Russian Journal of Organic Chemistry, Vol. 41, No. 4, 2005, pp. 591–598. Translated from Zhurnal Organicheskoi Khimii, Vol. 41, No. 4, 2005, pp. 601–608.

3-Oxy-5-phenyl-1*H*-1,2,3-triazole-4-carboxylic Acid. Synthesis, Structure, and Properties

O. V. Shtabova[1], S. D. Shaposhnikov[1], S. F. Mel'nikova[1], I. V. Tselinskii[1], Ch. Nather[2], T. Traulsen[2], and W. Friedrichsen[3]

[1] *St. Petersburg State Institute of Technology, Moskovskii pr. 26, St. Petersburg, 190013 Russia*
e-mail: sfm@fromru.com

[2] *Institute of Inorganic Chemistry, University of Kiel, Kiel, Germany*

[3] *Institute of Organic Chemistry, University of Kiel, Kiel, Germany*

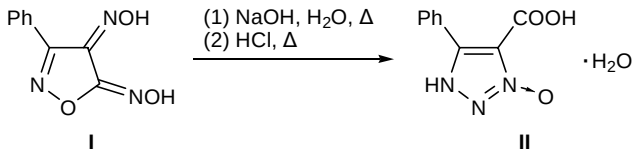
Received February 24, 2003

Abstract—The structure of 3-oxy-5-phenyl-1*H*-1,2,3-triazole-4-carboxylic acid was determined both experimentally (by the X-ray diffraction method) and by quantum-chemical calculations. Alkylation of 3-oxy-5-phenyl-1*H*-1,2,3-triazole-4-carboxylic acid (as crystal hydrate) with methyl iodide, depending on the reactant ratio, gives 1-methoxy-4-phenyl-1*H*-1,2,3-triazole-5-carboxylic acid and methyl 1-methoxy-4-phenyl-1*H*-1,2,3-triazole-5-carboxylate. Nitration of the title compound under mild conditions occurs at the 5-phenyl group with formation of *meta*-nitro derivative, while under more severe conditions 3,5-dinitrobenzoic acid is obtained. 3-Oxy-5-phenyl-1*H*-1,2,3-triazole-4-carboxylic acid was also converted into the corresponding acid chloride and substituted amide.

1,2,3-Triazole *N*-oxide derivatives attract interest from the viewpoint of synthetic organic chemistry due to diversity of their reactions. 1*H*-1,2,3-Triazole 3-oxides, which were formerly assigned the structure of *N*-hydroxy-1,2,3-triazoles, were synthesized as early as 1902 by treatment of diazo ketones with hydroxylamine in aqueous alcohol [1]. The first and the only review on the synthesis and reactivity of 1*H*-1,2,3-triazole 3-oxides was published in 1989 [2], and it stimulated further research in this field. As a result, methods for the preparation of substituted 4-amino-5-nitro-1,2,3-triazole 1-oxides via recyclization of 3,4-dinitro- and 4-alkylamino-3-nitrofuroxans [3, 4], as well as of 2-aryl-4,5-dinitro- [5] and mononitro-1,2,3-triazole 1-oxides [6] were developed. A number of 2-methyl-4(5)-nitro-5(4)-R-1,2,3-triazole 1-oxides were synthesized by nucleophilic substitution of the nitro group in 2-methyl-4,5-dinitro-1,2,3-triazole 1-oxide [7, 8].

We previously showed that heating of 4,5-bis-(hydroxyimino)-3-phenyl-4,5-dihydroisoxazole (**I**) in boiling 20% aqueous sodium hydroxide, followed by treatment with hydrochloric acid, gives 3-oxy-5-phenyl-1*H*-1,2,3-triazole-4-carboxylic acid (**II**) (Scheme 1); the product was isolated from the reaction mixture as crystal hydrate containing one water molecule [9]. The IR spectrum of *N*-oxide **II** contained absorption bands at 3490, 3371, and 3071 cm^{-1}, typical of NH and OH groups, carbonyl absorption band at 1747 cm^{-1}, and bands at 1696, 1616, 1164, 1090, and 798 cm^{-1}, which are typical of 1,2,3-triazoles and their *N*-oxides [2]. The UV spectrum of a solution of **II** in water displayed two maxima at λ 221 and 256 nm. According to the data of differential thermal analysis, compound **II** decomposes in 3 steps two of which are endothermic, and the third is exothermic. The first endothermic step starts at 90°C; it corresponds to slow elimination of water molecule and is complete at 180°C. Next follows melting (which is accompanied by decarboxylation) and fast exothermic decomposition.

Scheme 1.



I **II**

The structure of 3-oxy-5-phenyl-1*H*-1,2,3-triazole-4-carboxylic acid was studied theoretically by quantum-chemical methods and was proved by the X-ray diffraction data. Such compounds can exist as several

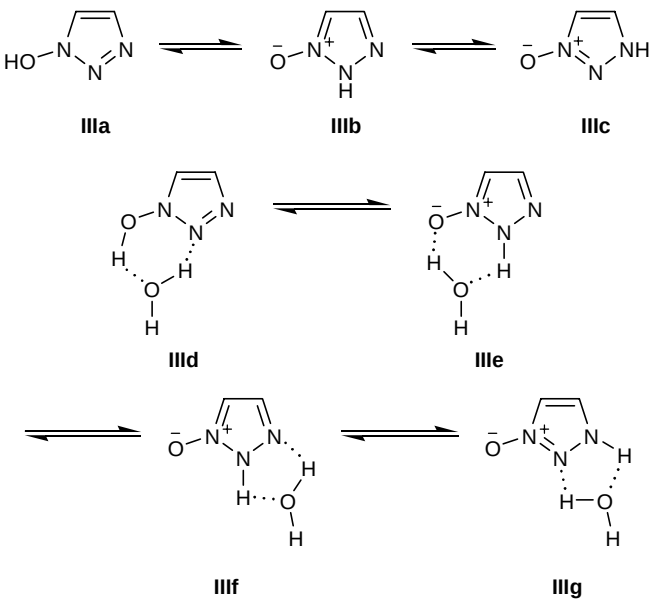
Table 1. Energies of compounds **II**–**IV** and transition states (in hartree)[a]

