

# Synthesis, Characterization and Biological Evaluation of Copper (ii) Metal Complex with 1,10-Phenanthroline

Akbar Ali Thebo<sup>1</sup>, Noor Ahmad Nahyoon<sup>2</sup>, Shah Nawaz Phulpoto<sup>3</sup>, Azim Khan<sup>4</sup>, Sohail Ahmad Shah<sup>4</sup>, Sajjad Ali<sup>4</sup> and Khalid H Thebo<sup>4\*</sup>

<sup>1</sup>National Center for Nanoscience and Technology (NCNST), Chinese Academy of Sciences (CAS), China

<sup>2</sup>School of Environmental Science & Technology, Dalian University of Technology, China

<sup>3</sup>College of Material Science & Engineering, Beijing University of Chemical Technology, China

<sup>4</sup>Institute of Metal Research, Chinese Academy of Science, China

**Submission:** March 08, 2017; **Published:** March 27, 2017

\*Corresponding author: Khalid H Thebo, Institute of Metal Research, Chinese Academy of Science, 110016 PR China, Tel: 13041129276; Email: khalidthebo@yahoo.com

## Abstract

Novel copper(II) complex,  $[\text{Cu}(\text{phen})_2(\text{OH})_2(\text{NO}_3)_2]$  (1) (where phen = 1,10-phenanthroline) have been synthesized and characterized by elemental analysis, FTIR, EPR, thermo gravimetric analysis, X-ray crystallography and biological activity. Crystal structure determination reveals that complexes (1) possess a neutral monomeric structure. In complex (1), five atoms (N and O) are coordinated with copper (II) ion to form distorted square pyramid structure. Amongst five coordinating atoms, four are nitrogen atoms from two 1,10-phenanthroline moieties and one oxygen atom. The thermal decomposition of the complex (1) under an inert atmosphere has also been studied. Furthermore the complex (1) was screened for their anti-microbial activity, and antifungal cytotoxicity. Antibacterial and antifungal results indicate that the metal complexes are more active than the ligand.

**Keywords:** Copper(II) complex; X-ray diffraction; Crystal structure; Cytotoxicity; Anti-microbial activity

## Introduction

Transition metal complexes have been extensively studied due to their potential applications in biological processes [1-3], catalysis [4], molecular reorganization, host-guest chemistry, photochemistry, analytical chemistry and magneto-chemistry [5-9]. Among transition metals, copper has its own unique identification due its coordinating ability with various ligands to form variety of geometrical structures such as square planar, square pyramidal, distorted square pyramidal, octahedral. The copper (II) complexes have also been investigated against a variety of bacterial, fungal as well as viral strains and showed profound activities against various diseases [10-12].

The copper complexes with N-donor ligands have proven to be active catalysts for the hydrolysis of phosphate ester [13], synthesis of crown ester [14], catenates and catenands [15] for formation of macromolecules [16]. Both 1,10-phenanthroline and 2,2'-bipyridine are attractive building blocks that are incorporated with various transition metals to form complexes. Both nitrogen

atoms in each ligand are ideally placed for cooperative binding with many metal cations. In addition, metal complexes of these two ligands are frequently employed for catalytic reactions. The metal ion complexes with 1,10-phenanthroline have been used as catalyst for various organic reactions such as the enantioselective hydrolysis of N-protected amino acid [17], for the oxidative cleavage of DNA [18], in palladium catalyzed allylic substitution [19] and enantioselective reduction of acetophenone [20]. Similarly, 2,2'-bipyridine have also been employed in the enantioselective alkylation of aldehydes [21], in the enantioselective hydrosilylation of ketone [22], in asymmetric alkylation of reaction [23] and as herbicides [24].

In continuation of our previous work on copper(II) complex of various chelates such as 1,10-phenanthroline, 2,2'-bipyridine, succinate and malonate [1,25-27], we are here in reporting another copper(II) complexes synthesized from 1,10-phenanthroline,  $[\text{Cu}(\text{phen})_2(\text{H}_2\text{O})_2(\text{NO}_3)_2]$  (1). The

synthesized compound was characterized by elemental analysis, IR spectra, EPR analysis, thermo gravimetric analysis and X-ray crystallography. The thermal decomposition of the complex (1) under an inert atmosphere has also been studied. Furthermore the complex (1) was initially screened for their anti-microbial activity, and antifungal cytotoxicity. As it showed good cytotoxicity, therefore it was also screened for in vitro cytotoxic activity in human cell lines and the results show a moderate level of cytotoxicity against these human cancer cell lines, comparable to that of the less active standard chemotherapeutic drugs used for comparison.

