DE GRUYTER DOI 10.1515/hc-2012-0108 — Heterocycl. Commun. 2012; 18(4): 165–167

Preliminary Communication

Hong Jiang, Hong Ding, Kaiqi Ge, Pei Guang, Yunfei Li, Xiang Liu, Guangsheng Pang and Yanhui Shi*

Synthesis of novel NHC-pyrrole-NHC C-N-C Pincer proligands

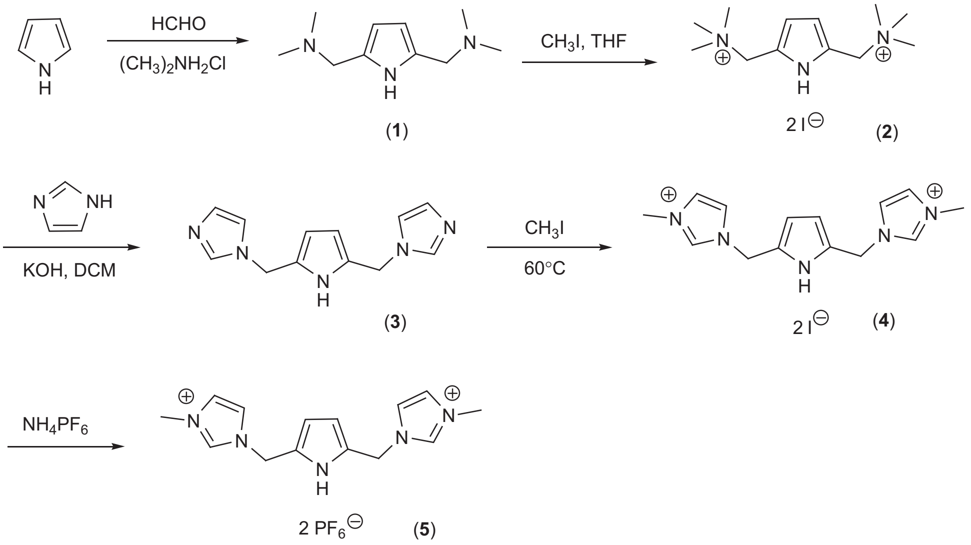
Abstract: Two novel pyrrole-functionalized bis(benzoimidazolium) salts, which are novel NHC-pyrrole-NHC C-N-C Pincer proligands were synthesized in high yield. Both of these compounds are fully characterized by ^{1}H and ^{13}C NMR, IR and elemental analysis.

Keywords: N-heterocyclic carbene ligand; Pincer ligand; tridentate; pyrrole.

Among polydentate N-heterocyclic carbenes (NHCs), an important class of tridentate chelating bis-NHCs ligands is Pincer ligands in which a donor-functional group is introduced between the two carbene edges (Pugh and Danopoulos, 2007; Poyatos et al., 2009). The Pincer ligands provide the ubiquitous coordination sphere and have attracted a lot of attention due to their good thermal stability and good rigidity (Choi et al., 2011; Selander and Szabo, 2011). The organometallic complexes with Pincer ligands have been widely studied in catalytic application (Albrecht and van Koten, 2001; Singleton, 2003; van der Boom and Milstein, 2003). A variety of atoms have been used in such structures, but, to the best of our knowledge, no example of N donor from pyrrole has been reported. Herein we report the preparation of a new type of NHC-pyrrole-NHC C-N-C Pincer proligands from pyrrole in multiple steps.

