

# Spectroscopic studies of the 1:1 complex of piperidine-4-carboxylic acid (isonipecotic acid) with 2,6-dichloro-4-nitrophenol



Michalina Anioła, Zofia Dega-Szafran\*, Andrzej Katrusiak, Anna Komasa, Mirosław Szafran

Faculty of Chemistry, Adam Mickiewicz University, Umultowska 89b, 61-614 Poznań, Poland

## ARTICLE INFO

### Article history:

Received 5 November 2015  
Received in revised form 3 March 2016  
Accepted 22 March 2016  
Available online 23 March 2016

### Keywords:

Piperidine-4-carboxylic acid  
2,6-Dichloro-4-nitrophenol  
X-ray diffraction  
DFT calculations  
Infrared spectra  
Hydrogen bond

## ABSTRACT

The 1:1 complex of piperidine-4-carboxylic acid (isonipecotic acid, P4C) with 2,6-dichloro-4-nitrophenol (DCNP), has been investigated by single-crystal X-ray analysis, Raman and FTIR spectroscopy and theoretical calculations. The hydrogen-bonded-ion-pair complex is observed in the crystalline state with the O···H···OOC hydrogen bond of 2.453(16) Å. FTIR spectrum shows a broad absorption in the 1600–400 cm<sup>-1</sup> region characteristic of very short OHO hydrogen bond, broken by the Evans holes. The complexes are joined through N—H···O into a H-bonding network. The N—H···O mode appears as a broad band in the range of 3100–2000 cm<sup>-1</sup>. In the structure optimized at the B3LYP/6–311++G(d,p) level of theory the proton is transferred from DCNP to P4C, and molecules are joined through the O···HOOC hydrogen bond of 2.640 Å. The experimental and theoretical infrared spectra are discussed. Detail interpretation of the vibrational spectra has been carried out with the use of computed Potential Energy Distribution (PED).

© 2016 Elsevier B.V. All rights reserved.

## 1. Introduction

Piperidine-4-carboxylic acid (P4C) is a heterocyclic compound which acts as  $\gamma$ -aminobutyric acid receptor (GABA) to a major group of proteins in the central nervous system [1]. It consists of a piperidine ring with a carboxylic group in the *para* position. It is also known as isonipecotic acid. P4C is a structural isomer of nipecotic acid (piperidine-3-carboxylic acid) [2] and pipecolic acid (piperidine-2-carboxylic acid) [3]. Piperidine-4-carboxylic acid can be treated as  $\gamma$ -amino acid. It crystallizes with one water molecule, which links P4C molecules through the NH···OOC and COO···HOH···OOC hydrogen bonds [4,5]. In the gas phase the amino acids exist in their neutral form, however, in the presence of solvent molecules, generally water, the amino acids rapidly undergo ionization forming zwitterions [6,7]. Piperidine-4-carboxylic acid in its zwitterionic form has two interacting centers, the proton-donor N<sup>+</sup>H<sub>2</sub> group and the proton-acceptor COO<sup>-</sup> group, which are characterized by the dissociation constants of 10.33 and 3.86, respectively [8], hence P4C is able to form hydrogen-bonded complexes with inorganic [9,10] and organic acids [11–13]. The zwitterionic compounds, being both the proton-

donors and proton-acceptors, are ideal models for investigation of a proton-transfer reaction and electrostatic attraction.

Presently, much attention is focused on the 1:1 hydrogen-bonded complex of piperidine-4-carboxylic acid, P4C, with 2,6-dichloro-4-nitrophenol, DCNP. 2,6-Dichloro-4-nitrophenol, with the pK<sub>a</sub> value of 3.70 [14], is one of the most acidic phenols. In complexes of DCNP with zwitterionic compounds such as betaines, the proton is transferred from DCNP to the carboxylate group of betaines and the O···O distances between the phenolate anion and protonated betaines are ca. 2.42 Å [15–17]. However, in the 1:1 complex of DCNP with 1-piperidineacetic acid, which can be treated as a synthetic  $\alpha$ -amino acid, the proton transfer is not observed and a short asymmetric O—H···O hydrogen bond of 2.469(2) Å is formed. Additionally, two such complexes are joined together through the N—H···OOC hydrogen bonds of 2.869(2) Å [18]. Recently, we have studied the complex of piperidine-3-carboxylic acid (nipecotic acid) with DCNP, in which the molecules are linked into a dimer and cyclamer involving the COOH···O<sup>-</sup>, NH···ONO and CH···Cl hydrogen bonds [19]. In the present work we synthesized a new crystalline complex of P4C with DCNP (**1**). The structure of **1** was determined by the single-crystal X-ray analysis and characterized by the Raman and FTIR spectra. The structure of the title compound was optimized at the B3LYP/6–311++G(d,p) level of theory.

