Electronic Supplementary Material (ESI) for Green Chemistry.
This journal is © The Royal Society of Chemistry 2022

Supporting Information

Divergent C(sp^2)-H Arylation of Heterocycles *via* Organic Photoredox Catalysis

Jie Ren, Chao Pi, Xiuling Cui* and Yangjie Wu*

† Henan Key Laboratory of Chemical Biology and Organic Chemistry, Key Laboratory of Applied Chemistry of Henan Universities, Green Catalysis Center and College of Chemistry, Zhengzhou University, Zhengzhou 450052, P. R. China

E-mail: cuixl@zzu.edu.cn

E-mail: wyj@zzu.edu.cn

Table of Contents

1. General Information……...……S2
2. General procedure for the synthesis of starting materials……..S2
3. Typical Catalytic Procedure…….....S5
4. Characterization of the Products……S5
5. Gram-scale Reaction……...……..…S19
6. Mechanism Studies……..S20
7. X-Ray Crystallographic Data of **3**……S23
8. References……....S24
9. Copies of NMR Spectra……...……..…....…S26

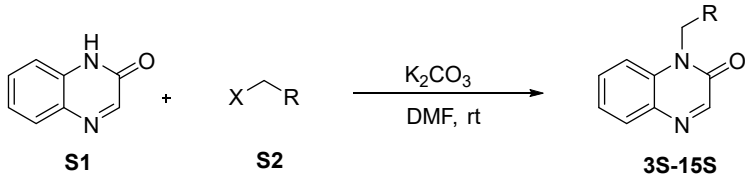
1. General Information

Unless otherwise noted, the reagents were purchased from commercial suppliers and used without additional purification. Melting points were measured on a microscopic apparatus and were uncorrected. X-ray analysis was performed with a single-crystal X-ray diffractometer (Gemini E) from Agilent. High resolution mass spectra (HRMS) were obtained on an Agilent LC- MSD- Trap-XCT spectrometer with micromass MS software using electrospray ionization (ESI). Gas Chromatograph Mass Spectrometer (GC-MS) was performed with DSQ II from Thermo. The UV/VIS Absorption spectra were recorded using a Perkin Elmer Lambda 35 Spectrometer and a Cary 5000 UV-VIS-NIR spectrometer. The Luminescence Quenching Experiments were recorded using a F-4500 FL Spectrophotometer in EtOH. The Cyclic voltammetry (CV) was recorded in CH_3CN by CHI660E. Silica gel was purchased from Qingdao Marine Chemical Co. Column chromatography was undertaken on silica gel (200-300 mesh) using a proper eluent system. ^1H NMR spectra were recorded on a Bruker DPX-400 (400 MHz) spectrometer in deuterated chloroform or deuterated dimethyl sulfoxide. The chemical shifts (δ) are reported in ppm relative to tetramethylsilane. The multiplicities of signals are designated by the following abbreviations: s (singlet), d (doublet), t (triplet), q (quarter), m (multiplet), dd (doublet and doublet), dt (doublet and triplet), td (triplet and doublet). Coupling constants (*J*) are reported in hertz (Hz). ^{13}C NMR spectra were recorded at 100 MHz on Bruker DPX-400. ^{19}F NMR spectra were recorded using a 376 MHz spectrometer. The reactions were performed with photoreaction apparatus (SSSTECH-LAL1CV1.0) from Shanghai 3S Technology Co., Ltd. The start materials, including quinoxalin-2(1H)-ones[1], coumarins [2], imidazopyridines[3] and iodonium ylides[4] were prepared according to literatures.

2. General procedure for the synthesis of starting materials

Synthesis of quinoxalin-2(1H)-ones[1]

Procedure A:

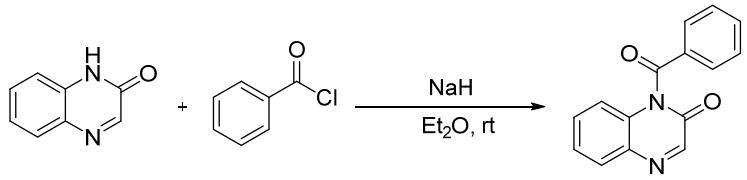


S1 **S2** **3S-15S**

To a 50 mL round-bottom flask, the starting material 2-quinoxalinone (5 mmol) was added into DMF (20 mL), and then the corresponding halide (1.6 equiv.) and potassium carbonate (1.2 equiv.) were added into the reaction mixture and stirred at room temperature overnight.

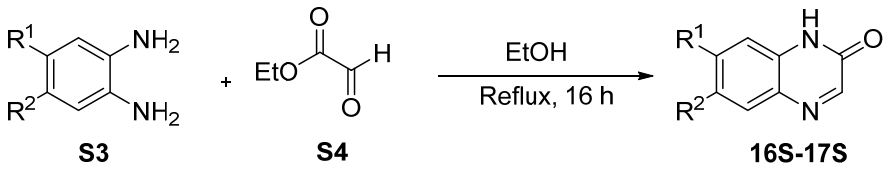
When TLC analysis indicated that the 2-quinoxalinone disappeared, the water (10 mL) was added to the reaction mixture, and the aqueous layer was extracted three times with DCM. The combined organic layers were washed with water (5-9 times), dried over Na_2SO_4, filtered and evaporated under reduced pressure. The residue was purified by column chromatography on silica gel to obtain product **3S-15S**.

Procedure B:



A 200 mL two-necked round-bottomed flask was equipped with a magnetic stirrer bar, a rubber septum, and an argon balloon. S1 (4.0 mmol) was dissolved in Et_2O (25 mL), and NaH (60% in oil; 10.2 mmol) was added. The mixture was stirred for 1 h at room temperature, then benzoyl chloride (6.0 mmol) was added. The mixture was stirred at room temperature for 14 h. The reaction mixture was poured into H_2O and extracted CH_2Cl_2 . The organic layer was dried over anhydrous Na_2SO_4. The solvent was removed in vacuum, and the product was purified by silica gel column chromatography.

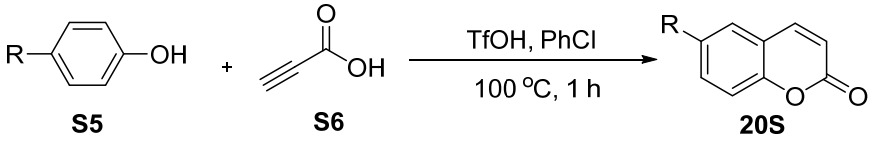
Procedure C:



To ethanol (20 ml) suspension solution of o-arylenediamine (**S3**, 5 mmol) was added Ethyl 2-oxoacetate (**S4**, 1.1 equiv.). The reaction solvent was stirred and heated to reflux for 16 h. After the reaction was completed (as monitored by TLC), the precipitate was filtered and washed with cooled ethanol, and finally dried to give the product **16S-17S**.

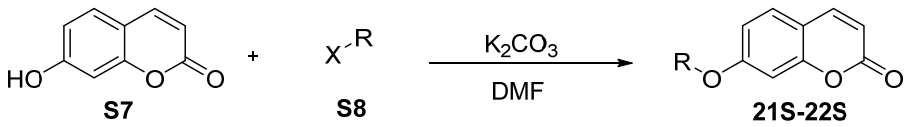
Synthesis of coumarins[2]

Procedure A:



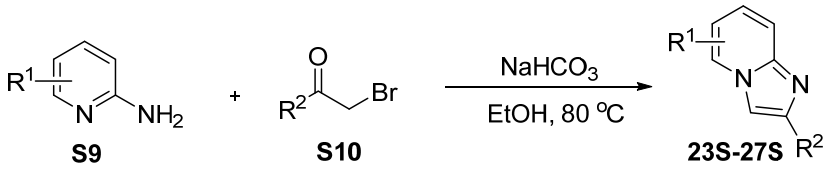
A mixture of phenol derivatives (10.0 mmol), trifluoromethanesulfonic acid (10.0 mmol) and propiolic acid (5.0 mmol) in PhCl (25 mL) was stirred at 100 °C for 1 h. After completion of reaction as indicated by TLC, the reaction mixture was poured into H_2O, neutralized with $NaHCO_3$ solution and extracted CH_2Cl_2 . The organic layer was dried over anhydrous Na_2SO_4. The solvent was removed in vacuum, and the products were purified by silica gel column chromatography to give the desired product **20S**.

Procedure B:



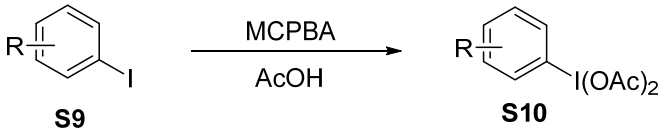
A mixture of 7-hydroxycoumarin (486.4 mg, 3.0 mmol), alkyl or aryl halide (6.0 mmol), and potassium carbonate (1.24 g, 9.0 mmol) in DMF (20 mL) was stirred at various temperatures (from 30 to 85 °C) for times ranging from 1 h to overnight. The reaction mixture was extracted with ethyl acetate, and the combined extracts were washed with water. The organic layer was dried over anhydrous Na_2SO_4 and evaporated to dryness. The residue then was purified by column chromatography on silica gel with petroleum ether/ethyl acetate to yield the products **21S-22S**.

Synthesis of imidazopyridines [3]

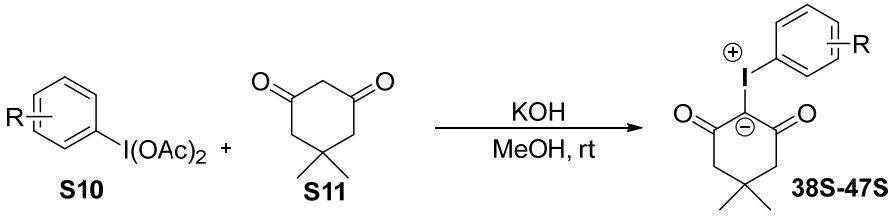


An oven-dried flask was charged with 2-aminopyridines (13 mmol), the corresponding α-bromo-ketones (10 mmol), $NaHCO_3$ (15 mmol), and EtOH (20 mL). The mixture was stirred at 80 °C under air for 3-4 h. After the completion of the reaction (monitored by TLC), the reaction mixture was cooled to ambient temperature and 15 mL water was added to the mixture, then extracted by EtOAc for 3 times (3×30 mL). The combined extracts were washed with brine, dried over Na_2SO_4, and the solvent was removed in vacuo to provide a crude product, which was purified by column chromatography on silica gel with petroleum ether/EtOAc (3/1) as eluent to afford pure product **23S-27S**.

Synthesis of iodonium ylides[4]



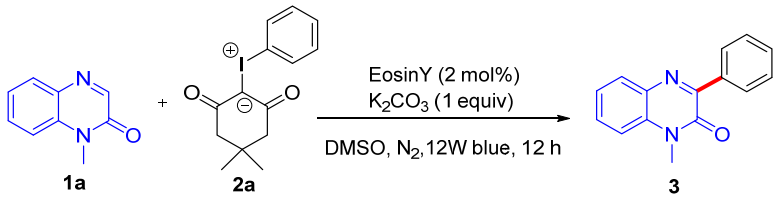
To a solution of iodobenzene derivative in acetic acid was added MCPBA (1.1 equiv). The mixture was stirred at rt for 24 hours. After the reaction, water was added to the mixture, and product was extracted with chloroform. After being dried over Na_2SO_4, filtration, and removal of the solvent, diethyl ether and hexane were added to the residue to product **S10**.



Taken in a 100 mL round bottom flask fitted with a magnetic stirrer, added solution of cyclic 1,3-dione (1.0 equiv) in 30 mL methanol at room temperature added 20 mL of 10% aqueous solution of KOH followed by addition of diacetoxy iodobenzene (1.2 equiv) in 40 mL

methanol. The reaction mixture was stirred for 2 h at room temperature and then quenched with ice cold water. The resulting white precipitate was filtered and mother solution was extracted with dichloromethane, then washed with water three times, dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. The resultant white solid was mixed with the first crop and the mixture recrystallized from DCM/Hexane the compound **38S-47S** was obtained.

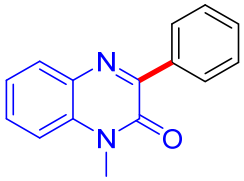
3. Typical Catalytic Procedure



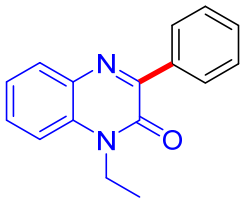
Under N_2 atmosphere, a Schlenk tube (15 mL) equipped with a magnetic stirrer bar was charged with quinoxalin-2(1H)-one **1a** (0.1 mmol) and iodonium ylide **2a** (0.15 mmol), EosinY (2 mol %) and K_2CO_3 in DMSO (2 mL). The reaction mixture was stirred and irradiated by the 12W blue LED at room temperature for 12 h. When the reaction was completed, the reaction mixture was added water (10 mL) and extracted with ethyl acetate (5 mL×3). The combined organic phase was dried over Na_2SO_4. The resulting crude residue was purified by column chromatography on silica gel (elute: EtOAc /petroleum ether) to give the desired product **3**.

Figure 1. Reactor

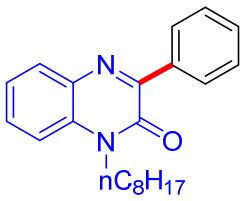
4. Characterization of the Products



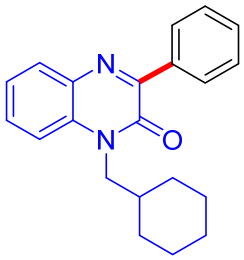
1-methyl-3-phenylquinoxalin-2(1H)-one (3) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 89% (21.0 mg); mp: 142.5-144.7 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.32-8.29 (m, 2 H), 7.92 (dd, *J* = 8.0 Hz, *J* = 1.2 Hz, 1 H), 7.54 (t, *J* = 7.9 Hz, 1 H), 7.47 (t, *J* = 3.3 Hz, 3 H), 7.32 (m, 2 H), 3.74 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.7, 154.1, 136.1, 133.4, 133.1, 130.5, 130.3, 130.3, 129.6, 128.1, 113.6, 29.3 ppm; HRMS (ESI): m/z calcd for $C_{15}H_{13}N_2O$ $[M+H]^+$, 237.1022. Found: m/z 237.1022.



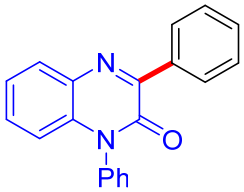
1-ethyl-3-phenylquinoxalin-2(1H)-one (4) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), yellow solid, isolated yield 84% (21.0 mg); mp: 149.9-151.2 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.33-8.30 (m, 2 H), 7.96 (dd, *J* = 8.4 Hz, *J* = 1.6 Hz, 1 H), 7.57 (td, *J* = 8.5 Hz, *J* = 1.5 Hz, 1 H), 7.50-7.47 (m, 3 H), 7.38-7.34 (m, 2 H), 4.40 (q, *J* = 7.2 Hz, 2 H), 1.43 (t, *J* = 7.3 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.2, 154.2, 136.1, 133.5, 132.3, 130.8, 130.3, 129.6, 128.1, 123.5, 113.4, 37.6, 12.4 ppm; HRMS (ESI): m/z calcd for $C_{16}H_{15}N_2O$ $[M+H]^+$, 251.1179. Found: m/z 251.1179.



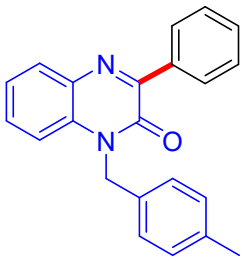
1-octyl-3-phenylquinoxalin-2(1H)-one (5) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), yellow solid, isolated yield 78% (26.1 mg); mp: 96.7-98.9 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.33-8.30 (m, 2 H), 7.95 (dd, *J* = 7.9 Hz, *J* = 1.1 Hz, 1 H), 7.55 (t, *J* = 7.8 Hz, 1 H), 7.47 (t, *J* = 3.5 Hz, 3 H), 7.37-7.32 (m, 2 H), 4.30 (t, *J* = 7.8 Hz, 2 H), 1.84-1.76 (m, 2 H), 1.52-1.45 (m, 2 H), 1.40-1.28 (m, 9 H), 0.88 (t, *J* = 6.5 Hz, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.4, 154.2, 136.1, 133.4, 132.6, 130.7, 130.3, 130.2, 129.6, 128.1, 123.5, 113.6, 42.7, 31.8, 29.3, 29.2, 27.3, 27.1, 22.6, 14.1 ppm; HRMS (ESI): m/z calcd for $C_{22}H_{27}N_2O$ $[M+H]^+$, 335.2118. Found: m/z 335.2119.



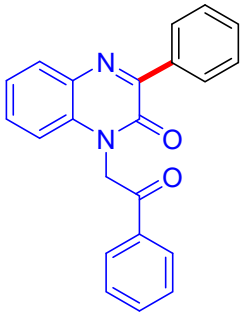
1-(cyclohexylmethyl)-3-phenylquinoxalin-2(1H)-one (6) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), yellow solid, isolated yield 90% (28.6 mg); mp: 99.6-101.1 ºC; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.32-8.29 (m, 2 H), 7.95 (d, *J* = 6.5 Hz, 1 H), 7.54 (td, *J* = 8.4 Hz, *J* = 1.4 Hz, 1 H), 7.47 (t, *J* = 3.6 Hz, 3 H), 7.35 (t, *J* = 7.5 Hz, 2 H), 4.22 (d, *J* = 7.0 Hz, 2 H), 1.96 (s, 1 H), 1.74-1.62 (m, 6 H), 1.22-1.18 (m, 4 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.9, 154.2, 136.2, 133.4, 133.1, 130.7, 130.3, 130.1, 129.6, 128.1, 123.5, 114.1, 48.3, 36.6, 31.0, 26.2, 25.9 ppm; HRMS (ESI): m/z calcd for $C_{21}H_{23}N_2O$ $[M+H]^+$, 319.1805. Found: m/z 319.1805.



1,3-diphenylquinoxalin-2(1H)-one (7) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 81% (24.1 mg); mp: 197.2-198.4 ºC; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.41-8.39 (m, 2 H), 8.00-7.98 (m, 1 H), 7.64 (t, *J* = 7.8 Hz, 2 H), 7.57 (t, *J* = 3.6 Hz, 1 H), 7.48-7.46 (m, 3 H), 7.36-7.34 (m, 4 H), 6.70-6.68 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.6, 154.5, 136.1, 135.8, 134.2, 133.0, 130.5, 130.3, 130.1, 130.0, 129.7, 129.4, 128.3, 128.0, 123.9, 115.4 ppm; HRMS (ESI): m/z calcd for $C_{20}H_{15}N_2O$ $[M+H]^+$, 299.1179. Found: m/z 299.1178.

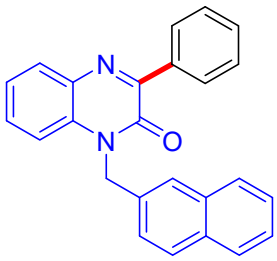


1-(4-methylbenzyl)-3-phenylquinoxalin-2(1H)-one (8) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 84% (27.4 mg); mp: 107.8-109.2 ºC; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.37-8.35 (m, 2 H), 7.95 (d, *J* = 8.0 Hz, 1 H), 7.49 (t, *J* = 3.5 Hz, 3 H), 7.46-7.42 (m, 1 H), 7.32 (t, *J* = 6.8 Hz, 2 H), 7.20 (d, *J* = 8.0 Hz, 2 H), 7.12 (d, *J* = 8.0 Hz, 2 H), 5.53 (s, 2 H), 2.30 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.8, 154.3, 137.4, 136.1, 133.4, 132.8, 132.4, 130.6, 130.4, 130.3, 129.7, 129.6, 128.1, 127.0, 123.8, 114.4, 45.9, 21.1 ppm; HRMS (ESI): m/z calcd for $C_{22}H_{19}N_2O$ $[M+H]^+$, 327.1492. Found: m/z 327.1491.

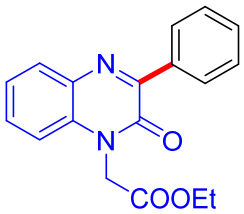


1-(2-oxo-2-phenylethyl)-3-phenylquinoxalin-2(1H)-one (9) was purified by flash silica

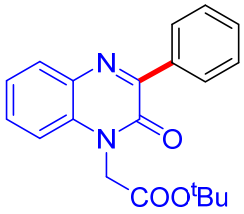
chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 61% (20.7 mg); mp: 199.1-200.5 ºC; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.34-8.32 (m, 2 H), 8.11 (d, *J* = 7.4 Hz, 2 H), 7.99 (dd, *J* = 8.0 Hz, *J* = 1.2 Hz, 1 H), 7.68 (t, *J* = 7.4 Hz, 1 H), 7.56 (t, *J* = 7.8 Hz, 2 H), 7.49-7.45 (m, 4 H), 7.36 (t, *J* = 7.3 Hz, 1 H), 6.99 (d, *J* = 8.3 Hz, 1 H), 5.80 (s, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 191.2, 154.5, 153.9. 135.9, 134.6, 134.3, 133.3, 132.8, 130.8, 130.4, 130.4, 129.6, 129.1, 128.2, 128.1, 123.9, 113.4, 48.7 ppm; HRMS (ESI): m/z calcd for $C_{22}H_{17}N_2O_2$ $[M+H]^+$, 341.1285. Found: m/z 341.1284.



1-(naphthalen-2-ylmethyl)-3-phenylquinoxalin-2(1H)-one (10) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 88% (31.8 mg); mp: 177.5-179.8 ºC; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.43-8.40 (m, 2 H), 8.15 (d, *J* = 8.4 Hz, 1 H), 8.02-7.99 (m, 1 H), 7.93 (d, *J* = 8.0 Hz, 1 H), 7.77 (d, *J* = 8.2 Hz, 1 H), 7.65 (td, *J* = 7.0 Hz, *J* = 1.1 Hz, 1 H), 7.58 (t, *J* = 7.9 Hz, 1 H), 7.50 (t, *J* = 3.3 Hz, 3 H), 7.34-7.32 (m, 2 H), 7.28 (t, *J* = 7.5 Hz, 1 H), 7.04-7.01 (m, 1 H), 6.86 (d, *J* = 6.8 Hz, 1 H), 6.02 (s, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.8, 154.1, 136.0, 133.9, 133.4, 132.9, 130.5, 130.5, 130.4, 129.7, 129.5, 129.2, 128.2, 128.1, 126.7, 126.1, 125.5, 123.9, 122.4, 122.2, 114.7, 44.0 ppm; HRMS (ESI): m/z calcd for $C_{25}H_{19}N_2O$ $[M+H]^+$, 363.1492. Found: m/z 363.1492.

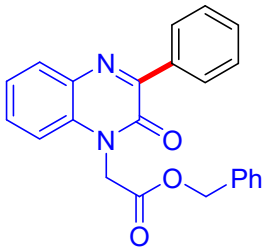


ethyl 2-(2-oxo-3-phenylquinoxalin-1(2H)-yl)acetate (11) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 83% (25.6 mg); mp: 117.8-119.2 ºC; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.34-8.31 (m, 2 H), 7.97 (dd, *J* = 8.0 Hz, *J* = 1.3 Hz, 1 H), 7.56-7.47 (m, 4 H), 7.40-7.36 (m, 1 H), 7.11 (d, *J* = 8.0 Hz, 1 H), 5.09 (s, 2 H), 4.27 (q, *J* = 7.1 Hz, 2 H), 1.28 (t, *J* = 7.1 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 167.2, 154.3, 153.9, 135.8, 133.2, 132.6, 130.8, 130.5, 130.5, 129.6, 128.1, 124.1, 113.0, 62.1, 43.8, 14.1 ppm; HRMS (ESI): m/z calcd for $C_{18}H_{17}N_2O_3$ $[M+Na]^+$, 331.1053. Found: m/z 331.1053.

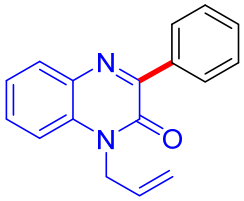


tert-butyl 2-(2-oxo-3-phenylquinoxalin-1(2H)-yl)acetate (12) was purified by flash silica

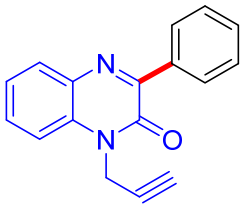
chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 78% (26.2 mg); mp: 116.5-118.2 ºC; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.33-8.30 (m, 2 H), 7.96 (dd, *J* = 8.0 Hz, *J* = 1.3 Hz, 1 H), 7.55-7.47 (m, 4 H), 7.38-7.34 (m, 1 H), 7.10 (d, *J* = 8.0 Hz, 1 H), 5.00 (s, 2 H), 1.47 (s, 9 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.2, 154.3, 154.0, 135.8, 133.2, 132.6, 130.8, 130.4, 130.4, 129.6, 128.1, 123.9, 113.1, 83.2, 44.4, 28.0 ppm; HRMS (ESI): m/z calcd for $C_{20}H_{21}N_2O_3$ $[M+H]^+$, 337.1547. Found: m/z 337.1546.



benzyl 2-(2-oxo-3-phenylquinoxalin-1(2H)-yl)acetate (13) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), yellow solid, isolated yield 74% (27.4 mg); mp: 163.7-165.4 ºC; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.33-8.30 (m, 2 H), 7.97 (dd, *J* = 8.0 Hz, *J* = 1.4 Hz, 1 H), 7.51-7.47 (m, 4 H), 7.39-7.29 (m, 6 H), 7.06 (d, *J* = 7.8 Hz, 1 H), 5.24 (s, 2 H), 5.15 (s, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 167.1, 154.3, 153.9, 135.7, 134.9, 133.2, 132.5, 130.8, 130.5, 130.5, 129.6, 128.7, 128.6, 128.4, 128.1, 124.1, 113.0, 67.7, 43.8 ppm; HRMS (ESI): m/z calcd for $C_{23}H_{19}N_2O_3$ $[M+H]^+$, 371.1390. Found: m/z 371.1389.

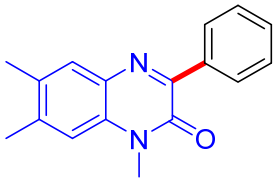


1-allyl-3-phenylquinoxalin-2(1H)-one (14) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), yellow solid, isolated yield 82% (21.5 mg); mp: 68.5-70.3 ºC; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.34-8.32 (m, 2 H), 7.96 (dd, *J* = 8.0 Hz, *J* = 1.2 Hz, 1 H), 7.56-7.51 (m, 1 H), 7.48 (t, *J* = 3.3 Hz, 3 H), 7.38-7.34 (m, 1 H), 7.32 (d, *J* = 8.4 Hz, 1 H), 6.04-5.94 (m, 1 H), 5.26 (q, *J* = 10.5 Hz, 2 H), 4.99-4.97 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.3, 154.2, 136.0, 133.3, 132.6, 130.7, 130.6, 130.4, 130.2, 129.6, 128.1, 123.7, 118.2, 114.1, 44.8 ppm; HRMS (ESI): m/z calcd for $C_{17}H_{15}N_2O$ $[M+H]^+$, 263.1179. Found: m/z 263.1179.

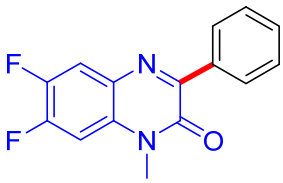


3-phenyl-1-(prop-2-yn-1-yl)quinoxalin-2(1H)-one (15) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 65% (16.9 mg); mp: 142.5-144.7 ºC; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.34-8.31 (m, 2 H), 7.97 (dd, *J* = 8.0 Hz, *J* = 1.3 Hz, 1 H), 7.63-7.59 (m, 1 H), 7.51-7.48 (m, 4 H), 7.43-7.39 (m, 1 H), 5.13 (d, *J* = 2.5 Hz, 2 H), 2.31 (t, *J* = 2.5 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.0, 153.7, 135.8, 133.3, 131.9, 130.6, 130.5, 130.4, 129.6, 128.1, 124.1, 114.0, 76.9, 73.2, 31.7 ppm;

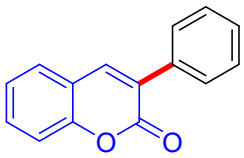
HRMS (ESI): m/z calcd for $C_{17}H_{13}N_2O$ $[M+Na]^+$, 283.0842. Found: m/z 283.0842



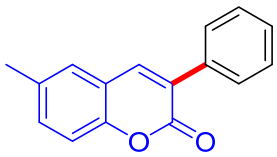
1,6,7-trimethyl-3-phenylquinoxalin-2(1H)-one (16) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), yellow solid, isolated yield 81% (21.4 mg); mp: 177.6-179.2 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.30-8.27 (m, 2 H), 7.69 (s, 1 H), 7.48-7.44 (m, 3 H), 7.09 (s, 1 H), 3.73 (s, 3 H), 2.43 (s, 3 H), 2.36 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.8, 152.9, 140.3, 136.4, 132.7, 131.6, 131.4, 130.5, 130.0, 129.4, 128.0, 114.1, 29.2, 20.7, 19.2 ppm; HRMS (ESI): m/z calcd for $C_{17}H_{17}N_2O$ $[M+H]^+$, 265.1335. Found: m/z 265.1335.



6,7-difluoro-1-methyl-3-phenylquinoxalin-2(1H)-one (17) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), yellow solid, isolated yield 85% (23.1 mg); mp: 173.5-174.8 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.30-8.27 (m, 2 H), 7.76-7.72 (m, 1 H), 7.50-7.46 (m, 3 H), 7.12 (q, J = 7.1 Hz, 1 H), 3.71 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.4 (d, J = 3.6 Hz), 154.3, 151.6 (dd, J = 254.1 Hz, J = 14.5 Hz), 146.8 (dd, J = 247.2 Hz, J = 14.2 Hz), 135.5, 130.7, 130.6 (d, J = 10.7 Hz), 129.5, 129.3 (dd, J = 9.5 Hz, J = 2.8 Hz), 128.1, 117.9 (dd, J = 18.1 Hz, J = 2.1 Hz), 102.2 (d, J = 23 Hz), 29.8 ppm; ^{19}F NMR (376 MHz, $CDCl_3$): -130.47 (d, J = 22.1 Hz), -141.94 (d, J = 22.4 Hz) ppm; HRMS (ESI): m/z calcd for $C_{15}H_{11}F_2N_2O$ $[M+H]^+$, 273.0834. Found: m/z 273.0834.

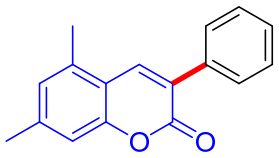


3-phenyl-2H-chromen-2-one (18) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 76% (16.9 mg); mp: 134.6-136.8 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.82 (s, 1 H), 7.72-7.70 (m, 2 H), 7.56-7.52 (m, 2 H), 7.48-7.37 (m, 4 H), 7.32-7.28 (m, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 160.6, 153.6, 139.9, 134.7, 131.4, 128.9, 128.5, 128.5, 128.4, 127.9, 124.5, 119.7, 116.5 ppm; HRMS (ESI): m/z calcd for $C_{15}H_{11}O_2$ $[M+H]^+$, 223.0754. Found: m/z 223.0754.

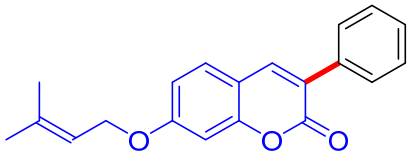


6-methyl-3-phenyl-2H-chromen-2-one (19) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 73% (17.2 mg); mp: 149.1-150.9 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.76 (s, 1 H), 7.70 (dd, J = 8.4 Hz, J = 1.5 Hz,

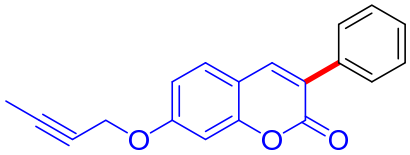
2 H), 7.48-7.40 (m, 3 H), 7.34 (d, J = 7.4 Hz, 2 H), 7.28 (s, 1 H), 2.43 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 160.3, 151.7, 139.9, 134.9, 134.2, 132.5, 128.8, 128.6, 128.5, 128.3, 127.7, 119.4, 116.2, 20.8 ppm; HRMS (ESI): m/z calcd for $C_{16}H_{13}O_2$ $[M+H]^+$, 237.0910. Found: m/z 237.0911.



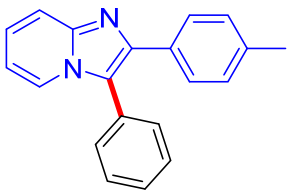
5,7-dimethyl-3-phenyl-2H-chromen-2-one (20) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 71% (17.8 mg); mp: 159.3-161.8 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.95 (s, 1 H), 7.70 (d, J = 6.9 Hz, 2 H), 7.48-7.40 (m, 3 H), 7.02 (s, 1 H), 6.95 (s, 1 H), 2.53 (s, 3 H), 2.42 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 160.8, 154.2, 142.4, 137.1, 135.7, 135.4, 128.6, 128.6, 128.5, 127.1, 126.4, 116.1, 114.7, 21.8, 18.3 ppm; HRMS (ESI): m/z calcd for $C_{17}H_{15}O_2$ $[M+Na]^+$, 273.0886. Found: m/z 273.0885.



7-((3-methylbut-2-en-1-yl)oxy)-3-phenyl-2H-chromen-2-one (21) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 64% (19.6 mg); mp: 117.8-119.1 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.76 (s, 1 H), 7.69 (d, J = 7.0 Hz, 2 H), 7.46-7.36 (m, 4 H), 6.89-6.89 (m, 2 H), 5.51-5.47 (m, 1 H), 4.60 (d, J = 6.6 Hz, 2 H), 1.82 (s, 3 H), 1.78 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 161.9, 161.0, 155.3, 140.1, 139.3, 135.1, 128.8, 128.4, 124.7, 118.7, 113.4, 113.3, 101.2, 65.5, 25.9, 18.3 ppm; HRMS (ESI): m/z calcd for $C_{20}H_{19}O_3$ $[M+H]^+$, 307.1329. Found: m/z 307.1328.

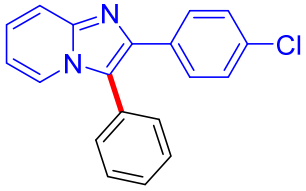


7-(but-2-yn-1-yloxy)-3-phenyl-2H-chromen-2-one (22) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 75% (21.8 mg); mp: 119.2-121.8 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.77(s, 1 H), 7.69 (d, J = 7.0 Hz, 2 H), 7.46-7.39 (m, 4 H), 7.00 (d, J = 2.2 Hz, 1 H), 6.92 (dd, J = 8.6 Hz, J = 2.5 Hz, 1 H), 4.74 (d, J = 2.3 Hz, 2 H), 1.88 (t, J = 2.3 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 160.9, 160.7, 155.1, 140.0, 135.0, 128.8, 128.5, 128.5, 128.4, 125.2, 113.7, 113.5, 101.6, 85.0, 72.9, 57.0, 3.7 ppm; HRMS (ESI): m/z calcd for $C_{19}H_{15}O_3$ $[M+H]^+$, 291.1016. Found: m/z 291.1015.