Structure no.	*E*	*E* + *ZPE*	*S*[b]
IIa	–737.00046	–736.84225	–11.54
IIb	–737.00491	–736.84642	–7.51
IIc	–737.01012	–	–12.85
IId	–737.00208	–	–10.88
IIe	–737.00101	–	–14.83
IIf	–737.01813	–	–15.99
IIIa	–317.38003	–317.31786	–7.95
IIIb	–317.37705	–317.31418	–8.73
IIIc	–317.37619	–317.31301	–15.09
IIId	–393.81570	–393.72776	–
IIIe	–393.81161	–393.72296	–
IIIf	–393.80175	–393.71415	–
IIIg	–393.80367	–393.71565	–
IVa	–505.95514	–505.87715	–7.37
IVb	–505.95090	–505.87264	–9.42
IVc	–505.95567	–505.87693	–18.90
TS(**IIIa**–**IIIb**)	–317.31554	–317.25768	–
TS(**IIIb**–**IIIc**)	–317.29616	–317.23865	–
TS(**IIId**–**IIIe**)	–393.79335	–393.71057	–
TS(**IIIf**–**IIIg**)	–393.75977	–393.67629	–

[a] B3LYP/6-31G(*d*).
[b] Solvation energy, kcal/mol (water, Truhlar–Cramer SM5.4).

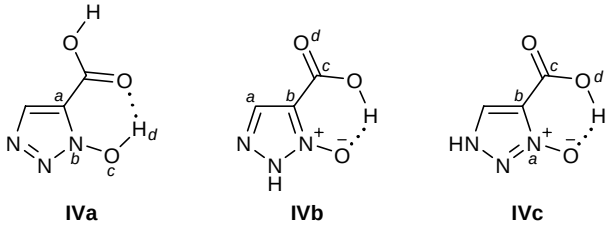
tautomers. We performed calculations in terms of the density functional theory (DFT) for both parent structures and substituted derivatives. Prototropic tautomerism of heterocycles has been extensively studied by both experimental and theoretical methods [10]. Tautomeric equilibria of heterocyclic compounds are usually described by methods taking into account electron correlation [11, 12] (e.g., Moeller–Plesset perturbation theory) and DFT methods [13–16]. If the energy difference between tautomers is small, solvent effects are to be considered [17].

Anders *et al*. in the early study [18] used high-level calculations (MP4SDTQ/6-31+G*//MP2/6-31+G*) to obtain the following relative energies of unsubstituted 1-hydroxy-1*H*-1,2,3-triazoles **IIIa**–**IIIc** in the gas phase: 0.0, 2.57, and 1.95 kcal/mol, respectively. Guimon *et al*. [19] assigned structure **IIIa** to the only tautomer detected by photoelectron spectroscopy [19]. With account taken of solvent effect (Tomasi's SCRF procedure [20]), tautomer **IIIc** turned out to be essentially stabilized, *E*(**IIIa**) – *E*(**IIIc**) = 28.89 kcal/mol (water). The DFT B3LYP calculations [21] using the 6-31G(*d*) basis set gave almost the same results; here, tautomer **IIIa** was more stable than **IIIb** (ΔE = 1.9 kcal/mol) and **IIIc** (ΔE = 2.4 kcal/mol, Table 1).



The solvent effect calculation in terms of the Cramer–Truhlar SM5.4 model [22] showed that the most stable isomer is **IIIc** (**IIIa**, 4.8 kcal/mol; **IIIb**, 5.9 kcal/mol; **IIIc**, 0.0 kcal/mol; see Table 1). Tautomeric transformations **IIIa** → **IIIb** → **IIIc** (proton migration) in the gase phase were characterized by the following energies of activation: **IIIa** → **IIIb**, $\Delta E^{\neq}$ = 40.5 kcal/mol; **IIIb** → **IIIc**, $\Delta E^{\neq}$ = 50.7 kcal/mol (Table 1). These values are consistent with the *ab initio* energies for intramolecular proton migrations like **IIIa** → **IIIb** in other azoles [8]. Participation of a solvent (in our case, water) strongly reduces the energy of activation: $\Delta E^{\neq}$(**IIId** → **IIIe**) = 14.0 kcal/mol, $\Delta E^{\neq}$(**IIIf** → **IIIg**) = 26.3 kcal/mol. The corresponding transition states [23] involve simultaneous transfer of two protons.

Introduction of a carboxy group into molecule **III** changes the energies of tautomers. In this case, rotamers **IVa**–**IVc** are expected to occupy energy minima. The most stable rotamer of triazole **IVa** gives rise to intramolecular hydrogen bond. Interestingly,

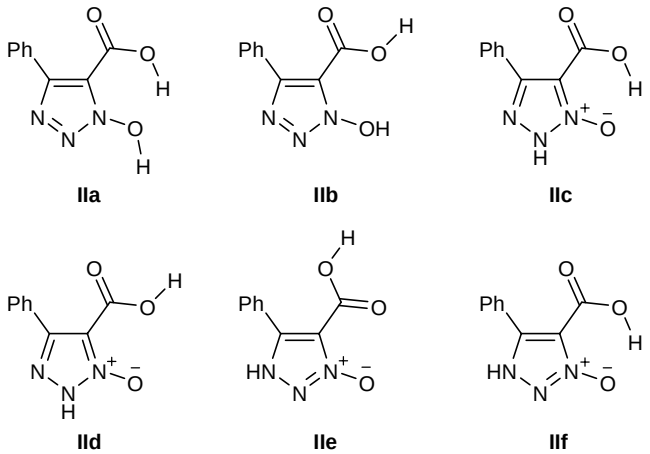


tautomer **IVc** has the lowest energy even in the gas phase. Obviously, this result originates from the stronger intramolecular hydrogen bond, as compared to structures **IIIa**–**IIIc**.

