



SYNTHESIS AND CHARACTERIZATION OF CO (II) COMPLEX WITH L-LEUCINE



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Abstract: Cobalt (II) amino acid complex in aqueous basic solution $\{[CoL_2(H_2O)_2] \cdot H_2O$ and $L = L\text{-leucine}\}$ was synthesized and analyzed by means of gravimetric analyses, molar conductivity measurements, UV-Visible and IR spectroscopies. Molar conductivity measurements showed that the composition of the metal complex corresponds to a metal-amino acid ligand ratio of 1:2. The IR spectra showed that the amino acid acts as bidentate ligand with coordination involving the carboxyl oxygen and the nitrogen of the amino group. The result also suggests the presence of water of crystallization in the complex. Electronic spectra measurements suggested octahedral local symmetry for Co ion. The results also suggested that the ligand, L-leucine, is a weak field ligand as it formed high spin complex with Co(II) ions. Metal content and hydration water analyses showed that the complex of Co contains one mole of water of crystallization. The results also suggested that the Co(II) complex contains two aqua ligands in their inner coordination sphere.

Keywords: Metal(II) Complex, L-leucine, Ligand, UV spectroscopy, gravimetry analysis

Introduction

A coordination complex consists of a central atom or ion, which is usually metallic and is called the coordination centre, and a surrounding array of bound molecules or ions that are in turn known as ligands or complexing agents. Many metal-containing compounds, especially those of transition metals, are coordination complexes. A coordination complex whose centre is a metal atom is called a metal complex (Lawrence *et al.*, 2010).

The study of transition metal complexes containing biologically important ligands is made easier because certain metal ions are active in many biological processes (Das *et al.*, 1990). The fact that transition metals are essential metallic elements and exhibit great biological activity when associated with certain metal-protein complexes, participating in oxygen transport, electronic transfer reactions or the storage of ions has created attention in the study of systems containing these metals. Mixed ligand complexes with metal ion bound to two different and biochemically important ligands have aroused interest as model for metallo-enzymes. The physiologically interesting mixed ligand complexes of transition metals with amino acids play an important role in biological systems and have been a subject of great interest for researchers (Calif *et al.*, 2000). It is also well established that mixed ligand complexes play a decisive role in the activation of enzyme and also storage and transport of active substances. These compounds present a great variety of biological activity ranging from antitumor, fungicide, anti-inflammatory, bactericides and antiviral activities (Sakiyan *et al.*, 2004)

Metals perform quite a number of functions in human body. Hemoglobin carries oxygen to vital areas of the body by binding it to the iron atom contained within it. Metal ions such as zinc provide the structural framework for the zinc fingers that regulate the function of genes in the nuclei of cells (O'Shea, 2004). Minerals containing calcium are the basis of bones which are the framework of the human body. Metals such as zinc, copper, iron and manganese are incorporated into catalytic processes which facilitate a number of chemical reactions needed for life (Da Silva and Williams, 1991). The ability of metals to lose electrons to form positively charged ions allow them to play important roles in biological systems. Whereas metal ions are electrophilic, most biological molecules such as protein and DNA are electron rich. The attraction of these opposing forces leads to interaction

between metal ions and biological molecules (O'Shea, 2004). Metal ions have been reported to improve, or induce the activity of biologically important moieties and that of some known drugs such as paracetamol, sulfamethoxazole and aspirin (Sadler and Guo, 1998)

Bacterial resistance to drugs is fast becoming a global concern with rapid increase in multidrug-resistant bacteria. This has mandated continued search for new antibacterial compounds, including coordination complexes of biologically important molecules (Agbaje *et al.*, 2014). The medicinal uses and applications of metals and metal complexes are of increasing clinical and commercial importance. The field of inorganic chemistry in medicine has been divided into two main categories: firstly, ligands as drugs which target metal ions in some form; and secondly, metal-based drugs and imaging agents where the central metal ion is usually the key feature of the mechanism of action (Reynold and Martidale, 1996; Farrell *et al.*, 2003). Continued research aimed at developing metal-based drugs which perhaps work by different mode of action and therefore arrest the challenge of resistance, is therefore, a way forward (Agbaje *et al.*, 2014)

