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Structural investigations of 3-acetamido-4-nitrobenzal derivatives

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Abstract

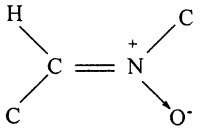
N-(*p*-dimethylaminophenyl)-α-(3acetamido-4-nitrophenyl)nitrone (**I**) and 3-acetamido-4-nitrobenzylpyridinium bromide (**II**) were synthesized and their crystal structures were determined by X-ray diffraction methods. The geometry of carbon–nitrogen bond in nitrone is *trans*. In **I** the acetamido moiety slightly deviates from plane to the rest of molecule. The intramolecular N–H···O and C–H···O as well as intermolecular C–H···O hydrogen bonds stabilize the crystal structures of both the compounds.

NMR investigations of **II** have given spectra with extra signals in comparison to the number of expected that suggests that dominating structure of this compound observed in crystal state coexists in solution with comparable amount of the additional form due to an interaction with solvent and increasing conformational freedom. For **II** duplication of signal number is observed for the 3-acetamido-4-nitrobenzyl substituent due to formation only of two different *edge to face* structures of this compound in DMSO and D_2O solution. For **I** in DMSO solution the major form has perpendicular orientation of *N*,*N*-dimethylaniline substituent on nitrone bond against the plane containing the rest of the molecule.

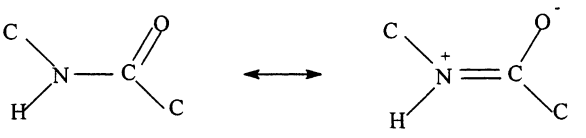
Keywords: Crystal structure; Nitro group; Inter- and intramolecular hydrogen bonds; Nitrones as amide isomers; Conformational equilibria by NMR; Edge to face interaction

1. Introduction

Investigations of substituted benzyl derivatives have been continued in our group for several years [1–3]. In this paper we present synthesis route and structure determination of the *N*-(*p*-dimethylamino-phenyl)-α-(3acetamido-4-nitrophenyl)nitrone using the 3-acetamido-4-nitrobenzylpyridinium bromide. Easy direct ways to obtain such substituted benzaldehydes are not known. Nitrones raise a possibility to obtain them in a blocked form with a good yield. Another aspect of this investigation is linked to the fact that nitrone moiety



is isomeric to the amide bond and very similar to the one (charged) from two resonance expressions of this group:



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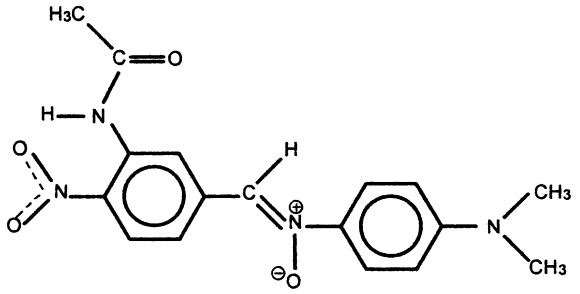
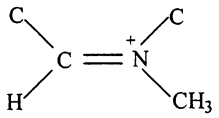


(I)

Scheme 1.

The substitution of amide bond by isomeric (peptidomimethic) nitrone group should give interesting compounds possessing different charge distribution and reactivity. In the course of investigation we were led by the properties of natural aminoacid *N*-methyl-4-aminoproline isolated lastly from linen [4]. The oxidation of this residue gave planar bond



in pyrolidyne ring with positively charged atom of nitrogen similar to the one in nitrone planar group –CH=$N^{+}(O^{-})$–. This similarity gives present work on nitrones a new importance in search of the synthetic pharmaceuticals like immunosupressant and antipathogen drugs [5].

This work is also connected to peptide area by the fact that edge to face interaction detected here for both simple compounds **I** and **II** was also found to be an important factor of structure organization in natural biologically active substances like CLA [6].

N-(*p*-Dimethylaminophenyl)-α-(3-acetamido-4-nitrophenyl) nitrone (Scheme 1) was prepared by us for further synthesis of 3-acetamido-4-nitrobenzaldehyde. Copper(II) nitrate in acetic anhydride [7] was chosen for the nitration of *m*-toluidine because of its ability to introduce the nitro group into the *ortho* position towards acetamide group (see Scheme 3). As it was mentioned in Ref. [7] the major product of nitration is 3-acetamido-4-nitrotoluidine. Additionally, another mononitro isomer (6-nitro) was obtained in a minor quantity. The crystal structures of the title compounds were determined as a part of studies on the influence of the nitro group position on the molecular structure of molecules investigated. Crystal structure of the intermediate 3-acetamido-4-nitrobenzylpyridinium bromide (Scheme 2) was also determined. The structure of the 4-nitro and 6-nitro isomer has been described previously [1,3].

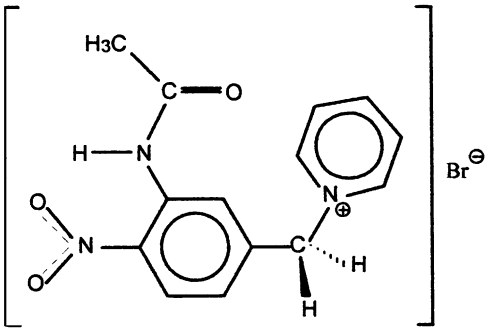
Route of reactions is shown in Scheme 3.

2. Experimental

2.1. Synthesis

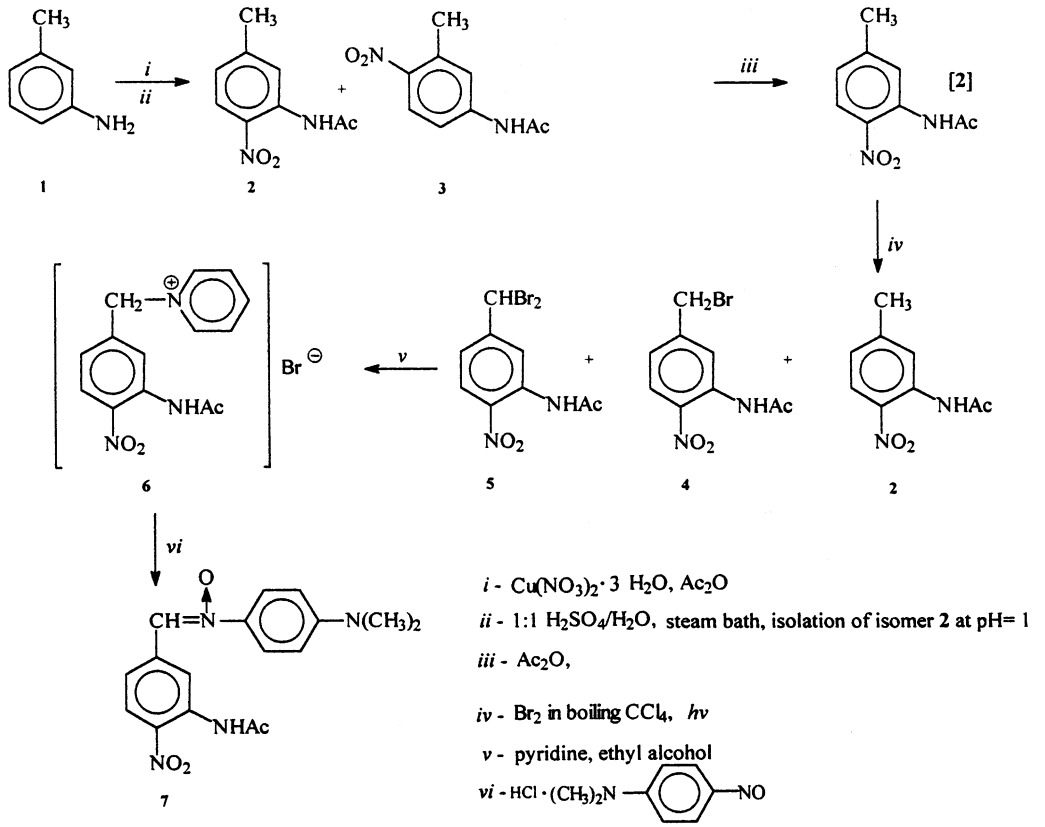
2.1.1. 3-Acetamido-4-nitrotoluidine

To a stirred solution of *m*-toluidine (0.1 mol) [7] in acetic anhydride (73.5 cm^3) copper(II) nitrate trihydrate (0.05 mol) was gradually added at 1–5°C. The reaction mixture was stirred for 24 h, then poured into ice and stirred until acetic anhydride disappeared. Precipitated brown solid was filtered off and washed until all copper salts were removed. Crude solid was dissolved in concentrated sulphuric acid [8] and then diluted with equal amount of water. The obtained solution was heated on steam bath for 5 h, cooled and diluted with water until no more precipitates were formed. Precipitate was filtered off and carefully washed and dried in air. Crude solid was dissolved in acetic anhydride after gently heating on heating mantle, and then the mixture was left to cool. Obtained crystals were recrystallized from ethyl acetate (6.39 g, mp 84.5–85.5°C, the earlier reported



