

AN *ab initio* MO STUDY OF CONFORMATION STRUCTURE OF NICOTINAMIDE AND ITS DERIVATIVES*

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Received December 23rd, 1981

Conformation of nicotinamide (*I*), 3-carbamoylpyridinium (*IIa*), 1-methyl-3-carbamoylpyridinium (*IIb*), and 1-methyl-1,4-dihydrinicotinamide (*IIIa*) has been studied in the rigid rotor approximation on the basis of non-empirical STO-3G wave functions. The rotation barriers decrease in the order: *IIIa* > *I* ~ *IIb* > *IIa*. When confronted with semiempirical calculations, the conformation curves of molecular energy show a better qualitative similarity to the EHT than to NDDO and particularly to CNDO/2 curves. Relation of the calculated characteristics to experimental findings is discussed.

Conformation behaviour of nicotinamide (*I*) is, in fact, restricted to rotation around the C—C' bond between amide group and the heterocycle resulting in formation of *syn* and *anti* conformer types. Whereas X-ray diffraction of crystalline compound *I* showed¹ exclusively the presence of the *anti* form, dielectric measurements² of solutions of *I* in benzene and dioxane revealed equilibria of the type $I(\textit{syn}) \rightleftharpoons I(\textit{anti})$. Semiempirical calculations on the basis of EHT (ref.³⁻⁵) and NDDO (ref.⁶) wave functions prefer energetically the form *I(anti)*, but the CNDO/2 (ref.²), MINDO/2 (refs^{2,7}), and PCILO data⁸ give no unequivocal results. X-Ray diffraction studies of more complex bioorganic systems involving the ionic fragment type *II* found *syn*-conformation of the amide group^{9,10} as well as *anti*-conformation, which depended on anion component (X^-) of the ion pair *II*—*X* ($R = CH_3$). In the 1,4-dihydro derivatives type *IIIb*, the *syn*-conformation could only be found¹¹. Whereas the experimentally found conformation of compound *III* fully agrees with results of MO calculations of the *IIIa* model in the basis of EHT (ref.¹²), CNDO/2 (ref.²), MINDO/2 (refs²), and PCILO (ref.⁸) wave functions, similar semiempirical MO studies¹³⁻¹⁵ of the ion *IIb* gave no such unequivocal results. Thus in application of the EHT method, relative energies of the ions *IIa(anti)* and *IIa(syn)* depend on how many geometry degrees of freedom were optimized¹³.

The aim of this paper is to elucidate the extent to which inconsistency of the above-mentioned MO calculations is affected by choice of empirical parameters; therefore

* Part XXI in the series On Calculations of Biologically Important Compounds; Part XX: Int. J. Quantum Chem., in press.

we decided to study the conformational behaviour in MO models of *I*, *IIa,b*, and *IIIa* by non-empirical *ab initio* calculation. The study was restricted to application of the contracted minimum STO-3G basis set of AOs. A recent analogous MO calculation¹⁶ of *IIIa* ion was only focused on study of interaction with hydride ion, the conformational aspect being not considered.

CALCULATIONS

All the calculations were carried out with the use of standard program Gaussian 76. For the starting geometry we used the bond lengths and angles obtained¹⁷ by gradient optimization¹⁸ on the basis of CNDO/2 wave function except for the torsion angle α between amide group and heterocyclic fragments which was considered variable (the rigid rotor model). This approximate procedure was chosen with respect to possible comparison with semiempirical data published earlier. Table I gives the non-empirically calculated total molecular energies E_{tot} of the STO-3G models of *I* to *IIIa*. The geometries corresponding to the minima at the respective curves $E_{\text{tot}} = f(\alpha)$ were not further optimized and were assigned to equilibrium conformational states

