

## REACTIVITY OF CERTAIN BIOLOGICALLY IMPORTANT AZOLES AND MORPHOLINE TOWARDS Ni(II) AND Cu(II) COMPLEXES OF *o*-HYDROXYACETOPHENONEETHANOLIMINE AND *N*-SALICYLIDENE DERIVATIVES

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حضر عدد من المترابكات مختلطة الليجندات للنيكل والنحاس الثنائيين مع قواعد شيف: أرثوهيدروكسي أسيتوفينون إيثانول إمين وسليسيليدين أرثو إمينو فينول وسليسيليدين أرثو تولودين وكذلك مع بعض الازولات والمورفولين. درست المترابكات باستخدام أطيف المنطقة المرئية والفوق بنفسجية والمنطقة تحت الحمراء وأيضا بالقياسات المغناطيسية.

*A number of mixed ligand complexes of Ni(II) and Cu(II) containing the Schiff bases: o-hydroxyacetophenoneethanolimine (OHAE), N-salicylidene-o-aminophenol (SOP) and N-salicylidene-o-toluidine (SOT) as well as morpholine or the azoles: 2-aminothiazole, benzothiazole and 2-methylbenzothiazole has been prepared and characterized. The IR, UV-VIS spectra and magnetic moment measurements of the complexes were discussed.*

### INTRODUCTION

Azomethine derivatives and their metal complexes perform an important role in biological

systems.<sup>1&2</sup> Many Schiff bases exhibit antiviral and antimicrobial activity<sup>3</sup> and are used as mimetic systems for enzyme models<sup>4</sup> besides their

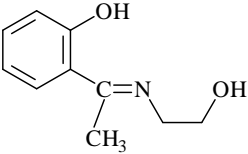
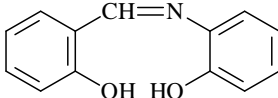
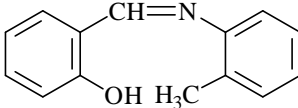
importance in pharmaceutical technology.<sup>5</sup>

Furthermore, the increasing interest in the chemistry of five membered heterocyclic molecules and their metal complexes is due to their biological and pharmaceutical importance.<sup>6&7</sup> It was recently reported that complexes of 2-aminothiazole exhibit some significant *in vivo* antitumor activity against P388 leukemia.<sup>8&9</sup> In view of this importance of Schiff bases and thiazoles and in view of our interest in the coordination chemistry of these Lewis bases,<sup>10-12</sup> the present paper deals with the preparation and characterization of ternary complexes of Ni(II) and Cu(II) comprising certain Schiff bases and thiazoles or morpholine.

## EXPERIMENTAL

All solvents and reagents used in this work were of analytical grade. The ligands used in this work were prepared according to reported literature procedures.<sup>13-15</sup> Their names, notations and structures are given in Table 1. The following binary complexes were prepared as described in the literature:<sup>13-16</sup> aqua(o-hydroxyacetophenoneethanoliminato)copper(II) (decomp. point 135°, light blue), aqua(N-salicylidene-o-iminophenolato)nickel(II) (decomp. point 190°, beige), aqua(N-allylidene-o-iminophenolato)copper(II) (decomp. point 210°, green) and bis(N-salicylidene-o-toluidine)copper(II) (decomp. point 297°, yellowish brown). The mixed ligand complexes were prepared as follows:

**Table 1:** Names, notations and structures of the ligands under investigation.

| Names                              | Notation | Structure  |
|------------------------------------|----------|--|
| o-Hydroxyacetophenone-ethanolimine | (OHAE)   |  |
| N-Salicylidene-o-iminophenol       | (SOP)    |  |
| N-Salicylidene-o-toluidine         | (SOT)    |  |

- (i) **Preparation of (o-hydroxyacetophenoneethanoliminato)(2-aminothiazole)copper(II), [Cu(OHAE)(2-Atz)], (o-hydroxyacetophenoneethanoliminato)(benzothiazole)copper(I I), [Cu(OHAE)(Btz)], (o-hydroxyacetophenoneethanoliminato)(3-methyl-2-selenoxobenzothiazole)copper (II), [Cu(OHAE)(3-Msbbtz)] and (o-hydroxyacetophenoneethanoliminato)(thiabendazole)copper (II)monohydrate, [Cu(OHAE)(Tbdz)].H<sub>2</sub>O**

A methanolic solution (50 ml) of [Cu(OHAE)(H<sub>2</sub>O)] (0.012 mol) was mixed with a methanolic solution (20 ml) of 2-aminothiazole (2-Atz), benzothiazole (Btz), 3-methyl-2-selenoxobenzothiazole (3-Msbtz) or thiabendazole (Tbdz) (0.012 mol) with continuous stirring for about 15 minutes. The mixture was then heated under reflux for 3-4 h. The solution was filtered and allowed to cool, whereby brown or green precipitates were obtained. The collected solid chelates were washed with methanol and dried in air.

