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Design, Synthesis, Spectral Characterization, DNA Binding and Antibacterial Studies of Ternary Metal Complexes with 1,10 Phenanthroline and 2-Acetylthiophene-4-phenyl-3-thiosemicarbazone

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Abstract

Bivalent metal complexes having the composition $M(Phen)Cl_2$ (where, M = Cu(II), Ni(II) and Co(II); Phen = 1,10-Phenonthroline) are reacted with 2-acetylthiophene-4-phenyl-3-thiosemicarbazone (ATPT) to produce ternary complexes with molecular formula $[M(Phen)(ATPT)Cl_2]$ H_2O. The complexes are characterized using physical (molar conductivity) and spectral (mass spectra, infrared and electronic spectroscopies) methods. Electrochemical behavior of complexes was uncovered using cyclic voltammetry. DNA binding properties of the complexes are determined by using absorption UV-Visible spectrophotometry. Metal complexes are screened for their antibacterial activity by using agar well diffusion method against pathogenic bacterial strains viz. Gram–ve such as *Escherichia coli*, *Klebsiella Pneumonia* and Gram+ve such as *Staphylococcus aureus*, *Bacillus cereus*. The $[Ni (Phen)(ATPT)Cl_2]$ 0.5 H_2O complex inhibits bacteria more stronger than any other complex.

Keywords: 2-Acetylthiophene-4-phenyl-3-thiosemicarbazone, Ternary transition metal complexes, Cyclic voltammetry, DNA binding, Antibacterial activity

Introduction

Sulphur has been used in a medicinal context since antiquity. It is one of the earliest known elements and was known to the Greeks to have healing power. Magnesium sulphate was the 1st sulphur-containing compound approved by the Food and Drug Administration (FDA), and sulphur-containing compounds were the hallmarks of several antibiotic breakthroughs that brought man into the modern antibiotic era. Several Nobel Prizes have been awarded for work done on sulphur-containing drugs. Sulphur containing compounds continue to represent a large portion of new FDA approvals.

Thiosemicarbazones are important class of sulphur containing ligands for the synthesis and characterization of transition metal complexes [1,2]. These ligands are extensively used as chromogenic reagents for the spectrophotometric determination of transition metal ions [3]. Transition metal complexes with heterocyclic thiosemicarbazones are expected to exhibit interesting stereochemical, electrochemical, and electronic properties [4,5]. Metal complexes of Phenanthroline (Phen) are known to function as potential anti-tumor agents [6].

Recently, mixed ligand metal complexes with Schiff bases as a main ligand Phen as a co-ligand are reviewed [7]. But no report is available in the literature [8-10] on mixed ligand metal complexes with Phen and 2-Acetylthiophene-4-phenyl-3-thiosemicarbazone(ATPT). The ligand was synthesized, characterized [11,12] and was used in our laboratory for the spectrophotometric determination of copper(II) in alloys, edible oils and seeds [13]. However, transition metal complexes with Phen as primary ligand and thiosemicarbazone as secondary ligand are not investigated so far [14].

Mixed ligand complexes of biologically important compounds may serve as models for biochemical processes [15,16]. We have studied [17-19] deoxyribonucleic acid binding and antibacterial activity of various transition metal complexes recently to develop antimicrobial agents. To renew our interests, herein we communicate our results on spectral characterization, DNA Binding and Antibacterial activity studies of ternary metal complexes with Phen and ATPT. The main objective of this work is to bring correlation between DNA binding and bacteria inhibition of complexes.

Materials and methods

4-phehyl-3-thiosemicarbazide, 2-Acetylthiophene and Phen, were purchased from Sigma-Aldrich. Elemental analyses were carried out on a Heraeus Vario EL III Carlo Erba 1108 instrument. Molar conductivity measurements at 298 ± 2K in dry and purified DMF were carried out using a CM model 162 conductivity cell (ELICO). ESR spectra were recorded on a Varian E-112 X-band spectrophotometer at room temperature (RT) and liquid nitrogen temperature (LNT) in solution (DMF) state. Cyclic voltammetric measurements were taken on degassed (N_2 bubbling for 5 min) solutions (10^{-3} M) containing 0.1 M Bu_4NPF_6 as the supporting electrolyte.

Preparation of ATPT

The ligand, ATPT was prepared using 4-pheyl-3-thiosemicarbazide and 2-Acetylthiophene. Ethanolic solutions of 4-phenyl-3-thiosemicarbazide (5 mmol), and 2-Acetylthiophene (5 mmol) were combined in a round bottom flask. Two drops of CH_3COOH were added and the reaction mixture was refluxed for 3 h and cooled to room temperature. The compound was obtained as shiny milk white crystalline product, which was subsequently used in the synthesis of metal complexes. Yield 83 %, M. Pt. 180 - 182 ºC, IR spectra (cm^{-1}) 3297, 1589. 1194 cm^{-1} are assigned to ν (N-H asym), ν (> C = N) and ν (> C = S) stretching vibrations respectively. NMR spectra (δ, in ppm) 9.31 (singlet 1H), 8.70 (singlet 1H), 7.25 - 7.44 (multiplet 5H), 7.71 (doublet 3H), 7.06 (doublet of doublet 3H), 2.34 (singlet 3H) are assigned to > NH, phenyl, thiophene H and CH_3 protons respectively. In the mass spectrum of ATPT, the molecular ion peak value coincides with its formula weight, 275. Mass spectrum of ATPT ligand is shown in **Figure 1**.

