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Synthesis and characterization studies of novel ternary complexes of Zn(II) and Ni(II) ion with norfloxacin drugs and amino acids

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Abstract:

In the present work, we have synthesized twenty (20) Zn(II) and Ni(II) ion ternary complex with fluoroquinolone drug (Norfloxacin (NOR)) as primary ligand and-proline, L-glycine, L-alanine, L-histidine, L-arginine, L-threonine, L-valine, L-methionine, L-tryptophan, L-lysine , L-leucine, L-tyrosine, L-cysteine amino acid (AA) as the secondary ligand. Initial characterization studies have been done by elemental analysis to get information on the percent composition of C, H, N, O, S elements and metal, while UV-Visible spectroscopy shows the effect of metal chelation on the different inter-ligand transitions. Magnetic moment confirms the diamagnetic and paramagnetic behaviour of Zn (II) complexes and Ni (II) because there are all paired and two unpaired electrons are present in the outer orbital of the central zinc and nickel metal ion respectively. So the Zn and Ni metal shows +2 oxidation state in all synthesized complexes. While IR studies confirm the presence of all functional groups in synthesized complexes. Synthesized new ternary complexes contains [Zn(II)(NOR)(AA)] and [Ni(II)(NOR)(AA)] is1:1:1 molar ratio. The zinc and nickel ion in these 20complexes have similar coordination modes, which can be described as six coordinated octahedral geometry. Stability of the all ternary complexes was determined by thermal gravimetric analysis (TGA) in temperature ranges between 25℃-900℃. The carboxylic and amino acid group participate in the bonding and the interaction of the metal ion with an amino acid.

Keywords*: Fluoroquinolone, Zn(II)/Ni(II) metal ion,amino acids, ternary complexes, spectral analysis.*

1. Introduction

The science of coordination originated from the work of Swiss chemist; Alfred Werner, who studied various compounds made up of cobalt (III) chloride and ammonia [1]. Complexes with one kind of ligand known as a binary complex whereas compound in which more than one type of ligand are bound to one metal ion are termed as mixed ligand complexes or ternary complexes[2]. The significance of mixed ligand complexes in the environment is evident as much biological reaction occurs within the metal ion coordination [3]. The ternary complexes of transition metals play an important role in biological processes (Das, 1990). The numbers of transition metal complexes are involved in storage, transport, detoxification, and catalytic processe[4], [5].Biological activity is revealed by several transition metals with the mixed amino acid. They provide information about biological processes to how they achieve their specificity and strategies [6].

The source of structural knowledge has evolved over recent decades to the point that almost all of the AA complexes of essential metal (II) ions have been structurally characterized [7]. The structural model can be utilized by amino acids that are noteworthy, from complex geometries of co-ordination to different properties, even with a minor change in the structure of neighborhood surroundings. In contrast, the feasibility of AA complexes has success and prosperity in the development of biocompatible nanoparticles and the development of therapeutic and diagnostic frameworks for cancer cell identification and mitigation (Dhankhar et al., 2020). With certain exceptions, amino acid coordination chemistry study has generally been conducted in the formulation where even the peculiar features of AA (bioavailability, a different mode of complexation, the ability to distinct hydrophobic, hydrophilic conditions, etc.) have resulted in a bunch of new methods and approaches [8]. In binding and isolation, selectivity was usually obtained after only crystallization, highlighting the significance of intermolecular interaction in the rigid crystal setting. In transition metals, amino acids with one or more co-ordinated site, along with various functional groups play a significant role. In the industrial and biomedical sectors, they have great importance (Zarándi and Szolomájer, 2017). They were directly involved in all the metabolic enzymatic activities of living organisms. In this study, we used L-proline, L-glycine, L-alanine, L-histidine, L-arginine, L-threonine, L-valine, L-methionine, L-tryptophan, L-lysine, L-arginine, L-leucine, L-tyrosine, L-cysteine amino acids as a secondary ligand in complex formation.

In the early 1960s, quinolone antibiotics emerged with the very first reports of a narrow spectrum of activity with adverse pharmacokinetics properties. The emergence of new quinolone antibiotics also led to enhanced equivalents with increased scope and easy implementation [9]. Fluoroquinolones (FQs) refers to the class of quinolone medications which are used via E. coli DNA gyrase inhibition to treat urinary tract infections (UTIs) through inhibition [10], [11]. Norfloxacin, 1-ethyl-6-fluoro-1,4-dihydro-4-oxo-7-(1-piperazinyl)-3-quinoline carboxylic acid, is the first representative of fluorinated quinolones and the very first quinolone derivatives drugs

used in medicinal products a piperazine substituent[12].It has been binding through carboxylate and carbonyl oxygen atom to the metallic center and behaved as a neutral bidentate chelating ligand (Lalegani et al., 2016) and demonstrate good activity against gram-positive and gram-negative bacteria [13].

The synthesis of complex metal ion are among the prominent influential [14], and the amino acids with and drug are important and versatile for research[15]. Ternary complexes like M(II)-A-Z,where M is Cu(II), Co(II), Ni(II), Mn(II), or Zn (II), and A is a primary ligand and Z is secondary ligand was investigated to understand the driving forces leading to mixed complexes in a biological system to determine the stability constants of these complexes[16], [17].

So based on the above literature, here in, we have synthesized a total of twenty (20) complexes of the fluoroquinolone with a metal ion(Zn(II)/Ni(II)); ten (10) complexes with [Zn((NOR)(AA)] and ten complexes with [Ni(NOR)(AA)] with characterization by physicochemical and spectroscopic techniques and discuss the interaction between both ligands and the central metal ion in coordination compounds.

2. Experimental:

2.1 Materials & methods:

All the primary ligands; L-proline, L-glycine, L-alanine, L-histidine, L-arginine, L-threonine, L-valine, L-methionine, L-tryptophan, L-lysine, L-arginine, L-leucine, L-tyrosine, L-cysteine were used extra pure Fluka products. Zinc sulphate ($ZnSO_4$) and nickel sulphate ($NiSO_4$) procured from Merck; Mumbai India.Pure drug sample norfloxacin was obtained from the pharmaceutical industry, Mumbai. Doubly distilled conductivity water was used for the preparation of all solutions. The precipitation process is carried out in a magnetic stir.

2.2. Preparation of [Zn (NOR) (AA)] and [Ni (NOR) (AA)] ternary complexes:

The complexes of zinc [Zn (NOR) (AA)] and nickel [Ni (NOR) (AA)] systems were prepared as follow; initially, 5% homogeneous metal salt solution prepared by dissolving 5 g zinc sulphate/nickel sulphate into 100 ml distilled water in various beakers. Next, we add 0.2 M of sodium hydroxide (NaOH) to the metal salt solution. Later on, the precipitate obtained, filter the precipitate after complete precipitation, and wash it several times with ethanol to remove extra impurity. Lastly, the complexes were eventually prepared by combining the primary ligand; norfloxacin, and secondary ligand amino acids with those of metal ion solutions followed by digestion in a water bath for 4 hrs. Filter the hot solution when digestion was complete and washed with deionized water 3-4 times followed by ethanol to remove all other impurities. The residues were dried and re-crystallized at room temperature. The pH kept at 7 in throughout the process, since complexes at this pH were easily prepared.

