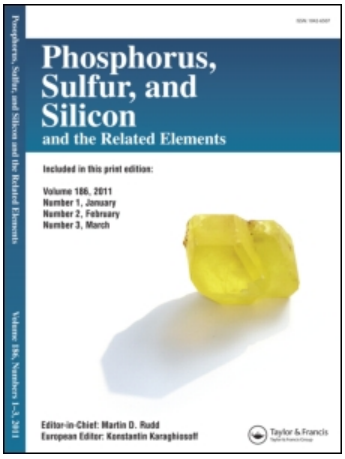


Phosphorus, Sulfur, and Silicon and the Related Elements
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713618290

The Preparation of Dicompartmental Multifunctional Group Ligands

Yeganeh Khaniani[a]; Hamid Golchoubian[a]
[a] Department of Chemistry, University of Mazandaran, Babolsar, Iran

To cite this Article Khaniani, Yeganeh and Golchoubian, Hamid(2006) 'The Preparation of Dicompartmental Multifunctional Group Ligands', Phosphorus, Sulfur, and Silicon and the Related Elements, 181: 12, 2817 — 2823
To link to this Article: DOI: 10.1080/10426500600864890
URL: http://dx.doi.org/10.1080/10426500600864890

Phosphorus, Sulfur, and Silicon, 181:2817–2823, 2006

ISSN: 1042-6507 print / 1563-5325 online
DOI: 10.1080/10426500600864890

Taylor & Francis
Taylor & Francis Group

The Preparation of Dicompartmental Multifunctional Group Ligands

Yeganeh Khaniani
Hamid Golchoubian
Department of Chemistry, University of Mazandaran, Babolsar, Iran

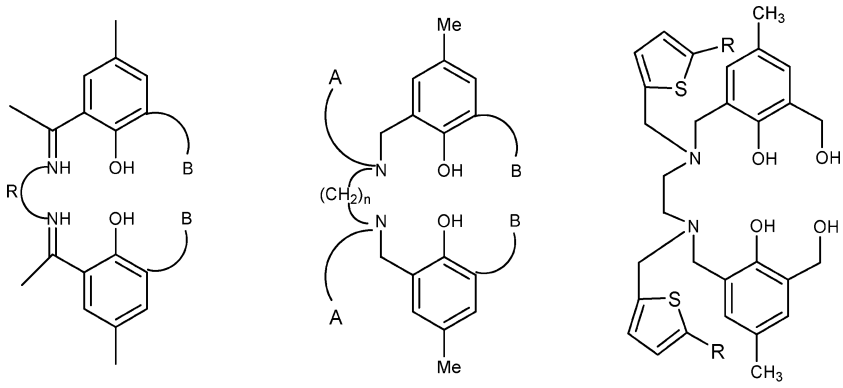
A convenient method for the preparation of the phenol-based ligands 1,6-bis(2-thiophenyl)-2,5-bis(2-hydroxy-3-hydroxymethyl-5-methylbenzyl)-2,5-diazahexane and 1,6-bis(5-methyl-2-thiophenyl)-2,5-bis(2-hydroxy-3-hydroxymethyl-5-methylbenzyl)-2,5-diazahexane possessing two dissimilar compartments having multifunctional groups is reported. To synthesize these ligands, an equivalent of 1,6-bis(2-thiophene)-2,5-diazahexane or 1,6-bis(5-methyl-2-thiophene)-2,5-diazahexane and two equivalents of 2,2-dimethyl-6-methyl-8-(chloromethyl)benzo-1,3-dioxin were reacted in the presence of Na_2CO_3 in 1,4-dioxane, followed by acid hydrolysis of an acetonide-protecting group. Characterization data for the new compounds is reported.

Keywords Acyclic ligand; compartmental ligand; multifunctional ligand; phenol-based ligand; synthesis

INTRODUCTION

Phenol-based binucleating ligands containing two different compartments have received attention because of their capability to bind two different metal centers in close proximity.[1–8] Since unsymmetrical dicompartmental ligands are of importance for providing discrete heterodinuclear core complexes, various types of compartmental ligands including the end-off, side-off, and their macrocyclic type have been developed.[9–11] They have a basic structure of type **1** (Figure 1) where "B" is an electron-pair donating atom. The introduction of donor auxiliary "A" residues to the two amino nitrogen atoms in **1** provides new unsymmetrical compartmental ligands of type **2**. A synthetic method

