Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.

Supporting Information

Manganese- and Rhenium-Catalyzed C–H Enaminylation: Expedient Access to Novel Indole-purine Hybrids with Anti-Tumor Bioactivities

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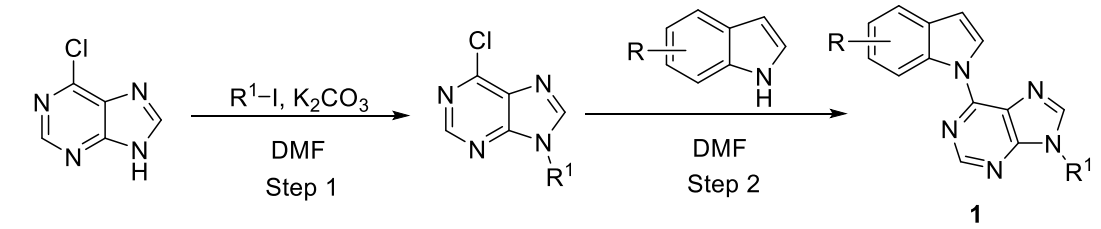
General Remarks

Catalytic reactions were performed under N_2 atmosphere using pre-dried glassware and standard Schlenk techniques. The substrates **1a**-**1n**[1] were first synthesized by a method we modified based on previous research. The substrates **2a-2f**[1] were synthesized according to previously described methods. Other chemicals were obtained from commercial sources and were used without further purification. Yields refer to isolated compounds, estimated to be >95% pure as determined by ^{1}H-NMR. TLC: Macherey-Nagel, TLC plates Alugram®Sil G/UV254. Detection under UV light at 254 nm. Chromatography separations were carried out on silica gel 60H (200-300 mesh) manufactured by Qingdao Haiyang Chemical Group Co. (China). High resolution mass spectrometry (HRMS) was measured on Thermo-DFS mass spectrometer. NMR spectra were recorded on *J*EOL 400 NMR (^{1}H 400 MHz; ^{13}C 100 MHz; ^{19}F 376 MHz) in $CDCl_3$. If not otherwise specified, chemical shifts (δ) are given in ppm.

General Procedure A for the Preparation of Substrates 1.



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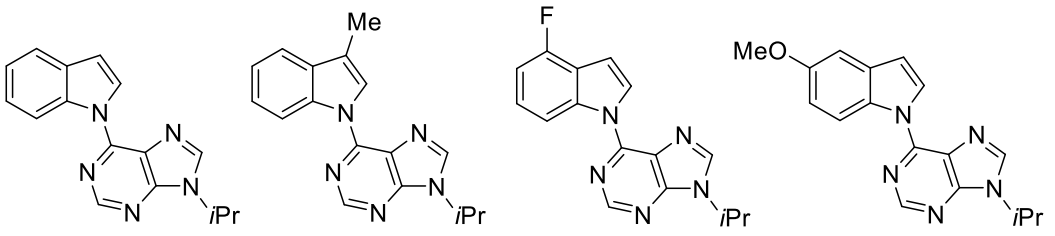
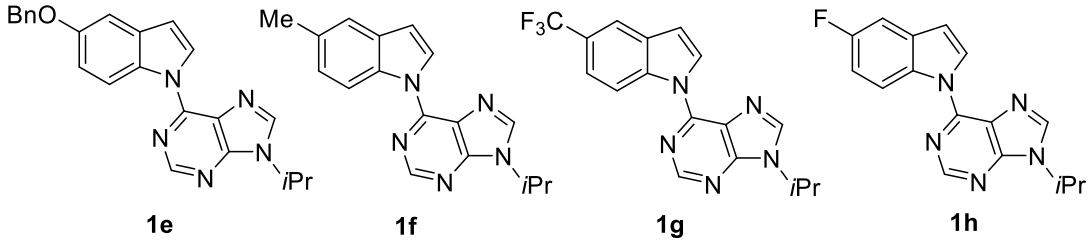
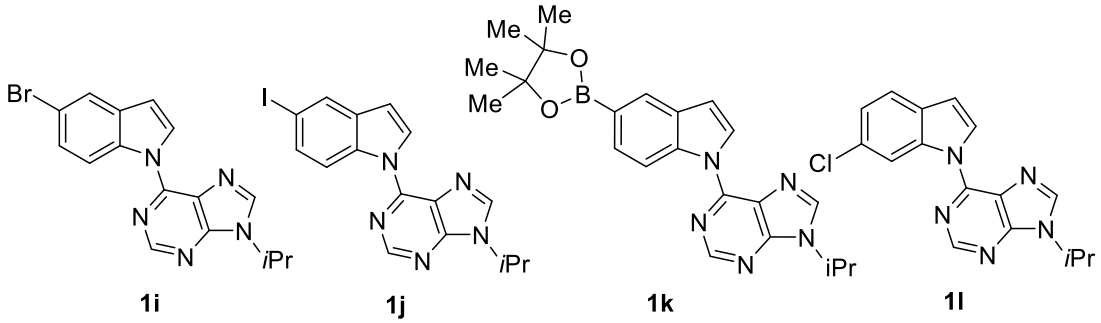


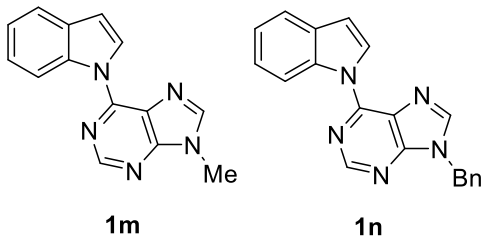
1a **1b** **1c** **1d**



1e **1f** **1g** **1h**



1i **1j** **1k** **1l**



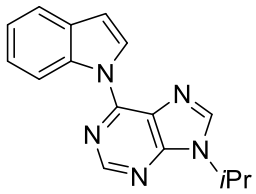
1m **1n**

Compounds **1a-1n** were prepared according to the following method.

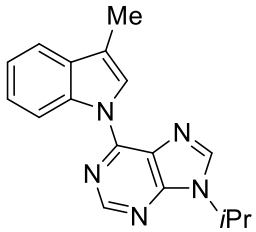
Step 1: Following a modified procedure by the reported lecture[1]. A stirred suspension of sodium hydride (60%, in mineral oil, 620 mg, 16.61 mmol) in DMF (30

mL) was treated with 6-chloro-9*H*-purine (2.0 g, 12.94 mmol) under N_2 atmosphere at room temperature for 2 h. Alkyl halide (16.54 mmol) was added to the reaction mixture, and the resultant was stirred at room temperature for 4 h. The mixture was poured into water (100 mL), and stirred for ten minutes. The mixture was coarsely filtered, the residue was washed with petroleum ether. The residue was dried under vacuum for half an hour and then recrystallized to give the title compound.

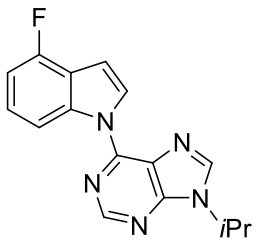
Step 2: NaH (60% dispersion in mineral oil, 180 mg, 4.5 mmol) was added in portions at 0 ℃ to a stirred solution of indole (1.59 g, 3.6 mmol) in DMF (30 mL). After stirring for 30 min at 0 ℃, alkyl derivative (3 mmol) was added and the mixture was stirred at room temperature for 20 h. Then, the reaction mixture was poured into H_2O (100 mL) and extracted with EtOAc (4×50 mL). The combined organic phase was dried over Na_2SO_4. After filtration and evaporation of the solvents under reduced pressure, the crude product was purified by column chromatography on silica gel to give the desired product **1**.



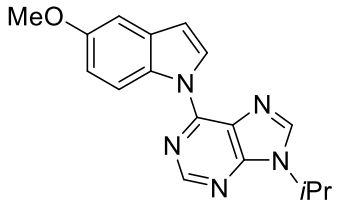
6-(1*H*-Indol-1-yl)-9-isopropyl-9*H*-purine (1a): Following the general procedure **A** afforded **1a** (749 mg, 90 %) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.18 (d, *J* = 3.7 Hz, 1H), 9.06 (d, *J* = 8.3 Hz, 1H), 8.83 (s, 1H), 8.07 (s, 1H), 7.64 (d, *J* = 7.7 Hz, 1H), 7.41 – 7.33 (m, 1H), 7.30 – 7.24 (m, 1H), 6.80 (d, *J* = 3.7 Hz, 1H), 5.01 – 4.91 (m, 1H), 1.66 (d, *J* = 6.8 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 152.4, 151.8, 150.0, 140.2, 136.2, 130.8, 128.7, 124.0, 123.0, 122.9, 120.9, 117.3, 108.5, 47.5, 22.7. HR-MS (ESI) *m/z* calcd for $C_{16}H_{16}N_5$ $[M+H]^+$ 278.1400, found 278.1394.



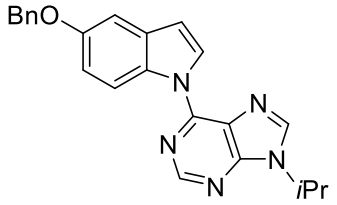
9-Isopropyl-6-(3-methyl-1*H*-indol-1-yl)-9*H*-purine (1b): Following the general procedure **A** afforded **1b** (566 mg, 65 %) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.05 (d, *J* = 8.3 Hz, 1H), 8.95 (d, *J* = 1.2 Hz, 1H), 8.80 (s, 1H), 8.07 (s, 1H), 7.58 (d, *J* = 7.7 Hz, 1H), 7.40 – 7.36 (m, 1H), 7.32 – 7.28 (m, 1H), 4.96 (hept, *J* = 6.8 Hz, 1H), 2.41 (d, *J* = 1.3 Hz, 3H), 1.66 (d, *J* = 6.8 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 152.2, 151.8, 149.9, 139.8, 136.5, 136.4, 131.7, 125.3, 124.0, 122.6, 118.8, 117.8, 117.4, 47.4, 22.7, 10.0. HR-MS (ESI) *m/z* calcd for $C_{17}H_{18}N_5$ $[M+H]^+$ 292.1557, found 292.1548.



6-(4-Fluoro-1*H*-indol-1-yl)-9-isopropyl-9*H*-purine (1c): Following the general procedure **A** afforded **1c** (800 mg, 91 %) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.16 (d, *J* = 3.8 Hz, 1H), 8.84 – 8.81 (m, 2H), 8.10 (s, 1H), 7.31 – 7.25 (m, 1H), 6.98 – 6.92 (m, 1H), 6.89 (dd, *J* = 3.7, 0.6 Hz, 1H), 4.97 (hept, *J* = 6.8 Hz, 1H), 1.67 (d, *J* = 6.8 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 155.9 (d, $^{1}J_{C\text{-}F}$ = 247.7 Hz), 152.5, 151.7, 149.7, 140.5, 138.3 (d, $^{3}J_{C\text{-}F}$ = 10.5 Hz), 128.7, 124.5 (d, $^{3}J_{C\text{-}F}$ = 6.3 Hz), 123.0, 119.5 (d, $^{2}J_{C\text{-}F}$ = 22.0 Hz), 113.4 (d, $^{4}J_{C\text{-}F}$ = 3.3 Hz), 108.0 (d, $^{2}J_{C\text{-}F}$ = 16.4 Hz), 103.8, 47.6, 22.7. ^{19}F NMR (376 MHz, $CDCl_3$) δ = -122.36. HR-MS (ESI) *m/z* calcd for $C_{16}H_{15}FN_5$ $[M+H]^+$ 296.1306, found 296.1298.

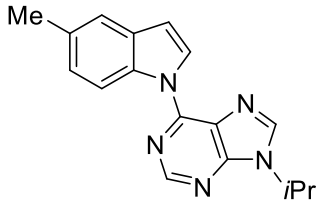


9-Isopropyl-6-(5-methoxy-1*H*-indol-1-yl)-9*H*-purine (1d): Following the general procedure **A** afforded **1d** (335 mg, 56 %) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.17 (d, *J* = 3.6 Hz, 1H), 8.96 (d, *J* = 9.1 Hz, 1H), 8.80 (s, 1H), 8.07 (s, 1H), 7.10 (d, *J* = 2.5 Hz, 1H), 6.99 (dd, *J* = 9.1, 2.6 Hz, 1H), 6.73 (d, *J* = 3.6 Hz, 1H), 4.96 (p, *J* = 6.8 Hz, 1H), 3.89 (s, 3H), 1.66 (d, *J* = 6.8 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 156.1, 152.3, 151.8, 149.8, 140.0, 131.7, 131.1, 129.3, 122.7, 118.2, 112.7, 108.4, 103.3, 55.8, 47.4, 22.8. HR-MS (ESI) *m/z* calcd for $C_{17}H_{18}N_5O$ $[M+H]^+$ 308.1506, found 308.1501.

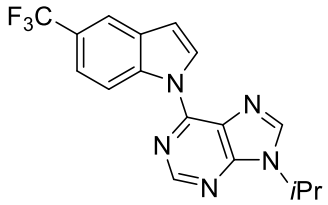


6-[5-(Benzyloxy)-1*H*-indol-1-yl]-9-isopropyl-9*H*-purine (1e): Following the general procedure **A** afforded **1e** (466 mg, 41 %) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.18 (d, *J* = 3.6 Hz, 1H), 8.98 (d, *J* = 9.1 Hz, 1H), 8.81 (s, 1H), 8.07 (s, 1H), 7.50 (d, *J* = 7.4 Hz, 2H), 7.42 – 7.38 (m, 2H), 7.35 – 7.31 (m, 1H), 7.19 (d, *J* = 2.4 Hz, 1H),

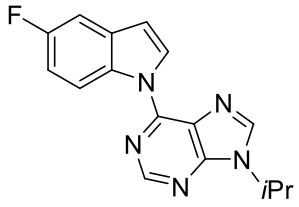
7.08 (dd, *J* = 9.1, 2.4 Hz, 1H), 6.73 (d, *J* = 3.6 Hz, 1H), 5.16 (s, 2H), 4.97 (hept, 6.9Hz, 1H), 1.67 (d, *J* = 6.8 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 155.3, 152.3, 151.8, 149.8, 140.0, 137.6, 131.6, 131.2, 129.3, 128.7, 128.0, 127.7, 122.7, 118.2, 113.5, 108.5, 104.8, 70.7, 47.4, 22.7. HR-MS (ESI) *m/z* calcd for $C_{23}H_{22}N_5O$ $[M+H]^+$ 384.1819, found 384.1810.



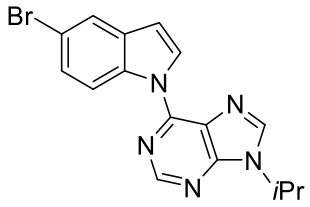
9-Isopropyl-6-(5-methyl-1*H*-indol-1-yl)-9*H*-purine (1f): Following the general procedure **A** afforded **1f** (610 mg, 70 %) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.16 (d, *J* = 3.6 Hz, 1H), 8.93 (d, *J* = 8.5 Hz, 1H), 8.82 (s, 1H), 8.08 (s, 1H), 7.43 (s, 1H), 7.19 (d, *J* = 8.4 Hz, 1H), 6.73 (d, *J* = 3.6 Hz, 1H), 4.97 (hept, 6.8 Hz, 1H), 2.48 (s, 3H), 1.66 (d, *J* = 6.8 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 152.3, 151.9, 150.0, 140.0, 134.5, 132.4, 131.0, 128.7, 125.4, 122.8, 120.8, 117.0, 108.3, 47.4, 22.7, 21.5. HR-MS (ESI) *m/z* calcd for $C_{17}H_{18}N_5$ $[M+H]^+$ 292.1557, found 292.1547.



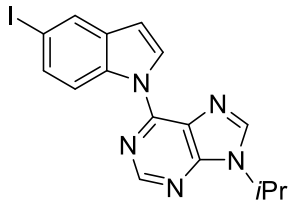
9-Isopropyl-6-[5-(trifluoromethyl)-1*H*-indol-1-yl]-9*H*-purine (1g): Following the general procedure **A** afforded **1g** (354 mg, 34 %) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.27 (d, *J* = 3.7 Hz, 1H), 9.15 (d, *J* = 8.8 Hz, 1H), 8.85 (s, 1H), 8.12 (s, 1H), 7.91 (s, 1H), 7.59 (dd, *J* = 8.8, 1.4 Hz, 1H), 6.85 (d, *J* = 3.7 Hz, 1H), 4.99 (hept, *J* = 6.8 Hz, 1H), 1.68 (d, *J* = 6.8 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 152.7, 151.7, 149.5, 140.7, 137.6, 130.4, 130.3, 125.0 (q, $^2J_{C\text{-}F}$ = 31.9 Hz), 123.7 (q, $^1J_{C\text{-}F}$ = 272.5 Hz), 123.0, 120.6 (q, $^3J_{C\text{-}F}$ = 3.5 Hz), 118.3 (q, $^3J_{C\text{-}F}$ = 3.5 Hz), 117.5, 108.4, 47.7, 22.7. ^{19}F NMR (376 MHz, $CDCl_3$) δ = -60.87. HR-MS (ESI) *m/z* calcd for $C_{17}H_{15}F_3N_5$ $[M+H]^+$ 346.1274, found 346.1268.



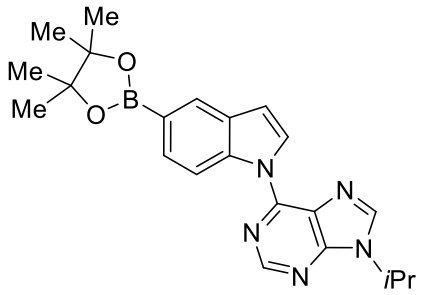
6-(5-Fluoro-1*H*-indol-1-yl)-9-isopropyl-9*H*-purine (1h): Following the general procedure **A** afforded **1h** (469 mg, 53 %) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.23 (d, J = 3.6 Hz, 1H), 9.01 (dd, J = 9.1, 4.9 Hz, 1H), 8.80 (s, 1H), 8.08 (s, 1H), 7.28 – 7.25 (m, 1H), 7.09 – 7.05 (m, 1H), 6.74 (d, J = 3.6 Hz, 1H), 4.97 (hept, J = 6.8 Hz, 1H), 1.67 (d, J = 6.8 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 159.4 (d, $^{1}J_{C\text{-}F}$ = 238.6 Hz), 152.4, 151.7, 149.6, 140.3, 132.6, 131.6 (d, $^{3}J_{C\text{-}F}$ = 10.7 Hz), 130.3, 122.8, 118.3 (d, $^{3}J_{C\text{-}F}$ = 9.4 Hz), 111.6 (d, $^{2}J_{C\text{-}F}$ = 24.9 Hz), 108.2 (d, $^{4}J_{C\text{-}F}$ = 3.9 Hz), 106.1 (d, $^{2}J_{C\text{-}F}$ = 23.3 Hz), 47.5, 22.7. ^{19}F NMR (376 MHz, $CDCl_3$) δ = -122.13, -122.16, -122.18. HR-MS (ESI) *m/z* calcd for $C_{16}H_{15}FN_5$ $[M+H]^+$ 296.1306, found 296.1299.



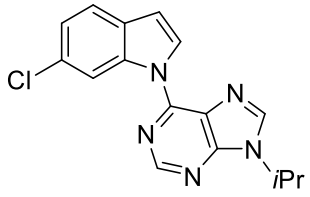
6-(5-Bromo-1*H*-indol-1-yl)-9-isopropyl-9*H*-purine (1i): Following the general procedure **A** afforded **1i** (829 mg, 78 %) as a pale yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.17 (d, J = 3.6 Hz, 1H), 8.91 (d, J = 8.9 Hz, 1H), 8.79 (s, 1H), 8.07 (s, 1H), 7.72 (d, J = 1.7 Hz, 1H), 7.41 (dd, J = 8.9, 1.8 Hz, 1H), 6.70 (d, J = 3.6 Hz, 1H), 4.95 (hept, J = 6.8 Hz, 1H), 1.66 (d, J = 6.8 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 152.5, 151.7, 149.5, 140.4, 134.8, 132.4, 129.8, 126.6, 123.3, 122.8, 118.7, 116.1, 107.6, 47.6, 22.7. HR-MS (ESI) *m/z* calcd for $C_{16}H_{15}BrN_5$ $[M+H]^+$ 356.0505 (^{79}Br), found 356.0499 (^{79}Br).



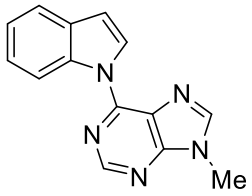
6-(5-Iodo-1*H*-indol-1-yl)-9-isopropyl-9*H*-purine (1j): Following the general procedure **A** afforded **Z-5** (616 mg, 51 %) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.15 (d, J = 3.7 Hz, 1H), 8.84 – 8.80 (m, 2H), 8.09 (s, 1H), 7.95 (d, J = 1.6 Hz, 1H), 7.60 (dd, J = 8.8, 1.7 Hz, 1H), 6.70 (d, J = 3.6 Hz, 1H), 4.97 (hept, J = 6.8 Hz, 1H), 1.67 (d, J = 6.8 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 152.5, 151.7, 149.6, 140.5, 135.4, 133.1, 132.3, 129.6, 129.5, 123.0, 119.2, 107.4, 87.0, 47.6, 22.7. HR-MS (ESI) *m/z* calcd for $C_{16}H_{15}IN_5$ $[M+H]^+$ 404.0367, found 404.0360.



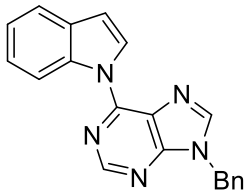
9-Isopropyl-6-[5-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1*H*-indol-1-yl]-9*H*-purine (1k): Following the general procedure **A** afforded **1k** (813 mg, 68 %) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.17 (d, J = 3.7 Hz, 1H), 9.03 (d, J = 8.5 Hz, 1H), 8.84 (s, 1H), 8.15 (s, 1H), 8.07 (s, 1H), 7.81 (dd, J = 8.4, 1.0 Hz, 1H), 6.80 (d, J = 3.6 Hz, 1H), 4.95 (hept, J = 6.8 Hz, 1H), 1.65 (d, J = 6.8 Hz, 6H), 1.38 (s, 12H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 152.4, 151.8, 149.9, 140.3, 138.2, 130.4, 130.2, 128.7, 128.3, 123.1, 123.0, 116.6, 108.7, 83.7, 47.5, 25.0, 22.7. HR-MS (ESI) *m/z* calcd for $C_{22}H_{27}BN_5O_2$ $[M+H]^+$ 404.2252, found 404.2249.



6-(6-Chloro-1*H*-indol-1-yl)-9-isopropyl-9*H*-purine (1l): Following the general procedure **A** afforded **1i** (800 mg, 85 %) as a pale yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.18 (d, *J* = 3.7 Hz, 1H), 9.13 (d, *J* = 1.9 Hz, 1H), 8.83 (s, 1H), 8.09 (s, 1H), 7.52 (d, *J* = 8.3 Hz, 1H), 7.24 (dd, *J* = 8.2, 1.9 Hz, 1H), 6.75 (dd, *J* = 3.7, 0.6 Hz, 1H), 4.97 (hept, *J* = 6.8 Hz, 1H), 1.67 (d, *J* = 6.8 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 152.6, 151.8, 149.6, 140.5, 136.4, 129.7, 129.3, 129.2, 123.4, 122.8, 121.4, 117.5, 108.1, 47.6, 22.8. HR-MS (ESI) *m/z* calcd for $C_{16}H_{15}ClN_5$ $[M+H]^+$ 312.1010, found 312.1009.



6-(1*H*-indol-1-yl)-9-methyl-9*H*-purine (1m): Following the general procedure **A** afforded **1m** (523 mg, 70 %) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.11 (d, *J* = 2.9 Hz, 1H), 9.03 (d, *J* = 8.3 Hz, 1H), 8.79 (s, 1H), 7.86 (s, 1H), 7.62 (d, *J* = 7.6 Hz, 1H), 7.36 (t, *J* = 7.7 Hz, 1H), 7.29 – 7.24 (m, 1H), 6.77 (d, *J* = 3.6 Hz, 1H), 3.79 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 152.9, 152.1, 149.8, 143.0, 136.1, 130.8, 128.6, 124.0, 122.9, 122.2, 120.8, 117.4, 108.5, 30.0. HR-MS (ESI) *m/z* calcd for $C_{14}H_{12}N_5$ $[M+H]^+$ 250.1087, found 250.1081.

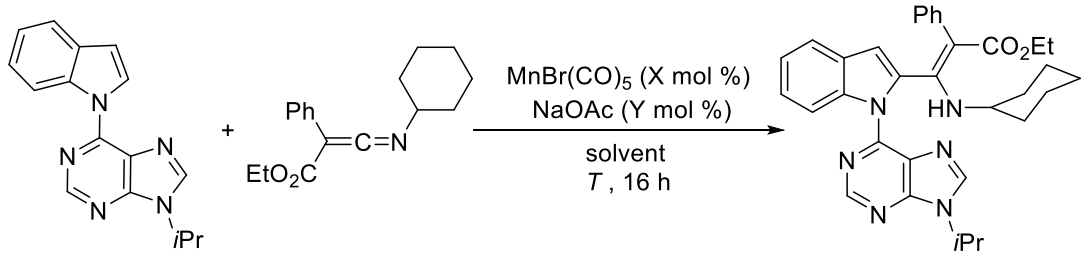


9-Benzyl-6-(1*H*-indol-1-yl)-9*H*-purine (1n): Following the general procedure **A** afforded **1n** (580 mg, 60 %) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.17 (d, *J* = 3.7 Hz, 1H), 9.09 (d, *J* = 8.5 Hz, 1H), 8.86 (s, 1H), 7.94 (s, 1H), 7.65 (d, *J* = 7.7 Hz, 1H), 7.40 – 7.29 (m, 7H), 6.80 (d, *J* = 3.6 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 152.8, 152.3, 150.0, 142.3, 136.2, 135.3, 130.8, 129.2, 128.7, 128.6, 127.9, 124.0,

123.0, 122.3, 120.9, 117.4, 108.6, 47.4. HR-MS (ESI) *m/z* calcd for $C_{20}H_{16}N_5$ $[M+H]^+$ 326.1400, found 326.1394.

Optimization Studies

Table S2. Manganese-Catalyzed C–H Enaminylation [a]

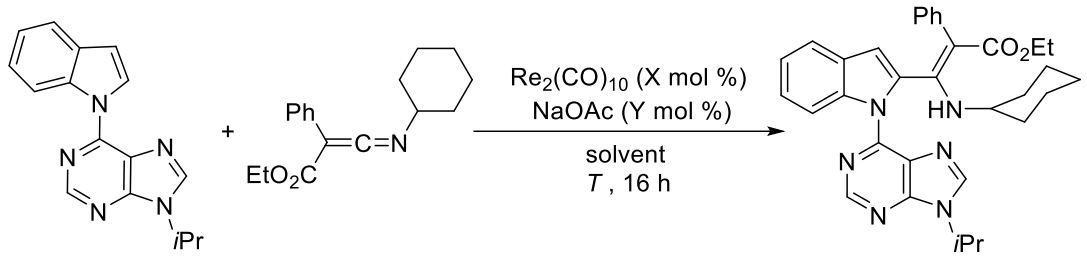


1a **2a** **3aa**

Entry	X	Y	Solvent	*T* (°C)	Yield (%)[b]
1	10	20	1, 4-dioxane	40	95
2	10	20	1, 4-dioxane	60	99
3	10	20	DMF	80	99
4	10	20	DCE	80	99
5	10	20	γ-Valerolactone	80	84
6	10	20	H_2O	80	98
7	10	20	H_2O	60	92
8	10	—	H_2O	60	88
9	—	20	H_2O	60	0
10	5	10	H_2O	60	73
11	5	10	H_2O	80	99 (95)[c]

[a]Reaction conditions: **1a** (0.25 mmol), **2a** (0.30 mmol), $MnBr(CO)_5$ (5 mol %), NaOAc (10 mol %), H_2O (1.0 mL), 80 ℃, N_2, 16 h. [b]Yields of isolated product. [c]Under air.

Table S3. Rhenium-Catalyzed C–H Enaminylation [a]



1a **2a** **3aa**

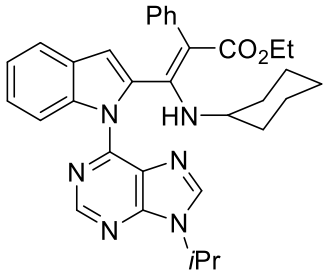
Entry	X	Y	Solvent	*T* (°C)	Yield (%)[b]
1	5	10	1, 4-dioxane	80	17
2	5	10	1, 4-dioxane	100	66
3	5	10	1, 4-dioxane	120	95
4	5	20	1, 4-dioxane	120	99
5	5	20	γ-Valerolactone	120	54
6	5	20	toluene	120	10
7	5	20	DCE	120	99
8	—	20	1, 4-dioxane	120	0
9	5	—	1, 4-dioxane	120	83
10	2.5	20	1, 4-dioxane	120	99 (73)[c]

[a]Reaction conditions: **1a** (0.25 mmol), **2a** (0.30 mmol), $Re_2(CO)_{10}$ (2.5 mol %), NaOAc (20 mol %), 1, 4-dioxane (1.0 mL), 120 ℃, N_2, 16 h. [b]Yields of isolated product. [c]Under air.

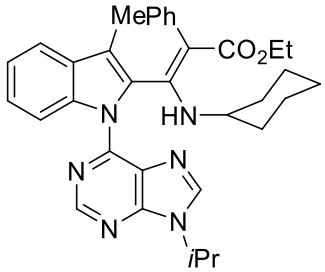
General Procedure for Aqueous Manganese- and Rhenium-Catalyzed C–H Enaminylation Reactions

General Procedure B: In an oven-dried Schlenk tube equipped with a magnetic stirring bar, a mixture of substrate **1a** (0.25 mmol), **2a** (0.30 mmol), $MnBr(CO)_5$ (5.0 mol %, 3.4 mg), NaOAc (10 mol %, 2.1 mg), and H_2O (1 mL) were added under N_2 atmosphere. The reaction mixture was stirred at 80 ℃ in oil bath for 16 hours. After completion of the reaction, the reaction mixture was poured into H_2O (10 mL) and extracted with EtOAc (4×5 mL). The combined organic phase was dried with Na_2SO_4. After filtration and concentration under reduced pressure, the residue was purified by column chromatography on silica gel afforded the desired product **3**.

General Procedure C: In an oven-dried Schlenk tube equipped with a magnetic stirring bar, a mixture of substrate **1a** (0.25 mmol), **2a** (0.30 mmol), $Re_2(CO)_{10}$ (2.5 mol %, 4.1 mg), NaOAc (20 mol %, 4.2 mg), and 1,4-dioxane (1 mL) were added under N_2 atmosphere. The reaction mixture was stirred at 120 ℃ in oil bath for 16 hours. After completion of the reaction, the reaction mixture was concentrated under reduced pressure. The residue was purified by column chromatography on silica gel afforded the desired product **3**.

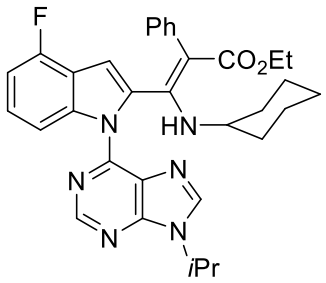


Ethyl (*Z*)-3-(cyclohexylamino)-3-[1-(9-isopropyl-9*H*-purin-6-yl)-1*H*-indol-2-yl]-2-phenylacrylate (3aa)： The general procedure **B** was followed using substrate **1a** (0.25 mmol, 70 mg), **2a** (0.30 mmol, 82 mg). Isolation by column chromatography (PE/EtOAc: 5/1→3/1) yielded **3aa** (137 mg, 99%) as a yellow solid. Also, the general procedure **C** was followed to give **3aa** (137 mg, 99%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.44 (d, J = 9.6 Hz, 1H), 8.80 (s, 1H), 8.04 (s, 1H), 7.61 (d, J = 8.0 Hz, 1H), 7.56 (d, J = 6.6 Hz, 1H), 7.24 – 7.12 (m, 2H), 6.82 – 6.75 (m, 1H), 6.70 – 6.62 (m, 5H), 5.02 (hept, J = 6.8 Hz, 1H), 4.06 (q, J = 7.1 Hz, 2H), 3.33 – 3.20 (m, 1H), 1.95 – 1.86 (m, 1H), 1.73 (d, J = 6.8 Hz, 3H), 1.70 (d, J = 6.8 Hz, 3H), 1.68 – 1.64 (m, 1H), 1.60 – 1.52 (m, 2H), 1.43 (s, 2H), 1.40 – 1.34 (m, 1H), 1.20 – 1.14 (m, 2H), 1.11 (t, J = 7.1 Hz, 3H), 1.06 – 0.96 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.2, 155.2, 153.0, 151.5, 148.0, 141.1, 137.2, 136.3, 132.9, 131.2, 128.3, 126.6, 126.5, 125.2, 123.8, 122.0, 121.1, 113.4, 110.9, 98.5, 59.1, 53.8, 47.6, 35.4, 34.0, 27.0, 25.6, 24.7, 22.7, 14.5. HR-MS (ESI) *m/z* calcd for $C_{33}H_{37}N_6O_2$ $[M+H]^+$ 549.2973, found 549.2964. The substrate of **3aa** was confirmed by single-crystal X-ray diffraction analysis.



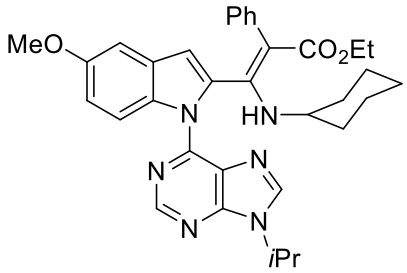
Ethyl (*Z*)-3-(cyclohexylamino)-3-(1-(9-isopropyl-9*H*-purin-6-yl)-3-methyl-1*H*-ind-ol-2-yl)-2-phenylacrylate (3ba)： The general procedure **B** was followed using substrate **1b** (0.25 mmol, 73 mg), **2a** (0.30 mmol, 82 mg). Isolation by column chromatography (PE/EtOAc: 5/1→3/1) yielded **3ba** (98 mg, 70%) as a yellow solid. Also, the general procedure **C** was followed to give **3ba** (63 mg, 45%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.38 (d, J = 10.0 Hz, 1H), 8.82 (s, 1H), 8.05 (s, 1H), 7.54 (d, J = 8.0

Hz, 1H), 7.47 (d, *J* = 7.1 Hz, 1H), 7.23 – 7.14 (m, 2H), 6.85 (d, *J* = 7.0 Hz, 2H), 6.81 – 6.77 (m, 1H), 6.72 – 6.68 (m, 2H), 5.02 (hept, *J* = 6.7 Hz, 1H), 4.15 – 4.04 (m, 2H), 3.04 – 2.93 (m, 1H), 2.18 (s, 3H), 1.73 (d, *J* = 6.8 Hz, 3H), 1.68 (d, *J* = 6.8 Hz, 3H), 1.63 – 1.57 (m, 4H), 1.46 – 1.36 (m, 2H), 1.24 – 1.19 (m, 1H), 1.15 (t, *J* = 7.1 Hz, 3H), 1.11 – 1.06 (m, 2H), 0.98 – 0.90 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.4, 154.5, 153.0, 151.7, 148.2, 141.0, 137.7, 136.0, 131.2, 129.6, 129.5, 126.5, 126.4, 125.1, 123.7, 121.5, 119.3, 117.1, 113.4, 99.6, 59.2, 53.5, 47.6, 35.3, 33.8, 25.6, 24.6, 24.5, 22.8, 22.7, 14.6, 9.8. HR-MS (ESI) *m/z* calcd for $C_{34}H_{39}N_6O_2$ $[M+H]^+$ 563.3120, found 563.3117.

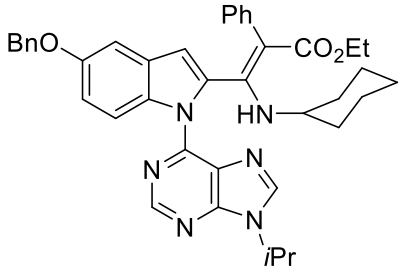


Ethyl (*Z*)-3-(cyclohexylamino)-3-(4-fluoro-1-(9-isopropyl-9*H*-purin-6-yl)-1*H*-indo-l-2-yl)-2-phenylacrylate (3ca)： The general procedure **B** was followed using substrate **1c** (0.25 mmol, 75 mg), **2a** (0.30 mmol, 82 mg),. Isolation by column chromatography (PE/EtOAc: 3/1→1/1) yielded **3ca** (148 mg, 99%) as a pale yellow solid. Also, the general procedure **C** was followed to give **3ca** (121 mg, 86%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.41 (d, *J* = 9.8 Hz, 1H), 8.82 (s, 1H), 8.05 (s, 1H), 7.36 (d, *J* = 8.4 Hz, 1H), 7.13 – 7.08 (m, 1H), 6.86 – 6.78 (m, 2H), 6.77 (s, 1H), 6.71 – 6.63 (m, 4H), 5.01 (hept, *J* = 6.8 Hz, 1H), 4.06 (q, *J* = 7.1 Hz, 2H), 3.28 – 3.17 (m, 1H), 1.94 – 1.88 (m, 1H), 1.72 (d, *J* = 6.8 Hz, 3H), 1.69 (d, *J* = 6.8 Hz, 3H), 1.59 – 1.49 (m, 2H), 1.48 – 1.39 (m, 2H), 1.39 – 1.34 (m, 1H), 1.20 – 1.14 (m, 2H), 1.11 (t, *J* = 7.2 Hz, 3H), 1.06 – 0.93 (m, 1H), 0.92 – 0.80 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.1, 156.0 (d, $^1J_{C\text{-}F}$ = 248.4 Hz), 154.4, 153.1, 151.4, 147.6, 141.5, 138.3 (d, $^3J_{C\text{-}F}$ = 9.6 Hz), 137.0, 131.1, 133.0, 126.6, 126.5, 125.3, 124.2 (d, $^3J_{C\text{-}F}$ = 7.2 Hz), 117.5 (d, $^2J_{C\text{-}F}$ = 23.7 Hz), 109.5 (d, $^4J_{C\text{-}F}$ = 3.4 Hz), 106.8 (d, $^2J_{C\text{-}F}$ = 17.9 Hz), 106.1, 99.0, 59.1, 53.8, 47.7, 35.3, 33.9, 29.7, 25.5, 24.6, 22.6, 14.4. ^{19}F NMR (376 MHz,

$CDCl_3$) δ = -121.93. HR-MS (ESI) *m/z* calcd for $C_{33}H_{36}FN_6O_2$ $[M+H]^+$ 567.2878, found 567.2871.

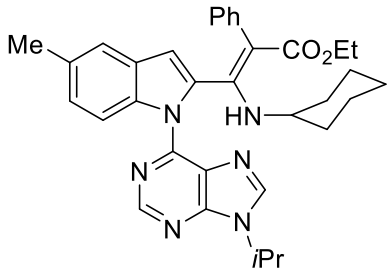


Ethyl (*Z*)-3-(cyclohexylamino)-3-(1-(9-isopropyl-9*H*-purin-6-yl)-5-methoxy-1*H*-in -dol-2-yl)-2-phenylacrylate (3da)： The general procedure **B** was followed using substrate **1d** (0.25 mmol, 77 mg), **2a** (0.30 mmol, 82 mg). Isolation by column chromatography (PE/EtOAc: 5/1→3/1) yielded **3da** (143 mg, 99%) as a yellow solid. Also, the general procedure **C** was followed to give **3da** (78 mg, 54%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.45 (d, *J* = 9.8 Hz, 1H), 8.78 (s, 1H), 8.02 (s, 1H), 7.53 (d, *J* = 8.8 Hz, 1H), 7.01 (d, *J* = 2.5 Hz, 1H), 6.86 – 6.82 (m, 1H), 6.80 – 6.75 (m, 1H), 6.69 – 6.60 (m, 5H), 5.00 (hept, *J* = 6.0 Hz, 1H), 4.06 (q, 2H), 3.83 (s, 3H), 3.32 – 3.19 (m, 1H), 1.94 – 1.85 (m, 1H), 1.72 (d, *J* = 4.2 Hz, 3H), 1.68 (d, 3H), 1.67 – 1.62 (m, 1H), 1.60 – 1.53(m, 2H), 1.51 – 1.30 (m, 3H), 1.21 – 1.14 (m, 2H), 1.11 (t, *J* = 7.1 Hz, 3H), 1.06 – 0.96 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.2, 155.5, 155.3, 152.9, 151.4, 147.9, 140.9, 137.3, 133.3, 131.2, 131.1, 129.0, 126.4, 126.3, 125.1, 114.4, 113.5, 110.7, 102.8, 98.3, 59.1, 55.8, 53.8, 47.5, 35.3, 34.0, 25.5, 24.7, 24.6, 22.7, 14.5. HR-MS (ESI) *m/z* calcd for $C_{34}H_{39}N_6O_3$ $[M+H]^+$ 579.3078, found 579.3070.



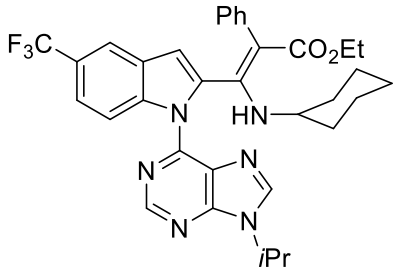
Ethyl (*Z*)-3-(5-(benzyloxy)-1-(9-isopropyl-9*H*-purin-6-yl)-1*H*-indol-2-yl)-3-(cyclo

-hexylamino)-2-phenylacrylate (3ea)： The general procedure **B** was followed using substrate **1e** (0.25 mmol, 96 mg), **2a** (0.30 mmol, 82 mg). Isolation by column chromatography (PE/EtOAc: 5/1→3/1) yielded **3ea** (150 mg, 92%) as a yellow solid. Also, the general procedure **C** was followed to give **3ea** (140 mg, 86%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.44 (d, *J* = 9.8 Hz, 1H), 8.77 (s, 1H), 8.01 (s, 1H), 7.53 (d, *J* = 9.1 Hz, 1H), 7.46 (d, *J* = 7.0 Hz, 2H), 7.41 – 7.37 (m, 2H), 7.34 – 7.30 (m, 1H), 7.08 (d, *J* = 2.4 Hz, 1H), 6.92 (dd, *J* = 9.1, 2.6 Hz, 1H), 6.80 – 7.76 (m, 1H), 6.69 – 6.60 (m, 5H), 5.09 (s, 2H), 5.01 (p, *J* = 6.8 Hz, 1H), 4.05 (q, *J* = 7.0 Hz, 2H), 3.31 – 3.20 (m, 1H), 1.92 – 1.86 (m, 1H), 1.72 (d, *J* = 6.8 Hz, 3H), 1.69 (d, *J* = 6.8 Hz, 3H), 1.58 (s, 3H), 1.55 – 1.50 (m, 1H), 1.48 – 1.37 (m, 2H), 1.19 – 1.13 (m, 2H), 1.10 (t, *J* = 7.1 Hz, 3H), 1.08 – 0.93 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.2, 155.3, 154.8, 153.0, 151.5, 147.9, 141.0, 137.6, 137.3, 133.4, 131.4, 131.1, 129.0, 128.6, 127.9, 127.6, 126.4, 126.3, 125.2, 114.4, 114.2, 110.8, 104.2, 98.4, 70.7, 59.1, 53.8, 47.5, 35.4, 34.0, 27.0, 25.6, 24.7, 22.7, 14.5. HR-MS (ESI) *m/z* calcd for $C_{40}H_{43}N_6O_3$ $[M+H]^+$ 655.3391, found 655.3381.

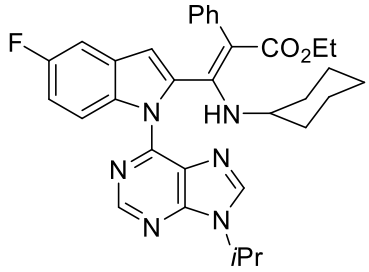


Ethyl (*Z*)-3-(cyclohexylamino)-3-(1-(9-isopropyl-9*H*-purin-6-yl)-5-methyl-1*H*-ind -ol-2-yl)-2-phenylacrylate (3fa)： The general procedure **B** was followed using substrate **1f** (0.25 mmol, 73 mg), **2a** (0.30 mmol, 82 mg). Isolation by column chromatography (PE/EtOAc: 5/1→3/1) yielded **3fa** (139 mg, 99%) as a yellow solid. Also, the general procedure **C** was followed to give **3fa** (137 mg, 98%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.45 (d, *J* = 9.7 Hz, 1H), 8.80 (s, 1H), 8.03 (s, 1H), 7.51 (d, *J* = 8.5 Hz, 1H), 7.35 (s, 1H), 7.03 (d, *J* = 8.6 Hz, 1H), 6.80 – 6.74 (m, 1H), 6.69 – 6.61 (m, 5H), 5.01 (hept, *J* = 6.8 Hz, 1H), 4.07 (q, *J* = 7.1 Hz, 2H), 3.31 – 3.02 (m, 1H), 2.42 (s, 3H), 1.93 – 1.86 (m, 1H), 1.72 (d, *J* = 6.8 Hz, 3H), 1.69 (d, *J* = 6.8 Hz, 3H),

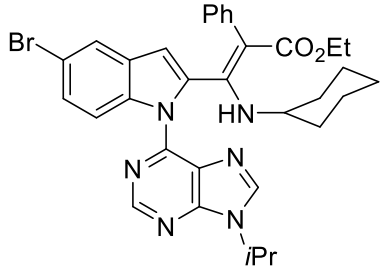
1.67 – 1.61 (m, 1H), 1.59 – 1.53 (m, 2H), 1.44 (s, 2H), 1.38 – 1.34 (m, 1H), 1.21 – 1.14 (m, 2H), 1.11 (t, J = 7.1 Hz, 3H), 1.06 – 0.98 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.2, 155.4, 152.9, 151.4, 148.0, 141.0, 137.3, 134.5, 132.7, 131.3, 131.1, 128.6, 126.4, 126.4, 125.3, 125.2, 120.7, 113.2, 110.5, 98.3, 59.0, 53.8, 47.5, 35.4, 34.0, 27.0, 25.6, 24.7, 22.7, 21.4, 14.5. HR-MS (ESI) *m/z* calcd for $C_{34}H_{39}N_6O_2$ $[M+H]^+$ 563.3119, found 563.3116.



Ethyl (*Z*)-3-(cyclohexylamino)-3-[1-(9-isopropyl-9*H*-purin-6-yl)-5-(trifluorometh -yl)-1*H*-indol-2-yl]-2-phenylacrylate (3ga)： The general procedure **B** was followed using substrate **1g** (0.25 mmol, 88 mg), **2a** (0.30 mmol, 82 mg). Isolation by column chromatography (PE/EtOAc: 5/1→3/1) yielded **3ga** (88 mg, 57%) as a yellow solid. Also, the general procedure **C** was followed to give **3ga** (152 mg, 99%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.37 (d, J = 9.8 Hz, 1H), 8.85 (s, 1H), 8.07 (s, 1H), 7.86 (s, 1H), 7.64 (d, J = 8.7 Hz, 1H), 7.42 (d, J = 8.8 Hz, 1H), 6.82 – 6.77 (m, 1H), 6.73 (s, 1H), 6.71 – 6.65 (m, 4H), 5.03 (hept, J = 6.8 Hz, 1H), 4.11 – 4.03 (m, 2H), 3.18 – 3.08 (m, 1H), 1.90 – 1.84 (m, 1H), 1.74 (d, J = 6.8 Hz, 3H), 1.71 (d, J = 6.8 Hz, 3H), 1.68 – 1.64 (m, 1H), 1.62 – 1.48 (m, 2H), 1.43 (s, 3H), 1.38 – 1.34 (m, 1H), 1.23 – 1.15 (m, 2H), 1.11 (t, J = 7.2 Hz, 3H), 1.02 – 0.94 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.2, 154.1, 153.2, 151.6, 147.4, 141.8, 137.4, 137.1, 134.8, 131.2, 127.7, 126.7, 126.6, 125.5, 124.3 (q, $^2J_{C\text{-}F}$ = 33.0 Hz), 123.7 (q, $^1J_{C\text{-}F}$ = 272.3 Hz), 120.4 (q, $^3J_{C\text{-}F}$ = 3.0 Hz), 118.8 (q, $^3J_{C\text{-}F}$ = 4.1 Hz), 113.8, 110.7, 99.2, 59.3, 54.0, 47.8, 35.4, 34.0, 27.0, 25.5, 24.7, 22.7, 14.5. ^{19}F NMR (376 MHz, $CDCl_3$) δ = -60.82. HR-MS (ESI) *m/z* calcd for $C_{34}H_{36}F_3N_6O_2$ $[M+H]^+$ 617.2845, found 617.2835.

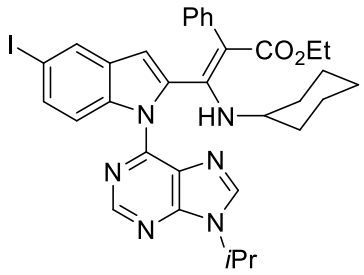


Ethyl (*Z*)-3-(cyclohexylamino)-3-[5-fluoro-1-(9-isopropyl-9*H*-purin-6-yl)-1*H*-indo-l-2-yl]-2-phenylacrylate (3ha)： The general procedure **B** was followed using substrate **1h** (0.25 mmol, 75 mg), **2a** (0.30 mmol, 82 mg). Isolation by column chromatography (PE/EtOAc: 5/1→3/1) yielded **3ha** (106 mg, 75%) as a yellow solid. Also, the general procedure **C** was followed using substrate **1h** (0.25 mmol, 75 mg), **2a** (0.30 mmol, 82 mg), $Re_2(CO)_{10}$ (8.2 mg, 5.0 mol %) and NaOAc (4.2 mg, 20 mol %) to give **3ha** (107 mg, 76%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.40 (d, J = 9.7 Hz, 1H), 8.80 (s, 1H), 8.04 (s, 1H), 7.53 (dd, J = 9.1, 4.4 Hz, 1H), 7.19 (dd, J = 9.0, 2.5 Hz, 1H), 6.94 – 6.90 (m, 1H), 6.81 – 6.77 (m, 1H), 6.70 – 6.61 (m, 5H), 5.02 (hept, J = 6.7 Hz, 1H), 4.06 (q, J = 7.0 Hz, 2H), 3.25 – 3.13 (m, 1H), 1.92 – 1.82 (m, 1H), 1.73 (d, J = 6.8 Hz, 3H), 1.70 (d, J = 6.8 Hz, 3H), 1.65 – 1.62 (m, 1H), 1.60 – 1.50 (m, 2H), 1.49 – 1.30 (m, 3H), 1.21 – 1.14 (m, 2H), 1.10 (t, J = 7.1 Hz, 3H), 1.06 – 0.97 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.2, 158.9 (d, $^1J_{C\text{-}F}$ = 237.7 Hz), 154.7, 153.1, 151.6, 147.7, 141.3, 137.2, 134.5, 132.6, 131.2, 128.9 (d, $^3J_{C\text{-}F}$ = 9.2 Hz), 126.5, 126.5, 125.3, 114.5 (d, $^3J_{C\text{-}F}$ = 10.3 Hz), 112.0 (d, $^2J_{C\text{-}F}$ = 23.2 Hz), 110.5 (d, $^4J_{C\text{-}F}$ = 2.3 Hz), 106.0 (d, $^2J_{C\text{-}F}$ = 24.5 Hz), 98.7, 59.2, 53.9, 47.7, 35.4, 34.0, 25.6, 24.7, 22.8, 22.7, 14.5. ^{19}F NMR (376 MHz, $CDCl_3$) δ = -122.14 (t, J = 9.1 Hz). HR-MS (ESI) *m/z* calcd for $C_{33}H_{36}FN_6O_2$ $[M+H]^+$ 567.2876, found 567.2866.



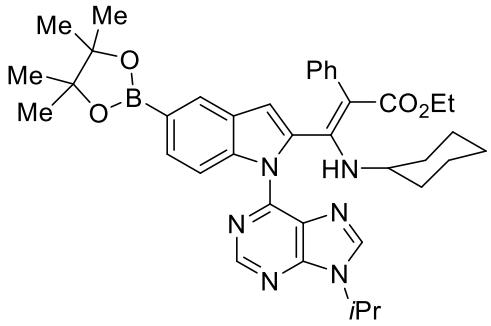
Ethyl (Z)-3-[5-bromo-1-(9-isopropyl-9H-purin-6-yl)-1H-indol-2-yl]-3-(cyclohexyl

-amino)-2-phenylacrylate (3ia)： The general procedure **B** was followed using substrate **1i** (0.25 mmol, 90 mg), **2a** (0.30 mmol, 82 mg). Isolation by column chromatography (PE/EtOAc: 5/1→3/1) yielded **3ia** (147 mg, 94%) as a yellow solid. Also, the general procedure **C** was followed to give **3ia** (150 mg, 96%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.36 (d, *J* = 9.7 Hz, 1H), 8.80 (s, 1H), 8.03 (s, 1H), 7.67 (s, 1H), 7.45 (d, *J* = 8.9 Hz, 1H), 7.25 (d, *J* = 5.0 Hz, 1H), 6.78 (t, *J* = 6.8 Hz, 1H), 6.69 – 6.62 (m, 4H), 6.58 (s, 1H), 5.00 (hept, *J* = 6.6 Hz, 1H), 4.09 – 4.01 (m, 2H), 3.17 – 3.07 (m, 1H), 1.87 – 1.82 (m, 1H), 1.71 (d, *J* = 6.8 Hz, 3H), 1.68 (d, *J* = 6.8 Hz, 3H), 1.66 – 1.61 (m, 1H), 1.57 – 1.51 (m, 1H), 1.48 – 1.41 (m, 2H), 1.36 – 1.28 (m, 2H), 1.20 – 1.12 (m, 2H), 1.09 (t, *J* = 7.1 Hz, 3H), 1.03 – 0.95 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.1, 154.4, 153.1, 151.5, 147.5, 141.5, 137.1, 134.8, 134.1, 131.1, 129.9, 129.1, 128.2, 126.5, 125.3, 123.5, 115.2, 115.0, 109.8, 98.9, 59.2, 53.9, 47.7, 35.4, 33.9, 29.8, 25.5, 24.7, 22.7, 14.5. HR-MS (ESI) *m/z* calcd for $C_{33}H_{36}BrN_6O_2$ $[M+H]^+$ 627.2078 (^{79}Br), found 627.2070 (^{79}Br).

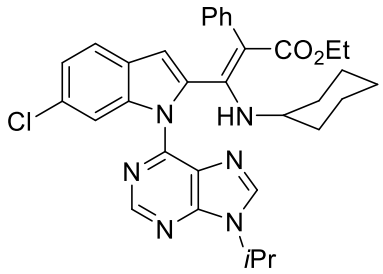


Ethyl (Z)-3-(cyclohexylamino)-3-[5-iodo-1-(9-isopropyl-9H-purin-6-yl)-1H-indol-2-yl]-2-phenylacrylate (3ja)： The general procedure **B** was followed using substrate **1j** (0.25 mmol, 101 mg), **2a** (0.30 mmol, 82 mg). Isolation by column chromatography (PE/EtOAc: 5/1→3/1) yielded **3ja** (165 mg, 99%) as a yellow solid. Also, the general procedure **C** was followed to give **3ja** (107 mg, 64%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.36 (d, J = 9.8 Hz, 1H), 8.81 (s, 1H), 8.04 (s, 1H), 7.89 (d, *J* = 8.8 Hz, 1H), 7.43 (dd, *J* = 8.8, 1.6 Hz, 1H), 7.37 – 7.34 (m, 1H), 6.81 – 6.75 (m, 1H), 6.71 – 6.63 (m, 4H), 6.58 (s, 1H), 5.01 (hept, *J* = 6.8 Hz, 1H), 4.08 – 4.02 (m, 2H), 3.19 – 3.08 (m, 1H), 1.88 – 1.83 (m, 1H), 1.72 (d, *J* = 6.8 Hz, 3H), 1.69 (d, *J* = 6.8 Hz, 3H), 1.67 – 1.63 (m, 1H), 1.57 – 1.52 (m, 1H), 1.46 – 1.41 (m, 2H), 1.38 – 1.27 (m,

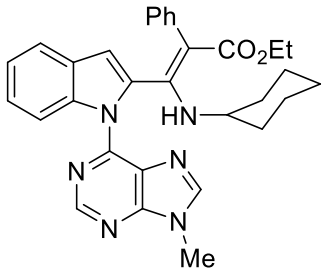
2H), 1.21 – 1.14 (m, 2H), 1.10 (t, J = 7.1 Hz, 3H), 1.04 – 0.95 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.1, 154.4, 153.1, 151.5, 147.4, 141.5, 137.2, 135.3, 133.7, 132.0, 131.2, 130.6, 129.8, 129.1, 128.2, 126.5, 125.4, 115.5, 109.5, 98.9, 85.8, 59.2, 53.9, 47.7, 35.4, 33.9, 29.8, 25.5, 24.7, 22.7, 14.5. HR-MS (ESI) *m/z* calcd for $C_{33}H_{36}IN_6O_2$ $[M+H]^+$ 675.1939, found 675.1943.



