Supporting Information for

The Chan-Lam-type synthesis of thioimidazolium salts for thiol-(hetero)arene conjugation

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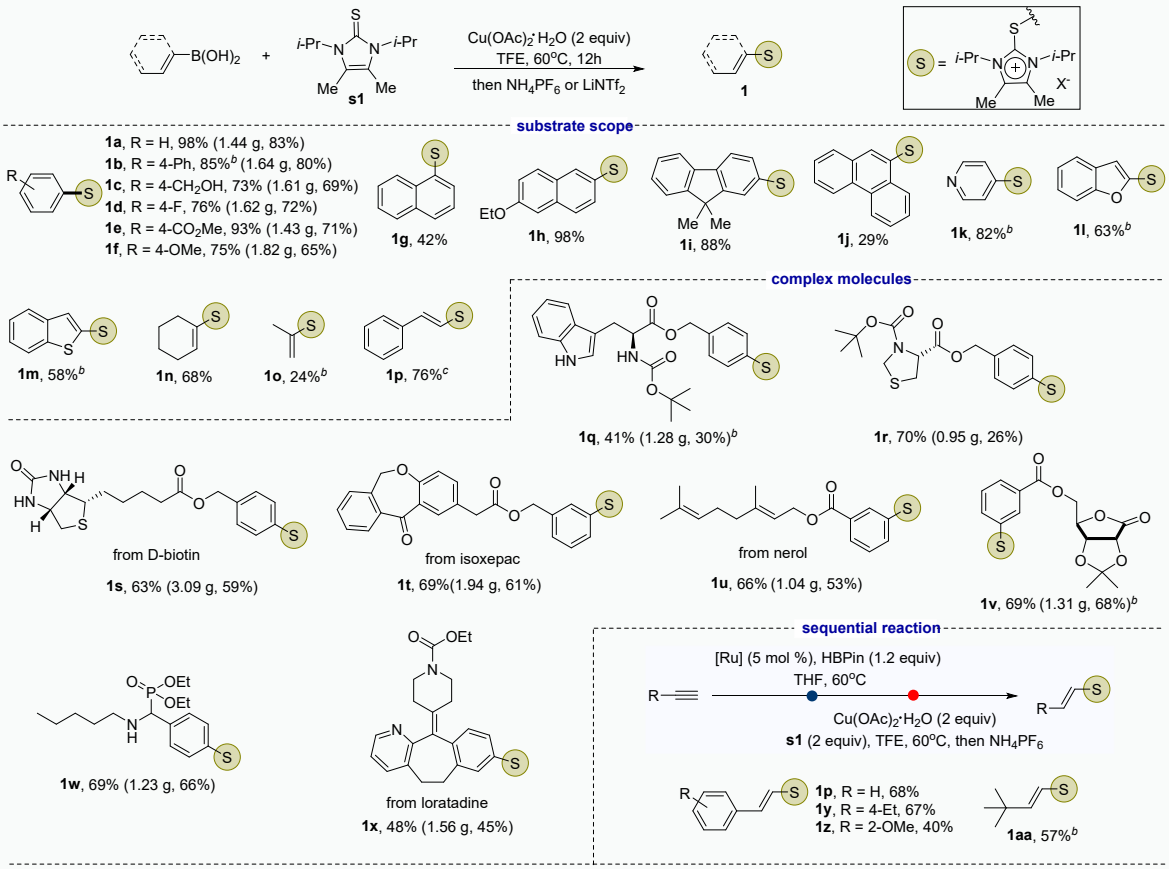
CONTENTS

1. General information: Unless otherwise noted, all reagents were purchased from commercial suppliers and used without further purification. All reactions were carried out in flame-dried glassware under an air atmosphere. NMR spectra were recorded on Bruker-400 spectrometers. Chemical shifts (δ) are given in ppm relative to TMS. The residual solvent signals were used as references and the chemical shifts were converted to the TMS scale ($CHCl_3$: δ 7.26 for proton and δ 77.16 for carbon). Multiplicities were given as: s (singlet); d (doublet); dd (doublet of doublets); t (triplet); Coupling constants are reported as a *J* value in Hz. High-resolution mass spectral analysis (HRMS) was performed on Waters XEVO G2 Q-TOF. The heat source used for the reaction is an oil bath. Column chromatography was performed on 300-400 mesh silica gel using petroleum ether-ethyl acetate or dichloromethane-methanol gradient system.

2. Substrates scope of Chan-Lam reaction[a]:



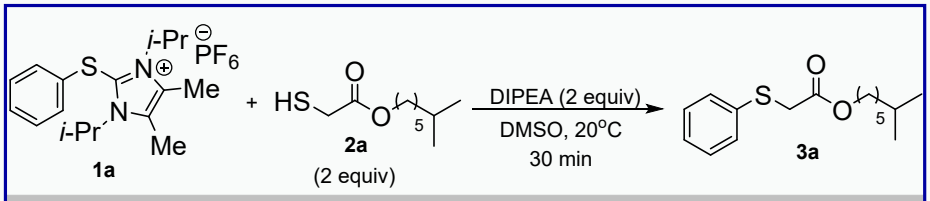
[a]Reactions were carried out with boronic acids (0.2 mmol), **s1** (0.4 mmol) and copper(ii) acetate monohydrate (0.4 mmol) in trifluoroethanol (1 mL) at 60°C for 12h. NH_4PF_6 (0.6 mmol) was then added and stirred at r.t. for 6-12h. Isolated yields were given. Please refer to supporting information for procedures of scal-up synthesis and sequential reactions. [b]$LiNTf_2$ (0.6 mmol) was used for anion exchange. [c]PhCHCHBpin was used.

A variety of aryl boronic acids bearing electron-withdrawing and electron-donating groups were firstly examined, delivering the desired products (**1a-1f**) with satisfactory yields. Notably, the arylthioimidazolium salts 1a-1f could also be prepared in gram-scale with slightly declined yields by chromatography-free separation. Along with the successful incorporation of **s1** into heteroaryl substrates, we found that vinyl boronic acids/esters were also capable of undergoing *S*-vinylation to give vinylthioimidazolium salts (**1n-1p**). Since the thioimidazolium salts were designed as linker units for conjugating pharmaceutically relevant compounds, several complex scaffolds bound substrates were tested thereafter. To our delight, representative samples derivatized from amino acids (**1q**, **1r**), vitamin (**1s**), drug molecule (**1t**, **1x**) and sugar (**1v**) were all well tolerated and afforded the products with moderate yields even in gram-scale synthesis.

Furthermore, a sequential hydroboration/Chan–Lam coupling process was realized to yield the vinylthioimidazolium salts (**1p**, **1y-1aa**) from alkynes in one-pot.

3. Optimization of the reaction conditions for thiol-(hetero)arene conjugation:

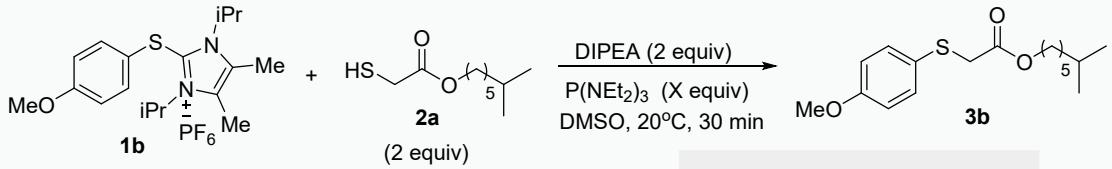
a) The evolution of bases and solvents



entry	deviation from standard conditions	**3a** (%)
1	none	80%
2	DIPEA (1 equiv)	69%
3	BTMG (1 equiv)	56%
4	**2a** (1 equiv)	58%
5	in DMSO:H_2O (1:1)	<10%
6	in H_2O	trace
7	in THF	<10%
8	in DCE	<10%

To a stirring solution of thioimidazolium salt **1a** (0.2 mmol) and thiol **2a** (0.4 mmol) in dry DMSO (1 mL) was added DIPEA (0.4 mmol) at 20 ℃. The solution was stirred at 20 ℃ for 30 min. After completed, the reaction mixture was subjected to silica gel column chromatography (300-400 mesh silica gel) to afford the product **3a**.

b) The introduction of phosphine

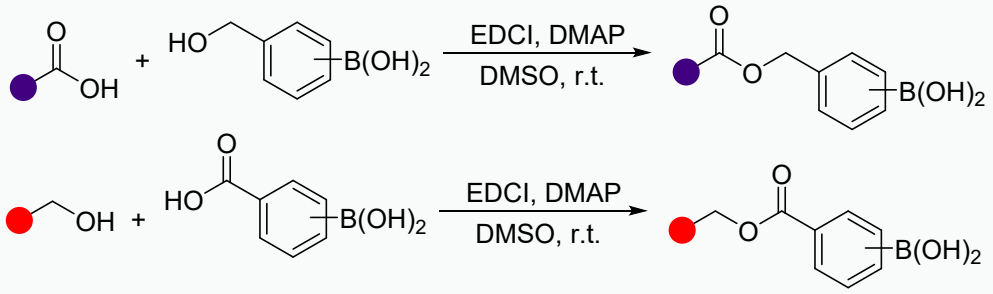


	yield of **3b**
w/o $P(NEt_2)_3$	62%
0.5 equiv $P(NEt_2)_3$	90%
2 equiv $P(NEt_2)_3$	98%

To a stirring solution of thioimidazolium salt **1b** (0.2 mmol), $P(NEt_2)_3$ and thiol **2a** (0.4 mmol) in dry DMSO (1 mL) was added DIPEA (0.4 mmol) at 20 ℃. The solution was

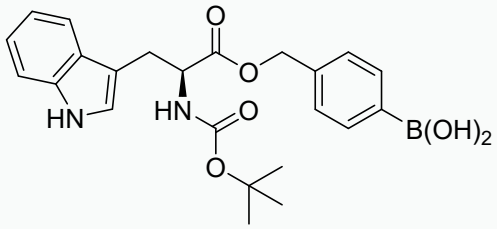
stirred at 20 ℃ for 30 min. After completed, the reaction mixture was subjected to silica gel column chromatography (300-400 mesh silica gel) to afford the product **3b**.

4. General procedure for the preparation of complex boronic acids:



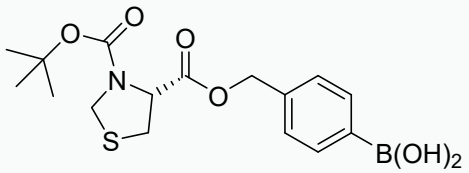
Add the alcohol (1.0 equiv), acid (1.0 equiv) and dry DMSO (0.5 M) to a dried flask equipped with a stirring bar. Add EDCI (1.5 equiv) and DMAP (1.5 equiv) at room temperature. The solution was stirred at room temperature and monitored by TLC. After the reaction was finished, the solution was diluted with EtOAc and washed with brine. The organic phase was dried over anhydrous Na_2SO_4 and concentrate in vacuo. The residue was purified by flash column chromatography (300-400 mesh silica gel) to afford the product.

(4-((((tert-butoxycarbonyl)-L-tryptophyl)oxy)methyl)phenyl)boronic acid (a1):



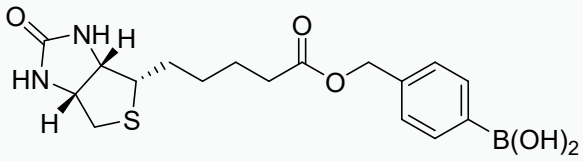
White foam. DCM/MeOH = 15/1, Rf = 0.4. Yield: 98% (3.5 g scale); **^{1}H NMR** (400 MHz, *d*-DMSO) δ 10.85 (s, 1H), 8.04 (s, 2H), 7.75 (d, *J* = 7.9 Hz, 2H), 7.49 (d, *J* = 7.8 Hz, 1H), 7.35 (d, *J* = 8.1 Hz, 1H), 7.29 (d, *J* = 7.7 Hz, 1H), 7.22 – 7.14 (m, 3H), 7.08 (t, *J* = 7.3 Hz, 1H), 6.99 (t, *J* = 7.4 Hz, 1H), 5.07 (s, 2H), 4.31 – 4.21 (m, 1H), 3.17 – 2.97 (m, 2H), 1.34 (s, 9H).; **^{13}C NMR** (100 MHz, *d*-DMSO) δ 172.5, 155.6, 137.8, 136.2, 134.2, 127.1, 126.6, 124.2, 123.9, 121.1, 118.6, 118.1, 111.6, 109.8, 78.4, 65.9, 55.0, 28.2, 26.8.; **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{23}H_{27}BN_2NaO_6^+$, 461.1854, Found. 461.1855.

(R)-(4-(((3-(tert-butoxycarbonyl)thiazolidine-4-carbonyl)oxy)methyl)phenyl)boronic acid (a2):



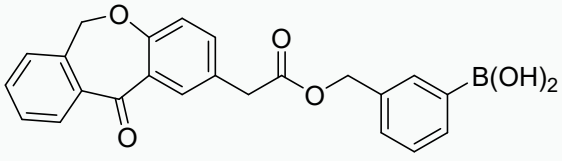
White foam. DCM/MeOH = 30/1, Rf = 0.5. Yield: 89% (3.3 g scale); **^{1}H NMR** (400 MHz, *d*-DMSO) δ 8.07 (s, 2H), 7.81 – 7.66 (m, 2H), 7.47 – 7.27 (m, 2H), 5.23 – 5.09 (m, 2H), 4.85 – 4.61 (m, 1H), 4.50 (d, *J* = 8.8 Hz, 1H), 4.44 – 4.29 (m, 1H), 3.51 – 3.39 (m, 1H), 3.23 – 3.07 (m, 1H), 1.33 (d, *J* = 51.9 Hz, 9H).; **^{13}C NMR** (100 MHz, *d*-DMSO) δ 170.3, 152.4, 134.5, 134.1, 133.9, 129.9, 129.6, 127.5, 79.7 (d, *J* = 101.3 Hz), 66.8, 61.1, 48.4 (d, *J* = 77.2 Hz), 33.3 (d, *J* = 134.6 Hz), 27.8 (d, *J* = 17.9 Hz).; **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{16}H_{22}BNNaO_6S^+$, 390.1153, Found. 390.1151.

(4-(((5-((3aS,4S,6aR)-2-oxohexahydro-1H-thieno[3,4-d]imidazol-4-yl)pentanoyl)oxy)methyl)phenyl)boronic acid (a3):



White solid. Obtained from recrystallization. Yield: 45% (650 mg scale); **Melting point**: 140 – 142 °C. **^{1}H NMR** (400 MHz, *d*-DMSO) δ 8.05 (br, 1H), 7.77 (d, *J* = 7.9 Hz, 2H), 7.30 (d, *J* = 7.9 Hz, 2H), 6.44 – 6.37 (d, *J* = 27.8 Hz, 2H), 5.08 (s, 2H), 4.32 – 4.25 (m, 1H), 4.15 – 4.06 (m, 1H), 3.11 – 2.99 (m, 1H), 2.86 – 2.77 (m, 1H), 2.60 – 2.45 (m, 2H), 2.36 (t, *J* = 7.4 Hz, 2H), 1.64 – 1.25 (m, 6H).; **^{13}C NMR** (100 MHz, *d*-DMSO) δ 172.7, 162.7, 138.0, 134.2, 126.8, 65.3, 61.1, 59.2, 55.3, 39.9, 33.3, 28.0, 24.5.; **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{17}H_{23}BN_2NaO_5S^+$, 401.1313, Found. 401.1321.

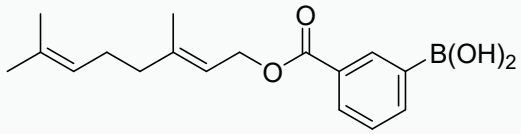
(3-((2-(11-oxo-6,11-dihydrodibenzo[b,e]oxepin-2-yl)acetoxy)methyl)phenyl)boronic acid (a4):



White foam. PE/EtOAc = 1/1, Rf = 0.5. Yield: 77% (2.5 g scale); **^{1}H NMR** (400 MHz, *d*-DMSO) δ 8.10 (s, 2H), 8.01 (d, *J* = 2.2 Hz, 1H), 7.80 – 7.74 (m, 3H), 7.69 – 7.62 (m, 1H), 7.59 – 7.48 (m, 3H), 7.36 – 7.32 (m, 2H), 7.07 (d, *J* = 8.4 Hz, 1H), 5.29 (s, 2H), 5.12 (s, 2H), 3.81 (s, 2H).; **^{13}C NMR** (100 MHz, *d*-DMSO) δ 190.1, 171.1, 159.9, 139.9, 136.9, 135.9, 134.9, 133.8, 133.0,

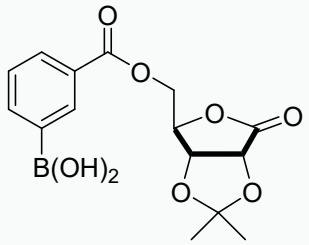
131.9, 129.7, 129.2, 128.8, 128.3, 128.1, 127.5, 124.6, 120.7, 79.2, 72.8, 66.2.; **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{23}H_{19}BNaO_6^+$, 425.1167, Found. 425.1164.

(E)-(3-(((3,7-dimethylocta-2,6-dien-1-yl)oxy)carbonyl)phenyl)boronic acid (a5):



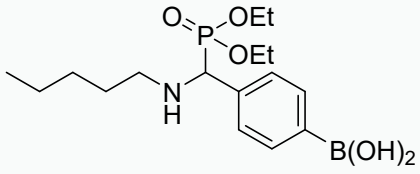
White solid. PE/EtOAc = 1/1, Rf = 0.6. Yield: 53% (2.4 g scale); **Melting point**: 94 – 96 °C. **^{1}H NMR** (400 MHz, *d*-DMSO) δ 8.41 (s, 1H), 8.25 (br, 2H), 8.08 – 7.91 (m, 2H), 7.47 (t, *J* = 7.6 Hz, 1H), 5.46 (t, *J* = 7.0 Hz, 1H), 5.09 (t, *J* = 6.9 Hz, 1H), 4.76 (d, *J* = 7.2 Hz, 2H), 2.20 – 1.99 (m, 4H), 1.75 (s, 3H), 1.60 (s, 3H), 1.54 (s, 3H).; **^{13}C NMR** (100 MHz, *d*-DMSO) δ 166.1, 142.3, 138.9, 135.0, 131.5, 130.8, 129.1, 127.9, 123.7, 119.5, 61.1, 31.8, 26.2, 25.6, 23.3, 17.6.; **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{17}H_{23}BNaO_4^+$, 325.1582. Found. 325.1585.

(3-((((4R)-2,2-dimethyl-6-oxotetrahydrofuro[3,4-d][1,3]dioxol-4-yl)methoxy)carbonyl)phenyl)boronic acid (a6):



White solid. DCM/MeOH = 20/1, Rf = 0.5. Yield: 93% (1.7 g scale); **Melting point**: 46 – 48 °C. **^{1}H NMR** (400 MHz, *d*-DMSO) δ 8.38 (s, 1H), 8.30 (br, 2H), 8.07 (d, *J* = 7.4 Hz, 1H), 7.95 (d, *J* = 7.9 Hz, 1H), 7.52 (t, *J* = 7.6 Hz, 1H), 5.02 (s, 2H), 4.98 (t, *J* = 3.5 Hz, 1H), 4.62 – 4.50 (m, 2H), 1.39 (s, 3H), 1.35 (s, 3H).; **^{13}C NMR** (100 MHz, *d*-DMSO) δ 173.8, 165.5, 139.2, 135.0, 130.7, 128.1, 128.0, 112.5, 79.7, 77.3, 74.6, 64.0, 26.5, 25.2.; **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{15}H_{17}BNaO_8^+$, 359.0909. Found. 359.0912.

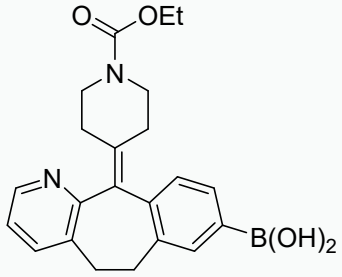
(4-((diethoxyphosphoryl)(pentylamino)methyl)phenyl)boronic acid (a7):



This compound was prepared following known procedure.[1] Mix n-pentylamine (758 mg), 4-formylphenylboronic acid (1 g) and diethyl phosphite (1.4 g) in 10 mL of acetonitrile-ethanol

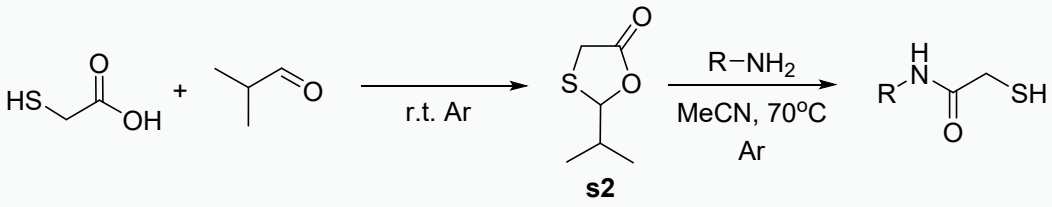
(1:1, v/v). Keep the mixture at 60 °C under argon for 12 hours. The solvent was removed in *vacuo* and the residue was purified by flash chromatography (300-400 mesh silica gel; DCM/MeOH). Colorless oil. DCM/MeOH = 20/1, Rf = 0.5. Yield: 74% (1.8 g); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.11 – 7.75 (m, 2H), 7.48 – 7.31 (m, 2H), 4.14 – 4.01 (m, 3H), 3.91 – 3.87 (m, 1H), 3.80 – 3.62 (m, 1H), 2.61 – 2.38 (m, 2H), 1.44 (br, 2H), 1.30 – 1.15 (m, 7H), 1.14 – 1.04 (m, 3H), 0.88 – 0.77 (m, 3H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 137.3, 134.7, 134.1, 127.8, 63.4 (d, J = 7.3 Hz), 63.3 (d, J = 7.3 Hz), 61.0 (d, J = 152.9 Hz), 48.1 (d, J = 15.9 Hz), 29.3, 29.2, 22.5, 16.4 (d, J = 5.7 Hz), 16.3 (d, J = 5.6 Hz), 14.0.; **HRMS (ESI)** m/z : $(M+H)^+$ Calc. for: $C_{16}H_{30}BNO_5P^+$, 358.1949. Found. 358.1952.

(11-(1-(ethoxycarbonyl)piperidin-4-ylidene)-6,11-dihydro-5H-benzo[5,6]cyclohepta[1,2-b]pyridin-8-yl)boronic acid (a8):



This compound was prepared following the known procedures, the NMR spectra was in accordance with the literature.[2]

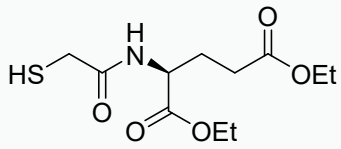
5. General procedure for the preparation of thiols:



Thiols were prepared following the known procedures.[3] To mercaptoacetic acid (25 mmol) under argon was added slowly isobutyraldehyde (27.5 mmol). The reaction was stirred at r.t. for 18 h. It was quenched with cold aq $NaHCO_3$ (5%) and extracted with Et_2O. The organic layer was dried ($MgSO_4$) and concentrated in vacuo to afford the **s2** in pure form.

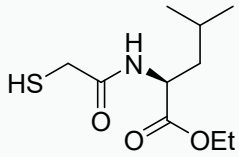
To the solution of amine (1 equiv) in dry MeCN (1 M) was added **s2** (1 equiv) dropwise at r.t under argon. The solution was heated at reflux for 6–8 h. The solution was cooled, the solvent was removed in vacuo and the residue was purified by flash chromatography (300-400 mesh silica gel; PE/EtOAc). **NOTE**: In cases of amine hydrochloride salts, Et_3N (1 equiv) was added for neutralization.

diethyl (2-mercaptoacetyl)-L-glutamate (2b):



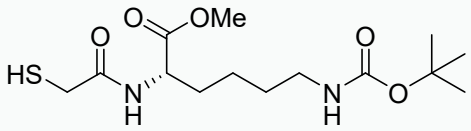
Colorless oil. PE/EtOAc = 2/1, Rf = 0.6. Yield: 24% (990 mg scale); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.22 (d, *J* = 7.5 Hz, 1H), 4.68 – 4.48 (m, 1H), 4.24 – 4.17 (m, 2H), 4.13 (q, *J* = 7.1 Hz, 2H), 3.25 (d, *J* = 9.0 Hz, 2H), 2.47 – 2.31 (m, 2H), 2.29 – 2.18 (m, 1H), 2.08 – 1.97 (m, 1H), 1.94 (t, *J* = 9.0 Hz, 1H), 1.32 – 1.23 (m, 6H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 172.8, 171.7, 169.4, 61.9, 60.9, 52.2, 30.4, 28.3, 27.4, 14.3, 14.2.; **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{11}H_{19}NNaO_5S^+$, 300.0876. Found. 300.0876.

ethyl (2-mercaptoacetyl)-L-leucinate (2c):



Colorless oil. PE/EtOAc = 2/1, Rf = 0.5. Yield: 30% (890 mg scale); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.98 (d, *J* = 7.5 Hz, 1H), 4.66 – 4.51 (m, 1H), 4.18 (q, *J* = 7.1 Hz, 2H), 3.25 (d, *J* = 9.0 Hz, 2H), 1.92 (t, *J* = 9.0 Hz, 1H), 1.71 – 1.55 (m, 3H), 1.27 (t, *J* = 7.1 Hz, 3H), 0.94 (d, *J* = 6.1 Hz, 6H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 172.9, 169.1, 61.6, 51.3, 41.7, 28.4, 25.0, 22.9, 22.1, 14.3.; **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{10}H_{19}NNaO_3S^+$, 256.0978. Found. 256.0977.

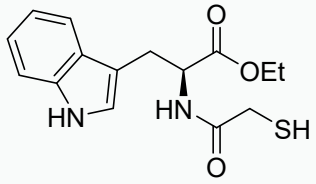
methyl N^6-(tert-butoxycarbonyl)-N^2-(2-mercaptoacetyl)-L-lysinate (2d):



Colorless oil. PE/EtOAc = 1/1, Rf = 0.2. Yield: 35% (1.2 g scale); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.15 (d, *J* = 7.8 Hz, 1H), 4.68 – 4.48 (m, 2H), 3.73 (s, 3H), 3.24 (d, *J* = 9.0 Hz, 2H), 3.10 – 3.05 (m, 2H), 1.96 (t, *J* = 9.0 Hz, 1H), 1.89 – 1.63 (m, 2H), 1.50 – 1.44 (m, 2H), 1.41 (s, 9H) 1.38 –

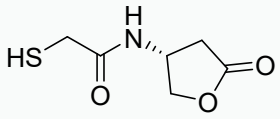
1.27 (m, 2H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 172.7, 169.4, 156.2, 79.3, 52.6, 52.4, 40.1, 32.0, 29.7, 28.5, 28.3, 22.5.; **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{14}H_{26}N_2NaO_5S^+$, 357.1455. Found. 357.1454.

ethyl (2-mercaptoacetyl)-L-tryptophanate (2e):



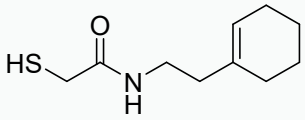
Colorless oil. PE/EtOAc = 1/1, Rf = 0.3. Yield: 17% (360 mg scale); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.41 (s, 1H), 7.54 (d, *J* = 7.9 Hz, 1H), 7.34 (d, *J* = 8.1 Hz, 1H), 7.22 – 7.15 (m, 1H), 7.15 – 7.08 (m, 2H), 6.99 (d, *J* = 2.2 Hz, 1H), 4.94 – 4.84 (m, 1H), 4.23 – 4.08 (m, 2H), 3.43 – 3.27 (m, 2H), 3.19 – 3.07 (m, 2H), 1.68 (t, *J* = 9.0 Hz, 1H), 1.24 (t, *J* = 7.1 Hz, 3H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 171.8, 169.2, 136.2, 127.8, 123.0, 122.4, 119.7, 118.6, 111.5, 109.9, 61.8, 53.5, 28.4, 27.5, 14.2.; **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{15}H_{18}N_2NaO_3S^+$, 329.0930. Found. 329.0932.

(R)-2-mercapto-N-(5-oxotetrahydrofuran-3-yl)acetamide (2f):



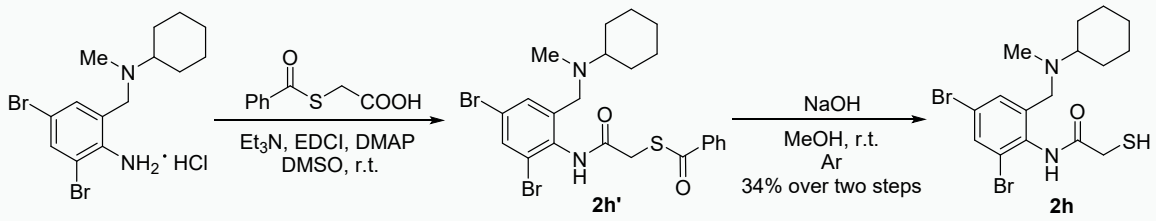
Colorless oil. PE/EtOAc = 2/1, Rf = 0.4. Yield: 19% (330 mg scale); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.28 (br, 1H), 4.65 – 4.54 (m, 1H), 4.48 (t, *J* = 8.7 Hz, 1H), 4.34 – 4.22 (m, 1H), 3.29 (d, *J* = 9.0 Hz, 2H), 2.83 – 2.70 (m, 1H), 2.30 – 2.14 (m, 1H), 2.01 (t, *J* = 9.0 Hz, 1H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 175.2, 170.3, 66.2, 49.5, 29.9, 28.1.; **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_6H_9NNaO_3S^+$, 198.0195. Found. 198.0197.

N-(2-(cyclohex-1-en-1-yl)ethyl)-2-mercaptoacetamide (2g):



Colorless oil. PE/EtOAc = 1/1, Rf = 0.7. Yield: 75% (1.5 g scale); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.76 (br, 1H), 5.44 (s, 1H), 3.31 – 3.27 (m, 2H), 3.17 (d, *J* = 8.9 Hz, 2H), 2.11 (t, *J* = 6.6 Hz, 2H), 2.00 – 1.77 (m, 5H), 1.66 – 1.40 (m, 4H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 169.1, 134.4, 124.0, 37.5, 37.4, 28.4, 27.9, 25.3, 22.8, 22.4.; **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{10}H_{17}NNaOS^+$, 222.0923. Found. 222.0924.

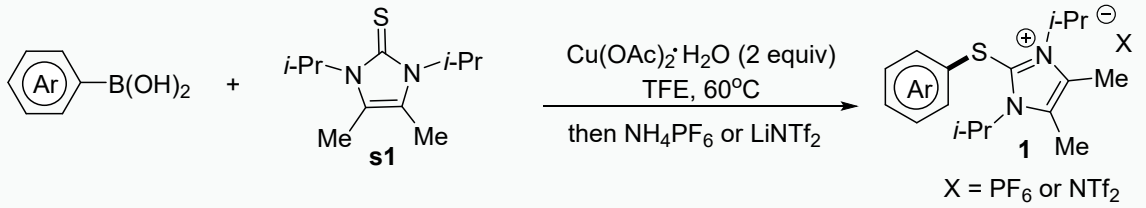
N-(2,4-dibromo-6-((cyclohexyl(methyl)amino)methyl)phenyl)-2-mercaptoacetamide (2h):



Add Bromhexine hydrochloride (6 mmol, 2.47 g), 2-(benzoylthio)acetic acid (6.6 mmol, 1.29 g) and dry DMSO (10 ml) to a dried flask equipped with a stirring bar. Add EDCI (9 mmol, 1.73 g), DMAP (2 mmol, 0.24 g) and Et_3N (7 mmol, 0.71 g) at room temperature. The solution was stirred at room temperature and monitored by TLC. After the reaction was finished, the solution was diluted with EtOAc and washed with brine. The organic phase was dried over anhydrous Na_2SO_4 and concentrate in vacuo. The residue was purified by flash column chromatography (300-400 mesh silica gel, PE:EtOAc = 5:1) to afford the product **2h'** as white solid (2.4 g) for the next step.

Add **2h'** (4.3 mmol, 2.4 g) and NaOH (5 mmol, 0.2 g) in MeOH (10 ml) under Ar. The solution was stirred at room temperature for 3h. After the reaction was finished, the solution was quenched with aq. NH_4Cl and extracted with EtOAc. The organic phase was dried over anhydrous Na_2SO_4 and concentrate in vacuo. The residue was purified by flash column chromatography (300-400 mesh silica gel, PE:EtOAc = 1:1) to afford the product **2h** as colorless oil (930 mg, 34% over two steps). PE/EtOAc = 1/1, Rf = 0.3.; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 9.75 (br, 1H), 7.71 (d, *J* = 2.1 Hz, 1H), 7.35 (d, *J* = 2.0 Hz, 1H), 3.56 (s, 2H), 3.38 (s, 2H), 2.56 – 2.38 (m, 1H), 2.11 (s, 3H), 1.83 – 1.80 (m, 4H), 1.66 – 1.63 (m, 1H), 1.37 – 0.99 (m, 6H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 167.5, 137.9, 135.4, 135.0, 132.1, 122.4, 120.0, 62.6, 57.4, 36.3, 29.0, 28.4, 26.3, 26.0.; **HRMS (ESI)** m/z : $(M+H)^+$ Calc. for: $C_{16}H_{23}Br_2N_2OS^+$, 448.9892. Found. 448.9904.

6. Procedures for preparation of arylisothiouronium salts (1a-1ac) :



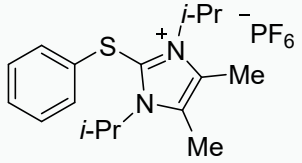
To a stirring solution of arylboronic acid (0.2 mmol) and **s1** (0.4 mmol) in trifluoroethanol (1 mL) was added copper(ii) acetate monohydrate (0.4 mmol) at room temperature. The solution was warmed to 60 °C in oil bath and stirred for 12 h. The reaction was monitored by TLC. NH_4PF_6 or $LiNTf_2$ (0.6 mmol) was then added and the

reaction mixture was stirred at r.t. for 6-12 h. The anion exchange process was monitored by TLC. After completed, the reaction mixture was subjected to silica gel column chromatography (300-400 mesh silica gel; DCM/MeOH) to afford the product **1**.

7. Scale-up synthesis of arylisothiouronium salts:

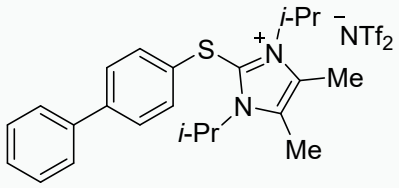
To a stirring solution of arylboronic acid (1.2 equiv) and **s1** (1 equiv) in trifluoroethanol (0.3 M) was added copper(ii) acetate monohydrate (1.5 equiv) at room temperature. The solution was warmed to 60 °C in oil bath and stirred for 8-12 h. The reaction was monitored by TLC. After completed, NH_4PF_6 solution (10 equiv, 3 M in H_2O) was added and the reaction mixture was stirred at r.t. The anion exchange process was monitored by TLC. After completed, the mixture was filtered through diatomite and the filtrate was concentrated under vacuum. The residue was extracted from dichloromethane/water (washed 3 times with water) and concentrated under vacuum to afford the crude product which was recrystallized from dichloromethane/petroleum ether. **NOTE**: In cases of complex arylisothiouronium salts (**1q**-**1x**), the products were purified by column chromatography.

1,3-diisopropyl-4,5-dimethyl-2-(phenylthio)-1H-imidazol-3-ium hexafluorophosphate(V) (1a):



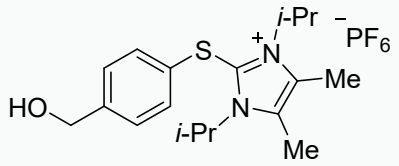
White solid. DCM/MeOH = 100/1, Rf = 0.4. Yield: 98% (85.1 mg). **Melting point**: 86 – 88 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.41-7.37 (m, 2H), 7.31 – 7.25 (m, 1H), 7.08 (d, *J* = 7.6 Hz, 2H), 5.15-5.12 (m, 2H), 2.40 (s, 6H), 1.49 (d, *J* = 7.0 Hz, 12H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 133.1, 131.3, 130.9, 130.7, 128.8, 127.9, 53.5, 21.0, 10.4.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -73.71 (d, *J* = 712.3 Hz). **FTMS (ESI)** m/z: $(M)^+$ Calc. for: $C_{17}H_{25}N_2S^+$, 289.1733, Found. 289.1727.

2-([1,1'-biphenyl]-4-ylthio)-1,3-diisopropyl-4,5-dimethyl-1H-imidazol-3-ium bis((trifluoromethyl)sulfonyl)amide (1b):



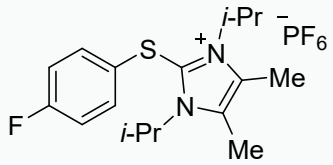
Colorless oil. DCM/MeOH = 100/1, Rf = 0.3. Yield: 85% (109.8 mg); **Melting point**: 69 – 72 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.65 – 7.63 (m, 2H), 7.58 – 7.52 (m, 2H), 7.45 – 7.43 (m, 2H), 7.38 – 7.36 (m, 1H), 7.19 – 7.17 (m, 2H), 5.25 – 5.12 (m, 2H), 2.44 (s, 6H), 1.54 (d, *J* = 7.0 Hz, 12H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 141.9, 139.2, 133.1, 131.4, 129.4, 129.2, 129.1, 128.4, 128.3, 127.1, 120.0 (q, *J* = 321.6 Hz), 53.6, 21.2, 10.6.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -78.73. **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{23}H_{29}N_2S^+$, 365.2046. Found. 365.2041.

2-((4-(hydroxymethyl)phenyl)thio)-1,3-diisopropyl-4,5-dimethyl-1H-imidazol-3-ium hexafluorophosphate(V) (1c):



White solid. DCM/MeOH = 20/1, Rf = 0.6. Yield: 73% (67.8 mg); **Melting point**: 171 – 172 °C. **^{1}H NMR** (400 MHz, *d*-DMSO) δ 7.37 (d, *J* = 8.3 Hz, 2H), 7.21 (d, *J* = 8.3 Hz, 2H), 5.29 (t, *J* = 5.7 Hz, 1H), 5.23 – 5.13 (m, 2H), 4.49 (d, *J* = 5.6 Hz, 2H), 2.42 (s, 6H), 1.45 (d, *J* = 7.0 Hz, 12H).; **^{13}C NMR** (100 MHz, *d*-DMSO) δ 143.2, 133.3, 130.3, 129.2, 128.1, 127.7, 62.0, 52.8, 20.5, 10.0.; **^{19}F NMR** (376 MHz, *d*-DMSO) δ -70.22 (d, *J* = 711.4 Hz). **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{18}H_{27}N_2OS^+$, 319.1839. Found. 319.1844.

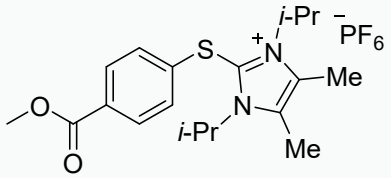
2-((4-fluorophenyl)thio)-1,3-diisopropyl-4,5-dimethyl-1H-imidazol-3-ium hexafluorophosphate(V) (1d):



White solid. DCM/MeOH = 50/1, Rf = 0.2. Yield: 76% (68.8 mg); **Melting point**: 58 – 60 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.20 – 7.09 (m, 4H), 5.19 – 5.09 (m, 2H), 2.41 (s, 6H), 1.52 (d, *J* = 7.0 Hz, 12H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 162.9 (d, *J* = 250.4 Hz),

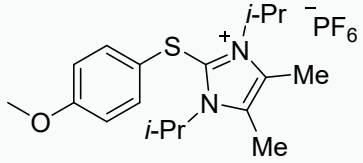
132.5, 131.7, 130.3 (d, J = 8.5 Hz), 125.9, 118.1 (d, J = 22.7 Hz), 53.6, 21.1, 10.6.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -73.71 (d, J = 712.4 Hz), -111.52. **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{17}H_{24}FN_2S^+$, 307.1639. Found. 307.1634.

1,3-diisopropyl-2-((4-(methoxycarbonyl)phenyl)thio)-4,5-dimethyl-1H-imidazol-3-ium hexafluorophosphate(V) (1e):



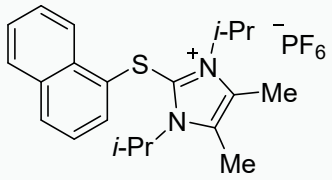
White solid. DCM/MeOH = 50/1, Rf = 0.5. Yield: 93% (91.6 mg); **Melting point**: 65 – 67 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.02 (d, J = 8.6 Hz, 2H), 7.13 (d, J = 8.6 Hz, 2H), 5.11 – 5.04 (m, 2H), 3.85 (s, 3H), 2.43 (s, 6H), 1.52 (d, J = 7.0 Hz, 12H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 166.0, 137.4, 132.2, 131.5, 130.4, 129.9, 126.4, 53.6, 52.4, 21.1, 10.5.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -73.63 (d, J = 712.3 Hz). **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{19}H_{27}N_2O_2S^+$, 347.1788. Found. 347.1795.

1,3-diisopropyl-2-((4-(methoxycarbonyl)phenyl)thio)-4,5-dimethyl-1H-imidazol-3-ium hexafluorophosphate(V) (1f):



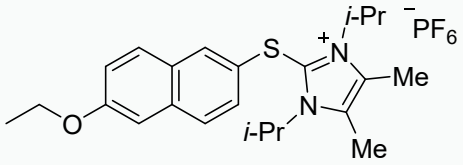
White solid. DCM/MeOH = 50/1, Rf = 0.3. Yield: 75% (69.7 mg); **Melting point**: 136 – 137 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.15 (d, J = 8.9 Hz, 2H), 6.95 (d, J = 8.9 Hz, 2H), 5.21 (br, 2H), 3.78 (s, 3H), 2.40 (s, 6H), 1.51 (d, J = 7.0 Hz, 12H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 160.6, 134.2, 131.1, 131.0, 120.3, 116.4, 55.7, 53.4, 21.1, 10.6.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -73.75 (d, J = 712.2 Hz). **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{18}H_{27}N_2OS^+$, 319.1839. Found. 319.1838.

1,3-diisopropyl-4,5-dimethyl-2-(naphthalen-1-ylthio)-1H-imidazol-3-ium hexafluorophosphate(V) (1g):



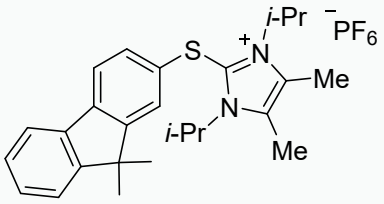
Brown solid. DCM/MeOH = 50/1, Rf = 0.4. Yield: 42% (40.7 mg); **Melting point**: 80 – 81 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.18 – 8.16 (m, 1H), 7.92 – 7.90 (m, 1H), 7.79 – 7.78 (m, 1H), 7.69 – 7.61 (m, 2H), 7.52 – 7.48 (m, 1H), 6.86 – 6.84 (m, 1H), 5.13 – 5.06 (m, 2H), 2.46 (s, 6H), 1.50 (d, *J* = 7.0 Hz, 12H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 134.2, 132.2, 131.8, 130.2, 129.2, 128.9, 128.4, 127.8, 127.4, 126.7, 125.8, 122.8, 53.6, 21.1, 10.6.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -73.62 (d, *J* = 712.4 Hz). **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{21}H_{27}N_2S^+$, 339.1889. Found. 339.1893.

2-((6-ethoxynaphthalen-2-yl)thio)-1,3-diisopropyl-4,5-dimethyl-1H-imidazol-3-ium hexafluorophosphate(V) (1h):



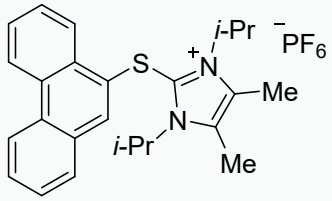
White solid. DCM/MeOH = 50/1, Rf = 0.3. Yield: 98% (103.6 mg); **Melting point**: 172 – 175 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.78 – 7.75 (m, 2H), 7.62 – 7.60 (m, 1H), 7.19 – 7.14 (m, 1H), 7.09 – 7.04 (m, 2H), 5.22 (br, 2H), 4.10 (q, *J* = 7.0 Hz, 2H), 2.42 (s, 6H), 1.50 (d, *J* = 6.9 Hz, 12H), 1.45 (t, *J* = 7.0 Hz, 3H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 158.3, 134.3, 133.8, 131.1, 129.6, 129.3, 129.2, 127.9, 125.5, 124.3, 121.0, 106.7, 63.8, 53.5, 21.1, 14.8, 10.5.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -73.55 (d, *J* = 712.5 Hz). **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{23}H_{31}N_2OS^+$, 383.2152. Found. 383.2150.

2-((9,9-dimethyl-9H-fluoren-2-yl)thio)-1,3-diisopropyl-4,5-dimethyl-1H-imidazol-3-ium hexafluorophosphate(V) (1i):



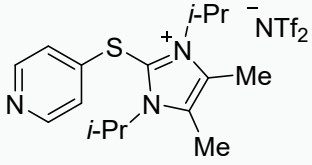
White solid. DCM/MeOH = 50/1, Rf = 0.3. Yield: 88% (96.9 mg); **Melting point**: 116 – 119 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.76 – 7.74 (m, 1H), 7.70 – 7.67 (m, 1H), 7.44 – 7.39 (m, 1H), 7.37 – 7.31 (m, 2H), 7.28 – 7.27 (m, 1H), 7.03 – 6.99 (m, 1H), 5.24 (br, 2H), 2.44 (s, 6H), 1.54 (d, *J* = 6.9 Hz, 12H), 1.47 (s, 6H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 156.1, 153.6, 140.3, 137.6, 133.2, 131.38 (s), 128.8, 128.4, 127.4, 127.3, 122.8, 122.6, 122.3, 120.6, 53.5, 47.4, 26.9, 21.1, 10.6.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -73.49 (d, *J* = 712.5 Hz). **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{26}H_{33}N_2S^+$, 405.2359, Found. 405.2367.

1,3-diisopropyl-4,5-dimethyl-2-(phenanthren-9-ylthio)-1H-imidazol-3-ium hexafluorophosphate(V) (1j):



White solid. DCM/MeOH = 50/1, Rf = 0.4. Yield: 29% (31.0 mg); **Melting point**: 75 – 78 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.77 (d, *J* = 7.8 Hz, 1H), 8.61 (d, *J* = 8.1 Hz, 1H), 8.23 (d, *J* = 7.7 Hz, 1H), 8.04 (d, *J* = 7.5 Hz, 1H), 7.84 – 7.71 (m, 2H), 7.68 – 7.52 (m, 2H), 7.11 (s, 1H), 5.19 – 5.01 (m, 2H), 2.51 (s, 6H), 1.56 (d, *J* = 7.0 Hz, 12H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 132.5, 131.5, 131.3, 130.7, 129.6, 129.2, 128.3, 128.2, 128.0, 127.7, 127.2, 125.7, 123.8, 123.6, 122.4, 53.7, 21.2, 10.8.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -73.22 (d, *J* = 712.6 Hz). **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{25}H_{29}N_2S^+$, 389.2046. Found. 389.2045.

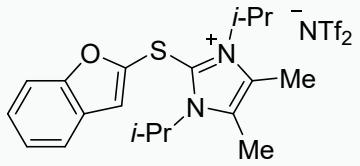
1,3-diisopropyl-4,5-dimethyl-2-(pyridin-4-ylthio)-1H-imidazol-3-ium bis((trifluoromethyl)sulfonyl)amide (1k):



Colorless oil. DCM/MeOH = 20/1, Rf = 0.7. Yield: 82% (93.6 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.55 (br, 2H), 6.98 (d, *J* = 4.1 Hz, 2H), 5.18 – 4.85 (m, 2H), 2.45 (s, 6H), 1.54 (d, *J* = 7.1 Hz, 12H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 151.0, 143.3, 132.6, 129.1, 120.4,

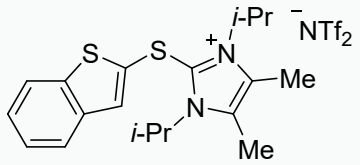
119.9 (q, J = 321.5 Hz), 53.9, 21.1, 10.7.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -78.83. **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{16}H_{24}N_3S^+$, 290.1686. Found, 290.1683.

2-(benzofuran-2-ylthio)-1,3-diisopropyl-4,5-dimethyl-1H-imidazol-3-ium bis((trifluoromethyl)sulfonyl)amide (1l):



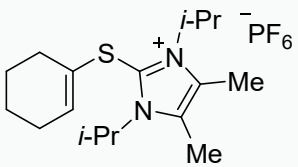
Brown solid. DCM/MeOH = 50/1, Rf = 0.3. Yield: 63% (76.8 mg); **Melting point**: 86 – 90 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.63 – 7.61 (m, 1H), 7.44 – 7.36 (m, 2H), 7.32 – 7.25 (m, 2H), 5.58 (br, 2H), 2.43 (s, 6H), 1.65 (d, J = 7.0 Hz, 12H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 156.7, 140.3, 131.7, 131.1, 127.4, 126.9, 124.3, 122.0, 120.0 (q, J = 321.7 Hz), 115.3, 111.4, 54.0, 21.1, 10.6.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -78.80. **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{19}H_{25}N_2OS^+$, 329.1682. Found. 329.1680.

2-(benzo[b]thiophen-2-ylthio)-1,3-diisopropyl-4,5-dimethyl-1H-imidazol-3-ium bis((trifluoromethyl)sulfonyl)amide (1m):



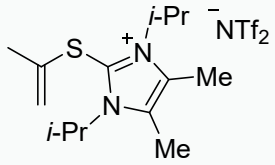
Brown solid. DCM/MeOH = 50/1, Rf = 0.3. Yield: 58% (72.6 mg); **Melting point**: 75 – 77 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.83 – 7.78 (m, 1H), 7.76 – 7.70 (m, 1H), 7.61 (s, 1H), 7.43 – 7.36 (m, 2H), 5.50 – 5.33 (m, 2H), 2.42 (s, 6H), 1.58 (d, J = 7.0 Hz, 12H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 141.5, 138.9, 133.6, 131.2, 131.0, 127.6, 126.6, 125.8, 124.6, 122.2, 120.0 (q, J = 321.6 Hz), 53.9, 21.2, 10.7.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -78.74. **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{19}H_{25}N_2S_2^+$, 345.1454. Found. 345.1458.

2-(cyclohex-1-en-1-ylthio)-1,3-diisopropyl-4,5-dimethyl-1H-imidazol-3-ium hexafluorophosphate(V) (1n):



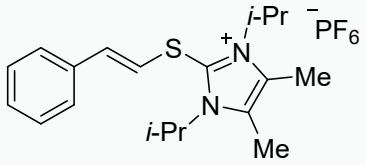
Light yellow oil. DCM/MeOH = 100/1, Rf = 0.2. Yield: 68% (59.6 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 5.91 (s, 1H), 5.29 – 5.08 (m, 2H), 2.40 (s, 6H), 2.19 – 2.07 (m, 2H), 2.07 – 1.95 (m, 2H), 1.75 – 1.65 (m, 2H), 1.62 – 1.46 (m, 14H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 133.4, 132.7, 131.0, 129.2, 53.2, 30.0, 29.8, 26.9, 23.4, 21.2, 10.6.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -73.93 (d, *J* = 712.2 Hz). **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{17}H_{29}N_2S^+$, 293.2046. Found, 293.2043.

1,3-diisopropyl-4,5-dimethyl-2-(prop-1-en-2-ylthio)-1H-imidazol-3-ium bis((trifluoromethyl)sulfonyl)amide (1o):



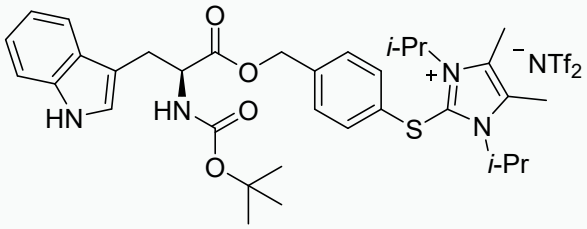
Brown oil. DCM/MeOH = 100/1, Rf = 0.4. Yield: 24% (25.6 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 5.30 – 5.26 (m, 1H), 5.19 – 5.06 (m, 2H), 4.65 (s, 1H), 2.42 (s, 6H), 2.01 (s, 3H), 1.60 (d, *J* = 7.1 Hz, 12H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 137.3, 132.5, 131.4, 120.0 (q, *J* = 321.6 Hz), 115.1, 53.6, 22.6, 21.2, 10.6.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -78.87. **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{14}H_{25}N_2S^+$, 253.1733. Found. 253.1731

(E)-1,3-diisopropyl-4,5-dimethyl-2-(styrylthio)-1H-imidazol-3-ium hexafluorophosphate(V) (1p):



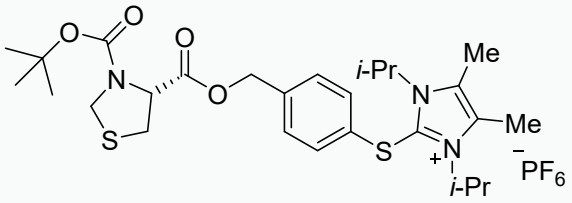
White solid. DCM/MeOH = 50/1, Rf = 0.3. Yield: 76% (70.0 mg); **Melting point**: 137 – 138 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.43 – 7.36 (m, 2H), 7.33 – 7.23 (m, 3H), 6.73 (d, *J* = 15.4 Hz, 1H), 6.56 (d, *J* = 15.4 Hz, 1H), 5.21 – 5.09 (m, 2H), 2.38 (s, 6H), 1.61 (d, *J* = 7.1 Hz, 12H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 136.0, 134.6, 132.6, 131.1, 129.2, 129.1, 126.8, 116.7, 53.4, 21.3, 10.4.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -73.62 (d, *J* = 712.5 Hz). **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{19}H_{27}N_2S^+$, 315.1889. Found. 315.1888.

2-((4-((((tert-butoxycarbonyl)-L-tryptophyl)oxy)methyl)phenyl)thio)-1,3-diisopropyl-4,5-dimethyl-1H-imidazol-3-ium bis((trifluoromethyl)sulfonyl)amide (1q):



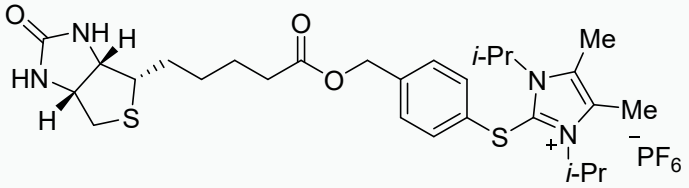
Colorless oil. DCM/MeOH = 50/1, Rf = 0.3. Yield: 41% (72.6 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.83 (s, 1H), 7.50 (d, *J* = 7.8 Hz, 1H), 7.36 (d, *J* = 8.1 Hz, 1H), 7.12 – 7.06 (m, 3H), 7.04 – 6.94 (m, 4H), 5.13 – 5.11 (m, 3H), 4.93 (s, 2H), 4.68 – 4.56 (m, 1H), 3.29 – 3.14 (m, 2H), 2.40 (s, 6H), 1.48 (d, *J* = 6.9 Hz, 12H), 1.41 (s, 9H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 172.3, 155.4, 136.5, 132.8, 131.5, 130.5, 130.3, 127.8, 127.7, 123.5, 121.9, 120.0 (q, *J* = 321.6 Hz), 119.3, 118.6, 111.7, 109.3, 80.0, 65.9, 54.7, 53.6, 28.4, 22.3, 21.1, 10.6.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -78.73. **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{34}H_{45}N_4O_4S^+$, 605.3156. Found, 605.3155.

(R)-2-((4-(((3-(tert-butoxycarbonyl)thiazolidine-4-carbonyl)oxy)methyl)phenyl)thio)-1,3-diisopropyl-4,5-dimethyl-1H-imidazol-3-ium hexafluorophosphate(V) (1r):



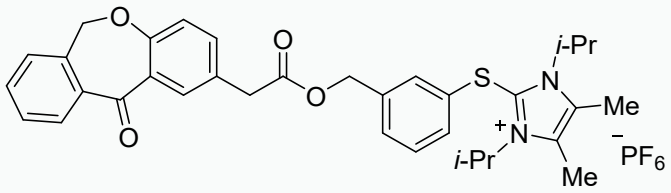
Colorless oil. DCM/MeOH = 50/1, Rf = 0.3. Yield: 70% (95.2 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.43 – 7.39 (m, 1H), 7.29 – 7.26 (m, 1H), 7.20 (s, 1H), 7.01 – 6.90 (m, 1H), 5.22 – 5.05 (m, 4H), 4.92 – 4.68 (m, 1H), 4.64 – 4.51 (m, 1H), 4.47 – 4.35 (m, 1H), 3.39 – 3.23 (m, 1H), 3.21 – 3.11 (m, 1H), 2.41 (s, 6H), 1.51 (d, *J* = 7.0 Hz, 12H), 1.40 (d, *J* = 41.8 Hz, 9H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 170.3, 153.2 (d, *J* = 15.6 Hz), 138.2, 131.6, 131.1, 128.1, 128.0, 127.5, 126.9, 126.7, 81.3, 66.1, 61.6, 53.5, 48.6 (d, *J* = 68.0 Hz), 33.9 (d, *J* = 132.7 Hz), 28.3, 21.0, 10.5.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -73.54 (d, *J* = 712.4 Hz). **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{27}H_{40}N_3O_4S_2^+$, 534.2455. Found, 534.2445.

1,3-diisopropyl-4,5-dimethyl-2-((4-(((5-((3aS,4S,6aR)-2-oxohexahydro-1H-thieno[3,4-d]imidazol-4-yl)pentanoyl)oxy)methyl)phenyl)thio)-1H-imidazol-3-ium hexafluorophosphate(V) (1s):



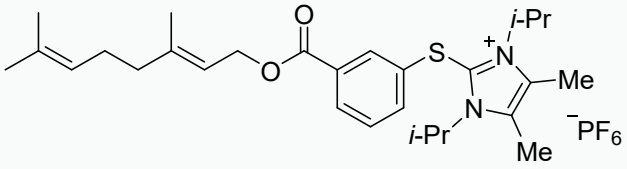
Colorless oil. DCM/MeOH = 20/1, Rf = 0.4. Yield: 63% (87.0 mg); **^{1}H NMR** (400 MHz, *d*-DMSO) δ 7.48 (d, *J* = 8.3 Hz, 2H), 7.31 (d, *J* = 8.3 Hz, 2H), 6.45 (d, *J* = 20.5 Hz, 2H), 5.22 (dt, *J* = 13.7, 6.7 Hz, 2H), 5.15 (s, 2H), 4.40 – 4.34 (m, 1H), 4.22 – 4.15 (m, 1H), 3.17 – 3.10 (m, 1H), 2.88 (dd, *J* = 12.4, 5.1 Hz, 1H), 2.64 (d, *J* = 12.4 Hz, 1H), 2.61 – 2.55 (m, 1H), 2.50 (s, 6H), 2.42 (t, *J* = 7.4 Hz, 2H), 1.71 – 1.59 (m, 3H), 1.52 (d, *J* = 7.0 Hz, 12H), 1.43 – 1.34 (m, 2H).; **^{13}C NMR** (100 MHz, *d*-DMSO) δ 172.6, 162.7, 136.6, 132.9, 131.2, 130.4, 129.5, 127.9, 64.4, 61.0, 59.2, 55.3, 52.8, 33.2, 27.9, 24.4, 20.5, 10.0.; **^{19}F NMR** (376 MHz, *d*-DMSO) δ -70.19 (d, *J* = 711.4 Hz). **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{28}H_{41}N_4O_3S_2^+$, 545.2615. Found, 545.2604.

1,3-diisopropyl-4,5-dimethyl-2-((3-((2-(11-oxo-6,11-dihydrodibenzo[b,e]oxepin-2-yl)acetoxy)methyl)phenyl)thio)-1H-imidazol-3-ium hexafluorophosphate(V) (1t):



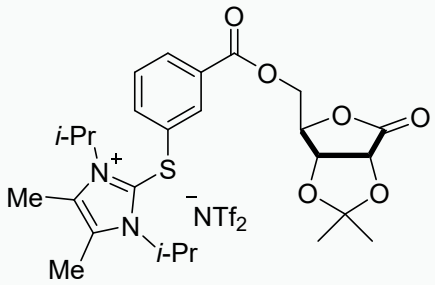
Colorless oil. DCM/MeOH = 50/1, Rf = 0.3. Yield: 69% (98.6 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.07 (d, *J* = 2.2 Hz, 1H), 7.84 (d, *J* = 7.6 Hz, 1H), 7.57 – 7.51 (m, 1H), 7.48 – 7.42 (m, 1H), 7.41 – 7.34 (m, 3H), 7.26 – 7.21 (m, 1H), 7.12 (s, 1H), 7.00 (d, *J* = 8.4 Hz, 1H), 6.93 (d, *J* = 7.9 Hz, 1H), 5.19 – 5.04 (m, 6H), 3.66 (s, 2H), 2.39 (s, 6H), 1.48 (d, *J* = 7.0 Hz, 12H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 190.7, 171.0, 160.6, 140.3, 138.5, 136.5, 135.7, 133.0, 132.4, 132.0, 131.6, 131.4, 131.0, 129.4, 129.3, 128.1, 128.0, 127.5, 127.3, 126.8, 125.2, 121.2, 73.7, 65.6, 53.4, 40.1, 21.0, 10.4.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -73.53 (d, *J* = 712.4 Hz). **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{34}H_{37}N_2O_4S^+$, 569.2469. Found, 569.2460.

(E)-2-((3-(((3,7-dimethylocta-2,6-dien-1-yl)oxy)carbonyl)phenyl)thio)-1,3-diisopropyl-4,5-dimethyl-1H-imidazol-3-ium hexafluorophosphate(V) (1u):



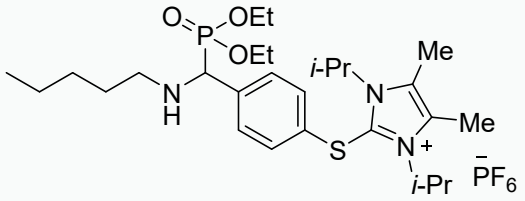
Colorless oil. DCM/MeOH = 100/1, Rf = 0.2. Yield: 66% (81.1 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.98 (d, *J* = 7.7 Hz, 1H), 7.84 (s, 1H), 7.57 – 7.47 (m, 1H), 7.30 – 7.20 (m, 1H), 5.51 – 5.38 (m, 1H), 5.25 – 5.04 (m, 3H), 4.80 (d, *J* = 7.2 Hz, 2H), 2.45 (s, 6H), 2.20 – 2.04 (m, 4H), 1.79 (s, 3H), 1.65 (s, 3H), 1.59 (s, 3H), 1.53 (d, *J* = 6.9 Hz, 12H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 165.2, 143.5, 132.4, 132.3, 131.9, 131.8, 131.6, 131.3, 129.5, 128.0, 123.5, 118.8, 62.3, 53.6, 32.3, 26.7, 25.7, 23.6, 21.0, 17.7, 10.5.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -73.68 (d, *J* = 712.4 Hz).. **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{28}H_{41}N_2O_2S^+$, 469.2883. Found, 469.2879.

2-((3-((((4R)-2,2-dimethyl-6-oxotetrahydrofuro[3,4-d][1,3]dioxol-4-yl)methoxy)carbonyl)phenyl)thio)-1,3-diisopropyl-4,5-dimethyl-1H-imidazol-3-ium bis((trifluoromethyl)sulfonyl)amide (1v):



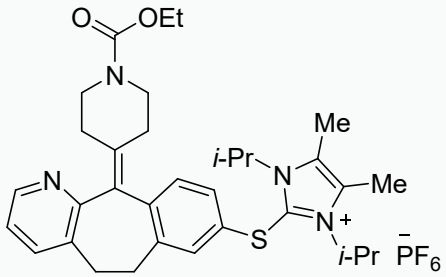
Colorless oil. DCM/MeOH = 50/1, Rf = 0.3. Yield: 69% (108.1 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.88 (d, *J* = 7.8 Hz, 1H), 7.64 (s, 1H), 7.57 (t, *J* = 7.9 Hz, 1H), 7.36 (d, *J* = 8.0 Hz, 1H), 5.26 – 5.07 (m, 2H), 4.87 (t, *J* = 2.9 Hz, 1H), 4.83 (d, *J* = 5.6 Hz, 1H), 4.66 (d, *J* = 5.6 Hz, 1H), 4.62 – 4.50 (m, 2H), 2.45 (s, 6H), 1.54 (d, *J* = 6.7 Hz, 12H), 1.48 (s, 3H), 1.38 (s, 3H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 173.6, 164.2, 132.7, 132.3, 132.0, 131.6, 131.5, 131.2, 129.8, 128.0, 120.0 (q, *J* = 321.8 Hz), 114.1, 79.9, 77.7, 75.2, 64.5, 53.8, 26.8, 25.6, 21.2 (d, *J* = 5.1 Hz), 10.7.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -78.80. **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{26}H_{35}N_2O_6S^+$, 503.2210. Found, 503.2195.

2-((4-((diethoxyphosphoryl)(pentylamino)methyl)phenyl)thio)-1,3-diisopropyl-4,5-dimethyl-1H-imidazol-3-ium hexafluorophosphate(V) (1w):



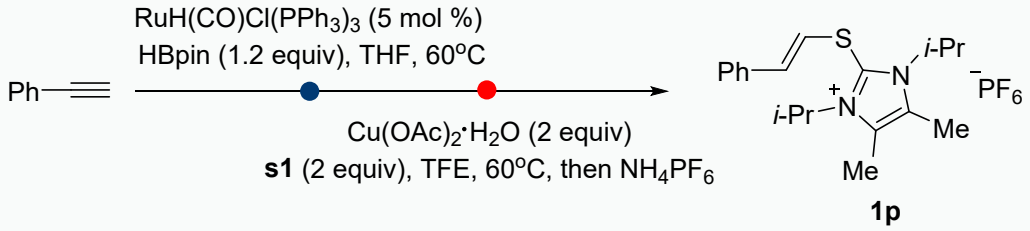
White solid. DCM/MeOH = 20/1, Rf = 0.6. Yield: 69% (92.5 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.45 (d, *J* = 7.2 Hz, 2H), 7.09 (d, *J* = 7.8 Hz, 2H), 5.13 (s, 2H), 4.09 – 3.86 (m, 5H), 2.40 (s, 8H), 1.98 (br, 1H), 1.49 (d, *J* = 5.6 Hz, 12H), 1.39 (s, 2H), 1.28 – 1.08 (m, 10H), 0.82 (s, 3H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 137.7, 132.7, 131.4, 130.8 (d, *J* = 5.6 Hz), 130.1, 128.1, 63.2 (d, *J* = 7.0 Hz), 63.0 (d, *J* = 6.9 Hz), 60.5 (d, *J* = 151.9 Hz), 53.4, 48.2 (d, *J* = 15.8 Hz), 29.4, 29.3, 22.5, 21.0 (d, *J* = 2.5 Hz), 16.4 (d, *J* = 5.4 Hz), 16.3 (d, *J* = 5.5 Hz), 14.0, 10.5.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -73.69 (d, *J* = 712.3 Hz). **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{27}H_{47}N_3O_3PS^+$, 524.3070. Found, 524.3059.

2-((11-(1-(ethoxycarbonyl)piperidin-4-ylidene)-6,11-dihydro-5H-benzo[5,6]cyclohepta[1,2-b]pyridin-8-yl)thio)-1,3-diisopropyl-4,5-dimethyl-1H-imidazol-3-ium hexafluorophosphate(V) (1x):



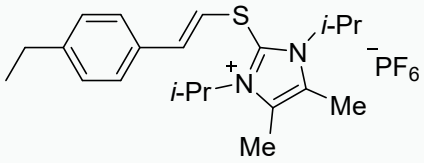
White solid. DCM/MeOH = 20/1, Rf = 0.5. Yield: 48% (67.7 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.34 (d, *J* = 4.0 Hz, 1H), 7.55 (br, 1H), 7.31 – 7.15 (m, 2H), 6.99 (s, 1H), 6.83 (d, *J* = 7.0 Hz, 1H), 5.20 – 4.99 (m, 2H), 4.07 (q, *J* = 7.0 Hz, 2H), 3.82 – 3.63 (m, 2H), 3.42 – 3.23 (m, 2H), 3.13 – 2.75 (m, 4H), 2.39 (s, 6H), 2.25 – 2.15 (m, 4H), 1.59 – 1.40 (m, 12H), 1.20 (t, *J* = 7.0 Hz, 3H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 156.9, 155.4, 146.9, 140.6, 138.7, 134.8, 134.1, 132.0, 131.6, 131.3, 130.1, 128.4, 125.2, 123.5, 61.4, 53.4, 44.6, 31.5, 31.1, 30.8, 21.1, 20.9, 14.7, 10.5.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -73.38 (d, *J* = 712.6 Hz). **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{33}H_{43}N_4O_2S^+$, 559.3101. Found, 559.3090.

8. General procedure for preparation of vinylthioimidazolium salts (1p, 1y, 1z, 1aa) :



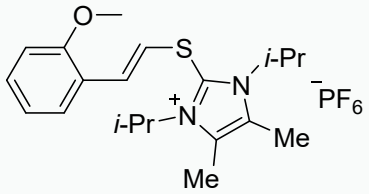
To a dried Schlenk tube was added ethynylbenzene (20.4 mg, 0.2 mmol), HBpin (30.7 mg, 0.24 mmol), $RuH(CO)Cl(PPh_3)_3$ (9.5 mg, 5 mol %) and THF (1 mL). The reaction mixture was stirred at 60 °C under argon for 14h and then dried under vacuum. The residue was redissolved in trifluoroethanol (1 mL) with copper(ii) acetate monohydrate (79.6 mg, 0.4 mmol) and **s1** (84.8 mg, 0.4 mmol). After stirring at 60 °C in oil bath for 12h, NH_4PF_6 or $LiNTf_2$ (0.6 mmol) was then added and the reaction mixture was stirred at r.t. The anion exchange process was monitored by TLC. After completed, the reaction mixture was subjected to silica gel column chromatography (300-400 mesh silica gel, DCM/MeOH = 50/1, Rf = 0.3) to afford the product **1p** (62.3 mg, 68 % yield).

(E)-2-((4-ethylstyryl)thio)-1,3-diisopropyl-4,5-dimethyl-1H-imidazol-3-ium hexafluorophosphate(V) (1y):



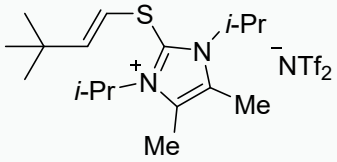
Light yellow solid. DCM/MeOH = 100/1, Rf = 0.4. Yield: 67% (65.5 mg); **Melting point**: 154 – 155 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.31 (d, *J* = 8.1 Hz, 2H), 7.14 (d, *J* = 8.0 Hz, 2H), 6.73 (d, *J* = 15.4 Hz, 1H), 6.49 (d, *J* = 15.4 Hz, 1H), 5.16 (br, 2H), 2.60 (q, *J* = 7.6 Hz, 2H), 2.38 (s, 6H), 1.61 (d, *J* = 7.0 Hz, 12H), 1.19 (t, *J* = 7.6 Hz, 3H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 145.6, 136.3, 132.6, 132.2, 131.0, 128.6, 126.9, 115.4, 53.3, 28.7, 21.3, 15.4, 10.4.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -73.66 (d, *J* = 712.4 Hz). **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{21}H_{31}N_2S^+$, 343.2202. Found. 343.2203.

(E)-1,3-diisopropyl-2-((2-methoxystyryl)thio)-4,5-dimethyl-1H-imidazol-3-ium hexafluorophosphate(V) (1z):



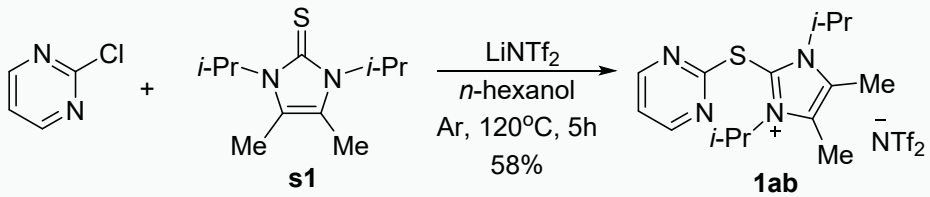
White solid. DCM/MeOH = 100/1, Rf = 0.3. Yield: 40% (39.2 mg); **Melting point**: 184 – 186 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.35 (d, *J* = 6.8 Hz, 1H), 7.30 – 7.22 (m, 1H), 6.98 – 6.84 (m, 3H), 6.68 (d, *J* = 15.4 Hz, 1H), 5.18 (br, 2H), 3.85 (s, 3H), 2.40 (s, 6H), 1.63 (d, *J* = 7.0 Hz, 12H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 157.1, 133.0, 132.1, 131.0, 130.3, 128.6, 123.4, 121.1, 117.6, 111.0, 55.6, 53.3, 21.3, 10.5.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -73.79 (d, *J* = 712.3 Hz). **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{20}H_{29}N_2OS^+$, 345.1995. Found. 345.1989.

(E)-2-((3,3-dimethylbut-1-en-1-yl)thio)-1,3-diisopropyl-4,5-dimethyl-1H-imidazol-3-ium bis((trifluoromethyl)sulfonyl)amide (1aa):



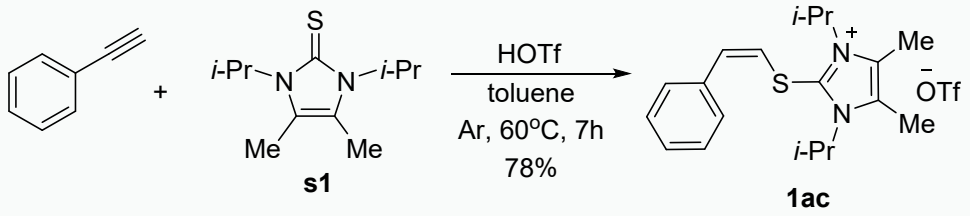
Colorless oil. DCM/MeOH = 100/1, Rf = 0.4. Yield: 57% (65.6 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.00 (d, *J* = 15.1 Hz, 1H), 5.75 (d, *J* = 15.1 Hz, 1H), 5.14 (br, 2H), 2.40 (s, 6H), 1.61 (d, *J* = 7.0 Hz, 12H), 1.03 (s, 9H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 150.8, 133.7, 130.7, 120.0 (q, *J* = 321.8 Hz), 113.0, 53.2, 35.3, 28.8, 21.3, 10.5.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -78.82. **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{17}H_{31}N_2S^+$, 295.2202. Found. 295.2200.