Received ; accepted .
Please send reprint requests to Dr. H. Golchoubian, E-mail: h.golchobian@umz.ac.ir
We appreciate financial support of the University of Mazandaran of the Islamic Republic of Iran.
Address correspondence to Hamid Golchoubian, University of Mazandaran, Department of Chemistry, P.O. Box 453, Babolsar, Iran. E-mail: h.golchobian@umz.ac.ir



1

R = $(CH_2)_2$, $(CH_2)_3$
B = CH_2OH, CHO

2

n = 2, 3
A = py
B = CH_2OH, CHO

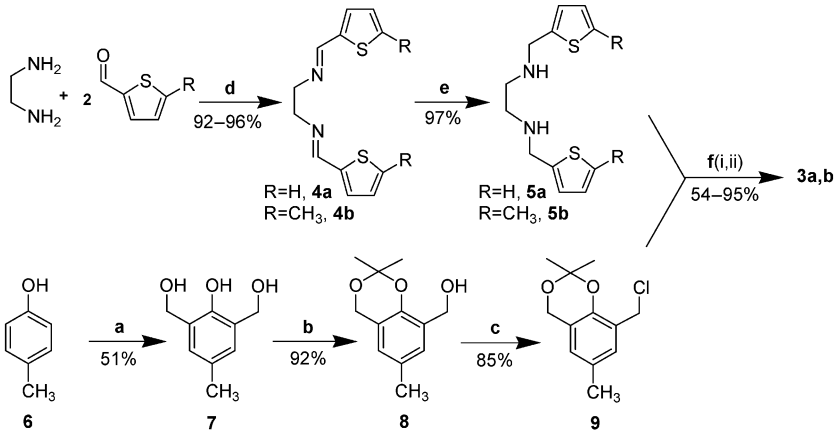
R = H: **3a**
R = CH_3: **3b**

FIGURE 1 (I) and (II) examples of dicompartmental ligands reported in the literature. (III) the dicompartmental ligands reported in this paper.

for the preparation of compounds **2** with pyridyl groups "A" and two dialdehyde groups "B" was reported by Fraser et al.[6] and is based upon nine consecutive steps. In this report we describe a successful four-step reaction leading to the new ligands **3a** and **3b**. This route has the potential of facilitating the synthesis of other analogues of compound **3**.

RESULTS AND DISCUSSION

The acyclic dialcohols **3a** and **3b** were prepared by the sequence steps outlined in Scheme 1. First, the diamine moiety of the desired compound was prepared by the condensation of ethylenediamine with two equivalents of 2-thiophenealdehyde or 5-methyl 2-thiophenealdehyde at r.t. under aerated conditions, which resulted in the formation of the crystalline diimine compounds **4a** and **4b** in a 92–96% yield. These compounds are sufficiently pure (95% based on ^{1}H NMR) for further treatment. Subsequently, these diimine compounds were converted to their diamine counterparts **5a** and **5b** quantitatively by $NaBH_4$ as a reducing agent. The infrared spectra of the imine and amine compounds are generally similar. The main spectral differences between the imines and amines are the emergence of a sharp but weak band at 3268 cm^{-1}, which is attributed to the N-H stretch of the quaternized amine and the disappearance of the strong band at 1643 cm^{-1}, which corresponds to the C=N stretch of the imine groups.[12] A band near 1550 cm^{-1} for compounds **4a** and **5a** is assigned to the skeletal vibration of the aromatic



a, HCHO, aq NaOH; **b**, $CH_3C(OCH_3)=CH_2$, cat. CH_3SO_3H, THF; **c**, *N*-chlorosuccinimide, Me_2S, CH_2Cl_2; **d**, EtOH; **e**, $NaBH_4$, EtOH; **f**, (i) Na_2CO_3, 1,4-dioxane, (ii) aq. HCl, CH_2Cl_2.

SCHEME 1

rings.[13] Also, the ^{1}H NMR spectrum of diimines **4** shows a singlet at 8.21 ppm corresponding to the proton attached to the imine moiety. However, the amine shows a singlet for the CH_2 moiety attached to the nitrogen in the ^{1}H NMR spectrum at 2.36 ppm. On the other hand, the triol **7** and its protected derivative **8** were made by a method described by Fraser et al.[14] In the next step, **8** was chlorinated efficiently by the Corey procedure.[15] Finally, the coupling of benzyl chloride **9** with diamine **5** under mild conditions followed by acid hydrolysis of the acetonide protecting group afforded dialcohol ligands **3a** or **3b** in yields of 54–94%.