Ethyl (*Z*)-3-(cyclohexylamino)-3-[1-(9-isopropyl-9*H*-purin-6-yl)-5-(4,4,5,5-tetram -ethyl-1,3,2-dioxaborolan-2-yl)-1*H*-indol-2-yl]-2-phenylacrylate (3ka) : The general procedure **B** was followed using substrate **1k** (0.25 mmol, 101 mg), **2a** (0.30 mmol, 82 mg), $MnBr(CO)_5$ (6.8 mg, 10 mol %), NaOAc (4.2 mg, 20 mol %), 1 mL 1,4-dioxane. Isolation by column chromatography (PE/EtOAc: 5/1→3/1) yielded **3ka** (163 mg, 97%) as a yellow solid. Also, the general procedure **C** was followed to give **3ka** (149 mg, 88%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.35 (d, J = 9.8 Hz, 1H), 8.81 (s, 1H), 8.08 (s, 1H), 8.03 (s, 1H), 7.64 (d, J = 9.5 Hz, 1H), 7.56 (d, J = 8.3 Hz, 1H), 6.79 – 6.75 (m, 1H), 6.68 – 6.66 (m, 5H), 5.04 – 4.98 (m, 1H), 4.08 – 4.04 (m, 2H), 3.26 – 3.11 (m, 1H), 1.87 – 1.82 (m, 1H), 1.73 (d, J = 6.8 Hz, 3H), 1.69 (d, J = 6.8 Hz, 3H), 1.66 – 1.63 (m, 1H), 1.59 – 1.49 (m, 2H), 1.45 – 1.41 (m, 2H), 1.37 (s, 1H), 1.34 (s, 12H), 1.13 – 1.09 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.2, 155.0, 153.1, 151.5, 147.9, 141.3, 138.2, 137.3, 133.0, 131.2, 129.7, 128.8, 128.0, 126.5, 125.3, 122.0, 121.1, 112.8, 111.2, 98.8, 83.7, 59.2, 53.8, 47.6, 35.4, 34.0, 29.8, 25.6, 25.0, 24.7, 22.8, 14.5. HR-MS (ESI) *m/z* calcd for $C_{39}H_{48}BN_6O_4$ $[M+H]^+$ 675.3825, found 675.3819.

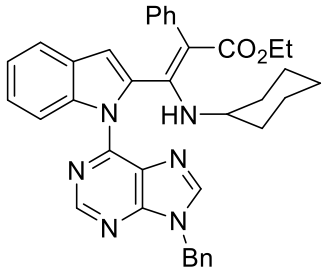


Ethyl (Z)-3-[6-chloro-1-(9-isopropyl-9*H*-purin-6-yl)-1*H*-indol-2-yl]-3-(cyclohexyl amino)-2-phenylacrylate (3la)： The general procedure **B** was followed using substrate **1l** (0.25 mmol, 78 mg), **2a** (0.30 mmol, 82 mg). Isolation by column chromatography (PE/EtOAc: 5/1→3/1) yielded **3la** (138 mg, 95%) as a yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.35 (d, J = 9.2 Hz, 1H), 8.82 (s, 1H), 8.07 (s, 1H), 7.57 (s, 1H), 7.45 (d, J = 8.4 Hz, 1H), 7.12 (dd, J = 8.4, 1.8 Hz, 1H), 6.83 – 6.79 (m, 1H), 6.74 – 6.69 (m, 4H), 6.60 (s, 1H), 5.01 (h, J = 6.8 Hz, 1H), 4.10 – 4.02 (m, 2H), 3.19 – 3.08 (m, 1H), 1.88 – 1.82 (m, 1H), 1.74 (d, J = 6.8 Hz, 3H), 1.71 (d, J = 6.8 Hz, 3H), 1.68 – 1.58 (m, 2H), 1.57 – 1.51 (m, 1H), 1.44 – 1.38 (m, 2H), 1.34 – 1.30 (m, 1H), 1.22 – 1.14 (m, 2H), 1.11 (t, J = 6.8 Hz, 3H), 1.07 – 0.99 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.2, 154.5, 153.1, 151.6, 147.5, 141.7, 137.3, 136.6, 133.7, 131.3, 129.6, 126.8, 126.6, 126.6, 125.4, 122.8, 121.9, 113.6, 110.4, 99.0, 59.2, 53.9, 47.7, 35.4, 34.0, 25.5, 24.7, 24.6, 22.8, 14.5. HR-MS (ESI) *m/z* calcd for $C_{33}H_{36}ClN_6O_2$ $[M+H]^+$ 583.2583, found 583.2580.

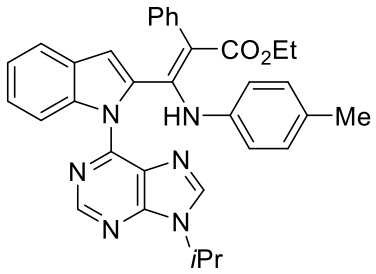


Ethyl (*Z*)-3-(cyclohexylamino)-3-[1-(9-methyl-9*H*-purin-6-yl)-1*H*-indol-2-yl]-2-ph -enylacrylate (3ma)： The general procedure **B** was followed using substrate **1m** (0.25 mmol, 63 mg), **2a** (0.30 mmol, 82 mg). Isolation by column chromatography (PE/EtOAc: 3/1→1/2) yielded **3ma** (118 mg, 91%) as a yellow solid. Also, the general procedure **C** was followed to give **3ma** (128 mg, 99%). ^{1}H NMR (400 MHz,

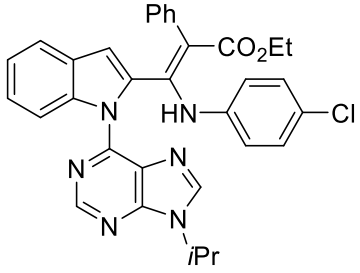
$CDCl_3$) δ = 9.44 (d, J = 9.6 Hz, 1H), 8.82 (s, 1H), 7.96 (s, 1H), 7.61 – 7.55 (m, 2H), 7.21 – 7.14 (m, 2H), 6.80 – 6.76 (m, 1H), 6.71 – 6.63 (m, 5H), 4.05 (q, J = 7.1 Hz, 2H), 3.92 (s, 3H), 3.35 – 3.25 (m, 1H), 1.95 – 1.88 (m, 1H), 1.69 – 1.58 (m, 3H), 1.48 – 1.33 (m, 3H), 1.20 – 1.14 (m, 2H), 1.13 – 1.07 (m, 4H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.2, 155.2, 153.7, 151.8, 148.0, 144.1, 137.2, 136.3, 132.9, 131.2, 128.3, 126.4, 126.0, 125.2, 123.8, 122.0, 121.1, 113.4, 111.0, 98.6, 59.1, 53.8, 35.4, 34.0, 30.1, 25.6, 24.7, 24.6, 14.5. HR-MS (ESI) *m/z* calcd for $C_{31}H_{33}N_6O_2$ $[M+H]^+$ 521.2660, found 521.2652.



Ethyl (*Z*)-3-[1-(9-benzyl-9*H*-purin-6-yl)-1*H*-indol-2-yl]-3-(cyclohexylamino)-2-ph -enylacrylate (3na)： The general procedure **B** was followed using substrate **1n** (0.25 mmol, 81 mg), **2a** (0.30 mmol, 82 mg). Isolation by column chromatography (PE/EtOAc: 5/1→3/1) yielded **3na** (98 mg, 66%) as a yellow solid. Also, the general procedure **C** was followed to give **3na** (98 mg, 66%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.43 (d, J = 9.7 Hz, 1H), 8.85 (s, 1H), 7.98 (s, 1H), 7.62 (d, J = 7.8 Hz, 1H), 7.57 (d, J = 6.8 Hz, 1H), 7.42 – 7.37 (m, 5H), 7.20 – 7.16 (m, 2H), 6.78 – 6.74 (m, 1H), 6.69 (s, 1H), 6.66 – 6.59 (m, 4H), 5.51 (s, 2H), 4.07 (q, J = 7.0 Hz, 2H), 3.32 – 3.22 (m, 1H), 1.93 – 1.87 (m, 1H), 1.68 – 1.53 (m, 3H), 1.44 – 1.35 (m, 3H), 1.20 – 1.14 (m, 2H), 1.12 (d, J = 7.1 Hz, 3H), 1.04 – 0.94 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.2, 155.2, 153.5, 152.0, 148.1, 143.3, 137.3, 136.3, 135.5, 132.9, 131.2, 129.3, 128.8, 128.4, 127.9, 126.5, 126.1, 125.2, 123.8, 122.0, 121.2, 113.4, 111.0, 98.6, 59.1, 53.8, 47.6, 35.4, 34.0, 29.8, 25.6, 24.7, 14.5. HR-MS (ESI) *m/z* calcd for $C_{37}H_{37}N_6O_2$ $[M+H]^+$ 597.2973, found 597.2963.

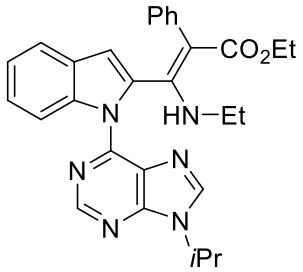


Ethyl (*Z*)-3-[1-(9-isopropyl-9*H*-purin-6-yl)-1*H*-indol-2-yl]-2-phenyl-3-(*p*-tolylami -no)acrylate (3ab)： The general procedure **B** was followed using substrate **1a** (0.25 mmol, 70 mg), **2b** (0.30 mmol, 84 mg). Isolation by column chromatography (PE/EtOAc: 3/1→2/1) yielded **3ab** (74 mg, 53%) as a yellow solid. Also, the general procedure **C** was followed using substrate **1a** (0.25 mmol, 70 mg), **2b** (0.30 mmol, 84 mg), $Re_2(CO)_{10}$ (8.2 mg, 5.0 mol %) and NaOAc (4.2 mg, 20 mol %) to give **3ab** (46 mg, 33%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 11.12 (s, 1H), 8.83 (s, 1H), 7.92 (s, 1H), 7.60 (d, *J* = 8.3 Hz, 1H), 7.42 (d, *J* = 7.7 Hz, 1H), 7.20 – 7.16 (m, 1H), 7.13 – 7.09 (m, 1H), 6.96 (d, *J* = 7.6 Hz, 2H), 6.88 – 6.79 (m, 3H), 6.63 (d, *J* = 8.3 Hz, 2H), 6.51 (d, *J* = 6.6 Hz, 3H), 5.03 – 4.92 (m, 1H), 4.21 – 4.11 (m, 2H), 2.07 (s, 3H), 1.70 (d, *J* = 6.8 Hz, 6H), 1.20 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.3, 152.8, 151.3, 150.6, 147.8, 140.5, 137.7, 137.1, 136.1, 132.2, 131.6, 130.1, 129.0, 128.3, 126.7, 126.1, 125.6, 124.0, 121.9, 121.3, 121.2, 113.6, 113.2, 102.0, 59.8, 47.4, 22.7, 20.7, 14.5. HR-MS (ESI) *m/z* calcd for $C_{34}H_{33}N_6O_2$ $[M+H]^+$ 557.2660, found 557.2650.



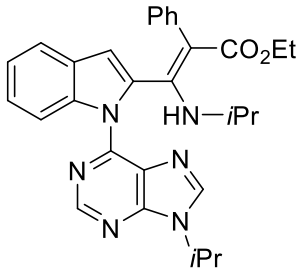
Ethyl (*Z*)-3-[(4-chlorophenyl)amino]-3-[1-(9-isopropyl-9*H*-purin-6-yl)-1*H*-indol-2-yl]-2-phenylacrylate (3ac)： The general procedure **B** was followed using substrate **1a** (0.25 mmol, 70 mg), **2c** (0.30 mmol, 90 mg), $MnBr(CO)_5$ (6.8 mg, 10 mol %), NaOAc (4.2 mg, 20 mol %). Isolation by column chromatography (PE/EtOAc:

3/1→2/1) yielded **3ac** (68 mg, 47%) as a yellow solid. Also, the general procedure **C** was followed using substrate **1a** (0.25 mmol, 70 mg), **2c** (0.30 mmol, 90 mg), $Re_2(CO)_{10}$ (8.2 mg, 5.0 mol %) and NaOAc (4.2 mg, 20 mol %) to give **3ac** (46 mg, 32%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 11.07 (s, 1H), 8.81 (s, 1H), 7.95 (s, 1H), 7.55 (d, *J* = 8.3 Hz, 1H), 7.41 (d, *J* = 7.7 Hz, 1H), 7.18 (t, *J* = 7.6 Hz, 1H), 7.11 (t, *J* = 7.4 Hz, 1H), 7.02 – 6.97 (m, 2H), 6.90 – 6.82 (m, 3H), 6.76 – 6.70 (m, 2H), 6.47 – 6.42 (m, 3H), 4.95 (hept, *J* = 6.6 Hz, 1H), 4.20 – 4.08 (m, 2H), 1.69 (d, *J* = 6.8 Hz, 6H), 1.19 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.4, 152.8, 151.3, 149.8, 147.7, 140.8, 138.8, 136.9, 136.1, 131.6, 131.6, 128.5, 128.2, 127.9, 126.8, 126.1, 125.8, 124.2, 122.2, 122.1, 121.3, 113.6, 113.5, 103.4, 60.0, 47.5, 22.7, 14.4. HR-MS (ESI) *m/z* calcd for $C_{33}H_{30}ClN_6O_2$ $[M+H]^+$ 577.2113, found 577.2116.

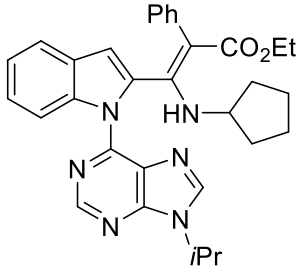


Ethyl (*Z*)-3-(ethylamino)-3-[1-(9-isopropyl-9*H*-purin-6-yl)-1*H*-indol-2-yl]-2-phen -ylacrylate (3ad)： The general procedure **B** was followed using substrate **1a** (0.25 mmol, 70 mg), **2d** (0.30 mmol, 66 mg). Isolation by column chromatography (PE/EtOAc: 5/1→3/1) yielded **3ad** (86 mg, 69%) as a yellow solid. Also, the general procedure **C** was followed using substrate **1a** (0.25 mmol, 70 mg), **2d** (0.30 mmol, 66 mg), $Re_2(CO)_{10}$ (8.2 mg, 5.0 mol %) and NaOAc (4.2 mg, 20 mol %) to give **3ad** (32 mg, 26%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.35 (t, *J* = 5.5 Hz, 1H), 8.78 (s, 1H), 8.03 (s, 1H), 7.66 – 7.61 (m, 1H), 7.60 – 7.55 (m, 1H), 7.21 – 7.14 (m, 2H), 6.80 – 6.75 (m, 2H), 6.66 – 6.62 (m, 2H), 6.49 (d, *J* = 7.2 Hz, 2H), 5.01 (hept, *J* = 6.8 Hz, 1H), 4.05 (q, *J* = 7.2 Hz, 2H), 3.36 – 3.28 (m, 2H), 1.73 (d, *J* = 2.4 Hz, 3H), 1.71 (d, *J* = 2.4 Hz, 3H), 1.20 (t, *J* = 7.2 Hz, 3H), 1.09 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.2, 155.3, 153.0, 151.4, 147.9, 141.1, 137.1, 136.2, 132.9, 131.1, 128.3, 126.5,

126.4, 125.3, 123.8, 122.1, 121.1, 113.5, 110.8, 98.7, 59.2, 47.5, 25.1, 23.8, 22.7, 14.5. HR-MS (ESI) *m/z* calcd for $C_{29}H_{31}N_6O_2$ $[M+H]^+$ 495.2503, found 495.2494.

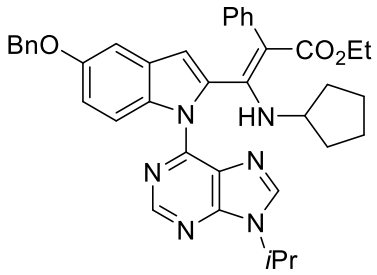


(*Z*)-3-(Ethylperoxy)-*N*-isopropyl-1-[1-(9-isopropyl-9*H*-purin-6-yl)-1*H*-indol-2-yl]-2-phenyl-3l2-prop-1-en-1-amine (3ae)： The general procedure **B** was followed using substrate **1a** (0.25 mmol, 70 mg), **2e** (0.30 mmol, 70 mg). Isolation by column chromatography (PE/EtOAc: 5/1→3/1) yielded **3ae** (116 mg, 91%) as a yellow solid. Also, the general procedure **C** was followed using substrate **1a** (0.25 mmol, 70 mg), **2e** (0.30 mmol, 70 mg), $Re_2(CO)_{10}$ (8.2 mg, 5.0 mol %) and NaOAc (4.2 mg, 20 mol %) to give **3ae** (57 mg, 45%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.27 (d, J = 9.7 Hz, 1H), 8.80 (s, 1H), 8.03 (s, 1H), 7.62 – 7.54 (m, 2H), 7.22 – 7.14 (m, 2H), 6.79 – 6.75 (m, 1H), 6.73 (d, J = 0.7 Hz, 1H), 6.66 – 6.62 (m, 2H), 6.61 – 6.56 (m, 2H), 5.01 (hept, J = 6.8 Hz, 1H), 4.05 (q, J = 7.1 Hz, 2H), 3.71 – 3.58 (m, 1H), 1.73 (d, J = 6.8 Hz, 3H), 1.71 (d, J = 6.8 Hz, 3H), 1.21 (d, J = 6.4 Hz, 3H), 1.12 – 1.07 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.2, 155.3, 153.0, 151.4, 147.9, 141.1, 137.1, 136.3, 132.9, 131.1, 128.3, 126.5, 126.5, 125.3, 123.8, 122.1, 121.1, 113.5, 110.8, 98.7, 59.2, 47.6, 47.4, 25.1, 23.8, 22.7, 14.5. HR-MS (ESI) *m/z* calcd for $C_{30}H_{33}N_6O_2$ $[M+H]^+$ 509.2660, found 509.2653.



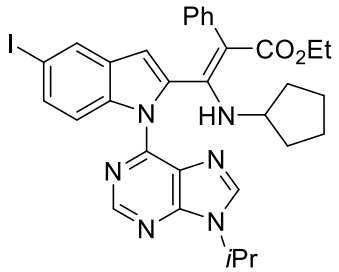
Ethyl (*Z*)-3-(cyclopentylamino)-3-[1-(9-isopropyl-9*H*-purin-6-yl)-1*H*-indol-2-yl]-2

-phenylacrylate (3af)： The general procedure **B** was followed using substrate **1a** (0.25 mmol, 70 mg), **2f** (0.30 mmol, 78 mg). Isolation by column chromatography (PE/EtOAc: 5/1→3/1) yielded **3af** (126 mg, 95%) as a yellow solid. Also, the general procedure **C** was followed using substrate **1a** (0.25 mmol, 70 mg), **2f** (0.30 mmol, 78 mg), $Re_2(CO)_{10}$ (8.2 mg, 5.0 mol %) and NaOAc (4.2 mg, 20 mol %) to give **3af** (53 mg, 40%). ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.52 (d, J = 9.4 Hz, 1H), 8.78 (s, 1H), 8.02 (s, 1H), 7.66 – 7.61 (m, 1H), 7.61 – 7.56 (m, 1H), 7.21 – 7.16 (m, 2H), 6.79 – 6.74 (m, 2H), 6.66 – 6.62 (m, 2H), 6.52 (d, J = 7.3 Hz, 2H), 5.01 (hept, J = 6.8 Hz, 1H), 4.07 – 4.00 (m, 2H), 3.91 – 3.83 (m, 1H), 1.92 – 1.85 (m, 1H), 1.73 – 1.70 (m, 6H), 1.64 – 1.59 (m, 2H), 1.43 (s, 2H), 1.37 (s, 1H), 1.34 (s, 1H), 1.29 (s, 2H), 1.09 (t, J = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.2, 155.7, 153.0, 151.4, 148.0, 141.1, 137.1, 136.2, 133.0, 131.1, 128.3, 126.5, 126.4, 125.2, 123.8, 122.0, 121.0, 113.5, 111.0, 98.2, 59.1, 57.4, 47.6, 35.1, 34.1, 29.8, 23.8, 22.7, 14.5. HR-MS (ESI) *m/z* calcd for $C_{32}H_{35}N_6O_2$ $[M+H]^+$ 535.2806, found 535.2809.



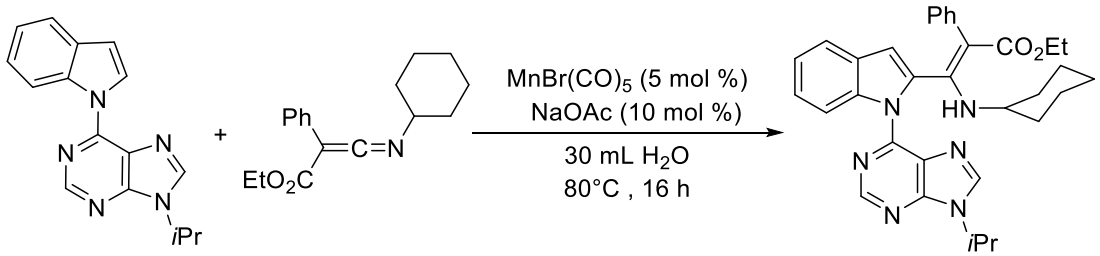
Ethyl (*Z*)-3-[5-(benzyloxy)-1-(9-isopropyl-9*H*-purin-6-yl)-1*H*-indol-2-yl]-3-(cyclo pentylamino)-2-phenylacrylate (3ef)： The general procedure **B** was followed using substrate **1e** (0.25 mmol, 96 mg), **2f** (0.30 mmol, 78 mg). Isolation by column chromatography (PE/EtOAc: 5/1→3/1) yielded **3ef** (146 mg, 91%) as a yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.53 (d, J = 9.4 Hz, 1H), 8.76 (s, 1H), 8.01 (s, 1H), 7.57 (d, J = 9.1 Hz, 1H), 7.46 (d, J = 7.1 Hz, 2H), 7.42 – 7.37 (m, 2H), 7.35 – 7.30 (m, 1H), 7.10 (d, J = 2.5 Hz, 1H), 6.92 (dd, J = 9.1, 2.5 Hz, 1H), 6.77 (t, J = 7.3 Hz, 1H), 6.68 (s, 1H), 6.64 (t, J = 7.5 Hz, 2H), 6.50 (d, J = 7.2 Hz, 2H), 5.10 (s, 2H), 5.00 (hept, J = 6.8 Hz, 1H), 4.07 – 3.98 (m, 2H), 3.93 – 3.83 (m, 1H), 1.94 – 1.87 (m, 1H), 1.72 (d, J = 6.5 Hz, 3H), 1.70 (d, J = 6.5 Hz, 3H), 1.69 – 1.55 (m, 4H), 1.53 – 1.43 (m, 3H),

1.09 (t, J = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.2, 155.8, 154.8, 152.9, 151.4, 147.9, 140.9, 137.6, 137.1, 133.5, 131.4, 131.0, 129.0, 128.7, 128.0, 127.6, 126.4, 126.2, 125.2, 114.5, 114.3, 110.9, 104.1, 98.0, 70.7, 60.6, 59.1, 57.4, 47.5, 35.1, 34.1, 23.9, 22.8, 14.5. HR-MS (ESI) *m/z* calcd for $C_{39}H_{41}N_6O_3$ $[M+H]^+$ 641.3235, found 641.3233.



Ethyl (*Z*)-3-(cyclopentylamino)-3-[5-iodo-1-(9-isopropyl-9*H*-purin-6-yl)-1*H*-indol-2-yl]-2-phenylacrylate (3jf)： The general procedure **B** was followed using substrate **1j** (0.25 mmol, 101 mg), **2f** (0.30 mmol, 78 mg). Isolation by column chromatography (PE/EtOAc: 5/1→3/1) yielded **3jf** (159 mg, 96%) as a yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.47 (d, J = 9.4 Hz, 1H), 8.79 (s, 1H), 8.02 (s, 1H), 7.92 (d, J = 1.4 Hz, 1H), 7.42 (td, J = 8.6, 1.4 Hz, 1H), 7.39 (t, J = 8.6 Hz, 1H), 6.80 – 6.75 (m, 1H), 6.67 – 6.62 (m, 3H), 6.51 (d, J = 7.3 Hz, 2H), 5.00 (hept, J = 6.7 Hz, 1H), 4.06 – 4.01 (m, 2H), 3.82 – 3.73 (m, 1H), 1.88 – 1.83 (m, 1H), 1.72 (d, J = 6.7 Hz, 3H), 1.72 (d, J = 6.7 Hz, 3H), 1.68 – 1.56 (m, 4H), 1.50 – 1.40 (m, 3H), 1.08 (t, J = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 170.1, 154.9, 153.1, 151.5, 147.5, 141.1, 136.9, 135.3, 133.8, 132.1, 131.0, 130.7, 129.8, 126.5, 126.4, 125.4, 115.6, 109.7, 98.5, 85.9, 60.5, 59.2, 57.4, 47.7, 35.0, 34.0, 23.8, 22.8, 22.7, 14.5. HR-MS (ESI) *m/z* calcd for $C_{32}H_{34}IN_6O_2$ $[M+H]^+$ 661.1782, found 661.1780.

Gram-scale synthesis

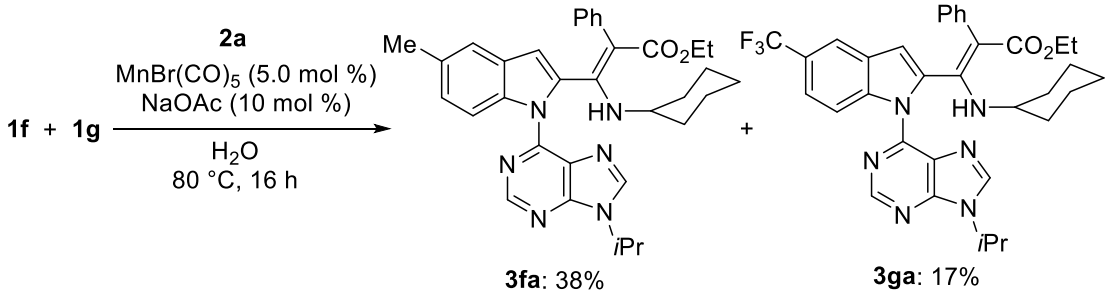


1a: 3 mmol **2a** **3aa**: 1.63 g, 99%

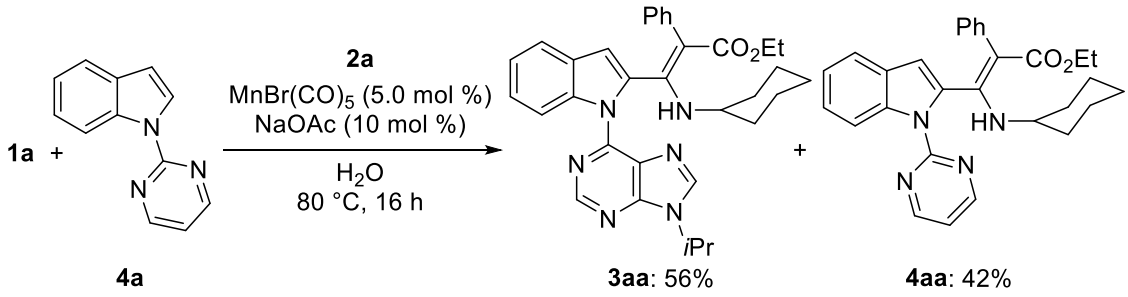
In an oven-dried Schlenk tube equipped with a magnetic stirring bar, a mixture of substrate **1a** (3 mmol, 832 mg), **2a** (3.6 mmol, 977 mg), $MnBr(CO)_5$ (0.15 mmol, 41 mg), NaOAc (0.3 mmol, 25 mg), and H_2O (30 mL) were added under N_2 atmosphere. The reaction mixture was stirred at 80 ℃ in oil bath for 16 hours. After completion of the reaction, the reaction mixture was poured into H_2O (20 mL) and extracted with EtOAc (4×15 mL). The combined organic phase was dried with Na_2SO_4. After filtration and evaporation of the solvents under reduced pressure, the residue was purified by column chromatography on silica gel afforded the desired product **3aa** (1.63 g, 99%) as a yellow solid. The spectral data was identical to its reported above.

Mechanistic Studies

Intermolecular Competition Experiments

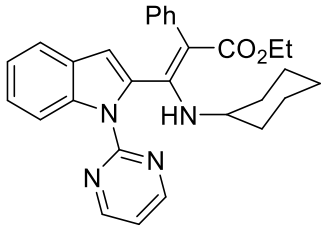


In an oven-dried Schlenk tube equipped with a magnetic stirring bar, a mixture of substrate **1f** (0.25 mmol, 73 mg), **1g** (0.25 mmol, 88 mg), **2a** (0.25 mmol, 68 mg), $MnBr(CO)_5$ (5.0 mol %, 3.4 mg), NaOAc (10 mol %, 2.1 mg), and H_2O (1 mL) were added under N_2 atmosphere. The reaction mixture was stirred at 80 ℃ in oil bath for 16 hours. After completion of the reaction, the reaction mixture was poured into H_2O (10 mL) and extracted with EtOAc (4×5 mL). The combined organic phase was dried with Na_2SO_4. After filtration and evaporation of the solvents under reduced pressure, the residue was purified by column chromatography on silica gel afforded **3fa** (54 mg, 38%) as a yellow solid and **3ga** (27 mg, 17%) as a yellow solid.



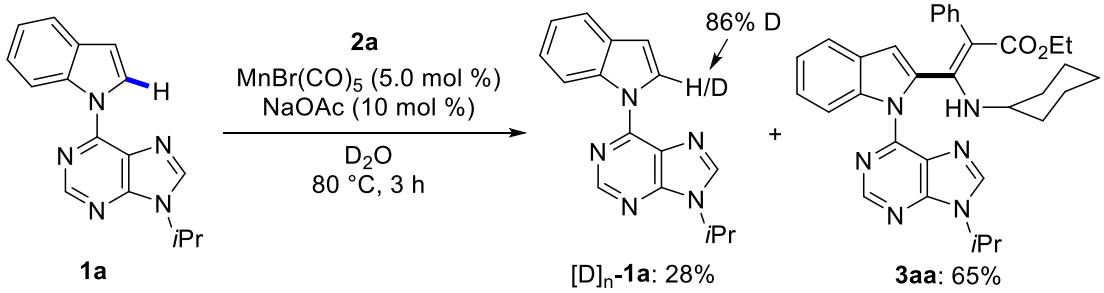
In an oven-dried Schlenk tube equipped with a magnetic stirring bar, a mixture of substrate **1a** (0.25 mmol, 70 mg), **4a** (0.25 mmol, 49 mg), **2a** (0.25 mmol, 68 mg), $MnBr(CO)_5$ (5.0 mol %, 3.4 mg), NaOAc (10 mol %, 2.1 mg), and H_2O (1 mL) were added under N_2 atmosphere. The reaction vessel was heated to 80 ℃ in oil bath for 16 hours. After completion of the reaction, the reaction mixture was poured into H_2O (10

mL) and extracted with EtOAc (4×5 mL). The combined organic phase was dried with Na_2SO_4. After filtration and evaporation of the solvents under reduced pressure, the residue was purified by column chromatography on silica gel afforded **3aa** (77 mg, 56%) as a yellow solid and **4aa** (49 mg, 42%) as a white solid.



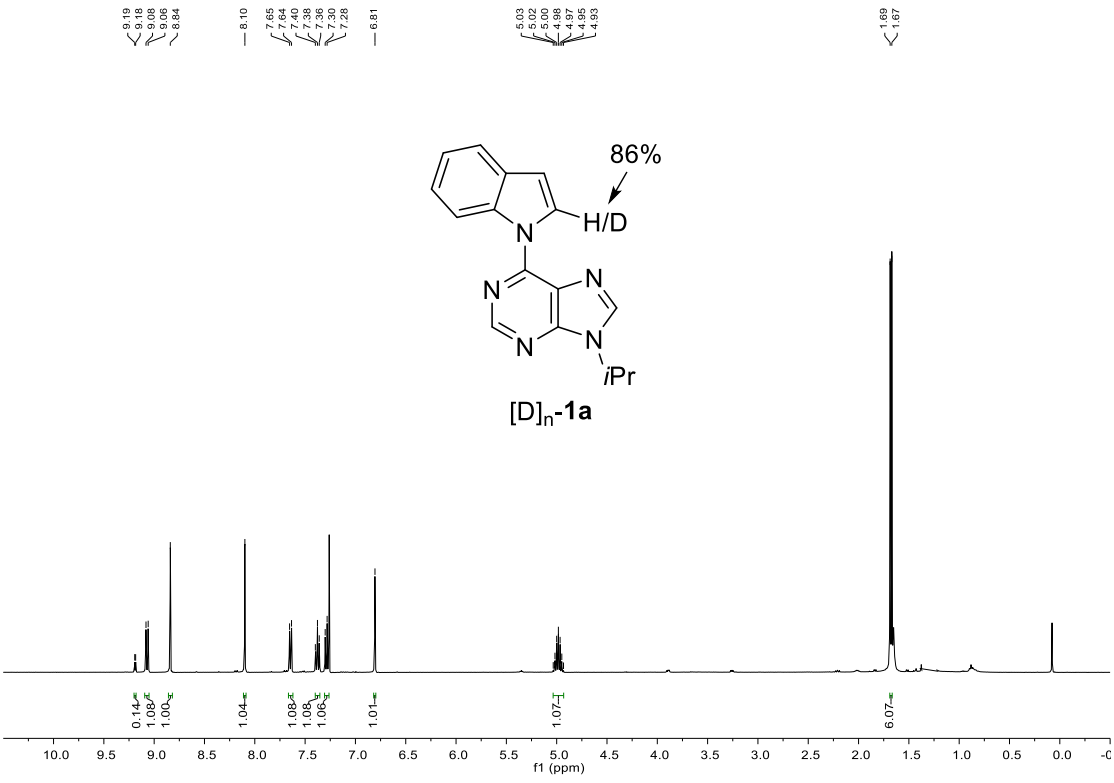
Ethyl (*Z*)-3-(cyclohexylamino)-2-phenyl-3-[1-(pyrimidin-2-yl)-1H-indol-2-yl]acrylate (4aa): ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.57 (d, *J* = 11.1 Hz, 1H), 8.66 (d, *J* = 4.5 Hz, 2H), 8.21 (d, *J* = 8.5 Hz, 1H), 7.52 (d, *J* = 7.5 Hz, 1H), 7.24 – 7.14 (m, 2H), 7.08 (t, *J* = 4.0 Hz, 1H), 6.87 – 6.74 (m, 3H), 6.61 (d, *J* = 8.8 Hz, 3H), 4.14 – 4.04 (m, 2H), 3.35 – 3.11 (m, 1H), 1.94 – 1.84 (m, 1H), 1.80 – 1.72 (m, 1H), 1.71 – 1.59 (m, 2H), 1.46 – 1.10 (m, 9H). HR-MS (ESI) *m/z* calcd for $C_{29}H_{31}N_4O_2$ $[M+H]^+$ 467.2442, found 467.2440. Analytical data for compound **4aa** was consistent with the literature.[1]

Manganese-Catalyzed H/D Exchange Experiments

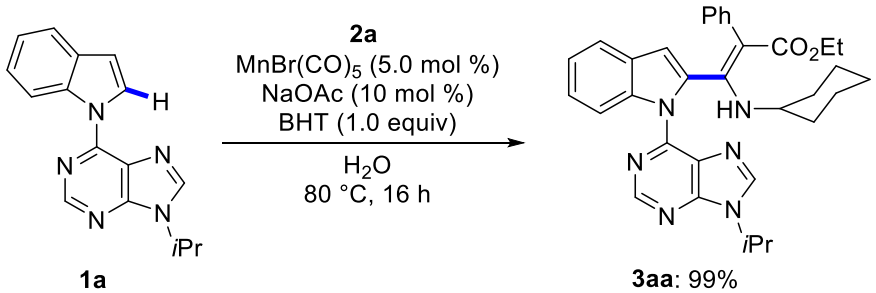


6-(1*H*-Indol-1-yl)-9-isopropyl-9*H*-purine (**1a**) (0.25 mmol, 70 mg), **2a** (0.30 mmol, 82 mg), $MnBr(CO)_5$ (5.0 mol %, 3.4 mg), NaOAc (10 mol %, 2.1 mg) and D_2O (1.0 mL) were placed in a 15 mL Schlenk tube under N_2 and were then stirred at 80 ℃ for 3 h. At ambient temperature, the reaction mixture was diluted with H_2O (10 mL) and extracted with EtOAc (4×5 mL). The combined organic phase was dried with Na_2SO_4.

After filtration and evaporation of the solvents under reduced pressure, the residue was purified by column chromatography on silica gel afforded $[D]_n$-**1a** (19 mg, 28%) as white solid and **3aa** (89 mg, 65%) as a yellow solid. The D incorporation was determined by ^{1}H-NMR spectroscopy.



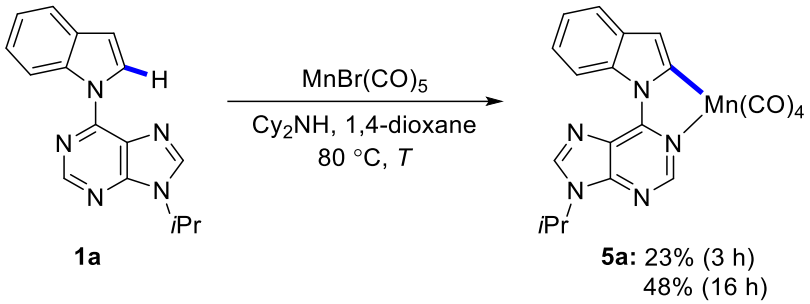
Reactions in the Presence of Radical Scavengers



6-(1*H*-Indol-1-yl)-9-isopropyl-9*H*-purine (**1a**) (0.25 mmol, 70 mg), **2a** (0.30 mmol, 82 mg), $MnBr(CO)_5$ (5 mol %, 3.4 mg), NaOAc (10 mol %, 2.1 mg), BHT (0.25 mmol, 56 mg) and H_2O (1.0 mL) were placed in a 15 mL Schlenk tube under N_2 and were then stirred at 80 ℃ for 3 h. At ambient temperature, the reaction mixture was diluted

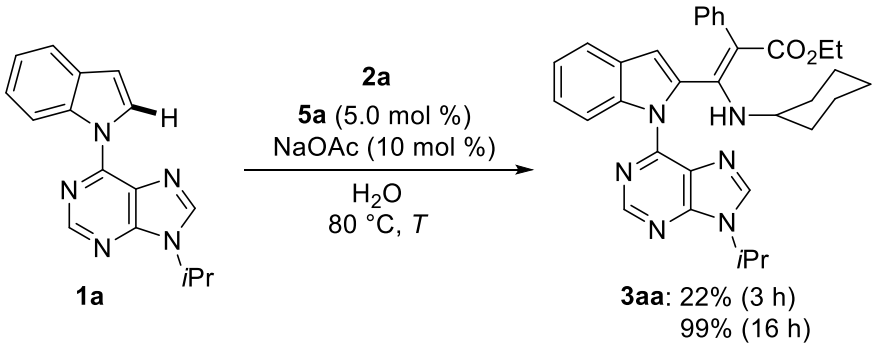
with H_2O (10 mL) and extracted with EtOAc (4×5 mL). The combined organic phase was dried with Na_2SO_4. After filtration and evaporation of the solvents under reduced pressure, the residue was purified by column chromatography on silica gel afforded **3aa** (136 mg, 99%) as a yellow solid.

C–H Enaminylation with Cyclometalated Complex 5a

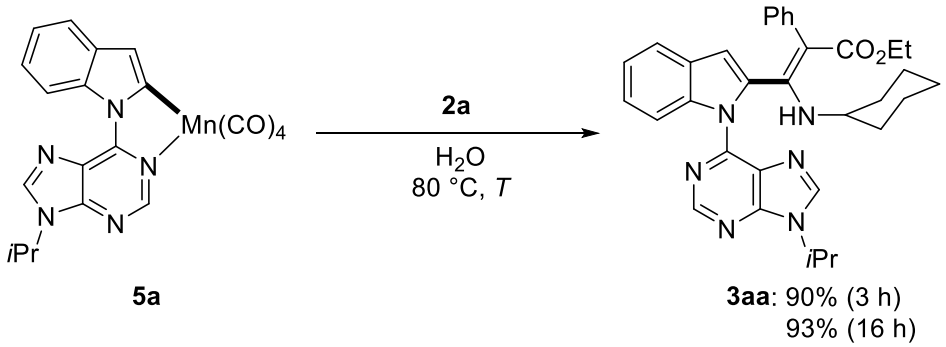


1a **5a:** 23% (3 h) 48% (16 h)

Following a modification of a reported procedure,[2] 6-(1*H*-indol-1-yl)-9-isopropyl-9*H*-purine (**1a**) (0.5 mmol, 140 mg), $MnBr(CO)_5$ (0.5 mmol, 137 mg), Cy_2NH (1.0 mmol, 182 mg) and 1,4-dioxane (1.0 mL) were placed in a 15 mL Schlenk tube under N_2 and then stirred at 80 ℃ for 3 h or 16 h. At ambient temperature, the mixture was diluted with EtOAc (20 ml) and filtered through a short pad of celite. The solvent was removed by rotary evaporation and the residue was purified by flash column chromatography on silica gel afforded **5a** (3 h: 20mg, 23%; 16 h: 107 mg, 48%) as a yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.98 (d, J = 7.9 Hz, 1H), 8.74 (s, 1H), 8.16 (s, 1H), 7.43 (d, J = 7.2 Hz, 1H), 7.29 – 7.22 (m, 1H), 7.19 (t, J = 7.2 Hz, 1H), 6.92 (s, 1H), 4.93 (hept, J = 6.7 Hz, 1H), 1.68 (d, J = 6.7 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 218.9, 213.5, 210.8, 167.7, 155.5, 153.5, 152.8, 139.7, 139.4, 136.6, 123.6, 121.1, 120.9, 117.3, 116.7, 48.0, 22.6. HR-MS (ESI) *m/z* calcd for $C_{20}H_{15}MnN_5O_4$ $[M+H]^+$ 444.0499, found 444.0495. The structure of **5a** was confirmed by single-crystal X-ray diffraction analysis.

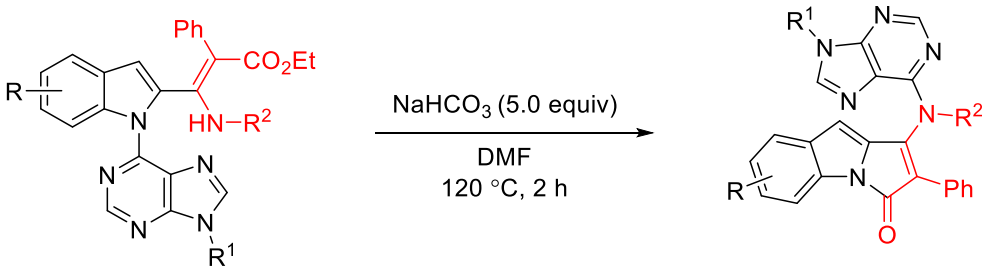


6-(1*H*-Indol-1-yl)-9-isopropyl-9*H*-purine (**1a**) (0.25 mmol, 70 mg), **2a** (0.30 mmol, 82 mg), **5a** (0.0125 mmol, 5.6 mg), NaOAc (0.025 mmol, 2.1 mg) and H_2O (1.0 mL) were placed in a 15 mL Schlenk tube under N_2 and then stirred at 80 ℃ for 3 h or 16 h. At ambient temperature, the reaction mixture was diluted with H_2O (10 mL) and extracted with EtOAc (4×5 mL). The combined organic phase was dried with Na_2SO_4. After filtration and evaporation of the solvents under reduced pressure, the residue was purified by column chromatography on silica gel afforded **3aa** (3h: 24 mg, 22%; 16h: 136 mg, 99%).



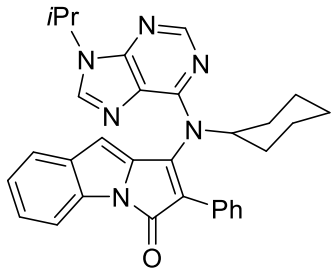
Complex **5a** (0.25 mmol, 111 mg), **2a** (0.30 mmol, 82 mg), and H_2O (1.0 mL) were placed in a 15 mL Schlenk tube under N_2 and were then stirred at 80 ℃ for 3 h or 16 h. At ambient temperature, the reaction mixture was diluted with H_2O (10 mL) and extracted with EtOAc (4×5 mL). The combined organic phase was dried with Na_2SO_4. After filtration and evaporation of the solvents under reduced pressure, the residue was purified by column chromatography on silica gel afforded **3aa** (3h: 99 mg, 90%; 16h: 127 mg, 93%).

Synthetic Procedure and Characterization Data for 6

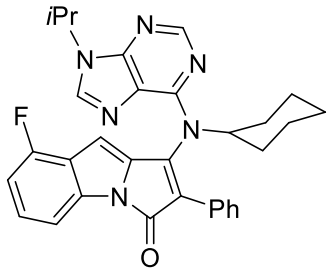


3 **6**

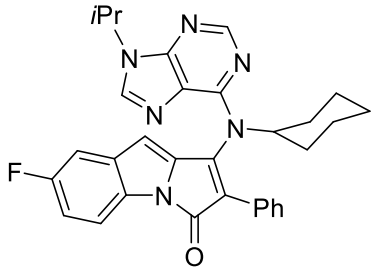
The mixture of **3** (0.1 mmol), $NaHCO_3$ (0.5 mmol) in 2 mL of DMF was stirred at 120 ℃ for 2 hours under N_2 atmosphere. Then the reaction mixture was poured into H_2O (30 mL) and extracted with EtOAc (3×15 mL). The combined organic phase was dried with Na_2SO_4. After filtration and evaporation of the solvents under reduced pressure, the residue was purified by column chromatography on silica gel afforded **6**.



1-[Cyclohexyl(9-isopropyl-9*H*-purin-6-yl)amino]-2-phenyl-3*H*-pyrrolo[1,2-*a*]indol-3-one (6a): The mixture of **3aa** (0.1 mmol, 55 mg), $NaHCO_3$ (0.5 mmol, 41 mg) and 2 mL DMF was stirred at 120 ℃ for 2 hours under N_2 atmosphere. Isolation by column chromatography (PE/EtOAc: 2/1→1/1) yielded **6a** (47 mg, 94%) as a red solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.47 (s, 1H), 7.81 – 7.77 (m, 2H), 7.52 – 7.48 (m, 2H), 7.33 (d, *J* = 7.7 Hz, 1H), 7.29 (td, *J* = 7.7, 1.0 Hz, 1H), 7.24 – 7.21 (m, 3H), 7.08 (td, *J* = 7.7, 1.0 Hz, 1H), 6.19 (s, 1H), 5.16 (t, *J* = 10.9 Hz, 1H), 4.85 (hept, *J* = 6.8 Hz, 1H), 1.90 – 1.81 (m, 2H), 1.75 – 1.70 (m, 2H), 1.65 – 1.61 (m, 3H), 1.58 (d, *J* = 6.8 Hz, 6H), 1.45 – 1.36 (m, 2H), 1.10 – 0.99 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 164.1, 153.9, 151.9, 151.2, 142.4, 140.8, 138.1, 134.6, 134.0, 130.5, 128.8, 128.7, 128.2, 127.3, 123.4, 122.7, 121.6, 112.9, 106.8, 59.0, 46.9, 31.6, 26.1, 25.5, 22.8. HR-MS (ESI) *m/z* calcd for $C_{31}H_{31}N_6O$ $[M+H]^+$ 503.2554, found 503.2555.

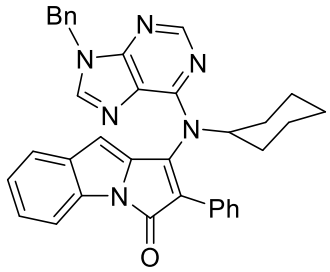


1-[Cyclohexyl(9-isopropyl-9*H*-purin-6-yl)amino]-8-fluoro-2-phenyl-3*H*-pyrrolo[1,2-*a*]indol-3-one (6b): The mixture of **3ca** (0.1 mmol, 56 mg), $NaHCO_3$ (0.5 mmol, 41 mg) and 2 mL DMF was stirred at 120 ℃ for 2 hours under N_2 atmosphere. Isolation by column chromatography (PE/EtOAc: 2/1→1/1) yielded **6b** (32 mg, 61%) as a red solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.48 (s, 1H), 7.81 (s, 1H), 7.59 (d, J = 8.0 Hz, 1H), 7.50 – 7.46 (m, 2H), 7.25 – 7.21 (m, 4H), 6.82 – 6.76 (m, 1H), 6.30 (s, 1H), 5.25 – 5.05 (m, 1H), 4.84 (hept, J = 6.8 Hz, 1H), 1.90 – 1.82 (m, 2H), 1.78 – 1.70 (m, 2H), 1.64 – 1.61 (m, 1H), 1.58 (d, J = 6.8 Hz, 6H), 1.45 – 1.37 (m, 2H), 1.11 – 1.00 (m, 1H), 0.90 – 0.83 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 164.1, 156.6 (d, $^1J_{C\text{-}F}$ = 253.8 Hz), 153.7, 151.8, 151.1, 142.5, 140.5, 138.2, 136.2 (d, $^3J_{C\text{-}F}$ = 8.2 Hz), 130.3, 128.8, 128.7, 128.5 (d, $^3J_{C\text{-}F}$ = 8.0 Hz), 128.2, 122.2 (d, $^2J_{C\text{-}F}$ = 21.8 Hz), 121.6, 109.4 (d, $^2J_{C\text{-}F}$ = 19.8 Hz), 109.1 (d, $^4J_{C\text{-}F}$ = 3.7 Hz), 102.1, 59.2, 47.0, 31.6, 26.1, 25.5, 22.8. ^{19}F NMR (376 MHz, $CDCl_3$) δ = -119.58. HR-MS (ESI) *m/z* calcd for $C_{31}H_{30}FN_6O$ $[M+H]^+$ 521.2460, found 521.2457. The structure of **6b** was confirmed by single-crystal X-ray diffraction analysis.

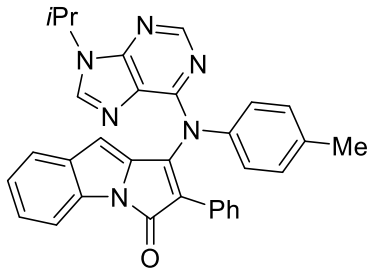


1-[Cyclohexyl(9-isopropyl-9*H*-purin-6-yl)amino]-7-fluoro-2-phenyl-3*H*-pyrrolo[1,2-*a*]indol-3-one (6c): The mixture of **3ha** (0.1 mmol, 56 mg), $NaHCO_3$ (0.5 mmol, 41 mg) and 2 mL DMF was stirred at 120 ℃ for 2 hours under N_2 atmosphere.

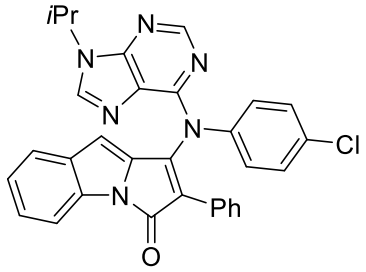
Isolation by column chromatography (PE/EtOAc: 2/1→1/1) yielded **6c** (49 mg, 95%) as a red solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.48 (s, 1H), 7.81 (s, 1H), 7.71 (dd, *J* = 8.3, 4.4 Hz, 1H), 7.50 – 7.46 (m, 2H), 7.25 – 7.21 (m, 3H), 7.01 (d, *J* = 9.0 Hz, 2H), 6.15 (s, 1H), 5.23 – 5.09 (m, 1H), 4.84 (hept, *J* = 6.8 Hz, 1H), 1.89 – 1.80 (m, 2H), 1.77 – 1.70 (m, 2H), 1.69 – 1.64 (m, 1H), 1.63 – 1.60 (m, 1H), 1.58 (d, *J* = 6.8 Hz, 6H), 1.55 – 1.51 (m, 1H), 1.44 – 1.36 (m, 2H), 1.10 – 0.97 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 163.8, 160.8, 158.4, 152.4 (d, $^{1}J_{C\text{-}F}$ = 269.0 Hz), 151.8, 142.3, 138.2, 134.9 (d, $^{3}J_{C\text{-}F}$ = 8.0 Hz), 130.9, 130.3, 129.4, 128.8, 128.8, 128.3, 121.6, 114.3 (d, $^{2}J_{C\text{-}F}$ = 24.0 Hz), 113.3 (d, $^{3}J_{C\text{-}F}$ = 8.4 Hz), 108.9 (d, $^{1}J_{C\text{-}F}$ = 26.0 Hz), 106.1 (d, $^{4}J_{C\text{-}F}$ = 3.5 Hz), 59.1, 47.0, 31.6, 26.0, 25.4, 22.8. ^{19}F NMR (376 MHz, $CDCl_3$) δ = -119.78. HR-MS (ESI) *m/z* calcd for $C_{31}H_{30}FN_6O$ $[M+H]^+$ 521.2460, found 521.2459.



1-[(9-Benzyl-9H-purin-6-yl)(cyclohexyl)amino]-2-phenyl-3H-pyrrolo[1,2-*a*]indol-3-one (6d): The mixture of **3na** (0.1 mmol, 59 mg), $NaHCO_3$ (0.5 mmol, 41 mg) and 2 mL DMF was stirred at 120 ℃ for 2 hours under N_2 atmosphere. Isolation by column chromatography (PE/EtOAc: 2/1→1/1) yielded **6d** (51 mg, 93%) as a red solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.51 (s, 1H), 7.78 (d, *J* = 7.7 Hz, 1H), 7.69 (s, 1H), 7.52 – 7.47 (m, 2H), 7.36 – 7.32 (m, 4H), 7.31 – 7.26 (m, 3H), 7.24 – 7.21 (m, 3H), 7.11 – 7.05 (m, 1H), 6.21 (s, 1H), 5.34 (s, 2H), 5.23 – 5.09 (m, 1H), 1.92 – 1.81 (m, 2H), 1.76 – 1.70 (m, 2H), 1.63 – 1.52 (m, 3H), 1.44 – 1.36 (m, 2H), 1.10 – 0.99 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 164.0, 153.9, 152.4, 151.6, 142.1, 140.7, 140.3, 135.5, 134.6, 134.0, 130.4, 129.1, 129.1, 128.7, 128.6, 128.5, 128.2, 128.0, 127.2, 123.4, 122.7, 121.0, 112.9, 106.7, 58.9, 47.2, 31.6, 26.0, 25.4. HR-MS (ESI) *m/z* calcd for $C_{35}H_{31}N_6O$ $[M+H]^+$ 551.2554, found 551.2556.



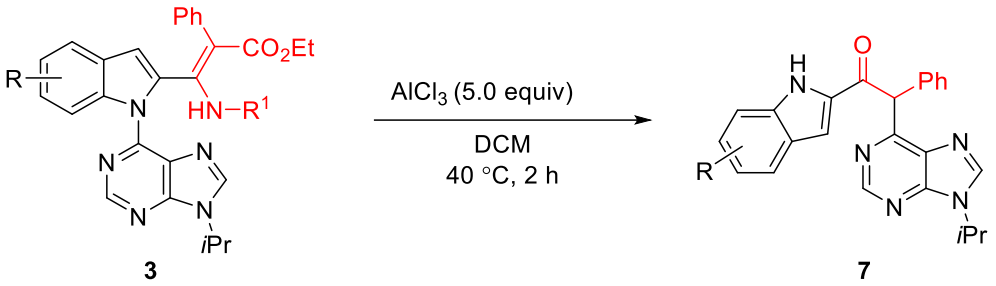
1-[(9-Isopropyl-9*H*-purin-6-yl)(*p*-tolyl)amino]-2-phenyl-3*H*-pyrrolo[1,2-*a*]indol-3-one (6e): The mixture of **3ab** (0.1 mmol, 55 mg), $NaHCO_3$ (0.5 mmol, 41 mg) and 2 mL DMF was stirred at 120 ℃ for 2 hours under N_2 atmosphere. Isolation by column chromatography (PE/EtOAc: 2/1→1/1) yielded **6e** (42 mg, 84%) as a red solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.43 (s, 1H), 7.83 – 7.75 (m, 2H), 7.39 – 7.34 (m, 2H), 7.29 – 7.24 (m, 4H), 7.14 – 7.11 (m, 2H), 7.06 – 7.00 (m, 1H), 6.91 – 6.85 (m, 3H), 5.61 (s, 1H), 4.68 (hept, J = 6.7 Hz, 1H), 2.44 (s, 3H), 1.47 (d, J = 6.7 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 164.6, 152.0, 151.9, 151.5, 143.6, 140.3, 139.4, 137.8, 137.6, 134.1, 133.6, 130.3, 130.0, 127.8, 127.4, 127.1, 126.9, 126.4, 124.6, 122.9, 122.6, 121.7, 112.7, 107.5, 47.2, 22.6, 21.4. HR-MS (ESI) *m/z* calcd for $C_{32}H_{27}N_6O$ $[M+H]^+$ 511.2241, found 511.2242.



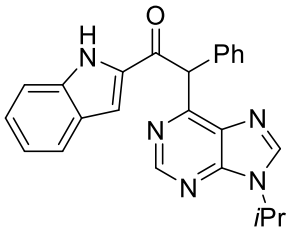
1-[(4-Chlorophenyl)(9-isopropyl-9*H*-purin-6-yl)amino]-2-phenyl-3*H*-pyrrolo[1,2-*a*]indol-3-one (6f): The mixture of **3ac** (0.1 mmol, 57 mg), $NaHCO_3$ (0.5 mmol, 41 mg) and 2 mL DMF was stirred at 120 ℃ for 2 hours under N_2 atmosphere. Isolation by column chromatography (PE/EtOAc: 2/1→1/1) yielded **6f** (33 mg, 61%) as a red solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.44 (s, 1H), 7.83 (s, 1H), 7.78 (d, J = 8.3 Hz, 1H), 7.45 – 7.39 (m, 4H), 7.30 – 7.26 (m, 2H), 7.14 – 7.11 (m, 2H), 7.08 – 7.03 (m, 1H), 6.96 – 6.88 (m, 3H), 5.69 (s, 1H), 4.70 (hept, J = 6.8 Hz, 1H), 1.49 (d, J = 6.8 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 164.3, 152.1, 151.6, 151.5, 142.9, 140.6, 140.4,

137.5, 134.2, 133.6, 133.0, 129.8, 129.8, 129.7, 127.9, 127.7, 127.5, 127.3, 127.1, 124.6, 123.2, 122.7, 112.8, 107.5, 47.4, 22.6. HR-MS (ESI) *m/z* calcd for $C_{31}H_{24}ClN_6O$ $[M+H]^+$ 531.1695, found 531.1670.

