An efficient and eco-friendly synthesis of 2-pyridones and functionalized azaxanthone frameworks \textit{via} indium triflate catalyzed domino reaction

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Experimental General:

All chemicals were purchased from Sigma Aldrich. All melting points are uncorrected. $^1$H and $^{13}$C NMR spectra were recorded in CDCl$_3$ and DMSO-$d_6$ using TMS as an internal standard on a Bruker avance spectrometer at 400 Mhz and 100 MHz and JEOL spectrometer at 500 and 125 Mhz, respectively. Mass spectra were recorded using a JEOL GCMate-II–HR mass spectrometer. Analytical TLC was performed on precoated aluminium sheets of siliga gel G/UV-254 of 0.2 mm thickness (Merck, Germany).

Starting materials

Starting materials 2 and 4 derivatives (Table 1 in manuscript) has been prepared according to the literature procedure.$^{13c,d}$

General procedure for the preparation of 2-pyridone and chrominopyridine derivatives: A mixture of 3-formylchromone 1 (1 mmol), (Z)-N-methyl-1-(methyl-thio)-2-nitroethenamine/N,N'-dimethyl-2-nitro-ethene-1,1-diamine 2/4 (1 mmol), and indium triflate (2 mol %) in ethanol (3 mL) were charged in a 25 mL round bottomed flask and the mixture was heated at reflux. The resulting solution was stirred for 1-3 hrs. The consumption of the starting material was monitored by TLC. After completion of the reaction, the products (3a-s) was filtered and washed with ethanol, dried under vacuum and the products 5a-p was purified by column chromatography to obtain pure products 3a-s and 5a-p in good yields (65-95 %). The identities of products 3a-s and 5a-p were confirmed by NMR and EI-HRMS, giving good agreement with the assigned structures.

Synthetic transformation of products 3a:

A mixture of γ-nitro-2-pyridone 3a (1 mmol) and stannous chloride dihydrate (7 equiv) in ethanol (3 mL) were charged in a 25 mL round bottomed flask and the mixture was heated at reflux. The resulting solution was stirred for 2 hrs. The consumption of the starting material was monitored by TLC. After completion of the reaction, the products was purified by column chromatography to obtain pure products 14 in good yield (82 %). The identities of products 14 was confirmed by NMR and EI-HRMS, giving good agreement with the assigned structures.

Isolated as yellow solid, 82%, mp: 188-190 °C,$^4$H NMR (400 MHz, DMSO-$d_6$) $\delta$ H 10.20 (1H, s), 7.74 (1 H, d, J = 1.3), 7.57 (1H, d, J = 1.8), 7.39 (2H, dd, J = 16.8, 8.0), 7.03 – 6.93 (2H, m), 3.72 (1H, s), 3.59 (3H, s), 3.57 (1H, s) ppm. $^{13}$C NMR (100 MHz, DMSO-$d_6$) $\delta$ C 192.73, 158.55, 156.44, 137.27, 132.98, 130.50, 130.26, 125.21, 119.55, 117.61, 117.23, 110.72, 38.43 ppm. EI-HRMS: Anal. Calcd for C$_{13}$H$_{12}$N$_2$O$_3$: 244.0848, Found: 244.0847
Catalyst recovery and reuse during the preparation of 2-pyridone 3a

A mixture of 3-formylchromone 1 (1 equiv), (Z)-N-methyl-1-(methyl-thio)-2-nitroethenamine 2 (1 equiv), and indium triflate (2 mol %) in ethanol were charged in a 25 mL round bottomed flask and the mixture was heated at reflux. The resulting solution was stirred for 1 hr. The consumption of the starting material was monitored by TLC. After completion of the reaction, the products 3a was filtered and washed with ethanol, dried under vacuum to obtain pure product 3a as 88 % yield. The filtrate was evaporated to dryness by repeated codistillation with toluene and finally dried under vacuum at 95–100°C. The recovered catalyst is effective in subsequent experiments. It should be noted that the yields in second and even fifth run are comparable to that of the first run (Table 1).

**Table 1** Catalyst recovery and reuse during the preparation of 2-pyridone 3a

<table>
<thead>
<tr>
<th>Run</th>
<th>In(OTf)$_3$ Product (%)</th>
<th>Yield$^{a,b,c}$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1$^{st}$</td>
<td>3a</td>
<td>88</td>
</tr>
<tr>
<td>2$^{nd}$</td>
<td>3a</td>
<td>86</td>
</tr>
<tr>
<td>3$^{rd}$</td>
<td>3a</td>
<td>84</td>
</tr>
<tr>
<td>4$^{th}$</td>
<td>3a</td>
<td>84</td>
</tr>
<tr>
<td>5$^{th}$</td>
<td>3a</td>
<td>80</td>
</tr>
</tbody>
</table>

$a$The reaction was performed with 3-formylchromone 1 (1 equiv), NMSM 2 (1 equiv), In(OTf)$_3$ (2 mol %) and ethanol, at reflux, $b$Reaction progress was followed by TLC analysis. $c$Yield of isolated products.

3a: 5-(2-hydroxybenzoyl)-1-methyl-3-nitropyridin-2(1H)-one

Isolated as yellow solid, 89%, mp: 219-221°C. $^1$H NMR (400 MHz, DMSO-d$_6$) $\delta$ 10.34 (s, 1H), 8.74 (s, 1H), 8.52 (d, $J$ = 2.3 Hz, 1H), 7.51–7.22 (m, 2H), 7.07–6.67 (m, 2H), 3.62 (s, 3H) ppm. $^{13}$C NMR (100 MHz, DMSO-d$_6$) $\delta$ 190.19, 155.83, 154.05, 150.44, 137.66, 136.15, 133.39, 130.21, 124.11, 119.45, 116.77, 114.28, 38.62 ppm. El-HRMS: Anal. Calcd for C$_{13}$H$_{10}$N$_2$O$_5$: 274.0590, Found: 274.0587.