There have been some reports of antibacterial activity of certain metal complexes of amino acids. However, there is little information on coordination compounds of leucine. Literature studies showed that there is scanty information on the structure of M(II) coordination compounds of leucine, as those reported have often been poorly characterized (Asemave *et al.*, 2015; Vilhena *et al.*, 2017). In spite of the interesting biological features exhibited by leucine, their coordination complexes with transition metals have not been well studied (Hakimi and Aliabadi, 2012). It will rather be a step forward to synthesize, characterize and study the biological activities of complexes of such ligands with other similar biologically important metal ions as well in order to add to the already existing body of knowledge available on such complexes.

The aim of this work is to synthesize and characterize amino acid complex of Co(II). The objective of this work is to synthesize Co(II) complex of L-leucine, to characterize the amino acid complex through spectrophotometric (UV and FT-IR), and classical methods (measurements, molar conductivity and gravimetric analyses).

Materials and Methods

Materials

Water bath, oven (heating and drying oven), furnace, digital weighing balance, melting point apparatus (Stuart Automatic Model SMP40) and magnetic stirring hot plate (BIBBY STERILIN Model HC500). conductivity meter (Jenway conductivity meter: Sension4510), UV-visible spectrophotometer (Agilent Cary Series), IR spectrophotometer (Agilent Cary 360).

L-leucine, cobalt (II) chloride hexahydrate, sodium hydroxide, dimethyl sulphoxide, methanol, ethyl acetate, ethanol and distilled water. The chemicals and solvents were of analytical grade and were used without further purification. The microbes were clinical strains and were obtained from the Department of Microbiology ABU, Samaru-Zaria Nigeria. The standard drug used was ciprofloxacin and fulcin.

Methods

Synthesis of metal (II) leucine complexes

The complex was synthesized using a procedure adopted from Aiyelabola *et al.* (2012) with slight modification as follows: Stoichiometric amounts of 1.530 g leucine (0.010 mol) was weighed and dissolved in 40 ml of distilled water. Appropriate amounts of 0.420 g (0.011 mol) sodium hydroxide was then weighed and dissolved in 10 ml of distilled water and added to the leucine solutions for deprotonation of the amino acid. Aqueous solution of the metal salt containing 1.230 g of CoCl₂.6H₂O (0.005 mol) was prepared using 40 mL distilled water. This was added to the deprotonated amino acid solution and the resultant mixture heated on a water bath with constant stirring for about 2 h. Precipitates obtained was filtered off, washed with water several times and dried in an oven at 60°C.

Characterization

The synthesized complex was subjected to spectrophotometric and classical analyses.

Melting point analysis

The temperature of decomposition of the complex was measured using open capillary tubes on a **stuart** automatic melting point apparatus model SMP40, with starting temperature of 40°C at a temperature ramp of 15°C min⁻¹

Solubility test

Solubility test for the complex was done at room temperature using the cold solvents, water, methanol, ethanol, ethyl acetate and DMSO. The test was carried out by placing a small amount of the sample in different test tubes each containing different solvent and the mixture was vigorously hand-shaken to check whether the complex dissolved or not.

Molar conductivity

Molar conductivity measurements were carried out at room temperature using a HACH conductivity meter model Sension. The analysis was done using a procedure adopted from Jamil *et al.* (2015). A 0.02 g of the sample was placed in a 10 cm³ of 0.001M dimethyl sulphoxide, DMSO solvent, in a test tube. The resultant solution was vigorously shaken to ensure complete dissolution of the sample. The electrode was dipped into the test tube containing the dissolved sample and the readings from the conductivity meter were obtained.

