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New Copper(II) and Nickel(II) Complexes with Dimethylglyoxime and Amino-acids: Synthesis, Characterization and Electrochemical Properties

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Abstract: Four new Cu(II) and Ni(II) ion complexes were created from the interaction of dimethylglyoxime as primary ligand and methionine or alanine as a secondary ligand, has been investigated using molar conductivity, infrared, UV/vis. The electrochemical behavior of these complexes was determined by cyclic voltammetry.The compounds prepared are solids, insoluble in water, ethanol and methanol, but soluble in dimethylsulfoxide (DMSO) and dimethylformamide (DMF). The molar conductance data confirm that two complexes are not electrolytic. The IR study shows that dimethylglyoxime ligand is coordinated to the metal ion in a bidentate manner with NN donor sites of the oxime function, where the secondary ligand is coordinated by the carboxylate oxygen and the N atom of the amino acid. The electronic spectral data indicated that the synthesized complexes have octahedral or square-planar geometries. An electrochemical application was carried out on these mixed complexes in order to study their redox properties, which indicated an irreversible oxidation corresponding of M to M(I) and of M(I) to M(II).

Keywords: Complexes, Dimethylglyoxime, Amino acids, Spectroscopic analysis, Electrochemical application

Introduction

The chemistry for oxime metal complexes has been investigated actively since the first synthesis of nickel (II) dimethylglyoximate and recognition of the chelate. Copper (II) complexes with dimethylglyoxime are known for their high stability, but their biological activity has been very scarcely studied (Bougherra et al, 2018). Amino acids are classified as promising biomolecules that can be complexed with metals to form stable and active catalysts. Therefore, Amino acid-metal complexes and their derivatives have attracted many researchers in the fields of pharmaceuticals and petrochemical industries (Alrufaydi et al., 2020).

Copper (II) and nickel (II) complexes with amino acids are of significant pharmacological interest because several of them exhibit a broad spectrum of effects, in particular anti-inflammatory, antiulcer, anticonvulsant and even anti-tumor. It has also been established that these complexes often exhibit higher pharmacological activity than that of their free ligands (Adkhis et al., 2022; Wagner et al.,2008; Baran et al. ,2009). In this work, we describe the synthesis, spectral characterization and electrochemical application of the new Ni(II) and Cu(II) complexes of dimethylglyoxime as the primary ligand and alanine or methionine as secondary one.

Experimental

Materials and Methods

- Selection and peer-review under responsibility of the Organizing Committee of the Conference

All the chemical reagents and solvents used in the synthesis of the complexes were (Fluka products) used without further purification. Melting points were determined on a Stuart scientific SPM3 apparatus fitted with a microscope and are uncorrected. The infrared spectra were recorded in the region 4000–400 cm^{-1} on a BRUKER TENSOR 27 IR spectrophotometer. Electronic spectra were measured on a thermo Scientific EVOLUTION 220 ultraviolet-visible spectrophotometers (in DMSO solution); measurements were made from 200 to 800 nm. The molar Conductance values were obtained for 10^{-3} M in DMSO solution at 25 °C determined using melting point meter MPM-H2. All electrochemical experiments were carried out using a potentiostat-galvanostat EGG-273 A controlled with Power-suite software. The electrochemical cell was equipped with a modified carbon past disk as the working electrode, a platinum electrode as counter electrode and silver/silver chloride (Ag/AgCl) electrode as the reference electrode. The electrolytic bath consisted of the complexes in DMSO solution (10^{-3} M) and sodium perchlorate ($NaClO_4$ 10^{-1} M) was used as a supporting electrolyte to increase the conductivity of the bath. The electrochemical characterization was performed using the cyclic voltammetry (CV) with a scan rate of 50 mV/s.

Synthesis of Complexes

To an aqueous solution of metal salt (5 mmol) and KI or KSCN (10 mmol) was added dropwise an ethanolic solution of amino acid (5mmol). After stirring and refluxing a hot ethanolic solution of dimethylglyoxime (5 mmol) was added. Then a few drops of NaOH solution were added to keep the pH at 8. The resulting mixture is left stirring under reflux at 70 ° C for 3 hours. The precipitate obtained was isolated by filtration and washed with ethanol and diethylether. The solid was dried at room temperature.