3b: 5-(5-chloro-2-hydroxybenzoyl)-1-methyl-3-nitropyridin-2(1H)-one

Isolated as yellow solid, 88 %, mp: 202-204 °C. $^1$H NMR (400 MHz, DMSO-d$_6$) $\delta$ 10.61 (s, 1H), 8.78 (d, $J$ = 2.5 Hz, 1H), 8.56 (d, $J$ = 2.5 Hz, 1H), 7.47 (dd, $J$ = 8.8, 2.7 Hz, 1H), 7.38 (d, $J$ = 2.7 Hz, 1H), 7.01 (d, $J$ = 8.8 Hz, 1H), 3.65 (s, 3H) ppm. $^{13}$C NMR (100 MHz, DMSO-d$_6$) $\delta$ 193.94, 159.51, 159.32, 156.00, 142.56, 141.67, 137.80, 134.30, 131.31, 128.28, 123.82, 119.25, 43.85 ppm. El-HRMS: Anal. Calcd for C$_{13}$H$_{9}$ClN$_2$O$_5$: 308.0200, Found: 308.0199.

3c: 5-(5-bromo-2-hydroxybenzoyl)-1-methyl-3-nitropyridin-2(1H)-one

Isolated as yellow solid, 85 %, mp: 210-212 °C. $^1$H NMR (400 MHz, DMSO-d$_6$) $\delta$ 10.65 (s, 1H), 8.78 (d, $J$ = 2.0 Hz, 1H), 8.57 (d, $J$ = 2.1 Hz, 1H), 7.69–7.37 (m,
2H), 6.97 (d, J = 8.7 Hz, 1H), 3.66 (s, 3H) ppm. $^{13}$C NMR (100 MHz, DMSO-$d_6$) δ 193.85, 159.92, 159.31, 156.06, 142.60, 141.64, 140.63, 137.14, 131.86, 124.26, 119.25, 115.71, 43.86. El-HRMS: Anal. Calcd for C$_{13}$H$_9$BrN$_2$O$_3$: 351.9695, Found: 351.9690.

3d:5-(5-fluoro-2-hydroxybenzoyl)-1-methyl-3-nitropyridin-2(1H)-one

Isolated as yellow solid, 83 %, mp: 210-212 °C, $^1$H NMR (400 MHz DMSO-$d_6$) δ 10.32 (s, 1H), 8.77 (d, J = 2.0 Hz, 1H), 8.57 (d, J = 2.4 Hz, 1H), 7.30 (td, J = 8.6, 3.2 Hz, 1H), 7.21 (dd, J = 8.6, 3.2 Hz, 1H), 7.00 (dd, J = 9.0, 4.4 Hz, 1H), 3.66 (s, 3H). $^{13}$C NMR (100 MHz, DMSO-$d_6$) . δ c 194.09, 161.62, 159.32-159.27 (d, J = 4.10 Hz), 157.06, 156.08, 142.66, 141.65, 130.24-130.17 (d, J = 6.70 Hz), 125.16-124.93 (d, J = 23.75 Hz), 123.40-123.32 (d, J = 8.70 Hz), 121.08-120.84 (d, J = 24.69 Hz), 119.21, 43.86.


3e:5-(4-fluoro-2-hydroxybenzoyl)-1-methyl-3-nitropyridin-2(1H)-one

Isolated as yellow solid, 86 %, mp: 260-261°C, $^1$H NMR (400 MHz, DMSO-$d_6$) δ 8.77 (d, J = 2.3 Hz, 1H), 8.58 (d, J = 2.4 Hz, 1H), 7.50 (dd, J = 8.2, 7.2 Hz, 1H), 6.80 (ddd, J = 12.8, 9.5, 2.1 Hz, 2H), 3.66 (s, 3H). $^{13}$C NMR (100 MHz, DMSO-$d_6$) . δ c 194.35, 171.37, 168.89, 163.37-163.25 (d, J = 13.62 Hz), 159.31, 155.74, 142.75-142.69 (d, J = 5.68 Hz), 141.56, 137.94-137.82 (d, J = 11.35 Hz), 126.34-126.32 (d, J = 2.25 Hz), 119.58, 112.15-108.71 (dd, J = 322.91, 23.01 Hz), 43.81ppm. El-HRMS: Anal. Calcd for C$_{13}$H$_9$FNO$_5$: 292.0495, Found: 292.0493.

3f:5-(3,5-dichloro-2-hydroxybenzoyl)-1-methyl-3-nitropyridin-2(1H)-one

Isolated as yellow solid, 84 %, mp: 209-211°C, $^1$H NMR (400 MHz, DMSO-$d_6$) δ 8.72 (d, J = 1.8 Hz, 1H), 8.56 (d, J = 2.0 Hz, 1H), 7.72 (d, J = 2.2 Hz, 1H), 7.36 (d, J = 2.2 Hz, 1H), 3.60 (s, 3H). $^{13}$C NMR (100 MHz, DMSO-$d_6$) δ 188.11, 154.03, 150.92, 150.50, 136.81, 136.60, 131.89, 128.11, 127.84, 123.54, 123.36, 113.82, 38.62 ppm. El-HRMS: Anal. Calcd for C$_{13}$H$_8$Cl$_2$N$_2$O$_5$: 341.9810, Found: 341.9810.

3g: 5-(2-hydroxy-5-methylbenzoyl)-1-methyl-3-nitropyridin-2(1H)-one

Isolated as yellow solid, 80 %, mp: 216-218 °C, $^1$H NMR (400 MHz, DMSO-$d_6$) δ 10.18 (s, 1H), 8.77 (d, J = 2.4 Hz, 1H), 8.56 (d, J = 2.5 Hz, 1H), 7.27 (dd, J = 8.3, 1.9 Hz, 1H), 7.20 (d, J = 1.7 Hz, 1H), 6.91 (d, J = 8.3 Hz, 1H), 3.68 (s, 3H), 2.26 (s, 3H). $^{13}$C NMR (100 MHz, DMSO-$d_6$) δ 195.55, 159.29, 158.83, 155.73, 143.10, 141.37, 139.31, 135.36, 133.50, 129.06, 121.92, 119.63, 43.86, 25.05 ppm. El-HRMS: Anal. Calcd for C$_{14}$H$_{12}$N$_2$O$_5$: 288.0746, Found: 288.0743.

