Tetrahedron: Asymmetry Vol. 1, No. 11, pp. 843-849, 1990
Printed in Great Britain

0957-4166/90 $3.00+.00
Pergamon Press plc

CHIRAL LIGANDS CONTAINING HETEROATOMS. 6.[1] 1-(2-PYRIDYLMETHYL)PYRROLIDINE IN THE CHIRAL CATALYSIS OF ADDITION OF DIETHYLZINC TO BENZALDEHYDE.

Giorgio Chelucci*, Massimo Falorni and Giampaolo Giacomelli

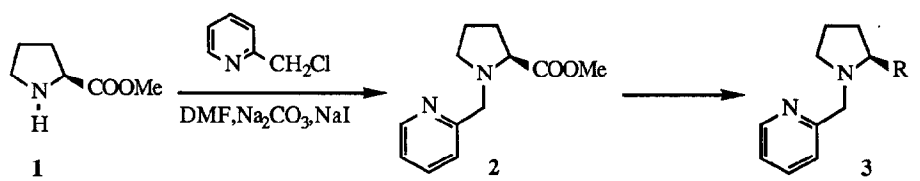
Dipartimento di Chimica, Universita' di Sassari, via Vienna 2, I-07100 Sassari, Italy

(*Received* 6 *August* 1990)

Abstract: The synthesis of a series of new optically active pyridine ligands from proline derivatives has been developed for the enantioselective addition of dialkyl zinc compounds to aldehydes. The results obtained indicate that the coordination of a metal atom to the nitrogen of the pyridine ring is essential in determining the stereochemistry of the process.

Increasing interest has been recently centered on the catalytic asymmetric induction in carbon-carbon bond-forming reactions[2,3] and many reports appeared on the enantioselective addition of dialkylzincs to aldehydes using chiral amino alcohols as catalysts.[4] In this context, chiral pyrrolidinylmethanols were found to be efficient catalysts for the formation of (*S*) alcohols with good enantioselectivities (up to 100%):[5,6] the stereochemistry of the process has been generally interpreted in terms of a cyclic transition state assembly.

In continuation with our study on the preparation of optically active nitrogen bidentate ligands, such as (*S*)-2-nornicotine and its derivatives,[7] we wish to report herein on some optically active 2-substituted-1-(2-pyridylmethyl)pyrrolidines (**3**), a new kind of bidentate nitrogen ligands, having another functional group, which can participate in a suitable catalytic sequence.



1 **2** **3**

Compound	3a	3b	3c	3d	3e
R	CH_2OH	CH_2OMe	$CONH_2$	CMe_2OH	CPh_2OH

To prepare this class of compounds, 2-methoxycarbonyl-1-(2-pyridylmethyl)pyrrolidine (**2**) was envisioned as the key intermediate from which a series of derivatives could be obtained. Compound **2** was prepared in good yield (84%) through condensation of (*S*)-proline methyl ester (**1**) with 2-

(chloromethyl)pyridine (CMP) in a mixture of Na_2CO_3 and NaI in DMF at 50 °C. With **2** in our hands we undertook the synthesis of some its derivatives. 2-Carboxamide-1-(2-pyridylmethyl)pyrrolidine (**3c**) was obtained in nearly quantitative yield by reaction of **2** with NH_3 in MeOH for 6 days. By reaction of methyl and phenyl magnesium halide, the corresponding carbinol **3d** and **3e** were obtained in good yields (83 and 76%, respectively). Unfortunately, reduction of **2** with LAH delivered a complex reaction mixture, from which the 2-hydroxymethyl-1-(2-pyridylmethyl)pyrrolidine (**3a**) was obtained in poor yield (<10%), through chromatographic purification. Then, we prepared **3a** in good yield (75%) by reaction of (*S*)-prolinol with CMP in DMF. Analogously, 2-methoxycarbonyl-1-(2-pyridylmethyl)pyrrolidine (**3b**) was obtained from (*S*)-2-methoxymethyl)pyrrolidine and CMP (78% yield).