Results and Discussion

The physical properties of the prepared complexes are summarized in Table 1**.** All the complexes are soluble in DMSO and DMF but insoluble in water, methanol and ethanol. The electrolyte or non-electrolyte nature of the complexes was confirmed by low or high values of molar conductance measured at 25°C (10^{-3} M) in a DMSO solution.

Table 1. Physical properties of the complexes

Compound formula	Yield (%)	Melting point(°C)	Color	$\Lambda(\Omega^{1}Cm^{2}mol\,mol^{-1})$	Metal (%) Cal	Found
$[Cu(H_2dmg)(Meth)(SCN)_2]$ **1**	65	260	Blue	15.2	14.35	13.98
$[Ni\ (H_2dmg)(Meth)](SCN)_2$ **2**	87	302	Red	170	13.4	13.58
$[Cu(H_2dmg)(Ala)]I_2$**3**	56	310	Gray	64.5	12.2	12
$[Ni\ (H_2dmg)(Ala)I_2]$**4**	47	312	pinck	11.2	11.38	11.2

Infrared Spectra

The assignments of the more significant IR absorption bands of the free ligands and their metal complexes are shown in Table 2 and Table 3, respectively, and the FT-IR spectrum of $[Cu(H_2dmg)(Meth)(SCN_2)]$ and $[Ni(H_2dmg)(Ala)(I_2)]$ are shown in figure 1 and figure 2, respectively. The IR spectrum of dimethylgloxime shows a band with medium intensity at 1447 cm^{-1}, which is attributed to (C=N) of the oxime. This band is shifted to higher frequency (1450-1503 cm^{-1}) in all the mixed-ligand complexes (Jadhav et al, 2013; Salih, et al, 2009; Chandar et al, 2011).

The strong absorption at 1143 cm^{-1} due to υ(N-O) of the oxime group in the free H_2dmg is shifted towards higher frequency in all the complexes (Osunlaja et al, 2009; Berradj et al, 2021). While the appearance of a band in all the complexes in the region 752- 772 cm^{-1} is due to the C=N-O deformation vibration of the oxime group, this band is shifted in free ligand at 750 cm^{-1}(Abane et al, 2019). All these features indicate that the H_2dmg is coordinated to the metal ion through the nitrogen of the oxime.

The $\upsilon(NH_3^+)$ of methionine and alanine is observed in 3146 and 3072 cm^{-1} respectively. In the complexes, NH_3^+ gets deprotonated and binds to metal through the neutral NH_2 group. The IR spectra of complexes show characteristic bands of $\upsilon(NH_2)$ in the region 3100- 3309 cm^{-1} (Mamun, et al, 2010; Wagner et al, 2004). Whereas the deformation frequency $\delta(NH_3^+)$, which is characteristic for the zwitterions, appear

at about 1615 cm^{-1} in amino acids, in the metal complexes with methionine, $\delta(NH_2)$ is shifted to higher wave numbers, while that of alanine is displaced to the lower wave numbers (Rosu et al., 2005). Hence, it can be concluded that the nitrogen of the amino group is involved in coordination.

The spectra of amino acids display $\upsilon_{as}(coo^-)$ and $\upsilon_s(coo^-)$ frequency in the 1583cm^{-1} and 1409 cm^{-1} range, respectively. In the metal complexes, $\upsilon_{as}(coo^-)$ and $\upsilon_s(coo^-)$ stretching bands are located in the region 1520-1616 cm^{-1} and 1373-1429 cm^{-1}, respectively (Tidjani-Rahmouni et al., 2014; Adkhis et al., 2000). The infrared spectra of the prepared complexes show weak bands in the range of 519-572 cm^{-1} and 426-441 cm^{-1}. They are attributed to the u(M-O) and u(M-N) vibration, respectively (Bougherra et al., 2018).

