Study of the conformational rearrangement of a tetradentate hydrazone ligand

Rocío Carballido,[1] Marcelino Maneiro,[1] Laura Rodríguez-Silva,[1] Rosa Pedrido,[2]
Ana M. González-Noya[2]
[1]*Departamento de Química Inorgánica, Facultade de Ciencias, Universidade de Santiago de Compostela, Lugo, 27002, Spain*
E-mail: rocio.carballido@usc.es
[2]*Departamento de Química Inorgánica, Facultade de Química, Campus Vida, Universidade de Santiago de Compostela, Santiago de Compostela, 15782, Spain*

ABSTRACT

We report herein the first example of a tetradentate hydrazone structurally studied. The analysis of the conformations of this molecule together with the hydrogen bonding interactions allowed us to investigate the changes experienced by this ligand upon coordination to metal centers.

KEYWORDS

Hydrazone, ligand, conformation, metal complex

INTRODUCTION

Hydrazones are very interesting molecules both in terms of their coordination chemistry and their wide range of biological applications.[1-6] In the past few years the coordination properties of hydrazone ligands have been extensively investigated.[7-12] The development of this coordination chemistry is, in part, the result of the interesting donor systems which could be obtained. The structural characterization of the resulting mononuclear or polynuclear complexes has led to some emerging patterns and improved the design of molecular threads that may be twisted, yielding helical molecular systems.[7]
In this context, we synthetized and characterized the tetradentade hydrazone ligand H_2L (Figure 1). The study of the crystal structure of H_2L will allow us to investigate the existence of hydrogen bonding interactions and the conformational changes experienced by this ligand upon coordination.

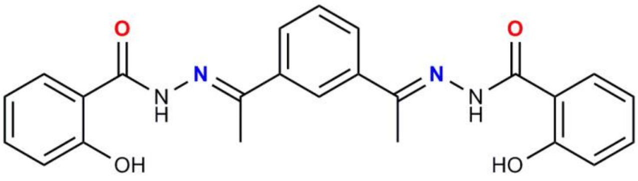
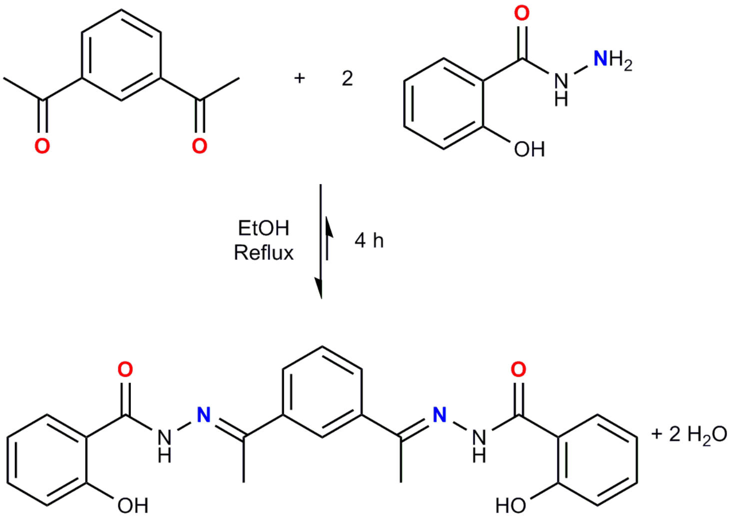


Figure 1

EXPERIMENTAL

The [N_2O_2] tetradentate hydrazone ligand H_2L was prepared by treatment of 1,3-diacetylbenzene (0.21 g, 1.30 mmol) with salicyloyl hydrazide (0.39 g, 2.60 mmol) in a 1:2 molar ratio, under standard reflux conditions during 4 hours in ethanol. The removal of the solvent with a Dean-Stark trap gave rise to a white powdery solid that was satisfactorily characterized as shown below.



