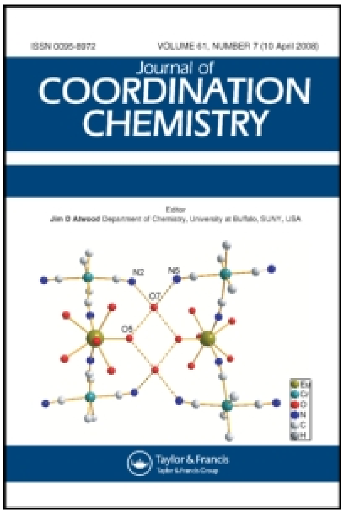

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A ZINC(II) COMPLEX OF VITAMIN B_1

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NOTE

A ZINC(II) COMPLEX OF VITAMIN B_1

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The importance of divalent metal ions in the catalytic efficiency of the enzyme pyruvate decarboxylase is well documented.[1-] Although Zn^{2+} is not the most effective of all the divalent metal ions, it is definitely important in this catalytic efficiency trend. All the metal - thiamine complexes reported[4-7] thus far have proved the two major points that metal-thiamine complexes do actually exist and that the binding site is the N(1′) position of the pyrimidine group of thiamine in agreement with Schellenberger's proposal.[8] Recently[7], we reported the preparation, proton and carbon-13 NMR data of a new Cd^{2+}-thiamine complex, Cd(thiamine)Cl_3, which was the first NMR report on a metal-thiamine complex whose structure had been previously determined by X-ray crystallographic methods.[5] In view of our continuing interest in metal-thiamine complexes, we report the preparation, infrared, proton and carbon-13 NMR studies of a new zinc(II)-thiamine complex, Zn(thiamine)Cl_3. We compare the proton and carbon-13 NMR data of Zn(thiamine)Cl_3 and Cd(thiamine)Cl_3.

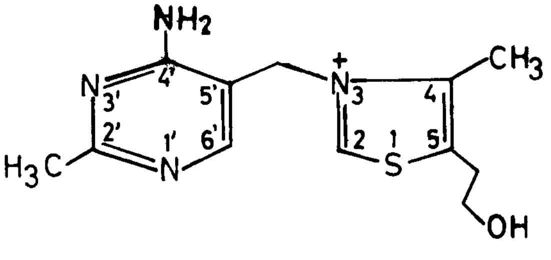

FIGURE 1 Numbering Scheme for N(1′) Deprotonated Thiamine.

EXPERIMENTAL

Thiamine chloride hydrochloride (Vitamin B_1) and deuterium oxide were obtained from the Aldrich Chemical Company while zinc acetate dihydrate was purchased from the Fischer Scientific Company. All chemical reagents were used as commercially available without any further purification.

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TABLE I
Proton NMR Data for Cd(thiamine)Cl_3 and Zn(thiamine)Cl_3 Complexes in D_2O.[a]

	Proton							
Complex	C2-H	C4′-NH_2	C6′-H	C5′-CH_2	5-CH_2O	5-CH_2	C4-CH_3	C2′-CH_3
Cd(thiamine)Cl_3			8.07	5.46	3.90 3.89 3.85	3.22 3.19 3.16	2.49	2.57
Zn(thiamine)Cl_3			8.6	5.44	3.909 3.87 3.84	3.22 3.18 3.15	2.48	2.56

[a] Chemical shifts in ppm relative to TMS.

Proton and carbon-13 NMR spectra were recorded on a Nicolet 200 MHz high resolution spectrophotometer. All chemical shifts were measured and expressed in ppm relative to the reference standard. The infrared spectra were recorded on a Beckman 621 infrared grating spectrophotometer in KBr pellets. The new complex, Zn(thiamine)Cl_3, was prepared using the conventional method.[6,7]

Ten grams (2.94×10^{-2} mol) of thiamine chloride hydrochloride was dissolved in 50 cm^3 of distilled water and then mixed with 3.27 grams (1.47×10^{-2} mol) of zinc(II) acetate dihydrate dissolved in 25 cm^3 of distilled water. The resulting solution was filtered to remove an undissolved particles. Slow evaporation of the solution afforded the new coplex which was rinsed with ice-cold distilled water, acetone and ether. The compound was dried at room temperature for three days and then over calcium chloride for three weeks.

Anal.: Calcd. for $Cl_3ZnC_{12}H_{17}N_4OS$: Zn, 14.92; C, 32.96; H, 3.89; N, 12.81; Cl, 24.37; S, 7.33%. Found: Zn, 14.84; C, 32.83; H, 4.02; N, 12.75; Cl, 24.52; S, 7.27%. The elemental analyses were performed by Atlantic Microlab, Inc., Atlanta, Georgia.

