X-ray powder diffraction analysis of a silver(I)-aspartame complex

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Synchrotron X-ray powder diffraction (XRPD) data were collected for the silver(I)-aspartame complex $[Ag(C_{14}H_{17}N_2O_5)]\cdot 1/2\ H_2O$. The complex was obtained from a stoichiometric mixture of aspartame (3-amino-N-(α-carboxyphenethyl)-succinamic acid N-methyl ester, $C_{14}H_{18}N_2O_5$), Na_2CO_3, and $AgNO_3$. Indexing using Crysfire and Chekcell proposed an orthorhombic unit cell with space group $P222_1$. The lattice parameters are $a=12.4750(1)$ Å, $b=21.60614(14)$ Å, and $c=4.88888(9)$ Å. © *2006 International Centre for Diffraction Data.* [DOI: 10.1154/1.2383065]

Key words: silver(I)-aspartame, X-ray diffraction, Le Bail method

I. INTRODUCTION

Silver and several of its compounds have been used as antimicrobial agents in medicine (Klasen, 2000a, b; De Gracia, 2001; Modak *et al.*, 1983; Nomiya *et al.*, 1995, 1997; Nomiya and Yokoyama, 2002). Silver(I)-sulfadiazine has been used clinically as an antimicrobial and antifungical agent. It is an insoluble polymeric compound that releases Ag(I) ions slowly, and it is applied topically as a cream to prevent bacterial infections in cases of severe burns.

Aspartame (3-amino-N-(α-carboxyphenethyl)-succinamic acid N-methyl ester, $C_{14}H_{18}N_2O_5$) is a compound used as a commercial sweetener (Figure 1). In general, sweeteners have functional groups like carbonyl, carboxylate, amino, and sulfamate, which allow them to be used as ligands in coordination and bioinorganic chemistry. The complexes formed with aspartame as ligand could have low toxicity for the human body and could be used as a pharmaceutical product.

Because silver compounds have antibacterial properties and aspartame has low toxicity and low manufacturing costs, a silver(I)-aspartame complex was obtained in our laboratory. In fact, the compound reported in this paper showed a potent antimicobacterial activity against species of mycobacteria, including *Mycobacterium tuberculosis*, which is responsible for tuberculosis infection. The other species tested were *Mycobacterium avium, Mycobacterium intracellulare, Mycobacterium malmoense*, and *Mycobacterium kansaii*.

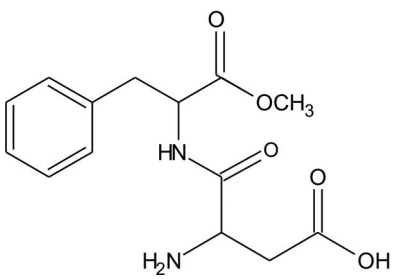

Figure 1. Schematic representation of aspartame.

The aim of the present work is to characterize the silver(I)-aspartame complex using a collection of techniques including X-ray powder diffraction.

II. EXPERIMENTAL

Aspartame was obtained from Monsanto, sodium carbonate from Sigma, and silver(I) nitrate from Acros Organics as analytical grade purity.

To synthesize the silver(I)-aspartame complex $[Ag(C_{14}H_{17}N_2O_5)]\cdot 1/2H_2O$, an aqueous solution of $AgNO_3$ (0.340 g, 2.0 mmol) was added to a solution containing 0.590 g (2.0 mmol) of aspartame and 0.106 g (1.0 mmol) of Na_2CO_3 under stirring. A white crystalline powder of the complex was obtained. The compound was washed with ~200 mL of water and dried over P_4O_{10} under vacuum.