The optical rotations of all prepared ligands were exactly reproduced in repeated syntheses following the same procedures. These results and ^{19}F NMR analysis of the MPTA ester[8] of compound **3d** make us confident that the chiral centers are not involved in the reaction sequences and therefore the enantiomeric purity of compounds **3** is not different from that of the starting commercial (*S*)-proline (>96%).

In order to examine the effect of the structure of the catalysts, enantioselective additions of diethylzinc to benzaldehyde were conducted at 25 °C in hexane and in the presence of a catalytic amount (3 mol%) of compounds **3** or of the corresponding lithium salts: in all cases the reactions are rather rapid and complete conversion is reached in about 4 h. All ligands afforded 1-phenylpropanol in over 85% synthetic yield: catalysts were easily removed from the reaction mixtures by washing with 10% H_2SO_4. The enantiomeric composition of the carbinol was evaluated, after purification by flash chromatography,[9] by direct measurement of the optical rotation and confirmed by HPLC on csp as earlier reported.[10] The data obtained are reported in the **Table.**

Table. Asymmetric Addition of Diethylzinc to Benzaldehyde.[a]

entry	catalyst	GLC conv.%	$[\alpha]^{25}_D$,deg (*c*, $CHCl_3$)[b]	ee, %
1	**3a**	99	+26.45 (3.0)	58 (*R*)
2	Li-**3a**	99	+25,00 (3.6)	55 (*R*)
3[c]	**3a**	98	+ 5.11 (2.9)	11 (*R*)
4	**3b**	97	- 3.67 (3.6)	8 (*S*)
5	**3c**	98	+ 7.32 (4.0)	16 (*R*)
6	**3d**	99	+16.64 (3.8)	37 (*R*)
7	Li-**3d**	97	+27.32 (3.3)	60 (*R*)
8	**3e**	93	+ 1.22 (4.1)	3 (*R*)
9	Li-**3e**	87	+15.04 (3.2)	33 (*R*)

a Benzaldehyde (1 eq) was added at 0 °C to a hexane solution of the catalyst (0.06 eq) and diethyl zinc (2 eq)

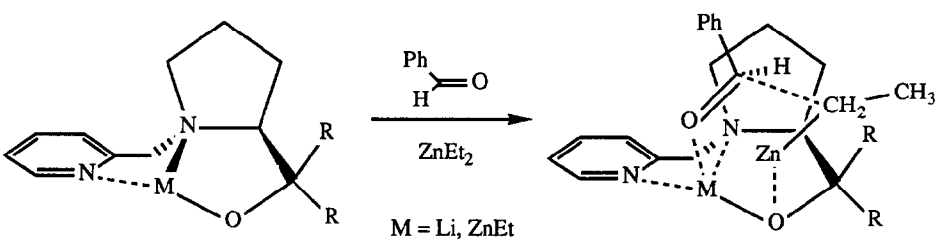
b Reported value for (*S*)-1-phenylpropanol is $[\alpha]^{25}_D$ -45.45° ($CHCl_3$): Pickard, R. H.; Kenyon, J. *J. Chem. Soc.* **1914**, 1115. *c* In this case, diethyl zinc was added at 0 °C to a solution of the catalyst and benzaldehyde.

The ligands used were effective enantioselective catalysts, affording (*R*)-1-phenylpropanol,in moderate enantiomeric excesses. The experimental data obtained deserve some comments. Contrary to what observed with

