Synthesis and Characterization of New Nitrogen Donor Ligands

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***Abstract*—Five new nitrogen donor ligands have been prepared with the bidentate Schiff bases derived from a 2:1 molar condensation of different types of aldehydes with ethylenediamine. Two new ligands with a 2-hydrazonomethyl-phenol moiety have also been prepared from a 1:1 molar condensation of the 2-hydrazonomethyl-phenol with an appropriate furaldehyde. The ligands were characterised on the basis of their elemental analysis, IR, 1H NMR.**

***Index Terms*—Schiff bases, ethylenediamine, condensation, ligands, characterization**

I. INTRODUCTION

THIS work originates from our interest in developing a new class of bidentate and tetradentate ligands [1]-[5] and to the best of our knowledge these Schiff base ligands that we have prepared are new and have not been reported in the literature. The chemistry of the transition metal complexes of Schiff-base ligands has played an important role in the development of coordination chemistry as a whole [6]. In this context, a great deal of information regarding the properties of synthetic Schiff-base ligands of potential interest has been accumulated during the last decades [7]. Several of these compounds have been characterized and used as models for biological systems [8]. Complexes of transition metals with Schiff bases have been reported to show better biological activity than the free ligands [9], however the activity of some ligands has been found to be more than their respective metal chelates [10]. Although there is a wealth of information concerning transition metal complexes with Schiff bases, it is largely confined to the first row metals, such as copper, iron, cobalt, nickel [11],[12] and silver [13]. Silver(I) triphenylphosphine complexes have been increasingly studied because of their interesting structure as well as their antimicrobial and anticancer properties [14]-[16]. According to our knowledge no study has been reported for complexes with platinum, palladium and gold before and hence attempts have been made to complex these novel ligands with platinum, palladium and gold.

II. METHODOLOGY

All manipulations were carried out under an atmosphere of nitrogen or argon using standard Schlenk techniques. All other glassware was thoroughly dried at 210ºC for at least four hours prior to use. Anhydrous magnesium sulphate or sodium sulphate were used for drying reaction solutions. Melting points were determined on the Kofler hotstage microscope (Reichart Thermovar) and are uncorrected. Microanalysis data were obtained using a Carlo Erba EA1108 elemental analyser. Infrared Spectra were recorded on a Perkin-Elmer 1000 FT-IR spectrometer, as Nujol Mull for solids. All data are given in wavenumbers (cm-1). 1H NMR spectra were recorded on a Varian Unity-400 instrument. Mass spectra (MS) were recorded on a Waters atmosphere pressure ionization quadruple time-of-flight (API Q-TOF) Ultima (electronspray ionization (ESI), 70 eV) and/or SA VG70-SEQ (Fast atom bombardment (FAB), 7 kV) instrument.

A. *Preparation of the Schiff base ligands (1 – 5)*

1) *Ligand 1*

To a stirred solution of p-anisaldehyde (2.33 g, 17.11 mmol) in ethanol (10 ml) ethylenediamine (0.5144 g, 8.56 mmol) was slowly added via a syringe with stirring at room temperature. Stirring continued for a further 5 hours and the white precipitate that had formed was filtered off with a Buchner funnel and washed with ethanol (5 ml) and diethyl ether (5 ml) before drying in vacuo affording a white crystalline powder in 43% yield. Anal. Calc. for $C_{18}H_{20}N_2O_2$: C, 72.59%; H, 6.80%; N 9.45%. Found: C 72.31%; H 6.67%; N 9.55%. M.p.:125 - 127°C. 1H NMR: (400 MHz, CDCl3): 8.21 (s, 2H), 7.65 (dd, 2H, J=0.7Hz, J=3.4Hz), 6.81 (dd, 2H, J=1.8Hz, J=3.4Hz), 3.91 (s, 4H), 3.83 (s, 6H). IR (KBr): 1615 cm-1 (C=N, imine).

