Chemistry of Heterocyclic Compounds, Vol. 39, No. 1, 2003

3-BENZOYLQUINOXALIN-2(1H)-ONE IN THE KOSTANECKI–ROBINSON REACTION. SYNTHESIS AND STRUCTURE OF 2-OXO-4-PHENYLPYRANO[2,3-*b*]QUINOXALINE

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3-Benzoylquinoxalin-2(1H)-one is cyclized with acetic anhydride in the presence of pyridine into 2-oxo-4-phenylpyrano[2,3-b]quinoxaline.

Keywords: pyranoquinoxaline, Kostanecki–Robinson reaction, Perkin reaction.

There has been little study of pyranoquinoxalines [1]. Of the possible annelated systems, including the quinoxaline and pyran units, the relatively most studied are the pyrano[3,4-*b*]quinoxalines [1], the preparation of which is based on the intramolecular condensation of quinoxalines containing substituents with alcohol or ester groups in positions 2 or 3 [3, 4]. The classical method for the annelation of α-pyrones, the Perkin reaction (the type synthesis for α-coumarins) is not known in the quinoxaline series.

In an attempt to acetylate benzoylquinoxalinone **1** with acetic anhydride in the presence of pyridine we observed that ring closure occurred to give pyrano[2,3-*b*]quinoxaline **2**. Taking into account the possibility of the presence of its lactim tautomer in equilibrium with lactam **1** and the formation of the *o*-acetyl derivative, this reaction may be viewed as a variant of the Kostanecki–Robinson [5, 6] reaction for the preparation of coumarins, which is itself a special case of the Perkin reaction. Usually in the conditions of the intermolecular Perkin reaction, anhydrides react with aromatic aldehydes and their vinylogues, but not with ketones [7], hence of the two routes for the formation of the pyranoquinoxaline shown in the scheme, route (2) with the formation of intermediate **4** seemed less probable than route (1) *via* intermediate 3.

In contrast to many cases of the Kostanecki–Robinson reaction, the formation of pyrano[2,3-*b*]-quinoxaline **2** is sufficiently selective, but a good yield of the end product was only achieved by refluxing the reaction mixture for 20 h. The reaction did not occur at room temperature. The structure of the product obtained was confirmed by elemental analysis and spectroscopic methods (IR, ^{1}H and ^{13}C NMR). The appearance of a single carbonyl absorption band in the IR spectrum, a single resonance for the this C=O group, and two signals for two different azomethine groups in the ^{13}C NMR spectrum, and also singlets for the vinyl groups in the ^{1}H NMR spectrum are in complete agreement with the proposed structure. Final confirmation was obtained by an X-ray crystallographic investigation.

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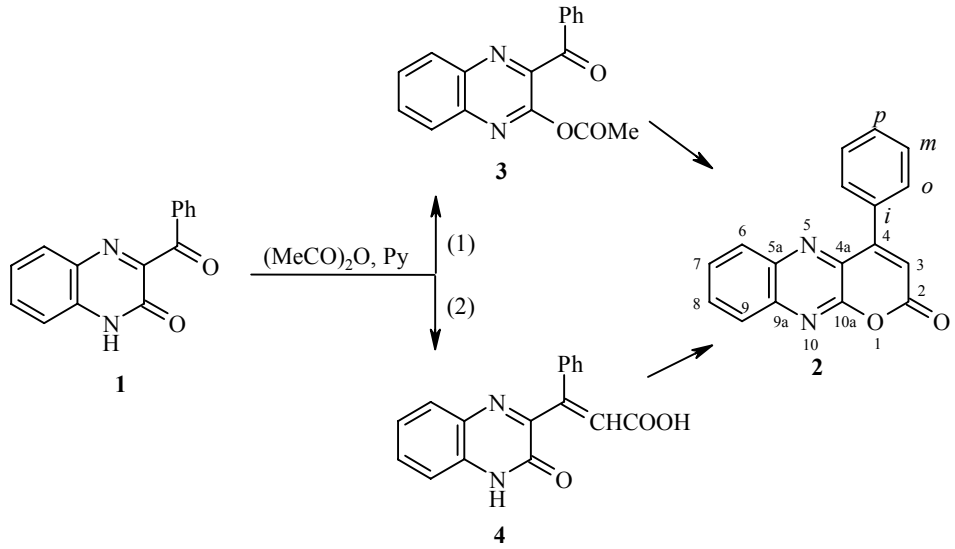

The symmetrically independent part of the unit cell of the crystal of compound **2** consist of a single molecule in the general position (Fig. 1). The pyranoquinoxaline system is planar within the limits of experimental error (0.05(1) Å) and the dihedral angle of the tricyclic system with the plane of the phenyl ring is 43.42(7)°. The molecule does not form hydrogen bonds of the classical type. Of the other intermolecular contacts the intramolecular bond CH···N should be noted between H(12) of the phenyl group and atom N(5), with the following parameters: *d* H(12)···N(5) 2.560(15) Å, ∠C(12)-H(12)···N(5) 106(1)°.

