Supporting Information

Copper-Catalyzed Tandem Aerobic Oxidative Cyclization for the Synthesis of the 4-Cyanoalkylpyrrolo[1,2-a]quinaxalines from 1-(2-Aminophenyl)pyrroles and Cyclobutanone Oxime Esters

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General remark
Experimental Section
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The data of products
Reference
NMR spectra

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S2-S6
S6-S7
S7-S26
S26
S27-S80
General remark

$^1$H NMR, and $^{13}$C NMR spectra were recorded on Bruker 400M and Mercury 300M in CDCl$_3$ or DMSO. All $^1$H NMR and $^{13}$C NMR chemical shifts were given as δ value (ppm) with reference to tetramethylsilane (TMS) as an internal standard. All compounds were further characterized by HRMS; copies of their $^1$H NMR and $^{13}$C NMR spectra were provided. Products were purified by flash chromatography on 200–300 mesh silica gels. All melting points were determined without correction. All reagents were purchased commercially and used as received, unless otherwise noted.

Figure S1. General procedure for trapping intermediates “C” and “E” by HRMS.

A mixture of 2-(1H-pyrrol-1-yl)aniline 1a (1 equiv, 0.3 mmol), 2a (1.2 equiv, 0.36 mmol), Cu(OPiv)$_2$ (10 mol %, 0.06 mmol), NMP (1-methyl-2-pyrrolidinone) (1 mL) were stirred at 80 °C under oxygen atmosphere for 2 h. The HRMS analysis indicates that intermediates C and E were captured in this reaction process. Unfortunately, the intermediate D can’t be detected by HRMS analysis.
General procedure for the synthesis of 1b-1r and 1t-1v.\textsuperscript{[1]}

![Chemical structure](image)

Compound 1a was purchased from commercial sources and used as received. Substituted 2-\((1H\text{-}pyrrol\text{-}1\text{-}yI)\)anilines 1b-1r and 2-\((1H\text{-}pyrrol\text{-}1\text{-}yI)\)pyridin-3-amines 1t-1v were prepared in the following method. A mixture of substituted \(S_1\) (5 mmol) and \(S_2\) (5 mmol) in acetic acid (25 mL) were refluxed for 2 h with vigorous stirring. After cooling, the reaction mixture was poured into water (100 mL) and extracted with ethyl acetate three times (3×20 mL). The combined organic layers were dried with anhydrous Na\(_2\)SO\(_4\) and the solvent was removed in vacuo to afford \(S_3\). Then, the residue \(S_3\) was added to iron powder (20 mmol) and NH\(_4\)Cl (2 mmol) in water (20 mL) and refluxed for 4 h. After cooling, the reaction mixture was poured into water (100 mL) and extracted with ethyl acetate three times (3×20 mL). The combined organic layers were dried with anhydrous Na\(_2\)SO\(_4\) and the solvent was removed in vacuo to afford a residue. The residue was purified by column chromatography on silica gel using petroleum ether/EtOAc as eluent to provide the desired product 1b-1r and 1t-1v.

General procedure for the synthesis of 1s.\textsuperscript{[2]}

![Chemical structure](image)

\(S_4\) was prepared from the method of synthesizing \(S_3\). Then, a mixture of \(S_4\) (5 mmol), pyrrole (5 mmol) and NaOH (5 mmol) in DMSO (15 mL) was stirred vigorously for 2 h. Then, the reaction mixture was poured into water (60 mL) and extracted with ethyl acetate three times (3×30 mL). The combined organic layers were dried with Na\(_2\)SO\(_4\) and the solvent was removed in vacuo to afford a residue \(S_5\).

The residue \(S_5\) was added to iron powder (20 mmol) and NH\(_4\)Cl (2 mmol) in water...
(60 mL) and refluxed for 4 h. After cooling, the reaction mixture was poured into water (100 mL) and extracted with ethyl acetate three times (3×60 mL). The combined organic layers were dried with anhydrous Na₂SO₄ and the solvent was removed in vacuo to afford a residue. The residue was purified by column chromatography on silica gel to provide the desired product 1s in 62% yield.

**General procedure for the synthesis of 1w.**[^3]

![General procedure for the synthesis of 1w.](image)

Compounds 1w were prepared in the following method. A screw-cap vial containing a stirring bar, was added 2-iodoanilines S₆ (5.0 mmol), CuI (10 mol %), DMEDA (N,N'-Dimethyl-1,2-ethanediame, 20 mol %), K₃PO₄ (2.2 equiv), pyrrole S₇ (1.2 equiv), and toluene (2.0 mL). The mixture was stirred at 110 °C for 24 h under argon. The reaction mixture was diluted with ethyl acetate (50 mL) after cooling to room temperature. The mixture was filtered through a plug of silica gel and additional ethyl acetate was used to elute the silica gel. The filtrate was concentrated and the resulting residue was purified by column chromatography (silica gel, petroleum ether/ethyl acetate) to provide 2-(2,4-dimethyl-1H-pyrrol-1-yl)aniline 1w in 79% yield.

**General procedure for the synthesis of 2a-2e.**[^4]

![General procedure for the synthesis of 2a-2e.](image)

Cyclobutanone α-benzoyl oximes were obtained from the corresponding cyclobutanones, which were commercial available or produced by the reduction of
1,1-dichlorocyclobutanones synthesized from the corresponding alkenes by the reported procedure\textsuperscript{[1]}. The following experimental procedure is typical: to a 50 mL three-necked flask under argon were added alkene derivatives (5.0 mmol, 1.0 equiv), zinc-copper couple (960 mg, 15.0 mmol, 3.0 equiv), and anhydrous ether (10 mL). To this was added a solution of trichloroacetyl chloride (1.12 mL, 10.0 mmol, 2.0 equiv) and phosphorus oxychloride (0.51 mL, 5.5 mmol, 1.1 equiv) in ether (10 mL) over 1 h through an addition funnel. The suspension was stirred overnight at reflux. The resulting mixture was filtered through a pad of celite and washed with ether (20 mL). The organic solution was successively washed with water (30 mL), a saturated aqueous solution of NaHCO\textsubscript{3} (30 mL) and brine (30 mL), and dried over MgSO\textsubscript{4}. Then the solution was filtered, concentrated and used in the next step without further purification.

A mixture of 2,2-dichlorocyclobutanones (1.0 equiv) and zinc dust (4.0 equiv) in acetic acid (10 mL) was stirred at room temperature for 2 h and then heated at 80 °C for 5 h. The resulting mixture was allowed to cool to room temperature, and the solution was diluted with water (30 mL) and extracted with ether (3*20 mL). The organic phase was washed successively with a saturated solution of aqueous NaHCO\textsubscript{3} (3*30 mL), water (30 mL) and brine (30 mL), then dried over MgSO\textsubscript{4} and concentrated \textit{in vacuo}. The crude material was purified by flash chromatography with a mixture of petroleum ether and ethyl acetate to afford various cyclobutanones.

