Supporting Information I (SI-I)

Gold-Catalyzed Atom-Economic Synthesis of Sulfone-Containing Pyrrolo[2,1-a]Isoquinolines from Diynamides: Evidence for Consecutive Sulfonyl Migration

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General information

Unless otherwise indicated, all glassware was dried by a heat gun before use and all reactions were performed under an atmosphere of Argon. All solvents were distilled from appropriate drying agents prior to use. All reagents were used as received from commercial suppliers unless otherwise stated. Several aryl ethylamines, bromocetylenes, and (Bromobuta-1,3-diyn-1-yl)benzene were prepared according to the procedures reported in the literatures. Reaction progress was monitored by thin layer chromatography (TLC). Visualization was achieved by ultraviolet light (254 nm). Flash column chromatography was performed using silica gel 60 (200-300 mesh, Merck and co.). Pressed KBr Disks for infra-red spectra were recorded using a Bruker-VERTEX 70 FT-IR spectrometer. Wavelengths (\(\nu\)) are reported in cm\(^{-1}\). Melting points were recorded using a SGW Melting Point thermometer (X-4). All \(^1H\) NMR, \(^{13}C\) NMR spectra were recorded on Bruker AV-III 400 in CDCl\(_3\), CD\(_3\)CN or DMSO-\(d_6\). Chemical shifts were given in parts per million (ppm, \(\delta\)), referenced to the peak of tetramethylsilane, defined at \(\delta = 0.00\) (\(^1H\) NMR), or the solvent peak of CDCl\(_3\), defined at \(\delta = 77.0\) (\(^{13}C\) NMR); the peak of CD\(_3\)CN, defined at \(\delta = 1.94\) (\(^1H\) NMR), defined at \(\delta = 1.32\) (\(^{13}C\) NMR); the peak of DMSO-\(d_6\), defined at \(\delta = 2.50\) (\(^1H\) NMR), defined at \(\delta = 40.0\) (\(^{13}C\) NMR). Coupling constants were quoted in Hz (\(J\)). \(^1H\) NMR Spectroscopy splitting patterns were designated as singlet (s), doublet (d), triplet (t), quartet (q), pentet (p), septet (se), octet (o). Splitting patterns that could not be interpreted or easily visualized were designated as multiplet (m) or broad (br).
General procedure for preparation of 1,3-Dynamides

Representative synthetic procedures A for the preparation of 1,3-diynamides 1 (1a-1j, 1s-1ac):

All bromocetylenes were synthesized according to known procedures reported in the literatures. 1

Choose 1a as an example:

Synthesis of B: A solution of N-(3-methoxyphenethyl)methanesulfonamide (3.78 g, 25 mmol) in DCM (100 mL) at 0 °C was added Et3N (6.7 mL, 50 mmol). Then methylsulfonyl chloride (2.13 mL, 27.5 mmol) was added drop-wise via syringe at this temperature. The mixture was allowed to warm up to room temperature and stirred for 2 hours. The reaction was diluted with DCM (60 mL) and water (60 mL), the organic layer was separated and the aqueous layer was extracted with DCM (3 × 60 mL). The combined organic layers were washed with brine, dried over anhydrous Na2SO4 and concentrated in vacuo to furnish the desired N-methyl indole. Recrystallization from PE/EA gave the product (5.55 g, 97%). Rf = 0.40 (petroleum ether : ethyl acetate = 1 : 1); 1H NMR (400 MHz, CDCl3) δ 7.26-7.21 (m, 1H), 6.81-6.75 (m, 3H), 4.51-4.39 (m, 1H), 3.80 (d, J = 1.6 Hz, 3H), 3.41-3.39 (m, 2H), 2.87-2.83 (m, 5H); 13C NMR (100 MHz, CDCl3) δ 159.8, 139.4, 129.8, 121.0, 114.6, 112.1, 55.1, 44.3, 40.2, 36.4.
**Synthesis of C:** To a sealed tube was added N-(3-methoxyphenethyl)methanesulfonamide (2.27 g, 10 mmol), CuSO$_4$·5H$_2$O (500 mg, 2.0 mmol), 1,10-phenanthroline (720 mg, 4.0 mmol) and K$_2$CO$_3$ (2.76 g, 20.0 mmol), and this mixture was treated with toluene (40 mL) and (bromoethynyl)trimethylsilane (2.65 g, 15 mmol) under argon. The solution was heated at 80 °C for 14 h. The resulting solution was cooled to room temperatures, filtered through celite, and concentrated in vacuo. Purification of the crude residue with silica flash chromatography gave the ynamide (2.30 g, 70 %). R$_f$ = 0.40 (petroleum ether : ethyl acetate = 5 : 1); $^1$H NMR (400 MHz, CDCl$_3$) δ 7.01 (t, $J = 8.0$ Hz, 1H), 6.63 (d, $J = 7.6$ Hz, 1H), 6.58 (dt, $J_1 = 8.0$ Hz, $J_2 = 2.4$ Hz, 2H), 3.58 (s, 3H), 3.50 (t, $J = 7.2$ Hz, 2H), 2.76 (t, $J = 7.2$ Hz, 2H), 2.48 (s, 3H), 0.00 (s, 9H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 159.7, 139.1, 129.6, 121.3, 114.7, 112.3, 93.7, 74.5, 55.0, 52.2, 38.0, 34.2. 0.1; IR (KBr) 2963, 2165, 1597, 1496, 1363, 125, 1163, 1044, 964, 852, 760, 701, 515 cm$^{-1}$; HRMS-(ESI) (m/z): [M+Na]$^+$ calcd for C$_{15}$H$_{23}$NNaO$_3$SSi, 348.1060; found 348.1060.

**Synthesis of D:** A solution of N-(3-methoxyphenethyl)-2-(trimethylsilyl)ethyn-1-amine (3.60 g, 11 mmol) in THF (80 mL) was cooled to 0 °C before drop-wise addition of TBAF (14.3 mL, 1 M in THF). The mixture was allowed to warm up to room temperature and stirred for 2 hours. The reaction mixture was diluted with ethyl acetate and washed with brine, dried over anhydrous Na$_2$SO$_4$, filtered, and concentrated. The residue was purified by column chromatography (petroleum: ethyl acetate = 6 : 1) to give N-(3-methoxyphenethyl)ethynamine (2.22 g, 80%) as a yellow oil. R$_f$ = 0.40 (petroleum ether : ethyl acetate = 5 : 1); $^1$H NMR (400 MHz, CDCl$_3$) δ 7.23 (t, $J = 8.0$ Hz, 1H), 6.85 (d, $J = 7.6$ Hz, 1H), 6.81-6.77 (m, 2H), 3.79 (s, 3H), 3.72 (t, $J = 7.2$ Hz, 2H), 3.00 (t, $J =$
7.2 Hz, 2H), 2.92 (s, 1H), 2.71 (s, 3H); 13C NMR (100 MHz, CDCl3) δ 159.7, 139.0, 129.6, 121.2, 114.7, 112.3, 74.9, 60.5, 55.1, 52.1, 38.1, 34.1; IR (KBr) 3282, 2939, 2837, 2133, 1597, 1492, 1356, 1163, 1044, 964, 781, 515 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C₁₂H₁₅NNaO₃S, 276.0665; found 276.0665.²

Synthesis of 1,3-diynamide 1a: To a sealed tube was added CuI (15 mg, 0.075 mmol), hydroxylamine hydrochloride (31 mg, 0.45 mmol), MeOH (15 mL), N-(3-methoxyphenethyl)ethynamine (380 mg, 1.5 mmol), n-BuNH₂ (0.30 mL, 3.0 mmol) and 1-bromopropyne (407 mg, 0.23 mmol) under argon. The reaction mixture was stirred at 40 °C. Upon completion, the suspension was cooled to room temperature, diluted with ethyl acetate (30 mL) and water (20 mL), the organic layer was separated and the aqueous layer was extracted with ethyl acetate (3 × 20 mL). The combined organic layers were washed with brine, dried over anhydrous Na₂SO₄ and concentrated in vacuo. The residue was purified by column chromatography to give N-(3-methoxyphenethyl)-N-(phenylbuta-1,3-diyn-1-yl) methanesulfonamide (392 mg, 74%).³

Representative synthetic procedures B for the preparation of 1,3-diynamides 1 (1k-1p, 1r, 1ad-1ah):

Aryl ethylamines were received from commercial suppliers or synthesized according to known procedures reported in the literatures.⁴ (Bromobuta-1,3-diyn-1-yl)benzene F was synthesized according to known procedures reported in the literature.⁵
Choose 1k as an example:

Synthesis of 1,3-diynamide 1k (same procedure as D to 1a): To a sealed tube was added N-(2,3-dimethoxyphenethyl)methanesulphonamide (390 mg, 1.5 mmol), CuSO₄·5H₂O (38 mg, 0.15 mmol), 1,10-phenanthroline (54 mg, 0.30 mmol) and K₂CO₃ (621 mg, 4.5 mmol), and this mixture was treated with toluene (15 mL) and (bromobuta-1,3-diyn-1-yl)benzene (460 mg, 2.25 mmol) under argon. The solution was heated at 80 °C for 14 h. The resulting solution was cooled to room temperatures, filtered through celite, and concentrated in vacuo. Purification of the crude residue with silica flash chromatography gave N-(2,3-dimethoxyphenethyl)-N-(phenylbuta-1,3-diyn-1-yl)methanesulphonamide (426 mg, 74%).³

Synthetic procedures for the preparation of 1,3-diynamides 1q:⁶

N-(3-isopropoxy-4-methoxyphenethyl)-4-methyl-N-((triethylsilyl)buta-1,3-diyn-1-yl)benzenesulfonamide (G)

Compound G was obtained according to the general procedure A outlined above as a yellow oil (748 mg, 95%); Rₓ = 0.7 (Petroleum ether : ethyl acetate = 4 : 1); ¹H NMR (400 MHz, CDCl₃) δ 7.52 (d, J = 8.0 Hz, 2H), 7.13 (d, J = 8.0 Hz, 2H), 6.60 (d, J = 8.0 Hz, 1H), 6.52 (d, J = 10.8 Hz, 2H), 4.35-4.29 (m, 1H), 3.66 (s, 3H), 3.40 (t, J = 7.2 Hz,
2H), 2.69 (t, $J = 7.2$ Hz, 2H), 2.28 (s, 3H), 1.19 (d, $J = 6.0$ Hz, 6H), 0.86 (t, $J = 8.0$ Hz, 9H), 0.49 (q, $J = 7.6$ Hz, 6H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 149.2, 147.0, 144.8, 134.2, 129.7, 129.2, 127.3, 121.1, 116.5, 111.9, 88.3, 88.0, 71.2, 68.2, 59.7, 55.7, 52.6, 33.6, 21.9, 21.4, 7.2, 4.0; IR (KBr) $\nu$ 2953, 2918, 2851, 2221, 1510, 1471, 1377, 1261, 1170, 1023, 809, 676, 578, 543 cm$^{-1}$; HRMS (ESI) m/z: $[M + Na]^+$ calcd for C$_{29}$H$_{39}$NNaO$_4$SSi, 548.2261; found 548.2258.

$N$-(buta-1,3-diyn-1-yl)-$N$-(3-isopropoxy-4-methoxyphenethyl)-4-methylbenzenesulfonamide (H)

To a solution of $G$ (1.30 g, 2.47 mmol) in THF (15 mL), TBAF (4.9 mL, 1M in THF, 4.94 mmol) was added dropwise at 0 °C. The solution was stirred for 2 h during which the temperature gradually increased to room temperature. The reaction was quenched by water and extracted with ethyl acetate (3 × 20 mL). The combined extracts was washed with brine and dried over Na$_2$SO$_4$. The solvent was removed under reduced pressure and the residual mass was purified by silica gel column chromatography using petroleum ether : ethyl acetate (5 : 1) as eluent to get $H$ as a yellow oil (822 mg, 81%); $R_f = 0.5$ (petroleum ether : ethyl acetate = 3 : 1); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.58 (d, $J = 8.4$ Hz, 2H), 7.21 (d, $J = 8.0$ Hz, 2H), 6.68 (d, $J = 8.0$ Hz, 1H), 6.61-6.58 (m, 2H), 4.45-4.36 (m, 1H), 3.73 (s, 3H), 3.50 (t, $J = 7.2$ Hz, 2H), 2.76 (t, $J = 7.2$ Hz, 2H), 2.46 (s, 1H), 2.35 (s, 3H), 1.26 (d, $J = 6.4$ Hz, 6H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 149.1, 146.9, 144.9, 134.0, 129.7, 129.1, 127.1, 121.1, 116.4, 111.9, 71.6, 71.1, 67.4, 58.7, 55.6, 52.4, 33.4, 21.8, 21.3; IR (KBr) $\nu$ 2942, 2354, 1636, 1464, 1257, 753, 417 cm$^{-1}$; HRMS (ESI) m/z: $[M + Na]^+$ calcd for C$_{29}$H$_{39}$NNaO$_4$SSi, 434.1396; found 434.1397.$^2$
Synthesis of 1,3-diynamide 1q: To a solution of H (400 mg, 0.97 mmol) in THF (10 mL), LHMDS (1.5 mL, 1M in THF, 1.5 equiv.) was added dropwise at -78 °C. The temperature was increased to -60 °C and stirred for one hour after which the temperature was again maintained at -78 °C. Then MeI (1.94 mmol, 2 equiv.) was added slowly and the temperature was gradually increased to room temperature. It was stirred for another 9 h after which it was diluted by adding 10 mL of ethyl acetate and carefully quenched by saturated NH₄Cl solution. The reaction mixture was partitioned in a separating flask and the aqueous layer was extracted by ethyl acetate (3 × 15 mL). The combined extracts was washed with brine and dried over Na₂SO₄. The solvent was removed under reduced pressure and the residual mass was purified by silica gel column chromatography using petroleum ether : ethyl acetate (5 : 1) as eluent to get 1q as a yellow oil (256 mg, 62%).

N-(3-methoxyphenethyl)-N-(phenylbuta-1,3-diyn-1-yl)methanesulfonamide (1a)

Compound 1a was obtained according to the general procedure A outlined above as a yellow oil; Rᵣ = 0.40 (petroleum ether : ethyl acetate = 5 : 1); ¹H NMR (400 MHz, CDCl₃) δ 7.50 (dd, J₁ = 7.6 Hz, J₂ = 1.6 Hz, 2H), 7.37-7.31 (m, 3H), 7.25 (t, J = 8.0 Hz, 1H), 6.88 (d, J = 7.6 Hz, 1H), 6.84-6.83 (m, 1H), 6.82-6.79 (m, 1H), 3.81 (s, 3H), 3.80 (t, J = 7.2 Hz, 2H), 3.04 (t, J = 7.2 Hz, 2H), 2.74 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 159.9, 138.8, 132.4, 129.8, 129.1, 128.4, 121.9, 121.4, 114.7, 112.6, 81.8, 73.2, 72.7, 59.7, 55.2, 52.7, 39.0, 34.4; IR (KBr) 3170, 1643, 1570, 1412, 1163, 1016, 803, 645, 526 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C₂₀H₁₉NNaO₃S, 376.0978; found 376.0976.
N-(3-methoxyphenethyl)-N-(p-tolylbuta-1,3-diyn-1-yl)methanesulfonamide (1b)

Compound 1b was obtained according to the general procedure A outlined above as a yellow oil (297 mg, 54%); Rf = 0.40 (petroleum ether : ethyl acetate = 5 : 1); 1H NMR (400 MHz, CDCl3) δ 7.39 (d, J = 8.0 Hz, 2H), 7.25-7.22 (m, 1H), 7.13 (d, J = 8.4 Hz, 2H), 6.87 (d, J = 7.6 Hz, 1H), 6.83 (s, 1H), 6.79 (dd, J1 = 8.4 Hz, J2 = 2.4 Hz, 1H), 3.80 (s, 3H), 3.79 (t, J = 7.2 Hz, 2H), 3.02 (t, J = 7.2 Hz, 2H), 2.72 (s, 3H), 2.35 (s, 3H); 13C NMR (100 MHz, CDCl3) δ 159.9, 139.5, 138.8, 132.3, 129.8, 129.2, 121.4, 118.7, 114.7, 112.6, 82.0, 72.5, 72.4, 59.8, 55.2, 52.7, 38.9, 34.4, 21.6; IR (KBr) ν 2890, 2217, 1619, 1492, 1405, 1244, 1167, 768, 614 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C21H21NNaO3S, 390.1134; found 390.1134.

