

Five-Membered 2,3-Dioxo Heterocycles: LII.* Reactions of 5-Aryl-4-(quinoxalin-2-yl)-2,3-dihydrofuran-2,3-diones with Schiff Bases and Dicyclohexylcarbodiimide. Crystalline and Molecular Structure of Substituted 2-(4-Oxo-3,4-dihydro-2*H*-1,3-oxazin-5-yl)quinoxalines

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Abstract—Aroyl(quinoxaliny)ketenes generated by thermolysis of 5-aryl-4-(quinoxalin-2-yl)-2,3-dihydrofuran-2,3-diones react with *N*-benzylideneanilines and *N,N'*-dicyclohexylcarbodiimide according to the [4+2]-cycloaddition pattern where the aroylketene acts as diene, and C=N component, as dienophile, to give 3-aryl-2-(2,3,6-triaryl- and 6-aryl-3-cyclohexyl-2-cyclohexylimino-4-oxo-3,4-dihydro-2*H*-1,3-oxazin-5-yl)quinoxalines. The structure of two cycloaddition products was proved by X-ray analysis.

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4,5-Disubstituted 2,3-dihydrofuran-2,3-diones are thermally unstable substances. Heating of these compounds in the crystalline state at about their melting point (130–140°C) or of their solutions at 80–110°C induces thermal decarbonylation with formation of the corresponding acylketenes that are capable of reacting with various dienophiles according to the [4+2]-cycloaddition pattern. In the absence of dienophile, the mode of stabilization (as a rule, intermolecular) of acylketenes depends on the nature of substituents therein [2–7].

Thermally induced decarbonylation of 5-aryl-4-(quinoxalin-2-yl)-2,3-dihydrofuran-2,3-diones **Ia** and **Ib** gives rise to aroyl(3-arylquinoxalin-2-yl)ketenes **IIa** and **IIb** which may be regarded as aroyl(imido)ylketenes; in the absence of reaction partner, ketenes **IIa** and **IIb** undergo [4+2]-cyclodimerization which involves the conjugated imido)ylketene bond system—N=C=C=C= of one molecule (diene) and ketene —C=C= bond of the other molecule (dienophile). As a result, substituted 4-aroyl-3-aroyloxy-2-(quinoxalin-2-yl)-1*H*-pyrido[1,2-*a*]quinoxalin-1-ones **IIIa** and **IIIb**

