Brønsted acid-promoted multicomponent reaction for the construction of pyrrolocoumarin derivatives

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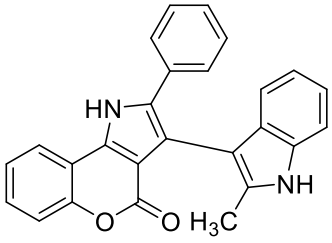
General information

All reagents were obtained from commercial sources (purity >99%) and used without further purification, unless otherwise indicated. Silica gel for column chromatography was purchased from Qingdao Haiyang Chemical Co., Ltd. Reactions were stirred using Teflon-coated magnetic stir bars. Thin-layer chromatography (TLC).

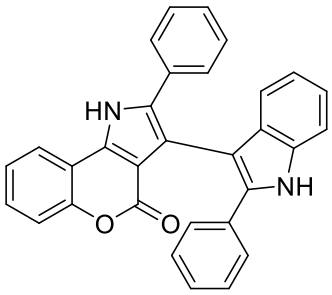
Melting points were determined using a Büchi B-540 capillary melting point apparatus. IR spectra were recorded with a Thermo Nicolet AVATAR 370 spectrophotometer in KBr. ^{1}H NMR and ^{13}C NMR were recorded with Varian instrument at 600 and 150 MHz, respectively, and TMS was used as internal standard. Mass spectra were measured with Thermo Finnigan LCQ-Advantage. High resolution mass spectral (HRMS) analyze were measured on a Bruker micrOTOF-Q II instrument using ESI techniques.

General procedure for the synthesis of indole-containing pyrrolocoumarin derivatives:

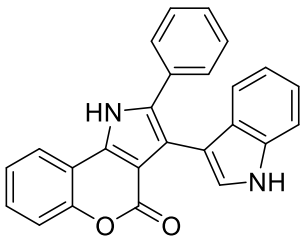
In a 10 mL reaction tube, 4-aminocoumarins **1** (1 mmol), arylglyoxal monohydrates **2** (1.1 mmol) and indoles **3** (1.1 mmol), *p*-TSA (34mg, 0.2 mmol), and EtOH (3 mL) were mixed and then capped. The mixture was heated for 3 h at 100 ^{o}C (oil bath). Upon completion of the reaction, monitored by TLC, the reaction solution was transferred to a 100 mL single-necked flask. Water (30 mL) was add to it. After being stirred for 3 h, the solution was filtered. The residue was purified by column chromatography (CH_2Cl_2/MeOH, 180:1 v/v) to afford target product **4**.



3-(2-Methyl-1*H*-indol-3-yl)-2-phenylchromeno[4,3-*b*]pyrrol-4(1*H*)-one (4a): Pale yellow powder (289 mg, 74%); mp 189-191 °C. IR (KBr): 3421, 1695, 1507 cm^{-1}. ^1H NMR (600 MHz, DMSO-d_6): δ = 12.74 (s, 1H), 11.00 (s, 1H), 8.34 (d, *J* = 7.8 Hz, 1H), 7.48 (t, *J* = 7.8 Hz, 1H), 7.41 (m, 4H), 7.33–7.25 (m, 3H), 7.22 (t, *J* = 7.2 Hz, 1H), 6.97 (t, *J* = 8.4 Hz, 2H), 6.79 (t, *J* = 7.2 Hz, 1H), 2.09 (s, 3H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 157.7, 151.8, 136.0, 136.0, 134.3, 134.3, 132.5, 129.1, 128.8, 127.7, 127.4, 124.4, 122.2, 120.4, 119.0, 118.8, 117.1, 114.3, 113.8, 110.9, 109.2, 104.6, 12.6. MS (ESI): *m/z* = 391 $[M + H]^+$. HRMS-ESI: calcd for $C_{26}H_{18}N_2NaO_2$ $[M + Na]^+$: 413.1266; found 413.1250.

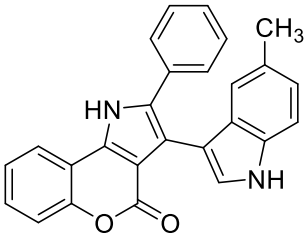


2-Phenyl-3-(2-phenyl-1*H*-indol-3-yl)chromeno[4,3-*b*]pyrrol-4(1*H*)-one (4b): Light green powder (230 mg, 51%); mp >300 °C. IR (KBr): 3361, 1660, 1505 cm^{-1}. ^1H NMR (600 MHz, DMSO-d_6): δ = 12.77 (s, 1H), 11.51 (s, 1H), 8.36 (dd, *J* = 7.8, 1.4 Hz, 1H), 7.53–7.47 (m, 3H), 7.46–7.35 (m, 5H), 7.25 (t, *J* = 7.8 Hz, 2H), 7.20 (t, *J* = 7.8 Hz, 2H), 7.16 (dt, *J* = 8.4, 3.2 Hz, 2H), 7.12–7.08 (m, 1H), 7.06 (d, *J* = 7.8 Hz, 1H), 6.88 (t, *J* = 7.2 Hz, 1H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 157.4, 151.8, 136.6, 136.2, 135.6, 134.7, 133.4, 132.0, 130.1, 129.3, 128.8, 128.8, 127.8, 127.4, 127.1, 126.9, 124.5, 122.2, 122.1, 119.6, 119.6, 117.1, 114.2, 114.0, 111.7, 109.3, 105.5. MS (ESI): *m/z* = 453 $[M + H]^+$. HRMS-ESI: calcd for $C_{31}H_{20}N_2NaO_2$ $[M + Na]^+$: 475.1422; found 475.1424.

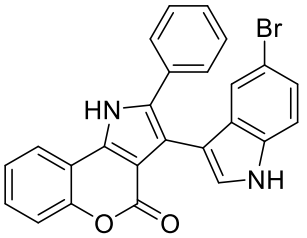


3-(1*H*-indol-3-yl)-2-phenylchromeno[4,3-*b*]pyrrol-4(1*H*)-one (4c): Brown-red powder (214 mg, 57%); mp 291-293 °C. IR (KBr): 3422, 1687, 1505 cm^{-1}. ^1H NMR (600 MHz, DMSO-d_6): δ = 12.74 (s, 1H), 11.18 (s, 1H), 8.33 (d, *J* = 7.2 Hz, 1H), 7.50–7.37 (m, 7H), 7.29 (t, *J* = 7.2 Hz, 2H), 7.24 (t, *J* = 7.2 Hz, 1H), 7.04 (t, *J* = 7.2 Hz, 1H), 6.98 (d, *J* = 7.8 Hz, 1H), 6.79 (t, *J* = 7.2 Hz, 1H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 157.9, 151.8, 136.5, 135.9, 134.0, 132.4,

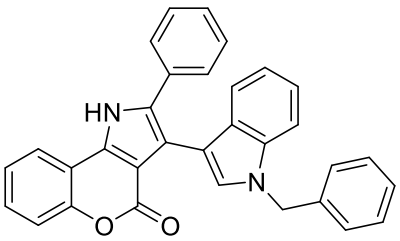
129.17, 128.8, 128.1, 127.8, 127.3, 126.3, 124.4, 122.2, 121.2, 120.0, 119.0, 117.1, 114.3, 114.2, 111.9, 108.5, 107.0. MS (ESI): *m/z* = 377 $[M + H]^+$. HRMS-ESI: calcd for $C_{25}H_{16}N_2NaO_2$ $[M + Na]^+$: 399.1109; found 399.1114.



3-(5-Methyl-1*H*-indol-3-yl)-2-phenylchromeno[4,3-*b*]pyrrol-4(1*H*)-one (4d): Light yellow powder (222 mg, 57%); mp 281-283 °C. IR (KBr): 3408, 1695, 1506 cm^{-1}. ^1H NMR (600 MHz, DMSO-d_6): δ = 12.73 (s, 1H), 11.01 (s, 1H), 8.30 (d, *J* = 7.8 Hz, 1H), 7.51–7.36 (m, 5H), 7.34–7.21 (m, 5H), 6.86 (d, *J* = 8.4 Hz, 1H), 6.77 (s, 1H), 2.17 (s, 3H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 157.9, 151.7, 135.8, 134.8, 134.1, 132.4, 129.2, 128.7, 128.1, 127.8, 127.3, 126.1, 124.4, 122.8, 122.1, 119.7, 117.1, 114.5, 114.2, 111.5, 108.6, 106.5, 21.6. MS (ESI): *m/z* = 391 $[M + H]^+$. HRMS-ESI: calcd for $C_{26}H_{18}N_2NaO_2$ $[M + Na]^+$: 413.1266; found 413.1259.

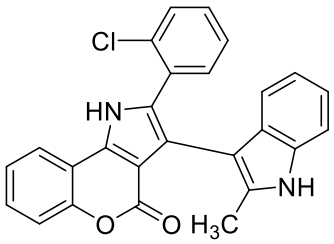


3-(5-Bromo-1*H*-indol-3-yl)-2-phenylchromeno[4,3-*b*]pyrrol-4(1*H*)-one (4e): Off-white powder (264 mg, 58%); mp 272-274 °C. IR (KBr): 3439, 1667, 1507 cm^{-1}. ^1H NMR (600 MHz, DMSO-d_6): δ = 12.80 (s, 1H), 11.41 (d, *J* = 1.8 Hz, 1H), 8.33 (dd, *J* = 7.8, 1.4 Hz, 1H), 7.51–7.38 (m, 7H), 7.36–7.31 (m, 2H), 7.31–7.27 (m, 1H), 7.16 (dd, *J* = 8.4, 1.8 Hz, 1H), 7.12 (d, *J* = 1.8 Hz, 1H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 157.9, 151.8, 136.0, 135.1, 134.2, 132.2, 129.3, 129.2, 128.9, 128.3, 128.0, 127.9, 124.5, 123.7, 122.3, 122.2, 117.1, 114.2, 113.9, 113.4, 111.7, 108.5, 106.9. MS (ESI): *m/z* = 455 $[M + H]^+$. HRMS-ESI: calcd for $C_{25}H_{15}BrN_2NaO_2$ $[M + Na]^+$: 477.0215; found 477.0213.

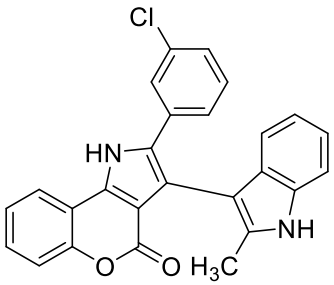


3-(1-Benzyl-1*H*-indol-3-yl)-2-phenylchromeno[4,3-*b*]pyrrol-4(1*H*)-one (4f): Brown powder (219 mg, 47%); mp 159-161 °C. IR (KBr): 3424, 1691, 1507 cm^{-1}. ^1H NMR (600 MHz, DMSO-d_6): δ = 12.78 (s, 1H), 8.33 (d, *J* = 7.8 Hz, 1H), 7.53 (s, 1H), 7.50–7.47 (m, 3H), 7.41 (dd, *J* = 16.8, 8.4 Hz, 3H), 7.31 (q, *J* = 7.2 Hz, 4H), 7.28–7.19 (m, 4H), 7.09 (d, *J* = 7.8 Hz, 1H), 7.05 (t, *J* = 7.8 Hz, 1H), 6.86 (t, *J* = 7.2

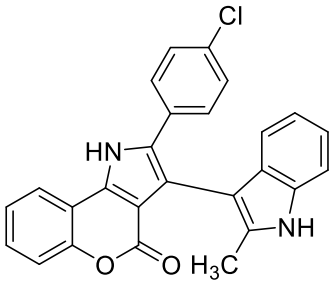
Hz, 1H), 5.47 (s, 2H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 157.8, 151.8, 138.8, 136.3, 135.9, 134.3, 132.2, 130.0, 129.2, 128.9, 128.8, 128.4, 128.2, 127.9, 127.7, 127.3, 124.5, 122.2, 121.5, 120.5, 119.4, 117.1, 114.2, 113.7, 110.6, 108.7, 107.0, 49.5. MS (ESI): *m/z* = 467 $[M + H]^+$. HRMS-ESI: calcd for $C_{32}H_{22}N_2NaO_2$ $[M + Na]^+$: 489.1579; found 489.1595.



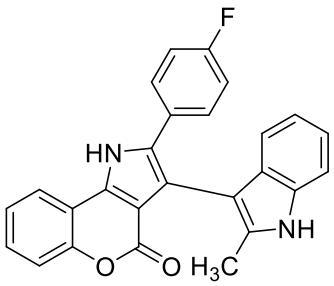
2-(2-Chlorophenyl)-3-(2-methyl-1*H*-indol-3-yl)chromeno[4,3-*b*]pyrrol-4(1*H*)-one (4g): Pale yellow powder (264 mg, 58%); mp 280-282 °C. IR (KBr): 3423, 1677, 1505 cm^{-1}. ^{1}H NMR (600 MHz, DMSO-d_6): δ = 12.96 (s, 1H), 10.92 (s, 1H), 8.19 (dd, *J* = 7.8, 1.0 Hz, 1H), 7.53 (d, *J* = 8.4 Hz, 1H), 7.51–7.46 (m, 1H), 7.44 (d, *J* = 7.8 Hz, 1H), 7.39 (t, *J* = 7.8 Hz, 1H), 7.35–7.30 (m, 1H), 7.23 (m, 3H), 7.06 (d, *J* = 7.8 Hz, 1H), 6.92 (t, *J* = 7.2 Hz, 1H), 6.77 (t, *J* = 7.2 Hz, 1H), 2.12 (s, 3H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 157.7, 151.8, 135.9, 135.6, 134.6, 133.7, 133.2, 132.1, 131.9, 130.5, 130.1, 129.3, 129.0, 127.5, 124.5, 121.8, 120.2, 118.8, 118.7, 117.2, 115.9, 114.3, 110.7, 108.1, 104.0, 12.5. MS (ESI): *m/z* = 425 $[M + H]^+$. HRMS-ESI: calcd for $C_{26}H_{17}ClN_2NaO_2$ $[M + Na]^+$: 447.0876; found 447.0886.



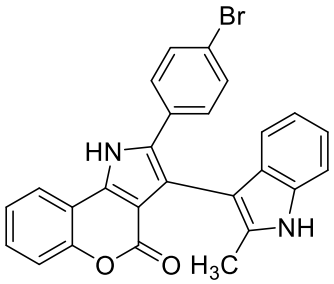
2-(3-Chlorophenyl)-3-(2-methyl-1*H*-indol-3-yl)chromeno[4,3-*b*]pyrrol-4(1*H*)-one (4h): Pale yellow powder (314 mg, 74%); mp 199-201 °C. IR (KBr): 3423, 1671, 1506 cm^{-1}. ^{1}H NMR (600 MHz, DMSO-d_6): δ = 12.80 (s, 1H), 11.08 (s, 1H), 8.34 (d, *J* = 7.8 Hz, 1H), 8.34 (d, *J* = 7.8 Hz, 1H), 7.57 (s, 1H), 7.51–7.47 (m, 1H), 7.42 (t, *J* = 7.8 Hz, 2H), 7.32 (d, *J* = 8.4 Hz, 1H), 7.29–7.21 (m, 3H), 7.02–6.94 (m, 2H), 6.81 (t, *J* = 7.8 Hz, 1H), 2.14 (s, 3H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 157.6, 151.9, 136.4, 136.0, 134.5, 134.4, 133.6, 132.4, 130.7, 129.4, 128.5, 127.4, 126.7, 125.7, 124.5, 122.3, 120.5, 119.0, 118.9, 117.1, 114.9, 114.1, 111.0, 109.3, 104.2, 12.7. MS (ESI): *m/z* = 425 $[M + H]^+$. HRMS-ESI: calcd for $C_{26}H_{17}ClN_2NaO_2$ $[M + Na]^+$: 447.0876; found 447.0882.



2-(4-Chlorophenyl)-3-(2-methyl-1*H*-indol-3-yl)chromeno[4,3-*b*]pyrrol-4(1*H*)-one (4i): Light yellow powder (348 mg, 82%); mp >300 °C. IR (KBr): 3373, 1662, 1471 cm^{-1}. ^1H NMR (600 MHz, DMSO-d_6): δ = 12.79 (s, 1H), 11.06 (s, 1H), 8.33 (d, *J* = 7.8 Hz, 1H), 7.52–7.47 (m, 1H), 7.45–7.40 (m, 4H), 7.36 (d, *J* = 8.4 Hz, 2H), 7.31 (d, *J* = 7.8 Hz, 1H), 6.98 (t, *J* = 7.2 Hz, 1H), 6.94 (d, *J* = 7.8 Hz, 1H), 6.80 (t, *J* = 7.2 Hz, 1H), 2.13 (s, 3H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 157.6, 151.9, 136.2, 135.9, 134.5, 132.9, 132.2, 131.3, 129.3, 129.0, 128.9, 128.5, 124.5, 122.2, 120.5, 118.9, 117.1, 114.4, 114.2, 111.0, 109.2, 104.2, 12.7. MS (ESI): *m/z* = 425 $[M + H]^+$. HRMS-ESI: calcd for $C_{26}H_{17}ClN_2NaO_2$ $[M + Na]^+$: 447.0876; found 447.0878.

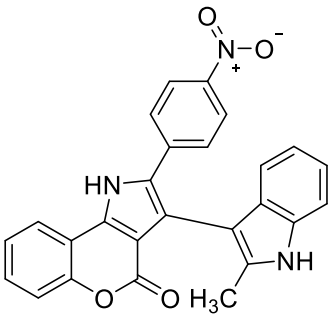


2-(4-Fluorophenyl)-3-(2-methyl-1*H*-indol-3-yl)chromeno[4,3-*b*]pyrrol-4(1*H*)-one (4j): Pale yellow powder (330 mg, 81%); mp 257-259 °C. IR (KBr): 3379, 1664, 1504 cm^{-1}. ^1H NMR (600 MHz, DMSO-d_6): δ = 12.78 (s, 1H), 11.05 (s, 1H), 8.34 (dd, *J* = 7.8, 1.0 Hz, 1H), 7.51–7.39 (m, 5H), 7.32 (d, *J* = 8.4 Hz, 1H), 7.16 (t, *J* = 8.4 Hz, 2H), 6.99 (q, *J* = 7.2 Hz, 2H), 6.81 (t, *J* = 7.2 Hz, 1H), 2.14 (s, 3H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 161.7 (d, J_{CF} = 245.0 Hz), 157.7, 151.8, 136.0, 135.9, 134.4, 133.3, 129.5, 129.1, 129.0, 128.7, 124.4, 122.1, 120.4, 119.0, 118.9, 117.1, 115.9, 115.8, 114.2, 113.7, 110.9, 109.1, 104.3, 12.7. MS (ESI): *m/z* = 409 $[M + H]^+$. HRMS-ESI: calcd for $C_{26}H_{17}FN_2NaO_2$ $[M + Na]^+$: 431.1172; found 447.1179.

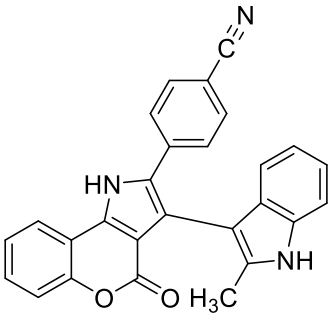


2-(4-Bromophenyl)-3-(2-methyl-1*H*-indol-3-yl)chromeno[4,3-*b*]pyrrol-4(1*H*)-one (4k): Yellow powder (388 mg, 83%); mp >300 °C. IR (KBr): 3394, 1691, 1507 cm^{-1}. ^1H NMR (600 MHz, DMSO-d_6): δ = 12.77 (s, 1H), 11.04 (s, 1H), 8.33 (d, *J* = 7.2 Hz, 1H), 7.56–7.27 (m, 8H), 6.98 (t, J = 7.8 Hz, 1H), 6.93 (d, *J* = 7.8 Hz, 1H), 6.80 (t, *J* = 7.2 Hz, 1H), 2.12 (s, 2H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 157.9, 151.8, 135.8, 134.8, 134.1, 132.4, 129.1, 128.7, 128.2, 127.8, 127.8, 127.3, 126.2, 124.4, 122.8, 122.2, 119.8, 117.1, 114.5,

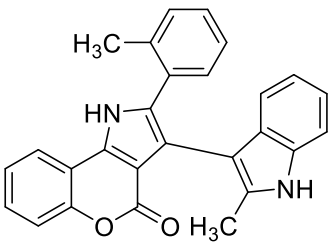
114.2, 111.5, 108.7, 106.6, 21.7. MS (ESI): *m/z* = 469 $[M + H]^+$. HRMS-ESI: calcd for $C_{26}H_{17}BrN_2NaO_2$ $[M + Na]^+$: 491.0371; found 491.0365.



3-(2-Methyl-1*H*-indol-3-yl)-2-(4-nitrophenyl)chromeno [4,3-*b*]pyrrol-4(1*H*)-one (4l): Tan powder (352 mg, 81%); mp > 300 °C. IR (KBr): 3450, 1694, 1515, 1340 cm^{-1}. ^1H NMR (600 MHz, DMSO-d_6): δ = 12.98 (s, 1H), 11.17 (s, 1H), 8.38 (d, *J* = 7.2 Hz, 1H), 8.15 (d, *J* = 8.4 Hz, 1H), 7.67 (d, *J* = 8.4 Hz, 2H), 7.56–7.51 (m, 1H), 7.45 (t, *J* = 7.2 Hz, 2H), 7.34 (d, *J* = 7.8 Hz, 1H), 7.00 (t, *J* = 7.2 Hz, 1H), 6.93 (d, *J* = 7.8 Hz, 1H), 6.81 (t, *J* = 7.2 Hz, 1H), 2.17 (s, 3H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 157.4, 152.1, 146.0, 138.9, 137.4, 136.0, 134.8, 131.7, 129.8, 128.2, 127.7, 124.6, 124.2, 122.5, 120.7, 119.1, 118.8, 117.2, 117.1, 113.9, 111.1, 109.5, 103.9, 12.7. MS (ESI): *m/z* = 436 $[M + H]^+$. HRMS-ESI: calcd for $C_{26}H_{17}N_3NaO_2$ $[M + Na]^+$: 458.1117; found 458.1110.