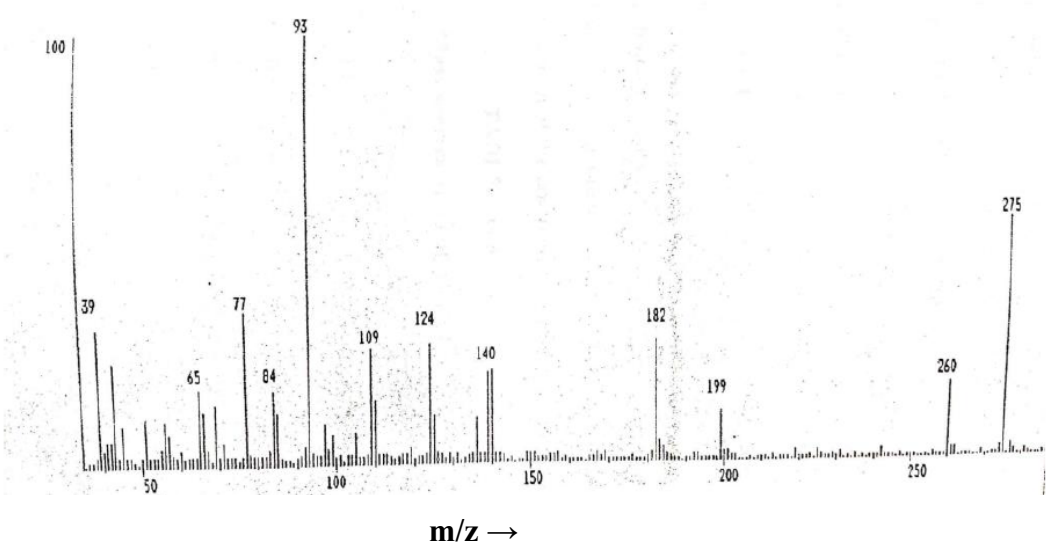


Figure 1 Mass spectrum of ATPT ligand.

Based on the positions of peaks (**m/z values**) in the mass spectrum, fragmentation of pattern of ATPT is shown in **Figure 2**.

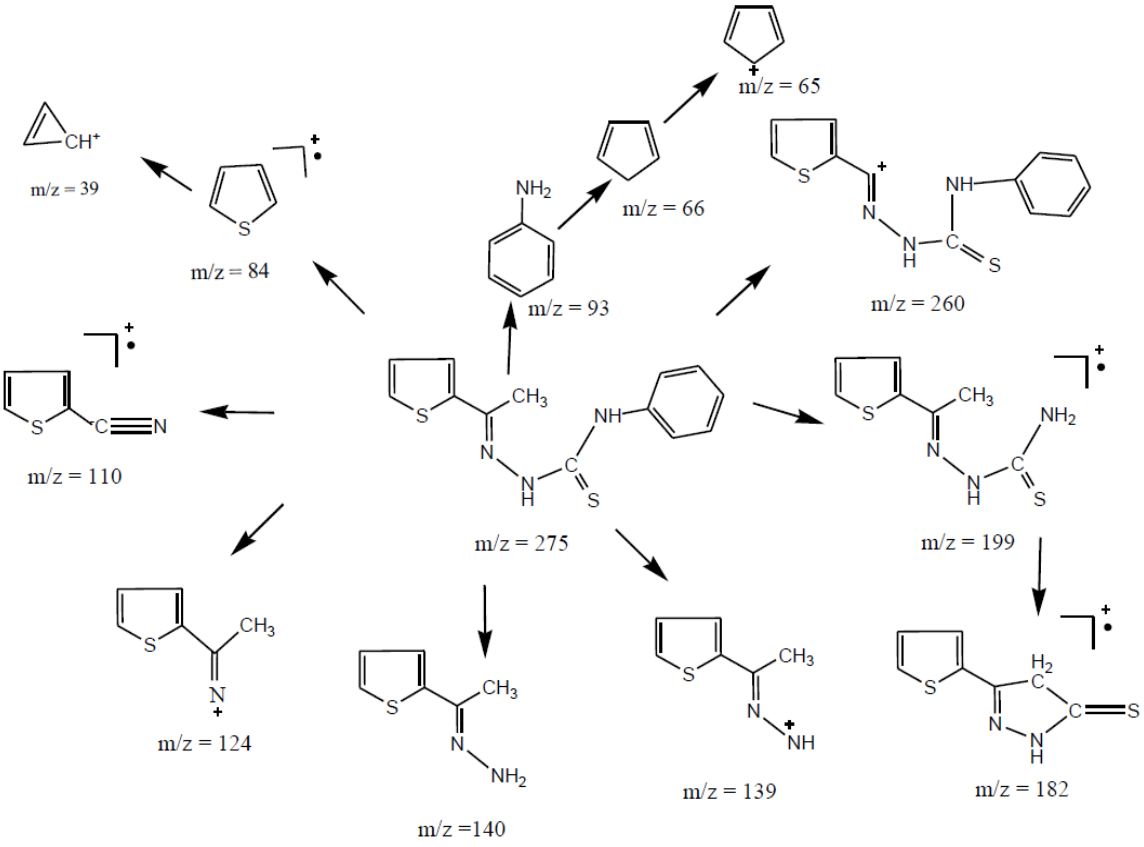


Figure 2 Mass spectral fragmentation of ATPT ligand.

