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Visible-light-induced aerobic C3–H fluoroalkoxylation of quinoxalin-2(1*H*)-ones with fluoroalkyl alcohols†

Xiaobo Xu,[ab] Chengcai Xia,[*a] Xiaojun Li,[c] Jian Sun[a] and Liqiang Hao[a]

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A novel and efficient method of visible-light-induced C3–H fluoroalkoxylation of quinoxalin-2(1*H*)-ones with fluoroalkyl alcohols is developed. This approach uses readily available fluoroalkyl alcohols as fluoroalkoxylation reagents and displays a wide substrate scope, providing the fluoroalkoxylated products in moderate to good yields. Compared with the previous method, such a transformation uses oxygen as an oxidant, which avoids the utilization of plenty of $PhI(TFA)_2$. In addition, this strategy also gives a practical tool for the rapid synthesis of histamine-4 receptor antagonist and new N-containing bidentate ligands. A radical mechanism was suggested according to the results of control experiments.

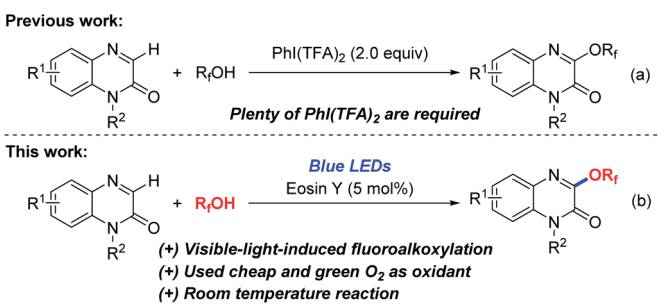
Introduction

As a class of fluorine-containing molecules, fluoroalkoxyl aryl ethers are widely used in agricultural agents, advanced materials and pharmaceuticals because of the unique impact of the fluorine atoms on physicochemical and biological properties.[1] The conventional methods to prepare such compounds are nucleophilic aromatic substitution reactions (S_NAr), which usually suffer from high temperature and low reactivity.[2] Consequently, the development of more practical and efficient approaches to access fluoroalkoxyl aryl ethers has recently received considerable attention.

In recent years, transition-metal-catalyzed reactions have been regarded as reliable strategies for the preparation of fluoroalkoxyl aryl ethers.[3] For example, Weng,[3a,b] Ji,[3c] Crousse,[3d] and Qing[3e] reported novel methods for the construction of fluoroalkoxyl aryl ethers through copper-catalyzed C–O cross couplings of aryl halides or aryl boronic acids with fluoroalkyl alcohols. In addition, the Singh group achieved a palladium-catalyzed dehalogenated coupling of aryl halides with fluoroalkyl alcohols for the synthesis of fluoroalkoxyl aryl ethers.[3f] Alternatively, palladium-catalyzed amide-directed C–H trifluoroethoxylation provided another route to fluoroalkoxyl aryl ethers.[3g] Despite the utilities, the pre-functionalization of the starting materials in above methods limited their applications. In addition, the metal catalysts are toxic, and trace amounts of metal residues in final products are quite difficult to remove, which is a crucial issue in the pharmaceutical industry.[4]

As an important class of heterocyclic units, quinoxalin-2(1*H*)-ones widely exist in natural products, organic intermediates and pharmaceuticals.[5] Therefore, great efforts have been devoted to the development of new methods for the synthesis of quinoxalin-2(1*H*)-ones and its derivatives.[6] Thanks to the development of C–H functionalization, lots of transformations so far have been achieved,[7] such as phosphorization,[8] amination,[9] alkylation,[10] arylation,[11] acylation,[12] trifluoromethylation,[13] difluoromethylation,[14] alkoxylation[15] and thiolation.[16] In sharp contrast, C–H fluoroalkoxylation of quinoxalin-2(1*H*)-ones was rarely reported. Very recently, the first example of C3–H fluoroalkoxylation of quinoxalin-2(1*H*)-ones with fluoroalkyl alcohols was reported by Li and Zhang (Scheme 1a).[17] However, such reaction suffers from plenty of $PhI(TFA)_2$, which failed to meet the requirements of green chemistry.[18]

As a clean and sustainable approach, photocatalyzed C–H functionalization has become an important strategy to introduce fluorine-containing functional groups into organic molecules.[19] For a long time, we are always working to develop



Scheme 1 The C3–H fluoroalkoxylation of quinoxalin-2(1*H*)-ones.

[a]*Pharmacy College, Shandong First Medical University, Shandong Academy of Medical Sciences, Taian 271000, China. E-mail: xiachc@163.com*
[b]*Shanghai Synmedia Chemical Co., Ltd, Shanghai 201201, China*
[c]*Department of Fundamental Medicine, Xinyu University, Xinyu 338004, China*

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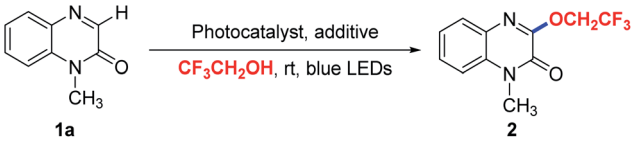
photocatalyzed C–H functionalization of N-heterocycle.[20] Recently, our group reported photocatalyzed aerobic C3–H perfluoroalkylation of quinoxalin-2(1*H*)-ones with sodium perfluoroalkanesulfinates.[13a] As a further work, herein, we demonstrated a visible light induced aerobic C3–H fluoroalkoxylation of quinoxalin-2(1*H*)-ones with fluoroalkyl alcohols, providing a green and efficient method to introduce fluoroalkoxy into quinoxalin-2(1*H*)-ones molecules (Scheme 1b). During the preparation of our manuscript, Wang and Li groups developed an useful approach for alkoxylation of quinoxalin-2(1*H*)-ones respectively, but it only gave one trifluoroethoxylated example.[15a,b] Therefore, the development of simple and widely applicable approaches for the C3–H fluoroalkoxylation of quinoxalin-2(1*H*)-ones is still meaningful. In addition, many further transformations have been done in our work, which clearly demonstrated the application value of the reaction.

Results and discussion

Initially, the coupling reaction of quinoxalin-2(1*H*)-ones with trifluoroethanol was performed in air by using 5 mol% of rose bengal as a photocatalyst under the radiation of 18 W blue LED. The desired product (**2**) was obtained in 25% yield (Table 1, entry 1). Encouraged by this result, we next screened a series of photocatalysts such as Acr^+–Mes ClO_4^-, fluorescein, eosin Y, methylene blue, erythrosine, $Ru(bpy)_3Cl_2$ and $Ir(ppy)_3$. It was found that eosin Y was the best photocatalyst, which provided the product in 70% yield (Table 1, entries 2–8). No desired product (**2**) was generated without photocatalyst (Table 1, entry 9). To further improve the product yield, some additives and solvents were explored, but no better result was gained (Table 1, entries 10–18). To our delight, the yield was enhanced to 85% when the reaction was performed under O_2 atmosphere (Table 1, entry 19). No desired product was generated when the transformation was carried out under N_2 atmosphere (Table 1, entry 20). These results implied that O_2 played a key role in this transformation. Further investigations on the light sources revealed that blue light was the best choice for the reaction (Table 1, entries 21–23).

Having established the best reaction conditions, we subsequently explored the substrate scope of quinoxalin-2(1*H*)-ones (Table 2). Generally, the C–H fluoroalkoxylation reaction showed good substituent group tolerance. Quinoxalin-2(1*H*)-ones bearing different of N-protecting groups such as methyl ($-CH_3$), ethyl ($-C_2H_5$), butyl ($-^nC_4H_9$), isoamyl ($-^iC_5H_{11}$), cyclopropylmethyl, cyclohexylmethyl and esteryl ($-CH_2CO_2R$) were well tolerant, giving the corresponding products (**2–9**) in 70–87% yields. The *N*-benzyl groups ($-CH_2Ar$) also were compatible, affording the target products in good yields (**10–19**). The molecular structure of product **18** was confirmed by X-ray diffraction studies (see ESI†). In addition, quinoxalin-2(1*H*)-ones with substituents on the benzene ring also could undergo this transformation smoothly, providing the trifluoroethoxylated products (**20–27**) in 45–82% yields. Furthermore, quinoxalin-2(1*H*)-one and 2*H*-benzo[*b*][1,4]oxazin-2-one were also tolerant under standard reaction conditions, yielding the corresponding products (**28** and **29**) in 75% and 78% yields, responsively.

