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THERMAL STUDIES ON METAL COMPLEXES OF 5-NITROSOPYRIMIDINE DERIVATIVES IV

Complexes of Fe(II), Co(II), Ni(II) and Cu(II) with 6-amino-5-nitrosouracil

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The thermal decomposition processes of the complexes of 6-amino-5-nitrosouracil with Fe(II), Co(II), Ni(II) and Cu(II) have been studied using TG and DSC techniques. Dehydration energies have been calculated from the DSC curves.

Pyrimidine derivatives and compounds in which the pyrimidine ring is part of a more complex system, are widely distributed in living organisms and find application in biochemistry and clinical chemistry [1]. The metal coordination properties of these compounds, like those of the other nucleic acids components, are of interest with respect to nucleic acid replication, carcinogenesis, etc. [2].

Uracil, thymine and cytosine are normal constituents of nucleic acids and contain several potential donor atoms for metal coordination. The number of donor sites is increased when exocyclic groups are introduced in positions five or six of the pyrimidine ring. The preference of a metal ion for these donor sites is a function of its specific soft or hard character.

Several studies, both in solution and in the solid phase, have been described on interactions between metal ions and pyrimidine derivatives [3–22]. The discovery by Davidson et al. [23] that cis-dichlorodiammineplatinum(II) (cis-platinum) would react with pyrimidine and substituted pyrimidines to form water-soluble deep-blue complexes (the "platinum pyrimidine blues"), which have the advantages over cis-platinum that they lack kidney toxicity and show highly potent antitumor action, increased interest in studies on this type of compound [24–26].

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As part of our studies on the interactions of metal ions with pyrimidine derivatives [27–35], the present paper reports the thermal behaviour of several Fe(II), Co(II), Ni(II) and Cu(II) complexes of 6-amino-nitrosouracil.

Experimental

The 6-amino-5-nitrosouracil (H_2ANU) was synthesized in the Department of Organic Chemistry in Granada, using a previously described method [36]. All chemicals used were of analytical reagent grade or chemically pure.

Table 1 Microanalysis data for H_2ANU and its isolated complexes

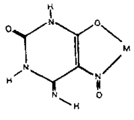
Compound	Colour	C		H		N	
		Calc. %	Found %	Calc. %	Found %	Calc. %	Found %
$Fe(HANU)_2 \cdot 2H_2O$	dark blue	23.88	24.56	2.49	2.55	27.86	26.97
$Co(HANU)_2 \cdot 2H_2O$	green	23.70	24.73	2.47	2.60	27.65	26.76
$Co(HANU)_3 \cdot 6H_2O$	orange	22.78	23.89	3.32	3.16	26.58	26.26
$Ni(HANU)_2 \cdot 2H_2O$	green	23.72	24.72	2.47	2.74	27.65	26.89
$Cu(HANU)_2 \cdot 4H_2O$	black	21.55	22.82	3.14	2.57	25.14	24.42
$Cu(HANU)_2$	brown	25.70	25.72	1.61	1.80	29.88	29.07
H_2ANU	pink	30.77	30.74	2.56	2.91	35.89	34.94

The thermal studies were carried out on a Mettler T.A–3000 system fitted with a Mettler TG 50 thermobalance and a Mettler DSC–20 differential scanning calorimeter. Thermogravimetric curves were recorded in a dynamic atmosphere (100 ml · min of pure air) at a heating rate of 10 deg min^{-1}. The temperature range employed was 40–800°. The residue of the pyrolytic processes was characterized by X-ray diffraction methods. The DSC curves were obtained under static conditions with a heating rate of 5 deg min^{-1}. In these cases, the 35–550° temperature range was explored. The weight of samples employed in our study was between 1.50 and 13.03 mg.

