Interaction of 3-*p*-toluoyl-1,2-dihydro-4*H*-pyrrolo-[2,1-*c*][1,4]benzoxazine-1,2,4-trione with benzylamine. Synthesis and crystal and molecular structure of *Z*-3-(1-benzyl-2-hydroxy-4,5-dioxo-2-*p*-tolyltetrahydropyrrol-3-idene)-3,4-dihydro-2*H*-1,4-benzoxazin-2-one

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3-*p*-Toluoyl-1,2-dihydro-4*H*-pyrrolo-[2,1-*c*][1,4]benzoxazine-1,2,4-trione reacts with benzylamine to yield *Z*-3-(1-benzyl-2-hydroxy-4,5-dioxo-2-*p*-tolyltetrahydropyrrol-3-idene)-3,4-dihydro-2*H*-1,4-benzoxazin-2-one. The crystal and molecular structure of the latter compound was studied by X-ray structural analysis.

Key words: 2,3-dihydropyrrole-2,3-dione, 1,2-dihydro-4*H*-pyrrolo-[2,1-*c*][1,4]benzoxazine-1,2,4-trione, crystal and molecular structure.

The reaction of methylamine or piperidine with 4-unsubstituted 5-aryl-2,3-dihydropyrrole-2,3-diones and 5-aryl-4-phenyl-2,3-dihydropyrrole-2,3-diones proceeds at the carbonyl group at position 2 and is accompanied by cleavage of the heterocycle to form methylamide or piperidide of 4-aryl-4-imino-2-oxobutyric acid.[1,2] The reaction of 4-aroyl-2,3-dihydropyrrole-2,3-diones with dialkylamines proceeds not only through the above-mentioned pathway but also through addition of dialkylamines at the C(5) atom of the heterocycle and yields dialkylamides of 3-aminomethylene-4-aryl-2,4-dioxobutyric acids and 4-aroyl-5-dialkylamino-3-hydroxy-2,5-dihydropyrrol-2-ones.[3]

As part of continuing studies of nucleophilic conversions of 4-aroyl-2,3-dihydropyrrole-2,3-diones fused with azaheterocycles *via* the [*a*] side, in particular, studies of reactions of 3-aroyl-1,2-dihydro-4*H*-pyrrolo[2,1-*c*][1,4]benzoxazine-1,2,4-triones with water, alcohols,[4] and arylamines,[5] we studied interactions of these compounds with alkylamines.

The reaction of 3-*p*-toluoyl-1,2-dihydro-4*H*-pyrrolo[2,1-*c*][1,4]benzoxazine-1,2,4-trione (**1**) with benzylamine yields a crystalline product as yellow thin needles. On keeping in air, the compound turned bright-red. Recrystallization of the yellow product from chloroform, which was not dehydrated, yields well-shaped bright-red prismatic crystals. Both compounds (yellow and bright-red) have close values of melting points, identical ^{1}H NMR spectra and identical values of R_f (TLC), but different IR spectra. This called for X-ray structural studies of the products.

X-ray structural analysis of red crystals demonstrated that they contain *Z*-3-(1-benzyl-2-hydroxy-4,5-dioxo-2-*p*-tolyltetrahydropyrrol-3-idene)-3,4-dihydro-2*H*-1,4-benzoxazin-2-one (**2**), which crystallizes with one water molecule.

Compound **2** forms as a result of nucleophilic attack of benzylamine on the carbonyl group at the α position of the dihydropyrroledione ring of compound **1** and cleavage at the C(1)—N(10) bond followed by intramolecular addition of the benzylamide NH group to the carbonyl group of the *p*-toluoyl substituent (Scheme 1).

The overall view of molecule **2** without crystallization water is shown in Fig. 1. The crystal packing of molecules **2** and crystallization water is shown in Fig. 2. The bond lengths and bond angles are given in Tables 1 and 2, respectively.

The planes of the tolyl and benzyl fragments are orthogonal to the plane of the five-membered ring and have a bisector orientation with respect to this ring. The angle between the planes of benzene rings is 80.7°. The oxazine ring is approximately planar with a slight deviation from planarity to an envelope conformation. The angle of the bend along the O(1)...C(8) line is 5°. Note that in 1-*p*-bromophenyl-4-*p*-toluoyltetrahydro-1,3-oxazino[4,3-*c*][1,4]-benzoxazine-3,5-dione (**3**),[6] the oxazine ring adopts a flattened boat conformation. The N and O heteroatoms deviate from the plane through