N-((4-fluorophenyl)buta-1,3-diyn-1-yl)-N-(3-ethoxyphenethyl)methanesulfonamide (1c)

Compound 1c was obtained according to the general procedure A outlined above as a yellow oil (395 mg, 71%); Rf = 0.50 (petroleum ether : ethyl acetate = 5 : 1); 1H NMR (400 MHz, CDCl3) δ 7.51-7.47 (m, 2H), 7.25 (t, J = 8.0 Hz, 1H), 7.03 (t, J = 8.0 Hz, 2H), 6.88 (d, J = 7.6 Hz, 1H), 6.83-6.79 (m, 2H), 3.82 (s, 3H), 3.81 (t, J = 7.2 Hz, 2H), 3.04 (t, J = 7.2 Hz, 2H), 2.73 (s, 3H); 13C NMR (100 MHz, CDCl3) δ 162.9 (d, Jc-F = 249.9 Hz), 159.9, 138.8, 134.4 (d, Jc-F = 8.5 Hz), 129.8, 121.4, 118.0 (d, Jc-F = 3.6 Hz), 115.8 (d, Jc-F = 8.5 Hz).
$F = 22.1 \text{ Hz}, 114.8, 112.6, 80.7, 73.0, 72.7, 59.6, 55.2, 52.7, 39.0, 34.4; {}^{19}\text{F NMR} (376 \text{ MHz, CDCl}_3) \delta -108.8; \text{IR (KBr)} \nu 2886, 1622, 1517, 1401, 1209, 620 \text{ cm}^{-1}; \text{HRMS-(ESI)} (m/z): [\text{M+Na}]^+ \text{calcd for C}_{20}\text{H}_{18}\text{FNNaO}_3\text{S, 394.0884; found 394.0882.}

\text{N-((4-chlorophenyl)buta-1,3-diyn-1-yl)-N-(3-ethoxyphenethyl)methanesulfonamide (1d)}

\text{Compound 1d was obtained according to the general procedure A outlined above as a yellow oil (273 mg, 47%); } R_f = 0.50 \text{ (petroleum ether : ethyl acetate = 5 : 1); } ^1\text{H NMR (400 MHz, CDCl}_3) \delta 7.42 (d, J = 6.4 \text{ Hz, 2H}), 7.30 (d, J = 8.4 \text{ Hz, 2H}), 7.25 (t, J = 8.0 \text{ Hz, 1H}), 6.87 (d, J = 7.6 \text{ Hz, 1H}), 6.83-3.79 (m, 2H), 3.81 (s, 3H), 3.80 (t, J = 7.2 \text{ Hz, 2H}), 3.03 (t, J = 7.2 \text{ Hz, 2H}), 2.73 (s, 3H); ^13\text{C NMR (100 MHz, CDCl}_3) \delta 159.9, 138.7, 135.2, 133.5, 129.8, 128.8, 121.3, 120.4, 114.8, 112.6, 80.6, 74.2, 73.3, 59.5, 55.2, 52.7, 39.0, 34.4; \text{IR (KBr)} \nu 3002, 2354, 1618, 1401, 1160, 620, 466 \text{ cm}^{-1}; \text{HRMS-(ESI)} (m/z): [\text{M+Na}]^+ \text{calcd for C}_{20}\text{H}_{18}\text{ClNNaO}_3\text{S, 410.0588; found 410.0588.}

\text{N-((2-chlorophenyl)buta-1,3-diyn-1-yl)-N-(3-ethoxyphenethyl)methanesulfonamide (1e)}

\text{Compound 1e was obtained according to the general procedure A outlined above as a yellow oil (336 mg, 58%); } R_f = 0.45 \text{ (petroleum ether : ethyl acetate = 5 : 1); } ^1\text{H NMR}
(400 MHz, CDCl₃) δ 7.52 (dd, J₁ = 7.2 Hz, J₂ = 1.6 Hz, 1H), 7.40 (dd, J₁ = 8.0 Hz, J₂ = 0.8 Hz, 1H), 7.31-7.27 (m, 1H), 7.26-7.24 (m, 1H), 7.21 (dd, J₁ = 7.6 Hz, J₂ = 1.2 Hz, 1H), 6.87 (d, J = 7.6 Hz, 1H), 6.83 (t, J = 2.0 Hz, 1H), 6.81 (dd, J₁ = 8.4 Hz, J₂ = 2.4 Hz, 1H), 6.87 (d, J = 7.2 Hz, 2H), 6.81 (dd, J₁ = 8.4 Hz, J₂ = 2.4 Hz, 1H), 3.82 (t, J = 4.8 Hz, 2H), 3.04 (t, J = 4.8 Hz, 2H), 2.75 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 159.9, 138.8, 136.7, 134.3, 130.1, 129.9, 129.34, 126.6, 122.1, 121.4, 114.8, 112.8, 78.3, 78.1, 74.3, 59.6, 55.3, 52.8, 39.1, 34.5; IR (KBr) ν 2935, 2231, 2150, 1590, 1478, 1370, 1268, 1167, 957, 897, 757, 508 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C₂₀H₁₈ClNNaO₃S, 410.0588; found 410.0585.

N-(3,4-dimethoxyphenethyl)-N-(phenylbuta-1,3-diyn-1-yl)methanesulfonamide (1f)

Compound 1f was obtained according to the general procedure A outlined above as a yellow solid (356 mg, 62%); Rₜ = 0.40 (petroleum ether : ethyl acetate = 5 : 1); mp: 120-123 °C; ¹H NMR (400 MHz, CDCl₃) δ 7.50 (dd, J₁ = 7.6 Hz, J₂ = 1.6 Hz, 2H), 7.39-7.31 (m, 3H), 6.84 (appeared as a singlet, 2H), 6.81 (s, 1H), 3.91 (s, 3H), 3.86 (s, 3H), 3.79 (t, J = 8.0 Hz, 2H), 3.01 (t, J = 8.0 Hz, 2H), 2.76 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 149.1, 148.1, 132.4, 129.7, 129.1, 128.4, 121.8, 121.2, 112.3, 111.4, 81.8, 73.1, 72.8, 59.7, 55.94, 55.93, 52.8, 39.0, 34.0; IR (KBr) ν 2834, 2361, 2235, 2158, 2158, 1513, 1398, 1349, 1156, 967, 746, 617, 512 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C₂₁H₂₁NNaO₄S, 406.1083; found 406.1083.
N-(3,4-dimethoxyphenethyl)-N-((4-fluorophenyl)buta-1,3-diyn-1-yl)methanesulfonamide (1g)

Compound 1g was obtained according to the general procedure A outlined above as a yellow oil (391 mg, 65%); R_f = 0.20 (petroleum ether : ethyl acetate = 5 : 1); ^1H NMR (400 MHz, CDCl_3) δ 7.48 (dd, J_1 = 8.4 Hz, J_2 = 5.2 Hz, 2H), 7.03 (t, J = 8.8 Hz, 2H), 6.82 (d, J = 9.6 Hz, 3H), 3.90 (s, 3H), 3.86 (s, 3H), 3.79 (t, J = 7.2 Hz, 2H), 3.00 (t, J = 7.2 Hz, 2H), 2.76 (s, 3H); ^13C NMR (100 MHz, CDCl_3) δ 162.9 (d, J_{C-F} = 249.9 Hz), 149.1, 148.1, 134.4 (d, J_{C-F} = 8.5 Hz), 129.6, 121.1, 117.9 (d, J_{C-F} = 3.6 Hz), 115.8 (d, J_{C-F} = 22.1 Hz), 112.2, 111.3, 80.7, 72.9, 72.8, 59.5, 55.89, 55.88, 52.8, 39.0, 34.0. ^19F NMR (376 MHz, CDCl_3) δ -108.7; IR (KBr) ν 3415, 2235, 2151, 1615, 1492, 1363, 1247, 1163, 1037, 764, 613 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]^+ calcd for C_{21}H_{20}FNNaO_4S, 424.0989; found 424.0989.

N-(3,4-dimethoxyphenethyl)-N-((4-methoxyphenyl)buta-1,3-diyn-1-yl)methanesulfonamide (1h)

Compound 1h was obtained according to the general procedure A outlined above as a yellow oil (316 mg, 51%); R_f = 0.15 (petroleum ether : ethyl acetate = 3 : 1); ^1H NMR (400 MHz, CDCl_3) δ 7.44 (dt, J_1 = 9.2 Hz, J_2 = 2.0 Hz, 2H), 6.87-6.83 (m, 4H), 6.81 (d, J = 0.8 Hz, 1H), 3.90 (s, 1H), 3.86 (s, 3H), 3.82 (s, 3H), 3.78 (t, J = 7.2 Hz, 2H), 3.00 (t, J = 7.2 Hz, 2H), 2.76 (s, 3H); ^13C NMR (100 MHz, CDCl_3) δ 160.3, 149.0, 148.0, 134.1, 129.7, 121.1, 114.1, 113.6, 112.2, 111.3, 81.9, 72.3,
N-((3-chlorophenyl)buta-1,3-diyn-1-yl)-N-(3,4-dimethoxyphenethyl)methanesulfonamide (1i)

Compound 1i was obtained according to the general procedure A outlined above as a yellow oil (394 mg, 63%); R_f = 0.20 (petroleum ether : ethyl acetate = 5 : 1); ^1H NMR (400 MHz, CDCl_3) δ 7.46 (s, 1H), 7.35-7.32 (m, 2H), 7.28-7.24 (m, 1H), 6.82 (d, J = 9.6 Hz, 3H), 3.90 (s, 3H), 3.86 (s, 3H), 3.79 (t, J = 7.2 Hz, 2H), 3.00 (t, J = 6.8 Hz, 2H), 2.75 (s, 3H); ^13C NMR (100 MHz, CDCl_3) δ 149.0, 148.1, 134.2, 131.9, 130.3, 129.6, 129.5, 129.3, 123.5, 121.1, 112.1, 111.3, 80.1, 74.3, 73.6, 59.3, 55.84, 55.82, 52.8, 39.0, 33.9; IR (KBr) ν 3105, 1644, 1528, 1417, 1165, 1028, 626 cm\(^{-1}\); HRMS-(ESI) (m/z): [M+Na]^+ calcd for C_{22}H_{23}NNaO_{5}S, 436.1189; found 436.1189.

N-(3,4-dimethoxyphenethyl)-N-(m-tolylbuta-1,3-diyn-1-yl)methanesulfonamide (1j)

Compound 1j was obtained according to the general procedure A outlined above as a yellow solid (425 mg, 72%); R_f = 0.30 (petroleum ether : ethyl acetate = 5 : 1); mp: 128-130 °C; ^1H NMR (400 MHz, CDCl_3) δ 7.31-7.27 (m, 2H), 7.21 (t, J = 7.8 Hz, 1H), 6.16 (d, J = 7.8 Hz, 1H), 6.82 (appeared as a
singlet, 2H), 6.81 (s, 1H), 3.89 (s, 3H), 3.87 (s, 3H), 3.77 (t, J = 6.8 Hz, 2H), 3.00 (t, J = 6.8 Hz, 2H), 2.75 (s, 3H), 2.32 (s, 3H); 13C NMR (100 MHz, CDCl3) δ 149.1, 148.1, 138.1, 132.8, 130.1, 129.7, 129.4, 128.3, 121.6, 121.1, 112.1, 111.3, 82.0, 72.7, 72.6, 59.7 55.90, 55.89, 52.8, 38.9, 34.0, 21.2; IR (KBr) ν 3137, 2237, 1589, 1512, 1393, 1260, 1238, 1155, 1028, 956, 851, 687, 520 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C22H23NNaO4S, 420.1240; found 420.1239.

N-(2,3-dimethoxyphenethyl)-N-(phenylbuta-1,3-diyn-1-yl) methanesulfonamide (1k)

Compound 1k was obtained according to the general procedure B outlined above as a yellow oil (426 mg, 74%); Rf = 0.70 (petroleum ether : ethyl acetate = 3 : 1); 1H NMR (400 MHz, CDCl3) δ 7.51-7.48 (m, 2H), 7.36-7.31 (m, 3H), 7.01 (t, J = 7.8 Hz, 1H), 6.87-6.84 (m, 2H), 3.90 (s, 3H), 3.86 (s, 3H), 3.79 (t, J = 6.8 Hz, 2H), 3.07 (t, J = 7.2 Hz, 2H), 2.86 (s, 3H); 13C NMR (100 MHz, CDCl3) δ 152.8, 147.6, 132.3, 130.8, 129.0, 128.4, 124.0, 122.7, 122.0, 111.7, 81.5, 73.3, 73.1, 60.7, 59.3, 55.7, 51.8, 39.1, 29.6; IR (KBr) ν 2928, 2834, 2235, 2151, 1583, 1485, 1359, 1163, 963, 893, 753, 680, 515 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C21H21NNaO4S, 406.1083; found 406.1079.

N-(phenylbuta-1,3-diyn-1-yl)-N-(3,4,5-trimethoxyphenethyl) methanesulfonamide (1l)

Compound 1l was obtained according to the general procedure B outlined above as a yellow solid (405 mg, 65%); Rf = 0.55 (petroleum ether : ethyl acetate = 3 : 1); mp: 116-
118 °C; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.50-7.48 (m, 2H), 7.37-7.33 (m, 3H), 6.51 (s, 2H), 3.88 (s, 6H), 3.82 (s, 3H), 3.80 (t, $J$ = 7.2 Hz, 2H), 3.00 (t, $J$ = 7.2 Hz, 2H), 2.84 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 153.1, 136.7, 132.6, 132.0, 128.9, 128.2, 121.4, 105.8, 81.6, 72.9, 72.8, 60.5, 59.3, 55.8, 52.3, 38.6, 34.5; IR (KBr) $\nu$ 3022, 2923, 2232, 2145, 1494, 1365, 1172, 570, 512 cm$^{-1}$; HRMS-(ESI) ($m/z$): [M+Na]$^+$ calcd for C$_{22}$H$_{23}$NNaO$_5$S, 436.1189; found 436.1187.

N-(phenylbuta-1,3-diyn-1-yl)-N-(2,3,4-trimethoxyphenethyl)methanesulfonamide

(1m)

Compound 1m was obtained according to the general procedure B outlined above as a yellow oil (371 mg, 60%); R$_f$ = 0.75 (petroleum ether : ethyl acetate = 3 : 1); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.50-7.47 (m, 2H), 7.36-7.27 (m, 3H), 6.90 (d, $J$ = 8.4 Hz, 1H), 6.60 (d, $J$ = 8.4 Hz, 1H), 3.93 (s, 3H), 3.84 (s, 3H), 3.82 (s, 3H), 3.75 (t, $J$ = 7.2 Hz, 2H), 2.97 (t, $J$ = 6.8 Hz, 2H), 2.86 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 152.9, 151.9, 141.9, 132.0, 128.8, 128.2, 124.8, 122.5, 121.6, 106.8, 81.3, 73.2, 73.1, 60.6, 60.4, 58.8, 55.7, 51.6, 38.8, 29.3; IR (KBr) $\nu$ 2939, 2827, 2231, 2158, 1563, 1496, 1370, 1170, 1104, 1013, 967, 761, 698, 551 cm$^{-1}$; HRMS-(ESI) ($m/z$): [M+Na]$^+$ calcd for C$_{22}$H$_{23}$NNaO$_5$S, 436.1189; found 436.1187.
N-(4-(benzoyloxy)-3-methoxyphenethyl)-N-(phenylbuta-1,3-diyn-1-yl)methanesulfonamide (1n)

Compound 1n was obtained according to the general procedure B outlined above as a yellow oil (427 mg, 62%); R_f = 0.25 (petroleum ether : ethyl acetate = 5 : 1); 1H NMR (400 MHz, CDCl_3) δ 7.48-7.45 (m, 2H), 7.40-7.38 (m, 2H), 7.34-7.26 (m, 6H), 6.83-6.81 (m, 2H), 6.72 (dd, J_1 = 8.0 Hz, J_2 = 2.0 Hz, 1H), 5.10 (s, 2H), 3.87 (s, 3H), 3.73 (t, J = 6.8 Hz, 2H), 2.94 (t, J = 6.8 Hz, 2H), 2.59 (s, 3H); 13C NMR (100 MHz, CDCl_3) δ 149.7, 146.9, 136.8, 132.1, 130.2, 129.0, 128.32, 128.29, 127.7, 127.1, 121.6, 121.0, 114.2, 112.7, 81.6, 73.1, 72.8, 70.2, 59.4, 55.8, 52.6, 38.7, 33.7; IR (KBr) ν 2921, 2231, 1646, 1510, 1366, 1160, 1012, 764, 536 cm^{-1}; HRMS-(ESI) (m/z): [M+Na]^+ calcd for C_{27}H_{25}NNaO_{4}S, 482.1396; found 482.1394.

