Pergamon

Tetrahedron: Asymmetry Vol. 5, No. 4, pp. 511-514, 1994
Elsevier Science Ltd
Printed in Great Britain
0957-4166/94 $6.00+0.00

0957-4166(94)E0066-J

Novel Atropisomeric Phosphorus Ligands: 4,5-Dihydro-3*H*-dinaphtho[2,1-*c*;1',2'-*e*]phosphepine Derivatives

Serafino Gladiali[a], Antonio Dore[a], Davide Fabbri[a], Ottorino De Lucchi[b] and Mario Manassero[c]

a) Dipartimento di Chimica, Università di Sassari, Via Vienna 2, 07100 Sassari, Italy; b) Dipartimento di Chimica, Università di Venezia, Dorsoduro 2137, I-30123 Venezia, Italy; c) Istituto di Chimica Strutturistica Inorganica, Università di Milano, Via Venezian 21, 20133 Milano, Italy

Abstract: Atropisomerically pure (S)-4-phenyl-4,5-dihydro-3*H*-dinaphtho[2,1-c;1',2'-e]phosphepine **2b** has been obtained by resolution of the racemic compound with an enantiopure palladium complex and its absolute configuration has been determined by X-ray analysis; it is an effective chiral ligand for the asymmetric hydroformylation of styrene with rhodium catalysts.

The atropisomeric 1,1'-dinaphthyl core is the parent framework of a steadily increasing family of C_2 symmetric chiral auxiliaries of high efficiency.[1] Among these, phosphorus derivatives deserve particular attention because they are effective ligands in several asymmetric reactions catalyzed by transition metal complexes. Enantioselective hydrogenation of olefins and ketones by Rh(I) and Ru(II) catalysts with BINAP provides an outstanding example of the efficiency of these ligands in asymmetric catalysis.[2]

Optically active phospholanes and phospholes have been recently introduced with remarkable success in enantioselective hydrogenation with rhodium catalysts[3] and in the hydroformylation of olefins with platinum-tin catalysts.[4] This stimulated our interest towards dinaphthyl-core phosphorus ligands having the heteroatom incorporated in a cyclic structure.

Recently Wild *et al.*[5] and ourselves[6] reported the preparation of P-substituted dinaphthophosphole derivatives **5**. These compounds, however, are not well suited for resolution since they undergo fast interconversion of atropisomeric conformations of the dinaphthyl framework at room temperature. As most dinaphthyl derivatives do not atropisomerise even well above room temperature, the fluxional behaviour of **5** is probably a consequence of the geometrical properties of the five membered phosphole ring.

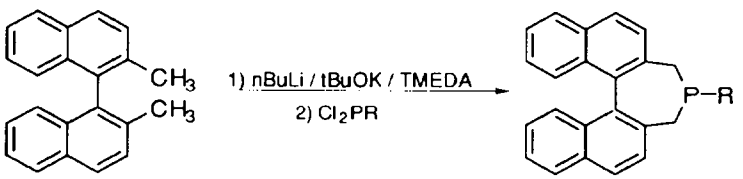
A few dinaphthepine derivatives, i. e. compounds where the two naphthyl rings are joined by a three atom chain connecting the 2,2'-carbons, have been prepared.[7] These compounds seem to be configurationally stable as some of them have been obtained enantiomerically pure. This prompted us to address our efforts towards the synthesis of P-containing dinaphthepines.

The preparation of **2** could be readily accomplished starting from racemic 2,2'-dimethyl-1,1'-dinaphthyl **1**, easily available from 1-bromo-2-methylnaphtalene.[8] Metallation of **1** with *n*-BuLi-*t*-BuOK-TMEDA in hexane afforded the relevant dianion which was quenched with the suitable P-substituted dichlorophosphine. The expected P-susbstituted phosphepines **2a** (R = Me) and **2b** (R = Ph) were isolated after flash chromatography in moderate yields (30%)[9] as air-stable, crystalline powders.

