3-(α-Chlorobenzyl)quinoxalin-2(1*H*)-ones as Versatile Reagents for the Synthesis of 3-Benzylquinoxalin-2(1*H*)-ones and Thiazolo[3,4-*a*] quinoxalin-4(5*H*)-ones

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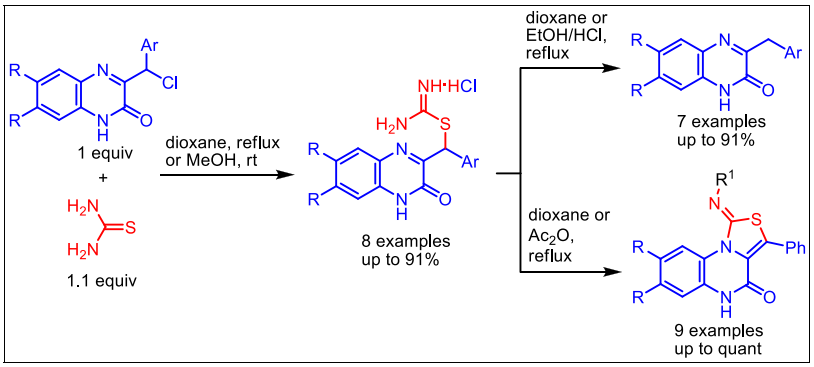


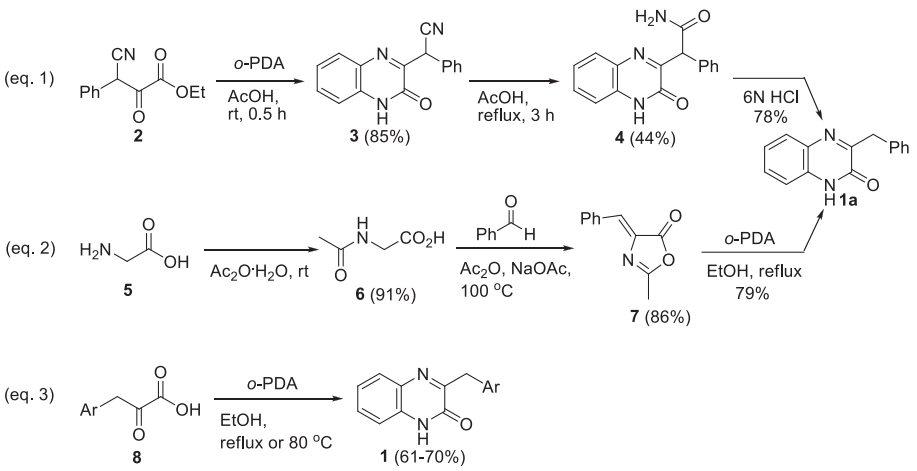
Facile and efficient methods for the synthesis of 3-benzylquinoxalin-2(1*H*)-ones and thiazolo[3,4-*a*] quinoxalin-4(5*H*)-ones by the reaction of the readily available 3-(α-chlorobenzyl)quinoxalin-2(1*H*)-ones and thiourea have been developed, with multiple roles of the latter. Possible mechanisms are discussed. These two-step sequences can be performed in a one-pot manner to produce the desired products in moderate to high yields.

INTRODUCTION

Quinoxaline derivatives[1] display a broad spectrum of pharmacological activities including insecticides [2], antimicrobial [3], antibacterial [4], antifungal 4a, antitubercular [5], anticancer [6], analgesic [4c, 7], anti-inflammatory [8], and PI3Kα inhibitory properties [9]. Some of the compounds derived from quinoxalines have been shown to display as antihypertensive agents and animal growth promoters [10]. Antibacterial, analgesic, tuberculostatic, and antileukemic activities of separate condensed quinoxalines have been widely reported [11]. Quinoxaline moieties have been shown to enter into the composition of biologically active polypeptides such as levomycin and echinomycin [12]. Recently, a series of 3-benzyl substituted quinoxalines have been synthesized. Among them, potential anticancer [13], antimicrobial [13a], antithrombotic [14] agents, MAO-A inhibitors [15], and agents for the treatment of tuberculosis [16] have been found.

Although the importance of this class of compounds is clear, only three methods of the synthesis of 3-benzylquinoxalin-2(1*H*)-ones (3-BQs) **1** have been developed (Scheme 1). The first one is based on 3-(α-cyano)benzylquinoxalin-2(1*H*)-one **3**, which is converted to the desired 3-BQ **1a** by acid hydrolysis *via* 3-(α-carboxamido)benzylquinoxalin-2(1*H*)-one **4** [eq. (1) in Scheme 1] [17]. The second one is based on 4-benzylidene-2-methyloxazol-5(4*H*)-one **7**, which reacts with *o*-phenylenediamine (*o*-PDA) with the direct formation of 3-BQ **1a** [eq. (2) in Scheme 1] [13a]. The necessary quinoxalinone derivatives for the first method and oxazole-5(4*H*)-one for the second method were synthesized from the ethyl ester of phenyl cyanopyruvic acid **2** [eq. (1) in Scheme 1] and acetylglycine **6** [eq. (2) in Scheme 1], respectively. The third method is based directly on arylpropionate acid derivatives **8**, which react with the *o*-PDA with the formation of 3-BQs **1** [eq. (3) in Scheme 1] [13b, 18]. Among these methods, the most effective one is the second [eq. (2) in Scheme 1], based on the oxazol-5(4*H*)-one derivative **7**, because the two-stage synthesis of this compound from glycine and the last stage of the formation of 3-BQ **1a** proceed with good yields. But, unfortunately, so far, only one compound has been synthesized by this method. The first method [eq. (1) in Scheme 1] has also been used for the synthesis

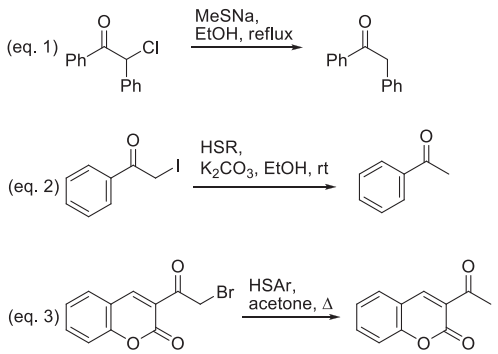
Scheme 1. Known methods for the synthesis of 3-benzylquinoxalin-2(1*H*)-ones.



of only one compound. As for the third method [eq. (3) in Scheme 1], it could be most effective if the derivatives of arylpyruvic acid **8** were available. Unfortunately, only phenylpyruvic acid is commercially available (the price works out at €49.30 for 5 g and €61.45 for 5 g of phenylpyruvic acid sodium salt) [19], and the synthesis of other aryl derivatives of pyruvic acid **8** is multistage [20–22].

Nakamura and co-workers [23] noted that α-(methylthio)-ketones and esters are easily reduced to the corresponding carbonyl compound by MeS^- anion. α-Halo or α,α-dihalo carbonyl compounds are analogously reduced with thiolate anion, presumably *via* the corresponding sulfides [eq. (1) in Scheme 2]. Israel and co-workers [24] also reported a rapid and unexpected reductive dehalogenation of 2-iodo-1-phenylethan-1-one in the presence of alkanethiols or thiophenol (2 equiv) with K_2CO_3 in ethanol at room temperature [eq. (2) in Scheme 2]. Veale and co-workers described the debromination and nucleophilic substitution of 3-(bromoacetyl)coumarin with a larch number of thiophenols, whose electron donating or withdrawing properties resulted in wide variations in the degree of nucleophilic substitution and dehalogenation products, correspondingly [eq. (3) in Scheme 2] [25].

Scheme 2. Known methods for the reductive dehalogenation of α-haloketones.



Earlier in a number of our works, we showed [26] that 3-(α-chlorobenzyl)quinoxalin-2(1*H*)-ones [27] behave as hetero-analogues of α-haloketones in the reactions with nucleophilic reagents. Therefore, we assumed that using the methods [23–25] mentioned earlier, their corresponding alkyl derivatives can be synthesized by the reductive dehalogenation of **9**. Unfortunately, attempts to obtain 3-BQ **1a** from 3-(α-chlorobenzyl)quinoxalin-2(1*H*)-one under the reductive dehalogenation conditions of α-haloketones, shown in Scheme 3, were unsuccessful. Each time, the reactions took place with the formation of a mixture of difficult-to-separate products, and the desired product in these mixtures was present in trace amounts.

RESULTS AND DISCUSSION

Reactions of quinoxalin-2(1*H*)-ones **9a–d** with thiourea when heated at reflux in dioxane for 4 h lead to the expected 3-BQs **1a–d** in 49–78% yields (Table 1, entries 1–4). The reactions of quinoxalin-2(1*H*)-ones **9e–h** under similar conditions lead to the tautomeric mixture of the corresponding carbamimidothioate **10e–h**, spiro[quinoxaline-2,4′-thiazolidin]-3(4*H*)-one **11e–h**, and spiro[quinoxaline-2,4′-thiazol]-3(4*H*)-one **12e–h** hydrochlorides in overall yields 71–89%, in the percentage ratio, as shown in Table 1 (entries 5–8). It should be pointed out that in the latter cases along with the **10e–h/11e–h/12e–h** tautomers, there has been observed the formation of trace amounts of the targets 3-BQs **1e–g** [R═H, Ar═C_6H_4Cl-4 (**e**), $C_6H_3Cl_2$–2,4 (**f**), C_6H_4Br-4 (**g**)] and **1h** (R═Cl, Ar═Ph) (Table 1, entries

Scheme 3. Proposed mechanism for the synthesis of compounds **1**.

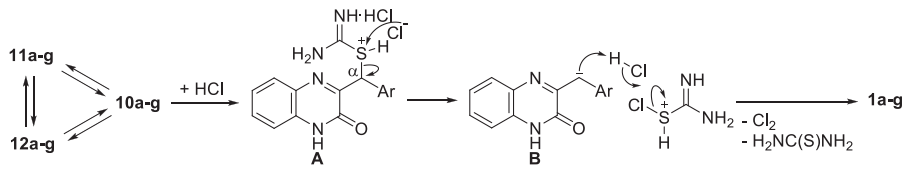
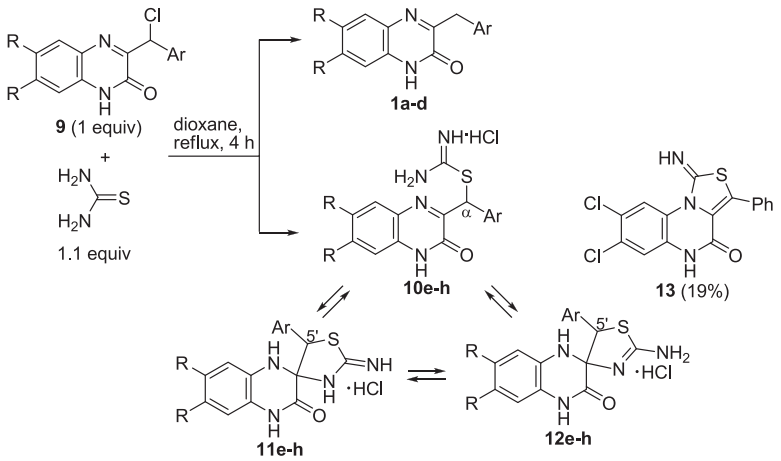


Table 1

Pathways of the reactions of 3-(α-chlorobenzyl)quinoxalin-2(1*H*)-ones **9a–h** with thiourea in dioxane.