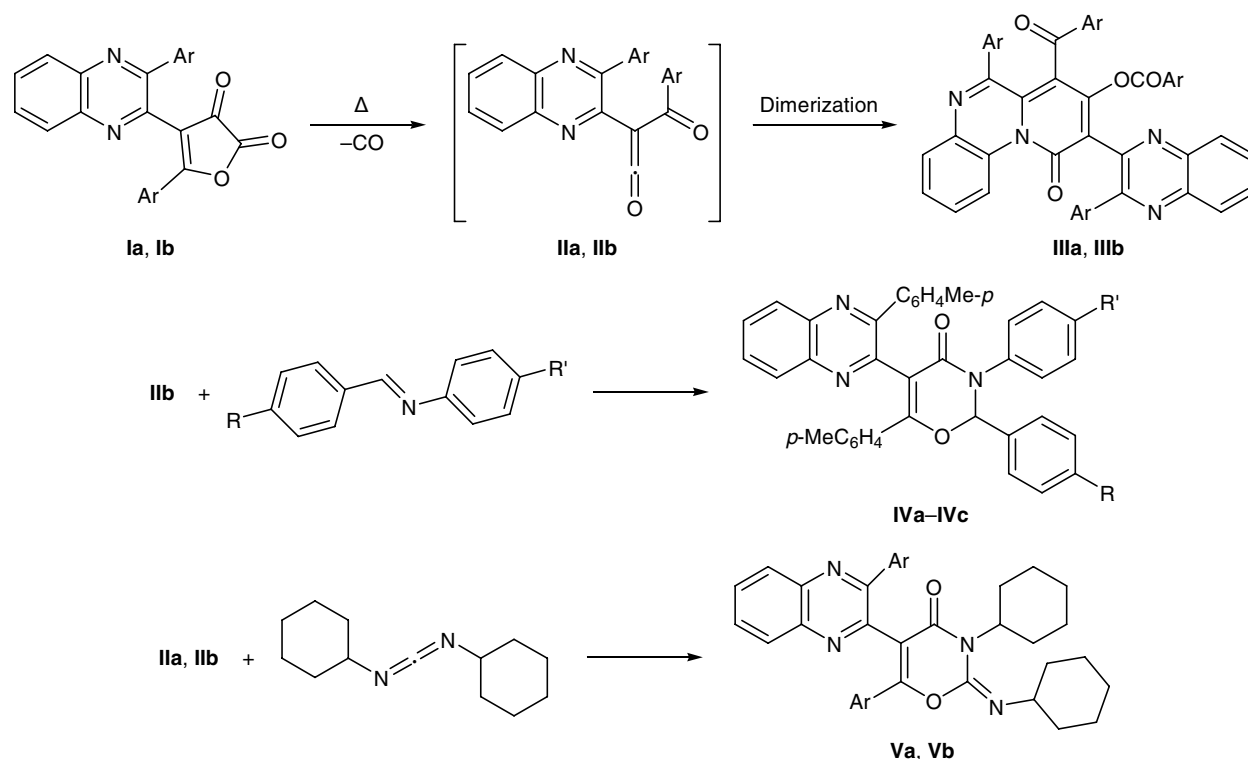
are formed [8, 9]. When thermolysis of furandiones **Ia** and **Ib** is performed in the presence of aldehydes or ketones, the products are 2-substituted 6-aryl-5-(3-arylquinoxalin-2-yl)-4*H*-1,3-dioxin-4-ones [10, 11]; they are formed via [4+2]-cycloaddition of ketenes **IIa** and **IIb** (at the conjugated aroylketene O=C—C=C= bond system) to the C=O bond of carbonyl compound acting as dienophile. Factors responsible for the regioselectivity in the cycloaddition of ketenes **IIa** and **IIb** to carbonyl compounds and their self-condensation (cyclodimerization [8, 9]) are not clear and are now under discussion.

With the goal of estimating the reactivity of compounds containing a C=N bond in the cycloaddition to ketenes **IIa** and **IIb** in comparison to the reactivity of aldehydes and ketones and aroylketenes themselves (cyclodimerization), in the present study we made an attempt to trap these ketene intermediates by Schiff bases and *N,N'*-dicyclohexylcarbodiimide. We were also interested in determining the regio- and stereoselectivity of these reactions.

Aroyl(imido)ylketenes **IIa** and **IIb** were generated by heating solutions of furandiones **Ia** and **Ib** in *p*-xylene for 15–20 min at 138–140°C, i.e., at a tem-

* For communication LI, see [1].

Scheme 1.

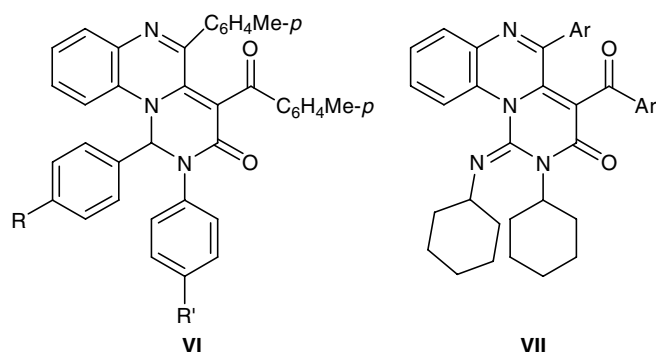


I-III, V, Ar = Ph (**a**), *p*-MeC₆H₄ (**b**); **IV**, R = Br, R' = MeO (**a**), R = MeO, R' = Br (**b**), R = F, R' = Me (**c**).