- (ii) **Preparation of (N-salicylidene-o-iminophenolato)(2-aminothiazole)nickel(II), [Ni(SOP)(2-Atz)], (N-salicylidene-o-iminophenolato)(benzothiazole)nickel (II), [Ni(SOP)(Btz)], (N-salicylidene-o-iminophenolato)(2-methylbenzothiazole)nickel(II), [Ni(SOP)(2-Mbtz)] and (N-salicylidene-o-iminophenolato)-(morpholine)nickel(II), [Ni(SOP)(Morph)]**

A methanolic solution (30 ml) of [Ni(SOP)(H<sub>2</sub>O)] (0.001 mol) was mixed with a methanolic solution (15

ml) of 2-aminothiazole (2-Atz), benzothiazole (Btz), 2-methylbenzothiazole (2-Mbtz) or morpholine (Morph) (0.001 mol), and then the mixtures were heated under reflux for 4-5 h. Upon reduction of the mixture volume and cooling, coloured solids of the ternary complexes separated out, which were filtered and dried in air.

- (iii) **Preparation of (N-salicylidene-o-iminophenolato)(benzothiazole)copper(II), [Cu(SOP)(Btz)]**

A methanolic solution (20 ml) of [Cu(SOP)(H<sub>2</sub>O)] (0.001 mol) was mixed with a methanolic solution (20 ml) of benzothiazole (Btz) (0.001 mol) and the mixture was heated under reflux for 4-5 h. The green product was collected, washed with methanol and air dried.

- (iv) **Preparation of bis(N-salicylidene-o-toluidine)bis-(morpholine) copper(II), [Cu(SOT)<sub>2</sub>(Morph)<sub>2</sub>]**

An ethanolic solution (50 ml) of [Cu(SOT)<sub>2</sub>] (0.001 mol) and an ethanolic solution (20 ml) of morpholine (Morph) (0.002 mol) were mixed in a 1:2 (complex : ligand) ratio. The mixture was refluxed on a water bath (70°) for about 3 h. The solution was filtered and allowed to cool. A pink precipitate was separated, washed with ethanol and finally dried in air.

#### *Physical measurements*

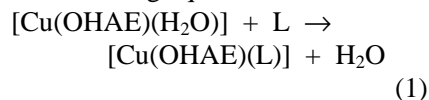
The carbon, hydrogen, nitrogen and sulfur contents of the solid

compounds were determined by Elementar Analysensystem GmbH Vario EL. The infrared spectra of all compounds were recorded on a 470 Shimadzu infrared spectrophotometer (4000-400  $\text{cm}^{-1}$ ) using KBr disks. The electronic absorption spectral measurements in the ultraviolet and visible regions were carried out as nujol mull on a UV-2102 PC Shimadzu spectrophotometer, using 1 cm matched quartz cell in the wavelength range 200-900 nm. The X-ray data were collected at room temperature (25°) on a Philips 1710 diffractometer. The patterns were run with Cu target ( $\lambda = 1.5418 \text{ \AA}$ ) in the range of  $2\theta = 10^\circ - 70^\circ$  with a scanning speed of 6°/min. Magnetic susceptibilities of the compounds were measured at room temperature using a magnetic susceptibility balance of the type MSB-Auto. Molar susceptibilities were corrected for diamagnetism of the component atoms by the use of Pascal's constants. The calibrant used was  $\text{Hg}[\text{Co}(\text{SCN})_4]$ .