1,3-diisopropyl-4,5-dimethyl-2-(pyrimidin-2-ylthio)-1H-imidazol-3-ium bis((trifluoromethyl)sulfonyl)amide (1ab)



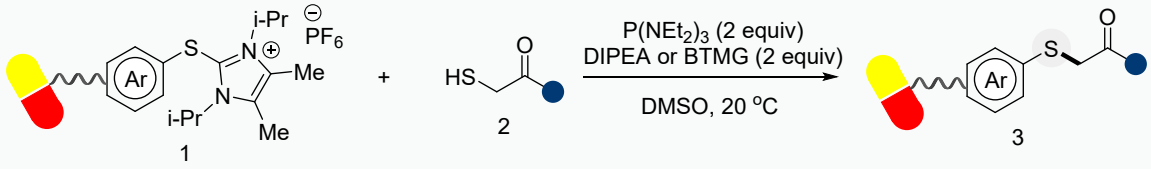
To a stirred solution of 2-chloropyrimidine (0.3 mmol, 34.4 mg), **s1** (0.3 mmol, 63.7 mg) in *n*-hexanol (1 mL) was added $LiNTf_2$ (0.3 mmol, 86.4 mg) under argon. The mixture was heated to 120°C and stirred for 5h. After completed, the reaction mixture was subjected to silica gel column chromatography (300-400 mesh silica gel, DCM:MeOH) to afford the product **1ab** (99.4 mg, 58%) as colorless oil. DCM/MeOH = 100/1, Rf = 0.4. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.56 (d, *J* = 4.9 Hz, 2H), 7.29 (t, *J* = 4.9 Hz, 1H), 5.10 (s, 2H), 2.45 (s, 6H), 1.52 (s, 12H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 166.9, 159.2, 131.3, 130.9, 120.2, 119.9 (q, *J* = 321.9 Hz), 53.7, 21.0, 10.6.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -78.86. **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{15}H_{23}N_4S^+$, 291.1638. Found. 291.1626.

(Z)-1,3-diisopropyl-4,5-dimethyl-2-(styrylthio)-1H-imidazol-3-ium trifluoromethanesulfonate (1ac):



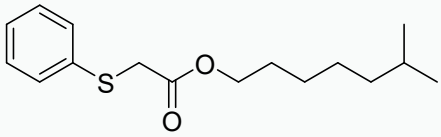
To a stirred solution of phenylacetylene (4.9 mmol, 500 mg), **s1** (9.8 mmol, 2.08 g) in toluene (15 mL) was added HOTf (9.8 mmol, 1.47 g) under argon. The mixture was heated to 60°C and stirred for 7h. After completed, the reaction mixture was diluted with DCM and washed with water. The organic phase was concentrate in vacuo. The residue was purified by flash column chromatography (300-400 mesh silica gel, DCM:MeOH) to afford the product **1ac** (1.77 g, 78%) as white solid. DCM/MeOH = 100/1, Rf = 0.3. **Melting point**: 112 – 115 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.46 – 7.33 (m, 5H), 6.86 (d, *J* = 10.1 Hz, 1H), 6.34 (d, *J* = 10.1 Hz, 1H), 5.13 – 4.98 (m, 2H), 2.40 (s, 6H), 1.62 (d, *J* = 7.0 Hz, 12H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 134.6, 133.5, 132.4, 130.8, 128.8, 128.7, 128.6, 126.6, 119.2, 119.1, 53.2, 21.3, 10.5.; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -78.33. **HRMS (ESI)** m/z : $(M)^+$ Calc. for: $C_{19}H_{27}N_2S^+$, 315.1889. Found. 315.1893.

9. Procedure of thiol-(hetero)arene conjugation:



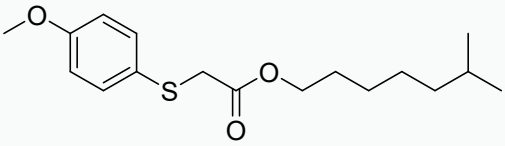
To a stirring solution of thioimidazolium salt **1** (0.2 mmol), $P(NEt_2)_3$ (0.4 mmol), and thiol **2** (0.4 mmol) in dry DMSO (1 mL) was added DIPEA or BTMG (0.4 mmol) at 20 ℃. The solution was stirred at 20 ℃ and monitored by TLC. After completed, the reaction mixture was subjected to silica gel column chromatography (300-400 mesh silica gel) to afford the product **3**. **NOTE**: $P(NEt_2)_3$ was used to prevent the oxidation of thiols. But in some cases, it would lead to unexpected side reactions.

6-methylheptyl 2-(phenylthio)acetate (3a):



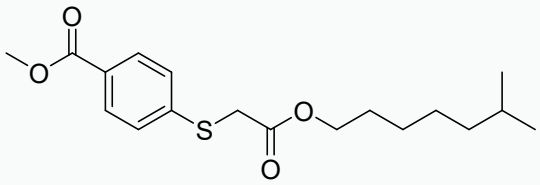
Colorless oil. PE/EtOAc = 20/1, Rf = 0.5. Yield: 80% (44.9 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.42 – 7.37 (m, 2H), 7.32 – 7.27 (m, 2H), 7.24 – 7.19 (m, 1H), 4.06 – 3.98 (m, 2H), 3.65 (s, 2H), 1.52 (dt, *J* = 11.6, 5.7 Hz, 1H), 1.33 – 1.21 (m, 8H), 0.93 – 0.80 (m, 6H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 170.1, 135.3, 129.8, 129.2, 127.0, 68.0, 38.8, 36.7, 30.4, 29.0, 23.7, 23.1, 14.2, 11.1. **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{16}H_{24}NaO_2S^+$, 303.1389. Found. 303.1397.

6-methylheptyl 2-((4-methoxyphenyl)thio)acetate (3b):



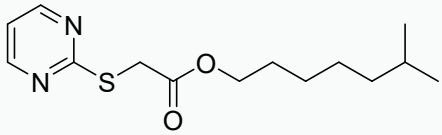
Colorless oil. PE/EtOAc = 20/1, Rf = 0.2. Yield: 98% (60.8 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.45 – 7.34 (m, 2H), 6.89 – 6.78 (m, 2H), 4.06 – 3.90 (m, 2H), 3.79 (s, 3H), 3.52 (s, 2H), 1.51 (dt, *J* = 11.7, 5.8 Hz, 1H), 1.32 – 1.19 (m, 8H), 0.94 – 0.78 (m, 6H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 170.3, 159.7, 134.0, 125.3, 114.8, 67.9, 55.4, 38.8, 38.7, 30.4, 29.0, 23.7, 23.1, 14.2, 11.1. **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{17}H_{26}NaO_3S^+$, 333.1495. Found. 333.1497.

methyl 4-((2-((6-methylheptyl)oxy)-2-oxoethyl)thio)benzoate (3c):



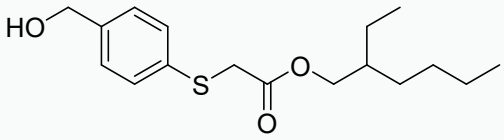
Colorless oil. PE/EtOAc = 20/1, Rf = 0.2. Yield: 30% (20.3 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.97 – 7.91 (m, 2H), 7.38 – 7.33 (m, 2H), 4.08 – 3.99 (m, 2H), 3.90 (s, 3H), 3.73 (s, 2H), 1.53 (dt, *J* = 11.8, 5.8 Hz, 1H), 1.33 – 1.20 (m, 8H), 0.90 – 0.80 (m, 6H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 169.5, 166.8, 142.3, 130.2, 127.8, 127.1, 68.3, 52.3, 38.8, 35.1, 30.4, 29.0, 23.7, 23.1, 14.2, 11.1. **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{18}H_{26}NaO_4S^+$, 361.1444. Found. 361.1448.

6-methylheptyl 2-(pyrimidin-2-ylthio)acetate (3d):



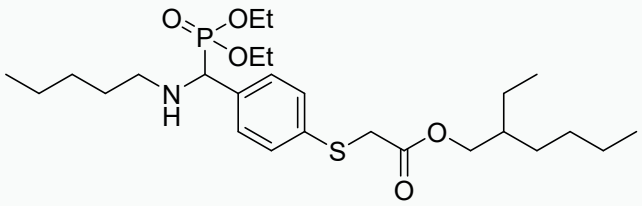
Colorless oil. PE/EtOAc = 10/1, Rf = 0.5. Yield: 48% (27.1 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.50 (d, *J* = 4.8 Hz, 2H), 6.98 (t, *J* = 4.8 Hz, 1H), 4.14 – 3.98 (m, 2H), 3.93 (s, 2H), 1.56 (dt, *J* = 11.8, 5.9 Hz, 1H), 1.37 – 1.22 (m, 8H), 0.90 – 0.79 (m, 6H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 171.1, 169.5, 157.4, 116.9, 68.1, 38.9, 33.6, 30.4, 29.0, 23.8, 23.1, 14.2, 11.1. **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{14}H_{22}N_2NaO_2S^+$, 305.1294. Found. 305.1301.

2-ethylhexyl 2-((4-(hydroxymethyl)phenyl)thio)acetate (3e):



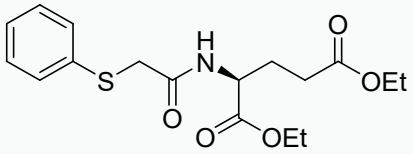
Colorless oil. PE/EtOAc = 5/1, Rf = 0.2. Yield: 36% (22.4 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.39 (d, *J* = 8.3 Hz, 2H), 7.29 (d, *J* = 8.3 Hz, 2H), 4.65 (s, 2H), 4.06 – 3.96 (m, 2H), 3.64 (s, 2H), 1.80 (br, 1H), 1.57 – 1.47 (m, 1H), 1.33 – 1.21 (m, 8H), 0.91 – 0.80 (m, 6H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 170.0, 139.8, 134.5, 130.1, 127.8, 68.1, 64.9, 38.8, 36.8, 30.4, 29.0, 23.7, 23.1, 14.2, 11.1. **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{17}H_{26}NaO_3S^+$, 333.1495. Found. 333.1499.

2-ethylhexyl 2-((4-((diethoxyphosphoryl)(pentylamino)methyl)phenyl)thio)acetate (3f):



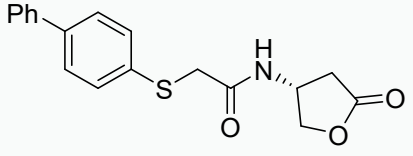
Colorless oil. PE/EtOAc = 2/1, Rf = 0.3. Yield: 54% (55.7 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.40 – 7.30 (m, 4H), 4.11 – 3.81 (m, 7H), 3.66 (s, 2H), 2.52 – 2.35 (m, 2H), 1.60 – 1.50 (m, 1H), 1.47 – 1.38 (m, 2H), 1.33 – 1.21 (m, 15H), 1.16 (t, *J* = 7.1 Hz, 3H), 0.91 – 0.80 (m, 9H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 170.0, 134.9, 129.4, 129.3, 129.2, 68.1, 63.1 (d, *J* = 6.6 Hz), 63.0 (d, *J* = 6.0 Hz), 60.9 (d, *J* = 152.8 Hz), 48.2 (d, *J* = 16.4 Hz), 38.8, 36.6, 30.4, 29.6, 29.5, 29.0, 23.8, 23.1, 22.7, 16.6 (d, *J* = 5.5 Hz), 16.4 (d, *J* = 4.9 Hz), 14.2, 14.1, 11.0. **^{31}P NMR** (162 MHz, $CDCl_3$) δ 23.09. **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{26}H_{46}NNaO_5PS^+$, 538.2727. Found. 538.2731.

diethyl (2-(phenylthio)acetyl)-L-glutamate (3g):



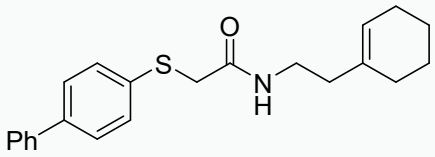
Colorless oil. PE/EtOAc = 2/1, Rf = 0.3. Yield: 67% (47.4 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.37 – 7.26 (m, 5H), 7.22 – 7.16 (m, 1H), 4.56 (td, *J* = 7.9, 4.5 Hz, 1H), 4.15 (qd, *J* = 7.1, 2.4 Hz, 2H), 4.08 (q, *J* = 7.1 Hz, 2H), 3.64 (q, *J* = 16.8 Hz, 2H), 2.22 – 2.08 (m, 3H), 1.96 – 1.85 (m, 1H), 1.26 – 1.19 (m, 6H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 172.6, 171.4, 168.0, 134.6, 129.4, 128.8, 127.0, 61.8, 60.7, 52.0, 37.7, 30.0, 27.4, 14.3, 14.2. **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{17}H_{23}NNaO_5S^+$, 376.1189. Found. 376.1197.

(R)-2-([1,1'-biphenyl]-4-ylthio)-N-(5-oxotetrahydrofuran-3-yl)acetamide (3h):



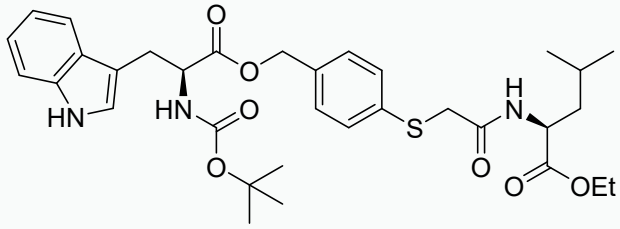
White solid. PE/EtOAc = 1/1, Rf = 0.5. Yield: 70% (45.8 mg); **Melting point**: 87 – 89 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.58 – 7.53 (m, 4H), 7.46 – 7.40 (m, 4H), 7.38 – 7.32 (m, 1H), 7.28 (d, *J* = 5.9 Hz, 1H), 4.59 – 4.50 (m, 1H), 4.47 – 4.39 (m, 1H), 4.29 – 4.20 (m, 1H), 3.70 (d, *J* = 1.0 Hz, 2H), 2.79 – 2.69 (m, 1H), 2.13 – 1.99 (m, 1H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 174.8, 168.9, 140.3, 140.1, 133.3, 129.6, 129.0, 128.1, 127.7, 127.1, 66.0, 49.5, 37.9, 30.1. **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{18}H_{17}NNaO_3S^+$, 350.0821. Found. 350.0831.

2-([1,1'-biphenyl]-4-ylthio)-N-(2-(cyclohex-1-en-1-yl)ethyl)acetamide (3i):



White solid. PE/acetone = 7/1, Rf = 0.3. Yield: 74% (52.0 mg); **Melting point**: 52 – 54 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ. 7.57 – 7.50 (m, 4H), 7.43 (t, *J* = 7.5 Hz, 2H), 7.39 – 7.29 (m, 3H), 6.91 (br, 1H), 5.32 (s, 1H), 3.66 (s, 2H), 3.39 – 3.25 (m, 2H), 2.08 (t, *J* = 6.5 Hz, 2H), 1.89 – 1.84 (m, 4H), 1.58 – 1.40 (m, 4H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ. 167.5, 140.2, 139.6, 134.2, 134.0, 129.0, 128.1, 128.0, 127.6, 127.0, 124.1, 37.4, 37.3, 37.2, 27.8, 25.3, 22.8, 22.3. **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{22}H_{25}NNaOS^+$, 374.1549. Found. 374.1555.

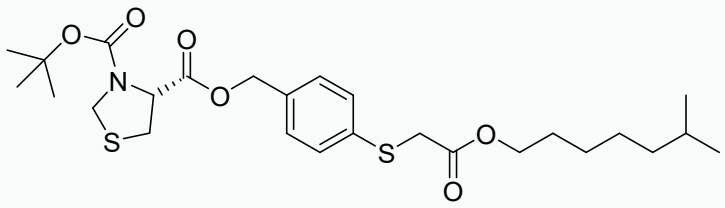
ethyl (2-((4-((((tert-butoxycarbonyl)-L-tryptophyl)oxy)methyl)phenyl)thio)acetyl)-L-leucinate (3j):



Colorless oil. PE/EtOAc = 2/1, Rf = 0.4. Yield: 40% (50.1 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.62 (s, 1H), 7.54 (d, *J* = 7.9 Hz, 1H), 7.35 (d, *J* = 8.1 Hz, 1H), 7.30 – 7.24 (m, 3H), 7.21 – 7.14 (m, 1H), 7.12 – 7.02 (m, 4H), 6.48 (s, 1H), 5.12 (d, *J* = 12.2 Hz, 1H), 4.94 (d, *J* = 12.2 Hz, 1H), 4.73 – 4.64 (m, 1H), 4.62 – 4.53 (m, 1H), 4.17 – 4.10 (m, 2H), 3.66 (d, *J* = 5.3 Hz, 2H), 3.26 (d, *J* = 4.0 Hz, 2H), 1.66 – 1.61 (m, 2H), 1.43 (s, 9H), 1.22 (t, *J* = 7.1 Hz, 3H), 0.98 – 0.91 (m, 1H), 0.87 – 0.82 (m, 6H).; **^{13}C NMR** (100 MHz,

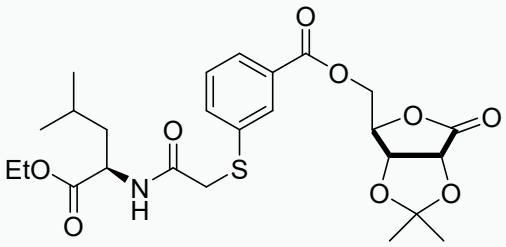
$CDCl_3$) δ 172.8, 172.2, 168.2, 155.4, 136.3, 134.7, 134.6, 129.7, 129.2, 127.9, 123.1, 122.1, 119.6, 118.8, 111.4, 109.5, 80.0, 66.3, 61.7, 54.6, 51.3, 41.6, 37.9, 28.5, 24.9, 22.9, 21.9, 14.2. **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{33}H_{43}N_3NaO_7S^+$, 648.2714. Found. 648.2725.

3-(tert-butyl) 4-(4-((2-(((6-methylheptyl)oxy)-2-oxoethyl)thio)benzyl) (R)-thiazolidine-3,4-dicarboxylate (3k):



Colorless oil. PE/EtOAc = 5/1, Rf = 0.5. Yield: 73% (76.7 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.36 – 7.33 (m, 2H), 7.30 – 7.25 (m, 1H), 7.19 – 7.17 (m, 1H), 5.22 – 5.06 (m, 2H), 4.81 (d, *J* = 90.5 Hz, 1H), 4.56 – 4.40 (m, 2H), 4.06 – 3.96 (m, 2H), 3.65 (s, 2H), 3.37 – 3.24 (m, 1H), 3.23 – 3.13 (m, 1H), 1.55 – 1.48 (m, 1H), 1.41 (d, *J* = 41.8 Hz, 9H), 1.31 – 1.18 (m, 8H), 0.88 – 0.79 (m, 6H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 170.5 (d, *J* = 27.1 Hz), 169.8 (s), 153.3 (d, *J* = 20.0 Hz), 136.5 (d, *J* = 11.5 Hz), 136.0 (d, *J* = 13.3 Hz), 129.3, 128.9 (d, *J* = 27.5 Hz), 126.4 (d, *J* = 22.0 Hz), 81.3, 68.1, 66.8, 61.7, 48.7 (d, *J* = 89.8 Hz), 38.8, 36.4, 34.0 (d, *J* = 140.7 Hz), 30.3, 29.0, 28.4, 23.7, 23.0, 14.1, 11.0. **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{26}H_{39}NNaO_6S_2^+$, 548.2111. Found. 548.2119.

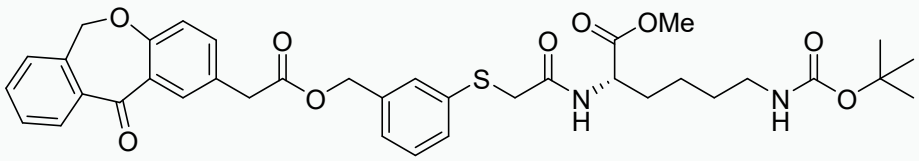
((4R)-2,2-dimethyl-6-oxotetrahydrofuro[3,4-d][1,3]dioxol-4-yl)methyl 3-((2-(((R)-1-ethoxy-4-methyl-1-oxopentan-2-yl)amino)-2-oxoethyl)thio)benzoate (3l):



Colorless oil. PE/EtOAc = 2/1, Rf = 0.3. Yield: 74% (77.5 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.88 (s, 1H), 7.72 (d, *J* = 7.8 Hz, 1H), 7.53 (d, *J* = 8.0 Hz, 1H), 7.39 (t, *J* = 7.8 Hz, 1H), 6.98 (d, *J* = 8.3 Hz, 1H), 4.89 (t, *J* = 2.6 Hz, 1H), 4.85 (d, *J* = 5.7 Hz, 1H), 4.79 (d, *J* = 5.7 Hz, 1H), 4.61 – 4.51 (m, 3H), 4.11 (q, *J* = 7.1 Hz, 2H), 3.69 (q, *J* = 16.6 Hz, 2H), 1.62 – 1.54 (m, 1H), 1.53 – 1.47 (m, 4H), 1.46 – 1.41 (m, 1H), 1.39 (s, 3H), 1.21 (t,

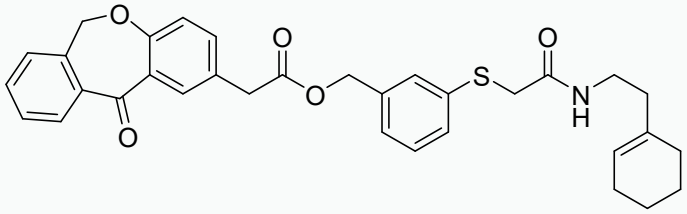
J = 7.1 Hz, 3H), 0.83 (d, *J* = 6.5 Hz, 6H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 173.7, 172.5, 167.3, 165.0, 136.4, 133.2, 130.0, 129.7, 129.1, 127.5, 114.1, 80.1, 77.9, 75.4, 64.2, 61.5, 51.2, 41.4, 37.1, 26.8, 25.6, 24.9, 22.9, 21.9, 14.2. **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{25}H_{33}NNaO_9S^+$, 546.1768. Found. 546.1776.

methyl N^6-(tert-butoxycarbonyl)-N^2-(2-((3-((2-(11-oxo-6,11-dihydrodibenzo[b,e]oxepin-2-yl)acetoxy)methyl)phenyl)thio)acetyl)-L-lysinate (3m):



Colorless oil. PE/EtOAc = 1/1, Rf = 0.4. Yield: 40% (55.3 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.13 – 8.12 (m, 1H), 7.89 – 7.87 (m, 1H), 7.58 – 7.53 (m, 1H), 7.49 – 7.41 (m, 2H), 7.36 (d, *J* = 7.4 Hz, 1H), 7.31 – 7.21 (m, 4H), 7.17 – 7.15 (m, 1H), 7.04 – 7.02 (m, 1H), 5.19 (s, 2H), 5.10 (s, 2H), 4.61 – 4.50 (m, 2H), 3.73 – 3.58 (m, 6H), 3.03 – 2.91 (m, 2H), 1.67 – 1.55 (m, 1H), 1.42 – 1.31 (m, 12H), 1.16 – 1.05 (m, 2H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 190.9, 172.4, 171.2, 167.7, 160.7, 156.1, 140.6, 137.2, 136.5, 135.7, 135.2, 132.9, 132.6, 129.6, 129.5, 129.4, 128.2, 128.0, 127.9, 127.7, 126.4, 125.3, 121.3, 79.2, 73.8, 66.1, 52.5, 52.3, 40.3, 37.5, 32.0, 29.6, 28.6, 22.4. **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{37}H_{42}N_2NaO_9S^+$, 713.2503. Found. 713.2547.

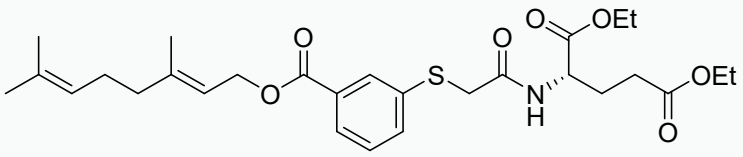
3-((2-((2-(cyclohex-1-en-1-yl)ethyl)amino)-2-oxoethyl)thio)benzyl 2-(11-oxo-6,11-dihydrodibenzo[b,e]oxepin-2-yl)acetate (3n):



Colorless oil. PE/EtOAc = 2/1, Rf = 0.2. Yield: 61% (67.8 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.13 (d, *J* = 2.3 Hz, 1H), 7.88 (d, *J* = 7.6 Hz, 1H), 7.58 – 7.53 (m, 1H), 7.49 – 7.40 (m, 2H), 7.36 (d, *J* = 7.4 Hz, 1H), 7.28 – 7.24 (m, 1H), 7.22 – 7.12 (m, 3H), 7.03 (d, *J* = 8.4 Hz, 1H), 6.84 (br, 1H), 5.27 (s, 1H), 5.18 (s, 2H), 5.09 (s, 2H), 3.69 (s, 2H), 3.61 (s, 2H), 3.30 (dd, *J* = 12.4, 6.5 Hz, 2H), 2.04 (t, *J* = 6.6 Hz, 2H), 1.89 – 1.77 (m, 4H), 1.56 – 1.48 (m, 2H), 1.48 – 1.40 (m, 2H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 190.9, 171.2,

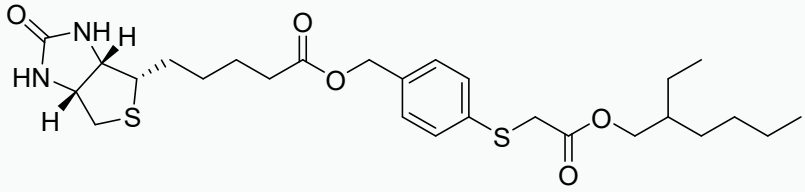
167.3, 160.7, 140.6, 137.1, 136.5, 135.7, 135.6, 134.3, 132.9, 132.6, 129.6, 129.5, 129.4, 127.9, 127.7, 127.2, 127.1, 126.1, 125.3, 124.1, 121.2, 73.8, 66.2, 40.2, 37.4, 37.4, 37.1, 27.8, 25.3, 22.8, 22.4. **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{33}H_{33}NNaO_5S^+$, 578.1972 . Found. 578.1977.

diethyl (E)-(2-((3-(((3,7-dimethylocta-2,6-dien-1-yl)oxy)carbonyl)phenyl)thio)acetyl)-L-glutamate (3o):



Colorless oil. PE/EtOAc = 2/1, Rf = 0.5. Yield: 25% (26.7 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.02 (t, *J* = 1.5 Hz, 1H), 7.88 (d, *J* = 7.8 Hz, 1H), 7.53 – 7.48 (m, 1H), 7.37 (t, *J* = 7.8 Hz, 1H), 7.32 (d, *J* = 7.9 Hz, 1H), 5.46 (t, *J* = 7.1 Hz, 1H), 5.11 (t, *J* = 6.8 Hz, 1H), 4.80 (d, *J* = 7.2 Hz, 2H), 4.60 – 4.52 (m, 1H), 4.20 – 4.12 (m, 2H), 4.07 (q, *J* = 7.1 Hz, 2H), 3.68 (q, *J* = 16.7 Hz, 2H), 2.26 – 2.07 (m, 7H), 1.97 – 1.88 (m, 1H), 1.79 (s, 3H), 1.67 (s, 3H), 1.60 (s, 3H), 1.29 – 1.19 (m, 6H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 172.6, 171.4, 167.6, 165.8, 143.0, 135.3, 132.8, 132.4, 131.8, 130.1, 129.4, 128.2, 123.7, 119.2, 62.1, 61.9, 60.8, 52.1, 37.7, 32.4, 30.1, 27.4, 26.8, 25.8, 23.7, 17.8, 14.3, 14.2. **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{28}H_{39}NNaO_7S^+$, 556.2339. Found. 556.2346.

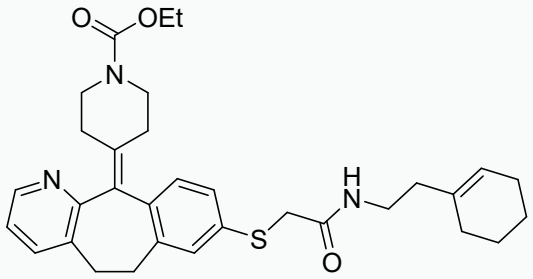
4-((2-((2-ethylhexyl)oxy)-2-oxoethyl)thio)benzyl 5-((3aS,4S,6aR)-2-oxohexahydro-1H-thieno[3,4-d]imidazol-4-yl)pentanoate (3p):



Colorless oil. DCM/MeOH = 20/1, Rf = 0.5. Yield: 58% (62.3 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.39 – 7.24 (m, 4H), 6.00 (br, 1H), 5.47 (br, 1H), 5.05 (s, 2H), 4.51 – 4.40 (m, 1H), 4.32 – 4.21 (m, 1H), 4.01 (dd, *J* = 5.5, 2.8 Hz, 2H), 3.65 (s, 2H), 3.15 – 3.06 (m, 1H), 2.86 (dd, *J* = 12.7, 4.7 Hz, 1H), 2.67 (d, *J* = 12.8 Hz, 1H), 2.36 (t, *J* = 7.4 Hz, 2H), 1.75 – 1.61 (m, 4H), 1.57 – 1.48 (m, 1H), 1.48 – 1.36 (m, 2H), 1.30 – 1.19 (m, 8H), 0.91 – 0.77 (m, 6H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 173.5, 169.9, 163.8, 135.5, 134.7, 129.5, 129.1, 68.1, 65.7, 62.0, 60.2, 55.5, 40.6, 38.8, 36.4, 34.0, 30.3, 29.0, 28.4, 28.3, 24.9,

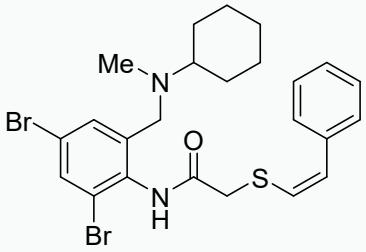
23.7, 23.0, 14.2, 11.0. **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{27}H_{40}N_2NaO_5S_2^+$, 559.2271. Found. 559.2279.

ethyl 4-(8-((2-((2-(cyclohex-1-en-1-yl)ethyl)amino)-2-oxoethyl)thio)-5,6-dihydro-11H-benzo[5,6]cyclohepta[1,2-b]pyridin-11-ylidene)piperidine-1-carboxylate (3q):



White solid. DCM/MeOH = 20/1, Rf = 0.5. Yield: 74% (80.8 mg); **Melting point**: 147 – 149 °C. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.35 (dd, *J* = 4.7, 1.3 Hz, 1H), 7.40 (dd, *J* = 7.7, 1.2 Hz, 1H), 7.11 – 6.97 (m, 4H), 6.86 (t, *J* = 5.1 Hz, 1H), 5.23 (s, 1H), 4.10 (q, *J* = 7.1 Hz, 2H), 3.77 (br, 2H), 3.56 (s, 2H), 3.40 – 3.22 (m, 4H), 3.14 – 3.04 (m, 2H), 2.84 – 2.69 (m, 2H), 2.48 – 2.39 (m, 1H), 2.34 – 2.21 (m, 3H), 2.00 (t, *J* = 6.6 Hz, 2H), 1.76 – 1.73 (m, 4H), 1.42 – 1.37 (m, 2H), 1.33 – 1.28 (m, 2H), 1.21 (t, *J* = 7.1 Hz, 3H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 167.4, 157.3, 155.5, 146.7, 138.9, 137.6, 137.4, 137.3, 134.5, 134.1, 133.8, 133.5, 130.2, 128.0, 125.2, 124.0, 122.3, 61.4, 44.9, 44.8, 37.3, 37.2, 37.1, 31.9, 31.6, 30.8, 30.6, 27.7, 25.2, 22.7, 22.2, 14.7. **HRMS (ESI)** m/z : $(M+H)^+$ Calc. for: $C_{32}H_{40}N_3O_3S^+$, 546.2785. Found. 546.2795.

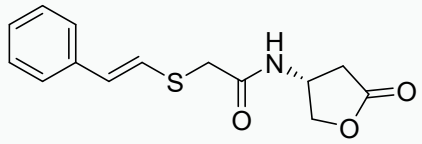
(Z)-N-(2,4-dibromo-6-((cyclohexyl(methyl)amino)methyl)phenyl)-2-(styrylthio)acetamide (3r):



Colorless oil. PE/acetone = 7/1, Rf = 0.4. Yield: 48% (53.0 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 9.78 (br, 1H), 7.71 – 7.70 (m, 1H), 7.46 – 7.74 (m, 2H), 7.40 – 7.32 (m, 2H), 7.30 – 7.29 (m, 1H), 7.24 – 7.23 (m, 1H), 6.56 (d, *J* = 10.8 Hz, 1H), 6.37 (d, *J* = 10.8 Hz, 1H), 3.60 (s, 2H), 3.51 (s, 2H), 2.46 – 2.31 (m, 1H), 2.04 (s, 3H), 1.82 – 1.69 (m, 5H), 1.23 – 1.04 (m, 5H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 166.2, 136.5, 135.3, 134.9, 132.0,

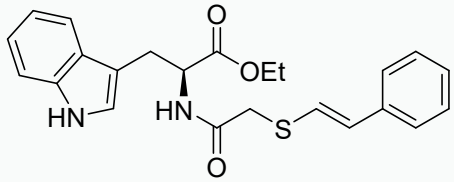
128.9, 128.5, 127.9, 127.3, 126.0, 124.8, 122.2, 120.1, 62.3, 57.2, 38.9, 36.3, 28.3, 26.3, 26.0. **HRMS (ESI)** m/z : $(M+H)^+$ Calc. for: $C_{24}H_{29}Br_2N_2OS^+$, 551.0362. Found. 551.0374.

(R,E)-N-(5-oxotetrahydrofuran-3-yl)-2-(styrylthio)acetamide (3s):



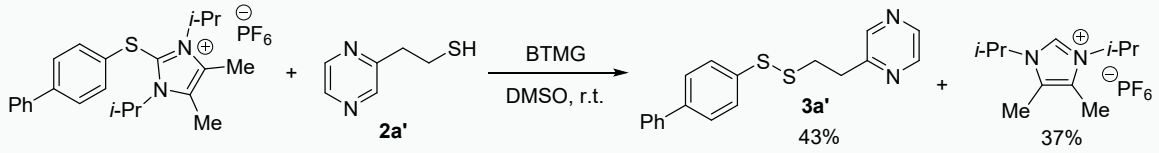
Colorless oil. PE/EtOAc = 1/1, Rf = 0.2. Yield: 57% (31.6 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.33 – 7.27 (m, 4H), 7.23 – 7.19 (m, 2H), 6.65 (d, *J* = 15.5 Hz, 1H), 6.57 (d, *J* = 15.5 Hz, 1H), 4.63 – 4.53 (m, 1H), 4.44 (td, *J* = 9.1, 0.9 Hz, 1H), 4.30 – 4.20 (m, 1H), 3.55 (s, 2H), 2.80 – 2.71 (m, 1H), 2.22 – 2.09 (m, 1H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 174.9, 168.8, 136.3, 130.5, 128.9, 127.8, 126.1, 121.6, 66.1, 49.6, 36.3, 30.0. **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{14}H_{15}NNaO_3S^+$, 300.0665. Found. 300.0674.

ethyl (E)-(2-(styrylthio)acetyl)-L-tryptophanate (3t):

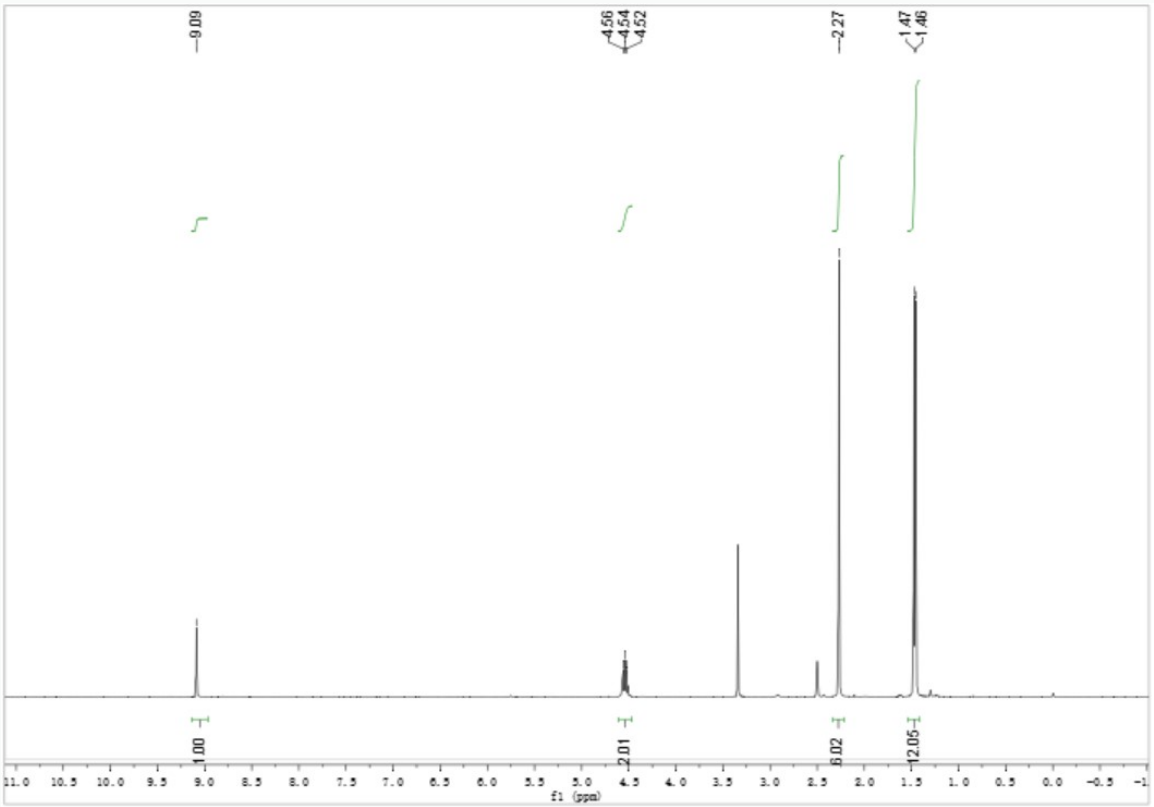


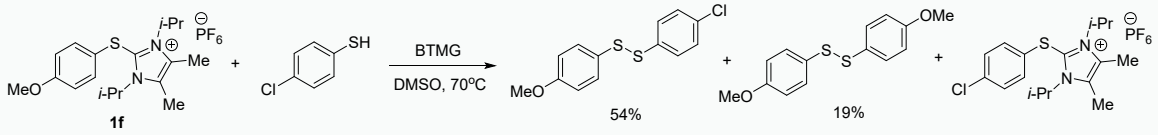
Colorless oil. PE/EtOAc = 2/1, Rf = 0.4. Yield: 56% (45.8 mg); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.83 (s, 1H), 7.54 (d, *J* = 7.9 Hz, 1H), 7.33 – 7.07 (m, 9H), 6.91 (d, *J* = 2.3 Hz, 1H), 6.47 (d, *J* = 15.5 Hz, 1H), 6.42 (d, *J* = 15.5 Hz, 1H), 4.92 – 4.84 (m, 1H), 4.17 – 4.04 (m, 2H), 3.45 (s, 2H), 3.40 – 3.25 (m, 2H), 1.18 (t, *J* = 7.1 Hz, 3H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 171.6, 167.8, 136.4, 136.1, 129.7, 128.8, 127.6, 126.0, 123.0, 122.3, 122.2, 119.7, 118.6, 111.4, 109.8, 100.1, 61.7, 53.4, 36.4, 27.5, 14.1. **HRMS (ESI)** m/z : $(M+Na)^+$ Calc. for: $C_{23}H_{24}N_2NaO_3S^+$, 431.1400. Found. 431.1408.

10. Control experiments:

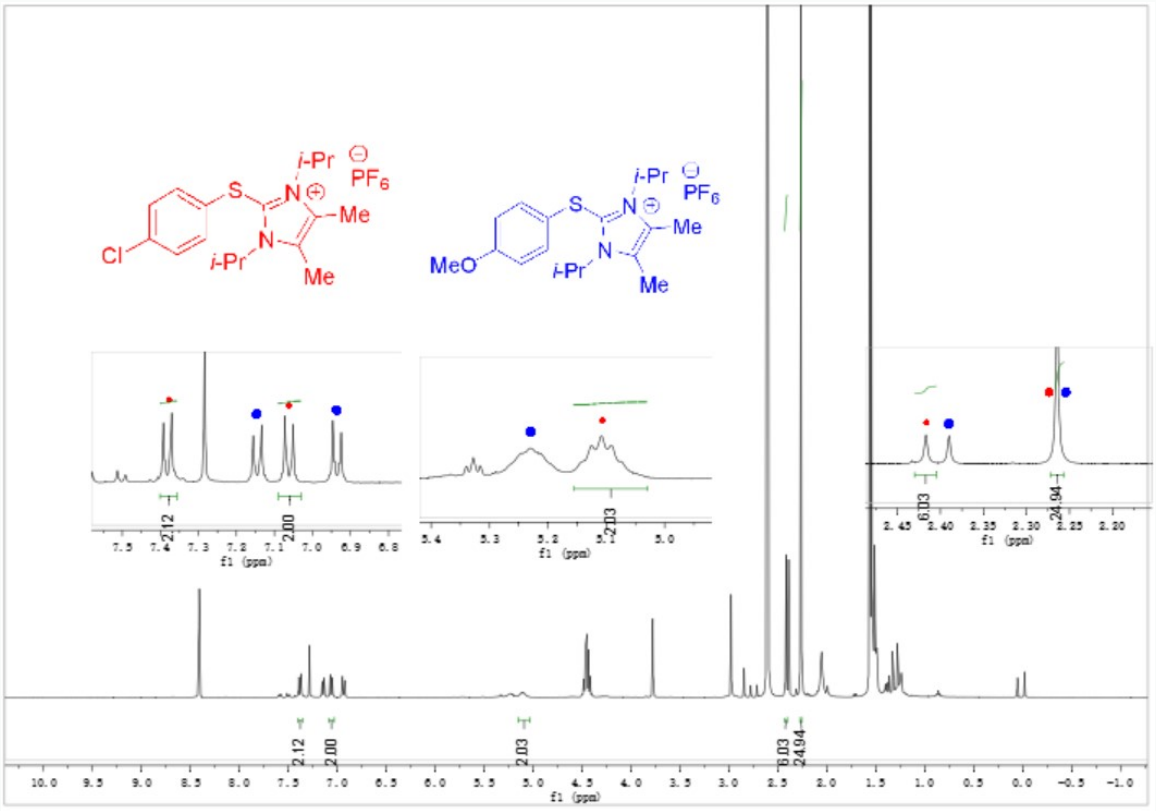


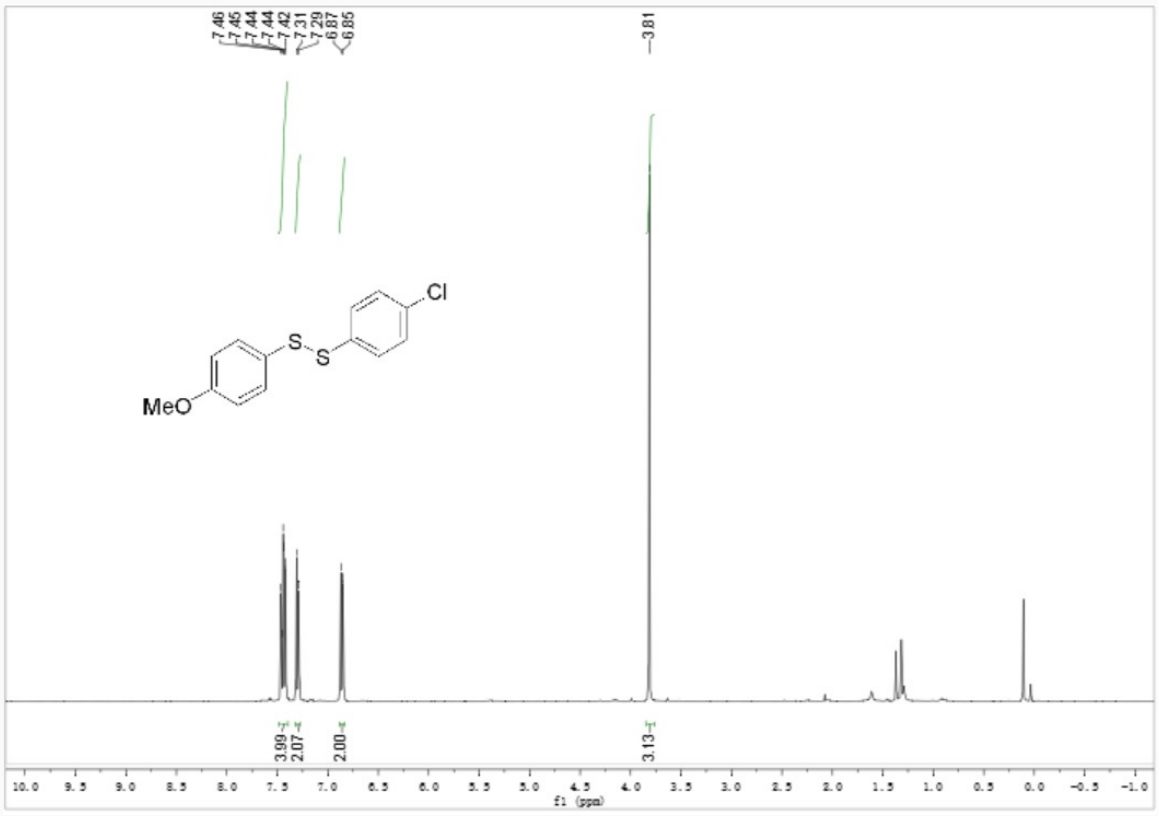
To a stirring solution of thioimidazolium salt **1b** (0.2 mmol, 102.1 mg), and thiol **2a'** (0.8 mmol, 112.0 mg) in DMSO (1 mL) was added BTMG (0.4 mmol, 68.4 mg) at 20 ℃. The solution was stirred at 20 ℃ for 10h. After completed, the reaction mixture was subjected to silica gel column chromatography (300-400 mesh silica gel) to afford the product **3a'** (27.9 mg, 43%). Colorless oil. PE/EtOAc = 2/1, Rf = 0.4. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.49 (s, 1H), 8.42 (d, *J* = 2.5 Hz, 2H), 7.63 – 7.53 (m, 6H), 7.46 – 7.42 (m, 2H), 7.37 – 7.34 (m, 1H), 3.29 – 3.13 (m, 4H).; **^{13}C NMR** (100 MHz, $CDCl_3$) δ 155.1, 145.1, 144.3, 142.8, 140.3, 140.2, 136.2, 129.0, 128.5, 127.9, 127.6, 127.1, 37.3, 34.4. **HRMS (ESI)** m/z : $(M+H)^+$ Calc. for: $C_{18}H_{17}N_2S_2^+$, 325.0828. Found. 325.0837. The imidazolium salt was meanwhile isolated in 37% yield (24.1 mg). **^{1}H NMR** (400 MHz, *d*-DMSO) δ 9.09 (s, 1H), 4.59 – 4.45 (m, 2H), 2.27 (s, 6H), 1.46 (d, *J* = 6.7 Hz, 12H).

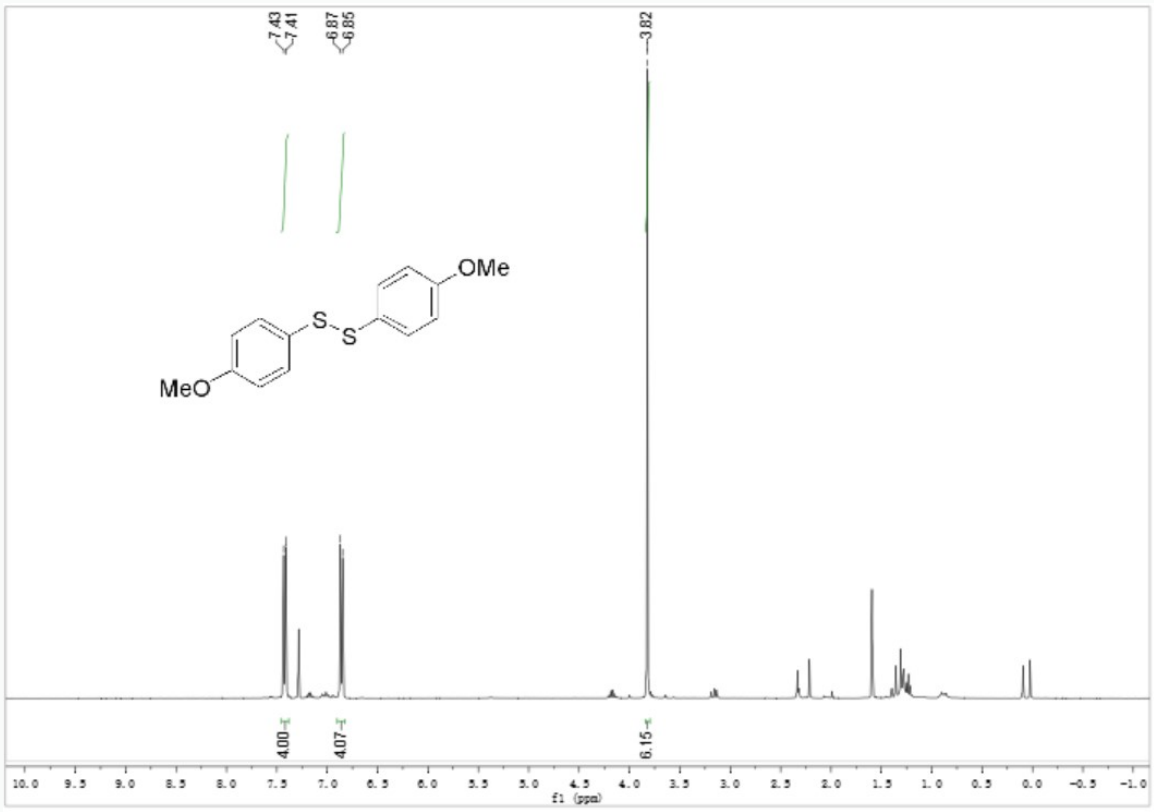




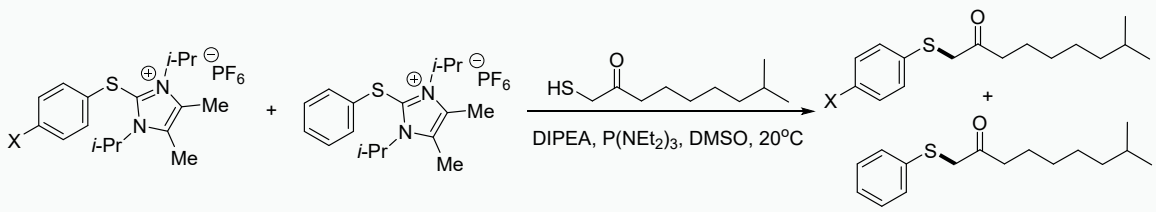
To a stirring solution of thioimidazolium salt **1f** (0.2 mmol, 92.9 mg), and 4-chlorothiophenol (0.6 mmol, 86.8 mg) in DMSO (1 mL) was added BTMG (0.2 mmol, 34.2 mg) at r.t.. The solution was stirred at 70 ℃ for 4h. After completed, the reaction mixture was subjected to silica gel column chromatography (300-400 mesh silica gel) to afford the disulfides. A mixture of **1f** and 4-Cl-phenylthioimidazolium salt was observed meanwhile.







11. Hammett-Analysis:

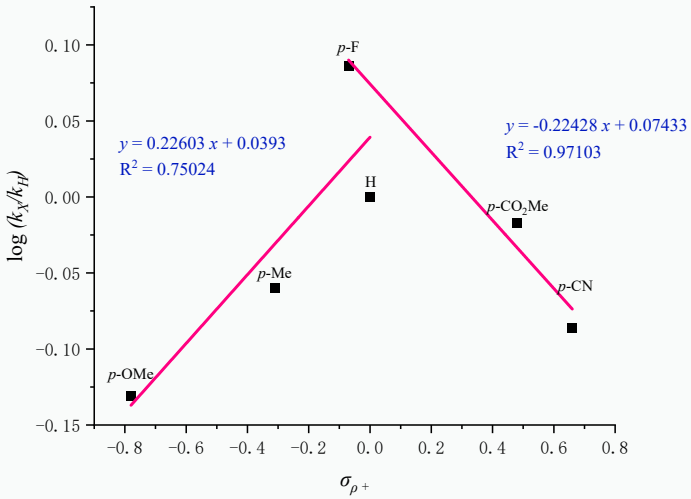


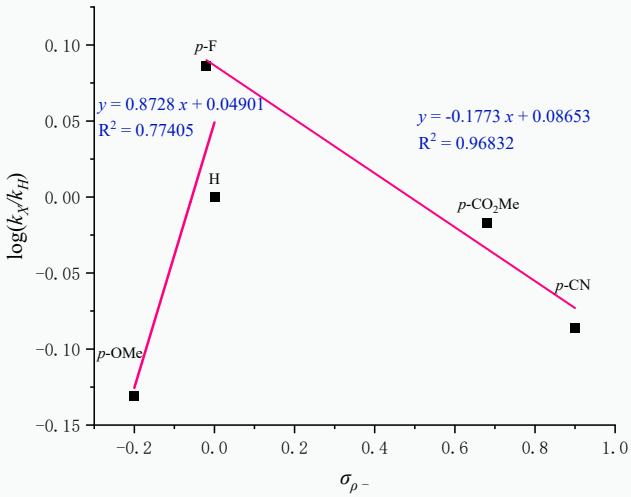
To a stirring solution of thioimidazolium salt **1a** (0.1 mmol), *para*-substitued thioimidazolium derivatives (0.1 mmol), $P(NEt_2)_3$ (0.4 mmol) and thiol **2a** (0.4 mmol) in DMSO (1 mL) was added DIPEA (0.4 mmol) at 20 ℃. The solution was stirred at 20 ℃ for 10 min. After completed, the reaction mixture was then passed through a short column (300-400 mesh silica gel, PE:EtOAc = 10:1) and concentrated under reduced pressure to afford the residue which was analyzed by ^1H NMR spectroscopy in $CDCl_3$. The resulting ^1H resonances of the -SCH_2- of the products were integrated to calculate the ratio of products. Based on the Hammett equation ($(\log (k_X/k_H) = \sigma_\rho$, k_H is the reference reaction rate of the unsubstituted reactant, and k_X that of a substituted reactant), for any two reactions with two aromatic reactants which only differs in the type of substituents, their change in free energy of activation is proportional to the change in Gibbs free energy.

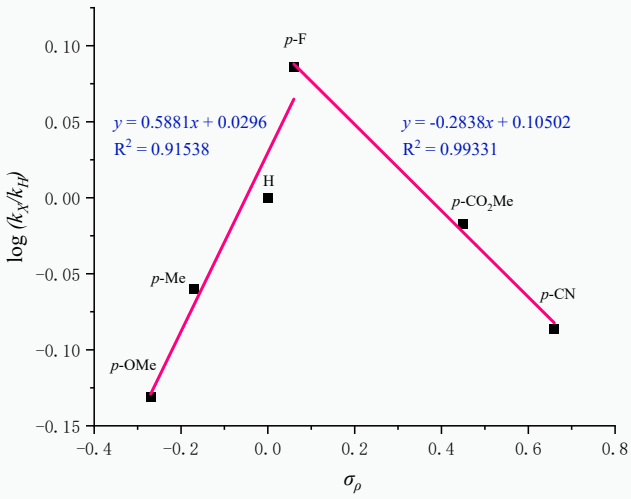
Table S1: Data for Hammett-Plot.

No.	Substituent X	$\sigma_{\rho+}$	$\sigma_{\rho-}$	σ_ρ	k_X/k_H	$\log (k_X/k_H)$
1	OMe	-0.78	-0.20	-0.27	0.74	-0.131
2	Me	-0.31		-0.17	0.87	-0.060
3	H	0	0	0	1	0
4	F	-0.07	-0.02	0.06	1.22	0.086
5	COOMe	0.48	0.68	0.45	0.96	-0.017
6	CN	0.66	0.90	0.66	0.82	-0.086

The values (No. 1-4 and No. 4-6, separately) of $\log(k_X/k_H)$ were plotted versus σ_{p+}, σ_{p-} and σ_p values and a linear fit was created to obtain the Hammett-slope ρ.


y = 0.22603 x + 0.0393
R2 = 0.75024
y = -0.22428 x + 0.07433
R2 = 0.97103
p-F
H
p-CO2Me
p-Me
p-CN
p-OMe
log (kX/kH)
σρ+


y = 0.8728 x + 0.04901
R2 = 0.77405
y = -0.1773 x + 0.08653
R2 = 0.96832
p-F
H
p-CO2Me
p-CN
p-OMe
log(kX/kH)
σρ−


y = 0.5881x + 0.0296
R2 = 0.91538
y = -0.2838x + 0.10502
R2 = 0.99331
p-F
H
p-CO2Me
p-Me
p-CN
p-OMe
log (kX/kH)
σρ

12. References:

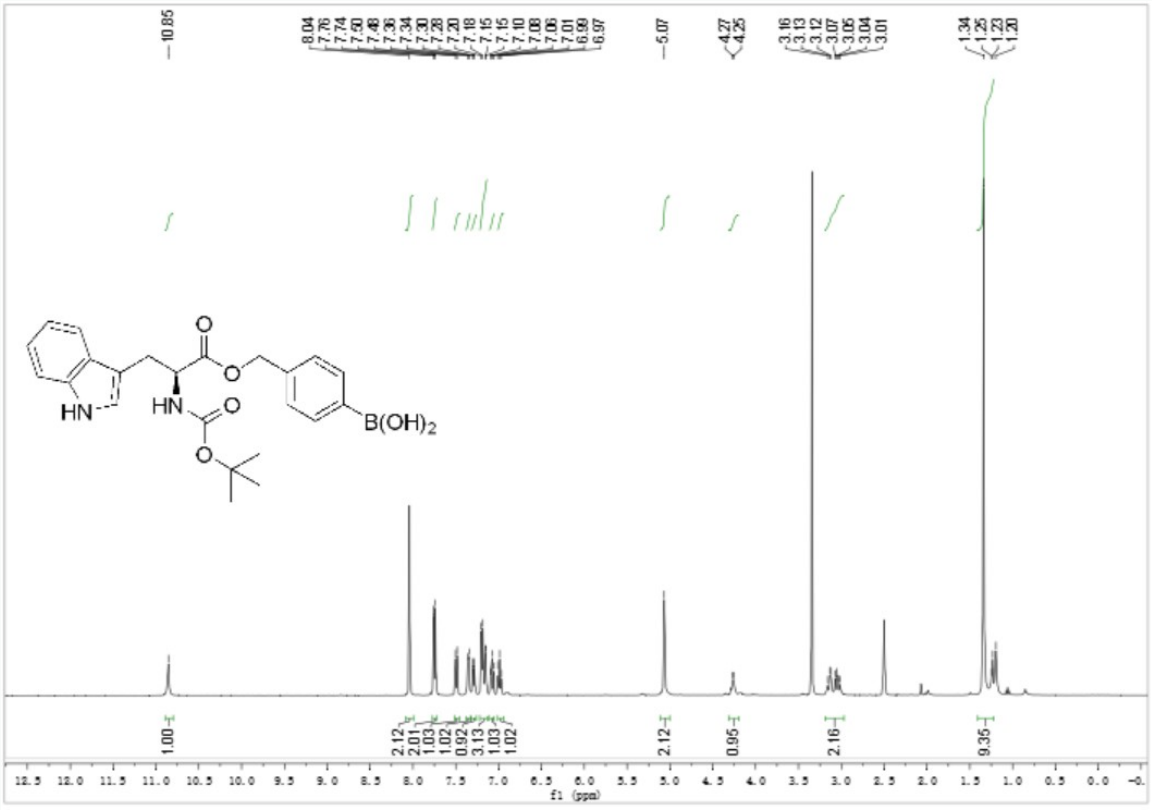
[1] Polyanionic self-healing hydrogels for the controlled release of cisplatin. Y. Tian, Y. Zeng, Y. Li, X. He, H. Wu, Y. Wei, Y. Wu, X. Wang, L. Tao, *Eur. Polym. J.* **2020**, *133*, 109773.

[2] *N*-Aminopyridinium reagents as traceless activating groups in the synthesis of *N*-Aryl aziridines. H. Tao, S. Samanta, A. Maity, P. Roychowdhury, D. Powers. *Nat Commun* **2022**, *13*, 3341.

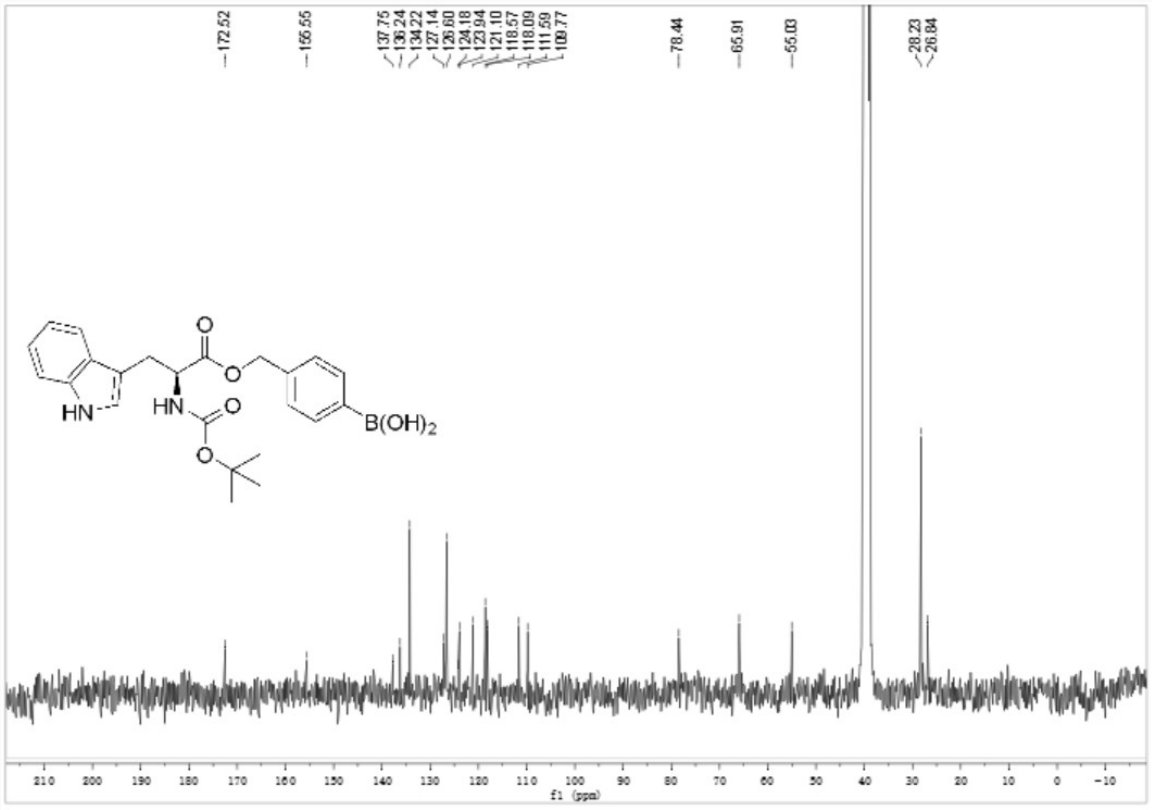
[3] A Direct Introduction of the Mercaptoacetic Acid Unit into Amino Acid Esters. G. A. Kraus,* J. Bae, P. K. Choudhury. *Syntheis,* **2003**, *1*, 19-20.

Spectra Data

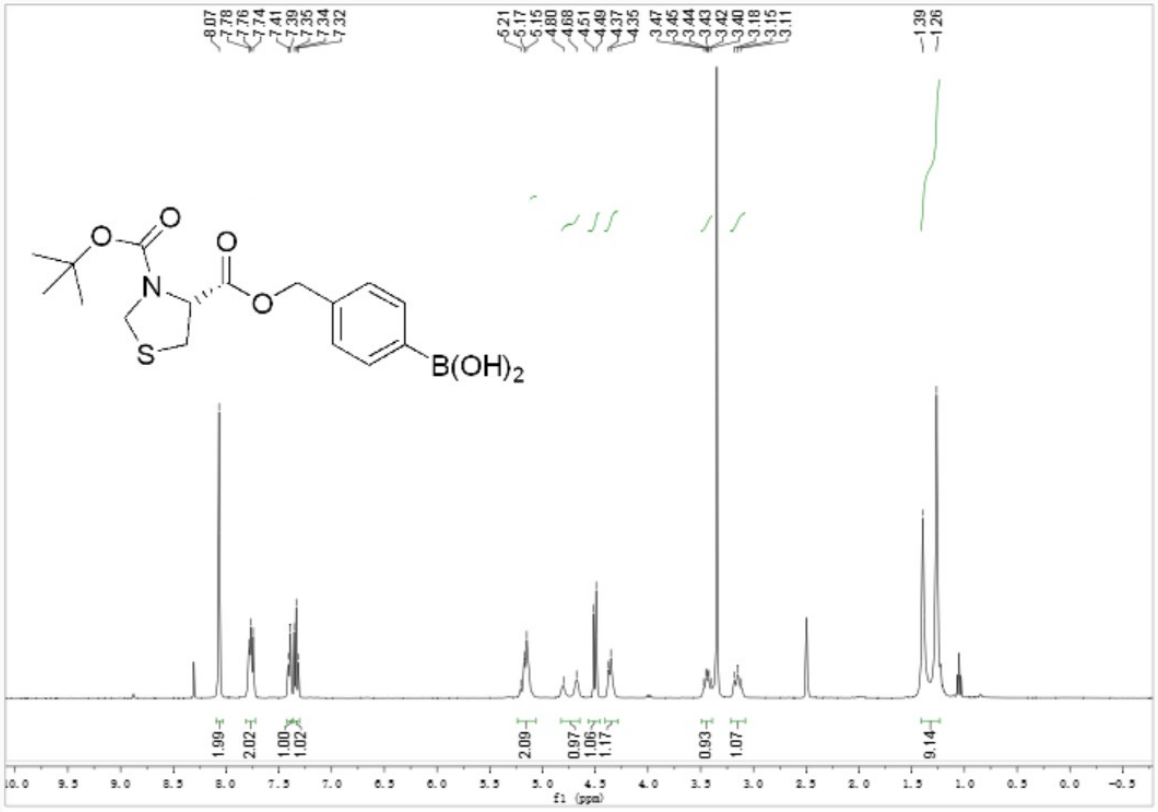
^{1}H NMR spectrum of **a1** (*d*-DMSO, 400 MHz)



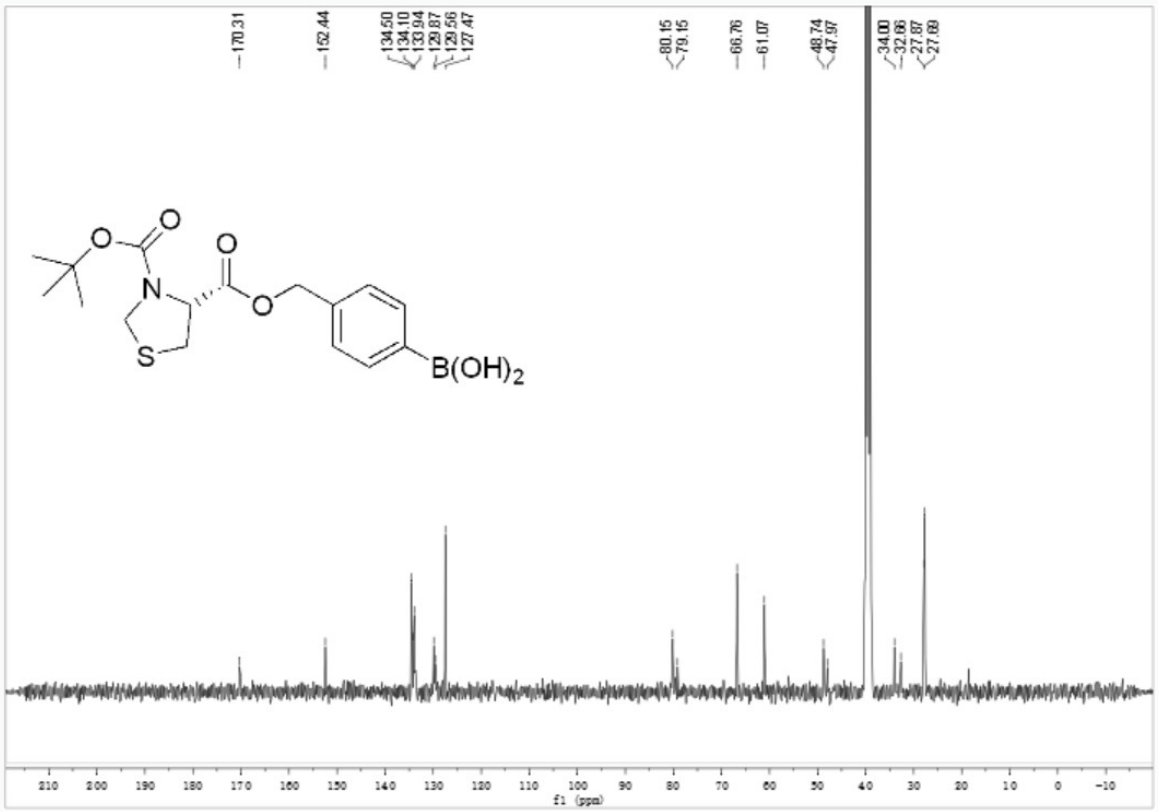
^{13}C NMR spectrum of **a1** (*d*-DMSO, 100 MHz)



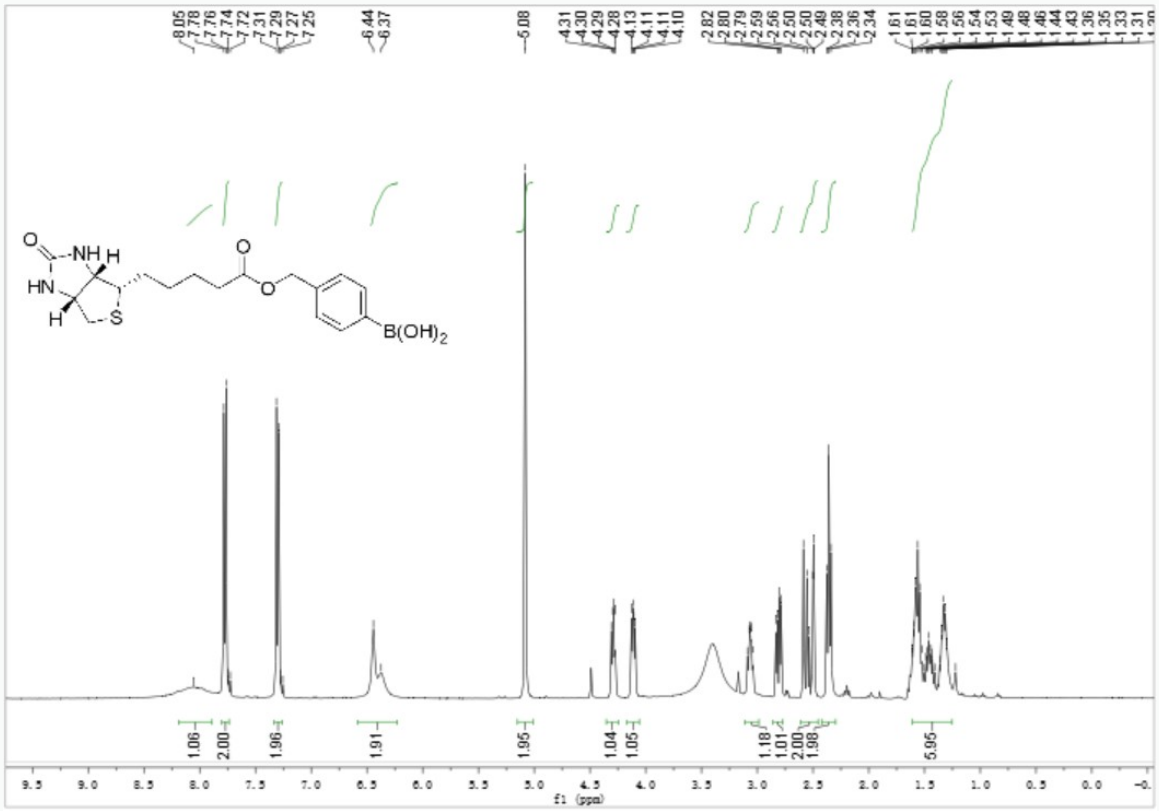
^{1}H NMR spectrum of **a2** (*d*-DMSO, 400 MHz)



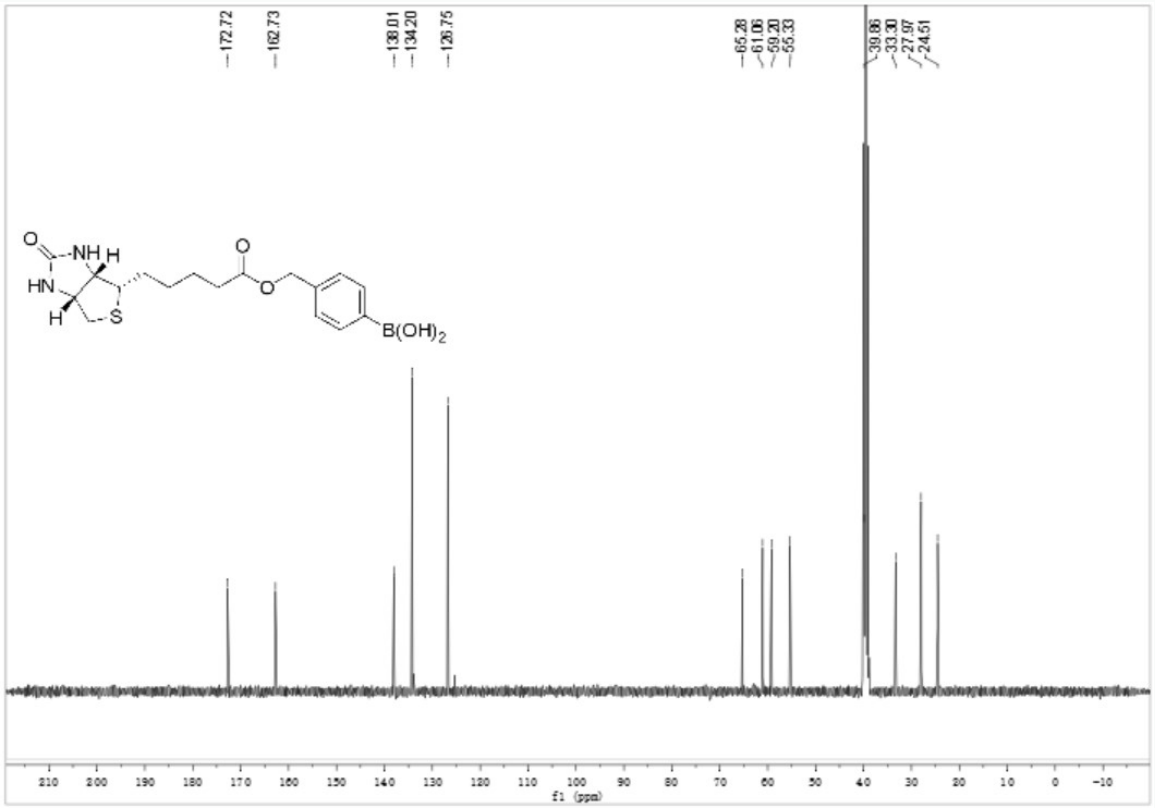
^{13}C NMR spectrum of **a2** (*d*-DMSO, 100 MHz)