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Scheme 1

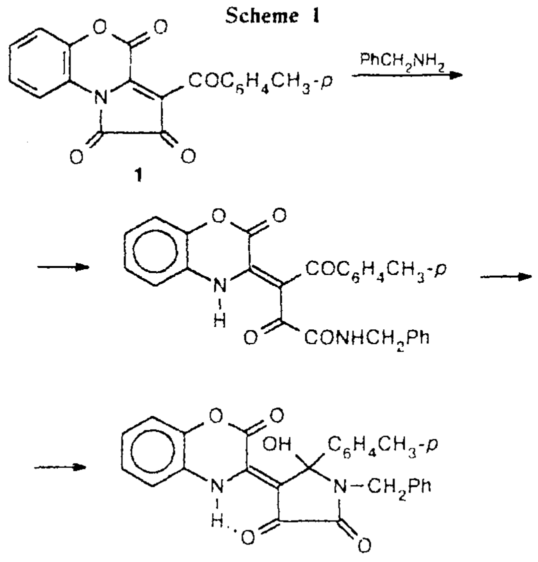


Table 1. Bond lengths in compound **2**.

Bond	*d*/Å	Bond	*d*/Å
O(1)—C(9)	1.384	O(1)—C(10)	1.406
O(2)—C(9)	1.186	O(3)—C(19)	1.400
O(4)—C(17)	1.249	O(5)—C(16)	1.222
N(6)—C(8)	1.344	N(6)—C(11)	1.391
N(7)—C(16)	1.343	N(7)—C(19)	1.517
N(7)—C(26)	1.476	C(8)—C(9)	1.490
C(8)—C(18)	1.392	C(10)—C(11)	1.327
C(10)—C(15)	1.403	C(11)—C(12)	1.421
C(12)—C(13)	1.394	C(13)—C(14)	1.400
C(14)—C(15)	1.410	C(16)—C(17)	1.498
C(17)—C(18)	1.439	C(18)—C(19)	1.537
C(19)—C(20)	1.539	C(26)—C(27)	1.533

Note. The atomic numbering scheme is given in Figs. 1 and 2.

Table 2. Bond angles in compound **2**.

Angle	ω/deg	Angle	ω/deg
C(9)—O(1)—C(10)	121.2	C(8)—N(6)—C(11)	121.8
C(16)—N(7)—C(19)	114.9	C(16)—N(7)—C(26)	122.0
C(19)—N(7)—C(26)	121.3	N(6)—C(8)—C(9)	118.9
N(6)—C(8)—C(18)	119.1	C(9)—C(8)—C(18)	122.0
O(1)—C(9)—O(2)	118.5	O(1)—C(9)—C(8)	116.2
O(2)—C(9)—C(8)	125.1	O(1)—C(10)—C(11)	120.6
O(1)—C(10)—C(15)	114.4	C(11)—C(10)—C(15)	125.0
N(6)—C(11)—C(10)	120.8	N(6)—C(11)—C(12)	119.8
C(10)—C(11)—C(12)	119.3	C(11)—C(12)—C(13)	119.0
C(12)—C(13)—C(14)	119.4	C(13)—C(14)—C(15)	121.9
C(10)—C(15)—C(14)	115.3	O(5)—C(16)—N(7)	127.2
O(5)—C(16)—C(17)	125.9	N(7)—C(16)—C(17)	106.8
O(4)—C(17)—C(16)	123.5	O(4)—C(17)—C(18)	127.9
C(16)—C(17)—C(18)	108.7	C(8)—C(18)—C(17)	120.9
C(8)—C(18)—C(19)	130.2	C(17)—C(18)—C(19)	108.8
O(3)—C(19)—N(7)	108.6	O(3)—C(19)—C(18)	114.5
O(3)—C(19)—C(20)	111.0	N(7)—C(19)—C(18)	100.5
N(7)—C(19)—C(20)	107.4	C(18)—C(19)—C(20)	113.9
N(7)—C(26)—C(27)	112.8		

four carbon atoms by 0.17 and 0.09 Å, respectively. The corresponding bond lengths and bond angles in the heterocycles of **3** and **2** have very close values. It is also noteworthy that in compound **2**, the N(6)—C(8) (1.344 Å) and O(1)—C(9) (1.384 Å) bonds are substantially shorter than the N(6)—C(11) (1.391 Å) and O(1)—C(10) (1.406 Å) bonds. An analogous situation is also observed in the heterocycle of compound **3**, which indicates that the electronic structures of the two heterocycles are similar. Hence it follows that the character of deviations of the oxazine ring from planarity is purely steric.