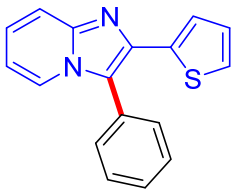


3-phenyl-2-(p-tolyl)imidazo[1,2-a]pyridine (23) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 52% (14.8

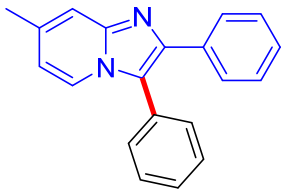
mg); mp: 122.5-123.9 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.95 (d, *J* = 7.0 Hz, 1 H), 7.67 (d, *J* = 9.1 Hz, 1 H), 7.57-7.44 (m, 7 H), 7.21-7.17 (m, 1 H), 7.09 (d, *J* = 8.0 Hz, 2 H), 6.72 (td, *J* = 6.8 Hz, *J* = 1.0 Hz, 1 H), 2.32 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 144.8, 142.5, 137.2, 131.3, 130.8, 130.1, 129.5, 129.0, 128.8, 128.0, 124.6, 123.2, 120.7, 117.5, 112.2, 21.2 ppm; HRMS (ESI): m/z calcd for $C_{20}H_{17}N_2$ $[M+H]^+$, 285.1386. Found: m/z 285.1386.



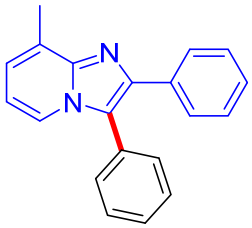
2-(4-chlorophenyl)-3-phenylimidazo[1,2-a]pyridine (24) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 66% (20.1 mg); mp: 141.7-142.5 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.95 (d, *J* = 6.9 Hz, 1 H), 7.67 (d, *J* = 9.1 Hz, 1 H), 7.60 (d, *J* = 8.6 Hz, 2 H), 7.56-7.50 (m, 3 H), 7.45-7.43 (m, 2 H), 7.24-7.19 (m, 3 H), 6.75 (t, *J* = 6.8 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 144.9, 141.3, 133.4, 132.7, 130.7, 129.7, 129.6, 129.3, 129.1, 128.5, 124.9, 123.3, 121.2, 117.6, 112.4 ppm; HRMS (ESI): m/z calcd for $C_{19}H_{14}N_2Cl$ $[M+H]^+$, 305.0840. Found: m/z 305.0842.



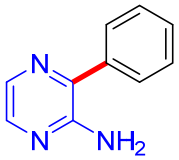
3-phenyl-2-(thiophen-2-yl)imidazo[1,2-a]pyridine (25) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), yellow solid, isolated yield 65% (17.9 mg); mp: 97.5-98.9 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.85 (d, *J* = 7.0 Hz, 1 H), 7.66 (d, *J* = 9.1 Hz, 1 H), 7.60-7.51 (m, 5 H), 7.24-7.17 (m, 2 H), 7.09 (dd, *J* = 3.7 Hz, *J* = 1.0 Hz, 1 H), 6.94-6.92 (m, 1 H), 6.72 (td, *J* = 6.8 Hz, *J* = 1.0 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 144.7, 137.0, 137.7, 131.1, 129.6, 129.4, 129.2, 127.4, 125.2, 124.9, 124.5, 123.3, 120.0, 117.3, 112.4 ppm; HRMS (ESI): m/z calcd for $C_{17}H_{13}N_2S$ $[M+H]^+$, 277.0794. Found: m/z 277.0794.



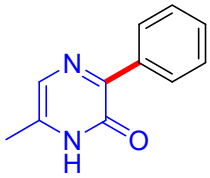
7-methyl-2,3-diphenylimidazo[1,2-a]pyridine (26) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 50% (14.2 mg); mp: 148.7-150.9 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.84 (d, *J* = 7.0 Hz, 1 H), 7.65 (dd, *J* = 8.3 Hz, *J* = 1.6 Hz, 2 H), 7.54-7.43 (m, 6 H), 7.29-7.22 (m, 3 H), 6.56 (dd, *J* = 7.1 Hz, *J* = 1.5 Hz, 1 H), 2.41 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 145.3, 142.1, 135.6, 134.3, 130.7, 130.1, 129.5, 128.7, 128.2, 128.0, 127.3, 122.5, 120.5, 115.9, 114.9, 21.4 ppm; HRMS (ESI): m/z calcd for $C_{20}H_{17}N_2$ $[M+H]^+$, 285.1386. Found: m/z 285.1386.



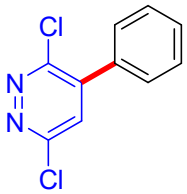
8-methyl-2,3-diphenylimidazo[1,2-a]pyridine (27) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 52% (14.8 mg); mp: 96.1-98.4 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.84 (d, *J* = 7.3 Hz, 1 H), 7.65 (dd, *J* = 8.3 Hz, *J* = 1.6 Hz, 2 H), 7.52-7.43 (m, 6 H), 7.29-7.27 (m, 1 H), 7.25-7.23 (m, 2 H), 6.57 (dd, *J* = 7.0 Hz, *J* = 1.5 Hz, 1 H), 2.41 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 145.3, 142.1, 135.6, 134.3, 130.7, 129.5, 128.7, 128.2, 128.0, 127.3, 126.0, 122.5, 120.5, 115.9, 114.9, 21.4 ppm; HRMS (ESI): m/z calcd for $C_{20}H_{17}N_2$ $[M+H]^+$, 285.1386. Found: m/z 285.1386.



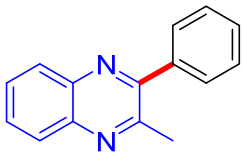
3-phenylpyrazin-2-amine (28) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 1:1), white solid, isolated yield 76% (13.0 mg); mp: 112.7-114.6 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.04 (d, *J* = 2.7 Hz, 1 H), 7.98 (d, *J* = 2.7 Hz, 1 H), 7.73-7.70 (m, 2 H), 7.53-7.43 (m, 3 H), 4.78 (s, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.3, 140.9, 137.2, 134.6, 129.1, 129.1, 128.1 ppm; HRMS (ESI): m/z calcd for $C_{10}H_{10}N_3$ $[M+H]^+$, 172.0869. Found: m/z 172.0867.



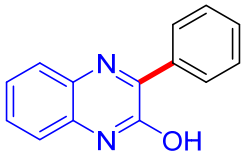
6-methyl-3-phenylpyrazin-2(1H)-one (29) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 2:1), white solid, isolated yield 83% (15.4 mg); mp: 209.8-211.7 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 13.38 (s, 1 H), 8.33 (dd, *J* = 8.0 Hz, *J* = 2.0 Hz, 2 H), 7.48-7.42 (m, 4 H), 2.40 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 157.9, 149.4, 136.3, 135.9, 129.6, 128.5, 128.1, 124.2, 16.0 ppm; HRMS (ESI): m/z calcd for $C_{11}H_{11}N_2O$ $[M+H]^+$, 187.0866. Found: m/z 187.0864.



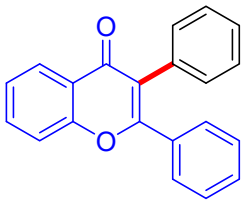
3,6-dichloro-4-phenylpyridazine (30) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 72% (16.1 mg); mp: 85.8-87.6 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.55-7.50 (m, 6 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 156.0, 154.9, 142.8, 133.2, 130.4, 129.6, 128.9, 128.9 ppm; HRMS (ESI): m/z calcd for $C_{10}H_7N_2Cl_2$ $[M+H]^+$, 224.9981. Found: m/z 224.9977.



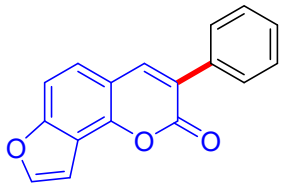
2-methyl-3-phenylquinoxaline (31) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 8:1), white solid, isolated yield 45% (9.9 mg); mp: 67.5-68.9 ºC; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.13-8.11 (m, 1 H), 8.08-8.05 (m, 1 H), 7.77-7.71 (m, 2 H), 7.67-7.65 (m, 2 H), 7.56-7.50 (m, 3 H), 2.79 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.9, 152.6, 141.3, 141.0, 139.1, 129.8, 129.3, 129.0, 128.9, 128.6, 128.3, 24.4 ppm; HRMS (ESI): m/z calcd for $C_{15}H_{13}N_2$ $[M+H]^+$, 221.1073. Found: m/z 221.1072.



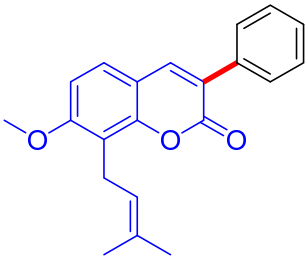
3-phenylquinoxalin-2-ol (32) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 84% (18.6 mg); mp: 189.6-190.7 ºC; ^{1}H NMR (400 MHz, DMSO): δ 12.57 (s, 1 H), 8.31 (dd, *J* = 7.1 Hz, *J* = 1.5 Hz, 2 H), 7.85 (d, *J* = 7.9 Hz, 1 H), 7.57-7.47 (m, 4 H), 7.34 (t, *J* = 8.2 Hz, 2 H); ^{13}C NMR (100 MHz, DMSO): δ 155.1, 154.6, 136.1, 132.5, 132.5, 130.8, 130.7, 129.7, 129.2, 128.3, 123.9, 115.6 ppm; HRMS (ESI): m/z calcd for $C_{14}H_{11}N_2O$ $[M+H]^+$, 223.0866. Found: m/z 223.0866.



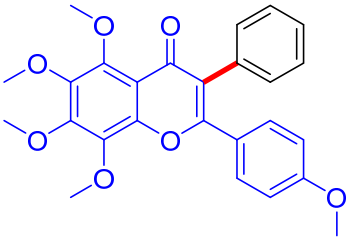
2,3-diphenyl-4H-chromen-4-one (33) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 43% (12.8 mg); mp: 129.5-131.2 ºC; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.30 (dd, *J* = 8.0 Hz, *J* = 1.5 Hz, 1 H), 7.73-7.69 (m, 1 H), 7.54 (d, *J* = 8.2 Hz, 1 H), 7.46-7.40 (m, 3 H), 7.34-7.27 (m, 6 H), 7.24-7.21 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 133.7, 133.3, 132.9, 131.2, 130.1, 129.6, 128.3, 128.1, 127.6, 126.4, 125.1, 123.6, 123.0, 118.0 ppm; HRMS (ESI): m/z calcd for $C_{21}H_{15}O_2$ $[M+H]^+$, 299.1067. Found: m/z 299.1065.



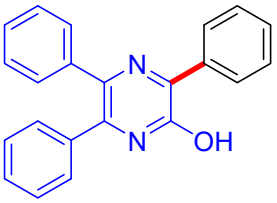
3-phenyl-2H-furo[2,3-h]chromen-2-one (34) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 55% (14.4 mg); mp: 152.4-154.1 ºC; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.93 (s, 1 H), 7.74-7.71 (m, 3 H), 7.49-7.41 (m, 5 H), 7.18 (d, *J* = 1.8 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 160.7, 157.2, 145.9, 141.1, 135.0, 130.6, 128.7, 128.5, 128.5, 126.0, 123.9, 116.6, 114.3, 109.0, 104.2 ppm; HRMS (ESI): m/z calcd for $C_{17}H_{11}O_3$ $[M+H]^+$, 263.0703. Found: m/z 263.0702.



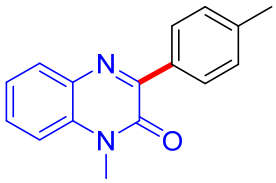
7-methoxy-8-(3-methylbut-2-en-1-yl)-3-phenyl-2H-chromen-2-one (35) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 5:1), white solid, isolated yield 65% (20.8 mg); mp: 121.2-123.4 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.74 (s, 1 H), 7.69 (d, *J* = 7.2 Hz, 2 H), 7.45-7.41 (m, 2 H), 7.39-7.33 (m, 2 H), 6.86 (d, *J* = 8.6 Hz, 1 H), 5.27-5.24 (m, 1 H), 3.93 (s, 3 H), 3.58 (d, *J* = 7.2 Hz, 2 H), 1.86 (s, 3 H), 1.68 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 160.9, 160.0, 151.3, 140.4, 135.3, 132.7, 128.4, 128.4, 128.3, 126.3, 124.7, 121.2, 117.6, 113.8, 107.6, 56.1, 25.8, 22.0, 18.0 ppm; HRMS (ESI): m/z calcd for $C_{21}H_{21}O_3$ $[M+H]^+$, 321.1485. Found: m/z 321.1485.



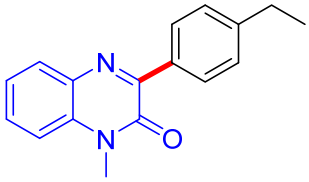
5,6,7,8-tetramethoxy-2-(4-methoxyphenyl)-3-phenyl-4H-chromen-4-one (36) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), yellow solid, isolated yield 51% (22.8 mg); mp: 134.5-136.8 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.37-7.29 (m, 5 H), 7.24-7.22 (m, 2 H), 6.77 (d, *J* = 9.0 Hz, 2 H), 4.11 (s, 3 H), 4.00 (s, 3 H), 3.95 (s, 3 H), 3.93 (s, 3 H), 3.79 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 176.3, 160.8, 159.1, 151.3, 148.6, 147.5, 144.1, 137.8, 133.3, 131.3, 131.1, 128.4, 127.5, 125.2, 122.1, 114.5, 113.6, 62.2, 62.0, 61.8, 61.7, 55.3 ppm; HRMS (ESI): m/z calcd for $C_{26}H_{25}O_7$ $[M+H]^+$, 449.1595. Found: m/z 449.1597.



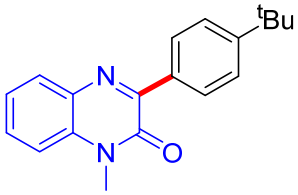
3,5,6-triphenylpyrazin-2-ol (37) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), yellow solid, isolated yield 70% (22.7 mg); mp: 273.5-274.8 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 12.33 (s, 1 H), 8.51-8.48 (m, 2 H), 7.49-7.40 (m, 10 H), 7.29-7.27 (m, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 156.3, 149.4, 137.3, 135.6, 135.1, 133.1, 132.5, 129.9, 129.8, 129.6, 129.0, 128.9, 128.1, 128.0, 127.6 ppm; HRMS (ESI): m/z calcd for $C_{22}H_{17}N_2O$ $[M+H]^+$, 325.1335. Found: m/z 325.1330.



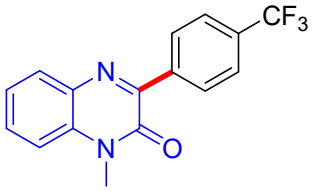
1-methyl-3-(p-tolyl)quinoxalin-2(1H)-one (38) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 75% (18.8 mg); mp: 159.1-162.3 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.24 (d, J = 8.2 Hz, 2 H), 7.93 (dd, J = 8.0 Hz, J = 1.3 Hz, 1 H), 7.55 (td, J = 7.5 Hz, J = 1.4 Hz, 1 H), 7.38-7.28 (m, 4 H), 3.77 (s, 3 H), 2.42 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.8, 154.1, 140.6, 133.3, 133.3, 133.2, 130.4, 130.1, 129.5, 128.8, 123.7, 113.5 ppm; HRMS (ESI): m/z calcd for $C_{16}H_{15}N_2O$ $[M+H]^+$, 251.1179. Found: m/z 251.1180.



3-(4-ethylphenyl)-1-methylquinoxalin-2(1H)-one (39) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 87% (23.0 mg); mp: 139.5-141.2 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.24 (d, J = 8.3 Hz, 2 H), 7.93 (dd, J = 8.0 Hz, J = 1.4 Hz, 1 H), 7.55 (td, J = 8.6 Hz, J = 1.5 Hz, 1 H), 7.38-7.30 (m, 4 H), 3.77 (s, 3 H), 2.72 (q, J = 7.6 Hz, 2 H), 1.27 (t, J = 7.6 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.8, 154.2, 146.9, 133.6, 133.3, 133.2, 130.4, 130.1, 129.6, 127.7, 123.7, 113.6, 29.3, 28.9, 15.5 ppm; HRMS (ESI): m/z calcd for $C_{17}H_{17}N_2O$ $[M+H]^+$, 265.1335. Found: m/z 265.1335.

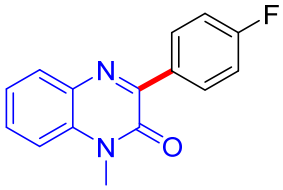


3-(4-(tert-butyl)phenyl)-1-methylquinoxalin-2(1H)-one (40) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 80% (23.4 mg); mp: 89.5-91.4 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.23 (d, J = 8.6 Hz, 2 H), 7.94 (dd, J = 8.0 Hz, J = 1.2 Hz, 1 H), 7.56 (td, J = 8.6 Hz, J = 1.4 Hz, 1 H), 7.51 (d, J = 8.6 Hz, 2 H), 7.35 (q, J = 7.9 Hz, 2 H), 3.77 (s, 3 H), 1.36 (s, 9 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.8, 154.3, 153.6, 133.3, 133.3, 133.2, 130.4, 130.1, 129.3, 125.2, 123.7, 113.6, 34.9, 31.2, 29.3 ppm; HRMS (ESI): m/z calcd for $C_{19}H_{21}N_2O$ $[M+H]^+$, 293.1648. Found: m/z 293.1647.

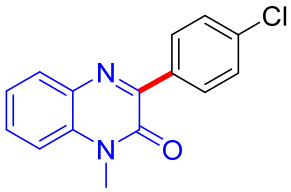


1-methyl-3-(4-(trifluoromethyl)phenyl)quinoxalin-2(1H)-one (41) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), yellow solid, isolated yield 67% (20.4 mg); mp: 103.7-105.4 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.46 (d, J = 8.1 Hz, 2 H), 7.96

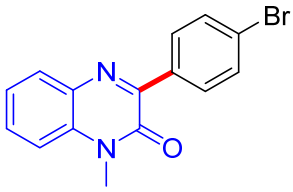
(dd, J = 8.0 Hz, J = 1.3 Hz, 1 H), 7.73 (d, J = 8.3 Hz, 2 H), 7.62 (td, J = 8.6 Hz, J = 1.4 Hz, 1 H), 7.43-7.36 (m, 2 H), 3.78 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.6, 152.6, 139.3, 133.5, 133.0, 131.8 (d, J = 32.1 Hz), 130.9 (d, J = 32.5 Hz), 129.9, 124.1 (d, J = 272.2 Hz), 125.0 (q, J = 3.7 Hz), 124.0, 113.7, 29.4 ppm; ^{19}F NMR (376 MHz, $CDCl_3$): -62.80 (s) ppm; HRMS (ESI): m/z calcd for $C_{16}H_{12}F_3N_2O$ $[M+H]^+$, 305.0896. Found: m/z 305.0894.



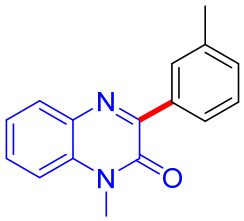
3-(4-fluorophenyl)-1-methylquinoxalin-2(1H)-one (42) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 74% (18.8 mg); mp: 149.3-151.6 ºC; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.41-8.37 (m, 2 H), 7.94 (dd, J = 8.0 Hz, J = 1.2 Hz, 1 H), 7.59 (td, J = 8.6 Hz, J = 1.4 Hz, 1 H), 7.38 (q, J = 9.5 Hz, 2 H), 7.16 (t, J = 8.8 Hz, 2 H), 3.78 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 164.2 (d, J = 251.0 Hz), 154.7, 152.8, 133.3, 133.0, 132.2 (d, J = 3.1 Hz), 131.9, 131.8, 130.4, 123.9, 115.1 (d, J = 21.5 Hz), 113.6, 29.4 ppm; HRMS (ESI): m/z calcd for $C_{15}H_{12}FN_2O$ $[M+H]^+$, 255.0928. Found: m/z 255.0927.



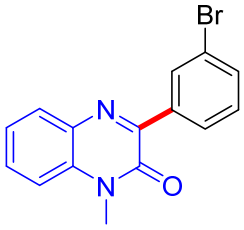
3-(4-chlorophenyl)-1-methylquinoxalin-2(1H)-one (43) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), yellow solid, isolated yield 81% (21.6 mg); mp: 182.3-183.8 ºC; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.34 (d, J = 8.7 Hz, 2 H), 7.94 (dd, J = 8.0 Hz, J = 1.3 Hz, 1 H), 7.59 (td, J = 7.5 Hz, J = 1.4 Hz, 1 H), 7.46-7.44 (m, 2 H), 7.41-7.34 (m, 2 H), 3.78 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.6, 152.7, 136.6,134.4, 133.4, 133.0, 131.0, 130.6, 130.5, 128.3, 123.9, 113.7, 29.4 ppm; HRMS (ESI): m/z calcd for $C_{15}H_{12}ClN_2O$ $[M+H]^+$, 271.0633. Found: m/z 271.0631.



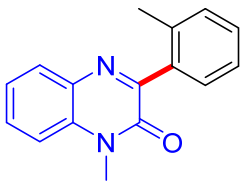
3-(4-bromophenyl)-1-methylquinoxalin-2(1H)-one (44) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), yellow solid, isolated yield 72% (22.6 mg); mp: 176.5-178.2 ºC; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.27 (d, J = 8.6 Hz, 2 H), 7.94 (dd, J = 8.0 Hz, J = 1.3 Hz, 1 H), 7.63-7.57 (m, 3 H), 7.41-7.34 (m, 2 H), 3.77 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.6, 152.8, 134.9, 133.4, 133.0, 131.3, 131.2, 130.6, 130.5, 125.1, 123.9, 113.7, 29.4 ppm; HRMS (ESI): m/z calcd for $C_{15}H_{12}BrN_2O$ $[M+H]^+$, 315.0128. Found: m/z 315.0125.



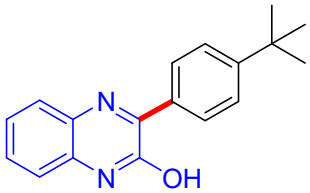
1-methyl-3-(m-tolyl)quinoxalin-2(1H)-one (45) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 55% (13.8 mg); mp: 107.5-109.1 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.09-8.08 (m, 2 H), 7.96 (dd, *J* = 8.0 Hz, *J* = 1.4 Hz, 1 H), 7.60-7.55 (m, 1 H), 7.40-7.36 (m, 3 H), 7.30 (d, *J* = 7.6 Hz, 1 H), 3.78 (s, 3 H), 2.45 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.8, 154.5, 137.7, 136.0, 133.4, 133.1, 131.2, 130.4, 130.3, 130.0, 128.0, 126.7, 123.8, 113.6, 29.3, 21.6 ppm; HRMS (ESI): m/z calcd for $C_{16}H_{14}N_2ONa$ $[M+Na]^+$, 273.0998. Found: m/z 273.0997.



3-(3-bromophenyl)-1-methylquinoxalin-2(1H)-one (46) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), yellow solid, isolated yield 74% (23.2 mg); mp: 113.7-115.6 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.51 (s, 1 H), 8.32 (d, *J* = 7.9 Hz, 1 H), 7.95 (dd, *J* = 8.0 Hz, *J* = 1.0 Hz, 1 H), 7.60 (t, *J* = 8.1 Hz, 2 H), 7.41-7.33 (m, 3 H), 3.77 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.5, 152.3, 137.9, 133.4, 133.2, 132.9, 132.4, 130.8, 130.6, 129.6, 128.3, 123.9, 122.3, 113.7, 29.4 ppm; HRMS (ESI): m/z calcd for $C_{15}H_{12}BrN_2O$ $[M+H]^+$, 315.0128. Found: m/z 315.0123.

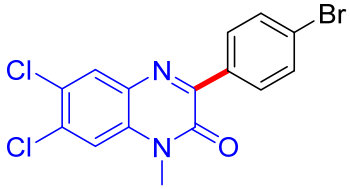


1-methyl-3-(o-tolyl)quinoxalin-2(1H)-one (47) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 68% (17.0 mg); mp: 105.7-106.8 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.93 (dd, *J* = 8.6 Hz, *J* = 1.6 Hz, 1 H), 7.63-7.59 (m, 1 H), 7.47-7.45 (m, 1 H), 7.41-7.33 (m, 3 H), 7.31-7.27 (m, 2 H), 3.78 (s, 3 H), 2.34 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 158.4, 154.6, 136.8, 136.1, 133.6, 132.9, 130.6, 130.5, 129.4, 129.2, 125.6, 123.8, 113.7, 29.4, 20.0 ppm; HRMS (ESI): m/z calcd for $C_{16}H_{15}N_2O$ $[M+H]^+$, 251.1179. Found: m/z 251.1178.

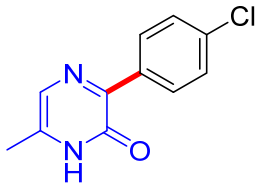


3-(4-(tert-butyl)phenyl)quinoxalin-2-ol (48) was purified by flash silica chromatography

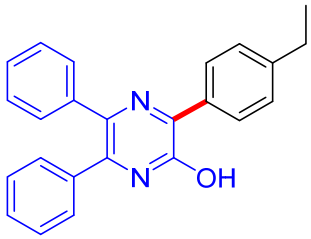
(pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 82% (22.8 mg); mp: 214.5-215.8 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.36 (d, *J* = 8.4 Hz, 2 H), 7.94 (d, *J* = 8.1 Hz, 1 H), 7.57-7.49 (m, 3 H), 7.39-7.35 (m, 2 H), 1.39 (s, 9 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 156.6, 154.4, 153.9, 133.4, 132.9, 131.1, 130.2, 129.4, 129.3, 125.3, 124.3, 115.5, 34.9, 31.3 ppm; HRMS (ESI): m/z calcd for $C_{18}H_{19}N_2O$ $[M+H]^+$, 279.1492. Found: m/z 279.1490.



3-(4-bromophenyl)-6,7-dichloro-1-methylquinoxalin-2(1H)-one (49) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 53% (20.2 mg); mp: 236.7-237.9 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.26 (d, *J* = 8.7 Hz, 2 H), 8.02 (s, 1 H), 7.62 (d, *J* = 8.7 Hz, 2 H), 7.43 (s, 1 H), 3.73 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.0, 153.8, 134.7, 134.2, 132.7, 132.0, 131.4, 131.3, 131.1, 127.8, 125.9, 115.2, 29.6 ppm; HRMS (ESI): m/z calcd for $C_{15}H_{12}BrCl_2N_2O$ $[M+H+2]^+$, 284.9328. Found: m/z 284.9323.

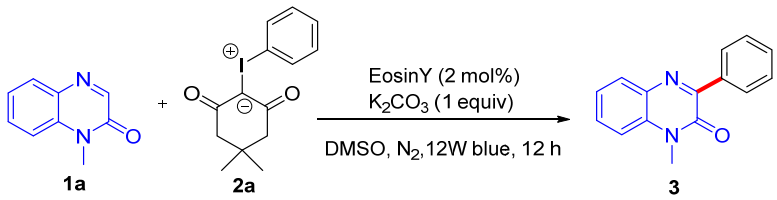


3-(4-chlorophenyl)-6-methylpyrazin-2(1H)-one (50) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), white solid, isolated yield 68% (15.0 mg); mp: 252.1-253.6 °C; ^{1}H NMR (400 MHz, DMSO): δ 12.63 (s, 1 H), 8.35 (d, *J* = 8.7 Hz, 2 H), 7.50-7.47 (m, 2 H), 7.35 (s, 1 H), 2.22 (s, 3 H); ^{13}C NMR (100 MHz, DMSO): δ 160.9, 140.2, 138.9, 134.9, 133.1, 127.3, 20.8 ppm; HRMS (ESI): m/z calcd for $C_{11}H_{10}ClN_2O$ $[M+H]^+$, 221.0476. Found: m/z 221.0473.



3-(4-ethylphenyl)-5,6-diphenylpyrazin-2-ol (51) was purified by flash silica chromatography (pertroleum ether/ethyl acetate = 3:1), yellow solid, isolated yield 78% (27.5 mg); mp: 258.4-259.7 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 12.55 (s, 1 H), 8.42 (d, *J* = 8.3 Hz, 2 H), 7.51-7.47 (m, 3 H), 7.44-7.40 (m, 4 H), 7.27 (s, 2 H), 7.26-7.25 (s, 3 H), 2.73 (q, *J* = 7.6 Hz, 2 H), 1.29 (t, *J* = 7.6 Hz, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 156.5, 149.4, 146.4, 137.5, 134.7, 133.2, 133.0, 132.6, 129.7, 129.7, 129.6, 129.1, 128.8, 128.1, 127.6, 127.5, 28.9, 15.6 ppm; HRMS (ESI): m/z calcd for $C_{24}H_{21}N_2O$ $[M+Na]^+$, 375.1468. Found: m/z 375.1463.

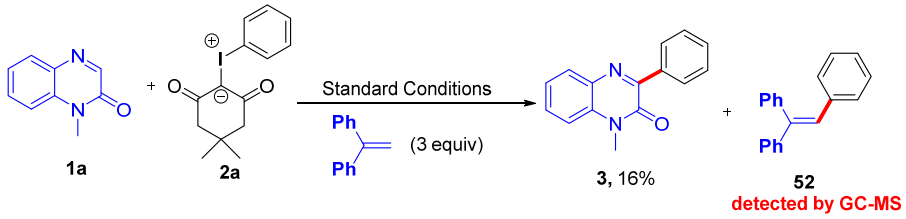
5. Gram-scale Reaction



A mixture of quinoxalin-2(1H)-one **1a** (3 mmol, 0.48 g, 1 equiv) and iodonium ylide **2a** (4.5 mmol, 1.54 g, 1.5 equiv), EosinY (2 mol %, 0.0390 g) and K_2CO_3 (3 mmol, 0.4140 g, 1equiv) was added in a dry round-bottomed flask under N_2 atmosphere. To the mixture, DMSO (10 mL) was added *via* a syringe and the reaction mixture was stirred and irradiated by the 12W blue LED at room temperature for 24 h, which was monitored with TLC. After completion of the reaction, the reaction mixture was added water and extracted with ethyl acetate. The combined organic phase was dried over Na_2SO_4. The resulting crude residue was purified by column chromatography on silica gel (elute: EtOAc /petroleum ether) to give the desired product **3** (0.50 g, 71%).

6. Mechanism Studies

Radical trapping experiment



A dried 25 mL Schlenk tube equipped with a magnetic stir bar was charged with quinoxalin-2(1H)-one **1a** (0.1 mmol) and iodonium ylide **2a** (0.15 mmol), EosinY (2 mol %), K_2CO_3 (1equiv) and DMSO (2 mL). The reaction mixture was then stirred and irradiation with a 12 W blue LED at room temperature for 12 h under N_2 atmosphere. The reaction mixture was washed with water and extracted with ethyl acetate three times. The combined organic layer was washed with saturated NaCl solution, dried with anhydrous Na_2SO_4 and filtered. The filtrate was concentrated in vacuo. The adduct **52** could be detected by GC-MS (m/z, relative intensity): 256.1.

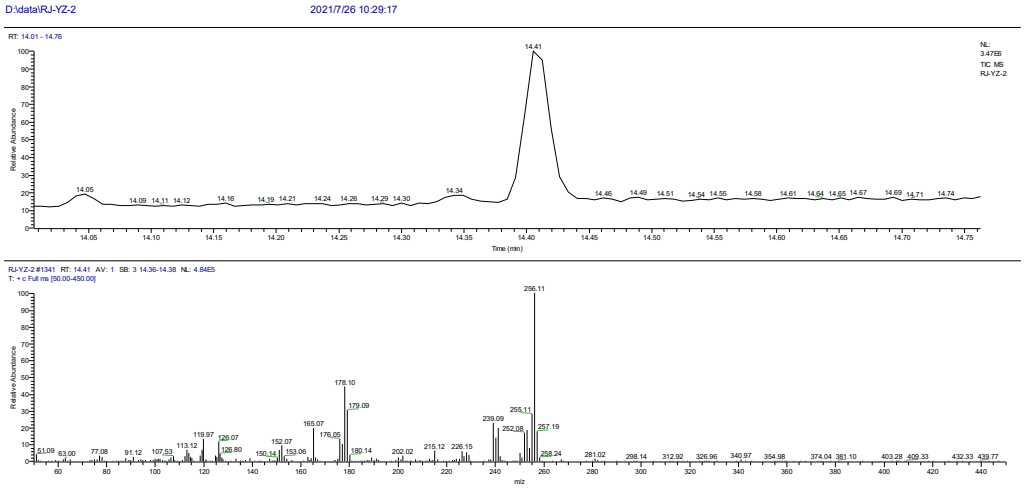


Figure 2. GC-MS spectrum of compound **52**

UV/VIS Absorption spectra

The UV/VIS Absorption spectra were recorded in EtOH of a 0.05 mM solution in 10 mm path length quartz cuvette on a Perkin Elmer Lambda 35 Spectrometer.

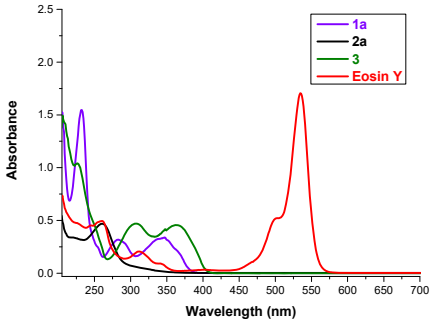


Figure 3. The UV/Vis absorption spectra of **1a**, **2a**, **3**, Eosin Y in EtOH (0.05 mM)

Stern-Volmer Quenching Experiments

Stern-Volmer fluorescence quenching experiments were run with freshly prepared 0.05 Mm solution of Eosin Y in EtOH and was added the appropriate amount of a quencher in a screw-top quartz cuvette at room temperature.

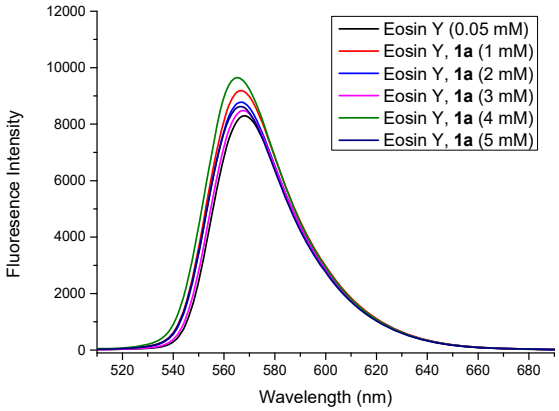


Figure 4. Luminescence quenching experiments of Eosin Y with **1a**

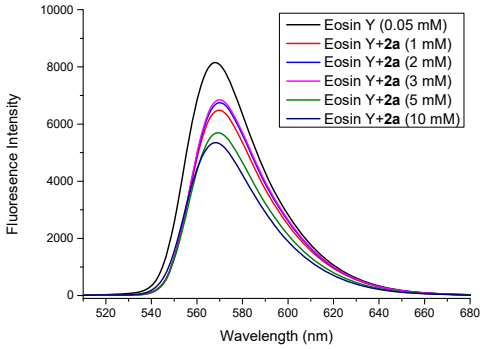


Figure 5. Luminescence quenching experiments of Eosin Y with **2a**

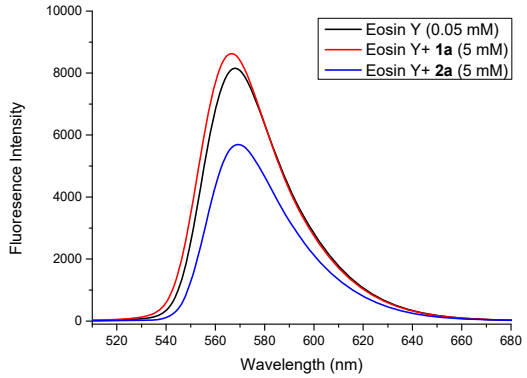


Figure 6. Luminescence quenching experiments of Eosin Y with reactants

Cyclic Voltammetry

Cyclic voltammetry was measured under Ar balloon protection with conventional three-electrode system (Reference electrode: Ag/AgCl, working electrode: Glassy carbon, counter electrode: Pt wire, Supporting electrolyte: 0.1 M TBAPF 6 in CH_3CN).

