

Comparative study of 1, 2 Naphthoquinone oximes and their Cu (II) metal chelates

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Abstract: Isomeric Cu (II) metal chelates with 1, 2 Naphthoquinone 1-oxime, 1, 2 Naphthoquinone 2-oxime and 1, 2 Naphthoquinone dioxime were synthesized and their comparative study were carried out with respect to their physical and chemical properties. The ligands and Cu (II) metal chelates were characterized by using electronic spectra, FT-IR, and elemental analysis and confirmed the composition of ligands and metal chelates. The FT-IR spectra of metal chelates and ligands (using KBr pellets in the range 4000-400 cm⁻¹) indicated that the isomeric chelates retain their identity even after chelation. In electronic spectra, BET and QET bands showed variation in wavelength after chelation. The compounds were studied for antimicrobial activity against Gram positive bacteria (*Staphylococcus aureus*, *Bacillus subtilis*) and Gram negative bacteria (*Escherichia coli*, *Proteus vulgaris*). Among all these ligands and metal chelates, 1, 2 Naphthoquinone dioxime showed comparatively more antimicrobial activity against *Escherichia coli* and *Staphylococcus aureus*.

Keywords: 1, 2 Naphthoquinone 1-oxime, 1, 2 Naphthoquinone 2-oxime, 1, 2 Naphthoquinone dioxime, *Staphylococcus aureus*, *Bacillus subtilis*, *Escherichia coli*, *Proteus vulgaris*.

1. Introduction:

1, 2 Naphthoquinone oximes are powerful chelating agents due to which they possess coordination characteristics, and it has been subject of interest in research field [1]. 1, 2 Naphthoquinone 1-oxime is versatile derivatives of 1, 2 Naphthoquinone oxime which finds important applications in the field of coordination chemistry and analytical chemistry [2]. 1, 2 Naphthoquinone 1-oxime and 1, 2 Naphthoquinone 2-oxime are equally important for their structural investigations as well as their metal chelates [3]. The complexing ability of oxime group (=NOH) is strongly influenced by the spatial arrangement of the group [4-6]. 1, 2 Naphthoquinone oximes are biologically active, possessing powerful antimicrobial activity [7-9]. Naphthoquinone oximes show very significant antimicrobial activity [10]. Many research workers were interested in the structural investigation of these monoximes as well as their metal chelates. Naphthoquinone and the derivatives find various applications in different branches of science [11, 12].

Sarawadekar et al [13] synthesized five metal chelates of 1, 2 Naphthoquinone 2-oxime and were characterized by using various techniques. These were also studied for antimicrobial activities. They further studied the compounds using Gaussian 09 code for NMR chemical shifts of proton, ¹³C and compared with computed chemical shifts.

Pankaj Kumar et al [14] explained synthesized, purified and characterized

spectroscopic studies such as UV, FT-IR, ¹H NMR, ¹³C NMR and elemental analysis of substituted 1,2-naphthoquinones. He explained compounds for cytotoxicity against a panel of human cancer cell lines.

Metal chelates of dioxime have important applications in co-ordination chemistry which has been reviewed in several research papers.

In this paper, the synthesis of 1, 2 Naphthoquinone dioxime from 1, 2 Naphthoquinone oximes and further syntheses of its metal chelates such as Cu (II) 1-oximate, Cu (II) 2-oximate and Cu(II)-dioximate were reported. These were characterized by elemental analysis, UV and FT-IR and also studied antimicrobial activity against Gram positive (*Bacillus subtilis* and *Staphylococcus aureus*) and Gram negative bacteria (*Escherichia coli* and *Proteus vulgaris*).

2. Material and Method:

Aldrich grade 1, 2 Naphthoquinone 1-oxime and 1, 2 Naphthoquinone 2-oxime were used. A.R. grade Copper sulphate was used.

Elemental analysis was carried out with Perkin Elmer 2400 series for C, H, O, and N. UV spectra were recorded by using JASCO UV spectrophotometer in region 200-700 nm using 1cm matched quartz cells. IR spectra were recorded on NICOLET iS5 using KBr pellets in the range 4000-400 cm⁻¹.