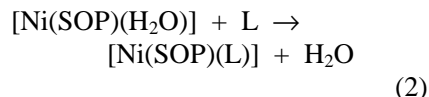
## RESULTS AND DISCUSSION

Binary complexes of Ni(II) and Cu(II) derived from o-hydroxyacetophenoneethanolimine, N-salicylidene-o-iminophenol or N-salicylidene-o-toluidine react readily with 2-aminothiazole (2-Atz), benzothiazole (Btz), 2-methylbenzothiazol (2-Mbtz), 3-methyl-2-selenoxobenzothiazole (3-Msbtz), thiabendazole (Tbdz) and morpholine (Morph) to form the

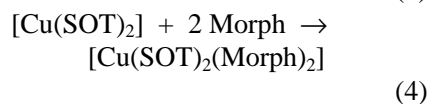
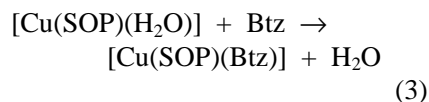
corresponding ternary complexes. The reactions proceed according to the following equations:



where L = (2-Atz), (Btz), (3-Msbtz) or (Tbdz)



where L = (2-Atz), (Btz), (2-Mbtz) or (Morph)



The resulting metal complexes can be divided into two categories according to their stoichiometric ratios, namely 1:1 in the ternary metal complexes  $[\text{Cu}(\text{OHAE})(2\text{-Atz})]$ ,  $[\text{Cu}(\text{OHAE})(\text{Btz})]$ ,  $[\text{Cu}(\text{OHAE})(3\text{-Msbtz})]$ ,  $[\text{Cu}(\text{OHAE})(\text{Tbdz})] \cdot \text{H}_2\text{O}$ ,  $[\text{Ni}(\text{SOP})(2\text{-Atz})]$ ,  $[\text{Ni}(\text{SOP})(\text{Btz})]$ ,  $[\text{Ni}(\text{SOP})(2\text{-Mbtz})]$ ,  $[\text{Ni}(\text{SOP})(\text{Morph})]$  and  $[\text{Cu}(\text{SOP})(\text{Bt})]$  and 1:2 metal complex to ligand in  $[\text{Cu}(\text{SOT})_2(\text{Morph})_2]$ . The complexes are partially soluble in DMF, but sparingly soluble in alcohol, acetone and ether. Elemental analysis, colour and decomposition points of the ternary complexes are tabulated in Table 2.

**Table 2:** Colour, elemental analysis and decomposition points of the mixed ligand complexes.

| Compound                                     | Colour               | C%<br>(calc.)    | H%<br>(calc.)  | N%<br>(calc.)    | S%<br>(calc.)   | Decomp<br>mp/°C |
|--|----------------------|------------------|----------------|------------------|-----------------|-----------------|
| Cu((OHAE)(2-Atz)]                            | Brown                | 46.48<br>(45.80) | 5.26<br>(4.43) | 13.38<br>(12.32) | 10.00<br>(9.40) | 215             |
| [Cu(OHAE)(Btz)]                              | Green                | 55.57<br>(54.31) | 4.31<br>(4.28) | 8.14<br>(7.45)   | 8.92<br>(8.52)  | 216             |
| [Cu(OHAE)(3-Msbtz)]                          | Yellow-<br>ish green | 47.00<br>(46.10) | 4.51<br>(3.86) | 6.43<br>(5.97)   | 7.51<br>(6.83)  | 219             |
| [Cu(OHAE)(Tbdz)].H <sub>2</sub> O            | Light<br>green       | 53.00<br>(52.22) | 4.71<br>(4.38) | 13.00<br>(11.18) | 7.50<br>(6.97)  | 224             |
| [Ni(SOP)(2-Atz)]                             | Brown                | 52.70<br>(51.92) | 4.05<br>(3.54) | 11.76<br>(11.35) | 9.02<br>(8.66)  | >300            |
| [Ni(SOP)(Btz)]                               | Yellow               | 60.00<br>(59.29) | 3.53<br>(3.48) | 7.50<br>(6.94)   | 8.61<br>(7.91)  | >300            |
| Ni(SOP)(2-Mbtz)]                             | Pale<br>yellow       | 61.01<br>(60.17) | 4.04<br>(3.84) | 7.20<br>(6.68)   | 8.10<br>(7.63)  | >300            |
| [Ni(SOP)(Morph)]                             | Deep<br>brown        | 58.08<br>(57.17) | 5.23<br>(5.07) | 8.14<br>(7.87)   | -<br>-          | >300            |
| [Cu(SOP)(Btz)]                               | Green                | 59.23<br>(58.59) | 3.56<br>(3.44) | 7.38<br>(6.83)   | 8.50<br>(7.82)  | >300            |
| [Cu(SOT) <sub>2</sub> (Morph) <sub>2</sub> ] | Pink                 | 67.05<br>(65.65) | 5.03<br>(6.43) | 9.47<br>(8.51)   | -<br>-          | 159             |

