Electrochemically Driven Tandem Addition–Cyclization: Synthesis of Thiadiazinanes and Thiophosphonates

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Total number of Figures: 11 (Figures S1-S11)

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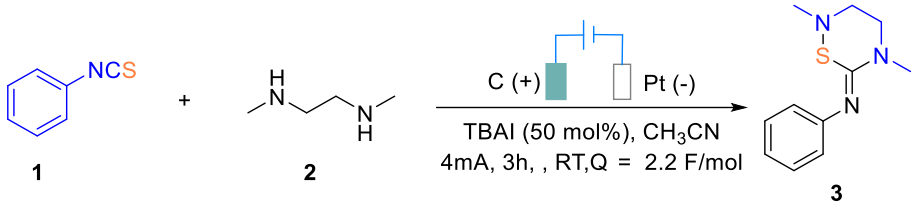
1. General Information

Unless otherwise noted, all reactions were carried out under an atmosphere of air in oven-dried glassware with magnetic stirring, all reagents obtained from commercial suppliers were used without further purification. Reactions were monitored by thin-layer chromatography (TLC) on silica gel precoated glass plates (0.2 ± 0.03 mm thickness, GF-254, particle size 0.01–0.04 mm) from Yantai Chemical Industry Research Institute. TLC were visualized by UV fluorescence (254 nm). Flash column chromatography was performed with silica gel (particle size 0.04–0.05 mm). ^{1}H NMR ^{13}C NMR and ^{19}F NMR spectroscopic data were recorded using Bruker AMX-400 instrument and calibrated by using the residual solvent peaks as an internal reference *($CDCl_3$ [^{1}H: 7.26, ^{13}C: 77.16])*. Coupling constants (*J*) are given in Hz. High-resolution mass spectra (HRMS) for all the compounds were determined on a Micromass GCT-TOF mass spectrometer with ESI or CI resource. Electrolysis reactions were conducted using a dual display potentiostat (Hong Sheng DPS-305CF).

2. Optimization of Reaction Conditions

1.1 Optimization of electrochemical alkoxycarbonylation of imidazoheterocycles

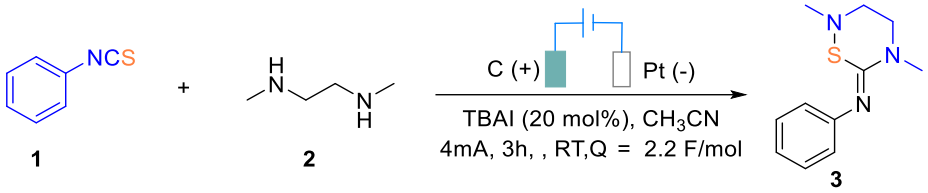
Supplementary Table 1: The effect of electrolyte.



Entry[a]	Electrolytes	Yield (%)[b]
1	KI	60
2	NaI	49
3	LiI	9
4	$TBAClO_4$	trace
5	$TBABF_4$	trace
6	TBAI	81
7	**TBAI[c]**	**85**
8	TBAI[d]	77
9	TBAI[e]	16

[a] Standard reaction conditions: undivided cell, graphite rods (ϕ 6 mm) as anode, Pt plate (10 mm × 15 mm × 0.20 mm) as cathode, **1** (0.2 mmol, 1.0 equiv.), **2** (0.2 mmol, 1.0 equiv.), TBAI (50 mol%), CH_3CN (5 mL), constant current = 4 mA, room temperature (about 25 °C), 3h (2.2 F/mol) under air atmosphere. [b]Yield of the isolated product. [c] TBAI (100 mol%). [d] TBAI (20 mol%). [e] TBAI (10 mol%).

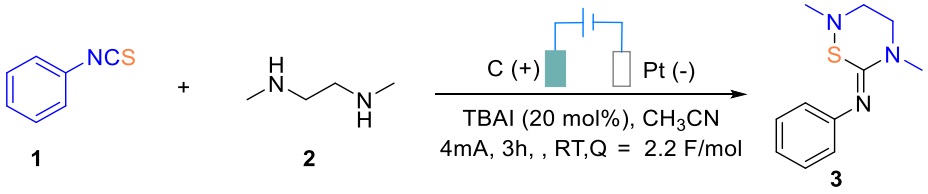
Supplementary Table 2: The effect of constant current.



Entry[a]	Current (x mA)	t (h)	Yield (%)[b]
1	2	6	41
2	3	4	54
3	**4**	**3**	**77**
4	5	2.4	46
5	6	2	38
6	8	1.5	52
7	10	1.2	42

[a] Standard reaction conditions: undivided cell, graphite rods (ϕ 6 mm) as anode, Pt plate (10 mm × 15 mm × 0.20 mm) as cathode, **1** (0.2 mmol, 1.0 equiv.), **2** (0.2 mmol, 1.0 equiv.), TBAI (50 mol%), CH_3CN (5 mL), constant current = 4 mA, room temperature (about 25 °C), 3h (2.2 F/mol) under air atmosphere. [b]Yield of the isolated product.

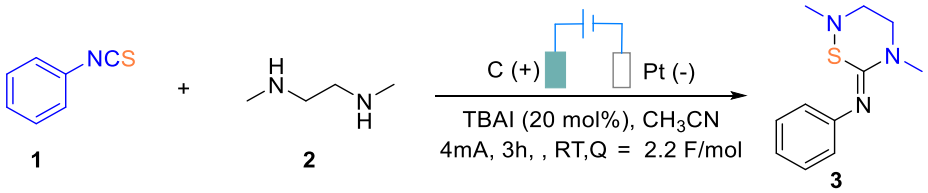
Supplementary Table 3: The effect of solvent.



Entry[a]	Solvents (mL)	Yield (%)[b]
1	**CH_3CN**	**77**
2	DMA	36
3	DMF	23
4	DMSO	10
5	DCE	56
6	Acetone	8

[a] Standard reaction conditions: undivided cell, graphite rods (ϕ 6 mm) as anode, Pt plate (10 mm × 15 mm × 0.20 mm) as cathode, **1** (0.2 mmol, 1.0 equiv.), **2** (0.2 mmol, 1.0 equiv.), TBAI (20 mol%), CH_3CN (5 mL), constant current = 4 mA, room temperature (about 25 °C), 3h (2.2 F/mol) under air atmosphere. [b]Yield of the isolated product.

Supplementary Table 4: The effect of electrode.

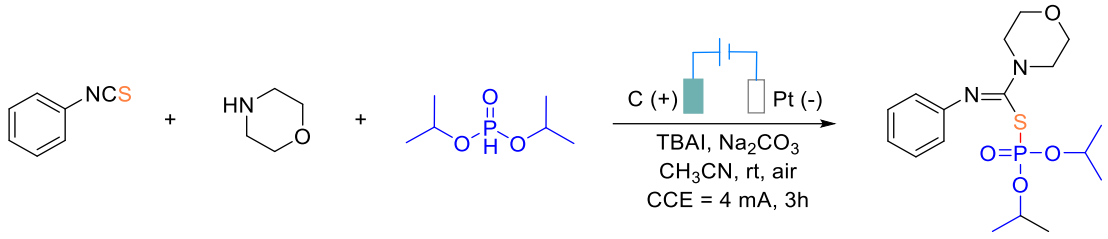


Entry[a]	Anode/Cathode	Yield(%)[b]
1	C(+)|C(-)	51
2	C(+)|Ni plate(-)	55
3	C(+)/GF(-)	53
4	C(+)/CF(-)	54
5	**C(+)/Pt plate(-)**	**77**
6	C(+)/Pt mesh(-)	37
7	C(+)/Pt wire(-)	23
8	C(+)/Ag plate(-)	31
9	C(+)/Zn plate(-)	64
10	C(+)/Mg plate(-)	n.d.[c]
11	C(+)/Al plate(-)	39
12	Pt plate(+)|Pt plate(-)	41
13	C cloth(+)|Pt plate(-)	61
14	GF(+)|Pt plate(-)	n.d.[c]
15	RVC(+)|Pt plate (-)	58

[a] Standard reaction conditions: undivided cell, **1** (0.2 mmol, 1.0 equiv.), **2** (0.2 mmol, 1.0 equiv.), TBAI (20 mol%), CH_3CN (5 mL), constant current = 4 mA, room temperature (about 25 °C), 3h (2.2 F/mol) under air atmosphere. [b]Yield of the isolated product. n.d.[c] = not dectected.

Optimization of three-component cross-dehydrogenative coupling.

Supplementary Table 5:

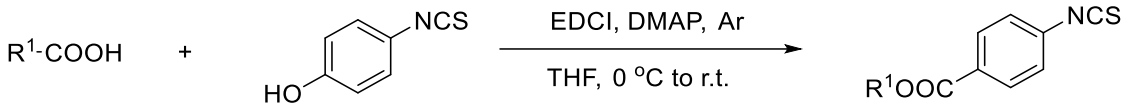


Entry[a]	Electrolytes	Base (1equiv.)	Yield (%)[b]
1	TBAI (20 mol%)	--	47
2	NH_4I (20 mol%)	Na_2CO_3	n.r.[c]
3	TBAI (20 mol%)	Et_3N	80
4	TBAI (10 mol%)	Na_2CO_3	22
5	**TBAI (20 mol%)**	**Na_2CO_3**	**88**

[a] Standard reaction conditions: undivided cell, isothiocyanatobenzene (0.2 mmol, 1.0 equiv.), morpholine (0.4 mmol, 2.0 equiv.), diisopropyl phosphonate (0.24 mmol, 1.2 equiv), Na_2CO_3 (0.2 mmol, 1.0 equiv) TBAI (20 mol%), CH_3CN (5 mL), constant current = 4 mA, room temperature (about 25 °C), 3h (2.2 F/mol) under air atmosphere. [b]Yield of the isolated product. [c]nr = no reaction.

Preparation of Starting Materials.

General procedure A:



The corresponding acid (10.0 mmol, 1.0 equiv.) was added to a solution of 1-(3 dimethylaminopropyl)-3-ethylcarbodiimide (EDCI, 17.0 mmol, 1.7 equiv.) and DMAP (2.0 mmol 0.2 equiv.) in THF (25 mL) at 0 °C. 4-isothiocyanatophenol (100.0 mmol 1.0 equiv.) was then added. The reaction mixture was allowed to warm to room temperature and stirred overnight. Then removal of solvent under reduced pressure. The crude product was purified by column chromatography on silica gel using a petroleum ether/ethyl acetate mixture as eluent to afford the pure desired compounds.

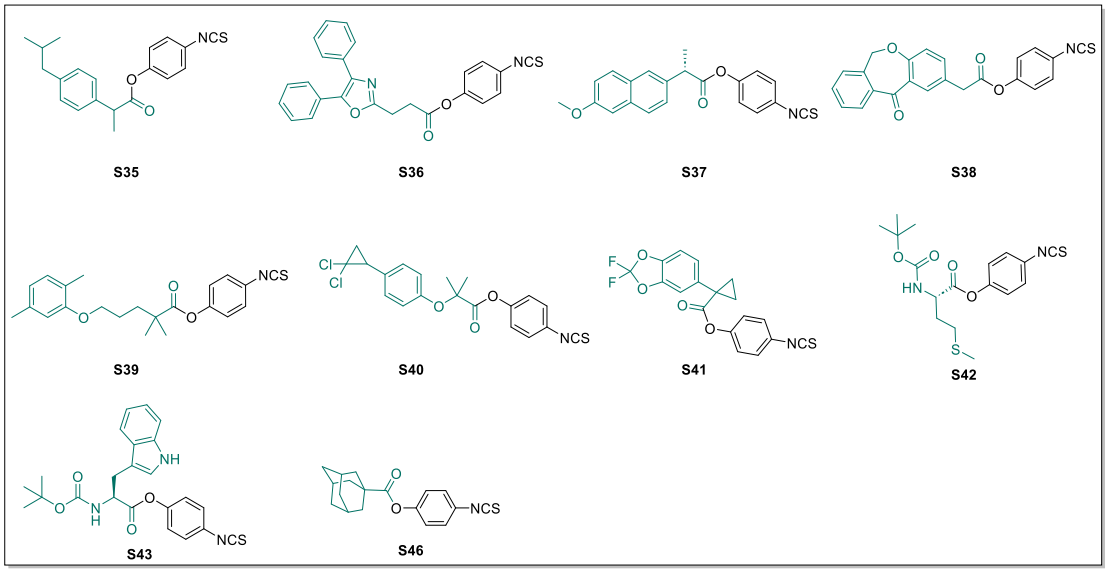
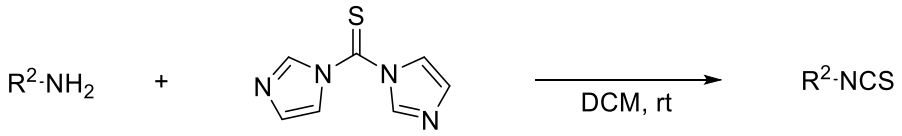


Figure S1. Substrates synthesized according to general procedure **A**

General procedure B:



A 50 mL round-bottom flask was charged with the amine (5 mmol, 1 equiv.) and CH_2Cl_2 (15 mL). To the reaction mixture was added in one portion 1,1'-thiocarbonyl diimidazole (6 mmol, 1.2 equiv.) at room temperature. After 1 h, water was added and the two phases were separated. The aqueous phase was extracted two times with CH_2Cl_2. The combined organic phases were dried over Na_2SO_4 and concentrated under reduced pressure. The crude product was purified by column chromatography on silica gel using a petroleum ether/ethyl acetate mixture as eluent to afford the pure desired compounds.

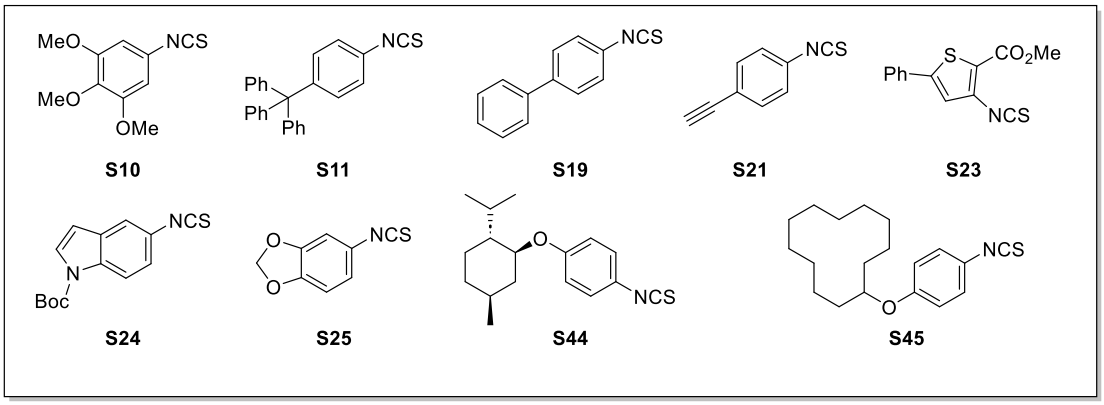
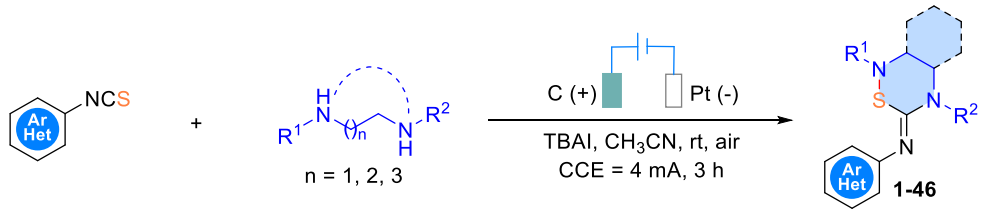


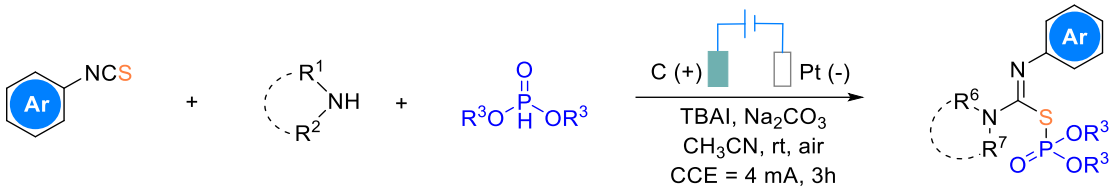
Figure S2. Substrates synthesized according to general procedure **B**

3. General Procedure for the Electrolysis



General procedure C:

The electrolysis process of 0.2 mmol scale was carried out in an undivided cell with a graphite rods anode (10 ×ϕ 6 mm) and a Pt plate cathode (10 × 15 × 0.20 mm). To a 10 mL oven-dried undivided electrochemical cell equipped with a magnetic bar was added isothiocyanates (0.2 mmol, 1.0 equiv), amines (0.2 mmol, 1.0 equiv), TBAI (0.04 mmol, 20 mol%), and CH_3CN (5 mL) under air atmosphere. The electrolysis process was performed at 4 mA of constant current for 3 h at room temperature. After that, the electrodes were washed with EtOAc (3 x 5 mL) in an ultrasonic bath. H_2O (20 mL) was added to the organic system, and the resulting mixture was extracted with EtOAc (3 x 20 mL) and the combined organic phase was washed with brine, dried by anhydrous Na_2SO_4, filtered, and concentrated in vacuo. The crude product was purified by column chromatography to furnish the desired product.



General procedure D:

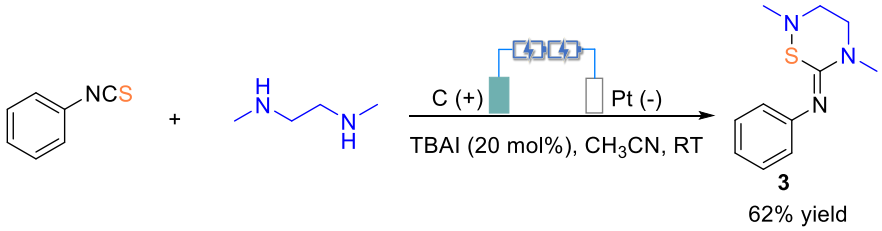
The electrolysis process of 0.2 mmol scale was carried out in an undivided cell with a graphite rods anode (10 ×ϕ 6 mm) and a Pt plate cathode (10 × 15 × 0.20 mm). To a 10 mL oven-dried undivided electrochemical cell equipped with a magnetic bar was added isothiocyanates (0.2 mmol, 1.0 equiv), amines (0.4 mmol, 2.0 equiv), dialkyl *H*-phosphonates (0.24 mmol, 1.2 equiv), Na_2CO_3 (0.2 mmol, 1.0 equiv), TBAI (0.04 mmol, 20 mol%), and CH_3CN (5 mL) under air atmosphere. The electrolysis process was performed at 4 mA of constant current for 3 h at room temperature. After that, the electrodes were washed with EtOAc (3 x 5 mL) in an ultrasonic bath. H_2O (20 mL) was added to the organic system, and the resulting mixture was extracted with EtOAc (3 x 20 mL) and the combined organic phase was washed with brine, dried by anhydrous Na_2SO_4, filtered, and concentrated in vacuo. The crude product was purified by column

chromatography to furnish the desired product.

Figure S3. Pictures of the reaction setup

General procedure E:

Procedure for the reaction with common battery:



The electrolysis process of 0.2 mmol scale was carried out in an undivided cell with a graphite rods anode (10 ×ϕ 6 mm) and a Pt plate cathode (10 × 15 × 0.20 mm). To a 10 mL oven-dried undivided electrochemical cell equipped with a magnetic bar was added isothiocyanates (0.2 mmol, 1.0 equiv), amines (0.2 mmol, 1.0 equiv), TBAI (0.04 mmol, 20 mol%), and CH_3CN (5 mL) under air atmosphere. The electrolysis process was performed at two 1.5-volt batteries as the sole power supply for 3 h at room temperature. After that, the electrodes were washed with EtOAc (3 x 5 mL) in an ultrasonic bath. H_2O (20 mL) was added to the organic system, and the resulting mixture was extracted with EtOAc (3 x 20 mL) and the combined organic phase was

washed with brine, dried by anhydrous Na_2SO_4, filtered, and concentrated in vacuo. The crude product was purified by column chromatography to furnish the desired product.

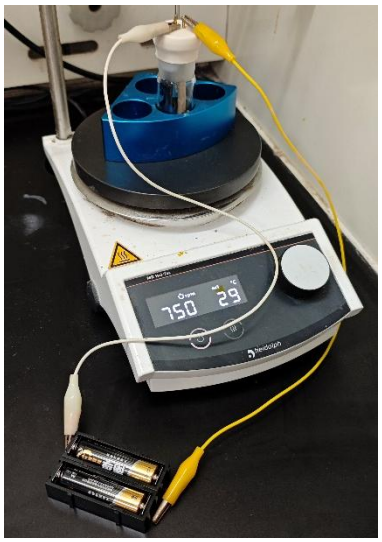
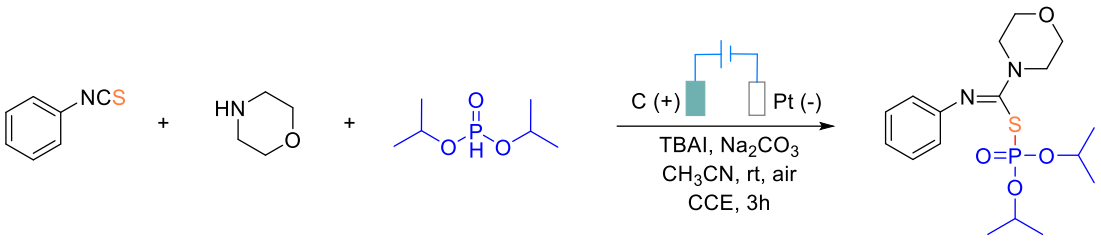


Figure S4. Reaction setup for the reaction with common battery

Gram-Scale Synthesis



Entry	Scale (mmol)	I (mA)	Yield (%)	Weight (mg)
1	1	4	84	324.4
2	3	4	69	800.2
3	3	8	78	899.5
4	4	8	78	1200

The electrolysis processes of 1-4 mmol scales were carried out in a 100 mL beaker with a graphite rods anode (10 ×ϕ 6 mm) and a Pt plate cathode (10 × 15 × 0.20 mm). To a 100 mL oven-dried beaker equipped with a magnetic bar was added isothiocyanatobenzene (1.0 equiv.), morpholine (2.0 equiv.), diisopropyl phosphonate (1.2 equiv), Na_2CO_3 (1.0 equiv), and TBAI (20 mol%) under air atmosphere and dissolved in CH_3CN (25 mL). The electrolysis process was performed at 4-8 mA of constant current for 3 h at room temperature. After that, the electrodes were washed with EtOAc (3 x 5 mL) in an ultrasonic bath. H_2O (20 mL) was added to the organic

system, and the resulting mixture was extracted with EtOAc (3 x 20 mL) and the combined organic phase was washed with brine, dried by anhydrous Na_2SO_4, filtered, and concentrated in vacuo. The crude product was purified by column chromatography to furnish the desired product.

Figure S5. The electrolysis setup and product.

4. Cyclic Voltammetry

The cyclic voltammetry was carried out with a CHI660E workstation. All Cyclic Voltammetry (CV) studies were conducted under air atmosphere. Measurements were performed in CH_3CN solution of $^{n}Bu_4PF_6$ (0.1 M) in a 10 mL glass vial. Scan rate is 100 mV/s unless specified. Working electrode: The working electrode is a 3.0 mm diameter glassy carbon electrode. Polished with aluminum oxide and then sonicated in distilled water and acetone and air dried. Reference electrode: The reference electrode is Ag/AgCl reference electrode (Saturated KCl aq.) in electrolyte solution. Counter electrode: The counter electrode is a platinum wire. The measurements were carried out at a scan rate of 100 mVs-1, ranging from 0 V to 2.5 V for all CV test. The direction of initial scan was oxidative direction. CV plotting convention is IUPAC.

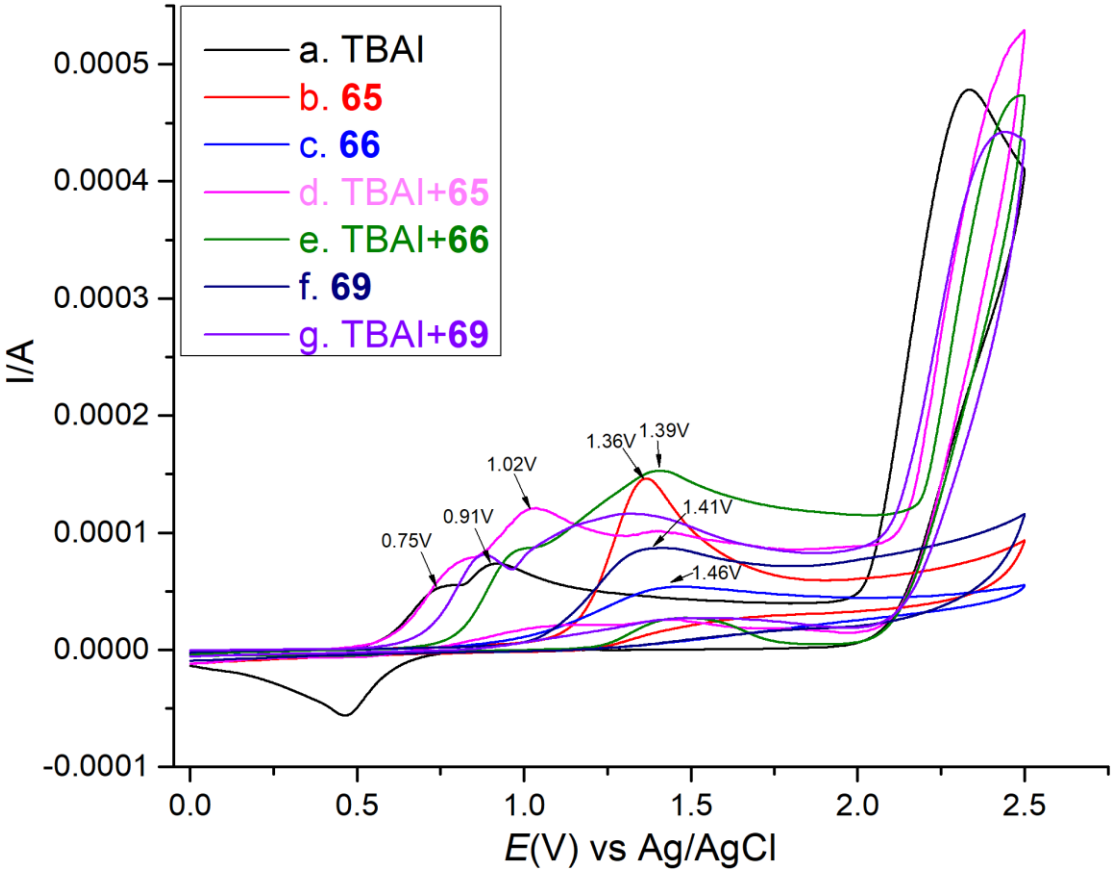
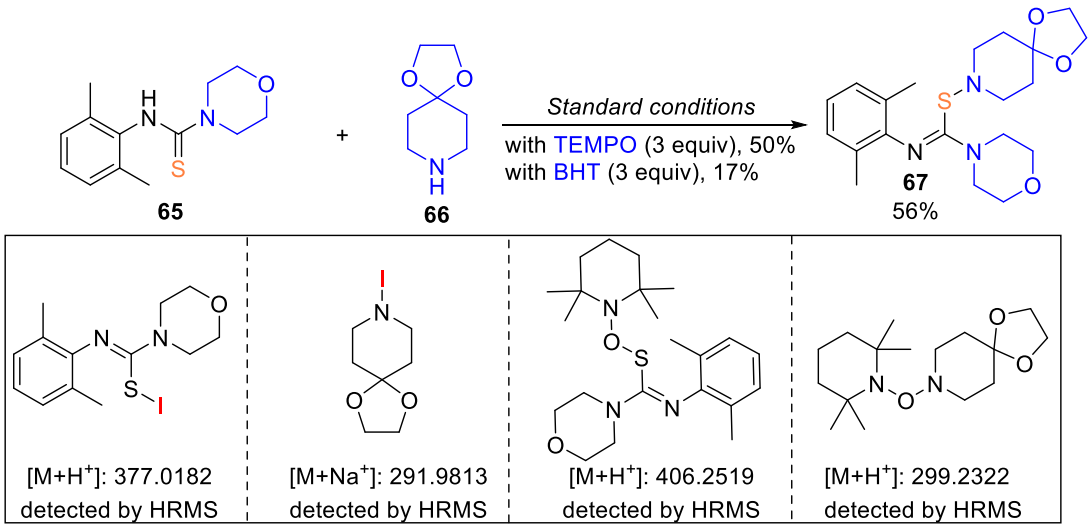


Figure S6 Cyclic voltammetry studies

CV data of related compounds. (a): 5 mM TBAI. (b): 5 mM **65**. (c): 5 mM **66**. (d): 5 mM TBAI and 5 mM **65**. (e): 5 mM TBAI and 5 mM **66**. (f): 5 mM **69**. (g): 5 mM TBAI and 5 mM **69**.

5. Mechanistic Studies

Radical scavenger experiments



The electrolysis process of 0.2 mmol scale was carried out in an undivided cell with a graphite rods anode (10 ×ϕ 6 mm) and a Pt plate cathode (10 × 15 × 0.20 mm). To a 10 mL oven-dried undivided electrochemical cell equipped with a magnetic bar was added *N*-(2,6-dimethylphenyl)morpholine-4-carbothioamide **65** (0.2 mmol, 1.0 equiv), amine **66** (0.2 mmol, 1.0 equiv), TBAI (0.04 mmol, 20 mol%), and CH_3CN (5 mL) under air atmosphere. The electrolysis process was performed at 4 mA of constant current for 3 h at room temperature. After that, the electrodes were washed with EtOAc (3 x 5 mL) in an ultrasonic bath. H_2O (20 mL) was added to the organic system, and the resulting mixture was extracted with EtOAc (3 x 20 mL) and the combined organic phase was washed with brine, dried by anhydrous Na_2SO_4, filtered, and concentrated in vacuo. The crude product was purified by column chromatography to furnish the desired product **67** with 56% yield.

In addition, the reactions were downregulated in 50% and 17% yields upon the addition of the radical scavengers such as 2,2,6,6-Tetramethyl-1-piperinedinyloxy (TEMPO) and 2,6-di-*tert*-butyl-4-methylphenol (BHT), and the related iodinated species and TEMPO adducts were detected by high resolution mass spectrum (HRMS).

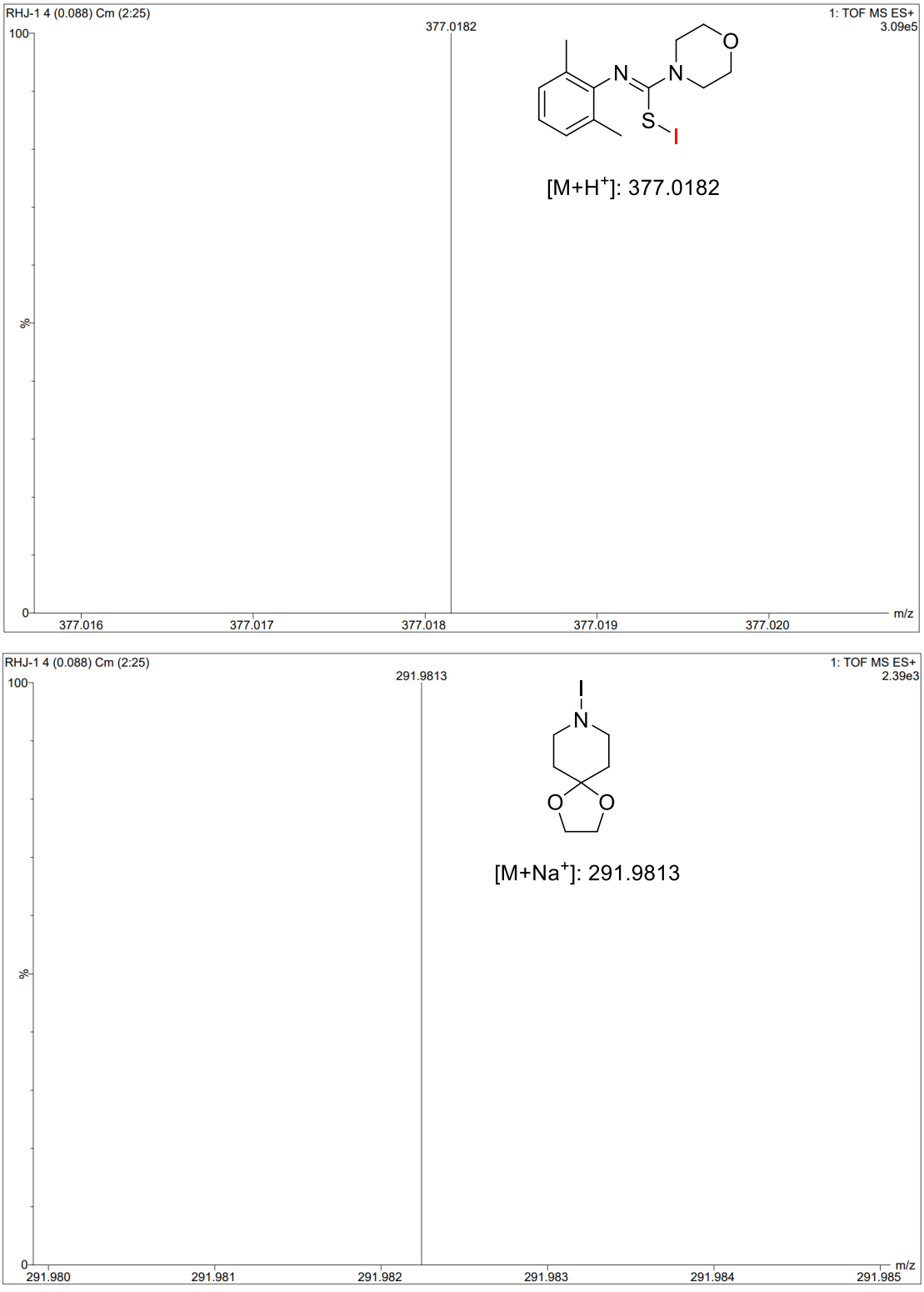
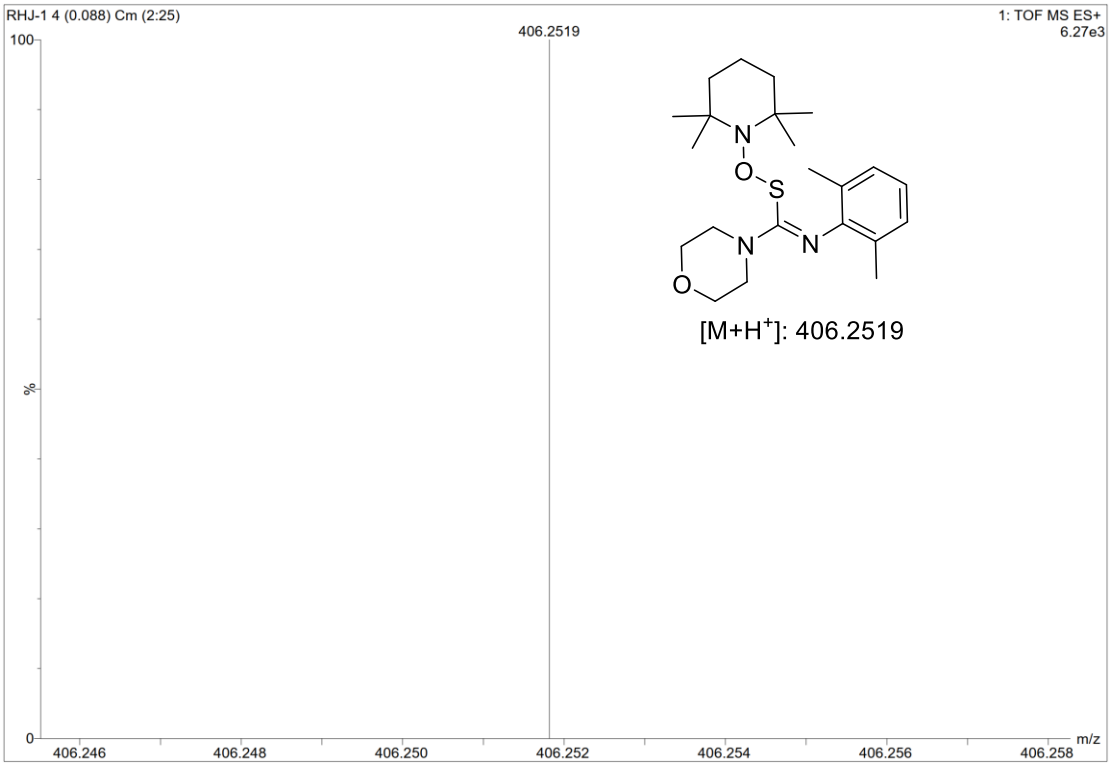


Figure S7. The HRMS of iodinated species.



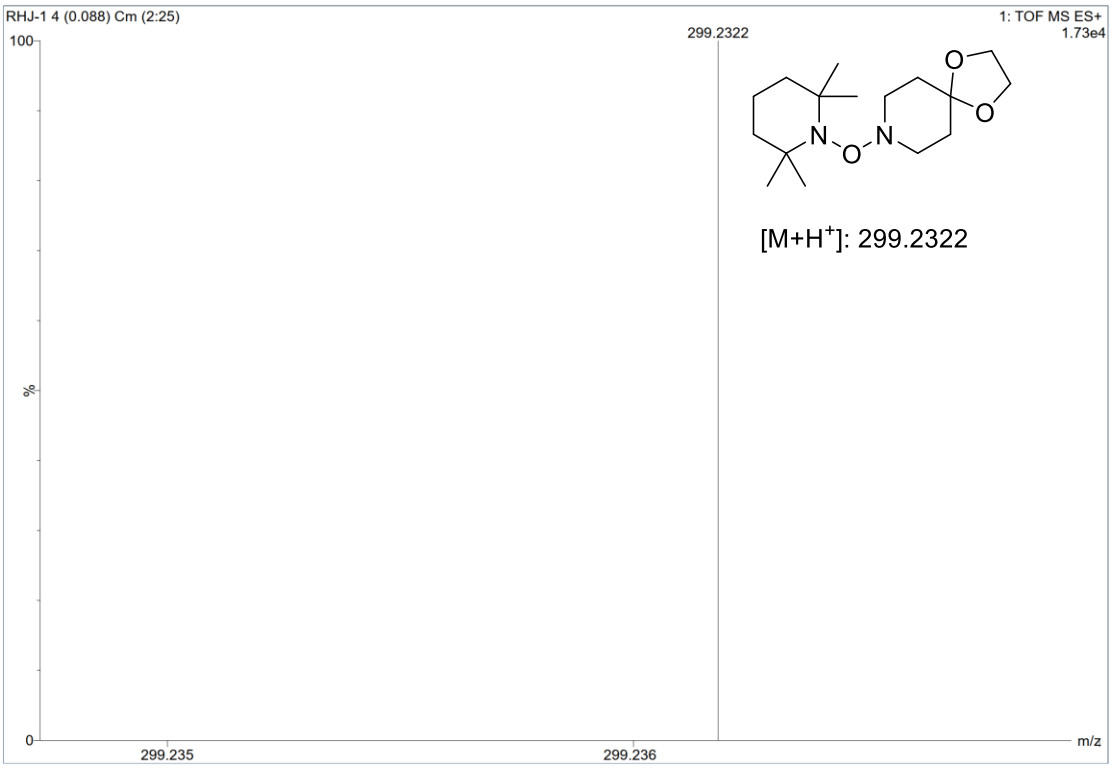
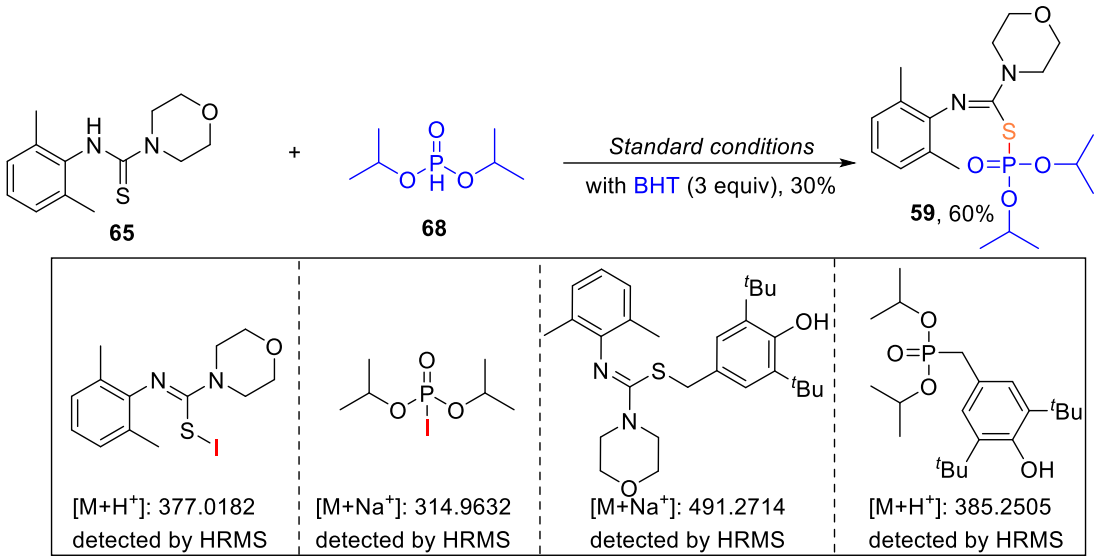


Figure S8. The HRMS of TEMPO adducts.



The electrolysis process of 0.2 mmol scale was carried out in an undivided cell with a graphite rods anode (10 ×ϕ 6 mm) and a Pt plate cathode (10 × 15 × 0.20 mm). To a 10 mL oven-dried undivided electrochemical cell equipped with a magnetic bar was added *N*-(2,6-dimethylphenyl)morpholine-4-carbothioamide **65** (0.2 mmol, 1.0 equiv), diisopropyl phosphonate **68** (0.24 mmol, 1.2 equiv), Na_2CO_3 (1.0 equiv), TBAI (0.04 mmol, 20 mol%), and CH_3CN (5 mL) under air atmosphere. The electrolysis process was performed at 4 mA of constant current for 3 h at room temperature. After that, the electrodes were washed with EtOAc (3 x 5 mL) in an ultrasonic bath. H_2O (20 mL) was added to the organic system, and the resulting mixture was extracted with EtOAc (3 x 20 mL) and the combined organic phase was washed with brine, dried by anhydrous Na_2SO_4, filtered, and concentrated in vacuo. The crude product was purified by column chromatography to furnish the desired product **59** with 60% yield.

In addition, the reactions were downregulated in 30% yields upon the addition of the radical scavengers 2,6-di-*tert*-butyl-4-methylphenol (BHT), and the related iodinated species and BHT adducts were detected by high resolution mass spectrum (HRMS).

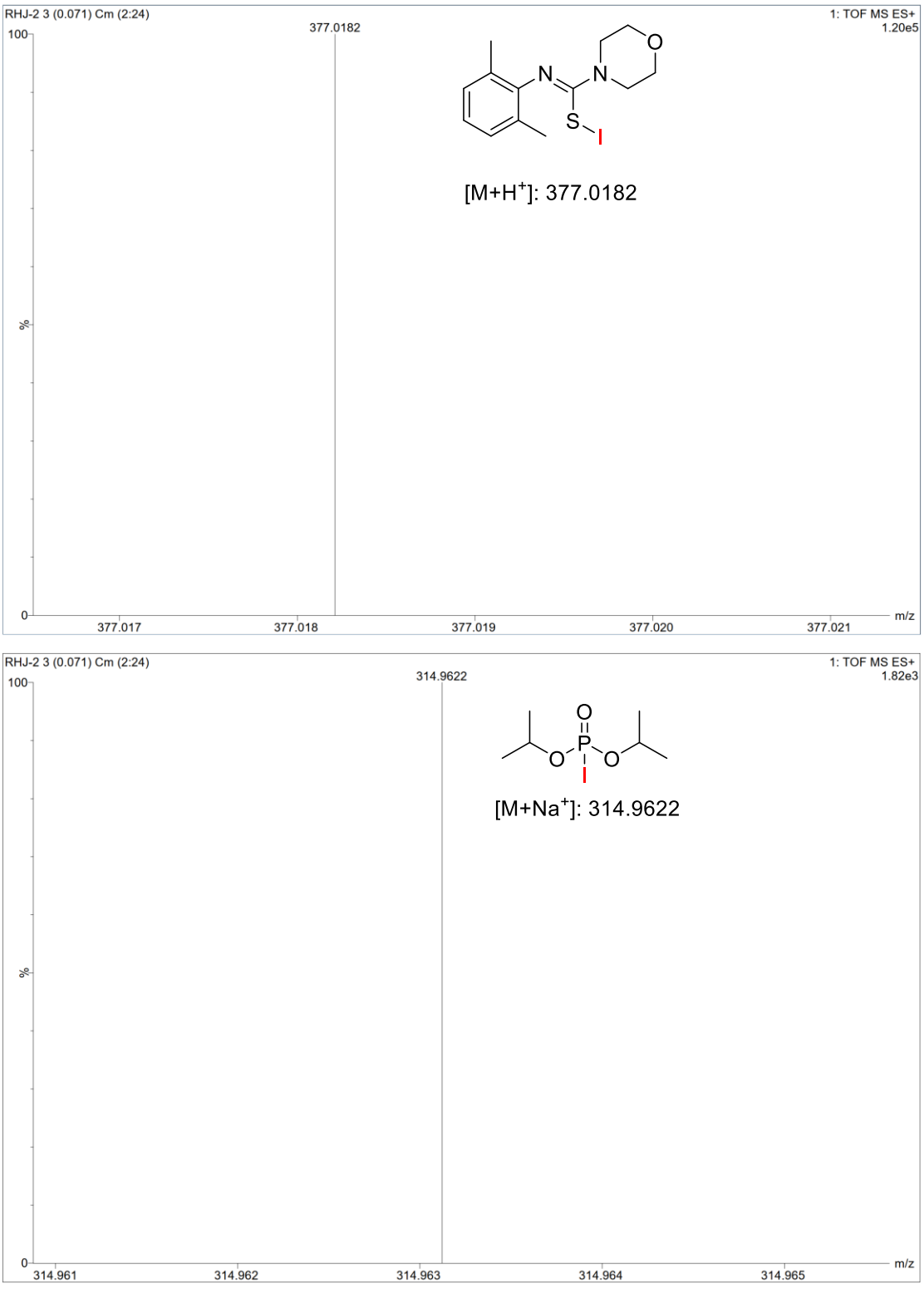


Figure S9. The HRMS of iodinated species.

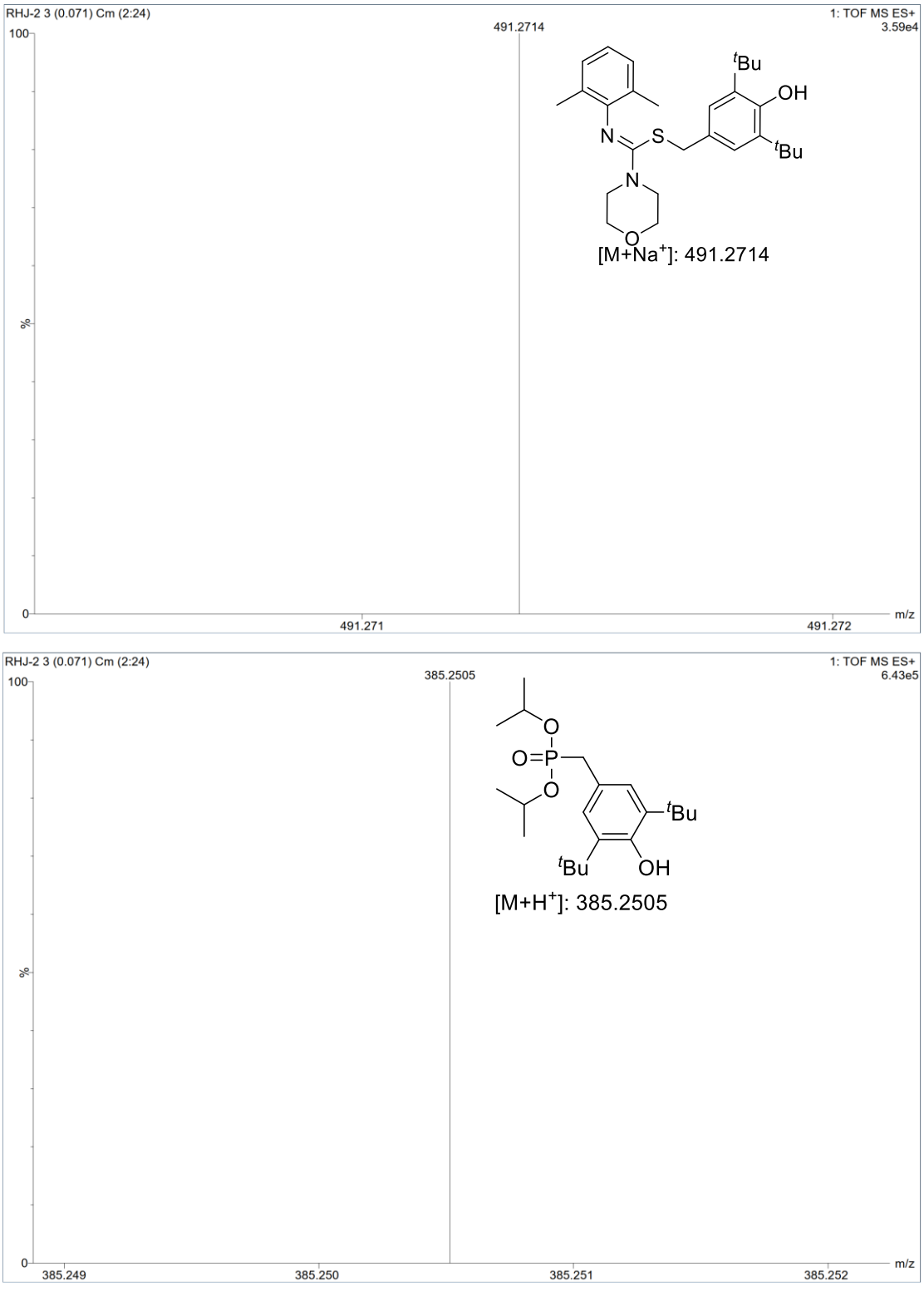
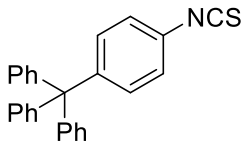


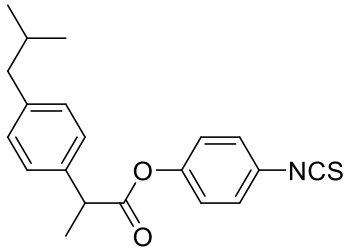
Figure S10. The HRMS of BHT adducts.

6. Characterization Data for Products



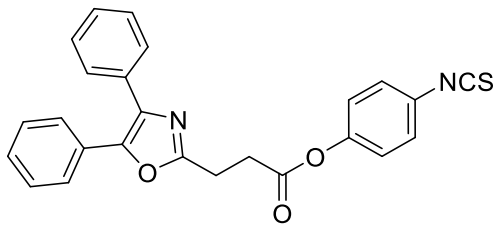
((4-isothiocyanatophenyl)methanetriyl)tribenzene (S11)

The title compound was prepared following the general procedure B, purification by column chromatography on silica gel as a white solid. m.p.: 182.3-183.2 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.27 - 7.21 (m, 7H), 7.21 - 7.14 (m, 10H), 7.09 (d, *J* = 8.4 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 146.6, 146.3, 135.3, 132.4, 131.1, 129.0, 127.8, 126.3, 124.9, 64.9. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{26}H_{20}NS^+$, 378.1311; found, 378.1304.



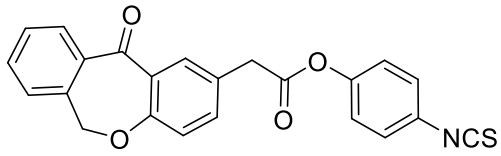
4-isothiocyanatophenyl 2-(4-isobutylphenyl)propanoate (S35)

The title compound was prepared following the general procedure A, purification by column chromatography on silica gel as a colorless liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31 (d, *J* = 8.1 Hz, 2H), 7.21 – 7.15 (m, 4H), 7.00 (d, *J* = 8.9 Hz, 2H), 3.95 (q, *J* = 7.1 Hz, 1H), 2.50 (d, *J* = 7.2 Hz, 2H), 1.96 - 1.83 (m, 1H), 1.62 (d, *J* = 7.2 Hz, 3H), 0.94 (d, *J* = 6.6 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.9, 149.5, 141.1, 137.0, 135.9, 129.7, 128.7, 127.3, 126.7, 122.8, 45.3, 45.1, 30.3, 22.5, 18.5. HRMS (ESI-TOF) m/z: $[M+Na]^+$ calcd for $C_{20}H_{21}NO_2SNa^+$, 362.1185; found, 362.1185.



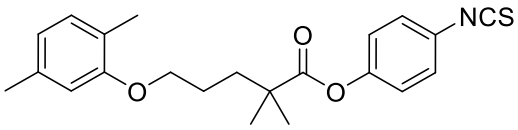
4-isothiocyanatophenyl 3-(4,5-diphenyloxazol-2-yl)propanoate (S36)

The title compound was prepared following the general procedure A, purification by column chromatography on silica gel as a White solid. m.p.: 70.6-71.6 ℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71 – 7.66 (m, 2H), 7.63 – 7.57 (m, 2H), 7.44 – 7.30 (m, 6H), 7.23 – 7.16 (m, 2H), 7.15 – 7.08 (m, 2H), 3.30 (t, *J* = 7.0 Hz, 2H), 3.17 (t, *J* = 7.0 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.4, 161.3, 149.3, 145.7, 136.0, 135.2, 132.1, 128.92, 128.89, 128.8, 128.7, 128.2, 127.9, 126.8, 126.6, 122.9, 31.2, 23.5. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{25}H_{19}N_2O_3S^+$, 427.1111; found, 427.1113.



4-isothiocyanatophenyl 2-(11-oxo-6,11-dihydrodibenzo[b,e]oxepin-2-yl)acetate (S38)

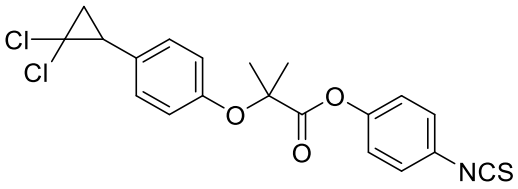
The title compound was prepared following the general procedure A, purification by column chromatography on silica gel as a white solid. m.p.: 132.6-133.5 ℃. ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.21 (d, *J* = 2.4 Hz, 1H), 7.89 (dd, *J* = 7.7, 1.5 Hz, 1H), 7.56 (td, *J* = 7.4, 1.4 Hz, 1H), 7.51 – 7.44 (m, 2H), 7.36 (d, *J* = 7.3 Hz, 1H), 7.20 (d, *J* = 8.9 Hz, 2H), 7.10 – 7.03 (m, 3H), 5.19 (s, 2H), 3.87 (s, 2H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 190.8, 169.6, 160.7, 149.3, 140.4, 136.3, 135.6, 133.0, 132.7, 129.6, 129.4, 129.0, 128.0, 126.9, 126.8, 125.3, 122.9, 121.4, 116.4, 73.7, 40.2. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{23}H_{16}NO_4S^+$, 402.0795; found, 402.0793.



4-isothiocyanatophenyl 5-(2,5-dimethylphenoxy)-2,2-dimethylpentanoate (S39)

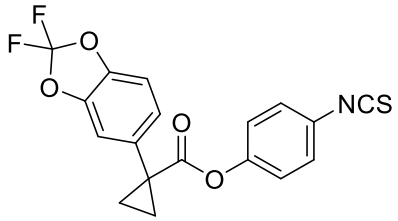
The title compound was prepared following the general procedure A, purification by column chromatography on silica gel as a colorless liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23 (d, *J* = 8.8 Hz, 2H), 7.03 (d, *J* = 8.7 Hz, 3H), 6.69 (d, *J* = 7.5 Hz, 1H), 6.64 (d, *J* = 1.6 Hz, 1H), 4.00 (t, *J* = 5.4 Hz, 2H), 2.33 (s, 3H), 2.19 (s, 3H), 1.96 – 1.80 (m, 4H), 1.39 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.1, 156.9, 149.7, 136.6, 135.9, 130.5, 128.7, 126.8, 123.7, 123.0, 120.9, 112.0, 67.7, 42.6, 37.2, 25.4, 25.2, 21.5, 15.9. HRMS

(ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{22}H_{26}NO_3S^+$, 384.1628; found, 384.1620.



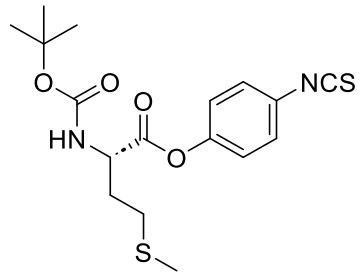
4-isothiocyanatophenyl 2-(4-(2,2-dichlorocyclopropyl)phenoxy)-2-methylpropanoate (S40)

The title compound was prepared following the general procedure A, purification by column chromatography on silica gel as a colorless liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.18 (t, *J* = 9.0 Hz, 4H), 6.94 (t, *J* = 8.8 Hz, 4H), 2.86 (dd, *J* = 10.7, 8.3 Hz, 1H), 2.00 - 1.79 (m, 2H), 1.76 (s, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.6, 155.0, 149.1, 136.3, 129.9, 129.2, 128.7, 126.8, 122.7, 118.5, 79.3, 60.9, 34.8, 25.9, 25.55, 25.52. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{20}H_{18}Cl_2NO_3S^+$, 422.0379; found, 422.0376.



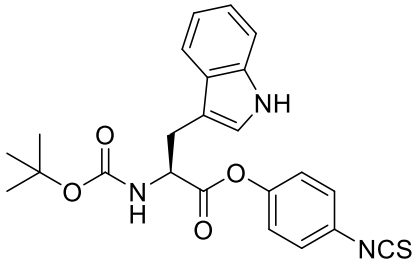
4-isothiocyanatophenyl 1-(2,2-difluorobenzo[d][1,3]dioxol-5-yl)cyclopropane-1-carboxylate (S41)

The title compound was prepared following the general procedure A, purification by column chromatography on silica gel as a colorless liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.21 - 7.15 (m, 4H), 7.07 - 7.00 (m, 3H), 1.84 (q, *J* = 4.2 Hz, 2H), 1.41 -1.35 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.3, 149.4, 143.5, 143.0, 135.9, 134.9, 131.7 (t, J_{C-F} = 255.1 Hz), 128.7, 126.6, 125.9, 122.7, 112.1, 109.1, 29.0, 17.8. ^{19}F NMR (376 MHz, $CDCl_3$) δ -49.56. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{18}H_{12}F_2NO_4S^+$, 376.0450; found, 376.0444.



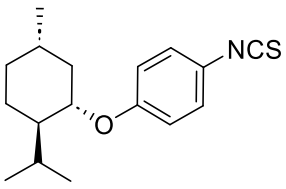
4-isothiocyanatophenyl (tert-butoxycarbonyl)-*L*-methioninate (S42)

The title compound was prepared following the general procedure A, purification by column chromatography on silica gel as a white solid. m.p.: 86.0-86.9 ℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.21 (d, *J* = 8.8 Hz, 2H), 7.08 (d, *J* = 8.8 Hz, 2H), 5.27 (d, *J* = 8.2 Hz, 1H), 4.65 - 4.57 (m, 1H), 2.69 - 2.55 (m, 2H), 2.32 - 2.22 (m, 1H), 2.10 (s, 3H), 2.09 - 2.00 (m, 1H), 1.44 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.9, 155.5, 149.0, 136.3, 129.2, 126.8, 122.7, 116.4, 80.5, 53.0, 31.6, 30.1, 28.3, 15.6. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{17}H_{23}N_2O_4S_2^+$, 383.1094; found, 383.1098.



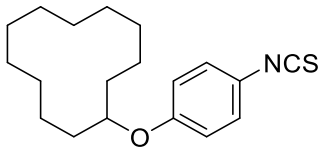
4-isothiocyanatophenyl (*tert*-butoxycarbonyl)-*L*-tryptophanate(S43)

The title compound was prepared following the general procedure A, purification by column chromatography on silica gel as a white solid. m.p.: 91.6-92.6 ℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.44 (s, 1H), 7.62 (d, *J* = 7.9 Hz, 1H), 7.37 (d, *J* = 8.1 Hz, 1H), 7.23 (t, *J* = 7.5 Hz, 1H), 7.13 (dd, *J* = 15.4, 8.0 Hz, 3H), 7.05 (s, 1H), 6.82 (d, *J* = 8.5 Hz, 2H), 5.23 (d, *J* = 8.0 Hz, 1H), 4.86 (q, *J* = 6.5 Hz, 1H), 3.53 – 3.31 (m, 2H), 1.47 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 171.0, 155.5, 149.0, 136.3, 136.0, 129.0, 127.5, 126.7, 123.1, 122.7, 122.4, 119.9, 118.8, 111.5, 109.6, 80.4, 54.6, 28.4, 28.0. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{23}H_{24}N_3O_4S^+$, 483.1482; found, 483.1481.



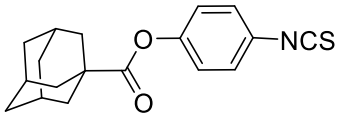
1-(((1S,2R,5S)-2-isopropyl-5-methylcyclohexyl)oxy)-4-isothiocyanatobenzene (S44)

The title compound was prepared following the general procedure B, purification by column chromatography on silica gel as a colorless liquid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.14 (d, *J* = 9.0 Hz, 2H), 6.84 (d, *J* = 9.0 Hz, 2H), 4.60 (q, *J* = 2.7 Hz, 1H), 2.08 - 2.00 (m, 1H), 1.84 - 1.46 (m, 5H), 1.11 - 0.95 (m, 3H), 0.92 (d, *J* = 6.7 Hz, 3H), 0.83 (dd, *J* = 8.4, 6.6 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.5, 133.7, 127.2, 123.0, 116.4, 74.0, 47.8, 37.6, 35.0, 29.4, 26.3, 24.9, 22.4, 21.2, 20.9. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{17}H_{24}NOS^+$, 290.1573; found, 290.1568.



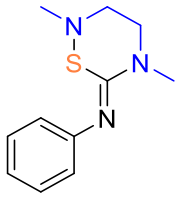
(4-isothiocyanatophenoxy)cyclododecane (S45)

The title compound was prepared following the general procedure B, purification by column chromatography on silica gel as a white solid. m.p.: 88.3-89.3 ℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.13 (d, *J* = 9.0 Hz, 2H), 6.82 (d, *J* = 9.0 Hz, 2H), 4.43 - 4.36 (m, 1H), 1.82 - 1.72 (m, 2H), 1.67 - 1.57 (m, 2H), 1.52 - 1.26 (m, 18H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.5, 133.8, 127.1, 123.2, 116.7, 76.0, 28.6, 24.6, 24.3, 23.21, 23.15, 20.7. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{19}H_{28}NOS^+$, 236.1216; found, 318.1886.



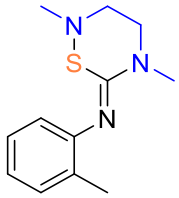
4-isothiocyanatophenyl (3r,5r,7r)-adamantane-1-carboxylate (46)

The title compound was prepared following the general procedure A, purification by column chromatography on silica gel as a white solid. m.p.: 85.8-86.6 ℃. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.22 (d, *J* = 8.9 Hz, 2H), 7.03 (d, *J* = 8.9 Hz, 2H), 2.08 (s, 3H), 2.04 (s, 6H), 1.83 – 1.70 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.9, 149.9, 135.8, 128.6, 126.8, 123.0, 41.2, 38.8, 36.5, 27.9. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{18}H_{20}NO_2S^+$, 314.1209; found, 314.1209.



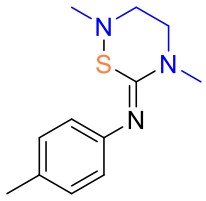
(*Z*)-2,5-dimethyl-*N*-phenyl-1,2,5-thiadiazinan-6-imine (3)

Brown solid (34.0 mg, 77% yield). m.p.: 52.3-53.3 ℃; R_f=0.32 (PE/EA=2:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.22 (t, *J* = 7.8 Hz, 2H), 6.99 (t, *J* = 7.4 Hz, 1H), 6.84 (d, *J* = 7.4 Hz, 2H), 3.50 (t, *J* = 5.9 Hz, 2H), 3.39 (t, *J* = 5.9 Hz, 2H), 3.19 (s, 3H), 2.80 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.5, 148.7, 128.8, 122.9, 122.7, 53.5, 46.2, 43.9, 39.5. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{11}H_{16}N_3S^+$, 222.1059; found, 222.1055.



(*Z*)-2,5-dimethyl-*N*-(*o*-tolyl)-1,2,5-thiadiazinan-6-imine (4)

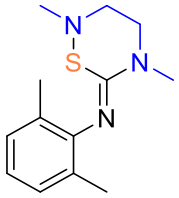
Brown liquid (36.2 mg, 77% yield); R_f = 0.34 (PE/EA=2:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.12 (dd, *J* = 7.3, 1.5 Hz, 1H), 7.05 (td, *J* = 7.6, 1.6 Hz, 1H), 6.93 (td, *J* = 7.4, 1.4 Hz, 1H), 6.74 (dd, *J* = 7.7, 1.4 Hz, 1H), 3.51 (t, *J* = 5.9 Hz, 2H), 3.39 (t, *J* = 5.9 Hz, 2H), 3.22 (s, 3H), 2.80 (s, 3H), 2.16 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 152.9, 147.0, 130.4, 130.3, 126.2, 123.2, 122.5, 53.5, 46.1, 43.7, 39.4, 18.1. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{12}H_{18}N_3S^+$, 236.1216; found, 236.1211.



(*Z*)-2,5-dimethyl-*N*-(*p*-tolyl)-1,2,5-thiadiazinan-6-imine (5)

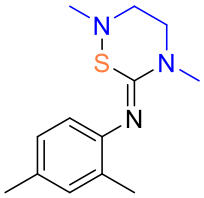
Yellow solid (32.4 mg, 69% yield). m.p.: 36.1-37.1 ℃; R_f = 0.33 (PE/EA=2:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.03 (d, *J* = 8.0 Hz, 2H), 6.73 (d, *J* = 8.2 Hz, 2H), 3.49 (t, *J* = 5.9 Hz, 2H), 3.39 (t, *J* = 5.9 Hz, 2H), 3.19 (s, 3H), 2.80 (s,3H), 2.29 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.5, 145.9, 132.3, 129.4, 122.5, 53.5, 46.1, 43.9, 39.5, 21.1. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{12}H_{18}N_3S^+$, 236.1216; found,

236.1217.



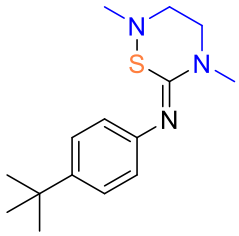
(*Z*)-*N*-(2,6-dimethylphenyl)-2,5-dimethyl-1,2,5-thiadiazinan-6-imine (6)

Yellow solid (47.3 mg, 95% yield). m.p.: 58.4-59.6 ℃; R_f = 0.35 (PE/EA=2:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.96 (d, *J* = 7.4 Hz, 2H), 6.87-6.82 (m, 1H), 3.51 (t, *J* = 5.9 Hz, 2H), 3.39 (t, *J* = 5.9 Hz, 2H), 3.26 (s, 3H), 2.80 (s, 3H), 2.13 (s, 6H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 152.5, 145.4, 130.0, 127.7, 122.9, 53.5, 46.1, 43.6, 39.5, 18.3. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{13}H_{20}N_3S^+$, 250.1372; found, 250.1364.



(*Z*)-*N*-(2,4-dimethylphenyl)-2,5-dimethyl-1,2,5-thiadiazinan-6-imine (7)

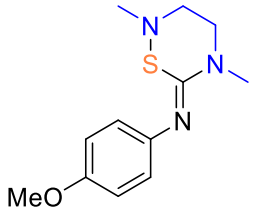
Yellow solid (43.8 mg, 88% yield). m.p.: 61.0-61.7 ℃; R_f = 0.34 (PE/EA=2:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.94 (s, 1H), 6.86 (d, *J* = 7.8 Hz, 1H), 6.62 (d, *J* = 7.8 Hz, 1H), 3.49 (t, *J* = 5.8 Hz, 2H), 3.39 (t, *J* = 5.9Hz, 2H), 3.21 (s, 3H), 2.79 (s, 3H), 2.26 (s, 3H), 2.13 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 152.9, 144.4, 132.4, 131.1, 130.0, 126.7, 122.2, 53.5, 46.1, 43.8, 39.3, 21.1, 18.1. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{13}H_{20}N_3S^+$, 250.1372; found, 250.1372.



(*Z*)-*N*-(4-(tert-butyl)phenyl)-2,5-dimethyl-1,2,5-thiadiazinan-6-imine (8)

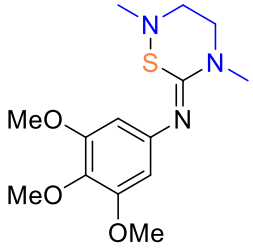
Yellow solid (39.9 mg, 72% yield). m.p.: 40.3-41.2 ℃; R_f = 0.32 (PE/EA=3:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.22 (d, *J* = 8.4 Hz, 2H), 6.76 (d, *J* = 8.4 Hz, 2H), 3.50 (t, *J* = 5.9 Hz, 2H), 3.39 (t, *J* = 5.9 Hz, 2H), 3.19 (s, 3H), 2.81 (s, 3H), 1.28 (s, 9H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.3, 145.64, 145.58, 125.6, 122.1, 53.5, 46.1, 43.9, 39.5,

34.3, 31.6. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{15}H_{24}N_3S^+$, 278.1685; found, 278.1687.



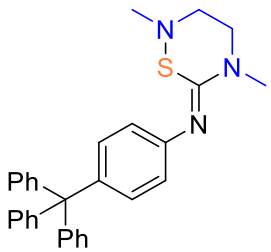
(*Z*)-*N*-(4-methoxyphenyl)-2,5-dimethyl-1,2,5-thiadiazinan-6-imine (**9**)

Yellow solid (36.7 mg, 73% yield). m.p.: 44.5-45.3 ℃; R_f = 0.30 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.80-6.74 (m, 4H), 3.76 (s, 3H), 3.49 (t, *J* = 5.9 Hz, 2H), 3.38 (t, *J* = 5.9 Hz, 2H), 3.18 (s, 3H), 2.79 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 155.7, 154.0, 141.8, 123.5, 114.0, 58.5, 55.5, 53.4, 46.1, 43.9, 39.5, 18.6. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{12}H_{18}N_3OS^+$, 252.1165; found, 252.1168.



(*Z*)-2,5-dimethyl-*N*-(3,4,5-trimethoxyphenyl)-1,2,5-thiadiazinan-6-imine (**10**)

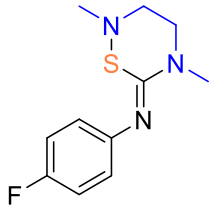
Yellow solid (23.6 mg, 38% yield). m.p.: 68.8-69.5 ℃; R_f = 0.28 (DCM/MeOH=20:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.08 (s, 2H), 3.81 (s, 6H), 3.80 (s, 3H), 3.50 (t, *J* = 5.9 Hz, 2H), 3.40 (t, *J* = 5.9 Hz, 2H), 3.18 (s, 3H), 2.81 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.9, 153.3, 144.6, 133.9, 99.8, 61.1, 56.1, 53.4, 46.1, 44.0, 39.6. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{14}H_{22}N_3O_3S^+$, 312.1376; found, 312.1375.



(*E*)-2,5-dimethyl-N-(4-tritylphenyl)-1,2,5-thiadiazinan-6-imine (11)

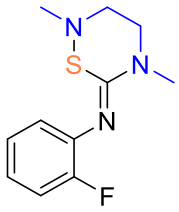
White solid (75.0 mg, 81% yield). m.p.: 223.4-224.3 ℃; R_f = 0.31 (DCM/MeOH=20:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28 – 7.13 (m, 15H), 7.01 (d, *J* = 8.6 Hz, 2H), 6.71

(d, J = 8.5 Hz, 2H), 3.50 (t, J = 5.8 Hz, 2H), 3.39 (t, J = 5.8 Hz, 2H), 3.17 (s, 3H), 2.82 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 153.3, 147.3, 146.1, 141.1, 131.7, 131.4, 127.4, 125.9, 121.6, 64.7, 53.5, 46.2, 43.8, 39.5. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{30}H_{30}N_3S^+$, 464.2155; found, 464.2162.



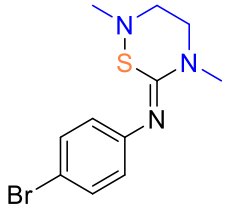
(Z)-N-(4-fluorophenyl)-2,5-dimethyl-1,2,5-thiadiazinan-6-imine (12)

White solid (36.3 mg, 76% yield). m.p.: 49.8-50.7 ℃; R_f = 0.35 (PE/EA=2:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.94-6.87 (m, 2H), 6.80-6.74 (m, 2H), 3.50 (t, J = 6.2 Hz, 2H), 3.39 (t, J = 5.7 Hz, 2H), 3.18 (s, 3H), 2.80 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 159.2 (d, J_{C-F} = 240.5 Hz), 154.1, 144.6 (d, J_{C-F} = 2.5 Hz), 123.8 (d, J_{C-F} = 7.9 Hz), 115.4 (d, J_{C-F} = 22.4 Hz), 53.4, 46.2, 43.8, 39.5. ^{19}F NMR (376 MHz, $CDCl_3$) δ -121.65. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{11}H_{15}FN_3S^+$, 240.0965; found, 240.0957.



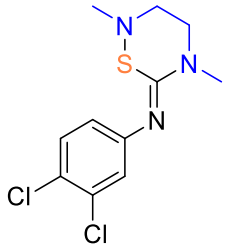
(*Z*)-*N*-(2-fluorophenyl)-2,5-dimethyl-1,2,5-thiadiazinan-6-imine (13)

Yellow solid (35.4 mg, 74% yield). m.p.: 66.5-67.4 ℃; R_f = 0.33 (PE/EA=2:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.04 – 6.92 (m, 3H), 6.91 – 6.84 (m, 1H), 3.52 (t, J = 5.9 Hz, 2H), 3.41 (t, J = 5.8 Hz, 2H), 3.24 (s, 3H), 2.82 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 155.2, 154.9 (d, J_{C-F} = 243.4 Hz), 136.3 (d, J_{C-F} = 14.0 Hz), 125.3 (d, J_{C-F} = 2.3 Hz), 124.1 (d, J_{C-F} = 3.7 Hz), 123.8 (d, J_{C-F} = 7.3 Hz), 115.9 (d, J_{C-F} = 20.5 Hz), 53.4, 46.2, 43.6, 39.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -126.09. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{11}H_{15}FN_3S^+$, 240.0965; found, 240.0959.



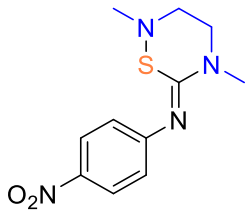
(*Z*)-*N*-(4-bromophenyl)-2,5-dimethyl-1,2,5-thiadiazinan-6-imine (14)

Yellow solid (44.3 mg, 74% yield). m.p.: 50.1-51.0 ℃; R_f = 0.36 (PE/EA=2:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.30 (d, *J* = 8.6 Hz, 2H), 6.71 (d, *J* = 8.7 Hz, 2H), 3.50 (t, *J* = 6.1 Hz, 2H), 3.38 (t, *J* = 5.7 Hz, 2H), 3.17 (s, 3H), 2.80 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.7, 147.8, 131.7, 124.5, 115.7, 53.3, 46.2, 43.7, 39.5. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{11}H_{15}BrN_3S^+$, 300.0165; found, 300.0160.



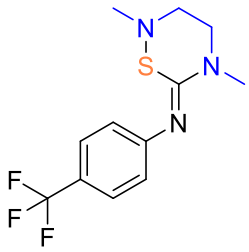
(*Z*)-*N*-(3,4-dichlorophenyl)-2,5-dimethyl-1,2,5-thiadiazinan-6-imine (15)

Yellow liquid (41.6 mg, 72% yield); R_f = 0.35 (PE/EA=2:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28 (d, *J* = 2.9 Hz, 1H), 6.97 (d, *J* = 2.4 Hz, 1H), 6.71 (m, 1H), 3.53 (t, *J* = 5.9 Hz, 2H), 3.42 (t, *J* = 5.8 Hz, 2H), 3.20 (s, 3H), 2.84 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 154.4, 148.3, 132.2, 130.3, 126.0, 124.6, 122.5, 53.2, 46.2, 43.6, 39.5. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{11}H_{14}Cl_2N_3S^+$, 290.0280; found, 290.0280.



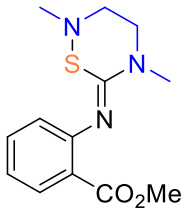
(*Z*)-2,5-dimethyl-*N*-(4-nitrophenyl)-1,2,5-thiadiazinan-6-imine (16)

Yellow solid (31.9 mg, 60% yield). m.p.: 53.6-54.8 ℃; R_f = 0.38 (DCM/MeOH=20:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09 (d, *J* = 9.0 Hz, 2H), 6.90 (d, *J* = 9.0 Hz, 2H), 3.54 (t, *J* = 5.9 Hz, 2H), 3.42 (t, *J* = 5.9 Hz, 2H), 3.21 (s, 3H), 2.83 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 155.7, 153.8, 142.9, 124.9, 122.9, 53.2, 46.2, 43.5, 39.5. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{11}H_{15}N_4O_2S^+$, 267.0910; found, 267.0913.



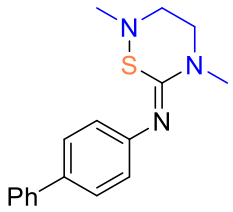
(*Z*)-2,5-dimethyl-*N*-(4-(trifluoromethyl)phenyl)-1,2,5-thiadiazinan-6-imine (17)

Yellow liquid (45.7 mg, 79% yield); R_f = 0.31 (PE/EA=2:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 (d, *J* = 8.3 Hz, 2H), 6.90 (d, *J* = 8.2 Hz, 2H), 3.52 (t, *J* = 5.9 Hz, 2H), 3.40 (t, *J* = 5.9 Hz, 2H), 3.19 (s, 3H), 2.81 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 153.6, 152.1, 126.0 (q, J_{C-F} = 3.8 Hz), 124.8 (q, J_{C-F} = 271.2 Hz), 124.5 (q, J_{C-F} = 32.1 Hz), 122.7, 53.3, 46.2, 43.6, 39.5. ^{19}F NMR (376 MHz, $CDCl_3$) δ -61.58. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{12}H_{15}F_3N_3S^+$, 290.0933; found, 290.0933.



Methyl (*Z*)-2-((2,5-dimethyl-1,2,5-thiadiazinan-6-ylidene)amino)benzoate (18)

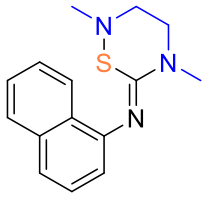
Brown solid (30.7 mg, 55% yield). m.p.: 57.1-57.9 ℃; R_f = 0.30 (PE/EA=2:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.82 (dd, *J* = 7.9, 1.7 Hz, 1H), 7.37 - 7.31 (m, 1H), 7.02 (td, *J* = 7.6, 1.2 Hz, 1H), 6.86 (dd, *J* = 8.0, 1.2 Hz, 1H), 3.83 (s, 3H), 3.53 (t, *J* = 5.9 Hz, 2H), 3.41 (t, *J* = 6.0 Hz, 2H), 3.24 (s, 3H), 2.81 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 167.3, 153.1, 149.9, 132.6, 131.2, 124.7, 122.7, 122.4, 53.6, 51.8, 46.1, 43.7, 39.4. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{13}H_{18}N_3O_2S^+$, 280.1114; found 280.1118.



