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# Vibrational Spectrum and Thermal Behaviour of $(NH_4)_{17}Na[NaW_{21}Sb_9O_{86}].28H_2O$ (HP-23); a Promising Drug in AIDS Therapy

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**SUMMARY. Infrared and Raman specta of the title compound were recorded and an approximate vibrational assignement is proposed. Its thermal behaviour was investigated by means of TG and DSC measurements in $N_2$ and $O_2$ atmospheres, and complemented with studies carried out in ovens and crucible furnaces, in air. The results show that the drug presents a very low thermal stability.**

*RESUMEN.* "Espectro Vibracional y Comportamiento Térmico de $(NH_4)_{17}Na[NaW_{21}Sb_9O_{86}].28H_2O$ (HP-23), una Droga Promisoria en la Terapia del SIDA". Se registraron los espectros infrarrojo y Raman del compuesto del título y se propone una asignación vibracional aproximada para el mismo. Su comportamiento térmico fue investigado mediante mediciones termogravimétricas y de calorimetría diferencial de barrido, en atmósferas de $N_2$ y $O_2$, y complementadas con estudios realizados en estufas y muflas, al aire. Los resultados muestran que la droga posee muy baja estabilidad térmica.

In recent years it has been recognized that certain polyoxometalates present high biological and pharmacological activity [1].

One of the most interesting compounds of this type is, undoubtedly, $(NH_4)_{17}Na[NaW_{21}Sb_9O_{86}].28H_2O$, commonly known as HP-23. In inhibited mouse leukemia-sarcoma *in vitro*, and reduced the development of desease caused by Friend leukemia or Moloney murine sarcoma virus [2]. Most recently, it has been shown that the reverse transcriptase activity of human immunodeficience virus (HIV), a causative agent of AIDS, is completely inhibited by HP-23 at a concentration of 60 µg/ml [3,4].

Ir order to advance in the characterization of this interesting drug we have now investigated its vibrational spectrum as well as its thermal stability and degradation.

KEY WORDS: HP-23; AIDS; Vibrational Spectrum; Thermal Behaviour
*PALABRAS CLAVE:* HP-23; SIDA; Espectro Vibracional; Comportamiento térmico

## EXPERIMENTAL

Samples of $(NH_4)_{17}Na[NaW_{21}Sb_9O_{86}].28H_2O$ were obtained as described by Jasmin *et al.* [2]: 11.4 g of $SbCl_3$ (Merck) were disolved in 50 ml of saturared $NH_4Cl$ solution. This solution was added to 125 ml of a 1 M solution of $Na_2WO_4.2H_2O$ (Merck) and heated to 80 °C. Sufficient concentrated $NH_4OH$ was added to keep the solution colourless. The precipitate was filtered through a fritted-glass funnel and washed several times with a diluted $NH_4Cl$ solution. The raw product, which is highly soluble, was recrystallized twice from distilled water and air dried. In our preparations a 28-hydrate has been obtained, although different other hydrates have been reported in the literature. This is probably strongly dependent on manipulation and drying conditions. On the other hand, as will be shown in this paper, most of the water is very loosely bound.

The infrared spectra were recorded with a Perkin Elmer 580 B spectrophotometer, using the KBr pellet technique. Raman spectra were scanned on a Brucker FRA 106 instrument mounted on a IFS 66 Fourier transform optical bench. A Nd/YAG laser was used for excitation.

Thermogravimetric (TG) measurements were carried out with a Perkin Elmer TGS 2 thermobalance, while a Mettler TA 4000 instrument was used for differential scanning calorimetry (DSC). The heating rate was 10 °C.min$^{-1}$ and the sample weight ranged between 1 and 5 mg. Thermal studies were carried out in $N_2$ -as well as in air- atmospheres.

## RESULTS AND DISCUSSION

### *Vibrational spectrum*

The structure of HP-23 was described some years ago [5]. The X-ray analysis revealed it to be a cryptate with a central sodium cation (*cf.* also [6,7]). The anionic structure can be represented by the formula $[Na(Sb_3O_7)_2.(SbW_7O_{24})_3]^{18-}$ and has a overall $C_{3h}$–symmetry. The $SbW_7O_{24}$ groups can formally be derived from the well known β-Keggin structure [1,6], by removal of five $WO^6$ octahedra.

The IR and Raman spectra of HP-23 in the region between 1100 and 200 cm$^{-1}$ are shown in Fig. 1.

In order to propose an approximate vibrational assignment for this complex structure it is necessary to have in mind the different building units present in the compound:

a) Terminal $WO_2$ groups, generated by the incomplete Keggin-structure.
b) W-O-W bridges ("inter" bridges between corner sharing octahedra).
c) W-O-W bridges ("intra" bridges between edge sharing octahedra).
d) –O–Sb–O–W–O–Sb–O– chains

Table 1 shows the measured band positions and the proposed assignment, which shall be briefly discussed in the next paragraphs, on the basis of known spectroscopic data for related polyoxoanions [8-13].