2) *Ligand 2*

A solution of ethylenediamine (0.347 g, 5.77 mmol) in dichloromethane (7 ml) was slowly to 4 chloro-3 nitrobenzaldehyde (2.15 g, 11.59 mmol) with stirring at room temperature. The solution was refluxed for 8 hours and MgSO4 was added and then filtered affording a yellow filtrate. The solvent was removed on the rotary evaporator affording a yellow crystalline powder which was isolated in 47 % yield. Anal. Calc. for $C_{16}H_{12}C_{l2}N_4O_4$: C, 48.58.59%; H, 3.04%; N 14.71%. Found: C 48.19%; H 3.12%; N 14.72

Manuscript received August 20, 2014; revised August 22, 2014. This work was supported by the National Research Foundation, DST-NRF Centre of Excellence in Catalysis and Anglo Platinum Corporation for funding this project, the University of Cape Town for facilities and the University of Johannesburg for funding conference registration and attendance.

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%. M.p.: 145-147°C. 1H NMR: (400 MHz, CDCl3): 8.31 (d, 4H), 7.80 (dd, 2H, J=0.7Hz, J=3.4Hz), 7.61 (dd, 2H, J=1.8Hz, J=3.4Hz), 4.03 (s, 4H). IR (KBr): 1622 cm^{-1} (C=N, imine).

3) *Ligand 3*

A solution of ethylenediamine (0.388 g, 6.46 mmol) in dichloromethane (10 ml) was slowly to 2,4 dichlorobenzaldehyde (2.26 g, 12.91 mmol) with stirring at room temperature. A pale white precipitate appears after 5 minutes and stirring continued for 4 hours. The precipitate was filtered on a Buchner funnel and washed with dichloromethane (2 ml) and dried *in* vacuo for 4 hours affording white microcrystals in 75% yield. Anal. Calc. for $C_{20}H_{14}N_2O_2$: C, 32.55%; H, 3.55%; N 4.12%. Found: C, 32.31%; H 3.12%; N 4.69%. M.p.: 185-187°C. ^{1}H NMR:(400 MHz, $CDCl_3$): 8.65 (2H, s), 7.95 (2H, d), 7.40 (2H, s), 7.25 (2H, s), 4.00 (4H,s). IR (KBr): 1629 cm^{-1} (C=N, imine).

4) *Ligand 4*

A solution of ethylenediamine (0.29 g, 4.83 mmol) in ethanol (10 ml) was slowly to 2,3 dimethoxybenzaldehyde (1.65 g, 9.93 mmol) and refluxed for 12 hours. MgSO4 was added and filtered on a Buchner funnel. The solvent was reduced on the rotary evaporator yielding a cream precipitate which was recrystallized from dichloromethane and hexane affording a cream precipitate in 51% yield. Anal. Calc. for $C_{16}H_{12}Cl_2N_4O_4$: C, 48.58.59%; H, 3.04%; N 14.71%. Found: C 48.19%; H 3.12%; N 14.72%. M.p.: 145-147°C. ^{1}H NMR: (400 MHz, $CDCl_3$): 8.31 (d, 4H), 7.80 (dd, 2H, *J*=0.7Hz, *J*=3.4Hz), 7.61 (dd, 2H, *J*=1.8Hz, *J*=3.4Hz), 4.03 (s, 4H). IR (KBr): 1625 cm^{-1} (C=N, imine)

5) *Ligand 5*

A solution of ethylenediamine (0.133 g, 2.21 mmol) in ethanol (10 ml) was slowly to 2,3,4 trimethoxybenzaldehyde (0.865 g, 4.41 mmol) and refluxed for 9 hours. MgSO4 was added and filtered on a Buchner funnel. On removal of the solvent a yellow oil was obtained. This was dissolved in a minimum amount of dichloromethane and on addition of hexane white crystal precipitate out of the oil. Anal. Calc. for $C_{16}H_{12}Cl_2N_4O_4$: C, 48.58.59%; H, 3.04%; N 14.71%. Found: C 48.19 %; H 3.12 %; N 14.72%. M.p.: 150-152°C. ^{1}H NMR: (400 MHz, $CDCl_3$): 8.31 (d, 4H), 7.80 (dd, 2H, *J*=0.7Hz, *J*=3.4Hz), 7.61 (dd, 2H, *J*=1.8Hz, *J*=3.4Hz), 4.03 (s, 4H). IR (KBr): 1630 cm-1 (C=N, imine).