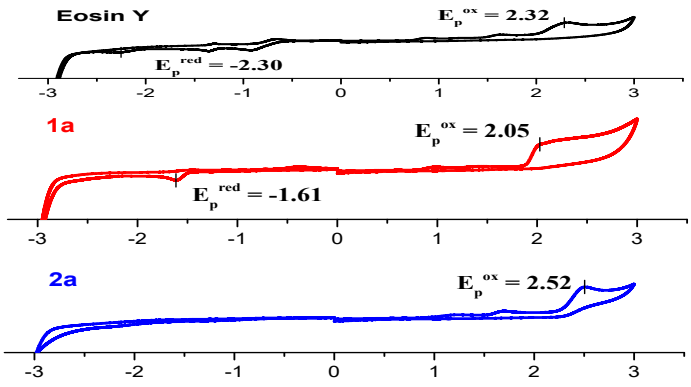


Figure 7. CV of Reaction reagents (5 mM in CH_3CN)

Light ON-OFF experiment

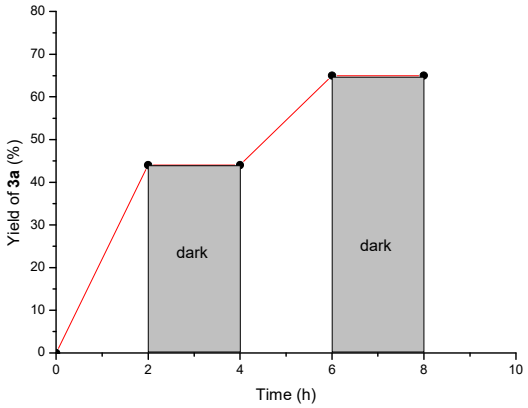


Figure 8. Light ON-OFF experiment

A dried 25 mL Schlenk tube equipped with a magnetic stir bar was charged with quinoxalin-2(1H)-one **1a** (0.1 mmol) and iodonium ylide **2a** (0.15 mmol), EosinY (2 mol %), K_2CO_3 (1equiv) and DMSO (2 mL). The reaction mixture was then stirred and irradiation with a 12 W blue LED at room temperature under N_2 atmosphere. After 2 h, the blue LED was turned off, and one vial was removed from the irradiation setup for analysis. The remaining three vials were stirred in the absence of light for an additional 2 h. Then, one vial was removed for analysis, and the blue LED was turned back on to irradiate the remaining two reaction mixtures. After an additional 2 h of irradiation, the blue LED was turned off, and one vial was removed for analysis. The remaining vial was stirred in the absence of light for an additional 2 h. Then, the last vial was removed for analysis. The yield of the product was isolated yield.

7. X-Ray Crystallographic Data of 3

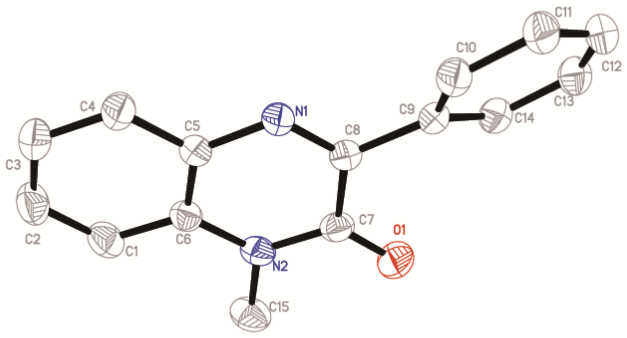


Figure 4. Single-crystal X-ray Molecular Structure of **3**

The structure of **3** (containing little solvent) was determined by the X-ray diffraction. Recrystallized from ethyl acetate/petroleum ether. Further information can be found in the CIF file. This crystal was deposited in the Cambridge Crystallographic Data and assigned as

CCDC: 2106532. ORTEP view of complex Ellipsoids are represented at the 50% probability level.

Table 1 Crystal data and structure refinement for 3.

Identification code	**3**
Empirical formula	$C_{15}H_{12}N_2O$
Formula weight	236.27
Temperature/K	293(2)
Crystal system	monoclinic
Space group	$P2_1/n$
a/Å	16.3920(6)
b/Å	7.1332(4)
c/Å	20.1084(8)
α/°	90
β/°	95.662(4)
γ/°	90
Volume/Å^3	2339.77(18)
Z	8
ρ_{calc}g/cm^3	1.341
μ/mm^{-1}	0.686
F(000)	992.0
Crystal size/mm^3	0.16 × 0.13 × 0.1
Radiation	CuKα (λ = 1.54184)
2Θ range for data collection/°	6.644 to 134.146
Index ranges	-19 ≤ h ≤ 19, -7 ≤ k ≤ 8, -16 ≤ l ≤ 24
Reflections collected	8634
Independent reflections	4191 [R_{int} = 0.0235, R_{sigma} = 0.0363]
Data/restraints/parameters	4191/0/327
Goodness-of-fit on F^2	1.045
Final R indexes [I>=2σ (I)]	R_1 = 0.0497, wR_2 = 0.1265
Final R indexes [all data]	R_1 = 0.0687, wR_2 = 0.1434
Largest diff. peak/hole / e Å^{-3}	0.19/-0.21

8. References

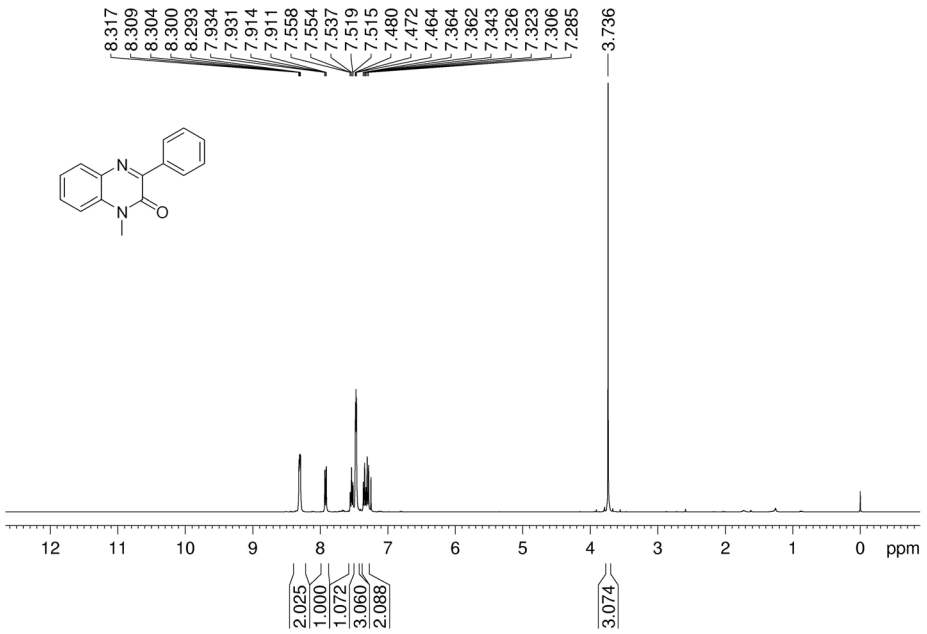
[1] (a) Jiang, Y.-y., Dou, G.-y., Zhang, L.-s., Xu, K., Little, R. D., Zeng, C.-C. *Adv. Synth. Catal.* **2019**, *361*, 5170-5175. (b) Miyamaru, S., Umezu, K., Ito, A., Shimizu, M. *Eur. J. Org. Chem.* **2015**, *15*, 3327-3337.

[2] Chen, X., Li, L., Pei, C., Li, J., Zou, D., Wu, Y., Wu, Y. *J. Org. Chem.* **2021**, *86*, 2772-2783.

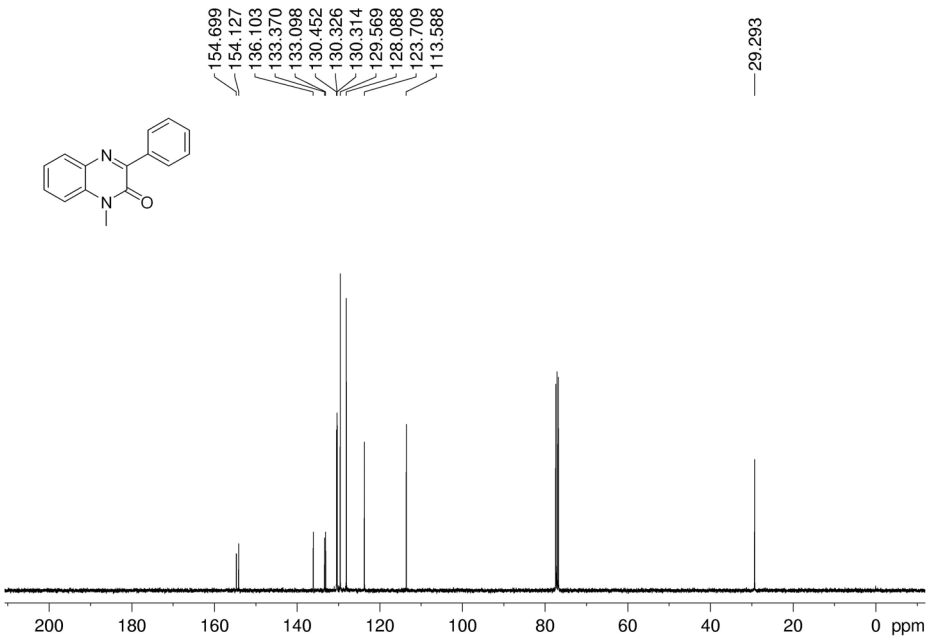
[3] Cao, G., Chen, Z., Song, J., Xu, J., Miao, M., Ren, H. *Adv. Synth. Catal.* **2018**, *360*, 881-886.

[4] (a) Iinuma, M., Moriyama,, K., Togo, H. *SYNLETT*. **2012**, *23*, 2663-2666. (b) Mayakrishnan, S., Tamizmani, M., Maheswari, N. U. *Chem. Commun*., **2020**, *56*, 15462-15465.

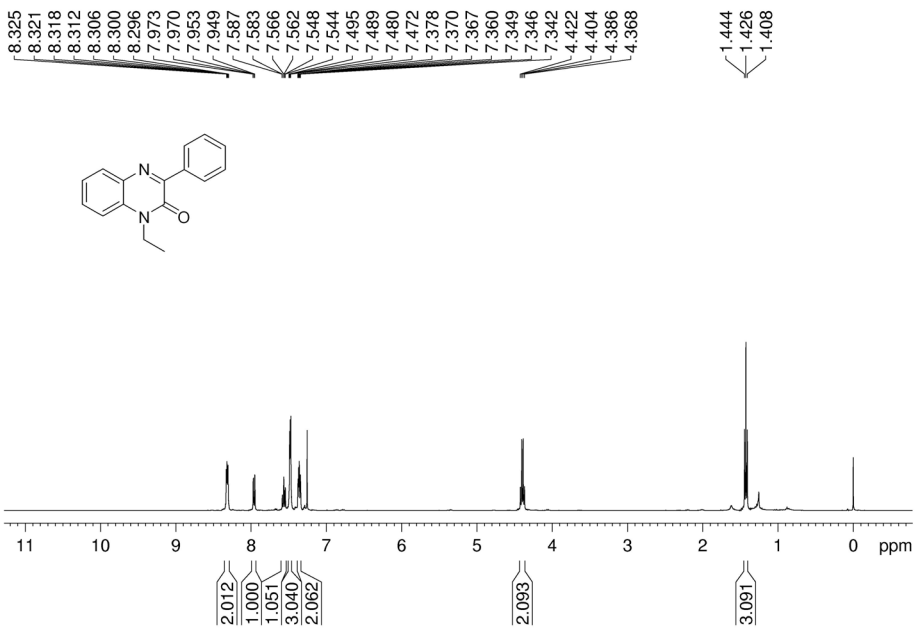
9. Copies of NMR Spectra



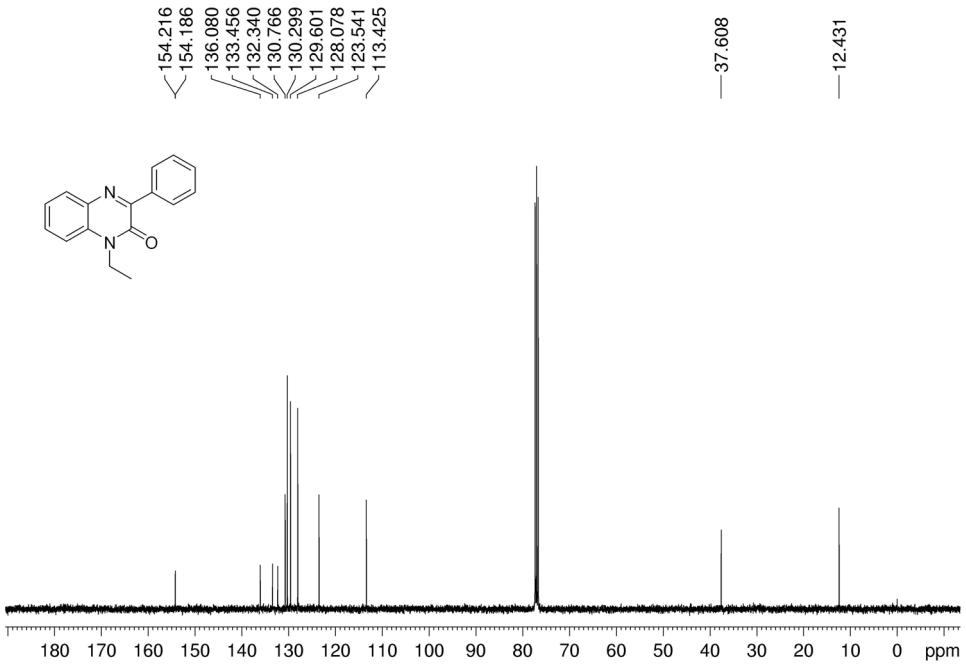
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 3



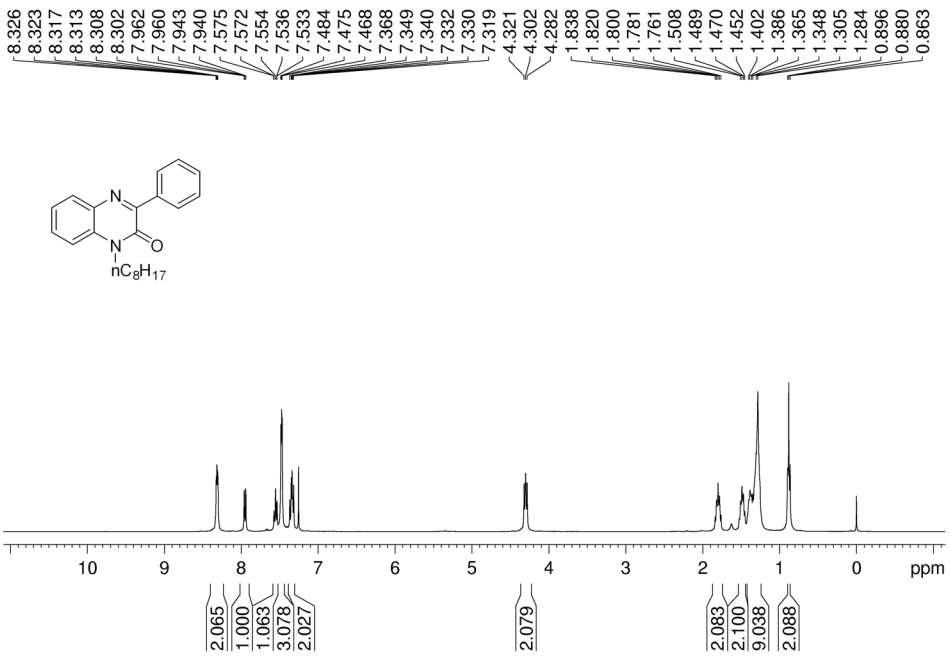
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 3



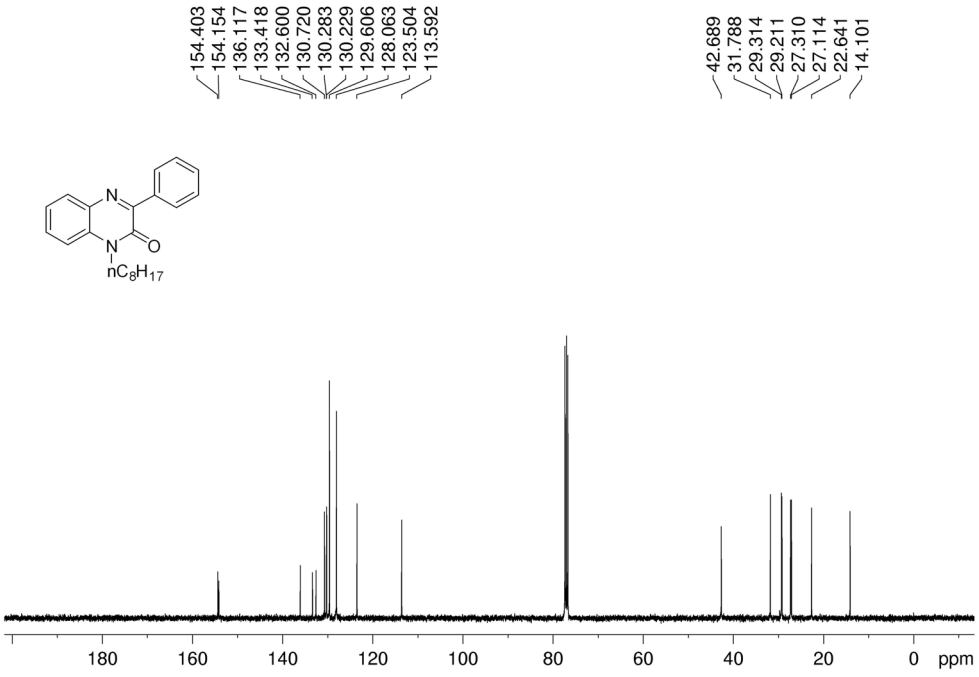
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 4



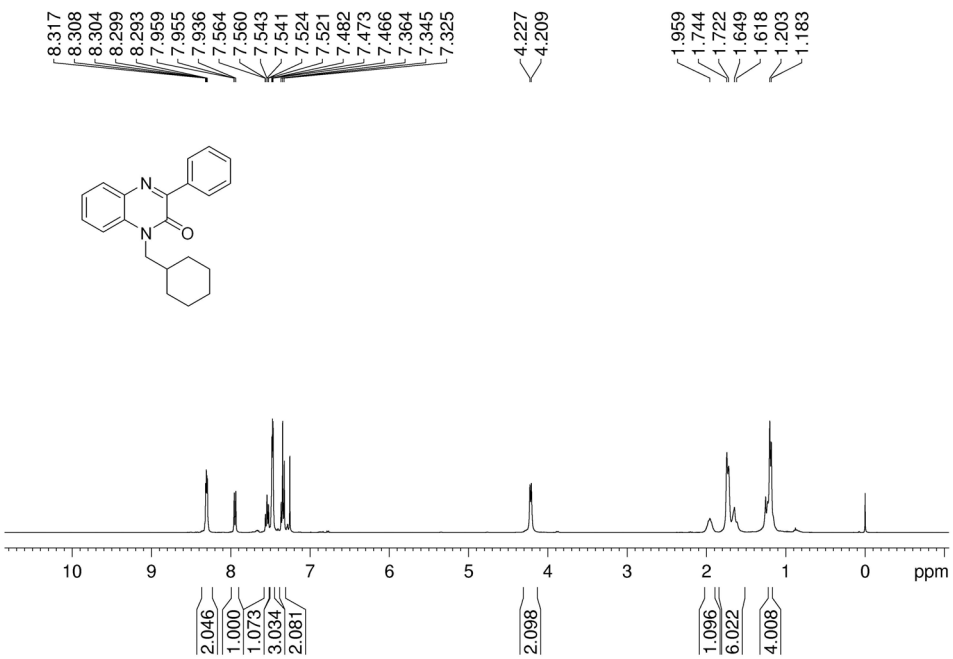
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 4



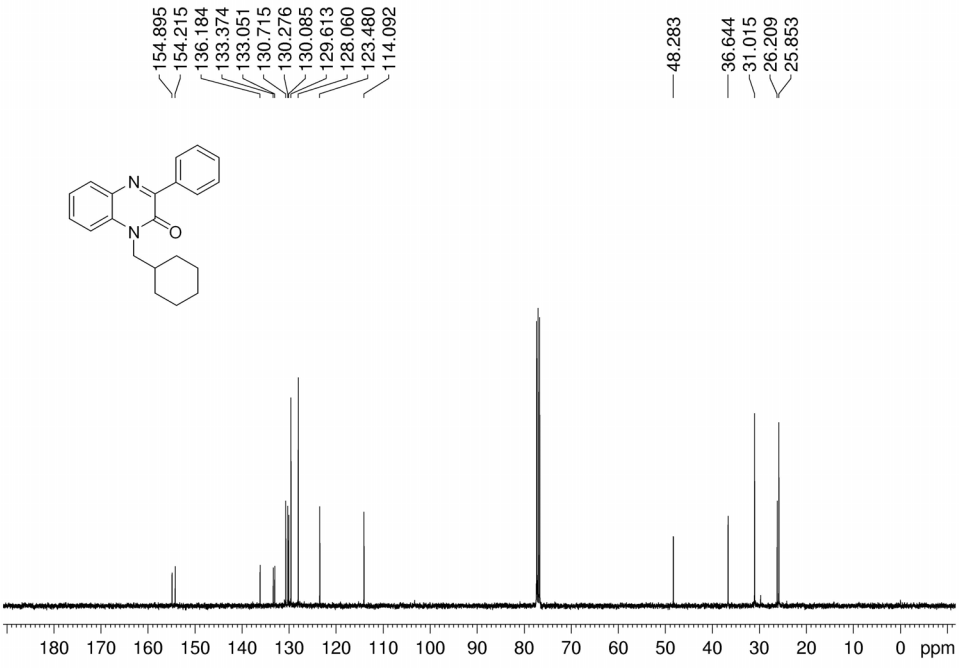
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 5



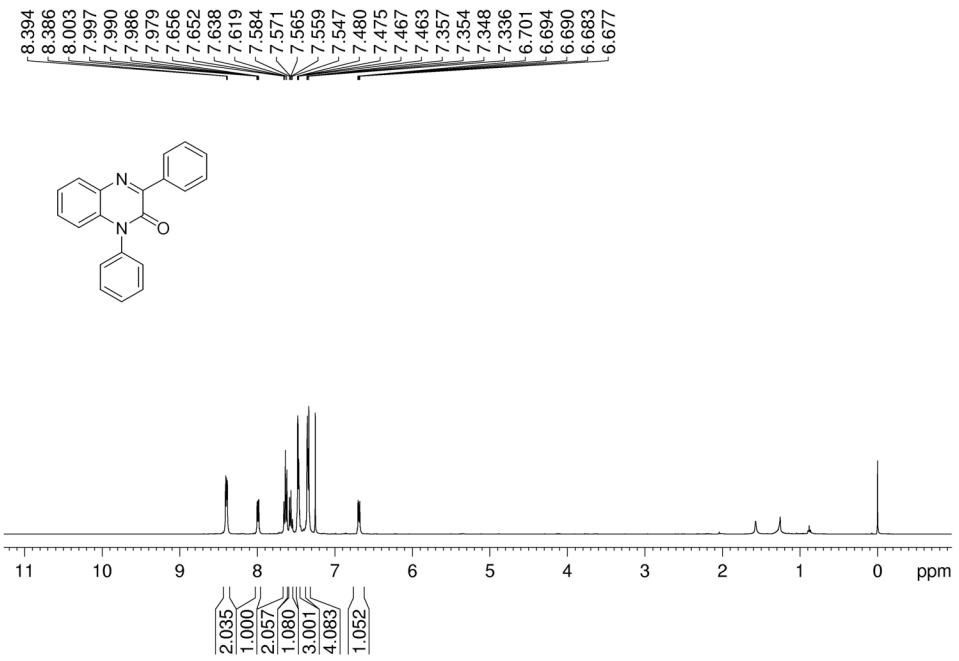
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 5



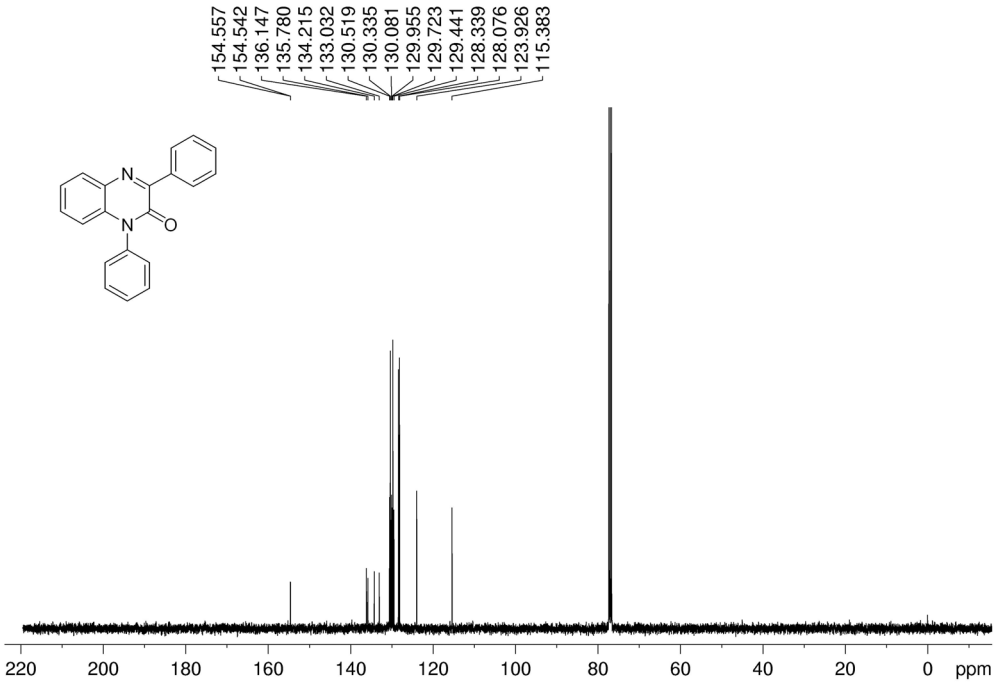
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 6



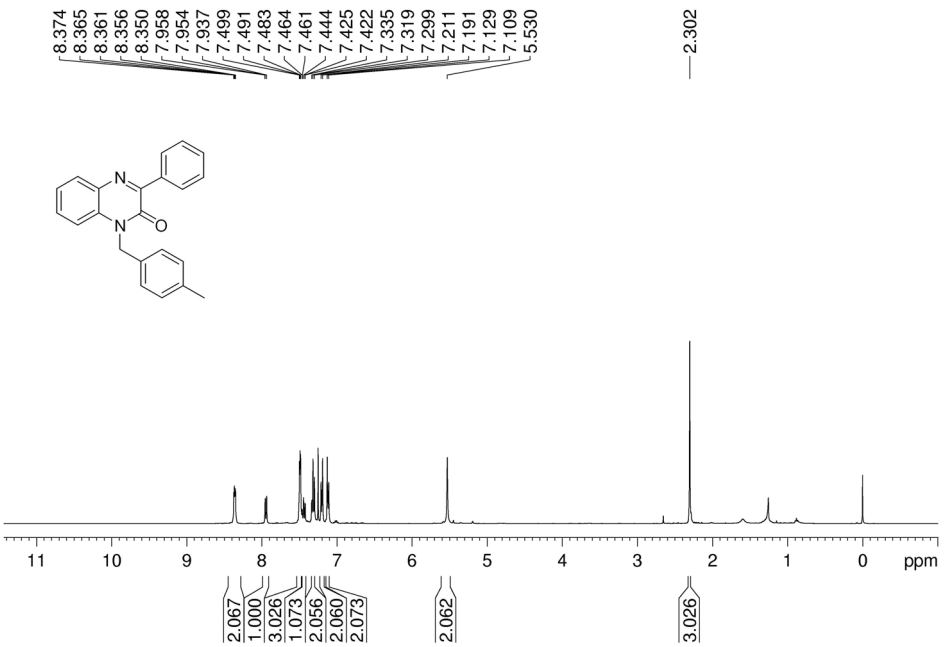
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 6



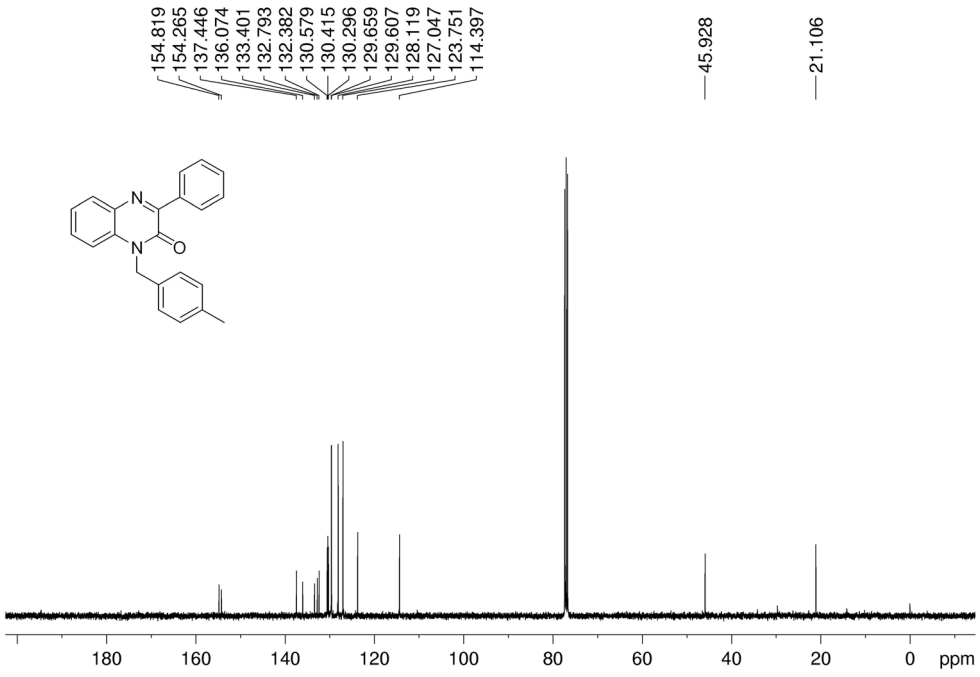
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 7



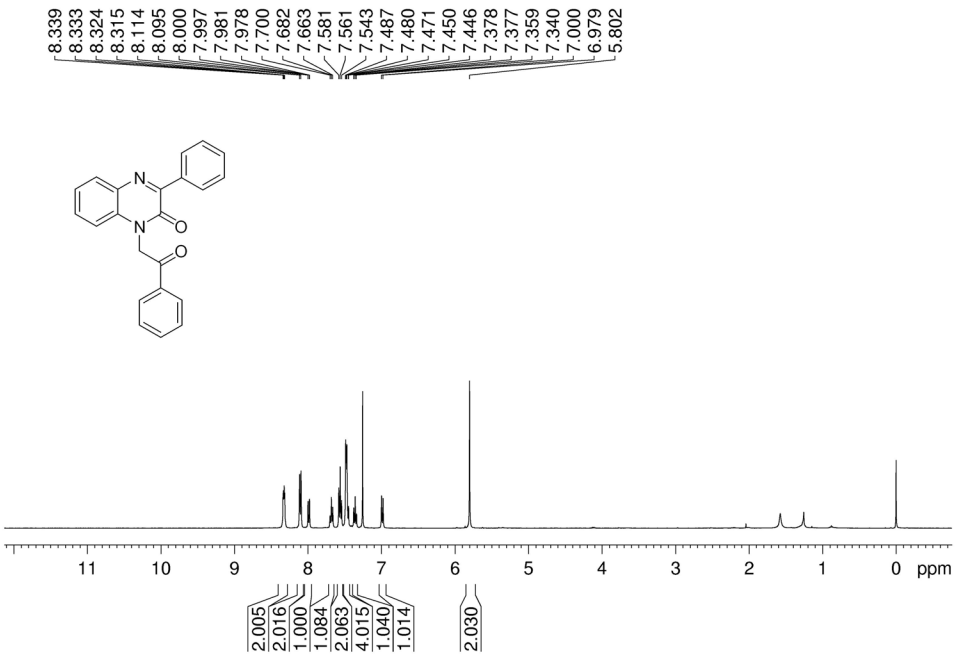
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 7



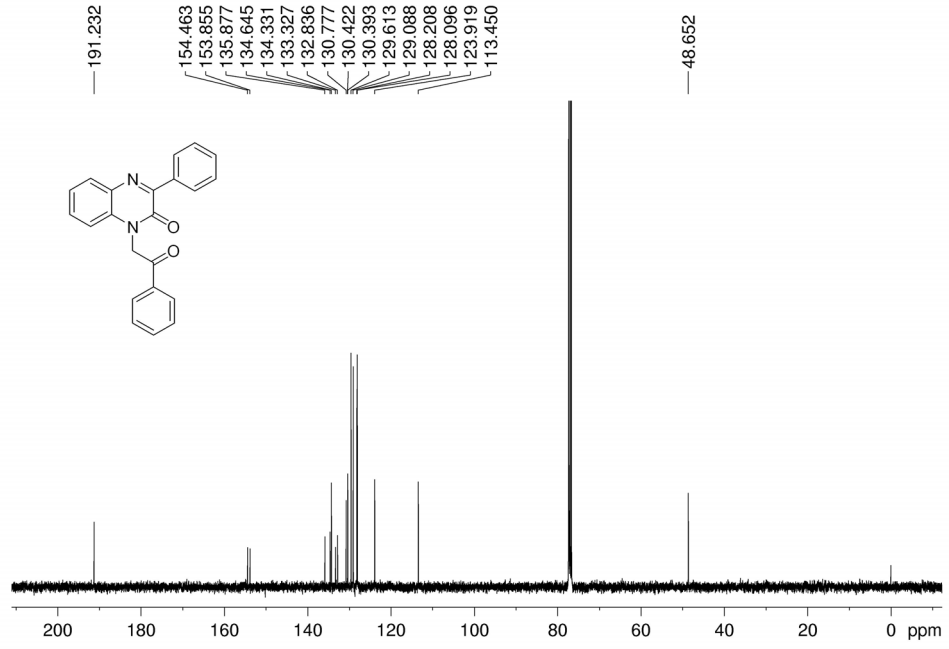
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 8



