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Medical Nutritional and Biochemical Role of N-Acetyl-L-Cysteine and its Spectrophotometric Determination by Complexion with RU (III) and Characterization by Elemental Analysis, FTIR, ESR, NMR, TGA, DTA Proposed Structure of the Complex

Research Article

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Abstract

Micro determination of the antioxidant, anti-HIV drug N- Acetyl-L-Cysteine was achieved by its complexation with Ru(III) using spectrophotometry, Ru(III) form very light brown colour complex with N-Acetyl-L-Cysteine at rooms temperature max of the complex is 464 nm, ---= $5.62X10^3$ L/mol/cm. Beer's law range is 7.871 x 10^{-8} mg to 9.445x 10^{-7} mg, Job's method of continuous and mole ration method confirms the metal to ligand ratio as 1:1. Effect of presence of foreign metal ions was also studied, and it was also studied and it was found that 1 ppm of N-Acetyl-L-Cysteine can bear 0.00047 ppm of zinc sulphate, 0.078 ppm of cobalt nitrate, 0.00021 ppm of Nickel sulphate, 0.0038ppm of ferric chloride and Os(VIII), Pd(III) interfere, Characterization of the complex was done by elemental analysis (CHN estimation) which confirms the metal to ligand ration as 1:1 FTIR spectrum of the complex ascertain the binding of sulphur atom and NH_2 group. ^1H NMR spectrum of the complex exhibit a disappearance of SH peak and NH peak hence confirming the binding of sulphur and nitrogen atom with Ru(III). Three ESR signals show paramagnetic nature of the complex. DTA, TGA confirms the presence of lattice and coordinated water molecules.

Keywords: FTIR; NMR; ESR; DSC; TGA; DTA

Introduction

N- Acetyl- L-Cysteine (NAC) is a biologically active substance with a mucolytic effect and it has been shown to be effective as an antidote for treatment of acetaminophen poisoning [1,2].

Sulfur-containing nutrients play several critical roles in the body including detoxification and protecting cells and cellular components against oxidative stress.

Sulfhydryl compounds, that are excellent radiation protectors, are also free radical scavengers peroxide decomposers, catalyst of sulfhydryl disulfide exchange and possibly can implement repair of damaged sites. These along with Vitamin E increase the limit of tolerance to selenium by the human body [3].

Nowadays, NAC is being ascribed with greater importance that even glutathione. It is produced in living organisms from the amino acid cysteine. Thus, NAC is natural sulphur containing amino acid

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derivative occurs in foods. It is a powerful antioxidant too [4,5]. These dual properties help repair oxidative damage in the body.

For example, by the Human Immunodeficiency Virus (HIV). It has been established that reduced intracellular glutathione in the direct and early consequence of retroviral infection [6].

Intracellular glutathione has a powerful influence on how well T and B-lymphocyte cells function [6,7]. In addition, intracellular glutathione availability affects the production of phagocytes (Macrophages, monocytes and neutrophils). T- Cell and B-Cell are lymphocytes. The phagocytes have the function of killing viruses, bacteria and fungi Free radicals can impair the immune system and NAC can protect against free radicals and may enhance the immune system [8-10].

NAC blocks the AIDS (HIV) virus production in vitro, by increasing glutathione levels in HIV infected cell [11-23]. Beside vitamin C reducing oxidized glutathione back to free reduced (active) glutathione, vitamin C and NAC had complementary actions to slow the replication of the AIDS virus.

Detoxification

These sulphur containing nutrients protect against toxins. NAC is particularly effective and NAC detoxifies several toxic agents including the heavy metals such as mercury, lead and cadmium [24-30], drugs including acetaminophen (eg. TylenoI™) [31-38], herbicides such as Paraquat [39], environmental pollutants such as carbon tetrachloride and urethane and microorganism including Aflatoxin and *Escherichia coli* [40-47].

NAC, cysteine and glutathione contain sulphur in the form of sulfhydryl groups. Sulfhydryl groups directly react with many poisons. Especially heavy metal such as lead, mercury and cadmium. They also offer second line and third line defenses in the liver and various individual cells. Sulfhydryl groups also help remove toxins indirectly via enzyme system called the P-450 system.