Preparation of mixed ligand metal complexes

A 1.2 g of ATPT ligand (0.006 moles) was dissolved in 15 mL of 0.05 N NaOH in methanol solvent in 100 mL beaker. A 1.0 g Cu $(Phen)_2Cl_2$ (0.003 moles) was dissolved in 15 mL of methanol solvent in 100 mL beaker. Ligand solution and $Cu(Phen)_2Cl_2$ solution were transferred into 100 mL round bottom flask and heated under reflux for 1 h. On cooling the contents of flask, light green coloured complex was formed. It was collected by filtration, washed with small quantities of methanol and dried in air. $Ni(Bpy)(ATPT)Cl_2$ and $Co(Bpy)(ATPT)Cl_2$ complexes were prepared similarly.

Results and discussion

Physico-chemical and analytical studies

Metal complexes having the composition $M(Phen)_2Cl_2$ (Where, M = Co(II), Ni(II) and Cu(II); Phen = 1,10-Phenanthroline) are reacted with ATPT to produce heteroleptic transition metal complexes with molecular formula $[M(Phen)(ATPT)\ Cl_2]\ H_2O$. All the complexes are stable at room temperature, non-hygroscopic, insoluble in water, slightly soluble in methanol and ethanol but readily soluble in DMF and DMSO. Molecular weights of the complexes are determined based on their ESI-mass spectra. ESI-mass spectrum of $[Co(Phen)(ATPT)Cl_2].\ 0.5\ H_2O$ complex is shown in **Figure 3**. The physico-chemical data for the complexes are summarized in **Table 1**.

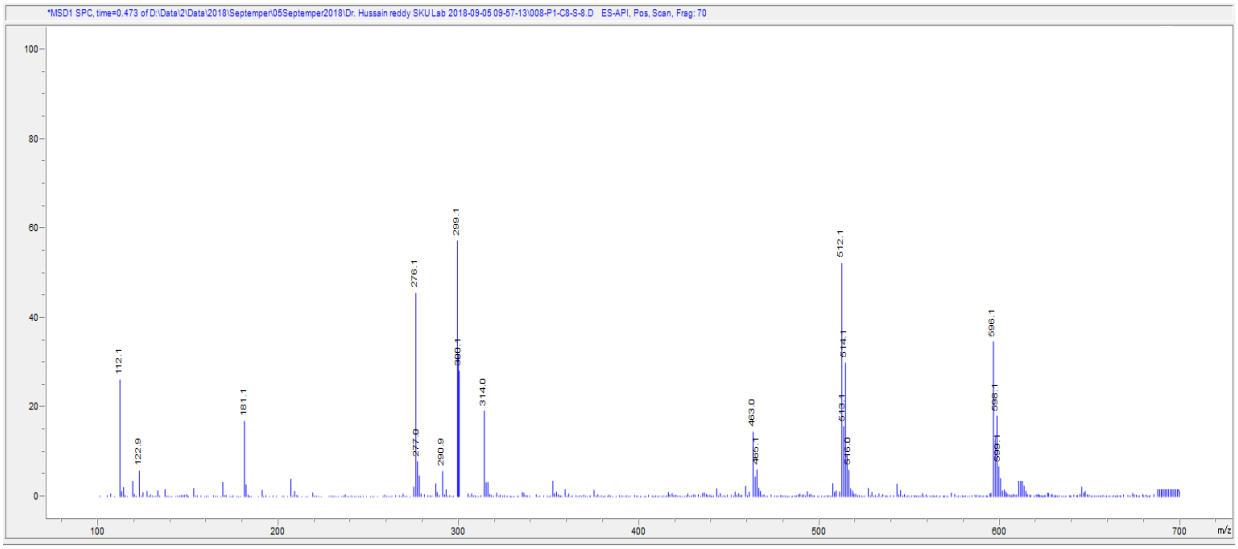


Figure 3 ESI-Mass spectrum of [Co(Phen)(ATPT)Cl_2]. 0.5 H_2O complex.

Conductivity measurements

Analytical data support the compositions of the complexes. For 1:1 electrolyte the molar conductivity values are in the range 65 - 90 Ω^{-1} cm^2 mol^{-1} in dimethylformamide (DMF). The observed values (18 - 25 Ω^{-1} cm^2 mol^{-1}) indicate non-electrolytic nature of complexes [20].

Table 1 Physicochemical and analytical data of Cu(II), Ni(II) and Co(II) complexes.