RESULTS AND DISCUSSION

Conformation: Fig. 1 gives energy dependences $E_{\text{tot}} = f(\alpha)$ for the STO-3G models of *I*, *IIa,b*, and *IIIa*. Mutual similarity is seen in the pairs *I-IIa* and *IIb-IIIa*, the former preferring *anti* conformations, and the latter preferring *syn* conformations. Comparison of the curves $E_{\text{tot}} = f(\alpha)$ shows also that the protonation process $I + H^+ \rightarrow IIa$ should result in lowering of rotation barrier of amide group and, hence, in acceleration of establishing of the *syn* \rightleftharpoons *anti* equilibrium. Moreover, the protonated form *IIa* shows a decrease in relative preference of the *anti*-conformer ($\alpha_{\text{min}} = 15^\circ$) as compared with analogous form of the non-protonated amide *I* ($\alpha_{\text{min}} = 25^\circ$). It is noteworthy in this context that the largest energy should be needed to overcome the stabilizing conjugation effects in the ion *IIa* ($\alpha_{\text{max}} = 90^\circ$), whereas in the free base *I* this energy should be needed to overcome the non-bonding interactions (*ortho*-effect) between NH_2 group of the amide fragment and hydrogen centre at 2-position ($\alpha_{\text{max}} = 0^\circ$). In the case of the latter pair *IIb-IIIa*, representing in fact a trivial model of $NAD^+ - NADH$, the curves $E_{\text{tot}} = f(\alpha)$ are quite similar. This finding can be interpreted as a theoretically justified argument supporting the idea that the biologically important process $NAD + 2e^- + H^+ \rightleftharpoons NADH$ could take place without any distinct conformational change in amide group of the nicotinamide fragment of the coenzyme. Thus *syn*-conformation is preferred in the compounds *IIb* and *IIIa* markedly ($\alpha_{\text{min}} = 165^\circ$ and 180° , respectively), the rotation barrier of the 1,4-dihydro derivative *IIIa* being higher than that of the *IIb* ion by 12.9 kJ mol^{-1} . According to the STO-3G calculation, the energy needed to interrupt conjugation of the π system in *IIIa* is even higher ($\alpha_{\text{max}} = 90^\circ$) than that for overcoming of the steric hindrance due to non-valence interactions ($\alpha_{\text{max}} = 0^\circ$).

TABLE I
STO-3G total and relative energies of rotation conformers of the structures studied

Angle	<i>I^a</i>			<i>IIa</i>			<i>IIb</i>			<i>IIIa^b</i>		
	E_{tot}^c	E_{rel}^d	E_{tot}^c	E_{rel}^d	E_{tot}^c	E_{rel}^d	E_{tot}^c	E_{rel}^d	E_{tot}^c	E_{rel}^d	E_{tot}^c	E_{rel}^d
0	-409-176816	1-4	-409-611214	0-3	-448-186051	20-1	-448-876969	30-0				
15	-409-177275	0-2	-409-611329	0-0	-448-188622	13-3	-448-878544	25-8				
30	-409-177275	0-2	-409-611080	0-7	-448-187758	15-6	-448-880649	20-3				
45	-409-174534	7-4	-409-609895	3-8	-448-186710	18-4	-448-880425	20-6				
60	-409-174534	7-4	-409-608183	8-3	-448-189611	10-7	-448-878814	25-1				
75	-409-172260	13-4	-409-606793	11-9	-448-877460	28-7	-448-877072	29-7				
90	-409-172260	13-4	-409-606309	13-2	-448-876481	31-2	-448-876481	31-2				
105	-409-173380	10-4	-409-606930	11-6	-448-879707	22-8	-448-877460	28-7				
120	-409-173380	10-4	-409-608365	7-8	-448-882528	15-3	-448-879707	22-8				
135	-409-173257	10-7	-409-609881	3-8	-448-885293	8-1	-448-882528	15-3				
150	-409-168941	22-1	-409-610424	2-4	-448-887478	2-3	-448-885293	8-1				
165	-409-168941	22-1	-409-609638	4-4	-448-88366	0-0	-448-887478	2-3				
180	-409-168941	22-1	-409-608944	6-3	-448-88366	0-0	-448-88366	0-0				

^a The compound *I* was, moreover, calculated for the angles 22-5°, 25-0°, 27-5°, 32-5°. The corresponding total/relative energies are: -409-177324/0-04, -409-177340/0-0, -409-177324/0-04, -409-177188/0-4; ^b the compound *IIIa*, was, moreover, calculated for the angles 170° and 175°. The corresponding total/relative energies are: -448-887911/1-2, -448-888215/0-4; ^c the values are given in dimensionless units $E = E_{\text{tot}}/E_h$ where $E_h = 2\ 628\text{-}1\ \text{kJ mol}^{-1}$; ^d the values are given in kJ mol^{-1} .