Entry	**9**	R	R	Ar	**1**	Yield (%)[a]	**10/11/12**	**10/11/12** ratio[b]	Overall yield of **10/11/12** (%)[a]
1	**9a**	H	H	Ph	**1a**	78	**10b/11b/12b**	—	—
2	**9b**	H	H	4-FC_6H_4	**1b**	71	**10b/11b/12b**	—	—
3	**9c**	H	H	2-FC_6H_4	**1c**	69	**10c/11c/12c**	—	—
4	**9d**	H	H	3-$O_2NC_6H_4$	**1d**	49	**10d/11d/12d**	—	—
5	**9e**	H	H	4-ClC_6H_4	**1e**	n/i	**10e/11e/12e**	29:28:43	82
6	**9f**	H	H	2,4-$Cl_2C_6H_3$	**1f**	n/i	**10f/11f/12f**	29:24:47	80
7	**9g**	H	H	4-BrC_6H_4	**1g**	n/i	**10g/11g/12g**	31:28:41	89
8	**9h**	Cl	Cl	Ph	**1h**	n/i	**10h/11h/12h**	4:37:59	71

n/i, not isolated.
[a]Isolated yield.
[b]The percentage ratio of **10/11/12** was determined from the ^{1}H NMR spectra.

5–8). This is evident by thepresence of signals 3-BQs 1e–h along with the signals of tautomers 10e-h/11e-h/12e-h in the ^{1}H NMR spectra of evaporated in vacuum to dryness of the reaction mixtures quinoxalin-2(1H)-ones 9e–h and thiourea. The singlet signals of protons of methylene group in the region 4.09–4.26 ppm indicate to the presence of 3-BQs **1e–h** in the mixture of products. In addition, in the case of the reaction of quinoxalin-2(1*H*)-one **9h** with thiourea, the formation of the 1-iminothiazolo[3,4-*a*]quinoxalin-4(5*H*)-one **13** as a by-product in 19% yield has also been obtained (Table 1). NMR spectra of solutions of the mixture of tautomers **10/11/12** in DMSO-d_6 indicate the presence of three compounds. The use of two-dimensional techniques makes it possible to identify and fully assign the peaks of three compounds, despite the complexity and partial overlapping of the peaks in both the ^{1}H and ^{13}C NMR spectra (see the example of the **10e/11e/12e** spectra in the Supporting Information). In the NMR spectra of these three compounds, namely, carbamimidothioate **10e**, spiro[quinoxalinethiazolidin]one **11e**, and spiro[quinoxalinethiazol]one **12e** hydrochlorides, we can distinguish characteristic signals that make it possible to easily identify their percentage ratio in the solution. These are the singlet peaks of the methine groups for structure **10e**, CH(α) (δ ^{1}H 6.76–6.91; ^{13}C 50.2 ppm); for structure **11e**, CH(5′) (δ ^{1}H 5.31; ^{13}C 58.5 ppm); and for structure **12e**, CH(5′) (δ ^{1}H 5.85; ^{13}C 55.8 ppm). The

presence of the latter in two forms is further confirmed by the peaks of quaternary spiro-carbon atom C(4′) at 84.2 and 82.0 ppm, respectively. This eliminates the need to carry out laborious work on the complete identification of all the peaks of the mixture of three compounds. Therefore, for tautomers **10/11/12**, only the chemical shifts of the identification peaks in the ^{1}H NMR spectra and the ratio of the solution components are presented in the Experimental section, and the NMR spectra are given in the Supporting Information.

The synthesis of the tautomeric mixtures of carbamimidothioate **10a–h**, spiro[quinoxaline-2,4′-thiazolidin]-3(4*H*)-one **11a–h**, and spiro[quinoxaline-2,4′-thiazol]-3(4*H*)-one **12a–h** hydrochlorides was also carried out by the reaction of quinoxalin-2(1*H*)-ones **9a–h** with thiourea in methanol at room temperature (Table 2, entries 1–3, 5, 6, and 8) or at room temperature, followed by heating at 45°C (Table 2, entry 4) or 50°C (Table 2, entry 7).

On the example of tautomeric mixtures **10d/11d/12d**, **10f/11f/12f**, and **10g/11g/12g**, it was shown that boiling the latter in EtOH in the presence of HCl leads to the formation of the corresponding 3-BQs **1d**,**f**,**g** (Table 3, entries 1–3). However, a more convenient method of obtaining 3-BQs **1** appears to be a one-pot two-stage process, without any isolation of the intermediate tautomeric mixtures of **10a–g/11a–g/12a–g**, formed in the first stage of the process (Table 3, entries 4–10).

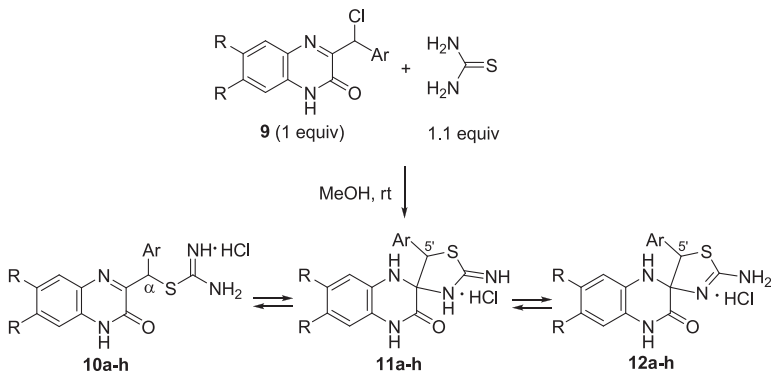
The formation of 3-BQs **1a–g** from carbamimidothioate hydrochlorides **10a–g** proceeds under the action of the chloride anion on the protonated sulfur atom by hydrochloric acid in intermediate **A** with the cleavage of the Cα—S bond with the generation of the anion **B**, which was stabilized by the protonation with hydrochloric acid with the involvement of carbamimidoylsulfonium chloride. In this case, the chlorine gas and thiourea are formed as by-products (Scheme 3).

Unlike the tautomeric mixtures **10b–g/11b–g/12b–g**, the tautomeric mixture **10h/11h/12h** when heated at reflux in EtOH/HCl for 5 h does not lead to BQ **1h**, as expected, but to the spiro-derivative **11h** in quantitative yield (Scheme 6). Heating of the latter at reflux in Ac_2O for 1.5 h gives 1-acetylimino-7,8-dichlorothiazolo[3,4-*a*]quinoxalin-4(5*H*)-one **14a** in a 83% yield as a result of the simultaneous occurrence of intramolecular cyclocondensation and acylation processes. Note that compound **14a** was also obtained in a 95% yield when the mixture of **10h/11h/12h** was heated under the same condition (Scheme 4).

With this result in hand, we next carried out the rearrangements of tautomeric mixtures of **10a–g/11a–g/**

Table 2

Reactions of 3-(α-chlorobenzyl)quinoxalin-2(1*H*)-ones **9a–h** with thiourea in methanol.

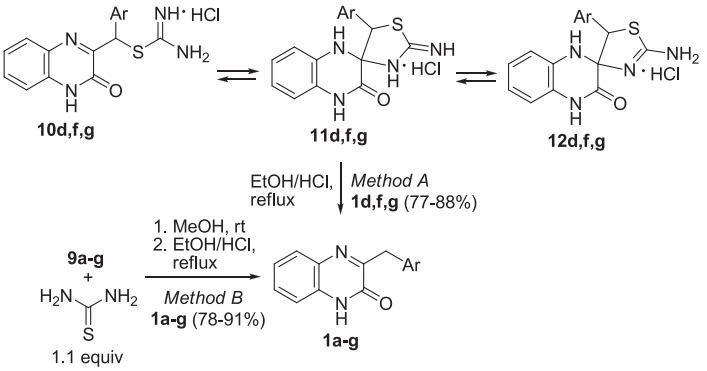


Entry	9	R	Ar	Time	10/11/12	10/11/12 ratio[d]	Overall yield (%)[a]
1	**9a**	H	Ph	8 h	**10a/11a/12a**	32:28:40	88
2	**9b**	H	4-FC_6H_4	6 h	**10b/11b/12b**	25:25:50	85
3	**9c**	H	2-FC_6H_4	7 h	**10c/11c/12c**	31:28:41	77
4	**9d**	H	3-$O_2NC_6H_4$	—[b]	**10d/11d/12d**	30:25:45	91
5	**9e**	H	4-ClC_6H_4	22 h	**10e/11e/12e**	35:25:40	88
6	**9f**	H	2,4-$Cl_2C_6H_3$	11 days	**10f/11f/12f**	30:26:44	80
7	**9g**	H	4-BrC_6H_4	—[c]	**10g/11g/12g**	31:31:38	89
8	**9h**	Cl	Ph	6 days	**10h/11h/12h**	3:35:62	75

[a]Isolated yield.
[b]Reaction conditions: MeOH, rt, 14 h → 45°C, 2 h.
[c]Reaction conditions: MeOH, rt, 3 days → 50°C, 5.5 h.
[d]The percentage ratio of **10/11/12** was determined from the ^{1}H NMR spectra.

Table 3

Synthesis of 3-benzylquinoxalin-2(1*H*)-ones **1**.



Entry	Substrate	Ar	Method	Time	**1**	Yield (%)[a]
1	**10d/11d/12d**	3-$O_2NC_6H_4$	A	8.5 h	**1d**	88
2	**10f/11f/12f**	2,4-$Cl_2C_6H_3$	A	15 h	**1f**	73
3	**10g/11g/12g**	4-BrC_6H_4	A	11 h	**1g**	77
4	**9a**	Ph	B	(1) 8 h (2) 8 h	**1a**	78
5	**9b**	4-FC_6H_4	B	(1) 8.5 h (2) 5.5 h	**1b**	83
6	**9c**	2-FC_6H_4	B	(1) 7 h (2) 5.5 h	**1c**	83
7	**9d**	3-$O_2NC_6H_4$	B	(1) and (2)[b]	**1d**	91
8	**9e**	4-ClC_6H_4	B	(1) 3 days (2) 8 h	**1e**	87
9	**9f**	2,4-$Cl_2C_6H_3$	B	(1) 11 days (2) 8 h	**1f**	79
10	**9g**	4-BrC_6H_4	B	(1) and (2)[c]	**1g**	81

[a]Isolated yield.
[b]Reaction conditions: (1) MeOH, 45°C, 19 h; (2) *n*-BuOH/HCl, reflux, 19 h.
[c]Reaction conditions: (1) MeOH, rt, 3 days → 50°C, 6.5 h → reflux, 1.5 h; (2) EtOH/HCl, reflux, 8 h.

