Lewis Base and Brønsted Base Dual-Catalyzed Formal [4+3] Cycloaddition Reaction:

Synthesis of Aza-spirocycloheptane Oxindole

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1. General Information

Chemicals and solvents were either purchased from commercial suppliers or purified by standard techniques. Analytical thin-layer chromatography (TLC) was performed on silicycle silica gel plates with F-254 indicator and compounds were visualized by irradiation with UV light. Flash chromatography was carried out utilizing silica gel 200-300 mesh. $^1$H NMR, $^{13}$C NMR spectra were recorded on a Bruker AM-400 spectrometer (400 MHz $^1$H, 100 MHz $^{13}$C). The spectra were recorded in CDCl$_3$ as the solvent at room temperature, $^1$H and $^{13}$CNMR chemical shifts are reported in ppm relative to either the residual solvent peak ($^{13}$C) (δ = 77.00 ppm) or TMS ($^1$H) (δ = 0 ppm) as an internal standard. Data for $^1$H NMR are reported as follows: chemical shift (δ ppm), multiplicity (s = singlet, d = doublet, t = triplet, m = multiplet, dd = doublet), integration, coupling constant (Hz) and assignment. Data for $^{13}$C NMR are reported as chemical shift. IR spectra were recorded using Nicolet NEXUS 670 FT-IR instrument and are reported in wavenumbers (cm$^{-1}$). HRMS were performed on Bruker Apex II mass instrument (ESI). Morita-Baylis-Hillman carbonates substrates 1 were prepared according to the literature procedures.$^1$ N-(ortho-chloromethyl)aryl amides 2 were prepared according to the literature procedures.$^2$

2. Preliminary condition optimization for [4 + 3] cycloaddition reaction

\[
\begin{align*}
    &1' & + & 2a & \xrightarrow{PBu_3, Cs_2CO_3, 4 Å MS, solvent, 25^\circ C} & 3' \\
    &\text{Boc} & \text{CO}_2\text{Me} & \text{N} & \text{Bn} & \\
    &\text{N} & \text{CO}_2\text{Me} & \text{Bn} & \\
    &\text{N} & \text{MeO}_2\text{C} & \text{Bn} & \\
\end{align*}
\]

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$^a$ Conditions: Reactions performed with 1' (0.1 mmol), 2a (0.2 mmol), PBu$_3$ (20 mol%), Cs$_2$CO$_3$ (0.2 mmol) and 4 Å MS (50 mg) in solvent (1 mL) at 25$^\circ$C. $^b$ Isolated yields.

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$^c$ Isolated yields.
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ᵃ Conditions: Reactions performed with 1 (0.1 mmol), 2a (0.2 mmol), PBu₃ (20 mol%), base (0.2 mmol) and 4 Å MS (50 mg) in solvent (1 mL) at 25 °C.ᵇ 1 : 2a = 1 : 3, Cs₂CO₃ (3 equiv.) was added. ᶜ Isolated yields.

3. Exploration of chiral phosphine catalysts

Chiral phosphine catalysts P₁-P₄ were also tested in the [4 + 3] cycloaddition reaction. However, the desired asymmetric product 3a was not observed, and the asymmetric [4 + 3] cycloaddition reaction was not successful. More substrates and more chiral phosphines remain to be explored.
4. General Procedure and Spectral Data of Products

4.1 General procedure for the synthesis of aza-spirocycloheptane oxindole

\[
\begin{align*}
\text{R}^1 & \quad \text{Boc} \quad \text{CO}_{2}\text{Me} \quad \text{N} \quad \text{Ac} \\
\text{R}^2 & \quad \text{PBu}_3 (30 \text{ mol%}) \quad \text{Cs}_2\text{CO}_3 \\
& \quad \text{4 Å MS, toluene, 40°C} \quad \text{N}_2 \\
\end{align*}
\]

To a flame dried vessel were successively added Morita-Baylis-Hillman carbonates \( \text{1} \) (0.1 mmol), 4 Å Molecular sieves (50.0 mg), N-(ortho-chloromethyl)aryl amides \( \text{2} \) (0.2 mmol), and \( \text{Cs}_2\text{CO}_3 \) (0.2 mmol, 65.2 mg) under \( \text{N}_2 \) atmosphere. Then, toluene (0.25 mL) and \( \text{PBu}_3 \) (0.03 mmol 7.9μL) was added to the mixture. The reaction was stirred at 40°C for 48 h. When the reaction was completed, the solvent was evaporated under reduced pressure and the residue was purified by silica gel flash column chromatography (petroleumether/EtOAc) to give the corresponding aza-spirocycloheptane oxindole \( \text{3} \).