(II)

Scheme 2.



Scheme 3.

[8] has mp 84.9–85.5°C). After addition of concentrated solution of ammonia into washing of 3-amino-4-nitrotoluidine another nitro isomer (6-nitro) was obtained.

^{1}H-NMR data for 3-acetamido-4-nitrotoluidyne (500 MHz, $CDCl_3$) σ: 10.5 (s, H1), 8.7 (s, H2), 8.2 (d, $J = 8.75$ Hz, H5), 7.2 (d, $J = 4.5$ Hz, H6), 2.45 (s, CH_3), 2.3 (s, CH_3).

2.1.2. 3-Acetamido-4-nitrobenzylpyridinium bromide

The 3-acetamido-4-nitrotoluidyne (30 mmol) [9] was dissolved in carbon tetrachloride (170 cm^3) and next solid potassium carbonate (61.8 mmol) was added into the solution. To the above mixture 37.5 mmol of bromine in carbon tetrachloride (45 cm^3) was added dropwise and everything was boiled and irradiated with 250 W tungsten lamp. After the bromine addition was completed the solution was refluxed and irradiated for next 5 h. The crude product 3-acetamido-4-nitrobromotoluidyne was crystallized from ethyl alcohol. To the crude product an absolute ethanol (53.76 cm^3) was added and 110 mmol of pyridine were dropped. The solution was heated at the reflux temperature for 45 min and immediately transferred to a wide-neck Erlenmeyer flask. After cooling the mixture, crude crystals of 3-acetamido-4-nitrobenzylpyridinium bromide were collected and recrystallized from ethyl alcohol (10.94 g, mp 236.5–237.5°C). Needle-like, yellow crystals of **II** were obtained by slow evaporation from a solution which contains a mixture of methanol and ethyl acetate.

^{1}H-NMR data for 3-acetamido-4-nitrobenzylpyridynium bromide (500 MHz, DMSO, TMS int. ref. σ: 0.00) σ: 10.47 (s, H1), 9.27 (m, $J = 6.86$ Hz, H10, H14), 8.74 (m, $J = 8.0$ Hz, H12), 8.24 (m, H11, H13), 8.00 (d, $J = 8.94$ Hz, H5), 7.67 (s, H2), 7.50 (d, $J = 8.64$ Hz, H6), 6.93 (s, H2), 6.65 (d,

Table 1
Crystal data for *N*-(*p*-dimethylaminophenyl)-α-(3-acetamido-4-nitrophenyl)nitrone (**I**) and 3-acetamido-4-nitrobenzylpyridinium bromide (**II**)

	I	**II**
Empirical formula	$C_{17}H_{18}N_4O_4$	$(C_{14}H_{14}N_3O_3)^+Br^-$
Temperature (K)	299(1)	120(1)
Formula weight	342.35	352.19
Colour	Brown	Yellow
Wavelength (λ)	0.71073	0.71073
Crystal system	Triclinic	Monoclinic
Space group	*P*1	*C*2/*c*
Unit cell dimensions:		
a (Å)	6.813(4)	24.87(2) [25.20(2)][a]
b (Å)	8.646(5)	6.919(5) [6.971(6)][a]
c (Å)	14.644(6)	20.034(15) [20.157(15)][a]
α (°0	75.45(4)	
β (°)	78.56(4)	124.28(7) [124.14(9)][a]
γ (°)	89.10(4)	
Volume (Å^3)	817.8(8)	2849(4)
Z	2	8
Density (calculated) (g cm^{-3})	1.390	1.642 [1.569][a]
Density (measured) (g cm^{-3})	1.372	1.548
Absorption coefficient (mm^{-1})	0.10	2.90
F(000)	360	1424
Crystal size (mm)	0.2 × 0.5 × 0.5	0.1 × 0.2 × 0.05
Index ranges	−9 → h → 8	−30 → h → 26
	−11 → k → 8	0 → k → 8
	−19 → l → 18	0 → l → 25
Reflections collected	5628	5038
Independent reflections	3614 (*R*(int) = 0.0218)	2849 (*R*(int) = 0.0879)
Refinement method	Full-matrix least-squares on F^2	
Data/parameters	3614/298	2849/232
Goodness-of-fit on F^2	1.089	1.043
Final *R* indices ($I > 2\sigma$(I))	*R*1 = 0.0773	0.0555
	*wR*2 = 0.1795	0.0819
R indices (all data)	*R*1 = 0.127	0.157
	*wR*2 = 0.222	0.101

[a] The values given in square brackets are for 291 K.

$J = 8.94$ Hz, H6), 6.05 (s, H71, H7), 5.91 (s, H71, H72), 2.07 (s, CH_3).

^{1}H-NMR data (500 MHz, D_2O, dioxan int. ref. σ: 3.68) σ: 8.88 (m, $^3J = 19.5$ Hz, $^4J = 4.5$ Hz, H10, H14), 8.55 (m, H12), 8.06 (m, H11, H13 and H5), 7.96 (d, $^3J = 8.80$ Hz, H5) 7.81 (s, H2), 7.34 (d, $^3J = 8.62$ Hz, H6), 6.90 (s, H2), 6.55 (d, $^3J = 8.44$ Hz, H6), 5.88 (s, H71, H72), 5.70 (s, H71, H72), 2.15 (s, CH_3).

2.1.3. N-(p-dimethylophenyl)-α-(3-acetamido-4-nitrophenyl)nitrone

The wet 3-acetamido-4-nitrobenzylpyridinium bromide (15 mmol) [9], together with of *p*-nitrosodimethylaniline hydrochloride (15 mmol) and ethanol (47.9 cm^3) were placed in a three-necked flask equipped with an efficient stirrer, thermometer, and a dropping funnel, and immersed in an ice-salt bath. To the stirred solution 40 mmol of sodium hydroxide in water (15 cm^3) was added at 0–5°C. The stirring was continued over a period of 1 h. At the end of this time ice-cold water (15 cm^3) was added and *N*-(*p*-dimethylophenyl)-α-(3-acetamido-4-nitrophenyl)nitrone crystals were collected on a Bűchner funnel. The crystals were washed with cold water. The crude product was then recrystallized from acetone (2.57 g, mp 192–193°C). Platy shapes, dark brown crystals of **I** were obtained by slow evaporation from acetone.