perature corresponding to decarbonylation of the initial furandiones. When the reaction was performed in the presence of *N*-benzylideneanilines or *N,N'*-dicyclohexylcarbodiimide, the corresponding [4+2]-cycloaddition products were formed with high regioselectivity. However, the spectral parameters of the products did not allow us to unambiguously distinguish between alternative structures **IV**, **V** and **VI**, **VII**, which could be formed with participation of the aroyl- and imido-ylketene fragment of ketenes **II**, respectively. Therefore, the structure of compounds **IVb** and **Va** was proved by X-ray analysis. The results showed that the cycloaddition products are 2,3,6-triaryl-5-(3-aryl-quinoxalin-2-yl)- and 6-aryl-5-(3-aryl-quinoxalin-2-yl)-3-cyclo-

hexyl-2-cyclohexylimino-3,4-dihydro-2*H*-1,3-oxazin-4-ones **IVa-IVc**, **Va**, and **Vb**. Presumably, aroyl(imido-yl)ketenes **IIa** and **IIb** generated by thermal decarbonylation of furandiones **Ia** and **Ib** added at the C=N bond of Schiff bases and dicyclohexylcarbodiimide (as diene component) with participation of the aroylketene O=C-C=C= conjugated bond system as dienophile. It should be noted that small amounts of aroylketene dimers **IIIa** and **IIIb** were present in the reaction mixtures obtained by thermolysis of furandiones **Ia** and **Ib** in the presence of *N*-benzylideneanilines and *N,N'*-dicyclohexylcarbodiimide (compounds **IIIa** and **IIIb** were generally detected by TLC).

Figures 1 and 2 show the structures of molecules **IVb** and **Va** according to the X-ray diffraction data. Molecules **IVb** and **Va** have essentially similar structures. All double bonds therein are localized, and the bond lengths fall into the ranges typical of the corresponding standard bonds. Orientation of the substituents in the quinoxaline ring of **IVb** is characterized by torsion angles of 37.4 ($\text{C}^2\text{C}^1\text{C}^{13}\text{C}^{18}$, *p*-tolyl ring) and -112.6° ($\text{C}^1\text{C}^2\text{C}^3\text{C}^4$, oxazine ring). The respective torsion angles in molecule **Va** are -67.1 and -72.2° . The oxazine ring in **Va** is planar, while in molecule **IVb** it adopts a distorted *envelope* conformation, the



dihedral angle along the $O^1 \cdots N^3$ line is 39° , and the C^6 atom deviates by $0.52 \text{ \AA}$ from the mean-square plane formed by the remaining five atoms. No hydrogen bonds or other shortened intermolecular contacts were found in the crystalline structures of compounds **IVb** and **Va**.

EXPERIMENTAL

The IR spectra were recorded on a UR-20 spectrometer from samples dispersed in mineral oil. The ^1H NMR spectra were measured on a Bruker AM-400 instrument at 400 MHz from solutions in $\text{DMSO}-d_6$ relative to tetramethylsilane as internal reference. The purity of compounds **IV** and **V** was checked by TLC on Silufol plates using benzene–ethyl acetate (5:1) as eluent.

2-*p*-Bromophenyl-3-*p*-methoxyphenyl-6-*p*-tolyl-5-(3-*p*-tolylquinoxalin-2-yl)-3,4-dihydro-2*H*-1,3-oxazin-4-one (IVa). A solution of 1 mmol of furandione **Ib** [8, 9] and 1.1 mmol of *N*-(*p*-bromobenzylidene)-*p*-methoxyaniline in 5 ml of anhydrous *p*-xylene was heated for 20 min at $138\text{--}140^\circ\text{C}$. The mixture was cooled, and the precipitate was filtered off. Yield 88%, mp $210\text{--}211^\circ\text{C}$ (from MeCN). IR spectrum: $\nu(\text{C}=\text{O})$ 1650 cm^{-1} . ^1H NMR spectrum, δ , ppm: 2.18 s (3H, Me), 2.37 s (3H, Me), 3.71 s (3H, OMe), 6.82–7.65 m (21H, H_{arom} , 2-H). Found, %: C 70.01; H 4.56; Br 12.07; N 6.21. $\text{C}_{39}\text{H}_{30}\text{BrN}_3\text{O}_3$. Calculated, %: C 70.06; H 4.52; Br 11.95; N 6.28.