2.1 Preparation of ligand 1, 2 Naphthoquinone dioxime

The third important ligand 1, 2 Naphthoquinone dioxime was formed by using 1, 2 Naphthoquinone 1-oxime and 1, 2 Naphthoquinone 2-oxime. The alcoholic solution of ligand and aqueous solution of hydroxyl amine hydrochloride mixed together and then acidified with dilute HCL and refluxed the whole solution for half an hour. Yellow precipitate was separated after addition of distilled water. Then this mixture was filtered and residue was dissolved in 2N NaOH and filtrate was acidified with 2N H₂SO₄. Then yellow colored precipitate of the ligand was obtained with 60% yield. Further product was recrystallized from benzene and ligroin. Yellow needles of 1, 2 Naphthoquinone dioxime got separated out.

2.2 Preparation of Metal Chelates

The chelates were prepared by mixing aqueous solution of metal salt and alcoholic solution of ligand in molar ratio as 1:2. This mixture was stirred and refluxed for about one hour with magnetic stirrer. The pH was maintained between 5-6 by the addition of dilute ammonia. Then this mixture was continuously stirred and kept for overnight. On the next day, metal chelate was obtained after filtration. Then it was dried.

2.3 Antimicrobial activity of Ligands and metal chelates

Antimicrobial studies of copper sulphate, 1, 2 Naphthoquinone 1-oxime, 1, 2 Naphthoquinone 2-oxime and 1, 2 Naphthoquinone dioxime and their corresponding metal chelates were carried out against two Gram positive (*Bacillus subtilis* and *Staphylococcus aureus*) and two Gram negative bacteria (*Escherichia coli* and *Proteus vulgaris*). These organisms were collected from National Chemical Laboratory, Pune. The antimicrobial activities of ligand and metal chelates were performed by well diffusion method. [15].

3. Characterization:

3.1 Elemental analysis

The aqueous solution of copper chloride and alcoholic solution of the oxime ligand led to formation of amorphous product with general formula ML₂.2H₂O.



The results of the elemental analysis are shown in Table 1.

Sr. No	Compound	Color	Yield	% Analysis			Molecular Composition
				Carbon	Hydrogen	Residue	
1.	Cu(II) 1-oximate	Dark brown	81%	56.40 (54.88)	3.28 (2.80)	6.57 (5.89)	ML ₂ .2H ₂ O
2.	Cu(II) 2-oximate	Chocolate	80 %	56.40 (54.88)	3.28 (2.20)	16.57 (15.89)	ML ₂ .2H ₂ O
3.	Cu(II) -dioximate	Brown	29%	54.50 (52.78)	3.63 (2.93)	12.71 (11.61)	ML ₂ .2H ₂ O

Table No. 1 Elemental analysis of the ligands and metal chelates

Cu (II) metal chelates of 1, 2 Naphthoquinone oxime derivatives showed brown - chocolate color. These chelates were highly soluble in DMSO. Elemental analysis indicated that observed percentages of carbon, hydrogen and residue are much closer to the theoretical values shown in the parentheses. Cu (II) dioximate has very low yield as compared to Cu (II) 1-oximate and Cu (II) 2-oximate.

3.2 Electronic spectra

Electronic spectra of ligands and metal chelates recorded in DMSO solution. The Ultraviolet spectra of 1, 2 Naphthoquinone 1-oxime, 1, 2 Naphthoquinone 2-oxime, 1, 2 Naphthoquinone dioxime and Cu (II) metal chelates were studied. These results were presented in Table 2.

Table 2: Electronic absorption data of ligands and Cu metal chelates

Sr. No	Compound	B.E.T.	Q.E.T	n-π*
1.	1-oxime	--	344	447
2.	Cu(II) 1-oximate	--	--	--
3.	2-oxime	265	343	472
4.	Cu(II) 2-oximate	263	341	531
5.	Dioxime	252	325	421
6.	Cu(II) -dioximate	254	341	529

Cu (II) 1-oximate

As BET was not observed, in Cu (II) 1-oximate, hence shown no change after chelation. QET and $n-\pi^*$ bands were found in ligand but not in Cu (II) 1-oximate suggesting change after chelation. The broad band formation takes place due to d-d and L-M overlapping.