NAC also has a secondary role in detoxification since it helps produce optimal amounts of glutathione which also conjugates with most "foreign" compounds and excess oxidizers that enter cells. The harmful compounds that have been conjugated with glutathione then pass harmlessly out of the body through biliary system [30].

NAC is approved a drug for use prevent liver damage from over dosages of acetaminophen. Either NAC tablets of solutions are prescribed to protect against acetaminophen overdose.

The Lancer reports that NAC is also effective in reducing the toxic effect of carbon tetrachloride, chloroform and carbon monoxide [31]. NAC can also reduce the side effects of drugs such as doxorubicin, Ifosfamide, valproic acid and alcohol [31,37,38].

NAC and cancer

NAC protects against cancer by both of its roles as antioxidant and detoxifier [47-53].

NAC also reduces the toxic effects of some chemotherapy agent such as cisplatin and oxazaphosphorine based agents. In addition, it is useful in the prevention or reduction of the side effects of cyclophosphamide treatment in cancer patient [54,55].

Mucolytic

NAC has been used for about thirty years to break up mucus in persons having bronchopulmonary disease including chronic bronchitis, cystic fibrosis, asthma, sinusitis and pneumonia [56]. NAC helps reduce the viscosity of mucus so that it may be more easily coughed up [57]. NAC accomplishes this by converting the disulfide bonds of the mucoprotein into sulfhydryl bonds and clearing the mucoproteins into smaller molecules.

Several companies provide a 10 or 20 percent. NAC solutions a nebulizer spray (such as Bristol Laboratories: Mucomyst TM), while others such as Italy's Zambon group provides NAC in tablet form. When a nutrient is topically applied or sprayed into the lungs, it can then be classified also as a drug because it does not enter into metabolism to nourish the body when it is administered in this way. [However, this is different from having a nutrients absorbed into the body by sublingual or nutrient absorbed into the body by sublingual or nasal membrane application which allows the nutrient to nourish the body].

Heart disease

A growing area of interest is a specific lipoprotein called Lp(a) as one of the two most reliable indicators of heart disease risk [58-62]. The other reliable indicator is the level of vitamin E in the blood [63]. Lp(a) is a much reliable indicator than blood cholesterol level, low density lipoprotein, high density lipoprotein or their ratios to each other.

Diets and drug designed to lower blood cholesterol level do not lower Lp(a) levels. Now recent research has found that NAC is most effective nutrient known to lower Lp(a) levels. NAC reduces Lp(a) by almost 70% [64-67]. Lp(a) consist of a LDL particle attached to the large lipoprotein apo(a) by one or more disulphide bonds. NAC breaks up the disulphide bonds converting each disulfide groups into two sulfhydryl groups, finally in two separate compounds.

NAC also inhibits heart damage by preventing TDL from being oxidized and by destroying free radicals produced after an infraction [68-71].

Antioxidant

NAC is the pre-catalyzed form of the simple amino acid and cysteine. N-acetyl-L-Cysteine is a powerful antioxidant and a premier antitoxin and immune support substance. Antioxidants neutralize free radicals, which are produced by normal metabolic activity. If free radicals are left unchecked they cause damage to cells and DNA and are considered by scientists to be a major factors in the aging process.

NAC IS currently the dietary supplement of choice for building up or conserving the body's stores of glutathione, cysteine and other sulfhydryl antioxidant resources.

Being a powerful antioxidant nutrient, it has been of special interest to athletes for some time as heavy exercise increases oxidative damage in the body [72-74]. NAC maintains GSH and GSH-related antioxidant levels. The enzyme the body produces to fight free radicals. Body needs L-cysteine to produce GSH (Glutathione) a very powerful antioxidant.

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As the body ages, its ability to digest and absorb protein become less and less over the year and the system becomes compromised. This directly results in shortage which in turn leads to any number of age related diseases, of the elderly people. Consequently, NAC has provided important benefit as an 'elderly' or age related disease antioxidant. It also works to maintain glutathione and related antioxidant levels that normally diseases with stress, injury, exercise or age, possessing antioxidant affects itself, NAC, also synergistically enhance vitamin C's ability to support the immune system.

