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THERMAL STUDIES ON Ni(II), Cu(II) AND PD(II) COMPLEXES OF 6-AMINO-5-FORMYLURACIL AND ITS N-METHYL DERIVATIVES

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The thermal behaviour of 6-amino-5-formyluracil (HFU), 6-amino-1-methyl-5-formyluracil (1-HFU), 6-amino-3-methyl-5-formyluracil (3-HFU) and 6-amino-1,3-dimethyl-5-formyluracil (HDFU) is described. Only HDFU is shown to contain crystallization water. Dehydration and fusion enthalpy values have been calculated from the DSC curves. Likewise, the thermal behaviour of new complexes obtained by reaction between the above pyrimidine derivatives and Ni(II), Cu(II) and Pd(II) ions is reported.

The importance of the interactions of metal ions with pyrimidine and purine is now well recognized [1–6]. Most metal complexes of this type are studied principally with spectroscopic techniques and X-ray diffraction methods [7–13].

By contrast, studies reporting the thermal behaviour of these complexes are scanty. For this reason and in connection with our studies on the synthesis, characterization and thermal behaviour of derivatives of biological importance [14–22], we describe here the thermal behaviour of four pyrimidine derivatives, 6-amino-5-formyluracil (HFU), 6-amino-1-methyl-5-formyluracil (1-HFU), 6-amino-3-methyl-5-formyluracil (3-HFU) and 6-amino-1,3-dimethyl-5-formyluracil (HDFU), and the new Ni(II), Cu(II) and Pd(II) complexes of these pyrimidine derivatives.

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Experimental

HFU and its *N*-methylated derivatives were synthesized according to Pfleiderer [22], using 6-aminouracil and its methylated derivatives as starting materials [23–24]. The results of elemental analysis are given in Table 1.

Ni(II) and Cu(II) complexes of these pyrimidine derivatives were synthesized in a similar way: 0.1 g of pyrimidine derivative was dissolved in 100 ml of a hot 1 : 1 H_2O/NH_4OH mixture and an equimolecular amount of $Ni(NO_3)_2 \cdot 6H_2O$ or $Cu(NO_3)_2 \cdot 3H_2O$ was added. During 15 or 30 min the solution was heated under

Table 1 Analytical date found % (calculated %)

Compound	C	H	N	M
HFU	39.0	2.8	26.9	—
	(38.71)	(3.22)	(27.10)	
1-HFU	42.5	4.2	24.6	—
	(42.60)	(4.14)	(24.85)	
3-HFU	42.4	3.8	24.6	—
	(42.60)	(4.14)	(24.85)	
$HDFU \cdot H_2O$	41.8	5.6	20.5	—
	(41.79)	(5.47)	(20.90)	
$Ni(FU)_2 \cdot 2NH_3$	29.9	3.4	27.0	14.1
	(29.94)	(3.49)	(27.95)	(14.65)
$Ni(1\text{-}FU)_2 \cdot 2NH_3$	34.1	4.3	25.2	12.9
	(33.59)	(4.20)	(26.12)	(13.69)
$Ni(3\text{-}FU)_2 \cdot 2NH_3$	33.0	4.1	25.7	13.3
	(33.59)	(4.20)	(26.12)	(13.69)
$Ni(DFU)(HDFU)NO_3$	35.6	4.0	21.0	11.8
	(34.59)	(3.50)	(20.17)	(12.08)
$Cu(FU)_2$	33.0	1.7	22.9	16.1
	(32.30)	(2.15)	(22.60)	(17.09)
$Cu(1\text{-}FU)_2$	36.2	3.1	21.1	16.0
	(36.04)	(3.00)	(21.02)	(15.89)
$Cu(3\text{-}FU)_2$	36.2	2.9	21.0	15.9
	(36.04)	(3.00)	(21.02)	(15.89)
$Cu(DFU)_2$	39.6	3.7	19.5	14.6
	(39.30)	(3.74)	(19.65)	(14.85)
$Pd(FU)_2(HFU)_4$	35.2	2.0	23.6	9.6
	(34.80)	(2.70)	(24.36)	(10.28)
$Pd(1\text{-}FU)_2$	32.2	3.2	19.2	23.9
	(32.55)	(2.71)	(18.99)	(24.05)
$Pd(3\text{-}FU)_2$	32.0	2.8	18.0	23.1
	(32.55)	(2.71)	(18.99)	(24.05)
$Pd(DFU)_2$	35.8	3.4	17.6	22.4
	(35.71)	(3.40)	(17.86)	(22.62)

stirring. The resulting solution was allowed to cool to room temperature, and yielded a pink (Ni) or violet (Cu) precipitate. The precipitate was washed in turn with aqueous NH_4OH and ethanol and dried with diethyl ether.