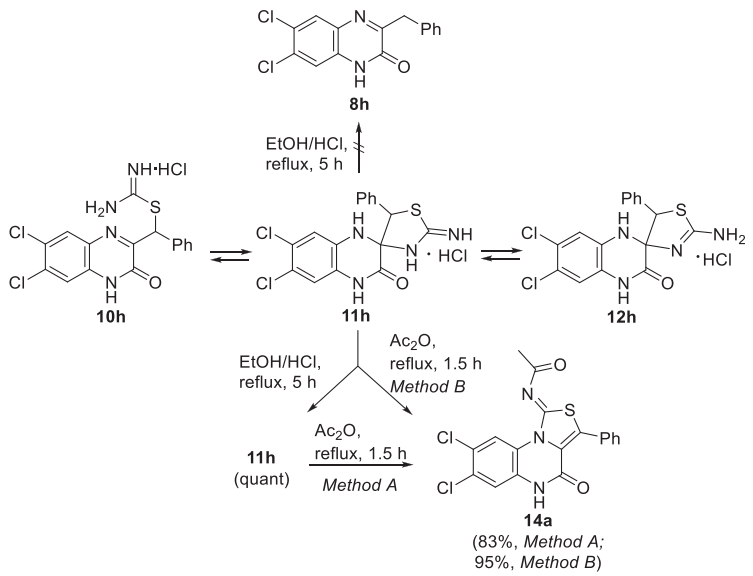
12a–g when heating at reflux in Ac_2O. As a result, the corresponding 1-acetylimino-3-arylthiazolo[3,4-*a*] quinoxalin-4(5*H*)-ones **14b–h** have been obtained in high to quantitative yields (Scheme 5). The characteristic signal indicating the formation of a thiazolo[3,4-*a*] quinoxalin-4(5*H*)-one system in ^{1}H NMR spectra is a doublet of doublet (J = ~8.0, ~1.0 Hz) signal of H(9), which resonates at ~10.0 ppm separately from other aromatic protons [28]. This indicates the formation of a stimulated intramolecular hydrogen bonding involving H(9) and a nitrogen atom of the imine group.

As to the mechanism of thiazolo[*a*]annelation in all probability, it proceeds *via* the open-chain *N*-acylated carbamimidothioate hydrochloride tautomeric form **C** produced by the action of acetic anhydride on the [(quinoxalin-2(1*H*)-on-2-yl)(aryl)methyl] isothiouronium chloride **10**. Further acylation took place on the more nucleophilic isothiouronium nitrogen atom with the formation of a diacylderivative **D** that contains a high electrophilic isothiouronium carbon atom. The nucleophilic attack by the nitrogen atom of the pyrazine ring of **C**, **D**, and **E** on the isothiouronium carbon atom leads to the closure of the thiazole ring on the *a* side of quinoxaline with the formation of **F**, **G**, and **H**. In these cases, thiazolo[*a*]annelation can proceed with the elimination of either $AcNH_2$ or Ac_2NH. The final product is produced either directly from **F** or after acylation of **H** and **I** (Scheme 6).

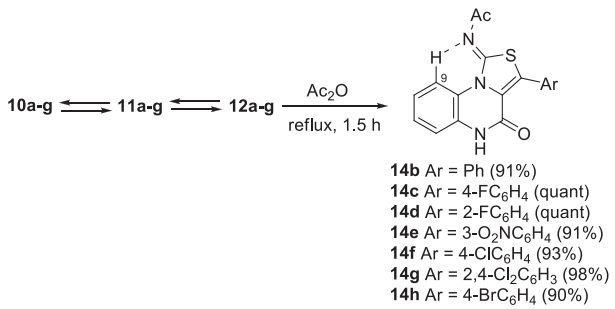
CONCLUSIONS

In summary, we have developed facile and efficient methods for the synthesis of highly functionalized 3-benzylquinoxalin-2(1*H*)-ones and thiazolo[3,4-*a*] quinoxalin-4(5*H*)-ones from readily accessible starting materials. These two-step sequences can be realized into a one-pot process, by evaporating the reaction mixture before performing the ensuing chloride anion-mediated reductive cleavage of (quinoxalin-2(1*H*)-on-2-yl)(aryl)

Scheme 4. The behavior of tautomeric mixture **10h/11h/12h** in boiling at reflux in EtOH/HCl and Ac_2O.



Scheme 5. Synthesis of 1-acetyliminothiazolo[3,4-*a*]quinoxalin-4(5*H*)-ones **14b–h**.



methyl carbamimidothioate hydrochlorides in the first case and acetic anhydride-mediated thiazoloannulation in the second. We assume that these protocols have a potential in the synthesis of various quinoxaline scaffolds, which are of considerable interest as potential biological active compounds or pharmaceuticals in synthetic and medicinal chemistry.

EXPERIMENTAL

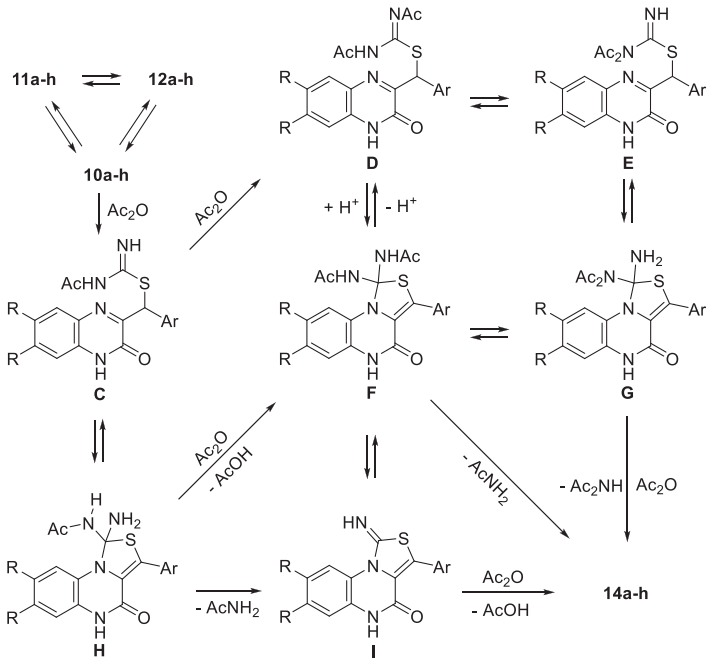
General. Melting points were determined on a Boetius melting point apparatus. IR spectra were recorded on a Tensor 27 (Bruker) FT-IR spectrometer with KBr pellets. NMR experiments were carried out with Bruker spectrometers AVANCE (III)-500 [500.1 MHz (^{1}H), 125.8 MHz (^{13}C), 50.7 MHz (^{15}N)] equipped with a pulsed gradient unit capable of producing magnetic field pulse gradients in the *z*-direction of 53.5 G cm^{-1}. All the spectra were obtained in a 5-mm gradient inverse broad band probehead. Chemical shifts (δ in ppm) are given from internal solvent, DMSO-d_6 (δ, ^{1}H, 2.49 ppm; ^{13}C, 39.5 ppm), and ^{15}N are referenced relative to external CD_3NO_2 (380.2 ppm).

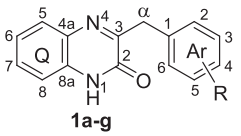
General procedures for the synthesis of 3-benzylquinoxalin-2(1*H*)-ones 1a–g. ***Method A.*** A mixture of tautomers **10d**,**f**,**g/11d**,**f**,**g/12d**,**f**,**g** (1.12 mmol) in EtOH/HCl (1.3/1.0, v/v) was heated at reflux with stirring for 8.5–15 h (Table 2). Gradually, a precipitate was formed, which was filtered off, washed with water (3 × 5 mL), and dried in air to afford analytically pure samples of **1d**,**f**,**g**, respectively.

Method B. A mixture of thiourea (0.15 g, 1.97 mmol) and the corresponding quinoxalin-2(1*H*)-ones **9a–g** (1.79 mmol) in dry MeOH (25 mL) was stirred at room temperature for an appropriate time (Table 3), and the reaction mixture was left overnight at room temperature and then was evaporated in vacuum to dryness, and the residue was dissolved with EtOH/HCl (1.3/1.0, v/v). The resulting reaction mixture was heated at reflux with stirring for 5.5–8 h. Gradually, a precipitate was formed, which was filtered off, washed with water (3 × 5 mL), and dried in air to afford analytically pure samples of corresponding benzylquinoxalin-2(1*H*)-ones **1a–g**.

Method C. A mixture of thiourea (0.10 g, 1.31 mmol) and the corresponding quinoxalin-2(1*H*)-ones **9b–d** (1.19 mmol) in dry dioxane (10 mL) was heated at reflux with stirring for 4 h. The solution was hot decanted and allowed to cool to room temperature, and a beige precipitate was removed by filtration to afford analytically pure samples of **1b–d**.

Scheme 6. Proposed mechanism for the synthesis of compounds **14**.





3-Benzylquinoxalin-2(1H)-one (1a). Beige powder; 0.33 g, 78% yield (Method B), mp 198–200°C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 4.12 (s, 2H, CHα), 7.20 (dd, J = 7.3 Hz, J = 7.3 Hz, 1H, H4-Ar), 7.22–7.30 (m, 4H, H6-Q, H3/H5-Ar, H8-Q), 7.33 (d, J = 7.2 Hz, 2H, H2/H6-Ar), 7.48 (ddd, J = 7.6 Hz, J = 7.4 Hz, J = 1.0 Hz, 1H, H7-Q), 7.71 (dd, J = 7.6 Hz, J = 1.0 Hz, 1H, H5-Q), 12.36 (s, 1H, NH1-Q); ^{13}C{^{1}H} NMR (126 MHz, DMSO-d_6): δ 38.9 (Cα), 115.2 (C8-Q), 123.1 (C6-Q), 126.3 (C4-Ar), 128.2 (C5-Q, 3/C5-Ar), 129.7 (C2/C6-Ar, C7-Q), 131.6 (C4a-Q), 131.9 (C8a-Q), 137.4 (C1-Ar), 154.5 (C3-Q), 160.3 (C2-Q); IR (KBr, cm^{-1}): ν 2960, 2832, 2716, 1661, 1559, 1486, 1434, 911, 753, 700, 600, 581; *Anal*. Calcd for (%) $C_{15}H_{12}N_2O$: C, 76.25; H, 5.12; N, 11.86. Found (%) C, 76.45; H, 4.95; N, 11.99.

3-(4-Fluorobenzyl)quinoxalin-2(1H)-one (1b). Dirty-beige powder; 0.38 g, 83% yield (Method B); 0.21 g, 71% yield (Method C); mp 218–220°C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 4.11 (s, 2H, CHα), 7.10 (dd, J_{HF} = 10.4 Hz, J_{HH} = 8.9 Hz, 2H, H3/H5-Ar), 7.27 (ddd, J = 8.0 Hz, J = 7.8 Hz, J = 1.2 Hz, 1H, H6-Q), 7.28 (d, J = 8.0 Hz, 1H, H8-Q), 7.36 (dd, J_{HH} = 8.9 Hz, J_{HF} = 7.3 Hz, 2H, H2/H6-Ar), 7.48 (ddd, J = 8.0 Hz, J = 7.8 Hz, J = 1.2 Hz, 1H, H7-Q), 7.70 (dd, J = 8.0 Hz, J = 1.2 Hz, 1H, H5-Q), 12.37 (s, 1H, NH1-Q); ^{13}C{^{1}H} NMR (126 MHz, DMSO-d_6): δ 38.1 (Cα), 115.0 (d, J_{CF} = 21.0 Hz, C3/C5-Ar), 115.3 (C8-Q), 123.2 (C6-Q), 128.2 (C5-Q), 129.8 (C7-Q), 130.9 (d, J_{CF} = 8.1 Hz, C2/C6-Ar), 131.6 (C4a-Q), 131.9 (C8a-Q), 133.5 (d, J_{CF} = 3.2 Hz, C1-Ar), 154.5 (C3-Q), 160.2 (C2-Q), 161.3 (d, J_{CF} = 246.5 Hz, C4-Ar); IR (KBr, cm^{-1}): ν 2969, 2846, 2714, 1665, 1609, 1564, 1511, 1224, 1157, 1141, 1019, 889, 819, 753, 589, 482, 467; *Anal*. Calcd for (%) $C_{15}H_{11}FN_2O$: C, 70.86; H, 4.36; N, 11.02. Found (%) C, 71.05; H, 4.51; N, 11.12.