Sulphur as compared to the other second row elements of the periodic table, is much more versatile as reaction center than that of its first row counterparts oxygen. Oxygen containing compounds often alter the chemistry of the carbon atom to which oxygen is attached (Table 1).

Similar effects are found in organosulfur compounds, but owing to the high reactivity of the sulphur atom itself towards electrophilic, nucleophilic and even radical reagent, an overwhelming majority of reaction occurs directly at sulphur function.

Sulphur compounds are of prime importance in many industrial operations, in pharmaceutical industry and also in metabolic process.

Sulfhydryl group containing thiols are the fundamental building blocks for synthesizing other organosulfur compounds in plants and animals. Thiols are highly reactive and even small quantities play key role in biological processes.

Together with a number of other sulphur compounds, thiols occur as a small, though significant fraction of crude petroleum.

The dithiol $HSCH_2$-CHSH-CH_2OH known as BAL (British Anti_ Lewisite) was developed as a protective agent against arsenical war gases and is an effective antidote for poisoning by arsenic, mercury and other heavy metal. Applications of disulphide includes polymerization catalyst, regulators in emulsions polymerization, dye intermediates, specific test reagents for thiol groups, floatation agent, softeners, vulcanization accelerators, plasticizers, insecticides, pesticides, fungicides and therapeutic drugs.

Table 1: Micro determination of the N-ACETYL-L-CYSTEIN as its Ru(III) complex.

S. No.	Amount of N-Acetyl-L-cystein taken in mg	Amount of N-Acetyl-L-cystein found mg	% Error	Standard Deviation	Coefficient of Variance
1	$7.871X10^{-8}$	$7.871X10^{-8}$	$1.397X10^{-1}$	$7.550X10^{-11}$	$9.593X10^{-2}$
2	$1.574X10^{-8}$	$1.574X10^{-8}$	$2.541X10^{-1}$	$8.017X10^{-11}$	$5.106X10^{-1}$
3	$2.361X10^{-7}$	$2.361X10^{-7}$	0	$7.991X10^{-10}$	$3.388X10^{-1}$
4	$3.148X10^{-7}$	$3.148X10^{-7}$	$2.541X10^{-1}$	$8.280X10^{-10}$	$2.645X10^{-2}$
5	$3.935X10^{-7}$	$3.935X10^{-7}$	$1.270X10^{-1}$	$8.450X10^{-10}$	$2.652X10^{-1}$
6	$4.722X10^{-7}$	$4.722X10^{-7}$	0	$7.800X10^{-10}$	$1.652X10^{-1}$
7	$5.509X10^{-7}$	$5.509X10^{-7}$	0	$7.550X10^{-11}$	$9.593X10^{-2}$
8	$6.296X10^{-7}$	$6.296X10^{-7}$	0	$7.550X10^{-11}$	$1.246X10^{-1}$
9	$7.083X10^{-7}$	$7.083X10^{-7}$	$1.835X10^{-1}$	$7.690X10^{-10}$	$1.087X10^{-1}$
10	$7.871X10^{-7}$	$7.871X10^{-7}$	0	$8.220X10^{-10}$	$1.049X10^{-1}$
11	$8.658X10^{-7}$	$8.658X10^{-7}$	0	$8.300X10^{-10}$	$9.586X10^{-2}$
12	$9.445X10^{-7}$	$9.445X10^{-7}$	0	$7.800X10^{-10}$	$8.297X10^{-2}$

Several methods have been proposed for the determination of NAC, however, the procedure have only been developed for aqueous solutions of NAC in the absence of other compounds.

The methods described in the literature are generally based on the quantification of this thiol group and can be classified into three types:

1. Oxidation of the thiol group.

2. Formation of metal mercaptides.

3. Use of chromophoric reagents

The oxidation of the third group can be performed with Iodine [75], chlorine and bromine [76], tetrathionate [77], or Fe^{III} [78]. The metal mercaptides can be obtained by the titration of the thiol with Hg^{II} and Ag^{I} or Pd^{II} [79-82].