N-methylprolinol, which failed to afford optically active 1-phenylpropanol,[4,6] N-(2-pyridylmethyl)prolinol, **3a**, gave the carbinol with satisfactory optical yield (entry 1). As to the effect of the substituents on the methanol moiety, using similar ligands, such as N-alkylpyrrolidinylmethanols, the enantioselectivity became higher, as the alcohol moiety became more bulky, on passing from 0%, in the case of N-methylprolinol, to 97%, in the case of 2-(diphenylmethanol)-N-methylpyrrolidine:[5] in our case, the sense of asymmetric induction was reversed, bulky substituents lowering the enantioselectivity (entries 1, 6 and 8). Regarding the influence of the N-substituents, it is to be noted that whereas chiral N-alkyl pyrrolidines afford substantially the (*S*)-1-phenylpropanol,[5] the N-(2-pyridylmethyl)-pyrrolidines seem to favour the (*R*) enantiomer, the only exception being the reaction carried out with the methyl ether **3b**. It is also noteworthy that better enantioselectivities are observed when the lithium salts of **3d** and **3e** (entries 7 and 9) were employed as catalysts that when **3d** and **3e** themselves were used: in the case of a less hindered ligand, such as **3a**, the use of the lithium alkoxide Li-**3a** does not increase the asymmetric induction of the reaction. Another important fact is that, at least employing these catalysts, the enantioselectivity of the alkylation depends on the order of the addition of the reactants: the addition of the diethyl zinc to the mixture of compound **3a** and benzaldehyde gave only 11% optical purity of the (*R*) alcohol.

Taking into account that, when N-methylprolinol was used, the reaction was not enantioselective[5] and that the use of the chiral methoxymethyl pyrrolidine **3b** afforded the (*S*) alcohol in only 8% ee, all the data indicate that the N-(2-pyridylmethyl) moiety and the lithiated hydroxymethyl group in the pyrrolidine ring are essential in determining both the trend and the extent of the asymmetric induction.

Even in these cases, the catalysis and stereochemistry can be rationalized satisfactorily in terms of a six-membered cyclic transition state assembly (**5**).[5] Such a supposition is based on the formation of a rigid complex (**4**) by virtue of the coordination of the oxygen and the two nitrogen atoms to the lithium atom or the ethylzinc residue, providing an effective chiral environment for the reaction.



4 **5**

This hypothesis, which is in accordance with literature data,[6] is further supported by the ^1H NMR spectrum of a C_6D_6 solution of compound **3d** and a stoichioimetric amount of diethylzinc. The examination of the spectrum shows the disappearance of the broad signal due to the alcoholic proton and that the resonance lines of the ortho-proton of the pyridine ring, which are severely broadened by the quadrupole interaction with nitrogen, are downfield shifted (0.84 ppm): in addition, a weaker but significant upfield shift of the signals of the other protons of the pyridine moiety occurs too (see **Experimental**). These data are clearly demonstrating the formation of a stable, coordinative bond between the pyridine nitrogen and the metal atom bound to the alcoholic oxygen atom. In fact the complexation of the nitrogen with the metal atom should lower the aromatic

character of the pyridine ring and consequently increase the deshielding of the ortho-proton and decrease those of the other ring protons. Even the resonance lines of aliphatic protons are downfield shifted, in particular those of the proton bound to the chiral center, all data being therefore indicative of structure **4**. Other authors[6] reported that no reaction occurred, over 19 h, between the catalyst and benzaldehyde. Actually no reaction occurs: the addition of the aldehyde to **4** causes only a slight further shift of the resonance of the ortho-proton of the pyridine ring, along with an upfield shift of the resonance of the protons of the benzaldehyde. This is, in our opinion, a clear evidence of the coordination of the aldehyde with the zinc atom of complex **4** without displacement of the pyridine ligand for maintaining the tetracoordinate status of zinc: presumably this tetracoordination is retained through displacement of the pyrrolidine nitrogen-zinc bond. The structure derived results however extremely constrained and this can explain the particular trend of the stereochemistry of the reaction with respect to that of similar processes.

Subsequent complexation of diethyl zinc with the nucleophilic oxygen of **4** should lead to assembly **5** from which the addition of an ethyl group from zinc to the carbonyl function occurs *via* a six-membered cyclic structure. Examination of molecular models shows that the diastereomeric assembly of **5**, which leads to the carbonyl adduct of (*S*) absolute configuration is sterically disfavored because of the repulsions between the phenyl group of the aldehyde and the pyrrolidine ring of the complex.