(*Z*)-N-([1,1'-biphenyl]-4-yl)-2,5-dimethyl-1,2,5-thiadiazinan-6-imine (19)

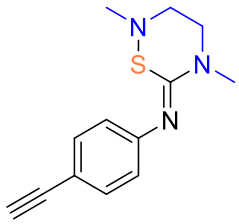
Yellow solid (33.9 mg, 57% yield). m.p.: 91.2-92.0 ℃; R_f = 0.33 (PE/EA=2:1, v/v). ^{1}H

NMR (400 MHz, $CDCl_3$) δ 7.59 (d, *J* = 7.2 Hz, 2H), 7.48 (d, *J* = 8.4 Hz, 2H), 7.40 (t, *J* = 7.7 Hz, 2H), 7.28 (t, *J* = 7.3 Hz, 1H), 6.91 (d, *J* =z 8.4 Hz, 2H), 3.52 (t, *J* = 5.9 Hz, 2H), 3.41 (t, *J* = 5.9 Hz, 2H), 3.21 (s, 3H), 2.83 (s, 3H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 153.5, 148.0, 141.2, 135.6, 128.7, 127.5, 126.8, 126.7, 123.0, 53.4, 46.2, 43.9, 39.5. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{17}H_{20}N_3S^+$, 298.1372; found, 298.1367.



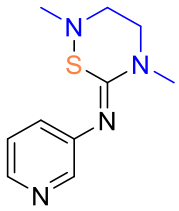
(*Z*)-2,5-dimethyl-*N*-(naphthalen-1-yl)-1,2,5-thiadiazinan-6-imine (20)

Yellow solid (43.4 mg, 80% yield). m.p.: 69.8-70.8 ℃; R_f = 0.34 (PE/EA=2:1, v/v). ^1H NMR (400 MHz, $CDCl_3$) δ 8.08-8.03 (m, 1H), 7.82-7.77 (m, 1H), 7.52 (d, *J* = 8.2 Hz, 1H), 7.47-7.39 (m, 2H), 7.35-7.29 (m, 1H), 6.89 (dd, *J* = 7.3, 1.1 Hz, 1H), 3.55 (t, *J* = 6.0 Hz, 2H), 3.41 (t, *J* = 6.0 Hz, 2H), 3.36 (s, 3H), 2.75 (s, 3H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 153.8, 145.0, 134.5, 128.6, 128.0, 125.9, 125.7, 125.0, 124.1, 122.9, 117.3, 53.5, 46.0, 43.9, 39.6. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{15}H_{18}N_3S^+$, 272.1216; found, 272.1210.



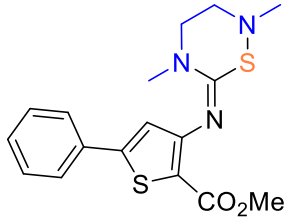
(*Z*)-*N*-(4-ethynylphenyl)-2,5-dimethyl-1,2,5-thiadiazinan-6-imine (21)

White solid (30.4 mg, 62% yield). m.p.: 121.5-122.4 ℃; R_f = 0.31 (PE/EA=2:1, v/v). ^1H NMR (400 MHz, $CDCl_3$) δ 7.35 (d, *J* = 8.4 Hz, 2H), 6.78 (d, *J* = 8.4 Hz, 2H), 3.50 (t, *J* = 5.9 Hz, 2H), 3.39 (t, *J* = 5.9 Hz, 2H), 3.18 (s, 3H), 3.00 (s, 1H), 2.80 (s, 3H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 153.5, 149.5, 132.9, 122.8, 116.0, 84.5, 76.0, 53.4, 46.2, 43.8, 39.5. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{13}H_{16}N_3S^+$, 246.1059; found, 246.1053.



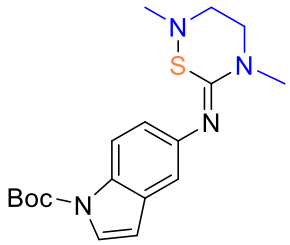
(*Z*)-2,5-dimethyl-*N*-(pyridin-3-yl)-1,2,5-thiadiazinan-6-imine (22)

Yellow liquid (33.8 mg, 76% yield); R_f = 0.35 (PE/EA=2:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.22 (dd, *J* = 4.4, 1.9 Hz, 1H), 8.17-8.14 (m, 1H), 7.18-7.09 (m, 2H), 3.52 (t, *J* = 5.9 Hz, 2H), 3.40 (t, *J* = 5.9Hz, 2H), 3.20 (s, 3H), 2.81 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 154.8, 144.9, 144.6, 143.9, 129.8, 123.3, 53.3, 46.2, 43.6, 39.5. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{10}H_{15}N_4S^+$, 223.1012; found, 223.1002.



Methyl (*Z*)-4-((2,5-dimethyl-1,2,5-thiadiazinan-6-ylidene)amino)-5-phenylthiophene-3-carboxylate (23)

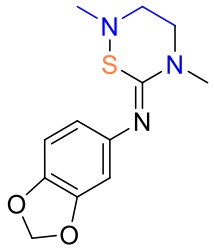
Yellow liquid (19.5 mg, 27% yield); R_f = 0.32 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60 (dt, *J* = 8.3, 2.4 Hz, 2H), 7.41 – 7.35 (m, 2H), 7.35 – 7.30 (m, 1H), 6.90 (s, 1H), 3.81 (s, 3H), 3.54 (t, *J* = 5.9 Hz, 2H), 3.42 (t, *J* = 5.9 Hz, 2H), 3.27 (s, 3H), 2.83 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 162.6, 155.2, 154.6, 147.4, 133.8, 129.1, 128.7, 126.0, 122.3, 113.5, 53.5, 51.5, 46.2, 43.6, 39.5. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{17}H_{20}N_3O_2S_2^+$, 362.0991; found, 362.0992.



Tert-butyl (*Z*)-5-((2,5-dimethyl-1,2,5-thiadiazinan-6-ylidene)amino)-1*H*-indole-1-carboxylate (24)

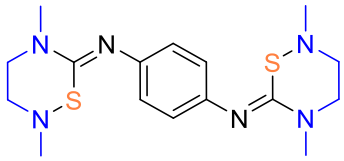
Yellow liquid (44.7 mg, 62% yield); R_f = 0.28 (PE/EA=2:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96 (d, *J* = 8.7 Hz, 1H), 7.53 (d, *J* = 3.7 Hz, 1H), 6.99 (d, *J* = 2.1 Hz, 1H),

6.82 (dd, *J* = 8.7, 2.1 Hz, 1H), 6.46 (d, *J* = 3.7 Hz, 1H), 3.50 (t, *J* = 5.9 Hz, 2H), 3.39 (t, *J* = 5.9 Hz, 2H), 3.22 (s, 3H), 2.79 (s, 3H), 1.65 (s, 9H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 154.0, 150.0, 143.9, 131.2, 126.2, 120.0, 115.3, 114.0, 107.5, 83.4, 53.5, 46.2, 44.0, 39.6, 28.4. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{18}H_{25}N_4O_2S^+$, 361.1693; found, 361.1698.



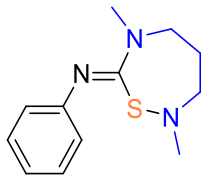
(*Z*)-*N*-(benzo[*d*][1,3]dioxol-5-yl)-2,5-dimethyl-1,2,5-thiadiazinan-6-imine (25)

Yellow solid (30.2 mg, 57% yield). m.p.: 60.5-61.4 ℃; R_f = 0.30 (PE/EA=2:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.66 (d, *J* = 8.1 Hz, 1H), 6.39 (d, *J* = 2.1 Hz, 1H), 6.26 (dd, *J* = 8.1, 2.1 Hz, 1H), 5.90 (s, 2H), 3.48 (t, *J* = 5.8 Hz, 2H), 3.38 (t, *J* = 5.9 Hz, 2H), 3.16 (s, 3H), 2.80 (s, 3H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 154.2, 147.7, 143.4, 143.2, 114.8, 108.0, 104.4, 101.0, 53.4, 46.1, 43.8, 39.5. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{12}H_{16}N_3O_2S^+$, 266.0958; found, 266.0953.



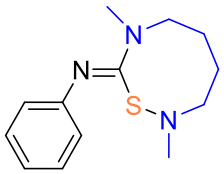
(6Z,6'Z)-N,N'-(1,4-phenylene)bis(2,5-dimethyl-1,2,5-thiadiazinan-6-imine) (26)

Yellow solid (52.4 mg, 72% yield). m.p.: 176.5-177.5 ℃; R_f = 0.29 (PE/EA=3:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.69 (s, 4H), 3.48 (t, *J* = 5.9 Hz, 4H), 3.37 (t, *J* = 5.9 Hz, 4H), 3.17 (s, 6H), 2.79 (s, 6H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 153.7, 143.7, 122.9, 53.5, 46.1, 44.0, 39.5. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{16}H_{25}N_6S_2^+$, 365.1577; found, 365.1577.



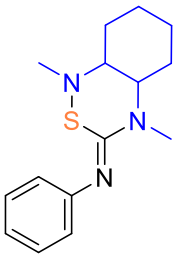
(*Z*)-2,6-dimethyl-*N*-phenyl-1,2,6-thiadiazepan-7-imine (27)

Yellow liquid (31.5 mg, 67% yield); R_f = 0.33 (PE/EA=3:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.22 (t, *J* = 7.8 Hz, 2H), 6.99 (t, *J* = 7.4 Hz, 1H), 6.72 (d, *J* = 7.3 Hz, 2H), 3.60 (s, 2H), 3.17 (t, *J* = 7.3 Hz, 2H), 3.13 (s, 3H), 2.73 (s, 3H), 1.86 (s, 2H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 161.8, 150.5, 128.6, 122.6, 122.2, 59.6, 58.6, 53.1, 44.8, 39.0, 25.8, 18.6. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{12}H_{18}N_3S^+$, 236.1216; found, 236.1211.



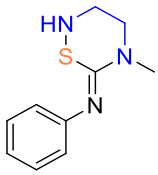
(Z)-2,7-dimethyl-N-phenyl-1,2,7-thiadiazocan-8-imine (28)

Yellow liquid (18.4 mg, 37% yield); R_f = 0.35 (PE/EA=3:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.21 (t, *J* = 7.8 Hz, 2H), 6.99 (t, *J* = 7.4 Hz, 1H), 6.70 (d, *J* = 7.2 Hz, 2H), 3.84 (s, 2H), 3.20 – 3.14 (m, 2H), 3.02 (s, 3H), 2.59 (s, 3H), 1.77 – 1.64 (m, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 157.8, 150.8, 128.4, 122.6, 122.3, 59.4, 50.7, 45.9, 35.1, 26.1, 20.3. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{13}H_{20}N_3S^+$, 250.1372; found, 250.1371.



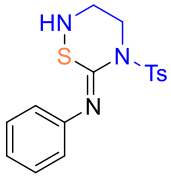
(*Z*)-1,4-dimethyl-N-phenyloctahydro-3*H*-benzo[*c*][1,2,5]thiadiazin-3-imine (29)

Yellow solid (30.3 mg, 55% yield). m.p.: 65.6-66.4 ℃; R_f = 0.31 (PE/EA=3:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.22 (t, *J* = 7.7 Hz, 2H), 7.00 (t, *J* = 7.4 Hz, 1H), 6.86 (d, *J* = 7.5 Hz, 2H), 3.29 – 3.20 (m, 1H), 3.19 (s, 3H), 2.65 (s, 3H), 2.37 (d, *J* = 11.3 Hz, 1H), 1.91 – 1.74 (m, 4H), 1.47 – 1.18 (m, 4H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 155.1, 148.7, 128.8, 123.0, 122.9, 68.1, 57.4, 40.8, 35.7, 32.0, 31.8, 25.5, 24.8. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{15}H_{22}N_3S^+$, 276.1529; found, 276.1534.



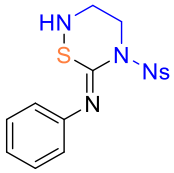
(Z)-5-methyl-N-phenyl-1,2,5-thiadiazinan-6-imine (30)

Yellow solid (29.8 mg, 72% yield). m.p.: 90.8-91.7 ℃; R_f = 0.27 (PE/EA=3:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23 (t, *J* = 7.8 Hz, 2H), 7.01 (t, *J* = 7.4 Hz, 1H), 6.85 (d, *J* = 7.4 Hz, 2H), 3.39 (s, 2H), 3.38 (s, 2H), 3.15 (s, 3H), 2.80 (s, 1H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 155.9, 148.6, 128.8, 123.1, 122.6, 50.8, 46.9, 39.7. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{10}H_{14}N_3S^+$, 208.0903; found, 208.0899.



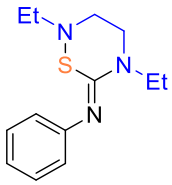
N-phenyl-5-tosyl-1,2,5-thiadiazinan-6-imine (31)

Yellow solid (31.9 mg, 46% yield). m.p.: 116.4-117.3 ℃; R_f = 0.26 (PE/EA=3:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.78 (d, *J* = 8.0 Hz, 2H), 7.48 (d, *J* = 8.0 Hz, 2H), 7.32 (t, *J* = 8.8 Hz, 4H), 7.04 (t, *J* = 7.4 Hz, 1H), 3.74 – 3.64 (m, 2H), 3.66 – 3.57 (m, 2H), 2.43 (s, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 147.9, 145.2, 140.1, 133.6, 130.2, 129.2, 127.8, 123.1, 119.4, 49.1, 47.0, 21.8. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{16}H_{18}N_3O_2S_2^+$, 348.0835; found, 348.0820.



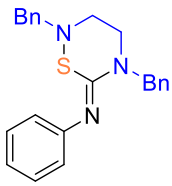
(*E*)-5-((4-nitrophenyl)sulfonyl)-*N*-phenyl-1,2,5-thiadiazinan-6-imine (32)

Yellow solid (30.2 mg, 40% yield). m.p.: 154.4-155.4 ℃; R_f = 0.29 (DCM/MeOH=20:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.39 (d, *J* = 8.4 Hz, 2H), 8.17 (d, *J* = 8.4 Hz, 2H), 7.33-7.26 (m, 4H), 7.06 (d, *J* = 7.3 Hz, 1H), 3.82 (t, *J* = 7.9 Hz, 2H), 3.61 (t, *J* = 7.9 Hz, 2H), 1.25 (s, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 150.9, 147.1, 142.6, 129.44, 129.39 (2C), 124.6, 123.6, 120.1, 47.0. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{15}H_{15}N_4O_4S_2^+$, 379.0529; found, 379.0528.



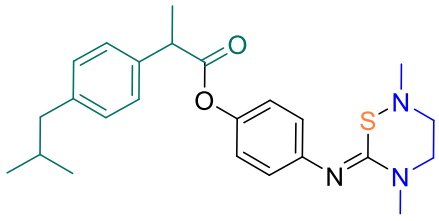
(*Z*)-2,5-diethyl-N-phenyl-1,2,5-thiadiazinan-6-imine (33)

Yellow liquid (34.9 mg, 70% yield); R_f = 0.35 (PE/EA=2:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.21 (t, *J* = 7.8 Hz, 2H), 6.98 (t, *J* = 7.4 Hz, 1H), 6.86-6.81 (m, 2H), 3.64 (q, *J* = 7.1 Hz, 2H), 3.51-3.46 (m, 2H), 3.46-3.41 (m, 2H), 2.94 (q, *J* = 7.1 Hz, 2H), 1.27 (t, *J* = 7.1 Hz, 3H), 1.09 (t, *J* = 7.1 Hz, 3H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 152.3, 149.0, 128.7, 122.7, 122.6, 52.0, 51.9, 46.1, 41.4, 14.0, 11.8. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{13}H_{20}N_3S^+$, 250.1372; found, 250.1371.



(*Z*)-2,5-dibenzyl-N-phenyl-1,2,5-thiadiazinan-6-imine (34)

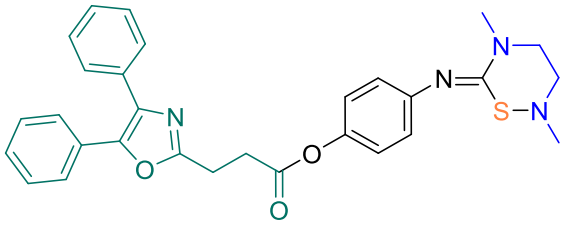
Colorless liquid (62.7 mg, 84% yield); R_f = 0.34 (PE/EA=2:1, v/v). ^{1}H NMR (400 MHz, $(CD_3)_2SO$) δ 7.48-7.38 (m, 4H), 7.34-7.21 (m, 6H), 7.15 (t, *J* = 7.7 Hz, 2H), 6.89 (t, *J* = 7.3 Hz, 1H), 6.72 (d, *J* = 7.5 Hz, 2H), 4.86 (s, 2H), 4.05 (s, 2H), 3.46 (t, *J* = 5.7 Hz, 2H), 3.34 – 3.32 (m, 2H). ^{13}C{^{1}H} NMR (101 MHz, $(CD_3)_2SO$) δ 151.7, 148.4, 137.8, 137.4 128.8, 128.62, 128.55, 128.3, 127.7, 127.6, 127.1, 122.2, 122.0, 61.1, 53.0, 50.4, 41.0. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{23}H_{24}N_3S^+$, 374.1685; found, 374.1683.



(Z)-4-((2,5-dimethyl-1,2,5-thiadiazinan-6-ylidene)amino)phenyl 2-(4-isobutylphenyl)propanoate (35)

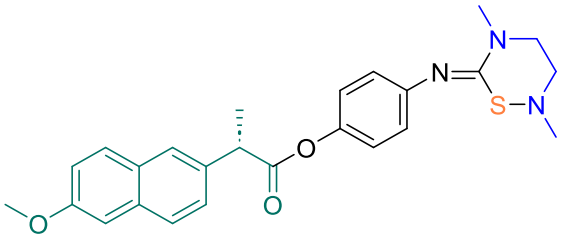
White solid (57.0 mg, 67% yield). m.p.: 62.7-63.7 ℃; R_f = 0.32 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29 (d, *J* = 8.0 Hz, 2H), 7.12 (d, *J* = 8.0 Hz, 2H), 6.85 (d,

J = 8.8 Hz, 2H), 6.77 (d, *J* = 8.8 Hz, 2H), 3.90 (q, *J* = 7.2 Hz, 1H), 3.48 (t, *J* = 5.9 Hz, 2H), 3.37 (t, *J* = 5.9 Hz, 2H), 3.16 (s, 3H), 2.78 (s, 3H), 2.46 (d, *J* = 7.1 Hz, 2H), 1.92-1.80 (m, 1H), 1.58 (d, *J* = 7.2 Hz, 3H), 0.91 (d, *J* = 6.6 Hz, 6H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 173.5, 154.0, 146.6, 146.2, 140.8, 137.6, 129.6, 127.4, 123.3, 121.5, 53.4, 46.2, 45.4, 45.2, 43.8, 39.4, 30.3, 22.6, 18.7. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{24}H_{32}N_3O_2S^+$, 426.2210; found, 426.2224.



(*Z*)-4-((2,5-dimethyl-1,2,5-thiadiazinan-6-ylidene)amino)phenyl 3-(4,5-diphenyloxazol-2-yl)propanoate (36)

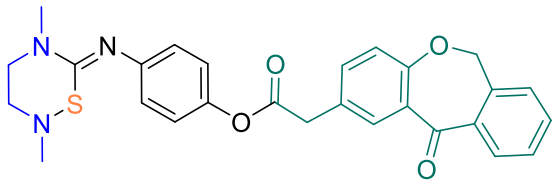
Yellow liquid (40.0 mg, 39% yield); R_f = 0.33 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, *J* = 6.8 Hz, 2H), 7.58 (dd, *J* = 8.0, 1.4 Hz, 2H), 7.40 – 7.28 (m, 6H), 6.96 (d, *J* = 8.7 Hz, 2H), 6.82 (d, *J* = 8.7 Hz, 2H), 3.49 (t, *J* = 5.9 Hz, 2H), 3.38 (t, *J* = 5.9 Hz, 2H), 3.29 (t, *J* = 7.3 Hz, 2H), 3.18 (s, 3H), 3.13 (t, *J* = 7.3 Hz, 2H), 2.79 (s, 3H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 170.9, 161.7, 154.2, 146.4, 146.1, 145.7, 135.3, 132.6, 129.1, 128.8, 128.7, 128.6, 128.2, 128.0, 126.7, 123.5, 121.6, 53.3, 46.1, 43.8, 39.6, 31.4, 23.7. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{29}H_{29}N_4O_3S^+$, 513.1955; found, 513.1957.



(*Z*)-4-((2,5-dimethyl-1,2,5-thiadiazinan-6-ylidene)amino)phenyl (*S*)-2-(6-methoxynaphthalen-2-yl)propanoate (37)

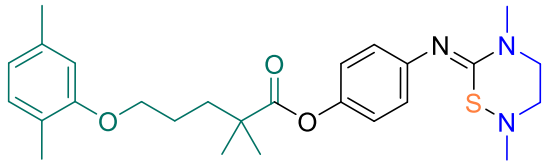
White solid (40.4 mg, 45% yield). m.p.: 128.5-129.4 °C; R_f = 0.35 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.79 – 7.70 (m, 3H), 7.50 (dd, *J* = 8.5, 1.9 Hz, 1H), 7.19 – 7.11 (m, 2H), 6.85 (d, *J* = 8.8 Hz, 2H), 6.77 (d, *J* = 8.8 Hz, 2H), 4.06 (q, *J* = 7.1 Hz, 1H), 3.92 (s, 3H), 3.47 (t, *J* = 5.9 Hz, 2H), 3.36 (t, *J* = 5.9 Hz, 2H), 3.17 (s, 3H), 2.77

(s, 3H), 1.67 (d, J = 7.1 Hz, 3H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 173.4, 157.8, 154.2, 146.6, 146.0, 135.5, 133.9, 129.5, 129.1, 127.4, 126.3, 126.2, 123.4, 121.5, 119.2, 105.7, 55.5, 53.3, 46.1, 45.7, 43.8, 39.5, 18.6. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{25}H_{28}N_3O_3S^+$, 450.1846; found, 450.1847.



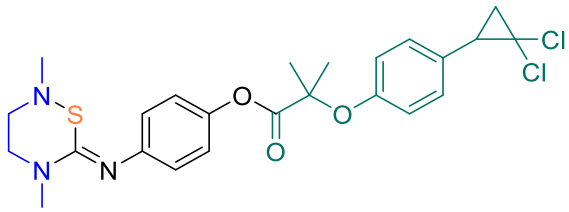
(*Z*)-4-((2,5-dimethyl-1,2,5-thiadiazinan-6-ylidene)amino)phenyl 2-(11-oxo-6,11-dihydrodibenzo[*b*,*e*]oxepin-2-yl)acetate (38)

Yellow liquid (22.4 mg, 23% yield); R_f = 0.33 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.20 (d, J = 2.4 Hz, 1H), 7.90 (dd, J = 7.7, 1.4 Hz, 1H), 7.59 - 7.44 (m, 3H), 7.37 (dd, J = 7.4, 1.3 Hz, 1H), 7.06 (d, J = 8.5 Hz, 1H), 6.94 (d, J = 8.8 Hz, 2H), 6.82 (d, J = 8.8 Hz, 2H), 5.20 (s, 2H), 3.85 (s, 2H), 3.49 (t, J = 5.9 Hz, 2H), 3.37 (t, J = 5.9 Hz, 2H), 3.19 (s, 3H), 2.79 (s, 3H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 191.0, 170.1, 160.7, 154.5, 146.5, 145.8, 140.6, 136.5, 135.7, 132.9, 132.7, 129.7, 129.4, 128.0, 127.6, 125.3, 123.5, 121.6, 121.3, 73.8, 53.3, 46.1, 43.8, 40.5, 39.7. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{27}H_{26}N_3O_4S^+$, 4702472; found, 488.1653.



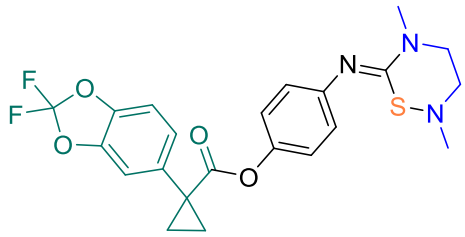
(Z)-4-((2,5-dimethyl-1,2,5-thiadiazinan-6-ylidene)amino)phenyl 5-(2,5-dimethylphenoxy)-2,2-dimethylpentanoate (39)

Colorless liquid (49.7 mg, 53% yield); R_f = 0.30 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.00 (d, J = 7.4 Hz, 1H), 6.89 (d, J = 8.8 Hz, 2H), 6.81 (d, J = 8.7 Hz, 2H), 6.71 – 6.57 (m, 2H), 3.97 (t, J = 3.0 Hz, 2H), 3.49 (t, J = 5.9 Hz, 2H), 3.38 (t, J = 5.9 Hz, 2H), 3.18 (s, 3H), 2.80 (s, 3H), 2.31 (s, 3H), 2.18 (s, 3H), 1.86 (d, J = 2.8 Hz, 4H), 1.35 (s, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 176.6, 157.0, 154.0, 146.6, 146.2, 136.6, 130.4, 123.8, 123.4, 121.6, 120.8, 112.1, 68.0, 53.3, 46.2, 43.8, 42.5, 39.5, 37.3, 25.4, 25.3, 21.5, 15.9. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{26}H_{36}N_3O_3S^+$, 470.2472; found, 470.2479.



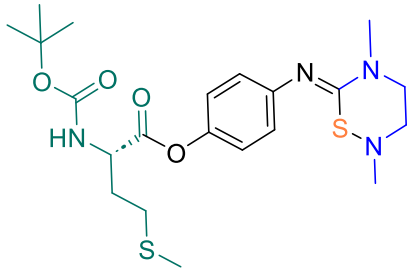
(Z)-4-((2,5-dimethyl-1,2,5-thiadiazinan-6-ylidene)amino)phenyl 2-(4-(2,2-dichlorocyclopropyl)phenoxy)-2-methylpropanoate (40)

Colorless liquid (51.7 mg, 51% yield); R_f = 0.33 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.15 (d, *J* = 8.7 Hz, 2H), 6.93 (d, *J* = 8.7 Hz, 2H), 6.87 – 6.74 (m, 4H), 3.49 (t, *J* = 5.9 Hz, 2H), 3.37 (t, *J* = 5.9 Hz, 2H), 3.18 (s, 3H), 2.85 (dd, *J* = 10.7, 8.3 Hz, 1H), 2.79 (s, 3H), 1.94 (dd, *J* = 10.7, 7.4 Hz, 1H), 1.80 (d, *J* = 7.9 Hz, 1H), 1.73 (s, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 173.1, 155.2, 154.3, 146.2, 129.9, 128.4, 123.5, 121.4, 118.7, 79.4, 61.0, 53.3, 46.1, 43.8, 39.6, 35.0, 26.0, 25.6. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{24}H_{28}Cl_2N_3O_3S^+$, 508.1223; found, 508.1231.



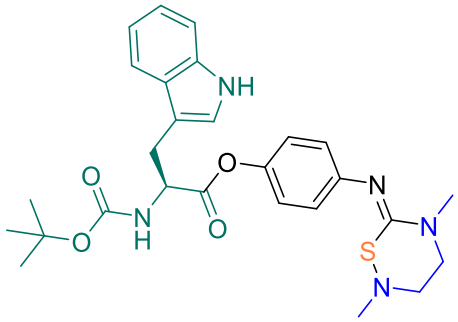
(Z)-4-((2,5-dimethyl-1,2,5-thiadiazinan-6-ylidene)amino)phenyl 1-(2,2-difluorobenzo[d][1,3]dioxol-5-yl)cyclopropane-1-carboxylate (41)

Colorless liquid (46.1 mg, 50% yield); R_f = 0.36 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.15 (dd, *J* = 10.3, 2.0 Hz, 2H), 7.00 (d, *J* = 8.1 Hz, 1H), 6.87 (d, *J* = 8.7 Hz, 2H), 6.78 (d, *J* = 8.7 Hz, 2H), 3.47 (t, *J* = 5.9 Hz, 2H), 3.36 (t, *J* = 5.9 Hz, 2H), 3.16 (s, 3H), 2.77 (s, 3H), 1.78 (q, *J* = 4.0 Hz, 2H), 1.29 (q, *J* = 4.1 Hz, 2H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 172.9, 154.0, 146.4, 146.3, 143.6, 143.0, 135.5, 131.8 (t, J_{C-F} = 255.0 Hz), 125.9, 123.3, 121.4, 112.2, 109.1, 53.3, 46.1, 43.7, 39.4, 29.2, 17.6. ^{19}F NMR (376 MHz, $CDCl_3$) δ -49.76. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{22}H_{22}F_2N_3O_4S^+$, 462.1294; found, 462.1309.



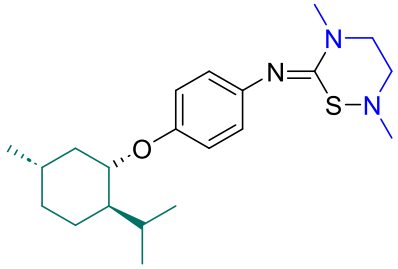
(*Z*)-4-((2,5-dimethyl-1,2,5-thiadiazinan-6-ylidene)amino)phenyl (tert-butoxycarbonyl)-*L*-methioninate (42)

Yellow liquid (29.0 mg, 31% yield); R_f = 0.29 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.95 (d, *J* = 8.7 Hz, 2H), 6.84 (d, *J* = 8.7 Hz, 2H), 5.20 (d, *J* = 8.5 Hz, 1H), 4.63 (t, *J* = 7.8 Hz, 1H), 3.50 (t, *J* = 5.9 Hz, 2H), 3.38 (t, *J* = 5.8 Hz, 2H), 3.19 (s, 3H), 2.80 (s, 3H), 2.63 (t, *J* = 7.5 Hz, 2H), 2.34 - 2.17 (m, 2H), 2.13 (s, 3H), 1.46 (s, 9H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 171.2, 155.5, 154.3, 146.3, 146.1, 123.6, 121.4, 80.3, 53.3, 53.1, 46.1, 43.8, 39.6, 32.3, 30.1, 28.5, 15.7. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{21}H_{33}N_4O_4S_2^+$, 469.1938; found, 469.1934.



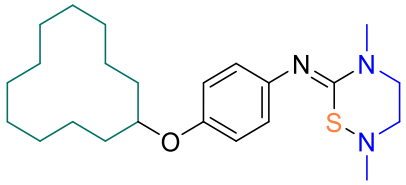
(Z)-4-((2,5-dimethyl-1,2,5-thiadiazinan-6-ylidene)amino)phenyl (tert-butoxycarbonyl)-L-tryptophanate (43)

White solid (68.0 mg, 65% yield). m.p.: 82.2-83.2 ℃; R_f = 0.34 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.35 (s, 1H), 7.63 (d, *J* = 7.9 Hz, 1H), 7.34 (d, *J* = 8.1 Hz, 1H), 7.19 (t, *J* = 7.5 Hz, 1H), 7.12 (t, *J* = 7.4 Hz, 1H), 7.04 (s, 1H), 6.80 (s, 4H), 5.20 (d, *J* = 8.2 Hz, 1H), 4.87 (d, *J* = 7.0 Hz, 1H), 3.48 (t, *J* = 5.9 Hz, 2H), 3.42 (d, *J* = 5.3 Hz, 2H), 3.37 (t, *J* = 5.8 Hz, 2H), 3.17 (s, 3H), 2.78 (s, 3H), 1.44 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 171.2, 155.4, 154.0, 146.4, 146.1, 136.3, 127.9, 123.4, 123.1, 122.3, 121.4, 119. 8, 119.1, 111.3, 110.1, 80.0, 54.7, 53.3, 46.1, 43.7, 39.5, 28.5, 28.2. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{27}H_{34}N_5O_4S^+$, 524.2326; found, 524.2331.



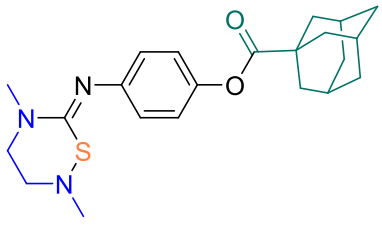
(*Z*)-N-(4-(((1S,2R,5S)-2-isopropyl-5-methylcyclohexyl)oxy)phenyl)-2,5-dimethyl-1,2,5-thiadiazinan-6-imine (44)

Colorless liquid (45.0 mg, 60% yield); R_f = 0.35 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.74 (q, *J* = 8.9 Hz, 4H), 4.51 (d, *J* = 2.8 Hz, 1H), 3.48 (t, *J* = 5.8 Hz, 2H), 3.38 (t, *J* = 5.9 Hz, 2H), 3.17 (s, 3H), 2.80 (s, 3H), 2.17 – 1.98 (m, 1H), 1.81 – 1.62 (m, 5H), 1.61 – 1.47 (m, 1H), 1.05 – 0.91 (m, 2H), 0.91 (d, *J* = 6.8 Hz, 3H), 0.87 (d, *J* = 6.7 Hz, 3H), 0.80 (d, *J* = 6.5 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 154.4, 153.7, 141.3, 123.4, 116.6, 74.1, 53.5, 48.1, 46.1, 43.9, 39.5, 38.0, 35.2, 29.3, 26.2, 25.0, 22.5, 21.2, 21.1. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{21}H_{34}N_3OS^+$, 376.2417; found, 376.2420.



(Z)-N-(4-(cyclododecyloxy)phenyl)-2,5-dimethyl-1,2,5-thiadiazinan-6-imine (45)

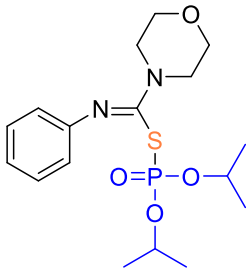
White solid (33.1 mg, 41% yield). m.p.: 88.3-89.3 ℃; R_f = 0.34 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.85 – 6.68 (m, 4H), 4.35 – 4.28 (m, 1H), 3.49 (t, *J* = 5.9 Hz, 2H), 3.38 (t, *J* = 5.8 Hz, 2H), 3.18 (s, 3H), 2.80 (s, 3H), 1.80 – 1.69 (m, 2H), 1.67 – 1.57 (m, 2H), 1.49 – 1.20 (m, 18H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 154.4, 154.1, 141.3, 123.5, 116.5, 75.9, 53.4, 46.1, 43.9, 39.6, 28.9, 24.7, 24.3, 23.3, 23.2, 20.8. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{23}H_{38}N_3OS^+$, 404.2730; found, 404.2726.



(Z)-4-((2,5-dimethyl-1,2,5-thiadiazinan-6-ylidene)amino)phenyl adamantane-1-

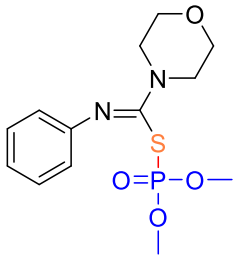
carboxylate (46)

White solid (36.7 mg, 46% yield). m.p.: 85.8-86.8 ℃; R_f = 0.35 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.90 (d, *J* = 8.7 Hz, 2H), 6.81 (d, *J* = 8.7 Hz, 2H), 3.49 (t, *J* = 5.9 Hz, 2H), 3.38 (t, *J* = 5.8 Hz, 2H), 3.18 (s, 3H), 2.79 (s, 3H), 2.06 (s, 3H), 2.03 (s, 6H), 1.75 (s, 6H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 176.4, 154.2, 146.8, 145.9, 123.4, 121.6, 53.3, 46.1, 43.8, 41.1, 39.5, 38.9, 36.6, 28.1. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{22}H_{30}N_3O_2S^+$, 400.2053; found, 400.2047.



(Z)-(diisopropyl phosphoric) (Z)-N-phenylmorpholine-4-carbimidic thioanhydride (47)

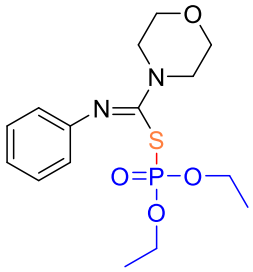
Yellow solid (68.0 mg, 88% yield). m.p.: 81.6-82.6 ℃; R_f = 0.35 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 - 7.27 (m, 4H), 7.12 (tt, *J* = 6.2, 2.1 Hz, 1H), 4.91 - 4.79 (m, 2H), 4.10 (t, *J* = 4.9 Hz, 4H), 3.74 (t, J = 4.9 Hz, 4H), 1.33 (s, 3H), 1.31 (s, 3H), 1.29 (s, 3H), 1.28 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.4 (d, J_{C-P} = 6.5 Hz), 141.4 (d, J_{C-P} = 3.0 Hz), 129.1, 124.8, 122.6 (d, J_{C-P} = 3.8 Hz), 73.4 (d, J_{C-P} = 6.0 Hz), 66.2, 51.2, 23.8 (d, J_{C-P} = 4.9 Hz). ^{31}P NMR (162 MHz, $CDCl_3$) δ -6.46. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{17}H_{28}N_2O_4PS^+$, 387.1502; found, 387.1507.



(Z)-(dimethyl phosphoric) (Z)-N-phenylmorpholine-4-carbimidic thioanhydride (48)

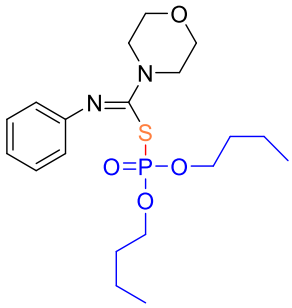
Yellow solid (42.3 mg, 64% yield). m.p.: 89.2-90.2 ℃; R_f = 0.32 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41 – 7.28 (m, 4H), 7.23 – 7.14 (m, 1H), 4.08 (t, *J* = 4.7

Hz, 4H), 3.87 (s, 3H), 3.84 (s, 3H), 3.69 (t, J = 4.8 Hz, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 185.1 (d, $J_{C\text{-}P}$ = 7.1 Hz), 140.9 (d, $J_{C\text{-}P}$ = 2.8 Hz), 129.5, 125.8, 123.6 (d, $J_{C\text{-}P}$ = 3.7 Hz), 66.1, 54.9 (d, $J_{C\text{-}P}$ = 5.9 Hz), 51.2. ^{31}P NMR (162 MHz, $CDCl_3$) δ -1.15. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{13}H_{20}N_2O_4PS^+$, 331.0876; found, 331.0876.



(Z)-(diethyl phosphoric) (Z)-N-phenylmorpholine-4-carbimidic thioanhydride (49)

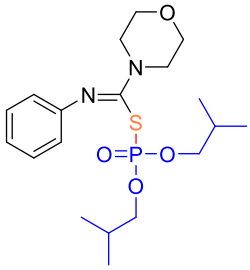
Yellow liquid (43.0 mg, 60% yield); R_f = 0.34 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38 – 7.29 (m, J = 9.1, 4H), 7.17 (tt, J = 6.7, 1.7 Hz, 1H), 4.30 – 4.18 (m, 4H), 4.09 (t, J = 5.0 Hz, 4H), 3.71 (t, J = 4.7 Hz, 4H), 1.33 – 1.28 (m, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 185.3 (d, $J_{C\text{-}P}$ = 6.8 Hz), 141.2 (d, $J_{C\text{-}P}$ = 3.0 Hz), 129.3, 125.5, 123.4 (d, $J_{C\text{-}P}$ = 3.7 Hz), 66.2, 64.5 (d, $J_{C\text{-}P}$ = 5.9 Hz), 51.2, 16.2 (d, $J_{C\text{-}P}$ = 7.0 Hz). ^{31}P NMR (162 MHz, $CDCl_3$) δ -4.04. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{15}H_{24}N_2O_4PS^+$, 359.1189; found, 359.1194.



(Z)-(dibutyl phosphoric) (Z)-N-phenylmorpholine-4-carbimidic thioanhydride (50)

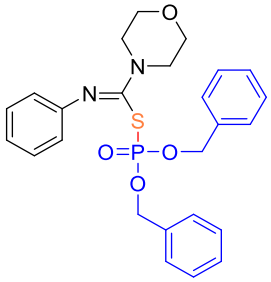
Yellow liquid (58.0 mg, 70% yield); R_f = 0.31 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37 - 7.28 (m, 4H), 7.16 (t, J = 6.6 Hz, 1H), 4.21 - 4.12 (m, 4H), 4.09 (t, J = 4.9 Hz, 4H), 3.72 (t, J = 4.8 Hz, 4H), 1.69 - 1.56 (m, 4H), 1.40 - 1.27 (m, 4H), 0.88 (t, J = 7.4 Hz, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 185.3 (d, $J_{C\text{-}P}$ = 6.6 Hz), 141.2 (d, $J_{C\text{-}P}$ = 2.9 Hz), 129.3, 125.4, 123.3 (d, $J_{C\text{-}P}$ = 3.7 Hz), 68.1 (d, $J_{C\text{-}P}$ = 6.0 Hz), 66.2, 51.2, 32.3 (d, $J_{C\text{-}P}$ = 7.1 Hz), 18.8, 13.7. ^{31}P NMR (162 MHz, $CDCl_3$) δ -3.88. HRMS (ESI-

TOF) m/z: $[M+H]^+$ calcd for $C_{19}H_{32}N_2O_4PS^+$, 415.1815; found, 415.1823.



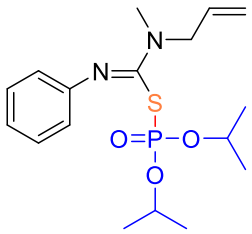
(Z)-(diisobutyl phosphoric) (Z)-N-phenylmorpholine-4-carbimidic thioanhydride (51)

Yellow liquid (59.6 mg, 72% yield); R_f = 0.33 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 - 7.27 (m, 4H), 7.16 (t, J = 6.9 Hz, 1H), 4.10 (t, J = 4.8 Hz, 4H), 3.99 - 3.87 (m, 4H), 3.72 (t, J = 4.8 Hz, 4H), 1.99 - 1.86 (m, 2H), 0.901 (s, 3H), 0.896 (s, 3H), 0.884 (s, 3H), 0.879 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 185.3 (d, J_{C-P} = 6.7 Hz), 141.1 (d, J_{C-P} = 2.9 Hz), 129.3, 125.4, 123.4 (d, J_{C-P} = 3.7 Hz), 74.1 (d, J_{C-P} = 6.3 Hz), 66.2, 51.2, 29.2 (d, J_{C-P} = 7.4 Hz), 18.8 (d, J_{C-P} = 1.8 Hz). HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{19}H_{32}N_2O_4PS^+$, 415.1815; found, 415.1816.



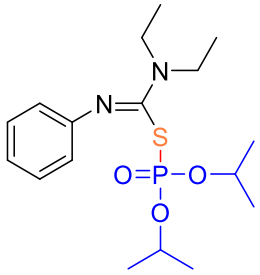
(Z)-(dibenzyl phosphoric) (Z)-N-phenylmorpholine-4-carbimidic thioanhydride (52)

Yellow liquid (46.3 mg, 48% yield); R_f = 0.34 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 (d, J = 8.0 Hz, 2H), 7.34 - 7.27 (m, 12H), 7.18 (t, J = 7.3 Hz, 1H), 5.31 – 5.09 (m, 4H), 4.01 (t, J = 4.9 Hz, 4H), 3.60 (t, J = 4.8 Hz, 4H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 185.0 (d, J_{C-P} = 6.9 Hz), 140.8 (d, J_{C-P} = 3.0 Hz), 135.8 (d, J_{C-P} = 7.6 Hz), 129.4, 128.7, 128.3, 125.8, 123.8 (d, J_{C-P} = 3.7 Hz), 69.8 (d, J_{C-P} = 5.6 Hz), 66.1, 51.2. ^{31}P NMR (162 MHz, $CDCl_3$) δ -3.57. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{25}H_{28}N_2O_4PS^+$, 483.1502; found, 483.1506.



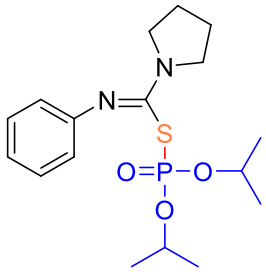
(Z)-(Z)-N-allyl-N-methyl-N'-phenylcarbamimidic (diisopropyl phosphoric) thioanhydride (53)

Yellow liquid (51.8 mg, 70% yield); R_f = 0.30 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37 - 7.26 (m, 4H), 7.11 (t, J = 7.2 Hz, 1H), 5.90 - 5.75 (m, 1H), 5.32 - 5.22 (m, 2H), 4.94 - 4.81 (m, 2H), 4.50 (d, J = 6.0 Hz, 2H), 3.31 (s, 3H), 1.33 (s, 3H), 1.32 (s, 3H), 1.28 (s, 3H), 1.26 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 186.2 (d, J_{C-P} = 6.8 Hz), 141.3 (d, J_{C-P} = 3.1 Hz), 130.9, 129.1, 124.5, 122.3 (d, J_{C-P} = 3.9 Hz), 119.5, 73.2 (d, J_{C-P} = 6.0 Hz), 58.0, 40.4, 23.8 (dd, J_{C-P} = 6.2, 4.9 Hz). ^{31}P NMR (162 MHz, $CDCl_3$) δ -6.26. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{17}H_{28}N_2O_3PS^+$, 371.1553; found, 371.1552.



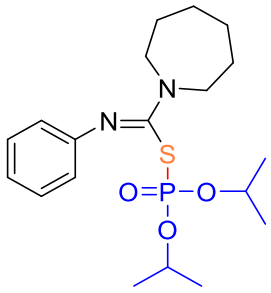
(Z)-(Z)-N,N-diethyl-N'-phenylcarbamimidic (diisopropyl phosphoric) thioanhydride (54)

Yellow solid (65.2 mg, 88% yield). m.p.: 67.6-68.6 ℃; R_f = 0.33 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37 (d, J = 8.2 Hz, 2H), 7.28 (t, J = 6.7 Hz, 2H), 7.07 (t, J = 7.3 Hz, 1H), 4.97 - 4.84 (m, 2H), 3.84 (s, 4H), 1.35 (s, 3H), 1.33 (s, 3H), 1.28 (s, 3H), 1.26 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.4 (d, J_{C-P} = 6.8 Hz), 141.4 (d, J_{C-P} = 3.3 Hz), 129.0, 123.9, 121.2 (d, J_{C-P} = 4.0 Hz), 73.0 (d, J_{C-P} = 5.9 Hz), 47.0, 23.8 (dd, J_{C-P} = 6.7, 4.9 Hz), 11.7. ^{31}P NMR (162 MHz, $CDCl_3$) δ -5.90. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{17}H_{30}N_2O_3PS^+$, 373.1709; found, 373.1708.



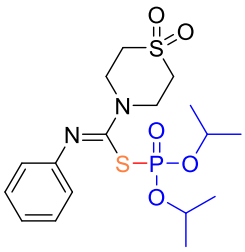
(Z)-(diisopropyl phosphoric) (Z)-N-phenylpyrrolidine-1-carbimidic thioanhydride (55)

Yellow solid (69.2 mg, 93% yield). m.p.: 94.1-95.1 ℃; R_f = 0.31 (PE/EA = 1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31 - 7.19 (m, 4H), 7.04 (t, *J* = 7.1 Hz, 1H), 4.96 - 4.72 (m, *J* = 6.3 Hz, 2H), 3.73 (s, 4H), 1.92 (s, 4H), 1.27 (s, 3H), 1.26 (s, 3H), 1.21 (s, 3H), 1.20 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 182.2 (d, J_{C-P} = 6.8 Hz), 140.9 (d, J_{C-P} = 3.1 Hz), 129.0, 124. 4, 122.3 (d, J_{C-P} = 4.0 Hz), 73.0 (d, J_{C-P} = 5.8 Hz), 53.0 (m), 25.4 (m), 23.84, 23.80, 23.76, 23.70. ^{31}P NMR (162 MHz, $CDCl_3$) δ -6.28. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{17}H_{28}N_2O_3PS^+$, 371.1553; found, 371.1551.



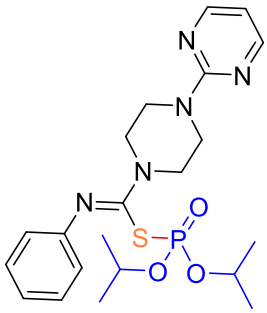
(Z)-(diisopropyl phosphoric) (Z)-N-phenylazepane-1-carbimidic thioanhydride (56)

Yellow solid (47.8 mg, 60% yield). m.p.: 62.8-63.8 ℃; R_f = 0.35 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.36 (d, *J* = 7.7 Hz, 2H), 7.29 (dd, *J* = 8.8, 7.2 Hz, 2H), 7.07 (t, *J* = 7.3 Hz, 1H), 5.01 – 4.79 (m, 2H), 3.94 (s, 4H), 2.00 – 1.74 (m, 4H), 1.68 – 1.54 (m, 4H), 1.34 (s, 3H), 1.33 (s, 3H), 1.27 (s, 3H), 1.25 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 184.9 (d, *J* = 6.9 Hz), 141.3 (d, *J* = 3.3 Hz), 129.0, 123.9, 121.3 (d, *J* = 4.0 Hz), 73.0 (d, *J* = 5.9 Hz), 53.2 (m), 27.2 (m), 25.7, 23.9, 23.82, 23.76. ^{31}P NMR (162 MHz, $CDCl_3$) δ -5.97. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{19}H_{32}N_2O_3PS^+$, 399.1866; found, 399.1864.



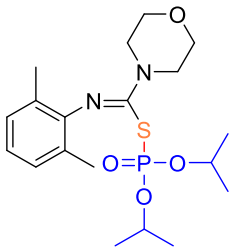
(*Z*)-(diisopropyl phosphoric) (*Z*)-N-phenylthiomorpholine-4-carbimidic 1,1-dioxide (57)

White solid (33.0 mg, 38% yield). m.p.: 100.4-101.3 ℃; R_f = 0.32 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38 -7.28 (m, 4H), 7.21 - 7.14 (m, 1H), 4.90 - 4.74 (m, 2H), 4.53 (s, 4H), 3.19 (s, 4H), 1.34 – 1.22 (m, 12H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 187.7 (d, J_{C-P} = 7.3 Hz), 141.0, 129.4, 125.6, 123.1 (d, J_{C-P} = 3.6 Hz), 73.8 (d, J_{C-P} = 6.0 Hz), 50.9, 48.5, 23.8 (dd, J_{C-P} = 8.7, 4.8 Hz). ^{31}P NMR (162 MHz, $CDCl_3$) δ -6.24. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{17}H_{28}N_2O_5PS_2^+$, 435.1172; found, 435.1183.



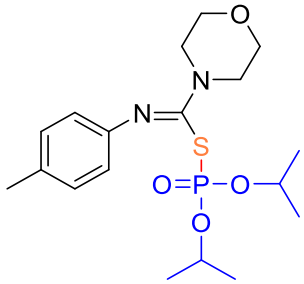
(*Z*)-(diisopropyl phosphoric) (*Z*)-N-phenyl-4-(pyrimidin-2-yl)piperazine-1-carbimidic thioanhydride (58)

White solid (43.5 mg, 47% yield). m.p.: 109.7-110.7 ℃; R_f = 0.30 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.31 (d, *J* = 4.8 Hz, 2H), 7.37 – 7.27 (m, 4H), 7.11 (t, *J* = 7.2 Hz, 1H), 6.53 (t, *J* = 4.8 Hz, 1H), 4.99 – 4.73 (m, 2H), 4.16 (t, *J* = 4.8 Hz, 4H), 3.92 (t, *J* = 5.3 Hz, 4H), 1.33 (s, 3H), 1.32 (s, 3H), 1.30 (s, 3H), 1.28 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 185.4 (d, J_{C-F} = 6.7 Hz), 161.4, 157.9, 141.4 (d, J_{C-F} = 3.1 Hz), 129.1, 124.7, 122.5 (d, J_{C-F} = 3.8 Hz), 110.7, 73.3 (d, J_{C-F} = 5.9 Hz), 50.4, 43.0, 23.9 - 23.7 (m). ^{31}P NMR (162 MHz, $CDCl_3$) δ -6.29. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{21}H_{31}N_5O_3PS^+$, 464.1880; found, 464.1884.



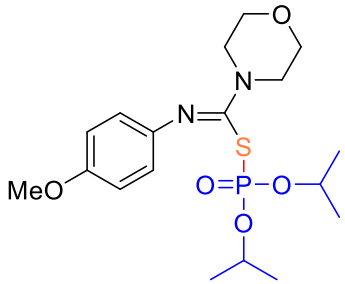
(Z)-(diisopropyl phosphoric) (Z)-N-(2,6-dimethylphenyl)morpholine-4-carbimidic thioanhydride (59)

Yellow solid (49.7 mg, 60% yield). m.p.: 120.5-121.5 ℃; R_f = 0.31 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.11 (t, J = 7.3 Hz, 1H), 7.03 (d, J = 7.7 Hz, 2H), 4.70 - 4.57 (m, 2H), 3.89 (t, J = 4.7 Hz, 4H), 3.71 (t, J = 4.7 Hz, 4H), 2.34 (s, 6H), 1.29 (s, 3H), 1.27 (s, 3H), 1.00 (s, 3H), 0.99 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.9 (d, J_{C-P} = 4.9 Hz), 140.5 (d, J_{C-P} = 2.3 Hz), 138.6 (d, J_{C-P} = 1.7 Hz), 128.8, 128.1 (d, J_{C-P} = 1.5 Hz), 73.9 (d, J_{C-P} = 6.5 Hz), 66.6, 54.0, 24.0 (d, J_{C-P} = 3.6 Hz), 23.1 (d, J_{C-P} = 6.5 Hz), 20.0. ^{31}P NMR (162 MHz, $CDCl_3$) δ -4.06. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{19}H_{32}N_2O_4PS^+$, 415.1815; found, 415.1827.



(Z)-(diisopropyl phosphoric) (Z)-N-(p-tolyl)morpholine-4-carbimidic thioanhydride (60)

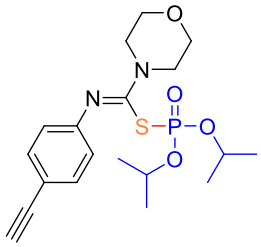
Colorless liquid (63.2 mg, 79% yield). R_f = 0.32 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23 (d, J = 8.2 Hz, 2H), 7.10 (d, J = 8.0 Hz, 2H), 4.90 – 4.74 (m, J = 6.3 Hz, 2H), 4.09 (t, J = 4.8 Hz, 4H), 3.72 (t, J = 4.8 Hz, 4H), 2.30 (s, 3H), 1.36 – 1.25 (m, 12H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 185.8 (d, J_{C-P} = 7.0 Hz), 138.9, 134.9, 129.7, 123.3 (d, J_{C-P} = 3.6 Hz), 73.3 (d, J_{C-P} = 6.1 Hz), 66.2, 51.2, 23.82 (d, J_{C-P} = 1.9 Hz), 23.77, 20.9. ^{31}P NMR (162 MHz, $CDCl_3$) δ -6.19. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{18}H_{30}N_2O_4PS^+$, 401.1658; found, 401.1671.



(*Z*)-(diisopropyl phosphoric) (*Z*)-N-(4-methoxyphenyl)morpholine-4-carbimidic thioanhydride (61)

Yellow liquid (44.9 mg, 54% yield). R_f = 0.29 (PE/EA=1:2, v/v).

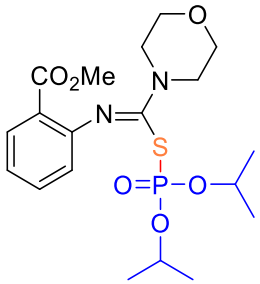
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.33 (d, *J* = 8.5 Hz, 2H), 6.84 (d, *J* = 8.6 Hz, 2H), 4.90 – 4.65 (m, *J* = 6.4 Hz, 2H), 4.10 (t, *J* = 4.9 Hz, 4H), 3.78 (s, 3H), 3.71 (t, *J* = 4.9 Hz, 4H), 1.29 (s, 6H), 1.27 (s, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 186.3 (d, J_{C-P} = 7.6 Hz), 157.7, 134.3 (d, J_{C-P} = 2.8 Hz), 126.7 (d, J_{C-P} = 3.3 Hz), 114.2, 73.3 (d, J_{C-P} = 6.1 Hz), 66.3, 55.5, 51.3, 23.8 (dd, J_{C-P} = 4.9, 2.3 Hz). ^{31}P NMR (162 MHz, $CDCl_3$) δ -5.77. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{18}H_{30}N_2O_5PS^+$, 417.1608; found, 417.1616.



(*Z*)-(*Z*)-N-(4-ethynylphenyl)morpholine-4-carbimidic (diisopropyl phosphoric) thioanhydride (62)

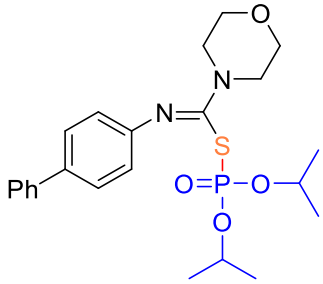
Yellow solid (45.9 mg, 56% yield). m.p.: 115.8-116.8 ℃; R_f = 0.30 (PE/EA=1:1, v/v).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 (d, *J* = 8.3 Hz, 2H), 7.23 (d, *J* = 8.4 Hz, 2H), 4.95 – 4.79 (m, *J* = 6.3 Hz, 2H), 4.08 (t, *J* = 4.9 Hz, 4H), 3.76 (t, *J* = 4.9 Hz, 4H), 3.05 (s, 1H), 1.34 (s, 3H), 1.33 (s, 3H), 1.30 (s, 3H), 1.28 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 184.4 (d, J_{C-P} = 6.4 Hz), 141.6 (d, J_{C-P} = 3.3 Hz), 133.0, 121.1 (d, J_{C-P} = 4.1 Hz), 117.7, 83.2, 73.7 (d, J_{C-P} = 5.9 Hz), 66.2, 51.1, 23.8 (d, J_{C-P} = 4.8 Hz). ^{31}P NMR (162 MHz, $CDCl_3$) δ -7.00. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{19}H_{28}N_2O_4PS^+$, 411.1502; found, 411.1509.



(*Z*)-(diisopropyl phosphoric) (*Z*)-N-(2-(methoxycarbonyl)phenyl)morpholine-4-carbimidic thioanhydride (63)

Yellow solid (40.0 mg, 45% yield). m.p.: 89.7-90.6 ℃; R_f = 0.32 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70 (dd, *J* = 8.0, 1.5 Hz, 2H), 7.55 – 7.44 (m, 1H), 7.32 (t, *J* = 7.6 Hz, 1H), 4.74 – 4.62 (m, 2H), 4.10 (t, *J* = 4.8 Hz, 4H), 3.84 (s, 3H), 3.68 (d, *J* = 4.7 Hz, 4H), 1.26 (s, 3H), 1.25 (s, 3H), 1.21 (s, 3H), 1.19 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 186.9 (d, J_{C-P} = 5.1 Hz), 167.0, 141.0 (d, J_{C-P} = 2.4 Hz), 132.3 (d, J_{C-P} = 2.1 Hz), 131.3, 130.3 (d, J_{C-P} = 3.3 Hz), 130.1, 127.4, 73.5 (d, J_{C-P} = 6.2 Hz), 66.5, 52.6, 52.3, 23.7 (d, J_{C-P} = 4.5 Hz), 23.6 (d, J_{C-P} = 5.8 Hz). ^{31}P NMR (162 MHz, $CDCl_3$) δ -4.73. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{19}H_{30}N_2O_6PS^+$, 445.1557; found, 445.1560.

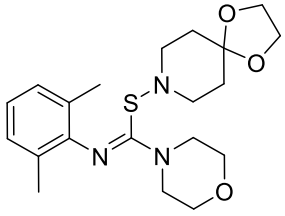


(*Z*)-(*Z*)-N-([1,1'-biphenyl]-4-yl)morpholine-4-carbimidic (diisopropyl phosphoric) thioanhydride (64)

Yellow liquid (53.6 mg, 58% yield). R_f = 0.34 (PE/EA=1:1, v/v).

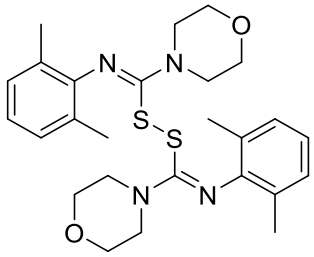
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55 (t, *J* = 7.5 Hz, 4H), 7.46 – 7.35 (m, 4H), 7.33 (t, *J* = 7.3 Hz, 1H), 4.97 – 4.80 (m, *J* = 6.3 Hz, 2H), 4.14 (t, *J* = 4.8 Hz, 4H), 3.79 (t, *J* = 4.2 Hz, 4H), 1.36 (s, 3H), 1.34 (s, 3H), 1.33 (s, 3H), 1.31 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 185.2 (d, J_{C-P} = 6.4 Hz), 140.6 (d, J_{C-P} = 3.1 Hz), 140.3, 137.4, 128.9, 127.8, 127.3, 127.0, 122.5 (d, J_{C-P} = 3.9 Hz), 73.5 (d, J_{C-P} = 6.1 Hz), 66.3, 51.2, 23.8 (dd, J_{C-P} = 4.9, 2.1 Hz). ^{31}P NMR (162 MHz, $CDCl_3$) δ -6.56. HRMS (ESI-TOF) m/z: $[M+H]^+$

calcd for $C_{23}H_{32}N_2O_4PS^+$, 463.1815; found, 463.1817.



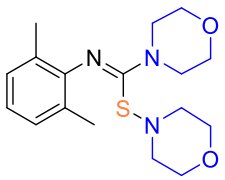
1,4-dioxa-8-azaspiro[4.5]decan-8-yl (Z)-N-(2,6-dimethylphenyl)morpholine-4-carbimidothioate (67)

Yellow solid (43.8 mg, 56% yield). m.p.: 62.5-63.5 ℃; R_f = 0.28 (PE/EA=3:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.96 (d, *J* = 7.5 Hz, 2H), 6.80 (t, *J* = 7.5 Hz, 1H), 3.87 (s, 4H), 3.77 (t, *J* = 4.8 Hz, 4H), 3.56 (t, *J* = 4.7 Hz, 4H), 2.78 (t, *J* = 5.7 Hz, 4H), 2.11 (s, 6H), 1.50 (t, *J* = 5.7 Hz, 4H). ^{13}C{^{1}H} NMR (101 MHz, $CDCl_3$) δ 157.2, 146.5, 127.7, 127.4, 122.1, 106.0, 67.0, 64.3, 55.2, 49.2, 35.6, 18.6. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{20}H_{30}N_3O_3S^+$, 392.2002; found, 392.2007.



(Z)-N-(2,6-dimethylphenyl)morpholine-4-carbimidic dithioperoxyanhydride (69)

Yellow solid (57.8 mg, 58% yield). m.p.: 132.9-133.9 ℃; R_f = 0.31 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.03 (d, *J* = 7.5 Hz, 4H), 6.94 (dd, *J* = 8.2, 6.7 Hz, 2H), 3.50 (t, *J* = 4.4 Hz, 8H), 3.32 (t, *J* = 4.6 Hz, 8H), 2.05 (s, 12H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 153.6, 146.5, 128.0, 127.7, 123.2, 65.8, 49.2, 18.6. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{26}H_{35}N_4O_2S_2^+$, 499.2196; found, 499.2196.



morpholino (Z)-N-(2,6-dimethylphenyl)morpholine-4-carbimidothioate (70)

Yellow solid (43.6 mg, 65% yield). m.p.: 99.5-100.5 ℃; R_f = 0.32 (PE/EA=1:1, v/v). ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.97 (d, *J* = 7.4 Hz, 2H), 6.80 (t, *J* = 7.5 Hz, 1H), 3.77

(t, *J* = 4.7 Hz, 4H), 3.57 (t, *J* = 4.7 Hz, 4H), 3.39 (t, *J* = 4.7 Hz, 4H), 2.65 (t, *J* = 4.6 Hz, 4H), 2.13 (s, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 156.3, 146.5, 127.8, 127.4, 122.1, 67.4, 66. 9, 56.9, 49.2, 18.7. HRMS (ESI-TOF) m/z: $[M+H]^+$ calcd for $C_{17}H_{26}N_3O_2S^+$, 336.1740; found, 336.1750.

7. Crystal data and ORTEP diagram for compound 21

Supplementary Table 6. Crystallographic Data of Compound **21**

Empirical formula	$C_{13}H_{15}N_3S$
Formula weight	245.34
Temperature	297(2) K
Wavelength	1.54178 Å
Crystal system	Orthorhombic
space group	Pbca
Unit cell dimensions	a = 14.3166 (4) Å α = 90 ° b = 10.3015 (3) Å β = 90 ° c = 17.5450 (4) Å γ = 90 °
Volume	2587.58 (12) Å^3
Z	8
Calculated density	1.260 Mg/m^3
Absorption coefficient	2.061 mm^{-1}
F(000)	1040
Crystal size	0.23 × 0.22 × 0.21 mm
Theta range for data collection	5.041 ° to 68.414 °
Limiting indices	-15≤h≤17, -12≤k≤10, -21≤l≤19
Reflections collected	21803
Independent reflections	2369 [R(int) = 0.0389]
Data / restraints / parameters	2369 / 0 / 157
Goodness-of-fit on F^2	1.074
Final R indices [I>2σ(I)]	R_1 = 0.0361, wR_2 = 0.1055
R indices (all data)	R_1 = 0.0389, wR_2 = 0.1074
Largest diff. peak and hole	0.240 and -0.222 e. Å^{-3}

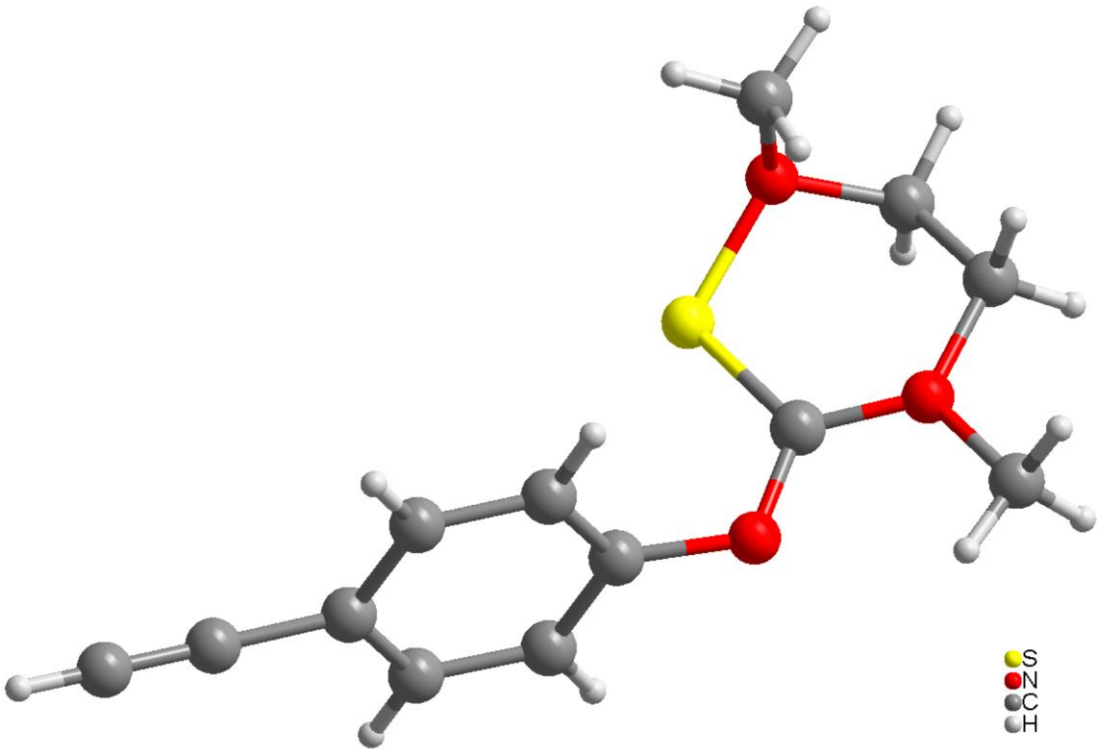
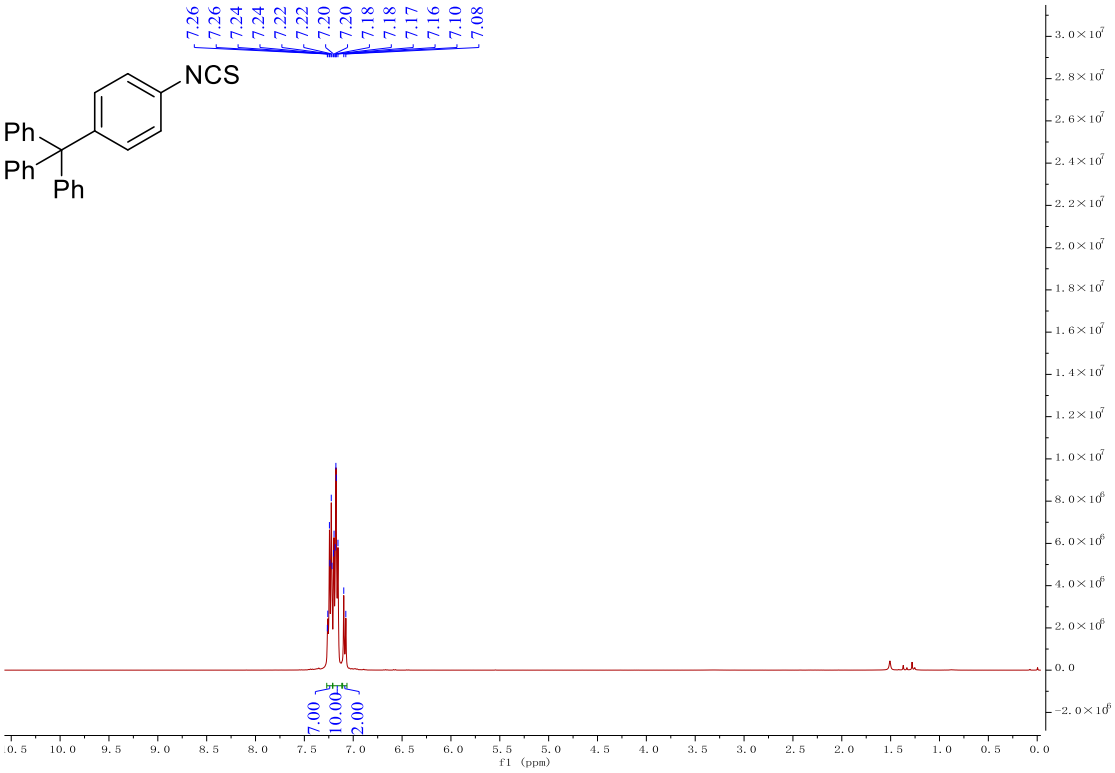


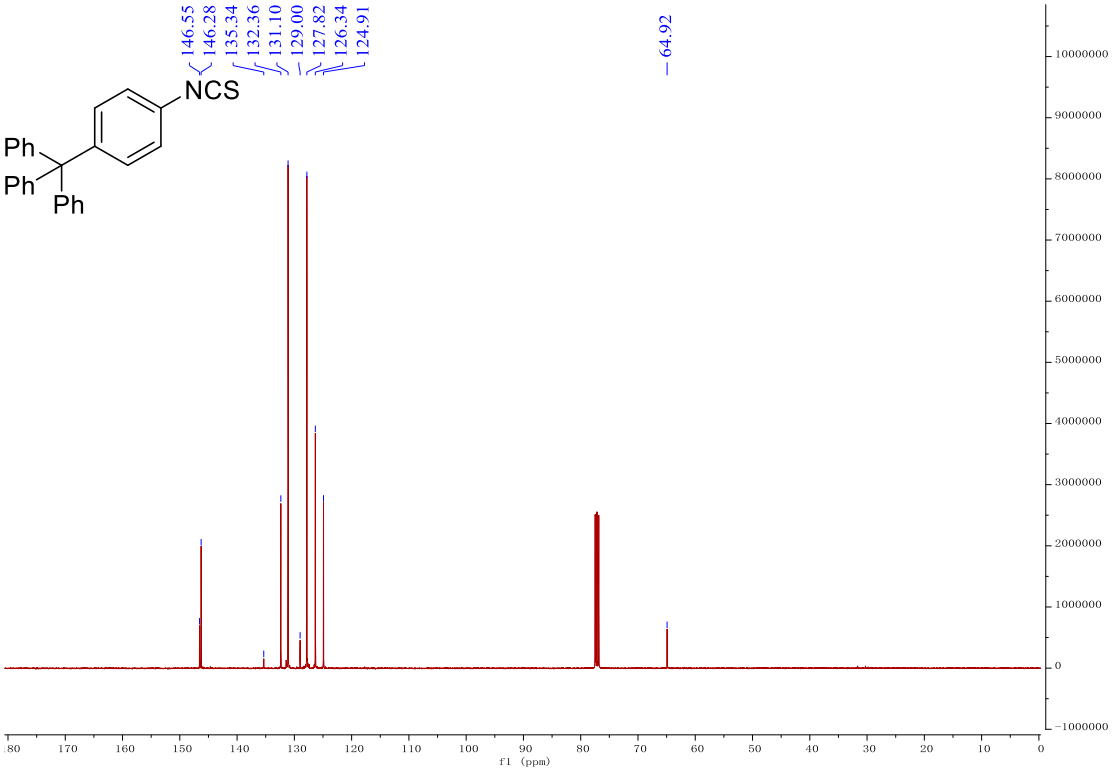
Figure S11. ORTEP drawing of **21** (thermal ellipsoids are shown at 50% probability level). The crystal was prepared from the solution of **21** in n-hexane/ethyl acetate. CCDC 2344626 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data request/cif.

