Palladium-Catalyzed Regioselective C-2 Arylation of 7-Azaindoles, Indoles, and Pyrroles with Arenes

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I. Plausible Mechanism of C-2 arylation

In line with the previous mechanism, we also propose a mechanism based on concerted metlation-deprotonation pathway (Scheme 1). As a C-3 substituted 7-azaindole formed the C-2 arylated product 12, the first palladation of 1 could occur at the C-2 position to form 54, largely via CMD pathway. Then, second palladation could occur with arenes also by CMD pathway to form 56, which upon reductive elimination could give 2 with a concomitant release of Pd(0). The active Pd(II) could be regenerated upon oxidation.

II. General Considerations

Unless noted otherwise, all reagents and solvents were purchased from commercial sources and used as received. All palladium-catalyzed reactions were performed in a screw-cap sealed tube. The $^1$H and $^{13}$C NMR spectra were obtained in CDCl$_3$ as solvent using a 400 MHz and 100 MHz spectrometer respectively with Me$_4$Si as an internal standard. Coupling constants ($J$ values) are reported in Hz. Column chromatography was performed using silica gel (100-200 mesh). High resolution mass spectra (HRMS) were obtained using electron spray ionisation (ESI) technique and as TOF mass analyser. All melting points were taken using a melting point apparatus equipped with a calibrated thermometer and are uncorrected. New compounds were characterized by melting point, $^1$H NMR, $^{13}$C NMR, IR, and HRMS data. Substrates 20, 38, 39, 40 were purchased from chemical vendors.
III. Experimental section

1. Typical Procedure for N-sulfonylation of Heterocycles (1, 21 – 26, 41)²

Following a literature procedure, a solution of aryl/alkyl sulfonyl chloride (1.2 equiv) in toluene (mL), Tetrabutylammonium hydrogensulfate (7 mol%) and potassium hydroxide (KOH; 50% aqueous solution, 2.5 mL), were added to a solution of indole/pyrrole (1 equiv) in toluene (2 mL) and stirred at room temperature. After completion of reaction, H₂O (10 mL) was added, and the layers were separated. The organic layer was washed with H₂O (2 x 10 mL) and brine (1 x 10 mL), dried over sodium sulfate, and concentrated under reduced pressure followed by chromatography [silica, EtOAc-hexanes = 1:9 ~ 2:8] gave corresponding N-sulfonlated heterocycle.

1-Tosyl-1H-pyrrolo[2,3-b]pyridine (1)

White solid, (209 mg, 77%); Rₖ (15% EtOAc/Hexane): 0.5; mp 89-95 °C; IR (KBr, cm⁻¹): 2919, 1579, 1268, 768; ¹H NMR(CDCl₃): δ 8.45 – 8.43 (m, 1H), 8.08 (dd, J = 8.4, 1.8 Hz, 2H), 7.86 – 7.83 (m, 1H), 7.74(dd, J = 3.9, 2.2 Hz, 2H), 7.29-7.27(m, 2H), 7.20-7.16(m, 1H), 6.60(dd, J = 4.0, 2.0 Hz, 1H), 2.38(s, 3H); ¹³C NMR(CDCl₃): δ 147.2, 145.1, 144.8, 135.4, 129.6, 129.5, 128.0, 126.4, 122.8, 118.8, 105.2, 21.6; HRMS (ESI) m/z calcd for C₁₄H₁₃N₂O₂S [M+H]⁺ 273.0698, found 273.0688.

2-Methyl-1-(methylsulfonyl)-1H-indole (23)

Brown liquid, (119 mg, 57%); Rₖ (10% EtOAc/Hexane): 0.3; IR (ATR, cm⁻¹): 2925, 1734, 1455, 1365, 1172; ¹H NMR(CDCl₃): δ 8.04-7.99 (m, 1H), 7.53-7.49 (m, 1H), 7.33-7.26 (m, 2H), 6.45 (s, 1H), 3.05 (s, 3H), 2.62 (s, 3H); ¹³C NMR(CDCl₃): δ 137.3, 136.6, 129.7, 123.9, 123.6, 120.2, 113.9, 109.4, 40.7, 15.5; HRMS (ESI) m/z calcd for C₁₀H₁₂NO₂S [M+H]⁺ 210.0589, found 210.0583.

1-(1-(Methylsulfonyl)-1H-indol-3-yl) ethanone (24)

White crystalline solid, (206 mg, 87%); Rₖ (10% EtOAc/Hexane): 0.1; mp 288-290 °C; IR (KBr, cm⁻¹): 2923, 1664, 1541, 1385, 971; ¹H NMR(CDCl₃): δ 8.45-8.43 (m, 1H), 8.11 (s, 1H), 7.91-7.88 (m, 1H), 7.48-7.43 (m, 2H), 3.28 (s, 3H),
2.59 (s, 3H); $^{13}$C NMR (CDCl$_3$): $\delta$ 193.4, 134.9, 132.0, 127.5, 126.1, 125.1, 123.5, 121.5, 112.5, 41.6, 27.7; HRMS (ESI) m/z calcd for C$_{11}$H$_{12}$NO$_3$S [M+H]$^+$ 238.0538, found 238.0530.

**Ethyl 1-(methylsulfonyl)-1H-indole-3-carboxylate (25)**

Colorless solid (240 mg, 90%); R$_f$ (10% EtOAc/Hexane): 0.2; mp 137-139 °C; IR (KBr, cm$^{-1}$): 2978, 1721, 1553, 1361, 1169; $^1$H NMR (CDCl$_3$): $\delta$ 8.21 (m, 1H), 8.15 (s, 1H), 7.89-7.88 (m, 1H), 7.44-7.41 (m, 2H), 4.43 (q, $J$ = 7.1 Hz, 2H), 3.23 (s, 3H), 1.45 (t, $J$ = 7.1 Hz, 3H); $^{13}$C NMR (CDCl$_3$): $\delta$ 163.5, 134.8, 131.7, 127.8, 125.6, 124.6, 122.4, 113.7, 112.7, 60.6, 41.5, 14.4; HRMS (ESI) m/z calcd for C$_{12}$H$_{14}$NO$_4$S [M+H]$^+$ 268.0644, found 268.0635.

**1-(Methylsulfonyl)-1H-indole 3-carbaldehyde (26)**

Off-white solid, (178 mg, 80%); R$_f$ (10% EtOAc/Hexane): 0.1; mp 164-166 °C. IR (KBr, cm$^{-1}$): 2923, 1676, 1541, 1367, 1128; $^1$H NMR (CDCl$_3$): $\delta$ 10.12 (s, 1H), 8.36 (d, $J$ = 4 Hz, 1H), 8.13 (s, 1H), 7.90 (d, $J$ = 7.4 Hz, 1H), 7.50-7.46 (m, 2H), 3.31 (s, 3H); $^{13}$C NMR (CDCl$_3$): $\delta$ 185.3, 135.9, 135.2, 126.6, 126.2, 125.3, 122.9, 122.2, 112.7, 41.8; HRMS (ESI) m/z calcd for C$_{10}$H$_{10}$NO$_3$S [M+H]$^+$ 224.0381, found 224.0375.