\* Corresponding author.

E-mail address: [degasz@amu.edu.pl](mailto:degasz@amu.edu.pl) (Z. Dega-Szafran).

## 2. Experimental

### 2.1. Synthesis of the 1:1 complex of piperidine-4-carboxylic acid with 2,6-dichloro-4-nitrophenol (**1**)

To 0.519 g (0.004 M) of piperidine 4-carboxylic acid dissolved in a mixture of 2 ml CH<sub>3</sub>OH and 1 ml H<sub>2</sub>O, 0.836 g (0.004 M) of 2,6-dichloro-4-nitrophenol, dissolved in 2 ml CH<sub>3</sub>OH was added. The reaction mixture was heated for 3 min up to dissolution of reagents. The crude product (1.11 g, 81% yield) was filtered off and recrystallized from methanol, m.p. 242–243 °C. Elemental analysis for C<sub>12</sub>H<sub>14</sub>Cl<sub>2</sub>N<sub>2</sub>O<sub>5</sub>, m. wt. 337.16; calc.: 42.75%C, 4.19%H, 8.31%N; found: 42.81%C, 4.29%H, 8.39%N. <sup>1</sup>H and <sup>13</sup>C NMR spectra (ppm) in DMSO-*d*<sub>6</sub> are shown in Fig. S1 (Supplementary material): δ<sup>1</sup>H: H (2A, 6A) 2.94, H(2E, 6E) 3.26, H(3A, 5A) 1.69, H(3E, 5E) 1.97, H(4) 2.58; δ<sup>13</sup>C: C(2, 6) 42.56, C(3, 5) 24.67, C(4) 37.66, C(7) 174.79, C(11) 167.03, C(12, 16) 122.95, C(13,15) 124.50, C(14) 126.89. Letters A and E denote the axial or equatorial positions of H-atoms.

### 2.2. Measurements

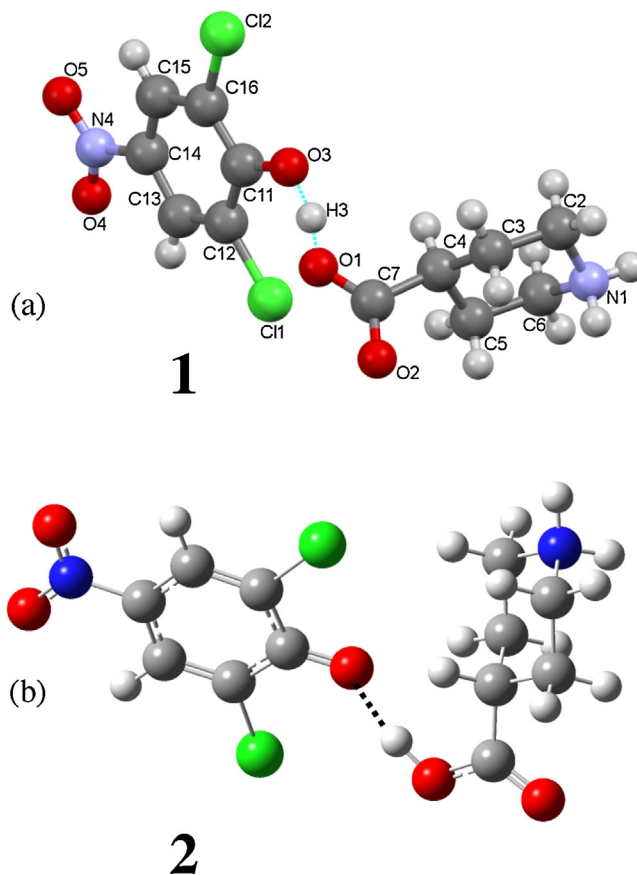
FTIR spectra were measured in Nujol and Fluorolube suspensions between KBr plates using a Bruker IFS 66 v/S instrument, with the resolution of 2 cm<sup>-1</sup>. Each spectrum was accumulated by acquisition of 64 scans. The FTIR spectrum presented was obtained with the use of the split mull technique, which combines the spectra recorded in two ranges, in the range of 4000–1325 cm<sup>-1</sup> from the spectrum measured in Fluorolube and in the range of 1325–400 cm<sup>-1</sup> from the spectrum measured in Nujol. The Raman spectrum of the powder sample was measured on a Bruker FRA-106/S instrument operating at the 1064 nm exciting line of Nd:YAG laser with the resolution of 1 cm<sup>-1</sup>. The spectrum was accumulated by acquisition of 200 scans.