The preparative methods for the isolated complexes $M(HANU)_2 \cdot 2H_2O$ (where M = Fe(II), Co(II) and Ni(II), $Co(HANU)_3 \cdot 6H_2O$, $Cu(HANU)_2 \cdot 4H_2O$ and $Cu(HANU)_2$ were described in a previous paper [37]. Their chemical analyses are detailed in Table 1.

Results and discussion

Spectroscopic studies on the above complexes suggested that the coordination of H_2ANU to these metal occurs in anionic form (HANU) through the groups in positions five and six of the pyrimidine ring, as indicated in the following scheme:



TG and DSC curves for 6-amino-5-nitrosouracil and some of its metal complexes are shown in Figs 1 and 2.

Figures 1a and 2a also give the TG and DSC curves for H_2ANU. The diagrams suggest that this pyrimidine base did not contain water of crystallization, in contrast with other nitrosopyrimidine bases [27], and it decomposes thermally in the temperature range 220–700°, not showing a definite melting point. The pyrolytic decomposition yields two exothermic effects, at 280° and 540°, in the DSC curve of H_2ANU.

For all the isolated complexes, the TG and DSC curves are similar, showing two thermal behaviour types; thus, the hydrated complexes exhibit three or more weight loss effects, whereas the anhydrous complexes display only two effects.

Dehydration processes appear as one endothermic effect in the corresponding DSC curves, except for tris-(6-amino-5-nitrosouracilato) cobalt(III) hexahydrate and bis-(6-amino-5-nitrosouracilato) diaquacopper(II) tetrahydrate, which show three and two endothermic effects, respectively. These results are in agreement with those obtained from spectroscopic data [37]. The observed and calculated weight losses, DSC temperature peaks and dehydration enthalpies for these dehydration processes are listed in Table 2. For $Co(HANU)_2 \cdot 2H_2O$ and $Ni(HANU)_2 \cdot 2H_2O$,

Table 2 TG and DSC data for dehydration processes

Complex	Dehydration temperature range, °C	Weight loss, Found, %	Calc. %	DSC temperature peak, °C	ΔH dehydration, Kj·mol^{-1}
$Fe(HANU)_2 \cdot 2H_2O$	40–150	9.70	8.95	95	26.3
$Co(HANU)_2 \cdot 2H_2O$	220–305	a	8.89	280	65.8
$Co(HANU)_3 \cdot 6H_2O$	40–165	16.7	17.09	87; 105; 140	46.4b
$Ni(HANU)_2 \cdot 2H_2O$	200–290	a	8.89	245	47.7
$Cu(HANU)_2 \cdot 4H_2O$	100–170	15.6	16.16	144; 168	30.2b