Determination of hydration water in the complex compounds

This was done by following a procedure reported by Aliyu and Abdullahi, (2009). Specific weight of the complexes (0.1000 g) in a crucible was placed in an oven at 110°C for 1 h. This was removed and reweighed after allowing it to cool in a desiccator. The procedure was repeated until constant weight was obtained. The loss in weight was recorded and the percentage composition of water of hydration in the complex determined using equation 1 below (Vogel, 1966; Aliyu and Abdullahi, 2009).

$$\frac{\text{Loss in weight (g)}}{\text{Weight of sample}} \times 100\% \dots\dots\dots(1)$$

Metal content analysis

The metal content was determined gravimetrically by converting the complex into its corresponding oxide. Weighed amount of the complex (in a crucible) was ignited using a Nabertherm programmable furnace (Model GmbH) at a temperature ramp of 20°C min⁻¹ and was held at a plateau temperature of 800°C for three hours (Refat *et al.*, 2013). The weight of the resultant residue was recorded, and percentage of metal content was determined using equation (2) below;

$$\frac{\text{weight of metal oxide} \times \text{gravimetric factor}}{\text{weight of complex taken}} \times 100\% \dots\dots\dots(2)$$

UV-visible spectroscopy

The UV-visible spectrum was determined in the DMSO solvent with concentration (1.0×10⁻³M) for the free ligands and their metal complex using Cary series UV-visible Spectrophotometer with 1cm quartz cell, in the range 200–800 nm (Refat *et al.*, 2013).

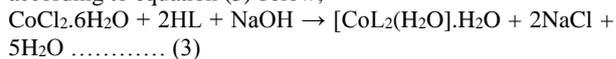
Infra-red spectroscopy

IR spectra was recorded on Agilent Cary 630 FTIR Spectrophotometer within wave number range of 4000–650 cm⁻¹. Information about metal (II) ions' coordination was obtained by comparing the IR frequencies of the ligands with those of their respective metal complexes (Stanila *et al.*, 2007).

Results and Discussion

Physical properties of the metal (II) complexes

The reaction of L-leucine (HL) with the metal (II) chlorides (Co), under alkaline pH gave a pink coloured compound which is Co.L complex. Good yield of 69.10% was obtained for the Co.L complex (Table 1). The complex was formed according to equation (3) below;



The decomposition temperature of the complex was measured using a Stuart automatic melting point apparatus model SMP40. The range of values observed for the complex was reasonably fair since they are in agreement with previous reports for similar compounds. The result obtained herein is akin to that obtained by Stanila and his coworkers in 2007 for similar complex compounds (Stanila *et al.*, 2007). The decomposition temperature of Co.L obtained was 377 – 385°C (Table 1).

Table 1: Physical parameters

Parameters	Complex (Co. L)
Formula weight (g/mol)	375.26
Melting point	377 – 385°C
Colour	Pink
Yield	69.10%

Co. L = cobalt leucine complex

Table 2: Solubility test

Solvent	Complex (Co. L)
Water	IS
Methanol	IS
Ethyl acetate	IS
Ethanol	IS
DMSO	S

Co. L = cobalt leucine complex, IS=Insoluble, PS = partially soluble, S= Solubles

Solubility

The solubility of the metal complex was tested in water, methanol, ethyl acetate, ethanol, and dimethylsulphoxide (DMSO) as shown in Table 2. DMSO was found to be the best solvent for the complex. Thus, studies of electronic spectroscopy and conductivity measurements were carried out by dissolving the complex in DMSO Solvent. The result is in concomitance with the findings of Selwin *et al.* (2009) for a similar complex (Selwin *et al.*, 2009).

Metal content analysis

Table 3 shows the results of metal content analysis. It can be observed therein that the calculated values of percentage metal in the complex are in close agreement with that of experimental. The calculated and observed percentage metal composition for Co.L complex is 15.70 and 15.73, respectively. This corroborated further the molecular formula.

Table 3: Metal complex analysis

Analysis	Co. L Complex
Weight of complex	0.15
Weight of oxide	0.03
Gravimetric factor	0.7865
Percentage of metal composition calculated	15.70
Percentage of metal composition observed	15.73

Table 4: Water of hydration

Analysis	Co. L Complex
Initial weight of complex	0.100
Final weight of complex	0.0947
Loss in weight	0.0053
Percentage of water of hydration calculated	4.8
Percentage of water of hydration observed	4.9

