DOI 10.1007/s10593-017-2090-0

Chemistry of Heterocyclic Compounds **2017**, *53*(5), 560–567

A new method for the synthesis of substituted 8,9,10,11-tetrahydroindolo[1,2-*a*]quinoxalin-6(5*H*)-ones

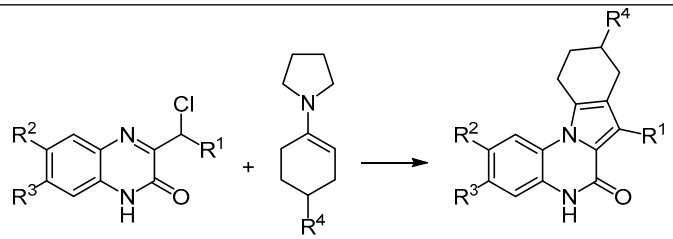
Vakhid A. Mamedov[1,2]*, Elena A. Khafizova[1,2], Anastasiya I. Zamaletdinova[1,2], Julia K. Voronina[1], Saniya F. Kadyrova[1], Ekaterina V. Mironova[1], Dmitry B. Krivolapov[1], Ildar Kh. Rizvanov[1], Oleg G. Sinyashin[1,2]

[1] *A. E. Arbuzov Institute of Organic and Physical Chemistry, Kazan Scientific Center of the Russian Academy of Sciences, 8 Akademika Arbuzova St., Kazan 420088, Republic of Tatarstan, Russia; e-mail: mamedov@iopc.ru*

[2] *Kazan National Research Technological University, 68 Karla Marksa St., Kazan 420015, Republic of Tatarstan, Russia*

Translated from Khimiya Geterotsiklicheskikh Soedinenii, 2017, *53*(5), 560–567

Submitted December 20, 2016
Accepted after revision February 14, 2017



The reaction of 1-(cyclohexen-1-yl)pyrrolidines with 3-(α-chlorobenzyl)quinoxalin-2(1*H*)-ones resulted in the formation of 8,9,10,11-tetrahydroindolo[1,2-*a*]quinoxalin-6(5*H*)-ones *via* a tandem sequence of Stork enamine alkylation and intramolecular annulation. Oxidative dehydrogenation gave indolo[1,2-*a*]quinoxalin-6(5*H*)-one.

Keywords: 3-(α-chlorobenzyl)quinoxalin-2(1*H*)-ones, 1-(cyclohexen-1-yl)pyrrolidines, 8,9,10,11-tetrahydroindolo[1,2-*a*]quinoxalin-6(5*H*)-ones, Stork reaction, tetrahydroindolo[*a*]annulation, X-ray structural analysis.

Quinoxalines are an important class of nitrogen heterocycles[1] that have shown a broad spectrum of biological activity and are known as antitumor[2a] and anti-HIV[2b] drugs, as well as antagonists of glucagon[2c] and angiotensin receptors.[2d] They are also used as matrix for the synthesis of GABA, benzodiazepines, receptor agonists or antagonists,[3] and other therapeutic targets.[4] Valuable biological activity has been discovered among condensed quinoxaline derivatives, such as pyrrolo[1,2-*a*]quinoxalines,[5–7] triazolo[4,3-*a*]quinoxalines,[7,8] and imidazo[1,5-*a*]-quinoxalines.[7–9] In a continuation of our studies[5–7,9] aimed at the development of synthetic methods and search for new biologically active molecules, in the current work we aimed at the synthesis of polycyclic condensed 5,6-dihydroindolo[1,2-*a*]quinoxaline derivatives, since the indole moiety represents a significant structural feature of various alkaloids[10] that exhibit a wide range of biological effects (for example, antiviral,[11] antitumor,[12] antimicrobial,[13] and anti-inflammatory activity).[14]

The methods for the synthesis of indolo[1,2-*a*]-quinoxalines are mainly based on the use of indole derivatives.[15–28] The most important among these are 1-(2-aminophenyl)indoles, which can react with various sources of carbon atom, such as aldehydes,[15] ketones,[16,17] alkenes,[18] and alkynes,[19–21] giving the respective indolo[1,2-*a*]-quinoxaline derivatives. Of secondary importance are methods based on the reaction of indole derivatives containing a carboxy,[22] alkoxycarbonyl,[23] amide,[24] or aldehyde[25] group at position 2, while the closure of pyrazine ring in the quinoxaline system can occur either in a single step[23c,24] or in two steps (starting with the creation of N(5)–C(6) bond and followed by ring closure forming the N(12)–C(6a) bond,[22] or starting by the formation of N(12)–C(12a) bond and then ring closure by forming the new N(5)–C(6) bond).[23a,b,25] The third type of methods are based on intramolecular reductive closure of 1-(2-nitrophenyl)-1*H*-indole derivatives containing an alkoxycarbonyl[26] or acetylene[27] group. Finally, the fourth type of methods rely on intramolecular ring closure reactions of ketals formed by reactions of dimethylketals derived from α-bromocyclohexanone with 2-benzoyl-3-methylindole derivatives in the presence of ammonium acetate.[28]

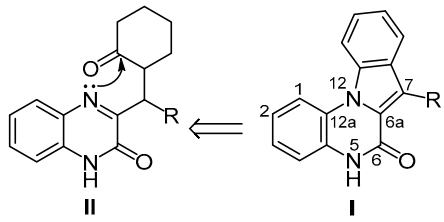
Besides these methods, there is only one additional route for the synthesis of indolo[1,2-*a*]quinoxalines, which requires the irradiation of 2-benzoylquinoxaline derivatives with high pressure mercury lamp in the presence of trifluoroacetic acid.[29]

It should be noted that the methods for the synthesis of indolo[1,2-*a*]quinoxalines starting from substituted indoles first require access to such indole derivatives, which can be obtained through laborious multistep processes. The method based on the use of quinoxaline derivatives has been applied only to their benzoyl derivatives and can not be extended to other quinoxalines.

During our studies aimed at the synthesis and use of nitrogen-containing heterocyclic compounds,[5–7,9,30,31] including quinoxalines and their condensed analogs, it was shown that quinoxalinone derivatives containing substituents with electrophilic reactive sites at position 3 were capable of annulation reactions. Depending on the nature of substituent, such reactions produced pyrrolo[1,2-*a*]-,[5] imidazo[1,5-*a*]-,[9] or thiazolo[3,4-*a*]quinoxalines.[30] Following this logic, in the current work we set out to perform the synthesis of tetrahydroindolo[1,2-*a*]quinoxalines **I** starting from 3-[(aryl)(2-oxocyclohexyl)methyl]quinoxalin-2(1*H*)-ones **II** (Scheme 1), assuming that the reaction conditions are suitable for annulation of tetrahydroindole ring as a result of intramolecular nucleophilic attack by the N-4 nitrogen atom at the carbon atom of the carbonyl group.

In order to achieve these goals, we employed the available 3-(α-chlorobenzyl)quinoxalin-2(1*H*)-one derivatives **1a**–**h**,[31] which reacted depending on the reaction conditions either as α-substituted benzyl chlorides, or as hetero analogs of α-chloro ketones – α-chloroimines. There are literature precedents for successful use of enamine alkylation with such electrophiles as benzyl halides, which is considered a convenient method for the Stork synthesis of alkyl ketones.[32] Involving α-chloro ketones in this reaction allowed to synthesize 1,4-diketones,[33] while the use of 3-α-(chlorobenzyl)quinoxalin-2(1*H*)-ones **1a**–**h** in the role of alkylating reagents and 1-(cyclohexen-1-yl)-pyrrolidines **2a**,**b** as alkylation substrates can lead to new quinoxalin-2(1*H*)-one derivatives, 3-[(aryl)(2-oxocyclohexyl)methyl]quinoxalin-2(1*H*)-ones **5** *via* the respective immonium derivatives **4** (Scheme 2, Table 1).