The strongest Raman line, at 936 cm$^{-1}$, can be assigned, unambigously, to the symmetric stretching vibration of the terminal $WO_2$ units. Its IR conterpart is the medium-intensity 921 cm$^{-1}$ band. Bands located at 891 and 843 cm$^{-1}$ in the Raman

| Infrared | Raman | Assignments |
|---|---|---|
| 966 sh | --- | ? |
| 921 m | 936 vs | $\nu s(WO_2)$ |
| 868 w | 891 m | $\nu_{as}(WO_2)$ |
| 826 vs | 843 m | |
| 770 vs | --- | |
| 735 vs | 749 w | $\nu_{as}$ (WOW) |
| 690 m | 695 vw | |
| 630 sh | 636 w | |
| 553 s | ~500 sh | |
| 483 s | 490 m | $\nu_s$ (WOW) |
| --- | 446 m | |
| 419 w | 405 vw | |
| 353 s | 378 m | |
| 333 s | 325 vw | δ(WO) |
| ~306 sh | 317 m | |
| | 288 vw | |
| | 229 s | lattice modes |
| | 157 m | |

**Table 1.** Assignment of the vibrational spectrum of the polyoxoanion.

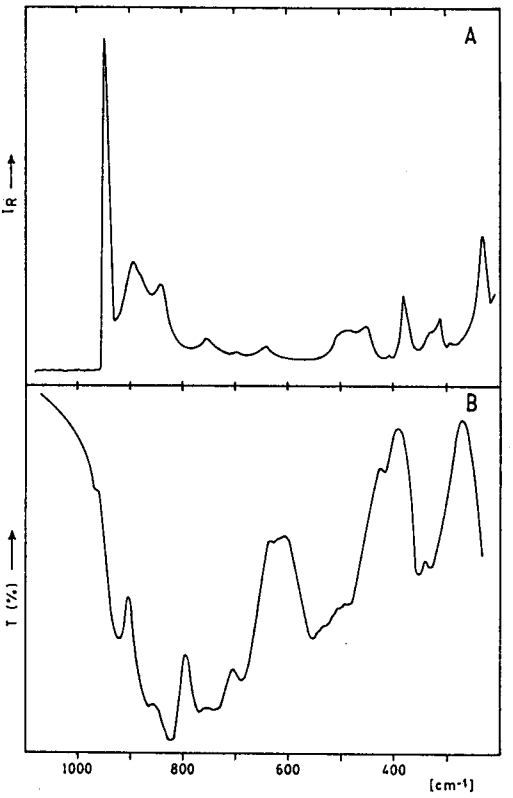


**Figure 1.** Raman (A) and infrared spectra (B) of $(NH_4)_{17}Na[NaW_{21}Sb_9)O_{86} \cdot 28H_2O$, between 1100 and 200 $cm^{-1}$.

spectrum and at 868/826 $cm^{-1}$ in the IR spectrum are assigned to the antisymmetric vibrations of these units. The existence of well separated bands, assignable to this mode, suggests the presence of $WO_2$ vibrators with slightly different bonding properties.

The next two block of bands are assigned to the antisymmetric and symmetric vibrations of the two types of W–O–W bridges present in the structure. But it should be remembered that these vibrations are not pure and are somewhat coupled with bending motions of the $WO_6$–octahedra [9]. Usually, the so-called "inter"-bridge vibrations lie at slightly higher frequencies than the "intra" vibrational modes. Therefore, in first approximations, the observed splittings in the two IR-blocks can be assigned to motions of these two different type of bridges.

Finally, bands between 400 and 300 $cm^{-1}$ can be assigned to bendings of the WO-polyhedra.

On the other hand, from this analysis it is not clear which bands can be ascribed to the chains involving Sb–O–bonds. Most probably, these vibrations are overlapped by the strong and broad W–O–W bridge motions. For comparison, it is useful to remember that $Sb_2O_3$ absorbs at 740, 590 and 383 $cm^{-1}$ [14] and in the mixed oxides $Ln_3Sb_5O_{11}$, which also contains Sb(III), the two strongest bands lie around 600 and 450 $cm^{-1}$ [15].