8. Copies of ^{1}H, ^{19}F and ^{13}C NMR Spectra

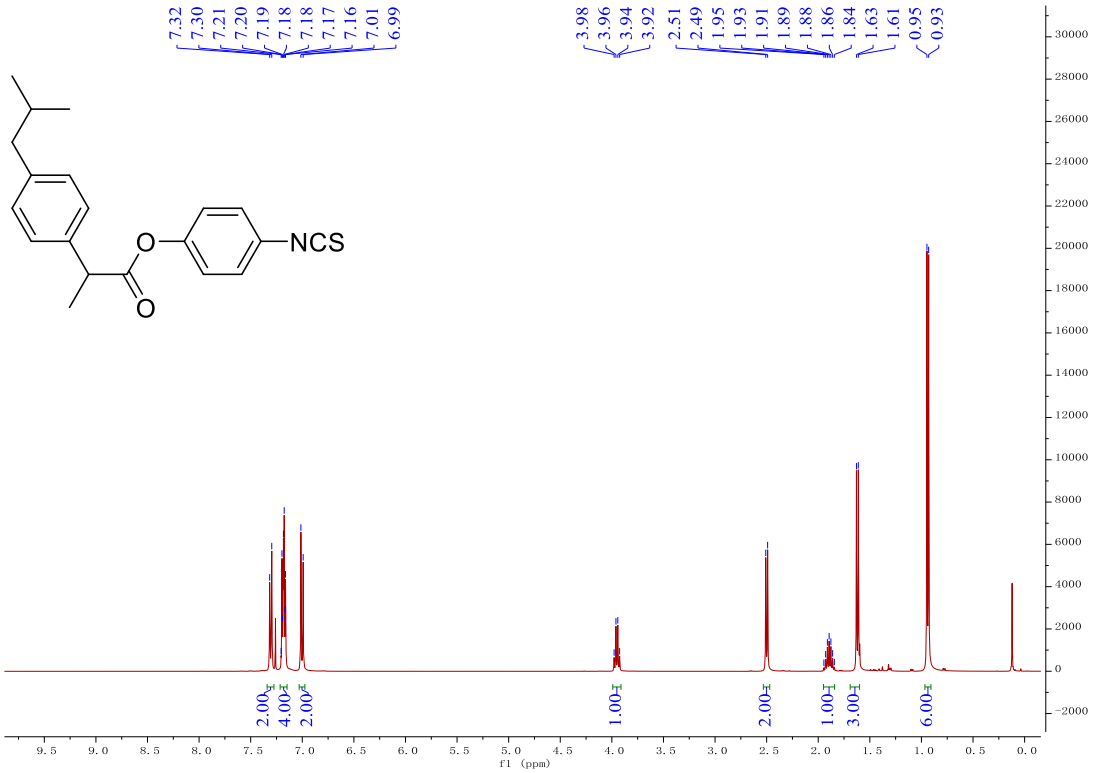
^{1}H NMR of Compound **S11** (400 MHz, $CDCl_3$):



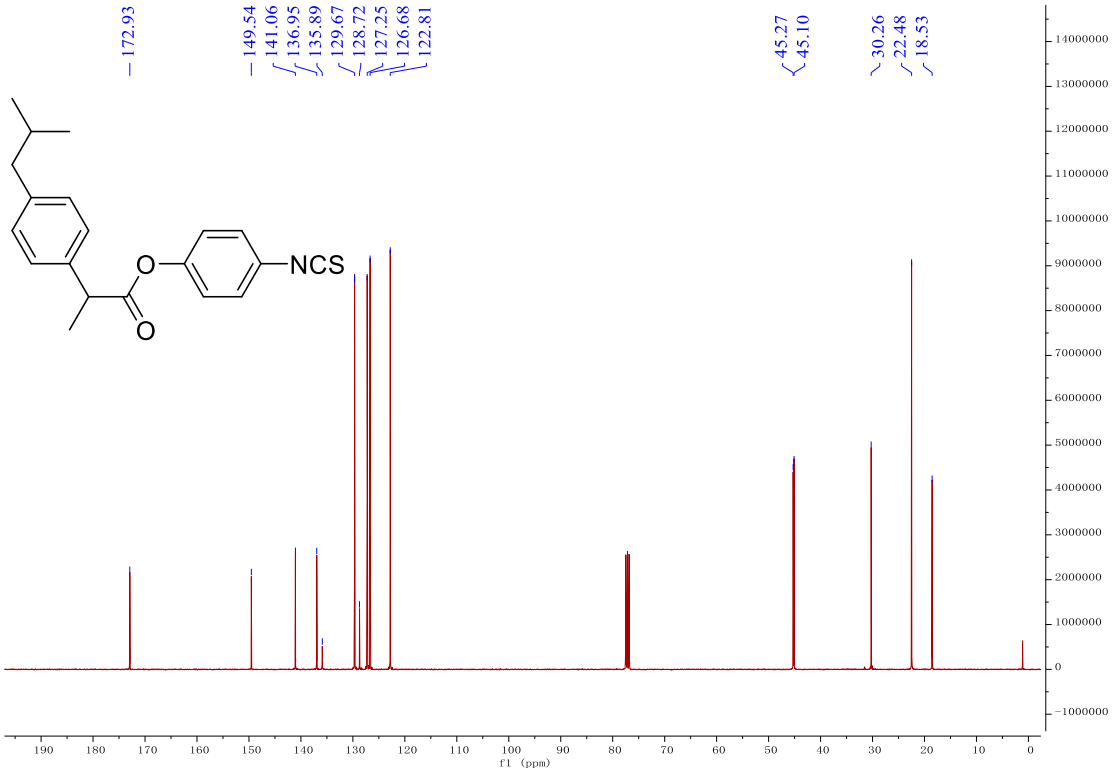
$^{13}C\{^{1}H\}$ NMR of Compound **S11** (101 MHz, $CDCl_3$):



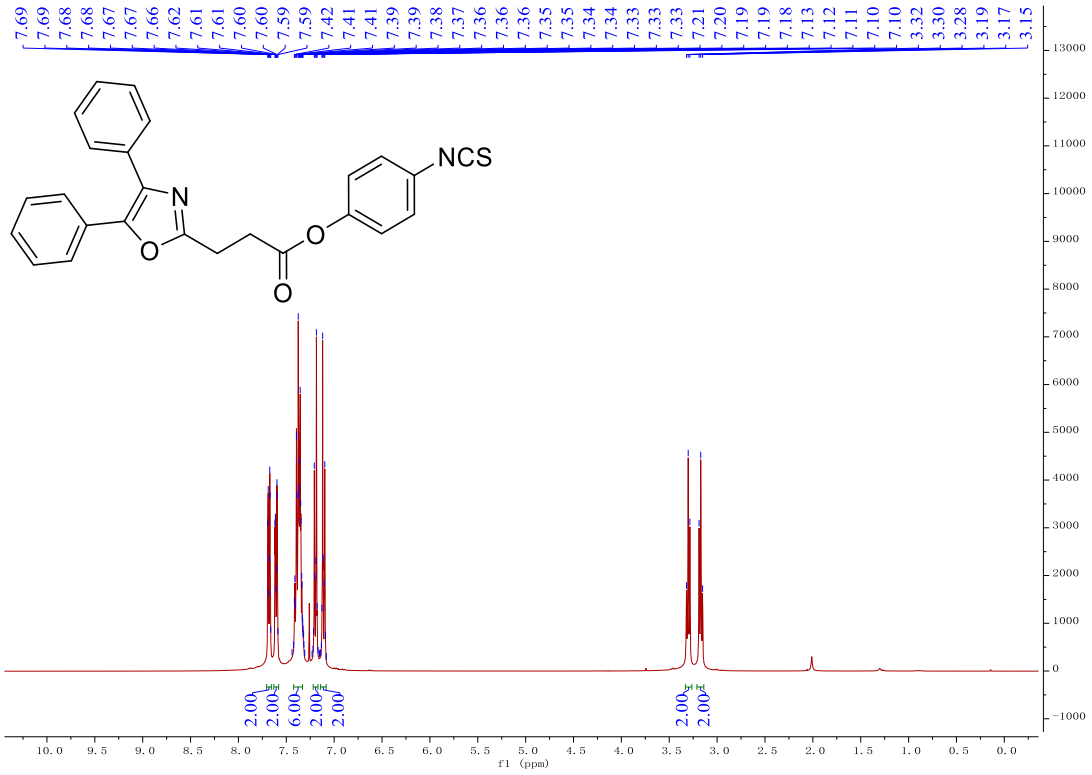
^{1}H NMR of Compound **S35** (400 MHz, $CDCl_3$):



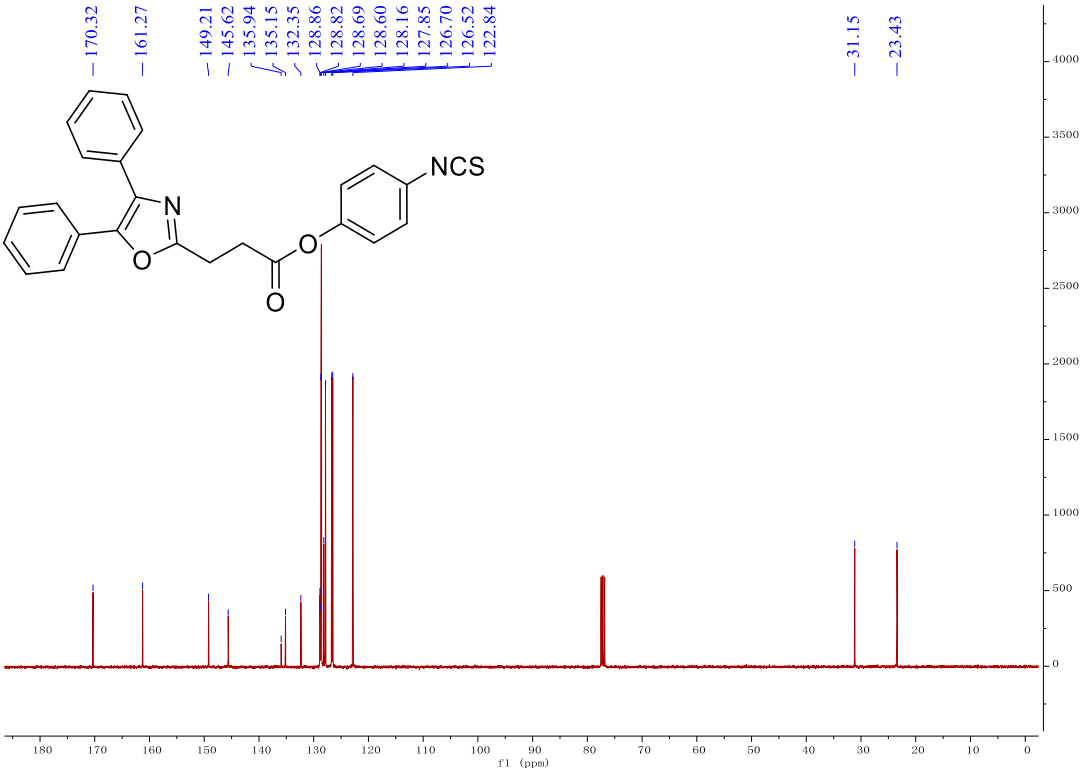
^{13}C{^{1}H} NMR of Compound **S35** (101 MHz, $CDCl_3$):



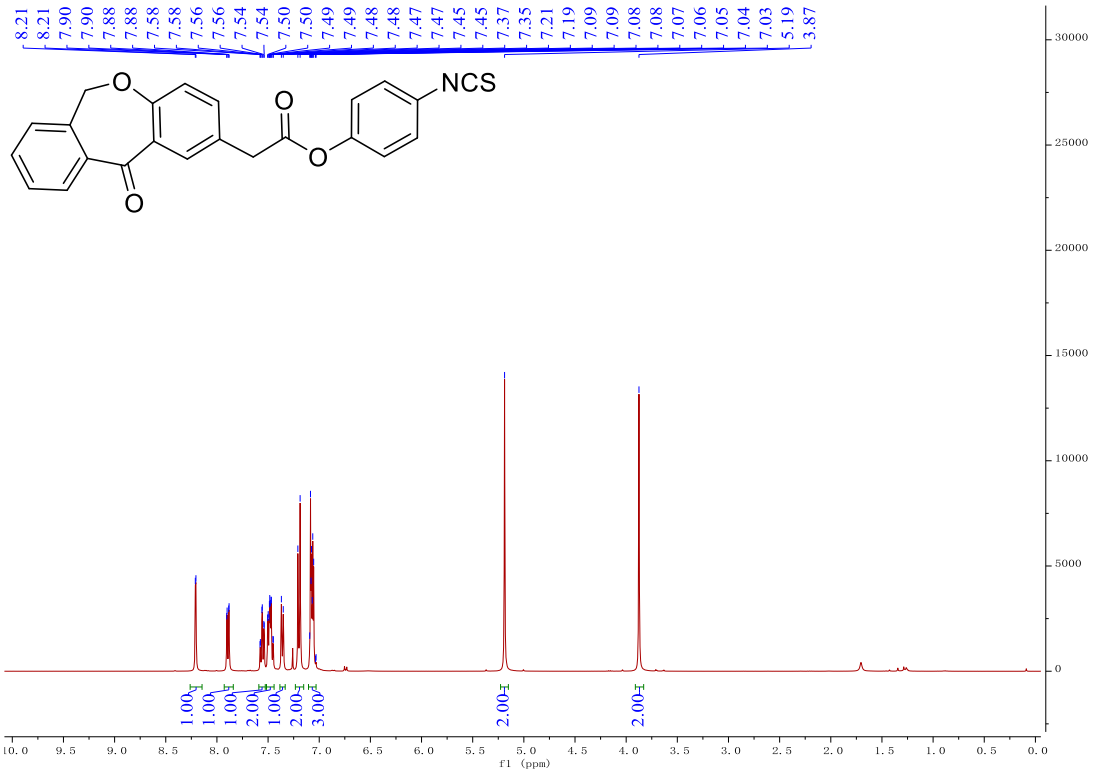
^{1}H NMR of Compound **S36** (400 MHz, $CDCl_3$):



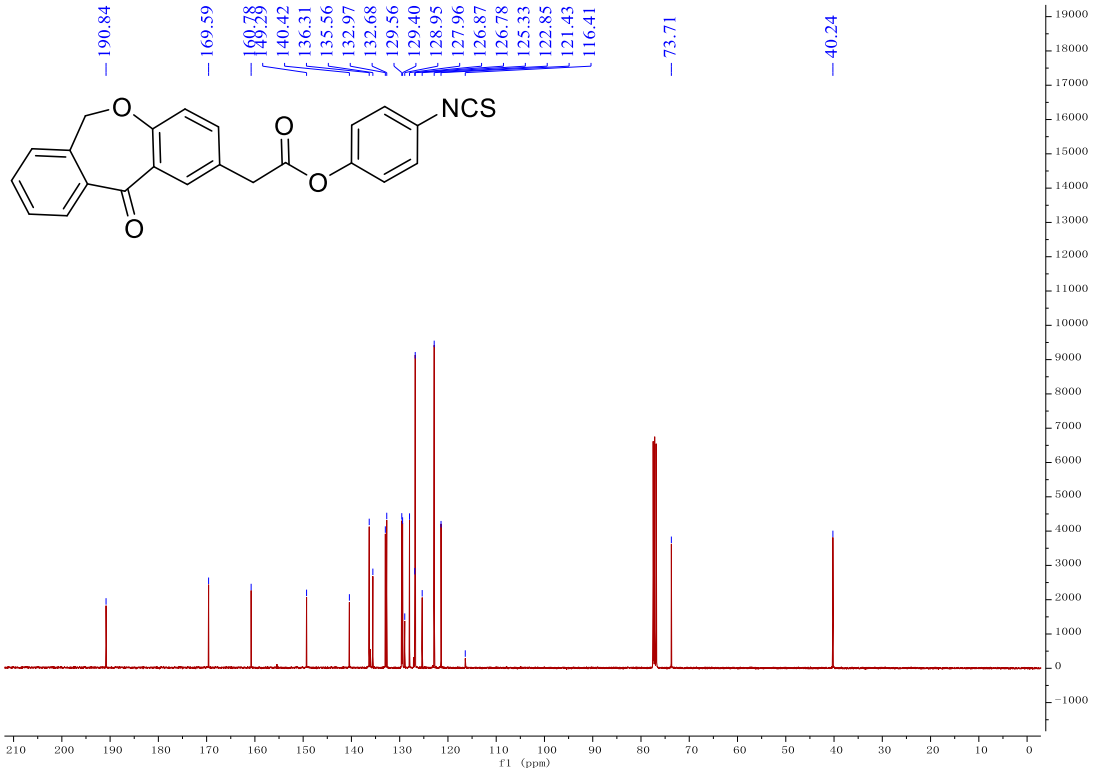
^{13}C{^{1}H} NMR of Compound **S36** (101 MHz, $CDCl_3$):



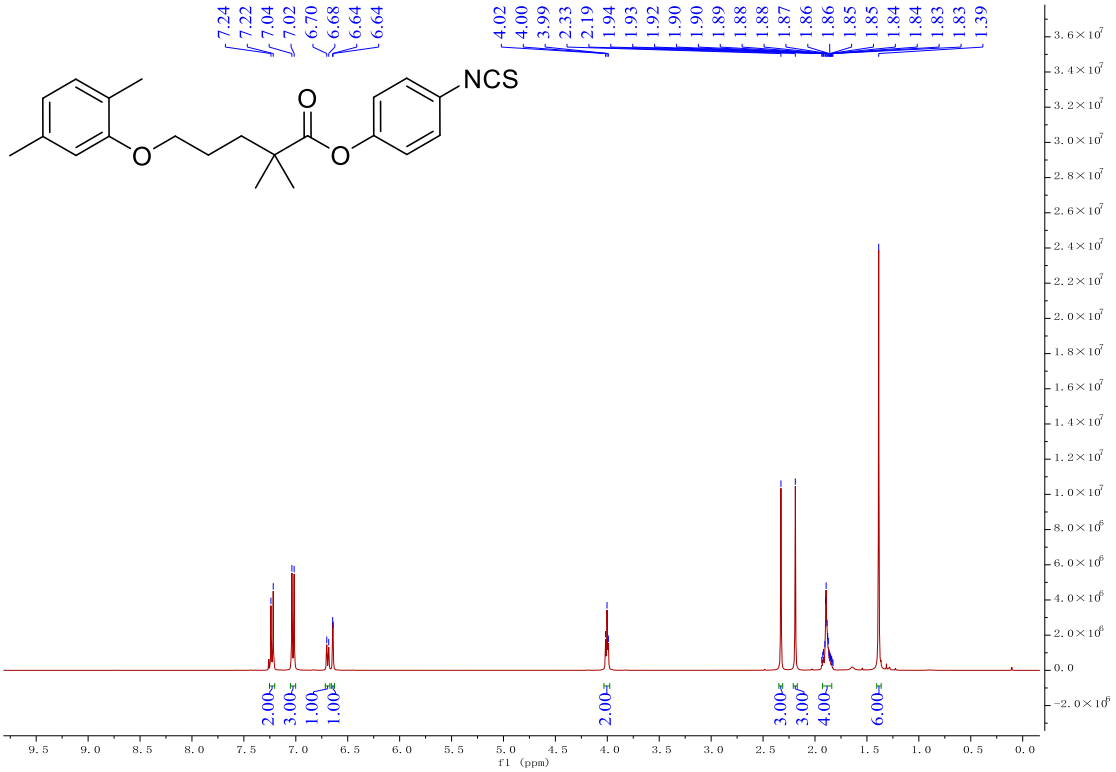
^{1}H NMR of Compound **S38** (400 MHz, $CDCl_3$):



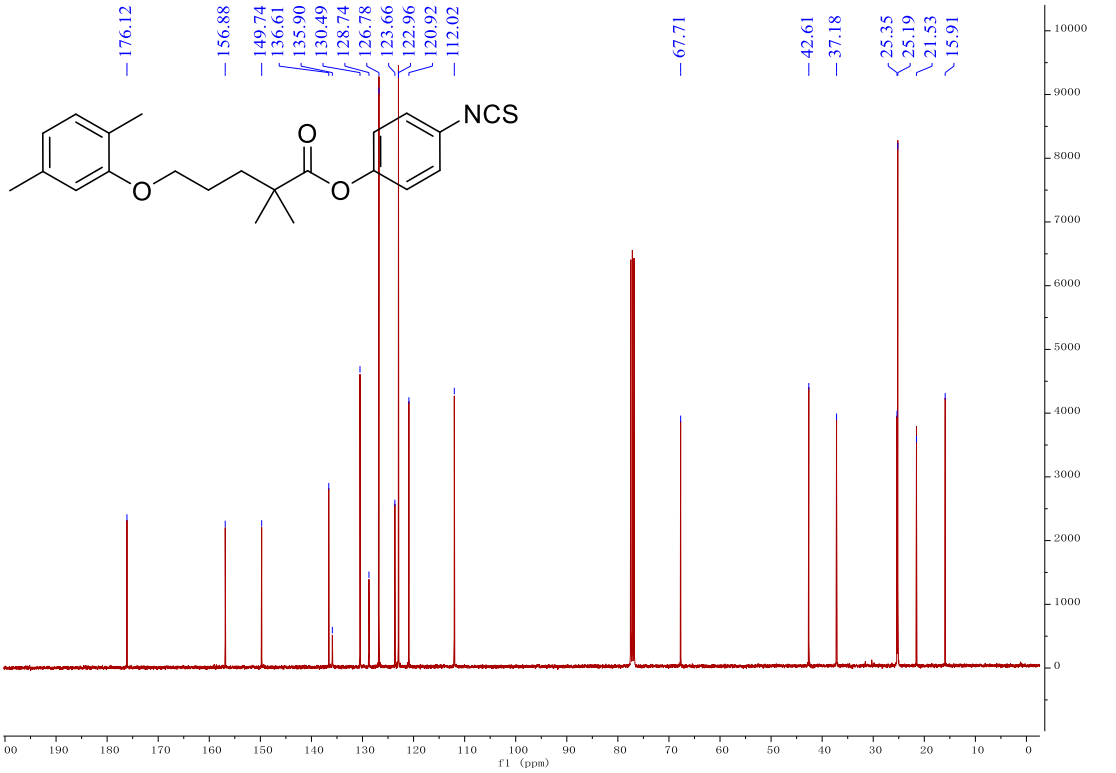
^{13}C{^{1}H} NMR of Compound **S38** (101 MHz, $CDCl_3$):



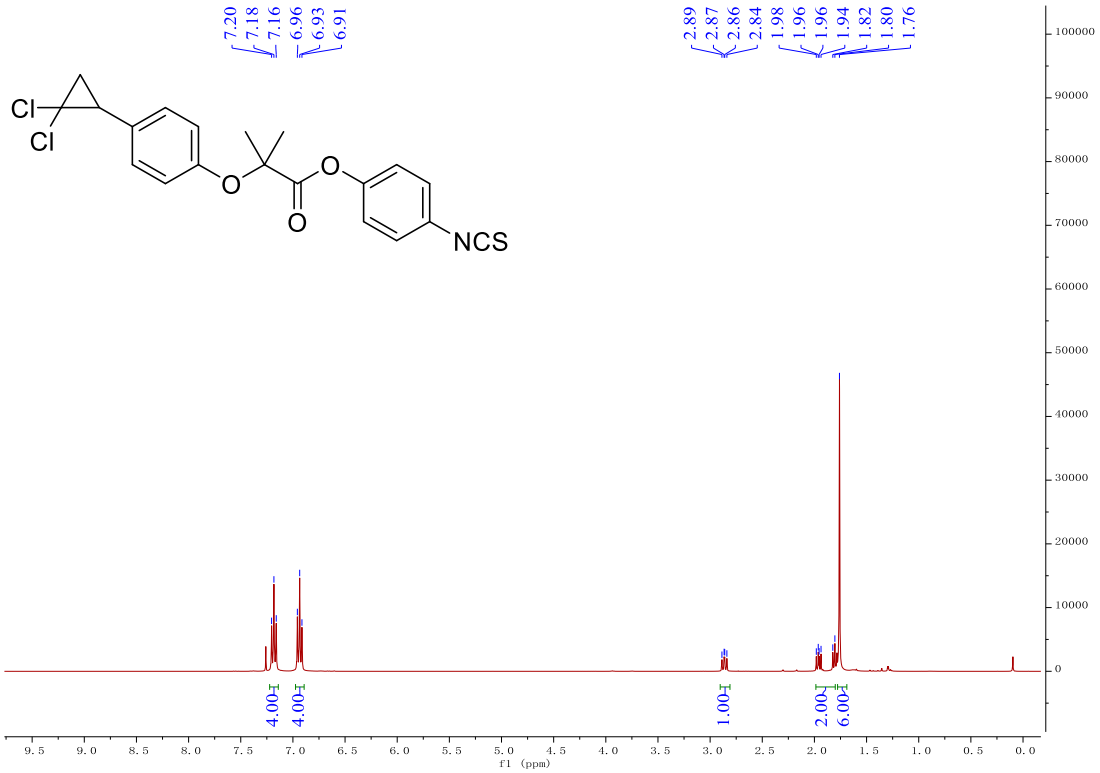
^{1}H NMR of Compound **S39** (400 MHz, $CDCl_3$):



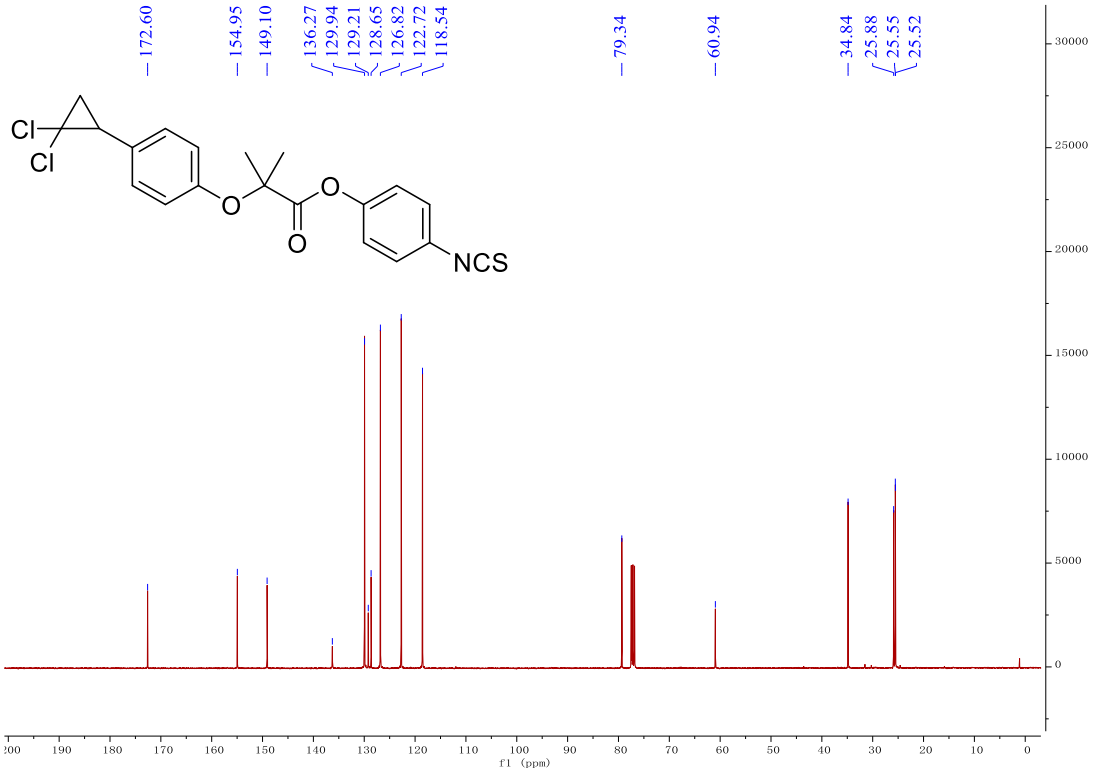
^{13}C{^{1}H} NMR of Compound **S39** (101 MHz, $CDCl_3$):



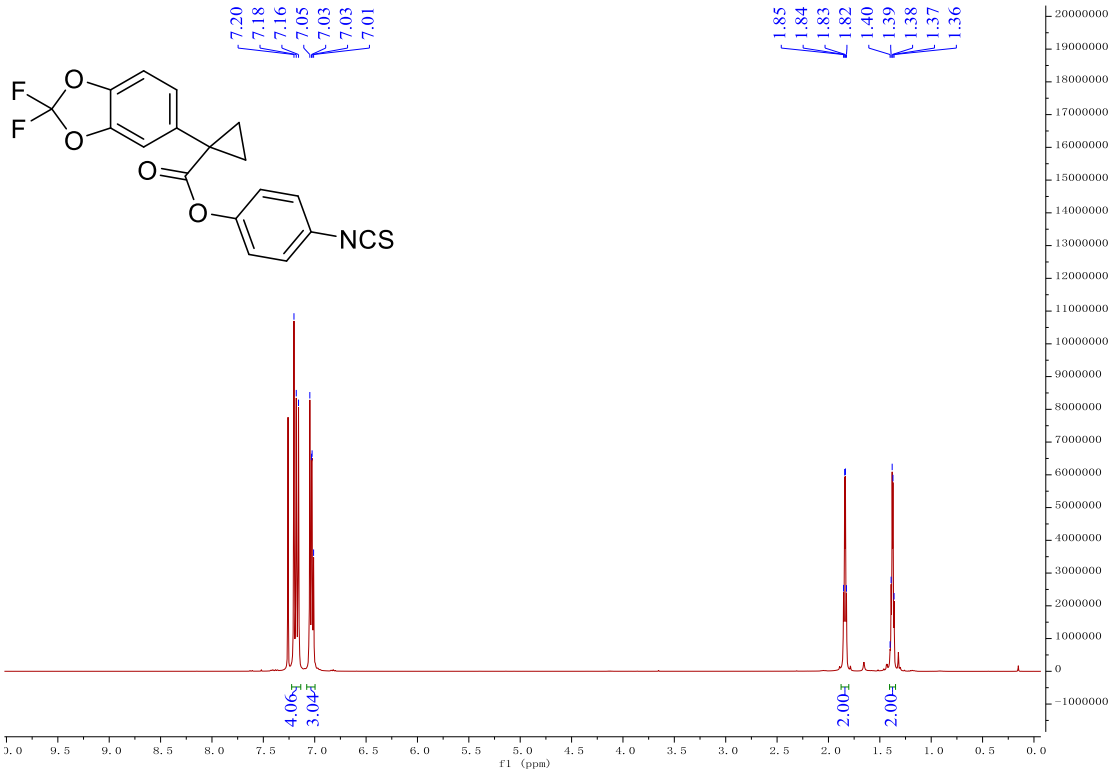
^{1}H NMR of Compound **S40** (400 MHz, $CDCl_3$):



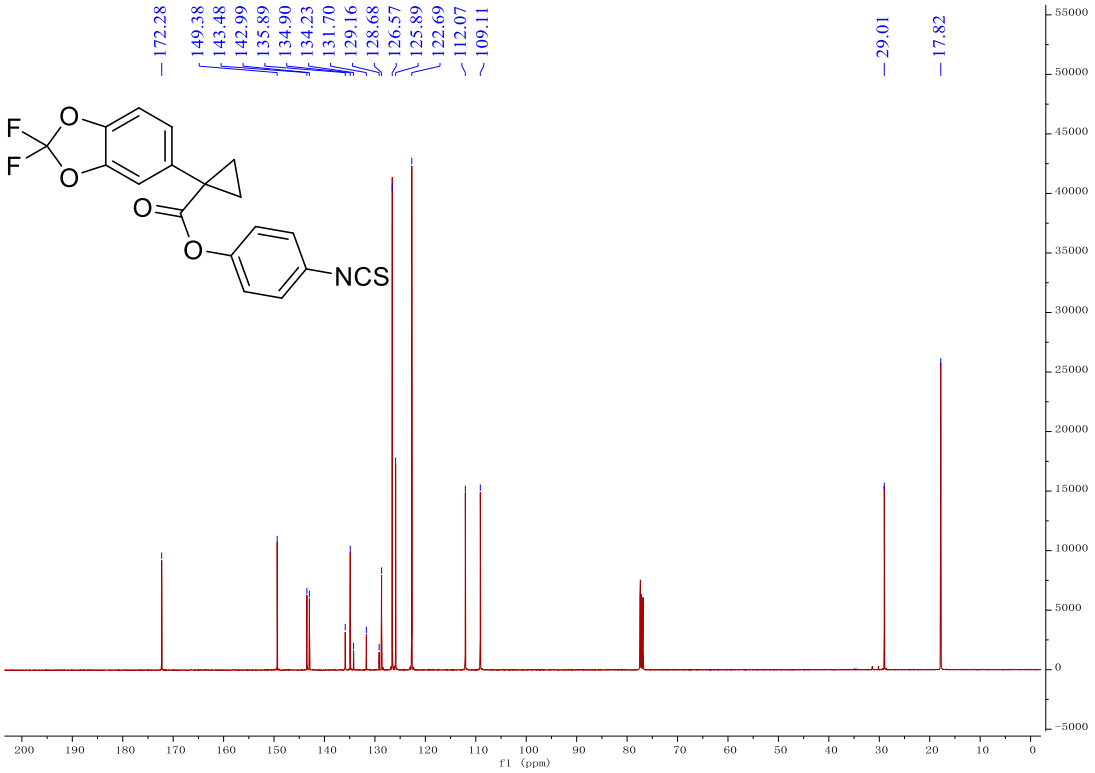
^{13}C{^{1}H} NMR of Compound **S40** (101 MHz, $CDCl_3$):



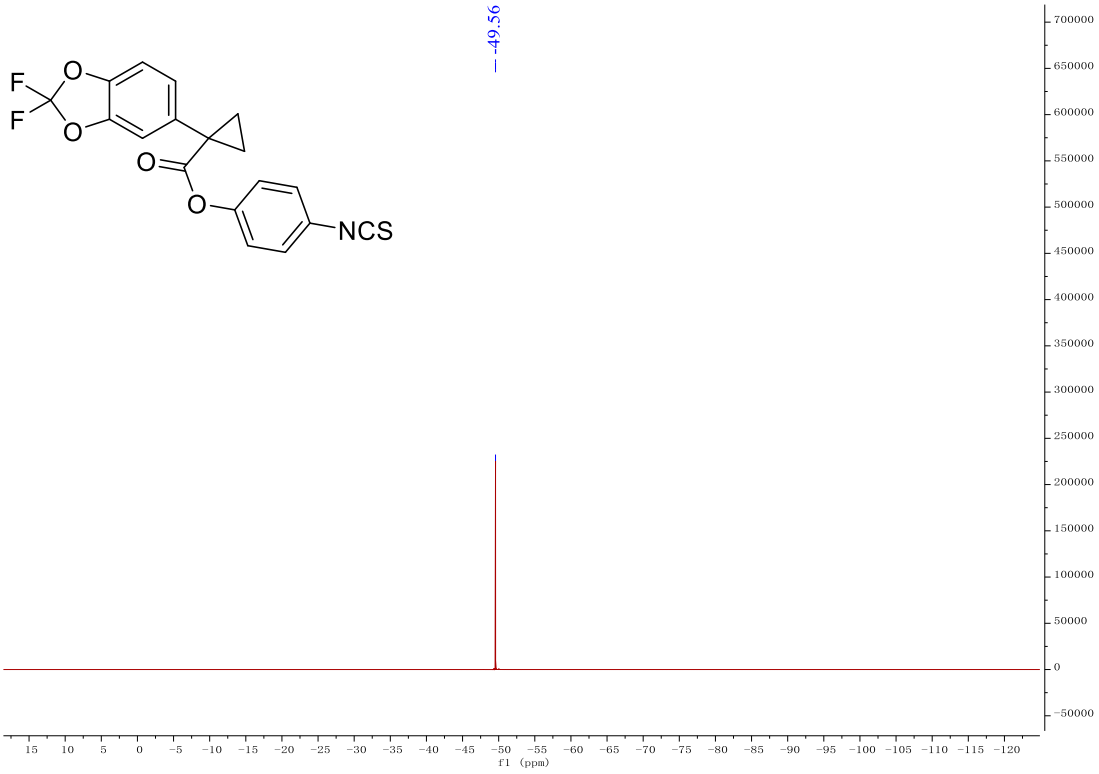
^{1}H NMR of Compound **S41** (400 MHz, $CDCl_3$):



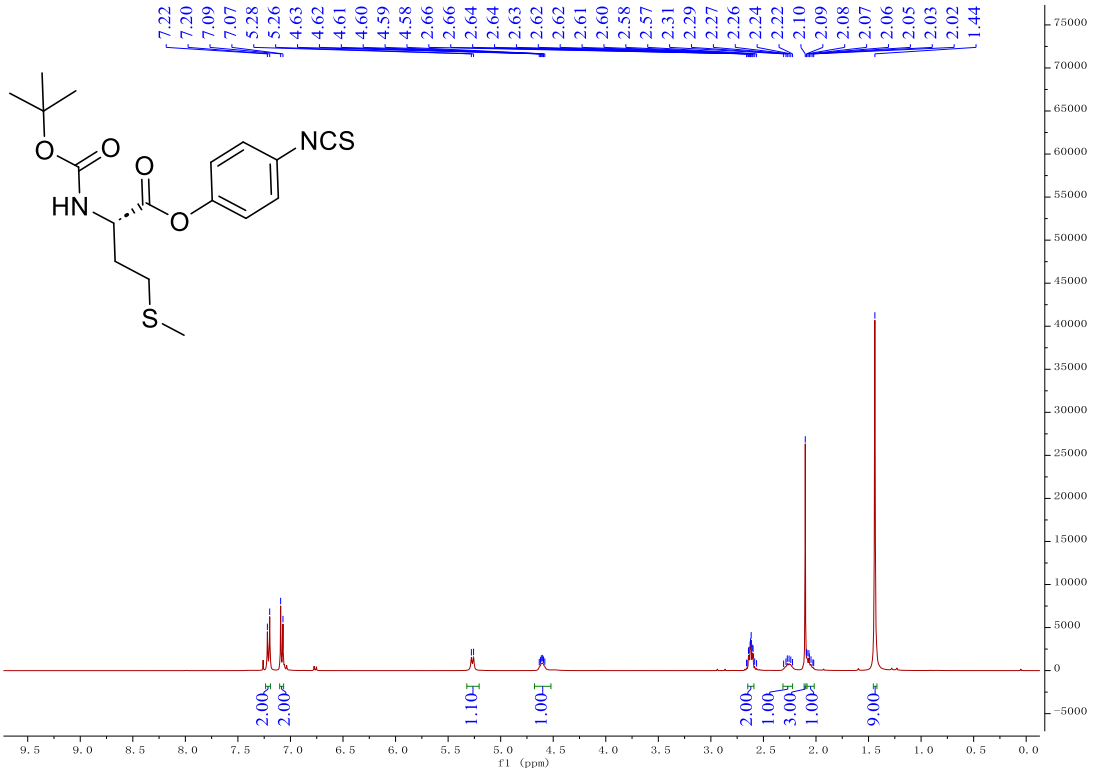
^{13}C{^{1}H} NMR of Compound **S41** (101 MHz, $CDCl_3$):



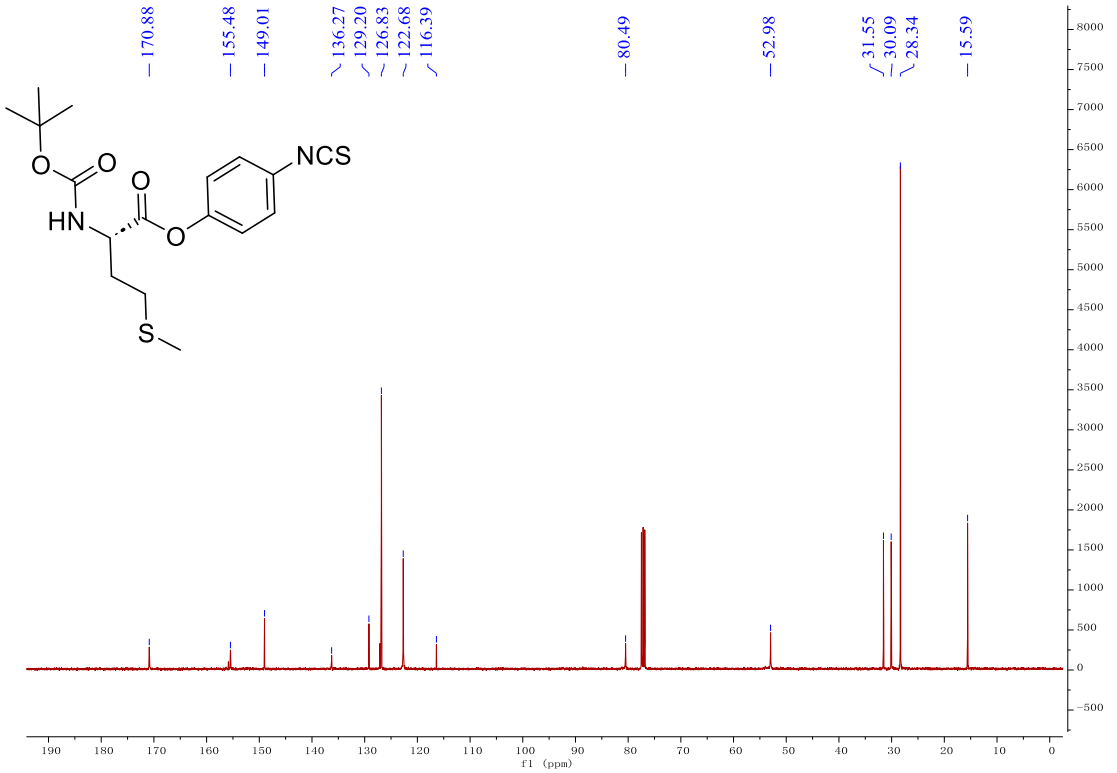
^{19}F NMR of Compound **S41** (376 MHz, $CDCl_3$):



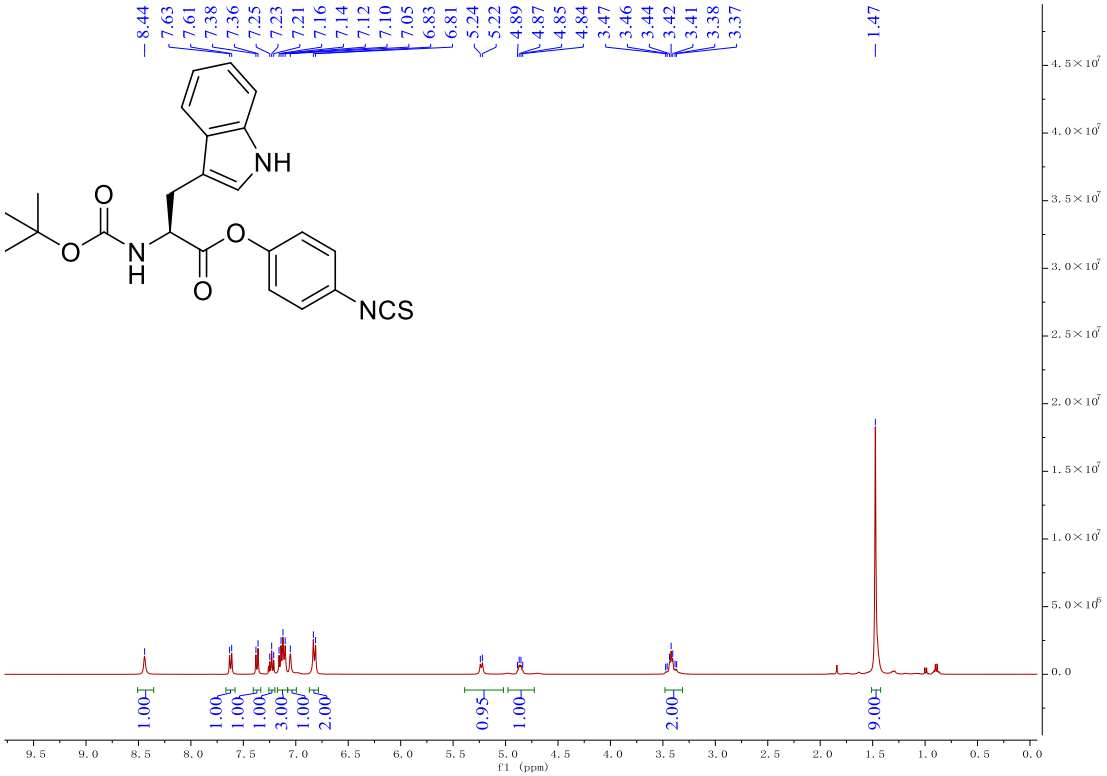
^{1}H NMR of Compound **S42** (400 MHz, $CDCl_3$):



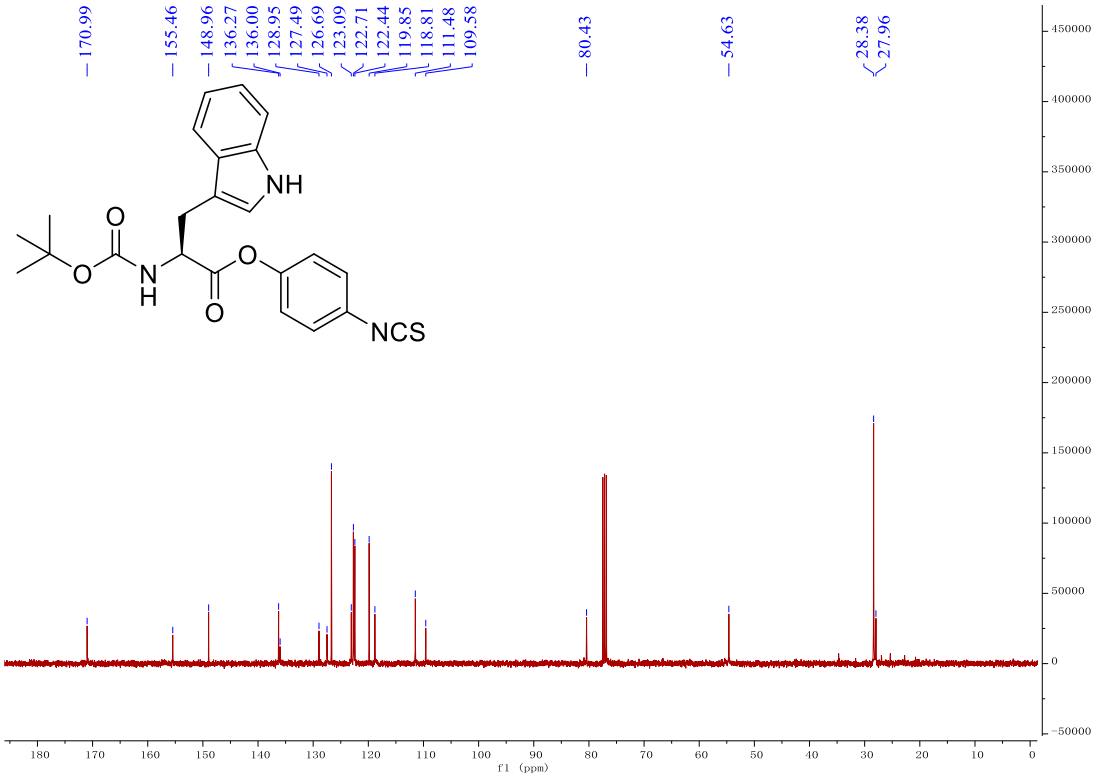
$^{13}C\{^{1}H\}$ NMR of Compound **S42** (101 MHz, $CDCl_3$):



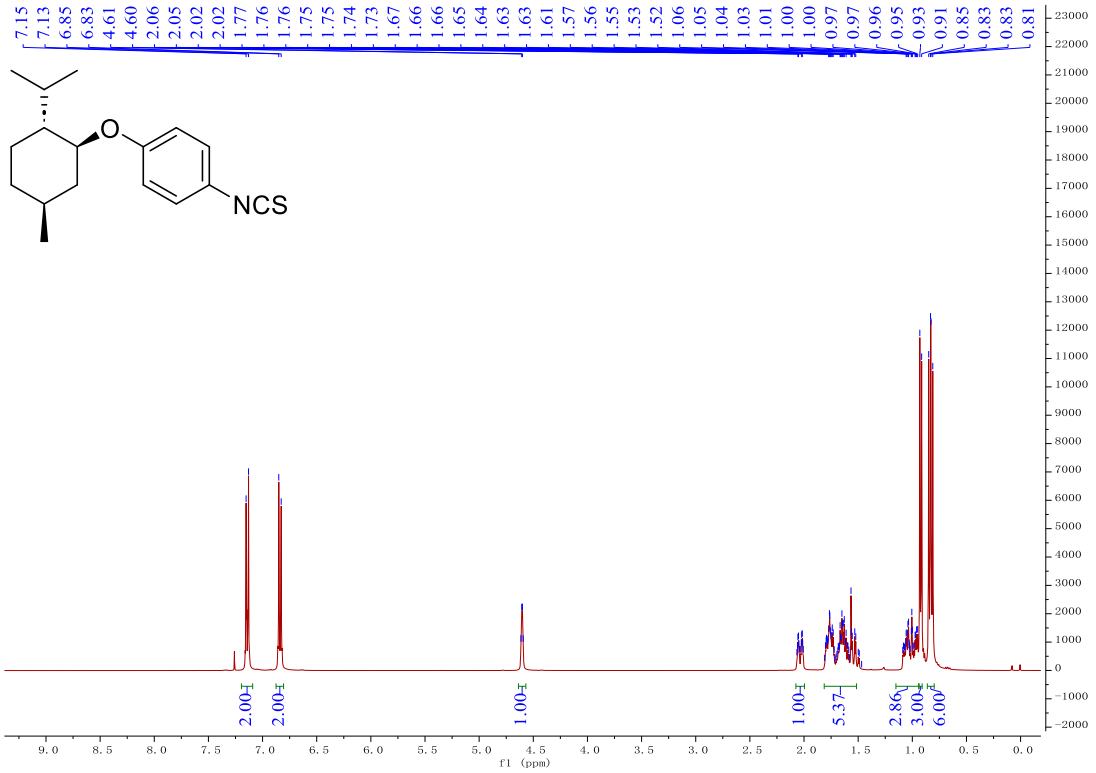
^{1}H NMR of Compound **S43** (400 MHz, $CDCl_3$):



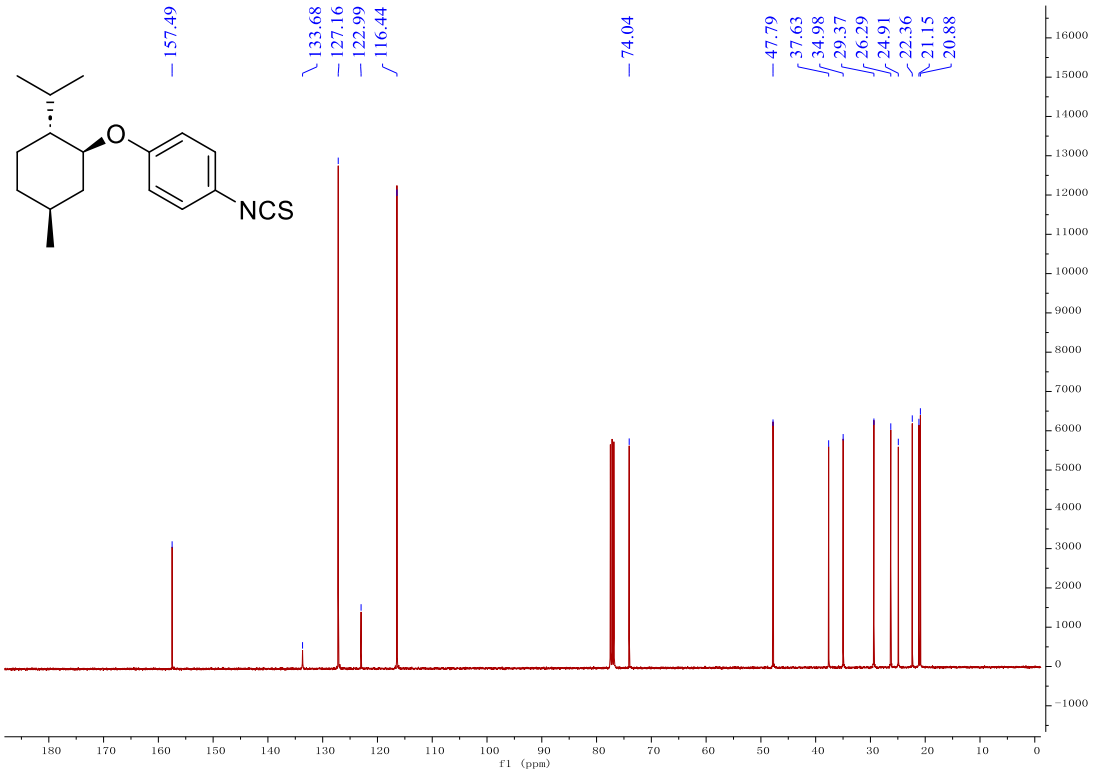
$^{13}C\{^{1}H\}$ NMR of Compound **S43** (101 MHz, $CDCl_3$):



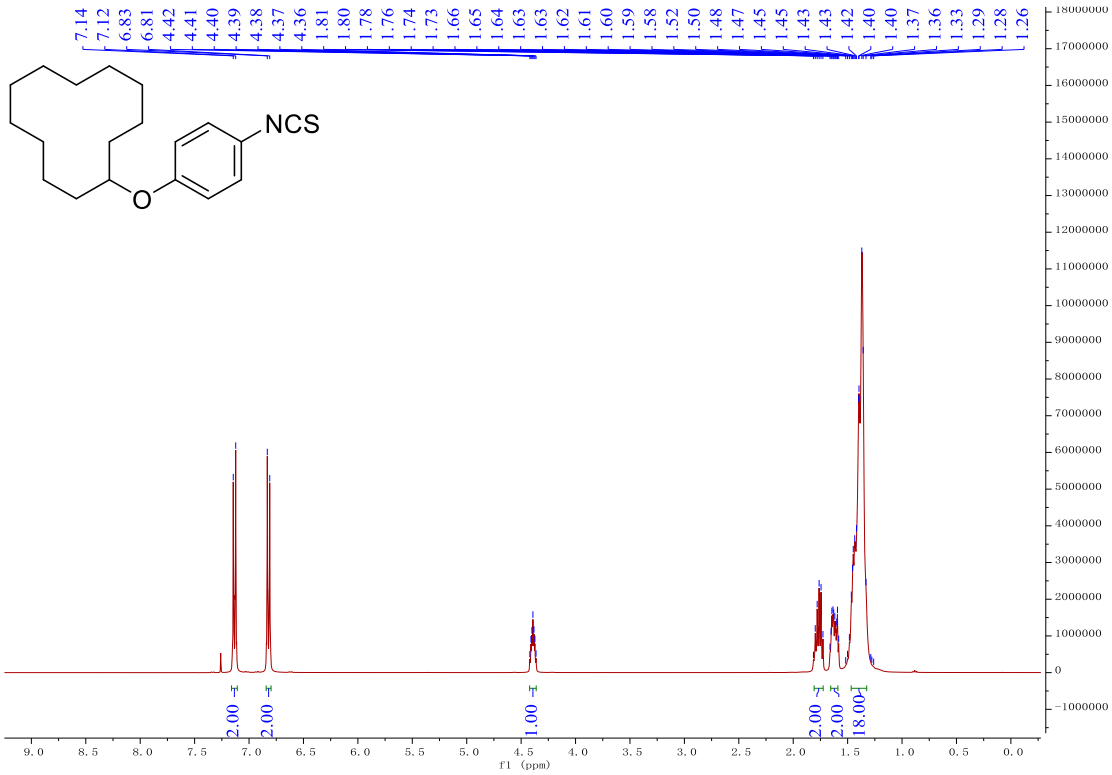
^{1}H NMR of Compound **S44** (400 MHz, $CDCl_3$):



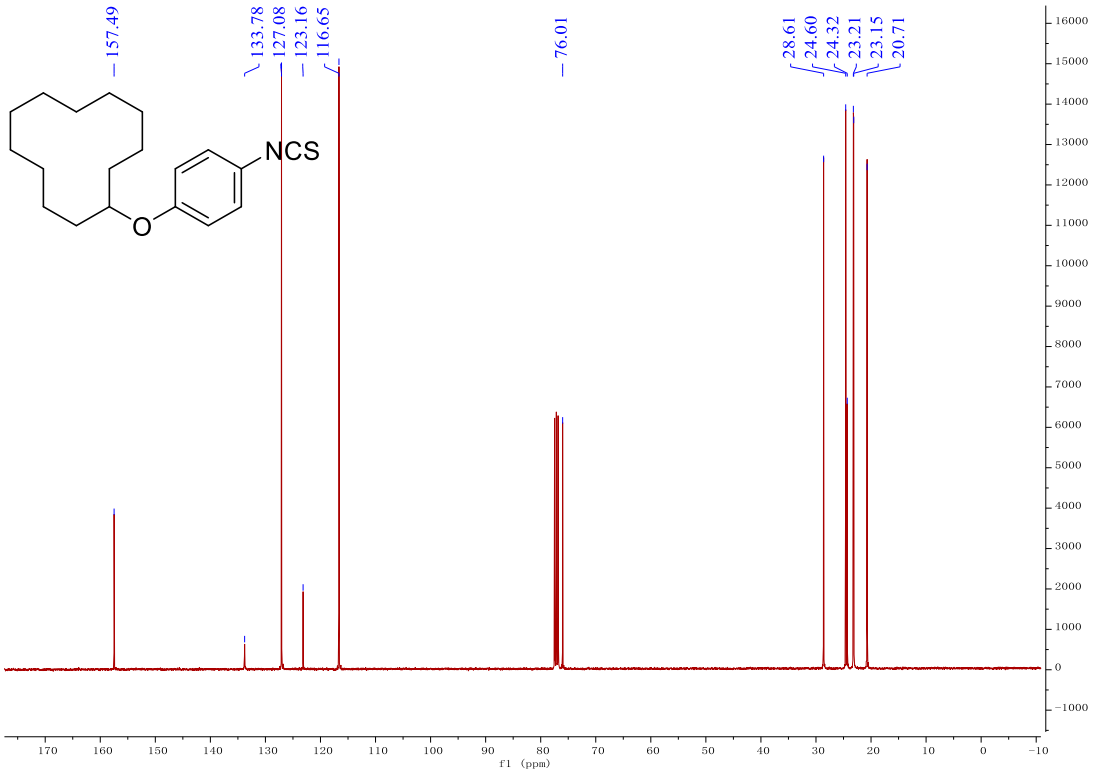
$^{13}C\{^{1}H\}$ NMR of Compound **S44** (101 MHz, $CDCl_3$):



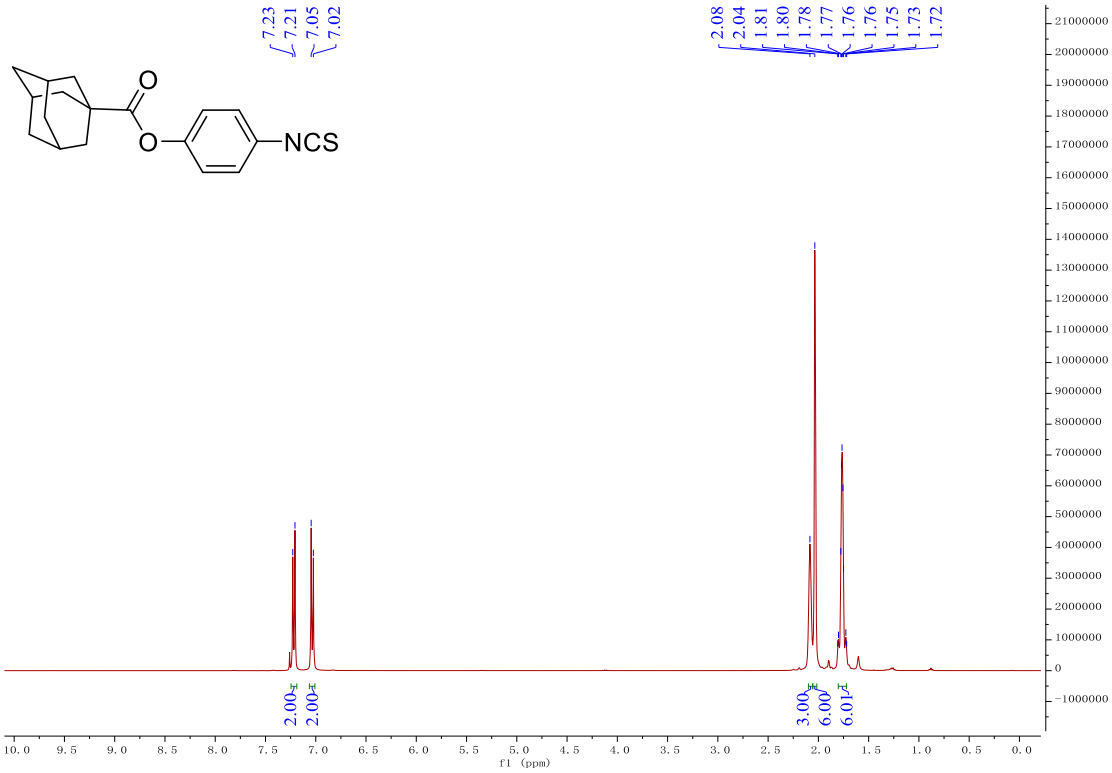
^{1}H NMR of Compound **S45** (400 MHz, $CDCl_3$):



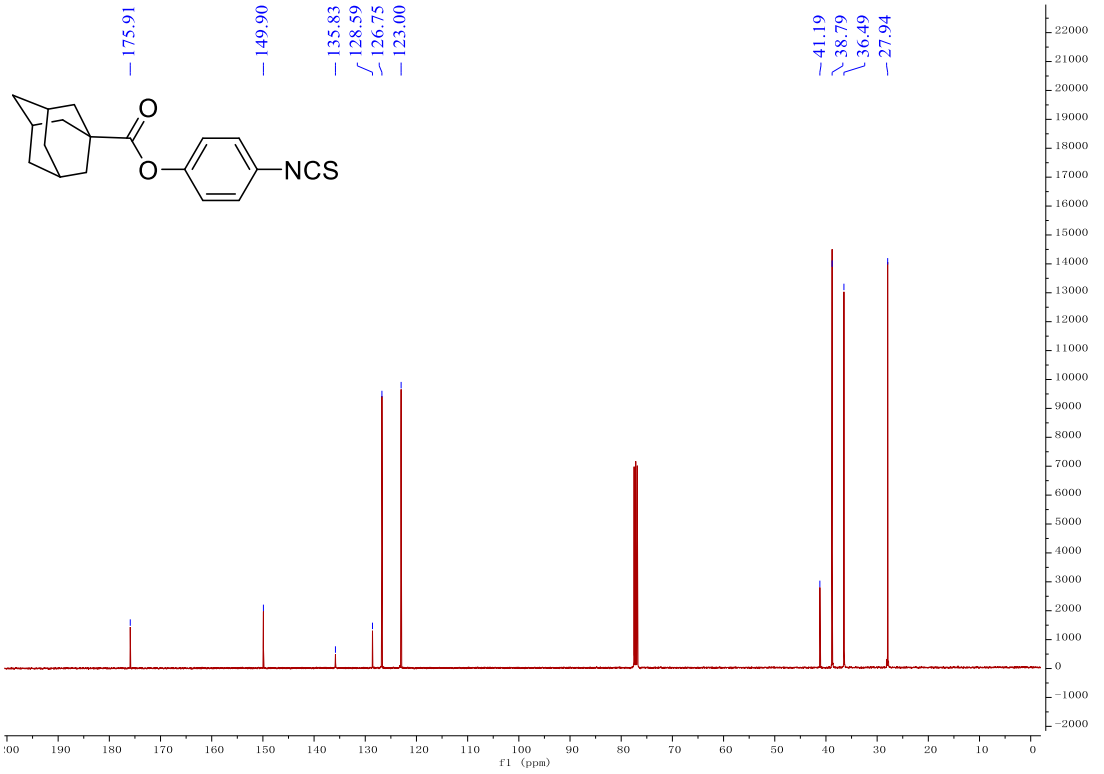
$^{13}C\{^{1}H\}$ NMR of Compound **S45** (101 MHz, $CDCl_3$):



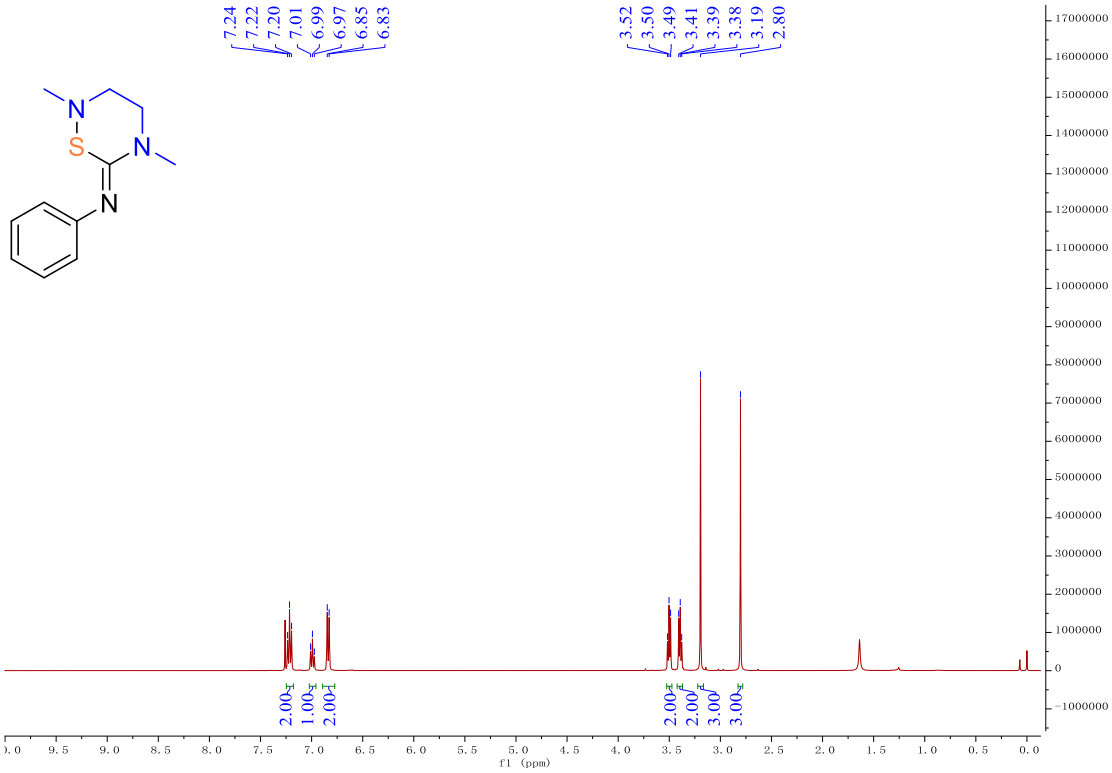
^{1}H NMR of Compound **S46** (400 MHz, $CDCl_3$):



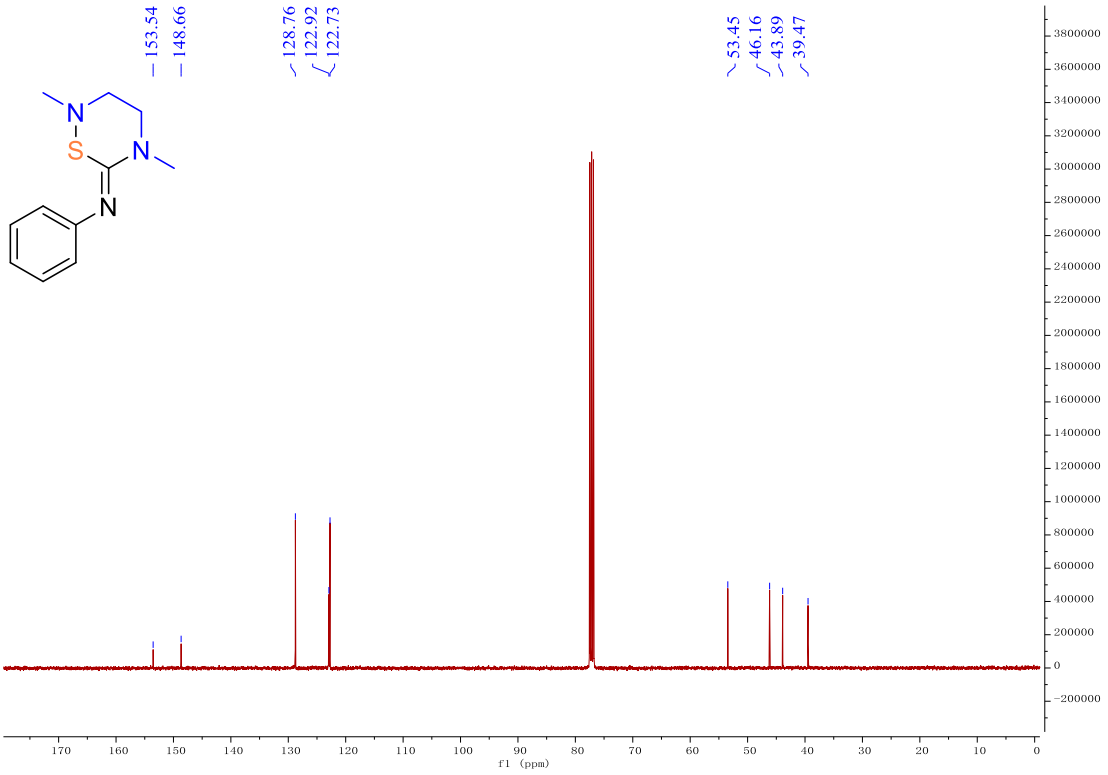
$^{13}C\{^{1}H\}$ NMR of Compound **S46** (101 MHz, $CDCl_3$):



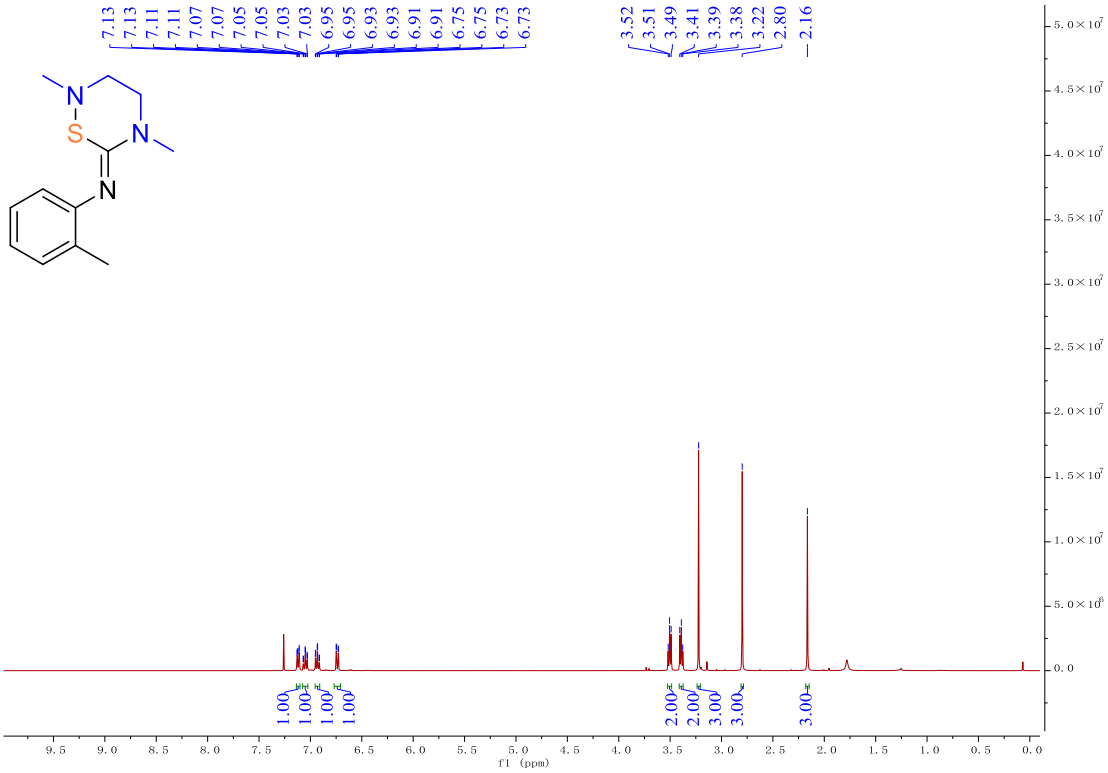
^{1}H NMR of Compound **3** (400 MHz, $CDCl_3$):



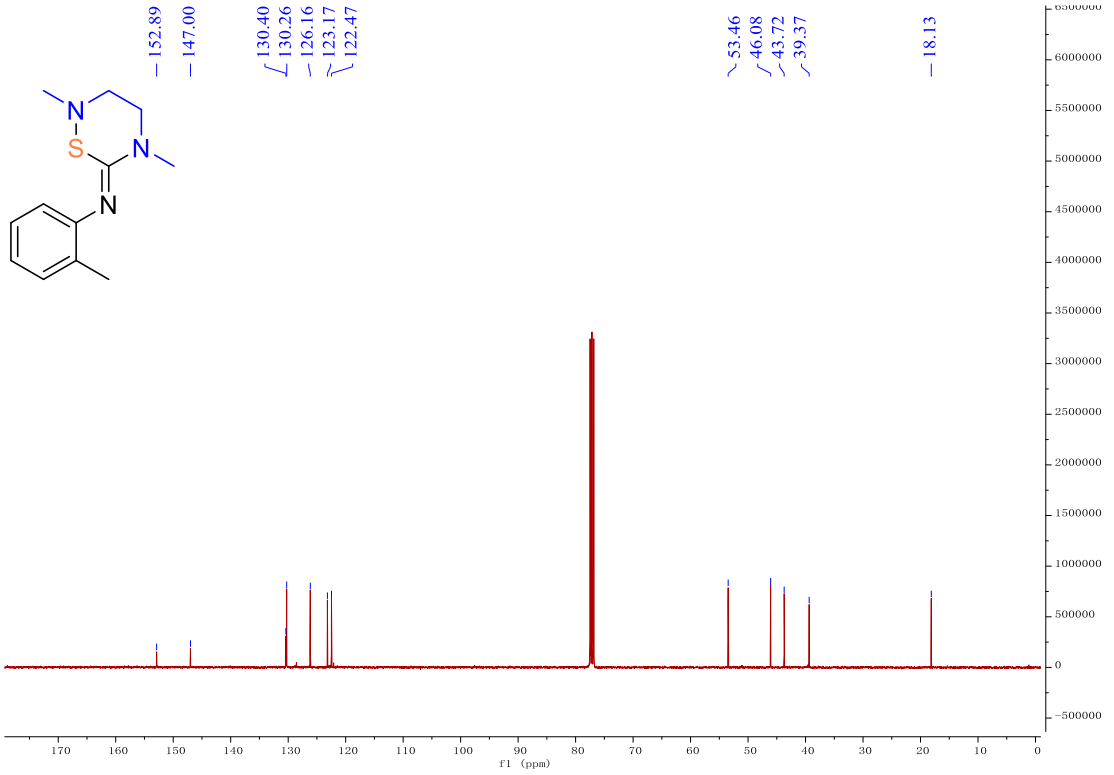
$^{13}C\{^{1}H\}$ NMR of Compound **3** (101 MHz, $CDCl_3$):



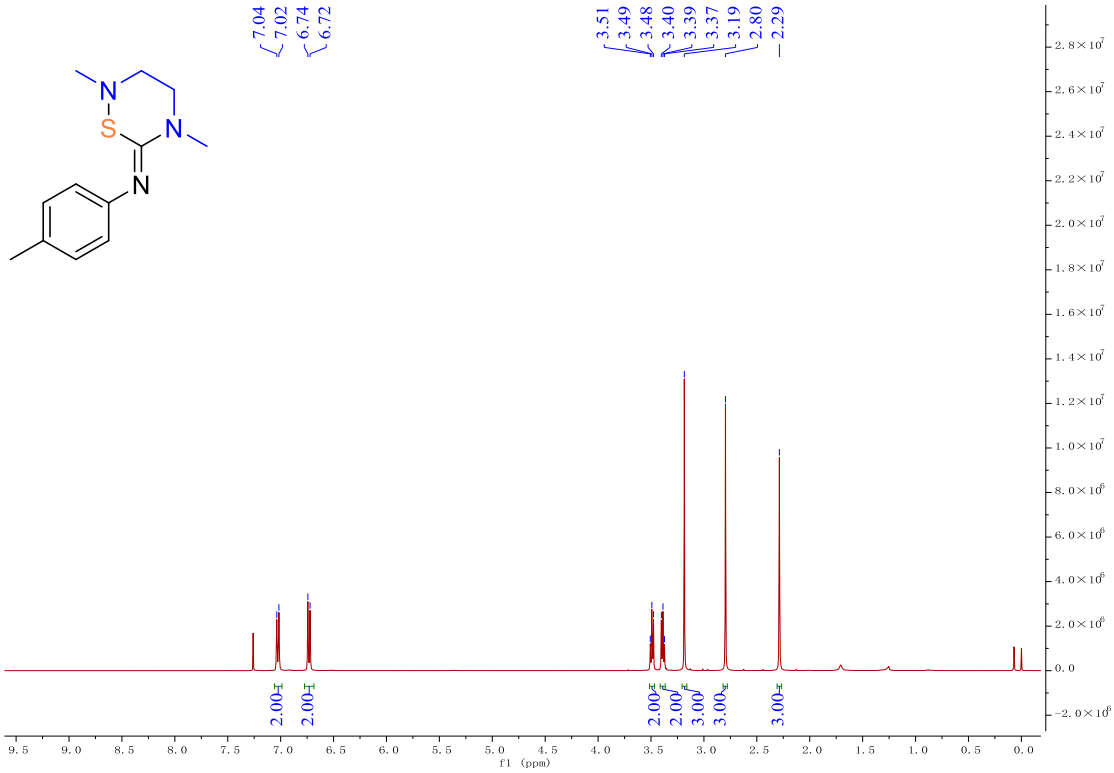
^{1}H NMR of Compound **4** (400 MHz, $CDCl_3$):



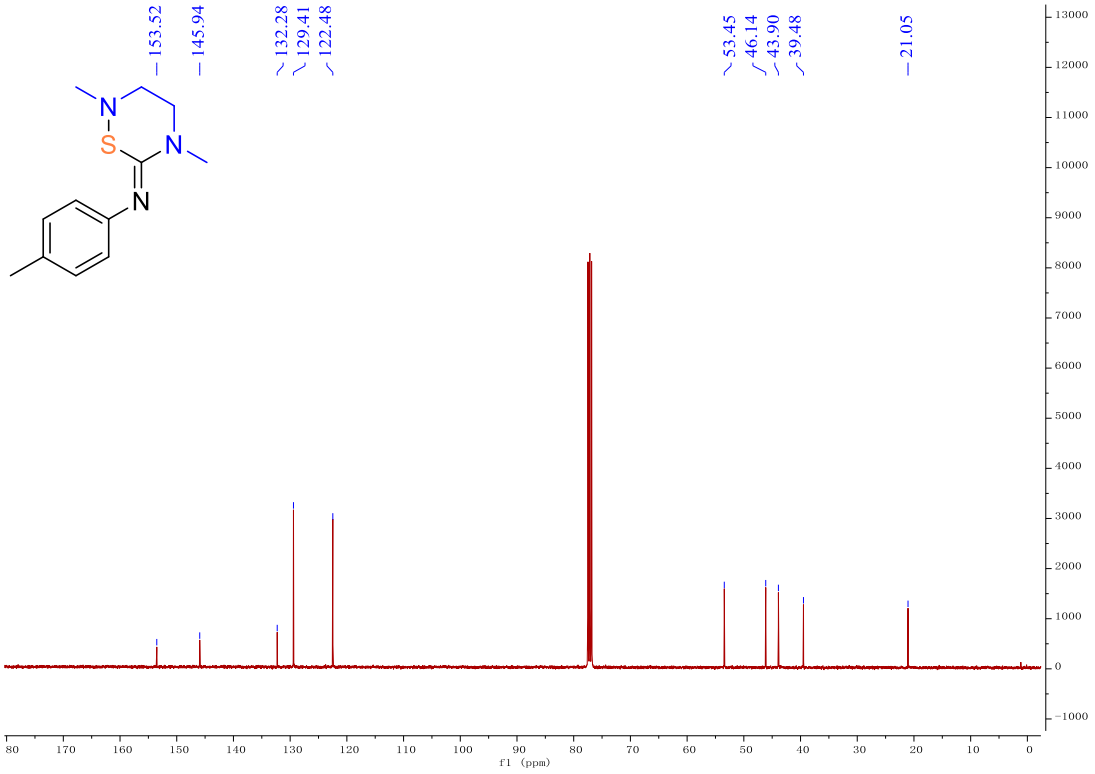
$^{13}C\{^{1}H\}$ NMR of Compound **4** (101 MHz, $CDCl_3$):



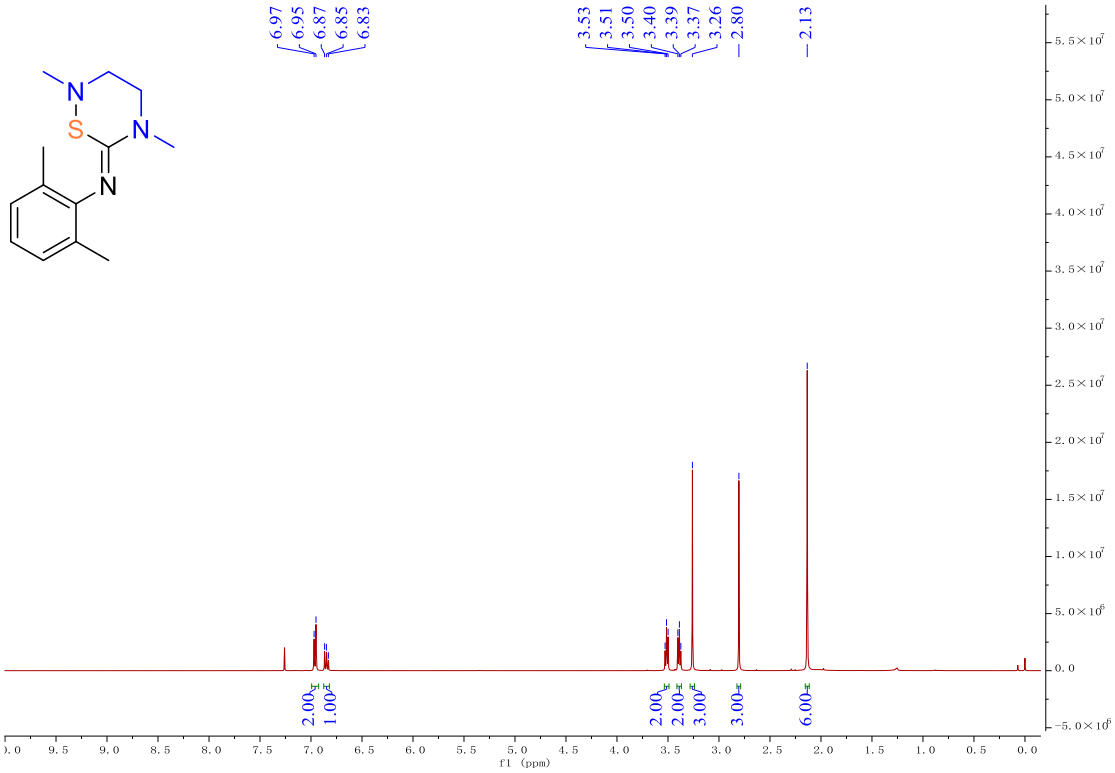
^{1}H NMR of Compound **5** (400 MHz, $CDCl_3$):



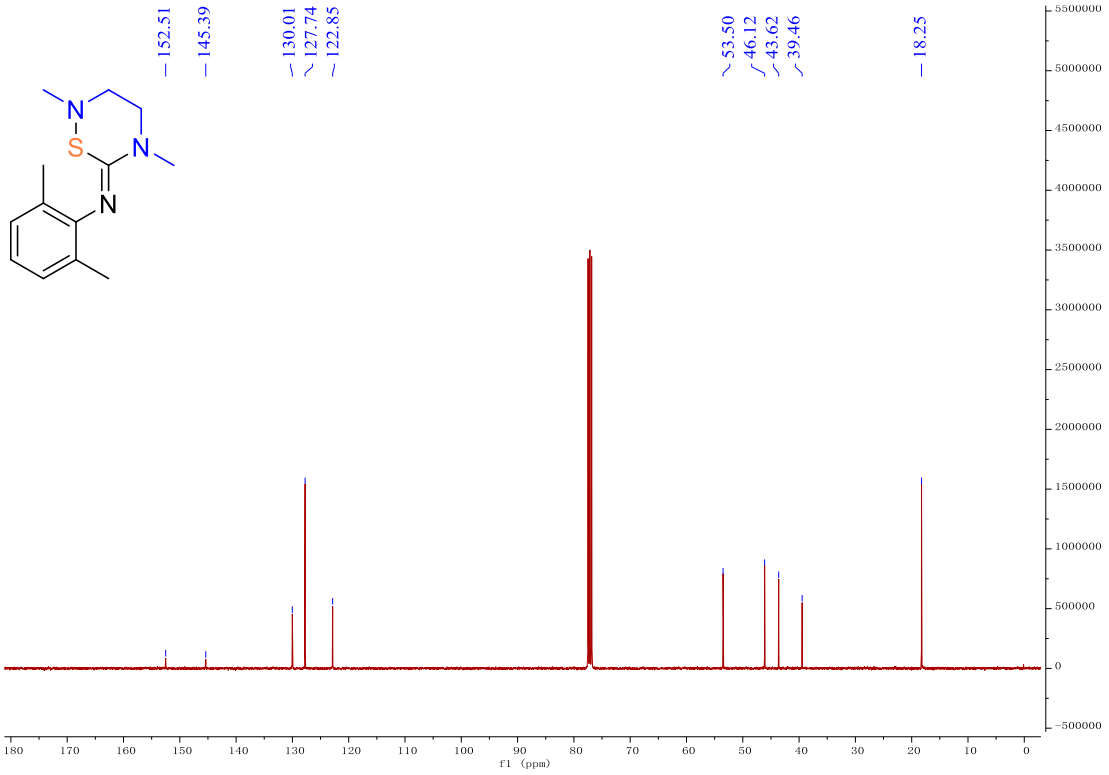
$^{13}C\{^{1}H\}$ NMR of Compound **5** (101 MHz, $CDCl_3$):