3-*p*-Bromophenyl-2-*p*-methoxyphenyl-6-*p*-tolyl-5-(3-*p*-tolylquinoxalin-2-yl)-3,4-dihydro-2*H*-1,3-oxazin-4-one (IVb). Yield 86%, mp $180\text{--}182^\circ\text{C}$ (from MeCN). IR spectrum: $\nu(\text{C}=\text{O})$ 1652 cm^{-1} . ^1H NMR spectrum, δ , ppm: 2.19 s (3H, Me), 2.33 s (3H, Me), 3.77 s (3H, OMe), 6.82–8.10 m (21H, H_{arom} , 2-H). Found, %: C 70.07; H 4.49; Br 11.97; N 6.31. $\text{C}_{39}\text{H}_{30}\text{BrN}_3\text{O}_3$. Calculated, %: C 70.06; H 4.52; Br 11.95; N 6.28.

2-*p*-Fluorophenyl-3,6-di-*p*-tolyl-5-(3-*p*-tolylquinoxalin-2-yl)-3,4-dihydro-2*H*-1,3-oxazin-4-one (IVc). Yield 86%, mp $198\text{--}200^\circ\text{C}$ (from MeCN). IR spectrum: $\nu(\text{C}=\text{O})$ 1655 cm^{-1} . ^1H NMR spectrum, δ , ppm: 2.18 s (3H, Me), 2.23 s (3H, Me), 2.33 s (3H, Me), 6.86–8.13 m (21H, H_{arom} , 2-H). Found, %: C 79.11; H 5.10; N 7.13. $\text{C}_{39}\text{H}_{30}\text{FN}_3\text{O}_2$. Calculated, %: C 79.17; H 5.11; N 7.10.

3-Cyclohexyl-2-cyclohexylimino-6-phenyl-5-(3-phenylquinoxalin-2-yl)-3,4-dihydro-2*H*-1,3-oxazin-4-one (Va). Yield 82%, mp $168\text{--}170^\circ\text{C}$ (from MeCN).

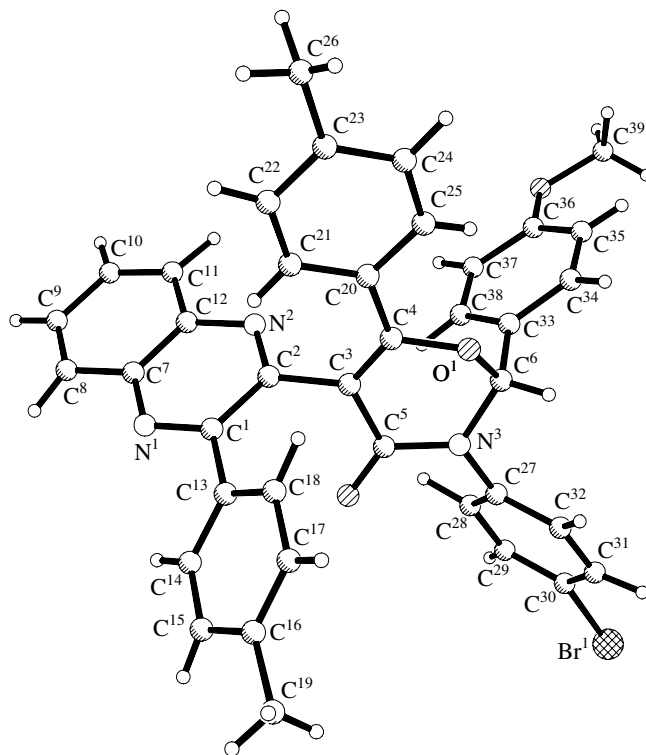


Fig. 1. Structure of the molecule of 3-*p*-bromophenyl-2-*p*-methoxyphenyl-6-*p*-tolyl-5-(3-*p*-tolylquinoxalin-2-yl)-3,4-dihydro-2*H*-1,3-oxazin-4-one (**IVb**) according to the X-ray diffraction data.