S. No	Complex	ESI-MS (F.W)	Melting point (ºC)	Colour (Yield %)	Elemental composition Found (Calcd.) (%)			Molar Conductivity (Ω^{-1} cm^2 mol^{-1})
					C	H	N	
1	[Cu(Phen)$_2$Cl$_2$]	498 (496)	Above 300	Light Green (72.98 %)	58.15 (58.06)	3.20 (3.22)	11.15 (11.29)	18
2	[Cu(Phen)(ATPT)Cl$_2$]. H_2O	608 (608)	264 - 265	Brown (81.58 %)	49.15 (49.34)	3.82 (3.78)	11.55 (11.51)	19
3	[Ni(Phen)$_2$Cl$_2$]	491 (491)	Above 300	Light Blue (73.72 %)	58.73 (58.65)	3.24 (3.25)	11.34 (11.40)	20
4	[Ni(Phen)(ATPT)Cl$_2$]. 0.5 H_2O	596 (595)	292 - 293	Light Green (82.55 %)	50.50 (50.42)	3.90 (3.86)	11.75 (11.76)	25
5	[Co(Phen)$_2$Cl$_2$]	492 (492)	Above 300	Light Blue (74.50 %)	58.65 (58.53)	3.30 (3.25)	11.43 (11.38)	18
6	[Co(Phen)(ATPT)Cl$_2$]. 0.5 H_2O	598 (596)	288 - 289	Brown (82.27 %)	50.25 (50.33)	3.82 (3.85)	11.65 (11.74)	21

Electronic spectra

The electronic spectra of the complexes are recorded in DMF and data are presented in **Table 2**. A strong and sharp peak is observed in the region of 37,313 - 31,250 cm^{-1} due to $\pi \rightarrow \pi^*$ transition of aromatic chromophore [21]. Medium intensity bands observed in the range of 30,303 - 27,472 cm^{-1} are assigned to which correspond to M → L charge transfer transition [22]. A weak band in the region of 16,611 - 13,245 cm^{-1} region may be assigned to d-d transitions.

Table 2 Electronic spectral data for Cu(II), Ni(II) and Co(II) complexes.

S. No	Complex	λ max (nm)	Frequency (cm^{-1})	Assignment
1	$Cu(Phen)_2Cl_2$	295	33,898	π- → π* transition
		330	30,303	M → L CT
		755	13,245	d-d transition
2	$[Cu(Phen)(ATPT)Cl_2]$ H_2O	320	31,250	π- → π* transition
		364	27,472	M → L CT
		602	16,611	d-d transition
		327	30,581	M → L CT
3	$Ni(Phen)_2Cl_2$	345	28,985	d-d transition
		627	15,948	d-d transition
		990	10,101	d-d transition
4	$[Ni(Phen)(ATPT)Cl_2]$ 0.5 H_2O	336	29,761	M → L CT
		290	34,482	π- → π* transition
5	$Co(Phen)_2$ Cl_2	351	28,490	d-d transition
		608	16,447	d-d transition
		677	14,771	d-d transition
6	$[Co(Phen)(ATPT)Cl_2]$ 0.5 H_2O	268	37,313	π- → π* transition
		365	27,397	M → L CT

Infrared spectra

Infrared (IR) spectral data of ATPT and its metal complexes and assignment of peaks are given in **Table 3**. A strong band is observed in the IR spectrum of ATPT at 1593 cm^{-1} which is assigned to ν(> C=N) group. In all the complexes, this band is shifted to lower frequency indicating the participation of azomethine nitrogen atom in coordination [23,24]. A medium band is appeared in the spectrum of ATPT at 1194 cm^{-1}, which is assigned to ν(C=S) group. This band is shifted to lower wave number suggesting participation thioketo sulphur in chelation. Thiophene ring deformation modes are observed around 710 and 610 cm^{-1}. These bands are shifted to higher wave number indicating coordination of thiophene sulphur to metal. In far IR region, new peaks are observed in 550 - 585 and 457 - 467 cm^{-1} regions which are assigned to υM-N and υM-S vibrations [25,26] respectively.

Table 3 IR spectral bands ($cm^{-1)}$ of Cu(II), Ni(II) and Co(II) complexes.

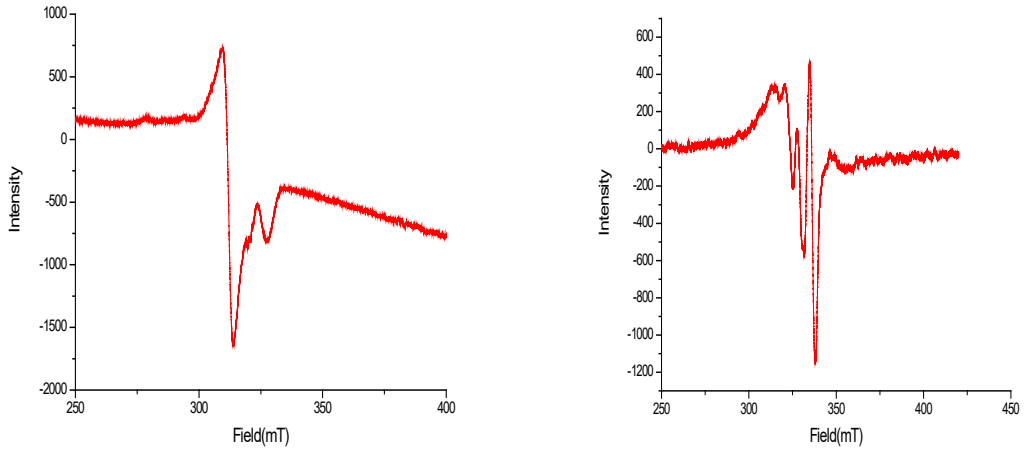
ATPT	$[Cu(Phen)(ATPT)]Cl_2H_2O$	$[Ni(Phen)(ATPT)]Cl_2$ 0.5 H_2O	$[Co(Phen)(ATPT)]$ $Cl_20.5$ H_2O	Assignment
1589	1548	1557	1562	υC=N)
	1485	1479	1475	υC-C
	1305	1315	1338	(thiophene)
1194	1158	1145	1142	υC=S (thione)
	1025	1032	1027	
	858	857	849	
710	720	730	728	
610	630	628	621	
	585	550	575	υM-N
	465	467	457	υM-S