Table 1 Optimization of reaction conditions[a,b]



1a 2

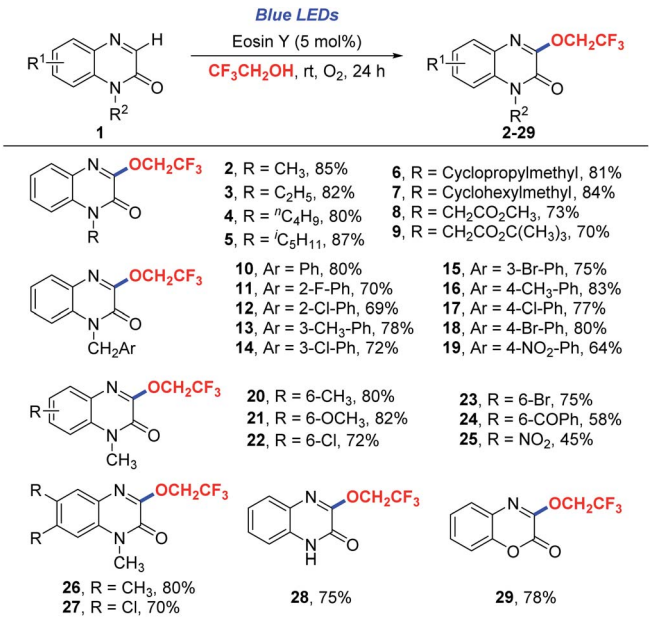
Entry	Photocatalyst	Additive	Solvent	Yield[b] [%]
1	Rose bengal	—	—	25
2	Acr^+–Mes ClO_4^-	—	—	65
3	Fluorescein	—	—	Trace
4	Eosin Y	—	—	70
5	Methylene blue	—	—	Trace
6	Erythrosine	—	—	Trace
7	$Ru(bpy)_3Cl_2$	—	—	28
8	$Ir(ppy)_3$	—	—	Trace
9	—	—	—	0
10	Eosin Y	TFA	—	66
11	Eosin Y	H_3PO_4	—	43
12	Eosin Y	Na_2CO_3	—	20
13	Eosin Y	AcONa	—	34
14	Eosin Y	Bu_4NBr	—	48
15[c]	Eosin Y	—	CH_3CN	52
16[c]	Eosin Y	—	DCE	Trace
17[c]	Eosin Y	—	DMF	24
18[c]	Eosin Y	—	H_2O	Trace
19[d]	Eosin Y	—	—	85
20[e]	Eosin Y	—	—	0
21[d,f]	Eosin Y	—	—	15
22[d,g]	Eosin Y	—	—	27
23[d,h]	Eosin Y	—	—	0

[a] Reaction conditions: **1a** (0.2 mmol), photocatalyst (5 mol%), additive (1.5 equiv.), CF_3CH_2OH (0.5 mL), blue LED (18 W), rt, under air atmosphere, 24 h. [b] Isolated yields. [c] CF_3CH_2OH (5.0 equiv.), solvent (0.5 mL). [d] Under O_2 atmosphere. [e] Under N_2 atmosphere. [f] Green LED (18 W). [g] White LED (18 W). [h] Without light.

After that, the efforts were further focused on the exploration of fluoroalkyl alcohols (Table 3). It was found that fluoroalkyl alcohols such as pentafluoro-1-propanol, heptafluoro-1-butanol, tetrafluoro-1-propanol, trifluorobutan-1-butanol, difluoro-1-ethanol and fluoro-1-ethanol could also undergo this reaction successfully, producing the corresponding products (**30–41**) in good yields. Regrettably, the longer-chain and bulky fluoroalkyl alcohols such as octafluoropentyl alcohol, hexafluoroisopropanol and nonafluoro-*tert*-butanol could not be converted into corresponding products (**42–44**) since the effect of large steric hindrance. We also tried to extend the method to the modification of other important N-containing molecules, but failed (see ESI, Scheme S1†).

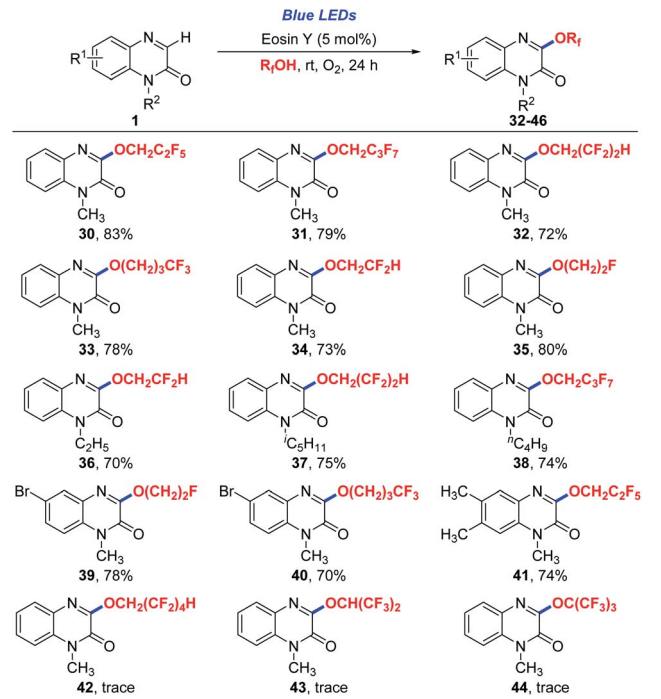
To demonstrate the application value of the reaction, we firstly performed a gram-scale reaction. To our delight, the product (**2**) could be isolated in 72% yield (Scheme 2a). In addition, the histamine-4 receptor antagonist **45** could be obtained in 63% yield through the C–H trifluoroethoxylation, followed by nucleophilic substitution (Scheme 2b).[21]

Table 2 Substrate scope of quinoxalin-2(1*H*)-ones[a,b]



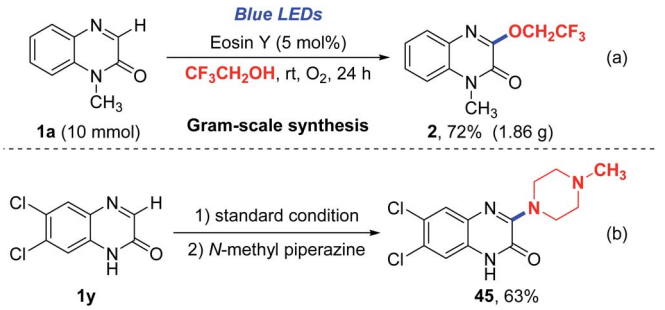
[a] Reaction conditions: **1** (0.2 mmol), eosin Y (5 mol%), CF_3CH_2OH (0.5 mL), blue LED (18 W), rt, O_2, 24 h. [b] Isolated yields.

Table 3 Substrate scope of fluoroalkyl alcohols[a,b]



[a] Reaction conditions: **1** (0.2 mmol), eosin Y (5 mol%), R_fOH (0.5 mL), blue LED (18 W), rt, O_2, 24 h. [b] Isolated yields.

Furthermore, the N-containing bidentate ligand **46** also could be synthesized in 50% yield by using product **28** as building block (Scheme 3). We further applied this ligand to catalyse

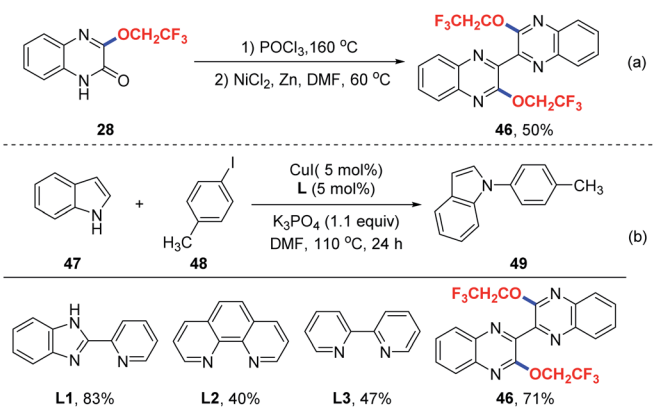


Scheme 2 Gram-scale synthesis and the synthesis of histamine-4 receptor antagonist.