3h:5-(2-hydroxy-5-methoxybenzoyl)-1-methyl-3-nitropyridin-2(1H)-one
Isolated as yellow solid, 78 %, mp: 215-217 °C, $^1$H NMR (400 MHz, DMSO-$d_6$) δ 9.86 (s, 1H), 8.71 (s, 1H), 8.52 (d, $J = 2.0$ Hz, 1H), 7.02 (dd, $J = 8.9, 2.9$ Hz, 1H), 6.91 – 6.77 (m, 2H), 3.68 (s, 3H), 3.62 (s, 3H), $^{13}$C NMR (100 MHz, DMSO-$d_6$) δ 195.05, 159.34, 157.40, 155.77, 154.79, 142.97, 141.35, 129.46, 125.20, 123.13, 119.46, 118.86, 60.74, 43.80. EI-HRMS: Anal. Calcd for C$_{18}$H$_{12}$N$_2$O$_6$: 304.0695, Found: 304.0689.

3i: 5-(2-hydroxybenzoyl)-3-nitro-1-propylypyridin-2(1H)-one

Isolated as yellow solid, 75 %, mp: 170-172°C, $^1$H NMR (400 MHz, DMSO-$d_6$) δ$_H$ 10.43 (1H, s), 8.70 (1H, d, $J = 2.5$), 8.55 (1H, d, $J = 2.5$), 7.51 – 7.36 (2H, m), 7.05 – 6.89 (2H, m), 4.08 (2H, t, $J = 7.2$), 1.70 (2H, dd, $J = 14.6, 7.3$), 0.88 (3H, t, $J = 7.4$) ppm. $^{13}$C NMR (100 MHz, DMSO-$d_6$): δ$_C$ 190.68, 156.30, 154.09, 150.36, 137.91, 137.26, 133.99, 130.84, 124.58, 120.00, 117.25, 115.02, 52.49, 22.24, 11.06 ppm. EI-HRMS: Anal. Calcd for C$_{13}$H$_{14}$N$_2$O$_5$: 302.0903, Found: 302.0900.

3j: 5-(5-chloro-2-hydroxybenzoyl)-3-nitro-1-propylypyridin-2(1H)-one

Isolated as yellow solid, 82 %, mp: 192-194°C, $^1$H NMR (400 MHz, DMSO-$d_6$): δ$_H$ 10.55 (1H, d, $J = 63.9$ ), 8.72 (1H, d, $J = 2.5$ ), 8.56 (1H, d, $J = 2.5$), 7.47 (1H, dd, $J = 8.8, 2.7$), 7.38 (1H, d, $J = 2.7$), 7.01 (1H, d, $J = 8.8$), 4.08 (2H, t, $J = 7.2$), 1.66 (2H, dd, $J = 14.5, 7.3$), 0.88 (3H, t, $J = 7.3$). $^{13}$C NMR (100 MHz, DMSO-$d_6$): δ$_C$ 189.13, 154.83, 154.09, 150.69, 137.50, 137.47, 133.15, 129.73, 126.47, 123.55, 119.10, 114.66, 52.44, 22.22, 11.04. EI-HRMS: Anal. Calcd for C$_{15}$H$_{13}$ClN$_2$O$_5$: 336.0513, Found: 336.0512.

3k: 5-(2-hydroxy-5-methylbenzoyl)-3-nitro-1-propylypyridin-2(1H)-one

Isolated as yellow solid, 79 %, mp: 177-179°C, $^1$H NMR (400 MHz, DMSO-$d_6$): δ$_H$ 10.16 (1H, s), 8.69 (1H, d, $J = 2.5$), 8.56 (1H, t, $J = 6.3$), 7.25 (1H, dt, $J = 17.6, 8.8$), 7.20 (1H, s), 6.90 (1H, d, $J = 8.3$), 4.16 – 3.98 (2H, m), 2.25 (3H, s), 1.77 – 1.63 (2H, m), 0.88 (3 H, t, $J = 7.6$) ppm. $^{13}$C NMR (100 MHz, DMSO-$d_6$): δ$_C$ 190.74, 154.13, 154.09, 150.38, 137.95, 137.28, 134.66, 130.76, 128.75, 124.27, 117.20, 115.05, 52.46, 22.23, 20.30, 11.07 ppm. EI-HRMS: Anal. Calcd for C$_{16}$H$_{16}$N$_2$O$_5$: 316.1059, Found: 316.1054.

3l: 1-buty1-5-(2-hydroxybenzoyl)-3-nitropyrindin-2(1H)-one

Isolated as yellow solid, 83 %, mp: 155-157°C, $^1$H NMR (400 MHz, DMSO-$d_6$): δ$_H$ 10.42 (1H, s), 8.70 (1H, d, $J = 2.5$), 8.55 (1H, d, $J = 2.5$), 7.50 – 7.35 (2H, m), 6.99 (2H, dd, $J = 16.0, 7.9$), 4.12 (1H, t, $J = 7.3$), 3.40 (1H, d, $J = 6.3$), 1.74 – 1.50 (2H, m), 1.37 – 1.22 (2 H, m), 0.88 (3 H, td, $J = 7.3, 3.4$) ppm. $^{13}$C NMR (100 MHz, DMSO-$d_6$): δ$_C$ 190.66, 156.37, 154.04, 150.30, 137.88, 133.96, 130.83, 124.54, 119.95, 117.25, 115.05, 112.70, 50.81, 30.96, 19.55, 13.87 ppm. EI-HRMS: Anal. Calcd for C$_{16}$H$_{16}$N$_2$O$_5$: 316.1059, Found: 316.1052.
3m: 1-butyl-5-(5-chloro-2-hydroxybenzoyl)-3-nitropyridin-2(1H)-one

Isolated as yellow solid, 78%, mp: 160-162°C, $^1$H NMR (400 MHz, DMSO-$d_6$): $\delta$H (400 MHz, DMSO) 10.61 (1H, s), 8.72 (1H, d, $J = 2.5$), 8.56 (1H, d, $J = 2.5$), 7.47 (1H, dd, $J = 8.8, 2.7$), 7.38 (1H, d, $J = 2.7$), 7.02 (1H, d, $J = 8.8$), 4.11 (2H, t, $J = 7.3$), 1.71 – 1.56 (2H, m), 1.29 (2H, m), 0.90 (3H, t, $J = 7.3$) ppm. $^{13}$C NMR (100 MHz, DMSO-$d_6$): $\delta$ C 189.11, 154.86, 154.07, 150.60, 137.51, 137.43, 133.15, 129.73, 126.48, 123.54, 119.11, 114.70, 50.77, 30.94, 19.52, 13.92 ppm. EI-HRMS: Anal. Calcd for C$_{16}$H$_{15}$ClN$_2$O$_5$: 350.0669, Found: 350.0664.