### IR spectra

The most important infrared spectral bands that provide the coordination sites in the formed ternary complexes are given in Table 3. The spectra of the ternary complexes display a band associated with a shoulder in the region 1590-1650 cm<sup>-1</sup> that can be attributed to  $\nu(\text{C}=\text{N})$  of the azomethine group and  $\nu(\text{C}=\text{N})$  of the 2-aminothiazole and benzothiazole. The  $\nu(\text{NH}_2)$  of 2-aminothiazole and  $\nu(\text{NH})$  of morpholine are observed in the range of 3190-3370 cm<sup>-1</sup>. A band appearing in the range 1200-1300 cm<sup>-1</sup> is attributed to  $\nu(\text{C}-\text{O})$  phenolic. The thiazole ligands exhibit in general

$\nu(\text{C}-\text{S})$  as a sharp band in the range 650-790 cm<sup>-1</sup>. Comparison of the spectra of the ternary complexes with those of the binary complexes was made. The bands associated with  $\nu(\text{C}=\text{N})$  and  $\nu(\text{C}-\text{O})$  phenolic of the binary complexes are observed in the range 1600-1620 and 1300-1320 cm<sup>-1</sup>, respectively. No significant shifts in the position of these two bands in the ternary complexes could be traced. Metal-nitrogen and metal-oxygen bonding display their absorptions at 460-470 and 480-490 cm<sup>-1</sup>, respectively.<sup>17-20</sup> This is a further evidence for coordination of the metal ions through oxygen and nitrogen atoms of the ligands.

**Table 3:** IR spectral data of the complexes (cm<sup>-1</sup>).

| Compound                                     | v(C=N)            | v(N-H) | v(C-O) | v(C-S) | v(M-O) | v(M-N) |
|--|-------------------|--------|--------|--------|--------|--------|
| Cu((OHAE)(2-Atz)]                            | 1660 s<br>1640 sh | 3290   | 1200 s | 790    | 490    | 470    |
| [Cu(OHAE)(Btz)]                              | 1610 s<br>1620 sh | -      | 1220   | 750    | 490    | 460    |
| [Cu(OHAE)(3-Msbtz)]                          | 1600 s            | -      | 1280   | 740    | 495    | 470    |
| [Cu(OHAE)(Tbdz)].H <sub>2</sub> O            | 1595 s<br>1640 sh | 3300   | 1290   | 743    | 480    | 460    |
| [Ni(SOP)(2-Atz)]                             | 1620 s<br>1650 sh | 3370   | 1300   | 660    | 490    | 470    |
| [Ni(SOP)(Btz)]                               | 1620 s<br>1655 sh | -      | 1290   | 655    | 485    | 475    |
| Ni(SOP)(2-Mbtz)]                             | 1590 s<br>1620 sh | -      | 1295   | 720    | 490    | 476    |
| [Ni(SOP)(Morph)]                             | 1605 s            | 3300   | 1310   | -      | 480    | 460    |
| [Cu(SOP)(Btz)]                               | 1610 s<br>1650 sh | -      | 1300   | 700    | 490    | 465    |
| [Cu(SOT) <sub>2</sub> (Morph) <sub>2</sub> ] | 1610 s            | 3190   | 1200   | -      | 480    | 470    |

s= sharp, sh = shoulder.

### Electronic spectra and magnetic measurements

The electronic spectral data of the ternary complexes in nujol mull are given in Table 4. The absorption spectra of the [Cu(OHAE)(2-Atz)], [Cu(OHAE)(Btz)], [Cu(OHAE)(3-Msbtz)], [Cu(OHAE)(Tbdz)].H<sub>2</sub>O, [Cu(SOP)(Btz)] and [Cu(SOT)<sub>2</sub>(Morph)<sub>2</sub>] ternary complexes are characterized mainly by three absorption bands in region 15,040-38,460 cm<sup>-1</sup>. The broad absorption band in the range 15,040-16,580 cm<sup>-1</sup> is attributed to a d-d transition. The band in the 21,230-25,520 cm<sup>-1</sup> range is assigned to a charge transfer transition.<sup>21&22</sup> Furthermore, the absorption band in the range 28,330-

34,015 cm<sup>-1</sup> is attributed to an intraligand transition.

