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# THERMAL STUDIES ON PURINE COMPLEXES.
# XV. THERMAL BEHAVIOUR OF SOME NEW COMPLEXES OF 8-ETHYLXANTHINE AND 8-ETHYL-3-METHYLXANTHINE

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## ABSTRACT

A study of the thermal behaviour of nine new complexes of 8-ethylxanthine (8EH) and 8-ethyl-3-methylxanthine (3MEH) with Ni(II), Zn(II), Pd(II), Ag(I), Cd(II), Pt(IV), $Hg_2$(II) and Hg(II) was carried out using their TG, DTG and DSC curves. Heats of dehydration and dehalogenation were calculated from the DSC curves.

## INTRODUCTION

The binding of cations to biomolecules, such as nucleic acid constituents, has been studied intensively in solution and by means of X-ray crystallography [1–7]. This interest is partly due to the importance of various metal ions in biochemical processes, such as DNA replication and the inhibition of neoplastic growth [8–14].

Among the nucleic acid constituents xanthine and its methyl-substituted derivatives have been used as model compounds for nucleosides and in the study of metal–nucleic acid interactions [6,15]. Several studies have been carried out on the spectroscopic and thermal characterization of metal complexes of xanthine and its methylated derivatives [16–26]. However, studies on xanthine derivatives substituted in the eighth position are scarce [25, 27–30].

As a continuation of our studies on the thermal behaviour of complexes of alkylated xanthine derivatives with metals [30], we report here the thermal

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behaviour of nine metal complexes of Ni(II), Zn(II), Pd(II), Ag(I), Cd(II), Pt(IV), $Hg_2$(II) and Hg(II) ions with 8-ethylxanthine (8EH) and 8-ethyl-3-methylxanthine (3MEH).

## EXPERIMENTAL

8-Ethylxanthine and 8-ethyl-3-methylxanthine were prepared using the methods reported previously [31]. The methods of preparation of the isolated metal complexes are described in ref. 32.

Thermogravimetric analyses were performed in air (flow rate, 100 ml $min^{-1}$) using a Mettler TA-3000 system with a Mettler TG 50 thermobalance at a heating rate of 10 °C $min^{-1}$. DSC runs were carried out on a Mettler DSC 20 differential scanning calorimeter at a heating rate of 10 °C $min^{-1}$. Sample weights varied between 3.427 and 15.889 mg for TG and between 0.912 and 4.547 mg for DSC. The temperature ranges investigated were 35–820 °C for TG and 35–600 °C for DSC.

TABLE 1

Analytical data and colour of the isolated complexes

| Complex | Colour | Analysis found (%) | | | |
|---|---|---|---|---|---|
| | | C | H | N | M |
| $Ni(3ME)_2(NH_3)(H_2O) \cdot 2H_2O$ **(I)** | Yellow | 37.93 | 5.09 | 24.54 | 10.63 |
| | | (37.29) | (5.23) | (24.43) | (11.38) |
| $Zn(3ME)_2(NH_3)(H_2O) \cdot 2H_2O$ **(II)** | White | 36.78 | 4.55 | 24.85 | 12.50 |
| | | (36.76) | (5.17) | (24.12) | (12.50) |
| $PdBr_2(8EH)_2$ **(III)** | Yellow | 26.82 | 2.47 | 17.04 | 17.21 |
| | | (26.83) | (2.56) | (17.83) | (16.99) |
| $Ag_2(8EH)_2(8E)NO_3 \cdot 2H_2O$ **(IV)** | White | 29.49 | 3.00 | 19.76 | 25.32 |
| | | (29.55) | (3.16) | (19.70) | (25.29) |
| $Cd(3ME)_2(3MEH)_2$ **(V)** | White-greyish | 42.76 | 4.46 | 24.86 | 11.74 |
| | | (43.32) | (4.28) | (25.27) | (12.68) |
| $Pt(3MEH_2)_2Cl_6 \cdot 3(3MEH_2Cl) \cdot 5H_2O$ **(VI)** | Orange | 31.81 | 4.16 | 18.64 | 13.10 |
| | | (31.82) | (4.31) | (18.56) | (12.93) |
| Ag(3ME)(3MEH) **(VII)** | White-greyish | 38.64 | 4.04 | 22.22 | 21.20 |
| | | (38.80) | (3.84) | (22.63) | (21.78) |
| $Hg(3MEH_2)_2Cl_4 \cdot 2(3MEH_2Cl) \cdot H_2O$ **(VIII)** | Yellow | 31.66 | 3.64 | 18.89 | – |
| | Pale | (31.69) | (3.79) | (18.49) | |
| $Hg_2(8EH)NO_3$ **(IX)** | Grey | 12.98 | 1.15 | 9.76 | – |
| | | (12.38) | (1.62) | (10.32) | |

