## Enantiomerically Pure C<sub>3</sub>-Symmetric Tripodal Pyridine Ligands

## Hans Adolfsson, Kenneth Wärnmark and Christina Moberg\*

Department of Organic Chemistry, Royal Institute of Technology, S-100 44 Stockholm, Sweden

Chiral, optically pure ligands with  $C_3$  symmetry have been prepared from tripyridylmethanol by substitution in the 6-position of the pyridine nuclei and asymmetric modification of the substituents.

Chiral ligands with rotational symmetry are presently attracting extensive interest for use in asymmetric reactions catalysed by transition metals. To date, ligands possessing a two-fold axis of symmetry have been the principal objects for study.<sup>1</sup> The high degree of stereocontrol often achieved is believed to originate from the homotopic nature of the two remaining coordination sites in a square planar complex containing a  $C_2$ -symmetric bidentate ligand, a situation which reduces the number of possible intermediate complexes and, therefore, the number of diastereoisomeric transition states. In an



Scheme 1 Reagents: i, m-chloroperbenzoic acid; ii, N,N-dimethylcarbamoyl chloride, trimethylsilyl cyanide; iii, EtMgBr; iv, (-)-Ipc<sub>2</sub>BCl, 2,2'-iminodiethanol; v, NaH, MeI

octahedral environment, diastereotopic coordination sites (equatorial and axial) are created by a bidentate  $C_2$  ligand. In contrast, three equivalent sites are obtained by coordination of a tridentate ligand with  $C_3$  symmetry. Since a number of synthetically important catalytic reactions proceed via octahedral intermediates, access to such compounds is desirable. The number of ligands of this type is limited and include, to the best of our knowledge, only a few phosphines<sup>2,3</sup> and the nitrogen-based ligands (imine and aliphatic amine).4 Since ligands with nitrogen atoms as donors have been found to show advantageous properties in various asymmetric reactions catalysed by transition metals,5 we envisaged chiral derivatives of tris(2-pyridyl)methanol<sup>6</sup> as promising candidates for complexation to catalytically active transition metal ions.7 As a continuation of our work concerning ligands derived from bis(2-pyridyl)methane,8 we have now prepared the first tripodal C<sub>3</sub>-symmetric pyridine ligands.

Ligands 1-3 were prepared from tris(2-pyridyl)methanol 4,6 readily available from bis(2-pyridyl) ketone, by peracid oxidation and subsequent treatment of the resulting tris(Noxide) (100% yield) with N,N-dimethylcarbamoyl chloride and trimethylsilyl cyanide<sup>9</sup> to yield silylated trinitrile 5 (25%, Scheme 1). Reaction of 5 with ethylmagnesium bromide (4.5 equiv.) gave a 3:4 mixture (70%) of triketones 6 and 7, which could be separated by flash chromatography. Asymmetric reduction of the keto groups of either of these compounds using (-)-B-chlorodiisopinocampheylborane [(-)-Ipc<sub>2</sub>BCl]<sup>10</sup> yielded the desired tetraalcohol 1† (38% from **6** using 6 equiv. of borane) along with a small amount of a product formed by reduction of only two keto groups.

Methylation of tetraalcohol **1** (using 4.4 equiv. of MeI) yielded a mixture of tri- and tetra-methoxy derivatives **2** (8%) and **3**<sup>†</sup> {48%,  $[\alpha]_D^{20} - 141$  (CHCl<sub>3</sub>, *c* 0.59)}, which both are potential ligands for transition metal ions.

The stereochemical purity of 1 could easily be determined from its <sup>1</sup>H NMR spectrum, which showed the presence of two isomers in a ratio of >97.5:2.5, thought to be the  $R^*, R^*, R^*$ and  $R^*, R^*, S^*$  stereoisomers, respectively. This was verified by comparison with the <sup>1</sup>H NMR spectrum of the product obtained from reduction of 7 using sodium borohydride, which showed a mixture of the same diastereoisomers, although in a 1:1 ratio. In order to check the enantiomeric purity, a chiral shift reagent, tris[3-(heptafluoropropylhydroxymethylene)-(+)-camphorato]europium(III), was added to 1 as well as to the product obtained from sodium borohydride reduction. This resulted in splitting of the signals for the protons in the methyl groups in the latter case, whereas no such splitting was observed in the spectrum of the product obtained by asymmetric reduction. This suggests that only two stereoisomers were formed and the enantiomeric excess in the reduction was thus shown to be >95%.

A rhodium complex, which according to <sup>1</sup>H NMR spectroscopy has  $C_3$  symmetry, has been prepared from 1 and RhCl<sub>3</sub>. Hydrosilylations using this complex as a precatalyst are presently under study. Furthermore, alternative procedures, starting from chiral monopyridine units, for the preparation of pyridine ligands with  $C_3$  symmetry are being investigated in order to allow for larger structural variations.

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<sup>†</sup> Spectroscopic data: 1: <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz)  $\delta$  0.88 (t, J 7.4 Hz, 9 H), 1.67 (dquint, J 14.1 and 7.4 Hz, 3 H), 1.84 (ddq, J 14.1, 4.7 and 7.4 Hz, 3 H), 3.73 (br d, J 5.6 Hz, 3 H), 4.65 (m, 3 H), 7.01 (br s, 1 H), 7.17 (br d, J 7.5 Hz, 3 H), 7.60 (dd, J 7.8 and 1.1 Hz, 3 H) and 7.68 (t, J 7.7 Hz, 3 H); MS *m/z* 437 (M) and 301 (base). 3: <sup>1</sup>H NMR (CDCl<sub>3</sub>, 400 MHz)  $\delta$  0.77 (t, J 7.4 Hz, 9 H), 1.68 (dq, J 6.4 and 7.4 Hz, 6 H), 3.24 (s, 9 H), 3.35 (s, 3 H), 4.14 (t, J 6.4 Hz, 3 H), 7.23 (dd, J 7.7 and 1.0 Hz, 3 H); MS *m/z* 494 (M) and 463.