The electronic spectra of [Ni(SOP)(2-Atz)], [Ni(SOP)(Btz)], [Ni(SOP)(2-Mbtz)] and [Ni(SOP)(Morph)] ternary complexes are recorded as nujol null. The d-d transitions could not be observed in the spectra of these complexes due to charge transfer tailing from UV to visible region, which precluded the assignment of the structure around the Ni(II) ion. The complexes exhibited, however, a band in the range 21,230-25,520 cm<sup>-1</sup>, ascribed to a charge transfer transition.<sup>23</sup> The intraligand transitions are associated with the bands appearing in the ranges 27,470-34,015 and 37,740-38,460 cm<sup>-1</sup>.

**Table 4:** Electronic spectral data of the ternary complexes (cm<sup>-1</sup>).

| Compound                                     | $\nu_{\max}$ (cm <sup>-1</sup> ) | Band assignment                           |
|--|----------------------------------|---|
| Cu((OHAE)(2-Atz)]                            | 15,780                           | d-d transition                            |
|  | 23,100                           | Charge transfer                           |
|  | 28,330                           | Intraligand transition                    |
| [Cu(OHAE)(Btz)]                              | 16,000                           | d-d transition                            |
|  | 24,390                           | Charge transfer                           |
|  | 32,570                           | Intraligand transition                    |
| [Cu(OHAE)(3-Msbtz)]                          | 16,580                           | d-d transition                            |
|  | 24,330                           | Charge transfer                           |
|  | 28,330                           | Intraligand transition                    |
| [Cu(OHAE)(Tbdz)].H <sub>2</sub> O            | 15,040                           | d-d transition                            |
|  | 23,700                           | Charge transfer                           |
|  | 33,440                           | Intraligand transition                    |
| [Ni(SOP)(2-Atz)]                             | 23,750<br>(27,470), (37,590)     | Charge transfer<br>Intraligand transition |
| [Ni(SOP)(Btz)]                               | 23,200<br>(32,470), (37,740)     | Charge transfer<br>Intraligand transition |
| Ni(SOP)(2-Mbtz)]                             | 23,700<br>(33,330), (38,460)     | Charge transfer<br>Intraligand transition |
| [Ni(SOP)(Morph)]                             | 24,940<br>(32,790), (37,740)     | Charge transfer<br>Intraligand transition |
| [Cu(SOP)(Btz)]                               | 15,650                           | d-d transition                            |
|  | 21,230                           | Charge transfer                           |
|  | 33,560                           | Intraligand transition                    |
| [Cu(SOT) <sub>2</sub> (Morph) <sub>2</sub> ] | 16,390                           | d-d transition                            |
|  | 25,520                           | Charge transfer                           |
|  | 34,015                           | Intraligand transition                    |

The above data can be discussed as follows:

- (i) For the copper complexes, the position of their d-d band in the range 15,040-16,580 cm<sup>-1</sup> is found to be similar to that of a d-d band exhibited by analogous imidazole, benzothiazole and benzoxazole complexes.<sup>24&25</sup> This may indicate coordination of the azoles and morpholine in the prepared copper complexes

through the nitrogen atoms. This is further supported from the above mentioned assignment of the IR band in the region 460-470 cm<sup>-1</sup> as  $\nu(\text{Cu-N})$ .

A further confirmation of this coordination site in these complexes comes from a study done by Y. Muto *et al.*<sup>26</sup> on a series of Cu(II) complexes having the general formula [Cu(Ac)<sub>2</sub>L] (where Ac= acetate and L represents some azoles derivatives). It

was reported that in this series the nitrogen atom of the ligand L is most probably the donor atom.

- (ii) A similar coordination mode is expected for the azoles and morpholine in the Ni(II) complexes ( $\nu_{\text{Ni-N}}$ , 460-470  $\text{cm}^{-1}$ , Table 3). Aly *et al.*<sup>10</sup> prepared a number of Ni(II) mixed ligand complexes of alkylxanthate with benzothiazole, benzoxazole and morpholine in which these azoles and morpholine coordinate via the nitrogen atom.