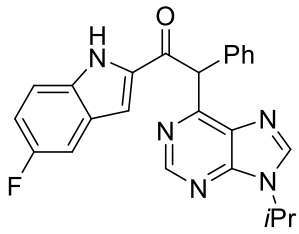
Synthetic Procedure and Characterization Data for 7



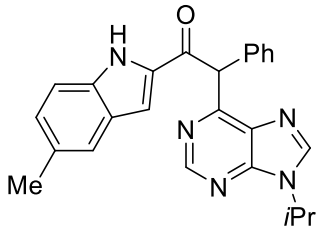
The mixture of **3** (0.1 mmol), $AlCl_3$ (0.5 mmol) in 2 mL of DCM was stirred at 120 ℃ for 2 hours under N_2 atmosphere. Then the reaction mixture was poured into H_2O (30 mL) and extracted with DCM (3×15 ml). The combined organic phase was dried with Na_2SO_4. After filtration and evaporation of the solvents under reduced pressure, the residue was purified by column chromatography on silica gel afforded **7** (note: containing uncertain impurity, ~95% pure).



1-(1*H*-Indol-2-yl)-2-(9-isopropyl-9*H*-purin-6-yl)-2-phenylethan-1-one (7a): The mixture of **3aa** (0.1 mmol, 55 mg), $AlCl_3$ (0.5 mmol, 66 mg) and 2 mL DCM was stirred at 120 ℃ for 2 hours under N_2 atmosphere. Isolation by column chromatography (PE/EtOAc: 2/1→3/2) yielded **7a** (32 mg, 81%) as yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.43 (s, 1H), 8.93 (s, 1H), 8.14 (s, 1H), 7.70 (d, J = 7.2 Hz, 2H), 7.57 (d, J = 8.0 Hz, 1H), 7.38 – 7.26 (m, 6H), 7.09 – 7.04 (m, 1H), 6.83 (s, 1H), 4.89 (hept, J = 6.8 Hz, 1H), 1.63 (d, J = 6.8 Hz, 3H), 1.61 (d, J = 6.8 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 187.7, 157.8, 152.4, 151.3, 142.5, 137.5, 135.7, 134.7, 132.6, 130.2, 128.6, 127.8, 127.5, 126.5, 123.2, 121.0, 112.3, 110.6, 56.6, 47.7, 22.6. HR-MS (ESI) *m/z* calcd for $C_{24}H_{22}N_5O$ $[M+H]^+$ 396.1819, found 396.1815. The structure of **7a** was confirmed by single-crystal X-ray diffraction analysis.

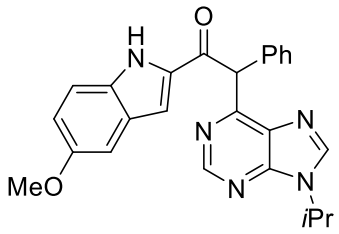


1-(5-Fluoro-1*H*-indol-2-yl)-2-(9-isopropyl-9*H*-purin-6-yl)-2-phenylethan-1-one (7b): The mixture of **3ha** (0.1 mmol, 56 mg), $AlCl_3$ (0.5 mmol, 66 mg) and 2 mL DCM was stirred at 120 ℃ for 2 hours under N_2 atmosphere. Isolation by column chromatography (PE/EtOAc: 2/1→3/2) yielded **7b** (19 mg, 45%) as yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.85 (s, 1H), 8.94 (s, 1H), 8.17 (s, 1H), 7.71 (d, J = 7.1 Hz, 2H), 7.40 – 7.34 (m, 2H), 7.32 – 7.28 (m, 1H), 7.22 – 7.17 (m, 3H), 7.00 (td, J = 9.1, 2.5 Hz, 1H), 6.84 (s, 1H), 4.90 (hept, J = 6.8 Hz, 1H), 1.64 (d, J = 6.8 Hz, 3H), 1.62 (d, J = 6.8 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 187.9, 158.1 (d, $^1J_{C\text{-}F}$ = 236.1 Hz), 157.6, 152.4, 151.4, 142.6, 136.0, 135.6, 134.3, 133.2, 132.6, 130.2, 129.0, 128.7, 127.9, 127.6 (d, $^3J_{C\text{-}F}$ = 9.0 Hz), 115.7 (d, $^2J_{C\text{-}F}$ = 24.7 Hz), 113.5 (d, $^3J_{C\text{-}F}$ = 8.9 Hz), 110.3 (d, $^4J_{C\text{-}F}$ = 3.0 Hz), 107.1 (d, $^2J_{C\text{-}F}$ = 25.6 Hz), 56.6, 47.8, 22.7. ^{19}F NMR (376 MHz, $CDCl_3$) δ = -122.44 – -122.50 (m). HR-MS (ESI) *m/z* calcd for $C_{24}H_{21}FN_5O$ $[M+H]^+$ 414.1725, found 414.1726.

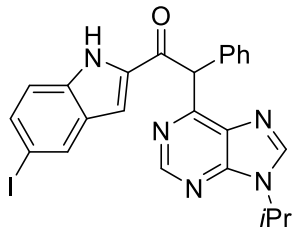


2-(9-Isopropyl-9*H*-purin-6-yl)-1-(5-methyl-1*H*-indol-2-yl)-2-phenylethan-1-one (7c): The mixture of **3fa** (0.1 mmol, 56 mg), $AlCl_3$ (0.5 mmol, 66 mg) and 2 mL DCM was stirred at 120 ℃ for 2 hours under N_2 atmosphere. Isolation by column chromatography (PE/EtOAc: 2/1→3/2) yielded **7c** (24 mg, 59%) as yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.15 (s, 1H), 8.94 (s, 1H), 8.16 (s, 1H), 7.74 – 7.71 (m, 2H), 7.38 – 7.34 (m, 3H), 7.31 – 7.27 (m, 1H), 7.26 – 7.21 (m, 1H), 7.18 – 7.16 (m, 1H), 7.12 (d, J = 8.4 Hz, 1H), 6.83 (s, 1H), 4.90 (hept, J = 6.8 Hz, 1H), 2.38 (s, 3H),

1.64 (d, J = 6.8 Hz, 3H), 1.62 (d, J = 6.8 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 187.4, 157.7, 152.2, 151.4, 142.6, 136.0, 135.8, 134.7, 132.6, 130.9, 130.4, 130.3, 128.7, 127.9, 122.4, 121.7, 112.0, 110.2, 56.6, 47.8, 22.7, 21.5. HR-MS (ESI) *m/z* calcd for $C_{25}H_{24}N_5O$ $[M+H]^+$ 410.1975, found 410.1977.



2-(9-Isopropyl-9*H*-purin-6-yl)-1-(5-methoxy-1*H*-indol-2-yl)-2-phenylethan-1-one (7d): The mixture of **3da** (0.1 mmol, 58 mg), $AlCl_3$ (0.5 mmol, 66 mg) and 2 mL DCM was stirred at 120 ℃ for 2 hours under N_2 atmosphere. Isolation by column chromatography (PE/EtOAc: 2/1→3/2) yielded **7d** (26 mg, 60%) as yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ = 9.46 (s, 1H), 8.94 (s, 1H), 8.14 (s, 1H), 7.73 – 7.69 (m, 2H), 7.38 – 7.33 (m, 2H), 7.31 – 7.26 (m, 1H), 7.23 – 7.16 (m, 2H), 6.97 – 6.93 (m, 2H), 6.82 (s, 1H), 4.90 (hept, J = 6.8 Hz, 1H), 3.79 (s, 3H), 1.64 (d, J = 6.8 Hz, 3H), 1.62 (d, J = 6.8 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 187.5, 157.9, 154.8, 152.4, 151.3, 142.5, 135.8, 135.1, 133.2, 133.2, 132.7, 130.2, 128.6, 127.8, 118.5, 113.4, 110.1, 102.6, 56.6, 55.7, 47.7, 22.7. HR-MS (ESI) *m/z* calcd for $C_{25}H_{24}N_5O_2$ $[M+H]^+$ 426.1925, found 426.1926.



1-(5-Iodo-1*H*-indol-2-yl)-2-(9-isopropyl-9*H*-purin-6-yl)-2-phenylethan-1-one (7e): The mixture of **3ja** (0.1 mmol, 68 mg), $AlCl_3$ (0.5 mmol, 66 mg) and 2 mL DCM was stirred at 120 ℃ for 2 hours under N_2 atmosphere. Isolation by column chromatography (PE/EtOAc: 2/1→3/2) yielded **7c** (29 mg, 56%) as yellow solid. ^{1}H

NMR (400 MHz, $CDCl_3$) δ = 9.78 (s, 1H), 8.93 (s, 1H), 8.16 (s, 1H), 7.71 – 7.68 (m, 2H), 7.51 – 7.43 (m, 2H), 7.38 – 7.34 (m, 2H), 7.32 – 7.28 (m, 1H), 7.12 – 7.10 (m, 1H), 7.07 – 7.04 (m, 1H), 6.81 (s, 1H), 4.90 (hept, *J* = 6.8 Hz, 1H), 1.65 (d, *J* = 6.8 Hz, 3H), 1.62 (d, *J* = 6.8 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ = 188.0, 157.6, 152.4, 151.3, 142.7, 136.5, 135.5, 135.0, 134.6, 131.8, 130.2, 129.9, 128.7, 128.6, 128.3, 128.0, 114.4, 109.4, 84.2, 56.6, 47.8, 22.7. HR-MS (ESI) *m/z* calcd for $C_{24}H_{21}IN_5O$ $[M+H]^+$ 522.0785, found 522.0779.

MTT Assay

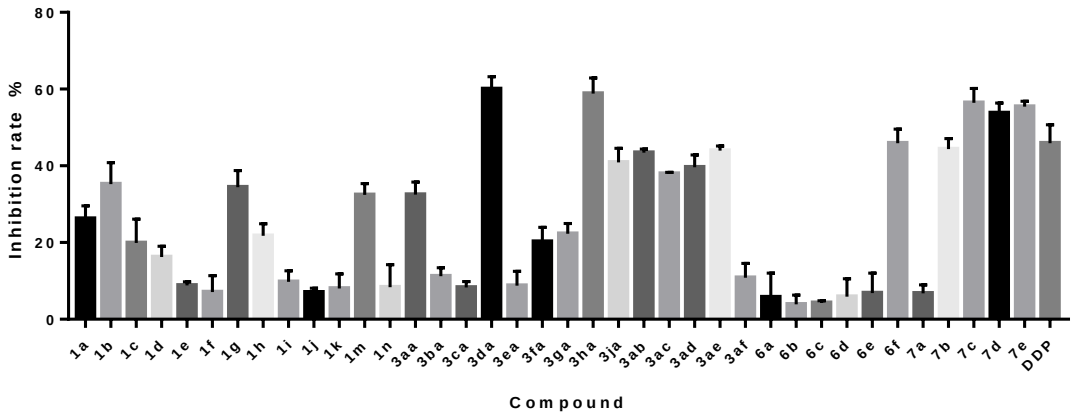


Figure S1 The inhibiting ability of compounds with the concentration of 20 μM of 48 h on the non-small cell lung cancer A549 cells.

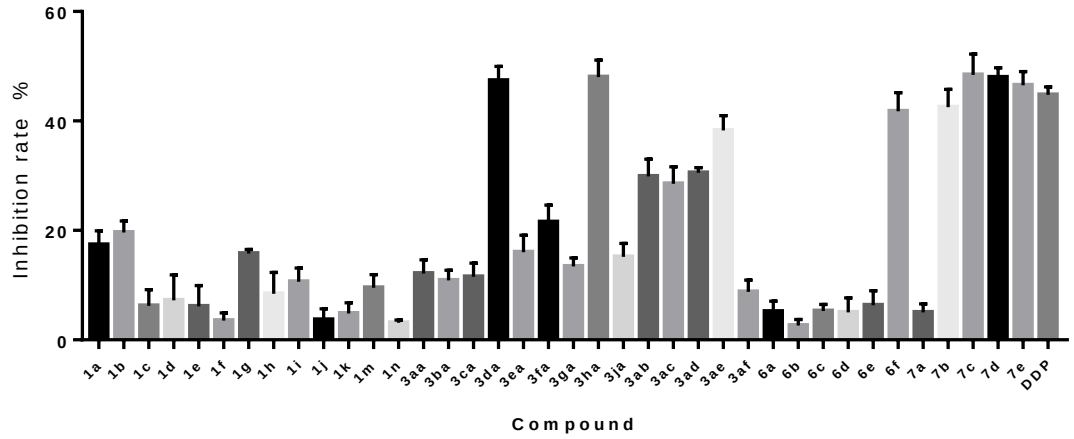


Figure S2 The inhibiting ability of compounds with the concentration of 20 μM of 48 h on the breast cancer MCF-7 cells.

Wound healing assay

We investigated the migration inhibition capacity by wound healing assay. Cancer cell migration is a multistep process involving cell motility and invasion, which is a

significant characteristic of malignant tumors. In this assay, standardized scratches (wounds) were made in confluent monolayers of non-small cell lung cancer A549 cells and breast cancer MCF-7 cells, and then they incubated with compounds **3da**, **3ha** and **7c** with the concentration of 0 and 20 μM. After the wounds were incubated 0 and 24 h, the number of cells migrated in to the wound area was captured by light microscope. As shown in Fig. S3 and S4, compound **3da**, **3ha** and **7c** showed significant inhibition of migration capacity in A549 cells and MCF-7 cells compared to control. These results indicated that compound **3da**, **3ha** and **7c** showed good antitumor activity.

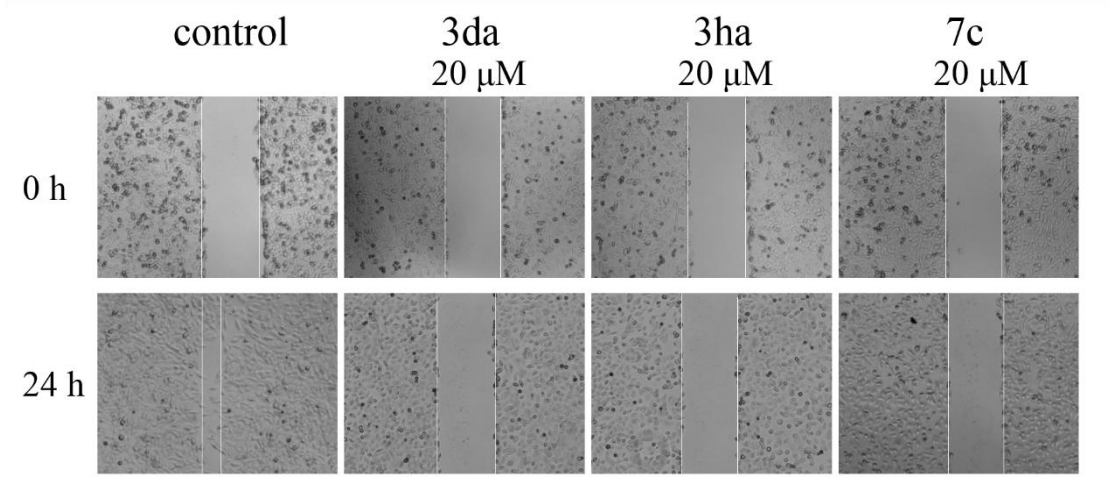


Figure S3. Effect of compound **3da**, **3ha** and **7c** on the migration of non-small cell lung cancer A549 cells. Scratches were created with sterile 10 m L pipette and images were captured using light microscope (Olympus CKX53) at 0 h and 24 h after treatment with 20 μM of compounds.

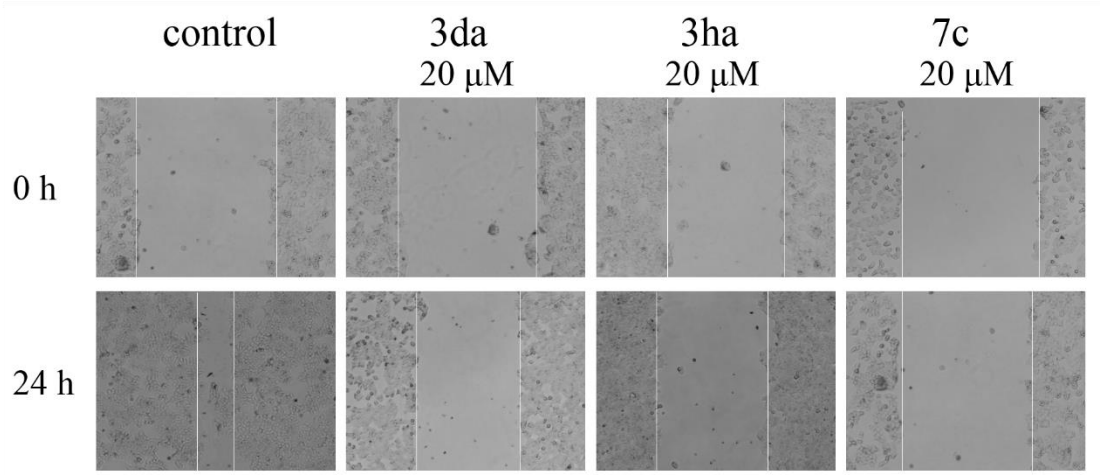


Figure S4. Effect of compound **3da**, **3ha** and **7c** on the migration of breast cancer MCF-7 cells. Scratches were created with sterile 10 m L pipette and images were captured using light microscope (Olympus CKX53) at 0 h and 24 h after treatment with 20 μM of compounds.

Crystallographic Details

The crystals were grown from a mixture of EtOAc and petroleum ether (b.p. 60–90 °C). Suitable single crystal was picked from the mother liquor and covered with perfluorinated polyether oil on a microscope slide.

Compounds **3aa**, **5a**, **6b** and **7a** were collected at 100 K on a Rigaku Oxford Diffraction Supernova Dual Source, Cu at Zero equipped with an AtlasS2 CCD using Cu Kα radiation. Data reduction was carried out with the diffractometer's software [3]. The structure was solved by direct methods using Olex2 software [4], and the non-hydrogen atoms were located from the trial structure and then refined anisotropically with SHELXL-2018[5] using a full-matrix least squares procedure based on F^2. The weighted *R* factor, *wR* and goodness-of-fit *S* values were obtained based on F^2. The hydrogen atom positions were fixed geometrically at the calculated distances and allowed to ride on their parent atoms. Crystallographic data has been deposited with the Cambridge Crystallographic Centre and allocated with the deposition numbers: CCDC 1874506, CCDC 1992409, CCDC 1992408, and CCDC 1992404 for compounds **3aa**, **5a**, **6b** and **7a**, respectively. Copies of the data can be obtained free of charge from The Cambridge Crystallographic Data Centre *via* www.ccdc.cam.ac.uk/data_request/cif.

Crystal structure determination of 3aa

Crystal Data for $C_{33}H_{36}N_6O_2$ (*M* =548.68 g/mol): triclinic, space group P-1 (no. 2), *a* = 11.3769(9) Å, *b* = 12.1582(12) Å, *c* = 13.2260(8) Å, *α* = 78.192(6) °, *β* = 79.374(6) °, *γ* = 63.184(9) °, *V* = 1589.3(2) Å^3, *Z* = 2, *T* = 100.00(10) K, μ(CuKα) = 0.583 mm^{-1}, *Dcalc* = 1.147 g/cm^3, 10734 reflections measured (6.866° ≤ 2Θ ≤ 147.8°), 6204 unique (R_{int} = 0.0358, R_{sigma} = 0.0379) which were used in all calculations. The final R_1 was 0.0680 (I > 2σ(I)) and wR_2 was 0.2031 (all data).

Crystal data and structure refinement for **3aa.**

Compound	**3aa**
CCDC Number	1874506
Empirical formula	$C_{33}H_{36}N_6O_2$
Formula weight [g mol^{-1}]	548.68
Temperature [K]	100.00(10)
Crystal system	triclinic
Space group	P-1
Unit cell dimensions [Å]	a = 11.3769(9)
	b = 12.1582(12)
	c = 13.2260(8)
α [°]	78.192(6)
β [°]	79.374(6)
γ [°]	63.184(9)
Volume [Å^3]	1589.3(2)
Z	2
ρ_{calc} [g cm^{-3}]	1.147
μ [mm^{-1}]	0.583
F(000)	584
Crystal size [mm^3]	0.15 × 0.13 × 0.12
Radiation	CuKα (λ = 1.54184)
Theta range for data collection [°]	6.866 to 147.8
Index ranges	-14 ⩽ h ⩽ 11, -15 ⩽ k ⩽ 13, -13 ⩽ l ⩽ 16
Reflections collected	10734
Independent reflections	6204 [R_{int} = 0.0358, R_{sigma} = 0.0379]
Data / restraints / parameters	6204 / 0 / 373
Goodness-of-fit on F^2	1.013
Final R indexes [I>=2σ (I)]	R_1 = 0.0680 wR_2 = 0.1927
Final R indexes (all data)	R_1 = 0.0757 wR_2 = 0.2031
Largest diff. peak/hole [e. Å^{-3}]	0.56 / -0.37

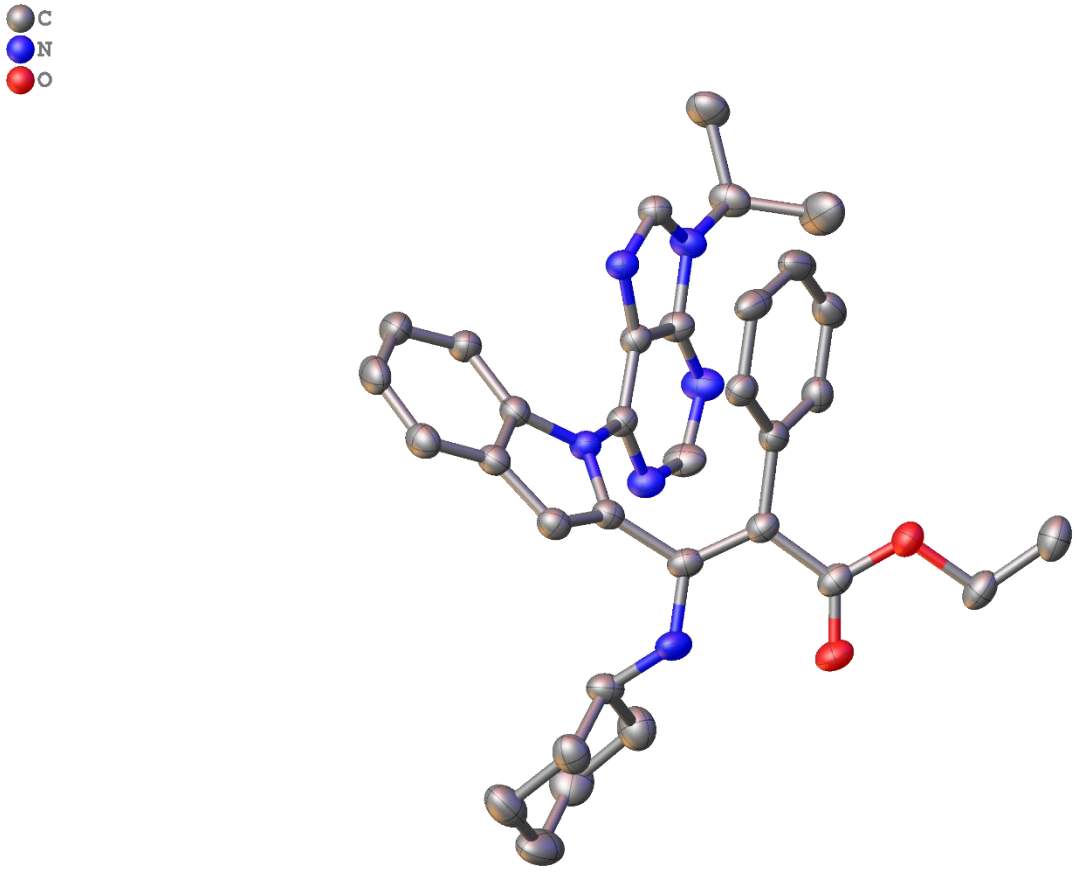


Figure S1. X-ray structure of **3aa**. Ellipsoids show 30% probability levels. H atoms are omitted for clarity.

Bond lengths [Å] and angles [°] of **3aa**

O2-C25	1.350(3)	C18-C19	1.512(3)	N2-C13-N3	114.80(17)
O2-C32	1.457(2)	C18-C23	1.548(3)	N6-C17-C7	114.17(17)
O1-C25	1.227(2)	C14-C16	1.510(3)	N6-C17-C24	123.08(18)
N1-C6	1.392(3)	C14-C15	1.510(4)	C24-C17-C7	122.36(17)
N1-C7	1.400(2)	C19-C20	1.504(3)	N5-C9-N1	116.74(17)
N1-C9	1.403(2)	C23-C22	1.515(3)	N5-C9-C12	120.36(18)
N2-C12	1.388(2)	C22-C21	1.513(4)	C12-C9-N1	122.87(17)
N2-C13	1.307(2)	C20-C21	1.532(4)	N3-C11-C12	105.42(17)
N3-C13	1.367(3)			N4-C11-N3	127.82(18)
N3-C11	1.372(3)	C25-O2-C32	115.20(16)	N4-C11-C12	126.70(18)
N3-C14	1.482(3)	C6-N1-C7	108.27(16)	C28-C27-C26	120.8(2)
N5-C9	1.340(2)	C6-N1-C9	126.34(16)	C7-C8-C1	108.64(17)
N5-C10	1.346(3)	C7-N1-C9	124.96(16)	C27-C26-C24	122.89(18)

N6-C17	1.353(3)	C13-N2-C12	103.39(16)	C31-C26-C24	119.48(18)
N6-C18	1.457(3)	C13-N3-C11	105.74(16)	C31-C26-C27	117.62(18)
N4-C11	1.333(3)	C13-N3-C14	129.24(17)	C4-C5-C6	118.0(2)
N4-C10	1.334(3)	C11-N3-C14	125.00(17)	C3-C2-C1	119.3(2)
C6-C1	1.409(3)	C9-N5-C10	117.41(17)	C29-C28-C27	120.5(2)
C6-C5	1.396(3)	C17-N6-C18	126.76(17)	O2-C32-C33	107.97(18)
C7-C17	1.493(3)	C10-N4-C11	111.59(18)	C5-C4-C3	121.3(2)
C7-C8	1.356(3)	N1-C6-C1	107.64(17)	C30-C31-C26	121.3(2)
C25-C24	1.464(3)	N1-C6-C5	130.92(18)	C28-C29-C30	119.5(2)
C24-C17	1.382(3)	C5-C6-C1	121.28(18)	N6-C18-C19	110.20(17)
C24-C26	1.488(3)	N1-C7-C17	125.23(17)	N6-C18-C23	108.75(18)
C12-C9	1.391(3)	C8-C7-N1	108.78(17)	C19-C18-C23	110.02(19)
C12-C11	1.399(3)	C8-C7-C17	125.56(18)	N3-C14-C16	110.79(18)
C1-C8	1.424(3)	O2-C25-C24	114.50(17)	N3-C14-C15	109.93(19)
C1-C2	1.401(3)	O1-C25-O2	119.78(18)	C15-C14-C16	112.1(2)
C27-C26	1.396(3)	O1-C25-C24	125.72(19)	C2-C3-C4	120.7(2)
C27-C28	1.392(3)	C25-C24-C26	118.99(17)	C29-C30-C31	120.3(2)
C26-C31	1.397(3)	C17-C24-C25	118.77(18)	N4-C10-N5	128.6(2)
C5-C4	1.383(3)	C17-C24-C26	122.16(17)	C18-C19-C20	112.63(19)
C2-C3	1.378(3)	N2-C12-C9	133.86(18)	C22-C23-C18	112.0(2)
C28-C29	1.377(3)	N2-C12-C11	110.64(16)	C21-C22-C23	111.4(2)
C32-C33	1.492(3)	C9-C12-C11	115.36(17)	C19-C20-C21	110.1(2)
C4-C3	1.401(3)	C6-C1-C8	106.68(17)	C22-C21-C20	110.4(2)
C31-C30	1.382(3)	C2-C1-C6	119.42(19)		
C29-C30	1.381(4)	C2-C1-C8	133.85(19)		

Crystal structure determination of 5a

Crystal Data for $C_{20}H_{14}MnN_5O_4$ (*M* =443.30 g/mol): monoclinic, space group C2/c (no. 15), *a* = 23.612(6) Å, *b* = 6.3254(14) Å, *c* = 25.263(7) Å, *β* = 97.31(3) °, *V* = 3742.6(17) Å^3, *Z* = 8, *T* = 100.00(10) K, μ(Mo Kα) = 0.745 mm^{-1}, *Dcalc* = 1.573 g/cm^3, 11051 reflections measured (4.448° ≤ 2Θ ≤ 49.992°), 3249 unique (R_{int} = 0.0721, R_{sigma} = 0.0876) which were used in all calculations. The final R_1 was 0.0491 (I > 2σ(I)) and wR_2 was 0.1026 (all data)

Crystal data and structure refinement for **5a.**

Compound	**5a**
CCDC Number	1992409
Empirical formula	$C_{20}H_{14}MnN_5O_4$
Formula weight [g mol^{-1}]	443.3
Temperature [K]	100.00(10)
Crystal system	monoclinic
Space group	C2 / c
Unit cell dimensions [Å]	a = 23.612(6)
	b = 6.3254(14)
	c = 25.263(7)
α [°]	90
β [°]	101.597(8)
γ [°]	90
Volume [Å^3]	3742.6(17)
Z	8
ρ_{calc} [g cm^{-3}]	1.573
μ [mm^{-1}]	0.745
F(000)	1808
Crystal size [mm^3]	0.12 × 0.1 × 0.08
Radiation	MoKα (λ = 0.71073)
Theta range for data collection [°]	4.448 to 49.992
Index ranges	-26 ⩽ h ⩽ 28, -7 ⩽ k ⩽ 7, -29 ⩽ l ⩽ 30
Reflections collected	11051
Independent reflections	3249 [R_{int} = 0.0721, R_{sigma} = 0.0876]
Data / restraints / parameters	3249 / 0 / 273
Goodness-of-fit on F^2	1.09
Final R indexes [I>=2σ (I)]	R_1 = 0.0491 wR_2 = 0.0858
Final R indexes (all data)	R_1 = 0.0769 wR_2 = 0.1026
Largest diff. peak/hole [e. Å^{-3}]	0.35 / -0.34

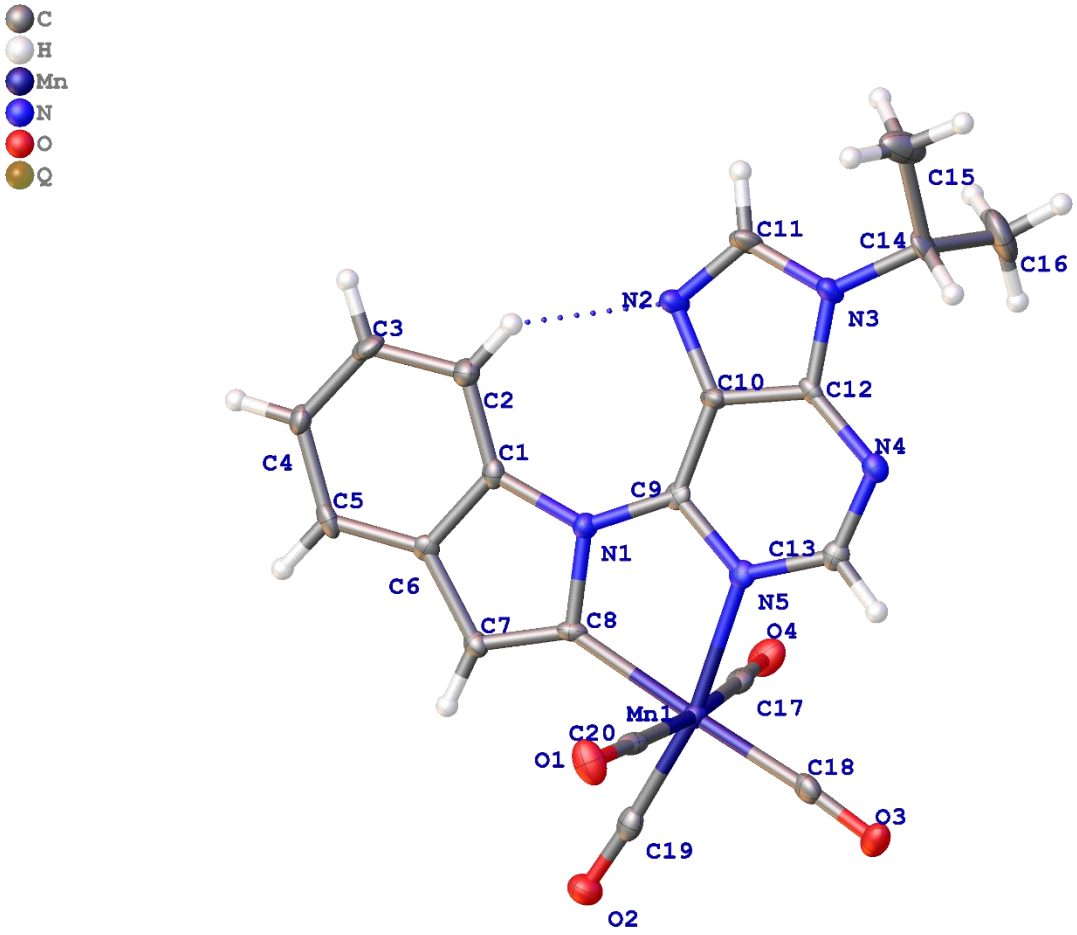


Figure S2. X-ray structure of **5a**. Ellipsoids show 30% probability levels.

Bond lengths [Å] and angles [°] of **5a**

Mn1-N5	2.063(3)	C14-C15	1.520(5)	C1-C2-C3	117.1(3)
Mn1-C8	2.002(3)	C14-C16	1.512(6)	C2-C3-C4	121.7(3)
Mn1-C17	1.848(4)			C5-C4-C3	120.4(3)
Mn1-C18	1.833(4)	C8-Mn1-N5	78.33(13)	C4-C5-C6	119.1(3)
Mn1-C19	1.799(4)	C17-Mn1-N5	86.43(14)	C1-C6-C5	119.4(3)
Mn1-C20	1.858(4)	C17-Mn1-C8	87.51(15)	C1-C6-C7	108.7(3)
O1-C20	1.134(4)	C17-Mn1-C20	172.72(16)	C5-C6-C7	131.9(3)
O2-C19	1.149(4)	C18-Mn1-N5	98.95(14)	C8-C7-C6	109.4(3)
O3-C18	1.150(4)	C18-Mn1-C8	176.67(15)	N1-C8-Mn1	114.1(2)
O4-C17	1.149(4)	C18-Mn1-C17	94.26(16)	C7-C8-Mn1	138.5(3)
N1-C1	1.429(4)	C18-Mn1-C20	92.95(16)	C7-C8-N1	107.4(3)
N1-C8	1.426(4)	C19-Mn1-N5	167.40(14)	N1-C9-N5	113.2(3)
N1-C9	1.367(4)	C19-Mn1-C8	89.44(15)	N1-C9-C10	129.8(3)

N2-C10	1.387(4)	C19-Mn1-C17	90.06(16)	N5-C9-C10	117.0(3)
N2-C11	1.310(4)	C19-Mn1-C18	93.37(16)	N2-C10-C9	134.0(3)
N3-C11	1.367(5)	C19-Mn1-C20	88.54(16)	N2-C10-C12	109.5(3)
N3-C12	1.367(4)	C20-Mn1-N5	93.41(13)	C9-C10-C12	116.5(3)
N3-C14	1.480(4)	C20-Mn1-C8	85.33(15)	N2-C11-N3	114.2(3)
N4-C12	1.346(4)	C8-N1-C1	109.1(3)	N3-C12-C10	106.3(3)
N4-C13	1.311(4)	C9-N1-C1	133.4(3)	N4-C12-N3	126.2(3)
N5-C9	1.370(4)	C9-N1-C8	117.6(3)	N4-C12-C10	127.5(3)
N5-C13	1.359(4)	C11-N2-C10	104.3(3)	N4-C13-N5	127.9(3)
C1-C2	1.384(5)	C11-N3-C12	105.7(3)	N3-C14-C15	109.7(3)
C1-C6	1.397(5)	C11-N3-C14	128.8(3)	N3-C14-C16	109.6(3)
C2-C3	1.395(5)	C12-N3-C14	125.4(3)	C16-C14-C15	112.8(4)
C3-C4	1.395(5)	C13-N4-C12	111.3(3)	O4-C17-Mn1	178.4(3)
C4-C5	1.377(5)	C9-N5-Mn1	116.4(2)	O3-C18-Mn1	175.6(3)
C5-C6	1.403(5)	C13-N5-Mn1	123.7(2)	O2-C19-Mn1	176.5(3)
C6-C7	1.430(5)	C13-N5-C9	119.6(3)	O1-C20-Mn1	175.6(3)
C7-C8	1.348(5)	C2-C1-N1	132.3(3)		
C9-C10	1.392(5)	C2-C1-C6	122.3(3)		
C10-C12	1.401(5)	C6-C1-N1	105.5(3)		

Crystal structure determination of 6b

Crystal Data for $C_{31}H_{29}FN_6O$ (*M* =520.60 g/mol): monoclinic, space group $P2_1/n$ (no. 14), *a* = 13.5375(12) Å, *b* = 12.2153(10) Å, *c* = 16.3297(14) Å, *β* = 102.160(9) °, *V* = 2639.8(4) $Å^3$, *Z* = 4, *T* = 293(2) K, μ(Mo Kα) = 0.087 mm^{-1}, *Dcalc* = 1.310 g/cm^3, 11453 reflections measured (4.198° ≤ 2Θ ≤ 49.996°), 4658 unique (R_{int} = 0.0378, R_{sigma} = 0.0534) which were used in all calculations. The final R_1 was 0.0567 (I > 2σ(I)) and wR_2 was 0.1236 (all data).

Crystal data and structure refinement for **6b.**

Compound	**6b**
CCDC Number	1992408
Empirical formula	$C_{31}H_{29}FN_6O$
Formula weight [g mol^{-1}]	520.6
Temperature [K]	293(2)
Crystal system	monoclinic
Space group	$P2_1$ / n
Unit cell dimensions [Å]	a = 13.5375(12)
	b = 12.2153(10)
	c = 16.3297(14)
α [°]	90
β [°]	102.160(9)
γ [°]	90
Volume [Å^3]	2639.8(4)
Z	4
ρ_{calc} [g cm^{-3}]	1.31
μ [mm^{-1}]	0.087
F(000)	1096
Crystal size [mm^3]	0.14 × 0.12 × 0.11
Radiation	MoKα (λ = 0.71073)
Theta range for data collection [°]	4.198 to 49.996
Index ranges	-14 ⩽ h ⩽ 16, -14 ⩽ k ⩽ 11, -16 ⩽ l ⩽ 19
Reflections collected	11453
Independent reflections	4658 [R_{int} = 0.0378, R_{sigma} = 0.0534]
Data / restraints / parameters	4658 / 0 / 354
Goodness-of-fit on F^2	1.054
Final R indexes [I>=2σ (I)]	R_1 = 0.0567 wR_2 = 0.1075
Final R indexes (all data)	R_1 = 0.0919 wR_2 = 0.1236
Largest diff. peak/hole [e. Å^{-3}]	0.17 / -0.19

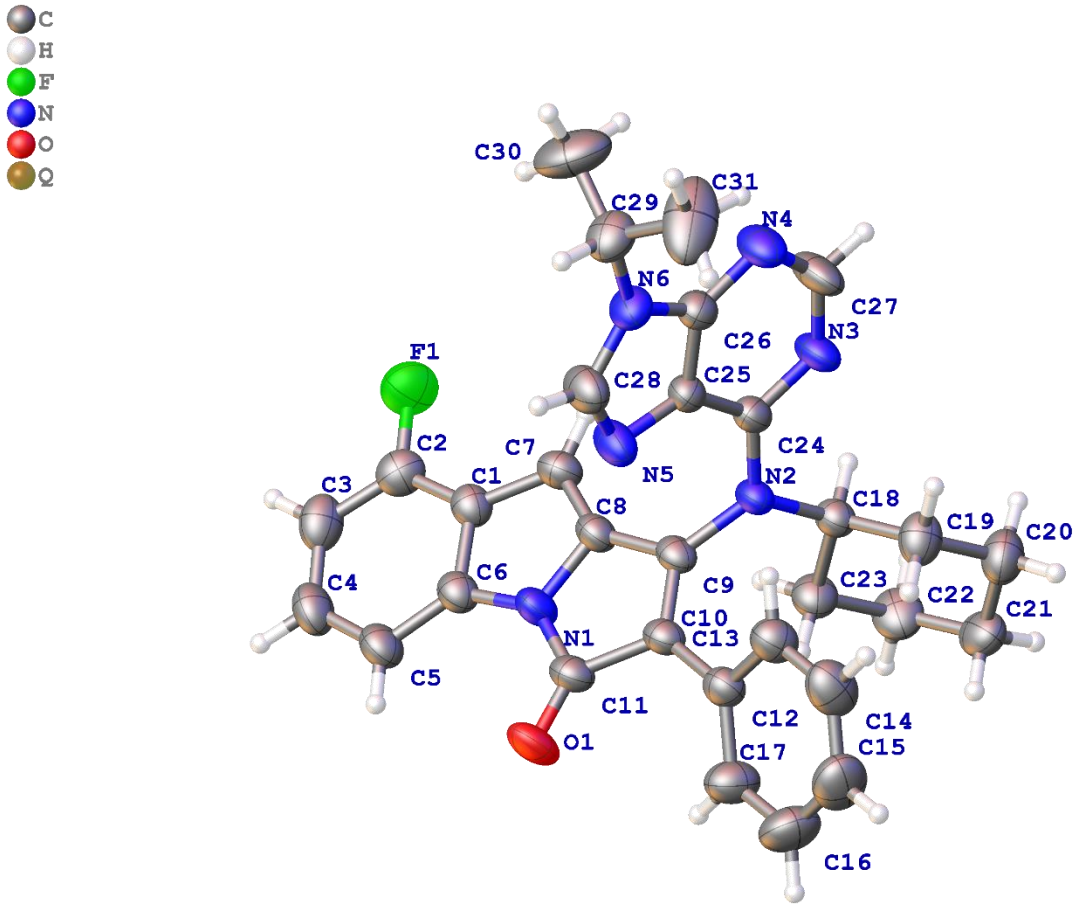


Figure S3. X-ray structure of **6b**. Ellipsoids show 30% probability levels.

Bond lengths [Å] and angles [°] of **6b**

F1-C2	1.358(3)	C20-C21	1.507(4)	C10-C9-C8	109.4(2)
O1-C11	1.208(3)	C21-C22	1.502(4)	C9-C10-C11	107.9(2)
N1-C6	1.399(3)	C22-C23	1.530(3)	C9-C10-C12	130.0(2)
N1-C8	1.388(3)	C24-C25	1.410(3)	C12-C10-C11	122.1(2)
N1-C11	1.395(3)	C25-C26	1.382(3)	O1-C11-N1	125.3(2)
N2-C9	1.416(3)	C29-C30	1.469(4)	O1-C11-C10	129.8(2)
N2-C18	1.502(3)	C29-C31	1.481(4)	N1-C11-C10	104.9(2)
N2-C24	1.372(3)			C13-C12-C10	120.9(2)
N3-C24	1.336(3)	C8-N1-C6	109.7(2)	C13-C12-C17	118.5(3)
N3-C27	1.341(3)	C8-N1-C11	111.4(2)	C17-C12-C10	120.6(2)
N4-C26	1.342(3)	C11-N1-C6	138.9(2)	C14-C13-C12	120.3(3)
N4-C27	1.326(3)	C9-N2-C18	119.74(17)	C15-C14-C13	120.4(3)
N5-C25	1.386(3)	C24-N2-C9	120.02(17)	C16-C15-C14	120.1(3)
N5-C28	1.305(3)	C24-N2-C18	119.39(18)	C15-C16-C17	120.2(3)

N6-C26	1.372(3)	C24-N3-C27	118.0(2)	C16-C17-C12	120.5(3)
N6-C28	1.354(3)	C27-N4-C26	110.7(2)	N2-C18-C19	110.96(18)
N6-C29	1.474(3)	C28-N5-C25	103.2(2)	N2-C18-C23	112.12(19)
C1-C2	1.380(3)	C26-N6-C29	129.7(2)	C19-C18-C23	110.5(2)
C1-C6	1.409(3)	C28-N6-C26	105.08(19)	C18-C19-C20	111.3(2)
C1-C7	1.445(3)	C28-N6-C29	125.2(2)	C21-C20-C19	111.0(2)
C2-C3	1.376(4)	C2-C1-C6	116.6(2)	C22-C21-C20	110.9(2)
C3-C4	1.386(4)	C2-C1-C7	134.9(2)	C21-C22-C23	111.4(2)
C4-C5	1.380(4)	C6-C1-C7	108.5(2)	C18-C23-C22	110.2(2)
C5-C6	1.376(3)	F1-C2-C1	118.6(2)	N2-C24-C25	123.6(2)
C7-C8	1.346(3)	F1-C2-C3	119.7(3)	N3-C24-N2	117.99(19)
C8-C9	1.455(3)	C3-C2-C1	121.6(3)	N3-C24-C25	118.4(2)
C9-C10	1.353(3)	C2-C3-C4	119.2(3)	N5-C25-C24	132.8(2)
C10-C11	1.502(3)	C5-C4-C3	122.2(3)	C26-C25-N5	110.3(2)
C10-C12	1.468(3)	C6-C5-C4	116.5(3)	C26-C25-C24	116.7(2)
C12-C13	1.388(3)	N1-C6-C1	105.3(2)	N4-C26-N6	127.3(2)
C12-C17	1.389(3)	C5-C6-N1	131.0(2)	N4-C26-C25	126.5(2)
C13-C14	1.374(4)	C5-C6-C1	123.7(2)	N6-C26-C25	106.2(2)
C14-C15	1.373(4)	C8-C7-C1	106.7(2)	N4-C27-N3	129.7(2)
C15-C16	1.364(4)	N1-C8-C9	106.4(2)	N5-C28-N6	115.2(2)
C16-C17	1.380(4)	C7-C8-N1	109.8(2)	N6-C29-C31	111.4(2)
C18-C19	1.510(3)	C7-C8-C9	143.8(2)	C30-C29-N6	110.8(2)
C18-C23	1.514(3)	N2-C9-C8	122.1(2)	C30-C29-C31	115.9(3)
C19-C20	1.521(3)	C10-C9-N2	128.3(2)		

Crystal structure determination of 7a

Crystal Data for $C_{24}H_{21}N_5O$ (*M* =395.46 g/mol): triclinic, space group P-1 (no. 2), *a* = 12.7739(5) Å, *b* = 13.0372(6) Å, *c* = 13.9428(5) Å, *α* = 99.281(3) °, *β* = 90.056(3) °, *γ* = 107.625(4) °, *V* = 2180.95(16) Å^3, *Z* = 4, *T* = 100.00(10) K, μ(CuKα) = 0.613 mm^{-1}, *Dcalc* = 1.204 g/cm^3, 15562 reflections measured (6.432° ≤ 2Θ ≤ 147.044 °), 8529 unique (R_{int} = 0.0408, R_{sigma} = 0.0544) which were used in all calculations. The final R_1 was 0.0616 (I > 2σ(I)) and wR_2 was 0.1742 (all data).

Crystal data and structure refinement for **7a.**

Compound	**7a**
CCDC Number	1992404
Empirical formula	$C_{24}H_{21}N_5O$
Formula weight [g mol^{-1}]	395.46
Temperature [K]	100.00(10)
Crystal system	triclinic
Space group	P-1
Unit cell dimensions [Å]	a = 12.7739(5)
	b = 13.0372(6)
	c = 13.9428(5)
α [°]	99.281(3)
β [°]	90.056(3)
γ [°]	107.625(4)
Volume [Å^3]	2180.95(16)
Z	4
ρ_{calc} [g cm^{-3}]	1.204
μ [mm^{-1}]	0.613
F(000)	832
Crystal size [mm^3]	0.14 × 0.12 × 0.11
Radiation	CuKα (λ = 1.54184)
Theta range for data collection [°]	6.432 to 147.044
Index ranges	-10 ⩽ h ⩽ 15, -16 ⩽ k ⩽ 15, -17 ⩽ l ⩽ 17
Reflections collected	15562
Independent reflections	8529 [R_{int} = 0.0408, R_{sigma} = 0.0544]
Data / restraints / parameters	8259 / 0 / 545
Goodness-of-fit on F^2	1.066
Final R indexes [I>=2σ (I)]	R_1 = 0.0616 wR_2 = 0.1657
Final R indexes (all data)	R_1 = 0.0730 wR_2 = 0.1742
Largest diff. peak/hole [e. Å^{-3}]	0.55 / -0.36

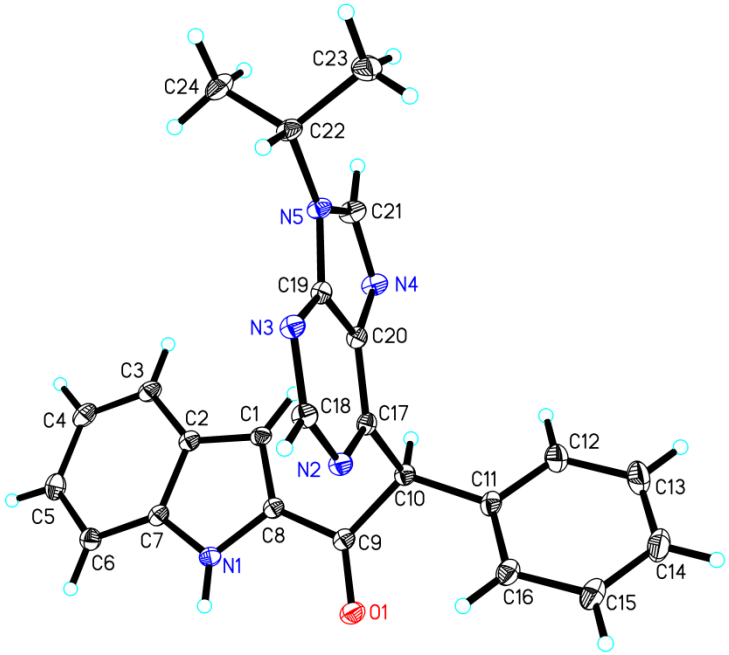


Figure S4. X-ray structure of **7a**. Ellipsoids show 50% probability levels.

