This article was downloaded by: [New York University] On: 30 May 2015, At: 10:37 Publisher: Taylor & Francis Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK

and Nano-Metal Chemistry



http://www.tandfonline.com/loi/Isrt20 Synthesis and Characterization of a Cobalt(II) Complex with(E)-Ń-(2-Hydroxy-3-Methoxybenzylidene)Isonicotinohydrazide and (E)-Ń-(2-Hydroxy-3-Methoxybenzylidene)Isonicotinohydrazidanium Nitrate as a By-Product

Synthesis and Reactivity in Inorganic, Metal-Organic,

Publication details, including instructions for authors and subscription information:

Masoumeh Tabatabaee^a, Azadeh Taghinezhadkoshknou^a, Michal Dušek^b & Karla Fejfarová^b ^a Department of Chemistry, Yazd Branch, Islamic Azad University, Yazd, Iran ^b Institute of Physics ASCR, v.v.i., Prague, Czech Republic Accepted author version posted online: 06 Apr 2015.

To cite this article: Masoumeh Tabatabaee, Azadeh Taghinezhadkoshknou, Michal Dušek & Karla Fejfarová (2015) Synthesis and Characterization of a Cobalt(II) Complex with(E)-Ń-(2-Hydroxy-3-Methoxybenzylidene)Isonicotinohydrazide and (E)-Ń-(2-Hydroxy-3-Methoxybenzylidene)Isonicotinohydrazide and (E)-Ń-(2-Hydroxy-3-Methoxybenzylidene)Isonicotinohydrazidanium Nitrate as a By-Product, Synthesis and Reactivity in Inorganic, Metal-Organic, and Nano-Metal Chemistry, 45:10, 1506-1512, DOI: <u>10.1080/15533174.2013.862827</u>

To link to this article: <u>http://dx.doi.org/10.1080/15533174.2013.862827</u>

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the "Content") contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden. Terms & Conditions of access and use can be found at http://www.tandfonline.com/page/terms-and-conditions



Synthesis and Characterization of a Cobalt(II) Complex with (E)-Ń-(2-Hydroxy-3-Methoxybenzylidene) Isonicotinohydrazide and (E)-Ń-(2-Hydroxy-3-Methoxybenzylidene)Isonicotinohydrazidanium Nitrate as a By-Product

MASOUMEH TABATABAEE¹, AZADEH TAGHINEZHADKOSHKNOU¹, MICHAL DUŠEK², and KARLA FEJFAROVÁ²

¹Department of Chemistry, Yazd Branch, Islamic Azad University, Yazd, Iran ²Institute of Physics ASCR, v.v.i., Prague, Czech Republic

Received 13 July 2013; accepted 2 November 2013

A Schiff base ligand was synthesized from the reaction of isonicotinic acid hydrazide with 3-methoxysalicylaldehyde. The reaction of LH with $Co(NO_3)_2$.6H₂O in methanol gave dark red crystals of $[Co(HL)_2](NO_3)_2$.3H₂O and colorless crystals of the protonated ligand (HLH)⁺ with nitrate as the counter ion, (HLH)(NO₃). In coordination to metal, Schiff base ligand was protonated *via* hetrocyclic nitrogen atom of the pyridine ring and deprotonated on the phenolic OH group, two ligands behave as neutral tridentate ligands. The extensive O–H…O and N–H…O hydrogen bonding interactions in the solid state contribute to the formation of an infinite one-dimensional chain in the complex.

Keywords: Schiff base ligand, cobalt complex, isonicotinic acid hydrazide

Introduction

Schiff base compounds attract considerable interest in the chemistry for their ability to act as ligands with different donor atoms, and also for their use in analytical applications.^[1-4] The tridentate Schiff base ligands provide a suitable coordination mode for transition metal ions and obtained complexes have great potential in catalysis and material chemistry.^[5,6] Cobalt complexes with tri- or tetradentate Schiff base ligands have been widely investigated for their important role in biology as coenzyme B_{12} and oxygen carriers. The insulin-like action of cobalt compounds has been reported Yang et al.^[7] Cobalt complexes have also interesting magnetic properties, antibacterial activity, spectroscopic characteristics, and the interaction between the metal and the ligand.^[8–10] There has been also considerable interest in the chemistry of aroylhydrazone derivatives and their complexes^[11,12] and the crystal structure of two Schiff base ligands derived from isonicotinic acid hydrazide has been

reported by Yang.^[13] In continuation of our work on synthesizing of Schiff base ligand and their complexes,^[14–19] in this article we report synthesis of a Schiff base ligand derived from the condensation of 3-methoxysalicylaldehyde with isonicotinic acid hydrazide (LH) and its Co complex. The treatment of Co(NO₃)₂. 6H₂O with L in ethanol and in 1:1 molar ratio led to the formation of ([Co(HL)₂](NO₃)₂.3H₂O) and protonated ligand salt as a by-product.