## Experimental

### Materials and Methods

All the reagents and solvents used for the synthesis and analysis were of analytical grades and used without further purification. Elemental analyses were carried out with CHNS/O Analyzer (Thermo Scientific Flash 2000 Organic Elemental Analyzer). The copper analysis was carried out by Fisons Horizon Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). Melting points were determined using a Gallenkamp melting point apparatus. Infrared spectra were recorded on FTIR Bio-RAD Merlin (Varian) FTIR spectrometer in the range of 4000–200 cm<sup>-1</sup>. Perkin- Elmer and Seiko thermal analyzer was used to obtain thermo gravimetric analysis (TGA).

### Synthesis of [Cu(phen)<sub>2</sub>(OH<sub>2</sub>)(NO<sub>3</sub>)<sub>2</sub>] (1)

An hot aqueous solution (25 ml) of dipotassium oxalate (0.24 g, 1.0 mmole) was added drop wise to the hot aqueous solution (25 ml) of copper(II) nitrate tri-hydrate (0.24 g, 1.0 mmole) followed by addition of 1,10-phenanthroline (0.54 g, 3.0 mmole) in ethanol (25 ml) to the resulting mixture. The mixture was stirred for 01 hour. The resulting blue solution was filtered and allowed to stand at room temperature for six months. The green crystals of compound (1) were obtained. The crystals were suitable for X-ray analysis. Yield = 76%; Elemental analysis: Calculated for C<sub>16</sub>H<sub>24</sub>CuN<sub>6</sub>O<sub>7</sub>: C, 51.1; H, 3.2; N, 15.0; Cu, 11.4%. Found: C, 50.9; H, 2.9; N, 14.8; Cu, 11.3 %. Main IR bands (ATAR): ν(O-H), 3058(m); (C=C), 1428(vs), 1307(vs); (C-H), 655(vs), 616.47(s); (C=N), 735(vs); (C-N), 1380(m); (Cu-N), 445(vs).

### Crystal structure analysis

Single-crystal X-ray diffraction data of the complexes (1) was collected through AXS SMART APEX (Bruker) diffractometer equipped with graphite crystal monochromator, using Mo-K $\alpha$  radiation ( $\lambda = 0.71073 \text{ \AA}$ ) at 100(2) K. Unit cell dimensions were obtained by least-squares refinement based on the setting angles of 935 reflections with theta ( $\theta$ ) angles ranging from 2.65° to 20.50°. The structures were solved by direct method and refined by full-matrix least-square on F<sup>2</sup> (SHELX97) [28-29]. All non-hydrogen atoms were refined with anisotropic atomic displacement parameters. Hydrogen atoms were placed in calculated positions, assigned by isotropic atoms.

Crystallographic details and selected interatomic distances and angles are given in Tables 1 & 2.

**Table 1:** Crystal data and structural refinement parameters of complex (1).

Parameters	Complex (1)
Empirical formula	C <sub>24</sub> H <sub>16</sub> CuN <sub>6</sub> O <sub>7</sub>
Formula weight	563.97
Temperature	100(2) K
Wavelength	0.71073 Å
Crystal system, space group	Triclinic, P-1
Unit cell dimensions	a = 7.065(2) Å $\alpha$ =78.010° b = 11.758(3) Å $\beta$ =79.846° c = 14.256(4) Å $\gamma$ =73.750°
Volume	1103.3 (5) Å <sup>3</sup>
Z, Calculated density	2, 1.698 Mg/m <sup>3</sup>
Absorption coefficient	1,053 mm <sup>-1</sup>
F(000)	574
Crystal size	0.30 x 0.20 x 0.10 mm
Theta range for data collection	1.47 to 26.37 deg.
Limiting indices	-8<=h<=8, -14<=k<=14, -13<=l<=17
Reflections collected / unique	6351 / 4386
[R (int) = 0.0582]	
Completeness to theta = 20.82	98.2 %
Max. and min. transmission	0.9020 and 0.7429
Refinement method	Full-matrix least-squares on F <sup>2</sup>
Data / restraints / parameters	4386 / 6 / 343
Goodness-of-fit on F <sup>2</sup>	0.944
Final R indices [I>2sigma(I)]	R <sub>1</sub> = 0.0788, wR <sub>2</sub> = 0.1846
R indices (all data)	R <sub>1</sub> = 0.1246, wR <sub>2</sub> = 0.2036
Largest diff. peak and hole	2.476 and -0.484 e.Å <sup>-3</sup>