4.2 Analytical Data of aza-spirocycloheptane oxindole

1-(tert-butyl) 3-methyl
1'-acetyl-2'-oxospino[benzo[b]azepine-4,3'-indoline]-1,3(5H)-dicarboxylate (3a)

\[
\begin{align*}
\text{MeOC} & \quad \text{Boc} \\
\text{Ac} & \quad \text{N} \quad \text{Ac} \\
\end{align*}
\]

White Solid. m. p.: 120–124°C. IR(KBr): 755, 1150, 1243, 1269, 1300, 1371, 1461, 1476, 1589, 1603, 1639, 1704, 1759, 2372, 2925, 2956, 3391 cm\(^{-1}\); \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta = 8.66 \) (s, 1H), 8.25 (d, \( J = 7.92 \) Hz, 1H), 7.30-7.38 (m, 2H), 7.21 (t, \( J = 7.92 \) Hz, 1H), 7.09 (t, \( J = 7.05 \) Hz, 1H), 6.76 (t, \( J = 7.39 \) Hz, 1H), 6.63 (d, \( J = 7.39 \) Hz, 1H), 5.55 (d, \( J = 7.46 \) Hz, 1H), 3.76 (d, \( J = 13.25 \) Hz, 1H), 3.55 (s, 3H), 2.73 (s, 3H), 2.51 (d, \( J = 13.25 \) Hz, 1H), 1.57 (s, 9H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): \( \delta = 178.59, 171.24, 166.44, 151.74, 141.15, 139.79, 139.48, 131.44, 131.23, 130.17, 128.30, 127.17, 126.68, 126.60, 123.88, 123.73, 116.08, 113.19, 84.06, 53.01, 51.94, 40.08, 27.92, 26.60. HRMS (ESI): [M+H]\(^+\) calcd for \([\text{C}_{26}\text{H}_{26}\text{N}_2\text{O}_6] \): 463.1864, found: 463.1862.
1-(tert-butyl) 3-methyl 

1'-acetyl-5'-fluoro-2'-oxospiro[benzo[b]azepine-4,3'-indoline]-1,3(5H)-dicarboxylate (3b)

Pale Yellow Solid. m. p.: 175–176 °C. IR(KBr): 743, 919, 1151, 1245, 1258, 1293, 1371, 1477, 1640, 1704, 1763, 2373, 2925, 2957, 3390. cm⁻¹; ¹H NMR (400 MHz, CDCl₃): δ = 8.68 (s, 1H), 8.24 (q, J = 4.79 Hz, 1H), 7.35-7.37 (m, 2H), 7.13-7.17 (m, 1H), 6.89-6.94 (m, 1H), 6.67 (d, J = 7.56 Hz, 1H), 5.52-5.24 (m, 1H), 3.77 (d, J = 13.19 Hz, 1H), 3.55 (s, 3H), 2.73 (s, 3H), 2.52 (d, J = 13.28 Hz, 1H), 1.57 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): δ = 178.26, 171.12, 166.48, 160.28, 157.86, 151.72, 141.59, 139.78, 135.54, 132.25, 131.38, 130.87, 127.54, 126.89, 117.51, 114.85, 114.63, 112.60, 111.67, 111.42, 84.34, 53.22, 52.11, 40.00, 27.98, 26.56. HRMS (ESI): [M+H]⁺ calcd for [C₂₆H₂₅FN₂O₆]: 481.1769, found: 481.1766.