2.3 Characterization studies:

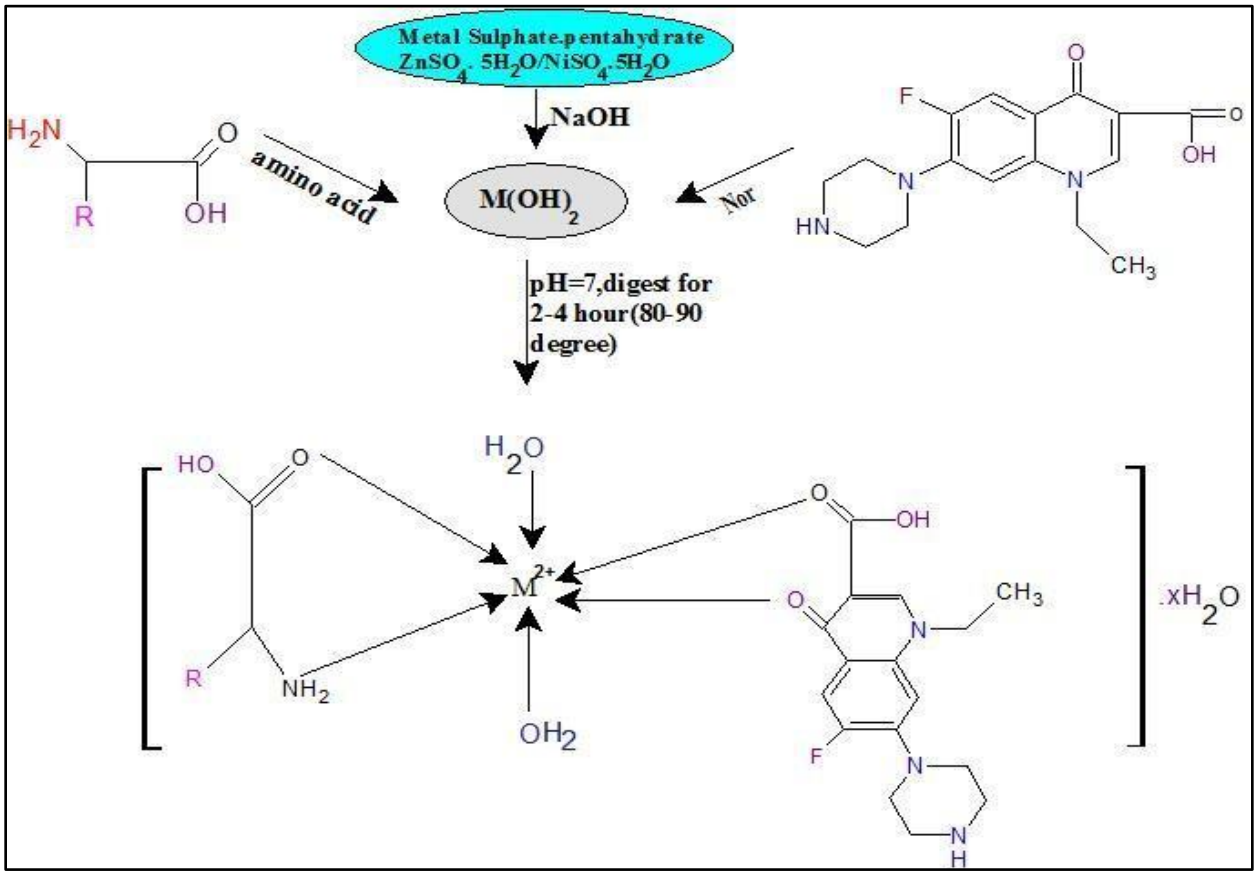
Various spectral techniques were used to characterize the synthesized complexes such as optical properties were determined by UV-Visible spectrophotometer using a Cary 5000 double beam

UV-Visible spectroscopy. Elemental analysis was performed on a Euro Vector EA 300 and Vario EI III CHNS. While Magnetic susceptibility balances, Sherwood MK-1 was used to find the magnetic moment of ternary complexes of Zn (II) and Ni (II) with norfloxacin. Thermo gravimetric analysis (TGA) was also done for these ternary complexes, TGA analysis was carried out by using a Perkin Elmer, Diamond instrument with a heating rate of 10 ℃/min. Fourier transform infrared (FTIR) spectra were obtained with Thermo Nicolet Avatar 370, in the range of 4000-400 cm^{-1}.

3. RESULTS & DISCUSSION

Characterization of [Zn (NOR) (AA)] and [Ni (NOR) AA) complexes:

A series of novel ternary complexes have been synthesized by adding primary ligand norfloxacin and different amino acids, L-proline, L-glycine, L-alanine, L-histidine, L-arginine, L-threonine, L-valine, L-methionine, L-tryptophan, L-lysine, L-arginine, L-leucine, L-tyrosine, L-cysteine s secondary ligand to synthesize ternary complexes; [Zn(NOR)(AA)] and [Ni(NOR)(AA)] (Scheme 1). Different characterization techniques, i.e. elemental, UV-Visible, magnetic moment,IR, TGA, etc. were used to confirm the synthesis of ternary complexes.



Scheme 1: Schematic representation of [Zn (NOR) (AA)] and [Ni (NOR) (AA)] ternary complexes synthesis.

3.1 Elemental analysis

Elemental analysis of synthesized complexes was used to determine the percent composition of C, H, O, N, F, and Zn (II) metal ion present in complexes. These data corresponded to the general formula as [Zn (NOR) (AA)].xH_2O for all the complexes with 1:1:1 stoichiometric ratio where NOR is norfloxacin, AA is amino acid and x is the number of water molecules respectively. Complexes are extremely soluble in water and sparingly or insoluble in organic solvents and stable at room temperature. The elemental analysis data of ternary zinc (II) complexes are summarized in table 1.

Table 1.Elemental data of ternary zinc (II) complexes.

S. N.	Name of complex	Molecular Formula	% analysis calculated (found)							Molecular weight
			C	H	N	O	F	S	M	
1.	[Zn(NOR)(threo)]. $6H_2O$	[Zn($C_{20}H_{27}N_4O_6F$)]. $6H_2O$	39.26% (38.65)	6.38% (6.35)	9.16% (9.02)	31.40% (31.05)	3.09% (3.01)	---	10.69% (10.25)	611.28
2.	[Zn(NOR)(arg)]. $5H_2O$	[Zn($C_{22}H_{32}N_7O_5F$)]. $5H_2O$	41.03% (40.84)	6.52% (6.23)	15.23% (15.21)	24.87% (24.56)	2.93% (2.05)	---	10.16% (10.02)	643.28
3.	[ZnNORr)(leu)]. $7H_2O$	[Zn($C_{22}H_{31}N_4O_6F$)]. $7H_2O$	48.41% (48.25)	8.25% (8.12)	10.26% (10.13)	3.46% (3.28)	3.46% (3.08)	---	11.99% (10.84)	545.28
4.	[Zn(NOR)(val)]. $8H_2O$	[Zn($C_{21}H_{29}N_4O_5F$)]. $8H_2O$	39.05% (39.00)	6.97% (6.28)	8.67% (8.65)	32.23% (32.58)	2.92% (2.56)	---	10.13% (10.11)	645.28
5.	[Z(NOR)(meth)]. $9H_2O$	[Zn($C_{21}H_{29}N_4O_5FS$)]. $9H_2O$	38.45% (38.44)	7.03% (7.01)	8.37% (8.18)	33.52% (33.26)	2.82% (2.56)	4.78% (4.28)	9.78% (9.28)	668.28
6.	[Zn(NOR)(cys)]. $6H_2O$	[Zn($C_{19}H_{25}N_4O_5FS$)]. $6H_2O$	39.22% (39.56)	6.36% (6.28)	9.63% (9.04)	30.27% (30.12)	3.25% (3.25)	5.50% (5.35)	11.24% (10.94)	581.28
7.	[Zn(NOR)(tryp)]. $8H_2O$	[Zn($C_{27}H_{30}N_5O_5F$)]. H_2O	43.64% (42.85)	6.19% (6.18)	10.77% (10.58)	28.02% (28.02)	2.54% (2.48)	---	8.80% (7.58)	742.28
8.	[Zn(NOR)(ala)]. $5H_2O$	[Zn($C_{19}H_{25}N_4O_5F$)]. $5H_2O$	40.47% (40.15)	6.21% (6.13)	9.94% (9.48)	28.40% (28.15)	3.35% (32.98)	---	11.60% (10.84)	563.28
9.	[Zn(NOR)(tyro)]. $7H_2O$	[Zn($C_{25}H_{29}N_4O_6F$)]. $7H_2O$	43.39% (43.28)	6.22% (6.21)	8.10% (8.00)	30.08% (30.05)	2.73% (2.58)	---	9.45% (8.25)	691.28
10.	[Zn(NOR)(hist)]. $6H_2O$	[Zn($C_{22}H_{27}N_6O_5F$)]. $6H_2O$	40.66% (40.02)	6.00% (6.01)	13.24% (12.95)	27.10% (27.02)	2.91% (2.89)	---	10.06% (10.02)	649.28

