Ruthenium-catalyzed aerobic oxidative cyclization of aromatic and heteroaromatic nitriles with alkynes: a new route to isoquinolones

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Electronic Supplementary Information (ESI)

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Experimental Section

General Procedure for the Cyclization of Aromatic Nitriles with Alkynes Catalyzed by Ruthenium Complex.

[{$RuCl_2$(*p*-cymene)}$_2$] (0.05 mmol, 5 mol %), KPF_6 (0.20 mmol, 20 mol %) and $Cu(OAc)_2.H_2O$ (0.30 mmol, 30 mol %) were taken in a 25-mL round bottom flask equipped with a magnetic stirrer. To the flask were then added substituted nitriles **1** (1.0 mmol), alkyne **2** (**2a-c** and **2g** 1.00 mmol and for alkynes **2d-f** and **2h** 1.50 mmol) and acetic acid solvent (3.0 mL) via syringes. Then, condenser was fitted with water circulation in the round bottom flask and the reaction mixture was allowed to stir at 120 °C for 10 h under an open atmosphere (Note: the top of the condenser was exposed to the air and has not been covered by anything. AcOH boiling point is 118 °C. Solvent evaporation was not observed during the reaction). After cooling to ambient temperature, the reaction mixture was diluted with CH_2Cl_2, filtered through Celite and silica gel, and the filtrate was concentrated. The crude residue was purified through a silica gel column using hexanes and ethyl acetate as eluent to give pure **3** and **4**.

General Procedure for the Chlorination or Bromination Reaction.[1]

In a 50 mL round-bottom flask fitted with a condenser, a suspension of isoquinolone (100 mg) in phosphorus oxychloride ($POCl_3$) or phosphorus tribromide (PBr_3) (2.0 mL) was heated at 100 ˚C for 2 h for chlorination (120 ˚C for 6 h for bromination). The reaction was monitored on TLC. After completion the reaction (approx. 2.0 h for chlorination and approx. 6.0 h for bromination), the reaction mixture was cooled to ambient temperature, and poured in ice and added saturated $NaHCO_3$, extracted with ethyl acetate. The organic layer was washed with water and brine, dried over Na_2SO_4. The solution was concentrated under reduced pressure to provide crude 1-halo isoquinolines **5a-d**. The crude residue was purified through a silica gel column using hexanes and ethyl acetate as eluent to give pure **5a-d**.

Ref. 1: M. Tobe, Y. Isobe, H. Tomizawa, T. Nagasaki, H. Takahashi, T. Fukazawa and H. Hayashi, *Bioorg. Med. Chem.* **2003**, *11*, 383.

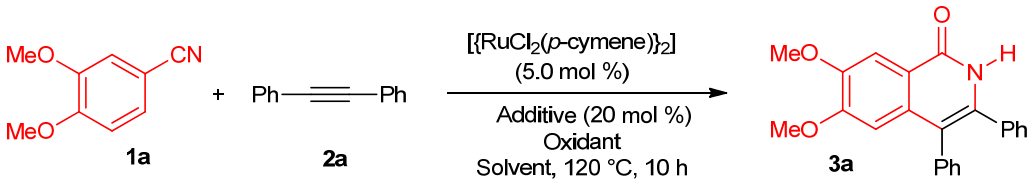
General Procedure for the Preparation of Compounds 5e and 5f.[2]

A mixture of isoquinolone (**3**) (1.0 equiv), diphenylacetylene (**2a**) (2.0 equiv), $[RuCl_2(p\text{-cymene})]_2$ (7.5 mol %), $Cu(OAc)_2{\cdot}H_2O$ (2.0 equiv) and Na_2CO_3 (2.0 equiv) were taken in a 15-mL pressure tube equipped with a magnetic stirrer and a septum. Dry PhCl (2.0 mL) was added to the reaction mixture and evacuated and purged with nitrogen gas three times. Then, the reaction mixture was stirred at 120 ˚C for 16 h under N_2 atmosphere (During this time, septum was removed under nitrogen atmosphere and a screw cap was used to cover the tube). After cooling to ambient temperature, the reaction mixture was diluted with CH_2Cl_2, filtered through Celite and silica gel, and the filtrate was concentrated. The crude residue was purified through a silica gel column using hexanes and ethyl acetate as eluent to give pure **5e** and **5f**.

Ref 2: B. Li, H. Feng, S. Xu and B. Wang, *Chem. Eur. J.* **2012**, *18*, 12873.

Spectral data and copies of ^1H and ^{13}C NMR spectra of all compounds **3a-t, 4a-h** and **5a-f** are listed below.

Table 1. Optimization Studies[a]



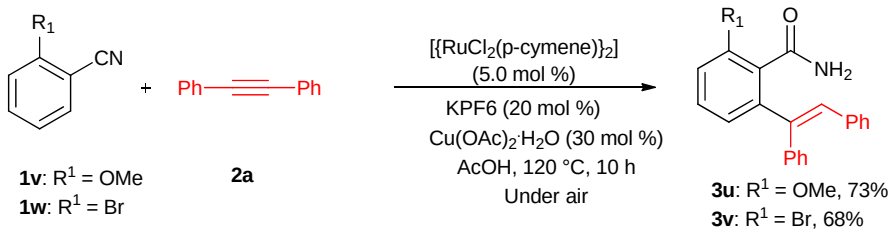
Entry	Solvent	Oxidant	Additive	Yield of **3a** (%)[b]
1	AcOH	No	No	NR
2	AcOH	$Cu(OAc)_2 \cdot H_2O$ (2.20 equiv)	No	65
3	AcOH	$Cu(OAc)_2 \cdot H_2O$ (2.20 equiv)	$AgSbF_6$	83
4	AcOH	$Cu(OAc)_2 \cdot H_2O$ (2.20 equiv)	KPF_6	89
5	AcOH	$Cu(OAc)_2 \cdot H_2O$ (2.20 equiv)	$AgBF_4$	72
6	AcOH	$Cu(OAc)_2 \cdot H_2O$ (2.20 equiv)	AgOTf	75
4	MeOH	$Cu(OAc)_2 \cdot H_2O$ (2.20 equiv)	KPF_6	10
8	*tert*-BuOH	$Cu(OAc)_2 \cdot H_2O$ (2.20 equiv)	KPF_6	trace
9	DCE	$Cu(OAc)_2 \cdot H_2O$ (2.20 equiv)	KPF_6	NR
10	DME	$Cu(OAc)_2 \cdot H_2O$ (2.20 equiv)	KPF_6	NR
11	DMSO	$Cu(OAc)_2 \cdot H_2O$ (2.20 equiv)	KPF_6	NR
12	DMF	$Cu(OAc)_2 \cdot H_2O$ (2.20 equiv)	KPF_6	NR
13	AcOH	KOAc	KPF_6	NR
14	AcOH	NaOAc	KPF_6	NR
15	**AcOH**	**$Cu(OAc)_2 \cdot H_2O$ (30 mol %, open air)**	**KPF_6**	**91**[c]
16	AcOH	No (open air)	KPF_6	NR[c]

[a] All reactions were carried out under the following conditions: **1a** (1.0 mmol), **2a** (1.0 mmol), [{$RuCl_2$(*p*-cymene)}$_2$] (5 mol %), additive (20 mol %) and oxidant in solvent (3.0 mL) at 120 °C for 10 h under N_2 atmosphere. [b] Yields were determined by the ^{1}H NMR integration method, using mesitylene as an internal standard. [c] Under an open atmosphere.

Note: The catalytic reaction was tried without ruthenium and copper and KPF_6. No product **3a** was observed in the reaction. The catalytic reaction was also tried without ruthenium and KPF_6 only in the presence of copper catalyst. In the reaction also, no product **3a** was observed. However, in the case, 3,4-dimethoxy benzamide was observed in 91% isolated yield.

The reaction of *ortho*-substituted aromatic nitriles with diphenylacetylene

The cyclization reaction of *ortho*-substituted aromatic nitriles with diphenylacetylene (**2a**) was also tested. The reaction of *ortho*-methoxy (**1v**) and bromo (**1w**) benzonitriles reacted with **2a** to provide hydroarylation products **3u** and **3v** in 73% and 68% yields, respectively, instead of the expected isoquinolone derivative. The exact reason for the observation of hydroarylation product is unclear to us. This is most probably due to the steric hindrance of ortho substituent in the substrates **1v** and **1w.**



1v: R^1 = OMe
1w: R^1 = Br

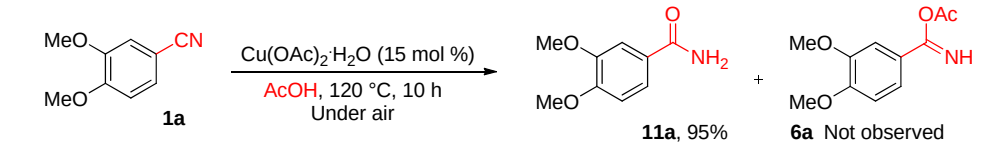
2a

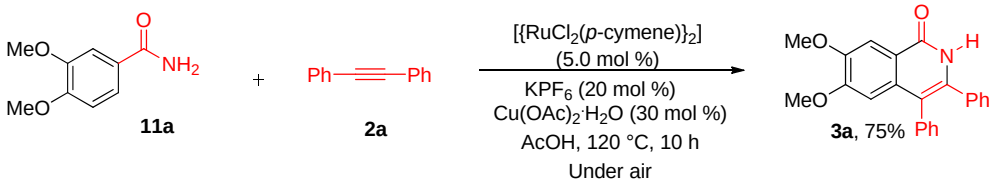
3u: R^1 = OMe, 73%
3v: R^1 = Br, 68%

Mechanistic Investigation

The cyclization reaction of **1a** and **2a** was also tested with commercial acetic acid. However, in the reaction, product **3a** was observed only in moderate 65% isolated yield. In the aqueous acetic acid solution (2.0 mL AcOH and 1.0 mL H_2O), product **3a** was observed only in less 40% isolated yield.

The reaction of **1a** was done without ruthenium catalyst and only in presence of copper(II) acetate. Treatment of 3,4-dimethoxy benzonitrile **1a** (1.0 mmol) with AcOH in the presence of $Cu(OAc)_2 \cdot H_2O$ (15 mol %) at 120 °C under air gave 3,4-dimethoxy benzamide **11a** in 95% yield. However, in the reaction, product **6a** was not observed. We strongly belive that initially product **6a** might formed in the reaction. Later, the acidic solvent, AcOH, might hydrolized the product **6a** to **11a**. In the meantime, the same reaction was tested without copper catalyst and only in the presence of ruthenium catalyst. In the reaction, no product **11a** or **6a** was observed and starting material **1a** was recovered. This result clearly revealed that copper catalyst plays an important role to convert aromatic nitrile to **6a** or **11a** as well give acetate source to ruthenium catalyst to do C-H bond activation.



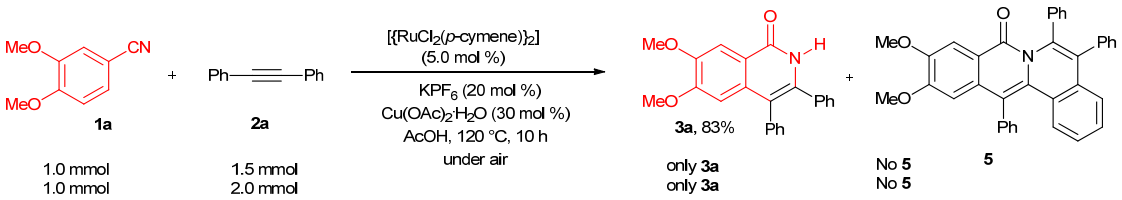


The treatment of 3,4-dimethoxy benzamide **11a** with diphenylacetylene (**2a**) (1.0 equiv) in the presence of [{$RuCl_2$(*p*-cymene)}$_2$] (5.0 mol %), KPF_6 (20 mol %) and $Cu(OAc)_2 \cdot H_2O$ (30 mol %) in acetic acid at 120 °C for 10 h under air provided isoquinolone derivative **3a** in 75% isolated yield.

At present the exact mechanism for the present recation is not very clear. Two different types of catalytic reactions are involved. The first reaction is $Cu(OAc)_2$-catalyzed nuleophilic addition of H_2O or AcOH to benzonitrile. The second reaction is *ortho* C-H bond activation of substituted aromatics followed by cyclization with alkyne in the presence of ruthenium and copper catalysts.

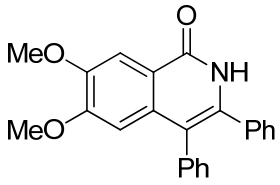
We have done the reaction of **1a** (1.0 mmol) with excess amount of **2a** (1.5 mmol or 2.0 mmol) under the optimized reaction conditions. In these reactions, only first insertion product

3 was observed and no two insertion product **5** was observed. This is most likly due to the first insertion takes place under acidic conditions and the second insertion does not take place under acidic conditions.



Spectral Data of Compounds 3a-v, 4a-h and 5a-f.

6,7-Dimethoxy-3,4-diphenylisoquinolin-1(2*H*)-one (3a).[3a]



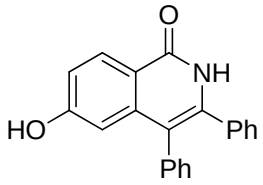
Dark brown solid; eluent (60% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.43 (bs, 1 H), 7.70 (s, 1 H), 7.31 - 7.25 (m, 3 H), 7.20 (bs, 5 H), 7.14 - 7.16 (m, 2 H), 6.56 (s, 1 H), 3.90 (s, 3 H), 3.57 (s, 3 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 161.0, 152.8, 148.5, 137.0, 136.1, 134.7, 133.2, 131.6, 129.8, 128.2, 127.9, 127.6, 127.0, 118.8, 115.1, 106.9, 105.5, 55.6, 55.1.

HRMS (ESI): calc. for [($C_{23}H_{19}NO_3$)H] (M+H) 358.1443, measured 358.1434.

6-Hydroxy-3,4-diphenylisoquinolin-1(2*H*)-one (3b).



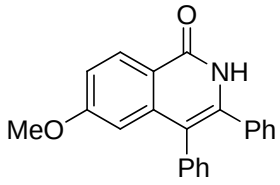
White solid; eluent (50% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.23 (bs, 1 H), 10.15 (s, 1 H), 8.15 (d, *J* = 8.7, 1 H), 7.31 – 7.22 (m, 3 H) 7.20 (bs, 5 H), 7.14 – 7.12 (m, 2 H), 6.94 (dd, *J* = 8.0, 4.0 Hz, 1 H), 6.48 (s, 1 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 161.4, 161.0, 140.3, 138.7, 136.2, 134.7, 131.7, 129.7, 129.1, 128.2, 128.0, 127.6, 126.9, 117.7, 116.0, 115.0, 108.8

HRMS (ESI): calc. for [($C_{21}H_{15}NO_2$)H] (M+H) 314.1181, measured 314.1180.

6-Methoxy-3,4-diphenylisoquinolin-1(2*H*)-one (3c).[3b]



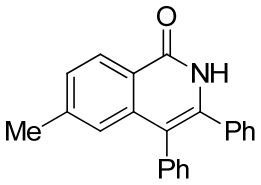
White solid; eluent (40% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.38 (bs, 1 H), 8.25 (d, *J* = 8.0 Hz, 1 H), 7.32 – 7.26 (m, 3 H), 7.22 (bs, 5 H), 7.16 – 7.13 (m, 3 H), 6.51 (s, 1 H), 3.67 (s, 3 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 162.3, 161.3, 140.1, 139.2, 135.9, 134.6, 131.6, 129.7, 129.1, 128.2, 128.1, 127.6, 127.0, 118.8, 115.1, 114.5, 107.13., 55.17.

HRMS (ESI): calc. for [($C_{22}H_{17}NO_2$)H] (M+H) 328.1338, measured 328.1333.

6-Methyl-3,4-diphenylisoquinolin-1(2*H*)-one (3d).[3b]



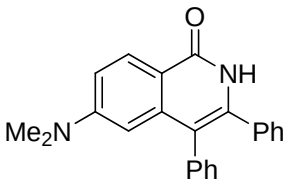
Colorless solid; eluent (30% ethyl acetate in hexanes).

^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.55 (bs, 1 H), 8.36 (d, *J* =8.0, 1 H), 7.33 – 7.30 (m, 4 H), 7.27 – 7.22 (m, 5 H), 7.19 – 7.16 (m, 2 H), 7.12 (s, 1 H), 2.37 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.8, 143.3, 138.7, 137.1, 135.8, 135.0, 131.8, 129.2, 128.5, 128.3, 128.2, 127.8, 127.4, 127.2, 125.3, 122.7, 117.1, 22.0.

HRMS (ESI): calc. for [($C_{22}H_{17}NO$)H] (M+H) 312.1388, measured 312.1382.

6-(Dimethylamino)-3,4-diphenylisoquinolin-1(2*H*)-one (3e).



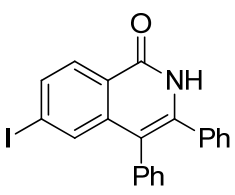
Yellow solid; eluent (40% ethyl acetate in hexanes).

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.89 (bs, 1 H), 8.31 (d, *J* = 8.0 Hz, 1 H), 7.28 – 7.26 (m, 4 H), 7.21 – 7.18 (m, 6 H), 6.91 (dd, *J* = 8.0, 4.0 Hz, 1 H), 6.37 (s, 1 H), 2.92 (s, 6 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.6, 153.1, 140.4, 137.1, 136.3, 135.5, 131.7, 129.1, 128.9, 128.3, 128.2, 127.0, 116.9, 114.5, 112.4, 105.2, 39.9.

HRMS (ESI): calc. for [($C_{23}H_{20}N_2O$)H] (M+H) 341.1654, measured 341.1661.

6-Iodo-3,4-diphenylisoquinolin-1(2*H*)-one (3f).[3b]



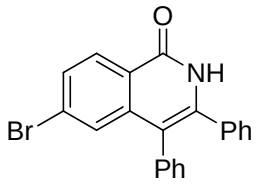
White solid; eluent (25% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.64 (bs, 1 H), 8.00 (d, *J* = 8.0 Hz, 1 H), 7.79 (d, *J* = 8.0 Hz, 1 H), 7.40 (s, 1 H), 7.29 – 7.22 (m, 3 H), 7.17 (bs, 5 H), 7.10 (d, *J* = 8.0, 2 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 161.4, 139.9, 139.7, 135.2, 134.8, 134.2, 133.2, 131.6, 129.7, 128.7, 128.4, 127.7, 127.3, 124.1, 114.2, 101.3.

HRMS (ESI): calc. for [($C_{21}H_{14}$INO)H] (M+H) 424.0198, measured 424.0192.

6-Bromo-3,4-diphenylisoquinolin-1(2*H*)-one (3g).[3b]



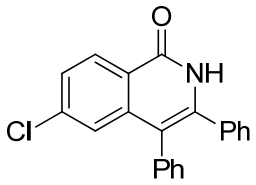
White solid; eluent (30% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.73 (s, 1 H), 8.23 (d, *J* = 8.0 Hz, 1 H), 7.67 (dd, *J* = 8.0, 4 Hz, 1 H), 7.34 - 7.28 (m, 3 H), 7.25-7.21 (m, 6 H), 7.17-7.14 (m, 2 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 161.2, 140.2, 139.8, 135.1, 134.1, 131.6, 129.7, 129.3, 129.1, 128.4, 127.7, 127.4, 126.9, 126.8, 123.8, 114.4.

HRMS (ESI): calc. for [($C_{21}H_{14}$BrNO)H] (M+H) 376.0337, measured 376.0343.

6-Chloro-3,4-diphenylisoquinolin-1(2*H*)-one (3h).[3b]



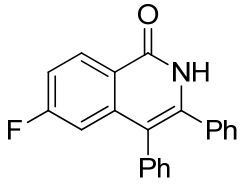
Colorless solid; eluent (30% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.73 (bs, 1 H), 8.31 (d, *J* = 8.0, 1 H), 7.55 (dd, *J* = 8.0, 4.0 Hz, 1 H), 7.34-7.28 (m, 3 H), 7.23 (bs, 5 H), 7.17-7.15 (m, 2 H), 7.05 (s, 1 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 161.1, 140.3, 139.7, 137.6, 135.1, 134.1, 131.6, 129.7, 129.3, 128.4, 127.7, 127.4, 126.4, 123.8, 123.6, 114.5.

HRMS (ESI): calc. for [($C_{21}H_{14}$ClNO)H] (M+H) 332.0842, measured 332.0844.

6-Fluoro-3,4-diphenylisoquinolin-1(2*H*)-one (3i).[3b]



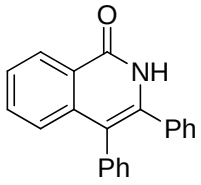
White solid; eluent (30% ethyl acetate in hexanes).

^{1}H NMR ($CDCl_3$, 400 MHz): δ 10.41 (bs, 1 H), 8.42 (dd, *J* = 8.0, 4.0 Hz, 1 H), 7.34-7.29 (m, 3 H), 7.27 - 7.22 (m, 5 H), 7.17 – 7.14 (m, 3 H), 6.98 (dd, *J* = 8.0, 4.0 Hz, 1 H)

^{13}C NMR ($CDCl_3$, 100 MHz): δ 166.7 and 164.2 (F coupling), 162.4, 141.2 and 141.1 (F coupling), 138.7, 135.2, 134.5, 131.6, 130.6 and 130.5 (F coupling), 129.3, 128.7, 128.5, 128.1, 127.4, 121.5, 116.74 and 116.70 (F coupling), 115.2 and 114.9 (F coupling), 110.8 and 110.6 (F coupling).

HRMS (ESI): calc. for [($C_{21}H_{14}FNO$)H] (M+H) 316.1138 , measured 316.1139.

3,4-Diphenylisoquinolin-1(2*H*)-one (3j).[3b]



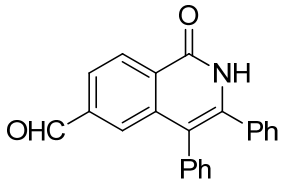
Colorless solid; eluent (30% ethyl acetate in hexanes).

^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.42 (bs, 1 H), 8.46 (dd, *J* = 8.0, 4.0 Hz, 1 H), 7.59 (t, *J* = 8.0 Hz, 1 H), 7.50 (t, *J* = 8.0 Hz, 1 H), 7.36 (d, *J* = 8.0 Hz, 1 H), 7.33 – 7.29 (m, 3 H), 7.27 – 7.23 (m, 5 H), 7.20 – 7.17 (m, 2 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 162.7, 138.6, 137.0, 135.6, 135.0, 132.6, 131.8, 129.2, 128.6, 128.37, 128.33, 127.4, 127.3, 126.6, 125.6, 125.0, 117.2.

HRMS (ESI): calc. for [($C_{21}H_{15}NO$)H] (M+H) 298.1232, measured 298.1228.

1-Oxo-3,4-diphenyl-1,2-dihydroisoquinoline-6-carbaldehyde (3k).[3b]



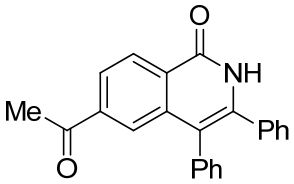
Pale yellow solid; eluent (45% ethyl acetate in hexanes).

^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.96 (s, 1 H), 9.40 (bs, 1 H), 8.55 (d, *J* = 8.0 Hz, 1 H), 7.91 (d, *J* = 8.0 Hz, 1 H) 7.79 (s, 1 H), 7.32 – 7.29 (m, 3 H), 7.25 – 7.19 (m, 7 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 192.1, 162.3, 139.2, 139.1, 138.4, 134.8, 134.5, 131.7, 129.5, 129.3, 129.1, 128.8, 128.7, 128.6, 127.9, 124.9, 117.5.

HRMS (ESI): calc. for [($C_{22}H_{15}NO_2$)H] (M+H) 326.1182, measured 326.1176.

6-Acetyl-3,4-diphenylisoquinolin-1(2*H*)-one (3l).



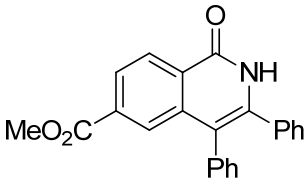
Yellow solid; eluent (40% ethyl acetate in hexanes).

^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.82 (bs, 1 H), 8.53 (d, *J* = 8.0 Hz, 1 H), 8.01 (dd, *J* = 8.0, 4.0 Hz, 1 H), 7.94 (s, 1 H), 7.36 – 7.32 (m, 3 H), 7.30 – 7.24 (m, 5 H), 7.20 – 7.18 (m, 2 H), 2.53 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 197.9, 162.3, 140.0, 138.7, 138.1, 134.9, 134.5, 131.6, 129.2, 128.8, 128.6, 128.3, 128.1, 127.7, 126.2, 125.1, 117.4, 26.8.

HRMS (ESI): calc. for [($C_{23}H_{17}NO_2$)H] (M+H) 340.1338, measured 340.1335.