RESULTS AND DISCUSSION

Proton NMR Spectra

Table I lists the chemical shifts of both Zn(thiamine)Cl_3 and Cd(thiamine)Cl_3 complexes for easy comparison. It is interesting to observe that the ^1H NMR spectrum of the Zn(thiamine)-Cl_3 complex is similar to that of Cd(thiamine)Cl_3 reported recently.[7] The sharp singlet at 8.06 ppm is assigned to the C6′ proton while the singlet at 5.44 ppm is assigned to the methylene protons, 5′-CH_2. The resonance at 4.82 ppm is due to H_2O. The well resolved triplet at 3.90, 3.87 and 3.84 ppm is attributed to 5-CH_2O signal while the more well resolved triplet at 3.21, 3.18 and 3.15 ppm is assigned to the 5-CH_2 protons. The two sharp singlets at 2.56 and 2.48 ppm are assigned to methyl protons, 2′-CH_3 and 4-CH_3, respectively. In the Zn(thiamine)Cl_3 complex, the C6′-H and 2′-CH_3 protons are shifted downfield by 0.06 ppm which is much smaller than expected for the fully coordinated species according to White and Drago[9] and Gallo *et al.*[10] who concluded that the metal is coordinated to N(1′). It is to be ntoed that crystallographic methods[5] have confirmed direct interaction between Cd^{2+} and N(1′) of thiamine. It is our belief that Zn^{2+} behaves in the same manner. Since Cd(thiamine)Cl_3 and Zn(thiamine)Cl_3 complexes are readily soluble in water or D_2O, dissociation is not

TABLE II
Carbon-13 NMR Data for Protonated Thiamine, Cd(thiamine)Cl_3 and Zn(thiamine)Cl_3 Complexes in D_2O.[a]

	Carbon						
Compound	4-CH_3	2'-CH_3	5-CH_2	5'-CH_2		OCH_2	
Thiamine HCl	12.1	22.0	30.3	50.7		61.2	
Cd(thiamine)Cl_3	11.0	24.9	30.1	51.7		61.3	
Zn(thiamine)Cl_3	11.9	24.8	30.1	51.7		61.3	
	C-5'	C-5	C-4	C-6'	C-2	C-4'	C-2'
Thiamine-HCl	107.2	137.5	143.6	145.5	156.0	163.9	164.1
Cd(thiamine)Cl_3	105.6	137.1	143.6	157.3	154.8	162.6	169.9
Zn(thiamine)Cl_3	105.7	137.1	143.6	157.3	155.0	162.7	169.6

[a] Shifts in ppm relative to TMS.

unlikely and this, perhaps, will provide a rationale for the small downfield chemical shifts (0.06 ppm) experienced by the C6'-H and 2'-CH_3 protons which are *ortho* to the assumed coordination site. It is interesting that Theophanides *et al.*[4] observed 0.50–0.65 ppm downfield shifts of the C6'-H proton for Pt(II) and Pd(II) complexes of thiamine. This discrepancy may be due to the solvent effects since they used DMSO-d_6 as the NMR solvent. It is, however, surprising that this difference in solvent systems is not reflected in the downfield shift experienced by the 2'-CH_3 protons in this work (0.06 ppm) and that reported earlier (0.06–0.10 ppm).[4]

^{13}C NMR Spectra

Table II lists the chemical shifts of carbon resonances of protonated thiamine, Zn(thiamine)Cl_3 and Cd(thiamine)-Cl_3 complexes for comparison. The assignment of the resonances is based on previous reports.[4,7,10–12] The spectra were recorded in D_2O for the ligand as well as for the Zn(thiamine)Cl_3 complex so as to ensure some internal consistency and to enable direct comparison of the chemical shifts. The resonances at 169.55 and 162.77 ppm are due to the C2' and C4' carbons, respectively. The clumsy signals at 157.28 and 155.02 are assigned to the C6' and C2 carbons, respectively.