The elemental analysis data of synthesized complexes of [Ni(NOR)(AA)] were listed in table 2. All the complexes were colored, highly water-soluble, and having a high melting point. The percentage composition was determined by the elemental analysis. From these data, we observed

that the tentative molar ratio of the complexes is metal: L_1: L_2 comes out to be 1:1:1, where L_1 = primary ligand (Norfloxacin) and L_2 = secondary ligand (amino acids) respectively.

Table 2: Physiochemical data of synthesized [Ni(II)(NOR)(AA)] **ternary complexes.**

S.N.	Name of complexes	Molecular formula	% analysis calculated (found)							Molecular weight	Colour
			%C	%H	%N	%O	%F	%S	%M		
1.	[Ni(NOR)(pro)].5H_2O	[Ni($C_{21}H_{27}N_4O_5F$)].5H_2O	51.26% (51.03)	5.2% (5.2)	11.39% (11.68)	16.59% (16.48)	3.84% (3.74)	---	11.93% (11.85)	491.59	Light blue
2.	[Ni(NOR)(gly)].8H_2O	[Ni($C_{18}H_{23}N_4O_5F$)].8H_2O	36.26% (36.51)	6.53% (6.38)	9.38% (9.31)	34.86% (34.28)	3.16% (3.00)	---	9.83% (9.82)	596.59	Light blue
3.	[Ni(NOR)(ala)].6H_2O	[Ni($C_{19}H_{25}N_4O_5F$)].6H_2O	39.68% (38.64)	6.43% (6.41)	9.74% (9.56)	30.63% (30.25)	3.28% (3.21)	---	10.21% (10.02)	574.59	Light blue
4.	[Ni(NOR)(hist)].4H_2O	[Ni($C_{22}H_{27}N_6O_5F$)].4H_2O	44.25% (44.12)	4.52% (4.49)	14.08% (14.00)	24.13% (24.10)	3.16% (3.24)	---	9.83% (9.48)	596.5	Light blue
5.	[Ni(NOR)(arg)].9H_2O	[Ni($C_{22}H_{32}N_7O_5F$)].9H_2O	31.70% (31.64)	6.08% (6.10)	13.86% (12.69)	31.70% (31.64)	2.67% (2.59)	---	8.20% (8.15)	706.59	Light blue
6.	[Ni(NOR)(threo)].5H_2O	[Ni($C_{20}H_{27}N_4O_6F$)].5H_2O	41.12% (41.00)	5.82% (5.79)	9.59% (9.46)	30.15% (30.05)	3.23% (3.28)	---	10.05% (10.02)	583.59	Light blue
7.	[Ni(NOR)(val)].7H_2O	[Ni($C_{21}H_{29}N_4O_5F$)].7H_2O	40.58% (40.02)	6.92% (6.89)	9.02% (9.01)	30.93% (30.84)	3.04% (3.64)	---	9.45% (9.46)	620.59	Light blue
8.	[Ni(NOR)(meth)].6H_2O	[Ni($C_{21}H_{29}N_4O_5FS$.6H_2O	39.71% (39.64)	6.46% (6.41)	8.82% (8.49)	27.73% (27.69)	2.97% (2.85)	5.0% (4.15)	9.24% (9.15)	634.59	Light blue
9.	[Ni(NOR)(tryp)].5H_2O	[Ni($C_{27}H_{30}N_5O_5F$)].5H_2O	49.49% (49.16)	5.65% (5.62)	8.55% (8.29)	24.44% (24.16)	2.88% (2.48)	---	8.96%	654.59	Light blue
10.	[Ni(NOR)(lys)].8H_2O	[Ni($C_{22}H_{32}N_5O_5F$)].8H_2O	39.90% (39.84)	6.34% (6.29)	10.58% (10,26)	31.43% (31.21)	2.85% (2.79)	---	8.87% (8.79)	661.59	Light blue

3.2 UV-Visible spectral analysis

In the electronic spectroscopic method, the recorded spectra were used to obtain the possible structure of synthesized complexes. These spectra for Zn (II) complexes occurred in the UV region at 200-400 nm wavelength range (Fig.1). The electronic spectral data of synthesized ternary complexes are listed in table 3. The UV spectrum of free norfloxacin displays two absorption peaks at 277 and 373 nm. It follows from the literature survey, the bands present at 270-290 nm and 320-394 nm wavelength range for free norfloxacin ligand are related to the π-π^* and n-π^* transitions respectively(Choudhary et al., 2013). Similarly, the UV spectra of different amino acids show a single peak under 280 nm which ascribed to n-π^* transitions (Gh and Er, 1952). In the electronic spectra of synthesized ternary complexes, the free ligand bands are moved to a lower wavelength region (hypsochromic effect) due to the involvement of

coordination sites of ligands with the metal ion in complexation. These bands occur at 232-330 nm range, indicating octahedral geometry for all the complexes (Al-Noor et al., 2014). In these complexes, zinc metal ion is present in the +2 oxidation state (d^{10}) with filled d-orbital. Hence, it does not give any d-d transition but exhibit charge transfers spectra.

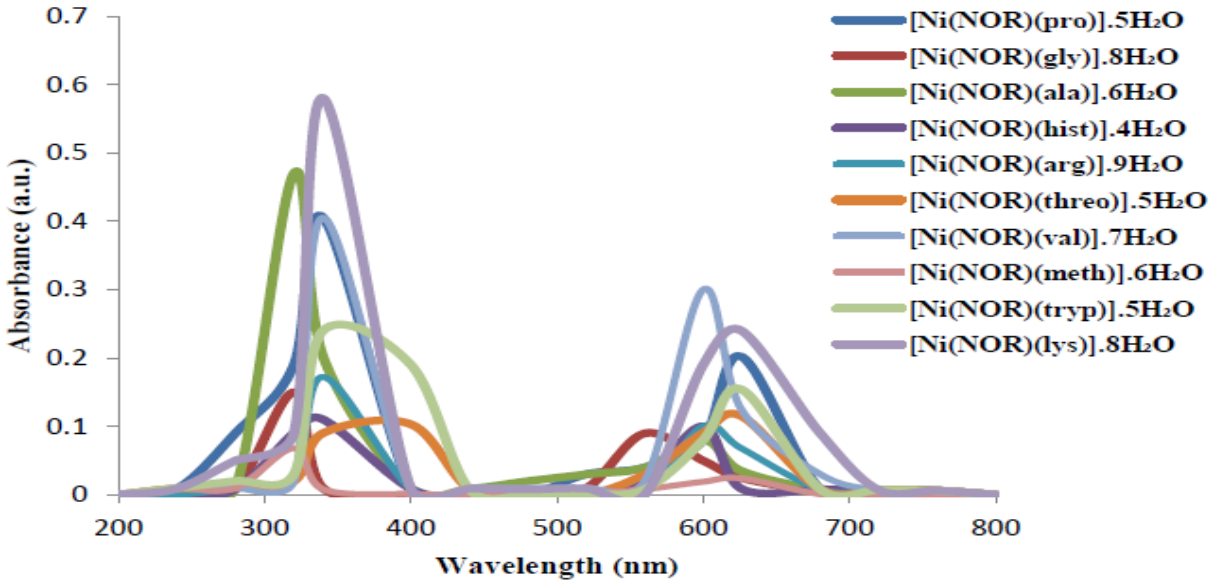


Fig.1: UV-Visible absorption spectrum of all [Zn(II)(NOR)(AA)] ternary complexes.

