ELECTROCHEMICAL AND SPECTROSCOPIC STUDIES OF INTERACTIONS OF Mn(III) COMPLEXES WITH NUCLEIC BASES AND NUCLEOSIDES

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ABSTRACT: *The complexes of $Mn(OAc)_3$ and/or $Mn(acac)_3$ with nucleic bases and nucleosides (adenine, guanine, xanthine, adenosine and guanosine) have been synthesized in nonaqueous solution. Polarographic and spectroscopic (IR and Visible) methods have been used to establish the active site(s) on the imidazole and pyrimidine rings in the nucleic bases and nucleosides for the interaction with the Mn(III) complexes. Infrared spectroscopic results, indicate the N.9 site for adenine, N.1 site for adenosine and N.7 site for guanosine are the most probable sites of interaction with $Mn(OAc)_3$. In addition, these results emphasize a dichotomy between N.9 and N.7 sites in adenine and between N.7 and N.1 sites of guanosine and adenosine. In the case of $Mn(acac)_3$, the binding site for adenine changes to N.7, which could be accounted for the formation of the hydrogen bond between acetylaceton ligand and NH_2 group.*

INTRODUCTION

Manganese is an essential component of several biological systems associated with electron transfer reactions, one of them is photosystem (II) in green plant photosynthesis [1,2]. In these cases the oxidation states +2, +3 and +4 are believed to be involved [3,4], but there are few data confirming the assumption. Chemical environment of manganese complexes in Oxygen-Evolving-Complexe (O.E.C) is one of the current interests in these studies.

Investigators who have studied the interactions of nucleic bases and nucleosides with metal ions report that [5] there is no dinstinct and fixed binding site on these molecules, especially in the case of transition metal ions. One should keep in mind that there is a different degree of binding between basic sites of them and the central metal ion and the latter is shifting within these sites in an interaction known as "Dichotomy". For instance, there is a dichotomy for binding to divalent metal ions, between N.7 and N.9 sites of imidazole ring of adenine, N.1 and N.9 of guanine, N.7 and N.1 sites of xanthine, N.1 and N.7 sites of adenosine and guanosine (Fig. 1).
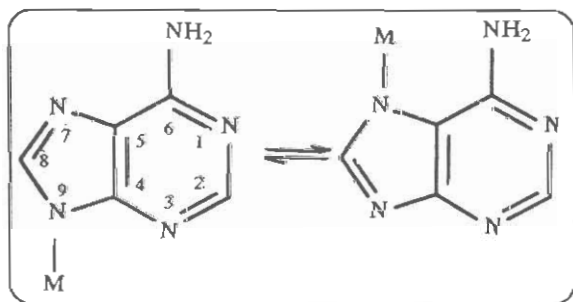

Fig. 1: Dichotomy in adenine.

It has been established [6] that there is also a dichotomy for Mn(II) cation between N.7 and N.9 site of purinic ring, however, because of much similarity in basic properties of N.1 and N.7 of adenine, scientists believed that N.1 site is also available for Mn(II). Even the remaining N.3 site of adenine which seems not to have any tendency to interact with Mn(II), has been reported to make a bond with divalent cation in

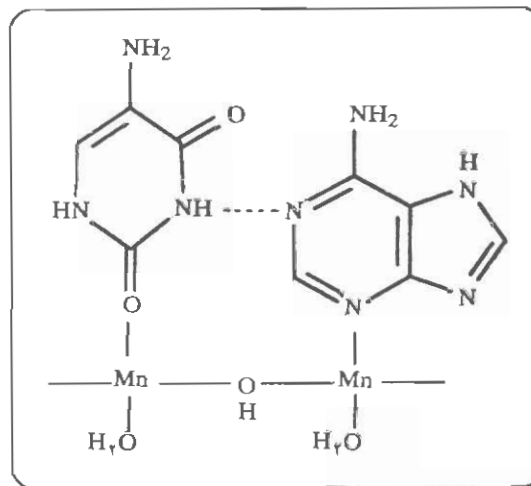a mixed- ligand complex of uracl and adenine [7] (Fig.2).

Fig. 2: Mn(II) interaction with N.3 site of purinic ring.

Divalent metal ions form polymeric complexes with guanine from the N.1 and N.9 sites of purinic ring [8]. In these reactions, guanine participates in the crystalline structure in the two forms of bridged and terminal guanine.

Recently the existence of a dichotomy between N.1 and N.7 of xanthine has also been established by other investigators [9]. On the other hand, it has been claimed that these conditions would be preserved for adenosine and guanosine too, but adenine nucleoside is suggested to interact with divalent cation from the N.1 site more than N.7 site [10]. Because of steric factors of rebosoic moiety, N.3 site of nucleoside would not be able to interact with metal ions.

On the basis of several observations [11] it has been reported that intramolecular hydrogen bonds between primary ligand such as acetylacetonato and purinic functional groups make fit some transition metal complexes in unusual sites.