Cu (II) 2-oximate

In Cu (II) 2-Oximate, the BET band is observed at 263nm and in 1, 2 Naphthoquinone 2-Oxime is observed at 265 nm. There is slight change after chelation. This band also shifted to lower wavelength. Hence blue shift was observed after of chelation. In Cu (II) 2-Oximate, the QET band at 343 nm was changed after chelation. This band was also shifted to lower wavelength (341nm). Hence there is a blue shift as a result of chelation.

In Cu (II) 2-Oxime, a band of medium intensity was observed at 531nm and for 1, 2

Naphthoquinone 2-oxime it is at 472nm, which was attributed due to $n-\pi^*$, d-d transition. This band is shifted to higher wavelength. Hence red shift was observed after chelation.

Cu (II) Dioximate

In the ligand 1, 2 Naphthoquinone-dioxime BET band is observed at 252 nm and Cu (II)-Dioximate is shifted to higher wavelength (254 nm) after chelation. The QET band observed in 1, 2-Naphthoquinone-Dioximate at 325 nm which was shifted to higher wavelength after chelation at 341 nm. Hence change in band position after chelation and red shift was observed.

The broad band is observed at 421 for Dioxime and is shifted to 529 nm for Cu (II)dioximate. It is again due to mixing of $n-\pi^*$ transition, d-d transition and L-M charge transfer.

3.3 IR Spectra:

The results of IR spectra are presented in Table3.

Table: 3 IR values of ligands and their metal chelates

Sr. No	Compound	O-H cm^{-1}	C=O cm^{-1}	C=N cm^{-1}	N-O cm^{-1}
1.	1-oxime	3038	1621	1557	1070
2.	Cu(II) 1-oximate	3383	1618	1556	1066
3.	2-oxime	3255	1669	1551	1067
4.	Cu (II) 2-oximate	3384	1681	1558	1094
5.	Dioxime	3248	-	1551	1110
6.	Cu(II) dioximate	3357	-	1552	1141

a) O-H frequency:

As a result of chelation, O-H stretching frequency in 1, 2 Naphthoquinone oxime is expected to be absent in spectra of its chelate. 1, 2 Naphthoquinone 1-oxime and 1, 2 Naphthoquinone 2-oxime contain one oxime group but in 1, 2 Naphthoquinone dioxime contains two oxime groups. In dioxime, one oxime group retain O-H group on chelation and another O-H group of ligand was converted to M-O after formation of metal chelates. In monoximes, O-H group was replaced by M-O in water-methanol system and water acts as powerful chelating agent. Accordingly all spectra showed the broad band in region $3600-3000 \text{ cm}^{-1}$ indicating presence of coordinated water.

b) C=O frequency

In the formation of chelates with the oxime, the C=O bond is important due to its variation in frequency. As per standard data the range of C=O frequency is at $1700-1600 \text{ cm}^{-1}$. On the basis of comparative study of IR frequency for C=O stretching in the ligand and their metal

chelates, showed change in frequencies for the ligands and corresponding Cu metal chelates.

c) C=N frequency

Another important frequency is C=N stretching which was involved in chelation for all the three ligands. According to the table, C=N frequency of 1, 2 Naphthoquinone 1-oxime and 1, 2 Naphthoquinone 2-oxime showed at 1557 and 1551 cm^{-1} respectively. In 1, 2 Naphthoquinone dioxime C=N frequency showed at 1551 cm^{-1} . These frequencies showed variation in frequency after chelation and it confirm the chelation of C=N stretching.

d) N-O frequency:

N-O stretching frequency for 1, 2 Naphthoquinone 1-oxime and 1, 2 Naphthoquinone 2-oxime was assigned at 1070 cm^{-1} and 1067 cm^{-1} respectively. In 1, 2 Naphthoquinone dioxime, N-O stretching frequency was found at 1110 cm^{-1} which is higher than the frequency found in monoximes. The variation in N-O stretching frequency indicated the formation of metal chelates.

In the comparative study of all the ligands with respect to metal chelates, O-H, C=O, C=N, N=O stretching showed changes at respective frequencies after chelation. Accordingly isomeric chelates retain their identity even after chelation which was recognized by IR study.