Ligand H_2L: M.p. 162 ºC. Yield 0.50 g (90%). Elemental analysis, Calc. for $C_{24}H_{22}N_4O_4$: C, 67.0; H, 5.2; N, 13.0; O, 14.9. Found: C, 67.1; H, 5.1; N, 13.1; O, 14.7. MS ESI$^-$ (m/z): 429.2 ([H_2L-H]$^-$); IR (ATR, cm^{-1}): ν(OH) 3440, ν(NH) 3261, ν(C=O) 1631, ν(C=N) 1604, δ(NH) +ν(N-CO) 1541, δ (NH)+ν(CO) 1311. ^{1}H NMR (DMSO-d_6, ppm), δ (m, nH): 11.82 (s, 2H), 11.38 (s, 2H), 8.31 (s, 1H), 8.01 (d, 2H, J= 7.5 Hz), 7.90 (d, 2H, J= 7.3 Hz), 7.52 (t, 1H, J= 7.5 Hz), 7.42 (t, 2H, J= 7.3 Hz), 7.02-6.99 (m, 2H+2H), 2.30 (s, 6H), 2.37 (s, 6H).

RESULTS AND DISCUSSION

Recrystallization of H_2L in methanol allowed us to obtain colourless crystals (**1**) suitable for X-ray diffraction studies. Subsequent recrystallization in dimethylsulfoxide afforded new crystals of the free ligand in which the molecules adopt a different conformation (**2**).

Selected bond lengths (Å) and angles (°) are shown in Table 1, while the hydrogen bond parameters are listed in Tables 2.a and 2.b. The two crystal structures of the ligand H_2L are shown in Figures 2 and 3, respectively.

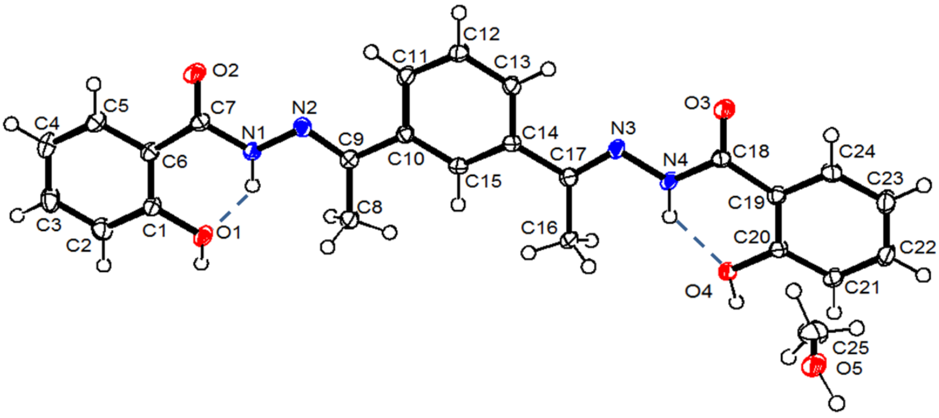


Figure 2

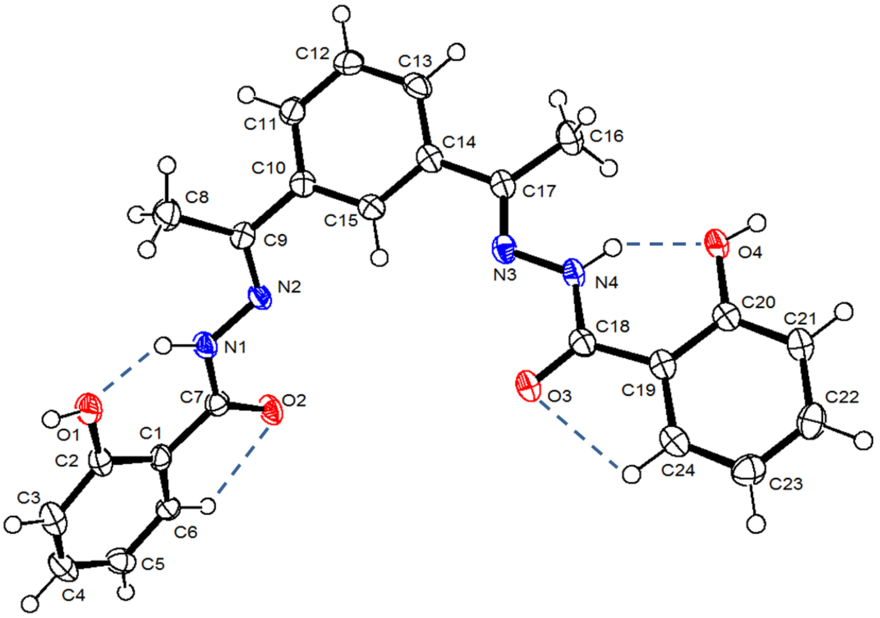
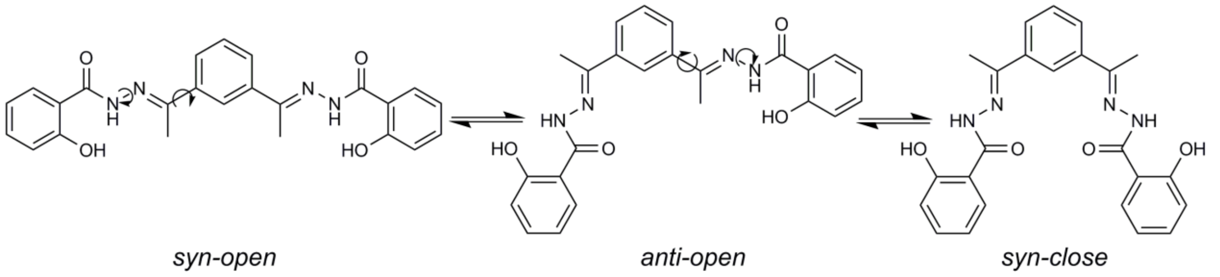