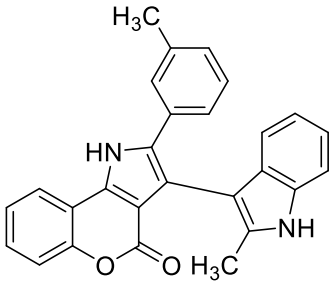


4-(3-(2-Methyl-1*H*-indol-3-yl)-4-oxo-1,4-dihydrochromeno[4,3-*b*]pyrrol-2-yl)benzonitrile (4m): Light yellow powder (344 mg, 83%); mp >300 °C. IR (KBr): 3397, 2224, 1692, 1507 cm^{-1}. ^1H NMR (600 MHz, DMSO-d_6): δ = 12.90 (s, 1H), 11.14 (s, 1H), 8.36 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.76 (d, *J* = 8.4 Hz, 2H), 7.59 (d, *J* = 8.4 Hz, 2H), 7.55–7.50 (m, 1H), 7.44 (dd, *J* = 7.8, 6.0 Hz, 2H), 7.33 (d, *J* = 7.8 Hz, 1H), 7.00 (t, *J* = 7.2 Hz, 1H), 6.92 (d, *J* = 7.8 Hz, 1H), 6.81 (t, *J* = 7.2 Hz, 1H), 2.15 (s, 3H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 157.4, 152.0, 137.1, 136.9, 136.019, 134.7, 132.8, 132.1, 129.7, 128.2, 127.5, 124.5, 122.4, 120.6, 119.3, 119.1, 118.8, 117.2, 116.3, 1140, 111.1, 109.5, 109.4, 104.0, 12.7. MS (ESI): *m/z* = 416 $[M + H]^+$. HRMS-ESI: calcd for $C_{27}H_{17}N_3NaO_2$ $[M + Na]^+$: 438.1218; found 438.1210.

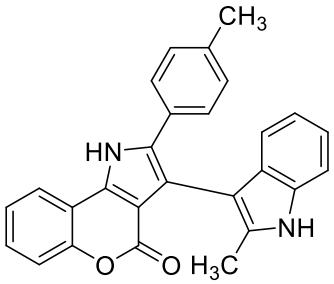


3-(2-Methyl-1*H*-indol-3-yl)-2-(o-tolyl)chromeno[4,3-*b*] pyrrol-4(1*H*)-one (4n): Pale yellow powder (263 mg, 65%); mp >300 °C. IR (KBr): 3419, 1687, 1505 cm^{-1}. ^1H

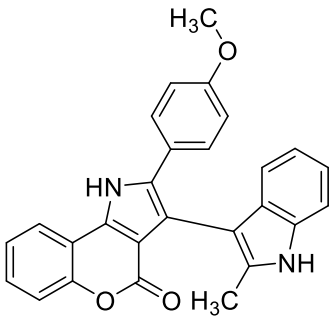
NMR (600 MHz, DMSO-d_6): δ = 12.79 (s, 1H), 10.88 (s, 1H), 8.19 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.49–7.41 (m, 2H), 7.40–7.36 (m, 1H), 7.29 (d, *J* = 7.8 Hz, 1H), 7.25–7.15 (m, 4H), 7.04 (d, *J* = 7.8 Hz, 1H), 6.93 (t, *J* = 7.8 Hz, 1H), 6.78 (t, *J* = 7.2 Hz, 1H), 2.05 (s, 3H), 2.05 (s, 3H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 157.8, 151.8, 137.4, 135.6, 135.6, 134.7, 134.2, 132.7, 131.3, 130.6, 129.0, 128.6, 126.1, 124.4, 121.8, 120.2, 119.0, 118.7, 117.1, 114.9, 114.4, 110.7, 108.2, 104.7, 20.2, 12.6. MS (ESI): *m/z* = 405 $[M + H]^+$. HRMS-ESI: calcd for $C_{27}H_{20}N_2NaO_2$ $[M + Na]^+$: 427.1422; found 427.1430.



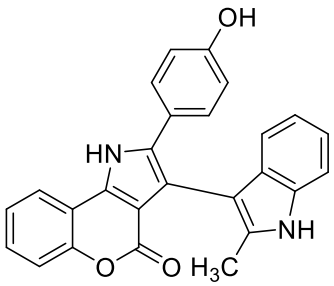
3-(2-Methyl-1*H*-indol-3-yl)-2-(m-tolyl)chromeno[4,3-*b*] pyrrol-4(1*H*)-one (4o): Yellow powder (291 mg, 72%); mp >300 °C. IR (KBr): 3360, 1665, 1506 cm^{-1}. ^{1}H NMR (600 MHz, DMSO-d_6): δ = 12.72 (s, 1H), 11.01 (s, 1H), 8.37 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.51–7.45 (m, 1H), 7.41 (dd, *J* = 15.6, 8.4 Hz, 3H), 7.32 (d, *J* = 8.4 Hz, 1H), 7.10 (d, *J* = 4.8 Hz, 2H), 7.06–7.03 (m, 1H), 7.01–6.95 (m, 2H), 6.81 (t, *J* = 7.2 Hz, 1H), 2.24 (s, 3H), 2.12 (s, 3H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 157.7, 151.8, 137.8, 135.9, 134.4, 134.3, 132.4, 129.1, 128.9, 128.7, 128.3, 127.9, 124.6, 124.4, 122.2, 120.3, 119.1, 118.8, 117.1, 114.3, 113.7, 110.8, 109.2, 104.7, 21.6, 12.7. MS (ESI): *m/z* = 405 $[M + H]^+$. HRMS-ESI: calcd for $C_{27}H_{20}N_2NaO_2$ $[M + Na]^+$: 427.1422; found 427.1431.



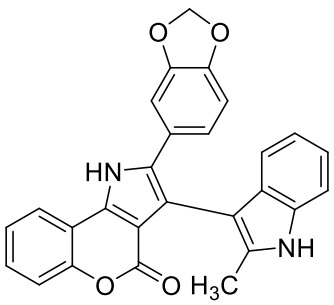
3-(2-Methyl-1*H*-indol-3-yl)-2-(p-tolyl)chromeno[4,3-*b*] pyrrol-4(1*H*)-one (4p): Yellow powder (287 mg, 71%); mp 290-292 °C. IR (KBr): 3397, 1664, 1506 cm^{-1}. ^{1}H NMR (600 MHz, DMSO-d_6): δ = 12.68 (s, 1H), 10.99 (s, 1H), 8.35 (d, *J* = 7.8 Hz, 1H), 7.49–7.44 (m, 1H), 7.43–7.38 (m, 2H), 7.31 (t, *J* = 7.2 Hz, 3H), 7.08 (d, *J* = 7.8 Hz, 2H), 7.00–6.94 (m, 2H), 6.80 (t, *J* = 7.2 Hz, 1H), 2.24 (s, 3H), 2.10 (s, 3H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 157.7, 151.8, 137.0, 135.9, 135.8, 134.4, 134.3, 129.6, 129.4, 129.0, 128.9, 127.2, 124.4, 122.2, 120.3, 119.1, 118.8, 117.0, 114.3, 113.3, 110.8, 109.2, 104.7, 21.2, 12.7. MS (ESI): *m/z* = 405 $[M + H]^+$. HRMS-ESI: calcd for $C_{27}H_{20}N_2NaO_2$ $[M + Na]^+$: 427.1422; found 427.1416.



2-(4-Methoxyphenyl)-3-(2-methyl-1*H*-indol-3-yl)chromeno[4,3-*b*]pyrrol-4(1*H*)-one (4q): Brown yellow powder (286 mg, 68%); mp 214-216 °C. IR (KBr): 3383, 1690, 1504 cm^{-1}. ^1H NMR (600 MHz, DMSO-d_6): δ = 12.65 (s, 1H), 10.99 (s, 1H), 8.33 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.48–7.45 (m, 1H), 7.43–7.38 (m, 2H), 7.37–7.34 (m, 2H), 7.30 (d, *J* = 8.4 Hz, 1H), 6.99–6.97 (m, 2H), 6.86 (d, *J* = 8.4 Hz, 2H), 6.82–6.79 (m, 1H), 3.72 (s, 3H), 2.11 (s, 3H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 158.9, 157.7, 151.7, 135.9, 135.5, 134.4, 134.3, 128.9, 128.7, 124.9, 124.4, 122.07, 120.3, 119.1, 118.81, 117.0, 114.3, 112.6, 110.9, 109.2, 104.7, 55.5, 12.7. MS (ESI): *m/z* = 421 $[M + H]^+$. HRMS-ESI: calcd for $C_{27}H_{20}N_2NaO_3$ $[M + Na]^+$: 443.1372; found 443.1379.

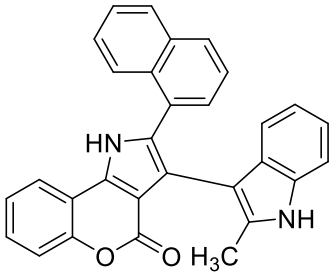


2-(4-Hydroxyphenyl)-3-(2-methyl-1*H*-indol-3-yl)chromeno[4,3-*b*]pyrrol-4(1*H*)-one (4r): Brown yellow powder (267 mg, 66%); mp 220-222 °C. IR (KBr): 3398, 1695, 1504 cm^{-1}. ^1H NMR (600 MHz, DMSO-d_6): δ = 10.97 (s, 1H), 9.55 (s, 1H), 8.32 (dd, *J* = 7.8, 1.2 Hz, 1H), 7.48–7.43 (m, 1H), 7.42–7.37 (m, 2H), 7.29 (d, *J* = 8.4 Hz, 1H), 7.23 (d, *J* = 8.4 Hz, 2H), 7.01–6.93 (m, 2H), 6.83–6.76 (m, 1H), 6.67 (d, *J* = 8.4 Hz, 2H), 2.11 (s, 3H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 162.5, 161.9, 156.4, 140.6, 140.1, 139.6, 139.0, 133.7, 133.7, 133.6, 129.1, 128.1, 126.7, 125.0, 123.9, 123.5, 121.7, 120.4, 119.1, 117.0, 115.6, 115.5, 113.8, 109.6, 17.4. MS (ESI): *m/z* = 407 $[M + H]^+$. HRMS-ESI: calcd for $C_{27}H_{18}N_2NaO_3$ $[M + Na]^+$: 429.1215; found 429.1210.

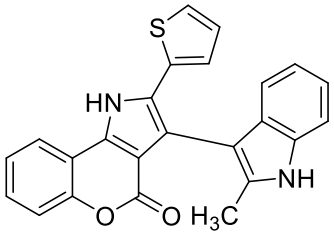


2-(Benzo[*d*][1,3]dioxol-5-yl)-3-(2-methyl-1*H*-indol-3-yl)chromeno[4,3-*b*]pyrrol-4(1*H*)-one (4s): Light yellow powder (299 mg, 69%); mp 224-226 °C. IR (KBr): 3413, 1682, 1503 cm^{-1}. ^1H NMR (600 MHz, DMSO-d_6): δ = 12.63 (s, 1H), 11.02 (s, 1H), 8.35–8.28 (m, 1H), 7.49–7.43 (m, 1H), 7.40 (d, *J* = 7.8 Hz, 2H), 7.30 (d, *J* = 8.4 Hz, 1H), 7.02–6.93 (m, 3H), 6.90 (d, *J* = 1.2 Hz, 1H), 6.87 (d, *J* = 7.8 Hz, 1H), 6.82 (t, *J* = 7.4 Hz, 1H), 5.98 (d, *J* = 2.4 Hz, 2H), 2.14 (s, 3H). ^{13}C NMR (150 MHz,

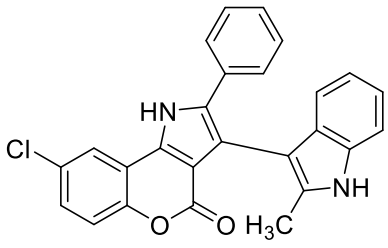
DMSO-d_6): δ = 157.7, 151.8, 147.6, 146.9, 135.9, 135.6, 134.4, 134.1, 129.0, 128.9, 126.3, 124.4, 122.1, 121.3, 120.4, 119.0, 118.9, 117.0, 114.3, 113.0, 110.9, 109.2, 108.9, 107.6, 104.6, 101.5, 12.7. MS (ESI): *m/z* = 435 $[M + H]^+$. HRMS-ESI: calcd for $C_{27}H_{18}N_2NaO_4$ $[M + Na]^+$: 457.1164; found 457.1168.



3-(2-Methyl-1*H*-indol-3-yl)-2-(naphthalen-1-yl)chromeno[4,3-*b*]pyrrol-4(1*H*)-one (4t): Light yellow powder (295 mg, 67%); mp >300 °C. IR (KBr): 3420, 1692, 1506 cm^{-1}. ^1H NMR (600 MHz, DMSO-d_6): δ = 1H NMR (600 MHz, DMSO) δ 13.05 (s, 1H), 10.80 (s, 1H), 8.22 (d, *J* = 7.6 Hz, 1H), 7.97–7.83 (m, 3H), 7.57–7.32 (m, 7H), 7.22–6.56 (m, 4H), 2.06 (s, 3H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 157.9, 151.9, 136.0, 135.5, 133.7, 133.7, 132.0, 130.56, 129.2, 129.1, 129.0, 128.6, 126.8, 126.5, 126.1, 125.8, 124.5, 121.9, 120.1, 118.6, 117.1, 115.8, 114.5, 110.6, 108.5, 104.6, 12.7. MS (ESI): *m/z* = 441 $[M + H]^+$. HRMS-ESI: calcd for $C_{30}H_{20}N_2NaO_4$ $[M + Na]^+$: 463.1422; found 463.1427.

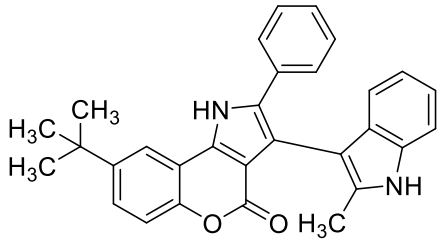


3-(2-Methyl-1*H*-indol-3-yl)-2-(thiophen-2-yl)chromeno[4,3-*b*]pyrrol-4(1*H*)-one (4u): Light green powder (295 mg, 64%); mp >300 °C. IR (KBr): 3418, 1687, 1506 cm^{-1}. ^1H NMR (600 MHz, DMSO-d_6): δ = 12.73 (s, 1H), 11.14 (s, 1H), 8.35 (d, *J* = 7.2 Hz, 1H), 7.60–7.29 (m, 6H), 7.11–6.97 (m, 3H), 6.85 (t, *J* = 6.6 Hz, 1H), 2.19 (s, 3H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 157.5, 151.9, 136.2, 135.9, 135.2, 133. 6, 130.0, 129.3, 129.0, 127.0, 126.7, 124.9, 124.5, 122.2, 120.5, 119.0, 118. 9, 117.1, 114.1, 113.6, 110.9, 109.4, 104.0, 12.7. MS (ESI): *m/z* = 397 $[M + H]^+$. HRMS-ESI: calcd for $C_{24}H_{16}N_2NaO_2S$ $[M + Na]^+$: 419.0830; found 419.0841.

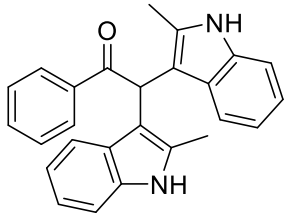


8-Chloro-3-(2-methyl-1*H*-indol-3-yl)-2-phenylchromeno[4,3-*b*]pyrrol-4(1*H*)-one (4v): Brown yellow powder (305 mg, 72%); mp 259-291 °C. IR (KBr): 3401, 1697, 1508 cm^{-1}. ^1H NMR (600 MHz, DMSO-d_6): δ = 12.77 (s, 1H), 11.02 (s, 1H), 8.47 (s, 1H), 7.53–7.37 (m, 4H), 7.34–7.20 (m, 4H), 6.97 (q, *J* = 7.8 Hz, 2H), 6.79 (t, *J* = 7.2

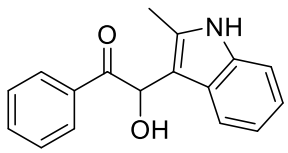
Hz, 1H), 2.10 (s, 3H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 157.2, 150.4, 135.9, 134.7, 134.6, 134.4, 132.2, 128.9, 128.7, 128.6, 128.4, 127.9, 127.2, 121.6, 120.4, 119.0, 118.9, 115.7, 114.0, 110.9, 109.6, 104.3, 12.63. MS (ESI): *m/z* = 426 $[M + H]^+$. HRMS-ESI: calcd for $C_{24}H_{16}N_2NaO_2S$ $[M + Na]^+$: 447.0876; found 447.0870.



8-(Tert-butyl)-3-(2-methyl-1*H*-indol-3-yl)-2-phenylchromeno[4,3-*b*]pyrrol-4(1*H*)-one (4w): Light yellow powder (343 mg, 77%); mp >300 °C. IR (KBr): 3456, 1694, 1523 cm^{-1}. ^{1}H NMR (600 MHz, DMSO-d_6): δ = 11.00 (s, 1H), 8.41 (s, 1H), 7.49 (d, *J* = 8.4 Hz, 1H), 7.42 (d, *J* = 7.8 Hz, 2H), 7.35–7.26 (m, 4H), 7.22 (t, *J* = 7.2 Hz, 1H), 7.00–6.94 (m, 2H), 6.79 (t, *J* = 7.2 Hz, 1H), 2.10 (s, 3H), 1.40 (s, 9H). ^{13}C NMR (150 MHz, DMSO-d_6): δ = 157.9, 149.9, 147.0, 136.4, 135.9, 134.3, 134.2, 132.6, 128.8, 127.7, 127.4, 126.4, 120.4, 119.1, 118.8, 116.5, 113.7, 113.6, 110.9, 109.1, 104.6, 35.1, 31.8, 12.6. MS (ESI): *m/z* = 447 $[M + H]^+$. HRMS-ESI: calcd for $C_{24}H_{16}N_2NaO_2S$ $[M + Na]^+$: 469.1892; found 469.1882.

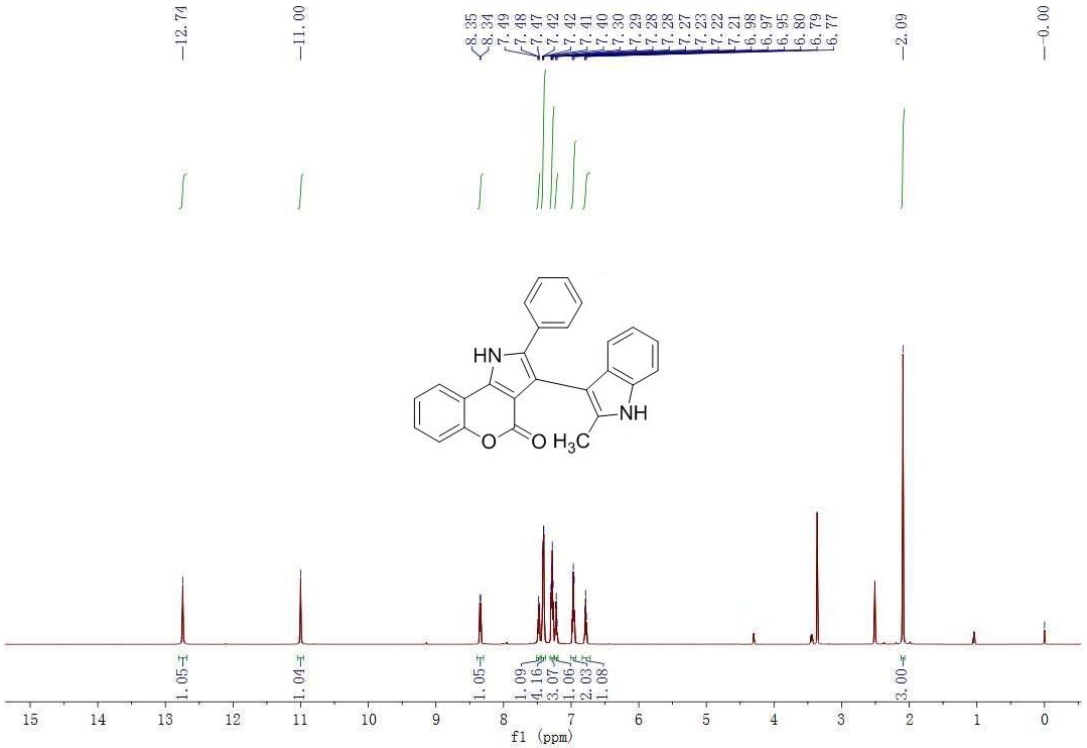


2,2-Bis(2-methyl-1*H*-indol-3-yl)-1-phenylethanone (5): Brown powder; mp 201-203 °C. ^{1}H NMR (600 MHz, DMSO-d_6): δ = 10.86 (s, 1H), 8.05 (d, *J* = 7.8 Hz, 1H), 7.53 (t, *J* = 7.2 Hz, 1H), 7.43 (t, *J* = 7.8 Hz, 1H), 7.22 (d, *J* = 8.4 Hz, 1H), 7.15 (d, *J* = 7.8 Hz, 1H), 6.93 (t, *J* = 7.8 Hz, 1H), 6.78 (t, *J* = 7.8 Hz, 1H), 6.44 (s, 1H), 2.16 (s, 3H). HRMS-ESI: calcd for $C_{26}H_{22}N_2NaO$ $[M + Na]^+$: 401.1630; found 401.1642.

