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Tetrahedron Letters 44 (2003) 9279–9281

TETRAHEDRON LETTERS

Homochiral cyclopentane-based C_1-symmetric *P,P* ligands $C_5H_8(PPh_2)(PR_2)$ from C_2-symmetric $C_5H_8(PCl_2)_2$

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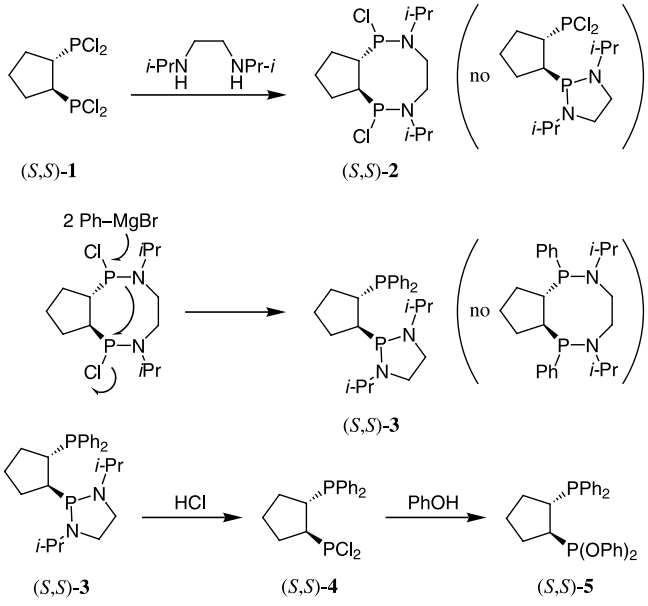
Received 4 September 2003; revised 10 October 2003; accepted 13 October 2003

Abstract—Treatment of 1,2-*trans*-$C_5H_8(PCl_2)_2$ with 1,2-$C_2H_4(NHPr\text{-}i)_2$ gave the C_2-symmetric perhydro-1,6,2,5-diazaphosphocine $C_5H_8\{P(Cl)N(Pr\text{-}i)CH_2\}_2$-*cyclo*, which produced dissymmetric $C_5H_8(PPh_2)\{P[N(Pr\text{-}i)CH_2]_2\text{-}cyclo\}$ on further reaction with PhMgBr. Cleavage of the P–N bonds with gaseous HCl afforded $C_5H_8(PPh_2)(PCl_2)$, which was converted to $C_5H_8(PPh_2)\{P(OPh)_2\}_2$ by reaction with phenol. All chiral *P,P* derivatives were obtained as racemates as well as resolved (1*R*,2*R*)- and (1*S*,2*S*)-enantiomers.

Dissymmetric P_2 ligands such as phosphine-phosphites $R_2P\frown OP(OR)_2$[1] phosphite-phosphoroamidites $(RO)_2PO\frown NP(OR)_2$,[2] or bisphosphines R_2P,PR'_2 bearing different donor groups[3,4] have attracted considerable interest in homogeneous catalysis, in particular because of the impressive performance of their rhodium complexes as carbonylation and hydrogenation catalysts.

In previous work carried out in other laboratories, bisphosphines with C_1 symmetry of the general type $Ar_2PC_2H_4PAr'_2$ were obtained either by base-catalyzed P–H/>C=C< addition of a diaryl phosphine to a suitable diarylvinylphosphine[3a–3c] or by nucleophilic substitution of $Ph_2PC_2H_4PCl_2$ (the source of which was not disclosed) by an appropriate Grignard or organolithium reagent.[3d] An analogous phosphine-phosphonous dichloride, having a rigid 1,2-*trans*-disubstituted cyclopentane backbone in place of a flexible ethylene linkage, $C_5H_8(PPh_2)(PCl_2)$, **4**, has now been obtained both as a racemate and as (1*R*,2*R*) and (1*S*,2*S*) enantiomers from racemic or optically pure $C_5H_8(PCl_2)_2$, **1**,[5,6] by the reaction sequence outlined in Scheme 1 for the (1*S*,2*S*) stereoisomers.