[a] Theoretical values are in parentheses.

## RESULTS AND DISCUSSION

In a previous paper [32] we reported the synthesis and spectroscopic characterization of the new complexes of 8-ethylxanthine and 8-ethyl-3-methylxanthine. The elemental analyses of the complexes are shown in Table 1.

Physical and chemical methods confirm that in $M(3ME)_2(NH_3)(H_2O) \cdot 2H_2O$ (M = Ni(II) and Zn(II)), $Pd(8EH)_2Br_2$, $Ag_2(8EH)_2(8E)NO_3 \cdot 2H_2O$, $Cd(3ME)_2(3MEH)_2$, Ag(3ME)(3MEH) and $Hg_2(8E)NO_3$ the ligands are

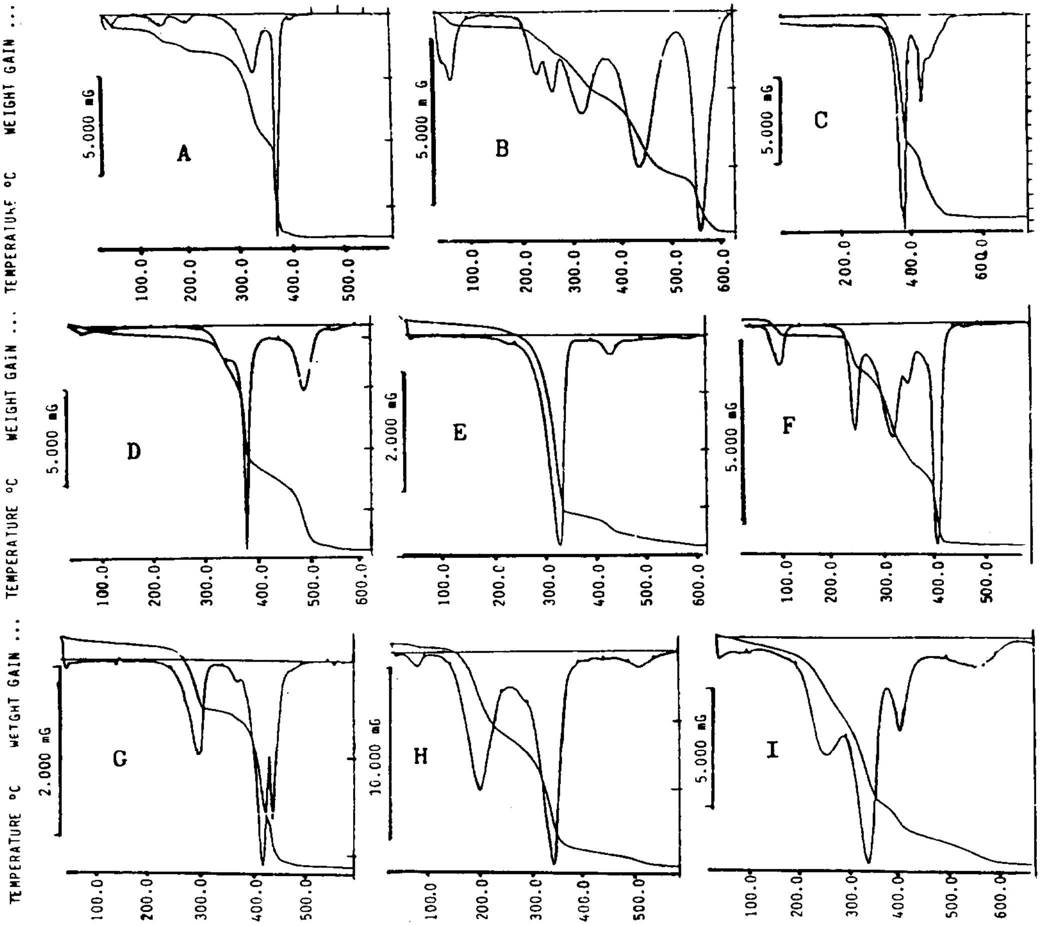

Fig. 1. TG curves: A, $Ni(3ME)_2(NH_3)(H_2O) \cdot 2H_2O$; B, $Zn(3ME)_2(NH_3)(H_2O) \cdot 2H_2O$; C, $PdBr_2(8EH)_2$; D, $Ag_2(8EH)_2(8E)NO_3 \cdot 2H_2O$; E, $Cd(3ME)_2(3MEH)_2$; F, $Pt(3MEH_2)_2Cl_6 \cdot 3(3MEH_2Cl) \cdot 5H_2O$; G, Ag(3ME)(3MEH); H, $Hg(3MEH_2)_2Cl_4 \cdot 2(3MEH_2Cl) \cdot H_2O$; I, $Hg_2(8EH)NO_3$.