The IR spectra of both **3a** and **3b** were similar and showed a weak band at around 3300 cm^{-1}, which is probably attributed to the OH stretch of the alcoholic groups. The total yields of the final products **3a** and **3b** are typically lower than 20% and 35%, respectively. These yields are limited mainly by the preparation of triol **7** (yield 51%) and by the condensation reaction of **5a** with **9** (yield 54%). The major reason for the low yield in the formation of **3a** is the polymerization of compound **5b** under the applied reaction condition. It has been proven that the unsubstituted α–position in thiophene is susceptible for polymerization.[16] In fact, using compound **5b**, in which the α-position is substituted by a methyl group, resulted in a significant increase in the yield of the

condensation reaction (95%). In the ^{1}H NMR spectra of compounds **3a** and **3b**, the signals belonging to the protons of the phenolic hydroxy groups were broad. This indicates that the protons are acidic and suggests the formation of O-H—N hydrogen bonds. This phenomenon has been observed in similar systems[17] and was also confirmed by single crystal X-ray diffraction.[18]

It can be concluded that the dissimilar two compartmental ligands **3** were prepared in satisfactory yields by a simple and convenient multistep method.

EXPERIMENTAL

All elemental analyses were performed on a LECO CHN-600 elemental analyzer. ^{1}H NMR spectra were recorded on a Bruker 300 fourier transform spectrometer. Infrared spectra were recorded in KBr pellets with a single beam Bruker VECTOR22 FTIR instrument. Mass spectra were obtained on a VG 70E double-focusing high-resolution spectrometer. All samples were dried to constant weight under high vacuum prior to analysis. Compounds 2,6-bis(hydroxymethyl)-4-methylphenol,[14] 2,2-dimethyl-6-methyl-8-(hydroxymethyl)benzo-1,3-dioxin,[14] and 1,6-bis(2-thiophene)-2,5-diazahexane[19] were prepared by standard methods. All reagents were commercial materials. Solvents used were dried over CaH_2 (CH_2Cl_2), $LiAlH_4$ (ether and dioxane), and K (THF).

N,N′-Bis(5-methyl-2-thiophenemethyl)-1,2-ethanediamine (4b) and 1,6-Bis(5-methyl-2-thiophenyl)-2,5-diazahexane (5b)

The diimine compound **4b** and its diamine counterpart **5b** were prepared by procedures similar to those described by Patra and Goldberg[19] using 5-methyl-2-thiophenealdehyde instead of 2-thiophenealdehyde as a starting material. The desired diimine was obtained as a brown solid (96%), and the diamine was obtained as a light-brown liquid with a quantitative yield. **4b**: m.p.: 44–45°C. IR: strong band at 1643 cm^{-1}. ^{1}H NMR (300.13 MHz, $CDCl_3$) δ: 2.54 (s, 6H, Thiophene-C**H**$_3$), 3.83 (s, 4H, N—C**H**$_2$), 6.67 (d, $J = 4.6$ Hz, 2H, thiophene-**H**), 7.03 (d, $J = 4.6$ Hz, 2H, thiophene-**H**), 8.21 (s, 2H, N=C**H**). Anal. calcd. for $C_{14}H_{16}N_2S_2$: C, 60.83; H, 5.83; N, 10.13%. Found: C, 60.54; H, 5.50; N 10.33%. **5b**: IR: medium band at 3268 cm^{-1}. ^{1}H NMR (300.13 MHz, $CDCl_3$) δ:1.56 (br. s, 2H, N-**H**), 2.36 (s, 4H, -C**H**$_2$-thiophene), 2.69 (s, 6H, thiophene-C**H**$_3$), 3.81 (s, 4H, -C**H**$_2$-C**H**$_2$-), 6.49 (*d*, J=3.8 Hz, 2H, thiophene-**H**), 6.60

(d, $J = 3.8$ Hz, 2H, thiophene-**H**). Anal. calcd. for $C_{14}H_{20}N_2S_2$: C, 59.96; H, 7.19; N, 9.99%. Found: C, 60.21; H, 7.50; N, 9.77%.