Table 3.UV-Visible absorption spectral data of all [Zn(II)(NOR)(AA)] ternary complexes.

S.N.	Name of complexes	λmax (nm)	Assignments	Ɛmax (M^{-1},cm^{-1})
1.	[Zn(NOR)(threo)].6H2O	300	Ligand to metal charge transfer transition	35.8
2.	[Zn(NOR)(arg)].5H2O	290	Ligand to metal charge transfer transition	86.6
3.	[Zn(NOR)(leu)].7H2O	224	Ligand to metal charge transfer transition	32.1
4.	[Zn(NOR)(val)].8H2O	261	Ligand to metal charge transfer transition	68.6
5.	[Zn(NOR)(meth)].9H2O	320	Ligand to metal charge transfer transition	79.9
6.	[Zn(NOR)(cys)].6H2O	232	Ligand to metal charge transfer transition	72.1
7.	[Zn(NOR)(tryp)].8H2O	283	Ligand to metal charge transfer transition	31.2
8.	[Zn(NOR)(ala)].5H2O	330	Ligand to metal charge transfer transition	41.5
9.	[Zn(NOR)(tyro)].7H2O	310	Ligand to metal charge transfer transition	20.5
10.	[Zn(NOR)(hist)].6H2O	262	Ligand to metal charge transfer transition	21.0

Electronic spectral detail of the prepared [Ni(II)(NOR)(AA)] ternary complexes are given in table 4.This was recorded in the UV-Visible region at 200-800 nm wavelength range in an aqueous medium.

Comparison of UV-Visible spectrum of ternary Ni(II) complexes with their parent ligands we observed that bands at 277 nm shifted to higher wavelength region due to the involvement of binding sites of ligands in coordination, which confirm the formation of ternary complexes. In all the synthesized ternary complexes, nickel metal is present as a divalent metal ion, which shows d^8 electronic configuration. So, there are two unpaired electrons present in its outer orbital, corresponds to d-d transitions in all the ternary complexes. The ground state term symbol for d^8 electronic configuration was $^3\mathbf{F_4}$.

In the UV spectrum of all the ternary Ni (II) complexes, two bands occur. The first intense band present at 300-379 nm and the second at 600-680 nm wavelength range assigned to spin-allowed transitions (π-π* and n-π* transitions). These bands were assigned to $^3\mathbf{A_{2g}}$-$^3\mathbf{T_{1g}}$ **(F)** and $^3\mathbf{A_{2g}}$-$^3\mathbf{T_{1g}}$ **(P)** transitions respectively, which corresponds to an octahedral structure for Ni^{2+} complexes [18], [19].

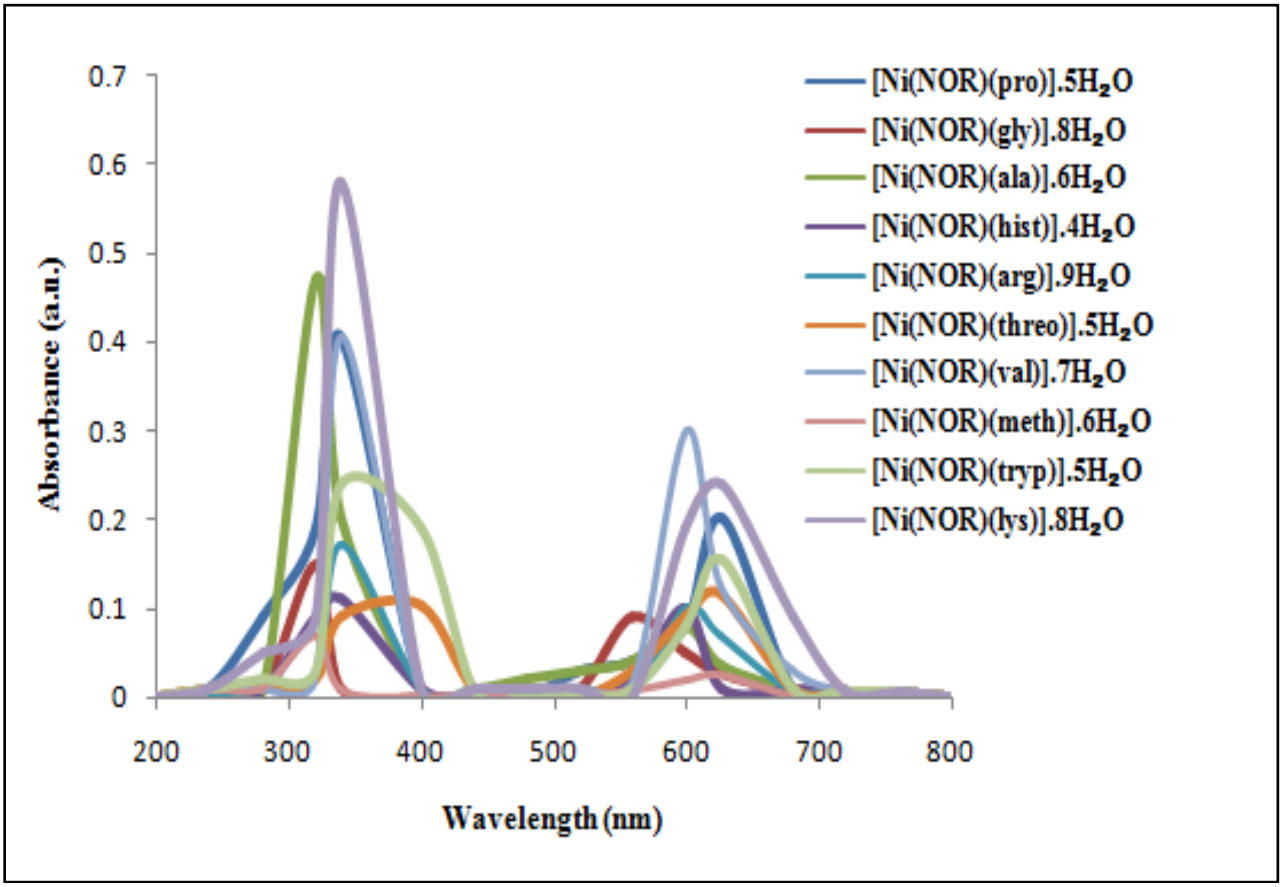


Fig. 2: UV-Visible absorption spectrum of all [Ni(II)(NOR)(AA)] ternary complexes.

Table 4: Electronic spectral data of [Ni(II)(NOR)(AA)] ternary complexes.