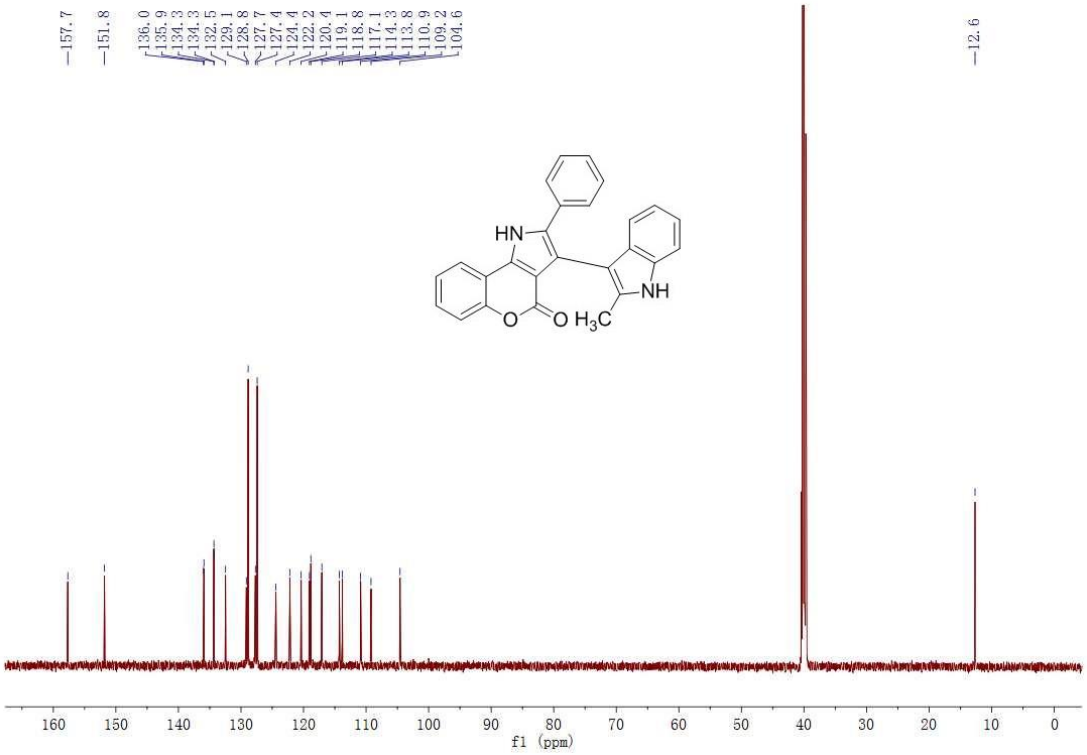


2-Hydroxy-2-(2-methyl-1*H*-indol-3-yl)-1-phenylethanone (A): White powder; mp 156-158 °C. ^{1}H NMR (600 MHz, DMSO-d_6): δ = 10.96 (s, 1H), 7.88 (d, *J* = 7.2 Hz, 2H), 7.49 (m, 2H), 7.38 (t, *J* = 7.8 Hz, 2H), 7.20 (d, J = 7.8 Hz, 1H), 6.94 (m, 2H), 5.32 (d, *J* = 4.2 Hz, 1H), 2.43 (s, 3H). HRMS-ESI: calcd for $C_{17}H_{16}NO_2$ $[M + H]^+$: 266.1181; found 266.1162.

