Synthesis，Spectroscopic Characterization and Thermogravimetric Analysis of Cr(Ⅱ)，Cu(Ⅱ)，Zn(Ⅱ) and Mg(Ⅱ)，Captopril Coordination Compounds

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Abstract In this work，we have reported the synthesis and spectroscopic characterization of captopril (Cap) coordination compounds：Cu(Cap)·$2H_2O$，Cr(Cap)·H_2O，Zn(Cap)·$3H_2O$ and $Mg(Cap)_4$. Herein，it is worthily mentioned that the FTIR spectroscopic technique was employed to recognized the nature of coordination between captopril ligand and copper，chromium，zinc and magnesium(Ⅱ) metal ions. In view of the infrared spectroscopic tool，the copper(Ⅱ) metal ion coordinated toward captopril drug ligand through sulfur atom of SH group dependent on the absent of stretching vibration band of —SH. Based on this result，the stretching motion of ν_a(COO) shifts clearly indicates that Cu^{2+}，Cr^{2+}，Zn^{2+} and Mg^{2+} the carboxylic group is employed as coordinative site for all compounds as a metal-ligand coordinative bond. As a general behavior，it is verified that the coordination compound thermal stability (considering the release of captopril molecules，not the release of water molecules) is affected by the metal cation radius：minor radius is associated with higher thermal stability，probably due to a higher metal-captopril bond dissociation enthalpy.

Keywords Captopril；Transition metals；Spectroscopy；Coordination compounds；Thermogravimetry

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Introduction

Transition metal complexes remain a very active area of investigation，among other reasons，to the need to understand the chemical behavior of a series of organic molecules towards these metals，taking into account the potential of biological and environmental impacts of these interactions. Hence，the chemical interaction between transition metals and a series of ligands such as caproates[1]，mercaptothiazolines and mercaptopyridines[2]，cyclic ureas[3]，methanesulfonates[4]，hexamethylenetetramine[5] and amino acids[6-8] have been investigated.

Captopril，1-[(2S)-3-mercapto-2 methylpropionyl]-

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Lproline, (also known as "capoten") whose structural formula is shown in Figure 1, is generally employed by the pharmaceutical industry as a blood pressure control agent. However, its interaction with transition metal cations is not so well investigated. Hence, the present work is insert in the above mentioned context and is dedicated to investigated some Cr(Ⅱ), Cu(Ⅱ), Zn(Ⅱ) and Mg(Ⅱ) captopril coordination compounds.

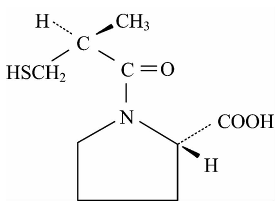

Fig. 1 Structural formula of captopril

1 Experimental

All reagents were of analytical grade and were employed without further purification. The coordination compounds were synthesized by reaction between the respective metal [Cr(Ⅱ), Cu(Ⅱ), Zn(Ⅱ) and Mg(Ⅱ)] nitrate and captopril aqueous (deionized water) solutions. Cr(Ⅱ)-captopril compound is obtained as a green precipitate. The other compounds were isolated as powders after evaporation at room temperature for five days in a fume hood.

CHN elemental analyses were performed in Perkin-Elmer equipment. The IR vibrational spectra were obtained in KBr discs on a Bruker IF 566 FTIR spectrophotometer. TG curves were obtained in a Shimadzu TG-50 apparatus under nitrogen atmosphere (50 $cm^3 \cdot min^{-1}$) at a heating rate of 10 ℃ $\cdot$ min^{-1}.

2 Results and discussion

The obtained CHN elemental analysis results and proposed formulas are summarized in Table 1.

Table 1 Elemental analysis for the synthesized captobril coordination compounds (The calculated values are between parenthesis)

Proposed formula	C/%	H/%	N/%
Cu(Cap) $\cdot$ $2H_2O$	34.9(34.1)	5.4(6.0)	5.8(4.4)
Cr(Cap) $\cdot$ H_2O	38.8(37.6)	5.4(5.9)	5.9(4.9)
Zn(Cap) $\cdot$ $3H_2O$	32.7(32.1)	4.2(6.2)	4.1(4.2)
$Mg(Cap)_4$	49.1(48.4)	7.2(6.7)	6.5(6.3)

The main infrared bands for free captopril and coordination compounds are summarized in Table 2. Taking into account the infrared data, can be proposed that to Cu(Ⅱ) compound there is a coordination involving sulfur, since the characteristic SH stretching band of captopril is absent in the copper compound. Furthermore, the ν_a(COO) band of captopril (1 694 cm^{-1}) is shifted to a higher wavenumber (1 724 cm^{-1}) in copper complex.