N-(3-(benzoyloxy)-4-methoxyphenethyl)-N-(phenylbuta-1,3-diyn-1-yl)methanesulfonamide (1o)

Compound 1o was obtained according to the general procedure B outlined above as a yellow oil (309 mg, 45%); R_f = 0.50 (petroleum ether : ethyl acetate = 3 : 1); 1H NMR (400 MHz, CDCl_3) δ 7.51-7.46 (m, 4H), 7.38-7.30 (m, 6H), 6.85-6.84 (m, 3H), 5.18 (s, 2H), 3.86 (s, 3H), 3.73 (t, J = 6.8 Hz, 2H), 2.93 (t, J = 6.8 Hz, 2H), 2.54 (s, 3H); 13C NMR (100 MHz, CDCl_3) δ 148.8, 148.0, 136.9, 132.3, 129.7, 129.1, 128.6, 128.4, 127.9, 127.4, 121.8, 121.7, 115.2, 112.0, 81.8, 73.3, 72.8, 70.9, 59.7, 56.0, 52.8, 38.9, 33.8; IR (KBr) ν 3026, 2932, 2371, 2224, 2158, 1513, 1394, 1352, 1261, 1167, 1009, 697, 519 cm^{-1}; HRMS-(ESI) (m/z): [M+Na]^+ calcd for C_{27}H_{25}NNaO_{4}S, 482.1396; found 482.1393.
N-(3-isopropoxy-4-methoxyphenethyl)-N-(phenylbuta-1,3-diyn-1-yl) methanesulfonamide (1p)

Compound 1p was obtained according to the general procedure B outlined above as a yellow oil (460 mg, 75%); \( R_f = 0.50 \) (petroleum ether : ethyl acetate = 3 : 1); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 7.49 (dd, \( J_1 = 8.0 \) Hz, \( J_2 = 2.0 \) Hz, 2H), 7.37-7.33 (m, 3H), 6.84 (s, appeared as a singlet, 3H), 4.60-4.51 (m, 1H), 3.83 (s, 3H), 3.78 (t, \( J = 7.2 \) Hz, 2H), 2.98 (t, \( J = 7.2 \) Hz, 2H), 2.71 (s, 3H), 1.38 (d, \( J = 6.0 \) Hz, 6H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \) 149.5, 147.4, 132.3, 129.6, 129.1, 128.4, 121.8, 121.6, 116.8, 112.1, 81.7, 73.2, 72.8, 71.5, 59.6, 56.0, 52.9, 38.9, 33.8, 22.1; IR (KBr) \( \nu \) 2928, 2230, 2155, 1647, 1509, 1362, 1260, 1168, 958, 754 cm\(^{-1}\); HRMS-(ESI) (m/z): [M+Na\(^+\)] calcd for C\(_{23}\)H\(_{25}\)N\(_2\)O\(_4\)S, 434.1396; found 434.1397.

N-(3-isopropoxy-4-methoxyphenethyl)-N-(phenylbuta-1,3-diyn-1-yl) methanesulfonamide (1q)

Compound 1q was obtained according to the general procedure outlined above as a yellow oil (256 mg, 62%); \( R_f = 0.5 \) (petroleum ether : ethyl acetate = 3 : 1); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 7.66 (d, \( J = 8.0 \) Hz, 2H), 7.28 (d, \( J = 8.0 \) Hz, 2H), 6.75 (d, \( J = 8.0 \) Hz, 1H), 6.69-6.66 (m, 2H), 4.50-4.44 (m, 1H), 3.80 (s, 3H), 3.53 (t, \( J = 8.0 \) Hz, 2H), 2.83 (t, \( J = 7.6 \) Hz, 2H), 2.41 (s, 3H), 1.96 (s, 3H), 1.34 (d, \( J = 6.0 \) Hz, 6H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \) 149.1, 147.0, 144.7, 134.2, 129.6, 129.4, 127.2, 121.1, 116.5, 111.9,
79.6, 71.2, 66.3, 63.5, 59.0, 55.7, 52.5, 33.5, 21.9, 21.4, 4.3; IR (KBr) \( \nu \) 2925, 2848, 2372, 2168, 1699, 1506, 1366, 1167, 1027, 655, 575, 417 cm\(^{-1}\); HRMS (ESI) \( m/z \): [M + Na]\(^+\) calcd for C\(_{24}\)H\(_{27}\)NNaO\(_4\)S, 448.1553; found 448.1552.

\[
\text{N-(2-(benzo[d][1,3]dioxol-5-yl)ethyl)-N-(phenylbuta-1,3-diyn-1-yl)methanesulfonamide (1r)}
\]

Compound 1r was obtained according to the general procedure B outlined above as a yellow oil (462 mg, 84%); \( R_f = 0.35 \) (petroleum ether : ethyl acetate = 3 : 1); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 7.50 (dd, \( J_1 = 8.0 \) Hz, \( J_2 = 2.0 \) Hz, 2H), 7.36-7.31 (m, 3H), 6.78-6.72 (m, 3H), 5.93 (s, 2H), 3.74 (t, \( J = 7.2 \) Hz, 2H), 2.97 (t, \( J = 7.2 \) Hz, 2H), 2.83 (s, 3H); \(^1^3\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \) 147.9, 146.6, 132.3, 130.8, 129.1, 128.4, 122.1, 121.8, 109.4, 108.5, 101.0, 87.8, 73.1, 72.7, 59.6, 52.9, 39.1, 34.2; IR (KBr) \( \nu \) 3135, 3112, 1639, 1619, 1402, 617 cm\(^{-1}\); HRMS-(ESI) \( m/z \): [M+Na]\(^+\) calcd for C\(_{20}\)H\(_{17}\)NNaO\(_4\)S, 390.0770; found 390.0767.

\[
\text{N-(3-methoxyphenethyl)-4-methyl-N-(phenylbuta-1,3-diyn-1-yl)benzenesulfonamide (1s)}
\]

Compound 1s was obtained according to the general procedure A outlined above as a yellow oil (373 mg, 58%); \( R_f = 0.60 \) (petroleum ether : ethyl acetate = 5 : 1); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 7.72 (d, \( J = 8.4 \) Hz, 2H), 7.49 (dd, \( J_1 = 7.6 \) Hz, \( J_2 = 1.6 \) Hz, 2H), 7.35-7.30 (m, 5H), 7.18 (t, \( J = 8.0 \) Hz, 1H), 6.76 (dd, \( J_1 = 8.0 \) Hz, \( J_2 = 2.4 \) Hz, 2H), 6.69
(d, J = 1.6 Hz, 1H), 3.76 (s, 3H), 3.61 (t, J = 8.0 Hz, 2H), 2.93 (t, J = 8.0 Hz, 2H), 2.43 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 159.7, 145.0, 138.6, 134.4, 132.3, 129.9, 129.6, 129.0, 128.4, 127.5, 122.0, 121.1, 114.4, 112.3, 81.3, 73.7, 73.5, 58.9, 55.1, 52.6, 34.4, 21.6; IR (KBr) $\nu$ 2991, 2364, 1618, 1401, 1167, 617, 480 cm$^{-1}$; HRMS-(ESI) (m/z): [M+Na]$^+$ calcd for C$_{26}$H$_{23}$NNaO$_3$S, 452.1291; found 452.1290.

N-(3-methoxyphenethyl)-4-methyl-N-(p-tolylbuta-1,3-diyn-1-yl)benzenesulfonamide (1t)

Compound 1t was obtained according to the general procedure A outlined above as a yellow solid (435 mg, 67%); $R_f$ = 0.60 (petroleum ether : ethyl acetate = 5 : 1); mp: 136-138 °C; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.73 (d, J = 8.0 Hz, 2H), 7.39 (d, J = 8.4 Hz, 2H), 7.31 (d, J = 8.4 Hz, 2H), 7.18 (t, J = 8.0 Hz, 1H), 7.13 (d, J = 8.0 Hz, 2H), 6.77-6.75 (m, 2H), 6.69 (d, J = 2.0 Hz, 1H), 3.77 (s, 3H), 3.61 (t, J = 8.0 Hz, 2H), 2.93 (t, J = 8.0 Hz, 2H), 2.44 (s, 3H), 2.36 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 159.7, 145.0, 139.4, 138.7, 134.5, 132.3, 129.9, 129.2, 127.5, 121.1, 118.9, 114.4, 112.4, 81.6, 73.4, 72.9, 59.1, 55.1, 52.7, 34.4, 21.7, 21.6; IR (KBr) $\nu$ 2837, 2235, 2154, 1580, 1370, 1265, 1174, 1030, 771, 680, 547 cm$^{-1}$; HRMS-(ESI) (m/z): [M+Na]$^+$ calcd for C$_{27}$H$_{25}$NNaO$_3$S, 466.1447; found 466.1448.

N-(3-methoxyphenethyl)-N-(phenylbuta-1,3-diyn-1-yl)benzenesulfonamide (1u)
Compound **1u** was obtained according to the general procedure A outlined above as a yellow solid (510 mg, 82%); \( R_f = 0.50 \) (petroleum ether : ethyl acetate = 5 : 1); mp: 113-115 °C; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 7.85-7.83 (m, 2H), 7.65-7.61 (m, 1H), 7.53-7.47 (m, 4H), 7.36-7.28 (m, 3H), 7.17 (t, \( J = 8.0 \) Hz, 1H), 6.76-6.73 (m, 2H), 6.69 (t, \( J = 2.0 \) Hz, 1H), 3.75 (s, 3H), 3.63 (t, \( J = 7.6 \) Hz, 2H), 2.92 (t, \( J = 8.0 \) Hz, 2H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \) 159.6, 138.4, 137.3, 133.8, 132.3, 129.6, 129.3, 129.0, 128.3, 127.4, 121.8, 121.0, 114.4, 112.3, 81.3, 73.5, 73.4, 59.0, 55.0, 52.6, 34.3; IR (KBr) \( \nu \) 2949, 2837, 2224, 2151, 1612, 1492, 1258, 1044, 887, 733, 694, 603, 452 cm\(^{-1}\); HRMS-(ESI) (m/z): \([\text{M+Na}]^+\) calcd for C\(_{25}\)H\(_{21}\)NNaO\(_3\)S, 438.1134; found 438.1134.

![Structural Diagram](image)

**N-(3-methoxyphenethyl)-N-(phenylhexa-1,3,5-triyn-1-yl)methanesulfonamide (1v)**

Compound **1v** was obtained according to the general procedure A outlined above as a yellow oil (306 mg, 51%); \( R_f = 0.40 \) (petroleum ether : ethyl acetate = 5 : 1); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 7.52 (d, \( J = 7.2 \) Hz, 2H), 7.38 (d, \( J = 7.2 \) Hz, 1H), 7.33 (t, \( J = 7.2 \) Hz, 2H), 7.27-7.23 (m, 1H), 6.86 (d, \( J = 7.6 \) Hz, 1H), 6.81 (d, \( J = 6.4 \) Hz, 2H), 3.81 (s, 3H), 3.80 (t, \( J = 7.2 \) Hz, 2H), 3.01 (t, \( J = 7.2 \) Hz, 2H), 2.70 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \) 159.9, 138.6, 132.9, 129.8, 129.6, 128.5, 121.3, 121.0, 114.7, 112.7, 79.0, 74.4, 69.9, 67.5, 65.8, 61.3, 55.2, 52.7, 39.2, 34.4; IR (KBr) \( \nu \) 2939, 2368, 2200, 1688, 1366, 1261, 1167, 957, 757, 687, 505 cm\(^{-1}\); HRMS-(ESI) (m/z): \([\text{M+Na}]^+\) calcd for C\(_{22}\)H\(_{19}\)NNaO\(_3\)S, 400.0978; found 400.0968.
N-phenethyl-N-(phenylbuta-1,3-diyn-1-yl)methanesulfonamide (1w)

Compound 1w was obtained according to the general procedure A outlined above as a yellow oil (363 mg, 75%); $R_f = 0.50$ (petroleum ether : ethyl acetate = 3 : 1); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.51-7.49 (m, 2H), 7.36-7.25 (m, 8H), 3.79 (t, $J = 7.2$ Hz, 2H), 3.04 (t, $J = 7.2$ Hz, 2H), 2.65 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 137.3, 132.3, 129.10, 129.05, 128.7, 128.4, 127.1, 121.8, 81.9, 73.2, 72.7, 59.6, 52.7, 38.8, 34.3; IR (KBr) $\nu$ 3303, 3016, 2932, 2228, 2161, 823, 753, 687 cm$^{-1}$; HRMS-(ESI) ($m/z$): [M+Na]$^+$ calcd for C$_{19}$H$_{17}$NNaO$_2$S, 346.0872; found 346.0872.

N-(3-methoxyphenethyl)-N-(thiophen-3-ybuta-1,3-diyn-1-yl)methanesulfonamide (1x)

Compound 1x was obtained according to the general procedure A outlined above as a yellow solid (340 mg, 63%); $R_f = 0.40$ (petroleum ether : ethyl acetate = 5 : 1), mp: 155-158 °C; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.56 (dd, $J_1 = 2.8$ Hz, $J_2 = 1.2$ Hz, 1H), 7.28-7.25 (m, 1H), 7.25-7.22 (m, 1H), 7.15 (dd, $J_1 = 5.2$ Hz, $J_2 = 1.2$ Hz, 1H), 6.86 (d, $J = 7.6$ Hz, 1H), 6.82-6.78 (m, 2H), 3.80 (s, 3H), 3.78 (t, $J = 7.2$ Hz, 2H), 3.02 (t, $J = 7.2$ Hz, 2H), 2.72 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 159.9, 138.8, 131.2, 130.1, 129.8, 125.6, 121.4, 120.9, 114.7, 112.6, 76.9 , 72.8, 72.6, 59.7, 55.2, 52.7, 38.9, 34.4; IR (KBr) $\nu$ 2911,
2224, 2154, 1597, 1513, 1366, 1223, 1167, 964, 834, 767, 515 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C₁₈H₁₇NNaO₃S₂, 382.0542; found 382.0542.

N-(3-methoxyphenethyl)-N-(octa-1,3-diyn-1-yl) methanesulfonamide (1y)

Compound 1y was obtained according to the general procedure A outlined above as a yellow oil (370 mg, 74%); R_f = 0.50 (petroleum ether : ethyl acetate = 5 : 1); ¹H NMR (400 MHz, CDCl₃) δ 7.23 (t, J = 7.6 Hz, 1H), 6.85 (d, J = 7.6 Hz, 1H), 6.80-6.78 (m, 2H), 3.81 (s, 3H), 3.74 (t, J = 7.2 Hz, 2H), 2.99 (t, J = 7.2 Hz, 2H), 2.71 (s, 3H), 2.34 (t, J = 7.2 Hz, 2H), 1.59-1.51 (m, 2H), 1.48-1.41 (m, 2H), 0.93 (t, J = 7.2 Hz, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 159.8, 138.9, 129.7, 121.3, 114.7, 112.6, 84.8, 66.0, 64.1, 60.0, 55.2, 52.5, 38.7, 34.4, 30.3, 21.9, 19.2, 13.5; IR (KBr) ν 3005, 2364, 2168, 1622, 1405, 1160, 960, 624, 477 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C₁₈H₂₃NNaO₃S, 356.1291; found 356.1292.

N-(5,5-dimethylhexa-1,3-diyn-1-yl)-N-(3-methoxyphenethyl)methanesulfonamide (1z)

Compound 1z was obtained according to the general procedure A outlined above as a yellow oil (275 mg, 55%); R_f = 0.50 (petroleum ether : ethyl acetate = 5 : 1); ¹H NMR (400 MHz, CDCl₃) δ 7.23 (t, J = 8.0 Hz, 1H), 6.85 (d, J = 7.2 Hz, 1H), 6.79 (d, J = 10.0 Hz, 2H), 3.80 (s, 3H), 3.73 (t, J = 7.2 Hz, 2H), 2.99 (t, J = 7.2 Hz, 2H), 2.71 (s, 3H), 1.27
(s, 9H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 159.8, 138.9, 129.7, 121.3, 114.7, 112.5, 92.0, 67.2, 62.8, 59.6, 55.2, 52.5, 38.7, 34.4, 30.5, 28.2; IR (KBr) v 2970, 2252, 2154, 1604, 1359, 1265, 1163, 1044, 767, 501 cm$^{-1}$; [M+Na]$^+$ calcd for C$_{18}$H$_{23}$NNaO$_3$S, 356.1291; found 356.1288.