Experimental

Boiling points are uncorrected. Melting points were determined on a Büchi 510 capillary apparatus and are uncorrected. The ^1H NMR (300 MHz), ^{13}C NMR (75.4 MHz), and ^{19}F NMR (282 MHz) were registered on a Varian VXR-300 spectrometer. All NMR spectra were obtained using $CDCl_3$ as solvent and TMS as an internal standard. Optical rotations were recorded with a Perkin-Elmer 241 automatic polarimeter in a 1 dm tube; concentrations are given in g/100 ml. Hexane was dried over sodium wire and kept over molecular sieves 4A. All reactions involving air-sensitive compounds were carried out under an argon atmosphere. For evaporative bulb-to-bulb distillation, a Büchi Kugelrohrofen was used.

Materials. A hexane solution of *n*-butyllithium and a hexane solution of diethyl zinc were supplied from Aldrich Chimica S.r.l. Ethereal alkyl magnesium halides were prepared by treating the appropriate alkyl halide with magnesium wire in THF. (*S*)-proline methyl ester, **1**,[11] 2-(hydroxymethyl)pyrrolidine[12] and 2-(methoxymethyl)pyrrolidine[13] were prepared according to reported procedures.

(*S*)-2-Methoxycarbonyl-1-(2-pyridylmethyl)pyrrolidine, 2. Compound **1** (5.81 g, 45 mmol) was added dropwise to a mixture of 2-(chloromethyl)pyridine (3.81 g, 30 mmol), anhydrous Na_2CO_3 (3.5 g) and NaI (0.2 g) in dry DMF (70 ml), kept at 50 °C. After 2 h at 50 °C, the mixture was taken up with water and extracted with CH_2Cl_2. The organic phase was dried (Na_2SO_4), the solvent removed and the oily residue distilled bulb-to-bulb to give pure 2-methoxycarbonyl-1-(2-pyridylmethyl)pyrrolidine (**2**), in 84% yield: bp 110 °C (0.1 mm); $[\alpha]^{25}_D$ -71.49 (*c* 2.5, $CHCl_3$); ^1H NMR δ 8.48 (m, 1H), 7.60 (m, 1H), 7.19 (m. 1H), 3.98 (d, 1H), 3.61 (s, 1H), 3.79 (d, 1H), 3.35 (m, 1H), 3.07 (m, 1H), 2.46 (m, 1H), 2.19 (m, 1H), 1.18 (m, 3H) ppm; ^{13}C NMR δ 174.4, 158.8, 148.8, 136.2, 123.4, 120.0, 65.2, 60.1, 53.2, 52.4, 29.2, 23.4. Found C 65.48; H, 7.27; N, 12.70 ppm. $C_{12}H_{16}N_2O_2$ requires C, 65.43; H, 7.32; N, 12.72.

(*S*)-2-Hydroxymethyl-1-(2-pyridylmethyl)pyrrolidine, 3a. The preparation of compound **3a** was performed as above, starting from (*S*)-prolinol (3.03 g, 30 mmol), 2-(chloromethyl)pyridine (3.81 g, 30 mmol), anhydrous Na_2CO_3 (3.5 g) and NaI (0.2 g) in hot DMF (70 ml). After usual work-up, 2-hydroxymethyl-1-(2-pyridylmethyl)pyrrolidine (**3a**) was isolated in 75% yield: bp 130 °C (0.1 mm); $[\alpha]^{25}_D$ -32.38(*c* 3.5,$CHCl_3$); ^1H NMR δ 8.53 (m, 1H),7.66 (m, 1H), 7.39 (d, 1H), 7.16 (m, 1H), 4.28 (broad, 1H), 4.10 (d, 1H), 3.66 (d, 1H), 3.61 (m, 1H), 3.48 (m, 1H), 3.05 (m, 1H), 2.81 (m, 1H), 2.43 (m, 1H), 1.92 (m, 1H), 1.74 (m, 3H) ppm; ^{13}C NMR δ 152.7, 142.2, 129,7 115.9, 115.1, 58.4, 56.2, 53.4, 48.2, 20.8, 16.6 ppm. Found C 68.58; H, 8.32; N, 14.62.ppm. $C_{11}H_{16}N_2O$ requires C, 68.72; H, 8.39; N, 14.57.