ESR spectra

ESR spectra of copper complexes were recorded in DMF solution at room temperature and at liquid nitrogen temperature. ESR spectra of [Cu(Phen)(ATPT)Cl_2]. H_2O recorded at LNT are shown in **Figure 4**. The spin Hamiltonian, orbital reduction and bonding parameters of complexes are given in **Table 4**.

Table 4 ESR spectral data of complexes.

Parameter	$Cu(Phen)_2Cl_2$		$[Cu(Phen)(ATPT)]Cl_2H_2O$	
	LNT	**RT**	**LNT**	**RT**
$g_{\|}$	2.26	2.23	2.16	2. 12
$g_{\perp}$,	2.05	2.16	2.06	2.09
g_{ave}	2.12	2.21	2.15	2.01
G	0.51	0.69	0.71	0.95
$A_{\|} \times 10^{-5}$	0.00104	-	0.00123	-
$A_{\perp} \times 10^{-5}$	-	-	0.00932	-
$K_{\|}$	0.991	-	0.087	-
$K_{\perp}$	1.061	-	0.059	-
λ	432	-	419	-
α	0.366	-	0.245	-



(A) (B)

Figure 4 ESR spectra of [Cu(Phen)(ATPT)Cl_2]. H_2O complex (A) at LNT and (B) at RT.

The $g_{||}$ and $g_{\perp}$ are computed from the spectra using tetracyanoethylene (TCNE) free radical as **g** marker. The observed g|| values for complexes are less than or equal to 2.3 suggesting significant covalent character of metal ligand bond in agreement with observation of Kivelson and Neiman [27]. The $g_{||}$ and $g_{\perp}$ were more than 2, corresponding to an axial symmetry. The trend $g_{||} > g_{\perp} > g_e$ (2.0023) observed for these complexes suggests that the unpaired electron is localized in the $d_{x^2-y^2}$ orbital of the copper ion. The axial symmetry parameter G is defined as:

$$G = \frac{[g_{\|} - 2.0023]}{[g_{\perp} - 2.0023]} \quad (1)$$

The calculated G values for these complexes are less than 4.0 which indicates the presence of small exchange coupling and misalignment of molecular axes. The $g_{\|}$, $g_{\perp}$, $A_{\|}$, $A_{\perp}$ of complexes and the energies of the d-d transitions are used to calculate the orbital reduction parameters ($K_{\|}$, $K_{\perp}$), the bonding parameter (α^2). The factor α^2 which is usually taken as a measure of covalence and it is evaluated by the expression:

$$\alpha^2 = -A_{\|}/ p + (g_{\|} - 2.0023) + 3/7(g_{\perp} - 2.0023) + 0.04 \quad (2)$$

Hathaway pointed out that for pure σ bonding $K_{\|} \approx K_{\perp} \approx 0.77$, for in-plane π-bonding $K_{\|} < K_{\perp}$, while out of plane π-bonding $K_{\|} > K_{\perp}$ the following simplified expressions were used to calculate $K_{\|}$ and $K_{\perp}$:

$$K_{\|}^2 (g_{\|} - 2.0023)/8x \boldsymbol{\lambda 0} \text{ X d-d transition}$$
$$K_{\perp} = (g_{\perp} - 2.0023)/8x \boldsymbol{\lambda 0} \text{ X d-d transition} \quad (3)$$

The observed $K_{\|} < K_{\perp}$ relation for $Cu(phen)_2Cl_2$ complex indicates the significant in plane π - bonding and $K_{\|} > K_{\perp}$ relation for $[Cu(Phen)(ATPT)]Cl_2$. H_2O complex indicates the out of plane π-bonding.

Cyclic voltammetry

Electrochemical properties of complexes are investigated by using cyclic voltammetry, Voltammograms of complexes are recorded in DMF using 0.1 M tetrabutylammonium hexafluorophosphate as supporting electrolyte. The cyclic voltammogram of $[Co(Phen)(ATPT)Cl_2]$. 0.5 H_2O complex is shown in **Figure 5** and the electrochemical data of complexes are summarized in **Table 5**.

