

## MODELING OF THE DNA–METAL INTERACTIONS VIA VIBRATIONAL SPECTROSCOPY: SPECTRA-STRUCTURE CORRELATIONS IN BIS(ISATINATO)MERCURY(II)

Frosa Anastasova, Pance Naumov

Institut za hemija, PMF, Univerzitet "Sv. Kiril i Metodij", POB 162, MK-91001 Skopje, Macedonia; e-mail: spance@iunona.pmf.ukim.edu.mk

**Abstract:** The complex bis(isatinato)mercury(II), model compound for the Hg(II)–DNA interactions, was synthesized and the  $\nu(\text{CO})$  region of its FT IR spectra at the boiling temperature of liquid nitrogen (LNT) were studied. The  $\nu(\text{CO})$  bands were assigned, compared with the corresponding data for the isatin itself and their frequencies were correlated with the available structural data. The spectral assignments were aided with the results from the harmonic vibrational analyses on the ab initio optimized structures of the free isatin molecule and the corresponding anion at the HF/6-31G\*\* level.

**Key words:** Ab initio calculations, Carbonyl stretchings, FT IR spectra, Isatinato complex. Spectra-structure correlations

### 1. Introduction

Interactions of the common heavy metal ions with DNA have been of scientific interest lately, mainly due to eventual involvement of such interactions in the toxic effects of the heavy metals on biological systems. In this sense, little yet is known about the mechanism of the reversible binding of Hg(II) to DNA. A bond formation between Hg(II) ions and thymidine N3 atoms was supposed [1, 2] to take role in such process. Recently, the crystal structure of the first complex of Hg(II) with isatin (2,3-indolinedione, denoted "HGISA" henceforward, Fig. 1), that could serve as model compound for the above interactions, was published [3].

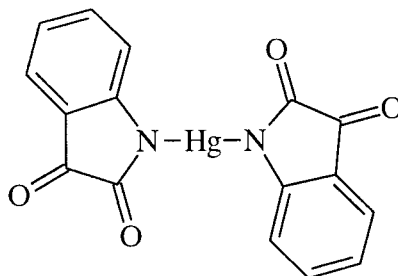


Fig. 1. Scheme of the bonding in bis(isatinato)mercury(II)

Within our study of the metal ion–biomolecule interactions with various structural and spectroscopic methods, we studied the  $\nu(\text{CO})$  region of the LNT FT IR spectrum of HGISA and compared it with the corresponding region of the spectrum of isatin. The assignments were aided with the ab initio calculations on the free isatinato ion and the isatin molecule.

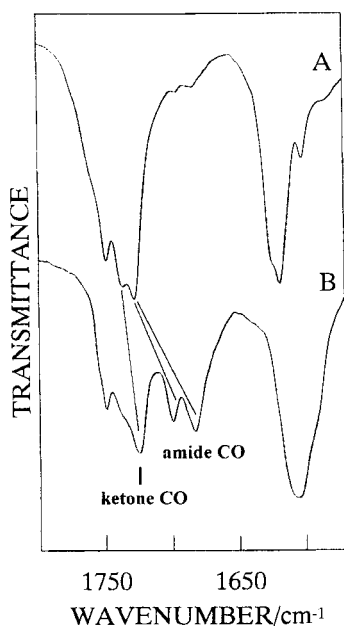
## 2. Experimental

Orange crystals of HGISA were prepared from  $\text{Hg}(\text{OAc})_2 \cdot \text{H}_2\text{O}$  and isatin in a warm solution of MeOH. Isatin was twice recrystallized prior to the recording of the spectra. The FT infrared spectra in the 1900–1500  $\text{cm}^{-1}$  frequency range were recorded with a System 2000 interferometer (Perkin–Elmer), using a P/N 21525 (Graseby Specac) variable-temperature cell. 16 background and 32 sample spectra were averaged (resolution was 4  $\text{cm}^{-1}$ ). Since no differences were found with the spectra recorded in Nujol suspensions, all spectra were recorded from KBr pellets.

## 2. Results and Discussion

The carbonyl stretching region in the LNT spectra of HGISA and isatin are shown in Fig. 2. The relevant structural and spectroscopic data are summarized in Table 1.

Very strong complex band, with *three* maxima (1748, 1736 and 1727  $\text{cm}^{-1}$ ), is present in the  $\nu(\text{CO})$  region of the LNT infrared spectrum of isatin (Fig. 2). According to the results from the harmonic vibrational analyses performed on the HF/6-31G\*\* optimized structure of the isatin molecule (Table 1), the split of the two carbonyl modes in its spectrum is rather small (about 9  $\text{cm}^{-1}$ ), resulting in complex appearance of this spectral region. The band at 1618  $\text{cm}^{-1}$  (Fig. 2), however, is not a carbonyl mode, but a benzenoid vibration [ $\nu(\text{CC})+\delta(\text{CNC})$ ].