A stirred solution of cyclobutanones (1.0 equiv) in pyridine (0.5 M) was added hydroxylamine hydrochloride (2.0 equiv) at rt. After stirring for 2 h, pyridine was removed under reduced pressure. The residue was diluted with water and extracted with EtOAc. The aqueous layer was extracted with EtOAc and the combined organic extracts were washed with brine, dried over MgSO\textsubscript{4}, and evaporated under reduced pressure to give the crude material, which was used in the next step without further purification.

A mixture of cyclobutanone oxime (1.0 equiv), triethylamine (2.0 equiv) and DCM (0.5 M) in a 30 mL two-necked flask was added benzoyl chloride (1.5 equiv) at 0 °C. After 6 h, water was added to the above solution, and the mixture was diluted with
diethyl ether. The organic layer was washed with water and dried over MgSO₄. The solvent was removed under vacuum and the residue was subjected to column chromatography on SiO₂ with EtOAc–hexane as an eluent to give cyclobutanone O-benzoyl oximes.

**General procedure for the synthesis of 5.**[⁵]

![Chemical structure](image)

A mixture of 2-(1H-pyrrol-1-yl)aniline 1a (1 equiv, 0.3 mmol), 4-chlorobutyronitrile (1.2 equiv, 0.36 mmol), Cs₂CO₃ (2 equiv, 0.6 mmol), KI (2 equiv, 0.6 mmol), DMF (N,N-Dimethylformamide) (1 mL) were stirred at 95 °C under air for 4 h (TLC monitored). Upon completion of the reaction, the reaction mixture was diluted with saturated brine (10 mL) and extracted with ethyl acetate (3 ×15 mL). The combined organic phase was dried over anhydrous Na₂SO₄. The solvent was evaporated in vacuo and the crude product was purified by column chromatography, eluting with petroleum ether/ethyl acetate (10 : 1) to afford the desired product 5.

**General procedure for the synthesis of copper pivalate Cu(OPiv)₂.**[⁶]

![Chemical structure](image)

Pivalic acid (55 mmol, 5.61 g) and NaOH (50 mmol, 2 g) were dissolved in water (40 mL) with stirring for 1 h. The resulting mixture was filtered to remove unreacted pivalic acid, and the filtrate was added to an aqueous solution (40 mL) of Cu(NO₃)₂ • 3H₂O (25 mmol, 6.04 g). After stirring for 2 h, the dark green precipitate was formed, which was filtered, and washed with water (20 mL×3), and dried in a vacuum oven at 100 °C for 12 h. Yield: 6.25 g, 94% (based on Cu).

**General procedure for the synthesis of pyrrolo[1,2-a]quinoxaline derivatives.**
A mixture of 2-((1H-pyrrol-1-yl)aniline 1a (1 equiv, 0.3 mmol), 2a (1.2 equiv, 0.36 mmol), Cu(OPiv)$_2$ (10 mol %, 0.06 mmol), NMP (1-methyl-2-pyrrolidinone) (1 mL) were stirred at 80 °C under oxygen atmosphere for 8 h (TLC monitored). Upon completion of the reaction, the reaction mixture was extracted with saturated brine (10 mL) and ethyl acetate (3×15 mL). The combined organic phase was dried over anhydrous Na$_2$SO$_4$. The solvent was evaporated in vacuo and the crude product was purified by column chromatography, eluting with petroleum ether/ethyl acetate (10:1) to afford the desired product 3aa.

The X-ray data of 3aa (CCDC 1842652)

An amount of 20 mg 3aa were dissolved in tetrahydrofuran/petroleum ether (1:1) on the brown small reagent bottle (5 mL), which acted as good solvent, and a layer of ether was injected on the surface of tetrahydrofuran, and the cap is covered with a thin film, white crystals will be presented after seven days.

The data were collected at 296 K using a SuperNova (Dual) X-ray diffractometer equipped with a graphite monochromated Mo K$\alpha$ radiation source ($\lambda = 0.71073$ Å) operation at 50 kV and 0.8 mA. Using Olex2$^7$, the structure was solved with the ShelXS$^8$ structure solution program using Direct Methods and refined with the ShelXL$^9$ refinement package using Least Squares minimisation. Nonhydrogen atoms were refined with anisotropic displacement parameters during the final cycles. All hydrogen atoms were placed by geometrical considerations and were added to the structure factor calculations.
Figure S1. X-ray crystal structure of compound 3aa, thermal ellipsoids are drawn at 30% probability level

Table S1. The crystal data and structure refinement for 3aa

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The data of products

5-methyl-2-(1H-pyrrol-1-yl)aniline (1b)
Yellow solid (627.8 mg, 73% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 7.03$-$7.01$ (d, $J = 8.0$ Hz, 1 H), 6.80-6.79 (m, 2 H), 6.60-6.56 (m, 2 H), 6.32-6.31 (m, 2 H), 3.62 (br s, 2 H), 2.30 (s, 3 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 141.9, 138.6, 127.0, 125.2, 121.9, 119.2, 116.6, 109.2, 21.2$.

4-methyl-2-(1H-pyrrol-1-yl)aniline (1c)
Yellow solid (610.6 mg, 71% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 6.97$-$6.96$ (m, 2 H), 6.83-6.82 (m, 2 H), 6.71-6.69 (d, $J = 6.5$ Hz, 1 H), 6.33-6.32 (m, 2 H), 3.57 (br s, 2 H), 2.26 (s, 3 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 139.3, 129.0, 127.9, 127.5, 127.4, 121.6, 116.2, 109.2, 20.2$.

3-methyl-2-(1H-pyrrol-1-yl)aniline (1d)
Yellow solid (626.9 mg, 73% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 7.09$-$7.05$ (m, 2 H), 6.65-6.64 (m, 4 H), 6.36-6.35 (m, 2 H), 3.43 (br s, 2 H), 2.00 (s, 3 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 143.8, 136.9, 128.7, 126.7, 121.4, 119.6, 113.1, 109.3, 17.1$.

4,5-dimethyl-2-(1H-pyrrol-1-yl)aniline (1e)
Yellow solid (610.6 mg, 71% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 6.91$ (s, 1 H), 6.79-6.78 (m, 2 H), 6.58 (s, 1 H), 6.31-6.30 (m, 2 H), 3.49 (br s, 2 H), 2.20 (s, 3
H), 2.15 (s, 3 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 139.7, 137.1, 128.1, 126.7, 125.5, 122.0, 117.7, 109.3, 19.7, 18.8.$

5-(tert-butyl)-2-(1H-pyrrol-1-yl)aniline (1f)

Yellow solid (727.6 mg, 68% yield). $^1$H NMR (300 MHz, CDCl$_3$, ppm): $\delta = 7.07$-$7.04$ (d, $J = 8.8$ Hz, 1 H), 6.82-$6.78$ (m, 4 H), 6.31-$6.30$ (m, 2 H), 3.62 (br s, 2 H), 1.31 (s, 9 H); $^{13}$C NMR (75 MHz, CDCl$_3$, ppm): $\delta = 151.8, 141.4, 126.6, 125.1, 121.7, 115.6, 113.2, 109.1, 34.5, 31.2.$

4-methoxy-2-(1H-pyrrol-1-yl)aniline (1g)