3.4 Antimicrobial activity:

Antimicrobial activity of 1-2 Naphthoquinone 1-oxime, 1, 2 Naphthoquinone 2-

oxime and 1, 2 Naphthoquinone dioxime and their metal chelates were studied against selected bacteria. i. e. two Gram positive bacteria *Staphylococcus aureus* and *Bacillus subtilis*, and two Gram negative bacteria *Escherichia coli* and *Proteus vulgaris*. In this antimicrobial activity studies, metal salt $\text{CuSO}_4 \cdot 6\text{H}_2\text{O}$ was used for comparison. [15] Inhibition zones of ligands and their metal chelates for the antimicrobial activity are presented in Table 4.

Table 4: Inhibition zones of Ligands and their metal chelates for the antimicrobial activity

Sr. No	Compound	Conc. mg/ml	Zone of inhibition in mm			
			<i>Staphylococcus aureus</i>	<i>Bacillus subtilis</i>	<i>Escherichia coli</i>	<i>Proteus vulgaris</i>
1.	DMSO	1.5/2.0	Nil	Nil	Nil	Nil
2.	copper Sulphate	1.5/2.0	Nil	Nil	Nil	Nil
3.	1,2 Naphthoquinone 1-oxime	1.5	24	20	14	16
		2.0	26	22	19	17
4.	1,2 Naphthoquinone 2-oxime	1.5	25	20	20	19
		2.0	27	24	18	19
5.	1,2 Naphthoquinone Dioxime	1.5	26	19	20	20
		2.0	28	23	19	19
6.	Cu(II) 1-oximate	1.5	22	24	15	14
		2.0	25	27	18	16
7.	Cu(II)2-oximate	1.5	23	18	18	16
		2.0	26	23	19	17
8.	Cu(II) -Dioximate	1.5	25	19	21	16
		2.0	27	17	18	18

Inhibition zones were measured in mm and this diameter was observed in the range 14-28 mm. All the three ligands and their Cu (II) metal chelate exhibit good activity against *Staphylococcus aureus*, *Bacillus subtilis*, and *Escherichia coli* and *Proteus vulgaris* microorganisms. In 1, 2 Naphthoquinone dioxime and its chelate, maximum activity were observed against *Staphylococcus aureus*. The similar trend was found for other two ligands and their chelates. Also significant activity was observed against *Bacillus subtilis* for all the ligands and chelates. Dimethyl sulphoxide and Copper sulphate show zero antimicrobial activity.

1, 2 Naphthoquinone dioxime and its metal chelate shows higher activity for *Staphylococcus aureus*, *Escherichia coli* and *Proteus vulgaris* when compared to other two ligands and their metal chelates. Cu (II) -1-oximate showed higher activity than its counterparts against *Bacillus subtilis*. 1, 2 Naphthoquinone dioxime showed maximum activity against all the organisms because of the presence of two oxime groups. Minimum activity was exhibited by Cu-1-oximate against both the gram negative bacteria *Escherichia coli* and *Proteus vulgaris* due to chelation.

4. Conclusions:

Isomeric Cu (II) metal chelates with 1, 2 Naphthoquinone 1-oxime, 1, 2 Naphthoquinone 2-oxime and 1, 2 Naphthoquinone dioxime were synthesized and characterized by various technique such as elemental analysis, Electronic spectra, IR, and antimicrobial activity. Elemental analysis indicates that observed values are closer to the calculated values which confirms formation of metal chelates. Ligands and the chelates have bright colors and monoximates gave better yields. From electronic spectra, chelation effect was seen on the basis of QET band, BET band and $n-\pi^*$ transition. FTIR spectra indicated, as a result of chelation, O-H stretching frequency in 1, 2 Naphthoquinone oxime is expected to be absent in spectra of its chelate. In dioxime, one oxime group retain O-H group on chelation and another O-H group of ligand was converted to M-O after formation of metal chelates. In antimicrobial studies, minimum inhibition zone (14mm) was seen for Cu(II) 1-oximate against *Escherichia coli* and maximum inhibition zone (28mm) was observed for Dioxime against *Staphylococcus aureus*.

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