**Table 2:** Selected bond lengths [Å] and angles [deg] in complex (1).

u(1)-N(1)	2.018(6)	Cu(1)-N(2)	2.023(6)
Cu(1)-N(3)	2.023(6)	Cu(1)-N(4)	1.998(6)
Cu(1)-O(1)	2.174(6)	N(4)-Cu(1)-N(3)	82.1(2)
N(4)-Cu(1)-N(1)	171.7 (3)	N(2)-Cu(1)-O(1)	103.6(2)
N(1)-Cu(1)-N(3)	100.0(2)	N(4)-Cu(1)-N(2)	100.0(2)
N(1)-Cu(1)-N(2)	83.1 (2)	N(3)-Cu(1)-N(2)	143.4(2)
N(4)-Cu(1)-O(1)	186.4 (2)	N(1)-Cu(1)-N(1)	85.4(2)
	N(3)-Cu(1)-O(1)	112.9(2)	

## Results and Discussion

### X-ray crystal structure of complex (1)

The monomeric molecular structure of complex (1) is shown in Figure 1. The crystallographic data and selected bond lengths and bond angles are given in Tables 1 & 2 respectively. The crystals of compound (1) consist of a packing of monomeric

molecule. The X-ray structure analysis shows that copper atom is five-coordinated in a distorted square pyramidal environment. Four of the coordinated atoms are nitrogen atoms (N1, N2, N3, N4) from two chelating 1,10-phenanthroline groups (Cu-N(1) = 2.018(6) Å, Cu-N(2) = 2.023(6) Å, Cu(1)-N(3) = 2.023(6) Å, Cu-N(4) = 1.998(6) Å, and it is noteworthy that one oxygen atom is the same side of plane with copper(II) ion and bonded at distance of 2.174(6) Å. All the nitrogen atoms are almost at equal distances.

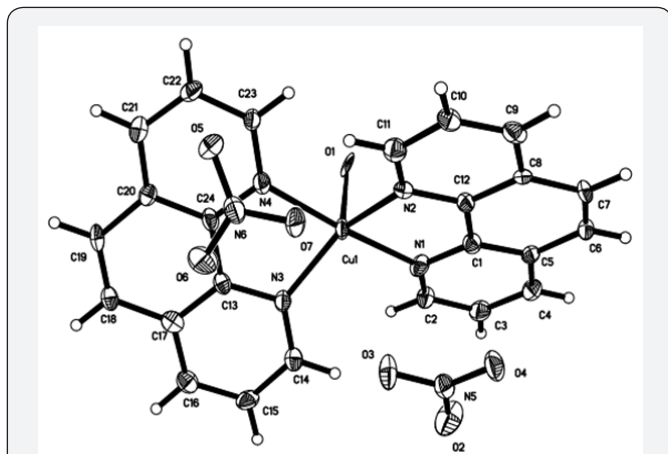


Figure 1: X-ray single crystal structure of compound (1).

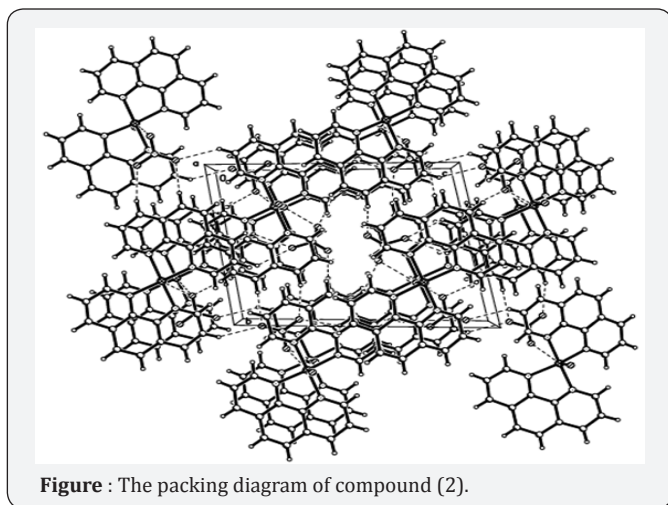


Figure : The packing diagram of compound (2).

