NMR and enantiomeric excesses determined by HPLC on a Chiralcel OJ-H chiral column, using heptane/isopropanol 90/10 as eluent, in a flow of 1 cm^3/min.

General procedure for the recycling

After each catalytic run (*rac*-**I**/**B**/Pd/L = 250/250/1/1.25, 1 cm^3 IL2, 1 h, 40 °C), the reaction mixture was cooled at room temperature and extractions were carried out with pentane (3x5 cm^3) in order to remove all the organic compounds (substrate, amination product and benzylamine) from the ionic liquid phase. Under these conditions, neither the ionic liquid nor catalyst (palladium species and ligand) was extracted (checked by NMR and ICP-MS analysis). Upon extractions, the catalytic ionic liquid phase was then treated under vacuum in order to remove the volatiles. The corresponding amounts of substrate (*rac*-**I**) and nucleophile ($BnNH_2$) were then added for starting a new run.

General procedure for palladium-catalysed allylic phosphination

The catalytic precursor was generated in situ from $[Pd(\eta^3\text{-}C_3H_5)Cl]_2$ and the appropriated ligand ($1.5x10^{-3}$ mmol of Pd and $3\ x10^{-3}$ mmol of the corresponding chiral ligand) dissolved in 1 cm^3 of IL or CH_2Cl_2 for 30 minutes before adding the substrate *rac*-3-acetoxy-1,3-diphenyl-1-propene (63 mg, 0.25 mmol) and diphenylphosphine (45 μL, 0.25 mmol). The mixture was stirred at 25 °C. At the end of the reaction, diethylether and 10 mg of sulphur were added and stirred during 1 h. Then the organic phase was filtered over celite and the solvent removed under reduced pressure. Conversions were determined by ^{1}H NMR and chemoselectivity by ^{31}P NMR. Enantiomeric excesses were determined by SFC on a Chiralcel AD-H column, MeOH 15% as eluent, in a flow of 4 cm^3/min under 100 bar CO_2. The by-product coming from **V** was isolated from the mixture by precipitation with diethyl ether.



Scheme S1. Pd-catalysed allylic phosphination of *rac*-**I** in IL2.