Figure 3

Both crystal structures show discrete molecules of the ligand H_2L, solvated by a methanol molecule in case of **1** (Figure 2). This is the first example of a tetradentate hydrazone ligand structurally studied. Similar structures of pentadentate ligands such as 2,6-diacetylpyridine bis(picolinoylhydrazone), H_2DIP[13] and the analogous ligand with a pyridine spacer, 2,6-diacetylpyridine bis(salicyloylhydrazone), H_4daps[14] have been previously studied. In both structures (**1** and **2**) the imine bonds show an E configuration.

The ligand molecules adopt a syn-open conformation in **1** (see Figure 2 and Scheme 1) similar to that previously found by our research group for the ligand H_4daps.[14a] The open arrangement of the ligand minimizes the unfavourable electronic interactions between the two terminal salicyloyl groups.[15] The syn-open conformation in **1** is conditioned by the establishment of intramolecular hydrogen bonds between the phenolic oxygen atoms as acceptors and the amide nitrogen atoms as donors [N(1)-H(1N)···O(1) 2.615(2) Å; N(4)-H(4N)···O(4) 2.627 (2) Å]. These hydrogen bonding interactions give rise to two six-membered chelate rings [O(4)-C(20)-C(19)-C(18)-N(4)-H(4A)] and [O(1)-C(1)-C(6)-C(7)-N(1)-H(1)] that adopt an almost planar conformation.[16]

In case of **2**, the ligand molecules adopt a syn-close type conformation (see Figure 3 and Scheme 1). This conformation is also conditioned by the establishment of intramolecular hydrogen bonds between the phenolic oxygen as acceptors and the amide nitrogen atoms as donors [N(1)-H (1N)···O (1) 2.630 (3) Å; N(4)-H (4N)···O (4) 2.606 (3) Å], giving rise to two six-membered chelate rings [O(1)-C(2)-C(1)-C(7)-N(1)-H (1A) and O(4)-C(20)-C19)-C(18)-N(4)-H(4)] that adopt an almost planar conformation. In addition, non-classical interactions between a carbon atom of the salicyloyl ring and the amide oxygen atom [C(6)-H(6)···O(2) 2.754 (4) Å; C (24)-H (24)···O (3) 2785 (3)] are established.[17]



syn-open *anti-open* *syn-close*

Scheme 1. Conformations of H_2L.

Of particular interest is the study of the conformation of the free ligand in the solid state to establish comparisons with that required to form a metal complex. Thus, it seems clear that the syn-open conformation found for H_2L in the solid state (Scheme 1 and Figure 2) is not suitable for direct coordination of the N_2O_2 donor set to the same metal ion. A significant rearrangement of the molecule structure must occur for the mononuclear complexation, as found in the case of the analogous pyridine ligand H_4daps for manganese, cobalt and cadmium compounds.[8,9,18] In these metal complexes, both molecular threads are almost planar and the ligand shows a syn-close conformation (Scheme 1) due to a similar twisting around the C–C bonds adjacent to the benzene ring. Consequently the metal ions will be coordinated to the [ONNO] donor set of $[L]^{2-}$.[8,9,18]

The syn-open arrangement of H_2L (**1**) would be suitable for the coordination of two units of ligand to two metal centers without crossing, thus yielding a mesohelical-type complex. In order to achieve the same coordinative arrangement than that found for dimeric helical structures in nickel and copper complexes derived from the ligand H_4daps,[8,9,14a] an anti-open conformation in the ligand is required, as it would allow the coordination of two different units of $[L]^{2-}$ to two metal ions through the [ON] + [NO] donor system.