Table 2
Positional coordinates and equivalent thermal parameters (with e.s.d.'s in parentheses)

	x	y	z	U_{equiv}/U_{iso}
I				
C1	0.3110(4)	0.5280(3)	0.1314(2)	0.0561(6)
C2	0.3655(4)	0.4574(3)	0.2197(2)	0.0531(7)
C3	0.2476(4)	0.3394(3)	0.2904(2)	0.0488(6)
C4	0.0683(4)	0.2891(3)	0.2692(2)	0.0504(6)
C5	0.0149(5)	0.3567(4)	0.1818(2)	0.0636(8)
C6	0.1318(5)	0.4753(4)	0.1133(2)	0.0646(8)
C7	0.4471(4)	0.6507(3)	0.0649(2)	0.0550(7)
C8	0.4529(4)	0.3213(3)	0.4161(2)	0.0600(6)
C9	0.4703(6)	0.2214(5)	0.5137(2)	0.0691(9)
C10	0.7401(5)	0.9003(4)	−0.0535(2)	0.0765(10)
C11	0.8720(5)	1.0174(4)	−0.1144(2)	0.0758(10)
C12	0.8376(4)	1.1003(3)	−0.2043(2)	0.0542(7)
C13	0.6637(4)	1.0557(3)	−0.2301(2)	0.0568(7)
C14	0.5328(4)	0.9375(3)	−0.1693(2)	0.0557(7)
C15	0.5671(4)	0.8591(3)	−0.0796(2)	0.0543(7)
C16	1.1505(6)	1.2558(6)	−0.2377(4)	0.0808(11)
C17	0.9350(6)	1.2986(4)	−0.3590(3)	0.0710(9)
N1	0.3027(4)	0.2729(3)	0.3793(2)	0.0561(6)
N2	−0.0662(4)	0.1641(3)	0.3351(2)	0.0603(6)
N3	0.4226(3)	0.7361(3)	−0.0191(2)	0.0579(6)
N4	0.9675(4)	1.2192(3)	−0.2638(2)	0.0665(7)
O1	−0.0317(4)	0.0991(3)	0.4149(2)	0.0899(8)
O2	−0.2148(3)	0.1237(3)	0.3106(2)	0.0856(8)
O3	0.5645(4)	0.4356(3)	0.3751(2)	0.0980(9)
O4	0.2669(4)	0.7190(3)	−0.0529(2)	0.1067(10)
H1	0.223(5)	0.193(4)	0.415(2)	0.077(10)
H2	0.502(5)	0.498(3)	0.228(2)	0.064(8)
H5	−0.104(5)	0.315(4)	0.168(2)	0.070(8)
H6	0.089(4)	0.519(3)	0.048(2)	0.073(9)
H7	0.568(4)	0.681(3)	0.084(2)	0.066(8)
H10	0.775(5)	0.855(4)	0.004(3)	0.090(10)
H11	1.001(5)	1.049(4)	−0.093(3)	0.094(10)
H13	0.629(4)	1.106(3)	−0.292(2)	0.052(7)
H14	0.418(4)	0.909(3)	−0.187(2)	0.065(8)
H91	0.368(6)	0.147(5)	0.541(3)	0.096(12)
H92	0.488(6)	0.290(5)	0.551(3)	0.110(13)
H93	0.602(7)	0.174(5)	0.510(3)	0.125(15)
H161	1.131(6)	1.274(4)	−0.176(3)	0.096(13)
H162	1.224(6)	1.343(5)	−0.281(3)	0.114(13)
H163	1.230(6)	1.170(5)	−0.234(3)	0.120(16)
H171	1.037(5)	1.385(4)	−0.385(2)	0.085(10)
H172	0.801(6)	1.352(4)	−0.354(3)	0.099(12)
H173	0.940(6)	1.224(5)	−0.396(3)	0.104(13)
II				
Br	0.38374(3)	0.53383(8)	0.12557(3)	0.02208(16)
C1	0.3170(2)	0.0490(8)	0.1782(3)	0.0155(10)
C2	0.3155(2)	0.0519(8)	0.2461(3)	0.0172(11)
C3	0.2568(2)	0.0635(7)	0.2408(3)	0.0126(11)
C4	0.1988(2)	0.0710(7)	0.1624(3)	0.0164(12)
C5	0.2000(2)	0.0669(7)	0.0936(3)	0.0165(11)
C6	0.2580(2)	0.0559(8)	0.1003(3)	0.0179(11)

Table 2 (*continued*)

	x	*y*	*z*	U_{equiv}/U_{iso}
C7	0.3793(2)	0.0354(10)	0.1825(3)	0.0193(10)
C8	0.3101(2)	0.0986(7)	0.3895(3)	0.0167(12)
C9	0.2962(3)	0.0733(9)	0.4530(3)	0.0197(13)
C10	0.4652(3)	−0.1182(10)	0.3101(4)	0.0259(15)
C11	0.5122(3)	−0.1082(10)	0.3908(4)	0.0256(16)
C12	0.5301(3)	0.0680(9)	0.4292(4)	0.0229(14)
C13	0.5016(3)	0.2369(9)	0.3848(4)	0.0237(14)
C14	0.4563(3)	0.2207(8)	0.3041(4)	0.0157(12)
N1	0.2571(2)	0.0655(6)	0.3110(2)	0.0156(10)
N2	0.1346(2)	0.0800(6)	0.1482(3)	0.0187(10)
N7	0.4372(2)	0.0449(7)	0.2675(2)	0.0156(9)
O1	0.1291(2)	0.0526(6)	0.2051(2)	0.0251(9)
O2	0.0872(2)	0.1140(6)	0.0797(2)	0.0339(11)
O3	0.3641(2)	0.1402(6)	0.4066(2)	0.0249(9)
H1	0.217(2)	0.047(8)	0.300(3)	0.019
H2	0.351(2)	0.034(8)	0.295(3)	0.021
H5	0.156(2)	0.065(7)	0.040(3)	0.020
H6	0.260(2)	0.052(8)	0.055(3)	0.021
H10	0.447(3)	−0.204(10)	0.278(4)	0.031
H11	0.523(3)	−0.206(9)	0.413(4)	0.031
H12	0.560(3)	0.069(8)	0.488(4)	0.027
H13	0.517(3)	0.383(8)	0.416(3)	0.028
H14	0.438(3)	0.322(8)	0.270(3)	0.019
H71	0.383(3)	0.138(9)	0.158(4)	0.023
H72	0.383(3)	−0.100(9)	0.160(4)	0.023
H91	0.253(3)	0.088(8)	0.440(3)	0.024
H92	0.314(3)	0.171(9)	0.482(4)	0.024
H93	0.319(2)	−0.064(8)	0.485(3)	0.024

^{1}H-NMR data for *N*-(*p*-dimethylophenyl)-α-(3-acetamido-4-nitrophenyl)nitrone (500 MHz, DMSO, TMS int. ref.) σ: 10.43 (s H7), 8.86 (s, H5), 8.59 (s, H1), 8.27 (s, H6), 8.16 (d, $J = 8.5$ Hz, H14), 8.03 (d, $J = 8.5$ Hz, H13), 7.82 (d, $J = 7.2$ Hz, H10), 7.35 (s, H2), 6.79 (d, $J = 7.2$ Hz, H11), 3.00 (s, H17, H16), 2.08 (s, H9).

2.2. X-ray diffraction

Diffraction data for crystal **I** were collected on a Kuma KM4CCD area detector diffractometer (ω scan) and for **II** on a Kuma KM4 κ-geometry diffractometer (ω–2θ scan), with graphite-monochromatized MoK_α radiation. Since crystal of **I** show phase transition below 210 K the data collection for this crystal was at room temperature. The experimental details are given in Table 1. Both structures were solved by direct methods using the SHELXS program [10] and refined using SHELXL [11]. For **II** the analytical corrections for absorption were applied; T_{min} and T_{max} 0.695 and 0.877, respectively. All positions of the H atoms were found from different Fourier maps and refined with U_{iso} equal to 1.2 U_{equiv} of the parent atoms. Final atom parameters with their estimated standard deviations are listed in Table 2. The density of **II** was measured by flotation in the mixture of $CCl_4/CHCl_3$.

3. Results and discussion

3.1. Analysis of crystallographical data

The molecular structure and numbering scheme of the *N*-(*p*-dimethylaminobenzyl)-α-(3-acetamido-4-nitrophenyl)nitrone, **I** is shown in Fig. 1.

