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SYNTHESIS AND RESOLUTION OF A NEW TYPE OF CHIRAL BISPHOSPHINE LIGAND, trans-BIS-1,2-(DIPHENYLPHOSPHINO)CYCLOBUTANE, AND ASYMMETRIC HYDROGENATION USING ITS RHODIUM COMPLEX

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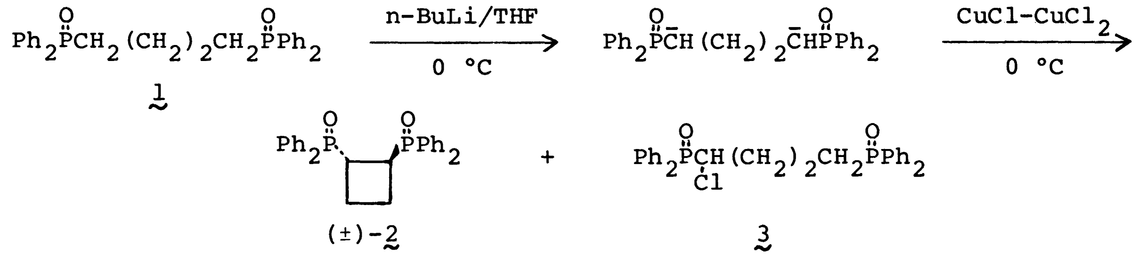
Oxidative coupling of the 1,4-dicarbanions derived from bis-1,4-(diphenylphosphinyl)butane gave (±)-trans-bis-1,2-(diphenylphosphinyl)cyclobutane. Asymmetric hydrogenation of dehydroamino acids using rhodium complex of the optically active bisphosphine obtained by reduction of the resolved bisphosphine oxide afforded hydrogenated products in high optical yields.

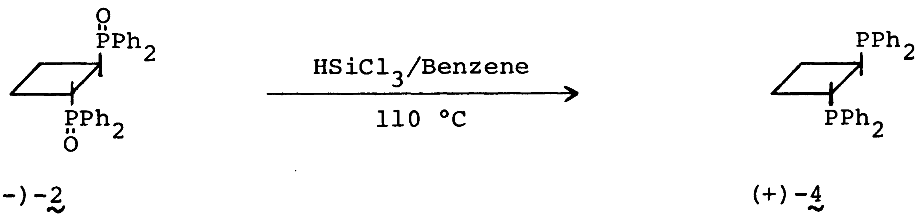
Although a variety of optically active bisphosphines as chelating agents for homogeneous catalysts have been synthesized,1) most of them have disadvantages such as difficulty and requirement of many steps in the synthesis. On the other hand, we have recently reported a new synthesis of 1,2-bisylidenecyclobutanes using an intermediate 2-(diethoxyphosphinyl)cyclobutylphosphonium ylide.2) In connection with our continuing interest in the synthesis and the utilization of cyclobutanes having phosphorus residues, we developed the simple synthesis of a new type of chiral bisphosphine ligand, trans-bis-1,2-(diphenylphosphino)cyclobutane (abbreviated DPCB) and applied its rhodium complex in asymmetric hydrogenation.

A typical experimental procedure for the synthesis of trans-bis-1,2-(diphenylphosphinyl)cyclobutane **2** is as follows.3) To a solution of bis-1,4-(diphenylphosphinyl)butane **1** (11.46 g, 25 mmol) in dry THF was added n-BuLi in hexane (70 mmol) with stirring at 0 °C and the solution was stirred at this temperature for 0.5 h. After dry CuCl (0.50 g, 5 mmol) was added to the solution and the mixture was stirred for 0.5 h, dry $CuCl_2$ (7.54 g, 55 mmol) was added keeping the temperature at 0 °C. Further, the reaction mixture was stirred at 0 °C for 0.5 h, then the mixture was warmed to room temperature and was continued to stir for 8 h, followed by saturation with O_2 for 0.5 h. After hydrolysis with concd HCl, the reaction mixture was concentrated in vacuo and extracted with $CHCl_3$, and organic layer was washed with dil. aqueous NH_3 and evaporated. Preparative thin layer chromatography of the residue with ethyl acetate-methanol (19:1) as the eluent gave pure **2**4) in 4.22 g (37%) yield, mp 214-214.5 °C, together with 1-chloro-1,4-di(diphenylphosphinyl)butane **3**5) (3.45 g, 28%), mp 153-154 °C (Scheme 1).