Elemental analysis of carbon, hydrogen, and nitrogen was performed using a CHNS-O EA1110 Analyzer, CE Instruments. High purity cysteine was used as a reference sub-

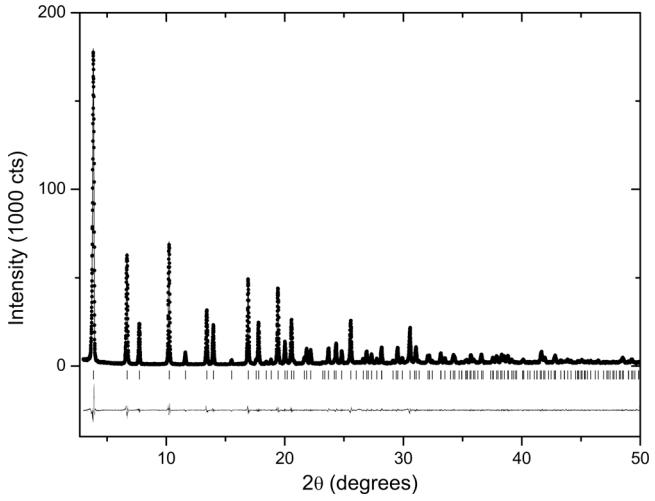

Figure 2. Observed (dots), calculated (continuous line), and difference (bottom line) diffractograms for silver(I)-aspartame. The small vertical lines above the difference plot indicate the Bragg peak positions.

TABLE I. Unit cell parameters before and after the Le Bail fit, for $[Ag(C_{14}H_{17}N_2O_5)]\cdot\frac{1}{2}\ H_2O$.

	Space group	a (Å)	b (Å)	c (Å)
after Crysfire	$P222_1$	12.472	21.603	4.887
after Le Bail refinement		12.4750(1)	21.60614(14)	4.88888(9)

stance. Silver content was determined by atomic absorption using a Perkin Elmer instrument. The infrared spectrum was recorded on a Spectrum 2000 FT-IR Perkin Elmer spectrophotometer. Sample was prepared as KBr pellets.

Synchrotron X-ray diffraction data were obtained, and the experimental setup consisted of a Si(111) double crystal monochromator with the first crystal refrigerated and the second sagitally curved. A scintillation detector was used. The monochromator was adjusted to select energy E =8.4995 keV(λ=1.458 64 Å), which is the energy close to the maximum flux at the Laboratório Nacional de Luz Síncrotron (LNLS)-Brazil. The sample was deposited in a plane sample holder of 10×12 mm^2. Data were collected from 3 to $50°2\theta$, with a step scan of $0.005°2\theta$. The software XFit (Coelho and Cheary, 1997) was used to fit 36 peaks that were used in the indexation with the Crysfire suite (Shirley, 2002). A Y_2O_3 sample was used as an external standard to check the wavelength and instrumental broadening.

III. RESULTS AND DISCUSSION

The silver(I)-aspartame complex has the formula $[Ag(C_{14}H_{17}N_2O_5)]\cdot1/2H_2O$, according to the analysis of C, H, N, and Ag. The experimentally measured weight concentrations are C 41.0%, H 4.93%, N 6.11%, and Ag 26.5%, which are in good agreement with the theoretically calculated concentrations of C 41.9%, H 4.27%, N 6.97%, and Ag 26.8%.

Main IR features of aspartame are 3324 cm^{-1} (s, ν N-H of NH_2), 3066–2850 cm^{-1} (s, ν C-H of the aromatic ring and aliphatic chain), 1738 cm^{-1} (s, ν C=O of the ester), 1666 cm^{-1} (s, ν C=O of the carboxylic group), 1588 cm^{-1} (s, ν C=C of the aromatic ring), 1547 cm^{-1} (s, δ N-H, scissoring of NH_2), 1498 cm^{-1} (m, δ C-H of the aromatic ring), 1446 cm^{-1} (m, δ C-O-H of the carboxylic group), 1379 cm^{-1} (s, ν C-O of the carboxylic group), and 1227 cm^{-1} (m, ν C-O of the ester) (Silverstein *et al.*, 1991). IR features of the silver(I) complex differ from those of the free aspartame with respect to the position and profile of some bands indicating the participation of the corresponding groups in the coordination to the silver(I) cations. A strong broad band at 3434 cm^{-1} is related to the O-H stretching of the hydration water molecules. The C-O-Ag bending and C-O stretching bands of the carboxylate group are located at 1461 and 1394 cm^{-1}, respectively, because of the monodentate coordination of the carboxylate group to silver(I) and consequent substitution of hydrogen by silver(I). Modifications are also observed in the NH_2 bending band (1547 to 1575 cm^{-1}), suggesting the coordination of silver(I) through the β-amino group. A thermogravimetric curve shows a weight loss at 393 K, which corresponds to a half of a hydration water molecule loss.