The molecular packing diagram (Figure 2) for compound (1) shows that the complex is of triclinic geometry. The units are connected in a packing diagram through a hydrogen bonding. The oxygen atoms of nitrate ion are bonded with hydrogen atoms of 1,10-phenanthroline molecule. Very weak interaction between the copper atom and oxygen atom of nitrate ion has been observed.

### General Characterization

The Infrared spectrum of the complex (1) exhibits several characteristic strong bands. The strong bands at 1428, 1307, 919 and 735  $\text{cm}^{-1}$  are due to C=C and C=N stretching vibrations of the coordinated 1,10-phenanthroline molecules. The

spectrum shows a wide range of bands below 500  $\text{cm}^{-1}$ , which may be considered to 1,10-phenanthroline ligand, but it seems reasonable to assign the very sharp band at 445(s)  $\text{cm}^{-1}$  as a copper-nitrogen stretching mode. The spectrum of complex (1) shows a single strong band at 3057  $\text{cm}^{-1}$  which may be due to the O-H vibration of water molecule (Table 3).

Table 3: Important IR bands ( $\text{cm}^{-1}$ ) Observed for complex (1).

OH	3465(b)	(C=C)s 1428(s)
NH	3362(m)	$\text{ClO}_4^-$ 1112(m)
(COO)as	1653(vs)	(C=N)s 817(s)
(COO)s 1463(s)		

(b) = Broad; (m) = Medium; (s) = Strong; (vs) = Very Strong; as = Asymmetric and s = Symmetric

Thermal decomposition of several copper (II) complexes containing phen and bipy and a dicarboxylic acid or amino acids have been studied [30-31]. The thermal decomposition of complex (1) was carried up to 600°C at the rate of 5°C/minute. The decomposition of complex completed in two steps mass loss process before 450°C and the first step between 80-200°C corresponds to the endothermic elimination of water molecules. The loss of water molecule occurs at a significantly higher temperature. This suggests that the coordinated water molecule is held more tightly to the metal centre, consistent with the relative magnitude of the Cu-O bond distances of 2.174 Å. The experimental mass loss of 3.4% agrees well with the calculated mass loss of 3.2%. The degradation of phen ligand takes place in second step at 250-450°C range and copper obtained as the final product at 450°C (Weight loss: found 44.0%; calculated 44.0%). The residue product of complexes (1) was further confirmed by XRD.

The compounds were also analyzed by electron spinning resonance (ESR) and observed g value for the crystalline samples lie in the range 2.07-2.35. The x-band spectra of compound (1) shows a broad band isotropic signal that is clearly resolved in the Q-band towards an axial-type spectra with g-tensor values of  $g_{\parallel} = 2.27$ ,  $g_{\perp} = 2.05$ . The axial spectrum is consistent with elongated octahedral geometry of the copper (II) chromophore found in the structural work.

### Biological Assays

#### *In vitro* antibacterial activity

Antibacterial screening of the synthesized compound (1) was carried out by using four bacterial strains two gram positive *Staphylococcus aureus* (ATCC 6538), *Micrococcus luteus* (ATCC 10240) and two Gram negative, *Escherichia coli* (ATCC 15224), *Salmonella setubal* (ATCC 19196). Cefixime and roxithromycine were used as standard antibiotics. Agar well diffusion method was applied as experiment was performed in triplicates readings of the zones of inhibition represent the mean value of the three readings with standard deviation [STDEV]. Activity was

determined based on the zones of the inhibition (mm). Zone more than 12 mm is considered significant activity, 10-12 mm good activity, 7-9 mm low, and below 7 mm non significant activity. The results revealed that ligand showed good activity against *M. leuteus*, *S. setubal*, and *S. aureus*, while its Cu complex did not show any activity. MIC values were calculated ranging from (1-0.4mg/ml). while as-prepared compound does not showed activity against *E.coli*. Observations of the results showed that *Phen* ligands did not show antibacterial activity (Table 4).