Scheme 1



However, performing the reaction of 3-(α-chlorobenzyl)-quinoxalin-2(1*H*)-one (**1a**) with 1-(cyclohexen-1-yl)pyrrolidine (**2a**) under various relatively mild conditions (in dioxane at room temperature for 12 h and at 70°C for 3 h, in DMF at room temperature for 12 h and at 70°C for 3 h, in refluxing acetonitrile for 3 h) resulted in a mixture of products **4a** and **3a** in variable ratio, according to ^{1}H NMR data. Elevated temperatures, as a rule, led to the formation of mostly the intramolecular condensation products **3** from

Scheme 2

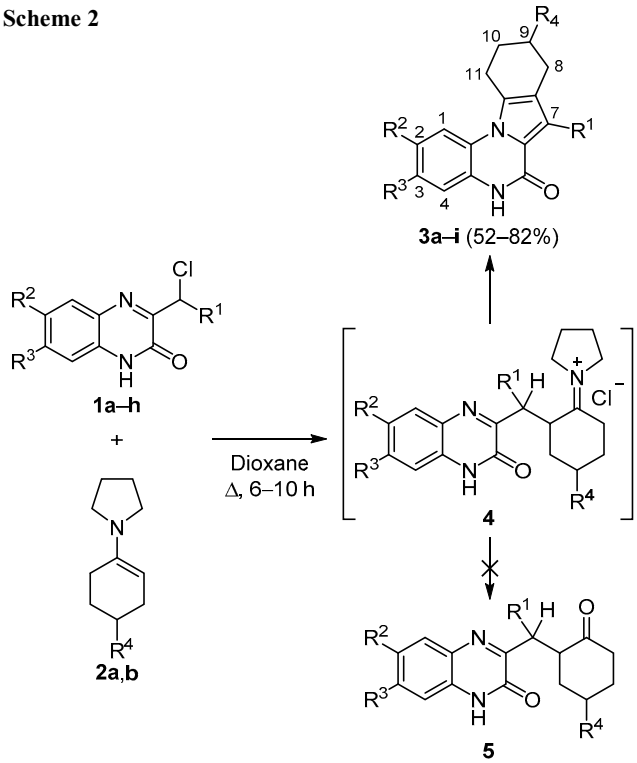


Table 1. The reaction conditions, yields, and melting points of 8,9,10,11-tetrahydroindolo[1,2-*a*]quinoxalin-6(5*H*)-ones **3a**–**i**

Quinoxalinone	Enamine	Product	R^1	R^2	R^3	R^4	Yield*, %	Mp, °C
1a	**2a**	**3a**	Ph	H	H	H	71 (45)	325–326
1b	**2a**	**3b**	4-$O_2NC_6H_4$	H	H	H	82 (42)	318–322
1c	**2a**	**3c**	4-ClC_6H_4	H	H	H	64 (42)	331–333
1d	**2a**	**3d**	4-BrC_6H_4	H	H	H	59 (19)	312–315
1e	**2a**	**3e**	Ph	Me	Me	H	80 (57)	>350
1f	**2a**	**3f**	Ph	Me	H	H	65 (35)	340–342
1g	**2a**	**3g**	Ph	H, CO_2H*[2]		H	52 (24)	>350
1a	**2b**	**3h**	Ph	H	H	*t*-Bu	67 (26)	328–332
1h	**2a**	**3i**	Hex	H	H	H	54 (12)*[3]	208–210

* Overall yield (the yield of analytically pure sample precipitated during the reaction is indicated in parentheses).
*[2] Mixture of isomers.
*[3] For the reaction performed in MeCN.

intermediate compound **4**, even though the latter also remained in the mixture. The evidence for the formation of intermediate compound **4** was provided by ^{1}H NMR spectrum of the residue obtained after evaporation of the reaction mixture. In addition to other signals, this spectrum contained a sharp doublet (J = 11.0 Hz), a double double doublet (J = 11.0, 6.0, and 3.2 Hz), and a double doublet (J = 6.1 and 6.8 Hz) at 4.66, 3.65, and 3.24 ppm, corresponding to the α-benzyl proton and protons at positions 1 and 5 of the cyclohexylidene ring.

The formation of 8,9,10,11-tetrahydroindolo[1,2-*a*]-quinoxalin-6(5*H*)-ones **3a**–**h** was first of all indicated by the presence of ^{1}H NMR doublet signal of the H-1 hydrogen atom (J = 8.3 Hz) at 8.01 ppm, which was characteristic for similar systems,[5–7,30,31c,d] as well as the signals of other protons belonging to aromatic rings, two multiplet signals at 1.69–1.72 and 1.90–1.93 ppm, and two double doublet signals ($J \approx 6$ Hz) at 2.47 and 3.24 ppm for the cyclohexene ring protons (the data are given for compound **3a**). Another characteristic signal is the broadened singlet of amide proton at ~11 ppm.

A comparative analysis of ^{1}H NMR spectra of compounds **3a**,**e**–**h** allowed us to achieve complete assignment of all signals. The phenyl group at position 7 of the tetrahydroindoloquinoxalinone system in all of these compounds, regardless of the presence or absence of substituents in the cyclohexene ring of the tetrahydroindole system or in the benzene ring of the quinoxalinone system, gave a distinct resonance that was dependent on the character of substituents, and the multiplicity was easily interpreted (see Experimental).

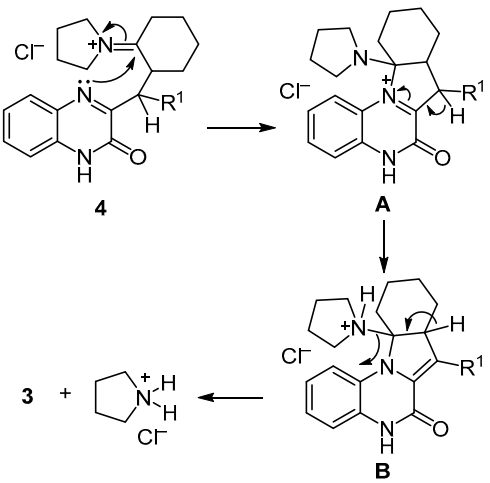
The comparison of ^{1}H NMR spectra for compound **3a** and 2-methyl-7-phenyl-8,9,10,11-tetrahydroindolo[1,2-*a*]-quinoxalin-6(5*H*)-one **3f**, the structure of which was established by X-ray structural studies, as well as spectra of compound **3f** with the spectrum of the major isomer of carboxylic acid **3g** enabled complete assignment of all proton signals of the benzene ring in the quinoxaline system. For example, the downfield doublet signals of H-1 proton at ~8.00 ppm in the case of compound **3f** were observed at 7.80 ppm as a singlet signal, due to the presence of electron-donating methyl group at position 2, which affected both the chemical shift and multiplicity of the adjacent H-1 proton signal. The signals of H-3 and H-4 protons in compound **3f** were observed as doublets with J = 8.2 and 8.1 Hz at 7.04 and 7.17 ppm. At the same time, in the case of compound **3e**, the H-1 and H-4 protons of 2,3-dimethylbenzene ring of quinoxaline system resonated as singlet signals at 7.77 and 7.04 ppm.

The comparison of ^{1}H NMR spectra of compounds **3f** and **3g** allowed to assign the proton signals of the benzene ring in product **3g** (both the major and minor isomers with the carboxy group at positions 3 and 2, respectively). The H-1, H-2, and H-4 protons of the major product gave a doublet signal (J = 8.9 Hz), double doublet (J = 8.9, 1.9 Hz), and another doublet (J = 1.9 Hz) at 8.08, 7.69, and 7.88 ppm, respectively. At the same time, the H-1, H-3, and H-4 protons of the minor product gave a broadened singlet and two broadened doublet signals (J = 8.7 Hz) at 8.60, 7.81, and ~7.35 ppm, respectively (the latter signal overlapped with the signals of phenyl group protons).