Comparison of the said curves $E_{\text{tot}} = f(\alpha)$ with analogous curves obtained^{2,6,8,12,15} by semiempirical MO procedures enables to specify some general features of the non-empirical approach in the terms of the rigid rotor approximation. Generally, the STO-3G calculation results in higher rotation barriers (Figs 2–4) and differs distinctly from the CNDO/2 rigid rotor model which underestimates the rotation barriers due to conjugation of the π system ($\alpha = 90^\circ$)^{19,20}. In the case of nicotinamide *I* itself (Fig. 2) the best similarity was obtained with the curve $E_{\text{tot}} = f(\alpha)$ calculated³ by EHT method, which resembles the situation of *I**b*** ion (see Fig. 3 in ref.¹⁵). The NDDO calculation⁶ of the model *I* approximates best the rotation barrier due to conjugation ($\alpha_{\text{max}} = 90^\circ$), but it underestimates the non-bonding *ortho* repulsion ($\alpha_{\text{max}} = 0^\circ$). In the case of 1,4-dihydro derivative *IIIa* (Fig. 3) there is a considerable similarity with the NDDO curve⁶ and with simple EHT calculation¹². At the same time it is obvious that the absence of the minimum at $\alpha \approx 40^\circ$ in the CNDO/2 calculation² represents an often observed artefact of underestimation of the rotation barrier due to conjugation effects ($\alpha \approx 90^\circ$) in this method.

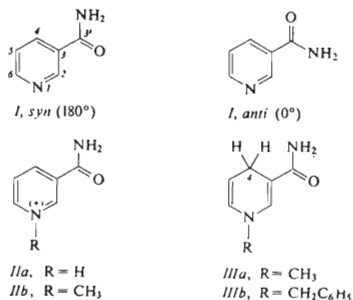


Table II summarizes the discussed energy characteristics of the STO-3G and semiempirical MO models of *I–IIIa* and compares them with the experimental findings obtained by X-ray diffraction^{1,9,10,11}. Obviously, the non-empirical calculation leads to some further differences in the energy characteristics of the conformational curves $E_{\text{tot}} = f(\alpha)$ as far as energy differences (ΔE) between *syn*- and *anti*-conformers and transformation (E_{trans}) and racemization energies (E_{rac}) are concerned. With respect to experimental findings it is clear that the torsion angles α obtained by the STO-3G calculation for the energetically most favourable conformation agree with the experimental data (α_{exp}) better than or comparably to the α angles calculated semiempirically.

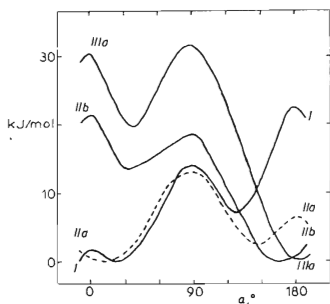


FIG. 1

Comparison of dependences of the STO-3G molecular energies of compounds I-III on the rotation angle α

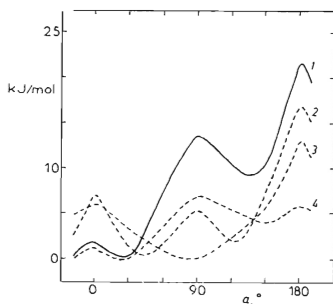


FIG. 2

Comparison of dependence of the STO-3G molecular energy of compound I on the rotation angle with similar semiempirical data^{2,3,6}. 1 - STO-3G; 2 - EHT, 3 - CNDO/2; 4 - NDDO

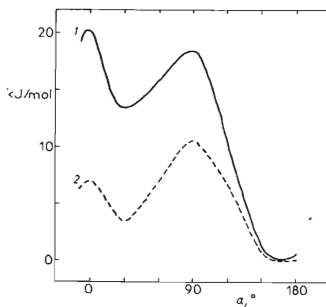


FIG. 3

Comparison of dependence of the STO-3G molecular energy of compound IIb on the rotation angle with analogous semiempirical data¹⁵. 1 - STO-3G; 2 - EHT

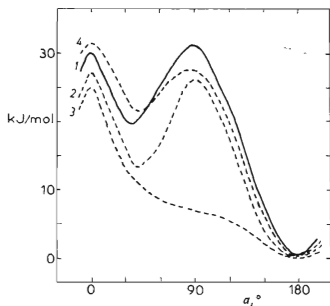


FIG. 4

Comparison of dependence of the STO-3G molecular energy of compound IIIa on the rotation angle with similar semiempirical data^{2,6,12}. 1 - STO-3G; 2 - EHT; 3 - CNDO/2; 4 - NDDO