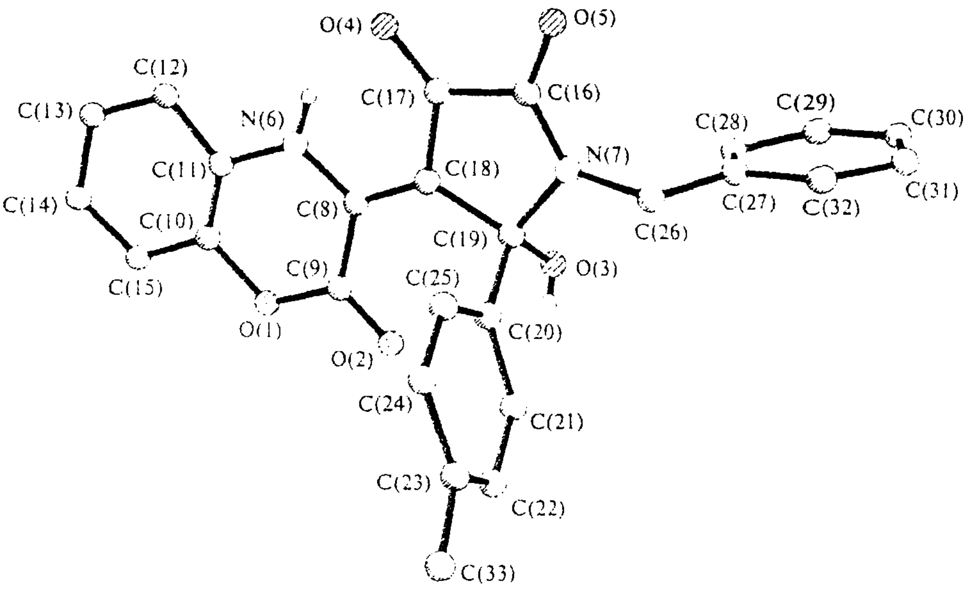
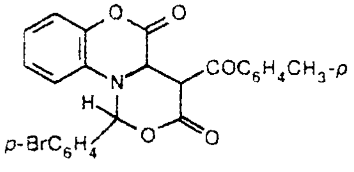


Fig. 1. Structure of molecule **2** and the atomic numbering scheme



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In compound **2**, the angle between the planes of the pyrrole ring and the benzoxazine fragment is 8°. The N(6)C(8)C(18)C(17) torsion angle is 4.3° (see Fig. 1). Apparently, deviations of the pyrrole and oxazine rings from planarity are determined by the difference in the steric interactions of the O(2) atom with the O(3) and C(20) atoms. The two heterocycles form a single conjugated system, which is evidenced not only by the color of the crystal but also by the elongated (compared to the double bond) C(8)—C(18) bond (1.39 Å). The planar structure is stabilized also through the intramolecular N—H...O(4) hydrogen bond (H...O(4) is 1.97 Å, and the NHO angle is 135°).

In the crystal of compound **2**, the O(4) atom forms a hydrogen bond with the molecule of crystallization water (see Fig. 2). The O(4)...O(34) and O(4)...H(34b) distances are 2.79 and 1.99 Å, respectively, which makes it possible to interpret the O(4)...H(34b) bond as a rather strong hydrogen bond. The participation of the O(4) atom in two hydrogen bonds (O(4)...O(34) and O(4)...N) results in an increase in the length of the C(17)—O(4) carbonyl bond (1.249 Å). The water molecule is also involved in a hydrogen bond (2.96 Å) with the O(5) atom of the second molecule **2** related to the first molecule by a center of symmetry (the O(5)...H(34a) distance is 2.30 Å). As a result, the crystal structure consists of centrosymmetric dimeric associates linked through hydrogen bonds. These dimers consist of two molecules **2** and two water molecules (see Fig. 2).

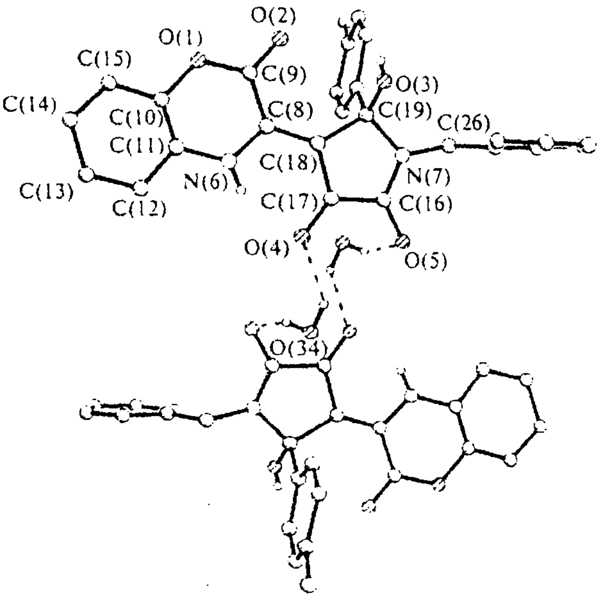
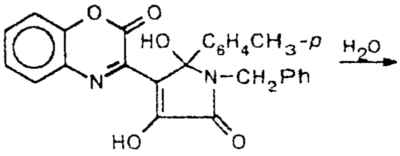