Bond lengths [Å] and angles [°] of **7a**

O1B-C9B	1.219(3)	C16B-C15B	1.390(4)	O1B-C9B-C10B	123.1(2)
O1-C9	1.223(3)	C6B-C5B	1.384(4)	C8B-C9B-C10B	115.8(2)
N1B-C8B	1.377(3)	C12B-C13B	1.390(4)	N2B-C17B-C10B	118.7(2)
N1B-C7B	1.367(3)	C4-C5	1.407(4)	N2B-C17B-C20B	118.6(2)
N1-C8	1.384(3)	C16-C15	1.389(4)	C20B-C17B-C10B	122.6(2)
N1-C7	1.370(3)	C13B-C14B	1.386(4)	C8-C1-C2	107.2(2)
N2-C17	1.348(3)	C14B-C15B	1.384(4)	C4B-C3B-C2B	118.8(2)
N2-C18	1.343(3)	C12-C13	1.392(4)	C17B-C10B-C9B	106.91(18)
N3-C19	1.338(3)	C15-C14	1.384(4)	C11B-C10B-C9B	115.46(19)

N3-C18	1.338(3)	C22B-C23B	1.494(4)	C11B-C10B-C17B	111.16(19)
N5-C19	1.376(3)	C22B-C24B	1.524(4)	C1B-C2B-C7B	106.8(2)
N5-C22	1.472(3)	C14-C13	1.378(5)	C3B-C2B-C1B	134.3(2)
N5-C21	1.376(3)			C3B-C2B-C7B	118.8(2)
N2B-C17B	1.343(3)	C7B-N1B-C8B	109.01(19)	C17-C10-C9	107.60(18)
N2B-C18B	1.345(3)	C7-N1-C8	108.64(19)	C17-C10-C11	109.64(18)
N4-C20	1.389(3)	C18-N2-C17	118.73(19)	C11-C10-C9	117.33(19)
N4-C21	1.315(3)	C18-N3-C19	111.28(19)	N3-C18-N2	128.4(2)
N3B-C19B	1.337(3)	C19-N5-C22	127.71(18)	C16B-C11B-C10B	119.2(2)
N3B-C18B	1.338(3)	C19-N5-C21	104.82(18)	C16B-C11B-C12B	118.7(2)
N4B-C19B	1.372(3)	C21-N5-C22	127.44(19)	C12B-C11B-C10B	122.0(2)
N4B-C21B	1.379(3)	C17B-N2B-C18B	118.7(2)	N5B-C20B-C19B	110.2(2)
N4B-C22B	1.485(3)	C21-N4-C20	103.26(19)	C17B-C20B-N5B	132.8(2)
N5B-C20B	1.388(3)	C19B-N3B-C18B	111.3(2)	C17B-C20B-C19B	116.9(2)
N5B-C21B	1.318(3)	C19B-N4B-C21B	105.31(19)	N3B-C19B-N4B	127.6(2)
C20-C19	1.396(3)	C19B-N4B-C22B	125.5(2)	N3B-C19B-C20B	126.1(2)
C20-C17	1.388(3)	C21B-N4B-C22B	128.9(2)	N4B-C19B-C20B	106.3(2)
C17-C10	1.515(3)	C21B-N5B-C20B	103.75(19)	C16-C11-C10	123.0(2)
C2-C7	1.418(3)	N4-C20-C19	110.54(19)	C16-C11-C12	118.5(2)
C2-C1	1.412(3)	C17-C20-N4	132.3(2)	C12-C11-C10	118.3(2)
C2-C3	1.416(3)	C17-C20-C19	117.2(2)	N5-C22-C24	109.91(19)
C1B-C8B	1.381(3)	N3-C19-N5	127.5(2)	N5-C22-C23	110.1(2)
C1B-C2B	1.419(3)	N3-C19-C20	126.2(2)	C23-C22-C24	112.2(2)
C8B-C9B	1.470(3)	N5-C19-C20	106.35(18)	N4-C21-N5	115.0(2)
C8-C9	1.469(3)	N2-C17-C20	118.2(2)	C3B-C4B-C5B	121.7(2)
C8-C1	1.379(3)	N2-C17-C10	118.44(19)	C5-C6-C7	116.8(2)
C7B-C2B	1.421(3)	C20-C17-C10	123.30(19)	C4-C3-C2	118.6(2)
C7B-C6B	1.400(3)	C1-C2-C7	107.1(2)	C11B-C16B-C15B	120.9(2)
C9-C10	1.529(3)	C1-C2-C3	133.9(2)	C5B-C6B-C7B	117.4(2)
C7-C6	1.397(3)	C3-C2-C7	119.0(2)	C13B-C12B-C11B	120.2(2)
C9B-C10B	1.532(3)	C8B-C1B-C2B	107.0(2)	N3B-C18B-N2B	128.3(2)
C17B-C10B	1.524(3)	N1B-C8B-C1B	109.4(2)	C3-C4-C5	121.5(2)
C17B-C20B	1.384(3)	N1B-C8B-C9B	119.5(2)	C15-C16-C11	120.7(3)
C3B-C2B	1.413(3)	C1B-C8B-C9B	131.1(2)	C14B-C13B-C12B	120.6(2)
C3B-C4B	1.371(4)	N1-C8-C9	120.0(2)	C6B-C5B-C4B	121.2(2)
C10B-C11B	1.520(3)	C1-C8-N1	109.2(2)	N5B-C21B-N4B	114.5(2)
C10-C11	1.518(3)	C1-C8-C9	130.7(2)	C15B-C14B-C13B	119.4(2)
C11B-C16B	1.388(3)	N1B-C7B-C2B	107.8(2)	C6-C5-C4	121.8(2)

C11B-C12B	1.397(3)	N1B-C7B-C6B	130.0(2)	C13-C12-C11	120.5(3)
C20B-C19B	1.404(3)	C6B-C7B-C2B	122.1(2)	C14-C15-C16	120.4(3)
C11-C16	1.392(4)	O1-C9-C8	121.3(2)	N4B-C22B-C23B	109.0(2)
C11-C12	1.394(3)	O1-C9-C10	123.9(2)	N4B-C22B-C24B	110.8(2)
C22-C24	1.528(4)	C8-C9-C10	114.75(19)	C23B-C22B-C24B	111.8(2)
C22-C23	1.517(3)	N1-C7-C2	107.8(2)	C14B-C15B-C16B	120.2(2)
C4B-C5B	1.411(4)	N1-C7-C6	129.7(2)	C13-C14-C15	119.5(3)
C6-C5	1.389(3)	C6-C7-C2	122.4(2)	C14-C13-C12	120.5(3)
C3-C4	1.369(4)	O1B-C9B-C8B	121.1(2)		

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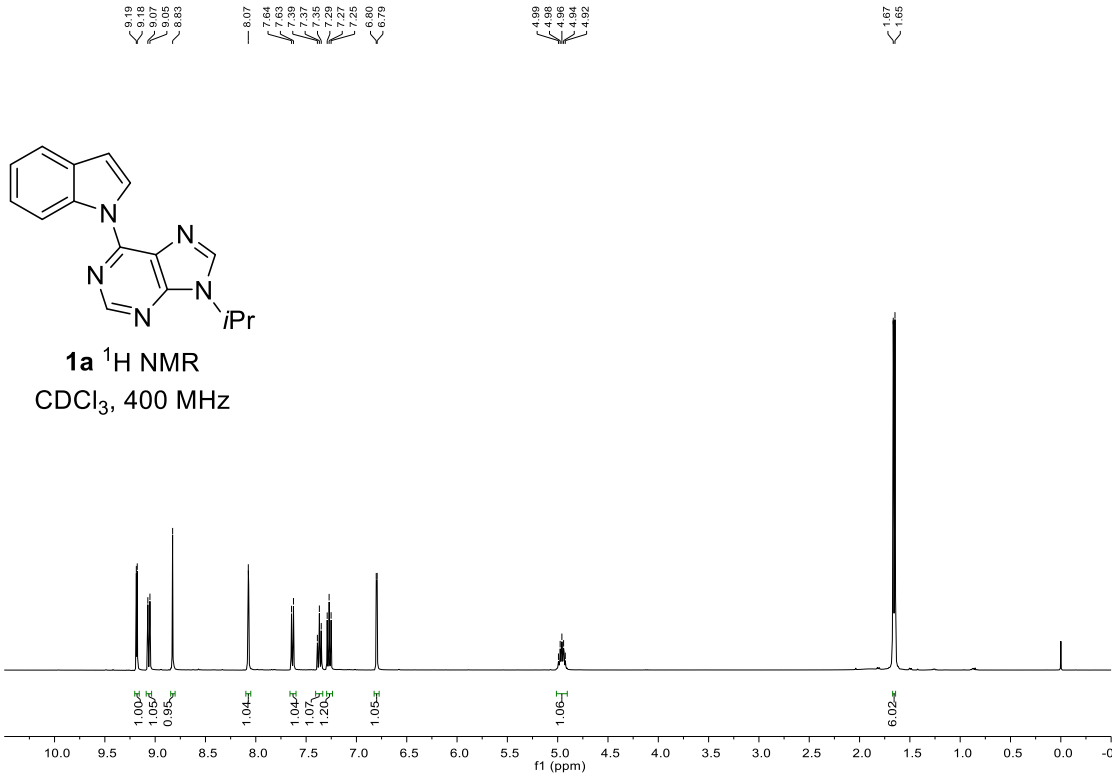
^{1}H, ^{13}C and ^{19}F NMR Spectra



1a ^{1}H NMR
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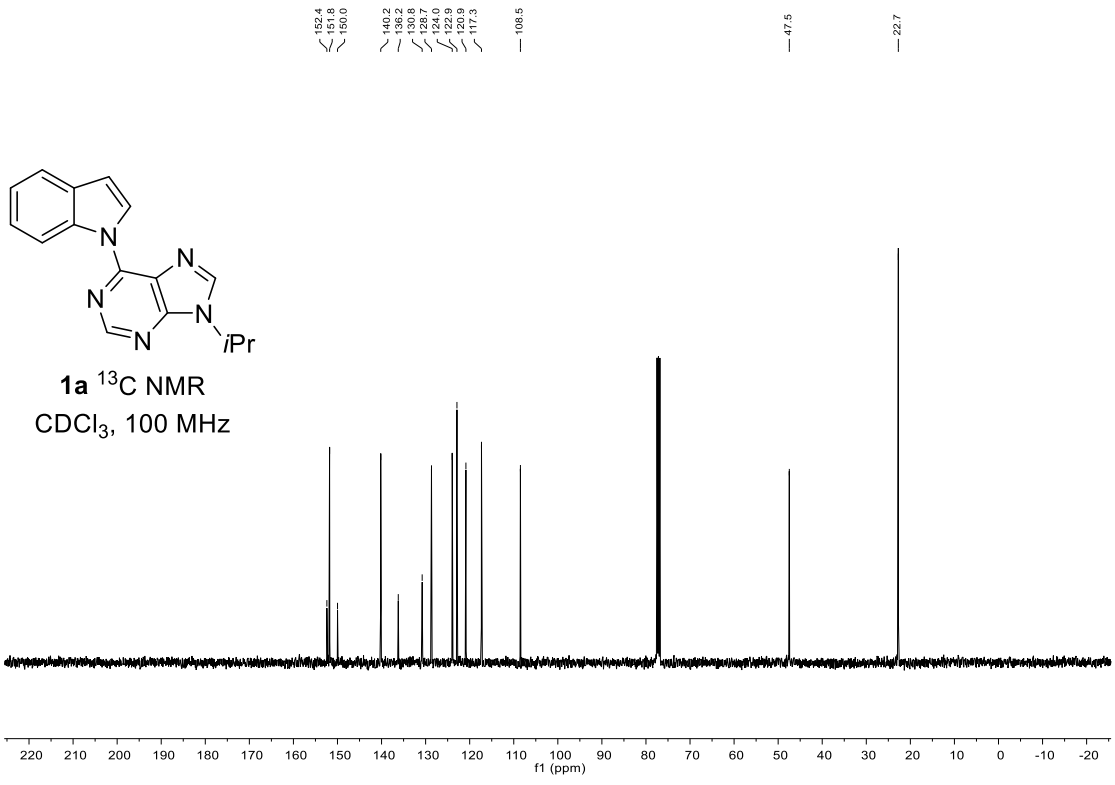

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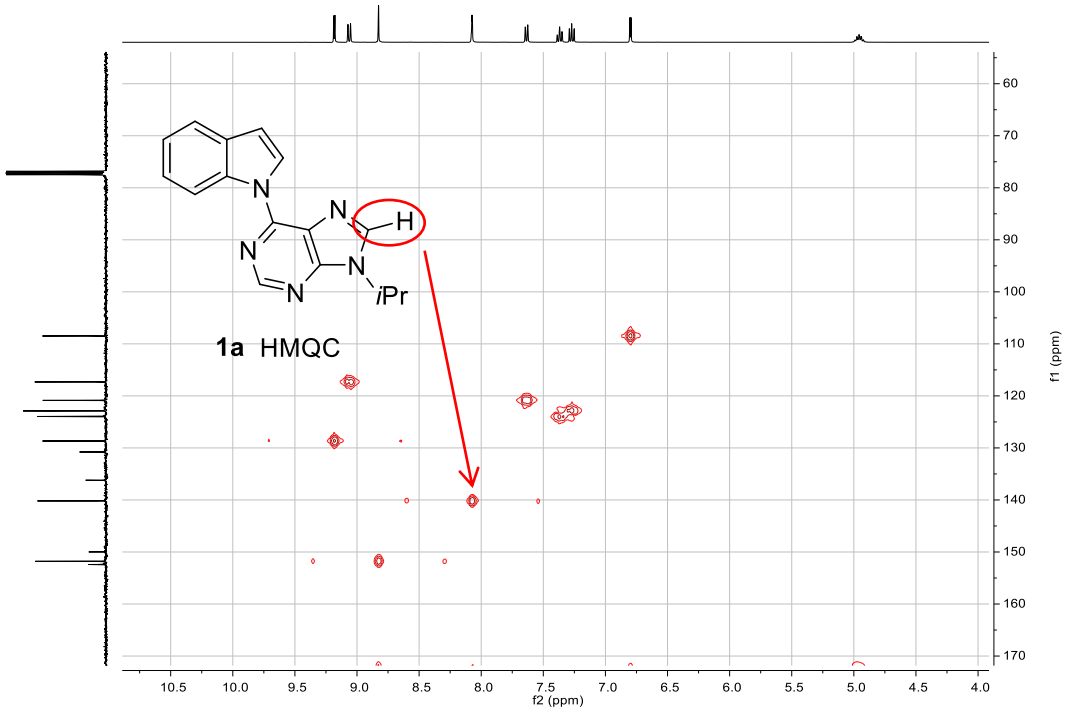
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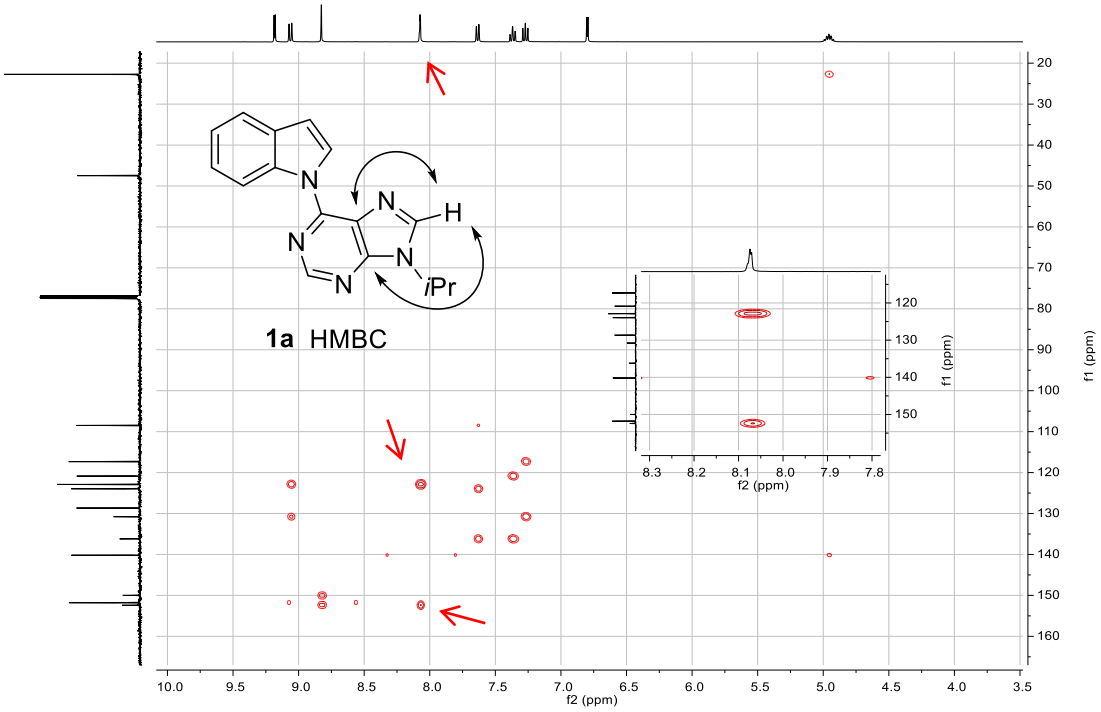
f1 (ppm)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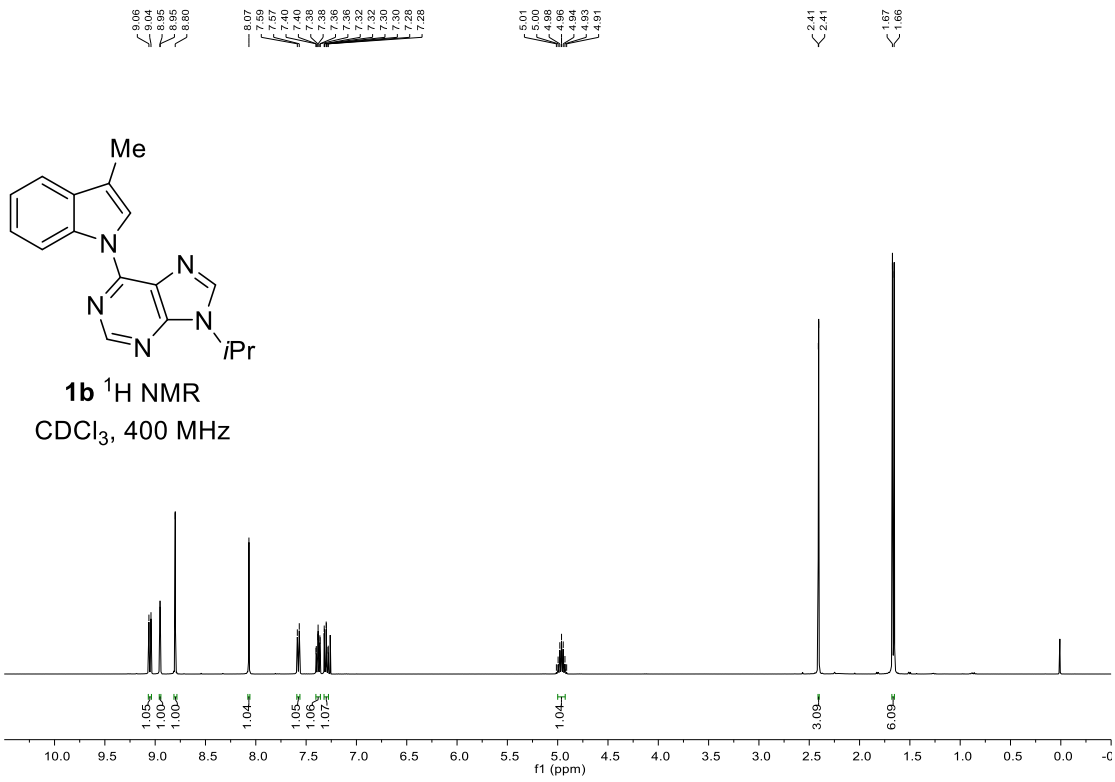
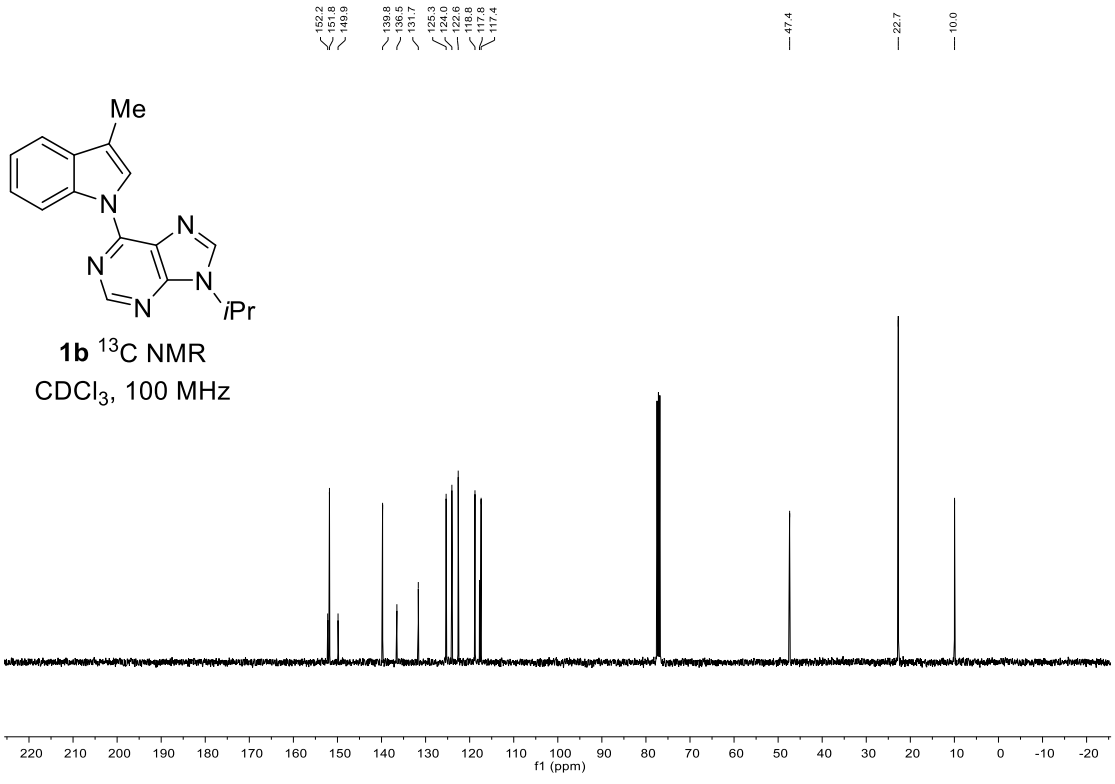
f1 (ppm)



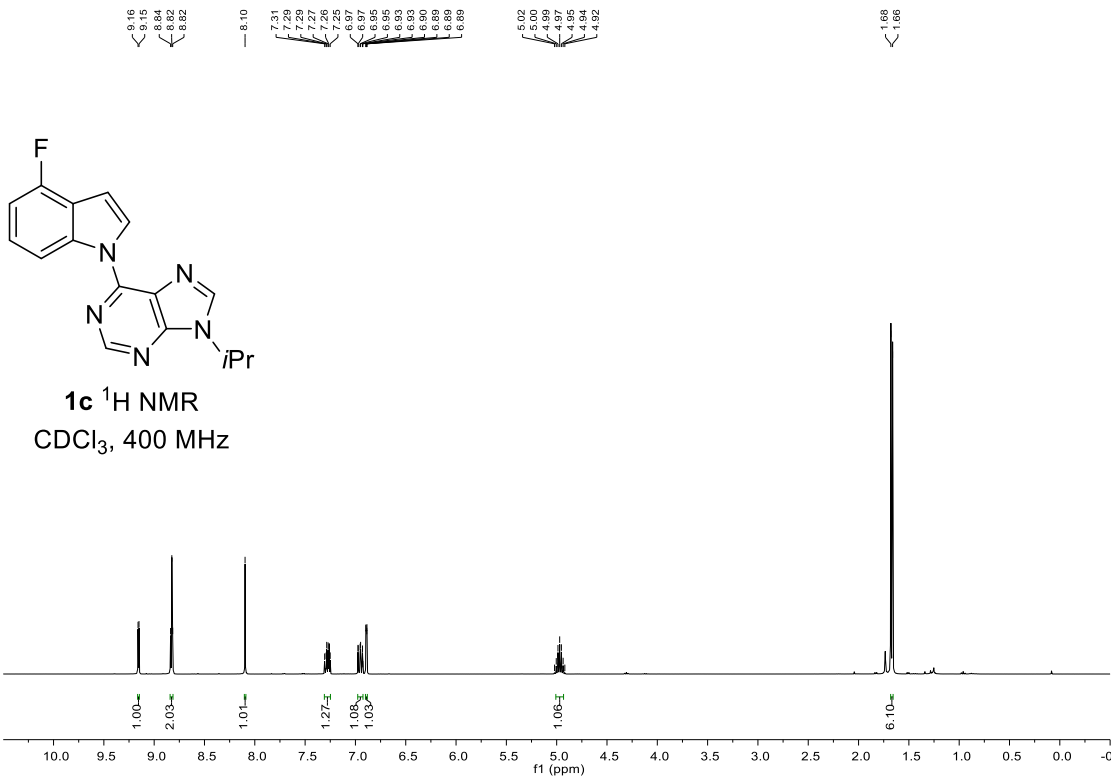
1b ^{1}H NMR

$CDCl_3$, 400 MHz



1b ^{13}C NMR

$CDCl_3$, 100 MHz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7.29
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7.27
7.26
7.25
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6.97
6.95
6.95
6.93
6.93
6.90
6.89
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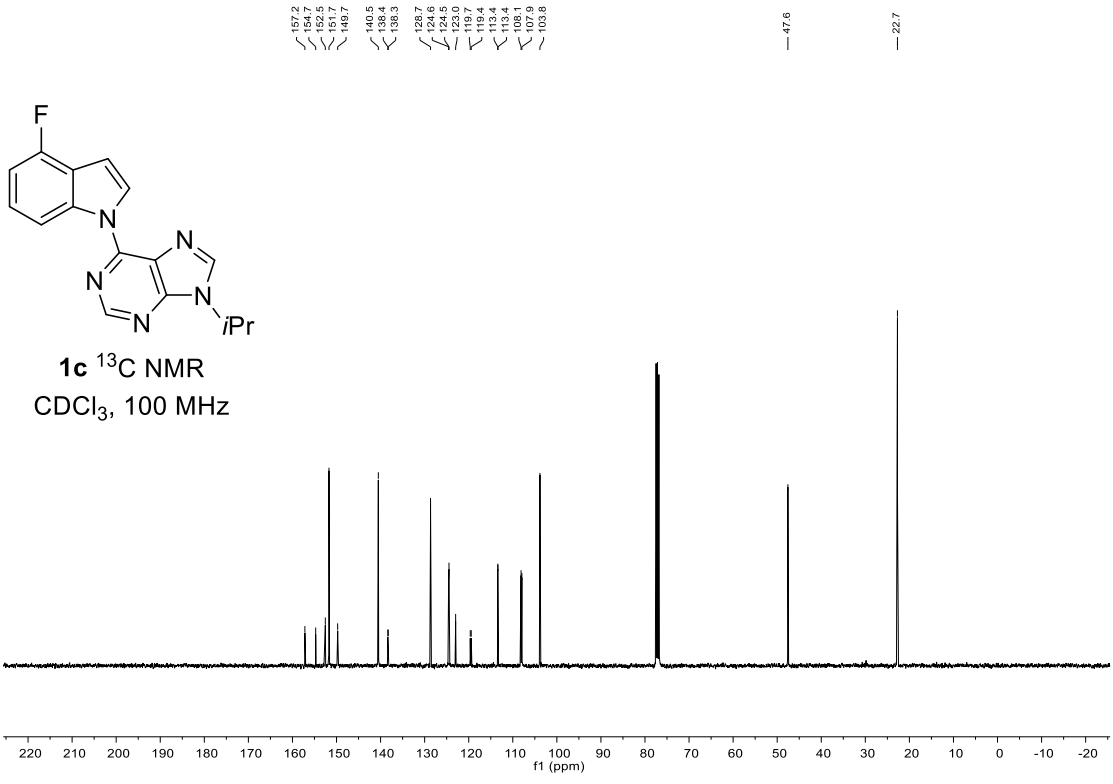
6.89
6.89
5.02
5.00
4.99
4.97
4.95
4.94
4.92
1.68
1.66
F
N
N
N
N
N
iPr
1c 1H NMR
CDCl3, 400 MHz
1.00
2.03
1.01
1.27
1.08
1.03
1.06
6.10
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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124.5
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119.7
119.4
113.4
113.4
108.1
107.9
103.8
47.6
22.7
F
N
N
N
N
N
iPr
1c 13C NMR
CDCl3, 100 MHz
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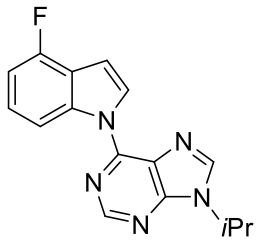
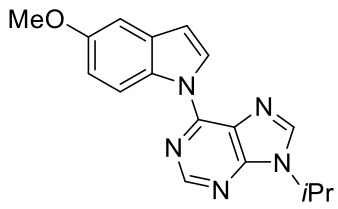
f1 (ppm)



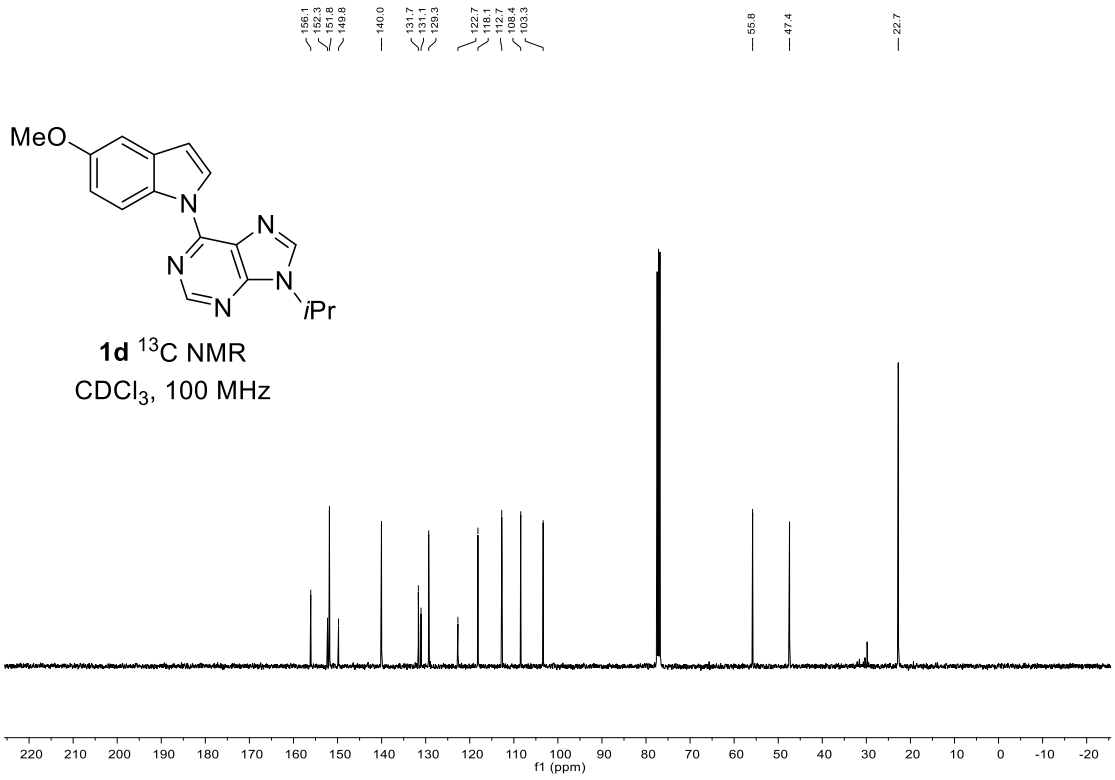
1c ^{19}F NMR

$CDCl_3$, 376 MHz

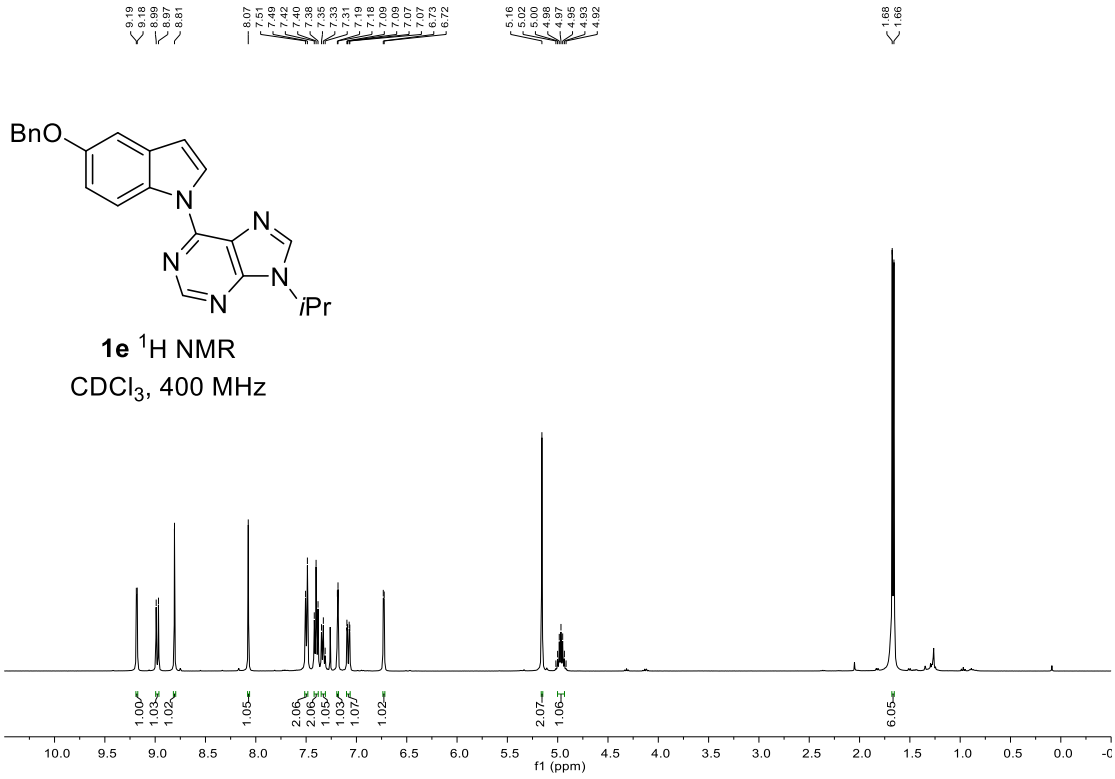


1d ^{1}H NMR

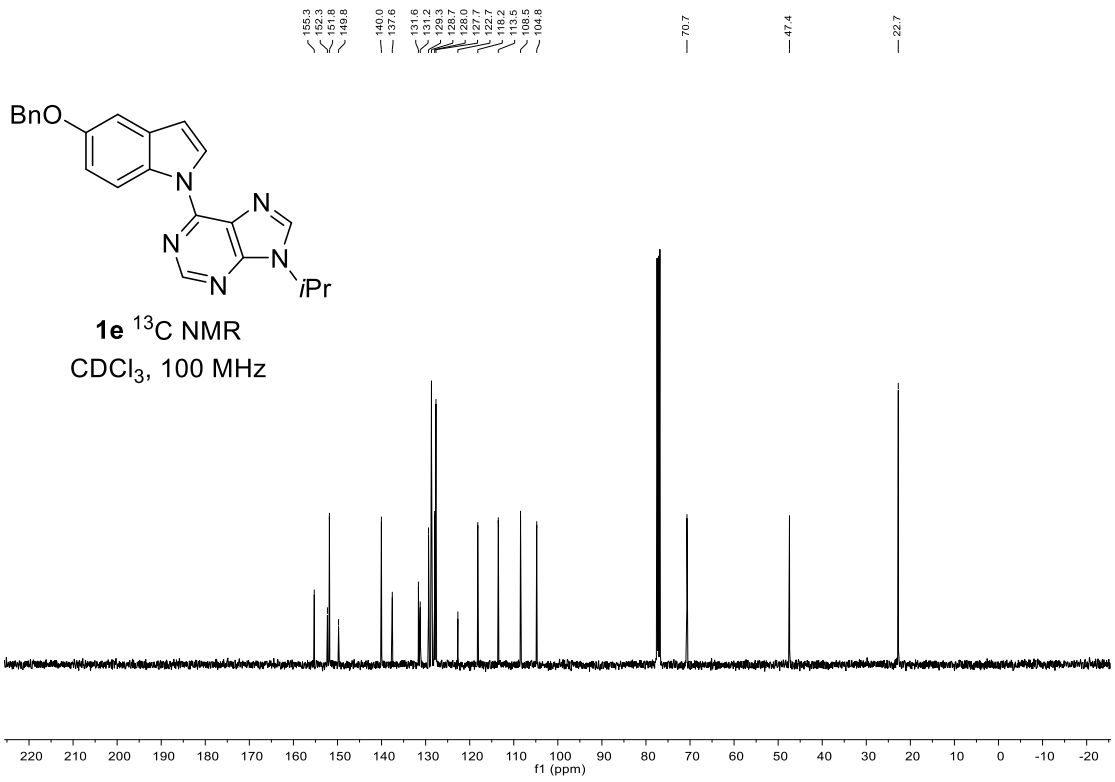
$CDCl_3$, 400 MHz



1d ^{13}C NMR
$CDCl_3$, 100 MHz



1e ^{1}H NMR
$CDCl_3$, 400 MHz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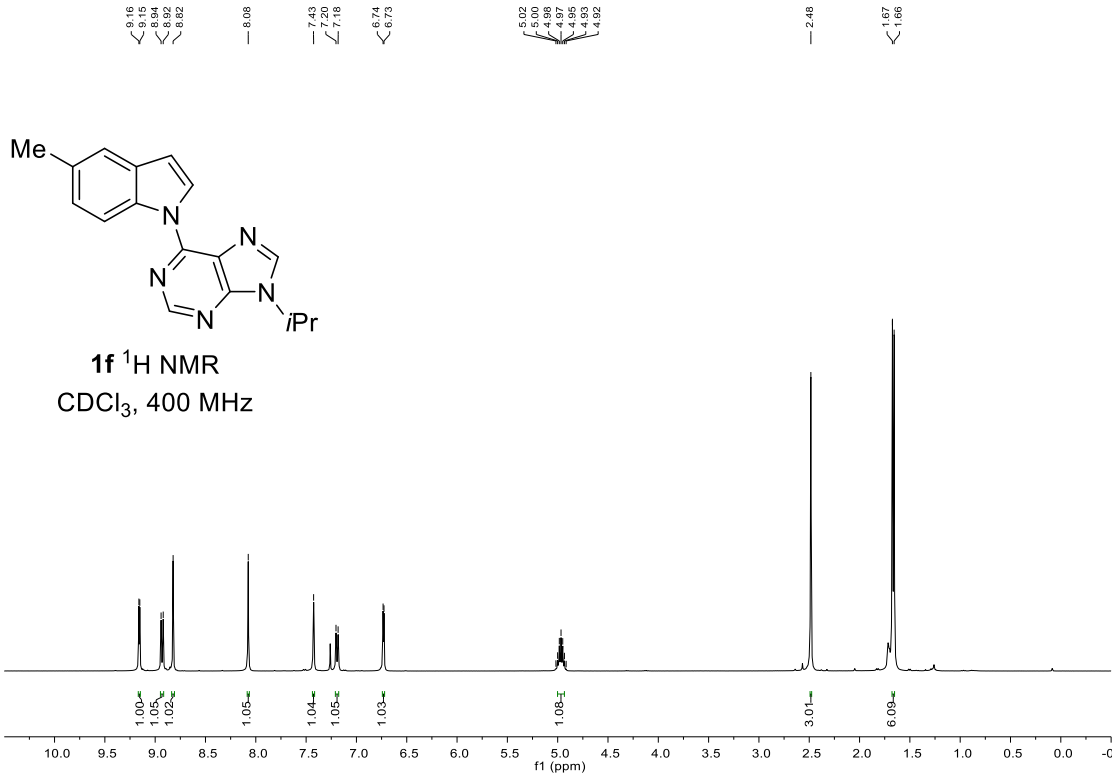
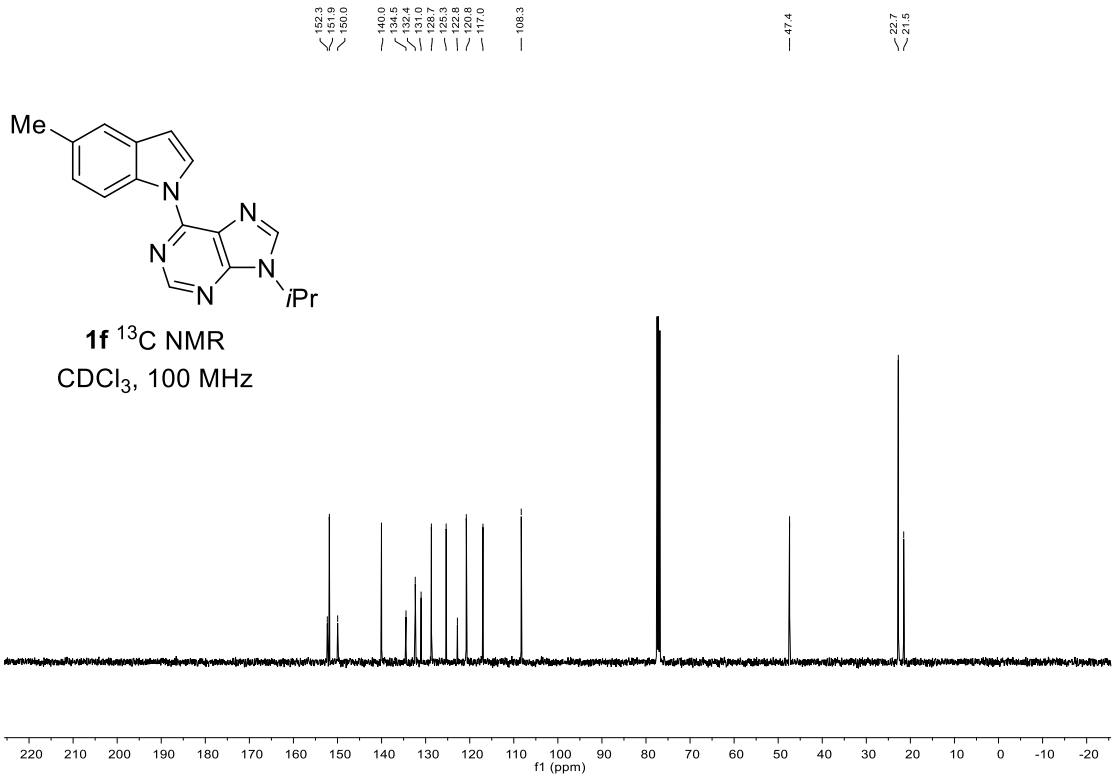
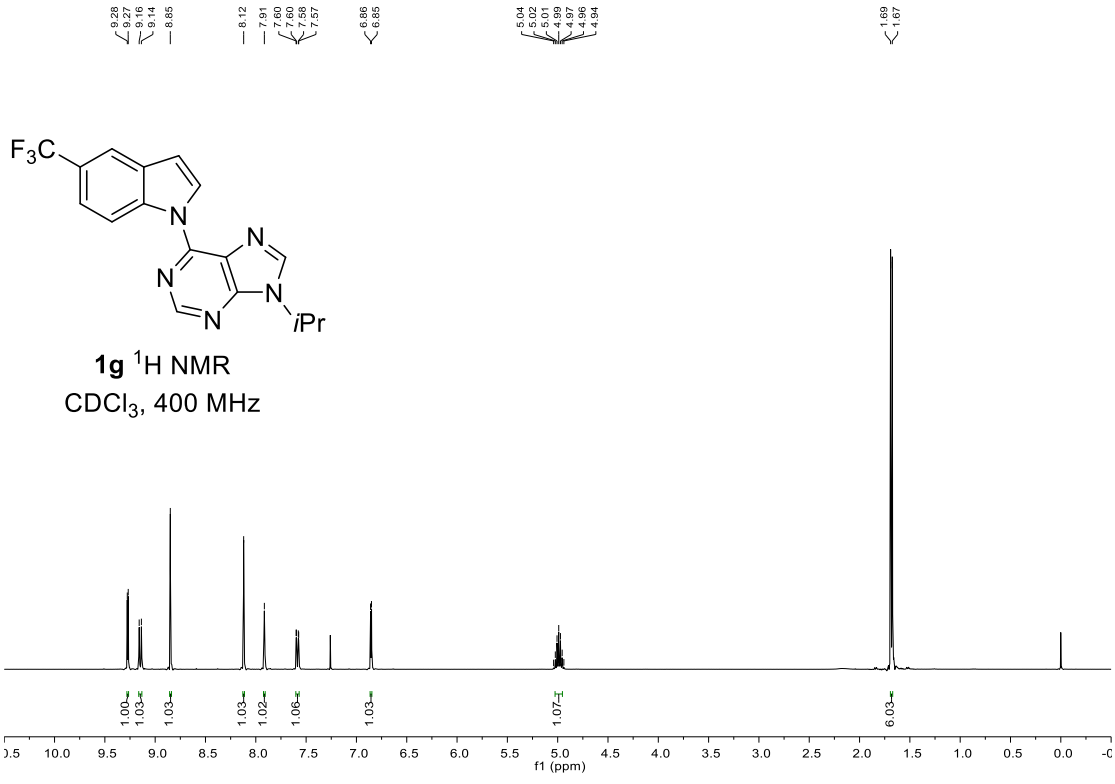
131.2
129.3
128.7
128.0
127.7
122.7
118.2
113.5
108.5
104.8
70.7
47.4
22.7
BnO
N
N
N
N
N
iPr
1e 13C NMR
CDCl3, 100 MHz
f1 (ppm)


9.16
8.15
8.94
8.92
8.82
8.08
7.43
7.20
7.18
6.74
6.73
5.02
5.00
4.98
4.97
4.95
4.93
4.92
2.48
1.67
1.66
Me
N
N
N
N
N
iPr
1f 1H NMR
CDCl3, 400 MHz
1.00
1.05
1.02
1.05
1.04
1.05
1.03
1.08
3.01
6.09
f1 (ppm)



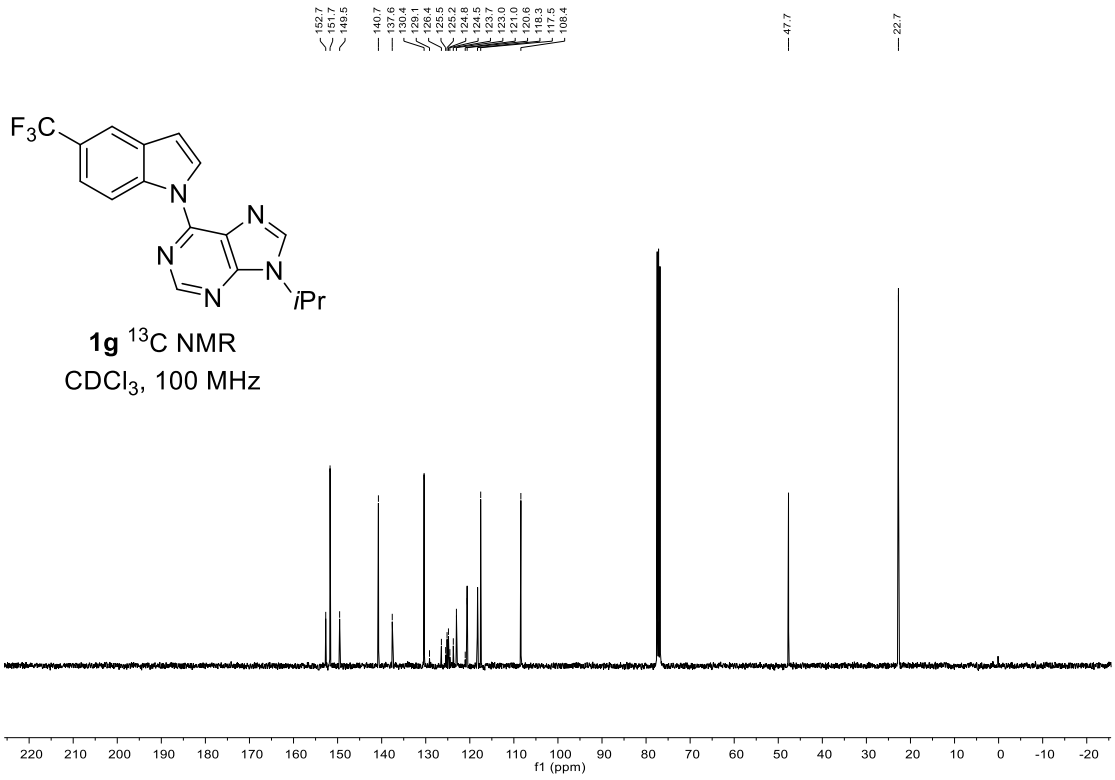
1f ^{13}C NMR

$CDCl_3$, 100 MHz



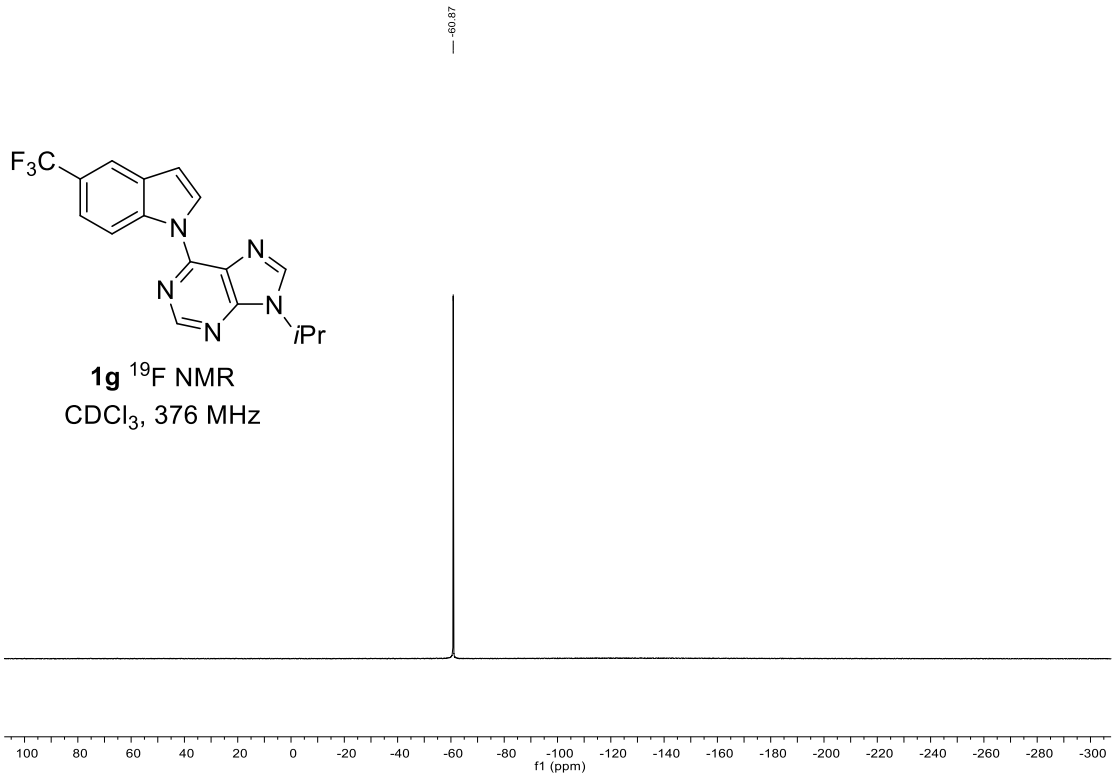
1g ^{1}H NMR

$CDCl_3$, 400 MHz



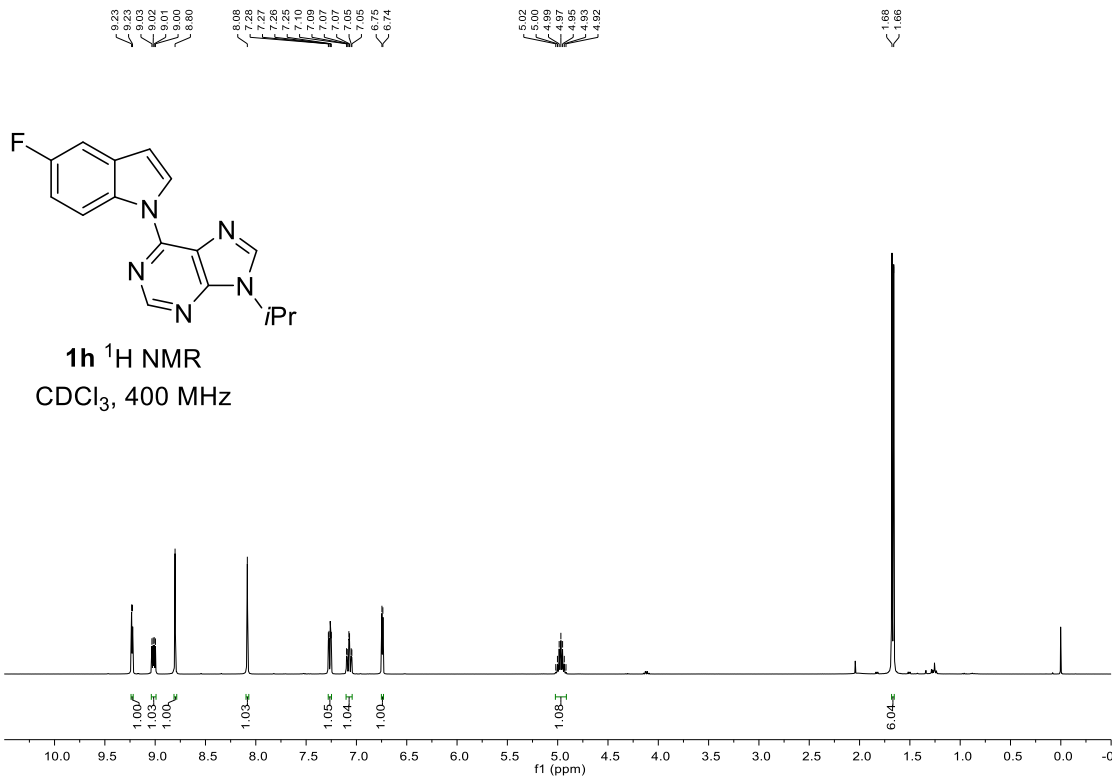
1g ^{13}C NMR

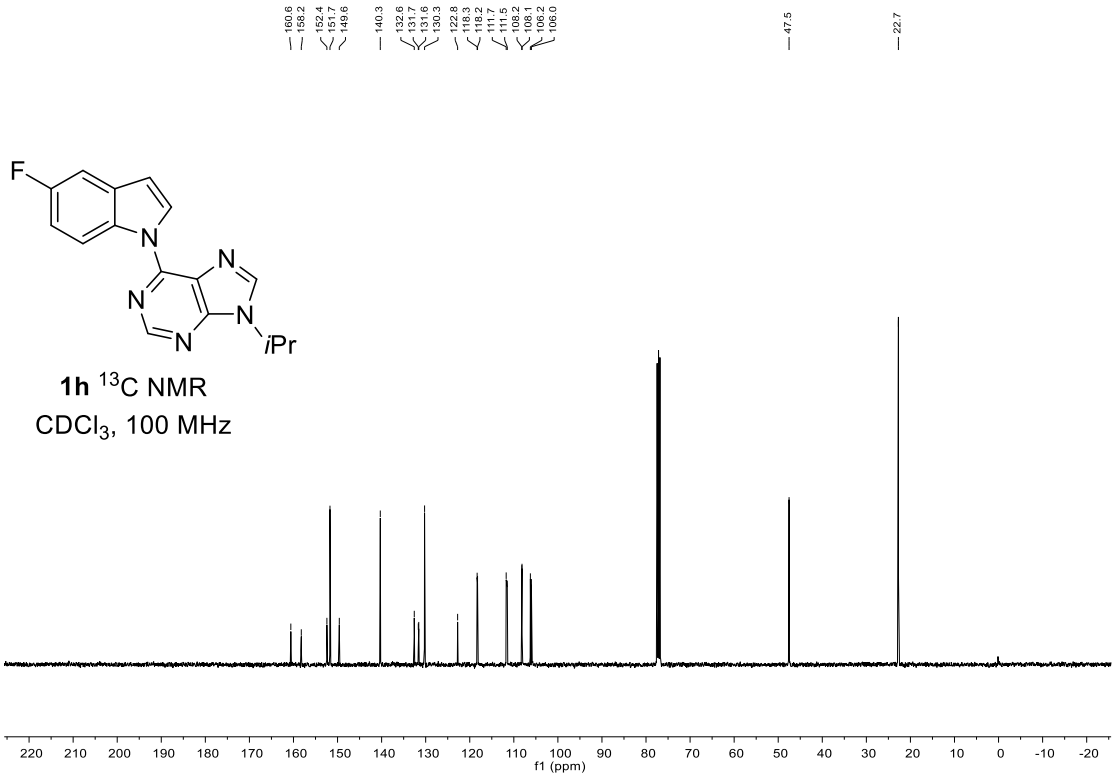
$CDCl_3$, 100 MHz

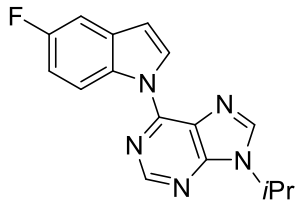


1g ^{19}F NMR

$CDCl_3$, 376 MHz

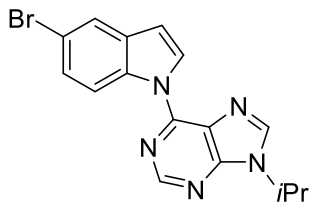

F
N
N
N
N
N
iPr
1h 1H NMR
CDCl3, 400 MHz
f1 (ppm)


F
N
N
N
N
N
iPr
1h 13C NMR
CDCl3, 100 MHz
f1 (ppm)



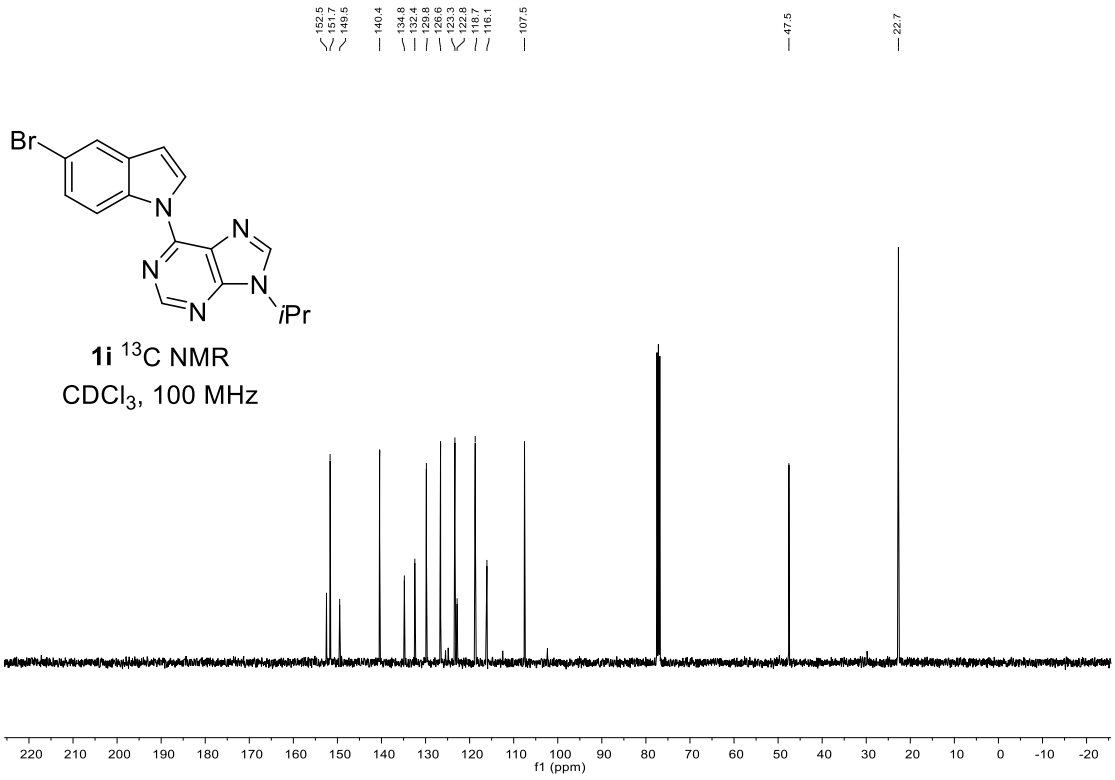
1h ^{19}F NMR

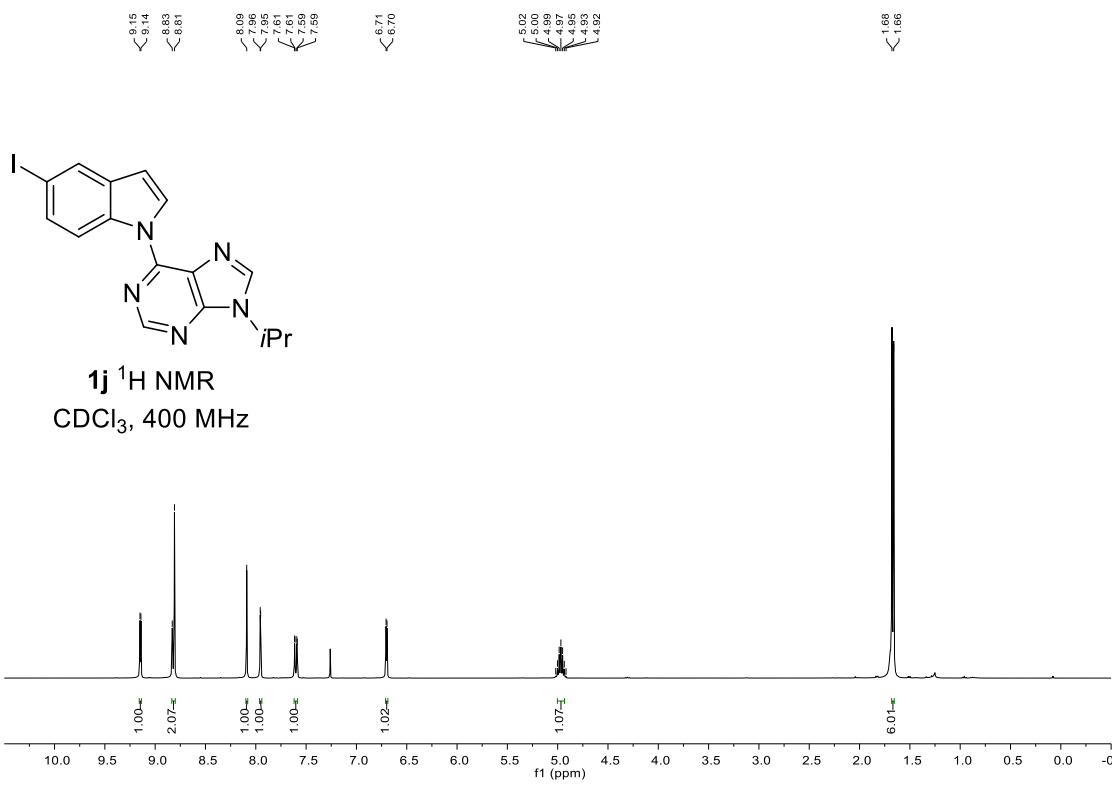
$CDCl_3$, 376 MHz

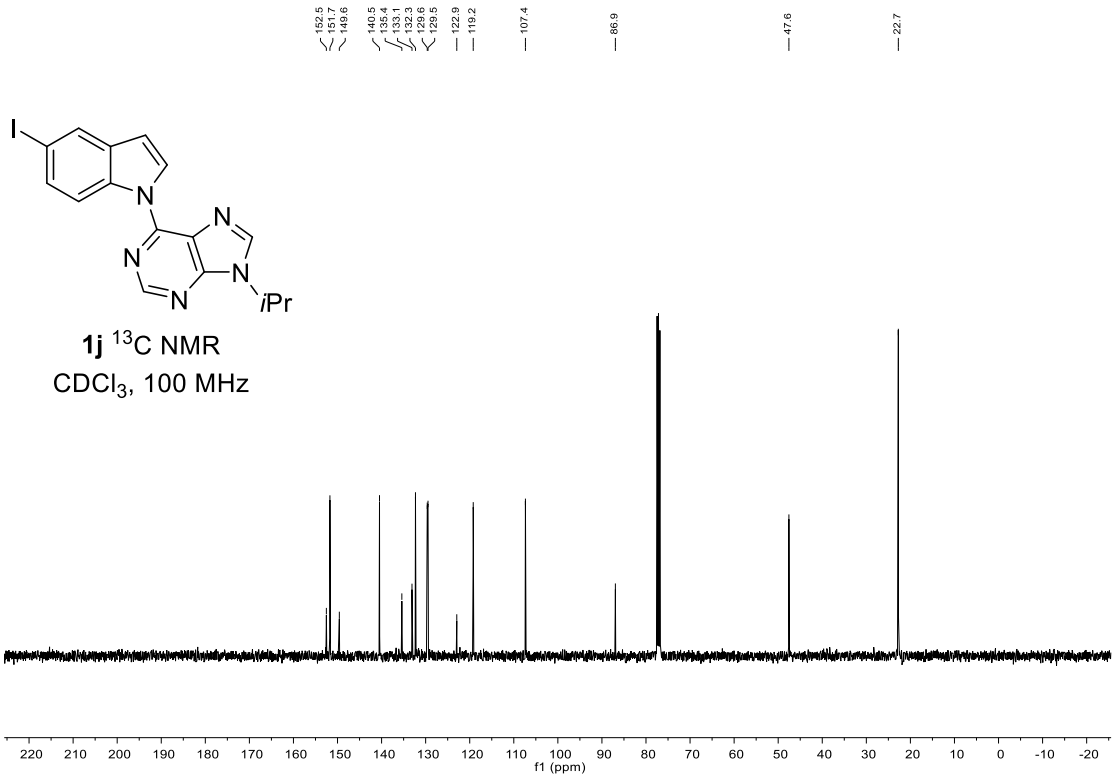


1i ^{1}H NMR

$CDCl_3$, 400 MHz

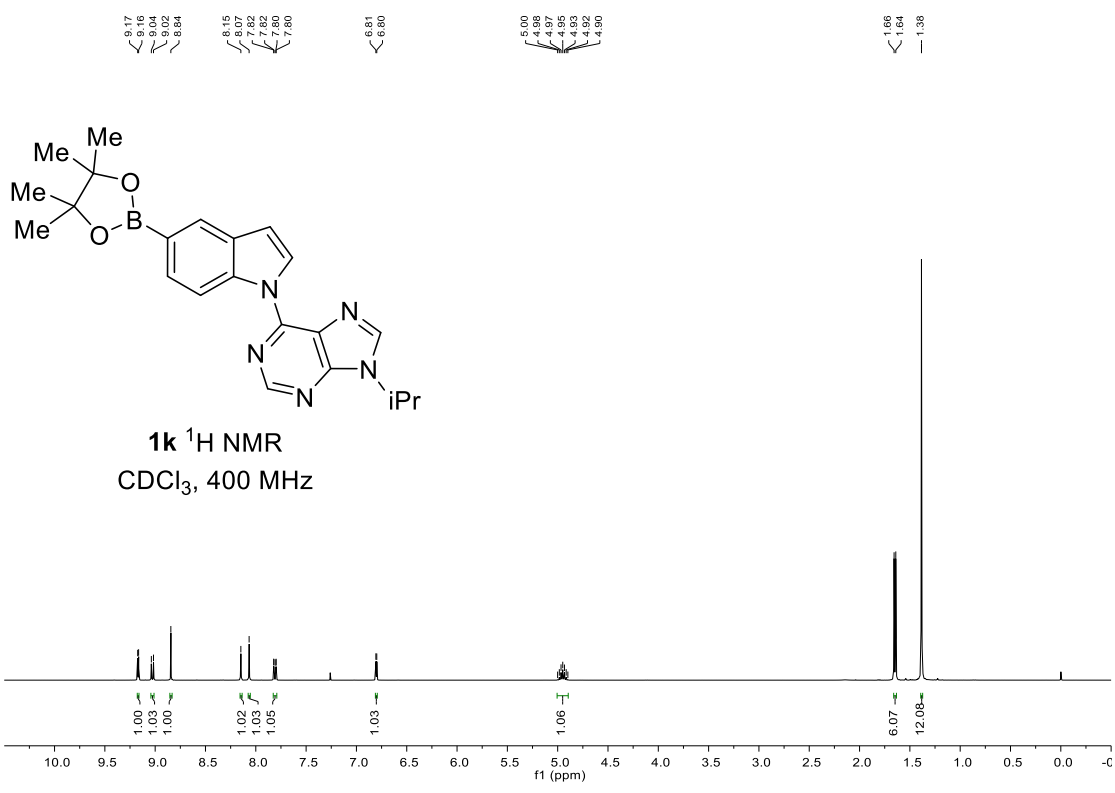

152.5
151.7
149.5
140.4
134.8
132.4
129.8
126.6
123.3
122.8
118.7
116.1
107.5
47.5
22.7
Br
N
N
N
N
N
N
iPr
1i 13C NMR
CDCl3, 100 MHz
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)