3-(2-Fluorobenzyl)quinoxalin-2(1H)-one (1c). Beige powder; 0.38 g, 83% yield (Method B); 0.21 g, 69% yield (Method C); mp 224–226°C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 4.17 (s, 2H, CHα), 7.13 (dd, J_{HH} = 7.8 Hz, J_{HF} = 1.4 Hz, 1H, H5-Ar), 7.16 (dd, J_{HF} = 10.4 Hz, J_{HH} = 7.8 Hz, 1H, H3-Ar), 7.25 (ddd, J = 8.0 Hz, J = 7.8 Hz, J = 1.3 Hz, 1H, H6-Q), 7.26–7.36 (m, 3H, H4-Ar, H8-Q, H6-Ar), 7.48 (ddd, J = 8.0 Hz, J = 7.8 Hz, J = 1.3 Hz, 1H, H7-Q), 7.63 (dd, J = 8.0 Hz, J = 1.3 Hz, 1H, H5-Q), 12.41 (s, 1H, NH1-Q); ^{13}C{^{1}H} NMR (126 MHz, DMSO-d_6): δ 32.1 (Cα), 115.2 (d, J_{CF} = 21.8 Hz, C3-Ar), 115.3 (C8-Q), 123.1 (C6-Q), 124.2 (d, J_{CF} = 3.4 Hz, C5-Ar), 124.2 (d, J_{CF} = 15.8 Hz, C1-Ar), 128.2 (C5-Q), 128.4 (d, J_{CF} = 8.2 Hz, C4-Ar), 129.8 (C7-Q), 131.5 (d, J_{CF} = 11.0 Hz, C6-Ar), 131.5 (C4a-Q), 131.9 (C8a-Q), 154.4 (C3-Q), 159.2 (C2-Q), 160.6 (d, J_{CF} = 244.2 Hz, C2-Ar); IR (KBr, cm^{-1}): ν 3104, 3016, 2968, 1664, 1621, 1562, 1492, 1417, 1230, 1105, 1099, 855, 755, 596, 496, 470; *Anal*. Calcd for (%)

$C_{15}H_{11}FN_2O$: C, 70.86; H, 4.36; N, 11.02. Found (%) C, 70.73; H, 4.32; N, 11.07.

3-(3-Nitrobenzyl)quinoxalin-2(1H)-one (1d). Dirty-beige powder; 0.28 g, 88% yield (Method A); 0.46 g, 91% yield (Method B); 0.16 g, 49% yield (Method C); mp 258–260°C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 4.29 (s, 2H, CHα), 7.26 (ddd, J = 7.9 Hz, J = 7.7 Hz, J = 1.1 Hz, 1H, H6-Q), 7.29 (dd, J = 7.9 Hz, J = 1.1 Hz, 1H, H8-Q), 7.48 (ddd, J = 7.9 Hz, J = 7.7 Hz, J = 1.1 Hz, 1H, H7-Q), 7.60 (dd, J = 8.0 Hz, J = 8.0 Hz, 1H, H5-Ar), 7.69 (dd, J = 7.9 Hz, J = 1.1 Hz, 1H, H5-Q), 7.80 (d, J = 8.0 Hz, 1H, H6-Ar), 8.09 (dd, J = 8.0 Hz, J = 1.7 Hz, 1H, H4-Ar), 8.21 (br s, 1H, H2-Ar), 12.42 (s, 1H, NH1-Q); ^{13}C{^{1}H} NMR (126 MHz, DMSO-d_6): δ 38.4 (Cα), 115.3 (C8-Q), 121.4 (C4-Ar), 123.2 (C6-Q), 123.9 (C2-Ar), 128.3 (C5-Q), 129.7 (C5-Ar), 129.9 (C7-Q), 131.5 (C4a-Q), 131.9 (C8a-Q), 136.2 (C6-Ar), 139.6 (C1-Ar), 147.7 (C3-Ar), 154.5 (C3-Q), 159.4 (C2-Q); IR (KBr, cm^{-1}): ν 2965, 2841, 1666, 1613, 1529, 1351, 1108, 907, 747, 726, 699, 595, 554, 469; *Anal*. Calcd for (%) $C_{15}H_{11}N_3O_3$: C, 64.05; H, 3.94; N, 14.94. Found (%) C, 63.98; H, 3.99; N, 14.90.

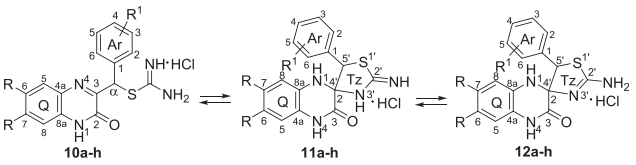
3-(4-Chlorobenzyl)quinoxalin-2(1H)-one (1e). Beige powder; 0.46 g, 87% yield (Method B); mp 224–226°C (ref. [12] 226–227°C); ^{1}H NMR (500 MHz, DMSO-d_6): δ 4.12 (s, 2H, CHα), 7.25 (ddd, J = 8.0 Hz, J = 7.8 Hz, J = 1.0 Hz, 1H, H6-Q), 7.30 (d, J = 8.0 Hz, 1H, H8-Q), 7.34 (br s, 4H, H2/H6-Ar, H3/H5-Ar), 7.48 (ddd, J = 8.0 Hz, J = 7.8 Hz, J = 1.0 Hz, 1H, H7-Q), 7.70 (dd, J = 8.0 Hz, J = 1.0 Hz, 1H, H5-Q), 12.40 (s, 1H, NH1-Q); ^{13}C{^{1}H} NMR (126 MHz, DMSO-d_6): δ 38.3 (Cα), 115.4 (C8-Q), 123.3 (C6-Q), 128.3 (C3/C5-Ar), 128.3 (C5-Q), 128.8 (C4-Ar), 129.9 (C7-Q), 131.1 (C2/C6-Ar), 131.7 (C4a-Q), 132.0 (C8a-Q), 136.5 (C1-Ar), 154.5 (C3-Q), 160.0 (C2-Q); ^{15}N NMR (51 MHz, DMSO-d_6): δ 150.5 (N1-Q), 329.8 (N4-Q); IR (KBr, cm^{-1}): ν 2965, 2837, 2713, 1662, 161 2, 1556, 1432, 1277, 1092, 1013, 917, 812, 758, 693; *Anal*. Calcd for (%) $C_{15}H_{11}ClN_2O$: C, 66.55; H, 4.10; N, 10.35. Found (%) C, 66.41; H, 4.06; N, 10.41.

3-(2,4-Dichlorobenzyl)quinoxalin-2(1H)-one (1f). Beige powder; 0.25 g, 73% yield (Method A); 0.43 g, 79% yield (Method B); mp 247–249°C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 4.26 (s, 2H, CHα), 7.23 (ddd, J = 7.7 Hz, J = 7.5 Hz, J = 1.1 Hz, 1H, H6-Q), 7.31 (dd, J = 7.7 Hz, J = 1.1 Hz, 1H, H8-Q), 7.38 (dd, J = 8.1 Hz, J = 2.1 Hz, 1H, H5-Ar), 7.41 (d, J = 8.1 Hz, 1H, H6-Ar), 7.48 (ddd, J = 7.7 Hz, J = 7.5 Hz, J = 1.1 Hz, 1H, H7-Q), 7.58 (dd, J = 7.7 Hz, J = 1.1 Hz, 1H, H5-Q), 7.60 (d, J = 2.1 Hz, 1H, H3-Ar), 12.44 (s, 1H, NH1-Q); ^{13}C{^{1}H} NMR (126 MHz, DMSO-d_6): δ 36.0 (Cα), 115.3 (C8-Q), 123.1 (C6-Q), 127.1 (C5-Ar), 128.2 (C5-Q), 128.5 (C6-Ar), 129.8 (C7-Q), 131.5 (C4a-Q), 131.8 (C8a-Q), 131.9 (C4-Ar), 133.1 (C3-Ar), 134.5 (C1-Ar), 134.7 (C2-Ar), 154.3 (C3-Q), 158.8 (C2-Q); IR (KBr, cm^{-1}): ν 2964, 2894, 2851, 1662, 1559, 1474, 1432, 1106, 860, 810, 766, 579, 472; *Anal*. Calcd for (%) $C_{15}H_{10}Cl_2N_2O$: C, 59.04; H, 3.30; N, 9.18. Found (%) C, 59.23; H, 3.40; N, 9.07.

3-(4-Bromobenzyl)quinoxalin-2(1H)-one (1g). Beige powder; 0.27 g, 77% yield (Method A); 0.46 g, 81% yield (Method B); mp 236–238°C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 4.09 (s, 2H, CHα), 7.26 (ddd, J = 7.9 Hz, J = 7.7 Hz, J = 1.1 Hz, 1H, H6-Q), 7.28 (d, J = 8.4 Hz, 2H, H2/H6-Ar), 7.28–7.31 (m, 1H, H8-Q), 7.46 (d, J = 8.4 Hz, 2H, H3/H5-Ar), 7.48 (ddd, J = 7.9 Hz, J = 7.7 Hz, J = 1.1 Hz, 1H, H7-Q), 7.69 (dd, J = 7.8 Hz, J = 1.1 Hz, 1H, H5-Q), 12.39 (s, 1H, NH1-Q); ^{13}C{^{1}H} NMR (126 MHz, DMSO-d_6): δ 38.4 (Cα), 115.4 (C8-Q), 119.6 (C4-Ar), 123.3 (C6-Q), 128.3 (C5-Q), 129.9 (C7-Q), 131.2 (C3/C5-Ar), 131.5 (C2/C6-Ar), 131.6 (C8a-Q), 132.0 (C4a-Q), 136.9 (C1-Ar), 154.4 (C3-Q), 159.9 (C2-Q); IR (KBr, cm^{-1}): ν 2965, 2884, 2824, 1659, 1556, 1482, 1422, 1274, 1071, 1009, 916, 757, 601, 578, 567, 468; *Anal*. Calcd for (%) $C_{15}H_{11}BrN_2O$: C, 57.16; H, 3.52; N, 8.89. Found (%) C, 57.02; H, 3.43; N, 9.00.