Methyl 1-oxo-3,4-diphenyl-1,2-dihydroisoquinoline-6-carboxylate (3m).[3b]



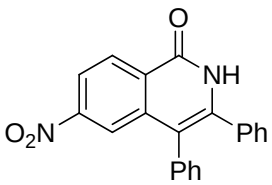
Colorless solid; eluent (40% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.81 (s, 1 H), 8.43 (d, *J* = 8.0 Hz, 1 H), 8.01 (dd, *J* = 8.0, 4.0 Hz, 1 H), 7.80 (s, 1 H) 7.33 – 7.29 (m, 3 H), 7.23 (bs, 5 H), 7.19 -7.16 (m, 2 H), 3.80 (s, 3 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 165.7, 161.1, 139.7, 138.0, 135.2, 134.2, 132.8, 131.7, 129.8, 128.3, 127.7, 127.6, 127.3, 126.3, 125.7, 115.4, 54.9, 52.5.

HRMS (ESI): calc. for [($C_{23}H_{17}NO_3$)H] (M+H) 356.1287, measured 356.1292.

6-Nitro-3,4-diphenylisoquinolin-1(2*H*)-one (3n).[3b]



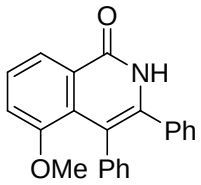
Yellowsolid; eluent (35% ethyl acetate in hexanes).

^{1}H NMR ($CDCl_3$, 400 MHz): δ 10.21 (s, 1 H), 8.57 (d, 1 H), 8.23 - 8.20 (m, 2 H), 7.38 – 7.35(m, 3 H), 7.33 – 7.31 (m, 1 H), 7.29 - 7.25 (m, 4 H), 7.19 – 7.17 (m, 2 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 161.7, 150.6, 139.7, 139.5, 134.2, 131.5, 129.5, 129.25, 129.22, 128.9, 128.6, 128.5, 128.4, 128.0, 121.1, 120.1, 117.1.

HRMS (ESI): calc. for [($C_{21}H_{14}N_2O_3$)H] (M+H) 343.1083, measured 343.1083.

5-Methoxy-3,4-diphenylisoquinolin-1(2*H*)-one (3o').[3b]



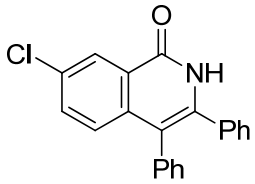
Colorless solid; eluent (40% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.50 (bs, 1 H), 7.95 (d, *J* = 8.0 Hz, 1 H), 7.46 (t, *J* = 8.0 Hz, 1 H), 7.15 (bs, 6 H), 7.06 -7.03 (m, 5 H), 3.25 (s, 3 H),

^{13}C NMR (DMSO-d_6, 100 MHz): δ 161.2, 156.0, 139.7, 138.7, 135.0, 130.9, 129.9, 127.9, 127.7, 127.3, 127.1, 126.9, 126.3, 125.4, 119.0, 114.9, 113.6, 55.7.

HRMS (ESI): calc. for [($C_{22}H_{17}NO_2$)H] (M+H) 328.1338, measured 328.1332.

7-Chloro-3,4-diphenylisoquinolin-1(2*H*)-one (3p).[3b]



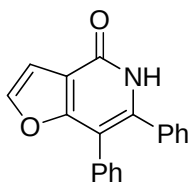
Colorless solid; eluent (30% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.77 (bs, 1 H), 8.24 (s, 1 H), 7.69 (dd, *J* = 8.0, 4.0, Hz, 1 H), 7.32 – 7.26 (m, 3 H), 7.23 (bs, 6 H), 7.17 - 7.14 (m, 2 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 160.6, 139.1, 136.8, 135.3, 134.2, 132.6, 131.6, 130.9, 129.8, 128.3, 127.7, 127.3, 127.2, 126.2, 125.7, 115.0.

HRMS (ESI): calc. for [($C_{21}H_{14}ClNO$)H] (M+H) 332.0842, measured 332.0844.

6,7-Diphenylfuro[3,2-c]pyridin-4(5*H*)-one (3q).



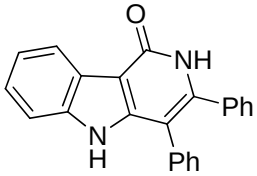
Pale yellow solid; eluent (40% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.70 (s, 1 H), 7.88 (d, *J* = 4.0 Hz, 1 H), 7.32-7.21 (m, 8 H), 7.14-7.17 (m, 2 H), 7.04 (d, *J* = 3.2 Hz, 1 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 159.1, 158.8, 144.6, 140.8, 133.3, 132.4, 130.7, 130.0, 128.7, 128.1, 127.9, 127.1, 114.4, 108.0, 107.0.

HRMS (ESI): calc. for [($C_{19}H_{13}NO_2$)H] (M+H) 288.1025, measured 288.1029.

3,4-Diphenyl-2,5-dihydro-1*H*-pyrido[4,3-*b*]indol-1-one (3r).



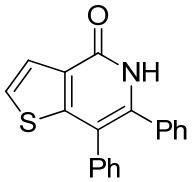
Grey solid; eluent (60% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.38 (br s, 1 H), 11.16 (s, 1 H), 8.17 (d, *J* = 8.0 Hz, 1 H), 7.50 (d, *J* = 8.0 Hz, 1 H), 7.37 - 7.30 (m, 3 H), 7.28 – 7.20 (m, 9 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 159.5, 144.6, 141.2, 138.1, 134.2, 134.1, 130.9, 130.0, 128.6, 128.3, 127.8, 127.2, 124.1, 123.6, 120.6, 120.4, 111.8, 107.7, 106.1.

HRMS (ESI): calc. for [($C_{23}H_{16}N_2O$)H] (M+H) 337.1341, measured 337.1347.

6,7-Diphenylthieno[3,2-*c*]pyridin-4(5*H*)-one (3s).



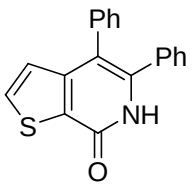
Pale yellow solid; eluent (35% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.71 (s, 1 H), 7.60 - 7.58 (d, *J* = 4.0 Hz, 1 H), 7.58 - 7.56 (d, *J* = 8.0 Hz, 1 H), 7.32-7.20 (m, 10 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 158.5, 151.2, 138.6, 136.5, 133.5, 130.1, 129.9, 129.2, 128.5, 127.8, 127.6, 125.8, 124.5, 113.6.

HRMS (ESI): calc. for [($C_{19}H_{13}NOS$)H] (M+H) 304.0796, measured 304.0802.

4,5-Diphenylthieno[2,3-*c*]pyridin-7(6*H*)-one (3t).[3b]



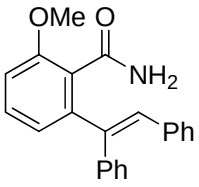
Light-yellow solid; eluent (35% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.78 (s, 1 H), 8.02 (d, *J* = 8.0 Hz, 1 H), 7.30 - 7.21 (m, 8 H), 7.13 - 7.15 (m, 2 H), 6.92 (d, *J* = 8.0 Hz, 1 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 158.0, 146.7, 139.8, 136.3, 134.1, 133.9, 130.7, 130.0, 128.3, 128.2, 128.0, 127.8, 127.0, 124.5, 114.7.

HRMS (ESI): calc. for [($C_{19}H_{13}NOS$)H] (M+H) 304.0796, measured 304.0803.

(*E*)-2-(1,2-Diphenylvinyl)-6-methoxybenzamide (3u).



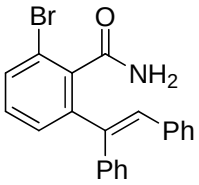
Colorless sold; eluent (50% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 7.72 (bs, 1 H), 7.36 (bs, 1 H), 7.28 -7.19 (m, 6 H), 7.14 – 7.11 (m, 3 H), 6.97 -6.95 (m, 3 H), 6.80 (s, 1 H), 6.56 (d, *J* = 8.0 Hz, 1 H), 3.80 (s, 3 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 168.5, 155.7, 142.0, 140.6, 140.3, 136.8, 129.83, 129.80, 129.0, 128.5, 128.3, 127.97, 127.93, 127.2, 126.8, 121.3, 109.8, 55.6.

HRMS (ESI): calc. for [($C_{22}H_{19}NO_2$)H] (M+H) 330.1494, measured 330.1498.

(*E*)-2-Bromo-6-(1,2-diphenylvinyl)benzamide (3v).



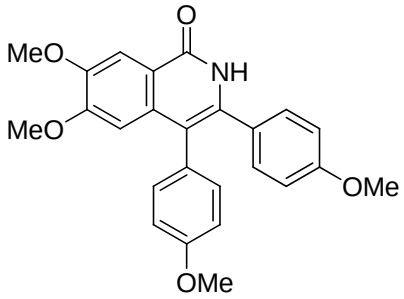
Colorless solid; eluent (40% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 8.01 (bs, 1 H), 7.64 (bs, 1 H), 7.56 (d, *J* = 8.0 Hz, 1 H), 7.31 – 7.28 (m, 5 H), 7.14 (t, *J* = 8.0 Hz, 1 H), 7.12 – 7.09 (m, 3 H), 6.96 – 6.90 (m, 3 H), 6.86 (s, 1 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 168.8, 142.9, 140.2, 139.6, 139.4, 136.5, 130.7, 130.9, 129.8, 129.4, 129.1, 128.6, 128.5, 128.1, 127.5, 127.1, 119.3.

HRMS (ESI): calc. for [($C_{21}H_{16}BrNO$)H] (M+H) 378.0494, measured 378.0497.

6,7-Dimethoxy-3,4-bis(4-methoxyphenyl)isoquinolin-1(2H)-one (4a).



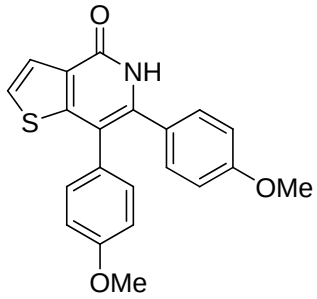
Brick-red solid; eluent (65% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.28 (bs, 1 H), 7.68 (s, 1 H), 7.10 (d, *J* = 8.0 Hz, 2 H), 7.05 (d, *J* = 8.0 Hz, 2 H), 6.86 (d, *J* = 8.0 Hz, 2 H), 6.76 (d, *J* = 8.0 Hz, 2 H), 6.58 (s, 1 H), 3.88 (s, 3 H), 3.73 (s, 3 H), 3.70 (s, 3 H), 3.58 (s, 3 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 161.1, 158.7, 157.9, 152.9, 148.4, 136.9, 134.1, 132.7, 131.1, 128.3, 127.2, 118.7, 114.5, 113.8, 113.1, 106.9, 105.6, 55.6, 55.2, 55.1, 54.9.

HRMS (ESI): calc. for [($C_{25}H_{23}NO_5$)H] (M+H) 418.1654, measured 418.1650.

6,7-Bis(4-methoxyphenyl)thieno[3,2-*c*]pyridin-4(5*H*)-one (4b).



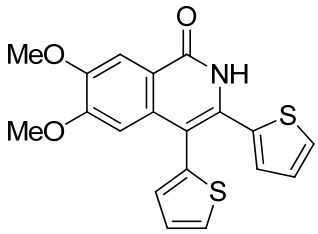
Pale yellow color semisolid; eluent (50% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.55 (s, 1 H), 7.54 (s, 2 H), 7.16 (d, *J* = 8.0 Hz, 2 H), 7.12 (d, *J* = 8.0 Hz, 2 H), 6.87 (d, *J* = 8.0 Hz, 2 H), 6.81 (d, *J* = 8.0 Hz, 2 H), 3.73 (s, 3 H), 3.72 (s, 3 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 159.1, 158.6, 158.3, 151.9, 138.3, 131.3, 128.8, 128.7, 125.8, 125.4, 124.5, 114.0, 113.3, 112.9, 55.1, 54.9.

HRMS (ESI): calc. for [($C_{21}H_{17}NO_3S$)H] (M+H) 364.1007, measured 364.1009.

6,7-Dimethoxy-3,4-di(thiophen-2-yl)isoquinolin-1(2*H*)-one (4c).



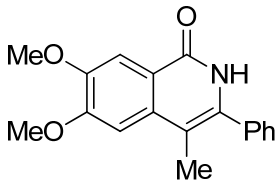
Black semisolid; eluent (55% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.46 (bs, 1 H), 7.76 (d, *J* = 8.0 Hz, 1 H), 7.56 (s, 1 H), 7.51 (t, *J* = 4.0 Hz, 2 H), 7.15 (d, *J* = 4.0 Hz, 1 H), 7.12 (d, *J* = 4.0 Hz, 1 H), 6.97 (d, *J* = 4.0 Hz, 1 H), 6.61 (s, 1 H), 3.90 (s, 3 H), 3.63 (s, 3 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 161.1, 153.2, 148.9, 136.1, 135.5, 133.9, 132.9, 131.2, 129.6, 128.9, 128.8, 127.9, 126.5, 119.0, 107.0, 106.9, 105.7, 55.7, 55.3.

HRMS (ESI): calc. for [($C_{19}H_{15}NO_3S_2$)H] (M+H) 370.0572, measured 370.0566.

6,7-Dimethoxy-4-methyl-3-phenylisoquinolin-1(2*H*)-one (4d).



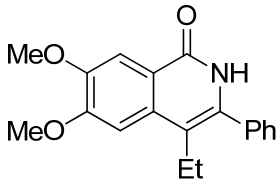
Off-white solid; eluent (60% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.11 (bs, 1 H), 7.65 (s, 1 H), 7.51 – 7.42 (m, 5 H), 7.11 (s, 1 H), 3.94 (s, 3 H), 3.88 (s, 3 H), 2.12 (s, 3 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 160.8, 153.0, 148.3, 136.2, 134.9, 133.5, 129.7, 128.4, 128.1, 107.0, 106.9, 104.6, 55.6, 55.4, 13.8.

HRMS (ESI): calc. for [($C_{18}H_{17}NO_3$)H] (M+H) 296.1287, measured 296.1283.

4-Ethyl-6,7-dimethoxy-3-phenylisoquinolin-1(2*H*)-one (4e).



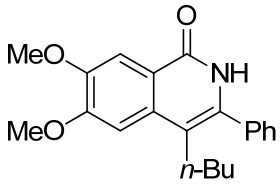
Grey solid; eluent (60% ethyl acetate in hexanes).

^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.71 (bs, 1 H), 7.80 (s, 1 H), 7.47 – 7.44 (m, 5 H), 7.10 (s, 1 H), 4.03 (s, 3 H), 4.02 (s, 3 H), 2.66 (q, *J* = 8.0 Hz, 2 H), 1.22 (t, *J* = 8.0 Hz, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 161.8, 153.6, 148.8, 135.8, 135.6, 133.3, 129.1, 128.9, 128.7, 115.2, 107.8, 104.2, 56.2, 56.1, 20.8, 15.3.

HRMS (ESI): calc. for [($C_{19}H_{19}NO_3$)H] (M+H) 310.1443, measured 310.1439.

4-Butyl-6,7-dimethoxy-3-phenylisoquinolin-1(2*H*)-one (4f).



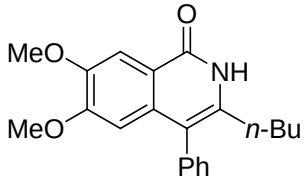
Pale yellow solid; eluent (60% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.12 (s, 1 H),7.68 (s, 1 H), 7 53 – 7.48 (m, 3 H), 7.44 – 7.41 (m, 2 H), 7.12 (s, 1 H), 3.94 (s, 3 H), 3.91 (s, 3 H), 2.54 – 2.52 (m, 2 H), 1.53 – 1.46 (m, 2 H), 1.27 - 1. 18 (m, 2 H), 0.79 (t, *J* = 8.0 Hz, 3 H).

^{13}C NMR (DMSO-d_6, 100 MHz): δ 160.6, 153.0, 148.2, 136.7, 135.1, 132.6, 129.3, 128.5, 128.2, 119.5, 111.9, 107.2, 104.4, 55.57, 55.51, 31.9, 26.2, 22.0, 13.5.

HRMS (ESI): calc. for [($C_{21}H_{23}NO_3$)H] (M+H) 338.1756, measured 338.1755.

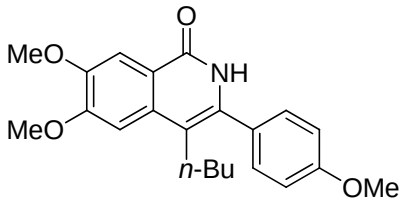
3-Butyl-6,7-dimethoxy-4-phenylisoquinolin-1(2*H*)-one (4f').



Brown solid; eluent (58% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.25 (s, 1 H), 7.61 (s, 1 H), 7.52 – 7.41 (m, 3 H), 7.27 (d, *J* = 8.0 Hz, 2 H), 6.33 (s, 1 H), 3.85 (s, 3 H), 3.53 (s, 3 H), 2.25 (t, *J* = 8.0 Hz, 2 H), 1.49 - 1.41 (m, 2 H), 1.16 -1.07 (m, 2 H), 0.69 (t, *J* = 8.0 Hz, 3 H).

4-Butyl-6,7-dimethoxy-3-(4-methoxyphenyl)isoquinolin-1(2*H*)-one (4g).



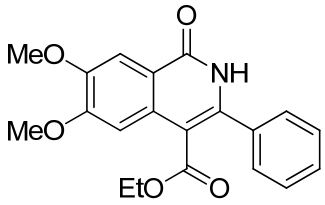
Pale yellow solid; eluent (65% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d6, 400 MHz): δ 11.01 (s, 1 H), 7.64 (s, 1 H), 7.32 (d, *J* = 8.0, 2 H), 7.08 (s, 1 H), 7.02 (d, *J* = 8.0 Hz, 2 H), 3.91 (s, 3 H), 3.87 (s, 3 H), 3.81 (s, 3 H), 2.53 – 2.50 (m, 2 H), 1.47 -1.46 (m, 2 H), 1.25 – 1.23 (m, 2 H), 0.79 (t, *J* = 7.3 Hz, 3 H).

^{13}C NMR (DMSO-d6, 100 MHz): δ 160.6, 159.2, 152.9, 148.1, 136.5, 132.7, 130.6, 127.4, 119.3, 113.5, 111.9, 107.1, 104.4, 55.57, 55.51, 55.1, 32.0, 26.3, 22.0, 13.6.

HRMS (ESI): calc. for [($C_{22}H_{25}NO_4$)H] (M+H) 368.1862, measured 368.1860.

Ethyl 6,7-dimethoxy-1-oxo-3-phenyl-1,2-dihydroisoquinoline-4-carboxylate (4h).



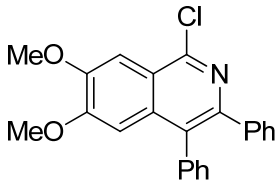
Pale yellow semisolid; eluent (65% ethyl acetate in hexanes).

^{1}H NMR (DMSO-d_6, 400 MHz): δ 11.65 (s, 1 H), 7.60 (s, 1 H), 7.44- 7.41 (m, 3 H), 7.37 (d, *J* = 8.0, 2 H), 7.21 (s, 1 H), 3.90 (q, *J* = 8.0 Hz, 2 H), 3.85 (s, 3 H), 3.81 (s, 3 H), 0.75 (t, *J* = 7.3 Hz, 3 H).

^{13}C NMR (DMSO-d6, 100 MHz): δ 167.3, 161.4, 153.9, 149.3, 142.3, 135.0, 130.3, 129.8, 128.9, 128.7, 118.9, 108.4, 107.4, 105.2, 61.1, 56.1 (2 OMe merged together), 13.8.

HRMS (ESI): calc. for [($C_{20}H_{19}NO_5$)H] (M+H) 354.1341, measured 354.1349.

1-Chloro-6,7-dimethoxy-3,4-diphenylisoquinoline (5a).



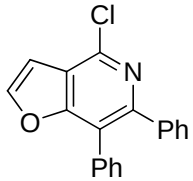
Colorless solid; eluent (18% ethyl acetate in hexanes).

^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.61 (s, 1 H), 7.37 -7.31 (m, 5 H), 7.24 - 7.22 (m, 2 H), 7.18 - 7.16 (m, 3 H), 6.90 (s, 1 H), 4.09 (s, 3 H), 3.77 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 153.2, 150.6, 148.6, 148.0, 139.5, 136.9, 134.6, 130.9, 130.1, 129.7, 128.4, 127.5, 127.1, 121.4, 104.6, 104.3, 56.2, 55.8.

HRMS (ESI): calc. for [($C_{23}H_{18}ClNO_2$)H] (M+H) 376.1104, measured 376.1112.

4-Chloro-6,7-diphenylfuro[3,2-*c*]pyridine (5b).



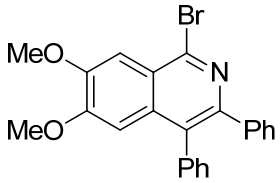
Colorless solid; eluent (5% ethyl acetate in hexanes).

^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.66 (d, *J* = 4.0 Hz, 1 H), 7.40 – 7.37 (m, 2 H), 7.35 – 7.29 (m, 5 H), 7.23 – 7.20 (m, 3 H), 6.93 (d, *J* = 4.0 Hz, 1 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 159.3, 152.1, 146.6, 141.9, 138.5, 132.8, 130.5, 130.3, 128.4, 128.0, 127.9, 122.7, 119.9, 105.2.

HRMS (ESI): calc. for [($C_{19}H_{12}ClNO$)H] (M+H) 306.0686, measured 306.0695.

1-Bromo-6,7-dimethoxy-3,4-diphenylisoquinoline (5c).



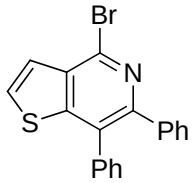
Colorless solid; eluent (18% ethyl acetate in hexanes).

^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.59 (s, 1 H), 7.37 – 7.31 (m, 5 H), 7.24 – 7.22 (m, 2 H), 7.18 – 7.16 (m, 3 H), 6.89 (s, 1 H), 4.10 (s, 3 H), 3.77 (s, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 153.2, 150.7, 149.1, 141.7, 139.4, 136.8, 134.2, 130.8, 130.1, 128.4, 127.5, 127.1, 123.5, 106.7, 104.5, 56.2, 55.8.

HRMS (ESI): calc. for [($C_{23}H_{18}BrNO_2$)H] (M+H) 420.0599, measured 420.0605.

4-Bromo-6,7-diphenylthieno[3,2-*c*]pyridine (5d).



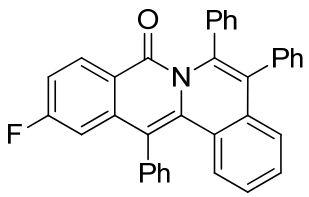
Colorless solid; eluent (5% ethyl acetate in hexanes).

^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.53 (bs, 2 H), 7.39 – 7.35 (m, 5 H), 7.32 – 7.30 (m, 2 H), 7.21 - 7.18 (m, 3 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 150.8, 150.1, 138.4, 137.2, 135.5, 135.2, 130.3, 129.5, 129.3, 129.0, 128.8, 128.2, 127.8, 124.4.

HRMS (ESI): calc. for [($C_{19}H_{12}BrNS$)H] (M+H) 365.9952, measured 365.9962.

11-Fluoro-5,6,13-triphenyl-8*H*-isoquinolino[3,2-*a*]isoquinolin-8-one (5e).[3a]

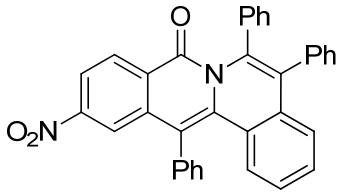


Yellow solid; eluent (13% ethyl acetate in hexanes).

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.27 – 8.23 (m, 1 H), 7.58 – 7.52 (m, 3 H), 7.51 – 7.49 (m, 2 H), 7.28 – 7.22 (m, 3 H), 7.18 – 7.10 (m, 6 H), 7.08 (bs, 5 H), 6.99 – 6.95 (m, 1 H), 6.91 – 6.87 (m, 1 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 166.6 and 164.1 (F coupling), 161.4, 139.6 and 139.5, 138.1, 137.0, 136.1, 135.9, 135.1, 133.1, 131.9, 131.3, 130.7 and 130.6 (F coupling), 129.8, 128.7, 128.3, 127.9, 127.1, 127.0, 128.3 , 127.9 , 127.1 , 127.0 , 126.87 , 126.80 ,126.3, 125.7, 122.3, 116.14 and 116.1 (F coupling), 115.1 and 114.8 (F coupling), 110.7 and 110.5 (F coupling). HRMS (ESI): calc. for [($C_{35}H_{22}FNO$)H] (M+H) 492.1764, measured 492.1754.

11-Nitro-5,6,13-triphenyl-8*H*-isoquinolino[3,2-*a*]isoquinolin-8-one (5f).[3a]

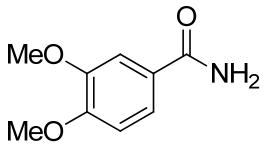


Pale yellow solid; eluent (15% ethyl acetate in hexanes).

^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.37 (d, *J* = 8.0 Hz, 1 H), 8.22 (d, *J* = 2.0 Hz, 1 H), 8.15 (dd, *J* = 8.0, 2.0 Hz, 1 H), 7.61 – 7.58 (m, 3 H), 7.52 – 7.50 (m , 2 H), 7.28 – 7.22 (m, 4 H), 7.17 – 7.15 (m, 4 H), 7.11 – 7.06 (m, 5 H), 6.95 – 6.91 (m, 1 H).

