

The synthesis and characterization of copper(II)-*p*-aminosalicylate complexes with diamine ligands

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Abstract The complexes were synthesized by the reaction between sodium salt of *p*-aminosalicylic acid (PAS) and Cu(II) for **1** and corresponding ethylenediamine (en) or its derivatives for **2–6**. The complexes were characterized by using elemental analyses, FT-IR, UV-Vis, magnetic moment measurements, and thermal analyses techniques. In complex **1** [Cu₂(PA)₄(H₂O)₂], two Cu(II) ions were found as bridged by four μ -O:O' *p*-aminosalicylate (PA) ligands, forming a cage structure, and two aqua ligands to form dinuclear square-pyramidal geometry around Cu(II) ions. In the complexes **2–6**, the PA (anionic form of *p*-aminosalicylic acid) coordinated to Cu(II) ions as monodentate manner by using its oxygen atom of deprotonated carboxylic acid and ethylenediamine derivatives coordinated to the Cu(II) ions in bidentate manner to form mononuclear octahedral complexes [Cu(PA)₂(L)₂] (L = ethylenediamine, *N,N*-dimethylethylenediamine, *N,N'*-dimethylethylenediamine, *N,N,N',N'*-tetramethylethylenediamine, and 1,3-propanediamine, for complexes **2**, **3**, **4**, **5**, and **6**, respectively). In all the complexes OH and NH₂ groups of PA ligands were not coordinated to metals.

Keywords 4-Aminosalicylic acid · 4-Amino-2-hydroxybenzoic acid · *p*-Aminosalicylic acid · Mixed ligand complex · Copper(II) complexes

Introduction

Many authors investigated coordination compounds due to their chemical, biological, environmental, ion-exchange, and catalytic importance. Recently, considerable attention has been devoted to the study of mixed ligands complexes of metal(II) containing nitrogen donor ligands [1].

The salicylic acid derivatives are widely used for treatment of various diseases [2]. 4-aminosalicylic acid (4-amino-2-hydroxybenzoic acid or *p*-aminosalicylic acid) which is a derivative of salicylic acid, also nicknamed PAS, PASER, Paramycin, or Parasal, has been used as an anti-tuberculosis drug since the early 1950s. In literature, there are a lot of knowledge including 4-aminosalicylic acid (PAS), can also use as a strong pain killer, antipyretic, reducing the body burden of Mn in manganism, treatment of inflammatory bowel diseases, ulcerative colitis and inhibition of CA isozymes [3–10].

Also, the copper complexes especially copper salicylate complex, are highly effective for anti-inflammatory agents and shown great potential in the treatment of numerous chronic diseases, inflammatory diseases, gastrointestinal ulcers, cancers, epilepsy, and diabetes [11].

In addition to these properties, the metal carboxylate chemistry has been of great interest in the field of catalysis, as antifungal agents, enzyme models, or mainly, in the field of molecular magnetism for their versatile co-ordination behavior as well as for making metallo-organic frameworks [12, 13].

Besides, PAS can be used as a carboxylic acid to handle versatile coordinated complexes, also can be used in organic synthesis as precursor, because of its NH₂, OH, and COOH substituents. So the PAS is ready for versatile usage than salicylic acid.

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The aim of this study is the synthesis and characterization of novel mixed ligands PAS complexes with Cu(II) ion.

Results and discussion

The complexes were synthesized by the reaction between sodium salt of *p*-aminosalicylic acid (PAS) and Cu(II) for **1** and corresponding ethylenediamine or its derivatives for **2–6**. The complexes were characterized with using elemental analyses, FT-IR, UV-Vis, magnetic moment measurements, and thermal analyses techniques. The colors, yields, magnetic moments, UV-Vis, and elemental analyses data are given in Table 1. The IR and thermal analyses data are collected in Tables 2 and 3, respectively.

IR, UV-Vis spectroscopy, and magnetic moment measurement

The IR spectrum of sodium salt of PAS (PA) showed peaks at 3400–3328, 3218, 1636, and 1504 cm^{-1} attributed to NH_2 , O–H, $\text{C}=\text{O}^+\text{COO}_{\text{sym}}^-$ and $\text{COO}_{\text{sym}}^-$ vibrations,

respectively, [9–16]. The IR spectra of the both the complexes except **1** were similar. The broad band at 3574 indicated the aqua ligands in complex **1**. The peaks at 3244–3204, 3147, 1614, and 1509 cm^{-1} were attributed to NH_2 , OH, $\text{COO}_{\text{asym}}^-$, and $\text{COO}_{\text{sym}}^-$ vibrations of PA, in complex **1** (Table 2).