General procedures for the synthesis of tautomeric mixtures 10a–h/11a–h/12a–h. ***Method A.*** A mixture of thiourea (0.15 g, 1.97 mmol) and the corresponding quinoxalin-2(1*H*)-ones **9a–h** (1.79 mmol) in dry MeOH (25 mL) was stirred at room temperature for an appropriate time (Table 1). The solvent was evaporated to dryness, and the resulting solid was washed with ethyl ether (3 × 5 mL) and filtered to afford analytically pure mixtures of tautomers **10a–h/11a–h/12a–h**.

Method B. A mixture of thiourea (0.10 g, 1.31 mmol) and the corresponding quinoxalin-2(1*H*)-ones **9e–g** (1.19 mmol) in dry dioxane (10 mL) was heated at reflux with stirring for 4 h. Gradually, a precipitate was formed, which was filtered off and dried in air to afford analytically pure samples of mixtures of tautomers **10e–g/11e–g/12e–g**.



(Quinoxalin-2(1*H*)-on-2-yl)(phenyl)methyl carbamimidothioate (**10a**), 2′-imino-5′-phenyl-1*H*-spiro[quinoxaline-2,4′-thiazolidin]-3(4*H*)-one (**11a**), and 2′-amino-5′-phenyl-1*H*,5′*H*-spiro[quinoxaline-2,4′-thiazol]-3(4*H*)-one (**12a**) hydrochlorides were characterized as the mixture of tautomers in percentage ratio 32:28:40, respectively. Bright yellow solid; 0.55 g, 88% yield (Method A); mp 173–175°C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 5.31 [s, 1H, CH5′ (**11a**)], 5.89 [s, 1H, CH5′ (**12a**)], 6.55–6.69 (m, 7H, Ar + Q), 6.73 [s,

1H, CHα (**10a**)], 6.88–7.86 (m, 20H, Ar + Q), 9.21–12.70 (s, 12H, NH); $^{13}C\{^{1}H\}$ NMR (126 MHz, DMSO-d_6): δ 50.8, 56.7, 59.4, 81.9, 84.3, 113.6, 113.8, 114.7, 115.6, 118.4, 119.2, 123.1, 123.3, 123.4, 123.7, 124.0, 128.1, 128.3, 2 × 128.5, 128.6, 2 × 128.9, 129.0, 129.4, 129.6, 129.7, 130.3, 130.8, 130.9, 131.0, 132.0, 132.3, 136.3, 152.8, 156.3, 159.7, 160.2, 167.8, 170.1, 170.8, 183.9; IR (KBr, cm^{-1}): ν 3059, 1655, 1613, 1505, 1419, 1387, 750, 697; *Anal*. Calcd for (%) $C_{16}H_{15}ClN_4OS$: C, 55.41; H, 4.36; N, 16.15; S, 9.25. Found (%) $C_{16}H_{14}N_4OS$: C, 55.16; H, 4.45; N, 16.26; S, 9.08.

(4-Fluorophenyl)(quinoxalin-2(1*H*)-on-2-yl)methyl carbamimidothioate (**10b**), 5′-(4-fluorophenyl)-2′-imino-1*H*-spiro[quinoxaline-2,4′-thiazolidin]-3(4*H*)-one (**11b**), and 2′-amino-5′-(4-fluorophenyl)-1*H*,5′*H*-spiro[quinoxaline-2,4′-thiazol]-3(4*H*)-one (**12b**) hydrochlorides were characterized as the mixture of tautomers in percentage ratio 25:25:50, respectively. Light brown solid; 0.56 g, 85% yield (Method A); mp 163–165°C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 5.35 [s, 1H, CH5′ (**11b**)], 5.83 [s, 1H, CH5′ (**12b**)], 6.53–6.70 (m, 7H, Ar + Q), 6.75 [s, 1H, CHα (**10b**)], 6.86–7.84 (m, 17H, Ar + Q), 7.89–12.80 (s, 12H, NH); $^{13}C\{^{1}H\}$ NMR (126 MHz, DMSO-d_6): δ 50.2, 55.9, 58.6, 82.0, 84.2, 113.6, 113.9, 114.7, 115.0, 183.9, 170.8, 170.3, 167.7, 163.3, 163.2, 162.9, 161.4, 161.2, 160.9, 160.3, 159.8, 156.1, 152.8, 115.1, 115.2, 115.3, 115.5, 115.6, 115.7, 118.5, 119.3, 123.2, 2 × 123.5, 132.7, 123.8, 123.9, 127.2, 127.3, 128.3, 128.4, 128.5, 129.7, 130.3, 130.7, 2 × 130.8, 131.1, 2 × 131.2, 131.7, 131.8, 132.4, 132.6; IR (KBr, cm^{-1}): ν 3360, 3071, 1678, 1661, 1604, 1508, 1420, 1231, 752, 571; *Anal*. Calcd for (%) $C_{16}H_{14}ClFN_4OS$: C, 52.67; H, 3.87; N, 15.36; S, 8.79. Found (%) C, 52.98; H, 3.74; N, 15.53; S, 8.95.

(2-Fluorophenyl)(quinoxalin-2(1*H*)-on-2-yl)methyl carbamimidothioate (**10c**), 5′-(2-fluorophenyl)-2′-imino-1*H*-spiro[quinoxaline-2,4′-thiazolidin]-3(4*H*)-one (**11c**), and 2′-amino-5′-(2-fluorophenyl)-1*H*,5′*H*-spiro[quinoxaline-2,4′-thiazol]-3(4*H*)-one (**12c**) hydrochlorides were characterized as the mixture of tautomers in percentage ratio 31:28:41, respectively. Bright yellow solid; 0.50 g, 77% yield (Method A); mp 165–167°C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 5.35 [s, 1H, CH5′ (**11c**)], 5.92 [s, 1H, CH5′ (**12c**)], 6.40–6.69 (m, 7H, Ar + Q), 6.79 [s, 1H, CHα (**10c**)], 6.79–7.83 (m, 17H, Ar + Q), 8.79–12.80 (s, 12H, NH); $^{13}C\{^{1}H\}$ NMR (126 MHz, DMSO-d_6): δ 46.2, 48.6, 50.3, 52.0, 81.9, 84.3, 113.3, 114.3, 114.6, 114.9, 115.0, 115.1, 115.2, 115.3, 115.7, 115.9, 116.1, 118.5, 118.8, 119.5, 120.2, 2 × 123.2, 123.4, 2 × 123.5, 123.8, 124.3, 2 × 124.4, 2 × 124.5, 2 × 124.9, 128.6, 129.6, 2 × 129.9, 130.2, 130.6, 2 × 130.8, 131.0, 131.1, 131.2, 2 × 131.4, 132.5, 152.9, 155.2, 158.8, 159.3, 160.8, 161.0, 161.1, 161.2, 167.8, 170.0, 171.5, 183.9; IR (KBr, cm^{-1}): ν 3064, 1656, 1613, 1506, 1490, 1420, 1234, 753; *Anal*. Calcd for (%) $C_{16}H_{14}ClFN_4OS$: C, 52.67; H, 3.87; N, 15.36; S, 8.79. Found (%) $C_{17}H_{13}FN_4OS$: C, 52.41; H, 3.78; N, 15.50; S, 8.98.

(3-Nitrophenyl)(quinoxalin-2(1*H*)-on-2-yl)methyl carbamimidothioate (**10d**), 5′-(3-nitrophenyl)-2′-imino-1*H*-spiro[quinoxaline-2,4′-thiazolidin]-3(4*H*)-one (**11d**), and 2′-amino-5′-(3-nitrophenyl)-1*H*,5′*H*-spiro[quinoxaline-2,4′-thiazol]-3(4*H*)-one (**12d**) hydrochlorides were characterized as the mixture of tautomers in percentage ratio 30:25:45, respectively. Light-brown solid; 0.63 g, 91% yield (Method A); mp 170–172°C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 5.51 [s, 1H, CHα (**11d**)], 5.93 [s, 1H, CH5′ (**12d**)], 6.37–6.91 (m, 7H, Ar + Q), 6.91 [s, 1H, CH5′ (**10d**)], 7.37–8.43 (m, 17H, Ar + Q), 9.26–12.76 (s, 12H, NH); $^{13}C\{^{1}H\}$ NMR (126 MHz, DMSO-d_6): δ 50.0, 55.6, 58.3, 84.4, 113.5, 114.2, 114.8, 115.8, 118.7, 119.5, 123.1, 123.4, 123.6, 2 × 123.8, 123.9, 124.5, 128.6, 129.7, 129.8, 130.1, 130.2, 130.9, 131.3, 132.5, 133.8, 134.9, 135.1, 135.5, 136.2, 138.7, 147.1, 147.4, 147.7, 152.8, 155.4, 159.7, 160.4, 167.1, 183.9; IR (KBr, cm^{-1}): ν 3073, 1647, 1614, 1530, 1351, 755, 730, 680; *Anal*. Calcd for (%) $C_{16}H_{14}ClN_5O_3S$: C, 49.04; H, 3.60; N, 17.87; S, 8.18. Found (%) C, 48.72; H, 3.48; N, 17.68; S, 8.39.

(4-Chlorophenyl)(quinoxalin-2(1*H*)-on-2-yl)methyl carbamimidothioate (**10e**), 5′-(4-chlorophenyl)-2′-imino-1*H*-spiro[quinoxaline-2,4′-thiazolidin]-3(4*H*)-one (**11e**), and 2′-amino-5′-(4-chlorophenyl)-1*H*,5′*H*-spiro[quinoxaline-2,4′-thiazol]-3(4*H*)-one (**12e**) hydrochlorides were characterized as the mixture of tautomers in percentage ratio 35:25:40, respectively. Beige solid; 0.60 g, 88% yield (Method A); 0.38 g, 82% yield (Method B); mp 202–204°C; NMR data for **10e**: ^{1}H NMR (500 MHz, DMSO-d_6): δ 6.76 (s, 1H, CHα), 7.36–7.40 (m, 2H, H6-Q, H8-Q), 7.44 (d, J = 8.6 Hz, 2H, H3/H5-Ar), 7.54 (d, J = 8.6 Hz, 2H, H2/H6-Ar), 7.59 (ddd, J = 7.8 Hz, J = 7.6 Hz, J = 0.9 Hz, 1H, H7-Q), 7.83 (dd, J = 7.8 Hz, J = 0.9 Hz, 1H, H5-Q), 12.74 (s, 1H, NH1-Q); $^{13}C\{^{1}H\}$ NMR (126 MHz, DMSO-d_6): δ 50.2 (Cα), 115.7 (C8-Q), 123.6 (C6-Q), 128.5 (C5-Q), 128.7 (C3/C5-Ar), 130.3 (C3-Q), 130.4 (C2/C6-Ar), 130.7 (C4a-Q), 131.4 (C7-Q), 132.3 (C8a-Q), 133.4 (C4-Ar), 135.5 (C1-Ar), 155.9 (C2-Q), 167.5 ($H_2N-C=NH$); ^{15}N NMR (51 MHz, DMSO-d_6): δ 153.7 (N1-Q), 328.1 (N4-Q). The signals of $H_2N-C=NH$, $H_2N-C=NH$, $H_2N-C=NH$, and $H_2N-C=NH$ have not been observed. NMR data for **11e**: ^{1}H NMR (500 MHz, DMSO-d_6): δ 5.31 (s, 1H, CH5′-Tz), 6.58 (d, J = 7.8 Hz, 1H, H8-Q), 6.66–6.68 (m, 1H, H5-Q), 6.68 (ddd, J = 7.8 Hz, J = 7.6 Hz, J = 1.2 Hz, 1H, H6-Q), 6.88 (ddd, J = 7.8 Hz, J = 7.6 Hz, J = 1.2 Hz, 1H, H7-Q), 7.16 (d, J = 8.5 Hz, 2H, H2/H6-Ar), 7.30 (d, J = 8.5 Hz, 2H, H3/H5-Ar), 7.92 (s, 1H, NH4-Q), 10.72 (s, 1H, NH1-Q);