Yellow solid (694.6 mg, 73% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 7.11$-$7.07$ (m, 1 H), 6.68-$6.67$ (m, 2 H), 6.39-$6.33$ (m, 4 H), 3.69 (s, 3 H), 3.56 (br s, 2 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 156.2, 144.7, 129.0, 122.0, 116.1, 108.9, 108.2, 100.9, 55.7.$

5-fluoro-2-(1H-pyrrol-1-yl)aniline (1h)

Yellow solid (589.4 mg, 68% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 7.09$-$7.05$ (m, 1 H), 6.77-$6.76$ (m, 2 H), 6.48-$6.42$ (m, 2 H), 6.33-$6.32$ (d, $J = 2.4$ Hz, 2 H), 3.77 (br s, 2 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 164.0$-$161.5$ (d, $J = 243.1$ Hz, 1 C), 144.0-$143.9$ (d, $J = 11.7$ Hz, 1 C), 128.6-$128.5$ (d, $J = 10.7$ Hz, 1 C), 123.6, 121.9, 109.6, 104.9-$104.7$ (d, $J = 22.9$ Hz, 1 C), 102.5-$102.3$ (d, $J = 25.9$ Hz, 1 C).

4-fluoro-2-(1H-pyrrol-1-yl)aniline (1i)
Yellow solid (589.6 mg, 67% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 6.91-6.87$ (m, 2 H), 6.83-6.82 (d, $J = 2.0$ Hz, 2 H), 6.74-6.70 (m, 1 H), 6.35-6.34 (m, 2 H), 3.59 (br s, 2 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 155.7-154.5$ (d, $J = 236.3$ Hz, 1 C), 138.1-138.1 (d, $J = 2.4$ Hz, 1 C), 127.7-127.6 (d, $J = 9.8$ Hz, 1 C), 121.6, 116.7-116.7 (d, $J = 8.2$ Hz, 1 C), 115.3-115.0 (d, $J = 21.9$ Hz, 1 C), 114.1-113.8 (d, $J = 23.6$ Hz, 1 C), 109.8.

**4,5-difluoro-2-(1H-pyrrol-1-yl)aniline (1j)**

Yellow solid (611.1 mg, 63% yield). $^1$H NMR (300 MHz, CDCl$_3$, ppm): $\delta = 7.03-6.99$ (m, 1 H), 6.77 (s, 2 H), 6.61-6.55 (m, 1 H), 6.34 (s, 2 H), 3.64 (br s, 2 H); $^{13}$C NMR (75 MHz, CDCl$_3$, ppm): $\delta = 151.9-148.7$ (d, $J = 170.1$ Hz, 1 C), 144.3-141.1 (d, $J = 238.1$ Hz, 1 C), 139.2-139.0 (d, $J = 9.0$ Hz, 1 C), 122.4-122.3 (d, $J = 4.0$ Hz, 1 C), 121.6, 116.0-115.8 (d, $J = 18.9$ Hz, 1 C), 109.8, 104.1-103.8 (d, $J = 21.1$ Hz, 1 C).

**5-chloro-2-(1H-pyrrol-1-yl)aniline (1k)**

Yellow solid (720.0 mg, 75% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 7.06-7.04$ (d, $J = 8.4$ Hz, 1 H), 6.79-7.77 (m, 3 H), 6.75-6.72 (m, 1 H), 6.34-6.33 (m, 2 H), 3.77 (br s, 2 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 143.2, 134.0, 128.2, 125.9, 121.6, 118.2, 115.6, 109.8.$

**4-chloro-2-(1H-pyrrol-1-yl)aniline (II)**

Yellow solid (729.6 mg, 76% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 7.14-7.09$ (m, 2 H), 6.81-6.80 (m, 2 H), 6.71-6.69 (d, $J = 8.4$ Hz, 1 H), 6.34-6.33 (m, 2 H), 3.72 (br s, 2 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 140.7, 128.4, 128.0, 127.0, 122.6, 121.5, 116.9, 109.9.$
2-chloro-6-(1H-pyrrol-1-yl)aniline (1m)

Yellow solid (723.6 mg, 74% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 7.29$-$7.25$ (m, 1 H), 7.08-7.06 (m, 1 H), 6.83-6.82 (m, 2 H), 6.73-6.69 (m, 1 H), 6.36-6.35 (m, 2 H), 4.12 (br s, 2 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 139.4, 128.5, 127.9, 125.5, 121.5, 119.6, 117.5, 109.7$.

4,5-dichloro-2-(1H-pyrrol-1-yl)aniline (1n)

Yellow solid (757.1 mg, 67% yield). $^1$H NMR (300 MHz, CDCl$_3$, ppm): $\delta = 7.22$ (s, 1 H), 6.88 (s, 1 H), 6.79-6.77 (m, 2 H), 6.35-6.33 (m, 2 H), 3.79 (br s, 2 H); $^{13}$C NMR (75 MHz, CDCl$_3$, ppm): $\delta = 141.8, 132.2, 128.6, 126.9, 121.7, 120.8, 117.1, 110.4$.

5-bromo-2-(1H-pyrrol-1-yl)aniline (1o)

Yellow solid (810.8 mg, 69% yield). $^1$H NMR (300 MHz, CDCl$_3$, ppm): $\delta = 7.00$-$6.97$ (m, 1 H), 6.94-6.93 (m, 1 H), 6.90-6.86 (m, 1 H), 6.80-6.78 (m, 2 H), 6.34-6.33 (m, 2 H), 3.77 (br s, 2 H); $^{13}$C NMR (75 MHz, CDCl$_3$, ppm): $\delta = 143.6, 128.6, 126.6, 122.1, 121.8, 121.4, 118.7, 110.0$.

4-chloro-5-methyl-2-(1H-pyrrol-1-yl)aniline (1p)

Yellow solid (729.6 mg, 76% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 7.10$ (s, 1 H), 6.75-6.74 (m, 2 H), 6.57 (s, 1 H), 6.31-6.28 (m, 2 H), 3.55 (br s, 2 H), 2.28 (s, 3 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 140.3, 136.0, 128.4, 128.3, 127.0, 121.5, 121.4$.  

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3-bromo-5-methyl-2-(1H-pyrrol-1-yl)aniline (1q)
Yellow solid (729.6 mg, 76% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 6.77$ (s, 1 H), 6.75 (s, 1 H), 6.60-6.58 (m, 2 H), 6.35-6.33 (m, 2 H), 3.56 (br s, 2 H), 1.94 (s, 3 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 145.0, 138.7, 125.4, 122.1, 122.0, 121.2, 115.6, 109.6, 17.0$.

2-(1H-pyrrol-1-yl)-5-(trifluoromethyl)aniline (1r)
Yellow solid (723.2 mg, 64% yield). $^1$H NMR (300 MHz, CDCl$_3$, ppm): $\delta = 7.25$-7.21 (d, $J = 10.2$ Hz, 1 H), 7.03-7.01 (m, 2 H), 6.85-6.83 (m, 2 H), 6.38-6.36 (m, 2 H), 3.93 (br s, 2 H); $^{13}$C NMR (75 MHz, CDCl$_3$, ppm): $\delta = 142.4, 131.4-130.1$ (q, $J = 32.2$ Hz, 1 C), 130.0, 127.6, 126.0-122.3 (d, $J = 270.6$ Hz, 1 C), 121.6, 115.2-115.1 (q, $J = 3.7$ Hz, 1 C), 113.0-112.9 (q, $J = 3.7$ Hz, 1 C), 110.3.