**Table 4:** *In vitro* antibacterial activity of synthesized complex (1) and standard drug.

Compound Codes	% Zone of Inhibition of Samples (mm)			
	M. Leuteus	E.Coli	1S. setubal	2S. Aureus
Complex (1)	10.8+ 0.163 1mg/ml	Nil	7.45+0.040 1mg/ml	9.5+ 0.40 1mg/ml

Conc. of the standard drug "Imipenem" = 10 µg/disc. Concentration of sample = 3 mg/mL (Stock solution) and 10 µg/disc

### Antifungal Activity

As prepared compound (1) was subjected to antifungal assay by using Agar tube dilution method against four fungal strains i.e. *Mucor species*, *Aspergillus niger*, *Aspergillus flavus*, and *Fusarium solani*. In this assay terbinafine was used as standard drug (Table 5). Activity was investigated on the basis of percent growth inhibition; inhibition more than 70% is considered significant activity, 60-70% inhibition good, 50-60% inhibition, moderate, below 50% inhibition, non-significant. Results show that complex (1) showed good activities against *Mucor*, *A. niger*, and *F. solani*.

**Table 5:** Antifungal activity of complexes (1).

Compound	%age inhibition in linear growth			
	<i>A.niger</i> .	<i>F.solani</i>	<i>Mucars</i>	<i>A. flaves</i>
Compound (1)	34.1	67.7	42.26	11.2
Linear length in -ve control	45	25	9	90

Standard drug = Terbinafine; Concentration of drug = 200 µg/mL. Concentration of tested compounds = 200 µg/mL.

### Conclusion

In summary, this work describes the preparation, crystals structures, spectroscopic characterization, thermal decomposition studies of copper (II) complexes containing *N*-donor ligands. The structures of complexes (1) consist of a packing of monomeric molecules. In complex (1) copper (II) is five-coordinated in a distorted square pyramidal environment. Four of the coordinated atoms are nitrogen atoms from two 1,10-phenanthroline molecules and one oxygen atom from water molecule. The complex (1) was initially screened for their antimicrobial activity, and antifungal cytotoxicity. As it showed good cytotoxicity, therefore it was also screened for *in vitro* cytotoxic

activity in human cell lines and the results show a moderate level of cytotoxicity against these human cancer cell lines, comparable to that of the less active standard chemotherapeutic drugs used for comparison.

### Acknowledgement

Authors are grateful to Government of Pakistan for the financial assistance and School of Chemistry, The University of Manchester, UK, for providing us the research facilities.

### Reference

- Hazoor A Shad, KH Thebo, MA Malik, M Helliwell (2011) Synthesis, characterization and X-ray diffraction of [Cu(malonate)(phen)<sub>2</sub>]<sub>2</sub>·17H<sub>2</sub>O complex. J Mol Structure 1001(1-3): 12-15.
- P O'Brien (1981) Reactivity of co-ordination compounds in the solid state. Part1. Mixed-ligand complexes of oxalate and 2,2'-bipyridyl with copper(II), their preparation, interconversion, and novel solid-state reactivity. J Chem Soc Dalton Trans 7: 1540-1543.
- A Bencini, MD Vaira, AC Fabretti, D Gatteschi, C Zanchini (1985) J Inorg Chem 26: 1620.
- O Castillo, A Luque, P Roman (2001) Synthesis, chemical characterization and crystal structure of the (oxalato-0,0')bis(1,10-phenanthroline)copper(II) pentahydrate. J Mol Structure 570: 181-188.
- D Venkataraman, GB Gardner, S Lee, JS Moore (1995) Zeolite-like Behavior of a Coordination Network. J Am Chem Soc 117(46): 11600.
- A Hauser, ME Von Arx, R Pellau, S Decurtins (1996) Photophysical and Photochemical Properties of Three-Dimensional Metal-Tris-Oxalate Network Structures. Mol Cryst Liq Cryst 286: 225-230.
- JY Baeg, SW Lee (2003) A porous, two-dimensional copper coordination-polymer containing guest molecules: hydrothermal synthesis, structure, and thermal property of [Cu(BDC)(bipy)](BDCH<sub>2</sub>) (BDC=1,4-benzenedicarboxylate; bipy=4,4'-bipyridine). Inorg Chem Commun 6(3): 313-316.
- En-Qing Gao, Dai-Zheng Liao, Zong-Hui Jiang, Shi-Ping Yan (2001) Synthesis, crystal structure and magnetic properties of novel copper(II)-nickel(II) complexes of macrocyclic oxamides. Polyhedron 20: 923-957.
- P O'Brien, C Stafford, LC Young (1988) Isomerism of mixed ligand copper(II) complexes containing 1,10-phenanthroline and oxalate. J Inorg Chim Acta 147: 3-4.
- P O'Brien (1980) Complexes of copper(II) with oxalate and 2,2'-bipyridyl: Preparation and interconversion in the solid state. Trans Met Chem 5: 314-315.
- M Afzal, E Flynn, MA Malik, P O'Brien, M Motevalli (2005) Mixed ligand chelates of copper(II) with substituted diamines. Polyhedron 24(9):1101-1107.
- International Tables for X-ray crystallography (1974) Kynoch press, Birmingham.
- BW Delf, RD Gillard, P O'Brien (1979) J Chem Soc Dalton Trans 1301-1305.
- ZH Chohan, Hazoor A Shad (2008) Structural elucidation and biological significance of 2-hydroxy-1-naphthaldehyde derived sulfonamides and their first row d-transition metal chelates. J Enz Inhib Med Chem 23(3): 369-378.
- ZH Chohan, Hazoor A Shad FH (2009) Synthesis, characterization and biological properties of sulfonamide-derived compounds and their transition metal complexes. Nasim Appl Organomet Chem 23(8): 319-328.