Both the compounds show in the ^{1}H-NMR spectrum twelve partially overlapping resonances for the aromatic protons and two sets of eight lines between 2.10-3.00 δ for each diastereotopic methylene group. These signals were unaffected upon varying the temperature in the range ±60 °C. One single peak was observed in the ^{31}P-NMR (62.83 and 6.97 δ for **2a** and **2b**, respectively), while the ^{13}C-NMR, besides the signals due to the aromatic carbons, was characterized by the presence of three (**2a**) or two (**2b**) doublets between 10.10 and 35.00 δ. These spectral data indicate that no atropisomerization of the dinaphthyl framework is occurring in the range of temperature explored and confirm that dinaphthepine derivatives are configurationally stable.

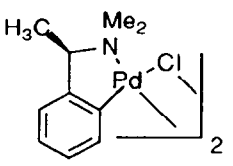
A noticeable feature of phosphepines **2** is that the P-atom is not a stereogenic center since it is located on the C_2-symmetry axis of the dinaphthyl substituent. As a consequence in these substrates, and in dinaphthophospholes as well, pyramidal inversion at phosphorus does not affect the chirality of the molecule which is determined exclusively by the atropisomeric dinaphthyl framework.

According to an established methodology[10], resolution of phosphepines **2a** and **2b** was accomplished by means of the enantiopure palladium amine complex **3**. Mixing the ligands and the dimeric complex in 2:1 molar ratio in CH_2Cl_2 afforded an equimolar mixture of the expected diastereoisomers. They displayed quite distinct solubility properties and, with both phosphepines, one single crystallization from CH_2Cl_2-hexane was successful in obtaining separation of the less soluble isomer in pure form and in more than 45% of the original weight.[11] Attempts to isolate in pure form the more soluble isomers from the mother liquors were unsuccessful. Both the couples of diastereoisomers obtained from **2a** (R = Me) and **2b** (R = Ph) are configurationally stable and no interconversion could be detected even after warming in toluene samples of **4a** and of **4b** for three hours at 100°C. Recrystallisation of the less soluble isomer of **4b** from CH_2Cl_2-hexane gave crystals well suited for X-ray structure determination. An ORTEP view and the most representative parameters of the structure are reported in Fig. 1.

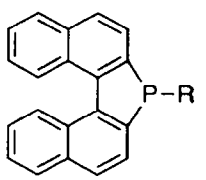


(±)-**1**

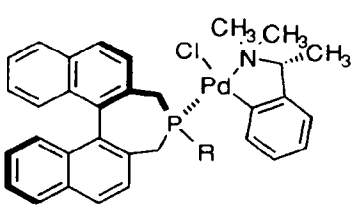
(±)-**2a** : R= Me
(±)-**2b** R= Ph



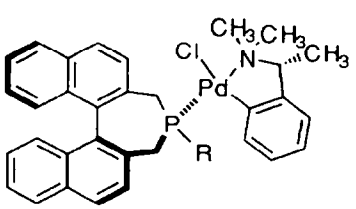
(R)-**3**



(±)-**5**



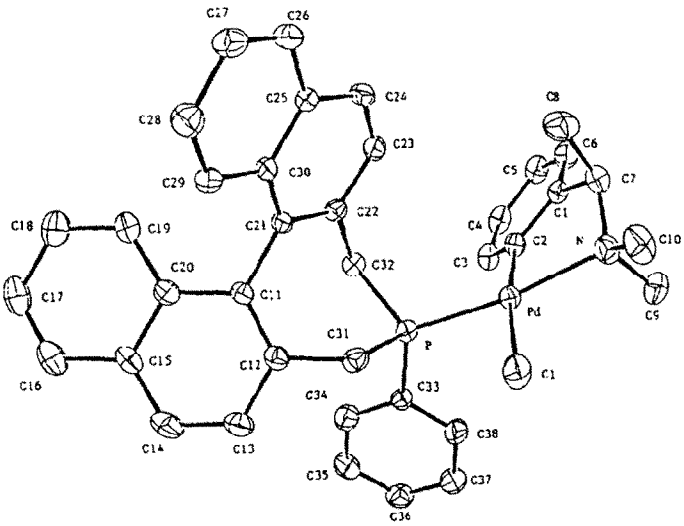
(R,R)-**4a** : R= Me
(R,R)-**4b** : R= Ph