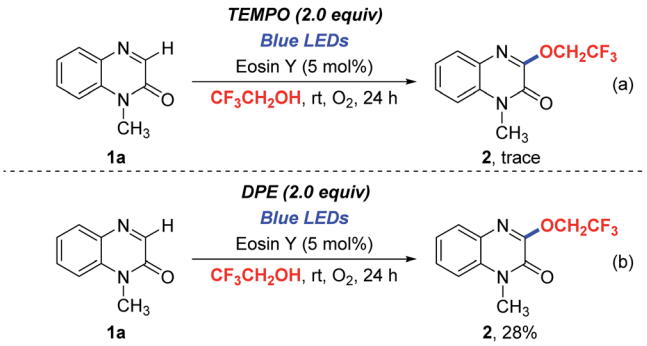
traditional C–N cross-couplings to examine its reactivity. It was found that compare to other ligands that were reported in the literature,[22] the ligand **46** has relatively good reactivity, providing the product in moderate yield.

To obtain more details of the C–H fluoroalkoxylation reaction, the mechanism investigations were started. Firstly, the C–H fluoroalkoxylation reaction was dramatically suppressed when two equivalents of TEMPO (2,2,6,6-tetramethylpiperidinooxy) or DPE (1,1-diphenylethlene) was added respectively (Scheme 4). These results implied that a radical pathway might be involved in this reaction. The visible light irradiation on/off experiments revealed that the visible light played a crucial role in this reaction (Fig. 1). In addition, the measurement result of potential indicated that the generation of trifluoroethoxy radical from trifluoroethanol is very difficult (Scheme S2†).

Based on the results of mechanism studies and previous works,[7–17] we proposed a reasonable mechanism for this visible-light-induced C–H fluoroalkoxylation reaction (Scheme 5). Initially, the excited eosin Y* was generated under the irradiation of blue LEDs. A subsequent single-electron-transfer (SET) process took place between eosin Y* and *N*-methyl-quinoxalin-2(1*H*)-one **1a** to form the eosin $Y^{\bullet-}$ species and intermediate **A**. The intermediate **A** was further trapped by trifluoroethanol to generate intermediate **B**. Meanwhile, the second single-electron-transfer (SET) process happened between eosin $Y^{\bullet-}$ species and O_2 to give $O_2^{\bullet-}$ species and eosin Y. The final



Scheme 3 Further chemistry.



Scheme 4 Mechanism studies.

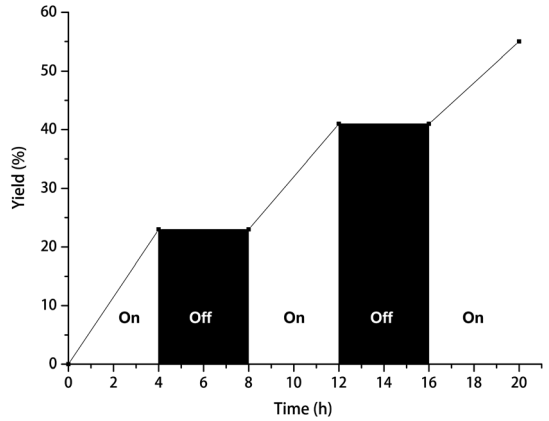
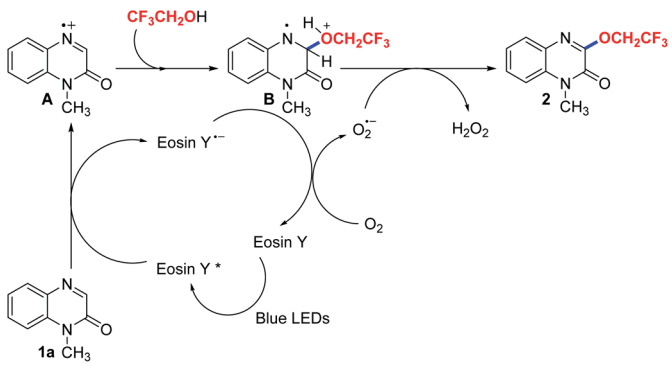


Fig. 1 Visible light irradiation on/off experiments.



Scheme 5 Plausible mechanism.

product was obtained through oxidation and proton transfer process with the release of H_2O_2, which was detected by a starch potassium iodide test paper.

Conclusions

We have reported a visible-light-induced aerobic C3–H fluoroalkoxylation of quinoxalin-2(1*H*)-ones with fluoroalkyl alcohols. This approach uses readily available fluoroalkyl alcohols as fluoroalkoxylation reagents and substrates with various functional groups were tolerant, providing the fluoroalkoxylated products in moderate to good yields. The control experiments results demonstrated that a radical pathway was answerable for this reaction.

Experimental section

General information

The starting materials, solvents and other chemicals used in experiments were purchased from Energy Chemical without further purification. All products were isolated by short chromatography on a silica gel (200–300 mesh) column using petroleum ether (60–90 °C) and ethyl acetate. ^{1}H, ^{13}C and ^{19}F NMR spectra were recorded on Bruker Avance DRX-500 spectrometers at ambient temperature with $CDCl_3$ as solvent and tetramethylsilane (TMS) as the internal standard. All chemical shift values are quoted in ppm and coupling constants quoted in Hz. Compounds for HRMS were analyzed by positive mode electrospray ionization (ESI) using Agilent 6530 QTOF mass spectrometer.

General procedure for the synthesis of fluoroalkoxylated quinoxalin-2(1*H*)-ones (2–41)

Quinoxalin-2(1*H*)-ones derivatives **1** (0.2 mmol), eosin Y (5 mol%), R_fOH (0.5 mL) were combined in a 15 mL tube. The mixture was then stirred for 24 hours under O_2 atmosphere by the radiation of 18 W blue LED. After the conversion was completed as indicated by TLC, to the residue was added water (10 mL) and extracted with ethyl acetate (5 mL × 3). The collected organic layer was washed with brine, dried with $MgSO_4$, filtered and concentrated *in vacuo*. The residue was purified directly by flash column chromatography.

General procedure for the gram-scale synthesis of fluoroalkoxylated quinoxalin-2(1*H*)-one (2)

Quinoxalin-2(1*H*)-ones derivatives **1a** (10.0 mmol), eosin Y (5 mol%), R_fOH (20 mL) were combined in a 100 mL flask. The mixture was then stirred for 24 hours under O_2 atmosphere by the radiation of 18 W blue LED. After the conversion was completed as indicated by TLC, to the residue was added water (10 mL) and extracted with ethyl acetate (50 mL × 3). The collected organic layer was washed with brine, dried with $MgSO_4$, filtered and concentrated *in vacuo*. The residue was purified directly by flash column chromatography.

General procedure for the synthesis of histamine-4 receptor antagonist (45)

Quinoxalin-2(1*H*)-ones derivative **1y** (0.5 mmol), eosin Y (5 mol%), R_fOH (1.0 mL) were combined in a 15 mL tube. The mixture was then stirred for 24 hours under O_2 atmosphere by the radiation of 18 W blue LED. After the conversion was completed as indicated by TLC, to the residue was added water (10 mL) and extracted with ethyl acetate (10 mL × 3). The collected organic layer was washed with brine, dried with $MgSO_4$, filtered and concentrated *in vacuo*. After the solvent was removed, DMSO (1.5 mL), Et_3N (1.5 equiv.) and *N*-

methylpiperazine (1.5 equiv.) were added to the residue, and the mixture was stirred at 120 °C for 12 hours. After the conversion was completed as indicated by TLC, to the residue was added water (10 mL) and extracted with ethyl acetate (10 mL × 3). The collected organic layer was washed with brine, dried with $MgSO_4$, filtered and concentrated *in vacuo*. The residue was purified directly by flash column chromatography.