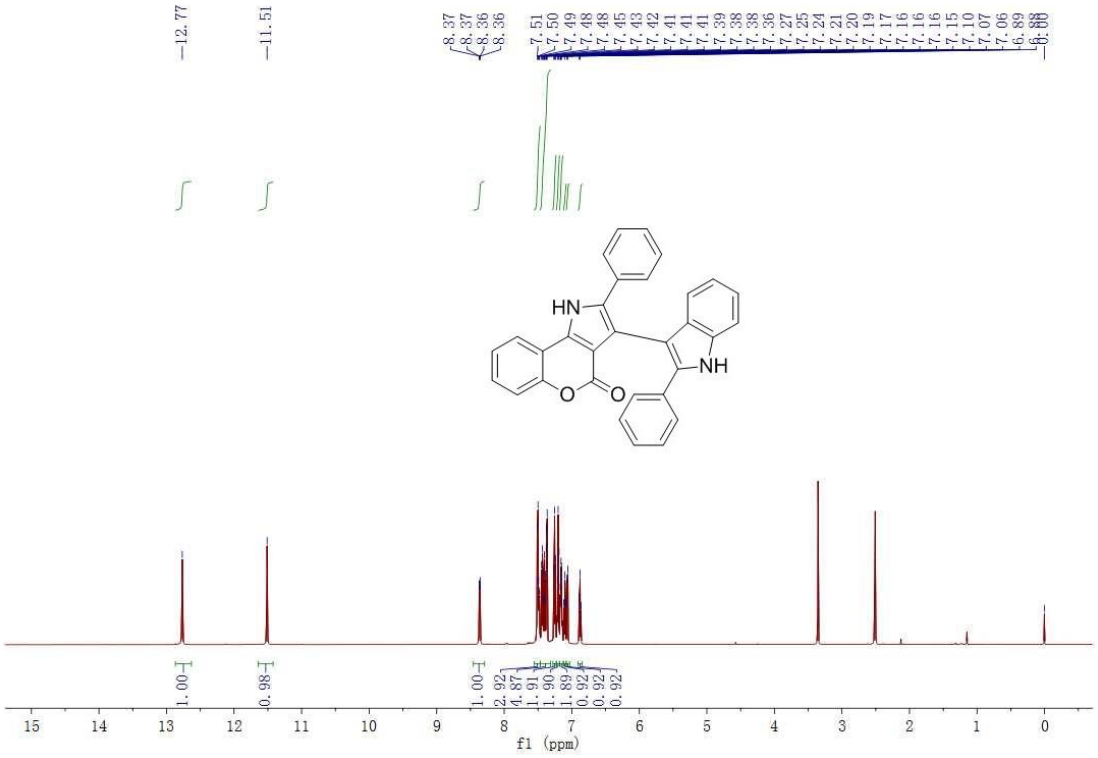
^{1}H NMR spectra of compound **4a**



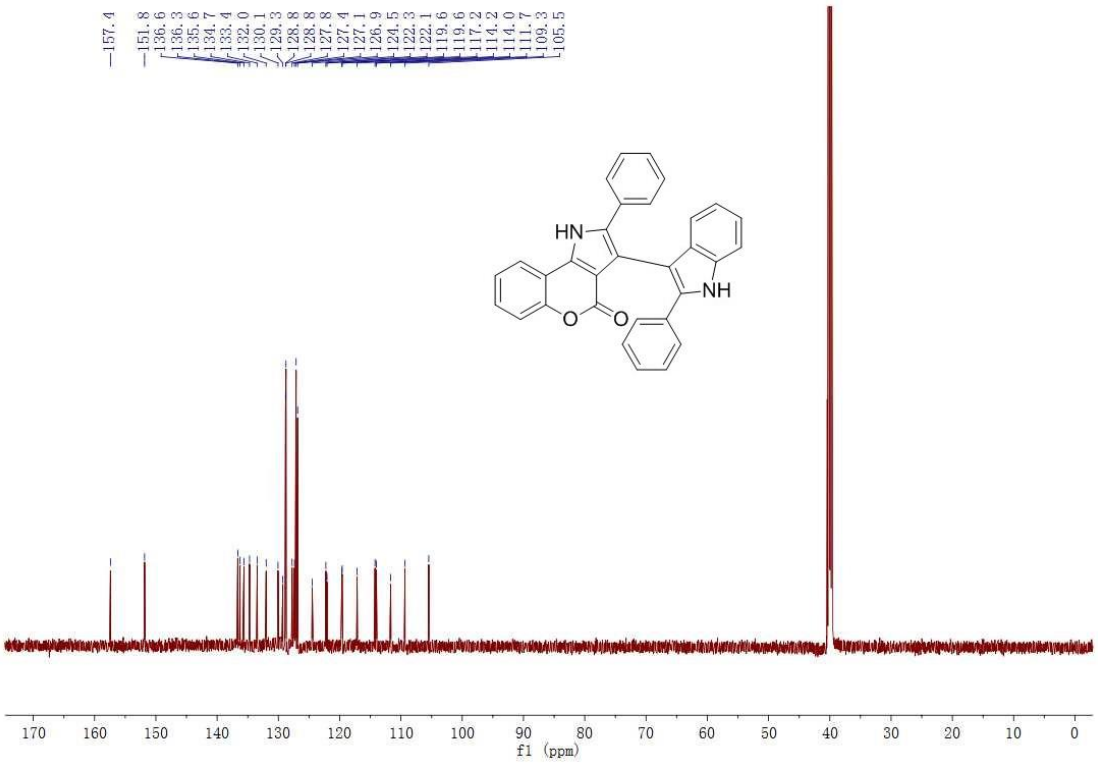
^{13}C NMR spectra of compound **4a**



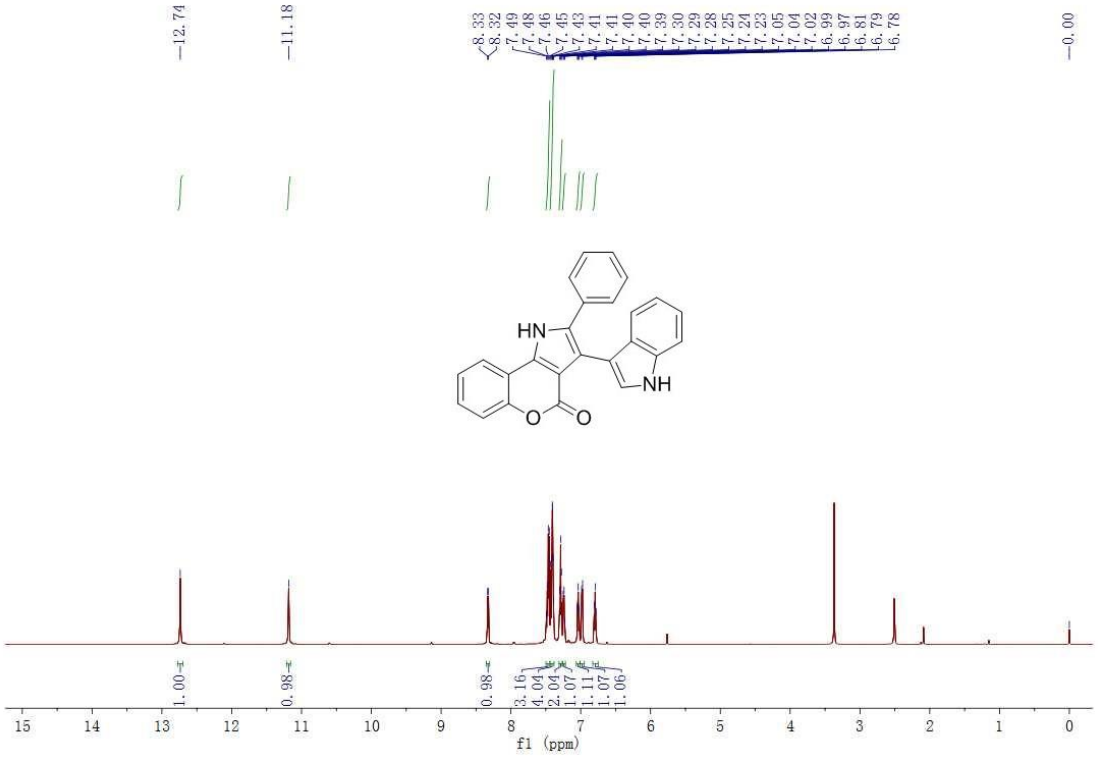
^{1}H NMR spectra of compound **4b**



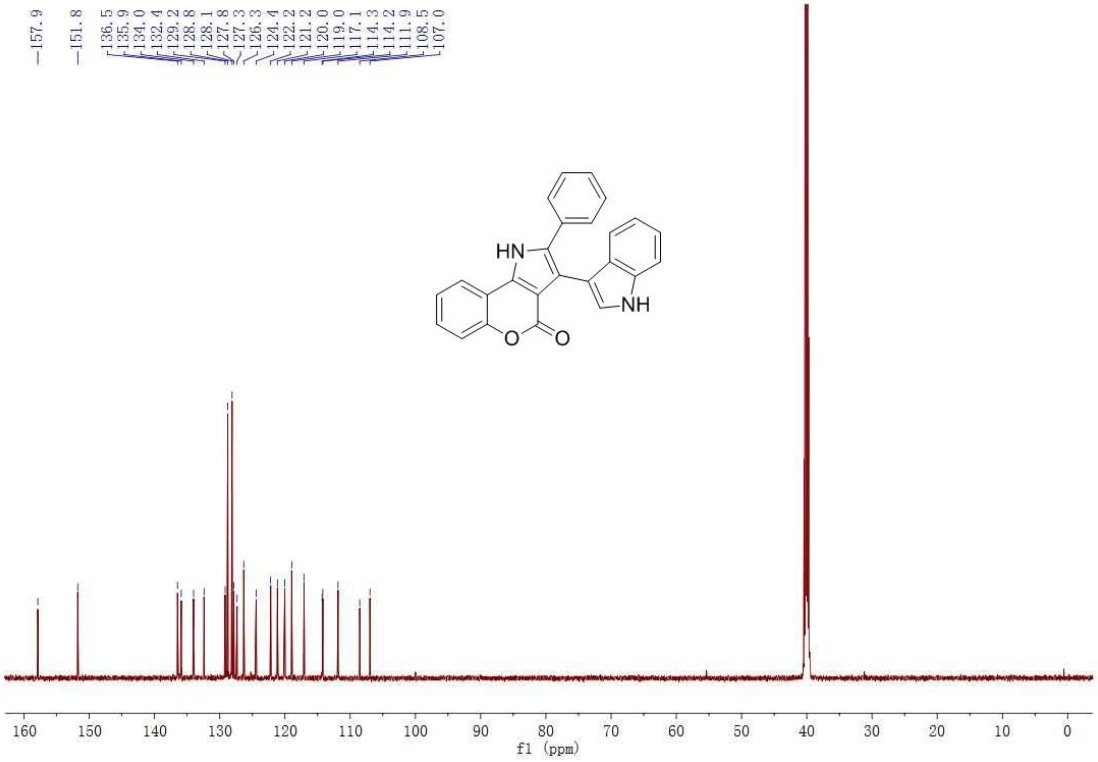
^{13}C NMR spectra of compound **4b**



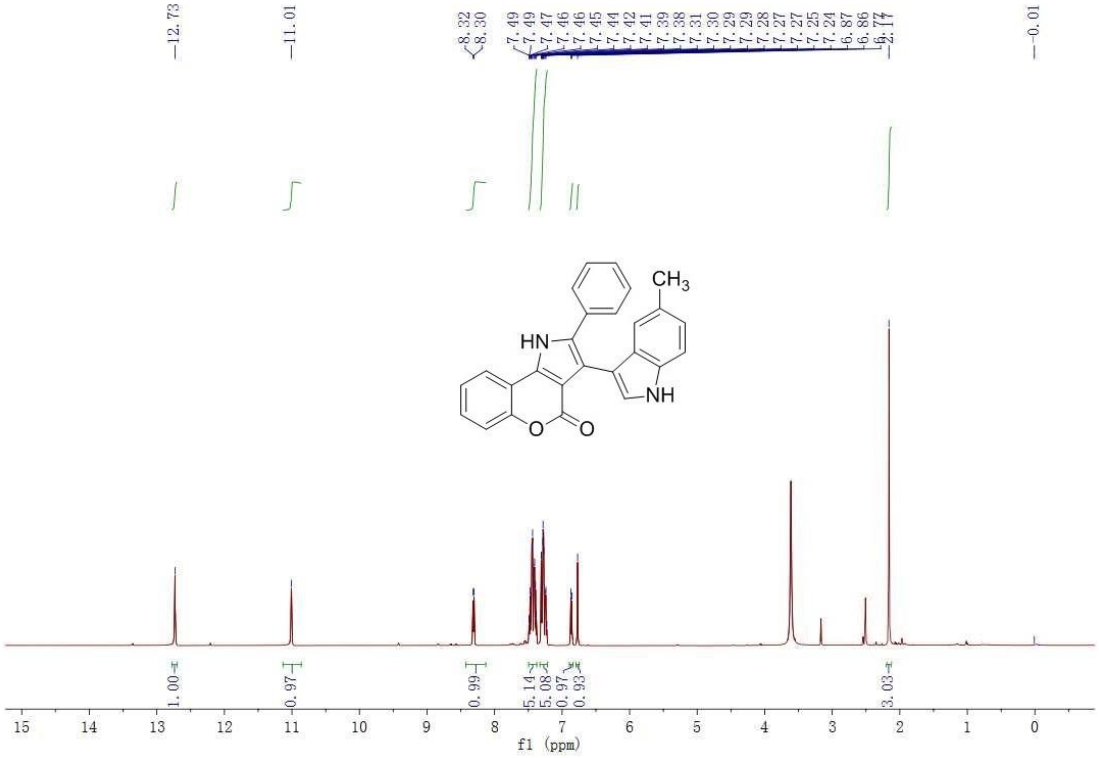
^{1}H NMR spectra of compound **4c**



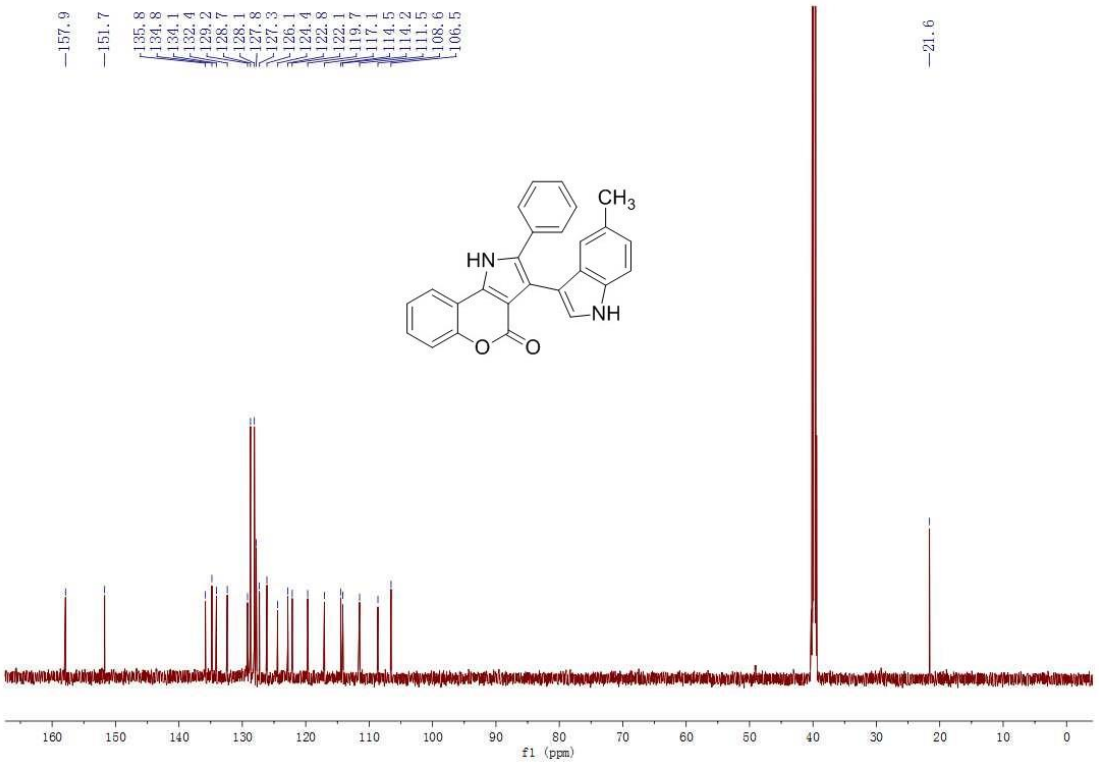
^{13}C NMR spectra of compound **4c**



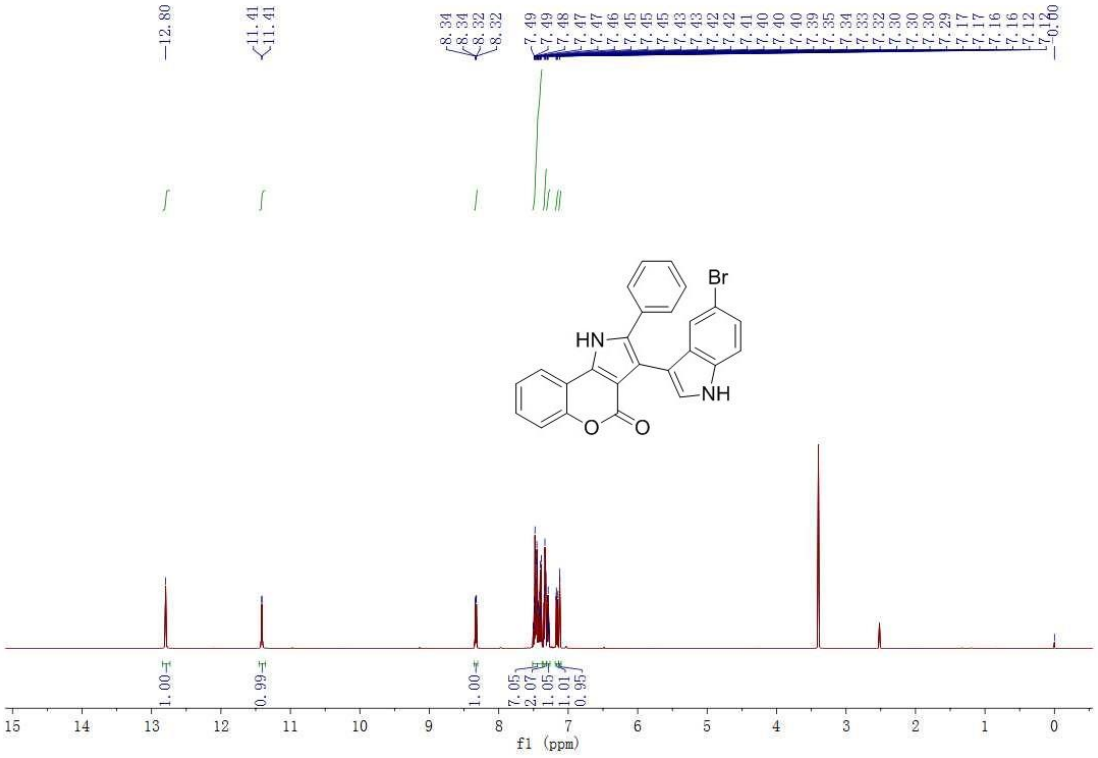
^{1}H NMR spectra of compound **4d**



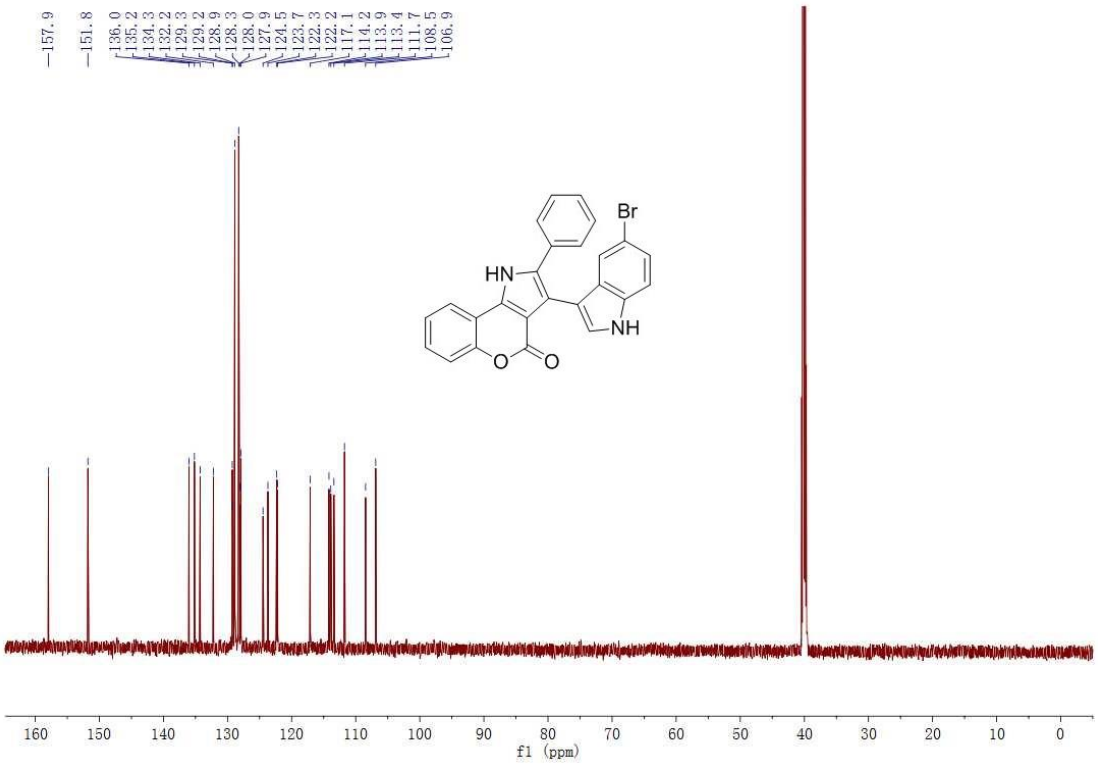
^{13}C NMR spectra of compound **4d**



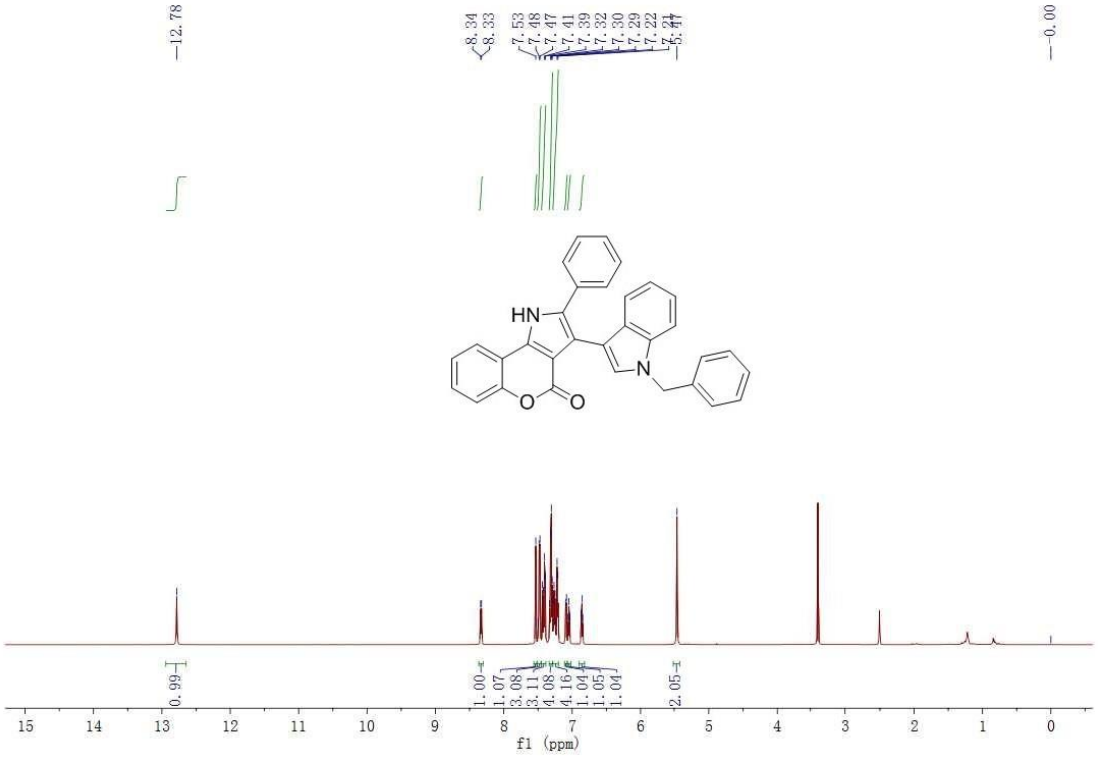
^{1}H NMR spectra of compound **4e**



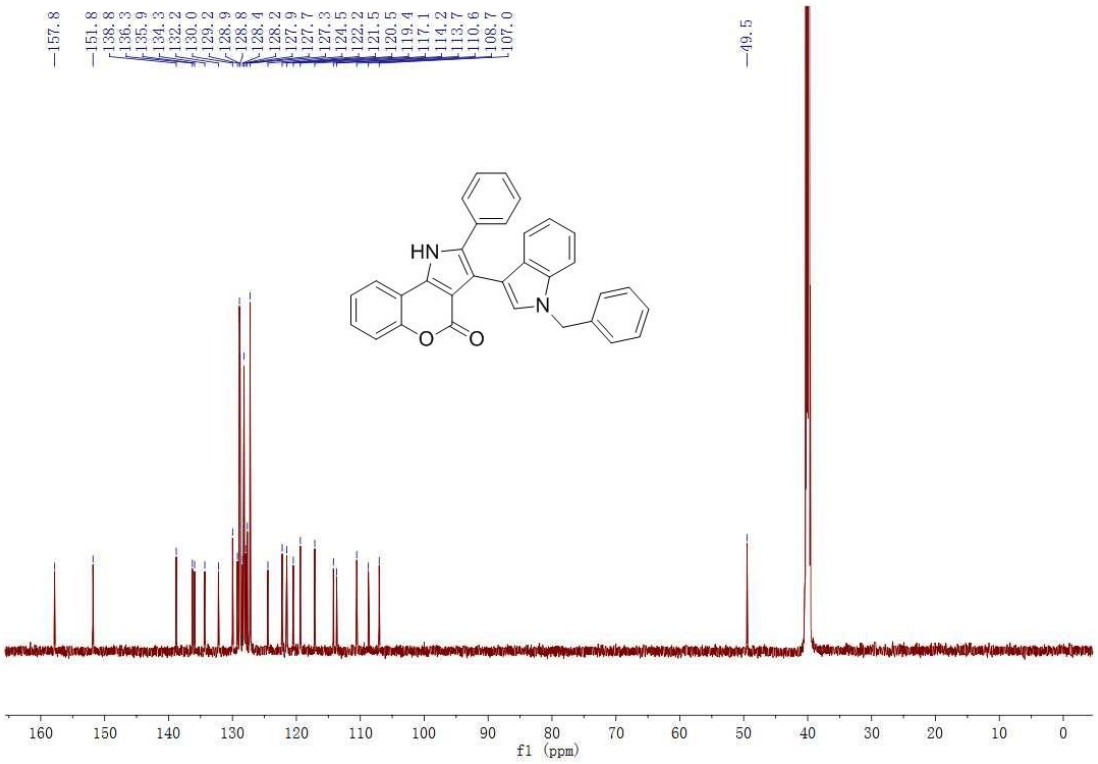