The molecule **I** has two aromatic rings attached to nitrone moiety. There are two different substituents

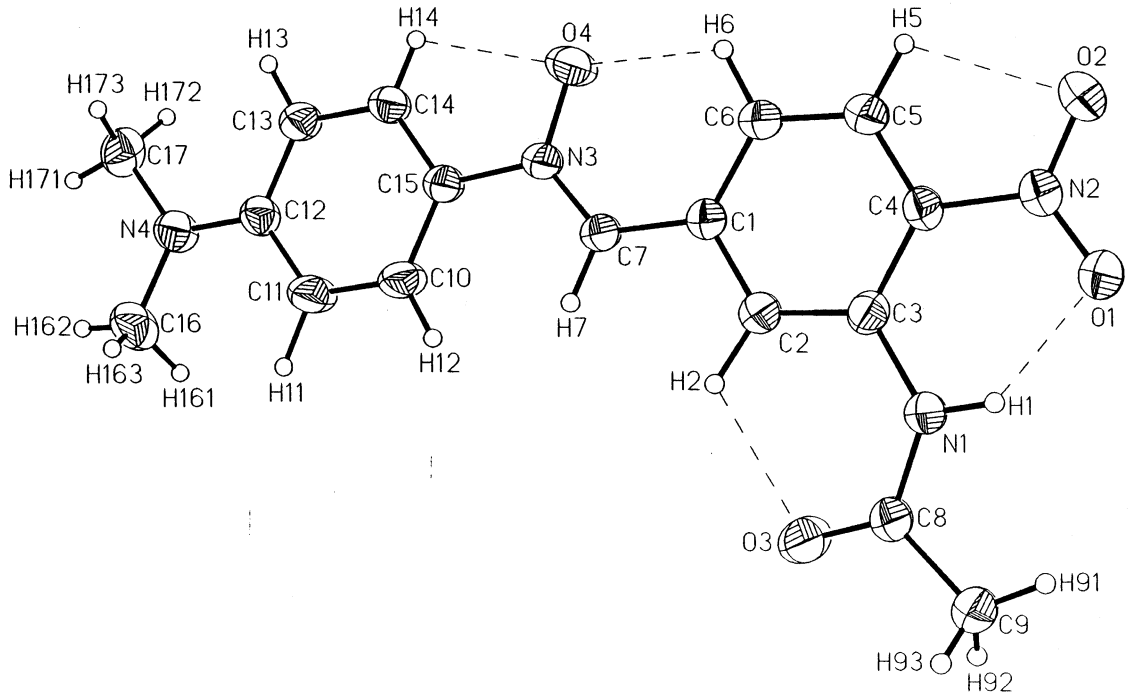


Fig. 1. The structure of the *N*-(*p*-dimethylaminobenzyl)-α-(4-nitro-3-acetaminotoluene)nitrone showing 50% probability displacement ellipsoids and atom-numbering scheme. Dashed lines indicate intramolecular hydrogen bonds.

connected to the benzene skeleton in the first ring: acetamido and nitro. The second ring is substituted by *N*,*N*-dimethylamine group. Both aromatic rings are coplanar (dihedral angle between the mean aromatic planes is 0.78°).

The crystal structure of **II** consists of 3-acetamido-4-nitrobenzylpyridinium cations and the Br^- anions. A plot of the cation is depicted in Fig. 2. In the cation the 3-acetamido-4-nitrobenzyl substituent is connected with pyridine ring. The pyridine ring is situated perpendicular to the benzene ring (dihedral angle between respective mean planes is 83°).

In both the structures the acetamide group is almost coplanar with the plane of the aromatic ring. The most displaced atoms from the plane are O3 (0.407(6) Å for **I** and 0.617(10) Å for **II**) and C8 (0.212(5) Å for **I** and 0.262(10) Å for **II**).

The most significant difference in the geometrical parameters is observed for the acetamide group and C1–C2 bond length (1.403(4) and 1.383(7) Å for **I** and **II**, respectively). The C8–N1 bond lengths are 1.364(3) and 1.389(7) Å for **I** and **II**, respectively; the C8–O3 bond lengths are 1.208(3) and 1.221(6) Å for **I** and **II**, respectively. The bond lengths and angles are given in Table 3. These differences are, probably, due to the intramolecular hydrogen bond between the aromatic H2 atom and the O3 atom of the carboxyl group [3]. Weak hydrogen bond existing between the amide H1 and the nitro O1 atoms explains the coplanarity of the acetamide and nitro group as it was observed for 4-nitro compounds [1]. The angle between the nitro group and the aromatic ring is 8.1(3)° and 11.06(1)° for **I** and **II**, respectively. This planar conformation is also stabilized by the intramolecular contact between the nitro O2 atom and the H5 atom of the aromatic ring. The intra- and intermolecular hydrogen bonds are presented in Table 4.

In **I** the O4 atom of the nitrone moiety makes hydrogen bonds with the H6 and the H14 atoms of the aromatic rings (see Table 4). It explains the elongating of the O4–N3 bond length, which has a partial double bond character (1.281(3) Å). However, this distance is shorter than it was observed in the other

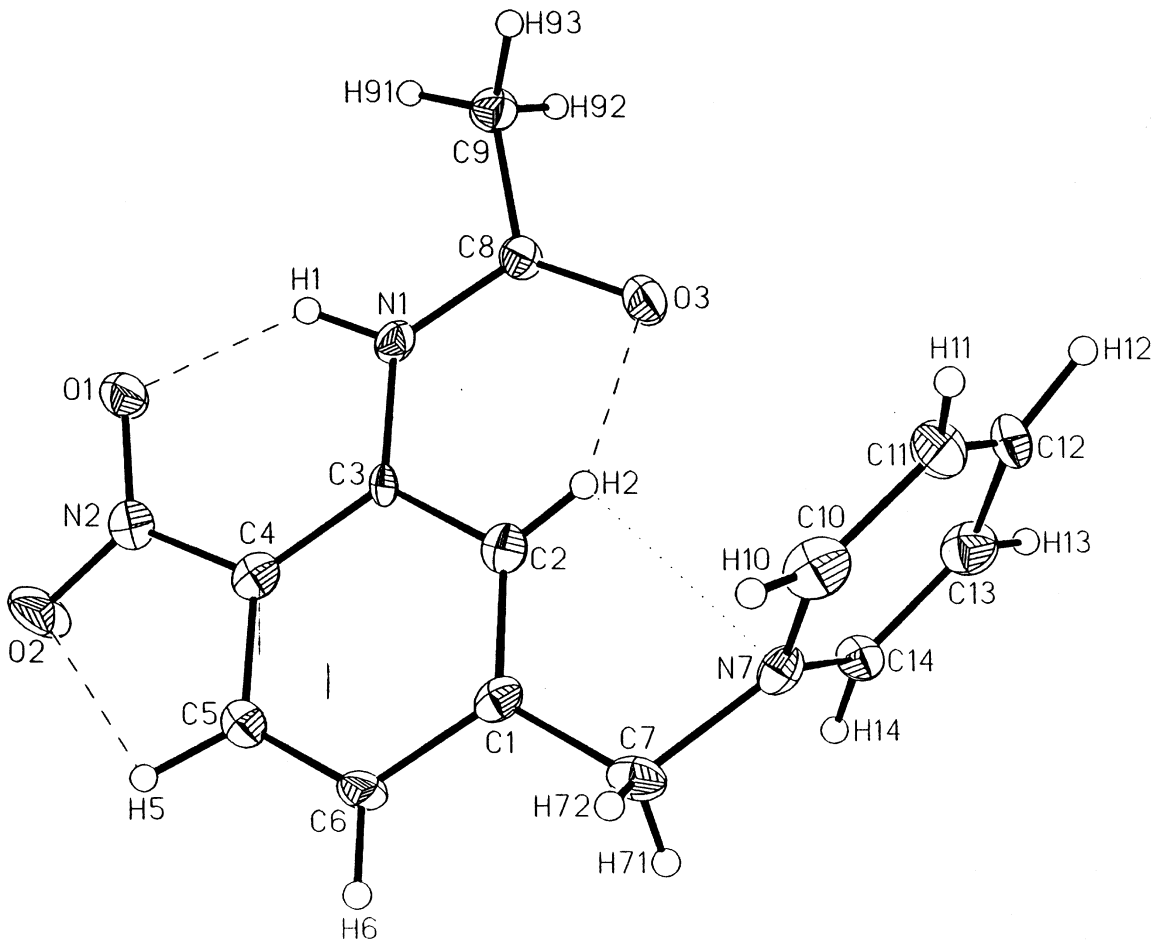


Fig. 2. The structure of 3-acetamido-4-nitrobenzylpyridinium cation showing 50% probability displacement ellipsoids and atom-numbering scheme. Dashed lines indicate intramolecular hydrogen bonds.

nitrones [12–14]. Here the conjugation is observed in the Ar–C=N → O region with N–O bond length shortened in relation to the unconjugated nitrones [12].