**Methyl 1-(methylsulfonyl)-1H-pyrrole-2-carboxylate (41)**

White solid; (285 mg, 77%); R$_f$ (10% EtOAc/Hexane): 0.4; mp 107-110 °C IR (ATR, cm$^{-1}$): 2931, 1735, 1147, 780; $^1$H NMR (CDCl$_3$): $\delta$ 7.89 (d, $J$ = 8.4, 1.9 Hz, 2H), 7.74-7.73 (m, 1H), 7.34 (d, $J$ = 8.1 Hz, 2H), 7.07-7.05 (m, 1H), 6.32 (t, $J$ = 3.5 Hz, 1H), 3.74 (s, 3H), 2.44 (s, 3H); $^{13}$C NMR (CDCl$_3$): $\delta$ 159.1, 144.9, 135.8, 129.4, 129.1, 128.2, 124.8, 123.3, 110.3, 51.7, 21.7; HRMS (ESI) m/z calcd for C$_{13}$H$_{14}$NO$_4$S [M+H]$^+$ 280.0644 found 280.0637.

**2. Procedure for the N-alkylation of 7-azaindoles (3-5, 8)**

A dried round bottom flask equipped with a magnetic stirrer bar was charged with 7-azaindoles and THF (5 mL) under nitrogen atmosphere. The reaction mixture was cool down to 0 °C and NaH (1.2 equiv) was added and stirred for 1 h. After 1 h stirring alkyl halide (1.1 equiv) was added and continued the stirring for another 1 h. After completion of the reaction it was quenched with water (10 mL) and was extracted with ethyl acetate (3 x 20 mL). The combined organic layer was dried
over Na₂SO₄ and the solvent was removed under reduced pressure to give N-alkyl-7-azaindoles in quantitative yield.

1-Benzyl-5-bromo-1H-pyrrolo[2,3-b] pyridine (8)

Colorless liquid, (140 mg, 49%); Rₓ (10% EtOAc/Hexane): 0.7; IR(ATR, cm⁻¹): 2923, 2850, 1455, 838, 740;¹H NMR(CDCl₃): δ 8.38 (d, J = 2.1 Hz, 1H), 8.05 (d, J = 2.1 Hz, 1H); 7.35-7.29 (m, 3H), 7.28-7.21 (m, 2H), 6.44(d, J = 3.5 Hz, 1H), 5.48 (s, 2H);¹³C NMR(CDCl₃): δ 146.6, 143.5, 137.3, 130.8, 129.3, 128.7, 128.5, 127.7, 127.4, 122.0, 111.7, 99.6, 48.0; HRMS (ESI) m/z calcd for C₁₄H₁₂BrN₂ [M+H]⁺ 287.0184 found 287.0179.

3. Procedure for Suzuki coupling of 5-Bromo-1-methyl-7-azaindole²

A solution of 5-bromo-1-methyl-1H-pyrrolo[2,3-b]pyridine (0.5 mmol ), phenylboronic acid (1.3 equiv), Pd(dppf)₂Cl₂-DCM complex (10 mol%) and Cs₂CO₃ (2 equiv) in 1,4-dioxane:water (4 mL, 3:1 mixture) was heated at 60 °C for 6 h. The reaction mixture was allowed to cool to room temperature, diluted with EtOAc (5 mL) and was concentrated under vacuum. The residue product was purified by silica gel column chromatography (hexane/EtOAc, 96:4) to give product (6) in 94% (97 mg) yield.

1-methyl-5-phenyl-1H-pyrrolo[2,3-b]pyridine (6)

Yellow viscous liquid; (97 mg, 94%); IR(ATR, cm⁻¹): 2924, 2853, 1634, 730;¹H NMR(CDCl₃): δ 8.60 (d, J = 2.1 Hz, 1H); 8.11 (d, J = 2.1 Hz, 1H), 7.65 (d, J = 8.4, 1.4 Hz, 2H), 7.49 (t, J = 7.4 Hz, 2H), 7.38 (t, J = 7.4, 1.2 Hz, 1H), 7.23 (d, J = 3.4 Hz, 1H), 6.52 (d, J = 3.4 Hz, 1H), 3.95 (s, 3H);¹³C NMR(CDCl₃): δ 147.3, 142.2, 139.7, 129.8, 129.3, 128.9, 127.4, 127.3, 126.9, 120.5, 99.6, 31.4; HRMS(ESI) m/z calcd for C₁₄H₁₃N₂ [M+H]⁺ 209.1079 found 209.1068.

3. Procedure for C-3 formylation of 5-Bromo-1-methyl-7-azaindole(5)

To the cooled solution of DMF (1.1 equiv), POCl₃ (1.1 equiv) was added slowly and reaction is allowed to stir at room temperature for 5 min. Then, 1,2-dichloroethane (4 mL) was added and mixture was cooled again to which solution of 5-Bromo-1-methyl-7-azaindole (5) (2 equiv) in
DCE (10 mL) was added. Reaction mixture was refluxed for 1.5 h following which cooled satd. solution of sodium bicarbonate (20 mL) was added slowly until effervescence ceases. Then, it was diluted with dichloromethane (30 mL), layers were separated. Organic layer was washed with water (10 mL), brine (10 mL). Then, organic layer was evaporated to dryness and washed with hexane, decanted and dried under reduced pressure to give yellow solid (7) in quantitative yield.

5-Bromo-1-methyl-1H-pyrrolo[2,3-b]pyridine-3-caraldehyde (7)

Yellow solid; IR(KBr, cm\(^{-1}\)): 3087, 2923, 2807, 1650, 725; \(^1\)H NMR(CDCl\(_3\)): \(\delta\) 9.96(s, 1H), 8.73(d, \(J = 2.2\) Hz, 1H), 8.48(d, \(J = 2.2\) Hz, 1H), 7.86(s, 1H), 3.94(s, 3H); \(^13\)C NMR (CDCl\(_3\)): \(\delta\) 184.2, 147.0, 145.8, 139.5, 132.7, 118.9, 115.6, 115.2, 32.3; HRMS(ESI) m/z calcd for C\(_9\)H\(_8\)BrN\(_2\)O [M+H\(^+\)]\(^+\) 238.9820 found 238.9815.

4. Procedure for \(N\)-mesylation of pyrrole (35-37)

To the cooled solution of pyrrole (2 mmol) in THF, NaH (1.2 equiv) was added slowly with vigorous stirring. After 10 min methane sulfonyl chloride (1.5 equiv) was added dropwise to the reaction mixture. Upon completion of reaction, H\(_2\)O (10 mL) was added and extracted with ethyl acetate (2 x 10 mL). Then, organic layer was dried over sodium sulphate and concentrated under reduced pressure followed by chromatography [silica, EtOAc-hexanes = 0.5:9.5 ~ 2:8] gave corresponding \(N\)-mesylated pyroles (35-37).