General procedure for the synthesis of 3,3′-bis(2,2,2-trifluoroethoxy)-2,2′-biquinoxaline (46)

Fluoroalkoxylated quinoxalin-2(1*H*)-one **28** (2.0 mmol), $POCl_3$ (1.2 equiv.) and pyridine (1.0 equiv.) were combined in a 15 mL tube. The mixture was then stirred at 160 °C for 30 min. After the conversion was completed as indicated by TLC, to the residue was added saturated $NaHCO_3$ solution (15 mL) and extracted with ethyl acetate (20 mL × 3). The collected organic layer was washed with brine, dried with $MgSO_4$, filtered and concentrated *in vacuo*. After the solvent was removed, $NiCl_2 \cdot 6H_2O$ (5 mol%), LiCl (1.0 equiv.), zinc dust (1.2 equiv.) and DMF (10.0 mL) in a 50 mL flask was heated to 50 °C, then, a grain of iodine crystal and two drops of acetic acid were added to the mixture. The mixture was stirred at 60 °C for 2 hours. After the conversion was completed as indicated by TLC, to the residue was added water (15 mL) and extracted with ethyl acetate (20 mL × 3). The collected organic layer was washed with brine, dried with $MgSO_4$, filtered and concentrated *in vacuo*. The residue was purified directly by flash column chromatography.

General procedure for the synthesis of 1-(*p*-tolyl)-1*H*-indole (49)

K_3PO_4 (2.2 mmol) was added to a Schlenk tube equipped with a stirring bar and the tube was dried under vacuum and then filled with an argon. CuI (0.1 mmol) and ligand (0.1 mmol) and DMF (4.0 mL) were added and the mixture was stirred at 50 °C for 1 h, 1-iodo-4-methylbenzene (2.0 mmol) and indole (3.0 mmol) were added, and then the mixture was stirred at 110 °C for 24 h. After the completion of the reaction, the mixture was cooled, then the precipitate was removed by filtration and the product was extracted with ethyl acetate (20 mL × 3). The collected organic layer was washed with brine, dried with $MgSO_4$, filtered and concentrated *in vacuo*. The residue was purified directly by flash column chromatography.

1-Methyl-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (2)

White solid (85% yield), mp 154–155 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.65 (dd, J = 8.0, 1.3 Hz, 1H), 7.51–7.45 (m, 1H), 7.36–7.32 (m, 1H), 7.30 (d, J = 8.3 Hz, 1H), 4.90 (q, J = 8.3 Hz, 2H), 3.74 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 151.03, 149.21, 131.10, 128.96, 127.14, 126.86, 123.21, 122.10 (q, J = 278.5 Hz), 112.79, 61.78 (q, J = 37.8 Hz), 28.60. ^{19}F NMR (471 MHz, $CDCl_3$) δ −73.02. HRMS (ESI): calculated for $C_{11}H_9F_3N_2O_2^+$: 259.0689 $[M + H]^+$, found: 259.0686.

1-Ethyl-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (3)

White solid (82% yield), mp 126–127 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.66 (dd, J = 8.2, 1.5 Hz, 1H), 7.50–7.45 (m, 1H), 7.35–7.30 (m, 2H), 4.90 (q, J = 8.3 Hz, 2H), 4.36 (q, J = 7.2 Hz, 2H), 1.40 (t, J = 7.2 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.03, 149.71, 130.99, 130.32, 128.16, 128.14, 124.03, 123.15 (q, J = 278.5 Hz), 113.67, 62.81 (q, J = 37.8 Hz), 37.87, 12.36. ^{19}F NMR (471 MHz, $CDCl_3$) δ −73.00. HRMS (ESI): calculated for $C_{12}H_{11}F_3N_2O_2^+$: 273.0846 $[M + H]^+$, found: 273.0849.

1-Butyl-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (4)

White solid (80% yield), mp 118–119 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.65 (dd, J = 7.9, 1.3 Hz, 1H), 7.50–7.44 (m, 1H), 7.31 (dd, J = 13.1, 8.1 Hz, 2H), 4.89 (q, J = 8.3 Hz, 2H), 4.33–4.26 (m, 2H), 1.79–1.72 (m, 2H), 1.49 (dd, J = 15.1, 7.5 Hz, 2H), 1.00 (t, J = 7.4 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.04, 149.94, 131.28, 130.29, 128.12, 128.05, 123.99, 123.15 (q, J = 278.5 Hz), 113.84, 62.82 (q, J = 37.8 Hz), 42.62, 29.25, 20.22, 13.76. ^{19}F NMR (471 MHz, $CDCl_3$) δ −73.01. HRMS (ESI): calculated for $C_{14}H_{15}F_3N_2O_2^+$: 301.1159 $[M + H]^+$, found: 301.1154.

1-Isopentyl-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (5)

White solid (87% yield), mp 123–124 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.65 (d, J = 7.8 Hz, 1H), 7.50–7.45 (m, 1H), 7.34–7.27 (m, 2H), 4.88 (q, J = 8.3 Hz, 2H), 4.32–4.26 (m, 2H), 1.78 (dd, J = 13.3, 6.6 Hz, 1H), 1.67–1.62 (m, 2H), 1.04 (d, J = 6.6 Hz, 6H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.01, 149.86, 131.22, 130.32, 128.13, 128.09, 124.00, 123.15 (q, J = 278.5 Hz), 113.75, 62.83 (q, J = 37.8 Hz), 41.44, 35.82, 26.44, 22.47. ^{19}F NMR (471 MHz, $CDCl_3$) δ −72.56. HRMS (ESI): calculated for $C_{15}H_{17}F_3N_2O_2^+$: 315.1315 $[M + H]^+$, found: 315.1318.

1-(Cyclopropylmethyl)-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (6)

White solid (81% yield), mp 136–137 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.66 (dd, J = 7.9, 1.0 Hz, 1H), 7.51–7.45 (m, 1H), 7.43 (d, J = 8.0 Hz, 1H), 7.33 (t, J = 7.5 Hz, 1H), 4.90 (q, J = 8.3 Hz, 2H), 4.23 (d, J = 7.0 Hz, 2H), 1.31–1.25 (m, 1H), 0.62–0.53 (m, 4H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.18, 150.28, 131.50, 130.22, 128.09, 128.05, 124.02, 123.17 (q, J = 278.5 Hz), 114.09, 62.86 (q, J = 37.8 Hz), 46.74, 9.57, 4.13. ^{19}F NMR (471 MHz, $CDCl_3$) δ −72.97. HRMS (ESI): calculated for $C_{14}H_{13}F_3N_2O_2^+$: 299.1002 $[M + H]^+$, found: 299.1006.

1-(Cyclohexylmethyl)-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (7)

White solid (84% yield), mp 145–146 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.57 (dd, J = 7.9, 1.4 Hz, 1H), 7.40–7.36 (m, 1H), 7.26–7.20 (m, 2H), 4.81 (q, J = 8.3 Hz, 2H), 4.10 (d, J = 7.3 Hz, 2H), 1.88–1.80 (m, 1H), 1.68–1.56 (m, 5H), 1.12 (t, J = 9.9 Hz, 5H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 151.05, 149.37, 130.67, 129.20, 127.07, 126.89, 122.92, 122.12 (q, J = 278.5 Hz), 113.28, 61.83 (q, J = 37.8 Hz), 47.53, 35.46, 29.83, 25.11, 24.73. ^{19}F NMR (471 MHz, $CDCl_3$) δ −72.98. HRMS (ESI): calculated for $C_{17}H_{19}F_3N_2O_2^+$: 341.1472 $[M + H]^+$, found: 341.1476.

Methyl-2-(2-oxo-3-(2,2,2-trifluoroethoxy)quinoxalin-1(2*H*)-yl) acetate (8)

White solid (73% yield), mp 133–134 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.67 (dd, J = 8.0, 1.4 Hz, 1H), 7.47–7.41 (m, 1H), 7.37–7.31 (m, 1H), 7.06 (dd, J = 8.3, 0.7 Hz, 1H), 5.07 (s, 2H), 4.90 (q, J = 8.3 Hz, 2H), 3.78 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 167.30, 151.79, 149.97, 131.26, 130.04, 128.39, 128.23, 124.57, 123.09 (q, J = 278.5 Hz), 113.24, 62.98 (q, J = 37.8 Hz), 52.95, 43.75. ^{19}F NMR (471 MHz, $CDCl_3$) δ −73.00. HRMS (ESI): calculated for $C_{13}H_{11}F_3N_2O_4^+$: 317.0744 $[M + H]^+$, found: 317.0746.