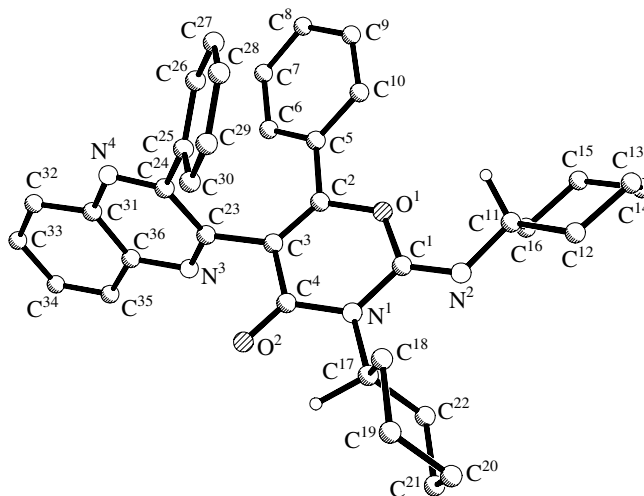


Fig. 2. Structure of the molecule of 3-cyclohexyl-2-cyclohexylimino-6-phenyl-5-(3-phenylquinoxalin-2-yl)-3,4-dihydro-2*H*-1,3-oxazin-4-one (**Va**) according to the X-ray diffraction data.

IR spectrum: $\nu(\text{C}=\text{O})$ 1675 cm^{-1} . ^1H NMR spectrum, δ , ppm: 1.06–2.40 m (20H, CH_2), 3.70 m (1H, CH), 4.56 m (1H, CH), 7.02–8.14 m (14H, H_{arom}). Found, %: C 77.70; H 6.47; N 10.05. $\text{C}_{36}\text{H}_{36}\text{N}_4\text{O}_2$. Calculated, %: C 77.67; H 6.52; N 10.06.

Principal crystallographic parameters of compounds **IVb** and **Va**

Parameter	IVb	Va
Formula	C ₃₉ H ₃₀ BrN ₃ O ₃	C ₃₆ H ₃₆ N ₄ O ₂
<i>a</i> , Å	22.330(4)	21.438(4)
<i>b</i> , Å	12.014(2)	11.733(2)
<i>c</i> , Å	12.012(2)	23.921(5)
α , deg	90	90
β , deg	93.20(3)	90
γ , deg	90	90
<i>V</i> , Å ³	3217.5(10)	6017(2)
<i>Z</i>	4	8
Space group	P2 ₁ /c	Pbca
<i>M</i>	668.57	556.69
<i>d</i> , g/cm ³	1.380	1.229
<i>F</i> (000)	1376	2368
μ , mm ⁻¹	2.083	0.606
$\theta_{\max}$, deg	80.37	80.16
Total number of reflections	5253	5490
Number of reflections with <i>I</i> > 2 σ	3063	1248
<i>R</i> -Factor (<i>I</i> > 2 σ)	0.0467	0.0561
GOOF	0.905	0.694

3-Cyclohexyl-2-cyclohexylimino-6-*p*-tolyl-5-(3-*p*-tolylquinoxalin-2-yl)-3,4-dihydro-2*H*-1,3-oxazin-4-one (Vb). Yield 78%, mp 179–181°C (from MeCN). IR spectrum: $\nu(\text{C}=\text{O})$ 1750 cm⁻¹. ¹H NMR spectrum, δ , ppm: 1.04–2.42 m (20H, CH₂), 2.22 s (3H, Me), 2.33 s (3H, Me), 3.70 m (1H, CH), 4.54 m (1H, CH), 6.93–8.15 m (12H, H_{arom}). Found, %: C 78.09; H 6.87; N 9.50. C₃₈H₄₀N₄O₂. Calculated, %: C 78.05; H 6.89; N 9.58.

X-Ray analysis. The principal crystallographic data for compounds **IVb** and **Va** are given in table. Sets of experimental reflections were acquired on a KM-4 (Kuma Diffraction) automatic four-circle diffractometer (χ -geometry, $\omega/2\theta$ scanning, monochromatized CuK α irradiation). The structures were solved by the direct method using SIR92 program [12], followed by

a series of calculations of the electron density maps. The positions of hydrogen atoms were set from the geometry considerations. Non-hydrogen atoms were refined by the full-matrix least-squares procedure in anisotropic approximation using SHELXL-97 software [13] built in WINGX package [14].

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