The C-N-C Pincer proligand **4** was prepared from pyrrole in an overall 34% yield in four steps (Scheme 1). Firstly, 2,5-bis(dimethylaminomethyl)pyrrole (**1**) (Heaney, 1997) was prepared by Mannich reaction of pyrrole in a basic medium with iminium ion generation from dimethylamine and formaldehyde. This reaction is very efficient and over 80% of 2,5-disubstituted pyrrole was reported to be isolated by chromatography. However, only 50% yield was achieved in our experiment due to the substantial loss of the product during distillation. The alkylation reaction of the tertiary amine arm of substituted pyrrole with methyl iodine gave quaternary ammonium salt **2** (Kim and Elsenbaumer, 1998) in high yield. The substitution reaction of quaternary ammonium iodide with imidazole gave compound **3** (Simons et al., 2002) in 85% yield. The substitution of imidazole-substituted pyrrole with methyl iodide generated NHC-pyrrole-NHC C-N-C Pincer proligand **4**. The imidazolinium iodide **4** was converted quantitatively to the imidazolinium hexafluorophosphate **5** by treatment with NH_4PF_6 in water. Compounds **1**–**3** are known compounds, and their ^{1}H NMR spectra were essentially identical with those of the authentic samples. Their IR data are reported herein. The final new products **4** and **5** are characterized by spectroscopy (^{1}H NMR, ^{13}C NMR and IR) and elemental analysis.

***Corresponding author: Yanhui Shi**, School of Chemistry and Chemical Engineering and Jiangsu Key Laboratory of Green Synthetic Chemistry for Functional Materials, Jiangsu Normal University, Xuzhou, Jiangsu 221116, PR China, e-mail: yhshi_2000@126.com
Yanhui Shi: State Key Laboratory of Inorganic Synthesis and Preparative Chemistry, College of Chemistry, Jilin University, Changchun, Jilin 130012, PR China
Hong Jiang: Key Laboratory of Biotechnology on Medical Plant of Jiangsu Province, Jiangsu Normal University, Xuzhou, Jiangsu 221116, PR China
Hong Ding: State Key Laboratory of Inorganic Synthesis and Preparative Chemistry, College of Chemistry, Jilin University, Changchun, Jilin 130012, PR China
Kaiqi Ge: School of Chemistry and Chemical Engineering and Jiangsu Key Laboratory of Green Synthetic Chemistry for Functional Materials, Jiangsu Normal University, Xuzhou, Jiangsu 221116, PR China
Pei Guang: School of Chemistry and Chemical Engineering and Jiangsu Key Laboratory of Green Synthetic Chemistry for Functional Materials, Jiangsu Normal University, Xuzhou, Jiangsu 221116, PR China
Yunfei Li: School of Chemistry and Chemical Engineering and Jiangsu Key Laboratory of Green Synthetic Chemistry for Functional Materials, Jiangsu Normal University, Xuzhou, Jiangsu 221116, PR China
Xiang Liu: School of Chemistry and Chemical Engineering and Jiangsu Key Laboratory of Green Synthetic Chemistry for Functional Materials, Jiangsu Normal University, Xuzhou, Jiangsu 221116, PR China
Guangsheng Pang: State Key Laboratory of Inorganic Synthesis and Preparative Chemistry, College of Chemistry, Jilin University, Changchun, Jilin 130012, PR China



Scheme 1 Synthesis of compounds **4** and **5**.

Experimental section

General

All reagents were commercially available and used without further purification. ^{1}H NMR (400 MHz) and ^{13}C NMR (100 MHz) spectra were recorded on a Bruker DPX spectrometer at room temperature. IR spectra were recorded in KBr pellets on a FTIR-Tensor 27 spectrometer. Melting points were detected by microscope melting point apparatus. Elemental analyses were performed on a EuroVektor Euro EA-300 elemental analyzer.

2,5-Bis(dimethylaminomethyl)pyrrole (1) An aqueous solution of 37–40% formaldehyde (40 mmol, 3.16 g) was treated with dimethylamine hydrochloride (40 mmol, 3.4 g) followed by addition of pyrrole (20 mmol, 1.34 g). The mixture was stirred on an ice bath for 1 h, then allowed to warm to room temperature, and stirred for an additional 12 h before dropwise treatment with an aqueous 20% solution of NaOH to pH 7–8. The mixture was extracted three times with ether and the extract was concentrated on a rotary evaporator. The oily residue was distilled (75–80°C/1–2 mm Hg) to yield 1.74 g (48%) of product **1**; IR: 3643, 3464, 2697, 1596, 1469, 1357, 1251, 1196, 1173, 1043, 1012, 990, 967, 847, 762, 712 cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 8.55 (br. s, 1H), 5.90 (d, *J* = 2.8 Hz, 2H), 3.37 (s, 4H), 2.20 (s, 12H) [^{1}H NMR (Heaney, 1997; 60 MHz, $CDCl_3$): 9.80 (br. s, 1H), 5.88 (d, 2H), 3.38 (s, 4H), 2.18 (s, 12H)].