N-(cyclopropylbuta-1,3-diyn-1-yl)-N-(3-methoxyphenethyl)methanesulfonamide (1aa)

Compound 1aa was obtained according to the general procedure A outlined above as a yellow solid (328 mg, 69%); $R_f = 0.40$ (petroleum ether : ethyl acetate = 5 : 1), mp: 118-120 °C; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.23 (t, $J = 8.0$ Hz, 1H), 6.84 (d, $J = 7.6$ Hz, 1H), 6.80-6.78 (m, 2H), 3.81 (s, 3H), 3.73 (t, $J = 7.2$ Hz, 2H), 2.99 (t, $J = 7.2$ Hz, 2H), 2.70 (s, 3H), 1.42-1.35 (m, 1H), 0.87-0.85 (m, 2H), 0.83-0.80 (m, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 159.8, 138.9, 129.7, 121.3, 114.7, 112.5, 88.1, 65.7, 60.4, 59.6, 55.2, 52.5, 38.7, 34.3, 9.0, 0.3; IR (KBr) v 2939, 2833, 2343, 2238, 2158, 1615, 1580, 1492, 1398, 1254, 1156, 1068, 943, 747, 687, 634, 515, 463 cm$^{-1}$; HRMS-(ESI) ($m/z$): [M+Na]$^+$ calcd for C$_{17}$H$_{19}$NNaO$_3$S, 340.0978; found 340.0979.

N-(3,4-dimethoxyphenethyl)-N-(5-hydroxyhexa-1,3-diyn-1-yl)methanesulfonamide (1ab)
Compound 1ab was obtained according to the general procedure A outlined above as a yellow oil (430 mg, 85%); Rf = 0.3 (petroleum ether : ethyl acetate = 2 : 1); 1H NMR (400 MHz, CDCl3) δ 6.82-6.77 (m, 3H), 4.38 (s, 2H), 3.88 (s, 3H), 3.84 (s, 3H), 3.74 (t, J = 7.2 Hz, 2H), 2.95 (t, J = 7.2 Hz, 2H), 2.71 (s, 3H); 13C NMR (100 MHz, CDCl3) δ 148.8, 147.8, 129.4, 121.0, 112.0, 111.2, 81.5, 69.8, 69.1, 59.0, 55.7, 52.5, 51.1, 38.7, 33.7; IR (KBr) ν 2914, 2245, 1643, 1517, 1363, 1160, 1023, 757, 526 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C16H19NNaO5S, 360.0876; found 360.0873.

**N-(3,4-dimethoxyphenethyl)-N-(6-hydroxyhexa-1,3-diyn-1-yl)methanesulfonamide (I)**

Compound I was obtained according to the general procedure A outlined above as a yellow oil (253 mg, 50%); Rf = 0.20 (petroleum ether : ethyl acetate = 1 : 1); 1H NMR (400 MHz, CDCl3) δ 6.83-6.79 (m, 3H), 3.88 (s, 3H), 3.84 (s, 3H), 3.75 (t, J = 6.4 Hz, 2H), 3.71 (t, J = 7.2 Hz, 2H), 2.94 (t, J = 7.2 Hz, 2H), 2.74 (s, 3H), 2.60 (t, J = 6.4 Hz, 2H); 13C NMR (100 MHz, CDCl3) δ 150.0, 148.0, 129.6, 121.1, 112.2, 111.3, 81.2, 66.7, 65.8, 60.6, 59.6, 55.8, 52.6, 38.8, 33.9, 23.9; IR (KBr) ν 2932, 2256, 2172, 1643, 1517, 1359, 1261, 1170, 1026, 960, 771, 536 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C17H21NNaO5S, 374.1033; found 374.1033.

**6-(N-(3,4-dimethoxyphenethyl)methylsulfonamido)hexa-3,5-diyn-1-yl acetate (1ac)**

A solution of I (425 mg, 1.26 mmol) in DCM (15 mL) at 0 °C was added Et3N (0.70 mL, 5.0 mmol). Then acetic anhydride (257 mg, 2.52 mmol) was added drop-wise via syringe at this temperature. The mixture was allowed to warm up to room temperature and stirred
for 7 h. The reaction was diluted with DCM (20 mL) and water (20 mL), the organic layer was separated and the aqueous layer was extracted with DCM (3 × 20 mL). The combined organic layers were washed with brine, dried over anhydrous Na₂SO₄ and concentrated in vacuo to furnish the product as a yellow oil (255 mg, 59%); Rₜ = 0.35 (petroleum ether : ethyl acetate = 1 : 1); ¹H NMR (400 MHz, CDCl₃) δ 6.84-6.79 (m, 3H), 4.18 (t, J = 6.8 Hz, 2H), 3.88 (s, 3H), 3.85 (s, 3H), 3.72 (t, J = 6.8 Hz, 2H), 2.96 (t, J = 6.8 Hz, 2H), 2.73 (s, 3H), 2.69 (t, J = 6.8 Hz, 2H), 2.09 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 170.5, 148.8, 147.9, 129.5, 120.9, 112.0, 111.2, 79.8, 66.8, 65.5, 61.5, 59.4, 55.7, 52.4, 38.6, 33.7, 20.6, 19.8; IR (KBr) ν 3170, 2537, 2252, 2165, 1739, 1517, 1400, 1240, 1026 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C₁₉H₂₃NNaO₆S, 416.1138; found 416.1138.⁷

N-(2-(7-methoxynaphthalen-1-yl)ethyl)-N-(phenylbuta-1,3-diyn-1-yl)methanesulfonamide (1ad)

Compound 1ad was obtained according to the general procedure B outlined above as a yellow solid (210 mg, 70%); Rₜ = 0.40 (petroleum ether : ethyl acetate = 5 : 1), mp: 105-108 °C; ¹H NMR (400 MHz, CDCl₃) δ 7.76 (d, J = 8.8 Hz, 1H), 7.70 (d, J = 8.0 Hz, 1H), 7.51 (d, J = 7.2 Hz, 2H), 7.41-7.25 (m, 6H), 7.18-7.16 (m, 1H), 3.99 (s, 3H), 3.87 (d, J = 8.0 Hz, 2H), 3.51 (d, J = 8.0 Hz, 2H), 2.85 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 158.3, 132.8, 132.4, 131.5, 130.4, 129.24, 129.18, 128.5, 128.0, 127.7, 123.2, 121.8, 118.8, 101.4, 81.9, 73.2, 73.1, 59.3, 55.4, 52.3, 39.3, 32.6; IR (KBr) ν 2921, 2361, 1468, 1307,
N-(phenylbuta-1,3-diyn-1-yl)-N-(2-(thiophen-2-yl)ethyl)methanesulfonamide (1ae)

Compound 1ae was obtained according to the general procedure B outlined above as a yellow solid (576 mg, 87%); Rf = 0.50 (petroleum ether : ethyl acetate = 5 : 1), mp: 90-93 °C; ¹H NMR (400 MHz, CDCl₃) δ 7.52-7.49 (m, 2H), 7.38-7.30 (m, 3H), 7.21-7.19 (m, 1H), 6.98-6.96 (m, 2H), 3.82 (t, J = 7.2 Hz, 2H), 3.28 (t, J = 7.2 Hz, 2H), 2.82 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 139.1, 132.4, 129.1, 128.4, 127.2, 126.5, 124.6, 121.8, 81.8, 73.1, 72.4, 59.8, 52.7, 39.0, 28.5; IR (KBr) ν 2925, 2364, 2221, 1594, 1493, 1366, 1156, 964, 761, 512 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C₂₄H₂₁NNaO₃S, 426.1134; found 426.1135.

N-(2-(furan-2-yl)ethyl)-N-(phenylbuta-1,3-diyn-1-yl)methanesulfonamide (1af)

Compound 1af was obtained according to the general procedure B outlined above as a yellow oil (253 mg, 67%); Rf = 0.40 (petroleum ether : ethyl acetate = 5 : 1); ¹H NMR (400 MHz, CDCl₃) δ 7.50-7.47 (m, 2H), 7.37-7.30 (m, 4H), 6.33-6.31 (m, 1H), 6.22-6.21 (m, 1H), 3.82 (t, J = 6.8 Hz, 2H), 3.09 (t, J = 6.8 Hz, 2H), 2.89 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 150.8, 141.8, 132.3, 129.1, 128.4, 121.8, 110.6, 107.8, 81.7, 73.1, 72.4, 59.3, 49.9, 39.1, 27.0; IR (KBr) ν 3026, 2231, 1769, 1493, 1317, 1146, 1076, 970, 764,
522 cm\(^{-1}\); HRMS-(ESI) \((m/z)\): [M+Na]\(^+\) calcd for C\(_{17}\)H\(_{15}\)NNaO\(_3\)S, 336.0665; found 336.0664.

N-(2-(1-methyl-1H-indol-2-yl)ethyl)-N-(phenylbuta-1,3-diyn-1-yl)methanesulfonamide (1ag)

Compound 1ag was obtained according to the general procedure B outlined above as a yellow oil (328 mg, 67%); \(R_f = 0.40\) (petroleum ether : ethyl acetate = 5 : 1); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.54 (d, \(J = 7.6\) Hz, 1H), 7.50-7.48 (m, 2H), 7.38-7.29 (m, 4H), 7.21-7.17 (m, 1H), 7.10-7.06 (m, 1H), 6.39 (s, 1H), 3.86 (t, \(J = 7.2\) Hz, 2H), 3.71 (s, 3H), 3.22 (t, \(J = 7.2\) Hz, 2H), 2.81 (s, 3H); \(^1^3\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 137.5, 135.3, 132.4, 129.2, 128.4, 127.5, 121.7, 121.4, 120.1, 119.7, 109.1, 100.9, 81.9, 73.0, 72.6, 59.6, 50.7, 39.2, 29.6, 26.0; IR (KBr) \(\nu\) 2983, 2883, 2399, 2207, 1482, 1388, 1179, 991, 724, 512 cm\(^{-1}\); HRMS-(ESI) \((m/z)\): [M+Na]\(^+\) calcd for C\(_{22}\)H\(_{20}\)N\(_2\)NaO\(_2\)S, 399.1138; found 399.1138.

N-(2-(1-methyl-1H-indol-3-yl)ethyl)-N-(phenylbuta-1,3-diyn-1-yl)methanesulfonamide (1ah)

Compound 1ah was obtained according to the general procedure B outlined above as a yellow oil (563 mg, 83%); \(R_f = 0.40\) (petroleum ether : ethyl acetate = 5 : 1); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.55 (d, \(J = 8.0\) Hz, 1H), 7.42-7.28 (m, 6H), 7.19 (t, \(J = 7.6\) Hz, 1H), 7.09 (t, \(J = 7.2\) Hz, 1H), 6.40 (s, 1H), 3.88 (t, \(J = 7.2\) Hz, 2H), 3.73 (s, 3H), 3.24 (t, \(J = \)
7.2 Hz, 2H), 2.82 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 137.5, 135.33, 135.28, 133.6, 128.8, 127.5, 121.5, 120.3, 120.2, 119.7, 109.1, 101.0, 80.8, 74.0, 73.1, 59.5, 50.7, 39.3, 29.7, 26.1; IR (KBr) $\nu$ 2983, 2883, 2399, 2207, 1482, 1388, 1179, 991, 724, 512, 463 cm$^{-1}$; HRMS-(ESI) ($m/z$): [M+Na]$^+$ calcd for C$_{22}$H$_{20}$N$_2$NaO$_2$S, 399.1138; found 399.1137.
General procedure for the synthesis of Pyrrolo [2,1-a] isoquinolines

A dry Schlenk tube was charged with gold catalyst (5 mol %) and evacuated and back filled with argon. To this tube was added the solution of 1,3-diynamide (0.15 mmol) in DCM (1 mL). The reaction mixture was stirred at 30 °C or 40 °C and the progress of the reaction was monitored by TLC. The reaction typically took 4 h. Upon completion, the mixture was then quenched with small amount of water, diluted with DCM, washed with brine, dried over anhydrous Na₂SO₄ and concentrated in vacuo. The residue was purified by chromatography on silica gel (eluent : petroleum ether/DCM) to afford the desired pyrrolo [2, 1-a] isoquinolines.

8-methoxy-1-(methylsulfonyl)-3-phenyl-5,6-dihydropyrrolo[2,1-a]isoquinoline (2a)

Compound 2a was obtained as a white solid, 45.8 mg, in 87% yield; Rf = 0.50 (petroleum ether : ethyl acetate = 3 : 1); mp: 212-214 °C; ¹H NMR (400 MHz, CDCl₃) δ 8.44 (d, J = 8.8 Hz, 1H), 7.47-7.43 (m, 2H), 7.39-7.36 (m, 3H), 6.92 (dd, J₁ = 8.8 Hz, J₂ = 2.8 Hz, 1H), 6.81 (d, J = 2.4 Hz, 1H), 6.77 (s, 1H), 4.08 (t, J = 6.4 Hz, 2H), 3.85 (s, 3H), 3.10 (s, 3H), 2.96 (t, J = 6.4 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 159.4, 135.4, 132.6, 130.9, 130.2, 128.9, 128.62, 128.57, 127.9, 120.2, 119.1, 113.7, 112.7, 110.9, 55.3, 43.8, 42.2, 30.0; IR (KBr) v 2932, 2231, 2154, 1601, 1493, 1370, 1265, 1170, 964, 764, 694, 512 cm⁻¹; HRMS-(ESI) (m/z): [M+Na⁺] calcd for C₂₀H₁₉NNaO₃S, 376.0978; found 376.0976.
8-methoxy-1-(methylsulfonyl)-3-(p-tolyl)-5,6-dihydropyrrolo[2,1-a]isoquinoline (2b)

Compound 2b was obtained as a white solid, 46.0 mg, in 83% yield; Rf = 0.60 (petroleum ether: ethyl acetate = 3:1); mp: 216-218 °C; ¹H NMR (400 MHz, CDCl₃) δ 8.44 (d, J = 8.8 Hz, 1H), 7.26 (appeared as a singlet, 4H), 6.92 (dd, J₁ = 8.8 Hz, J₂ = 2.0 Hz, 1H), 6.81 (s, 1H), 6.74 (s, 1H), 4.07 (t, J = 6.4 Hz, 2H), 3.85 (s, 3H), 3.10 (s, 3H), 2.95 (t, J = 6.4 Hz, 2H), 2.41 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 162.5 (d, J_C-F = 123.5 Hz), 159.4, 138.0, 135.4, 132.8, 130.0, 129.4, 128.9, 128.6, 128.0, 120.3, 119.1, 113.8, 112.7, 110.6, 55.3, 43.9, 42.2, 30.0, 21.2; IR (KBr) ν 2837, 2361, 1902, 1608, 1496, 1394, 1132, 946, 827, 767, 543 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calc for C₂₁H₂₁NNaO₃S, 390.1134; found 390.1129.

3-(4-fluorophenyl)-8-methoxy-1-(methylsulfonyl)-5,6-dihydropyrrolo[2,1-a]isoquinoline (2c)

Compound 2c was obtained as a white solid, 49.5 mg, in 89% yield; Rf = 0.50 (petroleum ether: ethyl acetate = 3:1); mp: 211-213 °C; ¹H NMR (400 MHz, CDCl₃) δ 8.44 (d, J = 8.4 Hz, 1H), 7.34 (dd, J₁ = 8.0 Hz, J₂ = 5.6 Hz, 2H), 7.14 (t, J = 8.4 Hz, 2H), 6.93 (dd, J₁ = 8.4 Hz, J₂ = 2.0 Hz, 1H), 6.82 (s, 1H), 6.74 (s, 1H), 4.04 (t, J = 6.4 Hz, 2H), 3.85 (s, 3H), 2.97 (t, J = 6.4 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 162.5 (d, J_C-F = 123.5 Hz), 159.5, 135.3, 131.6, 130.8 (d, J_C-F = 8.2 Hz), 130.2, 128.7, 127.1 (d, J_C-F = 3.3 Hz), 120.1, 119.1, 115.7 (d, J_C-F = 21.6 Hz), 113.81, 112.7, 111.0, 55.3, 43.8, 42.1,
30.0; $^{19}$F NMR (376 MHz, CDCl$_3$) $\delta$ -113.2; IR (KBr) $\nu$ 2921, 2368, 1611, 1496, 1391, 1135, 953, 837, 767, 655, 526, 480 cm$^{-1}$; HRMS-(ESI) ($m/z$): [M+Na]$^+$ calcd for C$_{20}$H$_{18}$FNNaO$_3$S, 394.0884; found 394.0887.

3-(4-chlorophenyl)-8-methoxy-1-(methylsulfonyl)-5,6-dihydropyrrolo[2,1-a]isoquinoline (2d)

Compound 2d was obtained as a white solid, 41.8 mg, in 72% yield; $R_f$ = 0.80 (petroleum ether : ethyl acetate = 3 : 1); mp: 211-213 $^\circ$C; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 8.45 (d, $J$ = 8.8 Hz, 1H), 7.43 (d, $J$ = 8.4 Hz, 2H), 7.31 (d, $J$ = 8.4 Hz, 2H), 6.93 (dd, $J_1$ = 8.8 Hz, $J_2$ = 2.8 Hz, 1H), 6.82 (d, $J$ = 2.4 Hz, 1H), 6.78 (s, 1H), 4.06 (t, $J$ = 6.4 Hz, 2H), 3.86 (s, 3H), 3.10 (s, 3H), 2.97 (t, $J$ = 6.4 Hz, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 159.5, 135.3, 134.0, 131.4, 130.5, 130.1, 129.3, 128.9, 128.6, 120.0, 119.3, 113.8, 112.7, 111.2, 55.3, 43.8, 42.2, 29.9; IR (KBr) $\nu$ 3009, 2364, 1615, 1394, 1296, 1146, 816, 617, 484 cm$^{-1}$; HRMS-(ESI) ($m/z$): [M+Na]$^+$ calcd for C$_{20}$H$_{18}$ClNNaO$_3$S, 410.0588; found 410.0588.