Experimental

Materials and Instrumentation

All purchased chemicals were of reagent grade and used without further purification. The IR spectra were recorded using FTIR Spectra Bruker Tensor 27 spectrometer (KBr pellets, Nujol mulls, 4000–400 cm⁻¹). ¹H was recorded on a Bruker (AX-200) 300 MH spectrometer using TMS as an external standard. The elemental analyses were performed using a Costech ECS 4010 CHNS analyzer.

Preparation of ligand (E)-Ń-(2-hydroxy-3-methoxybenzylidene)isonicotinohydrazide (LH) A solution of isonicotinic acid hydrazide in ethanol (10 mL) was treated with 3methoxysalicylaldehyde in a molar ratio of 1:1 and the resulting mixture was acidified by 37% hydrochloric acid (4 drops).

Address correspondence to Masmoumeh Tabatabaee, Department of Chemistry, Yazd Branch, Islamic Azad University, Yazd, Iran. E-mail: tabatabaee@iauyazd.ac.ir

Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/lsrt.

Cobalt(II) Complex

Table 1. Crystal data and details of the structure determination for 1 and 2

Compound	1	2
Formula	$C_{14}H_{14}N_4O_6$	$C_{28}H_{28}Co_1N_7O_{14\ 284}$
$M_{ m r}$	334.29	750
Colour and habit	yellow, block	dark red
Crystal system, space group	orthorhombic, $Pna2_1$	Triclinic, P-1
Crystal dimensions / mm ³	0.13 imes 0.23 imes 0.28	$0.165 \times 0.109 \times 0.043$
a / Å	19.5397(3)	10.6485(5)
b / Å	7.4951(6)	11.9968(5)
<i>c</i> / Å	20.0039(8)	13.9027(5)
α / °	90	104.387(4)
β / $^{\circ}$	90	110.146(4)
$\gamma / ^{\circ}$	90	95.378(4)
$V / Å^3$	2929.6(3)	1583.38(13)
Ζ	8	2
$D_{\rm calcd}$ / mg m ⁻³	1.5159(2)	1.5727
μ / mm^{-1}	1.033	
F(000)	1392	772
Temperature / K	120	120
θ range for data collection / °	3.16-66.78	3.55-62.23
h, k, l range	-20:22, -8:8, -22:23	-12:11, -11:13, -15:15
No. measured reflections	7130	6163
No. independent reflections (R_{int})	2629/0.0257	17888/0.0569
No. observed reflections, $I \ge 2\sigma(I)$	2450	3547
No. refined parameters	440	551
$R^{\mathrm{a}}, \mathrm{w}R^{\mathrm{b}}[I \geq 2\sigma(I)]$	0.0265, 0.0692	0.0545,0.1241
R, wR [all data]	0.0288, 0.0709	0.0789, 0.1356
Goodness of fit on F^2 , S^c	1.30	1.59
Max., min. electron density / e $Å^{-3}$	0.15, -0.11	0.68, -0.11

 ${}^{a}R = \Sigma ||F_{o}| - |F_{c}||/\Sigma |F_{o}|.$ ${}^{b}wR = [\Sigma(F_{o}^{2} - F_{c}^{2})^{2}/\Sigma w(F_{o}^{2})^{2}]^{1/2}.$ ${}^{c}S = \Sigma [w(F_{o}^{2} - F_{c}^{2})^{2}/(N_{obs} - N_{param})]^{1/2}.$



Sch. 1. The reaction for preparation of ligand.



Sch. 2. The reaction for preparation of complex.



Fig. 1. Molecular structure of (HLH)(NO₃).