The barrier to rotation of the carboxy group in **IVc** is ΔE = 19.0 kcal/mol, which is considerably higher than the corresponding barrier found for **IVa** (ΔE = 6.2 kcal/mol). The barrier to rotation of the carboxy group in **IVb** is comparable with that in **IVc** [ΔE(**IVb**) = 18.0 kcal/mol]. Application of the Cramer–Truhlar model with water as solvent leads to a strong shift of the tautomeric equilibrium toward **IVc**; E_{rel}, kcal/mol: 7.2 (**IVa**), 6.5 (**IVb**); 0 (**IVc**). Analogous calculations on compounds **IIa**–**IIf** showed that rotamer **IIa** is less stable than **IIb** (ΔE = 2.8 kcal/mol), but in going to aqueous solution the reverse order is obtained: $\Delta[E + S$ (solvation energy)] = 1.24 kcal/mol in favor of **IIa**. Intramolecular hydrogen bond stabilizes rotamer **IIc** by ΔE = 5.3 kcal/mol relative to **IId**. The stabilizing effect becomes even stronger due to solvation: $\Delta(E + S)$ = 7.3 kcal/mol. Analogous pattaern is observed for structures **IIe** and **IIf**: ΔE = 10.7, $\Delta(E + S)$ = 11.9 kcal/mol). These data indicate that structure **IIf** is the most stable, in keeping with the results of X-ray diffraction study (Figs.1, 2; Tables 2–4).

Comparison of the calculated and experimental geometric parameters (bond lengths, bond angles, and dihedral angles) shows that the B3LYP/6-31G(*d*) method is applicable to description of the heterocyclic compounds under study. The only exception was the N^1–O^1 bond (exocyclic N–O bond) which turned out to be considerably longer (1.310 Å) than the calculated value (1.275 Å); on the other hand, this parameter insignificantly affects the energy.

The presence of an *N*-oxide moiety and a carboxy group, as well as of crystallization water, should



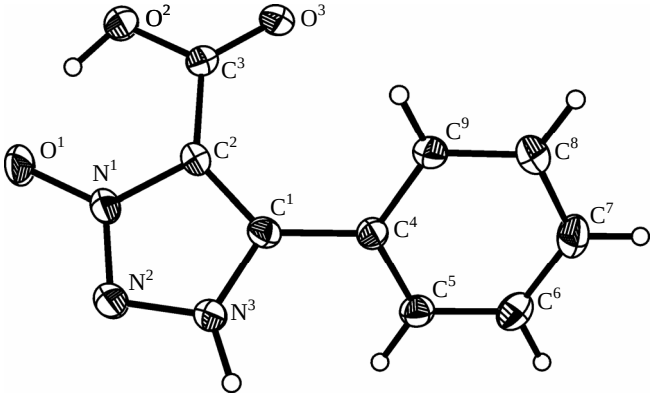


Fig. 1. Structure of the molecule of 3-oxy-5-phenyl-1*H*-1,2,3-triazole-4-carboxylic acid (**II**) with atom numbering according to the X-ray diffraction data. Thermal displacement ellipsoids are shown with a probability of 50%.

influence to some extent the reactivity of triazole derivative **II**. Treatment of triazole *N*-oxide **II** with excess nitrating mixture (HNO_3–H_2SO_4) under fairly mild conditions (50°C) resulted in introduction of a nitro group mainly into the *meta*-position of the benzene ring (compound **V**), and only traces of the corresponding *para* isomer were detected by TLC and ^{1}H NMR spectroscopy. Raising the temperature and increasing the amount of nitrating mixture led to decomposition of compound **II** and formation of 3,5-dinitrobenzoic acid **VI** (Scheme 2).

Table 2. Coordinates of atoms ($\times 10^4$) and their equivalent isotropic displacement parameters ($\times 10^3$ Å^2) in the structure of 3-oxy-5-phenyl-1*H*-1,2,3-triazole-4-carboxylic acid (**II**)

Atom	*x*	*y*	*z*	U_{eq}
C^1	8933(2)	6581(2)	6740(1)	20(1)
C^2	7248(2)	7163(2)	6345(1)	21(1)
N^1	7368(2)	6944(2)	5573(1)	26(1)
N^2	8941(2)	6284(2)	5461(1)	30(1)
N^3	9878(2)	6073(2)	6181(1)	25(1)
O^1	6089(2)	7358(2)	4984(1)	37(1)
C^3	5636(2)	8042(2)	6577(1)	21(1)
O^2	4392(2)	8621(2)	6001(1)	30(1)
O^3	5485(2)	8265(2)	7249(1)	27(1)
C^5	11594(2)	6937(2)	7797(1)	23(1)
C^6	12361(2)	6911(2)	8577(1)	28(1)
C^7	11299(2)	6448(2)	9128(1)	30(1)
C^8	9469(2)	5980(2)	8900(1)	27(1)
C^9	8682(2)	6006(2)	8121(1)	21(1)
O^4	3291(2)	4760(2)	6294(1)	27(1)

Table 3. Hydrogen bond parameters in 3-oxy-5-phenyl-1*H*-1,2,3-triazole-4-carboxylic acid (**II**) in crystal (D stands for donor, and A, for acceptor)

