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# Synthesis of 6-(Trifluoromethyl)phenanthridines via Palladium-Catalyzed Tandem Suzuki/C−H Arylation Reactions

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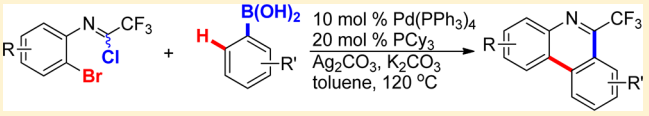
Supporting Information

**ABSTRACT:** A palladium-catalyzed tandem Suzuki/C−H arylation reaction of *N*-aryltrifluoroacetimidoyl chlorides with arylboronic acids has been developed. A variety of 6-(trifluoromethyl)phenanthridines were prepared in moderate to excellent yields from *N*-(2-bromophenyl)-trifluoroacetimidoyl chlorides which can be conveniently prepared from 2-bromoaniline derivatives.

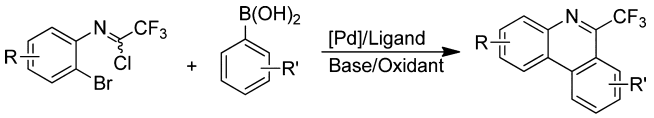



## INTRODUCTION

Phenanthridines are important heteroaromatic compounds and commonly encountered in biologically active molecules,[1] natural products,[2] and optoelectronic materials.[3] As a consequence, a number of useful synthetic procedures have been developed to prepare phenanthridines and their derivatives.[4] However, simple, mild, and versatile preparations of phenanthridines with specific substitution patterns are still highly desirable. For example, efficient synthetic methods for trifluoromethylated phenanthridines are scarcely reported although the incorporation of a $CF_3$ group into aromatics often enhances their biological activity and has become a powerful and widely used strategy in the process of drug design.[5,6]

Recently, transition-metal-catalyzed arene C−H bond functionalization reactions have emerged as versatile tools for the atom- and step-economical assembly of aromatic compounds.[7,8] For example, Yoshikai and co-workers reported a cobalt-catalyzed *ortho*-arylation of aromatic imines with aryl chlorides.[8] As part of our ongoing studies toward the synthesis of trifluoromethylated heterocyclic compounds,[9] we have been investigating the preparation of $CF_3$-containing phenanthridines from our previously reported building blocks which can be conveniently prepared from 2-bromoaniline derivative and trifluoroacetic acid.[10] Herein, we report a simple and efficient protocol for the synthesis of 6-trifluoromethylphenanthridines by the palladium-catalyzed tandem Suzuki coupling reaction and subsequent intramolecular C−H arylation of *N*-aryltrifluoroacetimidoyl chlorides with arylboronic acids in one pot (Scheme 1).

**Scheme 1**




## RESULTS AND DISCUSSION

The reaction of *N*-(2-bromophenyl)-2,2,2-trifluoroacetimidoyl chloride **1a** with phenylboronic acid **2a** was used as a model reaction to screen the optimal reaction conditions, and the results are summarized in Table 1. Initially, treatment of substrate **1a** with phenylboronic acid, $Pd(OAc)_2$ (10 mol %), $K_2CO_3$ (2 equiv), $PPh_3$, and $Ag_2CO_3$ in toluene at 120 °C afforded the desired product **3** in 49% yield (entry 1). Further investigation into catalysts demonstrated that Pd(0) was more effective than Pd(II) species, and the reaction yield increased to 73% using $Pd(PPh_3)_4$ as catalyst (entries 1−4). Some bulky phosphine ligands such as XPhos, SPhos, and RuPhos were examined with the aim of increasing the reaction yield, but all were less effective than $PPh_3$ (entries 5−7). To our surprise, a 94% yield was obtained when $PCy_3$ (tricyclohexylphosphine) was used as ligand (entry 8). Subsequently, some other oxidants and bases were also evaluated, but lower yields were observed (entries 9−13). It is noteworthy that only 18% yield was obtained in the absence of oxidant (entry 14). Polar solvents such as DMF, DMSO and MeCN were unfavorable for this transformation (entries 15−17). Lower yields were observed when the reaction was conducted at 100 °C or when the loading of catalyst reduced to 5 mol % (entries 18 and 19).

With these optimized conditions in hand, we surveyed the substrate scope of *N*-aryltrifluoroacetimidoyl chlorides and arylboronic acids (Table 2). Initially, a variety of arylboronic acids were investigated by reacting with substrate **1a** under standard conditions. The results demonstrated that both electron-rich and electron-poor phenylboronic acids were suitable coupling partners, and the reactions afforded the corresponding products in moderate to excellent yields (**4**−**14**). *o*- or *p*-methyl-substituted phenylboronic acid gave the product in 72% and 86% yield, respectively (**4** and **5**). Similar results were obtained for MeO-substituted phenylboronic acid (**6** and **7**). The reactions of biphenyl-4-boronic acid also

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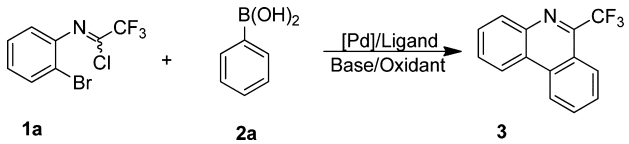
**Table 1. Screening Conditions**[a]