2,4-di(1H-pyrrol-1-yl)aniline (1s)
Yellow solid (691.3 mg, 62% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 7.22$-7.19 (m, 2 H), 6.98-6.97 (m, 2 H), 6.87-6.86 (m, 2 H), 6.85-6.82 (d, $J = 9.2$ Hz, 1 H), 6.37-6.36 (m, 2 H), 6.31-6.30 (m, 2 H), 3.74 (br s, 2 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 140.0, 132.7, 127.7, 121.6, 121.2, 120.0, 119.6, 116.7, 109.9, 109.8$.

2-(1H-pyrrol-1-yl)pyridin-3-amine (1t)
Yellow solid (667.8 mg, 81% yield). $^1$H NMR (300 MHz, CDCl$_3$, ppm): $\delta = 7.92$-7.90
(m, 1H), 7.15-7.14 (m, 2 H), 7.10-7.06 (m, 2 H), 6.36-6.35 (m, 2 H), 3.87 (br s, 2 H); $^{13}$C NMR (75 MHz, CDCl$_3$, ppm): $\delta =$ 139.8, 138.6, 136.1, 124.4, 123.1, 120.4, 110.2.

5-methyl-2-((1H-pyrrol-1-yl)pyridin-3-amine (1u)

Yellow solid (667.8 mg, 81% yield). $^{1}$H NMR (300 MHz, CDCl$_3$, ppm): $\delta =$ 7.71 (s, 1H), 7.08-7.07 (m, 2 H), 6.87 (s, 1 H), 6.33-6.32 (m, 2 H), 3.81 (br s, 2 H), 2.25 (s, 3H); $^{13}$C NMR (75 MHz, CDCl$_3$, ppm): $\delta =$ 138.7, 137.7, 135.8, 133.1, 124.9, 120.4, 109.8, 18.0.

6-chloro-2-((1H-pyrrol-1-yl)pyridin-3-amine (1v)

Yellow solid (667.8 mg, 81% yield). $^{1}$H NMR (300 MHz, CDCl$_3$, ppm): $\delta =$ 7.11-7.10 (m, 2H), 7.02-7.03 (m, 2 H), 6.33-6.32 (m, 2 H), 3.89 (br s, 2 H); $^{13}$C NMR (75 MHz, CDCl$_3$, ppm): $\delta =$ 138.4, 137.9, 134.9, 127.4, 123.1, 120.2, 110.5.

2-(2,4-dimethyl-1H-pyrrol-1-yl)aniline (1w)

Yellow solid (734.7 mg, 79% yield). $^{1}$H NMR (400 MHz, CDCl$_3$, ppm): $\delta =$ 7.19-7.13 (m, 1H), 7.08-7.05 (m, 1 H), 6.77-6.72 (m, 2 H), 6.37 (s, 1 H), 5.88 (s, 1 H), 3.53 (br s, 2 H), 2.10 (d, $J = 0.4$ Hz, 3 H), 1.99 (d, $J = 0.8$ Hz, 3 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta =$ 143.8, 129.8, 129.0, 128.7, 126.3, 119.0, 118.6, 118.1, 115.7, 108.9, 12.0, 11.9.

cyclobutanone O-benzoyl oxime (2a)

White solid (586 mg, 62% yield). $^{1}$H NMR (300 MHz, CDCl$_3$, ppm): $\delta =$ 8.06-8.02
(m, 2 H), 7.60-7.54 (m, 1 H), 7.47-7.42 (m, 2 H), 3.15-3.08 (m, 4 H), 2.14-2.03 (m, 2 H); $^{13}$C NMR (75 MHz, CDCl$_3$, ppm): $\delta = 169.0, 163.6, 132.8, 129.1, 128.5, 128.1, 31.4, 13.9$.

![Cyclobutanone O-acetyl oxime (2a-1)](image)

cyclobutanone O-acetyl oxime (2a-1)

White solid (464 mg, 73% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 3.08$-3.00 (m, 4 H), 2.14 (s, 3 H), 2.11-2.03 (m, 2 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 168.4, 31.9, 31.7, 19.5, 14.3$.

![Cyclobutanone O-(4-(trifluoromethyl)benzoyl) oxime (2a-2)](image)

cyclobutanone O-(4-(trifluoromethyl)benzoyl) oxime (2a-2)

White solid (886 mg, 69% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 8.17$-8.15 (d, $J = 8.4$ Hz, 2 H), 7.74-7.72 (d, $J = 8.4$ Hz, 2 H), 3.18-3.14 (m, 1 H), 2.19-2.11 (m, 2 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 170.0, 162.8, 135.0$-134.1 (q, $J = 32$ Hz, 1 C), 132.2, 129.9, 125.5-12.4 (d, $J = 4$ Hz, 1 C), 124.8-122.0 (d, $J = 271$ Hz, 1 C), 31.8, 14.2.

![Cyclobutanone O-(3-nitrobenzoyl) oxime (2a-3)](image)

cyclobutanone O-(3-nitrobenzoyl) oxime (2a-3)

White solid (702 mg, 60% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 8.85$-8.84 (m, 1 H), 8.47-8.44 (m, 1H), 8.40-8.38 (d, $J = 8.0$ Hz, 2 H), 7.73-7.69 (m, 1 H), 3.23-3.16 (m, 2 H), 2.21-2.13 (m, 2 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 170.4, 161.9, 148.1, 135.2, 130.7, 129.8, 127.6, 124.3, 31.8, 14.1$.  

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cyclobutanone *O-(4-methoxybenzoyl) oxime (2a-4)*

White solid (646 mg, 59% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta =$ 8.02-7.98 (m, 2 H), 6.95-6.91 (m, 2 H), 3.86 (s, 3 H), 3.15-3.10 (m, 4 H), 2.15-2.07 (m, 2 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta =$ 168.9, 163.9, 163.6, 131.7, 121.3, 113.8, 55.5, 31.9, 14.4.

3-benzylcyclobutanone *O-benzoyl oxime (2b)*

White solid (804 mg, 58% yield). $^1$H NMR (300 MHz, CDCl$_3$, ppm): $\delta =$ 8.05-8.02 (m, 2 H), 7.60-7.56 (m, 1 H), 7.47-7.42 (m, 2 H), 7.34-7.30 (m, 2 H), 7.26-7.17 (m, 3 H), 3.25-3.19 (m, 2 H), 2.92-2.74 (m, 5 H); $^{13}$C NMR (75 MHz, CDCl$_3$, ppm): $\delta =$ 166.8, 163.9, 139.2, 133.2, 129.5, 128.8, 128.5, 128.4, 128.3, 126.4, 41.6, 37.1, 29.3.