3n: 1-Butyl-5-(5-fluoro-2-hydroxybenzoyl)-3-nitropyridin-2(1H)-one

Isolated as yellow solid, 75%, mp: 144-146°C, $^1$H NMR (400 MHz, CDCl$_3$): $\delta$H 10.86 (1H, s), 8.68 (1H, d, $J = 2.6$), 8.30 (1H, d, $J = 2.6$), 7.33 (1H, dd, $J = 9.2, 7.7$), 7.21 (1H, dd, $J = 8.4, 3.0$), 7.10 (1H, dd, $J = 9.2, 4.5$), 4.22–4.04 (2H, m), 1.89–1.77 (2H, m), 1.44 (2H, dd, $J = 15.1, 7.5$), 1.00 (3H, t, $J = 7.4$). $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ C 192.21, 158.68-158.66 (d, $J = 2.18$ Hz), 156.10, 153.71, 153.65, 147.43, 137.42, 124.73-124.49 (d, $J = 23.84$ Hz), 120.70-120.63 (d, $J = 7.59$ Hz), 117.80-117.74 (d, $J = 7.11$ Hz), 116.13-115.89 (d, $J = 23.69$ Hz), 113.92, 52.04, 31.08, 19.80, 13.50 ppm. EI-HRMS: Anal. Calcd for C$_{16}$H$_{15}$FN$_2$O$_5$: 334.0965, Found: 334.0961.

3o: cyclohexyl-5-(2-hydroxybenzoyl)-3-nitropyridin-2(1H)-one

Isolated as yellow solid, 87%, mp: 206-208°C, $^1$H NMR (400 MHz, DMSO-$d_6$): $\delta$H 10.47 (1H, s), 8.51 (2H, d, $J = 3.7$), 7.56–7.28 (2H, m), 7.12–6.83 (2H, m), 4.72 (1H, dd, $J = 16.2, 7.5$), 1.85 (4H, t, $J = 13.5$), 1.62 (3H, dd, $J = 20.7, 11.8$), 1.41 (2H, q, $J = 12.7$), 1.22 (1H, t, $J = 12.8$) ppm. $^{13}$C NMR (100 MHz, DMSO-$d_6$): $\delta$ C 190.51, 156.29, 153.86, 146.42, 137.36, 137.17, 134.15, 131.02, 124.45, 120.09, 117.25, 115.09, 57.43, 31.61, 25.74, 24.90 ppm. EI-HRMS: Anal. Calcd for C$_{16}$H$_{18}$N$_2$O$_5$: 342.1216, Found: 342.1212.

3p: 5-(5-chloro-2-hydroxybenzoyl)-1-cyclohexyl-3-nitropyridin-2(1H)-one

Isolated as yellow solid, 85%, mp: 210-212°C, $^1$H NMR (400 MHz, CDCl$_3$): $\delta$H 11.05 (1H, s), 8.62 (1H, s), 8.29 (1H, s), 7.52 (H, d, $J = 8.9$), 7.47 (1H, s), 7.09 (1H, d, $J = 8.9$), 5.00 (1H, t, $J = 11.5$), 2.16 – 1.93 (4H, m), 1.82 (1H, d, $J = 13.9$), 1.66 – 1.40 (4H, m), 1.32 – 1.06 (1H, m) ppm. $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ C 192.38, 161.06, 153.52, 144.21, 137.67, 136.77, 136.41, 130.13, 124.27, 120.85, 118.88, 113.78, 57.05, 32.81, 25.63, 25.02 ppm. EI-HRMS: Anal. Calcd for C$_{18}$H$_{17}$ClN$_2$O$_5$: 376.0826, Found: 376.0820.

3q: 1-Benzyl-5-(5-chloro-2-hydroxybenzoyl)-3-nitropyridin-2(1H)-one
Isolated as yellow solid, 65%, mp: 186-188 °C, $^1$H NMR (400 MHz, CDCl$_3$): $^\delta$H 11.00 (s, 1H), 8.67 (d, $J = 2.6$ Hz, 1H), 8.23 (d, $J = 2.6$ Hz, 1H), 7.46 – 7.40 (m, 5H), 7.32 (d, $J = 2.6$ Hz, 1H), 7.26 (s, 1H), 7.05 (d, $J = 8.9$ Hz, 1H), 5.29 (s, 2H).

$^{13}$C NMR (100 MHz, CDCl$_3$): $^\delta$C 191.99, 161.00, 153.81, 146.69, 137.31, 136.80, 133.52, 129.95, 129.74, 129.57, 129.06, 127.42, 124.22, 120.81, 118.81, 114.01. 54.11 ppm. EI-HRMS: Anal. Calcd for C$_{19}$H$_{13}$Cl$_2$N$_2$O$_5$: 384.0513, Found: 384.0511.

**3r:** 1-Benzyl-5-(3,5-dichloro-2-hydroxybenzoyl)-3-nitropyridin-2(1H)-one

Isolated as yellow solid, 78%, mp: 180-182 °C, $^1$H NMR (400 MHz, CDCl$_3$): $^\delta$H 11.07 (1H, s), 8.66 (1H, d, $J = 2.6$), 8.24 (1H, d, $J = 2.6$), 7.61 (1H, d, $J = 2.4$), 7.48–7.37 (5H, m), 7.26 (1H, d, $J = 2.2$), 5.29 (2H, s).$^{13}$C NMR (100 MHz, CDCl$_3$): $^\delta$C 191.44, 160.47, 156.13, 153.78, 147.03, 137.17, 136.03, 133.38, 129.75, 129.62, 129.10, 128.56, 124.77, 124.24, 119.88, 113.70, 54.14 ppm. EI-HRMS: Anal. Calcd for C$_{19}$H$_{13}$Cl$_2$N$_2$O$_5$: 418.0123, Found: 418.0122.