(S,R)-**4 a**
(S,R)-**4 b**

The complex reveals the expected *trans*-relationship between the phosphorus and nitrogen atoms and a modest tetrahedric distortion of the palladium geometry. The main features of the phosphepine ligand are the distorted skew-boat conformation of the seven-membered ring and the large dihedral angle existing between the average planes of the naphthalene rings (63.8°). This can be compared with the one shown by phenyl phosphole **5** (33.0°) in the corresponding palladium complex[12]. The Tolman's cone angle θ[13] of the ligand **2b** determined from the crystal structure is 151°, slightly larger than triphenylphosphine (145°). The absolute configuration of the coordinated ligand **2b** is estabilished to be S. The phosphepine was liberated by treatment of the complex with 1,2-bis(diphenylphosphino)ethane, affording enantiomerically pure (-)-(S)-**2b** $[\alpha]_D^{25}$ = -90.2 (c = 0.79;

$CHCl_3$). The ligand was tested as chiral inducer in the asymmetric hydroformylation of styrene in the presence of $Rh(acac)(CO)_2$ as the catalyst precursor.[14] At 60°C under standard conditions (benzene; substrate:P:Rh: = 500:4:1; $CO:H_2$ = 1; 50 bars) the reaction was completely chemoselective towards aldehydes and a 96% conversion was attained in 3 h. The branched isomer accounted for 93% of the product and showed a 12% e.e. of the R-enantiomer. Decreasing the reaction temperature down to 30°C had a positive effect both on the regio- and the enantio- selectivities which improved up to 95% and 20%, respectively. These preliminary results show that, in comparison with triphenylphosphine, the P-phenylphosphepine based catalyst displays the same catalytic activity and is slightly more regioselective (93% *vs.* 85%).
The enantioselectivities are low, as expected for a monodentate ligand. However, they can be considered encouraging for future elaborations of the basic structure of the parent phosphepine since the 20% value is one of the highest so far obtained in Rh-catalysed hydroformylation with a monodentate ligand as a chiral auxiliary.



Principal bond lengths and angles

Pd-P	2.248(1)
Pd-N	2.148(4)
Pd-C(2)	2.010(5)
Pd-Cl	2.398(1)
P-C(31)	1.847(5)
P-C(32)	1.844(5)
P-C(33)	1.822(5)
Cl-Pd-P	92.41(5)
Cl-Pd-N	93.6(1)
P-Pd-C(2)	93.5(1)
N-Pd-C(2)	80.7(2)
Cl-Pd-C(2)	173.5(1)
P-Pd-N	171.4(1)
Pd-P-C(31)	111.5(2)
Pd-P-C(32)	116.0(2)
Pd-P-C(33)	115.5(2)
C(31)-P-C(32)	100.6(2)
C(31)-P-C(33)	105.4(2)
C(32)-P-C(33)	106.4(2)

Figure 1. X-ray crystal structure (hydrogens omitted) of compound **4b** (less soluble diastereoisomer). $C_{38}H_{35}Cl_1N_1P_1Pd_1.CH_2Cl_2$, M = 763.5, orthorombic, space group $P2_12_12_1$ (No. 19), a = 9.751(2), b = 10.881(3), c = 33.160(4) Å, V = 3518 $Å^3$, F(000) = 1560, Z = 4, D_c = 1.441 g cm^{-3}, Mo-K_α radiation, λ = 0.71073 Å, μ(Mo-K_α) = 8.22 cm^{-1}; the final R and R_w values for the correct enantiomorph are 0.029 and 0.035, respectively, for 3046 absorption-corrected reflections with $I>3\sigma(I)$. Full structural details have been deposited with the Cambridge Crystallographic Centre.

Acknowledgements
We thank CNR -Rome "Progetti Finalizzati" for financial support.

References

1 C. Rosini, L. Franzini, A. Raffaelli and P. Salvadori, *Synthesis* **1992**, 503.
2 R. Noyori, *Chem. Soc. Rev.* **1989**, *18*, 187.
3 M. J. Burk, J. E. Feaster, W. A. Nugent and R. L. Harlow, *J. Am. Chem. Soc.*, **1993**, *115*, 10125 and pertinent references cited therein.
4 J. K. Stille, H. Su, P. Brechot, G. Parrinello and L. S. Hegedus, *Organometallics* **1991**, *10*, 1183 and cited references.