Orbital structure: In analogy to the semiempirical calculations, the non-empirical HOMOs and LUMOs of all the investigated systems are of π type, and their character is not substantially affected by change of torsion angle in the region of planar molecular fragments. Figure 5 represents schematically nodal properties and shape of the two frontier MOs for nicotinamide (*I*), NAD^+ model *I**b***, and NADH model *I**IIa***. The orbital characteristics of the two ions *I**a***, *b* differ but slightly, and, therefore, the case *I**a*** is not discussed later. It is seen that the compound *I* exhibits nodal planes in the HOMO which are perpendicular to $\text{N}(1)\text{—C}(2)$, $\text{C}(4)\text{—C}(5)$, $\text{C}(3)\text{—C}(3')$ bonds, those in the LUMO being perpendicular to $\text{C}(2)\text{—C}(3)$, $\text{C}(3)\text{—C}(4)$, $\text{C}(5)\text{—C}(6)$, $\text{C}(6)\text{—N}(1)$, $\text{C}(3')\text{—O}$, and $\text{C}(3')\text{—N}(\text{H}_2)$ bonds. The HOMO of *I**b*** ion has identical character, but the LUMO already differs, its nodal planes being perpendicular to the bonds $\text{N}(1)\text{—C}(2)$, $\text{C}(3)\text{—C}(4)$, $\text{C}(4)\text{—C}(5)$, $\text{C}(6)\text{—N}(1)$, $\text{C}(3')\text{—O}$, and $\text{C}(3')\text{—N}(\text{H}_2)$. It is noteworthy that the HOMO of the model of the reduced form *I**IIa*** has a similar shape, especially so in the region of dihydropyridine ring, with the nodal planes for the bonds $\text{N}(1)\text{—C}(2)$, $\text{C}(3)\text{—C}(3')$, $\text{C}(3')\text{—N}(\text{H}_2)$, $\text{C}(3)\text{—}$

TABLE II

Comparison of energy barriers in the compounds studied. The energy values are given in $\text{kJ} \cdot \text{mol}^{-1}$, the angles in degrees. E_{rot} is given by difference of energy values of the maximum separating the two types of conformers and the deeper minimum belonging to one of the conformers; E_{transf} is given by difference of values of the maximum separating the two types of conformers and the shallower minimum belonging to one of the conformers; E_{rac} is given by difference of values of the local maximum and minimum belonging to the same conformer; $\Delta E = |E_{\text{rot}}(\text{syn}) - E_{\text{rot}}(\text{anti})|$

Compound	Method	<i>anti</i>		<i>syn</i>		E_{transf}	E_{rot}	E_{rac}		ΔE
		α_{calc}	α_{exp}	α_{calc}	α_{exp}			<i>syn</i>	<i>anti</i>	
<i>I</i>	STO-3G	25	24 ^a	138	—	4.3	13.4	12.3	1.8	9.2
	NDDO ^b	29	—	151	—	2.5	7.0	1.0	1.0	4.2
	EHT ^c	43	—	120	—	3.3	4.8	14.5	6.4	1.5
<i>IIa</i>	STO-3G	15	—	150	—	10.8	13.2	3.8	0.4	2.4
<i>IIb</i>	STO-3G	30	5 ^{d,e}	165	166 ^{d,i}	5.0	18.4	0.2	6.8	13.3
	EHT ^f	30	3 ^{g,h}	180	152 ^{d,j}	6.8	10.2	0.0	3.4	3.4
<i>IIIa</i>	STO-3G	37	—	180	176 ^k	11.7	31.2	0.0	10.3	19.5
	NDDO ^l	0	—	135	—	7.1	27.9	0.0	10.5	20.9
	EHT ^m	40	—	180	—	12.7	26.0	0.0	16.7	13.3

^a Ref. 1; ^b ref. 6; ^c ref. 3; ^d ref. 10; ^e picrate; ^f ref. 15; ^g ref. 9; ^h 9-adenyl acetate; ⁱ iodide; ^j chloride; ^k 1-benzyl derivative, ref. 11; ^l ref. 6; ^m ref. 12.