The reaction mixture was refluxed for 8 h. The solid residue was filtered, washed with cold solvent (10 mL) to afford the ligand. IR (KBr) ν (cm⁻¹): 1684 (s), 1604 (s), 1563 (s), 1459 (s), 1409 (m), 1353 (m), 1288 (s), 1253 (s), 1153 (m), 1074 (s), 967 (s), 836 (s), 777 (s), 735 (s), 687 (s); ¹H NMR

Table 2. Selected bond distances (Å) and angles (°) for 1 and 2

Bond distant	ces	Bond angles	
1			
N1-C1	1.339(3)	N2-N3-C7	117.80(18)
N1-C5	1.344(3)	N3-N2-C6	116.92(18)
N2-C6	1.357(3)	N5-N6-C21	116.6(2)
N3-C7	1.288(3)	N6-N5-C20	116.80(19)
N4-C15	1.339(3)	N4-C15-C16	120.2(2)
N4-C19	1.345(3)	N1-C1-C2	119.9(2)
N5-C20	1.356(3)	N1-C5-C4	119.6(2)
N6-C21	1.277(3)	N2-C6-C3	117.06(19)
N2-N3	1.378(2)	N3-C7-C8	119.3(2)
N5-N6	1.385(3)	N4-C19-C18	119.4(2)
		N5-C20-C17	116.3(2)
2			
Co1–O1	1.890(3)	O1-Co1-O2	177.62(11)
Co1–O2	1.901(3)	O1-Co1-O4	88.38(12)
Co1–O4	1.915(2)	O1-Co1-O5	89.72(12)
Co1–O5	1.876(2)	O1-Co1-N3	83.33(14)
Co1–N3	1.870(3)	O1-Co1-N6	91.54(14)
Co1-N6	1.859(4)	O2-Co1-O4	90.53(12)
		O2-Co1-O5	91.41(11)
		O2-Co1-N3	94.59(14)
		O2-Co1-N6	90.43(14)
		O4-Co1-O5	177.67(14)
		O4Co1N3	91.55(12)
		O4-Co1-N6	83.24(13)
		O5-Co1-N3	89.58(13)
		O5-Co1-N6	95.46(13)
		N3-Co1-N6	172.81(12)

(d₆- DMSO): δ = 3.82 (s, 3H, CH₃O), 6.76–7.21 (3H, Ar), 7.98 (d, 2H, Ar), 8.89 (d, 2H, Ar), 8.80 (s, 1H, CH=N), 10.69 (s, 1H, NH), 12.62 (s, 1H, OH) ppm.

Anal. Calcd. for $C_{14}H_{13}N_3O_3$ (M = 271): C, 61.99; H, 4.80; N, 15.50%. Found: C, 61.78; H, 4.71; N, 15.29%.

Preparation of [Co(HL)₂](NO₃)₂.3H₂O

1.164 g (4 mmol) $Co(NO_3)_2$.6H₂O was added to a solution of the ligand (1.085 g, 4 mmol) in 20 mL of methanol and ethanol (1:1) and was refluxed for 4 h at 80°C.

The reaction was monitored by TLC using n-hexane/ethyl acetate (1:2) as eluent. The crude product was filtered and the clear solution was kept at 4°C. The colorless crystals of HLHNO₃ and dark red crystals of complex ([Co(HL)₂] (NO₃)₂.3H₂O) were obtained after a few days. IR (KBr) ν (cm⁻¹): 1687 (s), 1605 (s), 1578 (s), 1498 (s), 1458 (s), 1398 (m), 1279 (s), 1250 (s), 1104 (w), 1033(s), 967 (s), 888(s), 773 (s), 747 (s), 670 (m).

X-Ray Crystallography

The single-crystal structure determination was based on data from the four-cycle kappa difractometer Gemini of Agilent Technologies, equipped with the CCD detector Atlas. We used CuK α radiation from a sealed x-ray tubed collimated by mirrors. The structures were solved by the direct methods program SIR 2002 ^[20] and refined by Jana 2006.^[21] Experimental details are given in Table 1.

The structure of the ligand contains two symmetry independent molecules of almost identical geometry. In order to test if they are exactly the same with respect to the diffraction data, we described the molecule as a rigid body in two positions and refined only the common atomic parameters of the molecule and the parameters (rotation + translation) placing the molecule to the two positions. This description increased



Fig. 2. A view of crystal packing of (HLH)(NO₃). Cationic and anionic parts are linked by hydrogen bonds of the N–H···O and O–H···N intermolecular hydrogen bonds.

the R value by 5%, thus confirming a slight difference between the two molecules.