a: See text: b: average value

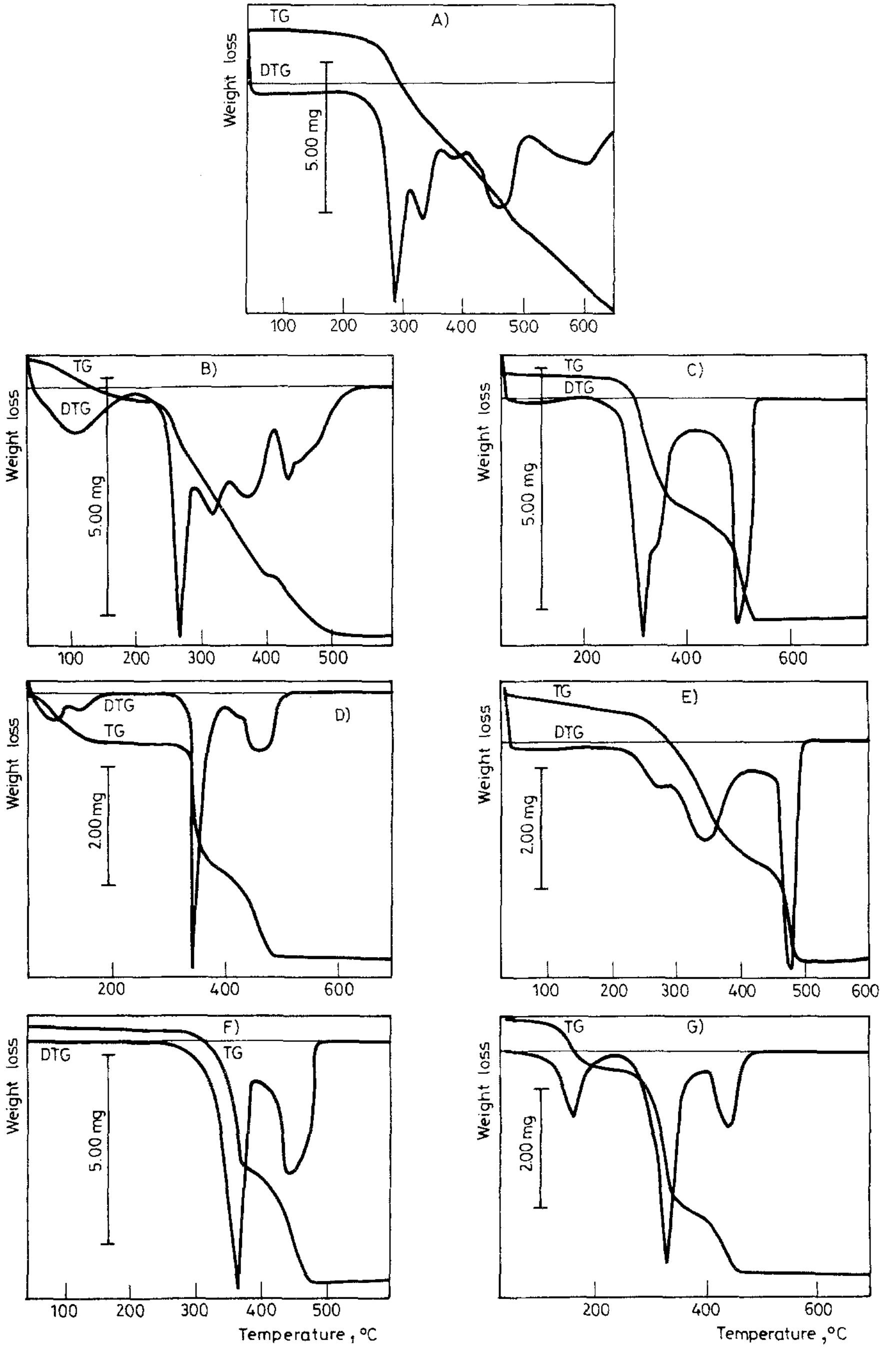


Fig. 1 Thermogravimetric curves for H_2ANU (a); $Fe(HANU)_2 \cdot 2H_2O$ (b); $Co(HANU)_2 \cdot 2H_2O$ (c); $Co(HANU)_3 \cdot 6H_2O$ (d); $Ni(HANU)_2 \cdot 2H_2O$ (e); $Cu(HANU)_2$ (f) and $Cu(HANU)_2 \cdot 4H_2O$ (g)