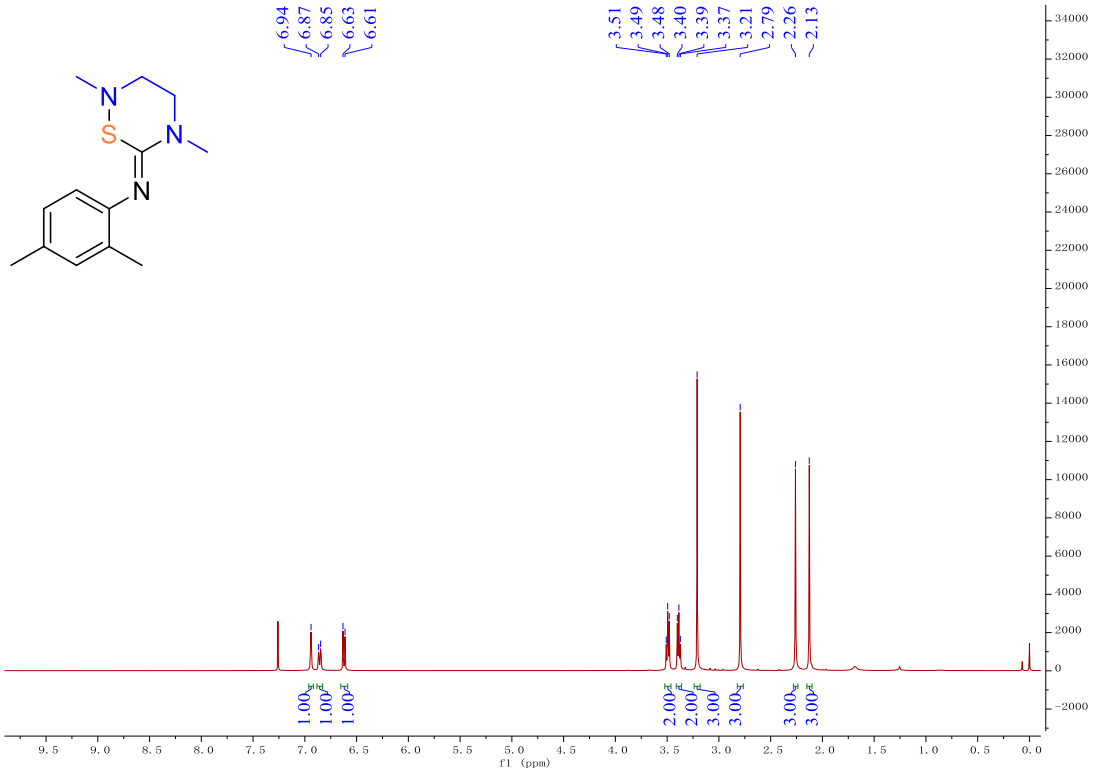
^{1}H NMR of Compound **6** (400 MHz, $CDCl_3$):



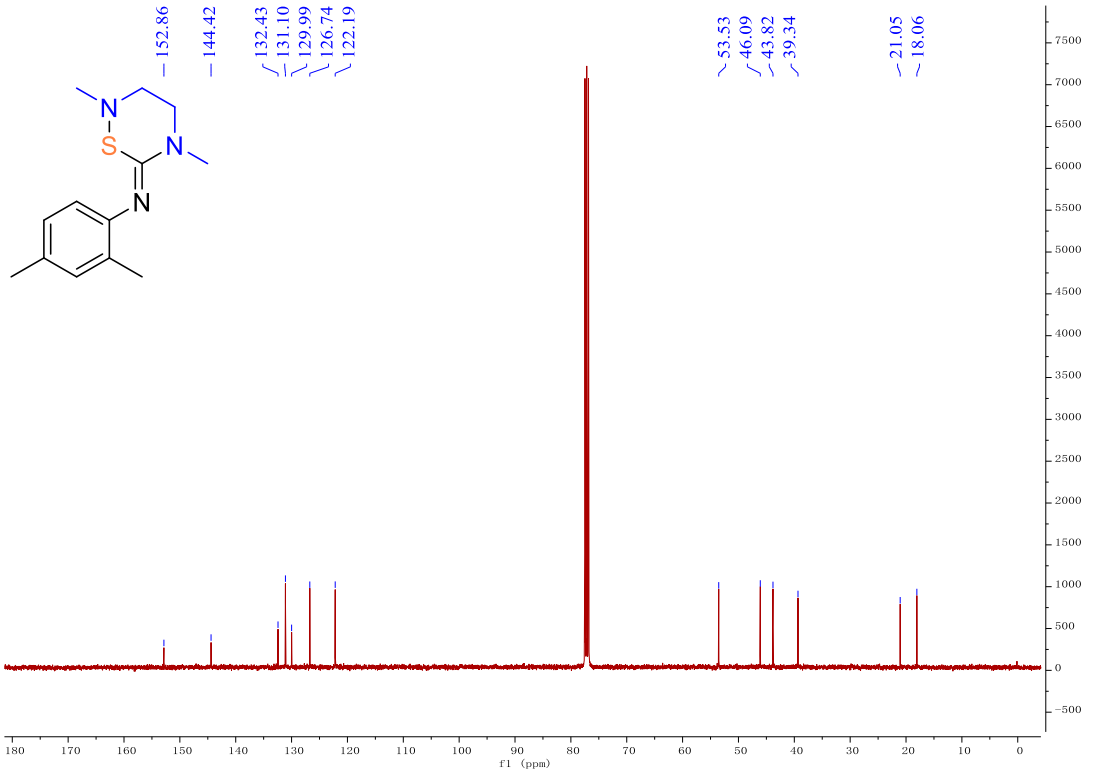
$^{13}C\{^{1}H\}$ NMR of Compound **6** (101 MHz, $CDCl_3$):



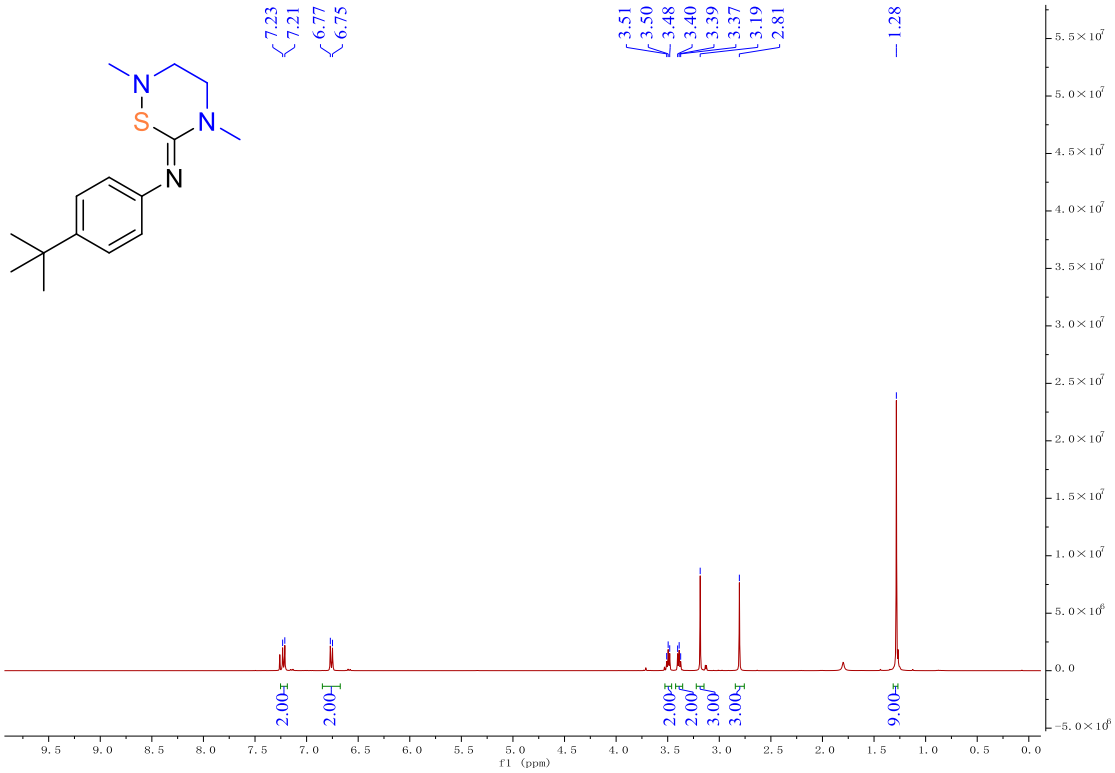
^{1}H NMR of Compound **7** (400 MHz, $CDCl_3$):



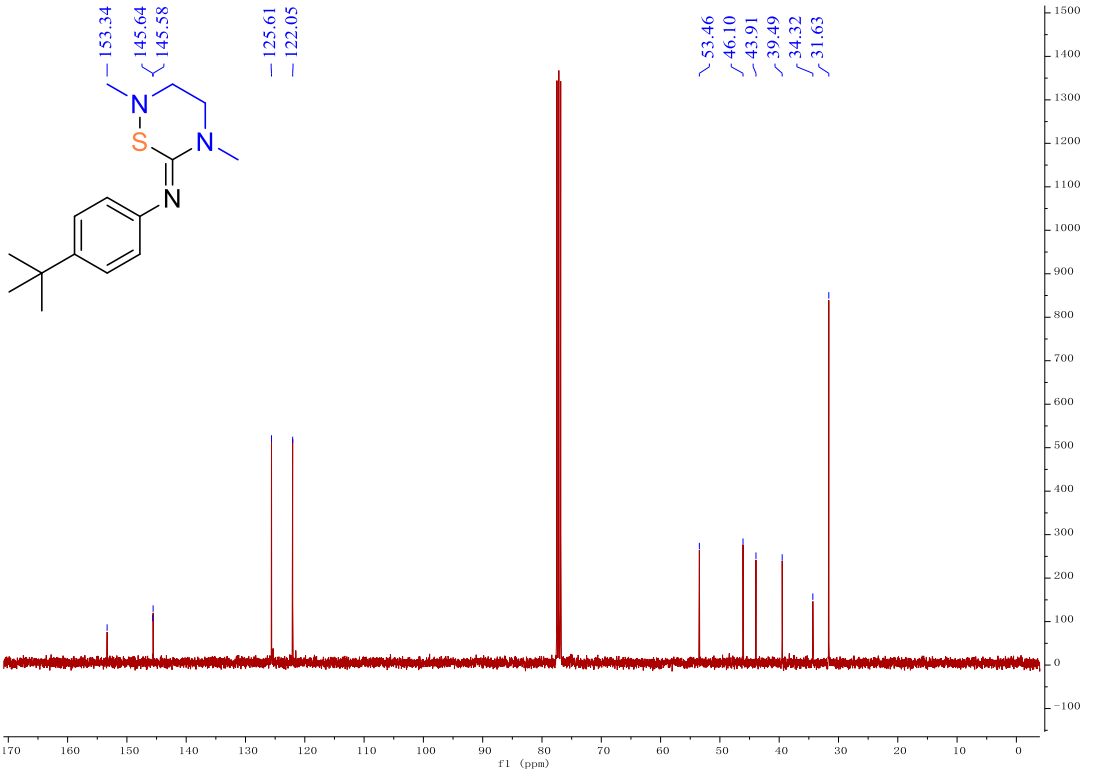
$^{13}C\{^{1}H\}$ NMR of Compound **7** (101 MHz, $CDCl_3$):



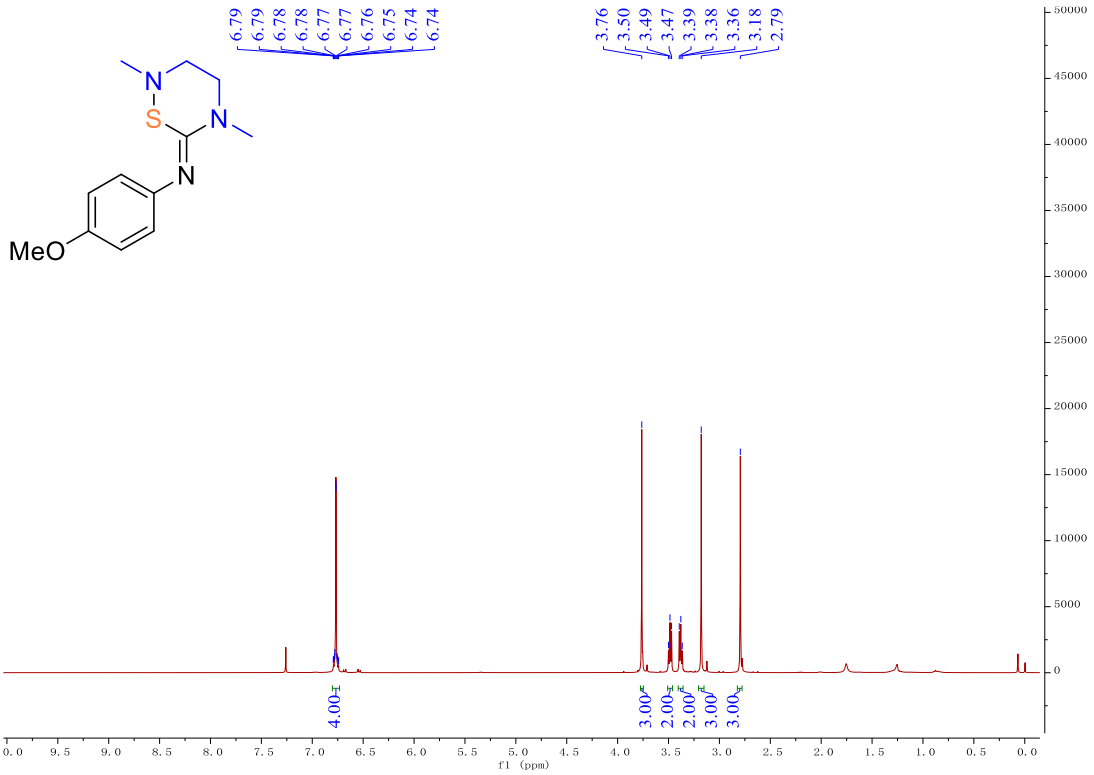
^{1}H NMR of Compound **8** (400 MHz, $CDCl_3$):



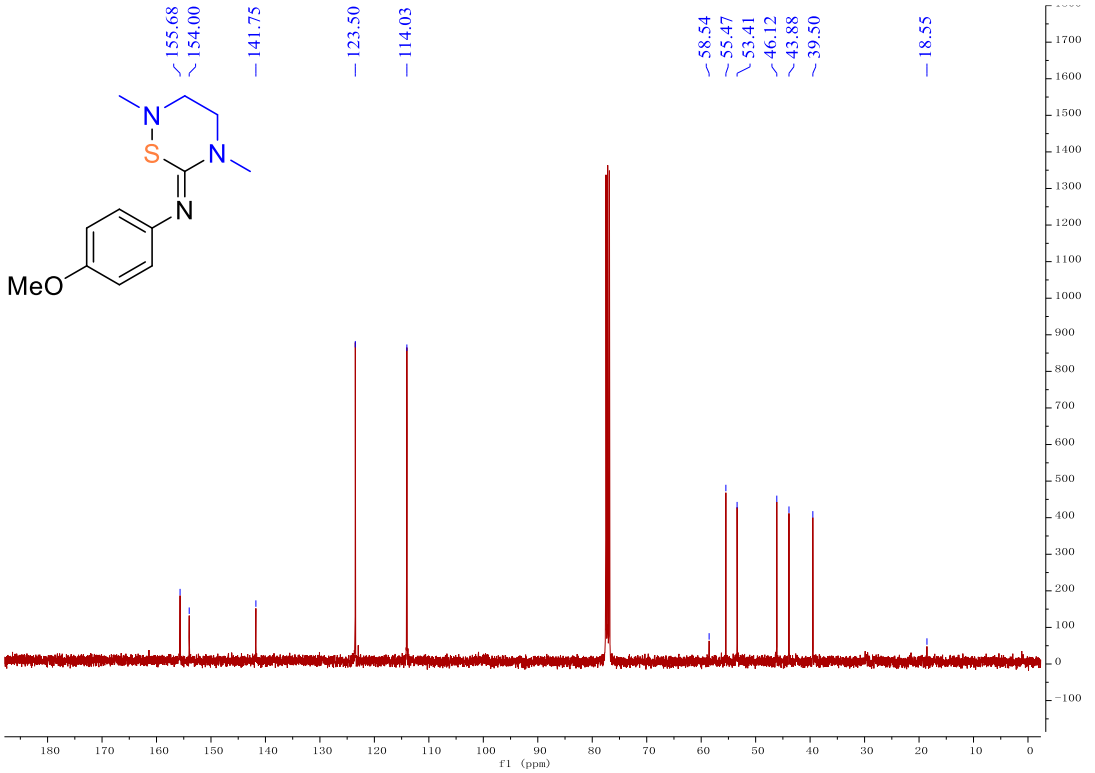
$^{13}C\{^{1}H\}$ NMR of Compound **8** (101 MHz, $CDCl_3$):



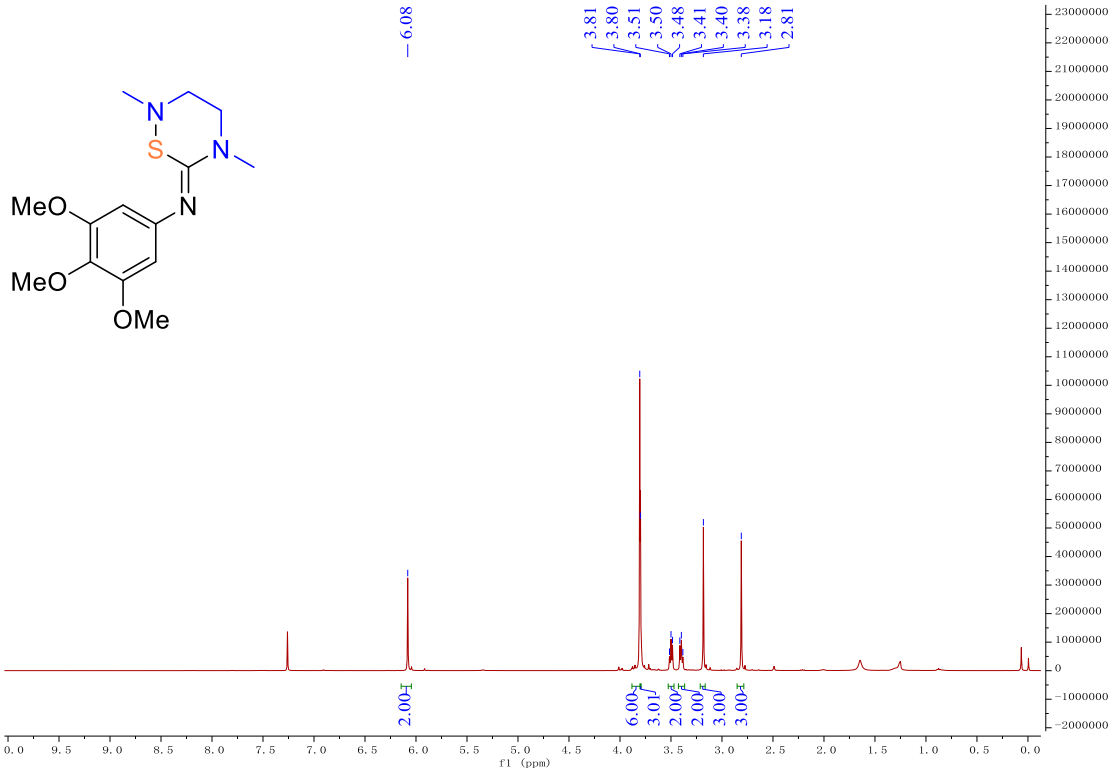
^{1}H NMR of Compound **9** (400 MHz, $CDCl_3$):



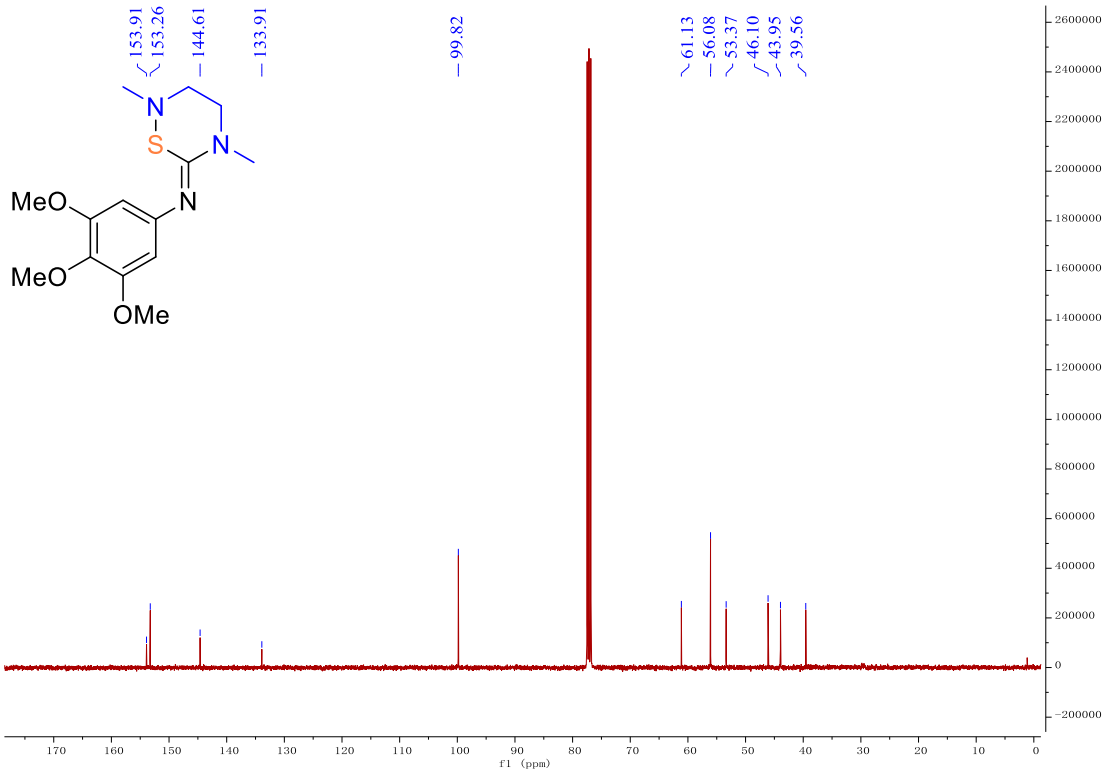
$^{13}C\{^{1}H\}$ NMR of Compound **9** (101 MHz, $CDCl_3$):



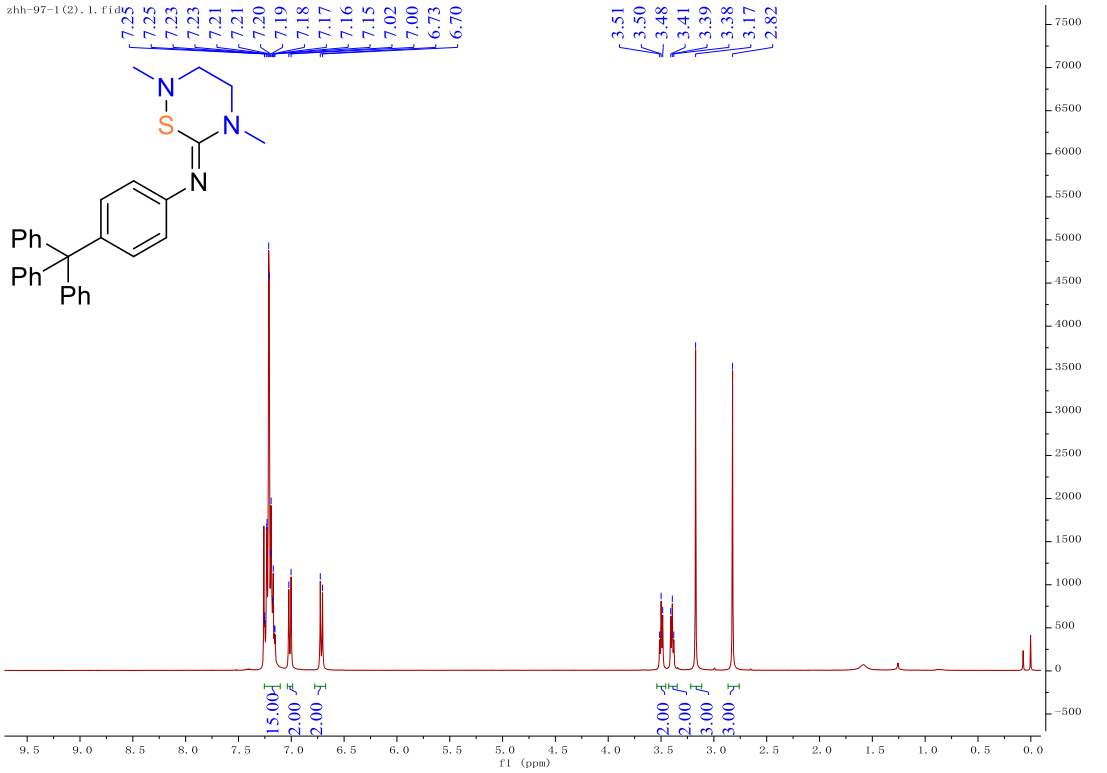
^{1}H NMR of Compound **10** (400 MHz, $CDCl_3$):



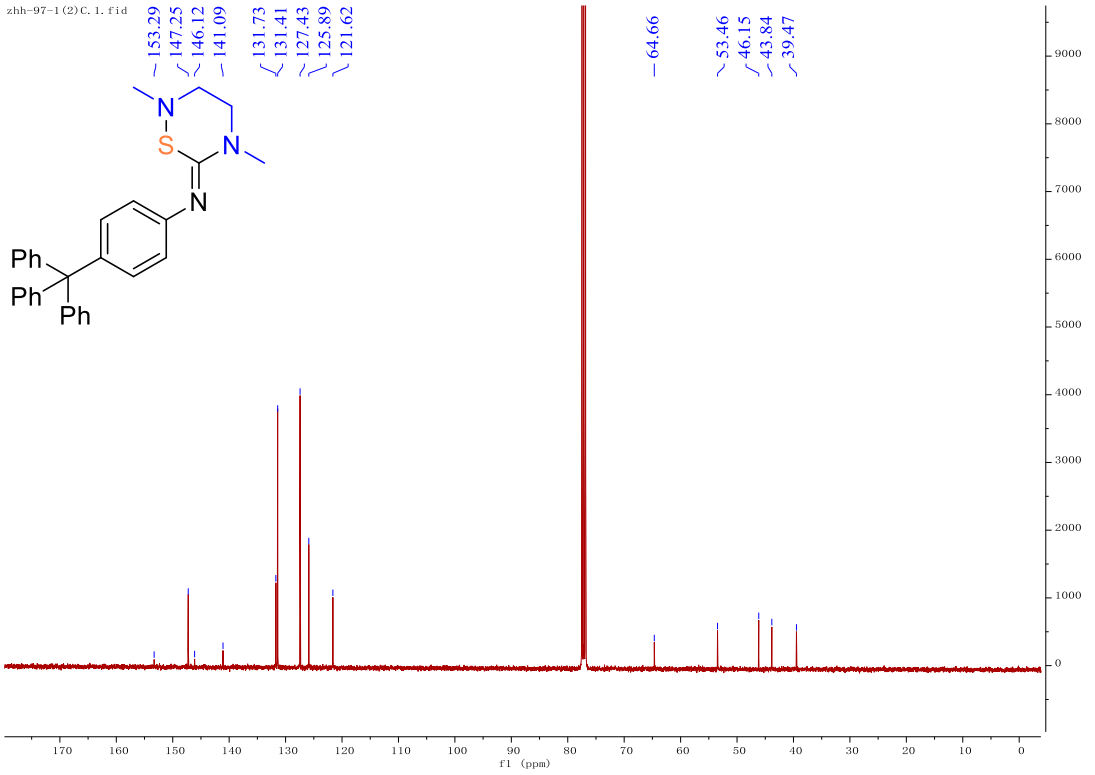
$^{13}C\{^{1}H\}$ NMR of Compound **10** (101 MHz, $CDCl_3$):



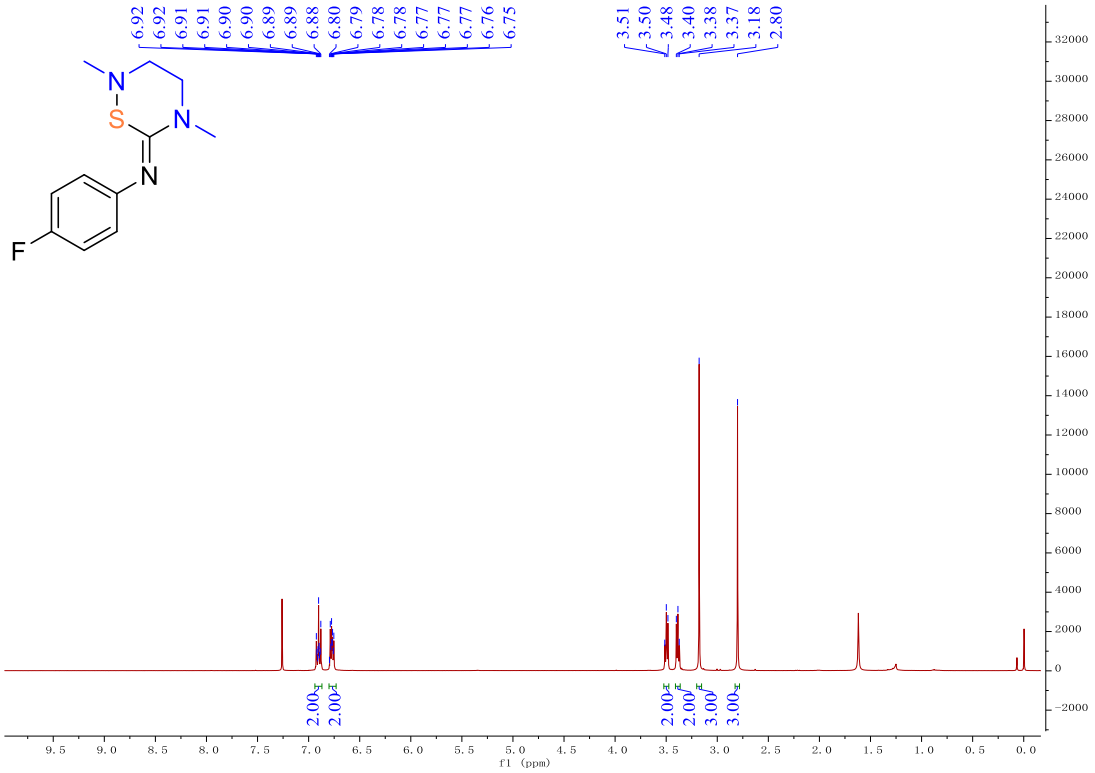
^{1}H NMR of Compound **11** (400 MHz, $CDCl_3$):



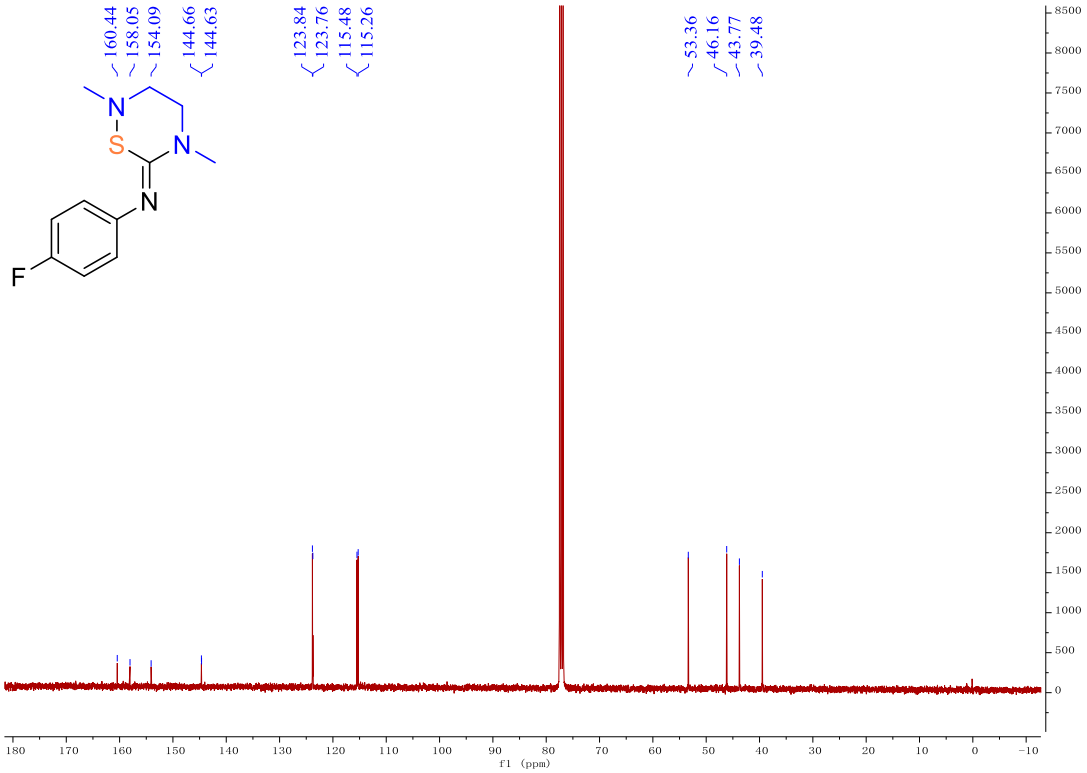
$^{13}C\{^{1}H\}$ NMR of Compound **11** (101 MHz, $CDCl_3$):



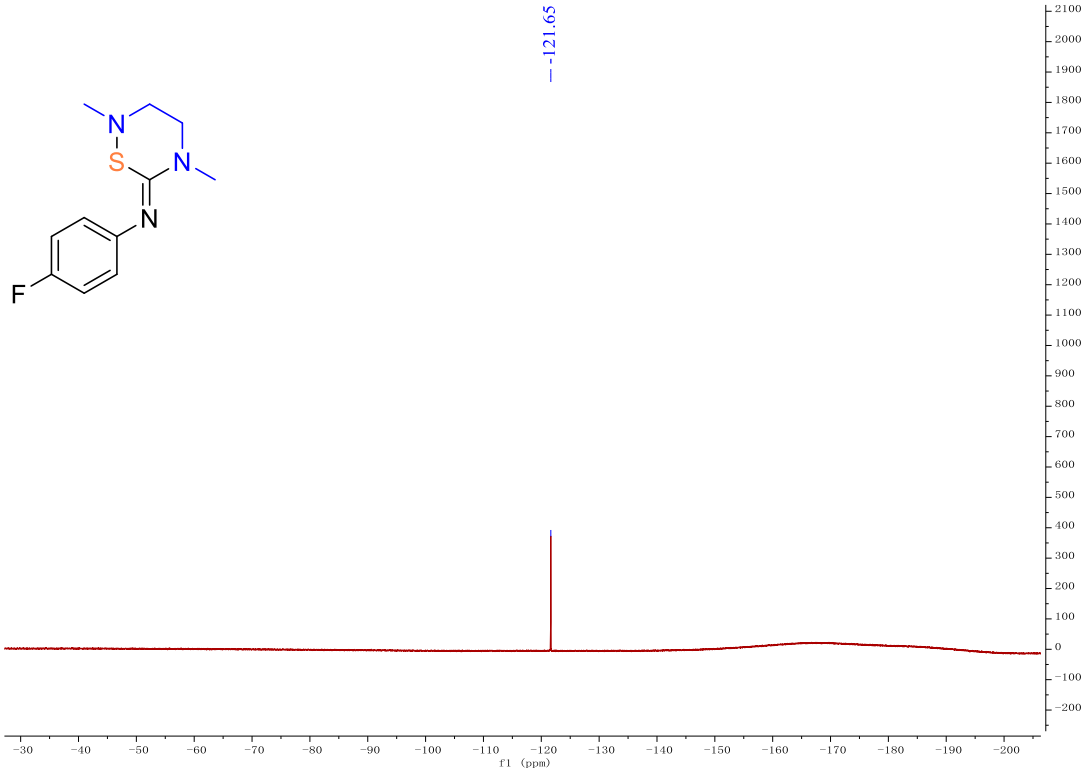
^{1}H NMR of Compound **12** (400 MHz, $CDCl_3$):



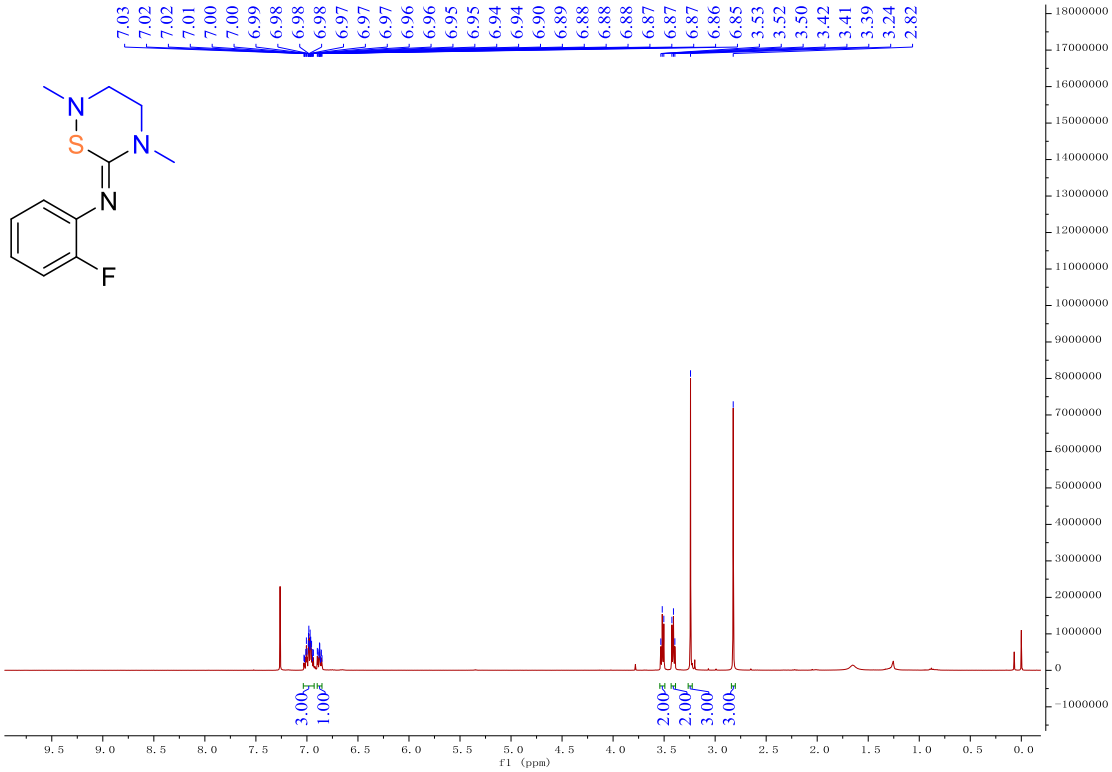
$^{13}C\{^{1}H\}$ NMR of Compound **12** (101 MHz, $CDCl_3$):



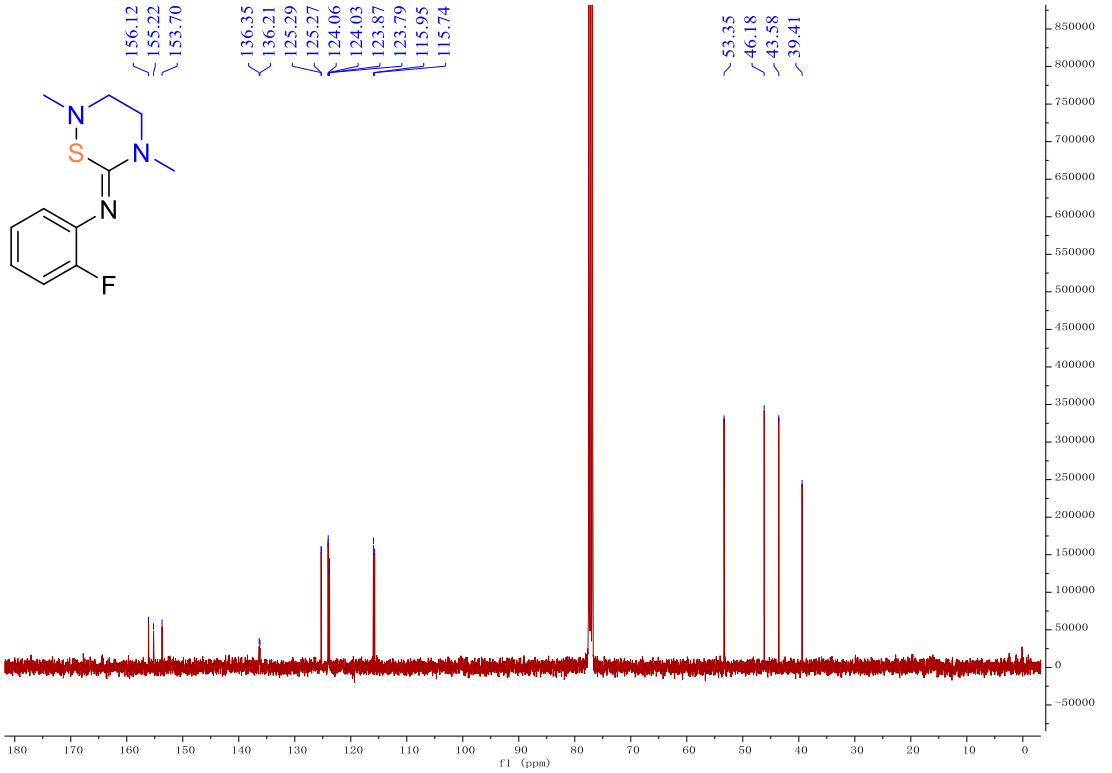
^{19}F NMR of Compound **12** (376 MHz, $CDCl_3$):



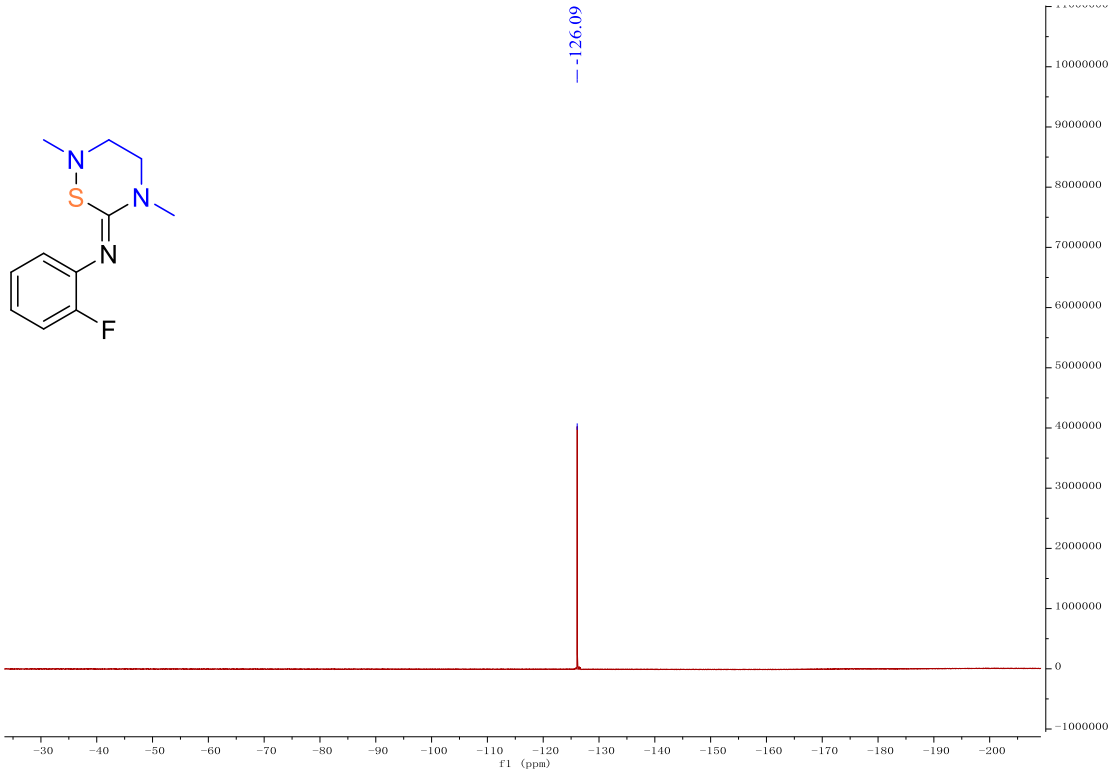
^{1}H NMR of Compound **13** (400 MHz, $CDCl_3$):



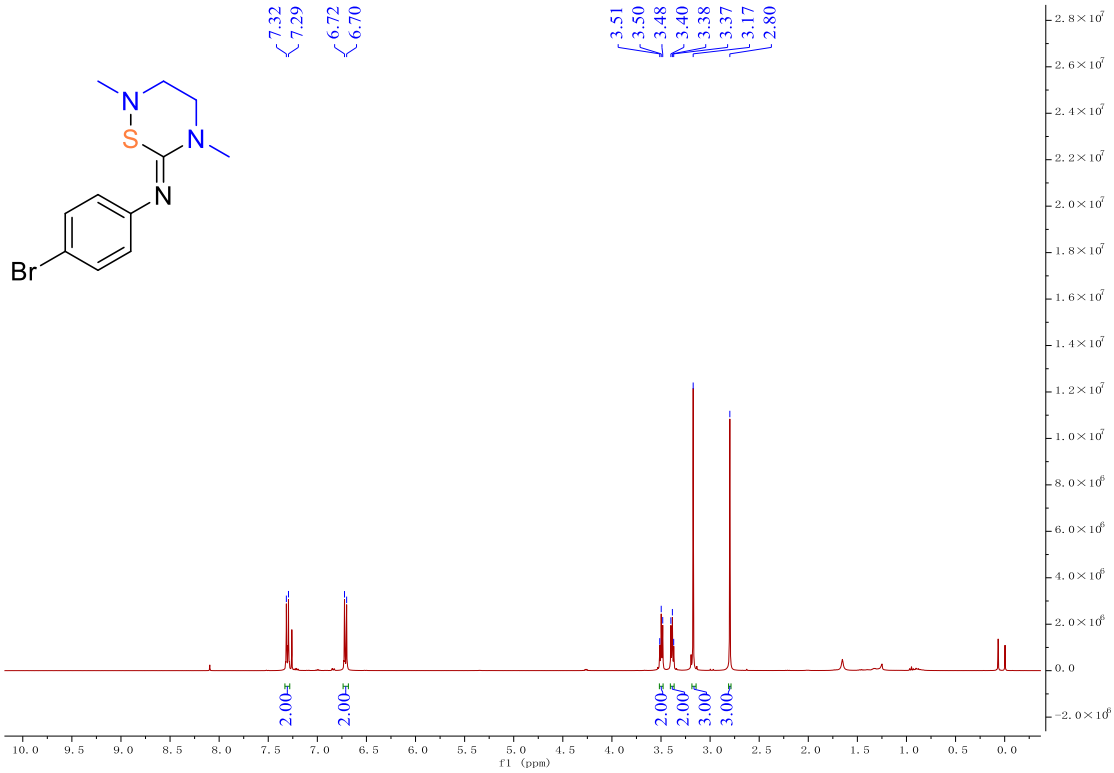
^{13}C{^{1}H} NMR of Compound **13** (101 MHz, $CDCl_3$):



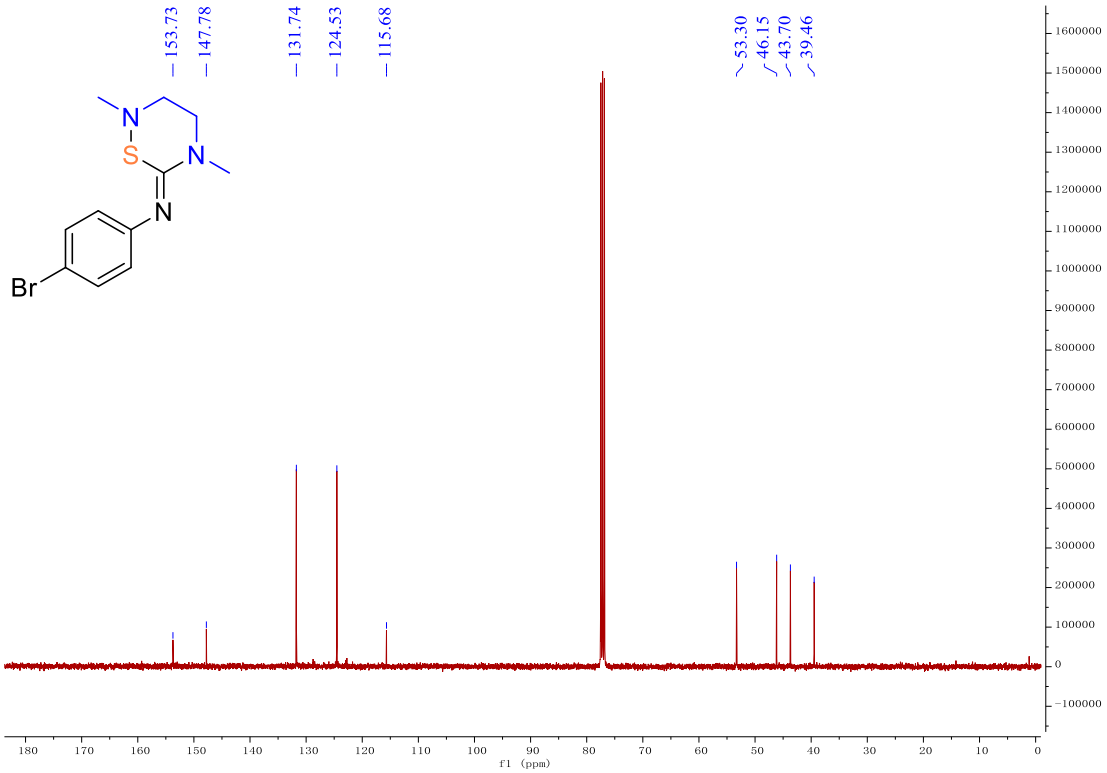
^{19}F NMR of Compound **13** (376 MHz, $CDCl_3$):



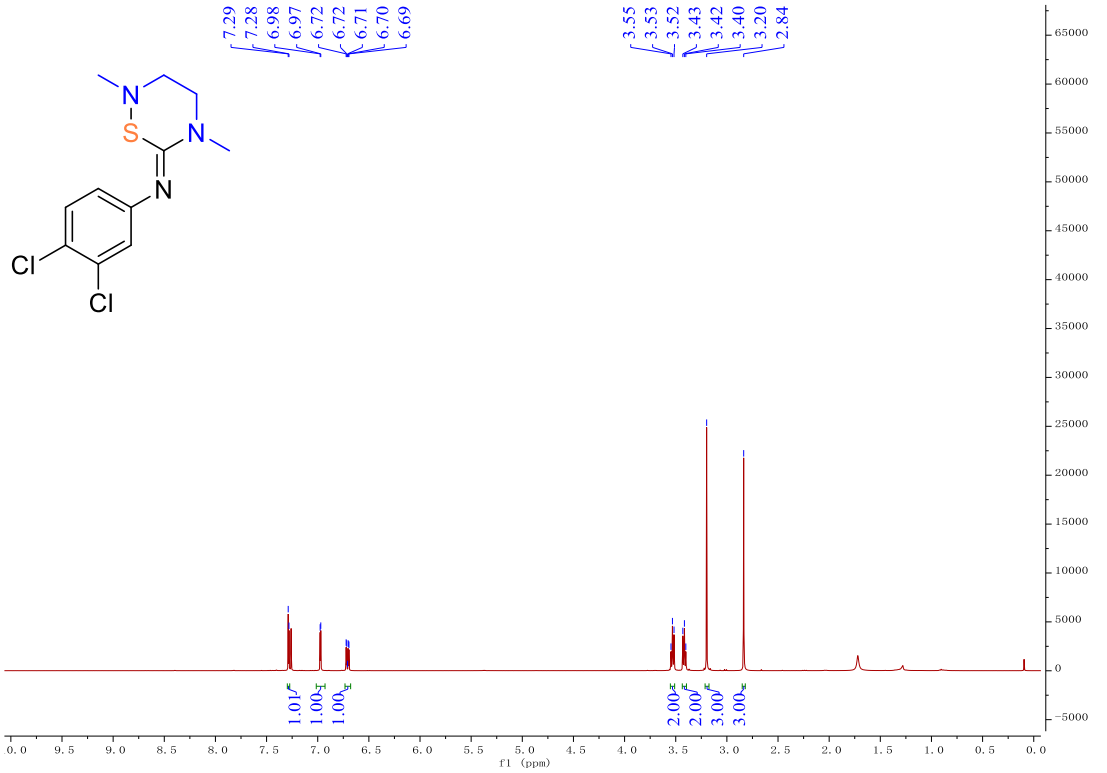
^{1}H NMR of Compound **14** (400 MHz, $CDCl_3$):



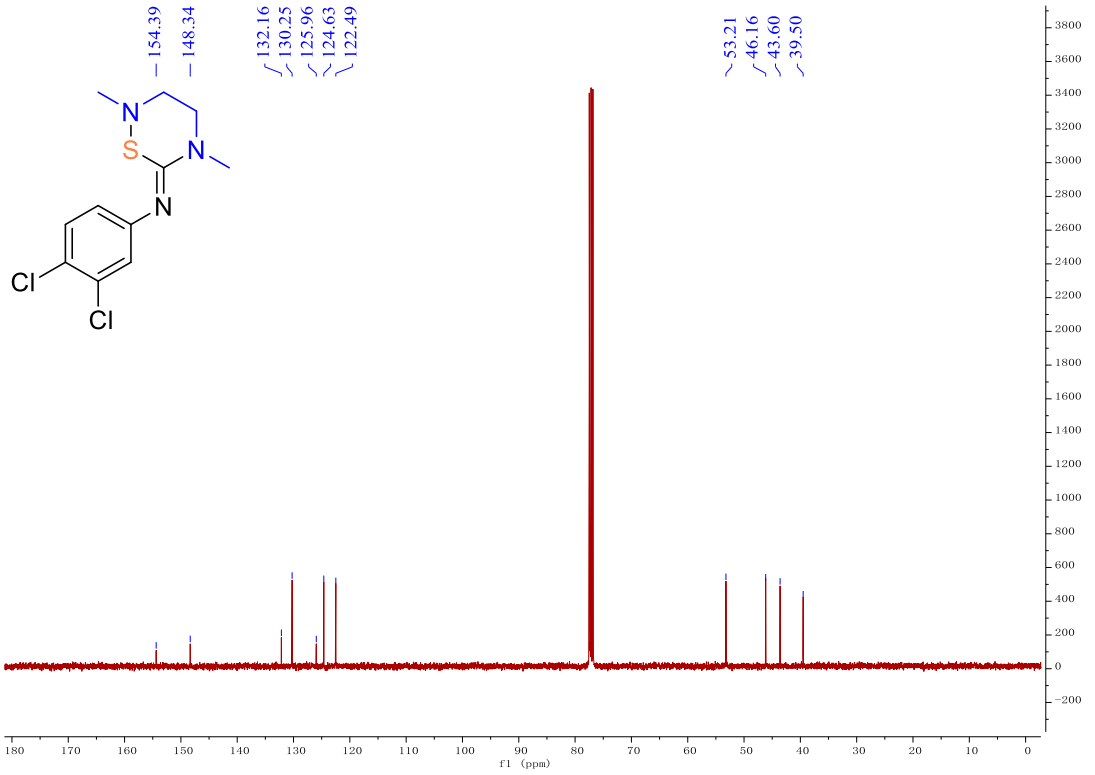
$^{13}C\{^{1}H\}$ NMR of Compound **14** (101 MHz, $CDCl_3$):



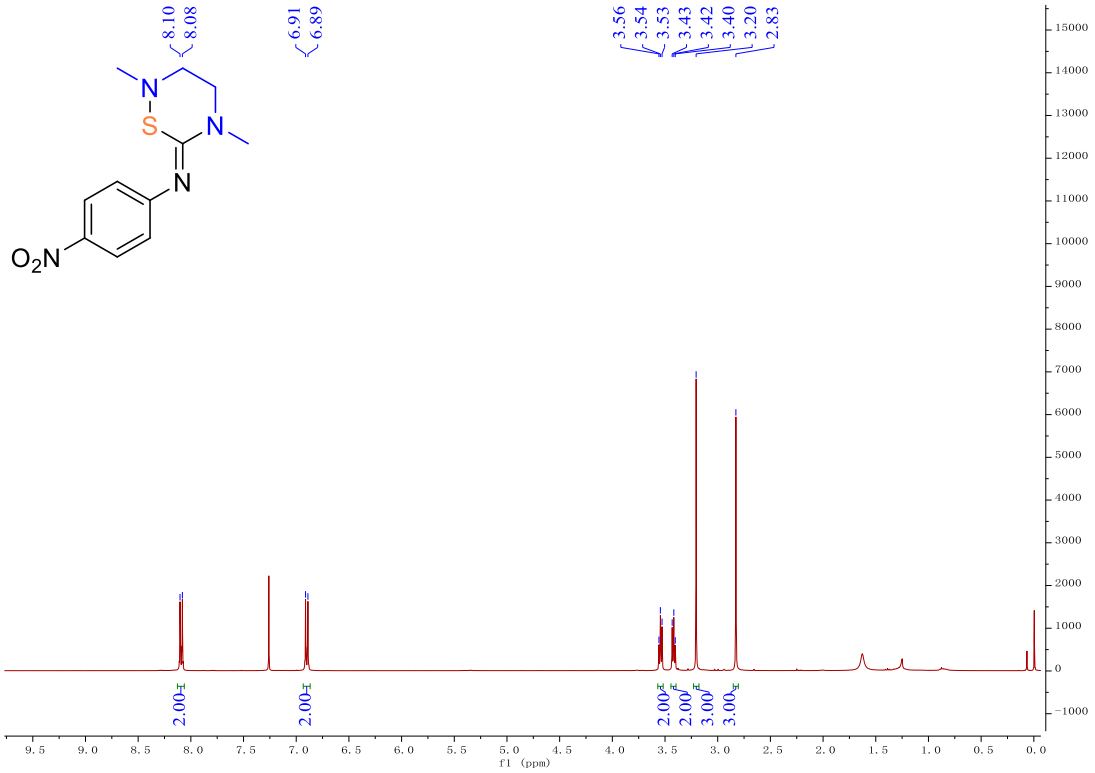
^{1}H NMR of Compound **15** (400 MHz, $CDCl_3$):



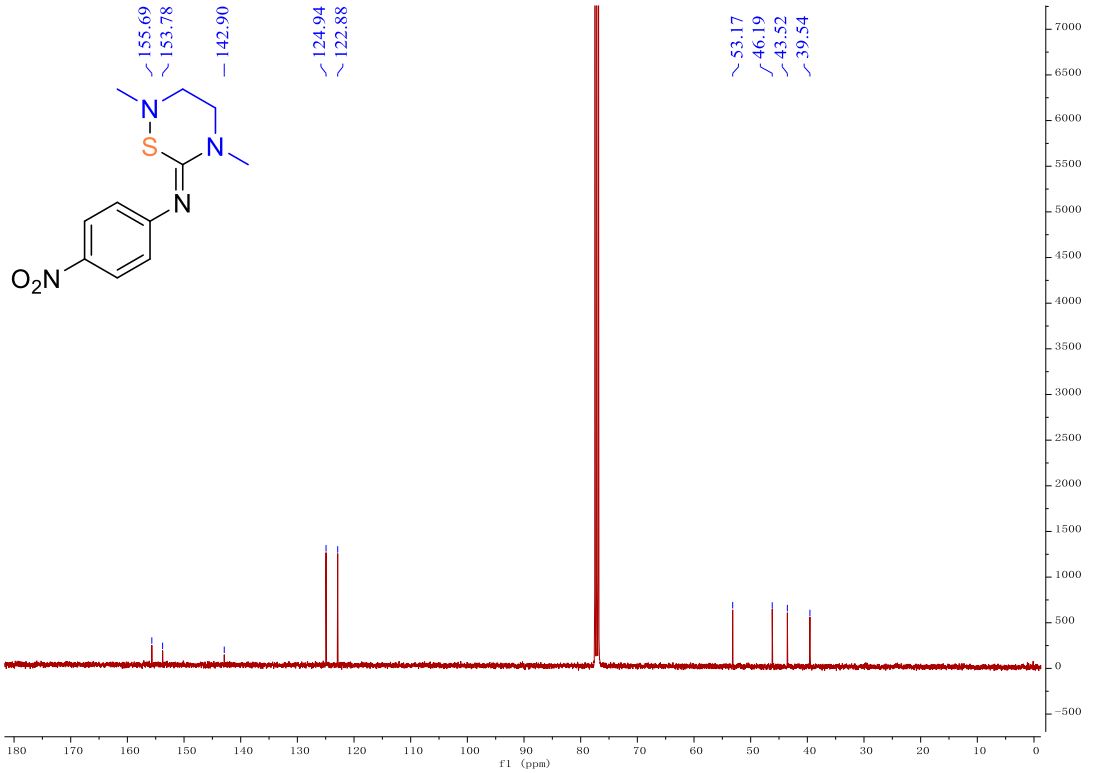
$^{13}C\{^{1}H\}$ NMR of Compound **15** (101 MHz, $CDCl_3$):



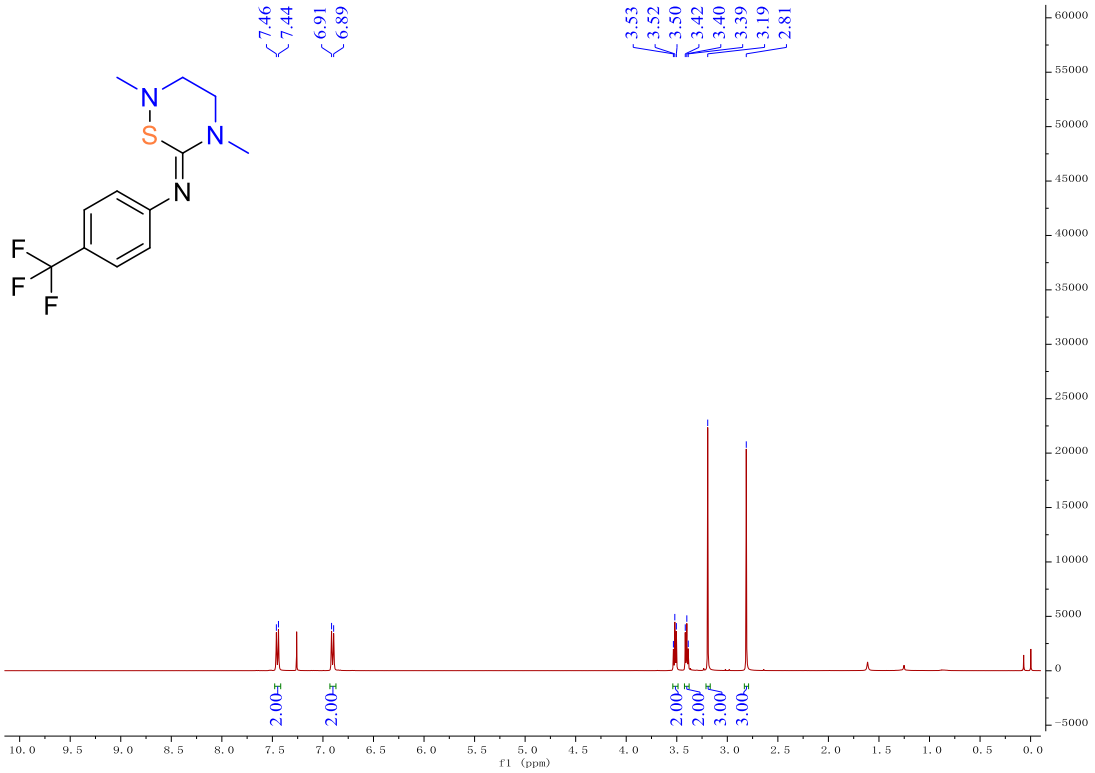
^{1}H NMR of Compound **16** (400 MHz, $CDCl_3$):



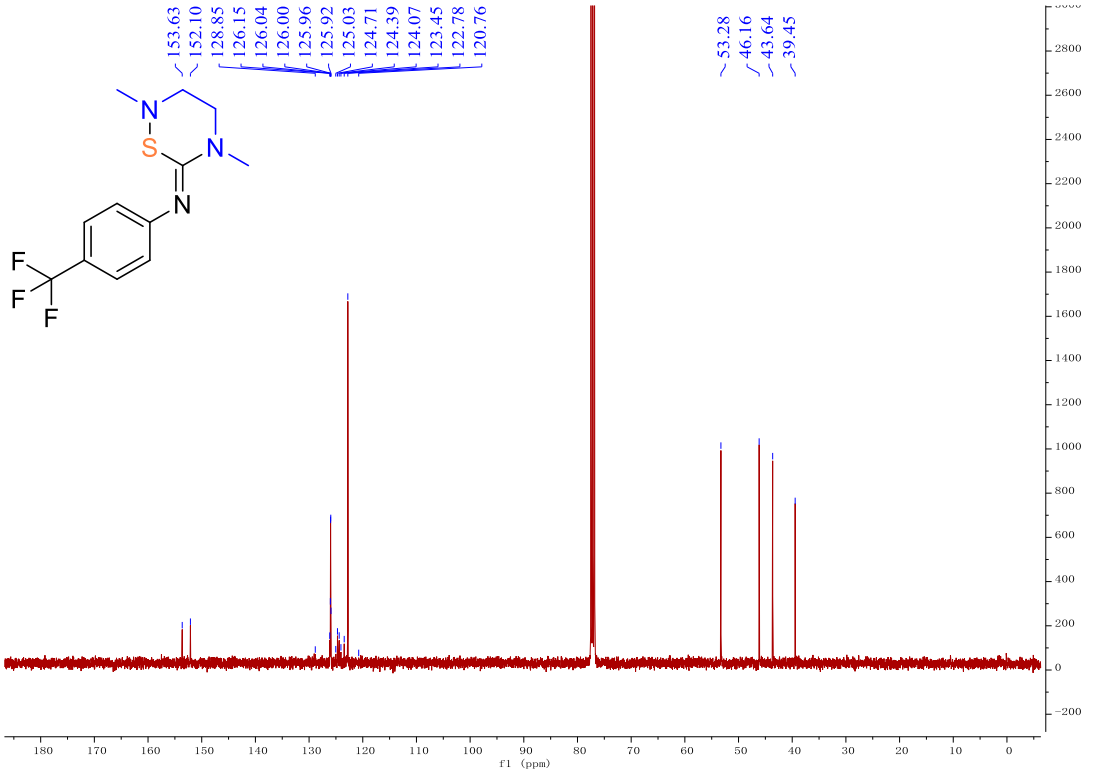
$^{13}C\{^{1}H\}$ NMR of Compound **16** (101 MHz, $CDCl_3$):



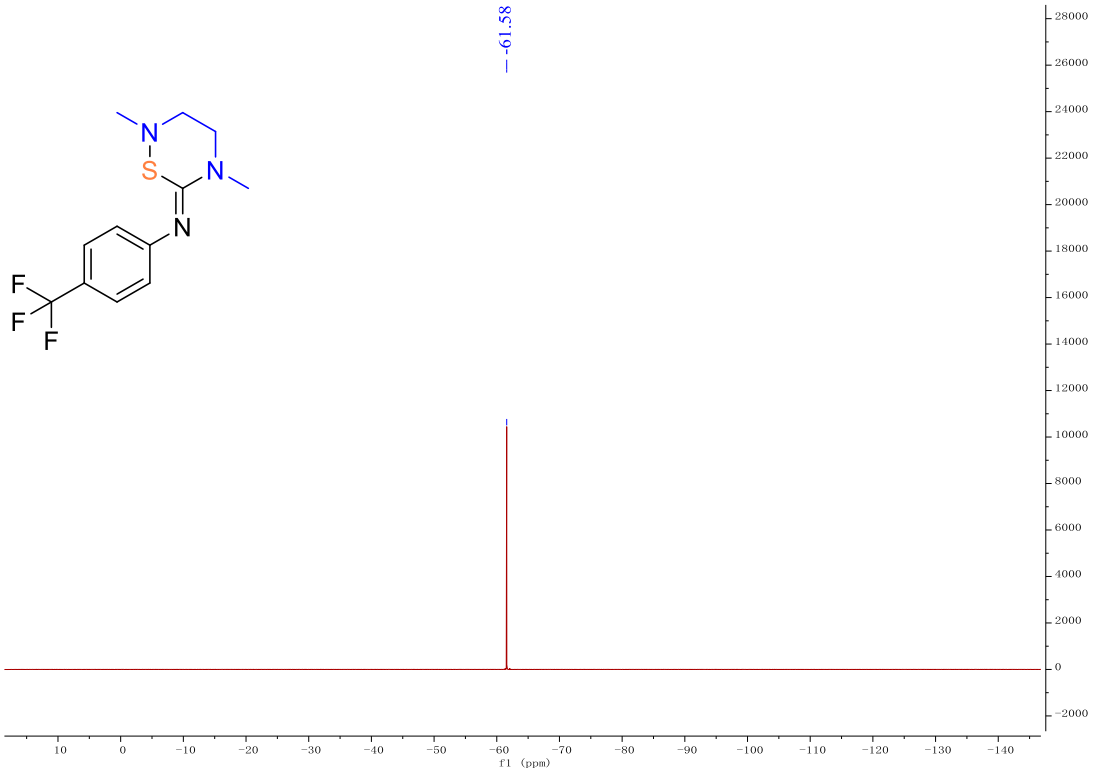
^{1}H NMR of Compound **17** (400 MHz, $CDCl_3$):



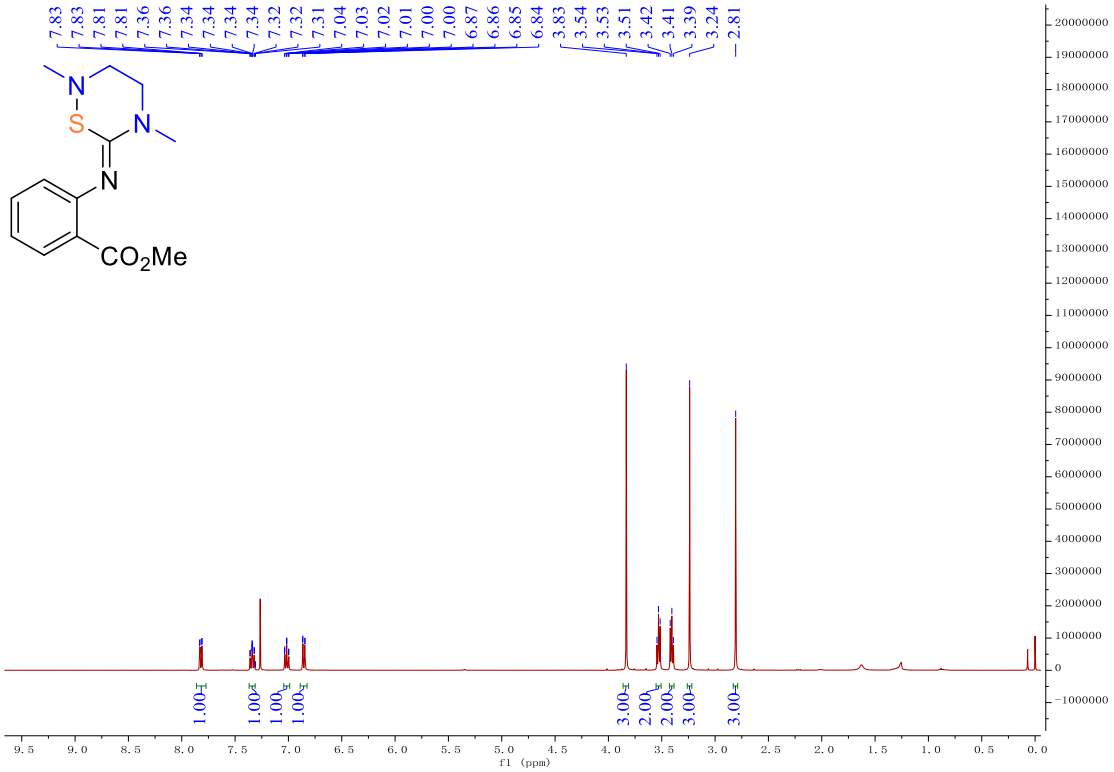
$^{13}C\{^{1}H\}$ NMR of Compound **17** (101 MHz, $CDCl_3$):



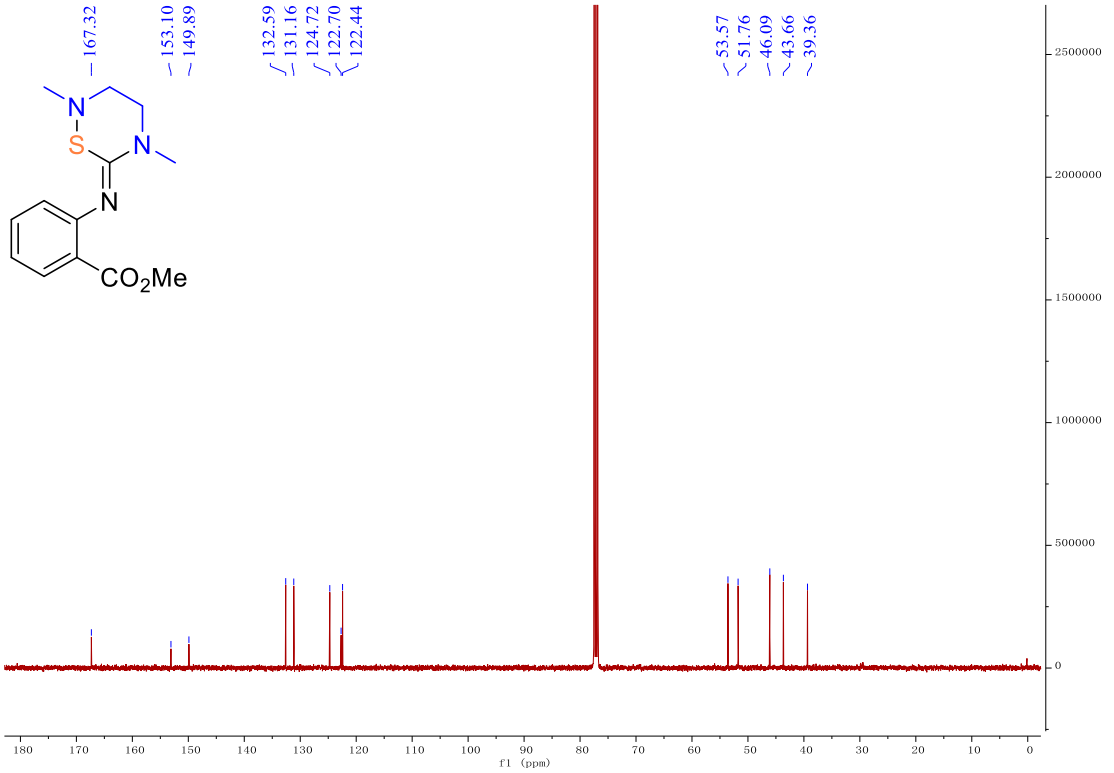
^{19}F NMR of Compound **17** (376 MHz, $CDCl_3$):



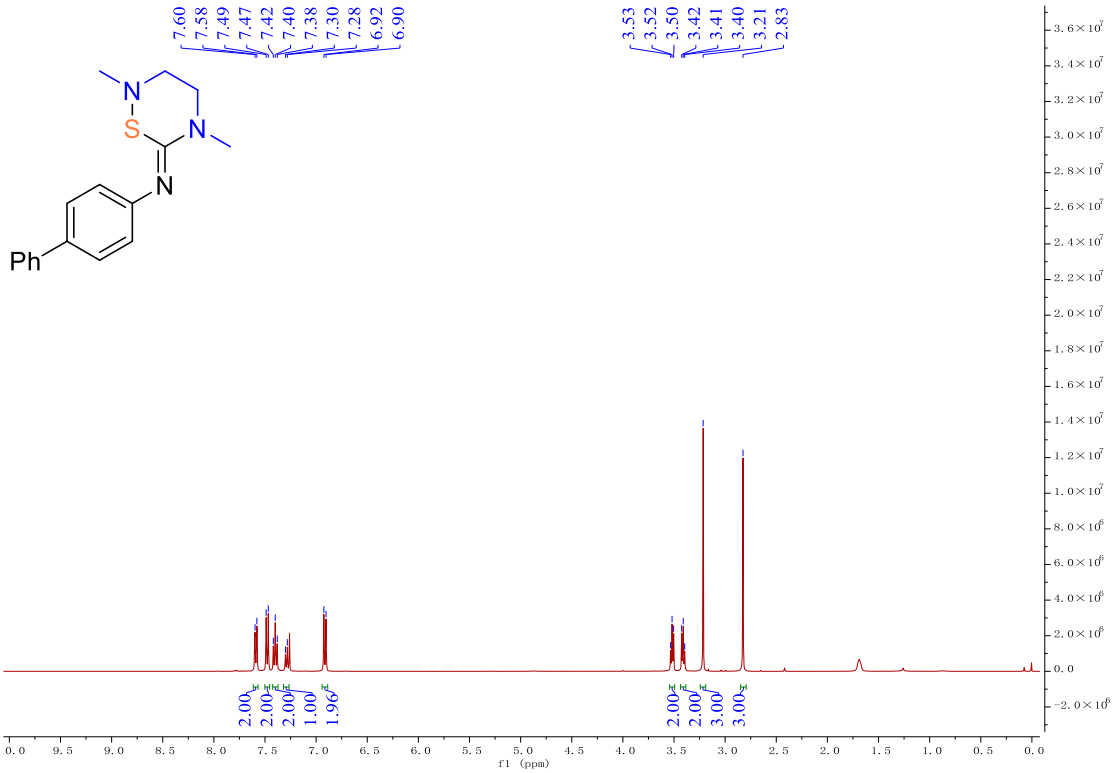
^{1}H NMR of Compound **18** (400 MHz, $CDCl_3$):