3-(4-methoxybenzyl)cyclobutanone *O-benzoyl oxime (2c)*

White solid (957 mg, 62% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta =$ 8.03-8.01 (m, 2 H), 7.57-7.53 (m, 1 H), 7.45-7.40 (m, 2 H), 7.09-7.07 (d, $J = 8.6$ Hz, 2 H), 6.85-6.83 (d, $J = 8.6$ Hz, 2 H), 3.77 (s, 3 H), 3.23-3.13 (m, 2 H), 2.84-2.67 (m, 5 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta =$ 167.0, 164.0, 158.2, 133.3, 131.3, 129.6, 129.5, 129.0, 128.5, 114.0, 55.3, 40.8, 37.1, 29.5.
3-(naphthalen-2-ylmethyl)cyclobutanone O-benzoyl oxime (2d)
White solid (674 mg, 41% yield). $^1$H NMR (400 MHz, CDCl₃, ppm): $\delta = 8.03$-$7.99$ (m, 3 H), 7.87-$7.85$ (d, $J = 7.8$ Hz, 1 H), 7.76-$7.74$ (d, $J = 8.2$ Hz, 1 H), 7.57-$7.49$ (m, 3 H), 7.44-$7.39$ (m, 3 H), 7.28-$7.23$ (m, 1 H), 3.37-$3.19$ (m, 4 H), 2.99-$2.83$ (m, 3 H); $^{13}$C NMR (100 MHz, CDCl₃, ppm): $\delta = 166.9$, 164.1, 135.2, 134.0, 133.3, 131.8, 129.7, 129.0, 128.9, 128.5, 127.4, 126.2, 125.8, 125.5, 123.4, 38.8, 37.6, 37.5, 28.5.

3-phenylcyclobutanone O-benzoyl oxime (2e)
White solid (779 mg, 59% yield). $^1$H NMR (400 MHz, CDCl₃, ppm): $\delta = 8.08$-$8.05$ (m, 2 H), 7.61-$7.56$ (m, 1 H), 7.48-$7.43$ (m, 2 H), 7.39-$7.34$ (m, 2 H), 7.30-$7.26$ (m, 3 H), 3.73-$3.51$ (m, 3 H), 3.29-$3.18$ (m, 2 H); $^{13}$C NMR (100 MHz, CDCl₃, ppm): $\delta = 165.9$, 163.8, 142.8, 133.2, 129.5, 128.6, 128.4, 126.7, 126.2, 39.4, 39.3, 32.3.

4-((2-(1H-pyrrol-1-yl)phenyl)amino)butanenitrile (5)
Yellow solid (734.7 mg, 79% yield). $^1$H NMR (400 MHz, CDCl₃, ppm): $\delta = 7.27$-$7.23$ (m, 1H), 7.14-$7.12$ (m, 1 H), 6.77-$6.72$ (m, 4 H), 6.34-$6.33$ (m, 2 H), 3.76 (s, 1 H), 3.26-$3.24$ (m, 2 H), 2.38-$2.34$ (m, 2 H), 1.91-$1.85$ (m, 2 H); $^{13}$C NMR (100 MHz, CDCl₃, ppm): $\delta = 143.1$, 129.0, 127.5, 127.2, 121.8, 119.0, 117.1, 111.0, 109.6, 41.9, 25.1, 14.6.
3-(pyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3aa)

Light yellow solid (53.0 mg, 80% yield), melting point: 118-120 °C. \(^1\)H NMR (400 MHz, CDCl\(_3\), ppm): \(\delta = 7.93-7.90\) (m, 2 H), 7.84-7.82 (m, 1 H), 7.53-7.48 (m, 1 H), 7.46-7.42 (m, 1 H), 6.89-6.86 (m, 2 H), 3.39-3.35 (m, 2 H), 3.08-3.04 (m, 2 H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\), ppm): \(\delta = 151.7, 135.5, 129.8, 127.6, 127.3, 125.3, 125.2, 119.7, 114.7, 113.8, 113.7, 105.7, 29.9, 14.1\); HRMS calcd for C\(_{14}\)H\(_{12}\)N\(_3\) [M+H]\(^+\) 222.1026; found: 222.1029.

3-(7-methylpyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3ba)

Light yellow solid (39.5 mg, 56% yield), melting point: 120-123 °C. \(^1\)H NMR (400 MHz, CDCl\(_3\), ppm): \(\delta = 7.84\) (s, 1 H), 7.69-7.66 (m, 2 H), 7.29-7.25 (m, 1 H), 6.81 (s, 2 H), 3.34-3.30 (m, 2 H), 3.04-3.00 (m, 2 H), 2.47 (s, 3 H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\), ppm): \(\delta = 151.5, 135.3, 135.0, 129.4, 128.6, 125.1, 125.0, 119.8, 114.4, 113.4, 113.3, 105.3, 29.8, 21.0, 14.0\); HRMS calcd for C\(_{15}\)H\(_{14}\)N\(_3\) [M+H]\(^+\) 236.1182; found: 236.1188.

3-(8-methylpyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3ca)

Light yellow solid (40.2 mg, 57% yield), melting point: 150-153 °C. \(^1\)H NMR (400 MHz, CDCl\(_3\), ppm): \(\delta = 7.89-7.88\) (m, 1 H), 7.79-7.77 (d, \(J = 8.4\) Hz, 1 H), 7.62 (s, 1 H), 7.24-7.23 (d, \(J = 1.6\) Hz, 1 H), 6.85-6.84 (d, \(J = 2.0\) Hz, 2 H), 3.37-3.33 (m, 2 H), 3.06-3.03 (m, 2 H), 2.54 (s, 3 H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\), ppm): \(\delta = 150.7, 138.1, 133.4, 129.3, 127.0, 126.5, 125.3, 119.8, 114.3, 113.7, 113.6, 105.3, 29.9, 21.8, 14.1\); HRMS calcd for C\(_{15}\)H\(_{14}\)N\(_3\) [M+H]\(^+\) 236.1182; found: 236.1176.
3-(9-methylpyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3da)
Light yellow solid (52.2 mg, 74% yield), melting point: 116-118 °C. ^1H NMR (400 MHz, CDCl₃, ppm): δ = 8.27-8.26 (m, 1 H), 7.78-7.75 (m, 1 H), 7.29-7.25 (m, 2 H), 6.87-6.85 (m, 1 H), 6.83-6.81 (m, 1 H), 3.33-3.30 (m, 2 H), 3.04-3.01 (m, 2 H), 2.89 (s, 3 H); ^13C NMR (100 MHz, CDCl₃, ppm): δ = 151.2, 137.0, 131.0, 128.1, 127.5, 126.4, 125.3, 124.6, 120.2, 119.8, 112.9, 104.9, 29.6, 23.8, 13.9; HRMS calcd for C₁₅H₁₄N₃ [M+H]^+ 236.1182; found: 236.1188.