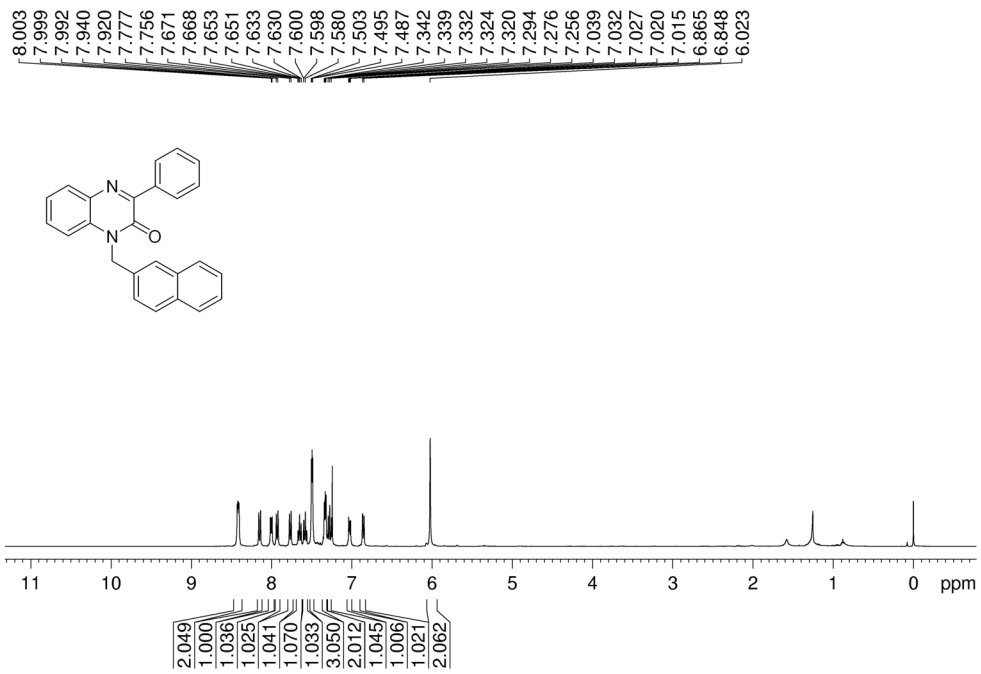
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 8



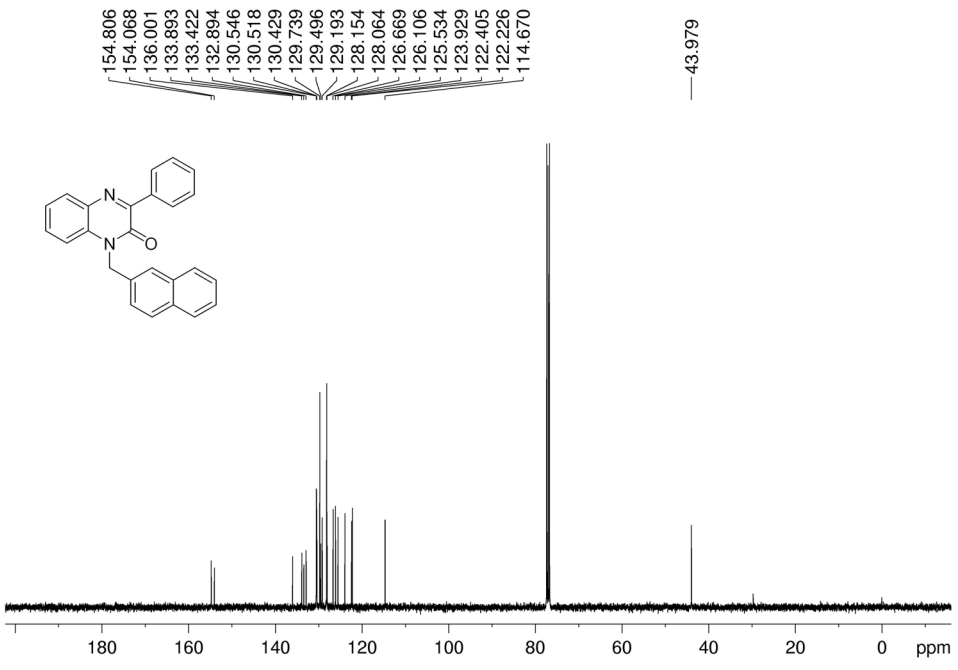
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 9



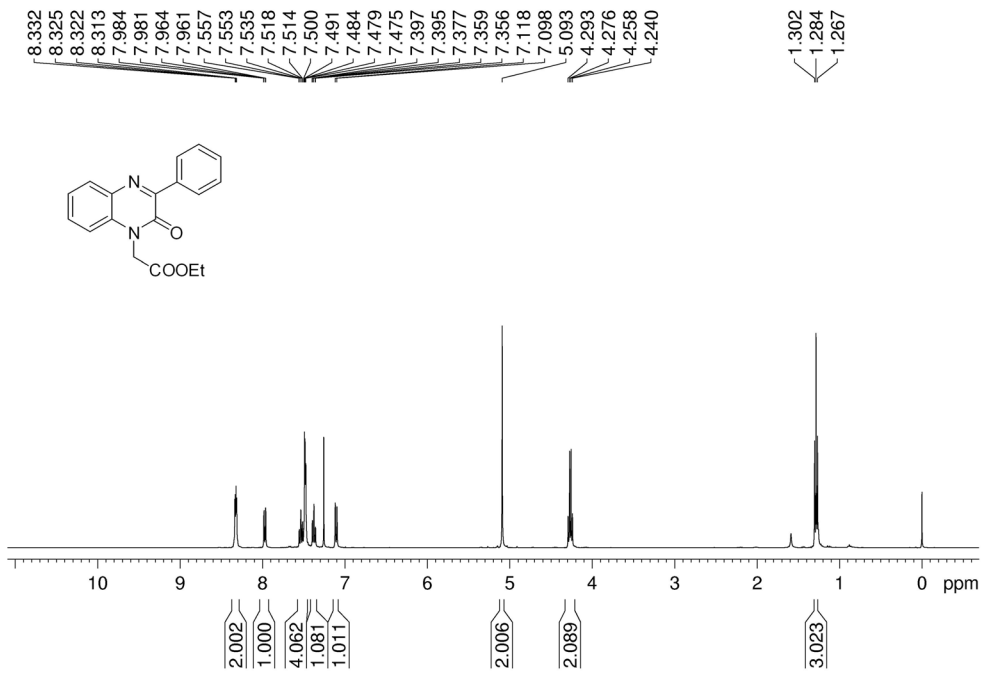
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 9



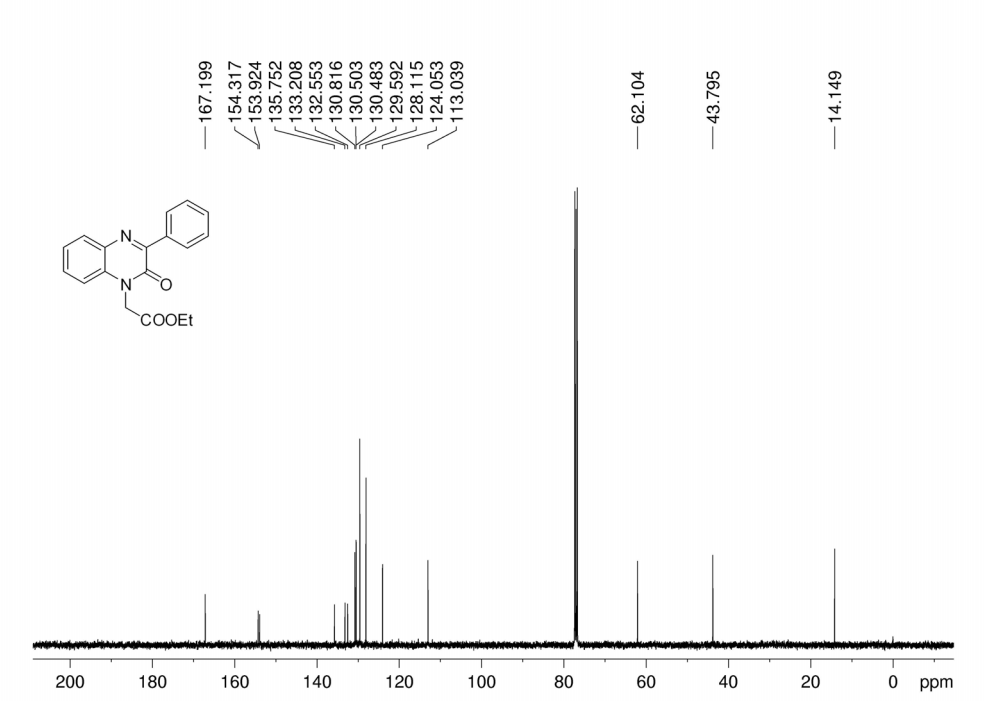
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 10



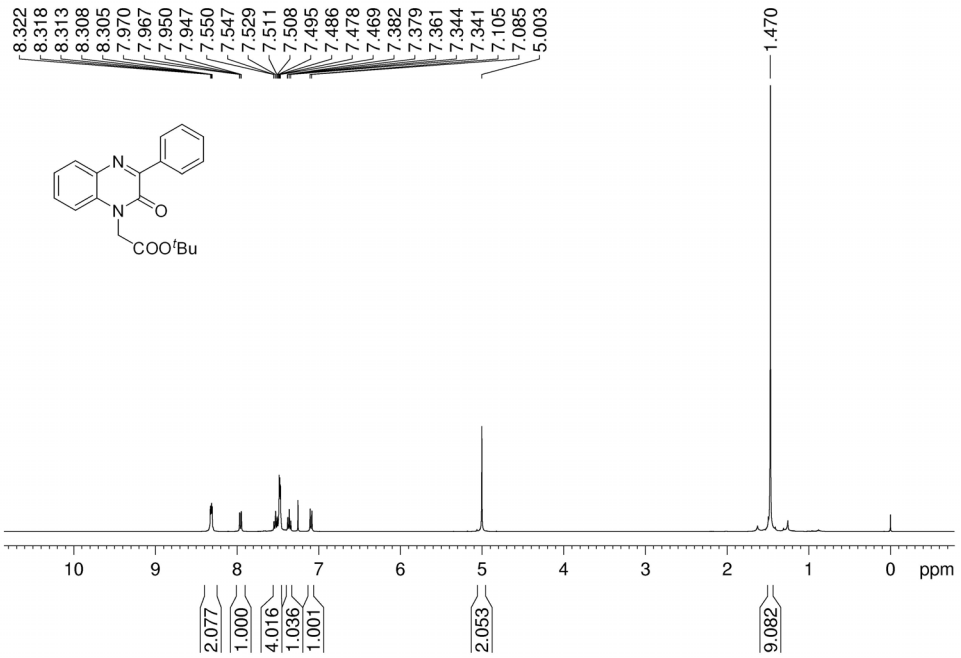
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 10



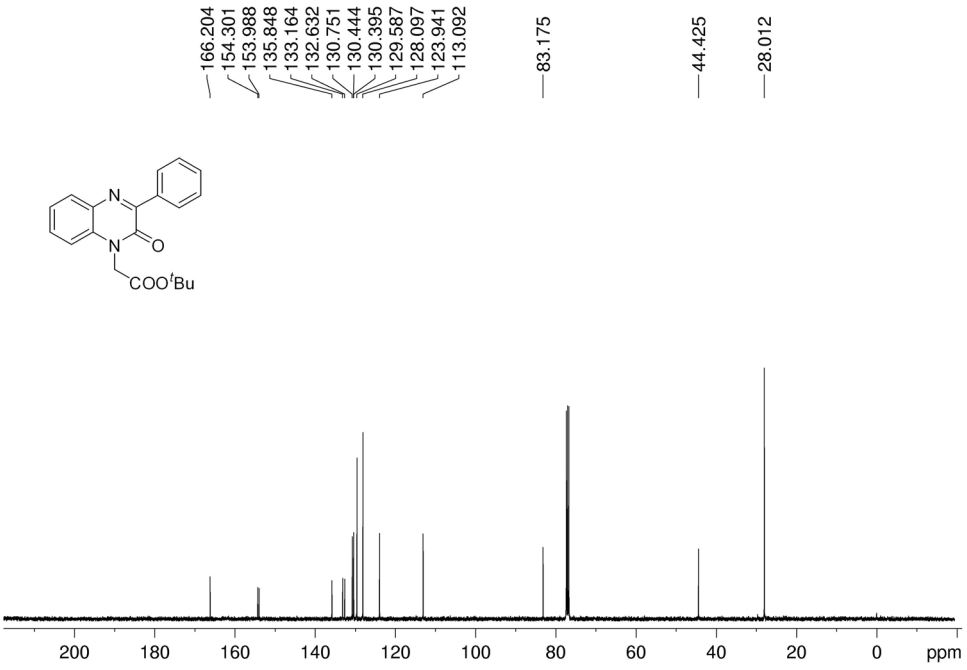
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 11



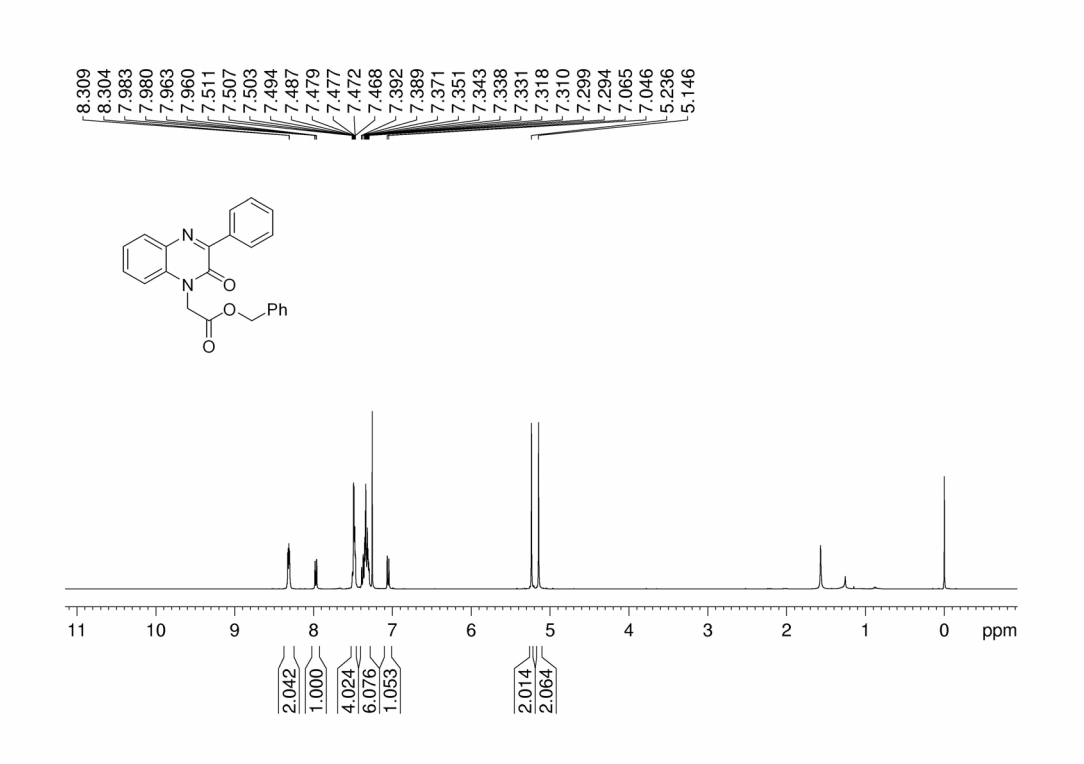
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 11



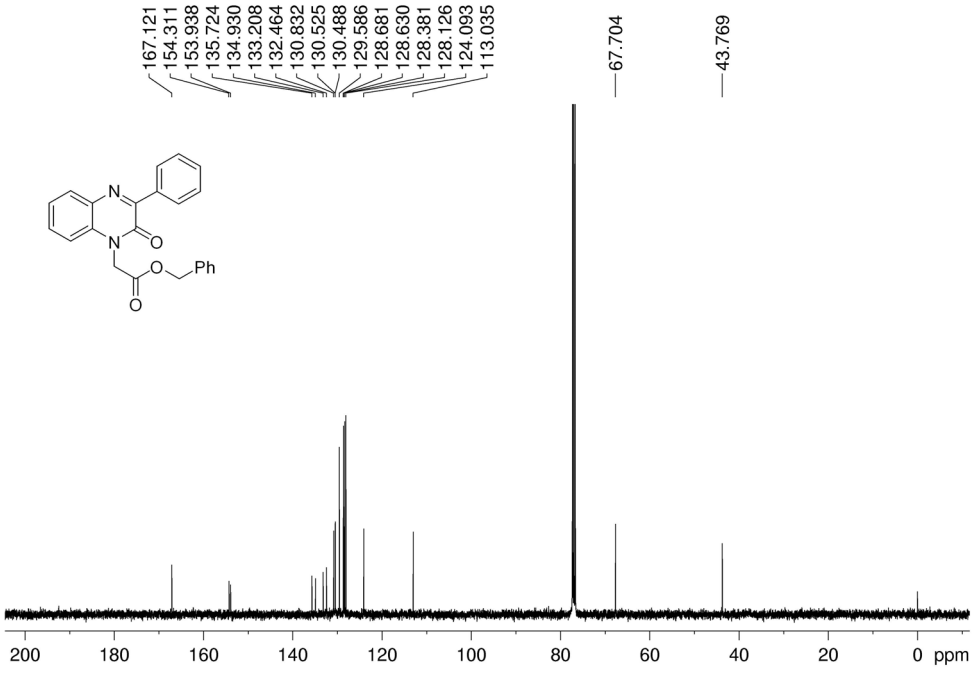
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 12



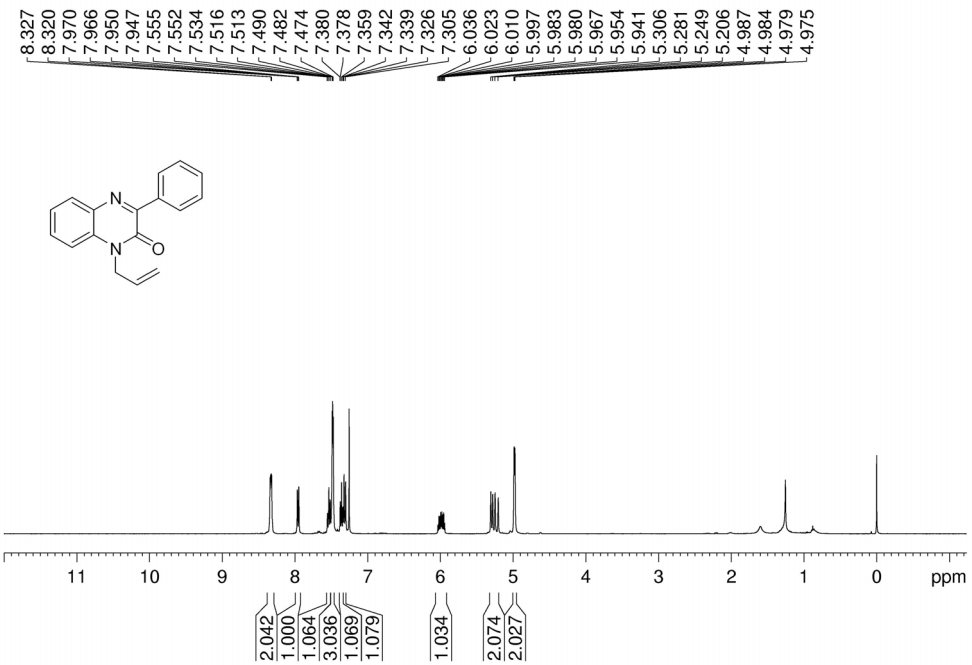
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 12



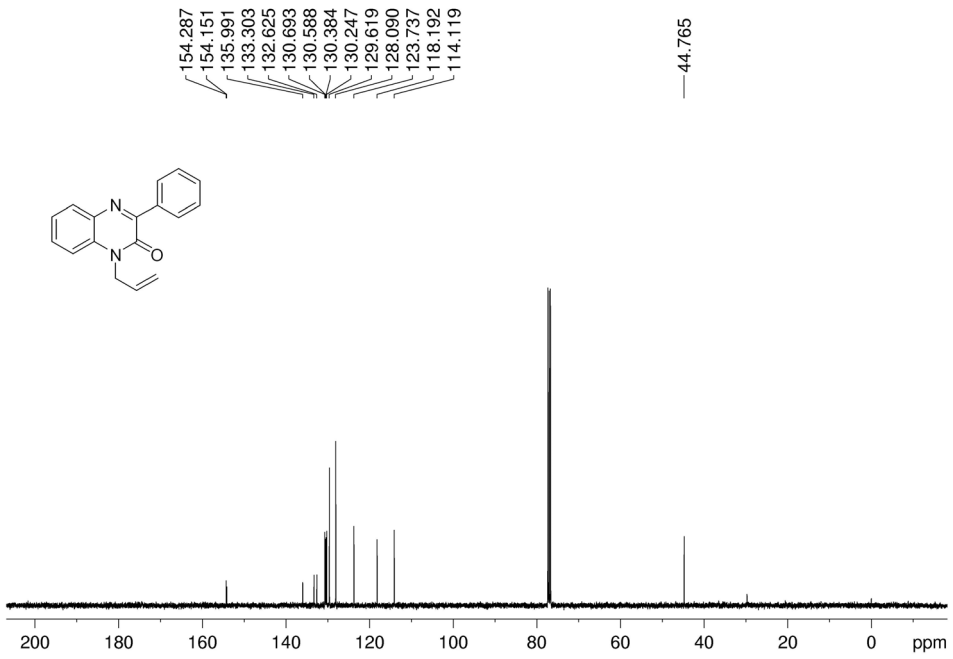
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 13



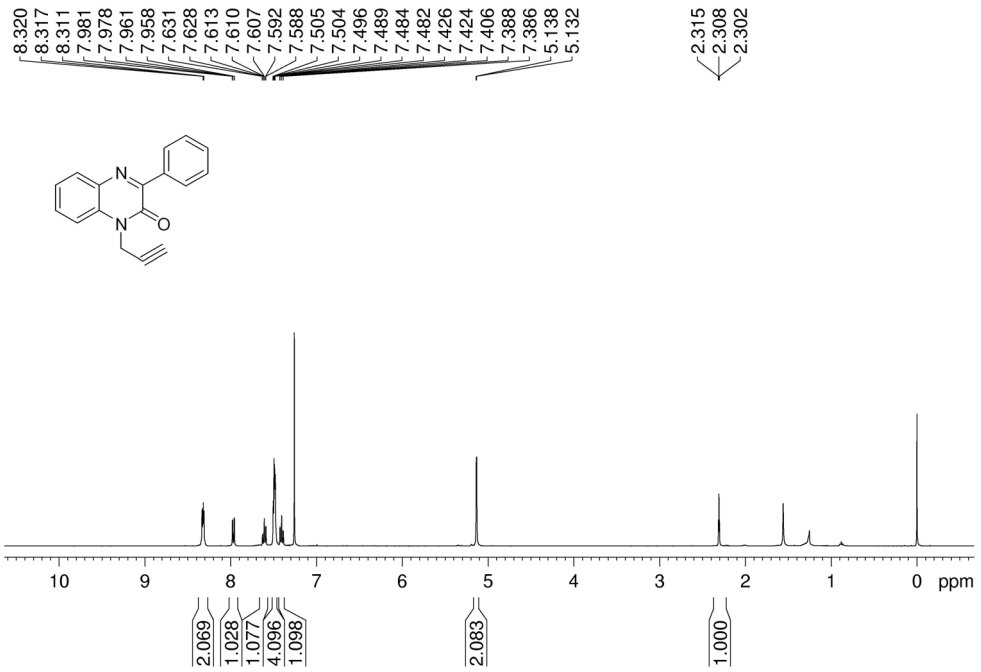
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 13



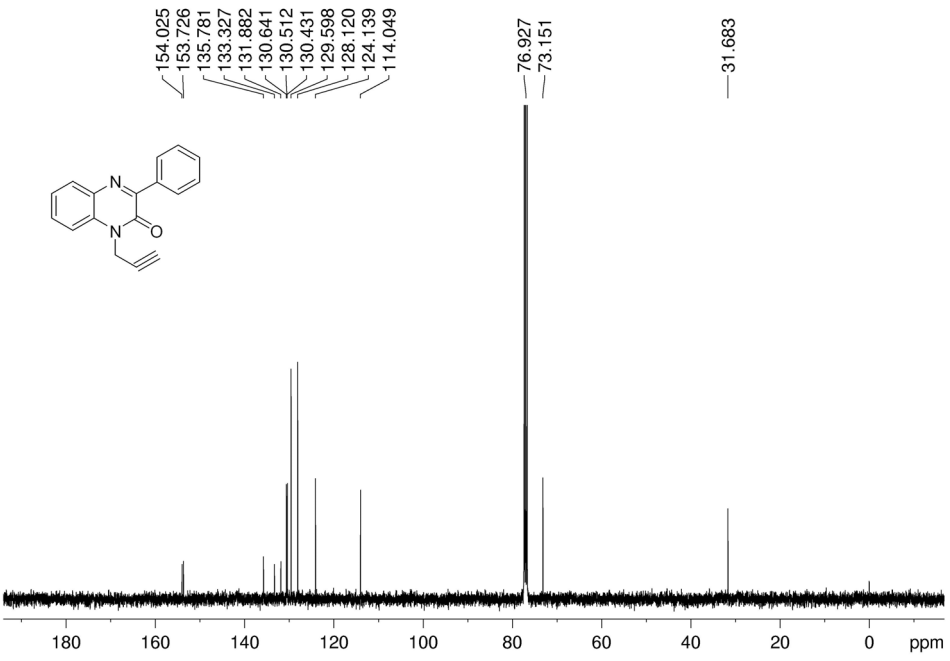
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 14



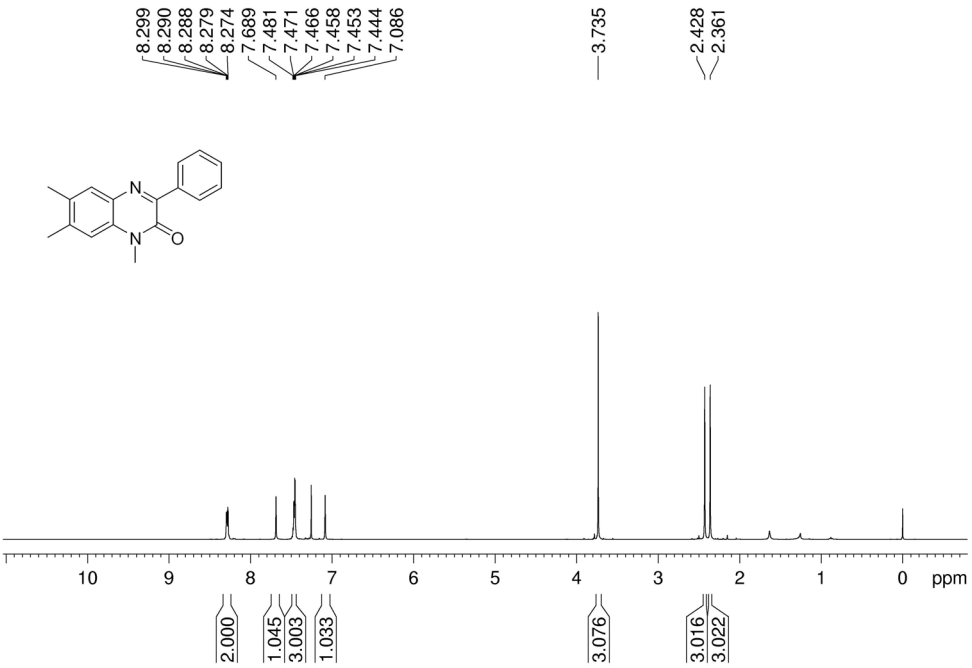
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 14



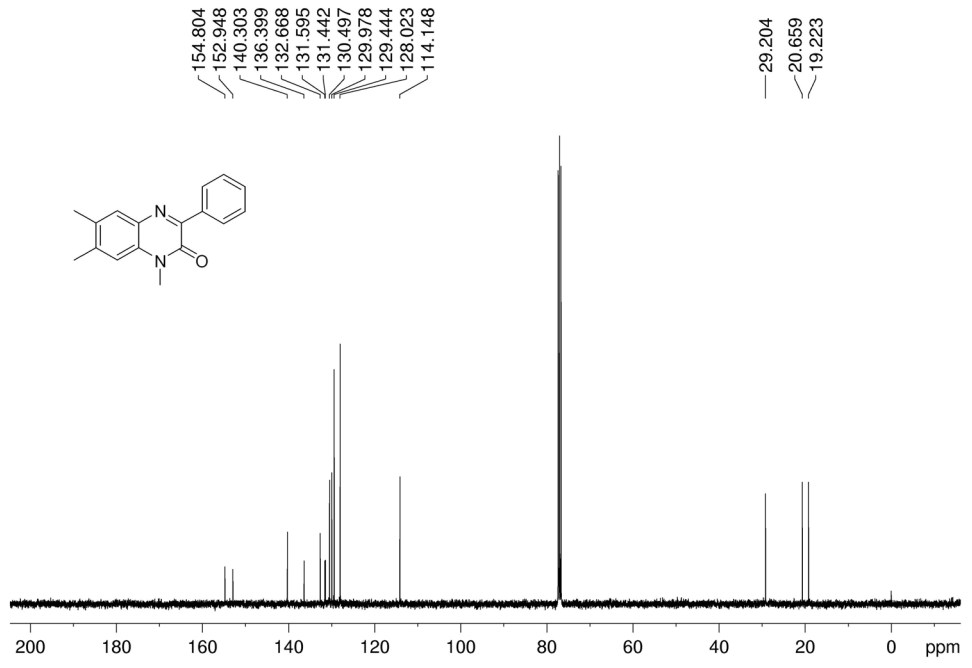
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 15



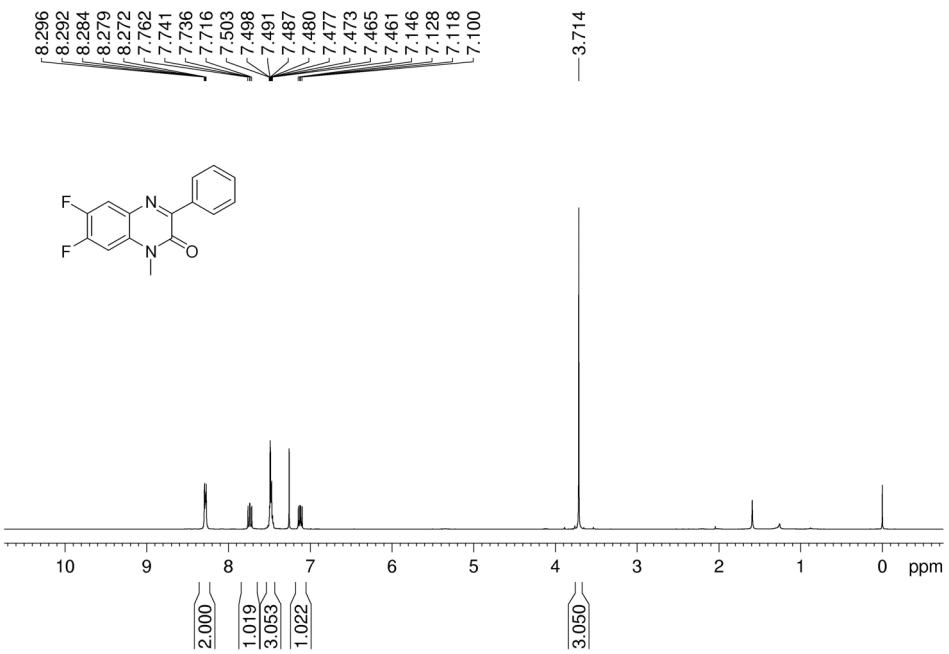
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 15



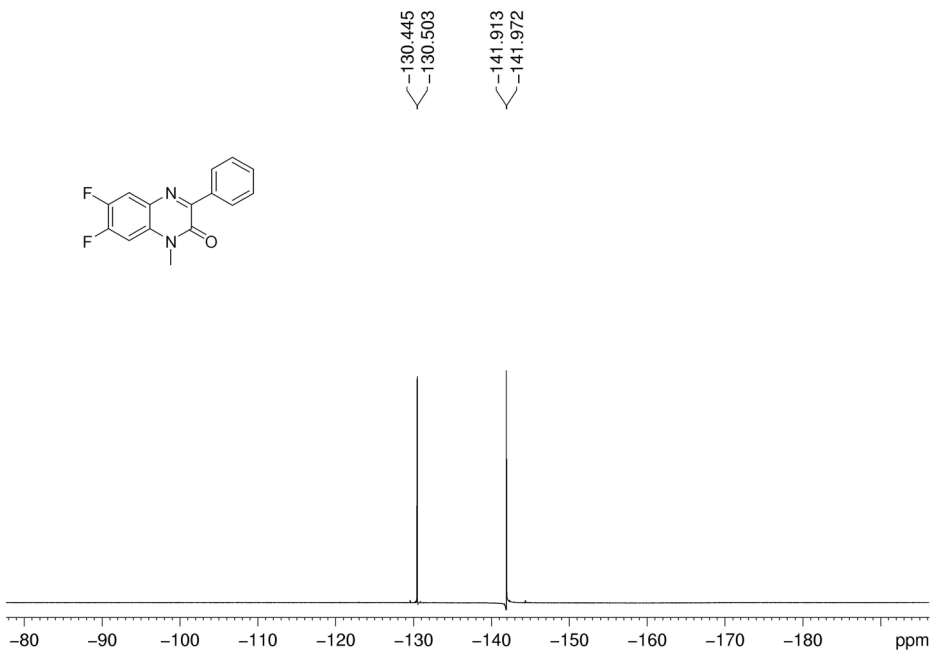
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 16



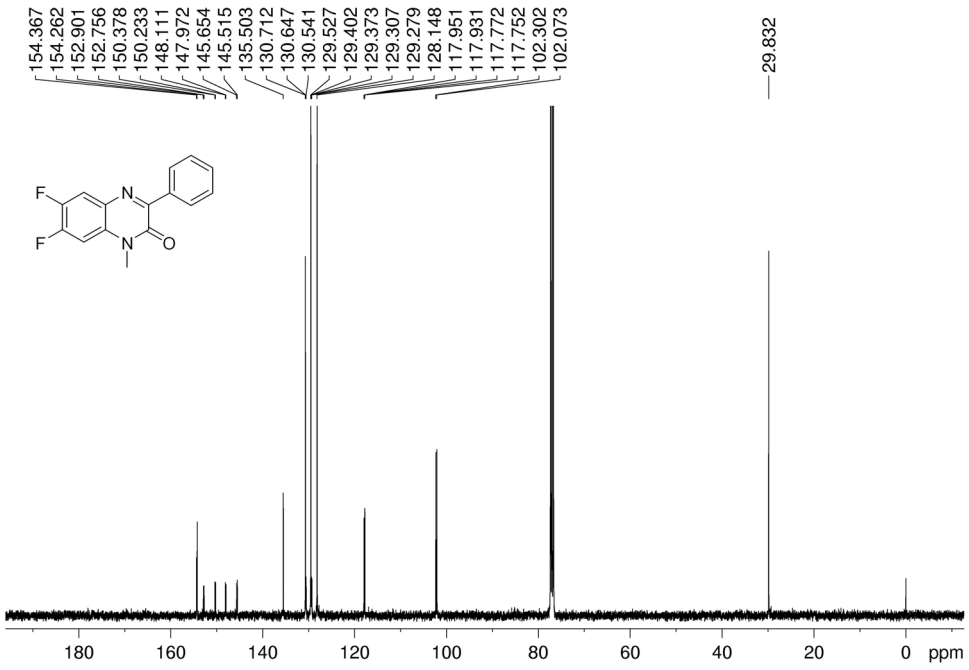
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 16