1a 2a 3

| entry | [Pd] | base | ligand | oxidant | solvent | yield[b] (%) |
|---|---|---|---|---|---|---|
| 1 | $Pd(OAc)_2$ | $K_2CO_3$ | $PPh_3$ | $Ag_2CO_3$ | toluene | 49 |
| 2 | $Pd(PPh_3)_2Cl_2$ | $K_2CO_3$ | $PPh_3$ | $Ag_2CO_3$ | toluene | 53 |
| 3 | $Pd(CH_3CN)_2Cl_2$ | $K_2CO_3$ | $PPh_3$ | $Ag_2CO_3$ | toluene | 5 |
| 4 | $Pd(PPh_3)_4$ | $K_2CO_3$ | $PPh_3$ | $Ag_2CO_3$ | toluene | 73 |
| 5 | $Pd(PPh_3)_4$ | $K_2CO_3$ | XPhos | $Ag_2CO_3$ | toluene | 47 |
| 6 | $Pd(PPh_3)_4$ | $K_2CO_3$ | SPhos | $Ag_2CO_3$ | toluene | 51 |
| 7 | $Pd(PPh_3)_4$ | $K_2CO_3$ | RuPhos | $Ag_2CO_3$ | toluene | 45 |
| 8 | $Pd(PPh_3)_4$ | $K_2CO_3$ | $PCy_3$ | $Ag_2CO_3$ | toluene | 94 |
| 9 | $Pd(PPh_3)_4$ | $K_2CO_3$ | $PCy_3$ | $Ag_2O$ | toluene | 59 |
| 10 | $Pd(PPh_3)_4$ | $K_2CO_3$ | $PCy_3$ | AgOTf | toluene | 31 |
| 11 | $Pd(PPh_3)_4$ | $K_2CO_3$ | $PCy_3$ | $K_2S_2O_8$ | toluene | 68 |
| 12 | $Pd(PPh_3)_4$ | $Cs_2CO_3$ | $PCy_3$ | $Ag_2CO_3$ | toluene | 88 |
| 13 | $Pd(PPh_3)_4$ | *t*-BuONa | $PCy_3$ | $Ag_2CO_3$ | toluene | 5 |
| 14 | $Pd(PPh_3)_4$ | $K_2CO_3$ | $PCy_3$ | | toluene | 18 |
| 15 | $Pd(PPh_3)_4$ | $K_2CO_3$ | $PCy_3$ | $Ag_2CO_3$ | DMF | 11 |
| 16 | $Pd(PPh_3)_4$ | $K_2CO_3$ | $PCy_3$ | $Ag_2CO_3$ | DMSO | trace |
| 17 | $Pd(PPh_3)_4$ | $K_2CO_3$ | $PCy_3$ | $Ag_2CO_3$ | $CH_3CN$ | NR |
| 18[c] | $Pd(PPh_3)_4$ | $K_2CO_3$ | $PCy_3$ | $Ag_2CO_3$ | toluene | 81 |
| 19[d] | $Pd(PPh_3)_4$ | $K_2CO_3$ | $PCy_3$ | $Ag_2CO_3$ | toluene | 65 |

[a]Reaction conditions: **1a** (0.2 mmol), **2a** (0.24 mmol), [Pd] (10 mol %), ligand (20 mol %), oxidant (2 equiv), and base (2 equiv) in solvent (2 mL) at 120 °C under $N_2$ atmosphere for 24 h. [b]Isolated yield. [c]At 100 °C. [d]$(PPh_3)_4$ (5 mol %).

afforded the desired product in 81% yield (**8**). 4-Fluoro- and 4-chlorophenylboronic acid provided 67% and 82% yields, respectively (**9** and **10**). 2-Position C−H-arylated product was exclusively obtained in 86% yield using 3-nitrophenylboronic acid as substrate (**11**). Other cyclizations of phenylboronic acids bearing strongly electron-withdrawing groups (such as cyano, acetyl, and trifluoromethyl) proceeded smoothly to give their corresponding products in 66−87% yields (**12**−**14**). Interestingly, naphthalen-1-ylboronic acid underwent the tandem reactions to afford *β*-position C−H arylation product in a 51% yield (**15**). Subsequently, various substituents on the 3- or 4-position of *N*-(2-bromophenyl)trifluoroacetimidoyl chlorides were tested. The reaction between 4-methyl-substituted phenylimine and various arylboronic acids gave excellent yields (**16**−**18**). 4-Chloro- and 4-fluorophenylimine also provided the corresponding product in 72−93% yields (**19**−**21**). The cyclization of 3-trifluoromethylphenylimine proceeded smoothly to give the corresponding product in 82% yield (**22**), whereas 3-nitrophenylimine afforded a lower yield (42%, **23**).

To elucidate the mechanism of the transformation, some control experiments were carried out as shown in Scheme 2. First, treatment of substrate **1a** with phenylboronic acid **2a** in the presence of $Pd(PPh_3)_4$, $PCy_3$, $Ag_2CO_3$, and $K_2CO_3$ at 60 °C for 5 h afforded the 2-bromo-*N*-(2,2,2-trifluoro-1-phenylethylidene)aniline **24** in 90% yield, and no product **3** was detected (Scheme 2, eq 1). These results indicated that the Suzuki coupling reaction occurred preferentially under the standard conditions. As expected, compound **24** could be converted into the desired product **3** in a 93% yield under standard conditions for 12 h (eq 2). It is noteworthy that no cyclization product was detected using *o*-bromostyrene derivative **25** as substrate under the standard conditions (eq 3), which suggested that the directing group of imine probably played a key role during C−H arylation reaction.

On the basis of the observed results and the reported mechanism,[11] a possible mechanism was proposed as outlined in Scheme 3. The reaction afforded product **3** in poor yield in the absence of oxidant, which suggested that the C−H arylation possibly proceeded through a Pd(II)/Pd(IV) pathway although a Pd(0)/Pd(II) pathway could not be ruled out. The Suzuki coupling reaction between substrate **1a** and **2a** occurred preferentially at low temperature to provide compound **24**. In path a, the oxidative addition of aryl bromide **24** to Pd(0) species afforded intermediate **A**. The elimination of HBr might yield palladacycle **B**, and the following reductive elimination furnished product **3**. In path b, imine-directing C−H activation produced palladium(II) complex **C**. Intramolecular oxidative addition with phenyl bromide moiety provided seven-membered palladacycle **D**,[12] and the subsequent reductive elimination afforded the desired product **3** and regenerated Pd(II) species. Study of the detailed mechanism is in progress.

## CONCLUSION

In summary, we have developed an efficient method for the synthesis of trifluoromethylated phenanthridines. In the presence of $Pd(PPh_3)_4$, $PCy_3$, $Ag_2CO_3$, and $K_2CO_3$, a variety of *N*-aryltrifluoroacetimidoyl chlorides underwent the tandem Suzuki/C−H arylation reactions with arylboronic acids to afford the corresponding phenanthridines in moderate to excellent yields. The present process could be used for the synthesis of trifluoromethyl-containing building blocks from simple starting materials, and it also provided a new optional route for constructing phenanthridine rings.