^{13}C NMR spectra of compound **4e**



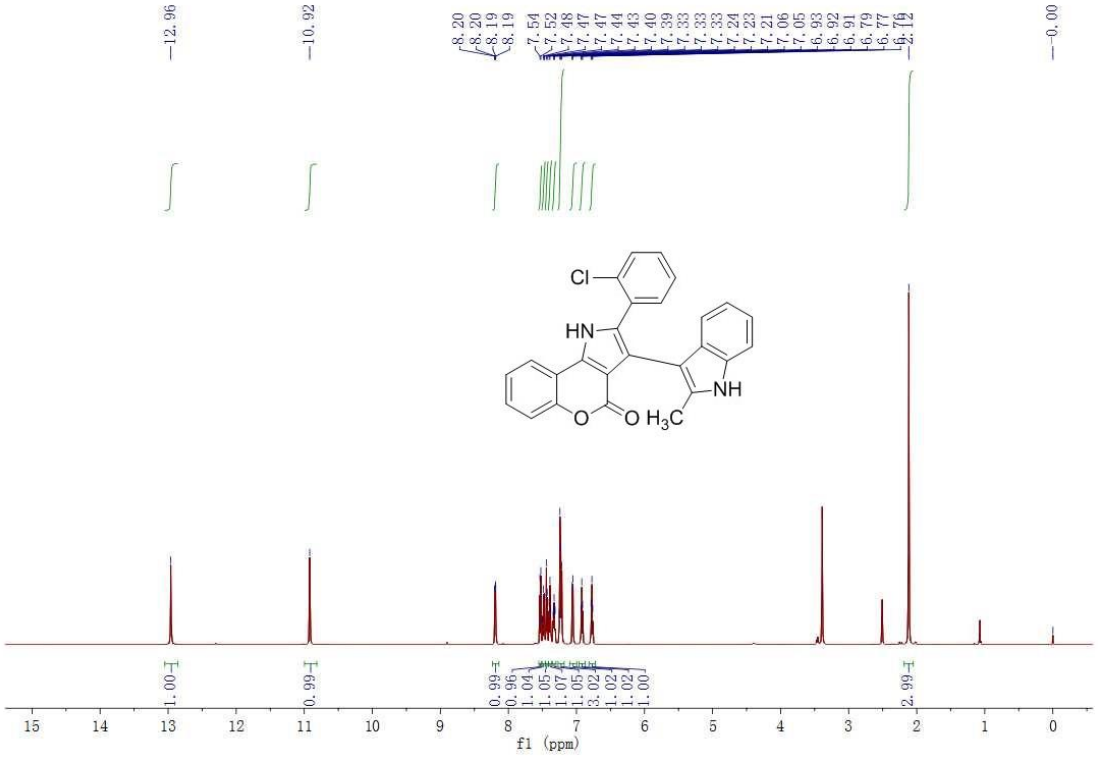
^{1}H NMR spectra of compound **4f**



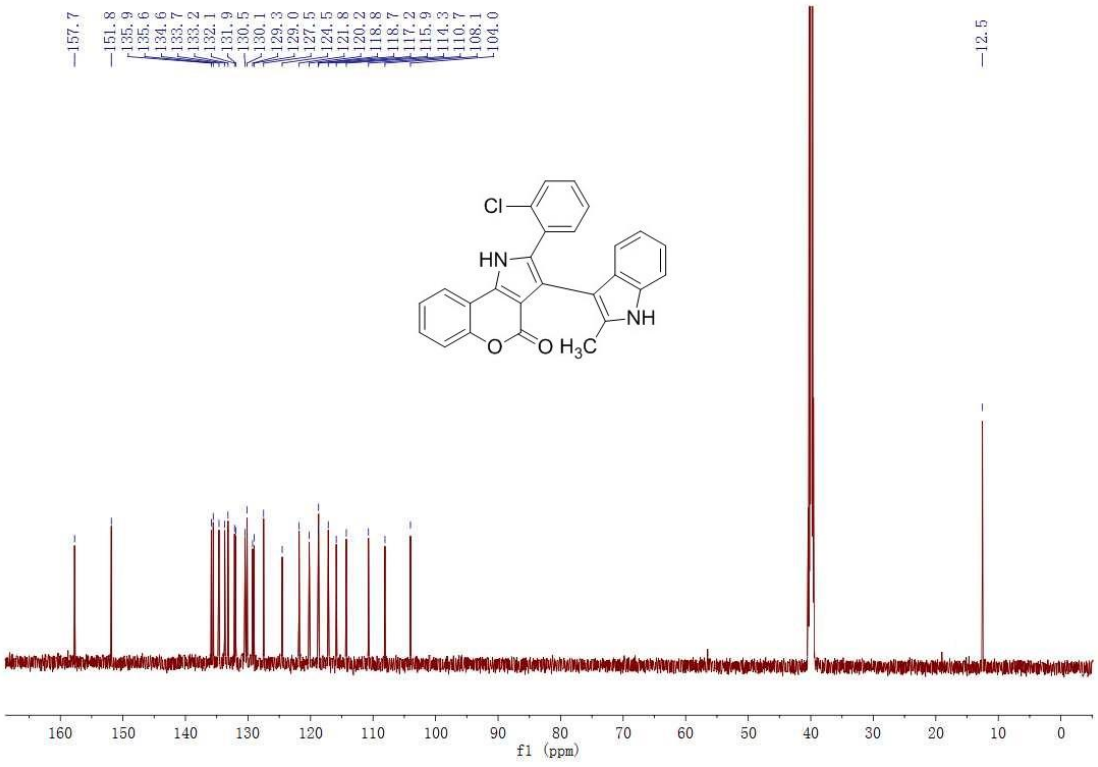
^{1}H NMR spectra of compound **4f**



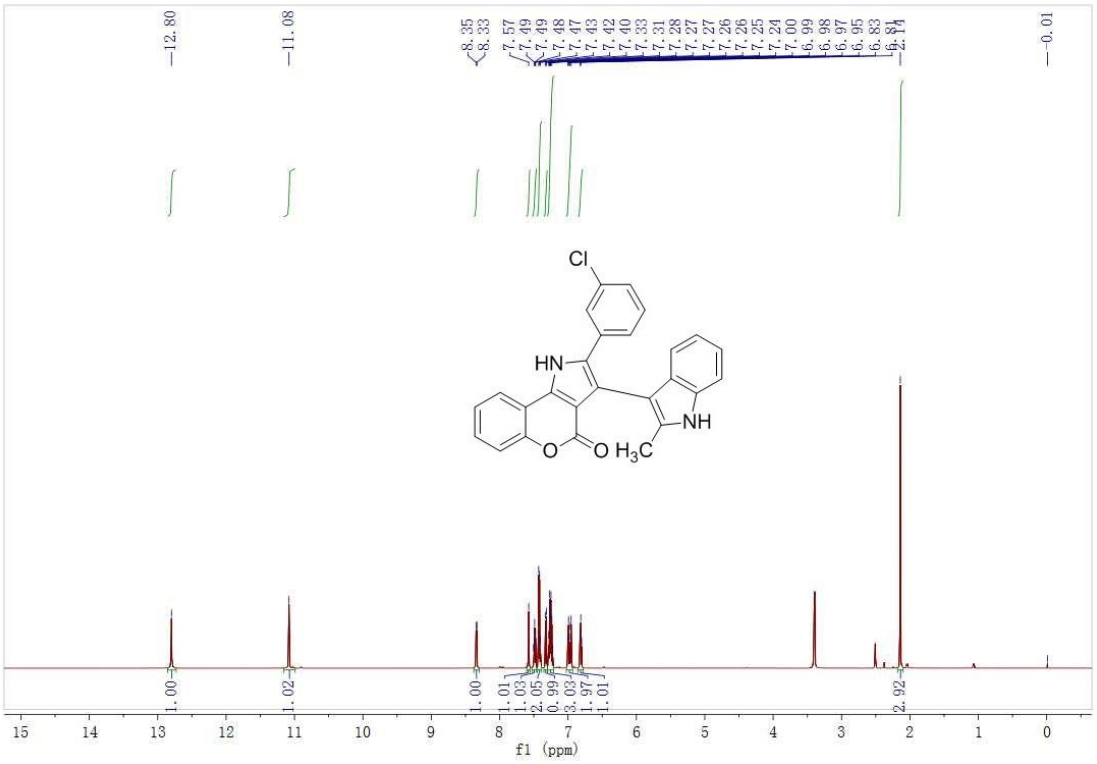
^{1}H NMR spectra of compound **4g**



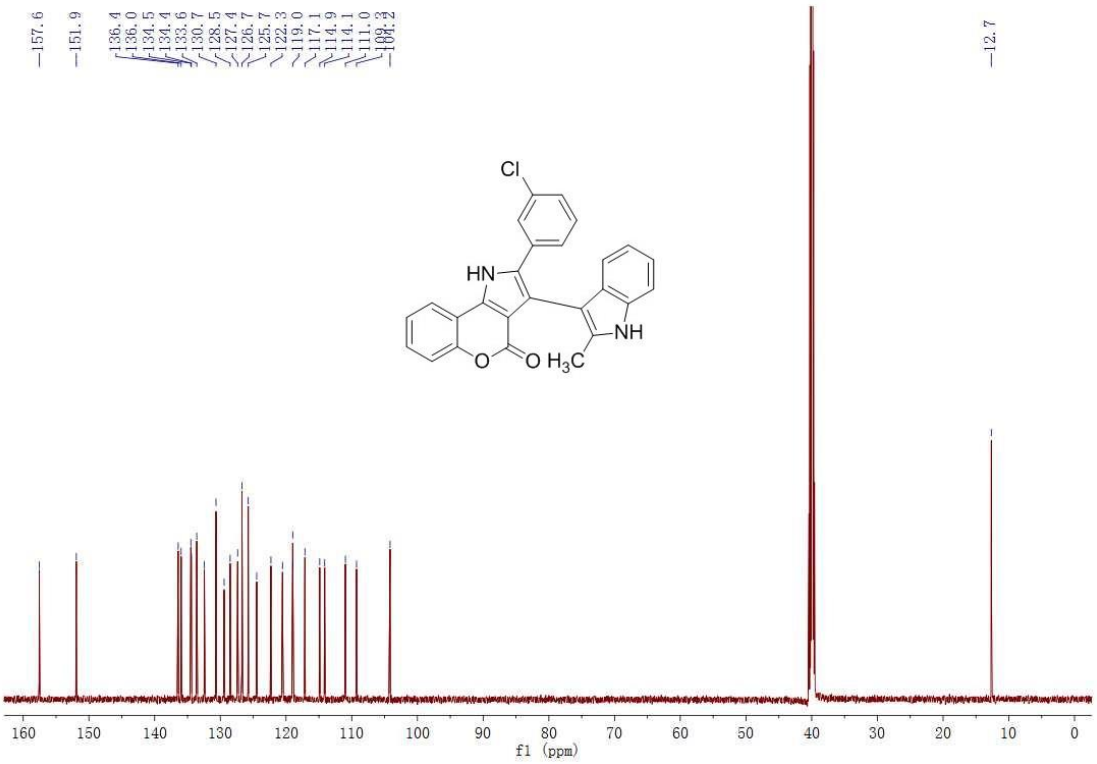
^{13}C NMR spectra of compound **4g**



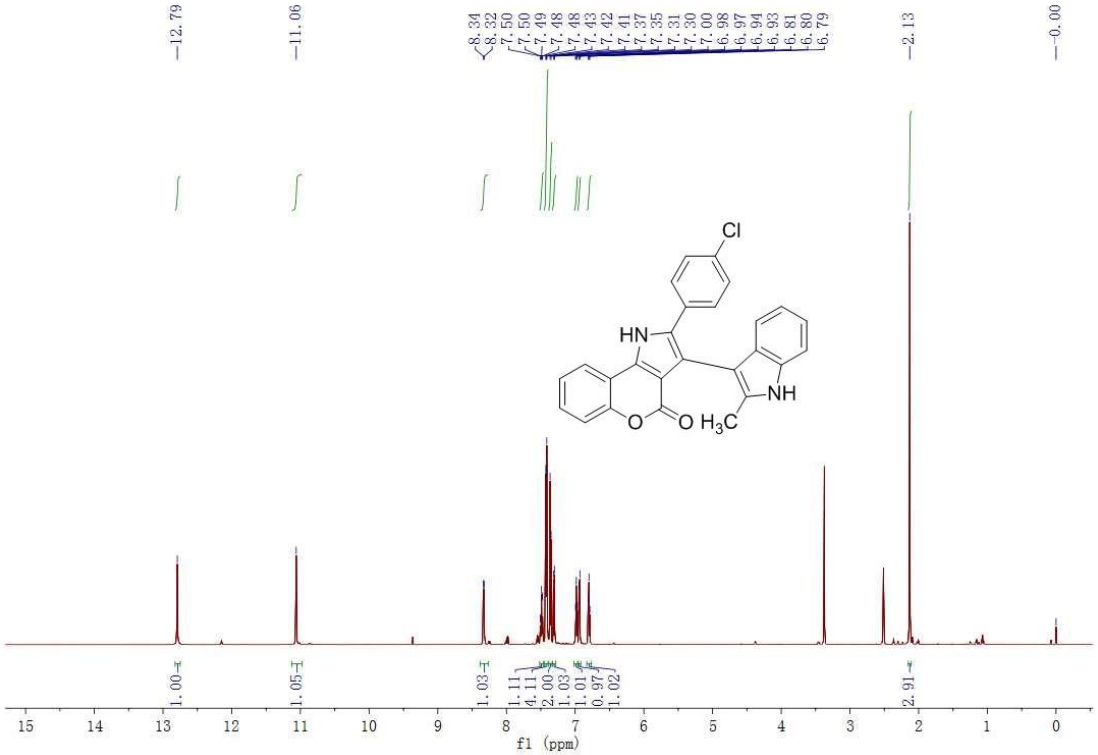
^{1}H NMR spectra of compound **4h**



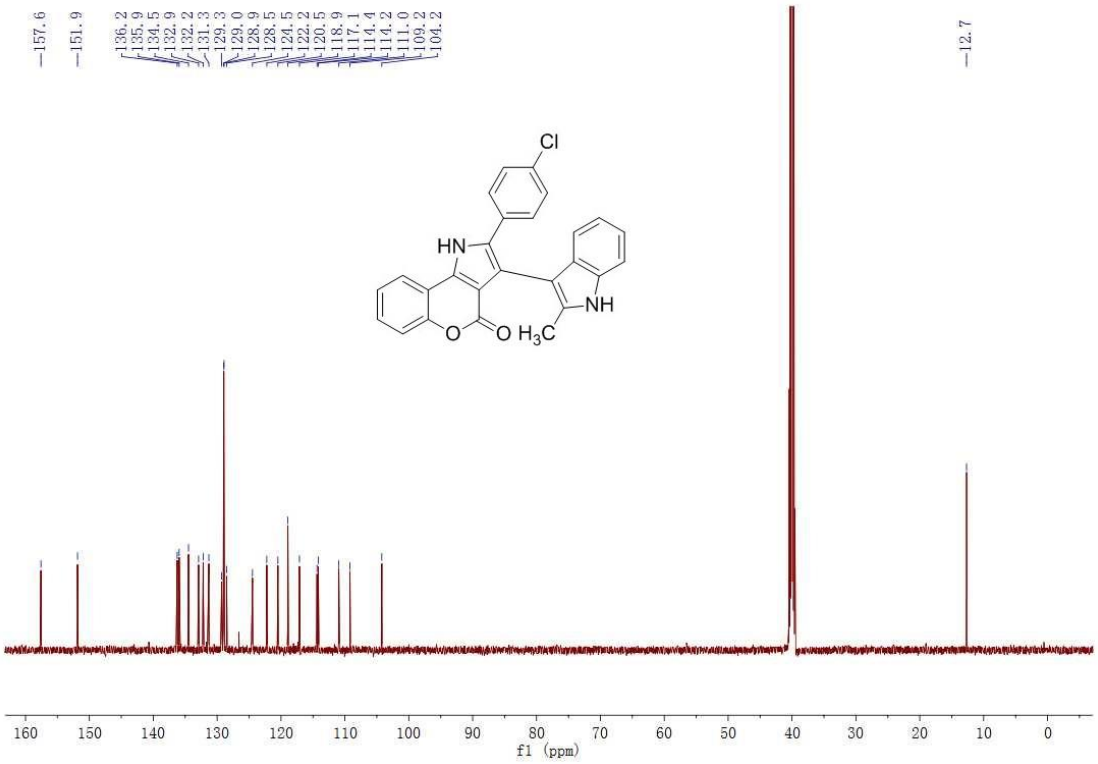
^{13}C NMR spectra of compound **4h**



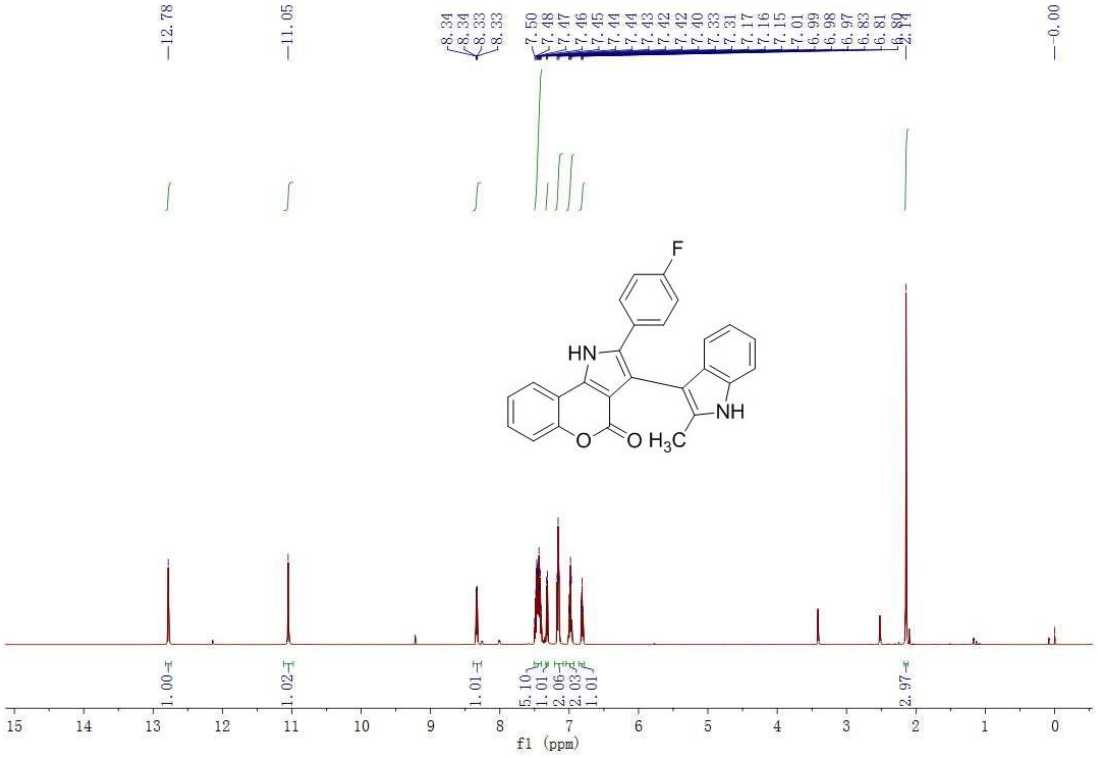
^{1}H NMR spectra of compound **4i**



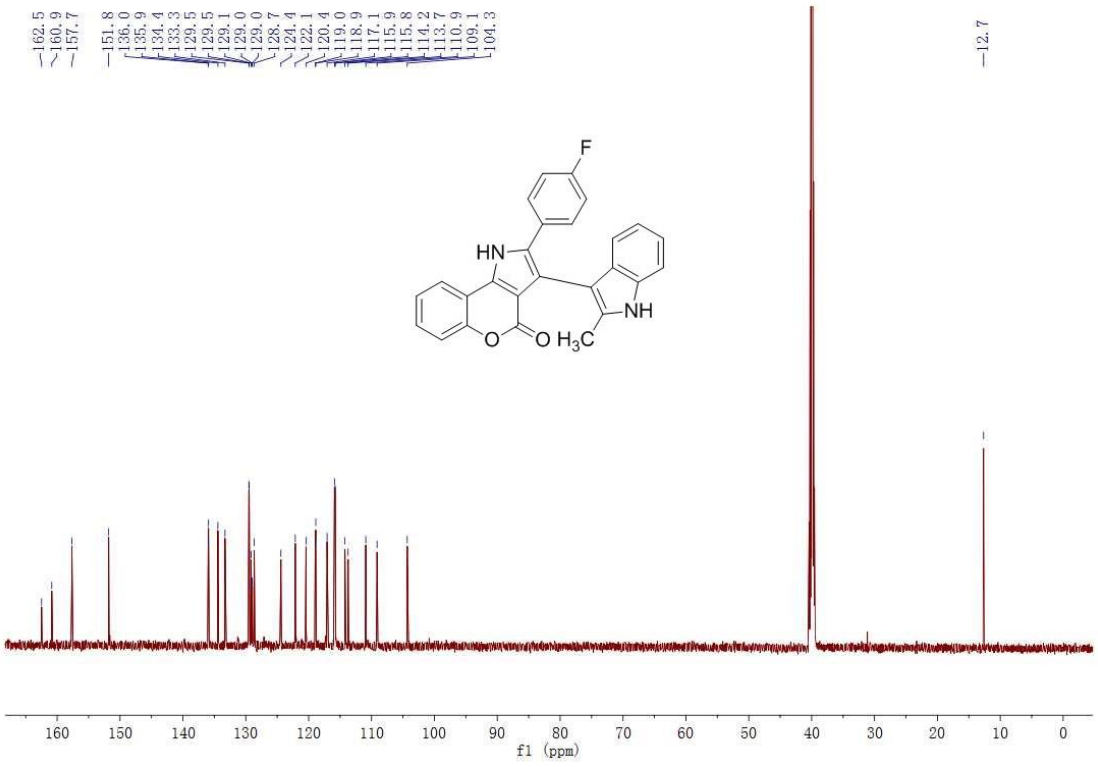
^{13}C NMR spectra of compound **4i**



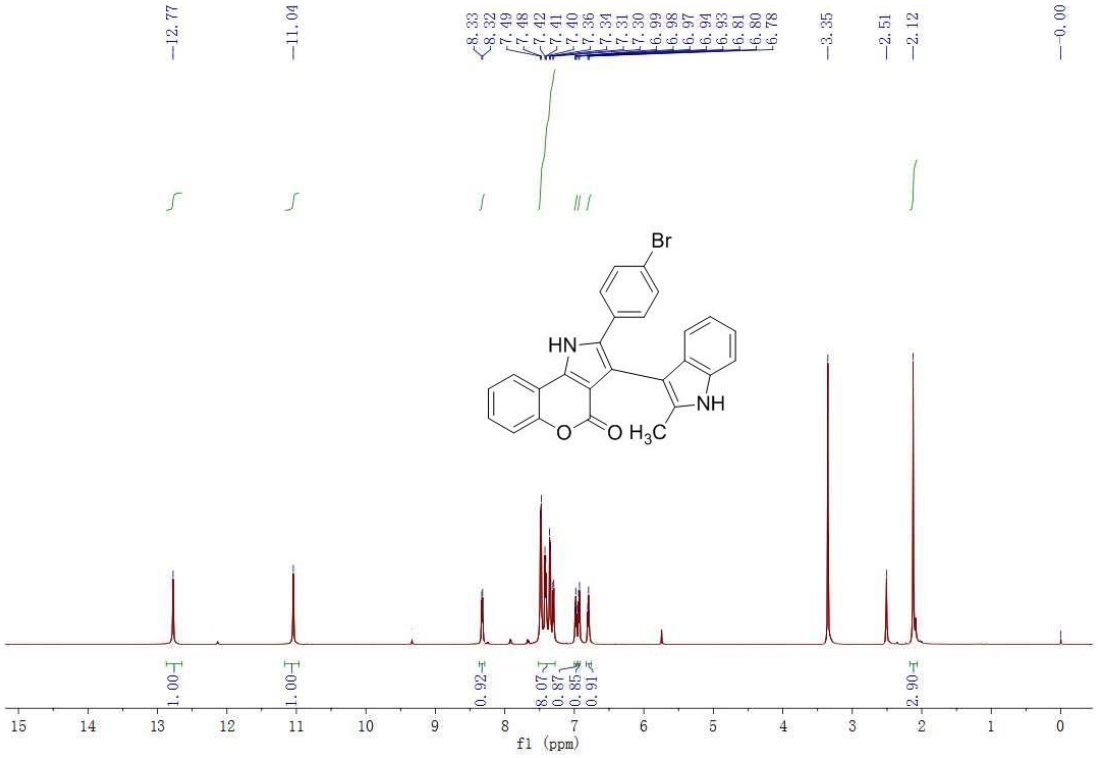