3-(2-chlorophenyl)-8-methoxy-1-(methylsulfonyl)-5,6-dihydropyrrolo[2,1-a]isoquinoline (2e)

Compound 2e was obtained as a white solid, 37.2 mg, in 64% yield; $R_f$ = 0.70 (petroleum ether : ethyl acetate = 3 : 1); mp: 195-197 $^\circ$C; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 8.47 (d, $J$ = 8.8 Hz, 1H), 7.50 (d, $J$ = 7.2 Hz, 1H), 7.40-7.35 (m, 3H), 6.93 (dd, $J_1$ = 8.4 Hz, $J_2$ = 2.4 Hz, 2H), 6.85 (d, $J$ = 2.4 Hz, 1H), 6.78 (s, 1H), 4.06 (t, $J$ = 6.4 Hz, 2H), 3.86 (s, 3H), 3.10 (s, 3H), 2.97 (t, $J$ = 6.4 Hz, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 159.5, 135.3, 134.0, 131.4, 130.5, 130.1, 129.3, 128.9, 128.6, 120.0, 119.3, 113.8, 112.7, 111.2, 55.3, 43.8, 42.2, 29.9; IR (KBr) $\nu$ 3009, 2364, 1615, 1394, 1296, 1146, 816, 617, 484 cm$^{-1}$; HRMS-(ESI) ($m/z$): [M+Na]$^+$ calcd for C$_{20}$H$_{18}$ClNNaO$_3$S, 410.0588; found 410.0588.
Hz, 1H), 6.81 (d, \( J = 2.4 \) Hz, 1H), 6.72 (s, 1H), 3.85 (appeared as a singlet, 5H), 3.12 (s, 3H), 2.98 (t, \( J = 6.4 \) Hz, 2H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \) 159.4, 135.4, 135.0, 132.9, 130.24, 130.25, 130.0, 129.7, 129.4, 128.7, 127.0, 120.1, 118.7, 113.9, 112.7, 112.0, 55.3, 43.9, 42.4, 29.8; IR (KBr) \( \nu \) 3117, 2960, 2837, 1604, 1520, 1468, 1293, 1237, 1132, 1030, 981, 844, 760, 554 cm\(^{-1}\); HRMS-(ESI) (m/z): [M+Na]\(^+\) calcd for C\(_{20}\)H\(_{18}\)ClNNaO\(_3\)S, 410.0588; found 410.0588.

8,9-dimethoxy-1-(methylsulfonyl)-3-phenyl-5,6-dihydropyrrolo[2,1-a]isoquinoline (2f)

Compound 2f was obtained as a white solid, 48.8 mg, in 85% yield; \( R_f = 0.60 \) (petroleum ether : ethyl acetate = 3 : 1); mp: 224-226 °C; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 8.31 (s, 1H), 7.48-7.44 (m, 2H), 7.41-7.38 (m, 3H), 6.78 (d, \( J = 1.6 \) Hz, 2H), 4.10 (t, \( J = 6.4 \) Hz, 2H), 3.98 (s, 3H), 3.93 (s, 3H), 3.10 (s, 3H), 2.94 (t, \( J = 6.4 \) Hz, 2H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \) 148.7, 148.3, 132.7, 130.9, 130.2, 129.0, 128.7, 128.0, 126.2, 120.0, 119.2, 111.1, 110.8, 110.4, 56.2, 55.9, 44.0, 42.5, 29.2; IR (KBr) \( \nu \) 2834, 2364, 1615, 1394, 1132, 890, 768, 610, 463 cm\(^{-1}\); HRMS-(ESI) (m/z): [M+Na]\(^+\) calcd for C\(_{21}\)H\(_{21}\)NNaO\(_3\)S, 406.1083; found 406.1083.

3-(4-fluorophenyl)-8,9-dimethoxy-1-(methylsulfonyl)-5,6-dihydropyrrolo[2,1-a]isoquinoline (2g)
Compound 2g was obtained as a white solid, 42.1 mg, in 70% yield; R_f = 0.60 (petroleum ether : ethyl acetate = 3 : 1); mp: 228-230 °C; ^1H NMR (400 MHz, CDCl_3) δ 8.30 (s, 1H), 7.35 (dd, J_1 = 8.4 Hz, J_2 = 5.6 Hz, 2H), 7.15 (t, J = 8.8 Hz, 2H), 6.76 (d, J = 14.0 Hz, 2H), 4.05 (t, J = 6.8 Hz, 2H), 3.97 (s, 3H), 3.93 (s, 3H), 3.10 (s, 3H), 2.95 (t, J = 6.8 Hz, 2H); ^13C NMR (100 MHz, CDCl_3) δ 162.6 (d, J_C-F = 246.9 Hz), 148.8, 148.4, 131.6, 130.8 (d, J_C-F = 8.2 Hz), 130.2, 127.0 (d, J_C-F = 3.4 Hz), 126.1, 119.9, 119.2, 115.8 (d, J_C-F = 21.6 Hz), 111.1, 110.9, 110.4, 56.2, 56.0, 44.0, 42.4, 29.2; ^19F NMR (376 MHz, CDCl_3) δ -113.2; IR (KBr) ν 2837, 2361, 1615, 1499, 1394, 1265, 995, 837, 795, 557, 456 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]^+ calcd for C_{21}H_{20}FNNaO_4S, 424.0989; found 424.0988.

8,9-dimethoxy-3-(4-methoxyphenyl)-1-(methylsulfonyl)-5,6-dihydropyrrolo[2,1-a]isoquinoline (2h)

Compound 2h was obtained as a white solid, 34.1 mg, in 55% yield; R_f = 0.45 (petroleum ether : ethyl acetate = 3 : 1); mp: 243-245 °C; ^1H NMR (400 MHz, CDCl_3) δ 8.29 (s, 1H), 7.30 (t, J = 8.4 Hz, 2H), 6.77 (s, 1H), 6.71 (s, 1H), 4.05 (t, J = 6.4 Hz, 2H), 3.97 (s, 3H), 3.93 (s, 3H), 3.86 (s, 3H), 3.10 (s, 3H), 2.93 (t, J = 6.4 Hz, 2H); ^13C NMR (100 MHz, CDCl_3) δ 159.5, 148.6, 148.3, 132.6, 130.3, 129.8, 126.1, 123.3, 120.1, 119.0, 114.1, 110.8, 110.5, 110.4, 56.2, 55.9, 55.4, 44.0, 42.3, 29.2; IR (KBr) ν 3137, 2923, 1549, 1499, 1499, 1402, 1278, 1127, 891, 806, 762, 550 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]^+ calcd for C_{22}H_{23}FNNaO_4S, 436.1189; found 436.1187.
3-(3-chlorophenyl)-8,9-dimethoxy-1-(methylsulfonyl)-5,6-dihydropyrrolo[2,1-a]isoquinoline (2i)

Compound 2i was obtained as a white solid, 45.7 mg, in 73% yield; Rf = 0.60 (petroleum ether : ethyl acetate = 3 : 1); mp: 213-215 °C; 'H NMR (400 MHz, CDCl3) δ 8.30 (s, 1H), 7.41-7.36 (m, 3H), 7.27 (d, J = 4.4 Hz, 1H), 6.79 (d, J = 6.4 Hz, 2H), 4.09 (t, J = 6.4 Hz, 2H), 3.97 (s, 3H), 3.94 (s, 3H), 3.09 (s, 3H), 2.96 (t, J = 6.4 Hz, 2H); 13C NMR (100 MHz, CDCl3) δ 148.9, 148.4, 134.6, 132.7, 131.2, 130.7, 130.0, 128.9, 128.1, 127.1, 126.1, 119.8, 119.5, 111.8, 110.8, 110.5, 56.3, 56.0, 44.0, 42.6, 29.2; IR (KBr) ν 3002, 2354, 1611, 1398, 1131, 1002, 557 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C21H20ClNNaO4S, 440.0694; found 440.0694.

8,9-dimethoxy-1-(methylsulfonyl)-3-(m-tolyl)-5,6-dihydropyrrolo[2,1-a]isoquinoline (2j)

Compound 2j was obtained as a white solid, 46.4 mg, in 78% yield; Rf = 0.60 (petroleum ether : ethyl acetate = 3 : 1); mp: 237-239 °C; 'H NMR (400 MHz, CDCl3) δ 8.30 (s, 1H), 7.34 (t, J = 8.0 Hz, 1H), 7.21-7.19 (m, 2H), 7.17 (d, J = 7.8 Hz, 1H), 6.78 (s, 1H), 6.76 (s, 1H), 4.09 (t, J = 7.2 Hz, 2H), 3.97 (s, 3H), 3.93 (s, 3H), 3.10 (s, 3H), 2.93 (t, J = 6.8 Hz, 2H), 2.41 (s, 3H); 13C NMR (100 MHz, CDCl3) δ 148.7, 148.4, 138.4, 129.7, 128.8, 128.5, 126.2, 126.0, 120.0, 119.1, 111.1, 110.8, 110.4, 56.2, 55.9, 44.0, 42.5, 29.2, 21.4;
IR (KBr) ν 3122, 1532, 1402, 1190, 1133, 983 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C₂₂H₂₃NNaO₄S, 420.1240; found 420.1241.

7,8-dimethoxy-1-(methylsulfonyl)-3-phenyl-5,6-dihydropyrrolo[2,1-a]isoquinoline (2k)

Compound 2k was obtained as a white solid, 50.6 mg, in 88% yield; Rᶠ = 0.75 (petroleum ether : ethyl acetate = 3 : 1); mp: 238-240 °C; ¹H NMR (400 MHz, CDCl₃) δ 8.25 (d, J = 8.8 Hz, 1H), 7.48-7.44 (m, 2H), 7.41-7.37 (m, 3H), 6.95 (d, J = 8.4 Hz, 1H), 6.78 (s, 1H), 4.07 (t, J = 6.4 Hz, 2H), 3.93 (s, 3H), 3.84 (s, 3H), 3.11 (s, 3H), 3.05 (t, J = 6.4 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 152.5, 145.5, 132.7, 130.9, 130.0, 128.9, 128.6, 127.92, 127.85, 123.4, 120.7, 119.3, 111.0, 110.9, 60.7, 55.7, 43.7, 42.1, 22.8; IR (KBr) ν 2924, 2851, 2357, 1601, 1489, 1272, 1139, 957, 806, 767, 694, 564, 449 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C₂₁H₂₁NNaO₄S, 406.1083; found 406.1084.

8,9,10-trimethoxy-1-(methylsulfonyl)-3-phenyl-5,6-dihydropyrrolo[2,1-a]isoquinoline (2l)

Compound 2l was obtained as a white solid, 50.2 mg, in 81% yield, Rᶠ = 0.40 (petroleum ether : ethyl acetate = 3 : 1); mp: 243-245 °C; ¹H NMR (400 MHz, CDCl₃) δ 7.47-7.40 (m, 4H), 7.39-7.37 (m, 1H), 6.78 (s, 1H), 6.59 (s, 1H), 4.00 (t, J = 6.0 Hz, 2H), 3.95 (s, 3H), 3.88 (s, 3H), 3.85 (s, 3H), 3.31 (s, 3H), 2.75 (t, J = 6.0 Hz, 2H); ¹³C NMR (100
MHz, CDCl₃) δ 153.6, 151.5, 140.9, 134.0, 131.9, 130.9, 128.9, 128.7, 128.6, 127.8, 121.3, 114.7, 110.3, 106.4, 61.3, 60.7, 56.1, 43.1, 42.4, 31.0; IR (KBr) ν 2930, 1599, 1484, 1420, 1293, 996, 846, 762, 550 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C₂₂H₂₃NNaO₅S, 436.1189; found 436.1191.

7,8,9-trimethoxy-1-(methylsulfonyl)-3-phenyl-5,6-dihydropyrrolo[2,1-a]isoquinoline (2m)

Compound 2m was obtained as a white solid, 21.1 mg, in 34% yield; Rₓ = 0.70 (petroleum ether : ethyl acetate = 3 : 1); mp: 259-261 °C; ¹H NMR (400 MHz, CDCl₃) δ 8.12 (s, 1H), 7.48-7.44 (m, 2H), 7.41-7.38 (m, 3H), 6.80 (s, 1H), 4.07 (t, J = 6.4 Hz, 2H), 3.95 (s, 3H), 3.94 (s, 3H), 3.89 (s, 3H), 3.12 (s, 3H), 2.97 (t, J = 6.4 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 152.7, 150.3, 142.0, 133.0, 130.8, 129.7, 129.0, 128.7, 128.1, 123.0, 120.0, 119.6, 111.4, 106.8, 61.1, 61.0, 56.3, 44.0, 42.4, 22.3; IR (KBr) ν 2921, 2858, 2368, 1720, 1601, 1461, 1293, 1139, 1111, 767, 561, 512 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C₂₂H₂₃NNaO₅S, 436.1189; found 436.1188.

9-(benzyloxy)-8-methoxy-1-(methylsulfonyl)-3-phenyl-5,6-dihydropyrrolo[2,1-a]isoquinoline (2n)

Compound 2n was obtained as a white solid, 47.5 mg, in 69% yield; Rₓ = 0.75 (petroleum ether : ethyl acetate = 3 : 1); mp: 262-264 °C; ¹H NMR (400 MHz, CDCl₃) δ 8.23 (s, 1H),
7.51 (d, J = 3.2 Hz, 2H), 7.45-7.42 (m, 2H), 7.39-7.34 (m, 5H), 7.28-7.26 (m, 1H), 6.79 (s, 1H), 6.73 (s, 1H), 5.32 (s, 2H), 4.05 (t, J = 6.4 Hz, 2H), 3.94 (s, 3H), 3.90 (t, J = 6.4 Hz, 2H), 2.77 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 149.2, 147.0, 137.0, 132.7, 130.9, 130.0, 128.9, 128.6, 128.4, 127.9, 127.6, 127.2, 126.5, 119.9, 119.3, 112.0, 111.3, 111.0, 70.1, 56.0, 43.4, 42.4, 29.2; IR (KBr) \(\nu\) 2921, 2851, 1527, 1494, 1293, 1270, 1133, 879, 759, 702, 550 cm\(^{-1}\); HRMS-(ESI) (m/z): [M+Na]\(^+\) calcd for C\(_{27}\)H\(_{25}\)NNaO\(_4\)S, 482.1397; found 482.1396.

8-(benzyloxy)-9-methoxy-1-(methylsulfonyl)-3-phenyl-5,6-dihydropyrrolo[2,1-a]isoquinoline (2o)

Compound 2o was obtained as a white solid, 42.0 mg, in 61% yield; \(R_f = 0.80\) (petroleum ether : ethyl acetate = 3 : 1); mp: 259-261 °C; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 8.31 (s, 1H), 7.47-7.32 (m, 10H), 6.78 (d, J = 6.0 Hz, 2H), 5.20 (s, 2H), 4.06 (t, J = 6.4 Hz, 2H), 3.98 (s, 3H), 3.10 (s, 3H), 2.87 (t, J = 6.4 Hz, 2H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 149.0, 147.8, 136.7, 132.8, 130.9, 130.2, 128.9, 128.64, 128.58, 128.0, 127.9, 127.2, 126.0, 120.5, 119.3, 113.3, 111.1, 110.8, 71.0, 56.3, 44.0, 42.5, 29.1; IR (KBr) \(\nu\) 2925, 1652, 1494, 1295, 1130, 803, 763, 697, 550 cm\(^{-1}\); HRMS-(ESI) (m/z): [M+Na]\(^+\) calcd for C\(_{27}\)H\(_{25}\)NNaO\(_4\)S, 482.1397; found 482.1393.
8-isopropoxy-9-methoxy-1-(methylsulfonyl)-3-phenyl-5,6-dihydropyrrolo[2,1-a]isoquinoline (2p)

Compound 2p was obtained as a white solid, 49.3 mg, in 80% yield; Rf = 0.60 (petroleum ether : ethyl acetate = 3 : 1); mp: 187-189 °C; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 8.28 (s, 1H), 7.46-7.43 (m, 2H), 7.43-7.36 (m, 3H), 6.78 (d, $J$ = 9.6 Hz, 2H), 4.60 (dt, $J_1$ = 12.0 Hz, $J_2$ = 6.0 Hz, 1H), 4.08 (t, $J$ = 6.4 Hz, 2H), 3.94 (s, 3H), 3.10 (s, 3H), 2.91 (t, $J$ = 6.4 Hz, 2H), 1.41 (d, $J$ = 6.0 Hz, 6H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 149.5, 147.0, 132.6, 130.9, 130.3, 128.9, 128.6, 127.9, 126.0, 120.1, 119.1, 114.7, 111.0, 110.9, 71.4, 56.2, 43.9, 42.5, 29.1, 22.0; IR (KBr) ν 3135, 3019, 2840, 1608, 1517, 1436, 1335, 1289, 1125, 887, 757, 690, 561, 515, 470 cm$^{-1}$; HRMS-(ESI) (m/z): [M+Na]$^+$ calcd for C$_{23}$H$_{25}$NNaO$_4$S, 434.1396; found 434.1395.