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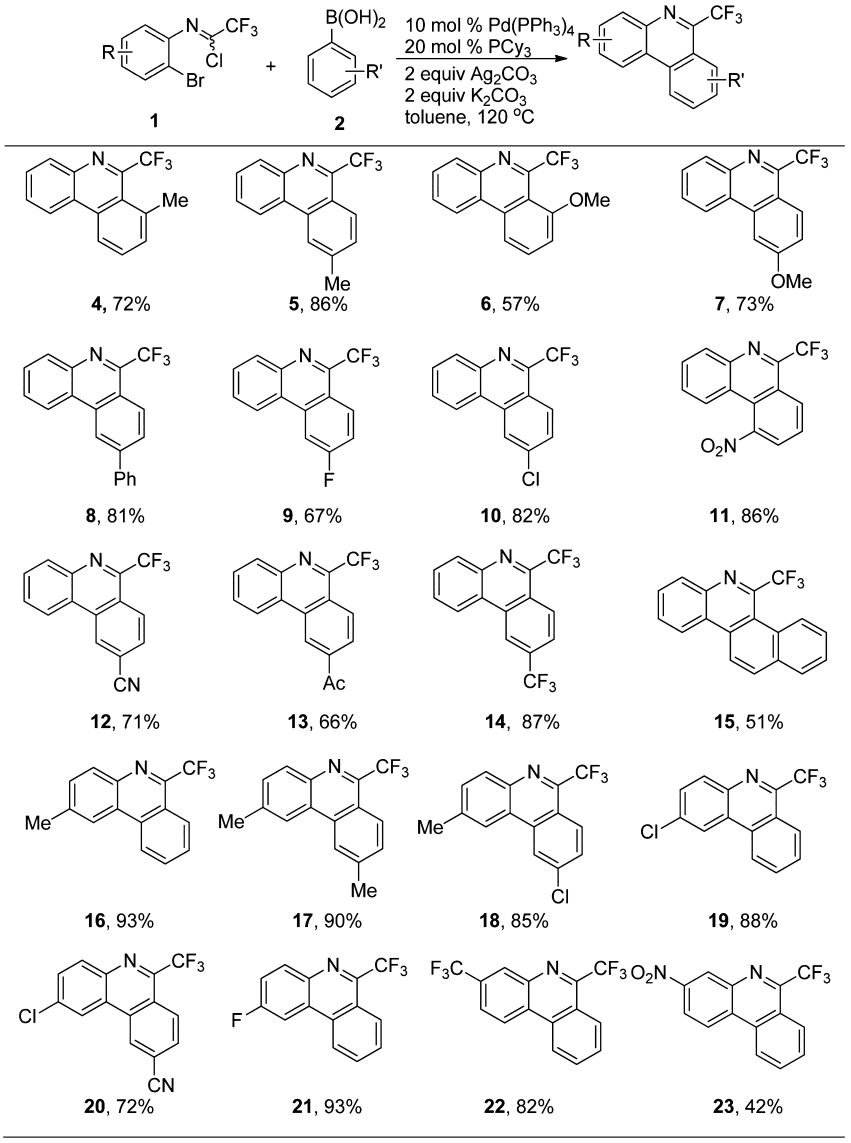
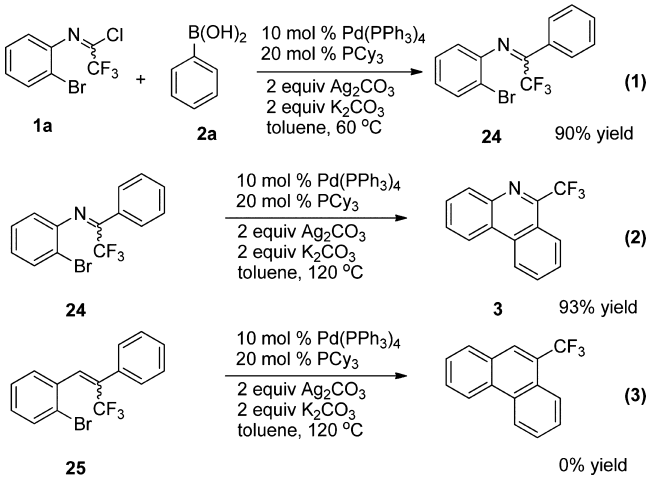
**Table 2. Palladium-Catalyzed Tandem Suzuki/C−H Arylation Reactions**[a]




[a]Reaction conditions: **1** (0.2 mmol), **2** (0.24 mmol), $Pd(PPh_3)_4$ (10 mol %), $PCy_3$ (20 mol %), $Ag_2CO_3$ (2 equiv) and $K_2CO_3$ (2 equiv) in toluene (2 mL) at 120 °C under $N_2$ atmosphere for 24 h.

**Scheme 2. Control Experiments**




## EXPERIMENTAL SECTION

**General Information.** Chemicals were either purchased or purified by standard techniques. $^1H$ NMR and $^{13}C$ NMR spectra were measured on a 500 MHz spectrometer ($^1H$: 500 MHz, $^{13}C$: 125 MHz), using $CDCl_3$ as the solvent with tetramethylsilane (TMS) as an internal standard at room temperature. Chemical shifts are given in $\delta$ relative to TMS, the coupling constants $J$ are given in Hz. $^{19}F$ NMR spectra were recorded on a 500 MHz spectrometer ($^{19}F$: 470 MHz) and are reported relative to the $CFCl_3$ as the internal standard. High-resolution mass spectra were recorded on ESI-Q-TOF mass spectrometry. All reactions under nitrogen atmosphere were conducted using standard Schlenk techniques. Column chromatography was performed using EM silica gel 60 (300−400 mesh).