^{1}H NMR spectra of compound **4j**



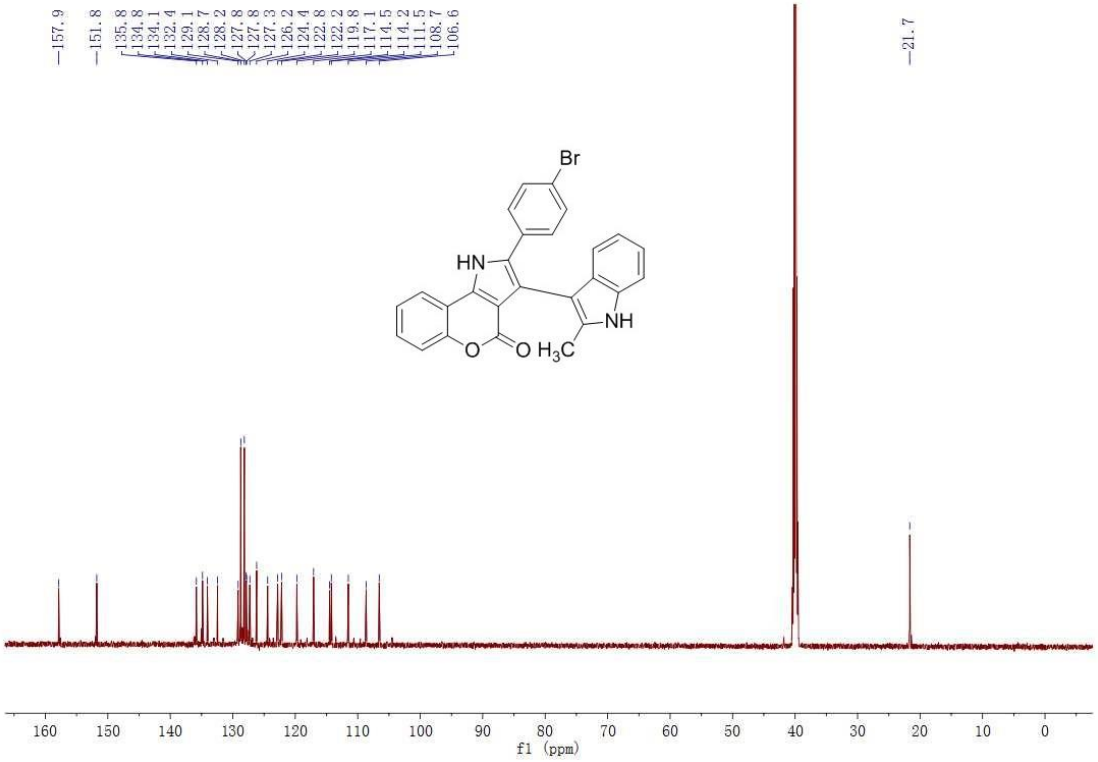
^{13}C NMR spectra of compound **4j**



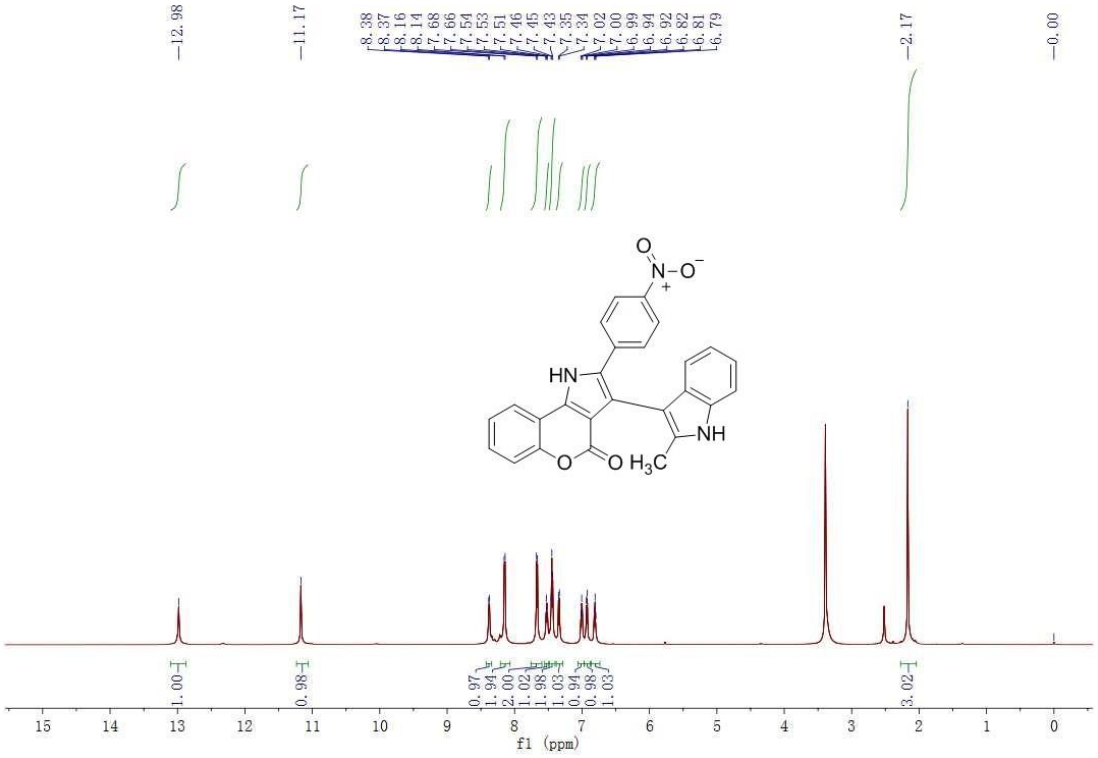
^{1}H NMR spectra of compound **4k**



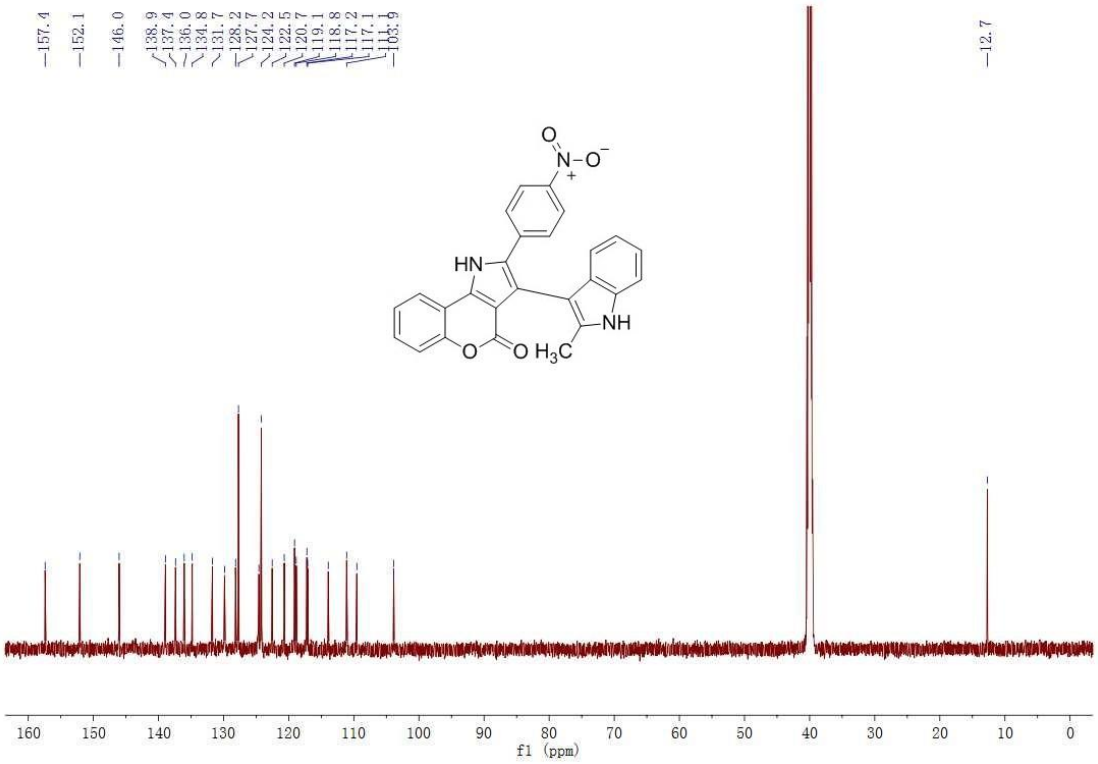
^{13}C NMR spectra of compound **4k**



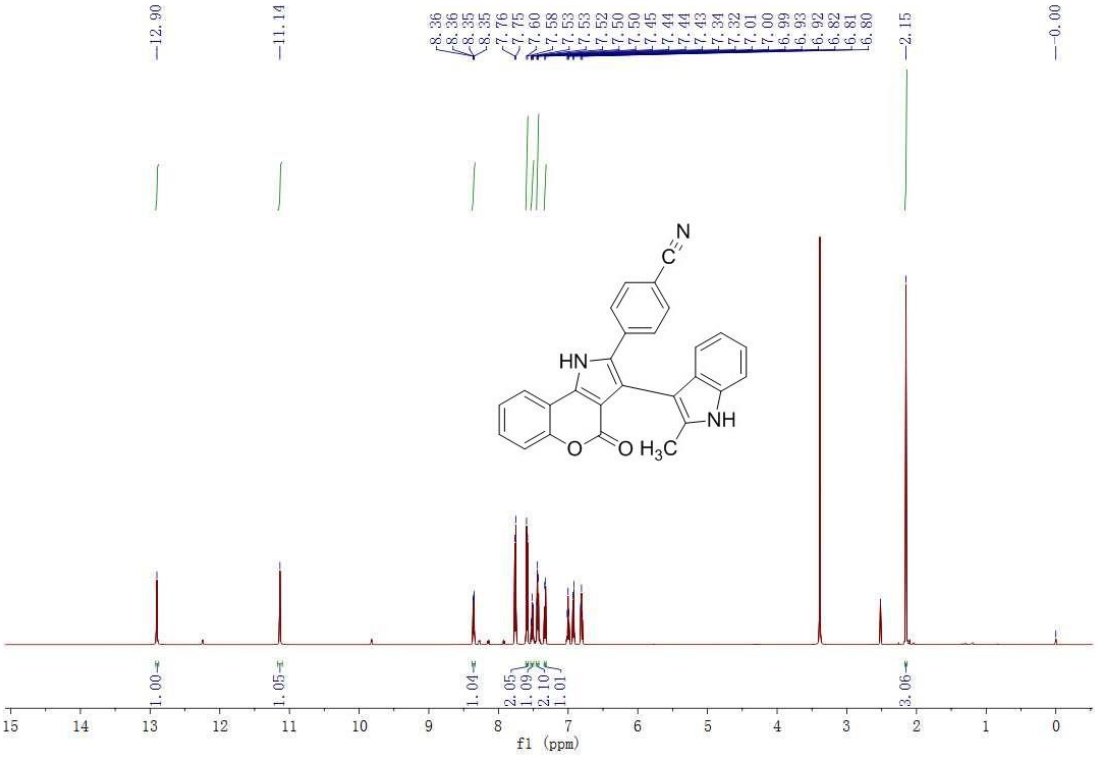
^{1}H NMR spectra of compound **4l**



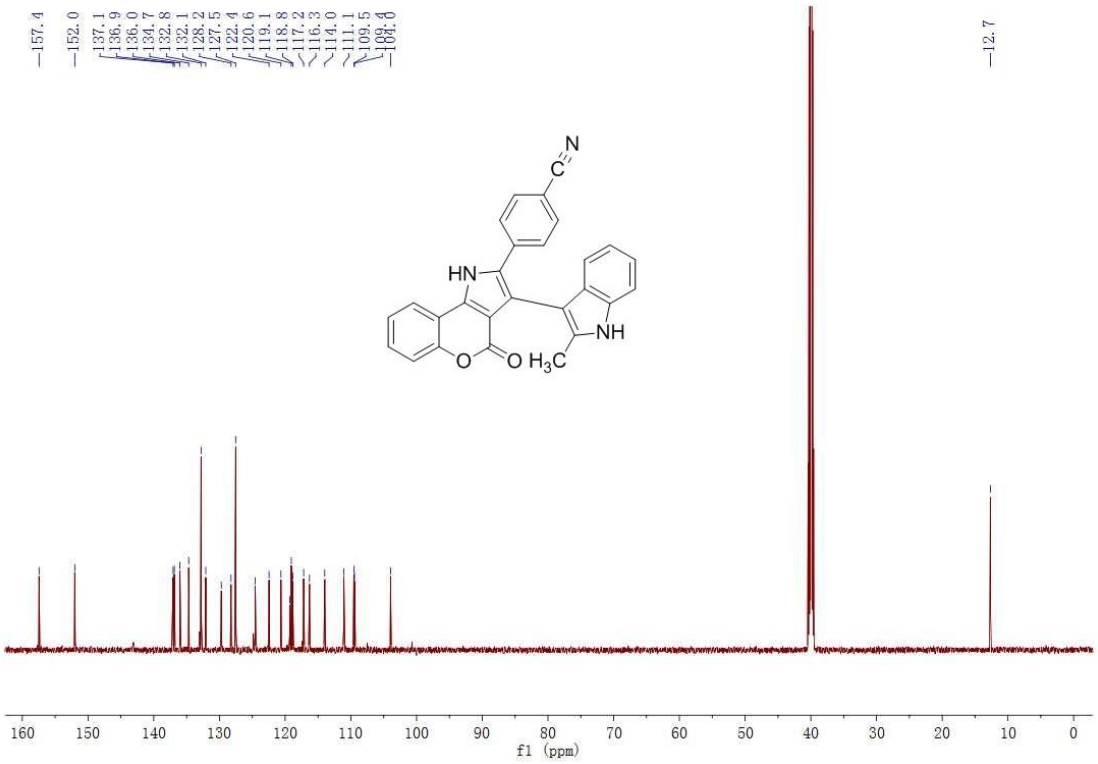
^{13}C NMR spectra of compound **4l**



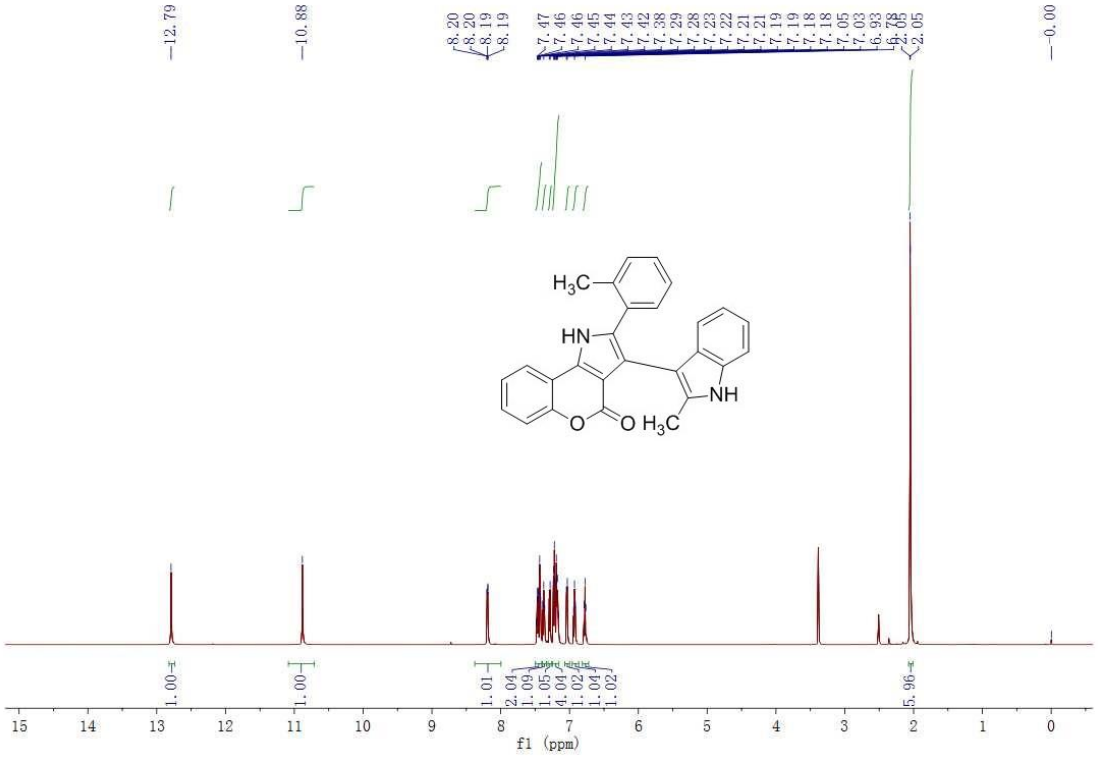
^{1}H NMR spectra of compound **4m**



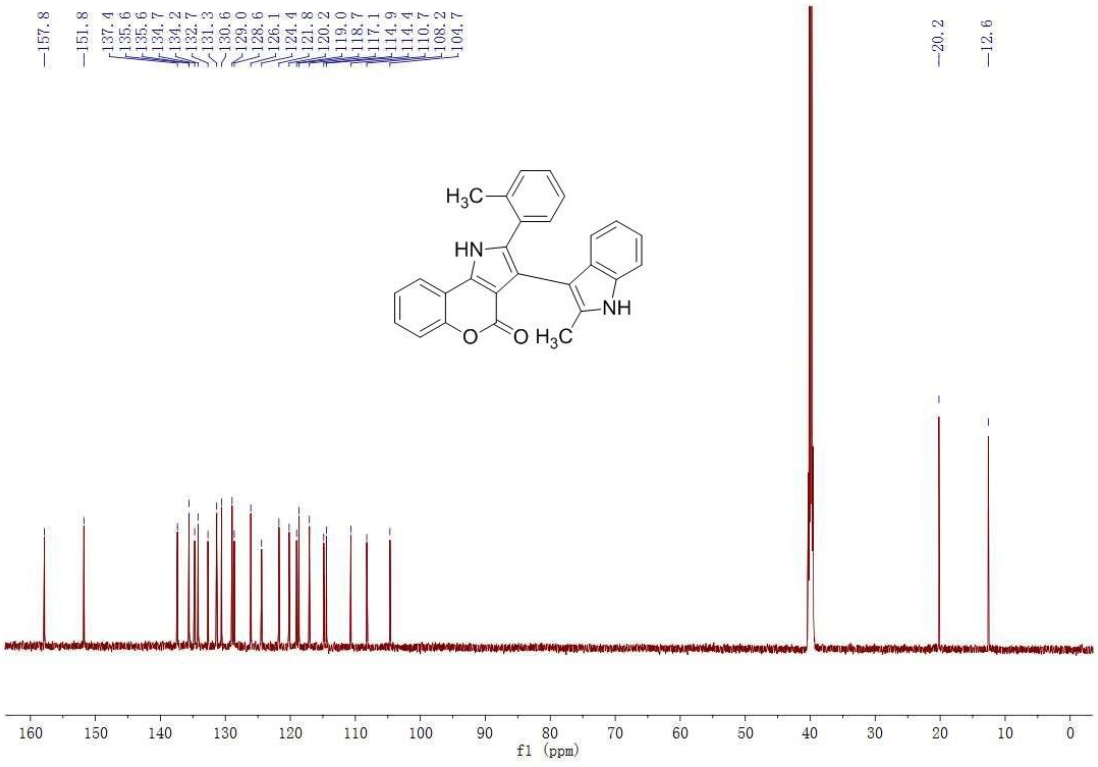
^{13}C NMR spectra of compound **4m**



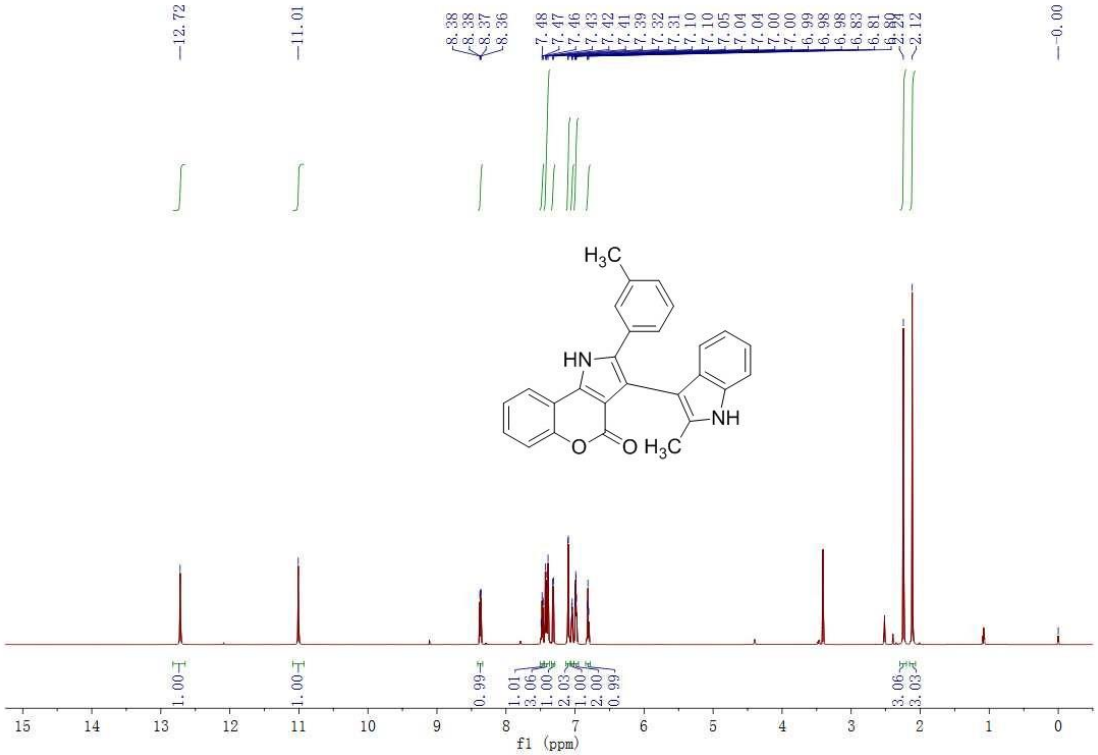
^{1}H NMR spectra of compound **4n**



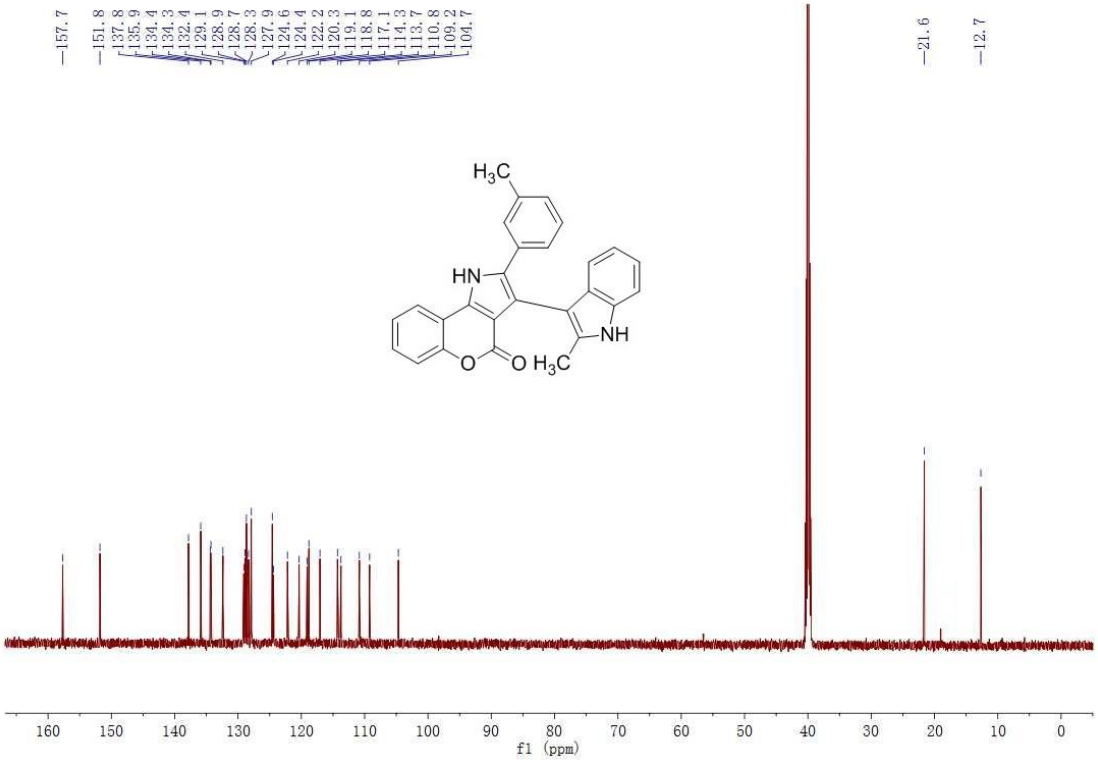
^{13}C NMR spectra of compound **4n**