^{13}C NMR ($CDCl_3$, 100 MHz): δ 160.8, 150.3, 137.7, 137.2, 136.4, 136.0, 135.8, 135.6, 133.1, 131.8, 131.2, 130.2, 129.4, 129.3, 129.2, 128.9, 128.8, 128.4, 128.0, 127.8, 127.3, 127.2, 127.1, 126.7, 126.6, 125.9, 121.2, 119.7, 116.3.

3,4-Dimethoxybenzamide (11a).[3c]



Pale yellow solid; eluent (70% ethyl acetate in hexanes).

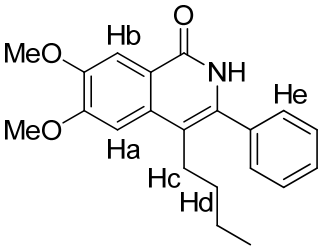
^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.46 (s, 1 H), 7.34 (d, *J* = 8.0 Hz, 1 H), 6.87 (d, *J* = 8.0 Hz, 1 H), 6.84 (bs, 2 H), 3.93 (s, 6 H).

Refs:

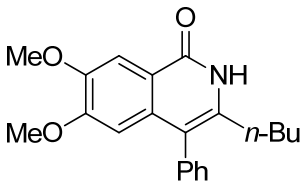
3. (*a*) B. Li, H. Feng, S. Xu and B. Wang, *Chem. Eur. J.* 2012, **18**, 12873. (*b*). B. Li, H. Feng, S. Xu and B. Wang, *Chem. Eur. J.* 2011, **17**, 12573. (*c*) M. D. Ganton and M. A. Kerr, *Org. Lett*. 2005, **7**, 4777.

NOESY Studies

Copy of NOESY Experiment of Compound **4f**.

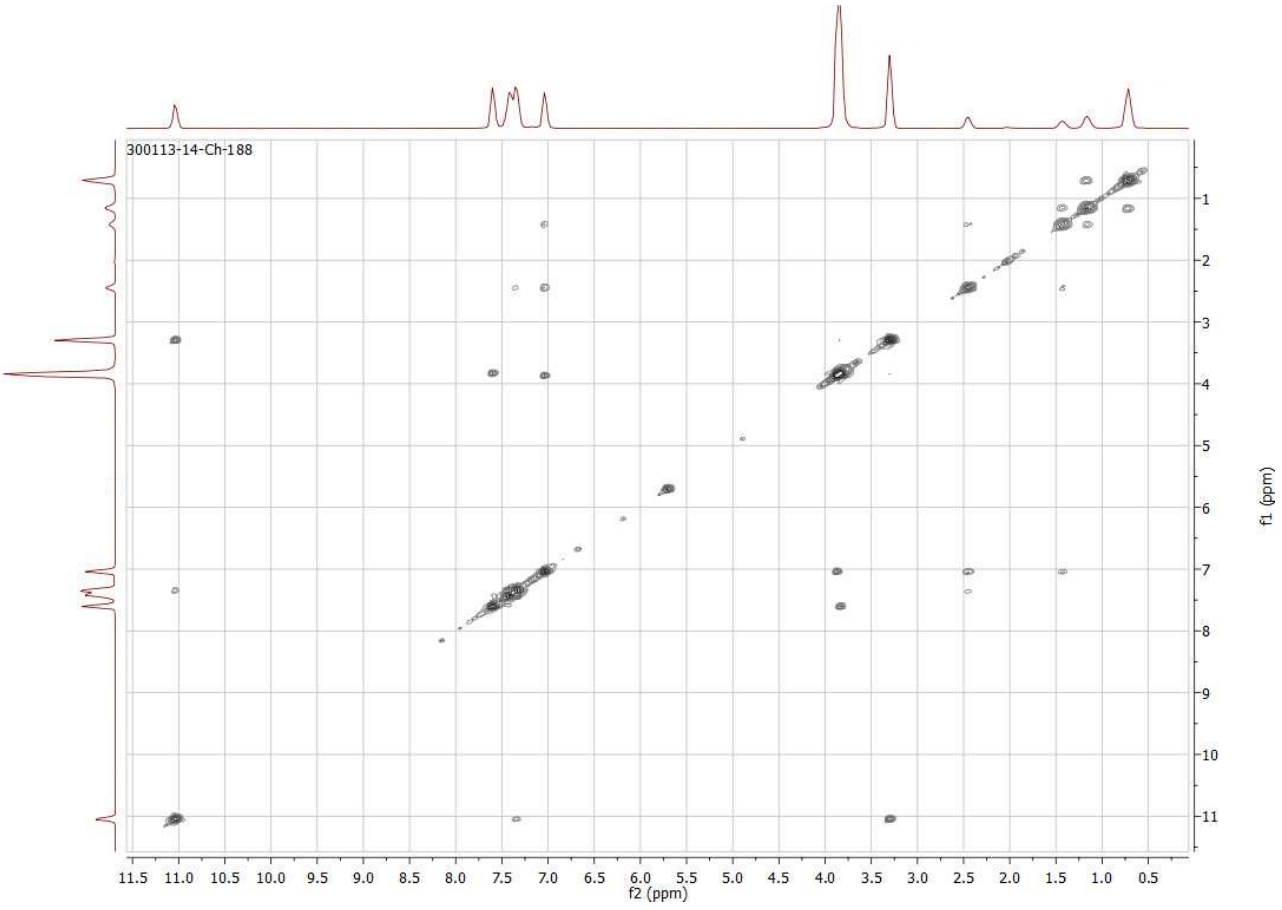


Ha δ = 7.12; Hb = 7.68; Hc = 2.54
Hd δ = 1.53, He = 7.53
Observed

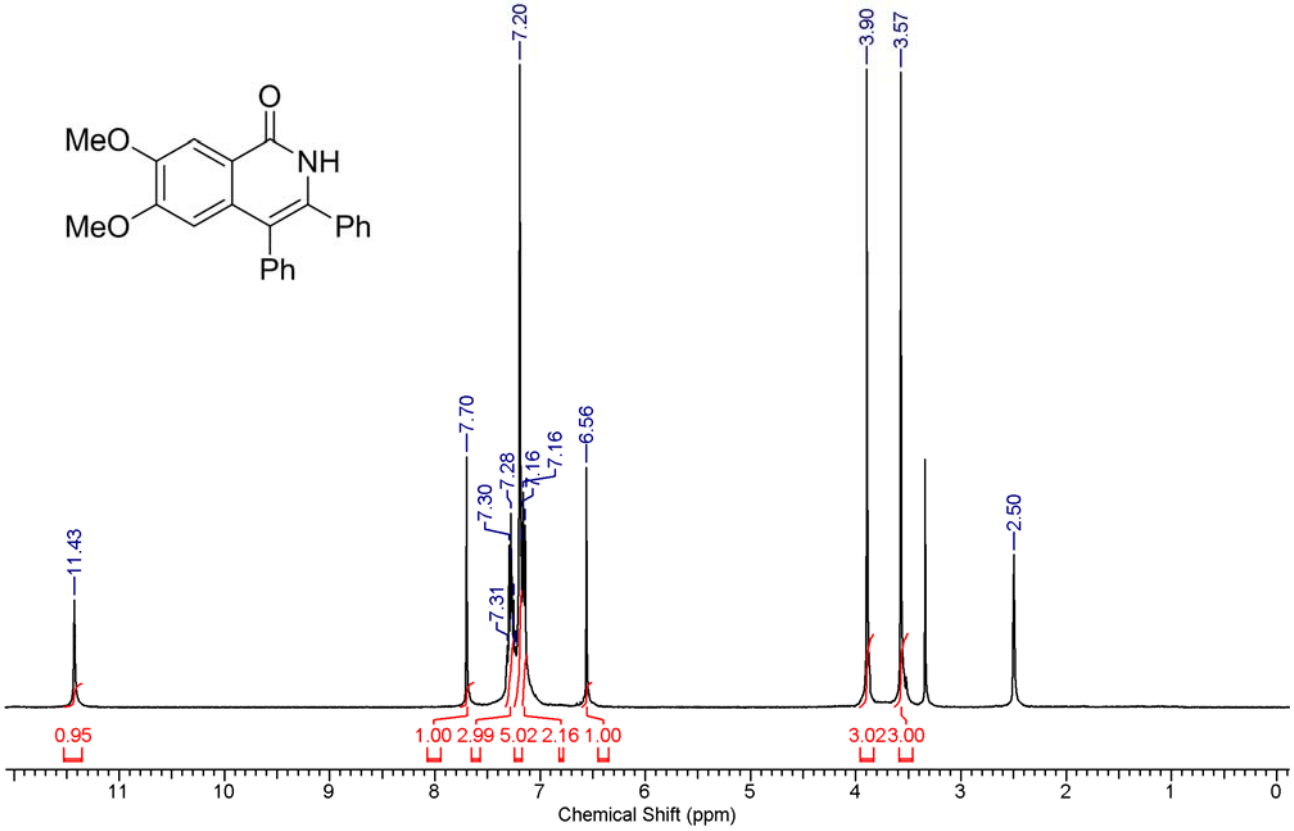


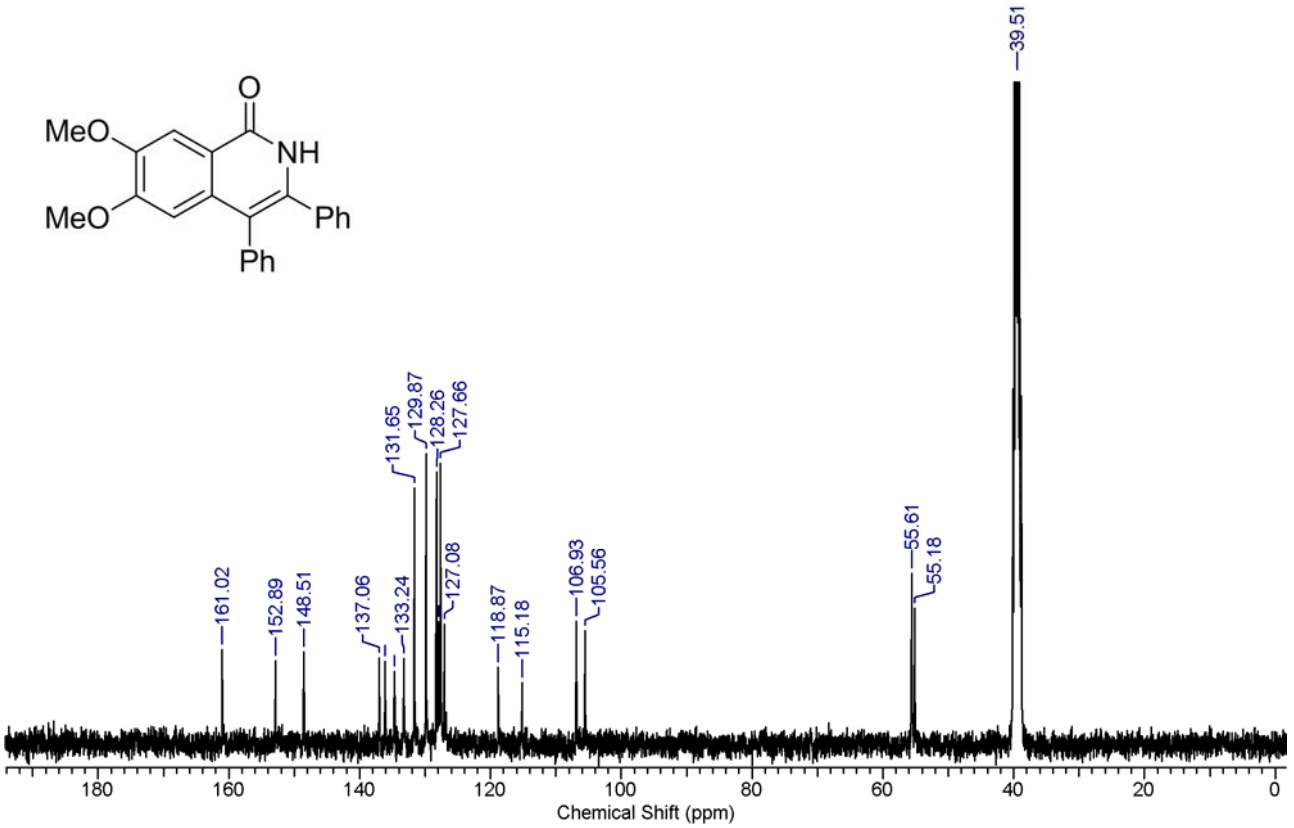
Not observed

There is a NOE correlation between Ha (δ 7.12, s) and Hc (δ 2.54, m). In meantime, there is also a correlation between Hc (δ 2.54, m) and He (δ 7.53, m). These results clearly revealed that the regiochemistry of compound **4f** is correct.