The difference between the $\text{COO}_{\text{asym}}^-$ (ν_{asym}), and $\text{COO}_{\text{sym}}^-$ (ν_{sym}) carboxylate vibrations ($\Delta = \nu_{\text{asym}} - \nu_{\text{sym}}$) is often used to determine the coordination modes of the carboxylate group [13, 17–20].

The reducing of the difference (Δ) between $\text{COO}_{\text{asym}}^-$, and $\text{COO}_{\text{sym}}^-$ vibrations indicated that the bridging bidentated manner of PA ligand in complex **1** [17–21]. Similar dinuclear structure for Cu(II) carboxylate complexes previously reported [21–25].

In the IR spectra of complexes **2–6**, the peaks at 3463–3349, 3360–3143, 3213–3222, 3037–2844, 1644–1629, and 1511–1506 cm^{-1} , were attributed to $\text{NH}_{2\text{-PA}}$, $\text{NH}_{2\text{-Dimen}}$, OH_{PA} , $\text{CH}_{\text{aliphatic}}$, $\text{C}=\text{O}+\text{COO}_{\text{asym}}^-$ and $\text{COO}_{\text{sym}}^-$ vibrations, respectively, (Table 2). Seeing of OH peaks in the IR spectra of the complexes **1–6** indicated the OH protons were not separated and not bonded to the Cu(II) ions.

Table 1 Colors, yields, magnetic moments, UV-Vis, and elemental analyses data of the complexes

	Color	$M_n/g/mol$	Yield%	μ/BM	$d \rightarrow d/nm$ $\epsilon/L/mol/cm$	Elemental analyses		
						C%	H%	N%
1 $C_{29}H_{31}Cu_2N_4O_{14}$	Green	786.67	88	2.32	572 144	44.38 (44.28)	4.12 (3.97)	7.41 (7.12)
2 $C_{18}H_{28}CuN_6O_6$	Violet	488.00	78	1.23	544 4.65	44.46 (44.30)	5.51 (5.78)	17.38 (17.22)
3 $C_{22}H_{36}CuN_6O_6$	Deep blue	544.10	65	1.21	572 9.10	48.62 (48.56)	6.34 (6.67)	15.63 (15.45)
4 $C_{22}H_{36}CuN_6O_6$	Blue	544.10	70	1.27	574 5.41	48.71 (48.56)	6.41 (6.67)	15.54 (15.45)
5 $C_{26}H_{44}CuN_6O_6$	Green	600.21	72	1.52	574 8.47	52.25 (52.03)	7.22 (7.39)	14.36 (14.00)
6 $C_{20}H_{32}CuN_6O_6$	Violet	516.05	84	1.31	580 5.91	46.71 (46.55)	6.09 (6.25)	16.47 (16.29)

Table 2 The IR spectra data of the sodium salt of PAS (PA-Na) and handled complexes

	H_2O	$NH_{2\text{-PA}}$	OH	$NH_{2\text{-Dimen}}$	$CH_{\text{aliphatic}}$	COO_{asym}^-	COO_{sym}^-	Δ
PA-Na	–	3393–3330	3226	–	–	1638	1509	129
1	3574	3244–3204	3147	–	–	1614	1514	100
2	–	3459–3354	3235	3296–3143	2970–2845	1644	1511	133
3	–	3463–3371	3213	3360–3340	3037–2844	1636	1509	127
4	–	3446–3364	3226	3156	3002–2808	1630	1506	124
5	–	3446–3358	3239	–	3010–2848	1636	1509	127
6	–	3459–3349	3222	3318–3261	2958–2857	1629	1509	120