5 A. A. Watson, A. C. Willis and S. B. Wild, *J. Organomet. Chem.* **1993**, *445*, 71.
6 A. Dore, D. Fabbri, S. Gladiali and O. De Lucchi, *J. Chem. Soc., Chem. Commun.* **1993**, 1124.
7 a) H. J. Bestmann and W. Both, *Chem. Ber.* **1974**, *107*, 2926. b) J-P. Mazaleyrat and D. J. Cram, *J. Am. Chem. Soc.* **1981**, *103*, 4585. c) S. L. Colletti and R. L. Halterman, *Organometallics* **1991**, *10*, 3438. d) O. De Lucchi, D. Fabbri and V. Lucchini, *Tetrahedron* **1992**, *48*, 1485. e) P. Maglioli, O. De Lucchi, G. Delogu and G. Valle, *Tetrahedron:Asymmetry* **1992**, *3*, 365. f) J. M. Chong, G. K. MacDonald, S. B. Park and S. H. Wilkinson, *J. Org. Chem.* **1993**, *58*, 1266.
8 N. Maigrot and J-P. Mazaleyrat, *Synthesis* **1985**, 317.
9 *Selected data for* (±)-**2a**: Yield: 30%; m.p 186-187°C (CH_2Cl_2/AcOEt); ^{1}H-NMR ($CDCl_3$) δ 0.96 (d, $^2J_{P-H}$ = 3.3 Hz, -CH_3), 2.11 (dd, J = 4.5, 11.7 Hz, 1H), 2.38 (dd, J = 6.00, 14.1 Hz, 1H), 2.63 (dd, J = 8.7, 14.1 Hz, 1H), 2.77 (dd, J = 5.7, 11.7 Hz, 1H), 7.20-7.26 (series of m, Ar, 4H), 7.31 (d, J = 8.4 Hz, 1H), 7.37-7.44 (series of m, Ar, 2H), 7.53 (d, J = 8.4, 1H), 7.86-7.95 (seies of m, Ar, 4H). ^{13}C-NMR ($CDCl_3$) (aliphatic carbons only) δ 10.12 (d, $^1J_{C-P}$ = 18.52 Hz, -CH_3), 30.72 (d, $^1J_{C-P}$ = 18.52 Hz, -CH_2-), 33.80 (d, $^1J_{C-P}$ = 14.02 Hz, -CH_2-); ^{31}P-NMR ($CDCl_3$) δ 62.83 (s). Anal. Calcd. for $C_{23}H_{19}P$: C, 84.64; H, 5.87. Found: C, 84.93; H, 6.08.
Selected data for (-)-(S)-**2b**: Yield: 30% ; m.p 189-190°C (CH_2Cl_2/hexane); ^{1}H-NMR ($CDCl_3$) δ 2.71-3.06 (series of m, 4H), 6.90 (d, J = 8.4 Hz, Ar, 1H), 7.20-7.33 (series of m, Ar, 9H), 7.38-7.47 (series of m, Ar, 2H), 7.67 (dd, J = 0.9, 8.4 Hz, Ar, 1H), 7.71 (d, J = 8.4 Hz, Ar, 1H), 7.88 (d, J = 8.4 Hz, Ar, 1H), 7.94 (dd, J = 1.5, 8.4 Hz, Ar, 2H). ^{13}C-NMR ($CDCl_3$) (aliphatic carbons only) δ 30.31 (d,$^1J_{C-P}$ = 16.5 Hz), 32.20 (d, $^1J_{C-P}$ = 22.0 Hz); ^{31}P NMR ($CDCl_3$) d 6.97 (s). $[\alpha]_D^{25}$ = -90.2 (c = 0.79; $CHCl_3$). Anal. Calcd. for $C_{28}H_{21}P$: C, 86.58; H, 5.45. Found: C, 86.81; H, 5.68.
10 a) K. Tani, L. D. Brown, J. Ahmed, J. A. Ibers, M. Yokota, A. Nakamura and S. Otsuka, *J. Am. Chem. Soc.* **1977**, *99*, 7876.