An alternative preparative method can be used for the Cu(II) complexes of HFU, 3-HFU and HDFU, the H_2O/NH_4OH mixture being replaced by N,N'-dimethylformamide.

Analytical data on the eight new Ni(II) and Cu(II) complexes are given in Table 1.

The synthetic conditions used for the preparation of the Pd(II) complexes were the same as those employed in a previous work for analogous purine derivative complexes [25]. In all cases a yellow precipitate was formed, which was filtered off, washed successively with water and ethanol and dried with ether. The elemental analysis results on these complexes are also given in Table 1.

C, H and N analyses were carried out in the Institute of Bioorganic Chemistry, C.S.I.C. (Barcelona). Ni(II), Cu(II) and Pd(II) were determined by thermogravimetry.

Thermogravimetric studies were carried out on a Mettler TG–50 thermobalance using a dynamic atmosphere of pure air (100 ml min^{-1}), with samples varying in weight from 2.15 to 17.21 mg, at a heating rate of 10 deg min^{-1}. DSC curves were recorded with a Mettler differential scanning calorimeter (Mod. DSC 20) at a heating rate of 10 deg min^{-1}, with a sample weight in the range 1.01–4.15.

Results and discussion

a) Pyrimidine derivatives

TG and DSC curves for HFU, 1-HFU, 3-HFU and HDFU are shown in Fig. 1. The four thermogravimetric curves are very similar, showing a decomposition process in the temperature range 325–700° (HFU), 350–675° (1-HFU), 180–650° (3-HFU) or 230–600° (HDFU). These decomposition processes seem to take place in three steps, and above 700° the samples are removed quantitatively from the reaction crucible.

Of the four pyrimidine derivatives, only HDFU shows a weight loss process below 100°. This weight loss takes place in the temperature range 50–105°, with an experimental weight loss of 8.6%, which is in agreement with the theoretical value calculated for the total dehydration of the pyrimidine derivative (8.95% weight loss).

The expected endothermic behaviour corresponding to this dehydration process appears as a strong endothermic effect at 99° in the DSC curve. From the area of