(*S*)-2-Methoxymethyl-1-(2-pyridylmethyl)pyrrolidine, 3b. Compound **3b** was prepared as above, starting from (*S*)-2-methoxymethylpyrrolidine (3.10 g, 27 mmol), 2-(chloromethyl)pyridine (3.43 g, 27 mmol), anhydrous Na_2CO_3 (3.1 g) and NaI (0.2 g) in hot DMF (60 ml). After usual work-up, 2-hydroxymethyl-1-(2-pyridylmethyl)pyrrolidine (**3b**) was isolated in 78% yield: bp 110 °C (0.1 mm); $[\alpha]^{25}_D$ -85.43 (*c* 3.5,$CHCl_3$); ^1H NMR δ 8.55 (m, 1H), 7.64 (m, 1H), 7.43 (m, 1H), 7.14 (m, 1H), 4.26 (d, 1H), 3.61 (d, 1H), 3.44 (dd, 1H), 3.34 (dd, 1H), 3.33 (s, 3H), 2.98 (m, 1H), 2.82 (m, 1H), 2.32 (m, 1H), 1.94 (m, 1H), 1.70 (m, 3H) ppm; ^{13}C NMR δ 159.8, 148.8, 136.2, 123.0, 121.7, 76.2, 63.1, 61.2, 58.9, 54.7, 28.3, 22.8 ppm. Found C 69.68; H, 8.82; N, 13.62. $C_{12}H_{18}N_2O$ requires C, 69.87; H, 8.80; N, 13.58.

(*S*)-2-Carboxamide-1-(2-pyridylmethyl)pyrrolidine, 3c. A solution of **2** (2.2 g, 10 mmol) in MeOH (40 ml) was saturated with gaseous NH_3 at 0 °C. After 6 days at room temperature, the solvent was evaporated and the residue distilled to give pure 2-carboxamide-1-(2-pyridylmethyl)pyrrolidine, **3c** (96% yield): bp 160 °C (0.1 mm); $[\alpha]^{25}_D$ -16.43 (*c* 4.3, MeOH); ^1H NMR δ 8.56 (m, 1H), 7.82 (broad, 1H), 7.66 (m, 1H), 7.24 (m, 2H), 6.34 (broad, 1H), 4.04 (d, 1H), 3.66 (d, 1H), 3.28 (m, 1H), 3.04 (m, 1H), 2.46 (m, 1H), 2.24 (m, 1H), 1.92 (m, 1H), 1.88 (m, 2H) ppm. Found C 64.48; H, 7.53; N, 20.65. $C_{11}H_{15}N_3O$ requires C, 64.37; H, 7.37; N, 20.47.

General procedure for the preparation of compounds 3d and 3e. A solution of **2** (3.30 g, 15 mmol) in THF (16 ml) was added to a vigorously stirred solution of CH_3MgI or C_6H_5MgBr (60 mmol) in THF (30 ml) at 0 °C. After 1 h at room temperature, 10% aqueous HCl was added and the resulting mixture stirred for 1 h. The aqueous phase was treated with 10% aqueous NaOH and extracted with CH_2Cl_2. The resulting mixture was filtered on celite and the solid washed with CH_2Cl_2. The combined organic phases were dried (Na_2SO_4), the solvent evaporated and the products isolated, depending on its physical properties.