Packing of the molecule in the crystal is determined by π-π interactions between the electron systems of the tricycles and is characterized by packing the molecules into infinite molecular layers with the tricyclic systems in parallel positions (Fig. 2). The benzo fragments of the pyranoquinoxaline systems only participate in π-π interactions with the benzo units of neighbouring molecules with a distance between the centers of the rings of 3.667(2) Å, and the dihedral angle between the planes is 0.0(2)°. At the same time the phenyl substituent is

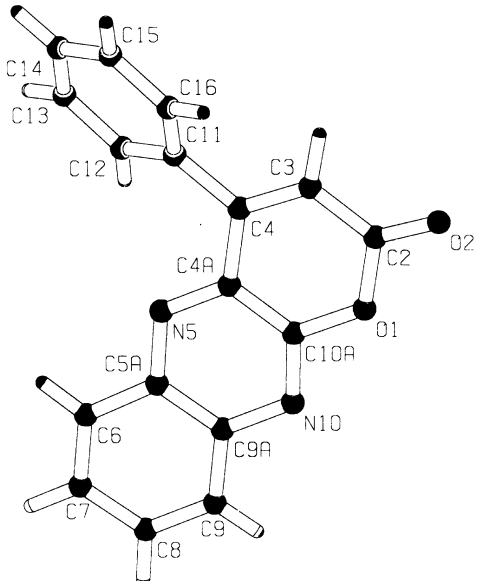

Fig. 1. Geometry of the molecule of compound **2**.

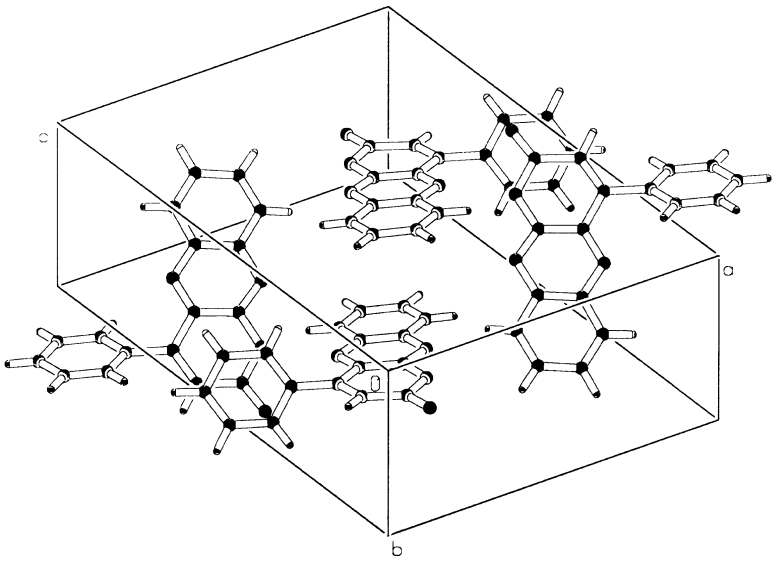

Fig. 2. Packing of molecules **2** in the crystal lattice.

involved in π-π interactions only with the pyran units of the two neighbouring molecules (connected by translation along the crystallographic axis OY) with a distance between centers of the neighbouring rings of 3.83(1) Å and dihedral angles between their planes of 3.92(2)°. The neighbouring molecular layers form stacks, rotated relative to one another by an angle corresponding to the dihedral angle between the phenyl substituent and the plane of the tricycle. In this way a chosen direction along the crystallographic OX axis can be detected since the planes of the rings are parallel to this direction. Such a disposition of the molecules in the crystal leads to their densest packing as indicated also by calculation of the free volume in the lattice, potentially sufficient for a solvent molecule.