**Typical Experimental Procedure for Synthesis of 6-(Trifluoromethyl)phenanthridine.** A mixture of *N*-(2-bromophenyl)-2,2,2-trifluoroacetimidoyl chloride (57.2 mg, 0.2 mmol), $Pd(PPh_3)_4$ (23.1 mg, 10 mol %), $PCy_3$ (11.2 mg, 20 mol %), $Ag_2CO_3$ (110.4 mg, 2 equiv), $K_2CO_3$ (55.2 mg, 2 equiv), and phenylboronic acid (29.3 mg, 1.2 equiv) in toluene (2 mL) was evacuated and backfilled with nitrogen (3 cycles) and then stirred at 120 °C until complete consumption of starting material as detected by TLC or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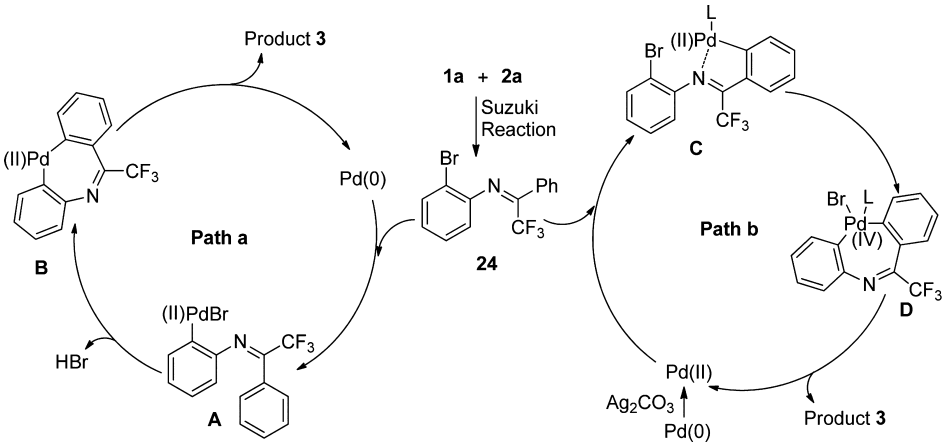
**Scheme 3. Possible Mechanism**




GC−MS analysis. After the reaction was finished, the mixture was poured into ethyl acetate, evaporated under vacuum. The residue was purified by flash column chromatography (hexane/ethyl acetate) to afford the desired product **3**.

*6-(Trifluoromethyl)phenanthridine (**3**):*[5] pale yellow solid (46.4 mg, 94% yield); mp 71.2−73.1 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 8.70 (d, $J$ = 8.5 Hz, 1H), 8.62−8.60 (m, 1H), 8.39−8.37 (m, 1H), 8.30−8.28 (m, 1H), 7.94−7.91 (m, 1H), 7.83−7.76 (m, 3H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 146.5 (q, $J_{C-F}$ = 32.8 Hz), 141.7, 133.9, 131.4, 131.1, 129.3, 129.2, 128.0, 125.9 (q, $J_{C-F}$ = 3.3 Hz), 125.1, 122.5, 122.1, 121.9 (q, $J_{C-F}$ = 275.5 Hz), 121.7; $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −63.5 (s, 3F); IR (neat, cm$^{-1}$): 1620, 1382, 1179, 972, 757, 611; LRMS (EI, 70 eV) $m/z$ 247 ($M^{+\bullet}$, 100), 178 (60), 151 (30), 124 (9), 75 (8); HRMS (ESI) calcd for $C_{14}H_9F_3N^+$ ([M + H]$^+$) 248.0682, found 248.0680.

*7-Methyl-6-(trifluoromethyl)phenanthridine (**4**):* pale yellow solid (37.6 mg, 72% yield); mp 46.8−48.5 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 8.56−8.51 (m, 2H), 8.22−8.20 (m, 1H), 7.78−7.70 (m, 3H), 7.56 (d, $J$ = 7.0 Hz, 1H), 2.81 (s, 3H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 145.0 (q, $J_{C-F}$ = 33.5 Hz), 140.6, 135.8, 135.5, 132.6, 130.6, 130.4, 129.2, 129.1, 125.3, 122.3, 122.2, 122.0 (q, $J_{C-F}$ = 273.8 Hz), 120.7, 23.4; $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −59.7 (s, 3F); IR (neat, cm$^{-1}$) 1600, 1346, 1168, 1121, 963, 758, 716; LRMS (EI, 70 eV) $m/z$ 261 ($M^{+\bullet}$, 100), 241 (15), 192 (41), 165 (43), 82 (11); HRMS (ESI) calcd for $C_{15}H_{11}F_3N^+$ ([M + H]$^+$) 262.0838, found 262.0840.

*9-Methyl-6-(trifluoromethyl)phenanthridine (**5**):* pale yellow solid (44.9 mg, 86% yield); mp 51.4−53.2 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 8.55 (d, $J$ = 7.5 Hz, 1H), 8.42 (s, 1H), 8.26−8.23 (m, 2H), 7.79−7.73 (m, 2H), 7.55 (d, $J$ = 8.5 Hz, 1H), 2.64 (s, 3H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 146.4 (q, $J_{C-F}$ = 32.8 Hz), 142.0, 141.9, 134.1, 131.0, 129.8, 129.1, 128.9, 125.7 (q, $J_{C-F}$ = 3.3 Hz), 124.9, 122.1, 122.0, 121.9 (q, $J_{C-F}$ = 275.5 Hz), 119.8, 22.3; $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −63.5 (s, 3F); IR (neat, cm$^{-1}$) 1626, 1251, 970, 744, 623, 556; LRMS (EI, 70 eV) $m/z$ 261 ($M^{+\bullet}$, 100), 241 (15), 165 (43), 192 (41), 82 (11); HRMS (ESI) calcd for $C_{15}H_{11}F_3N^+$ ([M + H $^+$) 262.0838, found 262.0847.

*7-Methoxy-6-(trifluoromethyl)phenanthridine (**6**):* pale yellow solid (31.6 mg, 57% yield); mp 92.1−94.0 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 8.54−8.52 (m, 1H), 8.24 (d, $J$ = 8.0 Hz, 2H), 7.82−7.72 (m, 3H), 7.15 (d, $J$ = 8.0 Hz, 1H), 4.05 (s, 3H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 156.8, 144.6 (q, $J_{C-F}$ = 34.8 Hz), 141.5, 136.2, 132.0, 130.9, 129.3, 129.0, 124.6, 122.4, 122.0 (q, $J_{C-F}$ = 273.4 Hz), 114.5, 114.3, 109.2, 56.1; $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −63.7 (s, 3F); IR (neat, cm$^{-1}$) 1609, 1462, 1275, 1142, 963, 739, 682; LRMS (EI, 70 eV) $m/z$ 277 ($M^{+\bullet}$, 100), 234 (53), 208 (14), 178 (12), 164 (10), 135 (8); HRMS (ESI) calcd for $C_{15}H_{11}F_3NO^+$ ([M + H]$^+$) 278.0787, found 278.0789.