Note: Special care has to be taken in case of mesylation of unsubstituted pyrrole that temperature has to be kept 0 \(^\circ\)C while addition of NaH and mesyl chloride. Also, mesyl chloride has to be added over period of 10 min. \(N\)-mesyl pyrrole(37) is only iodine active so TLC monitoring has to be done that way, followed by purification.

1-(Methylsulfonyl)-1H-pyrrolo-2-carbaldehyde (35)

Brown solid; (283 mg, 82%); \(R_f\) (20% EtOAc/Hexane): 0.4; mp 45-48 \(^\circ\)C; IR (KBr, cm\(^{-1}\)): 3017, 2933, 2843 2793, 1674, 1362, 743; \(^1\)H NMR(CDCl\(_3\)): \(\delta\) 9.69(d, \(J = 0.84\) Hz, 1H), 7.62-7.61 (m, 1H), 7.23-7.22 (m, 1H), 6.42(t, \(J = 3.3\) Hz, 1H), 3.64(s,
3H); $^{13}$C NMR (CDCl$_3$): $\delta$ 178.1, 133.0, 130.5, 129.2, 111.4, 42.8; HRMS (ESI) m/z calcd for C$_6$H$_8$NO$_3$S [M+H]$^+$ 174.0225 found 174.0219.

**Methyl 1-(methylsulfonyl)-1H-pyrrole-2-carboxylate (36)**

Colorless liquid; (285 mg, 77%); R$_f$ (10% EtOAc/Hexane): 0.2; IR (ATR, cm$^{-1}$): 2924, 2853, 1722, 1150, 757; $^1$H NMR (CDCl$_3$): $\delta$ 7.53-7.52 (m, 1H), 7.12-7.11 (m, 1H), 6.29 (t, $J$ = 3.4 Hz, 1H), 3.89 (s, 3H), 3.73 (s, 3H); $^{13}$C NMR (CDCl$_3$): $\delta$ 160.1, 128.7, 124.5, 123.5, 110.1, 52.0; HRMS (ESI) m/z calcd for C$_7$H$_{10}$NO$_3$S [M+H]$^+$ 204.331 found 204.324.

**1-(Methylsulfonyl)-1H-pyrrole (37)**

Brown liquid; (128 mg, 44%); R$_f$ (10% EtOAc/Hexane): 0.3; IR (ATR, cm$^{-1}$): 3025, 2933, 1730, 1456, 739; $^1$H NMR (CDCl$_3$): $\delta$ 7.15 (t, $J$ = 2.3 Hz, 2H), 6.39 (t, $J$ = 2.3 Hz, 2H), 3.16 (s, 3H); $^{13}$C NMR (CDCl$_3$): $\delta$ 120.4, 113.5, 42.8; HRMS (ESI) m/z calcd for C$_5$H$_8$NO$_2$S [M+H]$^+$ 146.0276 found 146.0269.

**III. Synthesis of C2-arylated compounds and characterization data**

1. **General procedure for the 2-aryl 7-azaindoles (2, 9-19)**

In an oven-dried screw cap vial equipped with a magnetic stir bar, 7-azaindole substrate (0.5 mmol), Pd(TFA)$_2$ (10 mol%), AgOAc (1.5 mmol), CsOPiv (40 mol%), 2.5 mL arene and 2 mL pivalic acid as solvent was heated at 130 ºC for 12 h. The reaction mixture was allowed to cool to room temperature and neutralized by the addition of saturated solution of Na$_2$CO$_3$ (10 mL). Then, it was extracted with ethyl acetate (2 x 10 mL). The organic layer was dried (Na$_2$SO$_4$), concentrated under reduced pressure, and purified by column chromatography on silica using (ethyl acetate/hexane) as an eluent to give the desired product.

**2-Phenyl-1-tosyl-1H-pyrrolo[2,3-b]pyridine (2)**

Off-white solid; (113 mg, 65%); R$_f$ (15% EtOAc/Hexane): 0.6; mp 108-110 ºC; IR (KBr, cm$^{-1}$): 3406, 2928, 1367, 1185; $^1$H NMR(CDCl$_3$): $\delta$ 8.51 (dd, $J$ = 4.8, 1.7 Hz, 1H), 7.80-7.77 (m, 3H), 7.58-7.55 (m, 2H), 7.49-7.47 (m, 3H), 7.22-7.17 (m, 3H), 6.51 (s, 1H), 2.35 (s, 3H); $^{13}$C NMR(CDCl$_3$): $\delta$ 150.1, 144.7, 144.6, 142.2, 135.7, 132.6, 129.9, 129.2, 128.8, 128.7, 127.7, 127.6, 122.3, 119.5, 109.0, 21.6; HRMS(ESI) m/z calcd for C$_{20}$H$_{17}$N$_2$O$_2$S [M+H]$^+$ 349.1011, found 349.1004.
1-Methyl-2-phenyl-1H-pyrrolo[2,3-b]pyridine (9)\textsuperscript{3}

As previously reported\textsuperscript{2}, yellowish liquid; (88 mg, 85%); R\textsubscript{f} (10% EtOAc/Hexane): 0.3; \textsuperscript{1}H NMR(CDC\textsubscript{3}): \(\delta 8.37 (dd, J = 4.8, 1.5 \text{ Hz}, 1H); 7.93 (dd, J = 7.8, 1.6 \text{ Hz}, 1H); 7.58 (dd, J = 8.5, 1.6 \text{ Hz}, 2H); 7.51 (dt, J = 7.1, 1.2 \text{ Hz}, 2H), 7.45 (tt, J = 7.2, 1.5 \text{ Hz}, 1H), 7.13-7.09 (m, 1H), 6.54 (s, 1H), 3.91 (s, 3H); \textsuperscript{13}C NMR(CDC\textsubscript{3}): \(\delta 149.2, 142.6, 141.8, 132.3, 129.1, 128.6, 128.3, 128.1, 120.6, 116.1, 99.4, 29.9.

1-Benzyl-2-phenyl-1H-pyrrolo[2,3-b]pyridine (10)

Off-white solid, (100 mg, 71%); R\textsubscript{f} (10% EtOAc/Hexane): 0.5; mp 114-116 °C; IR(KBr, cm\textsuperscript{-1}): 2924, 2854, 1593, 1417, 729; \textsuperscript{1}H NMR (CDCl\textsubscript{3}): \(\delta 8.36 (dd, J = 4.7, 1.4 \text{ Hz}, 1H); 7.96 (dd, J = 7.8, 1.4 \text{ Hz}, 1H), 7.43-7.39 (m, 5H), 7.24-7.18 (m, 3H), 7.15-7.12 (m, 1H), 6.97 (dd, J = 7.8, 1.8 Hz, 2H), 6.58 (s, 1H), 5.59 (s, 2H); \textsuperscript{13}C NMR (CDCl\textsubscript{3}): \(\delta 143.0, 141.9, 138.5, 132.3, 129.2, 128.5, 128.4, 128.2, 127.0, 126.5, 120.6, 116.4, 100.3, 45.9; \text{HRMS (ESI)} m/z calcd for C\textsubscript{20}H\textsubscript{16}N\textsubscript{2}Na [M+Na]\textsuperscript{+} 307.1211 found 307.1214.