D–H bond	*d*(D–H), Å	*d* (H···A), Å	∠D(H···A), deg	*d*(D···A), Å	A
N^3–H^1N	0.945	1.734	178.86	2.678	O^4 [*x* + 1, *y*, *z*]
O^2–H^1O	0.929	1.640	157.78	2.525	O^1
O^2–H^1O	0.929	1.640	157.78	2.525	O^1
O^4–H^3O	0.862	1.933	171.11	2.788	O^3 [–*x* + 1, *y*–1/2, –*z* + 3/2]
O^4–H^2O	0.889	1.960	170.21	2.840	O^1 [–*x* + 1, –*y* + 1, –*z* + 1]
O^4–H^2O	0.889	2.641	153.64	3.459	N^1 [–*x* + 1, –*y* + 1, –*z* + 1]
O^4–H^2O	0.889	2.687	128.79	3.317	N^2 [–*x* + 1, –*y* + 1, –*z* + 1]

Triazole **II** behaved in a specific fashion in the alkylation with methyl iodide. The reaction of **II** with an equimolar amount of methyl iodide in DMF in the presence of potassium carbonate involved the *N*-oxide oxygen atom to give 1-methoxy-4-phenyl-1*H*-1,2,3-triazole-5-carboxylic acid (**VII**); with 2 equiv of MeI or more, esterification of the carboxy group occurred to afford *O,O'*-dimethyl derivative **VIII** (Scheme 3).

The ^{1}H NMR spectra of compounds **VII** and **VIII** contained signals from the aromatic protons (δ 7.75–7.35 ppm) and methoxy groups [δ 4.33 ppm (**VII**); δ 4.35 (MeON) and 3.87 ppm (MeOC) (**VIII**)]. The assignment of the methoxy protons was confirmed by comparison with the ^{1}H NMR spectrum of methyl 3-oxy-5-phenyl-1*H*-1,2,3-triazole-4-carboxylate (**IXa**) which was synthesized by reaction of carbonyl chloride **X** with methanol. In the spectrum of **IXa**, the signal from the methoxy protons appeared at δ 3.86 ppm. Our results indicate that the alkylation of triazole *N*-oxide **II** does not involve the N^1 atom.

We succeeded in synthesizing 3-oxy-5-phenyl-1*H*-1,2,3-triazole-4-carbonyl chloride (**X**) only by fusion of **II** with PCl_5; our attempts to effect this transformation with the use of $SOCl_2$ resulted in removal of crystallization water. Chloride **X** is hydrolytically unstable. Presumably, the rate of hydrolysis is fairly high, as follows from the results of its reactions with alcohols. The reaction with methanol gave about 80% of ester **IXa**, while with 95% ethanol in the presence of potassium hydroxide we obtained a mixture of ester **IXb** and acid **II** at a ratio of 3:1. Only acid **II** was isolated (instead of the expected amide) in the reaction of **IXa** with aqueous ammonia. On the other hand, the reaction of chloride **X** with *p*-toluidine afforded substituted amide **XI** in a good yield (80%). Like acid **II**,

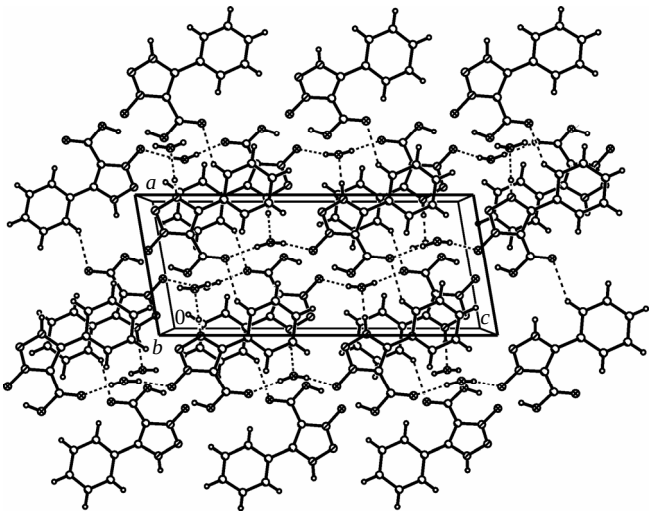
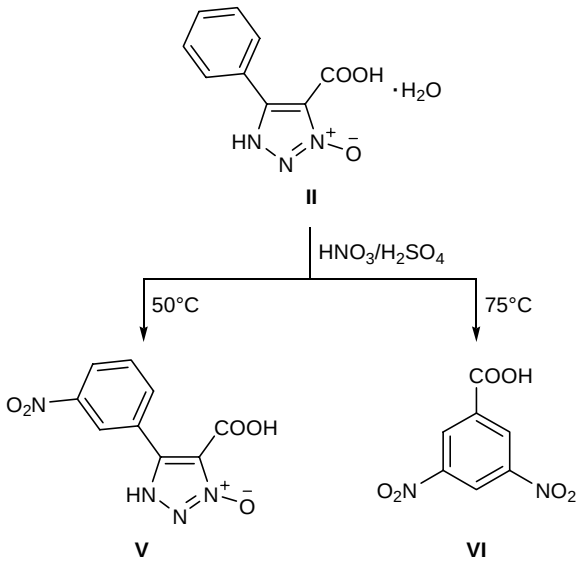
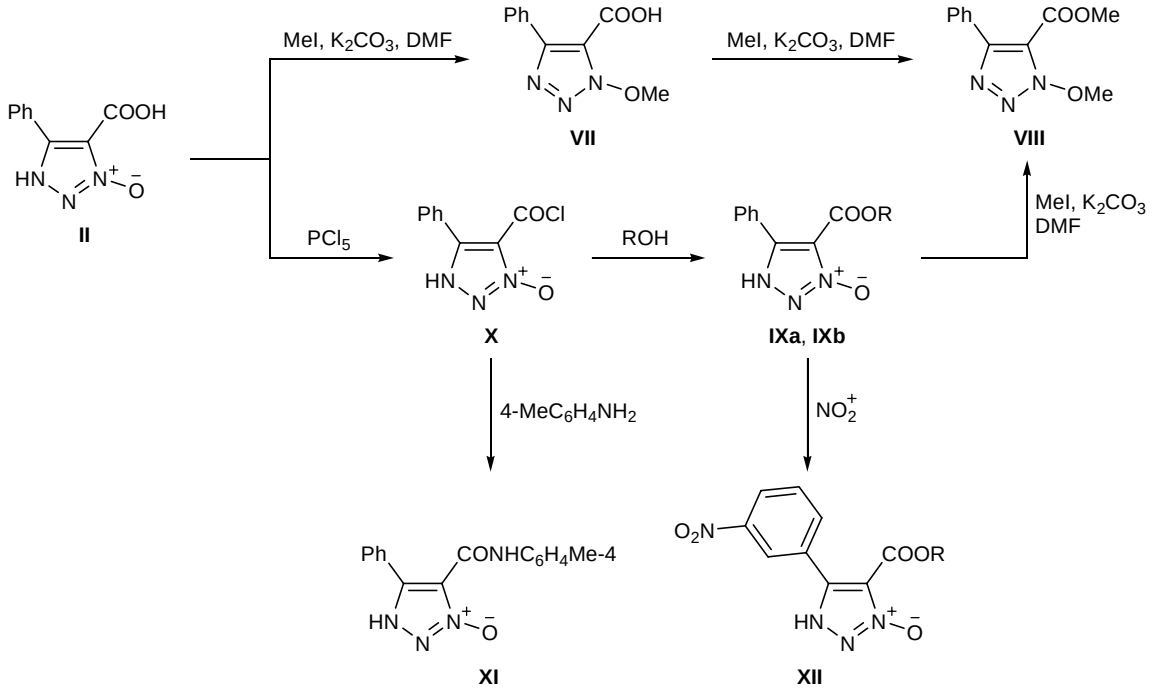