1-(tert-butyl) 3-methyl 

1'-acetyl-5'-chloro-2'-oxospiro[benzo[b]azepine-4,3'-indoline]-1,3(5H)-dicarboxylate (3c)

Pale Yellow Solid. m. p.: 178–180 °C. IR(KBr): 754, 1029, 1104, 1150, 1247, 1294, 1324, 1371, 1465, 1589, 1639, 1704, 1762, 2374, 2855, 2925, 2958, 3397 cm⁻¹; ¹H NMR (400 MHz, CDCl₃): δ = 8.67 (s, 1H), 8.20 (d, J = 8.73 Hz, 1H), 7.37 (d, J = 3.90 Hz, 2H), 7.10-7.20 (m, 2H), 6.89-6.94 (m, 1H), 6.66 (d, J = 7.62 Hz, 1H), 5.42 (s, 1H), 3.76 (d, J = 13.09 Hz, 1H), 3.60 (s, 3H), 2.73 (s, 3H), 2.50 (d, J = 13.19 Hz, 1H), 1.57 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): δ = 177.99, 171.17, 166.48, 151.72, 141.58, 139.72, 138.00, 132.00, 131.45, 130.90, 129.22, 128.29, 127.57, 126.95, 126.81, 124.35, 117.35, 112.51, 84.35, 53.07, 52.13, 39.95, 27.99, 26.01. HRMS (ESI): [M+H]⁺ calcd for [C₂₆H₂₅ClN₂O₆]: 497.1474, found: 497.1473.

1-(tert-butyl) 3-methyl 

1'-acetyl-5'-bromo-2'-oxospiro[benzo[b]azepine-4,3'-indoline]-1,3(5H)-dicarboxylate (3d)
**1-(tert-butyl) 3-methyl 1'-acetyl-5'-methyl-2'-oxospiro[benzo[b]azepine-4,3'-indoline]-1,3(5H)-dicarboxylate (3e)**

Yellow Solid. m. p.: 183–186 °C. IR(KBr): 747, 799, 1029, 1101, 1150, 1260, 1293, 1323, 1371, 1462, 1589, 1638, 1704, 2371, 2924, 2958, 3396 cm⁻¹; ¹H NMR (400 MHz, CDCl₃): δ = 8.67 (s, 1H), 8.14 (d, J = 8.70 Hz, 1H), 7.33-7.38 (m, 3H), 7.15-7.20 (m, 1H), 5.54 (s, 1H), 3.76 (d, J = 13.18 Hz, 1H), 3.59 (s, 3H), 2.72 (s, 3H), 2.50 (d, J = 13.29 Hz, 1H), 1.57 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): δ = 177.86, 171.16, 166.46, 151.71, 141.55, 139.69, 138.47, 132.27, 131.48, 131.17, 130.91, 127.56, 127.24, 126.96, 126.78, 117.73, 116.87, 112.49, 84.33, 53.02, 52.12, 39.97, 27.98, 26.59. HRMS (ESI): [M+H]⁺ calcd for [C₂₆H₂₅BrN₂O₆]: 541.0969, found: 541.0961.

**1-(tert-butyl) 3-methyl 1'-acetyl-5'-methoxy-2'-oxospiro[benzo[b]azepine-4,3'-indoline]-1,3(5H)-dicarboxylate (3f)**

Pale Yellow Solid. m. p.: 170–173 °C. IR(KBr): 740, 1034, 1150, 1244, 1267, 1298, 1371, 1327, 1437, 1459, 1481, 1590, 1638, 1704, 1753, 2373, 2857, 2924, 2958, 3393 cm⁻¹; ¹H NMR (400 MHz, CDCl₃): δ = 8.65 (s, 1H), 8.11 (d, J = 8.41 Hz, 1H), 7.31-7.38 (m, 2H), 7.10 (t, J = 7.72 Hz, 1H), 7.01 (d, J = 8.08 Hz, 1H), 6.62 (d, J = 7.60 Hz, 1H), 5.26 (s, 1H), 3.76 (d, J = 13.08 Hz, 1H), 3.58 (s, 3H), 2.73 (s, 3H), 2.48 (d, J = 13.29 Hz, 1H), 1.98 (s, 3H), 1.57 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): δ = 178.78, 171.21, 166.52, 151.83, 141.12, 139.86, 137.09, 133.24, 131.67, 131.51, 130.06, 128.69, 127.15, 126.80, 126.37, 124.82, 115.52, 113.33, 84.10, 53.08, 52.01, 40.17, 28.00, 26.61, 20.87. HRMS (ESI): [M+H]⁺ calcd for [C₂₇H₂₈N₂O₆]: 477.2022, found: 477.2022.
1-(tert-butyl) 3-methyl
1'-acetyl-6'-chloro-2'-oxospiro[benzo[b]azepine-4,3'-indoline]-1,3(5H)-dicarboxylate (3g)