B. *Preparation of ligands with a 2-hydrazonomethyl-phenol moiety (6 – 7)*

1) *Ligand 6*

2-hydrazonomethyl-phenol (1.33 g, 9.77 mmol) was taken up in dichloromethane (15 ml) and stirred under argon for *ca* 2 minutes before 2-furaldehyde (0.94 g, 9.77 mmol) in dichloromethane (8 ml) was added dropwise and stirred at room temperature for 36 hours. The solvent was reduced to give an orange oil to which hexane was added and product precipitated out as orange shiny microcrystals in 60 % yield. Anal. Calc. for $C_{12}H_{10}N_2O_2$: C, 66.94%; H, 4.71%; N, 13.08 %. Found: C, 66.84%; H, 4.80%; N, 13.05%. M.p.: 145-147°C. ^{1}H NMR: (400 MHz, $CDCl_3$): 8.81 (s, 1H), 8.47 (s, 1H), 7.62 (s, 1H), 7.44 (m, 3H) 7.2 (m, 4H), 6.60 (s, 1H). IR (KBr): 1634 cm-1 (C=N, imine)

2) *Ligand* **7**

2-hydrazonomethyl-phenol (1.19 g, 8.74 mmol) was taken up in dichloromethane (15 ml) and stirred under argon for *ca* 2 minutes before 5 methyl-2-furaldehyde (0.97 g, 8.81 mmol) in dichloromethane (7 ml) was added dropwise and the solution was refluxed for 3 hours. MgSO4 was added and stirred at room temperature before filtering, reducing the solvent on the rotary evaporator and precipitating out product with hexane affording yellow flakes which were dried *in* vacuo for 4 hours. Anal. Calc. for $C_{13}H_{10}N_2O_2$: C, 68.41%; H, 5.30%; N, 12.27%. Found: C, 68.84%; H, 5.45%; N, 12.05%. MP: 125-127°C. ^{1}H NMR: (400 MHz, $CDCl_3$): 11,64 (s, 1H), 8.81 (s, 1H), 8.36 (s, 1H), 7.33 (m, 6H), 2.44 (s, 3H). IR (KBr): 1631 cm-1 (C=N, imine).

III. Results and Discussion

The seven new ligands as shown in Table I were readily prepared in reasonable yields by condensation of appropriate aldehyde with ethylenediamine as shown in Fig. 1.

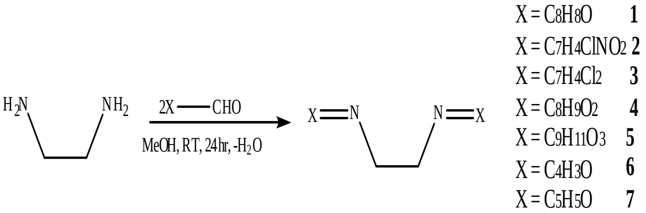


Fig. 1 - Synthetic route to nitrogen donor ligands

The prepared ligands are soluble in MeOH, DMSO, CH_2Cl_2 and EtOH, and insoluble in nonpolar solvents e.g. *n*-pentane. The first five ligands are bidentate in nature having an N_2 donor site capable of complexing transition metal ions as compared to other ligands that we have reported to contain a N_2O_2 donor sites. The other two ligands (6-7) are tetradendate having an extra 2 coordination sites.

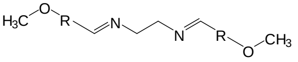
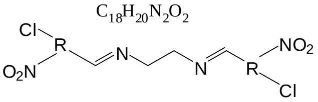
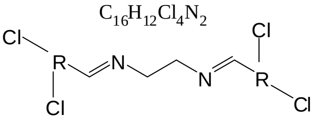
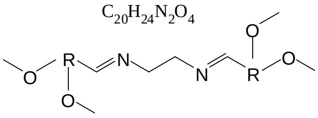
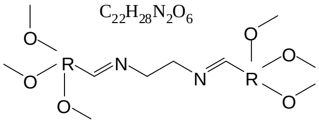
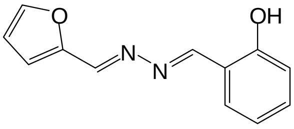
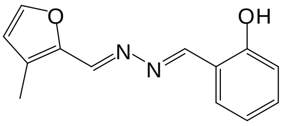
A. *1H NMR Spectra*

The ^{1}H NMR spectra of the prepared ligands were carried out in $CDCl_3$. The intensities of all the resonance lines were determined. The following conclusions can be derived by comparing the spectra of the ligands and their complexes. The chemical shift observed for the OH protons at *ca* (13.1 ppm) is not observed in the complexes and this confirms the bonding of oxygen to the metal ions. The presence of a sharp singlet for the –C(CH)=N protons (8.9 ppm) indicates that the magnetic environment is equivalent for all protons, suggesting the presence of a planar ligand in the complexes. The multiplets of the aromatic protons should not be affected by chelation.