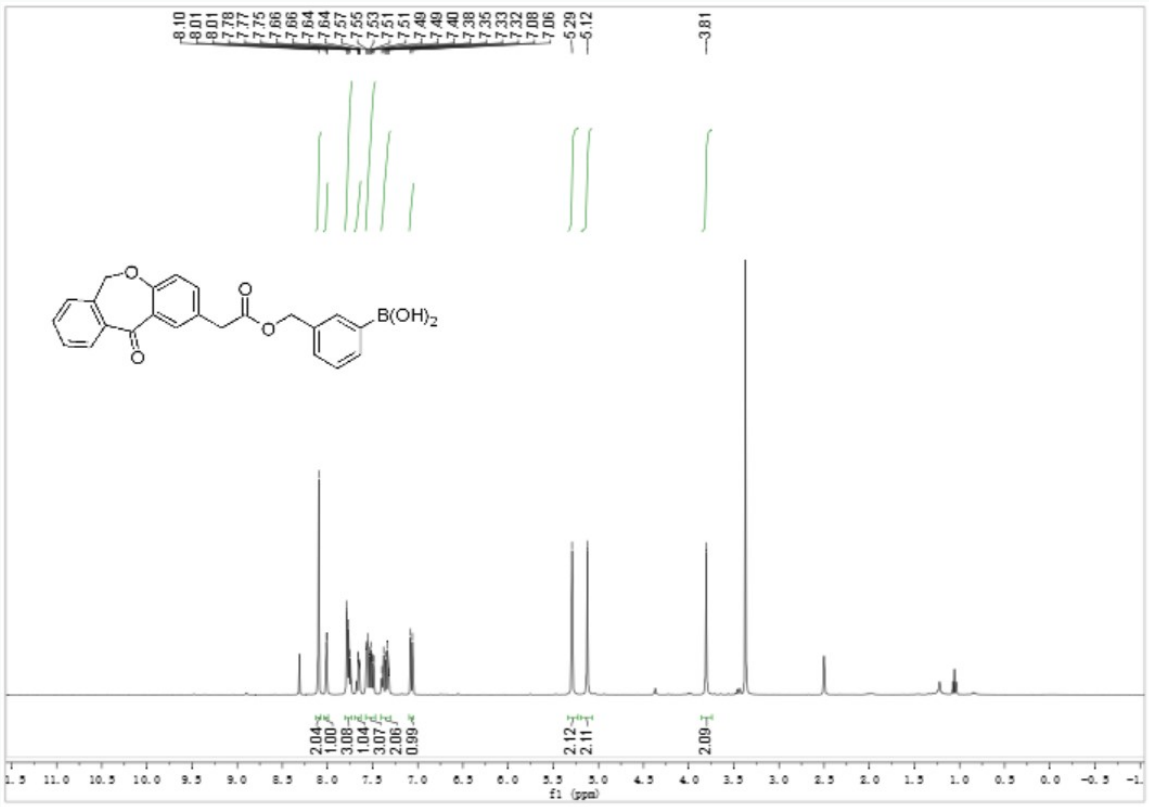
^{1}H NMR spectrum of **a3** (*d*-DMSO, 400 MHz)



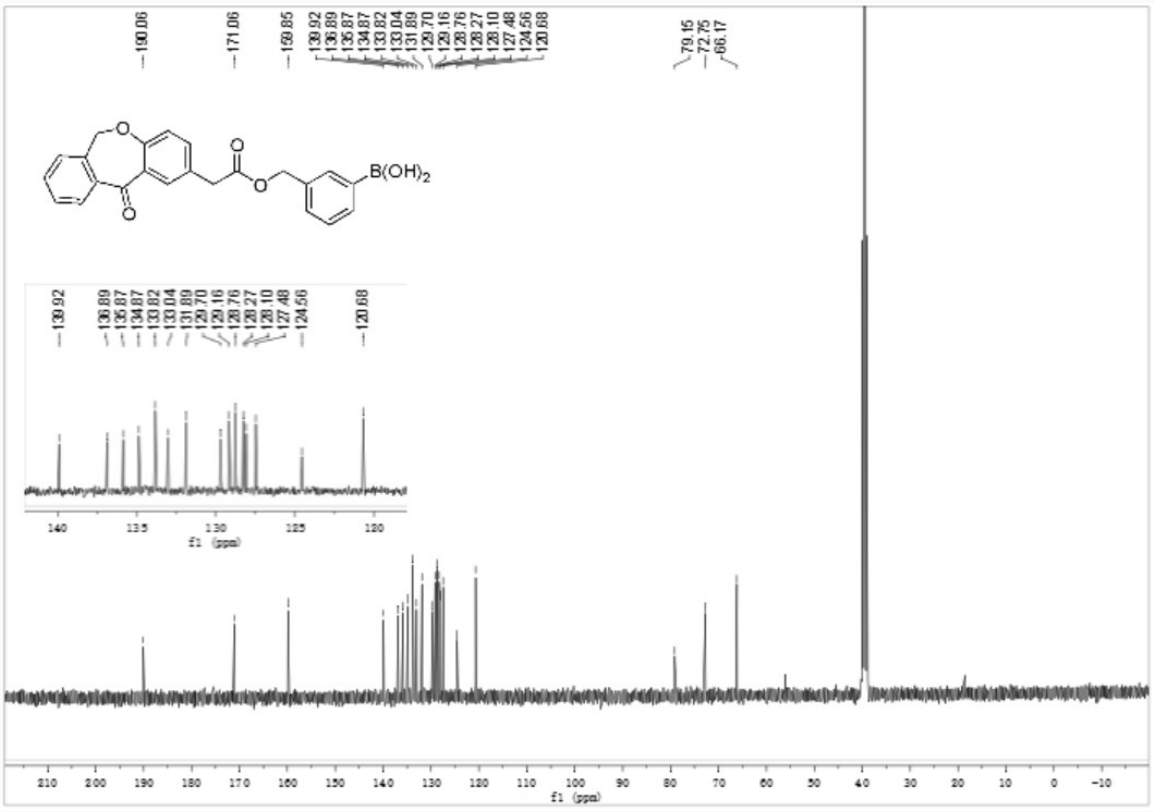
^{13}C NMR spectrum of **a3** (*d*-DMSO, 100 MHz)



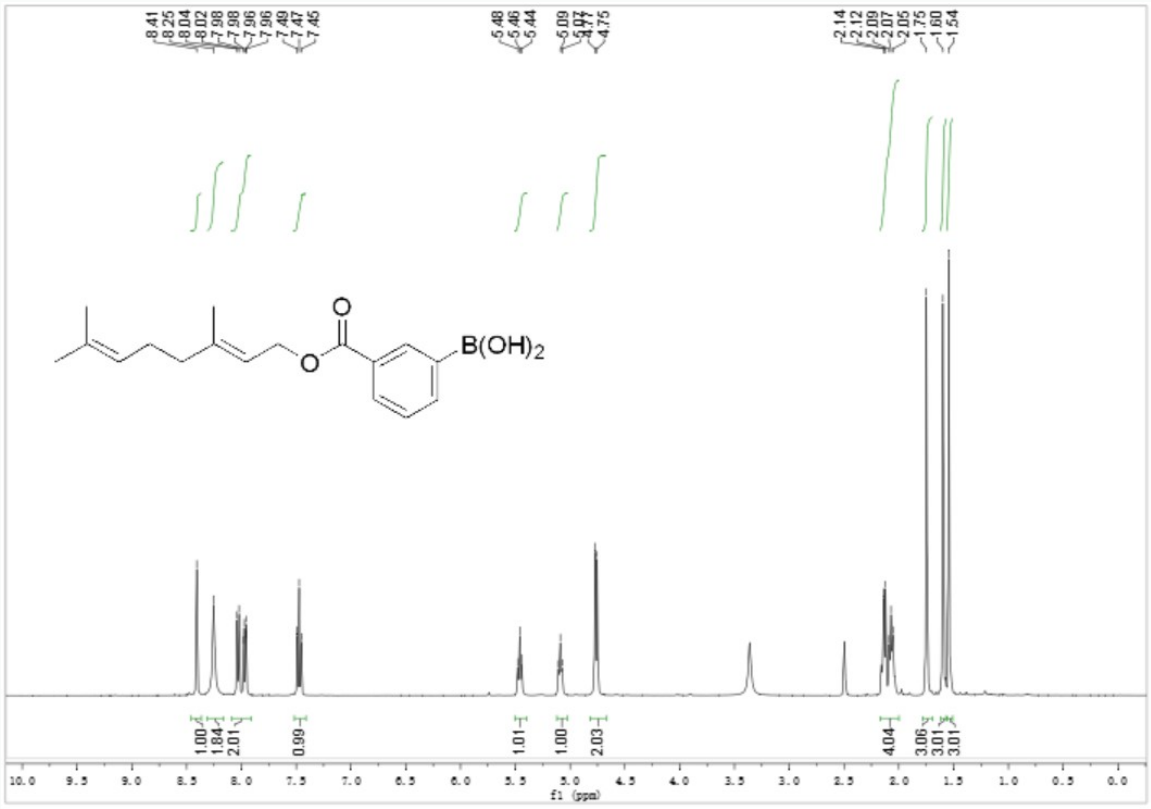
^{1}H NMR spectrum of **a4** (*d*-DMSO, 400 MHz)



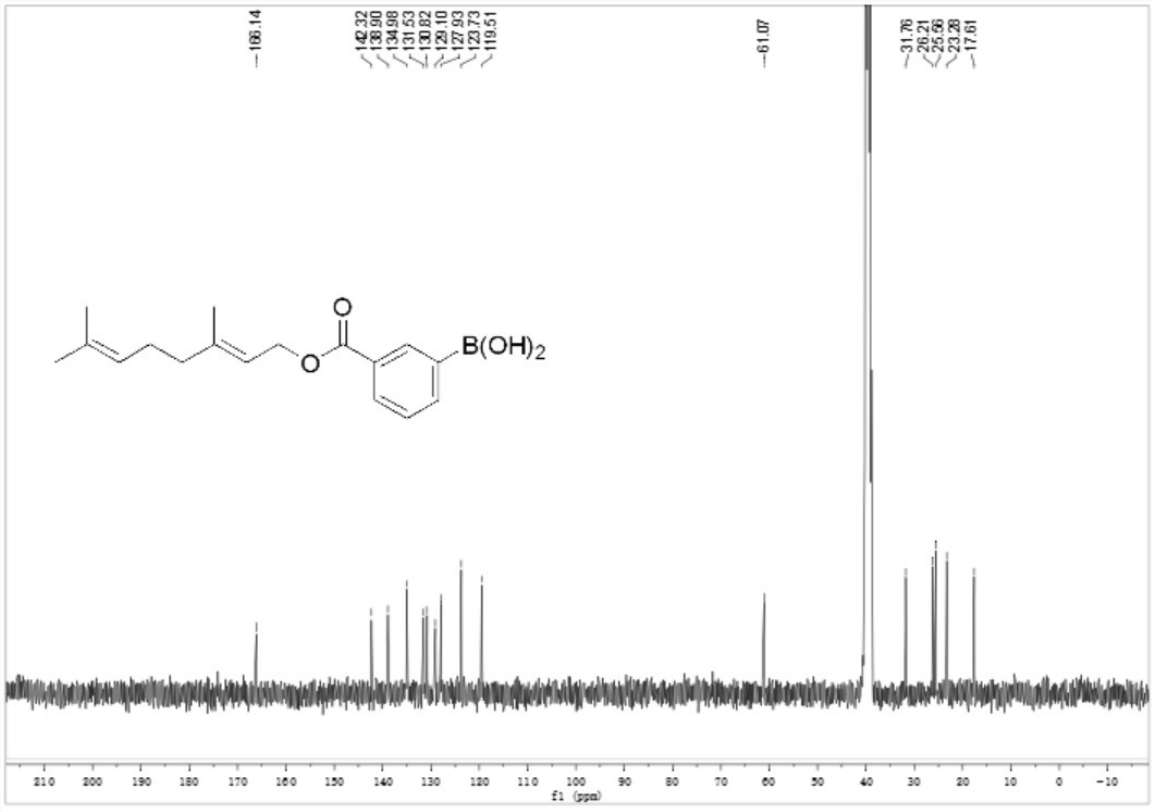
^{13}C NMR spectrum of **a4** (*d*-DMSO, 100 MHz)



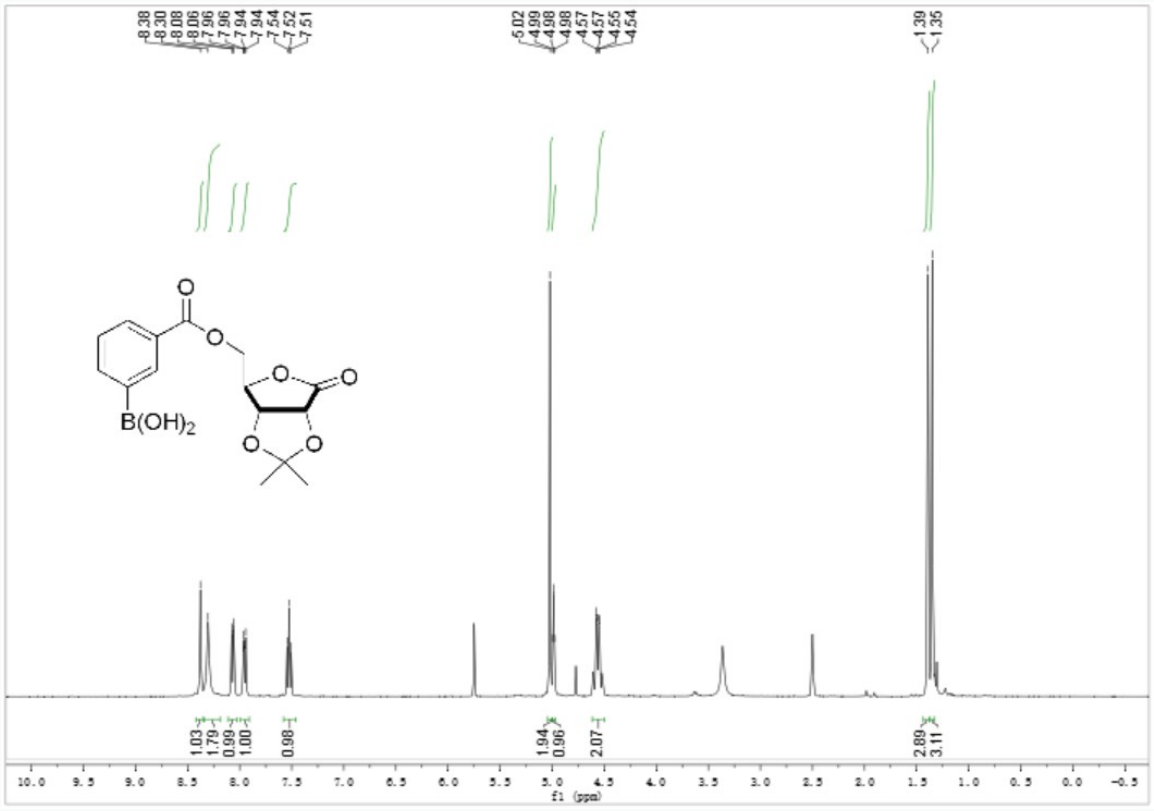
^{1}H NMR spectrum of **a5** (*d*-DMSO, 400 MHz)



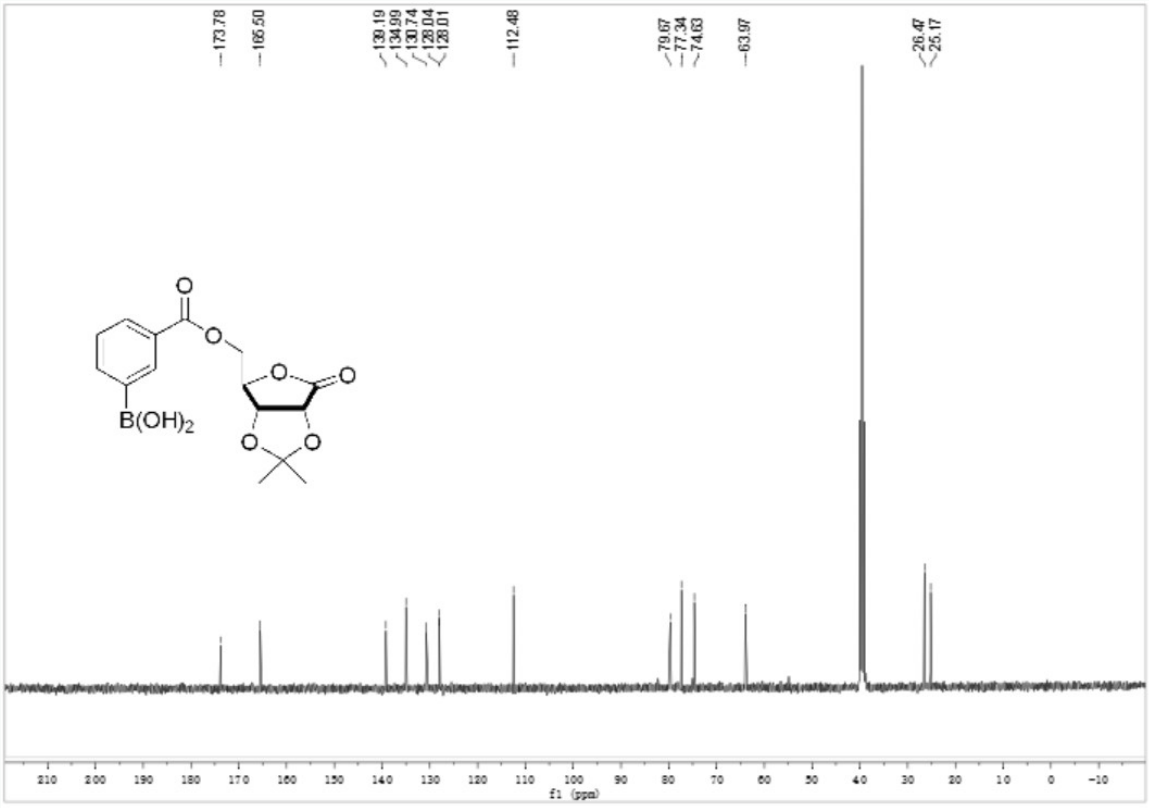
^{13}C NMR spectrum of **a5** (*d*-DMSO, 100 MHz)



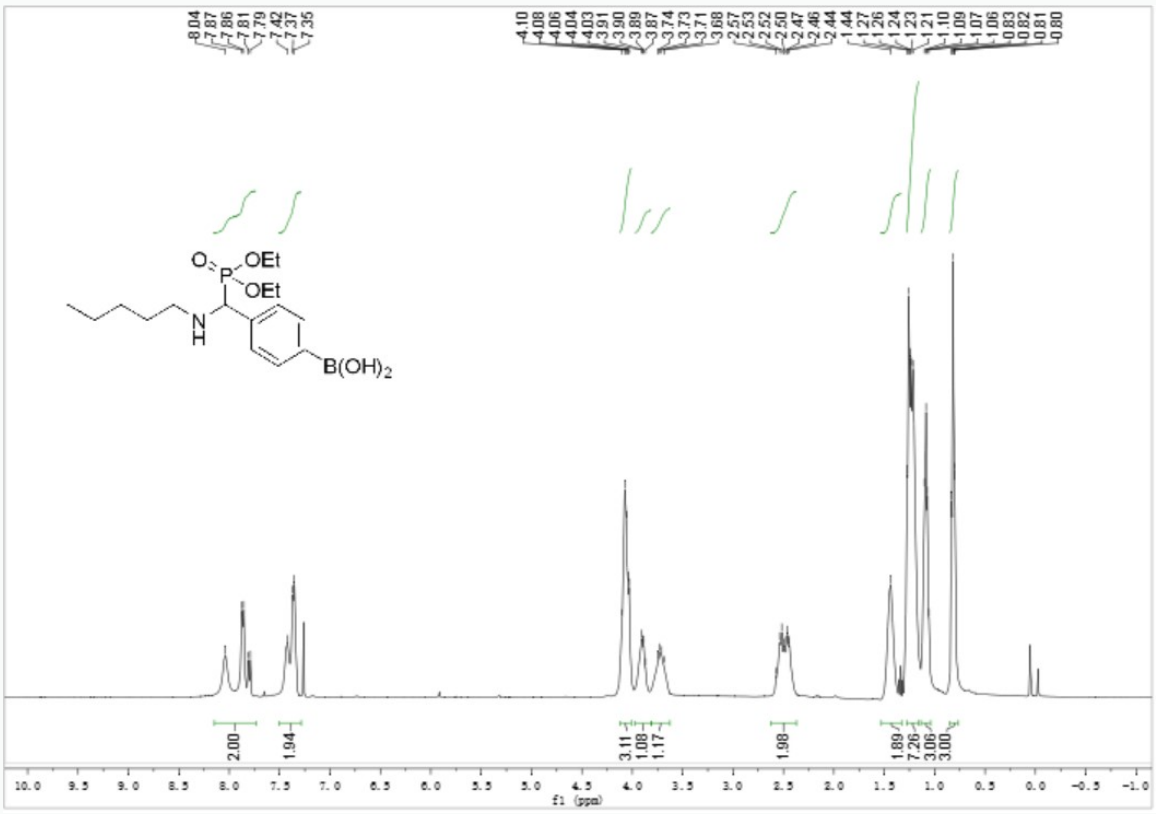
^{1}H NMR spectrum of **a6** (*d*-DMSO, 400 MHz)



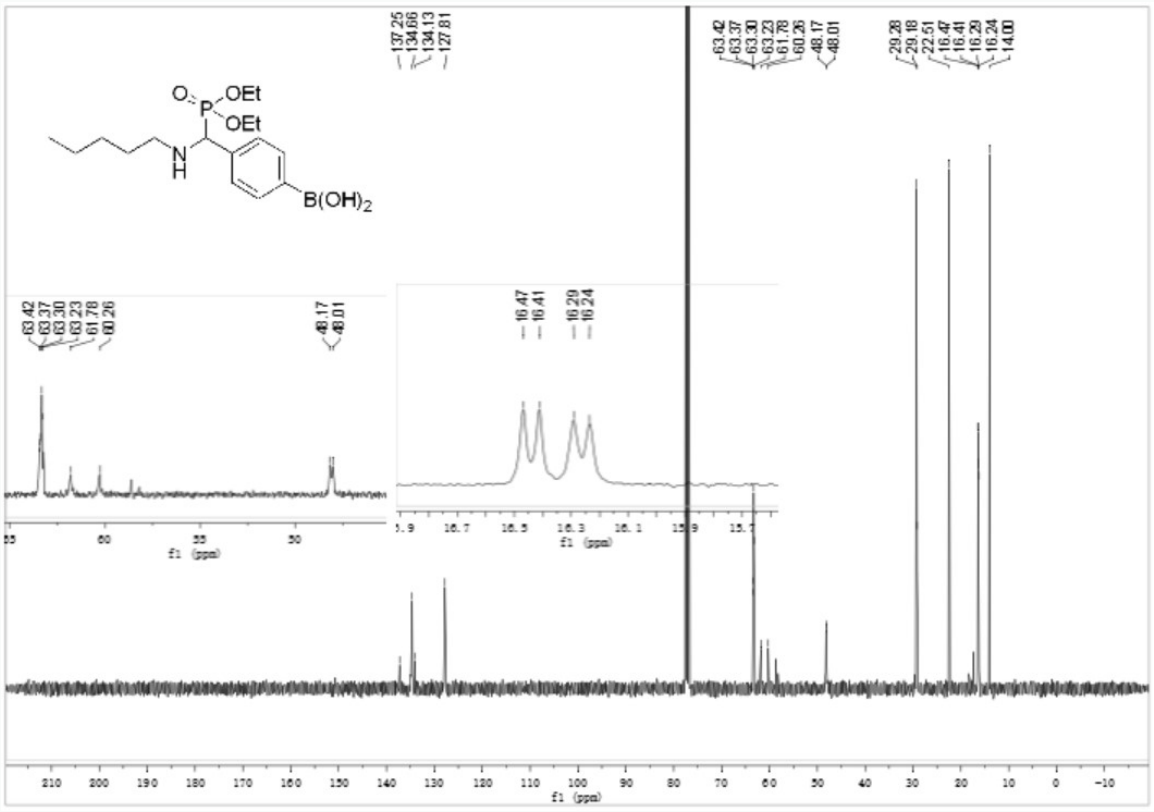
^{13}C NMR spectrum of **a6** (*d*-DMSO, 100 MHz)



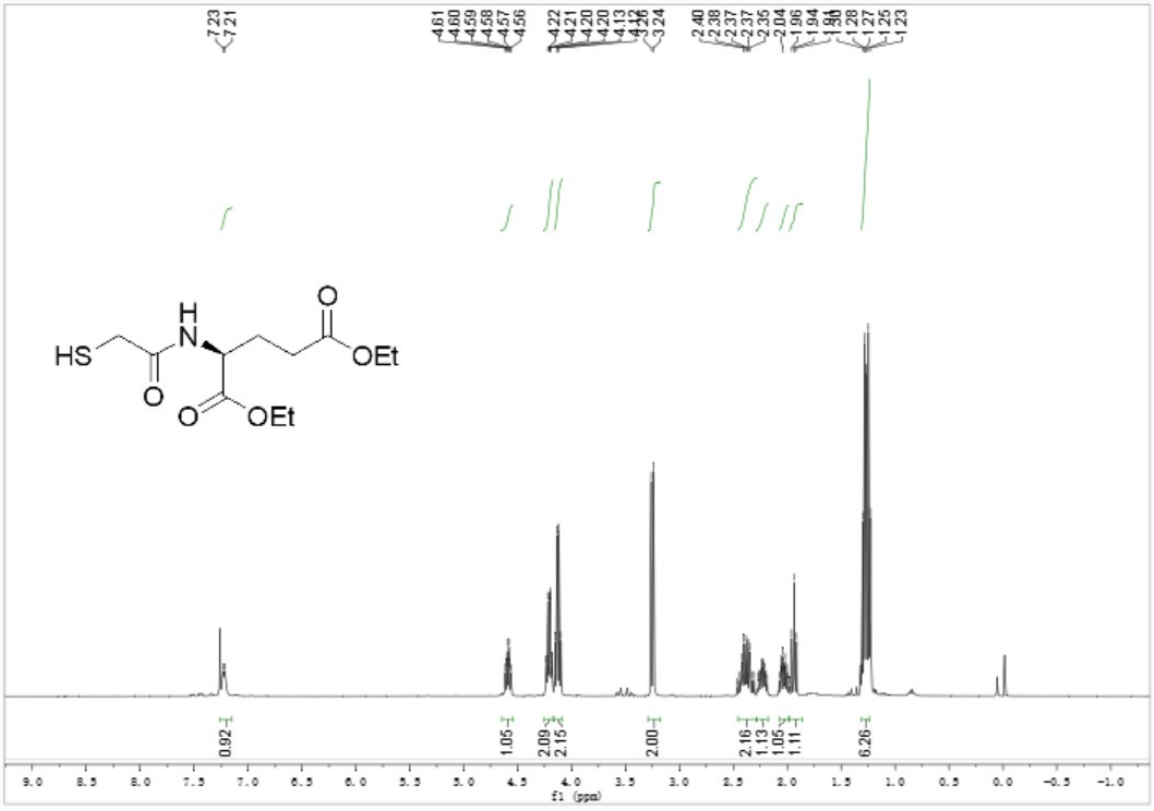
^{1}H NMR spectrum of **a7** ($CDCl_3$, 400 MHz)



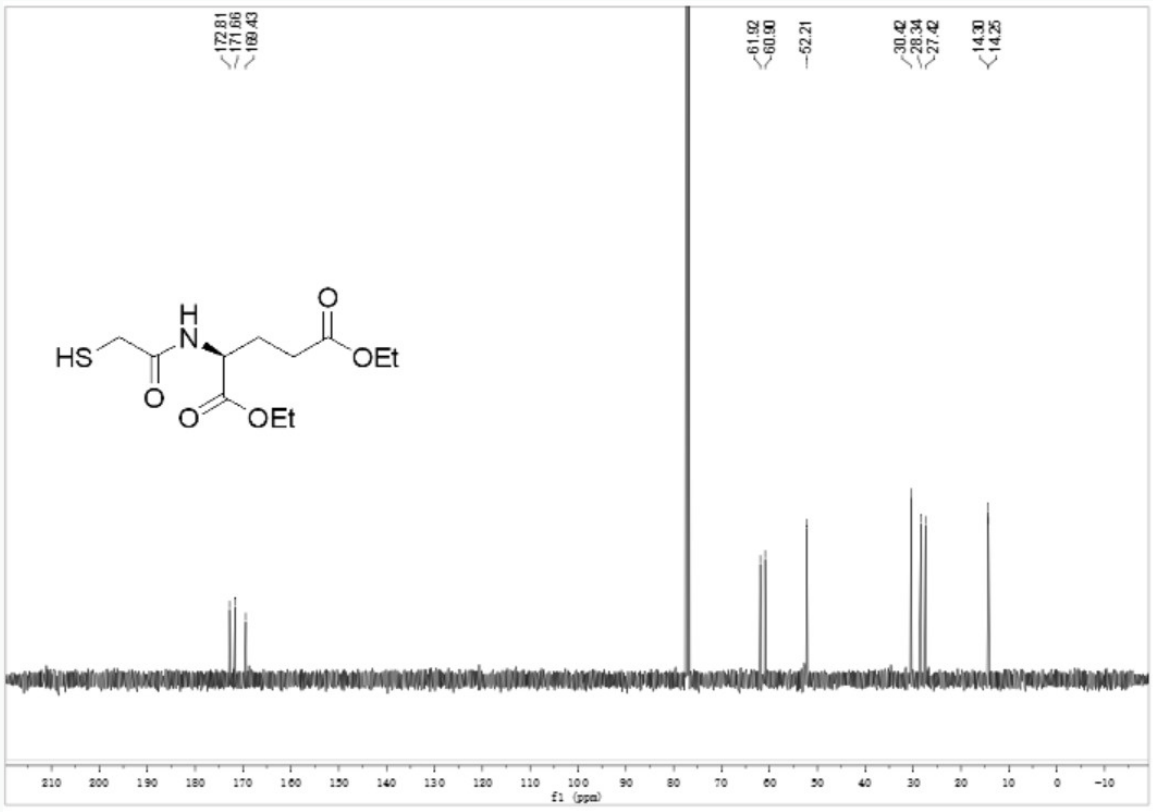
^{13}C NMR spectrum of **a7** ($CDCl_3$, 100 MHz)



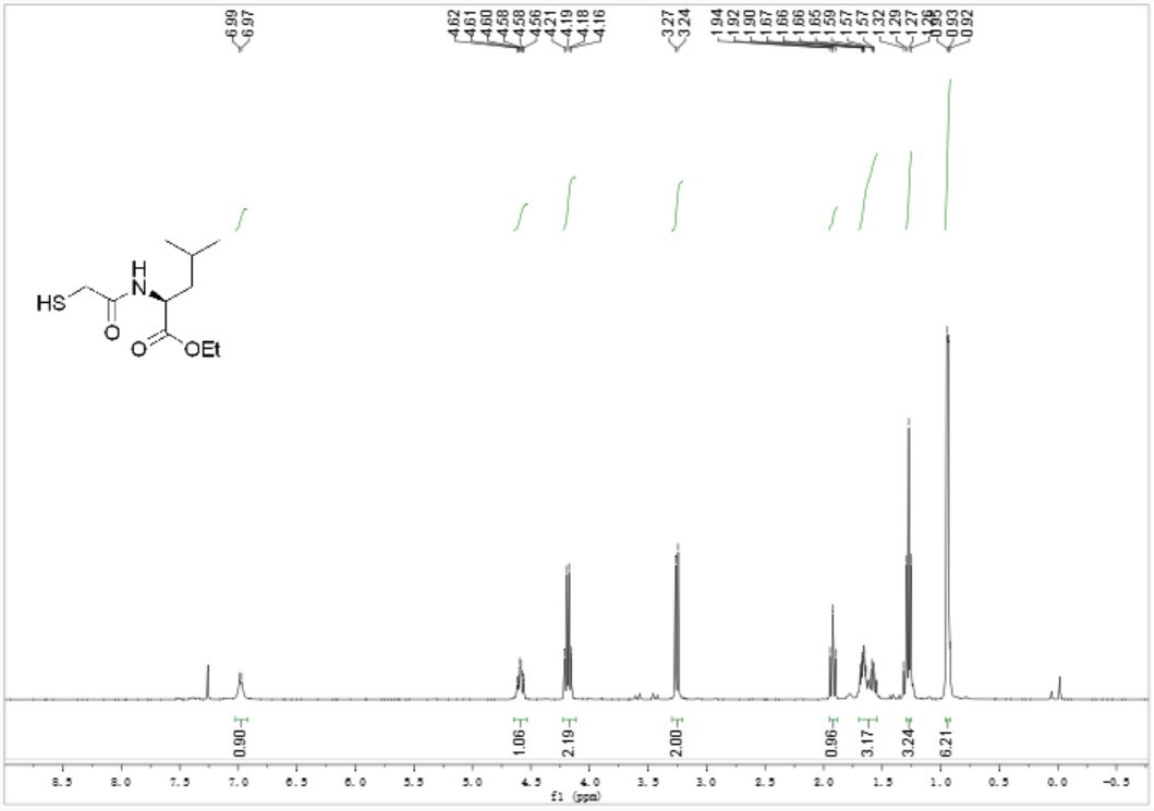
^{1}H NMR spectrum of **2b** ($CDCl_3$, 400 MHz)



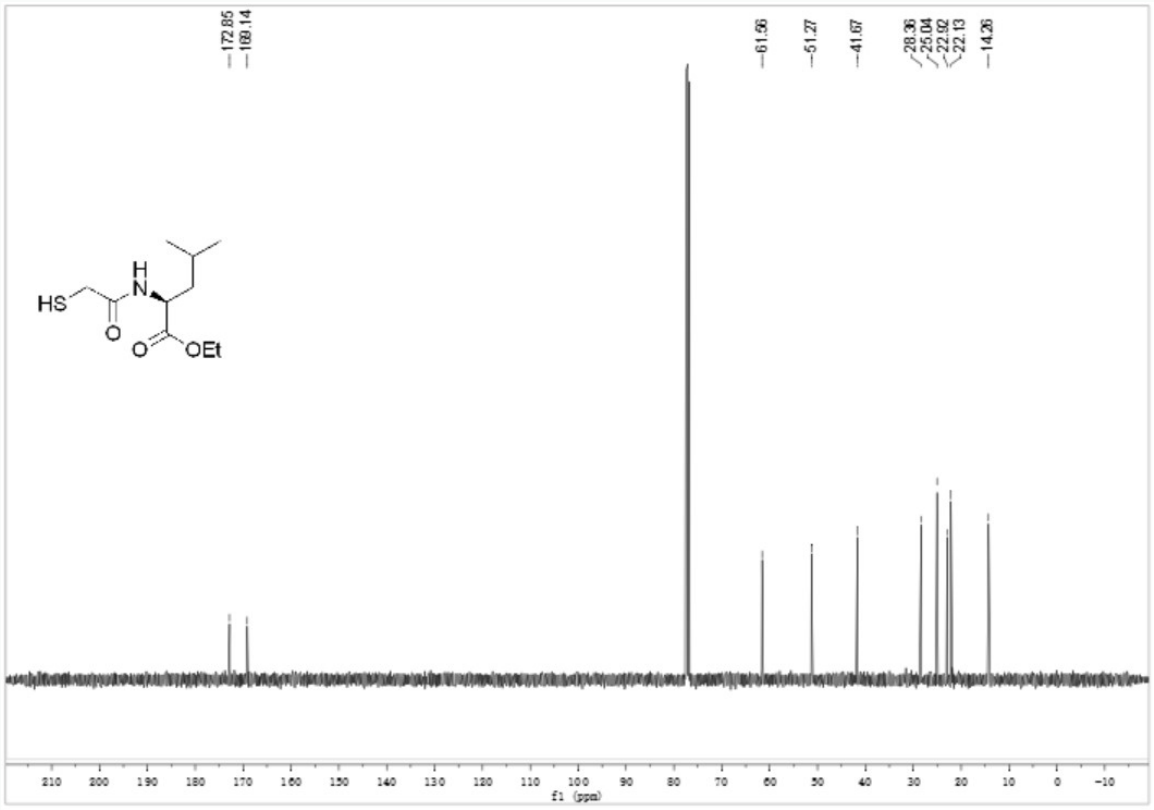
^{13}C NMR spectrum of **2b** ($CDCl_3$, 100 MHz)



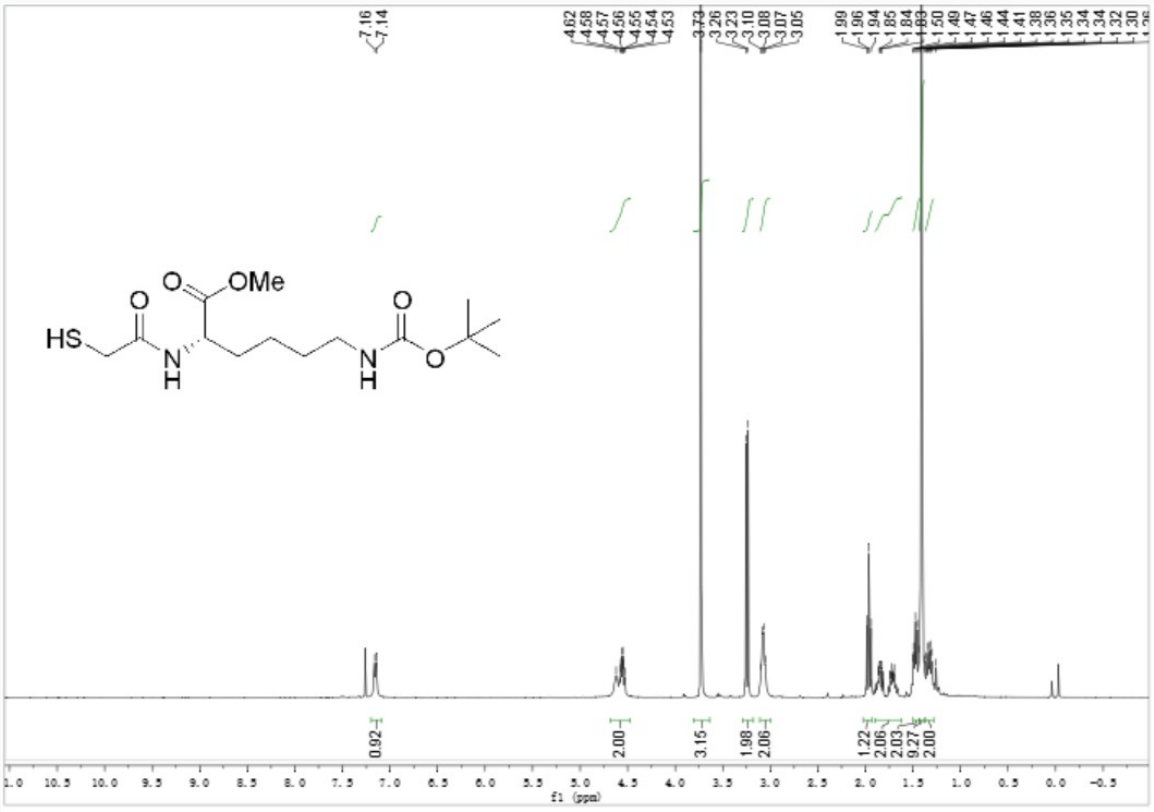
^{1}H NMR spectrum of **2c** ($CDCl_3$, 400 MHz)



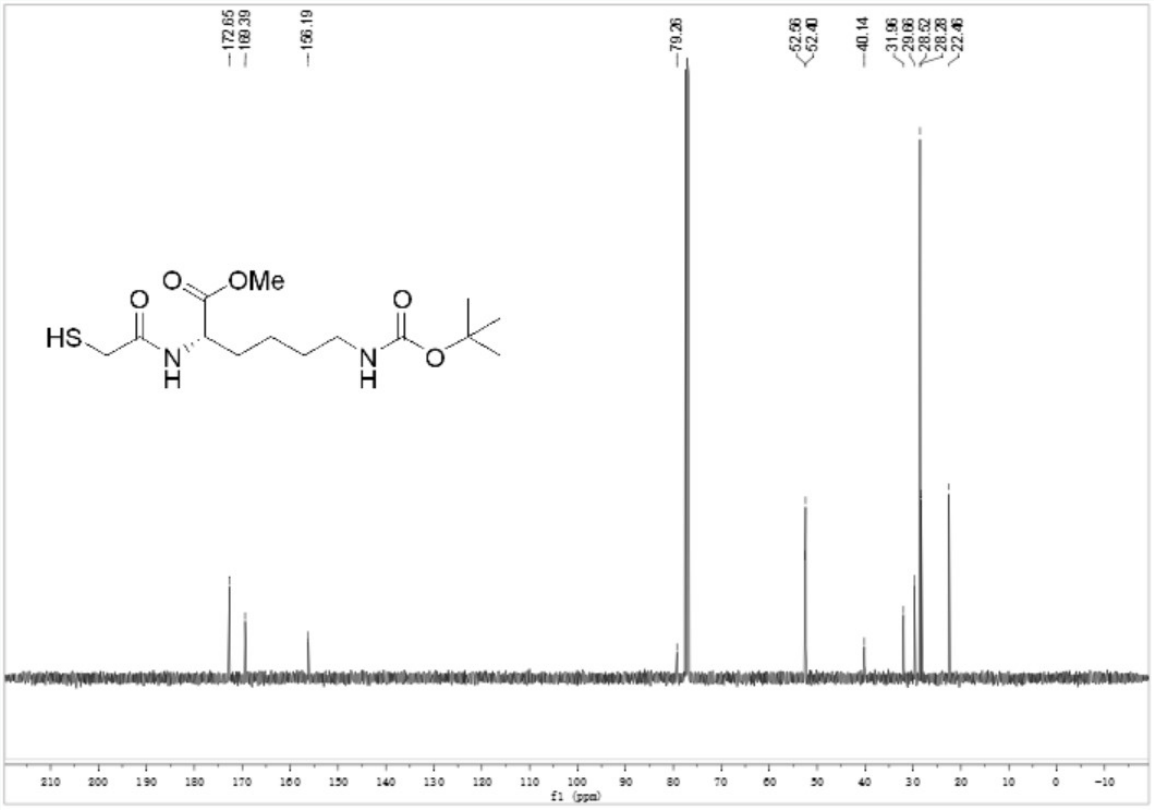
^{13}C NMR spectrum of **2c** ($CDCl_3$, 100 MHz)



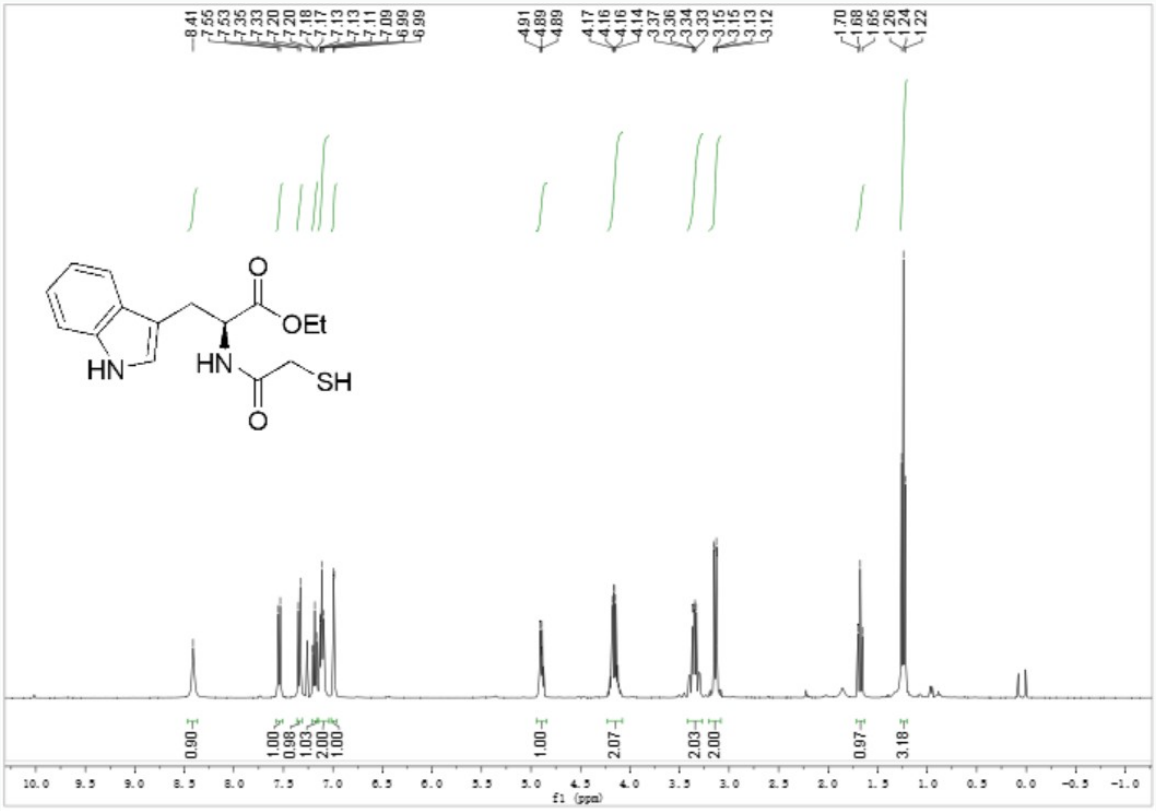
^{1}H NMR spectrum of **2d** ($CDCl_3$, 400 MHz)



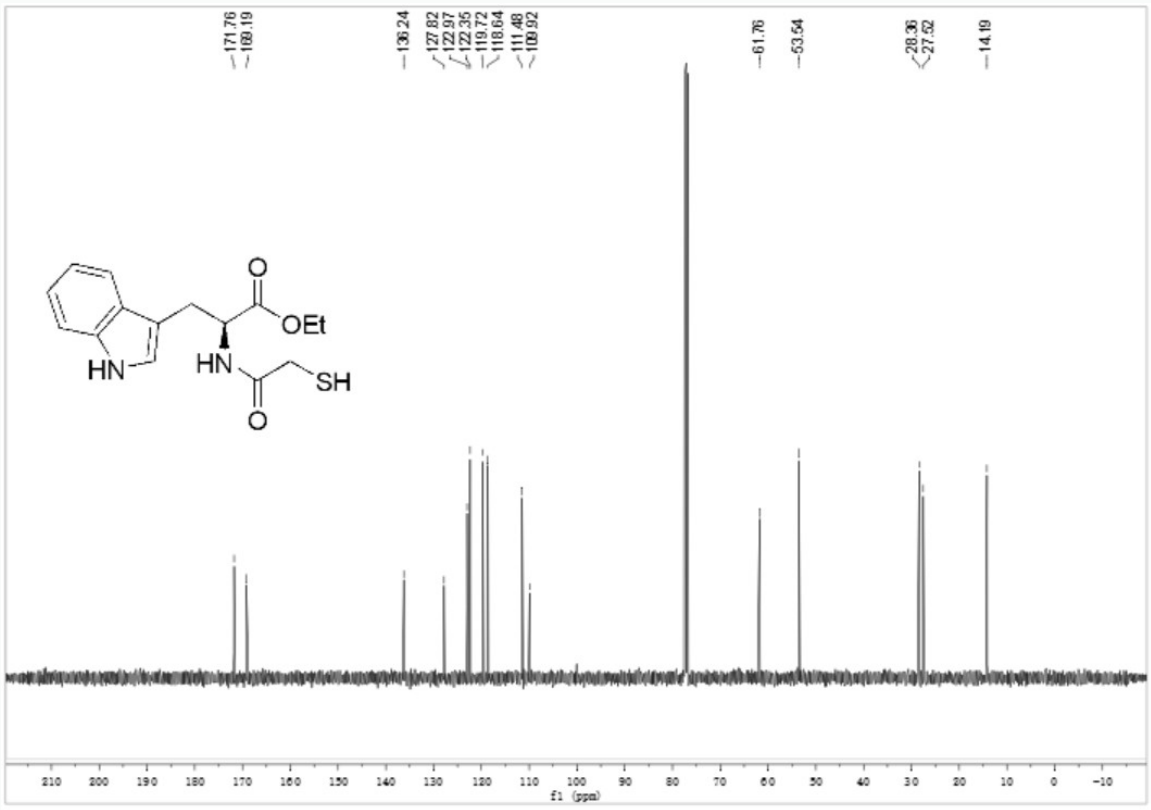
^{13}C NMR spectrum of **2d** ($CDCl_3$, 100 MHz)



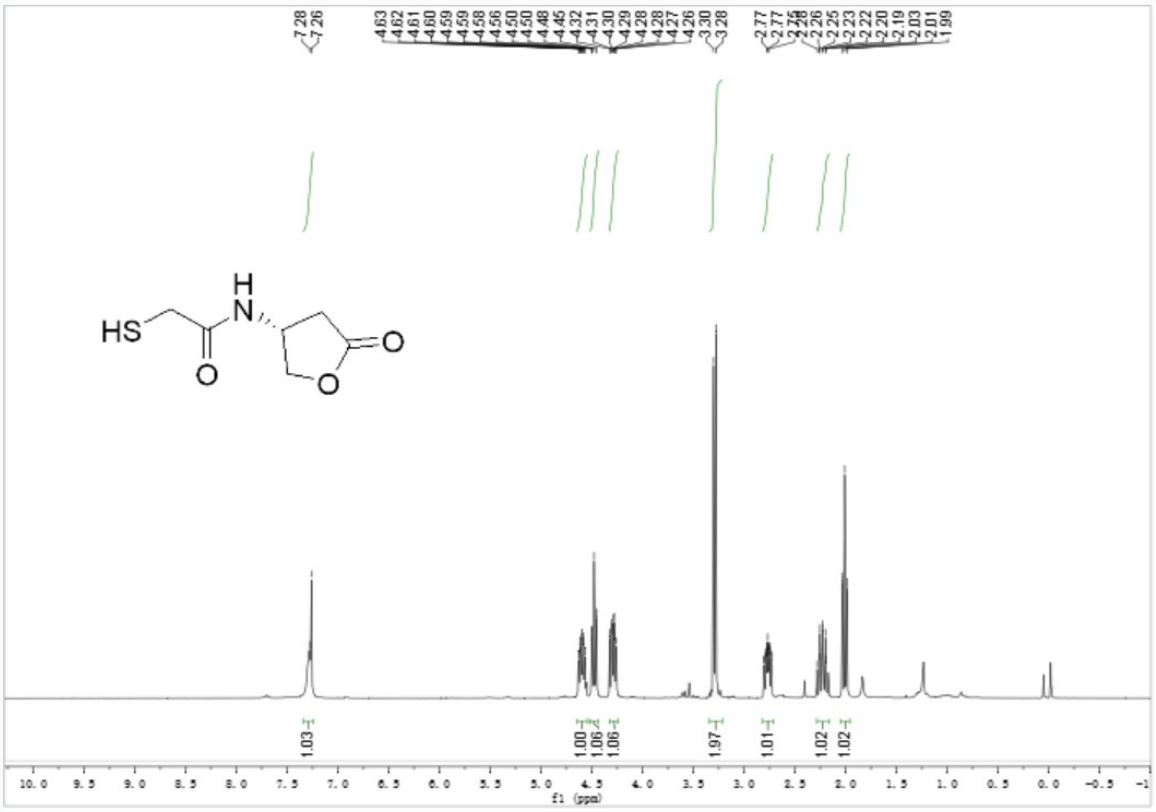
^{1}H NMR spectrum of **2e** ($CDCl_3$, 400 MHz)



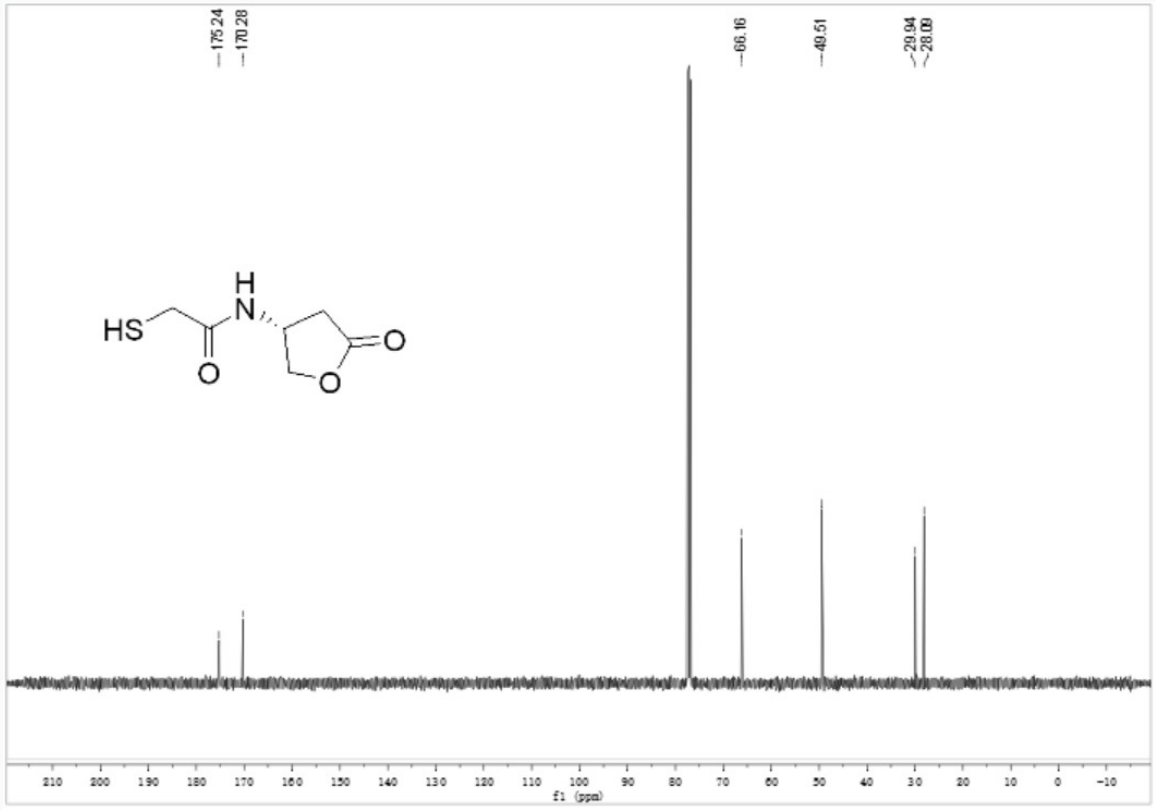
^{13}C NMR spectrum of **2e** ($CDCl_3$, 100 MHz)



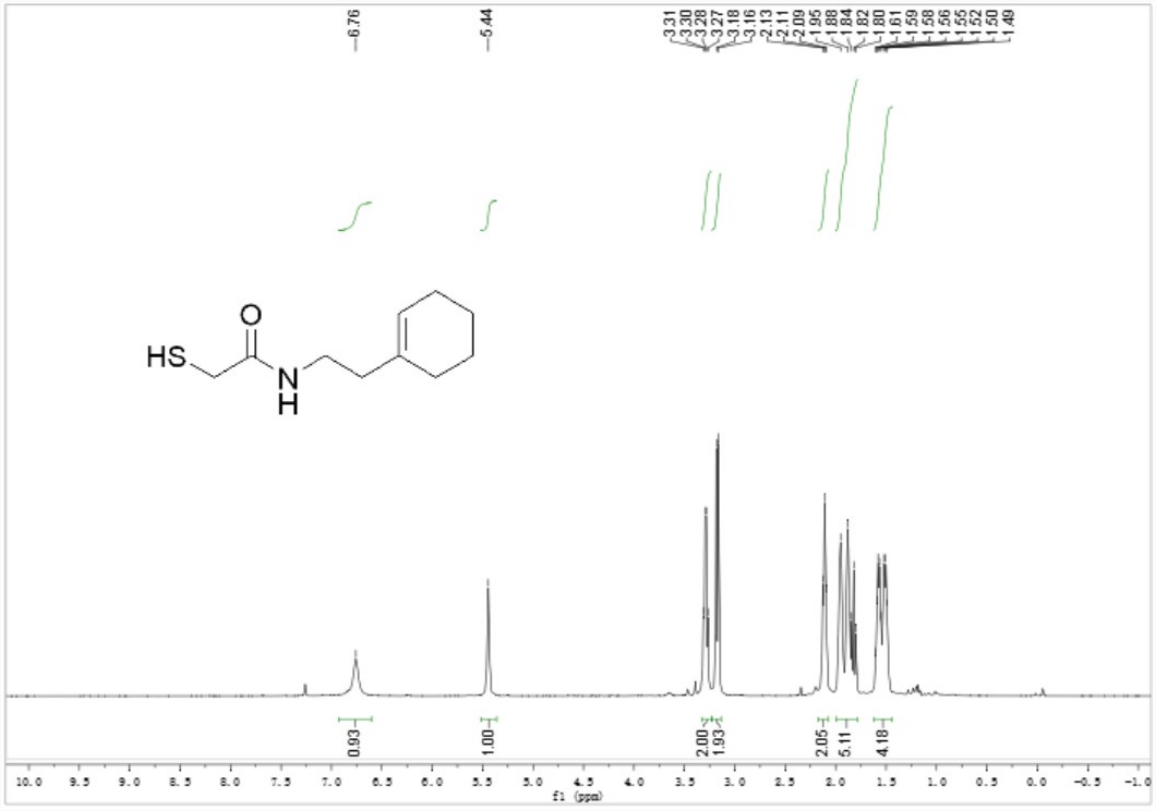
^{1}H NMR spectrum of **2f** ($CDCl_3$, 400 MHz)



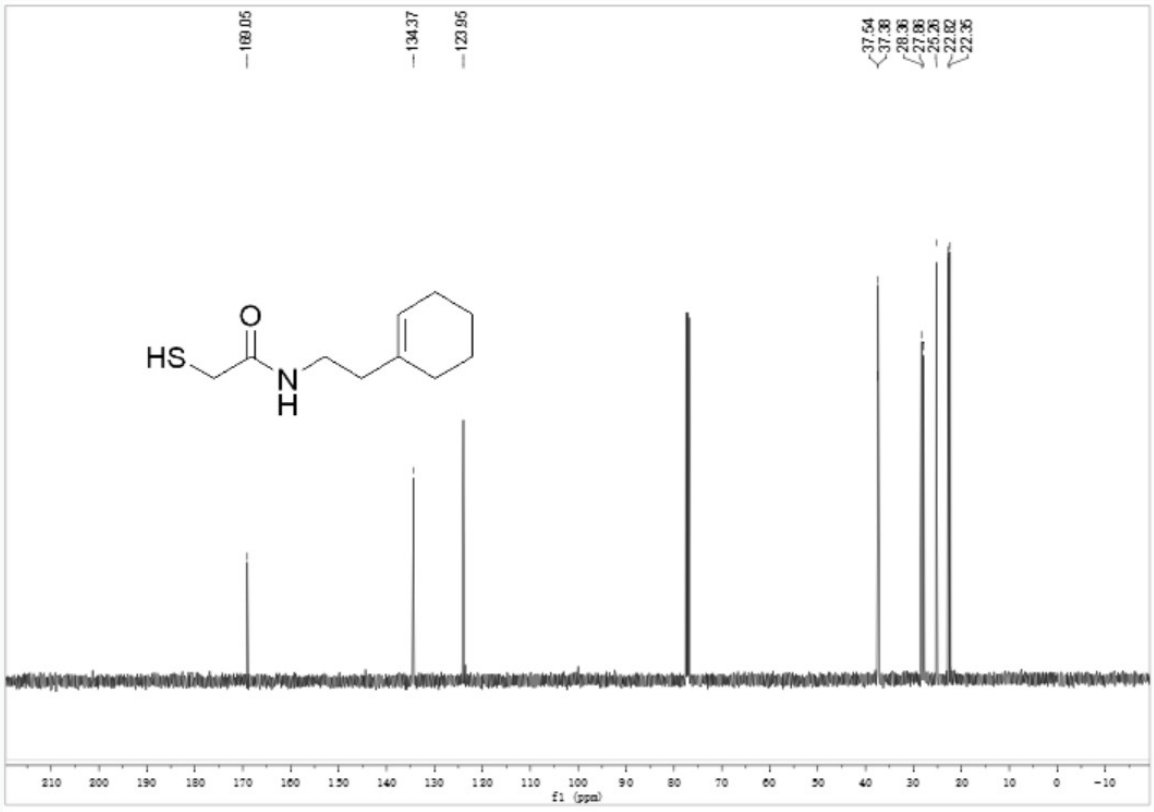
^{13}C NMR spectrum of **2f** ($CDCl_3$, 100 MHz)



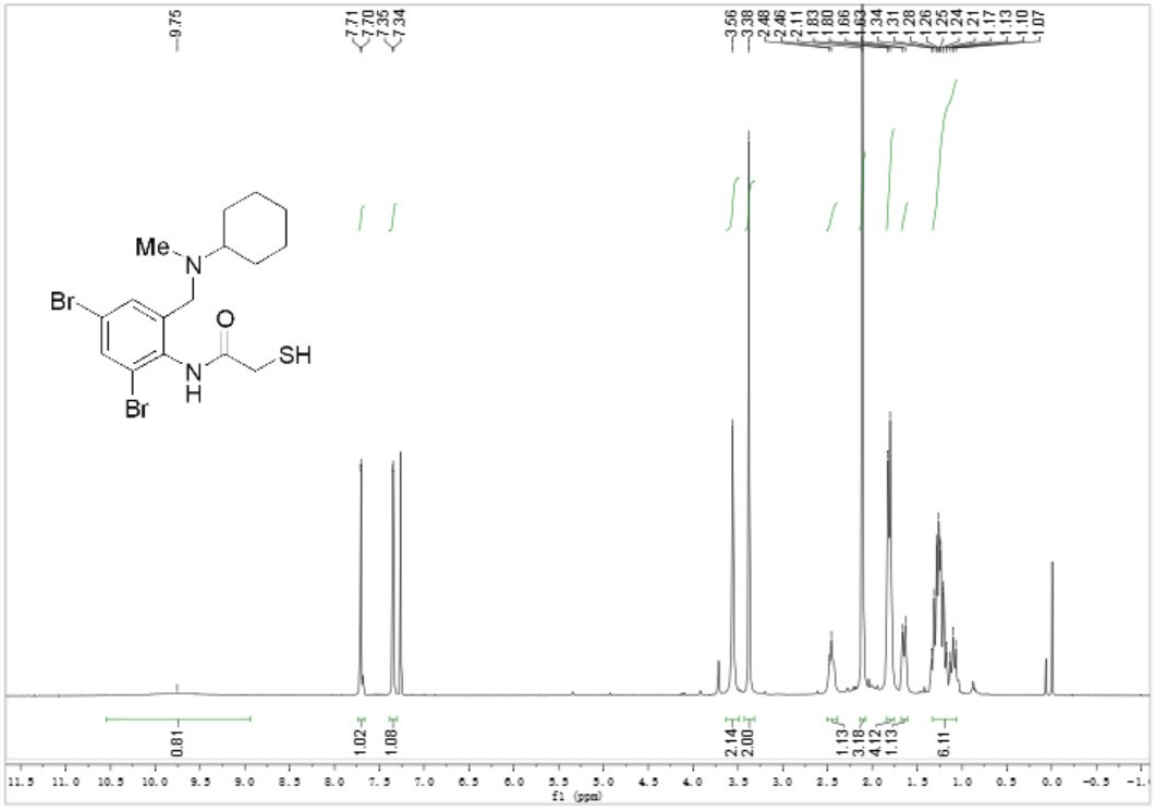
^{1}H NMR spectrum of **2g** ($CDCl_3$, 400 MHz)



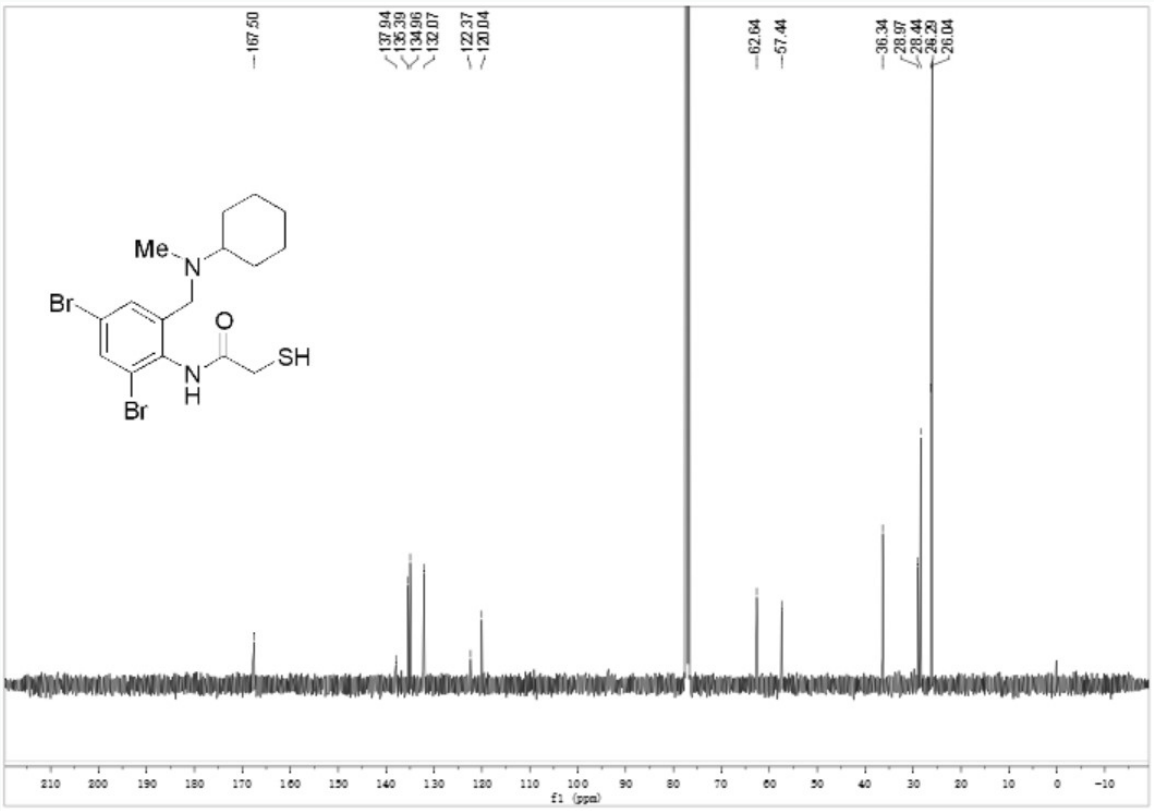
^{13}C NMR spectrum of **2g** ($CDCl_3$, 100 MHz)



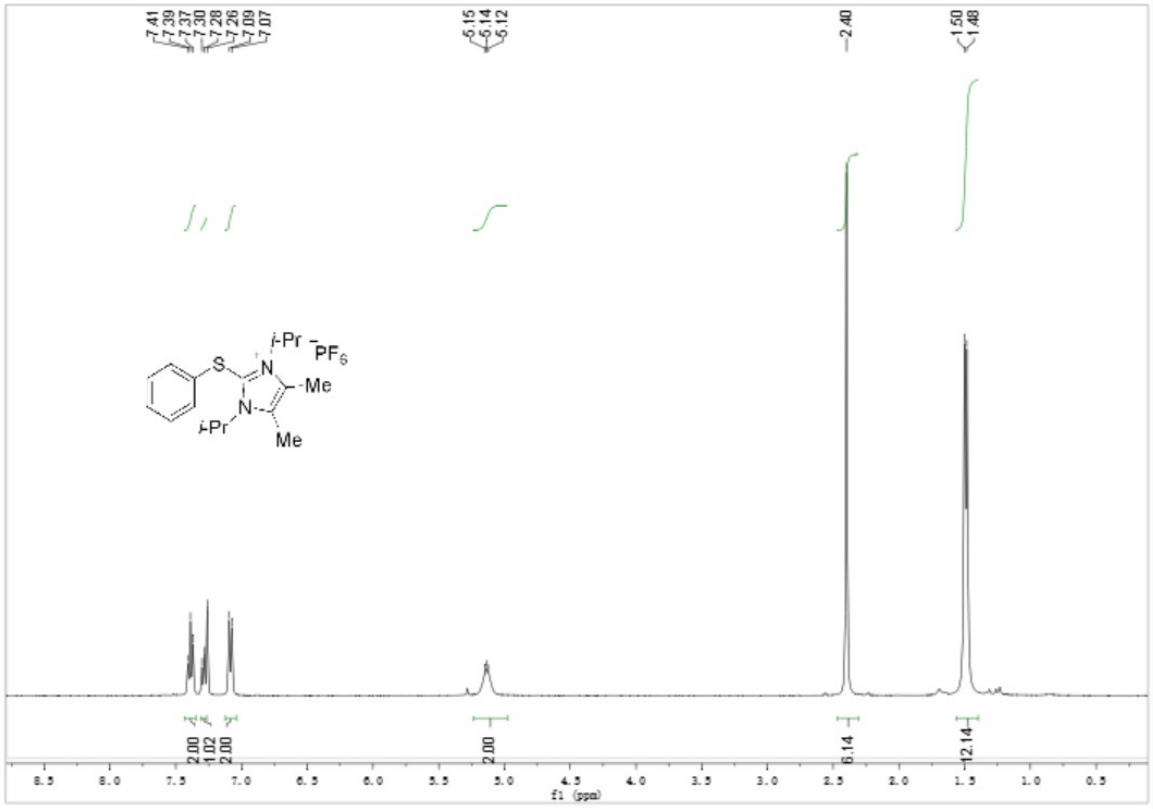
^{1}H NMR spectrum of **2h** ($CDCl_3$, 400 MHz)



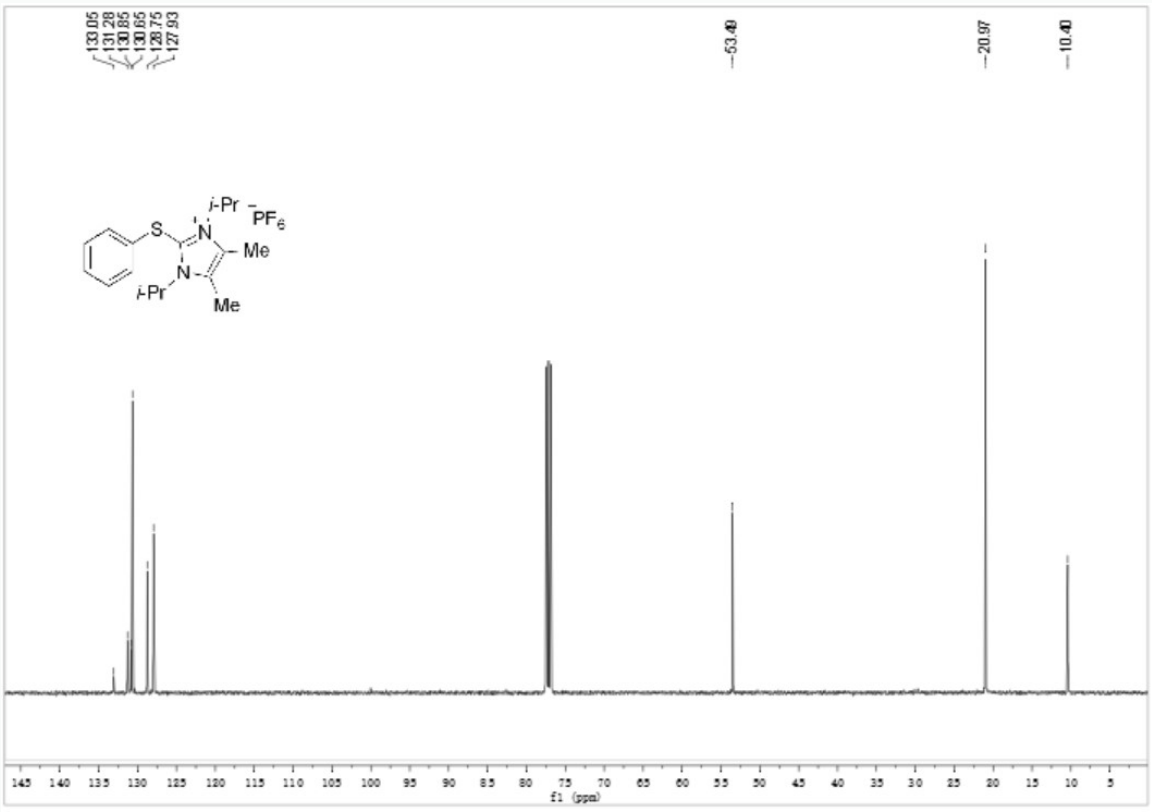
^{13}C NMR spectrum of **2h** ($CDCl_3$, 100 MHz)



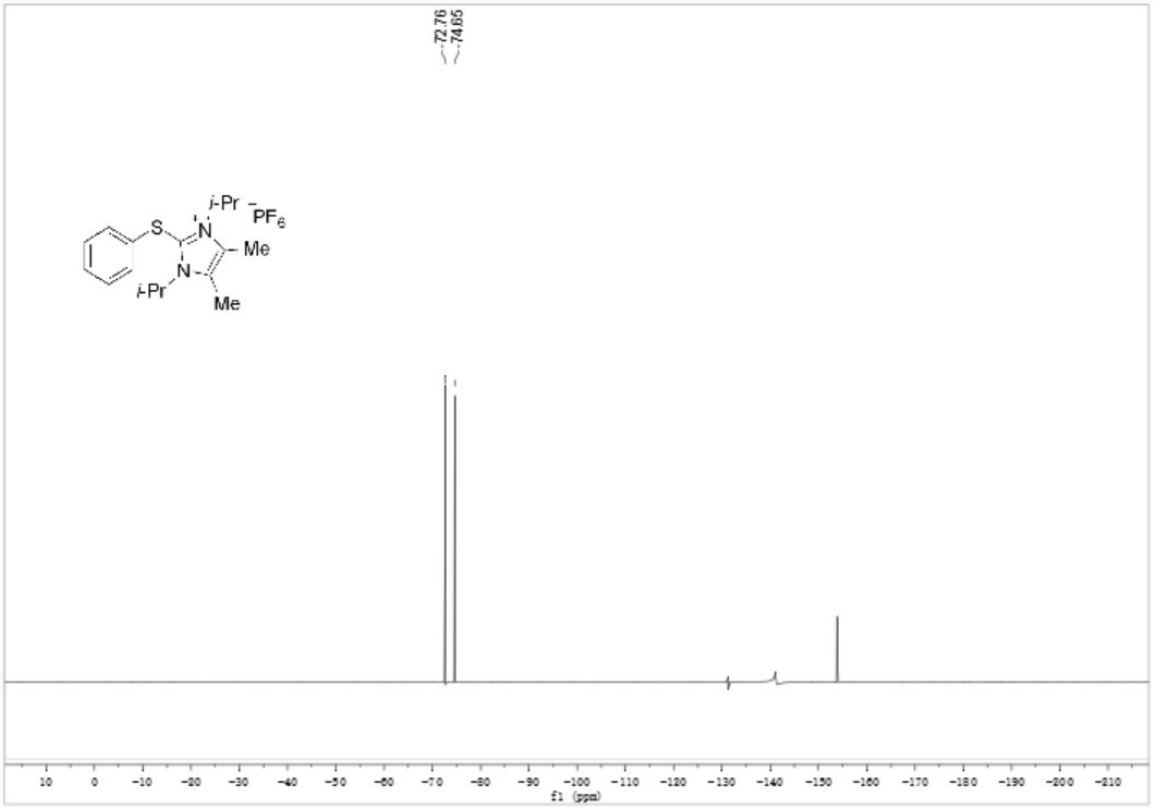
^{1}H NMR spectrum of **1a** ($CDCl_3$, 400 MHz)