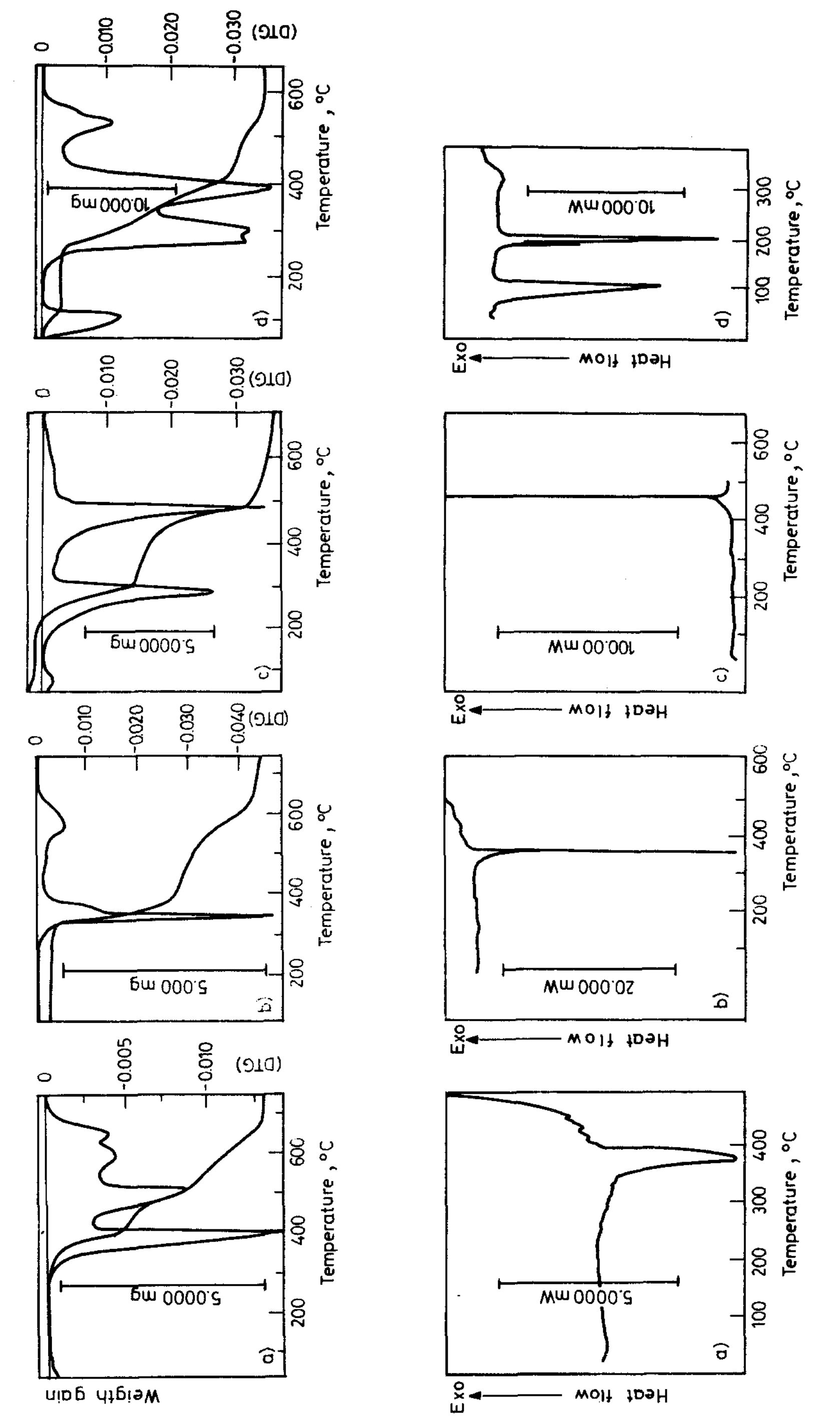

Fig. 1 TG and DSC curves for HFU (a), 1-HFU (b); 3-HFU (c) and HDFU (d)

this effect, a value of 61 kJ·mol^{-1} was found for the dehydration enthalpy of HDFU. This high value suggests strong hydrogen-bonding between the water molecule and the pyrimidine ring.

On the other hand, the DSC curves of 1-HFU and HDFU exhibit one endothermic effect, at 354.6 and 196.8°, respectively, which corresponds to the fusion of the sample. The fusion enthalpy values calculated from the areas of the corresponding endothermic effects were 41 and 20 kJ·mol^{-1}, respectively. The higher value found for 1-HFU is in accordance with the greater possibility of intermolecular hydrogen-bond formation between the 1-HFU molecules.

Finally, the DSC curve of HFU shows a broad and strong endothermic effect at 378.4°, associated with an enthalpy value of 50.4 kJ·mol^{-1}. This effect is due to the fusion and partial vaporization of the pyrimidine derivative.

b) Metal complexes of pyrimidine derivatives

1 Nickel complexes

Four pale-pink complexes, with the simplified formulas $Ni(FU)_2(NH_3)_2$, $Ni(1\text{-}FU)_2(NH_3)_2$, $Ni(3\text{-}FU)_2(NH_3)_2$ and $Ni(DFU)(HDFU)NO_3$, were synthesized using the experimental procedure indicated in the Experimental section. These complexes were characterized by IR spectroscopy [26], which did not reveal a direct interaction between the NH_3 molecules and the Ni(II) ion.