Table 2. Characteristic IR absorption bands (cm^{-1}) of the ligands

Compound	$\nu(NH_3^+)$	$\delta(NH_3^+)$	$\nu_{as}(COO^-)$	$\nu_s(COO^-)$	ν(CN)	ν(NO)	δ(NO)
Dimethylgloxime					1447	1143	750
Methionine	3146	1615	1583	14109			
Alanine	3072	1618	1583	1409			

Table 3. Characteristic IR absorption bands (cm^{-1}) of the complexes

Complex	$\nu(NH_2)$coord	$\delta(NH_2)$	$\nu_{as}(COO^-)$	$\nu_s(COO^-)$	ν(CN)	ν(NO)	δ(NO)	ν(M-O)	ν(M-N)
Complex 1	3117-3300	1661	1616	1404	1454	1205	772	572	441
Complex 2	3100-3200	1627	1558	1400	1503	1238	760	544	428
Complex 3	3309	1581	1520	1373	1450	1200	752	548	426
Complex 4	3165-3306	1603	1568	1429	1483	1238	752	519	430

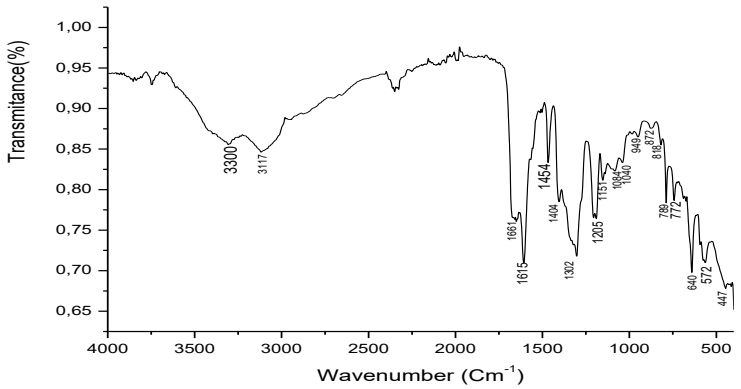

Figure 1. Infrared spectrum of [Cu(H_2dmg)(Meth)(SCN_2)]

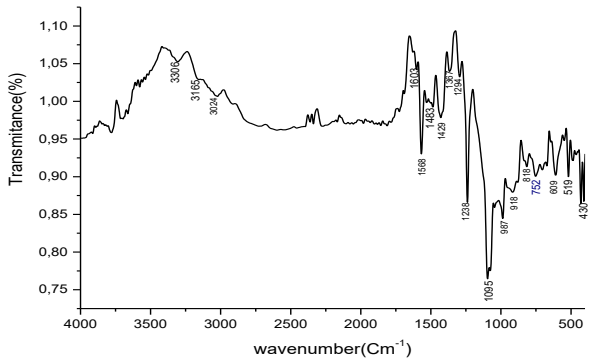

Figure 2. Infrared spectrum of [Ni(H_2dmg)(Ala)(I_2)]

Electronic Spectra

The electronic spectral data of the ligands and complexes are presented in Table 4 and Table 5 respectively, and the electronic absorption spectrum of [Ni(H_2dmg)(Meth)]($SCN)_2$ is given in Figure 3.

In the UV spectra of the ligands, the bands in the range 250-290 nm can be associated to $\pi \longrightarrow \pi^*$ intra-ligand transition. In the spectra of the complexes, these bands are shifted toward higher wavelengths, confirming the coordination of the ligands in the metal center. The spectra of complexes show a band at 430 nm for complexes with Copper(II) and at 375 nm for complexes with nickel(II) , which is assigned to charge transfer transition.

The electronic spectra of complexes 1 and 3 (complexes with Cu) show one band in the visible domain, respectively at 711 and 520 nm, this band is attributed to the d-d transition characteristic octahedral and square-planar geometry respectively (Solans-Monfort et al., 2011). In the visible range, the spectra of complex 2 exhibit two bands. These transitions are in agreement with a square-planar geometry around the Ni(II) ion (JieShen et al., 2005). Furthermore, the complex 4 shows three bands in the visible. These transitions are in agreement with an octahedral geometry around the Ni(II) ion (Randhır et al., 2000).