Direct UV spectrophotometry has also been used for the quantitative analysis of NAC solutions, but the method has been criticized because it suffers from numerous interferences and does not distinguish between NAC and inactive degradation product N, S-diacetylcysteine [83]. The official method for determining the NAC content in sterile solutions and inhalation solutions containing isoproterenol is based on the separation of NAC by High Performance Liquid Chromatography (HPLC) [84].

Other method are based on the reaction of NAC with 5,5'-dithiobis (2-nitrobenzoic acid) and hydroxylamine [85,86]. A fluorimetric method with monobromobimane (4-bromomethyl-2.3,5,- trimethyl-3a, 6a-diazapentalene -1, 6-dione has also been reported and the method has been applied to studies of the pharmacokinetic behavior of NAC by HPLC [87].

Primary amines react rapidly with O-Phthalaldehyde (OPA) in the presence of a thiol (usually 2-mercaptoethanol) to give 1-alkylthio-2alkyl-substituted isoindoles. The reaction has been used for the separation and fluorimetric detection of amino acid [88]. The reaction has also been applied to the fluorimetric determination of thiols with OPA and tryptophan as reagents [89-91]; however it does not include NAC. The procedure consists of the addition of 3.2×10^{-5} M OPA to a stirred mixture of 6.3×10^{-4} M tryptophan, boric acid borate buffer and the thiol in the concentration range 6.6×10^{-7}-6.6×10^{-6} M.

NAC has been used in place of 2-mercaptoamino acid and anti-tumors with fluorimetric detection [92-96]. The reaction may also be applicable to the assay of NAC. This method was applied for the determination of NAC in several pharmaceutical formulations.

NAC has also been determined by chromatographic, gas chromatographic [97-101], spectrophotometric and spectrofluorimetric techniques [102-107]. It has also recently been determined by kinetic and Flow Injection (F1) methods [108-110]. Flow injection method based on the reaction of NAC with $PdCl_2$ has been developed [111].

Numerous methods proposed for determination of N-acetyl-L-cysteine include 2-idoxybenzoate as a titrant for the determination

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but its end point is accomplished potentiometrically using platinum/ calomel electrode combination [112]. HPLC determination using N [4-(5,6-dimethoxy-2-phthalamidyl] maleimide as precolumn fluorescence derivatization reagent [113]. This method along with flow injection method, require highly sensitive and costly instrument.

Capillary Zone electrophoresis with ultraviolet and fluorescence detection for the analysis of NAC also require costly instrument and is time consuming [114]. Several electrophoretic parameters have to be optimized such as buffer, pH, concentration, applied voltage, loading conditions, and column length and column diameter [115].

Polarographic method for determination of N-acetyl-L-cysteine was proposed which also requires adjustment of pulse.

O-Phthalaldehyde was used as precolumn derivatization for reversed phase HPLC and fluorometric determination but detection limit is l pmol [116].

Potentiometric method was proposed for determination of N-acetyl-cysteine based on its reduction action on iron (III) [117]. Linearity is attained in the range from 2.0 x 10^{-4} mol cm^{-3} mol cm^{-3}.

Chemiluminescence - flow injection analysis of thiol containing drug. Procedures are based on the inhibition by the drug of the chemiluminescence generated in the copper catalyzed oxidation of luminal by H_2O_2 [118].

Cathode stripping voltammetry of N-acetyl-L-cysteine in presence of nickel ion and determination by means of mercury thiolate peak at (-0.4v) as NAC has no catalytic properties for the reduction of nickel [119]. So it is determined at pH 7 in phosphate- acetate buffer.

HPLC method developed for determination of NAC, on an ODS column using an isocratic mobile phase consisting of MeCN-MeOH-sodium hexanesulfonic acid buffer (pH 2.9) at a flow rate of 1.0 ml/ min. with UV detection at 220 nm [120]. Methionine as internal standard.

Experimental

Instruments

Toshniwal UV 2000 chemito spectrophotometric observations at Bose Memorial Research Lab, Govt. Science College, Jabalpur.

Elemental analysis was carried out at RSIC. Central Drug Research Institute, Lucknow.

The FTIR spectra were recorded in Nicolet FTIR spectrophotometer in the rage 4000-400 cm^{-1} using KBr pellets at RSIC, IIT, powai, Mumbai.