S.N.	Name of complexes	λ_{max} (nm)	Assignments	ε_{max} ($M^{-1}cm^{-1}$)
1.	[Ni(NOR)(pro)].5H_2O	340 626	π-π* transition n-π* transition	20.20
2.	[Ni(NOR)(gly)].8H_2O	320 628	π-π* transition n-π* transition	2.50
3.	[Ni(NOR)(ala)].6H_2O	300 603	π-π* transition n-π* transition	3.50
4.	[Ni(NOR)(hist)].4H_2O	335 600	π-π* transition n-π* transition	11.10
5.	[Ni(NOR)(arg)].9H_2O	380 620	π-π* transition n-π* transition	16.80
6.	[Ni(NOR)(threo)].5H_2O	350 650	π-π* transition n-π* transition	11.50
7.	[Ni(NOR)(val)].7H_2O	379 680	π-π* transition n-π* transition	12.50
8.	[Ni(NOR)(meth)].6H_2O	320 635	π-π* transition n-π* transition	6.80
9.	[Ni(NOR)(tryp)].5H_2O	390 625	π-π* transition n-π* transition	15.40
10.	[Ni(NOR)(lys)].8H_2O	339 615	π-π* transition n-π* transition	2.40

3.3 Infrared spectra

Table 5 and 6, summarized, the characterized infrared absorption frequencies of Zn (II) and Ni (II) synthesized ternary mixed ligands transition metal complexes. These spectra were recorded in the KBr disc. Infrared assignments of complexes were also confirmed from literature [20]. Based on FTIR spectral data we find out the bonding modes of ligands with the central metal ion in coordination. These data suggest that there are no changes in the structure of ligands although they bind to the metal ion through their different coordination sites.

In the IR spectra of free norfloxacin ligand, there is one characteristic peak present between 3550-3500 cm^{-1} assigned to OH stretching vibration and intermolecular hydrogen bonding. Band occurs at 3500-3300 cm^{-1} indicated the presence of a piperazinyl group with NH stretching vibration. Carbonyl stretching vibration is represented by the appearance of the band at 1700 cm^{-1}. Furthermore, strong absorption bands occur between 1050-100 cm^{-1} and were assigned to the C-F group. NH_2 bending vibration is presented by an 800 cm^{-1} band. Stretching vibration of the O-C-O acid group was observed at 1500-1450 cm^{-1}.

The amino acids having two different functional groups such as amino and carboxylate

groups.Their IR spectra exhibit significant features in νNH_2, νCOO^- groups. In the IR spectrum of all amino acids, the bands in the regions 1594-1586 cm^{-1} and 1412-1408 cm^{-1} ascribed to symmetrical and asymmetrical stretching vibrations of the carboxylate group. Free amino acids also display bands in the 1504-1570 cm^{-1} due to asymmetric vibration and in the 1411-1496 cm^{-1} region due to symmetric (COO^-) vibrations [21].The IR spectra of Zn (II) ternary complexes involving the above ligands showed characteristic band positions, band shifts, and band intensities, which are shifted to lower or higher frequencies from the ligand spectra. Analysis of the IR spectra of such complexes was done by many researchers [22].

In all the prepared norfloxacin Zn (II) ternary complexes showed a prominent peak in the region 3304-3392 cm^{-1}, suggest the NH_2 stretching frequency, which is lower than the free NH_2 group in all amino acids. Also the bands present at 1569-1597 cm^{-1} and 1411-1496 cm^{-1} shifted to lower and higher frequencies in some complexes, assigned to symmetrical and asymmetrical stretching Vibrations of the carboxylic group. Thus, from the IR spectra of Zn (II) ternary complexes, it is clear that amino acids bind to the central zinc ion through the nitrogen atom of an amino group and oxygen atom of the carboxylic group while primary ligand norfloxacin binds to the central zinc ion through both the carbonyl and carboxylic oxygen atoms in coordination.

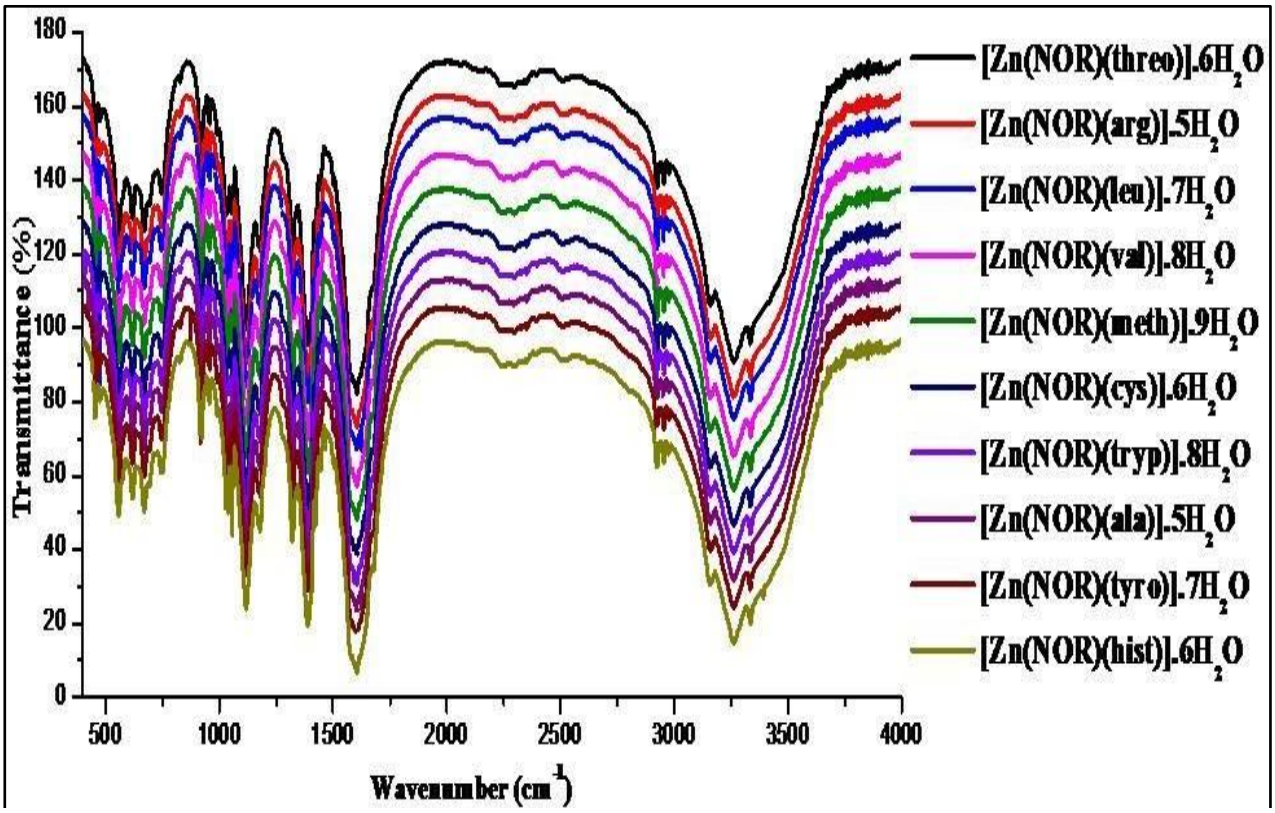


Fig. 3: IR spectrum of [Zn(NOR)(AA)] ternary complexes.

Table 5.IR assignments of [Zn(NOR)(AA)] ternary complexes.