Pale Yellow Solid. m. p.: 174–176 °C. IR(KBr): 742, 1025, 1038, 1150, 1244, 1265, 1371, 1483, 1593, 1640, 1703, 1758, 2926, 2955, 3388 cm⁻¹; ¹H NMR (400 MHz, CDCl₃): δ = 8.66 (s, 1H), 8.16 (d, J = 8.87 Hz, 1H), 7.30-7.38 (m, 2H), 7.14 (t, J = 7.13 Hz, 1H), 6.74 (d, J = 8.96 Hz, 1H), 6.68 (d, J = 7.39 Hz, 1H), 5.09 (s, 1H), 3.76 (d, J = 13.22 Hz, 1H), 3.58 (s, 3H), 3.40 (s, 3H), 2.72 (s, 3H), 2.51 (d, J = 13.13 Hz, 1H), 1.57 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): δ = 178.61, 170.98, 166.47, 155.84, 151.79, 141.24, 139.88, 132.98, 131.68, 131.54, 131.41, 127.21, 126.86, 126.69, 117.17, 113.94, 113.13, 109.40, 84.20, 55.03, 53.25, 52.03, 40.17, 28.00, 26.51. HRMS (ESI): [M+H]⁺ calcd for [C₂₇H₂₈N₂O₇]: 493.1969, found: 493.1963.

1-(tert-butyl) 3-methyl
1'-acetyl-6'-bromo-2'-oxospiro[benzo[b]azepine-4,3'-indoline]-1,3(5H)-dicarboxylate (3h)

Pale Yellow Solid. m. p.: 183–186°C. IR(KBr): 799, 1030, 1104, 1150, 1244, 1261, 1323, 1371, 1459, 1470, 1589, 1602, 1640, 1705, 1763, 2854, 2926, 2958, 3384 cm⁻¹; ¹H NMR (400 MHz, CDCl₃): δ = 8.66 (s, 1H), 8.31 (d, J = 1.89 Hz, 1H), 7.31-7.37 (m, 2H), 7.10-7.14 (m, 2H), 6.75-6.77 (m, 1H), 6.66 (d, J = 7.67 Hz, 1H), 5.44 (d, J = 8.18 Hz, 1H), 3.75 (d, J = 13.16 Hz, 1H), 3.59 (s, 3H), 2.73 (s, 3H), 2.49 (d, J = 13.16 Hz, 1H), 1.57 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): δ = 178.20, 171.20, 166.53, 151.73, 141.46, 140.27, 139.78, 134.13, 131.47, 131.02, 128.68, 127.41, 126.83, 124.74, 123.97, 116.82, 112.71, 84.34, 52.81, 52.13, 40.00, 27.99, 26.61. HRMS (ESI): [M+H]⁺ calcd for [C₂₇H₂₅ClN₂O₆]: 497.1474, found: 497.1469.
Yellow Solid. m. p.: 181–184 °C. IR(KBr): 740, 1029, 1149, 1261, 1327, 1371, 1467, 1588, 1599, 1640, 1704, 1761, 2854, 2927, 2955, 3396 cm⁻¹;¹H NMR (400 MHz, CDCl₃): δ = 8.66 (s, 1H), 8.47 (d, J = 1.76 Hz, 1H), 7.30–7.33 (m, 2H), 7.10–7.14 (m, 1H), 6.92 (d, J = 7.82 Hz, 1H), 6.66 (d, J = 7.41 Hz, 1H), 5.38 (d, J = 8.00 Hz, 1H), 3.74 (d, J = 13.29 Hz, 1H), 3.59 (s, 3H), 2.73 (s, 3H), 2.49 (d, J = 13.17 Hz, 1H), 1.57 (s, 9H);¹³C NMR (100 MHz, CDCl₃): δ = 178.20, 171.20, 166.53, 151.73, 141.46, 140.27, 139.78, 134.13, 131.47, 131.02, 128.68, 127.41, 124.74, 123.97, 116.82, 112.71, 84.34, 52.81, 52.13, 40.00, 27.99, 26.61. HRMS (ESI): [M+H]⁺ calcld for [C₂₆H₂₅BrN₂O₆]: 541.0969, found: 541.0959.