***tert*-Butyl-2-(2-oxo-3-(2,2,2-trifluoroethoxy)quinoxalin-1(2*H*)-yl)acetate (9)**

White solid (70% yield), mp 127–128 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.66 (dd, J = 8.0, 1.4 Hz, 1H), 7.47–7.41 (m, 1H), 7.35–7.29 (m, 1H), 7.05 (dd, J = 8.3, 0.7 Hz, 1H), 4.97 (s, 2H), 4.90 (q, J = 8.3 Hz, 2H), 1.46 (s, 9H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 165.76, 151.84, 149.96, 131.39, 130.00, 128.21, 128.16, 124.40, 123.09 (q, J = 278.5 Hz), 113.32, 83.41, 62.93 (q, J = 37.8 Hz), 44.54, 27.96. ^{19}F NMR (471 MHz, $CDCl_3$) δ −73.01. HRMS (ESI): calculated for $C_{16}H_{17}F_3N_2O_4^+$: 359.1213 $[M + H]^+$, found: 359.1216.

1-Benzyl-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (10)

White solid (80% yield), mp 126–127 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.65 (d, J = 7.8 Hz, 1H), 7.31 (ddd, J = 22.1, 13.2, 5.1 Hz, 8H), 5.52 (s, 2H), 4.92 (q, J = 8.2 Hz, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.11, 150.45, 134.91, 131.44, 130.22, 128.98, 128.15, 128.00, 127.87, 127.03, 124.27, 122.05 (q, J = 278.5 Hz), 114.67, 62.98 (q, J = 37.8 Hz), 46.42. ^{19}F NMR (471 MHz, $CDCl_3$) δ −72.94. HRMS (ESI): calculated for $C_{17}H_{13}F_3N_2O_2^+$: 335.1002 $[M + H]^+$, found: 335.1008.

1-(2-Fluorobenzyl)-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (11)

White solid (70% yield), mp 141–142 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.65 (dd, J = 7.9, 1.4 Hz, 1H), 7.40–7.35 (m, 1H), 7.31–7.28 (m, 1H), 7.26–7.23 (m, 2H), 7.15–7.07 (m, 2H), 7.05–7.00 (m, 1H), 5.58 (s, 2H), 4.93 (q, J = 8.3 Hz, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 160.30 (d, J = 245.7 Hz), 152.02, 150.62, 131.15, 130.17, 129.65 (d, J = 7.6 Hz), 128.72 (d, J = 3.8 Hz), 128.36, 128.03, 124.76 (d, J = 3.8 Hz), 124.43, 123.15 (q, J = 278.5 Hz), 122.00 (d, J = 13.8 Hz), 115.59 (d, J = 21.4 Hz), 114.26 (d, J = 2.5 Hz), 63.00 (q, J = 37.8 Hz), 39.83 (d, J = 5.0 Hz). ^{19}F NMR (471 MHz, $CDCl_3$) δ −72.95, −118.26. HRMS (ESI): calculated for $C_{17}H_{12}F_4N_2O_2^+$: 353.0908 $[M + H]^+$, found: 353.0905.

1-(2-Chlorobenzyl)-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (12)

White solid (69% yield), mp 150–151 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.67 (dd, J = 7.8, 1.6 Hz, 1H), 7.45 (dd, J = 8.0, 0.9 Hz, 1H), 7.36–7.32 (m, 1H), 7.30 (td, J = 7.6, 1.3 Hz, 1H), 7.22 (td, J = 7.9, 1.2 Hz, 1H), 7.13–7.08 (m, 1H), 7.04 (dd, J = 8.2, 1.1 Hz, 1H), 6.81 (d, J = 7.7 Hz, 1H), 5.61 (s, 2H), 4.94 (q, J = 8.3 Hz, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.02, 150.47, 132.63, 131.92, 131.15, 130.18, 129.82, 128.99, 128.39, 128.00, 127.39, 127.00, 124.49, 123.12 (q, J = 278.5 Hz), 114.58, 63.02 (q, J = 37.8 Hz), 44.00. ^{19}F NMR (471 MHz, $CDCl_3$) δ −72.92. HRMS (ESI): calculated for $C_{17}H_{12}ClF_3N_2O_2^+$: 369.0612 $[M + H]^+$, found: 369.0615.

1-(3-Methylbenzyl)-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (13)

White solid (78% yield), mp 127–128 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.65 (dd, J = 7.9, 1.4 Hz, 1H), 7.37–7.33 (m, 1H), 7.30–7.26 (m, 2H), 7.23–7.18 (m, 1H), 7.07 (d, J = 5.6 Hz, 3H), 5.49 (s, 2H), 4.93 (q, J = 8.3 Hz, 2H), 2.30 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.13, 150.47, 138.82, 134.83, 131.51, 130.22, 128.81, 128.65, 128.14, 127.95, 127.60, 124.22, 124.06, 123.15 (q, J = 278.5 Hz), 114.73, 62.98 (q, J = 37.8 Hz), 46.47, 21.41. ^{19}F NMR (471 MHz, $CDCl_3$) δ −72.94. HRMS (ESI): calculated for $C_{18}H_{15}F_3N_2O_2^+$: 349.1159 $[M + H]^+$, found: 349.1155.

1-(3-Chlorobenzyl)-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (14)

White solid (72% yield), mp 149–150 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.67 (dd, J = 7.9, 1.4 Hz, 1H), 7.40–7.35 (m, 1H), 7.31 (td, J = 7.8, 1.2 Hz, 1H), 7.26 (d, J = 4.7 Hz, 3H), 7.19 (dd, J = 8.3, 0.8 Hz, 1H), 7.17–7.10 (m, 1H), 5.49 (s, 2H), 4.93 (q, J = 8.3 Hz, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.03, 150.38, 136.92, 134.96, 131.23, 130.28, 130.23, 128.28, 128.20, 128.15, 127.11, 125.19, 124.47, 123.11 (q, J = 278.5 Hz), 114.38, 63.04 (q, J = 37.8 Hz), 45.91. ^{19}F NMR (471 MHz, $CDCl_3$) δ −72.94. HRMS (ESI): calculated for $C_{17}H_{12}ClF_3N_2O_2^+$: 369.0612 $[M + H]^+$, found: 369.0615.

1-(3-Bromobenzyl)-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (15)

White solid (75% yield), mp 154–155 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.67 (dd, J = 7.9, 1.5 Hz, 1H), 7.44–7.35 (m, 3H), 7.33–7.28 (m, 1H), 7.22–7.17 (m, 3H), 5.48 (s, 2H), 4.93 (q, J = 8.3 Hz, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.02, 150.37, 137.19, 131.22, 131.15, 130.54, 130.22, 129.98, 128.30, 128.15, 125.66, 124.48, 123.11 (q, J = 278.5 Hz), 123.10, 114.37, 63.04 (q, J = 37.8 Hz), 45.84. ^{19}F NMR (471 MHz, $CDCl_3$) δ −72.94. HRMS (ESI): calculated for $C_{17}H_{12}BrF_3N_2O_2^+$: 413.0107 $[M + H]^+$, found: 413.0109.

1-(4-Methylbenzyl)-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (16)

White solid (83% yield), mp 171–172 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.63 (dd, J = 8.2, 1.5 Hz, 1H), 7.36–7.32 (m, 1H), 7.29–7.25 (m, 2H), 7.17 (d, J = 8.1 Hz, 2H), 7.11 (d, J = 8.0 Hz, 2H), 5.47 (s, 2H), 4.91 (q, J = 8.3 Hz, 2H), 2.30 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.11, 150.44, 137.63, 131.91, 131.45, 130.21, 129.62, 128.11, 127.95, 127.07, 124.19, 123.16 (q, J = 278.5 Hz), 114.69, 62.95 (q, J = 37.8 Hz), 46.20, 21.08. ^{19}F NMR (471 MHz, $CDCl_3$) δ −72.94. HRMS (ESI): calculated for $C_{18}H_{15}F_3N_2O_2^+$: 349.1159 $[M + H]^+$, found: 349.1157.