S.N.	Name of complexes	$\nu_{asy}NH_2$	$\nu_{sy}(NH_2)$	$\nu_{asy}COO^-$	$\nu_{sy}COO^-$	ν M-N	C-W
1.	[Zn(NOR)threo)].$6H_2O$	3340	3056	1508	1410	449	840
2.	[Zn(NOR)(arg)].$5H_2O$	3271	3093	1524	1423	426	868
3.	[Zn(NOR)(leu)].$7H_2O$	3225	3075	1568	1450	430	870
4.	[Zn(NOR)(val)].$8H_2O$	3365	3085	1528	1475	428	902
5.	[Zn(NOR)(meth)].$9H_2O$	3365	3097	1547	1466	457	832
6.	[Zn(NOR)(cys)].$6H_2O$	3225	3089	1590	1456	428	850
7.	[Zn(NOR)(tryp)].$8H_2O$	3357	3090	1573	1480	408	816
8.	[Zn(NOR)(ala)].$5H_2O$	3304	3073	1585	1426	424	844
9.	[Zn(NOR)(tyro)].$7H_2O$	3341	3085	1569	1439	470	872
10.	[Zn(NOR)(hist)].$6H_2O$	3392	3069	1565	1481	445	840

The prominent peaks in the 1583 cm^{-1} and 1400 cm^{-1} regions in the spectrum of free norfloxacin ligand attributed to the asymmetric and symmetric vibrations of the carbonyl group occur at 1523-1593 cm^{-1} and 1411-1496 cm^{-1} regions in all the Ni (II) ternary complexes, indicating the participation of norfloxacin in the formation of a coordination compound with the Ni (II) ion.

Similarly, in the spectra of free amino acids, bands appear at 3257-3392cm^{-1}region, shows a negative shift in the spectra of all the complexes, suggesting coordination of the amino group through nitrogen atom with the Ni (II) ion. Furthermore, bands at 406-488 cm^{-1}shifted to lower frequencies in the spectra of all the complexes, indicate the M-N bond formation (Fig. 3&4).

The IR spectrum of free amino acids also displays bands in the 1504-1570 cm^{-1} due to asymmetric vibration and in the 1411-1496 cm^{-1} region due to symmetric (COO^-) vibrations.

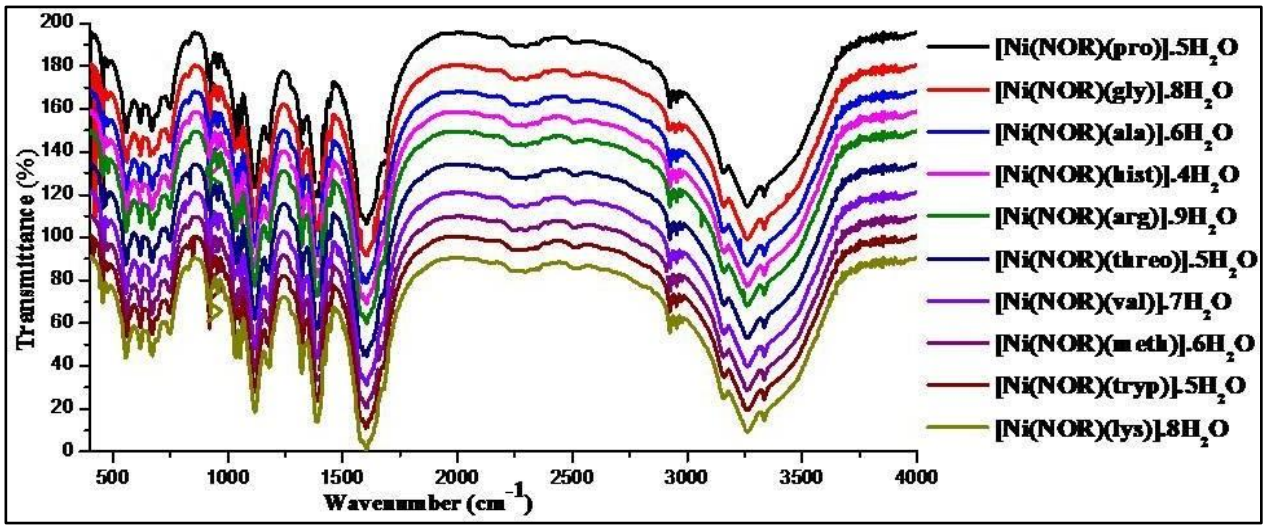


Fig. 4: IR spectrum of [Ni(NOR)(AA)] ternary complexes

These bands were also shifted to the lower region in the spectra of complexes to confirm the coordination of the carboxylate group via oxygen atom with the metal ion [23].

Table 6: IR assignments of synthesized [Ni(NOR)(AA)] complexes.

S.N.	Name of complexes	ν_{asy} NH_2	$\nu_{sy}(NH_2)$	$\nu_{asy}COO^-$	$\nu_{sy}COO^-$	νM-N	νC-W
1	[Ni(NOR)(pro)].5H_2O	3250	3040	1593	1454	455	852
2	[Ni(NOR)(gly)].8H_2O	3282	3032	1579	1442	447	840
3	[Ni(NOR)(ala)].6H_2O	3230	3050	1585	1411	435	852
4	[Ni(NOR)(hist)].4H_2O	3277	3029	1581	1496	464	817
5	[Ni(NOR)(arg)].9H_2O	3242	3061	1573	1460	478	858
6	[Ni(NOR)(threo)].5HO	3273	3016	1589	1411	468	835
7	[Ni(NOR)(val)].7H_2O	3288	3052	1523	1480	461	812
8	[Ni(NOR)(meth)].6H_2O	3284	3043	1581	1444	455	800
9	[Ni(NOR)(tryp)].5H_2O	3240	3020	1572	1454	416	850
10	[Ni(NOR)(lys)].8H_2O	3250	3035	1560	1430	440	860

3.4 Magnetic measurements of[Zn(NOR)(AA)] and [Ni(NOR)(AA)] ternary complexes

The magnetic susceptibility and other related data are present in table 7.These values are closer to those reported in a similar type of complexes [24], [25]. In Zn(II) norfloxacin ternary complexes, zinc metal is present in +2 oxidation state with filled d-orbital. ;fSo there is no

unpaired electron in the outer orbital in zinc metal ion. Hence, under investigation Zn(II) complexes were found to be diamagnetic with all paired electrons (Table 7).

Table 7: Magnetic data of synthesized ternary zinc complexes.

S. N.	Name of complexes	Molecular weight	Electronic configuration (M_{n+},d_n)	Number of unpaired electrons	μ_{eff} (B.M.)
1	[Zn(NOR)threo)].6H_2O	611.28	Zn^{2+},d^{10}	Zero	Zero
2	[Zn(NOR)(arg)].5H_2O	643.28	Zn^{2+},d^{10}	Zero	Zero
3	[Zn(NOR)(leu)].7H_2O	545.28	Zn^{2+},d^{10}	Zero	Zero
4	[Zn(NOR)(val)].8H_2O	645.28	Zn^{2+},d^{10}	Zero	Zero
5	[Zn(NOR)(meth)].9H_2O	668.28	Zn^{2+},d^{10}	Zero	Zero
6	[Zn(NOR)(cys)].6H_2O	581.28	Zn^{2+},d^{10}	Zero	Zero
7	[Zn(NOR)(tryp)].8H_2O	742.28	Zn^{2+},d^{10}	Zero	Zero
8	[Zn(NOR)(ala)].5H_2O	563.28	Zn^{2+},d^{10}	Zero	Zero
9	[Zn(NOR)(tyro)].7H_2O	691.28	Zn^{2+},d^{10}	Zero	Zero
10	[Zn(NOR)(hist)].6H_2O	649.28	Zn^{2+},d^{10}	Zero	Zero

The molar susceptibility values of all the Ni (II) complexes are positive; indicate that complexes are paramagnetic with two unpaired electrons present in the outer orbital of central nickel (II) ion.The magnetic moment data of ternary complexes are given in table 8.