1-(tert-butyl) 3-methyl 1'-acetyl-7-fluoro-2'-oxospiro[benzo[b]azepine-4,3'-indoline]-1,3(5H)-dicarboxylate (3i)

Pale Yellow Solid. m. p.: 161–164 °C. IR(KBr): 757, 766, 1060, 1150, 1246, 1266, 1301, 1371, 1463, 1476, 1502, 1641, 1705, 1759, 2927, 2957, 3394. cm⁻¹;¹H NMR (400 MHz, CDCl₃): δ = 8.61 (s, 1H), 8.26 (d, J = 8.22 Hz, 1H), 7.35 (dd, J = 9.35 Hz, J = 5.00 Hz, 1H), 7.23–7.28 (m, 1H), 7.01–7.06 (m, 1H), 6.84 (d, J = 7.41 Hz, 1H), 6.35–6.37 (m, 1H), 5.64 (d, J = 7.25 Hz, 1H), 3.74 (d, J = 13.22 Hz, 1H), 3.57 (s, 3H), 2.74 (s, 3H), 2.46 (d, J = 13.38 Hz, 1H), 1.57 (s, 9H);¹³C NMR (100 MHz, CDCl₃): δ = 178.46, 171.28, 166.37, 161.67, 159.20, 151.73, 141.18, 139.59, 135.88, 133.73, 129.88, 128.68, 128.60, 128.51, 124.06, 123.70, 117.80, 117.57, 116.39, 114.47, 114.25, 113.50, 84.43, 52.94, 52.10, 40.05, 28.03, 26.66. HRMS (ESI): [M+H]⁺ calcld for [C₂₆H₂₅BrN₂O₆]: 481.1769, found: 481.1775.

1-(tert-butyl) 3-methyl 1'-acetyl-7-chloro-2'-oxospiro[benzo[b]azepine-4,3'-indoline]-1,3(5H)-dicarboxylate (3j)
Pale Yellow Solid. m. p.: 178–180 °C. IR(KBr): 704, 738, 757, 1018, 1034, 1148, 1372, 1462, 1602, 1640, 1707, 1763, 2854, 2870, 2928, 2955, 3055, 3394 cm⁻¹; ¹H NMR (400 MHz, CDCl₃): δ = 8.62 (s, 1H), 8.27 (d, J = 8.14 Hz, 1H), 7.25-7.31 (m, 3H), 6.86 (d, J = 7.45 Hz, 1H), 6.64 (s, 1H), 5.63 (d, J = 7.25 Hz, 1H), 3.72 (d, J = 13.32 Hz, 1H), 3.57 (s, 3H), 2.74 (s, 3H), 2.44-2.47 (m, 1H), 1.57 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): δ = 178.38, 171.24, 166.31, 151.53, 140.94, 139.56, 138.39, 133.15, 132.15, 131.02, 129.88, 128.72, 128.08, 127.34, 124.00, 123.71, 116.36, 113.44, 84.57, 52.83, 52.11, 39.85, 27.99, 26.67. HRMS (ESI): [M+H]⁺ calcd for [C₂₆H₂₅ClN₂O₆]: 497.1474, found: 497.1470.

1-(tert-butyl) 3-methyl
1'-acetyl-7-bromo-2'-oxospiro[benzo[b]azepine-4,3'-indoline]-1,3(5H)-dicarboxylate (3k)

Yellow Solid. m. p.: 179–181 °C. IR(KBr): 704, 760, 796, 1116, 1149, 1263, 1371, 1462, 1601, 1636, 1707, 1742, 2926, 2960, 3401. cm⁻¹; ¹H NMR (400 MHz, CDCl₃): δ = 8.61 (s, 1H), 8.27 (d, J = 8.20 Hz, 1H), 7.45 (dd, J = 8.35 Hz, J = 2.13 Hz, 1H), 7.23-7.29 (m, 2H), 6.87 (t, J = 7.36 Hz, 1H), 6.79 (s, 1H), 5.62 (d, J = 7.26 Hz, 1H), 3.71 (d, J = 13.15 Hz, 1H), 3.57 (s, 3H), 2.73 (s, 3H), 2.45 (d, J = 13.15 Hz, 1H), 1.57 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): δ = 178.37, 171.24, 166.30, 151.46, 140.87, 139.53, 139.91, 134.01, 133.48, 130.28, 129.84, 128.74, 128.32, 123.97, 123.74, 120.02, 116.35, 113.41, 84.60, 52.82, 52.12, 39.75, 27.98, 26.69. HRMS (ESI): [M+H]⁺ calcd for [C₂₆H₂₅BrN₂O₆]: 541.0969, found: 541.0963.