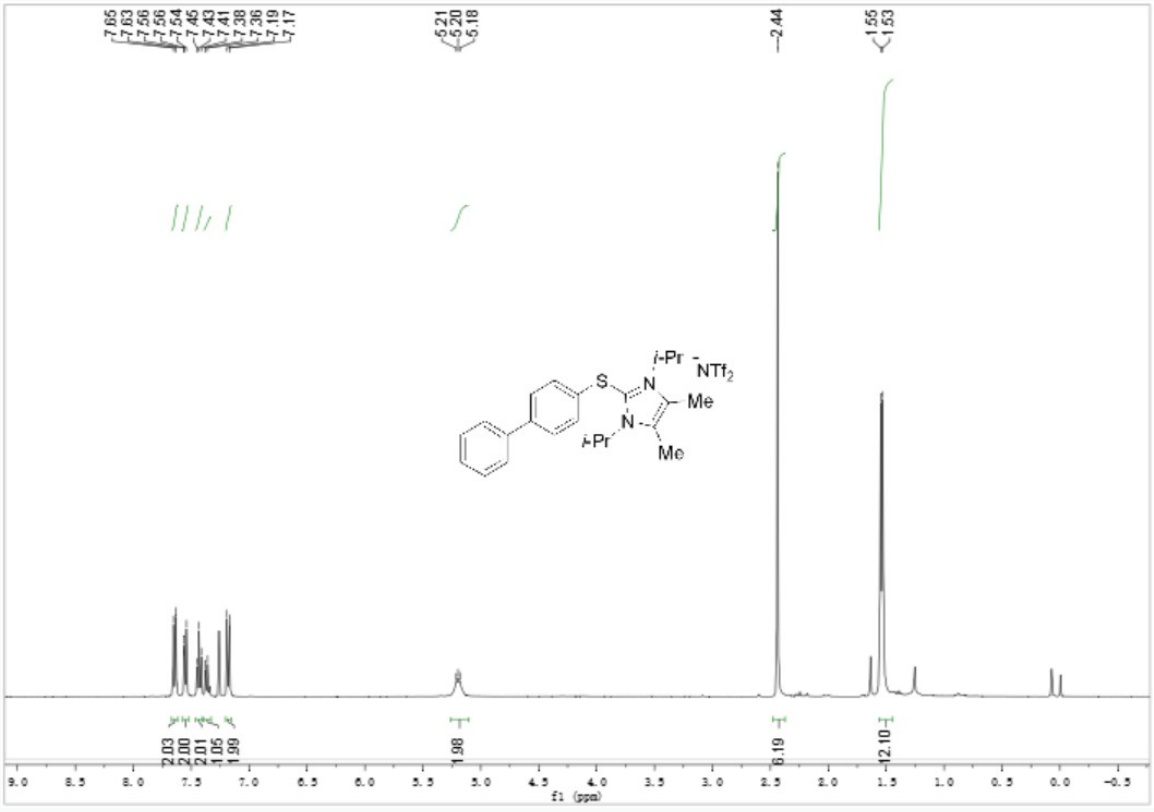
^{13}C NMR spectrum of **1a** ($CDCl_3$, 100 MHz)



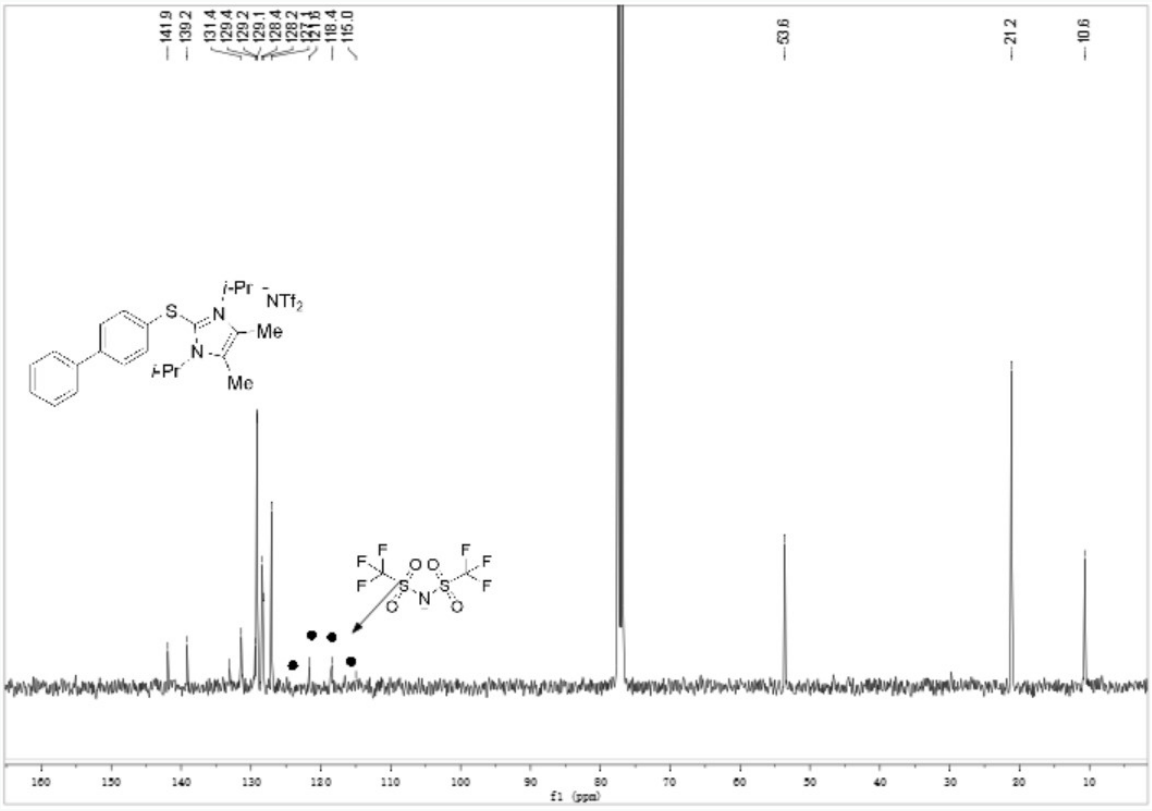
^{19}F NMR spectrum of **1a** ($CDCl_3$, 376 MHz)



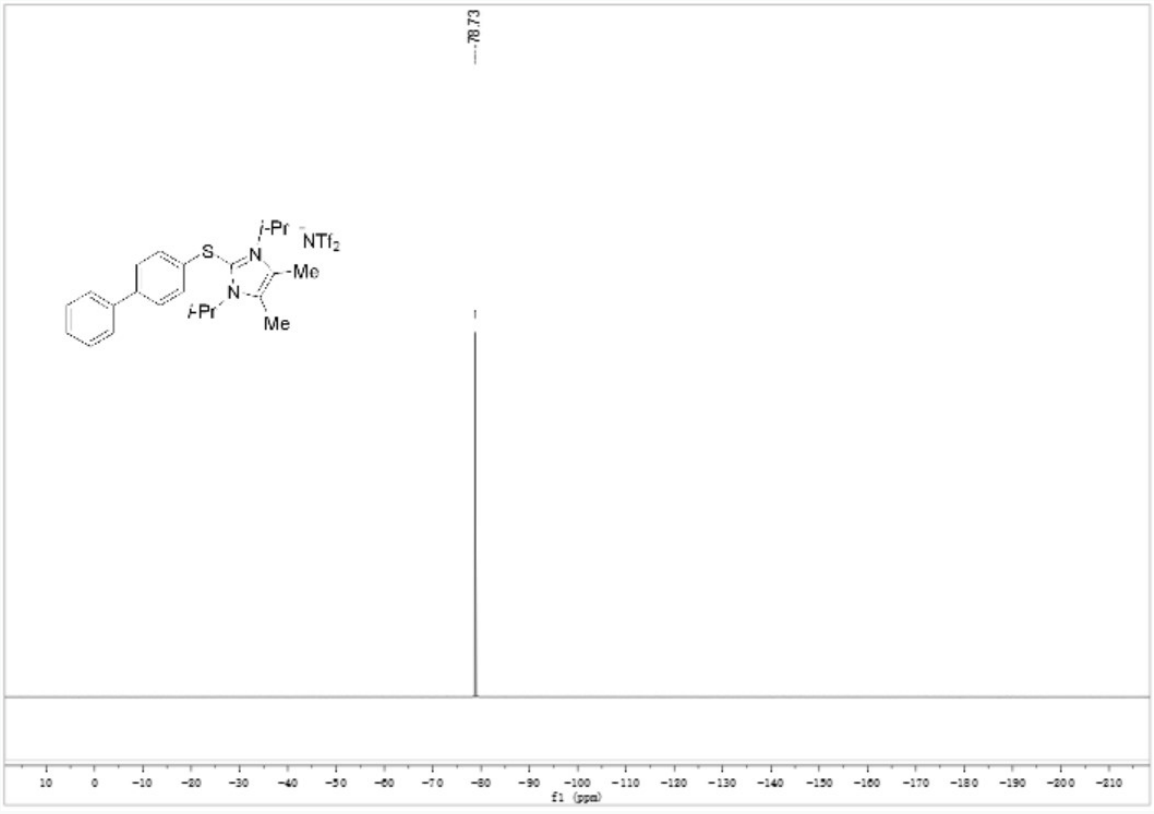
^{1}H NMR spectrum of **1b** ($CDCl_3$, 400 MHz)



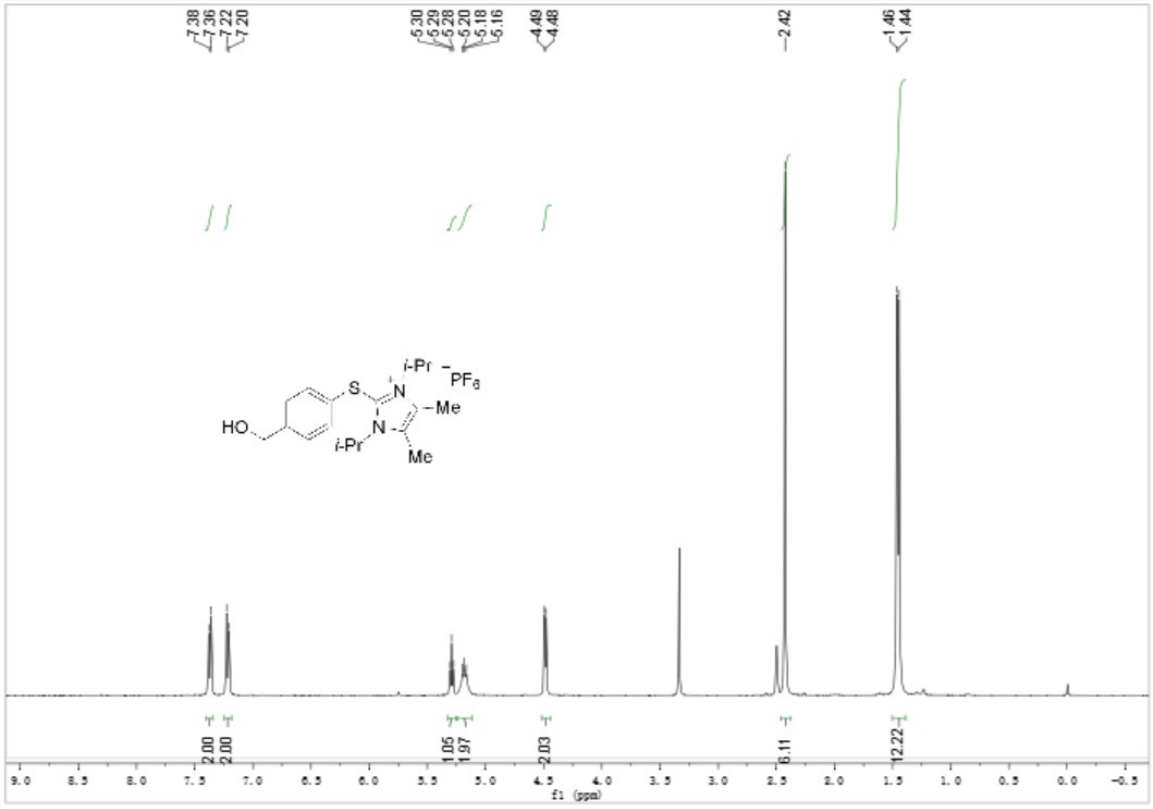
^{13}C NMR spectrum of **1b** ($CDCl_3$, 100 MHz)



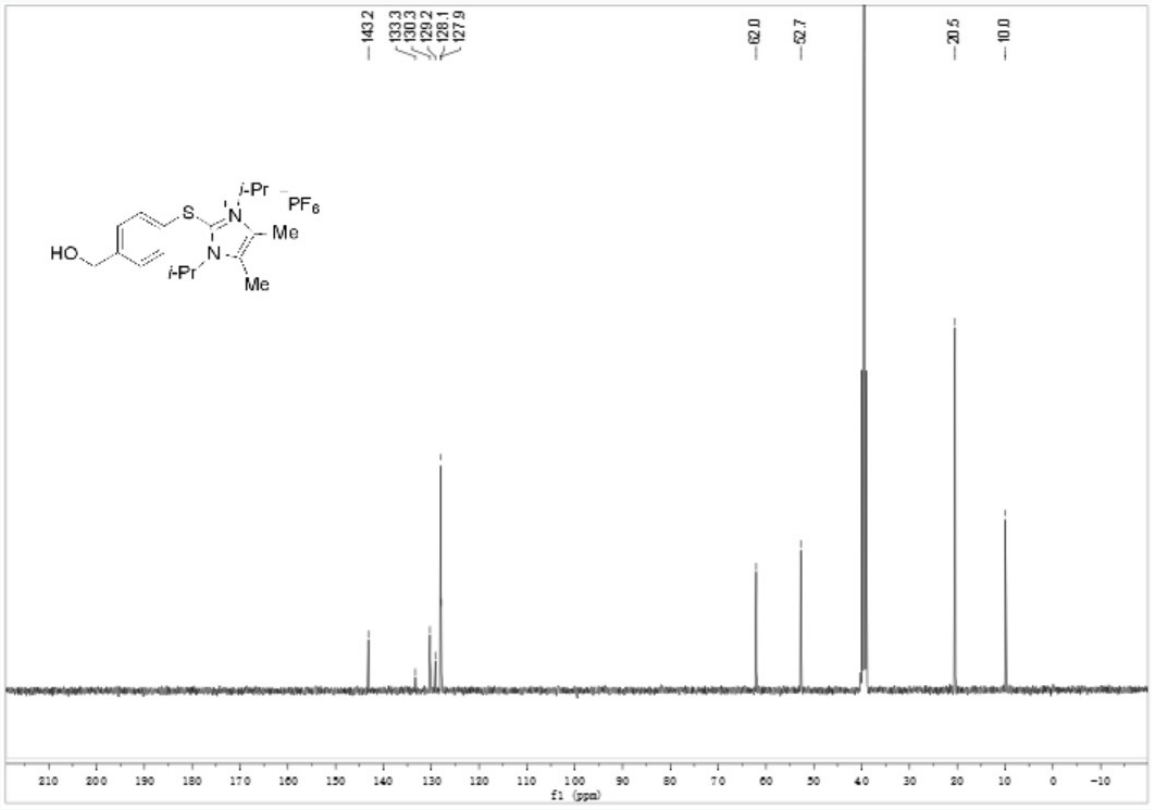
^{19}F NMR spectrum of **1b** ($CDCl_3$, 376 MHz)



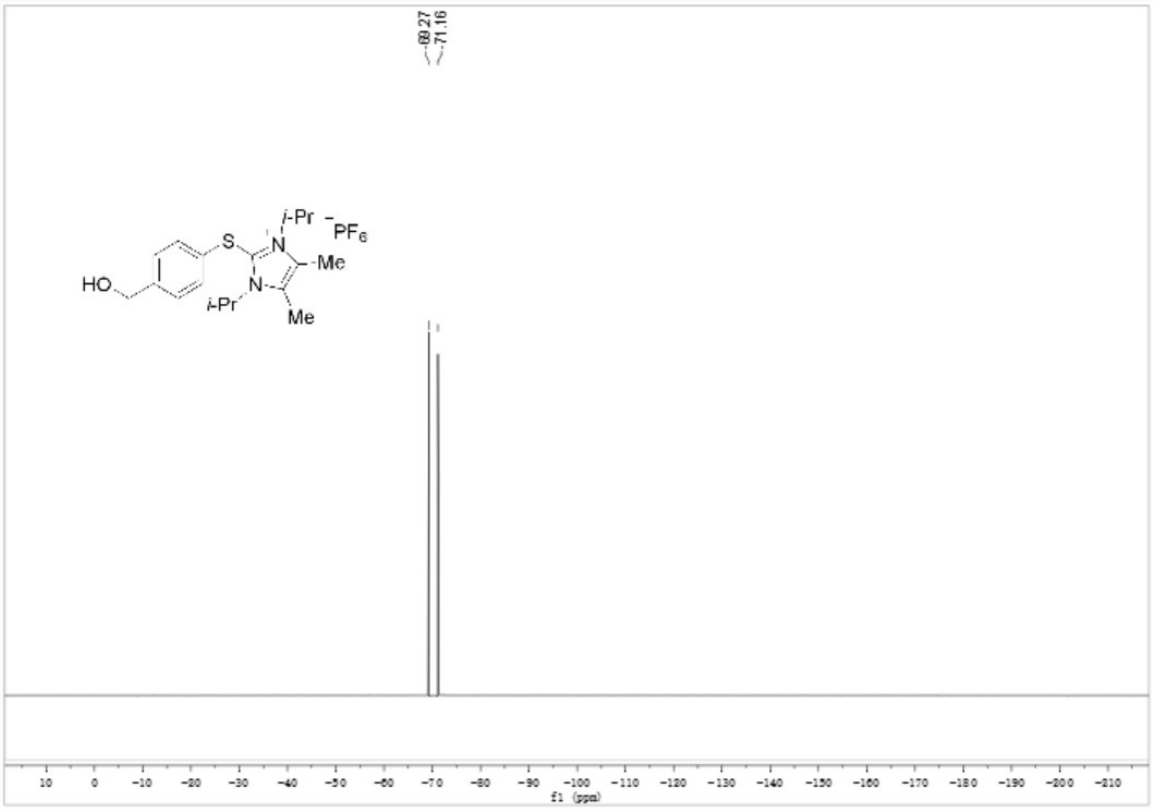
^{1}H NMR spectrum of **1c** (*d*-DMSO, 400 MHz)



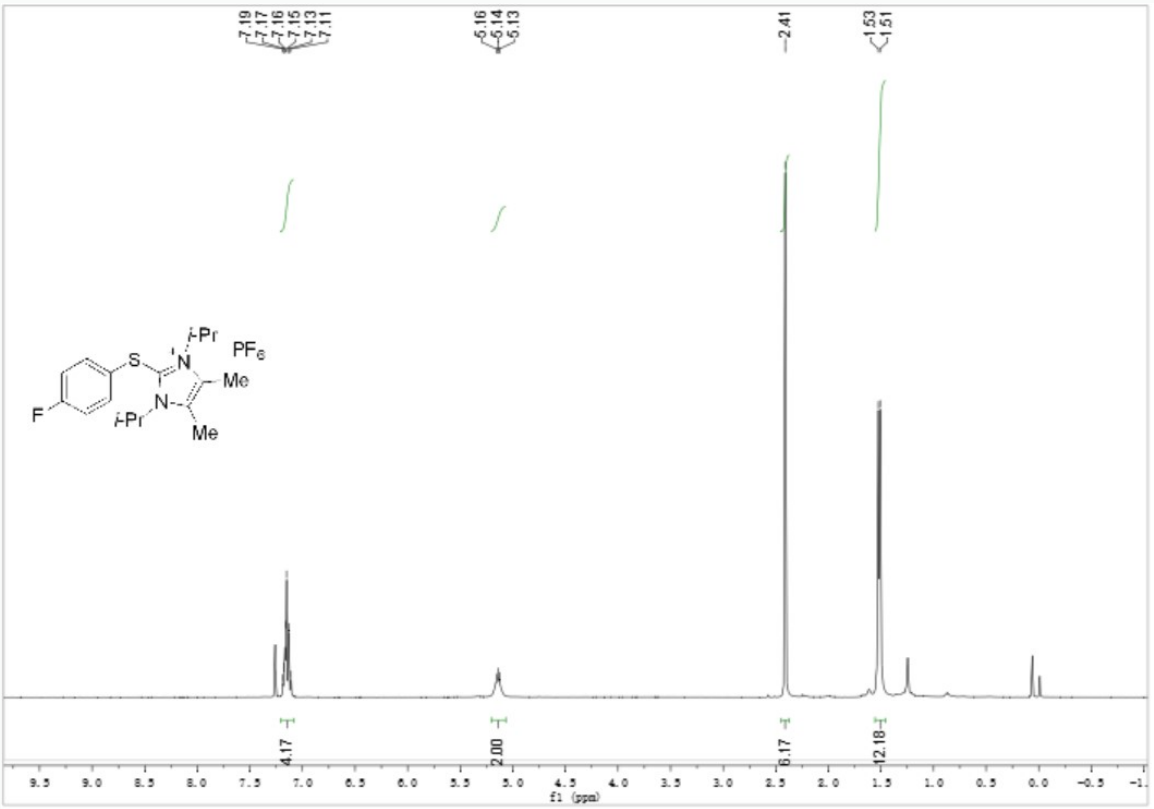
^{13}C NMR spectrum of **1c** (*d*-DMSO, 100 MHz)



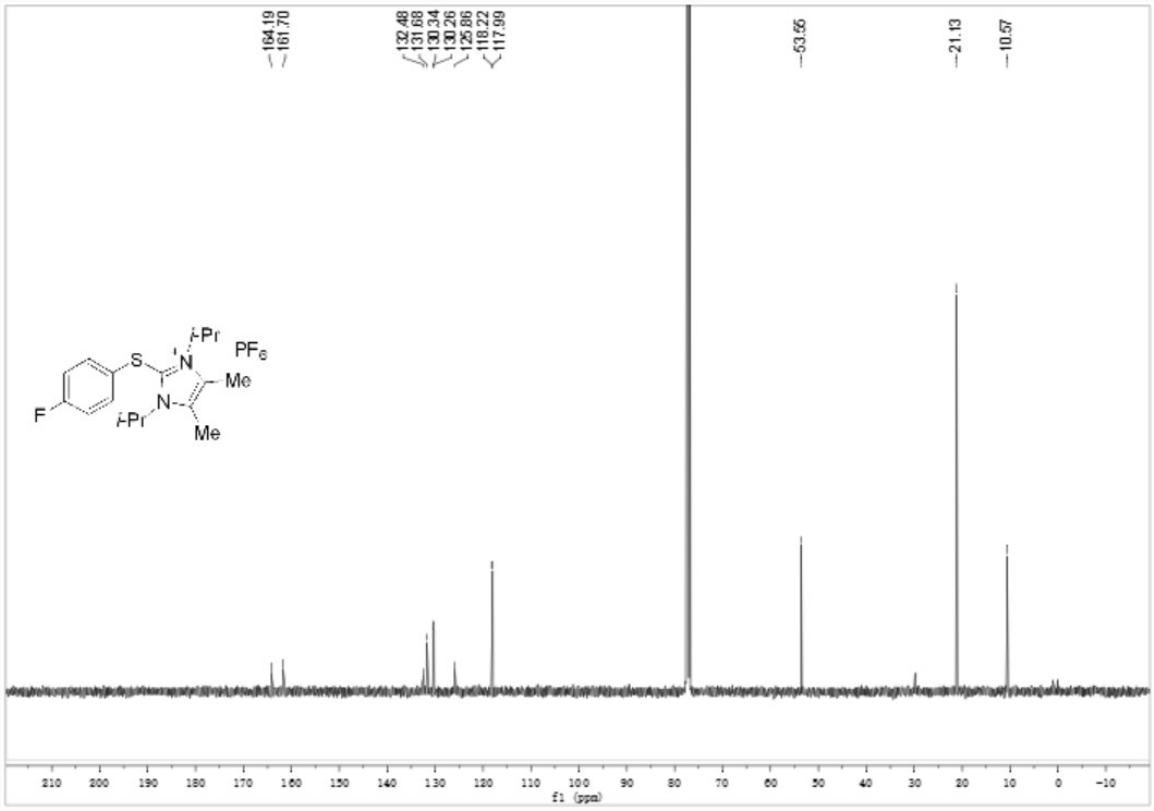
^{19}F NMR spectrum of **1c** (*d*-DMSO, 376 MHz)



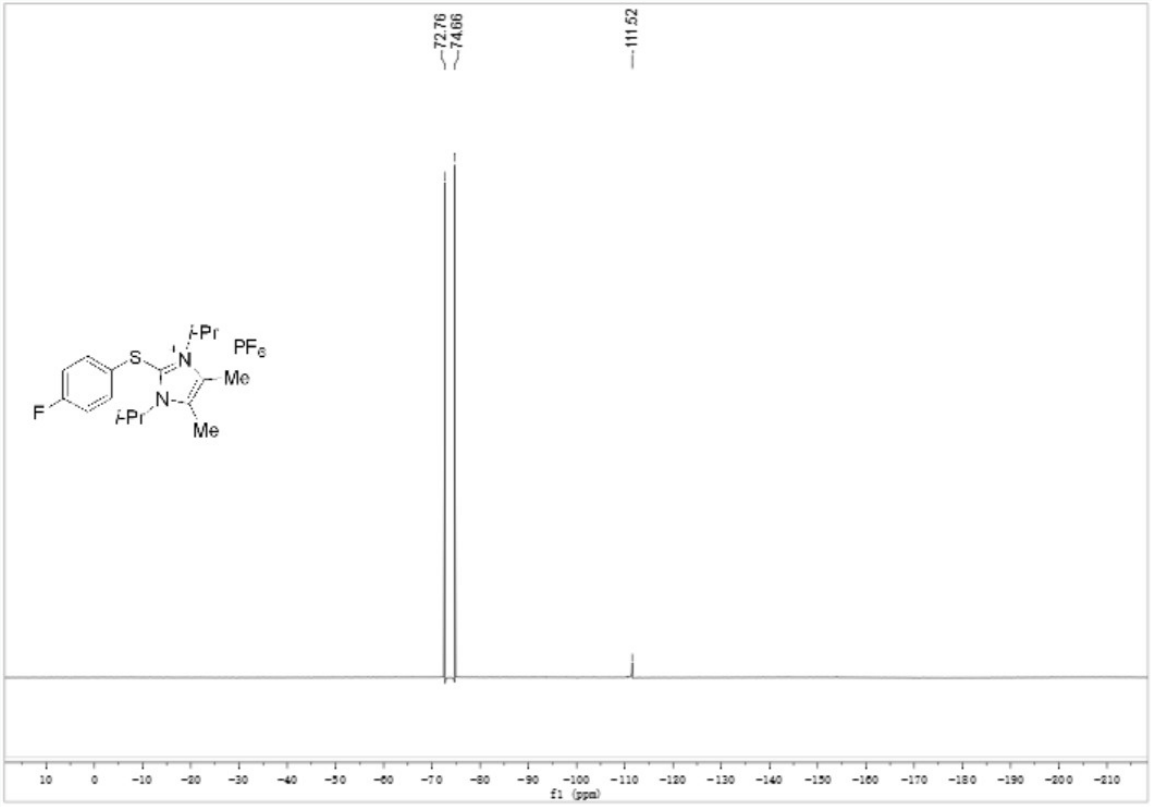
^{1}H NMR spectrum of **1d** ($CDCl_3$, 400 MHz)



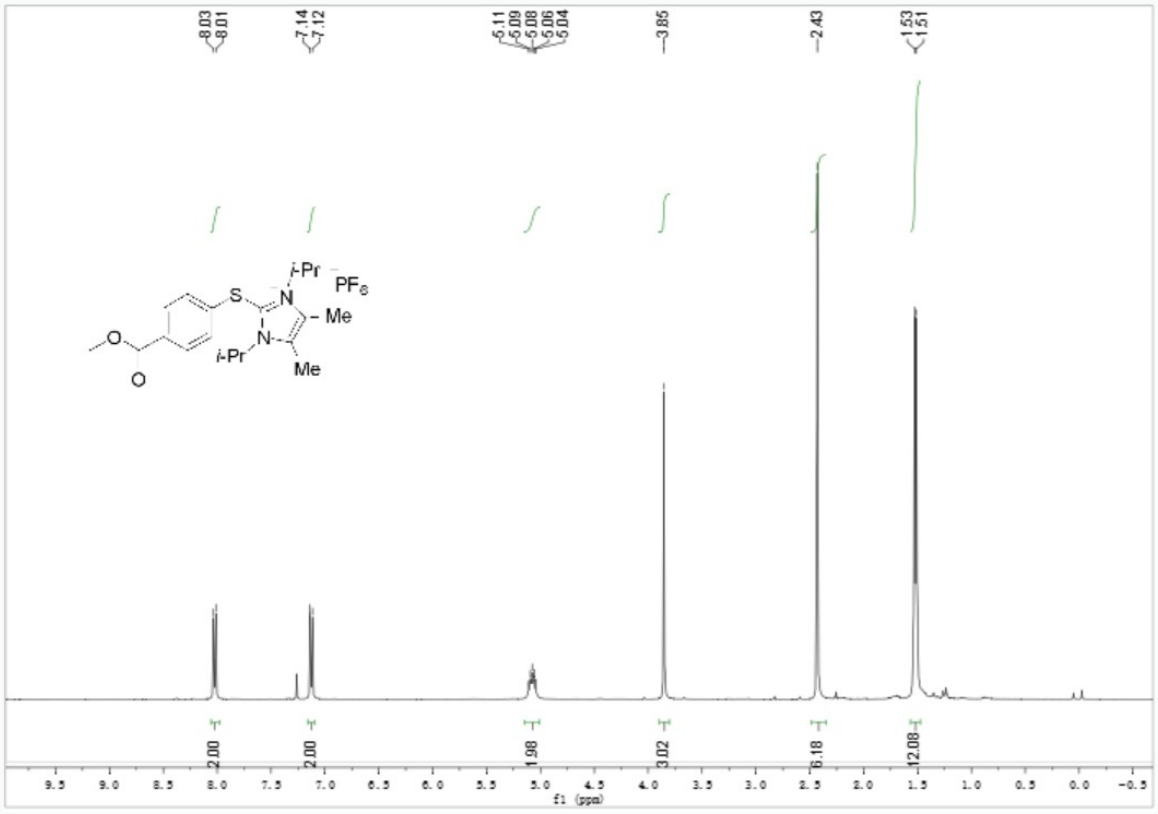
^{13}C NMR spectrum of **1d** ($CDCl_3$, 100 MHz)



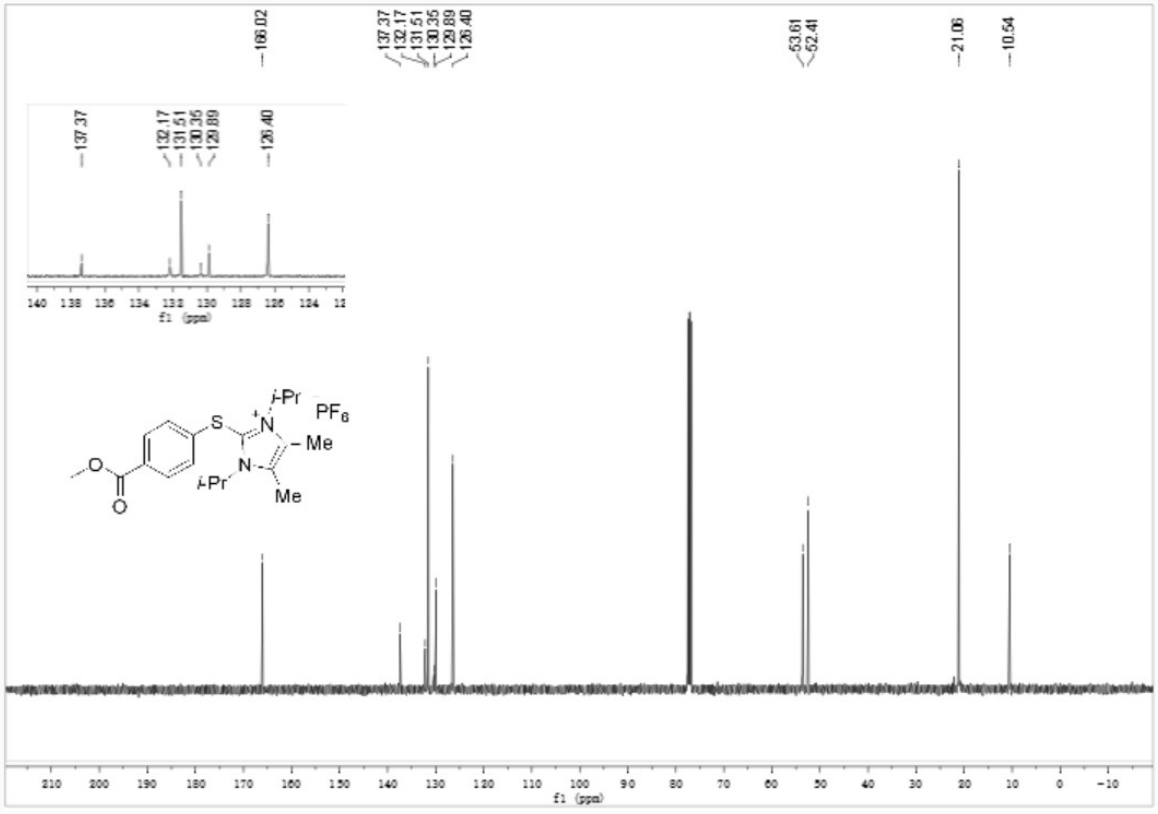
^{19}F NMR spectrum of **1d** ($CDCl_3$, 376 MHz)



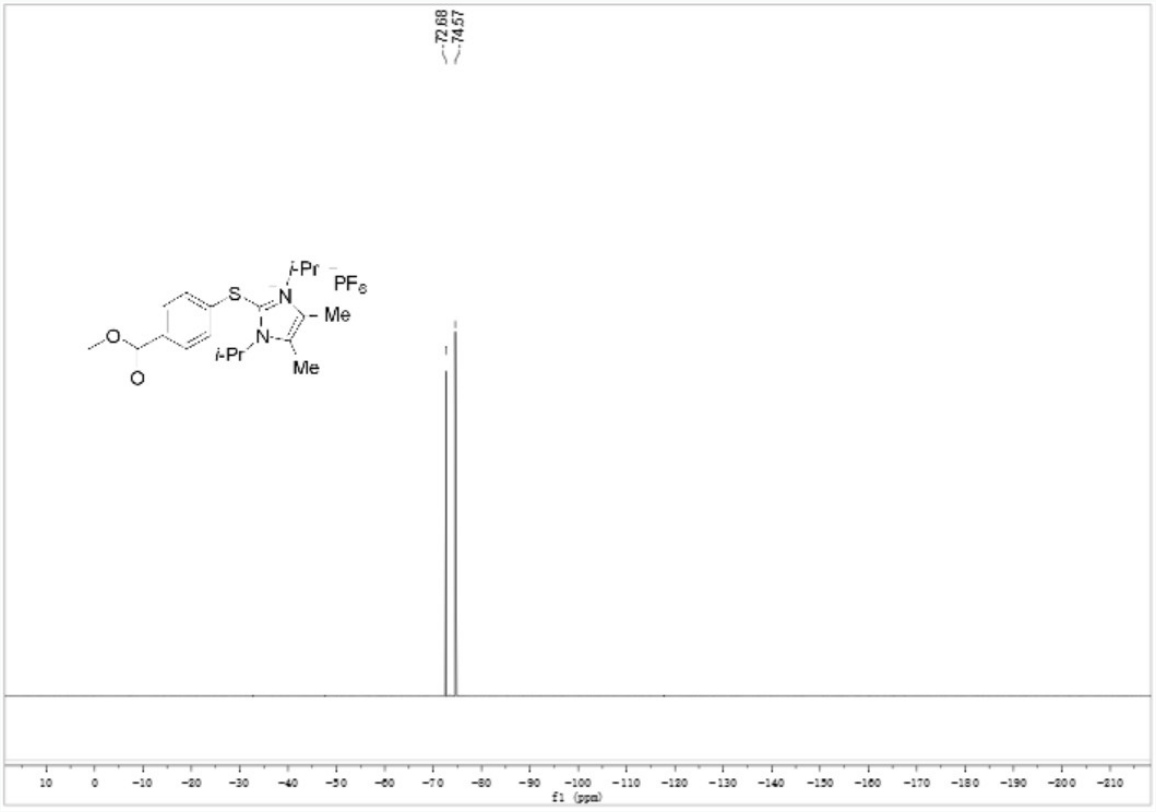
^{1}H NMR spectrum of **1e** ($CDCl_3$, 400 MHz)



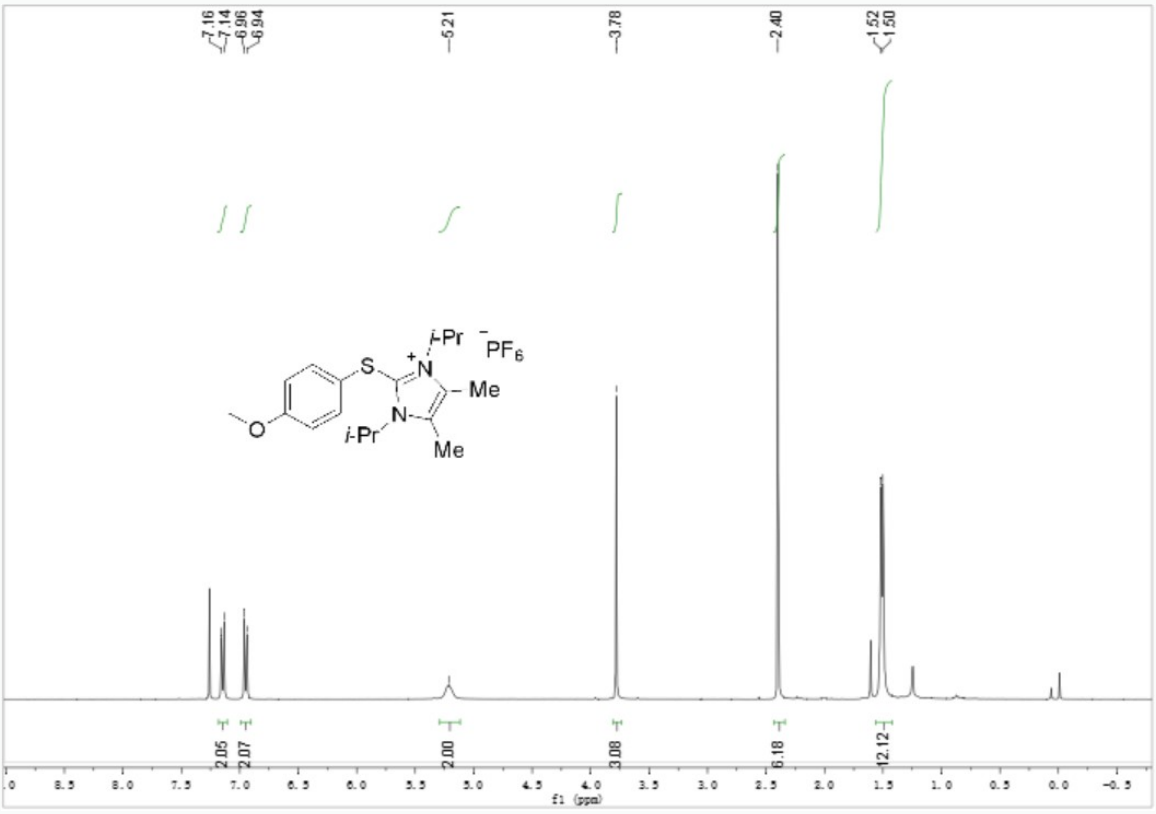
^{13}C NMR spectrum of **1e** ($CDCl_3$, 100 MHz)



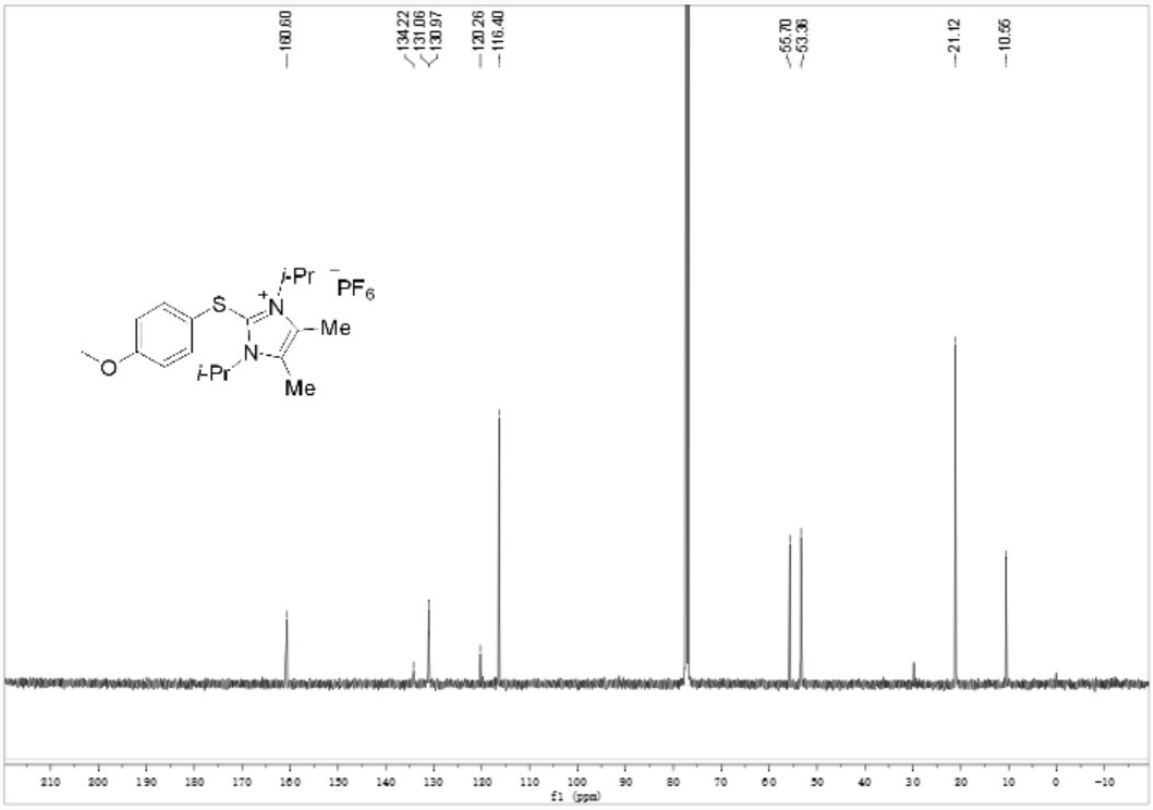
^{19}F NMR spectrum of **1e** ($CDCl_3$, 376 MHz)



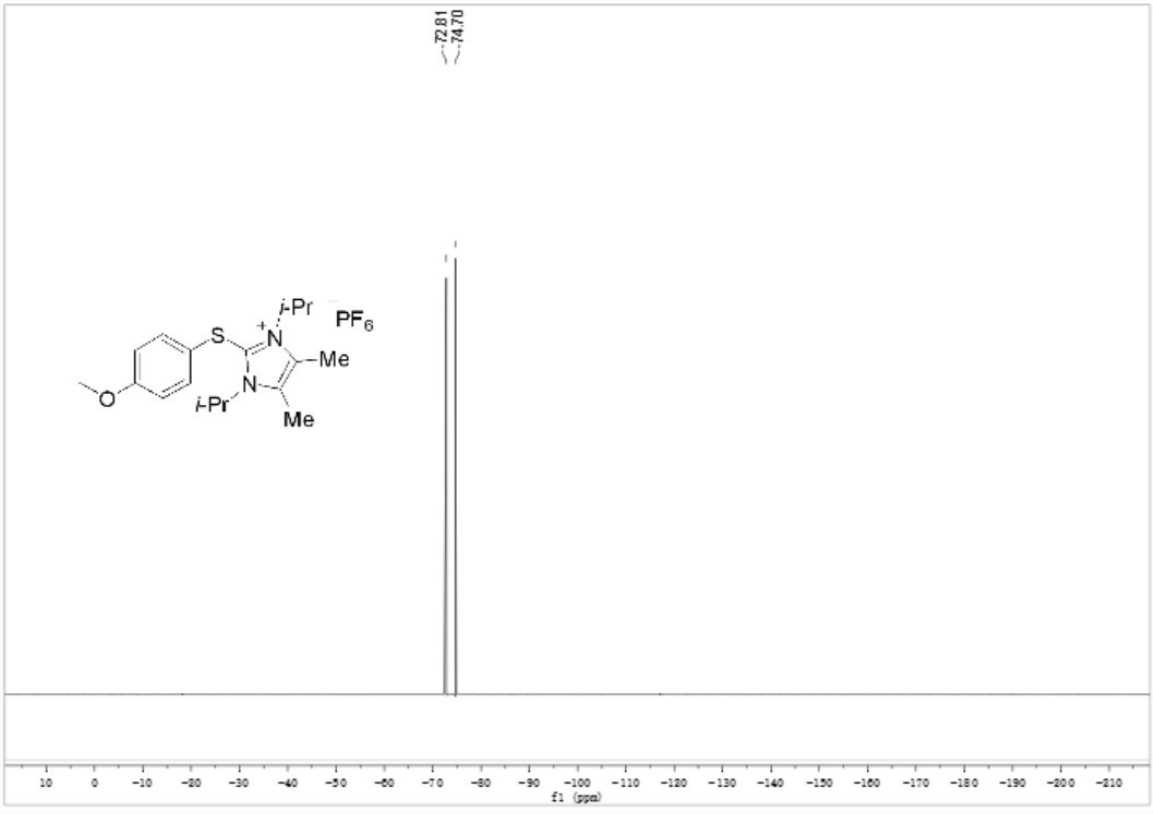
^{1}H NMR spectrum of **1f** ($CDCl_3$, 400 MHz)



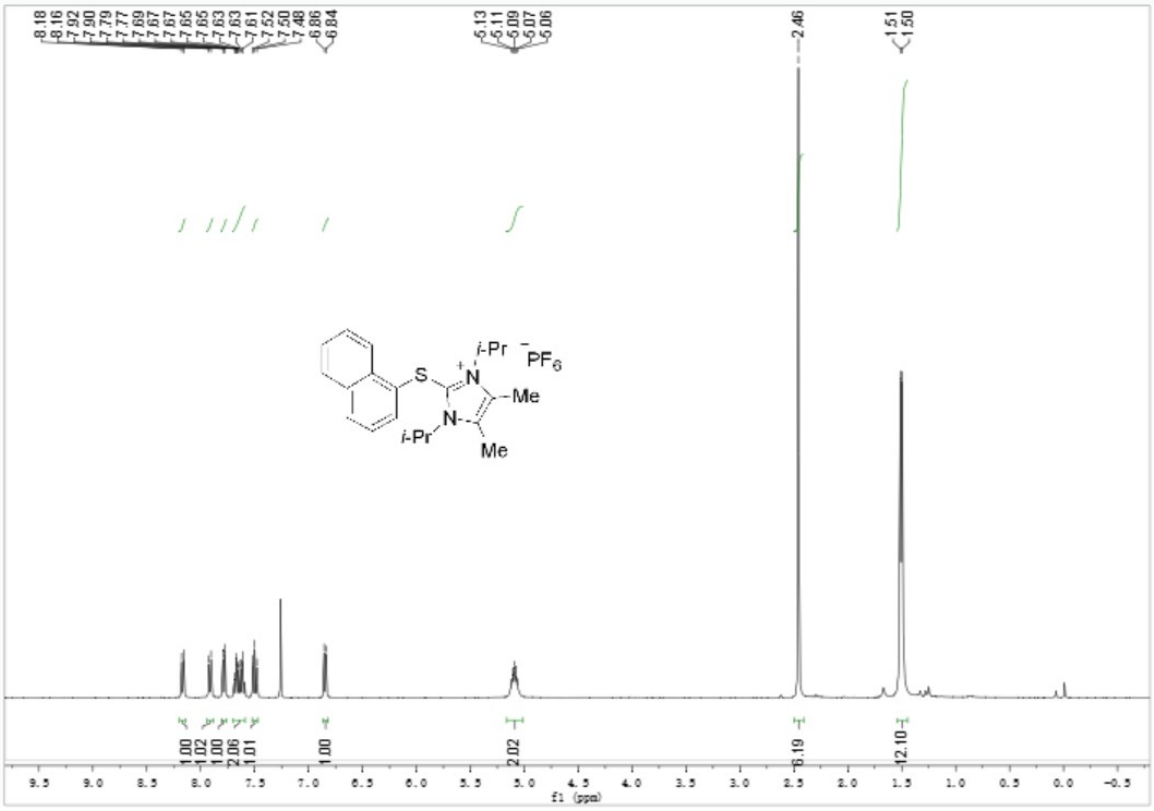
^{13}C NMR spectrum of **1f** ($CDCl_3$, 100 MHz)



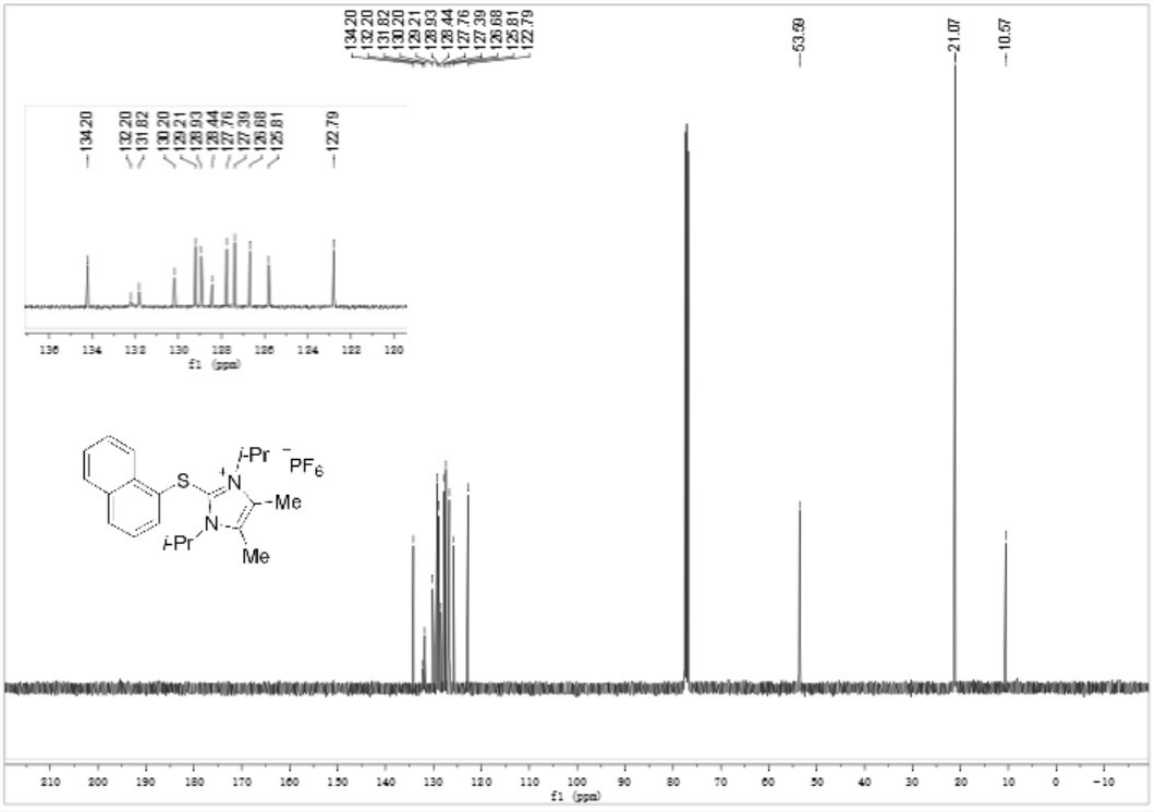
^{19}F NMR spectrum of **1f** ($CDCl_3$, 376 MHz)



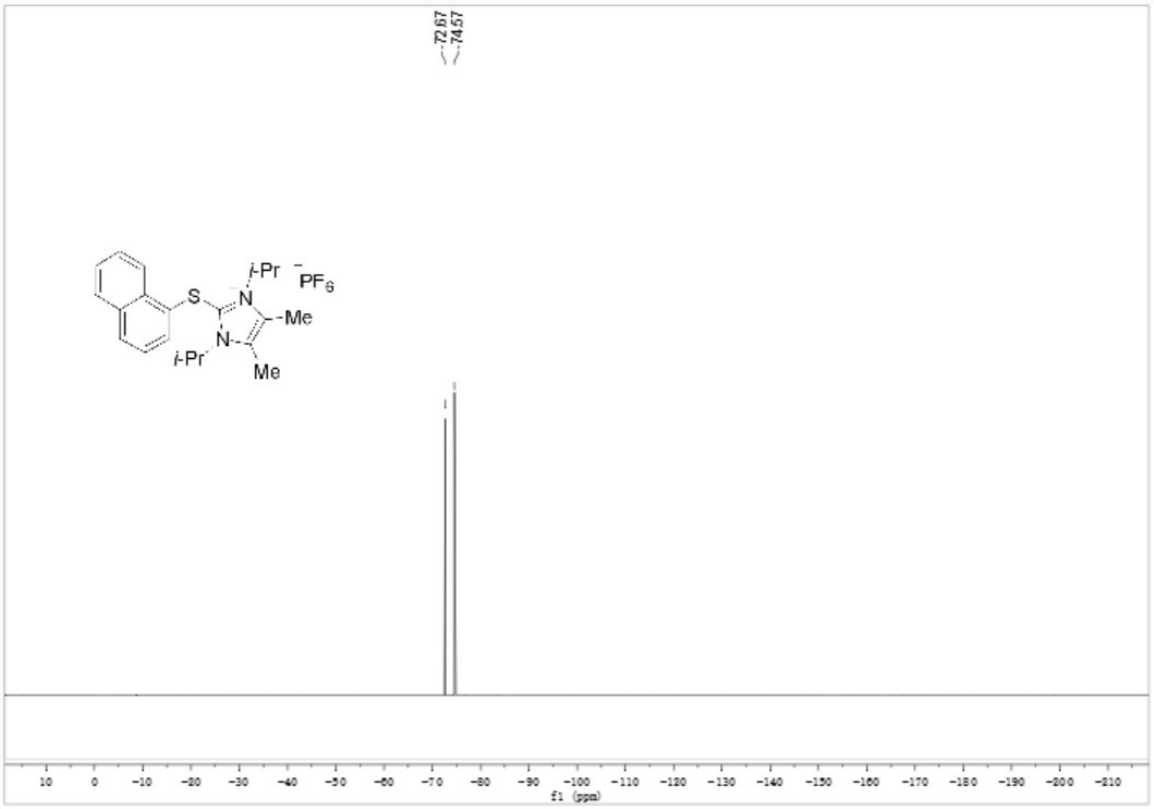
^{1}H NMR spectrum of **1g** ($CDCl_3$, 400 MHz)



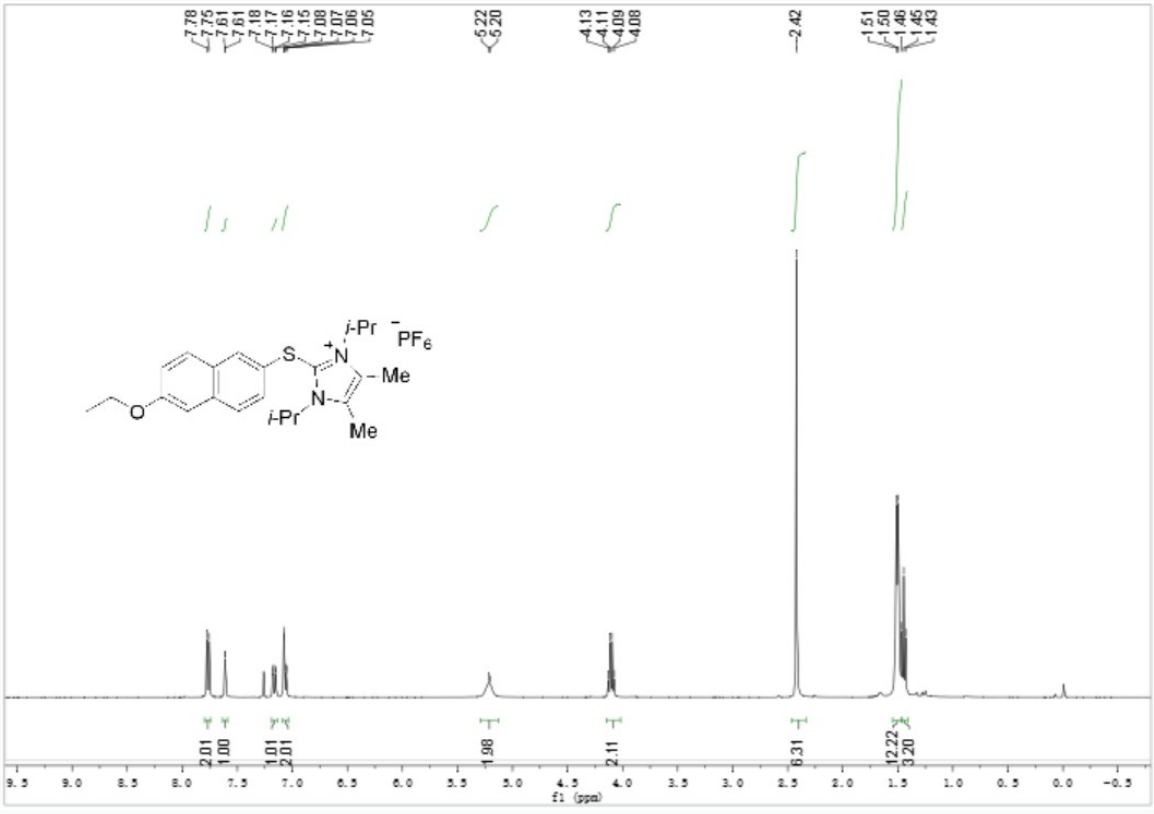
^{13}C NMR spectrum of **1g** ($CDCl_3$, 100 MHz)



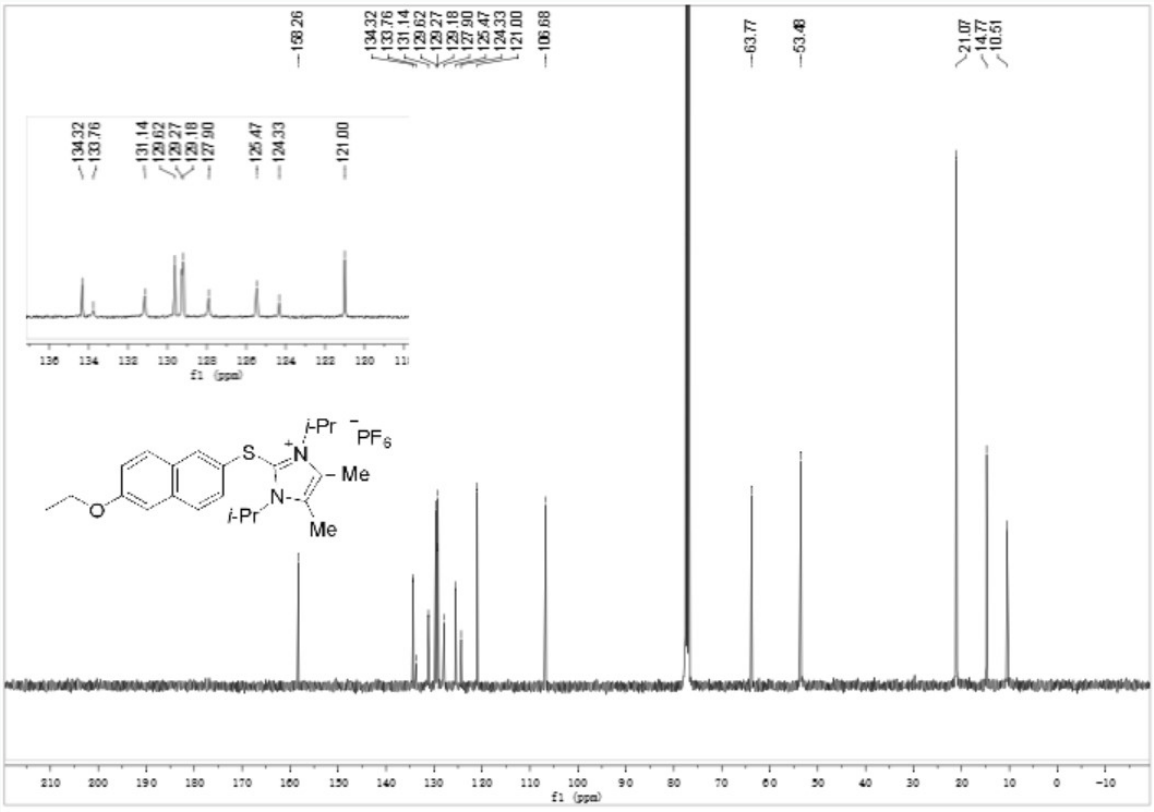
^{19}F NMR spectrum of **1g** ($CDCl_3$, 376 MHz)



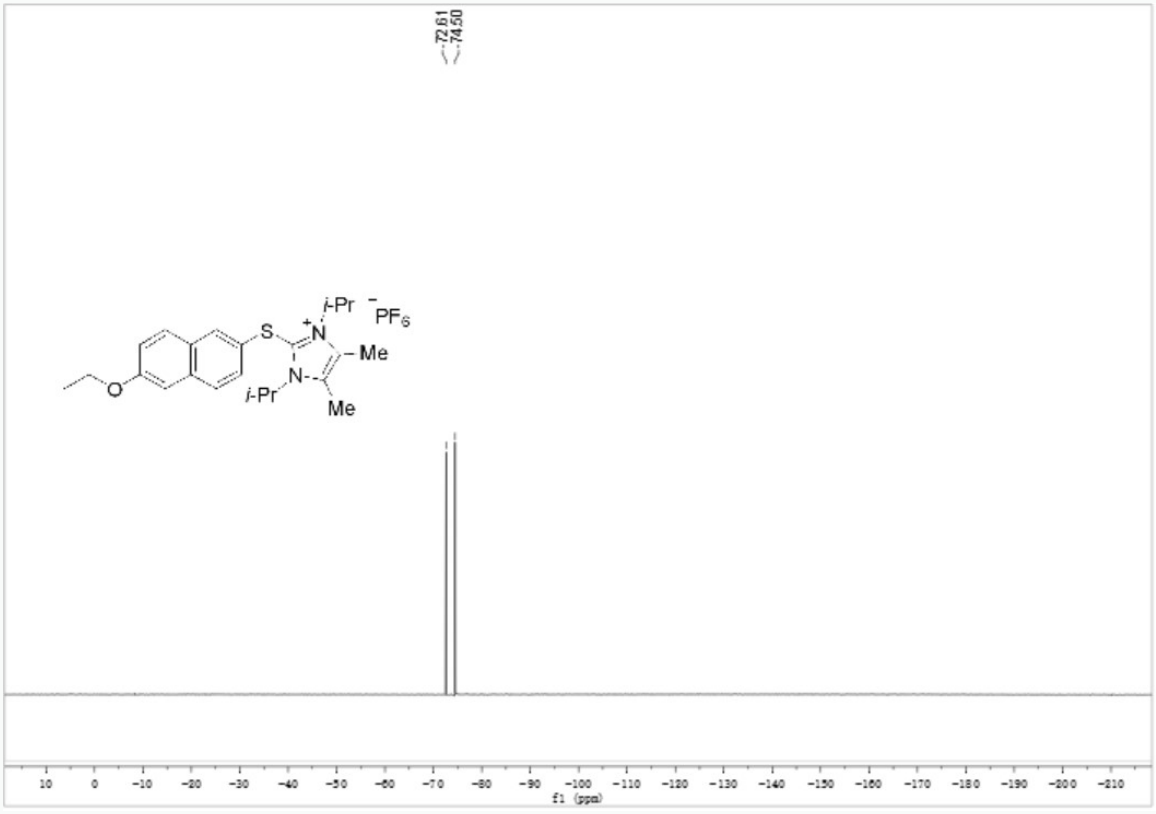
^{1}H NMR spectrum of **1h** ($CDCl_3$, 400 MHz)



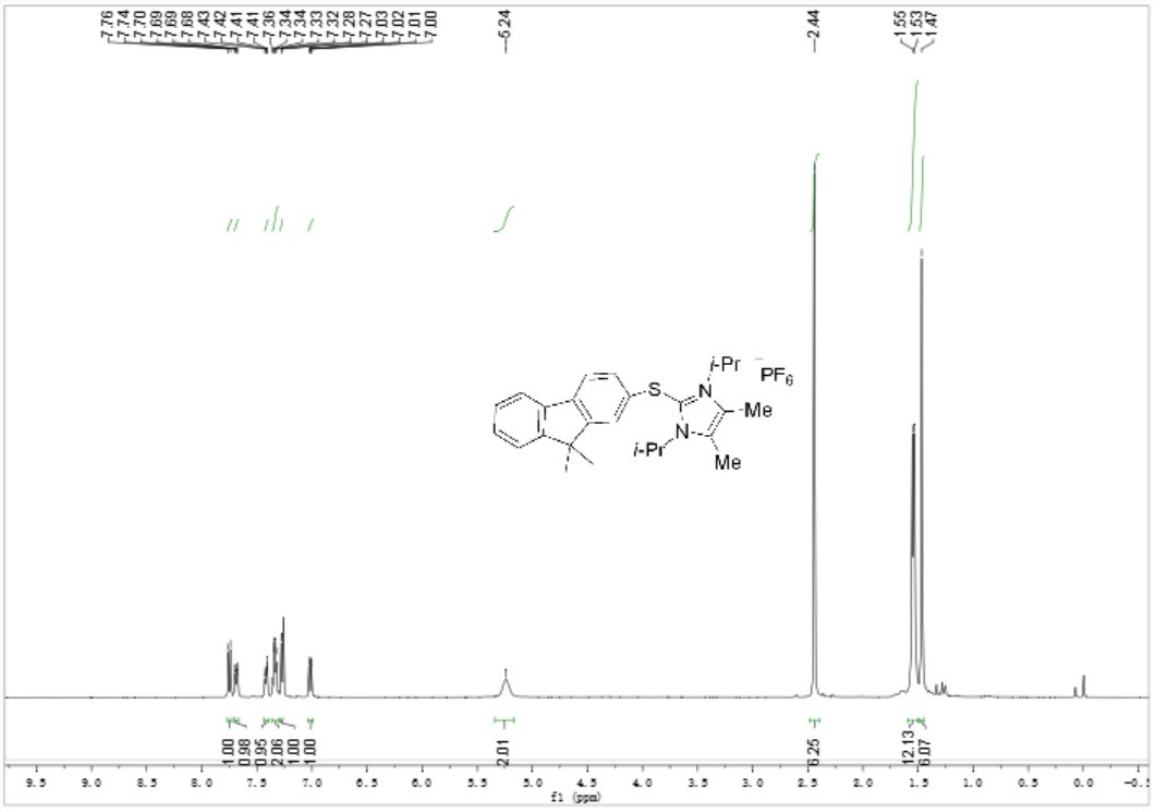
^{13}C NMR spectrum of **1h** ($CDCl_3$, 100 MHz)



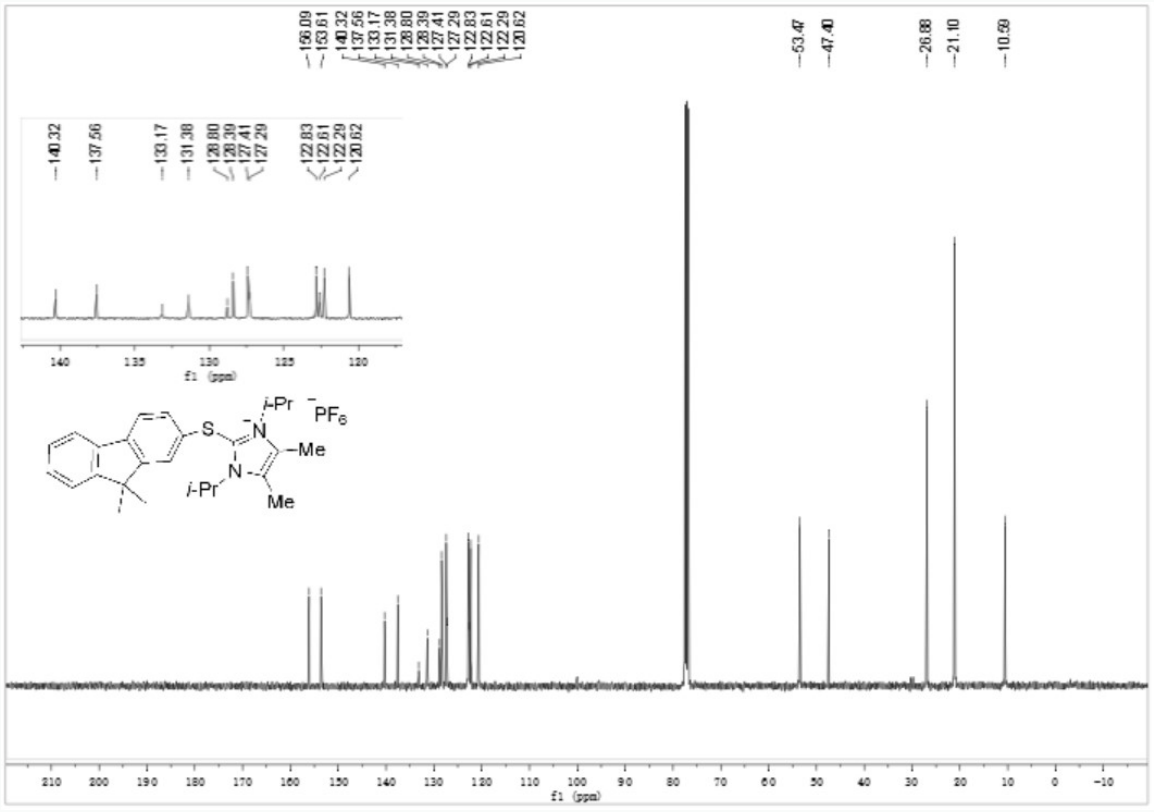
^{19}F NMR spectrum of **1h** ($CDCl_3$, 376 MHz)



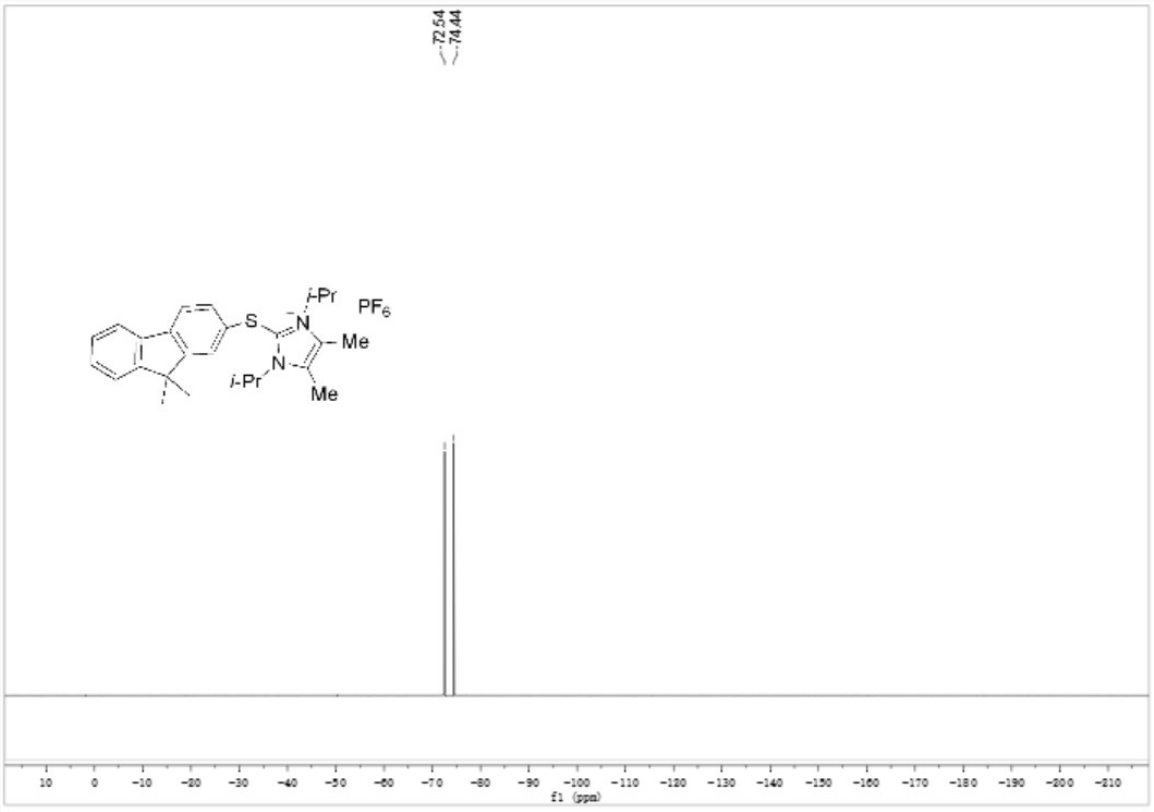
^{1}H NMR spectrum of **1i** ($CDCl_3$, 400 MHz)



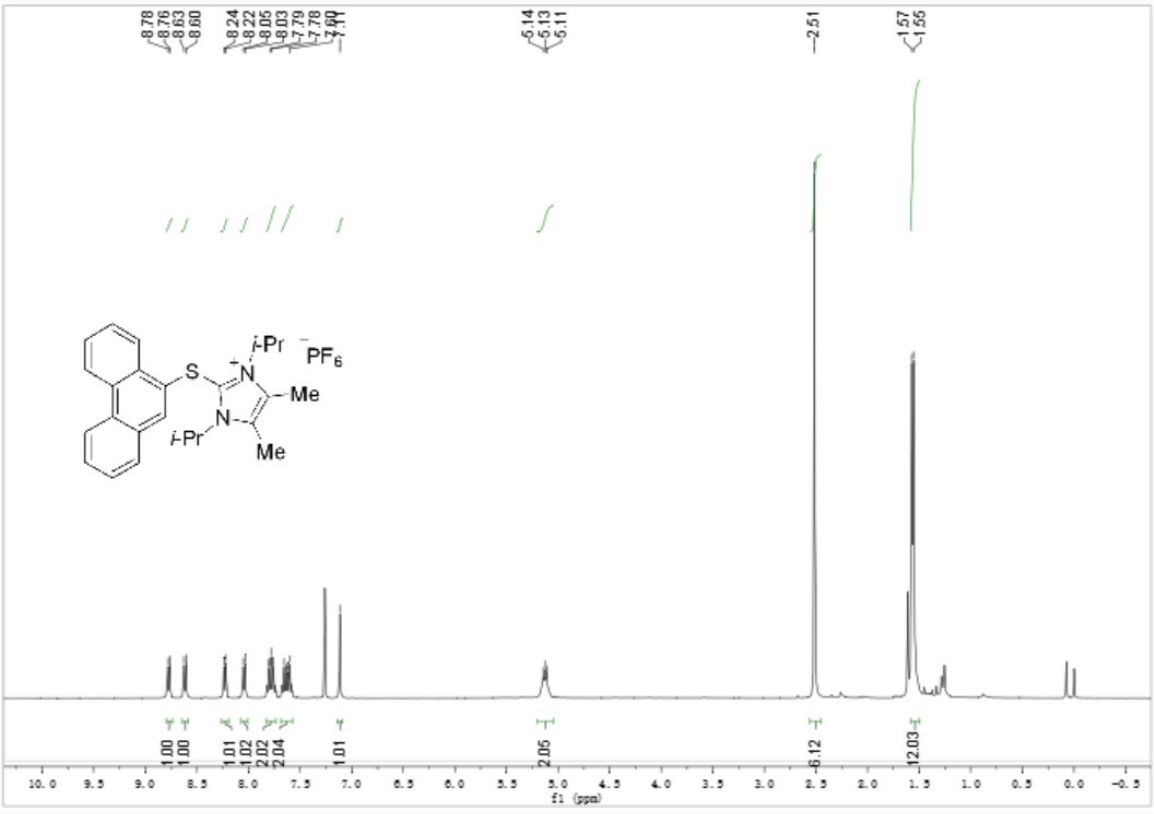
^{13}C NMR spectrum of **1i** ($CDCl_3$, 100 MHz)