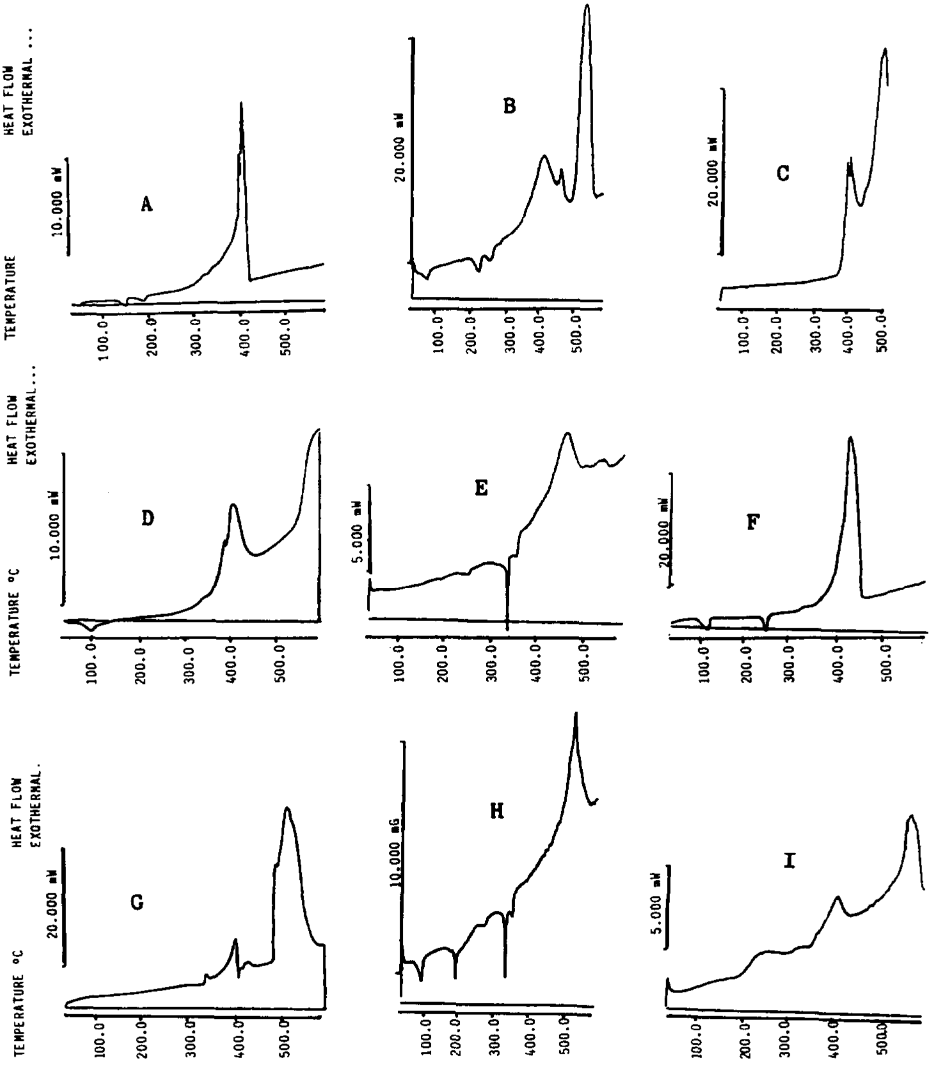

Fig. 2. DSC curves: A, $Ni(3ME)_2(NH_3)(H_2O)\cdot 2H_2O$; B, $Zn(3ME)_2(NH_3)(H_2O)\cdot 2H_2O$; C, $PdBr_2(8EH)_2$; D, $Ag_2(8EH)_2(8E)NO_3\cdot 2H_2O$; E, $Cd(3ME)_2(3MEH)_2$; F, $Pt(3MEH_2)_2Cl_6\cdot 3(3MEH_2Cl)\cdot 5H_2O$; G, Ag(3ME)(3MEH); H, $Hg(3MEH_2)_2Cl_4\cdot 2(3MEH_2Cl)\cdot H_2O$; I, $Hg_2(8EH)NO_3$.

monodentate, binding to the metal ions through a nitrogen atom on the imidazolic ring. However, in Pt(IV) and Hg(II) complexes the purine bases act in monoprotonated form, neutralizing the negative charge of the $(PtCl_6)^{2-}$ and $(HgCl_4)^{2-}$ ions.

The TG and DSC plots of the isolated complexes are given in Figs. 1 and 2. From these the following parameters were obtained: the dehydration, deammination and dehalogenation temperatures, the observed weight losses, the residue weight, the DSC peak temperatures and the dehydration,

TABLE 2

TG and DSC data for the isolated complexes

| Complex | Dehydration | | | Deammination | | | Dehalogenation | | | Residue | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\Delta W$ (%) | $T$ (°C) | $\Delta H$ (kJ $mol^{-1}$) | $\Delta W$ (%) | $T$ (°C) | $\Delta H$ (kJ $mol^{-1}$) | $\Delta W$ (%) | $T$ (°C) | $\Delta H$ (kJ $mol^{-1}$) | Nature | $W$ (%) |