3-(7,8-dimethylpyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3ea)
Light yellow solid (33.6 mg, 45% yield), melting point: 159-160 °C. ^1H NMR (400 MHz, CDCl₃, ppm): δ = 7.85-7.84 (m, 1 H), 7.66 (s, 1 H), 7.57 (s, 1 H), 6.83-6.82 (d, J = 2.0 Hz, 2 H), 3.36-3.32 (m, 2 H), 3.05-3.01 (m, 2 H), 2.42 (s, 3 H), 2.37 (s, 3 H); ^13C NMR (100 MHz, CDCl₃, ppm): δ = 150.7, 137.1, 134.2, 133.6, 129.7, 125.3, 125.2, 119.9, 114.2, 114.1, 113.4, 105.2, 29.9, 20.3, 19.6, 14.3; HRMS calcd for C₁₆H₁₆N₃ [M+H]^+ 250.1339; found: 250.1334.

3-(7-(tert-butyl)pyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3fa)
Light yellow solid (39.8 mg, 48% yield), melting point: 134-137 °C. ^1H NMR (400 MHz, CDCl₃, ppm): δ = 7.92-7.88 (m, 2 H), 7.77-7.74 (d, J = 8.8 Hz, 1 H), 7.57-7.54 (m, 1 H), 6.86-6.83 (m, 2 H), 3.38-3.34 (m, 2 H), 3.07-3.03 (m, 2 H), 1.41 (s, 9 H); ^13C NMR (100 MHz, CDCl₃, ppm): δ = 151.6, 148.5, 135.1, 125.9, 125.3, 125.2, 125.0, 119.7, 114.4, 113.5, 113.2, 105.4, 34.6, 31.4, 30.0, 14.3; HRMS calcd for C₁₈H₂₀N₃ [M+H]^+ 278.1652; found: 278.1659.
3-(9-methoxypyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3ga)
Light yellow solid (52.0 mg, 69% yield), melting point: 121-124 °C. \(^1\)H NMR (400 MHz, CDCl\(_3\), ppm): \(\delta = 8.70-8.69\) (m, 1 H), 7.51-7.49 (d, \(J = 8.0\) Hz, 1 H), 7.33-7.29 (m, 1 H), 7.00-6.98 (d, \(J = 8.0\) Hz, 1 H), 6.86-6.85 (m, 1 H), 6.79-6.77 (m, 1 H), 4.03 (s, 3 H), 3.33-3.30 (m, 2 H), 3.03-3.00 (m, 2 H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\), ppm): \(\delta = 151.8, 149.6, 137.5, 125.6, 124.3, 122.3, 121.5, 119.8, 118.5, 112.5, 108.9, 104.8, 56.1, 29.7, 14.0\); HRMS calcd for C\(_{15}\)H\(_{14}\)N\(_3\)O \([M+H]^+\) 252.1132; found: 252.1138.

3-(7-fluoropyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3ha)
Yellow solid (52.3 mg, 73% yield), melting point: 126-128 °C. \(^1\)H NMR (400 MHz, CDCl\(_3\), ppm): \(\delta = 7.87\) (s, 1 H), 7.86-7.74 (m, 1 H), 7.58-7.55 (m, 1 H), 7.24-7.19 (m, 1 H), 6.89-6.85 (m, 2 H), 3.37-3.33 (m, 2 H), 3.06-3.03 (m, 2 H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\), ppm): \(\delta = 161.0-158.6\) (d, \(J = 243\) Hz, 1 C), 153.0, 136.6-136.5 (d, \(J = 11\) Hz, 1 C), 125.1-119.8 (d, \(J = 528\) Hz, 1 C), 123.9, 115.4, 115.2, 115.0, 114.9, 114.8, 113.9, 106.1, 29.9, 14.0; HRMS calcd for C\(_{14}\)H\(_{11}\)FN\(_3\) \([M+H]^+\) 240.0932; found: 240.0937.

3-(8-fluoropyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3ia)
Light yellow solid (47.5 mg, 71% yield), melting point: 120-123 °C. \(^1\)H NMR (400 MHz, CDCl\(_3\), ppm): \(\delta = 7.88-7.87\) (m, 1 H), 7.78-7.75 (m, 1 H), 7.59-7.56 (m, 1 H), 7.24-7.19 (m, 1 H), 6.89-6.85 (m, 2 H), 3.37-3.34 (m, 2 H), 3.06-3.03 (m, 2 H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\), ppm): \(\delta = 160.9, 158.5, 152.9, 136.6-136.5\) (d, \(J = 11\) Hz, 1 C), 125.0-119.7 (d, \(J = 534\) Hz, 1 C), 123.9, 115.3, 115.1, 114.9, 114.8-114.7 (d, \(J = 10\) Hz, 1 C), 113.9, 106.0, 29.8, 13.9; HRMS calcd for C\(_{14}\)H\(_{11}\)FN\(_3\) \([M+H]^+\) 240.0932; found: 240.0938.
3-(7,8-difluoropyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3ja)

Light yellow solid (60.9 mg, 79% yield), melting point: 145-146 °C. \[^1\]H NMR (400 MHz, DMSO-\(d_6\), ppm): \(\delta = 8.42-8.37\) (m, 1 H), 8.35-8.34 (d, \(J = 1.6\) Hz, 1 H), 7.79-7.74 (m, 1 H), 7.10-7.09 (m, 1 H), 6.91-6.90 (m, 1 H), 3.32-3.29 (m, 2 H), 3.03-3.00 (m, 2 H); \(^{13}\)C NMR (100 MHz, DMSO-\(d_6\), ppm): \(\delta = 153.5, 149.8-148.2\) (dd, \(J = 154\) Hz, 15 Hz, 1 C), 147.4-145.7 (dd, \(J = 150\) Hz, 14 Hz, 1 C), 131.7-123.7 (dd, \(J = 801\) Hz, 10 Hz, 1 C), 124.3, 120.6, 117.1, 116.4-116.2 (dd, \(J = 18\) Hz, 1 C), 114.3, 107.3, 104.0, 103.7, 29.2, 13.5; HRMS calcd for C\(_{14}\)H\(_{10}\)F\(_2\)N\(_3\) [M+H]\(^+\) 258.0838; found: 258.0830.

3-(7-chloropyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3ka)

Light yellow solid (48.2 mg, 63% yield), melting point: 147-150 °C. \[^1\]H NMR (400 MHz, CDCl\(_3\), ppm): \(\delta = 7.91-7.90\) (d, \(J = 2.4\) Hz, 1 H), 7.90-7.89 (m, 1 H), 7.77-7.74 (d, \(J = 8.8\) Hz, 1 H), 7.47-7.44 (m, 1 H), 6.91-6.87 (m, 2 H), 3.39-3.35 (m, 2 H), 3.07-3.03 (m, 2 H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\), ppm): \(\delta = 152.9, 136.3, 130.4, 129.2, 127.6, 125.9, 125.2, 119.7, 115.0, 114.8, 114.2, 106.3, 29.8, 13.9; HRMS calcd for C\(_{14}\)H\(_{11}\)ClN\(_3\) [M+H]\(^+\) 256.0636; found: 256.0630.