8-isopropoxy-9-methoxy-3-methyl-1-tosyl-5,6-dihydropyrrolo[2,1-a]isoquinoline (2q)

Compound 2q was obtained as a white solid, 37.0 mg, in 58% yield; Rf = 0.40 (petroleum ether : ethyl acetate = 3 : 1); mp: 209-211 °C; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 8.04 (s, 1H), 7.73 (d, $J$ = 8.0 Hz, 2H), 7.17 (d, $J$ = 8.0 Hz, 2H), 6.67 (s, 1H), 6.40 (s, 1H), 4.55-4.49 (m, 1H), 3.85-3.83 (m, 5H (O-CH$_3$ and N-CH$_2$ overlapped)), 2.85 (t, $J$ = 6.4 Hz, 2H), 2.33 (s, 3H), 2.21 (s, 3H), 1.35 (d, $J$ = 6.0 Hz, 6H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 149.1, 146.5, 142.8, 141.0, 130.0, 129.2, 127.3, 126.3, 124.9, 120.3, 117.2, 114.6, 111.4, 110.6, 71.3, 56.1, 41.1, 28.7, 22.0, 21.4, 11.8; IR (KBr) ν 3135, 3019, 2840, 1608, 1517, 1436, 1335, 1289, 1125, 887, 757, 690, 561, 515 cm$^{-1}$; HRMS-(ESI) (m/z): [M+Na]$^+$ calcd for C$_{24}$H$_{27}$NNaO$_4$S, 448.1553; found 448.1551.
1-(methylsulfonyl)-3-phenyl-5,6-dihydro-[1,3]dioxolo[4,5-g]pyrrolo[2,1-a]isoquinoline (2r)

Compound 2r was obtained as a white solid, 40.2 mg, in 73% yield; R$_f$ = 0.70 (petroleum ether : ethyl acetate = 3 : 1); mp: 251-253 °C; $^1$H NMR (400 MHz, CDCl$_3$) δ 8.11 (s, 1H), 7.44-7.36 (m, 5H), 6.76 (d, $J = 11.2$ Hz, 2H), 5.99 (s, 2H), 4.05 (t, $J = 7.2$ Hz, 2H), 3.11 (s, 3H), 2.88 (t, $J = 7.2$ Hz, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 147.4, 147.2, 132.7, 130.8, 130.0, 128.9, 128.6, 128.1, 128.0, 121.0, 119.5, 111.0, 108.3, 107.6, 101.3, 44.1, 42.3, 29.8; IR (KBr) ν 3127, 1611, 1489, 1400, 1288, 1133, 781, 704 cm$^{-1}$; HRMS-(ESI) (m/z): [M+Na]$^+$ calcd for C$_{20}$H$_{17}$NNaO$_4$S, 390.0770; found 390.0764.

8-methoxy-3-phenyl-1-tosyl-5,6-dihydropyrrolo[2,1-a]isoquinoline (2s)

Compound 2s was obtained as a white solid, 47.0 mg, in 73% yield; R$_f$ = 0.40 (petroleum ether : ethyl acetate = 3 : 1); mp: 218-220 °C; $^1$H NMR (400 MHz, CDCl$_3$) δ 8.32 (d, $J = 8.8$ Hz, 1H), 7.84 (d, $J = 8.0$ Hz, 2H), 7.46-7.42 (m, 2H), 7.39-7.36 (m, 3H), 7.23 (d, $J = 8.0$ Hz, 2H), 6.85 (dd, $J_1 = 8.8$ Hz, $J_2 = 2.8$ Hz, 1H), 6.75 (s, 1H), 6.72 (d, $J = 2.4$ Hz, 1H), 4.04 (t, $J = 6.4$ Hz, 2H), 3.83 (s, 3H), 2.88 (t, $J = 6.4$ Hz, 2H), 2.37 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ 159.3, 143.1, 140.5, 135.1, 132.7, 131.1, 130.9, 129.40, 129.35, 129.0, 128.6, 127.9, 126.9, 120.1, 119.2, 113.4, 112.2, 111.8, 55.3, 42.3, 30.0, 21.5; IR
8-methoxy-3-(p-tolyl)-1-tosyl-5,6-dihydropyrrolo[2,1-a]isoquinoline (2t)

Compound 2t was obtained as a white solid, 42.9 mg, in 66% yield; R_f = 0.40 (petroleum ether : ethyl acetate = 3 : 1); mp: 223-225 °C; ^1H NMR (400 MHz, CDCl_3) δ 8.31 (d, J = 8.8 Hz, 1H), 7.83 (d, J = 8.0 Hz, 2H), 7.26-7.21 (m, 6H), 6.84 (dd, J_1 = 8.8 Hz, J_2 = 2.4 Hz, 1H), 6.71 (s, 2H), 4.01 (t, J = 6.4 Hz, 2H), 3.82 (s, 3H), 2.86 (t, J = 6.4 Hz, 2H), 2.40 (s, 3H), 2.36 (s, 3H); ^13C NMR (100 MHz, CDCl_3) δ 159.2, 143.0, 140.5, 137.9, 135.1, 132.8, 130.7, 129.4, 129.3, 128.9, 128.1, 126.9, 120.2, 119.0, 113.3, 112.1, 111.5, 55.3, 42.2, 30.0, 21.5, 21.2; IR (KBr) v 2935, 1611, 1496, 1244, 1146, 1030, 830, 683, 540 cm^{-1}; HRMS-(ESI) (m/z): [M+Na]^+ calcd for C_{26}H_{23}NNaO_3S, 452.1291; found 452.1291.

8-methoxy-3-phenyl-1-(phenylsulfonyl)-5,6-dihydropyrrolo[2,1-a]isoquinoline (2u)

Compound 2u was obtained as a white solid, 51.7 mg, in 83% yield; R_f = 0.40 (petroleum ether : ethyl acetate = 3 : 1); mp: 220-222 °C; ^1H NMR (400 MHz, CDCl_3) δ 8.30 (d, J = 8.8 Hz, 1H), 7.96-7.94 (m, 2H), 7.50-7.43 (m, 5H), 7.39-7.36 (m, 3H), 6.84 (dd, J_1 = 8.8 Hz, J_2 = 2.8 Hz, 1H), 6.78 (s, 1H), 6.72 (d, J = 2.4 Hz, 1H), 4.04 (t, J = 8.0 Hz, 2H), 3.82 (s, 3H), 2.88 (t, J = 8.0 Hz, 2H); ^13C NMR (100 MHz, CDCl_3) δ 159.4, 143.4, 135.2, 132.9, 132.4, 131.2, 131.0, 129.4, 129.0, 128.8, 128.7, 127.9, 126.8, 120.1, 118.7, 113.4,
8-methoxy-1-(methylsulfonyl)-3-(phenylethynyl)-5,6-dihydropyrrolo[2,1-[a]isoquinoline (2v)

Compound 2v was obtained as a white solid, 31.1 mg, in 55% yield; Rf = 0.50 (petroleum ether : ethyl acetate = 3 : 1); mp: 179-181 °C; 1H NMR (400 MHz, CDCl3) δ 8.45 (d, J = 8.8 Hz, 1H), 7.53-7.51 (m, 2H), 7.37-7.36 (m, 3H), 7.01 (s, 1H), 6.91 (dd, J1 = 8.8 Hz, J2 = 2.4 Hz, 1H), 6.83 (d, J = 2.4 Hz, 1H), 4.22 (t, J = 6.4 Hz, 2H), 3.85 (s, 3H), 3.07 (t, J = 6.4 Hz, 2H), 3.07 (s, 3H); 13C NMR (100 MHz, CDCl3) δ 159.8, 135.2, 131.3, 130.8, 128.75, 128.67, 128.4, 122.3, 119.5, 119.2, 117.2, 114.13, 114.09, 112.8, 95.2, 78.9, 55.3, 43.9, 42.2, 29.5; IR (KBr) ν 3019, 2203, 1604, 1517, 1457, 1296, 1135, 1026, 942, 753, 690, 557, 508 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C22H19NNaO3S, 400.0978; found 400.0977.

8-methoxy-1-(methylsulfonyl)-3-(thiophen-3-yl)-5,6-dihydropyrrolo[2,1-[a]isoquinoline (2x)

Compound 2x was obtained as a white solid, 44.7 mg, in 83% yield; Rf = 0.70 (petroleum ether : ethyl acetate = 3 : 1); mp: 214-216 °C; 1H NMR (400 MHz, CDCl3) δ 8.43 (d, J = 8.8 Hz, 1H), 7.52 (d, J = 2.4 Hz, 1H), 7.37-7.36 (m, 3H), 7.01 (s, 1H), 6.91 (dd, J1 = 8.8 Hz, J2 = 2.4 Hz, 1H), 6.83 (d, J = 2.4 Hz, 1H), 4.22 (t, J = 6.4 Hz, 2H), 3.85 (s, 3H), 3.07 (t, J = 6.4 Hz, 2H), 3.07 (s, 3H); 13C NMR (100 MHz, CDCl3) δ 159.8, 135.2, 131.3, 130.8, 128.75, 128.67, 128.4, 122.3, 119.5, 119.2, 117.2, 114.13, 114.09, 112.8, 95.2, 78.9, 55.3, 43.9, 42.2, 29.5; IR (KBr) ν 3019, 2203, 1604, 1517, 1457, 1296, 1135, 1026, 942, 753, 690, 557, 508 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C22H19NNaO3S, 400.0978; found 400.0977.
8.4 Hz, 1H), 7.42 (dd, \( J_1 = 4.8 \) Hz, \( J_2 = 4.0 \) Hz, 1H), 7.26-7.25 (m, 1H), 7.16 (d, \( J = 4.0 \) Hz, 1H), 6.92 (dd, \( J_1 = 8.8 \) Hz, \( J_2 = 2.8 \) Hz, 1H), 6.81 (d, \( J = 2.0 \) Hz, 1H), 6.78 (s, 1H), 4.12 (t, \( J = 6.4 \) Hz, 2H), 3.85 (s, 3H), 3.09 (s, 3H), 2.98 (t, \( J = 6.4 \) Hz, 2H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \) 159.4, 135.2, 131.4, 130.0, 128.6, 128.0, 127.8, 126.3, 123.2, 120.1, 119.0, 113.8, 112.7, 110.9, 55.3, 43.9, 41.9, 29.9; IR (KBr) ν 3019, 2841, 2357, 1611, 1576, 1471, 1398, 1132, 1030, 946, 859, 816, 760, 550 cm\(^{-1}\); HRMS-(ESI) (m/z): [M+Na]\(^+\) calcd for C\(_{18}\)H\(_{17}\)NNaO\(_3\)S\(_2\), 382.0542; found 382.0535.

3-buty1-8-methoxy-1-(methylsulfonyl)-5,6-dihydropyrrolo[2,1-a]isoquinoline (2y)

Compound 2y was obtained as a white solid, 35.0 mg, in 70% yield; \( R_f = 0.70 \) (petroleum ether : ethyl acetate = 3 : 1); mp: 203-205 °C; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \) 8.39 (d, \( J = 8.8 \) Hz, 1H), 6.89 (dd, \( J_1 = 8.8 \) Hz, \( J_2 = 2.4 \) Hz, 1H), 6.79 (d, \( J = 2.4 \) Hz, 1H), 6.43 (s, 1H), 3.93 (t, \( J = 6.4 \) Hz, 2H), 3.84 (s, 3H), 3.04 (s, 3H), 3.00 (t, \( J = 6.4 \) Hz, 2H), 2.56 (t, \( J = 7.6 \) Hz, 2H), 1.61 (dt, \( J_1 = 15.2 \) Hz, \( J_2 = 7.2 \) Hz, 2H), 1.42 (dq, \( J_1 = 14.8 \) Hz, \( J_2 = 7.2 \) Hz, 2H), 0.95 (t, \( J = 7.2 \) Hz, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \) 159.0, 134.6, 131.9, 129.1, 128.3, 120.3, 117.7, 113.7, 112.6, 108.6, 55.3, 43.9, 40.8, 30.3, 29.7, 25.7, 22.3, 13.8; IR (KBr) ν 2928, 2361, 1608, 1517, 1408, 1247, 1142, 1037, 949, 830, 757, 564, 480 cm\(^{-1}\); HRMS-(ESI) (m/z): [M+Na]\(^+\) calcd for C\(_{18}\)H\(_{23}\)NNaO\(_3\)S, 356.1291; found 356.1290.
3-(tert-butyl)-8-methoxy-1-(methylsulfonyl)-5,6-dihydropyrrolo[2,1-a]isoquinoline

(2z)

Compound 2z was obtained as a white solid, 31.0 mg, in 62% yield; R<sub>f</sub> = 0.60 (petroleum ether : ethyl acetate = 3 : 1); mp: 181-183 °C; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 8.63 (d, <i>J</i> = 8.8 Hz, 1H), 6.78 (d, <i>J</i> = 8.4 Hz, 1H), 6.68 (s, 1H), 6.08 (s, 1H), 3.83 (s, 3H), 3.80 (t, <i>J</i> = 6.0 Hz, 2H), 2.91 (t, <i>J</i> = 6.0 Hz, 2H), 2.78 (s, 3H), 1.30 (s, 9H); 13C NMR (100 MHz, CDCl<sub>3</sub>) δ 159.8, 139.3, 136.4, 128.9, 123.9, 113.1, 111.9, 107.1, 104.5, 55.3, 45.6, 38.5, 30.6, 29.7, 28.2; IR (KBr) ν 2960, 2851, 1608, 1492, 1342, 1160, 1020, 963, 869, 736, 578 cm<sup>-1</sup>; HRMS-(ESI) (m/z): [M+Na]<sup>+</sup> calcd for C<sub>18</sub>H<sub>23</sub>NaO<sub>3</sub>S, 356.1291; found 356.1292.

![2z](image)

3-cyclopropyl-8-methoxy-1-(methylsulfonyl)-5,6-dihydropyrrolo[2,1-a]isoquinoline

(2aa)

Compound 2aa was obtained as a white solid, 38.0 mg, in 80% yield; R<sub>f</sub> = 0.70 (petroleum ether : ethyl acetate = 3 : 1); mp: 204-206 °C; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 8.39 (d, <i>J</i> = 8.8 Hz, 1H), 6.89 (dd, <i>J</i> = 8.8 Hz, <i>J</i> = 2.8 Hz, 1H), 6.80 (d, <i>J</i> = 2.4 Hz, 1H), 6.34 (d, <i>J</i> = 0.4 Hz, 1H), 4.13 (t, <i>J</i> = 6.4 Hz, 2H), 3.84 (s, 3H), 3.04 (s, 3H), 3.02 (t, <i>J</i> = 6.4 Hz, 2H), 1.71-1.64 (m, 1H), 0.94-0.89 (m, 2H), 0.69-0.65 (m, 2H); 13C NMR (100 MHz, CDCl<sub>3</sub>) δ 159.1, 134.8, 133.7, 129.3, 128.3, 120.3, 117.4, 113.9, 112.6, 108.3, 55.3, 43.9, 41.0, 29.7, 6.4, 5.8; IR (KBr) ν 3002, 2837, 2361, 1615, 1577, 1524, 1524, 1293, 1090, 984, 823, 767, 645, 543, 508, 435 cm<sup>-1</sup>; HRMS-(ESI) (m/z): [M+Na]<sup>+</sup> calcd for C<sub>17</sub>H<sub>19</sub>NaO<sub>3</sub>S, 340.0978; found 340.0978.
(8,9-dimethoxy-1-(methylsulfonyl)-5,6-dihydropyrrolo[2,1-a]isoquinolin-3-yl)methanol (2ab)

Compound 2ab was obtained as a white solid (21.2 mg, 42%); R_f = 0.30 (petroleum ether : ethyl acetate = 3 : 1); mp: 249-251 °C; ^1H NMR (400 MHz, CDCl_3) δ 8.22 (s, 1H), 6.75 (s, 1H), 6.60 (s, 1H), 4.61 (s, 2H), 4.12 (t, J = 6.8 Hz, 2H), 3.91 (appeared as doublet as O-CH_3 protons overlapped, J = 2.4 Hz, 6H), 3.01-2.96 (appeared as multiplet as Ar-CH_2 and –SO_2-CH_3 overlapped, 5H); ^13C NMR (100 MHz, CDCl_3) δ 148.8, 148.3, 131.1, 130.1, 126.0, 119.5, 117.7, 111.5, 111.0, 110.3, 55.9, 44.0, 41.7, 28.7; IR (KBr) ν 2914, 2354, 1643, 715, 424 cm^{-1}; HRMS-(ESI) (m/z): [M+Na]^+ calcd for C_{16}H_{19}NNaO_5S, 360.0876; found 360.0876.