Replacing the aryl groups in the starting quinoxalin-2(1*H*)-ones with a hexyl group allowed to synthesize the respective 8,9,10,11-tetrahydroindolo[1,2-*a*]quinoxalin-6(5*H*)-one, albeit at a relatively low yield. The reaction of 3-(1-chloroheptyl)quinoxalin-2(1*H*)-one (**1h**) with 1-(cyclohexen-1-yl)-pyrrolidine (**2a**) in dioxane and DMF under various temperature regimes led to a mixture of products, while the reaction in refluxing acetonitrile proceeded with the formation of mostly the desired product **3i** (Scheme 2, Table 1).

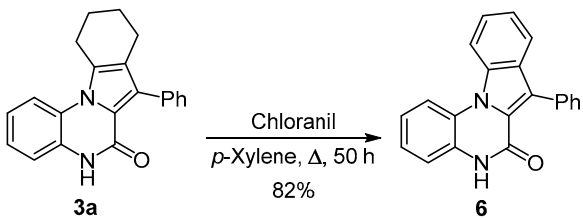
The formation of 8,9,10,11-tetrahydroindolo[1,2-*a*]-quinoxalin-6(5*H*)-ones **3a**–**i** can be explained with nucleophilic attack by the N-4 nitrogen atom on the electrophilic carbon atom of the immonium group in the Stork alkylation product **4**, accompanied by the closure of pyrroline ring, leading to the intermediate product **A**. This intermediate product underwent aromatization under the reaction conditions *via* intermediate **B** by elimination of pyrrolidinium chloride (Scheme 3).

Scheme 3



The presence of cyclohexene moiety in the structure of 8,9,10,11-tetrahydroindolo[1,2-*a*]quinoxalin-6(5*H*)-ones **3** suggests possibilities for the synthesis of their aromatic analogs, which was achieved in the case of 7-phenyl-8,9,10,11-tetrahydroindolo[1,2-*a*]quinoxalin-6(5*H*)-one (**3a**). Refluxing of the latter with chloranil in xylene for 50 h led to 7-phenylindolo[1,2-*a*]quinoxalin-6(5*H*)-one (**6**) as an oxidative dehydrogenation product (Scheme 4).

Scheme 4



The molecular and crystal structures of compounds **3a**,**d**–**f**,**h**,**i** were established and analyzed by X-ray crystallography. The molecular geometry of compounds **3a**,**d**–**f**,**h**,**i** (Fig. 1, in the case of compound **3f**) in the studied crystals featured a condensed tetracyclic framework including a 13-membered conjugated system of three rings (the largest deviation from the median plane was 0.157(9) Å in compound **3d**). The cyclohexene ring assumed a half chair conformation where the peripheral sp^3-hybridized C(9) and C(10) carbon atoms were located above and and below the plane of conjugated ring system, respectively.

The crystal structure motifs were the same in all of the studied samples: the molecules were linked in the crystal lattice by a classical N–H···O hydrogen bond, forming centrosymmetric dimers (shown in Fig. 2*a* for the case of compound **3e**), which were further ordered in stacks through π···π and CH···π interactions. The crystal structure of compound **3a** also generally corresponded to this description of linked array of molecular stacks, but it had some differences, being a crystal solvate with DMSO in 1:1 ratio (Fig. 2*b*). The presence of N–H···O hydrogen bonds in this compound resulted in the formation of a centrosymmetric tetramer instead of centrosymmetric dimer. The molecules of tetrahydroindolo[1,2-*a*]quinoxalin-6(5*H*)-one **3a** in the tetramer were not linked directly, but rather through DMSO molecules.

Another difference was observed for compounds **3d** and **3h** (Fig. 3), which crystallized with two independent molecules in the unit cell. At the same time, the geometry of molecules A and B in both compounds was practically identical, except for a very minor deviation of the bromophenyl substituent in the molecule of compound **3d** and a rotation of *tert*-butyl and phenyl substituents in the molecules A and B of compound **3h**.

A detailed analysis of short intermolecular contacts provided an explanation for the crystallization of these compounds with two independent molecules. Thus, in compound **3d** containing a bromine atom, a weak non-covalent Br···π interaction was observed (the distance from the Br atom to the centroid of the ring was 4.156(9) Å, to the ring plane – 3.640 Å, while the C–Br–centroid angle

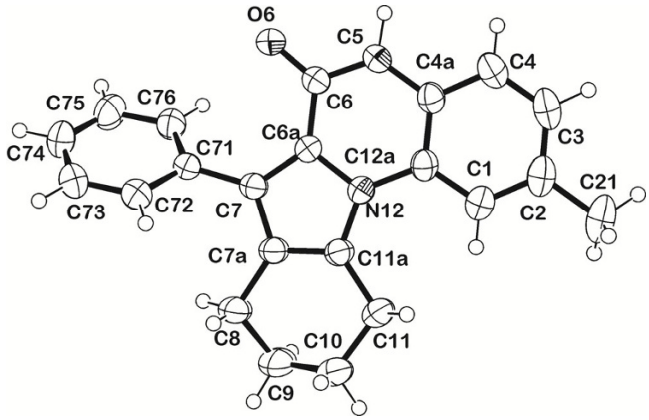


Figure 1. The molecular structure of compound **3f** with atoms represented by thermal vibration ellipsoids of 50% probability.

was 105.79°), which involved the bromine atom of molecule B, while the surroundings of the bromine atom in molecule A prevented any bonding, even the formation of very weak interactions. Thus, the crystallization of this compound with two independent molecules in the unit cell was associated with the differences in the environment around the bromine atoms.

The different geometry of molecules A and B in the crystals of compound **3h** can be also explained by the presence of weak noncovalent interactions, which were different for the molecules A and B. For example, the different orientation of the *tert*-butyl group can be explained by the presence of a short CH···π contact between the molecules A and B, involving the H(92F) atom of *tert*-butyl group in the molecule A and the five-membered heterocycle of molecule B (the H(92F)···centroid distance was equal to 3.009 Å, C(92A)···centroid – 3.668(7) Å), H(92F)···ring plane – 2.89 Å, the C(92A)–H(92F)···centroid angle was 126.96°, where centroid represents the centroid of ring moiety). The different orientation of the phenyl substituents was analogously caused by the presence of CH···π interaction between these substituents in the molecules A and B, involving the aromatic ring of molecule A and the

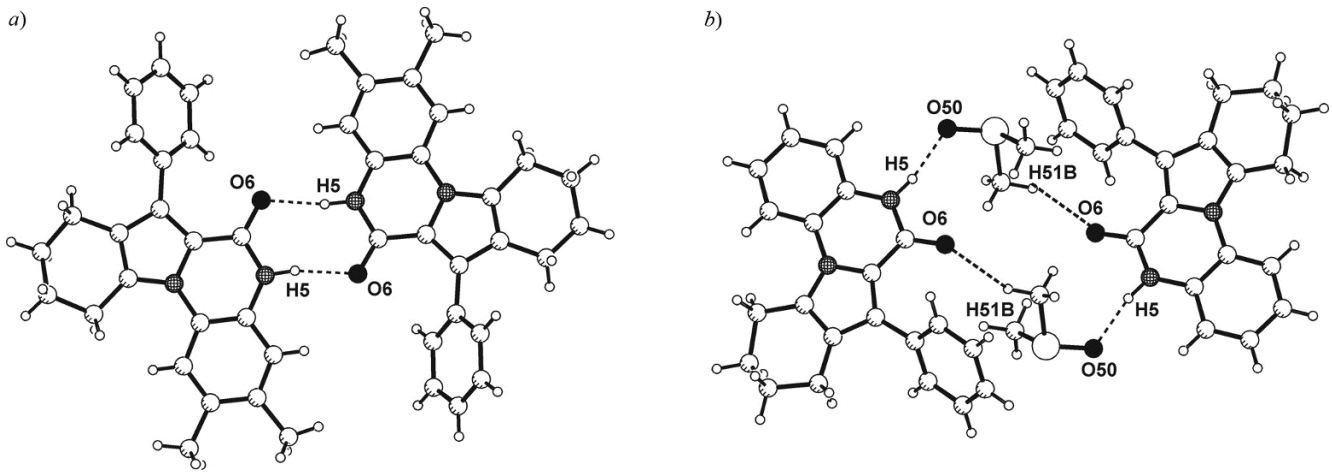


Figure 2. Hydrogen-bonded associates in the crystals of compounds (*a*) **3e**, (*b*) **3a**.