5-Bromo-1-methyl-2-phenyl-1H-pyrrolo[2,3-b]pyridine (11)\textsuperscript{3}

As previously reported, Colorless solid; (101 mg, 71%); R\textsubscript{f} (10% EtOAc/Hexane): 0.6; \textsuperscript{1}H NMR(CDC\textsubscript{3}): \(\delta 8.37 (d, J = 2.2 \text{ Hz}, 1H); 8.04 (d, J = 2.2 \text{ Hz}, 1H), 7.57-7.47 (m, 5H), 6.48 (s, 1H), 3.87 (s, 3H); \textsuperscript{13}C NMR(CDC\textsubscript{3}): \(\delta 147.6, 143.3, 143.0, 131.8, 130.0, 129.1, 128.7, 128.6, 122.0, 111.8, 98.8, 30.0.

1-Methyl-2,5-diphenyl-1H-pyrrolo[2,3-b]pyridine (12)

Yellowish solid; (99 mg, 70%); R\textsubscript{f} (10% EtOAc/Hexane): 0.4; mp 112-116 °C; IR(KBr, cm\textsuperscript{-1}): 2917, 1593, 1480, 886, 757; \textsuperscript{1}H NMR (CDCl\textsubscript{3}): \(\delta 8.61 (d, J = 2.1 \text{ Hz}, 1H); 8.11 (d, J = 2.1 \text{ Hz}, 1H), 7.67 (dd, J = 8.4, 1.4 Hz, 2H), 7.6 (dd, J = 8.5 ,1.6 Hz, 2H), 7.55-7.47 (m, 5H), 7.39 (tt, J = 7.4, 1.1 Hz, 1H), 6.59 (s, 1H), 3.94 (s, 3H); \textsuperscript{13}C NMR (CDCl\textsubscript{3}): \(\delta 148.9, 142.6, 142.0, 139.7, 132.3, 129.9, 129.1, 128.9, 128.6, 128.4, 127.4, 126.9, 126.6, 120.5, 99.6, 30.0; \text{HRMS (ESI)} m/z calcd for C\textsubscript{20}H\textsubscript{17}N\textsubscript{2} [M+H]\textsuperscript{+} 285.1392 found 285.1401.
5-Bromo-1-methyl-2-phenyl-1H-pyrrolo[2,3-b]pyridine (13)³

Yellow solid; (101 mg, 66%); Rf (10% EtOAc/Hexane): 0.3; mp 138-140 °C

IR(KBr, cm⁻¹): 2923, 1649, 742; ¹H NMR(CDCl₃): δ 9.75(s, 1H), 8.82 (d, J = 2.2 Hz, 1H), 8.50 (d, J = 2.2 Hz, 1H), 7.63-7.60 (m, 3H), 7.56-7.64 (m, 2H), 3.80 (s, 3H); ¹³C NMR(CDCl₃): δ 186.1, 152.0, 146.9, 132.5, 130.6, 130.4, 128.9, 127.7, 119.2, 115.4, 113.3, 29.9; HRMS (ESI) m/z calcd for C₁₅H₁₂BrN₂O [M+H⁺] 315.0133 found 315.0126.

2-(3,4-Dichlorophenyl)-1-tosyl-1H-pyrrolo[2,3-b]pyridine (14)

Colorless solid, (93 mg, 45%); Rf (10% EtOAc/Hexane): 0.2; mp 162-168 °C; IR(KBr, cm⁻¹): 2917, 1593, 1372, 1172, 815, 768; ¹H NMR(CDCl₃): δ 8.52 (dd, J = 4.8, 1.5 Hz, 1H); 7.83-7.79 (m, 3H), 7.56(d, J = 8.3 Hz, 1H), 7.55(d, J = 8.3 Hz, 1H), 7.43(dd, J = 8.3, 1.9 Hz, 1H), 7.25-7.20 (m, 3H), 6.54 (s, 1H), 2.37 (s, 3H); ¹³C NMR(CDCl₃): δ 150.0, 145.2, 145.1, 139.4, 135.4, 133.1, 132.5, 131.9, 131.2, 129.7, 129.4, 129.2, 129.1, 127.7, 122.0, 119.7, 109.7, 21.6; HRMS (ESI) m/z calcd for C₂₀H₁₅Cl₂N₂O₂S [M+H⁺] 417.0231 found 417.0239.

2-(3,4-Dichlorophenyl)-1-methyl-5-phenyl-1H-pyrrolo[2,3-b]pyridine (15)³

As previously reported², colorless solid; (120 mg, 87%); Rf (10% EtOAc/Hexane): 0.3; ¹H NMR(CDCl₃): δ 8.37 (dd, J = 4.7, 1.4 Hz, 1H); 7.92 (dd, J = 7.8, 1.5 Hz, 1H), 7.65(d, J = 2 Hz, 1H), 7.56(d, J = 8.3 Hz, 1H), 7.38 (dd, J = 8.3, 2.0 Hz, 1H), 7.12-7.09 (m, 1H), 6.54 (s, 1H), 3.88 (s, 3H); ¹³C NMR(CDCl₃): δ 149.3, 143.3, 139.1, 132.9, 132.6, 132.3, 130.7, 130.6, 128.5, 128.1, 120.3, 116.4, 100.4, 29.9.

2-(2,5-Dimethylphenyl)-1-methyl-2-phenyl-1H-pyrrolo[2,3-b]pyridine (16)

Yellowish liquid, (38 mg, 32%); Rf (10% EtOAc/Hexane): 0.6; IR(ATR, cm⁻¹): 2924, 2853, 1455, 771; ¹H NMR(CDCl₃): δ 8.36 (dd, J = 4.8, 1.5 Hz, 1H); 7.93 (dd, J = 7.8, 1.5 Hz, 1H), 7.25-7.19 (m, 2H), 7.14-7.10(m, 2H), 6.39 (s, 1H), 3.65(s, 3H), 2.39(s, 3H), 2.18(s, 3H); ¹³C NMR(CDCl₃): δ 148.3, 142.1, 141.2, 135.1, 134.6, 131.8, 131.4, 130.0, 129.7, 128.0, 120.6, 115.8, 99.3, 29.7, 20.9, 19.4; HRMS (ESI) m/z calcd for C₁₆H₁₇N₂ [M+H⁺] 237.1392 found 237.1399.
1-Methyl-2-(3-nitrophenyl)-1H-pyrrolo[2,3-b] pyridine (17a)

Colorless liquid, (39 mg, 31%); Rf (20% EtOAc/Hexane): 0.3; IR(ATR, cm\(^{-1}\)): 2930, 1598, 1438, 856; \(^1\)H NMR(CDCl\(_3\)): \(\delta\) 8.46 (s, 1H), 8.43 (d, \(J = 4.7\) Hz, 1H), 8.32 (d, \(J = 8\) Hz, 1H), 8.0 (d, \(J = 7.8\) Hz, 1H); 7.91 (d, \(J = 7.6\) Hz, 1H), 7.71 (t, \(J = 8.0\) Hz, 1H), 7.19 - 7.15(m, 1H), 6.67(s, 1H), 3.96(s, 3H); \(^{13}\)C NMR(CDCl\(_3\)): \(\delta\) 143.7, 138.8, 134.6, 134.2, 129.6, 129.4, 128.6, 123.9, 123.7, 122.8, 120.3, 116.5, 101.0, 29.8; HRMS (ESI) m/z calcd for C\(_{14}\)H\(_{12}\)N\(_3\)O\(_2\) [M+H]\(^+\) 254.0930 found 254.0921.