2-(8,9-dimethoxy-1-(methylsulfonyl)-5,6-dihydropyrrolo[2,1-a]isoquinolin-3-yl)ethyl acetate (2ac)

Compound 2ac was obtained as a white solid, 38.9 mg, in 66% yield; R_f = 0.22 (petroleum ether : ethyl acetate = 3 : 1); mp: 239-241 °C; ^1H NMR (400 MHz, CDCl_3) δ 8.25 (s, 1H), 6.77 (s, 1H), 6.52 (s, 1H), 4.27 (t, J = 6.8 Hz, 2H), 4.00 (t, J = 6.8 Hz, 2H), 3.94 (s, 3H), 3.92 (s, 3H), 3.04 (s, 3H), 3.00 (t, J = 6.4 Hz, 2H), 2.94 (t, J = 7.2 Hz, 2H), 2.07 (s, 3H); ^13C NMR (100 MHz, CDCl_3) δ 170.8, 148.6, 148.3, 129.8, 127.3, 125.4, 119.8, 118.2, 110.8, 110.2, 110.1, 62.6, 56.1, 55.9, 44.0, 41.4, 28.9, 25.6, 20.9; IR (KBr)
$\nu$ 3130, 1741, 1529, 1233, 1233, 1138, 891, 806, 552 cm$^{-1}$; HRMS-(ESI) (m/z): 
[M+Na]$^+$ calcd for C$_{19}$H$_{23}$NNaO$_6$S, 416.1138; found 416.1137.

12-methoxy-1-(methylsulfonyl)-3-phenyl-5,6-dihydronaphtho[1,8-cd]pyrrolo[1,2-a]azepine (2ad)

Compound 2ad was obtained as a white solid, 39.0 mg, in 65% yield; R$_f$ = 0.70
(petroleum ether : ethyl acetate = 3 : 1); mp: 178-180 °C; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$
8.53 (d, $J$ = 8.4 Hz, 1H), 7.80 (t, $J$ = 8.4 Hz, 2H), 7.50-7.39 (m, 5H), 7.25 (s, 1H), 7.19
(dd, $J_1$ = 8.0 Hz, $J_2$ = 2.0 Hz, 1H), 6.88 (s, 1H), 4.22 (t, $J$ = 6.4 Hz, 2H), 3.95 (s, 3H),
3.33 (t, $J$ = 6.4 Hz, 2H), 3.11 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 158.4, 133.0, 132.0,
130.8, 130.3, 130.2, 128.9, 128.7, 128.5, 128.14, 128.11, 127.5, 125.4, 122.2, 121.2,
118.5, 111.7, 102.3, 55.3, 44.2, 41.9, 25.1; IR (KBr) $\nu$ 2921, 2361, 1468, 1307, 1146, 964,
768, 554, 508, 435 cm$^{-1}$; HRMS-(ESI) (m/z): [M+Na]$^+$ calcd for C$_{24}$H$_{21}$NNaO$_3$S,
426.1134; found 426.1135.

9-(methylsulfonyl)-7-phenyl-4,5-dihydrothieno[2,3-g]indolizine (2ae)

Compound 2ae was obtained as a white solid, 35.0 mg, in 72% yield; R$_f$ = 0.70
(petroleum ether : ethyl acetate = 3 : 1); mp: 120-122 °C; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$
8.01 (d, $J$ = 5.2 Hz, 1H), 7.48-7.44 (m, 2H), 7.41-7.37 (m, 3H), 7.23 (d, $J$ = 5.6 Hz, 1H),
6.68 (s, 1H), 4.19 (t, $J$ = 6.8 Hz, 2H), 3.13 (t, $J$ = 6.8 Hz, 2H), 3.12 (s, 3H); $^{13}$C NMR
(100 MHz, CDCl₃) δ 133.9, 133.4, 131.1, 129.1, 128.7, 128.2, 128.1, 126.3, 123.7, 118.1, 110.2, 44.9, 43.0, 24.5; IR (KBr) ν 2914, 2368, 1293, 1139, 869, 767, 561, 515, 435 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C₁₇H₁₅NNaO₂S₂, 352.0436; found 352.0436.

9-(methylsulfonyl)-7-phenyl-4,5-dihydrofuro[2,3-g]indolizine (2af)

Compound 2af was obtained as a white oil, 15.0 mg, in 25% yield; Rᵣ = 0.70 (petroleum ether : ethyl acetate = 3 : 1); ¹H NMR (400 MHz, CDCl₃) δ 7.47-7.37 (m, 6H), 7.21 (s, 1H), 6.58 (s, 1H), 4.23 (t, J = 7.2 Hz, 2H), 3.11 (s, 3H), 3.09 (t, J = 7.2 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 149.6, 142.5, 133.9, 131.2, 129.0, 128.7, 128.2, 117.8, 112.1, 109.7, 108.9, 45.3, 43.2, 22.8; IR (KBr) ν 2928, 1758, 1478, 1310, 764, 561, 522, 435 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C₁₇H₁₅NNaO₃S, 336.0665; found 336.0665.

7-methyl-1-(methylsulfonyl)-3-phenyl-6,7-dihydro-5H-indolizino[7,8-b]indole (2ag)

Compound 2ag was obtained as a white solid, 36.6 mg, in 65% yield; Rᵣ = 0.70 (petroleum ether : ethyl acetate = 3 : 1); mp: 237-239 °C; ¹H NMR (400 MHz, CDCl₃) δ 8.65 (dd, J₁ = 6.4, J₂ = 2.4 Hz, 1H), 7.47-7.37 (m, 5H), 7.34-7.26 (m, 3H), 6.77 (s, 1H), 4.14 (t, J = 6.4 Hz, 2H), 3.74 (s, 3H), 3.16 (s, 3H), 3.02 (t, J = 6.4 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 137.2, 136.9, 132.2, 131.3, 129.2, 128.9, 128.5, 127.7, 123.6, 121.8, 121.4, 120.8, 117.5, 109.3, 109.2, 103.9, 44.4, 41.7, 29.7, 21.6; IR (KBr) ν 2925, 2368,
2329, 2035, 1398, 1356, 1212, 991, 687, 494 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C₂₂H₂₀N₂NaO₂S, 399.1138; found 399.1138.

11-methyl-1-(methylsulfonyl)-3-phenyl-6,11-dihydro-5H-indolizino[8,7-b]indole (2ah)

Compound 2ah was obtained as a white solid, 24.7 mg, in 45% yield; Rₙ = 0.70 (petroleum ether : ethyl acetate = 3 : 1); mp: 235-237 °C; ¹H NMR (400 MHz, CDCl₃) δ 7.55 (d, J = 8.0 Hz, 1H), 7.50-7.46 (m, 2H), 7.43-7.41 (m, 4H), 7.28 (t, J = 7.2 Hz, 1H), 7.17 (t, J = 7.2 Hz, 1H), 6.70 (s, 1H), 4.08 (t, J = 6.4 Hz, 2H), 3.98 (s, 3H), 3.20 (s, 3H), 2.99 (t, J = 6.4 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 140.3, 135.8, 130.9, 130.4, 129.1, 128.7, 128.3, 125.5, 124.8, 122.9, 120.3, 119.1, 118.6, 112.6, 110.8, 109.3, 45.2, 43.6, 34.5, 21.9; IR (KBr) ν 2935, 2848, 2364, 1566, 1457, 1349, 1293, 1132, 1019, 767, 708, 547 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C₂₂H₂₀N₂NaO₂S, 399.1138; found 399.1137.

Crossover experiments
A dry Schlenk tube was charged with gold catalyst (5 mol %) and evacuated and back filled with argon. To this tube was added the solution of 1a (0.15 mmol) and 1t (0.15 mmol) in DCM. The reaction mixture was stirred at 30 °C for 4 h. Upon completion, the mixture was then quenched with small amount of water, diluted with DCM, washed with brine, dried over anhydrous Na₂SO₄ and concentrated in vacuo. The residue was checked by ¹H NMR using as an internal standard.

**Separation of the intermediate 2aa’**

A dry Schlenk tube was charged with gold catalyst (26 mg, 5 mol %) and evacuated and back filled with argon. To this tube was added the solution of 1a (212 mg, 0.60 mmol) in DCM (4 mL). The reaction mixture was stirred at 30 °C for 15 min. Then the mixture was then quenched with small amount of water, diluted with DCM, washed with brine, dried over anhydrous Na₂SO₄ and concentrated in vacuo. The residue was purified by chromatography on silica gel (eluent: petroleum ether/DCM) and recrystallized (petroleum ether/DCM) to afford 2aa’ (21 mg, 10%). Rₜ = 0.35 (petroleum ether : ethyl acetate = 3 : 1); mp: 164-166 °C; ¹H NMR (400 MHz, CDCl₃) δ 7.55 (d, J = 8.8 Hz, 1H), 7.47-7.44 (m, 2H), 7.34-7.32 (m, 3H), 6.78 (dd, J₁ = 8.8 Hz, J₂ = 2.8 Hz, 1H), 6.63 (d, J = 2.8 Hz, 1H), 6.35 (s, 1H), 3.82 (t, J = 6.0 Hz, 2H), 3.81 (s, 3H), 3.26 (s, 3H), 3.09 (t, J = 6.0 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 160.3, 142.6, 135.6, 131.3, 128.5, 125.4, 124.0, 123.2, 113.7, 113.6, 101.8, 96.9, 87.7, 55.3, 46.0, 42.2, 28.9; IR (KBr) ν 2916,
1664, 1607, 1342, 1330, 1148, 1108, 970, 759, 520 cm\(^{-1}\); HRMS-(ESI) (m/z): [M+Na]\(^+\) calcd for C\(_{20}\)H\(_{19}\)NNaO\(_3\)S, 376.0978; found 376.0979.

A dry Schlenk tube was charged with gold catalyst (2.6 mg, 5 mol %) and evacuated and back filled with argon. To this tube was added the solution of 2aa\(^{*}\) (21 mg, 0.06 mmol) in DCM (1 mL). The reaction mixture was stirred at 30 °C for 4 h. Then the mixture was then quenched with small amount of water, diluted with DCM, washed with brine, dried over anhydrous Na\(_2\)SO\(_4\) and concentrated in vacuo. The residue was purified by chromatography on silica gel (eluent: petroleum ether/DCM) to afford 2a (19.7 mg, 94%).

**Transformations of the products**

a)

8-methoxy-3-phenyl-5,6-dihydropyrrolo[2,1-\(a\)]isoquinoline (3a)

In a two-neck RB, LiAlH\(_4\) (40 mg, 0.98 mmol, 7 equiv.) was weighed and 5 mL of dioxane (previously degassed with argon) was added under inert atmosphere. To this suspension solid 2a (50 mg, 0.14 mmol) was added at room temperature. The mixture was then refluxed for 9 h. The reaction mixture was cooled to 0 °C, diluted by adding 5 mL of ethyl acetate and carefully quenched by saturated NH\(_4\)Cl solution. It was then filtered using a short pad of celite and filtrate was then extracted by ethyl acetate (3 \times 10 mL). The combined extracts was washed with brine and dried over Na\(_2\)SO\(_4\). The solvent
was removed under reduced pressure and the residual mass was purified by silica gel column chromatography using petroleum ether : ethyl acetate (10 : 1) as eluent to afford the pure product 3a (27.7 mg, 72%); Rf = 0.70 (petroleum ether : ethyl acetate = 5 : 1); mp: 231-233 °C; 1H NMR (400 MHz, CDCl3) δ 7.50 (d, J = 8.4 Hz, 1H), 7.43-7.33 (m, 4H), 7.32-7.29 (m, 1H), 6.82 (d, J = 8.4 Hz, 1H), 6.76 (s, 1H), 6.50 (d, J = 3.6 Hz, 1H), 6.32 (d, J = 3.6 Hz, 1H), 4.14 (t, J = 6.4 Hz, 2H), 3.83 (s, 3H), 3.01 (t, J = 6.4 Hz, 2H); 13C NMR (100 MHz, CDCl3) δ 157.8, 133.6, 133.0, 132.4, 131.1, 128.5, 128.4, 126.6, 123.9, 123.1, 113.2, 112.8, 109.2, 102.8, 55.3, 42.0, 30.0; IR (KBr) ν 2960, 2364, 1646, 1247, 1034, 806, 536 cm⁻¹; HRMS (ESI) m/z: [M + H]+ calcd for C19H18NO, 276.1383; found 276.1383.8

b)

2-bromo-8-methoxy-1-(methylsulfonyl)-3-phenyl-5,6-dihydropyrrolo[2,1-a]isoquinoline (3b)

To a solution of 2a (40 mg, 0.11 mmol) in 2 mL of THF, a THF (1 mL) solution of NBS (1.2 equiv.) was added at 0 °C and stirred for 12 h during which the temperature raised to room temperature. The reaction was quenched with water and extracted with DCM (3 × 10 mL). The organic layers were combined, washed with brine and dried over sodium sulfate. The pure product 3b (45.6 mg, 95%) was obtained by flash column chromatography on silica gel (petroleum ether : DCM = 1 : 1); Rf = 0.40 (petroleum ether : DCM= 1 : 1); mp: 237-239 °C; 1H NMR (400 MHz, CDCl3) δ 8.19 (d, J = 8.8 Hz, 1H), 7.51-7.45 (m, 3H), 7.40 (dd, J1 = 7.6 Hz, J2 = 1.6 Hz, 2H), 6.90 (dd, J1 = 8.8 Hz, J2 =
2.8 Hz, 1H), 6.76 (d, J = 2.4 Hz, 1H), 3.84 (appeared as triplet, J = 6.4 Hz, 5H), 3.30 (s, 3H), 2.87 (t, J = 6.4 Hz, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 159.8, 136.2, 132.7, 132.5, 131.3, 130.7, 129.04, 129.00, 128.5, 119.1, 116.7, 113.3, 111.9, 96.2, 55.3, 44.9, 43.0, 30.0; IR (KBr) v 2921, 2844, 2368, 1608, 1454, 1303, 1146, 1030, 953.31, 708, 561 cm$^{-1}$; HRMS (ESI) m/z: [M + Na]$^+$ calcd for C$_{20}$H$_{18}$BrNNaO$_3$S, 454.0083; found 454.0081.9

c)

8-methoxy-1-(methylsulfonyl)-3-phenylpyrrolo[2,1-a]isoquinoline (3c)

A mixture of 2a (71 mg, 0.20 mmol) and activated MnO$_2$ (869 mg, 10 mmol) in dichloromethane (15 mL) was refluxed for 36 h. After cooling to room temperature, the mixture was passed through a pad of Celite and evaporated. The residue was purified by column chromatography eluted by petroleum ether/DCM to give 3c as a yellow solid (41.7 mg, 59%). $R_f$ = 0.25 (petroleum ether : ethyl acetate = 3 : 1); mp: 187-189 °C; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 9.12 (d, J = 9.2 Hz, 1H), 8.04 (d, J = 7.8 Hz, 1H), 7.53 (appeared as a singlet, 2H), 7.52 (appeared as a singlet, 2H), 7.48-7.43 (m, 1H), 7.29-7.25 (m, 2H), 7.10 (d, J = 2.8 Hz, 1H), 6.94 (d, J = 7.2 Hz, 1H), 3.94 (s, 3H), 3.26 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 159.1, 130.8, 130.4, 129.4, 129.2, 129.1, 128.5, 127.8, 127.4, 122.3, 118.5, 117.8, 115.3, 114.7, 113.7, 108.8, 55.4, 44.3; IR (KBr) v 2923, 1647, 1539, 1135, 766 cm$^{-1}$; HRMS-(ESI) (m/z): [M+Na]$^+$ calcd for C$_{20}$H$_{17}$NNaO$_3$S, 374.0821; found 374.0822.10

d)
To a mixture of 2a (150 mg, 0.42 mmol) and B(C₆F₅)₃ (10 mol%) in toluene (6 mL, degassed with argon), Et₃SiH (5 equiv.) was added at room temperature (immediate bubbling from the reaction mixture observed). It was then refluxed for 7 h during which the initial heterogeneous mixture turned into a yellow solution. The reaction was cooled to rt, diluted by adding 10 mL of ethyl acetate and quenched by saturated NH₄Cl solution. The reaction mixture was partitioned in a separating flask and the aqueous layer was extracted by ethyl acetate (3 × 15 mL). The combined extracts was washed with brine and dried over Na₂SO₄. The solvent was removed under reduced pressure and the residual mass was purified by silica gel column chromatography using petroleum ether : ethyl acetate (5 : 1) as eluent to give J as a yellow oil (138.0 mg, 74%). Rᵢ = 0.60 (petroleum ether : ethyl acetate = 5 : 1); ¹H NMR (400 MHz, CDCl₃) δ 8.38 (d, J = 8.4 Hz, 1H), 7.47-7.43 (m, 2H), 7.39-7.37 (m, 3H), 6.88 (d, J = 8.4 Hz, 1H), 6.80-6.77 (m, 2H), 4.09 (t, J = 6.0 Hz, 2H), 3.11 (s, 3H), 2.93 (t, J = 6.0 Hz, 2H), 1.03 (t, J = 8.0 Hz, 2H), 0.78 (dd, J₁ = 15.6 Hz, J₂ = 8.0 Hz, 6H); ¹³C NMR (100 MHz, CDCl₃) δ 155.7, 135.3, 132.7, 131.0, 130.3, 129.0, 128.7, 128.6, 127.9, 120.7, 119.4, 119.2, 118.9, 111.0, 43.9, 42.3, 31.6, 29.9, 22.6, 14.1, 6.6, 5.0; IR (KBr) v 2960, 2872, 2350, 1608, 1457, 1300, 1135, 953, 816, 757,
547 cm\(^{-1}\); HRMS-(ESI) \((m/z)\): [M+Na]\(^{+}\) calcd for C\(_{25}\)H\(_{31}\)NNaO\(_{3}\)SSi, 476.1686; found 476.1685.