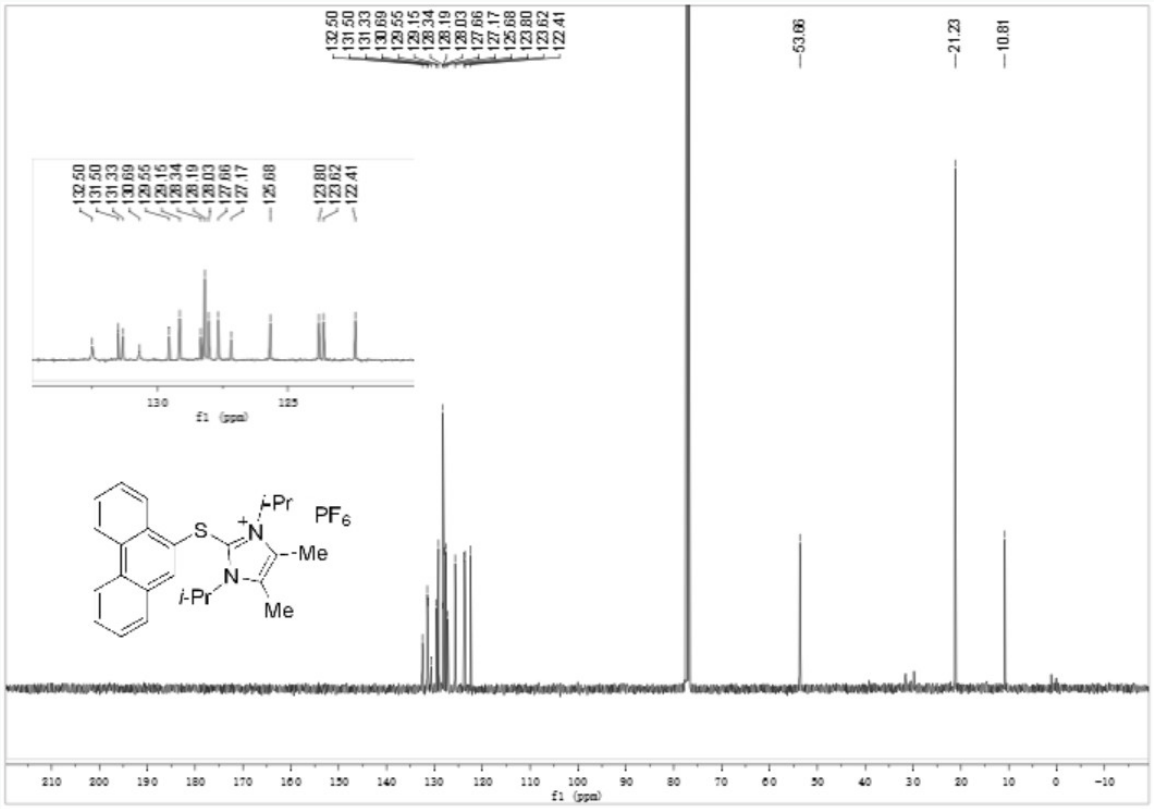
^{19}F NMR spectrum of **1i** ($CDCl_3$, 376 MHz)



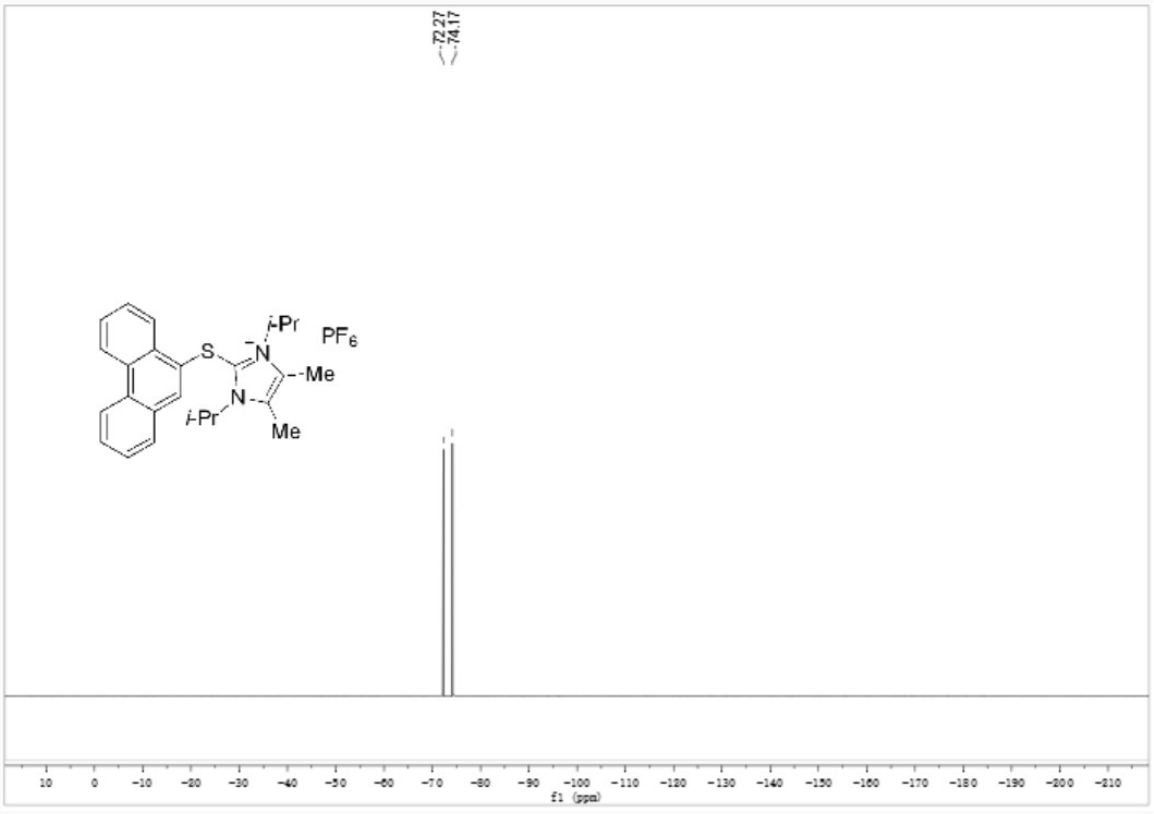
^{1}H NMR spectrum of **1j** ($CDCl_3$, 400 MHz)



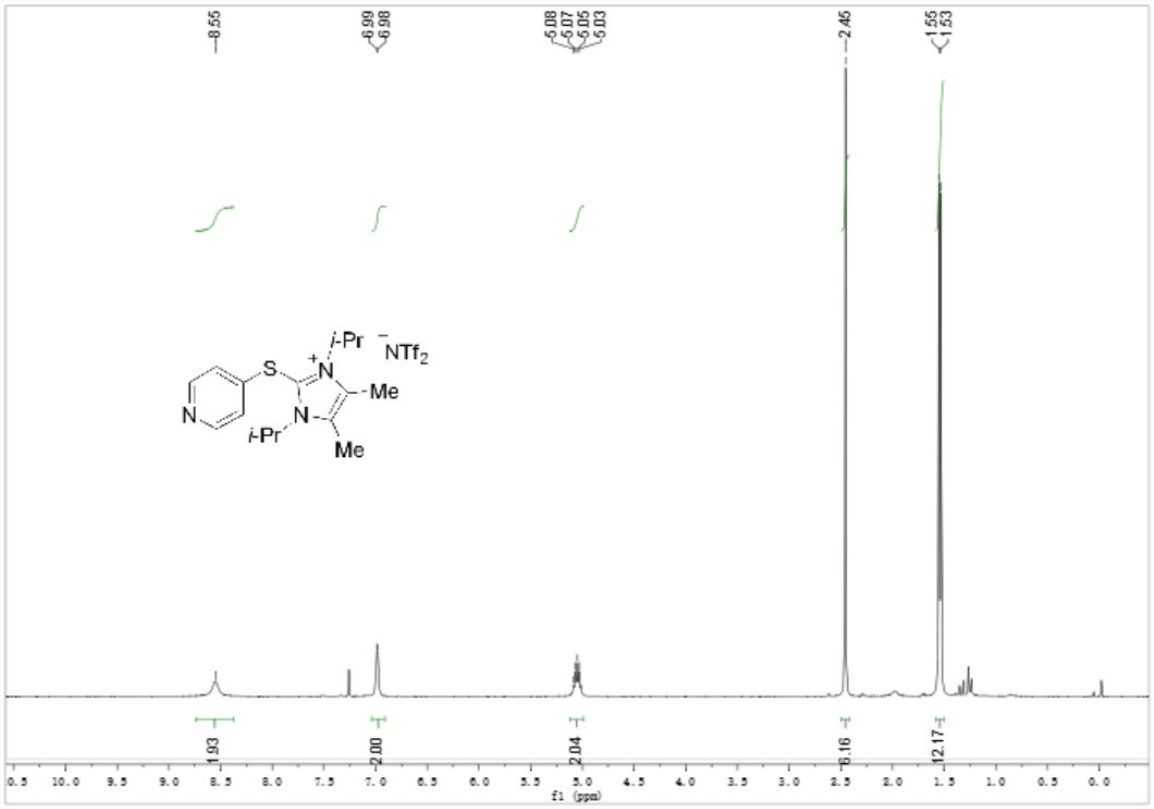
^{13}C NMR spectrum of **1j** ($CDCl_3$, 100 MHz)



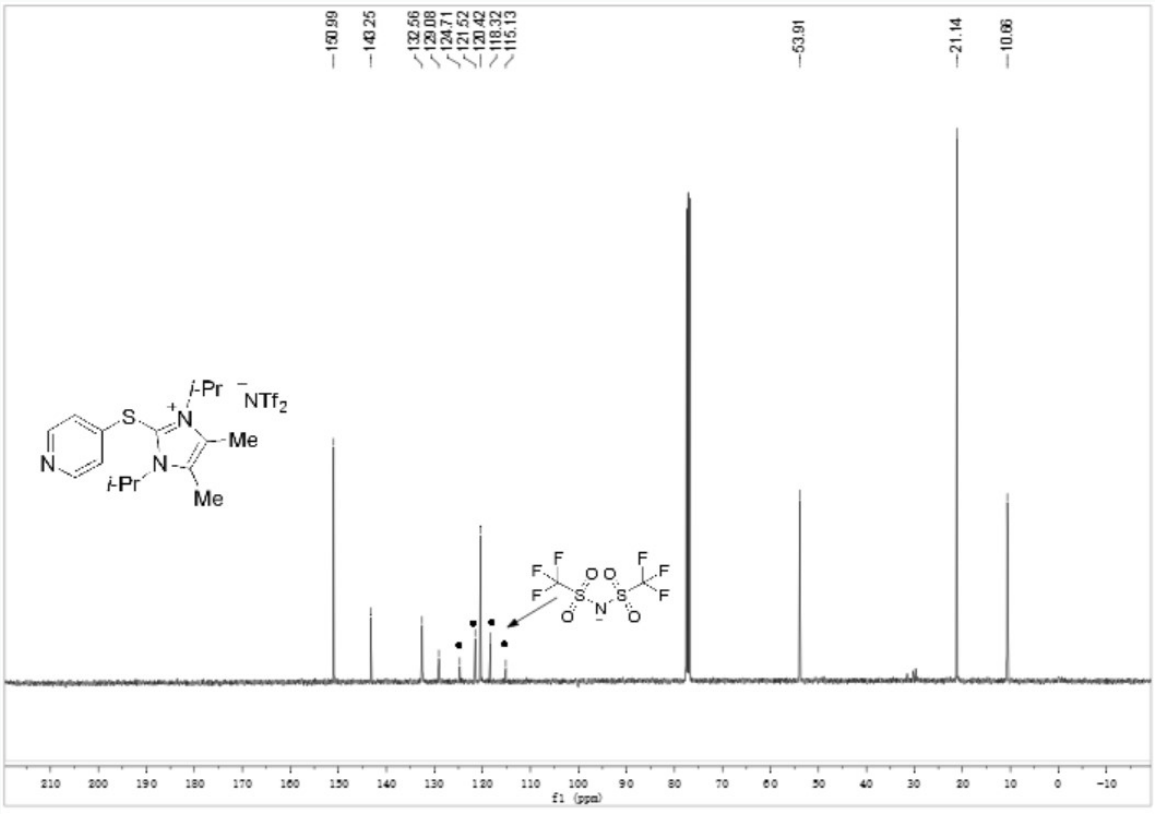
^{19}F NMR spectrum of **1j** ($CDCl_3$, 376 MHz)



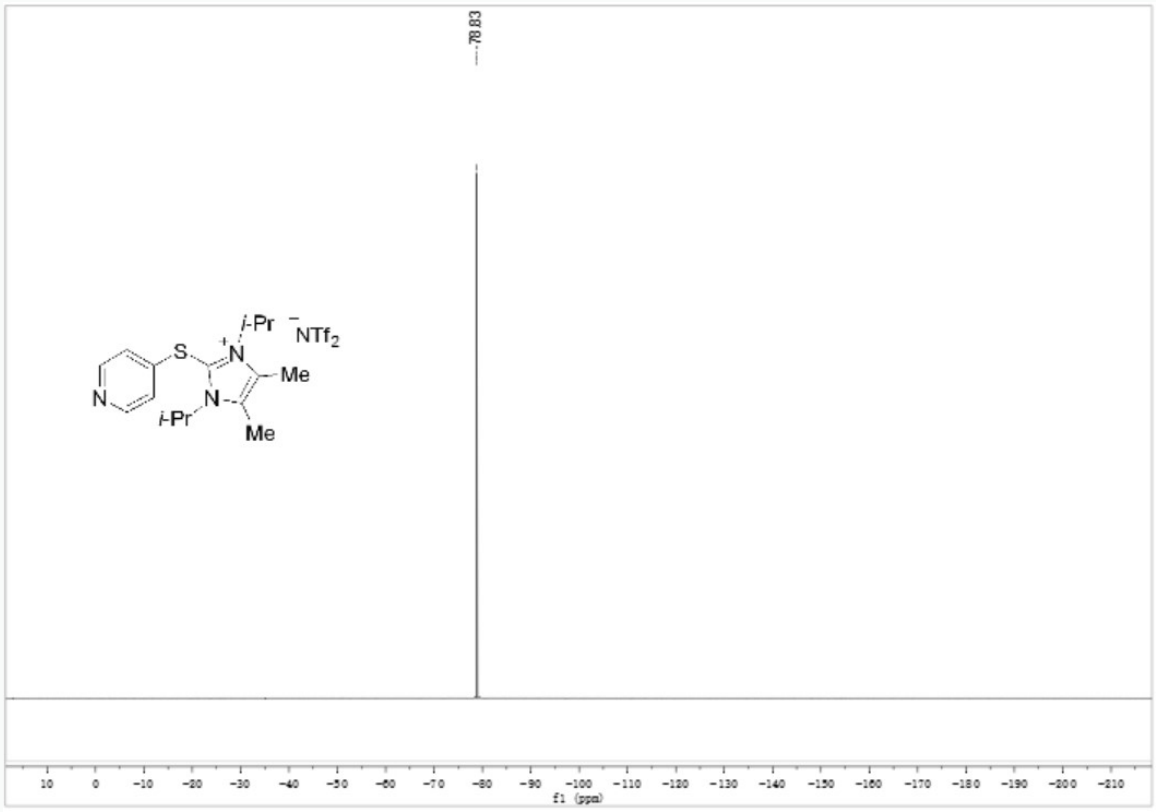
^{1}H NMR spectrum of **1k** ($CDCl_3$, 400 MHz)



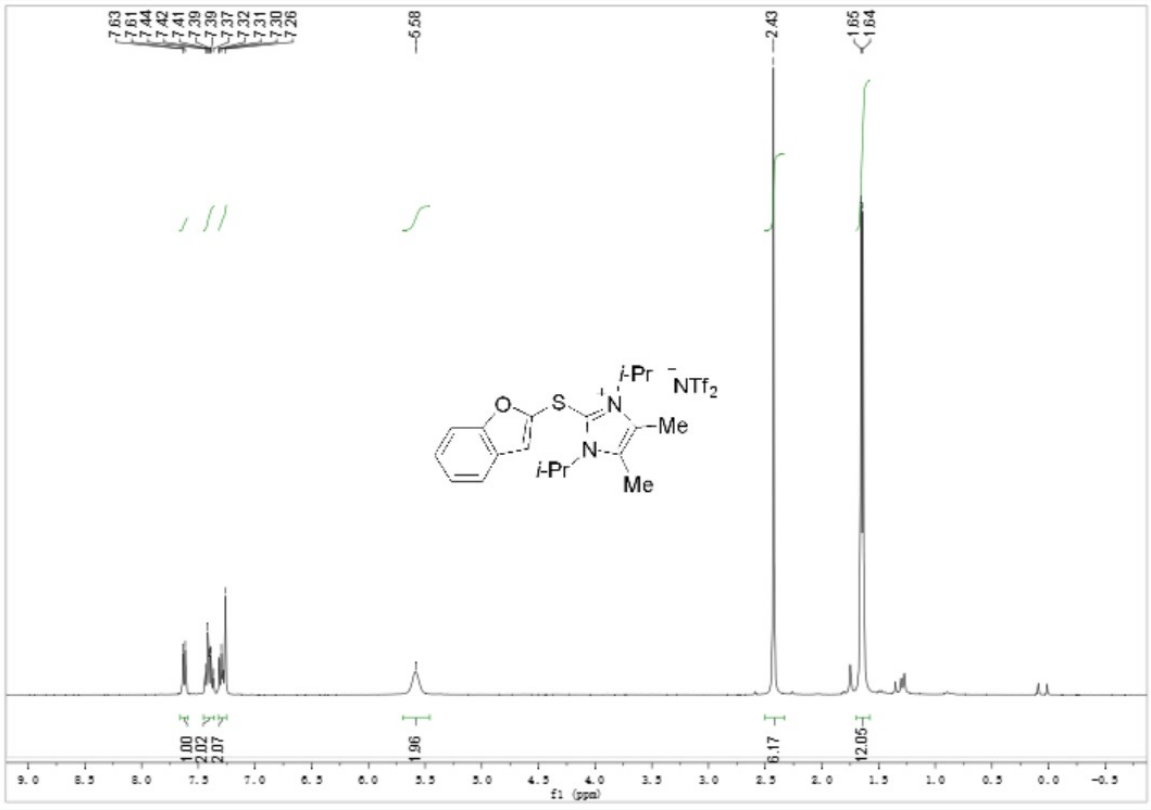
^{13}C NMR spectrum of **1k** ($CDCl_3$, 100 MHz)



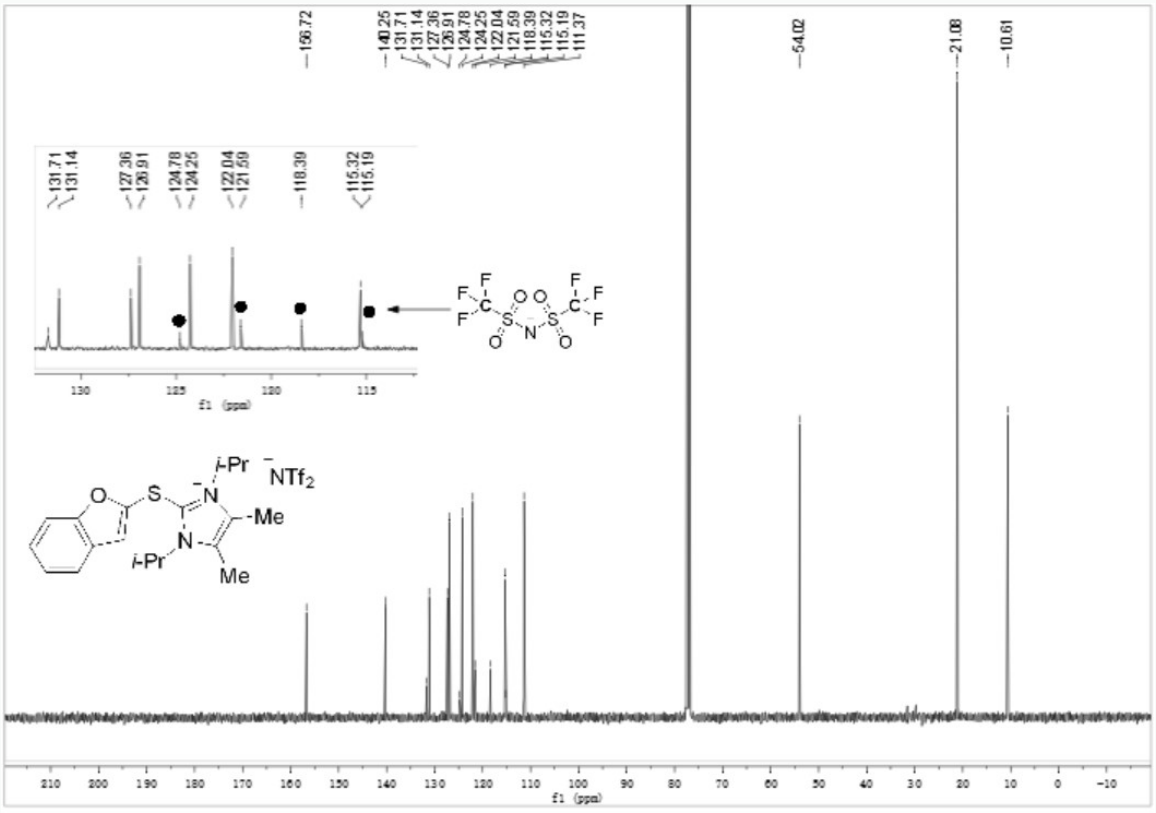
^{19}F NMR spectrum of **1k** ($CDCl_3$, 376 MHz)



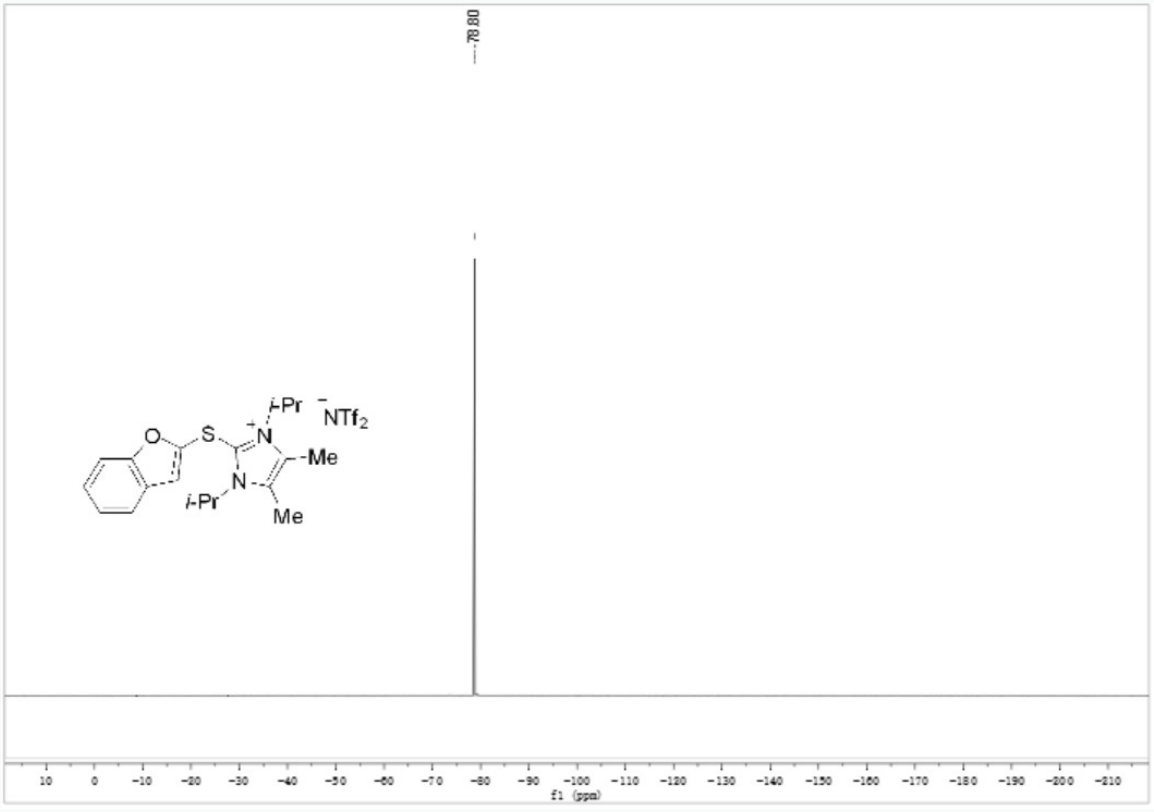
^{1}H NMR spectrum of **1l** ($CDCl_3$, 400 MHz)



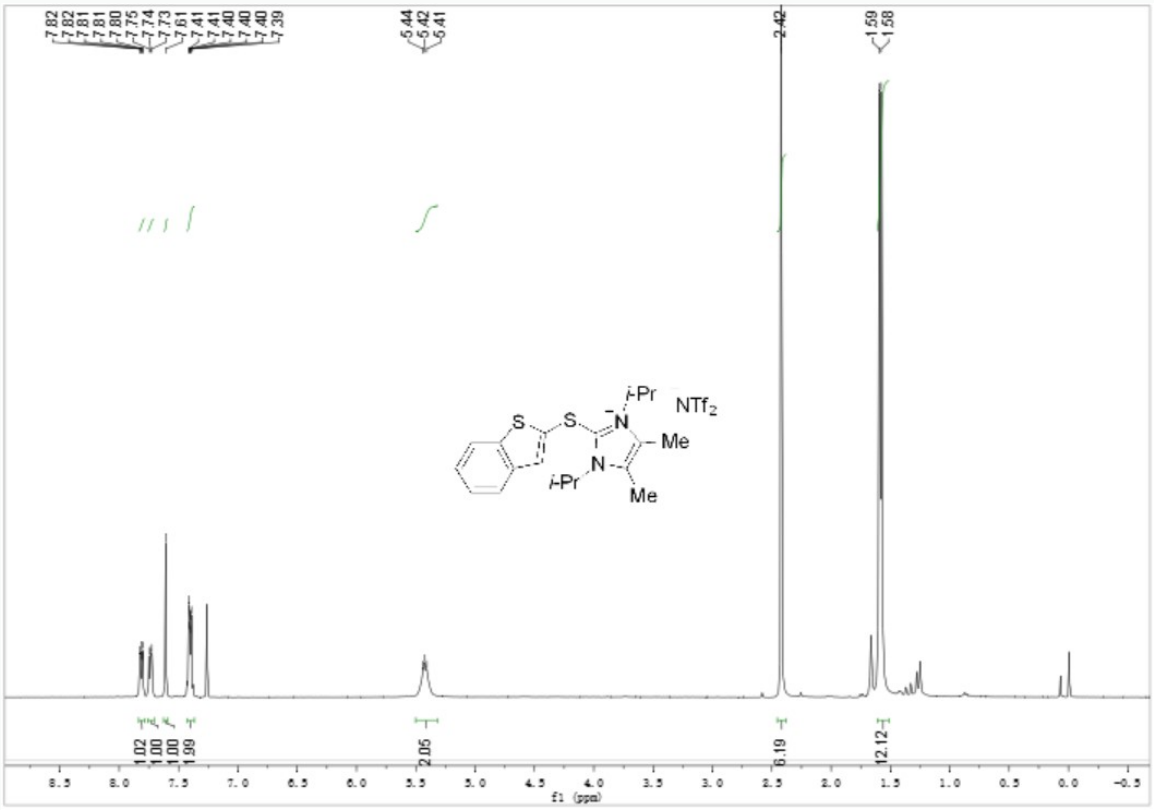
^{13}C NMR spectrum of **1l** ($CDCl_3$, 100 MHz)



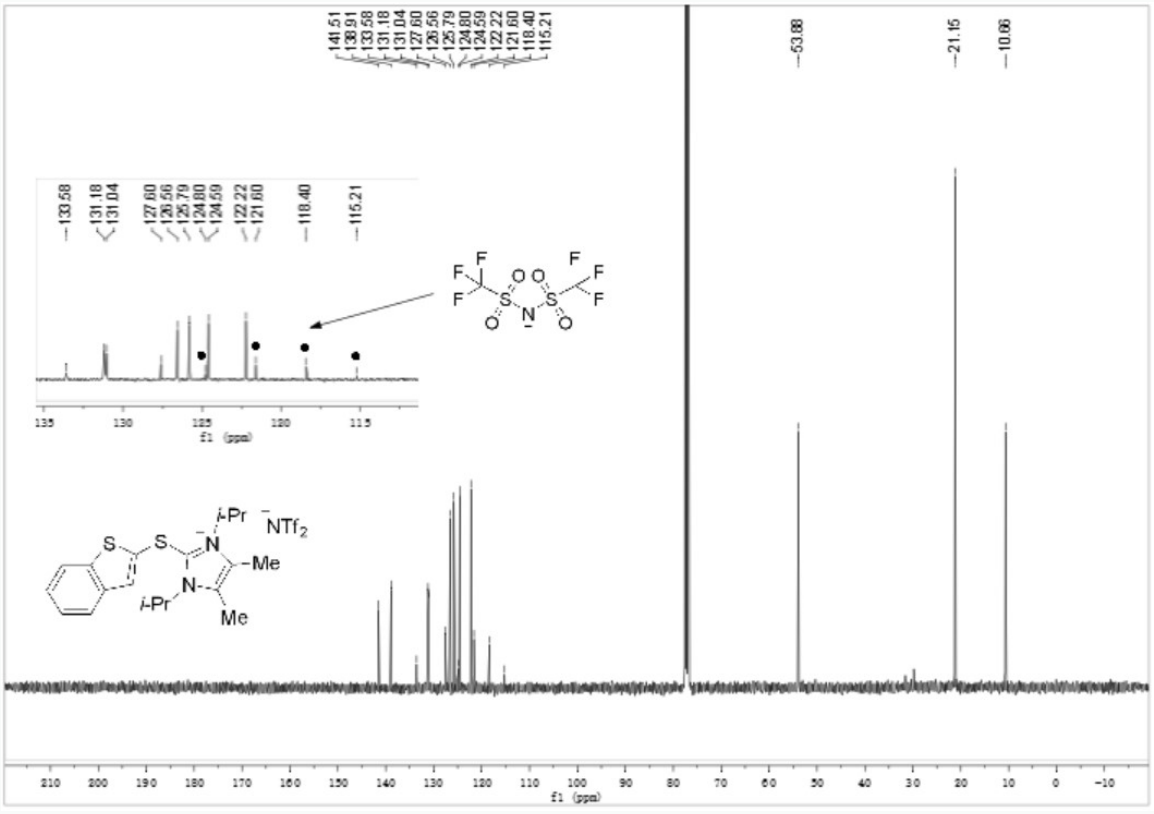
^{19}F NMR spectrum of **1l** ($CDCl_3$, 376 MHz)



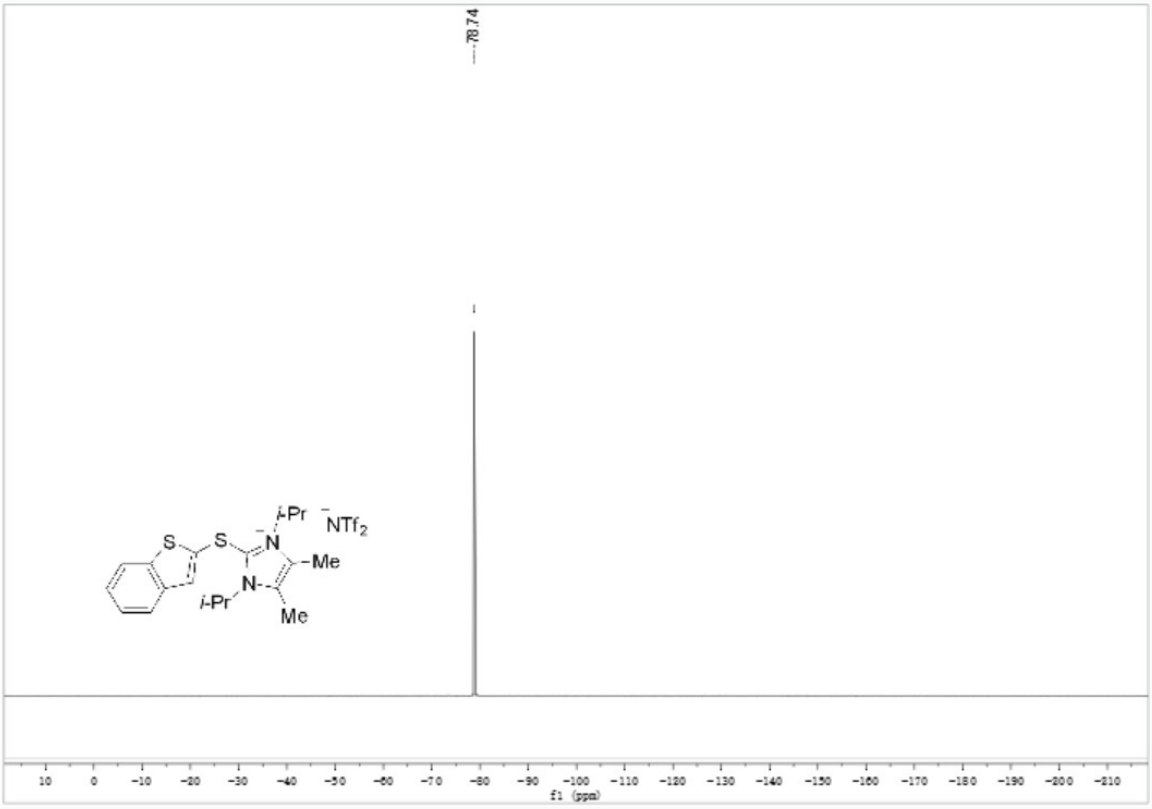
^{1}H NMR spectrum of **1m** ($CDCl_3$, 400 MHz)



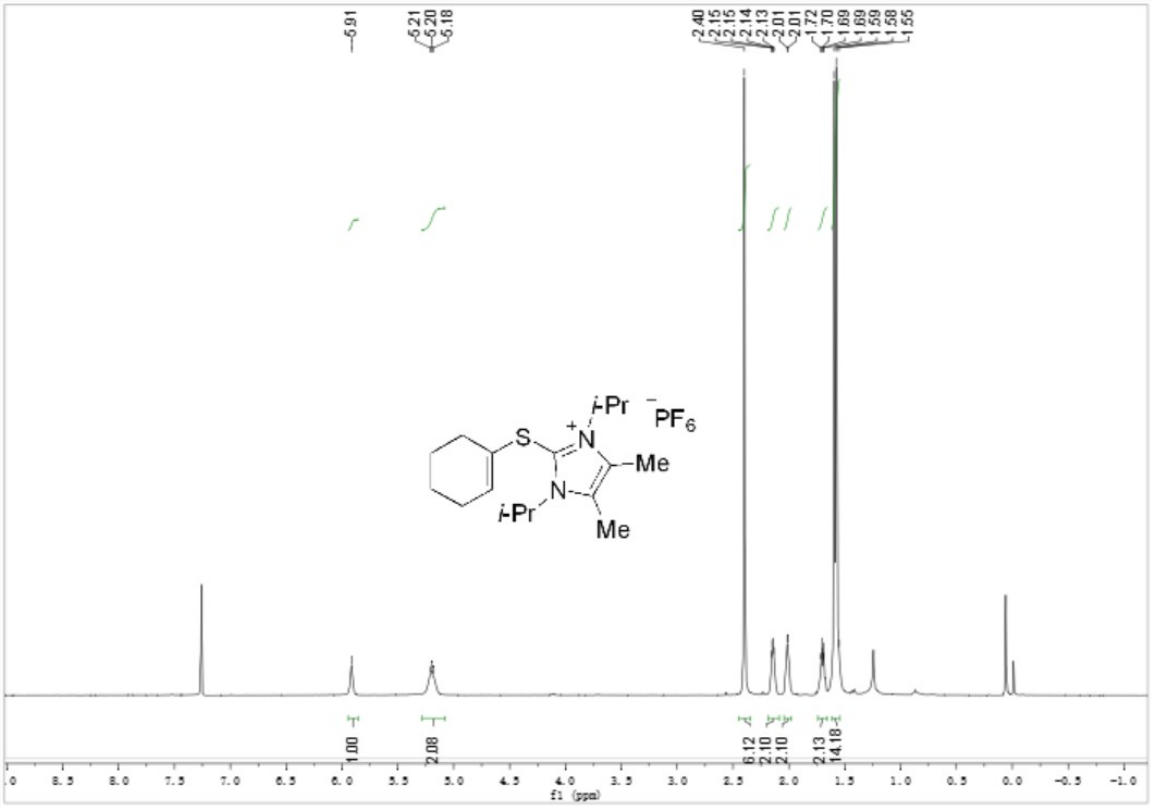
^{13}C NMR spectrum of **1m** ($CDCl_3$, 100 MHz)



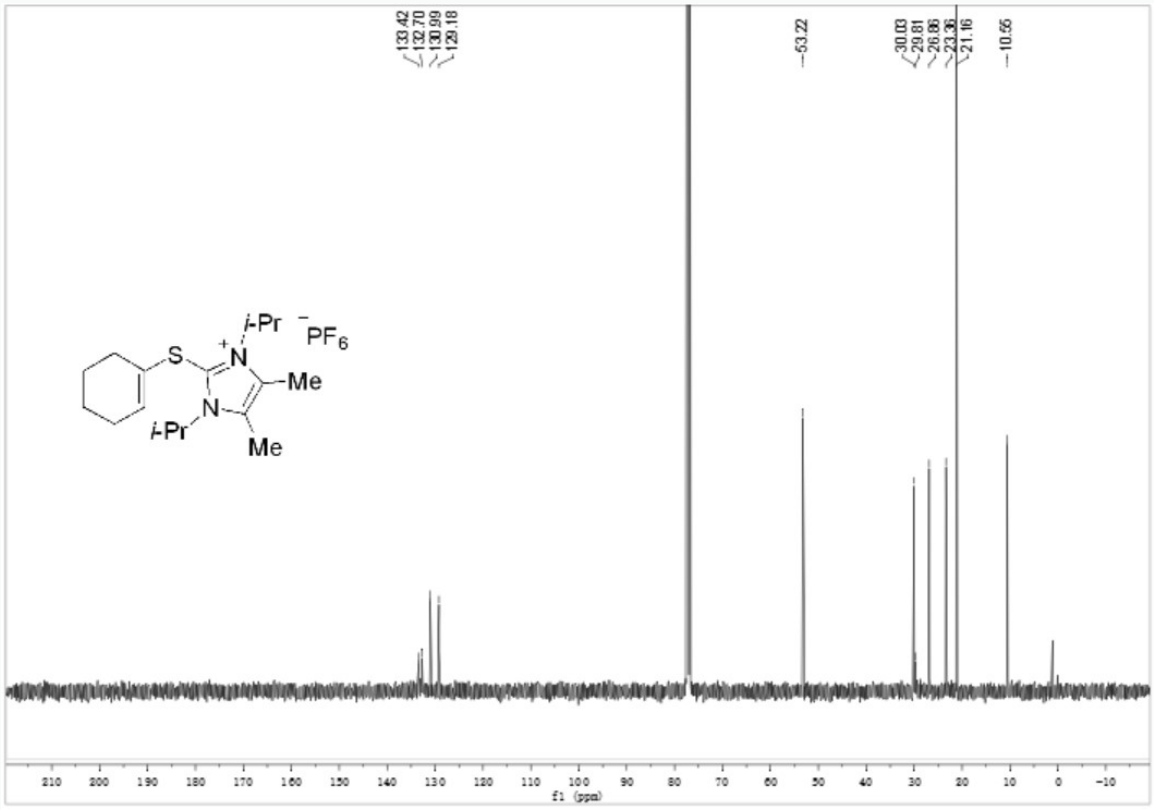
^{19}F NMR spectrum of **1m** ($CDCl_3$, 376 MHz)



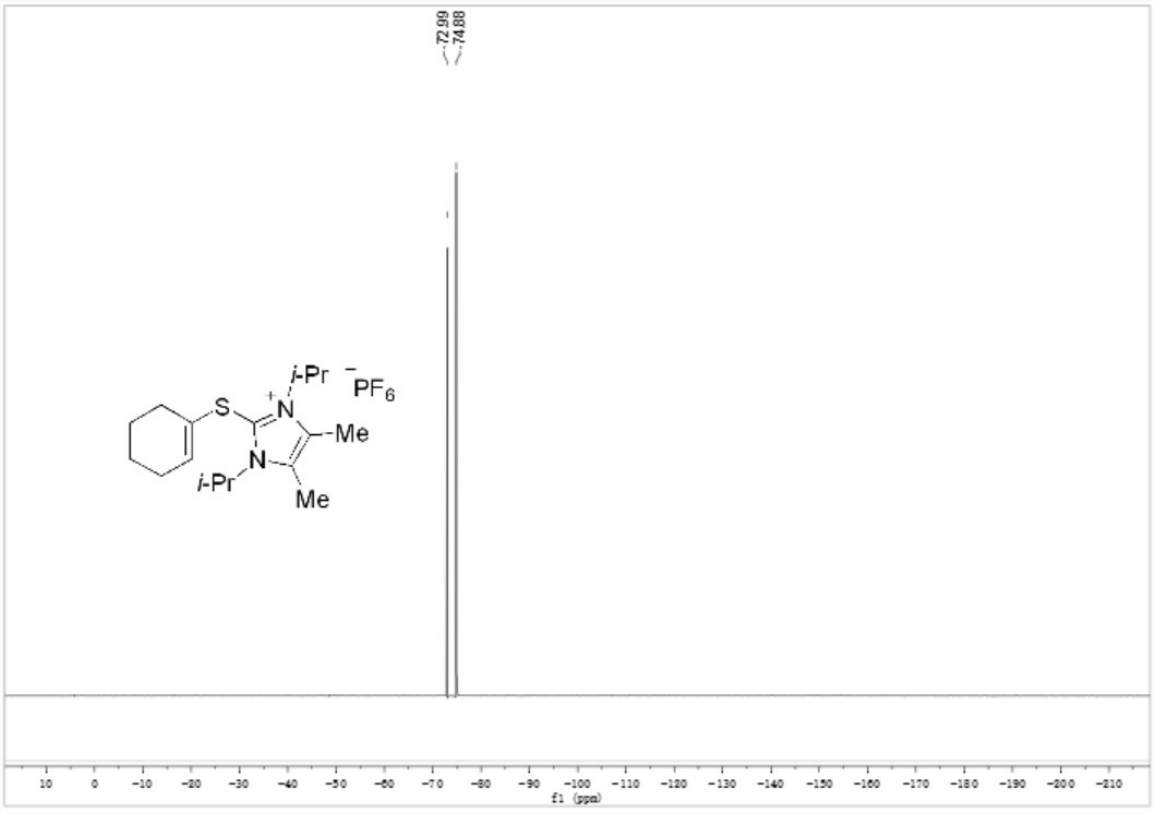
^{1}H NMR spectrum of **1n** ($CDCl_3$, 400 MHz)



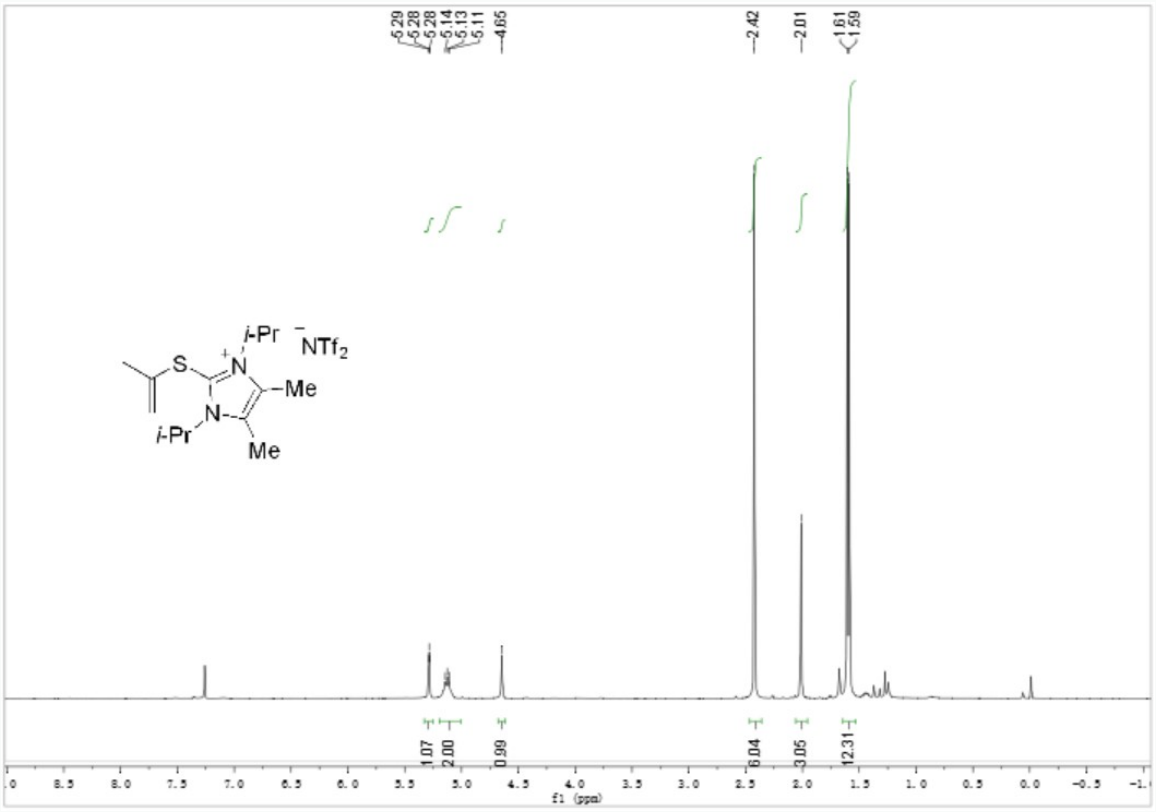
^{13}C NMR spectrum of **1n** ($CDCl_3$, 100 MHz)



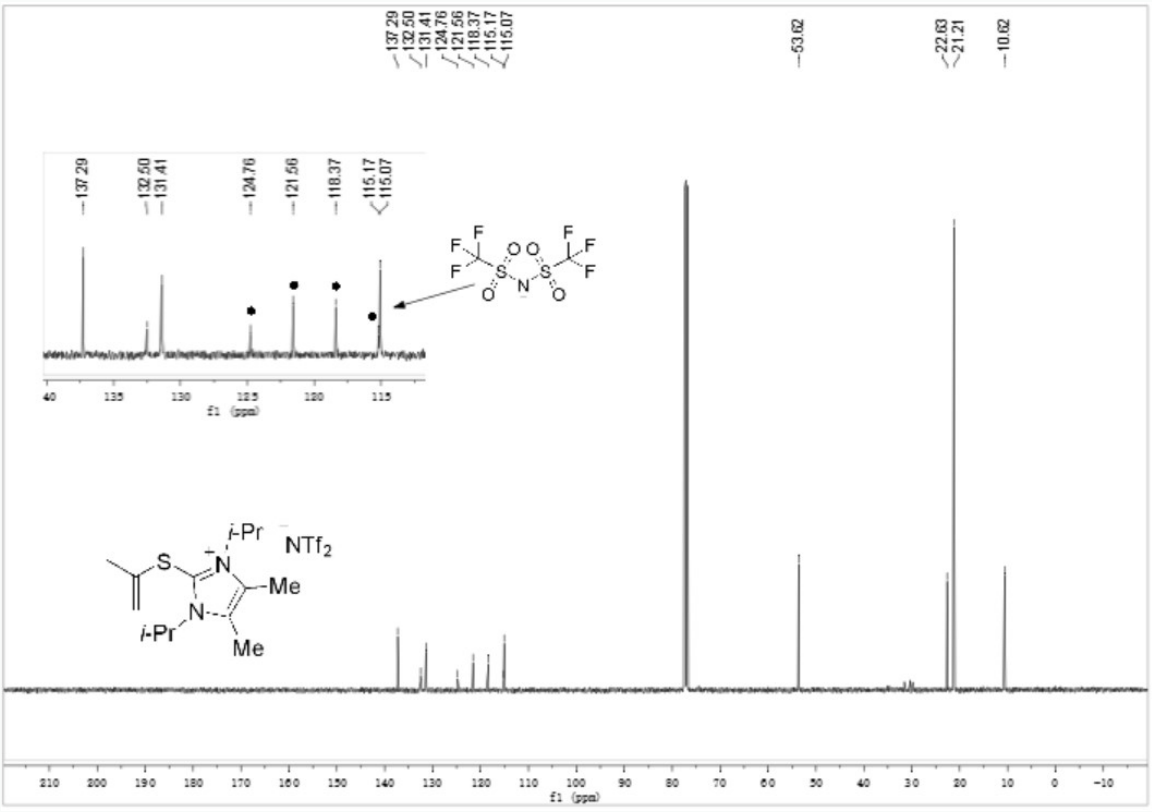
^{19}F NMR spectrum of **1n** ($CDCl_3$, 376 MHz)



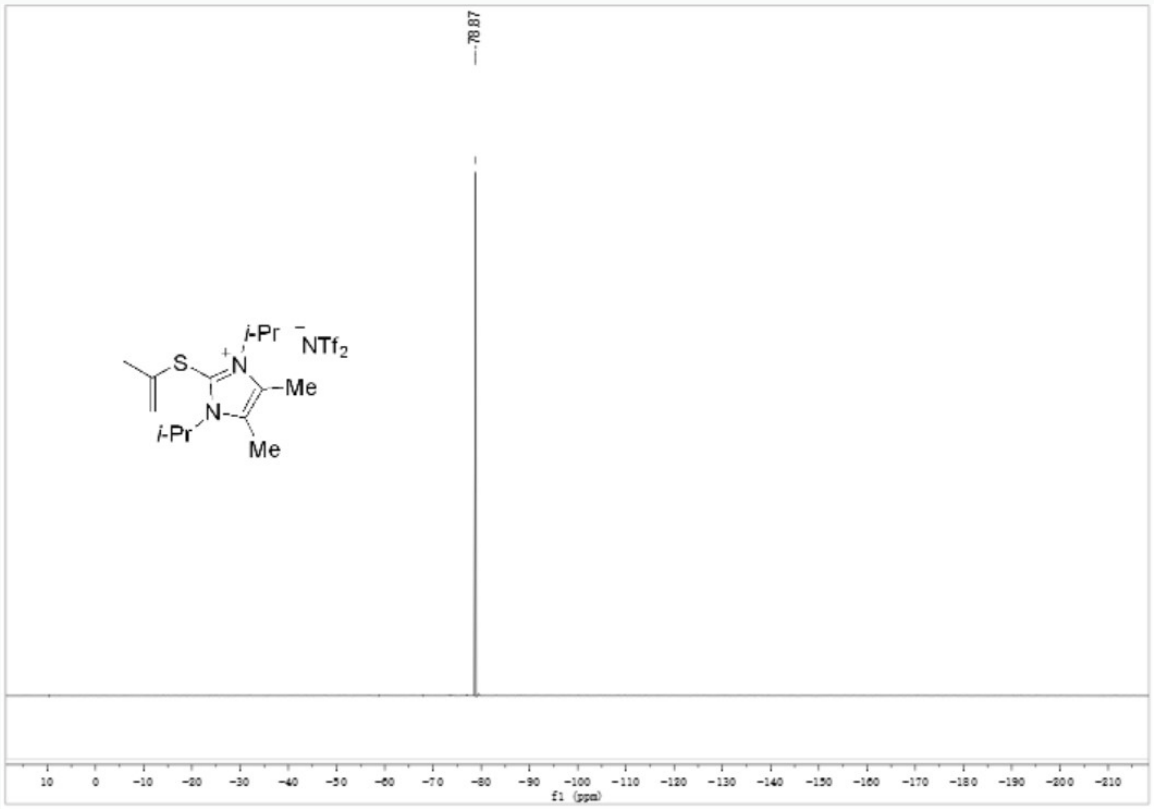
^{1}H NMR spectrum of **1o** ($CDCl_3$, 400 MHz)



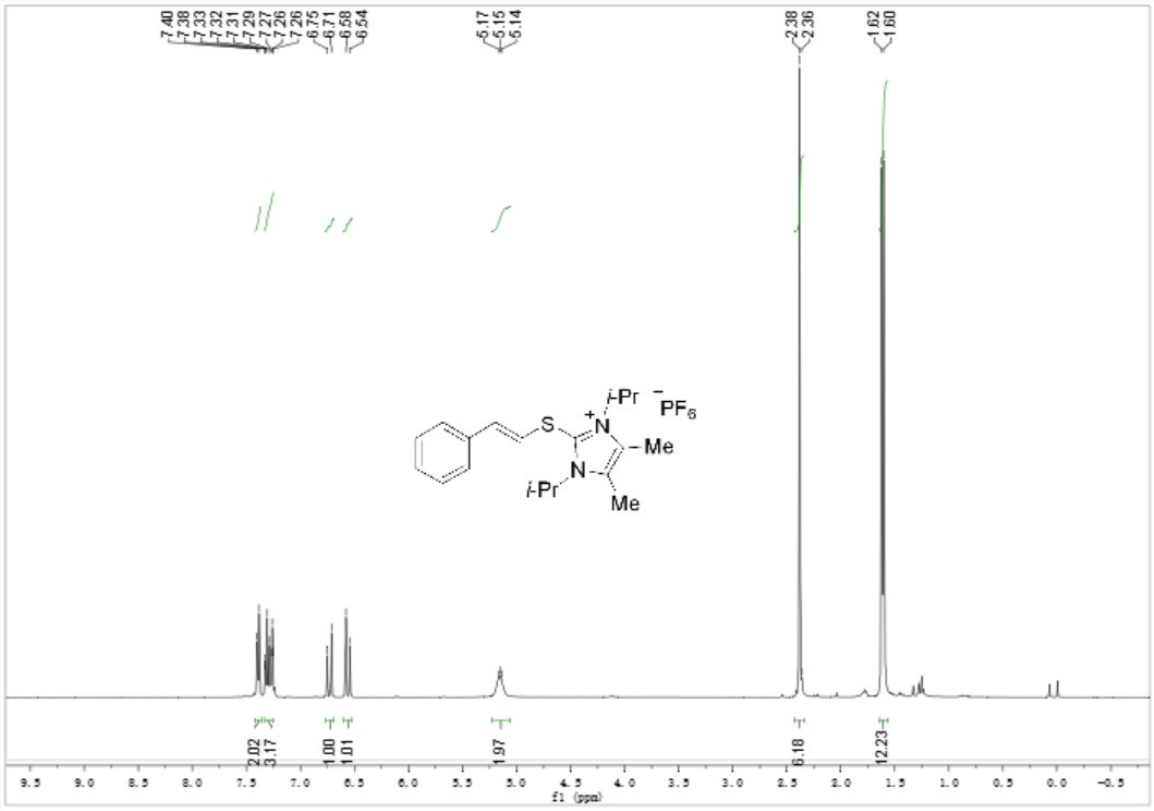
^{13}C NMR spectrum of **1o** ($CDCl_3$, 100 MHz)



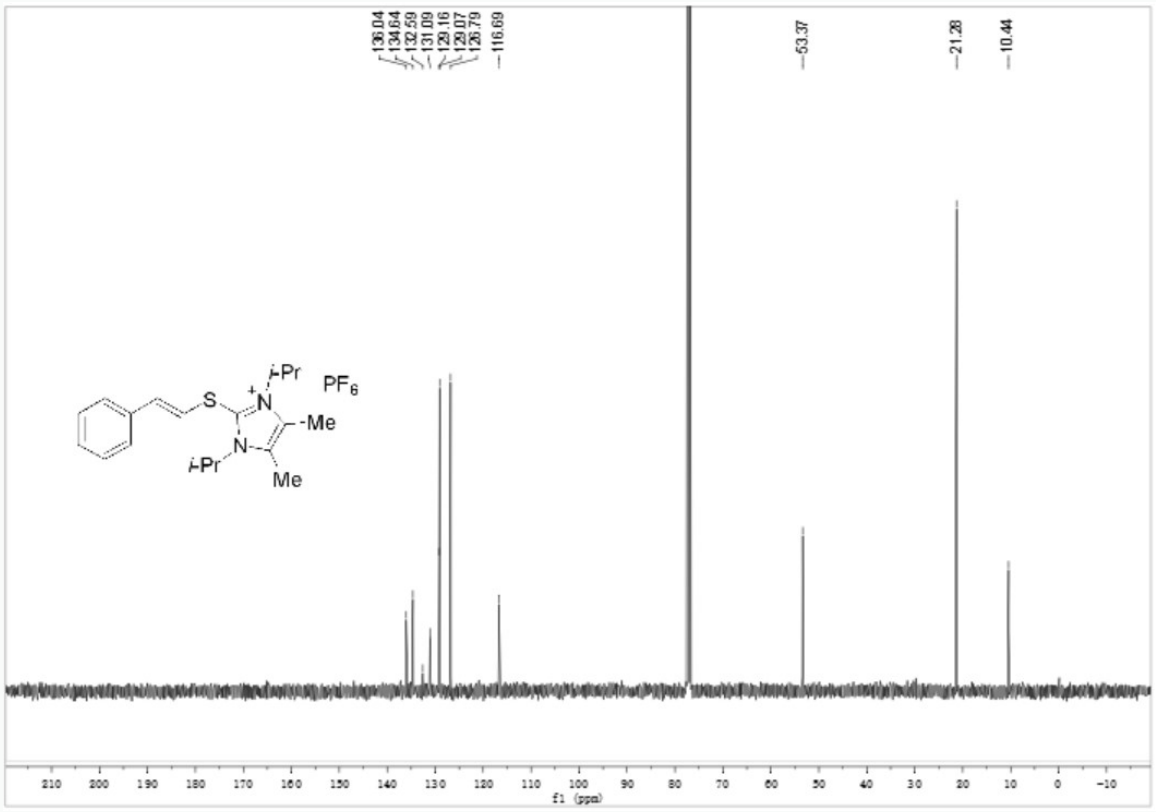
^{19}F NMR spectrum of **1o** ($CDCl_3$, 376 MHz)



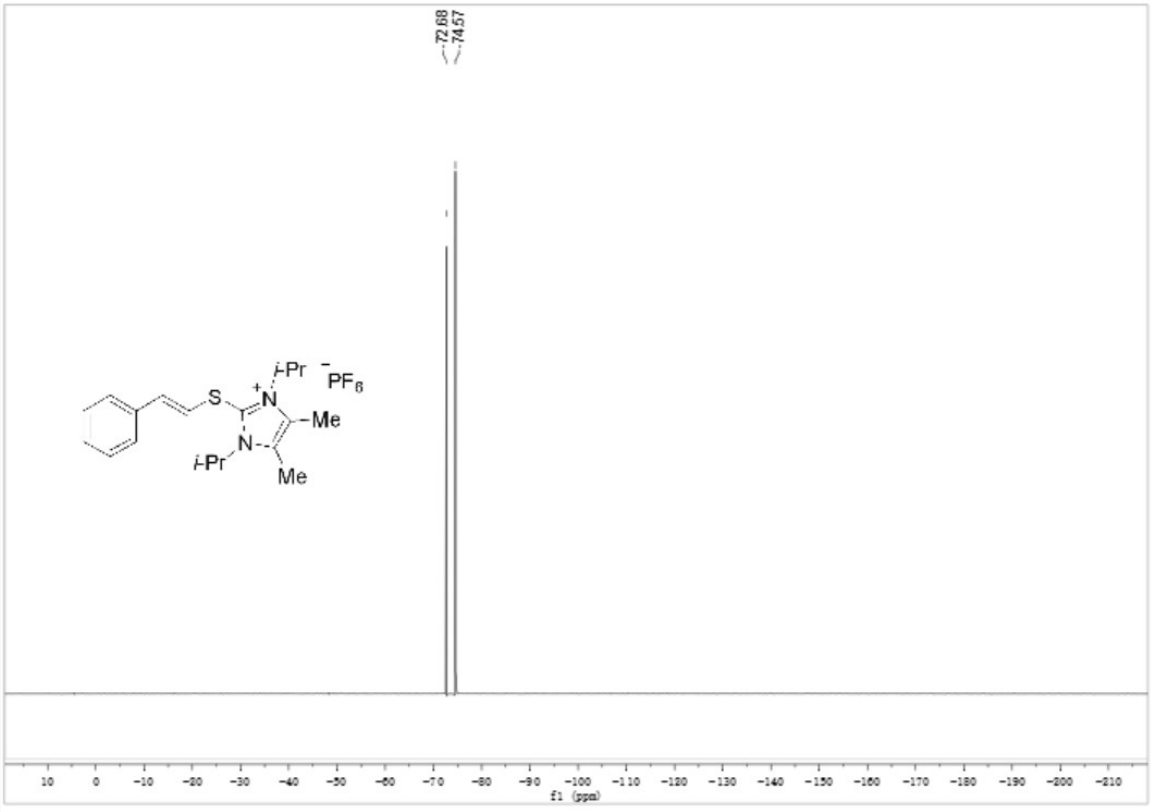
^{1}H NMR spectrum of **1p** ($CDCl_3$, 400 MHz)



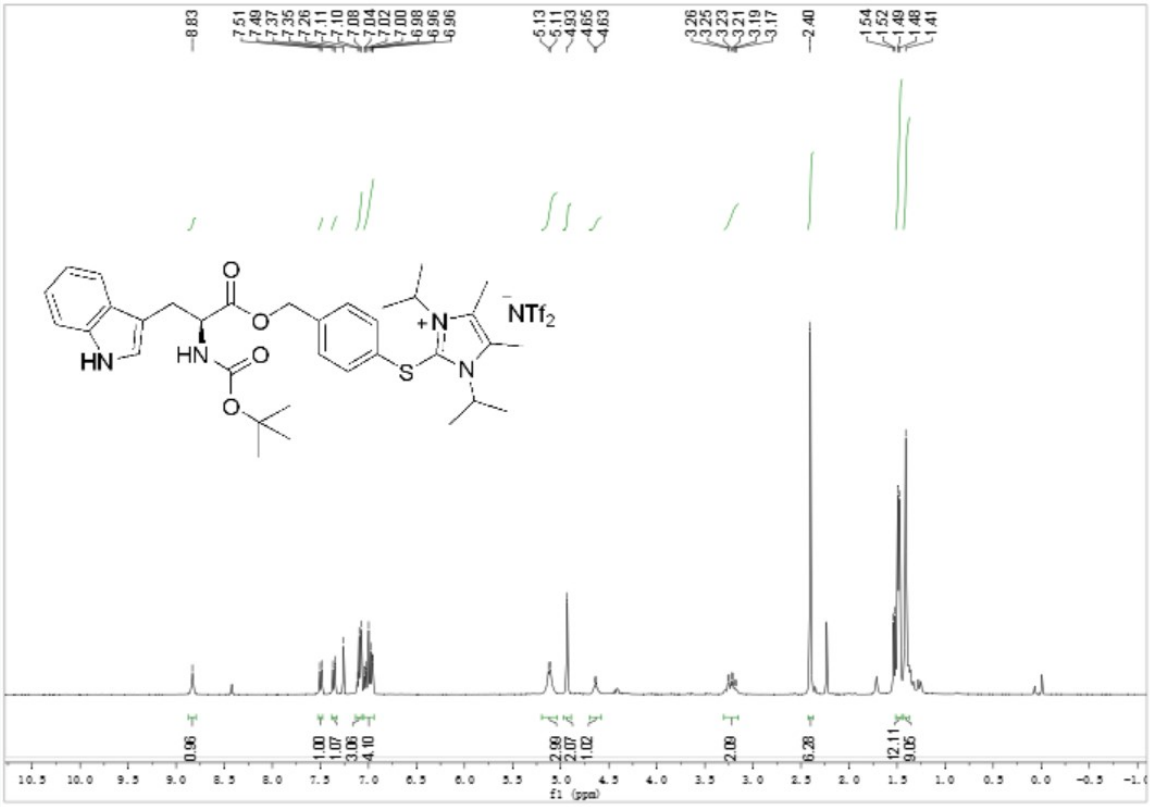
^{13}C NMR spectrum of **1p** ($CDCl_3$, 100 MHz)



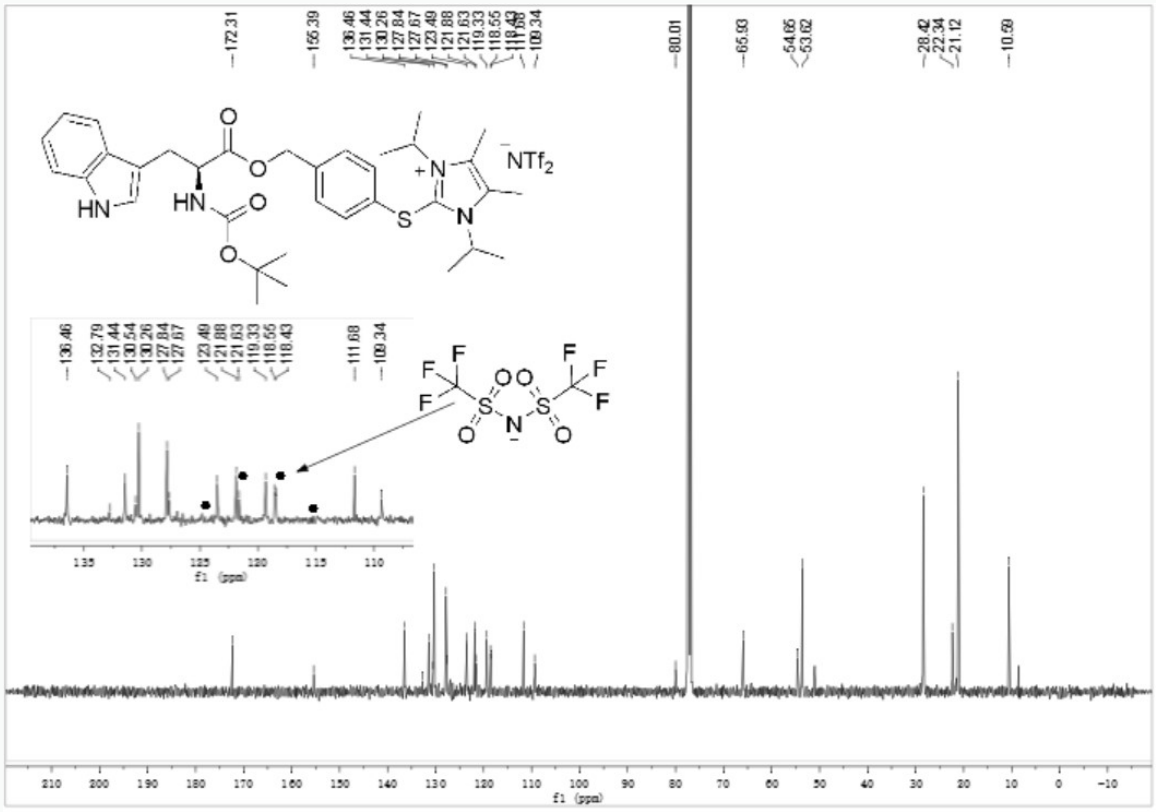
^{19}F NMR spectrum of **1p** ($CDCl_3$, 376 MHz)



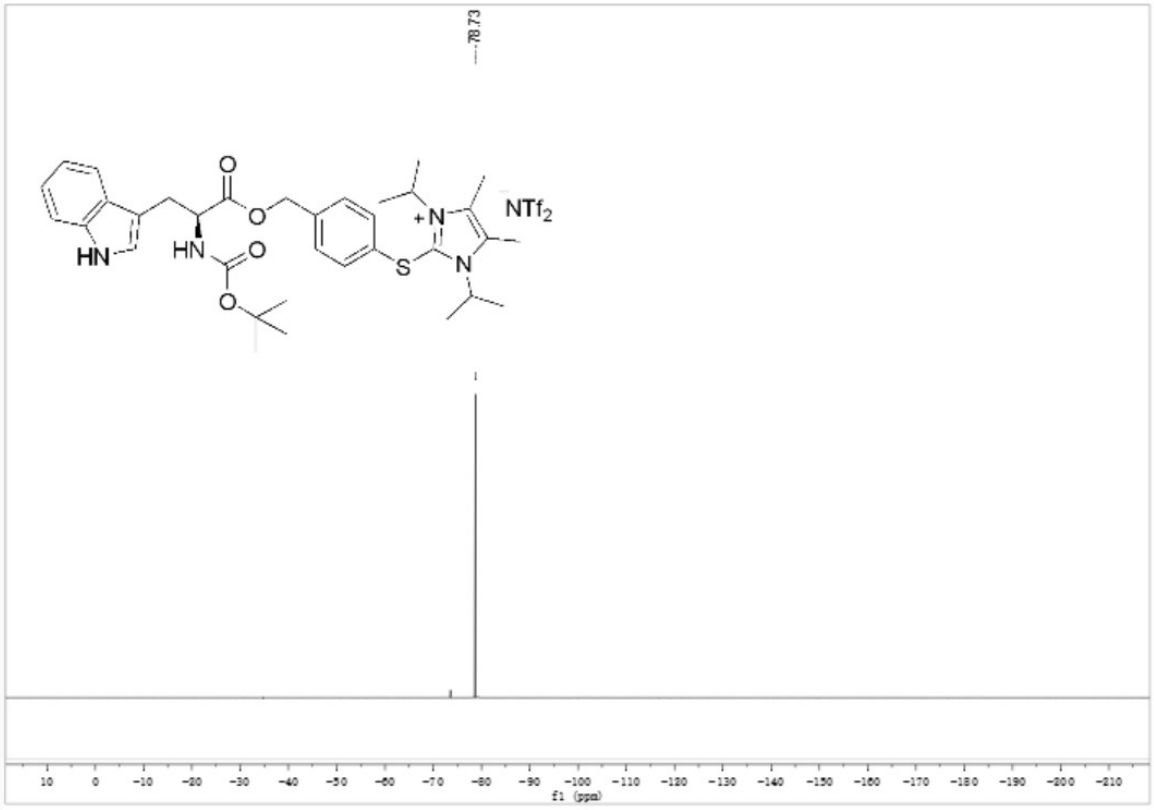
^{1}H NMR spectrum of **1q** ($CDCl_3$, 400 MHz)



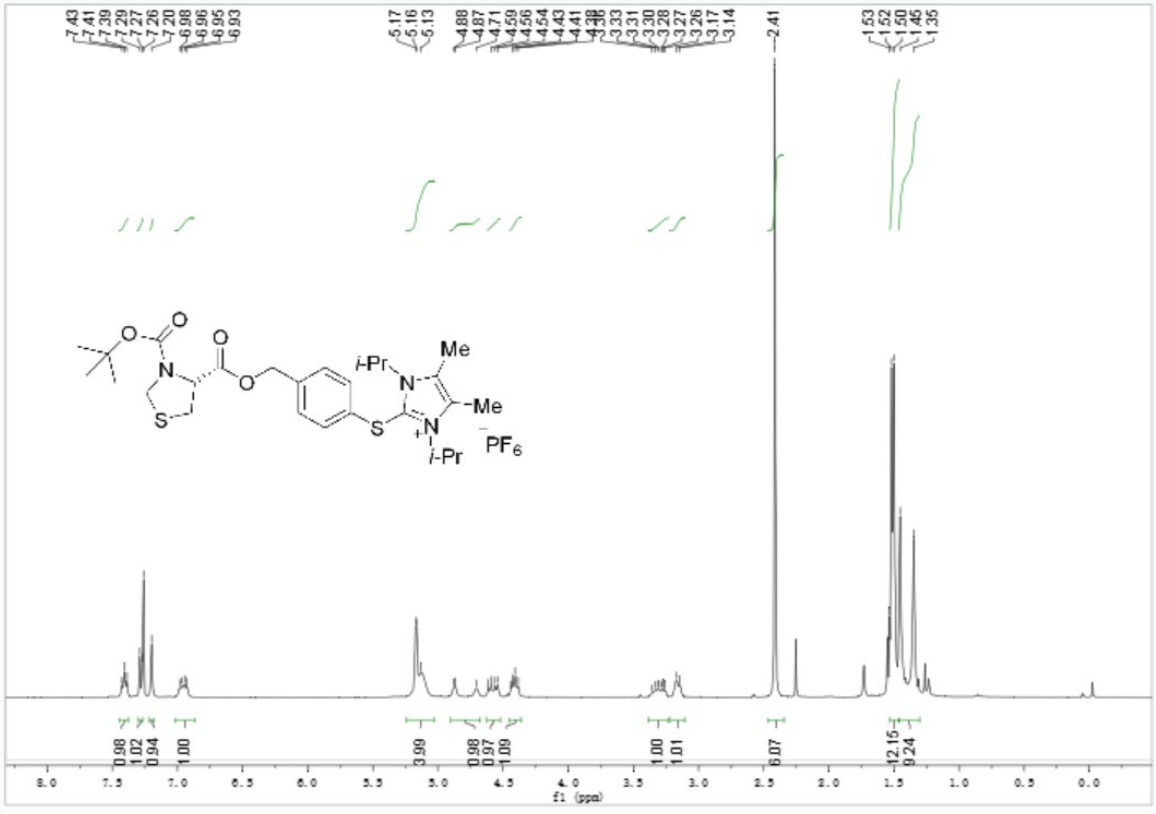
^{13}C NMR spectrum of **1q** ($CDCl_3$, 100 MHz)



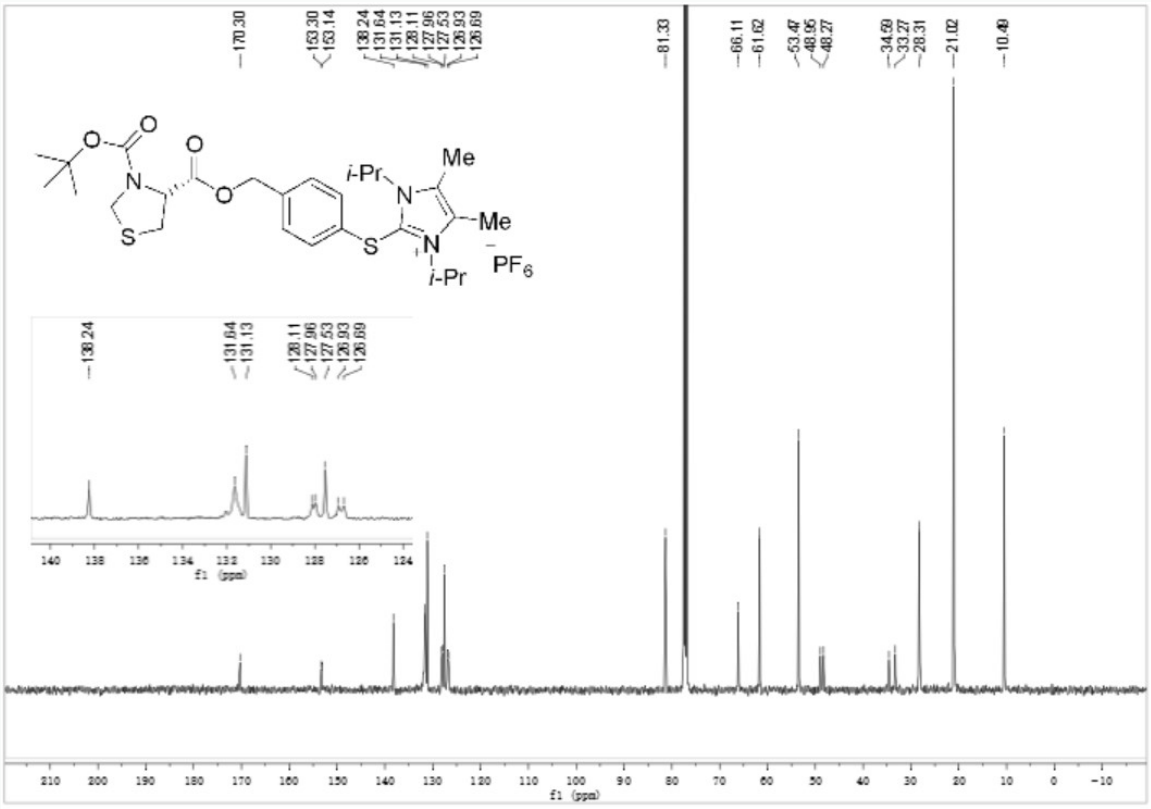
^{19}F NMR spectrum of **1q** ($CDCl_3$, 376 MHz)