1-Methyl-2-(4-nitrophenyl)-1H-pyrrolo[2,3-b] pyridine (17b)

Yellow semisolid, (18 mg, 14%); Rf (20% EtOAc/Hexane): 0.3; IR(ATR, cm\(^{-1}\)): 2912, 1438, 856, 778; \(^1\)H NMR(CDCl\(_3\)): \(\delta\) 8.43 (d, \(J = 4.7\), 1.5 Hz, 1H), 8.38 (dd, \(J = 6.9\), 1.9 Hz, 1H), 7.97 (dd, \(J = 7.8\), 1.5 Hz, 1H), 7.77 (dd, \(J = 8.8\), 2.4 Hz, 1H), 7.17 - 7.14(m, 1H), 6.69(s, 1H), 3.96(s, 3H); \(^{13}\)C NMR(CDCl\(_3\)): \(\delta\) 149.7, 147.3, 144.0, 139.0, 138.7, 129.4, 128.9, 124.0, 120.3, 116.7, 101.7, 30.2; HRMS (ESI) m/z calcd for C\(_{14}\)H\(_{12}\)N\(_3\)O\(_2\) [M+H]\(^+\) 254.0930 found 254.0928.

1-Benzyl-5-bromo-2-(3-methoxyphenyl)-1H-pyrrolo[2,3-b]pyridine (18a)

Whitish semisolid, (41 mg, 21%); Rf (10% EtOAc/Hexane): 0.68; IR(ATR, cm\(^{-1}\)): 2924, 1605, 1453, 1143, 771; \(^1\)H NMR(CDCl\(_3\)): \(\delta\) 8.37 (d, \(J = 2.1\) Hz, 1H), 8.07 (d, \(J = 2.1\) Hz, 1H); 7.33 (t, \(J = 7.9\) Hz, 1H), 7.24 - 7.20 (m, 3H), 7.02 - 6.94(m, 4H), 6.88(t, \(J = 1.7\) Hz, 1H) 6.53 (s, 1H), 5.55(s, 2H), 3.65(s, 3H); \(^{13}\)C NMR(CDCl\(_3\)): \(\delta\) 159.7, 147.6, 143.5, 143.2, 138.1, 133.0, 130.2, 129.7, 128.5, 127.1, 126.3, 122.0, 121.6, 114.9, 114.1, 112.2, 99.7, 55.0, 46.2; HRS (ESI) m/z calcd for C\(_{21}\)H\(_{17}\)BrN\(_2\)O [M+H]\(^+\) 393.0603 found 393.0601.

1-Benzyl-5-bromo-2-(4-methoxyphenyl)-1H-pyrrolo[2,3-b]pyridine (18b)

Creamish semisolid, (82 mg, 42%); Rf (10% EtOAc/Hexane): 0.7; IR(ATR, cm\(^{-1}\)): 2923, 2850, 1455, 740; \(^1\)H NMR(CDCl\(_3\)): \(\delta\) 8.34 (d, \(J = 1.9\) Hz, 1H), 8.04 (d, \(J = 2.0\) Hz, 1H); 7.32 (d, \(J = 8.6\) Hz, 1H), 7.24-7.22 (m, 3H), 6.97- 6.92(m, 4H), 6.46(s, 1H), 5.54(s, 2H), 3.86(s, 3H); \(^{13}\)C NMR(CDCl\(_3\)): \(\delta\) 160.0, 147.5, 143.3, 143.1, 138.1, 130.5, 129.8, 128.5, 127.1, 126.4, 124.2, 122.2, 114.0, 112.1, 99.1, 55.3, 46.3; HRMS (ESI) m/z calcd for C\(_{21}\)H\(_{17}\)BrN\(_2\)O [M+H]\(^+\) 393.0603 found 393.0597.
1-Methyl-2-(methylphenyl)-1H-pyrrolo[2,3-b] pyridine (19)

Colorless liquid, (114 mg, 76%); Rf (10% EtOAc/Hexane): 0.7; IR(ATR, cm\(^{-1}\)): 2921, 1679, 735; \(^1\)H NMR(CDCl\(_3\)): \(\delta\) 8.37 – 8.35 (m, 1.5 H), 8.03-8.01 (m ,1.5 H), 7.44 (d, \(J = 8.1\) Hz, 0.8 H), 7.41 (t, \(J = 7.5\) Hz, 1H), 7.36 -7.28(m, 4H), 6.46(s, 1H), 6.44(s, 0.4H), 3.86(s, 4H), 2.46(s, 4H); \(^13\)C NMR(CDCl\(_3\)): \(\delta\) 147.6, 143.5, 142.9, 142.8, 138.7, 138.4, 131.7, 129.9, 129.8, 129.4, 129.0, 128.5, 126.2, 122.1, 111.8, 98.7, 98.5, 30.0, 29.9, 21.5, 21.3; LCMS (ESI) m/z calcd for C\(_{15}\)H\(_{13}\)BrN\(_2\) [M+H]\(^+\) 301.0.

2. General procedure for the 2-aryl indoles (27-33)

In an oven-dried screw cap vial equipped with a magnetic stir bar, indole substrate (0.5 mmol), Pd(OAc\(_2\)) (10 mol%), AgOAc (1.5 mmol), CsOPiv (20 mol%), 2.5 mL arene and 2 mL pivalic acid as solvent was heated at 130 °C for 12 h. The reaction mixture was allowed to cool to room temperature and neutralized by the addition of saturated solution of Na\(_2\)CO\(_3\) (10 mL). Then, it was extracted with ethyl acetate (2 x 10 mL). The organic layer was dried (Na\(_2\)SO\(_4\)), concentrated under reduced pressure, and purified by column chromatography on silica using (ethyl acetate/ hexane) as an eluent to give the desired product.