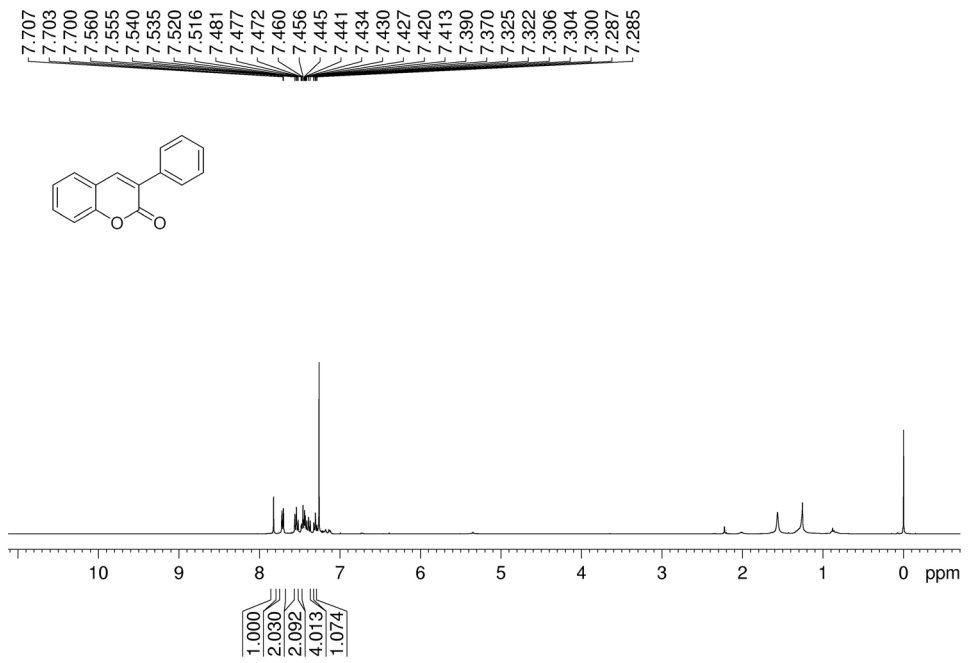
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 17



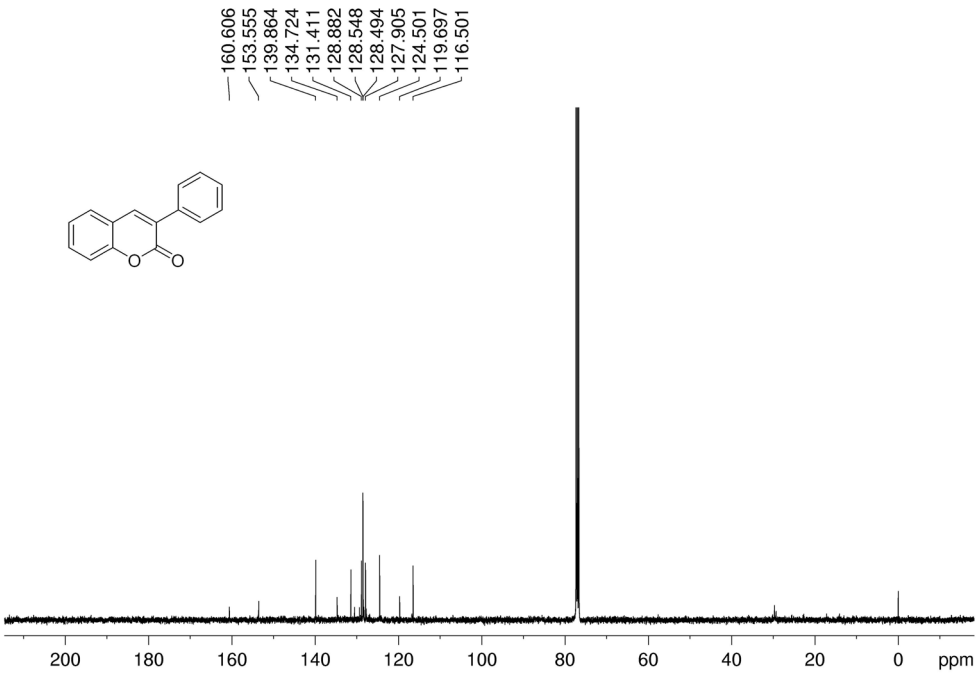
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound 17



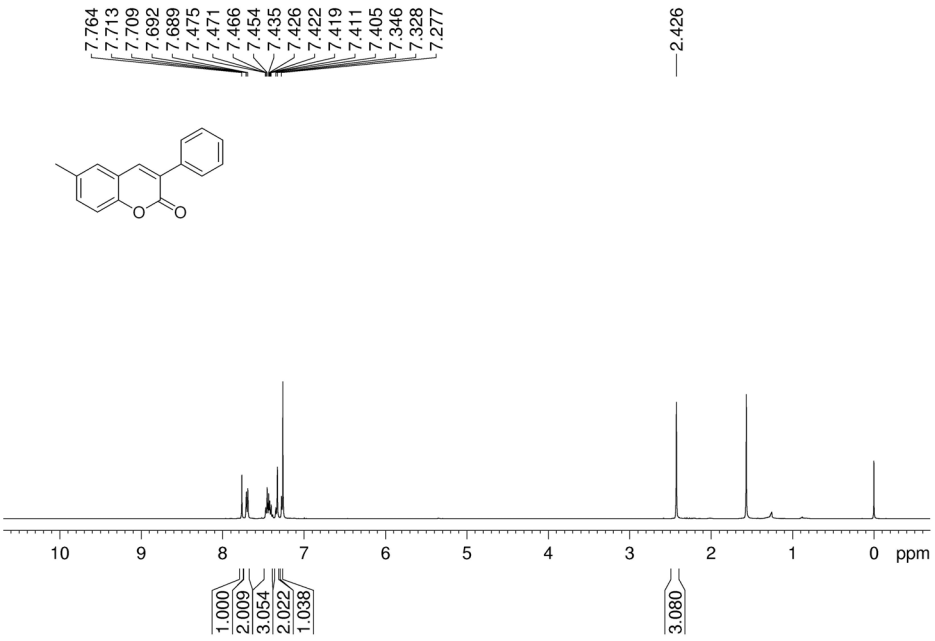
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 17



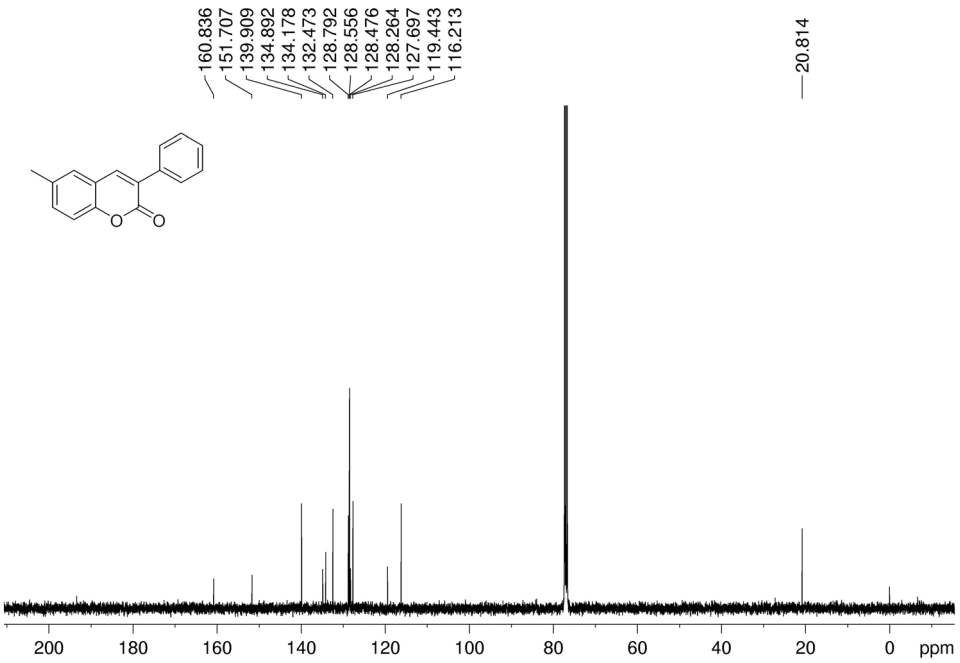
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 18



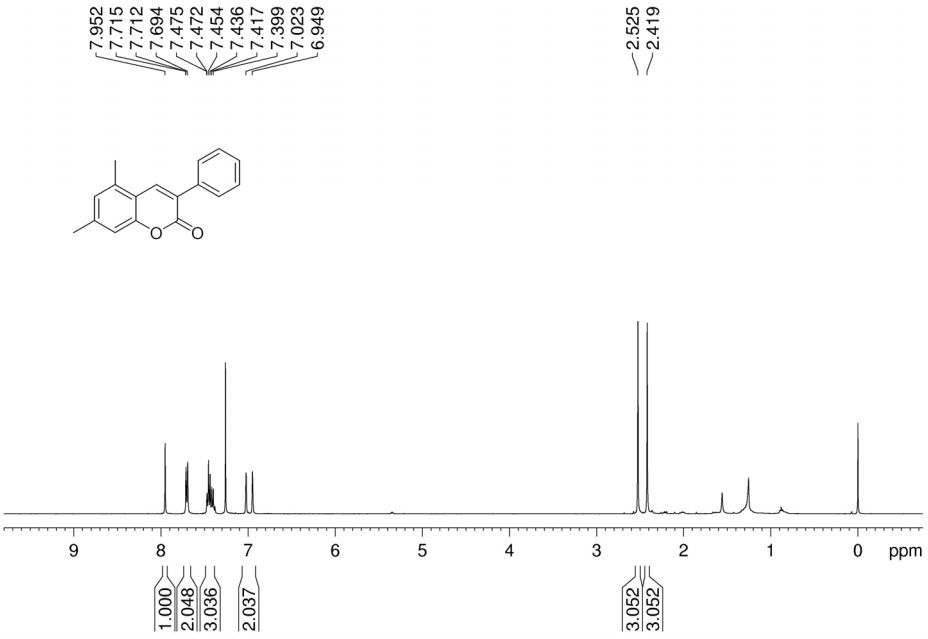
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 18



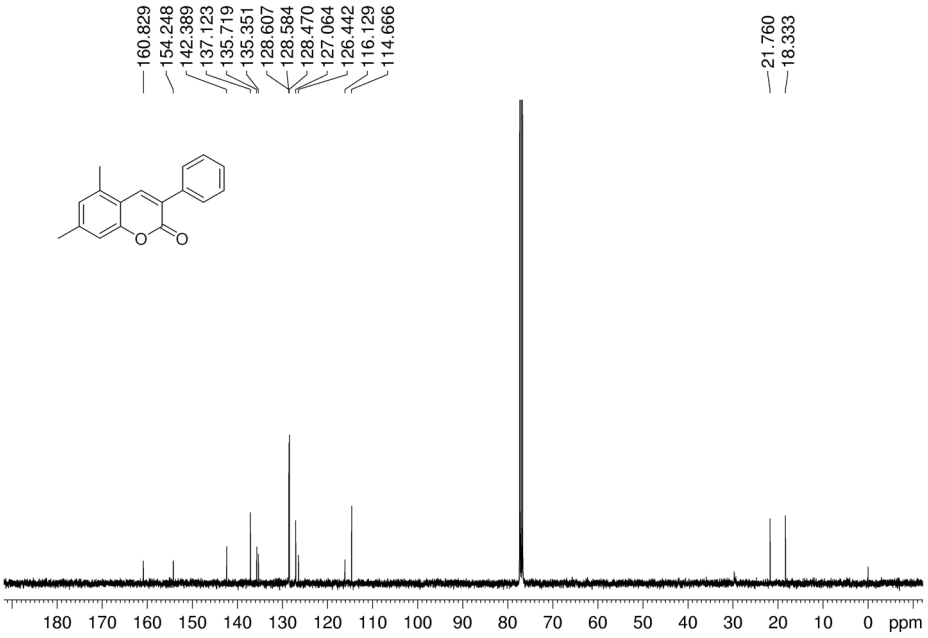
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 19



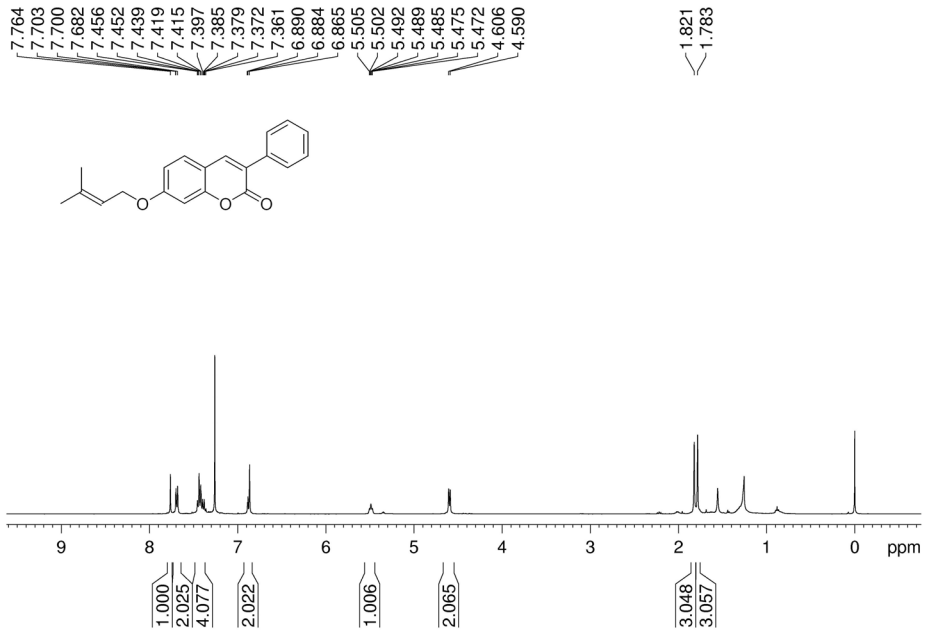
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 19



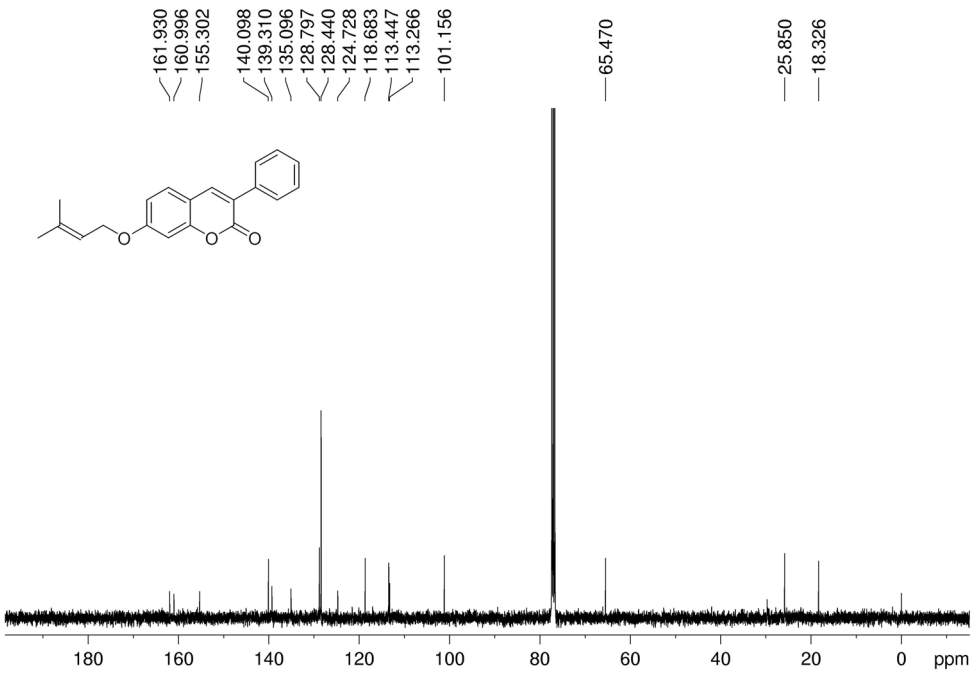
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 20



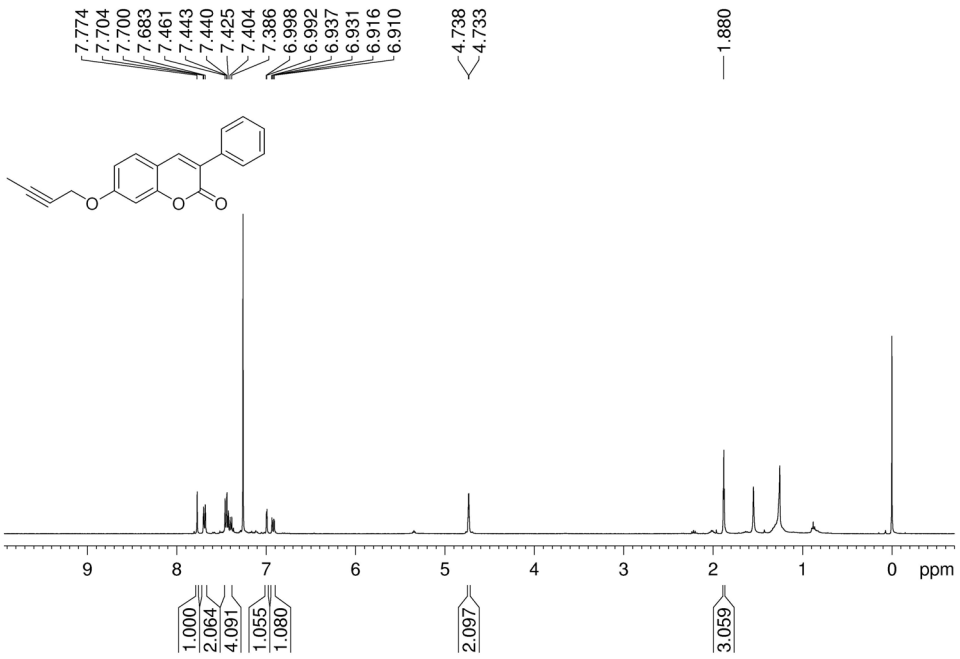
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 20



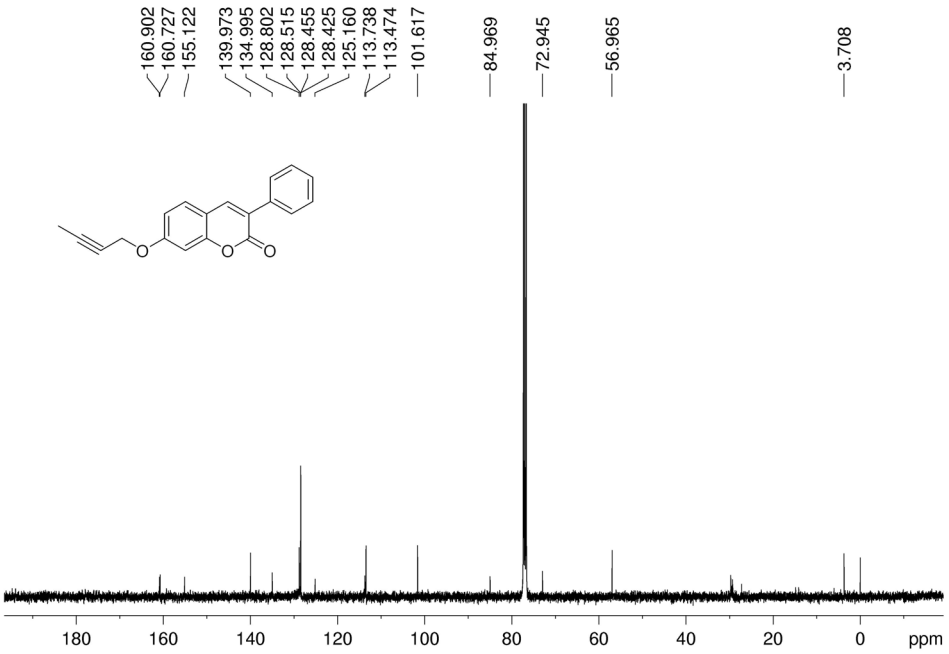
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 21



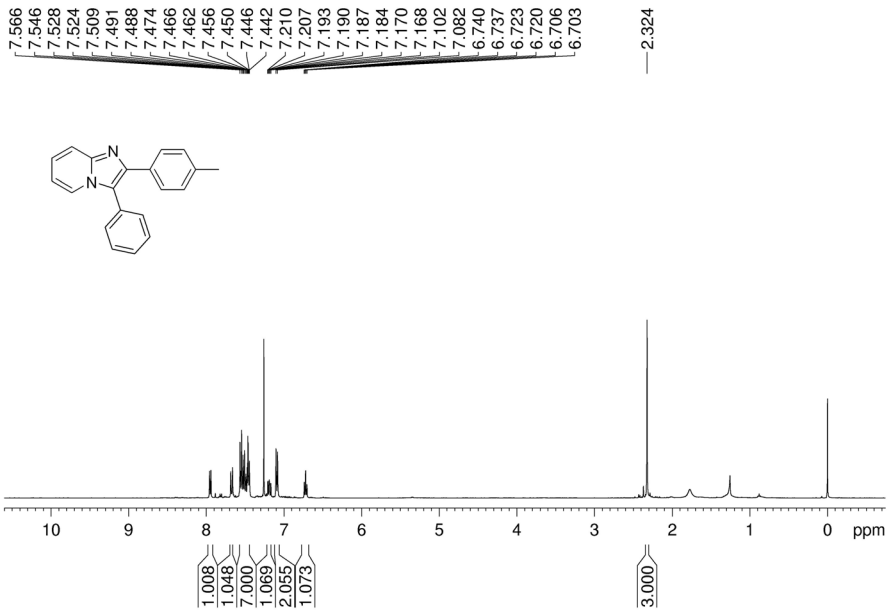
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 21



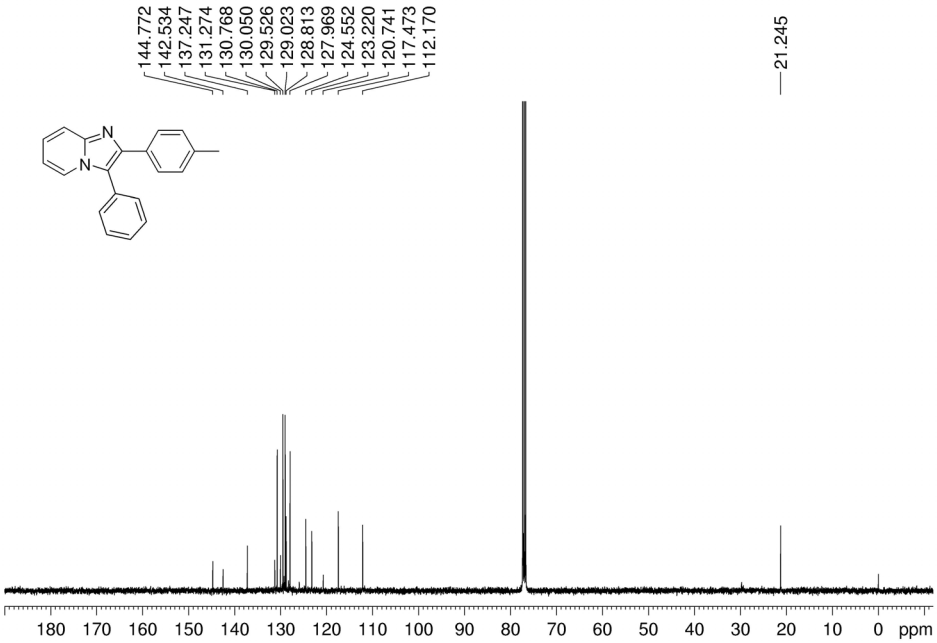
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 22



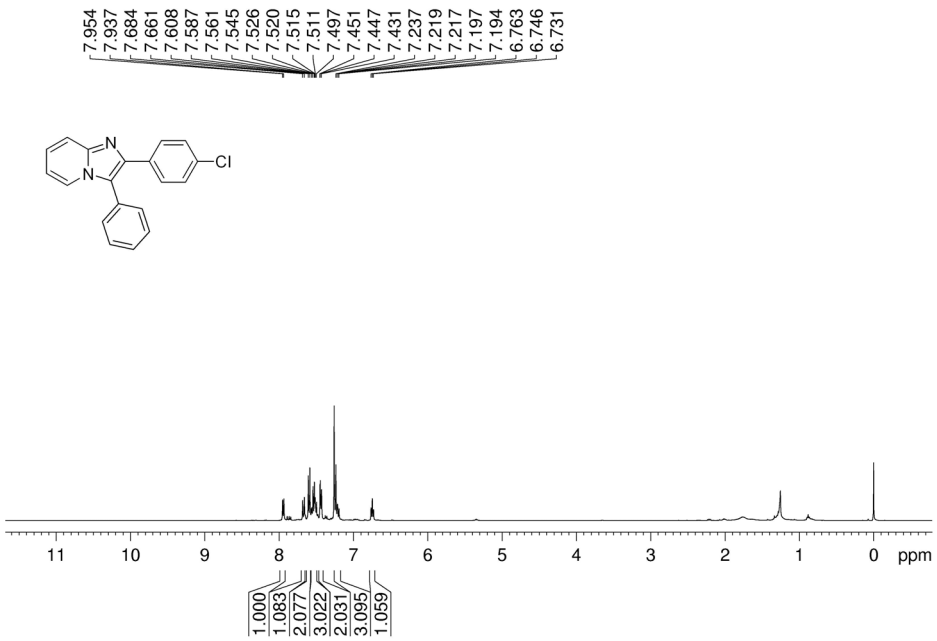
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 22



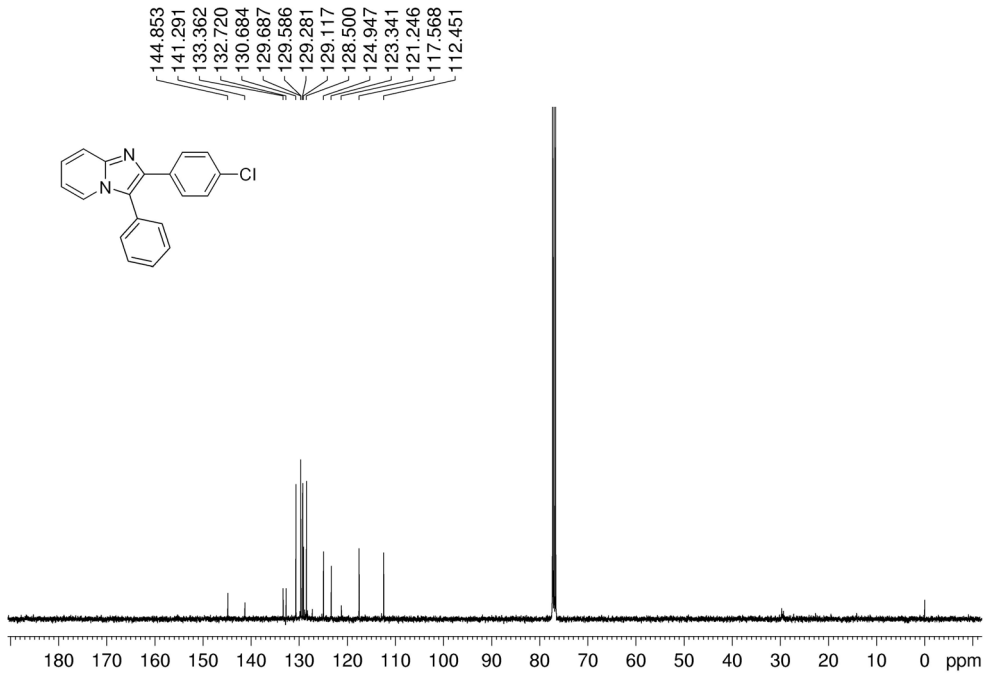
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 23



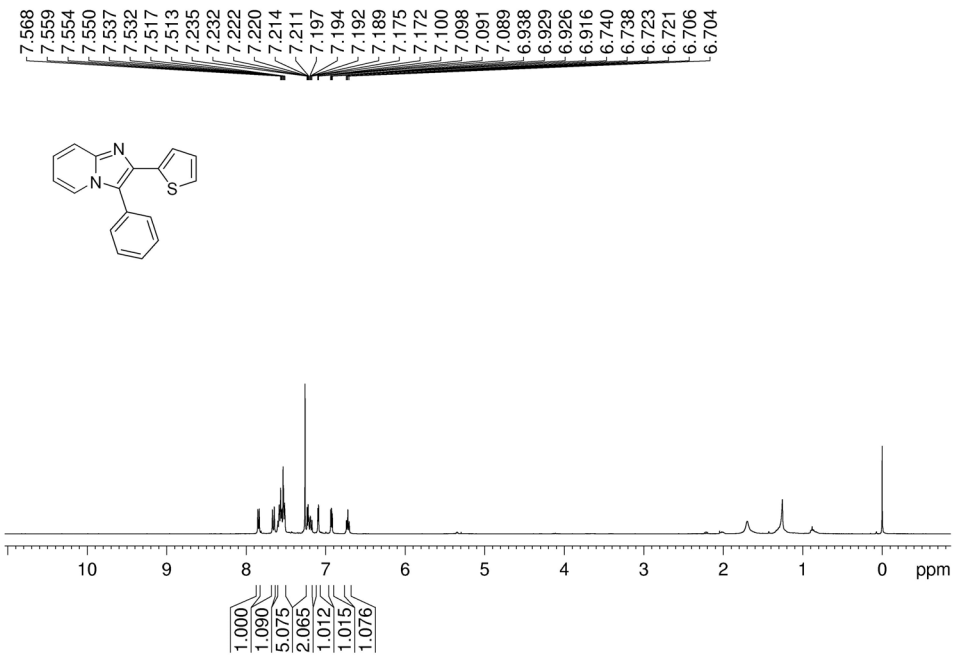
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 23



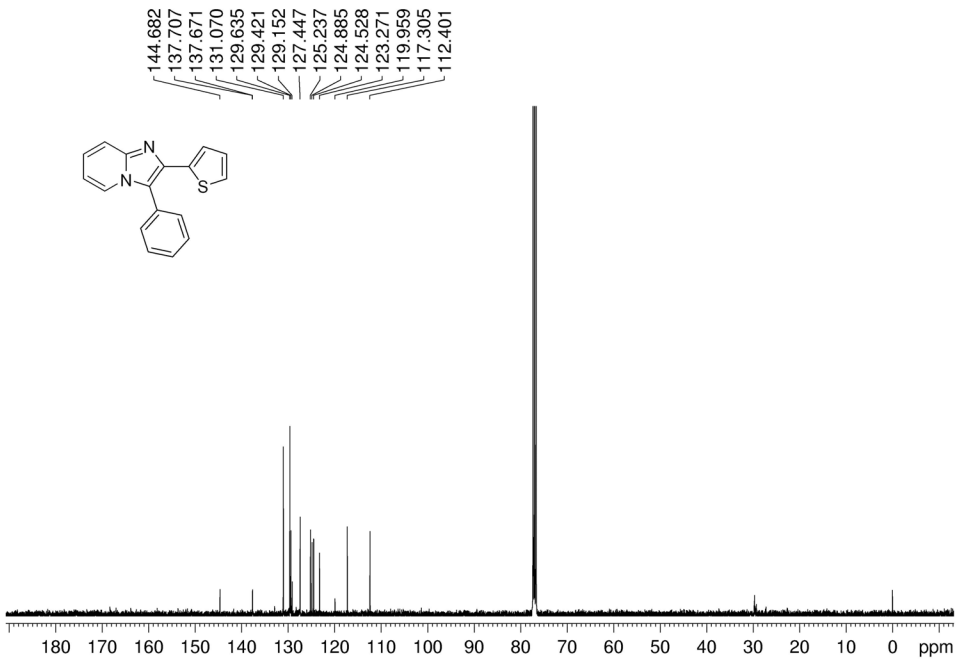
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 24



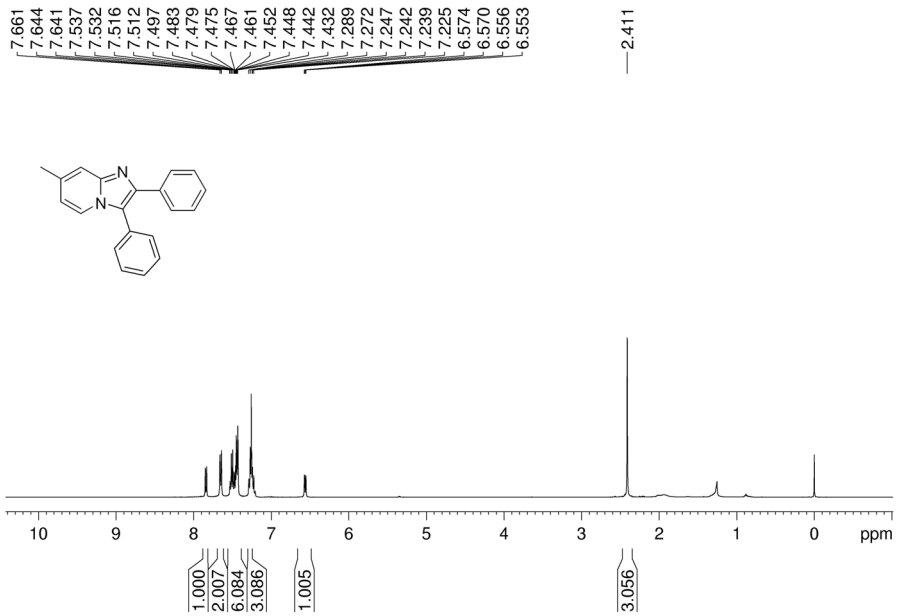
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 24