**3s:** 1-Benzyl-5-(2-hydroxy-5-methylbenzoyl)-3-nitropyridin-2(1H)-one

Isolated as yellow solid, 72%, mp: 184-186 °C, $^1$H NMR (400 MHz, CDCl$_3$): $^\delta$H 10.96 (1H, s), 8.67 (1H, d, $J = 2.5$), 8.26 (1H, d, $J = 2.5$), 7.46–7.39 (5H, m), 7.34 (1H, dd, $J = 8.5, 2.0$), 7.10 (1H, d, $J = 1.3$), 6.97 (1H, d, $J = 8.5$), 5.30 (2H, s), 2.22 (3H, s).$^{13}$C NMR (100 MHz, CDCl$_3$): $^\delta$C 192.91, 160.57, 153.93, 146.80, 138.09, 137.92, 137.80, 133.96, 130.73, 129.55, 129.37, 129.02, 128.69, 118.91, 117.83, 114.71, 53.84, 20.49 ppm. EI-HRMS: Anal. Calcd for C$_{20}$H$_{16}$N$_2$O$_5$: 364.1059, Found: 364.1056.

**5a:** 1-methyl-2-(methylamino)-3-nitro-1H-chromeno[2,3-b]pyridin-5(10aH)-one

Isolated as yellow solid, 94%, mp: 200-202 °C, $^1$H NMR (400 MHz, DMSO-d$_6$) $^\delta$ 10.59 (d, $J = 3.7$ Hz, 1H), 7.90 (s, 1H), 7.81 (dd, $J = 7.8, 1.5$ Hz, 1H), 7.63 – 7.56 (m, 1H), 7.15 (t, $J = 7.2$ Hz, 1H), 7.07 (d, $J = 8.2$ Hz, 1H), 6.40 (d, $J = 16.6$ Hz, 1H), 3.51 (s, 3H), 3.25 (d, $J = 5.1$ Hz, 3H).$^{13}$C NMR (100 MHz, DMSO-d$_6$) $^\delta$ 179.39, 157.41, 156.49, 136.07, 126.85, 126.52, 122.87, 122.47, 118.14, 113.10, 112.97, 90.49, 42.71, 33.89. EI-HRMS: Anal. Calcd for C$_{14}$H$_{13}$N$_3$O$_4$: 287.0906, Found: 287.0902.

**5b:** 7-chloro-1-methyl-2-(methylamino)-3-nitro-1H-chromeno[2,3-b]pyridin-5(10aH)-one

Isolated as yellow solid, 93%, mp: 219-221 °C, $^1$H NMR (400 MHz, DMSO-d$_6$) $^\delta$ 10.54 (s, 1H), 7.94 (s, 1H), 7.74 (d, $J = 2.7$ Hz, 1H), 7.65 (dd, $J = 8.8, 2.7$ Hz, 1H), 7.14 (d, $J = 8.8$ Hz, 1H), 6.44 (s, 1H), 3.52 (s, 3H), 3.25 (d, $J = 5.2$ Hz, 3H).$^{13}$C NMR (100 MHz, DMSO) $^\delta$ 179.42, 157.41, 154.48, 136.86, 131.61, 126.43, 126.36, 122.51, 117.94, 113.32, 112.92, 90.38, 42.68, 33.88 ppm. EI-HRMS: Anal. Calcd for C$_{14}$H$_{13}$ClN$_3$O$_4$: 321.0516, Found: 321.0513
5c: 7-bromo-1-methyl-2-(methylamino)-3-nitro-1H-chromeno[2,3-b]pyridin-5(10aH)-one

Isolated as yellow solid, 95 %, mp: 220-222°C. 1H NMR (400 MHz, DMSO-d6) δ 10.54 (s, 1H), 7.94-7.81 (m, 2H), 7.74 (dd, J = 8.7, 2.3, 1H) 7.08 (d, J = 8.8 Hz, 1H), 6.45 (s, 1H), 3.52 (s, 3H), 3.25 (d, J = 5.3 Hz, 3H) ppm. 13C NMR (100 MHz, DMSO-d6) δ C 178.67, 157.83, 156.03, 138.84, 132.12, 129.31, 124.96, 121.34, 114.69, 113.69, 112.39, 91.36, 43.32, 34.46 ppm. EI-HRMS: Anal. Calcd for C14 H12Br N3 O3: 365.0011, Found: 365.0010

5d: 7-methyl-1-methyl-2-(methylamino)-3-nitro-1H-chromeno[2,3-b]pyridin-5(10aH)-one

Isolated as yellow solid, 92 %, mp: 192-194°C. 1H NMR (400 MHz, DMSO-d6) δ 10.60 (d, J = 4.5 Hz, 1H), 7.90 (s, 1H), 7.60 (d, J = 1.5 Hz, 1H), 7.42 (dd, J = 8.4, 2.1 Hz, 1H), 6.98 (d, J = 8.4 Hz, 1H), 6.33 (s, 1H), 3.51 (s, 3H), 3.26 (d, J = 5.2 Hz, 3H), 2.30 (s, 3H). 13C NMR (100 MHz, DMSO-d6) δ 179.42, 157.42, 154.49, 136.86, 131.62, 126.43, 126.36, 122.52, 117.94, 113.32, 112.93, 90.39, 42.66, 33.87, 20.00. EI-HRMS: Anal. Calcd for C15 H15N3 O3: 301.1063, Found: 301.1060

5e: 1-Butyl-2-(butylamino)-3-nitro-1H-chromeno[2,3-b]pyridin-5(10aH)-one

Isolated as yellow semi solid, 87 %, 1H NMR (400 MHz, CDCl3) δ H 11.07 (1 H, d, J = 2.5), 8.16 (1 H, s), 7.92 (1 H, dd, J = 7.8, 1.6), 7.54 – 7.43 (1 H, m), 7.12 – 7.02 (1 H, m), 6.97 (1 H, d, J = 8.2), 6.13 (1 H, s), 3.91 – 3.43 (4 H, m), 1.92 – 1.71 (4 H, m), 1.50 (2 H, dd, J = 15.1, 7.5), 1.46 – 1.30 (2 H, m), 0.99 (6 H, td, J = 7.3, 5.7). 13C NMR (100 MHz, CDCl3) δ C 180.44, 157.03, 156.66, 135.87, 127.65, 123.39, 122.66, 117.98, 114.18, 114.12, 89.09, 54.18, 47.48, 32.10, 29.97, 19.86, 19.83, 13.73, 13.52 ppm. EI-HRMS: Anal. Calcd for C20 H25N3 O3: 371.1845, Found: 371.1838