Condensation of bis(phosphonous dichloride) **1** with an equimolar quantity of *N,N′*-diisopropylethylenediamine afforded the C_2-symmetric perhydro-1,6,2,5-diazadiphosphocine **2**[7] containing an eight-membered P_2N_2 heterocycle rather than the expected dissymmetric phosphonous(dichloride-diamide) $C_5H_8(PCl_2)\{P[N(Pr\text{-}i)CH_2]_2\text{-}cyclo\}$. The latter was originally thought of as being favored over **2** because of the presence of a conformationally more advantageous five-membered ring. However, degradation of the undesired eight-



Scheme 1. Yields: 79% of (*S,S*)-**2**, 83% of (*S,S*)-**3**, 94% of (*S,S*)-**4**, 84% of (*S,S*)-**5**.

Keywords: chirality; dissymmetric P_2 ligands; synthetic methods.
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0040-4039/$ - see front matter © 2003 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tetlet.2003.10.071

membered perhydro-1,6,2,5-diazadiphosphocine system with formation of the desired dissymmetric phosphine-phosphonous diamide **3**[8] possessing a five-membered 1,3,2-diazaphospholidine substituent in addition to a diphenylphosphino group was observed on combination of **2** with phenylmagnesium bromide in 1:2 stoichiometry—presumably as a result of nucleophile-induced ring contraction.

Cleavage of the P–N bonds of **3** with gaseous hydrogen chloride proceeded smoothly to afford the desired C_1-symmetric phosphine-phosphonous dichloride **4**,[9] which similar to **1** proved to be a convenient starting material for further derivatization, e.g. to $C_5H_8(PPh_2)\{P(OPh)_2\}$ **5**.[10]

In summary, we have shown that dissymmetric $C_5H_8(PPh_2)(PCl_2)$ is readily accessible from racemic or enantiomerically pure $C_5H_8(PCl_2)_2$ by sequential treatment with 1,2-$C_2H_4(NHPr\text{-}i)_2$, PhMgBr, and HCl. The usefulness of this protocol derives from the following features: Substitution reactions of P–Cl functional P(III) compounds by combination with oxygen, nitrogen, or carbon nucleophiles are among the most general and most easily accomplished coupling methods in organic chemistry, which permit the incorporation of virtually any other P–O-, P–N-, or P–C bonded residue into the homochiral $C_5H_8(PPh_2)(PCl_2)$ framework and thus provide a convenient procedure for the preparation of a wide range of dissymmetric diphosphorus ligands, both in racemic and optically active form.

Acknowledgements

Financial support by the Deutsche Forschungsgemeinschaft (Bonn) is gratefully acknowledged.