The NMR spectra were recorded on a Varian VNMRS-400 spectrometer operating at 402.64 and 101.24 MHz for <sup>1</sup>H and <sup>13</sup>C, respectively. The spectra were measured in DMSO-*d*<sub>6</sub> relative to an internal standard of TMS.

**Table 1**

Crystal data and experimental information for the 1:1 complex of piperidine-4-carboxylic acid with 2,6-dichloro-4-nitrophenol (**1**).

Empirical formula	C <sub>12</sub> H <sub>14</sub> Cl <sub>2</sub> N <sub>2</sub> O <sub>5</sub>
Formula weight	337.16
Temperature	293(2) K
Wavelength	0.56380 Å
Crystal system	Monoclinic
Space group	<i>P</i> 2 <sub>1</sub> / <i>n</i>
Unit cell dimensions	<i>a</i> = 8.609(2) Å <i>b</i> = 7.3319(14) Å <i>c</i> = 23.237(6) Å <i>β</i> = 96.50(3)°
Volume	1457.3(6) Å <sup>3</sup>
<i>Z</i>	2
Calculated density	1.534 g/cm <sup>3</sup>
Absorption coefficient	0.245 mm <sup>-1</sup>
<i>F</i> (000)	694
Crystal size	0.9 × 0.16 × 0.34 mm
<i>θ</i> range for data collection	3.46 – 21.49°
Limiting indices	–10 ≤ <i>h</i> ≤ 7, –6 ≤ <i>k</i> ≤ 8, –22 ≤ <i>l</i> ≤ 28
Reflections collected/unique	4091/2088 [R(int) = 0.0654]
Completeness to <i>θ</i> = 21.49°	62.1%
Absorption correction	None
Refinement method	Full-matrix least-squares on <i>F</i> <sup>2</sup>
Data/restraints/parameters	2088/104/194
Goodness-of-fit on <i>F</i> <sup>2</sup>	0.836
Final R indices [I > 2σ(I)]	R1 = 0.1413, wR2 = 0.3470
R indices (all data)	R1 = 0.2262, wR2 = 0.4167
Extinction coefficient	0.000(6)
Largest diff. peak and hole	0.520 and –0.419 eÅ <sup>-3</sup>



**Fig. 1.** The molecular structures of the 1:1 complex of piperidine-4-carboxylic acid with 2,6-dichloro-4-nitrophenol, (a) the crystalline complex **1** and (b) the optimized structure **2** at the B3LYP/6–311 + +G (d,p) level of theory.

Elemental analysis was made using an Elemental Model Vario EL III.

X-Ray diffraction data of the 1:1 complex of P4C with DCNP (**1**) were collected on a KUMA KM-4CCD diffractometer [20,21]. The structure was solved by direct methods using SHELXS-97 and refined on *F*<sup>2</sup> by the full-matrix least-squares with SHELXL-97 [22]. The crystal data, details of data collection and structure refinement are given in Table 1 and the final atomic coordinates in Table S1 (Supplementary material). The crystallographic and structural data in CIF format are available from the Cambridge Crystallographic Database Centre (CCDC 1432258).

### 2.3. Computational details

The DFT calculations were performed with the GAUSSIAN 09 program package [23]. The calculations employed the B3LYP exchange–correlation functional, which combines the hybrid exchange functional of Becke [24,25] with the gradient–correlation functional of Lee et al. [26] and the split-valence polarized 6–311 + +G(d,p) [27]. The X-ray geometry of **1** was used as a starting point for the calculations. The calculated IR frequencies are positive and confirmed that the optimized structure was in the state of minimum energy. To model the peaks in the calculated (scaled) IR spectrum of the optimized structure the following function was employed:  $L_i(\nu) = I_i / \{1 + [(\nu_i - \nu) / (w/2)]^2\}$ , where *L* is the bandshape function, *I* is the peak intensity, *ν* is wavenumber, *w* is full-width-at-half-height (FWHH), than *w*/2 is the half-width of simulated bands (*w* = 20).

The Potential Energy Distribution (PED) analysis was carried out with the aid of the VEDA 4 program [28,29]. Only the PED

Download English Version:

<https://daneshyari.com/en/article/1249549>

Download Persian Version:

<https://daneshyari.com/article/1249549>

[Daneshyari.com](https://daneshyari.com)