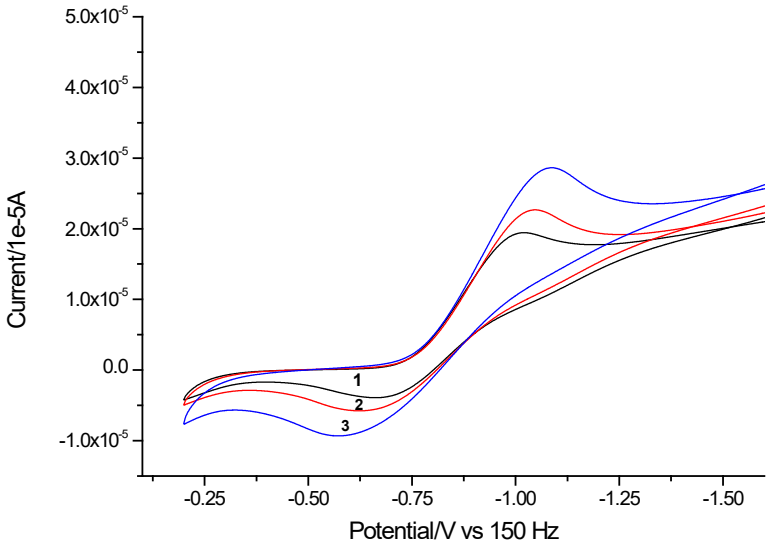


Figure 5 Cyclic voltammogram of $[Co (Phen)(ATPT)]Cl_2$. 0.5 H_2O at different scan rates (1) 0.05 (2) 0.1 and (3) 0.2 mVs^{-1}.

Table 5 CV data of Cu(II), Ni(II) and Co(II) complexes.

S. No	Complex	Epc	Epa	ΔEp (mv)	$E_{1/2}$	-ic/ia	Log Kc[a]	–ΔG°[b]
1	$Cu(Phen)_2Cl_2$	–0.086	0.140	226	0.113	1.461	0.0148	854
2	$[Cu(Phen)(ATPT)]Cl_2H_2O$	–0.096	0.125	221	0.110	1.770	0.0151	877
3	$Ni(Phen)_2Cl_2$	–1.83	–0.680	115	–1.25	1.317	0.0292	168
4	$[Ni(Phen)(ATPT)]\ Cl_2\ 0.5\ H_2O$	–1.070	–0.686	384	–0.878	1.981	0.0874	218
5	$Co(Phen)_2Cl_2$	–1.21	–0.55	660	–0.880	1.261	0.0508	293
6	$[Co(Phen)(ATPT)]\ Cl_2\ 0.5\ H_2O$	–1.017	–0.670	347	–0.843	1.612	0.0967	558

[a]$\log K_C = 0.434ZF/RT\Delta E_p$; [b]$\Delta G^o = -2.303RT \log K_C$.

Stability constants of complexes are calculated using ΔE_p values. Stability of complexes may be predicted based on standard free energy change (ΔG) values. The ΔG values are higher for mixed ligand complexes. Data suggest that mixed ligand complexes are more stable than the parent $[M(Phen)Cl_2]$ complexes.

Repeated scans at various scan rates suggest that the presence of stable redox species in solution. It has been observed that cathodic (Ipc) and anodic (Ipa) peak currents were not equal. The calculated $E_{1/2}$ values for $Cu(Phen)_2Cl_2$ and $Cu(Phen)(ATPT)]Cl_2H_2O$ are 0.113 and 0.110 V respectively. It may be concluded that all the bivalent metal complexes undergo 1 electron reduction to their respective M(I) complexes. The non-equivalent currents in cathodic and anodic peaks indicate quasi-reversible behaviour [28]. The difference, ΔEp for all the complexes is better than the Nerstian requirement 59/n mV (n = number of electrons involved in oxidation reduction). The ΔEp values indicate quasi-reversible character of electron transfer [29]. The complexes show large separation between anodic and cathodic peaks indicating quasi-reversible character. Based on analytical, physicochemical and spectral data, a general structure (**Figure 6**) is proposed for the complexes.

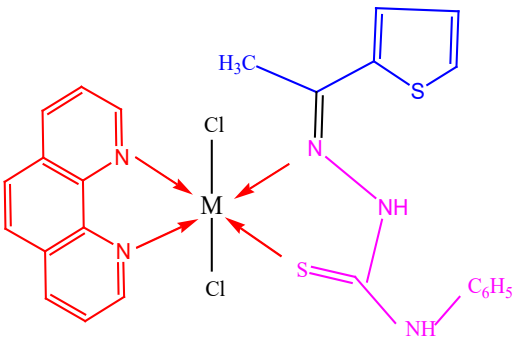


Figure 6 Proposed structure of ternary complexes. [M = Cu(II), Ni(II) and Co(II)].

DNA binding studies

The binding interaction of the complexes with DNA was monitored by comparing their absorption spectra with and without CT-DNA. Absorption spectra of $[Co(Phen)(ATPT)\ Cl_2]\ 0.5\ H_2O$ complex in the absence and in the presence of CT-DNA are shown in **Figure 7**. It has been observed (**Table 6**) that molar absorptivity of complexes decreases (hypochromism, Δε, +20.79 % to +38.07; and absorption maximum is shifted towards higher wavelength (bathochromic shift Δ λ = 0.5 - 1.5) upon each addition of CT-DNA.