1-(4-Chlorobenzyl)-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (17)

White solid (77% yield), mp 184–185 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.66 (d, J = 7.9 Hz, 1H), 7.39–7.34 (m, 1H), 7.32–7.27 (m, 3H), 7.21 (dd, J = 11.8, 8.3 Hz, 3H), 5.49 (s, 2H), 4.92 (q, J = 8.2 Hz, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.05, 150.39, 133.82, 133.41, 131.22, 130.24, 129.18, 128.51, 128.22, 128.15, 124.43, 123.10 (q, J = 278.5 Hz), 114.39, 63.01 (q, J = 37.8 Hz), 45.80. ^{19}F NMR (471 MHz, $CDCl_3$) δ −72.96. HRMS (ESI): calculated for $C_{17}H_{12}ClF_3N_2O_2^+$: 369.0612 $[M + H]^+$, found: 369.0617.

1-(4-Bromobenzyl)-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (18)

White solid (80% yield), mp 197–198 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.66 (dd, J = 7.9, 1.5 Hz, 1H), 7.45 (d, J = 8.5 Hz, 2H), 7.39–7.34 (m, 1H), 7.30 (td, J = 7.7, 1.3 Hz, 1H), 7.19 (dd, J = 8.3, 1.1 Hz, 1H), 7.16 (d, J = 8.5 Hz, 2H), 5.47 (s, 2H), 4.92 (q, J = 8.3 Hz, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.04, 150.40, 133.94, 132.13, 131.20, 130.24, 128.82, 128.23, 128.15, 124.45, 121.99 (q, J = 278.5 Hz), 121.88, 114.39, 63.01 (q, J = 37.8 Hz), 45.86. ^{19}F NMR (471 MHz, $CDCl_3$) δ −72.97. HRMS (ESI): calculated for $C_{17}H_{12}BrF_3N_2O_2^+$: 413.0107 $[M + H]^+$, found: 413.0106.

1-(4-Nitrobenzyl)-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (19)

White solid (64% yield), mp 193–194 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.19 (d, J = 8.7 Hz, 2H), 7.69 (dd, J = 7.8, 1.6 Hz, 1H), 7.44 (d, J = 8.7 Hz, 2H), 7.38 (td, J = 7.9, 1.6 Hz, 1H), 7.33 (td, J = 7.6, 1.2 Hz, 1H), 7.12 (dd, J = 8.2, 1.0 Hz, 1H), 5.62 (s, 2H), 4.94 (q, J = 8.3 Hz, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 151.97, 150.35, 147.66, 142.18, 131.00, 130.27, 128.41, 128.39, 127.87, 124.76, 124.28, 123.06 (q, J = 278.5 Hz), 114.04, 63.09 (q, J = 37.8 Hz), 45.85. ^{19}F NMR (471 MHz, $CDCl_3$) δ −72.96. HRMS (ESI): calculated for $C_{17}H_{12}F_3N_3O_4^+$: 380.0853 $[M + H]^+$, found: 380.0856.

1,6-Dimethyl-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (20)

White solid (80% yield), mp 164–165 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.52 (d, J = 8.1 Hz, 1H), 7.15 (d, J = 8.2 Hz, 1H), 7.09 (s, 1H), 4.88 (q, J = 8.4 Hz, 2H), 3.73 (s, 3H), 2.50 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 151.43, 150.32, 138.62, 131.93, 127.86, 127.53, 125.37, 123.15 (q, J = 278.5 Hz), 114.03, 62.70 (q, J = 37.8 Hz), 29.53, 21.86. ^{19}F NMR (471 MHz, $CDCl_3$) δ −73.04. HRMS (ESI): calculated for $C_{12}H_{11}F_3N_2O_2^+$: 273.0846 $[M + H]^+$, found: 273.0848.

6-Methoxy-1-methyl-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (21)

White solid (82% yield), mp 169–170 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.20 (d, J = 9.1 Hz, 1H), 7.13 (d, J = 2.8 Hz, 1H), 7.08 (dd, J = 9.1, 2.9 Hz, 1H), 4.90 (q, J = 8.3 Hz, 2H), 3.88 (s, 3H), 3.72 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 156.47, 152.57, 149.75, 130.82, 126.20, 123.12 (q, J = 278.5 Hz), 116.53, 114.65, 110.27, 62.79 (q, J = 37.8 Hz), 55.75, 29.73. ^{19}F NMR (471 MHz, $CDCl_3$) δ −73.12. HRMS (ESI): calculated for $C_{12}H_{11}F_3N_2O_3^+$: 289.0795 $[M + H]^+$, found: 289.0794.

6-Chloro-1-methyl-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (22)

White solid (72% yield), mp 145–146 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.58–7.55 (m, 1H), 7.32–7.29 (m, 1H), 7.29 (s, 1H), 4.88 (q, J = 8.3 Hz, 2H), 3.71 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.05, 149.95, 133.96, 132.95, 128.86, 128.52, 124.54, 121.15 (q, J = 278.5 Hz), 113.95, 62.93 (q, J = 37.8 Hz), 29.76. ^{19}F NMR (471 MHz, $CDCl_3$) δ −73.02. HRMS (ESI): calculated for $C_{11}H_8ClF_3N_2O_2^+$: 293.0299 $[M + H]^+$, found: 293.0296.

6-Bromo-1-methyl-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (23)

White solid (75% yield), mp 151–152 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.50 (dd, J = 7.7, 1.2 Hz, 1H), 7.45–7.42 (m, 2H), 4.88 (q, J = 8.3 Hz, 2H), 3.71 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.20, 149.89, 133.15, 129.07, 128.91, 127.43, 121.15 (q, J = 278.5 Hz), 121.76, 116.90, 62.94 (q, J = 37.8 Hz), 29.76. ^{19}F NMR (471 MHz, $CDCl_3$) δ −73.02. HRMS (ESI): calculated for $C_{11}H_8BrF_3N_2O_2^+$: 336.9794 $[M + H]^+$, found: 336.9798.

6-Benzoyl-1-methyl-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (24)

White solid (58% yield), mp 167–168 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.08 (d, J = 1.9 Hz, 1H), 8.00 (dd, J = 8.7, 1.9 Hz, 1H), 7.81 (d, J = 7.7 Hz, 2H), 7.64 (t, J = 7.5 Hz, 1H), 7.53 (t, J = 7.7 Hz, 2H), 7.41 (d, J = 8.7 Hz, 1H), 4.90 (q, J = 8.3 Hz, 2H), 3.80 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 194.98, 152.62, 150.16, 137.36, 135.12, 133.39, 132.66, 130.25, 129.91, 129.61, 129.31, 128.50, 122.97 (q, J = 278.5 Hz), 114.01, 63.01 (q, J = 37.8 Hz), 29.96. ^{19}F NMR (471 MHz, $CDCl_3$) δ −72.93. HRMS (ESI): calculated for $C_{18}H_{13}F_3N_2O_3^+$: 363.0951 $[M + H]^+$, found: 363.0953.

1-Methyl-6-nitro-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (25)

Yellow solid (45% yield), mp 172–173 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.92 (d, J = 2.4 Hz, 1H), 7.61 (dd, J = 9.0, 2.4 Hz, 1H), 7.27 (d, J = 9.0 Hz, 1H), 4.90 (q, J = 8.3 Hz, 2H), 3.67 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 151.23, 149.38, 133.57, 133.29, 131.31, 130.89, 130.02, 123.15 (q, J = 278.5 Hz), 115.23, 63.33 (q, J = 37.8 Hz), 29.40. ^{19}F NMR (471 MHz, $CDCl_3$) δ −73.12. HRMS (ESI): calculated for $C_{11}H_8F_3N_3O_4^+$: 304.0540 $[M + H]^+$, found: 304.0543.

1,6,7-Trimethyl-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (26)

White solid (80% yield), mp 137–138 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.40 (s, 1H), 7.04 (s, 1H), 4.87 (q, J = 8.4 Hz, 2H), 3.70 (s, 3H), 2.39 (s, 3H), 2.33 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 151.53, 150.24, 137.59, 133.13, 129.99, 128.09, 128.01, 123.21 (q, J = 278.5 Hz), 114.47, 62.66 (q, J = 37.8 Hz), 29.53, 20.32, 19.19. ^{19}F NMR (471 MHz, $CDCl_3$) δ −73.02. HRMS (ESI):

calculated for $C_{13}H_{13}F_3N_2O_2^+$: 287.1002 [M + H]$^+$, found: 287.1004.