On the contrary, to Cr(Ⅱ), Zn(Ⅱ) and Mg(Ⅱ) compounds a coordination involving the COO group can be proposed, based on the downshift observed to the ν_a(COO) band. In this context, it is worth noting the fact that the synthesized Zn(Cap) $\cdot$ $3H_2O$ is, probably, different from a structural point of view, of the previously[9] prepared Zn(cap). In a previous study[9-11] a series of 1 : 2 metal-Cap compounds (with Co, Ni, Zn, Cd and Cu) were studied and, based on IR, NMR, X-Ray spectroscopy (XPS) and wide angle X-ray scattering (WAXS) techniques, it was conclude that in such captopril compounds the carboxylic group is not involved in the metal-ligand coordination. Despite the fact that in this work the only employed spectroscopic technique was FTIR, the ν_a(COO) shifts clearly indicates that for Cu(Cap) $\cdot$ $2H_2O$, Cr(Cap) $\cdot$ H_2O, Zn(Cap) $\cdot$ $3H_2O$ and $Mg(Cap)_4$ the carboxylic group is employed as coordinative site. Moreover, to the 1 : 1 zinc-captopril compound[9], a chain structure was proposed and, in this case, the carboxylic group was coordinated.

Table 2 Main Infrared bands for captopril and its coordination compounds

Compound	Carboxylic ν(OH) hydrogen bonded	ν(SH)	ν_a(COO)	Amide ν(CO)	ν_s(COO)
Captopril	3 390～2 905	2 568	1 694	1 589	1 442
Cu(Cap) $\cdot$ $2H_2O$	3 409～2 881	—	1 724	1 584	1 445
Cr(Cap) $\cdot$ H_2O	3 860～2 882	2 622	1 600	1 470	1 446
Zn(Cap) $\cdot$ $3H_2O$	3 453～2 884	2 623	1 603	1 471	1 388
$Mg(Cap)_4$	3 833～2 983	2 560	1 752	1 590	1 476

The TG data are summarized in Table 3. The TG curves are shown in Figure 2. Based on the TG data, the following mass loss sequences can be proposed: To all compounds, with exception of Zn(Cap) $\cdot$ $3H_2O$ the first mass loss is associated with the release of physisorbed water molecules. To $Mg(Cap)_4$ is observed the release of captopril molecules in single mass loss. To Cu(Cap)·$2H_2O$, Cr(Cap)·H_2O, and Zn(Cap)·$3H_2O$, the release of crystallization water molecules is followed by the release of captopril molecules. As a general behavior, it is verified that the coordination compound thermal stability (considering the release of captopril molecules, not the release of water molecules) is affected by the metal cation radius: minor radius is associated with higher thermal stability, probably due to a higher metal-captopril bond dissociation enthalpy.

3 Conflict of interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and publication of this article.

Table 3 Thermal analysis (TG) data summery for the synthesized compounds

Compound	Temperature range/℃	Mass loss/%
Cu(Cap)·$2H_2O$	40～140	5.5
	140～210	11.2
	210～800	49.3
Cr(Cap)·H_2O	40～134	3.9
	134～210	12.9
	210～800	63.5
Zn(Cap)·$3H_2O$	40～125	13.3
	125～250	11.0
	250～460	46.4
	460～800	13.7
$Mg(Cap)_4$	40～160	2.4
	160～460	87.7
	460～800	7.1