*9-Methoxy-6-(trifluoromethyl)phenanthridine (**7**):* pale yellow solid (40.4 mg, 73% yield); mp 150.4−152.3 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 8.49 (d, $J$ = 8.0 Hz, 1H), 8.29−8.23 (m, 2H), 7.94 (s, 1H), 7.80−7.72 (m, 2H), 7.34−7.32 (m, 1H), 4.05 (s, 3H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 161.7, 146.1 (q, $J_{C-F}$ = 32.6 Hz), 142.1, 136.4, 131.1, 129.4, 128.6, 127.8 (q, $J_{C-F}$ = 3.4 Hz), 124.8, 122.0, 122.0 (q, $J_{C-F}$ = 275.5 Hz), 118.4, 116.6, 103.1, 55.6; $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −63.3 (s, 3F); IR (neat, cm$^{-1}$) 1616, 1393, 1177, 1113, 971, 839, 735; LRMS (EI, 70 eV) $m/z$ 277 ($M^{+\bullet}$, 100), 278 (17), 234 (38), 178 (12), 164 (9); HRMS (ESI) Calcd for $C_{15}H_{11}F_3NO^+$ ([M + H]$^+$) 278.0787, found 278.0799.

*9-Phenyl-6-(trifluoromethyl)phenanthridine (**8**):* pale yellow solid (52.3 mg, 81% yield); mp 85.9−87.8 °C ; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 8.85 (s, 1H), 8.68−8.66 (m, 1H), 8.45−8.43 (m, 1H), 8.30−8.29 (m, 1H), 8.00−7.98 (m, 1H), 7.81−7.77 (m, 4H), 7.57−7.54 (m, 2H), 7.49−7.46 (m, 1H) ; $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 146.4 (q, $J_{C-F}$ = 33.0 Hz), 144.1, 142.1, 140.0, 134.4, 131.2, 129.4, 129.2, 129.1, 128.6, 127.7, 127.5, 126.4 (q, $J_{C-F}$ = 3.4 Hz), 125.2, 122.1, 122.0 (q, $J_{C-F}$ = 275.4 Hz), 120.8, 120.6; $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −63.4 (s, 3F); IR (neat, cm$^{-1}$) 1616, 1252, 1117, 973, 832, 762, 610; LRMS (EI, 70 eV) $m/z$ 323 ($M^{+\bullet}$, 100), 254 (36), 226 (12), 127 (11), 113 (14); HRMS (ESI) calcd for $C_{20}H_{13}F_3N^+$ ([M + H]$^+$) 324.0995, found 324.1005.

*9-Fluoro-6-(trifluoromethyl)phenanthridine (**9**):* pale yellow solid (35.5 mg, 67% yield); mp 52.4−54.3 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 8.50−8.48 (m, 1H), 8.43−8.40 (m, 1H), 8.31−8.28 (m, 2H), 7.87−7.79 (m, 2H), 7.53−7.49 (m, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 164.1 (d, $J_{C-F}$ = 252.9 Hz), 146.0 (q, $J_{C-F}$ = 32.0 Hz), 142.0, 136.6 (d, $J_{C-F}$ = 9.5 Hz), 131.2, 130.1, 129.3, 129.1 (q, $J_{C-F}$ = 9.6 Hz), 124.6 (d, $J_{C-F}$ = 4.3 Hz), 122.3, 121.8 (q, $J_{C-F}$ = 275.3 Hz), 118.8, 117.5 (d, $J_{C-F}$ = 23.9 Hz), 107.8 (d, $J_{C-F}$ = 19.9 Hz); $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −63.4 (s, 3F), −104.4 (s, 1F) IR (neat, cm$^{-1}$) 1625, 1256, 1116, 972, 837, 705, 557; LRMS (EI, 70 eV) $m/z$ 262 ($M^{+\bullet}$, 100), 196 (63), 170 (5) 169 (18), 133 (6); HRMS (ESI) calcd for $C_{14}H_8F_4N^+$ ([M + H]$^+$) 266.0588, found 266.0579.

*9-Chloro-6-(trifluoromethyl)phenanthridine (**10**):* pale yellow solid (46.1 mg, 82% yield); mp 94.5−96.3 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 8.64 (s, 1H), 8.52−8.50 (m, 1H), 8.32−8.28 (m, 2H), 7.86−7.79 (m, 2H), 7.72−7.70 (m, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 146.1 (q, $J_{C-F}$ = 33.3 Hz), 142.1, 138.1, 135.3, 131.2, 130.0, 129.5, 128.8, 128.2, 127.5 (q, $J_{C-F}$ = 3.3 Hz), 122.3, 122.1, 121.7 (q, $J_{C-F}$ = 275.4 Hz), 120.0; $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −63.5 (s, 3F); IR (neat, cm$^{-1}$) 1607, 1383, 1249, 1113, 971, 825, 767; LRMS (EI, 70 eV) $m/z$ 281 ($M^{+\bullet}$, 100, $^{35}$Cl), 283 (33, $^{37}$Cl), 177 (63), 212 (43), 150 (16), 75 (12); HRMS (ESI) calcd for $C_{14}H_8F_3NCl^+$ ([M + H]$^+$) 282.0292, found 282.0296.