| $Ni(3ME)_2(NH_3)(H_2O) \cdot 2H_2O$ (**I**) | 6.4<br>(6.9) | 53.6 | 12.9 | | 195.7 | 52.3 | | | | NiO | 13.3<br>(14.5) |
| | 4.8 | 156.1 | 64.6 | | | | | | | | |
| $Zn(3ME)_2(NH_3)(H_2O) \cdot 2H_2O$ (**II**) | 6.9<br>(6.8) | 76.2 | 20.1 | [a] | 265.1 | [a] | | | | ZnO | 15.6<br>(15.6) |
| | [a]<br>(3.44) | 227.0 | 51.9 | | | | | | | | |
| $PdBr_2(8EH)_2$ (**III**) | | | | | | | [b] | [b] | [b] | PdO | 19.8<br>(19.5) |
| $Ag_2(8EH)_2(8E)NO_3 \cdot 2H_2O$ (**IV**) | 4.0<br>(4.2) | 97.1 | 21.0 | | | | | | | $Ag^0$ | 26.3<br>(25.2) |
| $Cd(3ME)_2(3MEH)_2$ (**V**) | | | | | | | | | | $Cd^0$ | 13.4<br>(12.9) |
| $Pt(3MEH_2)_2Cl_6 \cdot 3(3MEH_2Cl) \cdot 5H_2O$ (**VI**) | 6.2<br>(5.7) | 121.2 | 56.2 | | | | [b] | 247.9 | [b] | $Pt^0$ | 13.1<br>(12.9) |
| $Ag(3ME)(3MEH)$ (**VII**) | | | | | | | | | | $Ag^0$ | 20.9<br>(21.8) |
| $Hg(3MEH_2)_2Cl_4 \cdot 2(3MEH_2Cl) \cdot H_2O$ (**VIII**) | 1.6<br>(1.48) | 94.2 | 49.2 | | | | [b] | 205 | [b] | | – |