CONCLUSIONS

The novel hydrazone ligand H_2L could be obtained with high purity and yield. Its crystal structures reveal that this ligand can adopt two conformations (syn-open and syn-close), which are conditioned by the establishment of intramolecular hydrogen bonds between the phenolic oxygen atoms and the amide nitrogen atoms. The syn-open conformation can be considered as the optimal one taken by the free ligand in order to assembly mesohelical complexes.

	$[H_2L]\cdot$MeOH (1)	**$[H_2L]$ (2)**
Bond distances (Å)		
C(20)-O(4)	1.364(2)	1.356(3)
C(1)-O(1)	1.362(2)	1.358(3)
N(3)-N(4)	1.378(2)	1.374(3)
N(1)-N(2)	1.376(2)	1.382(3)
C(18)-O(3)	1.235(2)	1.237(3)
C(7)-O(2)	1.231(2)	1.232(3)
C(17)-N(3)	1.289(2)	1.286(3)
C(9)-N(2)	1.294(2)	1.284(3)
C(14)-C(17)	1.490(2)	1.483(4)
C(9)-C(10)	1.483(2)	1.480(4)
C(14)-C(15)	1.397(2)	1.401(3)
C(10)-C(15)	1.398(2)	1.390(4)
Bond angles (°)		
C(1)-O(1)-H(1O)	110.90(16)	111.9(19)
C(20)-O(4)-H(4O)	110.40(15)	114(2)
C(7)-N(1)-N(2)	120.50(16)	118.6(2)
C(18)-N(4)-N(3)	119.55(15)	120.6(2)
N(2)-C(9)-C(10)	116.00(16)	115.9(2)
N(3)-C(17)-C(14)	115.37(16)	116.1(2)
H(4N)-N(4)-C(18)	119.60(13)	117(2)
H(4N)-N(4)-N(3)	120.80(13)	122(2)
H(1N)-N(1)-C(7)	116.80(16)	117.6(16)
H(1N)-N(1)-N(2)	122.60(16)	121.8(16)
N(1)-N(2)-C(9)	115.13(15)	116.3(2)
N(4)-N(3)-C(17)	115.46(15)	115.8(2)

Table 1. Selected bond length (Å) and angles (°) for $[H_2L]\cdot$MeOH (**1**) and $[H_2L]$ (**2**).

Parameter	**D-H (Å)**	**H···A (Å)**	**D···A (Å)**	**D-H···A (<)**
N(1)-H(1N)···O(1)	0.90(2)	1.85(2)	2.615(2)	141(2)
O(1)-H(1O)···O(5)^{i}	0.92(2)	1.67(2)	2.581(2)	169(3)
N(4)-H(4N)···O(4)	0.92(2)	1.88(2)	2.627(2)	136.5(19)
O(4)-H(4O)···O(2)^{ii}	0.94(2)	1.67(2)	2.607(2)	177(2)
O(5)-H(5)···O(3)^{iii}	0.92(3)	1.78(3)	2.674(2)	162(3)
Symmetry codes: i = -x, 2-y, 1-z; ii = 1+x, -1+y, z; iii = -x, 1-y, -z				

Table 2.a. Hydrogen-bonding parameters [Å, º] for [H$_2$L]·MeOH (**1**).

Parameter	**D-H (Å)**	**H···A (Å)**	**D···A (Å)**	**D-H···A (<)**
N(1)-H(1N)···O(1)	0.96(3)	1.84(3)	2.630(3)	137(3)
O(1)-H(1O)···O(3)^{i}	0.87(3)	1.87(3)	2.721(3)	164(3)
O(1)-H(1O)···N(3)^{i}	0.87(3)	2.58(3)	3.138(3)	123(2)
N(4)-H(4N)···O(4)	0.84(3)	1.89(3)	2.606(3)	142(3)
O(4)-H(4O)···O(2)^{ii}	0.84(3)	1.81(3)	2.636(3)	173(3)
C(3)-H(3)···O(3)^{i}	0.95	2.50	3.198(3)	131
C(6)-H(6)···O(2)	0.95	2.41	2.754(4)	101
C(24)-H(24)···O(3)	0.95	2.45	2.785(3)	101
Symmetry codes: i = x, 1/2-y, -1/2+z; ii = 1-x,1-y,1-z				

Table 2.b. Hydrogen-bonding parameters [Å, º] for [H$_2$L] (**2**).