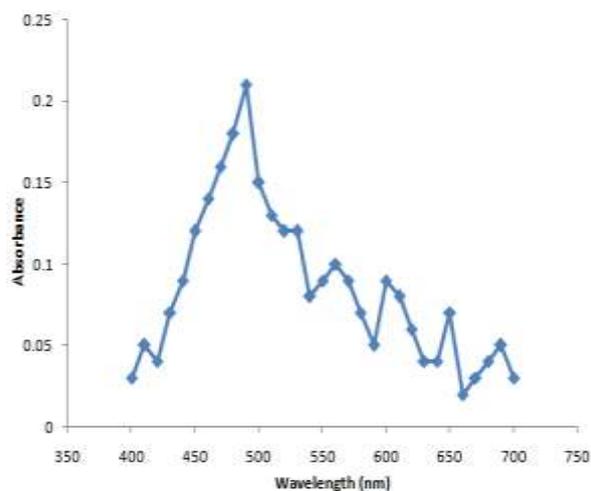


Fig. 1: Wavelength of maximum absorption of Cobalt Leucine Complex

Hydration water analysis

The proposed equation for the reaction and complex structure revealed the presence of coordinated water and water of hydration in the cobalt (II) complex (Fig. 1). Consequently, percentage hydration water in the complex compound was determined (Table 4). The experimental values of percentage water present in the complex is in close agreement with the

calculated value, with Co.L having percentage water of hydration for calculated and observed to be 4.8 and 4.9. This corroborated the molecular formula.

UV-visible spectroscopy

The electronic spectra of the Cobalt complex in DMSO is presented in Fig. 1. The visible spectrum of Co.L absorbs at a maximum wavelength of 490 nm.

Molar conductivity measurements

The molar conductivity value for the complex in 10^{-3} moldm⁻³ DMSO is presented in Table 5. The value obtained is 1.46 μ S, suggesting that this complex compound is a non-electrolytes. In cases of presence of ions outside the coordination sphere (electrolytes), higher conductivity measurements are observed in the electrolytic range (Refat *et al.*, 2013b). Conductivity measurements have frequently been used in structural elucidation of metal complexes (mode of coordination) within the limits of their solubility. They provide a method of probing the degree of ionization of the complex and the molar ions a complex liberates in solution (Refat, 2007). It becomes clear from the conductivity data that the complex under study is most likely a non-electrolytes complex. This would only infer that the complex formed in a 1:2 metal-ligand ratio since charge neutrality can only be maintained when 1 mole of M²⁺ combine with 2 moles of Leucine. This fact is important in establishing that there is the absence of such ions as Na⁺ in the outer coordination sphere of this complex which eliminates the possibility of a 1:3 metal-ligand ratio. Similarly, the possibility of a metal-ligand ratio of 1:1 is untenable as the non-electrolytic nature of this complex rationalizes the absence of Cl⁻ ions in their outer coordination sphere (Mohamed *et al.*, 2009; Abou-Hussein and Linert, 2015).

Table 5: Molar conductivity measurement

Parameters	Complex (Co.L)
Molar Conductivity (μ s)	1.46

Table 6: IR-Frequencies of Co.L absorption

Types of vibrations and group	Complex (frequencies in cm ⁻¹) Co.L
(O-H) Stretch	3280.1
(N-H 2°) Stretch	3365.8
(H-C-H) Stretch	2959.5
(C=O) Stretch	2870.1
Finger printing region	
(N-H scissoring) Bending	1587.8
(O-H) Bending	1401.5
(C-H & CH ₂) Stretch	972.8
(C-O) Stretch	1103.3
(CH ₂ & CH ₃) Bending	1472.3
(C=O) Stretch	182.7

FTIR spectra

Numerous chemical functional groups such as carboxyl, hydroxyl, amide, alkane, etc. have been identified to be responsible for the metal complex formation and their antimicrobial activities potentials. The FTIR absorption ranges for the complex is shown in Table 6 and the electronic spectrum of the pure leucine and Co.L complex is shown in Figs. 2 and 3, respectively.