Bipyridine, O- phenanthroline, gluconic acid, pyrocatechol, 8- hydroxyquinoline, picolinic acid, pyrophosphate, shiff bases, EDTA and many other molecules have been reacted with Mn(III)

and the effects of these interactions on stability of higher oxidation states of manganese and their chemical properties have been pursued with electrochemical and spectroscopic methods. In some cases these complexes have shown the ability to absorb and desorb molecular oxygen in their solutions [12] and by this way behave as O.E.C model.

EXPERIMENTAL

Manganese acetate and manganese (III) tris-acetylacetonato have been described methods elsewhere [13,14]. Preparation of adenine, adenosine and guanosine complexes of $Mn(OAc)_3$ have been performed by the method of *Taylor* [15]. $Mn(OAc)_3$, (or $Mn(acac)_3$), and nucleic bases or nucleoside with the ratio of 1mM:1mM mixed in DMSO until total volume 50mL (same procedure has been followed in the case of $Mn(acac)_3$, by using ethanol as solvent). The reaction mixture was heated to 40°C for 4 hours to evaporate the solvent, then dark brown precipitate filtered, collected and washed with DMSO and ethanol and heated in oven at 40°C for 12 hours.

KBr pellet of these complexes were prepared and their infrared spectra were obtained on a *Pye Unicam* SP1100. Reaction mixture of guanine and xanthine with $Mn(OAc)_3$ by this procedure failed to yield any precipitate. Polarographic studies were performed on a *Metrohm* E505 polarograph and E505 polaro-cord. Electrochemical cell was equipped with a 100mL pyrex double membrane cell, DME, as working electrode, *Russel* SCE as reference electrode and a platinum rod electrode as auxiliary electrode. Polarographic sample was prepared by adding 10mL, 1mM solution of $Mn(OAc)_3$, 40mL, 1mM solution of each of the nucleic bases and nucleosides solutions in DMSO, all of the solution should be 0.1F with respect to $NaClO_4$ as supporting electrolyte. After degasing the solution with nitrogen for 15 min. and passing 30°C water through double membrane cell for establishment of temperature equilibrium, each polarogram was recorded in

the potential region -0.8 to -2.00 volts to SCE by scan rate equals to $5mV.sec^{-1}$ [16]. Samples for visible spectroscopic studies were prepared by dissolving 0.0100g of each of the complex to 4mL $HClO_4$ 20% in a 25 volumetric flask then sulfuric acid 25% added to the volume.

RESULTS AND DISCUSSION

Infrared spectroscopic data in Tables 1 and 2, show several marked changes. Interaction of $Mn(OAc)_3$ with adenine brings about three evident consequences:

a) vibrational frequencies of C.8-N.7 ($1250cm^{-1}$ band) [7] for adenine decreases upon chelation with $Mn(OAc)_3$,

b) stretching frequencies of C.8-N.9 ($1450cm^{-1}$ band) [7] increases,

c) vibrational band of N.9-H is weakened as a result of this chelation.

It is concluded therefore, that $Mn(OAc)_3$ interacts with N.9 sites of adenine. However, since there is a dichotomy between N.9 and N.7 sites of adenine [6], this condition suggests that $Mn(OAc)_3$ would be able to bond to both mentioned sites:

Vibrational modes of NH_2 show no marked changes, thereby suggesting no intramolecular hydrogen bonding in the interaction of $Mn(acac)_3$ with adenine. But since the stretching frequency of C.8-N.7 ($1250cm^{-1}$) band of imidazol ring-N.7 site decreases and N.9-H band remains unchanged, another basic -N.7 site-participates in the interaction with $Mn(acac)_3$.

Increasing in frequency of NH_2 bending modes 940, $1680cm^{-1}$ confirm the intramolecular hydrogen band between NH_2 group of adenine and acetylacetonato groups of $Mn(acac)_3$. So one can conclude that secondary intramolecular interactions affect on site of binding.

Infrared spectra of guanosine and adenosine complexes of $Mn(OAc)_3$ show much more changes than the adenine complex. Vibrational bands of purinic ring as N.1-H bending, C=N and C=C stretching modes, shift to lower frequencies. Here there are two available binding

Table 1: Vibrational bands of Mn(OAc)₃ , Mn(acac)₃ , Adenine,Adenosine,Guanosine and their complexes.