(*S*)-2-(1-Hydroxy-1-methylethyl)-1-(2-pyridylmethyl)pyrrolidine, 3d. This compound was obtained by fractional distillation in 83% yield: bp 120 °C (0.1 mm); $[\alpha]^{25}_D$-5.41 (*c* 1.4,$CHCl_3$); ^1H NMR δ 8.52 (m, 1H), 7.65 (m, 1H), 7.36 (m, 1H), 7.14 (m, 1H), 4.20 (broad, 1H), 4.26 (d, 1H), 3.82 (d, 1H), 2.99 (m, 1H), 2.88 (m, 1H), 2.53 (m, 1H), 1.91 (m, 2H), 1,70 (m, 2H), 1.20 (s, 3H), 1.94 (s, 3H) ppm; ^{13}C NMR δ 160.6, 148.9, 136.3, 122.0, 121.6, 73.6, 72.9, 55.7, 27.9, 25.1, 24.4 ppm. Found C 70.77; H, 9.32; N, 12.65.. $C_{13}H_{20}N_2O$ requires C, 70.87; H, 9.15; N, 12.72. A sample of **3d** (286 mg, 1.3 mmol) and distilled (+)-MPTACl (392 mg, 1.55 mmol) were mixed with CCl_4 (1.1 ml) and dry pyridine (1.1 ml) and

allowed to stand for 12 h. Water was added, and the reaction mixture extracted with ether: the ethereal phase was washed sequentially with saturated Na_2CO_3, water and dried (Na_2SO_4). After removal of the solvent under vacuum, the residual 2-[1-(α-methoxy-α-trifluoromethylphenylacetyl)-1-methylethyl]-1-(2-pyridylmethyl)pyrrolidine was analyzed by ^{19}F NMR to be a 98:2 mixture of diastereoisomers.

(*S*)-2-(Diphenylmethanol)-1-(2-pyridylmethyl)pyrrolidine, 3e. The compound was obtained as a solid which was recrystallized from diethyl ether in 76% yield: mp 119 °C; $[\alpha]^{25}_D$+79.20 (*c* 2.6,$CHCl_3$); ^1H NMR δ 8.41 (m, 1H), 7.75-7.52 (m, 3H), 7.35-7.05 (m, 10H), 4.97 (broad, 1H), 4.08 (q, 1H), 3.35 (s, 2H), 2.96 (m, 1H), 2.51 (m, 1H), 1.96 (m, 1H), 1.80-1.58 (m, 3H) ppm; ^{13}C NMR δ 159.7, 148.6, 147.7, 146.4, 136.3, 128.0, 126.4, 126.2, 125.6, 122.4, 121.8, 78.0, 70.9, 62.2, 55.7, 29.6, 24.4 ppm. Found C 80.27; H, 7.12; N, 8.25.. $C_{23}H_{24}N_2O$ requires C, 80.19; H, 7.03; N, 8.14.

General Procedure for the Enantioselective Alkylation of Benzaldehyde, using Compounds 3 as Catalysts. A hexane solution of the chiral ligand **3** (0.37 mmol) was cooled at 0 °C. Diethylzinc in hexane (1 M, 12.4 ml) was added over a period of 5 min, the mixture stirred at room temperature for 20 min, then benzaldehyde (6.1 mmol) added and stirring prolonged for additional 6-24 h. H_2SO_4 (10%) was added to quench the reaction, then the mixture extracted with ether, the extracts dried (Na_2SO_4) and evaporated under reduced pressure (10 mm). The residue was distilled and purified by flash chromatography (80:20 light petroleum ether/ ethyl acetate). In the entry 3, diethylzinc in hexane (1 M, 12.4 ml) was added to a cooled (0 °C) hexane mixture containing compound **3a** (0.37 mmol) and the benzaldehyde (6.1 mmol).