2-Phenyl-1-tosyl-1H-indole (27)

Colorless solid; (87 mg, 50%); Rf (10% EtOAc/Hexane): 0.5; \(^1\)H NMR(CDCl\(_3\)): \(\delta\) 8.35 (d, \(J = 8.3\) Hz, 1H), 7.52-7.51 (m, 2H), 7.48-7.43 (m, 4H), 7.40 (dt, \(J = 7.3, 1.1\) Hz, 1H), 7.31 (d, \(J = 8.2\) Hz, 3H), 7.07 (d, \(J = 8.2\) Hz, 2H), 6.57 (s, 1H), 2.31 (s, 3H); \(^13\)C NMR(CDCl\(_3\)): \(\delta\) 144.5, 142.1, 138.2, 134.6, 132.4, 130.5, 130.3, 129.2, 128.6, 127.5, 126.8, 124.7, 124.3, 120.6, 116.6, 113.6, 21.5.

1-(Methylsulfonyl)-2-phenyl-1H-indole (28)

Colorless crystals; (119 mg, 88%); Rf (10% EtOAc/Hexane): 0.4; \(^1\)H NMR(CDCl\(_3\)): \(\delta\) 8.16 (d, \(J = 7.06\) Hz, 1H), 7.64-7.58 (m, 3H), 7.64-7.58 (m, 3H), 7.47-7.46 (m, 3H), 7.45-7.35 (m, 2H), 6.74 (s, 1H), 2.77 (s, 3H); \(^13\)C NMR(CDCl\(_3\)): \(\delta\) 142.0, 138.0, 132.0, 130.3, 130.1, 128.9, 127.7, 125.1, 124.6, 121.0, 115.8, 113.1, 39.4.

5-Methoxy-1-(methylsulfonyl)-2-phenyl-1H-indole (29)

Off-white solid (130 mg, 86%); Rf (10% EtOAc/Hexane): 0.3; mp 130-132 °C; IR (KBr, cm\(^{-1}\)): 2840, 1605, 1471, 1359, 1143; \(^1\)H NMR(CDCl\(_3\)): \(\delta\) 8.04 (d, \(J = 9.1\) Hz, 1H), 7.60-7.57 (m, 2H), 7.45-7.44 (m, 3H), 7.08 (d, \(J =2.6\)
Hz, 1H), 7.01 (dd, J = 9.1, 2.6 Hz, 1H), 6.69 (s, 1H), 3.90 (s, 3H), 2.70 (s, 3H); $^{13}$C NMR(CDCl$_3$): δ 157.3, 142.9, 132.6, 131.9, 131.4, 130.0, 128.9, 127.7, 116.9, 113.7, 113.3, 103.5, 55.7, 38.8; HRMS (ESI) m/z calcd for C$_{16}$H$_{16}$NO$_3$S [M+H]$^+$ 302.0851, found 302.0843.

1-(Methylsulfonyl)-2-(tolyl)-1H-indole (mixture) (30)

Yellowish liquid; (120 mg, 80%); $R_f$ (10% EtOAc/Hexane): 0.3; $^1$H NMR(CDCl$_3$): δ 8.15 (td, $J = 8.3$, 1 Hz, 1.5 H), 7.62-7.60 (m, 1.5 H), 7.48 (d, $J = 7.3$ Hz, 1H), 7.40-7.34 (m, 7H), 7.28-7.25 (m, 3H), 6.72 (s, 1H), 6.71 (d, $J = 0.2$ Hz, 0.5H), 2.76 (s, 3H), 2.75 (s, 1.5H), 2.44 (s, 5H).

2-(2,5-Dimethylphenyl)-1-(methylsulfonyl)-1H-indole (31)

Colorless solid; (99 mg, 66%); $R_f$ (10% EtOAc/Hexane): 0.4; mp 118-120 °C; IR (KBr, cm$^{-1}$): 2917, 1437, 1355, 1171, 1036; $^1$H NMR(CDCl$_3$): δ 8.14 (d, $J = 7.8$ Hz, 1H), 7.63 (d, $J = 7.4$ Hz, 1H), 7.46-7.36 (m, 2H), 7.20 (s, 2H), 7.15 (s, 1H), 6.62 (s, 1H), 2.89 (s, 3H), 2.39 (s, 3H), 2.29 (s, 3H); $^{13}$C NMR(CDCl$_3$): δ 140.6, 136.9, 136.0, 134.5, 131.8, 130.7, 130.1, 130.0, 129.7, 124.8, 124.0, 120.9, 115.0, 111.8, 40.5, 20.9, 20.0; HRMS (ESI) m/z calcd for C$_{17}$H$_{18}$NO$_2$S [M+H]$^+$ 300.1058, found 300.1054.

2-(3,4-Dimethylphenyl)-1-(methylsulfonyl)-1H-indole (32)

Colorless solid; (109 mg, 73%); $R_f$ (10% EtOAc/Hexane): 0.4; mp 157-159 °C; IR (KBr, cm$^{-1}$): 2929, 1450, 1365, 1172; $^1$H NMR(CDCl$_3$): δ 8.15 (dd, $J = 8$, 0.7 Hz, 1H), 7.61 (dd, $J = 6.9$, 2.6 Hz, 1H), 7.46-7.33 (m, 3H), 7.23 (d, $J = 7.4$ Hz, 1H), 7.22 (d, $J = 7.6$ Hz, 1H), 6.70 (s, 1H), 2.76 (s, 3H), 2.36 (s, 6H); $^{13}$C NMR(CDCl$_3$): δ 142.3, 137.9, 137.6, 135.9, 131.2, 130.4, 129.4, 129.0, 127.7, 124.9, 124.4, 120.8, 115.9, 112.6, 39.4, 19.8, 19.7; HRMS (ESI) m/z calcd for C$_{17}$H$_{18}$NO$_2$S [M+H]$^+$ 300.1058, found 300.1054.

2-(3,4-Dichlorophenyl)-1-(methylsulfonyl)-1H-indole (33)

Off-white solid; (127 mg, 75%); $R_f$ (10% EtOAc/Hexane): 0.3; mp 105-107 °C; IR (KBr, cm$^{-1}$): 3406, 2928, 1544, 1447, 1362, 1176, 957, 829; $^1$H NMR(CDCl$_3$): δ 8.13 (d, $J =$ 8.4 Hz, 1H), 7.68 (d, $J = 2.0$ Hz, 1H), 7.62 (dd, $J = 6.8$, 1.2, 1H), 7.51 (d, $J = 8.3$ Hz, 1H), 7.45-7.40 (m, 3H), 6.79 (s, 1H), 2.76 (s, 3H); $^{13}$C NMR(CDCl$_3$): δ 139.4, 138.1, 133.1, 132.0, 131.9, 131.2, 130.0, 129.7, 129.5, 125.8, 124.9, 121.3, 115.8, 114.1, 39.2; HRMS (ESI) m/z calcd for C$_{15}$H$_{11}$Cl$_2$NO$_2$SNa [M+Na]$^+$ 361.9785, found 361.9779
3. General procedure for the 2-aryl pyrroles (42-52)

In an oven-dried screw cap vial equipped with a magnetic stir bar, pyrrole substrate (0.5 mmol), Pd(TFA)$_2$ (10 mol%), AgOAc (1.5 mmol), PivOH (5 equiv), 1.5 mL arene as solvent was heated at 80 °C for 12 h. The reaction mixture was allowed to cool to room temperature and neutralized by the addition of saturated solution of Na$_2$CO$_3$ (10 mL). Then, it was extracted with ethyl acetate (2 x 10 mL). The organic layer was dried (Na$_2$SO$_4$), concentrated under reduced pressure, and purified by column chromatography on silica using (ethyl acetate/ hexane) as an eluent to give the desired product.