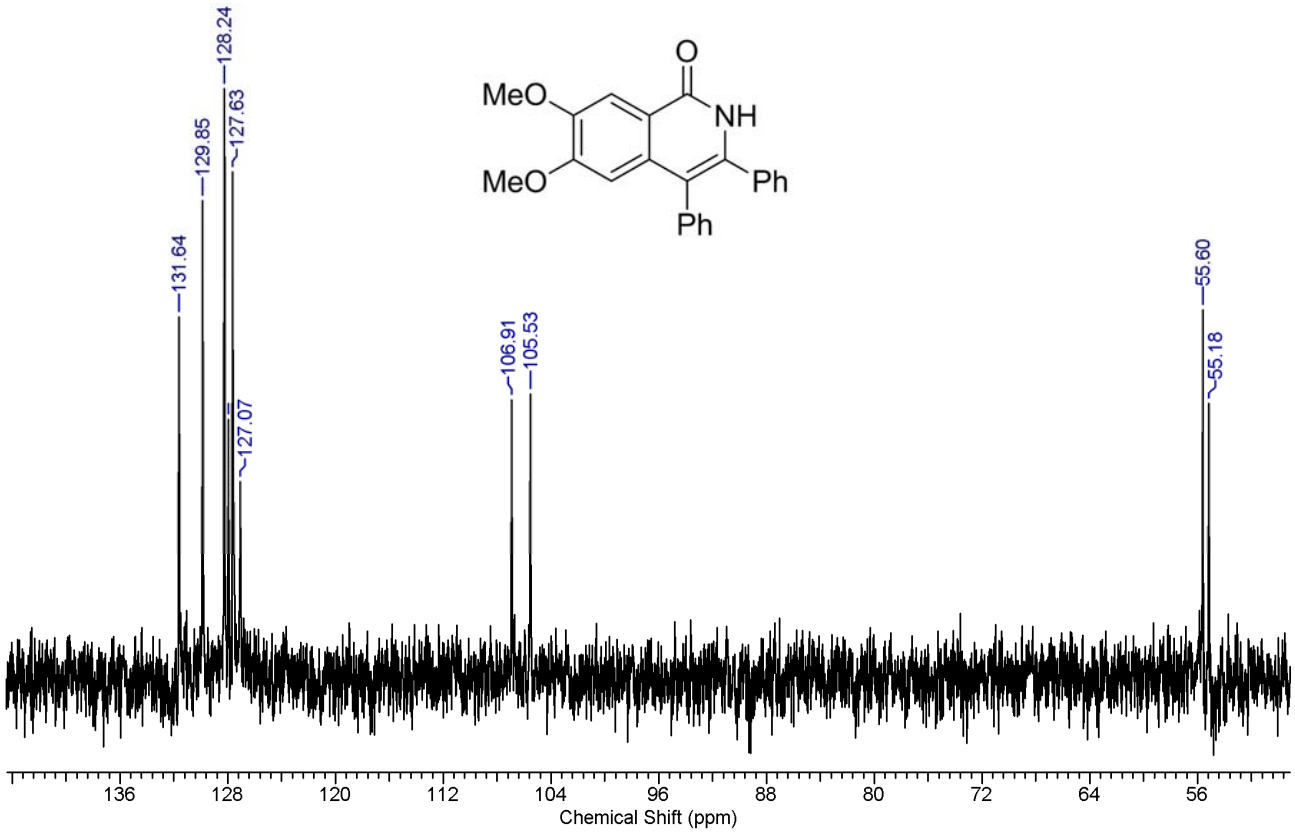


^{1}H and ^{13}C NMR Spectra of Compound **3a.**

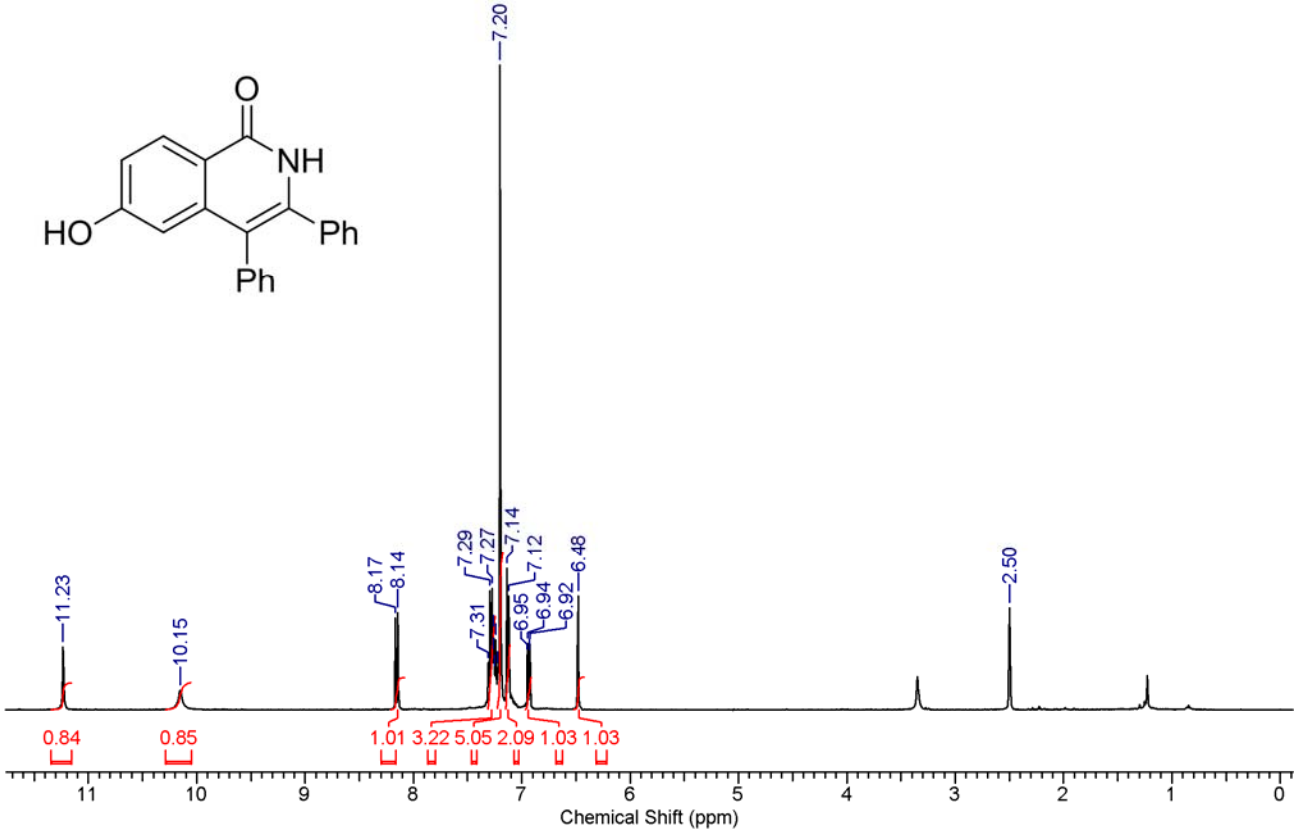


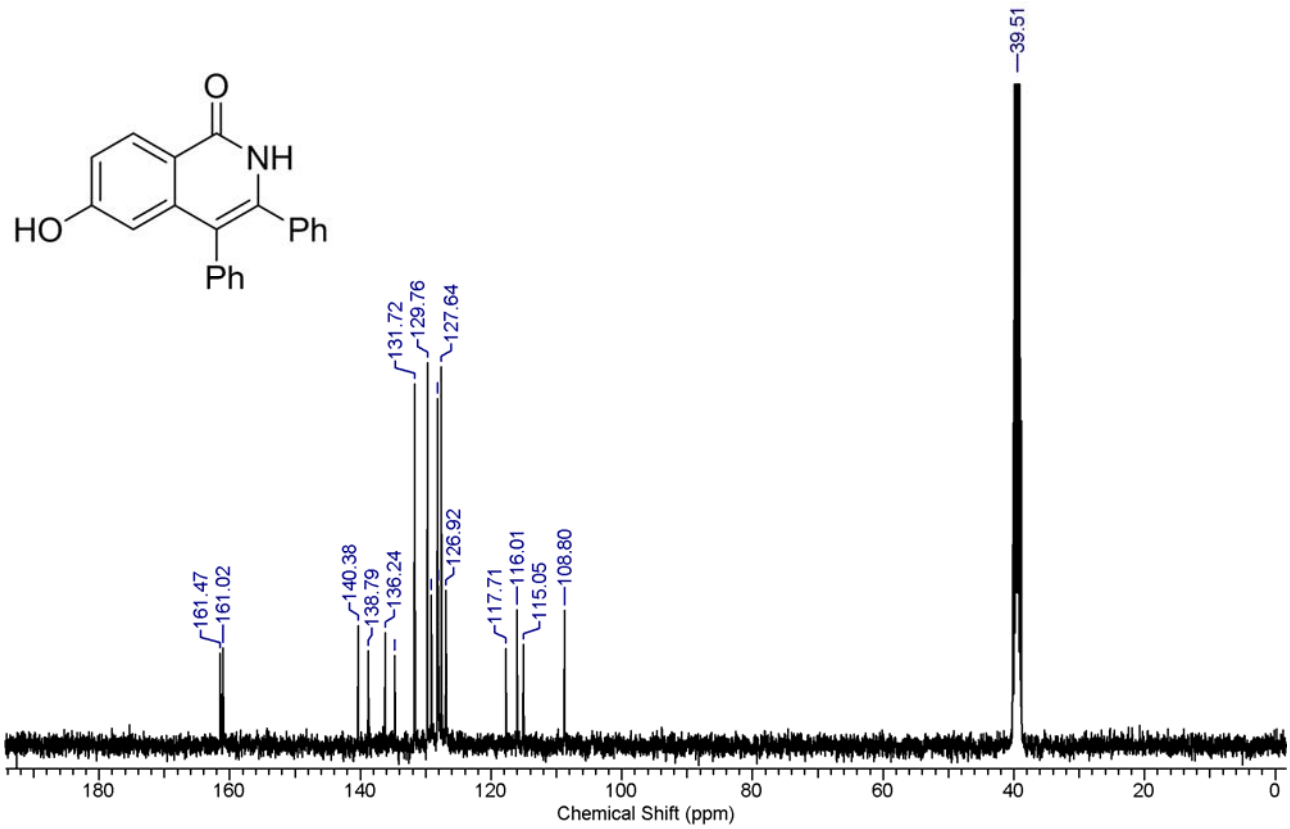


DEPT (135) NMR Spectrum of Compound **3a.**

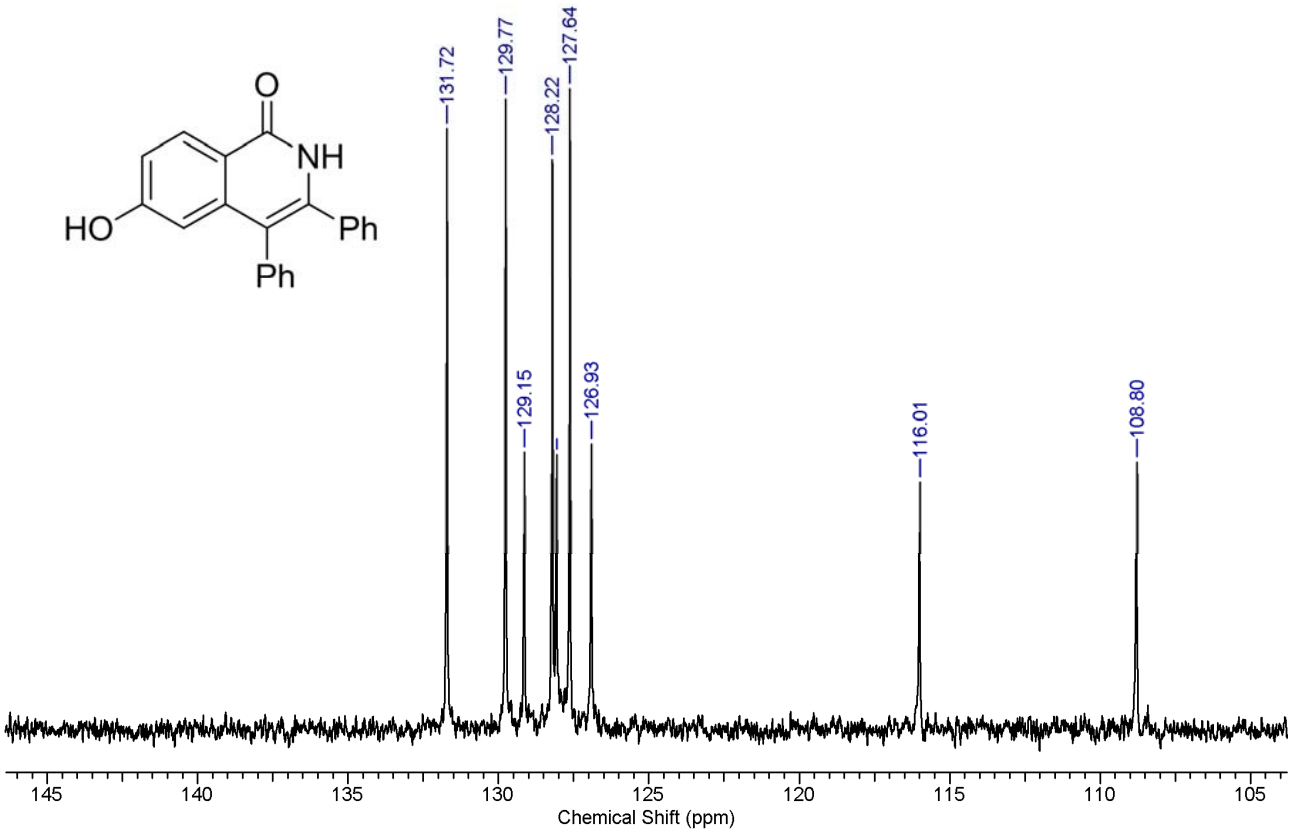


^{1}H and ^{13}C NMR Spectra of Compound **3b.**

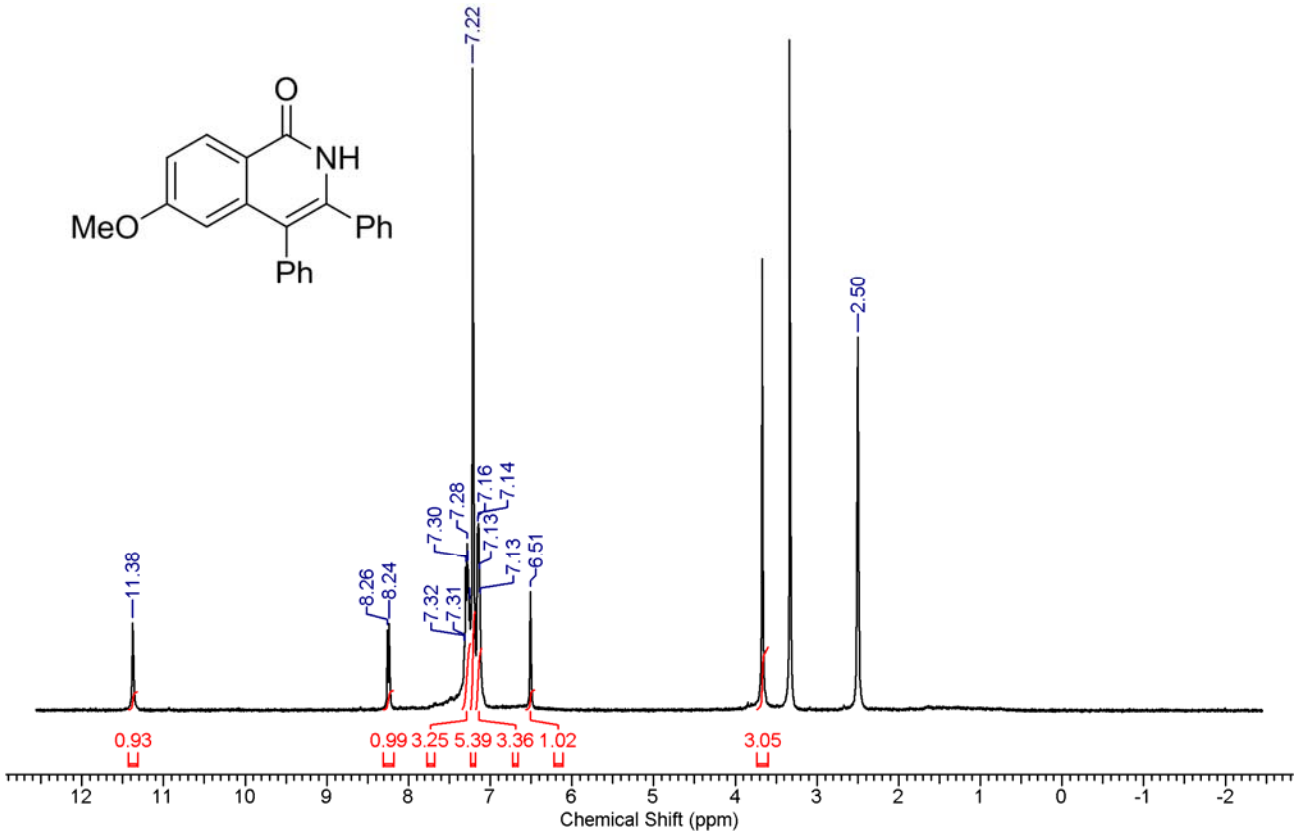


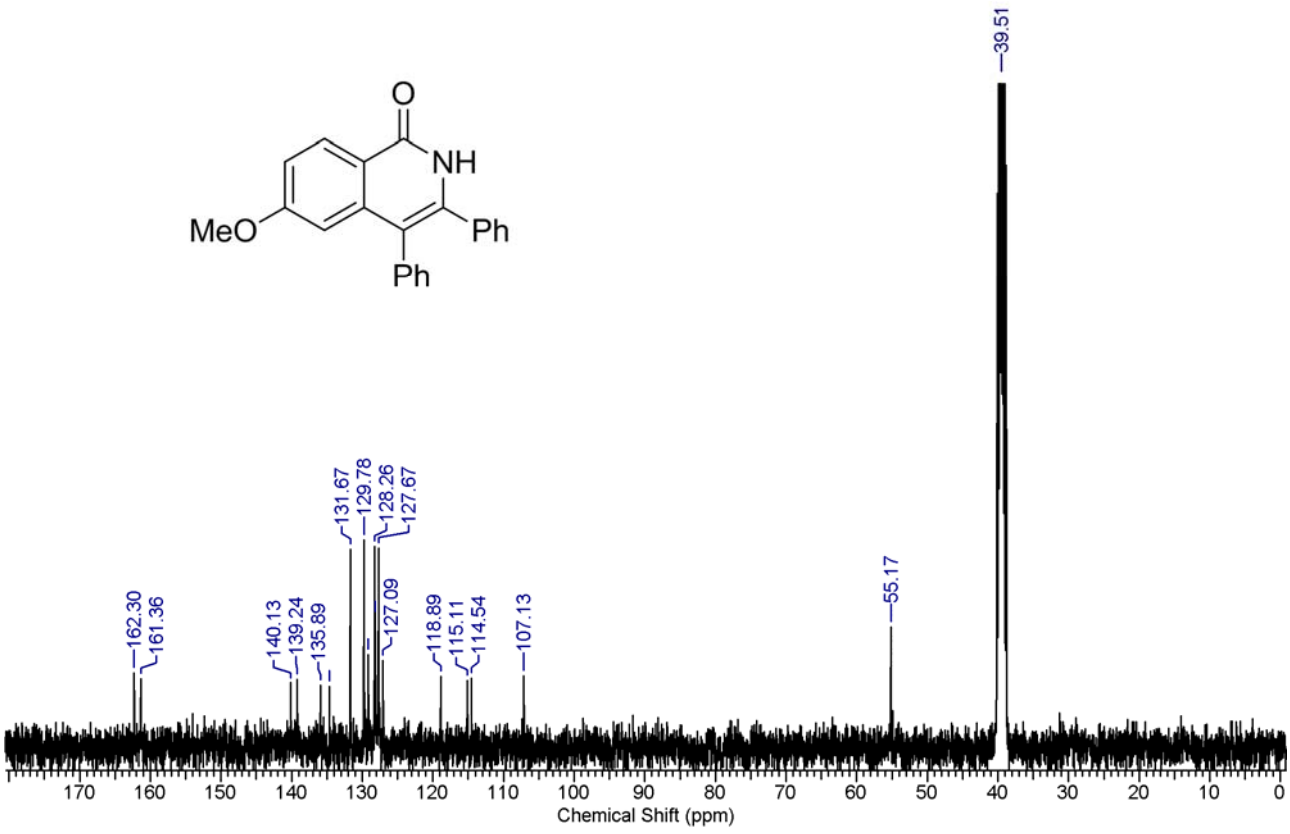


DEPT (135) NMR Spectrum of Compound **3b.**

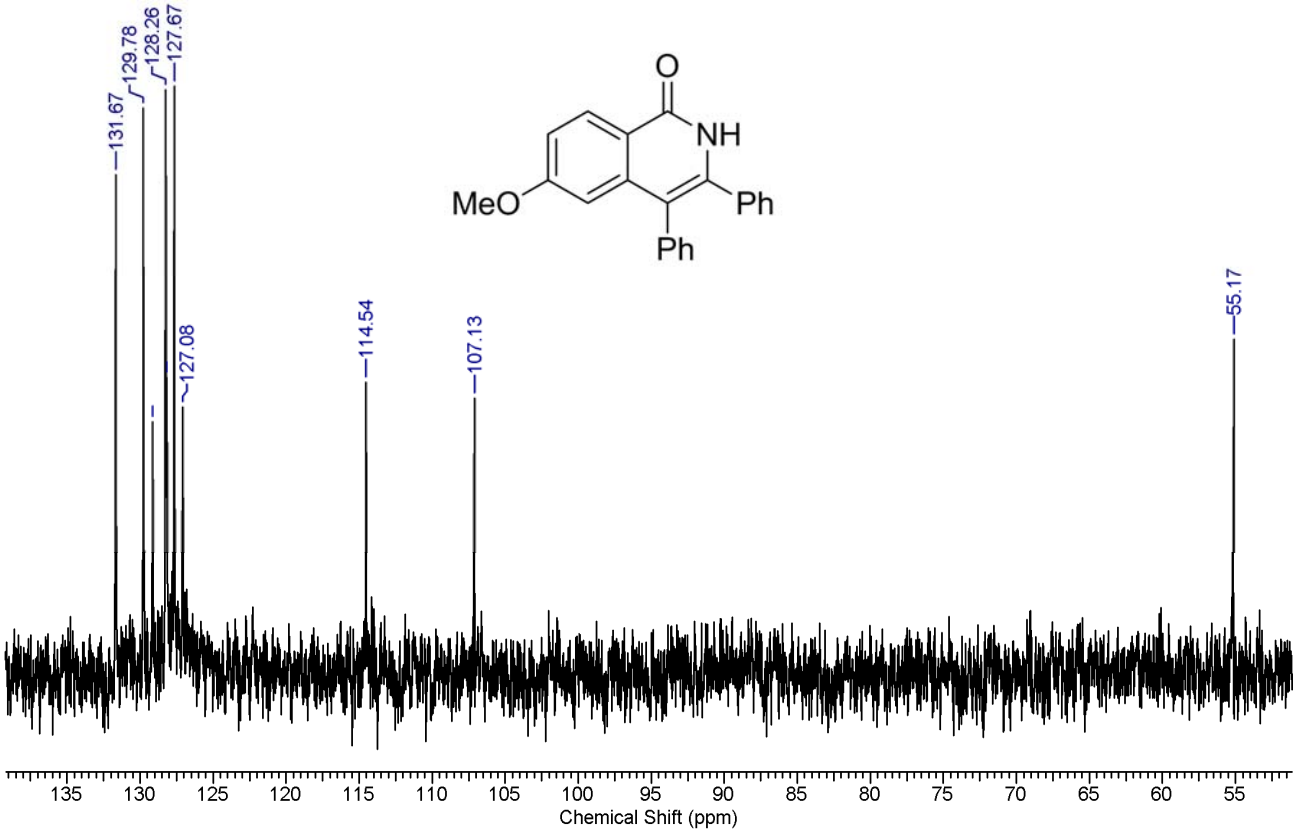


^{1}H and ^{13}C NMR Spectra of Compound **3c.**

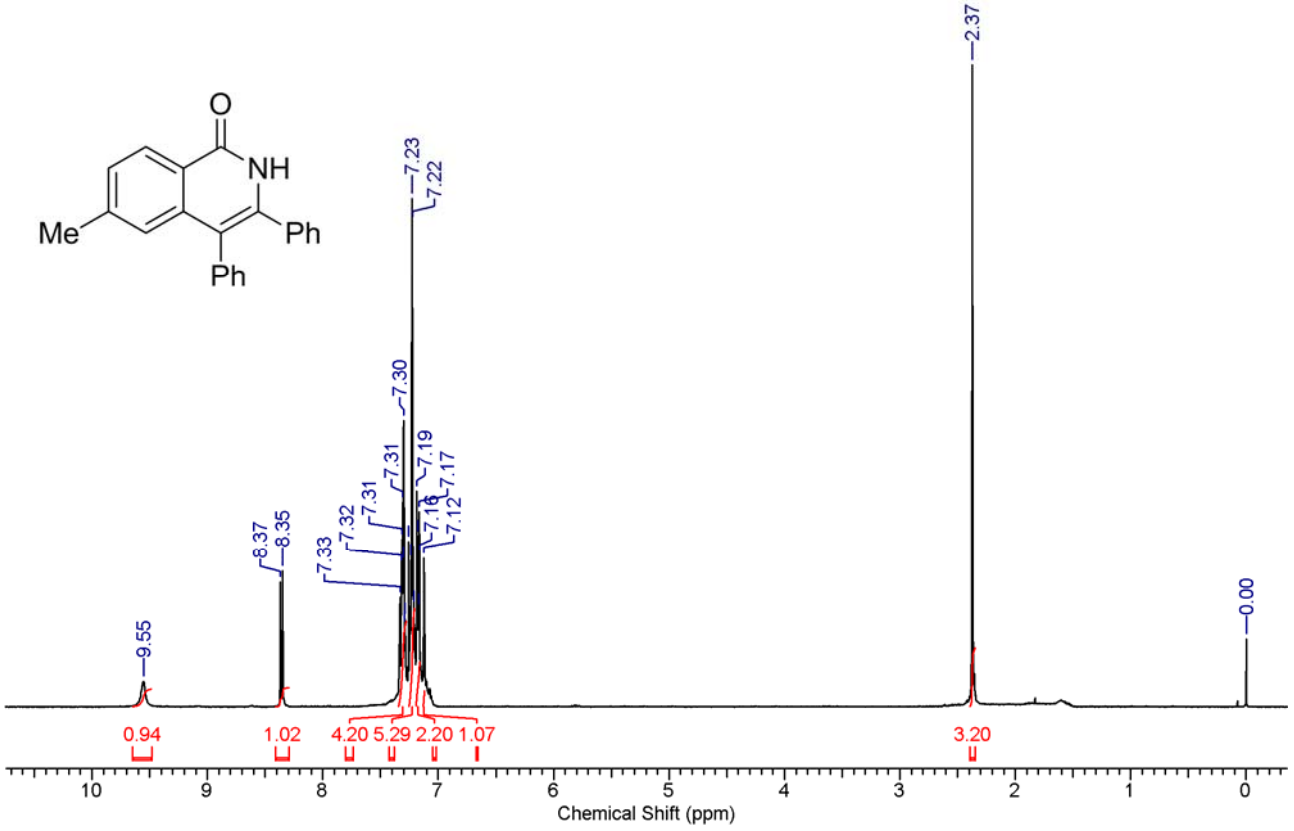


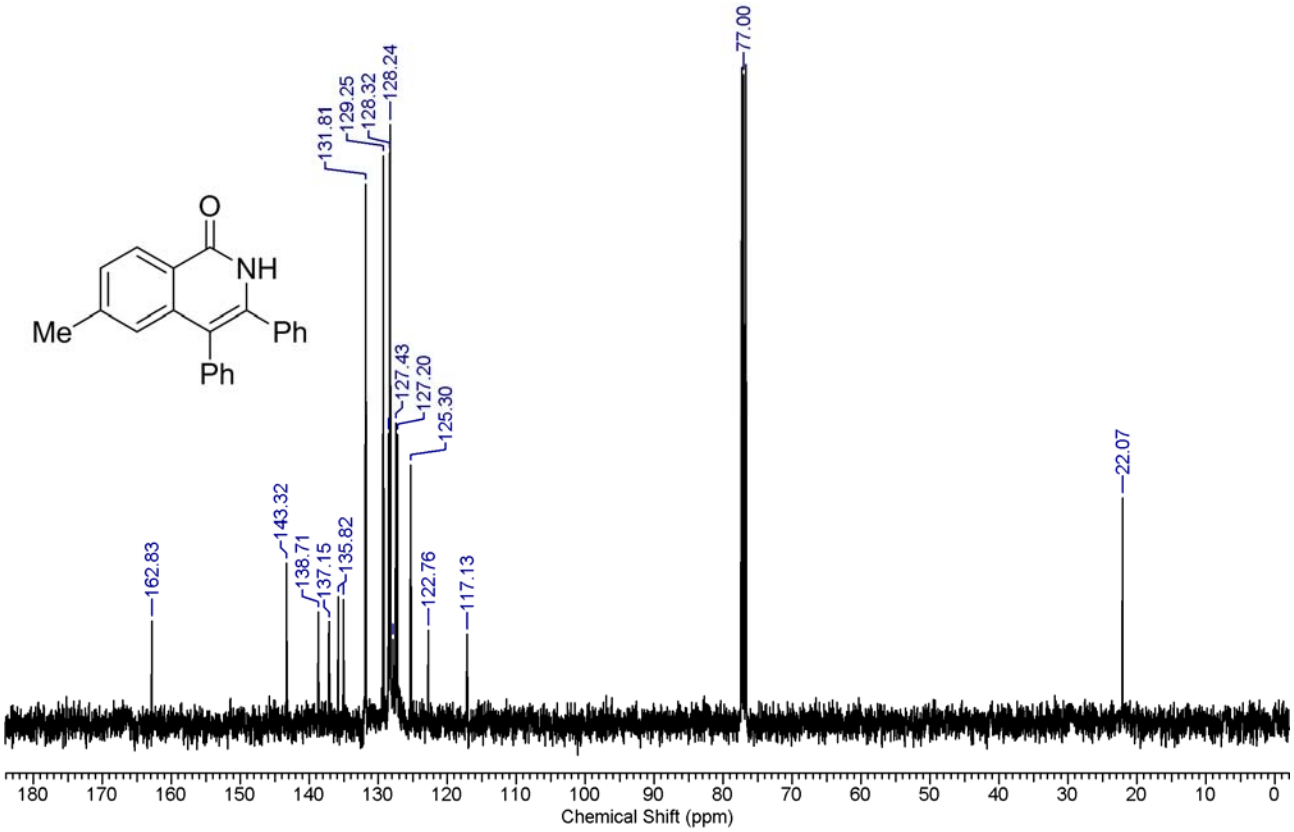


DEPT (135) NMR Spectrum of Compound **3c.**

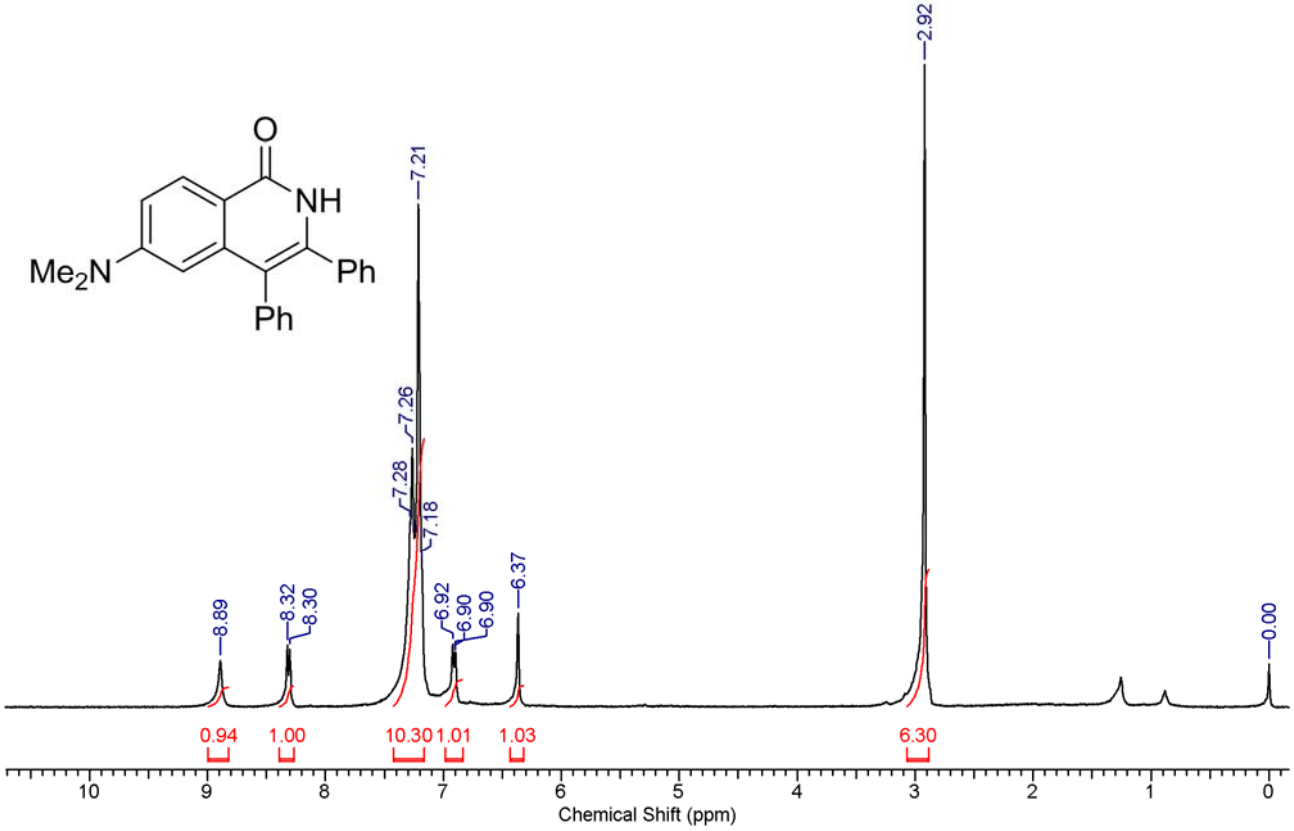


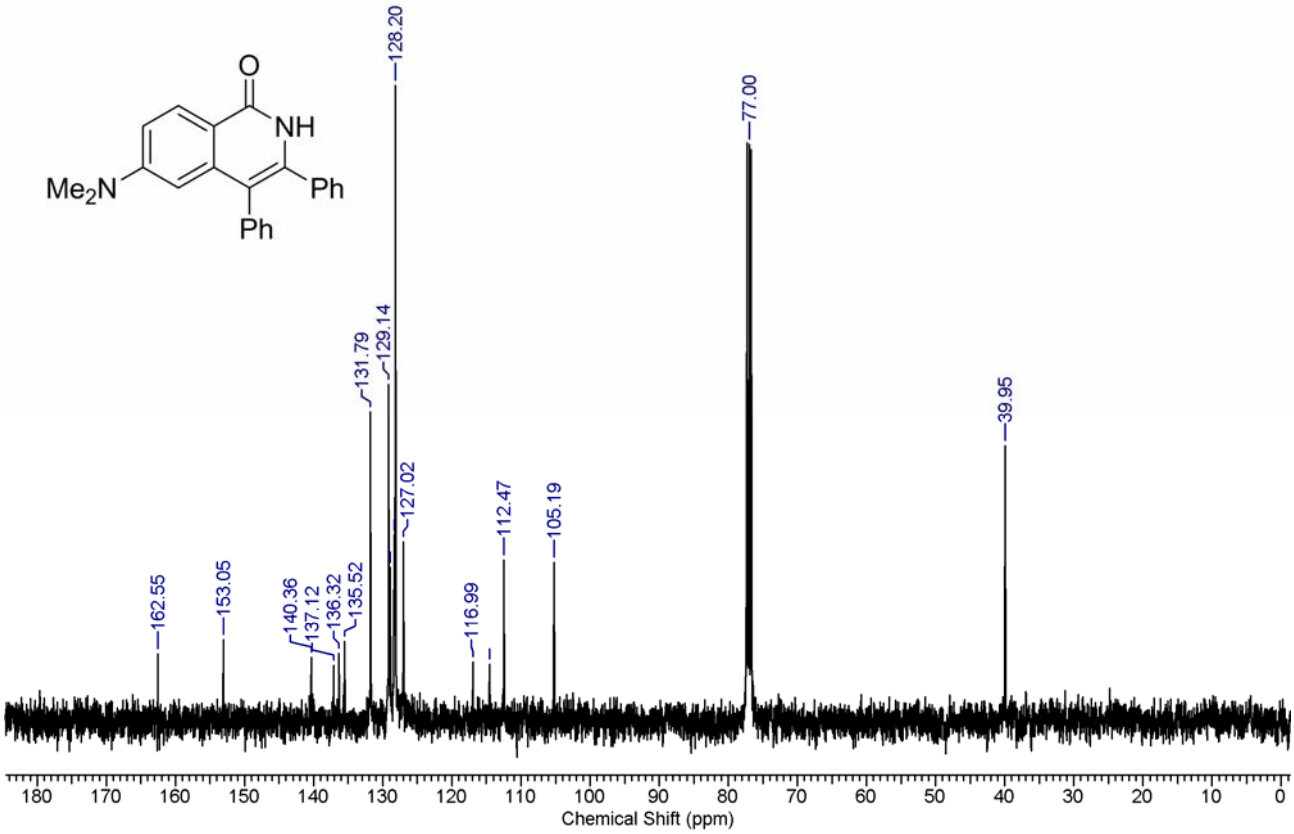
^{1}H and ^{13}C NMR Spectra of Compound **3d.**