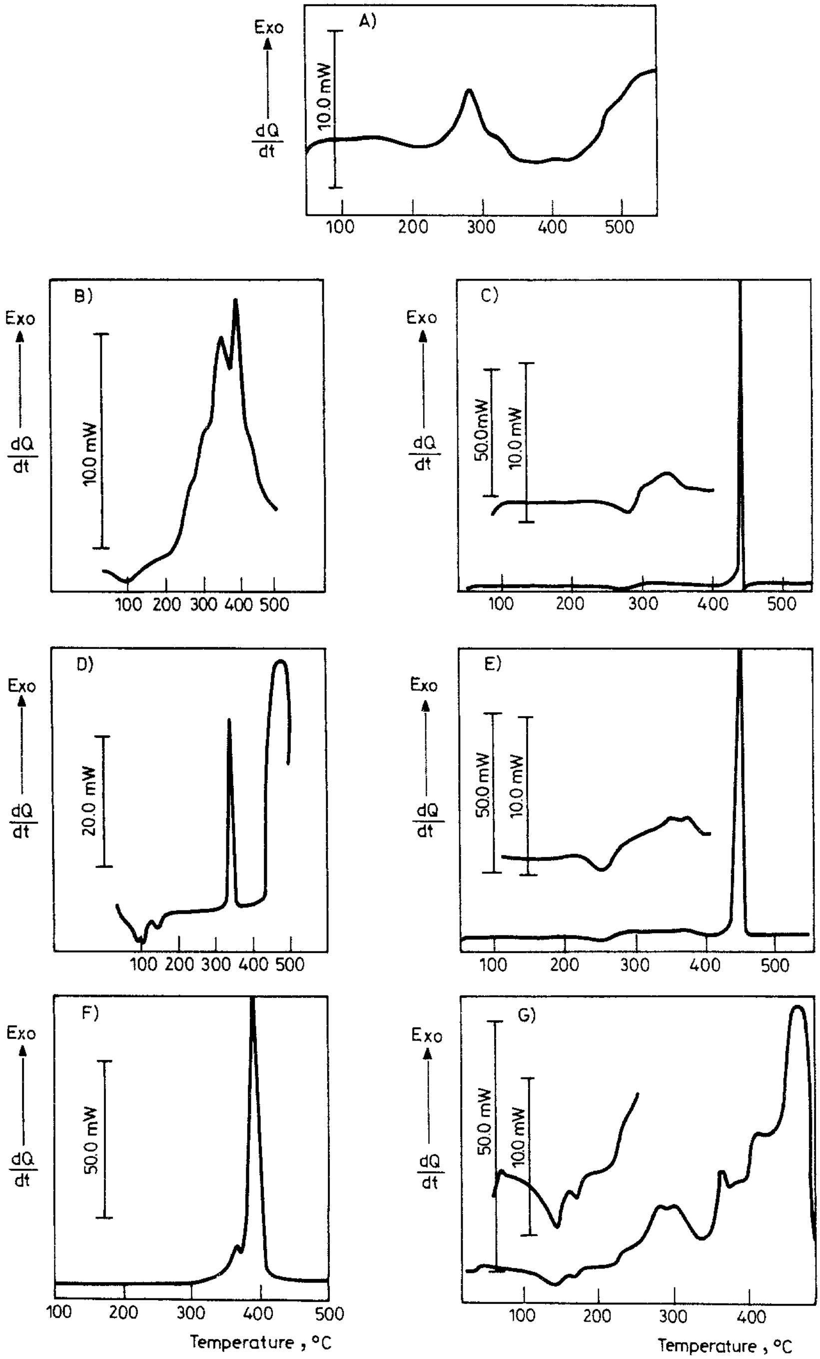


Fig. 2 DSC curves for H_2AHU (a); $Fe(HANU)_2 \cdot 2H_2O$ (b); $Co(HANU)_2 \cdot 2H_2O$ (c); $Co(HANU)_3 \cdot 6H_2O$ (d); $Ni(HANU)_2 \cdot 2H_2O$ (e); $Cu(HANU)_2$ (f) and $Cu(HANU)_2 \cdot 4H_2O$ (g)

Table 3 Thermogravimetric and DSC data for the pyrolitic processes

	Process	Oxide residue, %		DSC peak temperature, °C
		Found	Calcd.	Exo
H_2ANU	pyrolysis products	—	—	280, 540
$Fe(HANU)_2$	Fe_2O_3 + pyrolysis products	17.77	19.86	310, 355, 400
$Co(HANU)_2$	Co_3O_4 + pyrolysis products	21.39	19.83	450
$Co(HANU)_3$	Co_3O_4 + pyrolysis products	13.20	12.70	340, 440
$Ni(HANU)_2$	NiO + pyrolysis products	18.25	18.46	350, 450
$Cu(HANU)_2$	CuO + pyrolysis products	21.89	21.29	390 a
$Cu(HANU)_2$	CuO + pyrolysis products	16.93	17.84	300, 370, 410, 465 b

a — brown complex; b — black complex

the weight losses due to the dehydration processes could not be calculated, since these processes overlap with the pyrolytic decomposition of the pyrimidine ring. However, in the DSC curves (recorded at lower heating rate and with a lower sample weight), this overlap does not take place, which permits calculation of the corresponding dehydration enthalpy for each complex.