Fig. 2. Crystal structure of 3-oxy-5-phenyl-1*H*-1,2,3-triazole-4-carboxylic acid (**II**) (projection onto the *010* plane, hydrogen bonds are shown as dashed lines).

Scheme 2.



Scheme 3.



IX, R = Me (**a**), Et (**b**).

the nitration of methyl 3-oxy-5-phenyl-1*H*-1,2,3-triazole-4-carboxylate (**IXa**) resulted in formation of 5-(3-nitrophenyl) derivative **XII** (Scheme 3).

EXPERIMENTAL

The calculations were performed using Gaussian software [21]. All transition states described in this paper were characterized by calculations of vibration frequencies (one imaginary frequency) and by visual monitoring of the imaginary frequency with the aid of Gaus View [23]. X-Ray analysis of a single crystal of 3-oxy-5-phenyl-1*H*-1,2,3-triazole-4-carboxylic acid (**II**) was performed on a Nonius CAD-4 diffractometer. The following unit cell parameters were found: a = 7.372(1), b = 7.506(1), c = 17.468(4) Å; β = 99.76(3)°; V = 952.6(3) Å^3; d = 1.556 g/cm^3; space group $P2_1/c$; Z = 4; μ = 0.125 mm^{-1}. The ^{1}H and ^{13}C NMR spectra were recorded on a Bruker AC-500 spectrometer in DMSO-d_6 using the solvent as internal reference. The IR spectra were measured in KBr on a Perkin–Elmer Spectrum BX 1000 instrument.

4,5-Bis(hydroxyimino)-3-phenyl-4,5-dihydroisoxazole (**I**) was synthesized as described in [24].

3-Oxy-5-phenyl-1*H*-1,2,3-triazole-4-carboxylic acid (II). A solution of 6 g (29.3 mmol) of 4,5-bis(hydroxyimino)-3-phenyl-4,5-dihydroisoxazole (**I**) in 100 g of a 20% solution of sodium hydroxide was heated to the boiling point, kept for 5 min at that temperature, cooled, and acidified to pH 1–2 with concentrated hydrochloric acid. The red precipitate was filtered off, washed with water, and dispersed in 50 ml of cold water, 10 ml of concentrated hydrochloric acid was added, and the mixture was heated at the boiling point under stirring until it became colorless. The mixture was cooled, and the precipitate was filtered off, washed with 50 ml of water, and dried in air. Yield 4.2 g (65%), mp 180°C (with decomposition; from H_2O). ^{1}H NMR spectrum, δ, ppm: 8.93 br.s (2H, OH, NH), 7.78 d (2H, H_{arom}), 7.46 m (3H, H_{arom}). ^{13}C NMR spectrum, δ_C, ppm: 160.1 (C=O); 145.8, 120.9 (C^4, C^5); 130.5, 129.8, 129.2, 129.0 (C_{arom}). Found, %: C 48.49; H 4.00; N 18.23. $C_9H_7N_3O_3\cdot H_2O$. Calculated, %: C 48.43; H 4.06; N 18.83.

5-(3-Nitrophenyl)-3-oxy-1*H*-1,2,3-triazole-4-carboxylic acid (V). A mixture of 5 ml of 98% H_2SO_4 and 4 ml of HNO_3 (d = 1.5 g/cm^3) was added dropwise under stirring at 20°C to a solution of 2 g (9 mmol) of acid **II** in 20 ml of 98% H_2SO_4. The mixture was heated to 50°C under stirring, stirred for 30 min at that temperature, cooled, and poured into water. The precipitate was filtered off, washed with water until neutral washings, and dried in air. Yield 1.4 g (65%), mp 190–192°C (with decomposition; from H_2O).