1-(Methylsulfonyl)-5-phenyl-1H-pyrrole-2-carbaldehyde (42)

Brown Solid, (93 mg, 75%); R$_f$ (20% EtOAc/Hexane): 0.45; mp 150-154 °C; IR(KBr, cm$^{-1}$): 1663, 1377, 752; $^1$H NMR (CDCl$_3$): δ 9.88 (s, 1H), 7.48-7.45(m, 5H), 7.25(d, $J$ = 3.7 Hz, 1H), 6.39(d, $J$ = 3.7 Hz, 1H), 3.46(s, 3H); $^{13}$C NMR (CDCl$_3$): δ 179.8, 145.6, 136.9, 131.2, 129.5, 129.4, 128.1, 126.5, 115.4, 43.7; HRMS (ESI) m/z calcd for C$_{12}$H$_{12}$NO$_3$S [M+H]$^+$ 250.0538 found 250.0530.

Methyl 1-(methylsulfonyl)-5-phenyl-1H-pyrrole-2-carboxylate (43)

White Solid, (96 mg, 69%); R$_f$ (10% EtOAc/Hexane): 0.3; mp 183-187 °C; IR(KBr, cm$^{-1}$): 3017, 2938, 1723, 1472, 753; $^1$H NMR(CDCl$_3$): δ 7.44-7.41(m, 5H), 7.04(d, $J$ = 3.6 Hz, 1H), 6.23(d, $J$ = 3.6 Hz, 1H), 3.92(s, 3H), 3.78(s, 3H); $^{13}$C NMR (CDCl$_3$): δ 161.0, 144.3, 132.6, 128.8, 128.7, 128.1, 122.2, 113.5, 52.2, 44.6; HRMS (ESI) m/z calcd for C$_{13}$H$_{14}$NO$_4$S [M+H]$^+$ 280.0644 found 280.0637.

1-(Methylsulfonyl)-2-phenyl-1H-pyrrole (44)

Colorless solid; (77 mg, 70%); R$_f$ (10% EtOAc/Hexane): 0.4; mp 56-58 °C; IR(KBr, cm$^{-1}$): 2922, 1738, 1360, 764; $^1$H NMR (CDCl$_3$): δ 7.51-7.48(m, 2H), 7.40-7.38(m, 3H), 7.30(dd, $J$ = 3.3, 1.7 Hz, 1H), 6.36(t, $J$ = 3.3 Hz, 1H), 6.31(dd, $J$ = 3.3, 1.8 Hz, 1H), 2.83(s, 3H); $^{13}$C NMR(CDCl$_3$): δ 135.4, 131.1, 130.8, 128.7, 127.8, 123.6, 115.9, 111.8, 42.2; HRMS(ESI) m/z calcd for C$_{11}$H$_{12}$NO$_2$S [M+H]$^+$ 222.0589 found 222.0588.
2-(2,5-dimethylphenyl)-1-mesyl-1H-pyrrole (45)

Colorless crystalline solid; (77 mg, 70%); R_f (10% EtOAc/Hexane): 0.4; mp 114-116 °C; IR(KBr, cm⁻¹): 2927, 1473, 1352, 743; ^1H NMR (CDCl₃): 7.29(dd, J = 3.3, 1.7 Hz, 1H), 7.17(m, 2H), 7.11(s, 1H), 6.38(t, J = 3.3 Hz, 1H), 6.22(dd, J = 3.3, 1.7 Hz, 1H), 2.94(s, 3H), 2.35(s, 3H), 2.18(s, 3H); ^13C NMR (CDCl₃): 136.7, 134.4, 133.8, 131.8, 130.9, 130.0, 129.7, 122.3, 115.2, 111.6, 42.6, 20.8, 19.8; HRMS (ESI) m/z calcd for C₁₃H₁₆NO₂S [M+H]^+ 250.0902 found 250.0895.

2-(2,5-Dimethylphenyl)-1-tosyl-1H-pyrrole (46)

Colourless liquid; (56 mg, 35%); R_f (10% EtOAc/Hexane): 0.7; IR(ATR, cm⁻¹): 2924, 2854, 1367, 812, 669; ^1H NMR (CDCl₃): δ 7.48(dd, J = 3.3, 1.8 Hz, 1H), 7.28(d, J = 8.3 Hz, 2H), 7.16(d, J = 8.2 Hz, 2H), 7.10-7.08(m, 2H), 6.56(s, 1H), 6.34(t, J = 3.3 Hz, 1H), 6.08(dd, J = 3.2, 1.8 Hz, 1H), 2.41(s, 3H), 2.22(s, 3H), 1.93(s, 3H); ^13C NMR(CDCl₃): 144.6, 136.6, 135.8, 133.8, 133.6, 132.7, 130.7, 129.5, 129.3, 129.2, 127.6, 122.5, 114.8, 111.2, 21.6, 20.7, 19.5; HRMS (ESI) m/z calcd for C₁₉H₁₉NNaO₃S [M+Na]^+ 348.1034 found 348.1037

5-(2,5-Dimethylphenyl)-1-(methylsulfonyl)-1H-pyrrole-2-carbaldehyde (47)

Pale yellow solid, (106 mg, 72%); R_f (10% EtOAc/Hexane): 0.2; m.p. 112-114 °C; IR(KBr, cm⁻¹): 2925, 1662, 1474, 756; ^1H NMR (CDCl₃): δ 9.91 (s, 1H), 7.28(d, J = 3.7 Hz, 1H), 7.19(m, 2H), 7.05(s, 1H), 6.29(d, J = 3.8 Hz, 1H), 3.41(s, 3H), 2.36(s, 3H), 2.22(s, 3H); ^13C NMR (CDCl₃): δ 179.6, 144.0, 135.6, 135.0, 134.7, 131.0, 130.4, 130.3, 129.8, 125.9, 115.1, 43.6, 20.8, 19.8; HRMS (ESI) m/z calcd for C₁₄H₁₆NO₃S [M+H]^+ 278.0851 found 278.0841.

