

Transition Metal Complexes of *N*-(4,6-dimethoxypyrimidin-2-ylcarbamothioyl)benzamide: Design, Synthesis and Herbicidal Activity

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Transition metal (Cu(II), Zn(II), Co(II)) complexes of *N*-(4,6-dimethoxypyrimidin-2-ylcarbamothioyl)benzamide were prepared. The structures of all the newly synthesized complexes were identified by elemental analyses, IR, ¹H NMR, XPS, MS and TG. Their herbicidal activities were evaluated against a variety of weeds. The preliminary results showed that the target complexes had moderate biological activities against both broad leaf weeds and monocotyledon plants. More importantly, the complexes exhibited some improved herbicidal activities over their non-complexed counterparts. The present work provides a novel class of transition metal-based derivatives with potent herbicidal activities for further optimization.

Keywords: Transition metal; Complexes; Thiourea; Herbicidal activity.

INTRODUCTION

Transition metal complexes have received increasing attention in recent years because of their unique properties. They have been employed as antimalarial, anti-inflammatory, antitumor, antibiotic, antimicrobial agents, etc.¹⁻⁵ More importantly, these metal complexes usually showed significant biological activities when compared to their non-complexed counterparts.⁶⁻¹⁰ These inspired us to assume that the compounds with biological interests conjugated to transition metal might have some improved or different biological activities.

The herbicide *N*-(4,6-dimethoxypyrimidin-2-ylcarbamothioyl)benzamide (Bdpt), has been described as an effective herbicide due to its moderate activity and selectivity.¹¹⁻¹⁴ At the same time, Bdpt is a good building block for coordination chemistry because the carbonyl and thiocarbonyl groups of Bdpt could coordinate with transition metals of different types. Based on this consideration, different transition metal (Cu(II), Zn(II), Co(II)) complexes of Bdpt were designed and synthesized, and their herbicidal activities were evaluated against a variety of weeds. The preliminary results showed that the target complexes had improved biological activities over their non-complexed counter-

parts.

RESULTS AND DISCUSSION

Synthesis

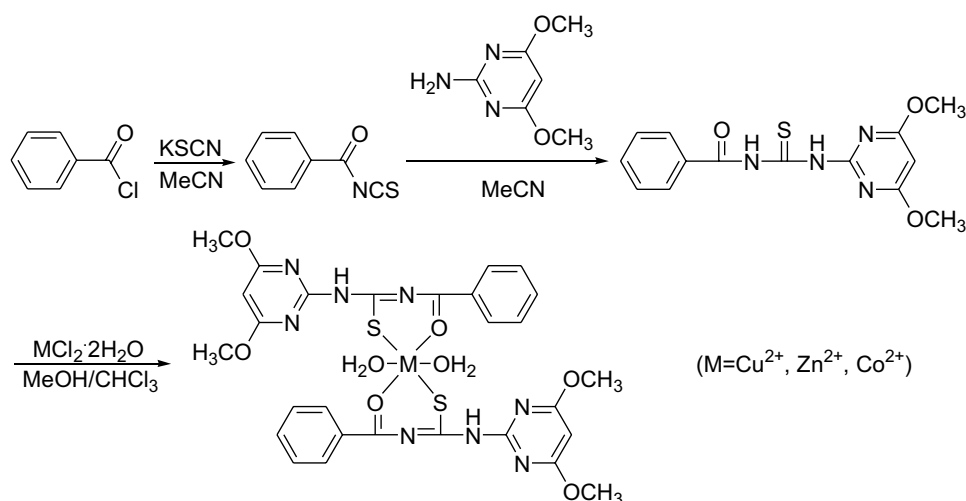
The synthetic routes of the target complexes M(Bdpt)₂·(H₂O)₂ (M=Cu(II), Zn(II), Co(II)) were shown in Scheme I. Compound Bdpt (0.257 g, 1 mmol), prepared by using a previously reported method,¹¹ was dissolved in methanol/chloroform (20 mL), then the solution of corresponding metal(II) chlorides·2H₂O (0.5 mmol) in methanol was added. The mixture was stirred and refluxed under nitrogen for 60 min. The precipitates were filtered and washed with methanol and chloroform twice, then dried in a vacuum. Yields were 60-70%.