1-(tert-butyl) 3-methyl
1'-acetyl-7-methyl-2'-oxospiro[benzo[b]azepine-4,3'-indoline]-1,3(5H)-dicarboxylate (3l)
Yellow Solid. m. p.: 176–179 °C. IR(KBr): 793, 1149, 1244, 1263, 1370, 1461, 1596, 1705, 2372, 2925, 2959, 3374 cm⁻¹; ¹H NMR (400 MHz, CDCl₃): δ = 8.65 (s, 1H), 8.25 (d, J = 7.92 Hz, 1H), 7.21-7.24 (m, 2H), 7.11 (dd, J = 1.70 Hz, J = 8.27 Hz, 1H), 6.78 (t, J = 7.48 Hz, 1H), 6.42 (S, 1H), 5.55 (d, J = 7.37 Hz, 1H), 3.72 (d, J = 13.00 Hz, 1H), 3.57 (s, 3H), 2.74 (s, 3H), 2.44 (d, J = 12.25 Hz, 1H), 2.21 (s, 3H), 1.57 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): δ = 178.76, 171.37, 166.61, 151.93, 141.45, 139.54, 137.24, 136.51, 131.93, 130.96, 128.37, 127.89, 126.44, 124.06, 123.66, 116.12, 113.07, 83.99, 53.18, 51.99, 40.17, 28.02, 26.68, 20.70. HRMS (ESI): [M+H]⁺ calcd for [C₂₇H₂₈N₂O₆]: 477.2020, found: 477.2018.

1-(tert-butyl) 3-methyl 1'-acetyl-8-fluoro-2'-oxospiro[benzo[b]azepine-4,3'-indoline]-1,3(5H)-dicarboxylate (3m)

Pale Yellow Solid. m. p.: 173–175 °C. IR(KBr): 740, 759, 916, 1153, 1245, 1371, 1436, 1462, 1477, 1507, 1604, 1641, 1706, 1755, 2927, 2955, 3056, 3395. cm⁻¹; ¹H NMR (400 MHz, CDCl₃): δ = 8.61 (s, 1H), 8.26 (d, J = 8.25 Hz, 1H), 7.25 (t, J = 7.21 Hz, 1H), 7.13 (dd, J = 2.06 Hz, J = 9.90 Hz, 1H), 6.80-6.87 (m, 2H), 6.56-6.63 (m, 1H), 5.63 (d, J = 6.88 Hz, 1H), 3.71 (d, J = 13.06 Hz, 1H), 3.57 (s, 3H), 2.73 (s, 3H), 2.50 (d, J = 13.20 Hz, 1H), 1.59 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): δ = 178.43, 171.31, 166.33, 162.45, 160.00, 151.42, 140.91, 140.82, 139.57, 132.53, 132.45, 130.18, 128.54, 127.29, 116.31, 114.26, 114.12, 114.01, 113.91, 113.62, 84.70, 52.95, 52.11, 39.53, 28.00, 26.67. HRMS (ESI): [M+H]⁺ calcd for [C₂₆H₂₅ClN₂O₆]: 481.1769, found: 481.1763.
Pale Yellow Solid. m. p.: 182–183 °C. IR(KBr): 741, 914, 1017, 1148, 1243, 1303, 1437, 1463, 1582, 1601, 1639, 1734, 2929, 2955, 3055, 3392 cm⁻¹; ¹H NMR (400 MHz, CDCl₃): δ = 8.60 (s, 1H), 8.26 (d, J = 8.11 Hz, 1H), 7.40 (d, J = 1.75 Hz, 1H), 7.25 (t, J = 7.63 Hz, 1H), 7.10 (d, J = 7.79 Hz, 1H), 6.84 (t, J = 7.00 Hz, 1H), 6.58 (d, J = 7.79 Hz, 1H), 5.67 (d, J = 6.84 Hz, 1H), 3.70 (d, J = 13.04 Hz, 1H), 3.57 (s, 3H), 2.73 (s, 3H), 2.49 (d, J = 13.20 Hz, 1H), 1.59 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): δ = 178.37, 171.28, 166.29, 151.38, 140.76, 139.56, 132.63, 132.34, 130.10, 129.88, 128.57, 127.03, 126.83, 123.98, 123.83, 116.32, 113.64, 84.70, 52.81, 52.12, 39.65, 27.99, 26.66. HRMS (ESI): [M+H]⁺ calcd for [C₂₆H₂₅FN₂O₆]: 497.1474, found: 497.1476.