General Procedure for the Enantioselective Alkylation of Benzaldehyde, using Lithium Salts of Compounds 3 as Catalysts. A hexane solution of the chiral ligand **3** (0.37 mmol) was cooled at 0 °C, and a hexane solution of butyllithium (1.6 M, 0.30 ml, 0.48 mmol) added through a hypodermic syringe. The mixture was kept at room temperature for 10 min, then cooled at 0 °C. Diethylzinc in hexane (1 M, 12.4 ml) was added over a period of 5 min, the mixture stirred at room temperature for 20 min, then benzaldehyde (6.1 mmol) added and stirring prolonged for additional 6-24 h. Quenching, extraction and purification were performed as described above.

Analysis ^1H NMR of the complex between 3d and diethyl zinc. A solution of 22 mmol of diethyl zinc in C_6D_6 (1.5 ml) was added, under an argon atmosphere, to 22 mmol of (S)-2-(1-Hydroxy-1-methylethyl)-1-(2-pyridylmethyl)pyrrolidine, **3d**, contained in a NMR tube, previously dried with accuracy: ^1H NMR (C_6D_6) δ 9.23 (m, broad, 1H, *Py*), 7.06 (m, 1H, *Py*), 6.76 (m, 1H, *Py*), 6.51 (m, 1H, *Py*), 4.06 (m, 0.2H, N*CH*CMe_2O), 3.78 (m, 0.8H, N*CH*CMe_2O), 3.27 (d, 1H, Py*CH*$_2$N), 3.07 (m, 1H, Py*CH*$_2$N), 2.44 (m, 1H, *pyrrolidine ring*), 2.29 (m, 1H, *pyrrolidine ring*), 1.60 (m, 4H, *pyrrolidine ring*), 1.30 (t, 3H, $ZnCH_2CH_3$), 1.27 (d, 6H, *Me*$_2$C), 0.88 (m, 2H, Zn*CH*$_2CH_3$). To the solution it was then added the stoichioimetric amount (22 mmol) of dry benzaldehyde: ^1H NMR (C_6D_6) δ 9.72 (s, 1H, *H* formyl), 9.37 (m, broad, 1H, Py), 7.53 (d, 2H, *Ph*), 7.10-7.00 (m, 4H, *Ph+Py*), 6.80 (m, 1H, *Py*), 6.51 (m, 1H, *Py*), 3.78 (m, 1H, N*CH*CMe_2O), 3.30 (d, 1H, Py*CH*$_2$N), 3.08 (m, 1H, Py*CH*$_2$N), 2.47 (m, 1H, *pyrrolidine ring*), 2.30 (m, 1H, *pyrrolidine ring*), 1.60 (m, 4H, *pyrrolidine ring*), 1.30 (t, 3H, $ZnCH_2CH_3$), 1.28 (d, 6H, *Me*$_2$C), 0.88 (m, 2H, Zn*CH*$_2CH_3$). The compound **3d** had: ^1H NMR (C_6D_6) δ 8.39 (d, 1H, *Py*), 7.14 (m, 1H, *Py*), 7.04

(d, 1H, *Py*), 6.64 (m, 1H, *Py*), 4.32 (d, 1H, Py*CH*$_2$N), 3.98 (s, broad, 1H, *H*O), 3.70 (d, 1H, Py*CH*$_2$N), 2.84 (m, 1H, *pyrrolidine ring*), 2.72 (dd, 1H, N*CH*CMe$_2$O), 2.32 (m, 1H, *pyrrolidine ring*), 1.53 (m, 4H, *pyrrolidine ring*), 1.12 (d, 6H, *Me*$_2$C).

Acknowledgements. This work was financially supported by the Ministero dell'Universita' e della Ricerca Scientifica e Tecnologica, Roma and by the Regione Autonoma Sardegna.