16. T Itoh, H Hisada, Y Usui, Y Fujii (1998) Hydrolysis of phosphate esters catalyzed by copper(II)-triamine complexes. The effect of triamine ligands on the reactivity of the copper(II) catalysts. *Inorganica Chimica Acta* 283: 51-60.
17. U Leuning, M Muller, M Gerbert, Petrs, et al. (1994) *M Chem Ber* 127: 2297.
18. KE Krakowiak, JS Bradshaw, Dalley, N K Wu, RM Izatt (1991) Preparation and structural properties of large-cavity peraza macrocycles containing pyridine, phenanthroline, or piperazine subcyclic units. *J Org Chem* 56: 2675-2680.
19. GR Newkome, S Pappalardo, VK Gupta, FR Fronczek (1983) Synthesis and structural aspects of macrocyclic polyamines containing 2,2'-bipyridinyl units(s). *J Org Chem* 48: 4848-4851.
20. COD Buchecker, C Hammert, AK Khemiss, JP Sauvage (1990) Synthesis of dicopper [3]-catenates and [3]-catenands by acetylenic oxidative coupling. Preparation and study of corresponding homodimetallic [3]-catenates [silver(1+), zinc(2+), cobalt(2+), and nickel(2+)]. *J Am Chem Soc* 112: 8002-8003.
21. J Sulk, SH Lee (1998) Catenands Built on Poly(ethylenimine). Attachment of Two Phenanthrolines in Close Proximity on the Polymer Backbone. *J Org Chem* 63(5): 1519-1526.
22. M Garcia, FJR Salguero, DM Bassani, JM Lehn, D. Fenske (1999) Self-Assembly and Characterization of Multimetallic Grid-Type Lead(II) Complexes. *J Chem Eur* 5(6): 1803-1808.
23. AJ Blake, SJ Hill, P Hubberstey, WS Li (1997) Rectangular grid two-dimensional sheets of copper(II) bridged by both co-ordinated and hydrogen bonded 4,4'-bipyridine(4,4'-bipy) in [Cu( $\mu$ -4,4'-bipy)(H<sub>2</sub>O)<sub>2</sub>(FBF<sub>3</sub>)<sub>2</sub>]-4,4'-bipy. *J Chem Soc Dalton Trans* 913-914.
24. PNW Baxter (2000) A Synthesis of Conjugatively Bridged Bis- and Tris-5-(2,2'-Bipyridines): Multitopic Metal Ion-Binding Modules for Supramolecular Nanoengineering. *J Org Chem* 65(5): 1257-1872.
25. JGJ Weijinen, A Koudijs, JFJ Engbersen (1992) Synthesis of chiral 1,10-phenanthroline ligands and the activity of metal-ion complexes in the enantioselective hydrolysis of N-protected amino acid esters. *J Org Chem* 57(26): 7258-7265.
26. DS Siegman (1990) Immunoprecipitation of adenylate cyclase with an antibody to a carboxyl-terminal peptide from Gs.alpha. *Biochemistry* 29(38): 9079-9084.
27. EP Cabrera, PONorrby, M Sjogren, A Vitagliano, VD Felice, et al. (1996) Molecular Mechanics Predictions and Experimental Testing of Asymmetric Palladium-Catalyzed Allylation Reactions Using New Chiral Phenanthroline Ligands. *J Am Chem Soc* 118(18): 4299-4313.
28. S Gladiali, G Chelucci, F Soccolini (1989) Optically active phenanthrolines in asymmetric catalysis: II. Enantioselective transfer hydrogenation of acetophenone by rhodium/alkyl phenanthroline catalysts. *J Organomet Chem* 370: 285-294.