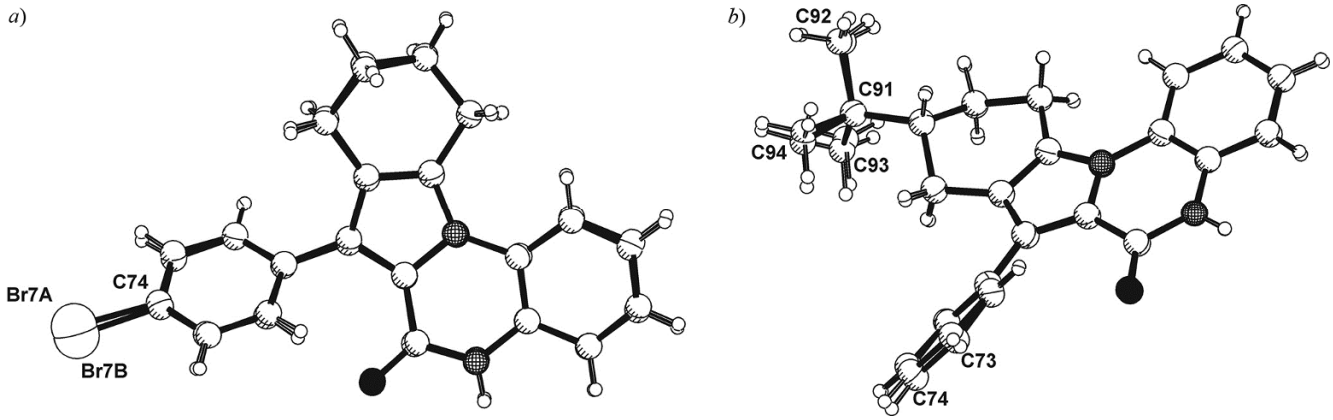


Figure 3. Geometry differences in two independent molecules in the crystals of compounds (*a*) **3d** and (*b*) **3h**.

CH group of molecule B (the H(3A)···centroid distance was 2.818 Å, C(3A)···centroid – 3.400(8) Å), H(92F)···ring plane – 2.74 Å, the C(92A)–H(92F)···centroid angle was 121.74°). The parameters of hydrogen bonds, stacking, and C–H···π-interactions in the crystals of the studied compounds are presented in Tables S2–S4 of the Supplementary information file.

Thus, we have developed a simple one-pot method for the synthesis of tetrahydroindolo[1,2-*a*]quinoxalin-6(5*H*)-ones and found suitable conditions for the aromatization of these compounds. The method is based on a two-stage process comprising a Stork alkylation reaction of 1-(cyclohexen-1-yl)pyrrolidines with 3-α-(chlorobenzyl)-quinoxalin-2(1*H*)-ones, followed by annulation of tetrahydroindole ring in the intermediate products, 1-{2-[aryl-(3-oxo-3,4-dihydroquinoxalin-2-yl)methyl]cyclohexylideno}-pyrrolidinium chlorides, accompanied by elimination of pyrrolidinium chloride. In the case of one of the tetrahydroindolo[1,2-*a*]quinoxalin-6(5*H*)-one derivatives, the possibility for synthesis of 7-arylindolo[1,2-*a*]quinoxalin-6(5*H*)-ones was demonstrated. The analysis of molecular and crystal structures of the studied compounds showed that the substituents had no substantial effect on the molecular conformation and crystal packing. The major factors affecting the structure were the presence of hydrogen bonding centers and a large planar ring system.

Experimental

IR spectra in the range of 4000–400 cm^{-1} were recorded on a Bruker Tensor 27 FT-IR spectrometer with optical resolution of 4 cm^{-1} and accumulation of 64 scans. The samples for recording of IR spectra were prepared as KBr pellets. ^{1}H NMR spectra were acquired on a Bruker DRX-400 (400 MHz), DRX-500 (500 MHz), or DRX-600 (600 MHz) spectrometers, while ^{13}C NMR spectra were acquired on a Bruker DRX-600 spectrometer (150 MHz) in DMSO-d_6, using the residual solvent signals as internal standard (2.5 ppm for ^{1}H nuclei, 39.5 ppm for ^{13}C nuclei). MALDI mass spectra were recorded on a Bruker Daltonics UltraFlex III TOF/TOF mass spectrometer. The high-resolution mass spectra were obtained in reflectron mode (the resolution was 10000) by using a metallic target and recording the positively charged ions. The data were processed with the FlexAnalysis 3.0 software (Bruker Daltonik GmbH, Bremen, Germany). The matrix was 2,5-dihydroxybenzoic acid or *p*-nitroaniline. Mass spectra with accurate mass values were obtained by using a mixture consisting of the sample in DMF (5 mg/ml) and the reference compound PEG-400 (1 mg/ml) in MeCN in the ratio of 1:5 with sequential addition and evaporation of 10 mg/ml matrix solution in MeCN (0.5 μl) and the sample mixture (0.5 μl). In a range of cases, CsCl was added for increasing the yield of positively charged cationized molecules. The indicated composition provided that the absolute error of mass determination did not exceed 0.0030 atomic mass units. Melting points were determined on a Boetius hot stage apparatus. All solvents were purified according to standard procedures prior to use.

Preparation of compounds 3a–i (General method). Equimolar amounts of the appropriate quinoxalin-2(1*H*)-one **1a**–**h** and 1-(1-pyrrolidino)cyclohexene were refluxed with dioxane (5–10 ml) in a flask with a reflux condenser for 6–10 h, until the reaction was complete (control by TLC method, eluent CH_2Cl_2–AcOEt, 1:2). The precipitate that formed during the reaction and additionally upon maintaining the reaction mixture at room temperature was filtered off, providing analytically pure samples of compounds **3a**–**i**. The filtrate was evaporated, the residue was washed with water (2×5–10 ml), extracted with chloroform (3×10 ml), dried, evaporated, and recrystallized from acetic acid, giving an additional crop of analytically pure compound **3** (Table 1). The synthesis of compound **3i** was performed by using acetonitrile as solvent instead of dioxane.

7-Phenyl-8,9,10,11-tetrahydroindolo[1,2-*a*]quinoxalin-6(5*H*)-one (3a) was obtained from 3-(α-chlorobenzyl)quinoxalin-2(1*H*)-one (**1a**) (1.00 g, 3.69 mmol) and 1-(1-pyrrolidino)cyclohexene (**2a**) (0.55 g, 3.69 mmol). Yield 0.83 g (71%), white crystals, mp 325–326°C (AcOH). IR spectrum, ν, cm^{-1}: 3439, 3108, 3028, 2931, 2853, 1647, 1611, 1514, 1483, 1439, 1394, 1328, 1215, 1120, 1072, 874, 803, 739, 726, 696, 666, 631, 569. ^{1}H NMR spectrum (400 MHz), δ, ppm (*J*, Hz): 1.69–1.72 (2H, m) and 1.90–1.93 (2H, m, 9,10-CH_2); 2.47 (2H, dd, *J* = 6.2, *J* = 6.0) and 3.24 (2H, dd, *J* = 6.2, *J* = 6.0, 8,11-CH_2); 7.14 (1H, ddd,

J = 7.9, *J* = 7.7, *J* = 1.6, H-2); 7.23 (1H, ddd, *J* = 7.7, *J* = 7.4, *J* = 1.0, H-3); 7.28–7.30 (2H, m, H-4, H-4 Ph); 7.35 (2H, dd, *J* = 7.7, *J* = 7.3, H-3,5 Ph); 7.39 (2H, dd, *J* = 8.5, *J* = 1.9, H-2,6 Ph); 8.01 (1H, br. d, *J* = 8.3, H-1); 10.95 (1H, s, NH). Found, *m/z*: 447.0431 $[M+Cs]^+$. $C_{21}H_{18}CsN_2O$. Calculated, *m/z*: 447.0468.