References

1. Part V: Falorni, M.; Giacomelli, G.; Lardicci, L. *Gazz. Chim. Ital.* **1990**, *120*, in the press.
2. See for representative example: Mazaleyrat, J.; Cram, D. J. *J. Am. Chem. Soc.* **1981**, *103*, 4585; Alper, H.; Hamel, N. *J. Chem. Soc., Chem. Commun.* **1990**, 135; for reviews, see: Bosnich, B. *Asymmetric Catalysts*; Martinus Nijhoff Publisher: Dordrecht, 1986; Coppola, G. M.; Schuster, H. F. *Asymmetric Synthesis*, John Wiley & Sons, New York, 1987.
3. Mukaiyama, T.; Soai, K.; Sato, T.; Shimizu, H.; Suzuki, K. *J. Am. Chem. Soc.* **1979**, *101*, 1455.
4. Soai, K.; Niwa, S.; Yamada, Y.; Inoue, H. *Tetrahedron Lett.* **1987**, *28*, 4841; Corey, E. J.; Hannon, J. *ibidem* **1987**, *28*, 5237; Soai, K.; Yokoyama, S.; Ebihara, K.; Hayasaka, T. *J. Chem. Soc., Chem. Commun.* **1987**, 1690; Smaardijk, Ab. A.; Wynberg, H. *J. Org. Chem.* **1987**, *52*, 135; Itsuno, S.; Fréchet, J. M. J. *ibidem* **1987**, *52*, 4140; Soai, K.; Niwa, S.; Watanabe, M. *ibidem* **1988**, *53*, 927; Soai, K.; Yokoyama, S.; Hayasaka, T.; Ebihara, K. *ibidem* **1988**, *53*, 4148; Takahashi, H.; Kawakita,T.; Yoshioka, M.; Kobayashi, S.; Ohno, M. *Tetrahedron Lett.* **1989**, *30*, 7095; Kitamura, M.; Okada, S.; Suga, S.; Noyori, R. *J. Am. Chem. Soc.* **1989**, *111*, 4028; Tanaka, K.; Ushio, H.; Suzuki, H. *J. Chem. Soc., Chem. Commun.* **1989**, 1700; Itsuno, S.; Sakurai, Y.; Ito, K.; Maruyama, T.; Nakahama, S.; Fréchet, J. M. J. *J. Org. Chem.* **1990**, *55*, 304; Noyori, R.; Suga, S.; Kawai, K.; Okada, S.; Kitamura, M.; Oguni, N.; Hayashi, M.; Kaneko, T.; Matsuda, Y. *J. Organomet. Chem.* **1990**, *382*, 19; Bolm, C.; Zehnder, M.; Bur, D. *Angew. Chem. Int. Ed. Engl.* **1990**, *29*, 205.
5. Soai, K.; Ookawa, A.; Kaba, T.; Ogawa, K. *J. Am. Chem. Soc.* **1987**, *109*, 7111.
6. Corey, E. J.; Yuen, P.; Hannon, F. J.; Wierda, D. A. *J. Org. Chem.* **1990**, *55*, 784.
7. Chelucci, G.; Falorni, M.; Giacomelli, G. *Synthesis* **1990**, in the press.
8. Dale, J. A.; Dull, D. L.; Mosher, H. S. *J. Org. Chem.* **1969**, *34*, 2543.
9. Still, W. C.; Kahn, M.; Mitra, A. I. *J. Org. Chem.* **1978**, *43*, 2923.
10. Falorni, M.; Lardicci, L.; Rosini, C.; Giacomelli, G. *J. Org. Chem.* **1986**, *51*, 2030.
11. Guttman, S. *Helv. Chim. Acta* **1961**, *44*, 721.
12. Gassman, P. G.; Fentman, A. *J. Org. Chem.* **1967**, *32*, 2388.
13. Seebach, D.; Kalinowski, H.; Bastani, B.; Crass, G.; Daum, H.; Dörr, H.; DuPreez, N.; Ehrig, V.; Langer, W.; Nüssler, C.; Oei, H.; Schmidt, M. *Helv. Chim. Acta* **1977**, *60*, 301.