The 3-acetamido-4-nitrobenzene substituent in the cation of the structure **II** is situated perpendicular to the pyridine ring. The C6–C1–C7–N7 and C1–C7–N7–C10 torsion angles are 175.6(5) and 93.7(6)°, respectively. The selected torsion angles for crystal **II** is given in Table 5. Intramolecular face-to-edge conformation is stabilized by the C2–H2···N7 hydrogen bond (see Table 4). The geometry of the 3-acetamido-4-nitrobenzylpirydynium cation is similar to the other salts of pyridinium [15–17].

In the crystal **I**, molecules related by the center of symmetry are linked by the weak intermolecular C–H···O hydrogen bonds (see Table 4), forming infinite chains along *a* (Fig. 3). These chains are related by the center of symmetry to make stacking along *b*; the distance formed is about 3.5 Å. The short intermolecular contacts are observed between the symmetry-related O1 atoms of the nitro group. The O1···O1 (x, $-y$, $1-z$) distance is 2.755(4) Å. Similar distances were observed previously in the other nitro compounds [18].

In the crystal **II** each Br^- anion is linked with five H atoms with H···Br < 2.95 Å (see Table 4). The 3-acetamido-4-nitrobenzene substituents of the molecules are related by the two-fold axis form columns

Table 3
Bond lengths (Å) and bond angles (°) (with e.s.d.'s in parentheses) for **I** and **II**

	I	II
C1–C2	1.403(4)	1.383(7)
C1–C6	1.406(4)	1.418(7)
C1–C7	1.445(4)	1.507(7)
C2–C3	1.387(4)	1.405(6)
C3–C4	1.418(4)	1.414(7)
C3–N1	1.405(3)	1.400(6)
C4–C5	1.384(4)	1.396(7)
C4–N2	1.448(3)	1.457(6)
C5–C6	1.373(4)	1.374(7)
C7–N3	1.307(3)	–
C7–N7	–	1.489(7)
C8–C9	1.499(4)	1.505(7)
C8–N1	1.364(3)	1.389(7)
C8–O3	1.208(3)	1.221(6)
C10–C11	1.372(4)	1.362(10)
C10–C15	1.387(4)	–
C10–N7	–	1.347(8)
C11–C12	1.395(4)	1.374(9)
C12–C13	1.400(4)	1.396(8)
C12–N4	1.369(3)	–
C13–C14	1.374(4)	1.357(9)
C14–C15	1.381(4)	–
C15–N3	1.448(3)	–
C16–N4	1.436(4)	–
C17–N4	1.449(4)	–
O1–N2	1.229(3)	1.235(5)
O2–N2	1.222(3)	1.227(6)
O4–N3	1.281(3)	–
C2–C1–C6	118.8(2)	119.9(4)
C2–C1–C7	116.5(2)	122.9(4)
C6–C1–C7	124.7(2)	117.3(4)
C1–C2–C3	122.5(3)	122.0(5)
N1–C3–C2	121.6(2)	120.4(4)
N1–C3–C4	121.4(2)	122.7(4)
C2–C3–C4	117.0(2)	116.9(4)
C5–C4–C3	120.8(2)	121.4(4)
C5–C4–N2	116.2(2)	116.0(4)
C3–C4–N2	123.0(2)	122.6(4)
C6–C5–C4	121.4(3)	120.7(5)
C5–C6–C1	119.5(3)	119.2(4)
N3–C7–C1	126.8(3)	–
N7–C7–C1	–	111.4(4)
O3–C8–N1	123.9(3)	123.2(4)
O3–C8–C9	121.4(3)	122.2(5)
N1 –C8 –C9	114.7(3)	114.6(4)
N7 –C10–C11	–	120.0(6)
C11–C10–C15	121.0(3)	–
C10–C11–C12	121.7(3)	120.0(6)
C11–C12–C13	116.6(2)	119.8(5)
N4–C12–C11	121.4(3)	–
N4–C12–C13	122.0(2)	–
C14–C13–C12	121.6(3)	118.2(6)
C13–C14–C15	121.1(3)	–
C13–C14–N7	–	121.3(5)
C14–C15–C10	118.1(3)	–
C14–C15–N3	118.1(2)	–
C10–C15–N3	123.8(2)	–
C8–N1–C3	128.8(2)	127.2(4)
O2–N2–O1	120.3(2)	121.8(4)
O2–N2–C4	119.3(2)	118.9(4)
O1–N2–C4	120.5(2)	119.3(4)
O4–N3–C7	122.2(2)	–
O4–N3–C15	115.3(2)	–
C7–N3–C15	122.4(2)	–
C12–N4–C16	120.6(3)	–
C12–N4–C17	120.7(3)	–
C16–N4–C17	118.3(3)	–
C10–N7–C7	–	120.6(5)
C10–N7–C14	–	120.6(4)
C14–N7–C7	–	118.3(5)

along *b*. The 4-nitro-3-acetamidobenzene substituents of the molecules related-symmetry of the former columns are nearly parallel to the *ac* plane with interplanar distances about 3.5 Å. The crystal packing can be described as being composed of the three-dimensional network via C–H···O intermolecular hydrogen bonds and interactions between the aromatic rings of the adjacent molecules (Fig. 4.).

3.2. NMR measurements and spectra analysis

NMR spectra were recorded on Brüker spectrometer operated on 500 MHz in DMSO solution with TMS as internal reference. Concentration of sample were 8 and 10 mg ml^{-1} for compounds **I** and **II**, respectively.

Changes in spectra going from **II** to **I** support the way of synthesis used. Assignments of the protons in molecules to signal in spectra were made based on the experiments carried out: COSY, C–H correlation, inverse C–H correlation, and for **II** from H–D exchange going from DMSO to D_2O solution.