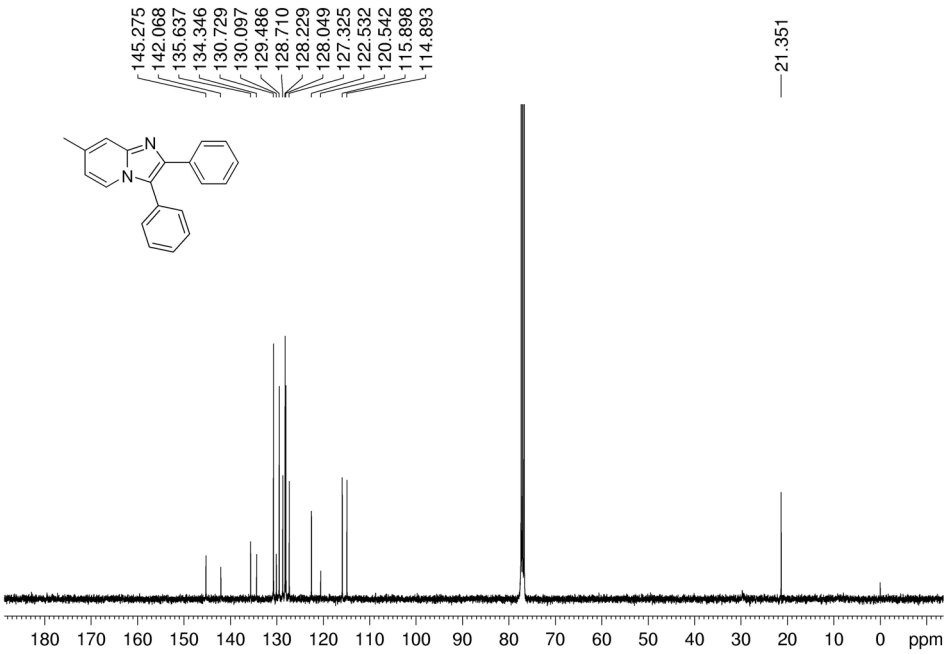
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 25



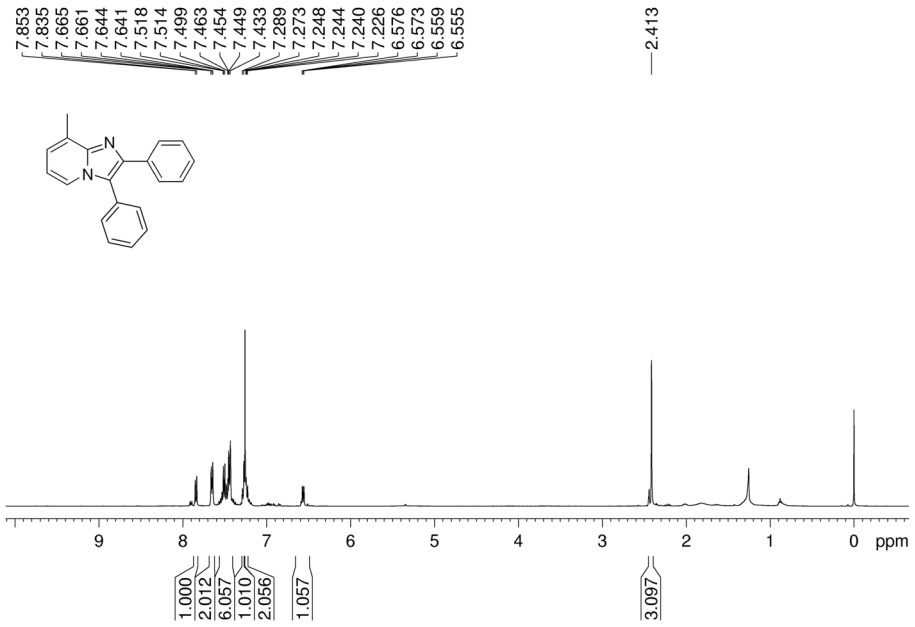
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 25



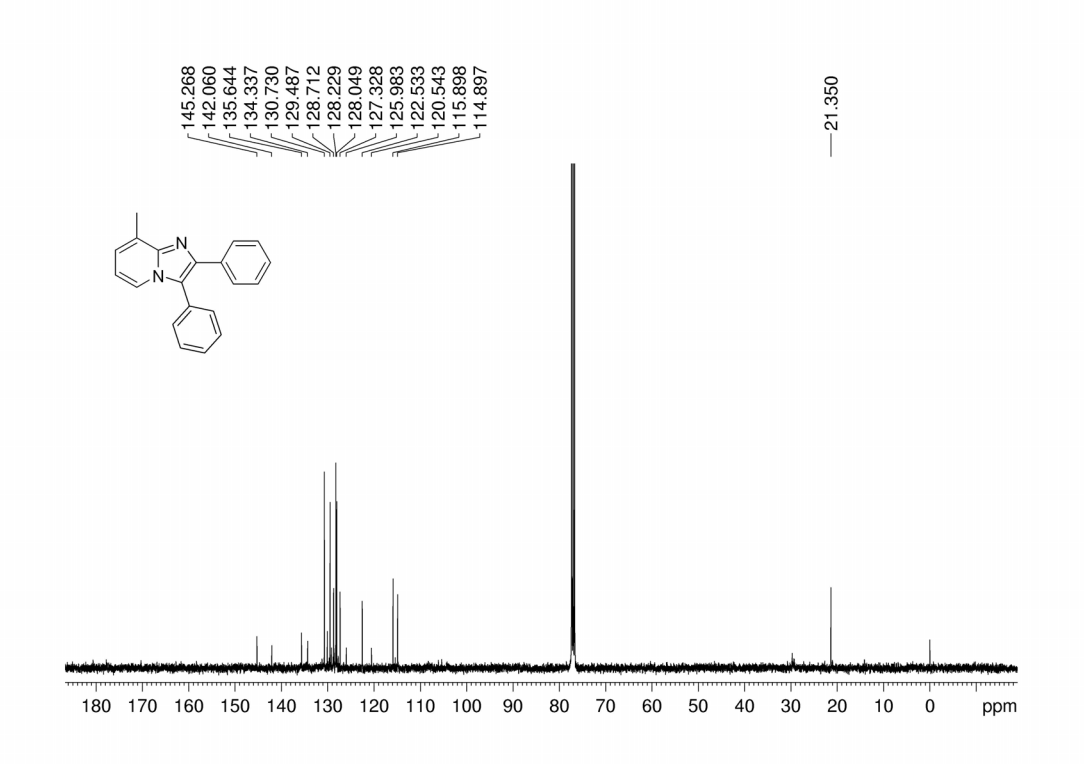
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 26



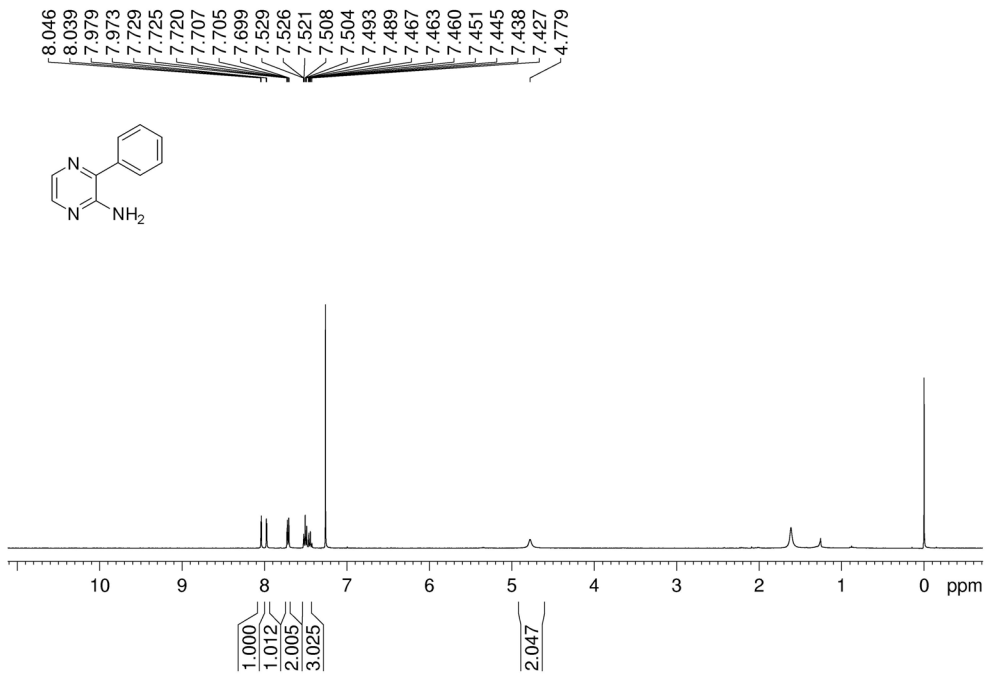
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 26



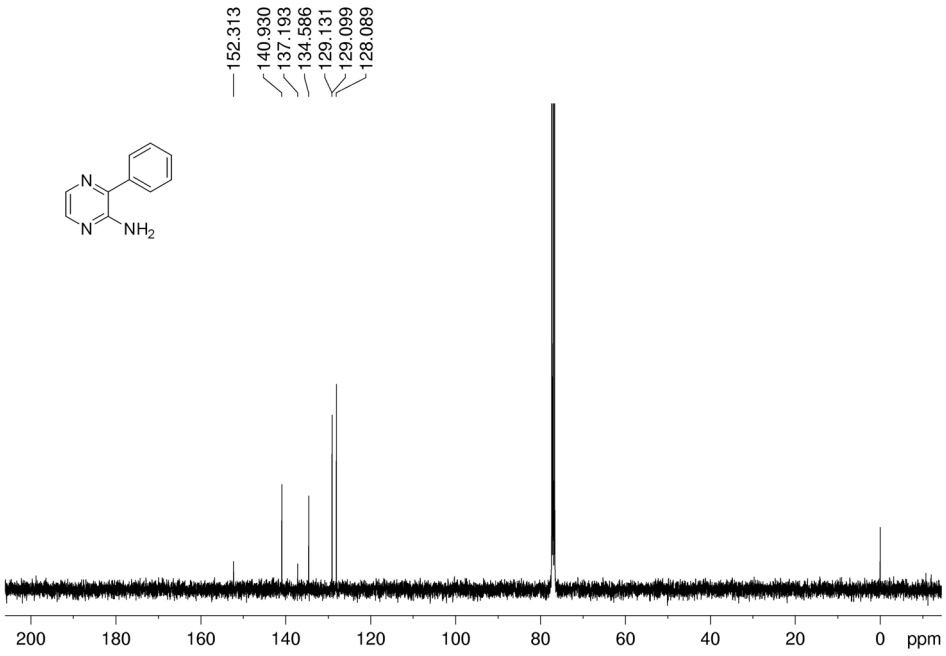
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 27



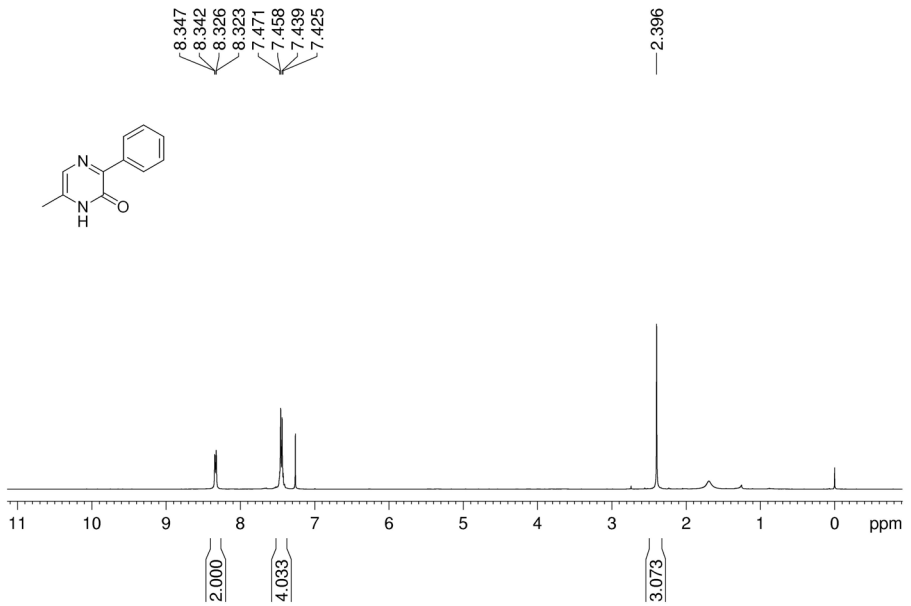
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 27



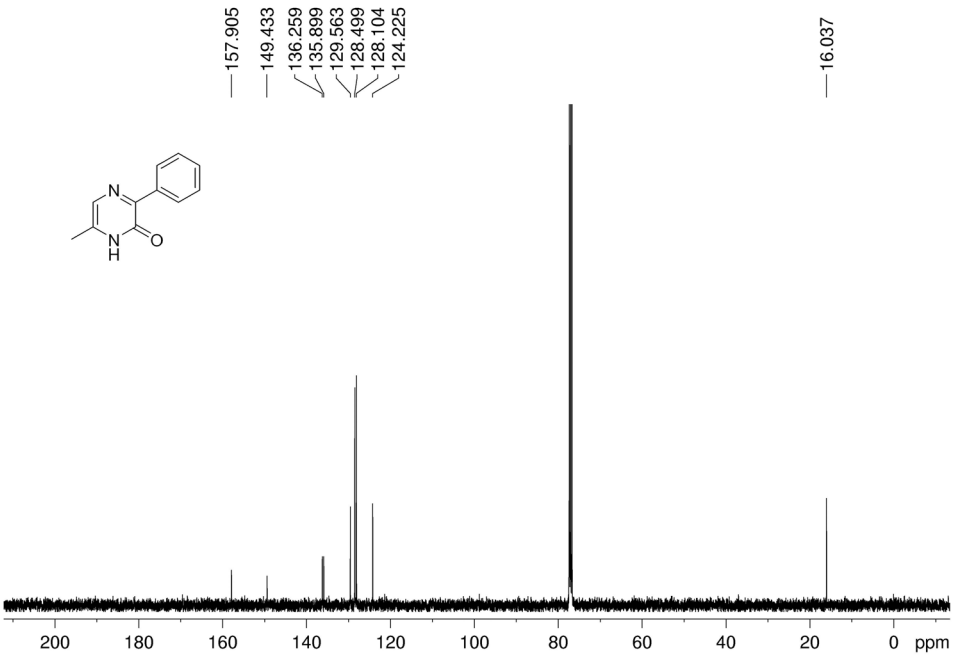
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 28



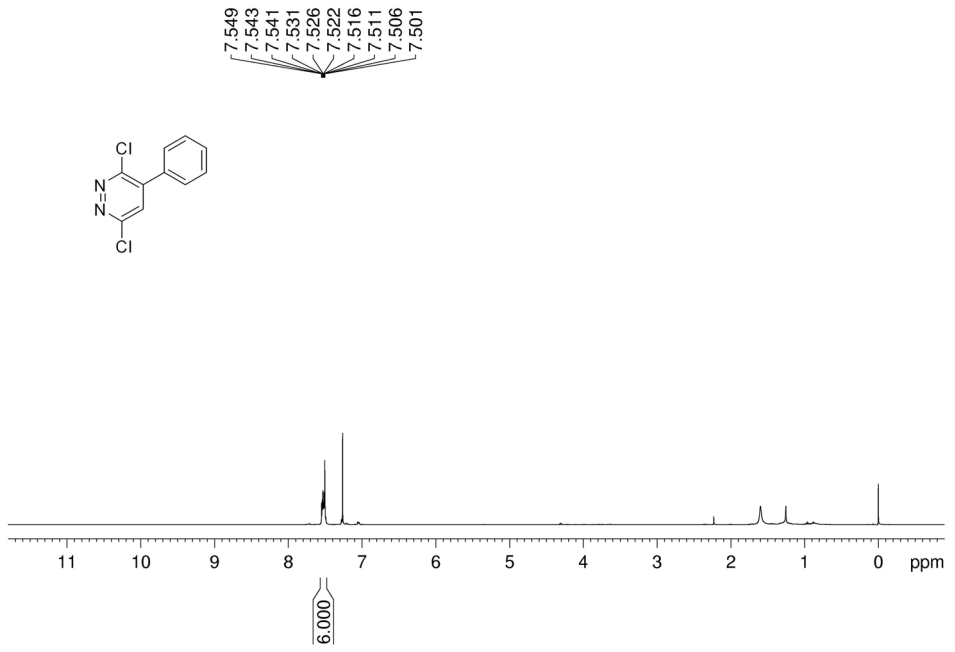
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 28



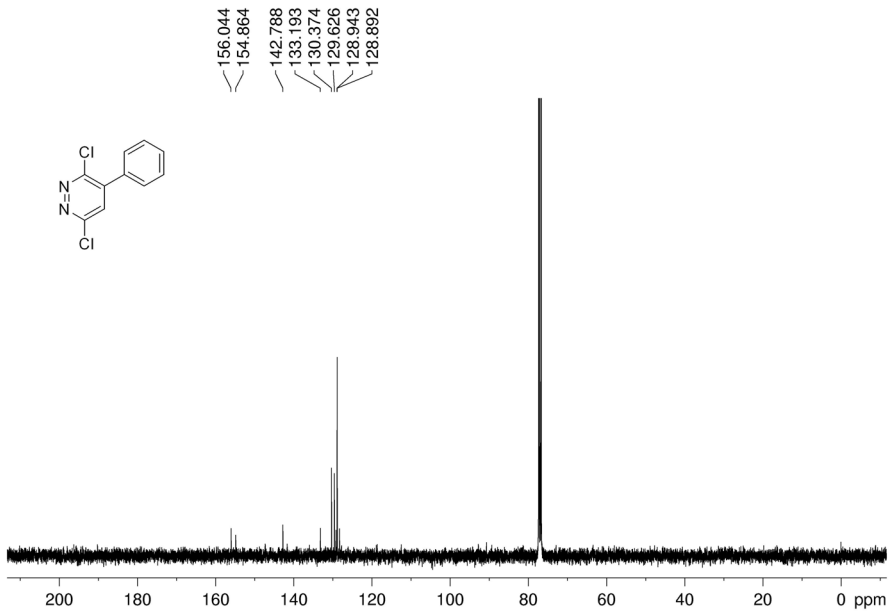
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 29



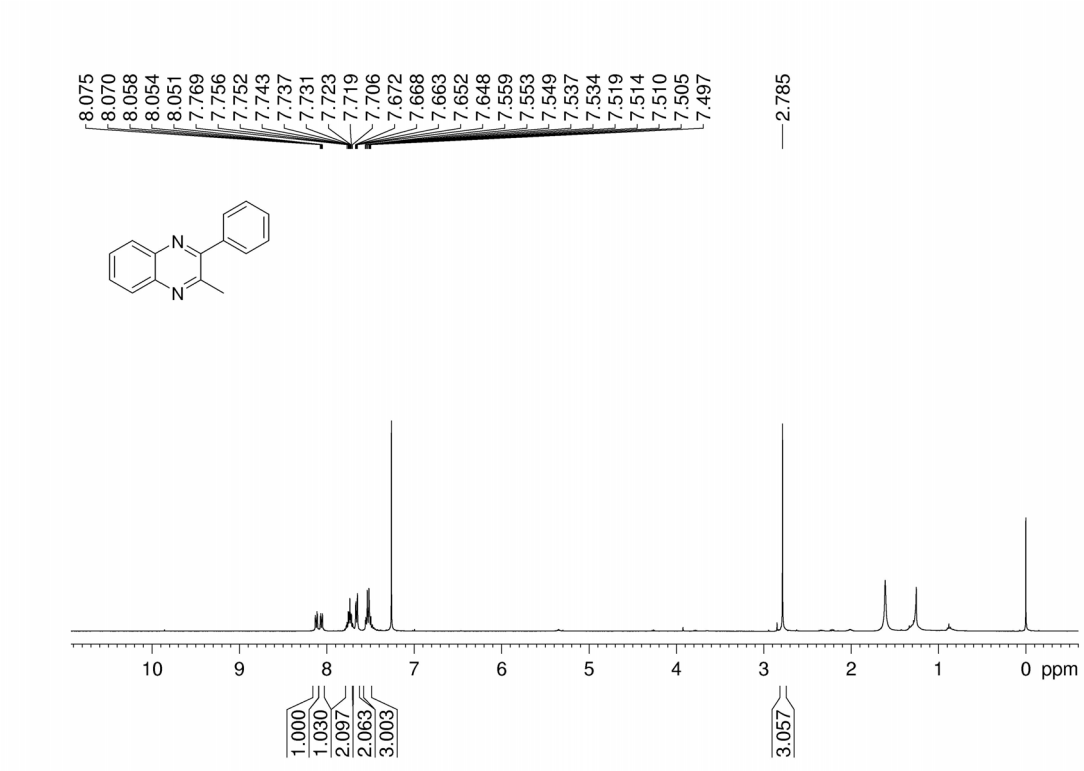
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 29



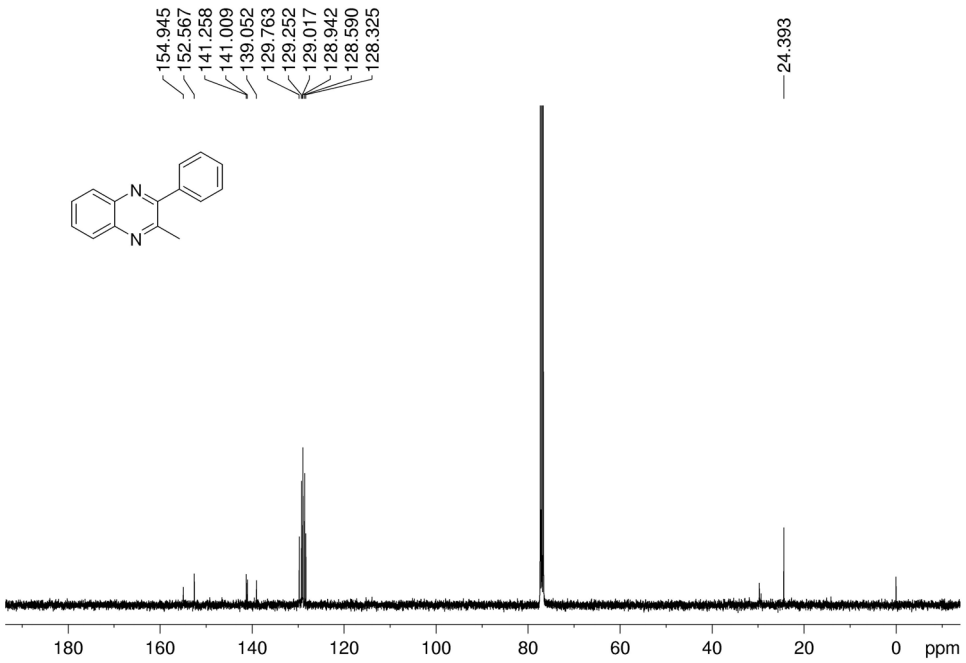
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 30



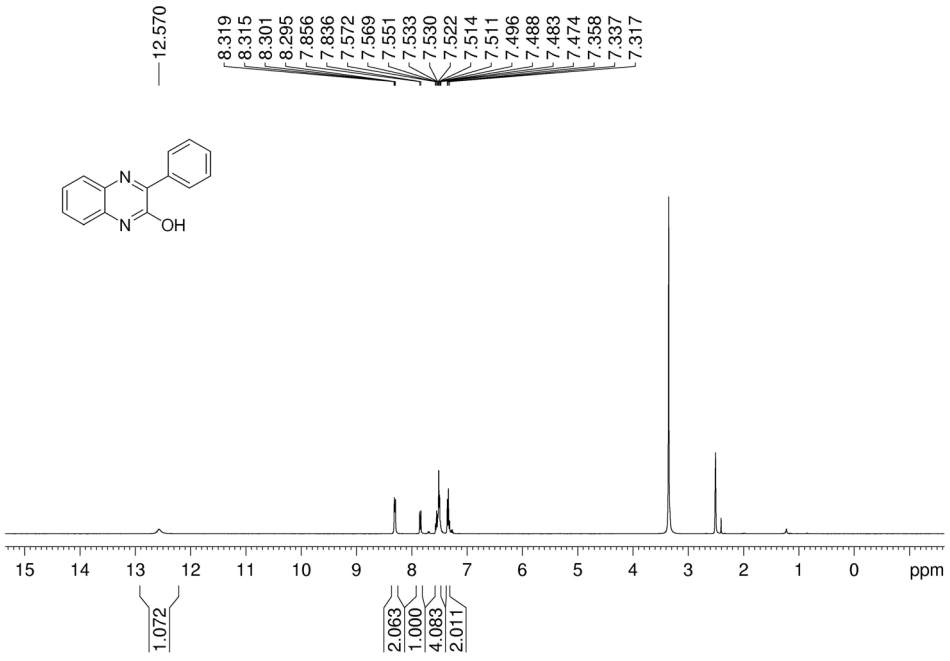
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 30



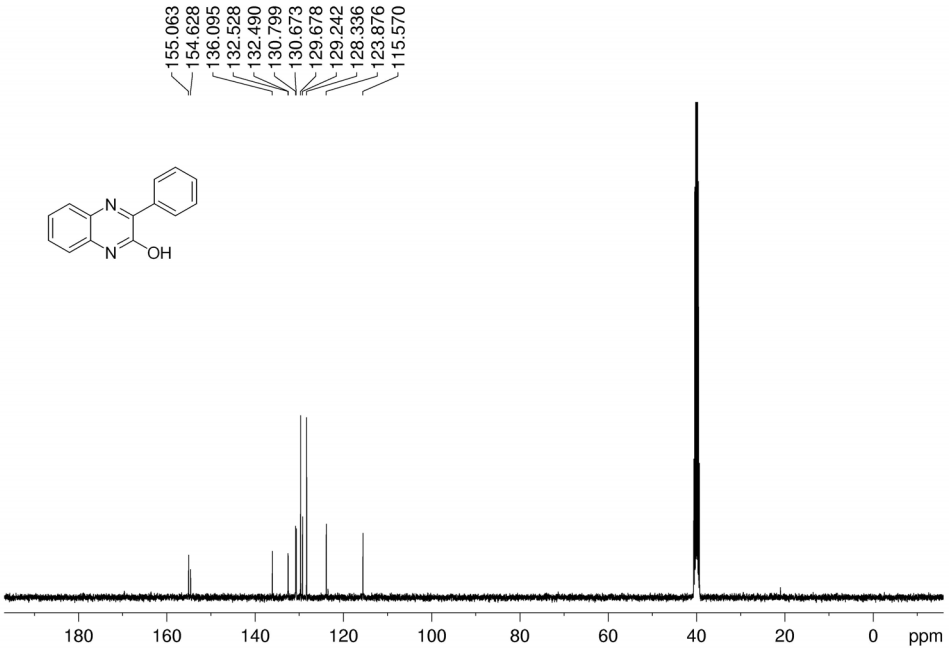
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 31



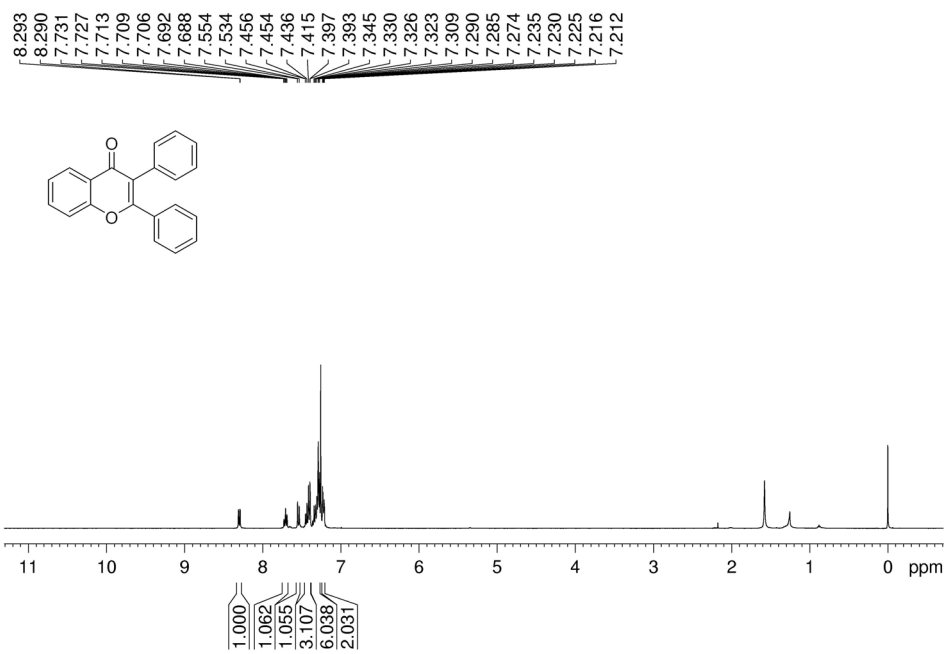
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 31



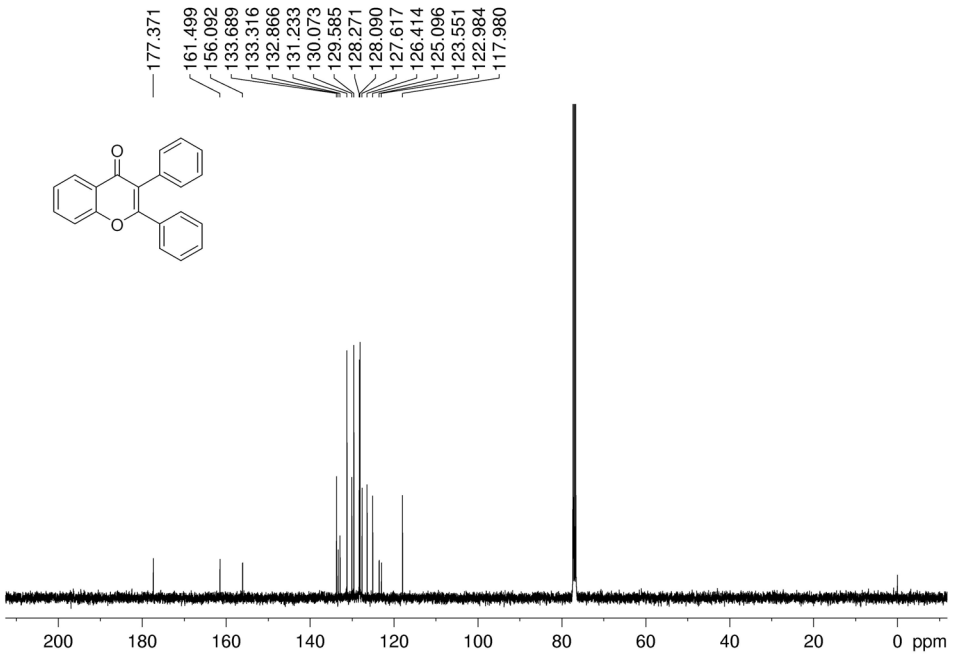
^{1}H NMR (400 MHz, DMSO) spectrum of compound 32



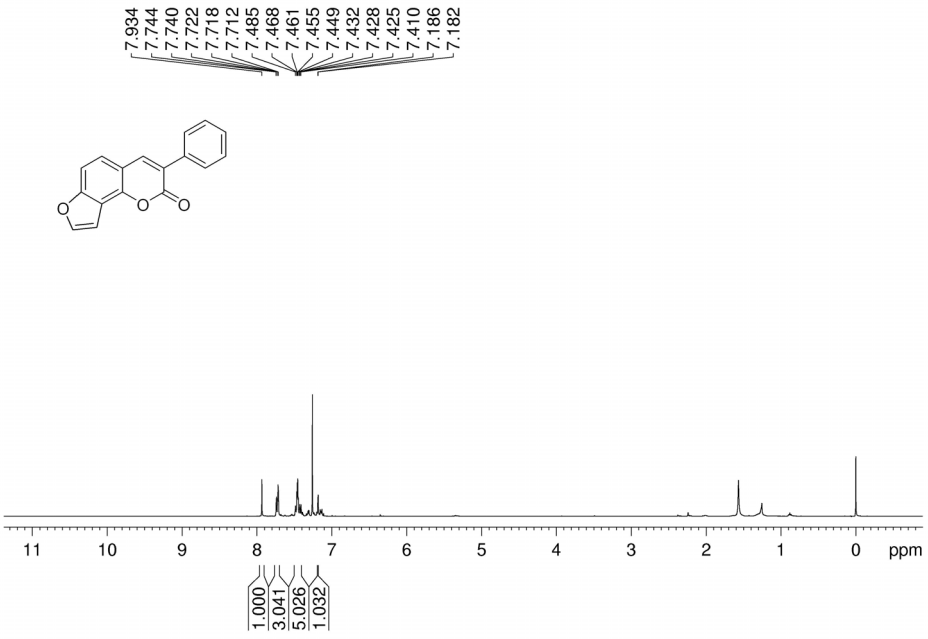
^{13}C NMR (100 MHz, DMSO) spectrum of compound 32



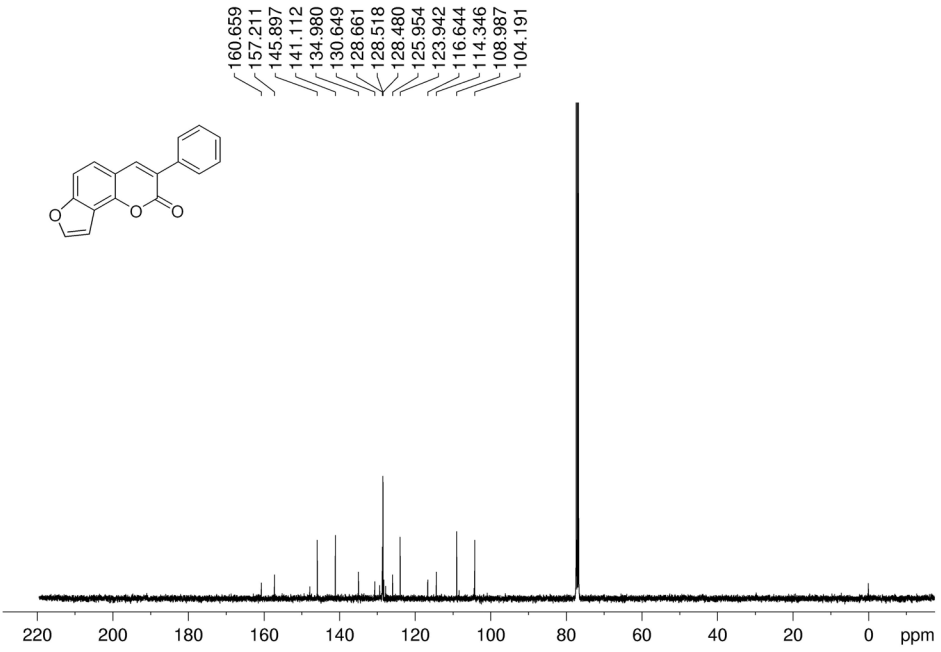
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 33



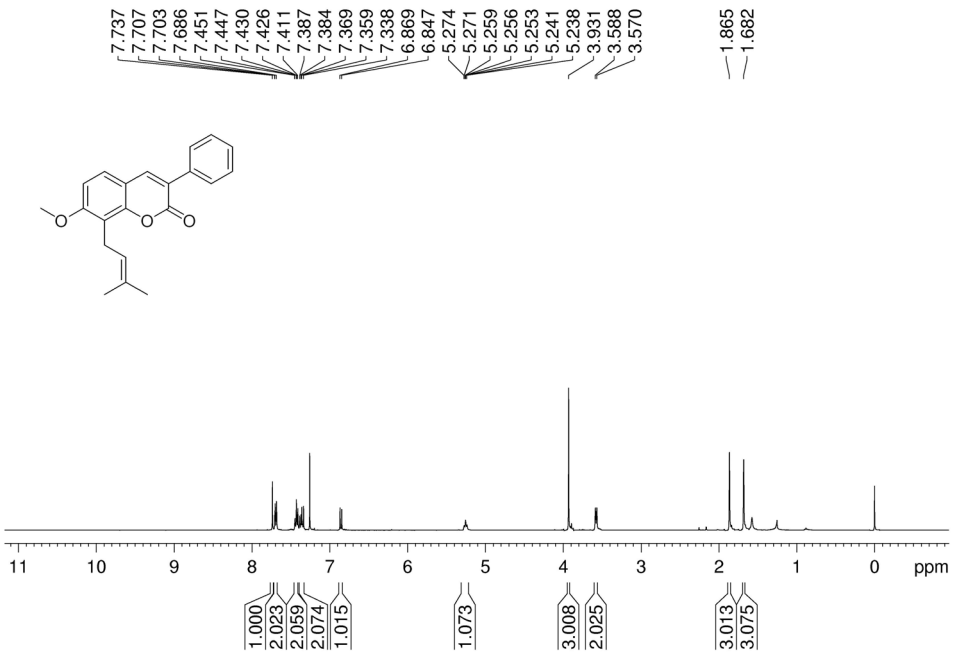
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 33