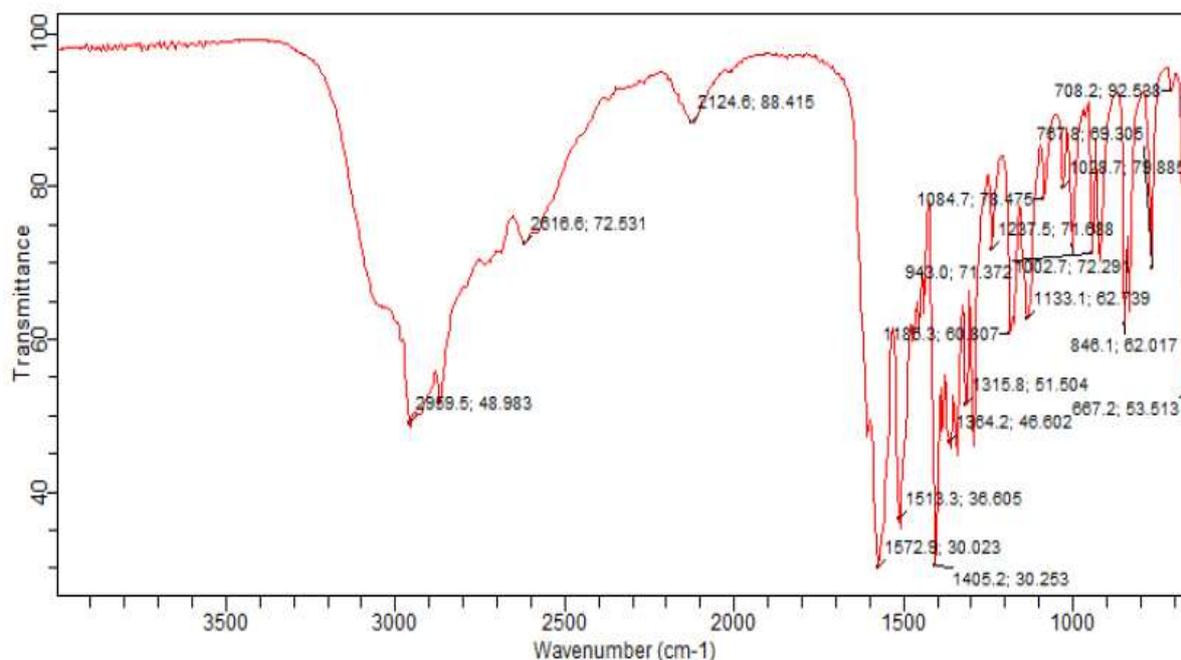


Fig. 2: IR-spectra of L-leucine

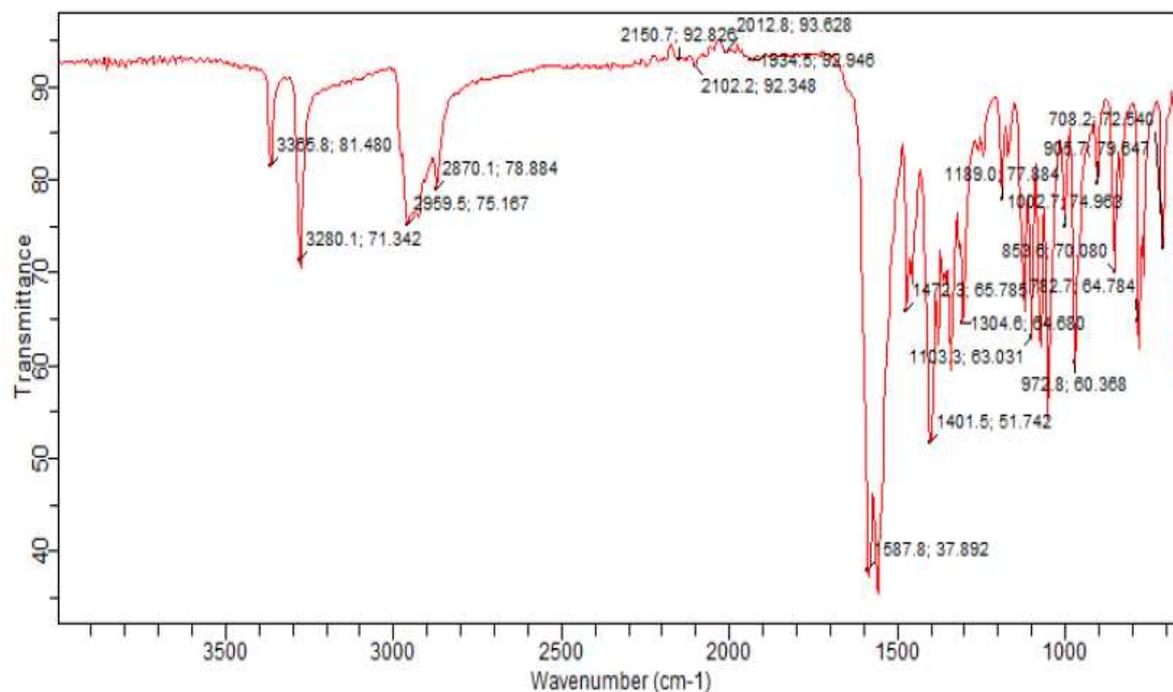


Fig. 3: IR-spectra of Cobalt-leucine (Co.L) complex

The spectrum of the complex showed peaks at 3350 – 3650 cm⁻¹ indicating the presence of OH or –NH groups. The peaks at 1705 – 1720 cm⁻¹ indicate the presence of C=O while peaks at 2850 – 3000 cm⁻¹ indicate the presence of an alkane. FTIR absorption ranges of Co.L shown in Table 6 shows the presence of different functional groups and the type of vibrations, as it absorbs at 3365.8 cm⁻¹ indicating the presence of 2° amine, 3280.1 cm⁻¹ indicate the presence of OH group, 2959.5 cm⁻¹ indicating the presence of H-C-H and 1934.6 cm⁻¹ indicating the presence of C=O, respectively. 3645.5 cm⁻¹ indicating the presence of OH group, 3369.5 cm⁻¹ proves the presence of N–H 2° amides, 2952.1 cm⁻¹ indicate the presence

of H-C-H and 1949.4 cm⁻¹ indicate the presence of C=O, respectively.

The spectrum of the synthesized Co(II) complex shows that the functional groups present in the ligands such as amine, carboxyl and hydroxyl where not destroy in the process of complex formation. The presence of those functional groups are responsible for the metal complex formation. Such groups appeared to be present in the complex formed and they serve as ligating atoms in the complex formation.

Equation for the reaction of Cobalt-leucine complex