Table 4. Electronic spectral data of the ligands

Compound	λ (nm)	υ (cm^{-1})	Ɛ ($lmol^{-1}cm^{-1}$)	Electronic transitions
Dimethylglyoxime	290	34483	100	$\pi \longrightarrow \pi^*$
	270	37037	1300	$\pi \longrightarrow \pi^*$
Methionine	283	35336	20	$\pi \longrightarrow \pi^*$
	259	38610	30	$\pi \longrightarrow \pi^*$
Alanine	276	36232	50	$\pi \longrightarrow \pi^*$
	261	38314	43	$\pi \longrightarrow \pi^*$

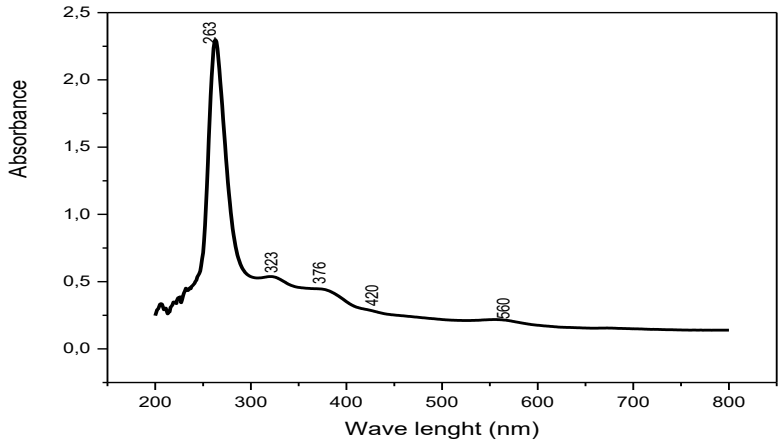

Figure 3. Electronic absorption spectrum of $[Ni(H_2dmg)(Meth)](SCN)_2$

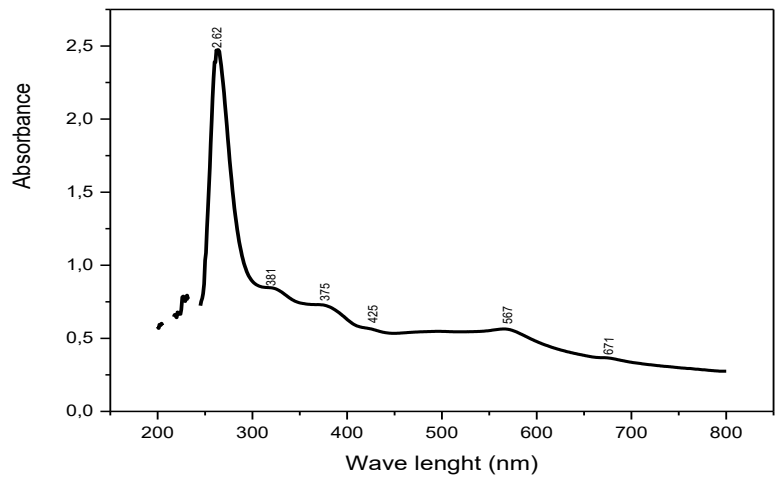

Figure 4. Electronic absorption spectrum of $[Ni(H_2dmg)(Ala)(I)_2]$

Table 5. Electronic spectral data of the complexes.

Complex	λ (nm)	υ (cm^{-1})	Ɛ ($lmol^{-1}cm^{-1}$)	Electronic Transitions
Complex 1	711	14065	711	d - d
	430	23256	300	charge transfer
	289	34602	343	π - π*
	275	36364	2810	π - π*
	268	37313	1850	π - π*
Complex 2	560	17857	200	d - d
	420	23809	300	d - d
	376	26596	400	charge transfer
	323	30960	500	π - π*
	263	38023	2300	π - π*
Complex 3	520	19231	1030	d - d
	430	23256	800	charge transfer
	316	31646	400	π - π*
	296	33784	4180	π - π*
	273	36630	4100	π - π*
Complex 4	671	14903	360	d - d
	567	17637	570	d - d
	425	23529	570	d - d
	375	26666	740	charge transfer
	321	31153	860	π - π*
	264	37879	2560	π - π*

Electrochemical Studies

The electrochemical properties of the ligands and their complexes were investigated by cyclic voltammetry in DMSO solution containing 0.1 M $NaClO_4$ as supporting electrolyte. All the measurements were carried out in 10^{-3} M solution at room temperature in the potential range +1.6 to -1.6 V with a scan rate of 50 mVs^{-1}. Electrochemical data of the ligands and the complexes are presented in Table 6 and Table 7, respectively. Typical cyclic voltammogram of [Ni (H_2dmg)(Ala)I_2] and $Ni(NO_3)_2$. $6H_2O$ are shown in Figure 5. Cyclic voltammogram of $Cu(NO_3)_2.3H_2O$ shows an irreversible oxidation process at +0.26 V assigned to the oxidation of Cu^+ to Cu^{2+} (Bougherra et al., 2018; Tidjani-Rahmouni et al., 2014).