**Fig. 2.** The 1800–1570  $\text{cm}^{-1}$  region in the LNT FT IR spectra of isatin (A) and bis(isatinato)mercury(II) (B)

Two pairs of rather strong bands are present in the  $\nu(\text{CO})$  region of the LNT spectrum of HGISA (Fig. 2), in addition to the benzenoid mode at 1605  $\text{cm}^{-1}$  (Fig. 2). The appearance and the position of the highest-frequency band in this region (1748  $\text{cm}^{-1}$ ) remain unchanged upon complexation and thus it is not probable that it originates from the carbonyl stretching modes. It might be, in fact, that this band is originally weak, but gains much of its intensity upon the overlap with the strong  $\nu(\text{CO})$  band.

The doublet of overlapped  $\nu(\text{CO})$  bands (1736 and 1727  $\text{cm}^{-1}$ ) in the spectrum of isatin is replaced by a single strong band in the case of HGISA (1724  $\text{cm}^{-1}$ ). This band can be assigned as the stretching mode of the *ketone* carbonyl groups of HGISA. A pair of bands with similar intensities that appear at 1699 and 1683  $\text{cm}^{-1}$  in the spectrum of HGISA, on the other hand, can be assigned to the stretching mode of the *amide* carbonyl groups. The appearance of *two*  $\nu(\text{CO})_{\text{amide}}$  bands besides the presence of only *one* crystallographic type of amide CO groups in HGISA [3] can be explained by the results from the HF/6-31G\*\* calculations on the free isatinato

anion (Table 1) showing that the amide carbonyl stretching in the deprotonated form of isatin is, in fact, a largely mixed vibration. As a result, *two* almost equally strong bands involving similar contribution from the  $\nu(\text{CO})_{\text{amide}}$  mode should be expected. The experimentally observed frequency difference ( $36 \text{ cm}^{-1}$ ) between the mean value of the two *amide*  $\nu(\text{CO})$  bands ( $1691 \text{ cm}^{-1}$ ) and the corresponding isatin mode ( $1727 \text{ cm}^{-1}$ ) is three times larger than the one in the case of the *ketone*  $\nu(\text{CO})$  mode ( $12 \text{ cm}^{-1}$ ). This, however, is quite understandable if the mass effect of the H/Hg substitution on the  $\nu(\text{CO})$  vibrations and the proximity of the amide group with the metallation center are taken into account.

**Table 1.** Structural and Spectroscopic Data on the Carbonyl Groups

Parameter	Isatin (ab initio)*	Isatinato ion/ligand	
		Ab initio*	Experimental
$d(\text{C-O})_{\text{amide}} / \text{\AA}$	1.1836	1.2065	1.215(8)
$d(\text{C-O})_{\text{ketone}} / \text{\AA}$	1.1835	1.1958	1.203(8)
$\nu[\nu(\text{CO})_{\text{amide}}] / \text{cm}^{-1}$	1851	1580	1699
		1553	1683
$\nu[\nu(\text{CO})_{\text{ketone}}] / \text{cm}^{-1}$	1860	1675	1724

\* The frequencies are scaled with the empirical factor 0.89876.

### 3. Conclusions

The two carbonyl stretching vibrations of isatin are separated and shifted to lower frequencies upon metallation, the amide one being about three times more shifted than the ketone one. The coupling of the amide  $\nu(\text{CO})$  mode is accordingly enhanced, resulting in its splitting in two almost equally intense bands.

### 4. References

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## МОДЕЛИРАЊЕ НА ДНК–МЕТАЛ ИНТЕРАКЦИИТЕ СО ВИБРАЦИОНА СПЕКТРОСКОПИЈА: СПЕКТАР-СТРУКТУРНИ КОРЕЛАЦИИ КАЈ БИС(ИЗАТИНАТО)ЖИВА(II)

Фроса Анастасова, Панче Наумов

*Институт за хемија, Природно-математички факултет,  
Универзитет “Св. Кирил и Методиј”, П. Фах 162, МК-91001 Скопје, Македонија*

**Апстракт:** Синтетизиран е комплексот бис(изатинато)жива(II), моделно соединение за интеракциите на Hg(II) со ДНК и проучувана е  $\nu(\text{CO})$  областа од неговиот Фурие трансформен инфрацрвен спектар снимен на температура на вриење на течниот азот. Асигнирани се лентите што се должат на  $\nu(\text{CO})$  вибрациите, споредени се со соодветните податоци кај изатинот и нивните фреквенции се корелирани со структурните податоци. Асигнацијата на спектрите е потпомогната со резултатите од вибрационата хармониска анализа на *ab initio* оптимизираните геометрии (при нивото HF/6-31G\*\*) на слободната молекула изатин и соодветниот анјон.