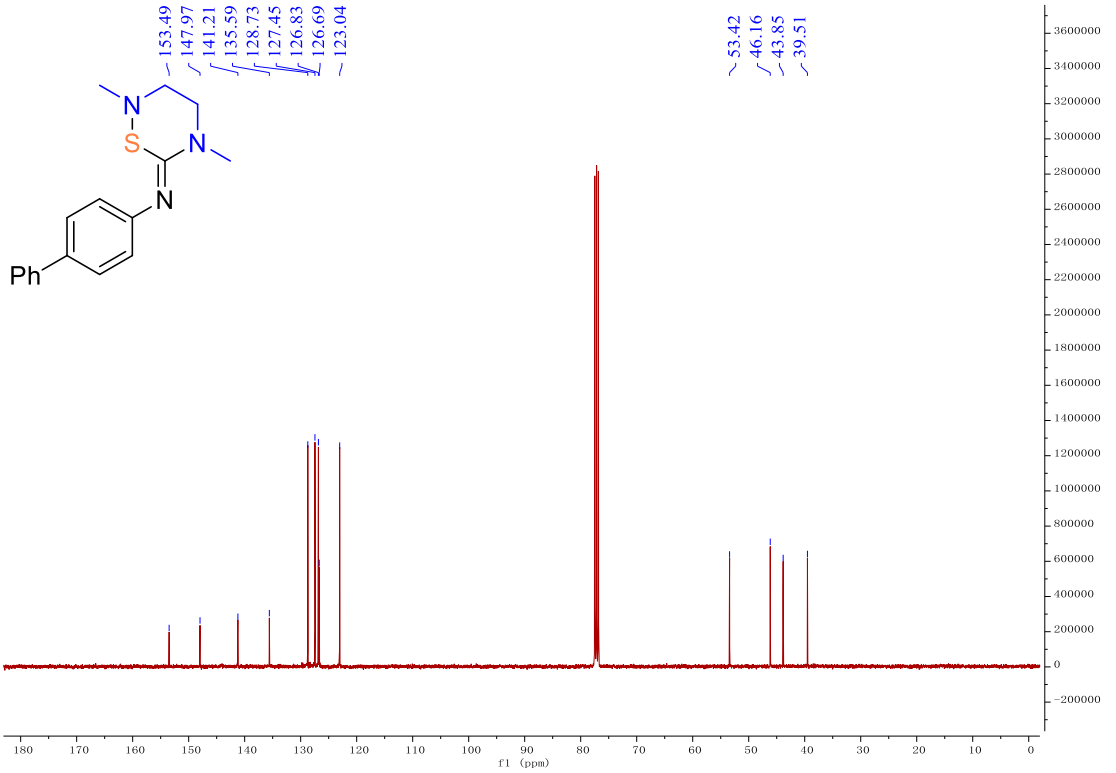
^{13}C{^{1}H} NMR of Compound **18** (101 MHz, $CDCl_3$):



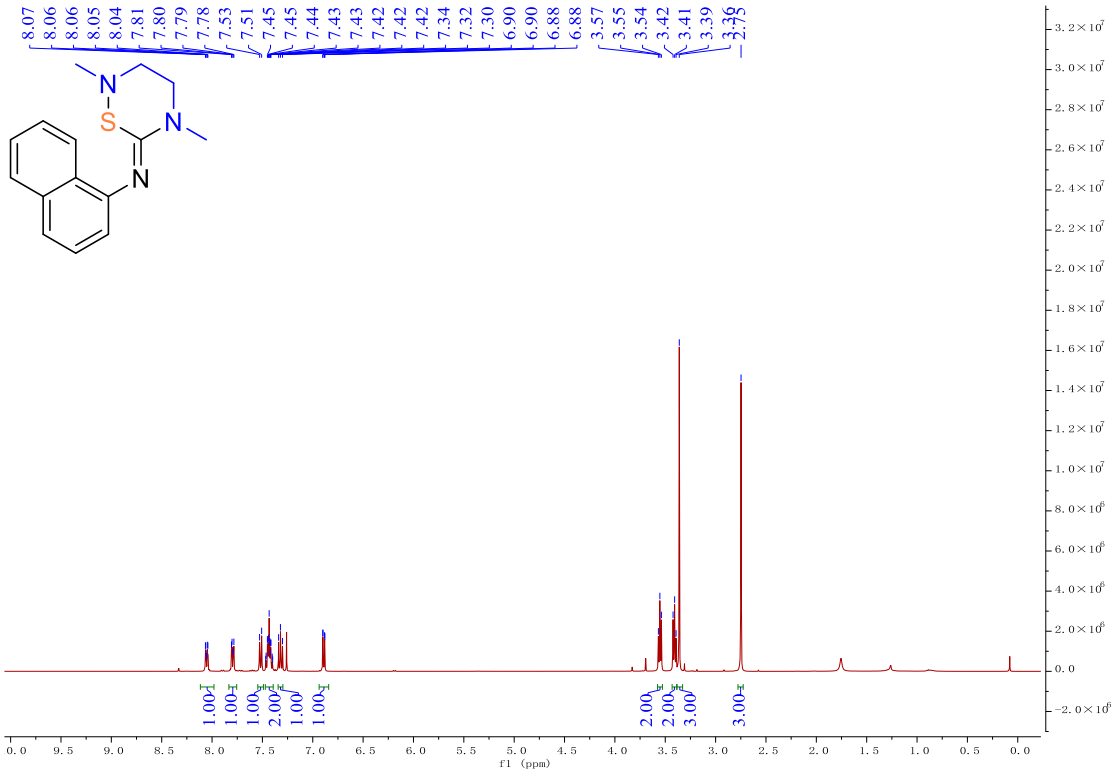
^{1}H NMR of Compound **19** (400 MHz, $CDCl_3$):



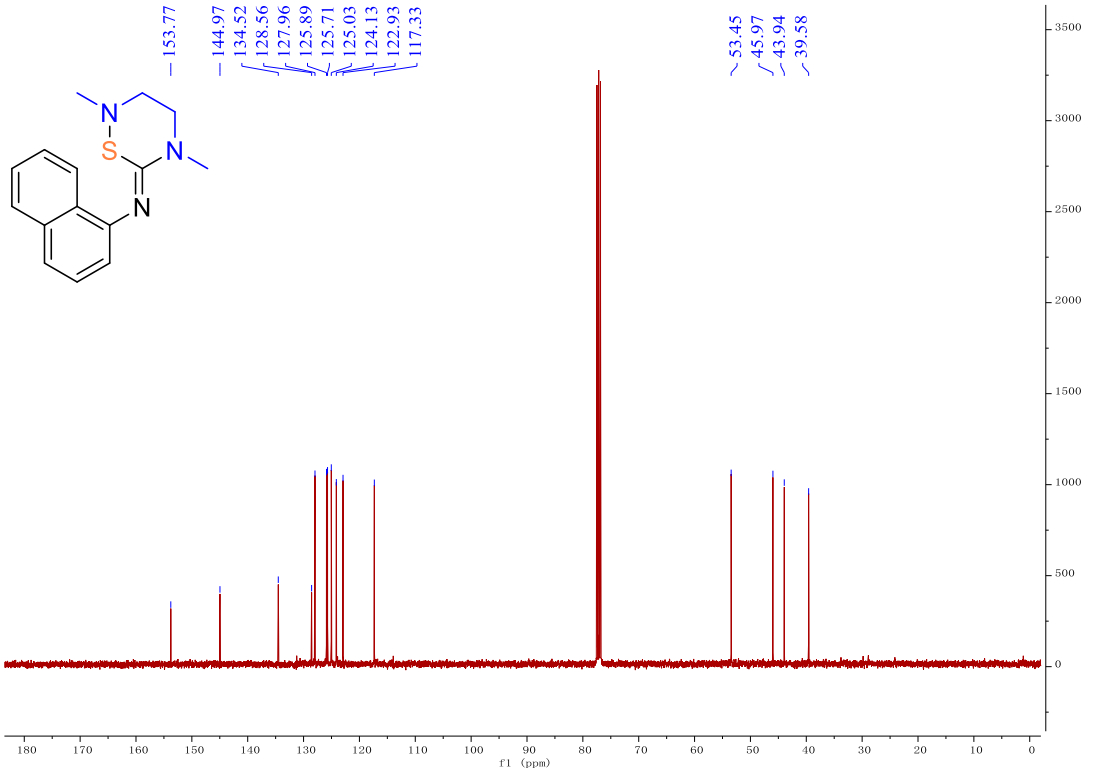
^{13}C{^{1}H} NMR of Compound **19** (101 MHz, $CDCl_3$):



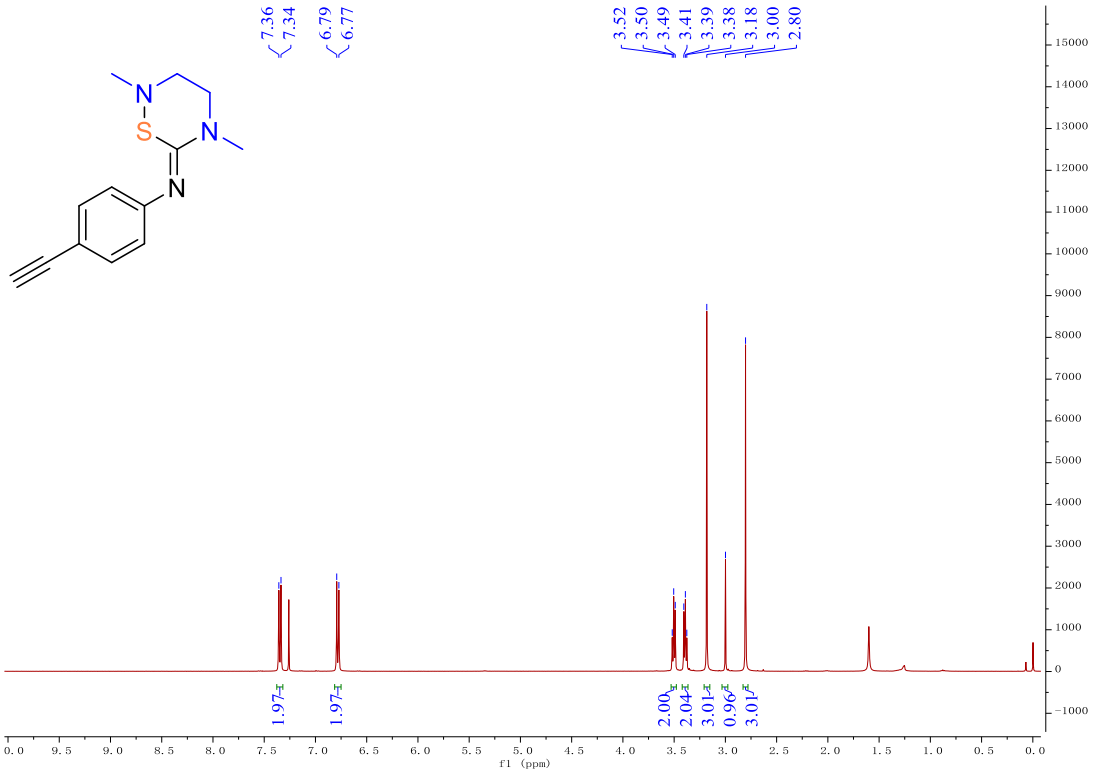
^{1}H NMR of Compound **20** (400 MHz, $CDCl_3$):



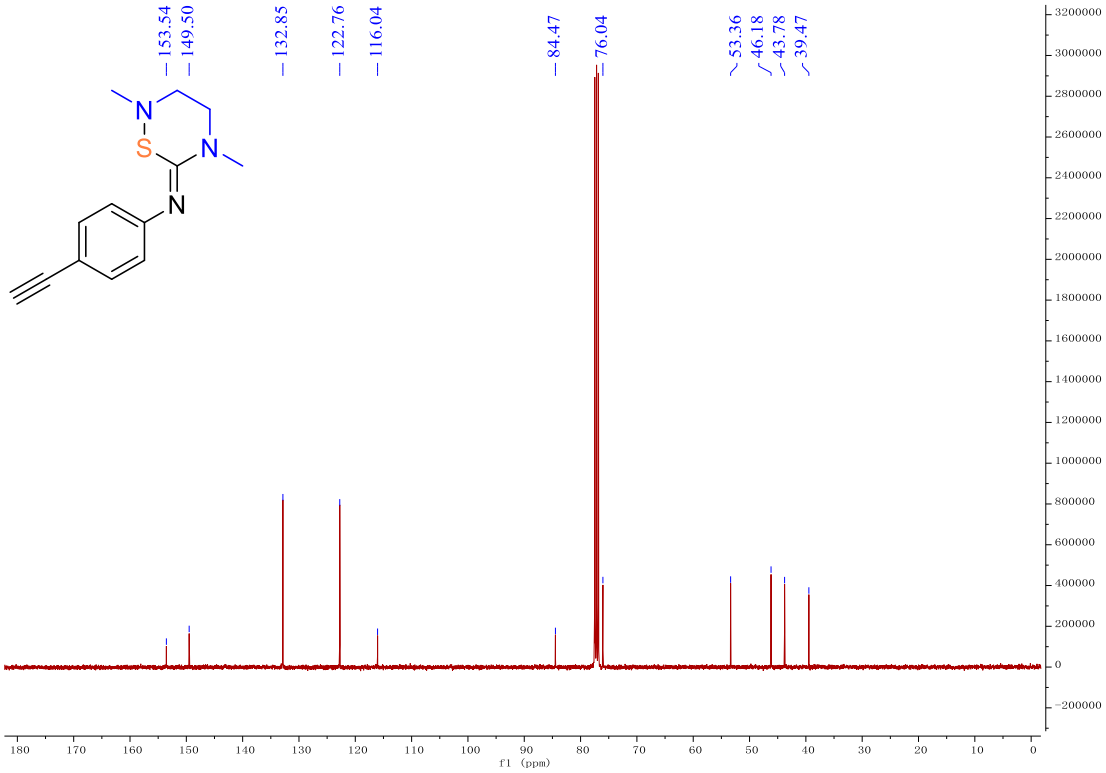
^{13}C{^{1}H} NMR of Compound **20** (101 MHz, $CDCl_3$):



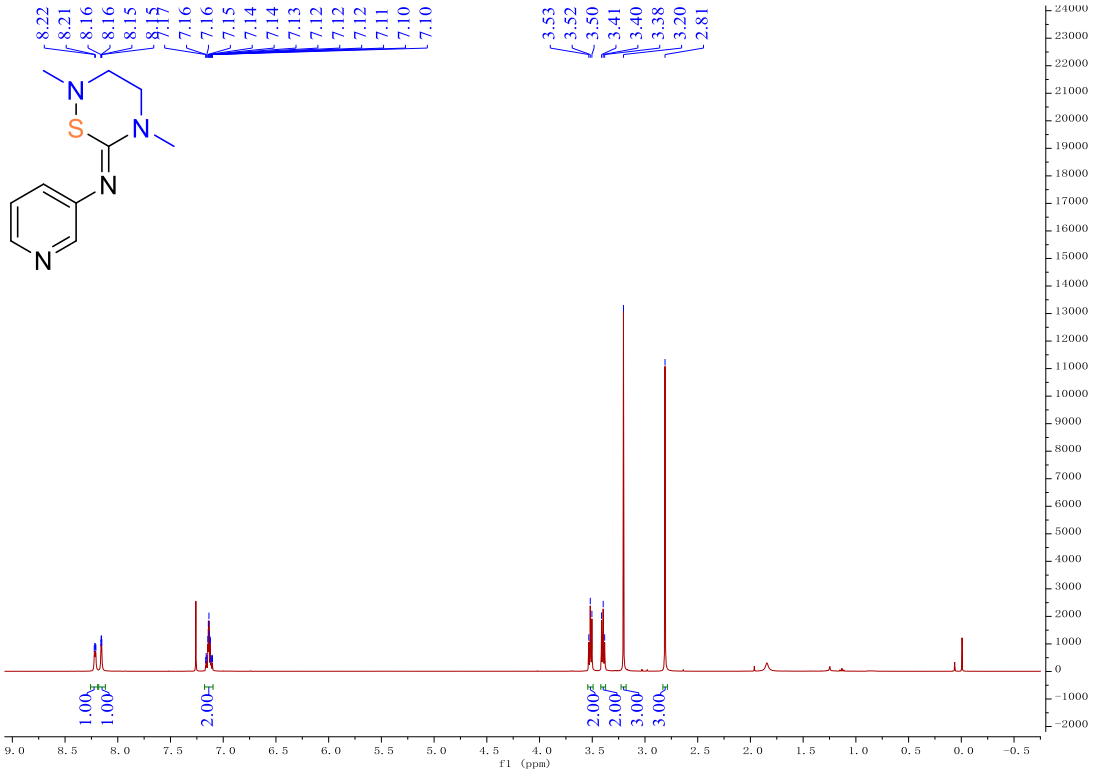
^{1}H NMR of Compound **21** (400 MHz, $CDCl_3$):



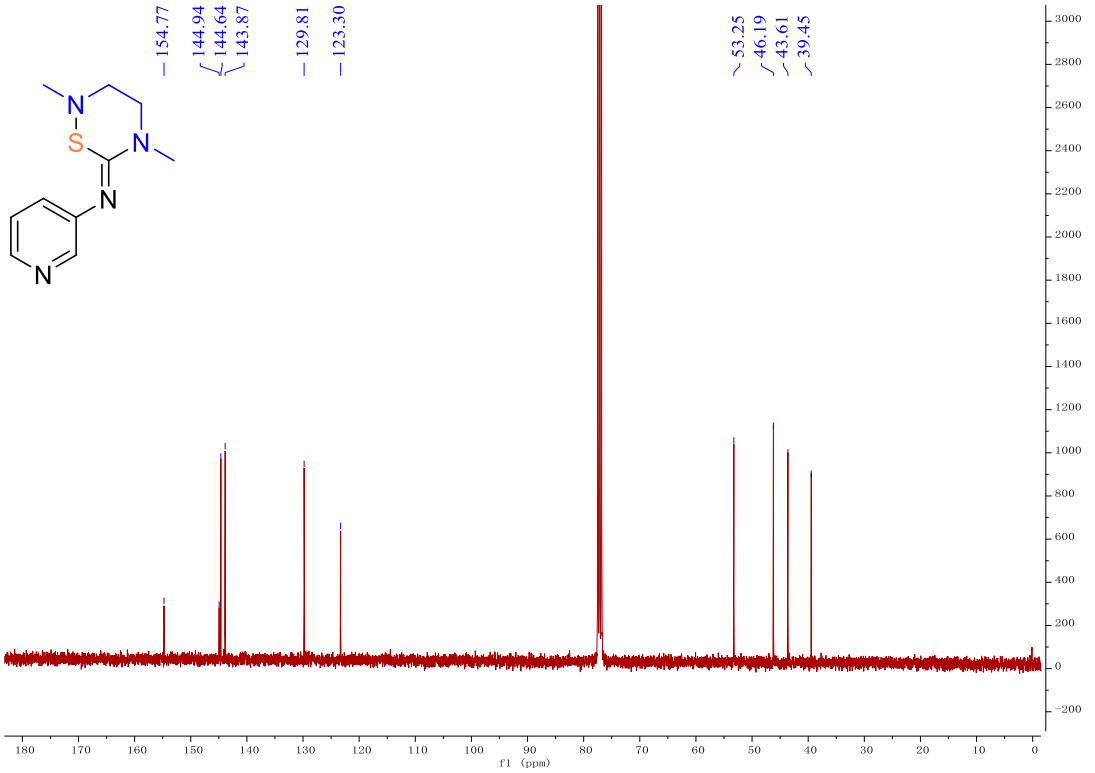
^{13}C{^{1}H} NMR of Compound **21** (101 MHz, $CDCl_3$):



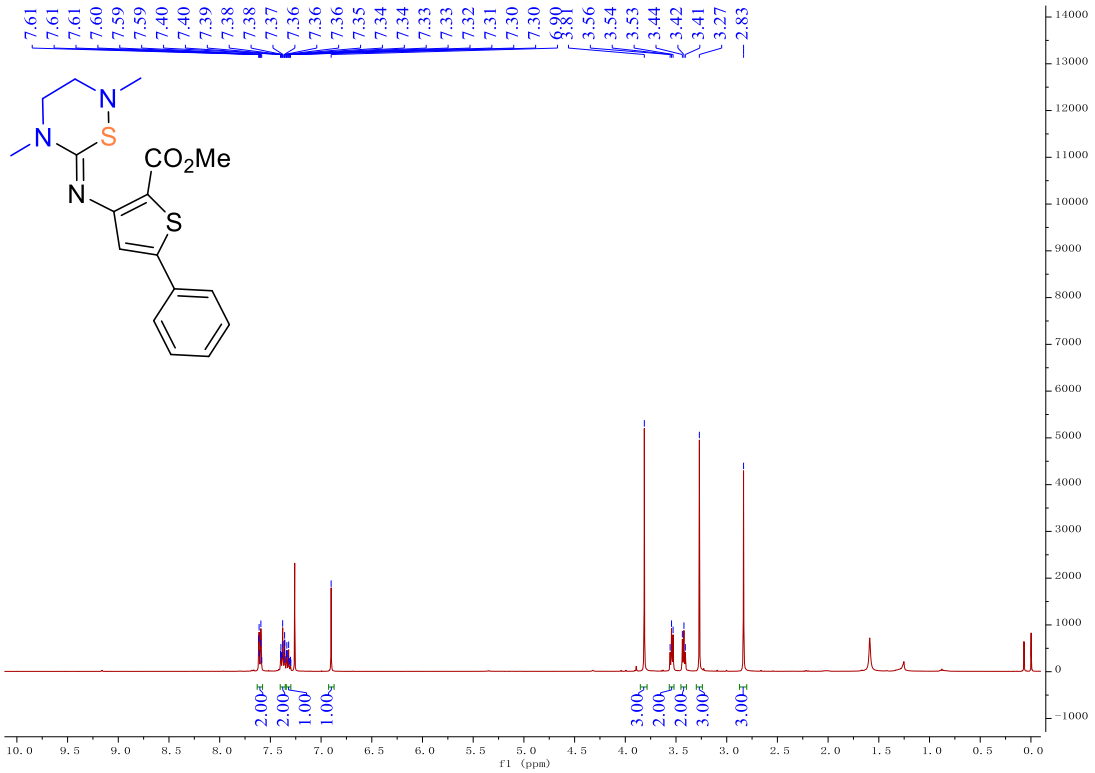
^{1}H NMR of Compound **22** (400 MHz, $CDCl_3$):



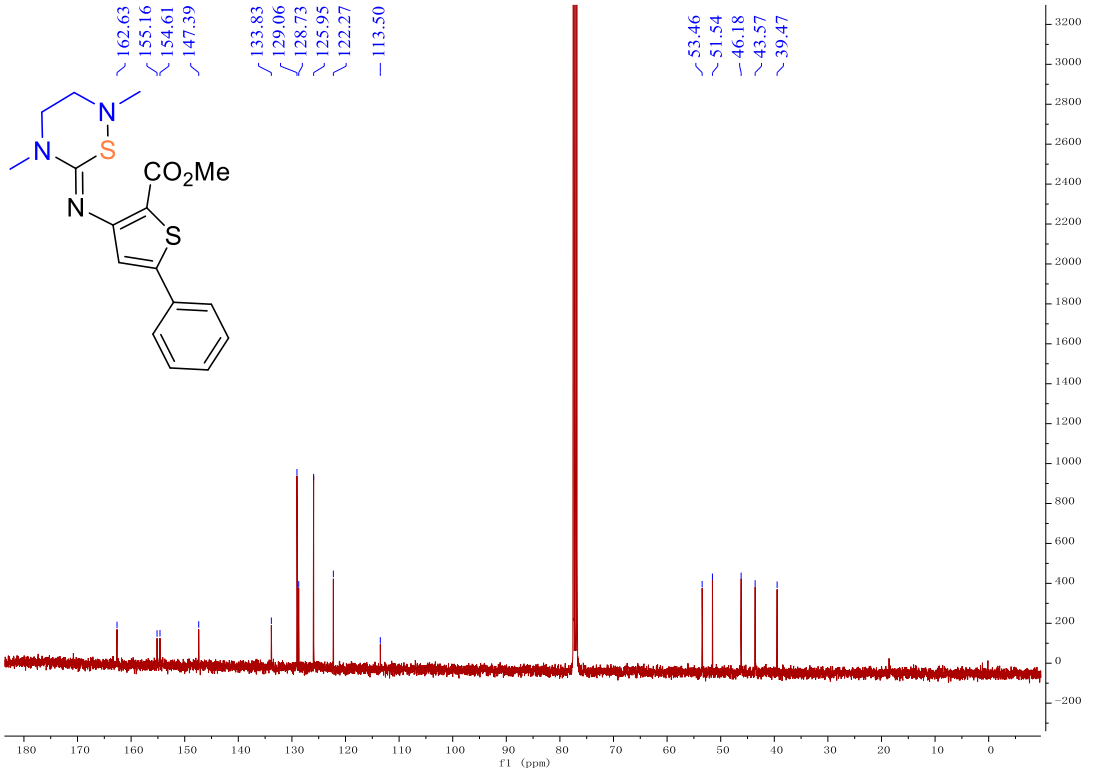
^{13}C{^{1}H} NMR of Compound **22** (101 MHz, $CDCl_3$):



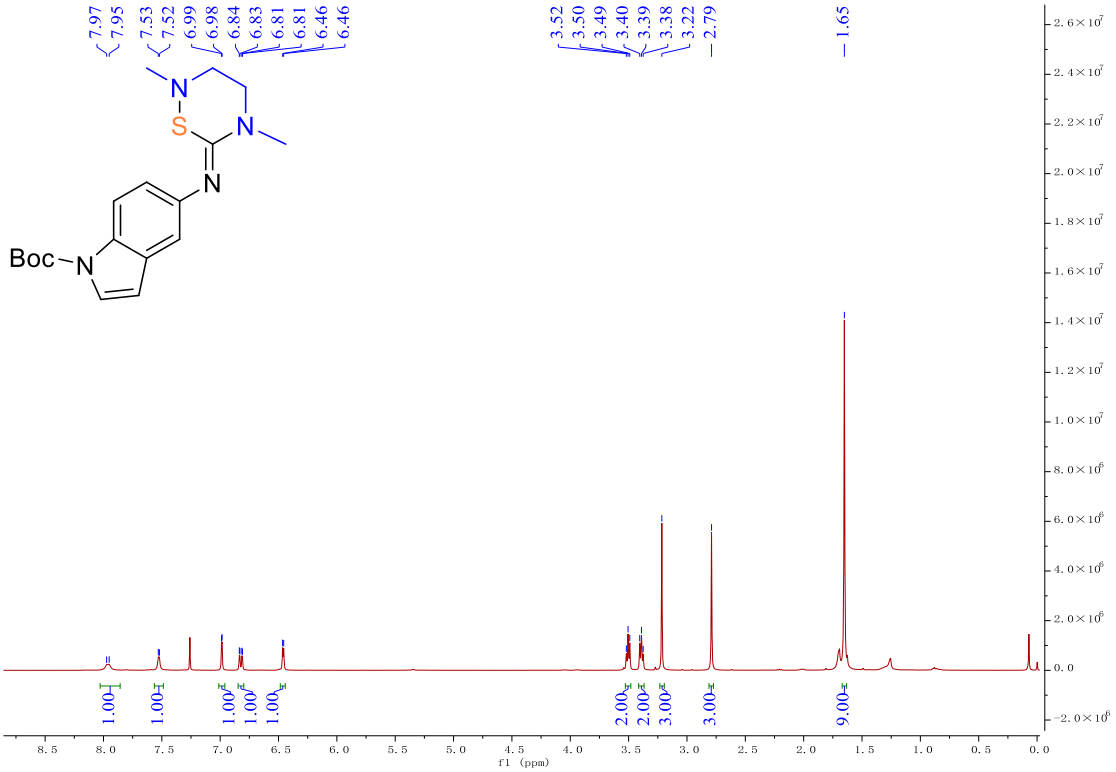
^{1}H NMR of Compound **23** (400 MHz, $CDCl_3$):



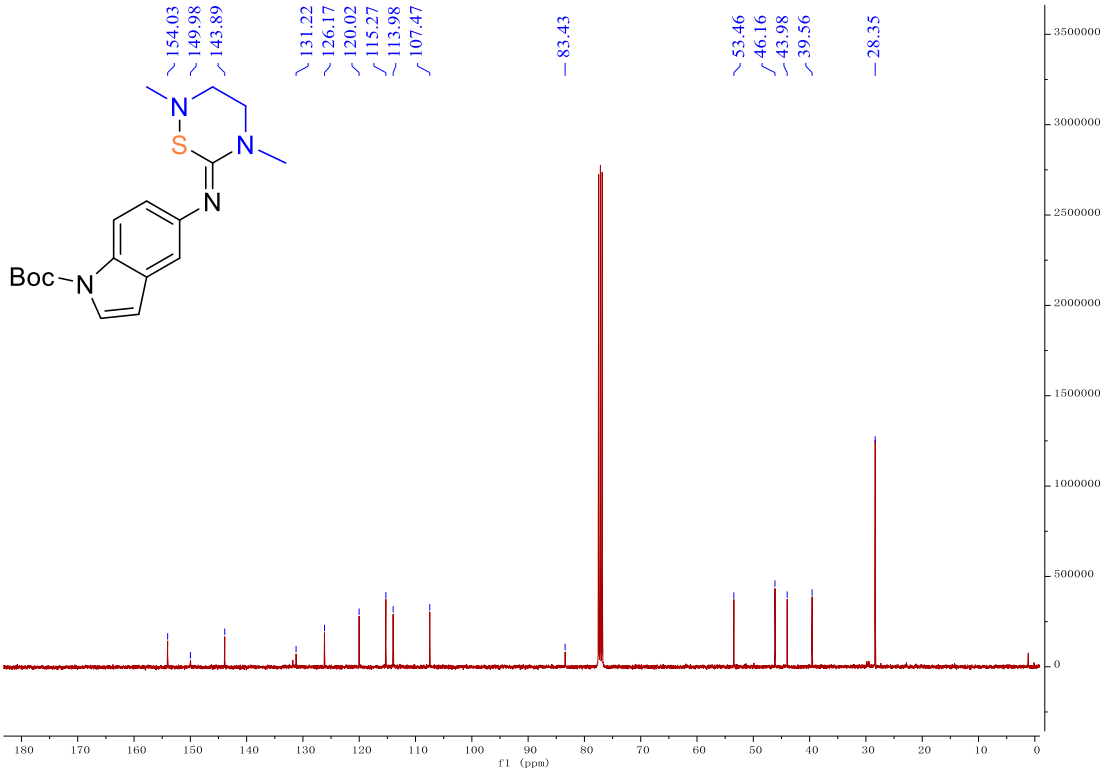
^{13}C{^{1}H} NMR of Compound **23** (101 MHz, $CDCl_3$):



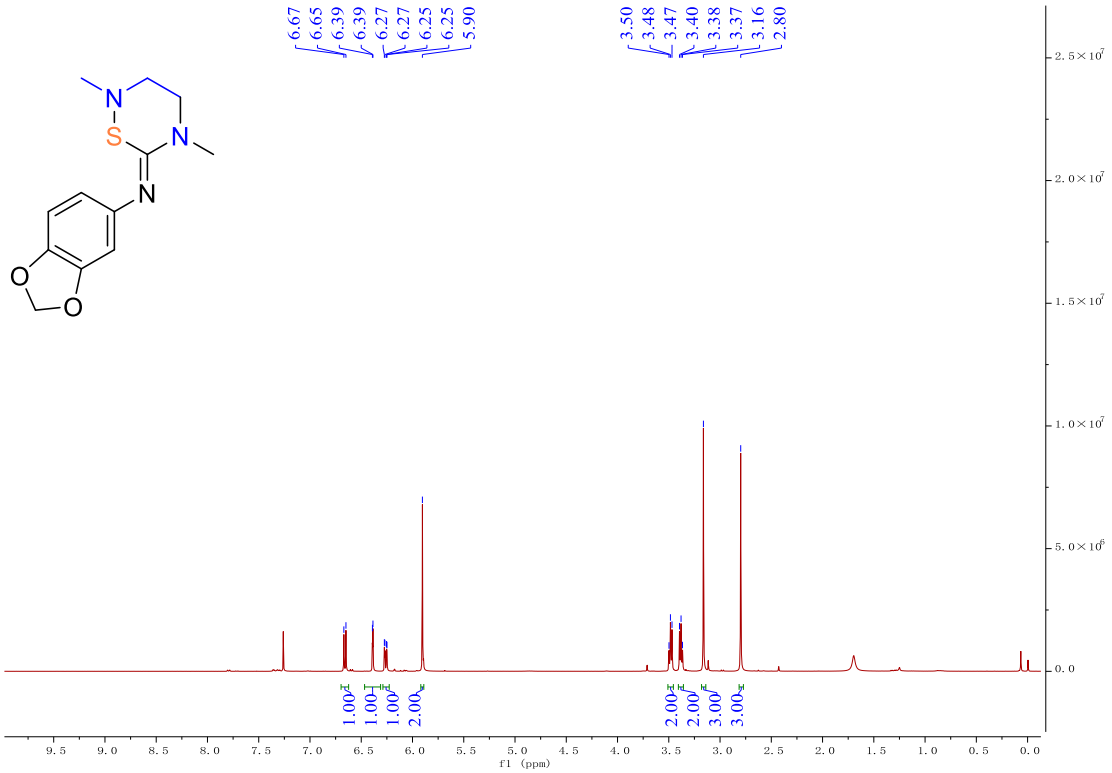
^{1}H NMR of Compound **24** (400 MHz, $CDCl_3$):



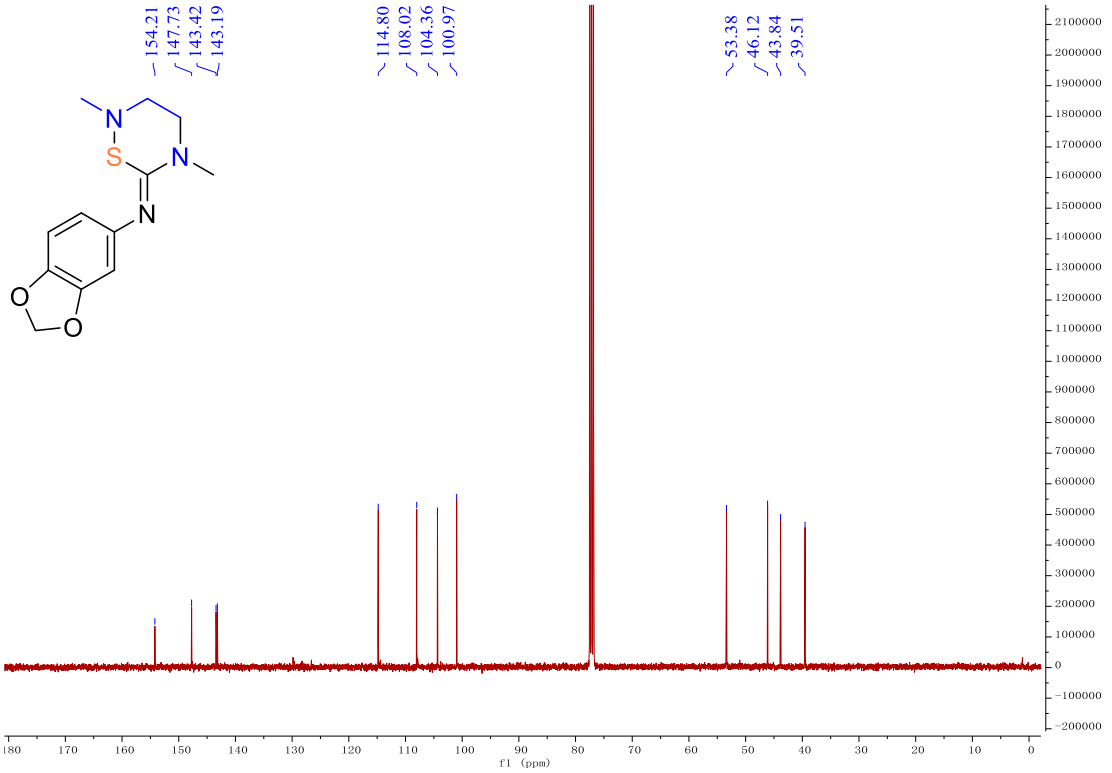
^{13}C{^{1}H} NMR of Compound **24** (101 MHz, $CDCl_3$):



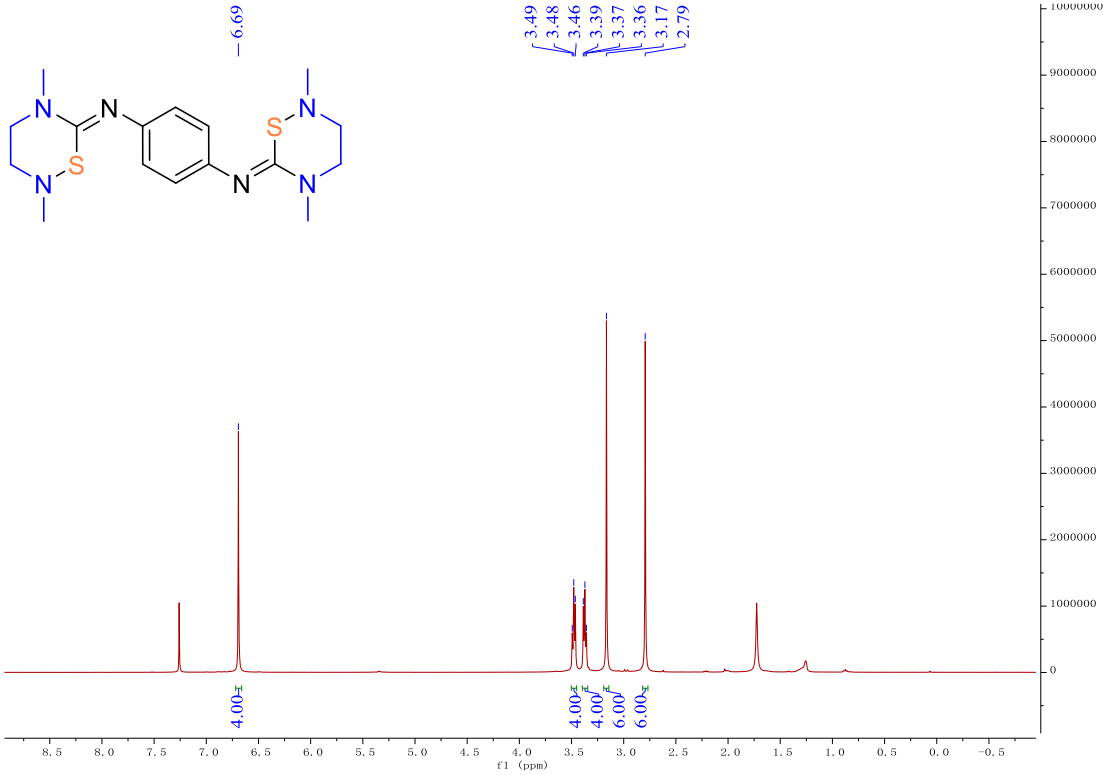
^{1}H NMR of Compound **25** (400 MHz, $CDCl_3$):



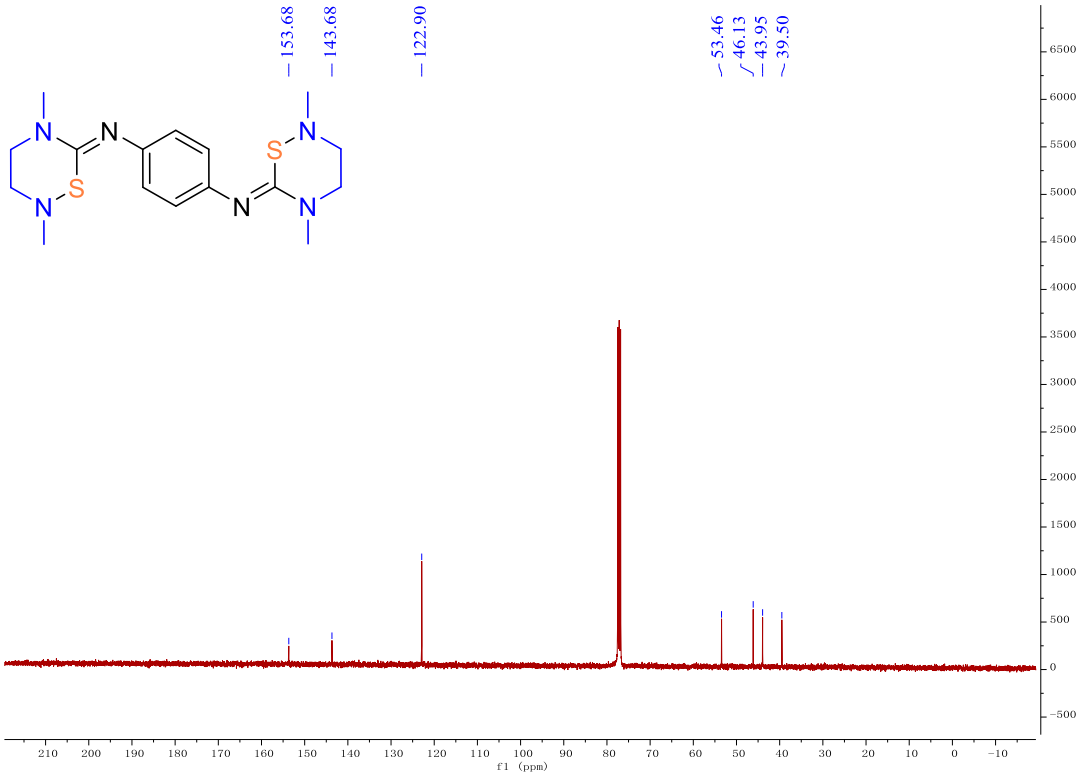
^{13}C{^{1}H} NMR of Compound **25** (101 MHz, $CDCl_3$):



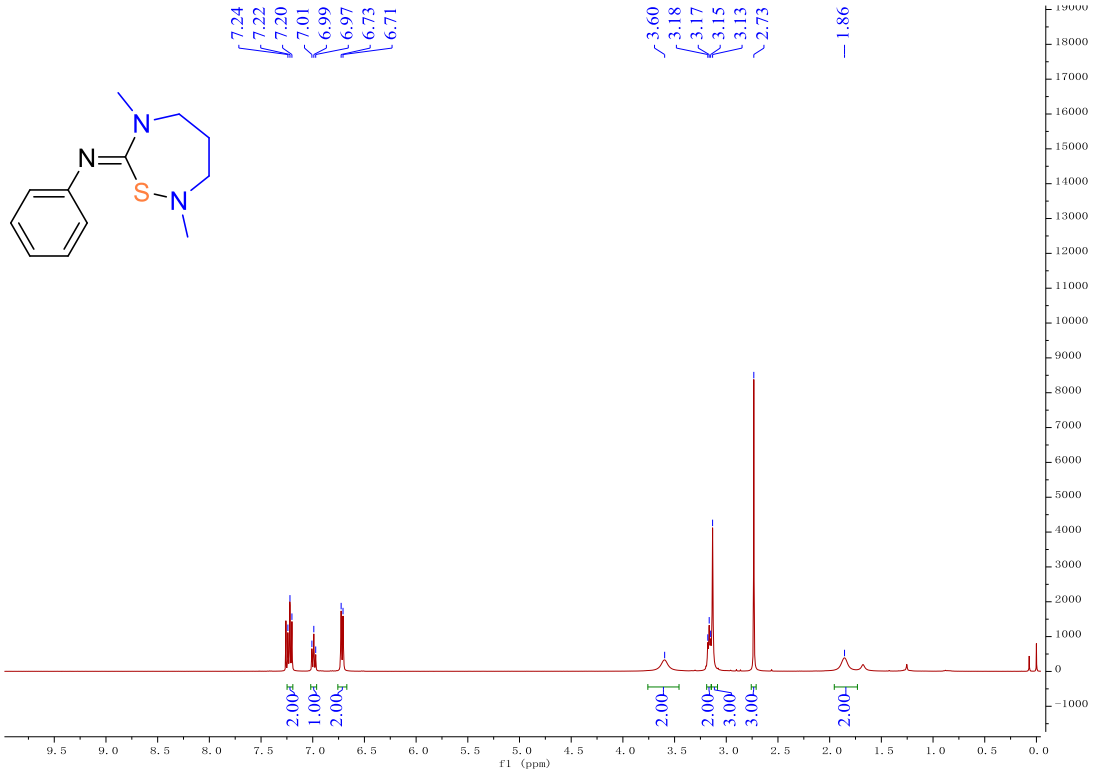
^{1}H NMR of Compound **26** (400 MHz, $CDCl_3$):



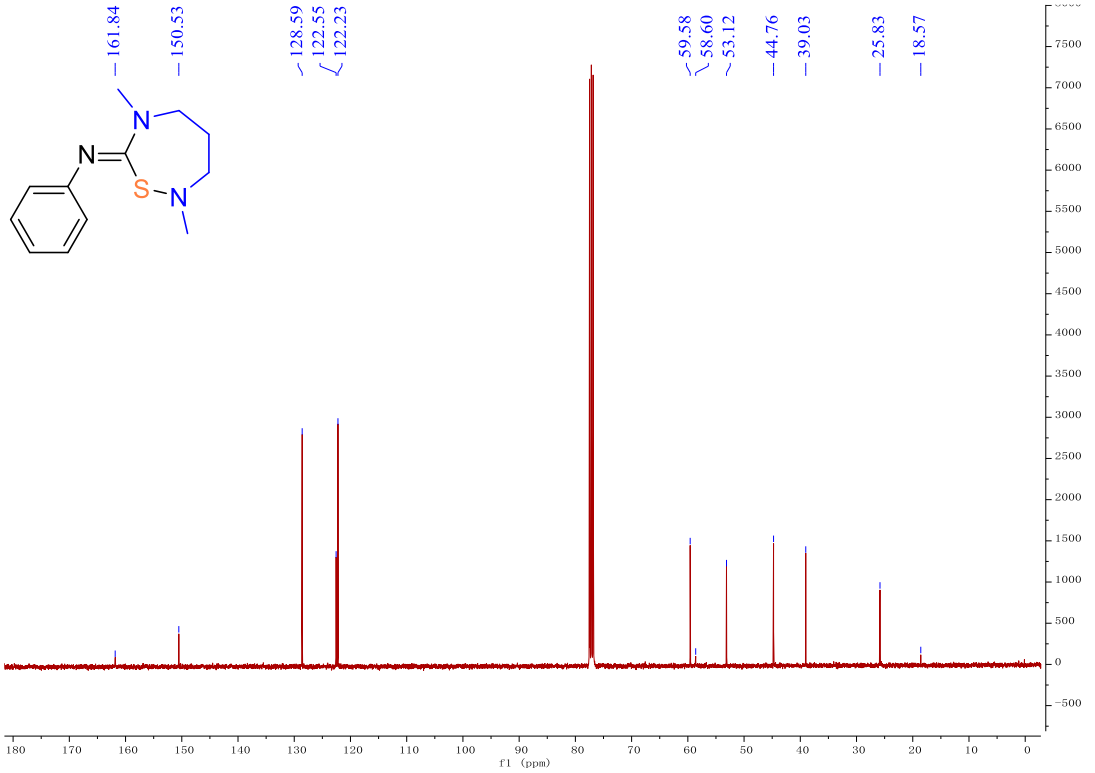
^{13}C{^{1}H} NMR of Compound **26** (101 MHz, $CDCl_3$):



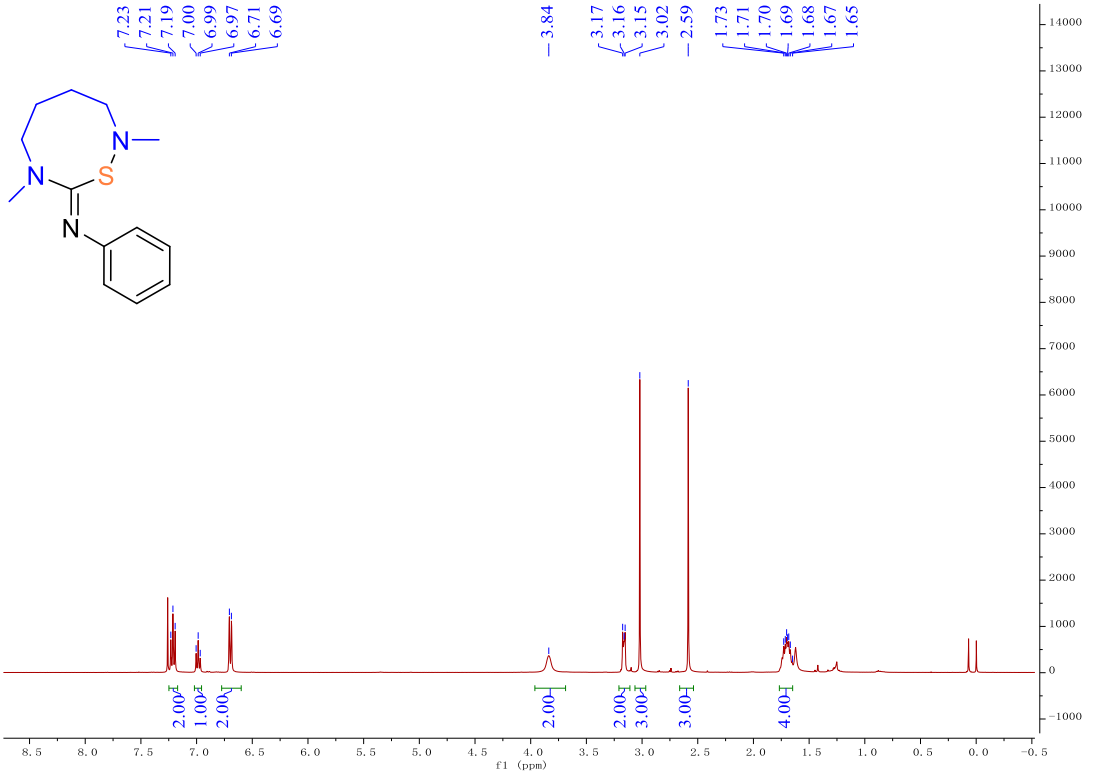
^{1}H NMR of Compound **27** (400 MHz, $CDCl_3$):



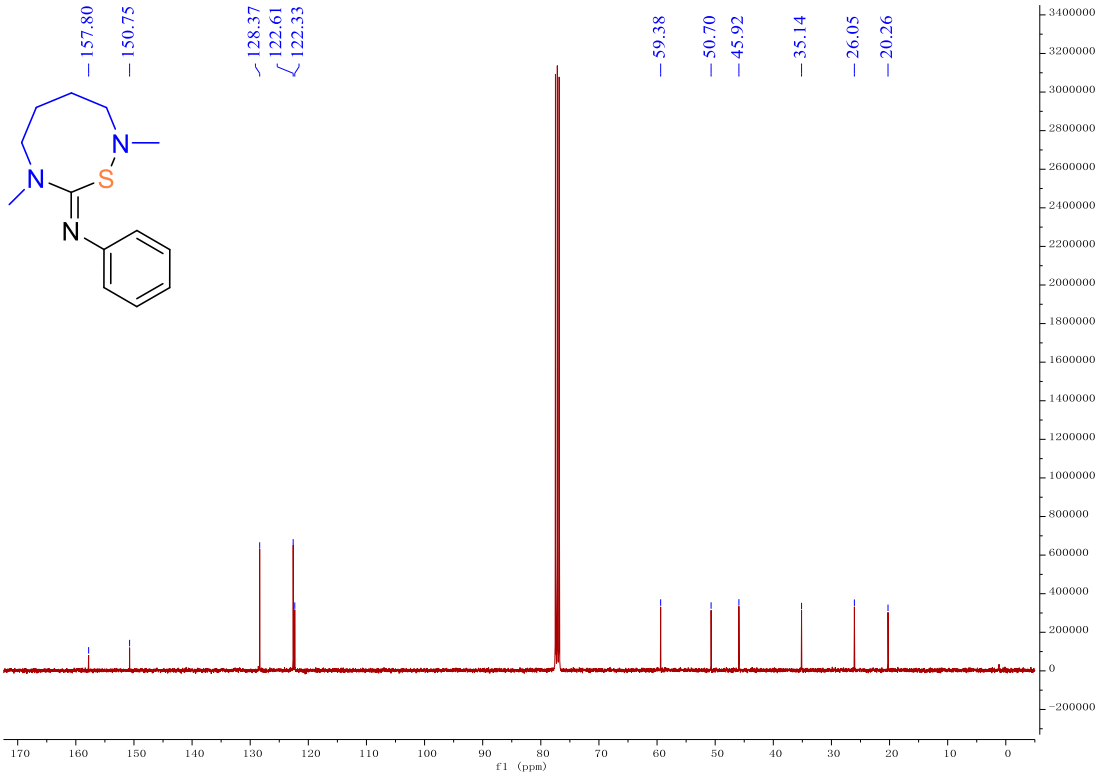
^{13}C{^{1}H} NMR of Compound **27** (101 MHz, $CDCl_3$):



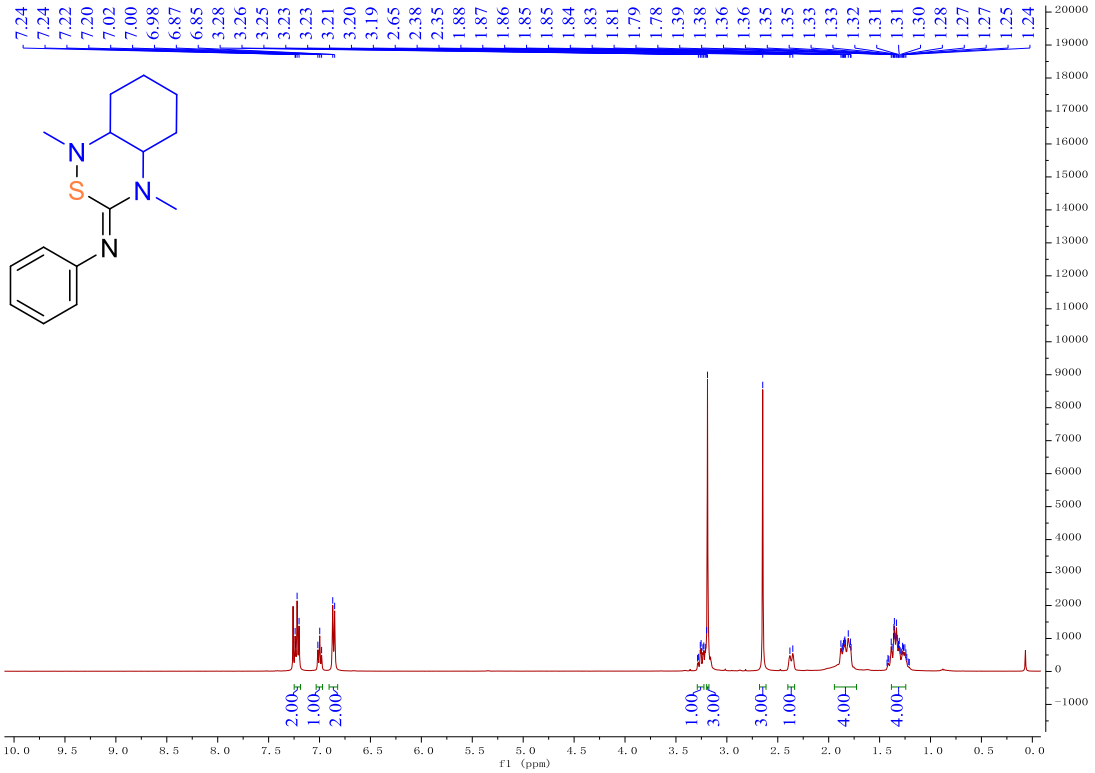
^{1}H NMR of Compound **28** (400 MHz, $CDCl_3$):



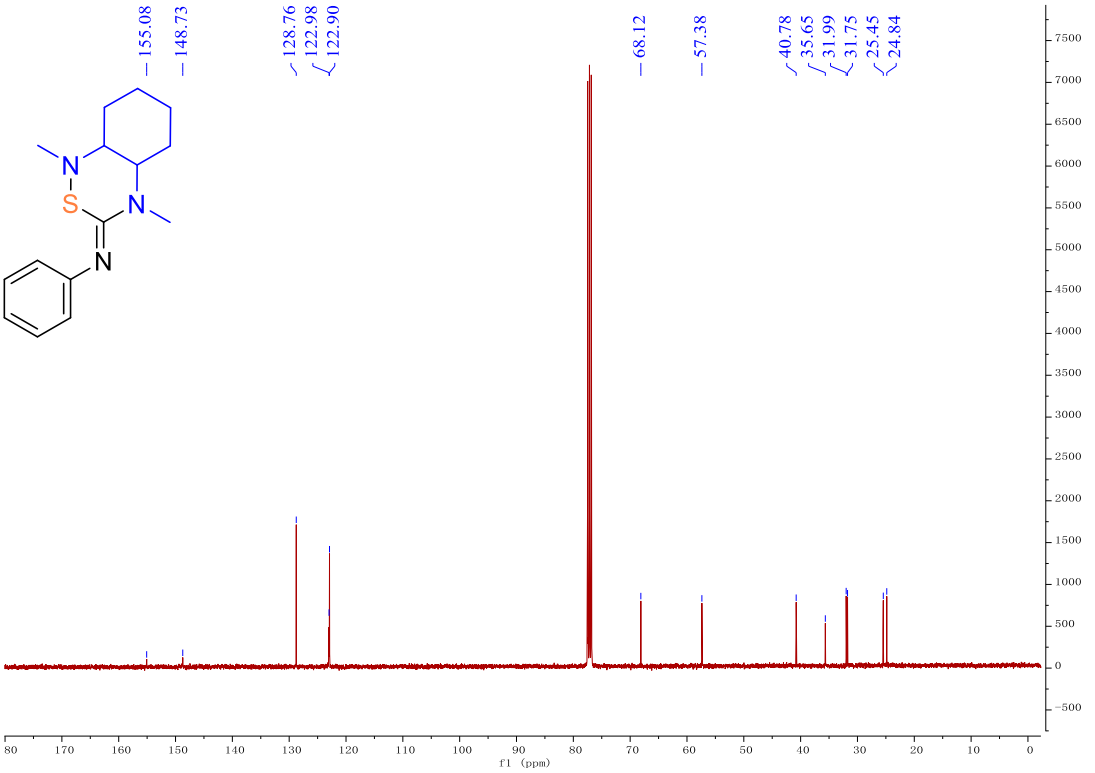
^{13}C{^{1}H} NMR of Compound **28** (101 MHz, $CDCl_3$):



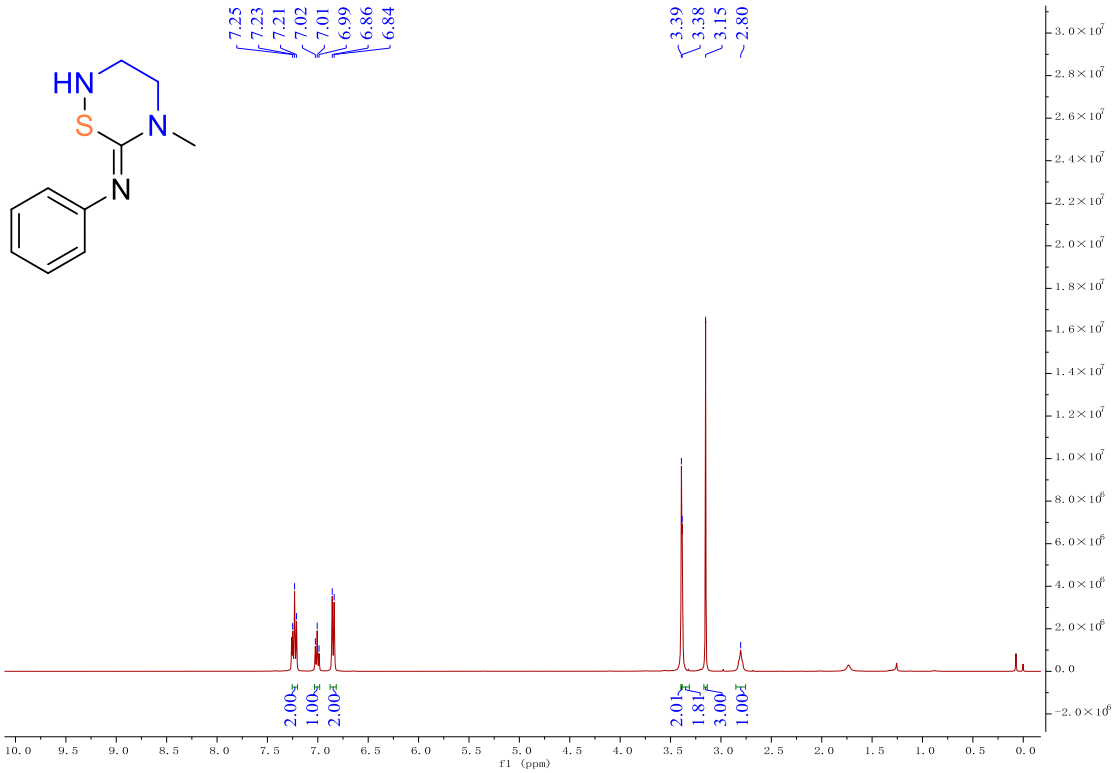
^{1}H NMR of Compound **29** (400 MHz, $CDCl_3$):



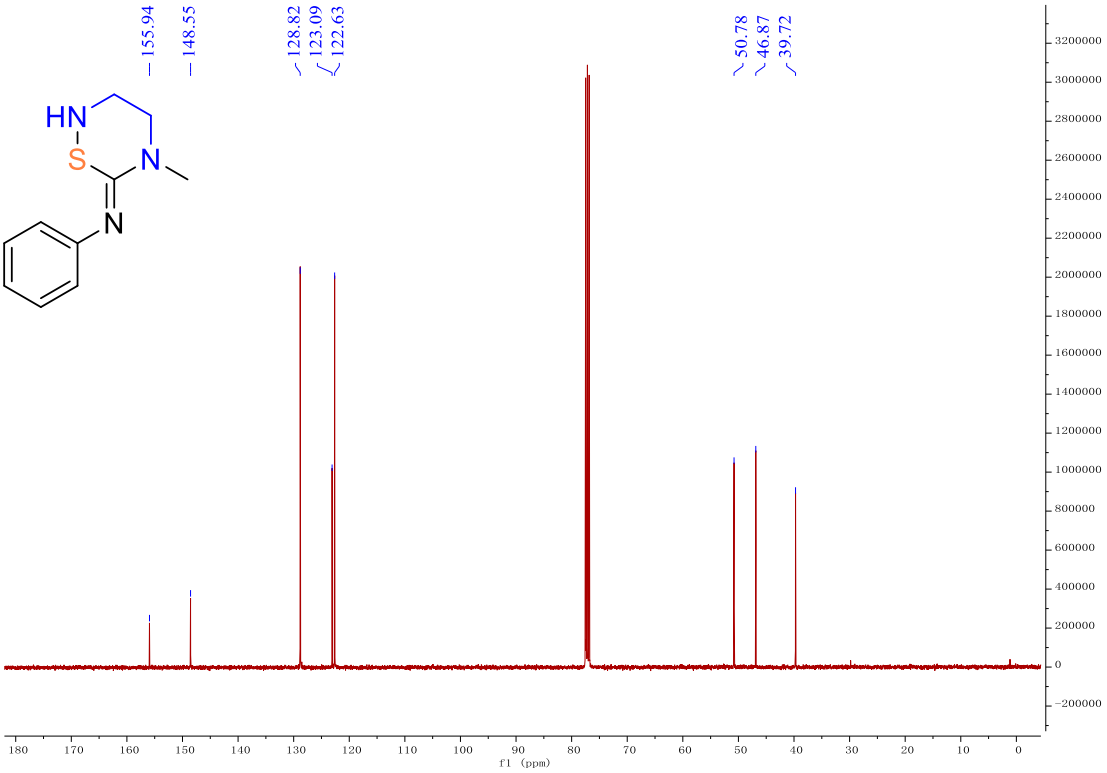
^{13}C{^{1}H} NMR of Compound **29** (101 MHz, $CDCl_3$):



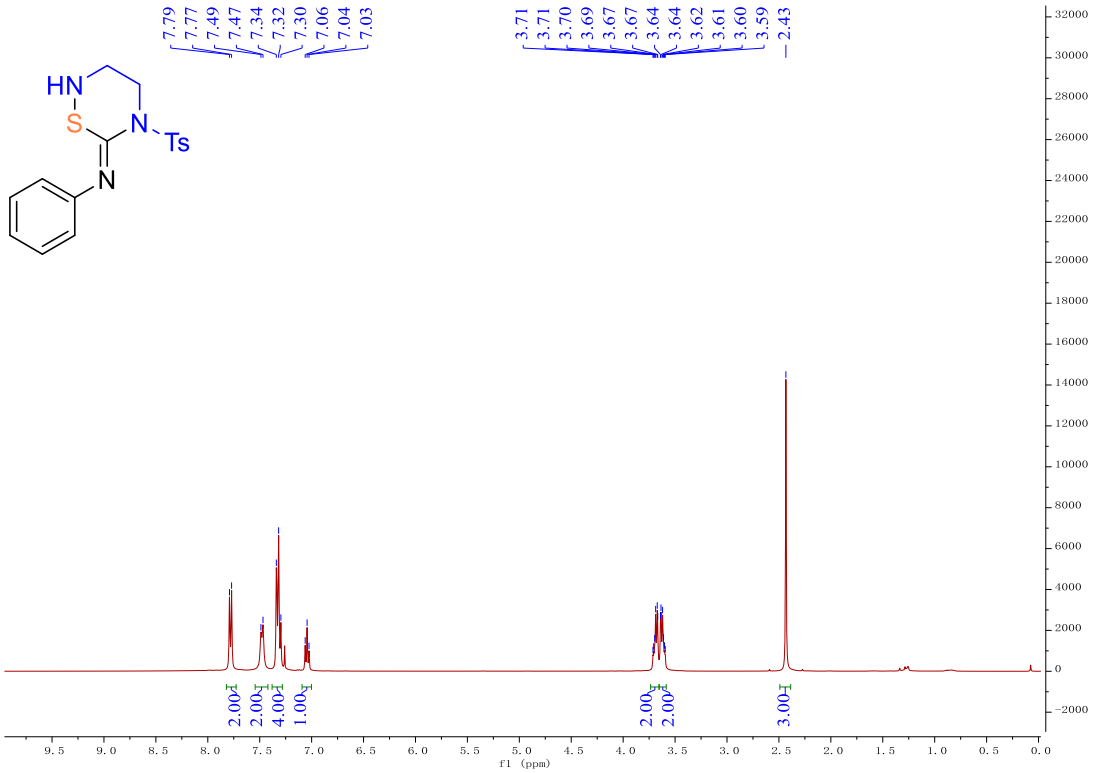
^{1}H NMR of Compound **30** (400 MHz, $CDCl_3$):



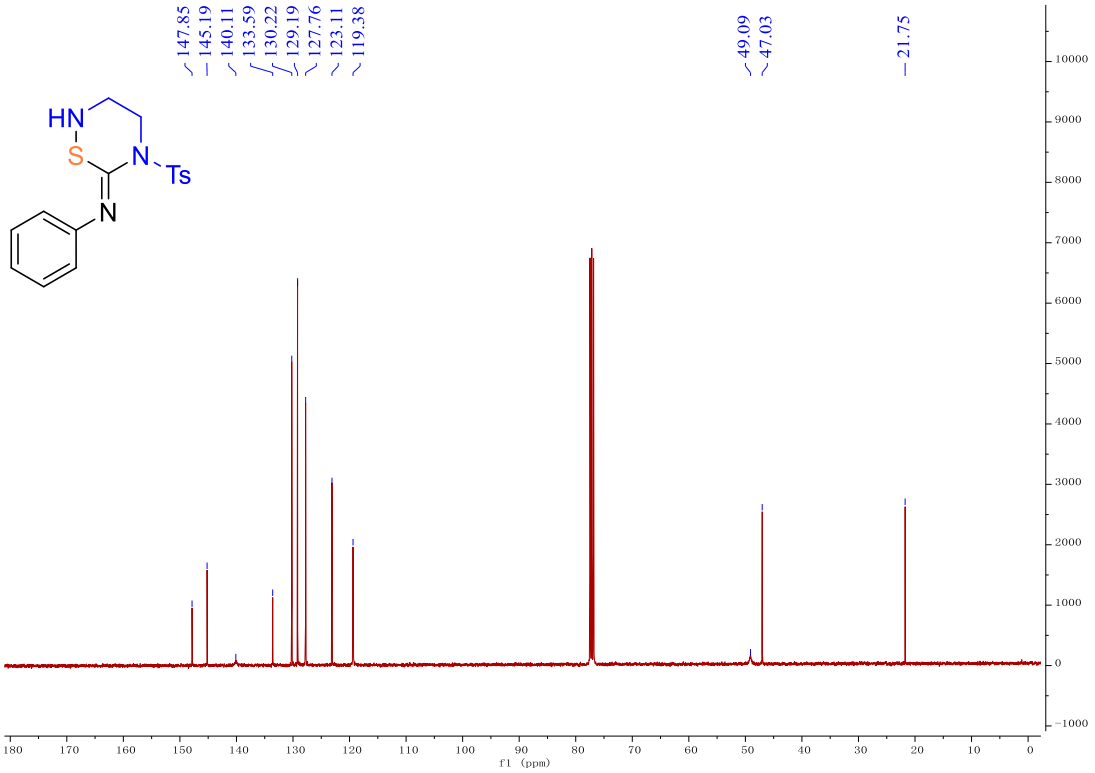
^{13}C{^{1}H} NMR of Compound **30** (101 MHz, $CDCl_3$):



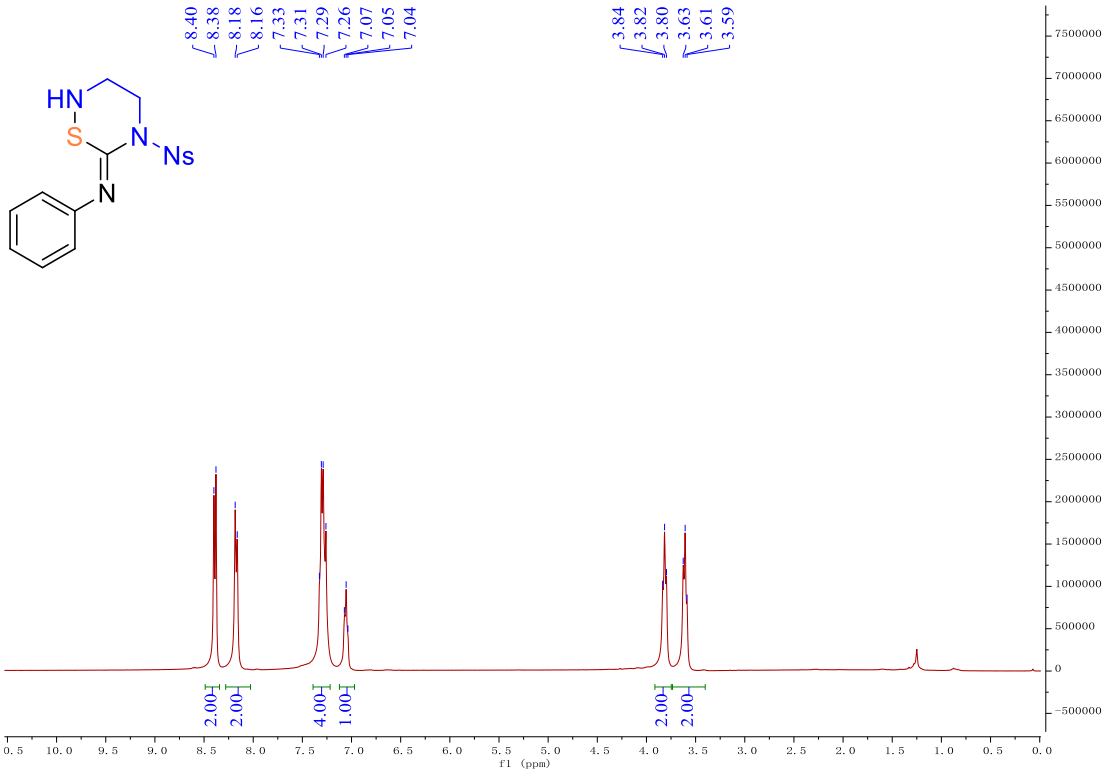
^{1}H NMR of Compound **31** (400 MHz, $CDCl_3$):



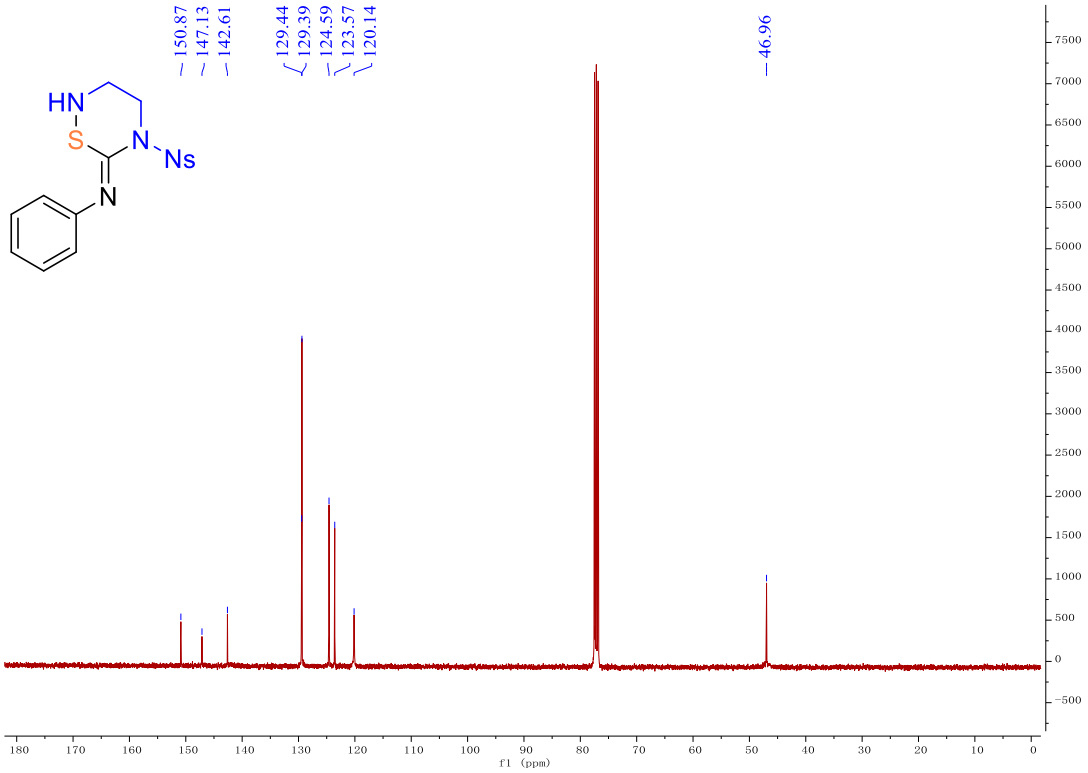
^{13}C{^{1}H} NMR of Compound **31** (101 MHz, $CDCl_3$):



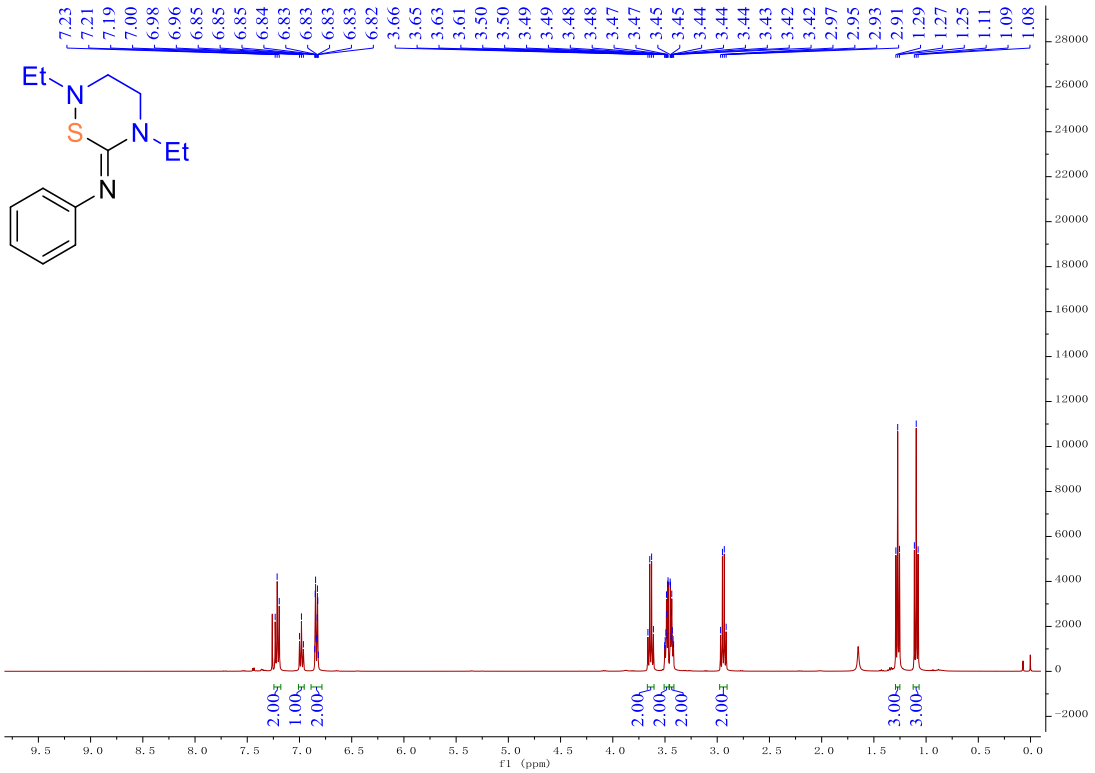
^{1}H NMR of Compound **32** (400 MHz, $CDCl_3$):



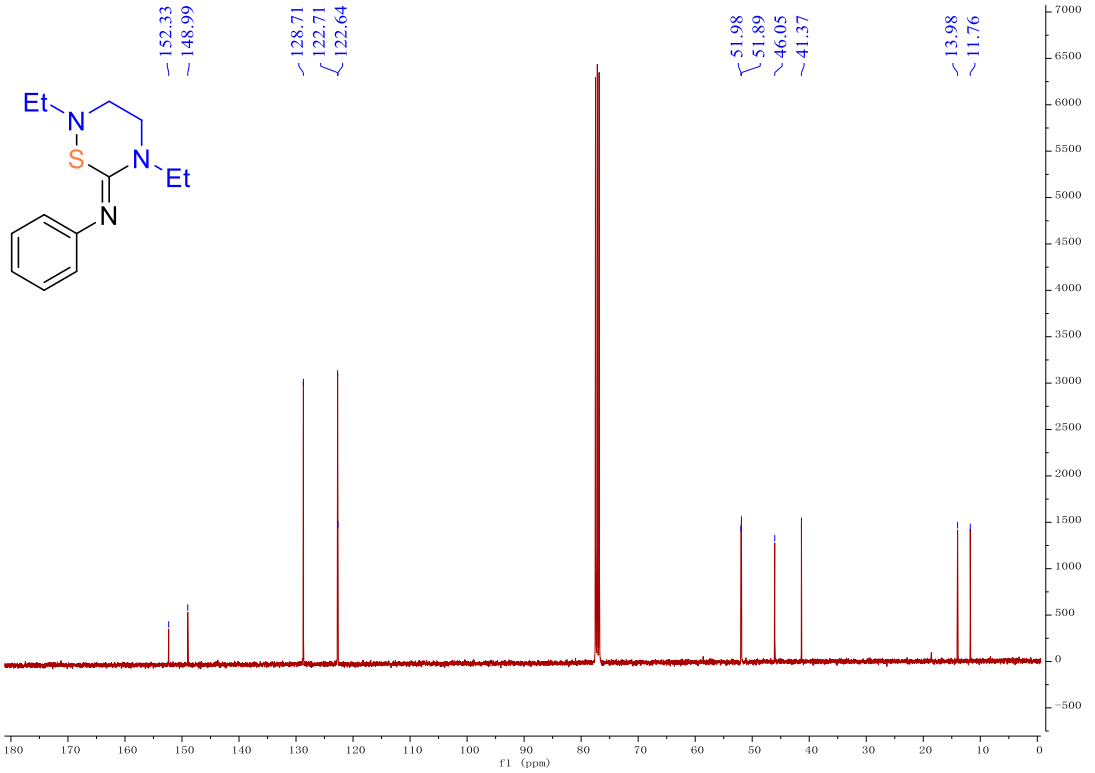
^{13}C{^{1}H} NMR of Compound **32** (101 MHz, $CDCl_3$):