The norfloxacin-amino acids Ni (II) complexes have magnetic moment values in the 1.6-2.9 B.M. range, which are expected of the metal ion with two unpaired electrons with no metal-metal interaction. They are within these ranges consistent with their octahedral geometry around the Ni (II) ion. The number of the unpaired electron is two.

Table 8: Magnetic moment data of synthesized ternary Ni (II) norfloxacin complexes with amino acids.

S.N.	Name of complexes	Molecular Weight	Electronic configuration (M^{n+},d^n)	No. of unpaired electron	μ_{eff} (B.M.)
1.	[Ni(NOR)(pro)].5H_2O	491.59	Ni^{2+},d^8	Two	1.6
2.	[Ni(NOR)(gly)].8H_2O	596.59	Ni^{2+},d^8	Two	2.8
3.	[Ni(NOR)(ala)].6H_2O	574.59	Ni^{2+},d^8	Two	2.4
4.	[Ni(NOR)(hist)].4H_2O	596.59	Ni^{2+},d^8	Two	2.1
5.	[Ni(NOR)(arg)].9H_2O	706.59	Ni^{2+},d^8	Two	2.3
6.	[Ni(NOR)(threo)].5H_2O	583.59	Ni^{2+},d^8	Two	2.6
7.	[Ni(NOR)(val)].7H_2O	620.59	Ni^{2+},d^8	Two	2.5
8.	[Ni(NOR)(meth)].6H_2O	634.59	Ni^{2+},d^8	Two	2.7
9.	[Ni(NOR)(tryp)].5H_2O	654.59	Ni^{2+},d^8	Two	2.8
10.	[Ni(NOR)(lys)].8H_2O	661.59	Ni^{2+},d^8	Two	2.9

3.5 Thermal analysis of [Zn(NOR)(AA)] and [Ni(NOR)(AA)] ternary complexes

The thermo gravimetric analysis (TGA) provides information regarding the thermal stability of coordination compounds at different temperatures. Based on these data, we have also confirmed the presence of coordinated as well as lattice water molecules in coordination compounds. Thermal analytical data of all ternary metal complexes of norfloxacin with different amino acids have been recorded in the nitrogen atmosphere at the constant heating rate of 10 $^{\circ}$C per minute with a temperature range from 25 to 900 ℃.

After several steps of decomposition, all complexes were converted to their corresponding metal oxides (ZnO and NiO)(Rusu et al., 2009). It is well known that amino acids exist only in a solid-state. When heated it in the range between 185^{0}C and 280^{0}C, its thermal decomposition has been occurred endothermic between range -72 and -151 KJ/mol. The thermal decomposition of free amino acids generally releases three gases like H_2O, NH_3, and CO_2. Their TGA gives the weight of these gases as weight loss calculations, which evolve in an appreciable amount[26].

The prepared Zn(II) ternary complexes decompose in three stages in the temperature range 30-260, 260-478, and 478-590 ^{0}C.In which the first stage involves the loss of water molecules, the second and third stages show the removal of both ligand moieties (amino acid and norfloxacin) and horizontal thermogram represent the complete decomposition of complexes. These stages are irreversible and all of these complexes undergo complete decomposition to the corresponding metal oxide(ZnO) (Table 9).

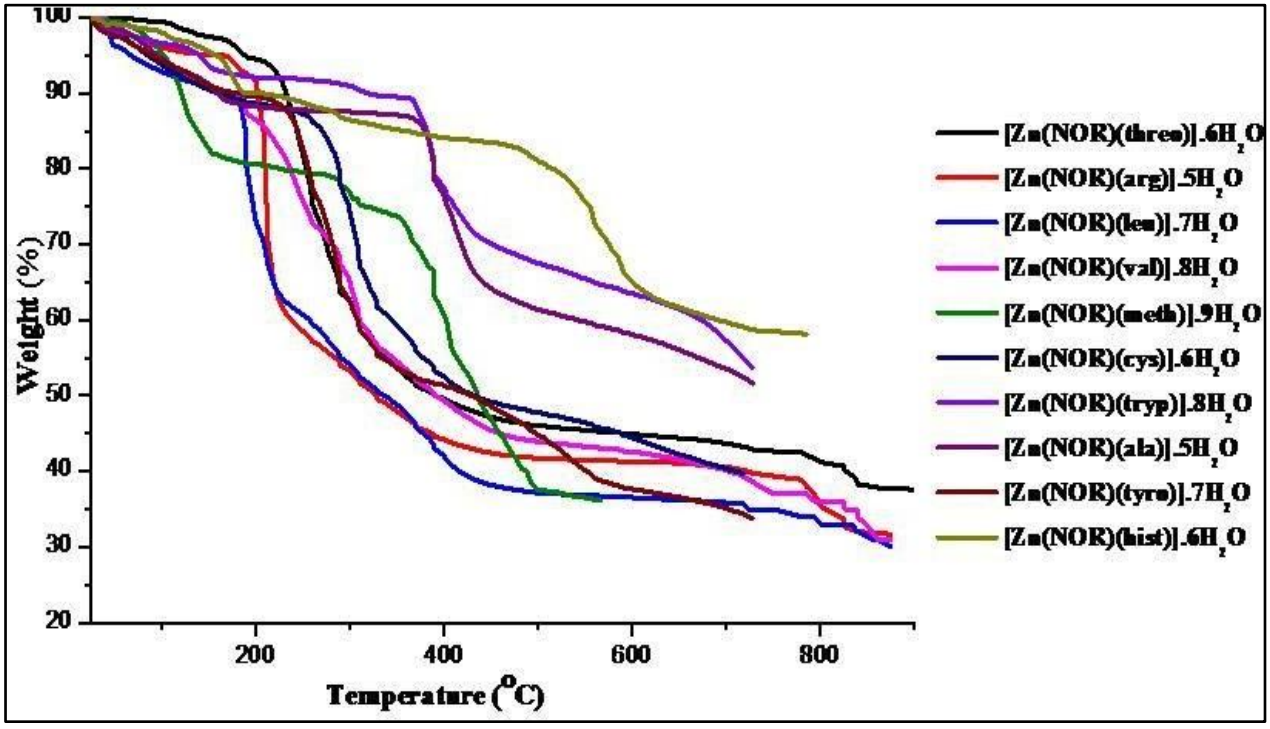


Fig 5.Thermal analysis (TGA) curve of [Zn(NOR)(AA)] ternary complexes.

Table 9.Thermal analytical data of Zn (II) ternary complexes.