11 *Selected data for* **4a** (less soluble isomer): Yield: 93%; m.p 239-40°C (CH_2Cl_2/hexane); ^{1}H-NMR ($CDCl_3$) δ 1.73 (d, J = 9.0 Hz, -CH_3), 1.81 (d, J = 6.0 Hz, PCH_3), 2.54 (dd, J = 12.6, 15.6 Hz, 1H), 2.68 (d, $^3J_{P-H}$ = 2.7 Hz, -$N(CH_3)_2$), 3.27 (dd, J = 10.5, 14.7 Hz, 1H), 3.53-3.77 (series of m, 3H), 7.04-7.35 (series of m, Ar, 6H), 7.50-7.57 (series of m, Ar, 2H), 7.80 (d, J = 8.1 Hz, 1H), 7.96 (d, J = 8.1 Hz, 1H), 8.00-8.05 (series of m, Ar, 2H). ^{13}C-NMR ($CDCl_3$) (aliphatic carbons only) δ 10.50 (d, $^1J_{C-P}$ = 20.0 Hz, PCH_3), 22.81 (s, -CH_3), 31.90 (d, $^1J_{C-P}$ = 28.0 Hz, -CH_2-), 33.20 (d, $^1J_{C-P}$ = 28.5 Hz, -CH_2-), 46.43 (d, $^3J_{C-P}$ = 2.5 Hz, NCH_3), 50.18 (d, $^3J_{C-P}$ = 3.0 Hz, NCH_3), 75.44 (d, $^3J_{C-P}$ = 3.5 Hz); ^{31}P-NMR ($CDCl_3$) δ 41.35 (s). $[\alpha]_D^{25}$ -169.6 (c= 0.5, CH_2Cl_2); Anal. Calcd. for $C_{33}H_{33}ClNPPd$: C, 64.30; H, 5.40; N, 2.27. Found: C, 64.52; H, 5.59; N, 2.32.
Selected data for (S,R)-**4b** (less soluble isomer). Yield: 94%; m.p : 253-54°C (CH_2Cl_2/hexane); ^{1}H-NMR ($CDCl_3$) δ 1.84 (d, J = 6.6 Hz, -CH_3), 2.64 (d, $^4J_{P-H}$ = 0.6 Hz, -NCH_3), 2.67 (d, $^4J_{P-H}$ = 3.3 Hz, NCH_3), 3.15-3.70 (series of m, 4H), 6.67-7.91 (series of m, Ar, 17H). ^{13}C-NMR ($CDCl_3$) (aliphatic carbons only) δ 24.22 (s, -CH_3), 29.36 (d, $^1J_{C-P}$ = 28.0 Hz, -CH_2-), 35.60 (d, $^1J_{C-P}$ = 26.0 Hz, -CH_2-), 47.06 (d, $^3J_{C-P}$ = 3.0 Hz, -NCH_3), 50.45 (d, $^3J_{C-P}$ = 3.0 Hz, NCH_3), 75.95 (d, $^3J_{C-P}$ = 2.55 Hz, -CH-); ^{31}P-NMR ($CDCl_3$) d 52.30 (s). $[\alpha]_D^{25}$ -208.7 (c=1.00, CH_2Cl_2); Anal. Calcd. for $C_{38}H_{36}ClNPPd$: C, 67.17; H, 5.34. Found: C, 67.38; H, 5.25.
12 S. Gladiali, G. Banditelli, D. Fabbri, M. Manassero and M. Sansoni, submitted for publication.
13 C. A. Tolman, Chem. Rev. **1977**, *77*, 313.
14 *Hydroformylation experiments: general procedure*. Styrene (1 ml, 9.6 mmol) was added to a solution of Rh[(acac)(CO_2)] (5 mg, 0.02 mmol) and (S)-(-)-**2b** (30 mg, 0.10 mmol) in benzene (10ml) placed in a 200 ml stainless steel autoclave. The air was evacuated, the vessel was pressurized with an equimolar mixture of CO/H_2 (50 bar) at room temperature and heated in a thermostatted oil bath at 60°C for 3 h. Conversion and composition of the reaction products were determined by GC with a 30 m cyclodex-β column (110°C). The e.e was determined by the same way on the corresponding carboxylic acids obtained by $KMnO_4$ oxidation[15] of a sample of the reaction mixture. Retention times (110° for 5', then warm to 170° at 5°C/min) of (S)- and (R)- 2-phenylpropanoic acid are 15.91 and 16.14 min, respectively.
15 A. Abiko, J. C. Roberts, T. Takemasa and S. Masamune, *Tetrahedron Lett.* **1986**, *27*, 4537.

(*Received in UK* 25 *January* 1994)