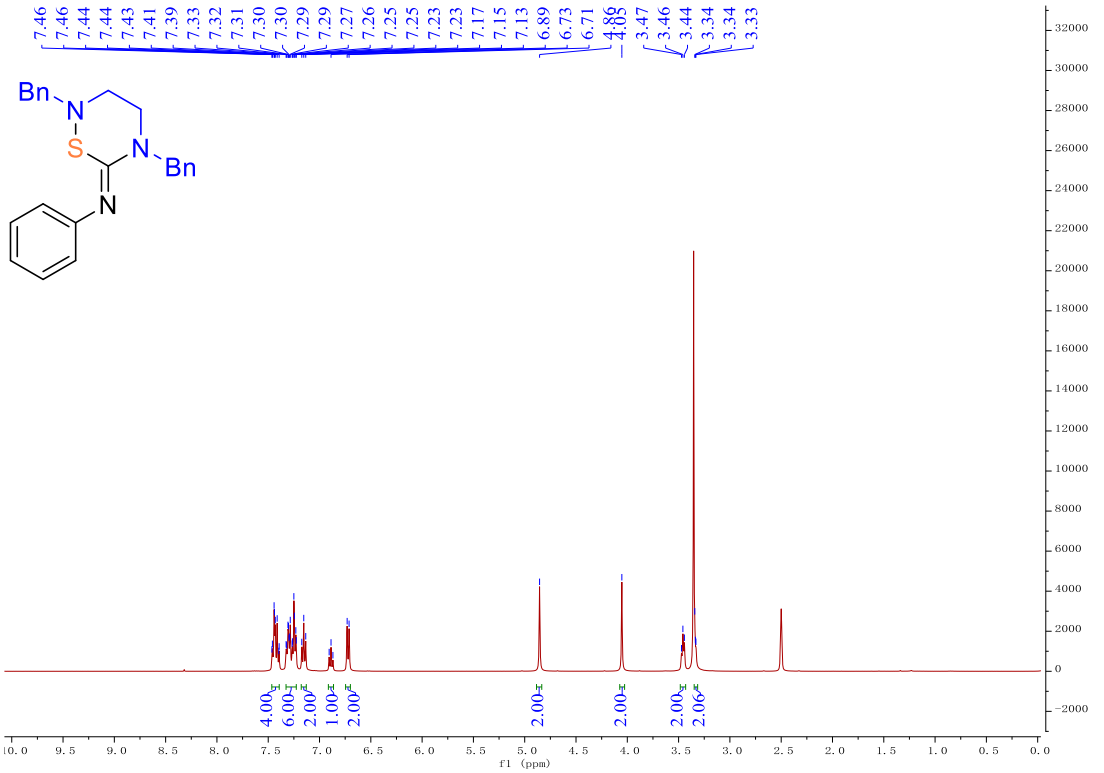
^{1}H NMR of Compound **33** (400 MHz, $CDCl_3$):



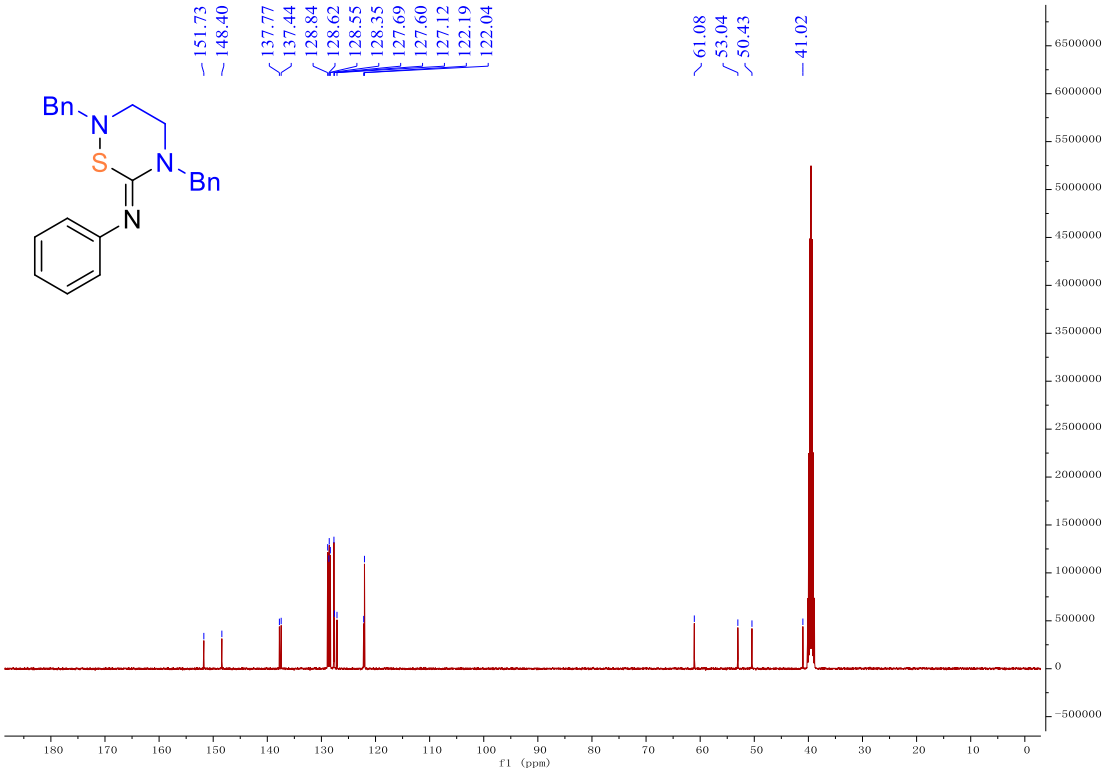
^{13}C{^{1}H} NMR of Compound **33** (101 MHz, $CDCl_3$):



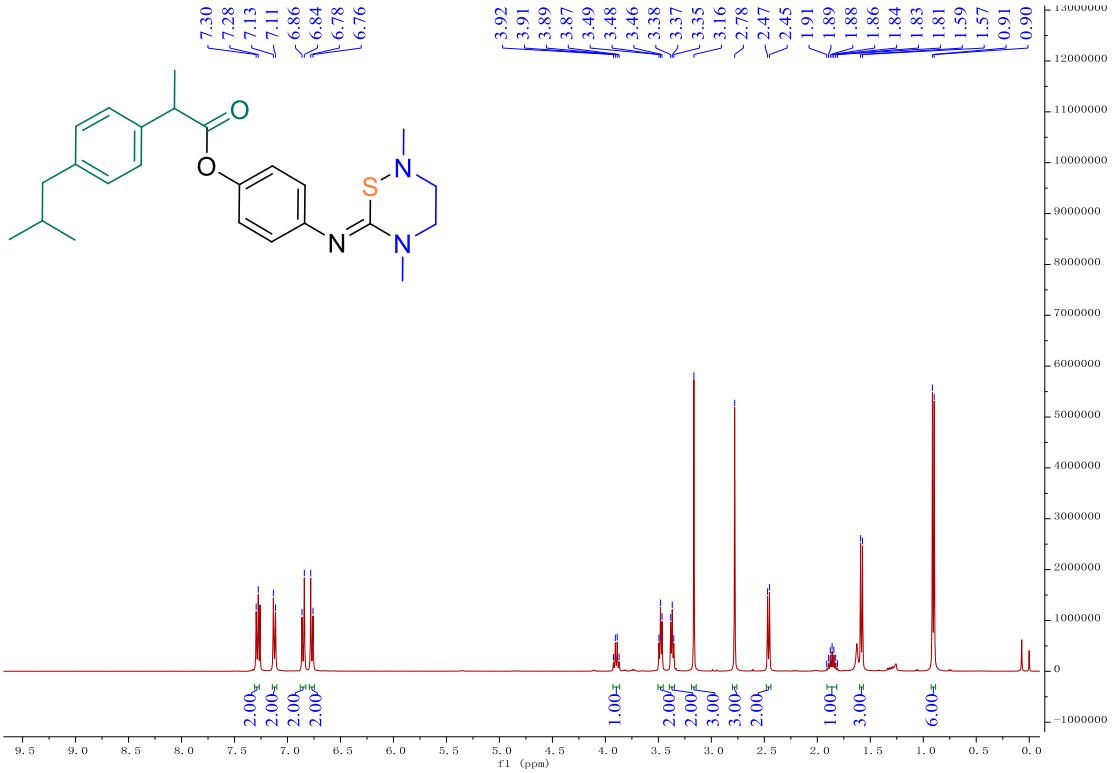
^{1}H NMR of Compound **34** (400 MHz, $(CD_3)_2SO$):



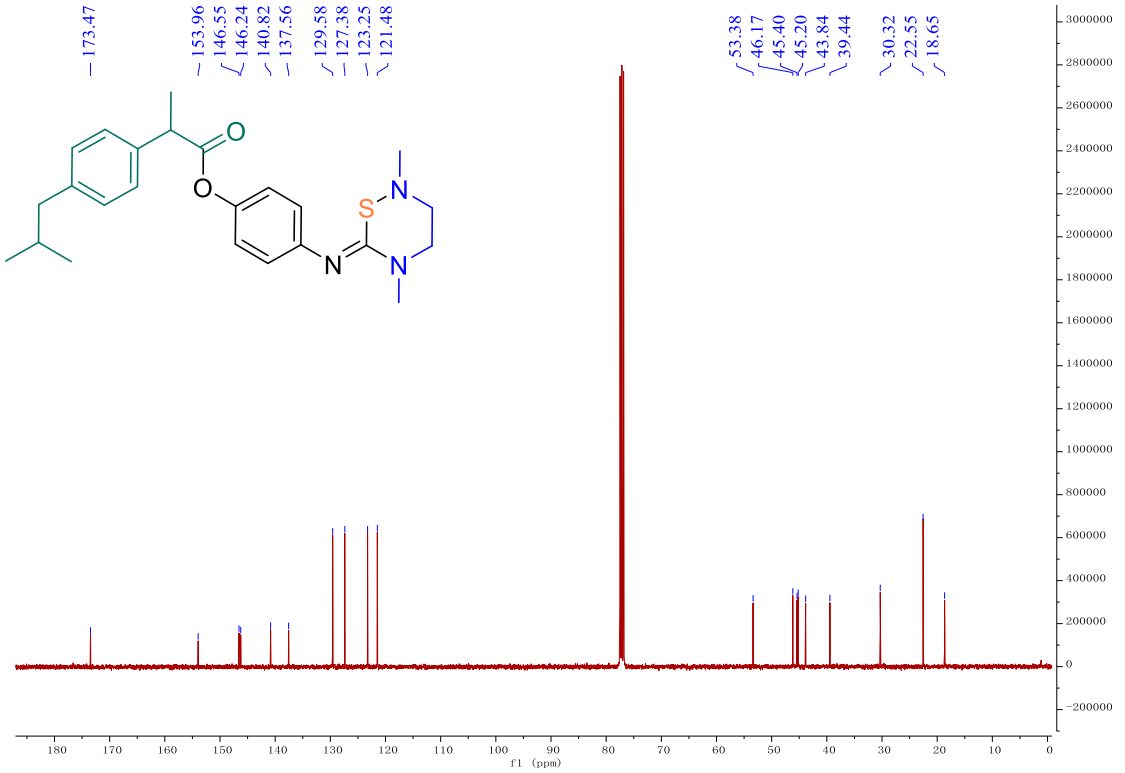
^{13}C{^{1}H} NMR of Compound **34** (101 MHz, $(CD_3)_2SO$):



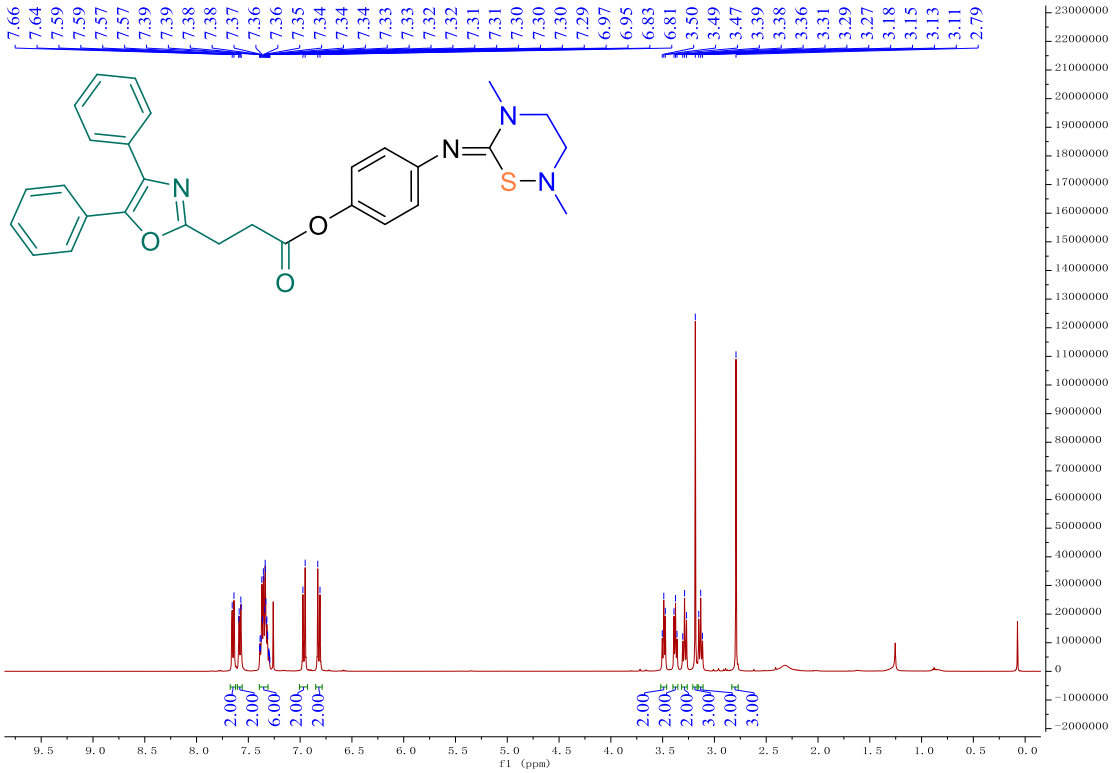
^{1}H NMR of Compound **35** (400 MHz, $CDCl_3$):



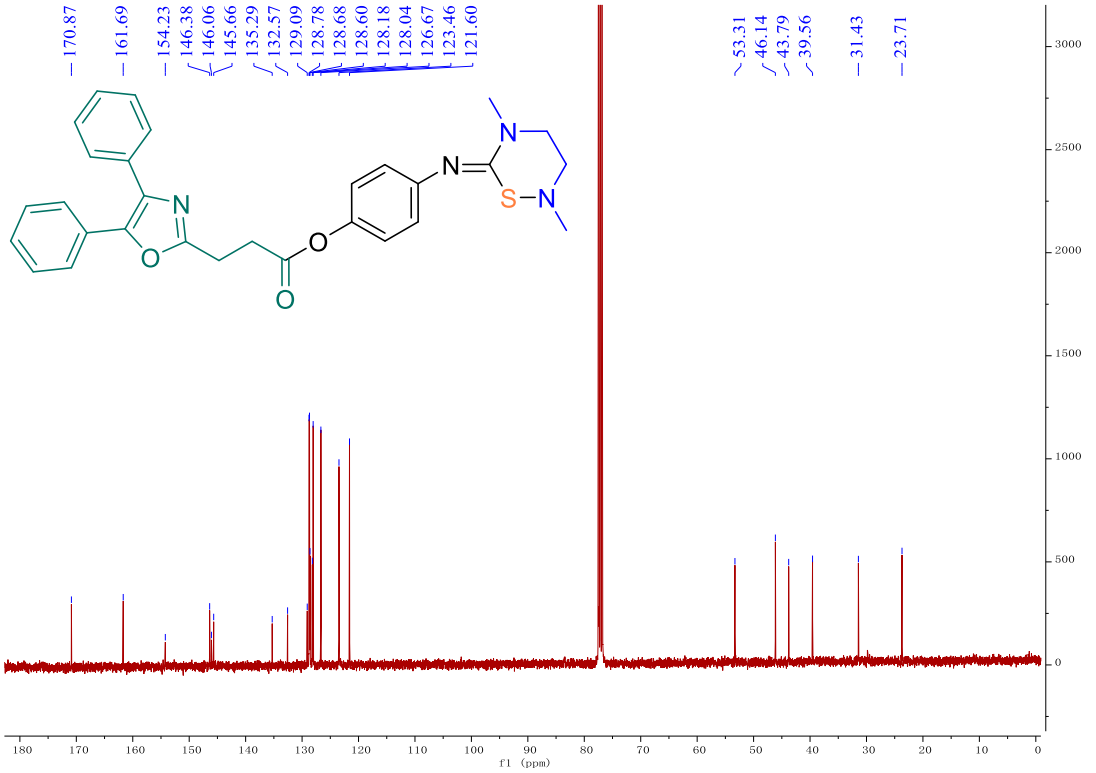
^{13}C{^{1}H} NMR of Compound **35** (101 MHz, $CDCl_3$):



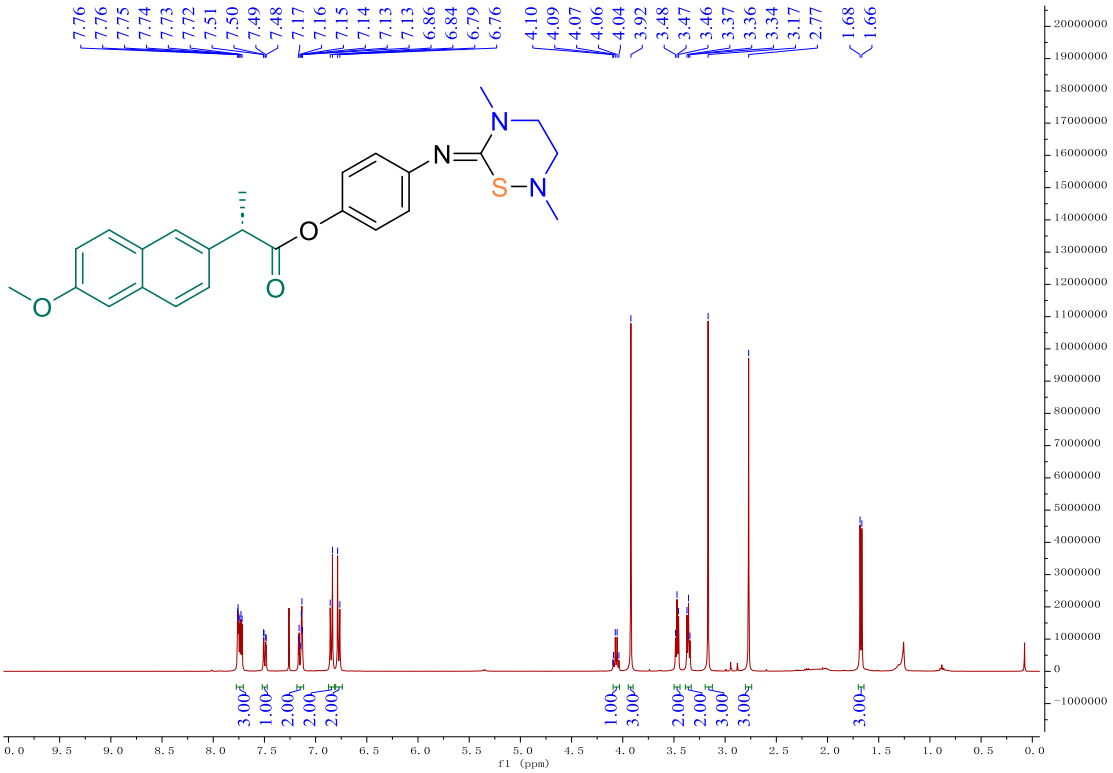
^{1}H NMR of Compound **36** (400 MHz, $CDCl_3$):



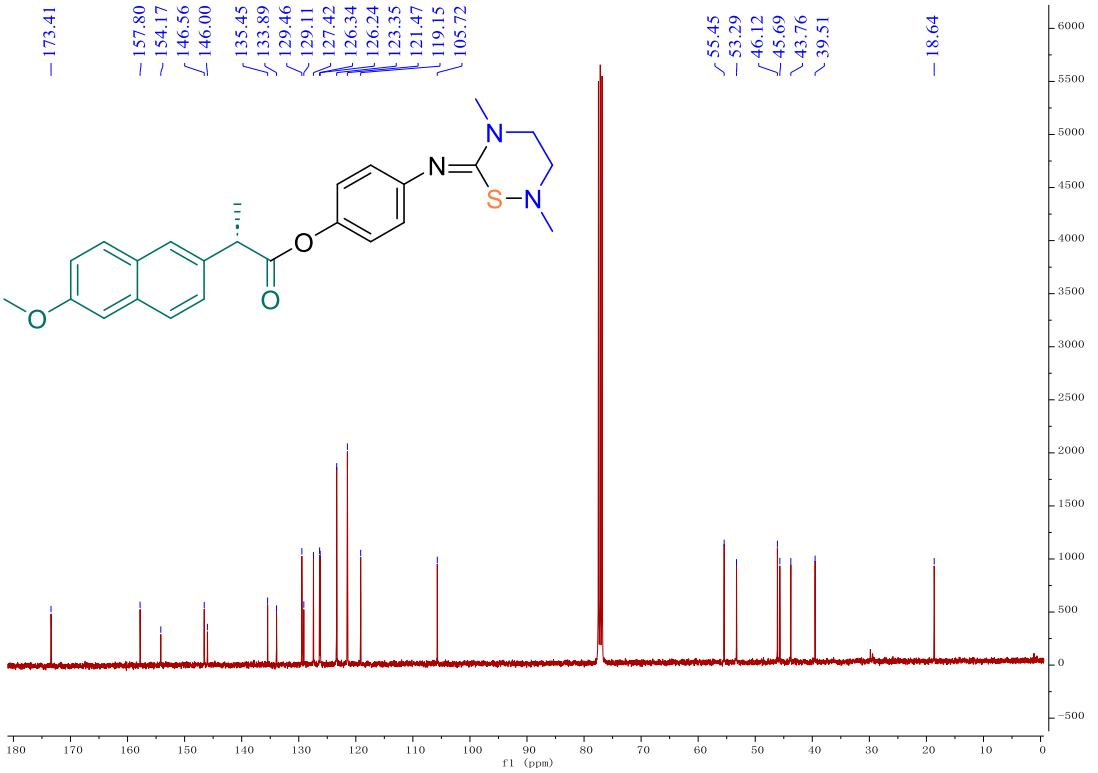
^{13}C{^{1}H} NMR of Compound **36** (101 MHz, $CDCl_3$):



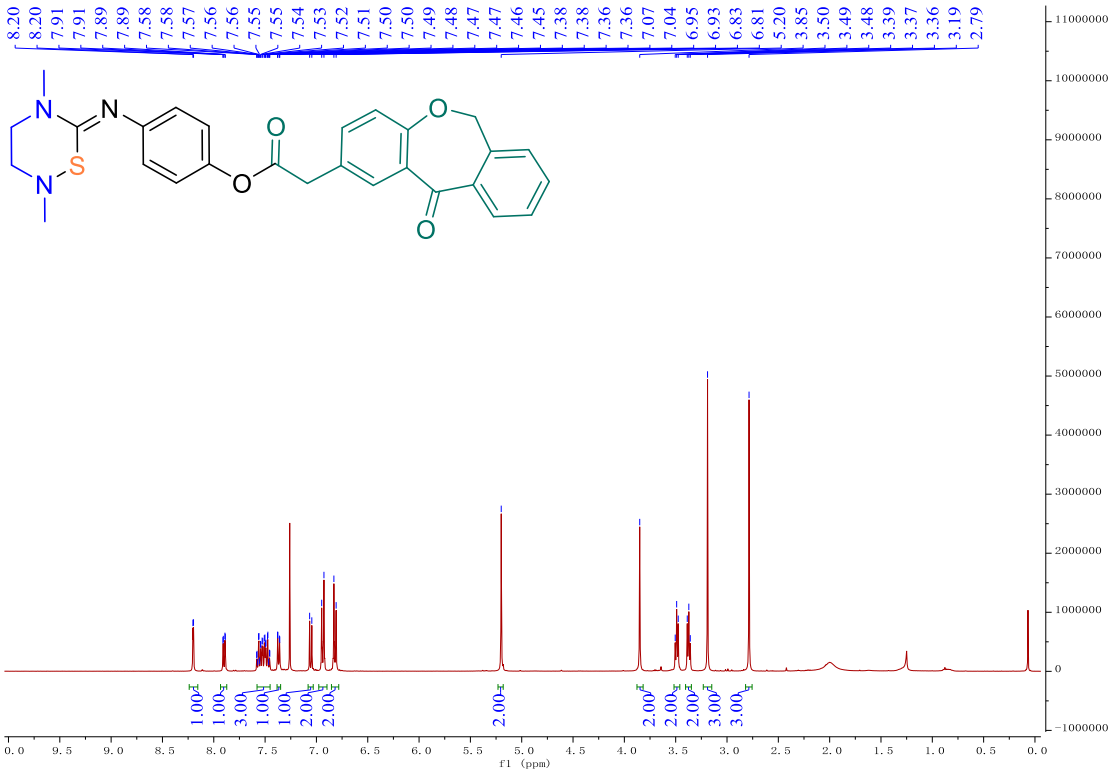
^{1}H NMR of Compound **37** (400 MHz, $CDCl_3$):



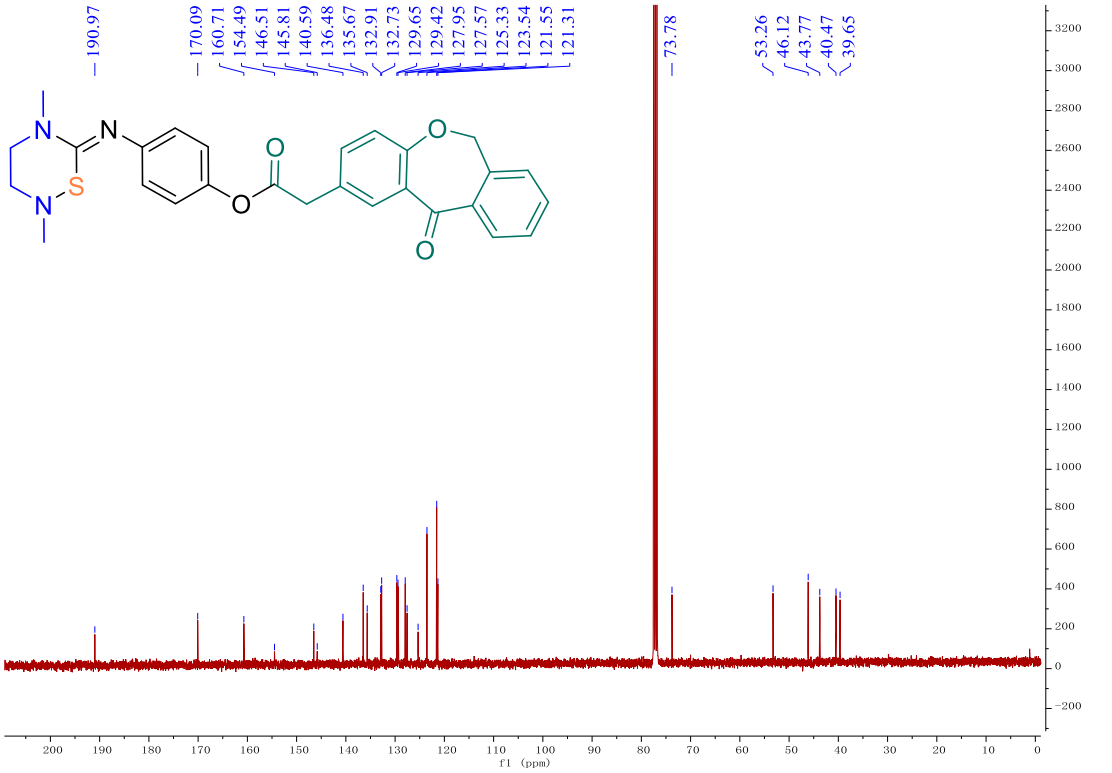
^{13}C{^{1}H} NMR of Compound **37** (101 MHz, $CDCl_3$):



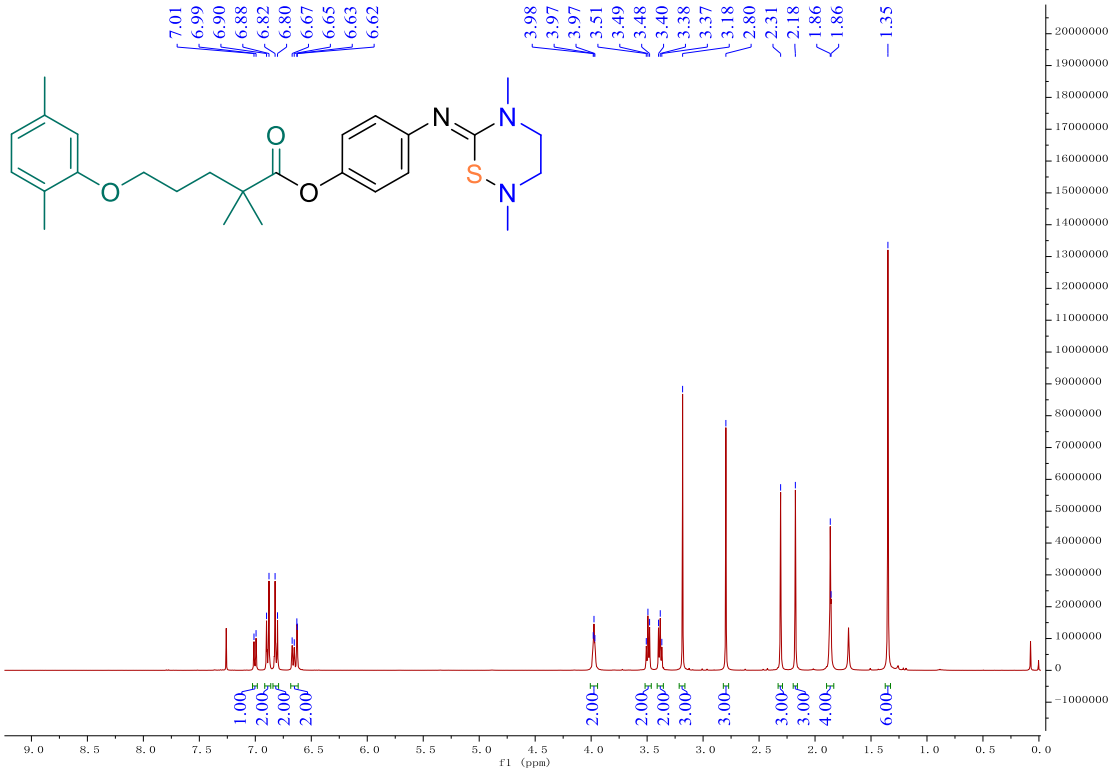
^{1}H NMR of Compound **38** (400 MHz, $CDCl_3$):



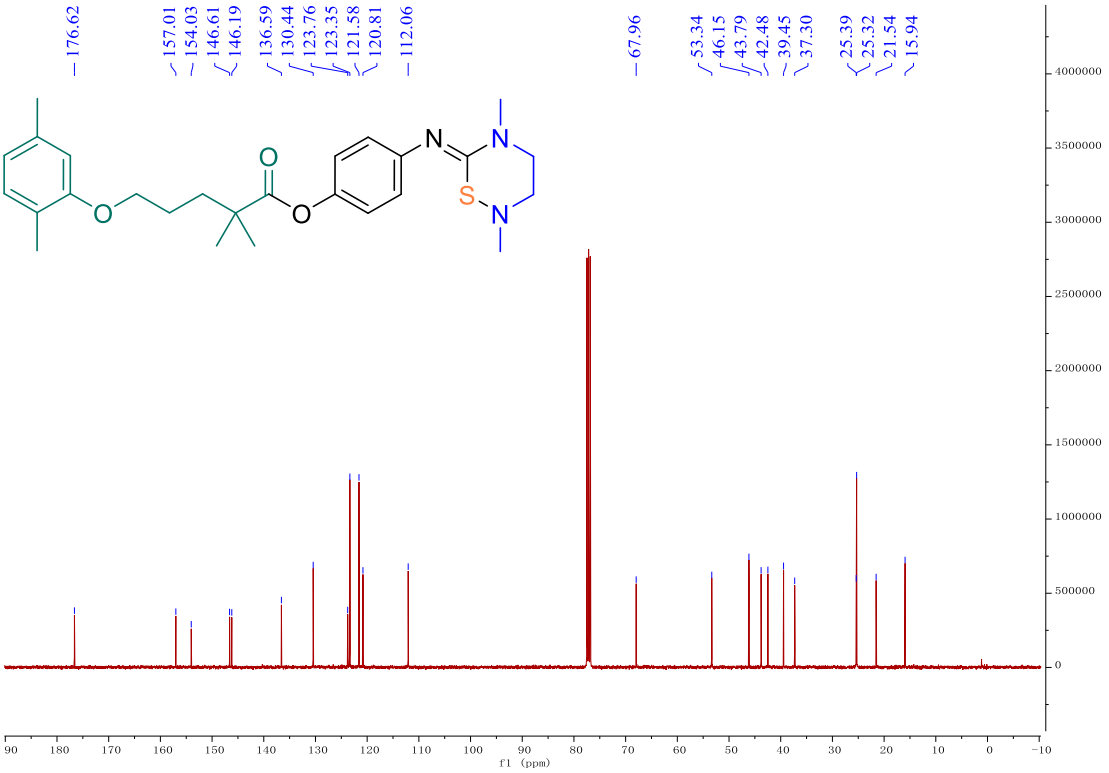
^{13}C{^{1}H} NMR of Compound **38** (101 MHz, $CDCl_3$):



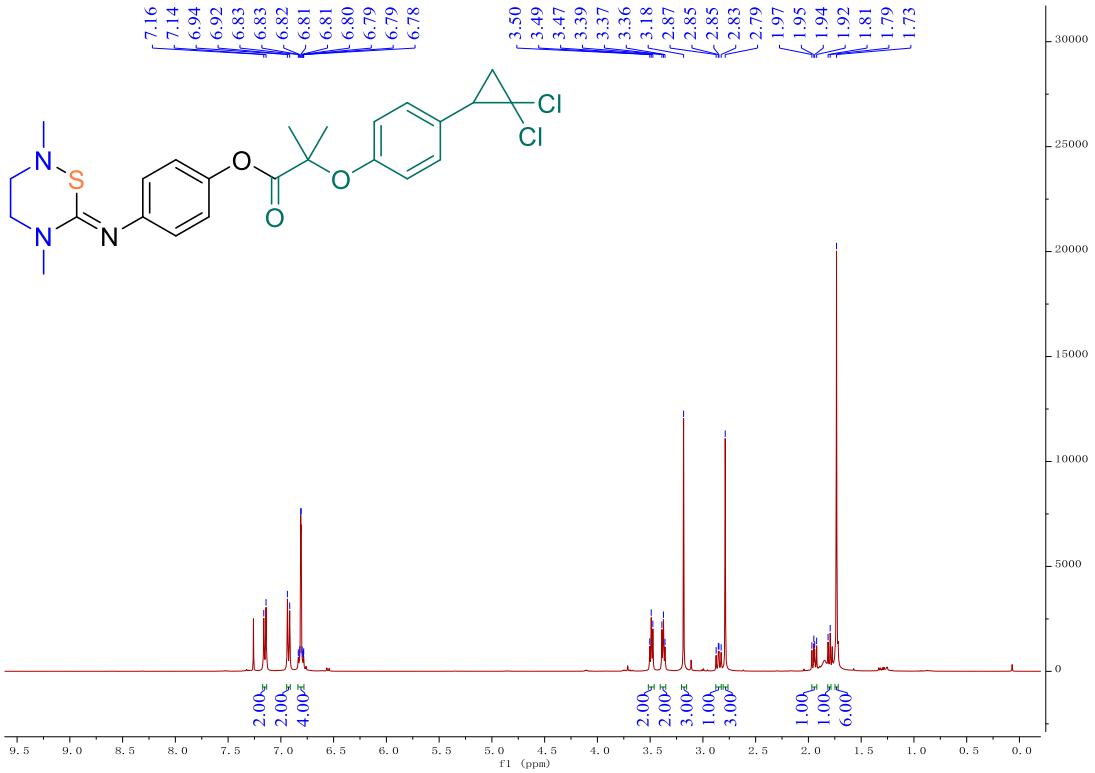
^{1}H NMR of Compound **39** (400 MHz, $CDCl_3$):



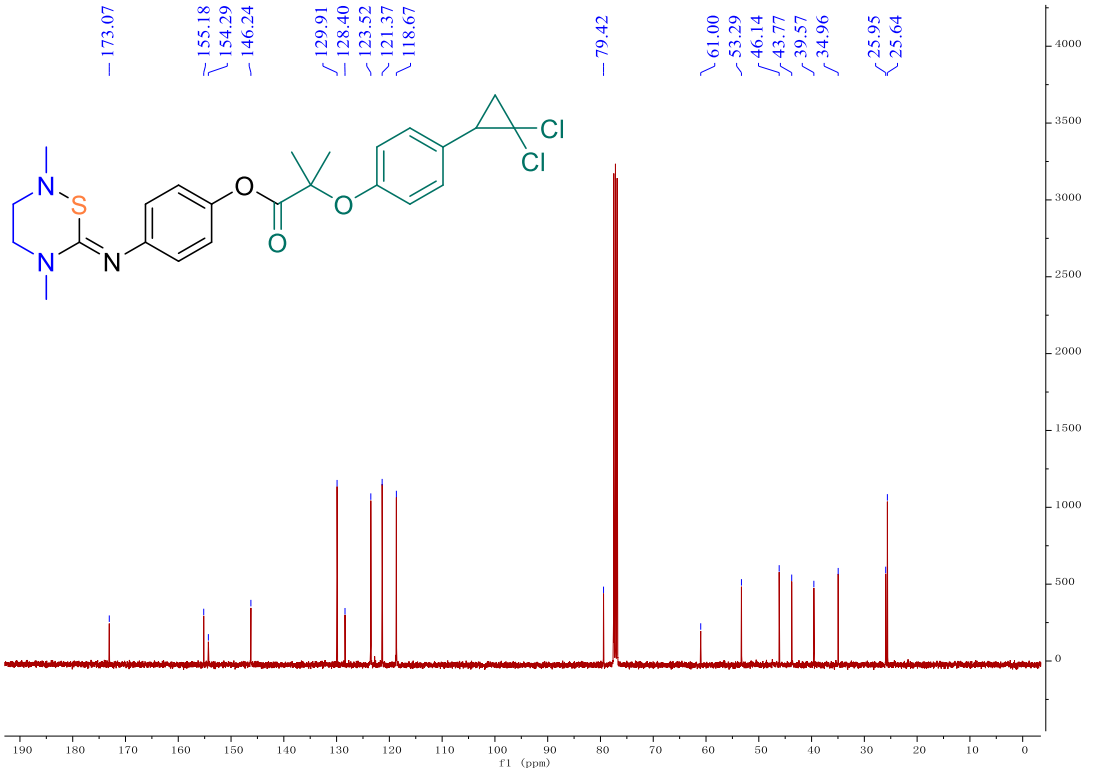
^{13}C{^{1}H} NMR of Compound **39** (101 MHz, $CDCl_3$):



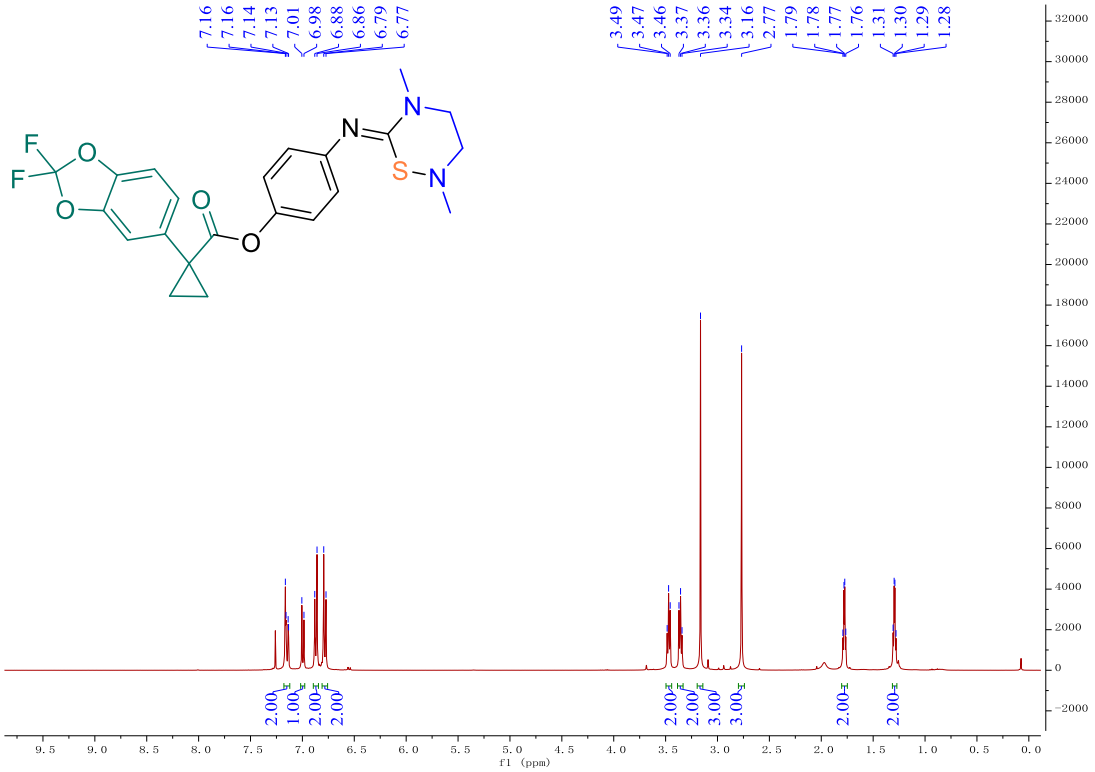
^{1}H NMR of Compound **40** (400 MHz, $CDCl_3$):



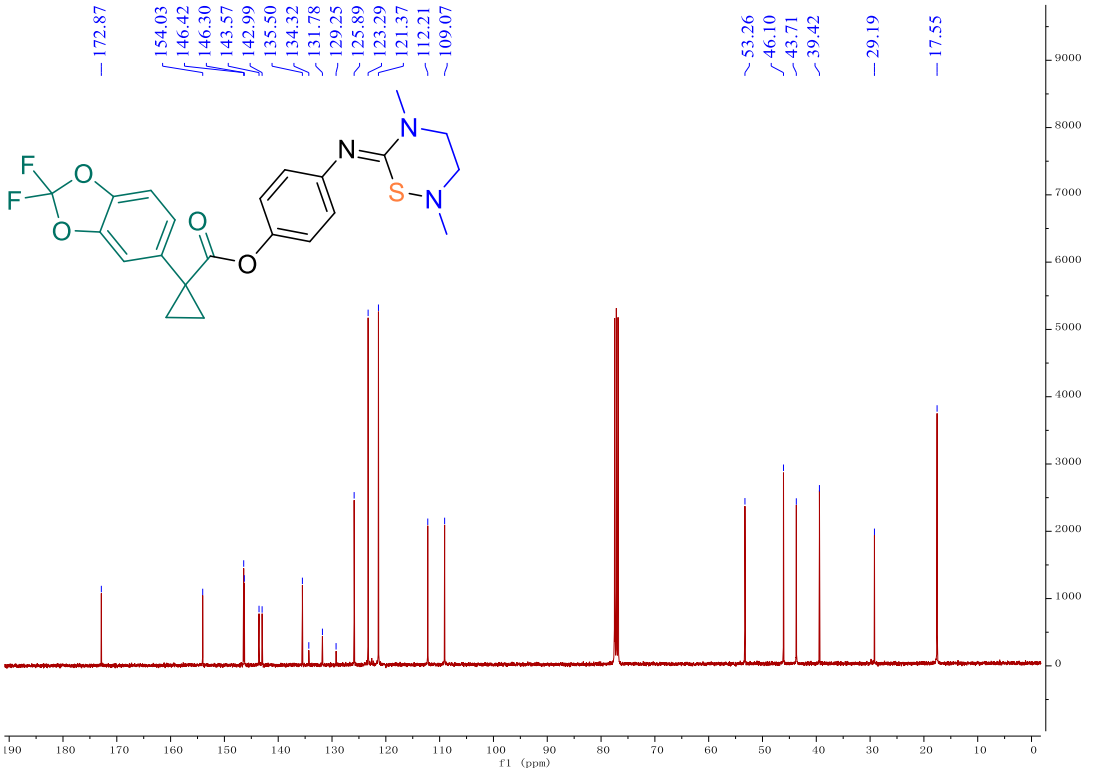
^{13}C{^{1}H} NMR of Compound **40** (101 MHz, $CDCl_3$):



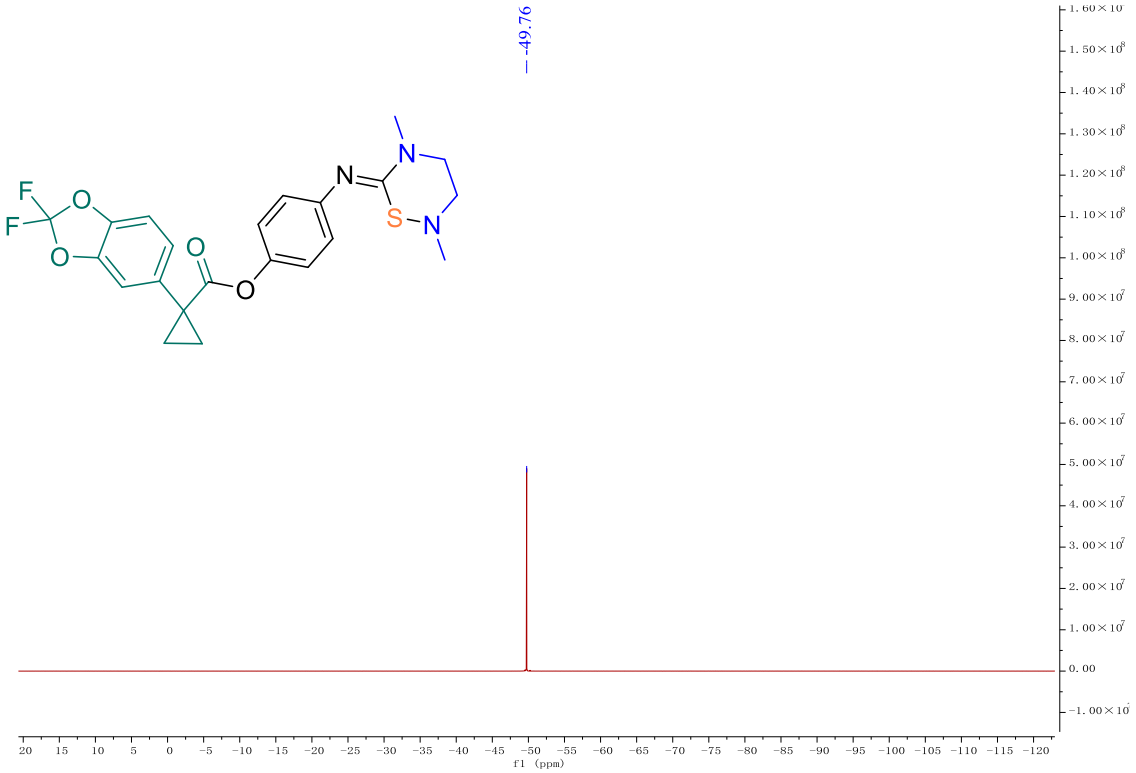
^{1}H NMR of Compound **41** (400 MHz, $CDCl_3$):



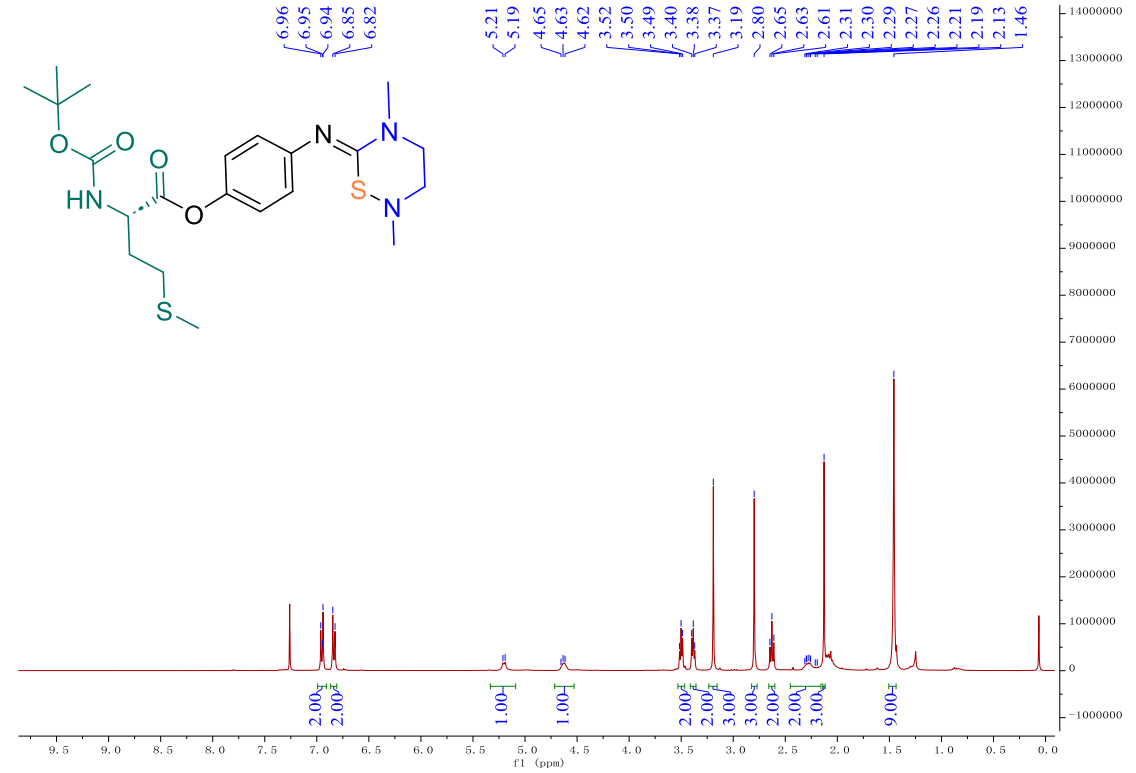
^{13}C{^{1}H} NMR of Compound **41** (101 MHz, $CDCl_3$):



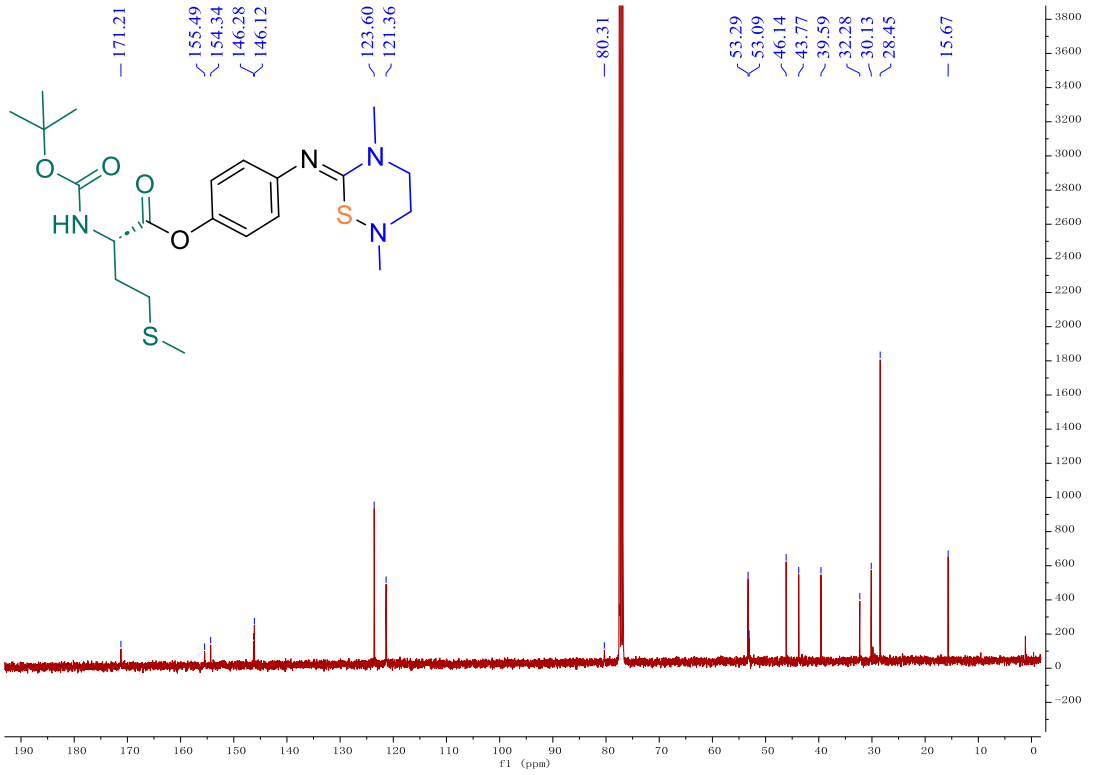
^{19}F NMR of Compound **41** (376 MHz, $CDCl_3$):



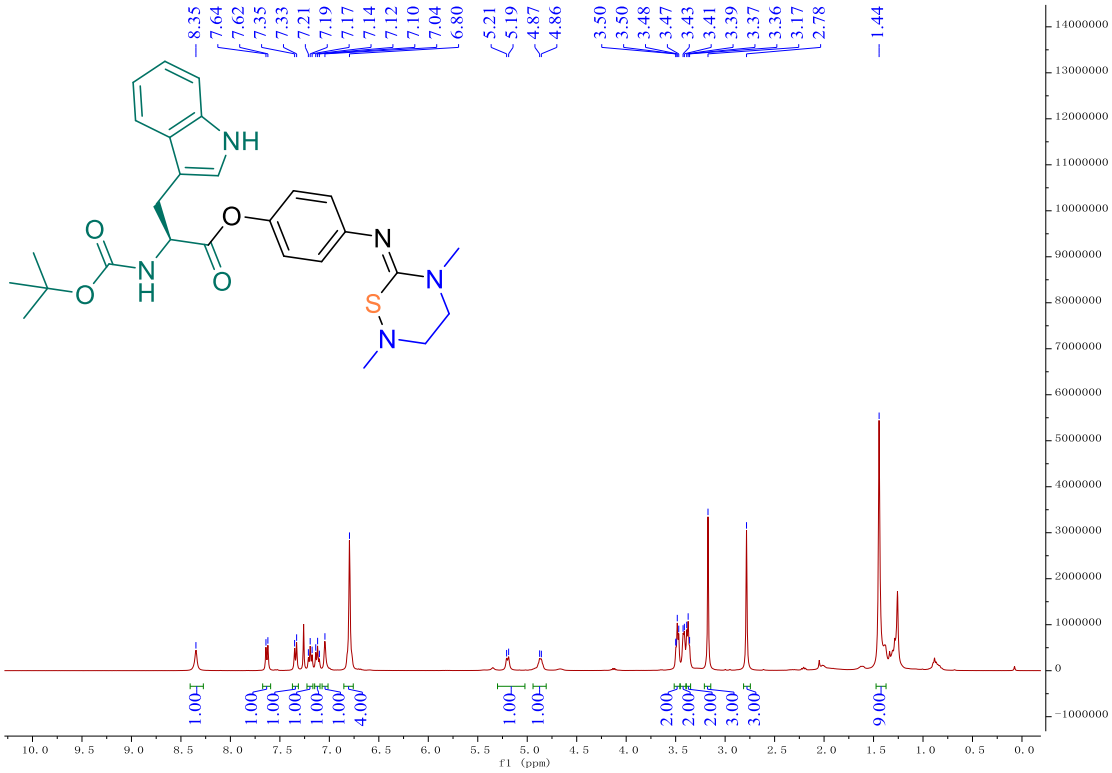
^{1}H NMR of Compound **42** (400 MHz, $CDCl_3$):



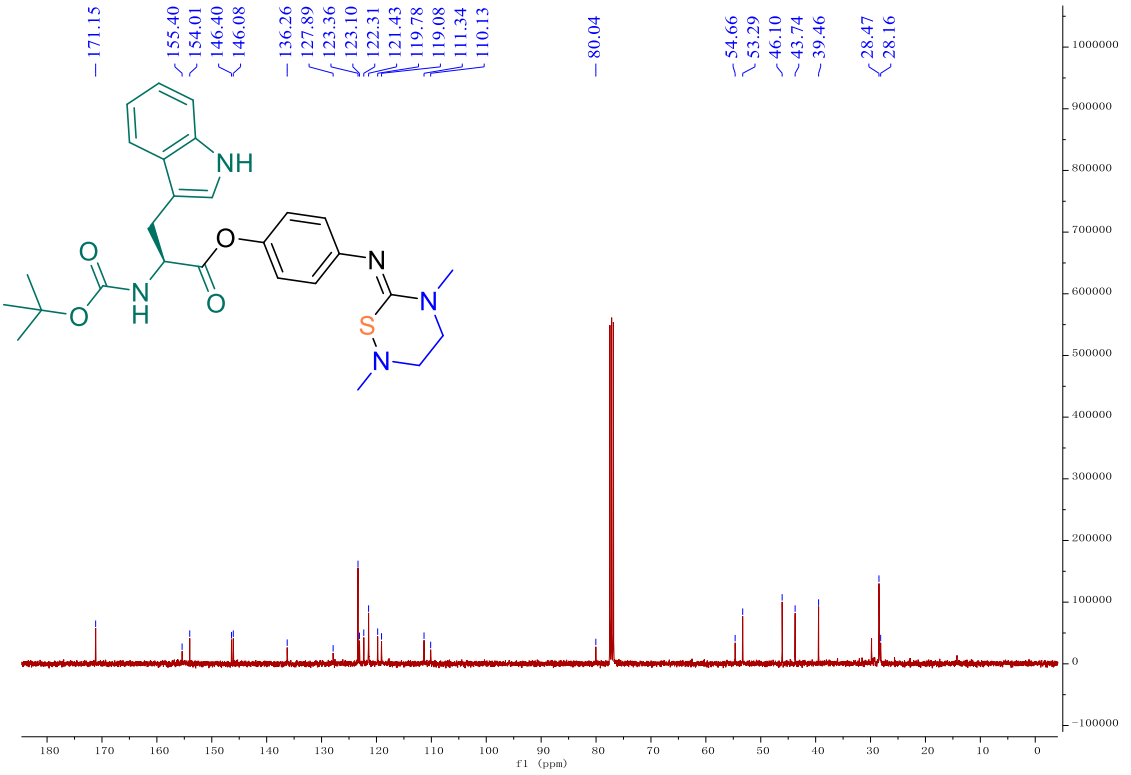
$^{13}C\{^{1}H\}$ NMR of Compound **42** (101 MHz, $CDCl_3$):



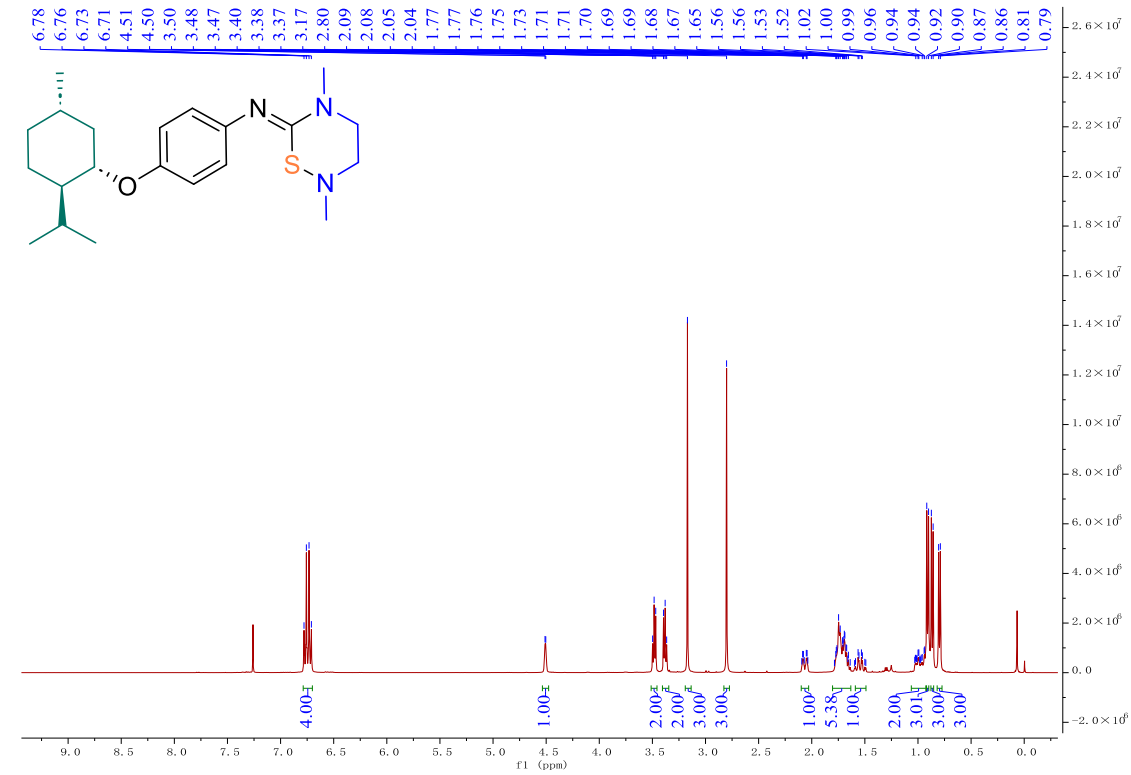
^{1}H NMR of Compound **43** (400 MHz, $CDCl_3$):



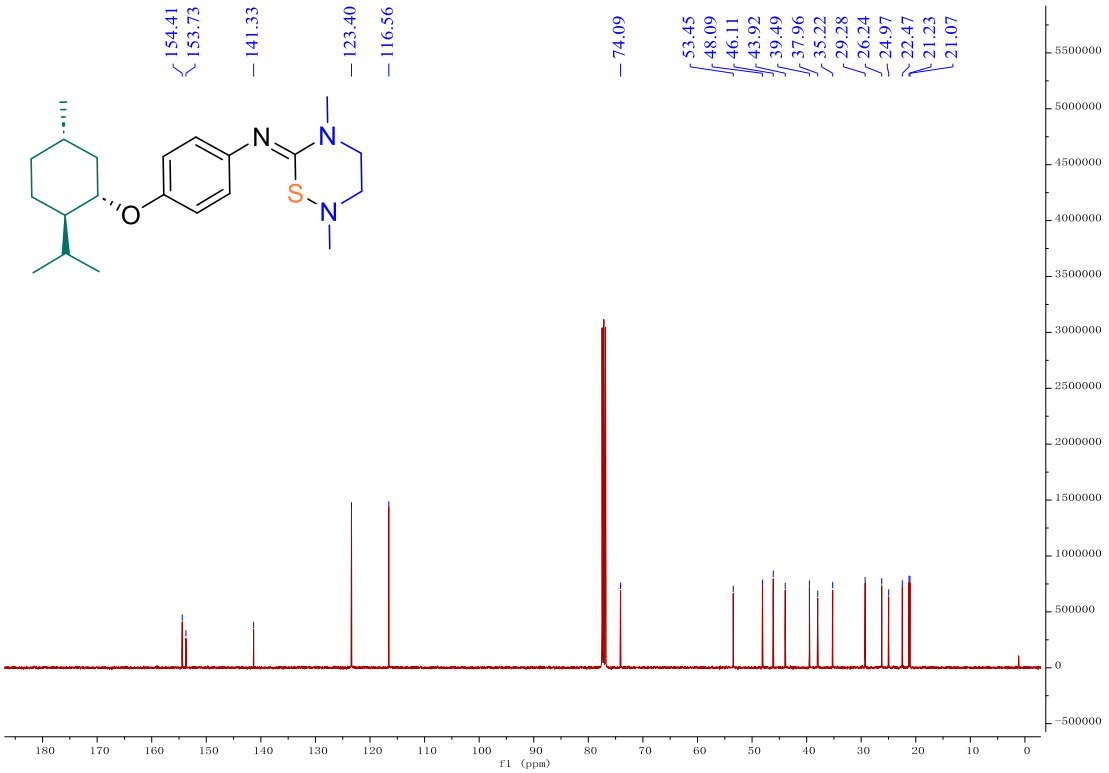
$^{13}C\{^{1}H\}$ NMR of Compound **43** (101 MHz, $CDCl_3$):



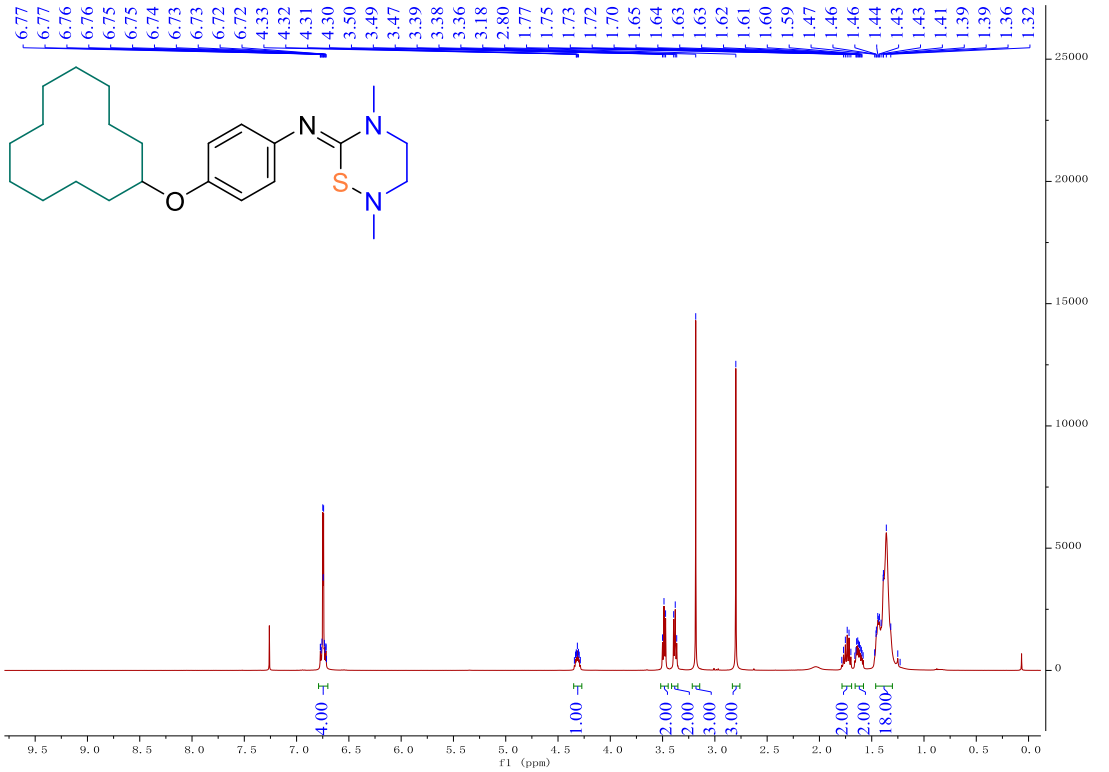
^{1}H NMR of Compound **44** (400 MHz, $CDCl_3$):



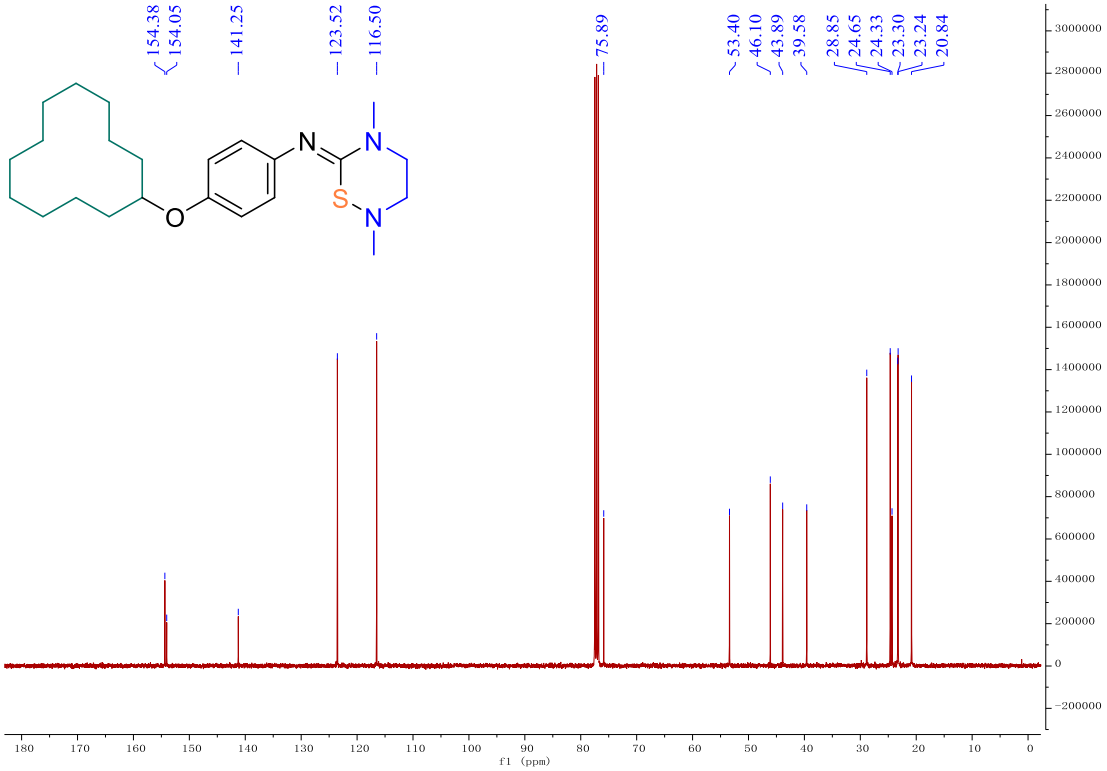
$^{13}C\{^{1}H\}$ NMR of Compound **44** (101 MHz, $CDCl_3$):



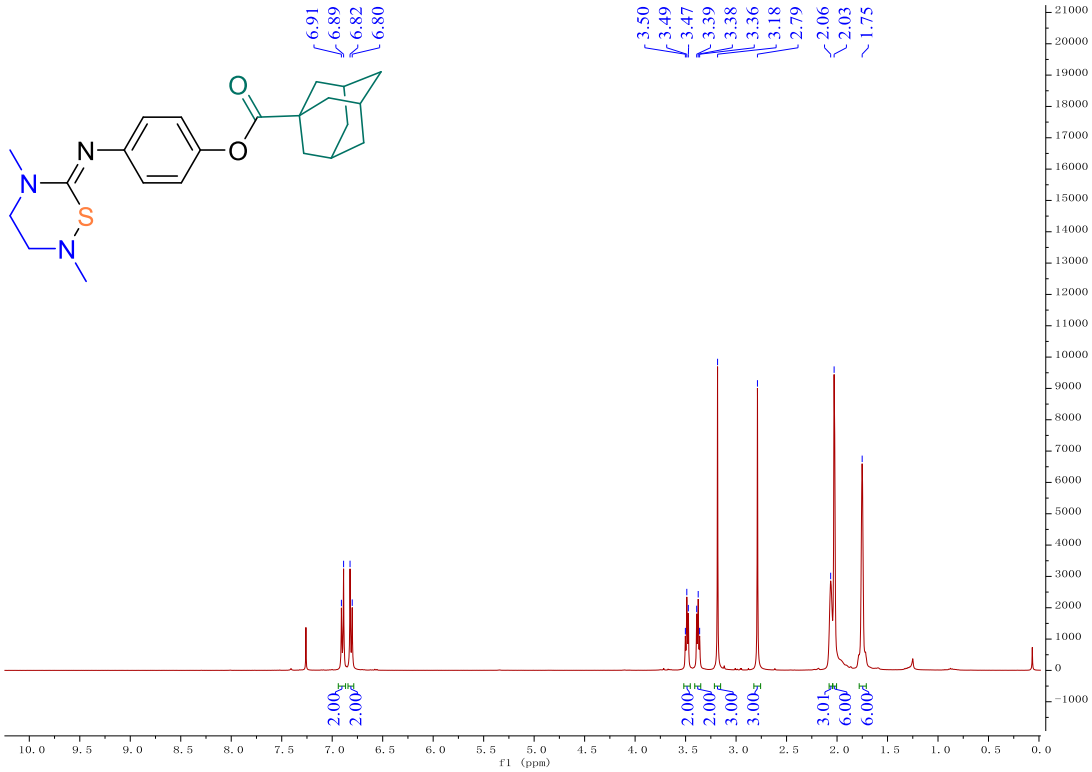
^{1}H NMR of Compound **45** (400 MHz, $CDCl_3$):



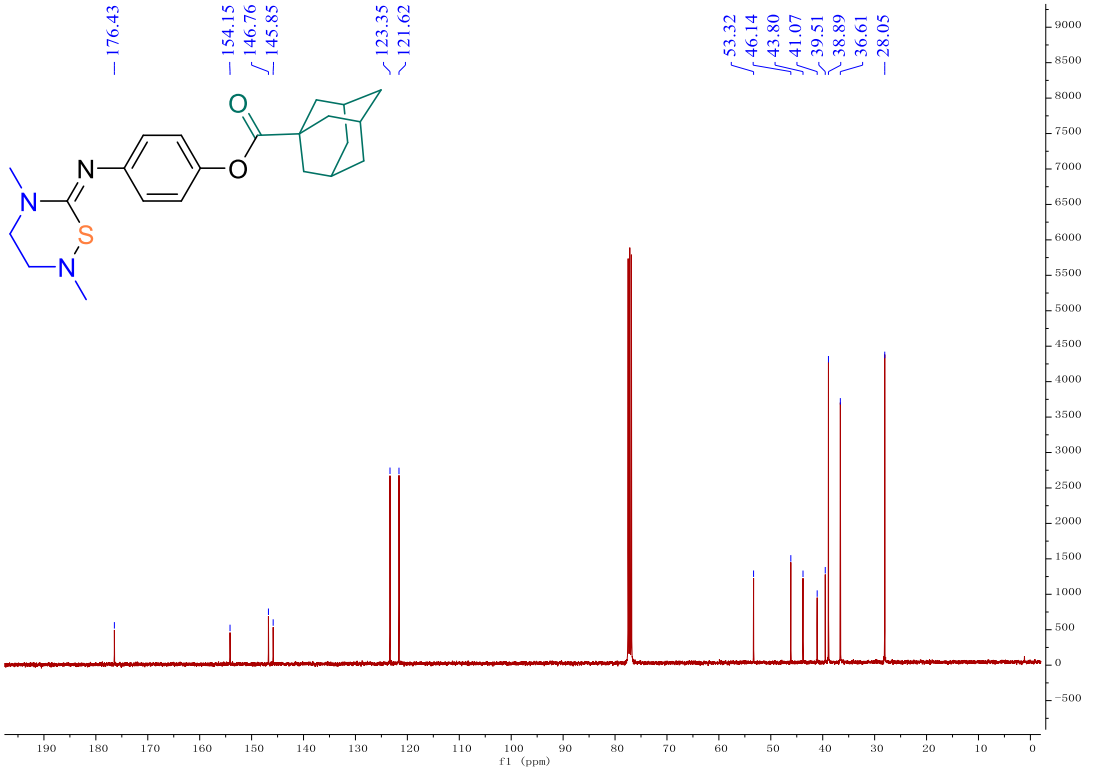
$^{13}C\{^{1}H\}$ NMR of Compound **45** (101 MHz, $CDCl_3$):



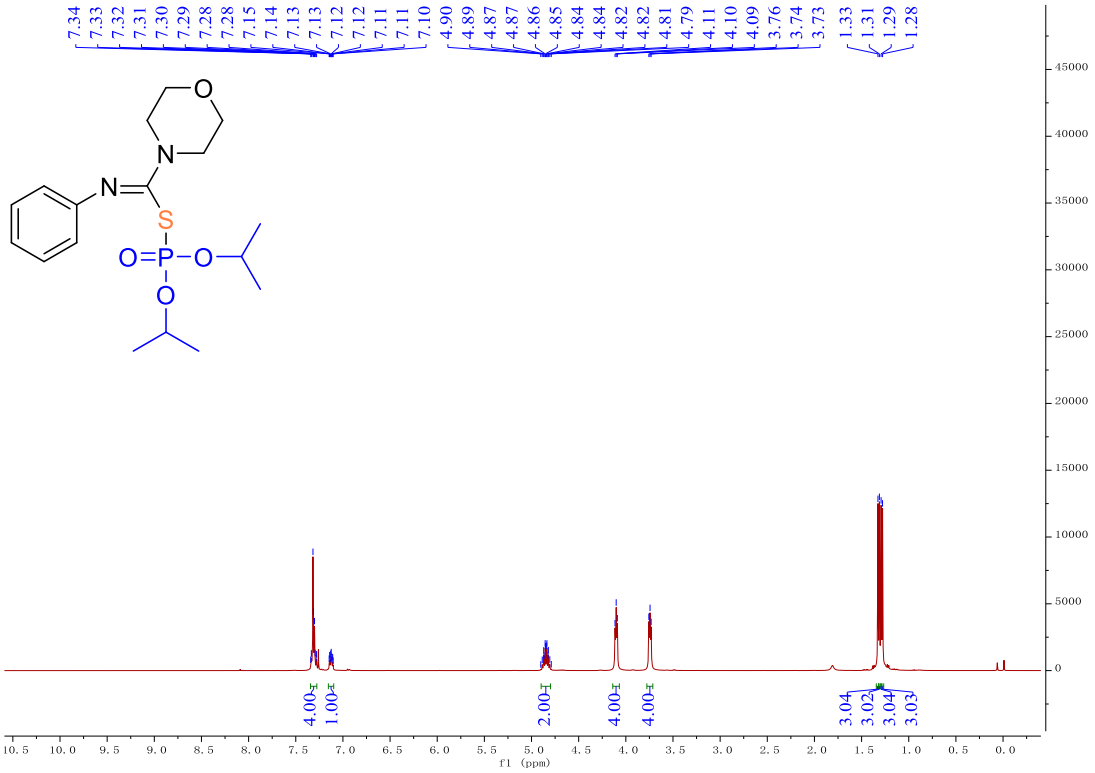
^{1}H NMR of Compound **46** (400 MHz, $CDCl_3$):