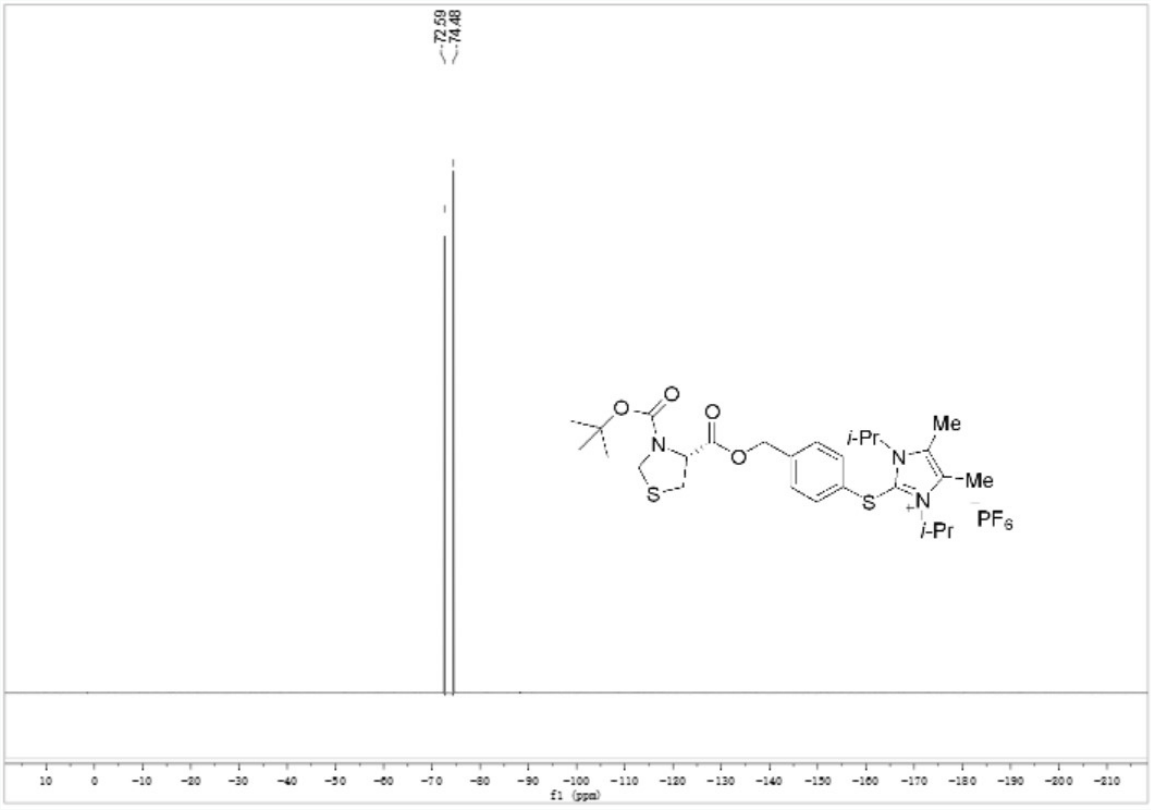
^{1}H NMR spectrum of **1r** ($CDCl_3$, 400 MHz)



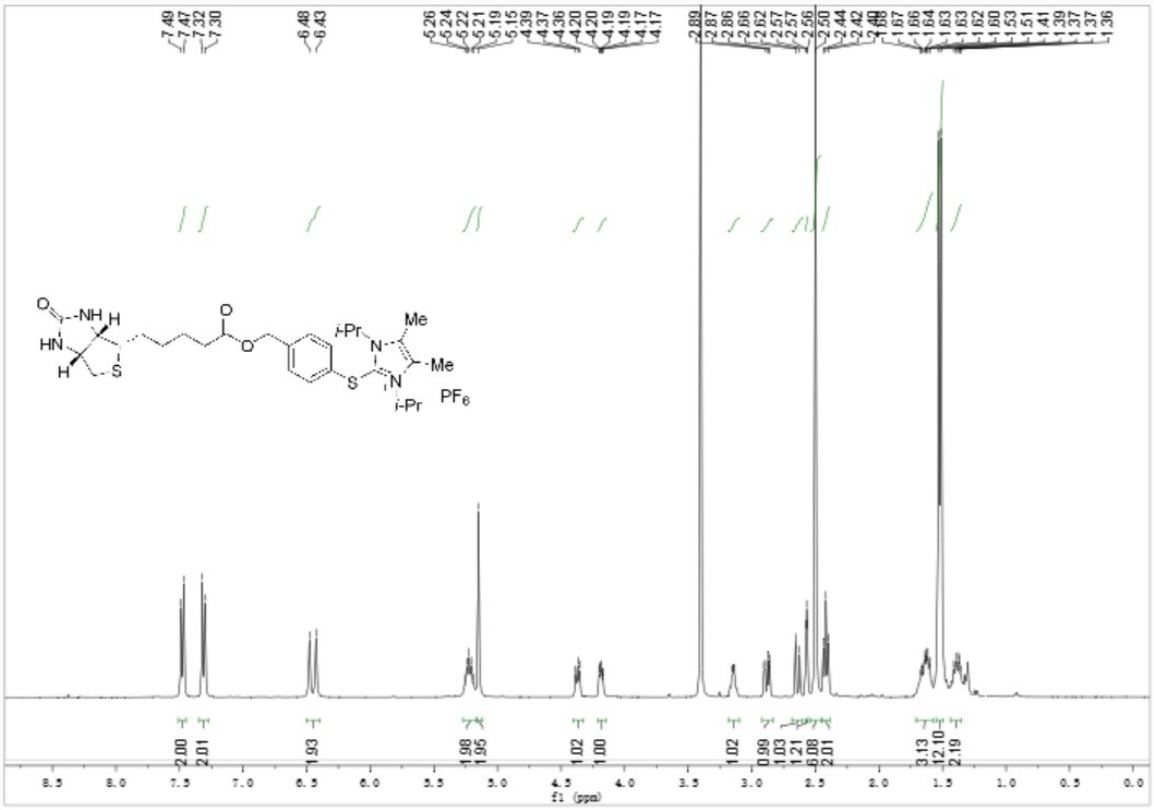
^{13}C NMR spectrum of **1r** ($CDCl_3$, 100 MHz)



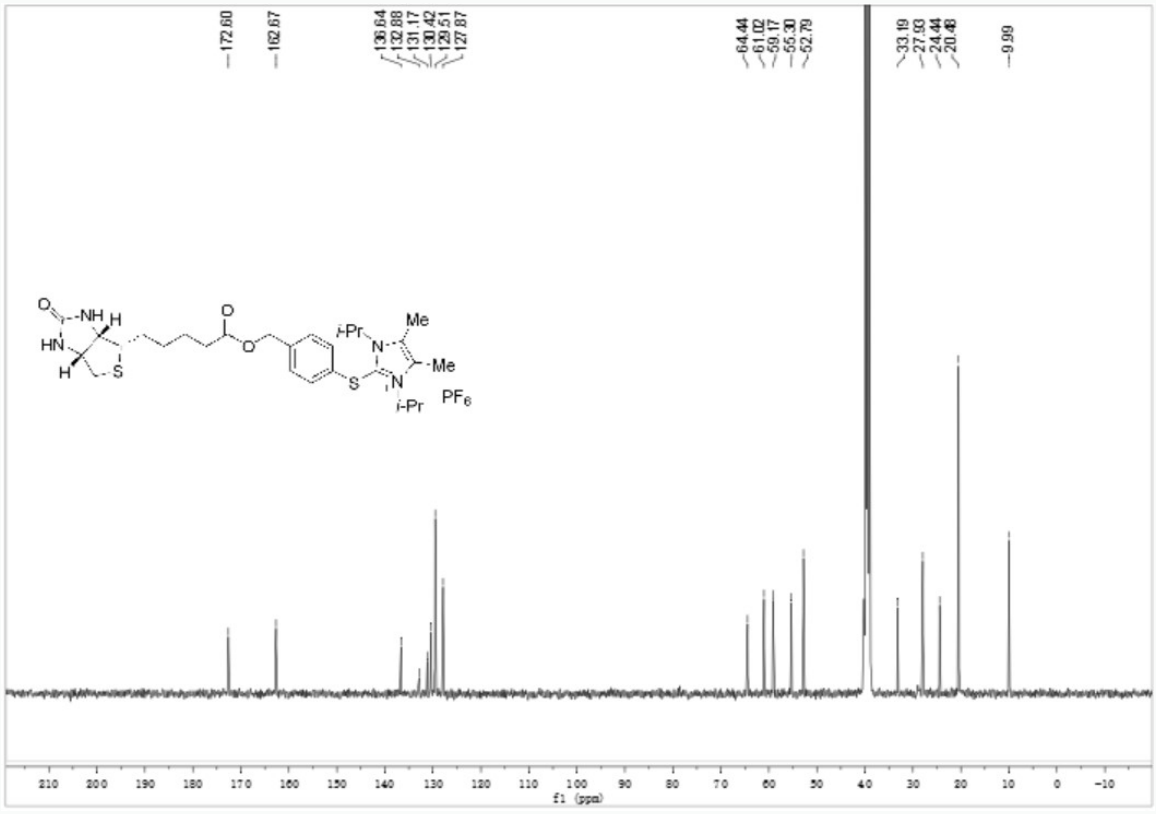
^{19}F NMR spectrum of **1r** ($CDCl_3$, 376 MHz)



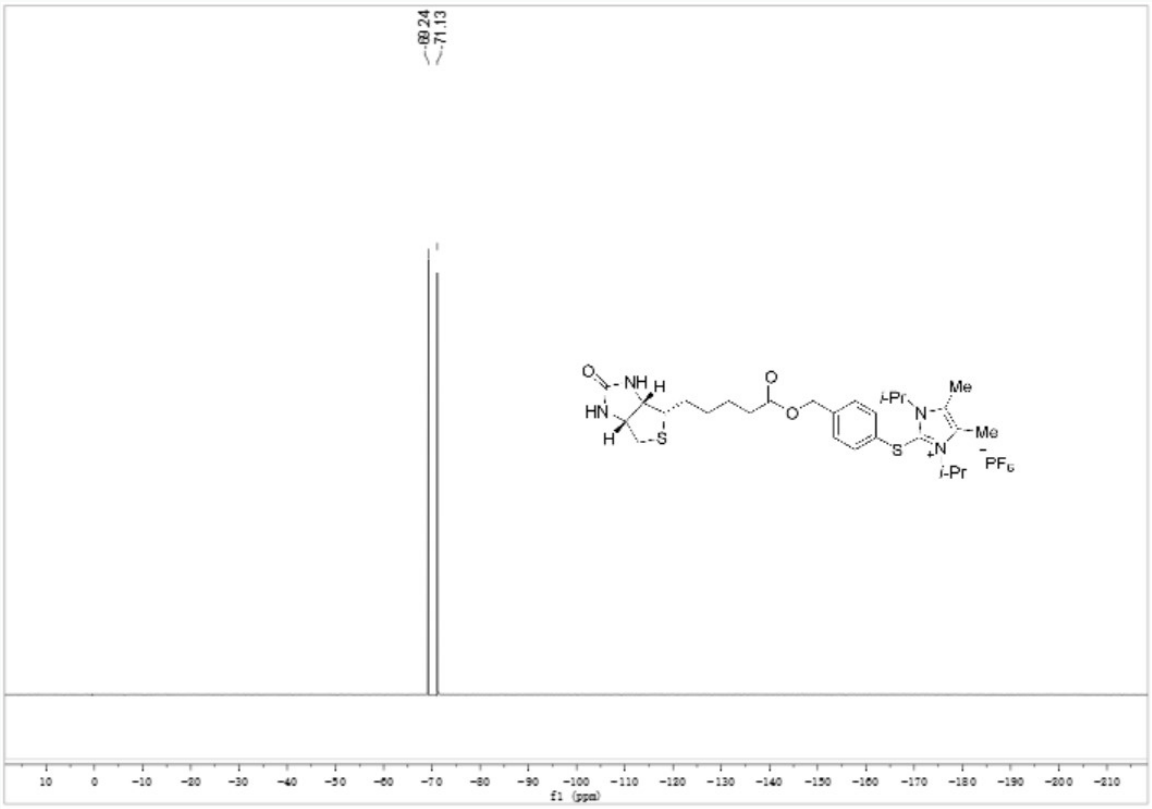
^{1}H NMR spectrum of **1s** (*d*-DMSO, 400 MHz)



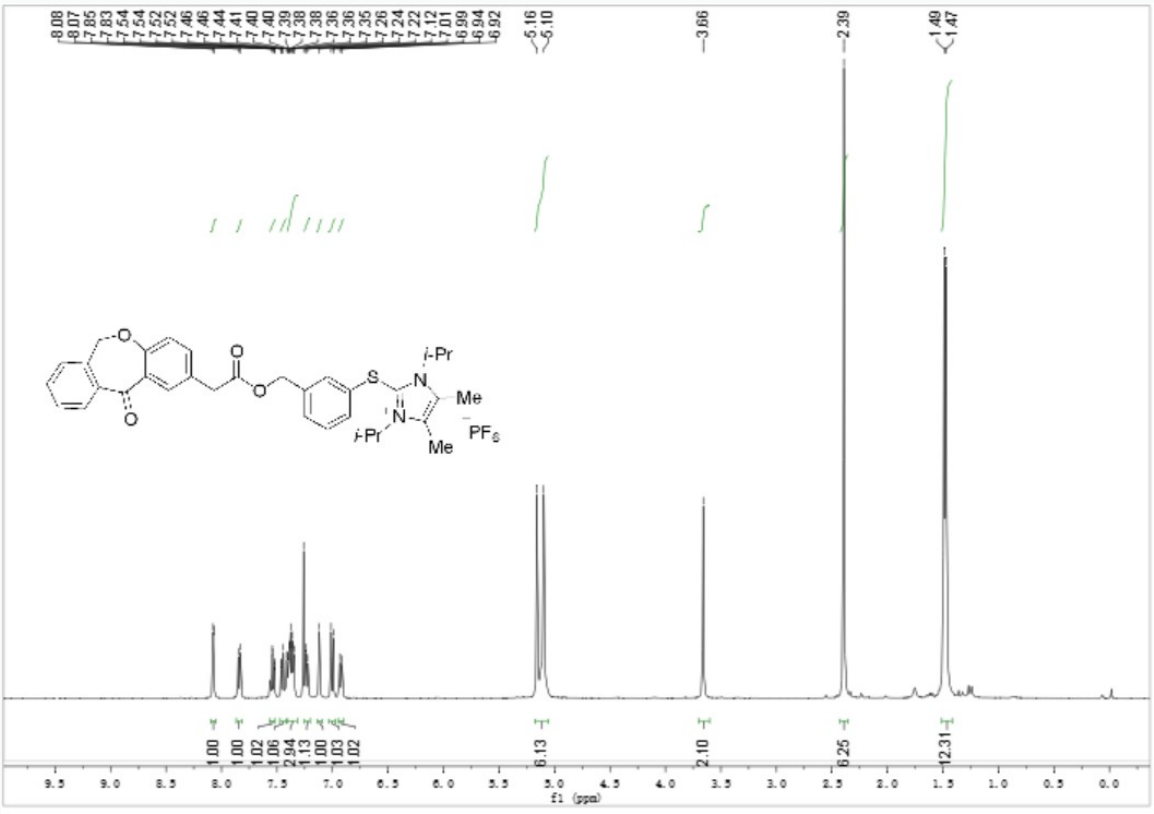
^{13}C NMR spectrum of **1s** (*d*-DMSO, 100 MHz)



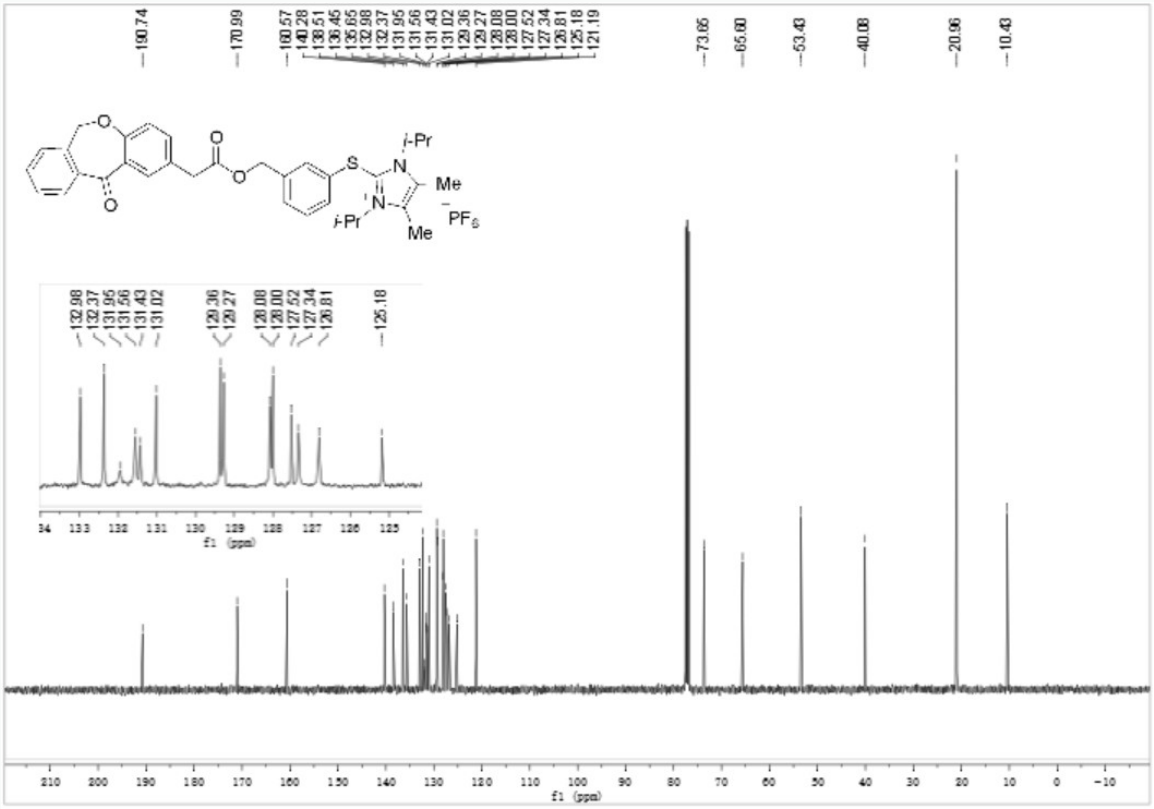
^{19}F NMR spectrum of **1s** (*d*-DMSO, 376 MHz)



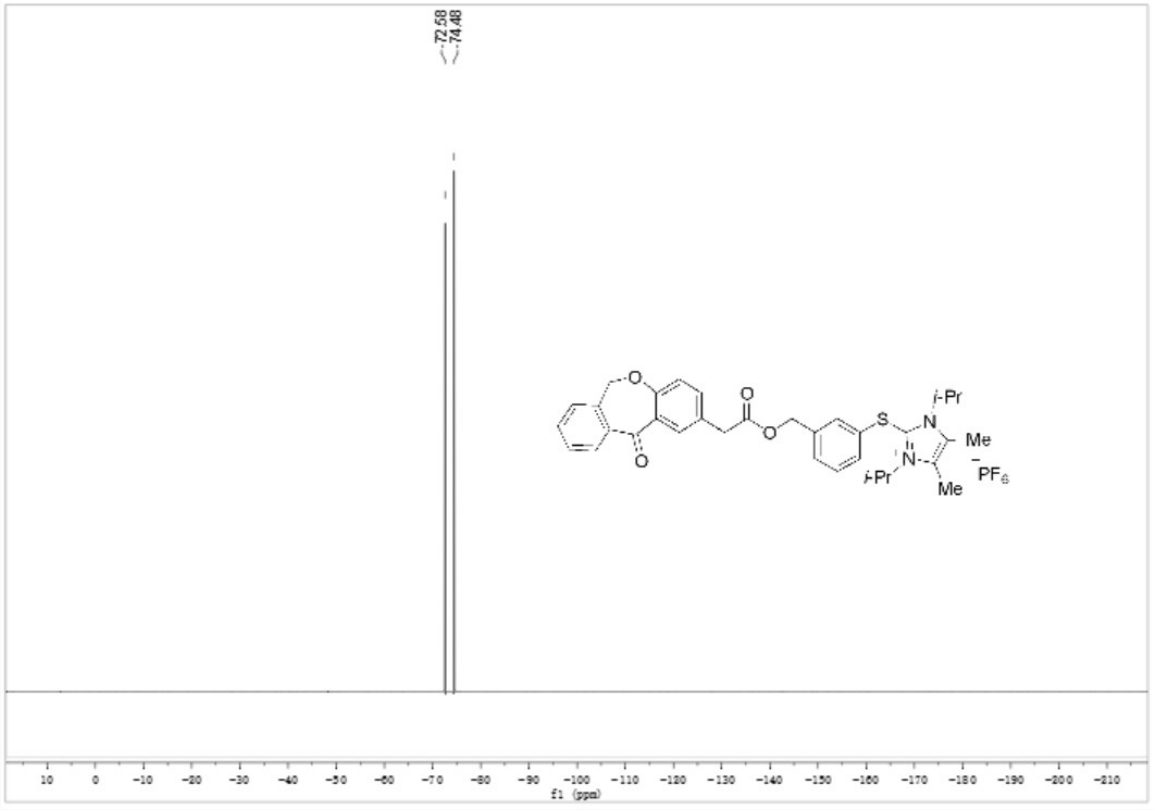
^{1}H NMR spectrum of **1t** ($CDCl_3$, 400 MHz)



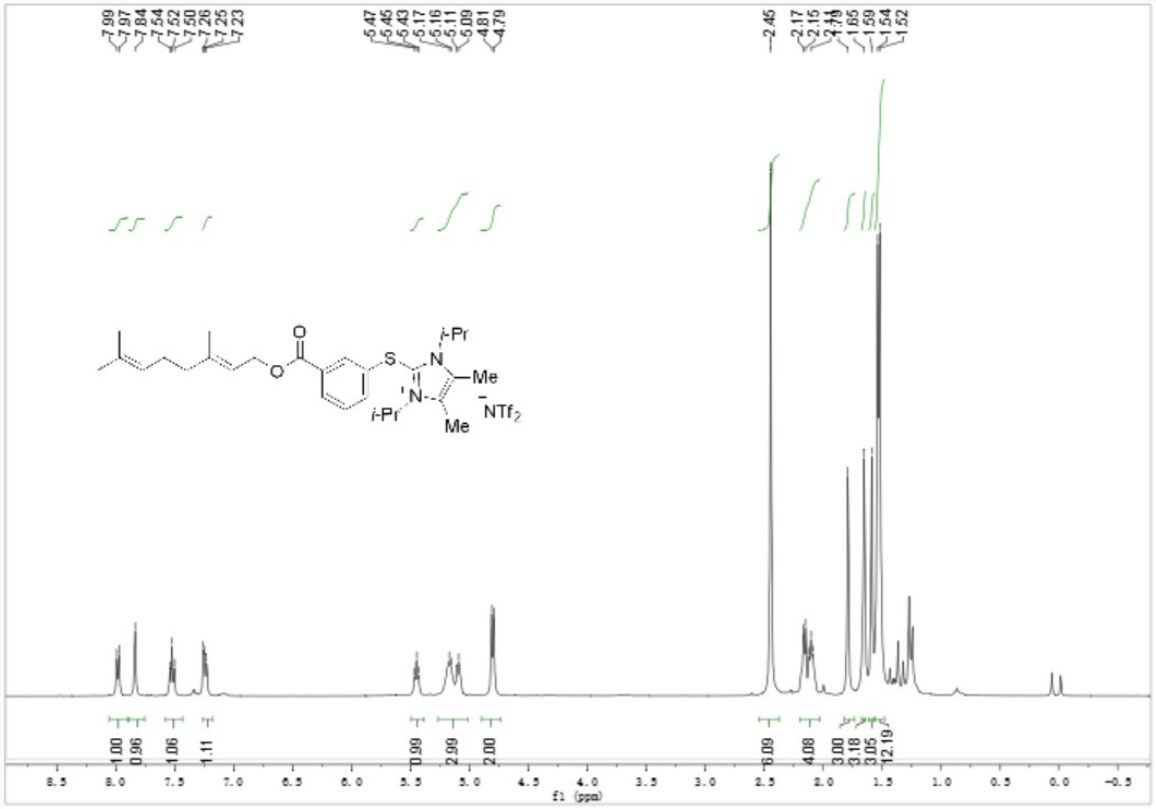
^{13}C NMR spectrum of **1t** ($CDCl_3$, 100 MHz)



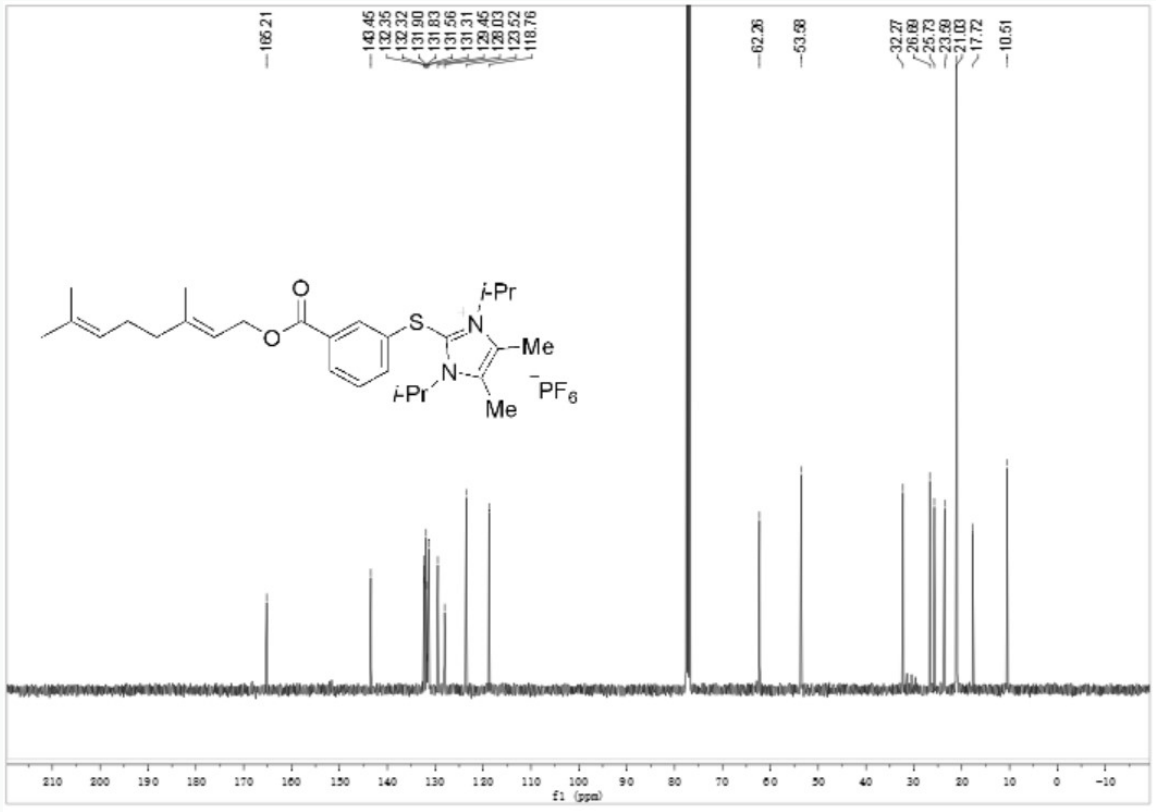
^{19}F NMR spectrum of **1t** ($CDCl_3$, 376 MHz)



^{1}H NMR spectrum of **1u** ($CDCl_3$, 400 MHz)

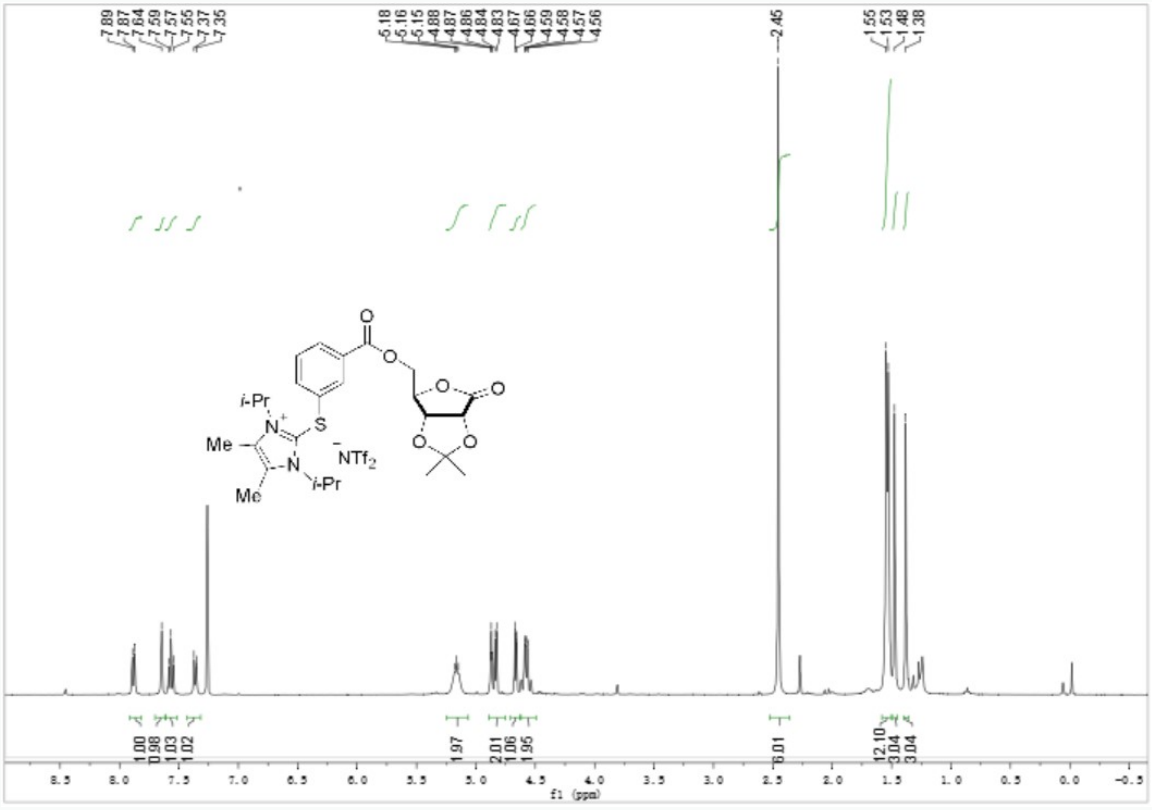


^{13}C NMR spectrum of **1u** ($CDCl_3$, 100 MHz)

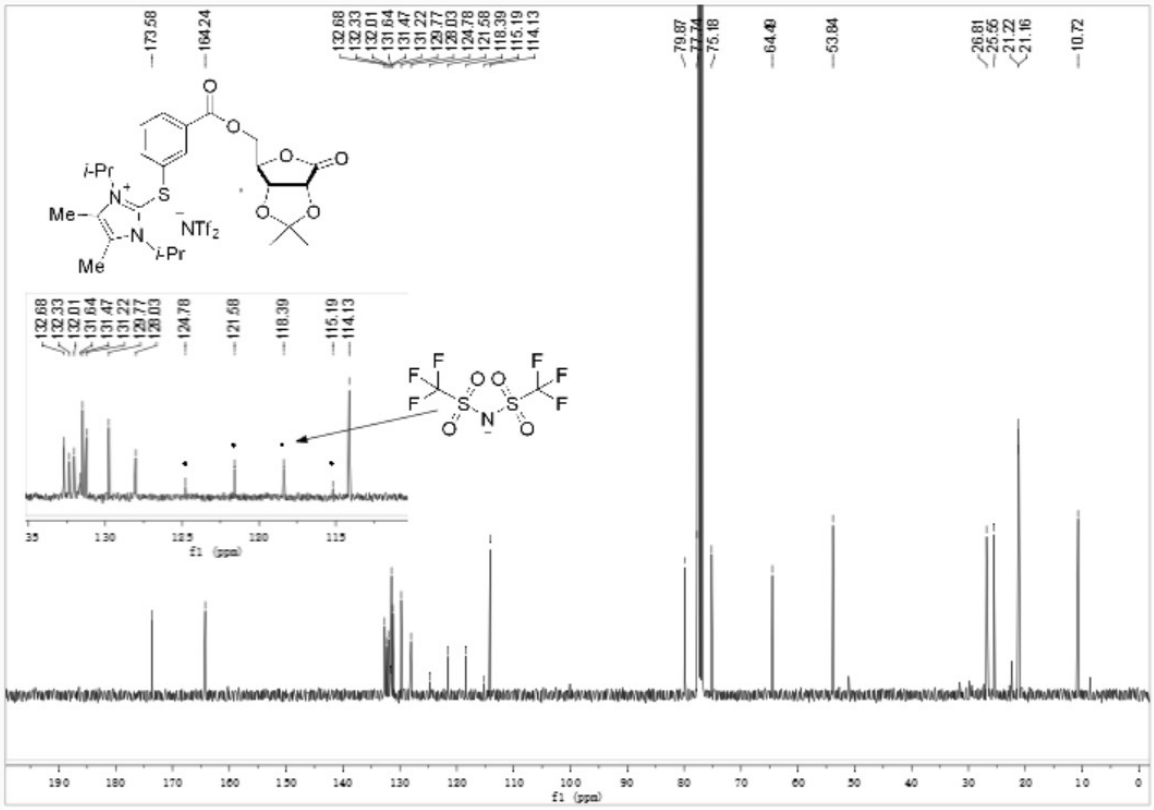


^{19}F NMR spectrum of **1u** ($CDCl_3$, 376 MHz)

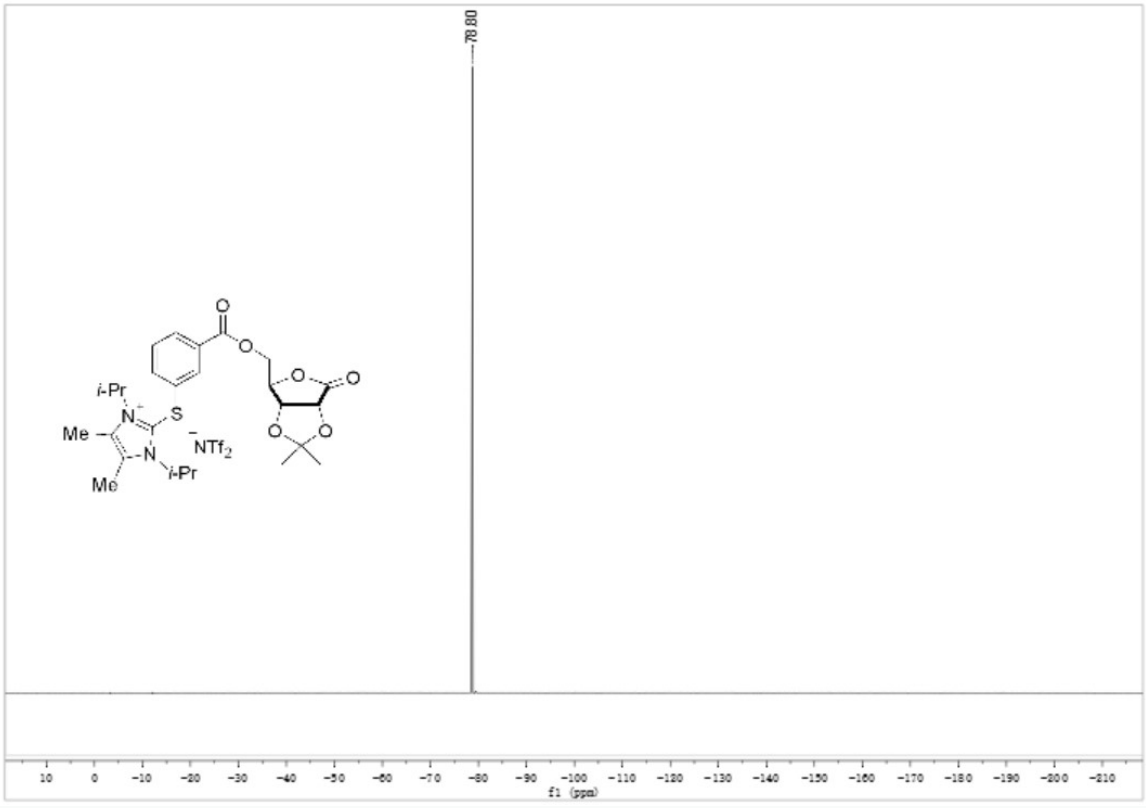
^{1}H NMR spectrum of **1v** ($CDCl_3$, 400 MHz)



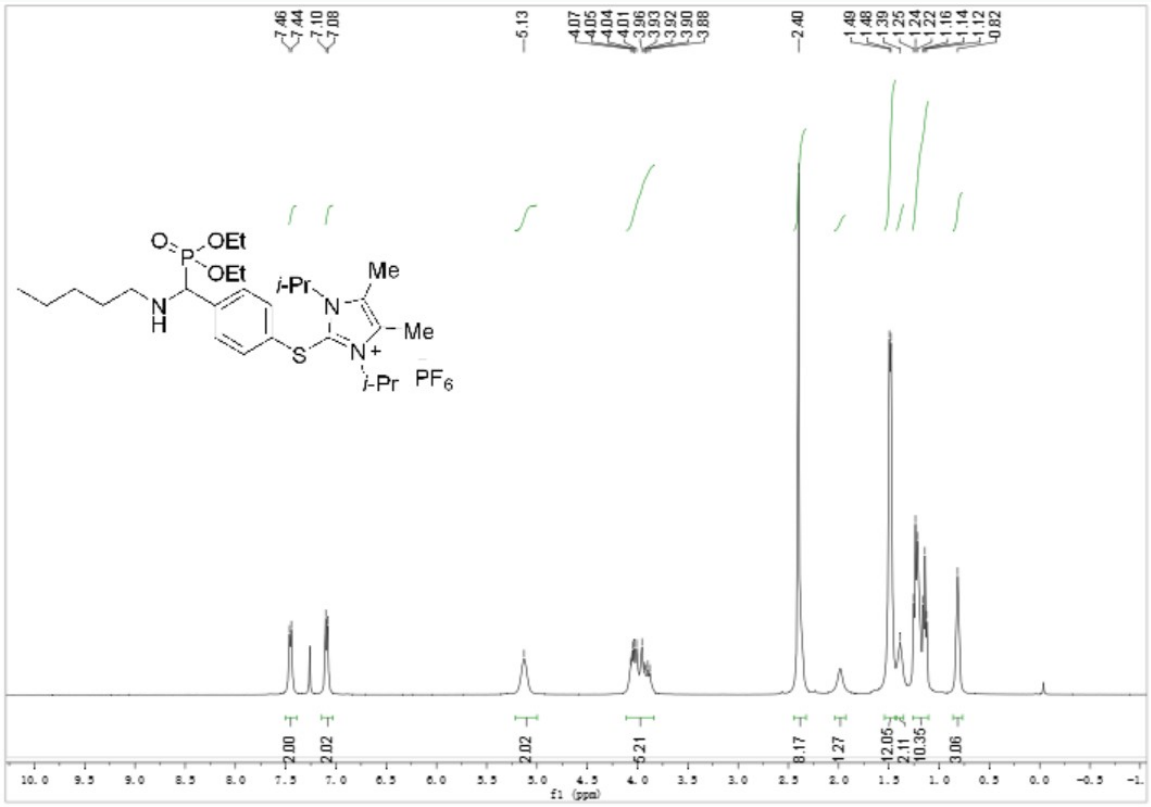
^{13}C NMR spectrum of **1v** ($CDCl_3$, 100 MHz)



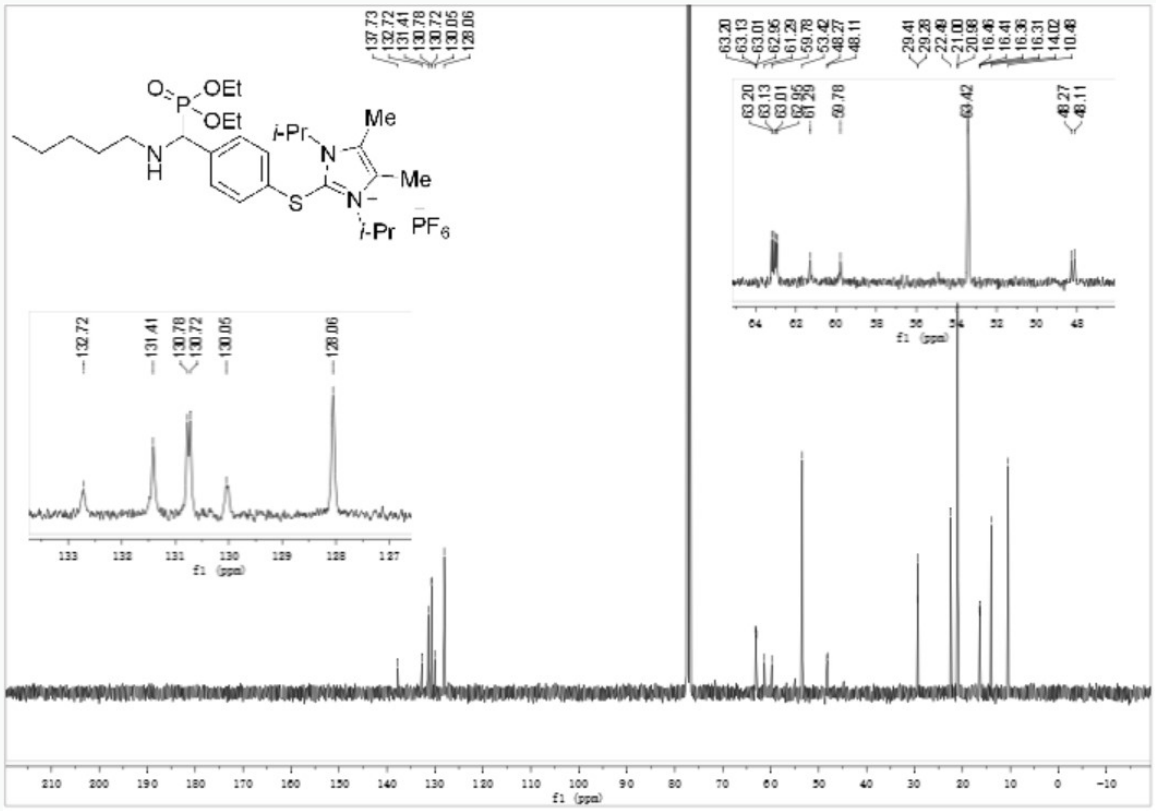
^{19}F NMR spectrum of **1v** ($CDCl_3$, 376 MHz)



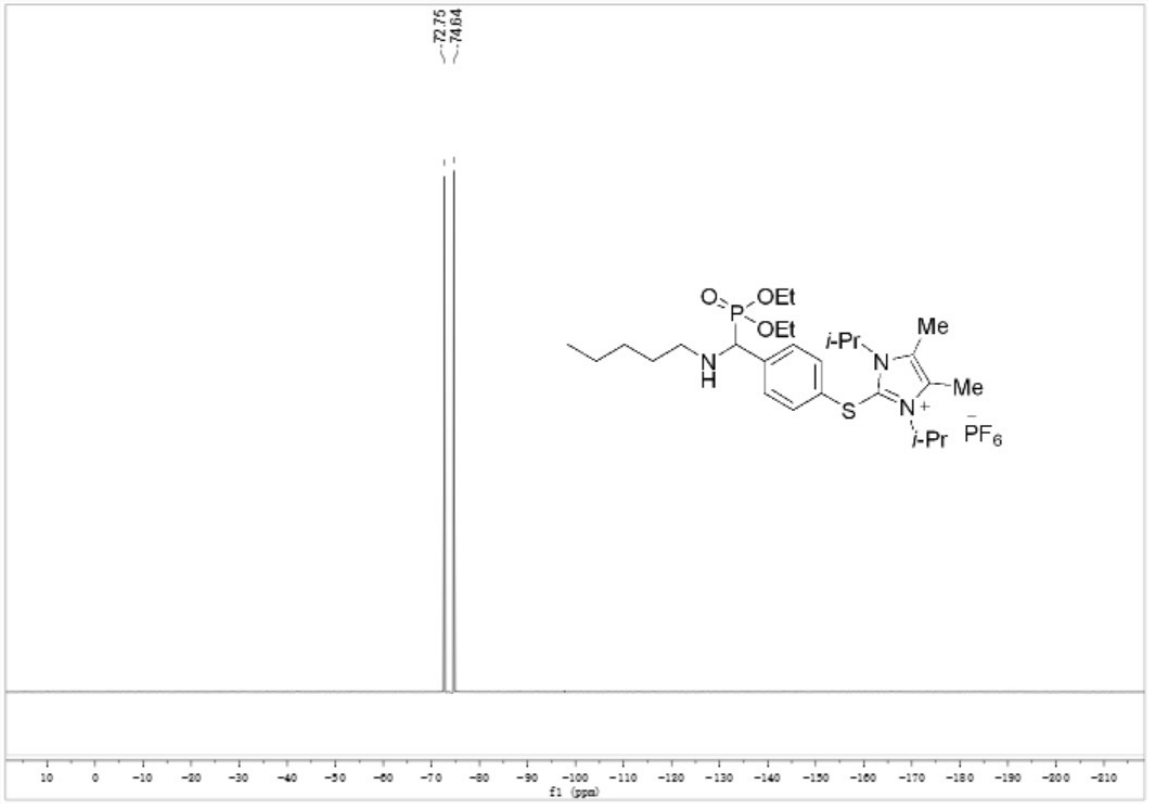
^{1}H NMR spectrum of **1w** ($CDCl_3$, 400 MHz)



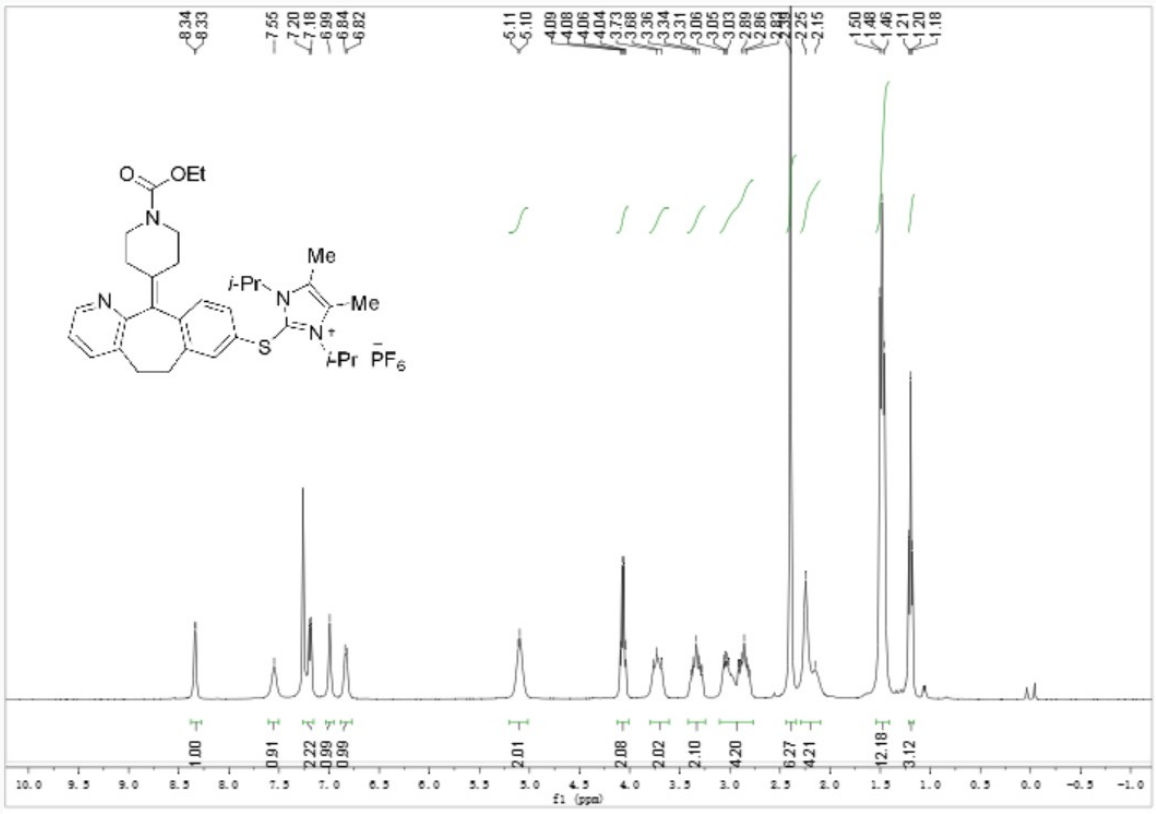
^{13}C NMR spectrum of **1w** ($CDCl_3$, 100 MHz)



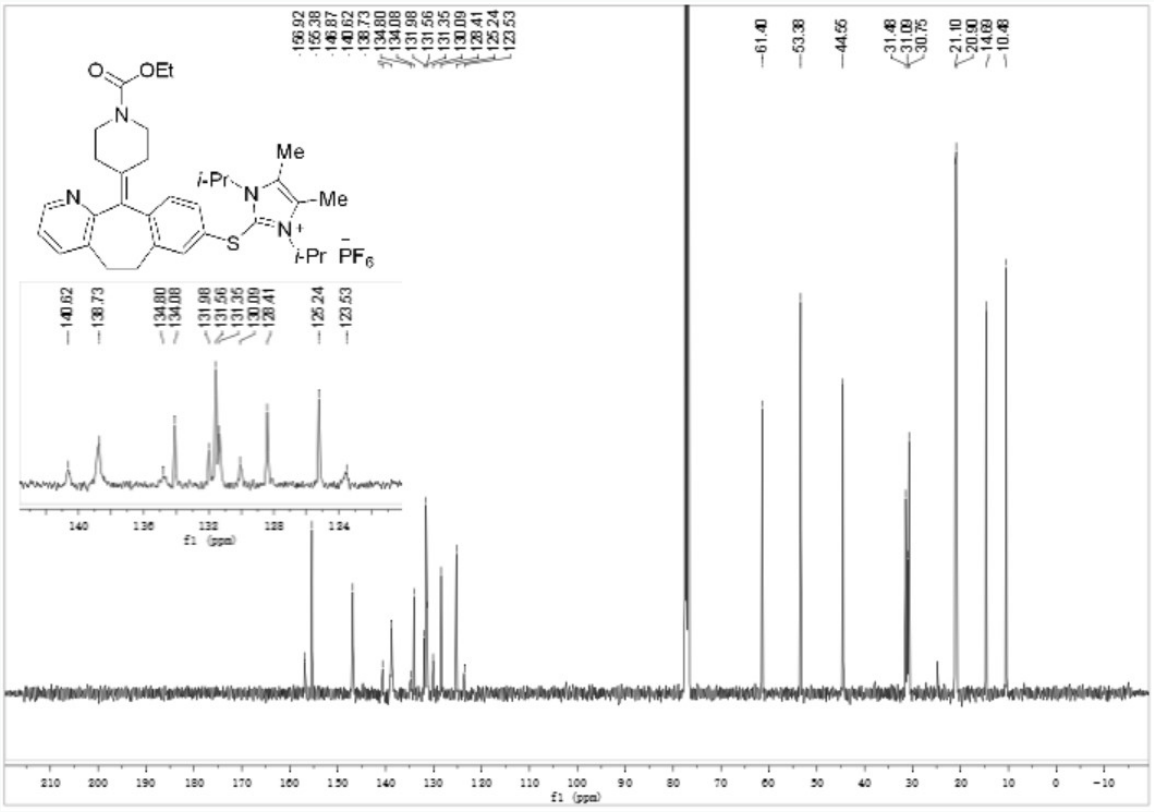
^{19}F NMR spectrum of **1w** ($CDCl_3$, 376 MHz)



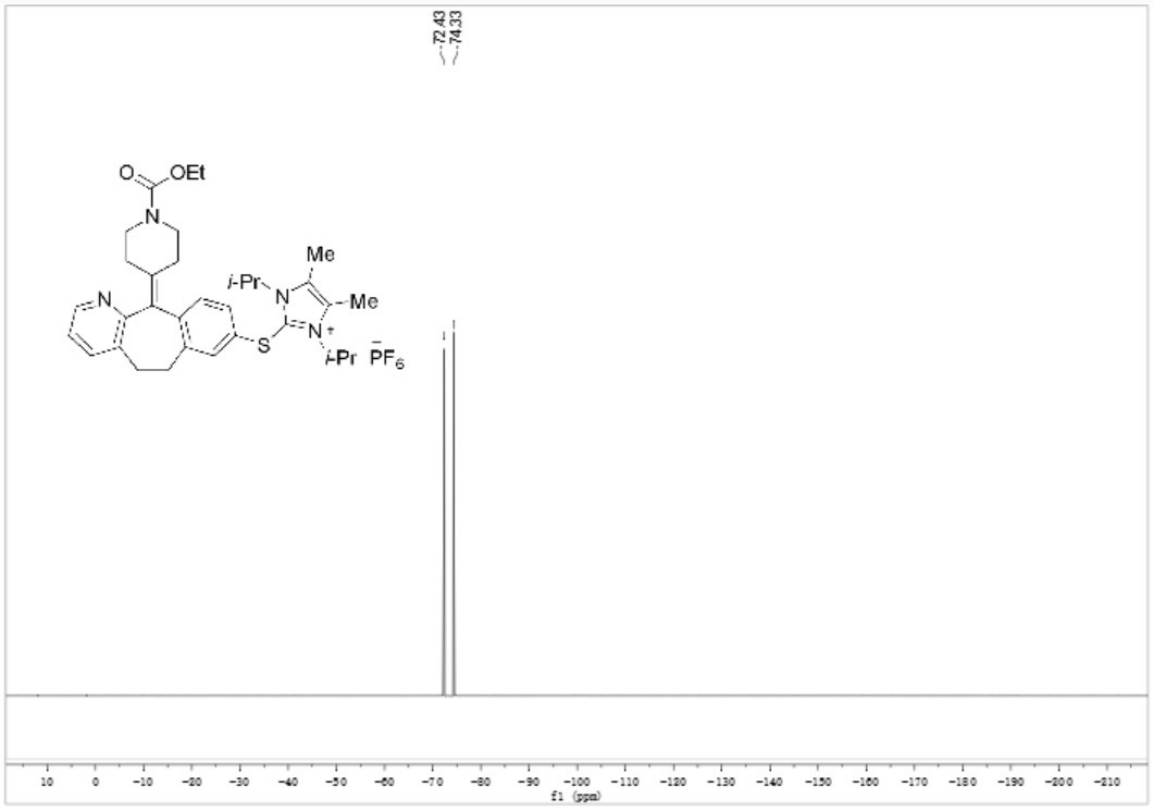
^{1}H NMR spectrum of **1x** ($CDCl_3$, 400 MHz)



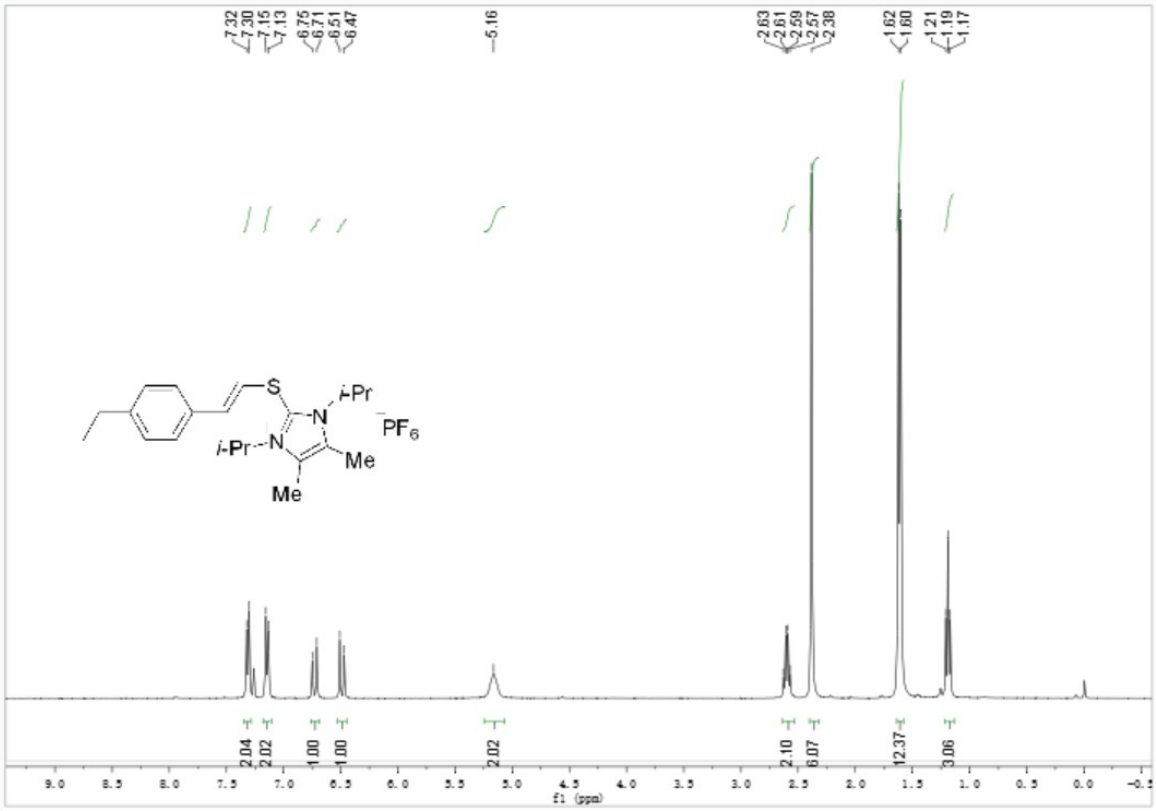
^{13}C NMR spectrum of **1x** ($CDCl_3$, 100 MHz)



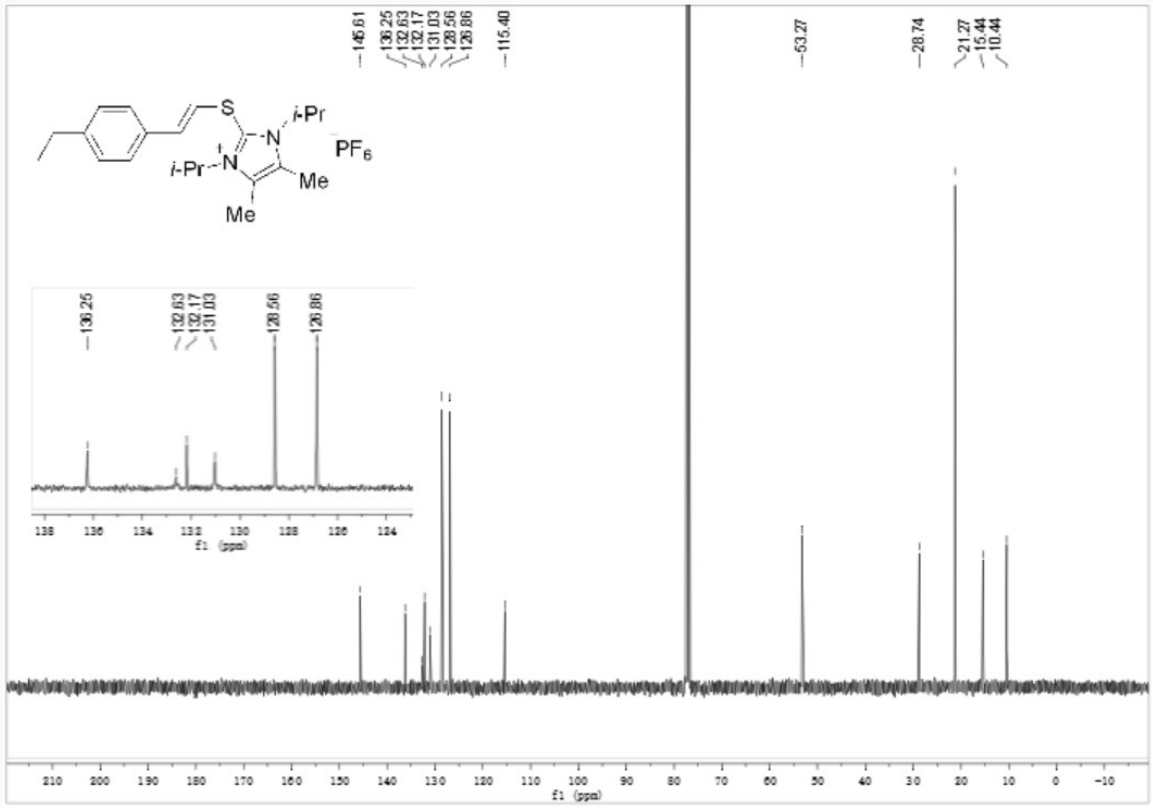
^{19}F NMR spectrum of **1x** ($CDCl_3$, 376 MHz)



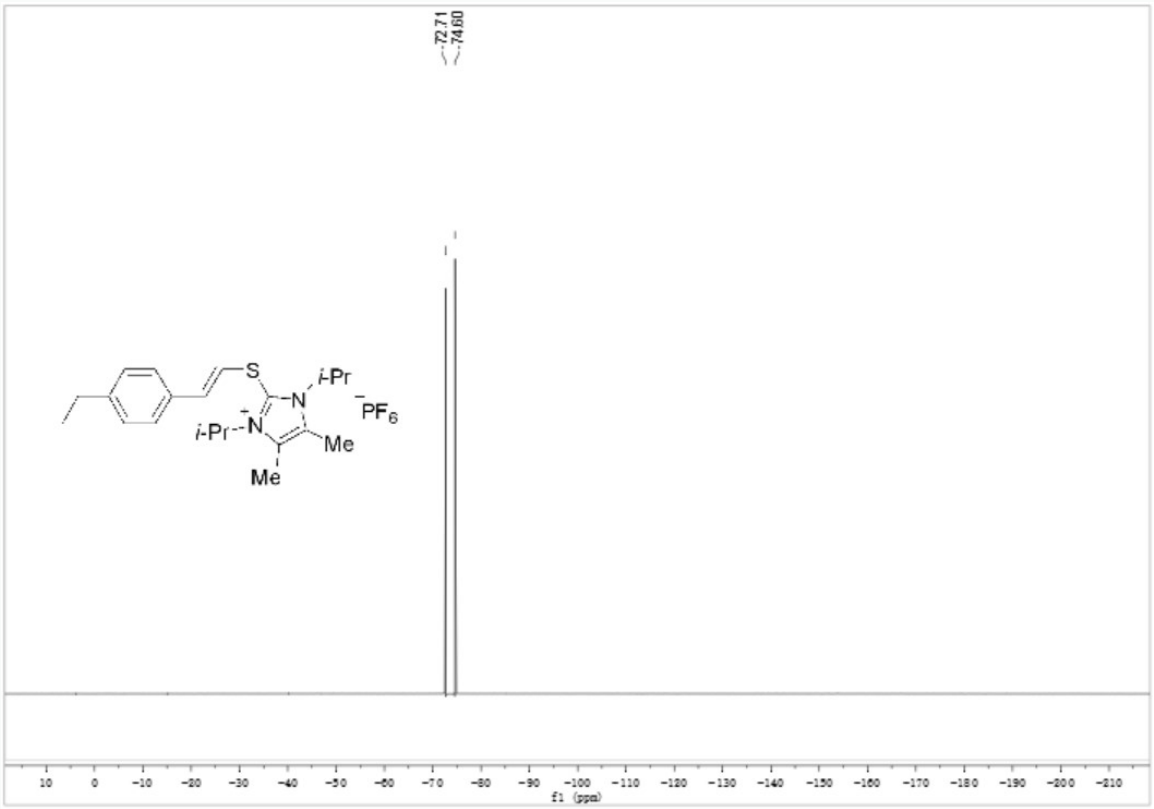
^{1}H NMR spectrum of **1y** ($CDCl_3$, 400 MHz)



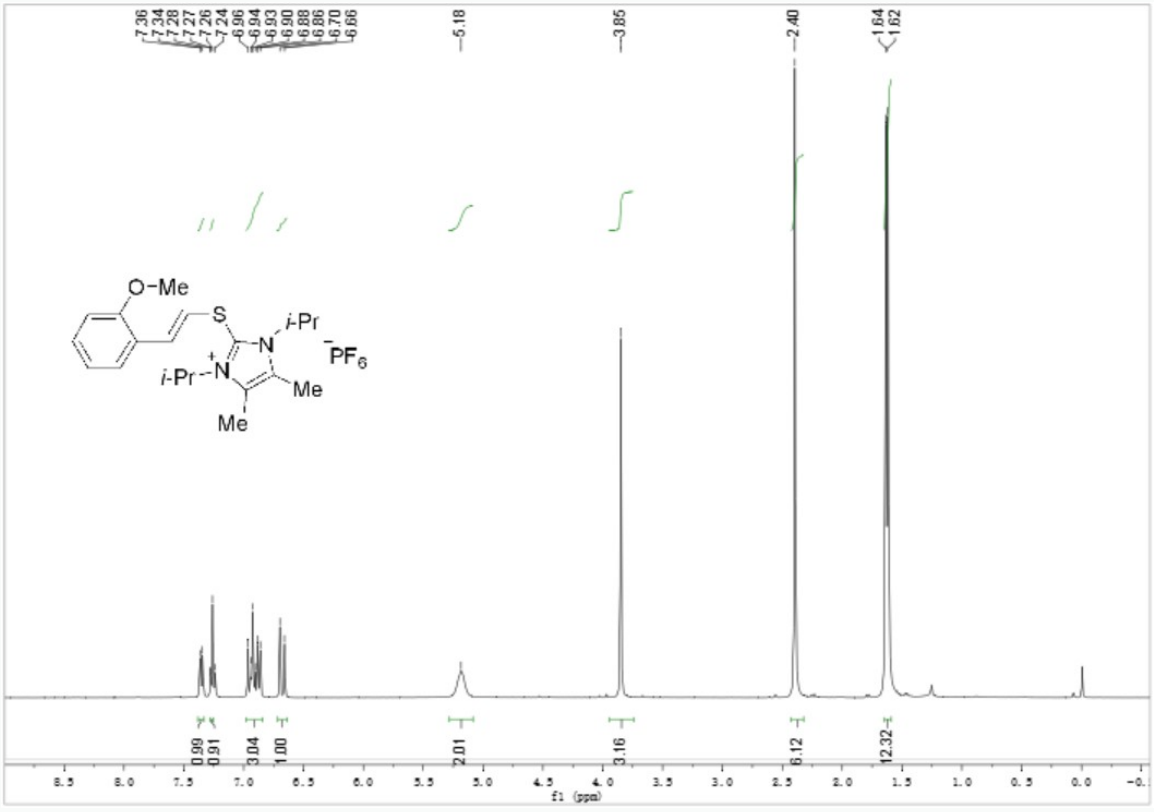
^{13}C NMR spectrum of **1y** ($CDCl_3$, 100 MHz)



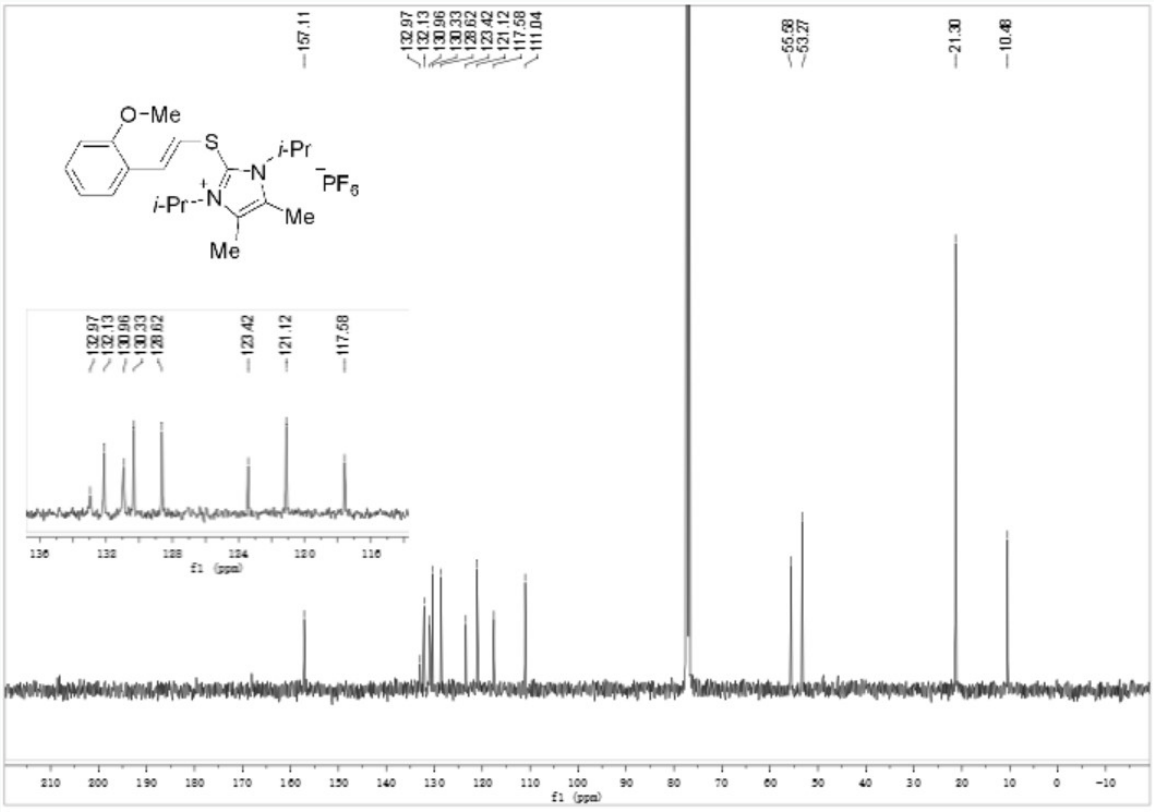
^{19}F NMR spectrum of **1y** ($CDCl_3$, 376 MHz)



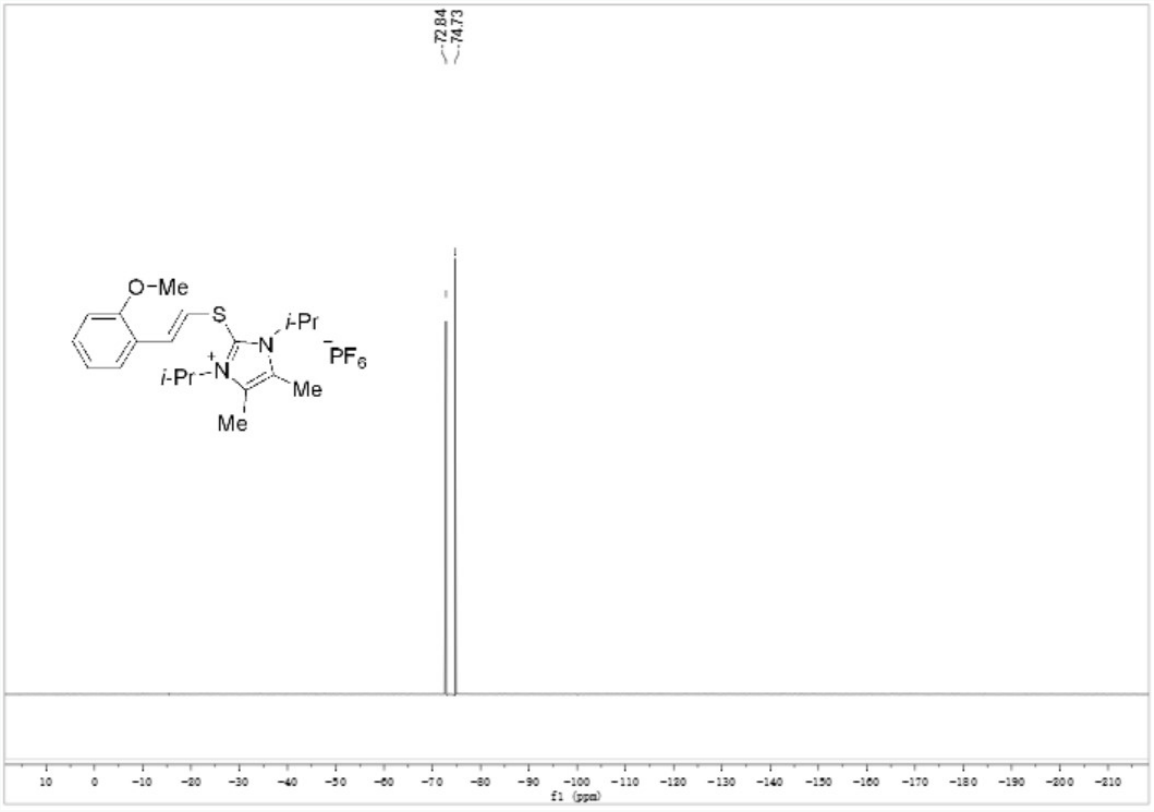
^{1}H NMR spectrum of **1z** ($CDCl_3$, 400 MHz)