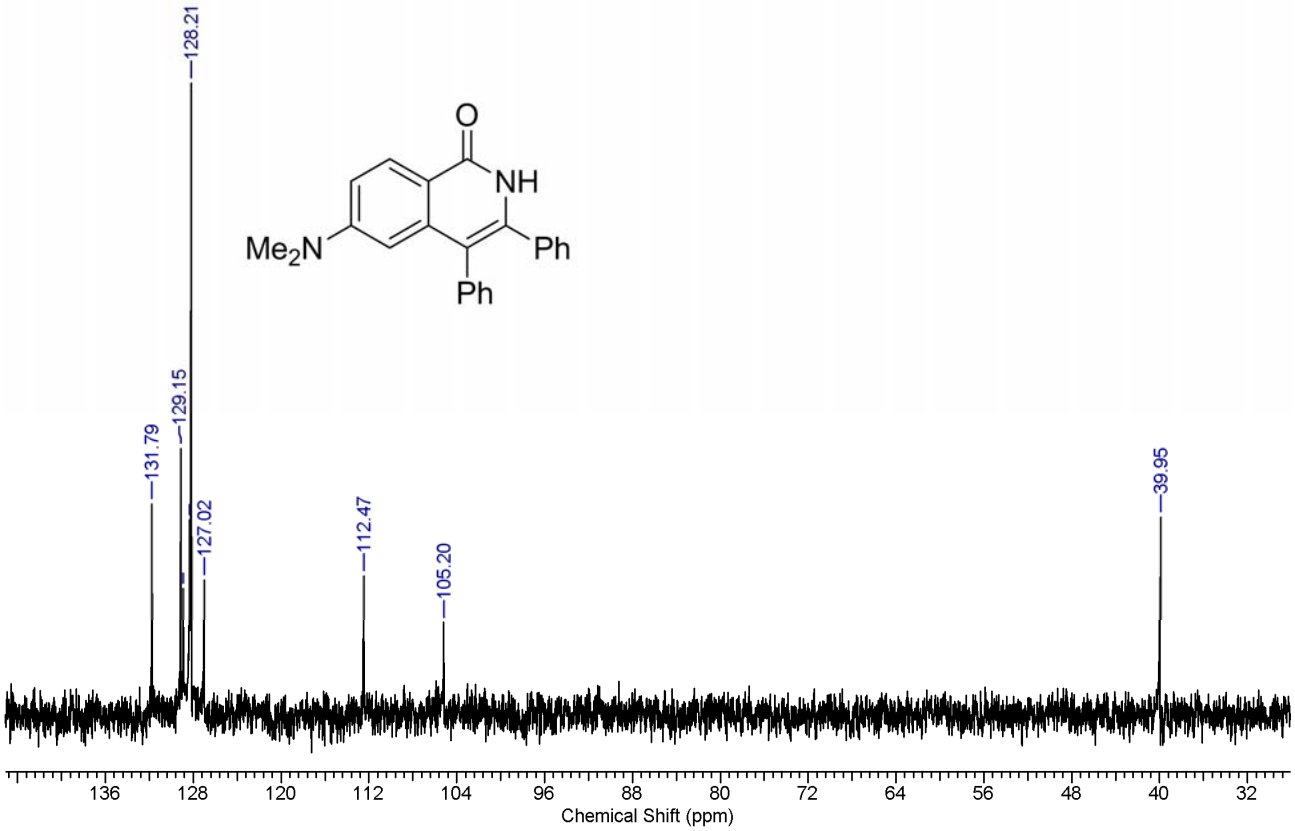


^{1}H and ^{13}C NMR Spectra of Compound **3e.**

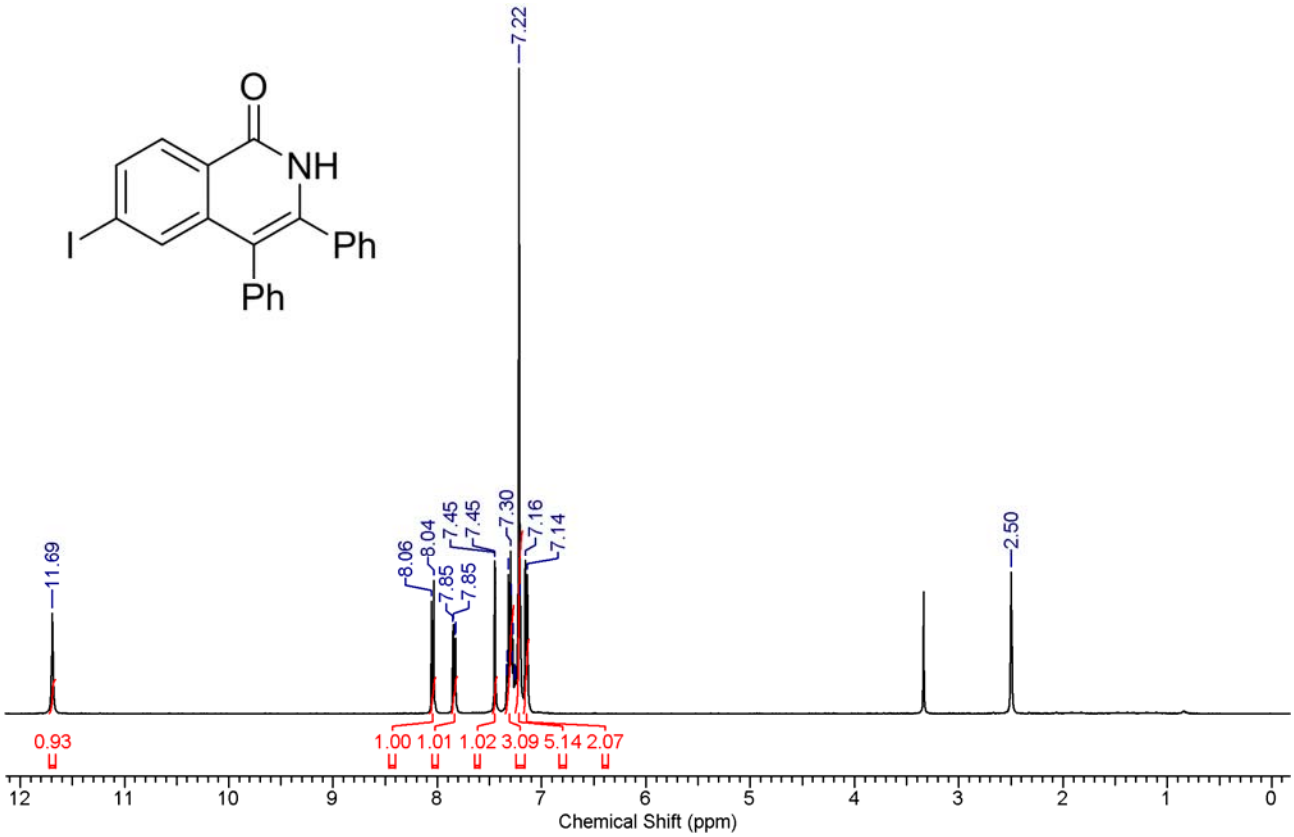


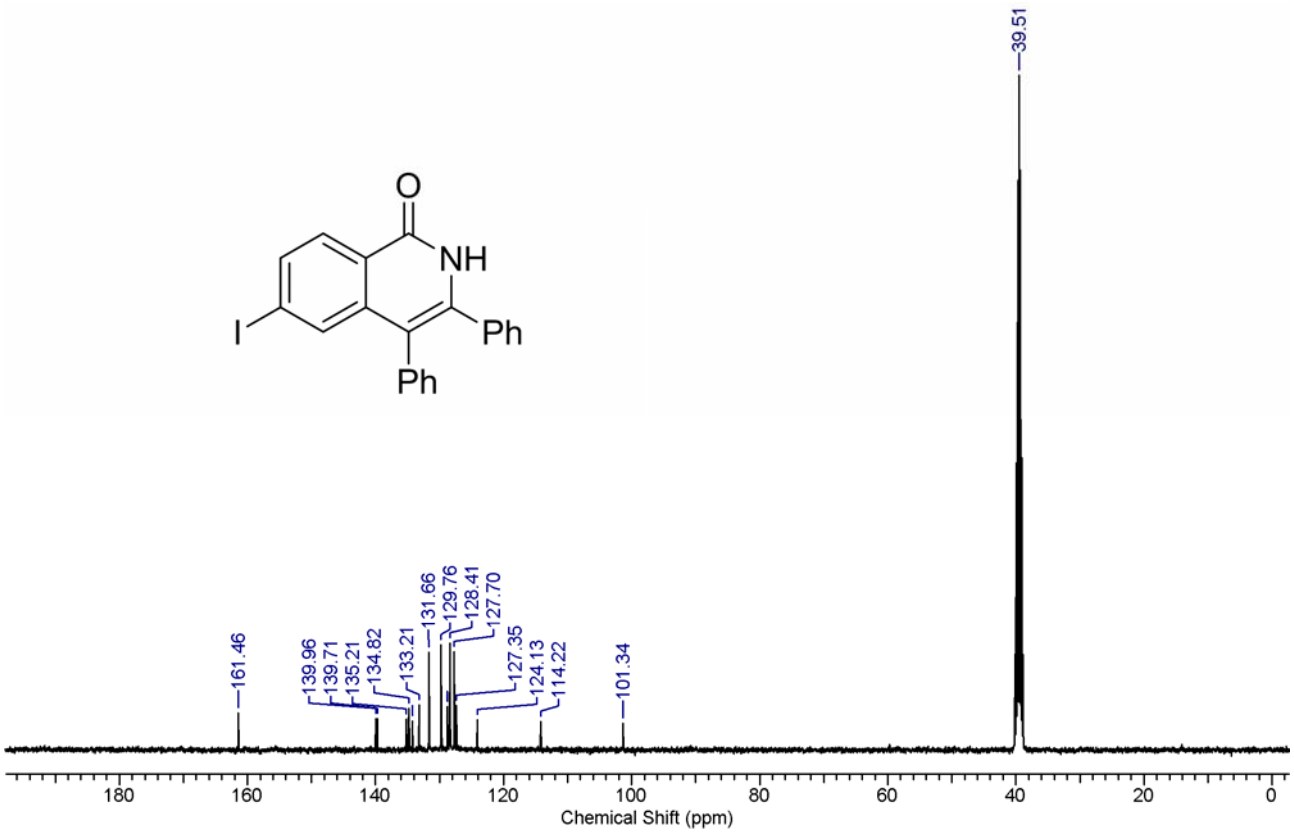


DEPT (135) NMR Spectrum of Compound **3e.**

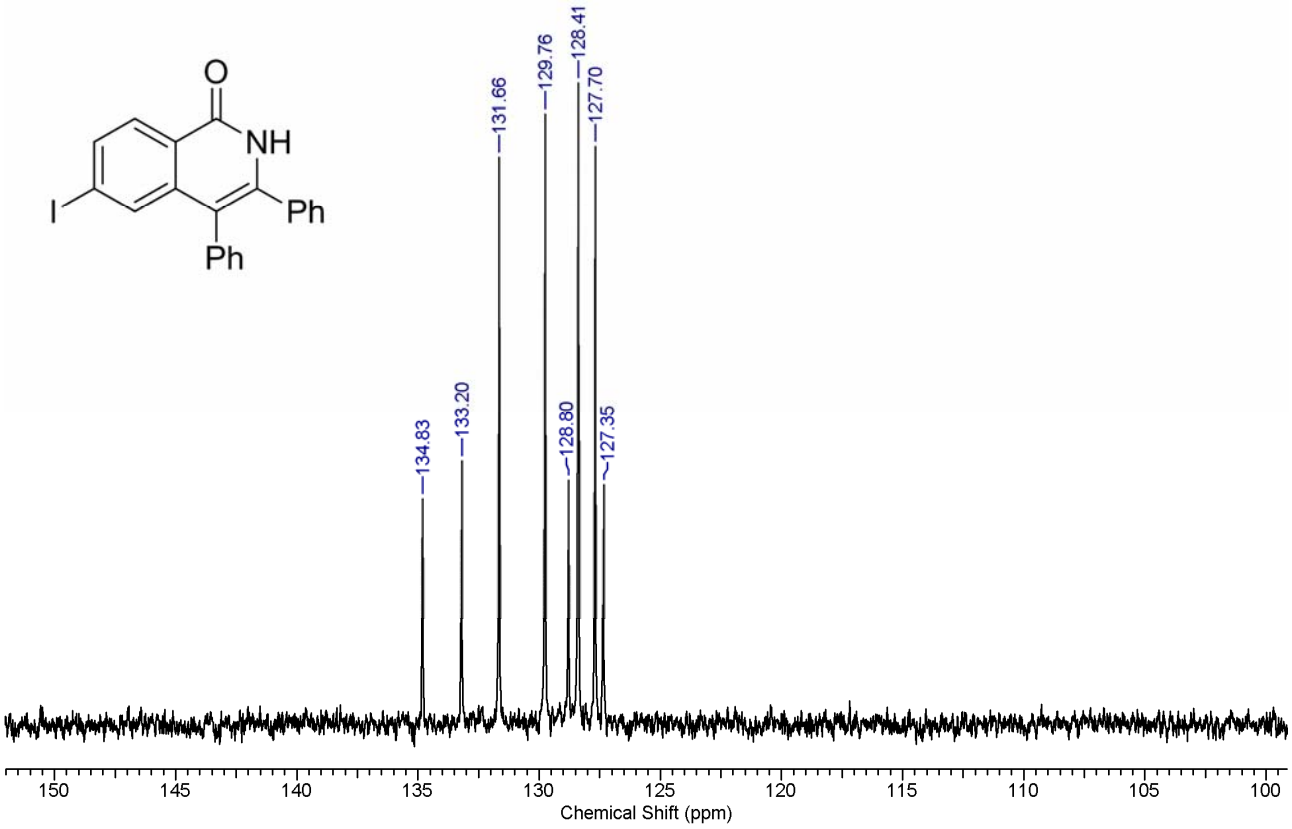


^{1}H and ^{13}C NMR Spectra of Compound **3f.**

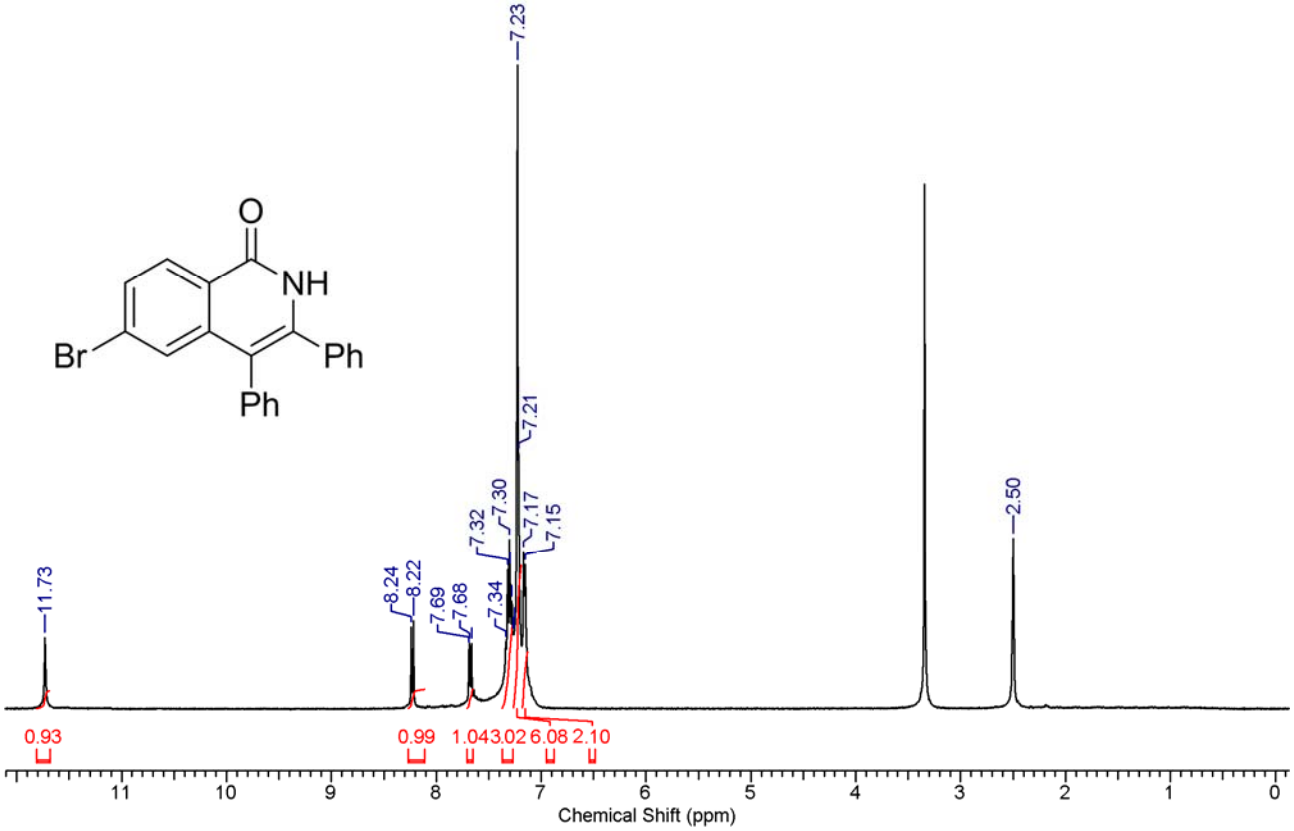


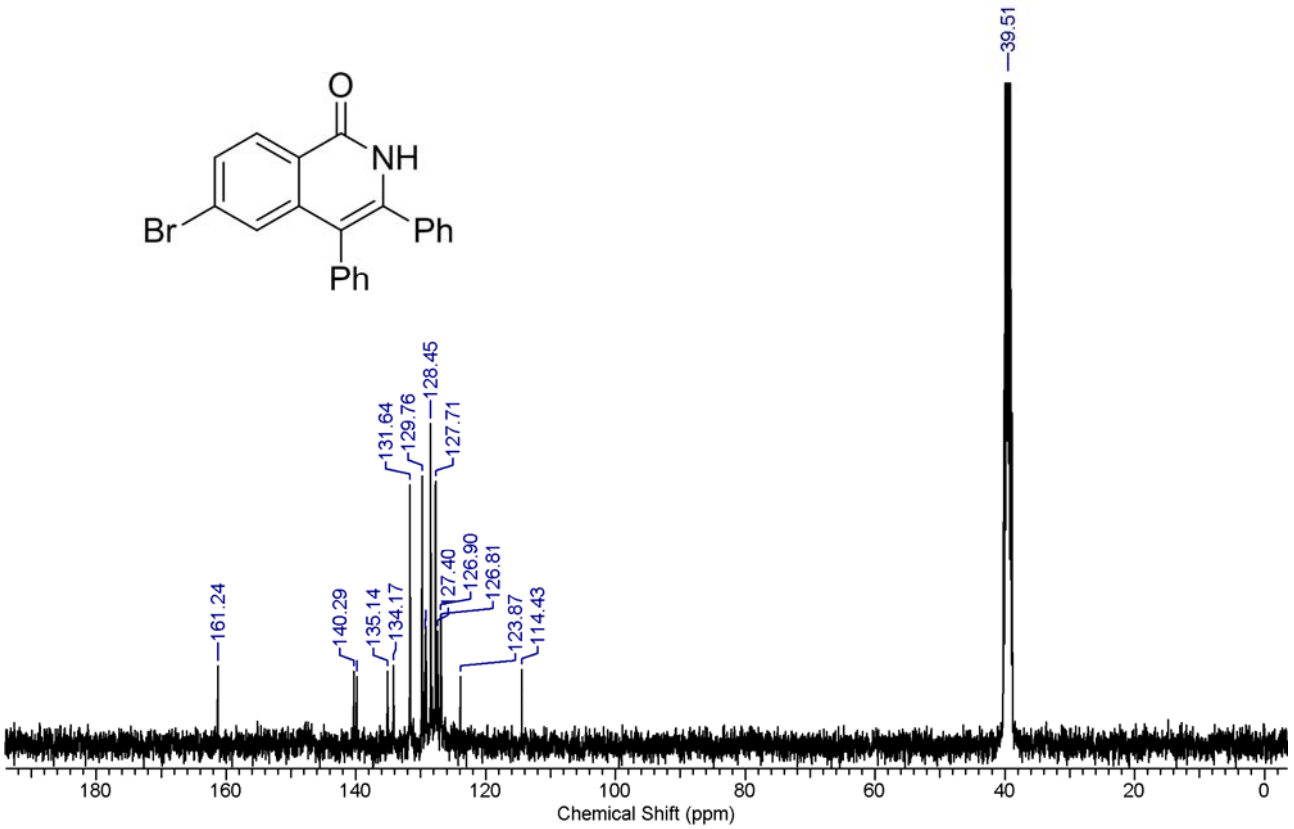


DEPT (135) NMR Spectrum of Compound **3f.**

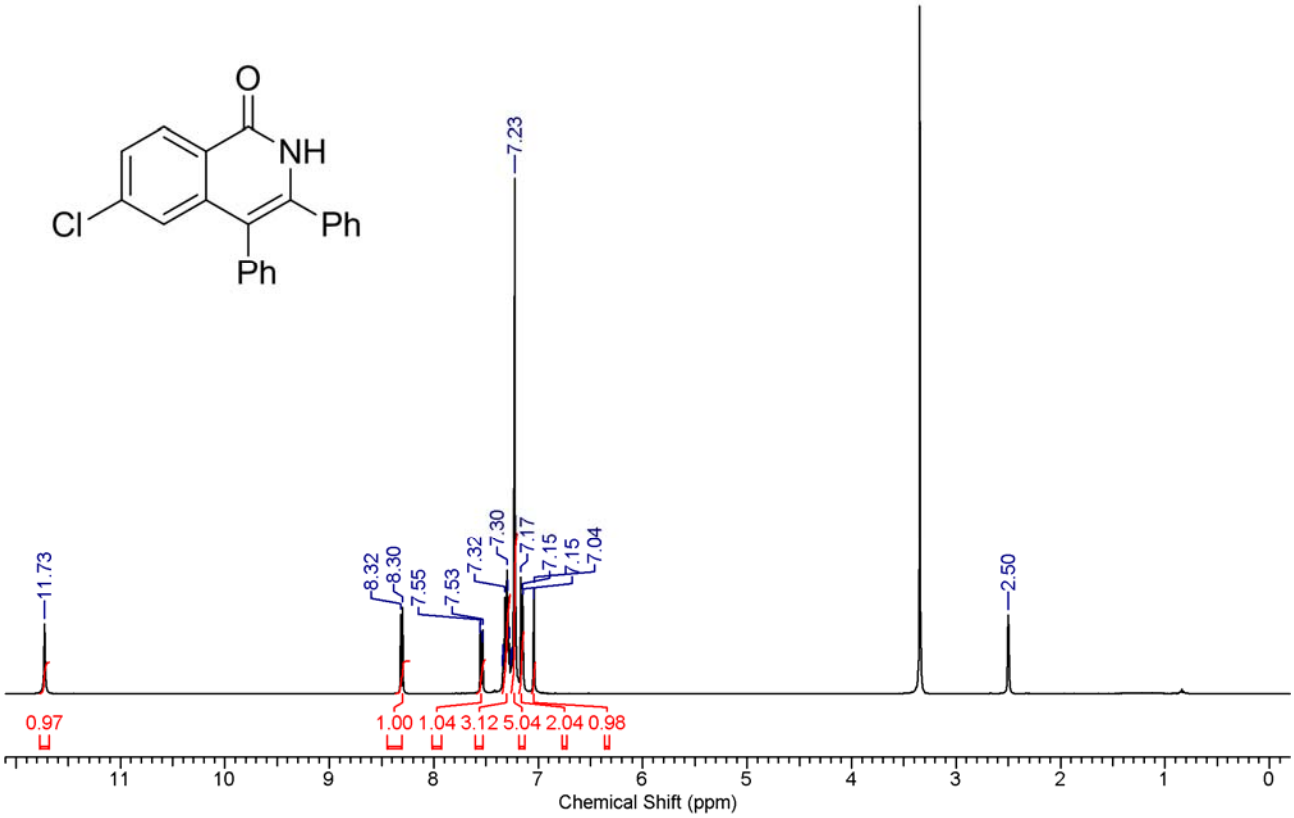


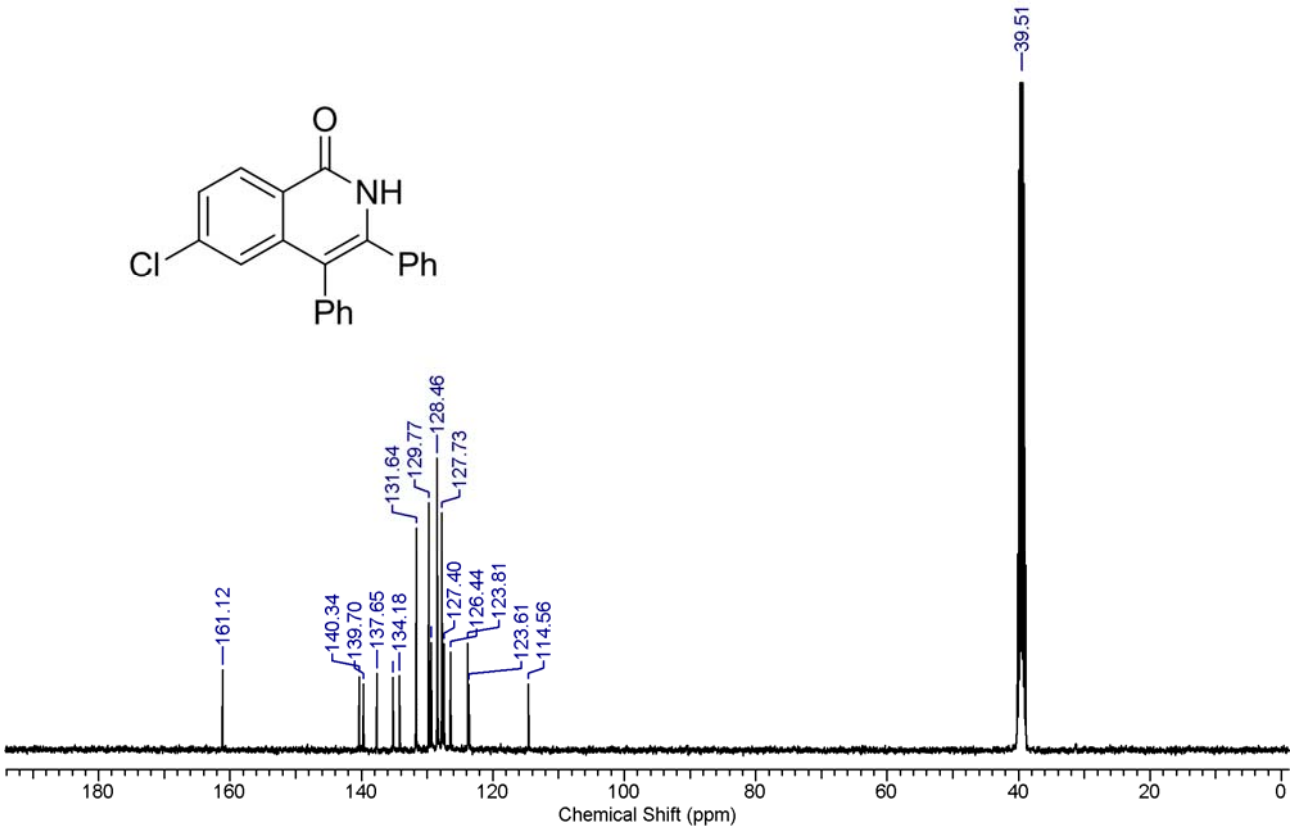
^{1}H and ^{13}C NMR Spectra of Compound **3g.**