6,7-Dichloro-1-methyl-3-(2,2,2-trifluoroethoxy)quinoxalin-2(1*H*)-one (27)

White solid (70% yield), mp 160–161 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.74 (s, 1H), 7.38 (s, 1H), 4.87 (q, J = 8.2 Hz, 2H), 3.70 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.80, 149.63, 132.13, 131.52, 129.23, 128.71, 128.02, 122.89 (q, J = 278.5 Hz), 115.32, 63.09 (q, J = 37.8 Hz), 29.92. ^{19}F NMR (471 MHz, $CDCl_3$) δ −73.00. HRMS (ESI): calculated for $C_{11}H_7Cl_2F_3N_2O_2^+$: 326.9910 [M + H]$^+$, found: 326.9915.

3-(2,2,2-Trifluoroethoxy)quinoxalin-2(1*H*)-one (28)

Brown solid (75% yield), mp 195–196 °C. ^{1}H NMR (500 MHz, DMSO) δ 12.63 (s, 1H), 7.64–7.60 (m, 1H), 7.49–7.44 (m, 1H), 7.36–7.30 (m, 2H), 5.11 (q, J = 8.9 Hz, 2H). ^{13}C NMR (126 MHz, DMSO) δ 153.28, 150.26, 131.31, 129.74, 128.20, 126.78, 124.23 (q, J = 278.5 Hz), 123.97, 115.66, 62.71 (q, J = 37.8 Hz). ^{19}F NMR (471 MHz, $CDCl_3$) δ −72.87. HRMS (ESI): calculated for $C_{10}H_7F_3N_2O_2^+$: 245.0533 [M + H]$^+$, found: 245.0536.

3-(2,2,2-Trifluoroethoxy)-2*H*-benzo[*b*][1,4]oxazin-2-one (29)

White solid (78% yield), mp 157–158 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.56 (dd, J = 7.9, 1.5 Hz, 1H), 7.45–7.40 (m, 1H), 7.37–7.30 (m, 2H), 4.87 (q, J = 8.2 Hz, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 149.02, 148.54, 145.60, 129.02, 128.84, 127.12, 125.95, 122.73 (q, J = 278.5 Hz), 116.35, 63.40 (q, J = 37.8 Hz). ^{19}F NMR (471 MHz, $CDCl_3$) δ −73.17. HRMS (ESI): calculated for $C_{10}H_6F_3NO_3^+$: 246.0373 [M + H]$^+$, found: 246.0373.

1-Methyl-3-(2,2,3,3,3-pentafluoropropoxy)quinoxalin-2(1*H*)-one (30)

White solid (83% yield), mp 110–111 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.65 (dd, J = 8.0, 1.4 Hz, 1H), 7.49 (ddd, J = 8.7, 7.4, 1.5 Hz, 1H), 7.36–7.32 (m, 1H), 7.30 (dd, J = 8.4, 1.0 Hz, 1H), 4.97 (td, J = 12.9, 0.9 Hz, 2H), 3.74 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.07, 150.13, 132.15, 129.92, 128.21, 127.88, 124.24, 119.72–117.15 (m), 113.82, 61.73 (t, J = 27.7 Hz), 29.59. ^{19}F NMR (471 MHz, $CDCl_3$) δ −83.67, −122.90. HRMS (ESI): calculated for $C_{12}H_9F_5N_2O_2^+$: 309.2153 [M + H]$^+$, found: 309.2155.

3-(2,2,3,3,4,4,4-Heptafluorobutoxy)-1-methylquinoxalin-2(1*H*)-one (31)

White solid (79% yield), mp 135–136 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.66 (dd, J = 8.0, 1.4 Hz, 1H), 7.50–7.46 (m, 1H), 7.36–7.32 (m, 1H), 7.30 (d, J = 8.3 Hz, 1H), 5.01 (t, J = 13.5 Hz, 2H), 3.74 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.08, 150.11, 132.13, 129.90, 128.18, 127.86, 124.21, 119.72–117.15 (m), 113.80, 61.81 (t, J = 27.7 Hz), 29.57. ^{19}F NMR (471 MHz, $CDCl_3$) δ −80.74, −119.93, −127.51. HRMS (ESI): calculated for $C_{13}H_9F_7N_2O_2^+$: 359.0625 [M + H]$^+$, found: 359.0627.

1-Methyl-3-(2,2,3,3-tetrafluoropropoxy)quinoxalin-2(1*H*)-one (32)

White solid (72% yield), mp 131–132 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.59 (dd, J = 8.0, 1.3 Hz, 1H), 7.43–7.38 (m, 1H), 7.29–7.25 (m, 1H), 7.23 (d, J = 8.3 Hz, 1H), 6.08 (tt, J = 53.0, 5.0 Hz, 1H), 4.78 (t, J = 12.2 Hz, 2H), 3.67 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.11, 150.18, 132.04, 130.06, 128.13, 127.89, 124.25, 113.79, 114.59–106.74 (m), 62.85 (t, J = 27.7 Hz), 29.55. ^{19}F NMR (471 MHz, $CDCl_3$) δ −124.57, −139.29. HRMS (ESI): calculated for $C_{12}H_{10}F_4N_2O_2^+$: 291.0751 [M + H]$^+$, found: 291.0752.

1-Methyl-3-(4,4,4-trifluorobutoxy)quinoxalin-2(1*H*)-one (33)

White solid (78% yield), mp 108–109 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.55 (dd, J = 7.9, 1.4 Hz, 1H), 7.38–7.32 (m, 1H), 7.23 (td, J = 7.8, 1.2 Hz, 1H), 7.21–7.18 (m, 1H), 4.47 (t, J = 6.3 Hz, 2H), 3.65 (s, 3H), 2.32–2.23 (m, 2H), 2.09 (dt, J = 13.5, 6.3 Hz, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 153.56, 150.92, 131.64, 130.91, 127.60, 127.26, 127.02 (q, J = 275.9 Hz), 124.02, 113.65, 65.60, 30.74 (q, J = 29.0 Hz), 29.46, 21.46 (q, J = 2.5 Hz). ^{19}F NMR (471 MHz, $CDCl_3$) δ −66.31. HRMS (ESI): calculated for $C_{13}H_{13}F_3N_2O_2^+$: 287.1002 [M + H]$^+$, found: 287.1006.

3-(2,2-Difluoroethoxy)-1-methylquinoxalin-2(1*H*)-one (34)

White solid (73% yield), mp 128–129 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.58 (dd, J = 7.9, 1.4 Hz, 1H), 7.42–7.37 (m, 1H), 7.26 (td, J = 8.0, 1.2 Hz, 1H), 7.22 (dd, J = 8.4, 0.8 Hz, 1H), 6.19 (tt, J = 55.4, 4.4 Hz, 1H), 4.61 (td, J = 13.0, 4.4 Hz, 2H), 3.67 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.66, 150.49, 131.97, 130.29, 127.89, 127.82, 124.19, 113.76, 112.91 (t, J = 241.9 Hz), 65.34 (t, J = 31.5 Hz), 29.58. ^{19}F NMR (471 MHz, $CDCl_3$) δ −125.03. HRMS (ESI): calculated for $C_{11}H_{10}F_2N_2O_2^+$: 241.0783 [M + H]$^+$, found: 241.0787.

3-(2-Fluoroethoxy)-1-methylquinoxalin-2(1*H*)-one (35)

White solid (80% yield), mp 136–137 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.54 (d, J = 7.9 Hz, 1H), 7.35 (t, J = 7.8 Hz, 1H), 7.23 (t, J = 7.6 Hz, 1H), 7.20–7.17 (m, 1H), 4.83–4.80 (m, 1H), 4.74–4.71 (m, 1H), 4.70–4.67 (m, 1H), 4.66–4.61 (m, 1H), 3.65 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 153.42, 150.78, 131.72, 130.68, 127.59, 127.36, 123.97, 113.65, 80.96 (d, J = 171.4 Hz), 66.03 (d, J = 21.4 Hz), 29.48. ^{19}F NMR (471 MHz, $CDCl_3$) δ −224.30. HRMS (ESI): calculated for $C_{11}H_{11}FN_2O_2^+$: 223.0878 [M + H]$^+$, found: 223.0879.