5f: 1-Butyl-2-(butylamino)-7-chloro-3-nitro-1H-chromeno[2,3-b]pyridin-5(10aH)-one

Isolated as yellow semi solid, 85 %, 1H NMR (400 MHz, CDCl3) δ H 11.01 (1H, s), 8.19 (1H, s), 7.88 (1H, d, J = 1.1), 7.43 (1H, dd, J = 8.7, 2.8), 6.93 (1H, d, J = 8.8), 6.12 (1H, s), 3.92 – 3.79 (1H, m), 3.78 – 3.64 (1H, m), 3.65 – 3.53 (1H, m), 3.48 (1H, dd, J = 12.5, 6.3), 1.79 (4 H, dd, J = 12.9, 5.7), 1.50 (2H, dd, J = 15.0, 7.5), 1.45 – 1.33 (2H, m), 0.99 (6H, td, J = 7.3, 5.4) ppm. 13C NMR (100 MHz, CDCl3) δ C 179.26, 157.01, 154.99, 135.60, 128.53, 128.21, 127.07, 124.33, 119.64, 114.36, 112.99, 89.32, 54.31, 47.54, 32.10, 29.95, 19.87, 19.83, 13.72, 13.51 ppm. EI-HRMS: Anal. Calcd for C20 H25Cl N3 O3: 405.1455, Found: 405.1454

5g: 1-Butyl-2-(butylamino)-7,9-dichloro-3-nitro-1H-chromeno[2,3-b]pyridin-5(10aH)-one

Isolated as yellow semi solid, 89 %, 1H NMR (400 MHz, CDCl3) δ H 11.04 (1H, s), 8.25 (1H, s), 7.81 (1H, d, J = 2.5), 7.55 (1H, d, J = 2.5), 6.19 (1H, s), 5.25 (s, 1H), 5.19 (s, 1H), 4.07 – 3.90 (1H, m), 1.40 – 1.24 (2H, m), 0.98 (6H, dd, J = 7.3, 3.6) ppm. 13C NMR (100 MHz, CDCl3) δ C 178.32, 157.01, 154.99, 135.60, 124.33, 119.64, 114.36, 112.99, 89.32, 54.31, 47.54, 32.10, 29.95, 19.87, 19.83, 13.72, 13.51 ppm. EI-HRMS: Anal. Calcd for C20 H19Cl2 N3 O3: 405.1455, Found: 405.1454
5h: 7-Bromo-1-butyl-2-(butylamino)-3-nitro-1H-chromeno[2,3-b]pyridin-5(10aH)-one

Isolated as yellow semi solid, 80 %. ¹H NMR (400 MHz, CDCl₃). δ H 11.01 (1H, d, J = 2.5), 8.18 (1H, s), 8.02 (1H, d, J = 2.5), 7.56 (1H, dd, J = 8.7, 2.5), 6.87 (1H, d, J = 8.7), 6.12 (1H, s), 3.97–3.34 (4H, m), 1.94–1.69 (4H, m), 1.58–1.33 (4H, m), 0.99 (6H, dt, J = 7.3, 5.1) ppm. ¹³C NMR (100 MHz, CDCl₃) δ C 179.14, 157.00, 155.47, 134.81, 130.16, 128.55, 124.75, 119.99, 115.42, 114.36, 110.90, 89.31, 54.32, 47.54, 32.10, 29.96, 19.87, 19.83, 13.73, 13.52 ppm. Ei-HRMS: Anal. Calcd for C₃₂H₂₃Cl₂N₃O₅: 439.1066, Found: 439.1063

5i: 1-Butyl-2-(butylamino)-7-fluoro-3-nitro-1H-chromeno[2,3-b]pyridin-5(10aH)-one

Isolated as yellow semi solid, 84 %. ¹H NMR (400 MHz, CDCl₃). δ H 11.03 (1H, s), 8.18 (1H, d, J = 2.5), 7.60–7.53 (1H, m), 7.24–7.15 (1H, m), 6.96 (1H, dd, J = 9.0, 4.2), 6.12 (1H, s), 3.90–3.43 (4H, m), 1.80 (4H, dd, J = 14.3, 7.0), 1.45 (4H, d, J = 14.7, 14.8, 7.4), 1.00 (6H, dt, J = 11.8, 6.0) ppm. ¹³C NMR (100 MHz, CDCl₃) δ C 179.56, 157.04, 152.69–152.68 (d, J = 1.96 Hz), 128.42, 124.27–124.20 (d, J = 6.47 Hz), 123.28–123.03 (d, J = 24.31 Hz), 119.64–119.56 (d, J = 7.59 Hz), 114.34, 113.20, 113.03, 112.79, 89.25, 54.24, 47.53, 32.09, 29.93, 19.86, 19.83, 13.72, 13.51 ppm. Ei-HRMS: Anal. Calcd for C₃₂H₂₄BrN₃O₅: 389.1751, Found: 389.1748

5j: 1-Butyl-2-(butylamino)-7-methyl-3-nitro-1H-chromeno[2,3-b]pyridin-5(10aH)-one

Isolated as yellow semi solid, 86 %. ¹H NMR (400 MHz, CDCl₃). δ H 11.09 (1H, d, J = 10.6), 8.20 (1H, d, J = 0.4), 7.76 (1H, d, J = 1.6), 7.32 (1H, dd, J = 8.3, 2.1), 6.87 (1H, d, J = 8.4), 6.08 (1H, s), 3.82–3.45 (4H, m), 1.78 (4H, m), 1.53 (2H, m), 1.37 (2H, dd, J = 14.7, 7.3), 1.0 (6H, t, J = 6.9) ppm. ¹³C NMR (100 MHz, CDCl₃) δ C 180.65, 157.12, 154.63, 136.87, 132.35, 127.64, 127.44, 123.07, 117.69, 114.36, 114.23, 89.02, 54.09, 47.50, 32.13, 29.92, 20.50, 19.88, 19.84, 13.73, 13.53 ppm. Ei-HRMS: Anal. Calcd for C₂₁H₂₇N₃O₅: 385.2002, Found: 385.2000