Methyl 5-(2,5-dimethylphenyl)-1-(methylsulfonyl)-1H-pyrrole-2-carboxylate (48)

White Solid, (83 mg, 54%); R_f (10% EtOAc/Hexane): 0.3; mp 107-109 °C; IR(KBr, cm⁻¹): 2928, 1740, 1484, 754; ^1H NMR(CDCl₃): δ 7.17-7.16 (m, 2H), 7.04-7.03 (m, 2H); 6.13 (d, J =3.6 Hz, 1H); 3.92 (s, 3H); 3.64 (s, 3H), 2.35 (s, 3H), 2.23 (s, 3H); ^13C NMR (CDCl₃): δ 161.0, 142.4, 134.5, 132.2, 130.3, 129.8, 129.8, 127.2, 121.5, 113.3, 52.2, 44.1, 20.8, 19.7; HRMS (ESI) m/z calcd for C₁₅H₁₈NO₄S [M+H]^+ 308.0957 found 308.0955.
Methyl 5-(3,4-dichlorophenyl)-1-(methylsulfonyl)-1H-pyrrole-2-carboxylate (49)

White Solid, (131 mg, 76%); Rf (10% EtOAc/Hexane): 0.2; mp 159-162 °C; IR(KBr, cm⁻¹): 2928, 1718, 1459, 804, 756; ¹H NMR (CDCl₃): δ 7.49-7.47(m, 2H), 7.21(dd, J = 8.2, 2 Hz, 1H), 7.01(d, J = 3.6 Hz, 1H), 6.22(d, J = 3.6 Hz, 1H), 3.90(s, 3H), 3.77(s, 3H); ¹³C NMR (CDCl₃): δ 160.7, 141.3, 133.0, 132.5, 132.4, 130.4, 130.1, 129.3, 128.0, 122.1, 114.2, 52.3, 44.8; HRMS (ESI) m/z calcd for C₁₃H₁₂Cl₂NO₄S [M+H]+ 347.9864 found 347.9861.

1-(5-(2,5-Dimethylphenyl)-1-methyl-1H-pyrrolyl-2-yl)ethan-1-one (50)

White viscous liquid; (73 mg, 65%); Rf (10% EtOAc/Hexane): 0.5; IR(KBr, cm⁻¹): 2924, 1650, 1370, 773; ¹H NMR (CDCl₃): 7.21-7.15(m, 2H), 7.03(s, 1H), 6.40(d, J = 4.0 Hz, 1H), 3.68(s, 3H), 2.44(s, 3H), 2.35(s, 3H), 2.14(s, 3H); ¹³C NMR (CDCl₃): 188.4, 142.4, 135.2, 134.7, 131.4, 131.2, 130.9, 130.0, 129.7, 119.4, 109.0, 34.3, 27.2, 20.8, 19.2; HRMS (ESI) m/z calcd for C₁₅H₁₈NO [M+H]+ 228.1388 found 228.1395.

1-(5-(2,5-Dimethylphenyl)-1-methyl-1H-pyrrolyl-2-yl)ethan-1-one (51)

White viscous liquid; (73 mg, 65%); Rf (10% EtOAc/Hexane): 0.15; IR(KBr, cm⁻¹): 2924, 1650, 1370, 773; ¹H NMR (CDCl₃): 7.35(d, J = 1.9 Hz, 1H), 7.20-7.13(m, 2H), 7.04(s, 1H), 6.49(d, J = 1.9 Hz, 1H), 3.42(s, 3H), 2.44(s, 3H), 2.35(s, 3H), 2.14(s, 3H); ¹³C NMR (CDCl₃): 193.5, 135.1, 135.1, 134.9, 131.7, 131.4, 130.0, 129.4, 126.7, 125.0, 108.8, 34.6, 26.9, 20.8, 19.4; HRMS (ESI) m/z calcd for C₁₅H₁₈NO [M+H]+ 228.1388 found 228.1395.

Methyl 5-phenyl-1H-pyrrole-2-carboxylate (52)

Colorless solid; (115 mg, 65%); Rf (10% EtOAc/Hexane): 0.3; mp 130-131 °C; IR(KBr, cm⁻¹): 2922, 1706, 1478, 1371, 763; ¹H NMR (CDCl₃): 7.41-7.37(m, 3H), 7.31(dt, J = 8.5, 1.4 Hz, 2H), 7.21(dd, J = 8.0, 1.0 Hz, 2H), 7.14(d, J = 8.0 Hz, 2H), 6.92(d, J = 3.5 Hz, 1H), 6.12(d, J = 3.5 Hz, 1H), 3.96(s, 3H), 2.40(s, 3H); ¹³C NMR (CDCl₃): 161.8, 144.9, 143.8, 135.6, 131.3, 130.6, 130.1, 129.1, 128.8, 127.6, 127.6, 121.8, 114.4, 52.5, 21.6; HRMS (ESI) m/z calcd for C₁₉H₁₈NO₄S [M+H]+ 356.0957 found 356.0951.
4. General procedure for the deprotection of N-sulfonyl group (53, 54)

To the solution of N-sulfonyl heterocycles (1.43) (0.1 mmol) in acetonitrile, TBAF.3H2O (4 equiv) was added and then, reaction was heated at 80 °C for 6 h. The reaction mixture was allowed to cool to room temperature and solvent was evaporated. It was diluted with ethyl acetate (2 mL) and then, washed with water and brine. The organic layer was dried (Na2SO4), concentrated under reduced pressure, and purified by column chromatography on silica using (ethyl acetate/ hexane) as an eluent to give the desired product.

2-Phenyl-1H-pyrrolo[2,3-b]pyridine (53)

Yellowish solid; (16 mg, 82%); Rf (10% EtOAc/Hexane): 0.2, mp 202-203 °C; IR(KBr, cm⁻¹): 3163, 1588, 1281, 74; 1H NMR (CDCl3): δ 12.13(bs, 1H), 8.33(d, J = 3.8 Hz, 1H), 7.98(dd, J = 7.8, 1.3 Hz, 1H), 7.90(d, J = 8 Hz, 2H), 7.55(t, J = 7.4 Hz, 2H), 7.43(tt, J = 7.4, 1.1 Hz, 1H), 7.15-7.12 (m, 1H), 6.82(s, 1H); 13C NMR (CDCl3): δ = 149.9, 142.1, 139.5, 132.4, 129.0, 128.7, 128.2, 125.9, 122.3, 116.1, 97.4; HRMS (ESI) m/z calcd for C13H11N2 [M+H]+ 195.0922 found 195.0918.

Methyl 5-phenyl-1H-pyrrole-2-carboxylate (54)

White Solid, (18 mg, 91%); Rf (10% EtOAc/Hexane): 0.4, mp 148-149 °C; IR(KBr, cm⁻¹): 3292, 1682, 1468, 764; 1H NMR (CDCl3): 9.47(s, 1H), 7.6(d, J = 8.5 Hz, 2H), 7.43 (t, J = 7.4 Hz, 2H), 7.33(tt, J = 7.4, 1.1 Hz, 1H), 6.99-6.97 (m, 1H), 6.59-6.56 (m, 1H), 3.90(s, 3H); 13C NMR (CDCl3): 161.7, 136.8, 131.2, 129.0, 127.8, 124.7, 123.0, 116.8, 108, 51.6; HRMS (ESI) m/z calcd for C12H12NO2 [M+H]+ 202.0868 found 202.0859.

IV. References

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