Table 4. Experimental and calculated bond lengths (*d*, Å) and bond angles (ω, deg) in the molecule of 3-oxy-5-phenyl-1*H*-1,2,3-triazole-4-carboxylic acid (**IIf**)

Bond	d_{exp}	d_{calc} [b]	Angle	ω_{exp}	ω_{calc} [b]
C^1–N^3	1.347(2)	1.357	$N^3C^1C^2$	105.0(2)	
C^1–C^4	1.466(2)	1.469	$C^2C^1C^4$	133.1(2)	135.37
C^2–C^3	1.474(2)	1.490	$N^1C^2C^3$	120.8(2)	
N^1–O^1	1.310(2)	1.275	$N^2N^1O^1$	120.8(2)	121.65
C^3–O^3	1.210(2)		$O^1N^1C^2$	125.7(2)	125.64
C^4–C^5	1.394(2)		$N^2N^3C^1$	113.6(2)	114.95
C^5–C^6	1.384(2)		$O^3C^3C^2$	122.7(2)	
C^7–C^8	1.385(2)		$C^5C^4C^9$	119.7(2)	
C^1–C^2	1.386(2)	1.394	$C^9C^4C^1$	120.8(2)	
C^2–N^1	1.376(2)	1.399	$C^5C^6C^7$	120.2(2)	
N^1–N^2	1.306(2)	1.319	$C^7C^8C^9$	120.2(2)	
N^2–N^3	1.339(2)	1.348	$N^3C^1C^4$	121.9(2)	
C^3–O^2	1.314(2)		$N^1C^2C^1$	104.4(2)	
C^4–C^9	1.397(2)		$C^1C^2C^3$	134.5(2)	
C^6–C^7	1.384(2)		$N^2N^1C^2$	113.5(2)	
C^8–C^9	1.386(2)		$N^1N^2N^3$	103.5(2)	
C^5–C^6	1.384(2)		$O^3C^3O^2$	122.0(2)	
			$O^2C^3C^2$	115.3(2)	
			$C^5C^4C^1$	119.4(2)	
			$C^6C^5C^4$	119.9(2)	
			$C^6C^7C^8$	120.1(2)	
			$C^8C^9C^4$	119.7(2)	

[a] For atom numbering, see Fig. 1.
[b] B3LYP/6-31G(*d*).

^{1}H NMR spectrum, δ, ppm: 12.82 (2H, NH, OH), 8.97 s (1H, H_{arom}), 8.51 d (1H, H_{arom}), 8.23 d (1H, H_{arom}), 7.74 t (1H, H_{arom}). ^{13}C NMR spectrum, δ_C, ppm: 160.3 (C=O); 142.9, 119.1 (C^4, C^5); 148.4, 134.5, 133.1, 130.3, 123.5, 122.8 (C_{arom}). Found, %: C 43.57; H 2.70; N 22.52. $C_9H_6N_4O_5$. Calculated, %: C 43.21; H 2.42; N 22.40.

1-Methoxy-4-phenyl-1*H*-1,2,3-triazole-5-carboxylic acid (VII). Finely powdered potassium carbonate, 4.6 g (33 mmol), was added under stirring to a solution of 2.5 g (11 mmol) of acid **II** in 25 ml of DMF, the mixture was stirred for 10 min, and 1.75 g (12 mmol) of methyl iodide was added. The mixture was stirred for 2 days, poured into 75 ml of water, and extracted with diethyl ether (2×50 ml). The aqueous phase was acidified to pH 1–2 with concentrated hydrochloric acid, and the precipitate was filtered off and dried in air. Yield 1.54 g (60%), mp 143–144°C (with decomposition; reprecipitated from acetone with water). ^{1}H NMR spectrum, δ, ppm: 14.36 s (1H, OH), 7.77 d (2H, H_{arom}), 7.46 m (3H, H_{arom}), 4.33 s (3H, OCH_3). ^{13}C NMR spectrum, δ_C, ppm: 158.9 (C=O); 146.9, 121.1 (C^4, C^5); 130.4, 129.6, 129.0, 128.8 (C_{arom}); 69.4 (CH_3). Found, %: C 54.87; H 4.21; N 19.15. $C_{10}H_9N_3O_3$. Calculated, %: C 54.80; H 4.14; N 19.17.

Methyl 1-methoxy-4-phenyl-1*H*-1,2,3-triazole-5-carboxylate (VIII). *a*. Finely powdered potassium carbonate, 15.5 g (110 mmol), and methyl iodide, 16 g (110 mmol), were added under vigorous stirring to a solution of 5 g (22.4 mmol) of acid **II** in 50 ml of DMF. The mixture was left to stand for 2 days at room temperature and diluted with 300 ml of water, and the precipitate was filtered off and dried in air. Yield 4.1 g (75%), mp 70–71°C (from aqueous ethanol). ^{1}H NMR spectrum, δ, ppm: 7.75 d (2H, H_{arom}), 7.48 m (3H, H_{arom}), 4.35 s (3H, 1-OCH_3), 3.87 s (3H, $COOCH_3$). ^{13}C NMR spectrum, δ_C, ppm: 157.8 (C=O); 147.7, 119.9 (C^4, C^5); 130.1, 129.8, 129.2, 128.8 (C_{arom}); 69.5 (1-OCH_3); 53.43 ($COOCH_3$). Found, %: C 56.99; H 4.79; N 20.62. $C_{11}H_{11}N_3O_3$. Calculated, %: C 56.65; H 4.75; N 20.58.

b. Finely powdered potassium carbonate, 2.3 g (16 mmol), and methyl iodide, 0.76 g (5.3 mmol), were added to a solution of 1 g (4 mmol) of methyl ester **VII** in 10 ml of DMF under stirring at 20°C. The mixture was left to stand for 24 h and diluted with 50 ml of water, and the precipitate was filtered off and dried in air. Yield 0.8 g (80%), mp 70–71°C; no depression of the melting point was observed on mixing with a sample prepared as described above in *a*.

c. Following method *b*, compound **VIII** was synthesized from ester **IXa**. Yield 83%.