7-(4-Nitrophenyl)-8,9,10,11-tetrahydroindolo[1,2-*a*]-quinoxalin-6(5*H*)-one (3b) was obtained from 3-(α-chloro-4-nitrobenzyl)quinoxalin-2(1*H*)-one (**1b**) (1.00 g, 3.16 mmol) and 1-(1-pyrrolidinocyclohexene (**2a**) (0.47 g, 3.16 mmol). Yield 0.93 g (82%), golden brown crystals, mp 318–322°C (AcOH). IR spectrum, ν, cm^{-1}: 3434, 3176, 2935, 2854, 1654, 1615, 1597, 1515, 1481, 1438, 1392, 1344, 1328, 1205, 1107, 855, 745, 698, 576. ^{1}H NMR spectrum (600 MHz), δ, ppm (*J*, Hz): 1.70–1.71 (2H, m) and 1.89–1.90 (2H, m, 9,10-CH_2); 2.48 (2H, dd, *J* = 5.5, *J* = 7.1) and 3.20 (2H, dd, *J* = 5.6, *J* = 6.2, 8,11-CH_2); 7.14 (1H, dd, *J* = 7.1, *J* = 7.4, H-2); 7.25 (1H, dd, *J* = 7.4, *J* = 7.4, H-3); 7.31 (1H, d, *J* = 8.0, H-4); 7.66 (2H, d, *J* = 8.8, H-3',5' Ar); 7.99 (1H, d, *J* = 8.4, H-1); 8.18 (2H, d, *J* = 8.8, H-2',6' Ar); 11.14 (1H, s, NH). ^{13}C NMR spectrum (150 Hz, DMSO-d_6), δ, ppm: 21.8; 22.3; 23.0; 26.3; 116.2; 116.4; 118.1; 122.0; 122.1; 122.4; 123.8; 124.1; 125.0; 128.9; 130.3; 131.8; 141.5; 145.6; 154.6. Found, *m/z*: 360.1386 $[M+H]^+$. $C_{21}H_{18}N_3O_3$. Calculated, *m/z*: 360.1343.

7-(4-Chlorophenyl)-8,9,10,11-tetrahydroindolo[1,2-*a*]-quinoxalin-6(5*H*)-one (3c) was obtained from 3-(α,4-dichlorobenzyl)quinoxalin-2(1*H*)-one (**1c**) (1.00 g, 3.27 mmol) and 1-(1-pyrrolidino)cyclohexene (**2a**) (0.50 g, 3.27 mmol). Yield 0.73 g (64%), beige crystals, mp 331–333°C (AcOH). IR spectrum, ν, cm^{-1}: 3170, 3107, 3026, 2976, 2943, 2855, 1645, 1614, 1515, 1478, 1439, 1391, 1327, 1268, 1216, 1146, 1091, 1016, 998, 867, 839, 792, 734, 711, 666, 576, 539. ^{1}H NMR spectrum (400 MHz), δ, ppm (*J*, Hz): 1.70–1.72 (2H, m) and 1.89–1.91 (2H, m, 9,10-CH_2); 2.46 (2H, dd, *J* = 5.8, *J* = 5.9) and 3.23 (2H, t, *J* = 5.8, *J* = 5.4, 8,11-CH_2); 7.14 (1H, dd, *J* = 8.1, *J* = 7.2, H-2); 7.24 (1H, dd, *J* = 7.3, *J* = 7.8, H-3); 7.29 (1H, dd, *J* = 8.2, *J* = 1.6, H-4); 7.38–7.41 (4H, m, H Ar); 8.00 (1H, d, *J* = 8.4, H-1); 11.00 (1H, s, NH). Found, *m/z*: 481.0071 $[M+Cs]^+$. $C_{21}H_{17}ClCsN_2O$. Calculated, *m/z*: 481.0078.

7-(4-Bromophenyl)-8,9,10,11-tetrahydroindolo[1,2-*a*]-quinoxalin-6(5*H*)-one (3d) was obtained from 3-(4-bromo-α-chlorobenzyl)quinoxalin-2(1*H*)-one (**1d**) (1.00 g, 2.53 mmol) and 1-(1-pyrrolidino)cyclohexene (**2a**) (0.38 g, 2.53 mmol). Yield 0.66 g (59%), light-beige crystals, mp 312–315°C (DMSO). IR spectrum, ν, cm^{-1}: 3437, 3028, 2924, 2857, 1651, 1615, 1511, 1479, 1440, 1397, 1329, 1071, 1013, 997, 836, 750, 667, 574. ^{1}H NMR spectrum (400 MHz), δ, ppm (*J*, Hz): 1.72–1.73 (2H, m) and 1.91–1.92 (2H, m, 9,10-CH_2); 2.47 (2H, dd, *J* = 5.8, *J* = 6.1) and 3.25 (2H, dd, *J* = 6.1, *J* = 5.1, 8,11-CH_2); 7.16 (2H, ddd, *J* = 7.9, *J* = 7.7, *J* = 1.7, H-2); 7.25 (2H, ddd, *J* = 7.9, *J* = 7.2, *J* = 1.0, H-3); 7.30 (2H, dd, *J* = 8.0, *J* = 1.7, H-4); 7.35 (2H, d, *J* = 8.5, H-3',5' Ar); 7.54 (2H, d, *J* = 8.5, H-2',6' Ar); 8.02 (1H, d, *J* = 8.4, H-1); 11.02 (1H, s, NH). Found, *m/z*: 526.9538 $[M+Cs]^+$. $C_{21}H_{17}BrCsN_2O$. Calculated, *m/z*: 526.9553.

2,3-Dimethyl-7-phenyl-8,9,10,11-tetrahydroindolo-[1,2-*a*]quinoxalin-6(5*H*)-one (3e) was obtained from 3-(α-chlorobenzyl)-6,7-dimethylquinoxalin-2(1*H*)-one (**1e**) (1.00 g, 3.34 mmol) and 1-(1-pyrrolidino)cyclohexene (**2a**) (0.50 g, 3.34 mmol). Yield 0.92 g (80%), light-cream colored crystals, mp >350°C (AcOH). IR spectrum, ν, cm^{-1}: 3440, 3166, 3045, 2955, 2934, 2843, 1650, 1605, 1517, 1479, 1446, 1410, 1384, 1370, 1332, 1277, 1213, 1022, 880, 807, 768, 638, 590, 503. ^{1}H NMR spectrum (400 MHz), δ, ppm: 1.69–1.71 (2H, m) and 1.91–1.93 (2H, m, 9,10-CH_2); 2.22 (3H, s, CH_3); 2.29 (3H, s, CH_3); 2.45–2.47 (2H, m) and 3.24–3.26 (2H, m, 8,11-CH_2); 7.04 (1H, s, H-4); 7.26–7.36 (5H, m, H Ph); 7.77 (1H, s, H-1); 10.79 (1H, s, NH). Found, *m/z*: 475.0791 $[M+Cs]^+$. $C_{23}H_{22}CsN_2O$. Calculated, *m/z*: 475.0781.