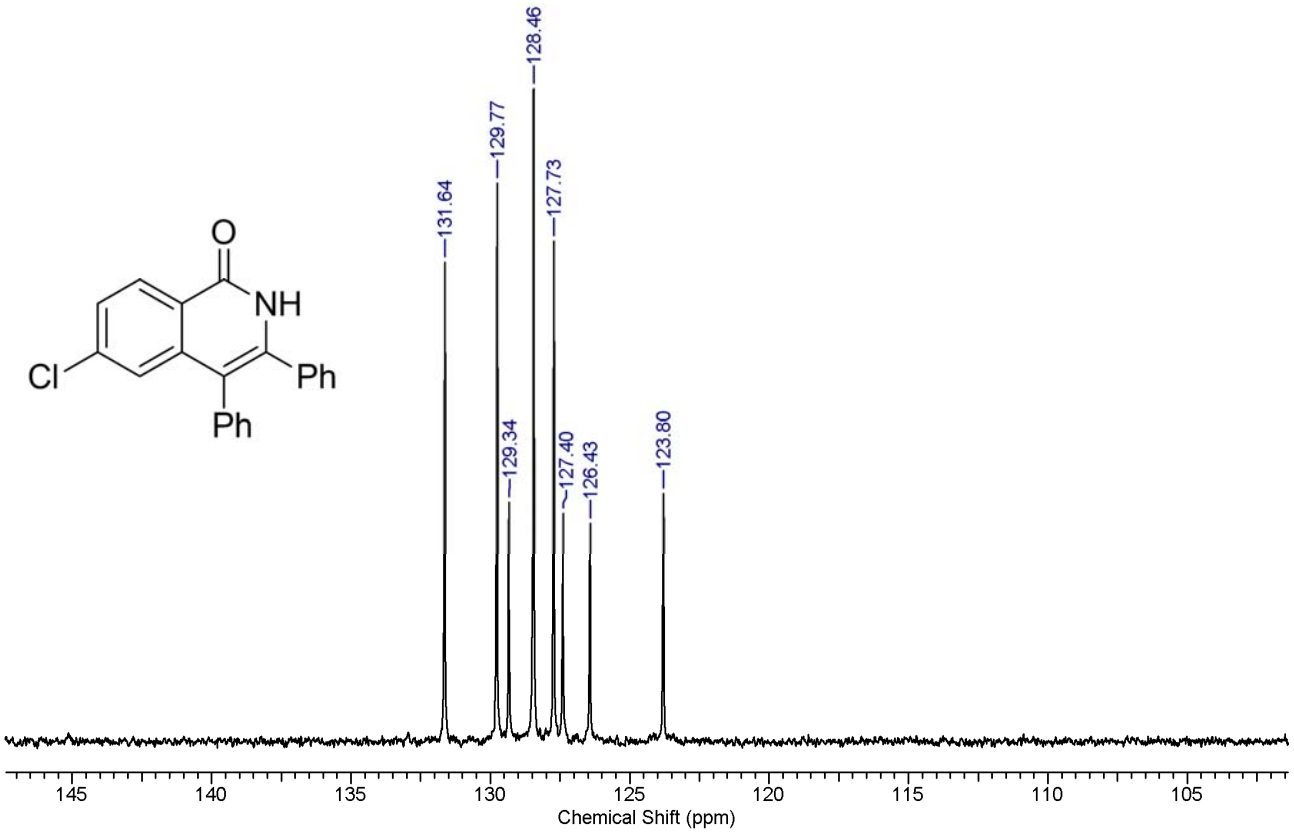


^{1}H and ^{13}C NMR Spectra of Compound **3h.**

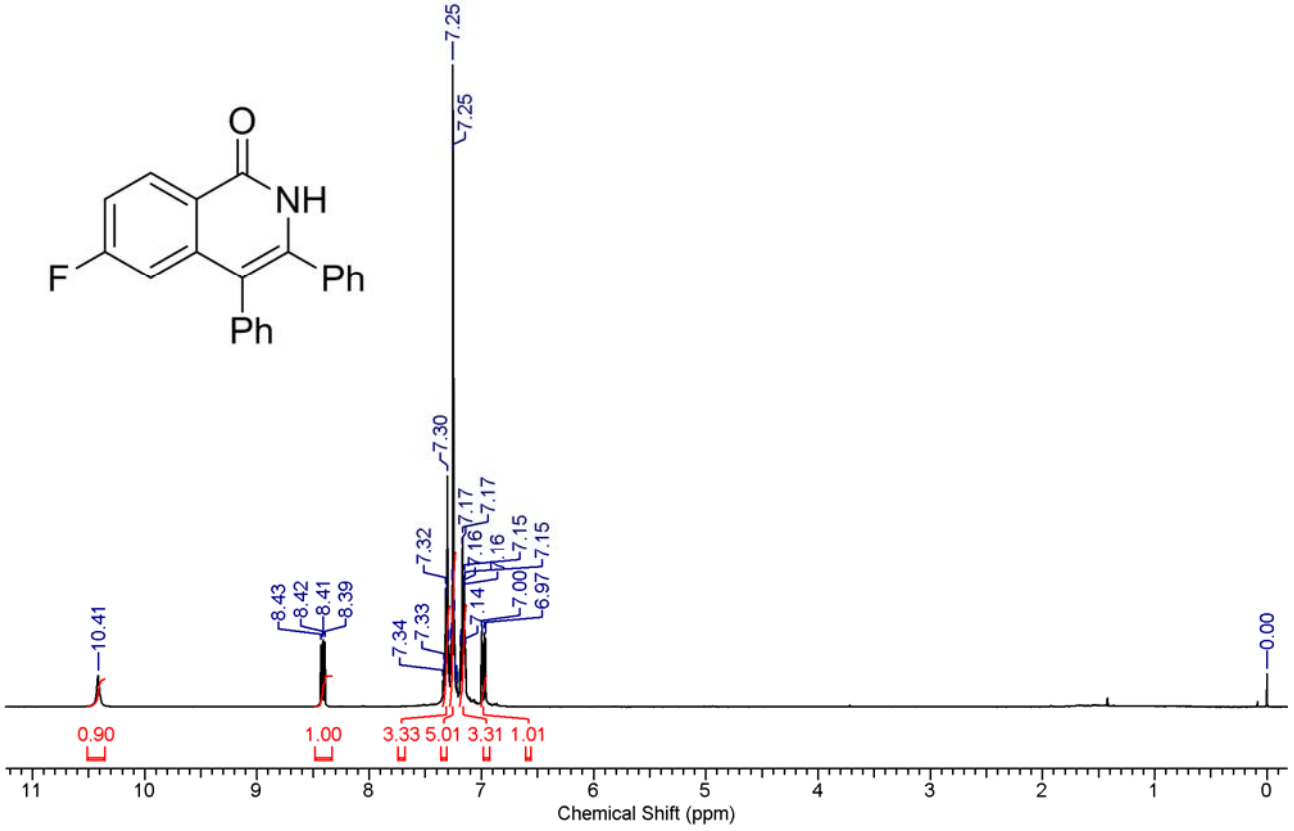


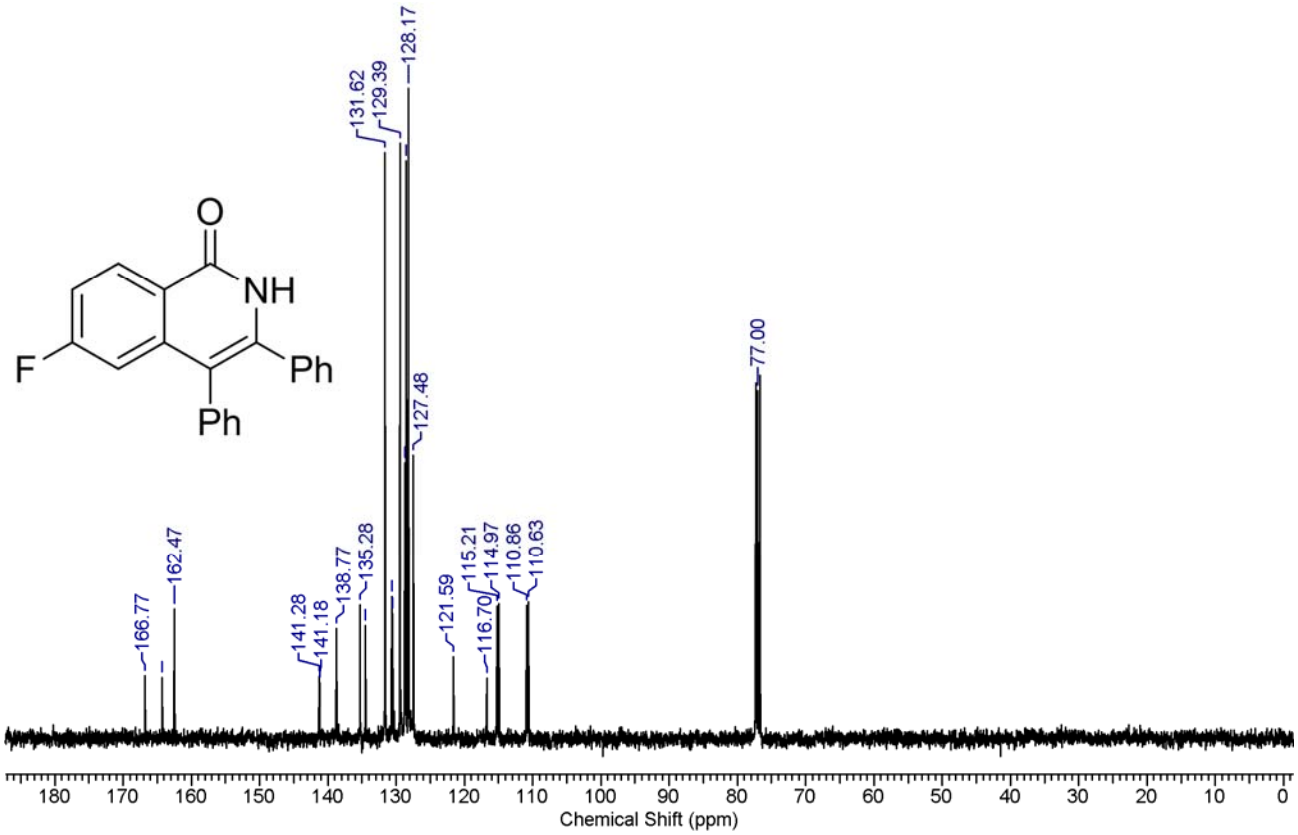


DEPT (135) NMR Spectrum of Compound **3h.**

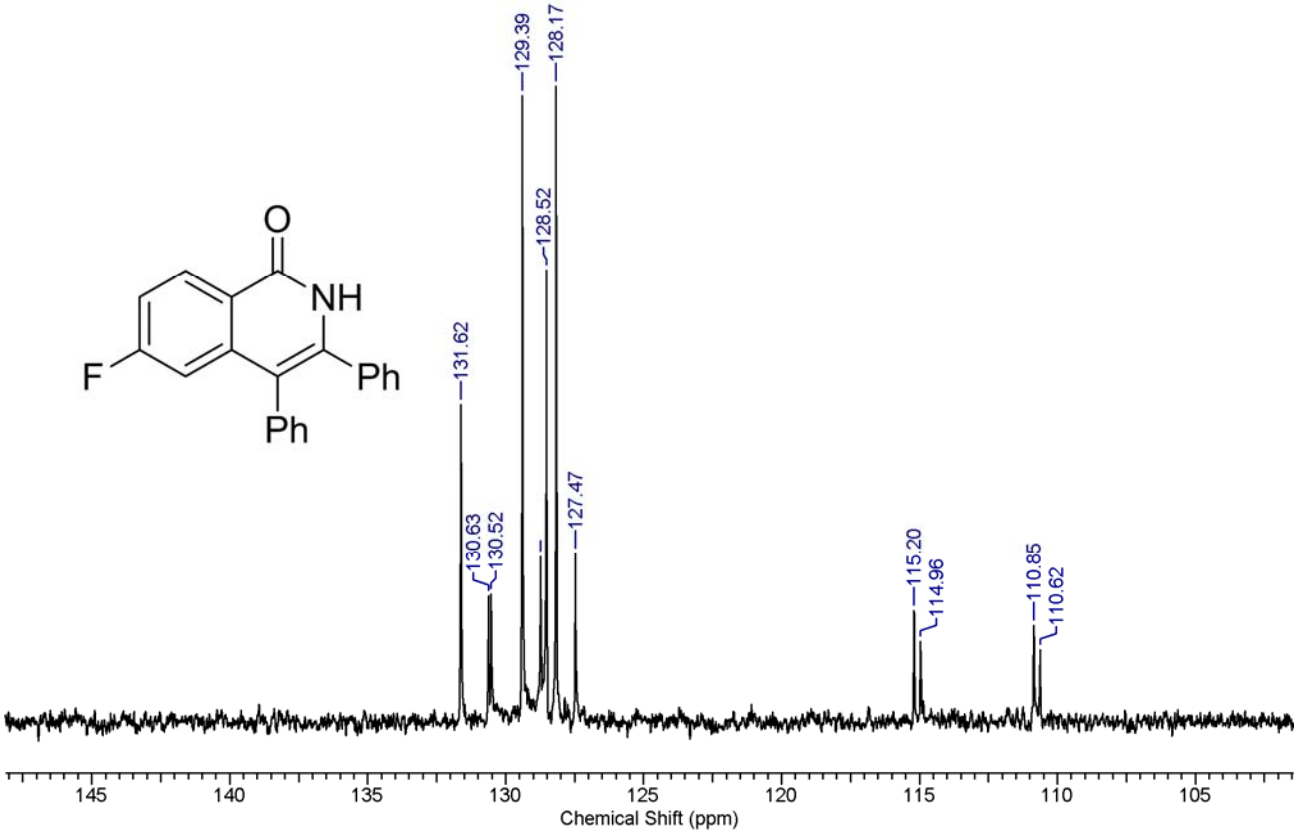


^{1}H and ^{13}C NMR Spectra of Compound **3i.**

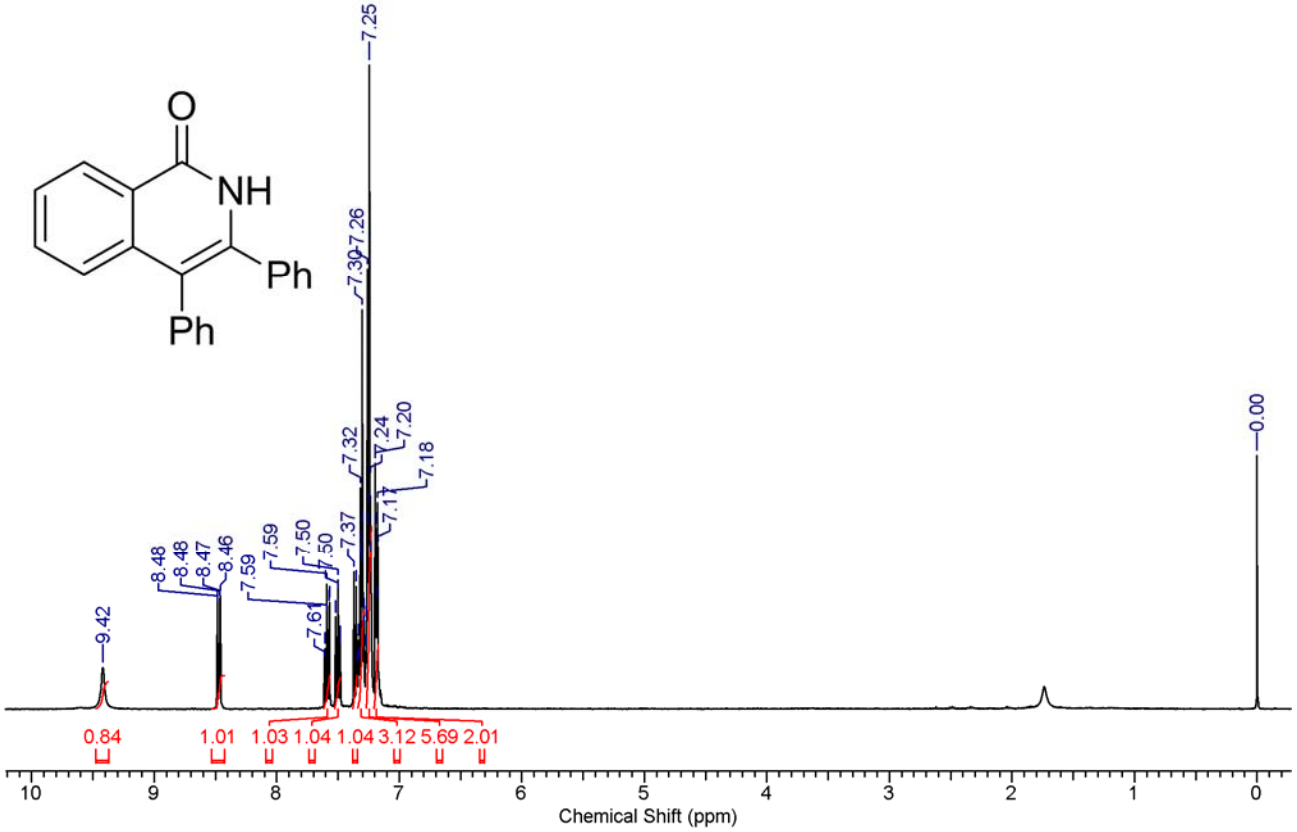


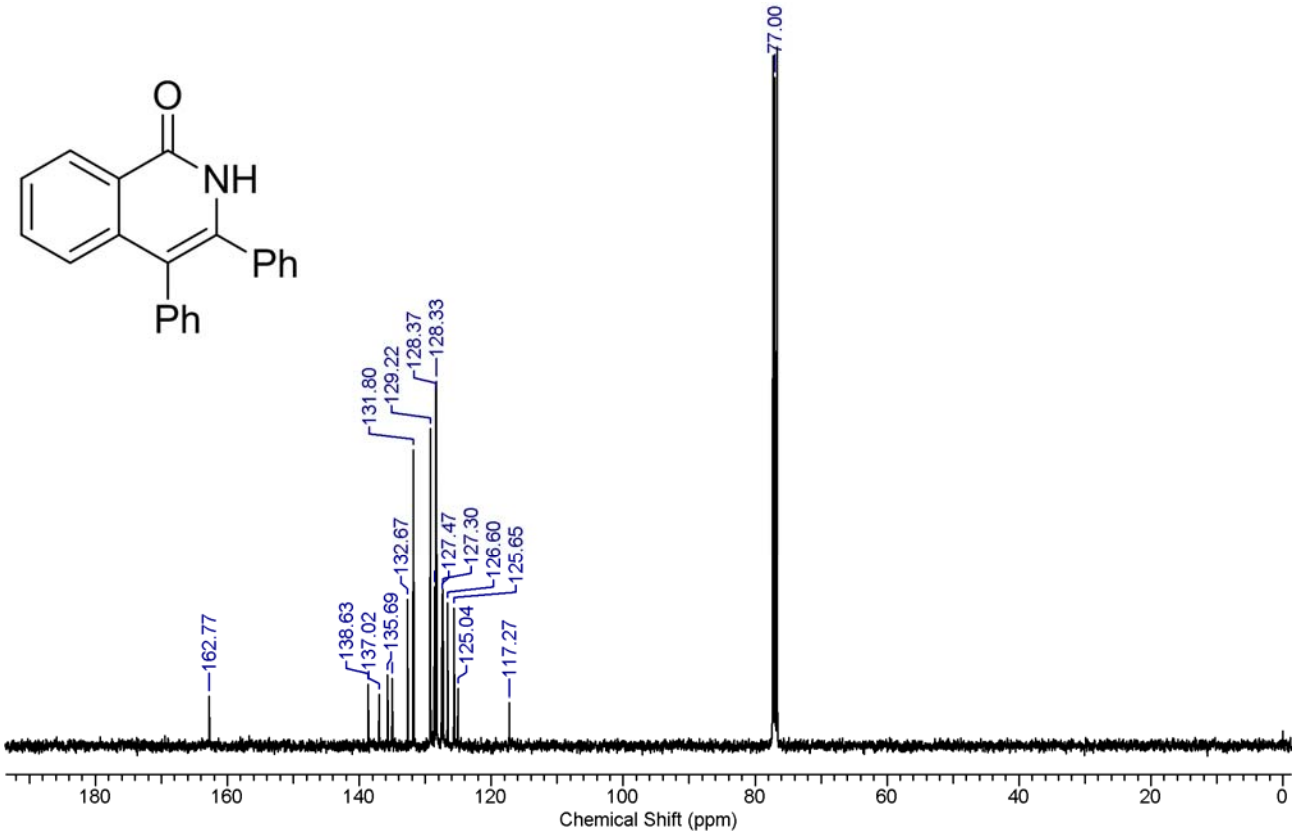


DEPT (135) NMR Spectrum of Compound **3i.**

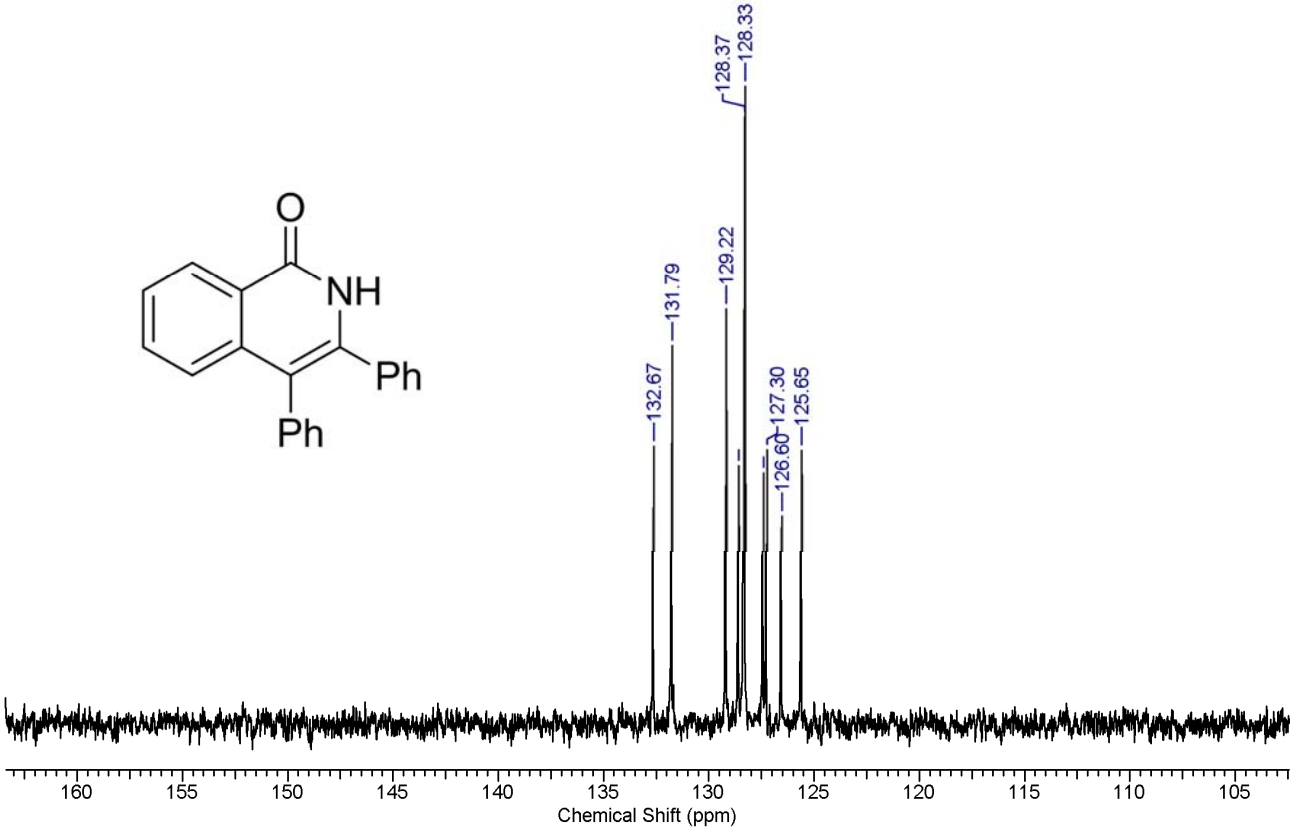