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7. Representative procedure for **2**: A solution of 1.85 mL (10.26 mmol) of *N*,*N*′-diisopropylethylenediamine and 2.86 mL (20.52 mmol) of triethylamine in 100 mL of diethyl ether was added dropwise at −70°C to 2.79 g (10.26 mmol) of *rac*-**1** dissolved in 100 mL of Et_2O. Warming to room temperature caused the precipitation of $[Et_3NH]Cl$, which was filtered off. The filtrate was evaporated under vacuum to leave 2.89 g (8.41 mmol, 82%) of *rac*-**2** as a white solid. (1*R*,2*R*)-**2** and (1*S*,2*S*)-**2** were obtained analogously in 83 and 79% yields. Anal. (%) calcd for $C_{13}H_{26}Cl_2N_2P_2$ (343.2) C, 45.49; H, 7.64; N 8.16. Found: C, 44.70; H, 7.69; N, 7.55. Spectroscopic data proving the C_2 symmetry: ^{1}H NMR (C_6D_6, 400.1 MHz) δ 0.90, 1.10 (both d, J(H,H) = 6.8 Hz each, 6H each, both $CH(CH_3)_2$), 1.9–2.1, 2.4–2.6, 2.7–2.9 (all m, 4H, 2H, 4H, all CH_2), 3.5–3.7 (m, 2H, $CH(CH_3)_2$). $^{13}C\{^1H\}$ NMR (C_6D_6, 100.6 MHz) δ 21.5, 22.6 (both d, J(P,C) = 4.4, 15.3 Hz, $CH(CH_3)_2$), 27.8 (t, J(P,C) = 6.5 Hz, C^4H_2), 30.0 (d, J(P,C) = 32.7 Hz, $CH(CH_3)_2$), 46.8 (dd, J(P,C) = 2.8, 11.6 Hz, $C^{3,5}H_2$), 48.2 (dd, J(P,C) = 10.9, 29.1 Hz, $C^{1,2}H$), 56.9 (d, J(P,C) = 35.6 Hz, NCH_2). $^{13}C\{^1H,^{31}P\}$ NMR (C_6D_6, 100.6 MHz) δ 21.5, 22.6, 27.8, 30.0, 32.7, 46.8, 48.2, 56.9 (all s). $^{31}P\{^1H\}$ NMR (C_6D_6, 161.9 MHz) δ 161.4 (s). Optical rotations $[\alpha]_\lambda$ (*c* 1, $CHCl_3$, 20°C); (1*R*,2*R*)-**2**: +78 (589 nm), +85 (578 nm), +95 (546 nm), +176 (436 nm), +299 (365 nm). (1*S*,2*S*)-**2**: −96 (589 nm), −107 (578 nm), −124 (546 nm), −220 (436 nm), −355 (365 nm).
8. Representative procedure for **3**: A solution of 3.28 g (9.56 mmol) of (1*S*,2*S*)-**2** in 100 mL of diethyl ether was slowly added dropwise to 20 mL of an ethereal solution containing 19.12 mmol of phenylmagnesium bromide. Stirring overnight, followed by filtration over Celite and evaporation of volatiles left a semi-solid residue which was re-dissolved in *n*-pentane. Filtration and removal of the solvent from the filtrate gave 3.37 g (7.90 mmol, 83%) of (1*S*,2*S*)-**3** as a clear colorless oil. The (1*R*,2*R*) enantiomer and the

racemate were similarly isolated in 75 and 87% yields. Spectroscopic data proving the C_1 symmetry: ^{1}H NMR (C_6D_6, 400.1 MHz) δ 1.16, 1.20, 1.22, 1.26 (all d, J(H,H) = 6.4 Hz each, 3H each, CH(CH_3)$_2$), 1.8–2.1, 2.1–2.3, 2.6–2.8, 2.8–3.0, 3.1–3.3 (all m, 14H, CH_2 and CH), 7.0–7.4, 7.7–7.8, 7.8–7.9 (all m, 10H, C_6H_5). ^{13}C{^{1}H} NMR (C_6D_6, 100.6 MHz) δ 23.2, 23.4, 23.7, 23.8 (all d, J(P,C) = 8.0, 8.7, 12.3, 14.5 Hz, CH(CH_3)$_2$), 25.4 (ABX-t, ΣJ(P,C) = 8.0 Hz, C^4H_2), 27.7, 29.7 (both ABX-dd, ΣJ(P,C) = 22.5, 17.4 Hz, $C^{3,5}H_2$), 37.8, 44.4 (both ABX-dd, ΣJ(P,C) = 29.8, 33.4 Hz, $C^{1,2}$H), 49.2, 49.6 (both d, J(P,C) = 6.5, 7.3 Hz, both $CH(CH_3)_2$), 52.0, 52.8 (both d, J(P,C) = 21.8, 22.5 Hz, both NCH_2), 128.0–140.0 (C_6H_5). ^{31}P{^{1}H} NMR (C_6D_6, 161.9 MHz) δ 5.7 (d, J(P,P) = 9.3 Hz, PPh_2), 115.6 (d, J(P,P) = 9.3 Hz, PN_2). Optical rotations $[\alpha]_\lambda$ (c 1, $CHCl_3$, 20°C); (1R,2R)-**3**: +164 (589 nm), +171 (578 nm), +199 (546 nm), +383 (436 nm), +724 (365 nm). (1S,2S)-**3**: −130 (589 nm), −138 (578 nm), −159 (546 nm), −307 (436 nm), −682 (365 nm).