(1-(tert-butyl) 3-methyl 1'-acetyl-8-bromo-2'-oxospiro[benzo[b]azepine-4,3'-indoline]-1,3(5H)-dicarboxylate (3o)

Yellow Solid. m. p.: 180–182 °C. IR(KBr): 758, 1149, 1242, 1266, 1302, 1371, 1462, 1640, 1706, 1759, 2371, 2927, 2959, 3389 cm⁻¹; ¹H NMR (400 MHz, CDCl₃): δ = 8.60 (s, 1H), 8.26 (d, J = 8.29 Hz, 1H), 7.54 (d, J = 0.98 Hz, 1H), 7.23-7.27 (m, 2H), 6.84 (t, J = 7.09 Hz, 1H), 6.51 (d, J = 7.86 Hz, 1H), 5.67 (d, J = 7.03 Hz, 1H), 3.69 (d, J = 13.14 Hz, 1H), 3.57 (s, 3H), 2.73 (s, 3H), 2.48 (d, J = 13.31 Hz, 1H), 1.59 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): δ = 178.35, 171.25, 166.27, 151.35, 140.91, 140.72, 139.55, 132.60, 130.34, 130.09, 129.92, 129.68, 128.56, 123.81, 120.20, 113.63, 84.69, 52.71, 52.11, 39.70, 27.98, 26.64. HRMS (ESI): [M+H]⁺ calcd for [C₂₆H₂₅BrN₂O₆]: 541.0969, found: 541.0964.

1-(tert-butyl) 3-methyl 1'-acetyl-8-methyl-2'-oxospiro[benzo[b]azepine-4,3'-indoline]-1,3(5H)-dicarboxylate (3p)

Yellow Solid. m. p.: 193–195 °C. IR(KBr): 741, 809, 923, 1017, 1262, 1371, 1461, 1511, 1640, 1704, 1753, 2924, 2959, 3392 cm⁻¹; ¹H NMR (400 MHz,
CDCl₃): δ = 8.63 (s, 1H), 8.25 (d, J = 8.17 Hz, 1H), 7.23 (t, J = 7.82 Hz, 1H), 7.17 (s, 1H), 6.91 (d, J = 7.56 Hz, 1H), 6.79 (t, J = 7.20 Hz, 1H), 6.51 (d, J = 7.56 Hz, 1H), 5.55 (d, J = 7.21 Hz, 1H), 3.71 (d, J = 13.12 Hz, 1H), 3.56 (s, 3H), 2.74 (s, 3H), 2.46 (d, J = 13.12 Hz, 1H), 2.39 (s, 3H), 1.58 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): δ = 178.75, 171.38, 166.60, 151.87, 141.36, 139.67, 139.54, 137.14, 131.27, 130.42, 128.31, 128.17, 124.49, 127.17, 124.07, 123.81, 116.13, 113.27, 84.00, 53.20, 52.01, 39.84, 28.04, 26.69, 21.12. HRMS (ESI): [M+H]+ calcd for [C₂₇H₂₈N₂O₆]: 477.2020, found: 477.2016.