2,5-Bis[(trimethylammonio)methyl]pyrrole diiodide (2) A solution of compound **1** (50 mmol, 9.06 g) in THF (30 mL) was cooled on an ice bath and treated dropwise with methyl iodide (150 mmol, 7.6 mL). The mixture was stirred at room temperature for 5 h, then treated with acetone (20 mL), and stirred for an additional 12 h. The white precipitate of **2** was collected by filtration: yield 22.3 g (96%); IR: 3433, 3008, 1586, 1486, 1401, 1375, 1207, 1096, 1056, 1005, 982, 969, 945, 912, 872, 801, 751 cm^{-1}; ^{1}H NMR (D_2O): δ 6.49 (s, 2H), 4.41 (s, 4H), 2.97 (s, 18H); ^{13}C NMR (DMSO-d_6): 121.5, 114.8, 61.2, 51.7. [^{13}C NMR (Kim and Elsenbaumer, 1998): 121.4, 114.8, 61.1, 51.7].

2,5-Bis[(imidazol-1-yl)methyl]pyrrole (3) A mixture of compound **2** (2.73 g, 6 mmol), KOH (1.34 g, 24 mmol) and imidazole (1.63 g, 24 mmol) in dichloromethane (40 mL) was stirred at room temperature for 16 h. The solution was filtered and the solvent was removed under reduced pressure to yield a light red solid of **3** that was crystallized from water: yield 1.16 g (85%); an off-white solid; mp 145–146°C; IR: 3010, 2880, 2758, 1668, 1628, 1544, 1507, 1432, 1393, 1339, 1271, 1222, 1204, 1168, 1112, 1073, 1028, 997, 918, 822, 794, 756, 723, 663, 615 cm^{-1}; ^{1}H NMR (DMSO-d_6): δ 11.10 (s, 1H, pyrrole N-H), 7.60 (s, 2H, N-C(H)-N), 7.09 (s, 2H, CH), 6.84 (s, 2H, NCH), 5.96 (s, 2H, NCH), 5.03 (s, 4H, CH_2). [^{1}H NMR (Simons et al., 2002) (300 MHz DMSO-d_6): 5.03 (s, 4H), 5.96 (s, 2H), 6.84 (s, 2H), 7.09 (s, 2H), 7.60 (s, 2H), 11.10 (s, 1H); ^{13}C NMR (Simons et al., 2002) (100 MHz, DMSO-d_6): 136.9, 128.4, 127.8, 119.2, 107.8, 42.7.

Compound 4

A mixture of compound **3** (3.1 g, 13.6 mmol) and methyl iodide (10 mL) in a heavy wall pressure tube was heated at 60°C for 10 h. After cooling the solid product **4** was filtered and washed with anhydrous ethanol: yield 5.98 g (86%); IR: 3221, 3172, 3136, 3093, 3035, 2951, 1631, 1569, 1502, 1381, 1339, 1318, 1235, 1187, 1160, 1032, 994, 871, 794, 769, 757, 649, 615. ^{1}H NMR (DMSO-d_6): δ 11.34 (s, 1H), 9.08 (s, 2H), 7.69 (m, 4H), 6.21 (m, 2H), 5.35 (s, 4H), 3.86 (s, 6H); ^{13}C NMR (DMSO-d_6): δ 136.2, 125.7, 123.8, 122.0, 109.9, 45.2, 36.0. Anal. Calcd for $C_{14}H_{19}I_2N_5$ (511.14): C, 32.90; H, 3.75; N, 13.70. Found: C, 32.76; H, 3.71; N, 13.87.