9. Typical preparation of **4**: Bubbling dry HCl gas through an ethereal solution (150 mL) of 1.34 g (3.14 mmol) of (1R,2R)-**3** for 10 min under ambient conditions caused the deposition of [i-PrN$H_2C_2H_4NH_2$Pr-i]Cl_2 as a white precipitate, which was removed by filtration. Evaporation of the filtrate left 1.00 g (2.83 mmol, 90%) of (1R,2R)-**4** as a clear colorless oil. The (1S,2S) stereoisomer and the racemic mixture were similarly obtained in 94 and 93% yields. Spectroscopic data: ^{13}C{^{1}H} DEPT-NMR (C_6D_6, 100.6 MHz) δ 26.9, 29.1, 31.7 (all ABX-dd, ΣJ(P,C) = 6.9, 13.8, 6.2 Hz, all CH_2), 36.1, 51.3 (both ABX-dd, ΣJ(P,C) = 32.5, 61.6 Hz, both CH), 129.9, 130.0 (both d, J(P,C) = 4.2, 3.5 Hz, both phenyl *meta*-C), 132.8, 132.9 (both d, J(P,C) = 28.4, 29.1 Hz, both phenyl *ortho*-C), 133.7, 133.9 (both s, both phenyl *para*-C), 134.4, 134.5 (both d, J(P,C) = 14.5 Hz each, both phenyl *ipso*-C). ^{31}P{^{1}H} NMR (C_6D_6, 161.9 MHz) δ 9.5 (d, J(P,P) = 12.9 Hz, PPh_2), 211.8 (d, J(P,P) = 12.9 Hz, PCl_2). Optical rotations $[\alpha]_\lambda$ (c 1, $CHCl_3$, 20°C); (1R,2R)-**4**: −16 (589 nm), −17 (578 nm), −19 (546 nm), −31 (436 nm), +45 (365 nm). (1S,2S)-**4**: +15 (589 nm), +17 (578 nm), +18 (546 nm), +30 (436 nm), −45 (365 nm).
10. The experimental procedures used for transforming (1R,2R)-**4** and (1S,2S)-**4** to the respective enantiomers of **5** were the same as those previously described for the preparation of *rac*-C_5H_8{P(OPh)$_2$}$_2$ from racemic **1**.[11] The products were isolated as colorless waxes in 79–84% yield. Spectroscopic data: ^{13}C{^{1}H} NMR (C_6D_6, 100.6 MHz) δ 26.9 (m, CH_2) 27.6, 31.8 (both dd, J(P,C) = 4.4/7.3, 2.2/13.8 Hz, both CH_2), 36.5, 47.4 (ABX-dd and ABX-t, ΣJ(P,C) = 26.2, 34.2 Hz, both CH), 116.2–134.8 (all C_6H_5). ^{31}P{^{1}H} NMR (C_6D_6, 161.9 MHz) δ 8.9 (d, J(P,P) = 11.1 Hz, PPh_2), 112.0 (d, J(P,P) = 11.1 Hz, P(OPh)$_2$). Optical rotations $[\alpha]_\lambda$ (c 1, $CHCl_3$, 20°C); (1R,2R)-**5**: +6 (589 nm), +7 (578 nm), +8 (546 nm), +20 (436 nm), +44 (365 nm). (1S,2S)-**5**: −9 (589 nm), −10 (578 nm), −12 (546 nm), −26 (436 nm), −57 (365 nm).
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