Table 3 The thermal analyses data of the complexes

		Stage 1	Stage 2	Stage 3	Total mass loss residue
1	Temperature/°C	30–103	103–380		Found: 79.3
	DTA _{max} /°C	68	257, 292		Calc.: 79.8
	Mass loss%	5.5	73.5		CuO
2	Temperature/°C	70–137	137–257	257–587	Found: 83.2
	DTA _{max} /°C	106	187, 213	505	Calc.: 83.7
	Mass loss%	6.9	60.1	16.7	CuO
3	Temperature/°C	100–152	152–229	229–510	Found: 86.3
	DTA _{max} /°C	137	175	419	Calc.: 85.4
	Mass loss%	2.7	49	34.9	CuO
4	Temperature/°C	61–125	125–240	240–540	Found: 88.6
	DTA _{max} /°C	88	190, 203	431	Calc.: 88.3
	Mass loss%	5.5	49.3	33.8	Cu
5	Temperature/°C	30–80	80–197	197–495	Found: 90.0
	DTA _{max} /°C	70	180	228, 263, 301, 355, 406	Calc.: 89.4
	Mass loss%	2.2	26.1	62.1	Cu
6	Temperature/°C	64–138	138–260	260–564	Found: 84.1
	DTA _{max} /°C	110	171, 175, 199	443, 489	Calc.: 84.5
	Mass loss%	11.1	49.3	23.9	Cu

The complex **5** which has *N,N,N',N'*-tetramethylethylenediamine (Ten) as a secondary ligand, was a key to understand of coordination manner of PA ligand in the complexes. The Ten ligand had no NH or NH₂ parts, so it does not cause overlapping of the peaks for NH_{2-PA} or OH_{PA} of PA ligand. In the IR spectra of complex **5**, the peaks of NH_{2-PA} shifted to higher frequencies and became clear and the OH_{PA} peak showed small shift indicating the NH₂ and OH groups of PA were not coordinated to metals. The IR spectra of the other complexes were similar with the complex **5** and the additional peaks of NH₂ for **2**, **3**, **6** and NH peak for **4** were seen in their spectra indicating the en ligands or its derivatives were in the coordination spheres.

The difference (Δ) between the ν_{asym} and ν_{sym} frequencies of PA was 129 cm⁻¹ and the small shifts were found for Δ values were in the range 120–133 cm⁻¹ for complexes **2–6**. These results indicated that the carboxylate group participated in the coordination with the metal ions in unidentate manner in complexes **2–6** [17–21] (Table 2).

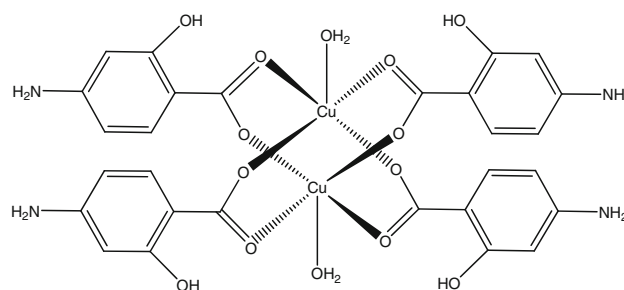
The room temperature spin-only magnetic moments were found as 2.32 for complex **1** which was suitable with square-planar geometry around Cu(II) centers of dinuclear complex and between 1.21 and 1.52 BM for complexes **2–6** which were suitable with octahedral geometry around the Cu(II) centers of mononuclear complexes [26] (Table 1). The lower magnetic moment values indicate anti-ferromagnetic coupling between the two Cu(II) centers

for complex **1** and spin-only magnetic moments acceptable for other complexes.

The UV–Vis spectra of an ethanol solution of the complexes had one band. The absorption coefficients were in the range of approximately 5–9 for complexes **2–6** and 144 for complex **1** which consistent with octahedral and square-planar environments for a *d*⁹ electron configuration (Table 1) [26]. Based on the lights of these overall results, the suggested structures of the complexes are shown in Figs. 1 and 2.

Thermal analyses

The thermal analyses data of the complexes are given in Table 3. All the complexes undergo complete endothermic