The structure of the complex contained well-defined atomic position of the complex and the lattice water and undistinguishable molecules of a solvent, probably (according to the synthesis) ethanol or methanol. In the difference Fourier map the solvent molecules appeared as clouds of electron density where the individual atomic positions could not be determined. In the refinement, we represented these clouds by atoms of oxygen, with occupancy larger that 1 and with a shape described by anharmonic atomic displacement parameters. This technique is a compromise between rigorous description of the solvent and using of the Platon Squeeze^[22] the latter producing idealized solution by modification of the

input diffraction data. In Figure 3 the solvent molecules are shown as large simitransparent ellipsoids, because the used plotting software Diamond cannot visualize anharmonic shapes.

Results and Discussion

As shown in Scheme 1, (E)-Nó'-(2-hydroxy-3-methoxybenzylidene)isonicotinohydrazide (LH) was obtained by the reaction of 3-methoxysalicylaldehyde and isonicotinic acid hydrazide. Treatment of ligand with $Co(NO_3)_2$.6H₂O led to the formation of a cobalt complex, $[Co(HL)_2](NO_3)_2$.3H₂O, and (HLH)(NO₃) as a by-product (Scheme 2).

Table 3. Hydrogen bond geometry for 1 and 2

D–H…A	<i>d</i> (D–H)/Å	d(H…A)/Å	$d(\mathbf{D}\cdots\mathbf{A})/\mathbf{\mathring{A}}$	∠(D–H····A)/°
1				
N1-H(1N)O10	087	2.49	3.144(3)	133
N1-H(1N)O11	0.87	1.88	2.731(3)	164
N2-H(2N)O9	0.87	2.08	2.923(2)	162
O2–H(2O)····N3	0.81(3)	1.92(3)	2.603(2)	142(3)
N4–H(4N)····O7	0.87	1.89	2.754(2)	170
N4-H(4N)O9	0.87	2.46	3.109(3)	132
N5-H(5N)O10	0.87	2.17	3.017(3)	165
O5–H(5O)····N6	0.83(3)	1.93(3)	2.630(2)	142(3)
2				. ,
N1-H(1N)····O8	0.87	1.90	2.735 (5)	161
N2-H(2N)O11	0.87	2.16	2.91(3)	144
N4-H(4N)O2	0.87	1.94	2.772(5)	158
N4–H(4N)····O3	0.87	2.57	3.218(4)	132
O10–H(10A)····O8	0.85(3)	2.29(5)	2.990(6)	139(5)
O10–H(10B)····O2	0.85(4)	2.47(5)	3.157(5)	139(5)
O10-H(10B)····O3	0.85(4)	2.17(6)	2.932(6)	149(6)



Fig. 3. Perspective view of $[Co(HL)_2](NO_3)_2$. 3H₂O. The large semitransparent ellipsoids denote the disordered molecules of the solvent.

Infrared Spectra

The IR spectra of (E)-Nó'-(2-hydroxy-3-methoxybenzylidene)isonicotinohydrazide (LH) shows two characteristic bands at 1684 (s) and 1604 cm⁻¹, which can be assigned as stretching vibration ν C=O and azomethine groups (ν_{as} N=CH), respectively. These bands are obtained at 1687, 1605 cm⁻¹ for complex. The similar range for azomethine is also reported in the literature.^[14,18] ¹H NMR spectra of the compound showed a sharp signal (singlet) at 8.80 ppm, which can be assigned to the azomethine proton.

Crystal Structure of the Protonated Ligand

The molecular structure of the protonated ligand is depicted in Figure 1. The selected molecular geometry parameters are listed in Table 2, and the hydrogen bond geometry in Table 3. As it is shown in Figure 1, the compound contains two symmetry-independent protonated ligand (HLH⁺) and two nitrate ions. E)-Nó'-(2-hydroxy-3-methoxybenzylidene) isonicotinohydrazide is protonated from heterocyclic nitrogen atom of isonicotinic acid hydrazide. The bond lengths are comparable to those of the unprotonated ligand.^[13] The



Fig. 4. A view of the crystal structure of $[Co(HL)_2](NO_3)_2$. $3H_2O$ in the (010) plane. The cations, anions and lattice water molecules are connected into an infinite 1D chain by the O-H···O and N-H···O hydrogen bonds (shown by the dotted lines).

C7=N3 and C21=N6 bond lengths of 1.287(3) Å and 1.277 (3) in HLH⁺ confirm them as double bonds and the molecule displays trans configuration with respect to the C=N double bonds. In the crystal structure of **1**, cations and anions are linked through N–H···O and O–H···N intermolecular hydrogen bonds which form an infinite one dimensional network, parallel to [010] chain (Figure 2).