TABLE 1. Coordinates of Atoms in the Structure of Pyranoquinoxaline **2** and Their Equivalent Isotropic Temperature Parameters $B = 4/3 \cdot \sum_{i=1}^{3} \sum_{j=1}^{3} (\mathrm{a}_i \cdot \mathrm{a}_j) B(i,j)$

Atom	*x*	*y*	*z*	*B*, Å^2
1	2	3	4	5
O(1)	0.2690(1)	0.0355(2)	0.65399(7)	4.12(3)
O(2)	0.1484(1)	0.1394(2)	0.52238(8)	5.34(4)
N(5)	-0.2101(1)	-0.6081(2)	0.63652(8)	2.94(3)
N(10)	0.3978(1)	-0.0771(2)	0.78362(9)	3.73(4)
C(2)	0.1565(2)	0.0921(3)	0.5999(1)	3.83(4)
C(3)	0.0604(2)	0.0895(3)	0.6410(1)	3.41(4)
C(4)	-0.0731(1)	-0.4725(2)	0.7734(1)	2.74(4)
C(4a)	-0.1916(1)	-0.5382(2)	0.7195(1)	2.76(4)
C(5a)	0.3240(1)	-0.1641(2)	0.9096(1)	2.89(4)
C(6)	0.3481(1)	-0.2413(3)	0.9978(1)	3.53(4)
C(7)	-0.4615(2)	-0.7925(3)	0.4535(1)	4.27(5)

TABLE 1 (continued)

1	2	3	4	5
C(8)	0.5548(2)	-0.2717(3)	1.0081(1)	4.63(5)
C(9)	-0.5346(1)	-0.7027(3)	0.5777(1)	4.28(5)
C(9a)	0.4179(2)	-0.1458(2)	0.8706(1)	3.30(4)
C(10a)	0.2878(2)	-0.0276(2)	0.7423(1)	3.20(4)
C(11)	0.0295(1)	-0.4743(2)	0.7358(1)	2.72(4)
C(12)	-0.0165(1)	0.0795(2)	0,8542(1)	3.10(4)
C(13)	-0.1144(2)	0.0849(3)	0.8859(1)	3.78(4)
C(14)	-0.2273(2)	0.0362(3)	0.8287(1)	4.09(5)
C(15)	-0.2405(2)	-0.0195(3)	0.7398(1)	3.84(5)
C(16)	0.1430(2)	-0.5243(2)	0.7926(1)	3.27(4)
H(3)	0.983(1)	0.140(2)	0.6041(9)	4.1(4)*
H(6)	0.716(1)	0.251(2)	0.4765(9)	4.4(4)*
H(7)	0.522(1)	0.158(2)	0.392(1)	5.5(4)*
H(8)	0.366(1)	0.194(2)	0.459(1)	5.6(4)*
H(9)	0.405(1)	0.189(2)	0.103(1)	4.8(4)*
H(12)	0.060(1)	0.112(2)	0.8944(9)	3.9(4)*
H13)	0.895(1)	0.123(2)	0.9471(9)	3.7(4)*
H(14)	0.707(1)	0.043(2)	0.854(1)	5.4(4)*
H(15)	0.320(2)	0.058(2)	0.301(1)	6.2(5)*
H(16)	0.151(1)	0.062(2)	0.3523(9)	4.3(4)*

* Calculated in the isotropic approximation.

TABLE 2. Bond Lengths (*d*), Valence (ω), and Torsion Angles (τ) for Pyranoquinoxaline **2**

Bond	*d*, Å	Valence angle	ω,deg.	Torsion angle	τ, deg.
O(1)–C(2)	1.383(2)	C(2)–O(1)–C(10a)	121.3(1)	C(10a)–O(1)–C(2)–O(2)	-177.6(2)
O(1)–C(10a)	1.374(2)	C(9a)–N(10)–C(10a)	114.9(2)	C(10a)–O(1)–C(2)–C(3)	2.6(2)
O(2)–C(2)	1.204(2)	O(1)–C(2)–O(2)	116.2(2)	C(2)–O(1)–C(10a)–N(10)	179.3(2)
N(5)–C(4a)	1.320(2)	O(1)–C(2)–C(3)	117.6(1)	C(10a)–N(10)–C(9a)–C(5a)	1.6(2)
N(10)–C(9a)	1.369(2)	O(2)–C(2)–C(3)	126.2(2)	C(9a)–N(10)–C(10a)–O(1)	-178.0(1)
N(10)–C(10a)	1.297(2)	C(4a)–C(4)–C(11)	121.5(1)	C(11)–C(4)–C(4a)–N(5)	2.7(2)
C(2)–C(3)	1.444(3)	N(5)–C(4a)–C(4)	121.0(2)	C(4a)–C(4)–C(11)–C(16)	-138.2(1)
C(4)–C(4a)	1.458(2)	C(6)–C(5a)–C(9a)	119.4(1)	C(6)–C(5a)–C(9a)–N(10)	177.7(2)
C(4)–C(11)	1.480(3)	N(10)–C(9a)–C(5a)	121.5(1)	H(12)–C(12)–C(13)–C(14)	-179(1)
C(5a)–C(6)	1.405(2)	O(1)–C(10a)–N(10)	113.9(2)	C(12)–C(13)–C(14)–C(15)	0.6(3)
C(5a)–C(9a)	1.406(3)	C(4)–C(11)–C(16)	119.6(1)		
C(11)–C(16)	1.390(2)	C(13)–C(12)–H(12)	120(1)		
C(12)–C(13)	1.372(3)	C(12)–C(13)–C(14)	120.6(2)		
C(12)–H(12)	0.95(1)	C(13)–C(14)–C(15)	119.3(2)		
C(13)–C(14)	1.385(2)				
C(14)–C(15)	1.374(3)				