Recently a mixed ligand complex of Co(III)-N,N'-disalicylidene-1,2-phenylenediamine dianion and morpholine was prepared where the latter coordinates through its nitrogen atom. Crystal structure determination confirmed this type of bonding.<sup>27</sup>

The effective magnetic moment values for the investigated Ni(II) complexes are in the range 3.4-3.6 B.M., which may indicate their tetrahedral structure. These values are lower than expected value (4.1 B.M.), probably due to the effect of covalency or distortion from the tetrahedral structure.<sup>28</sup> The Cu(II) complexes display, however, effective magnetic moment values in the range 1.62-1.79 B.M. It is assumed that the

copper complexes adopt a tetragonal geometry which is produced probably through the interaction of the copper in the complexes with adjacent ligands of neighboring complex molecules.

#### X-ray powder diffraction

The compounds [Cu(OHAE)-(Tbdz)].H<sub>2</sub>O, [Ni(SOP)(2-Atz)], [Ni(SOP)(Btz)], [Cu(SOP)(Btz)] and [Cu(SOT)<sub>2</sub>(Morph)<sub>2</sub>] were studied by X-ray powder diffraction. In Table 5, the (d) spacing, (2 $\theta$ ) and the relative intensities of the lines in the powder diffraction pattern of [Cu(OHAE)-(Tbdz)].H<sub>2</sub>O are tabulated. The patterns of the complexes display lines indicating that the complexes are more or less crystalline.

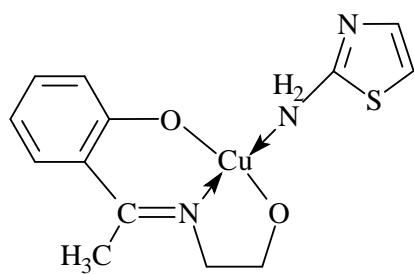
#### Tentative structures

Although it was difficult to assign the structures of the complexes from the electronic spectral data due to the great broadness of the d-d transition band in the copper complexes and the absence of this band in the nickel complexes, the magnetic moment data indicate the tetrahedral structure of the Ni(II) complexes and the tetragonal structure of the Cu(II) complexes. In the following are the tentative structures of the complexes:

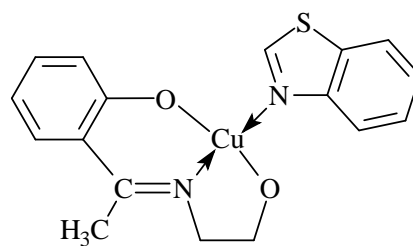


**Table 5:** X-ray powder diffraction data for [Cu(OHAE)(Tbdz)].H<sub>2</sub>O.

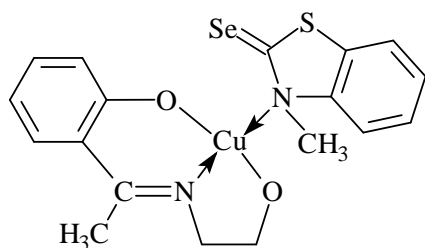
| (2θ)  | (d) spacing | Relative intensity (I/I <sub>0</sub> ) | (2θ)  | (d) spacing | Relative intensity (I/I <sub>0</sub> ) |
|-------|-------------|--|-------|-------------|--|
| 10.52 | 8.409       | 15                                     | 37.85 | 2.377       | 37                                     |
| 11.08 | 7.986       | 17                                     | 38.68 | 2.328       | 23                                     |
| 12.70 | 6.969       | 28                                     | 39.88 | 2.26        | 21                                     |
| 14.84 | 5.969       | 16                                     | 43.08 | 2.1         | 22                                     |
| 16.54 | 5.36        | 52                                     | 44.48 | 2.037       | 27                                     |
| 17.55 | 5.054       | 46                                     | 45.32 | 2.001       | 18                                     |
| 18.24 | 4.863       | 23                                     | 45.52 | 1.993       | 19                                     |
| 21.03 | 4.224       | 100                                    | 46.00 | 1.973       | 20                                     |
| 22.01 | 4.039       | 19                                     | 48.44 | 1.879       | 19                                     |
| 22.64 | 3.927       | 14                                     | 49.0  | 1.858       | 21                                     |
| 23.91 | 3.721       | 27                                     | 50.32 | 1.813       | 19                                     |
| 24.89 | 3.578       | 38                                     | 51.52 | 1.774       | 20                                     |
| 25.52 | 3.49        | 29                                     | 52.56 | 1.74        | 18                                     |
| 26.31 | 3.387       | 59                                     | 55.36 | 1.717       | 19                                     |
| 27.25 | 3.273       | 24                                     | 54.16 | 1.693       | 20                                     |
| 27.72 | 3.218       | 19                                     | 54.56 | 1.682       | 18                                     |
| 28.76 | 3.104       | 19                                     | 54.68 | 1.679       | 19                                     |
| 29.44 | 3.034       | 16                                     | 56.24 | 1.636       | 19                                     |
| 31.84 | 2.81        | 29                                     | 56.64 | 1.625       | 19                                     |
| 32.40 | 2.763       | 19                                     | 60.44 | 1.532       | 19                                     |
| 33.28 | 2.692       | 23                                     | 61.76 | 1.502       | 17                                     |
| 34.24 | 2.619       | 18                                     | 62.36 | 1.489       | 19                                     |
| 35.56 | 2.525       | 23                                     | 62.99 | 1.476       | 22                                     |
| 37.04 | 2.427       | 20                                     | 65.08 | 1.433       | 18                                     |