1-(methylsulfonyl)-3-phenyl-5,6-dihydropyrrolo[2,1-a]isoquinolin-8-ol (3d)

To a solution of J (120 mg, 0.26 mmol) in THF (5 mL), TBAF (0.52 mL, 1M in THF, 0.52 mmol) was added dropwise at 0 °C. The solution was stirred for 2 h during which the temperature gradually increased to room temperature. The reaction was quenched by water and extracted with ethyl acetate (3 × 10 mL). The combined extracts was washed with brine and dried over Na\(_{2}\)SO\(_{4}\). The solvent was removed under reduced pressure and the residual mass was purified by silica gel column chromatography using petroleum ether : ethyl acetate (3 : 1) as eluent to give 3d as a yellow solid (81.2 mg, 92%). R\(_f\) = 0.70 (petroleum ether : ethyl acetate = 5 : 1); mp: 199-201 °C; \(^1\)H NMR (400 MHz, (CD\(_3\))\(_2\)SO) \(\delta\) 9.77 (broad singlet, 1H), 8.14 (d, \(J = 8.4\) Hz, 1H), 7.47 (appeared as doublet, \(J = 4.4\) Hz, 4H), 7.42-7.36 (m, 1H), 6.78-6.76 (m, 2H), 6.62 (s, 1H), 4.07 (t, \(J = 6.4\) Hz, 2H), 3.11 (s, 3H), 2.89 (t, \(J = 6.4\) Hz, 2H); \(^13\)C NMR (100 MHz, (CD\(_3\))\(_2\)SO) \(\delta\) 158.0, 136.6, 132.5, 131.1, 130.5, 129.2, 128.7, 128.3, 119.2, 118.6, 115.3, 114.5, 110.2, 44.2, 42.5, 29.6; IR (KBr) \(\nu\) 3348, 2364, 1611, 1457, 1264, 1132, 985, 767, 550 cm\(^{-1}\); HRMS-(ESI) \((m/z)\): [M+Na]\(^{+}\) calcd for C\(_{19}\)H\(_{17}\)NNaO\(_{3}\)S, 362.0821; found 362.0820.

1-(methylsulfonyl)-3-phenyl-5,6-dihydropyrrolo[2,1-a]isoquinolin-8-yl trifluoromethanesulfonate (K)

3d (80 mg, 0.24 mmol) was dissolved in DCM (3.0 mL) and then cooled to -78 °C. Triethylamine (TEA, 70.0 \(\mu\)L, 0.50 mmol) was added, followed by addition of trifluoromethanesulfonic anhydride (Tf\(_2\)O, 60.0 \(\mu\)L, 0.53 mmol) within 3 minutes via a syringe. The resulting solution was gradually warmed to room temperature and stirred for
2 h until 3d had been completely consumed as determined by TLC. The solvent was then removed under reduced pressure to get the crude product, which was purified by flash column chromatography on silica gel, eluted by petroleum ether/DCM to afford the pure product K as a yellow solid (100.0 mg, 90% yield). Rf = 0.50 (petroleum ether : ethyl acetate = 5 : 1); mp: 161-163 °C; 1H NMR (400 MHz, CDCl3) δ 8.63 (d, J = 8.8 Hz, 1H), 7.50-7.46 (m, 2H), 7.41-7.37 (m, 2H), 7.29 (dd, J1 = 8.8 Hz, J2 = 2.8 Hz, 1H), 7.22 (d, J = 2.4 Hz, 1H), 6.83 (s, 1H), 4.15 (t, J = 6.4 Hz, 2H), 3.12 (s, 3H), 3.04 (t, J = 6.4 Hz, 2H); 13C NMR (100 MHz, CDCl3) δ 148.4, 135.9, 134.1, 130.4, 129.1, 129.0, 128.8, 128.5, 127.8, 127.7, 121.7, 120.8, 120.6, 118.7 (q, J_C-F = 319.1 Hz), 111.8, 44.3, 42.0, 29.7; 19F NMR (376 MHz, CDCl3) δ -72.8; IR (KBr) ν 2361, 1636, 1422, 1212, 1135, 932, 757, 606 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]⁺ calcd for C20H16F3NNaO5S2, 494.0314; found 494.0313.

e) Ethyl (E)-3-(1-(methylsulfonyl)-3-phenyl-5,6-dihydropyrrolo[2,1-a]isoquinolin-8-yl)acrylate (L)

K (48.0 mg, 0.1 mmol), ethyl acrylate (106.4 μL, 1.0 mmol), palladium(II) acetate (Pd(OAc)₂, 4.4 mg, 0.02 mmol), triphenylphosphine (PPh₃, 15.7 mg, 0.06 mmol), potassium carbonate (K₂CO₃, 27.6 mg, 0.2 mmol), and toluene (1.0 mL) were added to a pressure tube. The reaction mixture was heated at 110 °C under N₂ condition for 9 h until K had been completely consumed as determined by TLC. The reaction mixture was cooled to room temperature and the solvent was removed under reduced pressure to get
the crude product, which was purified by flash column chromatography on silica gel, eluted by petroleum ether/DCM to afford the pure product L as a white solid (36.2 mg, 86% yield). R<sub>f</sub> = 0.50 (petroleum ether : ethyl acetate = 5 : 1); mp: 162-164 °C; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 8.52 (d, J = 8.0 Hz, 1H), 7.67 (d, J = 16.0 Hz, 1H), 7.55 (d, J = 8.0 Hz, 1H), 7.49-7.45 (m, 2H), 7.43-7.38 (m, 4H), 6.84 (s, 1H), 6.47 (d, J = 15.6 Hz, 1H), 4.28 (q, J = 7.2 Hz, 2H), 4.14 (t, J = 6.4 Hz, 2H), 3.13 (s, 3H), 3.02 (t, J = 6.4 Hz, 2H), 1.35 (t, J = 7.2 Hz, 3H); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 166.8, 143.5, 133.9, 133.8, 130.6, 129.03, 128.97, 128.9, 128.8, 128.3, 127.5, 127.4, 121.5, 118.8, 111.9, 60.6, 44.0, 42.4, 29.7, 14.3; IR (KBr) ν 2918, 2364, 1713, 1268, 1135, 754, 561 cm<sup>-1</sup>; HRMS-(ESI) (m/z): [M+Na]<sup>+</sup> calcd for C<sub>24</sub>H<sub>23</sub>NNaO<sub>4</sub>S, 444.1240; found 444.1242.<sup>12</sup>

f)

1-(methylsulfonyl)-3-phenyl-8-(phenylethynyl)-5,6-dihydropyrrolo[2,1-a]isoquinoline (M)

K (48.0 mg, 0.1 mmol), phenylacetylene (33.0 μL, 0.3 mmol), bis(triphenylphosphine)palladium(II) dichloride (Pd(PPh<sub>3</sub>)<sub>2</sub>Cl<sub>2</sub>, 7.0 mg, 0.01 mmol), copper(I) bromide (CuBr, 0.7 mg, 0.005 mmol), diisopropylethylamine (DIPEA, 52.0 μL, 0.3 mmol), and DMF (1.0 mL) were added to a pressure tube. The reaction mixture was heated to 80 °C under N<sub>2</sub> condition for 6 h until K had been completely consumed as determined by TLC. The reaction mixture was cooled down to room temperature and then diluted with ethyl acetate (50 mL). The organic phase was washed with brine (4 × 10 mL) and dried with Na<sub>2</sub>SO<sub>4</sub>. The solvent was removed under reduced pressure to get the
crude product, which was purified by flash column chromatography on silica gel, eluted by petroleum ether/DCM to afford the product M as a white solid (38.0 mg, 90% yield). 

Rf = 0.50 (petroleum ether : ethyl acetate = 5 : 1); mp: 209-211 °C; 1H NMR (400 MHz, CDCl3) δ 8.50 (d, J = 8.0 Hz, 1H), 7.55-7.53 (m, 3H), 7.48-7.35 (m, 9H), 6.83 (s, 1H), 4.12 (t, J = 6.4 Hz, 2H), 3.12 (s, 3H), 2.99 (t, J = 6.4 Hz, 2H); 13C NMR (100 MHz, CDCl3) δ 133.7, 133.3, 131.6, 131.0, 130.8, 130.6, 129.1, 129.0, 128.7, 128.5, 128.4, 128.2, 127.1, 126.9, 123.0, 122.8, 121.2, 111.7, 90.9, 89.0, 43.9, 42.3, 29.5; IR (KBr) v 2361, 1485, 1300, 1135, 985, 767, 701, 550 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]+ calcd for C27H21NNaO2S, 446.1185; found 446.1183.12

g) NMeO Ph Ts PdCl2(PPh3)2 THF, 80 °C, 10 h

42% yield (brsm 55%)

3e2s PhMgBr

8-methoxy-1,3-diphenyl-5,6-dihydropyrrolo[2,1-a]isoquinoline (3e)

Under argon atmosphere, 2s (43.0 mg 0.1mmol), PdCl2(PPh3)2 (7.02mg, 10 mol%), dehydrated THF 1.0 mL were charged in a flask and cooled to 0 °C. Phenyl magnesium bromide (1M in THF, 0.4 mL, 4.0 equiv.) was added dropwise and stirred for 10 hours at 80 °C, water 2 mL were added and then filtered. The organic layer of the filtrate was dried over magnesium sulfate. Concentration and flash chromatography on a silica column (PE : EA = 100 : 1) afforded compound 3e as yellow oil (14.7 mg, 42% yield). Rf = 0.50 (petroleum ether : ethyl acetate = 100 : 1); 1H NMR (400 MHz, CDCl3) δ 8.18-8.16 (m, 1H), 7.46-7.40 (m, 4H), 7.36-7.30 (m, 1H), 7.24-7.18 (m, 4H), 7.09-7.04 (m, 1H), 6.76-6.74 (m, 2H), 6.41 (s, 1H), 4.16 (t, J = 6.4 Hz, 2H), 3.78 (s, 3H), 2.98 (t, J = 6.4 Hz, 2H). 13C NMR (100 MHz, CDCl3) δ 158.3, 140.0, 134.2, 133.4, 132.6, 132.0,
128.8, 128.6, 128.5, 127.1, 126.3, 125.7, 124.5, 122.2, 116.4, 113.4, 112.2, 103.7, 55.2, 42.3, 30.4; IR (KBr) v 2830, 2375, 2333, 1772, 1608, 1580, 1485, 1433, 1433, 1314, 1240, 1037, 813, 764, 694, 512 cm⁻¹; HRMS-(ESI) (m/z): [M+Na]^+ calcd for C_{25}H_{21}NNaO, 374.1515; found 374.1511.¹³

h)

Methyl 8,9-dimethoxy-1-(methylsulfonyl)-5,6-dihydropyrrolo[2,1-a] isoquinoline-3-carboxylate (3f)

PdCl₂(PPh₃)₂ (17.5 mg, 0.025 mmol) and K₂CO₃ (139.0 mg, 1.0 mmol) were placed in a Schlenck tube, which was filled with argon by using standard Schlenk techniques. THF (2.0 mL), benzyl chloride (126.6 mg, 1.0 mmol), alcohol 2ab (0.50 mmol) and methanol (5.0 mmol) were consequently added to the reaction tube. The reaction mixture was stirred at 90 °C for 16 h. Then the resulting mixture was quenched with saturated NH₄Cl solution and suspension was extracted by ethyl acetate (3 × 5 mL). The organic layers were combined, washed with brine and dried over sodium sulfate. The pure product 3f (141 mg, 85%) was obtained by flash column chromatography on silica gel (petroleum ether : ethyl acetate = 2 : 1); Rₘ= 0.60 (petroleum ether : ethyl acetate = 1 : 1); ¹H NMR (400 MHz, CDCl₃) δ 8.29 (s, 1H), 7.47 (s, 1H), 6.78 (s, 1H), 4.64 (t, J = 6.8 Hz, 2H), 3.92 (appeared as doublet as O-CH₃ protons overlapped, J = 3.6 Hz, 6H), 3.85 (s, 3H), 3.04 (s, 3H), 2.99 (t, J = 6.8 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ 160.9, 149.8, 148.4, 134.6, 127.2, 120.6, 120.2, 119.8, 118.5, 110.8, 56.2, 55.9, 51.6, 43.8, 42.6, 28.5; IR
(KBr) ν 3075, 2074, 1636, 1132, 621, 477 cm⁻¹; HRMS (ESI) m/z: [M + Na]⁺ calcd for C₁₇H₁₉NNaO₆S, 388.0825; found 388.0822.¹
Crystal structures

General procedure for preparation of the crystals: The product (20 mg) was dissolved in DCM and filtered through a pad of filter paper. The filtrate was then transferred into several test-tubes by different volumes. Then to these solutions was added hexane in dropwise. These samples were allowed to be evaporated slowly at room temperature, which would eventually give colorless crystals on the surface of the tubes.

Crystal data of product 2a

Bond precision: C-C = 0.0020 Å Wavelength=0.71073

Cell: a=8.2877(17) b=14.334(3) c=14.903(3)

alpha=90 beta=103.09(3) gamma=90

Temperature: 293 K

Calculated: Volume 1724.4(6) Space group P 21/c Hall group -P 2ybc Moiety formula C20 H19 N O3 S

Reported: Volume 1724.4(6) Space group P2(1)/c Hall group ? Moiety formula ?
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Crystal data of product 3i

Identification code                      d
Empirical formula                       C₁₇ H₁₉ N O₆ S
Formula weight                           365.39
Temperature                                293(2) K
Wavelength                                 0.71073 Å
Crystal system, space group       ?, ? P21/c
Unit cell dimensions                   a = 7.5531(15) Å  alpha = 90 °.
b = 28.802(6) Å  beta = 113.57(3) °.
c = 8.5314(17) Å  gamma = 90 °.
Volume                                       1701.2(6) Å³
Z, Calculated density                  4,  1.427 Mg/m³
Absorption coefficient                0.224 mm⁻¹
F(000)                                          768
Crystal size                                  ? x ? x ? mm
Theta range for data collection    2.70 to 27.48 °.
Limiting indices                          -9<=h<=9, -37<=k<=37, -10<=l<=11
Reflections collected / unique 13063 / 3843 [R(int) = 0.0277]
Completeness to theta = 27.48 98.4 %
Refinement method Full-matrix least-squares on F^2
Data / restraints / parameters 3843 / 0 / 230
Goodness-of-fit on F^2 1.084
Final R indices [I>2sigma(I)] R1 = 0.0468, wR2 = 0.1165
R indices (all data) R1 = 0.0573, wR2 = 0.1232
Largest diff. peak and hole 0.219 and -0.289 e.A^-3
Reference


Copy of $^1$H NMR and $^{13}$C NMR spectra
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