$^{13}C\{^1H\}$ NMR (126 MHz, DMSO-d_6): δ 58.5 (C5′-Tz), 84.2 (C4′-Tz, C3-Q), 114.1 (C6-Q), 114.7 (C8-Q), 119.5 (C5-Q), 123.4 (C7-Q), 123.9 (C8a-Q), 128.1 (C3/C5-Ar), 130.2 (C4a-Q, C1-Ar), 130.7 (C2/C6-Ar), 133.4 (C4-Ar), 159.6 (C2-Q), 170.7 (C2′-Tz); ^{15}N NMR (51 MHz, DMSO-d_6): δ 134.2 (N1-Q), 78.3 (N4-Q). The signals of N<u>H</u>3′-Tz, C=N<u>H</u>-Tz, <u>NH</u>3′-Tz, and C=<u>NH</u>-Tz have not been observed. NMR data for **12e**: ^1H NMR (500 MHz, DMSO-d_6): δ 5.85 (s, 1H, C<u>H</u>5′-Tz), 6.52–6.56 (m, 2H, H6-Q, H7-Q), 6.70 (d, J = 7.6 Hz, 1H, H8-Q), 6.89–6.91 (m, 1H, H5-Q), 7.40 (d, J = 8.5 Hz, 2H, H2/H6-Ar), 7.31 (d, J = 8.5 Hz, 2H, H3/H5-Ar), 7.49 (s, 1H, NH4-Q), 11.14 (s, 1H, NH1-Q); $^{13}C\{^1H\}$ NMR (126 MHz, DMSO-d_6): δ 55.8 (C5′-Tz), 82.0 (C4′-Tz, C3-Q), 113.7 (C6-Q), 114.0 (C5-Q), 114.7 (C8-Q), 118.6 (C7-Q), 123.4 (C8a-Q), 128.3 (C3/C5-Ar), 129.7 (C4a-Q), 131.3 (C2/C6-Ar), 133.7 (C1-Ar), 133.9 (C4-Ar), 152.7 (C2′-Tz), 160.2 (C2-Q); ^{15}N NMR (51 MHz, DMSO-d_6): δ 134.8 (N1-Q), 174.6 (N4-Q). The signals of N<u>H</u>$_2$-Tz, <u>NH</u>3′-Tz, and <u>NH</u>$_2$-Tz have not been observed. IR (KBr, cm^{-1}): ν 3071, 1643, 1614, 1487, 1423, 1093, 758, 607, 567; *Anal*. Calcd for (%) $C_{16}H_{14}Cl_2N_4OS$: C, 50.40; H, 3.70; N, 14.69; S, 8.41. Found (%) C, 50.51; H, 3.76; N, 14.62; S, 8.31.

(2,4-Dichlorophenyl)(quinoxalin-2(1*H*)-on-2-yl)methyl carbamimidothioate (**10f**), 5′-(2,4-dichlorophenyl)-2′-imino-1*H*-spiro[quinoxaline-2,4′-thiazolidin]-3(4*H*)-one (**11f**), and 2′-amino-5′-(2,4-dichlorophenyl)-1*H*,5′*H*-spiro[quinoxaline-2,4′-thiazol]-3(4*H*)-one (**12f**) hydrochlorides were characterized as the mixture of tautomers in percentage ratio 30:26:44, respectively. Yellow solid; 0.60 g, 80% yield (Method A); 0.40 g, 80% yield (Method B); mp 160–162°C; ^1H NMR (500 MHz, DMSO-d_6): δ 5.43 [s, 1H, C<u>H</u>5′ (**11f**)], 5.93 [s, 1H, C<u>H</u>5′ (**12f**)], 6.38–6.70 (m, 5H, Ar + Q), 6.73 [s, 1H, C<u>H</u>α (**10f**)], 6.87–7.98 (m, 16H, Ar + Q), 8.98–12.71 (s, 12<u>H</u>, NH); $^{13}C\{^1H\}$ NMR (126 MHz, DMSO-d_6): δ 49.2, 52.5, 54.9, 81.6, 84.5, 113.2, 114.4, 114.6, 114.9, 115.7, 118.5, 119.4, 123.0, 123.4, 2 × 123.6, 124.3, 2 × 127.5, 128.0, 128.3, 128.4, 128.7, 128.9, 129.4, 129.6, 130.1, 130.2, 130.9, 2 × 131.0, 132.4, 132.5, 133.1, 133.4, 2 × 134.0, 2 × 134.2, 134.5, 134.7, 153.0, 155.0, 158.8, 161.2, 167.9, 170.1, 171.3; IR (KBr, cm^{-1}): ν 3064, 1653, 1614, 1588, 1505, 1472, 1383, 1103, 749; *Anal*. Calcd for (%) $C_{16}H_{13}Cl_3N_4OS$: C, 46.23; H, 3.15; N, 13.48; S, 7.71. Found (%) C, 46.51; H, 3.01; N, 13.31; S, 7.50.

(4-Bromophenyl)(quinoxalin-2(1*H*)-on-2-yl)methyl carbamimidothioate (**10g**), 5′-(4-bromophenyl)-2′-imino-1*H*-spiro[quinoxaline-2,4′-thiazolidin]-3(4*H*)-one (**11g**), and 2′-amino-5′-(4-bromophenyl)-1*H*,5′*H*-spiro[quinoxaline-2,4′-thiazol]-3(4*H*)-one (**12g**) hydrochlorides were characterized as the mixture of tautomers in percentage ratio 31:31:38, respectively. Beige solid; 0.68 g, 89% yield (Method A); 0.45 g, 89% yield (Method B); mp 208–210°C; ^1H NMR (500 MHz, DMSO-d_6): δ 5.24 [s, 1H, C<u>H</u>5′ (**11g**)], 5.85 [s, 1H, C<u>H</u>5′ (**12g**)], 6.53–6.721 (m, 7H, Ar + Q), 6.72 [s, 1H, C<u>H</u>α (**10g**)], 6.89–7.84 (m, 17H, Ar + Q), 7.85–12.72 (s, 12H, NH); $^{13}C\{^1H\}$ NMR (126 MHz, DMSO-d_6): δ 50.3, 56.0, 58.6, 81.6, 84.3, 113.7, 114.0, 114.7, 114.8, 115.7, 118.6, 119.4, 121.7, 122.1, 122.3, 123.1, 123.5, 123.6, 123.7, 124.0, 128.5, 129.7, 129.8, 130.2, 130.7, 130.8, 131.0, 131.0, 131.1, 131.2, 131.5, 131.6, 131.8, 132.1, 132.4, 135.9, 152.8, 155.8, 159.5, 167.5, 170.4, 170.8; IR (KBr, cm^{-1}): ν 3268, 2998, 2960, 2887, 1641, 1483, 1422, 1120, 873, 762, 716, 567; *Anal*. Calcd for (%) $C_{16}H_{14}BrClN_4OS$: C, 45.14; H, 3.31; N, 13.16; S, 7.53. Found (%) C, 45.28; H, 3.40; N, 13.21; S, 7.42.

(6,7-Dichloroquinoxalin-2(1*H*)-on-2-yl)(phenyl)methyl carbamimidothioate (**10h**), 6,7-dichloro-2′-imino-5′-phenyl-1*H*-spiro[quinoxaline-2,4′-thiazolidin]-3(4*H*)-one (**11h**), and 2′-amino-6,7-dichloro-5′-phenyl-1*H*,5′*H*-spiro[quinoxaline-2,4′-thiazol]-3(4*H*)-one (**12h**) hydrochlorides were characterized as the mixture of tautomers in percentage ratio 3:35:62, respectively. Gray-green solid; 0.56 g, 75% yield (Method A); mp 241–243°C; ^1H NMR (500 MHz, DMSO-d_6): δ 5.41 [s, 1H, C<u>H</u>5′ (**11h**)], 5.82 [s, 1H, C<u>H</u>5′ (**12h**)], 6.65–6.67 (m, 2H, Q), 6.70 [s, 1H, C<u>H</u>α (**10h**)], 6.81–8.21 (m, 19H, Ar + Q), 8.42–11.40 (s, 12H, NH); $^{13}C\{^1H\}$ NMR (126 MHz, DMSO-d_6): δ 48.6, 57.1, 59.4, 81.5, 83.7, 114.2, 114.5, 2 × 115.4, 119.2, 119.9, 123.9, 124.2, 124.3, 124.5, 125.0, 127.0, 128.3, 2 × 128.4, 2 × 129.0, 2 × 129.1, 2 × 129.2, 129.4, 2 × 129.6, 129.7, 130.2, 130.4, 130.8, 131.0, 131.4, 153.4, 157.7, 159.5, 160.3, 167.1, 170.5, 171.0; IR (KBr, cm^{-1}): ν 3078, 3057, 1690, 1651, 1615, 1499, 1377, 1125, 698; *Anal*. Calcd for (%) $C_{16}H_{13}Cl_3N_4OS$: C, 46.23; H, 3.15; N, 13.48; S, 7.71. Found (%) C, 46.10; H, 3.03; N, 13.57; S, 7.83.

Reaction of quinoxalin-2(1*H*)-one 9h with thiourea in dioxane. (6,7-Dichloroquinoxalin-2(1*H*)-on-2-yl)(phenyl)methyl carbamimidothioate (**10h**), 6,7-dichloro-2′-imino-5′-phenyl-1*H*-spiro[quinoxaline-2,4′-thiazolidin]-3(4*H*)-one (**11h**), and 2′-amino-6,7-dichloro-5′-phenyl-1*H*,5′*H*-spiro[quinoxaline-2,4′-thiazol]-3(4*H*)-one (**12h**) hydrochlorides were characterized as the mixture of tautomers in percentage ratio 4:37:59, respectively. A mixture of quinoxalin-2(1*H*)-one **9h** (0.40 g, 1.19 mmol) and thiourea (0.10 g, 1.31 mmol) in dry dioxane (10 mL) was heated at reflux with stirring for 4 h and then was evaporated in vacuum to dryness, and the residue was washed in boiling *i*-PrOH, and the undissolved part of precipitate was filtered hot and dried in air to afford analytically pure samples of the by-product **13**. The filtrate was evaporated in vacuum to 2/3 of volume. The precipitate was filtered off and dried in air to afford analytically pure samples of the mixture of

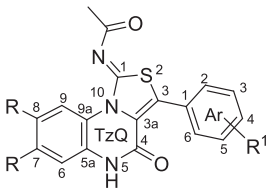
tautomers **10h/11h/12h** in a 71% yield, the characteristics of which are similar to the characteristics of the mixture of tautomers **10h/11h/12h**, obtained by the method described earlier.