—C(4), C(4)—H, C(4)—C(5), C(6)—N(1), and C—(H₃). This fact could facilitate considerably the effectiveness of electron-transfer between the two heterocyclic system *I Ib* and *I IIIa*. Participation of antisymmetrical combination of 1s AOs of hydrogen atoms in the C(4)—H bonds confirms the high degree of hydrogen hyperconjugation found already^{2,6,12} with the semiempirical HOMOs of 1,4-dihydropyridine derivatives. High values of the expansion coefficients of AOs at 4 position in LCAO of the both discussed frontier MOs of the NAD⁺—NADH models *I Ib* and *I IIIa* agree (similarly as the semiempirical calculations^{2,6,12}) with behaviour of the respective coenzymes in biochemical redox processes. The less important (for these considerations) LUMO of dihydro derivative *I IIIa* exhibits nodal planes crossing the bonds N(1)—C(2), C(2)—C(3), C(3')—N(H₂), C(3')—O, C(4)—C(5), and C(5)—C(6), showing thus no distinct similarity to some of the discussed frontier orbitals. Orbital energies of the HOMO and the LUMO are characteristically changes on variation of the torsion angle α . From Table III it follows that the HOMO energies decrease, and the LUMO energies increase for $\alpha \rightarrow 90^\circ$, the highest sensitivity of these changes being seen with the neutral forms *I* and *I IIIa*.

Electron distribution: The electric dipole moments calculated for the considered set of nicotinamide rotamers (*I*, $0^\circ \leq \alpha \leq 180^\circ$) vary within the limits $3.308 \cdot 10^{-30}$ to $14.514 \cdot 10^{-30}$ Cm (the experimental data² is $11.239 \cdot 10^{-30}$ Cm), being always lower than those obtained by semiempirical calculations^{2,3,6}. With 1,4-dihydro-nicotinamide (*I IIIa*, $0^\circ \leq \alpha \leq 180^\circ$) the range of the corresponding values ($16.208 \cdot 10^{-30}$ to $9.438 \cdot 10^{-30}$ Cm; experimental data¹² is $13.340 \cdot 10^{-30}$ Cm) suggests that the STO-3G moments again are much too low with respect to the fact that the *syn*-conformer ($\mu_{\text{calc}} = 9.438 \cdot 10^{-30}$ Cm) should by far predominate according to the above-mentioned analysis and also with respect to the calculated² CNDO/2 moment ($\mu_{\text{calc}} = 12.406 \cdot 10^{-30}$ Cm). These findings indicate with respect to the characteristic underestimation of values, in accordance with analogous literature data (refs²¹⁻²³), that the minimum STO-3G basis set is insufficient for desirable accuracy of calculation of electric dipole moments of compounds *I* and *I IIIa*. Nevertheless, other partial STO-3G characteristics of electron distribution (as e.g. electronic charges and bond populations) exhibit obviously more reliable relations to the experimental characteristics than the analogous semiempirical data.

Table IV compares the STO-3G charge distributions in the MO models *I*—*I IIIa* with analogous Q_{tot} charges obtained semiempirically^{2,7,15}. It is seen that introduction of non-empirical values Q_{tot} for hydrogen atoms removes the artificial negative charge densities at some centres. The Q_{tot} values show, however, the most important differences from the NDO calculations at heteroatoms, where the non-empirical calculation locates more distinctly the electrons at oxygen atoms of amide groups. The STO-3G values Q_{tot} are supported by their being more reproducibly related to chemical shifts in ¹H and ¹³C NMR spectra^{24,25}. From Table V it follows that the

TABLE III
Change of the HOMO and LUMO energies of compounds I–III in rigid rotor model^a

α	0	30	60	90	120	150	180
Nicotinamide I							
HOMO	-0.289	-0.290	-0.293	-0.296	-0.292	-0.288	-0.287
LUMO	0.217	0.222	0.233	0.233	0.231	0.221	0.216
3-Carbamoylpyridinium (IIa)							
HOMO	-0.426	-0.425	-0.425	-0.425	-0.425	-0.424	-0.424
LUMO	-0.042	-0.042	-0.042	-0.042	-0.042	-0.043	-0.044
1-Methyl-3-carbamoylpyridinium IIb							
HOMO	-0.425	-0.424	-0.424	-0.424	-0.423	-0.423	-0.423
LUMO	-0.039	-0.038	-0.038	-0.037	-0.037	-0.038	-0.039
1-Methyl-1,3-dihyronicotinamide IIIa							
HOMO	-0.197	-0.196	-0.197	-0.197	-0.198	-0.197	-0.196
LUMO	0.243	0.250	0.271	0.289	0.271	0.254	0.248

^a The values are given in dimensionless units $E = E_n/h$, where $h = 2.628 \cdot 1 \text{ kJ mol}^{-1}$.