2-Methyl-7-phenyl-8,9,10,11-tetrahydroindolo[1,2-*a*]-quinoxalin-6(5*H*)-one (3f) was obtained from 3-(α-chlorobenzyl)-6-methylquinoxalin-2(1*H*)-one (**1f**) (1.00 g, 3.51 mmol) and 1-(1-pyrrolidino)cyclohexene (**2a**) (0.53 g, 3.51 mmol). Yield 0.75 g (65%), light-brown crystals, mp 340–342°C (AcOH). IR spectrum, ν, cm^{-1}: 3435, 3160, 3025, 2939, 2848, 1648, 1625, 1609, 1518, 1483, 1444, 1432, 1392, 1371, 1330, 1214, 1026, 874, 804, 749, 727, 696, 635, 569. ^{1}H NMR spectrum (400 MHz), δ, ppm (*J*, Hz): 1.70–1.71 (2H, m) and 1.90–1.91 (2H, m, 9,10-CH_2); 2.37 (3H, s, CH_3); 2.46 (2H, dd, *J* = 5.7, *J* = 5.9) and 3.25 (2H, dd, *J* = 5.9, *J* = 6.1, 8,11-CH_2); 7.04 (1H, d, *J* = 8.2, H-3); 7.17 (1H, d, *J* = 8.1, H-4); 7.27 (1H, dd, *J* = 6.8, *J* = 6.8, H-4 Ph); 7.32–7.38 (4H, m, H-2,3,5,6 Ph); 7.80 (1H, s, H-1); 10.84 (1H, s, NH). ^{13}C NMR spectrum (150 MHz), δ, ppm: 20.2; 24.7; 28.0; 32.2; 42.0; 45.8; 54.1; 114.8; 126.7; 127.8; 128.3; 128.8; 129.1; 130.4; 131.1; 132.2; 138.6; 153.9; 162.5; 211.1. Found, *m/z*: 461.0594 $[M+Cs]^+$. $C_{22}H_{20}CsN_2O$. Calculated, *m/z*: 461.0625.

6-Oxo-7-phenyl-5,6,8,9,10,11-hexahydroindolo[1,2-*a*]-quinoxaline-2(3)-carboxylic acid (3g) was obtained from 3-(α-chlorobenzyl)-2-oxo-1,2-dihydroquinoxaline-6(7)-carboxylic acid (mixture of isomers) (**1g**) (1.00 g, 3.17 mmol) and 1-(1-pyrrolidino)cyclohexene (**2a**) (0.48 g, 3.17 mmol). Yield 0.59 g (52%, mixture of isomers), milky crystals, mp >350°C (AcOH). IR spectrum, ν, cm^{-1}: 3222, 3055, 2935, 2853, 1695, 1689, 1655, 1621, 1519, 1482, 1385, 1330, 1296, 1234, 1215, 911, 806, 766, 698, 678, 589, 516. ^{1}H NMR spectrum (400 MHz), δ, ppm (*J*, Hz): 1.71–1.73 (2H, m) and 1.92–1.94 (2H, m, 9,10-CH_2); 2.46–2.48 (2H, m) and 3.25–3.27 (2H, m, 8,11-CH_2); 7.29 (1H, dd, *J* = 6.8, *J* = 6.7, H-4 Ph); 7.34–7.41 (5H, m, H-2,3,5,6 Ph, H-4*); 7.69 (1H, dd, *J* = 8.8, *J* = 1.9, H-2); 7.81* (1H, dd, *J* = 8.8, *J* = 1.7, H-3*); 7.88 (1H, d, *J* = 1.9, H-4); 8.08 (1H, d, *J* = 8.9, H-1); 8.60* (1H, br. s, H-1*); 11.12 (1H, s, NH). Found, *m/z*: 359.1353 $[M+H]^+$. $C_{22}H_{19}N_2O_3$. Calculated, *m/z*: 359.1390.

9-(*tert*-Butyl)-7-phenyl-8,9,10,11-tetrahydroindolo[1,2-*a*]-quinoxalin-6(5*H*)-one (3h) was obtained from 3-(α-chlorobenzyl)quinoxalin-2(1*H*)-one (**1a**) (1.00 g, 3.69 mmol) and 1-(4-*tert*-butylcyclohexenyl)piperidine (**2b**) (0.76 g, 3.69 mmol). Yield 0.92 g (67%), white crystals, mp 328–332°C (AcOH). IR spectrum, ν, cm^{-1}: 3422, 3177, 3034, 2955, 2865, 1656, 1611, 1505, 1483, 1440, 1387, 1364, 1327, 1246, 1215, 1075, 926, 870, 820, 744, 729, 698, 666,

* Signal of the minor isomer.

578, 554, 541. ^{1}H NMR spectrum (400 MHz), δ, ppm (*J*, Hz): 0.90 (9H, s, $(CH_3)_3$); 1.39–1.42 (2H, m) and 2.17–2.20 (1H, m, 9,10-CH_2); 2.34–2.38 (2H, m) and 3.35–3.39 (2H, m, 8,11-CH_2); 7.14 (1H, ddd, *J* = 7.8, *J* = 7.8, *J* = 1.7, H-2); 7.23 (1H, dd, *J* = 7.2, *J* = 7.1, H-3); 7.27–7.31 (2H, m, H-4, H-4 Ph); 7.37 (2H, dd, *J* = 7.8, *J* = 7.2, H-3,5 Ph); 7.41 (2H, dd, *J* = 8.1, *J* = 1.7, H-2,6 Ph); 7.99 (1H, d, *J* = 8.3, H-1); 10.94 (1H, s, NH). Found, *m*/*z*: 371.2097 $[M+H]^+$. $C_{25}H_{27}N_2O$. Calculated, *m*/*z*: 371.2118.

7-Hexyl-8,9,10,11-tetrahydroindolo[1,2-*a*]quinoxalin-6(5*H*)-one (3i) was obtained from 3-(1-chloroheptyl)-quinoxalin-2(1*H*)-one (**1h**) (1.00 g, 3.58 mmol) and 1-(1-pyrrolidino)cyclohexene (**2a**) (0.54 g, 3.58 mmol). Yield 0.63 g (54%), white crystals, mp 208–210°C (DMF–2-PrOH, 1:1). IR spectrum, ν, cm^{-1}: 3443, 3168, 3025, 2953, 2922, 2852, 1643, 1613, 1505, 1441, 1399, 1378, 1329, 1245, 1176, 1111, 873, 738, 726, 716, 665, 614, 562, 549, 516. ^{1}H NMR spectrum (500 MHz), δ, ppm (*J*, Hz): 0.83–0.87 (3H, m, CH_3); 1.24–1.31 (6H, m, $(CH_2)_3$); 1.48–1.52 (2H, m, CH_2); 1.73–1.77 (2H, m) and 1.85–1.89 (2H, m, 9,10-CH_2); 2.87 (2H, dd, *J* = 7.4, *J* = 7.1) and 3.13–3.16 (2H, m, 8,11-CH_2); 7.07 (1H, dd, *J* = 8.0, *J* = 7.3, H-2); 7.16 (1H, dd, *J* = 7.6, *J* = 6.9, H-3); 7.23 (1H, d, *J* = 7.7, H-4); 7.88 (1H, d, *J* = 7.9, H-1); 10.78 (1H, s, NH). Found, *m*/*z*: 323.2155 $[M+H]^+$. $C_{21}H_{27}N_2O$. Calculated, *m*/*z*: 323.2118.

7-Phenylindolo[1,2-*a*]quinoxalin-6(5*H*)-one (6). 7-Phenyl-8,9,10,11-tetrahydroindolo[1,2-*a*]quinoxalin-6(5*H*)-one (**3a**) (1.00 g, 3.18 mmol) and chloranil (3.12 g, 12.72 mmol) were refluxed in xylene (30 ml) for 50 h. After the evaporation of solvent, the residue was purified by silica gel column chromatography (Silica gel 100/160 μm, eluent hexane–AcOEt, 4:1→1:1, R_f 0.36). Yield 0.81 g (82%), pinkish-beige crystals, mp 312–314°C. IR spectrum, ν, cm^{-1}: 3395, 3180, 3030, 2979, 2923, 2859, 1663, 1615, 1601, 1560, 1506, 1493, 1449, 1438, 1405, 1371, 1327, 1242, 1179, 1074, 991, 927, 839, 803, 743, 699, 666, 631, 611, 566. ^{1}H NMR spectrum (400 MHz), δ, ppm (*J*, Hz): 7.29–7.33 (2H, m, H Ar); 7.36–7.42 (3H, m, H Ar); 7.46–7.49 (2H, m, H Ar); 7.55–7.62 (3H, m, H Ar); 7.70 (1H, d, *J* = 8.0, H Ar); 8.51–8.54 (1H, m, H Ar); 8.59 (1H, d, *J* = 8.8, H Ar); 11.40 (1H, s, NH). Found, *m*/*z*: 443.0157 $[M+Cs]^+$. $C_{21}H_{14}CsN_2O$. Calculated, *m*/*z*: 443.0155.