For the compound **II** duplicate number of signals for the 3-acetamido-4-nitrobenzyl substituent is observed in the standard COSY spectrum similar to the ^{1}H-NMR spectrum (see Fig. 5). As it was expressed in NMR data for **II** signal for proton H2

Table 4
Probable hydrogen bonds intra- and intermolecular for crystals **I** and **II**

D–H···A	D–H (Å)	H…A (Å)	D…A (Å)	D–H…A (°)
I				
N1–H1···O1	0.88(3)	1.93(3)	2.639(3)	137(3)
C2–H2···O3	1.04(3)	2.21(3)	2.838(4)	117(2)
C5–H5···O2	0.96(3)	2.31(3)	2.662(4)	101(2)
C5–H5···O4[a]	0.96(3)	2.28(3)	3.127(4)	147(2)
C6–H6···O4	1.03(3)	2.17(3)	2.794(4)	117(2)
C14–H14···O4	0.93(3)	2.29(3)	2.649(4)	102(2)
C14–H14···O2[a]	0.93(3)	2.55(3)	3.409(4)	154(2)
C16–H162···O3[b]	0.93(4)	2.37(5)	3.295(5)	173(3)
II				
N1–H1···O1	0.90(5)	1.92(5)	2.652(6)	137(4)
C2–H2···O3	0.89(5)	2.19(5)	2.790(7)	124(4)
C2–H2···N7	0.89(5)	2.50(5)	2.811(6)	101(3)
C5–H5···Br[c]	1.02(5)	2.96(5)	3.716(6)	132(3)
C5–H5···O2	1.02(5)	2.27(5)	2.678(6)	102(3)
C7–H71···Br	0.89(6)	2.82(6)	3.653(7)	156(5)
C7–H72···Br[d]	1.06(6)	2.63(6)	3.674(7)	168(4)
C9–H91···Br[e]	0.97(5)	2.89(5)	3.641(9)	164(4)
C12–H12···O3[f]	0.98(6)	2.37(6)	3.173(8)	139(5)
C14–H14···Br	0.91(6)	2.82(6)	3.671(6)	157(4)
C14–H14···O1[g]	0.91(6)	2.54(5)	3.063(7)	117(4)

[a] Symmetry codes: $-x, 1-y, -z$.
[b] $2-x, 2-y, -z$.
[c] $0.5-x, 0.5-y, -z$.
[d] $x, y-1, z$.
[e] $0.5-x, y-0.5, 0.5-z$.
[f] $1-x, -y, 1-z$.
[g] $0.5-x, 0.5+y, 0.5-z$.

appear in two positions of spectrum δH2c = 6.93 ppm and δH2s = 7.67 ppm, where designation c is valid for *crystal like structure* and s means position of proton appeared in structure found only in solution. The difference between these two positions

$$\delta\text{H2c} - \delta\text{H2s} = -0.74 \text{ ppm}$$

Table 5
Selected torsion angles (°) (with e.s.d's in parentheses) for crystal **II**

C6–C1–C7–N7	175.6(5)
O3–C8–N1–C3	3.6(8)
C9–C8–N1–C3	− 174.7(5)
C2–C3–N1–C8	15.0(8)
C4–C3–N1–C8	− 165.6(5)
C11–C10–N7–C7	− 170.8(5)
C13–C14–N7–C7	169.1(5)
C1–C7–N7–C10	93.7(6)
C1–C7–N7–C14	− 78.5(6)

represents change the orientation of edge the 3-acetamido-4-nitrobenzyl substituent against face pyridine ring. This effect is accompanied by similar situation observed for the pair of coupled protons H5 and H6 giving two AB systems. Like for H2, we can write an equation for proton H6

$$\delta\text{H6c} - \delta\text{H6s} = 0.79 \text{ ppm}$$

The distinct difference in chemical shifts H2 and H6 for two conformations of **II** derived from two edge to face structures where one is similar to this observed in crystal state and second is with bond –H6C6–C5H5– almost coaxially oriented toward high-field shielding plane of pyridine ring. It must be marked here that similar absolute values of above differences evidences existence only two edge to face forms in solution (see Fig. 6) and there is no other form visible in equilibrium. It is surprising, that edge to face interaction in **II** is strong enough to form two different

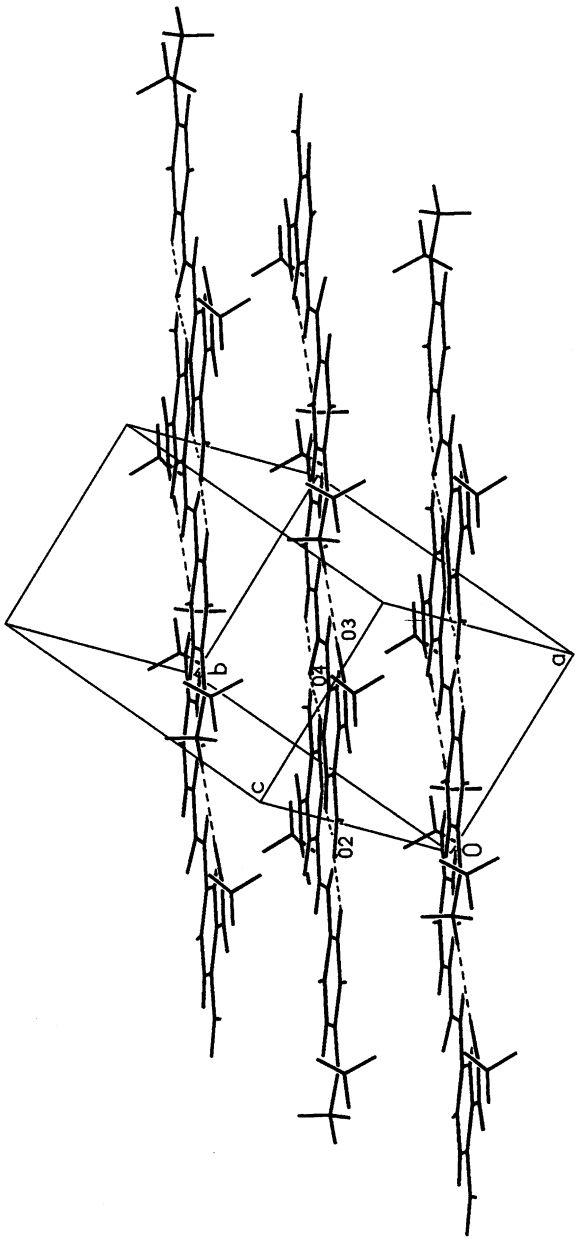


Fig. 3. View of the crystal packing of the compound **I** with dashed lines indicating the intermolecular hydrogen bonds.