As a by-product, 7,8-dichloro-1-imino-3-phenylthiazolo[3,4-*a*]quinoxalin-4(5*H*)-one (**13**) was obtained as a yellow-green solid, 82.0 mg, 19% yield; mp 323–325°C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 7.26 (s, 1H, H6-TzQ), 7.38–7.42 (m, 3H, H4-Ar, H3/H5-Ar), 7.46–7.49 (m, 2H, H2/H6-Ar), 9.60 (s, 1H, H9-TzQ), 11.34 (s, 1H, NH5-TzQ); ^{13}C{^{1}H} NMR (126 MHz, DMSO-d_6): δ 115.5 (C6-TzQ), 118.8 (C9-TzQ), 120.3 (C3a-TzQ), 123.4 (C8-TzQ), 124.5 (C3-TzQ), 124.6 (C9a-TzQ), 126.1 (C7-TzQ), 127.9 (C3-Ar), 128.7 (C5a-TzQ), 128.9 (C4-Ar), 130.0 (C2-Ar), 130.3 (C1-Ar), 153.5 (C4-TzQ), 158.4 (C1-TzQ); ^{15}N NMR (51 MHz, DMSO-d_6): δ 135.5 (N5-TzQ), 144.7 (N10-TzQ). The signal of $\underline{N}C(O)CH_3$ has not been observed. IR (KBr, cm^{-1}): ν 3332, 3028, 2926, 2854, 1686, 1619, 1600, 1479, 1401, 1200, 689, 617; *Anal*. Calcd for (%) $C_{16}H_9Cl_2N_3OS$: C, 53.05; H, 2.50; N, 11.60; S, 8.85. Found (%) C, 52.85; H, 2.57; N, 11.71; S, 8.71.

Transformation of the tautomeric mixture 10h/11h/12h to the 6,7-dichloro-2'-imino-5'-phenyl-1H-spiro[quinoxaline-2,4'-thiazolidin]-3(4H)-one hydrochloride (11h). A mixture of tautomers **10h/11h/12h** (0.10 g, 0.26 mmol) in EtOH/HCl (1.3:1, v/v) was heated at reflux with stirring for 5 h. The reaction mixture was evaporated in vacuum to dryness to afford analytically pure samples of compound **11h** in quantitative yield. Yellow-green powder; 0.10 g, quant. yield; mp 218–220°C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 5.81 (s, 1H, C$\underline{H}$5′-Tz), 6.71 (s, 1H, H8-Q), 6.86 (s, 1H, H5-Q), 7.22–7.28 (m, 3H, H4-Ar, H3/H5-Ar), 7.38–7.42 (m, 2H, H2/H6-Ar), 8.04 (s, 1H, NH1-Q), 9.85 (s, 1H, NH3′-Tz), 10.41 (s, 1H, NH2′-Tz), 11.45 (s, 1H, NH4-Q); ^{13}C{^{1}H} NMR (126 MHz, DMSO-d_6): δ 57.0 (C5′-Tz), 81.3 (C4′-Tz, C2-Q), 114.2 (C8-Q), 115.4 (C5-Q), 119.1 (C4a-Q), 124.0 (C6-Q), 124.3 (C7-Q), 128.4 (C3/C5-Ar), 129.2 (C4-Ar), 129.6 (C2/C6-Ar), 130.3 (C8a-Q), 130.5 (C1-Ar), 160.2 (C3-Q), 170.6 (C2′-Tz); ^{15}N NMR (51 MHz, DMSO-d_6): δ 74.5 (N1-Q), 110.2 ($\underline{N}$H3′-Tz), 134.2 (N4-Q). The signal of C=$\underline{N}$H-Tz has not been observed. IR (KBr, cm^{-1}): ν 3343, 3178, 3061, 1688, 1671, 1500, 1376, 1125, 872, 702, 595, 577; *Anal*. Calcd for (%) $C_{16}H_{13}Cl_3N_4OS$: C, 46.23; H, 3.15; N, 13.48; S, 7.71. Found (%) C, 46.37; H, 3.24; N, 13.52; S, 7.59.

General procedures for the synthesis of 14a–f. ***Method A.*** A mixture of tautomers **10a–f/11a–f/12a–f** (0.30 mmol) in Ac_2O (6 mL) was heated at reflux with stirring for 1.5 h. The precipitate was filtered off and dried in air to afford analytically pure samples of compounds **14a–f**.

Method B. Compound **11h** (0.10 g, 0.26 mmol) in Ac_2O (6 mL) was heated at reflux with stirring for 1.5 h. The precipitate was filtered off and dried in air to afford an analytically pure sample of compound **14a**.



14a-f

1-Acetylimino-7,8-dichloro-3-phenylthiazolo[3,4-a] quinoxalin-4(5H)-one (14a). Yellow-green solid; 100.7 mg, 83% yield (Method A); 99.9 mg, 95% yield (Method B); mp >350°C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 2.36 [s, 3H, C(O)C$\underline{H}_3$], 7.37 (s, 1H, H6-Q), 7.43–7.48 (m, 3H, H4-Ar, H2/H6-Ar), 7.53–7.56 (m, 2H, H3/H5-Ar), 10.24 (s, 1H, H9-TzQ), 11.53 (s, 1H, NH5-TQ); ^{13}C{^{1}H} NMR (126 MHz, DMSO-d_6): δ 26.8 [C(O)$\underline{C}H_3$], 116.1 (C6-TQ), 119.5 (C3a-TzQ), 122.5 (C9-TzQ), 123.3 (C9a-TQ), 123.8 (C3-TzQ), 127.8 (C2/C6-Ar), 128.5 (C5a-TzQ), 128.9 (C4-Ar), 130.0 (C3-Ar), 130.1 (C1-Ar), 131.2 (C7-TzQ), 131.4 (C8-TQ), 153.1 (C4-TzQ), 162.3 (C1-TQ), 179.6 [$\underline{C}$(O)CH$_3$]; IR (KBr, cm^{-1}): ν 3121, 3054, 2947, 1709, 1583, 1478, 1454, 1366, 1263, 1217, 995, 692, 574; *Anal*. Calcd for (%) $C_{18}H_{11}Cl_2N_3O_2S$: C, 53.48; H, 2.74; N, 10.39; S, 7.93. Found (%) C, 53.34; H, 2.66; N, 10.49; S, 8.06.

1-Acetylimino-3-phenythiazolo[3,4-a]quinoxalin-4(5H)-one (14b). Light-yellow solid; 91.6 mg, 91% yield; mp 343–345°C (ref. [26] 341–343°C); ^{1}H NMR (500 MHz, DMSO-d_6): δ 2.36 [s, 3H, C(O)C$\underline{H}_3$], 7.235 (ddd, J = 8.0 Hz, J = 7.8 Hz, J = 1.1 Hz, 1H, H8-TzQ), 7.244 (d, J = 8.0 Hz, 1H, H6-TzQ), 7.35 (ddd, J = 8.0 Hz, J = 7.8 Hz, J = 1.1 Hz, 1H, H7-TzQ), 7.42–7.47 (m, 3H, H4-Ar, H3/H5-Ar), 7.53–7.57 (m, 2H, H2/H6-Ar), 9.93 (dd, J = 8.0 Hz, J = 1.1 Hz, 1H, H9-TQ), 11.36 (s, 1H, NH5-TzQ); ^{13}C{^{1}H} NMR (126 MHz, DMSO-d_6): δ 26.8 [C(O)$\underline{C}H_3$], 115.6 (C6-TzQ), 120.2 (C3a-TzQ), 121.2 (C9-TzQ), 122.2 (C8-TzQ), 124.3 (C9a-TzQ), 127.0 (C7-TzQ), 127.7 (C3/C5-Ar), 128.7 (C4-Ar), 129.0 (C5a-TzQ), 130.1 (C2/C6-Ar), 130.6 (C1-Ar), 130.7 (C3-TzQ), 153.3 (C4-TzQ), 162.2 (C1-TzQ), 179.6 [$\underline{C}$(O)CH$_3$]; ^{15}N NMR (51 MHz, DMSO-d_6): δ 135.0 (N5-TzQ), 162.3 (N10-TzQ), 222.7 [$\underline{N}$C(O)CH$_3$]; IR (KBr, cm^{-1}): ν 3036, 2993, 2917, 1681, 1626, 1466, 1358, 1264, 1218, 762, 690, 660, 571; *Anal*. Calcd for (%) $C_{18}H_{13}N_3O_2S$: C, 64.46; H, 3.91; N, 12.53; S, 9.56. Found (%) C, 64.34; H, 4.02; N, 12.40; S, 9.36.

1-Acetylimino-3-(4-fluorophenyl)thiazolo[3,4-a]quinoxalin-4(5H)-one (14c). Pale yellow solid; 106.0 mg, quant. yield; mp >350°C; ^{1}H NMR (500 MHz, DMSO-d_6): δ 2.36 [s, 3H, C(O)C$\underline{H}_3$], 7.22–7.26 (m, 2H, H6-TzQ, H8-TzQ), 7.27 (dd, J_{HF} = 9.9 Hz, J_{HH} = 8.4 Hz, 2H, H3/H5-Ar), 7.36 (ddd, J = 8.2 Hz, J = 8.0 Hz, J = 1.3 Hz, 1H,

H7-TzQ), 7.61 (dd, J_{HF} = 8.8 Hz, J_{HH} = 8.4 Hz, 2H, H2/H6-Ar), 9.93 (dd, J = 8.2 Hz, J = 1.3 Hz, 1H, H9-TzQ), 11.38 (s, 1H, NH5-TzQ); $^{13}C\{^1H\}$ NMR (126 MHz, DMSO-d_6): δ 26.8 [C(O)$\underline{C}H_3$], 114.7 (d, J_{CF} = 22.0 Hz, C3-Ar), 115.6 (C8-TzQ), 120.5 (C3a-TzQ), 121.2 (C9-TzQ), 121.5 (C3-TzQ), 122.3 (C6-TzQ), 124.3 (C9a-TzQ), 127.1 (C7-TzQ), 129.0 (C5a-TzQ), 129.5 (d, J_{CF} = 2.7 Hz, C1-Ar), 132.3 (d, J_{CF} = 9.3 Hz, C2-Ar), 153.4 (C4-TzQ), 162.1 (C1-TzQ), 162.3 (d, J_{CF} = 246.3 Hz, C4-Ar), 179.6 [$\underline{C}$(O)CH_3]; IR (KBr, cm^{-1}): ν 3038, 2992, 2909, 1681, 1631, 1607, 1507, 1470, 1398, 1365, 1310, 1265, 1216, 833, 762, 603, 549, 512; *Anal*. Calcd for (%) $C_{18}H_{12}FN_3O_2S$: C, 61.18; H, 3.42; N, 11.89; S, 9.07. Found (%) C, 61.24; H, 3.35; N, 11.80; S, 9.18.