*10-Nitro-6-(trifluoromethyl)phenanthridine (**11**):* pale yellow solid (50.2 mg, 86% yield); mp 129.7−131.5 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 8.58−8.56 (m, 1H), 8.35−8.33 (m, 1H), 8.12−8.10 (m, 1H), 8.04−8.03 (m, 1H), 7.91−7.85 (m, 2H), 7.77−7.73 (m, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 148.2, 145.6 (q, $J_{C-F}$ = 33.4 Hz), 142.7, 131.8, 130.9, 130.0, 129.2 (q, $J_{C-F}$ = 3.6 Hz), 127.5, 126.5, 125.1, 124.0, 123.1, 121.5 (q, $J_{C-F}$ = 275.5 Hz), 120.5; $^{19}$F NMR (470 MHz,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$CDCl_3$) $\delta$ −63.1 (s, 3F); IR (neat, $cm^{-1}$) 1521, 1172, 1028, 823, 764, 657; LRMS (EI, 70 eV) $m/z$ 262 ($M^{+\bullet}$, 100), 260 (80), 242 (77), 191 (32), 292 (31), 234 (25), 139 (23); HRMS (ESI) calcd for $C_{14}H_8F_3N_2O_2^+$ ([M + H]$^+$) 293.0533, found 293.0538.

*6-(Trifluoromethyl)phenanthridine-9-carbonitrile* ***(12)****:* pale yellow solid (38.6 mg, 71% yield); mp 192.4−194.2 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 9.03 (s, 1H), 8.59−8.57 (m, 1H), 8.48−8.46 (m, 1H), 8.35−8.33 (m, 1H), 7.97−7.95 (m, 1H), 7.92−7.88 (m, 2H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 145.9 (q, $J_{C-F}$ = 33.6 Hz), 142.1, 133.7, 131.5, 130.7, 130.4, 129.3, 127.9, 127.1 (q, $J_{C-F}$ = 3.4 Hz), 123.7, 123.1, 122.0, 121.5 (q, $J_{C-F}$ = 275.4 Hz), 117.9, 115.0; $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −63.5 (s, 3F); IR (neat, $cm^{-1}$) 1374, 1174, 972, 772, 569, 549; LRMS (EI, 70 eV) $m/z$ 272 ($M^{+\bullet}$, 100), 203 (52), 176 (26), 149 (7), 136 (5); HRMS (ESI) calcd for $C_{15}H_8F_3N_2^+$ ([M + H]$^+$) 273.0634, found 273.0634.

*1-(6-(Trifluoromethyl)phenanthridin-9-yl)ethanone* ***(13)****:* pale yellow solid (38.1 mg, 66% yield); mp 154.0−156.0 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 9.26 (s, 1H), 8.70−8.68 (m, 1H), 8.45 (d, $J$ = 8.5 Hz, 1H), 8.32−8.30 (m, 1H), 8.26 (d, $J$ = 8.5 Hz, 1H), 7.87−7.85 (m, 2H), 2.83 (s, 3H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 197.3, 146.1 (q, $J_{C-F}$ = 33.3 Hz), 142.0, 138.3, 133.8, 131.4, 130.0, 129.9, 126.7, 126.5 (q, $J_{C-F}$ = 3.4 Hz), 125.2, 123.7, 123.0, 122.1, 121.7 (q, $J_{C-F}$ = 275.4 Hz), 27.0; $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −63.6 (s, 3F); IR (neat, $cm^{-1}$) 1686, 1244, 1117, 972, 768, 548; LRMS (EI, 70 eV) $m/z$ 274 ($M^{+\bullet}$, 100), 289 (62), 246 (45), 226 (27), 151 (13), 247 (8); HRMS (ESI) calcd for $C_{16}H_{11}F_3NO^+$ ([M + H]$^+$) 290.0787, found 290.0793.

*6, 9-Bis(trifluoromethyl)phenanthridine* ***(14)****:* pale yellow solid (54.8 mg, 87% yield); mp 87.2−89.1 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 8.96 (s, 1H), 8.64−8.62 (m, 1H), 8.51 (d, $J$ = 9.0 Hz, 1H), 8.34−8.32 (m, 1H), 7.98−7.96 (m, 1H), 7.90−7.85 (m, 2H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 145.8 (q, $J_{C-F}$ = 27.3 Hz), 142.1, 133.8, 132.9 (q, $J_{C-F}$ = 32.8 Hz), 131.5, 130.3, 130.0, 127.1 (q, $J_{C-F}$ = 3.4 Hz), 124.6, 124.1 (q, $J_{C-F}$ = 2.9 Hz), 123.6 (q, $J_{C-F}$ = 271.3 Hz), 123.2, 122.1, 121.6 (q, $J_{C-F}$ = 275.4 Hz), 120.1 (q, $J_{C-F}$ = 4.4 Hz); $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −63.5 (s, 3F), −62.9 (s, 3F); IR (neat, $cm^{-1}$) 1576, 1321, 1077, 974, 829, 740, 684; LRMS (EI, 70 eV) $m/z$ 315 ($M^{+\bullet}$, 100), 296 (9), 246 (58), 226 (29), 177 (15); HRMS (ESI) calcd for $C_{15}H_8F_6N^+$ ([M + H]$^+$) 316.0556, found 316.0561.

*5-(Trifluoromethyl)benzo[i]phenanthridine* ***(15)****:* pale yellow solid (30.3 mg, 51% yield); mp 138.7−140.5 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 8.74 (d, $J$ = 8.5 Hz, 1H), 8.53−8.47 (m, 2H), 8.25−8.23 (m, 1H), 8.08 (d, $J$ = 9.0 Hz, 1H), 7.91−7.89 (m, 1H), 7.77−7.69 (m, 2H), 7.66−7.59 (m, 2H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 144.4 (q, $J_{C-F}$ = 33.4 Hz), 142.4, 135.1, 133.1, 132.9, 130.4, 129.6, 129.0, 128.4, 128.3, 127.7 (q, $J_{C-F}$ = 7.9 Hz), 127.4, 127.2, 124.8, 122.6 (q, $J_{C-F}$ = 274.6 Hz), 122.6, 119.9, 119.6; $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −60.1 (s, 3F); IR (neat, $cm^{-1}$) 1322, 1125, 945, 736, 594, 535; LRMS (EI, 70 eV) $m/z$ 297 ($M^{+\bullet}$, 100), 228 (78), 200 (22), 138 (14), 100 (30); HRMS (ESI) calcd for $C_{18}H_{11}F_3N^+$ ([M + H]$^+$) 298.0838, found 298.0842.