All the target complexes were stable at room temperature, not hygroscopic, insoluble in water and readily soluble in DMF and DMSO. The molar conductivity of these complexes was 19-26 Ω⁻¹cm²mol⁻¹, which indicated that the target complexes were nonelectrolytes.

Structure determination

Elemental analyses results and the compositions of

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Scheme I The synthetic routes of the target complexes $M(\text{Bdpt})_2(\text{H}_2\text{O})_2$ 

the complexes are listed in Table 1. The results showed that two ligands and two water molecules might coordinate to the metal ion (Scheme I). It was a pity that we could not obtain the single crystals of the complexes. In order to identify the structures of the complexes, their IR, ¹H NMR, XPS, MS and TG-DTA spectra were also investigated.

IR spectra of the free Bdpt showed a strong band at 1710–1730 cm⁻¹, which is the characteristic peak of the carbonyl group (C=O); while in the complexes, this band shifted to the region at 1650–1670 cm⁻¹, indicating the coordination of the carbonyl oxygen atom of the ligand with metal ion. Meanwhile, a strong band at 820–840 cm⁻¹ in the free ligand, which was assigned to the C=S group, significantly disappeared in the complexes, indicating that the sulfur atom contributed to the formation of the complexes. Additionally, the appearance of a strong and sharp band between 3553–3600 cm⁻¹ demonstrated the presence of a hydroxyl group in the complexes.

In the ¹H NMR spectra of Bdpt, two resonance peaks at δ 12.79 and δ 11.73 ppm were observed for the two NH protons, respectively, and which disappeared on D₂O ex-

change. The spectra of the complexes showed only the peak at δ 11.73 ppm for NH, while the peak at δ 12.79 ppm for NH between C=S and C=O groups disappeared, indicating the removal of this proton and the formation of a C=N group. A peak appearing at δ 2.51 ppm should be assigned to the proton of H₂O in the complexes.

To obtain further insight into the nature of bonding, the XPS spectra of the complexes were measured at room temperature (Table 2). It was obvious that the intensity components of O and S atoms showed different changes except for the N atom after coordination with metal ions. Furthermore, S2p exhibited a striking contrast compared to O1s, suggesting that a favorable interaction existed between the S atom and a metal ion. Different metal ions also had influence on their binding energy. These collectively demonstrated that only O and S atoms of the ligand coordinated with metal ion.

The mass spectra of the target complexes were recorded. For complex Cu(Bdpt)₂(H₂O)₂, the molecule ion peak (M⁺: 734, 6.22) was observed. But for complexes Co(Bdpt)₂(H₂O)₂ and Zn(Bdpt)₂(H₂O)₂, their molecule ion

Table 1. Analytical data of the target complexes

Complex	Formula	Molecular Weight	Melting Point (°C)	Found (Calc.) %		
				C	H	N
Bdpt	C ₁₄ H ₁₄ N ₄ O ₃ S	318.35	196~197	53.24 (52.99)	4.40 (4.43)	17.82 (17.70)
Cu(Bdpt) ₂ (H ₂ O) ₂	C ₂₈ H ₃₀ CuN ₈ O ₈ S ₂	734.26	180~181	45.92 (45.80)	4.18 (4.12)	15.34 (15.26)
Co(Bdpt) ₂ (H ₂ O) ₂	C ₂₈ H ₃₀ CoN ₈ O ₈ S ₂	729.65	160~162	46.23 (46.09)	4.22 (4.14)	15.43 (15.36)
Zn(Bdpt) ₂ (H ₂ O) ₂	C ₂₈ H ₃₀ N ₈ O ₈ S ₂ Zn	736.13	171~173	45.81 (45.69)	4.15 (4.11)	15.34 (15.22)