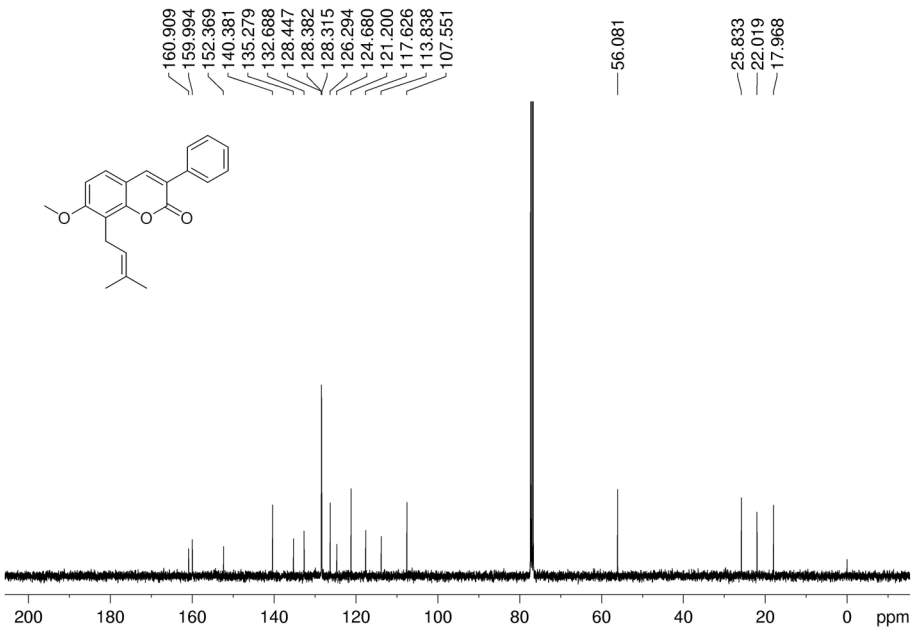
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 34



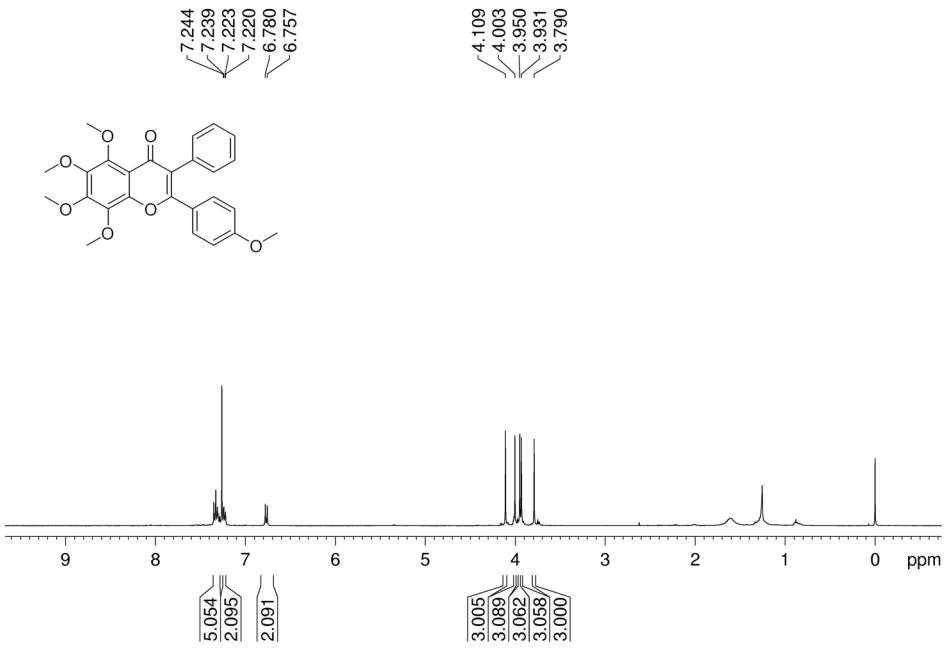
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 34



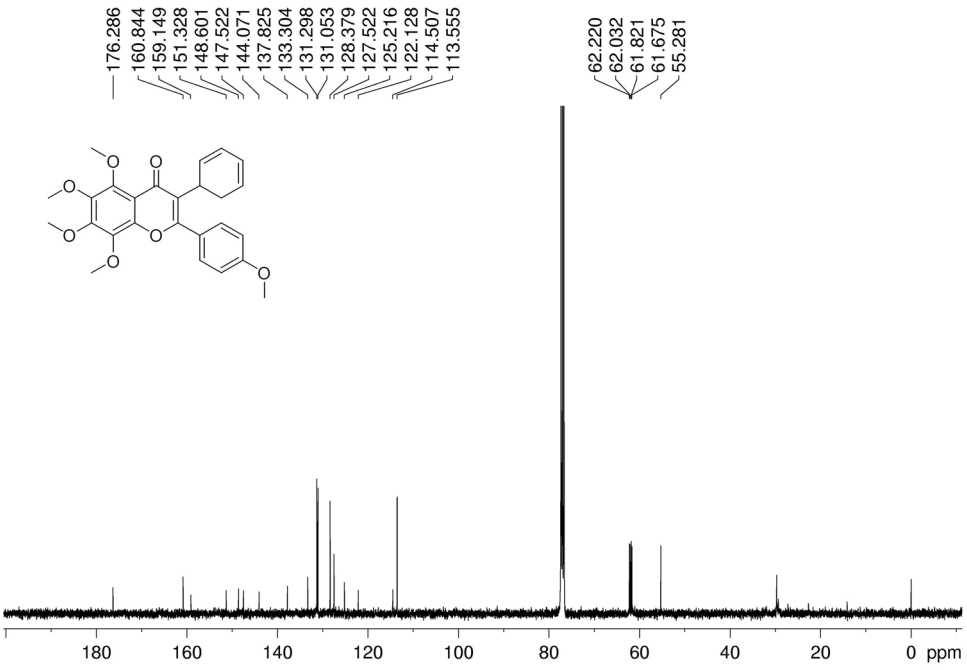
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 35



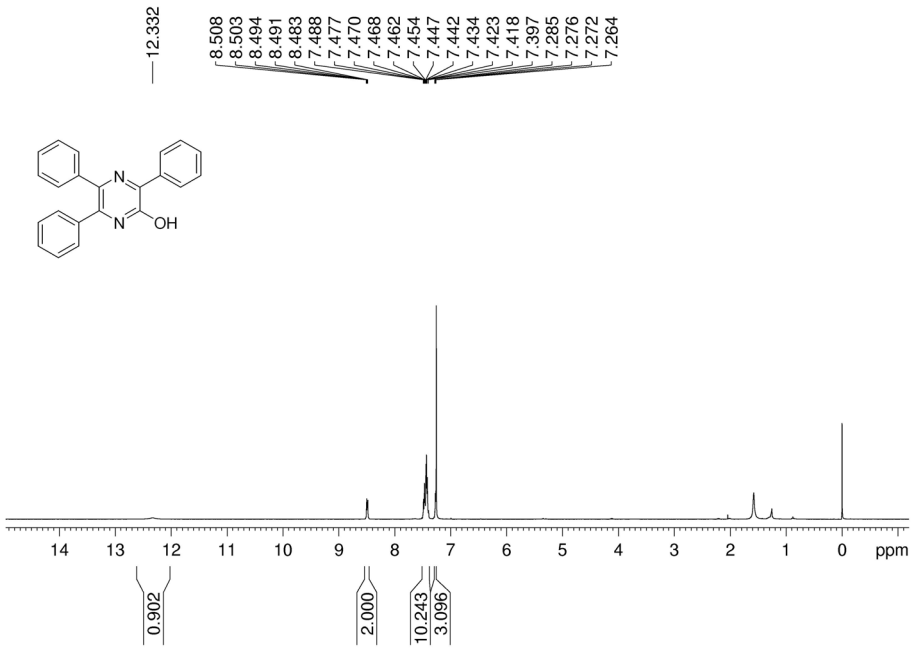
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 35



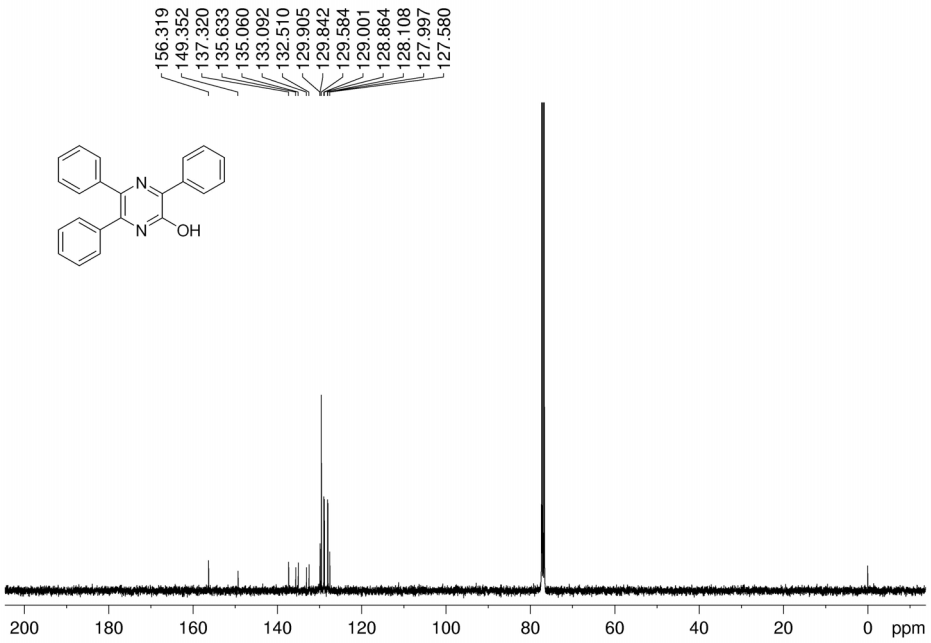
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 36



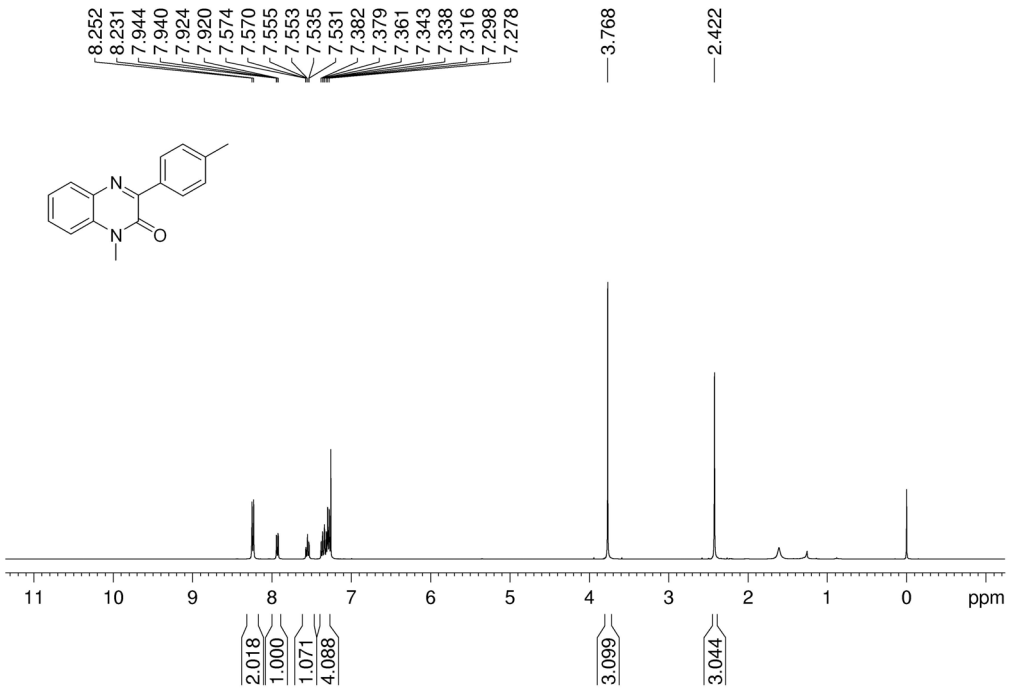
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 36



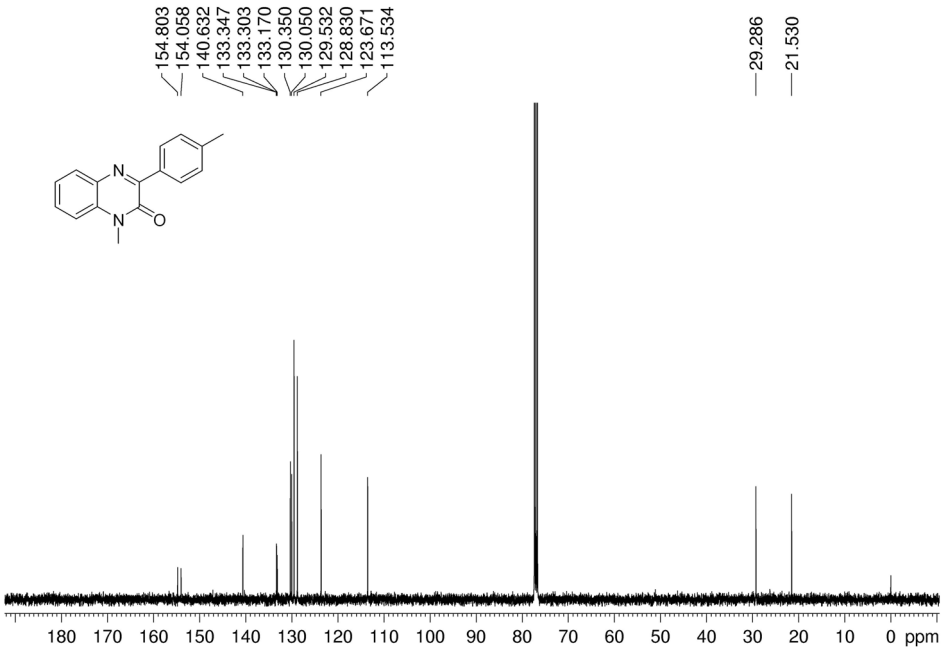
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 37



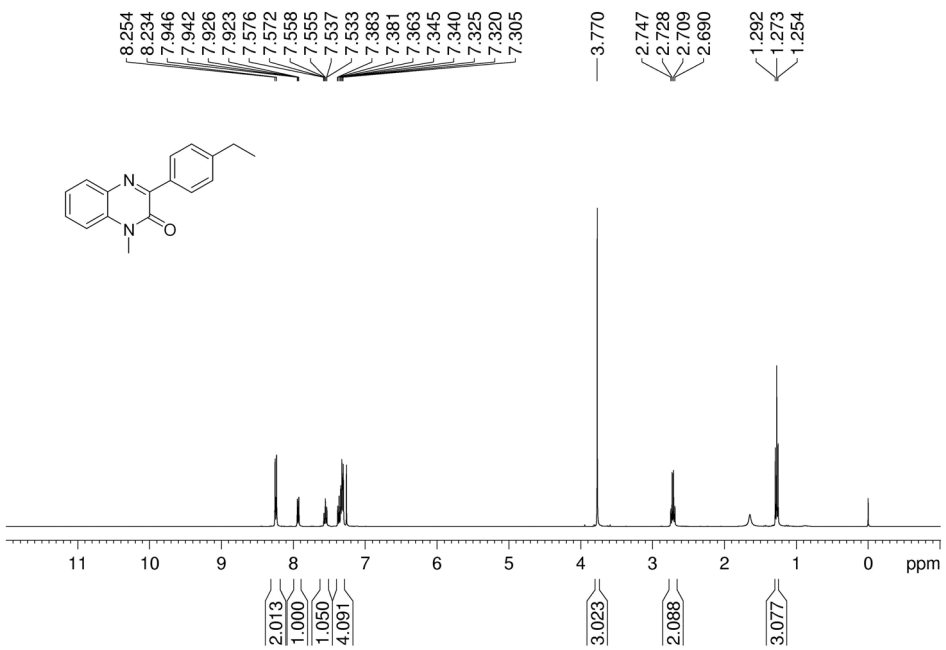
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 37



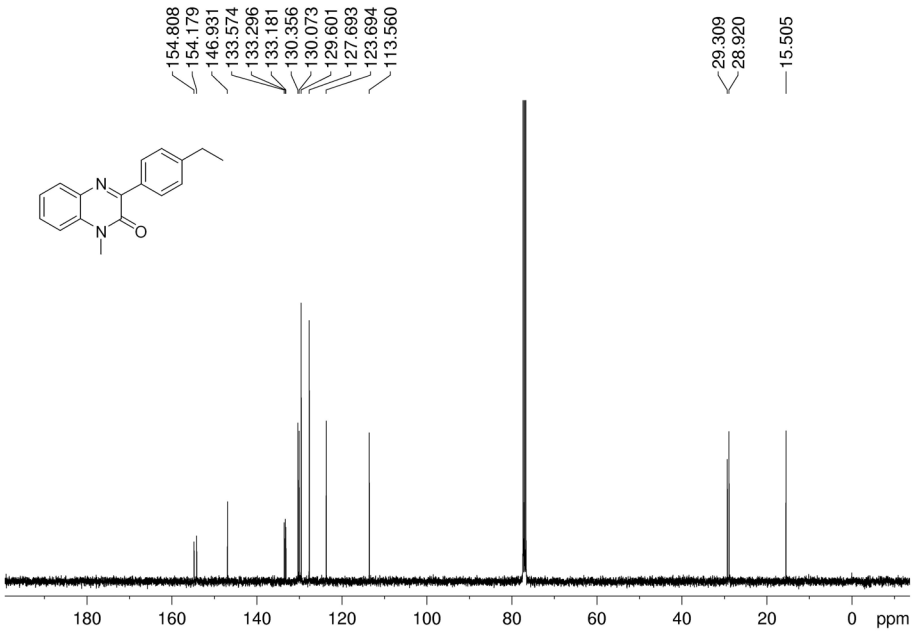
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 38



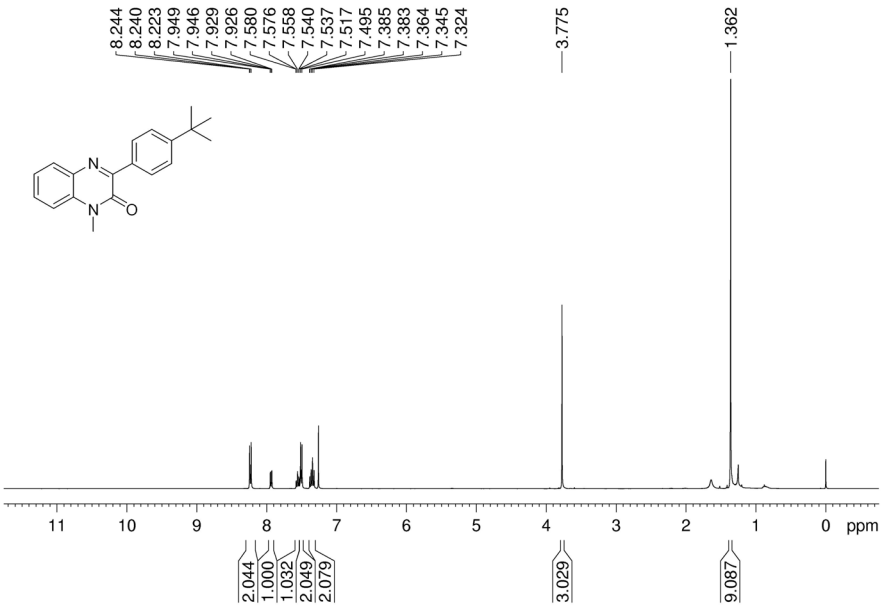
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 38



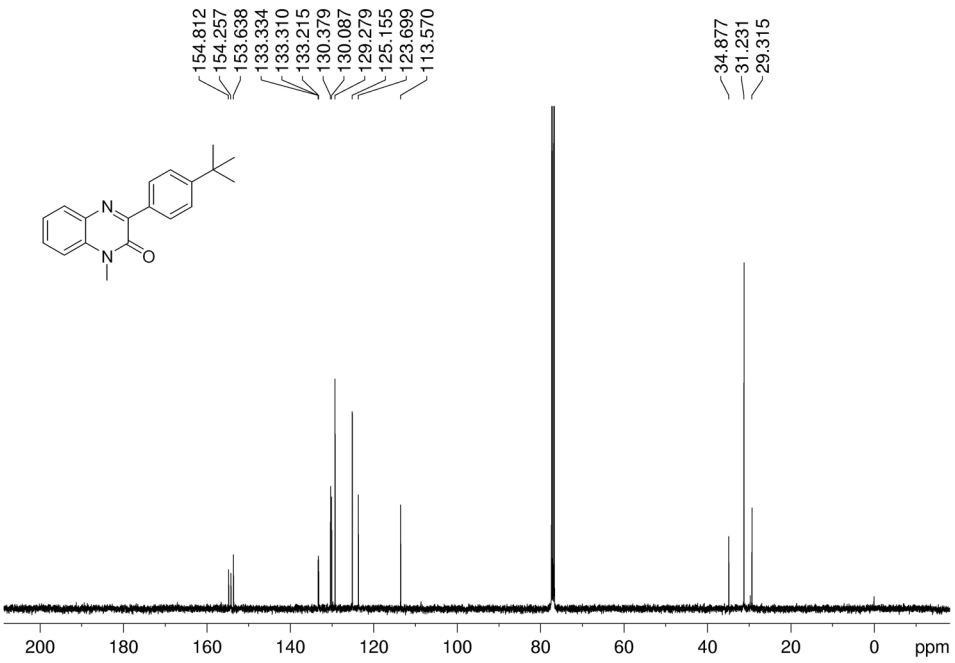
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 39



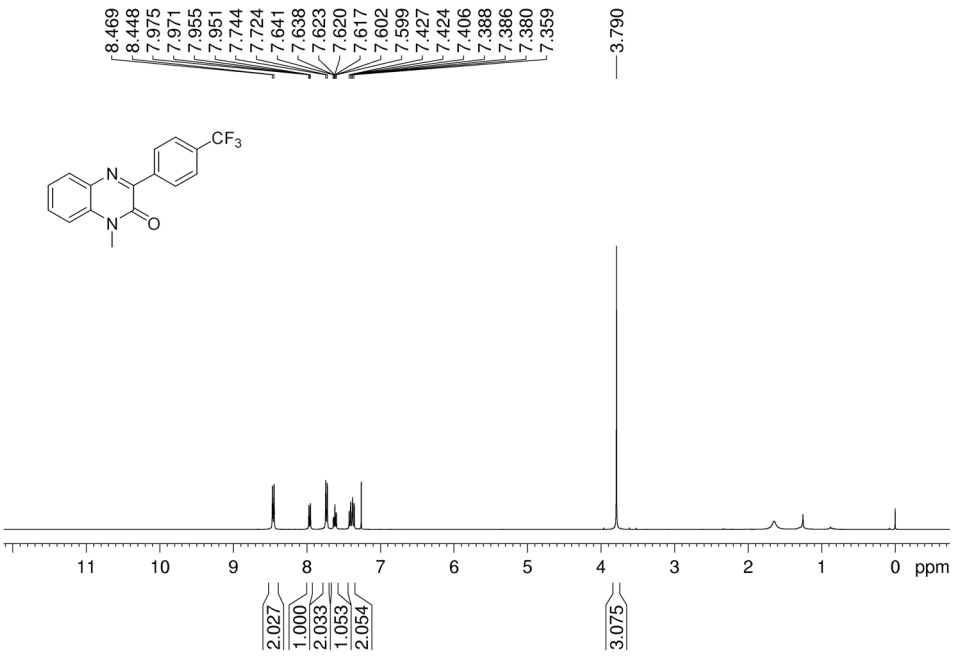
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 39



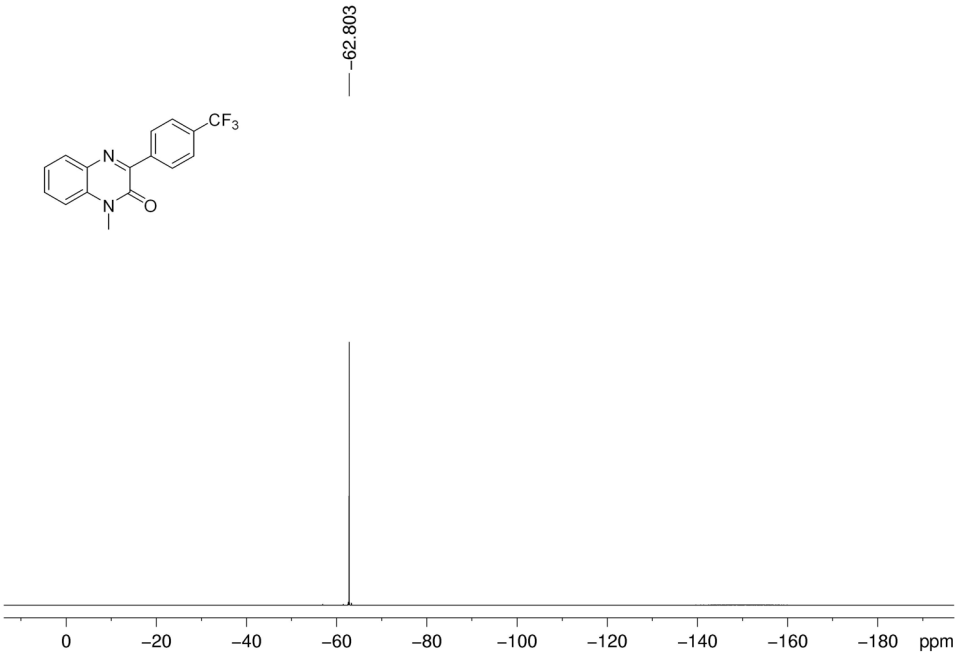
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 40



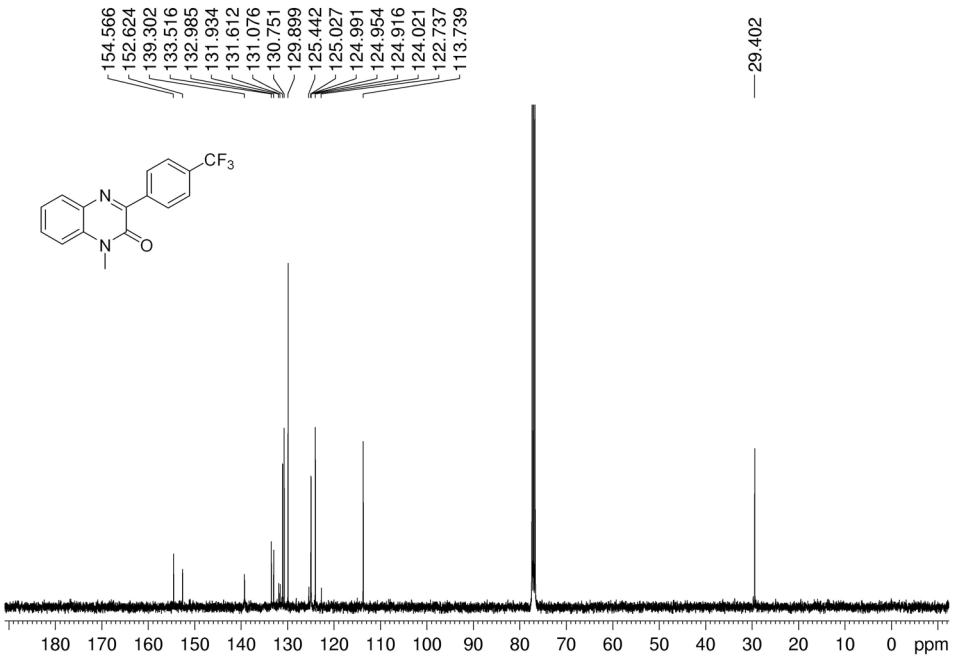
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 40



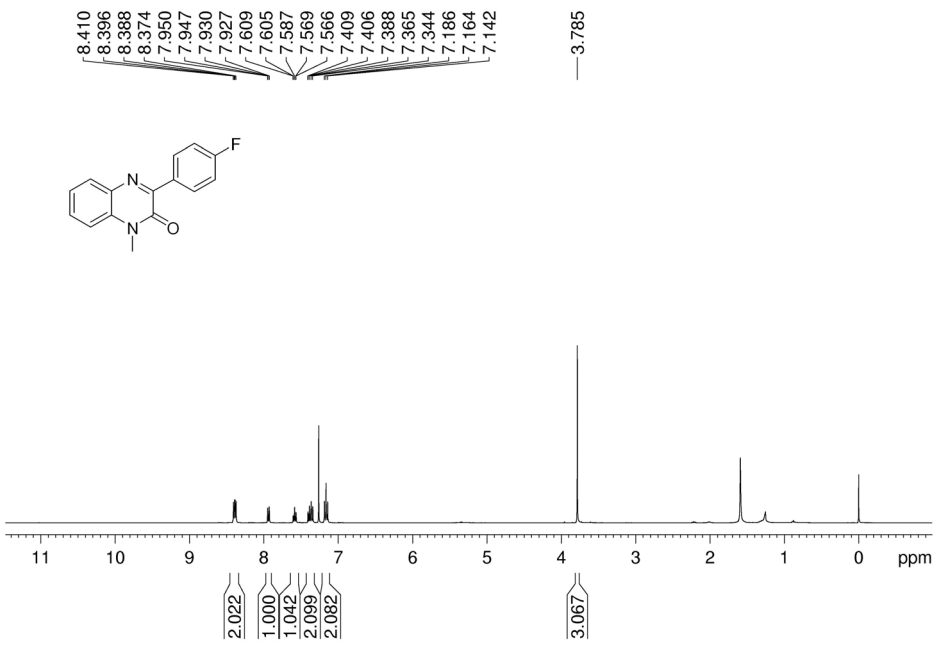
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 41



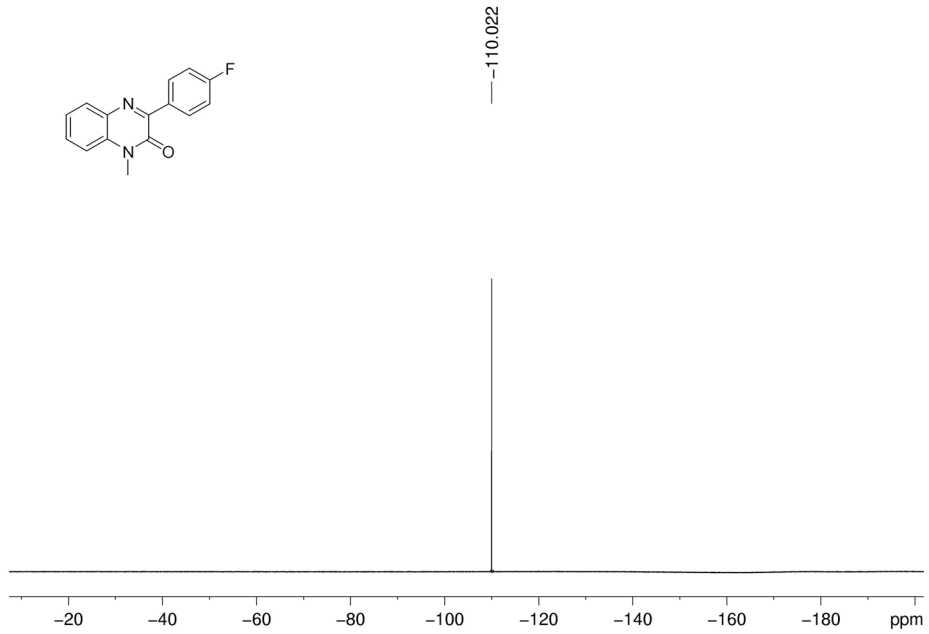
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound 41



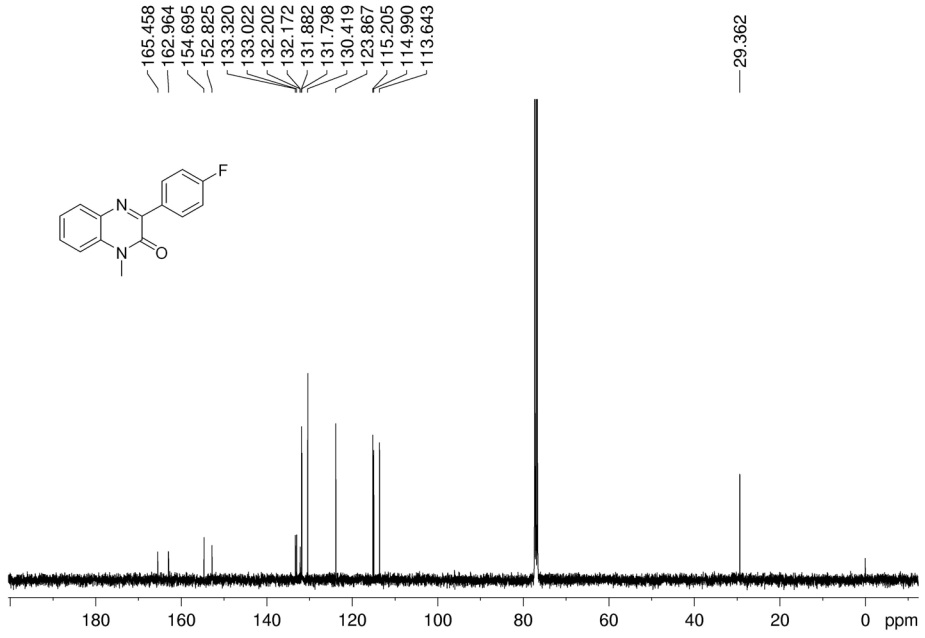
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 41