9.15
9.14
8.83
8.81
8.09
7.96
7.95
7.61
7.61
7.59
7.59
6.71
6.70
5.02
5.00
4.99
4.97
4.95
4.93
4.92
1.68
1.66
I
N
N
N
N
N
N
iPr
1j 1H NMR
CDCl3, 400 MHz
1.00
2.07
1.00
1.00
1.00
1.02
1.07
6.01
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)



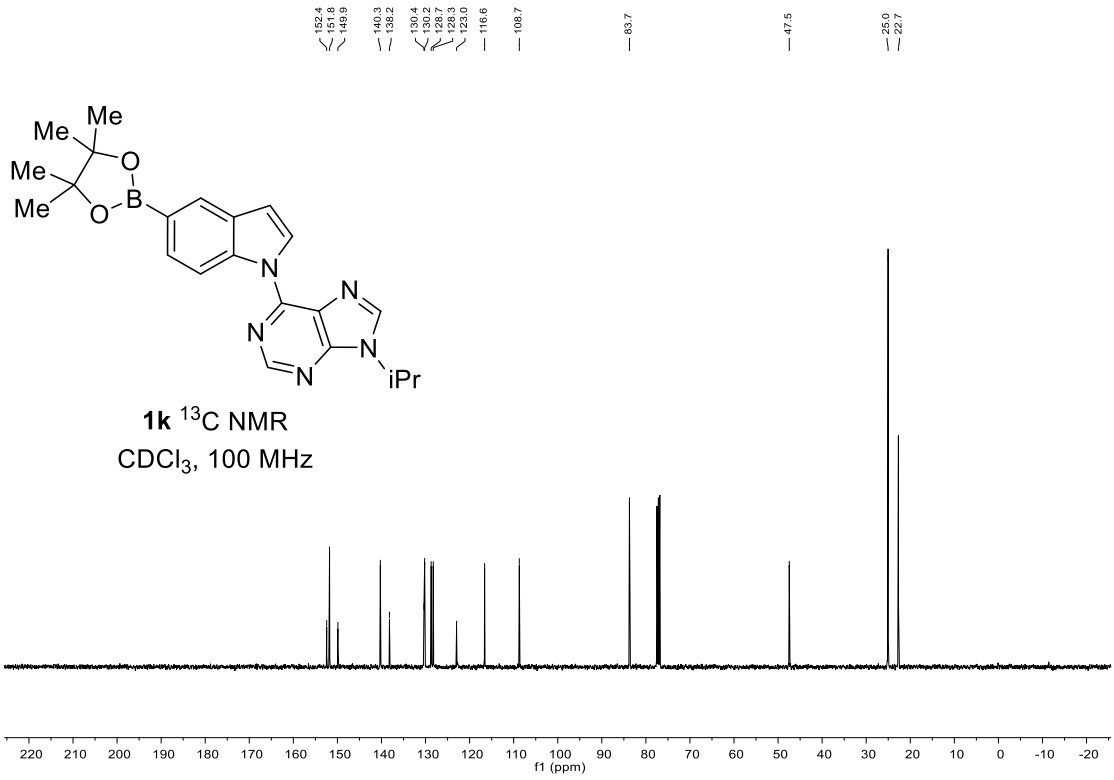
1j ^{13}C NMR

$CDCl_3$, 100 MHz



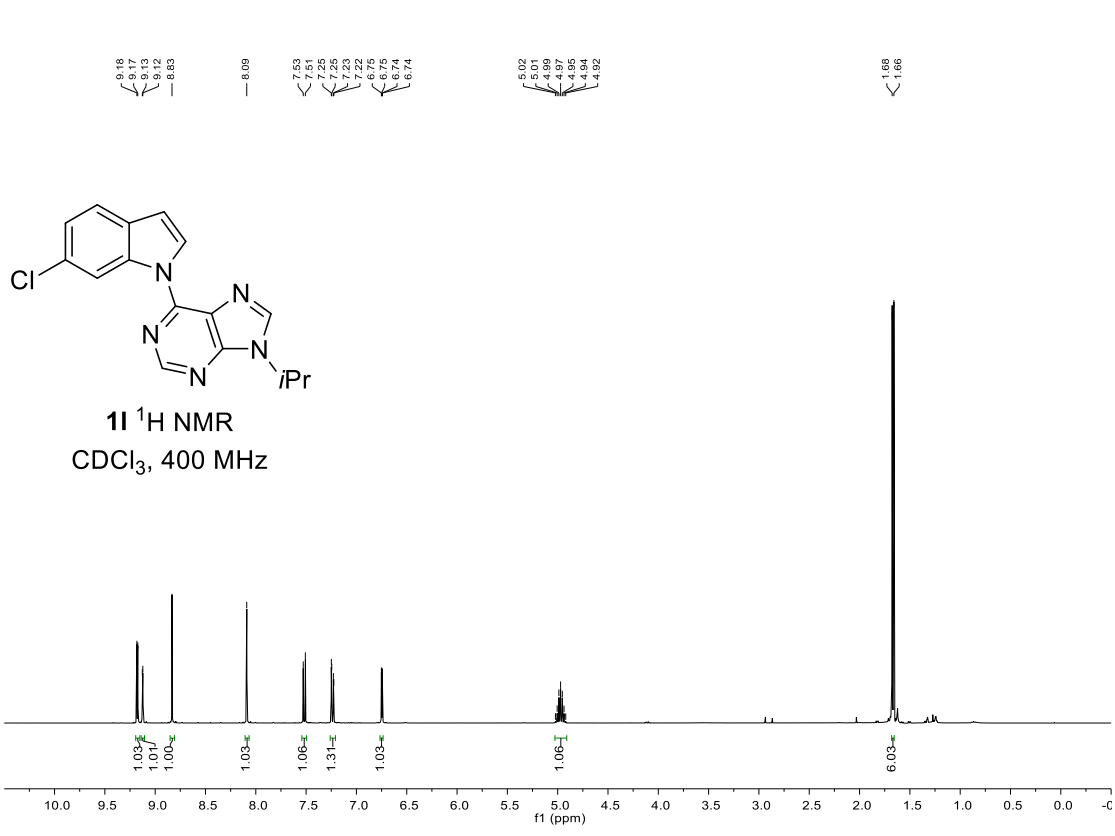
1k ^{1}H NMR

$CDCl_3$, 400 MHz



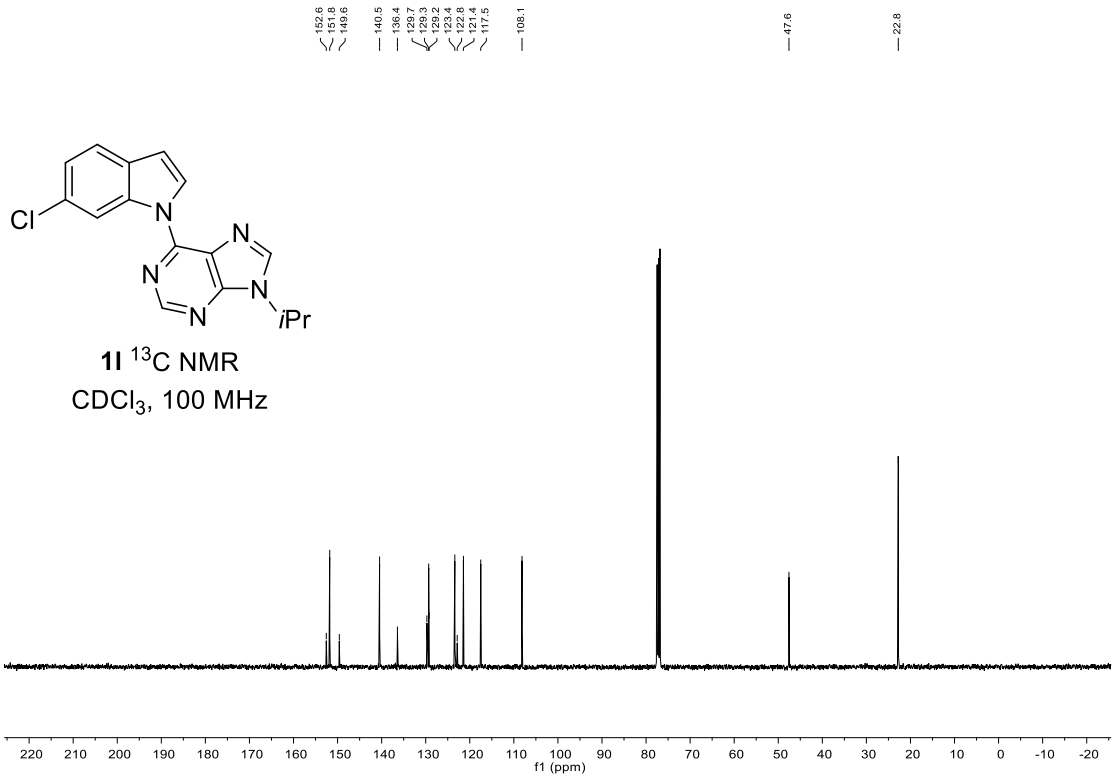
1k ^{13}C NMR

$CDCl_3$, 100 MHz



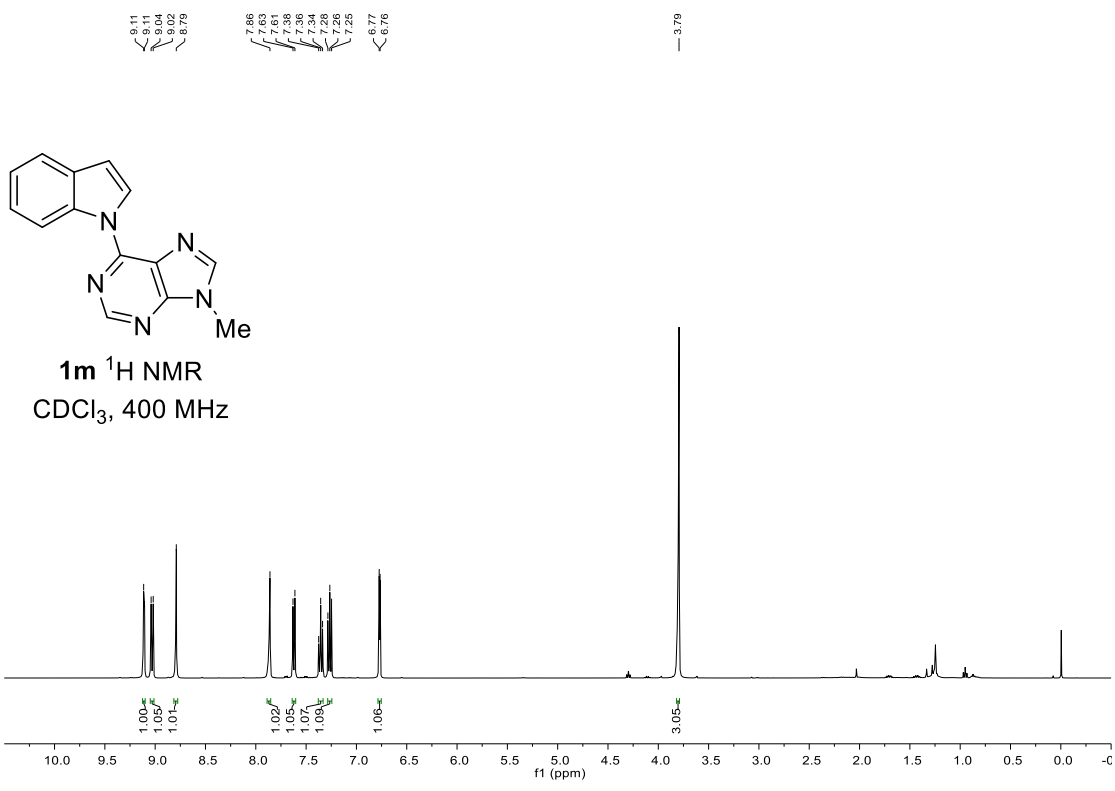
1l ^{1}H NMR

$CDCl_3$, 400 MHz



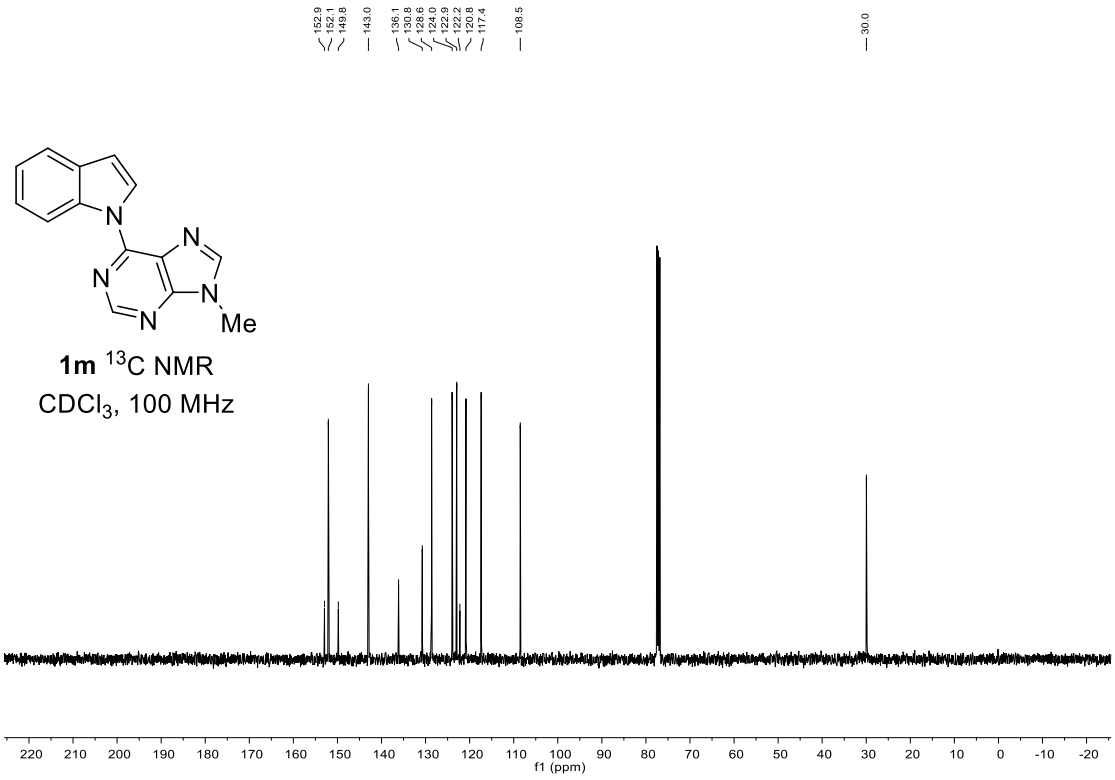
1l ^{13}C NMR

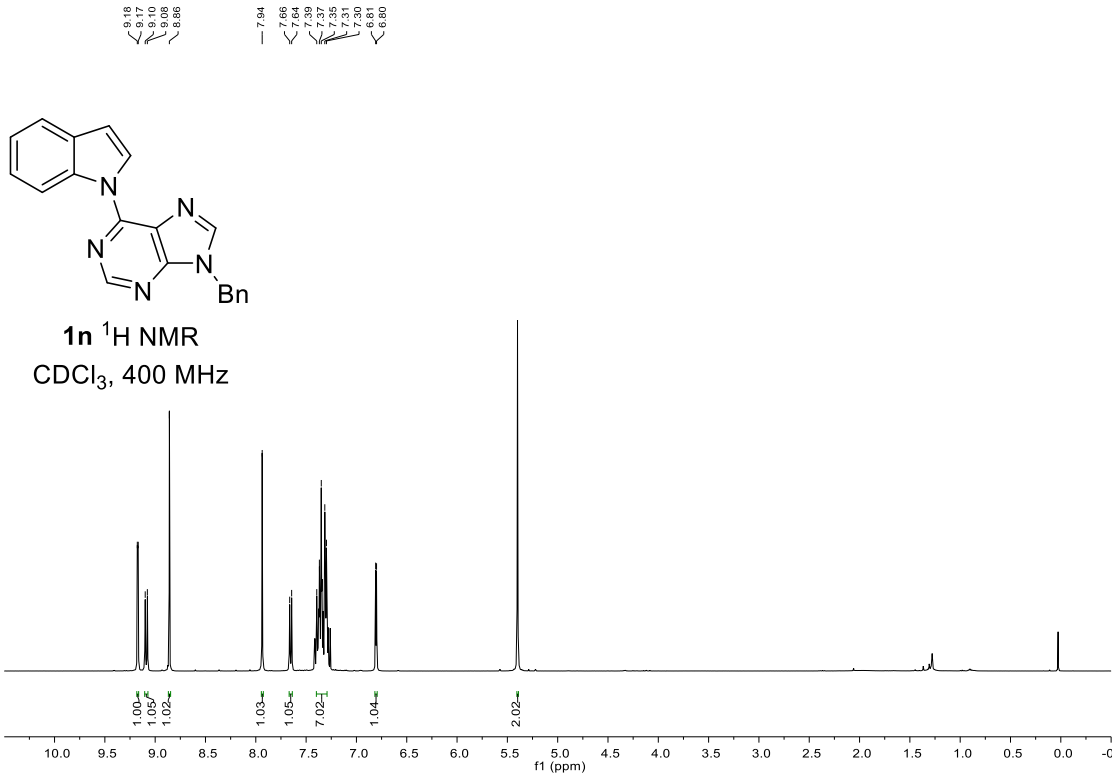
$CDCl_3$, 100 MHz

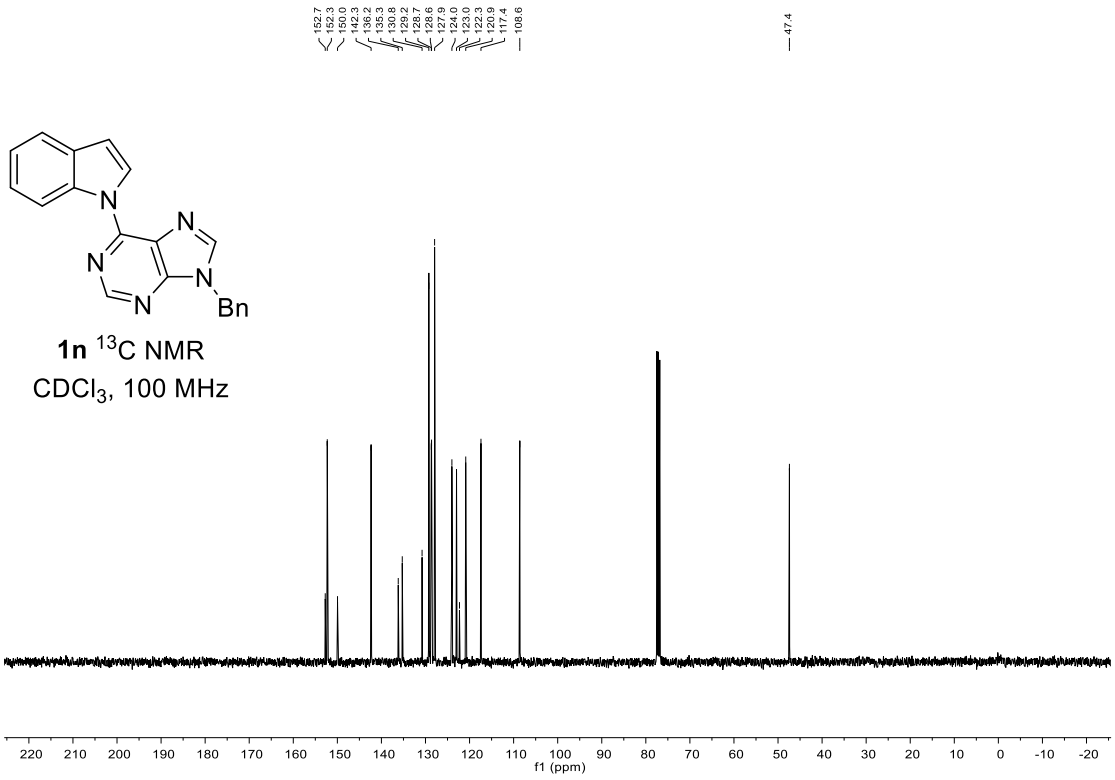


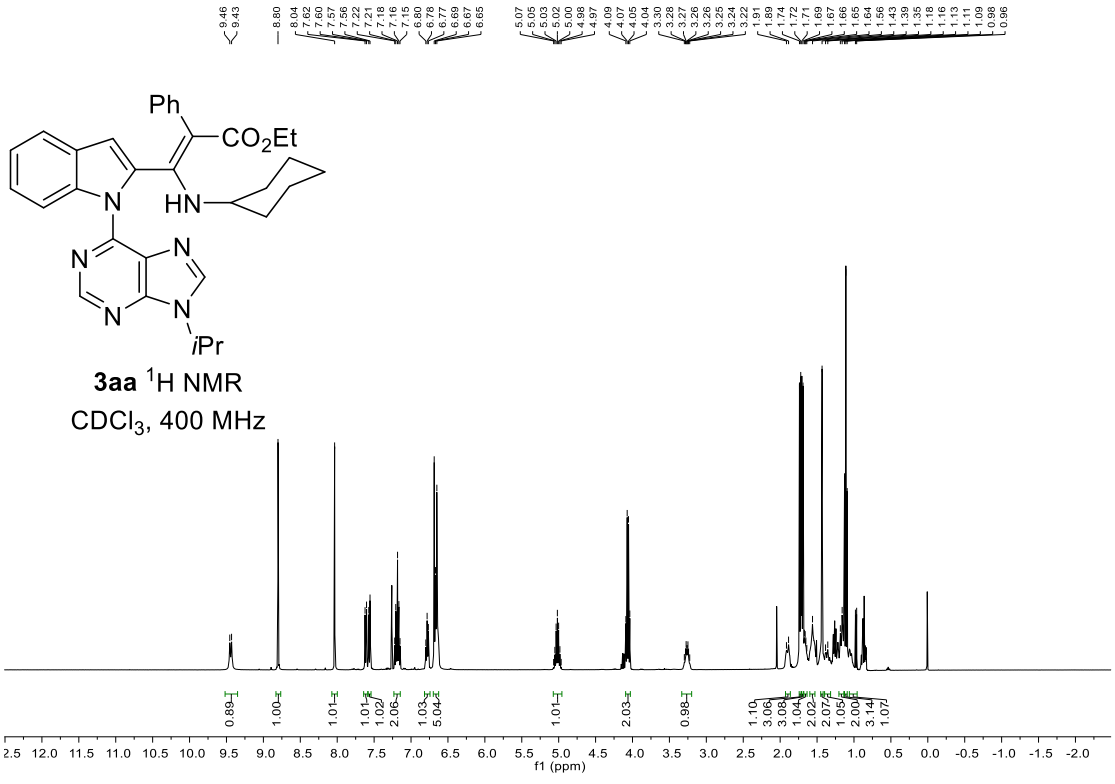
1m ^{1}H NMR

$CDCl_3$, 400 MHz


152.9
152.1
149.8
143.0
136.1
130.8
128.6
124.0
122.9
122.2
120.8
117.4
108.5
30.0
N
N
N
N
N
Me
1m 13C NMR
CDCl3, 100 MHz
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)


9.18
9.17
9.10
9.08
8.86
7.94
7.66
7.64
7.39
7.37
7.35
7.31
7.30
6.81
6.80
N
N
N
N
N
Bn
1n 1H NMR
CDCl3, 400 MHz
1.00
1.05
1.02
1.03
1.05
7.02
1.04
2.02
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


152.7
152.3
150.0
142.3
136.2
135.3
130.8
129.2
128.7
128.6
127.9
124.0
123.0
122.3
120.9
117.4
108.6
47.4
N
N
N
N
N
Bn
1n 13C NMR
CDCl3, 100 MHz
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)


8.46
8.43
8.80
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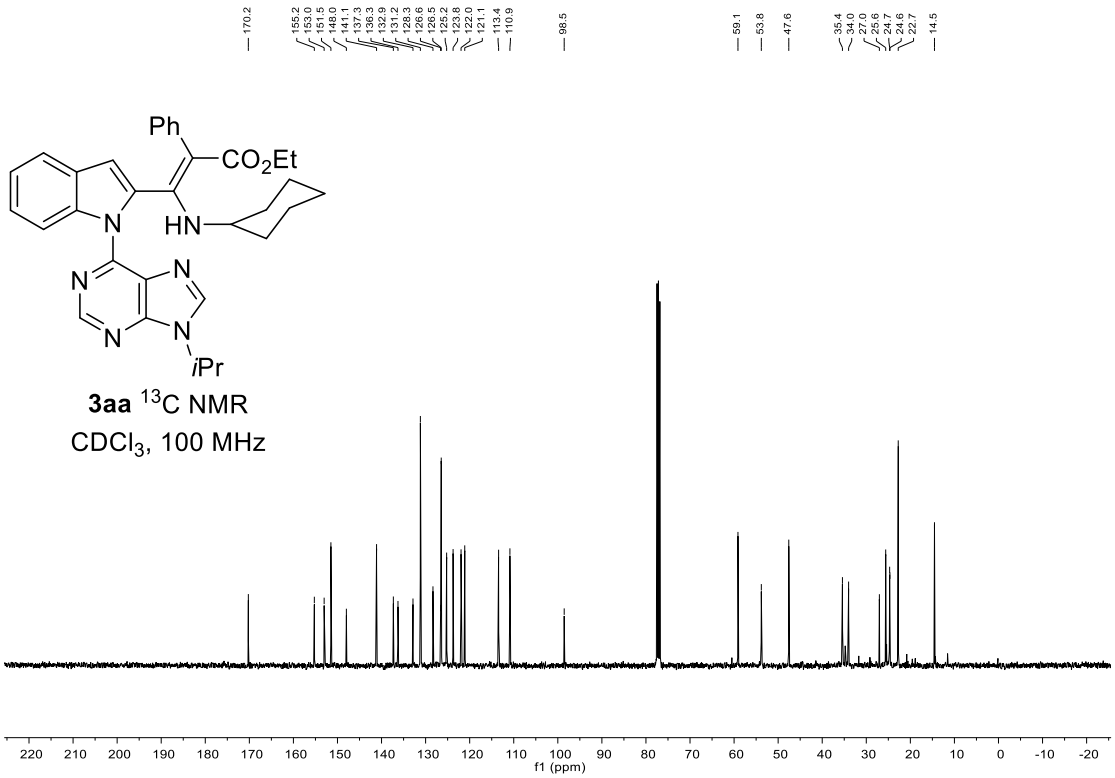
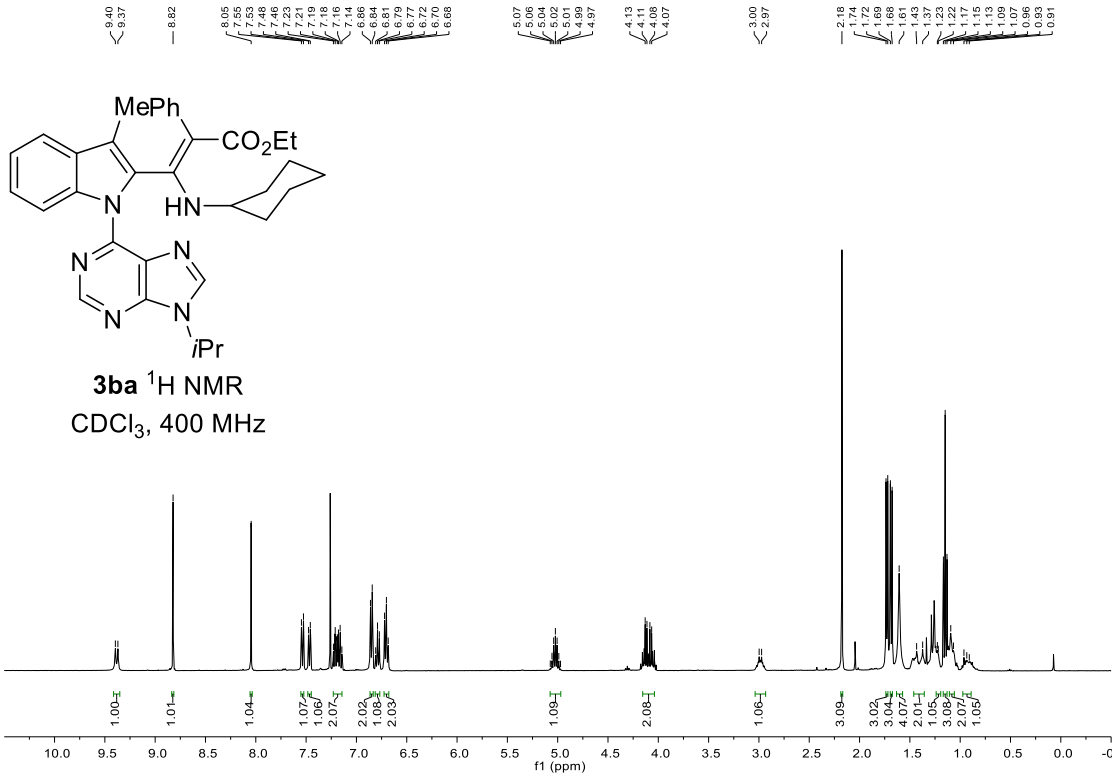
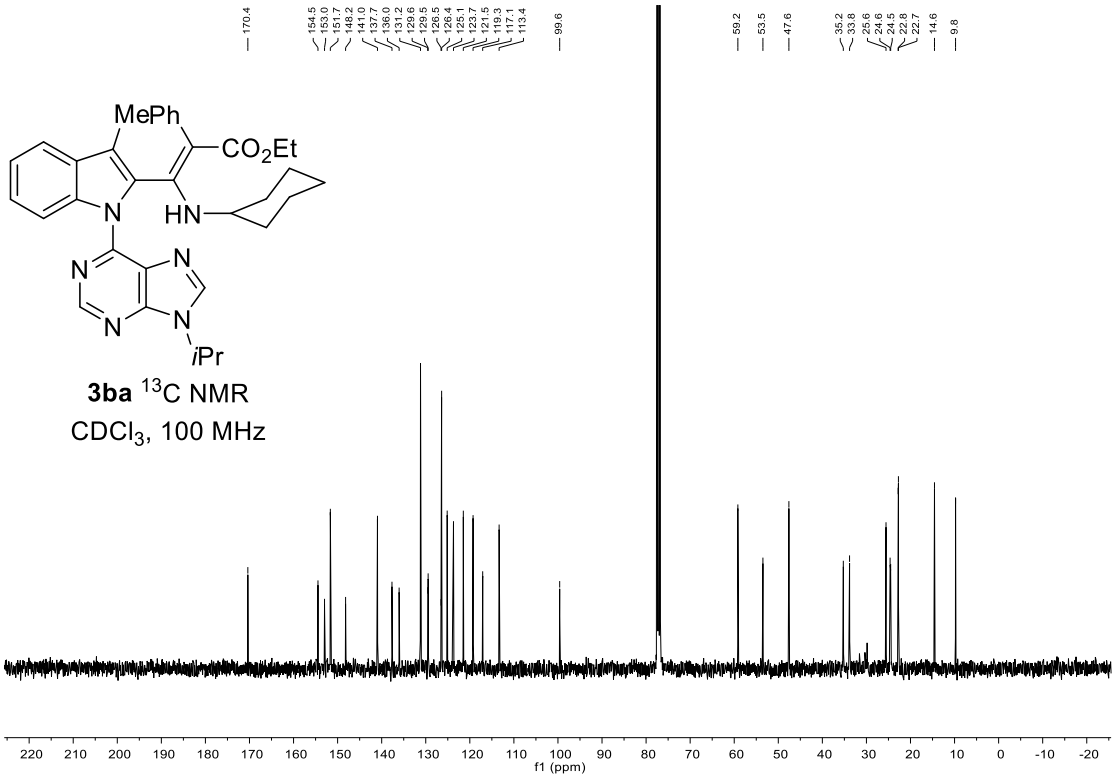
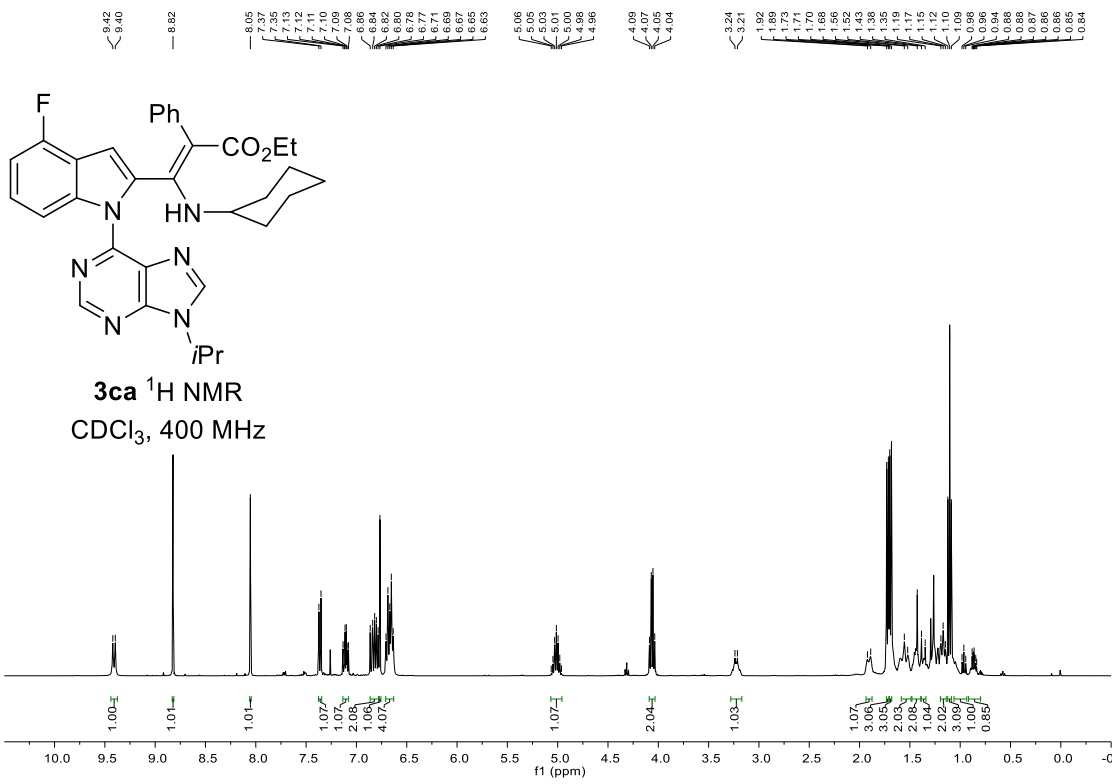
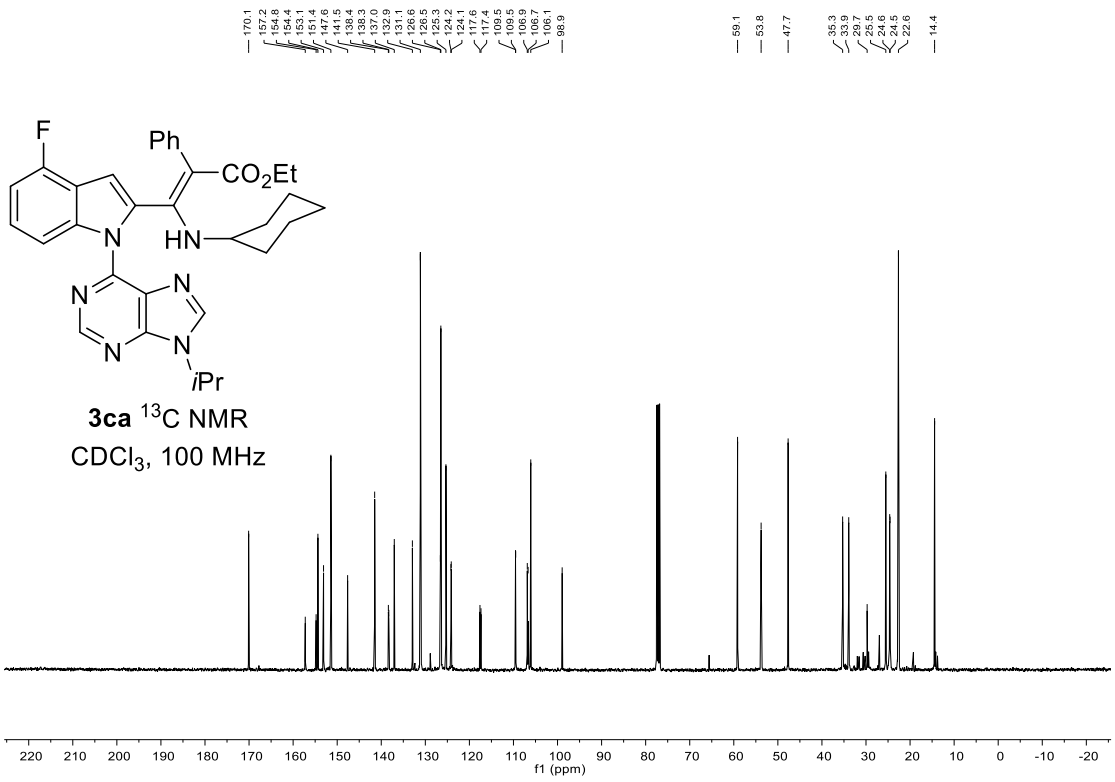
7.62
7.60
7.57
7.56
7.22
7.21
7.18
7.16
7.15
6.80
6.78
6.77
6.69
6.67
6.65
5.07
5.05
5.03
5.02
5.00
4.98
4.97
4.09
4.07
4.05
4.04
3.30
3.28
3.27
3.26
3.26
3.25
3.24
3.22
1.91
1.89
1.74
1.72
1.71
1.69
1.67
1.66
1.65
1.64
1.56
1.43
1.39
1.35
1.18
1.16
1.13
1.11
1.09
0.98
0.96
Ph
CO2Et
N
HN
N
N
N
N
iPr
3aa 1H NMR
CDCl3, 400 MHz
0.89
1.00
1.01
1.01
1.02
2.06
1.03
5.04
1.01
2.03
0.98
1.10
3.06
3.08
1.04
2.02
2.07
1.05
2.00
3.14
1.07
12.5 12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0 -1.5 -2.0
f1 (ppm)


Ph
CO2Et
HN
N
N
N
N
iPr
3aa 13C NMR
CDCl3, 100 MHz
f1 (ppm)


MePh
CO2Et
HN
N
N
N
N
iPr
3ba 1H NMR
CDCl3, 400 MHz
f1 (ppm)

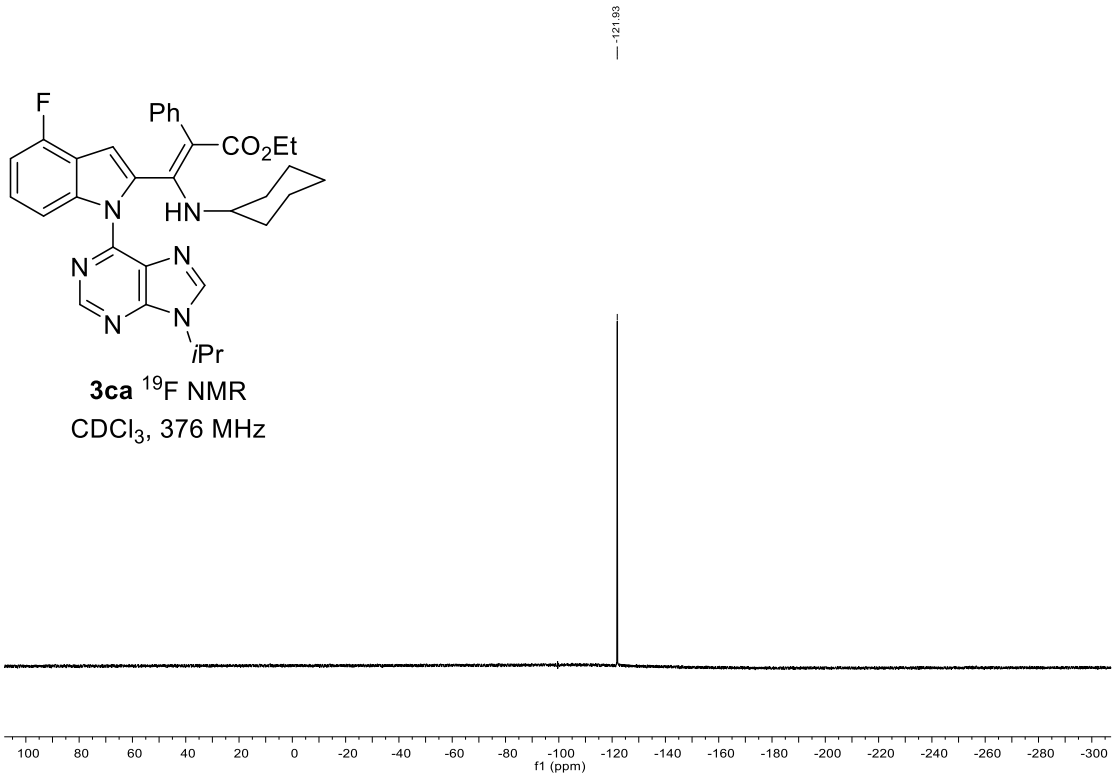

MePh
CO2Et
HN
N
N
N
N
iPr
3ba 13C NMR
CDCl3, 100 MHz
f1 (ppm)


F
Ph
CO2Et
HN
N
N
N
N
iPr
3ca 1H NMR
CDCl3, 400 MHz
f1 (ppm)



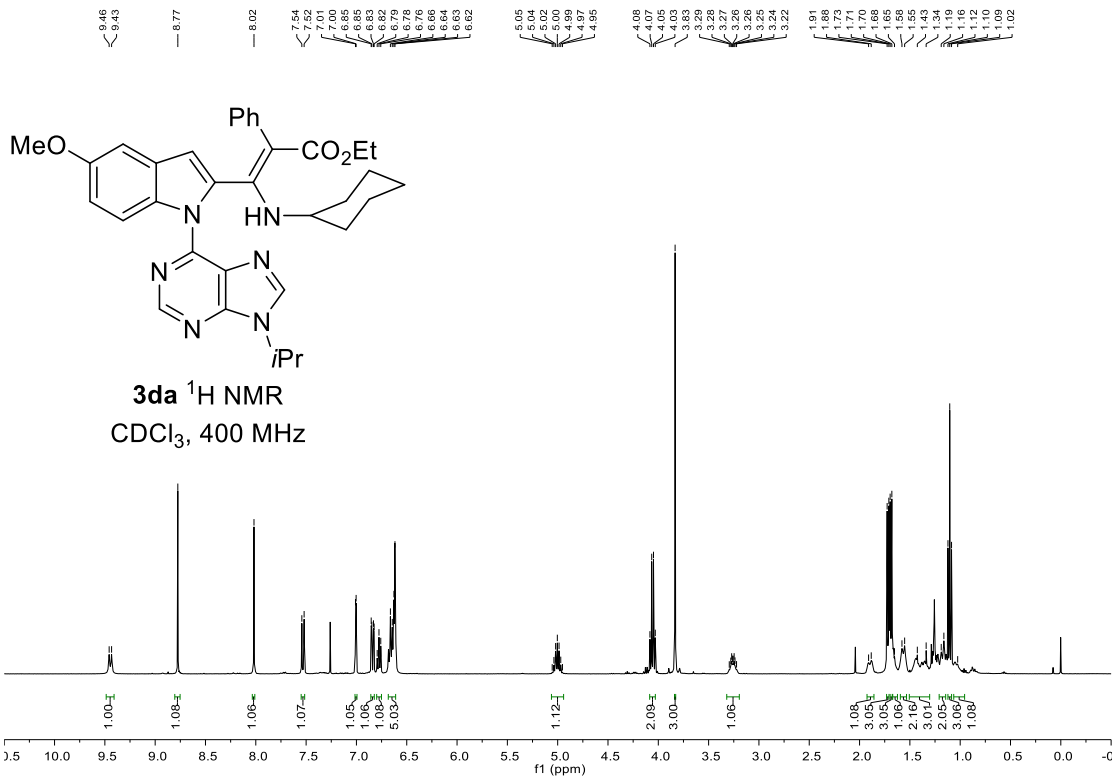
3ca ^{13}C NMR

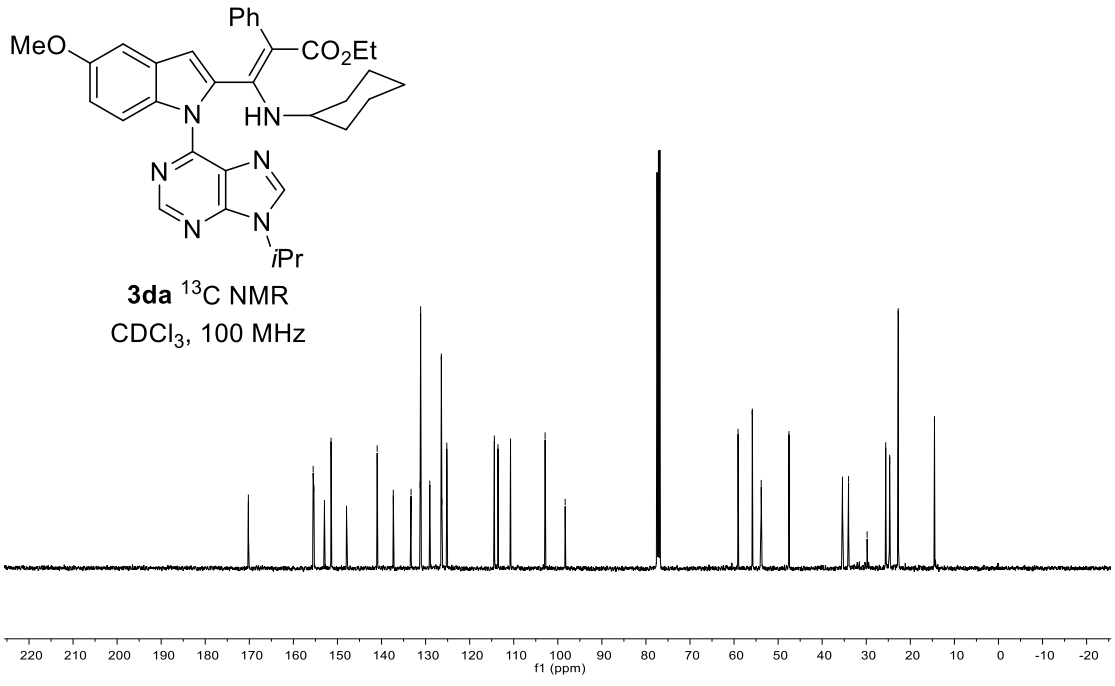
$CDCl_3$, 100 MHz

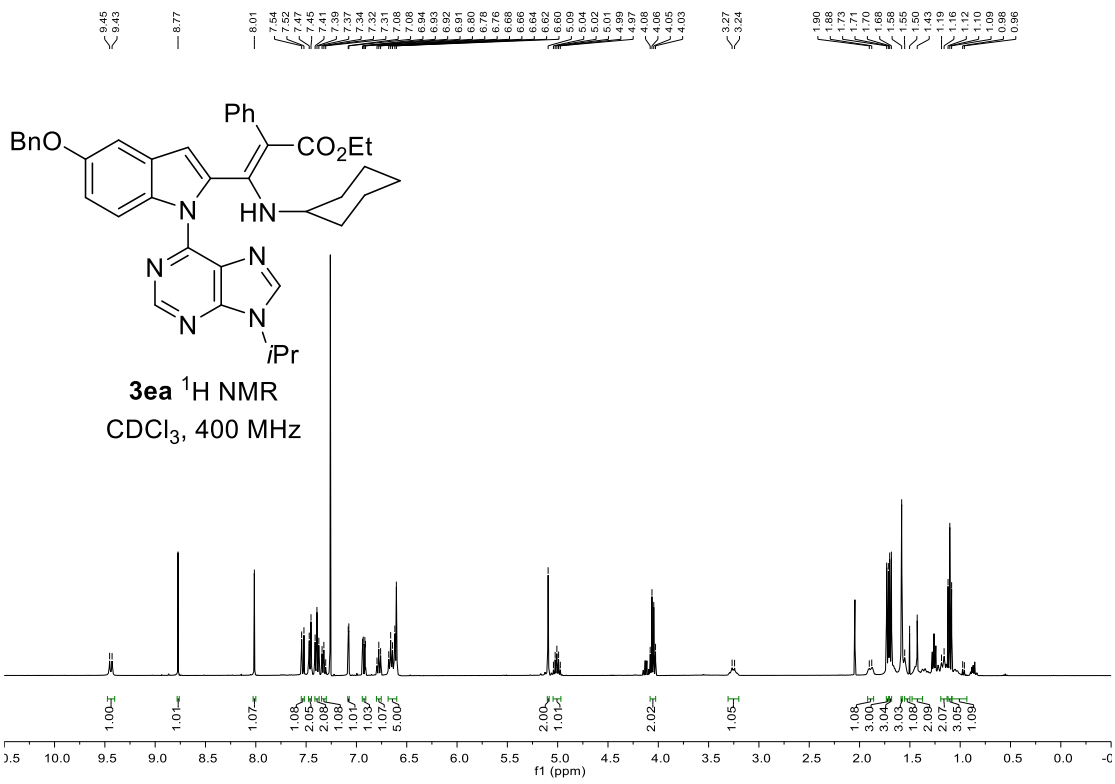


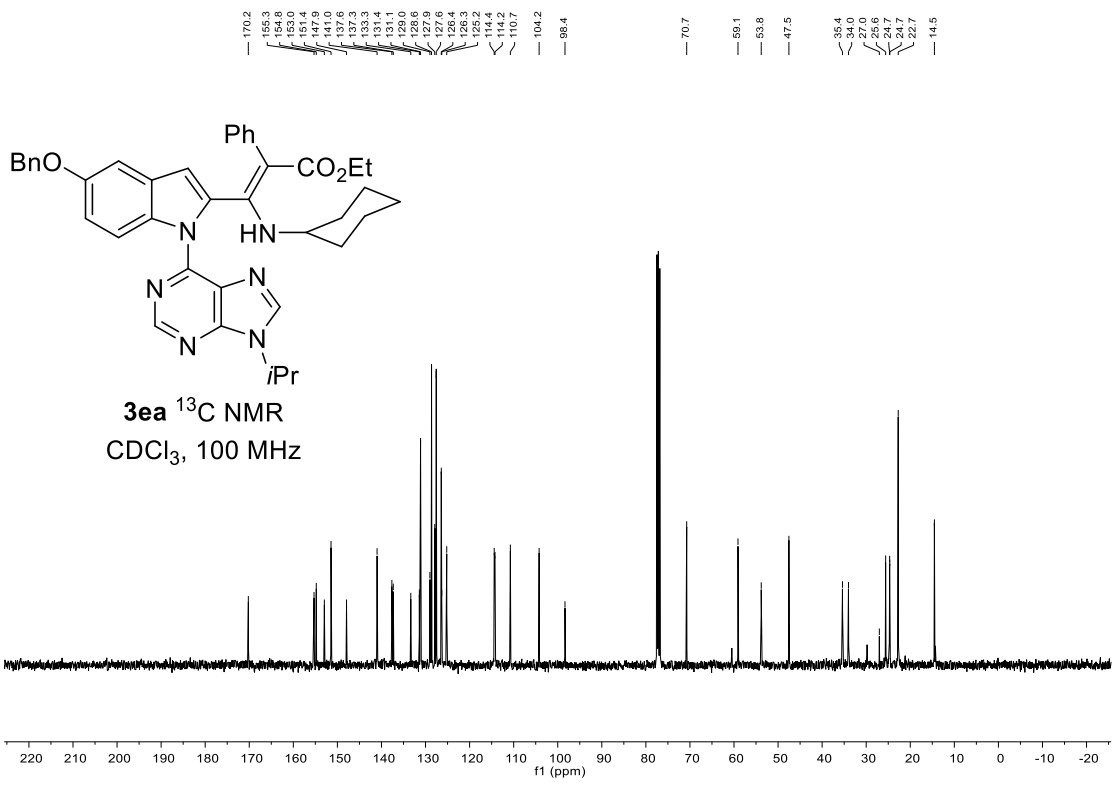
3ca ^{19}F NMR

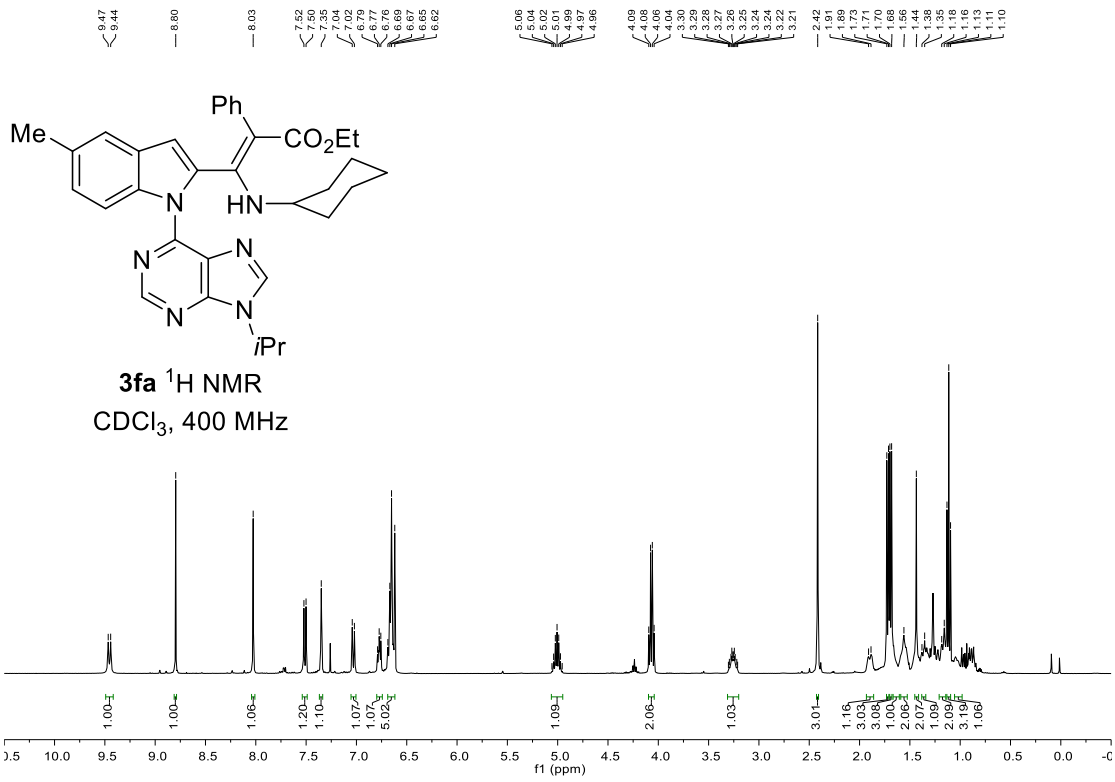
$CDCl_3$, 376 MHz


Ph
MeO
CO2Et
HN
N
N
N
N
iPr
3da 1H NMR
CDCl3, 400 MHz
f1 (ppm)