**Fig. 1** The suggested structure of complex **1**

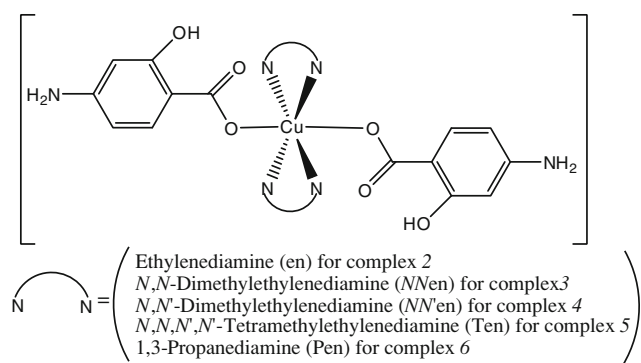


Fig. 2 The suggested structure of complexes 2–6

and exothermic decompositions. Complex 1 undergoes complete decompositions in two stages (Fig. 3). The first stage occurred at 30–103 °C (DTA_{max}: 68 °C) and were corresponded to an endothermic removal of two water ligands (calc.: 4.6%, found: 5.5%). In the second stage, between 103 and 380 °C the organic parts of the PA was lost by highly exothermic reaction. Thus, the total of 79.3% of the original mass of complex 1 was removed to form CuO (calc.: 79.8%) during thermolysis, which was consistent with the proposed structure (Fig 1).

The complexes 2–6 were decomposed with endothermic and exothermic reactions in three stages (Figs. 4, 5, 6, 7, and 8). Averagely, the complexes were stable until around 100 °C and it was not easy to reasonable explain without mass spectra of evolution fragments during thermal decompositions. The complexes formed CuO and metallic Cu as final products for 2–3 and 4–6, respectively. The increasing of carbon numbers may consume the amount of oxygen in the static air atmospheres to result metallic Cu around 500 °C as final products for 4–6.

The overall weight loss and residue weights agree well with the proposed structures (Fig. 2).