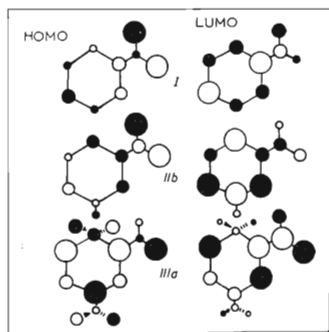


FIG. 5
Comparison of character of the STO-3G HOMO and LUMO of the compounds I–III at $\alpha = 0^\circ$

said quantities exhibit similar trends, the correlations being even quantitative in the cases of ^{13}C chemical shifts of *I*, *IIa* and ^1H chemical shifts of *IIIa*. Noteworthy differences in σ and π charge distributions of the pair *I**IIb*–*IIIa* are given in Table VI. Typically, N(1) and N(H₂) centres carry strong positive σ charge (Q_σ) and even stronger negative π charge (Q_π), hence the resulting negative charge (Q_{tot}) corresponds to the non-compensated part of the π component (Q_π). On the contrary, the σ charges (Q_σ) at oxygen centres are negligible, and the resulting negative charge (Q_{tot}) is practically equal to the π component alone (i.e. $Q_{\text{tot}} \approx Q_\pi$). A different situation is encountered with the amide C(3') atom whose resulting positive charge Q_{tot} is due practically to σ component of *I**IIb* ion (i.e. $Q_{\text{tot}} \approx Q_\sigma$), whereas in the 1,4-dihydro derivative *IIIa* it is composed of almost equal contributions of Q_π and Q_σ components. At the other carbon centres the combinations of the two charge types (Q_π , Q_σ) are irregular. The overall Q_{tot} charge distribution depends little on the torsion angle α , which is due to mutual compensations of larger changes in Q_π and Q_σ .

TABLE IV

Comparison of non-empiric and semiempiric charges of atomic centres of compounds *I*–*III*. The values are given for $\alpha = 0^\circ$

Position	<i>I</i>		<i>IIa</i>		<i>IIb</i>		<i>IIIa</i>	
	STO-3G	CNDO/2 ^a	STO-3G	MINDO/2 ^b	STO-3G	CNDO/2 ^c	STO-3G	CNDO/2 ^d
N(1)	-0.244	-0.143	-0.237	-0.279	-0.185	0.075	-0.286	-0.118
C(2)	0.035	0.097	0.133	0.296	0.140	0.145	0.096	0.152
C(3)	-0.031	-0.064	-0.001	-0.205	-0.005	-0.035	-0.069	-0.122
C(4)	-0.035	0.056	0.040	0.217	0.027	0.105	-0.095	0.049
C(5)	-0.065	-0.034	-0.045	-0.070	-0.045	-0.002	-0.078	-0.056
C(6)	0.041	0.106	0.135	0.305	0.128	0.136	0.053	0.093
C(1)	—	—	—	—	-0.063	^e	-0.044	0.090
C(3')	0.310	0.358	0.290	0.826	0.289	0.366	0.275	0.360
N(H ₂)	-0.411	-0.243	-0.399	-0.592	-0.394	-0.257	-0.409	-0.243
O	-0.294	-0.354	-0.227	-0.576	-0.236	-0.310	-0.312	-0.401
H(1)	—	—	0.303	^e	0.121 ^f	^e	0.067 ^f	-0.041 ^f
H(2)	0.065	-0.015	0.138	^e	0.159	^e	0.091	0.009
H(4) ^f	0.092	0.007	0.153	^e	0.123	^e	0.043	-0.018
H(5)	0.072	0.007	0.141	^e	0.136	^e	0.054	0.002
H(6)	0.074	-0.016	0.153	^e	0.144	^e	0.066	-0.034
H(NH ₂) ^f	0.196	0.119	0.211	^e	0.210	^e	0.183	0.120

^a Taken from ref.²; ^b taken from ref.⁷; ^c taken from ref.¹⁵; ^d ref.²; ^e the value is not given in the paper cited; ^f average value.