Methyl 3-oxy-5-phenyl-1*H*-1,2,3-triazole-4-carboxylate (IXa). A solution of 1.9 g (23 mmol) of potassium hydroxide in a minimal amount of methanol was added to 2.4 g (11 mmol) of acid chloride **X** in 50 ml of methanol. The mixture was stirred for 3 h at room temperature, diluted with 100 ml of water, acidified to pH 1–2 with concentrated hydrochloric acid, and extracted with methylene chloride (2× 50 ml). The extract was washed with water (2×20 ml) and evaporated in air. Yield 1.9 g (77%), mp 122–123°C (from CCl_4–$CHCl_3$, 1:1). ^{1}H NMR spectrum, δ, ppm: 7.73 d (2H, H_{arom}), 7.46 m (3H, H_{arom}), 3.86 (3H, CH_3). ^{13}C NMR spectrum, δ_C, ppm: 158.1 (C=O); 146.2, 119.5 (C^4, C^5); 129.8, 128.9, 128.2, 128.1

(C_{arom}); 52.8 ($COOCH_3$). Found, %: C 55.00; H 4.56; N 19.32. $C_{10}H_9N_3O_3$. Calculated, %: C 54.79; H 4.14; N 19.17.

Ethyl 3-oxy-5-phenyl-1*H*-1,2,3-triazole-4-carboxylate (IXb) was synthesized in a similar way using 95% ethanol. During extraction with methylene chloride, a solid precipitated and was filtered off, washed with water, and dried in air. Yield 0.6 g (20%), mp 180°C; the product showed no depression of the melting point on mixing with acid **II**. From the methylene chloride extract we isolated 1.8 g (60%) of compound **IXb**, mp 134–135°C (from CCl_4). ^{1}H NMR spectrum, δ, ppm: 11.70 (1H, NH), 7.73 d (2H, H_{arom}), 7.46 m (3H, H_{arom}), 4.32 q (2H, CH_2), 1.23 t (3H, CH_3). ^{13}C NMR spectrum, δ_C, ppm: 157.8 (C=O); 146.2, 119.9 (C^4, C^5); 130.0, 129.1, 128.4, 128.3 (C_{arom}); 61.9 (OCH_2), 13.8 (CH_3). Found, %: C 56.72; H 4.83; N 17.98. $C_{11}H_{11}N_3O_3$. Calculated, %: C 56.65; H 4.75; N 18.02.

3-Oxy-5-phenyl-1*H*-1,2,3-triazole-4-carbonyl chloride (X). Finely powdered acid **II**, 2.5 g (11 mmol), was mixed with 4.7 g (23 mmol) of finely powdered phosphorus pentachloride. The mixture was slowly heated to 100°C under stirring, kept at that temperature until it solidified completely, cooled, and ground in a mortar under a layer of hexane. The solid substance was filtered off and was used in further syntheses without additional purification. Yield 2.4 g (quantitative).

***N*-(*p*-Tolyl)-3-oxy-5-phenyl-1*H*-1,2,3-triazole-4-carboxamide (XI).** A mixture of 1.3 g (12 mmol) of *p*-toluidine, 20 ml of pyridine, and 2.7 g (12 mmol) of chloride **IX** was heated to the boiling point over a period of 15 min. The mixture was then cooled to 20°C, diluted with 50 ml of water, and acidified to pH 2 with concentrated hydrochloric acid. The precipitate was filtered off, washed with water until neutral washings, and dispersed in 70 ml of boiling water. The suspension was filtered while hot, and the precipitate was dried in air. Yield 24 g (80%), mp 245–246°C (decomp.). ^{1}H NMR spectrum, δ, ppm: 12.0 (1H, 1-H), 11.21 (1H, NH, amide), 7.78 (2H, C_6H_5), 7.56 d (2H, C_6H_4), 7.45 m (3H, C_6H_5), 7.18 d (2H, C_6H_4), 2.28 s (3H, CH_3). ^{13}C NMR spectrum, δ_C, ppm: 155.97 (C=O); 141.65, 119.88 (C^4, C^5); 135.61, 133.74, 129.95, 129.50, 129.04, 128.82 (C_{arom}); 20.63 (CH_3). Found, %: C 65.36; H 4.73; N 19.12. $C_{16}H_{14}N_4O_2$. Calculated, %: C 65.30; H 4.79; N 19.04.

Methyl 5-(3-nitrophenyl)-3-oxy-1*H*-1,2,3-triazole-4-carboxylate (XII). A mixture of 5 ml of 98% H_2SO_4 and 4 ml of HNO_3 (d = 1.5 g/cm^3) was added dropwise to a solution of 2 g (9 mmol) of ester **XIa** in 20 ml of 98% H_2SO_4 under stirring at ~20°C. The mixture was stirred for 2 h at 60°C, cooled, and poured into water. The precipitate was filtered off, washed with water until neutral washings, and dried in air. Yield 1.5 g (64%), mp 159–160°C (with decomposition; from H_2O). ^{1}H NMR spectrum, δ, ppm: 11.8 (NH), 8.64 s (1H, H_{arom}), 8.31 d (1H, H_{arom}), 8.22 d (1H, H_{arom}), 7.78 t (1H, H_{arom}), 3.88 s (3H, CH_3). Found, %: C 45.57; H 2.70; N 22.02. $C_{10}H_8N_4O_5$. Calculated, %: C 45.46; H 3.05; N 21.21.