*2-Methyl-6-(trifluoromethyl)phenanthridine* ***(16)****:* pale yellow solid (48.5 mg, 93% yield); mp 100.7−102.5 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 8.66 (d, $J$ = 8.5 Hz, 1H), 8.36−8.34 (m, 2H), 8.16 (d, $J$ = 8.0 Hz, 1H), 7.90−7.87 (m, 1H), 7.75−7.72 (m, 1H), 7.63−7.61 (m, 1H), 2.65 (s, 3H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 145.5 (q, $J_{C-F}$ = 32.6 Hz), 140.1, 139.5, 133.6, 131.1 (2C), 130.8, 127.9, 125.8 (q, $J_{C-F}$ = 3.3 Hz), 125.0, 122.5, 122.0 (q, $J_{C-F}$ = 275.3 Hz), 121.8, 121.6, 22.1; $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −63.3 (s, 3F); IR (neat, $cm^{-1}$) 1613, 1257, 1109, 971, 825, 768; LRMS (EI, 70 eV) $m/z$ 261 ($M^{+\bullet}$, 100), 241 (35), 190 (18), 165 (16), 121 (7), 82 (7); HRMS (ESI) calcd for $C_{15}H_{11}F_3N^+$ ([M + H]$^+$) 262.0838, found 262.0842.

*2,9-Dimethyl-6-(trifluoromethyl)phenanthridine* ***(17)****:* pale yellow solid (49.5 mg, 90% yield); mp 99.3−101.2 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 8.40 (s, 1H), 8.32 (s, 1H), 8.23−8.21 (m, 1H), 8.13 (d, $J$ = 8.5 Hz, 1H), 7.60−7.58 (m, 1H), 7.54−7.52 (m, 1H), 2.64 (s, 3H), 2.63 (s, 3H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 145.4 (q, $J_{C-F}$ = 32.6 Hz), 141.7, 140.2, 139.2, 133.8, 130.9, 130.7, 129.6, 125.6 (q, $J_{C-F}$ = 3.3 Hz), 124.8, 122.1 (q, $J_{C-F}$ = 275.4 Hz), 122.0, 121.6, 119.9, 22.3, 22.1; $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −63.4 (s, 3F); IR (neat, $cm^{-1}$) 1621, 1256, 1105, 812, 710, 535; LRMS (EI, 70 eV) $m/z$ 275 ($M^{+\bullet}$, 100), 255 (35), 240 (12), 206 (14), 190 (17), 102 (9); HRMS (ESI) calcd for $C_{16}H_{13}F_3N^+$ ([M + H]$^+$) 276.0995, found 276.0997.

*9-Chloro-2-methyl-6-(trifluoromethyl)phenanthridine* ***(18)****:* pale yellow solid (50.2 mg, 85% yield); mp 96.5−98.1 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 8.56 (s, 1H), 8.26−8.24 (m, 1H), 8.22 (s, 1H), 8.13 (d, $J$ = 8.0 Hz, 1H), 7.67−7.62 (m, 2H), 2.64 (s, 3H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 145.1 (q, $J_{C-F}$ = 33.0 Hz), 140.4, 139.9, 137.8, 134.9, 131.8, 130.9, 128.5, 127.4 (q, $J_{C-F}$ = 3.3 Hz), 123.8, 122.2, 121.8 (q, $J_{C-F}$ = 275.1 Hz), 121.6, 120.0, 22.1; $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −63.4 (s, 3F); IR (neat, $cm^{-1}$) 1607, 1383, 1114, 971, 814, 708; LRMS (EI, 70 eV) $m/z$ 295 ($M^{+\bullet}$, 100, $^{35}$Cl), 297 (34, $^{37}$Cl), 275 (42), 190 (40), 163 (20), 82 (20); HRMS (ESI) calcd for $C_{15}H_{10}F_3NCl^+$ ([M + H]$^+$) 296.0449, found 296.0455.

*2-Chloro-6-(trifluoromethyl)phenanthridine* ***(19)****:* pale yellow solid (49.5 mg, 88% yield); mp 101.3−103.1 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 8.53 (d, $J$ = 8.5 Hz, 1H), 8.47 (s, 1H), 8.3 (d, $J$ = 8.5 Hz, 1H), 8.17 (d, $J$ = 8.5 Hz, 1H), 7.91−7.88 (m, 1H), 7.79−7.76 (m, 1H), 7.72−7.70 (m, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 146.7 (q, $J_{C-F}$ = 33.1 Hz), 140.1, 135.4, 132.8, 132.5, 131.6, 129.9, 128.7, 126.1, 126.0 (q, $J_{C-F}$ = 3.3 Hz), 122.5, 121.9, 121.8 (q, $J_{C-F}$ = 275.5 Hz), 121.7; $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −63.5 (s, 3F); IR (neat, $cm^{-1}$) 1601, 1387, 1178, 973, 829, 767,681; LRMS (EI, 70 eV) $m/z$ 281 ($M^{+\bullet}$, 100, $^{35}$Cl), 283 (33, $^{37}$Cl), 212 (41), 177 (73), 150 (14), 123 (7); HRMS (ESI) Calcd for $C_{14}H_8F_3NCl^+$ ([M + H]$^+$) 282.0292, found 282.0299.

*2-Chloro-6-(trifluoromethyl)phenanthridine-9-carbonitrile* ***(20)****:* pale yellow solid (44.1 mg, 72% yield); mp 177.5−179.4 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 8.96 (s, 1H), 8.56 (s, 1H), 8.51−8.49 (m, 1H), 8.28 (d, $J$ = 8.5 Hz, 1H), 8.02−8.00 (m, 1H), 7.88−7.85 (m, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 146.1 (q, $J_{C-F}$ = 33.9 Hz), 140.6, 136.9, 132.9, 132.8, 131.4, 130.1, 127.8, 127.3 (q, $J_{C-F}$ = 3.4 Hz), 124.8, 123.3, 121.8, 121.4 (q, $J_{C-F}$ = 275.6 Hz), 117.6, 115.4; $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −63.5 (s, 3F); IR (neat, $cm^{-1}$) 1507, 1254, 1133, 975, 826, 743, 680; LRMS (EI, 70 eV) $m/z$ 306 ($M^{+\bullet}$, 100, $^{35}$Cl), 308 (34, $^{37}$Cl), 237 (36), 202 (52), 175 (15), 153 (6); HRMS (ESI) calcd for $C_{15}H_7F_3N_2Cl^+$ ([M + H]$^+$) 307.0245, found 307.0247.