5k: 2-(butylamino)-1-methyl-3-nitro-1H-chromeno[2,3-b]pyridin-5(10aH)-one

Isolated as yellow semi solid, 80 %. ¹H NMR (400 MHz, DMSO-d₆). δ H 11.68 (1H, s), 8.94 (1H, s), 8.85 (1H, d, J = 7.6), 8.65 (1H, t, J = 7.6), 8.20 (1H, t, J = 7.5), 8.12 (1H, d, J = 8.3), 7.42 (1H, s) 4.81–4.74 (1H, m), 4.63 (1H, d, J =
4.6), 4.55 (3H, s), 2.73–2.61 (2H, m), 2.41 (2H, dd, J = 14.9, 7.3), 1.95 (3H, t, J = 7.3) ppm. ^{13}C NMR (100 MHz, DMSO-d$_6$) δ C 181.03, 158.18, 158.02, 137.75, 128.41, 127.85, 124.34, 124.12, 119.70, 115.08, 114.48, 91.85, 48.25, 44.32, 33.15, 20.70, 14.92 ppm. EI-HRMS: Anal. Calcd for C$_{17}$H$_{19}$N$_3$O$_4$: 329.1376, Found: 329.1371.

5i:2-(butylamino)-7-chloro-1-methyl-3-nitro-1H-chromeno[2,3-b]pyridin-5(10aH)-one

Isolated as yellow semi solid, 84 %. ^{1}H NMR (400 MHz, DMSO-d$_6$) δ H 10.60 (1H, s), 7.93 (1H, s), 7.73 (1H, d, J = 2.7), 7.64 (1H, dd, J = 8.8, 2.7), 7.13 (1H, d, J = 8.8), 6.44 (1H, s), 3.84–3.67 (1H, m), 3.67–3.54 (1H, m), 3.51 (3H, s). 1.65 (2H, dt, J = 14.0, 6.9), 1.45–1.31 (2H, m), 0.92 (3H, t, J = 7.4) ppm. ^{13}C NMR (100 MHz, DMSO-d$_6$) δ C 178.80, 157.09, 155.63, 136.13, 127.13, 126.28, 124.48, 121.03, 118.86, 113.65, 112.89, 91.13, 47.24, 43.40, 32.09, 19.67, 13.89 ppm. EI-HRMS: Anal. Calcd for C$_{17}$H$_{19}$ClN$_3$O$_4$: 363.0986, Found: 363.0980.

5m:2-(butylamino)-1,7-dimethyl-3-nitro-1H-chromeno[2,3-b]pyridin-5(10aH)-one

Isolated as yellow semi solid, 83 %. ^{1}H NMR (400 MHz, DMSO-d$_6$) δ H 10.65 (1H, d, J = 2.5), 7.88 (1H, s), 7.59 (1H, d, J = 1.6), 7.41 (1H, dd, J = 8.4, 2.1), 6.96 (1H, d, J = 8.4), 6.31 (1H, s), 3.85–3.64 (1H, m), 3.57 (1H, dd, J = 13.6, 7.1), 3.50 (3H, s), 2.29 (3H, s), 1.71–1.57 (2H, m), 1.36 (2H, m), 0.91 (3H, t, J = 7.4) ppm. ^{13}C NMR (100 MHz, DMSO-d$_6$) δ C 179.95, 157.14, 154.98, 137.43, 132.20, 126.93, 126.65, 122.97, 118.44, 114.21, 113.40, 90.72, 47.21, 43.20, 32.14, 20.49, 19.68, 13.87,. EI-HRMS: Anal. Calcd for C$_{19}$H$_{21}$N$_3$O$_4$: 343.1532, Found: 343.1529.

5n:1-benzyl-5-(5-chloro-2-hydroxybenzoyl)-3-nitropyridin-2(1H)-one

Isolated as yellow semi solid, 85 %. ^{1}H NMR (400 MHz, DMSO-d$_6$) δ H 10.69 (1H, d, J = 8.2), 7.89 (1H, s), 7.81 (1H, dd, J = 7.8, 1.3), 7.6–7.51 (1H, m), 7.16 (2H, d, J = 7.4), 6.40 (1H, s), 4.02–3.92 (1H, m), 3.50 (3H, s). 2.08 (1H, d, J = 9.6), 1.91–1.81 (1H, m), 1.71 (1H, d, J = 8.8), 1.60–1.14 (7H, m) ppm. ^{13}C NMR (100 MHz, DMSO-d$_6$) δ C 179.94, 156.92, 156.37, 136.66, 127.35, 126.64, 123.32, 123.06, 118.68, 114.12, 113.84, 90.94, 55.21, 43.24, 34.12, 33.15, 25.17, 24.07, 23.88 ppm. EI-HRMS: Anal. Calcd for C$_{19}$H$_{21}$N$_3$O$_4$: 355.1532, Found: 355.1533.

5o:7-chloro-2-(cyclohexylamino)-1-methyl-3-nitro-1H-chromeno[2,3-b]pyridin-5(10aH)-one

Isolated as yellow semi solid, 87 %. ^{1}H NMR (400 MHz, DMSO-d$_6$) δ H 10.45 (1H, d, J = 7.7), 7.71 (1H, s), 7.51 (1H, d, J = 2.1), 7.42 (1H, dd, J = 8.7, 2.2), 6.92 (1H, d, J = 8.8), 6.23 (1H, s), 3.77 (1H, s), 3.29 (3H, s), 1.87 (1H, s), 1.67 (1H, d,
$J_1 = 8.5$, 1.50 (1H, s), 1.44 – 1.02 (7H, m) ppm. $^{13}$C NMR (100 MHz, DMSO-$d_6$) $\delta$ C 178.87, 156.32, 155.59, 136.19, 127.50, 127.18, 126.28, 124.47, 121.10, 114.02, 113.08, 91.21, 55.27, 43.40, 34.07, 33.11, 25.14, 24.05, 23.89 ppm. EI-HRMS: Anal. Calcd for C$_{19}$H$_{20}$ClN$_3$O$_4$: 389.1142, Found: 389.1140.