1-(tert-butyl) 3-methyl
1'-acetyl-6-chloro-2'-oxospiro[benzo[b]azepine-4,3'-indoline]-1,3(5H)-dicarboxylate (3q)

Pale Yellow Solid. m. p.: 178–180 °C. IR(KBr): 758931, 1150, 1246, 1263, 1371, 1463, 1578, 1603, 1641, 1706, 1759, 2928, 2957, 3055, 3397 cm⁻¹; ¹H NMR (400 MHz, CDCl₃): δ = 8.60 (s, 1H), 8.26 (d, J = 8.14 Hz, 1H), 7.19-7.30 (m, 4H), 6.81 (d, J = 7.57 Hz, 1H), 5.63 (d, J = 7.33 Hz, 1H), 3.58 (s, 3H), 3.52 (d, J = 13.53 Hz, 1H), 3.24 (d, J = 13.41 Hz, 1H), 2.76 (s, 3H), 1.57 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): δ = 170.40, 171.30, 166.21, 151.27, 141.46, 140.86, 139.65, 135.69, 130.15, 129.75, 128.61, 127.83, 127.48, 125.56, 124.26, 122.84, 116.28, 114.02, 84.55, 52.51, 52.11, 35.25, 28.00, 26.75. HRMS (ESI): [M+H]+ calcd for [C₂₆H₂₅ClN₂O₆]: 497.1474, found: 497.1468.

1-(tert-butyl) 3-methyl
1'-acetyl-6-methyl-2'-oxospiro[benzo[b]azepine-4,3'-indoline]-1,3(5H)-dicarboxylate (3r)

Yellow Solid. m. p.: 158–160 °C. IR(KBr): 736, 762, 1152, 1245, 1303, 1371, 1463, 1475, 1604, 1642, 1705, 1760, 2979, 3395 cm⁻¹; ¹H NMR (400 MHz, CDCl₃): δ = 8.63 (s, 1H), 8.25 (d, J = 8.08 Hz, 1H), 7.16-7.26 (m, 3H), 6.96 (dd, J = 6.63 Hz, J = 2.01 Hz, 1H), 6.67-6.78 (m, 1H), 5.55-5.58 (m, 1H), 3.58 (s, 3H), 3.53 (d, J = 13.47 Hz, 1H), 2.75-2.80 (m, 4H), 1.56 (s, 9H), 1.45 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ = 178.73, 171.44, 166.50, 151.99, 141.55, 140.42, 139.45, 138.39, 130.27, 130.14, 128.65, 128.45, 126.65, 124.64, 124.06, 123.32, 116.10, 113.51, 83.96, 52.89, 51.99, 34.88, 28.01, 26.75, 19.31. HRMS (ESI): [M+H]+ calcd for [C₂₇H₂₈N₂O₆]: 477.2020, found: 477.2025.
1'-{(tert-butyl) 3'-methyl 1-acetyl-2-oxospiro[indoline-3,4'-naphtho[2,3-b]azepine]-1',3'(5'H)-dicarboxylate (3s)

White Solid. m. p.: 188–190 °C. IR(KBr): 797, 1151, 1262, 1371, 1462, 1603, 1639, 1705, 1758, 2372, 2925, 2959, 3395 cm⁻¹; ¹H NMR (400 MHz, CDCl₃): δ = 8.69 (s, 1H), 8.26 (d, J = 8.14 Hz, 1H), 7.84-7.87 (m, 2H), 7.63 (d, J = 8.05 Hz, 1H), 7.43-7.53 (m, 2H), 7.18 (t, J = 7.70 Hz, 1H), 7.12 (m, 1H), 6.59 (t, J = 7.44 Hz, 1H), 5.40 (d, J = 7.44 Hz, 1H), 3.94 (d, J = 13.16 Hz, 1H), 3.57 (s, 3H), 2.77 (s, 3H), 2.67 (d, J = 13.16 Hz, 1H), 1.58 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): δ = 178.84, 171.35, 166.52, 152.08, 141.79, 139.50, 137.59, 132.12, 131.60, 130.14, 129.59, 128.39, 127.65, 127.28, 126.57, 126.54, 125.36, 123.96, 123.79, 116.17, 113.69, 84.13, 53.71, 52.08, 40.49, 28.08, 26.70. HRMS (ESI): [M+H]+ calcd for [C₃₀H₂₈N₂O₆]: 513.2020, found: 513.2014.

5. X-ray Crystallographic Data

X-ray Crystallographic Data of Compound 3n
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Correction method: # Reported T Limits: Tmin=0.978 Tmax=1.000
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Data completeness= 0.990 Theta(max)= 26.020
R(reflections)= 0.0580( 2666) wR2(reflections)= 0.1533( 4874)
S = 1.049 Npar= 321
6. NMR spectrogram