*2-Fluoro-6-(trifluoromethyl)phenanthridine* ***(21)****:* pale yellow solid (49.3 mg, 93% yield); mp 104.3−106.2 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 8.51 (d, $J$ = 8.5 Hz, 1H), 8.36 (d, $J$ = 8.0 Hz, 1H), 8.27−8.24 (m, 1H), 8.15−8.13 (m, 1H), 7.92−7.89 (m, 1H), 7.80−7.77 (m, 1H), 7.54−7.50 (m, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 162.6 (d, $J_{C-F}$ = 249.1 Hz), 145.8 (q, $J_{C-F}$ = 32.9 Hz), 138.5, 133.5 (d, $J_{C-F}$ = 9.5 Hz), 133.3, 131.4, 128.7, 126.7, 126.0, 122.7, 121.9 (q, $J_{C-F}$ = 275.3 Hz), 121.8, 118.4 (d, $J_{C-F}$ = 24.4 Hz), 107.1 (d, $J_{C-F}$ = 23.5 Hz); $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −63.5 (s, 3F), −108.8 (s, 1F); IR (neat, $cm^{-1}$) 1619, 1453, 1128, 971, 863, 767, 557; LRMS (EI, 70 eV) $m/z$ 265 ($M^{+\bullet}$, 100), 215 (5), 196 (71), 169 (21), 132 (7); HRMS (ESI) calcd for $C_{14}H_8F_4N^+$ ([M + H]$^+$) 266.0588, found 266.0582.

*3, 6-Bis(trifluoromethyl)phenanthridine* ***(22)****:* pale yellow solid (51.7 mg, 82% yield), mp 104.7−106.5 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 8.68−8.65 (m, 2H), 8.56 (s, 1H), 8.40 (d, $J$ = 8.5 Hz, 1H), 7.99−7.94 (m, 2H), 7.86−7.83 (m, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 148.0 (q, $J_{C-F}$ = 33.1 Hz), 141.0, 133.2, 132.0, 131.2 (q, $J_{C-F}$ = 33.0 Hz), 129.3, 128.6 (q, $J_{C-F}$ = 4.1 Hz), 127.3, 126.2 (q, $J_{C-F}$ = 3.3 Hz), 125.0 (q, $J_{C-F}$ = 3.4 Hz), 123.7 (q, $J_{C-F}$ =270.9 Hz), 123.2, 122.9, 122.3, 121.6 (q, $J_{C-F}$ = 275.8 Hz); $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −63.7 (s, 3F), −62.5 (s, 3F); IR (neat, $cm^{-1}$) 1610, 1332, 1116, 971, 834, 775, 686; LRMS (EI, 70 eV) $m/z$ 315 ($M^{+\bullet}$, 100), 296 (10), 246 (66), 226 (38), 177 (22); HRMS (ESI) calcd for $C_{15}H_8F_6N^+$ ([M + H]$^+$) 316.0556, found 316.0559.

*3-Nitro-6-(trifluoromethyl)phenanthridine* ***(23)****:* pale yellow solid (24.5 mg, 42% yield); mp 168.7−170.2 °C; $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 9.15 (s, 1H), 8.77−8.74 (m, 2H), 8.58−8.56 (m, 1H), 8.46 (d, $J$ = 8.5 Hz, 1H), 8.08−8.05 (m, 1H), 7.95−7.92 (m, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 149.0 (q, $J_{C-F}$ = 33.5 Hz), 147.8, 141.2, 132.9, 132.4, 130.1, 129.5, 126.8, 126.4 (q, $J_{C-F}$ = 3.4 Hz), 123.7, 123.4, 122.8, 122.7, 121.4 (q, $J_{C-F}$ = 275.9 Hz); $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −63.8 (s, 3F); IR (neat, $cm^{-1}$) 1610, 1539, 1345, 1121, 974, 734; LRMS (EI, 70 eV) $m/z$ 292 ($M^{+\bullet}$, 100), 262 (73), 234 (44), 226


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(54), 177 (20), 149 (12); HRMS (ESI) calcd for $C_{14}H_8F_3N_2O_2^+$ ([M + H]$^+$) 293.0533, found 293.0536.

*2-Bromo-N-(2,2,2-trifluoro-1-phenylethylidene)aniline (24):* pale yellow liquid (58.9 mg, 90% yield); $^1$H NMR (500 MHz, $CDCl_3$) $\delta$ 7.53−7.51 (m, 1H), 7.37−7.32 (m, 1H), 7.31−7.25 (m, 4H), 7.08−7.05 (m, 1H), 6.91−6.88 (m, 1H), 6.50−6.48 (m, 1H); $^{13}$C NMR (125 MHz, $CDCl_3$) $\delta$ 158.6 (q, $J_{C-F}$ = 34.0 Hz), 146.5, 133.7 (q, $J_{C-F}$ = 19.4 Hz), 132.8, 130.7, 128.5, 128.1, 127.8, 126.1, 119.9, 119.6 (q, $J_{C-F}$ = 277.8 Hz), 114.3; $^{19}$F NMR (470 MHz, $CDCl_3$) $\delta$ −69.8 (s, 3F); IR (neat, cm$^{-1}$) 1673, 1466, 1231, 1134, 970, 760, 697; LRMS (EI, 70 eV) *m/z* 258 (100), 260 (91), 327 ($M^{+\bullet}$, 32, $^{79}$Br), 329 (32, $^{81}$Br), 76 (24), 155 (20); HRMS (ESI) calcd for $C_{14}H_{10}BrF_3N^+$ ([M + H] $^+$) 327.9949, found 327.9943.

## ■ ASSOCIATED CONTENT

### Supporting Information

$^1$H and $^{13}$C NMR spectra of compounds **3**−**24**. This material is available free of charge via the Internet at http://pubs.acs.org.

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### Notes

The authors declare no competing financial interest.

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