Scheme 1.

Similar to the resolution of (±)-Norphos oxide,6) treatment of a solution of the racemic mixture of DPCB oxide (3.00 g, 6.6 mmol) in methanol with a stoichiometric quantity of L-(-)-dibenzoyltartaric acid (abbreviated DBT) in methanol resulted in the formation of the precipitate, in which diastereoisomer (-)-DPCB oxide/(-)-DBT is enriched. After separation of (-)-DPCB oxide by KOH-treatment of the precipitate, three times a repetition of the similar resolution procedure for the separated (-)-DPCB oxide gave a 1.40 g (3.1 mmol) yield of pure (-)-DPCB oxide (-)-**2**, $[\alpha]_D^{22}$=-7.38° (c 1.25, CH_3OH).7) Reduction of the optically pure bisphosphine oxide (-)-**2** (2.00 g, 4.4 mmol) in dry benzene (20 ml) with trichlorosilane (1.0 ml, 10 mmol) in a sealed tube (8 h at 110 °C) gave optically active (+)-trans-bis-1,2-(diphenylphosphino)cyclobutane (DPCB) **4**8) in quantitative yield, mp 116 °C (from CH_2Cl_2-CH_3OH), $[\alpha]_D^{24}$=6.27° (c 2.92, $CHCl_3$).



The absolute configuration of (+)-**4** was unambiguously determined by X-ray analysis of its $NiCl_2$ complex **5**. The preparation of the complex **5** was as follows.

Treatment of a solution of (+)-4 (0.50 g, 1.1 mmol) in CH_2Cl_2 with a solution of $NiCl_2$ (0.14 g, 1.1 mmol) in aqueous ethanol at room temperature, followed by the usual work-up and recrystallization from CH_2Cl_2-Et_2O, gave a 0.49 g (80%) yield of pure 5, mp 264.5-266 °C.

Crystal data: $C_{28}H_{26}Cl_2P_2Ni$, M=554.1, triclinic, space group P1, a=9.635(5), b=9.165(5), c=8.678(4) Å, α=67.12(4), β=95.15(4), γ=109.60(5)°, U=664.4 $Å^3$, Z=1, D_c=1.385 $g.cm^{-3}$. Intensities of 1950 independent reflection were measured ($2\theta_{max}$=120°) on a Rigaku four-circle diffractmeter using Ni-filtered Cu-Kα radiation. The structure was solved by the heavy-atom method and refined by the block-diagonal least-squares method.[9)] The absolute configuration was confirmed by the Bijvoet method. All non-hydrogen atoms were refined anisotropically, and hydrogen atoms isotropically. Current R-value is 0.075 (R_w=0.090) for 1872 reflections with I>2σ (I). The atomic scattering factors were taken from Ref. 10. Molecular structure of the complex 5 was illustrated in Fig. 1.

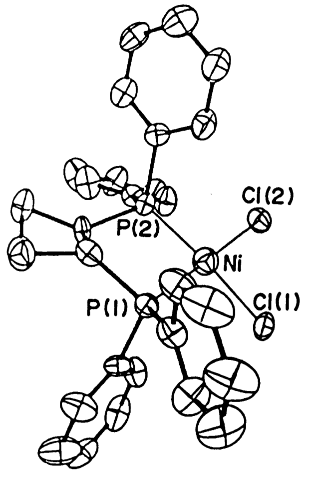


Fig. 1. Molecular structure of the $NiCl_2$ complex 5. Hydrogen atoms are omitted for clarity. Selected bond lengths (Å) and angles (°) are: Ni-P(1) 2.191(4), Ni-P(2) 2.202(4), Ni-Cl(1) 2.186(4), Ni-Cl(2) 2.192(4); P(1)-Ni-P(2) 90.4(1), P(1)-Ni-Cl(1) 85.8(1), P(2)-Ni-Cl(2) 90.6(2), Cl(1)-Ni-Cl(2) 93.3(2).