Compound 5

A solution of compound **4** (0.51 g, 1.0 mmol) in water (5 mL) was added dropwise to a saturated solution of NH_4PF_6 in water (20 mL). The resultant white solid of **5** was filtered and washed with water: yield 0.54 g (99%); IR: 3432, 3174, 1630, 1574, 1357, 1330, 1317, 1196, 1160, 1147, 1111, 1048, 1025, 884, 808, 773, 758, 731, 625 cm^{-1}; ^{1}H NMR (DMSO-d_6): δ 11.35 (s, 1H), 9.01 (s, 2H), 7.65 (m, 4H), 6.20 (m, 2H), 5.34 (s, 4H), 3.84 (s, 6H); ^{13}C NMR (DMSO-d_6): δ 136.2, 125.8, 123.9, 122.1, 110.0, 45.4, 35.9. Anal. Calcd for $C_{14}H_{19}F_{12}N_5P_2$ (546.08 g mol^{-1}): C, 30.73; H, 3.50; N, 12.80. Found: C, 30.62; H, 3.42; N, 12.97.

Acknowledgments: We gratefully acknowledge the Project of Laboratory Development of Jiangsu Normal University (L2011Y32), Qing Lan Project (08QLT001 and 08QLD006), the Foundation of State Key Laboratory of Inorganic Synthesis and Preparative Chemistry at Jilin University (2013-03), the Priority Academic Program Development of Jiangsu Higher Education Institutions (PAPD), and National Natural Science Foundation of China (NSFC) (21071121) for financial support of this work.

Received July 10, 2012; accepted July 19, 2012; previously published online September 15, 2012

References

Albrecht, M.; van Koten, G. Platinum group organometallics based on “Pincer” complexes: sensors, switches, and catalysts. *Angew. Chem. Int. Ed.* **2001**, *40*, 3750–3781.

Choi, J.; MacArthur, A. H. R.; Brookhart, M.; Goldman, A. S. Dehydrogenation and related reactions catalyzed by iridium Pincer complexes. *Chem. Rev.* **2011**, *111*, 1761–1779.

Heaney, H. The generation of iminium ions using chlorosilanes and their reactions with electron rich aromatic heterocycles. *Tetrahedron* **1997**, *53*, 2941–2958.

Kim, I. T.; Elsenbaumer, R. L. Convenient synthesis of 1-alkyl-2,5-bis(phenylthiomethyl)pyrroles using the Mannich reaction. *Tetrahedron Lett.* **1998**, *39*, 1087–1090.

Poyatos, M.; Mata, J. A.; Peris, E. Complexes with poly(*N*-heterocyclic carbene) ligands: structural features and catalytic applications. *Chem. Rev.* **2009**, *109*, 3677–3707.

Pugh, D.; Danopoulos, A. A. Metal complexes with ‘Pincer’-type ligands incorporating *N*-heterocyclic carbene functionalities. *Coord. Chem. Rev.* **2007**, *251*, 610–641.

Selander, N.; Szabo, K. J. Catalysis by palladium Pincer complexes. *Chem. Rev.* **2011**, *111*, 2048–2076.

Simons, R. S.; Garrison, J. C.; Kofron, W. G.; Tessier, C. A.; Youngs, W. J. Synthesis and structural characterization of two bis-imidazolium-linked cyclophanes: precursors toward ‘carbeneporphyrinoid’ ligands. *Tetrahedron Lett.* **2002**, *43*, 3423–3425.

Singleton, J. T. The uses of Pincer complexes in organic synthesis. *Tetrahedron* **2003**, *59*, 1837–1857.

van der Boom, M. E.; Milstein, D. Cyclometalated phosphine-based Pincer complexes: mechanistic insight in catalysis, coordination, and bond activation. *Chem. Rev.* **2003**, *103*, 1759–1792.