Ph
MeO
CO2Et
HN
N
N
N
N
iPr
3da 13C NMR
CDCl3, 100 MHz
f1 (ppm)

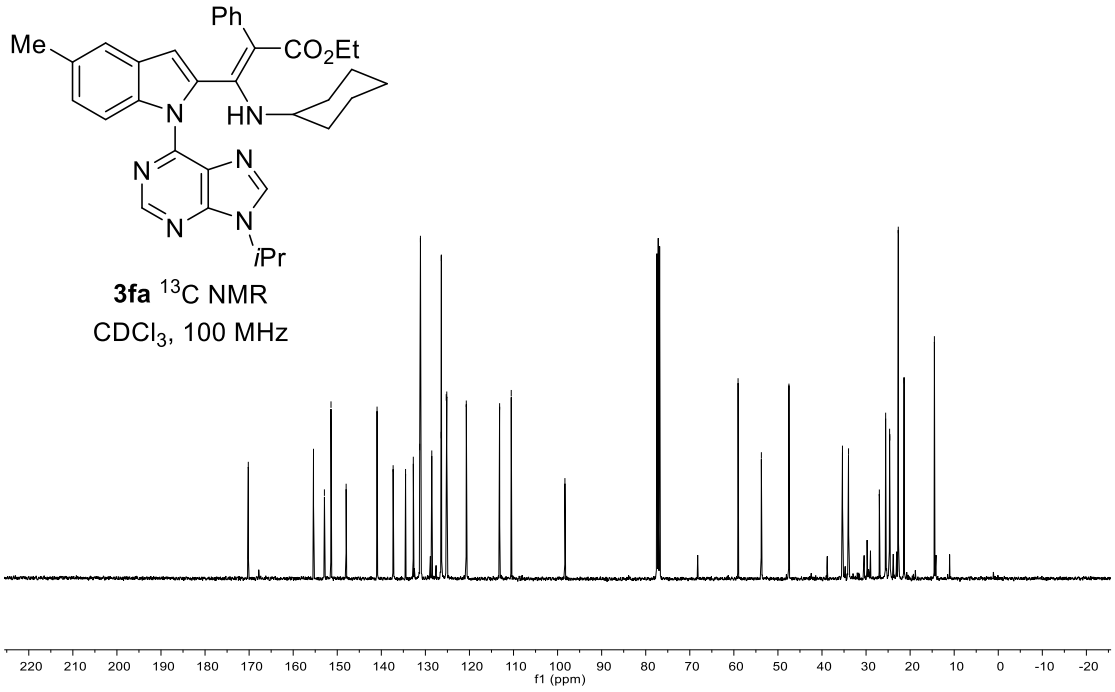

BnO
Ph
CO2Et
HN
N
N
N
N
N
iPr
3ea 1H NMR
CDCl3, 400 MHz
f1 (ppm)


BnO
Ph
CO2Et
HN
N
N
N
N
N
iPr
3ea 13C NMR
CDCl3, 100 MHz
f1 (ppm)



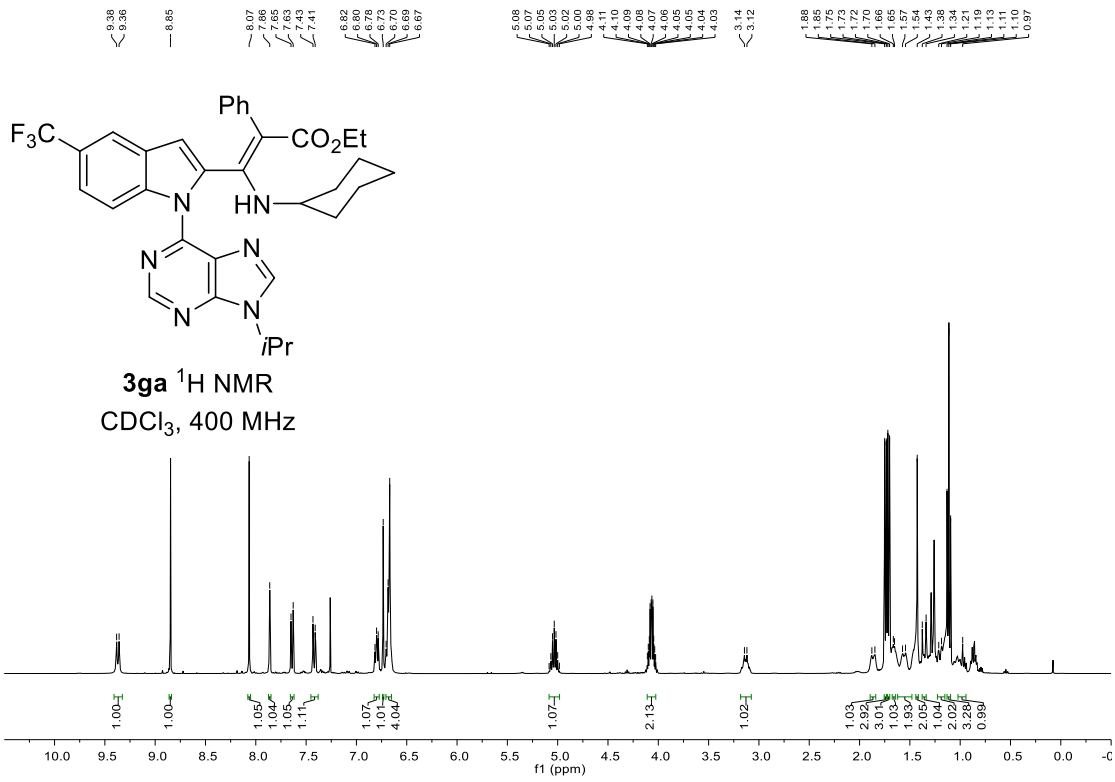
3fa ^{1}H NMR

$CDCl_3$, 400 MHz



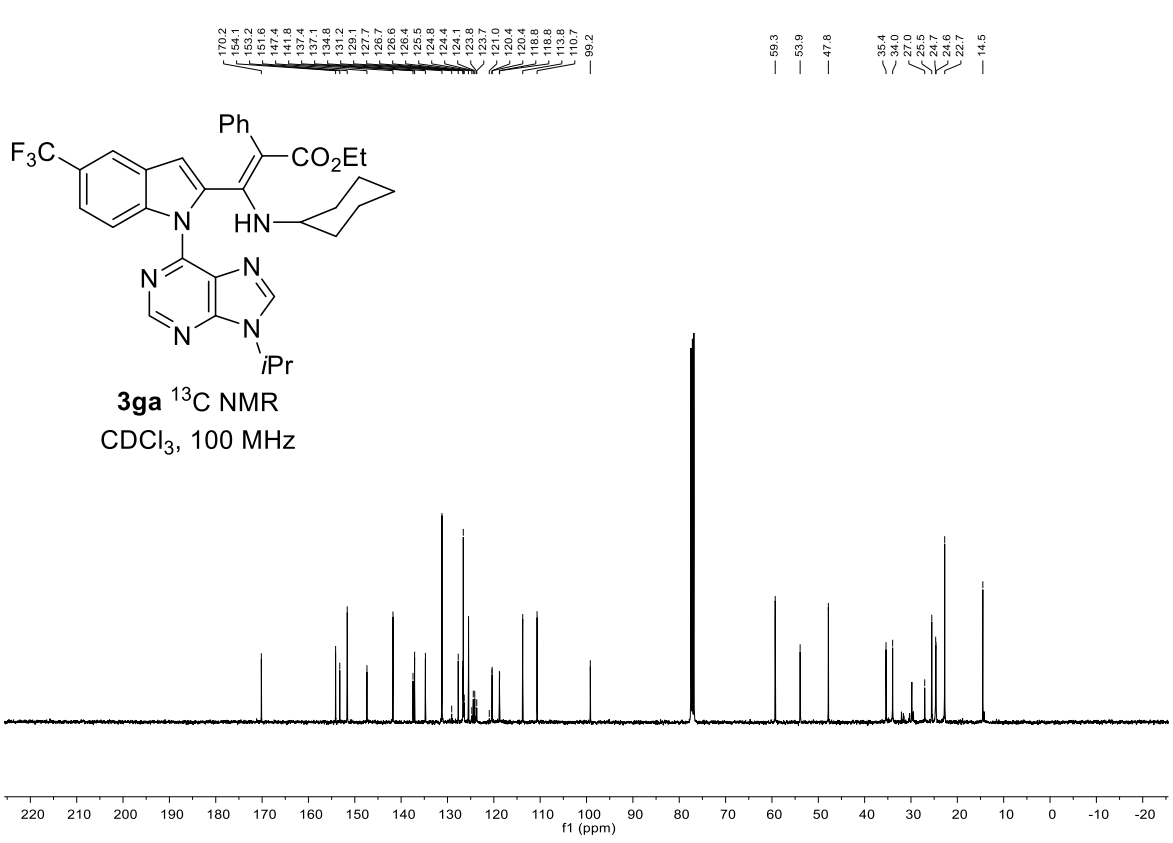
3fa ^{13}C NMR

$CDCl_3$, 100 MHz



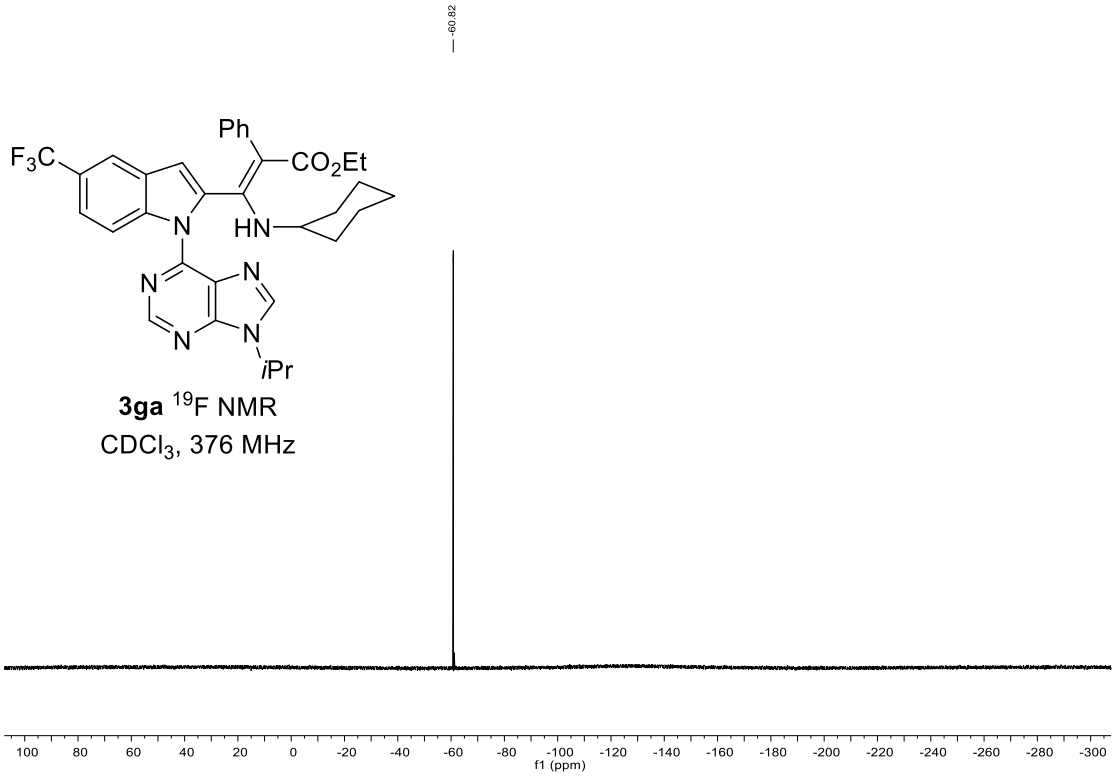
3ga ^{1}H NMR

$CDCl_3$, 400 MHz



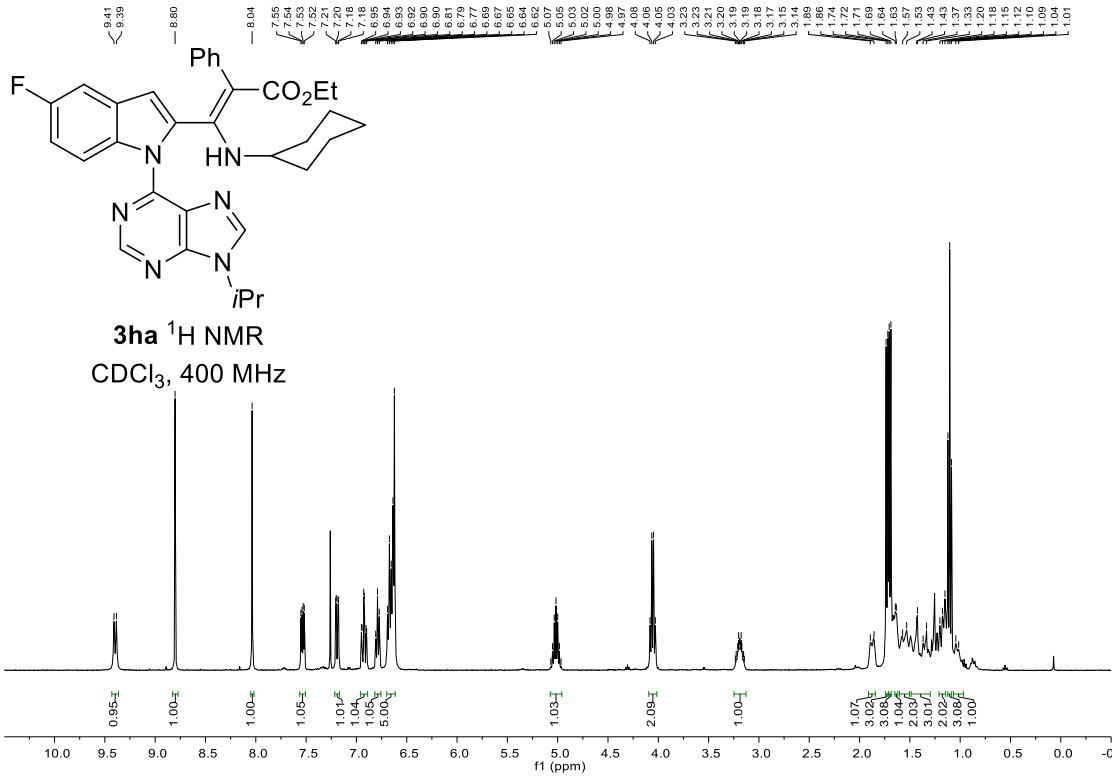
3ga ^{13}C NMR

$CDCl_3$, 100 MHz



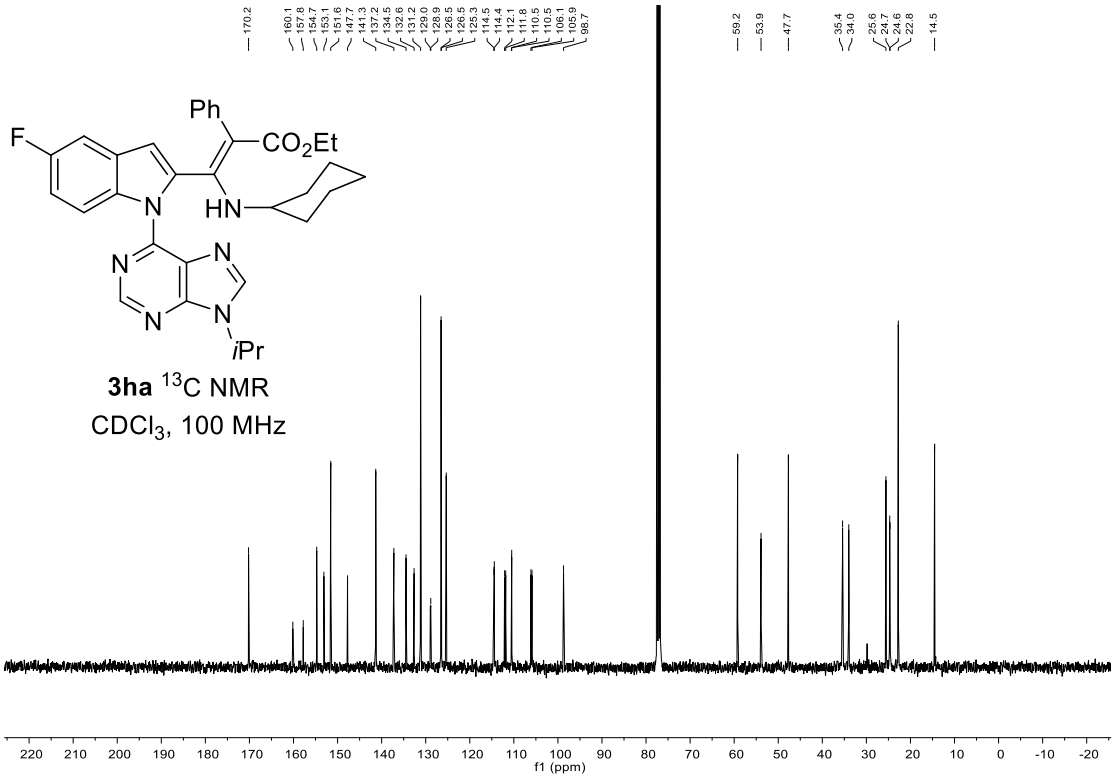
3ga ^{19}F NMR

$CDCl_3$, 376 MHz



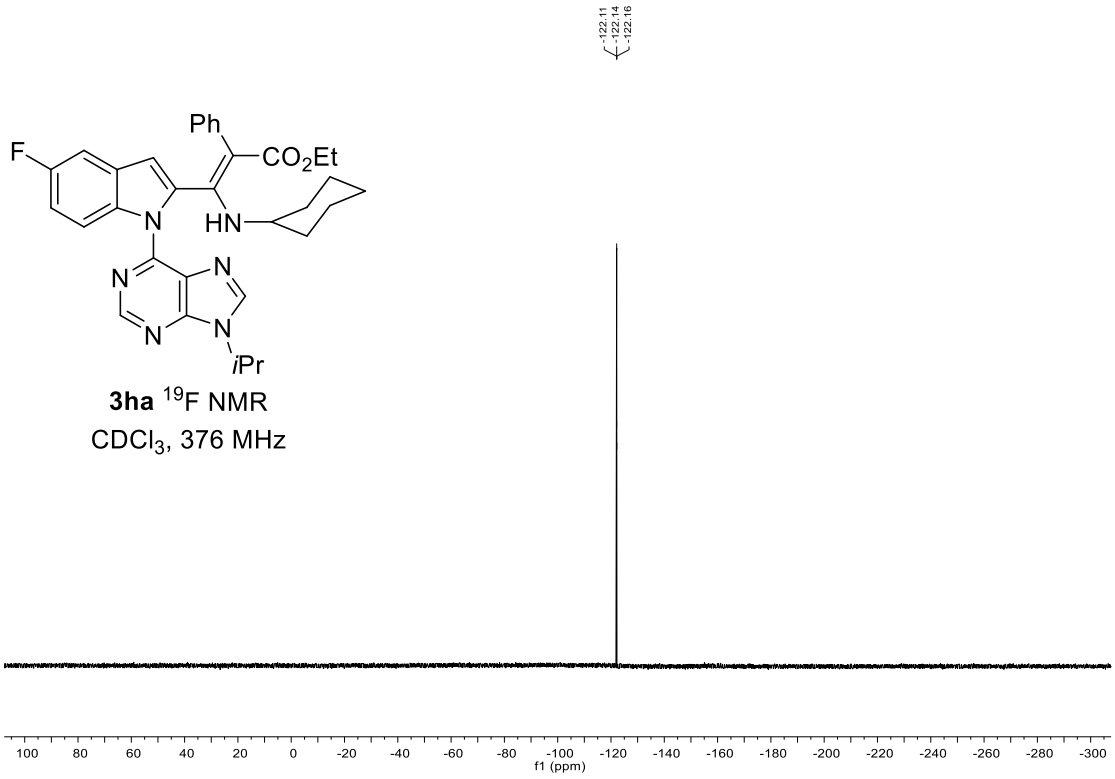
3ha ^{1}H NMR

$CDCl_3$, 400 MHz



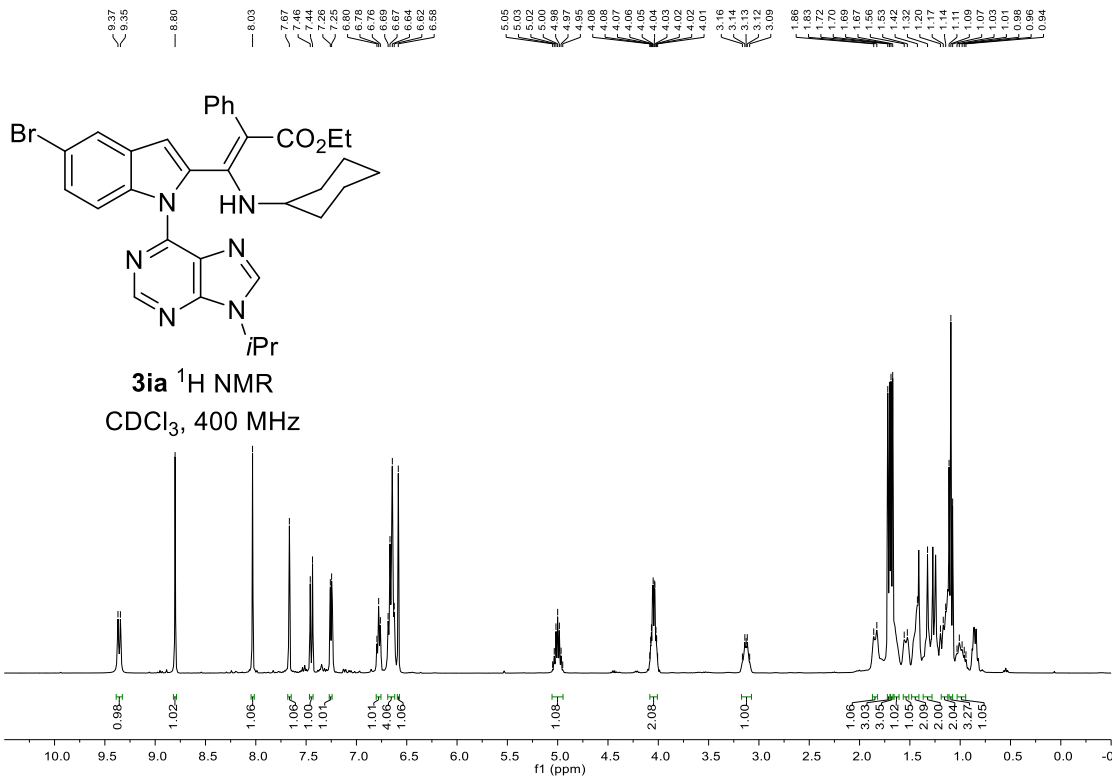
3ha ^{13}C NMR

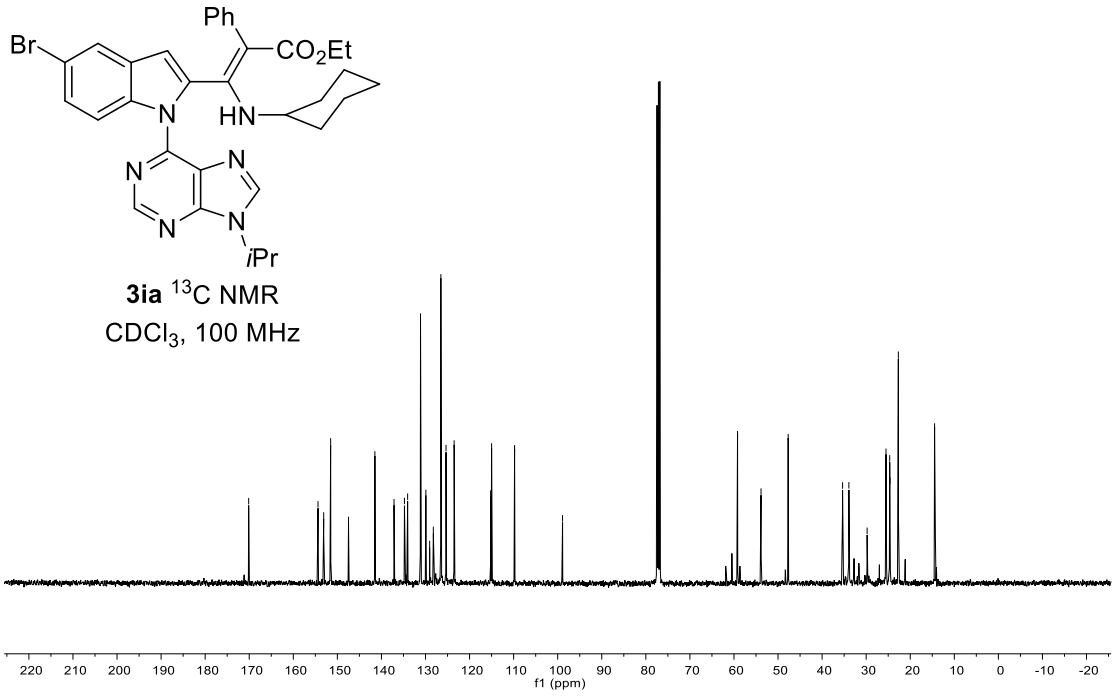
$CDCl_3$, 100 MHz



3ha ^{19}F NMR

$CDCl_3$, 376 MHz


Ph
Br
CO2Et
HN
N
N
N
N
iPr
3ia 1H NMR
CDCl3, 400 MHz
f1 (ppm)


Ph
Br
CO2Et
HN
N
N
N
N
iPr
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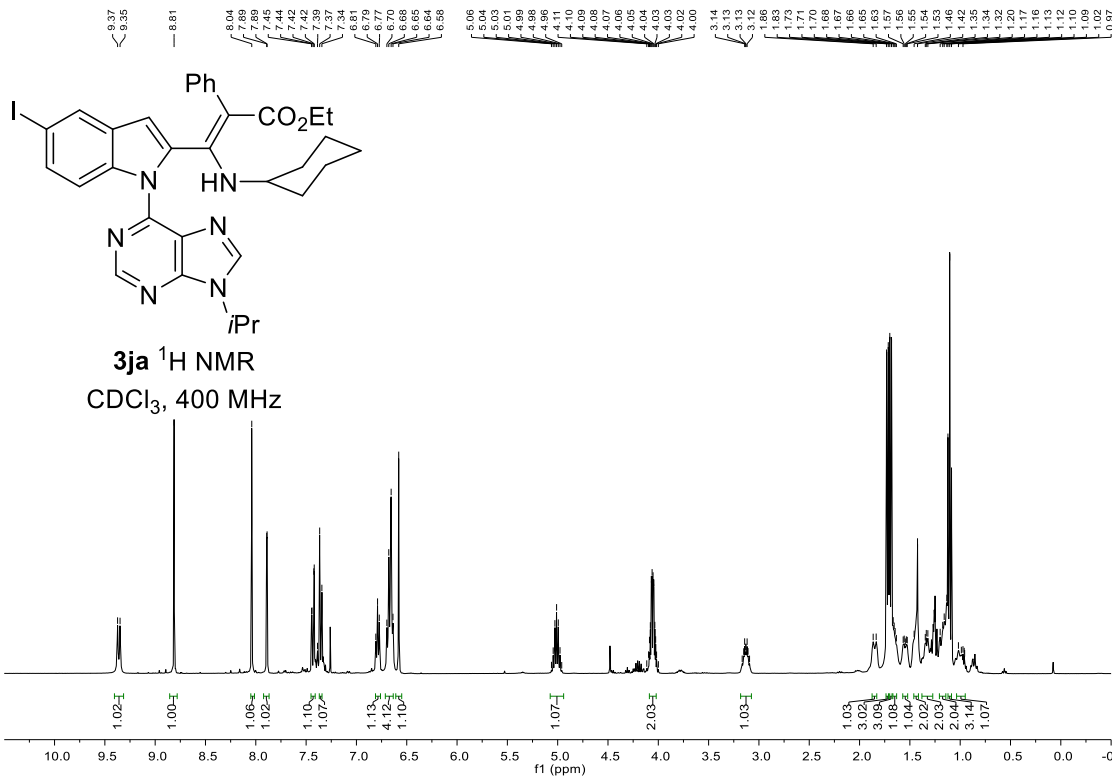
CDCl3, 100 MHz
f1 (ppm)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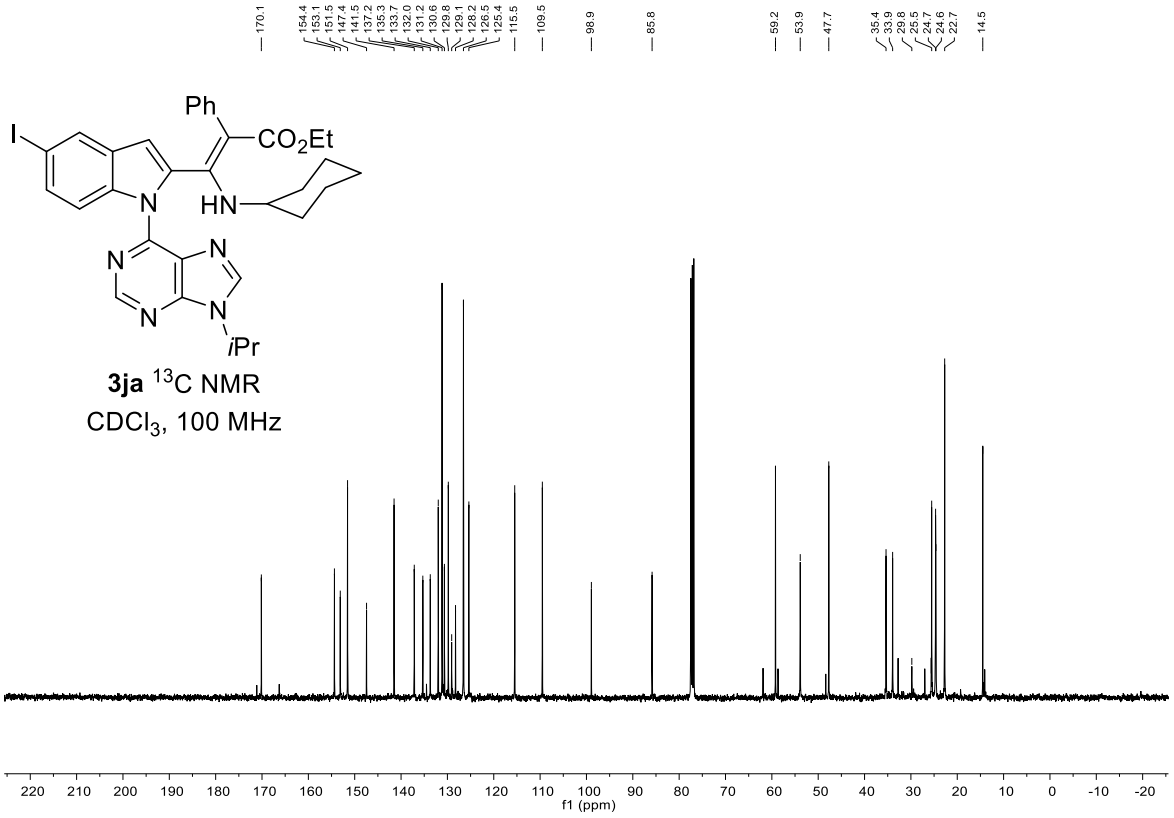
CDCl3, 400 MHz
f1 (ppm)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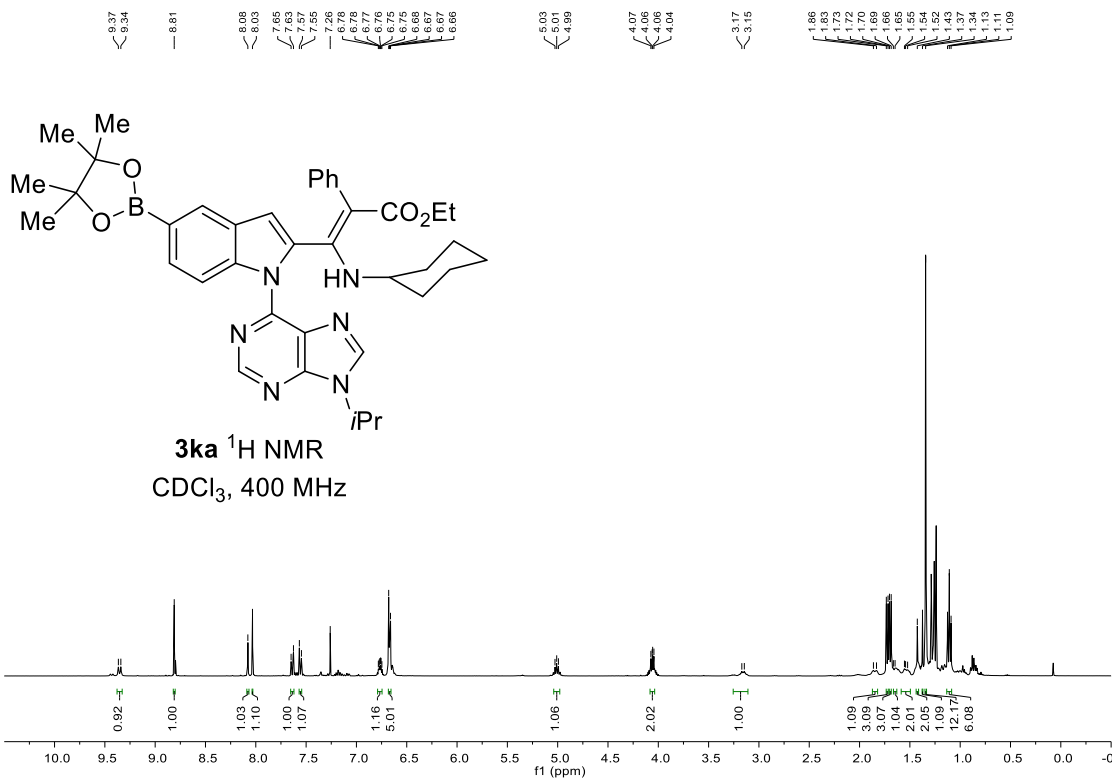
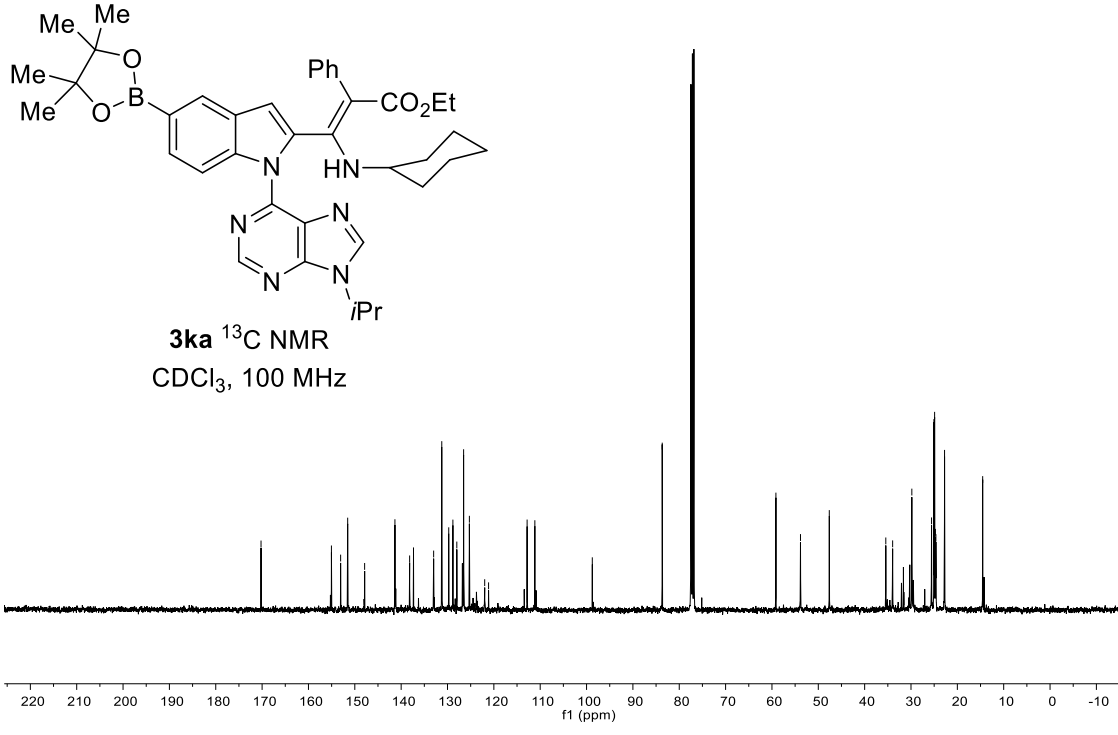
3ja 13C NMR
CDCl3, 100 MHz
f1 (ppm)



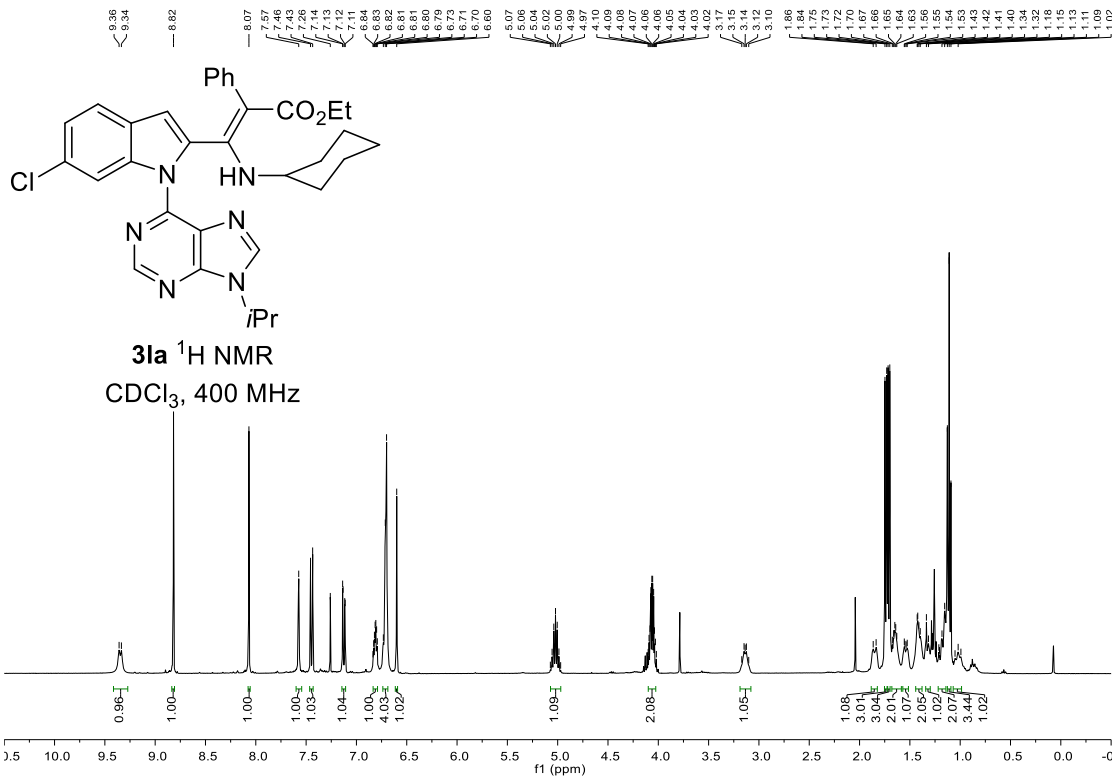
3ka ^{1}H NMR

$CDCl_3$, 400 MHz



3ka ^{13}C NMR

$CDCl_3$, 100 MHz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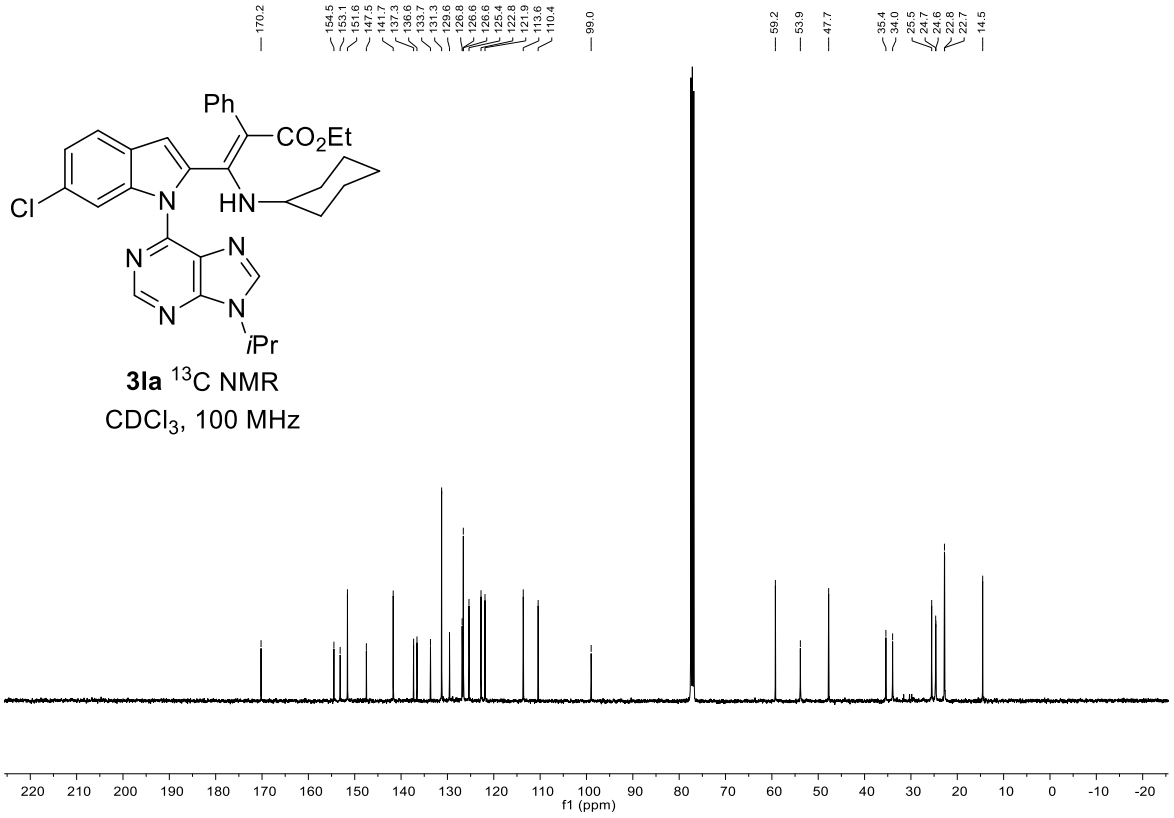
iPr
3Ia 1H NMR
CDCl3, 400 MHz
f1 (ppm)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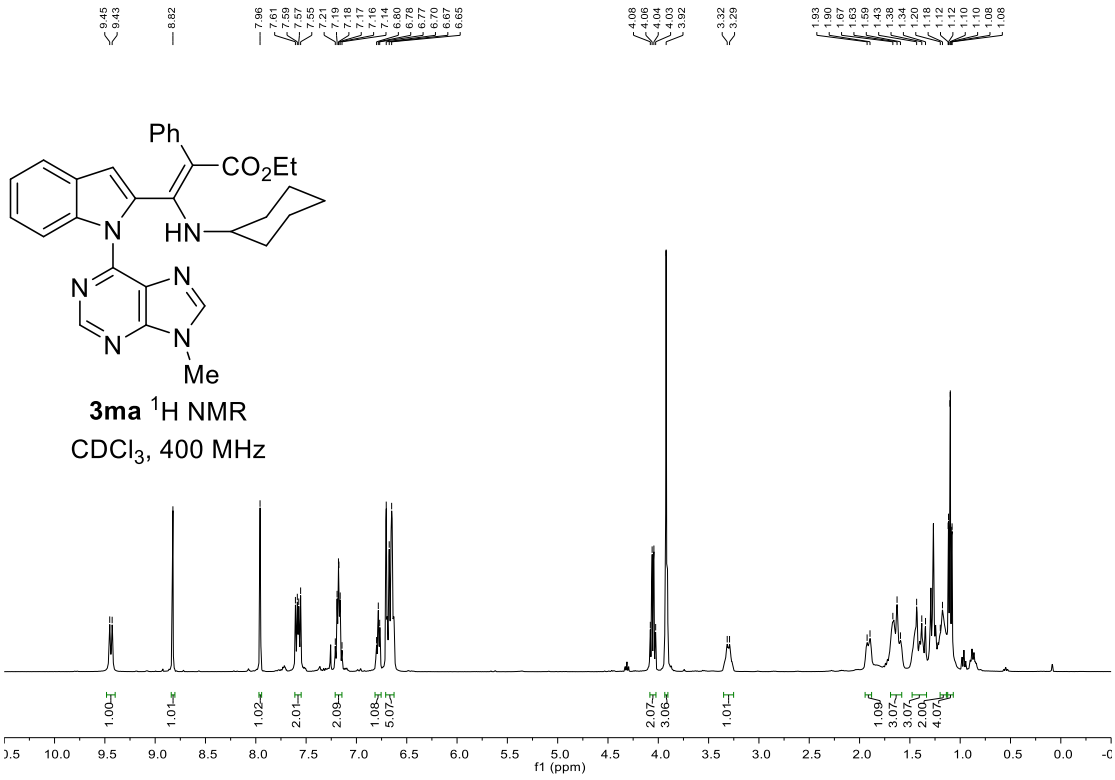
CDCl3, 100 MHz
f1 (ppm)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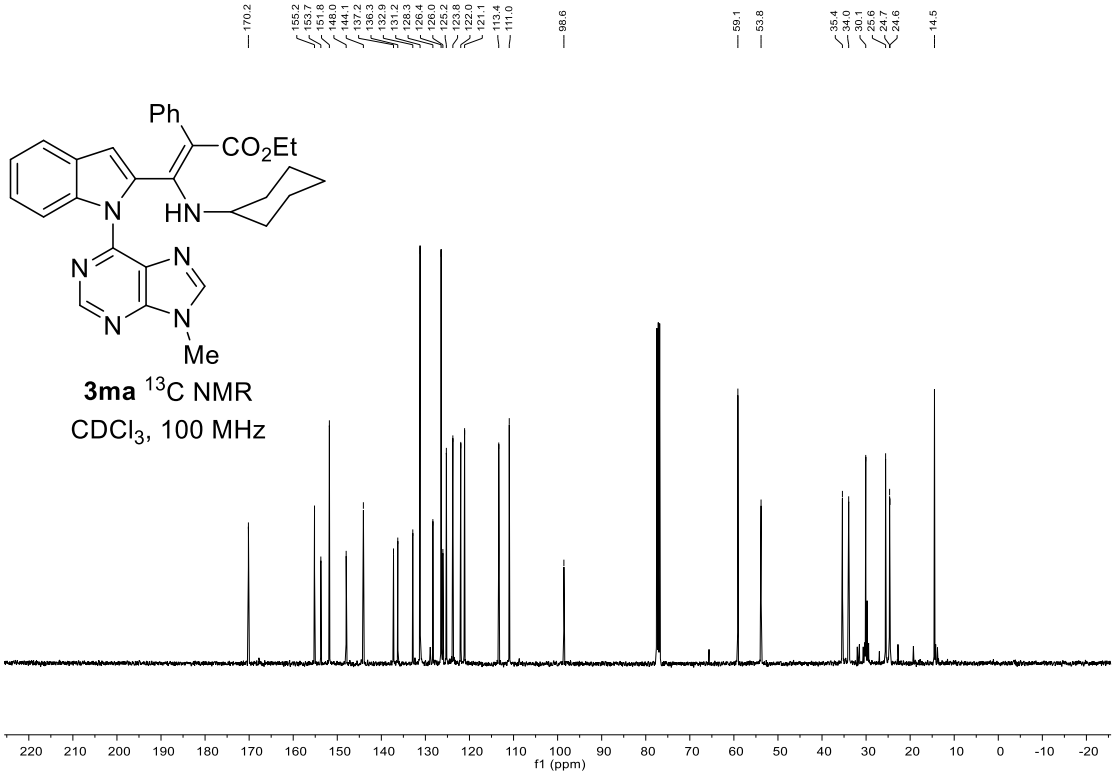
CDCl3, 400 MHz
f1 (ppm)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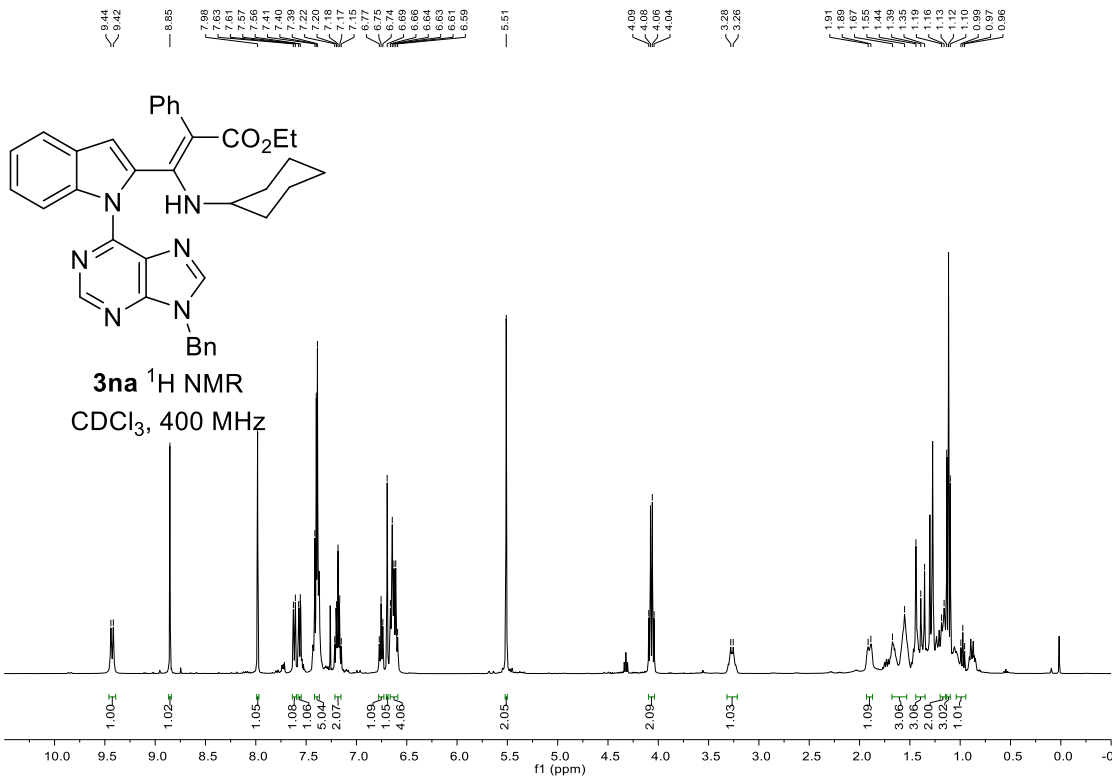
f1 (ppm)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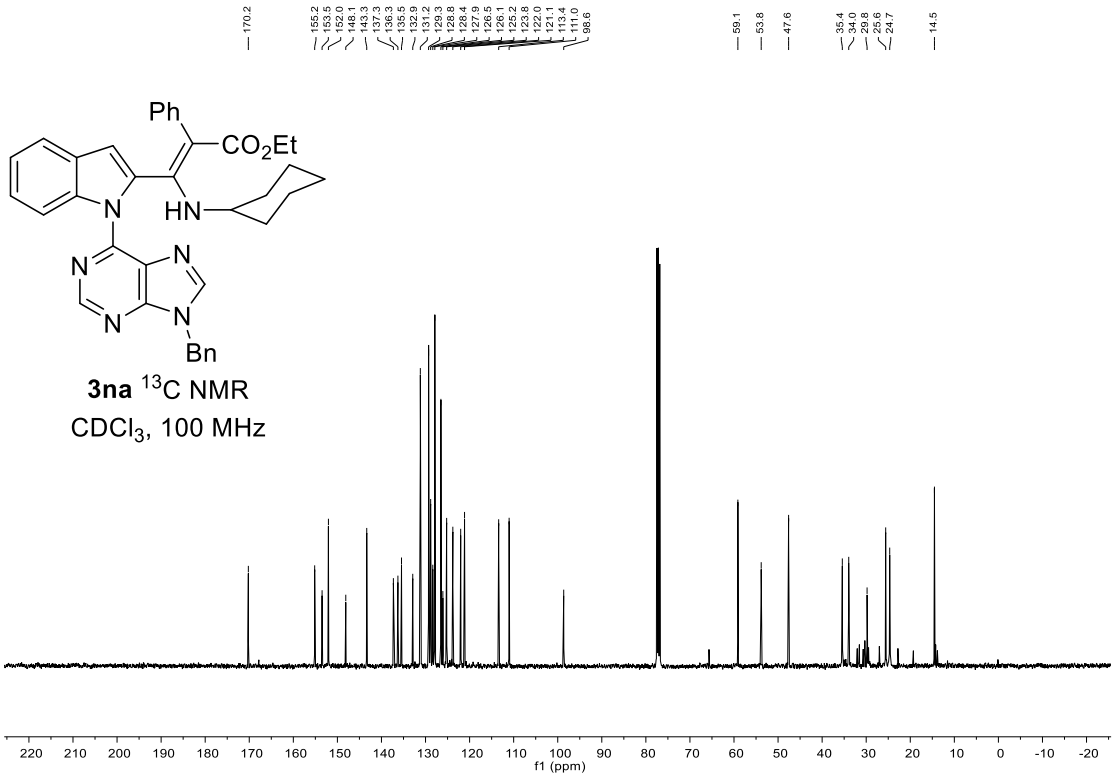
CDCl3, 400 MHz
f1 (ppm)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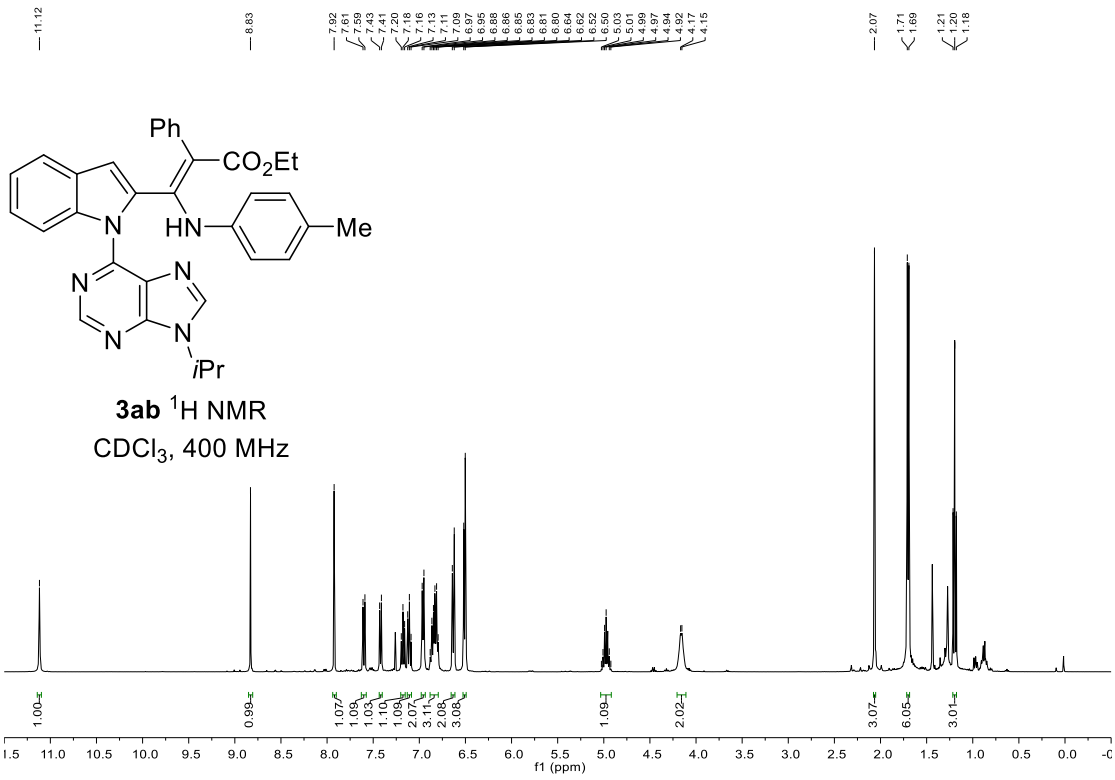
f1 (ppm)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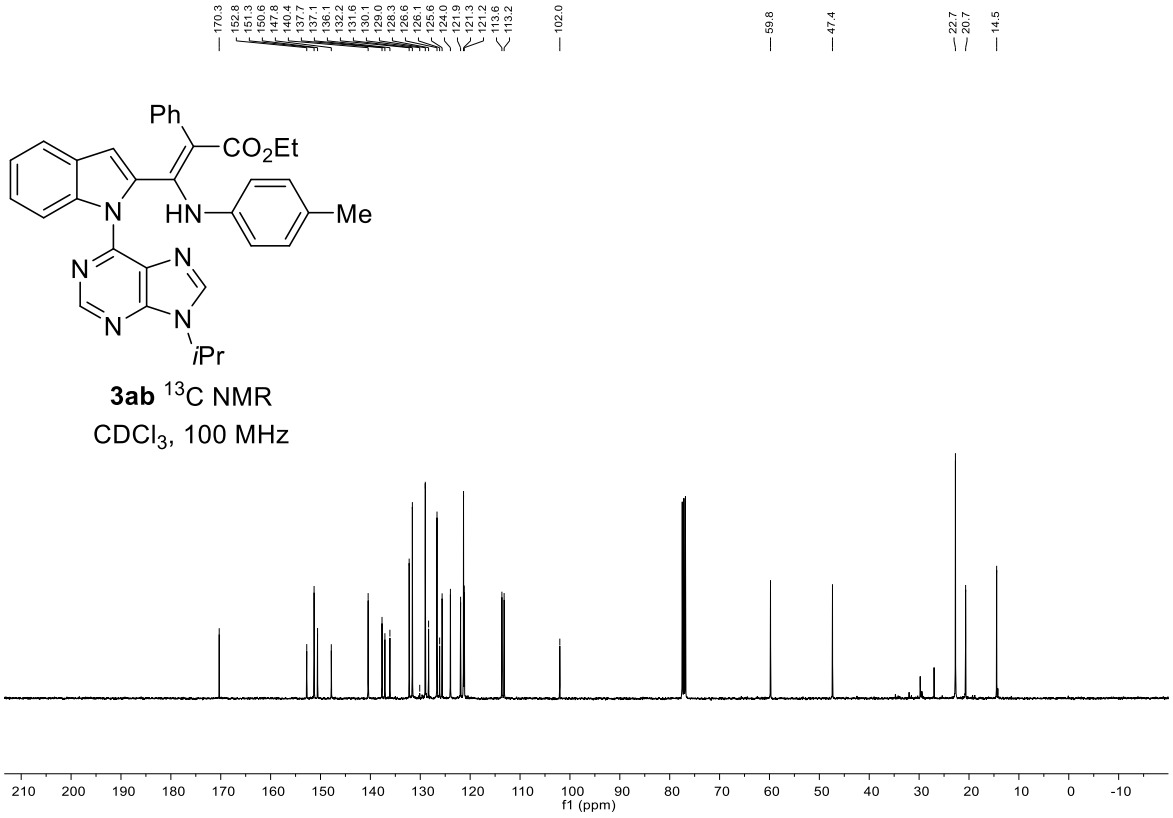
3ab 1H NMR
CDCl3, 400 MHz
f1 (ppm)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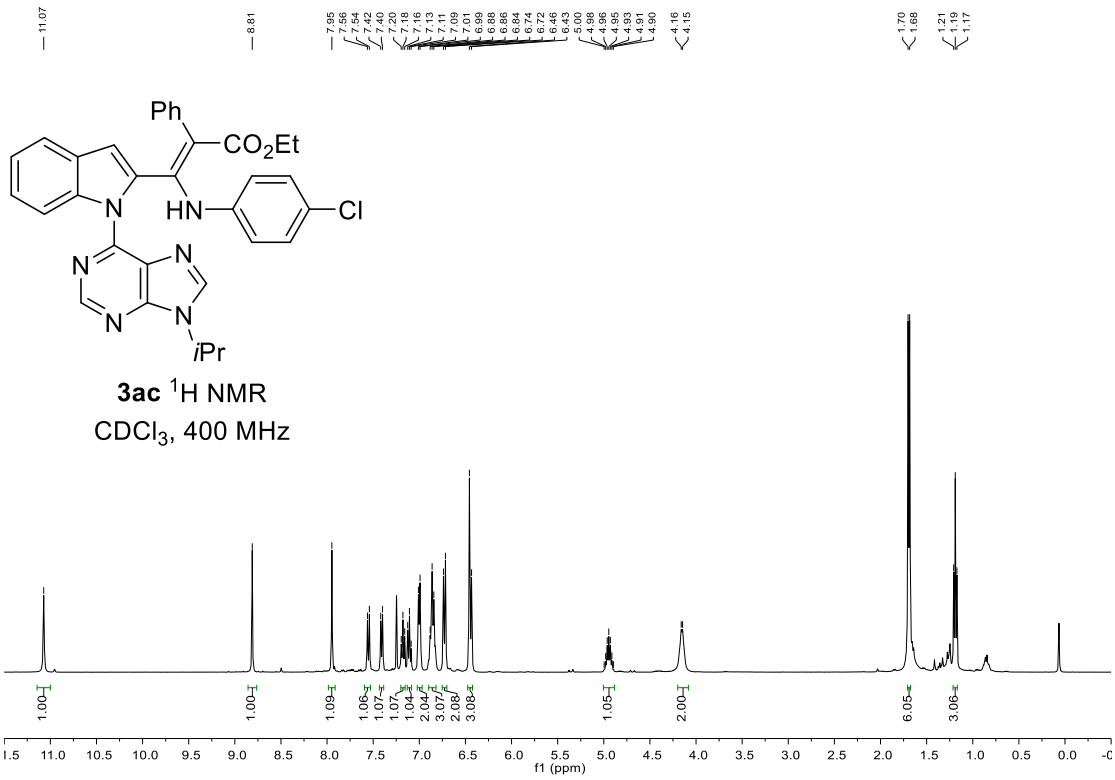
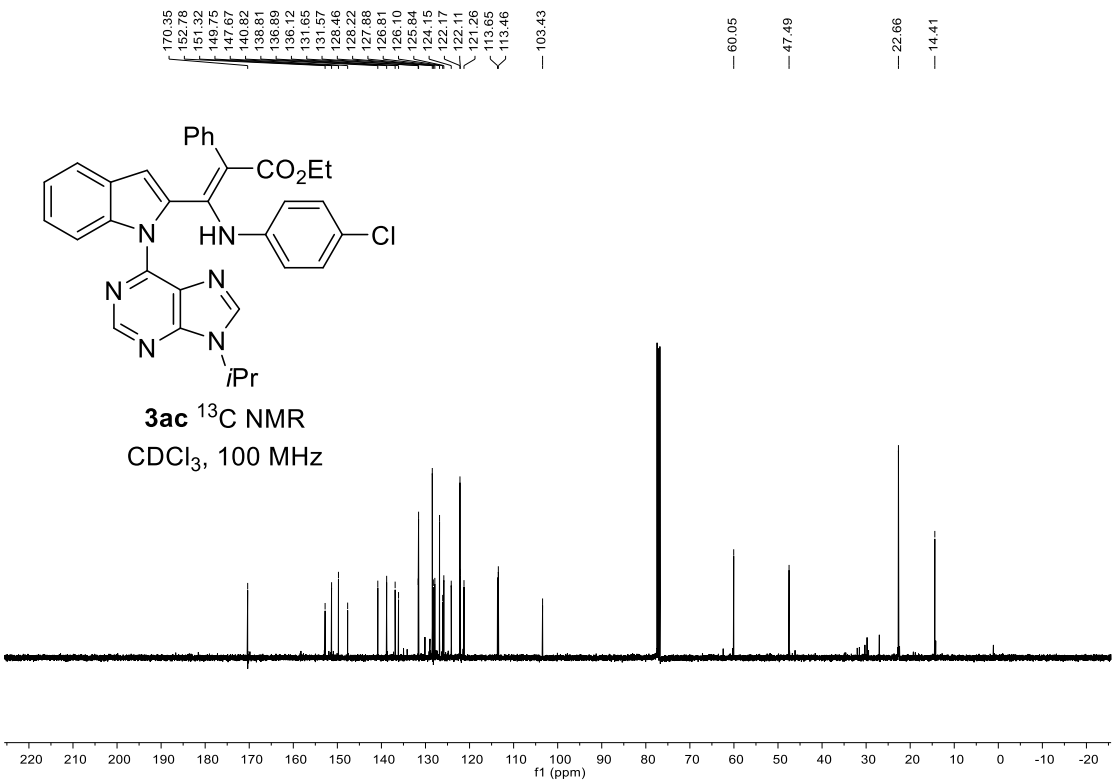
CDCl3, 100 MHz
f1 (ppm)