The ESR spectra were recorded in Varian ESR spectrometer in the scan range of 3000 gauss. Tetracyanoethylene was used as marker at RSIC, IIT Powai, Mumbai.

'H HMR spectra were recorded in vrian-300 MHz spectrometer using deuterium oxide as solvent at RSIC, IIT, Powai, Mumbai.

Thermal Studies (Differential Thermal Analysis (DTA) and Thermo Gravimetric Analysis (TGA) were carried out in DuPont thermal analysis system under nitrogen atmosphere from 0 °C - 800 °C temperature range at a rate of 20 °C/Min a RSIC, IIT, Powai, Mumbai.

Reagents and sample

Ruthenium chloride: A standard stock solution of ruthenium chloride was prepared by dissolving 1.00 g of hydrated ruthenium (purris, Bombay) in 2M HCI acid and volume is made up to 1 liter. Standardization of ruthenium chloride was done spectrophotometrically by thiourea. Solutions of lower concentration were prepared by diluting aliquots of stock solution.

N-acetyl-L-cysteine: N-acetyl-L cysteine solution is prepared in double distilled water. NAC is completely soluble in distilled water. N-acetyl-L-cysteine is sigma product. The NAC s standardized isometrically using starch as indicator.

Preliminary studies: When ruthenium chloride solution is added to the solution of N-acetyl-L-cysteine at room temperature, a light yellow colored is formed. Absorption curve obtained for the complex has maximum absorbance at 464 nm.

Effect of pH: In acid medium pH ranging from 3-6.0, the absorbance remains unaffected but above this pH slight turbidity appears.

Effect of foreign metal ions: Effect of presence of different metal ions was studied. The results are summarized in Table 2.

Analysis

Procedure

To an aliquot containing 9.44 x 10^{-7} mg N-acetyl-cysteine and excess amount of Ru(III) was made up to 20 ml with water Allow to react the contents for a period of 30 min. Thereafter fill the reference cell with the reaction mixture and record the absorbance on the λ_{max} 464 nm. The concentration of the N-Acetyl-L-Cysteine is found out from the Beer's law graph by drawing a perpendicular from the point at which the absorbance values crosses it to the concentration axis.

Molar composition of complex: The composition of the complex was determined by Job's method of continuous variation as modified by Vosburgh and mole ration method and was found to be 1:1 with Ru(III) : W-acetyl-L-cysteine.

Adherence to beer's law

Beer's law is obeyed over the range 7.87x10^{-8} mg to 9.445x10^{-7} mg mole extinction coefficient = 5.62x10^{3} $Lmol^{-1}$.

Results and Discussion

Micro determination of N-Acetyl-L-cysteine was performed spectrophotometrically by complexation with Ru(III) Ru(III) forms

Table 2: Interference of foreign metal ions on Os (VIII): N-ACETYL-L- cystein complex.

S. No.	Interference	Sample: Interference ppm	% Recovery
1	Zinc Sulphate	1: 0.0047	98%
2	Cobaltg Nitrate	1: 0.078	97%
3	Nickel Sulphate	1: 0.00021	100%
4	Ferric Chloride	1: 0.0038	100%
5	Palladium Chloride	Interferes Severely	-
6	Osmium Tetraoxide	Interferes severely	-

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1:1 complex with N-acetyl-L-cysteine at room temperature, the complex formed follow the Beer's law in the range 7.871 x 10^{-8} to 9.445 x 10^{-7}.

Characterization of the complex formed between Ru(III): N-Acetyl-L-Cysteine was done by elemental analysis, FTIR, NMR, ESR and TGA.

Elemental Analysis: Reaction product (complex) of Ru(III): N-Acetyl-L-Cysteine is characterized by elemental analysis. Calculated results have been found in good agreement with the actually found experimentally. The results of elemental analysis are summarized in Table 3.

A perusal of these results confirms that M:L ration is 1:1. This has further been confirmed by Job's method of continuous variance as well as mole ration method.

FTIR spectrum

FTIR spectrum of N-Acetyl-L-Cysteine and its Ru(III) complex recorded in the range 4000-400 cm^{1} exhibit following bands (Figure 1).