Density measurements (pycnometric determination under helium, after a careful evacuation) permitted us to determine the experimental density, which is $\delta=1.2956$ g/cm^3. This value is around 60% of the XRD density ($\delta x=\delta/0.6=2.159$ g/cm^{-3}). This experimental value, combined with the molar mass of the complex, permitted us to calculate the number of formula units Z in a cell ($Z=4$).

By using the Crysfire suite, one solution with space group $P222_1$ was found (by the program Chekcell, as listed in Table I). The solution was used for the Le Bail fit using the GSAS suite. The GSAS suite program (Larson and Von Dreele, 2001) was used for calculations. A pseudo-Voigt function was used as the profile function. During the refinement, only the profile parameters that varied with sec θ and tg θ were refined, including the anisotropic strain parameters defined by Stephens (1999).

The final lattice parameters after the refinement are also listed in Table I. Peak intensities and Miller indexes are given in Table II. The observed, calculated, and difference diffractograms are plotted in Figure 2.

TABLE II. Powder X-ray diffraction data for Ag-aspartame.

h	k	l	d	I100	h	k	l	d	I100
0	1	0	21.606	100	1	6	1	2.824	1
1	0	0	12.475	31	2	7	0	2.766	12
1	1	0	10.804	7	3	6	0	2.722	5
0	2	0	10.803	3	3	4	1	2.732	<1
1	2	0	8.167	33	4	4	0	2.701	<1
0	3	0	7.202	3	0	8	0	2.701	<1
1	3	0	6.237	10	1	8	0	2.640	2
2	0	0	6.238	5	0	7	1	2.610	<1
2	1	0	5.993	10	4	0	1	2.629	<1
2	2	0	5.402	<1	2	6	1	2.629	1
0	4	0	5.402	<1	4	1	1	2.610	<1
1	4	0	4.957	24	3	5	1	2.555	1
0	1	1	4.769	1	1	7	1	2.555	1

TABLE II. (*Continued.*)

h	k	l	d	I100	h	k	l	d	I100
2	3	0	4.715	12	4	2	1	2.555	1
1	0	1	4.552	<1	4	5	0	2.529	1
1	1	1	4.454	<1	5	0	0	2.495	<1
0	2	1	4.454	<1	5	1	0	2.479	<1
0	5	0	4.321	22	3	7	0	2.478	<1
1	2	1	4.195	5	2	8	0	2.478	<1
3	0	0	4.158	<1	4	3	1	2.470	1
3	1	0	4.083	4	5	2	0	2.431	<1
2	4	0	4.083	4	0	0	2	2.445	<1
1	5	0	4.083	4	0	1	2	2.429	<1
0	3	1	4.045	<1	2	7	1	2.408	<1
3	2	0	3.881	1	0	9	0	2.401	<1
1	3	1	3.848	2	0	2	2	2.384	<1
2	0	1	3.848	1	1	0	2	2.399	<1
2	1	1	3.788	3	3	6	1	2.378	2
0	4	1	3.625	<1	1	1	2	2.384	<1
3	3	0	3.601	<1	4	4	1	2.364	<1
0	6	0	3.601	<1	0	8	1	2.364	<1
2	2	1	3.625	<1	5	3	0	2.358	<1
2	5	0	3.552	4	4	6	0	2.358	<1
1	4	1	3.481	<1	1	9	0	2.357	<1
1	6	0	3.460	6	1	2	2	2.342	<1
2	3	1	3.394	3	1	8	1	2.323	2
3	4	0	3.295	13	0	3	2	2.315	<1
0	5	1	3.238	<1	3	8	0	2.265	<1
3	0	1	3.168	1	1	3	2	2.276	<1
2	4	1	3.134	1	5	4	0	2.265	<1
1	5	1	3.134	1	2	0	2	2.276	<1
4	0	0	3.119	<1	2	9	0	2.240	<1
2	6	0	3.119	<1	2	1	2	2.263	<1
3	1	1	3.134	1	4	5	1	2.246	2
4	1	0	3.087	1	0	4	2	2.227	<1
0	7	0	3.087	<1	5	0	1	2.222	2
3	2	1	3.040	1	2	2	2	2.227	<1
3	5	0	2.996	1	5	1	1	2.211	<1
4	2	0	2.996	1	3	7	1	2.211	<1
1	7	0	2.996	1	2	8	1	2.211	<1
3	3	1	2.900	<1	4	7	0	2.194	1
0	6	1	2.899	<1	1	4	2	2.192	<1
4	3	0	2.862	4	5	2	1	2.177	<1
2	5	1	2.874	<1	5	5	0	2.161	<1
0	10	0	2.161	<1	5	6	1	1.891	<1
2	3	2	2.170	<1	4	8	1	1.884	<1
0	9	1	2.155	<1	2	10	1	1.884	<1
1	10	0	2.129	<1	4	2	2	1.894	<1
0	5	2	2.128	<1	3	5	2	1.894	<1
5	3	1	2.124	<1	1	7	2	1.894	<1
4	6	1	2.124	<1	6	5	0	1.874	<1
1	9	1	2.123	<1	2	11	0	1.873	<1
2	4	2	2.097	<1	6	2	1	1.884	<1
1	5	2	2.097	<1	6	3	1	1.849	<1
3	0	2	2.107	<1	4	3	2	1.859	<1
3	9	0	2.079	<1	5	8	0	1.833	<1
3	1	2	2.097	<1	0	11	1	1.823	<1
6	1	0	2.070	<1	2	7	2	1.832	<1
6	0	0	2.079	<1	0	8	2	1.812	<1
3	2	2	2.068	<1	3	6	2	1.819	<1
3	8	1	2.055	<1	6	4	1	1.804	<1
5	6	0	2.051	4	5	7	1	1.804	<1
5	4	1	2.055	<1	1	11	1	1.803	<1