^{1}H and ^{13}C NMR Spectra of Compound **3j.**

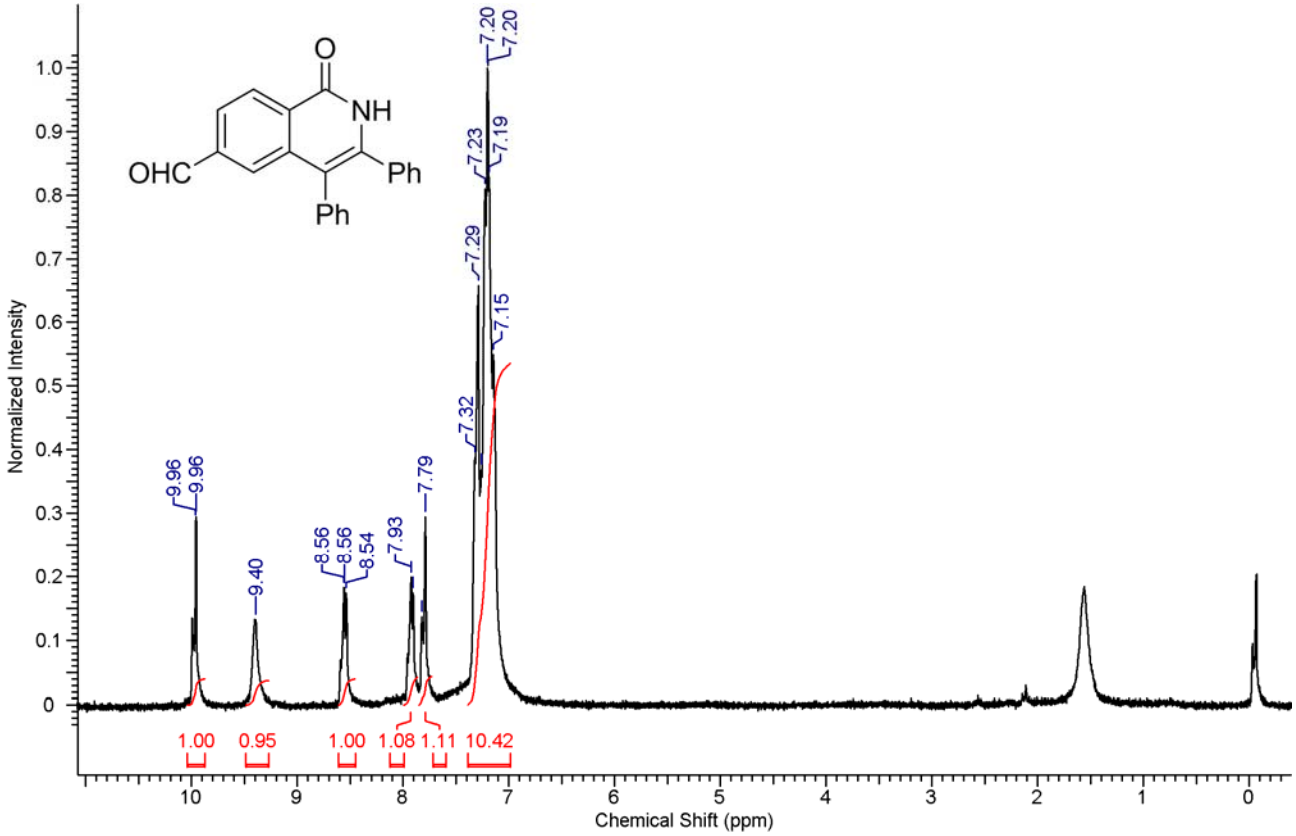


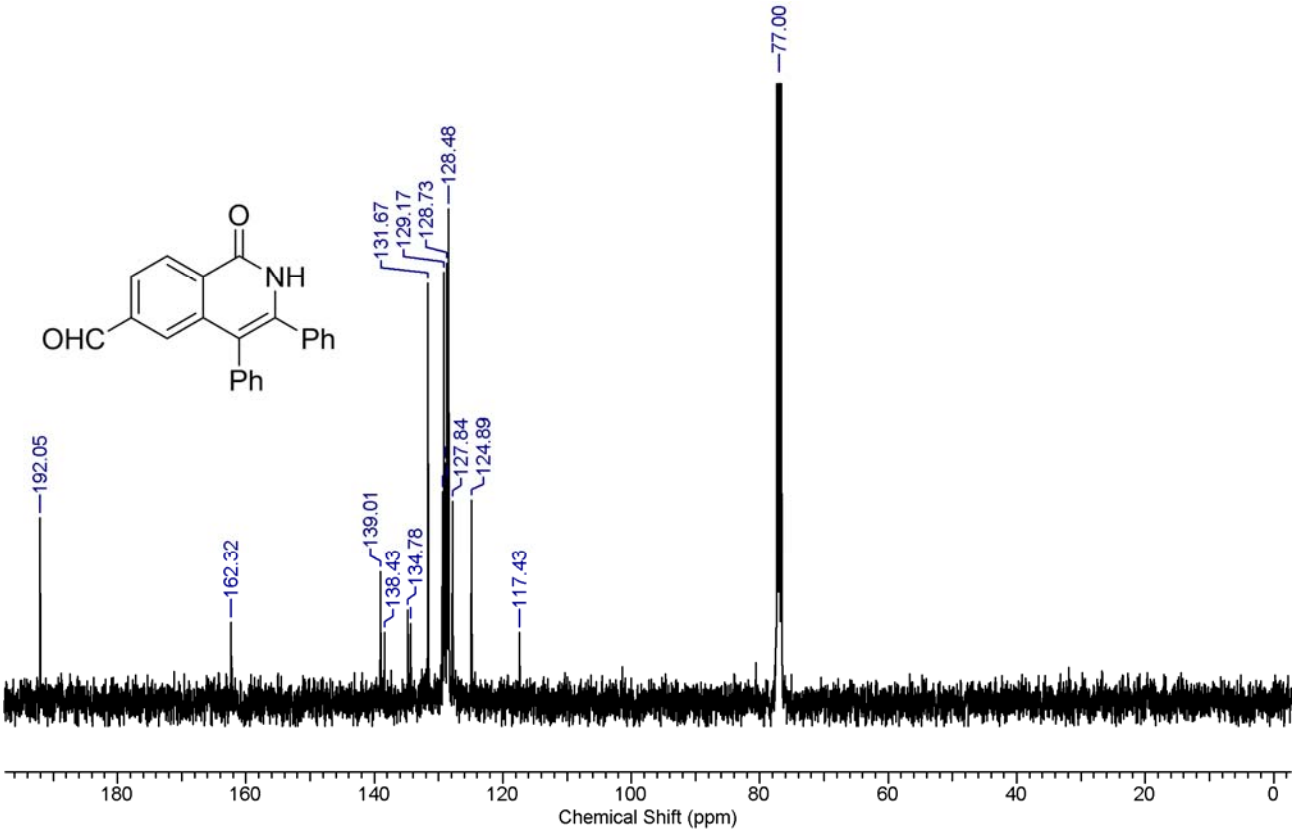


DEPT (135) NMR Spectrum of Compound **3j.**

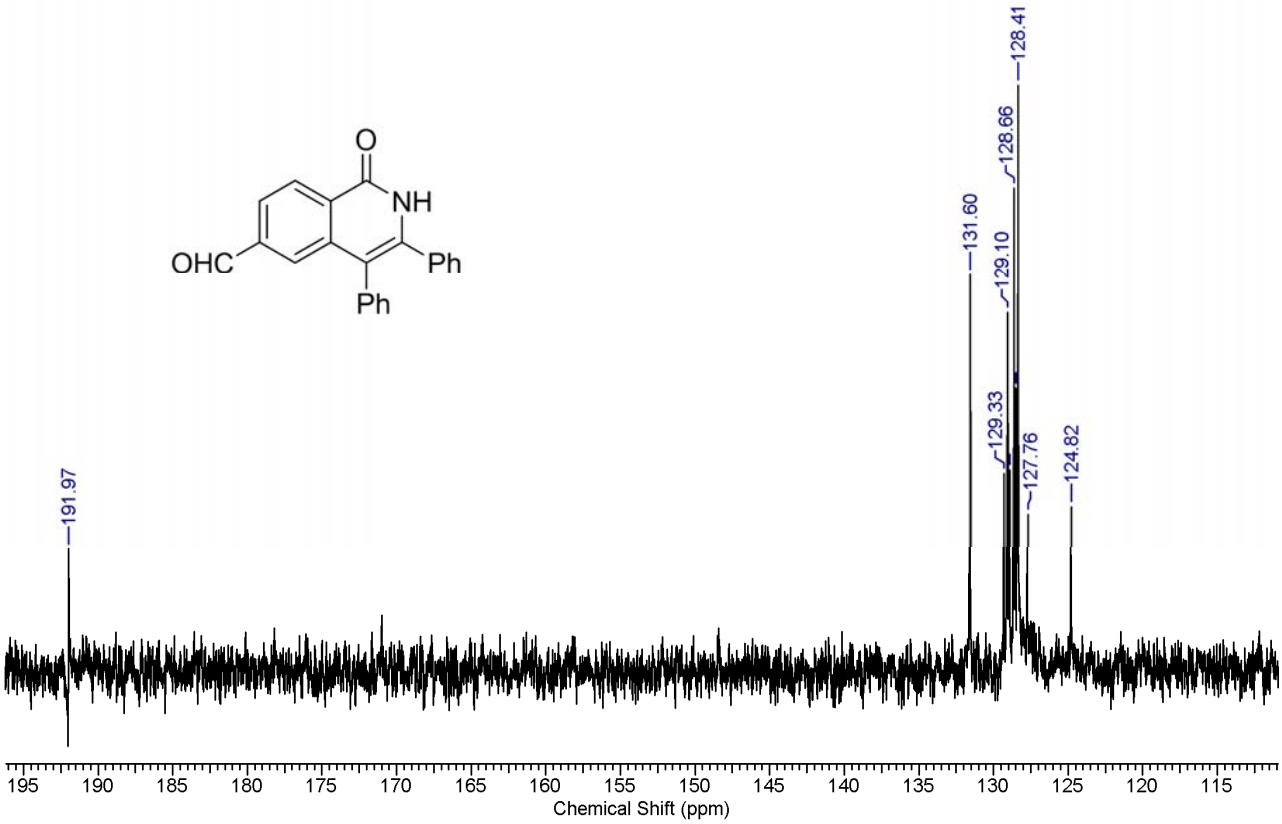


^{1}H and ^{13}C NMR Spectra of Compound **3k.**

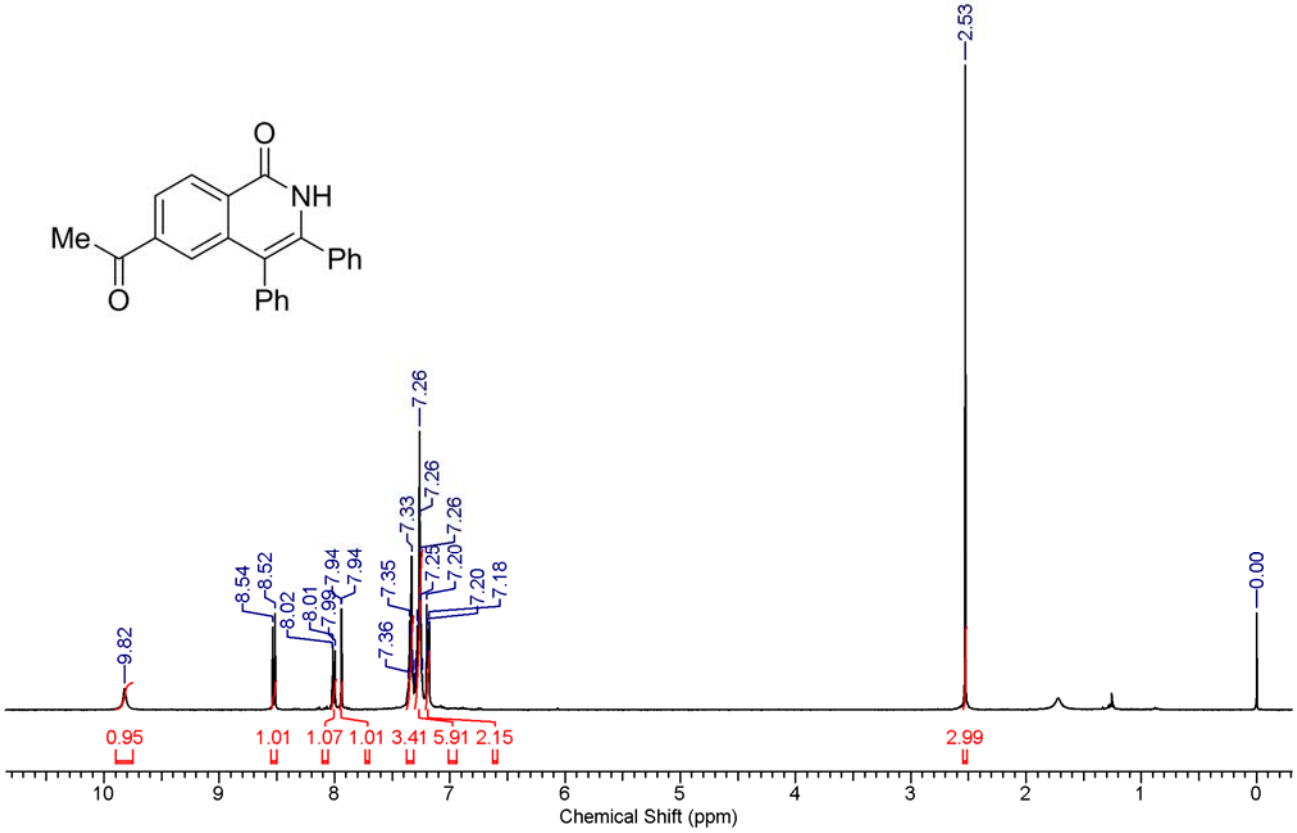


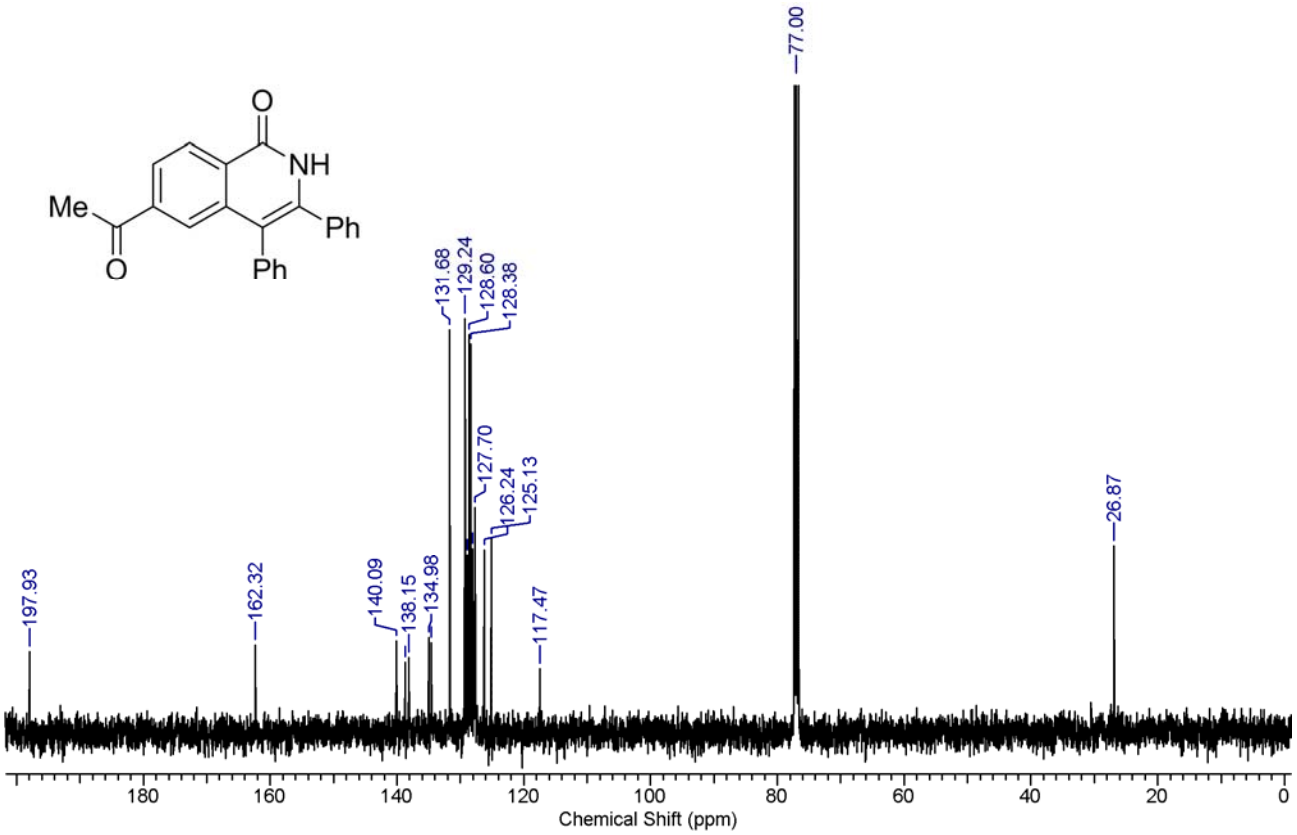


DEPT (135) NMR Spectrum of Compound **3k.**

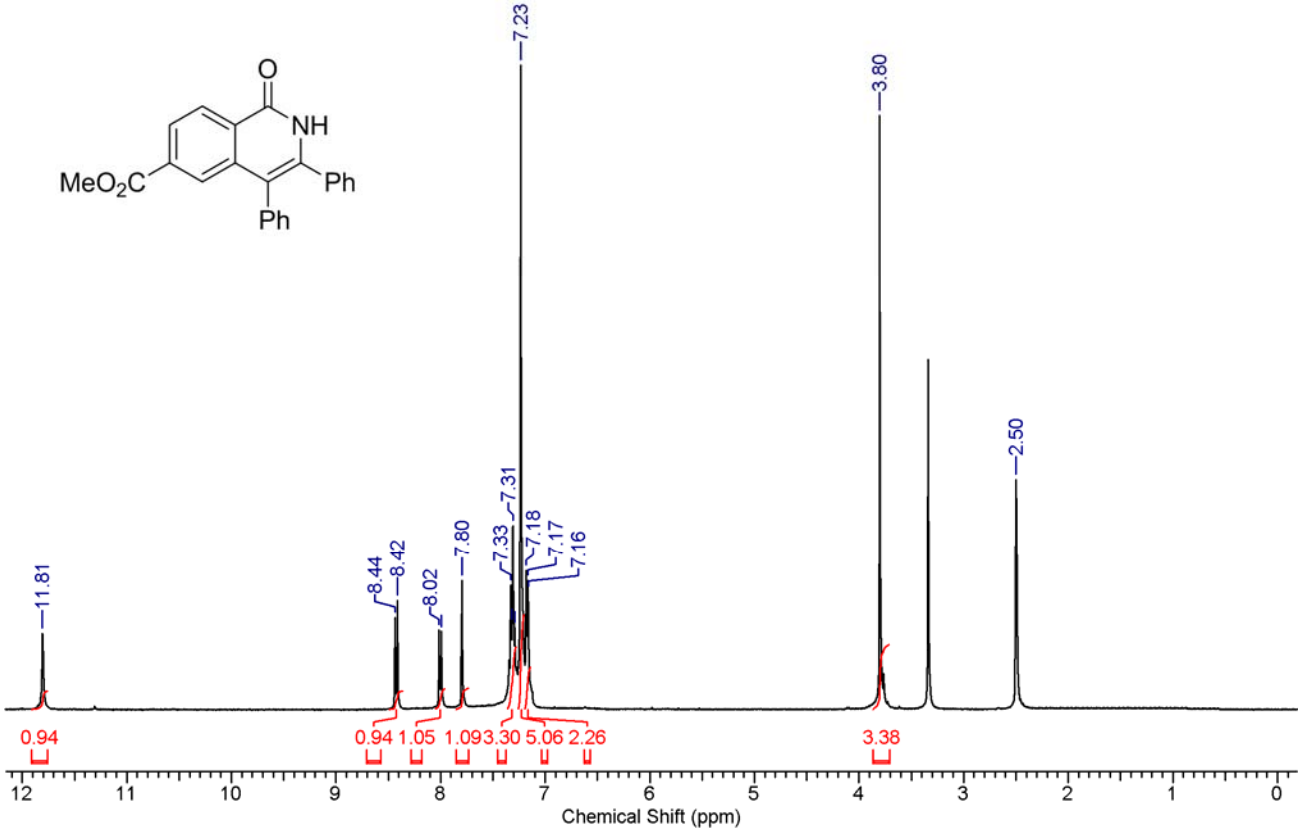


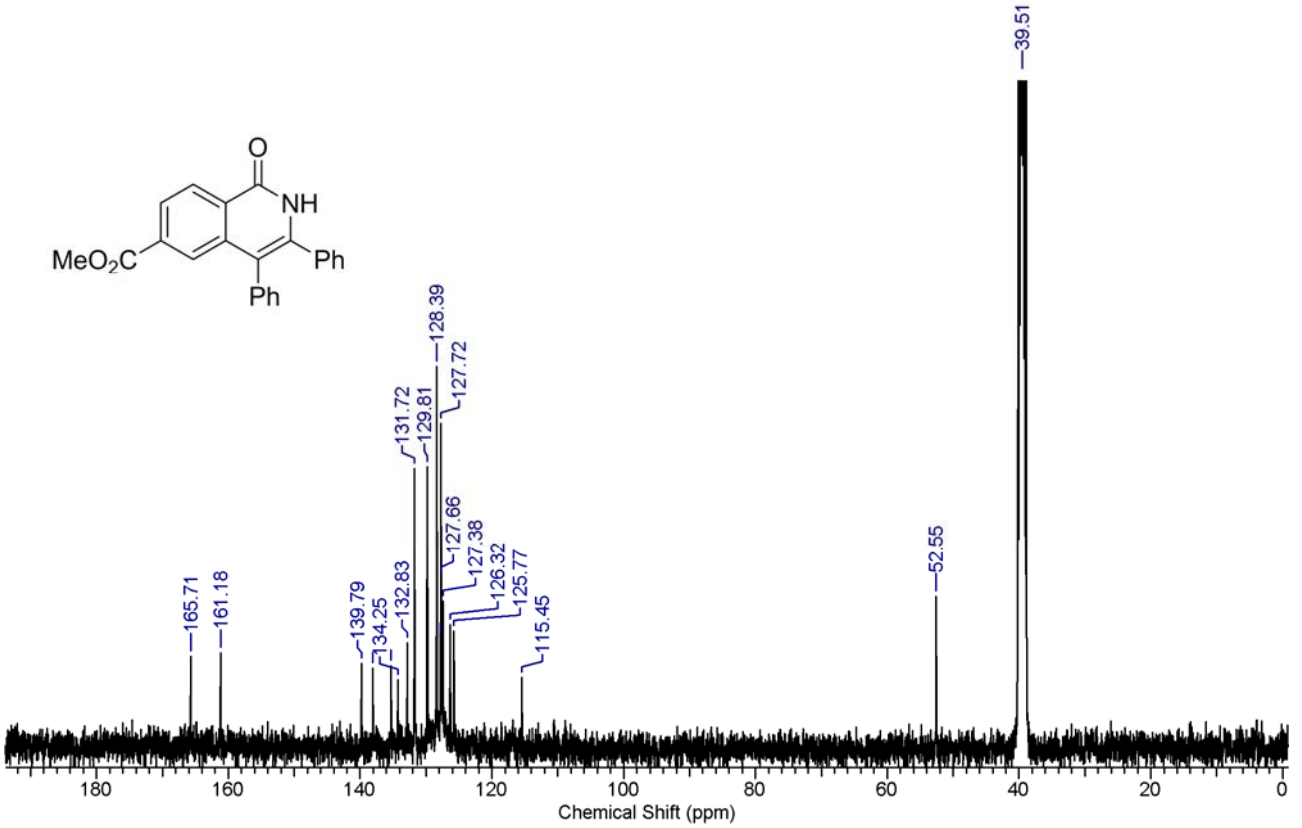
^{1}H and ^{13}C NMR Spectra of Compound **3l.**