3-(8-chloropyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3la)

Light yellow solid (53.6 mg, 70% yield), melting point: 200-203 °C. \[^1\]H NMR (400 MHz, CDCl\(_3\), ppm): \(\delta = 7.82-7.78\) (m, 3 H), 7.37-7.34 (m, 1 H), 6.88 (s, 2 H), 3.37-3.33 (m, 2 H), 3.06-3.02 (m, 2 H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\), ppm): \(\delta = 151.8, 133.9, 132.9, 130.8, 127.8, 125.6, 125.1, 119.7, 114.9, 114.3, 113.8, 106.1, 29.8, 13.9; HRMS calcd for C\(_{14}\)H\(_{11}\)ClN\(_3\) [M+H]\(^+\) 256.0636; found: 256.0643.
3-(6-chloropyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3ma)
Light yellow solid (36.0 mg, 47% yield), melting point: 138-140 °C. ¹H NMR (400 MHz, CDCl₃, ppm): δ = 7.89-7.88 (m, 1 H), 7.71-7.69 (m, 1 H), 7.50-7.48 (m, 1 H), 7.38-7.34 (m, 1 H), 6.90-6.87 (m, 2 H), 3.40-3.36 (m, 2 H), 3.13-3.10 (m, 2 H); ¹³C NMR (100 MHz, CDCl₃, ppm): δ = 152.1, 134.2, 132.3, 128.3, 127.2, 125.9, 119.8, 115.3, 114.4, 112.4, 106.2, 29.9, 13.8; HRMS calcd for C₁₄H₁₁ClN₃ [M+H]⁺ 256.0636; found: 256.0642.

3-(7,8-dichloropyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3na)
Light yellow solid (58.9 mg, 68% yield), melting point: 141-143 °C. ¹H NMR (400 MHz, DMSO-d₆, ppm): δ = 8.60 (s, 1 H), 8.48-8.47 (d, J = 2.0 Hz, 1 H), 7.94 (s, 1 H), 7.15-7.14 (d, J = 3.6 Hz, 1 H), 6.94-6.92 (m, 1 H), 3.35-3.31 (m, 2 H), 3.05-3.01 (m, 2 H); ¹³C NMR (100 MHz, DMSO-d₆, ppm): δ = 154.7, 134.6, 129.7, 129.6, 127.3, 126.6, 124.6, 120.6, 117.6, 116.8, 114.6, 108.0, 29.2, 13.5; HRMS calcd for C₁₄H₁₀Cl₂N₃ [M+H]⁺ 290.0247; found: 290.0240.

3-(7-bromopyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3oa)
Light yellow solid (48.4 mg, 54% yield), melting point: 156-158 °C. ¹H NMR (400 MHz, CDCl₃, ppm): δ = 8.04-8.03 (d, J = 1.6 Hz, 1 H), 7.86 (s, 1 H), 7.66-7.64 (d, J = 8.8 Hz, 1 H), 7.56-7.53 (m, 1 H), 6.89-6.86 (m, 2 H), 3.37-3.33 (m, 2 H), 3.05-3.02 (m, 2 H); ¹³C NMR (100 MHz, CDCl₃, ppm): δ = 152.8, 136.5, 132.1, 130.2, 126.2, 125.1, 119.7, 117.7, 114.9, 114.2, 106.3, 29.7, 13.8; HRMS calcd for C₁₄H₁₁BrN₃ [M+H]⁺ 300.0131; found: 300.0138.
3-(8-chloro-7-methylpyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3pa)
Light yellow solid (46.0 mg, 57% yield), melting point: 176-178 °C. $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 7.80$-7.79 (m, 1 H), 7.80 (s, 1 H), 7.74 (s, 1 H), 6.86-6.83 (m, 2 H), 3.36-3.32 (m, 2 H), 3.05-3.01 (m, 2 H), 2.47 (s, 3 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 151.8, 134.0, 133.3, 133.2, 131.1, 125.9, 125.0, 119.7, 114.7, 114.0, 113.9, 105.9, 29.8, 19.8, 13.9$; HRMS calcd for C$_{15}$H$_{13}$ClN$_3$ [M+H]$^+$ 270.0793; found: 270.0798.

3-(9-bromo-7-methylpyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3qa)
Light yellow solid (59.2 mg, 63% yield), melting point: 141-144 °C. $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 8.26$-8.25 (m, 1 H), 7.95-7.94 (d, $J = 2.4$ Hz, 1 H), 7.41-7.40 (d, $J = 2.0$ Hz, 1 H), 6.93-6.92 (m, 1 H), 6.88-6.86 (m, 1 H), 3.36-3.34 (m, 2 H), 3.06-3.02 (m, 2 H), 2.88 (s, 3 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 152.3, 138.2, 133.3, 130.5, 127.3, 126.7, 126.5, 120.5, 119.8, 117.1, 113.6, 105.7, 29.6, 23.7, 13.9$; HRMS calcd for C$_{15}$H$_{13}$BrN$_3$ [M+H]$^+$ 314.0288; found: 314.0284.

3-(7-(trifluoromethyl)pyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3ra)
Light yellow solid (64.2 mg, 74% yield), melting point: 162-165 °C. $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 8.21$-8.20 (d, $J = 1.2$ Hz, 1 H), 7.97-7.96 (m, 1 H), 7.92-7.90 (d, $J = 8.4$ Hz, 1 H), 7.73-7.71 (m, 1 H), 7.00-6.92 (m, 2 H), 3.41-3.37 (m, 2 H), 3.10-3.06 (m, 2 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 153.2, 135.1, 129.4, 127.5$-127.2 (q, $J = 18$ Hz, 1 C), 125.4, 125.2-122.5 (d, $J = 270$ Hz, 1 H), 124.0-123.9 (d, $J = 3.0$ Hz, 1 H), 119.6, 115.4, 114.7, 114.4, 106.8, 29.8, 13.8; HRMS calcd for C$_{15}$H$_{11}$F$_3$N$_3$ [M+H]$^+$ 290.0900; found: 290.0908.
3-(8-(1H-pyrrol-1-yl)pyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3sa)
Light yellow solid (68.6 mg, 80% yield), melting point: 170-173 °C. $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 7.97-7.95$ (d, $J = 8.7$ Hz, 1 H), 7.93-7.92 (m, 1 H), 7.79-7.78 (d, $J = 8.7$ Hz, 1 H), 7.50-7.47 (m, 1 H), 7.22-7.21 (m, 2 H), 6.92-6.91 (d, $J = 1.8$ Hz, 2 H), 6.44-6.43 (m, 2 H), 3.41-3.37 (m, 2 H), 3.10-3.06 (m, 2 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 151.2, 139.7, 133.2, 131.1, 128.0, 125.4, 119.8, 119.6, 117.8, 114.8, 114.3, 111.3, 106.1, 105.1, 29.9, 14.1$; HRMS calcld for C$_{18}$H$_{15}$N$_4$ [M+H]$^+$ 287.1291; found: 287.1298.

3-(pyrido[3,2-e]pyrrolo[1,2-a]pyrazin-6-yl)propanenitrile (3ta)
Light yellow solid (36.0 mg, 54% yield), melting point: 143-145 °C. $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 8.52-8.50$ (m, 1 H), 8.37-8.36 (m, 1 H), 8.19-8.17 (m, 1 H), 7.43-7.40 (m, 1 H), 6.94-6.93 (m, 1 H), 6.89-6.88 (m, 1 H), 3.39-3.35 (m, 2 H), 3.07-3.03 (m, 2 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 152.7, 146.7, 139.3, 137.0, 130.2, 126.6, 121.5, 119.6, 115.9, 114.2, 107.2, 29.7, 14.0$; HRMS calcld for C$_{13}$H$_{11}$N$_4$ [M+H]$^+$ 223.0978; found: 223.0982.