S.N.	Name of complexes	Molecular Weight	Decomposition temperature	
			Steps	Temp.(°C)
1.	[Zn(NOR)(threo)].6H_2O	611.28	I	30-185
			II	185-260
			III	260-478
2.	[Zn(NOR)(arg)].5H_2O	643.28	I	35-189
			II	189-284
			III	284-490
3.	[Zn(NOR)(leu)].7H_2O	545.28	I	40-190
			II	190-290
			III	290-496
4.	[Zn(NOR)(val)].8H_2O	645.28	I	48-200
			II	200-399
			III	399-500
5.	[Zn(nor)(meth)].9H_2O	668.28	I	25-180
			II	180-310
			III	310-510
6.	[Zn(NOR)(cys)].6H_2O	581.28	I	40-260
			II	260-329
			III	329-555
7.	[Zn(NOR)(tryp)].8H_2O	742.28	I	37-200
			II	200-370
			III	370-560
8.	[Zn(NOR)(ala)].5H_2O	563.28	I	35-200
			II	200-375
			III	375-566
9.	[Zn(NOR)(tyro)].7H_2O	691.28	I	30-195
			II	195-390
			III	390-585
10.	[Zn(NOR)(hist)].6H_2O	649.28	I	40-185
			II	185-478
			III	478-590

According to the observation of thermograms of Ni (II) complexes, there are three decomposition steps, in which the first step (30-200˚C) shows a small weight loss corresponds to the removal of two coordinated water molecules in the temperature range [27]. Also, the removal of another water molecule was observed in this range in all norfloxacin ternary complexes confirm the presence of both coordinated (inside the coordination sphere) and lattice (outside the coordination sphere) water molecules. Rapid weight loss was observed in the range 200-500^{0}C shows there may be the simultaneous decomposition of norfloxacin or amino acid moieties.

At the second decomposition step, which shows in the 200-389˚C range, loss of amino acid ligand moiety was observed. Removal of norfloxacin ligand was denoted by 389-500˚C range. After that, the horizontal thermogram represents the final decomposition step which is assigned to the completion of decomposition and the formation of stable nickel oxide residue. In an inert atmosphere, metal complexes were decomposing and produce a fine powder which transformed into metal oxide in the presence of a trace of oxygen.

In this investigation, it has been concluded that complexes loss water molecules at30-120˚C and 120-200˚C confirming the presence of both coordinated and lattice water molecules in all complexes which melted at 240^0-320 ^{0}C.In the temperature range, 200 - 500 ^{0}C complexes show rapid weight loss with the loss of both ligand moieties, and metal oxides are formed beyond 500 ˚C. The decomposition steps with temperature ranges of complexes are presented in table 10.

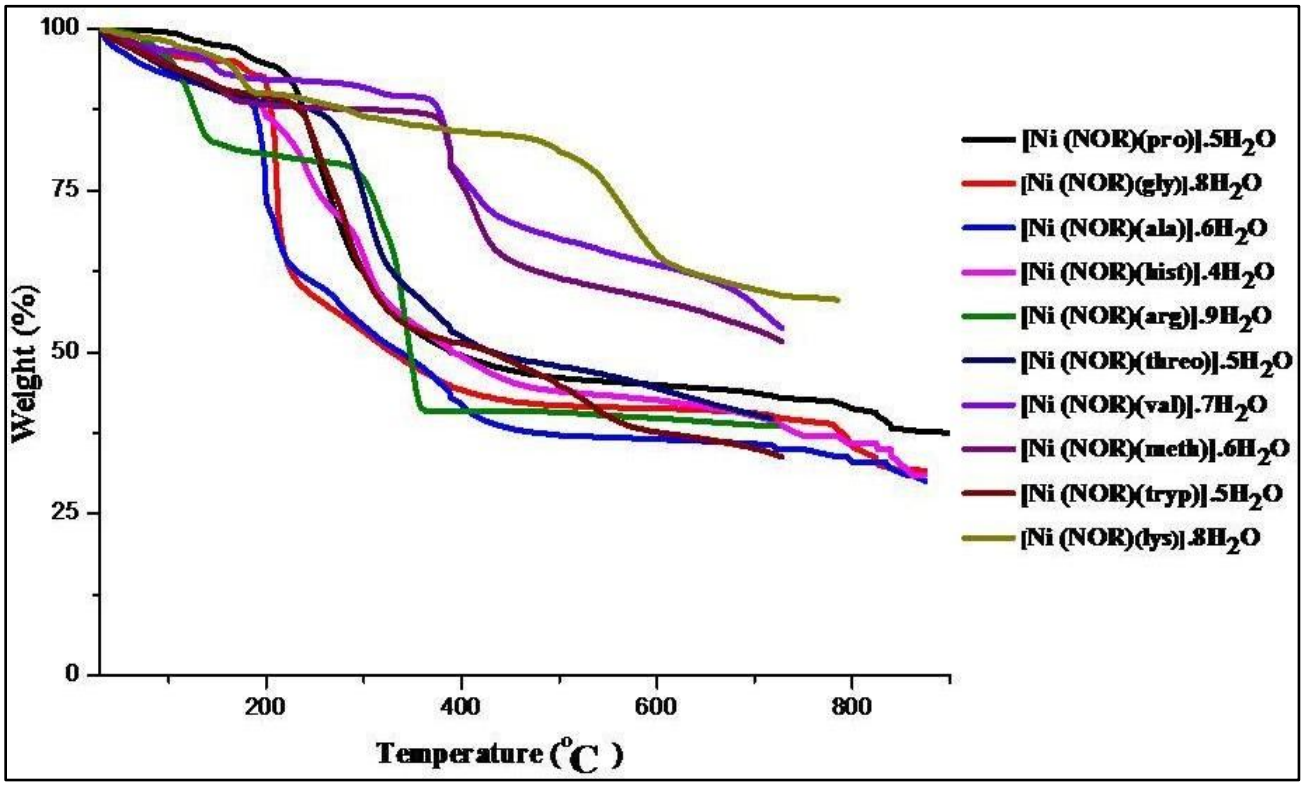


Fig.6:Thermal analysis (TGA) curve of [Ni(NOR)(AA)] ternary complexes.

Table 10: Thermal analysis data of synthesized [Ni(NOR)(AA)] **ternary complexes.**

S.N.	Name of complexes	Molecular weight	Decomposition temperature	
			Steps	Temperature(°C)
1.	[Ni(NOR)(pro)].5H2O	491.59	I II III	30-190 190-380 380-500
2.	[Ni(NOR)(gly)].8H2O	596.59	I II III	34-178 178-350 350-449
3.	[Ni(NOR)(ala)].6H2O	574.59	I II III	38-200 200-375 375-500
4.	[Ni(NOR)(hist)].4H2O	596.59	I II III	37-189 189-365 365-447
5.	[Ni(nor)(arg)].9H2O	706.59	I II III	35-180 180-300 300-456
6.	[Ni(NOR)(threo)].5H2O 583.59	583.59	I II III	40-200 200-369 369-458
7.	[Ni(NOR)(val)].7H2O	620.59	I II III	39-198 198-345 345-499

8.	[Ni(NOR)(meth)].6H2O	634.59	I II III	36-185 185-365 365-500
9.	[Ni(NOR)(tryp)].5H2O	654.59	I II III	34-190 190-389 389-458
10.	[Ni(NOR)(lys)].8H2O	661.59	I II III	35-200 200-354 354-489

4. Conclusion

In summary, twenty (20) ternary complexes of transition metals with mixed ligands; primary ligand norfloxacin and secondary ligand amino acids with Zn(II)/Ni(II) ions are used as central metal ion were successfully synthesized and characterized. The results of elemental analysis, spectroscopic analysis, and magnetic moment measurements indicate that all complexes of Zn(II) and Ni(II) possessed an octahedral geometry. Magnetic moment data confirmed diamagnetic and paramagnetic nature for both Zn(II) and Ni(II) ion complexes respectively. Thermal stability and presence of coordinated water molecules were confirmed by the thermogram of these complexes. Based on IR spectral analysis, we conclude that the binding modes of both ligands with the central metal ion in complexation reaction. In these reactions, norfloxacin and amino acids both acted as neutral bidentate ligand coordinated with the metal ion in all these complexes.

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Conflict of interest

Authors declare no competing financial interest.

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