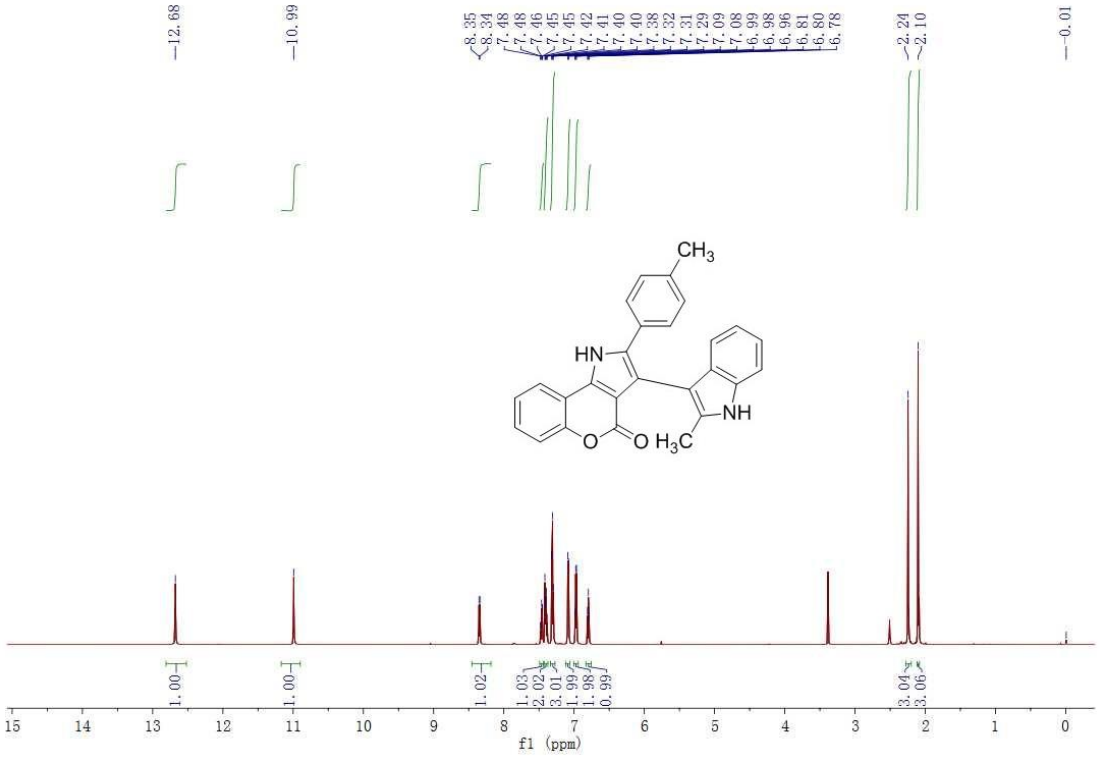
^{1}H NMR spectra of compound **4o**



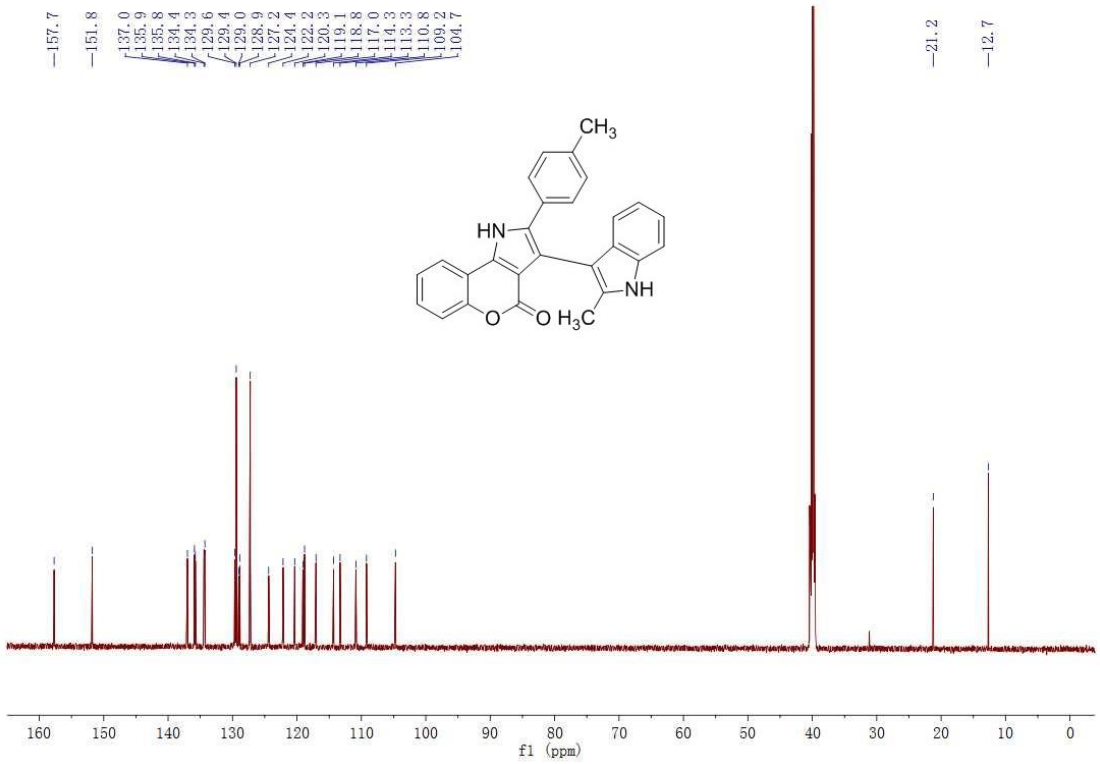
^{13}C NMR spectra of compound **4o**



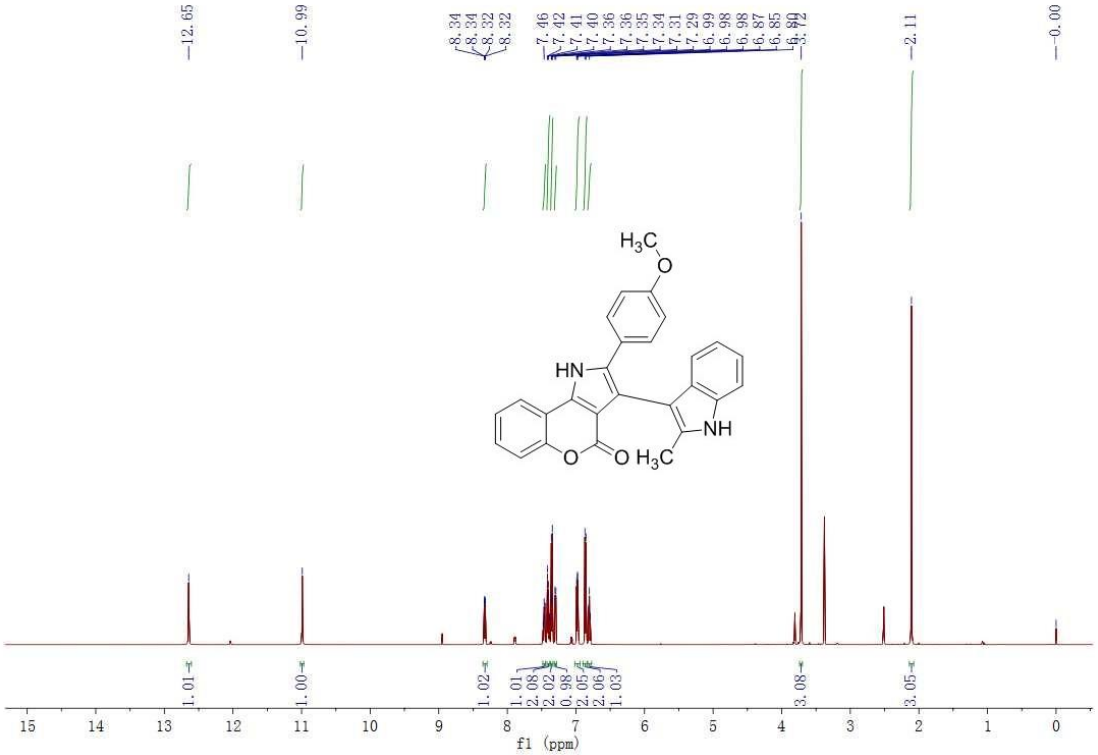
^{1}H NMR spectra of compound **4p**



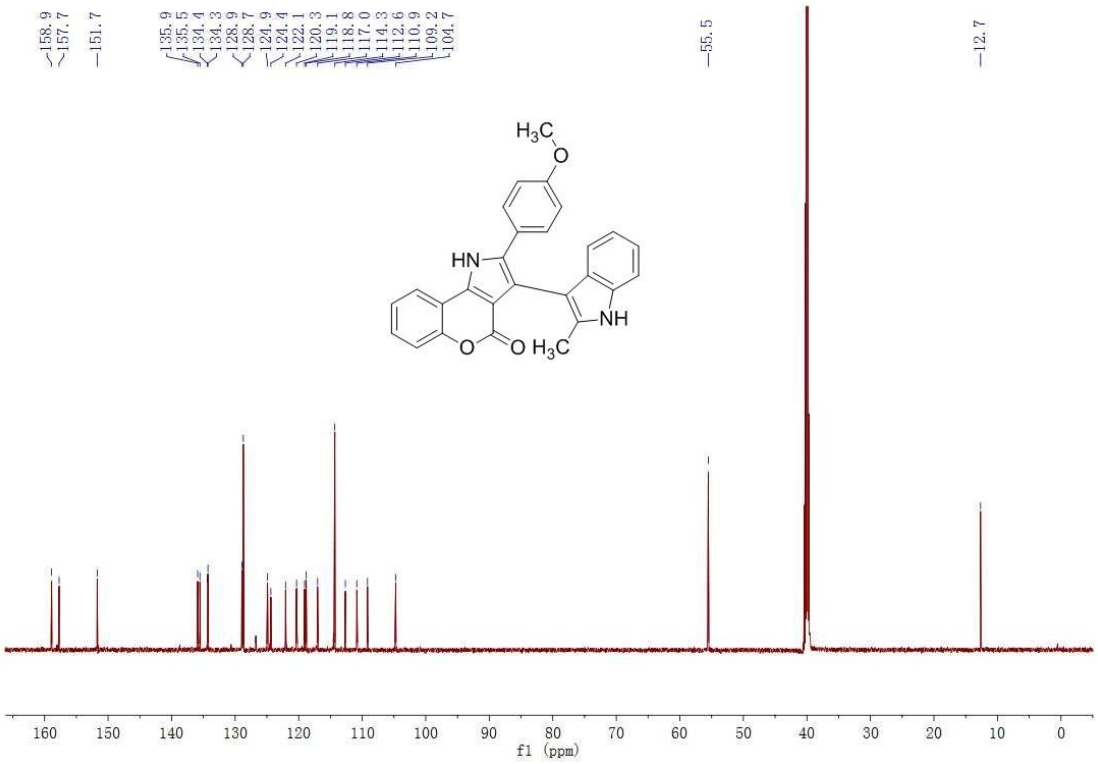
^{13}C NMR spectra of compound **4p**



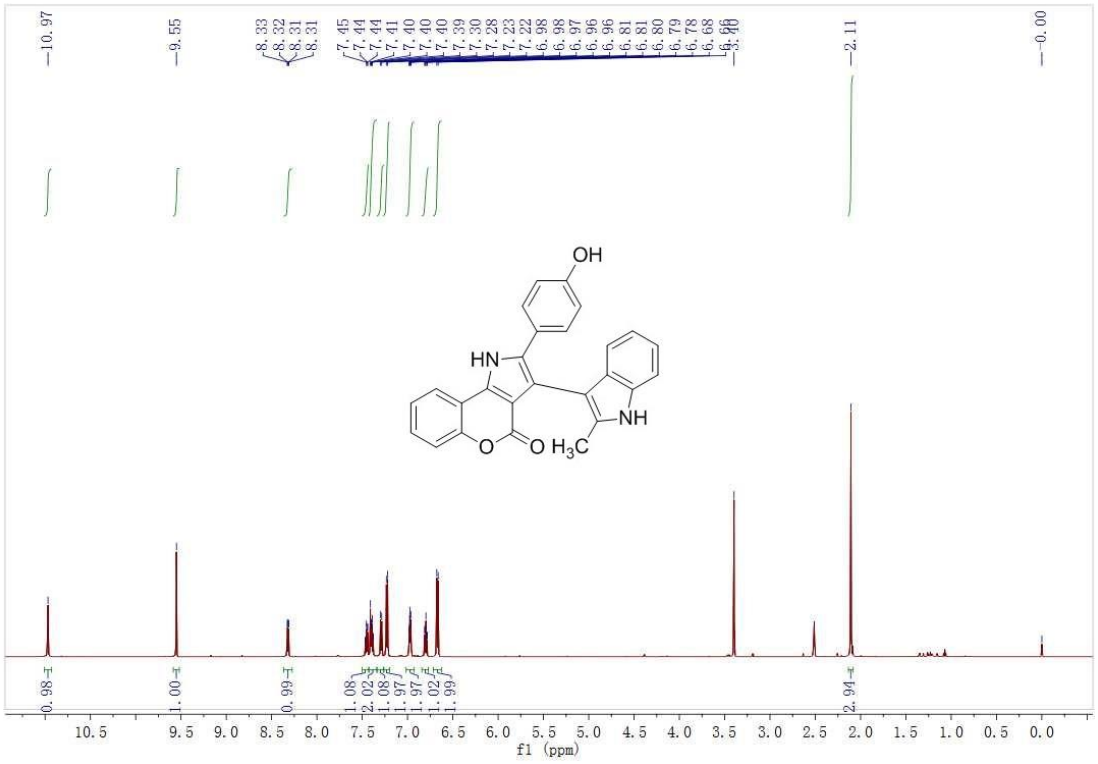
^{1}H NMR spectra of compound **4q**



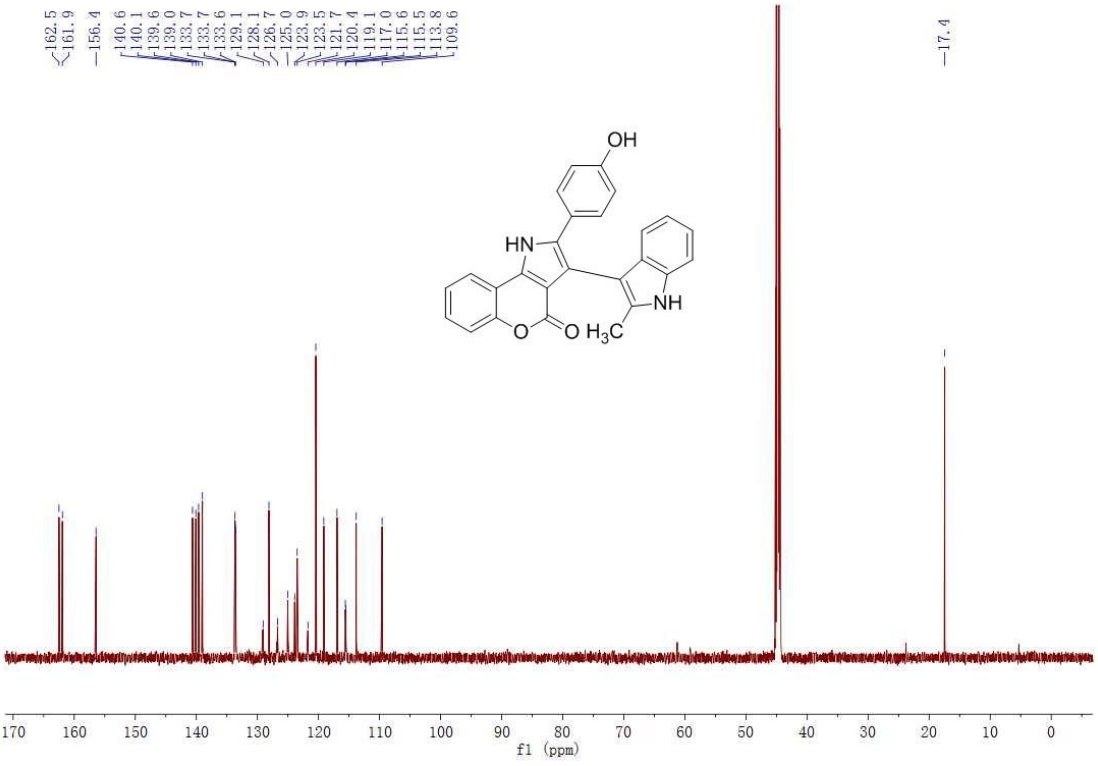
^{13}C NMR spectra of compound **4q**



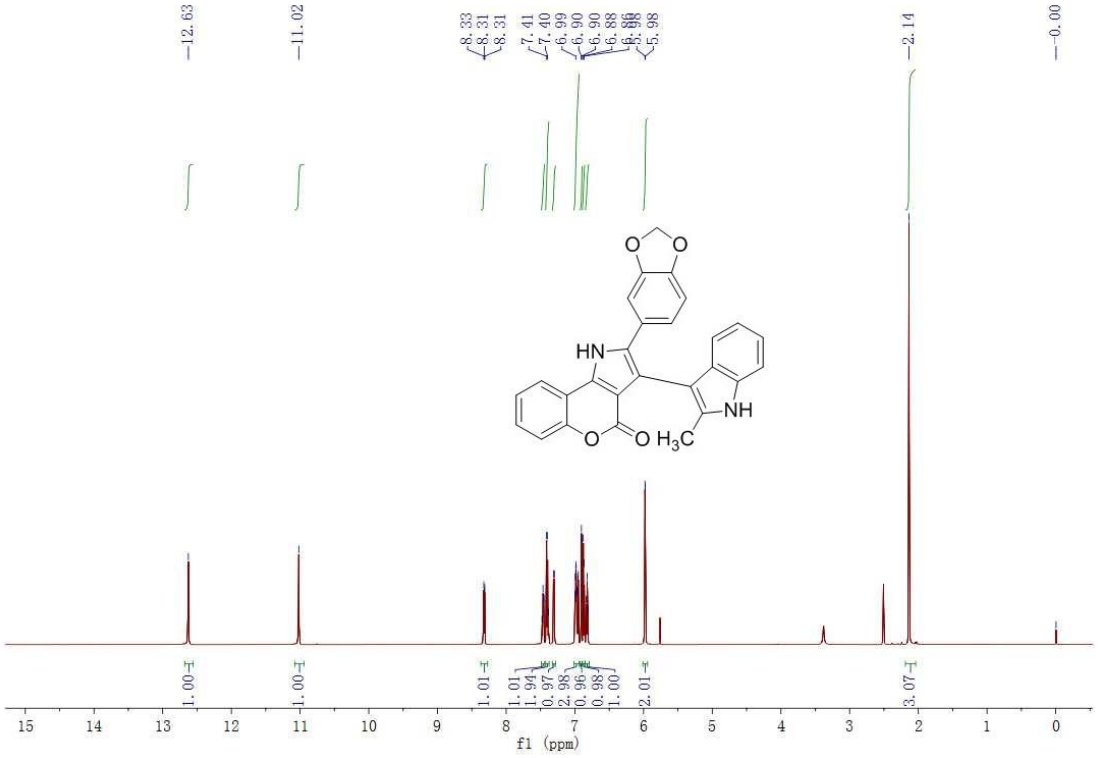
^{1}H NMR spectra of compound **4r**



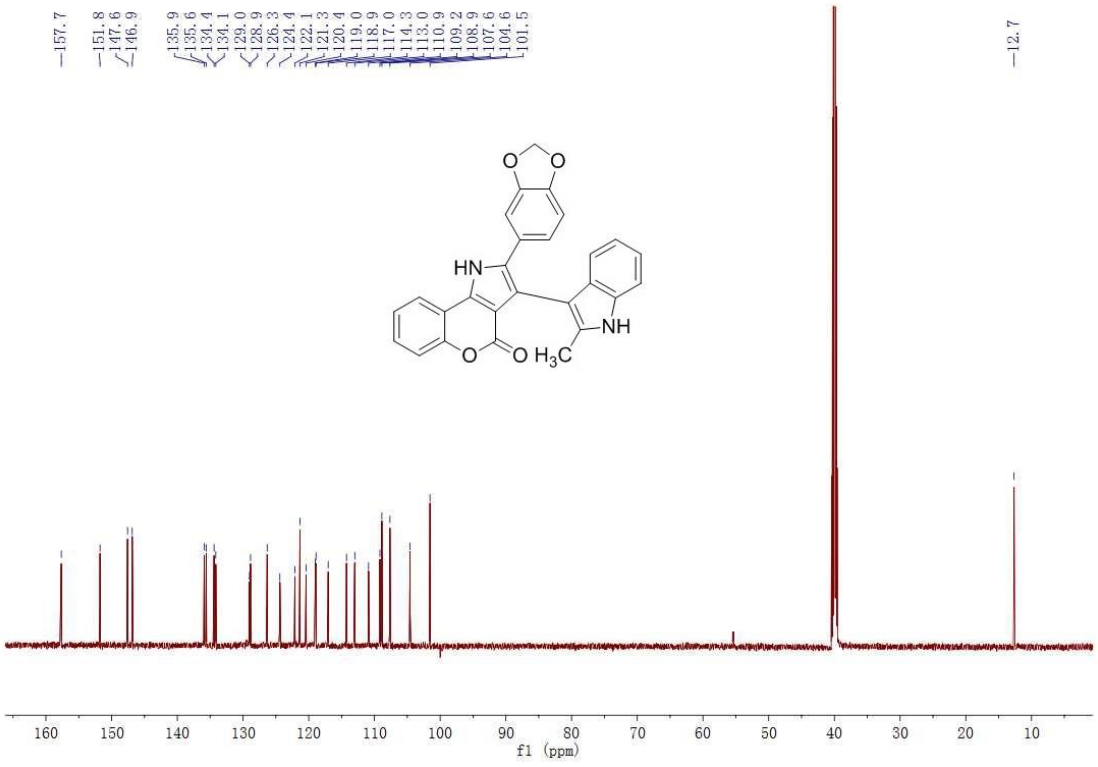
^{13}C NMR spectra of compound **4r**



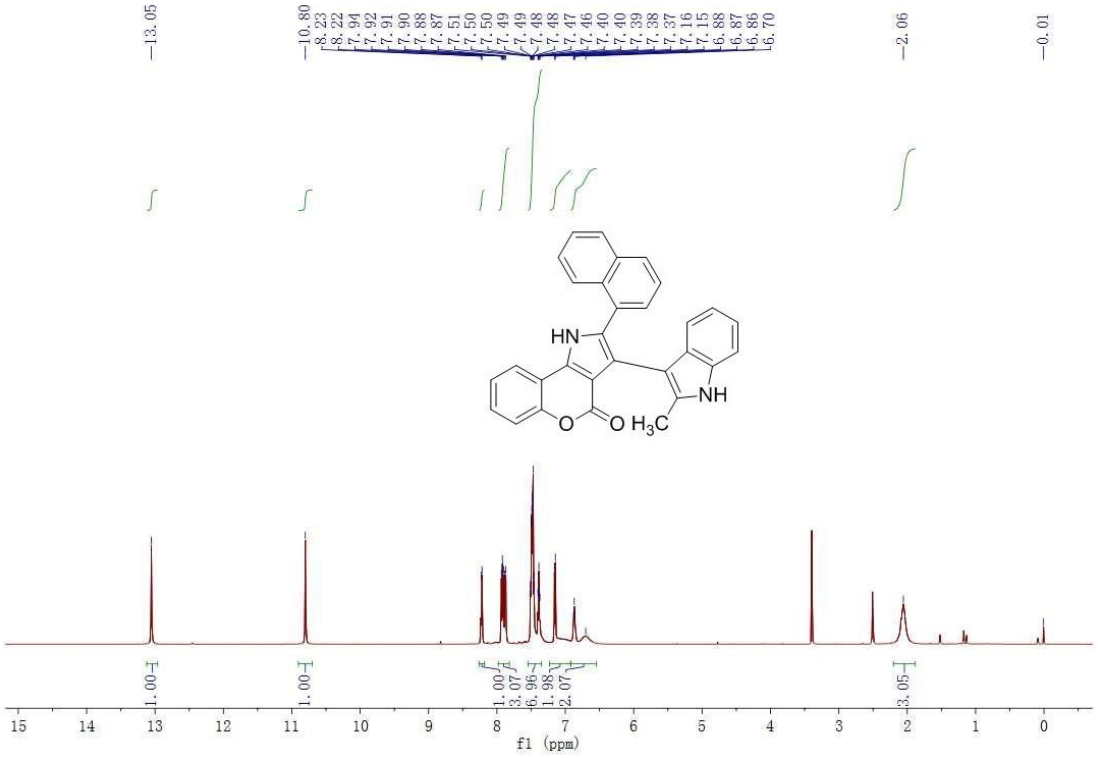
^{1}H NMR spectra of compound **4s**