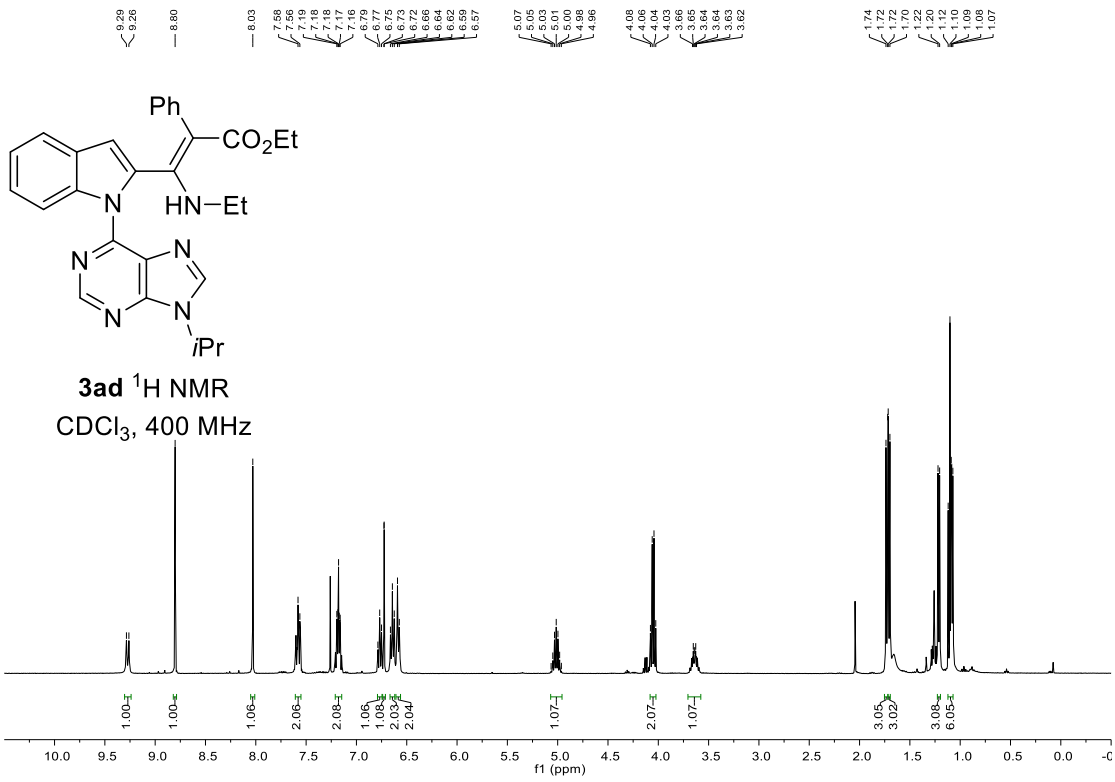
3ac ^{1}H NMR

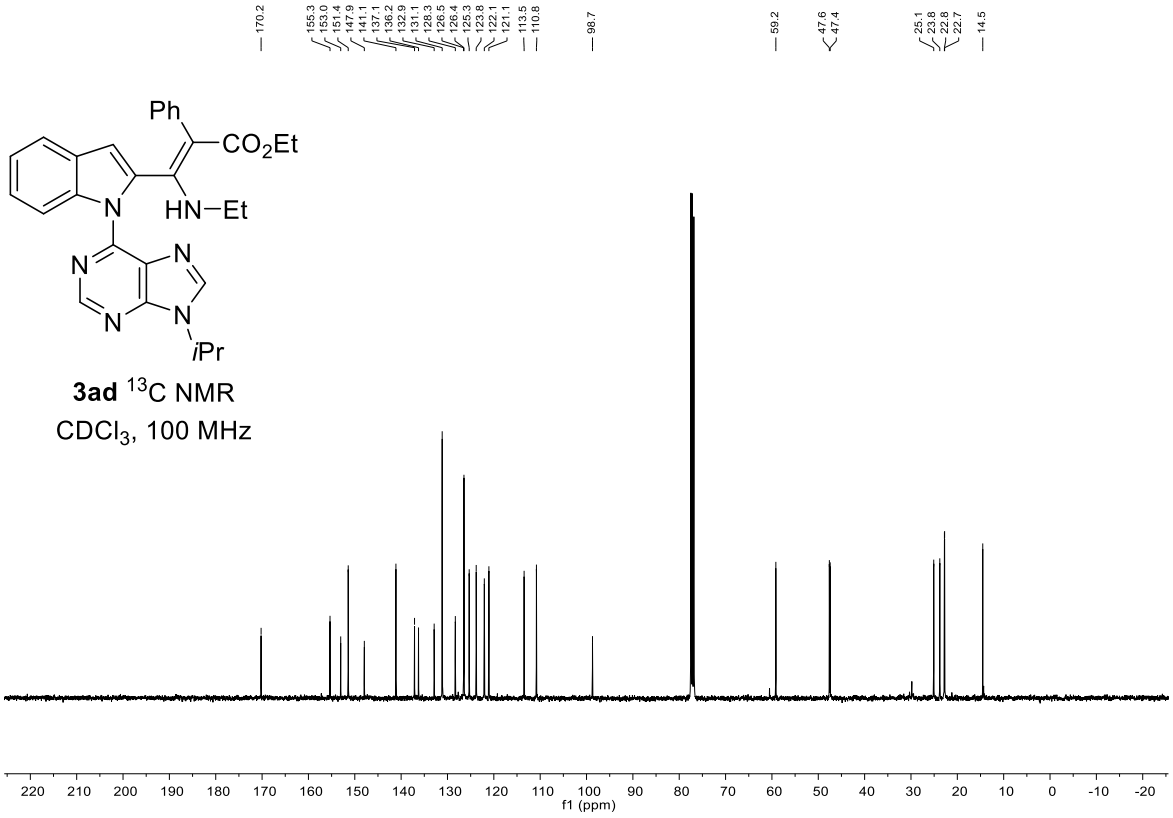
$CDCl_3$, 400 MHz

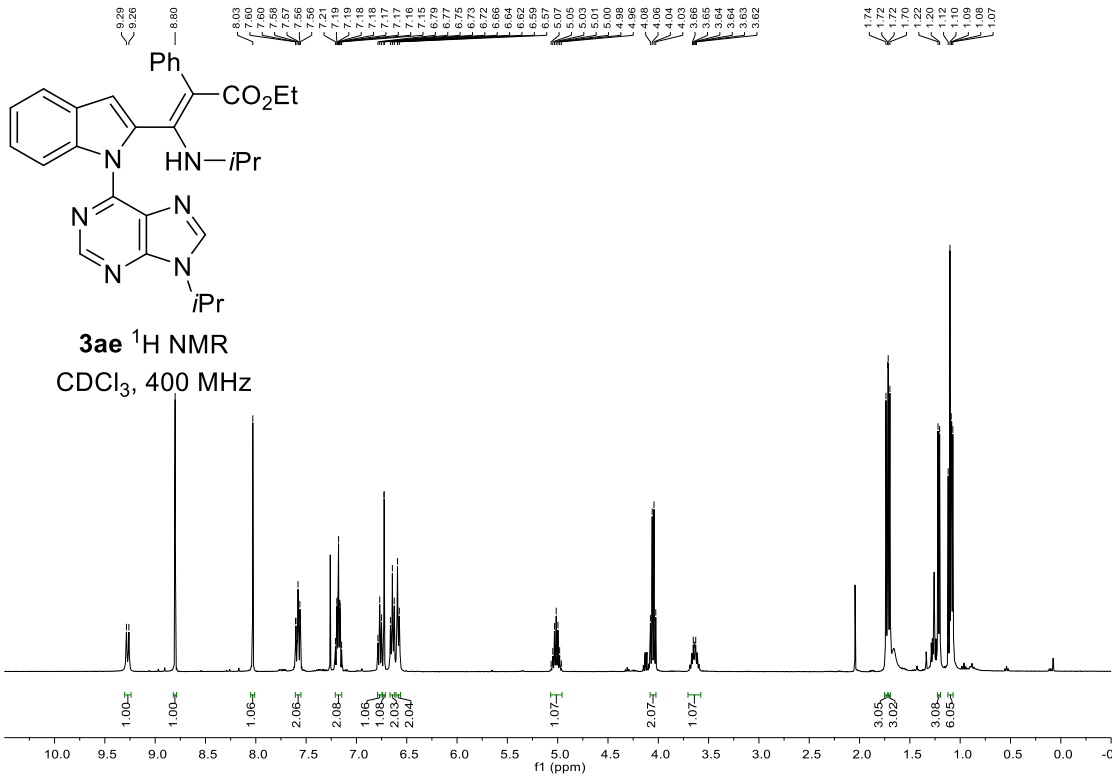


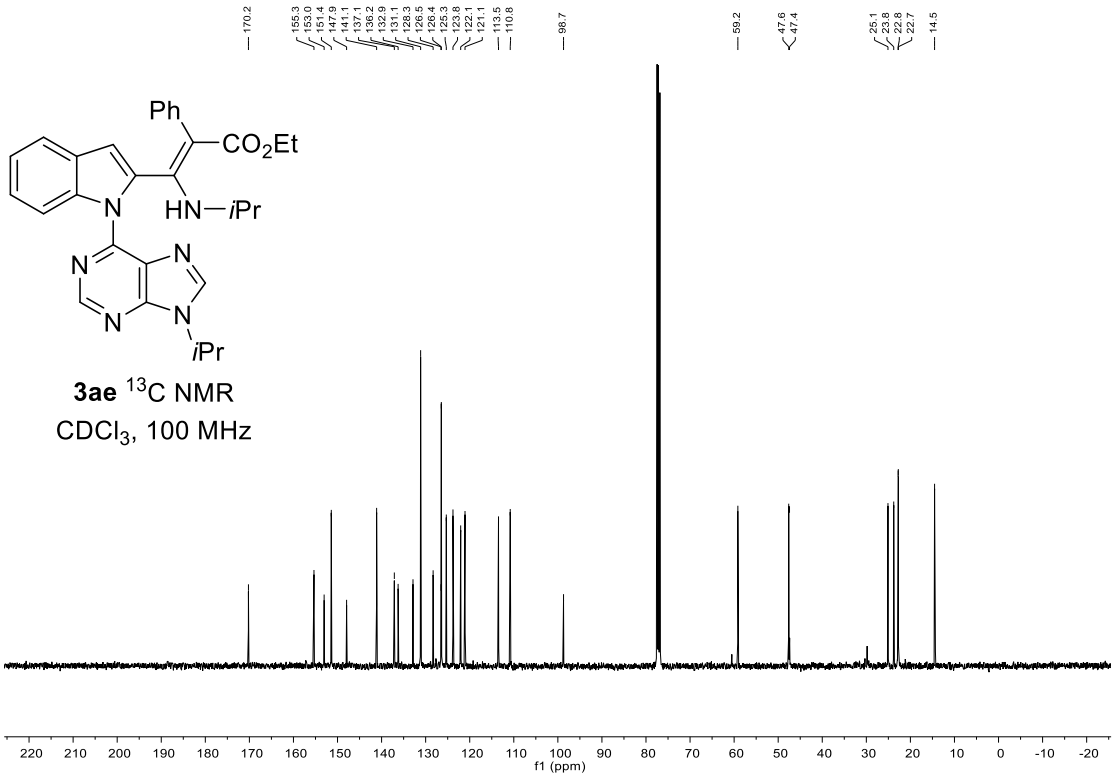
3ac ^{13}C NMR

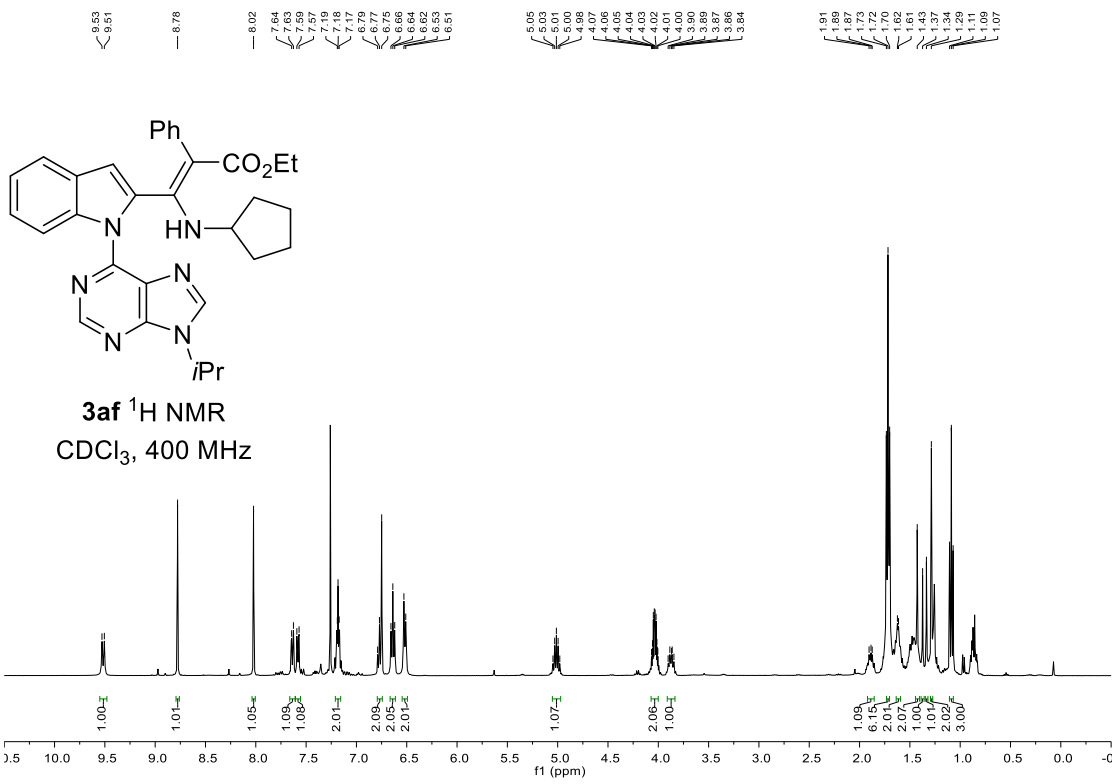
$CDCl_3$, 100 MHz


Ph
CO2Et
HN−Et
N
N
N
N
iPr
3ad 1H NMR
CDCl3, 400 MHz
f1 (ppm)


Ph
CO2Et
HN−Et
N
N
N
N
iPr
3ad 13C NMR
CDCl3, 100 MHz
f1 (ppm)


Ph
CO2Et
HN—iPr
iPr
3ae 1H NMR
CDCl3, 400 MHz
f1 (ppm)


Ph
CO2Et
HN—iPr
iPr
3ae 13C NMR
CDCl3, 100 MHz
f1 (ppm)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HN
N
N
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N
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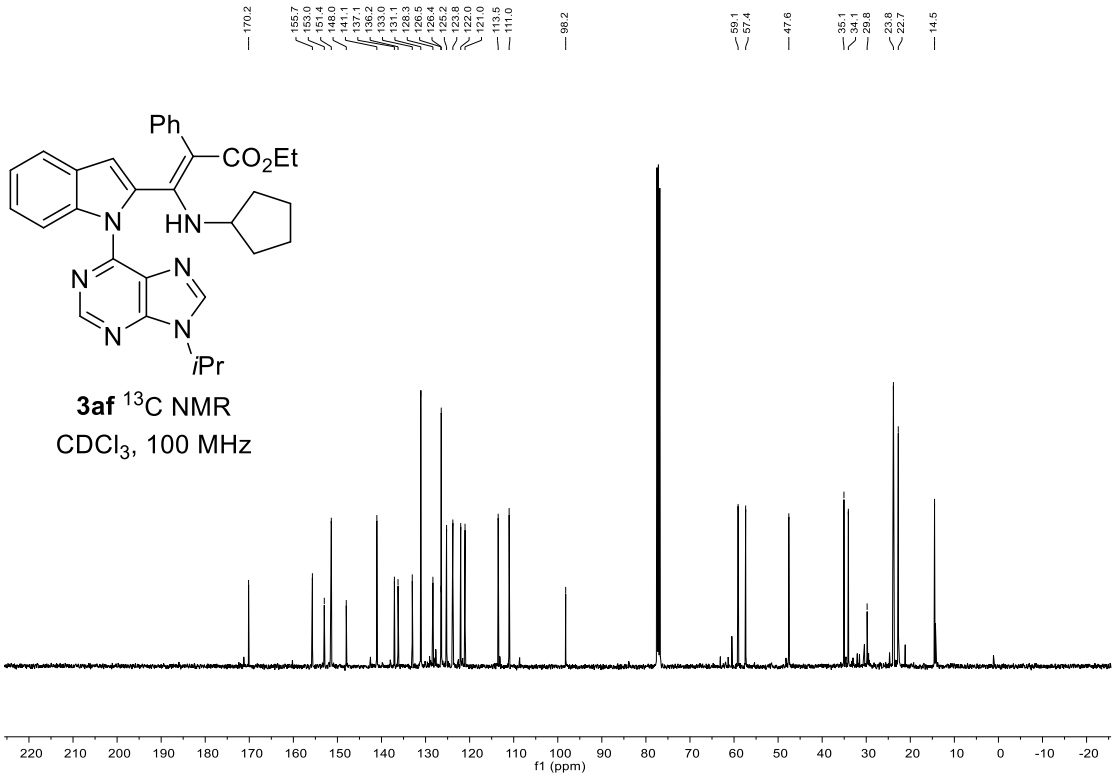
3af 1H NMR
CDCl3, 400 MHz
f1 (ppm)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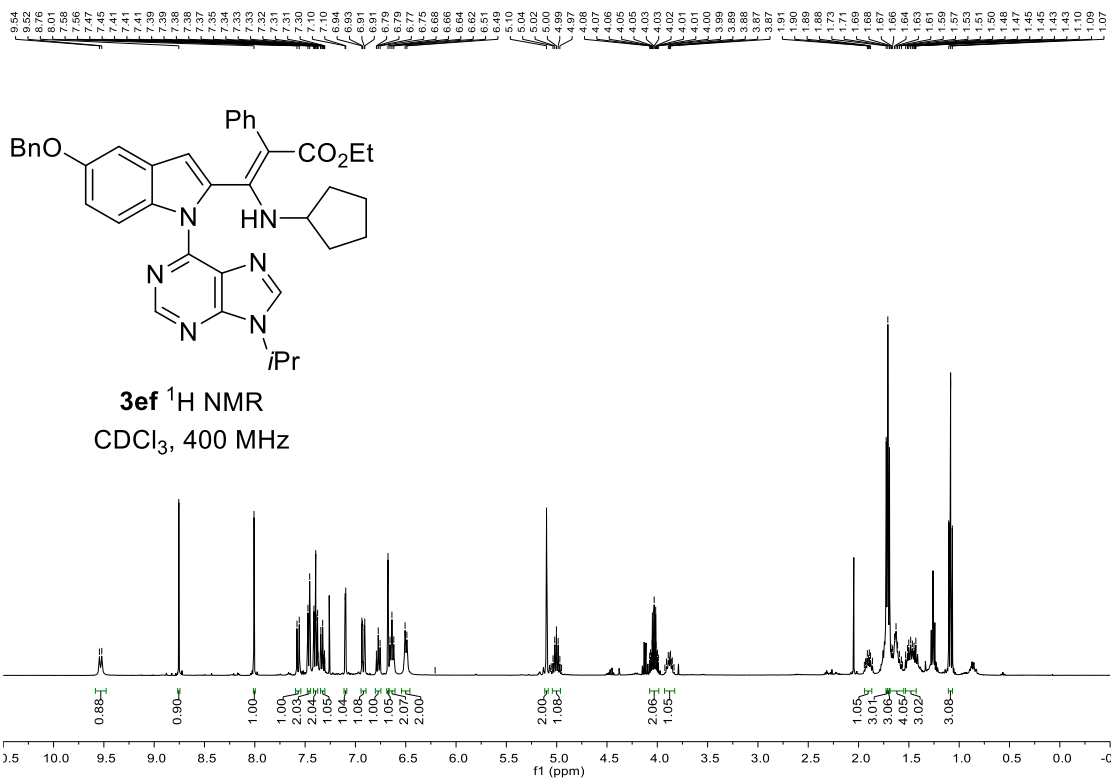
f1 (ppm)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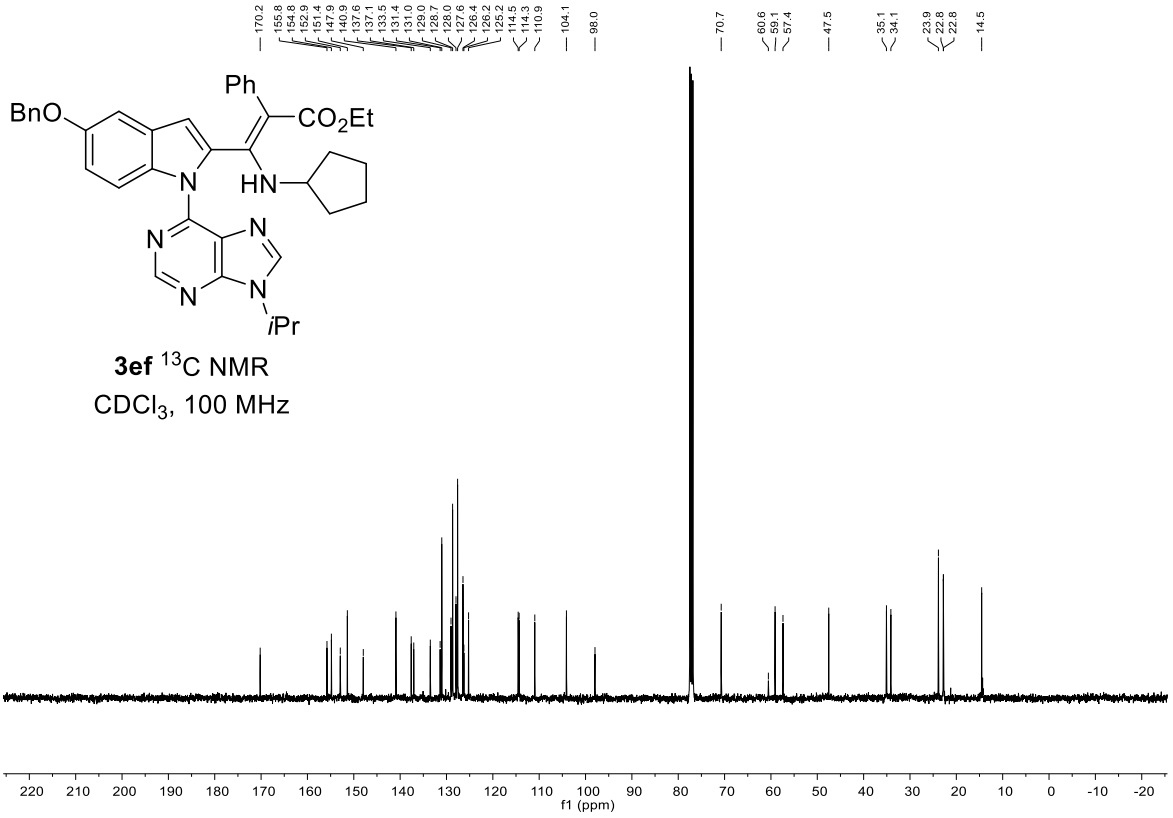
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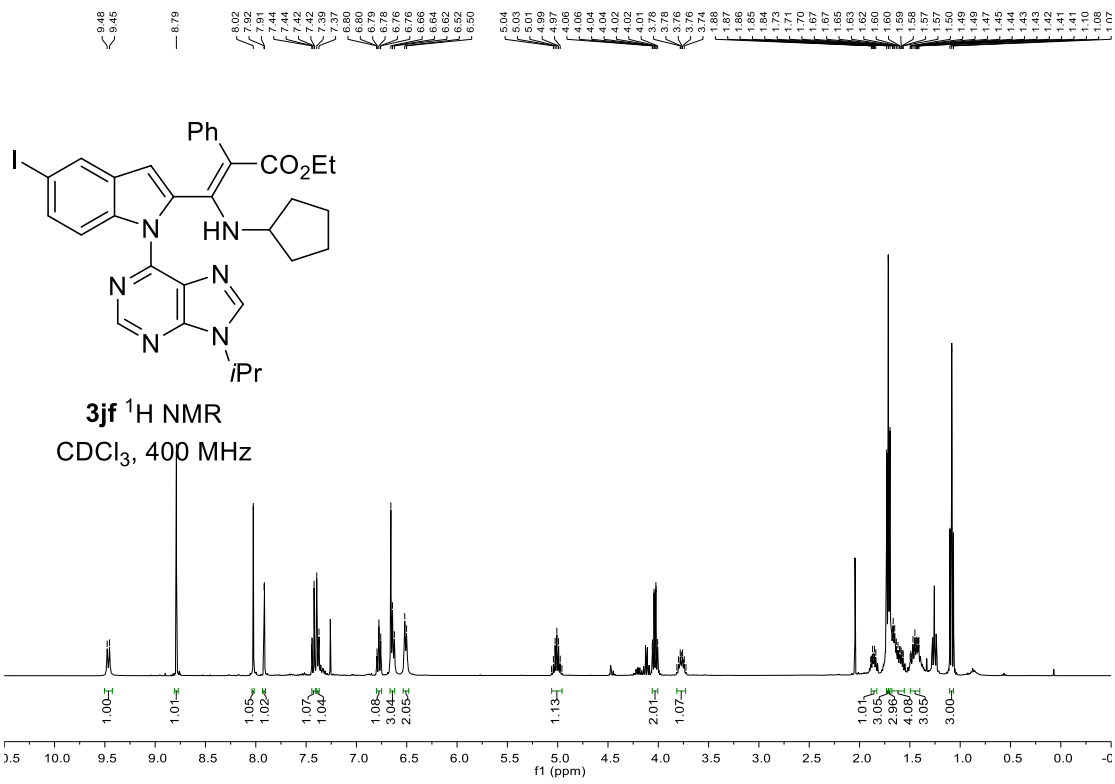
f1 (ppm)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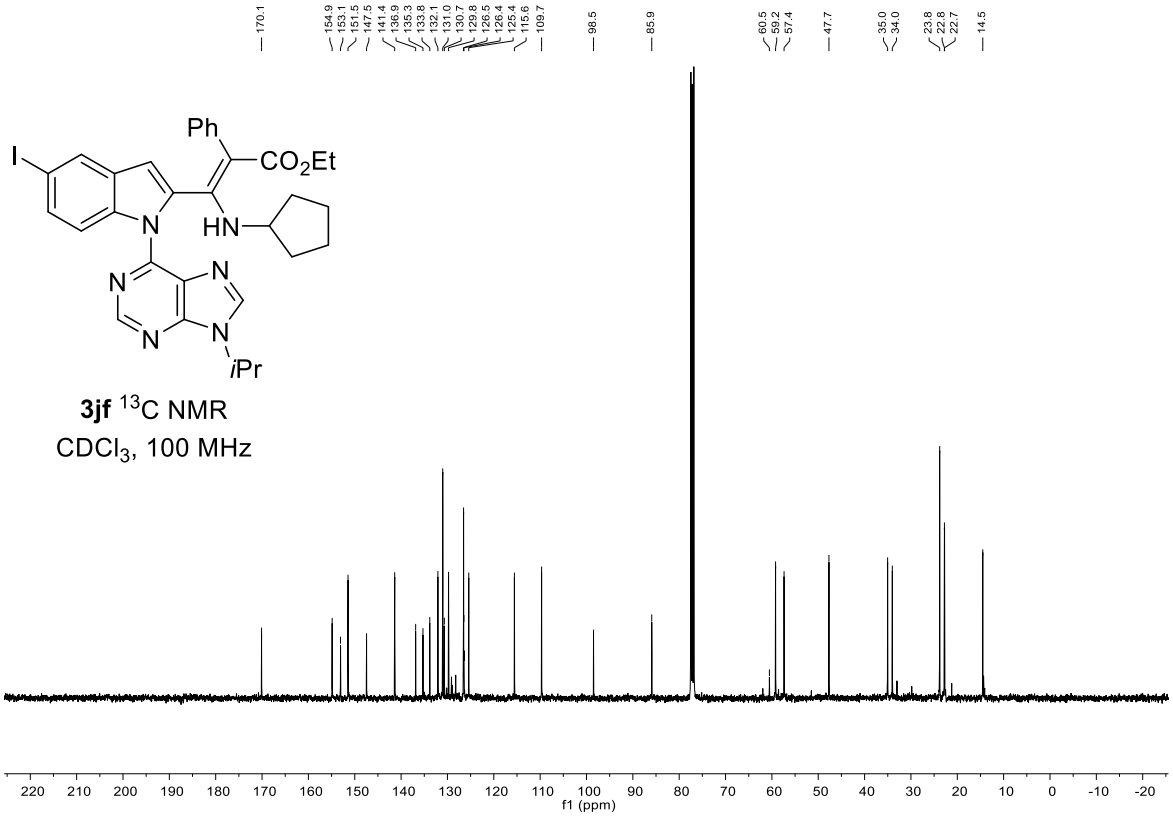
f1 (ppm)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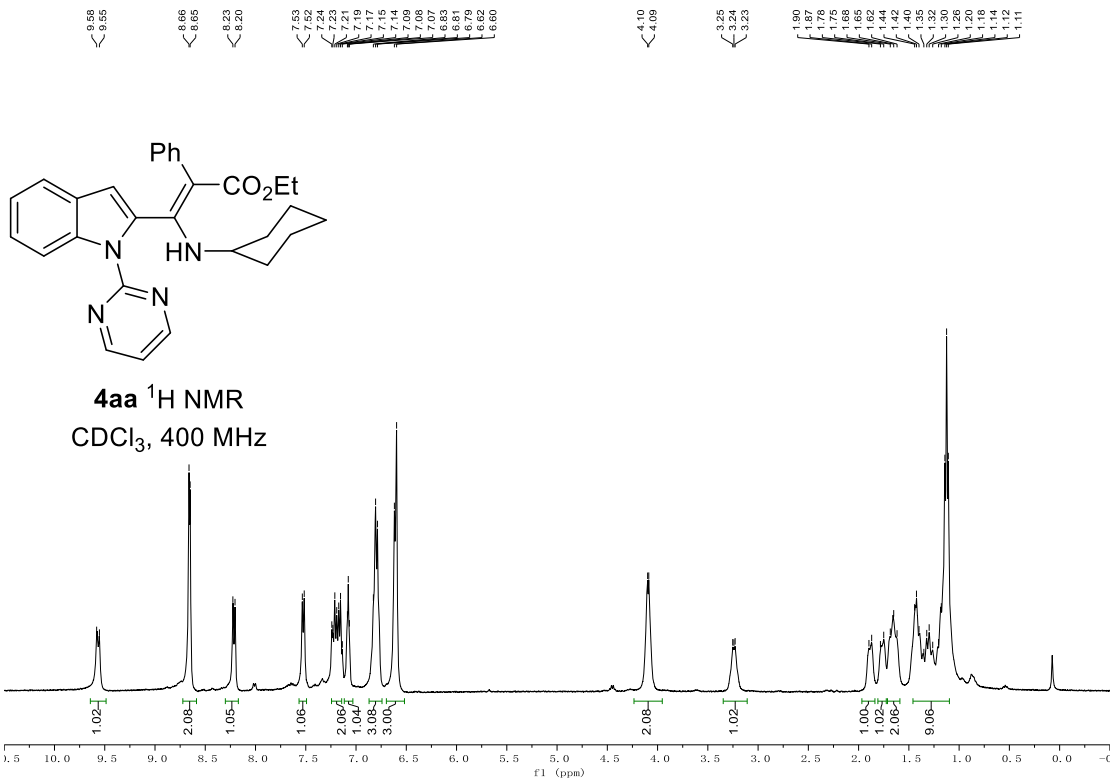
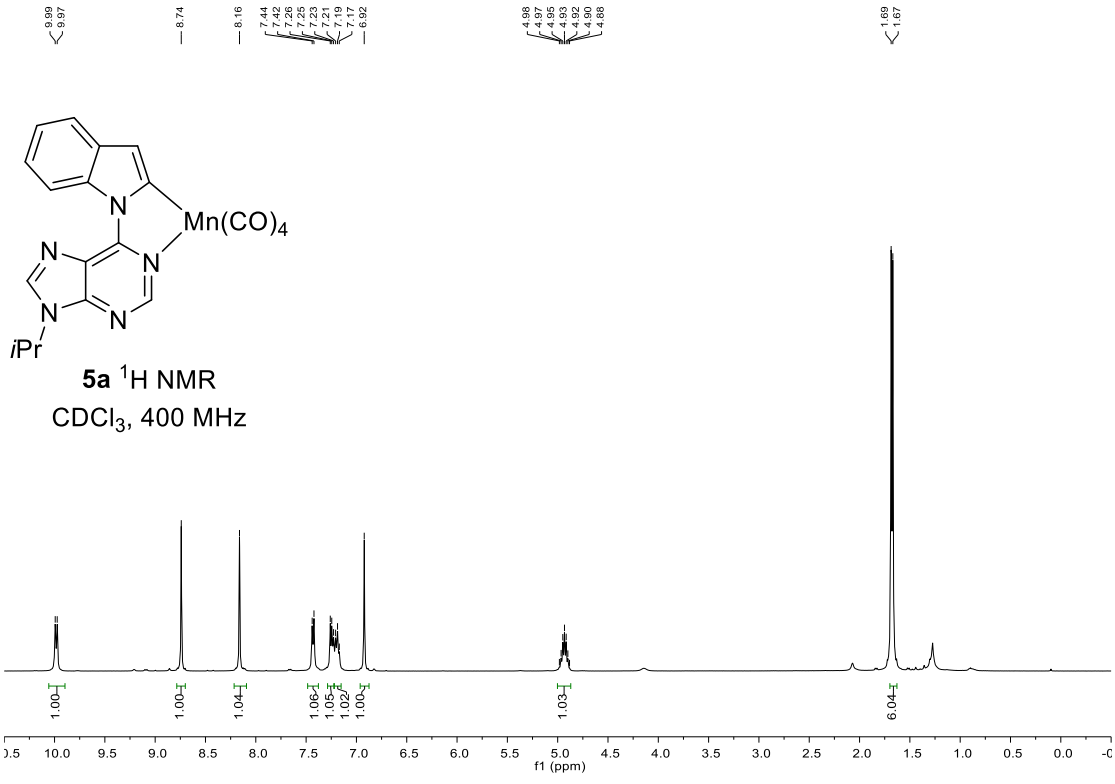
f1 (ppm)