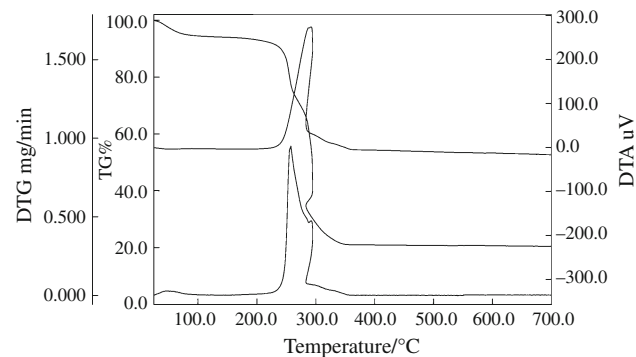


Fig. 3 Thermal analyses curves of complex 1

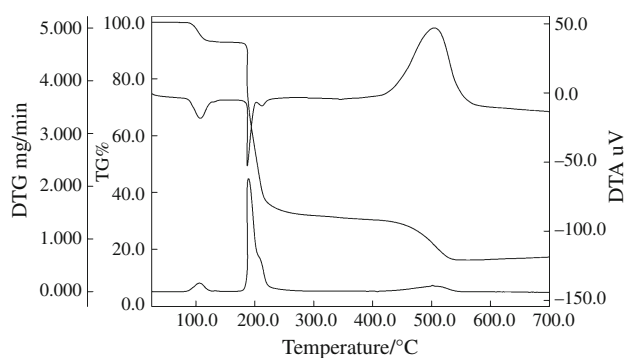


Fig. 4 Thermal analyses curves of complex 2

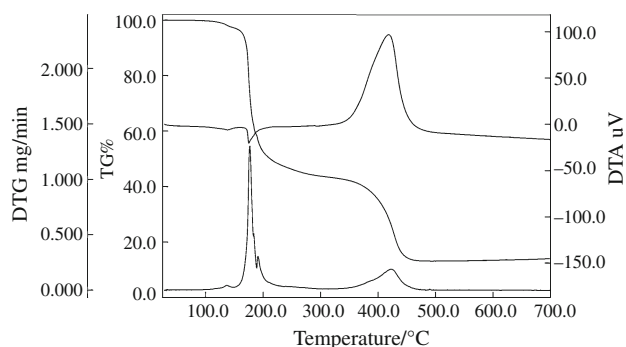


Fig. 5 Thermal analyses curves of complex 3

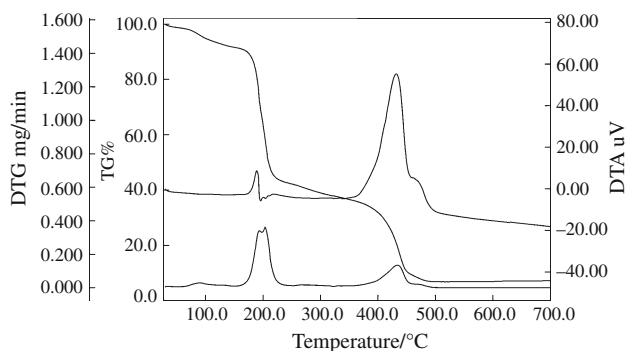


Fig. 6 Thermal analyses curves of complex 4

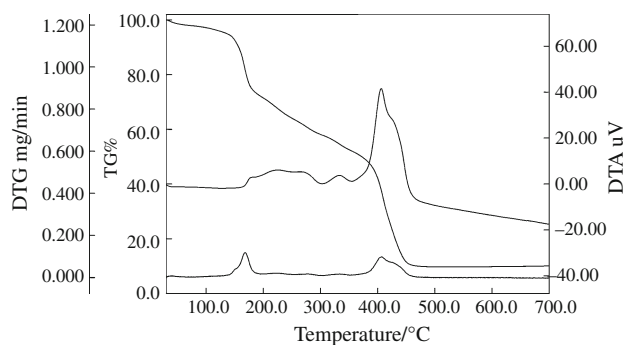


Fig. 7 Thermal analyses curves of complex 5

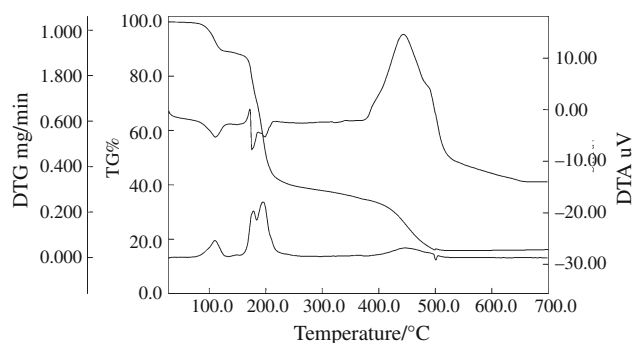


Fig. 8 Thermal analyses curves of complex **6**

Experimental

Materials and measurements

Only commercially available reagent grade chemicals were used. FT-IR spectra ($4000\text{--}400\text{ cm}^{-1}$) were recorded on a Perkin-Elmer Spectrum 100 FT-IR spectrophotometer with samples prepared as KBr pellets. Magnetic susceptibilities were measured using a Sherwood Scientific MX1 Gouy Magnetic Balance at room temperature. UV-Vis spectra were recorded with a PG-T80 + UV-Vis spectrometer. A SII-O Extar 6000 thermal analyzer was used to simultaneously record TG, DTG, and DTA curves in static air atmosphere at a heating rate of 10 K min^{-1} from 30 to $700\text{ }^{\circ}\text{C}$ using platinum crucibles. Highly sintered $\alpha\text{-Al}_2\text{O}_3$ was used as a reference. Elemental analysis for C, H, and N were performed using a Carlo Erba 1106 microanalyser.

Preparation of the complexes

To synthesis complex **1**, $[\text{Cu}_2(\text{PA})_4(\text{H}_2\text{O})_2]$, sodium salt of 4-aminosalicylic acid (PA) (1.53 g, 0.01 mol) were dissolved in ethanol (20 mL) and heated to $50\text{ }^{\circ}\text{C}$. To the solution $\text{CuCl}_2\cdot\text{H}_2\text{O}$ (0.85 g, 0.005) 10 mL ethanol was added. After 0.5 h, 10 mL water was slowly added to the mixture. The participated complex **1** $[\text{Cu}_2(\text{PA})_4(\text{H}_2\text{O})_2]$ was filtered and rinsed with water and cold ethanol.

To synthesis complex **2–6**, $[\text{Cu}(\text{PA})_2(\text{L})_2]$, to the 20 mL ethanol solution of PA (1.53 g, 0.01 mol) were added the solution of $\text{CuCl}_2\cdot\text{H}_2\text{O}$ (0.85 g, 0.005) in ethanol (10 mL). After 0.5 h, the ethylenediamine or its derivatives were directly added to the mixture in 1:1 mol ratio with PA [0.60 g ethylenediamine (en) for **2**, 0.88 g *N,N*-dimethylethylenediamine (*NN*) for **3**, 0.88 g *N,N'*-dimethylethylenediamine (*NN'*) for **4**, 1.16 g *N,N,N',N'*-Ten for **5** and 0.74 g 1,3-propanediamine (Pen) for **6**]. And then 10 mL water slowly added to mixtures and the participated complexes were filtered and rinsed with water and cold ethanol.

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