X-ray structural studies of crystals were performed on Bruker SMART Apex II (compounds **3a**,**e**,**f**) and Bruker KAPPA Apex (compounds **3d**,**h**,**i**) diffractometers, using MoKα radiation at 0.71073 Å. The structure was solved by direct method with the SHELXS software.[34] The non-hydrogen atom positions were refined in isotropic and then anisotropic approximations using SHELXL-97 program.[34] The amino group hydrogen atoms were revealed from electron density difference maps (except for compounds **3d**,**h**), the rest of the atoms were placed in the calculated positions. All calculations were performed with WinGX[35] and APEX2[36] software. Graphical representations were prepared by using the PLATON software.[37]

Supplementary information file containing X-ray crystallography data for compounds **3a**,**d**–**f**,**h**,**i** is available from the journal website at http://link.springer.com/journal/10593.

This work received financial support from the Russian Science Foundation (project No. 14-23-00073-p).

References

1. (a) Mamedov, V. A. *Quinoxalines. Synthesis, Reactions, Mechanisms and Structure*; Springer International Publishing, 2016. (b) *The Chemistry of Heterocyclic Compounds: Condensed Pyrazines*; Cheeseman, G. W. H.; Cookson, R. F., Eds.; John Wiley & Sons: New York, 1979, Vol. 35.
2. (a) Alleca, S.; Corona, P.; Lorigo, M.; Paglietti, G.; Loddo, R.; Mascia, V.; Busonera, B.; La Colla, P. *Farmaco* **2003**, *58*, 639. (b) Patel, M.; Mc Hugh, R. J.; Cordova, B. C.; Klabe, R. M.; Erickson-Vitanen, S.; Trainor, G. L.; Rodgers, J. D. *Bioorg. Med. Chem. Lett.* **2000**, *10*, 1729. (c) Guillon, J.; Dallemagne, P.; Pfeiffer, B.; Renard, P.; Manechez, D.; Kervran, A.; Rault, S. *Eur. J. Med. Chem.* **1998**, *33*, 293. (d) Kim, K. S.; Qian, L.; Bird, J. E.; Dickinson, K. E. J.; Moreland, S.; Schaeffer, T. R.; Waldron, T. L.; Delaney, C. L.; Weller, H. N.; Miller, A. V. *J. Med. Chem.* **1993**, *36*, 2335.
3. (a) Jacobsen, E. J.; Stelzer, L. S.; Belonga, K. L.; Carter, D. B.; Im, W. B.; Sethy, V. H.; Tang, A. H.; VonVoigtlander, P. F.; Petke, J. D. *J. Med. Chem.* **1996**, *39*, 3820. (b) Davey, D. D.; Erhardt, P. W.; Cantor, E. H.; Greenberg, S. S.; Ingebretsen, W. R.; Wiggins, J. *J. Med. Chem.* **1991**, *34*, 2671. (c) Colotta, V.; Cecchi, L.; Catarzi, D.; Filacchioini, G.; Martini, C.; Tacchi, P.; Lucacchini, A. *Eur. J. Med. Chem.* **1995**, *30*, 133.
4. (a) Sakata, G.; Makino, K.; Kurasawa, Y. *Heterocycles* **1988**, *27*, 2481. (b) Seitz, L. E.; Suling, W. J.; Reynolds, R. C. *J. Med. Chem.* **2002**, *45*, 5604. (c) Gazit, A.; App, H.; McMahon, G.; Chen, J.; Levitzki, A.; Bohmer, F. D. *J. Med. Chem.* **1996**, *39*, 2170. (d) Ali, M. M.; Ismail, M. M. F.; El-Gaby, M. S. A.; Zahran, M. A.; Ammar, Y. A. *Molecules* **2000**, *5*, 864. (e) Campiani, G.; Nacci, V.; Corelli, F.; Anzini, M. *Synth. Commun.* **1991**, *21*, 1567. (f) Kher, S. S.; Penzo, M.; Fulle, S.; Ebejer, J. P.; Finn, P. W.; Blackman, M. J.; Jirgensons, A. *Chem. Heterocycl. Compd.* **2015**, *50*, 1457. [*Khim. Geterotsikl. Soedin.* **2014**, 1583.]
5. (a) Mamedov, V. A.; Kalinin, A. A. *Chem. Heterocycl. Compd.* **2010**, *46*, 641. [*Khim. Geterotsikl. Soedin.* **2010**, 803.] (b) Kalinin, A. A.; Mamedov, V. A. *Chem. Heterocycl. Compd.* **2011**, *46*, 1423. [*Khim. Geterotsikl. Soedin.* **2010**, 1763.]
6. Mamedov, V. A.; Zhukova, N. A. In *Progress in Heterocyclic Chemistry*; Gribble, G. W.; Joule, J. A., Ed.; Elsevier: Oxford, 2012, Vol. 24, p. 55.
7. Mamedov, V. A.; Zhukova, N. A. In *Progress in Heterocyclic Chemistry*; Gribble, G. W.; Joule, J. A., Ed.; Elsevier: Oxford, 2013, Vol. 25, p. 1.
8. Corona, P.; Vitale, G.; Loriga, M.; Paglietti, G.; La Colla, P.; Collu, G.; Sanna, G.; Loddo, R. *Eur. J. Med. Chem.* **2006**, *41*, 1102.
9. (a) Mamedov, V. A.; Kalinin, A. A. *Russ. Chem. Rev.* **2014**, *83*, 820. [*Usp. Khim.* **2014**, *83*, 820.] (b) Mamedov, V. A.; Kalinin, A. A., Balandina A. A., Rizvanov, I. Kh.; Latypov, Sh. K. *Tetrahedron* **2009**, *65*, 9412. (c) Kalinin, A. A.; Voloshina, A. D.; Kulik, N. V.; Zobov, V. V.; Mamedov, V. A. *Eur. J. Med. Chem.* **2013**, *66*, 345.
10. (a) Somei, M.; Yamada, F. *Nat. Prod. Rep.* **2003**, *20*, 216. (b) Gupta, L.; Talwar, A.; Chauhan, P. M. S. *Curr. Med. Chem.* **2007**, *14*, 1789.
11. (a) Xu, H.; Lv, M. *Curr. Pharm. Des.* **2009**, *15*, 2120. (b) Ran, J. Q.; Huang, N.; Xu, H.; Yang, L. M.; Lv, M.; Zheng, Y. T. *Bioorg. Med. Chem. Lett.* **2010**, *20*, 3534. (c) Williams, J. D.; Chen, J. J.; Drach, J. C.; Townsend, L. B. *J. Med. Chem.* **2004**, *47*, 5753.