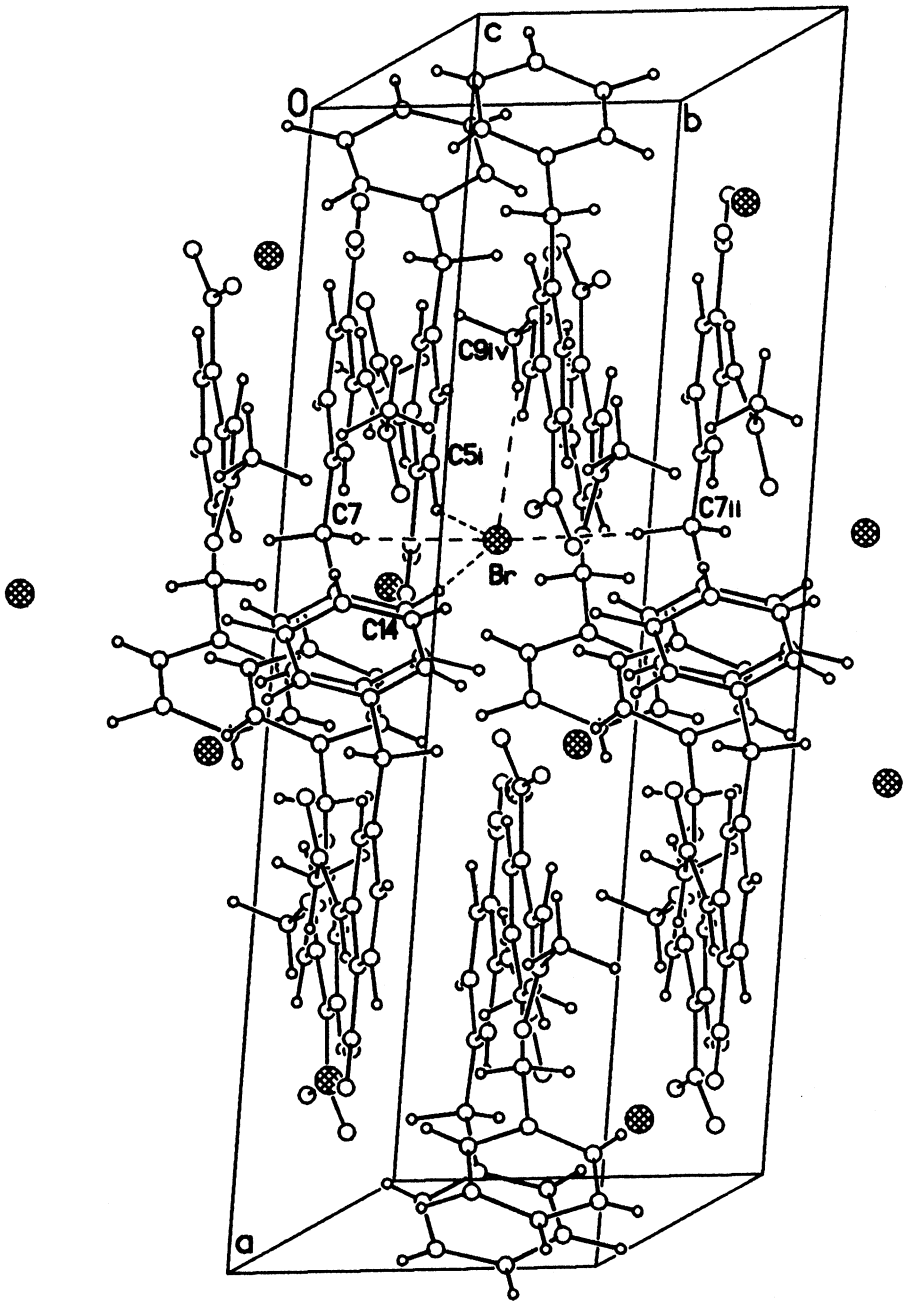


Fig. 4. View of the crystal packing of the compound **II** with dashed lines indicating the intermolecular hydrogen bonds (symmetry codes: (i) $0.5 - x, 0.5 - y, -z$; (ii) $x, y - 1, z$; (iv) $0.5 - x, -0.5 + y, 0.5 - z$; (v) $1 - x, -y, 1 - z$; (vi) $0.5 - x, 0.5 + y, 0.5 - z$).

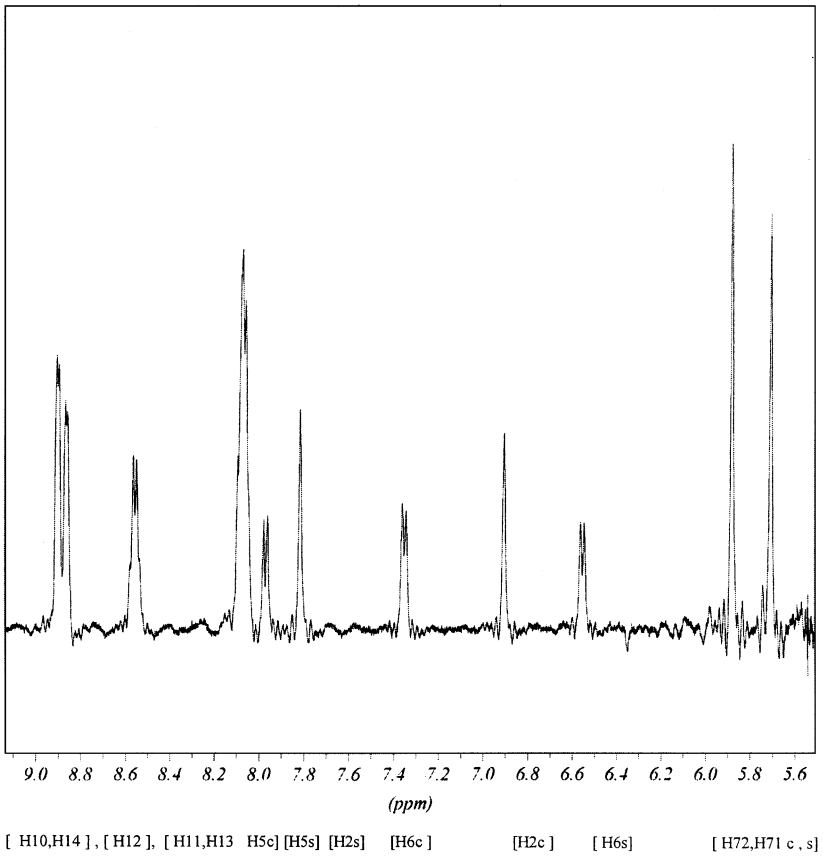


Fig. 5. ^{1}H-NMR spectrum (aromatic region) for compound **II** in D_2O. Designations c and s indicate that signals derived from crystal like and solution appeared structures respectively (both of them are in equilibrium in solution). The H5c dublet is overlapped by H11 and H13 multiplet.

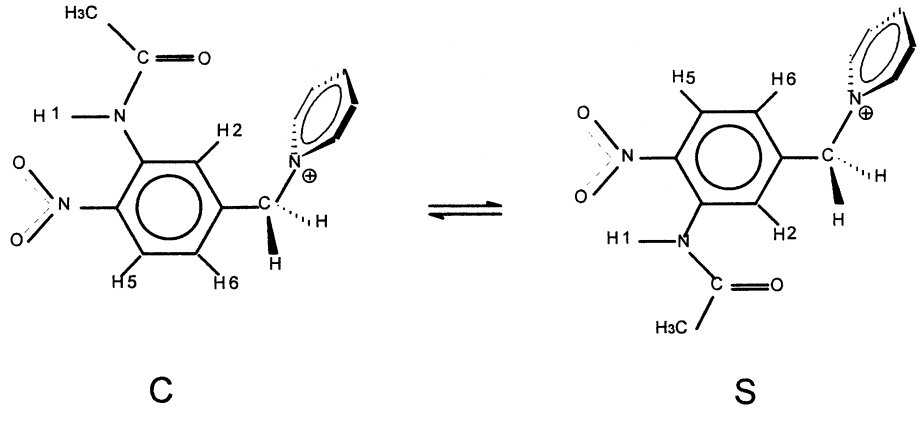


Fig. 6. Two structures in solution of compound **II**; designation: c — structure in solution same like in crystal, s — structure appeared in solution only.