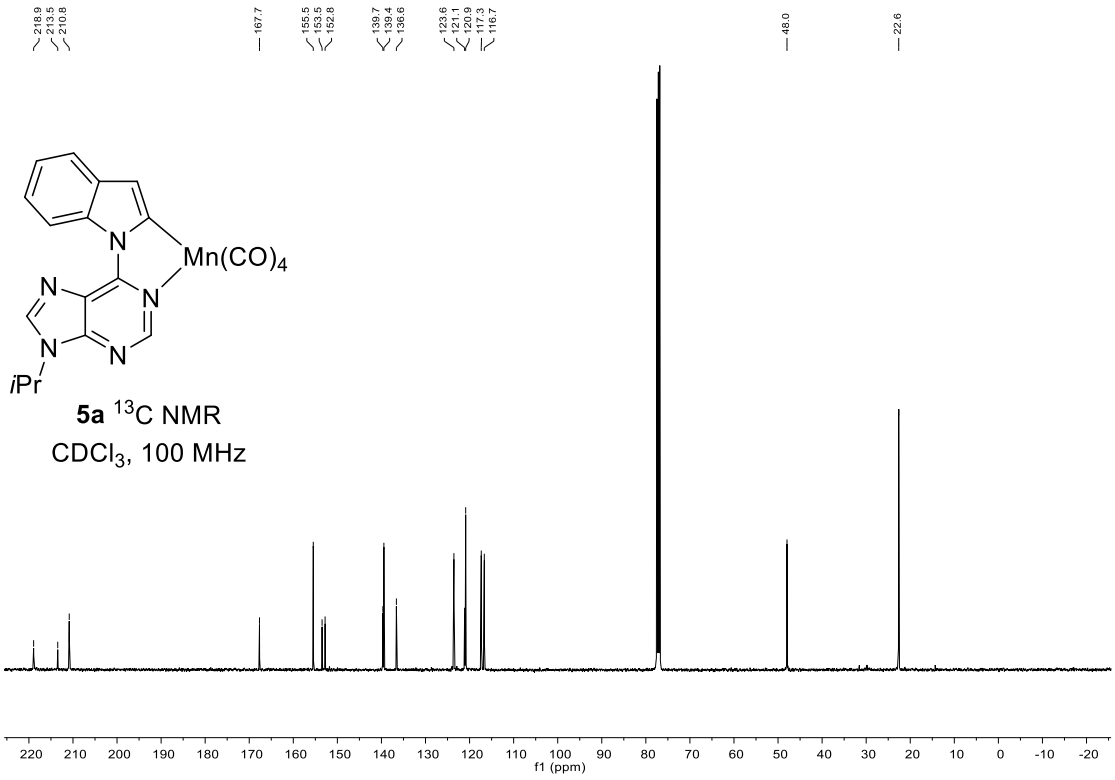
4aa ^{1}H NMR

$CDCl_3$, 400 MHz



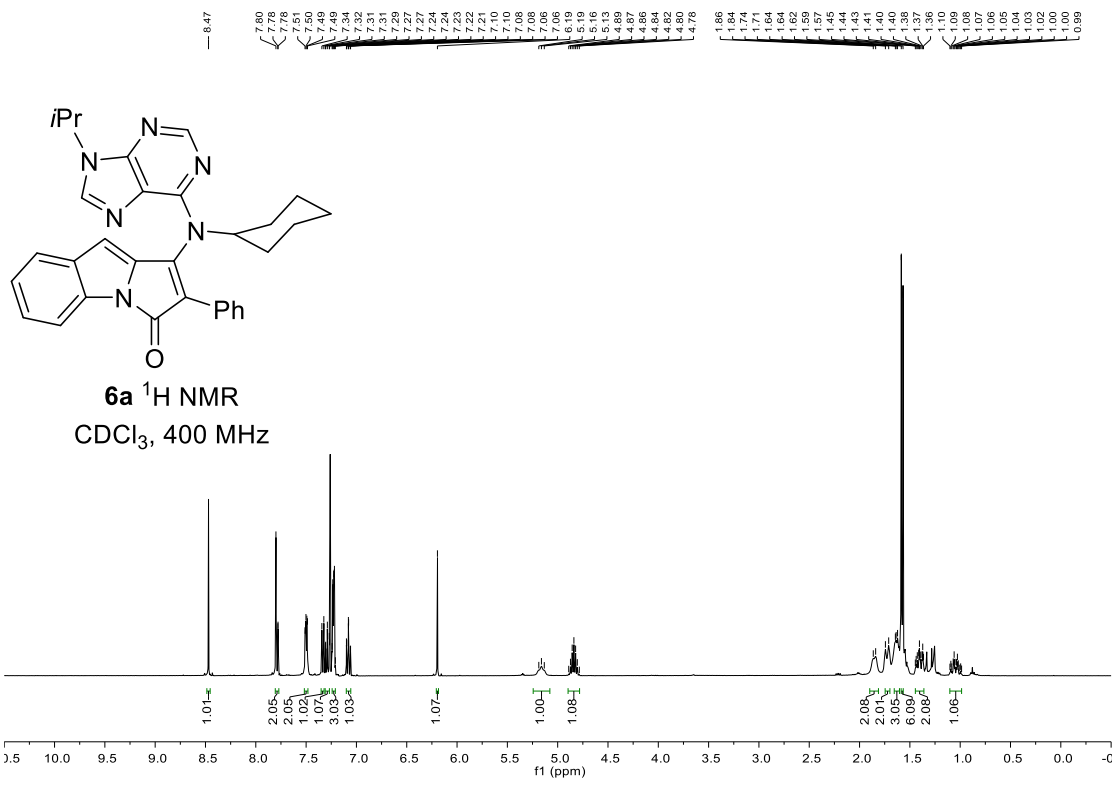
5a ^{1}H NMR

$CDCl_3$, 400 MHz



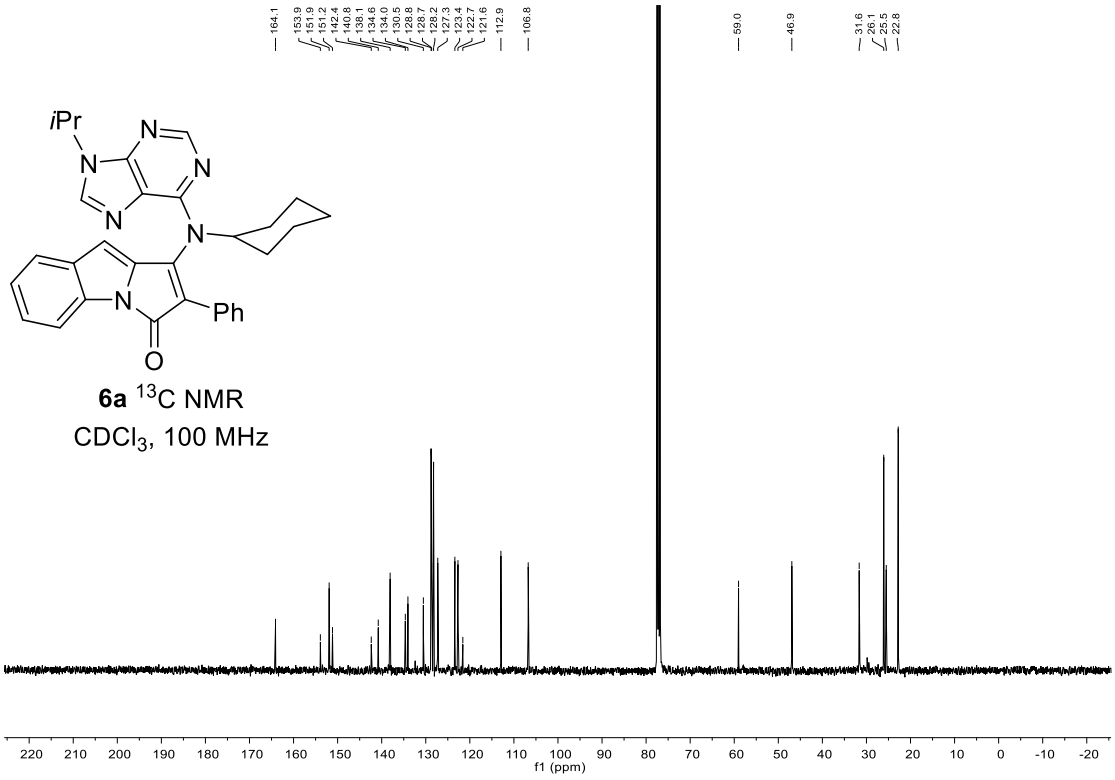
5a ^{13}C NMR

$CDCl_3$, 100 MHz



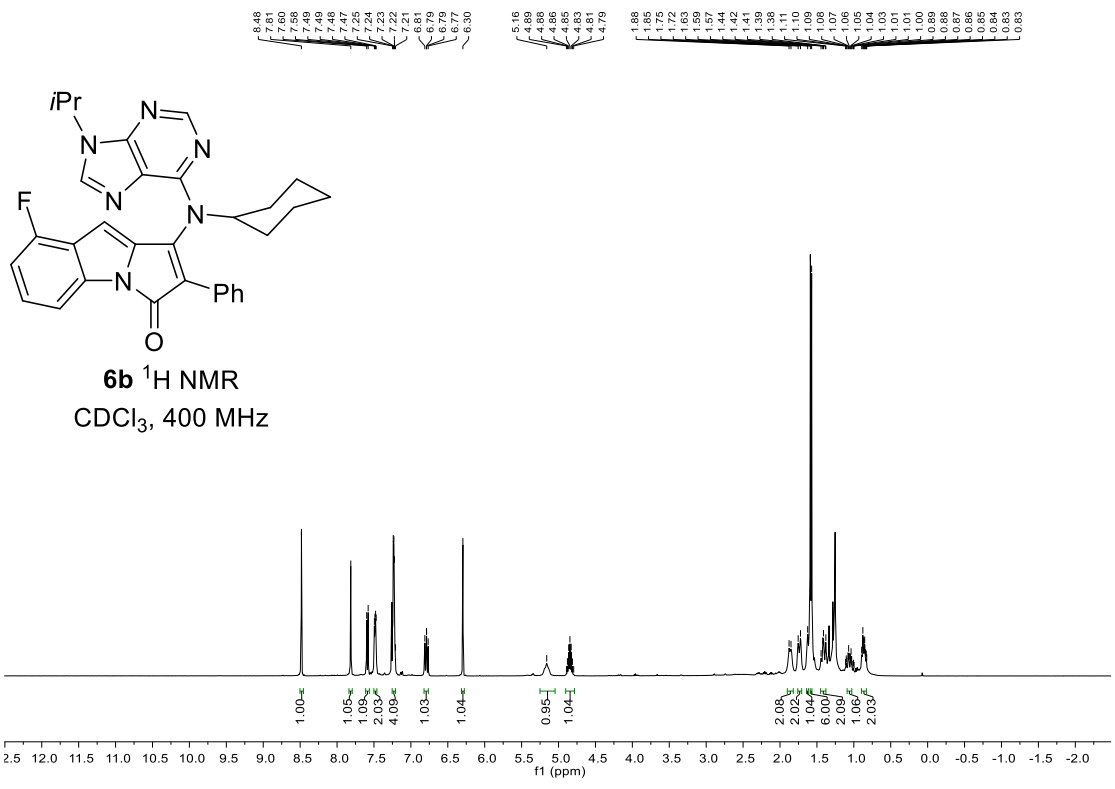
6a ^{1}H NMR

$CDCl_3$, 400 MHz



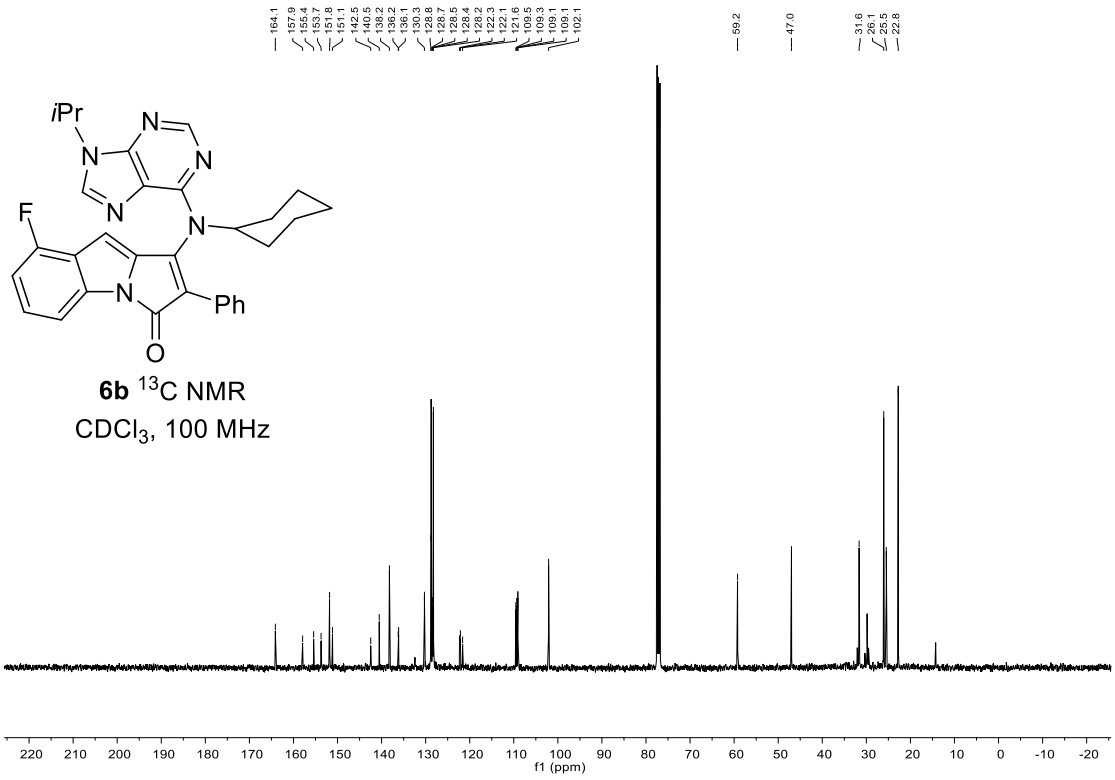
6a ^{13}C NMR

$CDCl_3$, 100 MHz



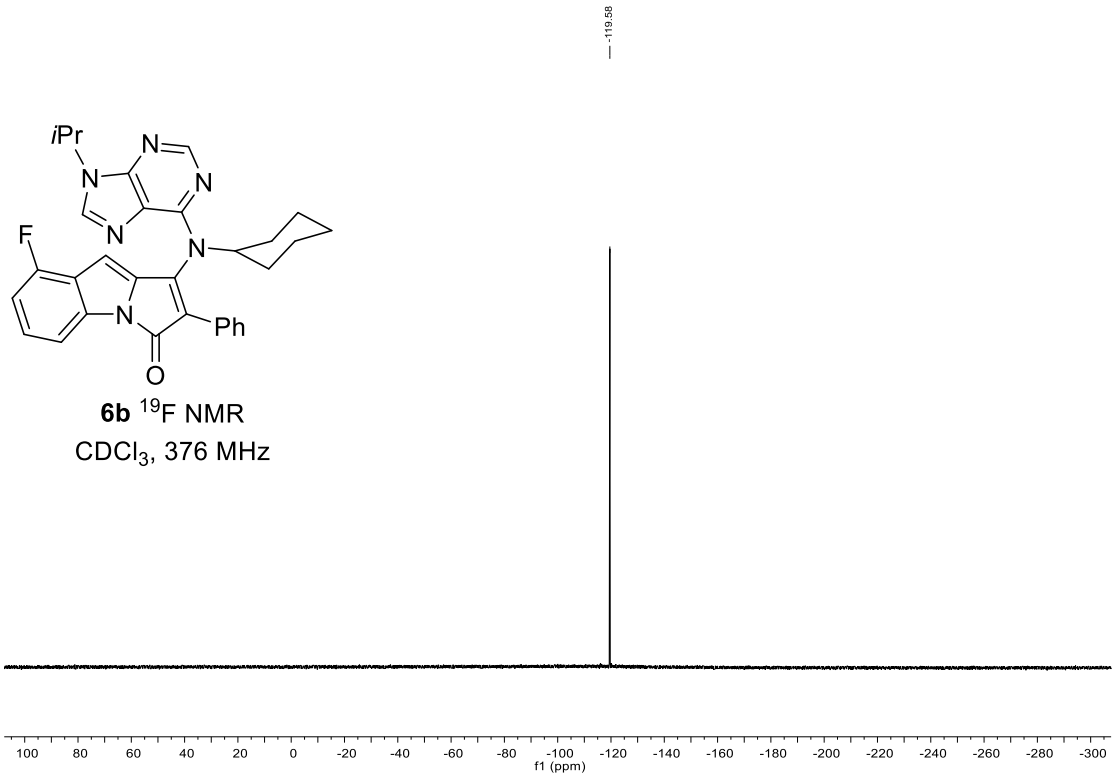
6b ^{1}H NMR

$CDCl_3$, 400 MHz



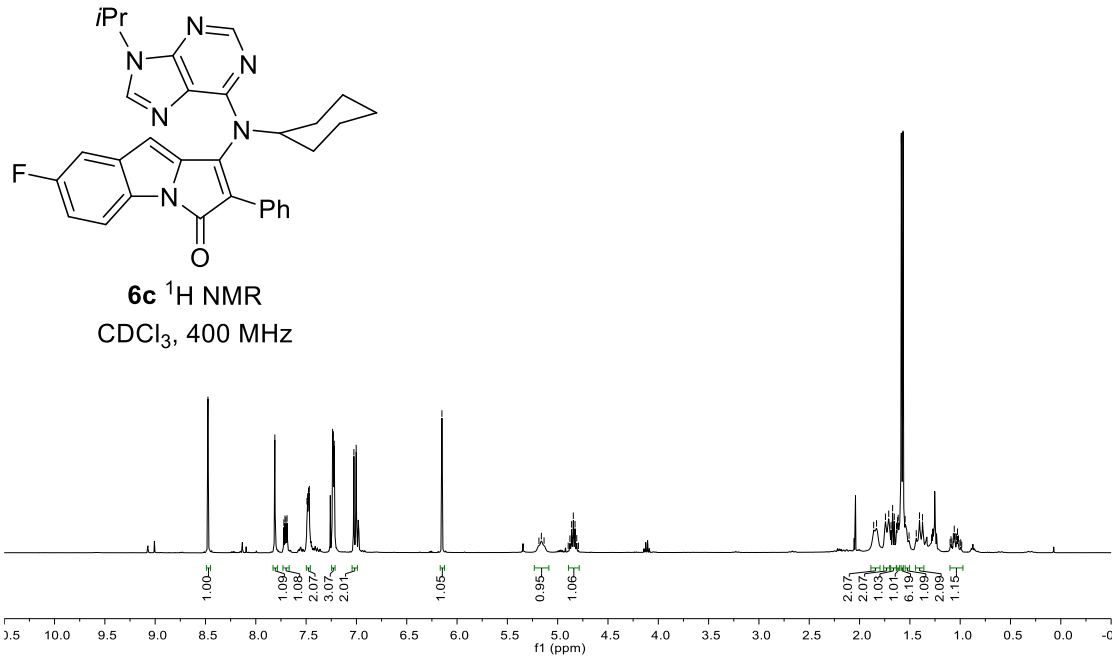
6b ^{13}C NMR

$CDCl_3$, 100 MHz



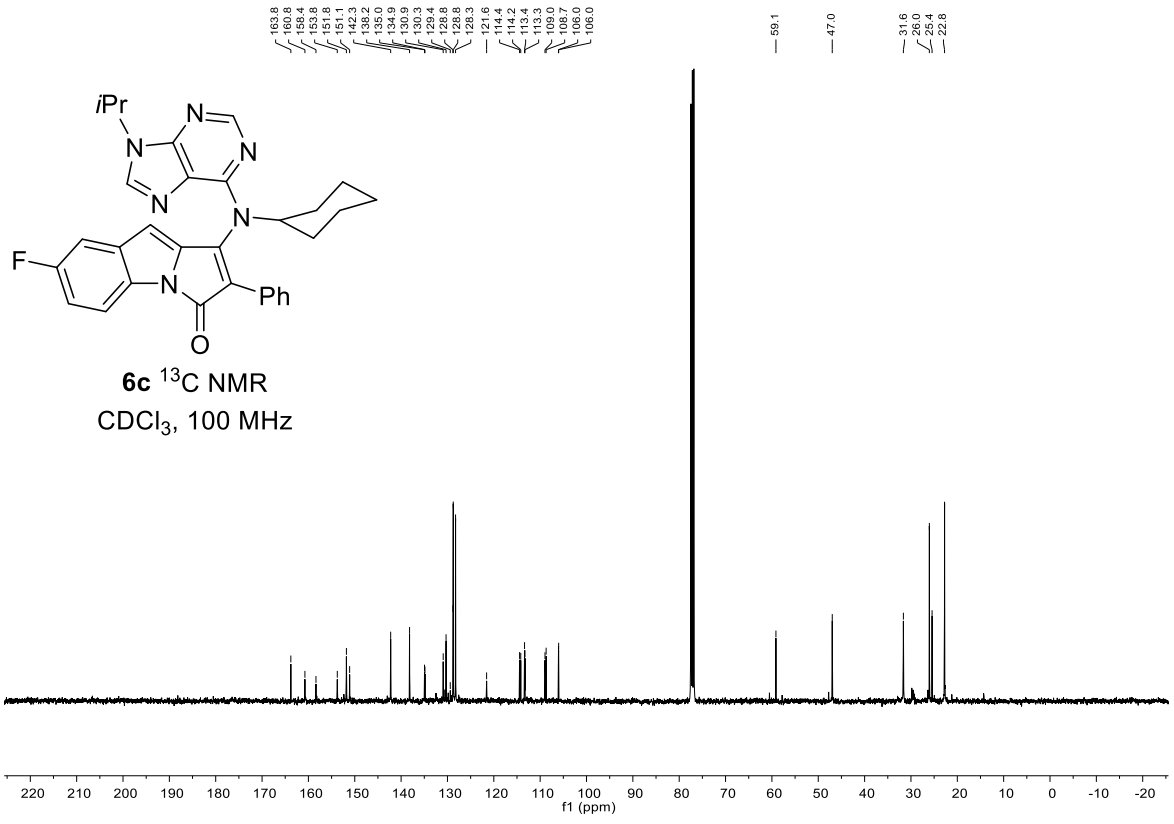
6b ^{19}F NMR

$CDCl_3$, 376 MHz



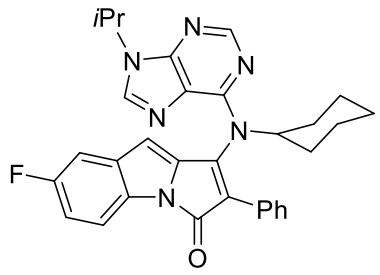
6c ^{1}H NMR

$CDCl_3$, 400 MHz



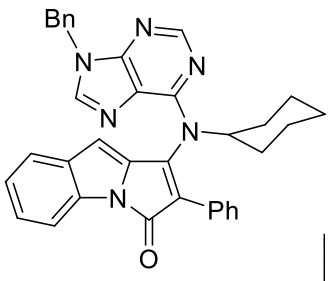
6c ^{13}C NMR

$CDCl_3$, 100 MHz



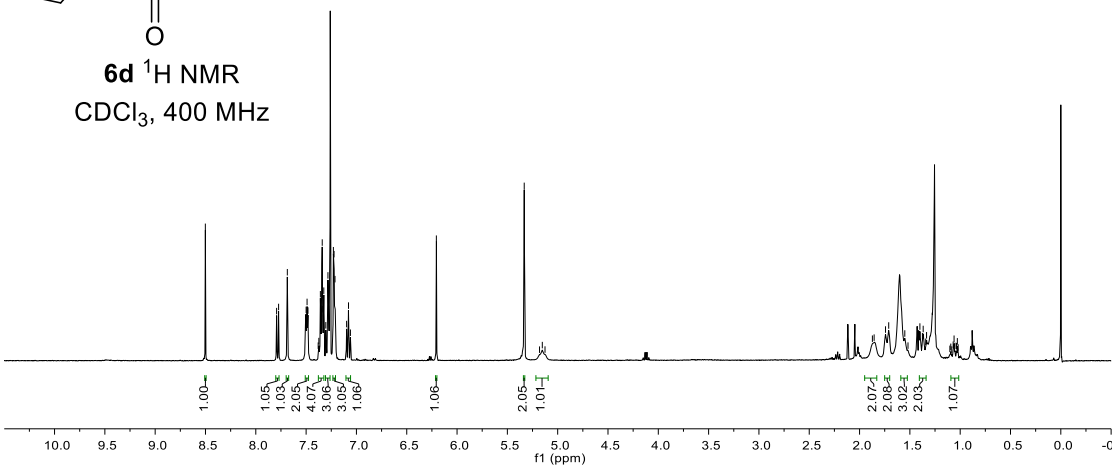
6c ^{19}F NMR

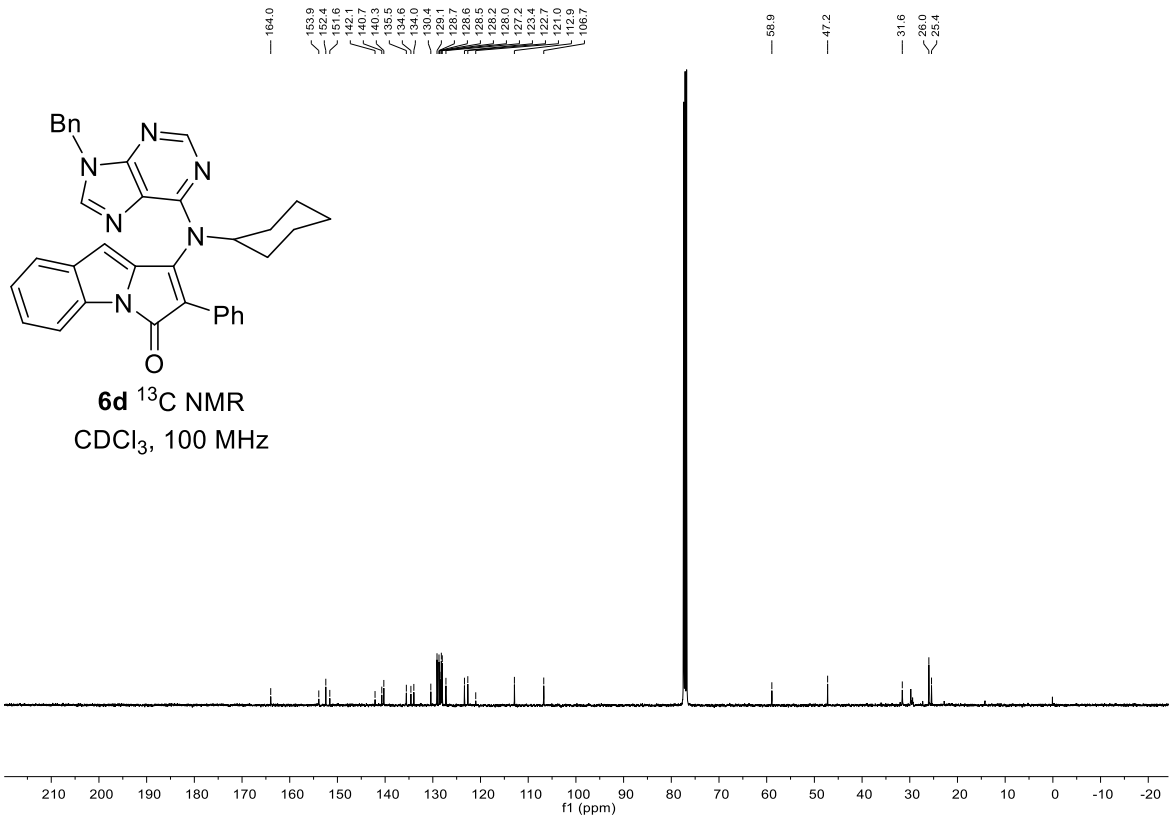
$CDCl_3$, 376 MHz



6d ^{1}H NMR

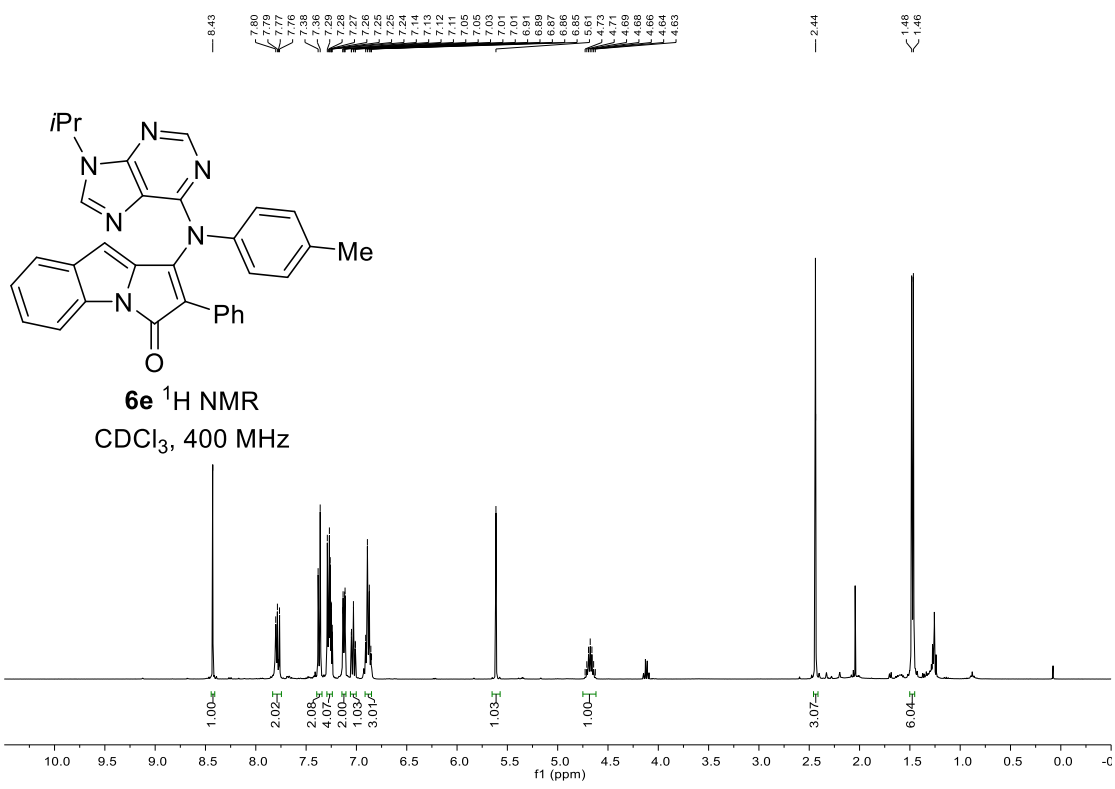
$CDCl_3$, 400 MHz





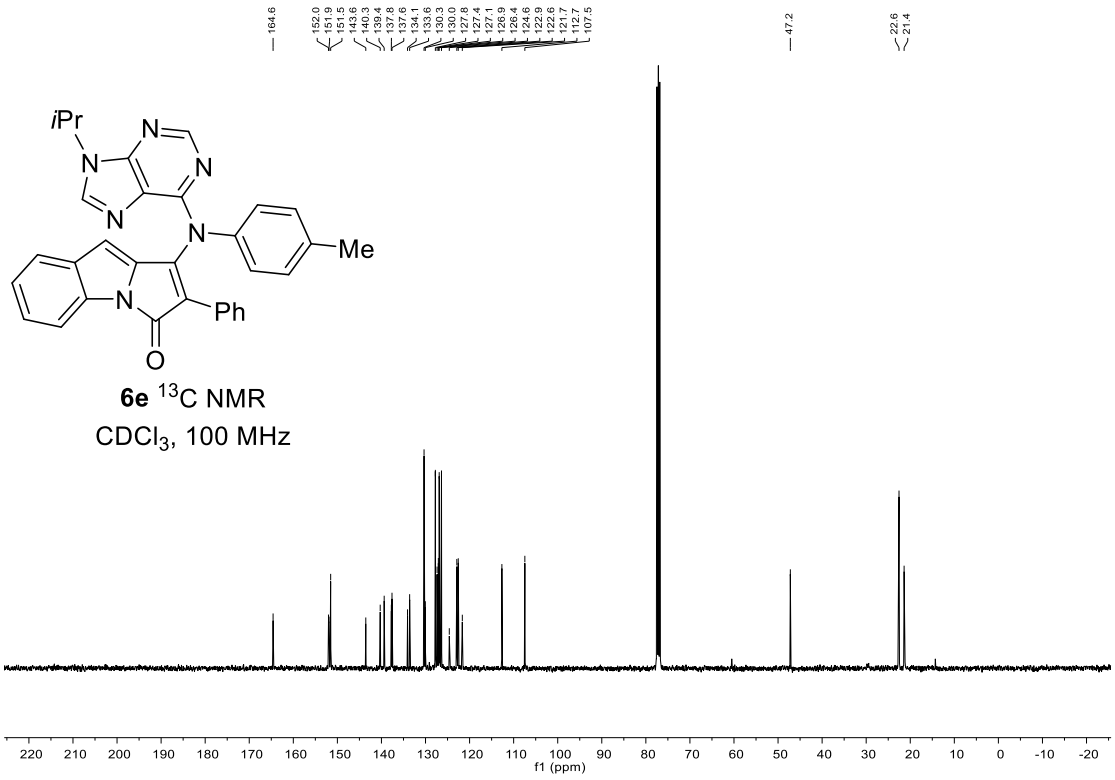
6d ^{13}C NMR

$CDCl_3$, 100 MHz



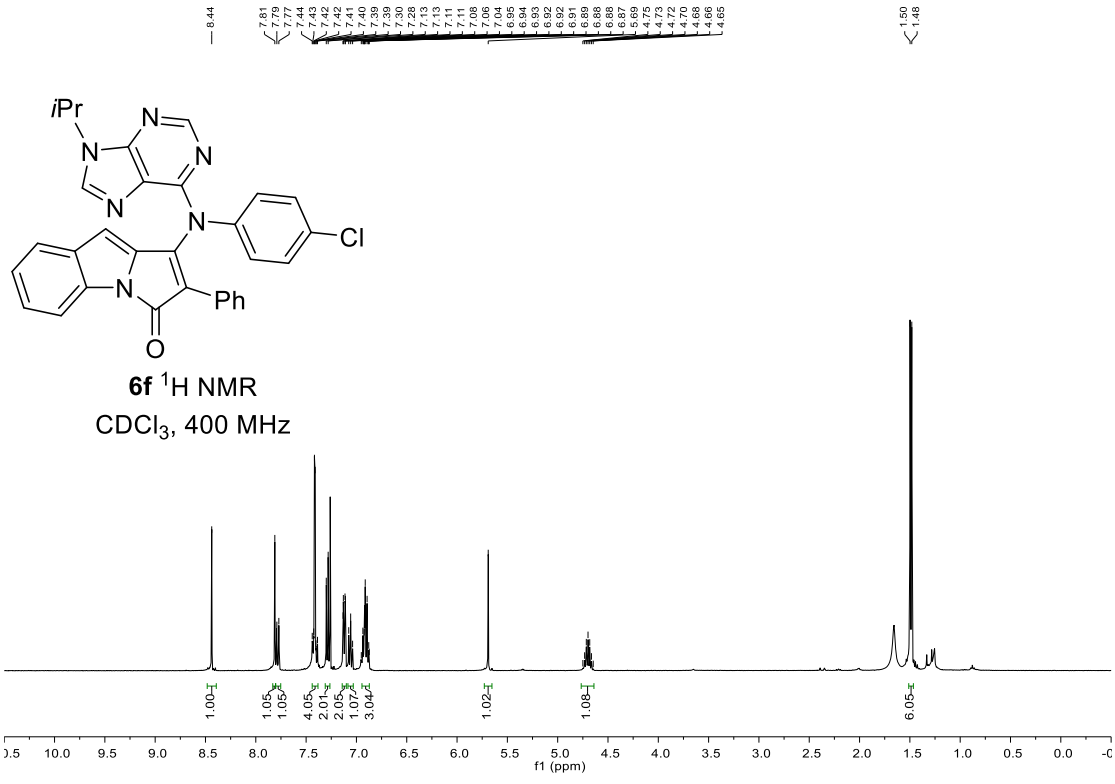
6e ^{1}H NMR

$CDCl_3$, 400 MHz



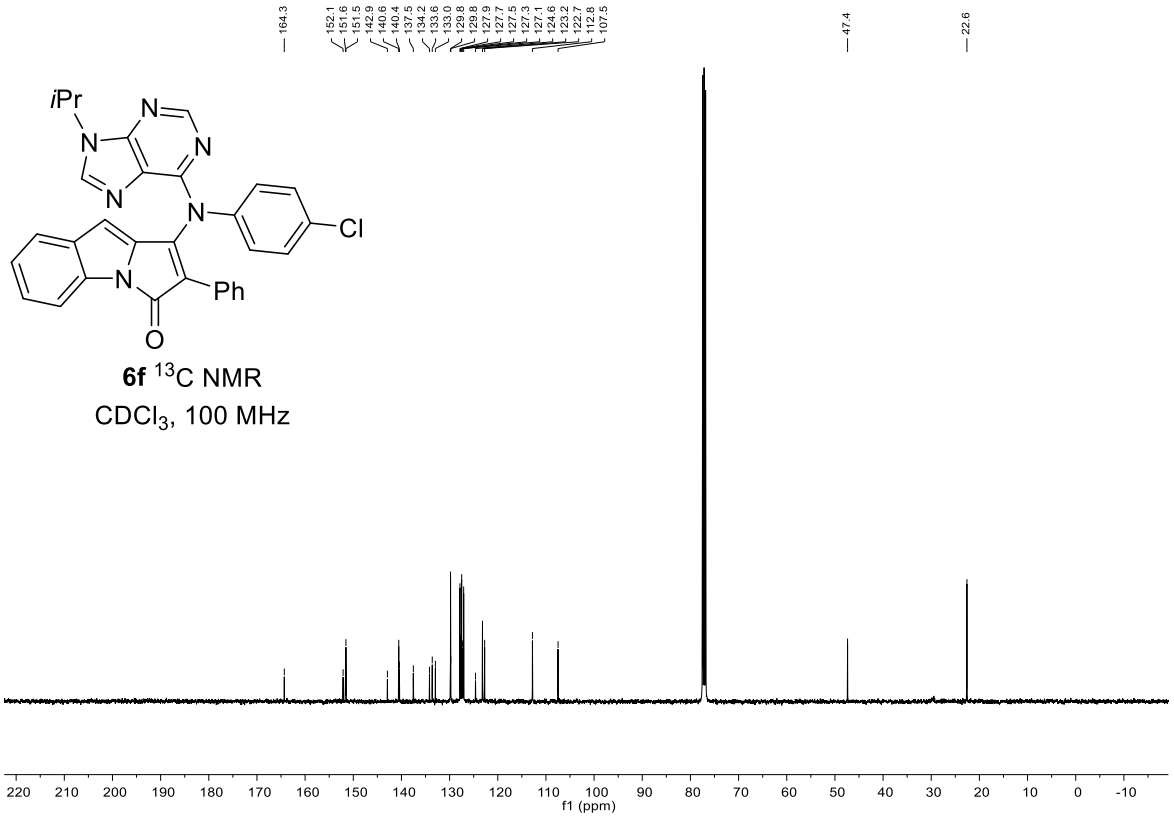
6e ^{13}C NMR

$CDCl_3$, 100 MHz



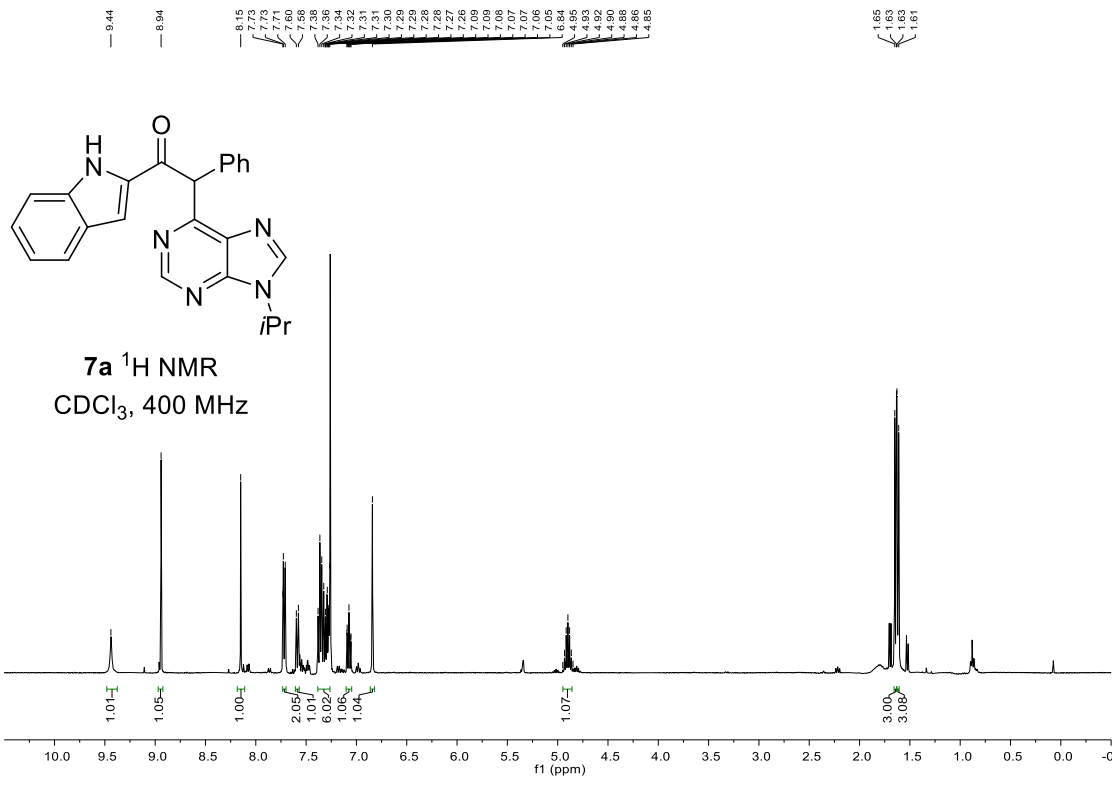
6f ^{1}H NMR

$CDCl_3$, 400 MHz



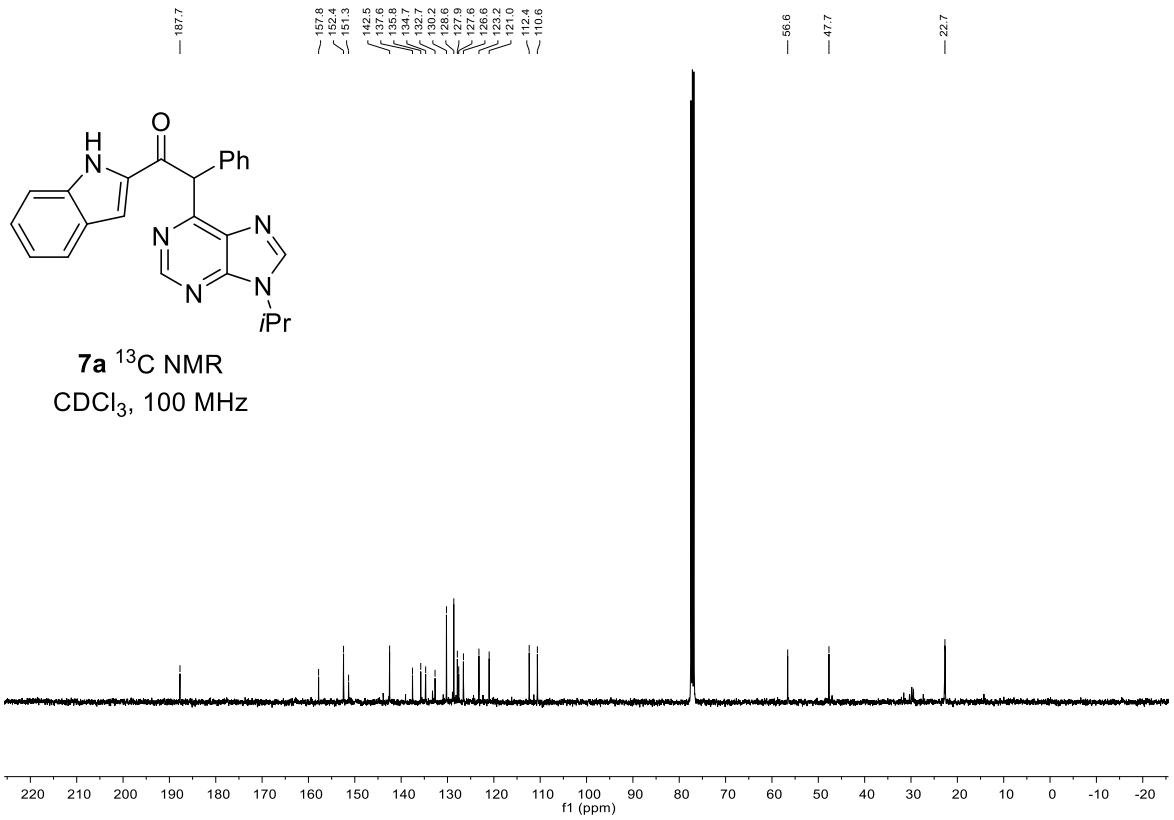
6f ^{13}C NMR

$CDCl_3$, 100 MHz

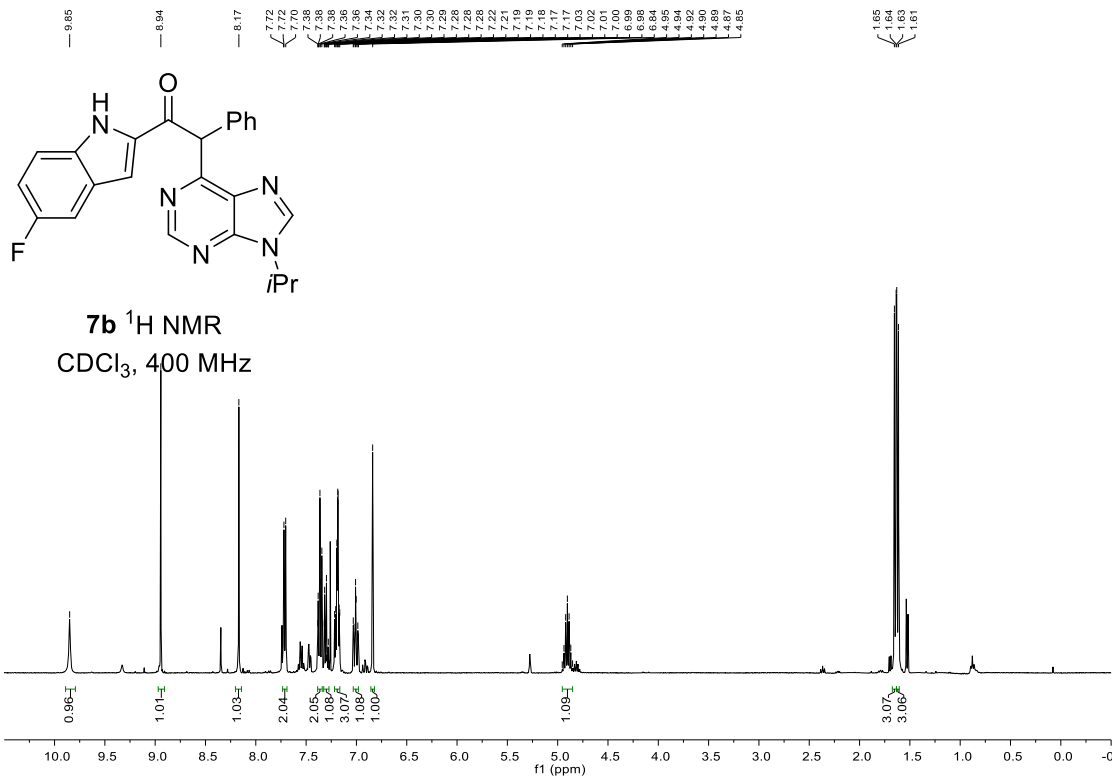


7a ^{1}H NMR

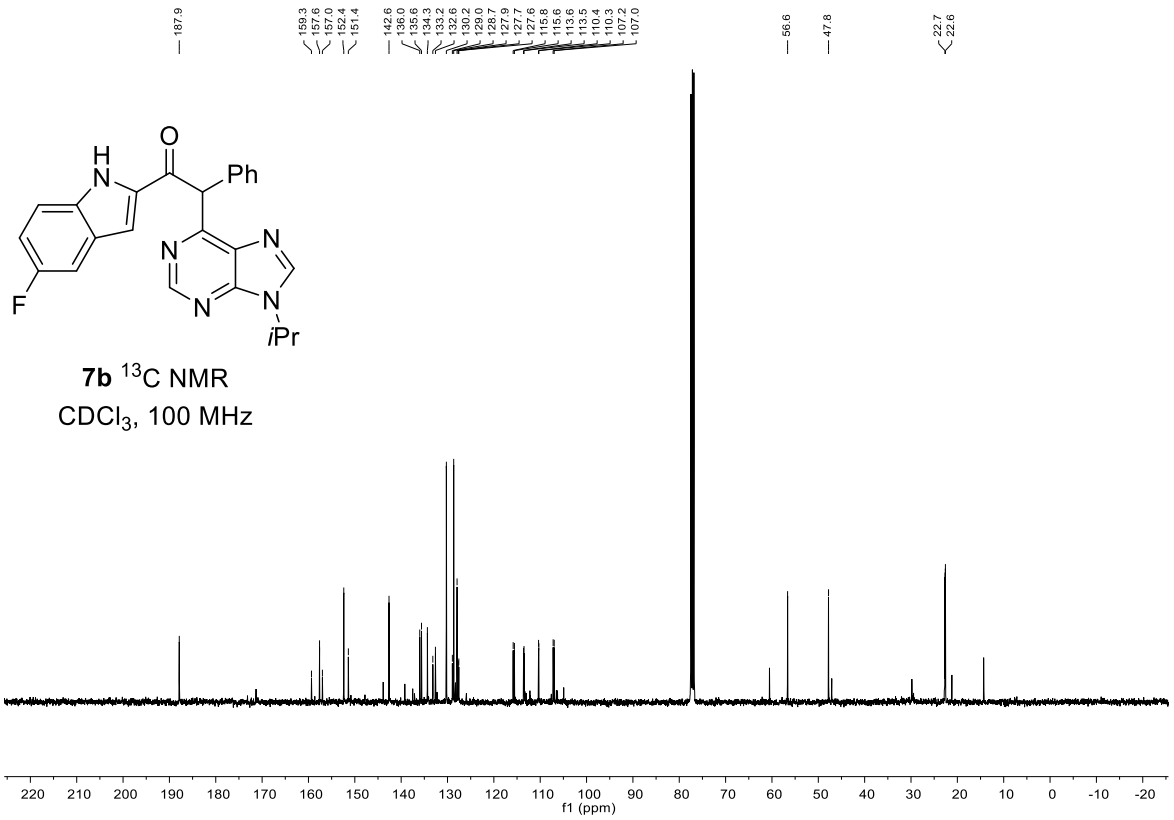
$CDCl_3$, 400 MHz



7a ^{13}C NMR
$CDCl_3$, 100 MHz

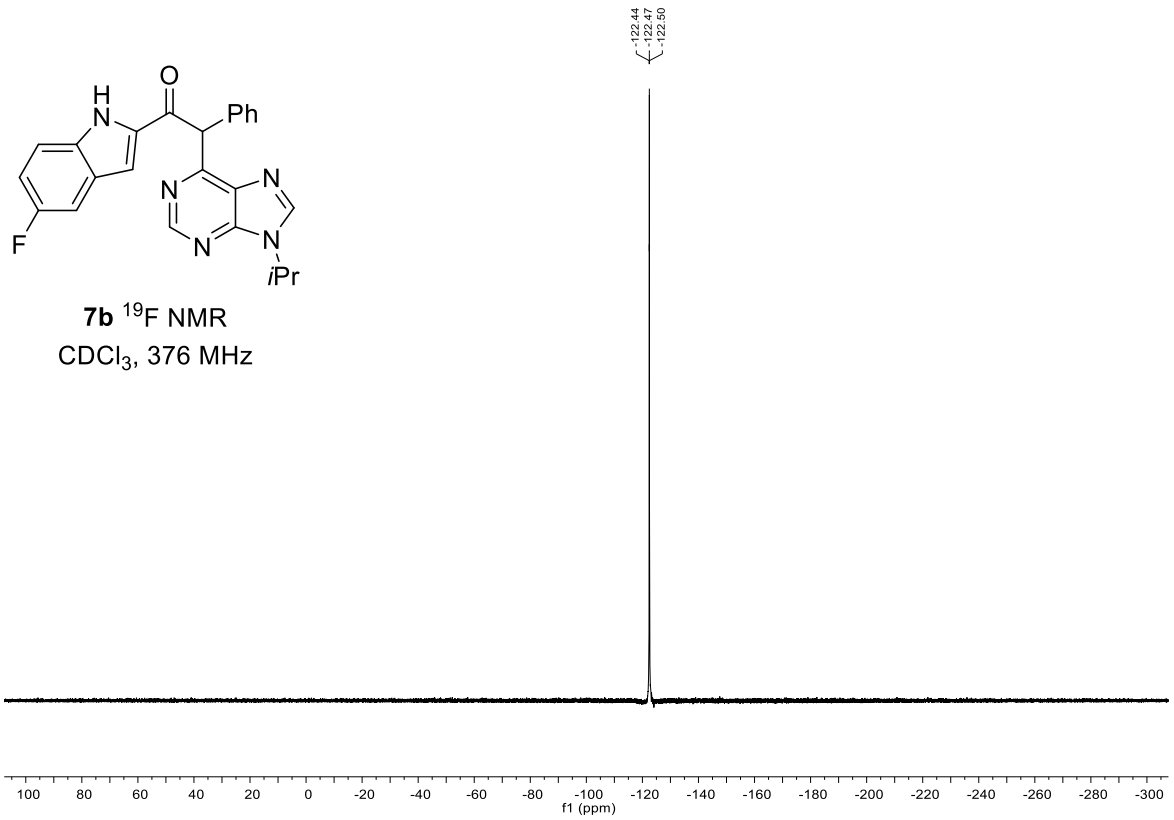


7b ^{1}H NMR
$CDCl_3$, 400 MHz



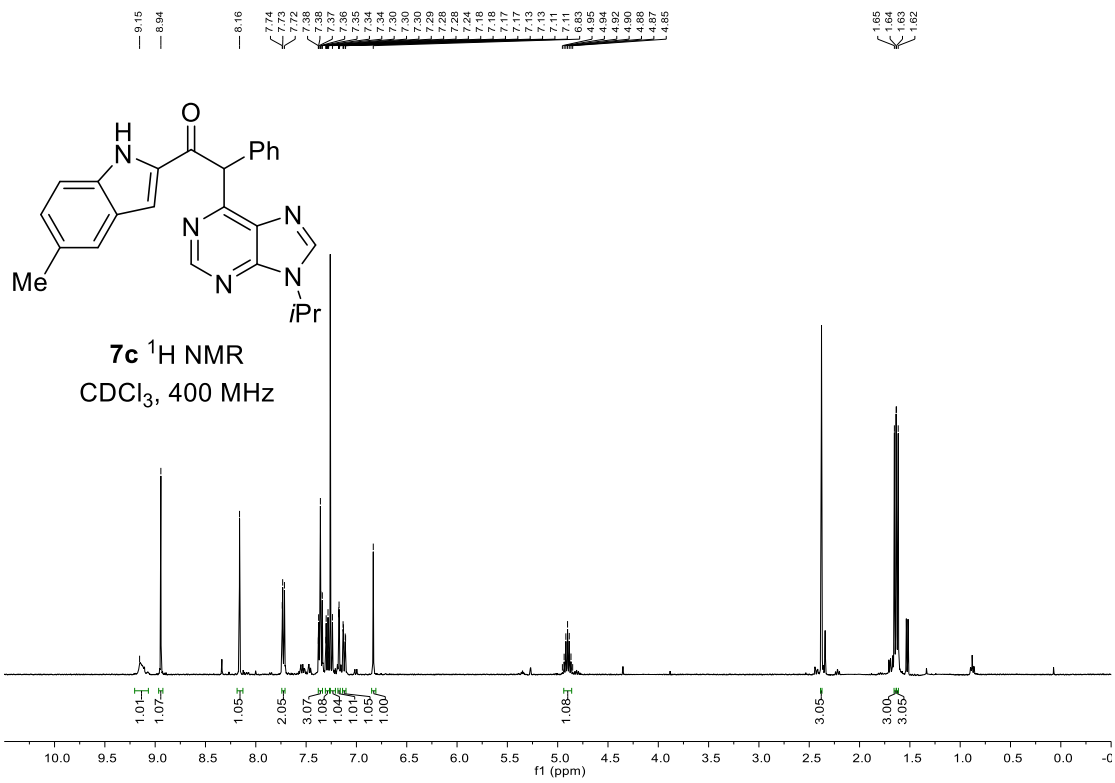
7b ^{13}C NMR

$CDCl_3$, 100 MHz



7b ^{19}F NMR

$CDCl_3$, 376 MHz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7.13
7.11
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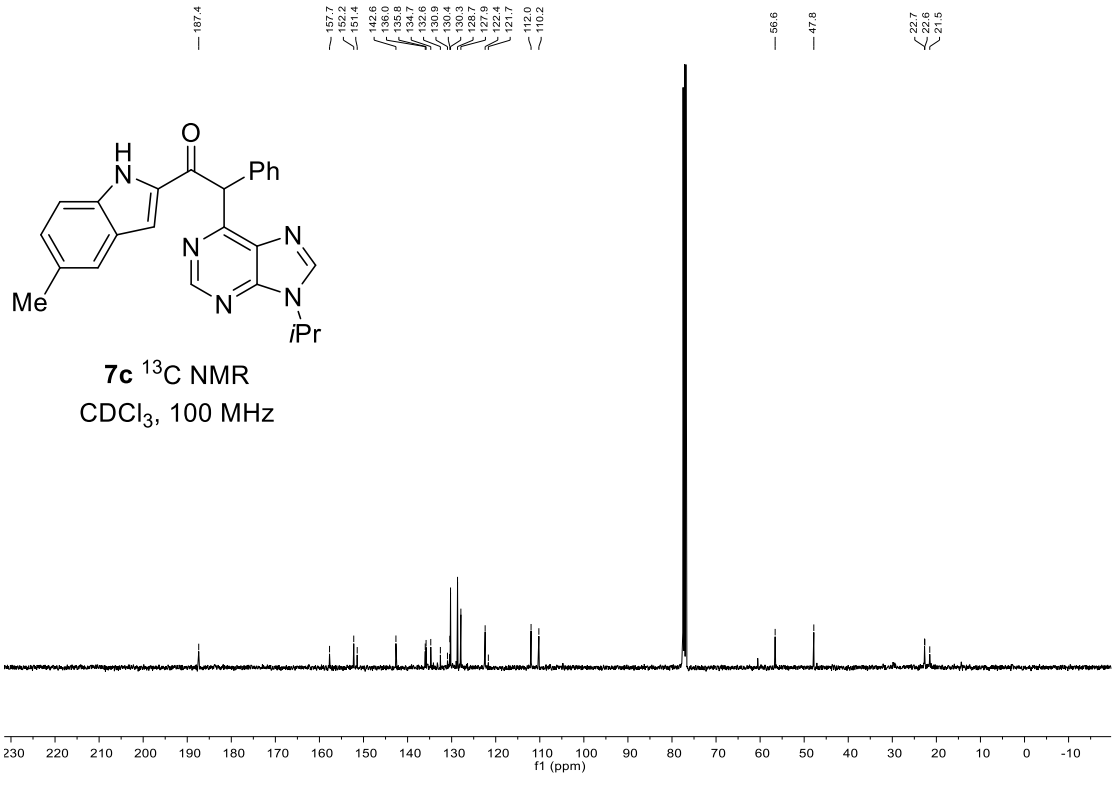
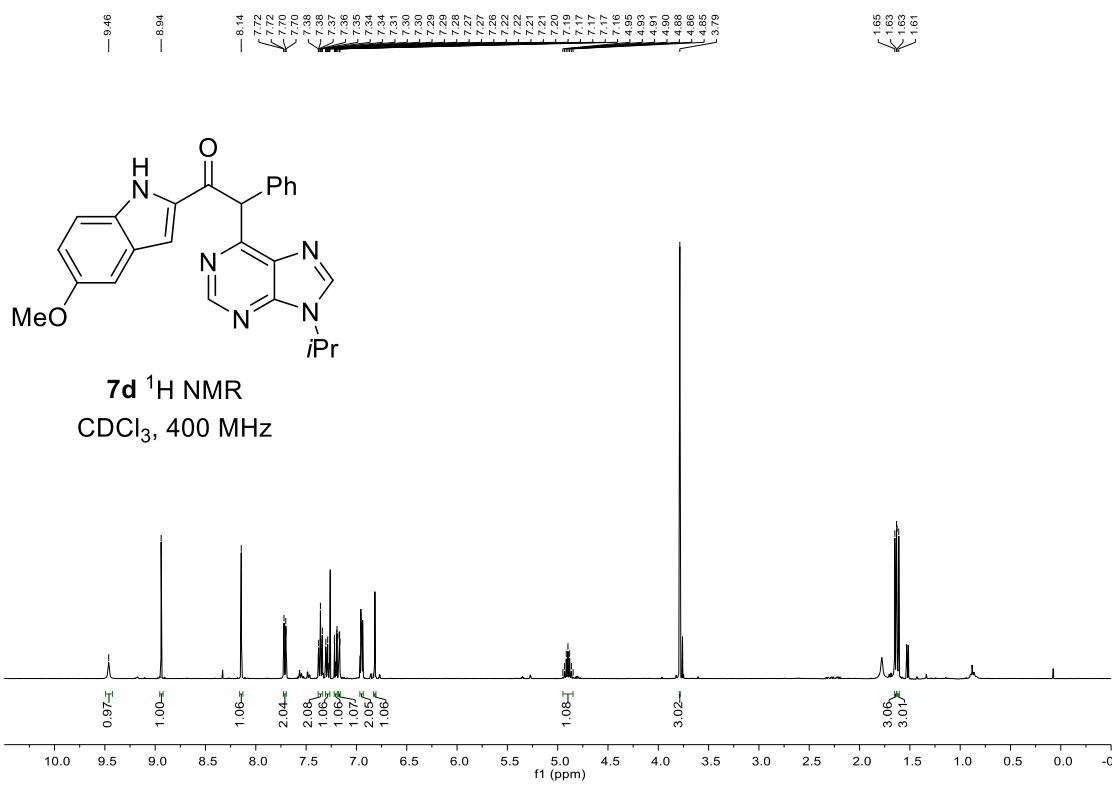
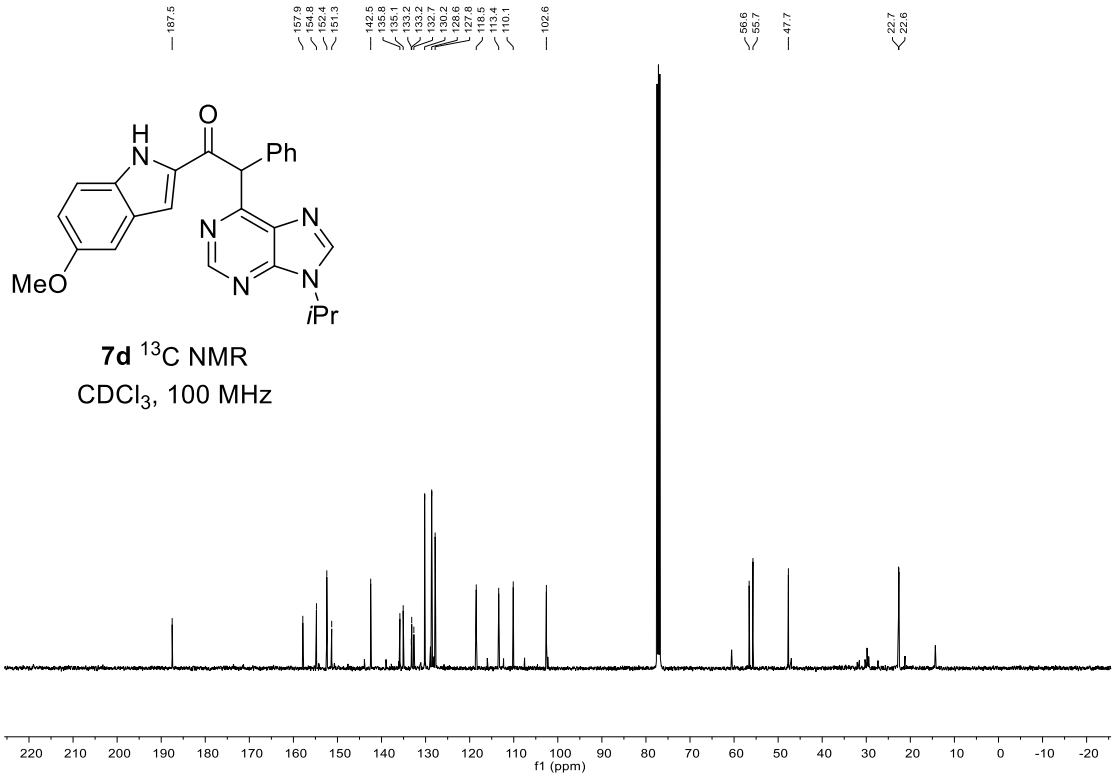
4.94
4.92
4.90
4.88
4.87
4.85
1.65
1.64
1.63
1.62
O
H
N
Ph
N
N
N
N
Me
iPr
7c 1H NMR
CDCl3, 400 MHz
1.01
1.07
1.05
2.05
3.07
1.08
1.04
1.01
1.05
1.00
1.08
3.05
3.00
3.05
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


187.4
157.7
152.2
151.4
142.6
136.0
135.8
134.7
132.6
130.9
130.4
130.3
128.7
127.9
122.4
121.7
112.0
110.2
56.6
47.8
22.7
21.6
21.5
O
H
N
Ph
N
N
N
N
Me
iPr
7c 13C NMR
CDCl3, 100 MHz
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)



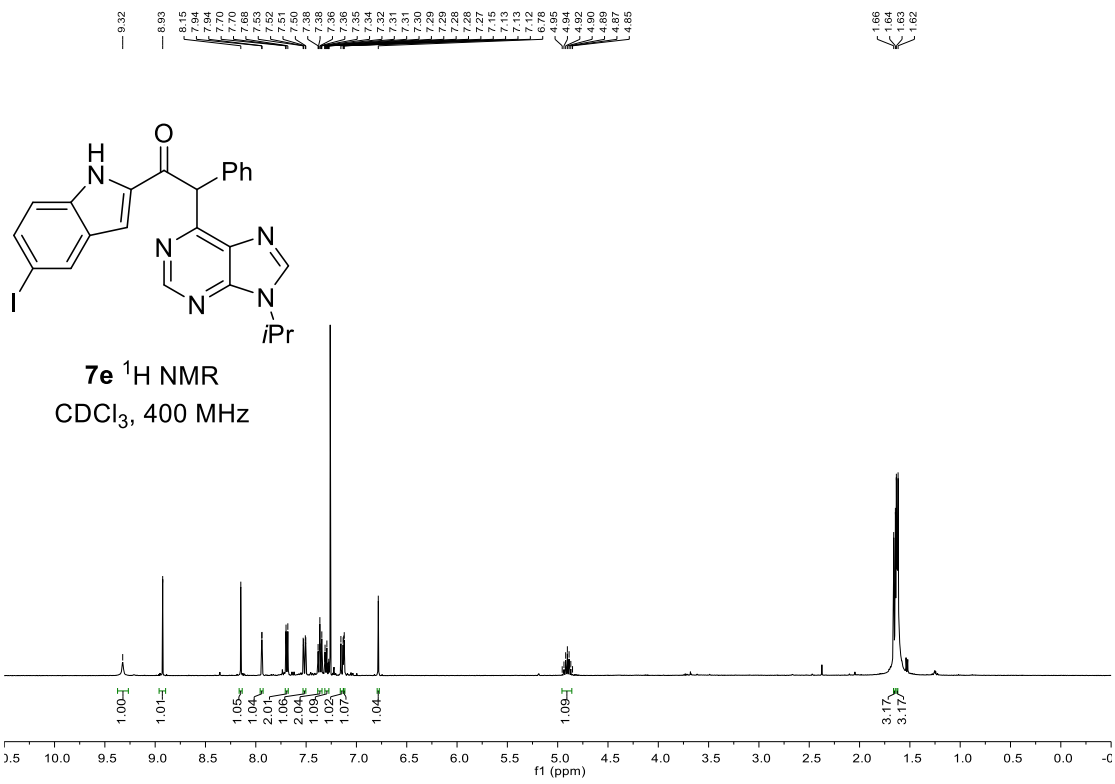
7d ^{1}H NMR

$CDCl_3$, 400 MHz



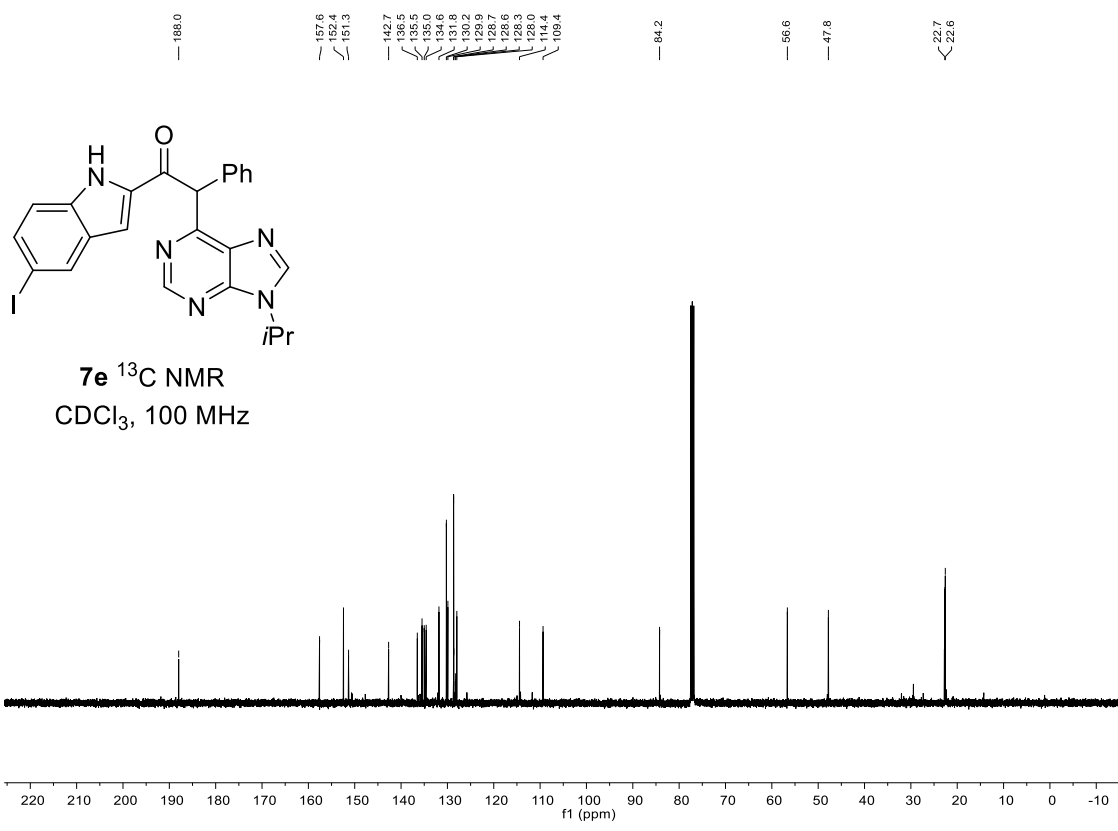
7d ^{13}C NMR

$CDCl_3$, 100 MHz



7e ^{1}H NMR

$CDCl_3$, 400 MHz



7e ^{13}C NMR

$CDCl_3$, 100 MHz