TABLE V

Application of correlations of chemical shifts in NMR spectra of the compounds I-III to estimation of charge densities at the carbon and hydrogen atoms

Parameter	$Q(H) = a\delta(H) + b$					$Q(C) = a\delta(^{13}C) + b$					
	H(2)	H(4)	H(5)	H(6)	<i>a, b, r</i>	C(2)	C(3)	C(4)	C(5)	C(6)	<i>a, b, r</i>
Nicotinamide I											
$\delta(\text{ppm})^a$	8.89	8.18	7.52	8.68	$5.4148 \cdot 10^{-3}$	80.87	62.22	69.56	57.60	85.04	$-5.1773 \cdot 10^{-3}$
$Q_{\text{STO-3G}}$	0.935	0.908	0.928	0.926	$8.7921 \cdot 10^{-1}$	5.965	6.031	6.035	6.065	5.959	6.3764
Q_{calc}	0.879	0.972	0.920	0.926	0.287	6.958	6.054	6.016	6.078	5.936	0.990
3-Carbamoylpyridinium IIa											
$\delta(\text{ppm})^a$	9.33	9.03	8.28	9.13	$-3.3828 \cdot 10^{-3}$	74.44	66.07	78.97	61.15	76.98	$-8.5159 \cdot 10^{-3}$
$Q_{\text{STO-3G}}$	0.862	0.847	0.859	0.847	$8.8400 \cdot 10^{-1}$	5.867	6.001	5.960	6.045	5.865	6.5561
Q_{calc}	0.852	0.853	0.856	0.853	0.197	5.922	5.993	5.884	6.035	5.900	0.927
1-Methyl-3-carbamoylpyridinium IIb											
$\delta(\text{ppm})^a$	9.32	8.94	8.25	9.03	$-1.6951 \cdot 10^{-2}$	78.36	67.08	77.17	61.85	80.75	$-8.9480 \cdot 10^{-3}$
$Q_{\text{STO-3G}}$	0.841	0.877	0.864	0.856	1.0101	5.860	6.005	5.973	6.045	5.872	7.2077
Q_{calc}	0.852	0.859	0.870	0.857	0.510	5.903	6.004	5.914	6.051	5.882	0.891
1-Methyl-1,4-dihydropyridinamide IIIa											
$\delta(\text{ppm})^b$	6.97	2.86	4.72	5.68	$-1.1935 \cdot 10^{-2}$	138.1	96.7	20.6	101.0	127.9	$-1.4755 \cdot 10^{-3}$
$Q_{\text{STO-3G}}$	0.909	0.957	0.946	0.934	$9.9779 \cdot 10^{-1}$	5.904	6.049	6.095	6.078	5.947	6.1616
Q_{calc}	0.913	0.961	0.942	0.930	0.976	5.958	6.019	6.131	6.012	5.973	0.783

^a Ref.^{2,4}, ^b refs.^{1,2,25}.

TABLE VI
Comparison of the STO-3G σ and π charge populations in compounds *Ib* and *IIIa*

Position	<i>Ib</i>		<i>IIIa</i>	
	Q_{σ}	Q_{π}	Q_{σ}	Q_{π}
N(1)	0.244	-0.429	0.442	-0.728
C(2)	0.007	0.133	0.028	0.068
C(3)	-0.003	-0.002	0.078	-0.147
C(4)	-0.148	0.175	-0.089	-0.006
C(5)	-0.057	0.011	-0.009	-0.069
C(6)	0.019	0.109	0.074	-0.021
C(3')	0.224	0.065	0.168	0.107
N(H ₂)	0.427	-0.821	0.429	-0.838
O	0.007	-0.243	0.021	-0.333

charges. The values of bond populations $P(\text{CO})$ and $P(\text{CNH}_2)$ also agree qualitatively with experiment. The calculated $P(\text{CO})$ values for the structures *I-IIIa* are: 0.433, 0.403, 0.404, 0.497. The corresponding $P(\text{CNH}_2)$ values are: 0.385, 0.391, 0.389, 0.380. The $P(\text{CO})$ values of the 1,4-dihydro derivative *IIIa* is remarkably lower than those of the other compounds, which agrees with lower values of force constant of the C=O bond, with higher degree of its conjugation with the heterocyclic π system, as well as with the characteristics of the respective IR spectra²⁶. It is worth saying that analogous conclusion can be also made from the Wiberg indices calculated by CNDO/2 method².

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Translated by J. Panchartek.