REFERENCES

1 M. Carcelli, P. Mazza, C. Pelizzi, G. Pelizzi, F. Zanni, *J. Inorg. Biochem*., **1995**, *57*, 43 and refs. therein.

2 R. Todeschini, A. L. P. De Miranda, K. C. M. Da Silva, S. C. Parrini, E. J. Barreiro, *Eur. J. Med. Chem*., **1998**, *33*, 189.

3 A. Bachi, A. Bonardi, M. Carcelli, P. Mazza, P. Pelagatti, C. Pelizzi, G. Pelizzi, C. Solinas, F. Zanni, *J. Inorg. Biochem*., **1998**, *69*, 101.

4 V. P. Singh, A.Katiyar, S. Singh, *Biometals*, **2008**, *21*, 491.

5 S. Song, T. Christova, S. Perusini, S. Alizadeh, R.-Y. Bao, B. W. Miller, R. Hurren, Y. Jitkova, M. Gronda, M. Isaac, B. Joseph, R. Subramaniam, A. Aman, A. Chau, D. E. Hogge, S. J. Weir, J. Kasper, A. D. Schimmer, R. Al-awar, J. L. Wrana, L. Attisano, *Cancer Res*, **2011**, *71*, 7628.

6 C. Chen, N. K. Dolla, G. Casadei, J. B. Bremner, K. Lewis, M. J. Kelso, *Bioorg. Med. Chem. Lett.*, **2014**, *24*, 595.

7 E. C. Constable, *Comprehensive Supramolecular Chemistry*, eds. J. L. Atwood, J. E. D. Davies, D. D. McNicol, F. Vögtle, J. P.Sauvag, M. W. Hosseini, Pergamon, Oxford, **1996**, vol. 9, p. 213.

8 M. R. Bermejo, M. Fondo, A. M. González, O. L. Hoyos, A. Sousa, C. A. McAuliffe, W. Hussain, R. G. Pritchard, V. M. Novotorsev, *J. Chem. Soc., Dalton Trans*., **1999**, 2211.

9 M. R. Bermejo, A. Sousa, M. Fondo, A. M. González, O. L. Hoyos, R. Pedrido, M. A. Maestro, J. Mahía, *Z. Anorg. Allg. Chem*., **2000**, *626*, 506.

10 L. N. Dawe, L. K. Thompson, *Dalton Trans.*, **2008**, 3610.

11 D. Y. Wu, G.-H.Wu, W. Huang, C.-Y. Duan, *Polyhedron*, **2008**, *27*, 947.

12 M. Albrecht, *Z. Anorg. Allg.Chem.*, **2010**, *636*, 2198.

13 C. Pelizzi, G. Pelizzi, *Acta Crystallogr.*, **1979**, *B35*, 126.

14 a) M. R. Bermejo, R. Pedrido, A. M. González-Noya, M. J. Romero, M. Vázquez, L. Sorace, *New J. Chem.*, **2003**, *27*, 1753; b) R. Pedrido, M. J. Romero, M. R. Bermejo, A. M. González-Noya, M. Maneiro, M. J. Rodríguez, G. Zaragoza, *Dalton Trans*., **2006**, 5304.

15 N. Yoshida, H. Oshio, T. Ito, *Chem. Commun*., **1998**, 63.

16 F. H. Allen, O. Kennard, D. G. Watson, L. Brammer, A. G. Orpen, R. Taylor, *J. Chem. Soc*., *Perkin Trans*., **1987**, *2*, S1.

17 Th. Steiner, *Cryst. Rev.*, **1996**, *6*, 1.

18 M. Fondo, A. Sousa, M. R. Bermejo, A. García-Deibe, A. Sousa-Pedrares, O. L. Hoyos, M. Helliwell, *Eur. J. Inorg. Chem*., **2002**, 703.