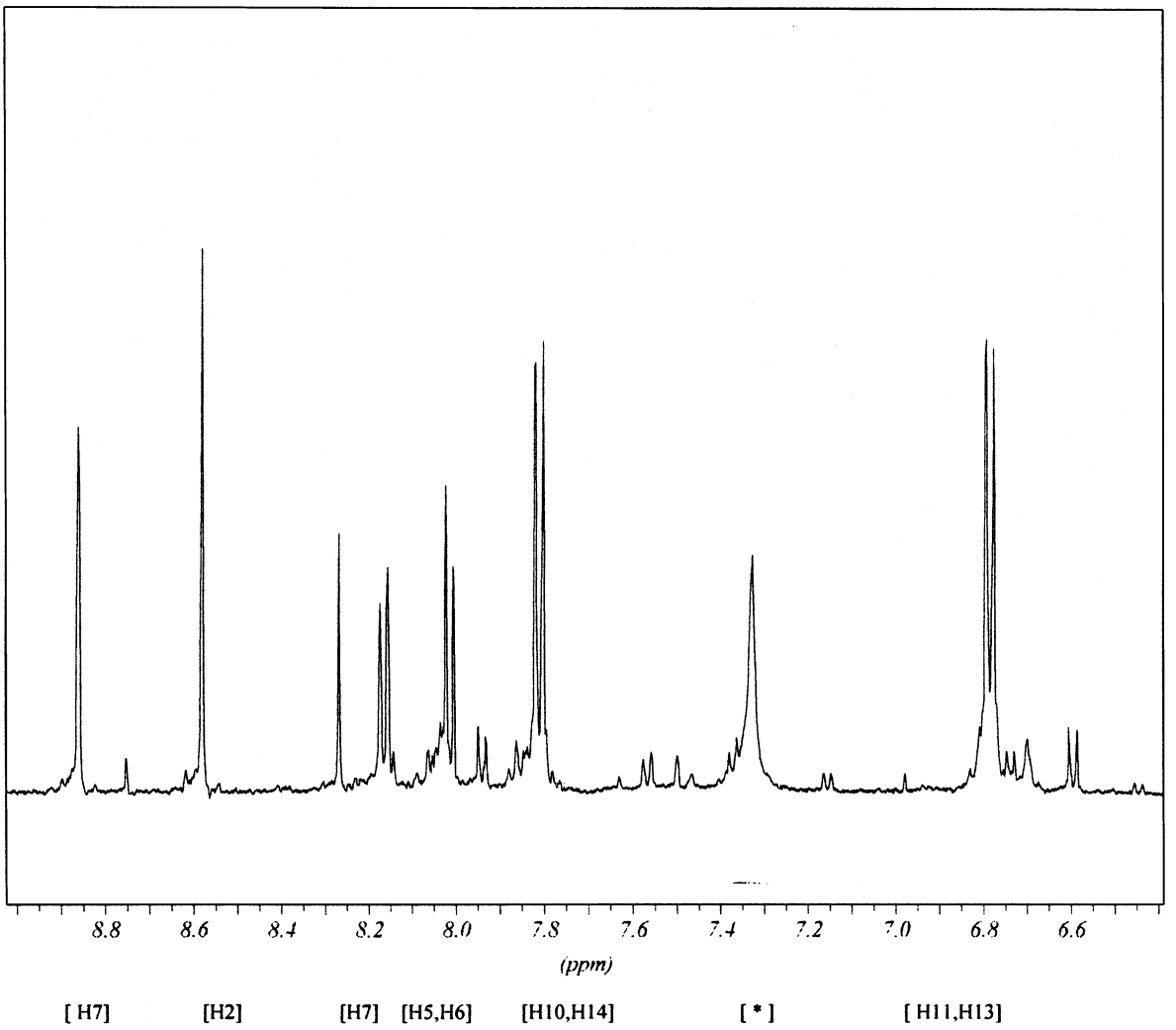


Fig. 7. ^{1}H-NMR spectrum (aromatic region) for compound **I**. Strongly predominate AB system from two pairs protons (H14, H13) and (H10, H11) giving dublets at 6.85 and at 7.80 ppm as well as double less intensity AB system for H5, H6 pair evidenced the structure with perpendicularly oriented parts of molecule (see text). Low intensity signals appeared in spectrum were excluded from consideration. The signal for H7 at 8.85 ppm represents protonated on nitrone oxygen form of molecule while signal at 8.25 ppm derived from this same unprotonated group. There is no influence visible for this process on longer distance distributed protons.

structures only in solution (DMSO, D_2O) where are no limits for conformational changes contrary to situation in the crystal net. The picture presented is also consistent with the the fact of appearance in the spectrum only one set of signals for pyridine ring. Its perpendicular orientation against second ring in both structures does not differ chemical shifts and only one spin system characteristic for pyridine moiety is observed.

For **I** crystallographical data have shown almost planar structure. For such a structure in solution we should expect for the *N*,*N*-dimethylaniline substituent on the nitrone bond two AB systems in COSY spectra. In opposition to this only one distinct AB system is observed for two pairs of protons H10, H11 and H14, H13 (see Fig. 7). The equivalence of these two pairs protons is possible only in the case of perpendicular orientation of this aromatic substituent to the plane

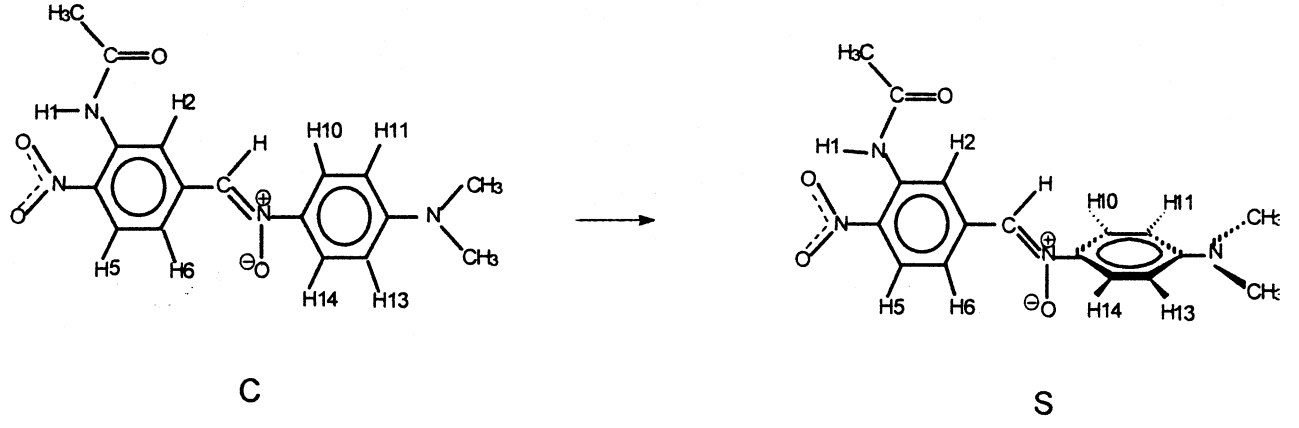


Fig. 8. The structure change of compound **I** due to transfer from crystal state c to solution s. Designations: c — structure in crystal, s — structure appeared in solution only.

containing the rest of the molecule (see Fig. 8). Conclusion is that in this case 'transfer' of the molecule from crystal state to the solution gives possibility to form open edge to face like structure. The role of face in this structure plays the *N*,*N*-dimethylaniline substituent while the nitrone bond appears here as edge (the angle between face and edge is close to 120° so we called it open edge to face structure). All this gave us an argument to state that for nitrones like compound **I** in solution the **tendency for edge to face structure creation** predominates the **electron pair in nitrone bond coupling** with aromatic substituents, which needs the planar structure of whole molecule like the one found in crystal net. The last statement is consistent with negative results of trials to obtain liquid crystal nitrones where two aromatic substituents are settled on this moiety. In respect to the need of coplanar orientation of aromatic parts in molecules possessing liquid crystal phases our observation presented in this paper explains why aromatic nitrones do not reveal such properties. Using the comparison of nitrones to amides presented in introductory part of this work, we can predict that also an amide bond is not a good candidate for construction of liquid crystals because of charged resonance form of this bond presence what might destroy coplanar orientation of aromatic rings in liquid state. An examination of liquid crystals database for aromatically substituted nitrones and amides fully support our conclusions [19]. None of the nitrones and amides present possessed liquid crystals properties.

Presented above are the results that are in good agreement with analysis of benzyl pirydynium bromide given by Anders et al. [15] where the perpendicular orientation of aromatic ring is observed in the crystal and 90° torsion angle between pyridinium ring and the rest of the molecule is postulated by PM3, MNDO and MINDO/3 for minimum energy conformation. Presented here investigations are supported also by data of Martin et al. [17] where for *N*-benzyl-2-phenylpyridinium bromide derivatives the orientation of two coplanar aromatic substituents are perpendicular to the pyridine ring.

4. Conclusions

The data presented above is an evidence that 3-acetamido-4-nitrobenzylpyridynium bromide appears in edge to face conformation in crystal state as well as in solution. There in solution only two possible edge to face structures of this compound were detected.

For *N*-(*p*-dimethylaminophenyl)-α-(3acetamido-4-nitrophenyl) nitrone the planar structure of whole molecule was established by crystallographical method.

The NMR measurements have given proofs that main conformation of this compound in solution has perpendicularly oriented *N*,N-dimethylaniline substituent against the rest of the molecule.

This tendency has been recognized as the main cause of impossibility (known from literature) to obtain aromatically substituted nitrones possessed liquid crystal phases.

Above results are giving an argument to state that edge to face interaction between aromatic rings is very important and common factor of the structure formation in small molecules like the ones presented here as well as in the larger peptides that was discussed in the article.

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