The TG and DSC curves for these Ni(II) complexes are given in Fig. 2. Under the experimental conditions used in the present work, the deammination of the ammine complexes takes place in one step. The observed weight losses for these processes (7.9, 7.6 and 9.0%, respectively) are in good agreement with the theoretical values: 8.48% ($Ni(FU)_2(NH_3)_2$) and 7.93% ($Ni(1\text{-}FU)_2(NH_3)_2$ and $Ni(3\text{-}FU)_2(NH_3)_2$). These deammination processes appear as broad endothermic effects centred at 80.7, 103.7 and 134.2°, respectively, in the corresponding DSC curves. From the areas of these effects the following deammination enthalpy values were calculated: 47 kJ·mol^{-1} ($Ni(FU)_2(NH_3)_2$); 44 kJ·mol^{-1} ($Ni(1\text{-}FU)_2(NH_3)_2$) and 84 kJ·mol^{-1} ($Ni(3\text{-}FU)_2(NH_3)_2$). The last value is similar to those found in the deammination of other Ni(II) metal complexes with xanthine derivative ligands [27], and this could suggest a coordinative interaction between the Ni(II) and the ammonia molecules.

The deamminated Ni(II) complexes are stable in a wide temperature range (150–370°), but above this the pyrolysis of these complexes starts. These processes involve only one step and lead to the formation of NiO as final residue. The experimental percentages for these residues for the complexes $Ni(FU)_2(NH_3)_2$, $Ni(1\text{-}FU)_2(NH_3)_2$ and $Ni(3\text{-}FU)_2(NH_3)_2$ (18.0, 16.4 and 16.9%, respectively) are in agreement with the theoretical ones (18.64, 17.42 and 17.42%).