Table 3: Elemental analysis (CHN estimation) of Ru(III): N-ACETYL-L- cysteine complex.

Calculated	Found
% C 19.76	20.00
% H 3.57	4.12
% N 4.86	4.50

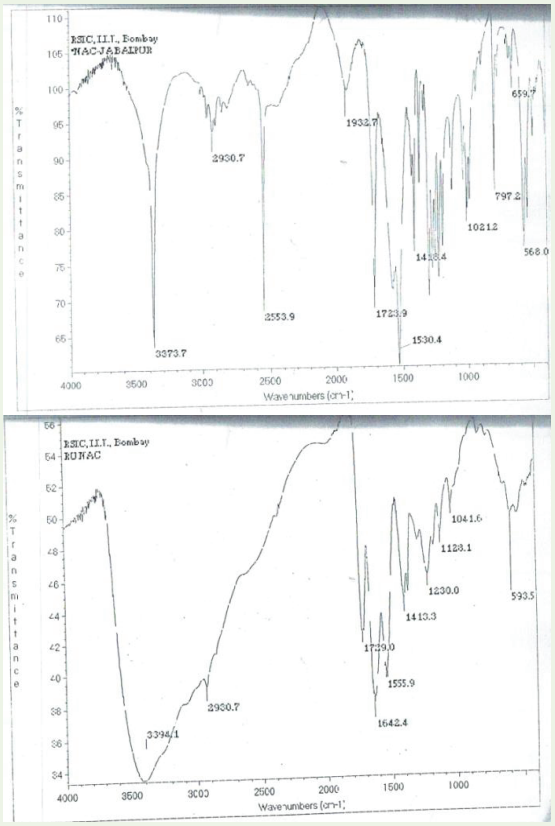

Figure 1: (a): FTIR spectrum of N-Acetyl-L cysteine complex; **(b):** FTIR spectrum of Ru(III): N-Acetyl-L cysteine complex.

A stretching band at 2553.9cm^{-1} of pure N-Acetyl-L-Cysteine assigned to -SH stretching band and a band at 659 cm^{-1} which is assigned to SH bending, are completely disappeared in the corresponding FTIR spectrum of Ru(III) : N-Acetyl-L-cysteine complex confirming the involvement of sulfhydryl group in complex formation.

A small band at 568 cm^{-1} in the FTIR spectrum of N-Acetyl-Cysteine attributed to C-S stretch is shifted to 593.0 cm^{-1} in its complex owing to complexation of thiol group with ruthenium.

In the FTIR spectrum of N-Acetyl-L-Cysteine there is sharp intensity band at 3373 cm^{-1} assigned to NH_2 stretching frequency, is shifted to 3394 cm^{-1} in its Ru(III) complex with reduced intensity and broadening of band takes place which confirms the involvement of NH group in bonding with Ru(III).

A prominent stretching band at 1340 cm^{-1} assigned to C-N stretch in the FTIR spectrum of pure N-Acetyl-L-Cysteine is almost diminished in the spectrum of Ru(III) complex, confirming the involvement of amino group in complexation.

Stretching band at 1530 cm^{-1} is attributed to asymmetric stretching and 1418 band attributed to symmetric stretching of carboxylic group in the FTIR spectrum of NAC are at 155.9 cm^{-1}, 1413.3 cm^{-1} in Ru(III) complex but the intensity of the band is reduced.

Medium intensity bands at 1021.2 cm^{-1}, 1129 cm^{-1}, 1723 cm^{-1}, 2930.7 cm^{-1}, exhibited by N-Acetyl-L-Cysteine molecules are assigned to stretching mode of -CO, bending mode of -OH group of carboxylic group v-OH mode of carboxylic group, these bands are shifted to 1041 cm^{-1}, 1128 cm^{-1}, 1728 cm^{-1} 2930 cm^{-1} which is an indication of presence of uncoordinated-COOH group.

NAC as its Ru(III) complex exhibits stretching bands at 1642 cm^{-1} which are assigned to -OH and banding mode of coordinated water molecules.