Mn(OAc)₃ [17]	Adenine[17] in DMSO	Mn(Ad-OAc)	Mn(acac)₃	Mn(Ad-acac)	Adenosine[17] in DMSO	Mn(Adns-OAc)	Guanosine[17] in DMSO	Mn(Guns-OAc)
							1730s	1720sh
1680st	1660st		1690st	1680st	1650st	1690s	1690s	1680sh
	1610st	1610st		1650st	1610st	1600st	1640st	1650st
					1580st	1580st	1570s	1570st
1560st		1460b	1590st	1590st		1550sh		1550s
							1490s	1460sh
1480st			1570sh	1580sh	1480w		1540s	1530sh
			1520s	1520sh				
	1450w			1440sh				
1440sh						1430st		1430sh
1420st	1420s	1420s	1420s	1430st	1420b	1410sh	1420s	1420st
1400sh		1400st	1390s				1400s	
1390s	1370s	1370w		1390b	1390b	1390sh		1370w
			1360s	1370sh				
1340s	1340s	1340b		1340s	1340s	1340s	1340s	1350w
1310s	1310s	1310s		1310s	1300st			
1280w		1260w	1260st	1290s				1260b
	1250s	1210b	1190w	1230s	1250b		1250w	1240w
					1230b	1210b	1230s	1220b
					1180s	1190sh	1180s	1180b
				1170w				
	1150w	1190s			1150sh			
1130s	1150s		1130s	1130b	1110st	1130s	1120b	
	1120s	1120w		1100w				
					1160b	1180b	1080sh	1090b
							1050b	1050sh
1040s								
1030s	1020	1020st	1020s	1000s		1120st	1020sh	1030sh
					1010s	1000sh	1000s	990sh
					980s			
					970sh	970sh		
950w						950w		950w
	940s	940s		960sh				
930w						930w		
					900s	900w		
	910s	910s		910b				
	870b	850w		880s				
	840w	880sh		850b				
	800s	800s		820w				
		780s		770s				
	720s			700s				

b= Broad; s= Sharp; st= Strong; w= Weak; sh= Shoulder.

sites N.1 and N.7, so the mentioned changes could be related to the interaction of Mn(OAc)₃ with these sites. The dichotomy between these two sites, could be responsible for deep changes in both pyrimidine and imidazol rings' vibrational bands. Another interesting observation is associated with the bands in the region 900-1200cm^{-1} of these complexes. These bands are related to C-O and C-C stretching vibrations of rebosoic moiety [17]. The above changes introduce rebosoic moiety as another interacting site for binding of Mn(OAc)₃ .

As it was expected [19] the polarograms of purinic derivatives in nonaqueous solution (DMSO) have no polarographic waves, that is, the reduction of these molecules in their purinic rings need to have hydronium ions, however, reducing half-wave of:

$$Mn(III) \longrightarrow Mn(0)$$

in the presence of nucleic bases and nucleosides. Table 2 shows the half-wave potentials of these interacting molecules:

Table 2: Half wave potentials of Mn(OAc)₃ complexes with nucleic bases and nucleosides.

$E_{3/4} - E_{1/4}$ (mv)	III⟶0	Complex
-56	-1.748	Mn(OAc)₃
-56	-1.708	Mn(Adenine)
-48	-1.700	Mn(Xanthine)
-56	-1.716	Mn(Guanine)
-68	-1.716	Mn(Adenosine)
-56	-1.700	Mn(Guanosine)

By analysis of these wave, $E_{3/4}-E_{1/4}$, in accordance with other reportes [16] they are not reversible. From this viewpoint positive shifts in reduction of half waves could be attributed to kinetic parameters, that is, the chelation of nucleic bases and nucleosides to Mn(OAc)₃ faciliate reduction of Mn(III) to Mn(0). In addition, there seems to be some relationship between positive shifts of potentials and sites of binding. As is seen in Table 3, chelation of Mn(OAc)₃ to xanthine, guanosine, guanine and adenosine have similar positive shifts of potential.

Table 3: Visible bands of Mn(OAc)₃ complexes with adenine, adenosine, guanosine.

$E_{1/2}$ (complex)$-E_{1/2}${Mn(OAc)₃} (mv)	Complex
+40	Mn(Adenine)
+48	Mn(Xanthine)
+32	Mn(Guanine)
+32	Mn(Adenosine)
+48	Mn(Guanosine)

Refering to the other reports [20] and the infrared results, it is concluded that these pairs of interactions have similar sites of binding. For instance xanthine and guanosine both have two sites N.7 and N.1 available for interaction with Mn(OAc)₃ but for adenosine and guanine N.1

site is preferred. All of these iminic sites are conjugated with pyrimidine rings. However, N.9 site of adenine has a very basic aminic nitrogen which is not conjugated with other sites of purinic ring. Table 3 shows the absorbing wavelength in the visible region of three synthesized complexes:

Mn(III) cation in sulfuric acid media has two absorbing wavelengths 476nm and 833nm. The former wavelength is related to ligand field transition of d^4 electronic configuration:

$$^5E_g \longrightarrow {}^5T_{2g}$$

So every change in site of binding to Mn(III) cation would be reflected in absorbing wavelength. As seen in the above Table the ligand field transition of adenine complex with Mn(OAc)₃ has the most different wavelength than the others. In accordance with polarographic results, this observation confirms the fact that adenine binding site would be N.9 which is not conjugated with purinic ring, so interaction of nonbonding of Mn(III) with LUMO of purinic rings in adenine is more negligible than guanosine and adenosine. (Figs. 1 and 2).

CONCLUSIONS

It is found that nucleic bases and nucleosides interact with Mn(III) complexes from different sites of their purinic ringes and the extent of these interactions depend on conjugation of binding sites and the interaction of nonbonding MO of Mn(III) with LUMO of nucleic bases and nucleosides.

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