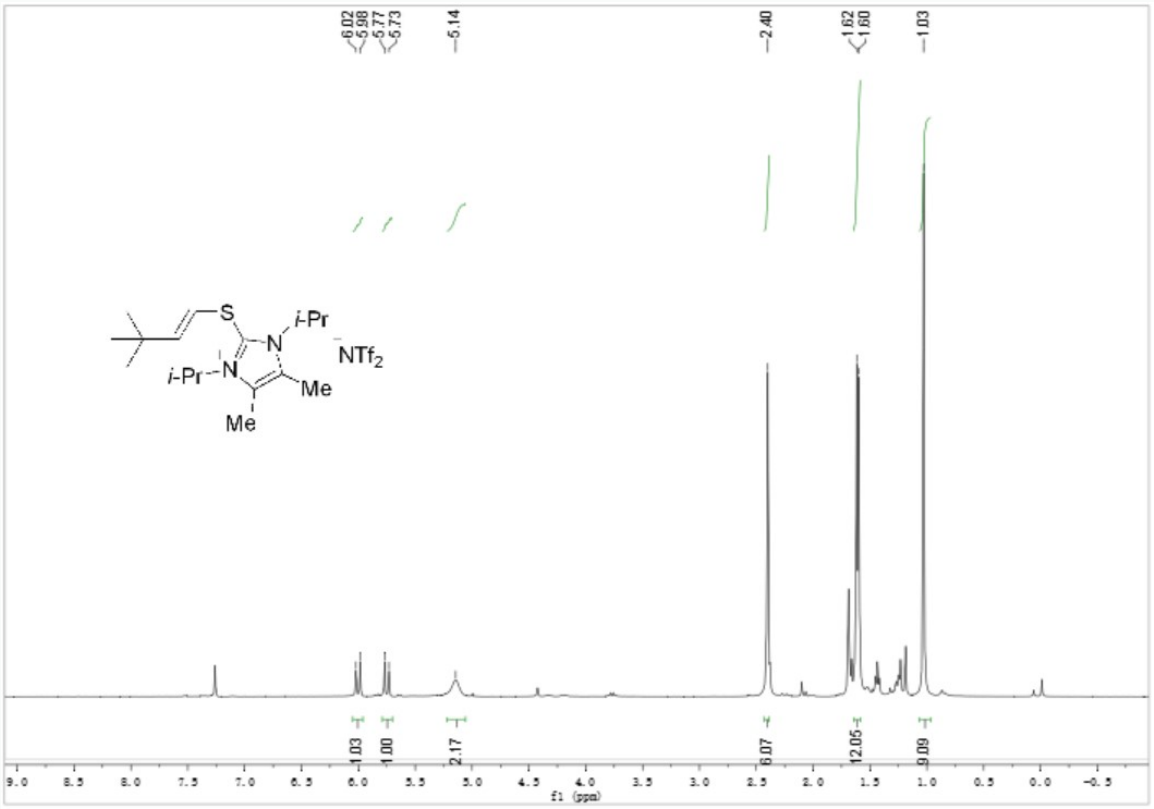
^{13}C NMR spectrum of **1z** ($CDCl_3$, 100 MHz)



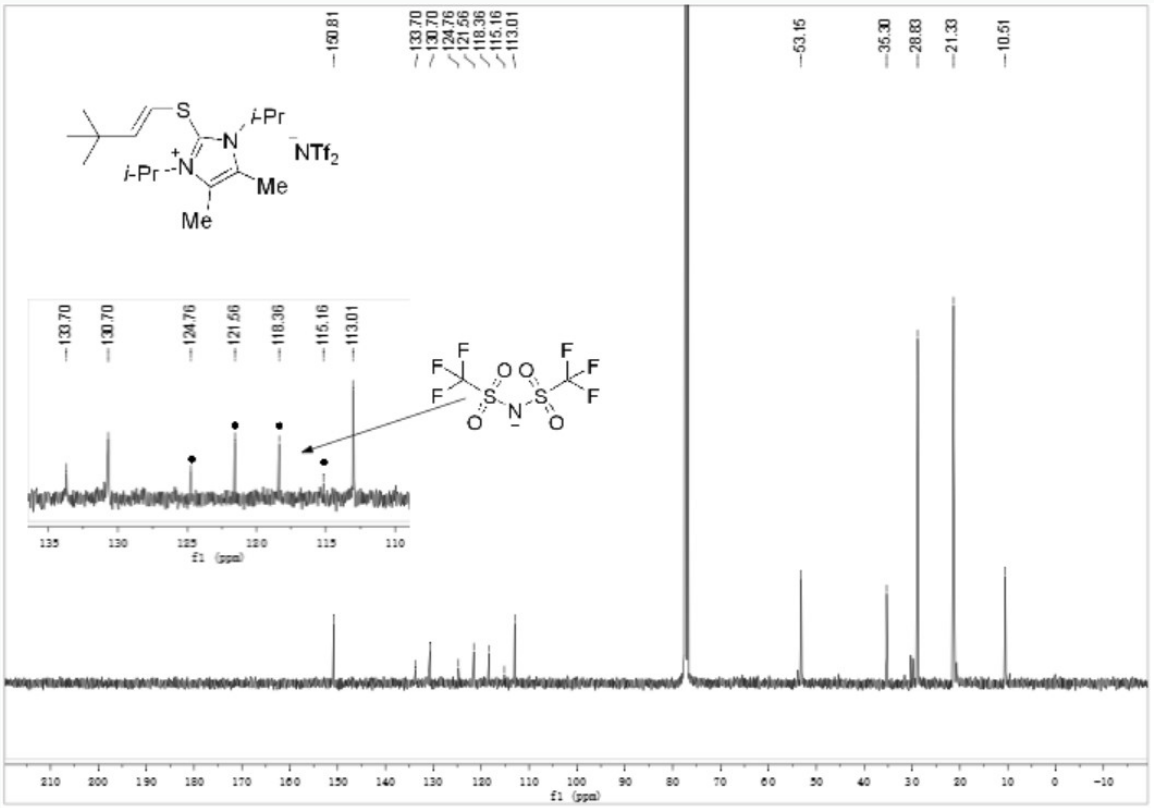
^{19}F NMR spectrum of **1z** ($CDCl_3$, 376 MHz)



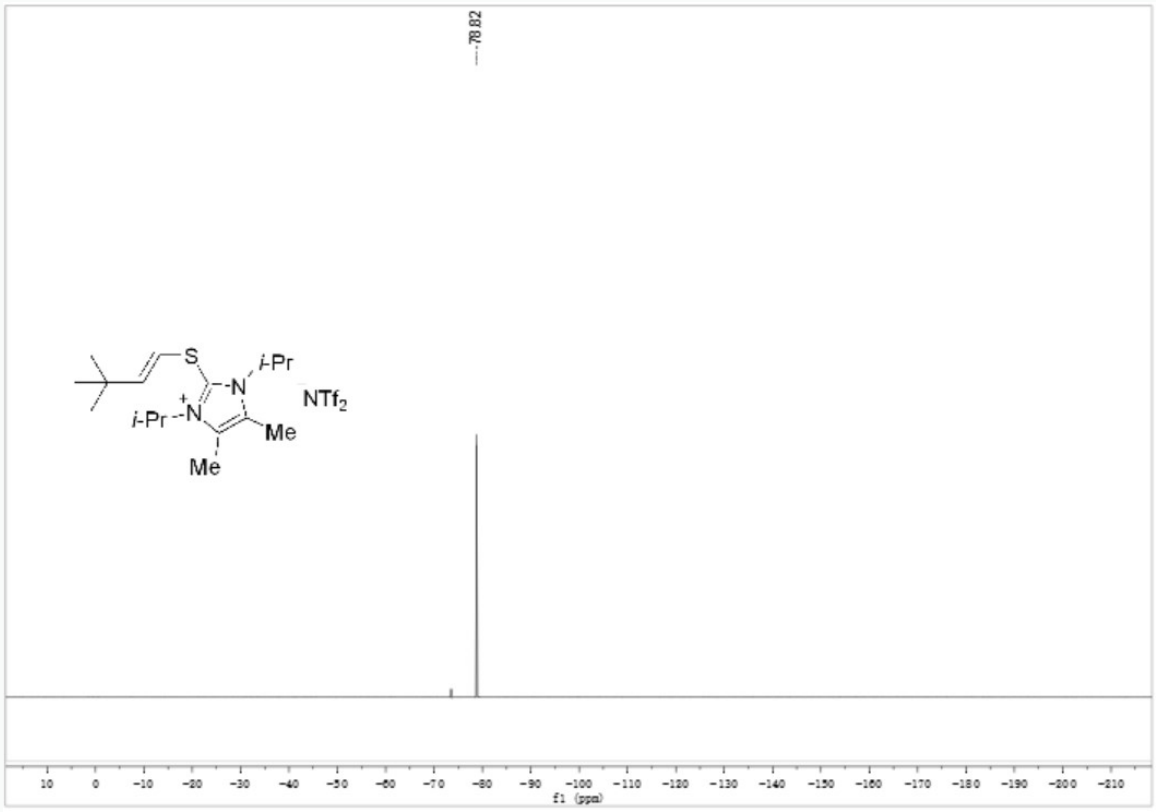
^{1}H NMR spectrum of **1aa** ($CDCl_3$, 400 MHz)



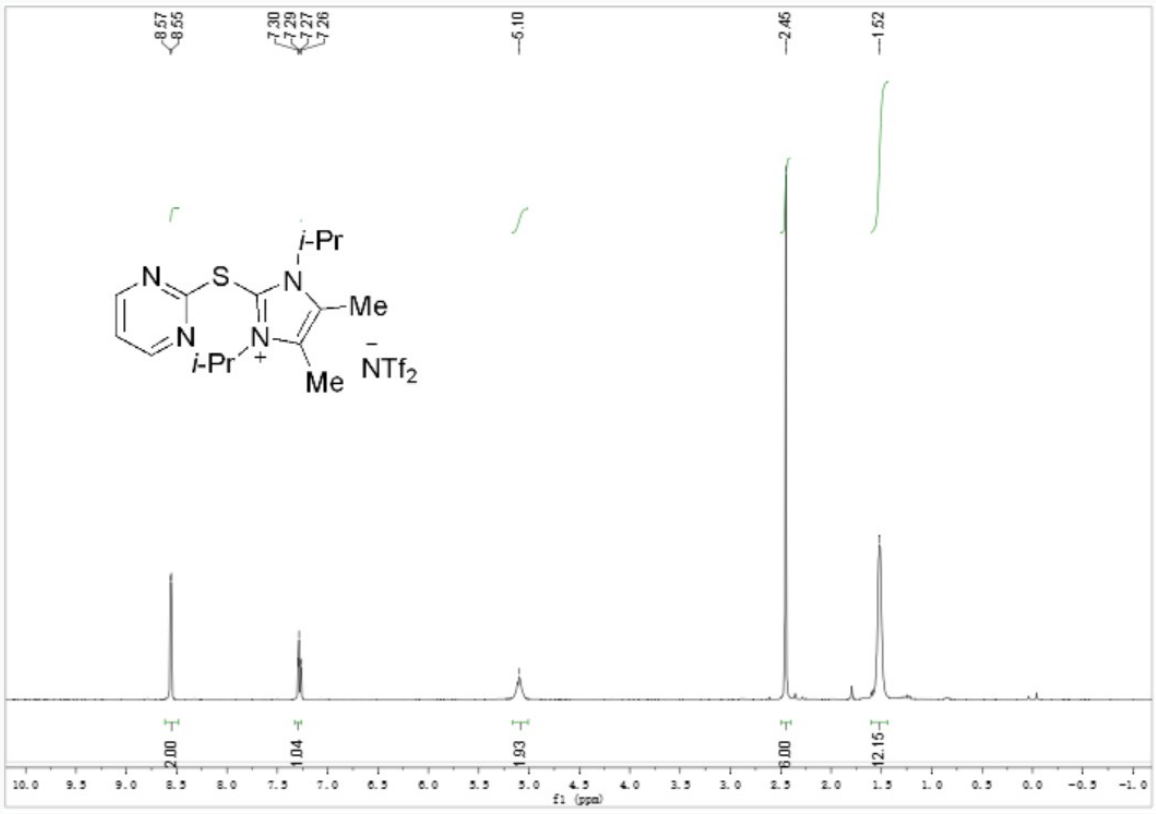
^{13}C NMR spectrum of **1aa** ($CDCl_3$, 100 MHz)



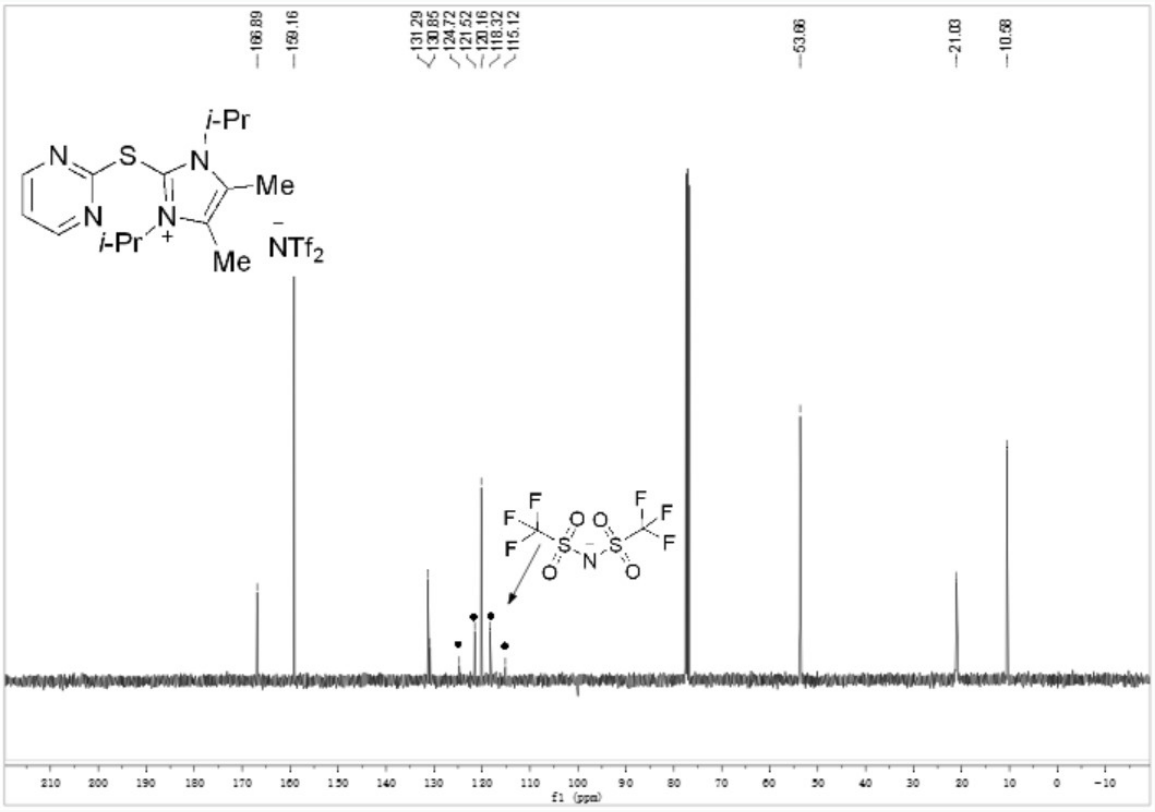
^{19}F NMR spectrum of **1aa** ($CDCl_3$, 376 MHz)



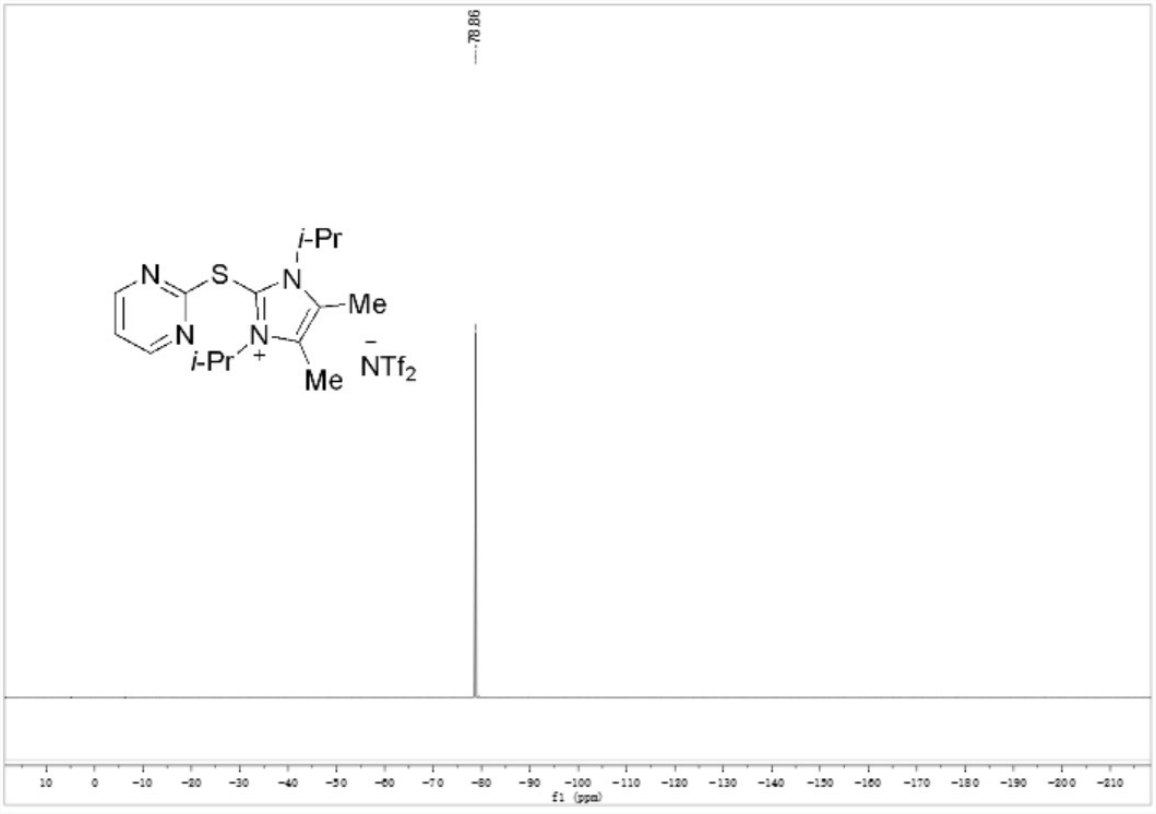
^{1}H NMR spectrum of **1ab** ($CDCl_3$, 400 MHz)



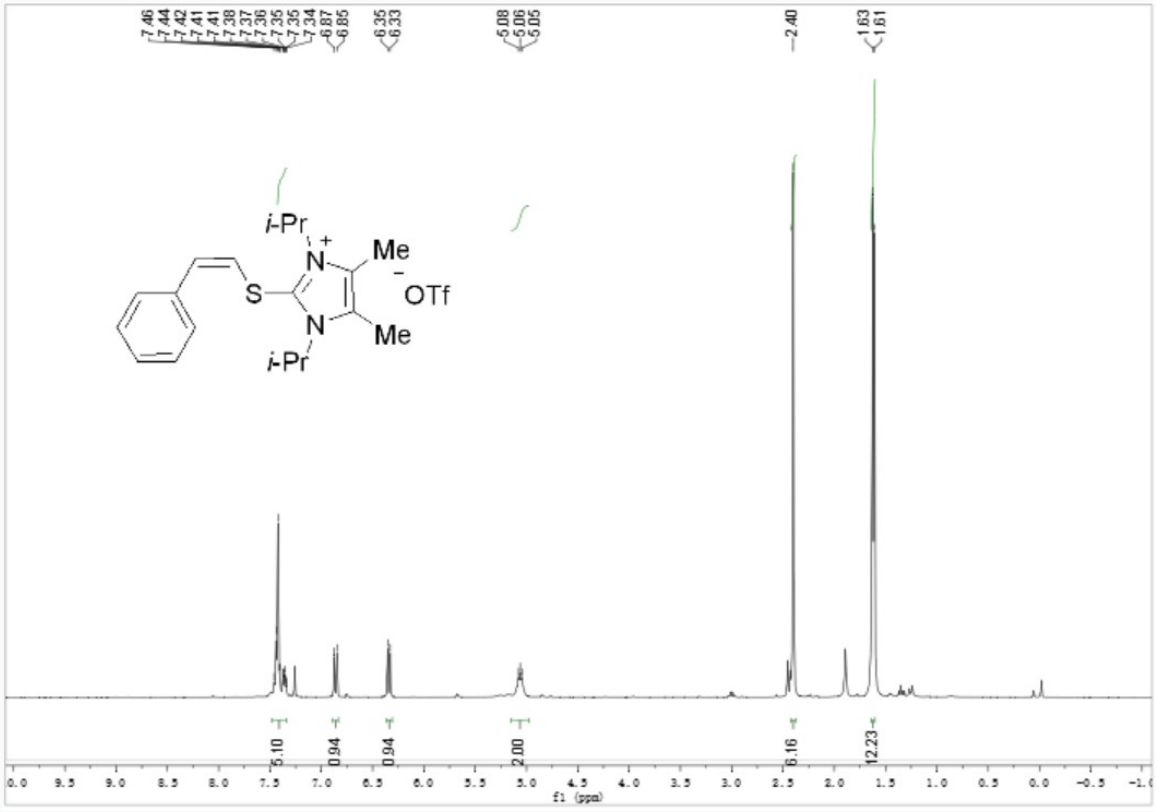
^{13}C NMR spectrum of **1ab** ($CDCl_3$, 100 MHz)



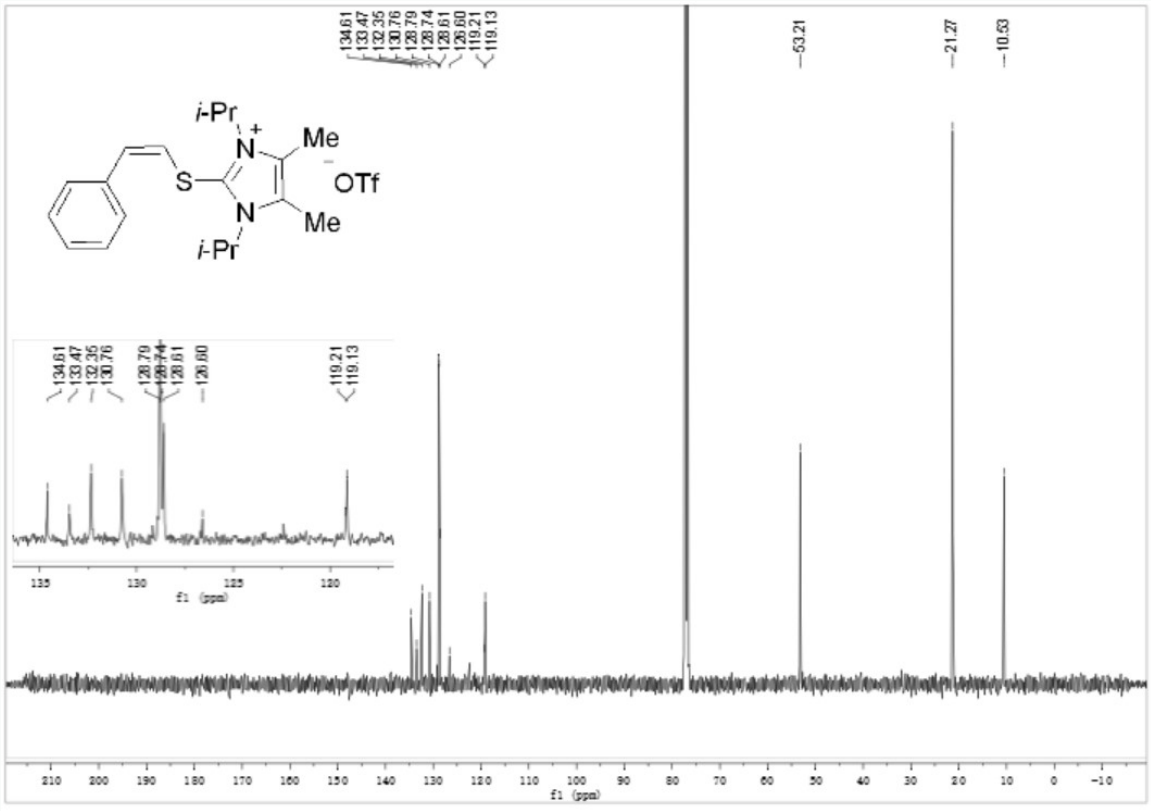
^{19}F NMR spectrum of **1ab** ($CDCl_3$, 376 MHz)



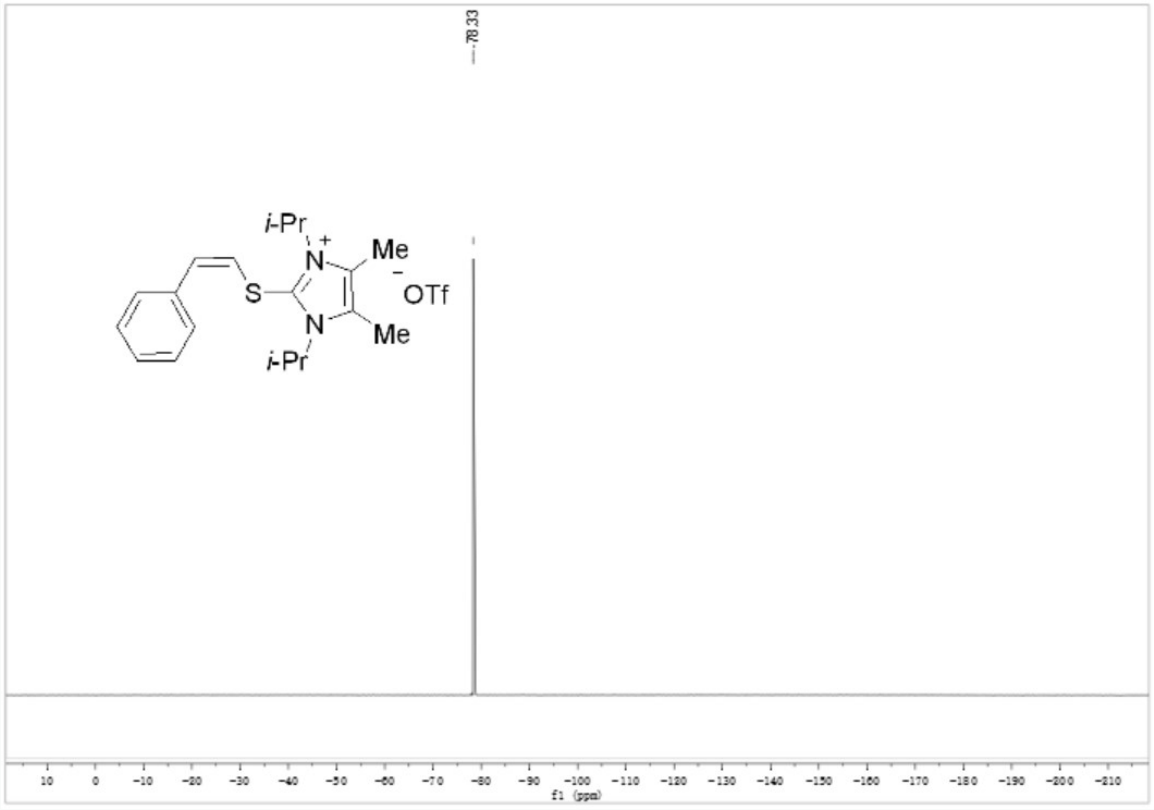
^{1}H NMR spectrum of **1ac** ($CDCl_3$, 400 MHz)



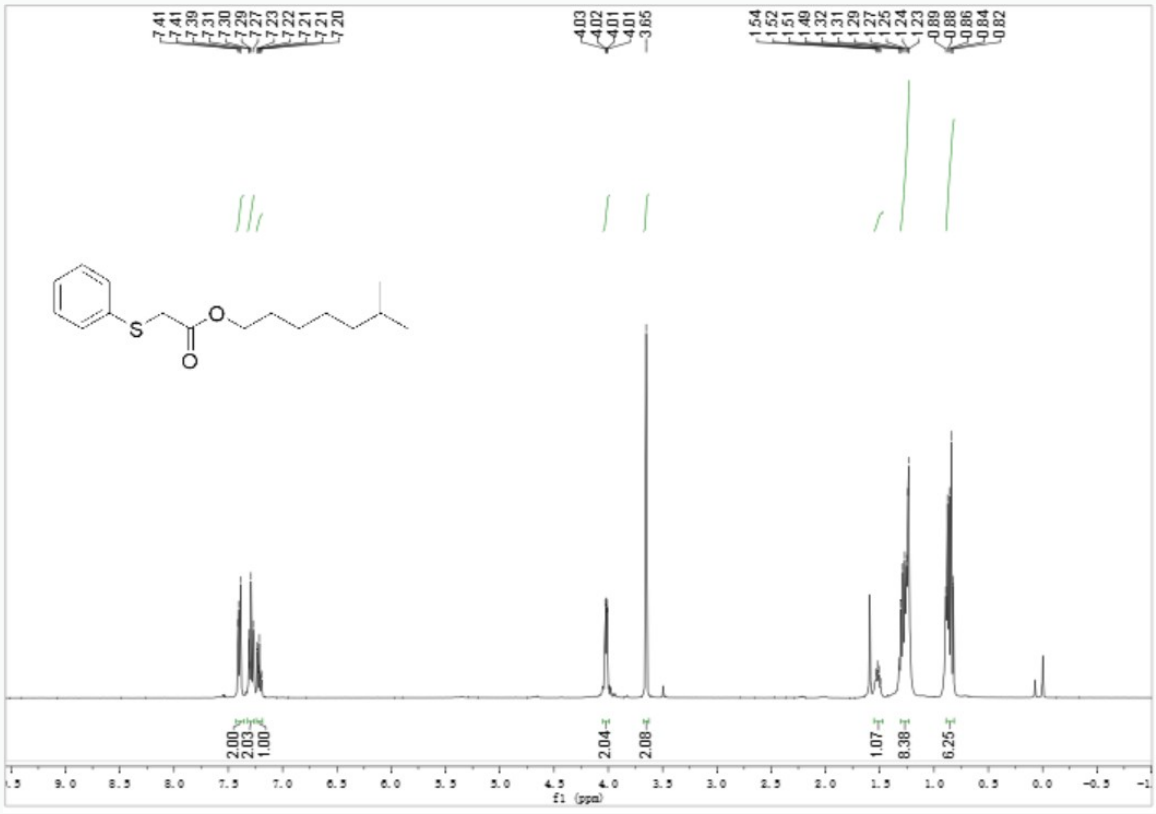
^{13}C NMR spectrum of **1ac** ($CDCl_3$, 100 MHz)



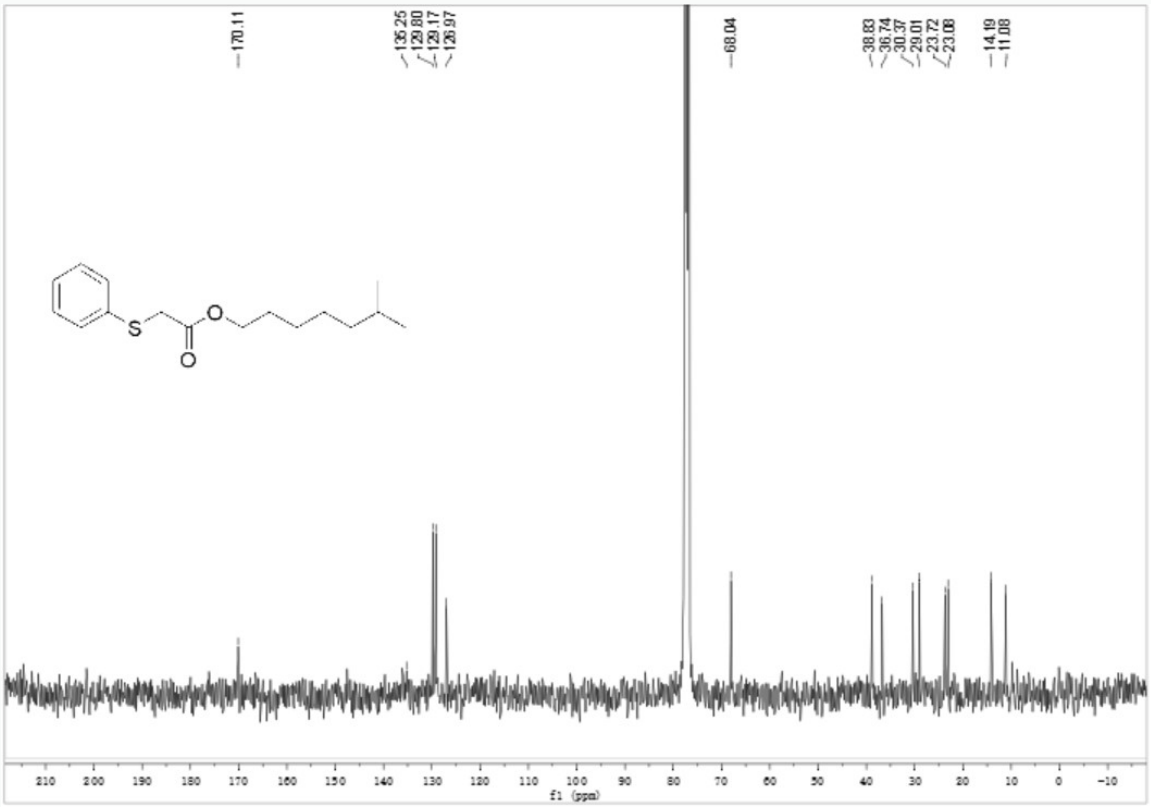
^{19}F NMR spectrum of **1ac** ($CDCl_3$, 376 MHz)



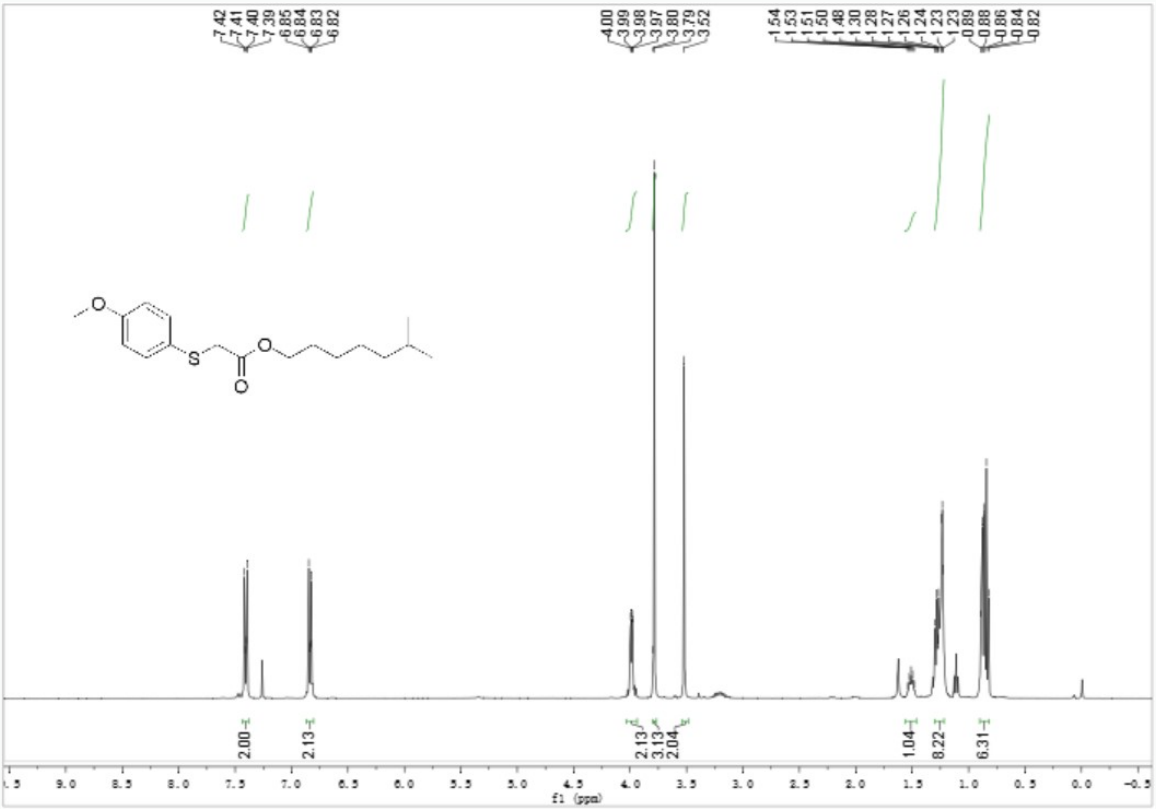
^{1}H NMR spectrum of **3a** ($CDCl_3$, 400 MHz)



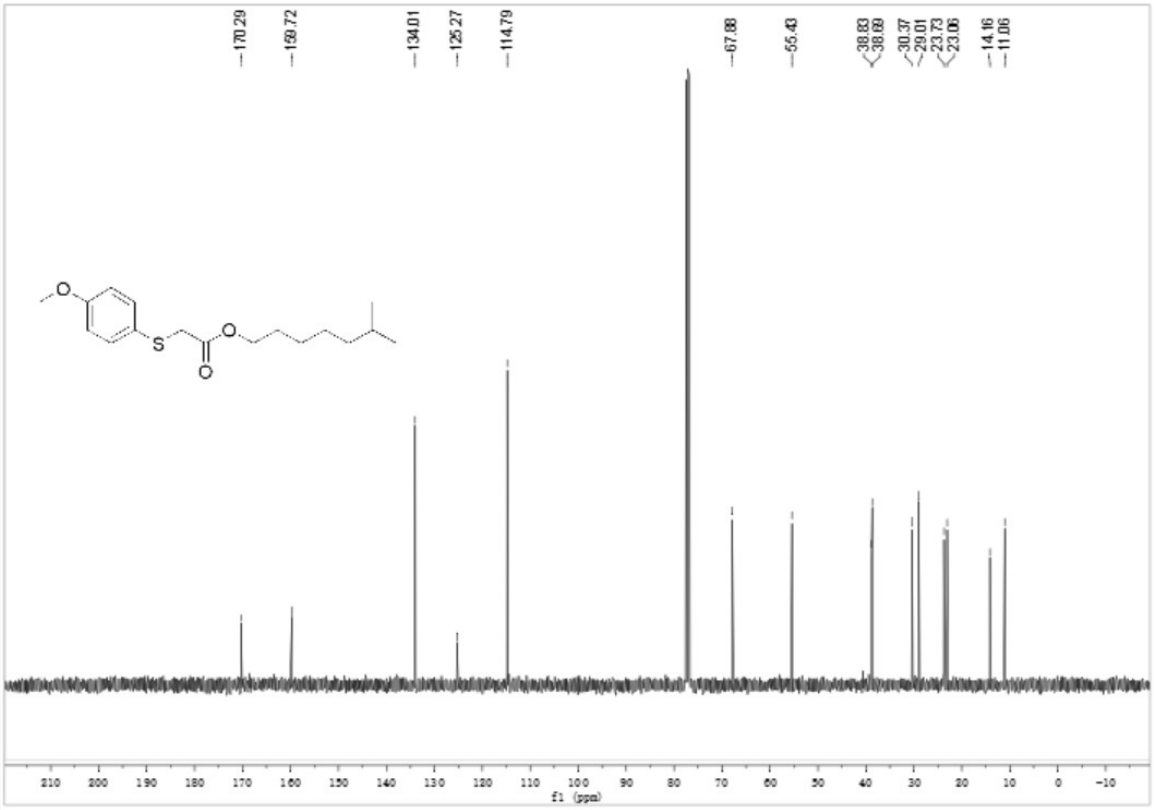
^{13}C NMR spectrum of **3a** ($CDCl_3$, 100 MHz)



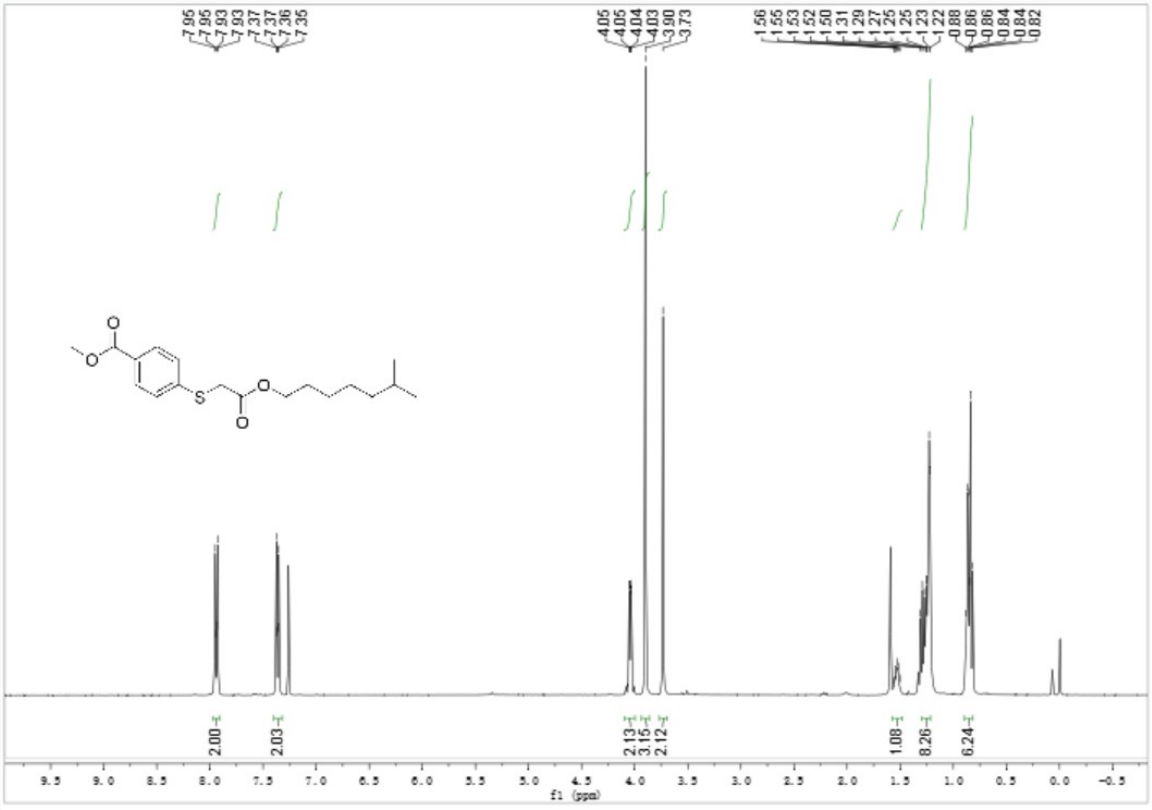
^{1}H NMR spectrum of **3b** ($CDCl_3$, 400 MHz)



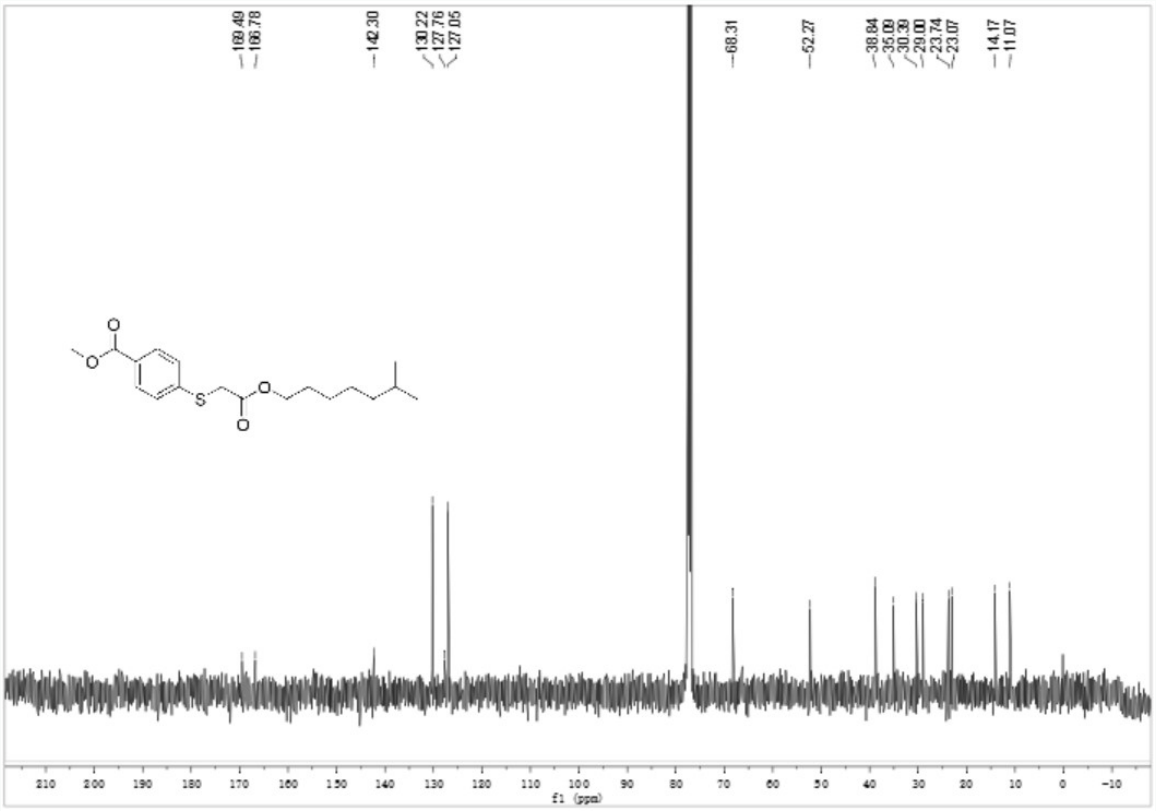
^{13}C NMR spectrum of **3b** ($CDCl_3$, 100 MHz)



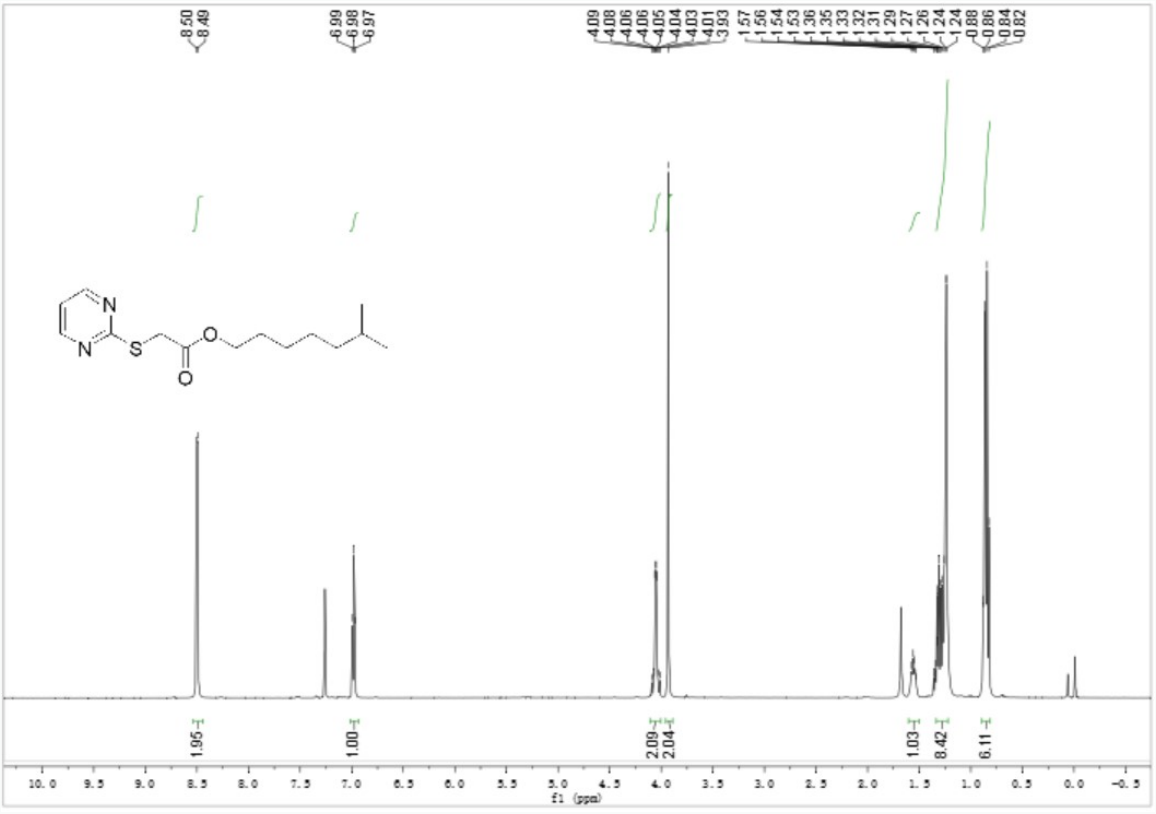
^{1}H NMR spectrum of **3c** ($CDCl_3$, 400 MHz)



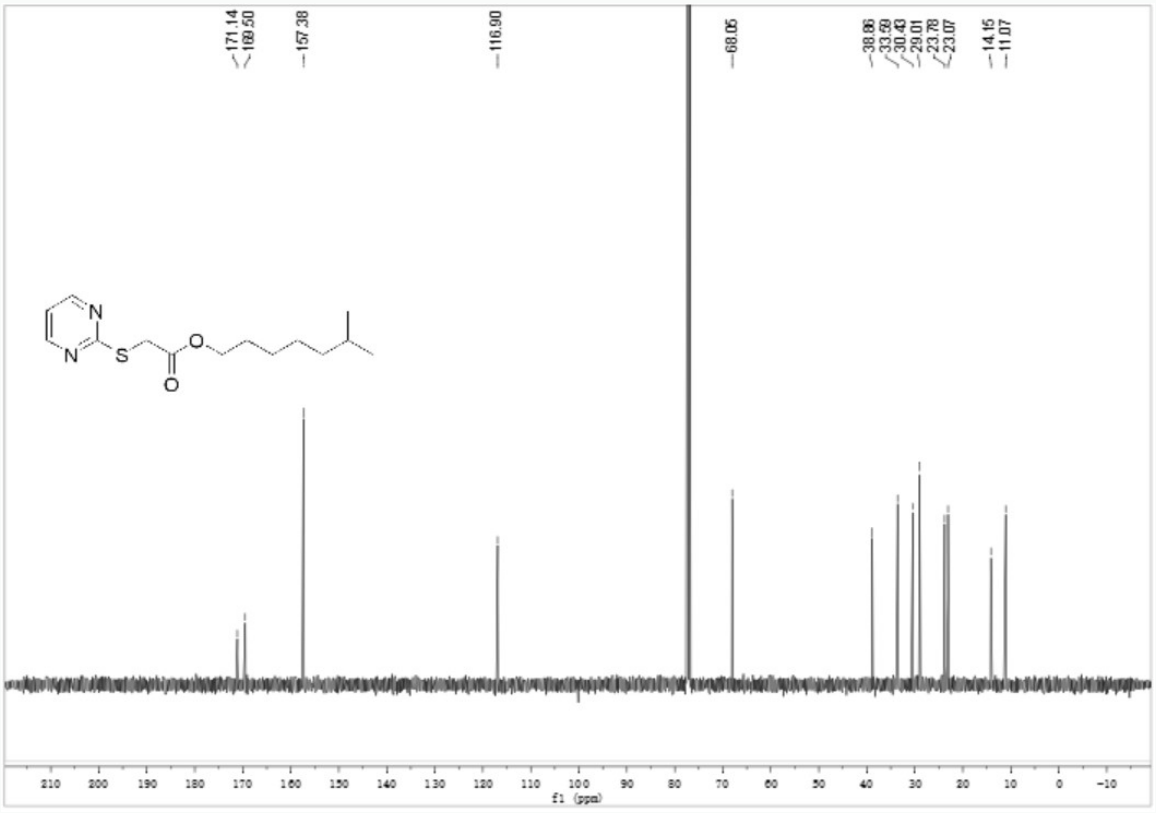
^{13}C NMR spectrum of **3c** ($CDCl_3$, 100 MHz)



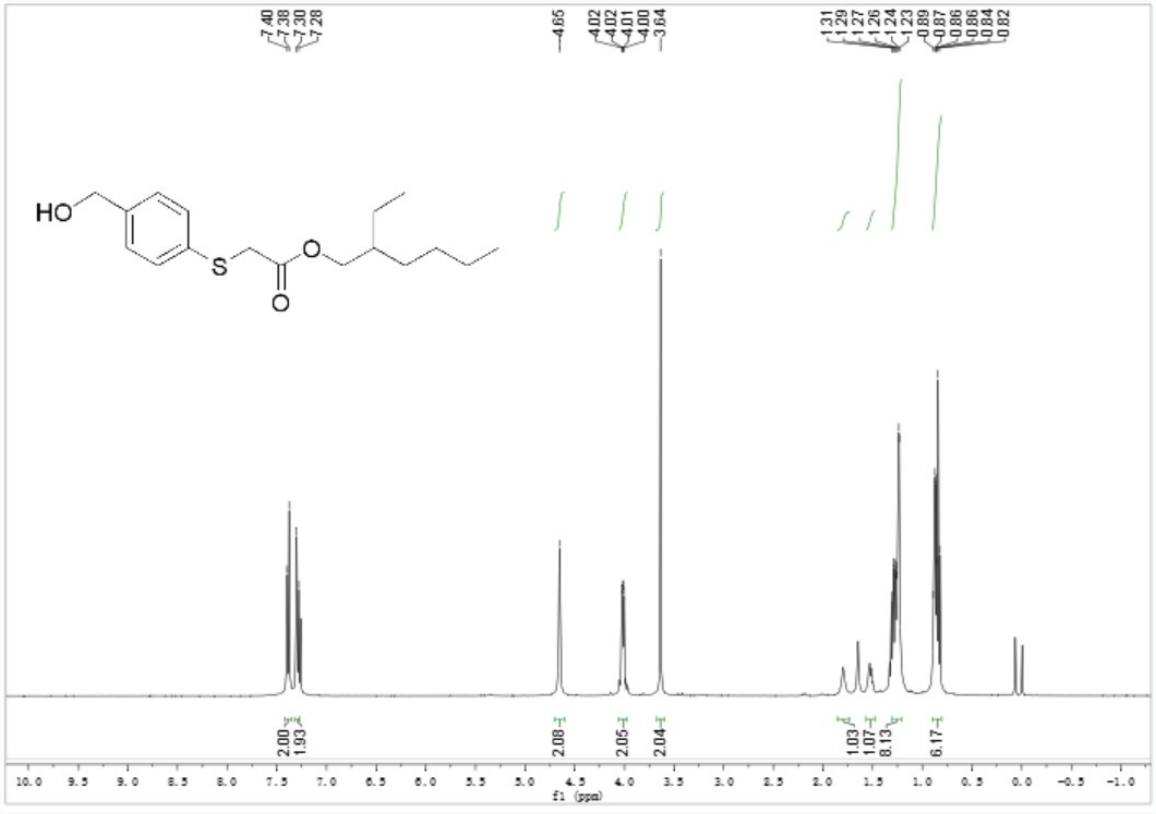
^{1}H NMR spectrum of **3d** ($CDCl_3$, 400 MHz)



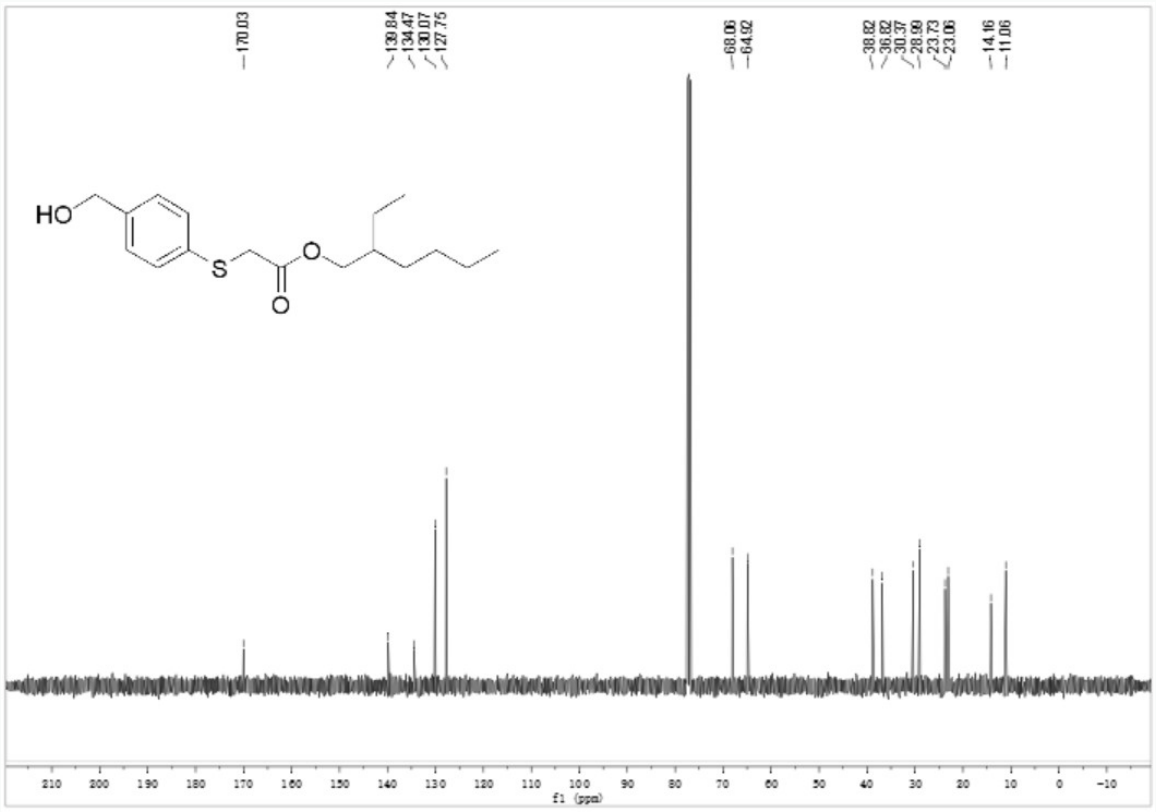
^{13}C NMR spectrum of **3d** ($CDCl_3$, 100 MHz)



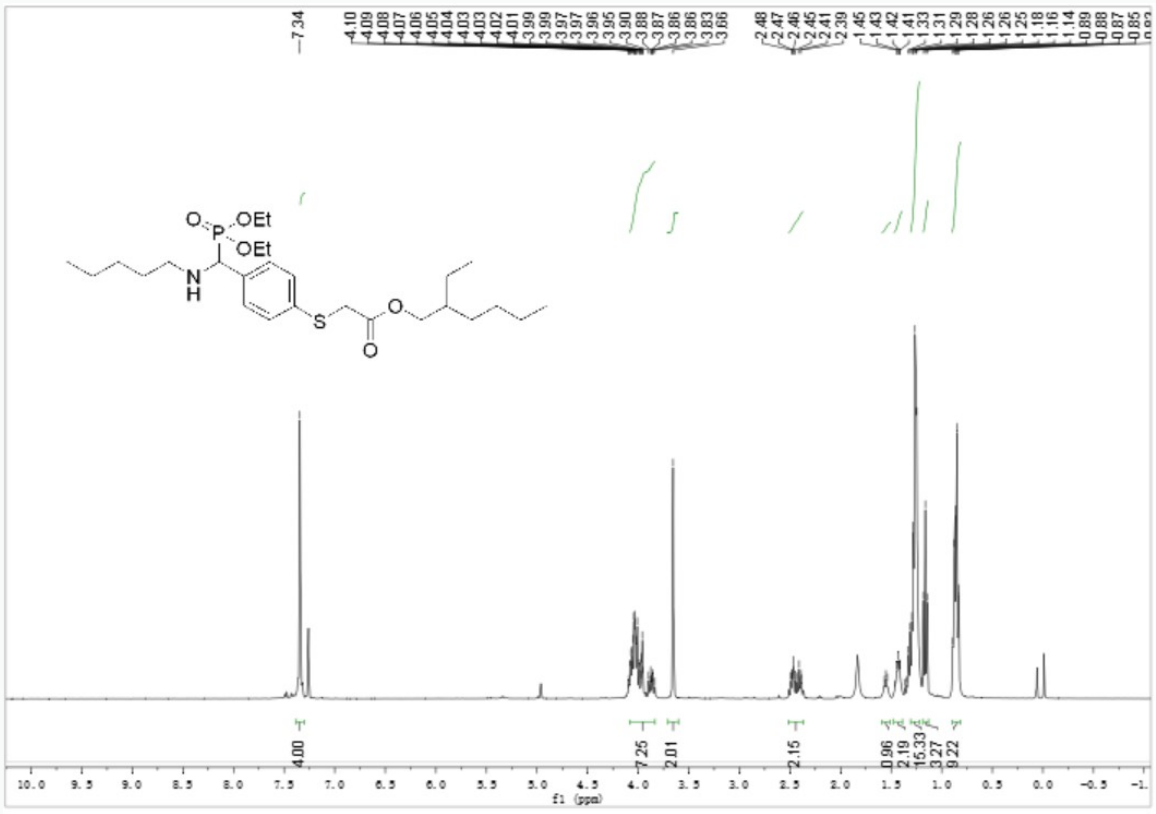
^{1}H NMR spectrum of **3e** ($CDCl_3$, 400 MHz)



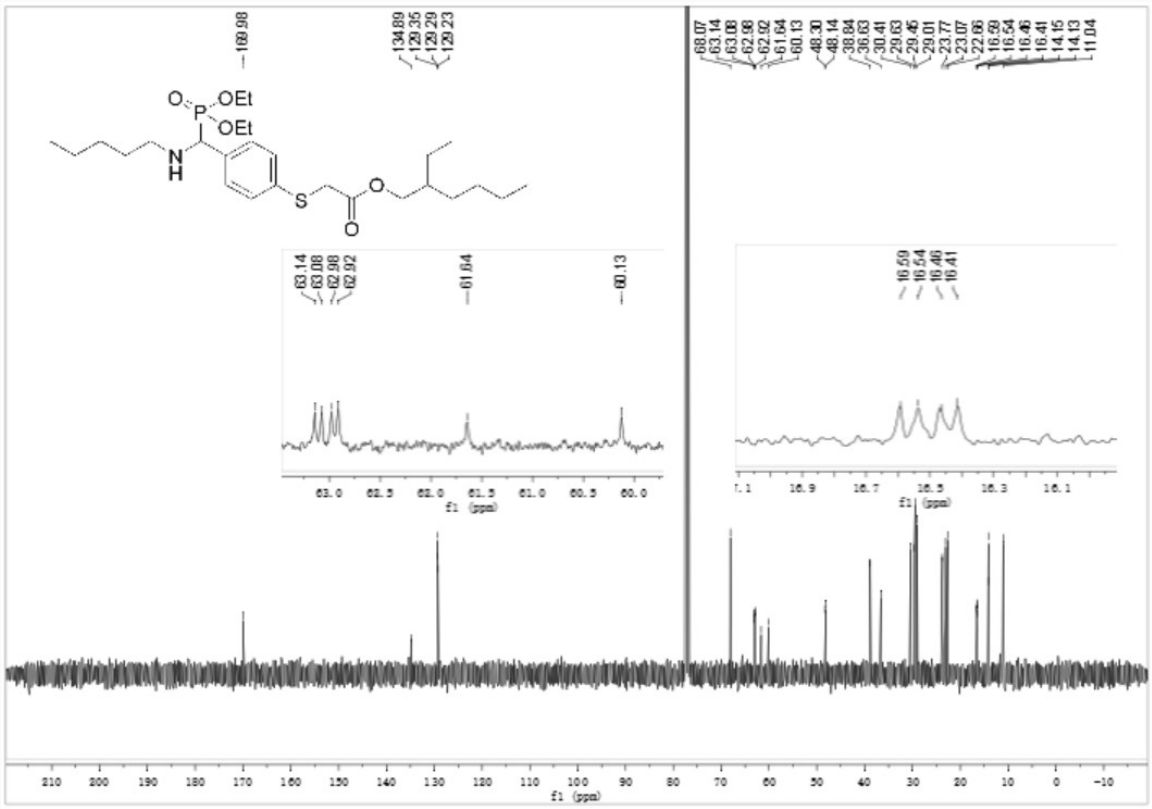
^{13}C NMR spectrum of **3e** ($CDCl_3$, 100 MHz)



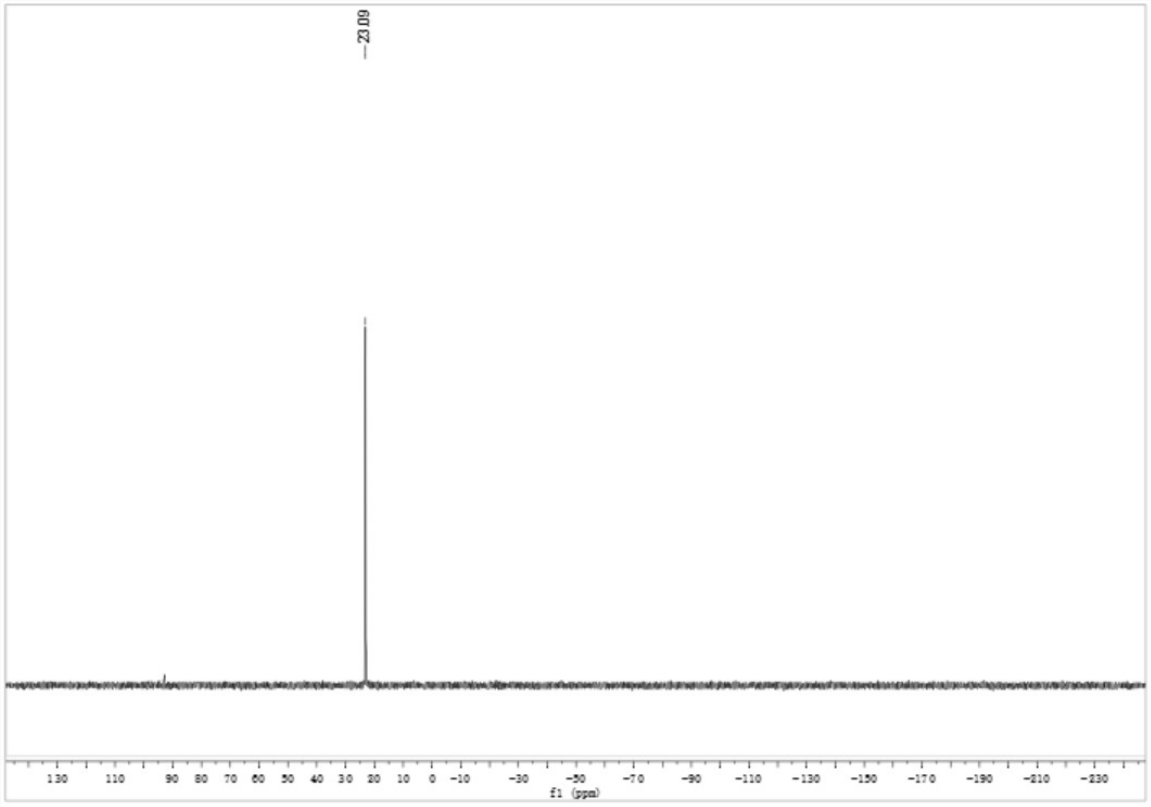
^{1}H NMR spectrum of **3f** ($CDCl_3$, 400 MHz)



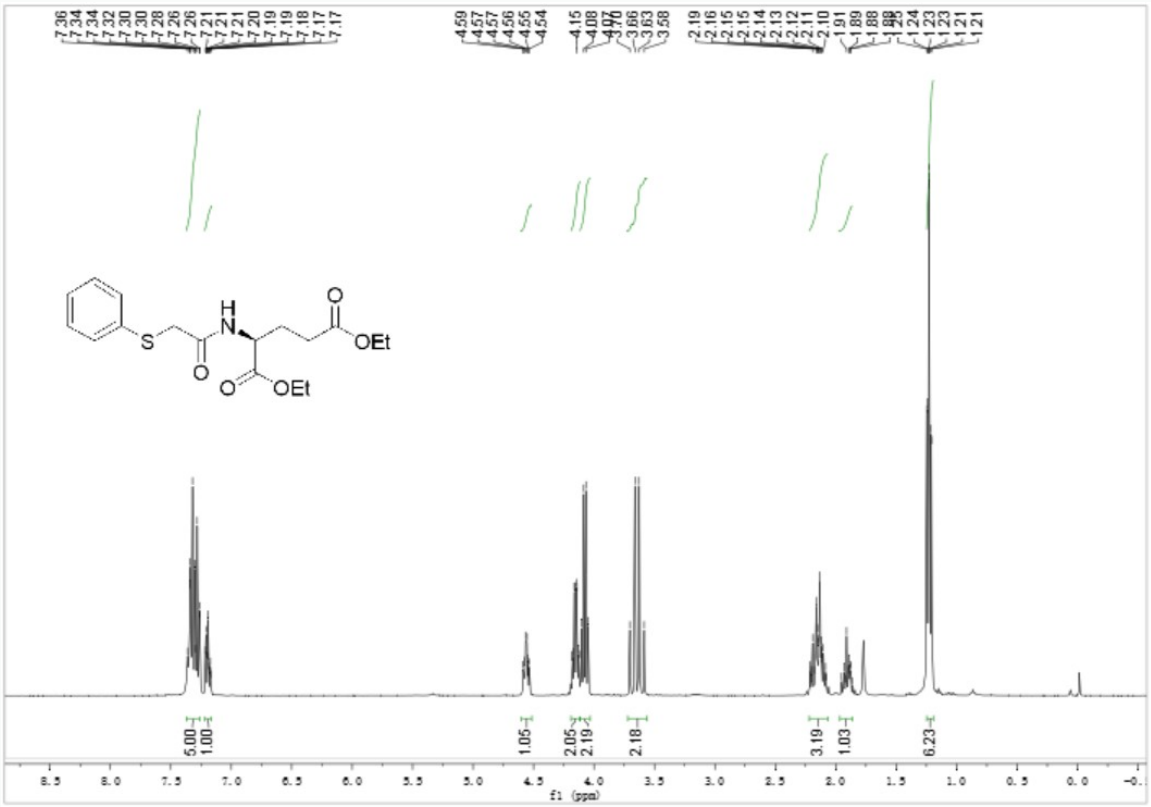
^{13}C NMR spectrum of **3f** ($CDCl_3$, 100 MHz)



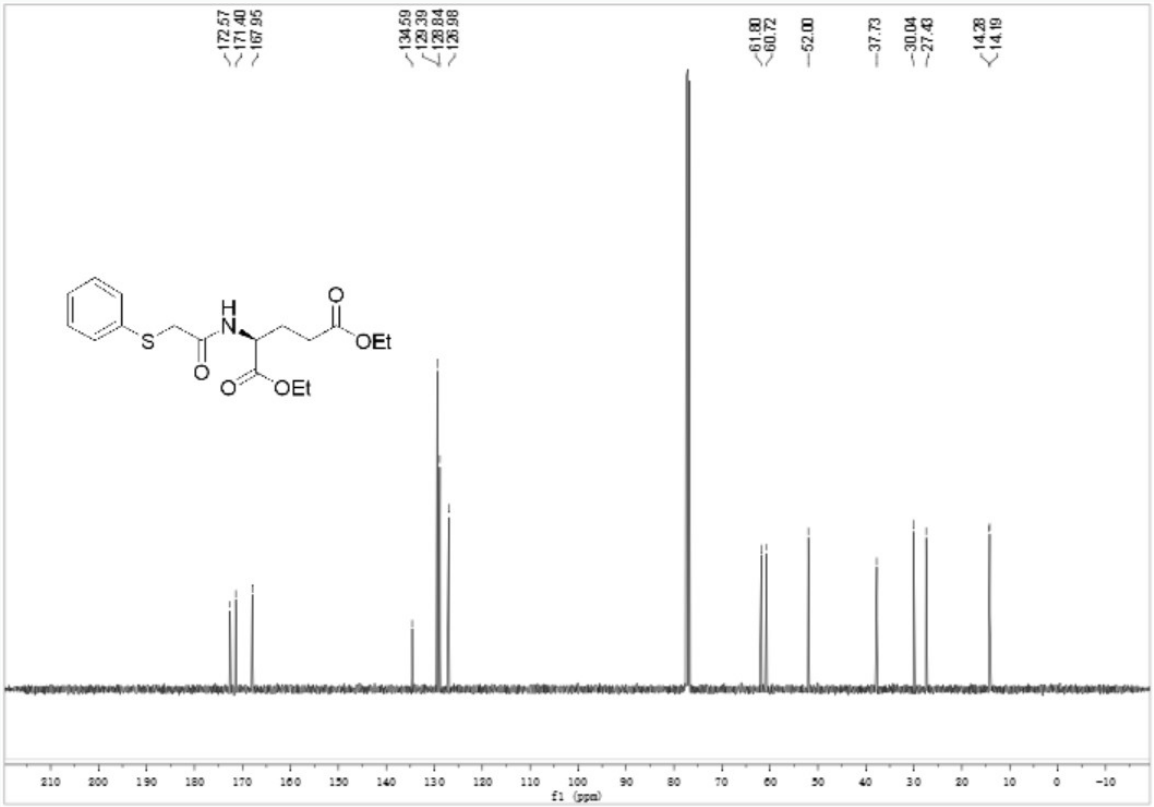
^{31}P NMR spectrum of **3f** ($CDCl_3$, 162 MHz)



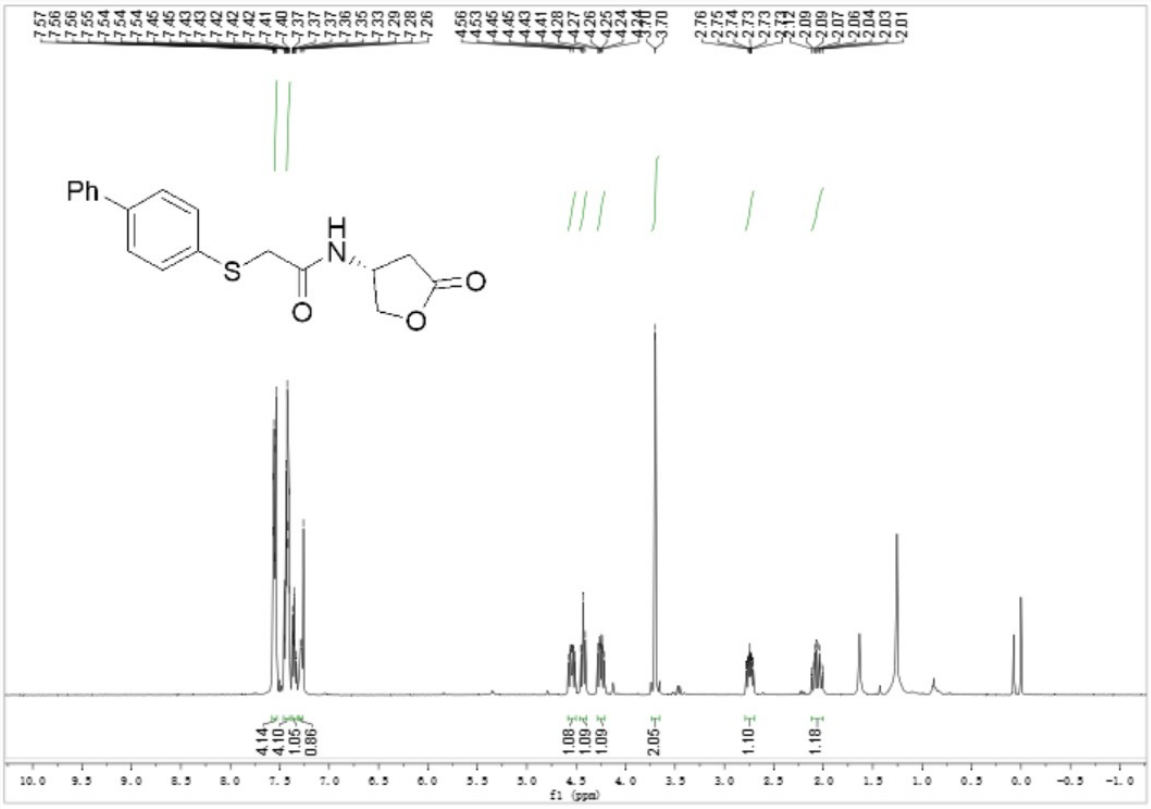
^{1}H NMR spectrum of **3g** ($CDCl_3$, 400 MHz)