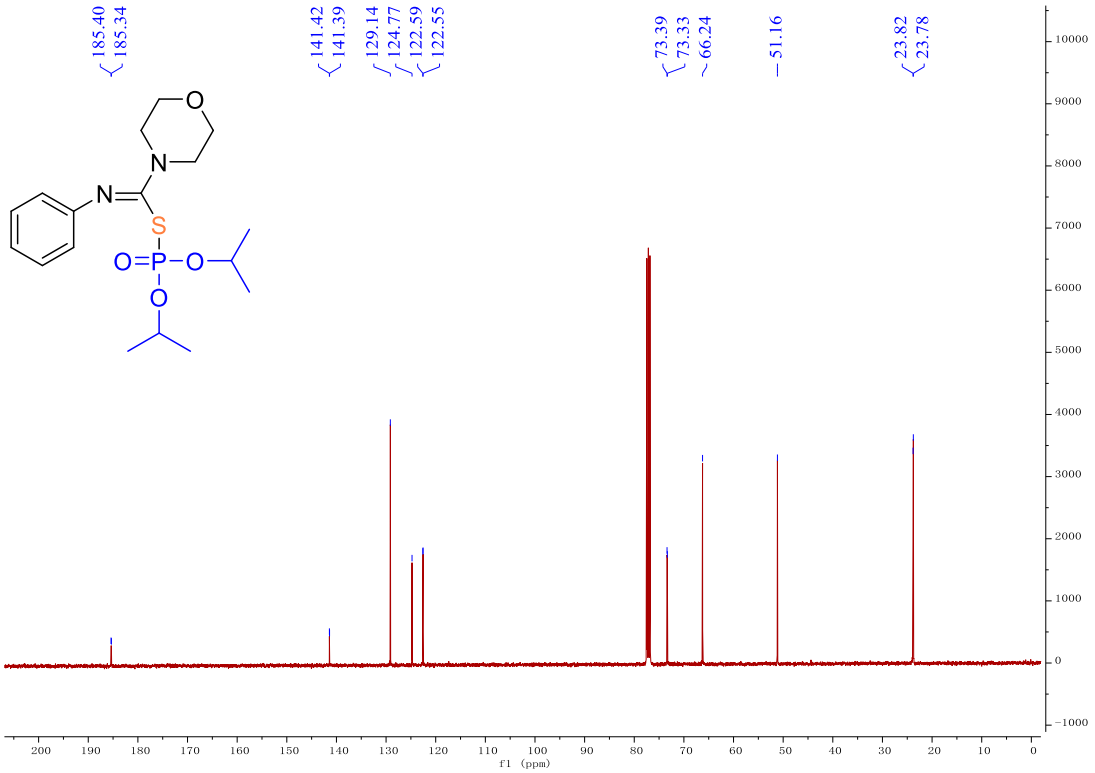
$^{13}C\{^{1}H\}$ NMR of Compound **46** (101 MHz, $CDCl_3$):



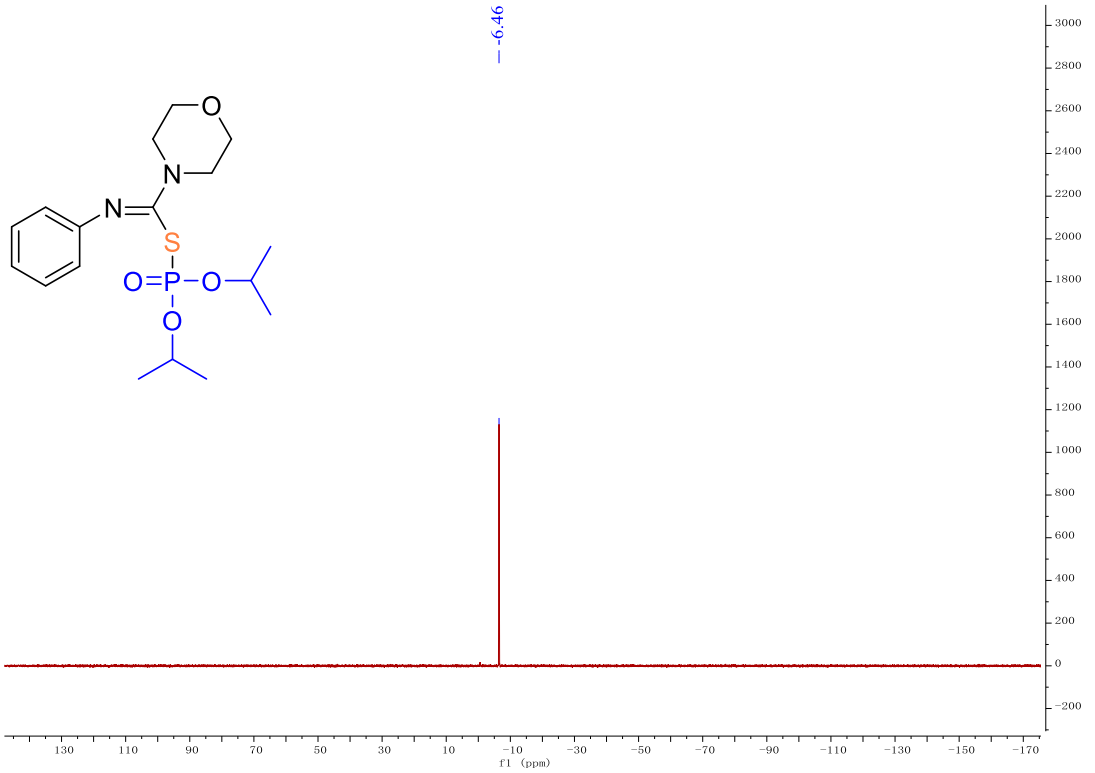
^{1}H NMR of Compound **47** (400 MHz, $CDCl_3$):



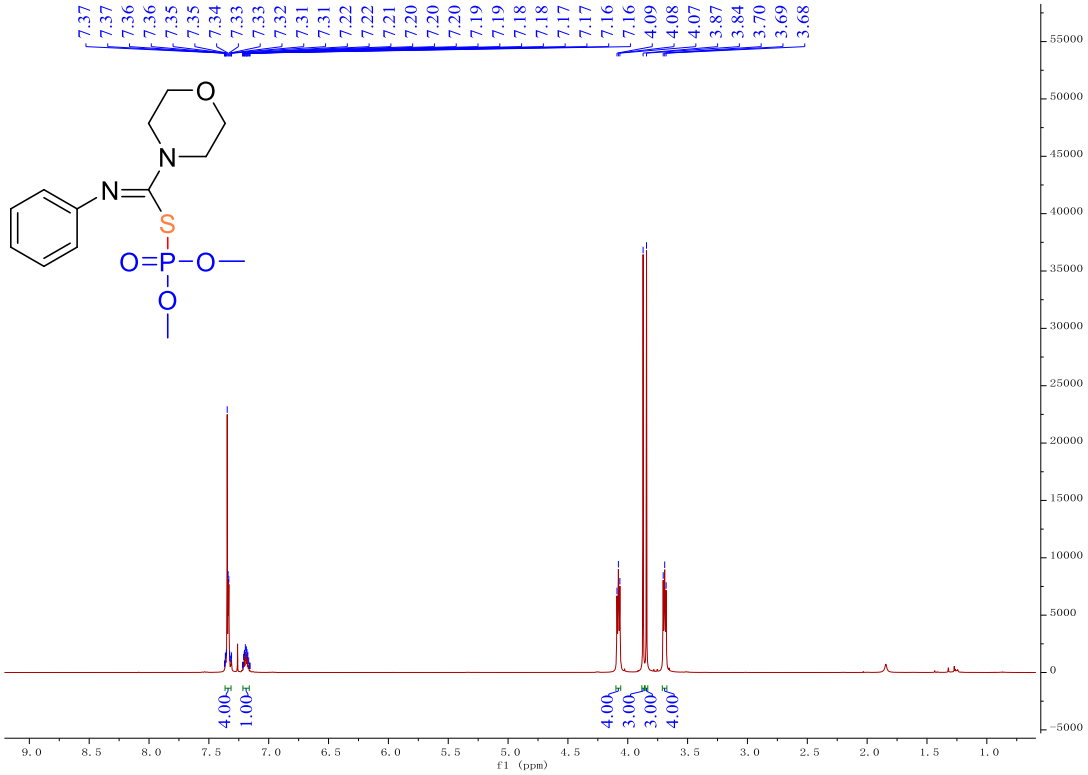
$^{13}C\{^{1}H\}$ NMR of Compound **47** (101 MHz, $CDCl_3$):



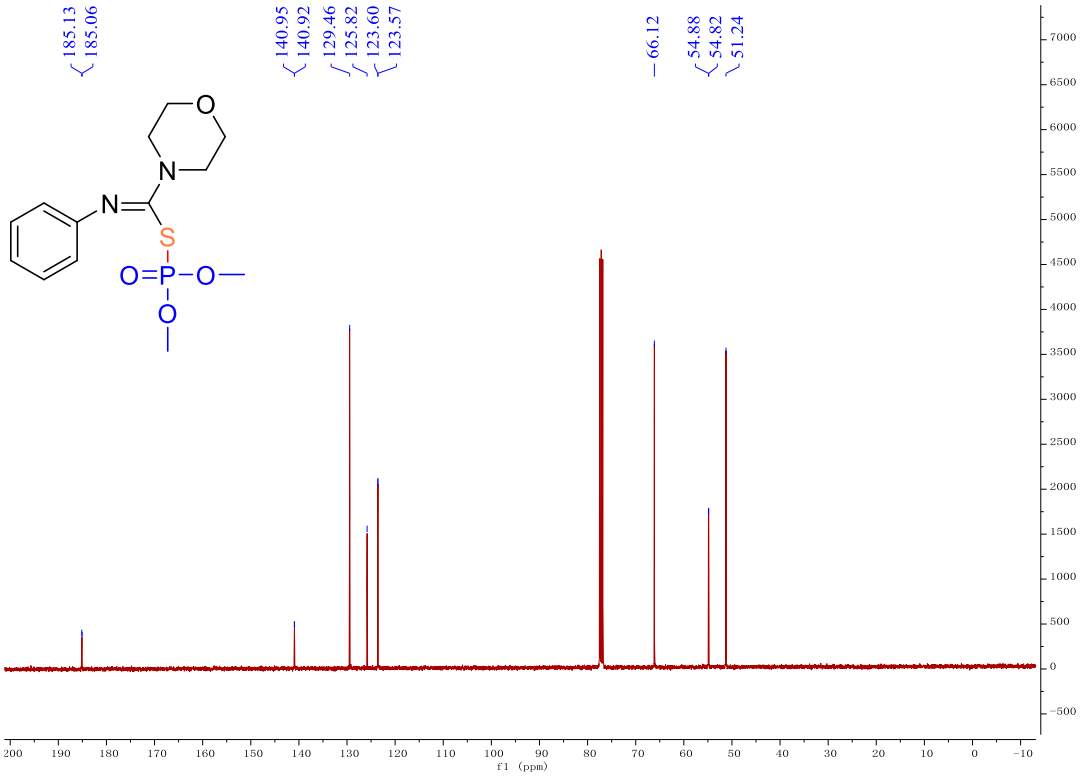
^{31}P NMR of Compound **47** (162MHz, $CDCl_3$):



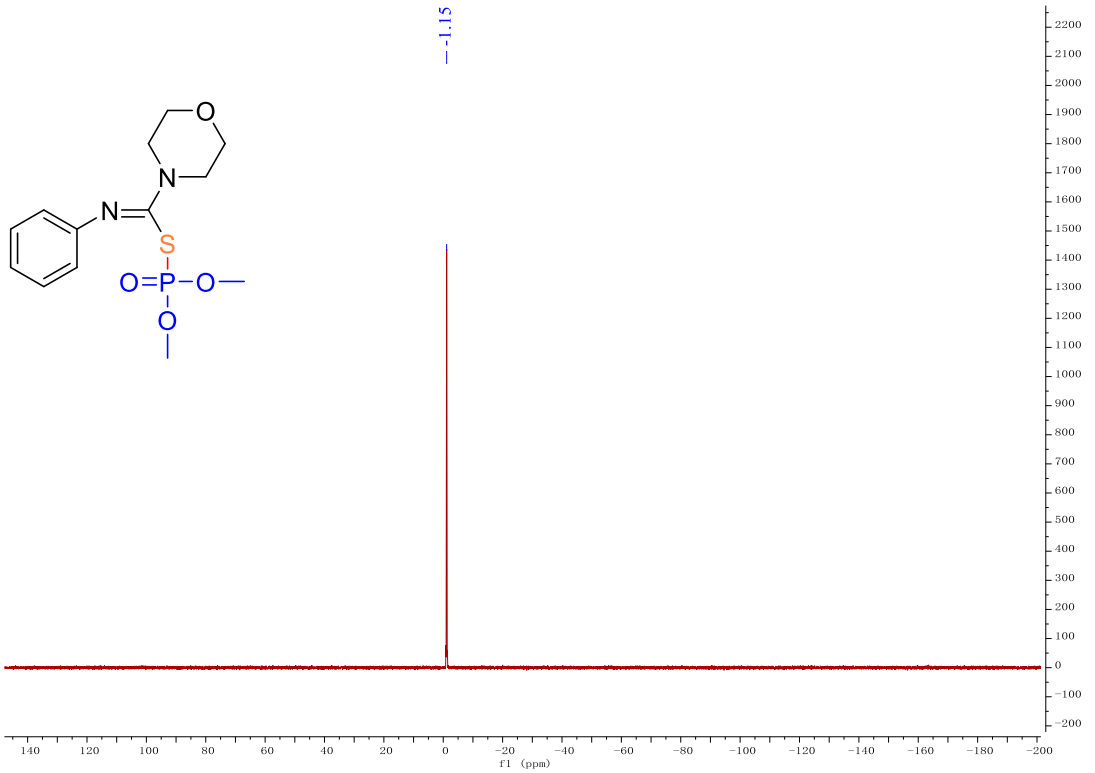
^{1}H NMR of Compound **48** (400 MHz, $CDCl_3$):



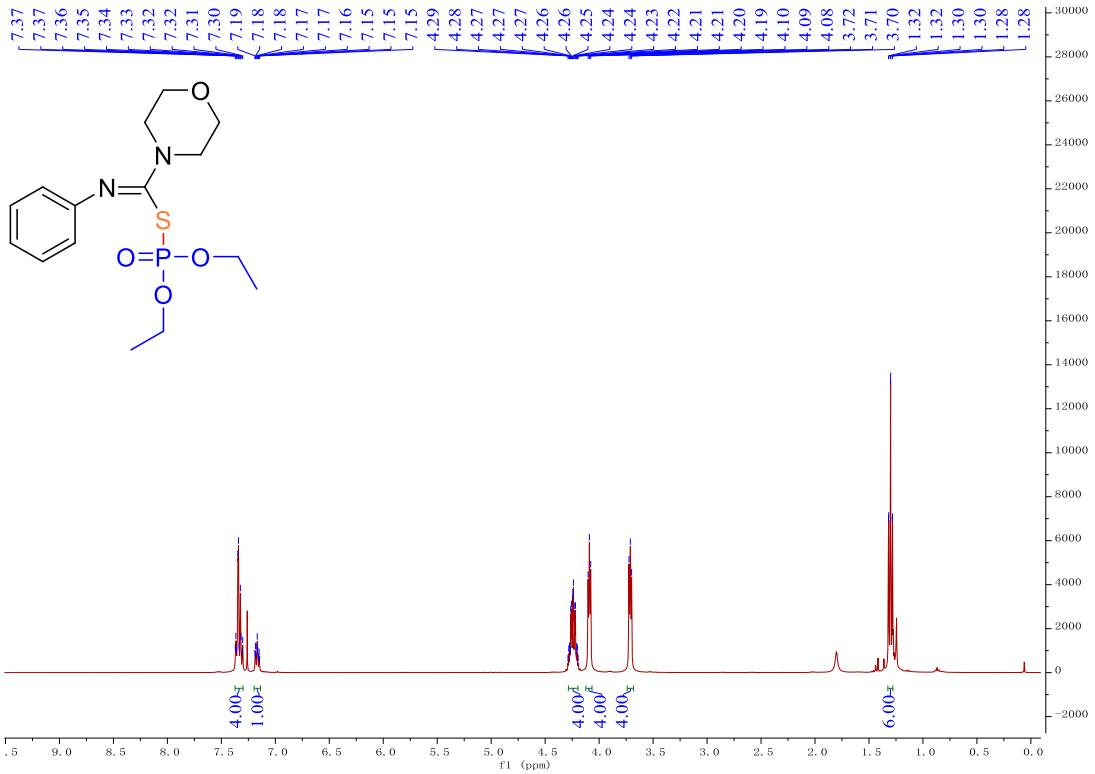
^{13}C{^{1}H} NMR of Compound **48** (101 MHz, $CDCl_3$):



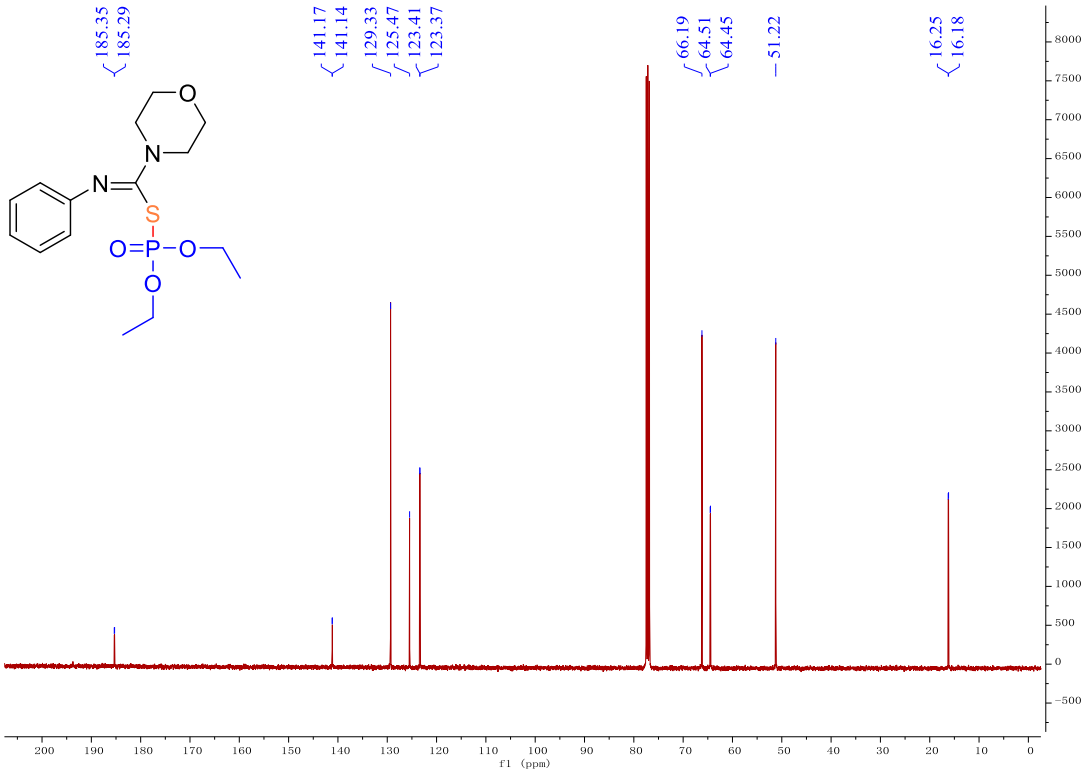
^{31}P NMR of Compound **48** (162MHz, $CDCl_3$):



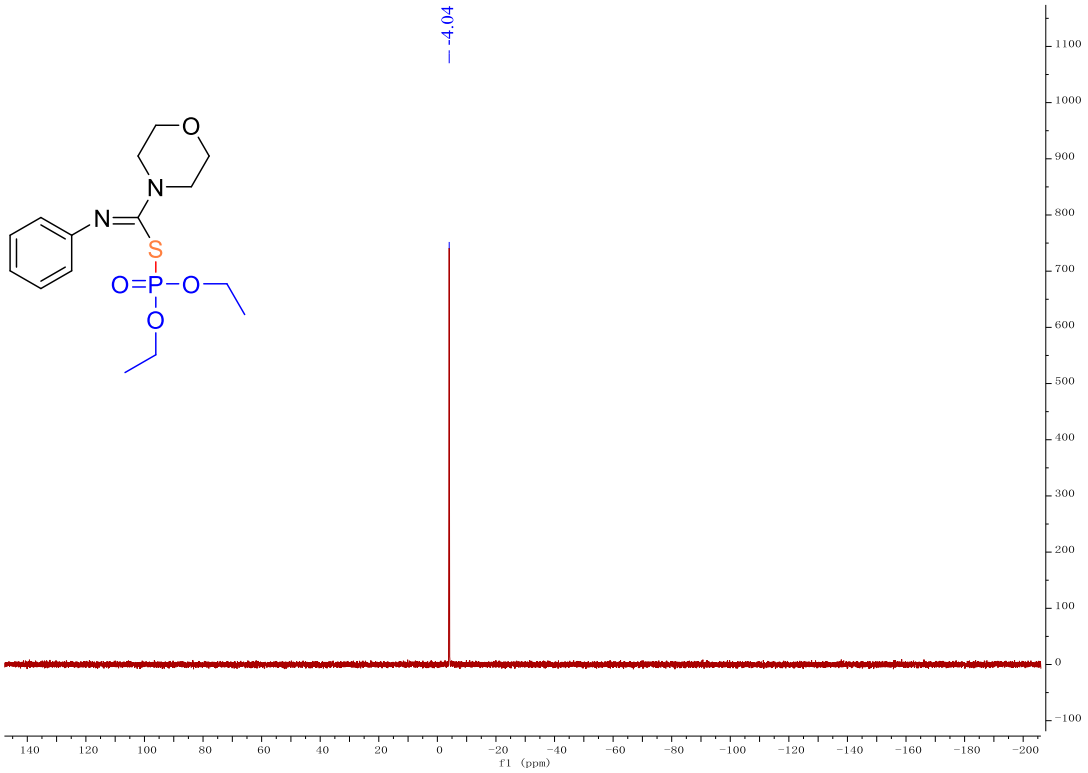
^{1}H NMR of Compound **49** (400 MHz, $CDCl_3$):



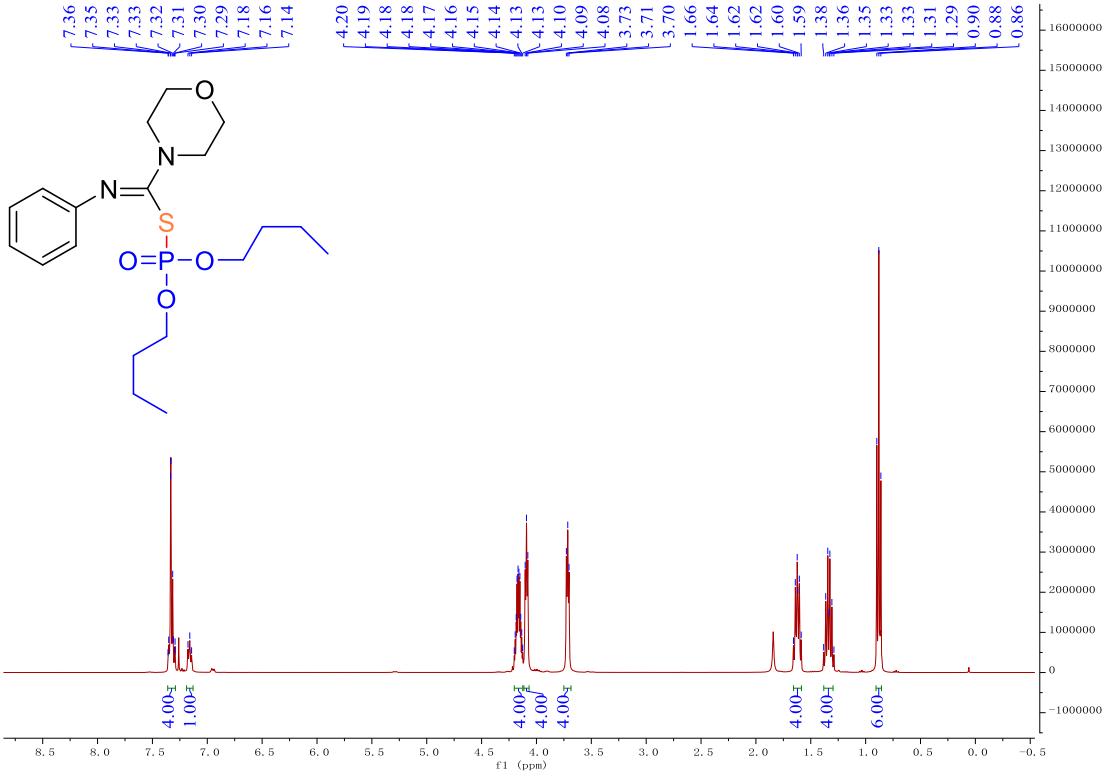
$^{13}C\{^{1}H\}$ NMR of Compound **49** (101 MHz, $CDCl_3$):



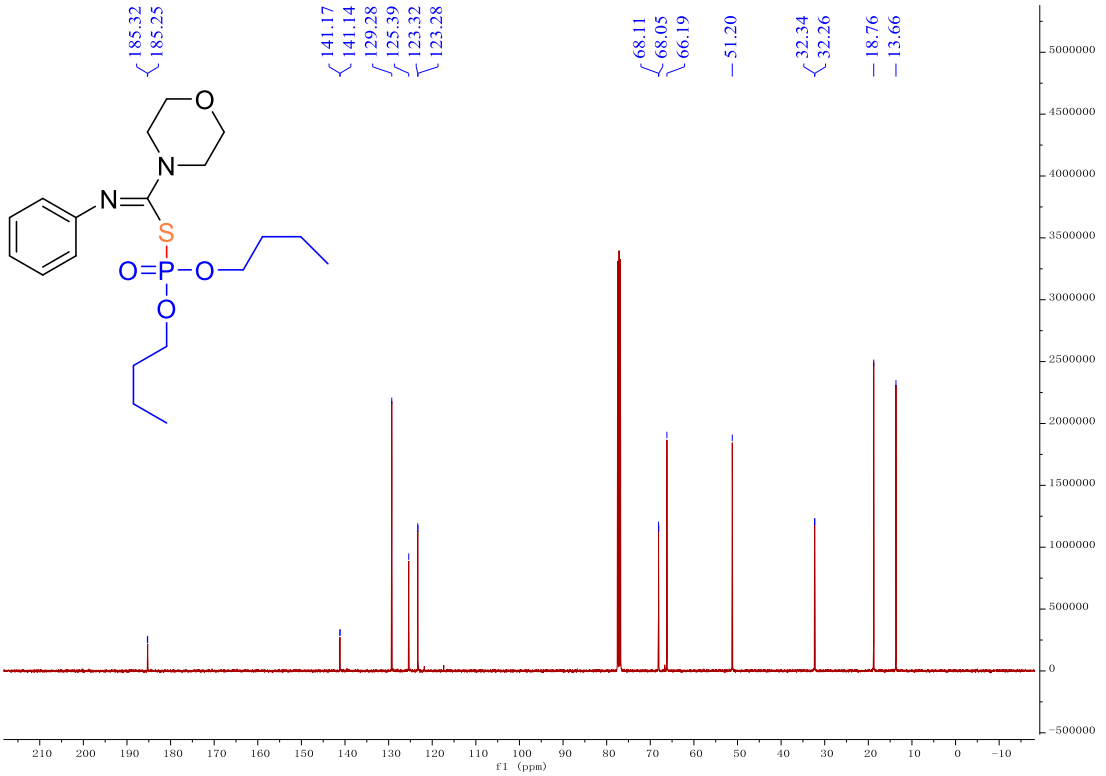
^{31}P NMR of Compound **49** (162MHz, $CDCl_3$):



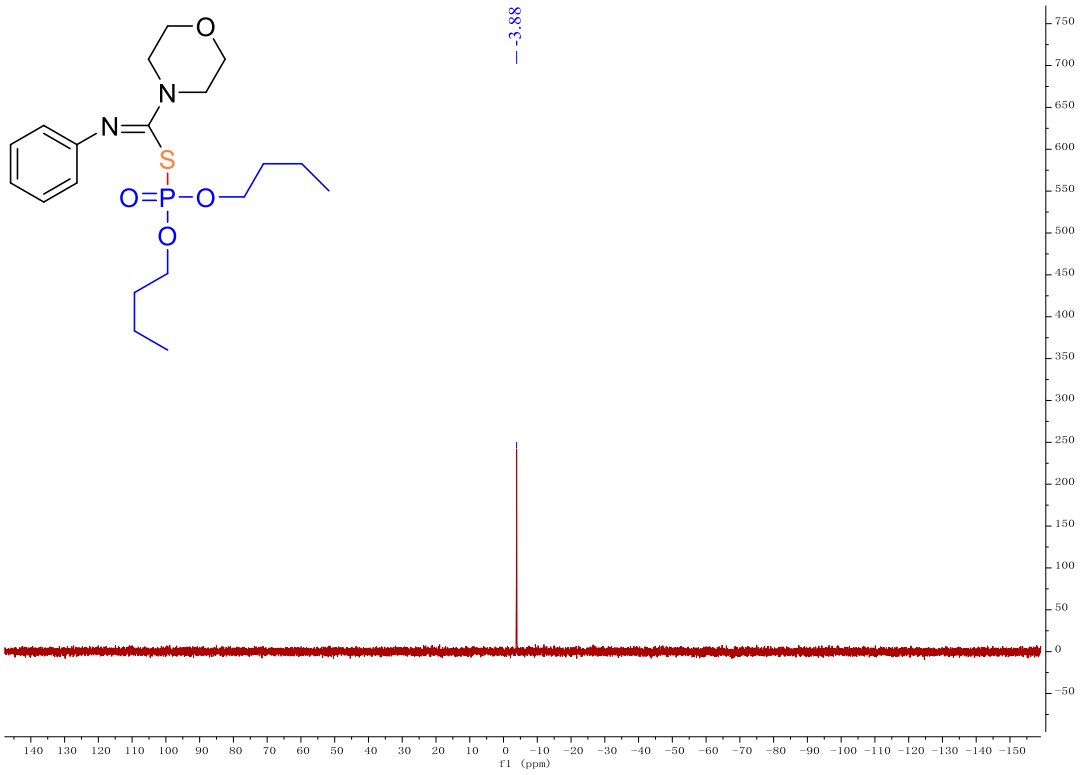
^{1}H NMR of Compound **50** (400 MHz, $CDCl_3$):



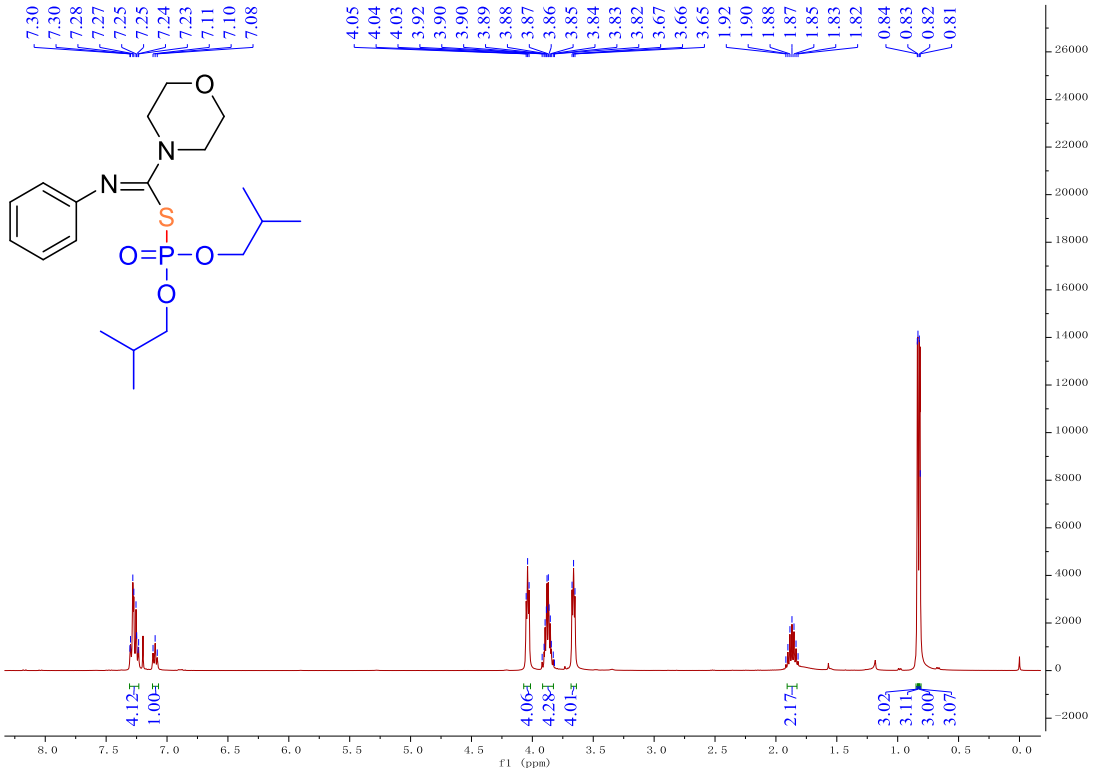
^{13}C{^{1}H} NMR of Compound **50** (101 MHz, $CDCl_3$):



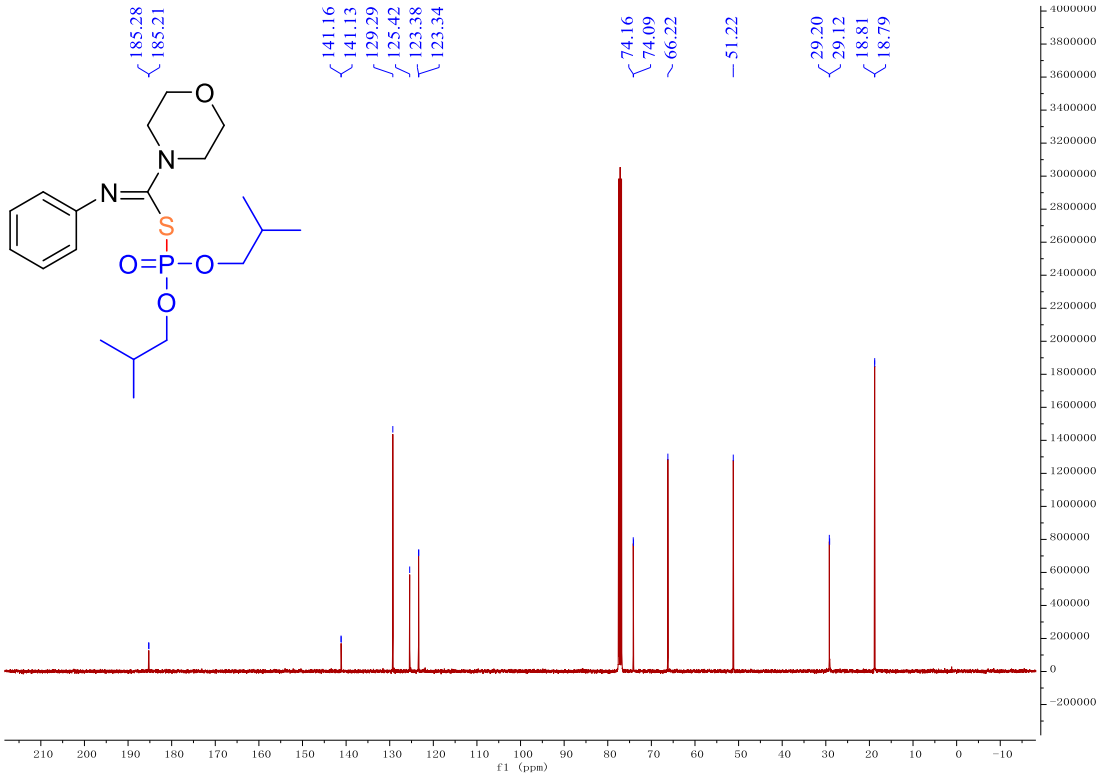
^{31}P NMR of Compound **50** (162MHz, $CDCl_3$):



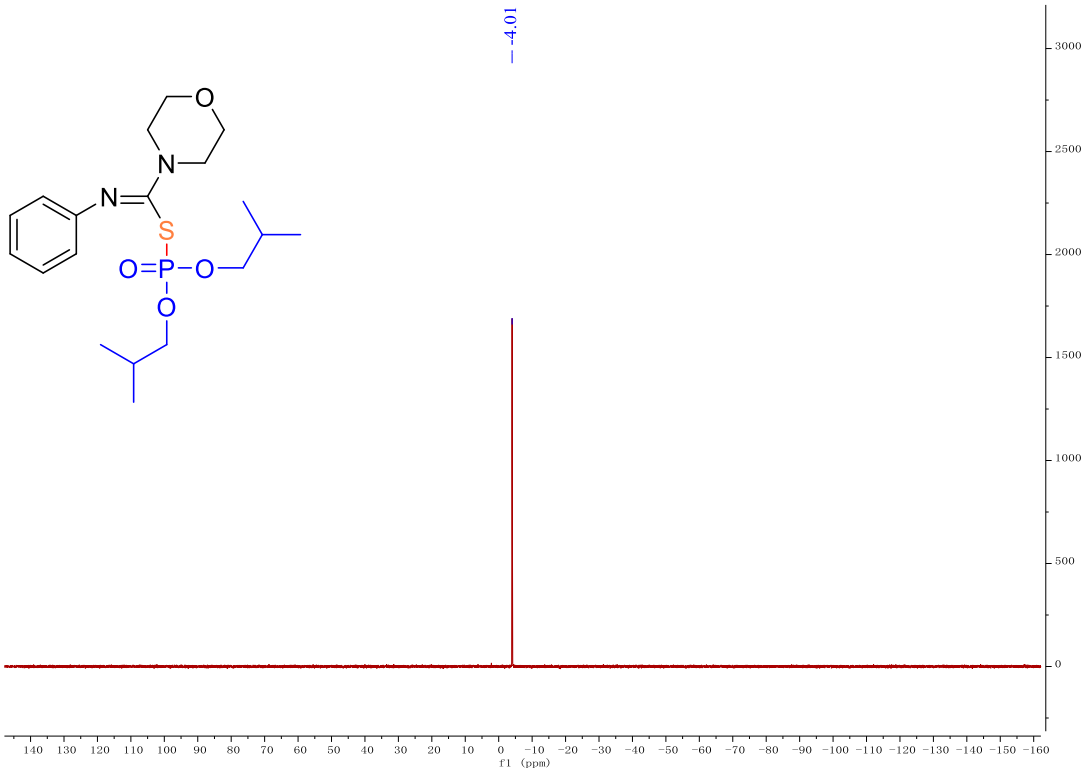
^{1}H NMR of Compound **51** (400 MHz, $CDCl_3$):



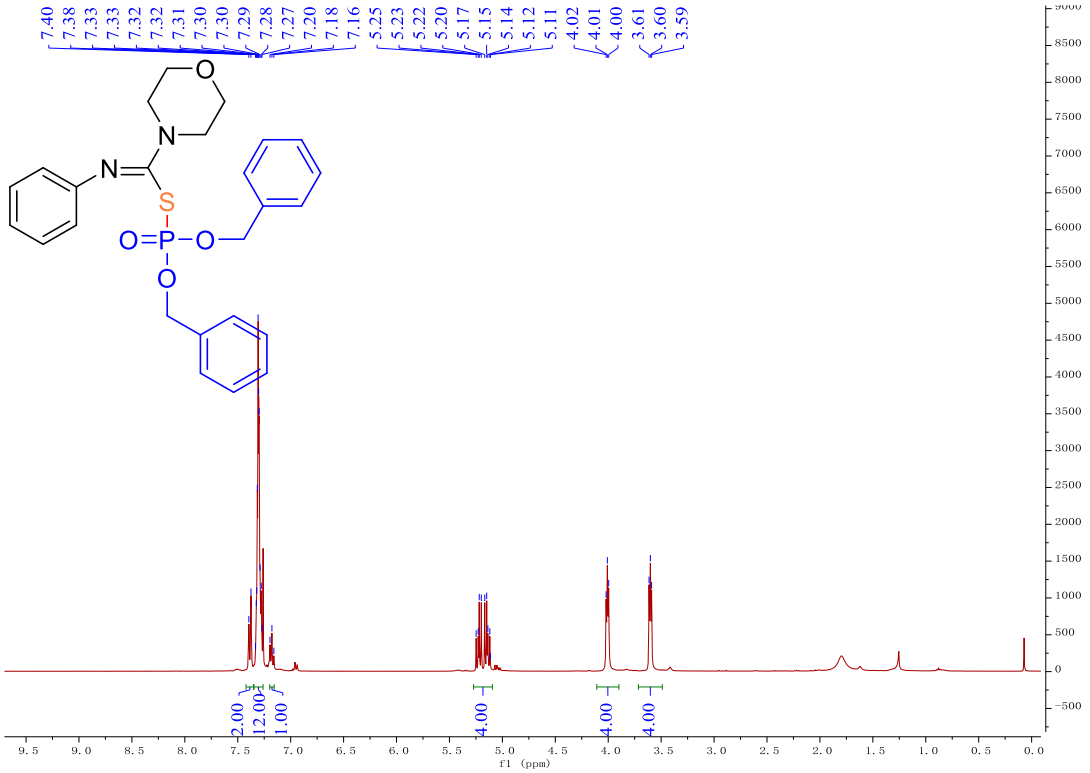
$^{13}C\{^{1}H\}$ NMR of Compound **51** (101 MHz, $CDCl_3$):



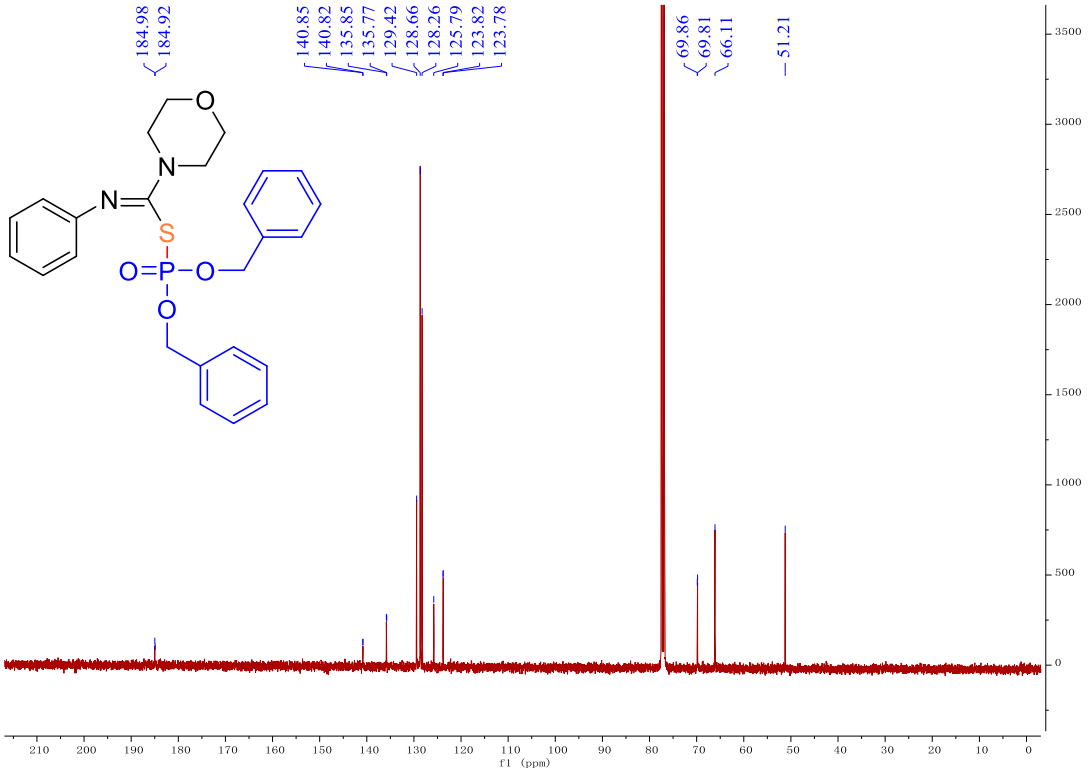
^{31}P NMR of Compound **51** (162MHz, $CDCl_3$):



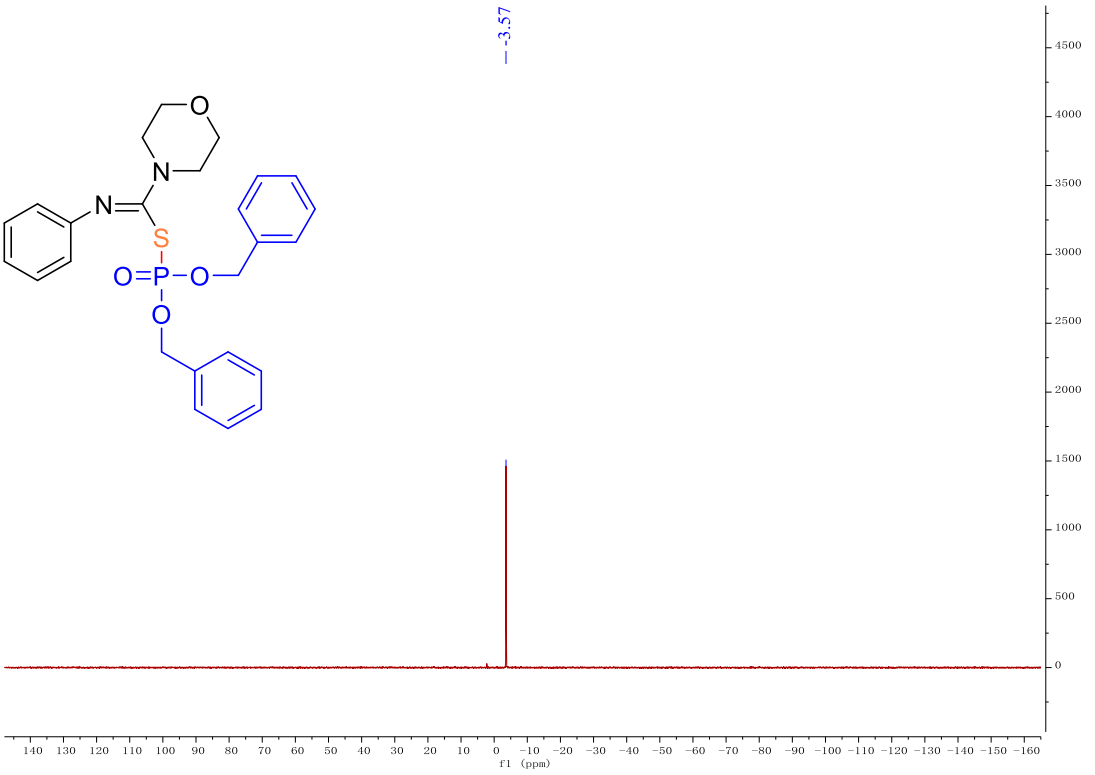
^{1}H NMR of Compound **52** (400 MHz, $CDCl_3$):



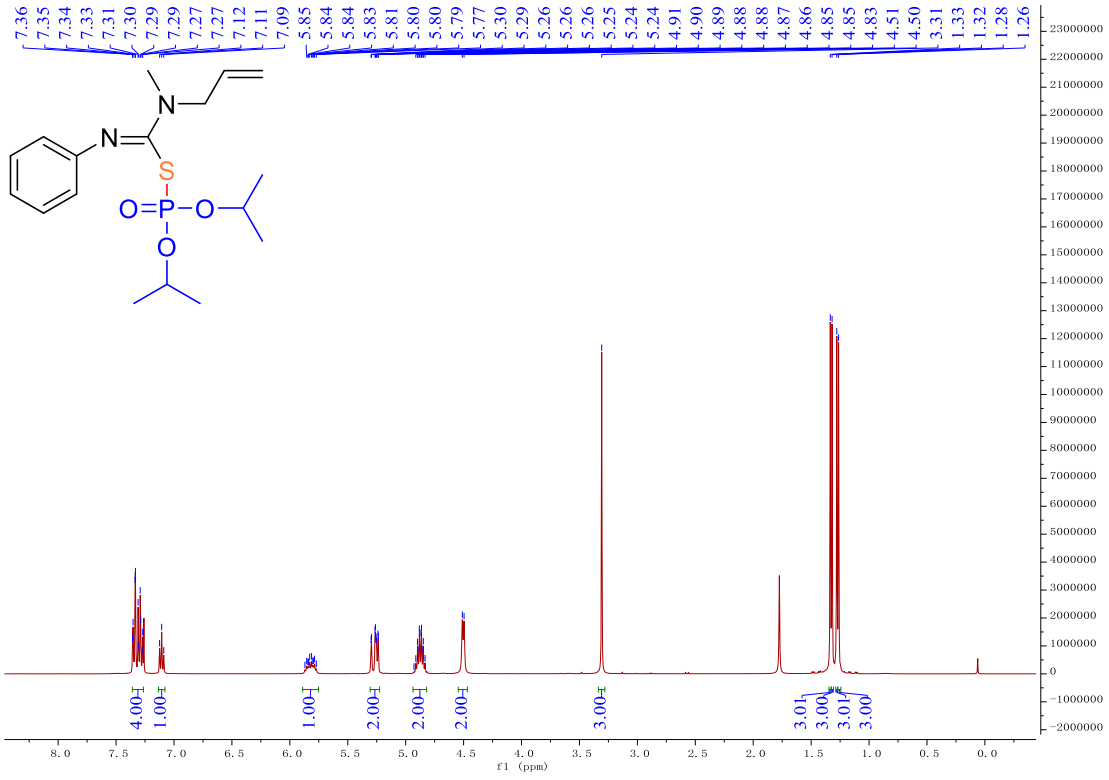
^{13}C{^{1}H} NMR of Compound **52** (101 MHz, $CDCl_3$):



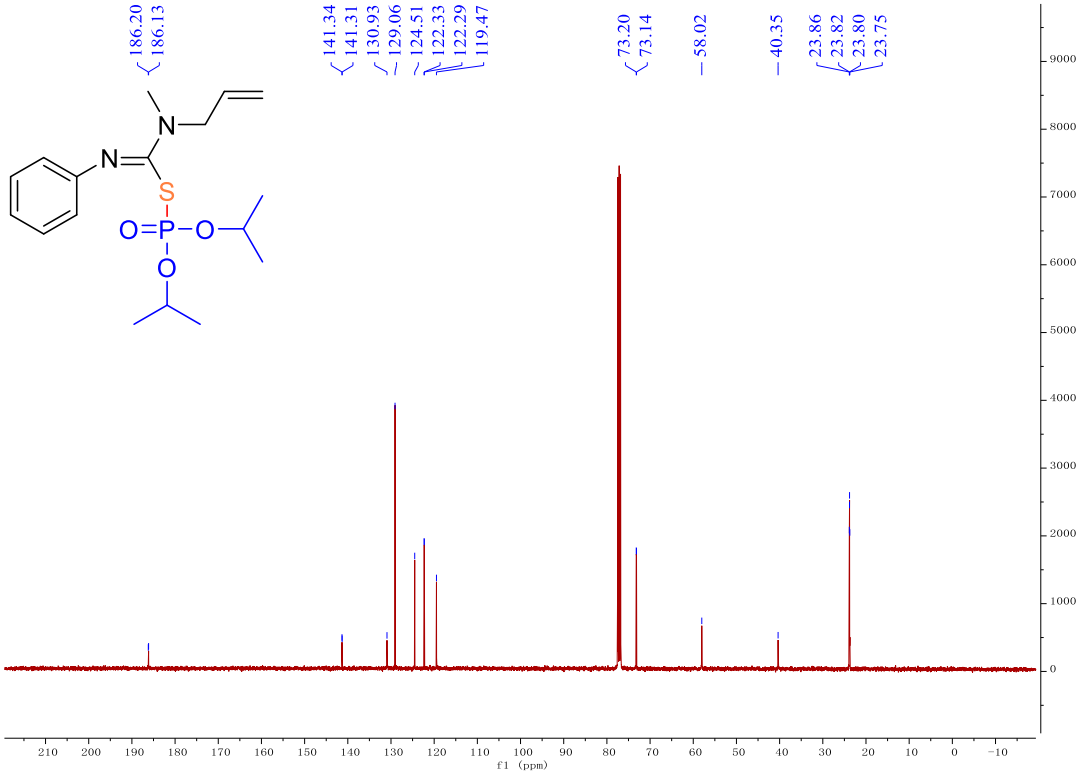
^{31}P NMR of Compound **52** (162MHz, $CDCl_3$):



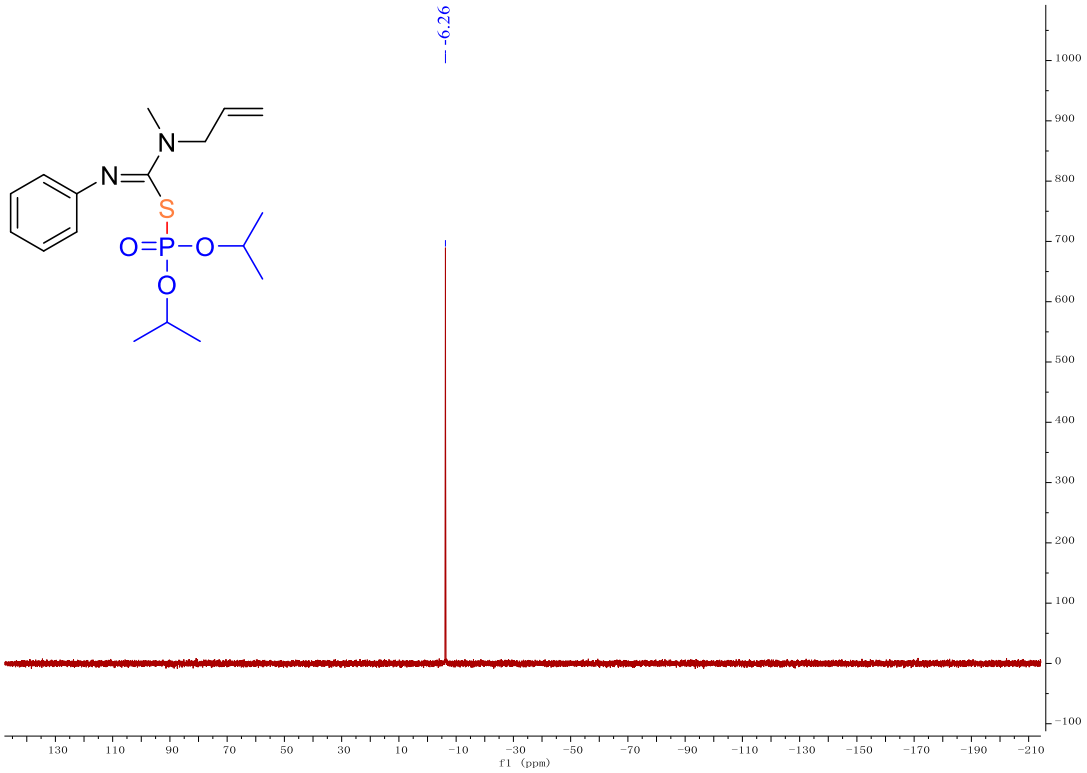
^{1}H NMR of Compound **53** (400 MHz, $CDCl_3$):



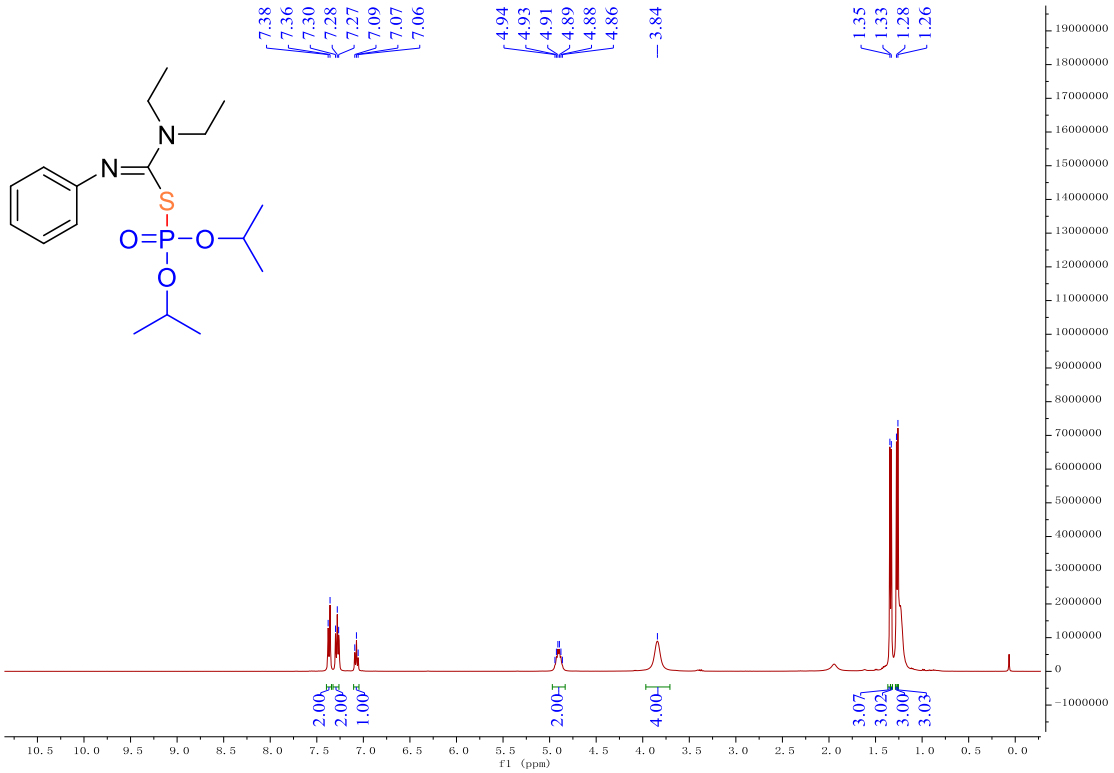
$^{13}C\{^{1}H\}$ NMR of Compound **53** (101 MHz, $CDCl_3$):



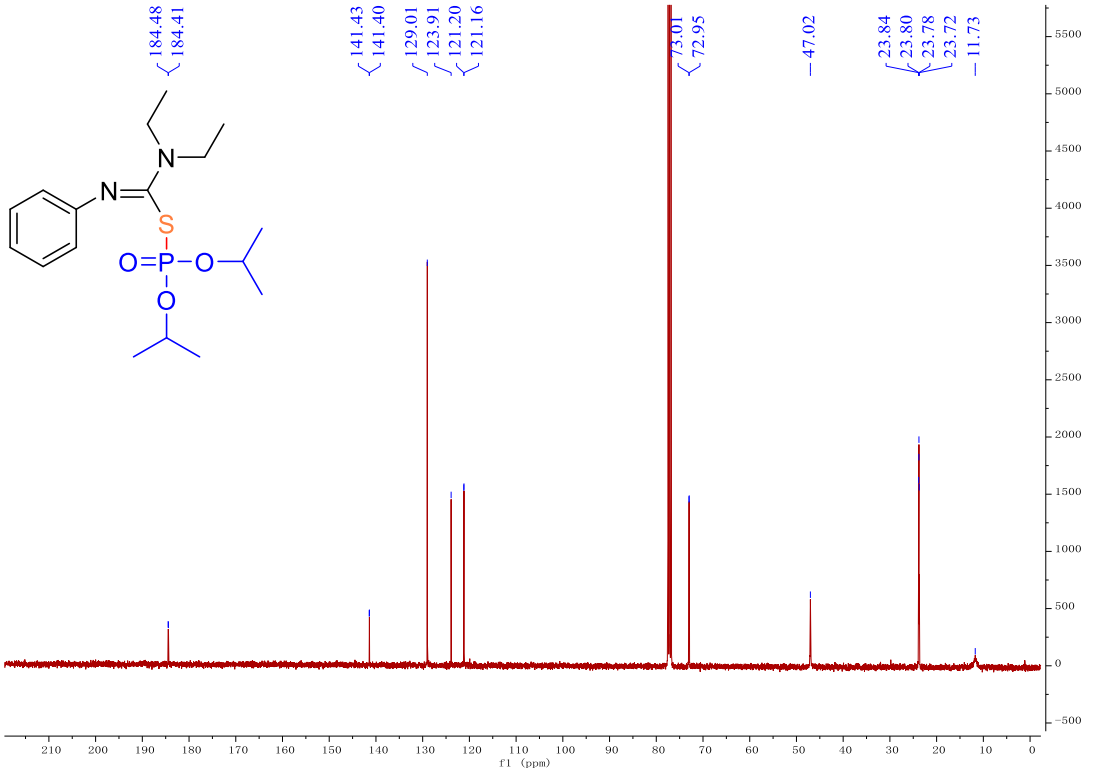
^{31}P NMR of Compound **53** (162MHz, $CDCl_3$):



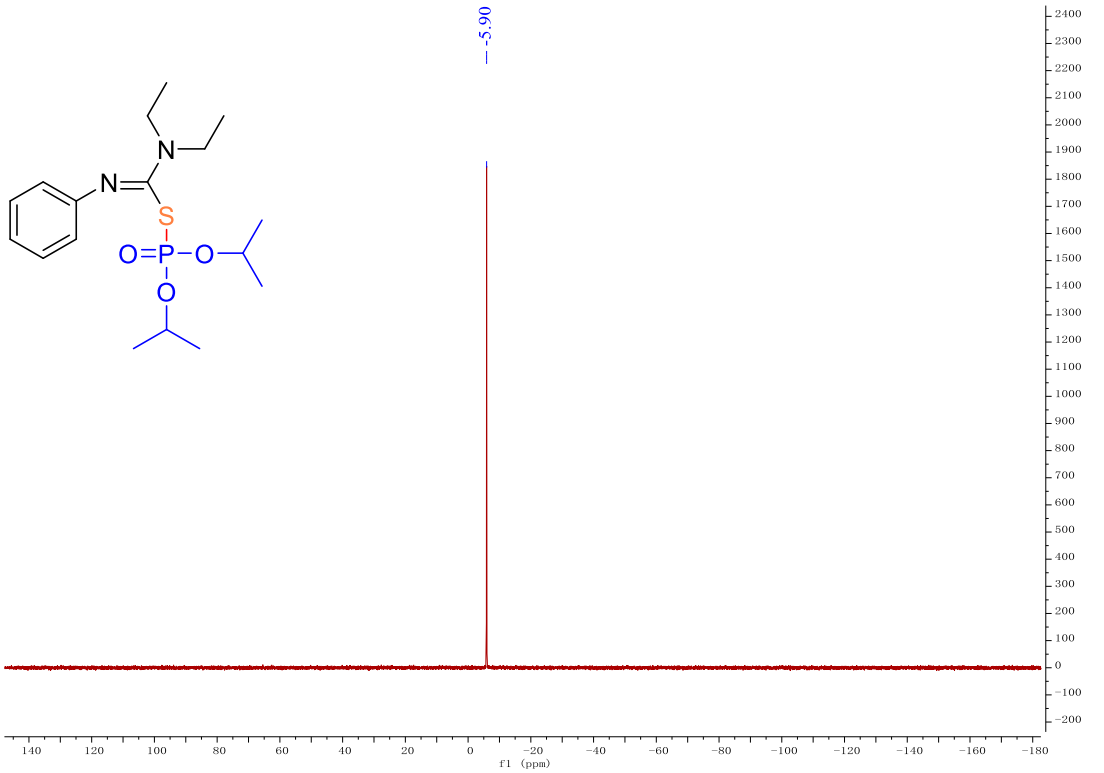
^{1}H NMR of Compound **54** (400 MHz, $CDCl_3$):



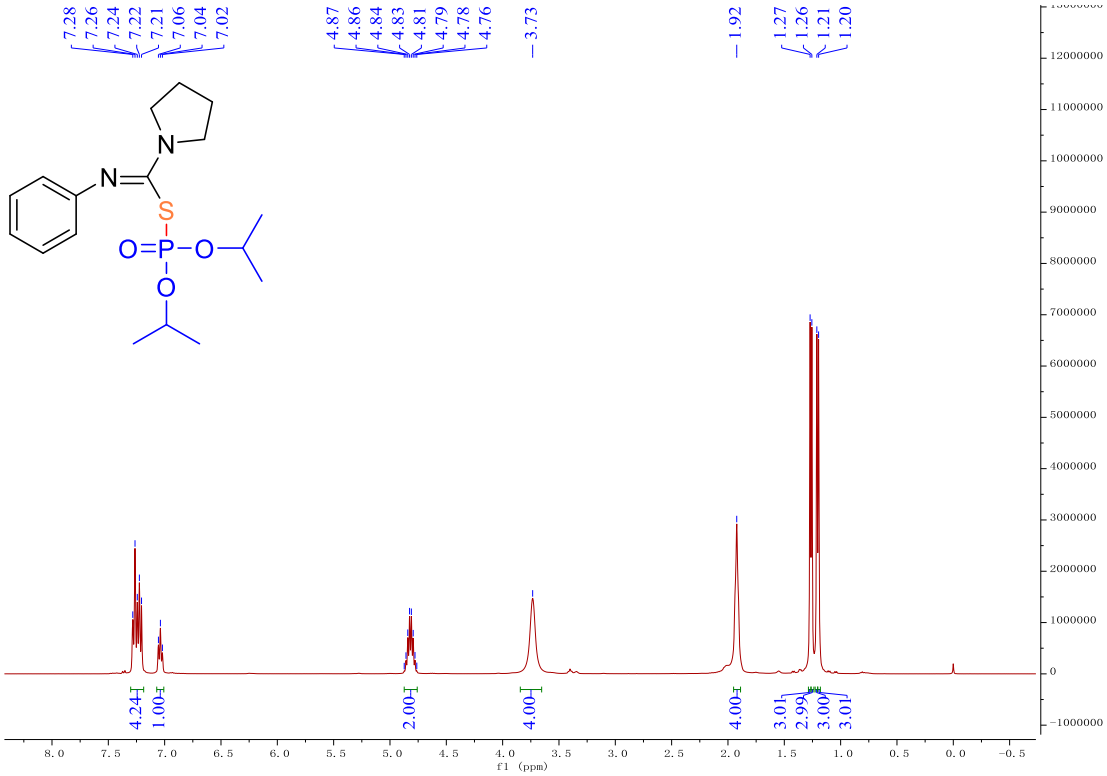
^{13}C{^{1}H} NMR of Compound **54** (101 MHz, $CDCl_3$):



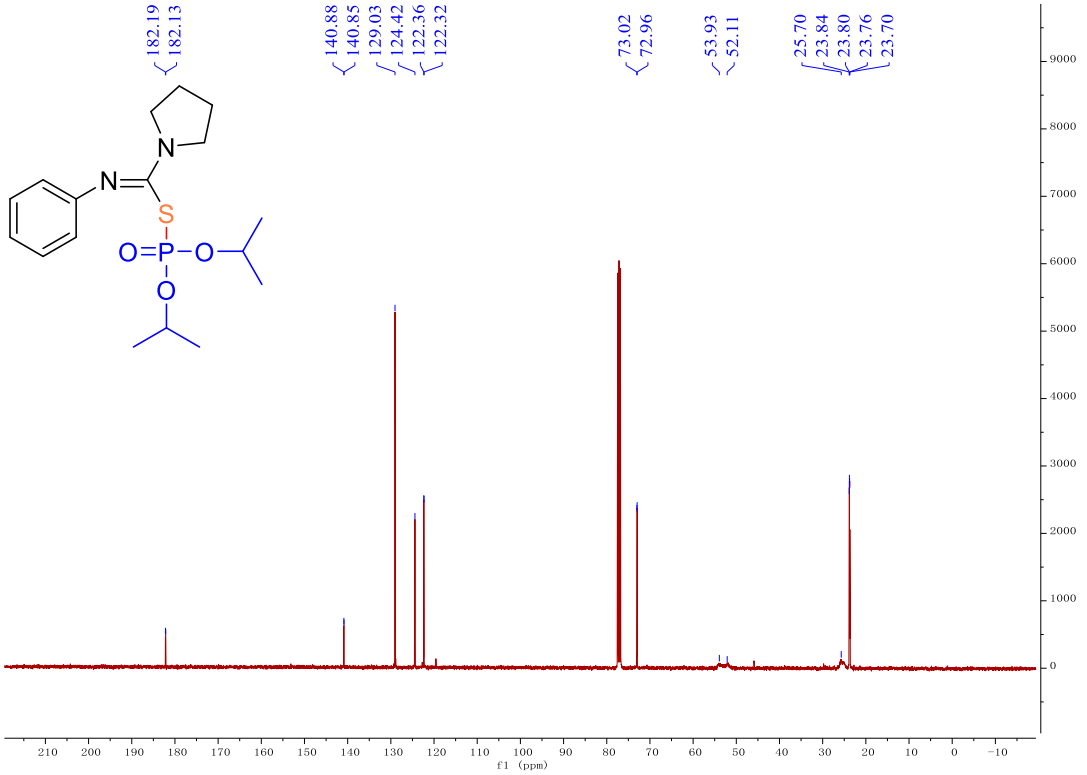
^{31}P NMR of Compound **54** (162MHz, $CDCl_3$):



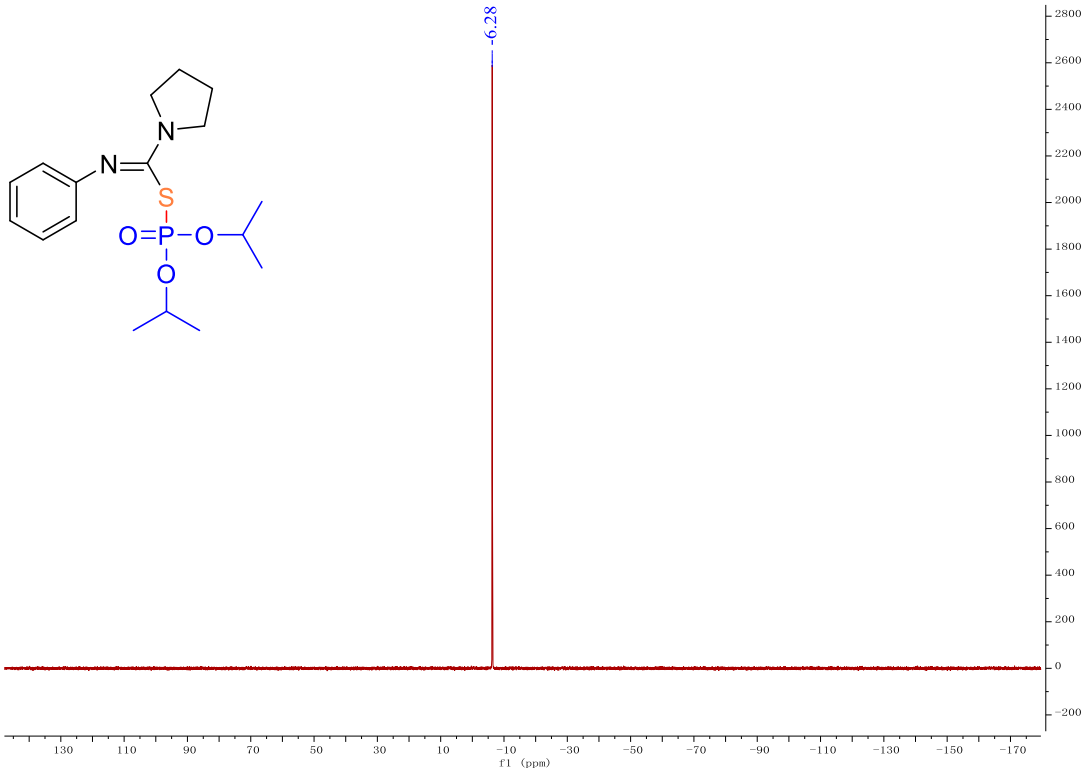
^{1}H NMR of Compound **55** (400 MHz, $CDCl_3$):



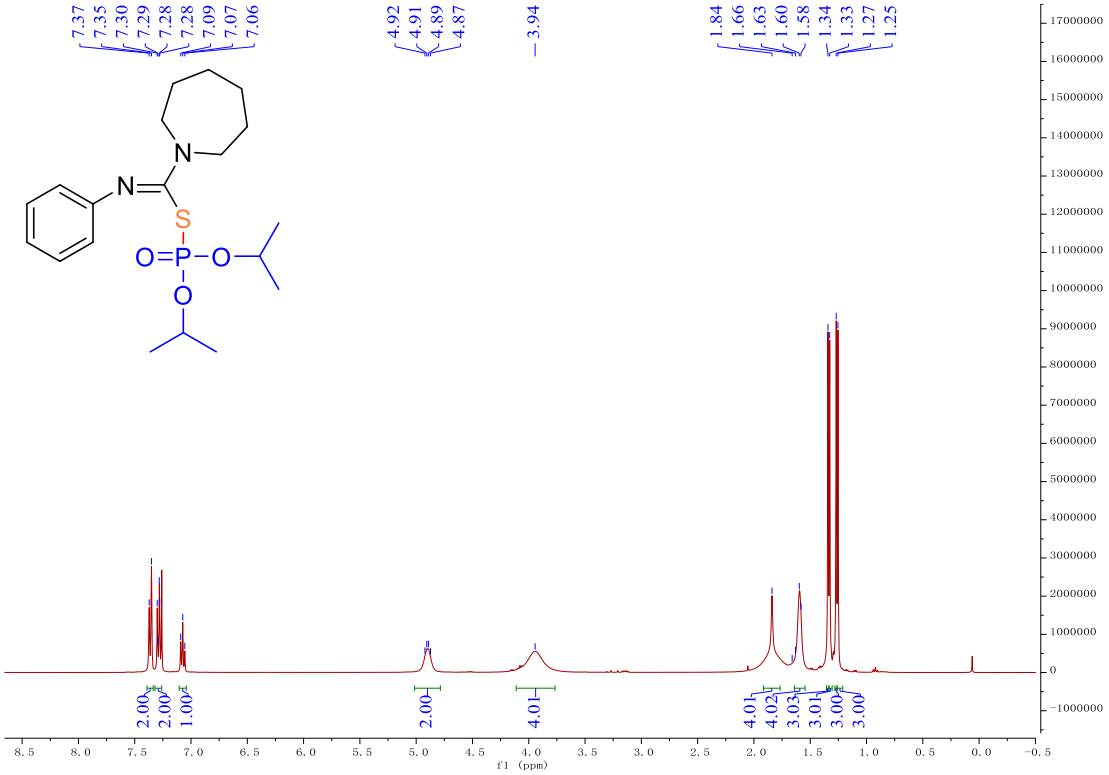
$^{13}C\{^{1}H\}$ NMR of Compound **55** (101 MHz, $CDCl_3$):



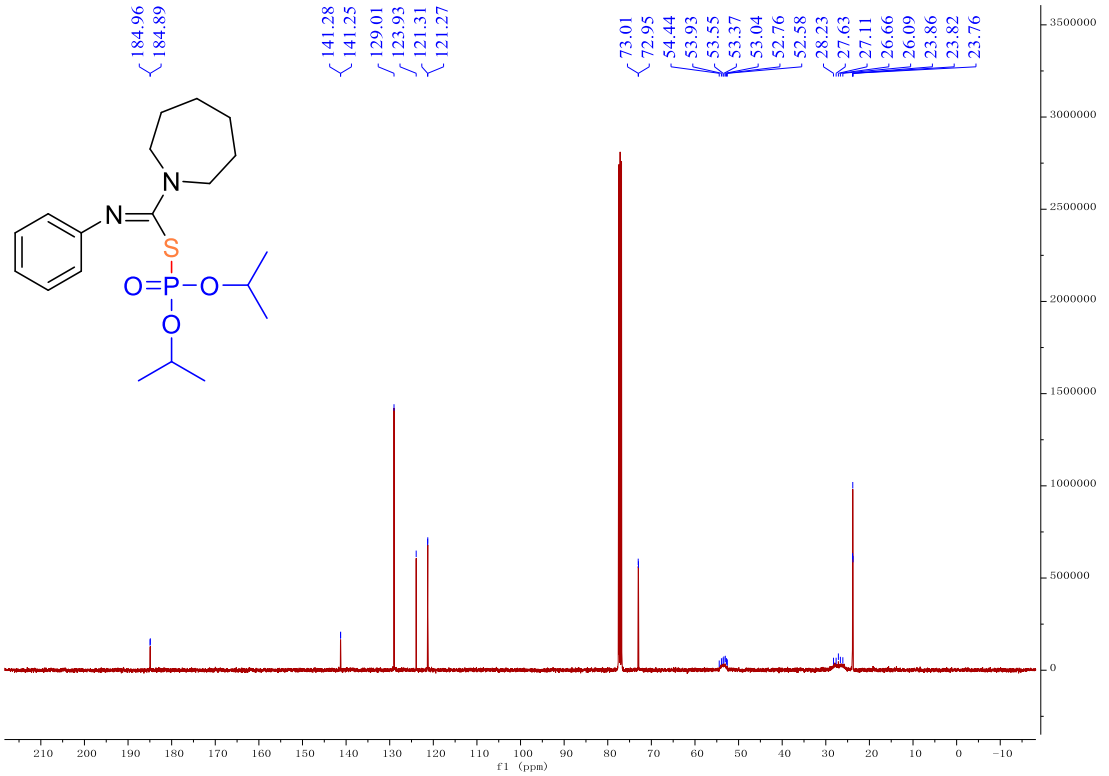
^{31}P NMR of Compound **55** (162MHz, $CDCl_3$):



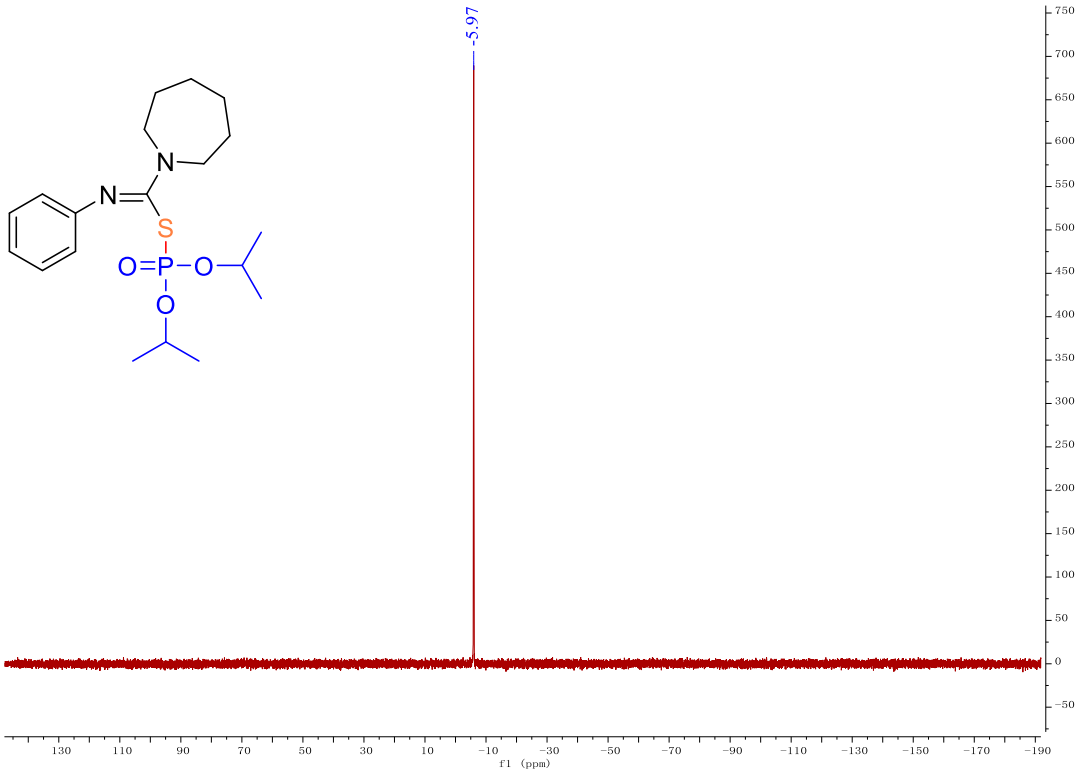
^{1}H NMR of Compound **56** (400 MHz, $CDCl_3$):