The cyclic voltammogram of $Ni(NO_3)_2.6H_2O$ shows a quasi-reversible process characterized by the potentials Epa = -1.04, Epc = -0.92 V, which can be attributed to the reduction of Ni(II) to Ni(0), furthermore, this voltammogram also shows three anodic peaks without cathodic responses. The first and the second peaks observed at Epa1 = 0.05 and Epa2 = 0.2 V could be attributed to the successive oxidation of Ni(0) to Ni(I) and the third peak observed at Epa3 = 0.84 V can be attributed to the oxidation of Ni(I) to Ni(II) (El-Gahami et al., 2004; Ben Mansour, 2014).

By comparing the cyclic voltammograms of complexes to those of the ligands and that of metal salt taken as reference, it is easy to confirm the presence of the metal cation and ligands in the complexes. The cyclic voltammogram of the complexes 1 and 3 (complexes with copper) shows a cathodic peak, without any anodic response, observed at -0.98 V and -1.07V respectively, this peak could be assigned to the reduction of Cu(II) to Cu(0). In addition, these complexes show four peaks anodic without any cathodic response. The first peak located at 0.01 V for complex 1 and at -0.1 V for complex 3 can be attributed to the oxidation of Cu(0) to Cu(I). the second peak at 0.23 V for complex 1 and at 0.13 V for complex 3 could be assigned to the oxidation of Cu(I) to Cu(II).

The peaks anodic at -0.47 V and 1.03 V for complex 1 and at -0.6 V and 0.94 V for complex 3. All these peaks can be attributed to the oxidation of the ligands. The cyclic voltammogram of the complexes 2 and 4 (complexes with nickel) shows a cathodic peak, without any anodic response, observed at -0.66 V and -1.30 V respectively, this peak could be assigned to the reduction of Ni(II) to Ni(0)

In addition, these complexes show three peaks anodic without any cathodic response. The first peak located at -0.24 V for complex 2 and at 0.06 V for complex 4 can be attributed to the oxidation of Ni(0) to Ni(I). the second peak at 0.7 V for complex 2 and at 0.62 V for complex 4 could be assigned to the oxidation of Ni(I) to Ni(II).

However, the peaks anodic at -0.5 V for complex 2 and 1.24 V for complex 4 can be attributed to the oxidation of the ligands.

Table 6. Electrochemical data of the ligands

Compound	Epa (V)	Epc (V)	ΔE(Mv)
$Cu(NO_3)_2 .3H_20$	-	0.26	-
	-1.04	-0.92	120
$Ni(NO_3)_2 .6H_20$	0.05	-	-
	0.2	-	-
	0.84	-	-
Dimethylglyoxime	-0.7	-0.56	140
Methionine	-	1.24	-
	-0.82	-	-
Alanine	-0.38	-0.66	280

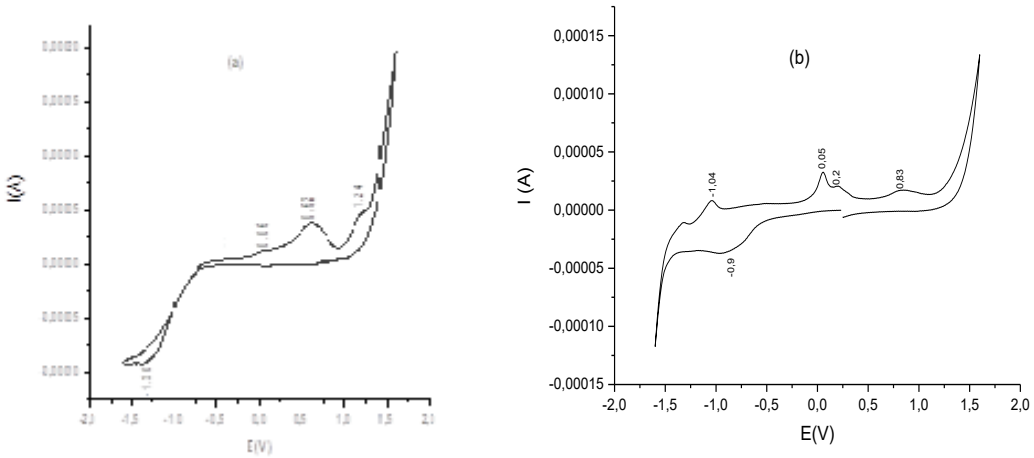

Figure 5. (a) Cyclic voltammogram of $[Ni(H_2dmg)(Ala)_2 I_2]$ and (b) of $Ni(NO_3)_2.6H_2O$