REFERENCES

1. Wolff, L., *Justus Liebigs Ann. Chem*., 1902, vol. 325, p. 129.
2. Godovikova, T.I., Ignat'eva, E.L., and Khmel'nitskii, L.I., *Khim. Geterotsikl. Soedin*., 1989, p. 147.
3. Godovikova, T.I., Golova, S.P., Vozchikova, S.A., Ignat'eva, E.L., Povorin, M.V., and Khmel'nitskii, L.I., *Khim. Geterotsikl. Soedin*., 1996, p. 675.
4. Godovikova, T.I., Golova, S.P., Vozchikova, S.A., Ignat'eva, E.L., Povorin, M.V., Pivina, T.S., and Khmel'nitskii, L.I., *Khim. Geterotsikl. Soedin*., 1999, p. 203.
5. Shafeev, M.A., Al'mukhamedov, A.A., Shcherbakov, V.V., Gareev, G.A., and Vereshchagin, L.I., *Zh. Org. Khim*., 1994, vol. 30, p. 918.
6. Vereshchagin, L.I., Nikitin, V.M., Meshcheryakov, V.I., Gareev, G.A., Kirillova, L.P., and Shul'gina, V.M., *Zh. Org. Khim*., 1989, vol. 25, p. 1744.
7. Godovikova, T.I., Ignat'eva, E.L., Golova, S.P., Kuz'min, V.S., and Khmel'nitskii, L.I., *Russ. J. Org. Chem*., 1997, vol. 33, p. 1133.
8. Godovikova, T.I., Golova, S.P., Vozchikova, S.A., Ignat'eva, E.L, Povorin, M.V., Kuz'min, V.S, and Khmel'nitskii, L.I., *Mendeleev Commun*., 1995, p. 194.
9. Shaposhnikov, S.D., Pirogov, S.V., Mel'nikova, S.F., and Tselinskii, I.V., *Khimiya i biologicheskaya aktivnost' azotistykh geterotsiklov i alkaloidov* (Chemistry and Biological Activity of Nitrogen-Containing Heterocycles and Alkaloids), Moscow. 2001, vol. 2, p. 334.
10. See, e.g., *Adv. Heterocycl. Chem*., 2000, vol. 76, pp. 1–323.
11. Wilson, S., *Electron Correlation in Molecules*, Oxford: Clarendon, 1984.
12. *Methods in Computational Chemistry. Electron Correlation in Atoms and Molecules*, Wilson, S., Ed., New York: Plenum, 1987, vol. 1.
13. Koch, W. and Holthausen, M.C., *A Chemist's Guide to Density Functional Theory*, Weinheim: Wiley, 2001, 2nd ed.

14. Hehre, W.J. and Lou, L., *A Guide to Density Functional Calculations in Spartan*, Irvine, CA: Wavefunction, 1997.
15. Foresman, J.B. and Frisch, A.E., *Exploring Chemistry with Electronic Structure Methods*, Pittsburgh, PA: Gaussian, 1996.
16. For an exhaustive review on computational chemistry, see *Encyclopedia of Computational Chemistry*, Schleyer, P.v.R., Chichester: Wiley, 1998, vols. 1–5.
17. Rauhut, G., *Adv. Heterocycl. Chem*. 2001, vol. 81, p. 1.
18. Anders, E., Katritzky, A.R., Malhotra, N., and Stevens, J., *J. Org. Chem.*, 1992, vol. 57, p. 3698.
19. Guimon, C., Khayar, S., Pfister-Guillouzo, G., and Begtrup, M., *Spectrosc. Lett*., 1987, vol. 20, p. 105.
20. Steinke, T., Hausele, E., and Clark, T., *J. Am. Chem. Soc*., 1989, vol. 111, p. 9107.
21. Frisch, M.J., Trucks, G.W., Schlegel, H.B., Scuseria, G.E., Robb, M., Cheeseman, J.R., Zakrzewski, V.G., Montgomery, J.A., Jr., Stratmann, R.E., Burant, J.C., Dapprich, S., Millam, J.M., Daniels, A.D., Kudin, K.N., Strain, M.C., Farkas, O., Tomasi, J., Barone, V., Cossi, M., Cammi, R., Mennucci, B., Pomelli, C., Adamo, C., Clifford, S., Ochterski, J., Petersson, G.A., Ayala, P.Y., Cui, Q., Morokuma, K., Malick, D.K., Rabuck, A.D., Raghavachari, K., Foresman, J.B., Cioslowski, J., Ortiz, J.V., Baboul, A.G., Stefanov, B.B., Liu, G., Liashenko, A., Piskorz, P., Komaromi, I., Gomperts, R., Martin, R.L., Fox, D.J., Keith, T., Al-Laham, M.A., Peng, C.Y., Nanayakkara, A., Challacombe, M., Gill, P.M.W., Johnson, B., Chen, W., Wong, M.W., Andres, J.L., Gonzalez, C., Head-Gordon, M., Replogle, E.S., and Pople J.A., *Gaussian 98. Revision A.9*, Pittsburgh, PA: Gaussian, 1998; *TITAN. Version 1.0.5*, Irvine, CA: Wavefunction, 2000.
22. Giesen, D.J., Chambers, C.C., Hawkins, G.D., Cramer, C.J., and Truhlar, D.G., *Computational Thermochemistry: Prediction and Estimation of Molecular Thermodynamics*, Irikura, K. and Frurip, D.J., Eds., Washington, DC: Am. Chem. Soc., 1998, ACS Symposium Series, vol. 677, p. 285 (abstract).
23. Frisch, A.E., Nielsen, A.B., and Holder, A.J., *Gaus ViewW. User's Reference*, Pittsburgh, PA: Gaussian, 2000, 2nd ed.
24. Tselinsky, I.V., Melnikova, S.F., Pirogov, S.V., Shaposhnikov, S.D., Nather, Ch., Traulsen, T., and Friedrichsen, W., *Heterocycl. Commun*., 2000, vol. 6, p. 35.