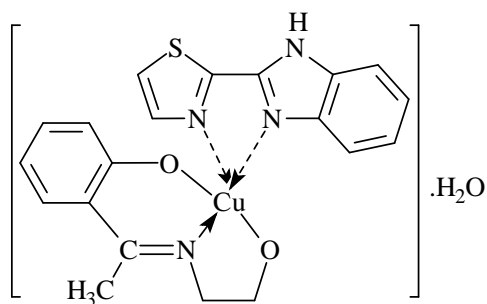
Cu((OHAE)(2-Atz)]



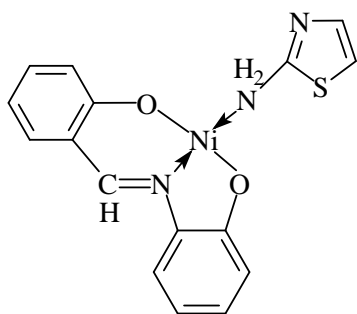
[Cu(OHAE)(Btz)]



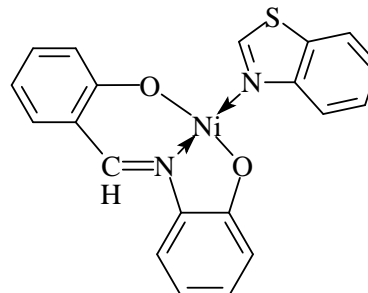
[Cu(OHAE)(3-Msbtz)]



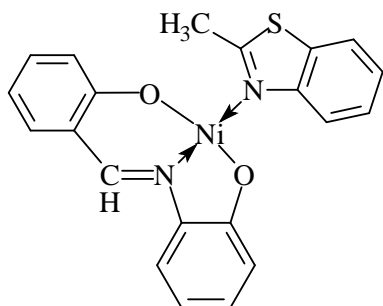
[Cu(OHAE)(Tbdz)].H<sub>2</sub>O



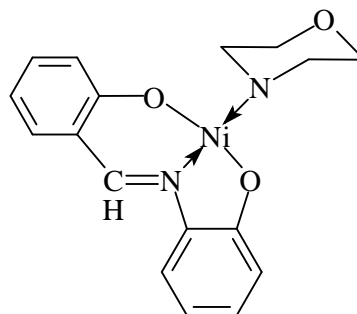
[Ni(SOP)(2-Atz)]



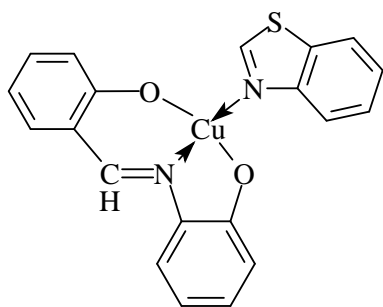
[Ni(SOP)(Btz)]



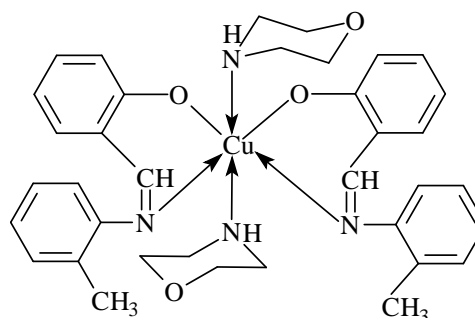
Ni(SOP)(2-Mbtz)]



[Ni(SOP)(Morph)]



[Cu(SOP)(Btz)]



[Cu(SOT)<sub>2</sub>(Morph)<sub>2</sub>]

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