Fig. 2. Structure of the dimeric associate with the molecule of crysatllization water

There is also a shortened intermolecular contact between dimeric associates. The length of this contact (2.83 Å) formed by the oxygen atoms of the water molecule (O(34)) and the hydroxyl group (O(3)) corresponds to the lengths of a hydrogen bond. However, the H(3) atom is repeatedly located from the difference electron density synthesis on the opposite side of the O(34)...O(3) contact. The C(19)—O(3) bond length (1.400 Å) corresponds to the single bond, *i.e.*, the participation of the O(3) atom in hydrogen bonding does not cause an elongation of this bond. However, it is not inconceivable that the position of the H(3) atom was in error, and a hydrogen bond between the O(34) and O(3) atoms occurs.

The structure of the yellow product is still an open question. As mentioned above, when stored in air or recrystallized from chloroform, which was not subjected to dehydration, the yellow compound transformed into a red compound. Therefore, it is believed that the yellow product is anhydrous. Apparently, formula **4** corresponds to its structure. Under the above-mentioned conditions, the yellow product transformed into form **2** with a more extensive conjugated system.



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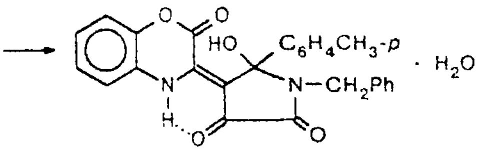

2

We plan to carry out X-ray structural study of the yellow product with the aim of testing this suggestion and revealing the effect of the molecule of crystallization water on the color of the compound.

Experimental

The IR spectrum were obtained on an UR-20 instrument (as Nujol mulls). The ^1H NMR spectra were recorded on a Bruker WP-80-54 instrument (80 MHz) in $CDCl_3$ with HMDS as the internal standard. The purities of compounds **2** and **4** were confirmed by TLC on Silufol plates using a 3 : 2 benzene—ether mixture as the eluent.

***Z*-3-(1-Benzyl-2-hydroxy-4,5-dioxo-2-*p*-tolyltetrahydropyrrol-3-idene)-3,4-dihydro-2*H*-[1,4]benzoxazin-2-one (2) and 3-(1-benzyl-2,4-dihydroxy-5-oxo-2-*p*-tolyl-2,5-dihydropyrrol-**

Table 3. Atomic coordinates ($\times 10^4$) and equivalent isotropic temperature factors ($U_{\text{iso}}^{\text{eq}} \cdot 10^3$/ Å^2) in compound **2**.

Atom	*x*	*y*	*z*	$U_{\text{iso}}^{\text{eq}}$
O(1)	1411(4)	1594(8)	9599(5)	47(4)
O(2)	2548(4)	379(9)	7985(5)	60(5)
O(3)	2716(4)	−1536(8)	5316(5)	37(4)
O(4)	−15(4)	2176(8)	5993(4)	37(4)
O(5)	1062(4)	1631(9)	3579(5)	42(4)
N(6)	231(4)	1907(10)	8085(6)	36(5)
N(7)	2204(4)	494(9)	4321(5)	36(4)
C(8)	1125(5)	1328(11)	7573(7)	27(5)
C(9)	1763(6)	1005(13)	8348(8)	37(6)
C(10)	470(6)	2227(12)	10074(7)	50(6)
C(11)	−94(6)	2373(11)	9339(7)	26(5)
C(12)	−1046(6)	2970(13)	9839(7)	33(5)
C(13)	−1362(6)	3409(14)	11096(9)	45(6)
C(14)	−733(7)	3295(14)	11840(8)	62(8)
C(15)	211(7)	2693(13)	11350(8)	46(7)
C(16)	1349(6)	1223(12)	4378(7)	36(5)
C(17)	818(6)	1554(12)	5643(7)	31(5)
C(18)	1429(5)	1073(12)	6341(7)	52(6)
C(19)	2397(5)	432(13)	5528(7)	33(5)
C(20)	3139(3)	1962(8)	5955(5)	26(5)
C(21)	3981(4)	1354(7)	6143(5)	40(6)
C(22)	4653(3)	2753(14)	6488(5)	76(8)
C(23)	4483(3)	4760(9)	6644(5)	41(6)
C(24)	3642(4)	5368(6)	6455(5)	55(7)
C(25)	2970(3)	3968(9)	6111(5)	37(5)
C(26)	2965(6)	279(14)	3278(7)	40(6)
C(27)	3022(5)	−1799(9)	2225(5)	60(7)
C(28)	2625(5)	−3537(13)	2315(6)	52(7)
C(29)	2778(6)	−5361(10)	1304(9)	98(10)
C(30)	3328(6)	−5448(12)	202(7)	117(17)
C(31)	3725(6)	−3710(16)	111(6)	175(31)
C(32)	3572(6)	−1886(13)	1123(7)	120(14)
C(33)	5241(7)	6307(16)	700(1)	108(15)
O(34)	−1169(4)	3989(9)	4997(5)	100(10)