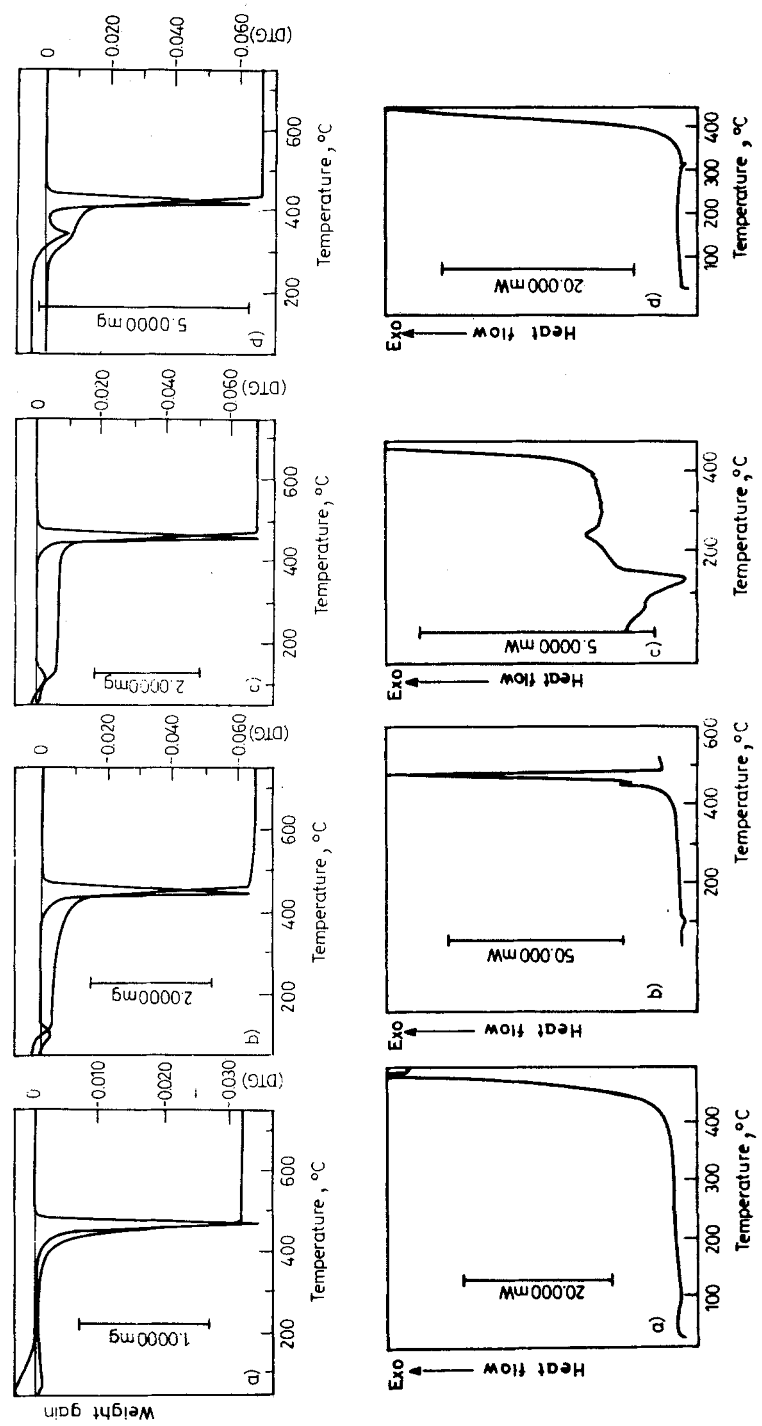

Fig. 2 TG and DSC curves for $Ni(FU)_2(NH_3)_2$ (a); $Ni(1\text{-}FU)_2(NH_3)_2$ (b); $Ni(3\text{-}FU)_2(NH_3)_2$ and $Ni(DFU)(HDFU)NO_3$ (d)

Different thermal behaviour was found for Ni(DFU)(HDFU)NO_3. This is thermally stable up to 200°; at this temperature the pyrolytic decomposition of the complex starts. This process occurs in two steps; in the first the nitrate ion is eliminated. At the end of the pyrolysis the accumulated weight loss is 85.0% (theoretical value for NiO 84.60%).

2 Copper complexes

Four new copper(II) complexes, with the simplified formulas $Cu(FU)_2$, $Cu(1\text{-}FU)_2$, $Cu(3\text{-}FU)_2$ and $Cu(DFU)_2$, were synthesized. In these complexes the pyrimidine derivative is coordinated to the Cu(II) ion through the oxygen atoms of the 5-formyl and 4-hydroxy groups. The geometry of these complexes is square-planar, with the formyl groups in the cis position, as has been proved in $Cu(DFU)_2$ [26].

The TG and DSC curves of the Cu(II) complexes are given in Fig. 3. The four complexes display appreciable thermal stability and decompose in all cases at around 340°. The thermal stability sequence, based on the initial decomposition temperatures, is $Cu(FU)_2 > Cu(1\text{-}FU)_2 \simeq Cu(3\text{-}FU)_2 > Cu(DFU)_2$, which could be related with the potential abilities of these complexes to form hydrogen-bonds, which is one of the principal causes of structural stability in this type of compounds [1–2].

The pyrolytic decomposition of the four Cu(II) complexes gave CuO as final product. The experimental percentages of the residues for the complexes $Cu(FU)_2$, $Cu(1FU)_2$, $Cu(3\text{-}FU)_2$ and $Cu(DFH)_2$ (20.2, 20.0, 19.9 and 18.3%, respectively) are in agreement with the theoretical ones (21.40, 19.90, 19.90 and 18.59%).

3 Palladium complexes

Thermogravimetric and DSC curves for $Pd(FU)_2(HFU)_4$, $Pd(1\text{-}FU)_2$, $Pd(3\text{-}FU)_2$ and $Pd(DFU)_2$ are depicted in Fig. 4.

The four Pd(II) complexes show square-planar geometry and the pyrimidine derivative is coordinated to the Pd(II) in bidentate form, through the oxygen atoms of the substituents in positions 4 and 5 [26]. This coordination type is analogous to that found in the Pd(II) acetylacetonate complexes [28], yielding considerable electronic delocalization through the chelate ring formed in the coordination of the pyrimidine derivatives to the Pd(II) ion.

The thermal decomposition of these Pd(II) complexes occurs at temperatures higher than 300°. The pyrolysis of these compounds yields PdO as final product. The percentages at 600° were 11.1, 27.5, 26.6 and 25.8% respectively, which are in agreement with the theoretical percentages: 11.83% ($Pd(FU)_2(HFU)_4$), 27.67% ($Pd(1\text{-}FU)_2$ and $Pd(3\text{-}FU)_2$) and 26.02% ($Pd(DFU)_2$).