29. S Gladiali, L Pinna, G Delogu, S De martin, G Zassinovich, G Mestroni (1990) Optically active phenanthrolines in asymmetric catalysis. III. Highly efficient enantioselective transfer hydrogenation of acetophenone by chiral rhodium/3-alkyl phenanthroline catalysts. *Tetrahedron: Asymmetry*, 1: 635-648.
30. C Bolm, G Schlingloff, K Harms (1992) Catalyzed Enantioselective Alkylation of Aldehydes. *Chem Ber* 125(5): 1191-1203.
31. C Bolm, M Zehender, D Bur, Angew (1990) Optically Active Bipyridines in Asymmetric Catalysis. *Chem Int Ed Engl* 29(2): 205-207.
32. H Nishiyama, S Yamaguchi, S Park (1993) New chiral bis (oxazolonyl) bipyridine ligand (bipymox): Enantioselection in the asymmetric hydrosilylation of ketones. *Tetrahedron: Asymmetry* 4:143-150.
33. HL Kwong, KM Lau, WS Lee, WT Wrong (1999) Chiral zinc(II) bipyridine complex. Crystal structure and catalytic activity in asymmetric allylation reaction. *New J Chem* 23: 629-632.
34. LA Summers (1980) *The Pryridinium Herbicides*; Academic Press: London. Uk.
35. Khalid H Thebo, Hazoor A Shad, Mohammad A Malik, Madeleine Helliwell (2010) Synthesis, characterization and crystal structure of copper(II) complex of succinate and 2,2'-bipyridyl. *Journal of Molecular Structure* 970: 75-78.
36. Hazoor A Shad, Khalid H Thebo, Zafar H Ibupoto Mohammad, A Malik, Paul O'brien (2011) Synthesis, characterization, and crystal structure of a copper(II) complex of 1,10-phenanthroline and succinate. *Journal of Coordination Chemistry* 64(13): 2353-2360.
37. V G Kohn, N V Tsvigun (2014) Computer simulation of images of photonic crystals for hard X rays in a transmission scheme. *Near field. Crystallography Reports* 59: 1-5.
38. Sheldrick, GM SHELXL97, SHELXS 97 (1997) University of Gottingen, Germany.
39. Bruker, SHELXTL (2000) Version 6.10 Bruker AXS Inc. Madison, Wisconsin, USA.
40. KH Thebo, Hazoor A Shad, MA Malik, M Helliwell (2010) Synthesis, characterization and crystal structure of copper(II) complex of succinate and 2,2'-bipyridyl. *J Mol Structure* 970: 75-78.
41. WL kwick, KP Ang, HSO Chan (1986) Thermal, spectroscopic, and structural properties of aqua(malonato-0,0')(1,10-phenanthroline) copper(II) hydrate (1/1.5). *J Chem Soc Dalton Trans* Pp: 2519-2523.



This work is licensed under Creative Commons Attribution 4.0 License  
 DOI: [10.19080/OMCIJ.2017.02.555578](https://doi.org/10.19080/OMCIJ.2017.02.555578)

Your next submission with Juniper Publishers  
 will reach you the below assets

- Quality Editorial service
- Swift Peer Review
- Reprints availability
- E-prints Service
- Manuscript Podcast for convenient understanding
- Global attainment for your research
- Manuscript accessibility in different formats  
 ( Pdf, E-pub, Full Text, Audio)
- Unceasing customer service

Track the below URL for one-step submission

<https://juniperpublishers.com/online-submission.php>