This clumsiness may be ascribed to partial decoupling of the C6'-H and C2-H protons. The signals at 143.64, 137.06, 105.74 and 61.31 ppm are assigned to C4, C5, C5'

TABLE III
Selected Infrared Frequencies (cm^{-1}) for Thiamine[4] and the Zn(thiamine)Cl_3 Complex.[a]

Assignments	Thiamine	Zn(thiamine)Cl_3
OH, NH_2, CH	3450s	3445br
aromatic or aliphatic	3435s	3330s
stretchings	3270s	3240s
	3075s	3090s
NH_2 bending +	1658vs	1640s
ring stretching	1608s	1615s
skeletal C=C	1538s	1595s
C=N vibrations	1505sh	1505s
C=OH stretching	1035vs	1050–1070s
N(1')-Zn	–	350, 380, 508w
Zn-Cl	–	293s

[a] Abbreviations: vs = very strong, s = strong, sh = shoulder, w = weak.

and)CH_2 carbons, respectively. The most intense peak at 67.40 ppm is due to dioxane while the signals at 51.74, 30.09, 24.81 and 11.92 ppm are due to the $5'$-CH_2, 5-CH_2, $2'$-ch_3 and 4-CH_3 carbons, respectively. Complexation causes downfield shifts of carbons adjacent to the coordination site.[16] The most downfield shifted resonances are those of the C6′(11.80 ppm), C2′(5.5 ppm) and $2'$-CH_3 (2.8 ppm) carbon atoms. These chemical shifts are similar to those reported[4,7] earlier. It is therefore concluded that Zn^{2+} is coordinated through N(1′), since only the carbon atoms in the immediate environment of this nitrogen are affected.

Infrared Spectra

The tentative IR assignments of the Zn(thiamine)Cl_3 complex are given in Table III. Thiamine chloride hydrochloride shows strong bands at 3450, 3435, 3270 and 3075 cm^{-1} due to OH, NH_2 and CH aromatic and aliphatic stretching motions[4,13] while in the Zn(thiamine)Cl_3 complex, these bands occur at 3440, 3340, 3240, 3195 and 3000 cm^{-1}. Thiamine shows two strong bands at 1658 and 1608, while Zn(thiamine)Cl_3 shows three bands at 1640, 1615 and 1595 cm^{-1}. Protonation of a nitrogen atom of the pyrimidine ring causes a larger shift of higher frequencies of the ring stretching vibration than does metallation.[14,15] This could imply a possible interaction of a nitrogen pyrimidine ring with Zn^{2+} on complexation. The Zn-Cl stretch appears at 293 cm^{-1} while the weak bands at 350, 380 and 408 cm^{-1} are assigned to N(1′)-Zn stretching frequencies. It should be borne in mind that all these bands are absent in thiamine and thus IR spectroscopy has provided additional support for the assumption that the coordination site is the N(1′) position of the pyrimidine ring.

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REFERENCES

1. G.A. Kochetor, P.P. Fillipov and R.A. Usmanov, *Biokhimiya*, **31**, 810 (1969).
2. E.Z. Auhagen, *Physiol. Chem.*, **204**, 149 (1932).
3. D.E. Green, D. Herbert and V. Subrahamanyan, *J. Biol. Chem.*, **135**, 795 (1940).
4. N. Hadjiliadis, J. Markopoulos, G. Pneumatikakis and T. Theophanides, *Inorg. Chim. Acta*, **25**, 21 (1977).
5. R.E. Cramer, R.B. Maynard, J.A. Ibers, *J. Am. Chem. Soc.*, **103**, 76 (1981).
6. A. Adeyemo and A. Shamim, *Inorg. Chim. Acta Letters*, **78**, 21 (1983).
7. A. Adeyemo and A. Shamim, *Inorg. Chim. Acta Letters*, **91**, 19 (1984).
8. Schellengerger, *Agnew. Chem. Int. Ed. Eng.*, **6**, 1024 (1967).
9. W.D. White and R.S. Drago, *Inorg. Chem.*, **10**, 2727 (1971).
10. A.A. Gallo, I.L. Hansen, H.Z. Sable and T.T. Swift, *J. Biol. Chem.*, **247**, 5913 (1972).
11. A.A. Gallo and H.Z. Sable, *J. Biol. Chem.*, **249**, 1382 (1974).
12. N. Hadjiliadis and J. Markopoulos, *J. Chem. Soc., Dalton. Trans.*, 1635 (1981).
13. C.H. Willits, J.C. Dacius, K.L. Dille and B.E. Christensen, *J. Am. Chem. Soc.*, **77**, 2567 (1955).
14. R. Fogglizo and A. Novak, *Spectr. Acta*, **26A**, 2281 (1970).
15. A. Lautie and A. Novak, *J. Chim. Phys.*, **10**, 1492 (1971).
16. T. Yasui and T. Ama, *Bull. Chem. Soc. Japan*, **48**, 3171 (1975).