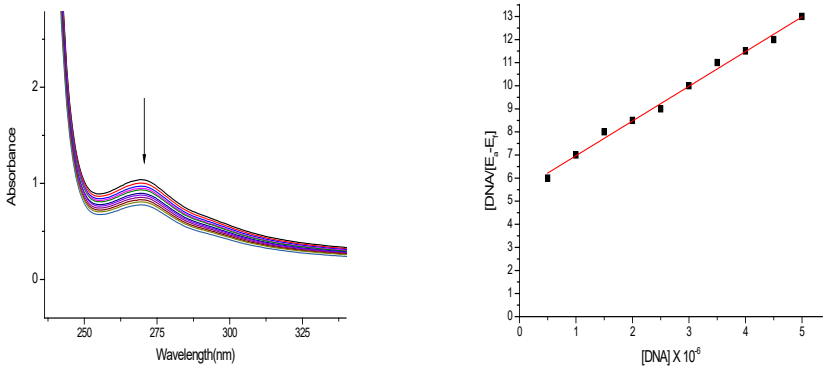


Figure 7 (A) Absorption Spectra of [Co(Phen)(ATPT) Cl_2] 0.5 H_2O in the absence and in the presence of increasing concentration of CT-DNA; [The top most spectrum is recorded in the absence of CT-DNA and below spectra on addition 20 µL DNA each time]. (B) A plot [DNA]/ (Ea-Ef) vs [DNA] X 10^{-6} is shown.

Table 6 Electronic absorption data upon addition of CT-DNA to the complex.

S. No	Complexes	λ max(nm)		Δ λ	H %	Kb [M^{-1}]
		Free	Bound			
1	$Cu(Phen)_2Cl_2$	269.0	270.0	1.0	20.79	1.44×10^5
2	$[Cu(Phen)(ATPT)]Cl_2H_2O$	271.0	272.0	1.0	38.07	5.25×10^5
3	$Ni(Phen)_2Cl_2$	270.0	270.5	0.5	15.83	1.26×10^5
4	$[Ni(Phen)(ATPT)]Cl_20.5\ H_2O$	268.0	269.5	1.5	35.89	1.42×10^5
5	$Co(Phen)_2Cl_2$	269.5	270.5	1.0	12.19	1.73×10^5
6	$[Co(Phen)(ATPT)]Cl_20.5\ H_2O$	272.0	273.0	1.0	21.74	4.14×10^5

The intrinsic binding constants of complexes are given in **Table 6**. Hyperchromic effect and hypochromic effect are the special features of DNA concerning its double helix structure. Hypochromism results from the contraction of DNA in the helix axis as well as from the change in conformation on DNA while hyperchromism emerges from the damage of the double helix structure. Hypochromism and bathochromic shift suggest that these complexes bind DNA through intercalation involving a strong π-stacking interaction between the aromatic chromophore and base pairs of DNA [30].

Antibacterial activity

The diameters of inhibition of zones were measured with Verniercallipers in mm and its values are depicted in the **Table 7**. Antibacterial activity of present complexes is compared (**Figure 8**) with the reference compound, ciprofloxacin. The reference compound shows higher activity even in the presence of its smaller quantities (5 µg/µL). However, all the complexes show significant antibacterial activity with its higher amounts (100 - 300 µg/µL).

The zone of inhibition data suggest that the $[Ni(Phen)(ATPT)]Cl_2$ 0.5 H_2O complex inhibits bacteria more strongly than any other complex. Further, the mixed ligand complex, for example [Ni (Phen)(ATPT)] $Cl_2$0.5 H_2O complex shows more activity than the parent complex $Ni(Phen)_2Cl_2$ possibly due to the synergistic effect of Phen and ATPT ligands against bacteria.