1-Acetylimino-3-(2-fluorophenyl)thiazolo[3,4-a]quinoxalin-4(5H)-one (14d). Yellowish solid; 106.0 mg, quant. yield; mp >350°C; ^1H NMR (500 MHz, DMSO-d_6): δ 2.38 [s, 3H, C(O)C$\underline{H}_3$], 7.21–7.31 (m, 4H, H6-TzQ, H8-TzQ, H5-Ar, H4-Ar), 7.36 (ddd, J = 7.9 Hz, J = 7.7 Hz, J = 1.3 Hz, 1H, H7-TzQ), 7.48–7.55 (m, 2H, H6-Ar, H3-Ar), 9.94 (dd, J = 7.9 Hz, J = 1.3 Hz, 1H, H9-TzQ), 11.44 (s, 1H, NH5-TzQ); $^{13}C\{^1H\}$ NMR (126 MHz, DMSO-d_6): δ 26.8 [C(O)$\underline{C}H_3$], 115.3 (d, J_{CF} = 21.7 Hz, C4-Ar), 115.8 (C6-TzQ), 118.6 (d, J_{CF} = 15.2 Hz, C1-Ar), 121.9 (C9-TzQ), 122.1 (C3a-TzQ), 122.4 (C8-TzQ), 123.0 (C3-TzQ), 123.3 (d, J_{CF} = 3.3 Hz, C5-Ar), 124.2 (C9a-TzQ), 129.0 (C5a-TzQ), 129.7 (C7-TzQ), 131.1 (d, J_{CF} = 8.3 Hz, C6-Ar), 131.8 (d, J_{CF} = 1.7 Hz, C3-Ar), 152.9 (C4-TzQ), 159.3 (d, J_{CF} = 247.9 Hz, C2-Ar), 162.6 (C1-TzQ), 179.7 [$\underline{C}$(O)CH_3]; ^{15}N NMR (51 MHz, DMSO-d_6): δ 135.1 (N5-TzQ), 162.1 (N10-TzQ), 223.4 [$\underline{N}$C(O)CH_3]; IR (KBr, cm^{-1}): ν 3051, 2915, 1681, 1624, 165, 1467, 1370, 1310, 1264, 1226, 762, 579, 461; *Anal*. Calcd for (%) $C_{18}H_{12}FN_3O_2S$: C, 61.18; H, 3.42; N, 11.89; S, 9.07. Found (%) C, 61.29; H, 3.50; N, 11.84; S, 8.95.

1-Acetylimino-3-(3-nitrophenyl)thiazolo[3,4-a]quinoxalin-4(5H)-one (14e). Yellow solid; 103.8 mg, 91% yield; mp 346–348°C; ^1H NMR (500 MHz, DMSO-d_6): δ 2.38 [s, 3H, C(O)C$\underline{H}_3$], 7.27 (d, J = 8.0 Hz, 1H, H6-TzQ), 7.28 (ddd, J = 8.0 Hz, J = 7.8 Hz, J = 1.1 Hz, 1H, H8-TzQ), 7.38 (ddd, J = 8.0 Hz, J = 7.8 Hz, J = 1.1 Hz, 1H, H7-TzQ), 7.75 (dd, J = 8.1 Hz, J = 8.1 Hz, 1H, H5-Ar), 8.00 (br d, J = 8.1 Hz, 1H, H6-Ar), 8.30 (dd, J = 8.1 Hz, J = 1.9 Hz, 1H, H4-Ar), 8.41 (dd, J = 1.9 Hz, J = 1.9 Hz, 1H, H2-Ar), 9.56 (dd, J = 8.0 Hz, J = 1.1 Hz, 1H, H9-TzQ), 11.56 (s, 1H, NH5-TzQ); $^{13}C\{^1H\}$ NMR (126 MHz, DMSO-d_6): δ 27.0 [C(O)$\underline{C}H_3$], 115.9 (C6-TzQ), 121.2 (C9-TzQ), 121.9 (C3a-TzQ), 122.6 (C8-TzQ), 123.5 (C4-Ar), 124.4 (C9a-TzQ), 125.2 (C2-Ar), 127.4 (C7-TzQ, C3-TzQ), 129.1 (C5a-TzQ), 129.4 (C5-Ar), 132.1 (C1-Ar), 136.6 (C6-Ar), 147.1 (C3-Ar), 153.5 (C4-TzQ), 162.3 (C1-TzQ), 179.9 [$\underline{C}$(O)CH_3]; IR (KBr, cm^{-1}): ν 3094, 2991, 1676, 1624, 1530, 1461, 1370, 1350, 1311, 1272, 1214, 751, 569; *Anal*. Calcd for (%) $C_{18}H_{12}N_4O_4S$: C, 56.84; H, 3.18; N, 14.73; S, 8.43. Found (%) C, 56.78; H, 3.14; N, 14.79; S, 8.50.

1-Acetylimino-3-(4-chlorophenyl)thiazolo[3,4-a]quinoxalin-4(5H)-one (14f). Light-yellow solid; 103.0 mg, 93% yield; mp >350°C; ^1H NMR (500 MHz, DMSO-d_6): δ 2.37 [s, 3H, C(O)C$\underline{H}_3$], 7.25 (ddd, J = 8.0 Hz, J = 7.8 Hz, J = 1.1 Hz, 1H, H8-TzQ), 7.26 (d, J = 8.0 Hz, 1H, H6-TzQ), 7.36 (ddd, J = 8.0 Hz, J = 7.8 Hz, J = 1.1 Hz, 1H, H7-TzQ), 7.50 (d, J = 8.6 Hz, 1H, H2/H6-Ar), 7.58 (d, J = 8.6 Hz, 1H, H3/H5-Ar), 9.93 (dd, J = 8.0 Hz, J = 1.1 Hz, 1H, H9-TzQ), 11.41 (s, 1H, NH5-TzQ); $^{13}C\{^1H\}$ NMR (126 MHz, DMSO-d_6): δ 26.8 [C(O)$\underline{C}H_3$], 115.7 (C6-TzQ), 120.8 (C3a-TzQ), 121.1 (C9-TzQ), 122.3 (C8-TzQ), 124.3 (C9a-TzQ), 127.1 (C7-TzQ), 127.7 (C2/C6-Ar), 129.0 (C5a-TzQ), 129.1 (C4-Ar), 129.5 (C3-TzQ), 131.9 (C3/C5-Ar), 133.6 (C1-Ar), 153.3 (C4-TzQ), 162.2 (C1-TzQ), 179.6 [$\underline{C}$(O)CH_3]; ^{15}N NMR (51 MHz, DMSO-d_6): δ 135.6 (N5-TzQ), 162.7 (br, N10-TzQ), 223.3 [$\underline{N}$C(O)CH_3]; IR (KBr, cm^{-1}): ν 3045, 2992, 2910, 1671, 1624, 1461, 1396, 1363, 1266, 1215, 1089, 989, 825, 749, 586; *Anal*. Calcd for (%) $C_{18}H_{12}ClN_3O_2S$: C, 58.46; H, 3.27; N, 11.36; S, 8.67. Found (%) C, 58.68; H, 3.37; N, 11.51; S, 8.55.

1-Acetylimino-3-(2,4-dichlorophenyl)thiazolo[3,4-a] quinoxalin-4(5H)-one (14g). Yellow-brown solid; 118.9 mg, 98% yield; mp 294–296°C; ^1H NMR (500 MHz, DMSO-d_6): δ 2.38 [s, 3H, C(O)C$\underline{H}_3$], 7.265 (d, J = 7.8 Hz, 1H, H6-TzQ), 7.267 (ddd, J = 7.8 Hz, J = 7.6 Hz, J = 1.2 Hz, 1H, H8-TzQ), 7.37 (ddd, J = 7.8 Hz, J = 7.6 Hz, J = 1.2 Hz, 1H, H7-TzQ), 7.51 (dd, J = 8.2 Hz, J = 2.0 Hz, 1H, H5-Ar), 7.55 (d, J = 8.2 Hz, 1H, H6-Ar), 7.73 (d, J = 2.0 Hz, 1H, H3-Ar), 9.94 (dd, J = 7.8 Hz, J = 1.2 Hz, 1H, H9-TzQ), 11.47 (s, 1H, NH5-TzQ); $^{13}C\{^1H\}$ NMR (126 MHz, DMSO-d_6): δ 26.8 [C(O)$\underline{C}H_3$], 115.8 (C6-TzQ), 120.9 (C9-TzQ), 122.5 (C8-TzQ), 122.6 (C9a-TzQ), 124.1 (C3a-TzQ), 125.3 (C3-TzQ), 126.9 (C5-Ar), 127.2 (C7-TzQ), 128.6 (C3-Ar), 128.9 (C5a-TzQ), 129.1 (C1-Ar), 133.1 (C6-Ar), 134.2 (C4-Ar), 134.3 (C2-Ar), 152.8 (C4-TzQ), 162.5 (C1-TzQ), 179.7 [$\underline{C}$(O)CH_3]; IR (KBr, cm^{-1}): ν 3054, 2991, 2913, 1681, 1614, 1581, 1461, 1373, 1278, 1224, 833, 757, 587; *Anal*. Calcd for (%) $C_{18}H_{11}Cl_2N_3O_2S$: C, 53.48; H, 2.74; N, 10.39; S, 7.93. Found (%) C, 53.30; H, 2.81; N, 10.50; S, 7.78.

1-Acetylimino-3-(4-bromophenyl)thiazolo[3,4-a]quinoxalin-4(5H)-one (14h). Light-yellow solid; 111.9 mg, 90% yield; mp 333–335°C; ^1H NMR (500 MHz, DMSO-d_6): δ 2.36 [C(O)C$\underline{H}_3$], 7.24–7.28 (m, 2H, H8-TQ, H6-TzQ), 7.35 (ddd, J = 8.0 Hz, J = 7.8 Hz, J = 1.3 Hz, 1H, H7-TzQ), 7.50 (d, J = 8.5 Hz, 1H, H3/H5-Ar), 7.64 (d,

J = 8.5 Hz, 1H, H2/H6-Ar), 9.92 (dd, *J* = 8.5 Hz, *J* = 1.3 Hz, 1H, H9-TzQ), 11.41 (s, 1H, NH5-TzQ); $^{13}C\{^{1}H\}$ NMR (126 MHz, DMSO-d_6): δ 26.8 [C(O)$\underline{C}H_3$], 115.7 (C8-TzQ), 120.7 (C3a-TzQ), 121.1 (C9-TzQ), 122.3 (C4-Ar, C6-TzQ), 124.3 (C9a-TzQ), 127.1 (C7-TzQ), 129.0 (C5a-TzQ), 129.1 (C1-Ar), 129.9 (C3-TzQ), 130.7 (C2/C6-Ar), 132.1 (C3/C5-Ar), 153.3 (C4-TzQ), 162.1 (C1-TzQ), 179.6 [$\underline{C}(O)CH_3$]; ^{15}N NMR (51 MHz, DMSO-d_6): δ 135.5 (N5-TzQ), 162.6 (N10-TzQ), 222.6 [$\underline{N}C(O)CH_3$]; IR (KBr, cm^{-1}): ν 3042, 2989, 2900, 1670, 1605, 1459, 1392, 1362, 1265, 1215, 987, 822, 760, 748, 582; *Anal*. Calcd for (%) $C_{18}H_{12}BrN_3O_2S$: C, 52.19; H, 2.92; N, 10.14; S, 7.74. Found (%) C, 52.30; H, 2.84; N, 10.19; S, 7.84.

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CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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