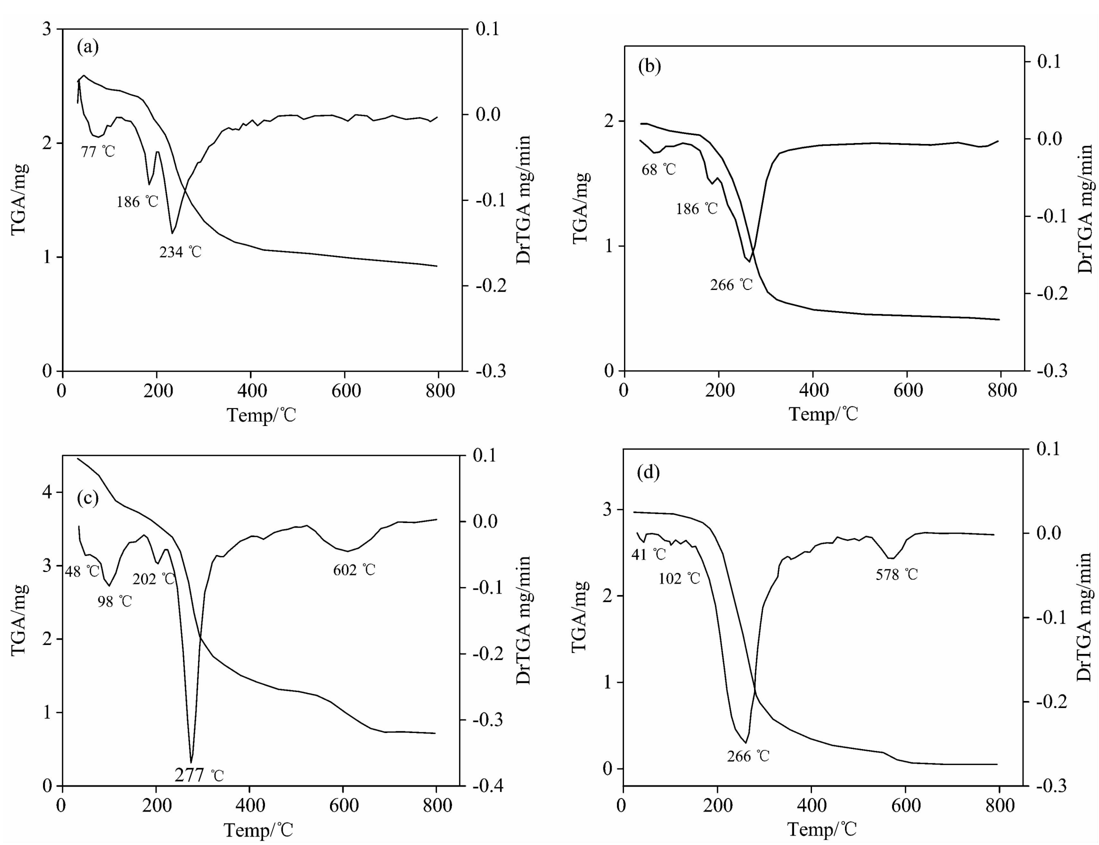

Fig. 2 TG curves

(a): Cu(Cap)·$2H_2O$; (b): Cr(Cap)·H_2O; (c): Zn(Cap)·$3H_2O$; (d): $Mg(Cap)_4$

References

[1] Refat M S, Kumar D N, de Farias R F. J. Coord. Chem., 2006, 59: 1857.
[2] Refat M S, de Farias R F. J. Serbian Chem. Soc., 2006, 71: 1289.
[3] de Farias R F, Airoldi C. Thermochim. Acta, 2004, 413: 111.
[4] de Moura M V F, Matos J R, de Farias R F. Thermochim. Acta, 2004, 414: 159.
[5] Silva W E, Alves Jr S, de Farias R F. J. Coord. Chem., 2004, 57: 967.

[6] Martinez L, de Farias R F, Airoldi C. Thermochim. Acta, 2003, 395: 21.
[7] de Farias R F, Nunes L M, Airoldi C. J. Thermal Anal. Cal., 2003, 74: 923.
[8] de Farias R F, Martinez L, Airoldi C. Trans. Met. Chem., 2002, 27: 253.
[9] Atzei D, De Filippo D, Rossi A, et al. Spectrochim. Acta A, 1992, 48: 911.
[10] Atzei D, Caminiti R, Sadun C, et al. Phosphorus Sulfur Silicon, 1993, 79: 13.
[11] Atzei D, Sadun C, Pandoffi L. Spectrochim. Acta, 2000, 56: 531.