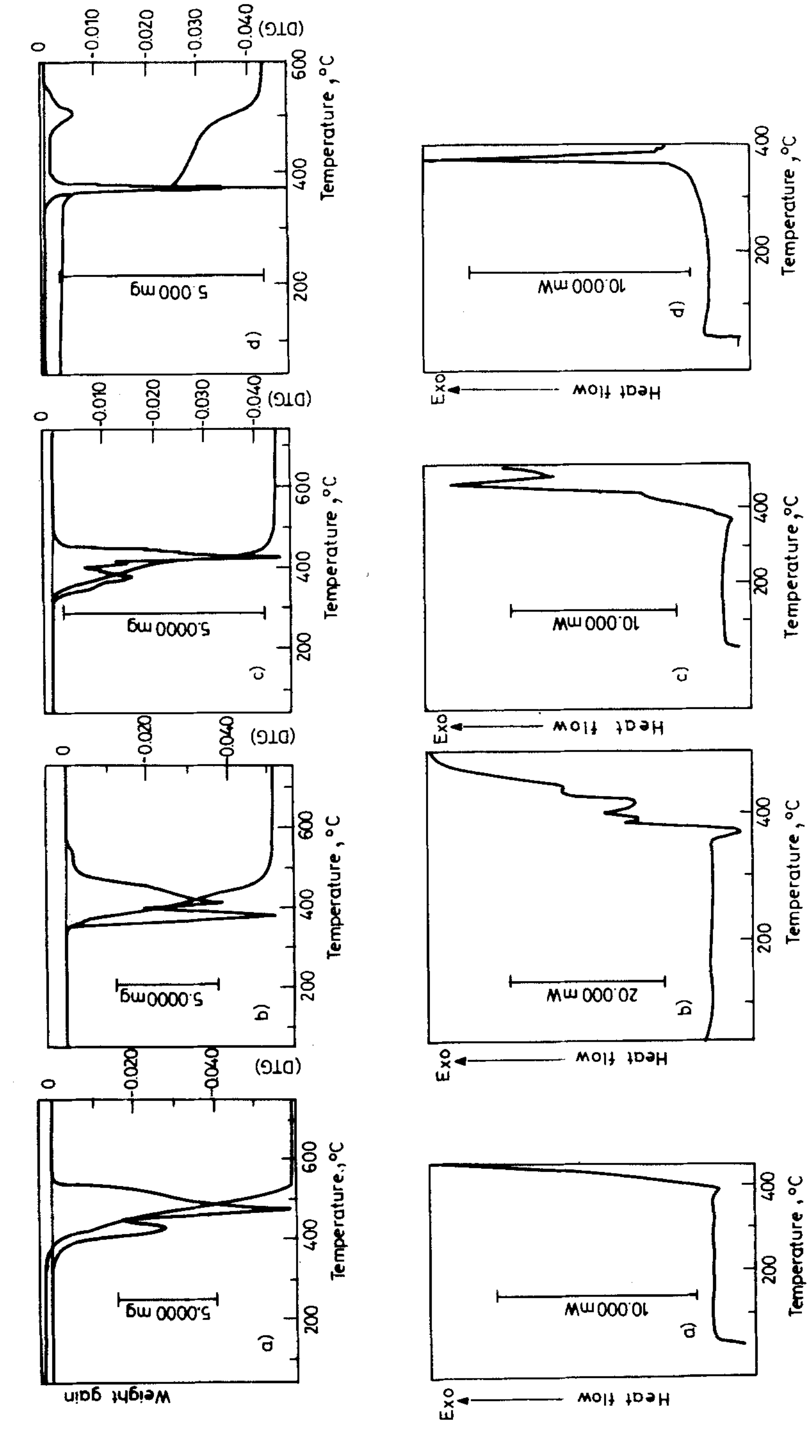

Fig. 3 TG and DSC curves for Cu(FU)$_2$ (a); Cu(1-FU)$_2$ (b); Cu(3-FU)$_2$ (c) and Cu(DFU)$_2$ (d)