5p: 2-(cyclohexylamino)-1,7-dimethyl-3-nitro-1H-chromeno[2,3-b]pyridin-5(10H)-one

Isolated as yellow semi solid, 86 %. $^1$H NMR (400 MHz, DMSO-$d_6$) $\delta$ H 10.70 (1H, d, $J_1 = 8.2$), 7.88 (1H, s), 7.60 (1H, d, $J_1 = 1.3$), 7.42 (1H, dd, $J_1 = 8.4$, 2.0), 6.99 (1H, d, $J_1 = 8.4$), 6.36 (1H, s), 4.01 – 3.91 (1H, m), 3.49 (3H, s), 2.29 (3H, s), 2.08 (1H, d, $J_1 = 9.9$), 1.95 – 1.82 (1H, m), 1.72 (1H, dd, $J_1 = 9.4$, 3.8), 1.45 (7H, m) ppm. $^{13}$C NMR (100 MHz, DMSO-$d_6$) $\delta$ C 180.04, 156.41, 154.95, 137.52, 132.27, 126.95, 126.49, 122.98, 118.52, 114.40, 113.79, 90.84, 55.20, 43.24, 34.10, 33.14, 25.16, 24.06, 23.87, 20.50 ppm. EI-HRMS: Anal. Calcd for C$_{20}$H$_{23}$N$_3$O$_4$: 369.1689, Found: 369.1684.
$^1$H and $^{13}$C NMR Spectra of Compound (3a)
\(^1\text{H} \text{ and } ^{13}\text{C} \text{ NMR Spectra of Compound (3b)}\)
$^1$H and $^{13}$C NMR Spectra of Compound (3c)
\(^1\text{H}\) and \(^{13}\text{C}\) NMR Spectra of Compound (3d)
$^1$H and $^{13}$C NMR Spectra of Compound (3e)
$^1$H and $^{13}$C NMR Spectra of Compound (3f)
$^1$H and $^{13}$C NMR Spectra of Compound (3g)
$^1$H and $^{13}$C NMR Spectra of Compound (3h)
$^1$H and $^{13}$C NMR Spectra of Compound (3i)
$^1$H and $^{13}$C NMR Spectra of Compound (3j)
$^1$H and $^{13}$C NMR Spectra of Compound (3k)
$^1$H and $^{13}$C NMR Spectra of Compound (3l)
$^{1}H$ and $^{13}C$ NMR Spectra of Compound (3m)
$^1$H and $^{13}$C NMR Spectra of Compound (3n)
$^{1}H$ and $^{13}C$ NMR Spectra of Compound (3o)
$^1$H and $^{13}$C NMR Spectra of Compound (3p)
$^1$H and $^{13}$C NMR Spectra of Compound (3r)
$^1$H and $^{13}$C NMR Spectra of Compound (3s)
$^1$H and $^{13}$C NMR Spectra of Compound (5a)
\(^1\)H and \(^{13}\)C NMR Spectra of Compound (5b)
H NMR Spectra of Compound (5c)
$^1$H and $^{13}$C NMR Spectra of Compound (5d)
\[^1\text{H}\] and \[^{13}\text{C}\] NMR Spectra of Compound (5e)
$^1$H and $^{13}$C NMR Spectra of Compound (5f)
$^{1}H$ and $^{13}C$ NMR Spectra of Compound (5g)
$^1$H and $^{13}$C NMR Spectra of Compound (5h)
$^1$H and $^{13}$C NMR Spectra of Compound (5i)
$^{1}$H and $^{13}$C NMR Spectra of Compound (5j)

![NMR Spectra Image]

The spectra show the chemical shifts and integrals for various protons and carbons in the compound. The spectra are labeled with chemical shifts (ppm) and are used to identify the structural components of the molecule.
$^1$H and $^{13}$C NMR Spectra of Compound (5k)
$^{1}H$ and $^{13}C$ NMR Spectra of Compound (5l)
$^1$H and $^{13}$C NMR Spectra of Compound (5m)
$^1$H and $^{13}$C NMR Spectra of Compound (5n)
\(^1\)H and \(^{13}\)C NMR Spectra of Compound (5o)
$^1$H and $^{13}$C NMR Spectra of Compound (5p)
$^{1}$H and $^{13}$C NMR Spectra of Compound (14)
EI-HRMS Spectrum:

EI-HRMS spectrum of compound 3a
EI-HRMS spectrum of compound 3b
EI-HRMS spectrum of compound 3c
EI-HRMS spectrum of compound 3d
EI-HRMS spectrum of compound 3e
EI-HRMS spectrum of compound 3f
EI-HRMS spectrum of compound 3g
EI-HRMS spectrum of compound 3h
EI-HRMS spectrum of compound 3i
EI-HRMS spectrum of compound 3j
EI-HRMS spectrum of compound 3k
EI-HRMS spectrum of compound 31
EI-HRMS spectrum of compound 3m
EI-HRMS spectrum of compound 3n
EI-HRMS spectrum of compound 3o
EI-HRMS spectrum of compound 3p
EI-HRMS spectrum of compound 3q
EI-HRMS spectrum of compound 3r
EI-HRMS spectrum of compound 3s
EI-HRMS spectrum of compound 5a
EI-HRMS spectrum of compound 5b
EI-HRMS spectrum of compound 5d
EI-HRMS spectrum of compound 5e
EI-HRMS spectrum of compound 5f
EI-HRMS spectrum of compound 5g
EI-HRMS spectrum of compound 5h
EI-HRMS spectrum of compound 5i
EI-HRMS spectrum of compound 5j
EI-HRMS spectrum of compound 5k
EI-HRMS spectrum of compound 51
EI-HRMS spectrum of compound 5m
EI-HRMS spectrum of compound 5n
EI-HRMS spectrum of compound 5o
EI-HRMS spectrum of compound 5p
EI-HRMS spectrum of compound 14