EXPERIMENTAL

Melting points were determined on a Boetius block. IR spectra of nujol mulls were recorded on a UR-20 spectrometer. ^{1}H NMR spectra were recorded with Bruker MCL-250 (250 MHz) spectrometer and ^{13}C NMR spectra on a Bruker WV-400 (400MHz) spectrometer. Chemical shifts were measured relative to DMSO-d_6.

3-Benzoylquinoxalin-2(1H)-one (**1**) was prepared by Kornblum oxidation of 3-(α-chlorobenzyl)-2-oxo-quinoxalin-2(1H)-one with dimethylsulfoxide [8].

2-Oxo-4-phenylpyrano[2,3-*b*]quinoxaline (2). A solution of benzoquinoxalinone **1** (1.00 g, 4.00 mmol) in acetic anhydride (20 ml) and pyridine (2 ml) was refluxed for 20 h, poured into water, the crystals were filtered off, washed with water (2 × 10 ml) and *i*-PrOH (2 × 5 ml). Yield 0.67 g (73%); mp 232-235°C (AcOH). IR spectrum, ν, cm^{-1}: 1612 (C=N), 1728 (C=O). ^{1}H NMR spectrum, δ, ppm: 7.00 (1H, s, CH pyran); 7.37-8.05 (9H, m, C_6H_5 and C_6H_4). ^{13}C NMR spectrum (DMSO), δ, ppm (*J*, Hz): 120.96 (d, C(3), *J* = 173.4), 127.59 (dd, C(9) or C(6) *J* = 160.5, *J* = 7.6), 128.23 (dm, C_m, *J* = 160.9), 129.33 (dd, C(8) or C(7), *J* = 162.2, *J* = 7.4), 129.61 (dd, C(7) or C(8), *J* = 160.6, *J* = 6.8), 129.82 (dm, C_o, *J* = 161.3), 130.13 (dt, C_p, *J* = 160.5, *J* = 7.9), 132.59 (dd, C(6) or C(9), *J* = 165.6, *J* = 10.7), 133.04 (m, C_i), 135.47 (d, C(4), *J* = 9.2), 139.47 (m, C(9a) or C(5a)), 139.99 (m, C(5a) or C(9a)), 152.32 (m, C(4a)), 152.65 (br. m, C(10a)), 158.87 (d, C(2), *J* = 3.6). Found, %: C 73.86; H 3.35; N 9.69. $C_{17}H_{10}N_2O_2$. Calculated, %: C 74.44; H 3.68; N 10.21.

The reaction did not occur in the absence of pyridine.

X-Ray Structural Analysis. Crystals of pyranoquinoxaline **2** are monoclinic. Unit cell parameters at 20°C: *a* = 11.6835(9), *b* = 7.5584(6), *c* =15.171(2) Å; β = 108.1(5)°; *V* = 1273.0(2) $Å^3$; *Z* = 4; d_{calc} = 1.43 g/cm^3; space group $P2_1/c$. Unit cell parameters and the intensities of 1704 reflections, 1205 with $I \geq 3\sigma$, were measured on an automatic 4-circle Enraf-Nonius CAD-4 diffractometer at 20°C (λMoKα, graphite monochromator, ω/2θ scanning, θ ≤ 23°). There was no decrease in intensity of three control reflexions during collection of the data. The structure was determined by the direct method using the SIR program [9] and was refined initially isotropically and in the anisotropic approximation. The positions of all hydrogen atoms were revealed from difference syntheses and their contributions to the structure amplitudes were calculated in the final stages with fixed thermal and positional parameters. The final values residual factors were *R* = 0.034, R_w = 0.042 for 1205 independent reflexions with $F^2 \geq 3\sigma$. All calculations were carried out with the MolEN suite of programs [10] using an Alpha Station 200 computer. Figures were drawn using the PLATON program [11].

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