Crystal Structure of [Co(HL)₂](NO₃)₂,3H₂O

Figure 3 gives a view of the cobalt complex with atom labels. The cobalt(II) is coordinated by two Schiff base ligands *via* the phenolic oxygen atom and azomethine and pyridine nitrogen atoms. Due to deprotonation of the phenolic group and protonation of the heterocyclic nitrogen atom of pyridine rings, each ligand behaves as a neutral tridentate ligand. The charge is balanced by two nitrate ions. The geometry around the Co^{II} ion can be described as a distorted octahedron. The bond distances Co–N and Co–O in **1** are in accordance with the values from the literature.^[8]

The bond angles around Co(II) ion are in the range of 177.62(11)–172.81(12)° *trans* pairs of donor atoms and 83.24 (13)–95.46(13)° for the *cis* pairs (Table 2). These values indicate a large distortion from the ideal octahedral geometry due to the binding of Schiff base ligands in the O,N,N'-tridentate fashion. The average bond lengths are Co–O_{phe} = 1.901 Å and 1.876Å, Co–N = 1.927(5) Å, which lie well within the range of reported values for corresponding bond lengths and angles of other mononuclear cobalt (III) complexes.^[9,10] In the solid state, cations, anions, and water molecules are linked through the hydrogen bonds forming a network, as shown in Figure 4.

Funding

This research was supported by the Islamic Azad University, Yazd Branch, Iran, and the project Praemium Academiae of the Academy of Sciences.

References

- Saadeh, S. M.; Abu Shawish, H. M.; Dalloul, H. M.; El-Halabi, N. M.; Daher, B. K. Lead(II) complexes with some SNO and ONO tridentate Schiff base ligands and their evaluation as lead(II) sensors. *Mater. Sci. Eng., C.* 2012, *32*, 619–624.
- Malathy Sony, S. M.; Saraboji, K.; Ponnuswamy, M. N.; Manonmani, J.; Kandasamy, M.; Fun, H.-K. Structure and conformation of a nickel complex: {2-hydroxo-3-piperidine-1-yl-methyl-*N*,*N*'-(bis-5-bromobenzylpropylenediimine) nickel(II) perchlorate}. *Cryst. Res. Technol.* 2004, *39*, 185–192.
- Ray, A.; Banerjee, S.; Rosair, G. M.; Gramlich, V.; Mitra, S. Variation in coordinative property of two different N2O2 donor Schiff base ligands with nickel(II) and cobalt(III) ions: characterization and single crystal structure elucidation. *Struct. Chem.* 2008, 19, 459–465.