Table 7. Electrochemical data of the complexes

Complex	Epa (V)	Epc (V)
Complex 1	-	-0.98
	-0.47	-
	0.01	-
	0.23	-
	1.03	-
Complex 3	-	-1.07
	-0.6	-
	-0.1	-
	0.13	-
	0.94	-
Complex 2	-	-0.66
	-0.50	-
	-0.24	-
	0.70	-
Complex 4	-	-1.30
	0.06	-
	0.62	-
	1.24	-

Conclusion

Four complexes of (Cu or Ni) with dimethylglyoxime and amino acids (methionine or alanine) were synthesized and characterized by different physico-chemical and spectroscopic techniques. Conductimetric analysis shows

that two complexes are non-electrolytes. The IR study reveals that all the ligands are bidentate. The electron absorption spectra can be concluded that the investigated mixed-ligand complexes have an octahedral or square-planar geometries. The electrochemical behavior of complexes was determined by cyclic voltammetry, which shows an irreversible redox process corresponding of M(II) to M(0) and irreversible oxidation of M(0) to M(I) and M(I) to M(II).

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM Journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

Acknowledgements or Notes

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References

Abane, L, Adkhis, A, Terrachet,S., & Makhloufi, M. (2019). Synthesis, DFT/TD-DFT theoretical studies, experimental characterization, electrochemical and antioxidant activity of fe (III) complexes of bis(dimethylglyoximato)guanine. *Journal of Molecular Structure, 1186*, 413-422.

Adkhis, A., Benali-Baitich, O., Khan, M. A., & Bouet, G. (2000). Synthesis, characterization and the thermal behavior of mixed ligand complexes of cobalt (III) with dimethylglyoxime and some amino acids. *Synthesis and Reactions in Inorganic Metals Organometallic and Nanomaterial Chemistry, 30,* 1849-1858.

Adkhis, A., Belhocine, F., Makhloufi, M., Amrouche, T., & Terrachet, S. (2022). New copper (II) complexes with ethylenediamine, bipyridine and amino acids: Synthesis, characterization, optimization of geometry by theoretical DFT studies, electrochemical properties and biological activities. *Journal of Chemical and*,*Pharmaceutical Research, 14*(6), 1-23

Alrufaydi, Z. A., Ahmed, S. M., & Mubarak -Mater, A.T. (2020). Synthesis andcharacterization of novel transition metal complexes with L-proline and their catalytic activity evaluation towards cyclohexane oxidation. *Materials Research Express,7,* 045103

Baran, E.J., & Torre, M.H. (2009), Colegio de farmacéuticos de la provincia de buenos aires. *Latin American Journal of Pharmacy*, 28(5), 89-792.

Ben Mansour, Y (2014). *Synthèse etude physico-chimique et activité biologique des complexes de cuivre et nickel dérivés d'hydrazone et thiadiazole.* (Doctoral dissertation, Université de Tlemcen).

Berradj,O., Bougherra,H., Adkhis, A., Amrouche, T., Amraoui, N.E., & Hammoutène, D, (2021). Synthesis, spectroscopic, thermal decomposition, DFT studies and antibacterial activity of uracil cobalt (III) dimethylglyoximato complexes. *Journal of Molecular Structure 1232,* 130040.

Bougherra, H., Berradj, O., Adkhis, A., & Amrouche, T. (2018). Synthesis, characterization, electrochemical and biological activities of mixed ligand copper (II) complexes with dimethylglyoxime and amino acids. *Journal of Molecular Structure 1173,* 280-290.

Bougherra,' H., Berradj, O., & Adkhis, A. (2018). Synthesis, characterization, electrochemical studies and antioxidant activity of some new dimethylglyoxime copper (II) complexes with purine bases and ortho-phenylenediamine**.** *Journal of Chemical and Pharmaceutical Research,10*(4), 93-103.