To complement the spectroscopic information a brief comment on the water and ammonium vibrational modes is also of interest. In the high frequency region, the IR spectrum shows a very broad band with maxima at 3369 and 3174 $cm^{-1}$ and two shoulders at 3026 and *ca.* 2845 $cm^{-1}$; in this region the stretching vibrations of both $H_2O$ and $NH_4^+$ are expected [16]. The bending mode of water is seen as a medium intensity and well defined IR-band located at 1634 $cm^{-1}$. The symmetric bending of $NH_4^+$, which usually is not very strong, is expected to lie in the same region [16] and this fact probably explains the broadening of the 1634 $cm^{-1}$ band at its high frequency side. The antisymmetric bending of $NH_4^+$ appears as a very strong band at 1401 $cm^{-1}$, with a weak shoulder at 1425 $cm^{-1}$.

### *Thermal behaviour*

Typical TG and DSC traces, recorded in $N_2$-atmosphere, are shown in Fig. 2. The behaviour in air is totally similar.

As can be seen from this figure, a rapid weight loss begins practically when a slight increase of temperature above room values is applied. This decomposition extends up to 480 °C and in this unique step water and ammonia must be released, simultaneously or in subsequent, overlapped, stages, according to:

$$(NH_4)_{17}Na[NaW_{21}Sb_9O_{86}].28H_2O \longrightarrow (NH_4)_{17}Na[NaW_{21}Sb_9O_{86}] + 28\ H_2O \quad (1)$$

$$(NH_4)_{17}Na[NaW_{21}Sb_9O_{86}] \longrightarrow 21\ WO_3 + 4.5\ Sb_2O_3 + Na_2O + 17\ NH_3 + 8.5\ H_2O \quad (2)$$

(alternative solid residues may be $20\ WO_3 + Na_2WO_4$)

The total weight loss of these two steps is 13.2% [6.16 (1) + 7.03 (2)], which matched exactly the experimentally determined value. A further small weight loss of around 0.5%, observed above 520 °C, can be related with an additional small oxygen release of the degradation products, as observed also in other similar materials [12].

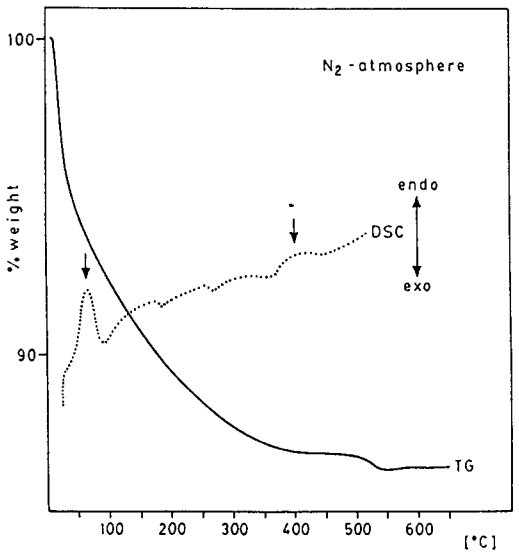


**Figure 2.** TG and DSC traces of $(NH_4)_{17}Na[NaW_{21}Sb_9)O_{86}].28H_2O$, in $N_2$-atmosphere.

The begining of the degradation is related to a weak, but well defined endothermic signal in the DSC trace, with a peak temperature of 67 °C. Interestingly, no other defined signals on this trace can be seen except some irregularities around 180° and 260 °C and a broad one, around 400 °C. The origin of this last signal is not clear, but it is probably related with the final depolimerization of the polyoxoanion.

The enthalpy changes associated with the two DSC signals at 67° and 400°C, although not easy to determine, due to the scarce definition of the peaks, were estimated to be 220 ± 20 Kcal/mol and 17 ± 3 Kcal/mol, respectively.

On the other hand, we have found that carefully heating of the material in an oven at 40°C during 40-45 minutes produces the release of 13-15 moles of water and this partial dehydratation does not introduce changes in the IR spectrum of the substance.

Heating in air, in a crucible furnace up to 500 °C, reproduces exactly the weight loss found in the TG experiments and a pale yellow powder remains. The X-ray powder diagram of this residue reveals poor crystallinity and no defined reflextions could be found. Its IR spectrum shows a very broad and undefined band between 1000 and 450 $cm^{-1}$ and a weaker one at 340 $cm^{-1}$. The strongest IR band of $WO_3$ lie at ca. 840 $cm^{-1}$, whereas that of $Sb_2O_3$ is expected, as mentioned above, around 740 $cm^{-1}$ [14].

## CONCLUSIONS

This paper presents an analysis of the IR and Raman spectra of $(NH_4)_{17}Na[NaW_{21}Sb_9O_{86}].28H_2O$, a novel and promising drug employed in AIDS therapy. These spectra are very characteristic, and therefore may be useful for a rapid and simple characterization of the drug. Its thermal behaviour shows rapid weight losses after heating slightly above room temperature. This behaviour suggests that a part of the hydration water is only weakly bound and probably different hydrates exist. On the other hand, the overall thermal degradation begins also at relatively low temperatures, pointing to a particularly low thermal stability of the substance.

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