Table 2. XPS spectra data of the target complexes

Complexes	Binding Energy (eV)		
	O1s	N1s	S2p
Bdpt	532.0	399.3	162.0
Cu(Bdpt) ₂ (H ₂ O) ₂	532.2	399.3	162.5
Co(Bdpt) ₂ (H ₂ O) ₂	531.8	399.3	163.5
Zn(Bdpt) ₂ (H ₂ O) ₂	532.1	399.3	166.5

peaks were not observed. One mole of ligand being removed from the complexes was the main broken pattern for these complexes: Cu(Bdpt)⁺ (381, 45.89); Co(Bdpt)⁺ (376, 25.71); Zn(Bdpt)⁺ (382, 42.19). To be sure of these, DTA-TG experiments were carried out and the results are summarized in Table 3.

As shown in Table 3, the complexes were thermally stable up to 160 °C. The first weight loss of these complexes was observed in the range of 165–217 °C corresponding to the loss of water. Generally in thermal analysis, the water eliminated below 150 °C could be considered as water of hydration and the water eliminated above 150 °C might be due to water of coordination.¹⁵ The second stage was in the range of 220–350 °C due to the decomposition of one mole ligand from the complexes, which was in

accordance with the results obtained from MS. Finally, the complexes changed into metal oxide at high temperatures of 480–620 °C. Therefore, we confirmed that the target complexes were composed of two Bdpt and two water molecules which coordinated to the central metal ion through O and S atoms based on elemental analyses, IR, ¹H NMR, XPS, MS and TG experiments though single crystals of the complexes could not be obtained.

Herbicidal activity

The herbicidal activities of the target complexes were evaluated by the flat-utensil method according to the standard bioactivity test procedures of the Anhui Agriculture Academy in China. The preliminary results (Table 4) showed that the target complexes have moderate inhibitory activities against both broad leaf weeds and monocotyledon plants. It is worth noting that the complexes showed some improved herbicidal activities over their non-complexed counterparts. The present work provides a novel class of transition metal-based derivatives with potent herbicidal activities for further optimization.

EXPERIMENTAL

All the reagents and solvents were of commercial

Table 3. TG-DTA data of the target complexes

Complex	Stage	Range (°C)	Mass loss (Calc.) %	Reaction
Cu(Bdpt) ₂ (H ₂ O) ₂	1	195~217	4.80 (4.90)	Cu(Bdpt) ₂ (H ₂ O) ₂ → Cu(Bdpt) ₂
	2	224~289	43.61 (43.36)	Cu(Bdpt) ₂ → Cu(Bdpt)
	3	500~606	41.84 (41.18)	Cu(Bdpt) → CuO
Co(Bdpt) ₂ (H ₂ O) ₂	1	165~177	4.86 (4.93)	Co(Bdpt) ₂ (H ₂ O) ₂ → Co(Bdpt) ₂
	2	220~278	43.92 (43.63)	Co(Bdpt) ₂ → Co(Bdpt)
	3	480~590	42.02 (41.44)	Co(Bdpt) → CoO
Zn(Bdpt) ₂ (H ₂ O) ₂	1	185~207	4.96 (4.89)	Zn(Bdpt) ₂ (H ₂ O) ₂ → Zn(Bdpt) ₂
	2	270~350	43.71 (43.25)	Zn(Bdpt) ₂ → Zn(Bdpt)
	3	510~620	41.42 (41.07)	Zn(Bdpt) → ZnO