The high values of the DSC temperature peaks for dehydration of $Co(HANU)_2 \cdot 2H_2O$ and $Ni(HANU)_2 \cdot 2H_2O$ suggest that the molecules of water are linked directly to the Co(II) and Ni(II) ions, in accordance with the results obtained from the visible spectra of these complexes [37]. For the remaining complexes, the temperature peaks are lower than those observed for the Ni(II) and Co(II) complexes, and the corresponding endothermic effects can be asigned to the release of water of crystallization. These molecules are eliminated in one step from the complex $Fe(HANU)_2 \cdot 2H_2O$; however, for $Co(HANU)_3 \cdot 6H_2O$ the dehydration process takes place in three steps, as can be observed from the corresponding DSC and TG curves, and suggests a non equivalent distribution of these molecules in the crystal lattice of the complex. Finally, the dehydration processes for $Cu(HANU)_2 \cdot 4H_2O$ occurs in two steps, which is in accordance with the distorted tetragonal geometry proposed for this complex on the basis of spectral data.

The following stages in the decomposition of these complexes are much more difficult to determine due to the great complexity; however, all of them show two pronounced weight loss effects between 270 and 500°. These effects are similar to those observed in the TG curve for 6-amino-5-nitrosouracil and are due to pyrolysis of the pyrymidine ring.

Thermogravimetric and DSC data for these pyrolytic processes are given in Table 3. The identity of the final products of the complexes was confirmed by comparing the X-ray diffraction data with those given in the literature [38]. The variation between the experimental and theoretical values for the pyrolytic residues of $Fe(HANU)_2 \cdot 2H_2O$ and $Cu(HANU)_2$ can be ascribed to partial reduction of the corresponding metallic oxide.