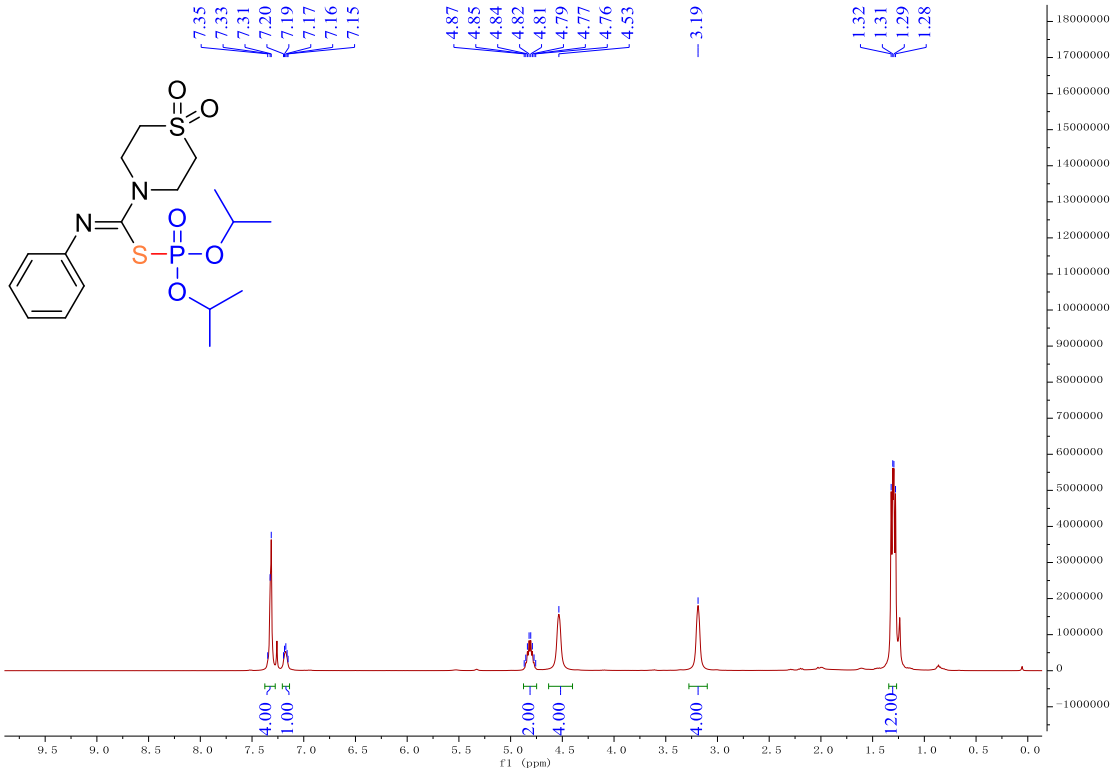
^{13}C{^{1}H} NMR of Compound **56** (101 MHz, $CDCl_3$):



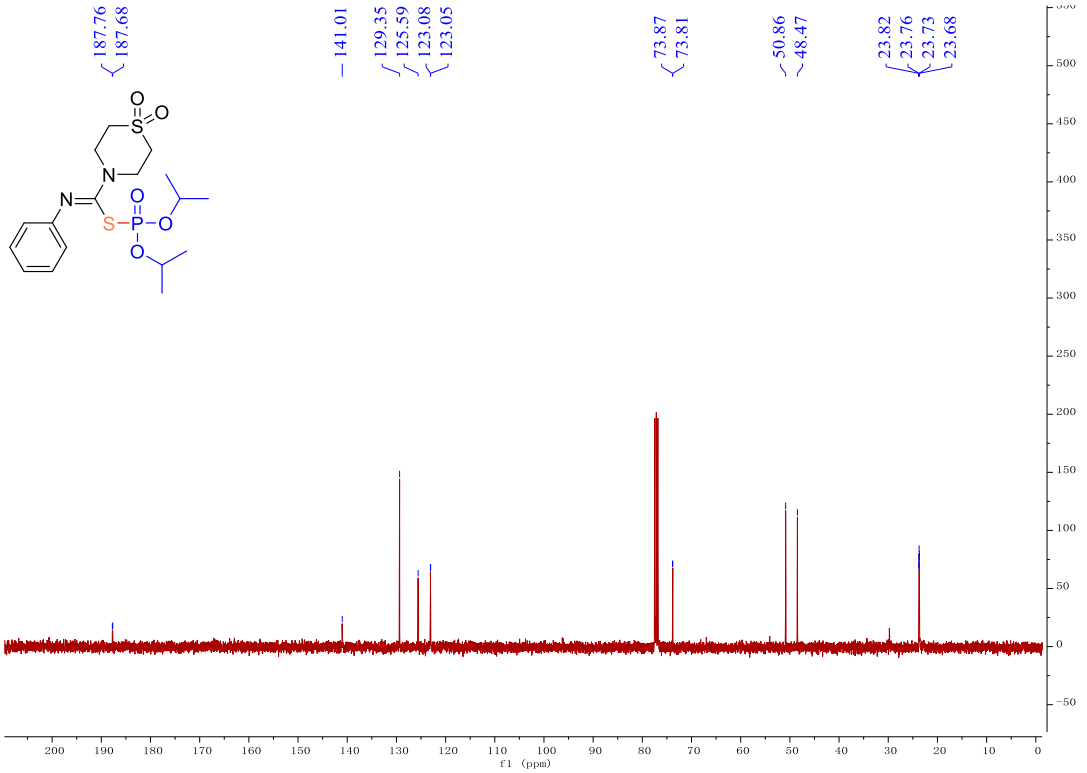
^{31}P NMR of Compound **56** (162MHz, $CDCl_3$):



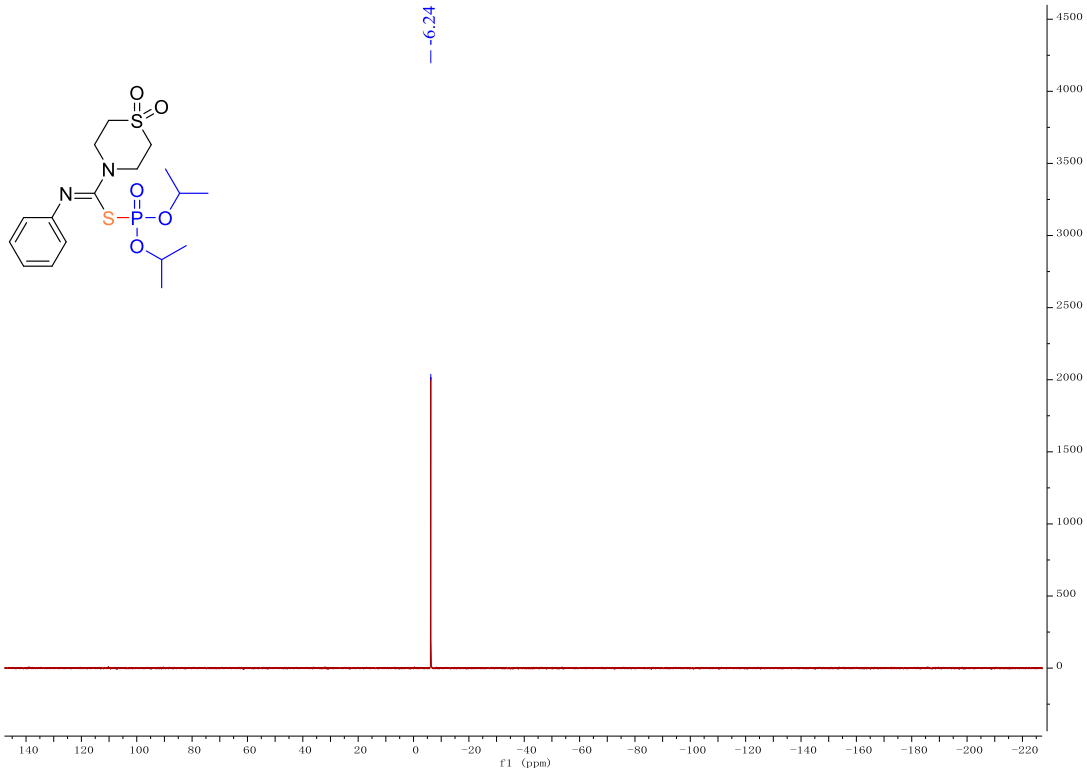
^{1}H NMR of Compound **57** (400 MHz, $CDCl_3$):



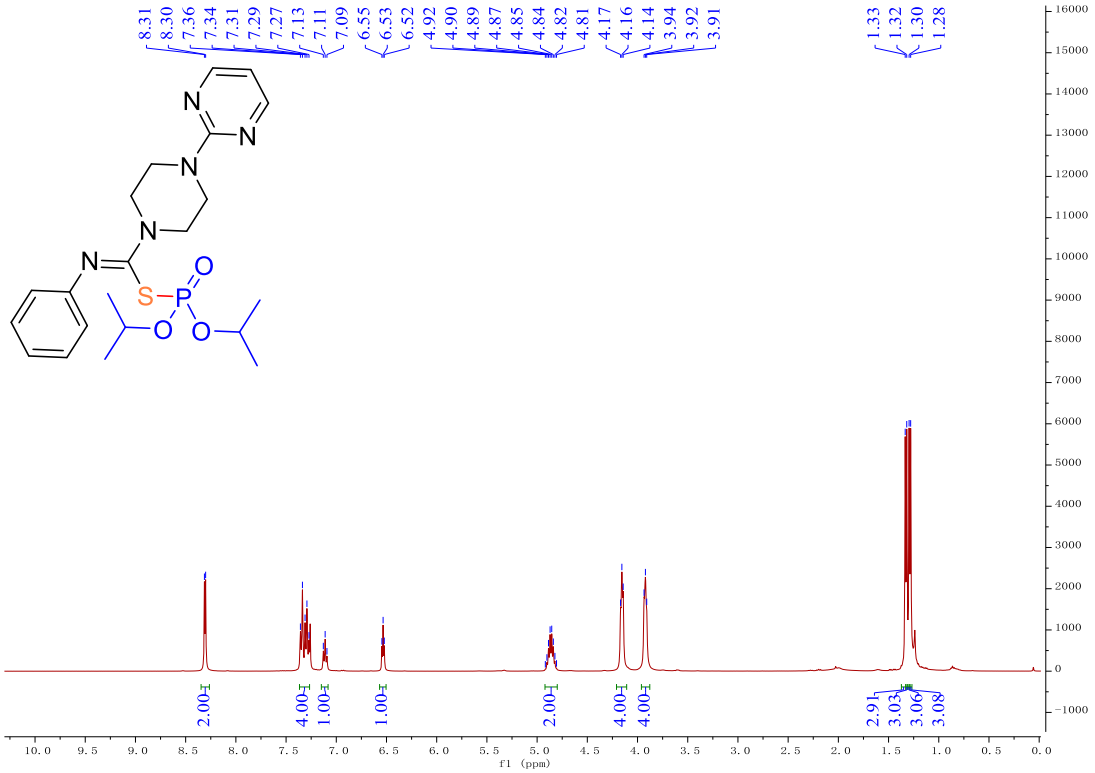
$^{13}C\{^{1}H\}$ NMR of Compound **57** (101 MHz, $CDCl_3$):



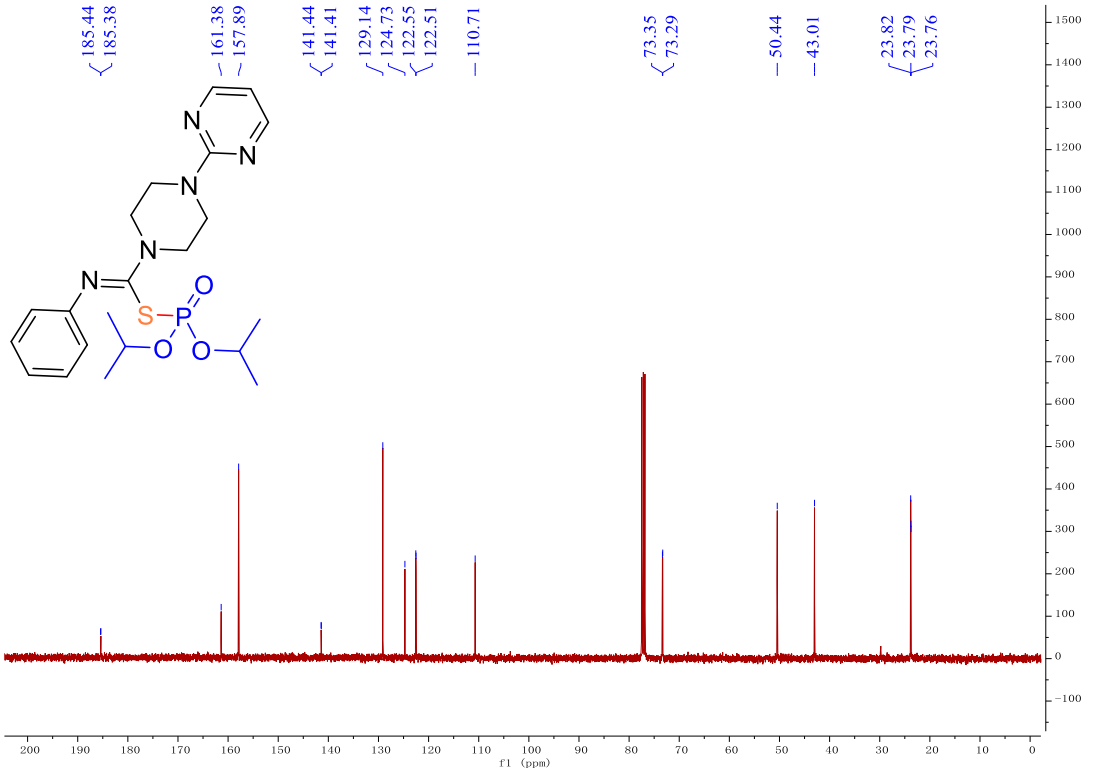
^{31}P NMR of Compound **57** (162MHz, $CDCl_3$):



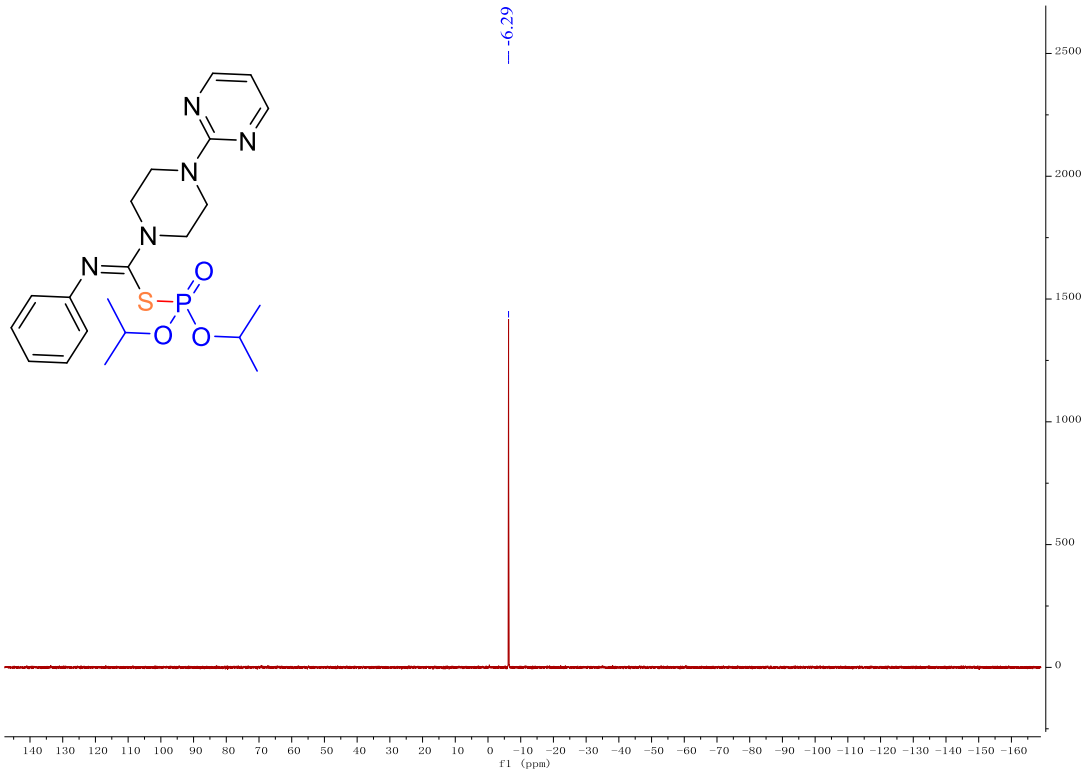
^{1}H NMR of Compound **58** (400 MHz, $CDCl_3$):



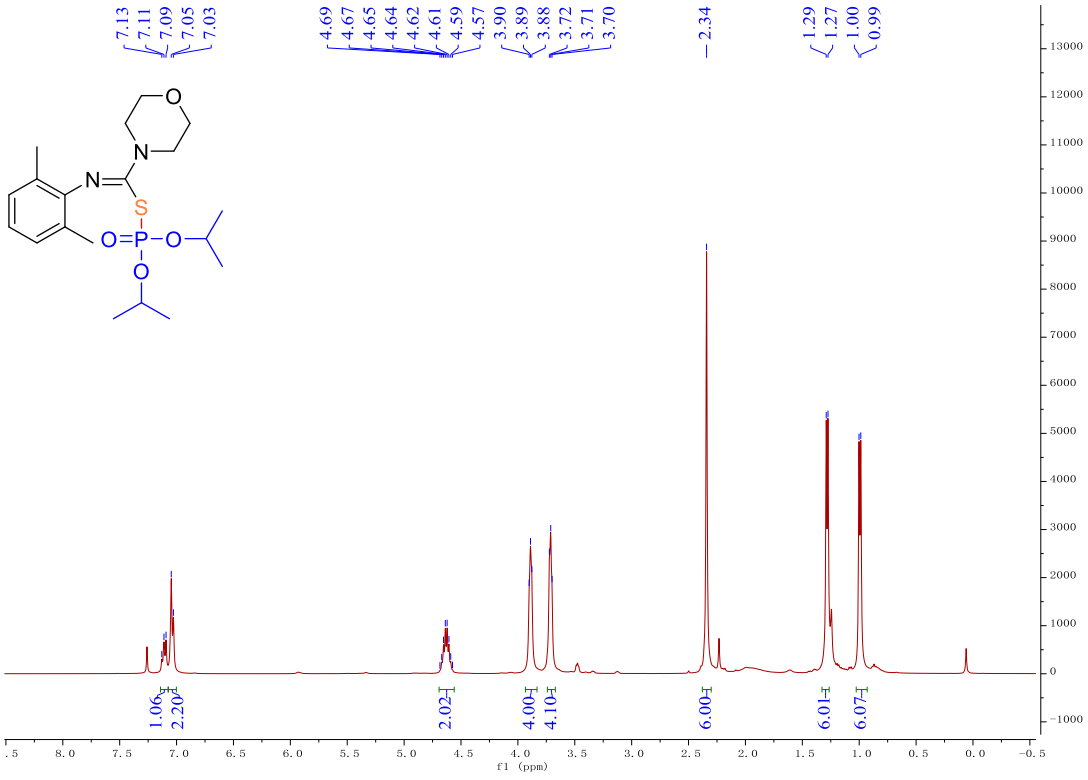
^{13}C{^{1}H} NMR of Compound **58** (101 MHz, $CDCl_3$):



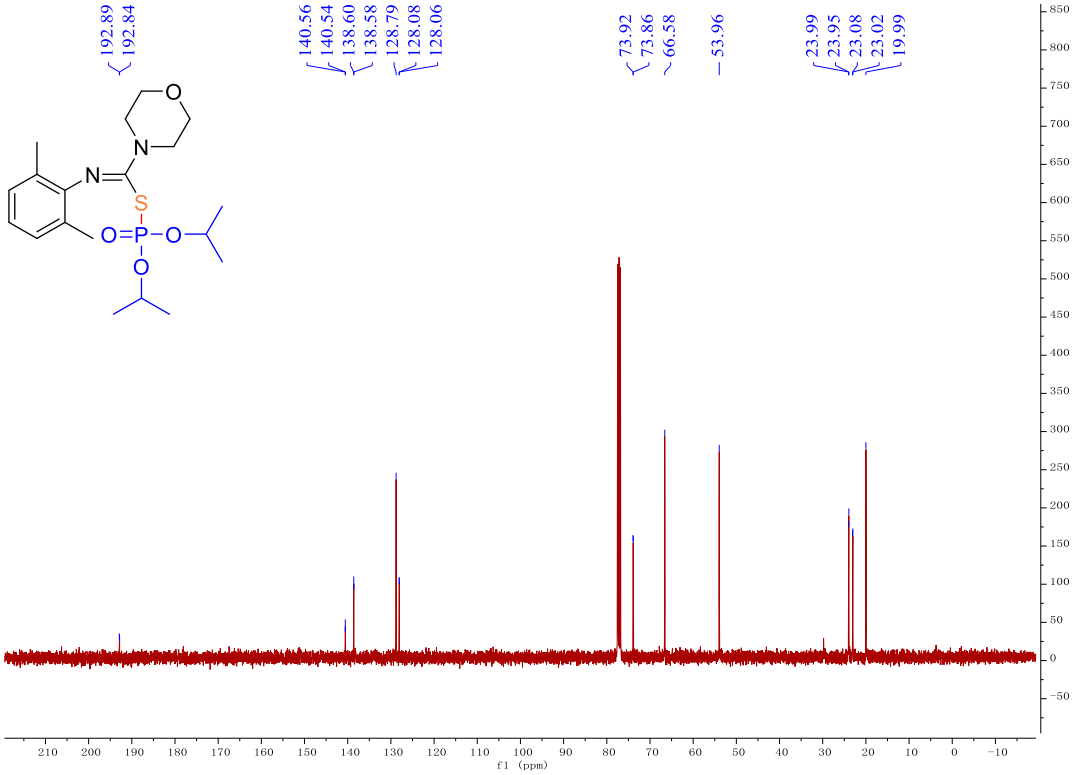
^{31}P NMR of Compound **58** (162MHz, $CDCl_3$):



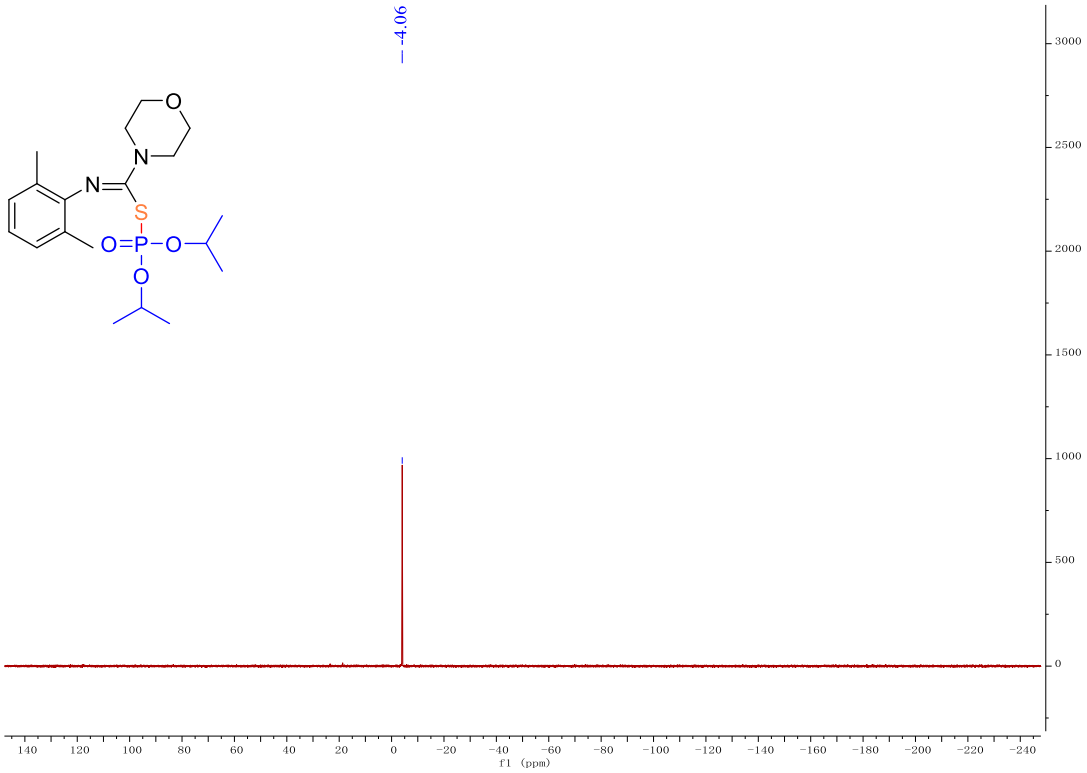
^{1}H NMR of Compound **59** (400 MHz, $CDCl_3$):



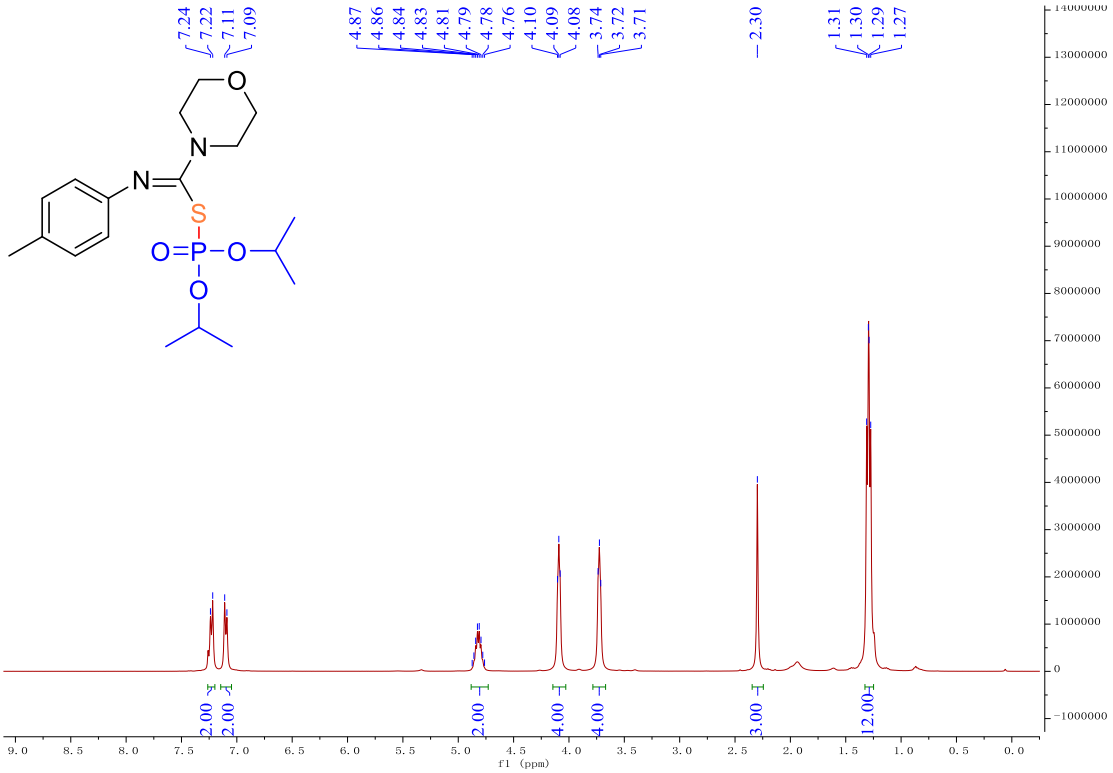
$^{13}C\{^{1}H\}$ NMR of Compound **59** (101 MHz, $CDCl_3$):



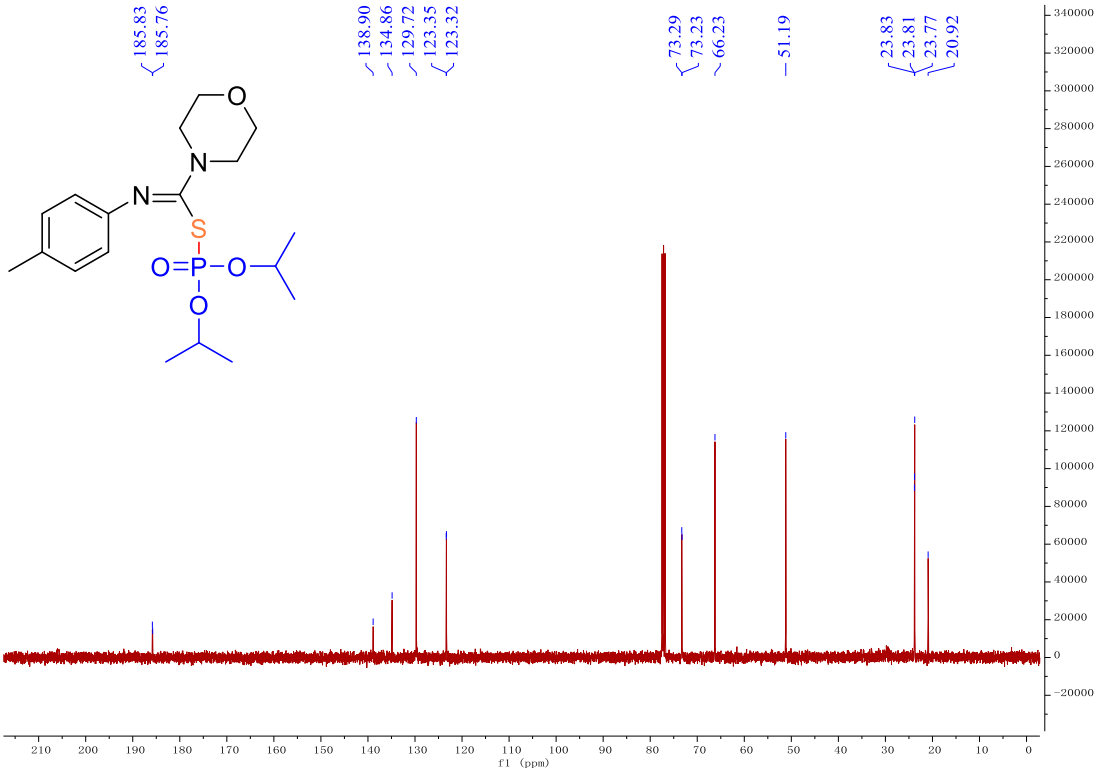
^{31}P NMR of Compound **59** (162MHz, $CDCl_3$):



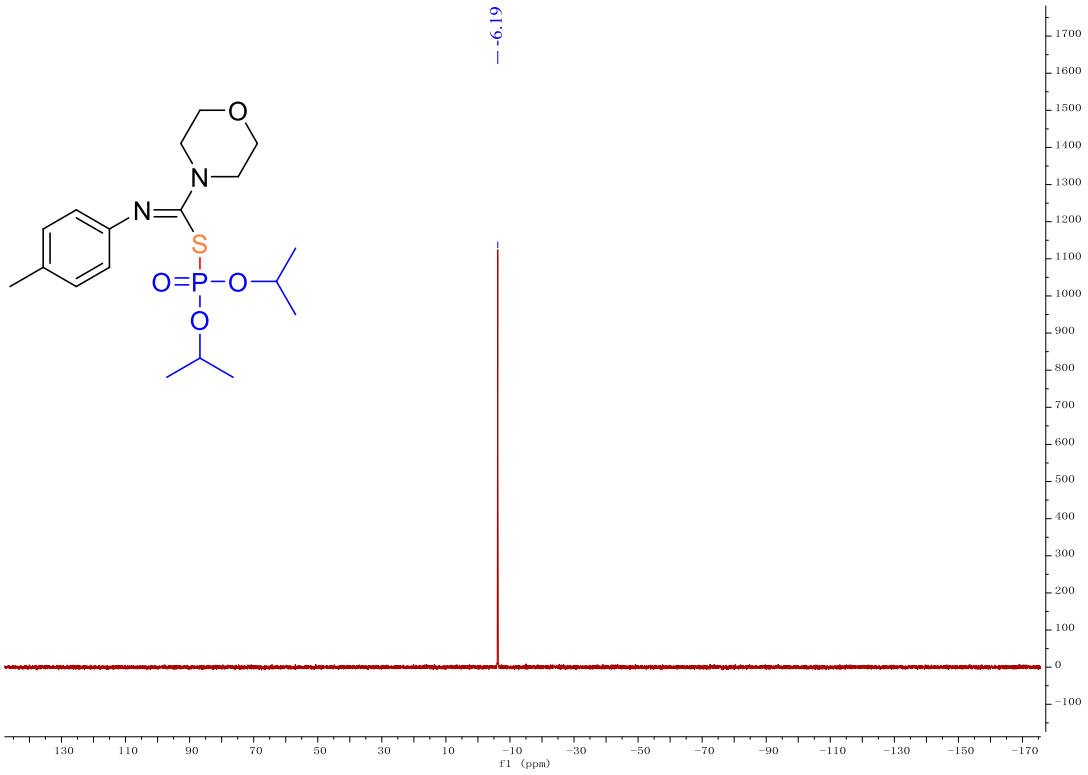
^{1}H NMR of Compound **60** (400 MHz, $CDCl_3$):



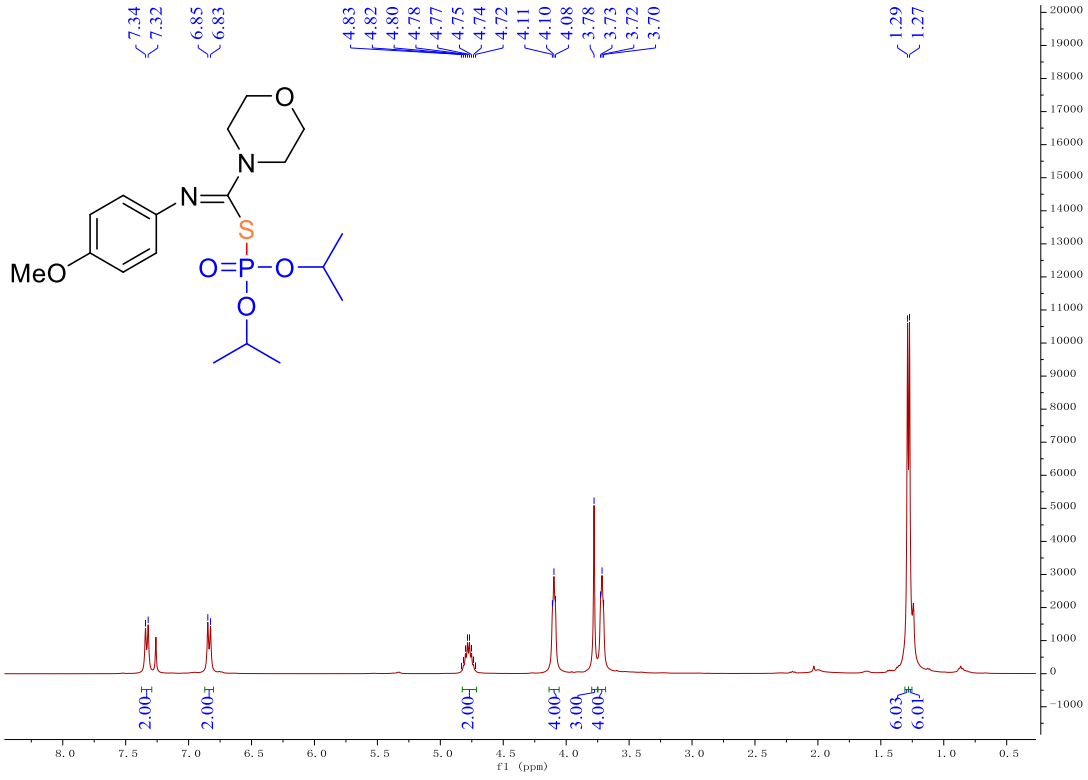
^{13}C{^{1}H} NMR of Compound **60** (101 MHz, $CDCl_3$):



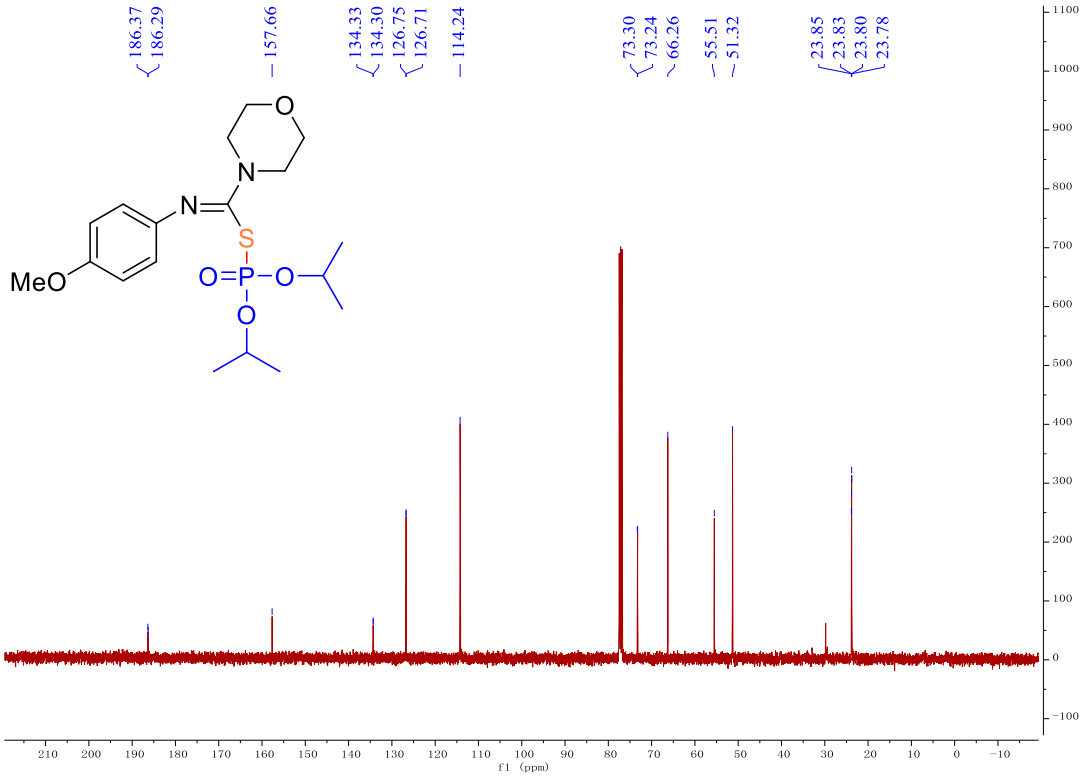
^{31}P NMR of Compound **60** (162MHz, $CDCl_3$):



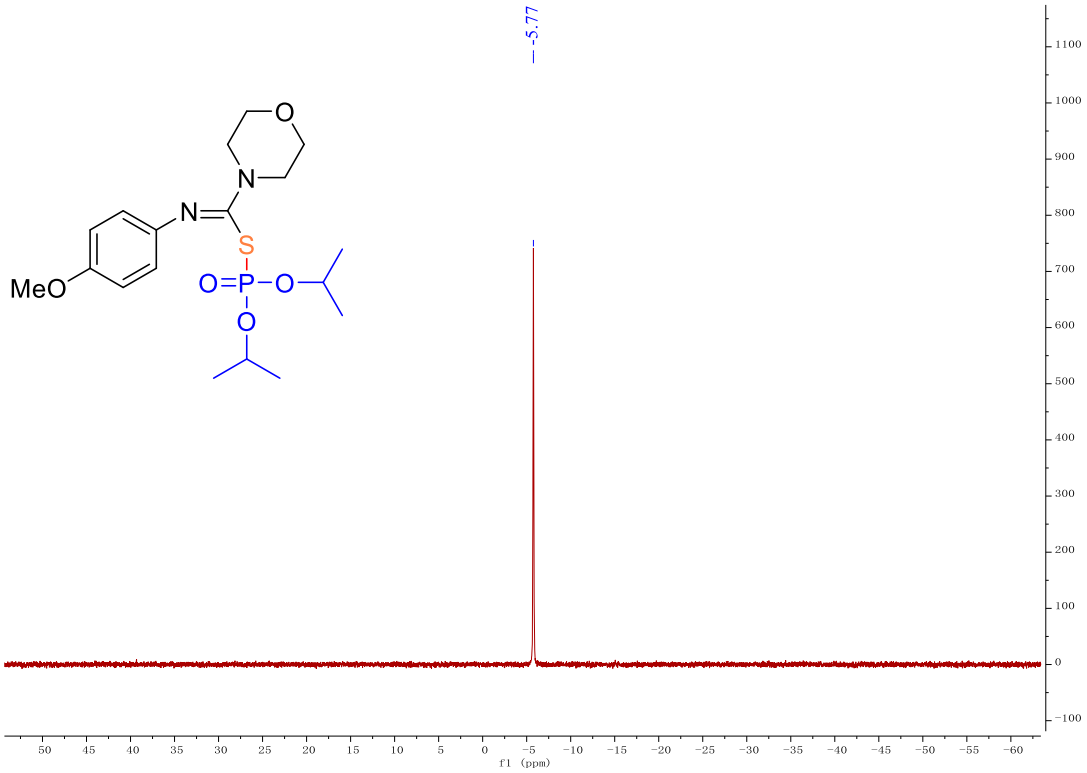
^{1}H NMR of Compound **61** (400 MHz, $CDCl_3$):



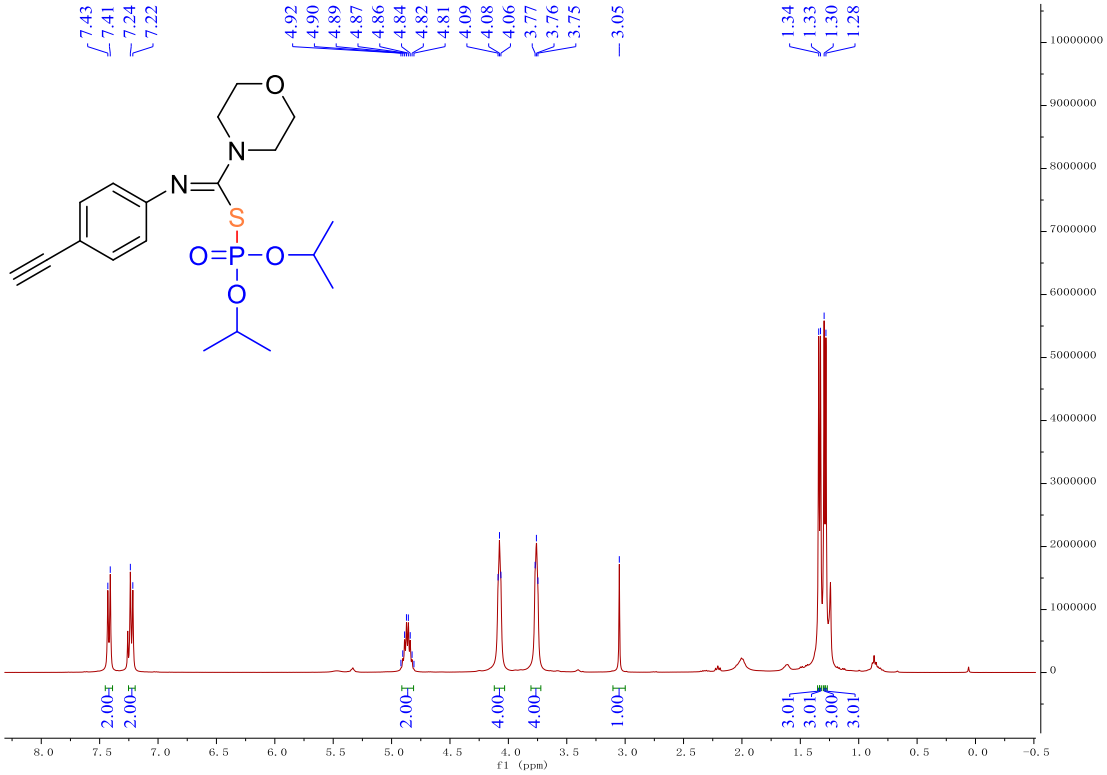
$^{13}C\{^{1}H\}$ NMR of Compound **61** (101 MHz, $CDCl_3$):



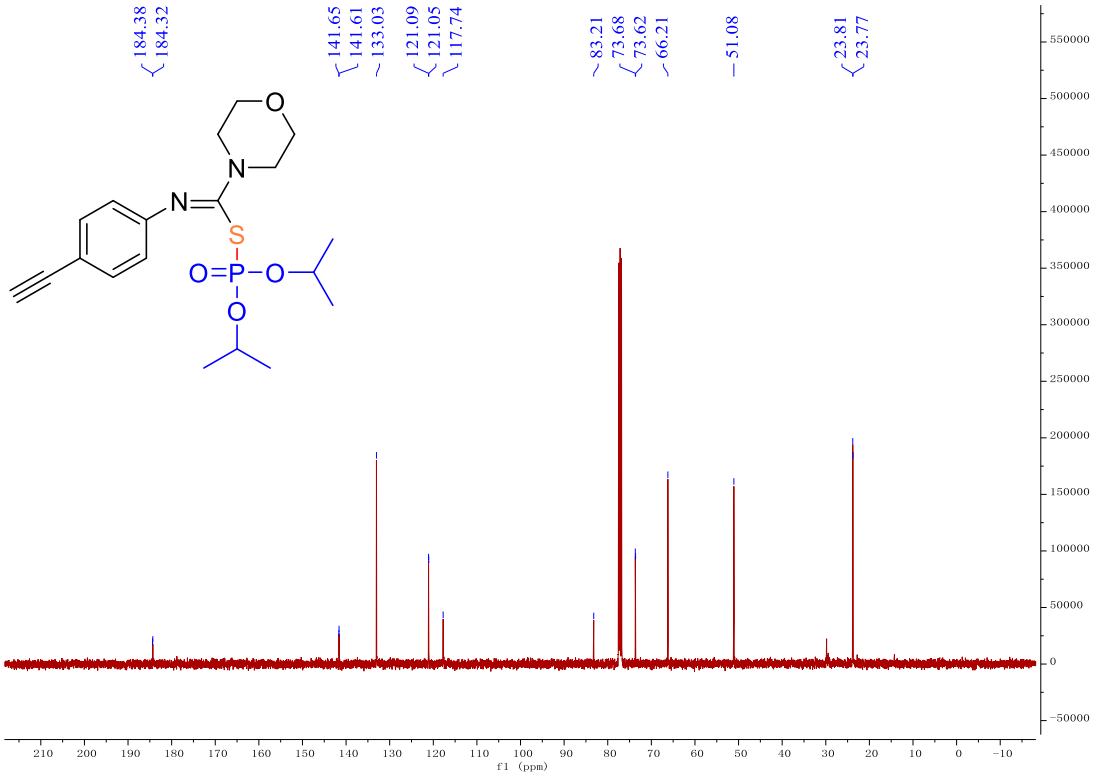
^{31}P NMR of Compound **61** (162MHz, $CDCl_3$):



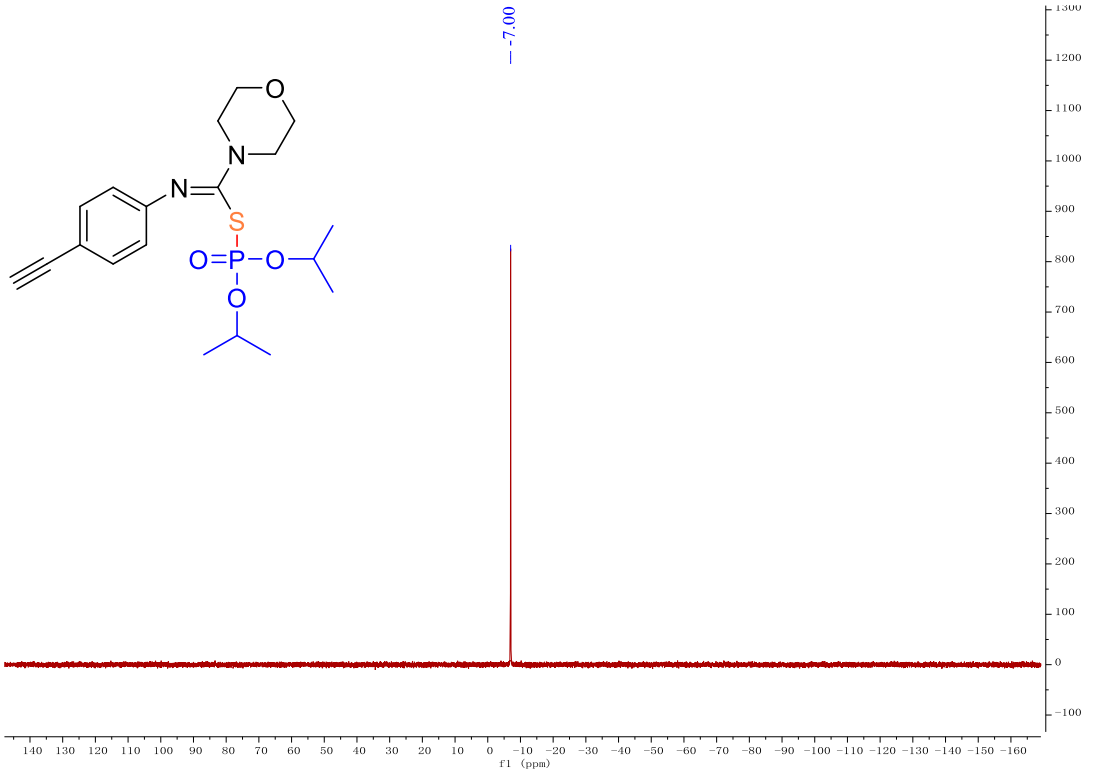
^{1}H NMR of Compound **62** (400 MHz, $CDCl_3$):



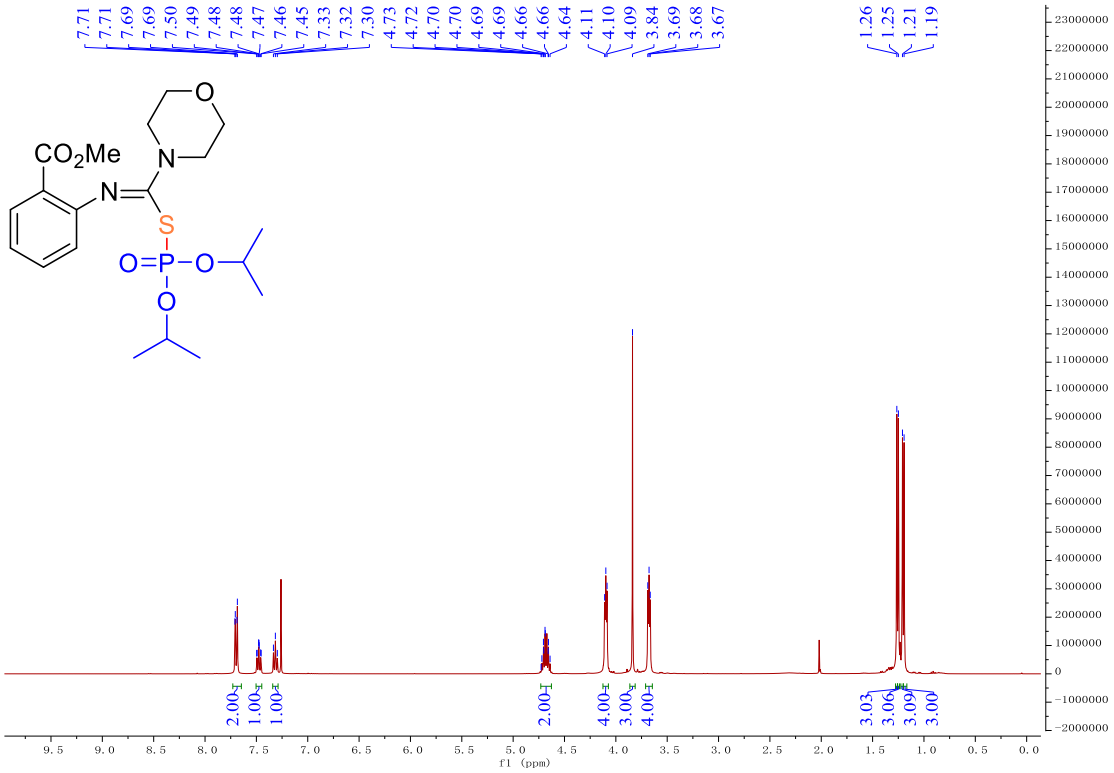
^{13}C{^{1}H} NMR of Compound **62** (101 MHz, $CDCl_3$):



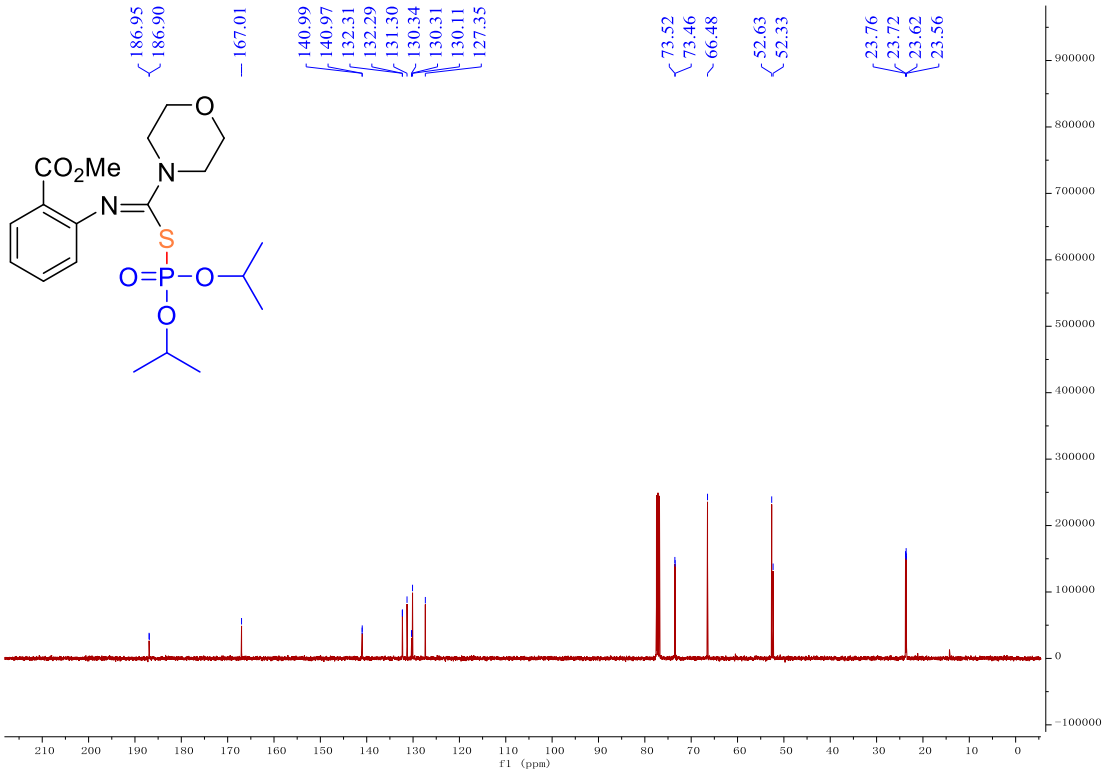
^{31}P NMR of Compound **62** (162MHz, $CDCl_3$):



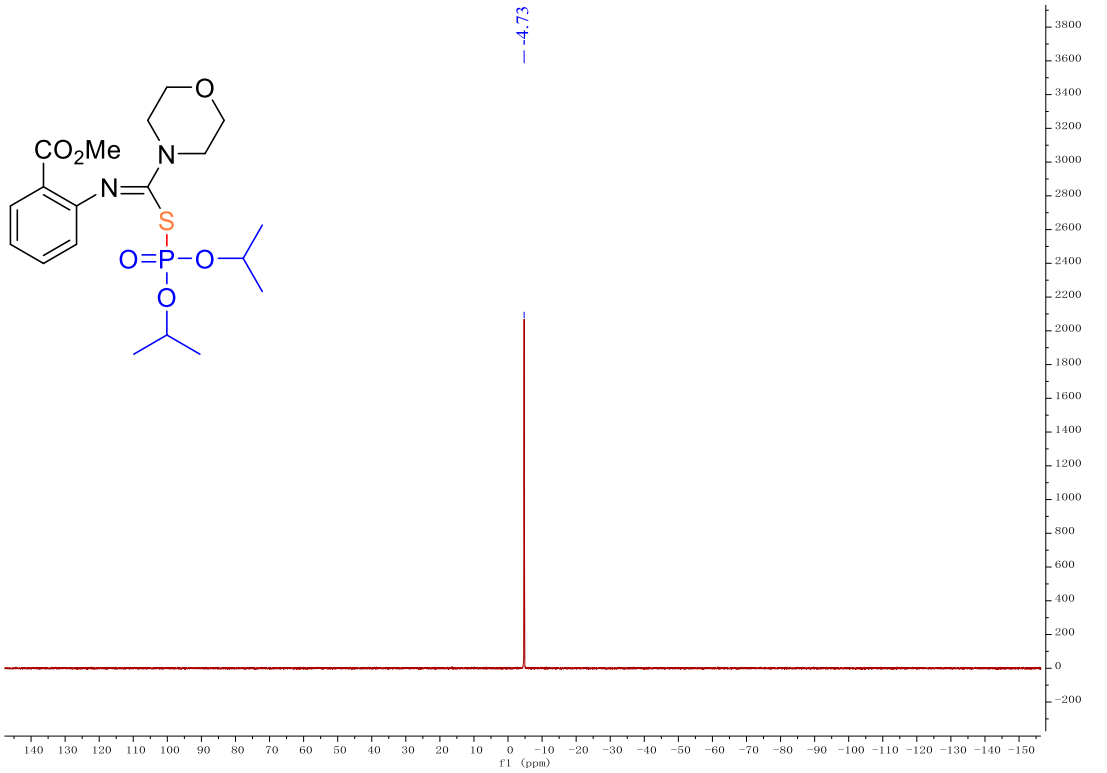
^{1}H NMR of Compound **63** (400 MHz, $CDCl_3$):



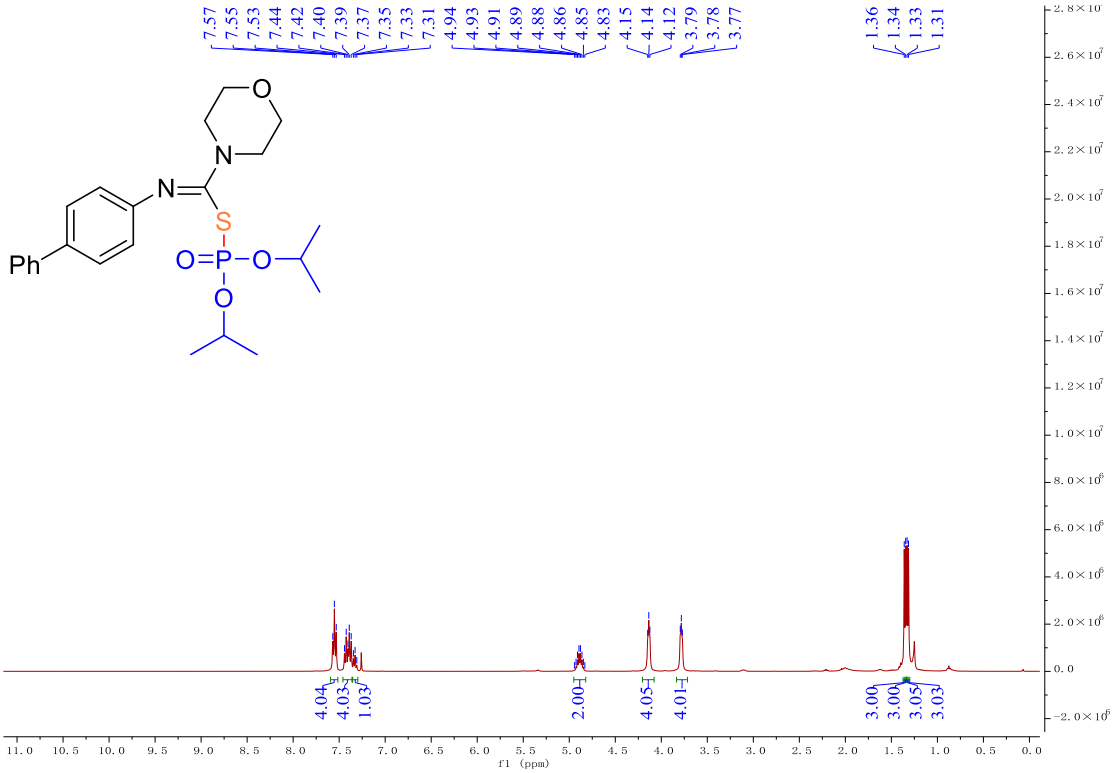
$^{13}C\{^{1}H\}$ NMR of Compound **63** (101 MHz, $CDCl_3$):



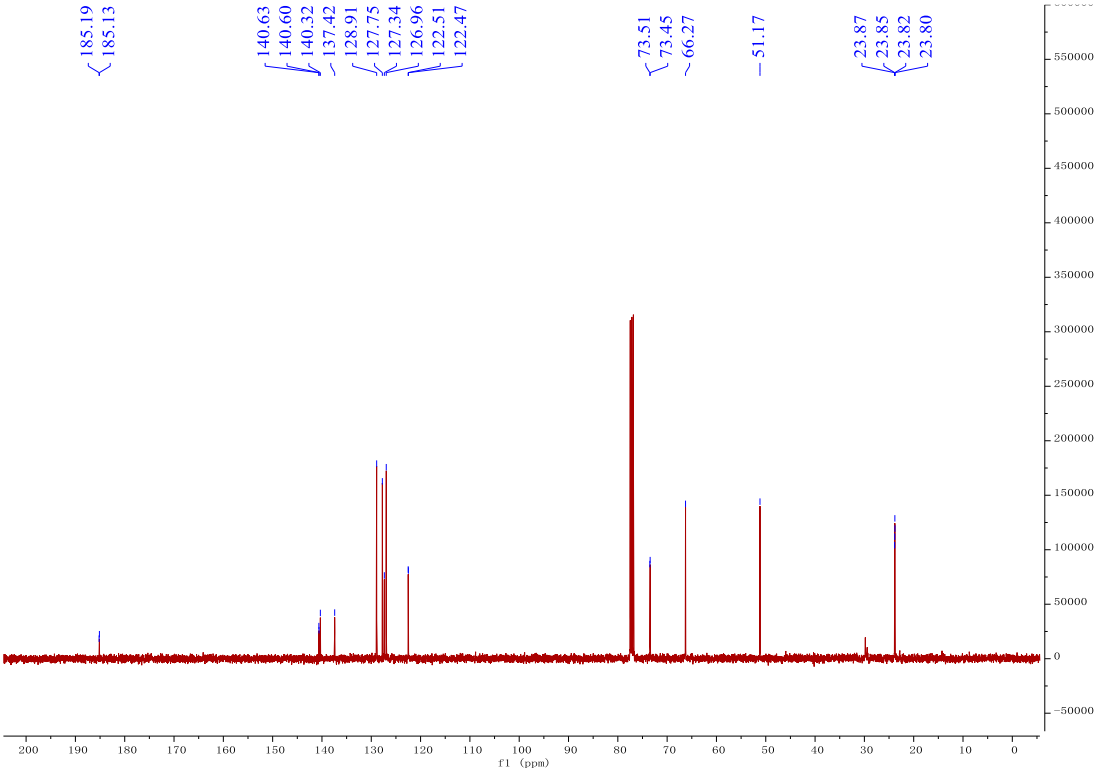
^{31}P NMR of Compound **63** (162MHz, $CDCl_3$):



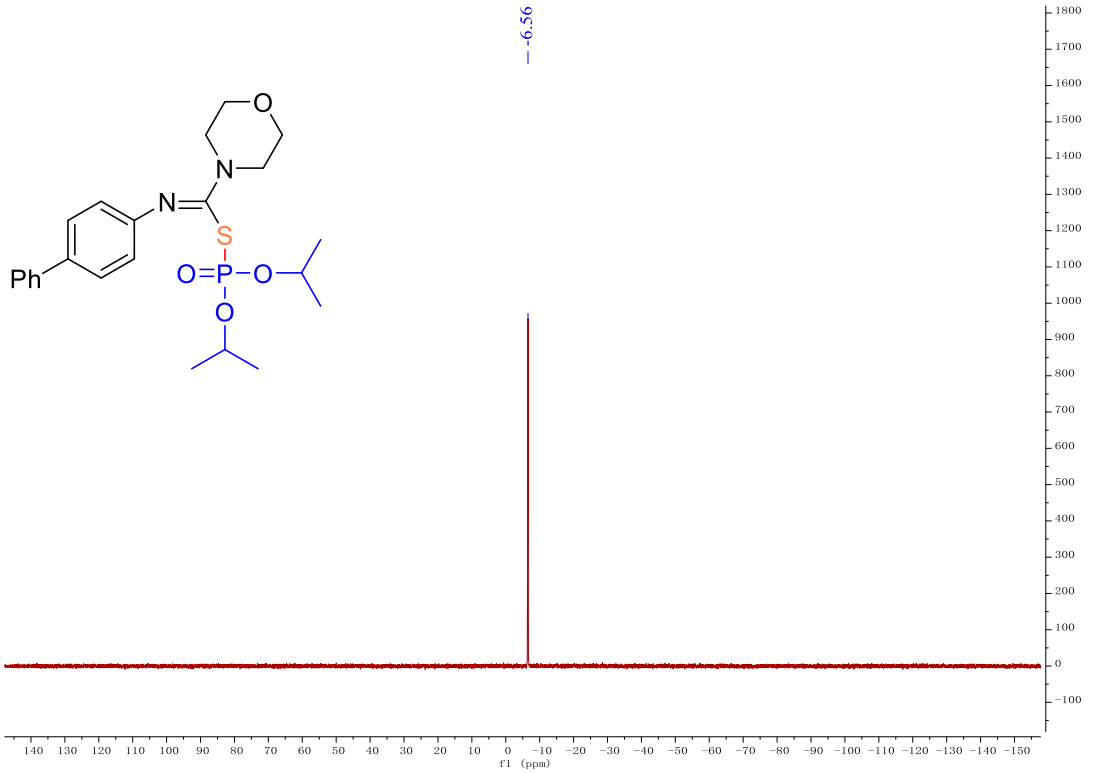
^{1}H NMR of Compound **64** (400 MHz, $CDCl_3$):



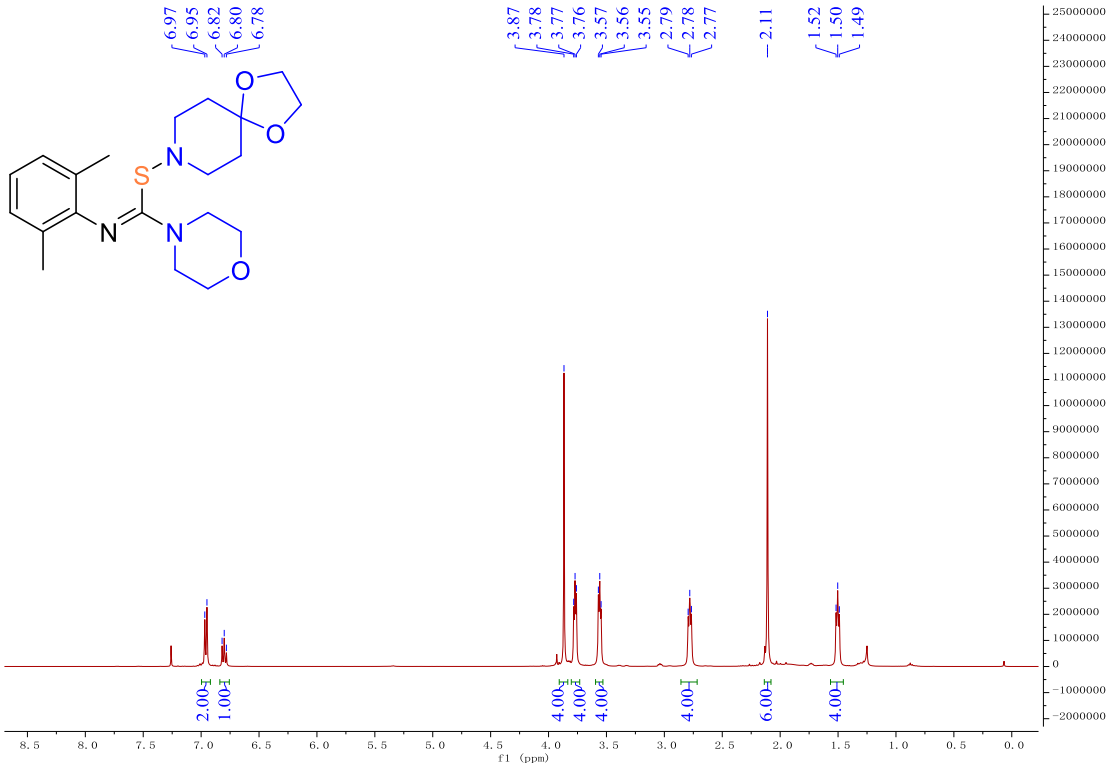
^{13}C{^{1}H} NMR of Compound **64** (101 MHz, $CDCl_3$):



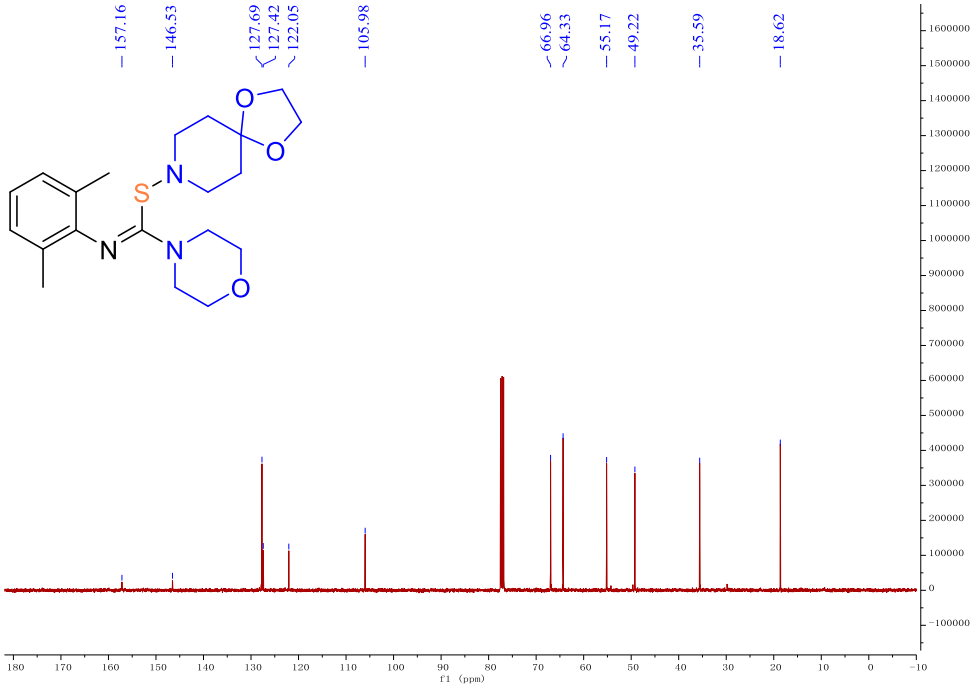
^{31}P NMR of Compound **64** (162MHz, $CDCl_3$):



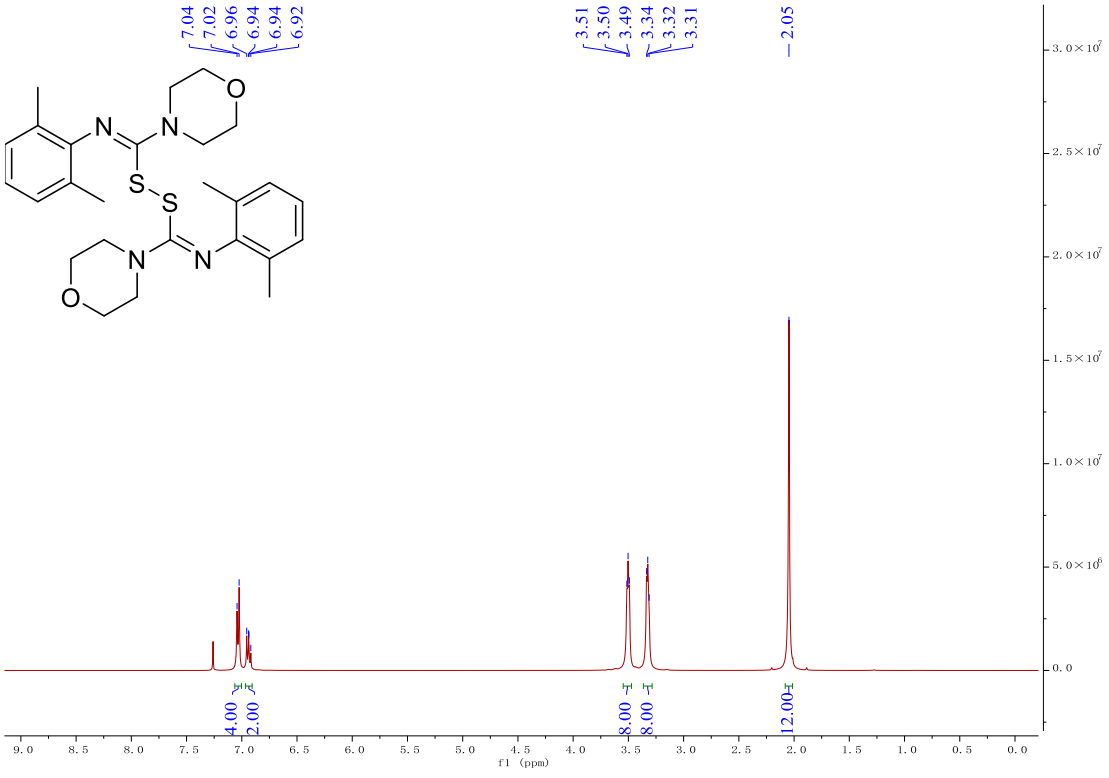
^{1}H NMR of Compound **67** (400 MHz, $CDCl_3$):



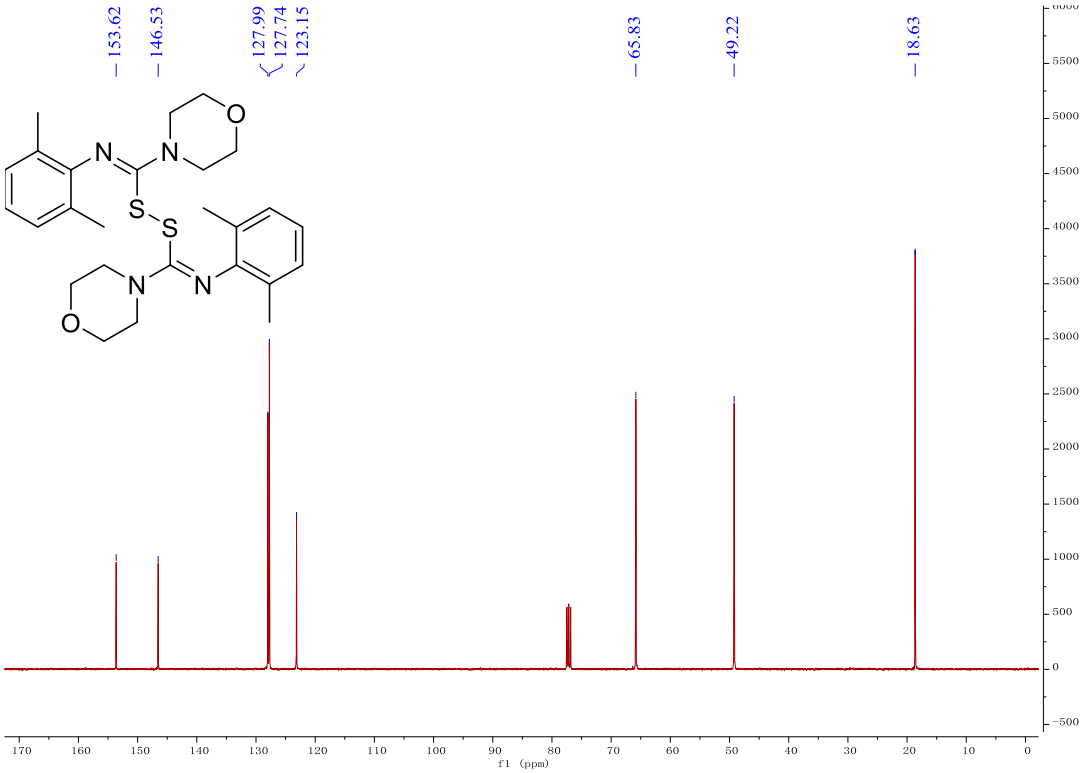
$^{13}C\{^{1}H\}$ NMR of Compound **67** (101 MHz, $CDCl_3$):



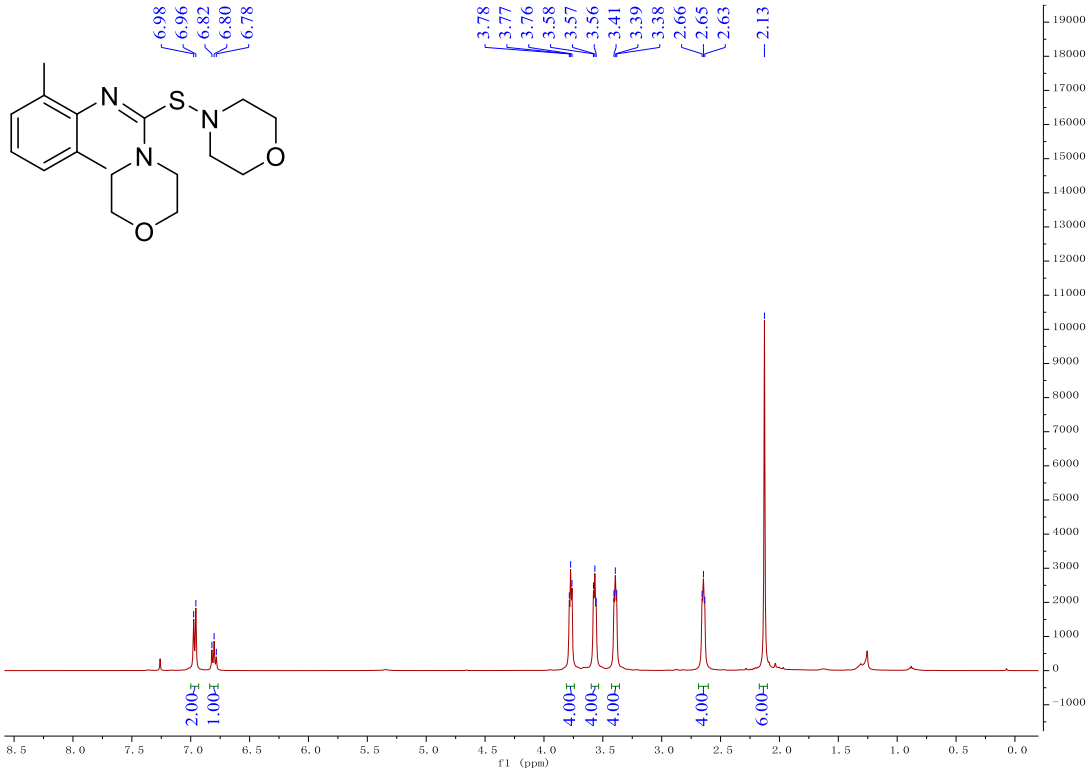
^{1}H NMR of Compound **69** (400 MHz, $CDCl_3$):



$^{13}C\{^{1}H\}$ NMR of Compound **69** (101 MHz, $CDCl_3$):



^{1}H NMR of Compound **70** (400 MHz, $CDCl_3$):



$^{13}C\{^{1}H\}$ NMR of Compound **70** (101 MHz, $CDCl_3$):