Table 4. The inhibition percentage of the target complexes on various weeds

Complexes	Bdpt (ppm)			Cu(Bdpt) ₂ (H ₂ O) ₂ (ppm)			Co(Bdpt) ₂ (H ₂ O) ₂ (ppm)			Zn(Bdpt) ₂ (H ₂ O) ₂ (ppm)		
	10	50	100	10	50	100	10	50	100	10	50	100
<i>Digitaria sanguinalis</i> (L)	5	15	30	10	40	80	30	50	70	20	35	65
<i>Scop</i>												
<i>Echinochloa crusgalli</i>	10	15	20	30	45	60	65	75	80	25	45	65
<i>Chenopodium serotinum</i> L	10	12	25	35	40	50	70	75	80	50	55	60
<i>Amaranthus retroflexus</i> L	5	8	16	10	15	20	45	67	78	32	40	50

quality and were used without purification. The C, H and N analyses were repeated twice. IR spectra were obtained using a Perkin-Elmer 2000 FTIR instrument. ^1H NMR spectra were obtained with a Jeol FX-90Q spectrometer with chemical shifts reported as ppm (in $\text{DMSO-}d_6$, TMS as internal standard). The experiments of XPS were performed in an ESCALAB 2201-XL X-ray photoelectron spectra using AlK_α radiation, with the pressure of the residual gases better than 5×10^{-10} Torr. The working power (P) of the X-ray gun was 300 w using the C_{1s} spectrum (284.8 eV) as internal reference. Mass spectra were recorded on an HP-5988A mass spectrometer at 70 eV. The thermal analysis of the complexes were carried out using a Shimadzu thermogravimetric analyzer with a TGA-50H detector in nitrogen (flow rate = 30.0 mL/min), and the heating rates were suitably controlled at $10^\circ\text{C min}^{-1}$ and the weight loss was measured from ambient temperature up to 800°C .

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REFERENCES

1. Dimitrakopoulou, A.; Dendrinou-Samara, C.; Pantazaki, A. A.; Raptopoulou, C.; Terzis, A.; Samaras, E.; Kessissoglou, D. P. *Inorg. Chim. Acta* **2007**, *360*, 546.
2. Katsarou, M. E.; Efthimiadou, E. K.; Psomas, G.; Karaliota, A.; Vourloumis, D. *J. Med. Chem.* **2008**, *51*, 470.
3. Dimitrakopoulou, A.; Dendrinou-Samara, C.; Pantazaki, A. A.; Alexiou, M.; Nordlander, E.; Kessissoglou, D. P. *J. Inorg. Biochem.* **2008**, *102*, 618.
4. Han, G.; Luo, H.; Ye, Q.; Xiong, R. *Z. Anorg. Allg. Chem.* **2008**, *634*, 1991.
5. Psomas, G.; Raptopoulou, C. P.; Iordanidis, L.; Dendrinou-Samara, C.; Tangoulis, V.; Kessissoglou, D. P. *Inorg. Chem.* **2000**, *39*, 3042.
6. Brownlee, J. M.; Johnson-Winters, K.; Harrison, D. H. T.; Moran, G. R. *Biochemistry* **2004**, *43*, 6370.
7. Xing, S.; Hu, C.; Qu, J.; He, H.; Yang, M. *Environ. Sci. Technol.* **2008**, *42*, 3363.
8. Undabeytla, T.; Morillo, E.; Maqueda, C. *J. Agric. Food Chem.* **2002**, *50*, 1918.
9. Karki, L.; Lakshmi, K. V.; Szalai, V. A.; Brudvig, G. W. *J. Am. Chem. Soc.* **2000**, *122*, 5180.
10. Larrivee, E. M.; Elkins, K. M.; Andrews, S. E.; Nelson, D. J. *J. Inorg. Biochem.* **2003**, *97*, 32.
11. Xue, S.; Tan, D.; Sun, C. *Chin. Chem. Lett.* **1998**, *8*, 721.
12. Xue, S.; Duan, L.; Zou, J. etc. *Chin. J. Org. Chem.* **2004**, *24*, 1244.
13. Xue, S.; Duan, L.; Ke, S. etc. *Chin. J. Org. Chem.* **2004**, *24*, 686.
14. Xue, S.; Duan, L.; Ke, S. etc. *Chin. J. Org. Chem.* **2004**, *23*, 441.
15. Abdel-Ghani, N. T.; Sherif, O. E. *Thermochim. Acta.* **1989**, *156*, 69.