B. *FT-IR Spectra*

All the Schiff base ligands show a strong IR band in the 1613-1634 cm^{-1} region characteristic of azomethine absorption (CH=N) It is envisaged that this band will shift to lower frequencies (10-20 cm^{-1}) and should appear appeared at 1590-1630 cm^{-1} in the metal complexes, indicating coordination of the nitrogen atom of Schiff base to the metal. If the Schiff bases coordinate *via* the nitrogen atom, a reduction in the >(C=N) frequency due, to a lowering of electron density is to be expected. There is, however, a tendency of this band of Schiff base ligands of aromatic diamines to shift to lower frequencies on coordination to the metal than occurs with those of aliphatic diamines. This is due to electron delocalization over the whole molecule on complexation. Thus, the IR spectra gives clear evidence that bonding of the ligand to the metal ion can occur through nitrogen atoms and that the ligands act in a bidentate manner.

TABLE I
THE SEVEN NEW LIGANDS

Ligand	Name	Structure
1	N,N'-Bis-(4-methoxy-benzylidene)-ethane-1,2-diamine	$C_{18}H_{20}N_2O_2$ 
2	N,N'-Bis-(4-chloro-3-nitro-benzylidene)-ethane-1,2-diamine	$C_{18}H_{20}N_2O_2$ 
3	Synthesis of N,N'-Bis-(2,4-dichloro-benzylidene)-ethane-1,2-diamine	$C_{16}H_{12}Cl_4N_2$ 
4	Synthesis of N,N'-Bis-(2,3-dimethoxy-benzylidene)-ethane-1,2-diamine	$C_{20}H_{24}N_2O_4$ 
5	Synthesis of N,N'-Bis-(2,3,4-trimethoxy-benzylidene)-ethane-1,2-diamine	$C_{22}H_{28}N_2O_6$ 
6	2-(Furan-2-ylmethylene-hydrazonomethyl)-phenol	
7	2-[(3 Methyl-furan-2-ylmethylene)-hydrazonomethyl]-phenol	

*For Ligands (**1**-**5**) R is a phenyl group

C. *Attempted Complexation of Schiff base ligands with platinum, palladium and Gold*

Attempts to complex the Schiff base ligands with either palladium or platinum precursors gave mixtures of products which were difficult to characterize due to their insolubility in organic solvents as shown in Fig. 2.

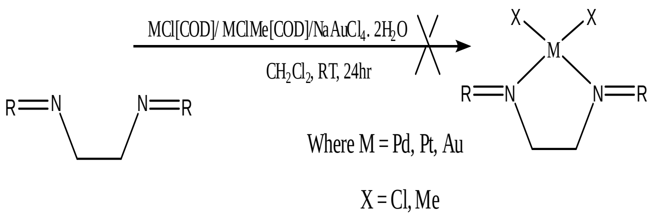


Fig. 2 - Attempted synthesis of palladium and platinum complexes with Schiff base ligands

IV. CONCLUSIONS AND FUTURE WORK

Seven new nitrogen donor ligands have been synthesised and fully characterised. The synthesis of the platinum, palladium and gold complexes needs to be investigated further. To our knowledge there has been limited success in preparing potent anti-tumor gold(III) compounds that are stable in physiologically relevant conditions thus it will be very critical to determine the solution stability of these compounds in physiologically related medium. In particular, the complexation with $NaAuCl_4.2H_2O$ has proved to be a very tedious and unsuccessful way of getting the targeted gold(III) complexes and a mixture of products was always obtained and a gold mirror to formed inside the reaction vessel.

ACKNOWLEDGEMENTS

Grateful acknowledgement is made to the National Research Foundation, DST Centre of Excellence in Catalysis and Anglo Platinum for funding this project.