Caleb Noble Chandar, S., Sangeetha, D., & Arumugham, M. N. (2011), Synthesis, structure, CMC values, thermodynamics of micellization, steady-state photolysis and biological activities of hexadecylamine cobalt(III) dimethyl glyoximato complexes. *Transition Metal Chemistry, 36, 211-216*.

El-Gahami, M.A., Khafagy, Z.A., Azza, M.M.A., & Ismail, N.M. (2004), Thermal, spectroscopic, cyclic voltammetric and biological activity studies of cobalt (II), nickel (II), and copper (II) complexes of dicarboxylic amino acids and 8hHydroxyquinolin. *Journal of Inorganic and Organometallic*

Polymers, 14, 117-129

Jadhav, S.S., Kolhe, N.H., & Athare, A.E. (2013) Synthesis, and characterization of mixed ligans complexes of salicyladoxime, dimethylglyoxime and benzoin with mn (II) and their biological activity. *International Journal of Pharmacy and Biological Sciences, 4,* 45-54.

JieShen, X., Xiao, L., & RenXu., R. (2005), *N*-(4-ferrocenylphenyl)-4-piperidino-1,8-naphthalimide, the ferrocene redox centre is linked to the naphthalimide fluorophore by a benzene bridge. *Acta Cryst.E61.*1185-1187.

Mamun, MA, Ahmed, P.K. Bakshi, Ehsan, MQ (2010) Synthesis and spectroscopic, magnetic and cyclic voltammetric characterization of some metal complexes of methionine: $[(c_5h_{10}no_2s)_2m^{ii}]$; m^{ii} = mn(II), co(II), ni(II), cu(II), zn(II), cd(II) and hg(II). *Journal of Saudi Chemistry Society, 14* (2010), 23-31.

Osunlaja, A.A., Ndahi, N.P., & Ameh, J.A. (2009). Synthesis, physico-chemical and antimicrobial properties of co(ıı), ni(ıı) and cu(II) mixed-ligand complexes of dimethylglyoxime - part I. *African Journal of Biotechnology, 8*(1)*,* 4-11.

Randhır, S., Suresh, K., & Amarendra, B. (2000). Synthesis and electrochemical studies of phenylazo substituted tetraaza macrocyclic complexes of ni(II). *Procee Indian Acad. Sci. (Chem. Sci.), 112*(6), 601–605.

Rosu, T., Negoiu, M., Pasculescu, S., Pahontu, E., Poirier, D., & Gulea, A. (2010) Metal-based biologically active agents: Synthesis, characterization, antibacterial and antileukemia activity evaluation of cu(II), V(IV) and ni(II) complexes with antipyrine-derived compounds. *European Journal of Medicinal Chemistry, 45*(2), 774-781.

Salih, B.M.M., & Satyanarayana, S. (2009). Vitamin b12 models: Synthesis and characterization of cyano bridged dicobaloximes and antimicrobial activity. *African Journal of Pure Application Chemistry, 3, 170-176.*

Solans-Monfort, X., Fierro, J.L.G., Hermosilla, L., Sieiro, C., Sodupe, M., and MasBalleste, R, (2011), O-o bond activation in h_2o_2 and $(ch_3)_3c$-ooh mediated by $[ni(cyclam)(ch_3cn)_2](clo_4)_2$: different mechanisms to form the same ni(III) product?. *Dalton Transactions*, 40, 6868 – 6876.

Tidjani-Rahmouni, N., Bensiradj, N.H., Djebbar, S., & Benali-Baitich, O. (2014). Synthesis, characterization, electrochemical studies and DFT calculations of amino acids ternary complexes of copper (II) with isonitrosoacetophenone biological activities. *Journal of Molecular. Structures, 1075*, 254-263.

Wagner, C. C., & Baran, E. J. (2004). Spectroscopic and magnetic behaviour of the copper (II) complex of L-tryptophan. *Acta Farm. Bonaerense 23, 339-342*.

Wagner, C.C., Torre,M.H., & Bara, E. J. (2008). Vibrational spectra of copper(II) complexes of L-proline. *Latin American Journal of Pharmacy, 27*(2), 195-197.

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