References

1 T. G. Spiro, "Nucleic acid-metal ion interactions", Vol. 1. John Wiley and Sons, New York, 1980.

2 G. L. Eichhorn, Met. Ions Biol. System, 10 (1980) 1–21.

3 T. J. Kistenmacher, T. Sorrell and L. G. Marzilli, Inorg. Chem., 14 (1975) 2479.

4 A. K. Singh, M. Katyal, A. M. Bhatti and N. K. Ralhan, Talanta, 23 (1976) 337.

5 A. K. Singh, M. Katyal, R. P. Singh and N. K. Ralhan, Talanta, 23 (1976) 851.

6 M. Authier-Martin and A. L. Beauchamp, Can. J. Chem., 55 (1977) 1213.

7 N. Saha and S. K. Kar, J. Inorg. Nucl. Chem., 39 (1977) 195.

8 R. C. Srivastava and M. N. Srivastava, J. Inorg. Nucl. Chem., 40 (1978) 1439.

9 M. Goodgame and K. W. Johns, J. C. S. Dalton, (1977) 1680.

10 A. Sakaguchi, H. Anzai, K. Furuhata, H. Ogura and Y. Itaka, Chem. Pharm. Bull., 25 (9) (1977) 2267.

11 Pi-Chang Kong and F. D. Rochon, Can J. Chem., 57 (1979) 526.

12 M. Tsuchiya, Nippon Kagaku Kasshi, (1978) 1645.

13 F. A. Cotton, R. H. Niswander and J. C. Sekutowski, Inorg. Chem., 18 (4) (1979) 1152.

14 F. A. Cotton, R. H. Niswander and J. C. Sekutowski, Inorg. Chem., 18 (4) (1979) 1149.

15 R. Faggiani, B. Lippert and C. J. L. Lock, Inorg. Chem., 19 (1980) 295.

16 D. M. L. Goodgame and G. A. Leach, J. Chem. Soc. Dalton (1978) 1705.

17 D. M. L. Goodgame and I. Jeeves, Inorg. Chim. Acta, 32 (1979) L57.

18 Pi-Chang Kong and F. D. Rochon, Can. J. Chem., 59 (1981) 3293.

19 R. Beyerle and B. Lippert, Inorg. Chim. Acta, 66 (1982) 141.

20 R. Battistuzzi and G. Peyronel, Spectrochim. Acta, 36A (1980) 113.

21 A. Adeyemo and A. Shodeinde, Inorg. Chim. Acta, 54 (1981) L105.

22 I. Mutikanen and P. Lumme, Acta Cryst., 36B (1980) 2237.

23 A. R. Beaudoin, Life Sci., 31 (8) (1982) 757.

24 B. Lippert, H. Shollhorn and U. Thewalt, Z. Naturforsch., 38 (11) (1983) 1441.

25 D. Neugebauer and B. Lippert, J. Am. Chem. Soc., 104 (24) (1982) 6596.

26 R. Pfab, P. Jandik and B. Lippert, Inorg. Chim. Acta, 66 (6) (1982) 193.
27 C. Valenzuela-Calahorro, J. M. Salas-Peregrin and J. D. López-González, An. Quim., 76B (1980) 197.
28 J. D. López-González, J. M. Salas-Peregrin, J. S. García-Mino and C. Valenzuela-Calahorro, An. Quim., 76B (1980) 256.
29 J. M. Salas-Peregrin, C. Valenzuela-Calahorro, J. D. López-González and F. Girela-Vílchez, An. Quim., 77B (1981) 189.
30 J. S. García-Mino, J. D. López-González, M. N. Moreno-Carretero and J. M. Salas-Peregrin, An. Quim., 77B (1981) 335.
31 J. M. Salas-Peregrin, M. N. Moreno-Carretero, J. D. López-González and C. Valenzuela-Calahorro, J. Thermal Anal., 26 (1983) 251.
32 M. A. Romero-Molina, J. M. Salas-Peregrin, J. D. López-González and C. Valenzuela-Calahorro, An. Quim., 79B (1983) 383.
33 M. A. Romero-Molina, J. M. Salas-Peregrin, A. García-Rodríguez and C. Valenzuela-Calahorro, An. Quim., 79B (1983) 507.
34 J. M. Salas-Peregrin, M. N. Moreno-Carretero, M. Nogueras-Montiel and A. Sánchez-Rodrigo, An. Quim., 79B (1983) 547.
35 M. N. Moreno-Carretero, J. M. Salas-Peregrin and A. Mata-Arjona, J. Thermal Anal., 29 (1984) 553.
36 W. Traube, Chem. Ber., 33 (1900) 1371.
37 J. M. Salas-Peregrin, M. A. Romero-Molina, M. A. Ferro-García and A. Mata-Arjona, An. Quim., 80B (1984) 432.
38 ASTM (1970), Index (Inorganic) to the powder difraction file, 70 (Ed.) The Joint Committee on Powder Difraction Standard.

Zusammenfassung — Die thermischen Zersetzungsprozesse von Komplexen von 6-Amino-5-nitrosouracil mit Fe(II), Co(II), Ni(II) und Cu(II) wurde mittels TG und DSC untersucht. Aus den DSC-Kurven wurden die Dehydratisierungsenergien berechnet.

Резюме — Методом ТГ и ДСК изучены процессы термического разложения комплексов 6-амино-нитрозоурацила с двухвалентными железом, кобальтом, никелем и медью. На основе кривых ДСК вычислены энергии дегидратации.