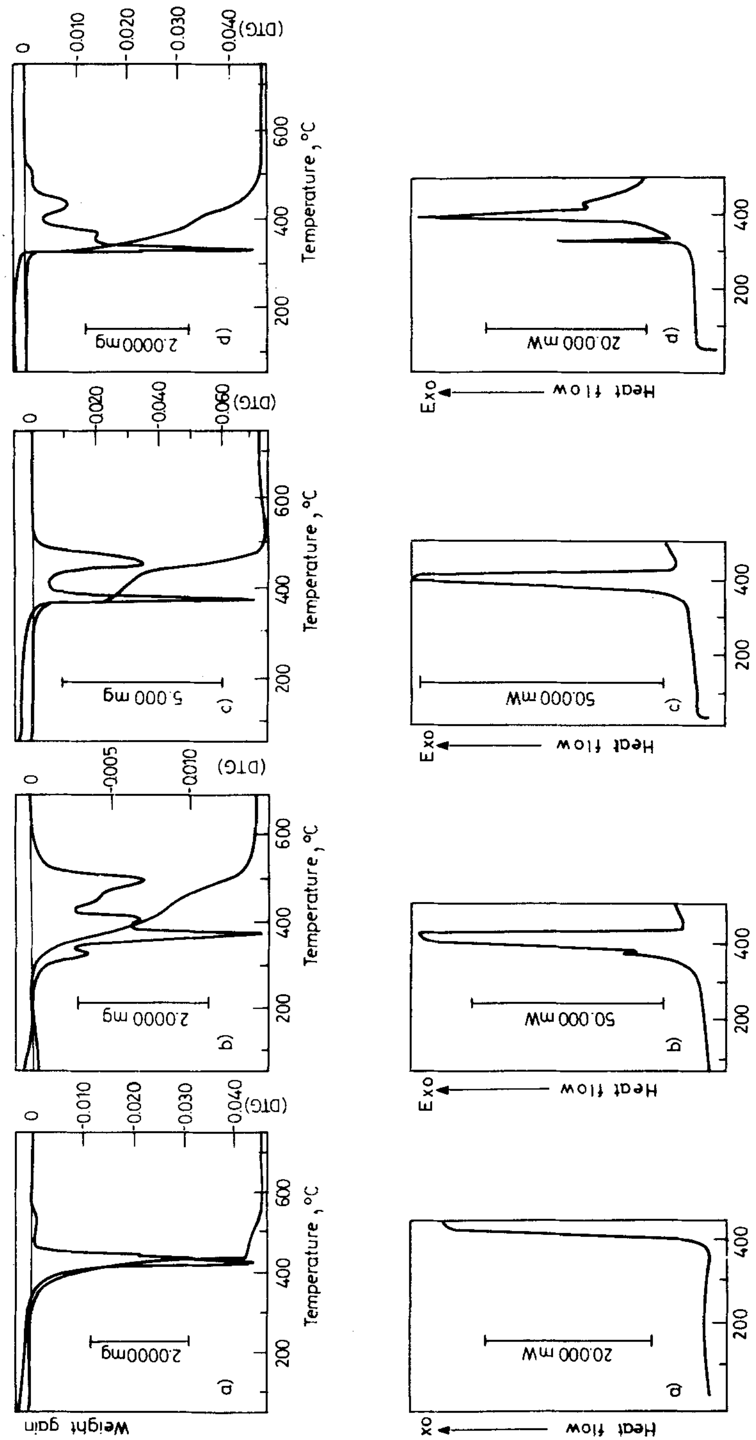

Fig. 4 TG and DSC curves for Pd(FU)$_2$(HFU)$_4$ (a); Pd(1-FU)$_2$ (b); Pd(3-FU)$_2$ (c) and Pd(DFU)$_2$(d)

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Zusammenfassung — Das thermische Verhalten von 6-Amino-5-formyluracil (HFU), 6-Amino-1-methyl-5-formyluracil (1-HFU), 6-Amino-3-methyl-5-formyluracil (3-HFU) und 6-Amino-1,3-dimethyl-5-formyluracil (HDFU) wird beschrieben. Nur HDFU enthält Kristallwasser. Dehydratisierungs- und Schmelzenthalpiewerte wurden aus den DSC-Kurven berechnet. Auch über das thermische Verhalten neuer, durch Reaktion der obigen Pyrimidin-Derivate mit Ni(II)-, Cu(II)- und Pd(II)-Ionen erhaltenen Komplexe wird berichtet.

Резюме — Описано термическое поведение 6-амино-5-формил-, 6-амино-1-метил-5-формил-, 6-амино-3-метил-5-формил- и 6-амино-1,3-диметил-5-формилурацилов. Показано, что только последнее соединение содержит кристаллизационную воду. На основе кривых ДСК вычислены значения энтальпии дегидратации и плавления. Подобным образом изучено также термическое разложение комплексов вышеприведенных производных пиримидина с двухвалентными никелем, медью и палладием.