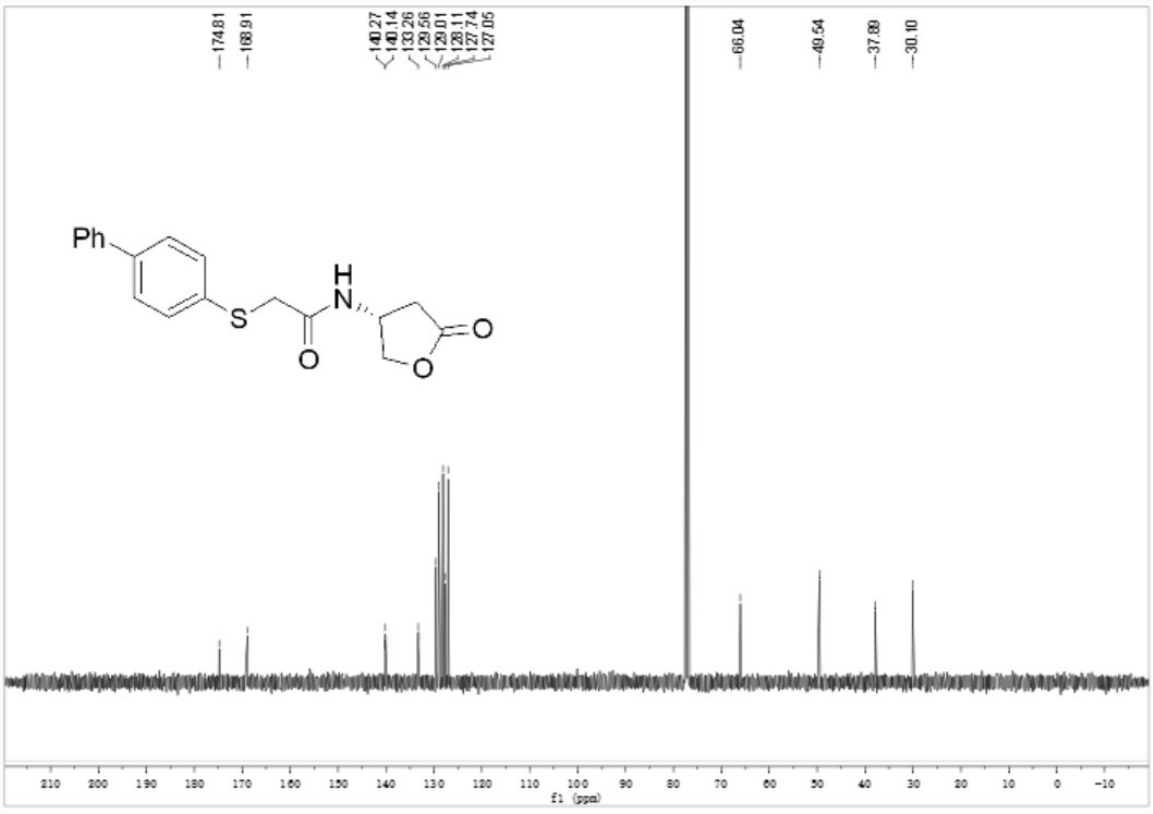
^{13}C NMR spectrum of **3g** ($CDCl_3$, 100 MHz)



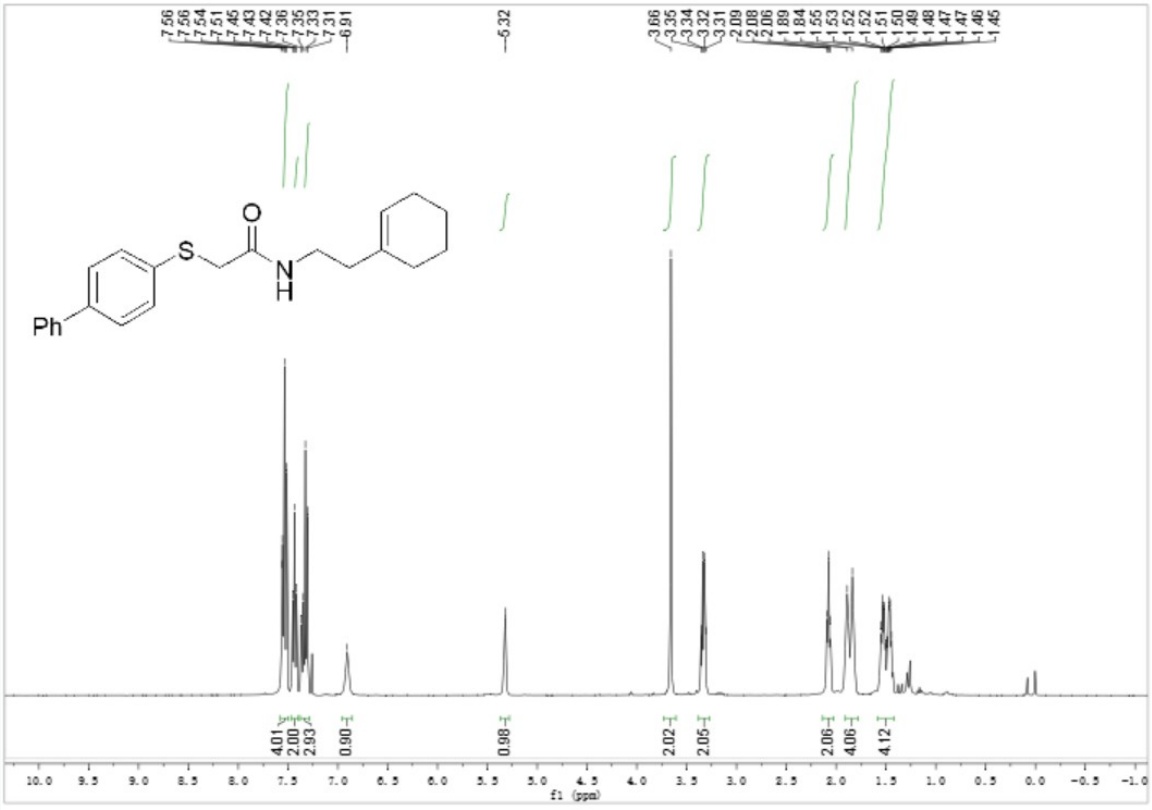
^{1}H NMR spectrum of **3h** ($CDCl_3$, 400 MHz)



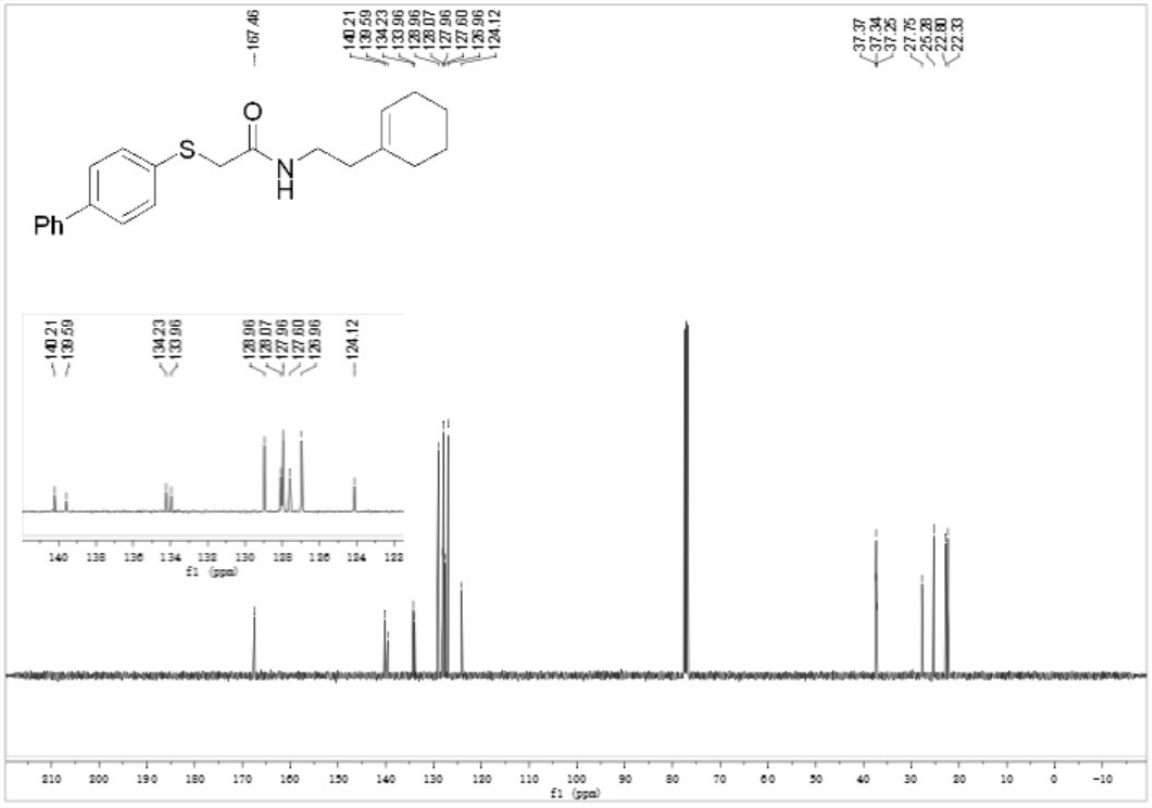
^{13}C NMR spectrum of **3h** ($CDCl_3$, 100 MHz)



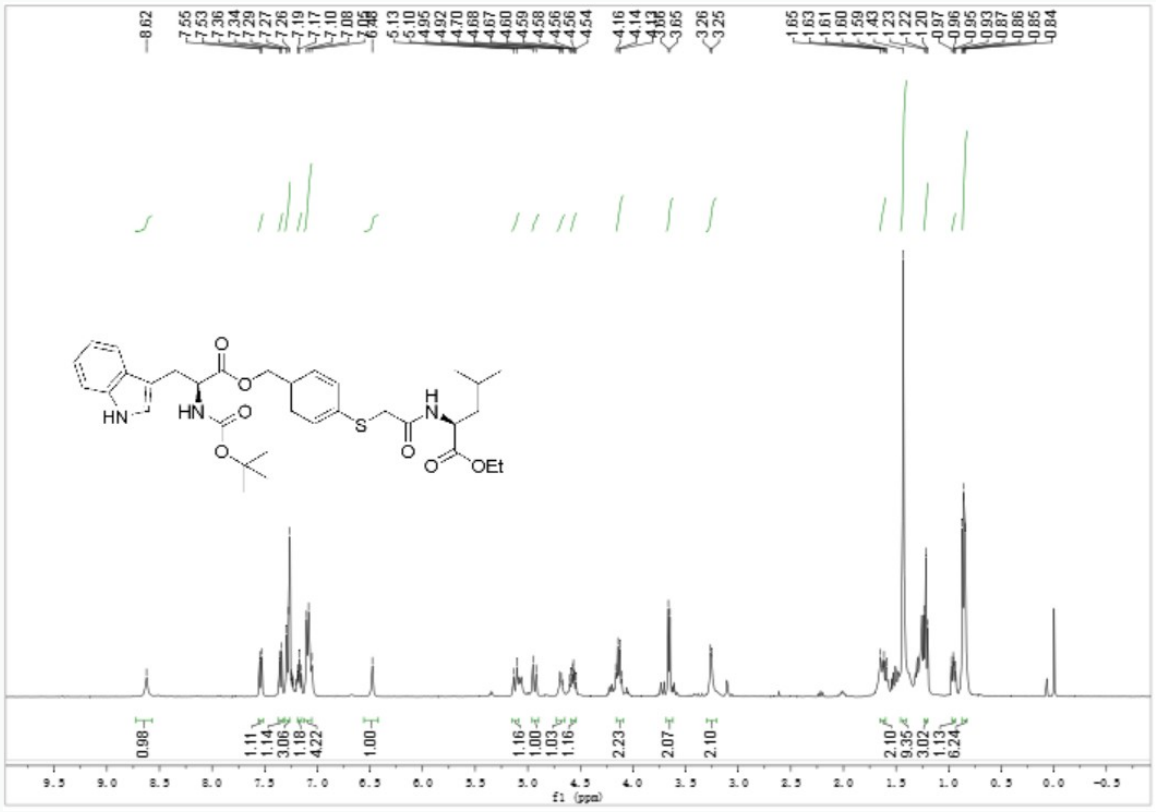
^{1}H NMR spectrum of **3i** ($CDCl_3$, 400 MHz)



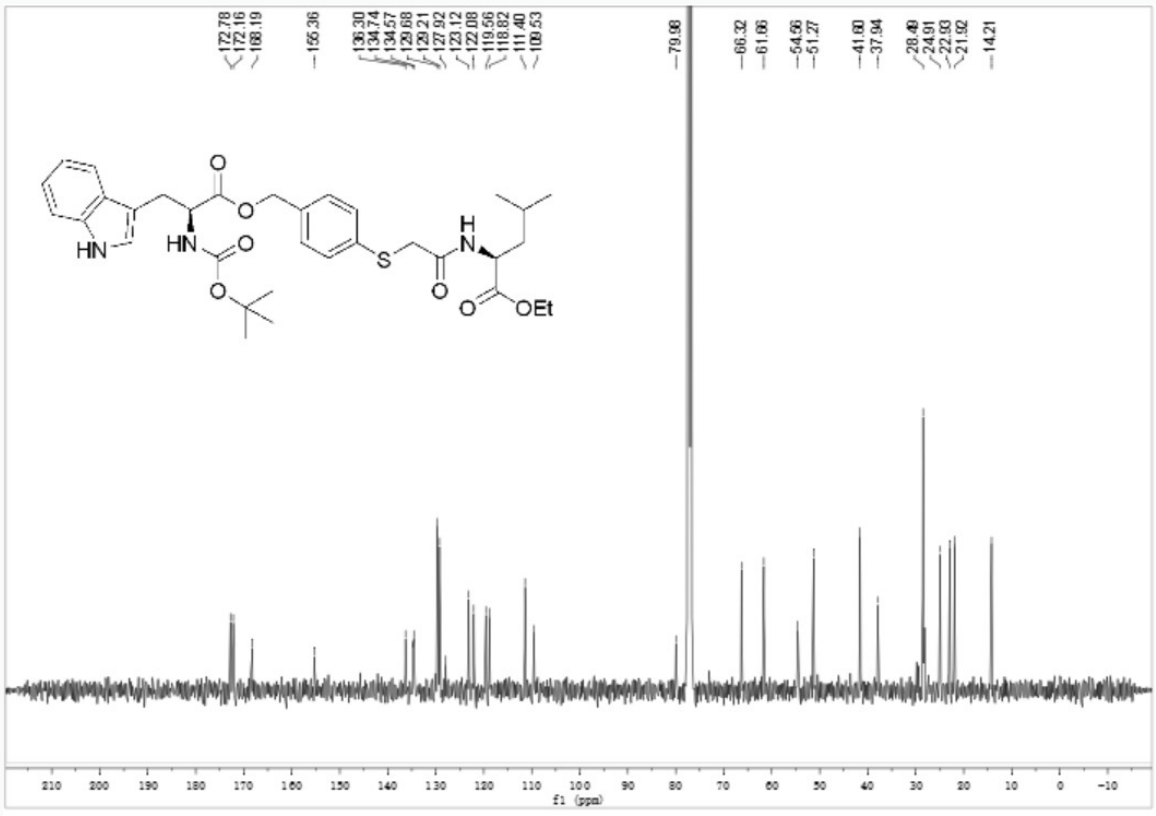
^{13}C NMR spectrum of **3i** ($CDCl_3$, 100 MHz)



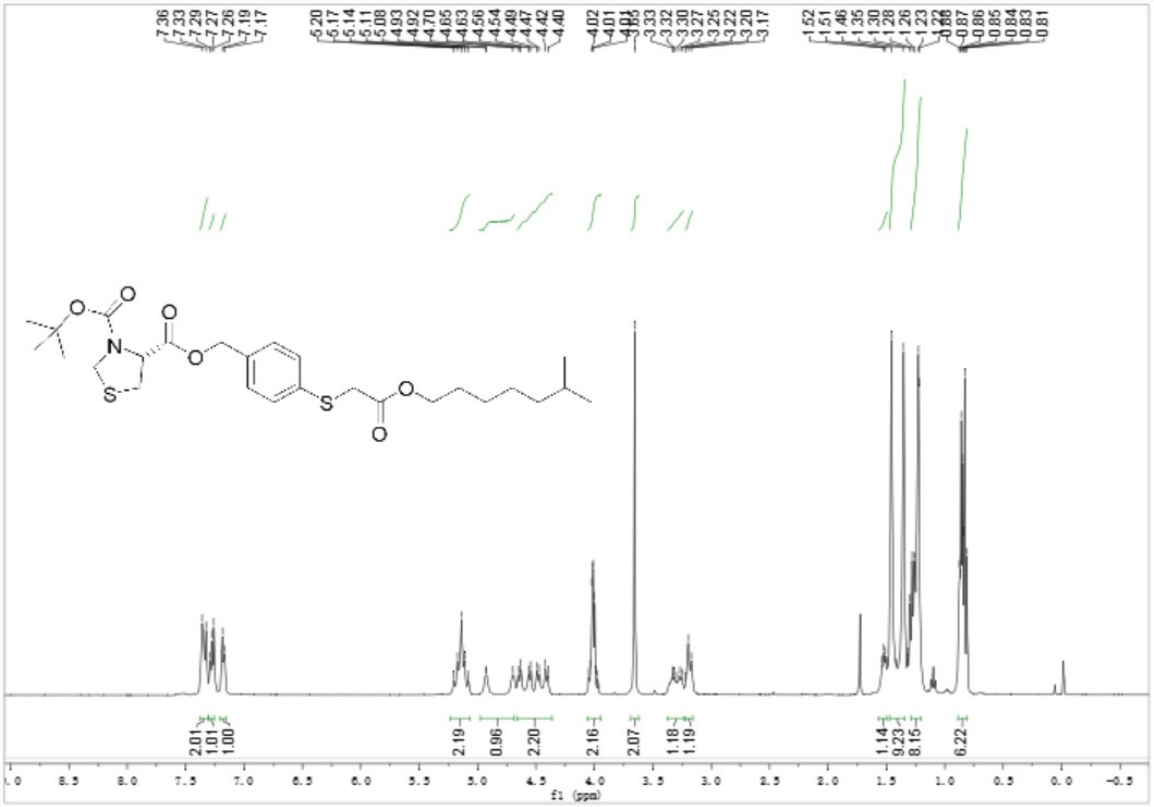
^{1}H NMR spectrum of **3j** ($CDCl_3$, 400 MHz)



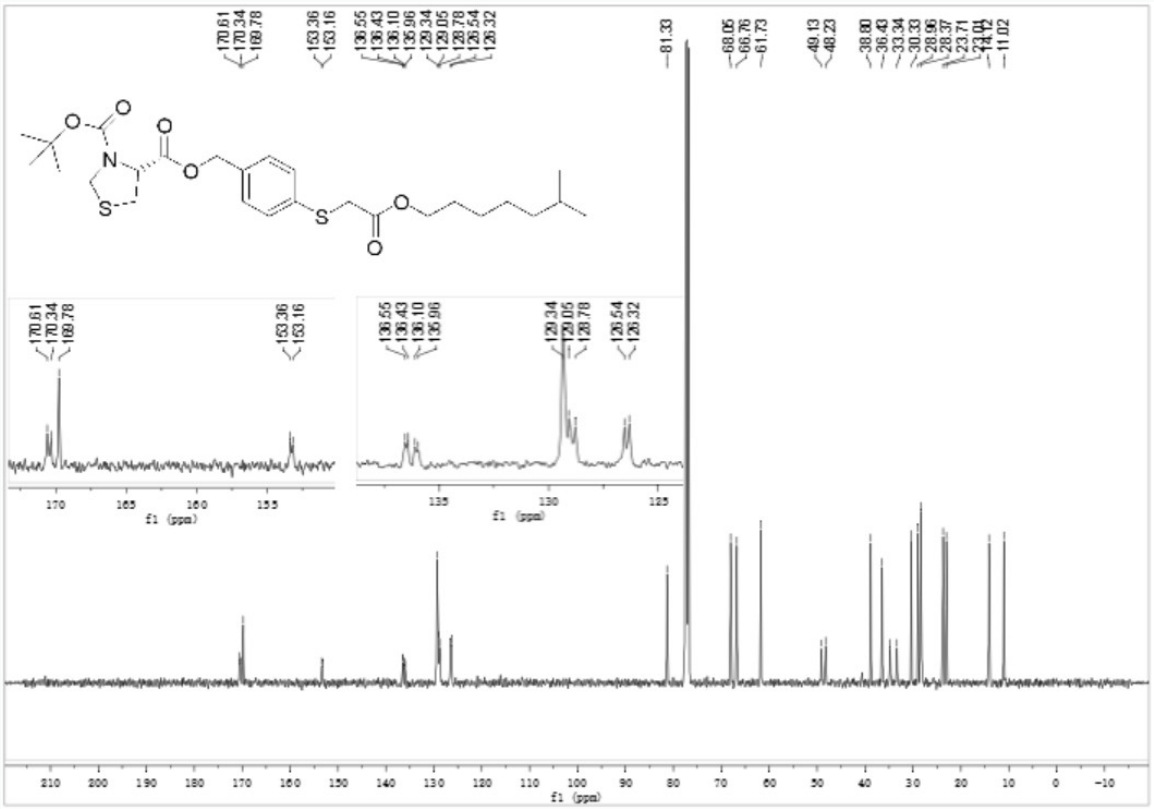
^{13}C NMR spectrum of **3j** ($CDCl_3$, 100 MHz)



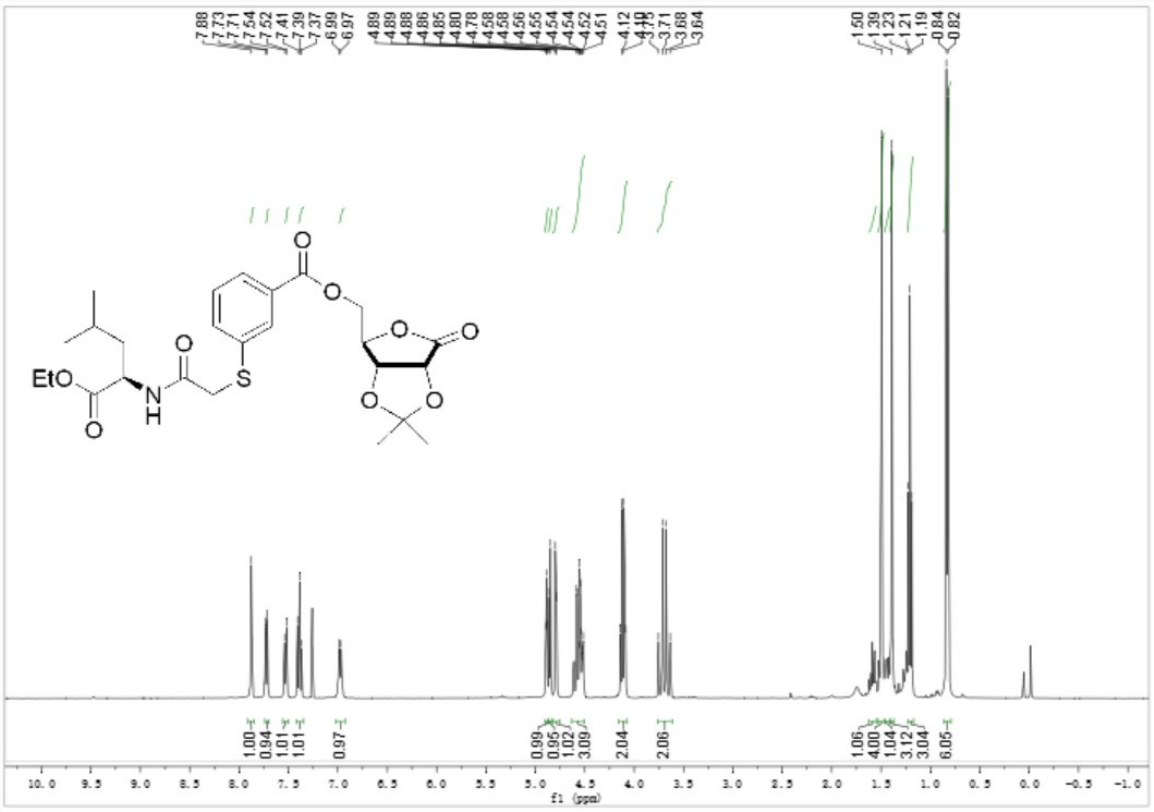
^{1}H NMR spectrum of **3k** ($CDCl_3$, 400 MHz)



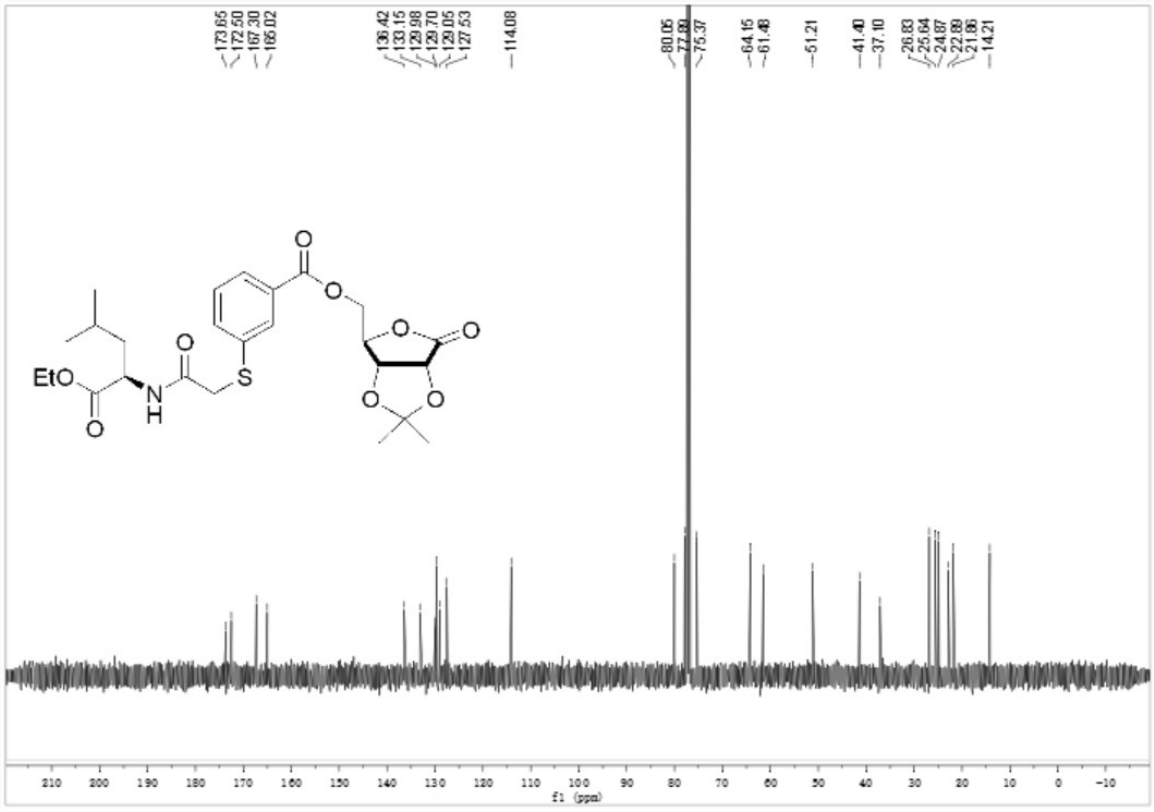
^{13}C NMR spectrum of **3k** ($CDCl_3$, 100 MHz)



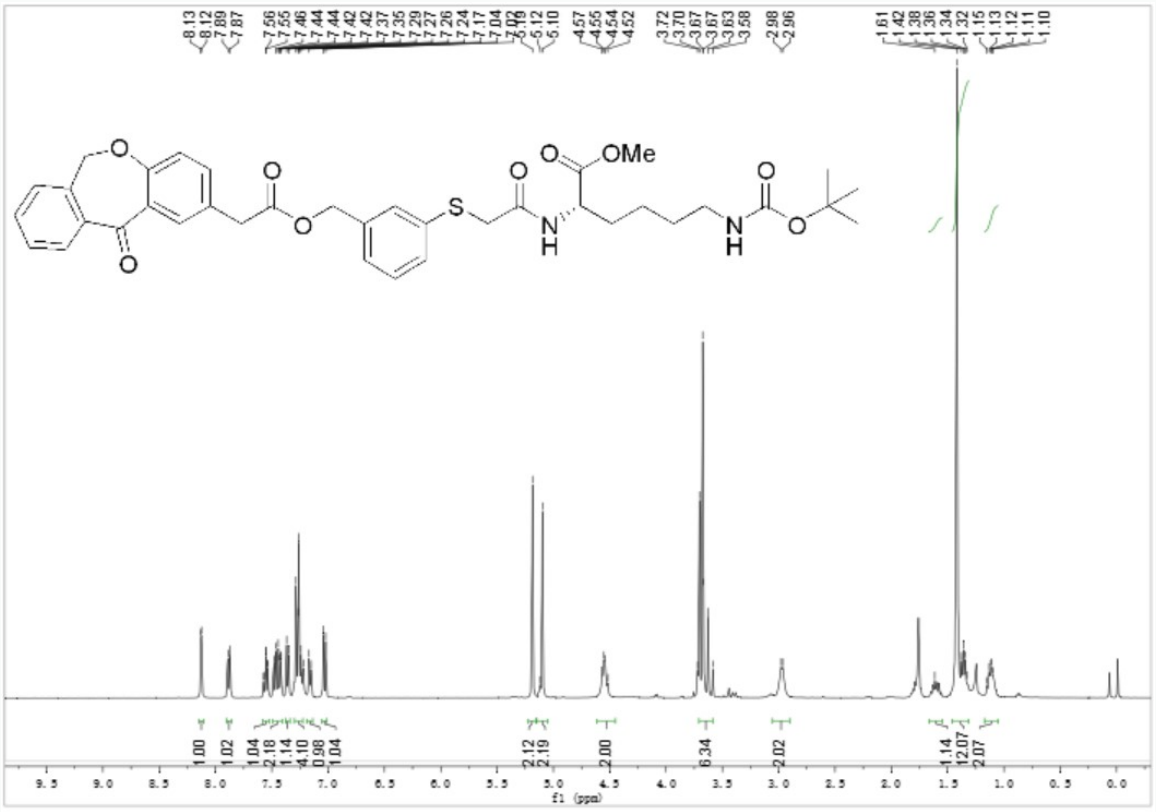
^{1}H NMR spectrum of **3l** ($CDCl_3$, 400 MHz)



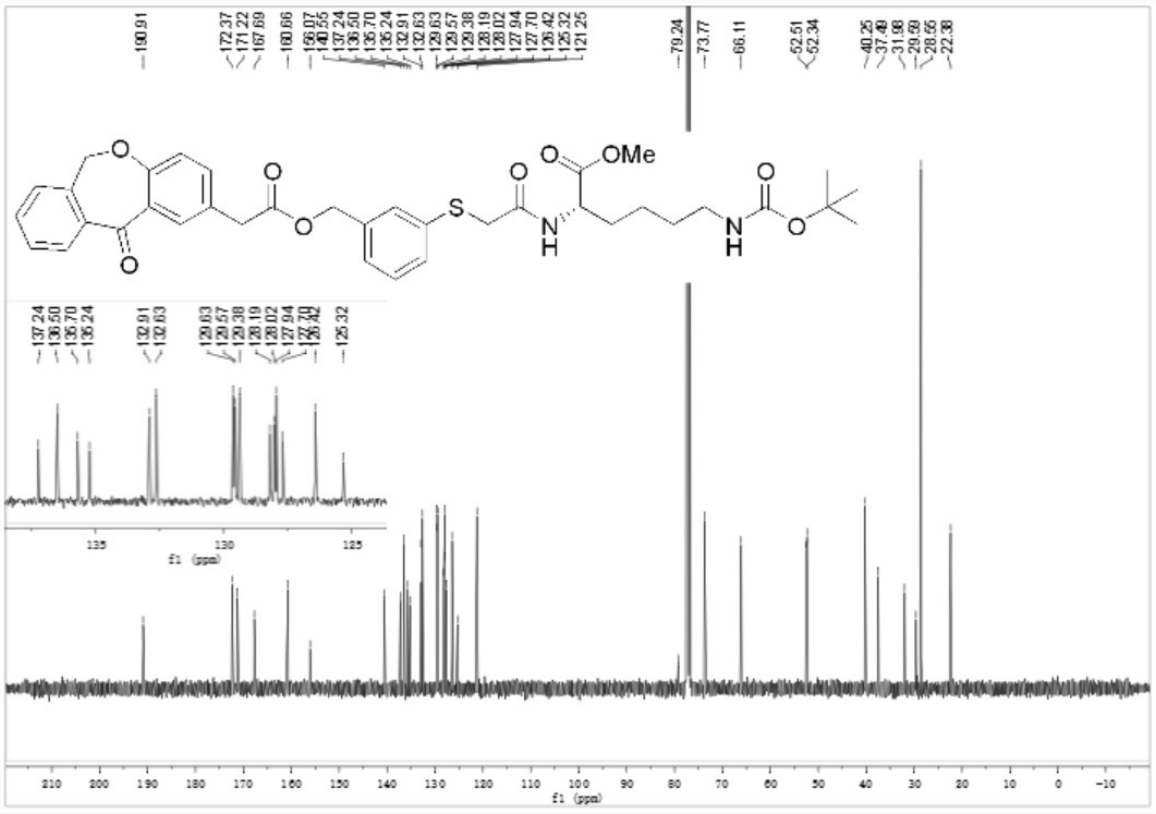
^{13}C NMR spectrum of **3l** ($CDCl_3$, 100 MHz)



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

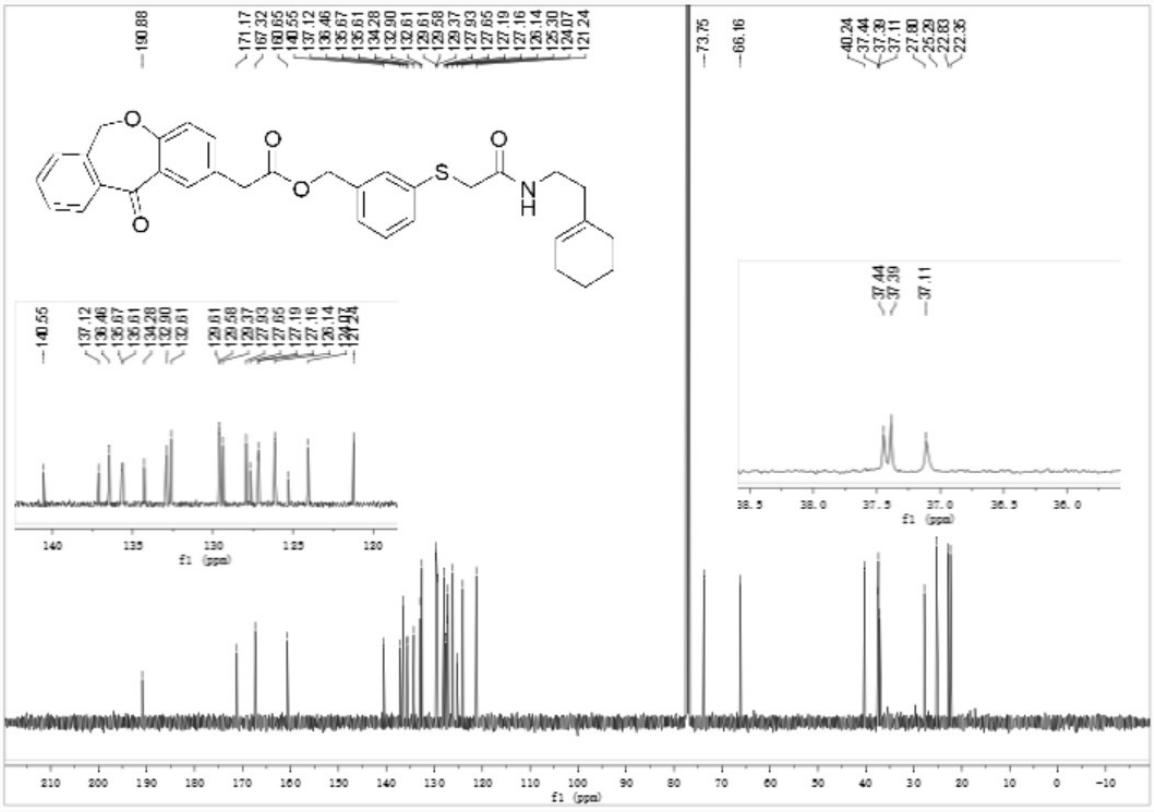


^{13}C NMR spectrum of **3m** ($CDCl_3$, 100 MHz)

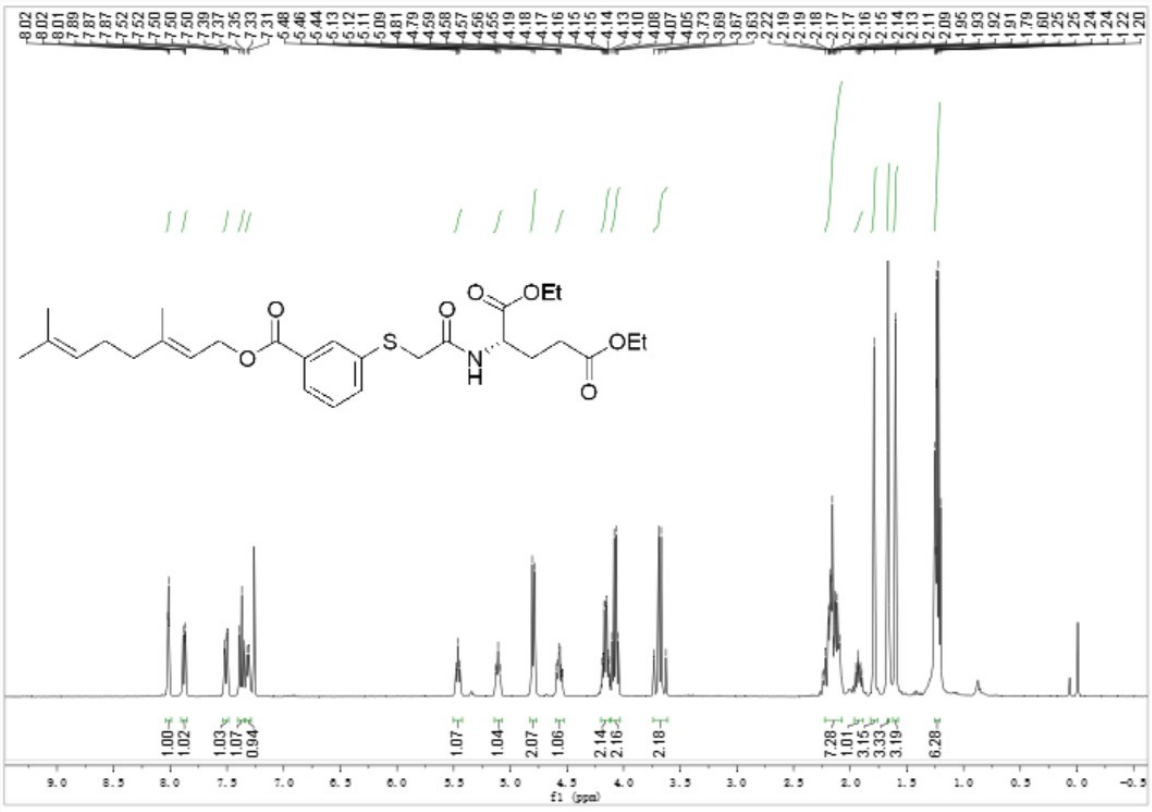


^{1}H NMR spectrum of **3n** ($CDCl_3$, 400 MHz)

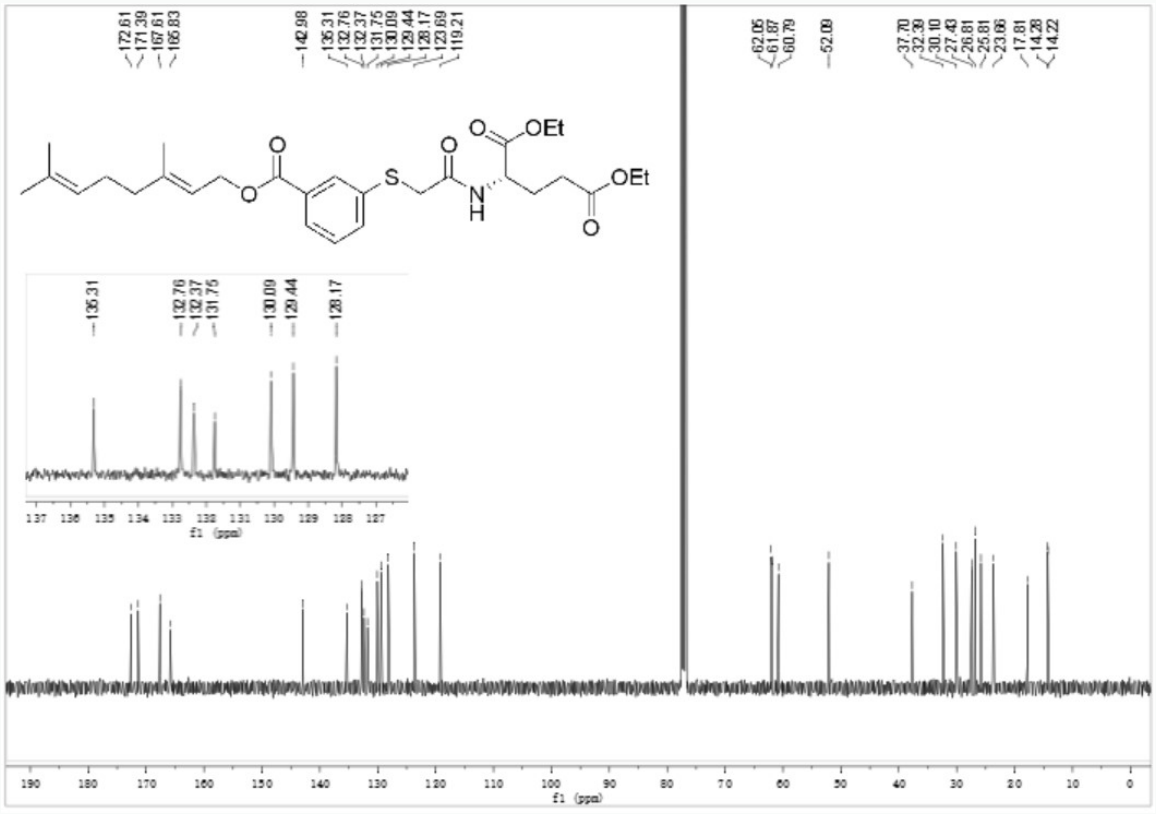
^{13}C NMR spectrum of **3n** ($CDCl_3$, 100 MHz)



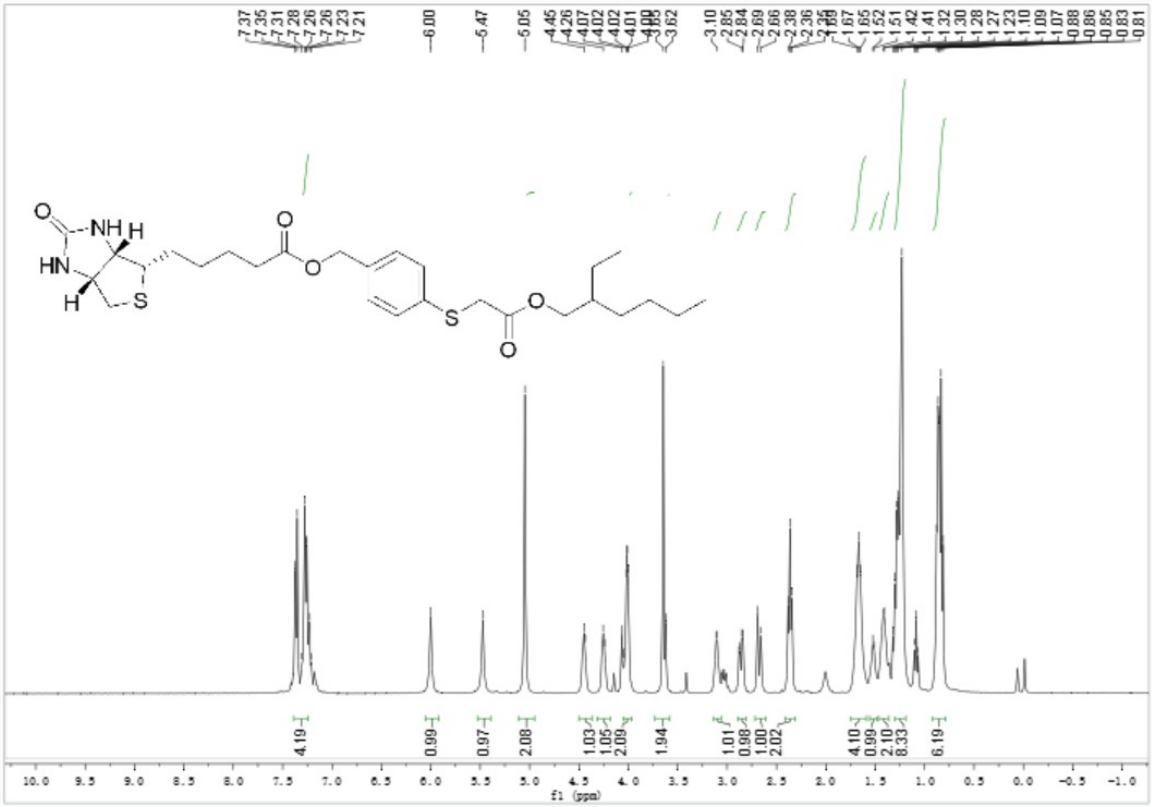
^{1}H NMR spectrum of **3o** ($CDCl_3$, 400 MHz)



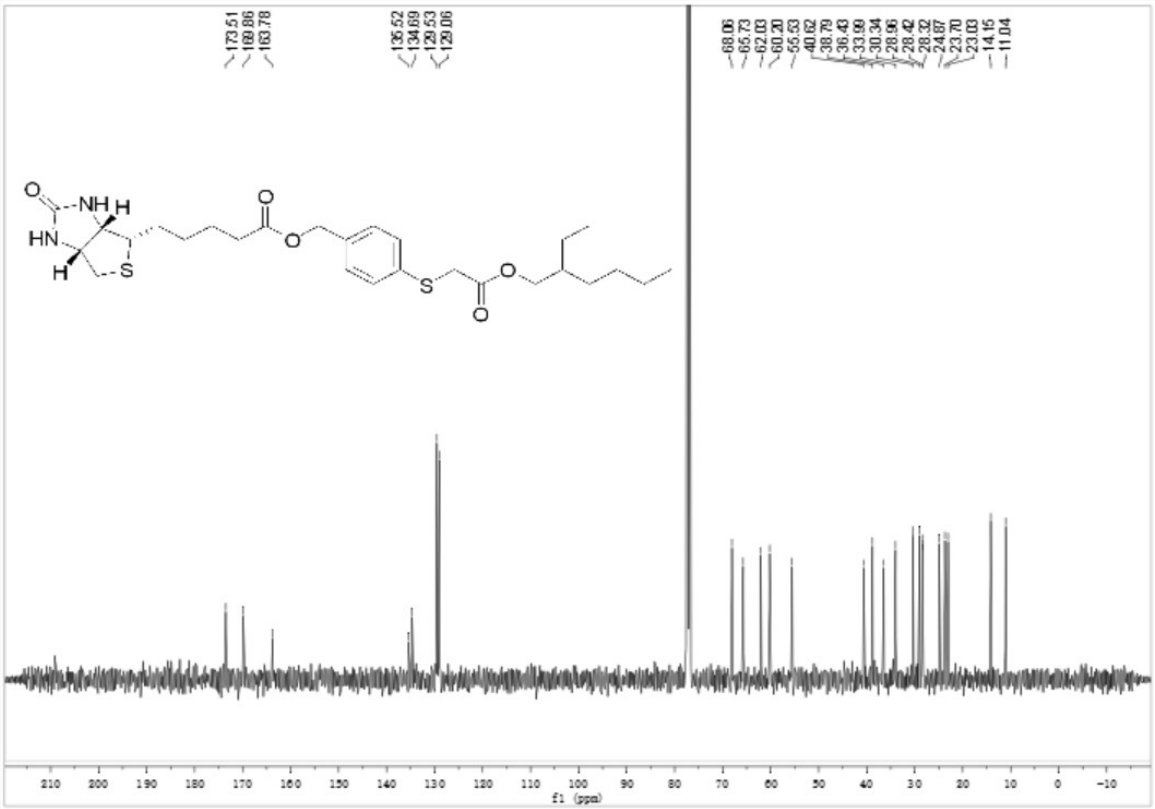
^{13}C NMR spectrum of **3o** ($CDCl_3$, 100 MHz)



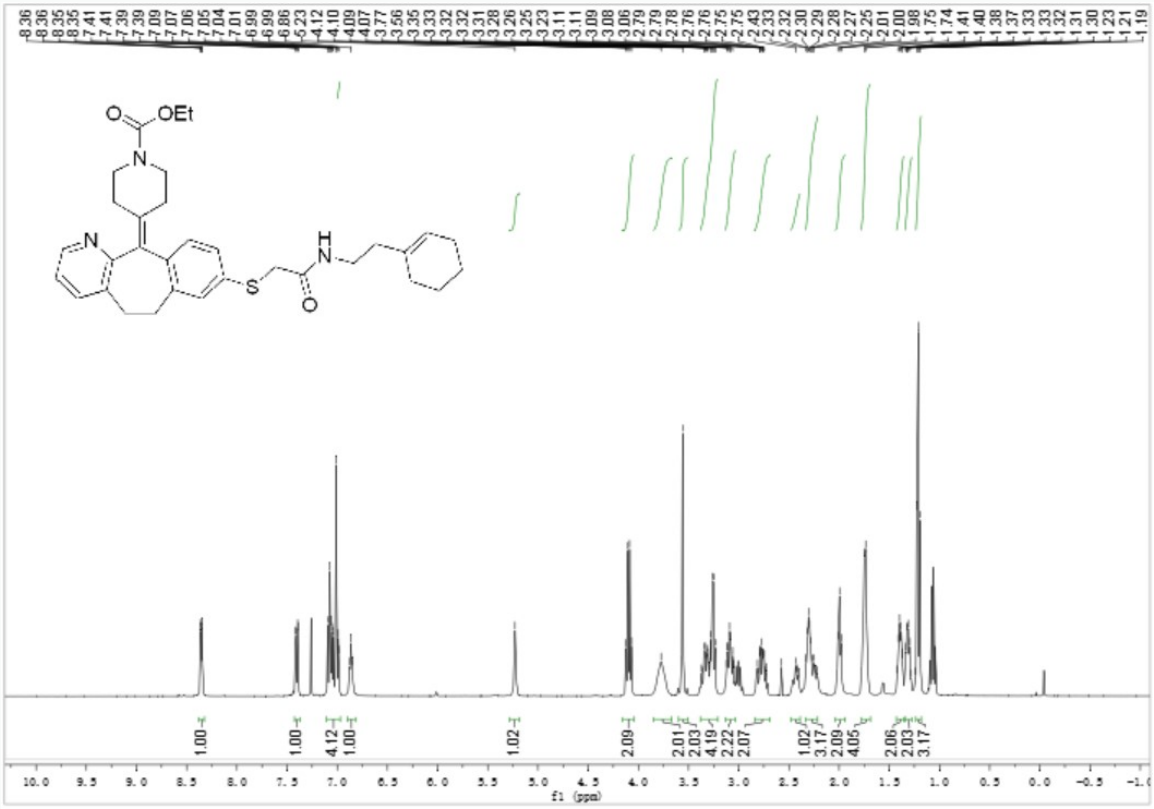
^{1}H NMR spectrum of **3p** ($CDCl_3$, 400 MHz)



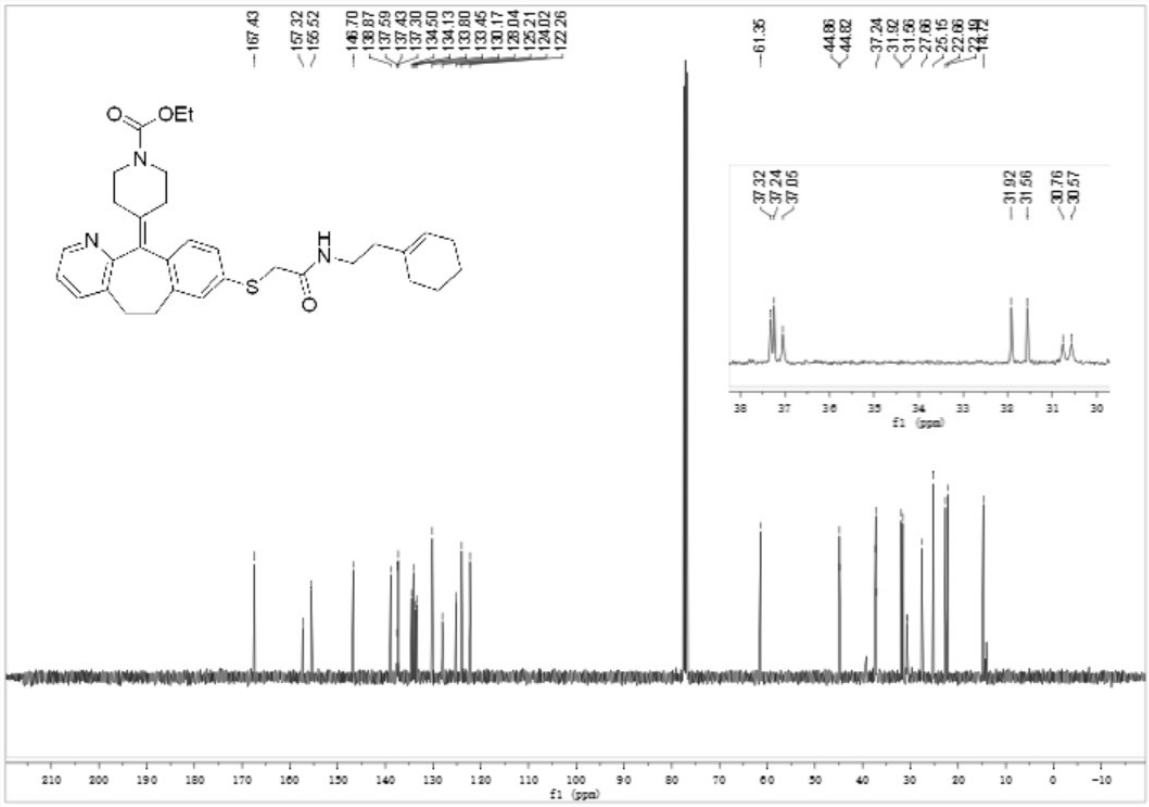
^{13}C NMR spectrum of **3p** ($CDCl_3$, 100 MHz)



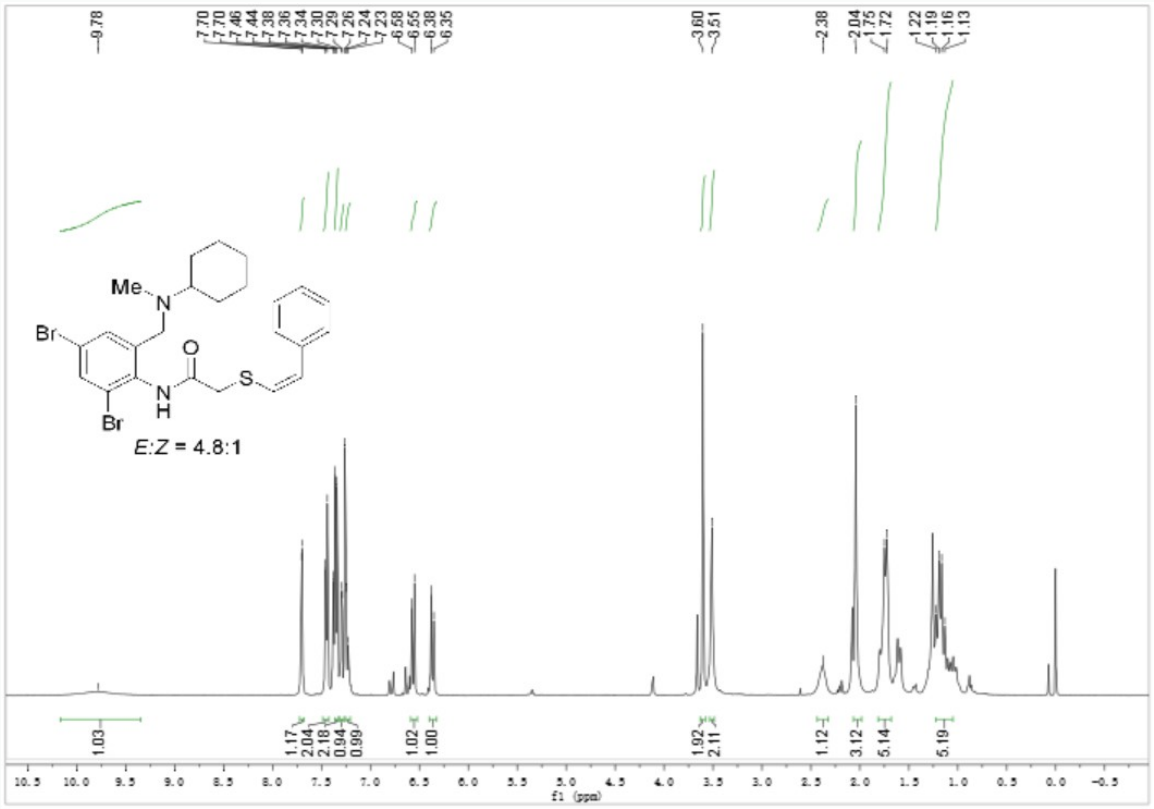
^{1}H NMR spectrum of **3q** ($CDCl_3$, 400 MHz)



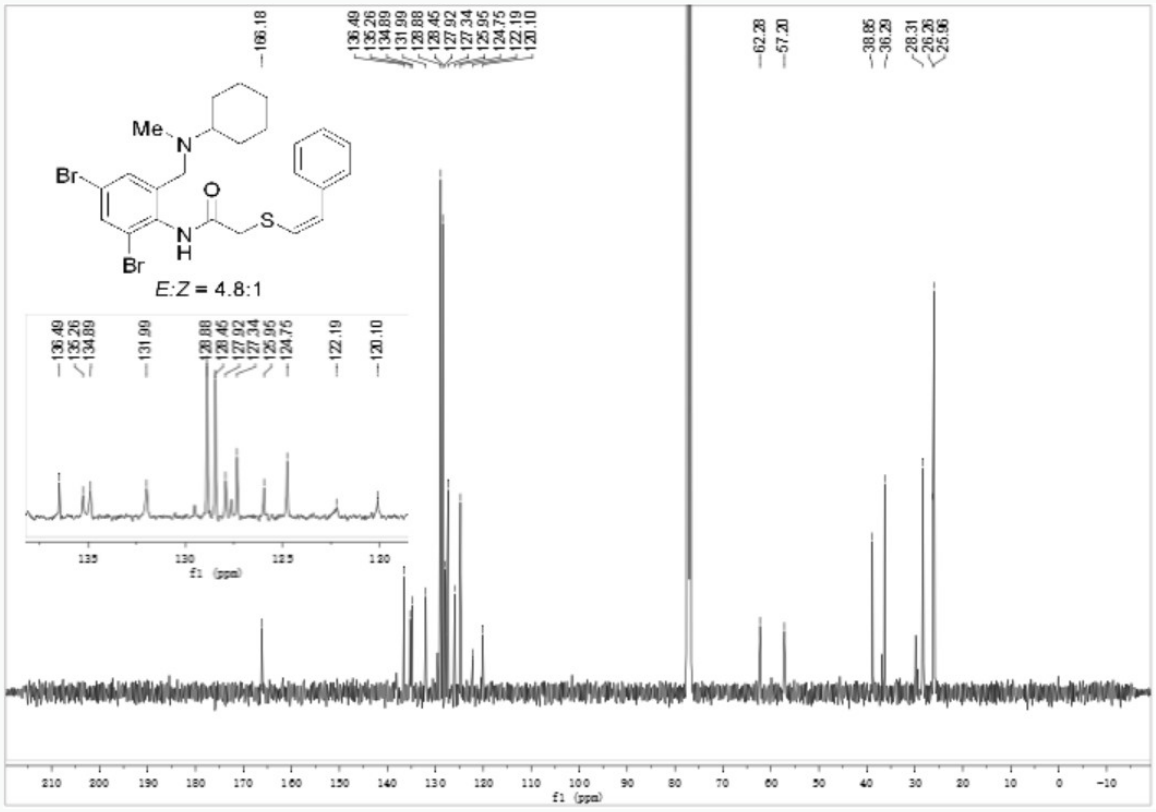
^{13}C NMR spectrum of **3q** ($CDCl_3$, 100 MHz)



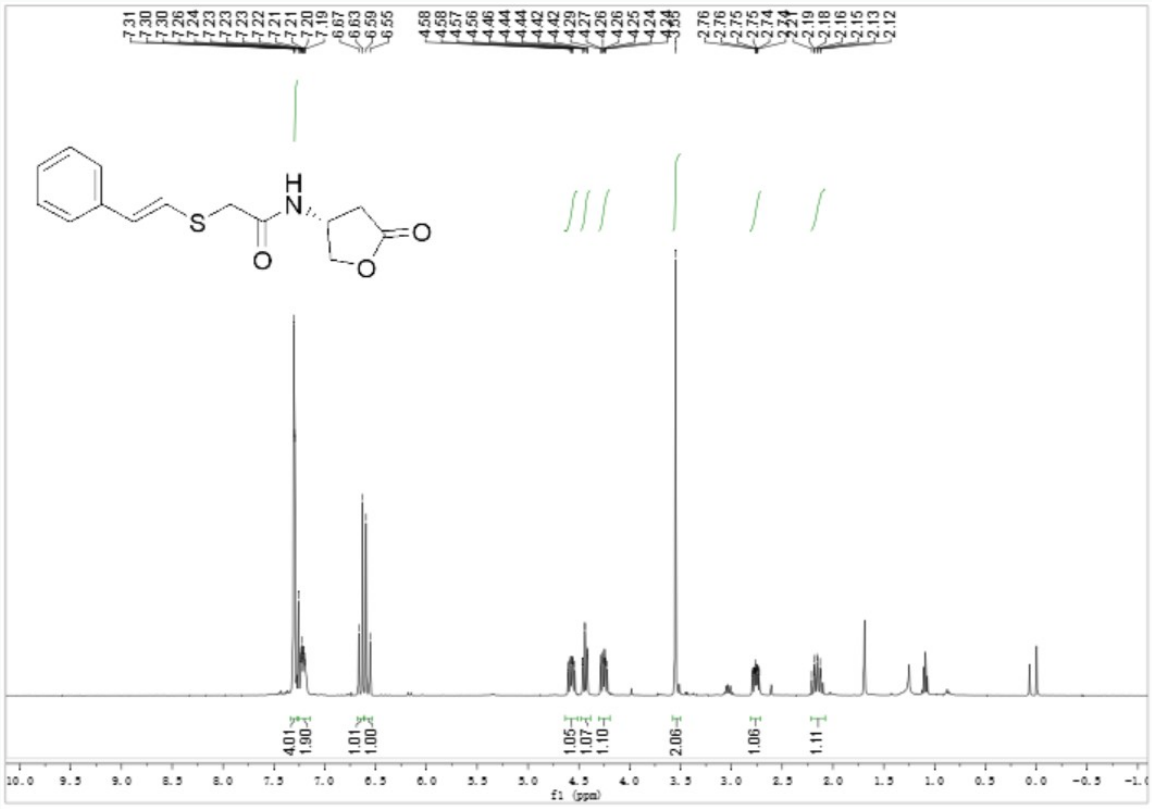
^{1}H NMR spectrum of **3r** ($CDCl_3$, 400 MHz)



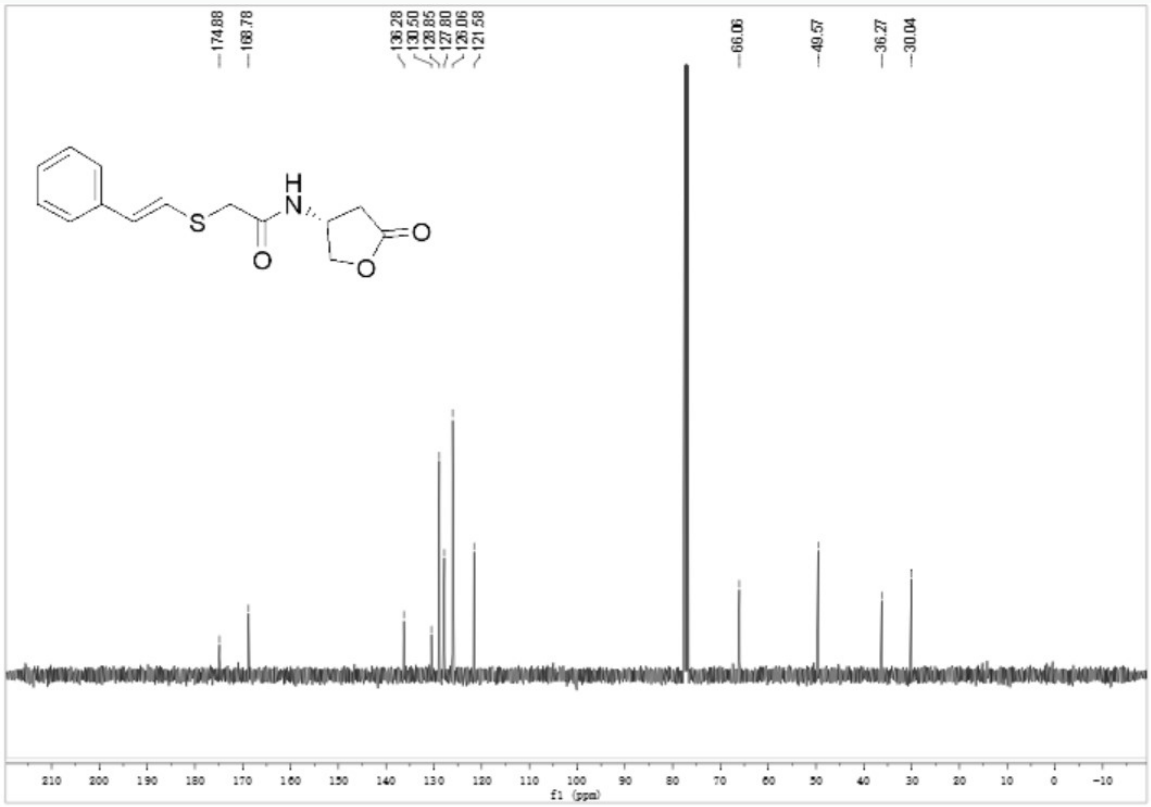
^{13}C NMR spectrum of **3r** ($CDCl_3$, 100 MHz)



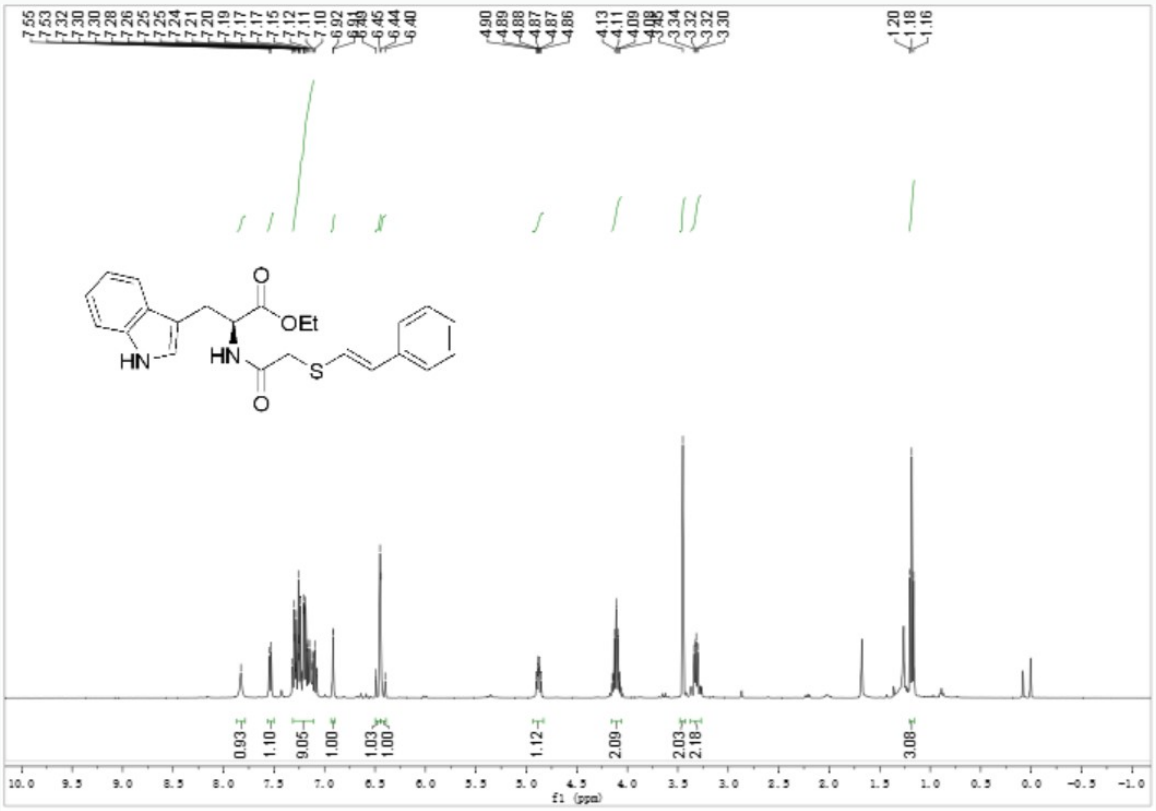
^{1}H NMR spectrum of **3s** ($CDCl_3$, 400 MHz)



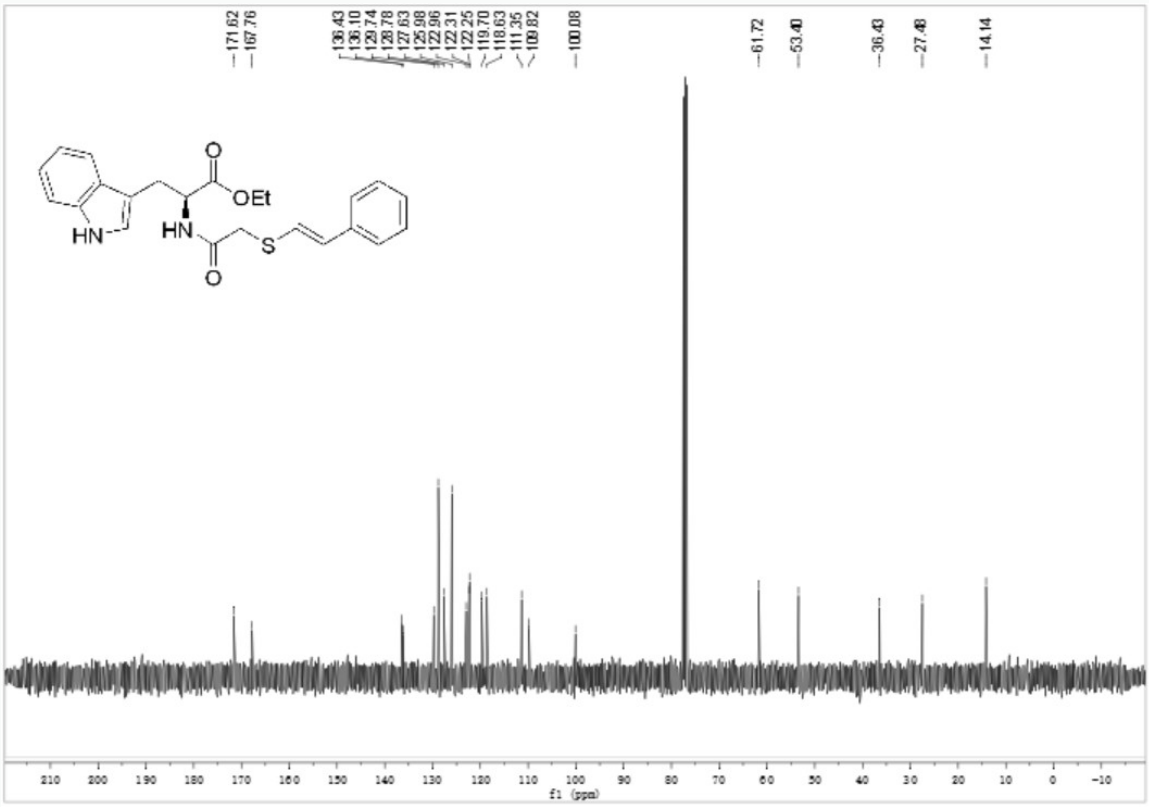
^{13}C NMR spectrum of **3s** ($CDCl_3$, 100 MHz)



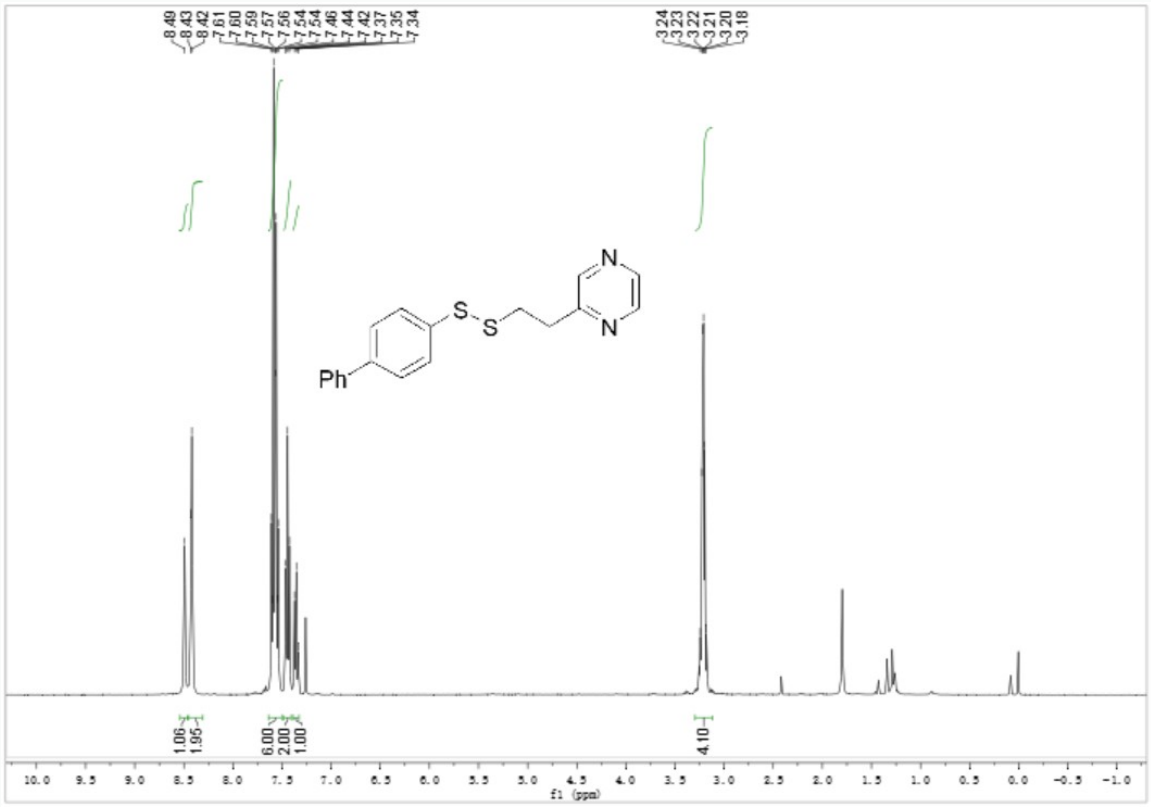
^{1}H NMR spectrum of **3t** ($CDCl_3$, 400 MHz)



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



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



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