TABLE II. (*Continued.*)

h	k	l	d	I100	h	k	l	d	I100
6	2	0	2.042	<1	4	4	2	1.812	<1
4	8	0	2.042	<1	6	6	0	1.801	<1
2	10	0	2.042	<1	0	12	0	1.801	<1
2	9	1	2.037	1	1	8	2	1.794	<1
3	3	2	2.023	<1	4	10	0	1.776	<1
0	6	2	2.023	<1	3	11	0	1.776	<1
4	7	1	2.002	<1	3	10	1	1.785	<1
2	5	2	2.014	<1	7	0	0	1.782	<1
6	3	0	1.998	<1	1	12	0	1.782	<1
1	6	2	1.996	1	7	1	0	1.776	<1
5	5	1	1.976	<1	4	9	1	1.773	1
0	10	1	1.976	<1	7	2	0	1.758	<1
0	11	0	1.964	<1	6	5	1	1.750	<1
1	10	1	1.952	1	2	11	1	1.749	<1
3	4	2	1.963	<1	4	5	2	1.758	<1
6	4	0	1.940	<1	3	7	2	1.740	<1
5	7	0	1.940	<1	2	8	2	1.740	<1
1	11	0	1.940	<1	5	9	0	1.730	<1
3	10	0	1.917	<1	2	12	0	1.730	<1
3	9	1	1.913	<1	5	0	2	1.746	<1
4	0	2	1.924	<1	6	7	0	1.724	<1
2	6	2	1.924	<1	5	1	2	1.740	<1
4	1	2	1.916	<1	7	3	0	1.730	1
0	7	2	1.916	<1	5	8	1	1.716	4
4	9	0	1.902	<1	5	2	2	1.724	<1
6	0	1	1.913	<1	0	9	2	1.713	2
6	1	1	1.906	<1					

IV. CONCLUSION

The silver(I)-aspartame complex was obtained, which presents a potent antimicobacterial activity against species of mycobacteria, including *Mycobacterium tuberculosis*. The formula of the complex, determined by elemental analysis, is $[Ag(C_{14}H_{17}N_2O_5)]\cdot 1/2\ H_2O$. The silver(I)-aspartame complex presents orthorhombic symmetry with unit cell parameters $a=12.4750(1)$ Å, $b=21.606\,14(14)$ Å, and $c=4.888\,89(9)$ Å with space group $P222_1$.

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