2,2-Dimethyl-6-methyl-8-(chloromethyl)benzo-1,3-dioxine (9)

A stirred solution of *N*-chlorosuccinimide (7.61 g, 57.0 mmol) in dry distilled CH_2Cl_2 (200 mL) in a fume hood was cooled to 0°C, and dimethylsulfide (37.0 g, 600 mmol) was added dropwise. The resulting colorless reaction mixture was further cooled to −25°C, and 2,2-dimethyl-6-methyl-8-(hydroxymethyl)benzo-1,3-dioxine **8** (11.30 g, 50.0 mmol) in dry distilled CH_2Cl_2 (10 mL) was added slowly dropwise. After stirring at 0°C for 2 h, the resulting reaction mixture was poured into cold brine (~200 mL), the aqueous layer was extracted with Et_2O (2 × 50 mL), and the combined organic layers were dried over anhydrous Na_2SO_4. The filtration and concentration under reduced pressure gave a crude product as yellow oil. The crude compound was dissolved in a minimal amount of Et_2O: *n*-hexane (1:1) mixture, loaded onto a short column (1 inch diameter) containing silicagel (20 g), and eluted with Et_2O: *n*-hexane (1:1). The desired compound came out with the first fraction. The concentration of the eluent under reduced pressure gave pure compound **9** as yellow oil, 10.3 g (85%). ^{1}H NMR (300.13 MHz, $CDCl_3$) δ: 1.54 (s, 6H, C-**CH_3**), 2.26 (s, 3H, Ar-**CH_3**), 4.57 (s, 2H, Ar**CH_2**-Cl), 4.80 (s, 2H, Ar**CH_2**-O), 6.76 (s, 1H, Ar-**H**), 7.04 (s, 1H, Ar-**H**). The high-resolution mass spectrum showed the main peak at *m/z* 226.0756 corresponding to the molecular formula of $C_{12}H_{15}O_2Cl$. FT-IR (KBr): 1445 cm^{-1} (aromatic skeleton).

1,6-Bis(2-thiophenyl)-2,5-bis(2-hydroxy-3-hydroxymethyl-5-methylbenzyl)-2,5-diazahexane(3a)

1,6-bis(2-thiophenyl)-2,5-diazahexane **5a** (0.512 g, 2.0 mmol) and 2,2-dimethyl-6-methyl-8-(chloromethyl)benzo-1,3-dioxine **9** (1.00 g, 4.1 mmol) were dissolved under argon in dry distilled 1,4-dioxane (30 mL), and anhydrous Na_2CO_3 (1.900 g, 17.9 mmol) was added. The reaction mixture was stirred at 100°C for 2 days, allowed to cool to r.t., and then filtered through Celite. Dioxane was removed in vacuo to give a viscous orange-brown oil, which was treated with aqueous HCl (1.16 M, 50 mL) and heated on a steam bath for 10 min. After cooling, the yellow suspension was extracted with Et_2O (4 × 20 mL). The aqueous layer was adjusted to pH ≈ 7.0 with aqueous NaOH (1 M) and then to pH ≈ 8.4 by an addition of saturated aqueous $NaHCO_3$. The oily mixture was extracted with CH_2Cl_2(8 × 10 mL), and the combined organic extracts were dried over Na_2SO_4. The filtration and concentration under

reduced pressure gave **3a** as pale-brown oil (ca. 85% by ^{1}H NMR) that slowly solidified, 0.64 g, (54%). ^{1}H NMR (300.13 MHz, $CDCl_3$) δ:1.73 (t, J = 5.7 Hz, 2H, Ar-CH_2-O**H**), 2.60 (s, 6H, Ar-**C**$\mathbf{H}_3$**)**, 2.79 (s, 4H, N-C$\mathbf{H}_2$-thiophene), 3.75 (s, 4H, N-C$\mathbf{H}_2$-Ph), 3.88 (s, 4H, N-C$\mathbf{H}_2$-C$\mathbf{H}_2$-N), 4.54 (d, J=5.7 Hz, 4H, Ar-C$\mathbf{H}_2$-OH), 6.97 (s, 2H, Ar-**H**), 6.98 (s, 2H, Ar-**H**), 6.97–7.46 (m, 6H, thiophene-**H**), 11.00 (br. s, 2H, Ar-OH). When one drop of D_2O was added to the ^{1}H NMR sample, the signals at 11.00 and 1.73 ppm disappeared, and the doublet at 4.54 ppm sharpened into a singlet at 4.53 ppm. The high-resolution mass spectrum showed the main peak at m/z = 552.2132 corresponding to a monopositively charged compound. Anal. calcd. for $C_{30}H_{36}N_2O_4S_2$: C, 65.19; H, 6.56; N, 5.07. Found: C, 65.01; H, 6.78; N, 5.21.