- Kondo, M.; Nabari, K.; Horiba, T.; Irie, Y.; Kabir, Md. K.; Sarker, R. P.; Shimizu, E.; Shimizu, Y.; Fuwa, Y. Synthesis and crystal structure of [Ni(2,5-dihydroxysalicylidene)ethylenediaminato]: a hydrogen bonded assembly of Ni(II)-salen complex. *Inorg. Chem. Comm.* 2003, 6, 154–156.
- Keypour, H.; Salehzadeh, S.; Parish, R. V. Synthesis of two potentially heptadentate (N4O3) Schiff-base ligands derived from condensation of tris(3-aminopropyl)amine and salicylaldehyde or 4hydroxysalicylaldehyde. Nickel(II) and copper(II) complexes of the former ligand. *Molecules*. 2002, 7, 140–144.
- Abd El Halima, H. F.; Omar, M. M.; Mohamed, G. G.; Abou El Ela Sayed, M. Spectroscopic and biological activity studies on tridentate Schiff base ligands and their transition metal complexes. *Euro. J. Chem.* 2011, *2*, 178–188.
- Yang, L.; Crans, D. C.; Miller, S. M.; la Cour, A.; Anderson, O. P.; Kaszynski, P. M.; Godzala, M. E.; Austin, L. D.; Willsky, G. R. Cobalt(II) and cobalt(III) dipicolinate complexes: solid state, solution, and in vivo insulin-like properties. *Inorg. Chem.* 2002, *41*, 4859–4871.
- Gungor, E.; Celen, S.; Azazb, D.; Kara, H. Two tridentate Schiff base ligands and their mononuclear cobalt (III) complexes: synthesis, characterization, antibacterial and antifungal activities. *Spectrochim. Acta, Part A.* 2012, 94, 216–221.
- Zhu, H.; Li, W.-H. Syntheses, crystal structures and antibacterial activities of azido-bridged cobalt(III) complexes with Schiff bases. *Transition Met. Chem.* 2010, 35, 745–749.
- Titiš, J.; Hudák, J.; Kožíšek, J.; Krutošiková, A.; Moncol, J.; Tarabová, D.; Boča, R. Structural, spectral and magnetic properties of carboxylato cobalt(II) complexes with heterocyclic N-donor ligands: reconstruction of magnetic parameters from electronic spectra. *Inorg. Chim. Acta.* 2012, *388*, 106–113.
- Fouda, A. S.; Gouda, M. M.; Abd El-Rahman, S. I. 2-Hydroxyacetophenone-aroyl hydrazone derivatives as corrosion inhibitors for copper dissolution in nitric acid solution. *Bull. Korean Chem. Soc.* 2000, 21, 1085–1089.
- Tai, X.-S.; Yin, X.-H.; Tan, M.-Y.; Li, Y.-Z. 3-Indolylformaldehyde isonicotinoylhydrazone methanol solvate Acta Crystallogr. 2003, *E59*, o681–o682.
- Yang, D-S. Syntheses, characterization and crystal structures of two structurally similar Schiff bases isonicotinic acid [1-(3-methoxy-2hydroxyphenyl)methylidene]hydrazide and isonicotinic acid [1-(4dimethylaminophenyl) methylidene]hydrazide monohydrate. J. Chem. Crystallogr. 2007, 37, 343–348.
- Tabatabaee, M.; Ghassemzadeh, M.; Zarabi, B.; Neumüller, B. Synthesis and crystal structure of Schiff bases based on AMTTO (AMTTO = 4-amino-6-methyl-3-thio-3,4-dihydro-1,2,4-triazin-5 (2H)-one). Z. Naturforsch. 2006, B61, 1421–1425.
- Ghassemzadeh, M.; Tabatabaee, M.; Soleimani, S.; Neumüller, B. Synthesis, characterization and crystal structures of new 1,2,4-triazole based Schiff-bases and their copper(I) complexes. *Anorg. Allg. Chem.* 2005, 631, 1871–1876.
- Tabatabaee, M.; Ghassemzadeh, M.; Sadeghi, A.; Shahriary, M.; Neumüller, B. Synthesis, characterization and X-ray structures of AMTT-type Schiff bases and two CuI complexes (AMTT_ 4amino-5-methyl-2H-1,2,4-triazole-3(4H)-thione). Z. Anorg. Allg. Chem. 2009, 635, 120–124.
- Hajmohammadi, S.; Tabatabaee, M.; Hajmohammadi, S.; Basir Ghafoori, N.; Parvez, M. Crystal structure of N,N'-bis(2-hydroxy-4-methoxysalicylidene)-ethylenediaminatonickel(II), Ni(C18H1₈N₂O₄). Z. Kristallogr. NCS. 2011, 226, 131–132.
- Tabatabaee, M.; Ghassemzadeh, M.; Zarabi, B.; Heravi, M. M.; Anary-Abbasinejad, M.; Neumüller, B. Solvent-free microwave synthesis of (aryland heteroaryl-methylene)amino derivatives of 4-amino-6-methyl-5-oxo-3-thioxo-2H-1,2,4-triazine and 4-amino-5-methyl-3-thioxo-2H-1,2,4-triazole: crystal structure of

6-methyl-4-(3-nitrobenzylideneamino)-5-oxo-3-thioxo-2H-1,2,4-triazine. *Phosphorus Sulfur Silicon Relat. Elem.* **2007**, *182*, 677–686.

- Tabatabaee, M.; Ghassemzadeh, M.; Solemani, N. Structural characterization of a new Schiff-base ligand, 1,4-bis-(5-methyl-4-methyl-enamino-2,4-dihydro[1,2,4]triazol-3-thion)benzene [C₁₄H₁₄N₈S₂ · 2C₂H₆OS]. Anal. Sci. 2008, 24, x173–x174.
- Gungora, M. C.; Burla, M.; Camalli, B.; Carrozzini, G.; Cascarano, C.; Giacovazzo, G.; Polidori, R.; Spagna, R. SIR 2002: the program. J. Appl. Cryst. 2003, 36, 1103.
- 21. Petricek, V.; Dusek, M.; Palatinus, L. *Structure Determination Software Programs*; Institute of Physics, Praha, Czech Republic, 2006.
- 22. Spek, A. L. *PLATON, A Multipurpose Crystallographic Tool*; Utrecht University, Utrecht, The Netherlands, 2005.