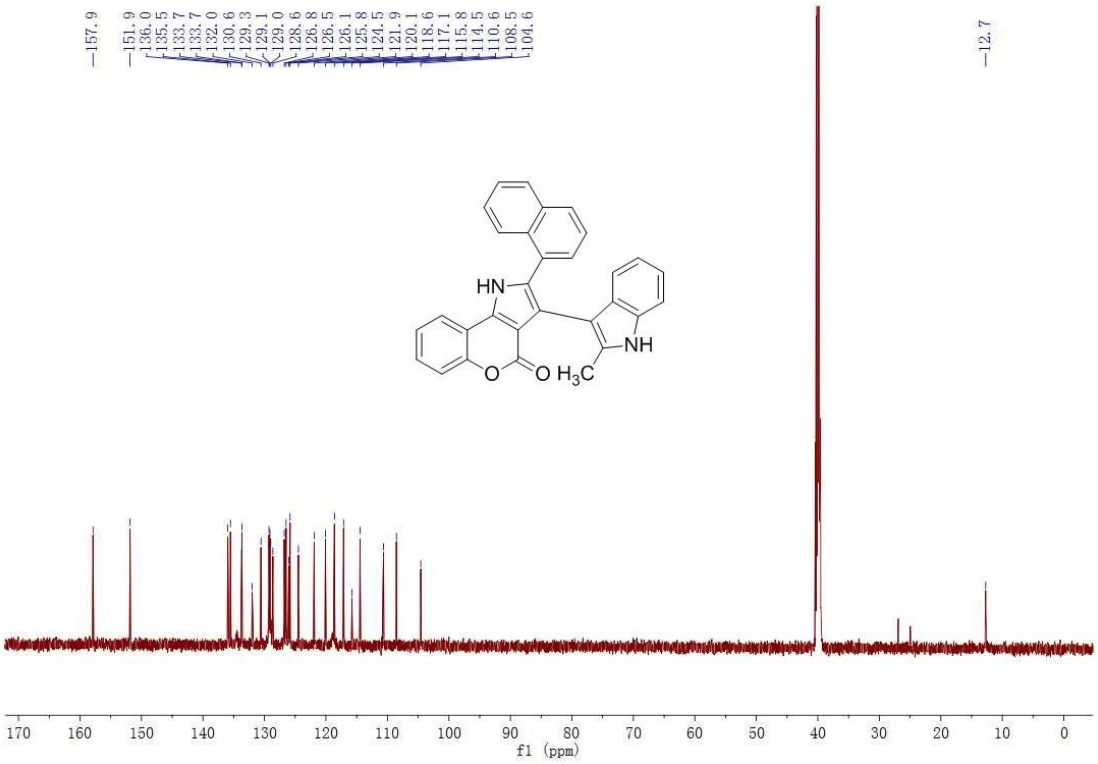
^{13}C NMR spectra of compound **4s**



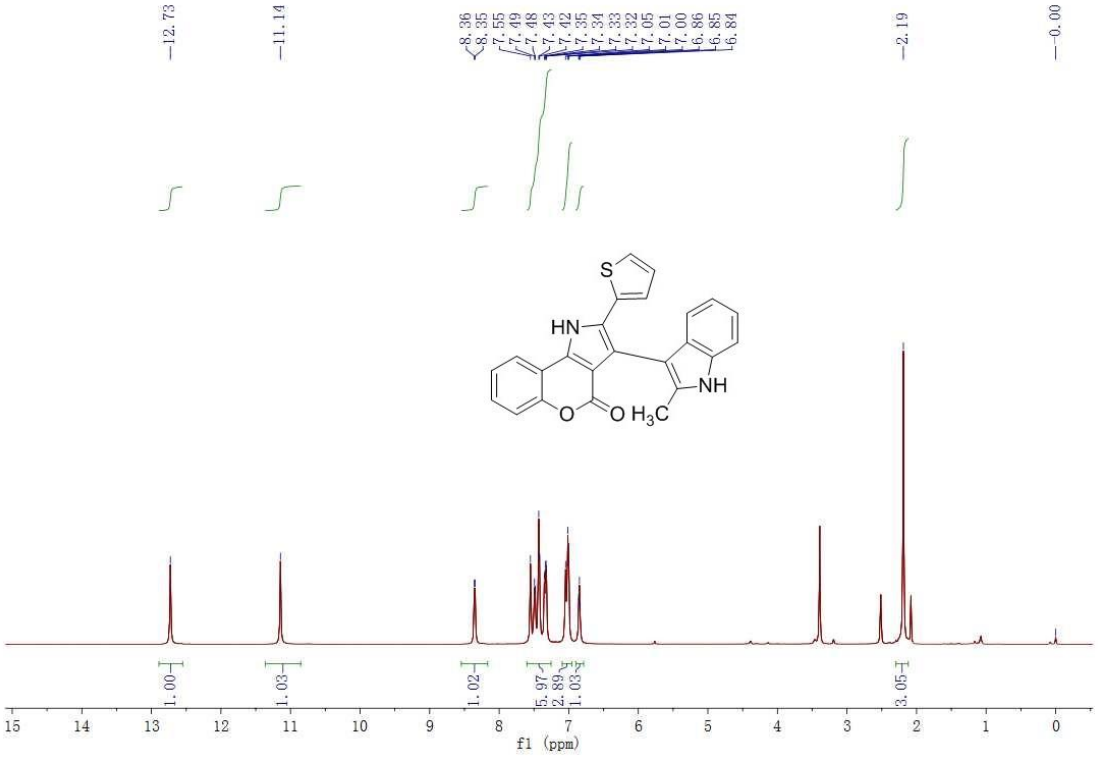
^{1}H NMR spectra of compound **4t**



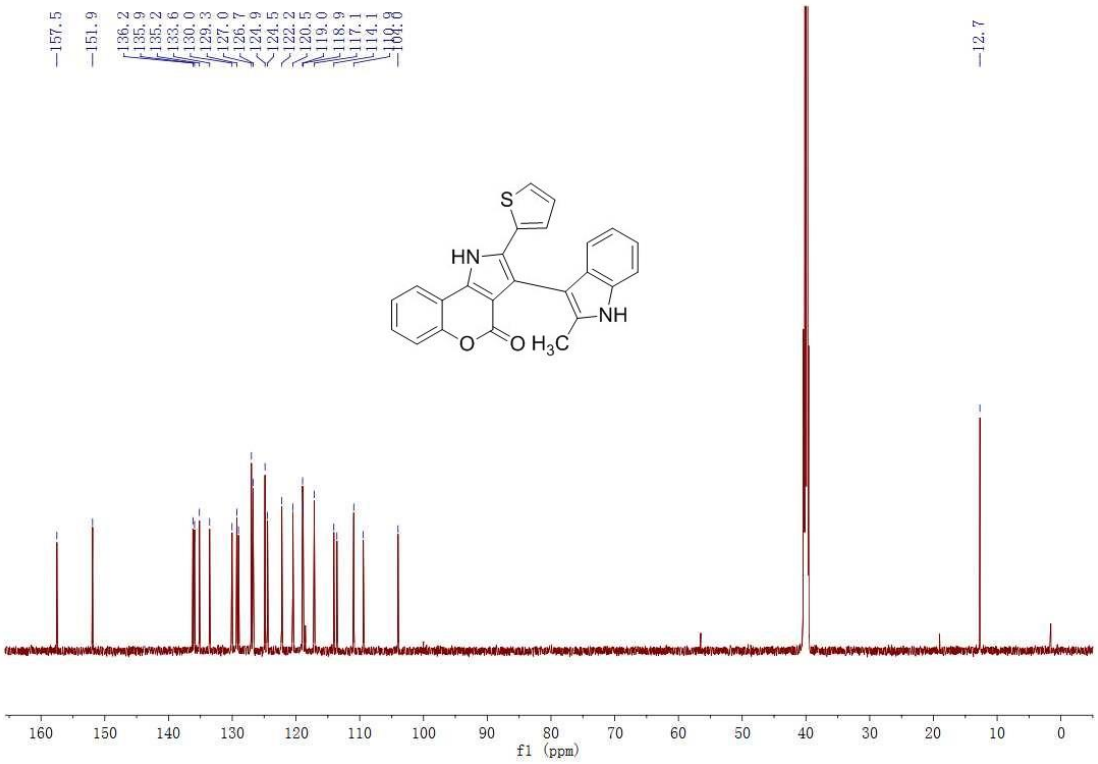
^{13}C NMR spectra of compound **4t**



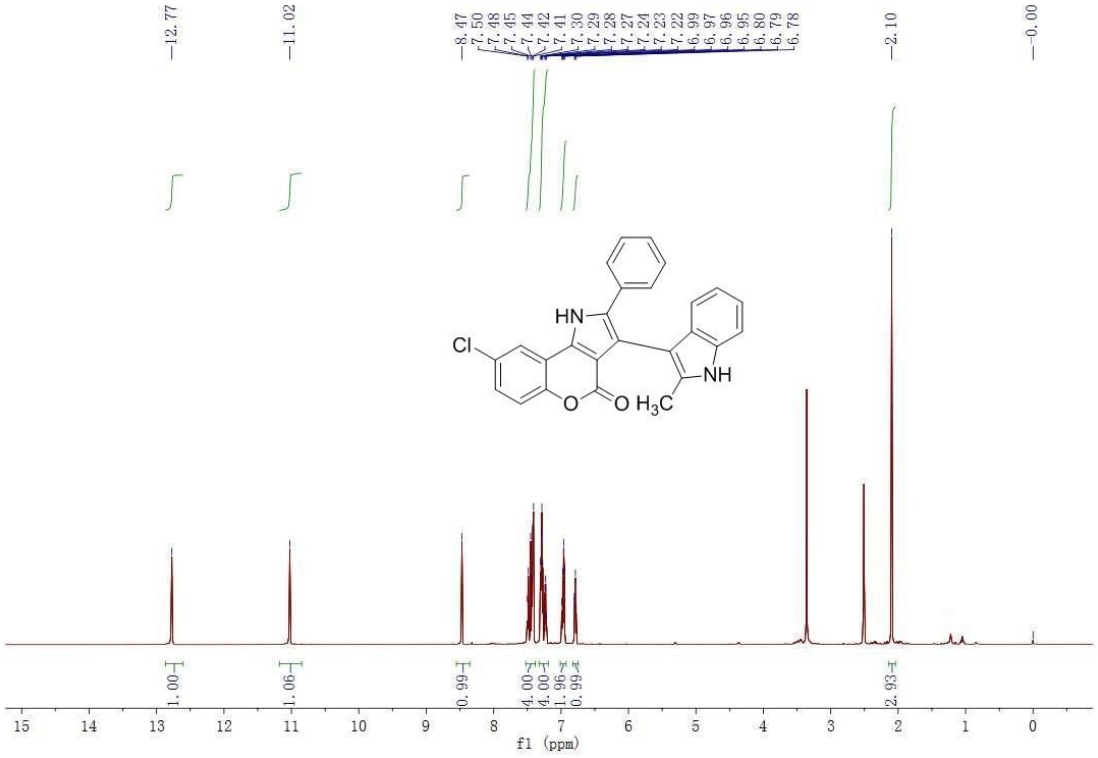
^{1}H NMR spectra of compound **4u**



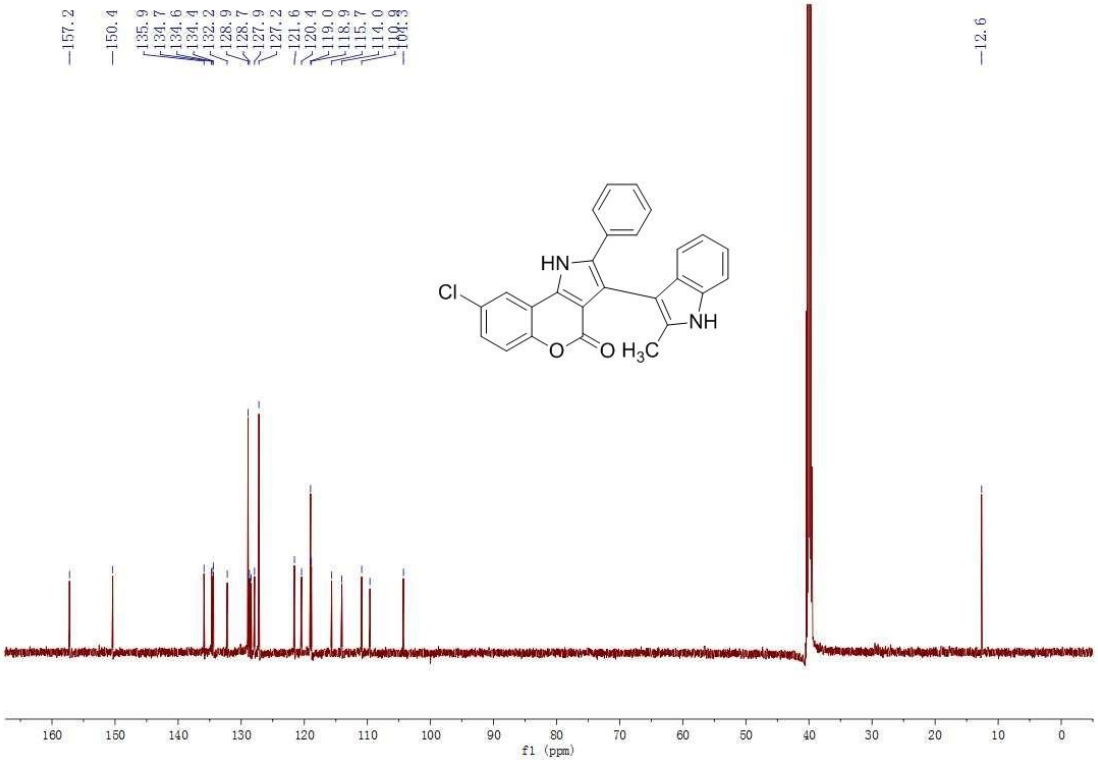
^{13}C NMR spectra of compound **4u**



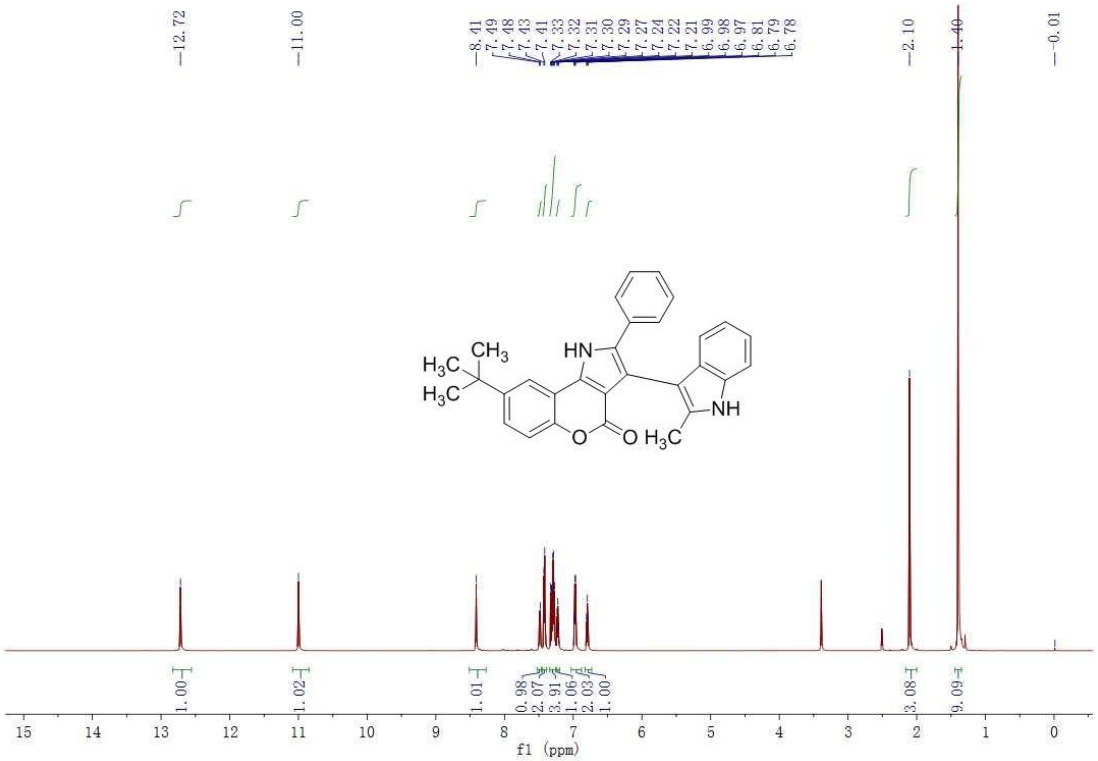
^{1}H NMR spectra of compound **4v**



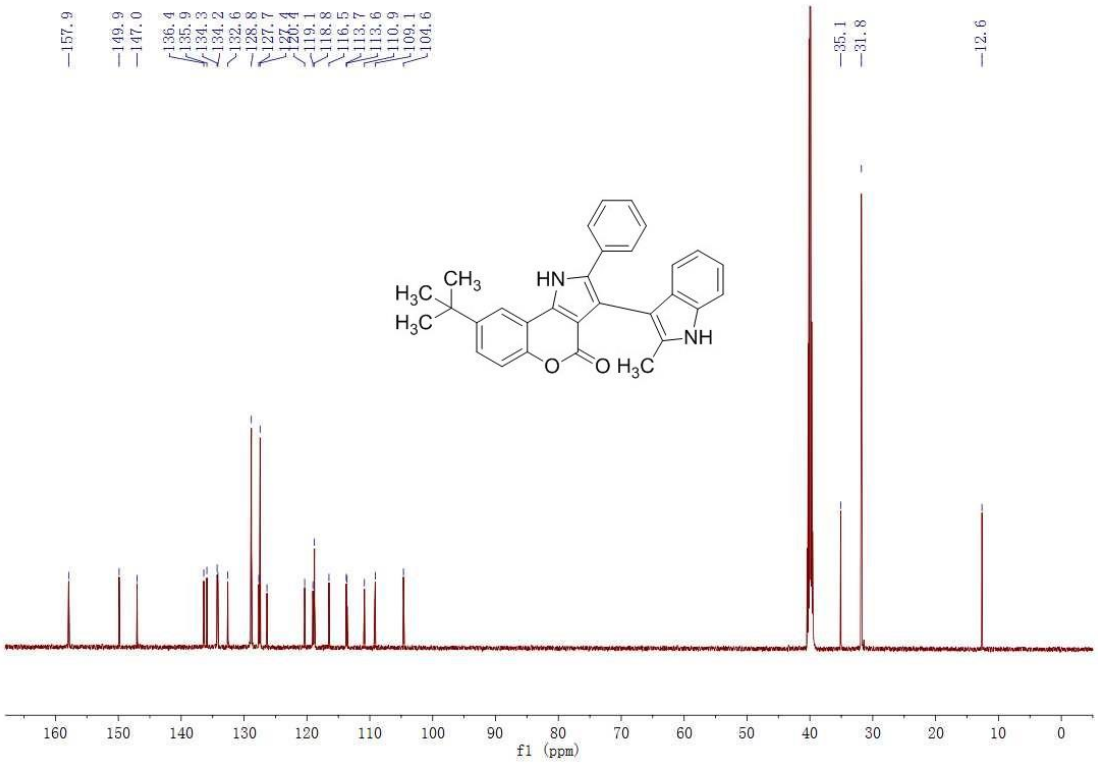
^{13}C NMR spectra of compound **4v**



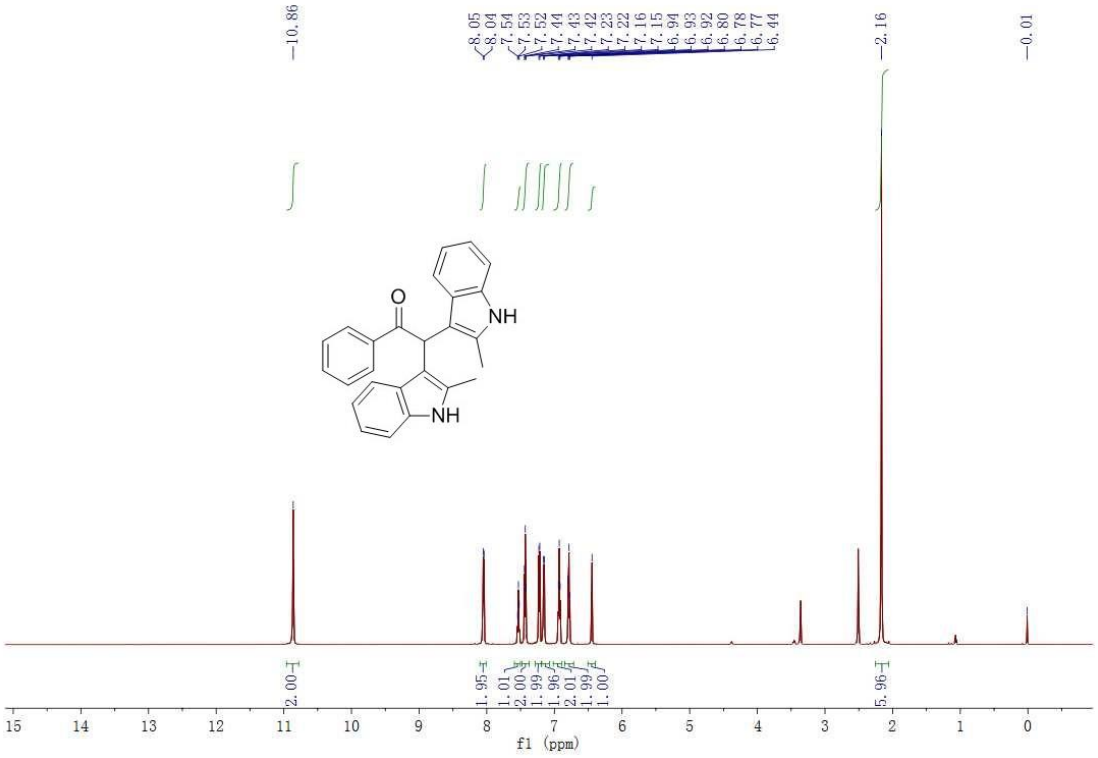
^{1}H NMR spectra of compound **4w**



^{13}C NMR spectra of compound **4w**



^{1}H NMR spectra of compound **5**



^{1}H NMR spectra of compound **A**