1,6-Bis(5-methyl-2-thiophenyl)-2,5-bis(2-hydroxy-3-hydroxymethyl-5-methylbenzyl)-2,5-diazahexane (3b)

Compound **3b** was prepared in the manner as previously described for the preparation of **3a** using 1,6-bis(5-methyl-2-thiophene)-2,5-diazahexane instead of 1,6-bis(2-thiophenyl)-2,6-diazahexane. Compound **3b** was obtained as a pale-brown solid (94%). ^{1}H NMR (300.13 MHz, $CDCl_3$) δ: 1.70 (t, J=5.5 Hz, 2H, Ar-CH_2-O**H**), 2.60 (s, 6H, Ar-**C**$\mathbf{H}_3$), 2.68 (s, 6H, thiophene-C$\mathbf{H}_3$), 2.81 (s, 4H, N-C$\mathbf{H}_2$-thiophene), 3.80 (s, 4H, N-C$\mathbf{H}_2$-Ph), 3.88 (s, 4H, N-C$\mathbf{H}_2$-C$\mathbf{H}_2$-N), 4.50 (d, J=5.5 Hz, 4H, Ar-C$\mathbf{H}_2$-OH), 7.01 (s, 2H, Ar-**H**), 7.05 (s, 2H, Ar-**H**), 7.45 (d, J=3.8 Hz, 2H, thiophene-**H**), 7.62 (d, J=3.8 Hz, 2H, thiophene-**H**), 10.11 (br. s, 2H, Ar-O**H**). When one drop of D_2O was added to the ^{1}H NMR sample, the signals at 10.11 and 1.70 ppm disappeared, and the doublet at 4.50 ppm sharpened into a singlet at 4.49 ppm. The high-resolution mass spectrum showed the main peak at m/z = 580.2435 corresponding to the monopositively charged compound. Anal. calcd. for $C_{32}H_{40}N_2O_4S_2$: C, 66.17; H, 6.94; N, 4.82. Found: C, 66.48; H, 6.66; N, 4.51.

REFERENCES

[1] H. Golchoubian, W. L. Waltz, and J. W. Quail, *Can. J. Chem.*, **37,** 77 (1999).
[2] E. V. Rybak-Akimova, N. W. Alcock, and D. H. Busch, *Inorg. Chem.*, **37,** 1563 (1998).
[3] H. Okawa, H. Furutachi, and D. E. Fenton, *Coord. Chem. Rev.*, **51,** 174 (1998).
[4] D. G. McCollum, C. Fraser, R. Ostrander, A. L. Rheingold, and B. Bosnich, *Inorg. Chem.*, **33,** 2383 (1994).
[5] D. G. McCollum, L. Hall, C. White, R. Ostrander, A. L. Rheingold, J. Whelan, and B. Bosnich, *Inorg. Chem.*, **33,** 924 (1994).

[6] C. Fraser, R. Ostrander, A. L. Rheingold, C. White, and B. Bosnich, *Inorg. Chem.*, **33,** 324 (1994).
[7] D. M. Hong, H. H. Wei, K. H. Chang, G. H. Lee, and Y. Wang, *J. Chin. Chem. Soc.*, **45,** 701 (1998).
[8] H. Golchoubian and W. L. Waltz, *Synth. Commun.*, **28,** 3907 (1998).
[9] U. Casellato, P. A. Vigato, and M. Vidali, *Coord. Chem. Rev.,* **23,** 31 (1977).
[10] D. E. Fenton, U. Casellato, P. A. Vigato, and M. Vidali, *Inorg. Chim. Acta,* **62,** 57 (1982).
[11] S. F. Groh, *Israel J. Chem*., **15,** 277 (1976/1977).
[12] A. J. Gordon and R. A. Ford, *The Chemist's Companion*, (Wiley, New York, 1972).
[13] H. Okawo and S. Kida, *Bull. Chem. Soc. Jpn.*, **45,** 1759 (1972).
[14] C. Fraser, L. Johnston, A. L. Rheingold, B. S. Haggerty, G. K. Williams, J. Whelan, and B. Bosnich, *Inorg. Chem.*, **31,** 1835 (1992).
[15] E. J. Corey, C. U. Kim, and M. Takeda, *Tetrahedron Lett.*, **13,** 4339 (1972).
[16] S. Trikes, A. Cihaner, and A. M. Onal, *J. Electroanal. Chem.*, **373,** 189 (2004).
[17] K. Wozniak, E. Grech, and A. Szady-Chelmieniecka, *Polish J. Chem.*, **74,** 717 (2000).
[18] J. P. Corden, W. Errington, P. Moore, and M. G. H. Wallbridge, *Acta Cryst.*, **C53,** 486 (1997).
[19] G. K. Patra and I. Goldberg, *Eur. J. Inorg. Chem.*, 969 (2003).