^{1}H HMR spectra

^{1}H NMR spectrum: The proton NMR spectrum of Ru(III) : N-Acetyl-L-Cysteine complex shows the following features:

1. In the proton NMR spectrum of N-Acetyl-L-cysteine in D2O, the signal at signal at 4.60 ppm is attributed to CH, quaterete 3.00 ppm attributed CH_2 group have downfield to 4.77 ppm and 3.29 ppm respectively.

2. Chemical shift at 1.2 ppm and 1.4 ppm of N-Acetyl-L-Cysteine are attributed to SH and NH proton respectively. In the Ruthenium: N-Acetyl-L-Cysteine complex the signal at 1.2 ppm and 1.4 ppm is disappeared confirming the involvement of SH group and NH group in complex atom (Figure 2).

ESR studies

ESR spectrum of Ru complex of N-Acetyl-L-Cysteine was recorded at room temperature on microwave frequency of 9.1 GHz. It exhibit following features:

1. The +3 oxidation state of Ru has d^5 configuration and it forms low spin hexa-coordinated complexes with one unpaired electron. Therefore all the complexes of Ru(III) exhibit ESR spectrum owing to the presence of unpaired electron and having I=7/2 for Ru.

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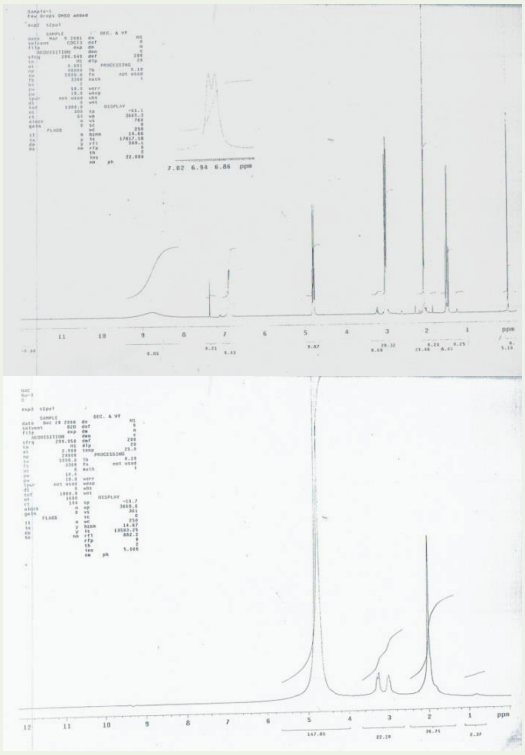

Figure 2: (a): Proton NMR spectrum of N-Acetyl-L cysteine complex; **(b):** Proton NMR spectrum of Ru(III): N-Acetyl-L cysteine complex.

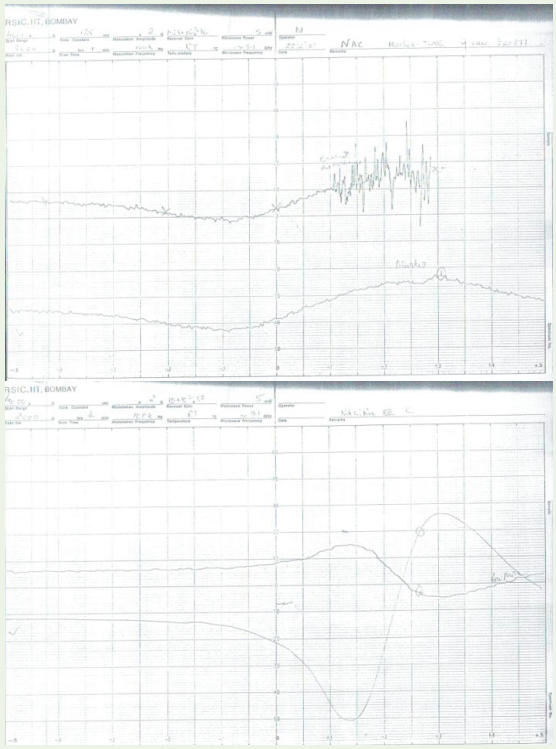

Figure 3: (a): ESR spectrum of N-Acetyl-L cysteine complex; **(b):** ESR spectrum of Ru(III): N-Acetyl-L cysteine complex.