With optically pure (+)-DPCB, we have examined the asymmetric hydrogenation of (Z)-α-(benzamido)cinnamic acid and (Z)-α-(benzamido)-β-(4-hydroxy-3-methoxyphenyl)acrylic acid catalyzed by the cationic rhodium (I) complex $[Rh\cdot(+)\text{-DPCB}\cdot(1,5\text{-COD})]^+BF_4^-$ (COD: cyclooctadiene). The optical yields of the hydrogenated products, N-benzoyl-(S)-phenylalanine and N-benzoyl-3-(4-hydroxy-3-methoxyphenyl)-(S)-alanine, were found to be 82% ee and 90% ee, respectively, determined by optical rotation[11)] and by ^1H-NMR (270 MHz) of their methyl esters using a chiral shift reagent.

Thus, trans-bis-1,2-(diphenylphosphinyl)cyclobutane 2 prepared via an intramolecular oxidative cyclization was successfully resolved into an optically pure enantiomer (−)-**2**. The phosphine oxide (−)-**2** can be readily converted into a new type of optically active bisphosphine ligand which is applicable as asymmetric hydrogenation catalyst.

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References

1) For some recent reviews of asymmetric hydrogenation reactions using chiral diphosphine complexes of rhodium, see: V. Caplar, G. Comisso, and V. Sunjic, Synthesis, 1981, 85; J. M. Brown and P. A. Chaloner, "Homogeneous Catalysis with Metal Phosphine Complexes," ed L. H. Pignolet, Plenum Press, New York (1983), Chap. 4, p. 107.
2) T. Minami, Y. Taniguchi, and I. Hirao, J. Chem. Soc., Chem. Commun., 1984, 1046.
3) For the syntheses of 1,2-ethano bisphosphine oxides by using the oxidative coupling of phosphoryl-stabilized carbanions: C. A. Maryanoff, B. E. Maryanoff, R. Tang, and K. Mislow, J. Am. Chem. Soc., 95, 2567 (1973); B. D. Vineyard, W. S. Knowles, M. J. Sabacky, G. L. Bachman, and D. J. Weinkauff, ibid., 99, 5946 (1977).
4) **2**: ^{1}H-NMR($CDCl_3$) δ 2.20-2.80 (m, 4H), 3.50-4.20 (m, 2H), 6.80-8.00 (m, 20H); ^{13}C-NMR($CDCl_3$) δ 30.72 (dd, $^{1}J_{pc}$75.64 Hz, $^{2}J_{pc}$9.46 Hz, C^{α}), 20.23 (s, C^{β}). This compound **2** was alternatively synthesized in 46% yield by the Michael addition of a diphenylphosphide anion to (1-cyclobutenyl)triphenylphosphonium perchlorate (J. Org. Chem., 48, 2569 (1983)), followed by hydrolysis.
5) **3**: ^{1}H-NMR($CDCl_3$) δ 1.00-2.50 (m, 6H), 4.20-4.60 (m, 1H), 7.00-8.20 (m, 20H).
6) See, for examples, H. Brunner and W. Pieronczyk, Angew. Chem., 91, 655 (1979); H. Brunner and M. Pröbster, Inorg. Chim. Acta, 61, 129 (1982).
7) More than three times a repetition of the resolution step did not change the specific rotation.
8) **4**: ^{1}H-NMR($CDCl_3$) δ 1.00-3.20 (m, 6H), 6.52-7.50 (m, 20H); ^{13}C-NMR($CDCl_3$) δ 35.06 (dd, $^{1}J_{pc}$16.33 Hz, $^{2}J_{pc}$18.91 Hz, C^{α}), 23.78 (t, $^{2}J_{pc}$=$^{3}J_{pc}$7.74 Hz, C^{β}). M. L. H. Green and co-workers (J. Chem. Soc., Chem. Commun., 1983, 895) have recently reported an alternative synthesis of the related chiral bisphosphine, trans-bis-1,2-(diphenylphosphino)cyclopentane as the ligand in asymmetric hydrogenation.
9) T. Ashida, HBLS-V, 1973, Osaka University.
10) "International Tables for X-Ray Crystallography," Kynoch Press, Birmingham (1974), Vol. IV, pp. 72-79 and 149.
11) A. Miyashita, A. Yasuda, T. Ito, H. Takaya, T. Souchi, K. Toriumi, and R. Noyori, J. Am. Chem. Soc., 102, 7932 (1980).

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