3-yl)-2*H*-[1,4]benzoxazin-2-one (4). Benzylamine (0.01 mol) was added dropwise to a solution of 3-*p*-toluoyl-1,2-dihydro-4*H*-pyrrolo-[2,1-*a*][1,4]benzoxazine-1,2,4-trione (0.01 mol) in anhydrous acetonitrile (30 mL). After 10 min, the precipitate of compound **4** that formed was filtered off. The yield was 3.61 g (79%), m.p. 158–160 °C (anhydrous chloroform). Found (%): C, 70.87; H, 4.58; N, 6.11. $C_{26}H_{20}N_2O_5$. Calculated (%): C, 70.89; H, 4.58; N, 6.36. IR (ν/cm^{-1}): 3436 (OH), 3000 (br. NH), 1780 (COO), 1704 (C=O), 1598 (br. C=O). ^{1}H NMR, δ: 2.32 (s, 3 H, CH_3), 4.13, 4.55 (both dd, 2 H, CH_2N, the AB-system), 5.17 (s, 1 H, NH), 7.15 (m, 13 H, ArH), 13.07 (s, 1 H, OH).

When kept in air or recrystallized from chloroform, which was not subjected to dehydration, compound **4** transformed into compound **2**, m.p. 167–169 °C (with decomp., chloroform). Found (%): C, 68.28; H, 4.62; N, 6.11. $C_{26}H_{20}N_2O_5 \cdot H_2O$. Calculated (%): C, 68.11; H, 4.84; N, 6.11. IR (ν/cm^{-1}): 3564, 3528, 3416, 3304 (br. OH), 3060 (br. NH), 1774 (COO), 1696 (C=O), 1618 (br. C=O).

Table 4. Atomic coordinates of hydrogens ($\times 10^3$)

Atom	*x*	*y*	*z*	Atom	*x*	*y*	*z*
H(3)	294	−153	591	H(26b)	288	127	297
H(6)	14	199	−764	H(28)	225	−343	303
H(12)	145	304	−934	H(29)	254	−650	138
H(13)	197	377	−1143	H(30)	342	−673	−43
H(14)	93	360	−1267	H(31)	405	−381	−61
H(15)	60	257	1183	H(32)	381	−76	105
H(21)	409	3	605	H(33a)	542	634	773
H(22)	519	235	661	H(33b)	499	761	709
H(24)	353	669	656	H(33c)	577	590	632
H(25)	243	437	597	H(34a)	−112	486	561
H(26a)	354	40	359	H(34b)	−73	296	493

Crystals of compound **2** are triclinic: a = 14.631(6), b = 7.112(4), c = 11.825(7) Å, α = 111.71(5), β = 80.15(4), g = 90.80(4)°, V = 1124.69 Å^3, M = 458.45, d_{calc} = 1.354 g cm^{-3}, Z = 2, space group $P\bar{1}$.

The unit cell parameters and intensities of 1936 independent reflections with $I > 2\sigma(I)$ (2913 measured reflections) were measured on an automated four-circle KM-4 (KUMA DIFFRACTION) diffractometer (Mo-Kα-radiation, graphite monochromator, θ/2θ-scanning technique, 2θ <43.9°). The structure was solved by the direct method and refined by the full-matrix least-squares method with anisotropic thermal parameters for nonhydrogen atoms. The positions of hydrogen atoms of the methyl group and two phenyl groups were calculated geometrically. The remaining hydrogen atoms were located from the difference electron density synthesis. The final value of the R factor was 0.061. Hydrogen atoms were not refined. Absorption was ignored. All calculations were carried out on a PC AT computer using the AREN program package.[7] The atomic coordinates and thermal parameters are given in Tables 3 and 4.

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