12. (a) Andreani, A.; Burnelli, S.; Granaiola, M.; Leoni, A.; Locatelli, A.; Morigi, R.; Rambaldi, M.; Varoli, L.; Landi, L.; Prata, C.; Berridge, M. V.; Grasso, C.; Fiebig, H. H.; Kelter, G.; Burger, A. M.; Kunkel, M. W. *J. Med. Chem.* **2008**, *51*, 4563. (b) Mahboobi, S.; Sellmer, A.; Eichhorn, E.; Beckers, T.; Fiebig, H. H.; Kelter, G. *Eur. J. Med. Chem.* **2005**, *40*, 85. (c) Girgis, A. S. *Eur. J. Med. Chem.* **200**9, *44*, 1257.
13. Mathada, B. S. D.; Mathada, M. B. H. *Chem. Pharm. Bull.* **2009**, *57*, 557.
14. (a) Bhati, S. K.; Kumar, A. *Eur. J. Med. Chem.* **2008**, *43*, 2323. (b) Fakhr, I. M. I.; Radwan, M. A. A.; El-Batran, S.; Abd El-Salam, O. M. E.; El-Shenawy, S. M. *Eur. J. Med. Chem.* **2009**, *44*, 1718.
15. (a) Xu, H.; Fan, L. L. *Eur. J. Med. Chem.* **2011**, *46*, 1919. (b) Verma, A. K.; Jha, R. R.; Sankar, V. K.; Aggarwal, T.; Singh, R. P.; Chandra, R. *Eur. J. Org. Chem.* **2011**, 6998. (c) Agarwal, P. K.; Sawant, D.; Sharma, S.; Kundu, B. *Eur. J. Org. Chem.* **2009**, 292. (d) Lin, P. T; Salunke, D. B.; Chen, L. H.; Sun, C. M. *Org. Biomol. Chem.* **2011**, *9*, 2925. (e) Sokolova, E. A; Festa, A. A. *Chem. Heterocycl. Compd.* **2016**, *52*, 219. [*Khim. Geterotsikl. Soedin.* **2016**, *52*, 219.]
16. (a) Maiti, B.; Sun, C. M. *New J. Chem.* **2011**, *35*, 1385. (b) Lai, J. J.; Salunke, D. B.; Sun, C. M. *Org. Lett.* **2010**, *12*, 2174.
17. Fan, Y. S.; Jiang, Y. J.; An, D.; Sha, D.; Antilla, J. C.; Zhang, S. *Org. Lett.* **2014**, *16*, 6112.
18. Wang, L.; Guo, W.; Zhang, X. X.; Xia, X. D.; Xiao, W. D. *Org. Lett.* **2012**, *14*, 740.
19. (a) Yi, C. S.; Yun, S. Y. *J. Am. Chem. Soc.* **2005**, *127*, 17000. (b) Patil, N. T.; Lakshmi, P. G. V. V.; Singh, V. *Eur. J. Org. Chem.* **2010**, 4719.
20. (a) Zhou, Y.; Ji, X.; Liu, G.; Zhang, D.; Zhao, L.; Jiang, H.; Liua, H. *Adv. Synth. Catal.* **2010**, *352*, 1711. (b) Patil, N. T.; Kavthe, R. D.; Shinde, V. S.; Sridhar, B. *J. Org. Chem.* **2010**, *75*, 3371.
21. (a) Rustagi, V.; Tiwari, R.; Verma, A. K. *Eur. J. Org. Chem.* **2012**, 4590. (b) Rustagi, V.; Aggarwal, T.; Verma, A. K. *Green Chem.* **2011**, *13*, 1640.
22. (a) Luo, X.; Chenard, E.; Martens, P.; Cheng, Y. X.; Tomaszewski, M. J. *Org. Lett.* **2010**, *12*, 3574. (b) Abbiati, G.; Beccalli, E. M.; Broggini, G.; Paladino, G,; Rossia, E. *Synthesis* **2005**, 2881.
23. (a) Maddirala, S. J.; Basanagoudar, L. D. *Synth. Commun.* **2003**, *33*, 851. (b) Beach, M. J.; Hope, R.; Klaubert, D. H.; Russel R. K. *Synth. Commun.* **1995**, *25*, 2165. (c) Yuan, Q.; Ma, D. *J. Org. Chem.* **2008**, *73*, 5159.
24. Huang, A.; Liu, F.; Zhan, C.; Liu,Y.; Ma, C. *Org. Biomol. Chem.* **2011**, *9*, 7351.
25. (a) Biswas, S.; Singh, V.; Batra, S. *Tetrahedron* **2010**, *66*, 7781. (b) Zhao, F.; Zhang, L.; Liu, H.; Zhou, S.; Liu, H. *Beilstein J. Org. Chem.* **2013**, *9*, 2463.
26. Chicharro, R.; Castro, S.; Reino, J. L.; Arán, V. J. *Eur. J. Org. Chem.* **2003**, 2314.
27. Samala, S.; Arigela, R. K.; Kant, R.; Kundu, B. *J. Org. Chem.* **2014**, *79*, 2491.
28. Shvedov, V. I.; Altukhova, L. B.; Alekseev, V. V.; Grinev, A. N. *Chem. Heterocycl. Compd.* **1970**, *6*, 1255. [*Khim. Geterotsikl. Soedin.* **1970**, 1348.]
29. Atfah, A.; Abu-Shuheil, M. Y.; Hill, J. *Tetrahedron* **1990**, *46*, 6483.
30. (a) Mamedov, V. A.; Kalinin, A. A.; Gubaidullin, A. T.; Nurkhametova, I. Z.; Litvinov, I. A.; Levin, Ya. A. *Chem. Heterocycl. Compd.* **1999**, *35*, 1459. [*Khim. Geterotsikl. Soedin.* **1999**, 1664.] (b) Mamedov, V. A.; Zhukova, N. A.; Balandina, A. A.; Kharlamov, S. V.; Beschastnova, T. N.; Rizvanov, I. Kh.; Latypov, Sh. K. *Tetrahedron* **2012**, *68*, 7363.
31. (a) Mamedov, V. A.; Nuretdinov, I. A.; Sibgatullina, F. G. *Bull. Acad. Sci. USSR*, *Div. Chem. Sci.* **1989**, *38*, 1292. [*Izv. Akad. Nauk SSSR*, *Ser. Khim.* **1988**, 1412.] (b) Saifina, D. F.; Ganieva, V. R.; Mamedov, V. A. *Russ. J. Org. Chem.* **2009**, *45*, 1244. [*Zh. Org. Khim.* **2009**, *45*, 1252.] (c) Kalinin, A. A.; Mamedov, V. A. *Chem. Heterocycl. Compd.* **2004**, *40*, 129. [*Khim. Geterotsikl. Soedin.* **2004**, 133.] (d) Mamedov, V. A.; Kalinin, A. A.; Azancheev, N. M.; Levin, Ya. A. *Russ. J. Org. Chem.* **2003**, *39*, 125. [*Zh. Org. Khim.* **2003**, *39*, 135.]
32. (a) Bagal, S. K.; Adlington, R. M.; Baldwin, J. E.; Marquez, R. *J. Org. Chem.* **2004**, *69*, 9100. (b) Maiti, S.; Achari, B.; Mukhopadhyay, R.; Banerjee, A. K. *J. Chem. Soc.*, *Perkin Trans. 1* **2002**, 1769. (c) McNally, J. J.; Youngman, M. A.; Lovenberg, T. W.; Nepomuceno, D. H.; Wilson, S. J.; Dax, S. L. *Bioorg. Med. Chem. Lett.* **2000**, *10*, 213.
33. (a) Overman, L. E.; Wolfe, J. P. *J. Org. Chem.* **2002**, *67*, 6421. (b) Mitschke, U.; Osteritz, E. M.; Debaerdemaeker, T.; Sokolowski, M.; Bauerle, P. *Chem.–Eur. J.* **1998**, *4*, 2211. (c) Ma, Li-J., Inokuchi, T. *Chem. Commun.* **2010**, *46*, 7037.
34. Sheldrick, G. M. *Acta Crystallogr.*, *Sect. A: Found. Crystallogr.* **2008**, *A64*, 112.
35. Farrugia, L. J. *J. Appl. Crystallogr.* **1999**, *32*(4), 837.
36. *APEX (Version 2.1). SAINTPlus. Data Reduction and Correction Program. Version 7.31A*. *Bruker Advansed X-Ray Solutions*; BrukerXS Inc.: Madison, 2006.
37. Spek, A. L. *J. Appl. Crystallogr.* **2003**, *36*, 7.