REFERENCES

[1] Chiririwa H, Moss J. R, Su H, Hendricks D and Meijboom R, 2011, 1,4-Bis[(2-pyridylethyl)iminomethyl]benzene,Acta Crystallographica Section E, E67, o921.
[2] Chiririwa H, Meijboom and Omondi B, 2011, 2-(Thiophen-2-yl)-N-(4-{(E)-[2-(thiophen-2-yl)ethyl]iminomethyl} benzylidene)ethanamine, Acta Crystallographica Section E, E67, o922.
[3] Chiririwa H, Moss J. R, Hendricks D and Meijboom R, 2012, 1-(Thiophen-2-yl)-N-(4-{(E)-[(thiophen-2-yl)methyl]iminomethyl} benzylidene)methanamine, Acta Crystallographica Section E, E68, o3137.
[4] Chakraborty, S., Munshi, P. & Lahiri, G. K. 1999. Dinuclear ruthenium(II) bipyridine complexes having non-symmetric α,α'-diimine based neutral bridging ligands. - Synthesis, spectroscopic and electrochemical properties, Polyhedron, Volume 18, Number 10, 1437–1444.
[5] Haga M and Koizumi K, 1985, Synthesis and electrochemical properties of binuclear molybdenum carbonyl complexes with bridging α,α′-diimine ligands, Inorganica Chimica Acta, Volume 104, Issue 1, 47–50.
[6] S. Yamada, Coordination Chemistry Reviews, 1999, 537, 190–192.
[7] Amirnasr M, Schenk K. J, Salavati M, Dehghanpour S, Taeb A and Tadjarodi A , J. Coord. Chem., 2003, Vol. 56, No. 3, pp. 231–243.
[8] J. Costamagna, J. Vaargas, R. Latorre, A. Alvarado and G. Mena, 1992, Coordination Chemistry Reviews, 119, 67.
[9] Singh K, Barwa M. S, Tyagi P, 2007, Synthesis and characterization of cobalt(II), nickel(II), copper(II) and zinc(II) complexes with Schiff base derived from 4-amino-3-mercapto-6-methyl-5-oxo-1,2,4-triazine, European Journal of Medicinal Chemistry, Volume 42, Issue 3, 394–402.
[10] Parashar R. K and Sharma R. C, 1988, Stability studies in relation to IR data of some schiff base complexes of transition metals and their biological and pharmacological studies, Inorganica Chimica Acta, Volume 151, Issue 3, 201–208.
[11] Mohammad Akbar Ali, Chowdhury M. Haroon, Mohamed Nazimuddin, S. M. Mahbub-ul-Haque Majumder, Mohammad T. H. Tarafder, Mohammad A. Khair, 1992, Synthesis, characterization and biological activities of some new nickel(II), copper(II), zinc(II) and cadmium(II) complexes of quadridentate SNNS ligands, Transition Metal Chemistry, Volume 17, Issue 2, 133-136.
[12] N. Raman, V. Muthuraj, S. Ravichandran, A. Kulandaisamy 2003, Synthesis, characterisation and electrochemical behaviour of Cu(II), Co(II), Ni(II) and Zn(II) complexes derived from acetylacetone andp-anisidine and their antimicrobial activity, Journal of Chemical Sciences, Volume 115, Issue 3, 161-167.
[13] Khalaji A. D, Amirnasr M and Aoki K, 2006, Crystal Structures of Trigonal Planer of Silver(I) Complexes [Ag(ca2en)(PPh3)]X (1: X = PF6, 2: X = BF4) with the ca2en Schiff-base Ligand, Analytical Sciences, Volume 22, 149-150.
[14] Hannon M. J, Painting C. L, and Alkock N. W, 1999, A metallo-supramolecular double-helix containing a major and a minor groove, Chemical Communications, 2023.
[15] Berners-Price S. G, Johnson R. K, Mirabelli C. K, Faucette L. F, McCabe F. L, and Sadler P. J, 1987, Copper (I) complexes with

bidentate tertiary phosphine ligands: solution chemistry and antitumor activity, Inorganic Chemistry, 26, 3383.

[16] Liu S.-Q, Konaka H, Kuroda-Sowa T, Ning G.-L, and Munakata M, 2005, (-2,11 Dithia[3.3]paracyclophane-2S:S')bis[(6-carboxypyridine-2-carboxylato-2N,O6)silver(I)]:a mixed-ligand silver-based dinuclear compound, Acta Crystallographica Section C, C61, m194.