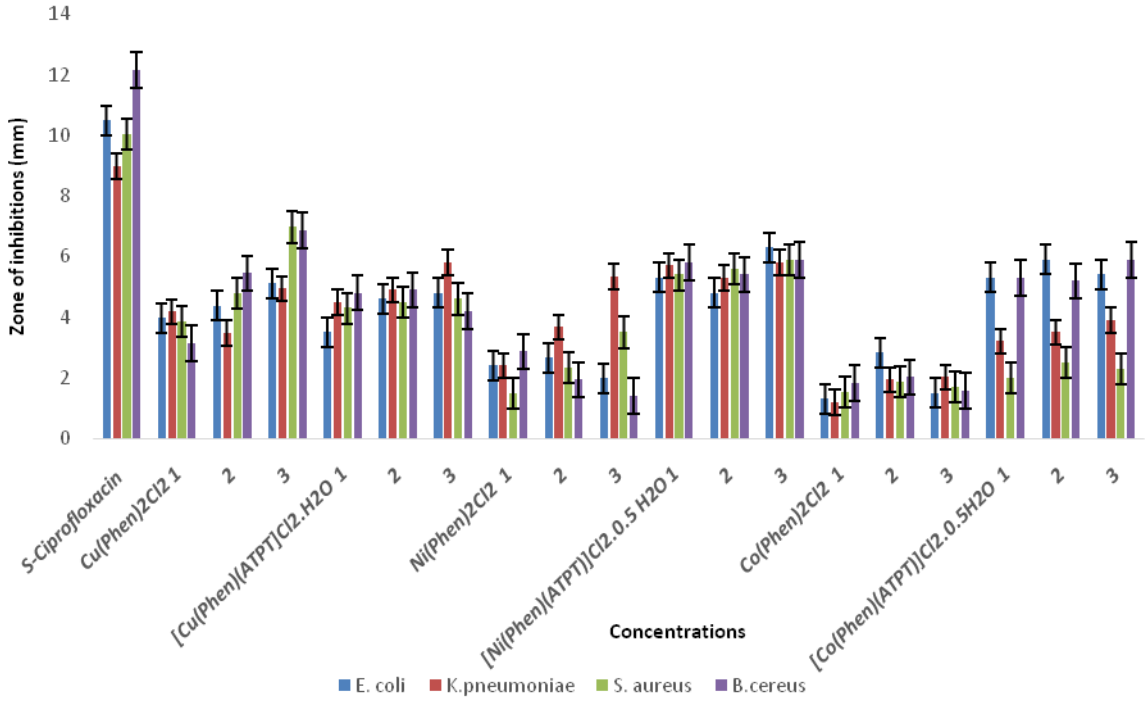


Figure 8 Graphical representation of antibacterial activity of metal complexes against pathogenic bacterial strains. (1 - 100; 2 - 200; 3 - 300 µg/µL).

Table 7 Antibacterial activity of different metal complexes against pathogenic bacterial strains.

S. No	Sample	Treatment (Concentration) (µg/µL)	E. coli (Mean ± SE)	K. pneumoniae (Mean ± SE)	S. aureus (Mean ± SE)	B. cereus (Mean ± SE)
1	S-Ciprofloxacin	5	10.5 ± 0.02	8.98 ± 0.09	10.03 ± 0.03	12.16 ± 0.05
2	$Cu(Phen)_2Cl_2$	100	3.98 ± 0.14	4.17 ± 0.17	3.87 ± 0.18	3.14 ± 0.25
		200	4.37 ± 0.47	3.47 ± 0.47	4.8 ± 0.32	5.45 ± 0.75
		300	5.12 ± 0.8	4.93 ± 0.3	6.97 ± 0.06	6.87 ± 0.36
3	$[Cu(Phen)(ATPT)]Cl_2$ H_2O	100	3.5 ± 0.03	4.5 ± 0.07	4.3 ± 0.07	4.8 ± 0.07
		200	4.6 ± 0.04	4.9 ± 0.08	4.5 ± 0.09	4.9 ± 0.05
		300	4.8 ± 0.08	5.8 ± 0.09	4.6 ± 0.25	4.2 ± 0.36
4	$Ni(Phen)_2Cl_2$	100	2.4 ± 0.11	2.4 ± 0.17	1.5 ± 0.28	2.87 ± 0.16
		200	2.67 ± 0.09	3.67 ± 0.17	2.34 ± 0.15	1.93 ± 0.26
		300	1.98 ± 0.06	5.33 ± 0.17	3.5 ± 0.63	1.4 ± 0.32
5	[Ni(Phen)(ATPT)] Cl_2 0.5 H_2O	100	5.3 ± 0.07	5.7 ± 0.07	5.4 ± 0.36	5.8 ± 0.67
		200	4.8 ± 0.08	5.3 ± 0.06	5.6 ± 0.01	5.4 ± 0.89
		300	6.3 ± 0.01	5.8 ± 0.07	5.9 ± 0.06	5.9 ± 0.35
6	$Co(Phen)_2Cl_2$	100	1.3 ± 0.15	1.2 ± 0.18	1.53 ± 0.3	1.83 ± 0.01
		200	2.83 ± 0.17	1.93 ± 0.13	1.87 ± 0.87	2.01 ± 0.34
		300	1.5 ± 0.29	2.01 ± 0.15	1.69 ± 0.23	1.57 ± 0.36
7	[Co(Phen)(ATPT)] Cl_2 0.5 H_2O	100	5.3 ± 0.04	3.2 ± 0.24	2 ± 0.32	5.3 ± 0.01
		200	5.9 ± 0.09	3.5 ± 0.05	2.5 ± 0.89	5.2 ± 0.05
		300	5.4 ± 0.06	3.9 ± 0.07	2.3 ± 0.47	5.9 ± 0.14

Conclusions

Mixed ligand transition metal complexes with Phen and ATPT are synthesized and characterized based on ESI mass spectra, molar conductivity, infrared and electronic spectroscopy. Electrochemical properties of complexes are uncovered by using cyclic voltammetry. The complexes show quasi-reversible cyclic voltammetric responses for the M(II)/M(I) couple. The binding properties of these complexes with calf-thymus DNA are investigated by using absorption spectrophotometry. Mixed ligand metal complexes show high binding affinity towards DNA. Metal complexes are screened for their antibacterial activity by using agar well diffusion method against pathogenic bacterial strains. Although antibacterial activity of present complexes is less than the reference compound (Ciprofloxacin), the mixed ligand compounds show significant activity when taken in higher amounts (100 - 300 μg/μL).

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