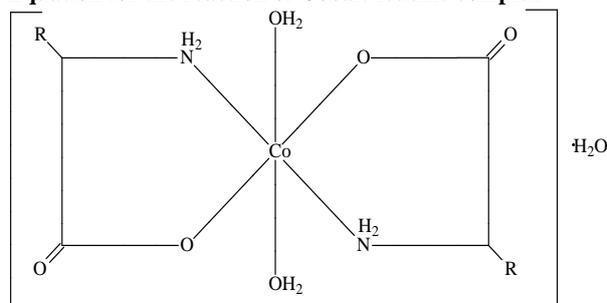


Fig. 4: Proposed structure of Cobalt-leucine complex

Conclusion

Cobalt (II) amino acids complex in aqueous basic solution, $[CoL_2(H_2O)_2].H_2O$ with L-leucine was synthesized and analyzed by metal content analysis, molar conductivity measurements, magnetic susceptibility measurements, UV-Visible and FTIR spectroscopies. Molar conductivity measurement showed that the complex is non-electrolytic and the compositions correspond to a metal-ligand ratio of 1:2. The IR spectra showed that the amino acid acts as bidentate ligand with coordination involving the carboxyl oxygen and the nitrogen of the amino group. The result also suggests the presence of water of crystallization in the complex. Electronic spectra and magnetic susceptibility measurements suggested an octahedral local symmetry for Co (II) ion. Magnetic susceptibility studies also revealed that the complex is paramagnetic. The result also suggested the ligand, L-leucine to be weak field ligand as it formed high spin complex with Co ions.

Metal content and hydration water analysis showed that the complex of Co contains one mole of hydration water. The obtained structural data thus allows for the proposition of the structural formula for the studied metal (II) complex.

Conflict of Interest

Authors declare that there is no conflict of interest related to this work.

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