3-(2,2-Difluoroethoxy)-1-ethylquinoxalin-2(1*H*)-one (36)

White solid (70% yield), mp 102–103 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.59 (dd, J = 8.4, 1.5 Hz, 1H), 7.45–7.34 (m, 1H), 7.25 (t, J = 7.4 Hz, 2H), 6.19 (tt, J = 55.4, 4.4 Hz, 1H), 4.61 (td, J = 13.0, 4.4 Hz, 2H), 4.29 (q, J = 7.2 Hz, 2H), 1.32 (t, J = 7.2 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.65, 149.96, 130.82, 130.63, 128.11, 127.87, 123.98, 113.62, 112.94 (t, J = 241.9 Hz), 65.32 (t, J = 31.5 Hz), 37.79, 12.36. ^{19}F NMR (471 MHz, $CDCl_3$) δ −124.95. HRMS (ESI): calculated for $C_{12}H_{12}F_2N_2O_2^+$: 255.0940 [M + H]$^+$, found: 255.0946.

1-Isopentyl-3-(2,2,3,3-tetrafluoropropoxy)quinoxalin-2(1*H*)-one (37)

White solid (75% yield), mp 119–120 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.58 (dd, J = 8.0, 1.3 Hz, 1H), 7.40 (t, J = 7.8 Hz, 1H), 7.25 (t, J = 7.6 Hz, 1H), 7.21 (d, J = 8.4 Hz, 1H), 6.10 (tt, J = 53.0, 5.0 Hz, 1H), 4.75 (t, J = 12.1 Hz, 2H), 4.22–4.17 (m, 2H), 1.71–1.69 (m, 1H), 1.59–1.54 (m, 2H), 0.97 (d, J = 6.6 Hz, 6H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.06, 149.86, 131.14, 130.43, 128.17, 128.10, 124.07, 113.75, 114.43–107.04 (m), 62.94 (t, J = 27.7 Hz), 41.45, 35.81, 26.45, 22.45. ^{19}F NMR (471 MHz, $CDCl_3$) δ −124.65, −139.38. HRMS (ESI): calculated for $C_{16}H_{18}F_4N_2O_2^+$: 347.1377 $[M + H]^+$, found: 347.1379.

1-Butyl-3-(2,2,3,3,4,4,4-heptafluorobutoxy)quinoxalin-2(1*H*)-one (38)

White solid (74% yield), mp 129–130 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.66 (dd, J = 7.9, 1.3 Hz, 1H), 7.49–7.45 (m, 1H), 7.31 (dd, J = 13.9, 7.6 Hz, 2H), 5.00 (t, J = 13.5 Hz, 2H), 4.31–4.25 (m, 2H), 1.80–1.72 (m, 2H), 1.49 (dd, J = 15.1, 7.5 Hz, 2H), 1.00 (t, J = 7.4 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 152.10, 149.84, 131.31, 130.23, 128.13, 128.10, 123.99, 119.72–117.15 (m), 113.85, 61.88 (t, J = 27.7 Hz), 42.65, 29.24, 20.23, 13.76. ^{19}F NMR (471 MHz, $CDCl_3$) δ −80.74, −119.93, −127.51. HRMS (ESI): calculated for $C_{16}H_{15}F_7N_2O_2^+$: 401.1095 $[M + H]^+$, found: 401.1098.

6-Bromo-3-(2-fluoroethoxy)-1-methylquinoxalin-2(1*H*)-one (39)

White solid (78% yield), mp 172–173 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.78 (d, J = 2.2 Hz, 1H), 7.52 (dd, J = 8.8, 2.3 Hz, 1H), 7.14 (d, J = 8.9 Hz, 1H), 4.90–4.87 (m, 1H), 4.79 (dd, J = 5.0, 3.6 Hz, 1H), 4.77–4.74 (m, 1H), 4.70 (dd, J = 5.0, 3.6 Hz, 1H), 3.71 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.16, 150.49, 131.80, 130.93, 130.14, 130.00, 116.64, 115.05, 80.87 (d, J = 171.4 Hz), 66.38 (d, J = 21.4 Hz), 29.71. ^{19}F NMR (471 MHz, $CDCl_3$) δ −224.13. HRMS (ESI): calculated for $C_{11}H_{10}BrFN_2O_2^+$: 300.9983 $[M + H]^+$, found: 300.9989.

6-Bromo-1-methyl-3-(4,4,4-trifluorobutoxy)quinoxalin-2(1*H*)-one (40)

White solid (70% yield), mp 119–120 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.78 (d, J = 2.2 Hz, 1H), 7.52 (dd, J = 8.8, 2.2 Hz, 1H), 7.13 (d, J = 8.8 Hz, 1H), 4.53 (t, J = 6.3 Hz, 2H), 3.70 (s, 3H), 2.38–2.30 (m, 2H), 2.17 (dd, J = 15.3, 6.6 Hz, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 154.24, 150.59, 132.00, 130.82, 130.11, 130.02, 126.98 (q, J = 277.2 Hz), 116.66, 115.03, 65.96, 30.72 (q, J = 29.0 Hz), 29.67, 21.44 (q, J = 3.8 Hz). ^{19}F NMR (471 MHz, $CDCl_3$) δ −66.21. HRMS (ESI): calculated for $C_{13}H_{12}BrF_3N_2O_2^+$: 365.0107 $[M + H]^+$, found: 365.0108.

1,6,7-Trimethyl-3-(2,2,3,3,3-pentafluoropropoxy)quinoxalin-2(1*H*)-one (41)

White solid (74% yield), mp 132–133 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.41 (s, 1H), 7.05 (s, 1H), 4.94 (td, J = 13.0, 0.7 Hz, 2H), 3.71 (s, 3H), 2.40 (s, 3H), 2.34 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 151.58, 150.15, 137.61, 133.10, 130.04, 128.10, 127.96, 119.72–117.15 (m), 114.47, 61.57 (t, J = 27.7 Hz), 29.50, 20.33, 19.19. ^{19}F NMR (471 MHz, $CDCl_3$) δ −83.70, −122.92. HRMS (ESI): calculated for $C_{14}H_{13}F_5N_2O_2^+$: 337.0970 $[M + H]^+$, found: 337.0972.

6,7-Dichloro-3-(4-methylpiperazin-1-yl)quinoxalin-2(1*H*)-one (45)

Yellow solid (63% yield), mp 234–235 °C. ^{1}H NMR (500 MHz, DMSO) δ 7.46 (s, 1H), 7.39 (s, 1H), 3.92 (s, 4H), 2.45–2.37 (m, 4H), 2.19 (s, 3H). ^{13}C NMR (126 MHz, DMSO) δ 151.78, 151.27, 132.56, 129.34, 125.49, 125.40, 124.63, 115.39, 54.62, 45.98, 45.68. HRMS (ESI): calculated for $C_{13}H_{14}Cl_2N_4O^+$: 313.0618 $[M + H]^+$, found: 313.0615.

3,3′-Bis(2,2,2-trifluoroethoxy)-2,2′-biquinoxaline (46)

White solid (50% yield), mp 213–214 °C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.24–8.19 (m, 1H), 7.99–7.95 (m, 1H), 7.84–7.78 (m, 1H), 7.74–7.69 (m, 1H), 4.93 (q, J = 8.3 Hz, 2H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 153.67, 142.47, 140.16, 139.50, 131.49, 129.71, 128.09, 127.19, 123.16 (q, J = 278.5 Hz), 62.62 (q, J = 37.8 Hz). ^{19}F NMR (471 MHz, $CDCl_3$) δ −72.93. HRMS (ESI): calculated for $C_{20}H_{12}F_6N_4O_2^+$: 455.0937 $[M + H]^+$, found: 455.0939.

1-(*p*-Tolyl)-1*H*-indole (49)

Yellow liquid (71% yield), ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.67 (d, J = 7.7 Hz, 1H), 7.52 (dd, J = 8.2, 0.6 Hz, 1H), 7.37 (d, J = 8.3 Hz, 2H), 7.31–7.27 (m, 3H), 7.22–7.18 (m, 1H), 7.17–7.13 (m, 1H), 6.65 (dd, J = 3.2, 0.6 Hz, 1H), 2.42 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 137.34, 136.36, 136.02, 130.19, 129.22, 128.11, 124.37, 122.24, 121.10, 120.22, 110.55, 103.23, 21.09.

Conflicts of interest

There are no conflicts to declare.

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