Theoretical values are in parentheses. [a] Dehydration and deammination processes overlap. [b] Dehalogenation and pyrolytic decomposition overlap.

deammination and dehalogenation energies. The results obtained are given in Table 2.

### *Dehydration processes*

Compounds **I** and **II** show both water of crystallization and coordination water, which can be distinguished by the temperatures of dehydration and by the dehydration enthalpies. For all the complexes, the calculated dehydration enthalpies for water of crystallization have values between 12.9 kJ (mol $H_2O)^{-1}$ (**I**) and 56.2 kJ (mol $H_2O)^{-1}$ (**VI**). For coordination water, these values are higher, varying between 51.9 kJ (mol $H_2O)^{-1}$ (**II**) and 64.6 kJ (mol $H_2O)^{-1}$ (**I**). The high value found for the Pt(IV) complex is in agreement with the values obtained by Moreno Carretero et al. [33] in other hexachloroplatinates of alkylxanthines. This high value can be explained by the existence of strong hydrogen bonds between the water molecules, the carbonyl oxygens of the ligands and the chlorine ions.

### *Deammination processes*

Compounds **I** and **II** undergo deammination processes in one step. In the case of compound **II** it was not possible to determine the deammination enthalpy accurately because it overlapped with the loss of coordinated water. The value found for compound **I** is of the same order as the values obtained by Colacio Rodriguez et al. [34] in their study of the thermal behaviour of complexes of the type $M(\text{theophyllinate})_2(NH_3)_2$ (where M = Co, Zn, Cd). Its order of magnitude corresponds to the loss of the $NH_3$ coordinated to the central ion.

### *Dehalogenation processes*

In the case of compound **III** the dehalogenation process could not be observed due to the overlapping of this process with the pyrolytic decomposition of the ligand in the complex.

For compound **VI** the dehalogenation process is complicated and also appears to overlap with the pyrolytic decomposition of the ligand. Nevertheless, an endothermic effect centred at 247.9 ° C is observed, which is typical of a dehalogenation process in this type of complex [35].

The TG diagram of compound **VIII** shows a strong weight loss effect, centred at 205 ° C, in which 38.1% of the initial sample is lost. This effect is assigned to the total dehalogenation and removal of $HgCl_2$ from the compound, in accordance with the literature data [36].

The DSC diagram shows a new endothermic effect, centred at 336.1° C, which corresponds to the fusion of the 8-ethyl-3-methylxanthine remaining after dehalogenation and the loss of $HgCl_2$. The value found for the fusion enthalpy (38.1 kJ $mol^{-1}$) is in good agreement with that obtained for a pure sample of 8-ethyl-3-methylxanthine (39.3 kJ $mol^{-1}$).

From the TG and DSC curves of compound **VIII** the following scheme of thermal decomposition is proposed

$$(3MEH_2)_2(HgCl_4)2(3MEH_2Cl)\cdot H_2O$$

$$\xrightarrow[94.2°C]{endo} (3MEH_2)_2(HgCl_4)2(3MEH_2Cl)$$

$$\xrightarrow[194.1°C]{endo} HgCl_2\uparrow + 4HCl + 4(3MEH)(s) \xrightarrow[336.1°C]{endo} 4(3MEH)(l)$$

$$\xrightarrow[340°C]{exo} \text{pyrolysis products}$$

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