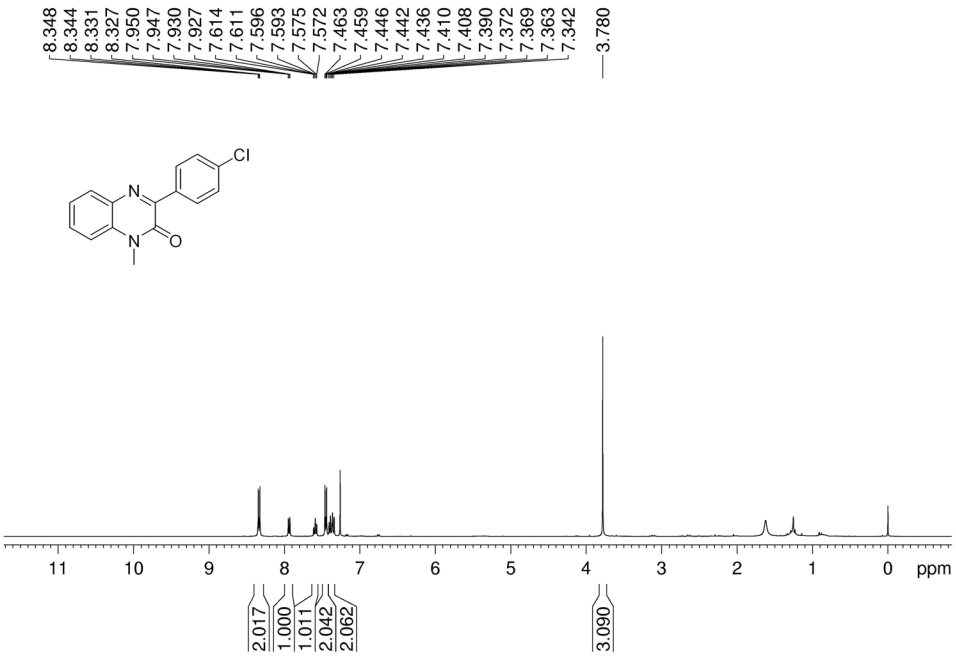
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 42



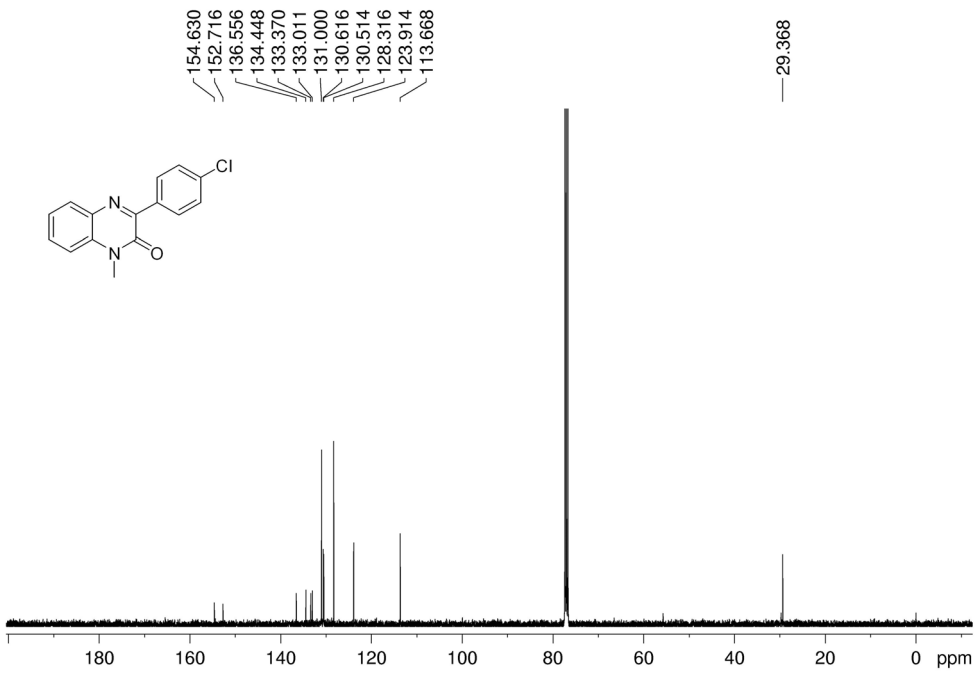
^{19}F NMR (376 MHz, $CDCl_3$) spectrum of compound 42



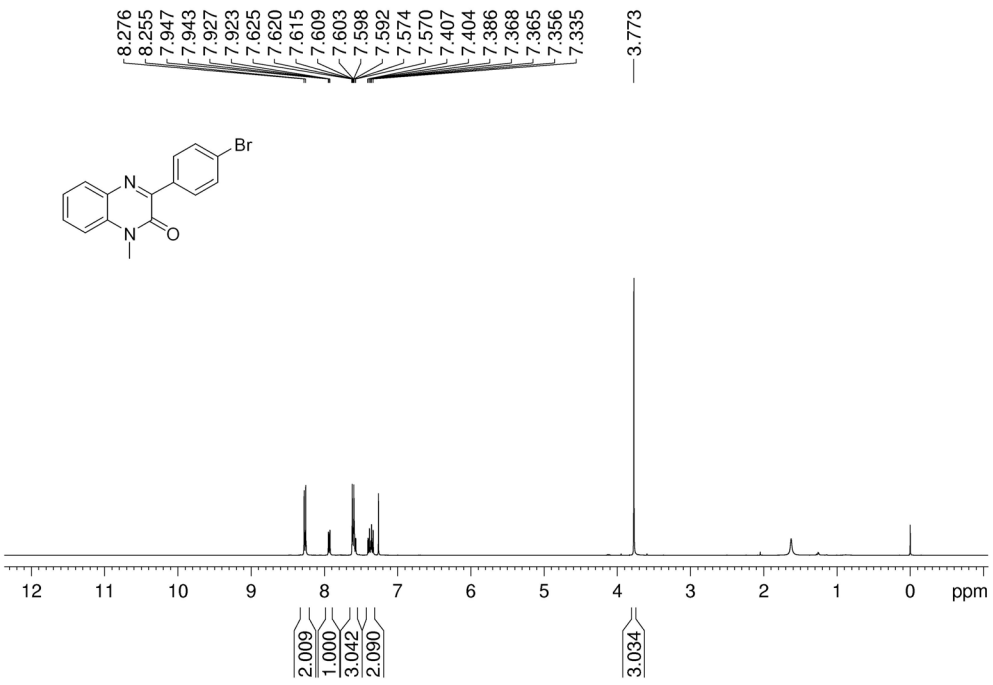
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 42



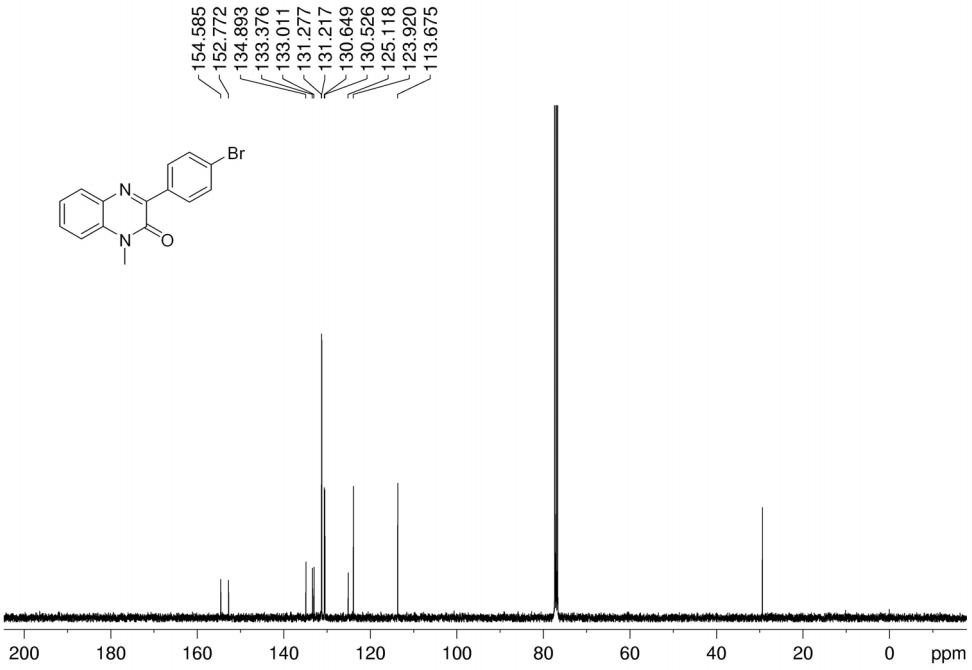
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 43



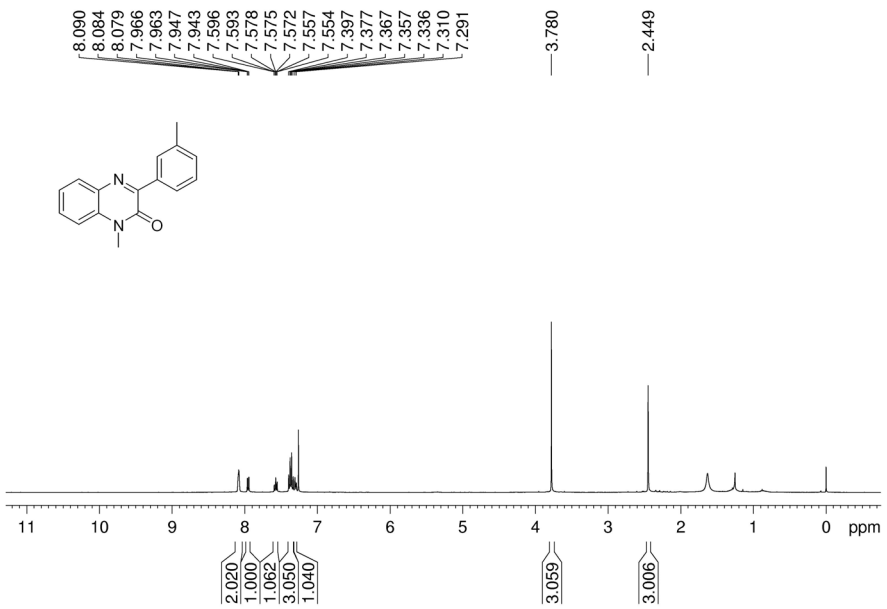
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 43



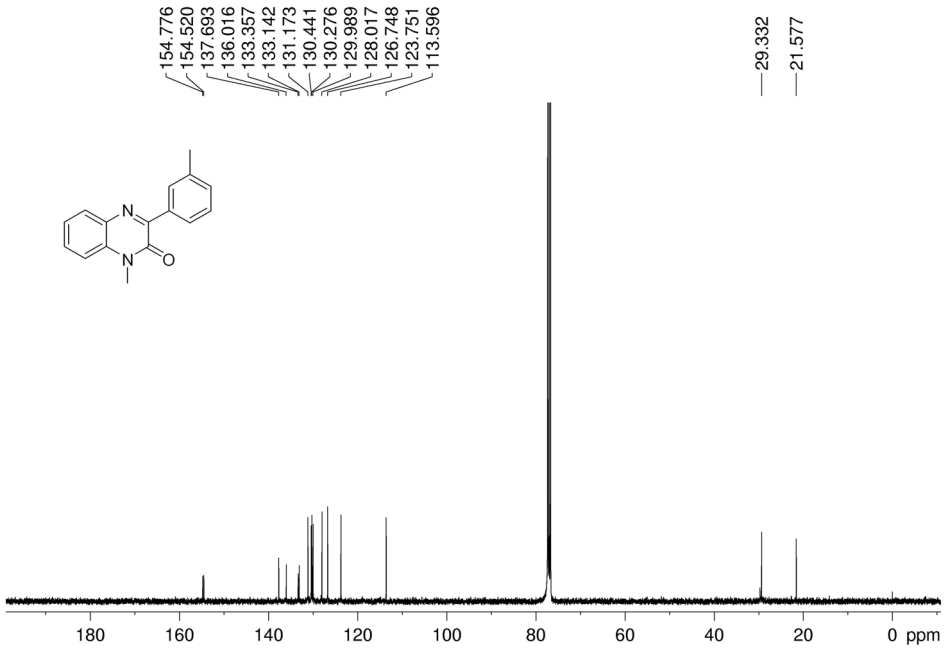
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 44



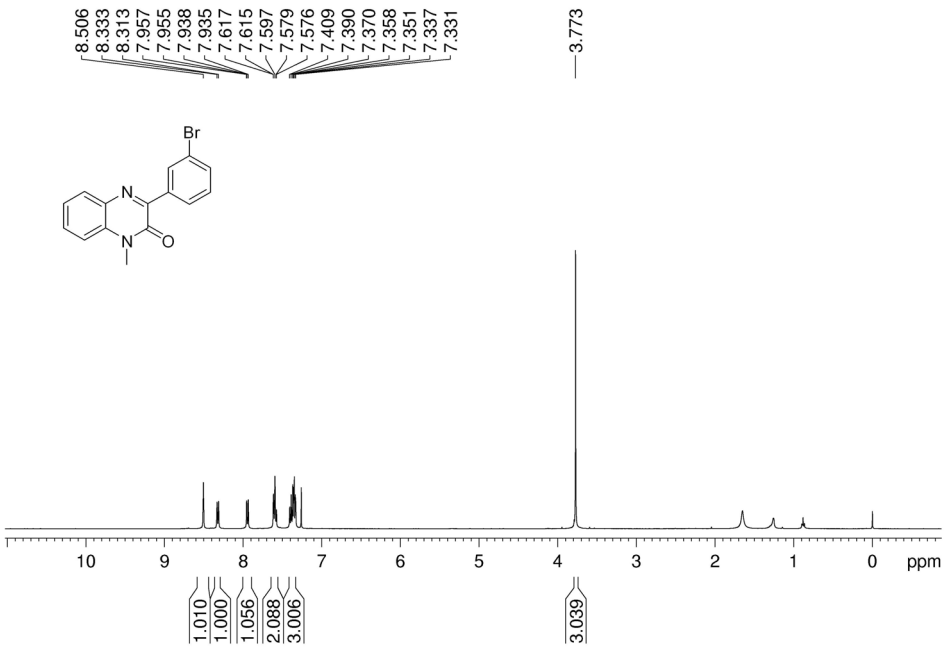
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 44



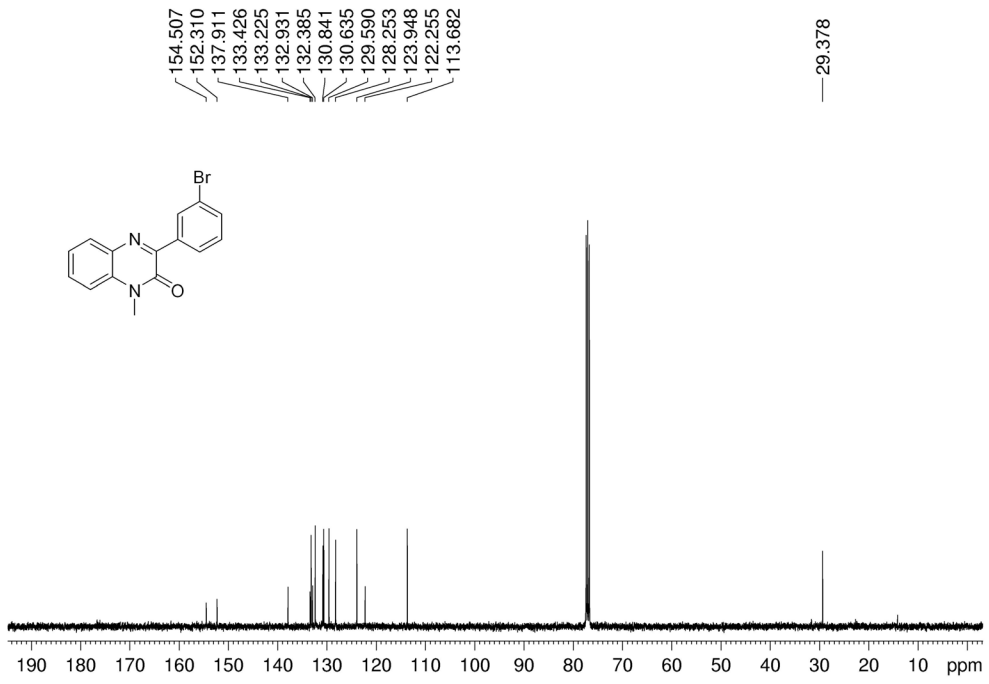
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 45



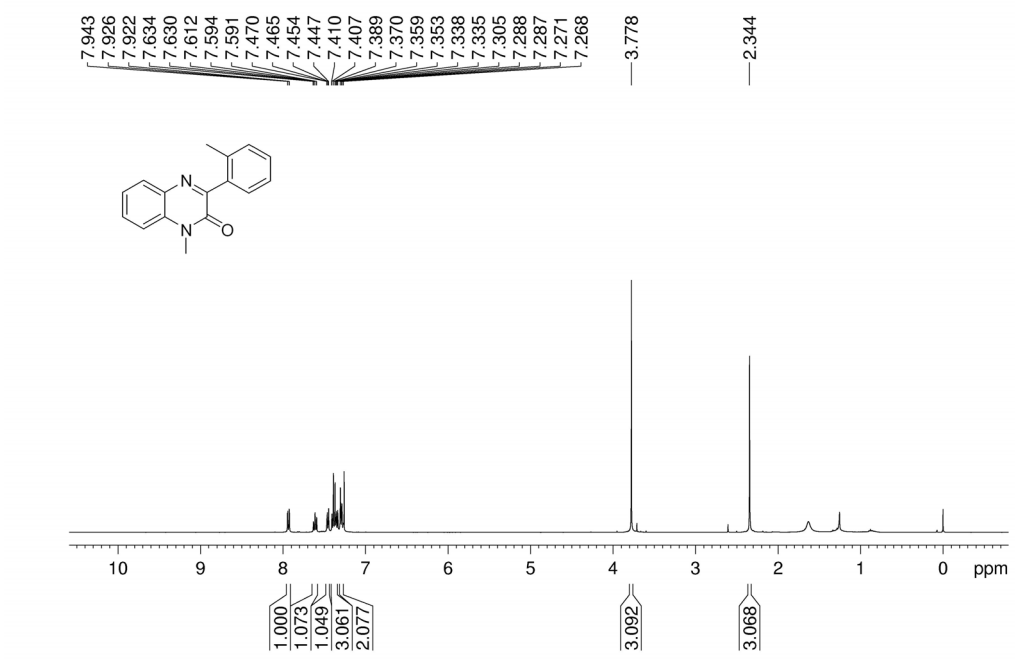
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 45



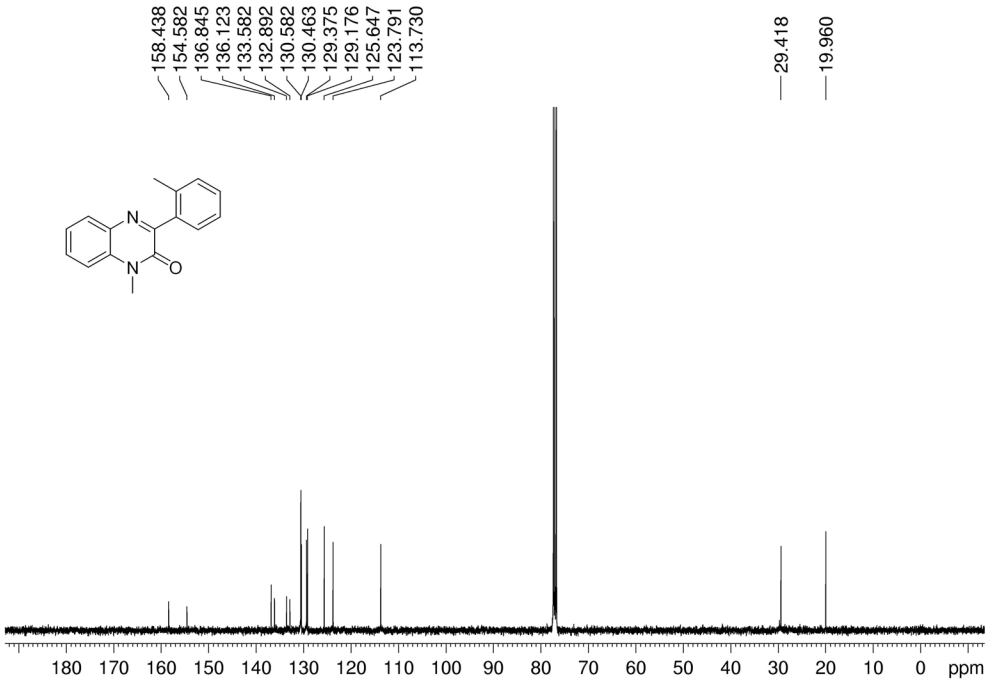
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 46



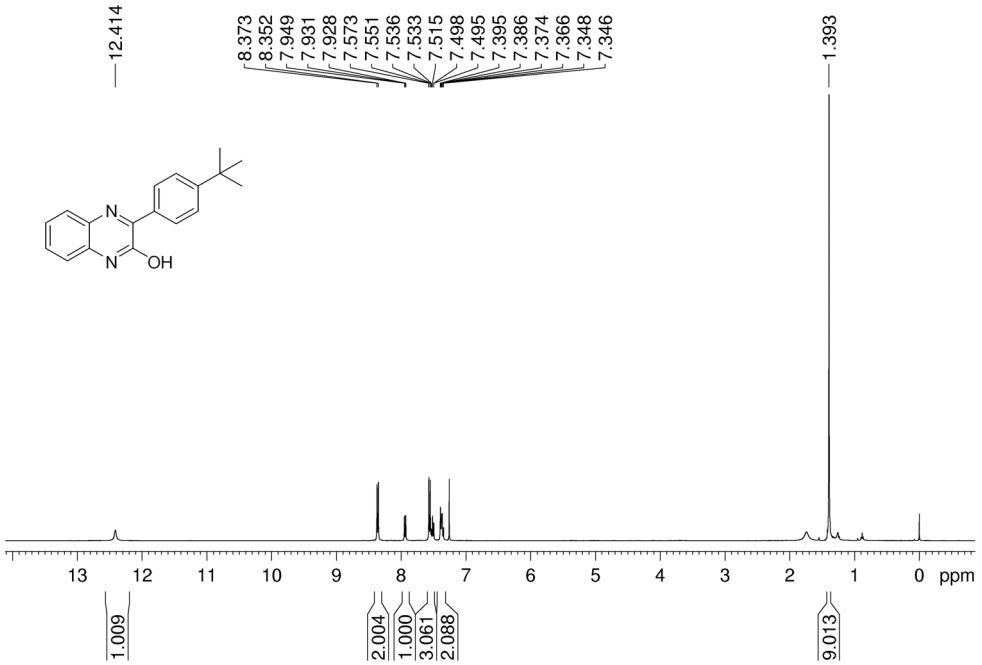
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 46



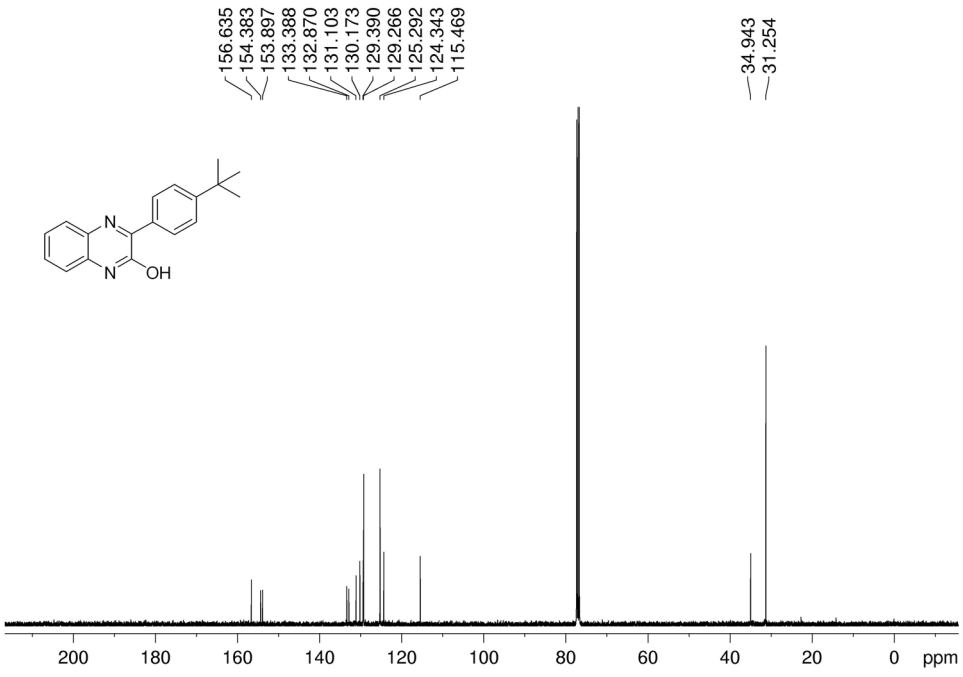
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 47



^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 47

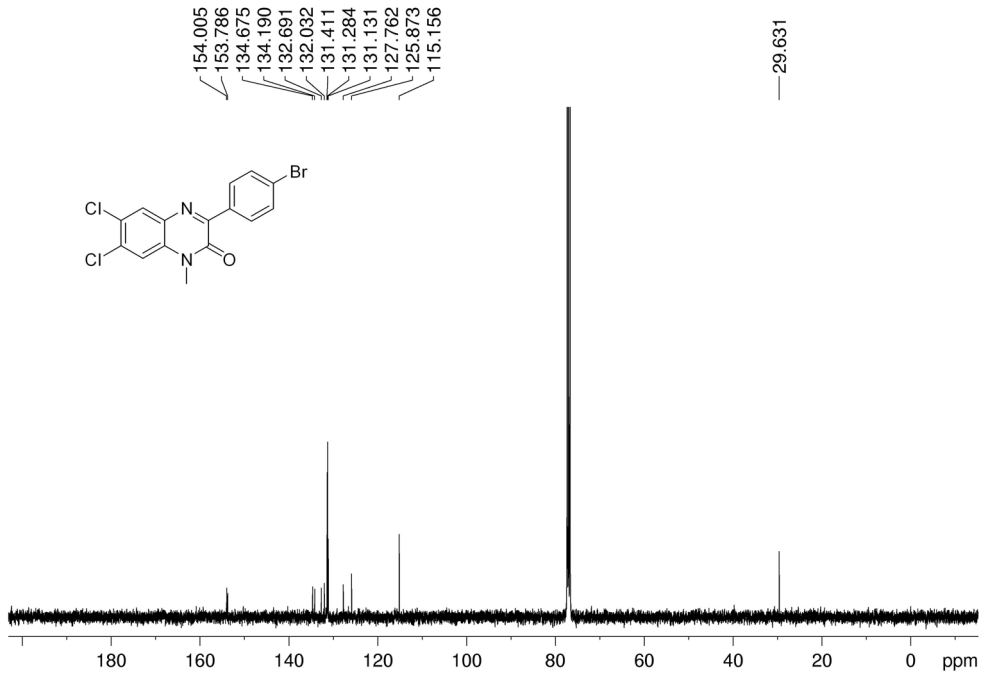


^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 48

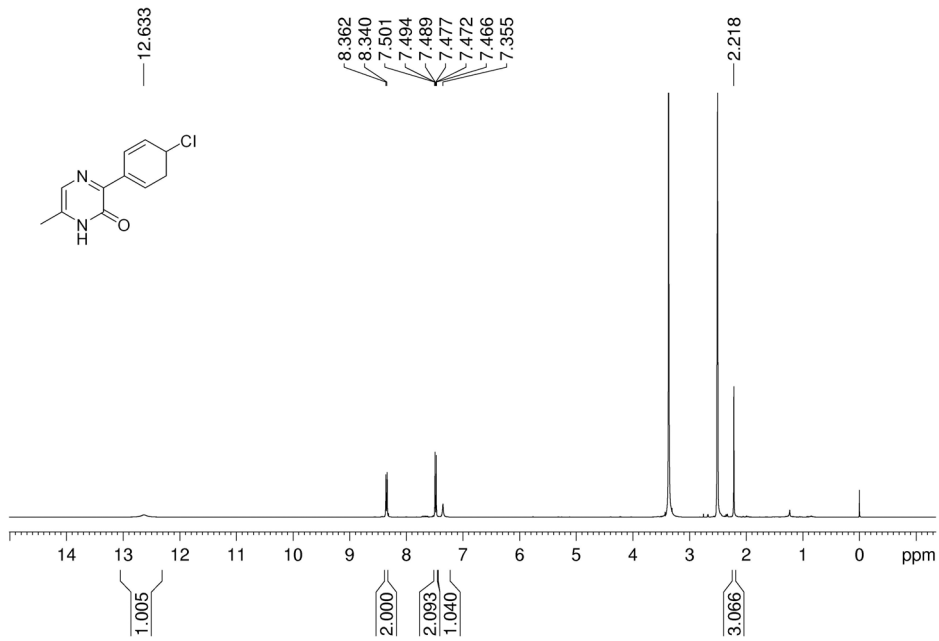


^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 48

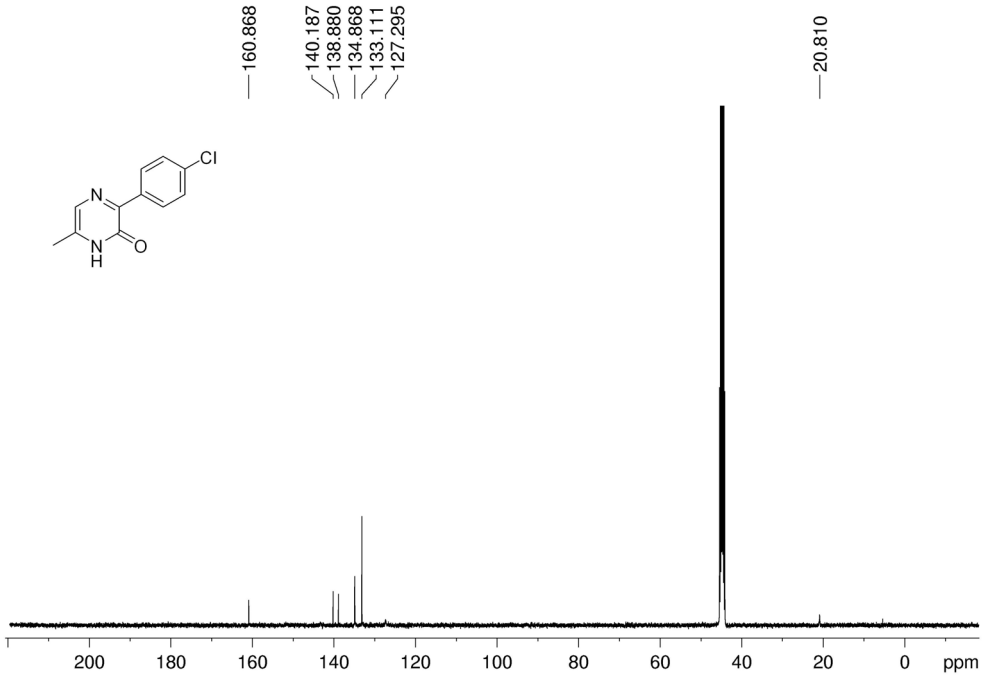
^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 49



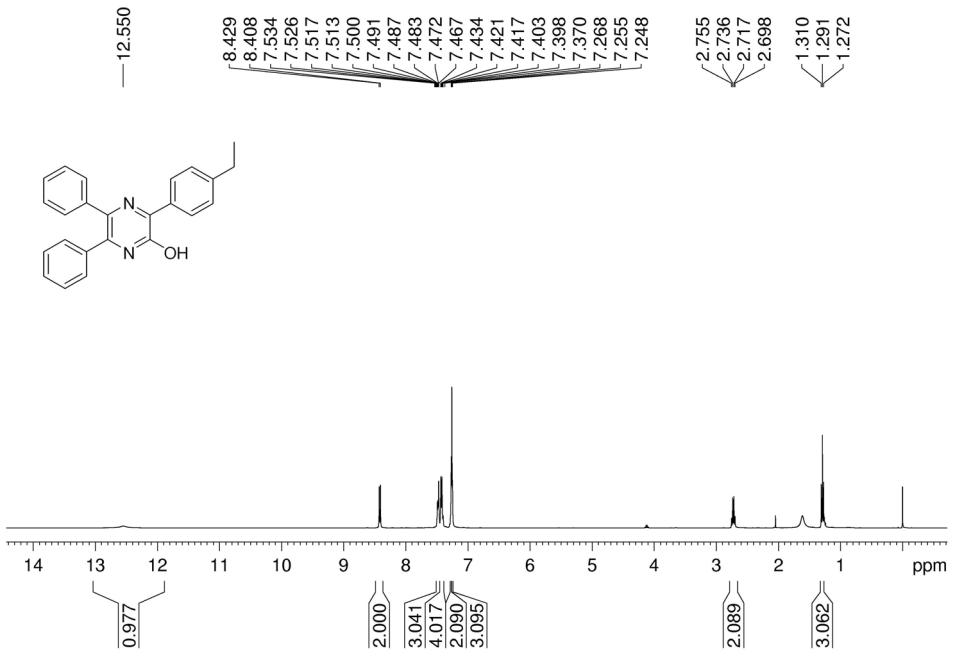
^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 49



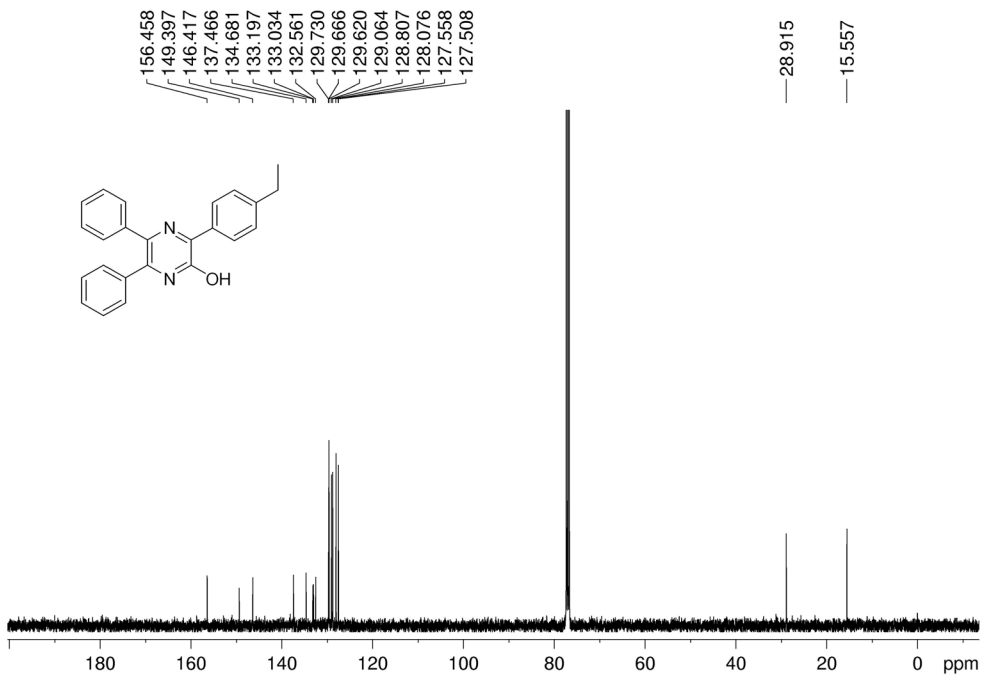
^{1}H NMR (400 MHz, DMSO) spectrum of compound 50



^{13}C NMR (100 MHz, DMSO) spectrum of compound 50



^{1}H NMR (400 MHz, $CDCl_3$) spectrum of compound 51



^{13}C NMR (100 MHz, $CDCl_3$) spectrum of compound 51