2. Ru complex of N-Acetyl-L-cysteine given ESR signal, which confirms the fact that reduction of Ru(III) to Ru(II) by sulfhydryl group of N-Acetyl-L- cysteine has taken place (Figure 3).

Thermal studies (TGA and DTA)

Thermogravimetric analysis of Ru (III): N-Acetyl-L-cysteine complex were carried out under nitrogen atmosphere at a rate of 20 ˚C/ min from 0 ˚C to 800 ˚C.

The TGA curve of the complex shows the loss in weight at 59.65 ˚C which is due to loss of lattice water molecule, because such water molecules has been found to be lost in complex below 100 ˚C

At 142.46 ˚C (weight loss 5 209.65 ˚C 429, 96 ˚C, 489 33 ˚C (weight loss is 9%) which is attributed to loss of coordinated water molecules (Figure 4).

At 429.96 ˚C there is 28% weight loss. This weight loss correspond to elimination of N-Acetyl-L-Cysteine moiety from the remaining complex, at 489.33 ˚C 8% weight loss takes place which is due to decomposition of remaining N-Acetyl-L-Cysteine moiety to give chemical carbon, hydrogen, nitrogen. At 648 ˚C the weight loss is from 39% to 35.12% show the breakage of Ru and sulphur bond.

Differential Thermal Analysis (DTA): DTA curve of the complex between Ru(III) : N-Acetyl-L-Cysteine exhibits following endotherm/ exothermal changes.

Below 100 ˚C small endotherm is observed, confirms the presence of lattice water molecule.

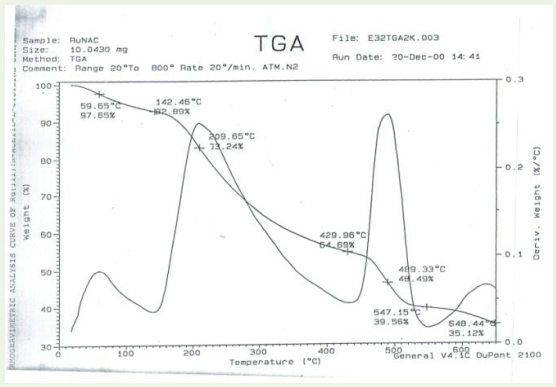

Figure 4: TGA spectrum of Ru (III): N-Acetyl-L cysteine complex.

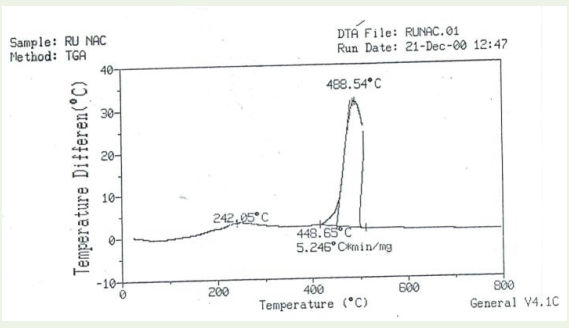

Figure 5: DTA spectrum of Ru (III): N-Acetyl-L cysteine complex.

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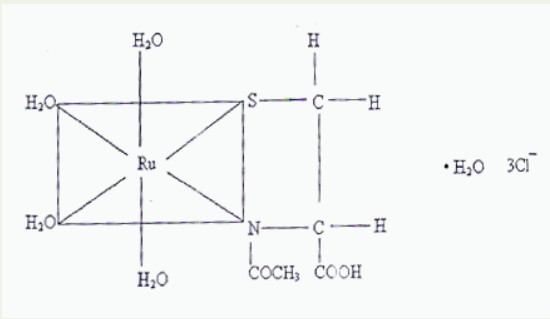

Figure:

From 100 ˚C to 242 ˚C small exotherm shows the removal of coordinated water molecule from the complex.

A broad exotherm at 488.54 ˚C is associated with breaking of bond between Ru(III) and N-Acetyl-l-L-Cysteine and also decomposition of N-Acetyl-L-cysteine moiety starts.

On the basis of all the instrumental methods of characterization the structure of the complex is:-

Proposed structure of Ru(III) : N-Acetyl-L-Cysteine complex

Acknowledgment

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