3-(3-methylpyrido[3,2-e]pyrrolo[1,2-a]pyrazin-6-yl)propanenitrile (3ua)
Light yellow solid (30.4 mg, 43% yield), melting point: 158-160 °C. $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 8.34-8.33$ (m, 2 H), 8.00-7.99 (d, $J = 1.2$ Hz, 1 H), 6.92-6.91 (m, 1 H), 6.87-6.86 (m, 1 H), 3.38-3.35 (m, 2 H), 3.06-3.02 (m, 2 H), 2.49 (s, 3 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 152.6, 147.3, 137.4, 137.0, 131.3, 129.9, 126.6, 119.6, 115.7, 113.9, 106.9, 29.7, 18.1, 14.0$; HRMS calcld for C$_{14}$H$_{13}$N$_4$ [M+H]$^+$ 237.1135; found: 237.1140.
3-(2-chloropyrido[3,2-e]pyrrolo[1,2-a]pyrazin-6-yl)propanenitrile (3va)
Light yellow solid (35.3 mg, 46% yield), melting point: 184-186 °C. $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 8.36-8.35$ (d, $J = 1.2$ Hz, 1 H), 8.16-8.14 (d, $J = 8.4$ Hz, 1 H), 7.43-7.41 (d, $J = 8.4$ Hz, 1 H), 6.98-6.92 (m, 2 H), 3.42-3.38 (m, 2 H), 3.09-3.05 (m, 2 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 152.9$, 147.7, 139.6, 138.7, 129.1, 126.7, 122.0, 119.6, 116.4, 114.8, 107.6, 29.8, 13.9; HRMS calcd for C$_{13}$H$_{10}$ClN$_4$ [M+H]$^+$ 257.0589; found: 257.0594.

3-(1,3-dimethylpyrrolo[1,2-a]quinoxalin-4-yl)propanenitrile (3wa)
Light yellow solid (52.3 mg, 70% yield), melting point: 162-165 °C. $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 8.18-8.15$ (m, 1 H), 7.84-7.82 (m, 1 H), 7.40-7.34 (m, 2 H), 6.38 (s, 1 H), 3.47-3.43 (m, 2 H), 3.06-3.02 (m, 2 H), 2.88 (s, 3 H), 2.57 (s, 3 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 152.0$, 136.4, 129.9, 129.3, 127.8, 126.2, 124.4, 123.2, 120.2, 118.4, 116.3, 115.0, 31.1, 17.7, 14.7, 14.0; HRMS calcd for C$_{16}$H$_{16}$N$_3$ [M+H]$^+$ 250.1339; found: 250.1331.

4-phenyl-3-(pyrrolo[1,2-a]quinoxalin-4-yl)butanenitrile (3ab)
Colorless oil (60.6 mg, 65% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 7.96-7.92$, (m, 2 H), 7.84-7.82 (m, 1 H), 7.53-7.48 (m, 1 H), 7.46-7.42 (m, 1 H), 7.28-7.22 (m, 2 H), 7.21-7.18 (m, 3 H), 6.85-6.82 (m, 2 H), 3.86-3.79 (m, 1 H), 3.40-3.35 (m, 1 H), 3.11-3.02 (m, 2 H), 2.78-2.72 (m, 1 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 155.0$, 138.2, 135.6, 130.0, 129.1, 128.7, 127.7, 127.3, 126.9, 125.4, 125.3, 119.2, 114.8, 113.8, 113.7, 105.7, 42.4, 40.2, 20.0; HRMS calcd for C$_{21}$H$_{18}$N$_3$ [M+H]$^+$ 312.1495; found: 312.1490.
4-(4-methoxyphenyl)-3-(pyrrolo[1,2-a]quinoxalin-4-yl)butanenitrile (3ac)

Colorless oil (53.2 mg, 52% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): δ = 7.95-7.91, (m, 2 H), 7.84-7.82 (m, 1 H), 7.52-7.41 (m, 2 H), 7.10-7.08 (d, $J = 8.6$ Hz, 2 H), 6.85-6.82 (m, 2 H), 6.80-6.78 (d, $J = 8.6$ Hz, 2 H), 3.82-3.76 (m, 4 H), 3.34-3.29 (m, 1 H), 3.08-2.97 (m, 2 H), 2.77-2.72 (m, 1 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): δ = 158.5, 155.2, 135.6, 130.2, 130.0, 127.6, 127.3, 125.4, 125.2, 119.2, 114.8, 114.7, 114.1, 113.8, 113.7, 105.7, 55.3, 42.6, 39.2, 19.9; HRMS calcd for C$_{22}$H$_{20}$N$_3$O [M+H]$^+$ 342.1601; found: 342.1606.

4-(naphthalen-2-yl)-3-(pyrrolo[1,2-a]quinoxalin-4-yl)butanenitrile (3ad)

Colorless oil (45.5 mg, 42% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): δ = 8.13-8.11, (d, $J = 8.4$ Hz, 1 H), 7.99-7.97 (m, 1 H), 7.85-7.84 (m, 2 H), 7.80-7.77 (m, 1 H), 7.71-7.69 (m, 1 H), 7.56-7.52 (m, 1 H), 7.51-7.43 (m, 3 H), 7.30-7.25 (m, 2 H), 6.71-6.70 (m, 1 H), 6.59-6.58 (m, 1 H), 4.05-3.98 (m, 1 H), 3.78-3.72 (m, 1 H), 3.60-3.55 (m, 1 H), 3.16-3.09 (m, 1 H), 2.83-2.77 (m, 1 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): δ = 155.5, 135.7, 134.3, 134.0, 131.9, 129.9, 129.1, 127.7, 127.6, 127.2, 126.3, 125.8, 125.7, 125.4, 125.3, 125.2, 123.3, 119.1, 114.9, 114.8, 113.7, 105.7, 41.3, 37.5, 20.9; HRMS calcd for C$_{25}$H$_{20}$N$_3$ [M+H]$^+$ 362.1652; found: 362.1656.

4-((2,2,6,6-tetramethylpiperidin-1-yl)oxy)butanenitrile (4)
Colorless oil (42.3 mg, 63% yield). $^1$H NMR (400 MHz, CDCl$_3$, ppm): $\delta = 3.86$-$3.83$, (m, 2 H), 2.51-$2.47$ (m, 2 H), 1.92-$1.86$ (m, 2 H), 1.55-$1.43$ (m, 6 H), 1.15 (s, 6 H), 1.09 (s, 6 H); $^{13}$C NMR (100 MHz, CDCl$_3$, ppm): $\delta = 119.7$, 73.6, 59.8, 39.6, 33.1, 25.1, 20.1, 17.1, 14.5; HRMS calcd for C$_{13}$H$_{25}$N$_2$O [M+H]$^+$ 225.1962; found: 225.1967.

3da
3ha

160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 ppm
3va

![Molecular Structure]

![NMR Spectrum]