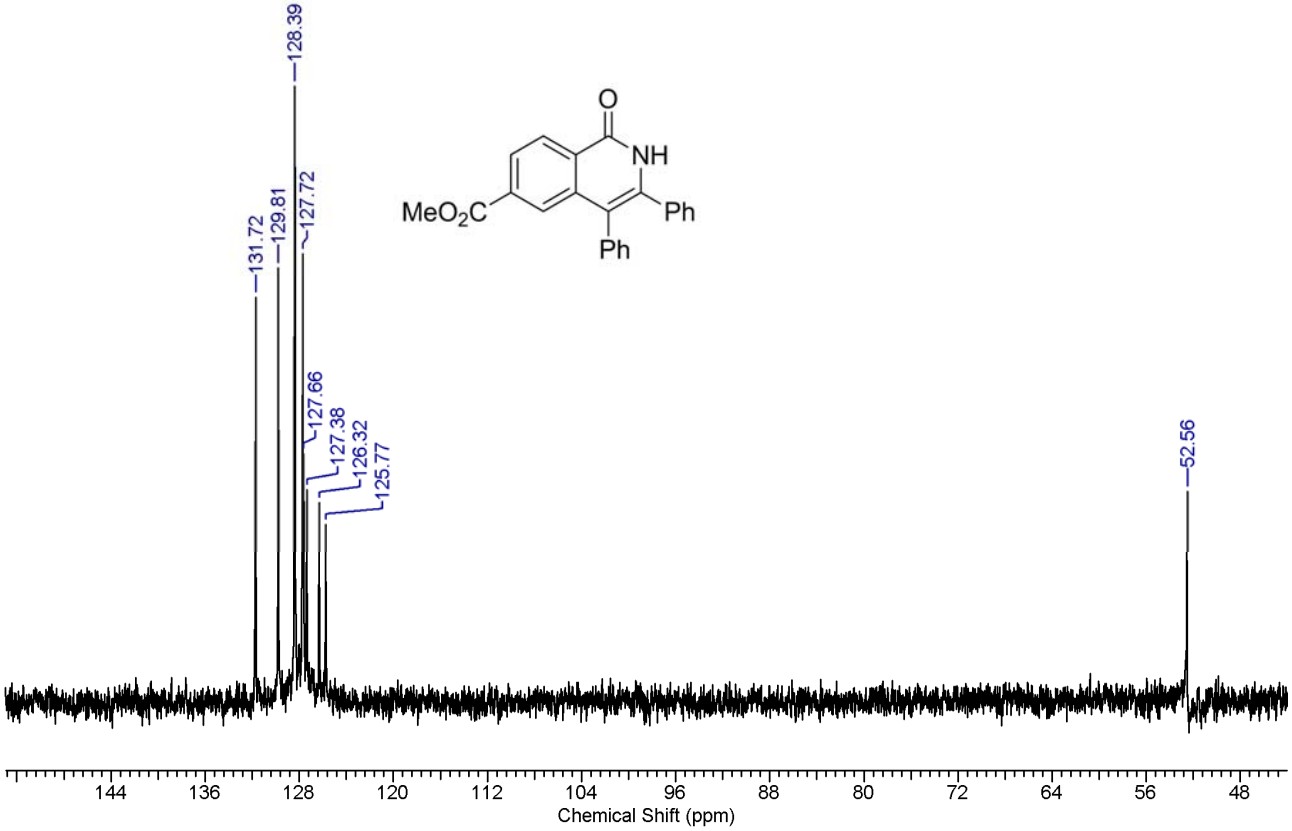


^{1}H and ^{13}C NMR Spectra of Compound **3m.**

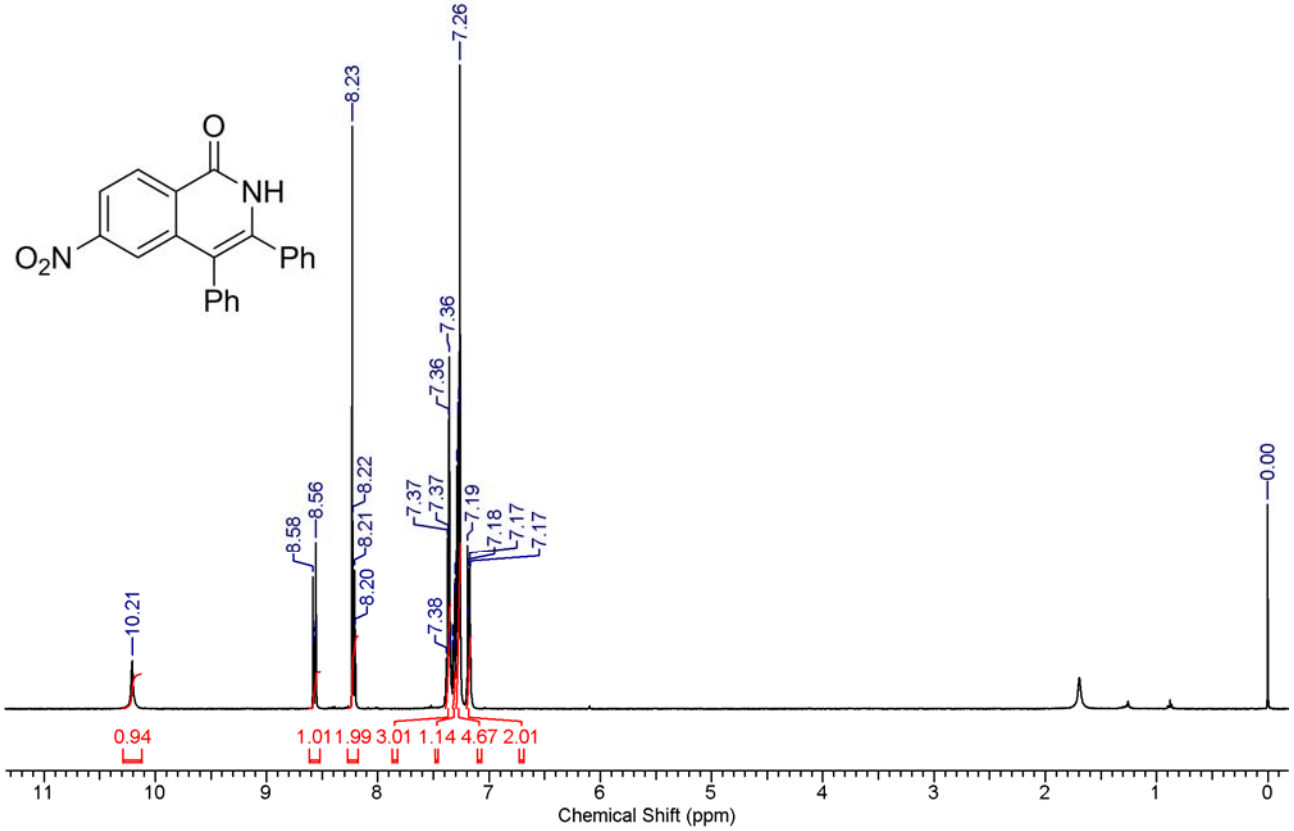


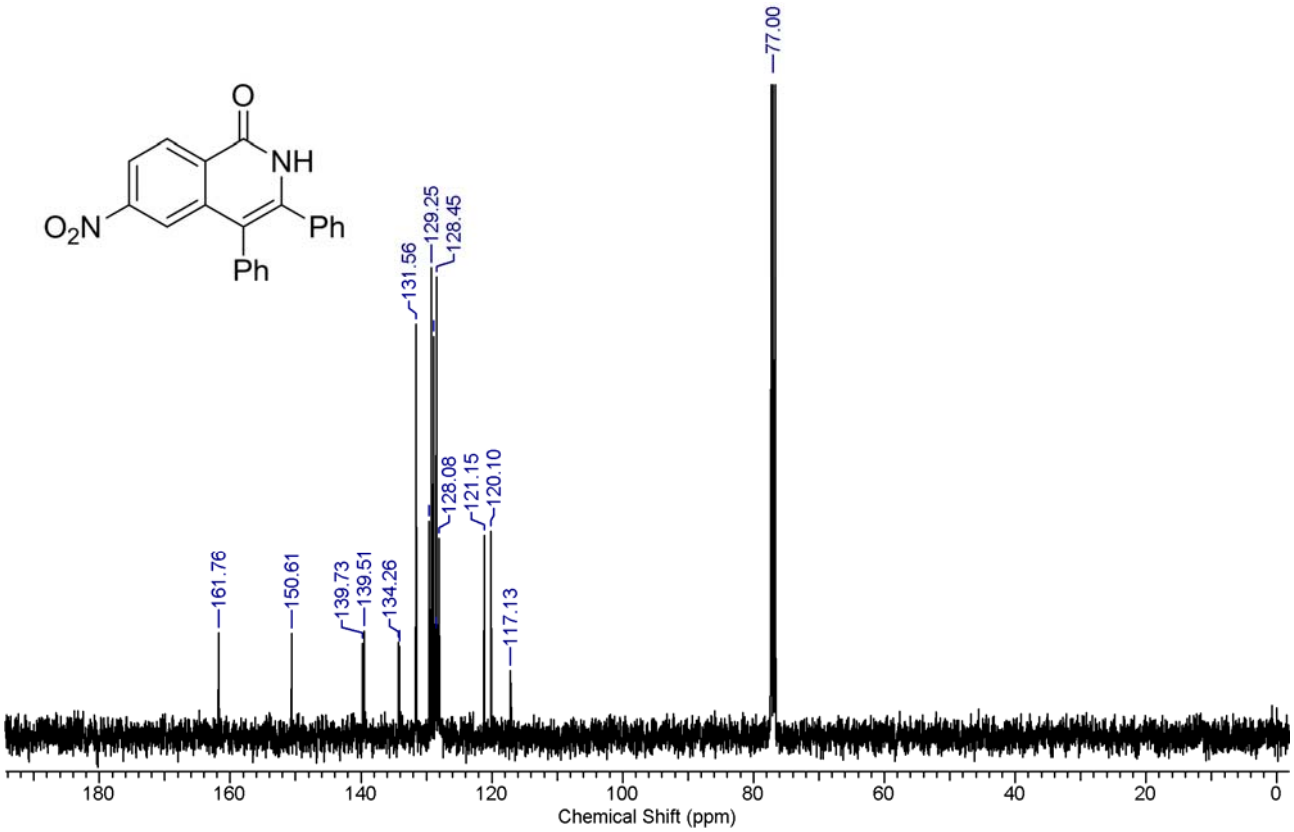


DEPT (135) NMR Spectrum of Compound **3m.**

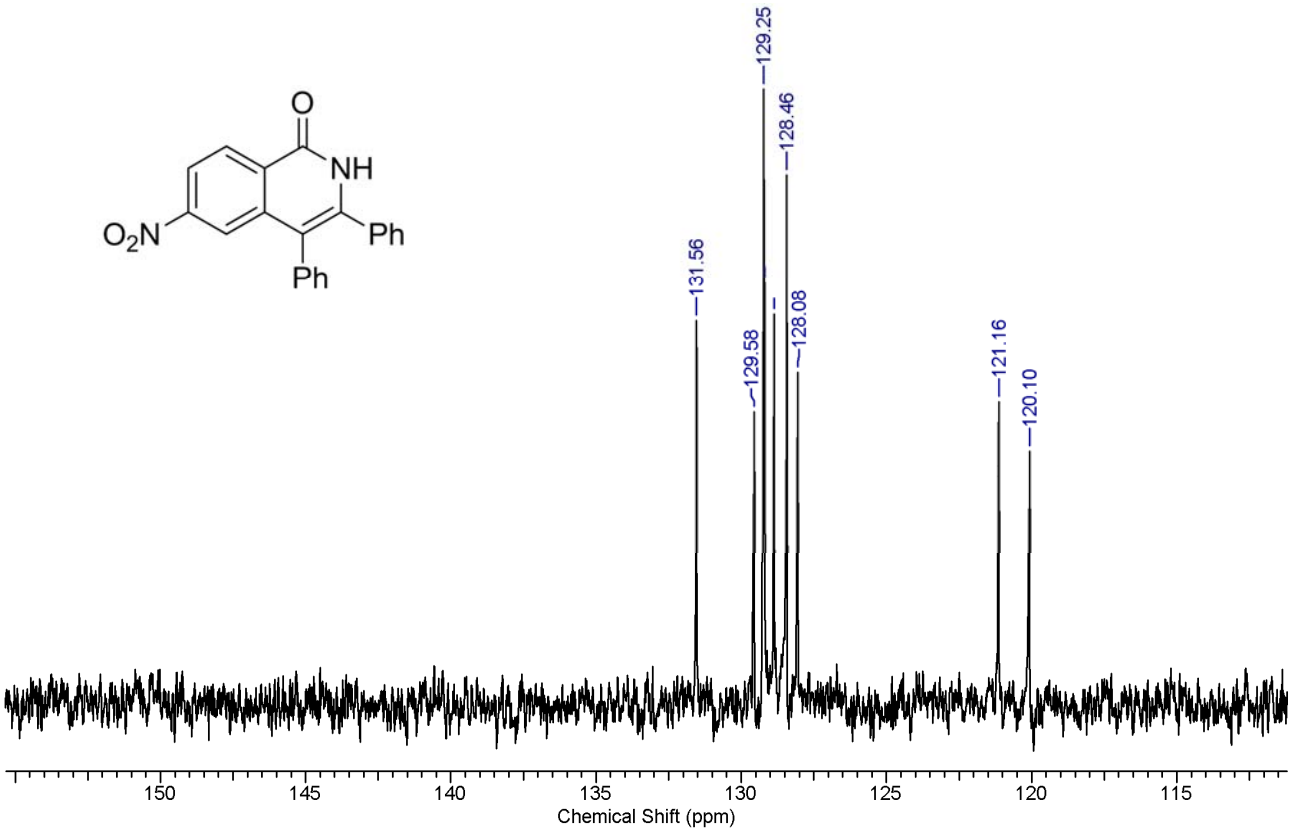


^{1}H and ^{13}C NMR Spectra of Compound **3n.**

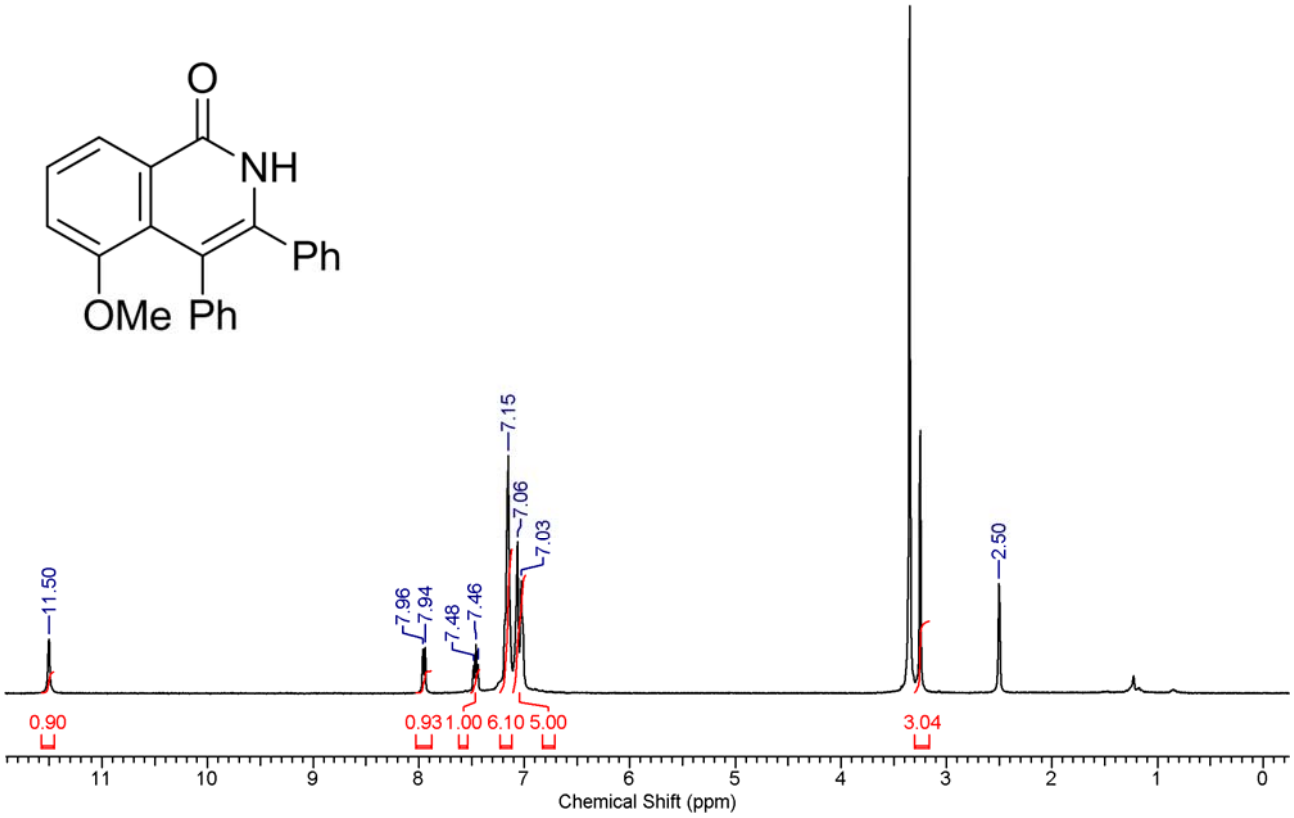


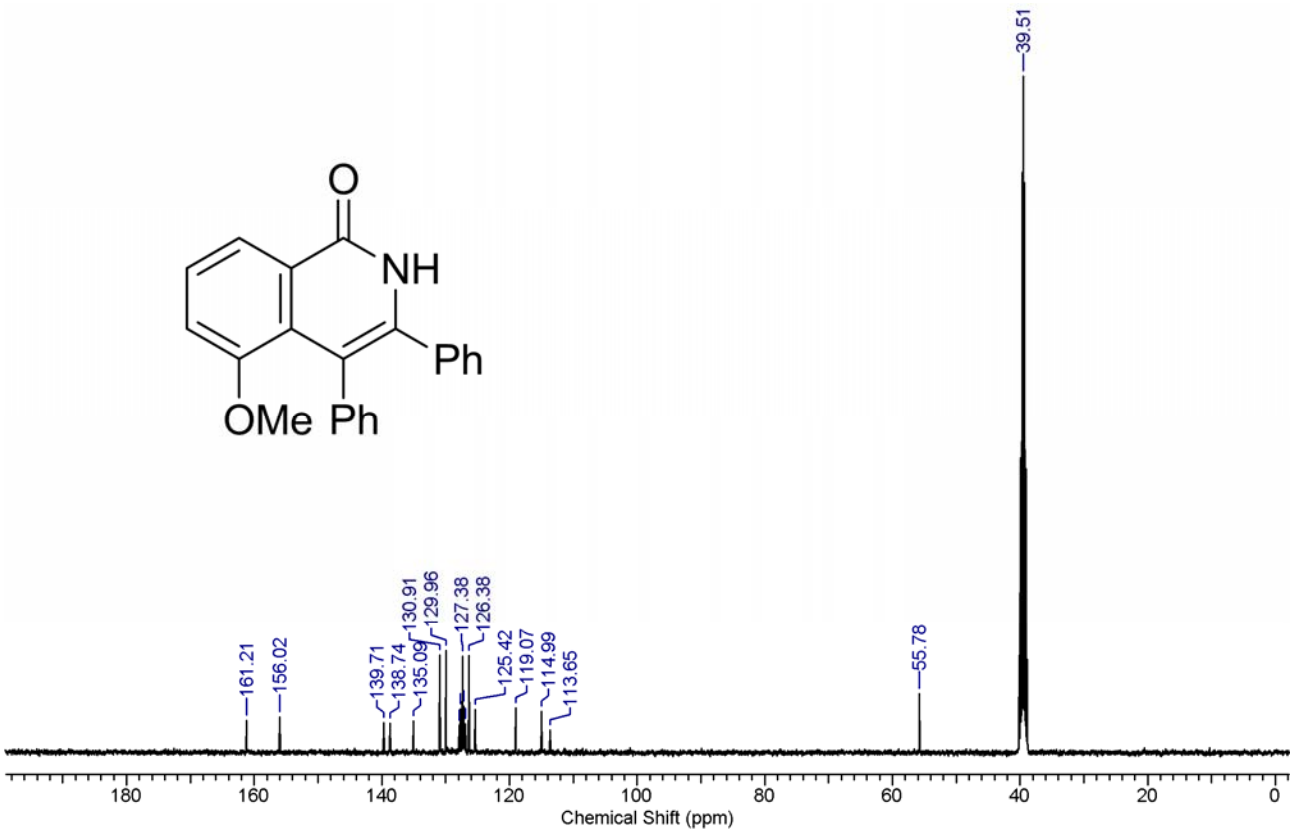


DEPT (135) NMR Spectrum of Compound **3n.**

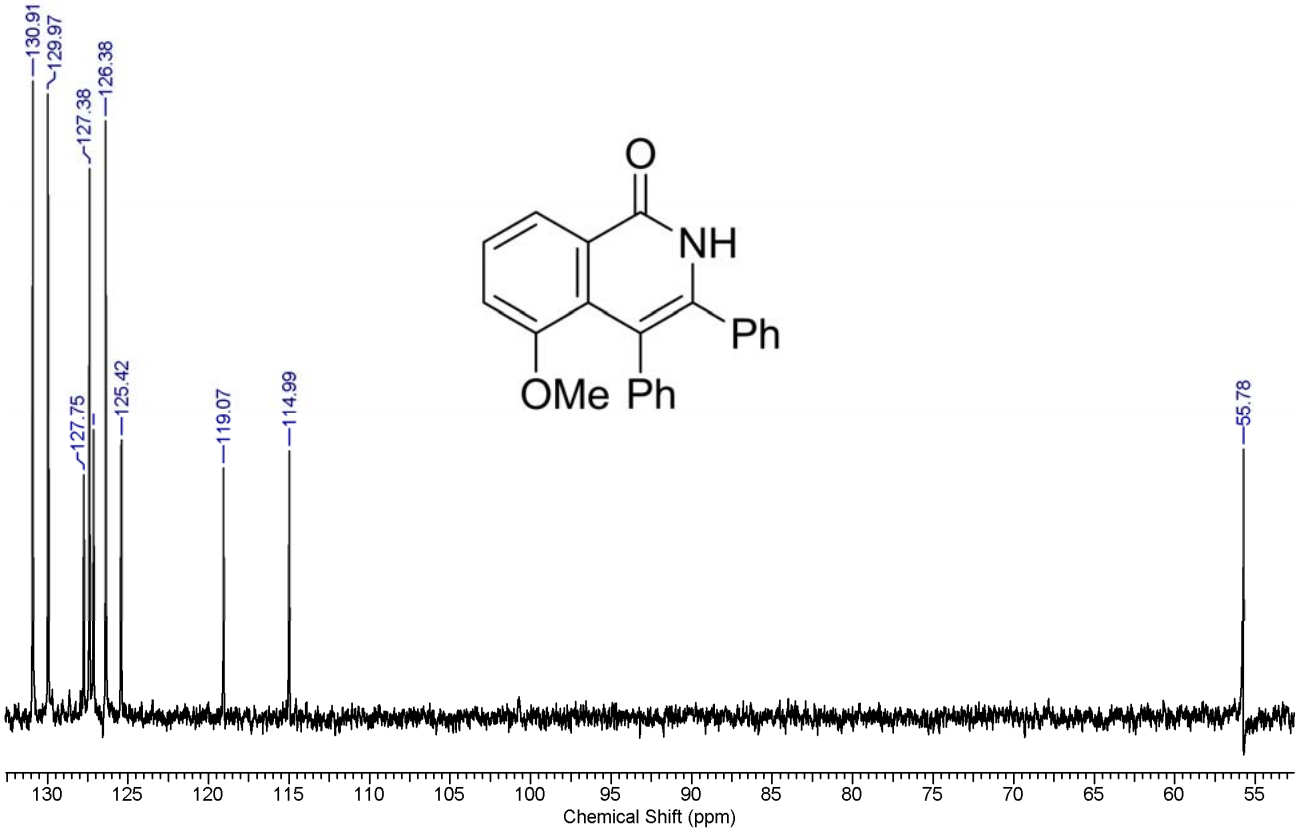


^{1}H and ^{13}C NMR Spectra of Compound **3o.**

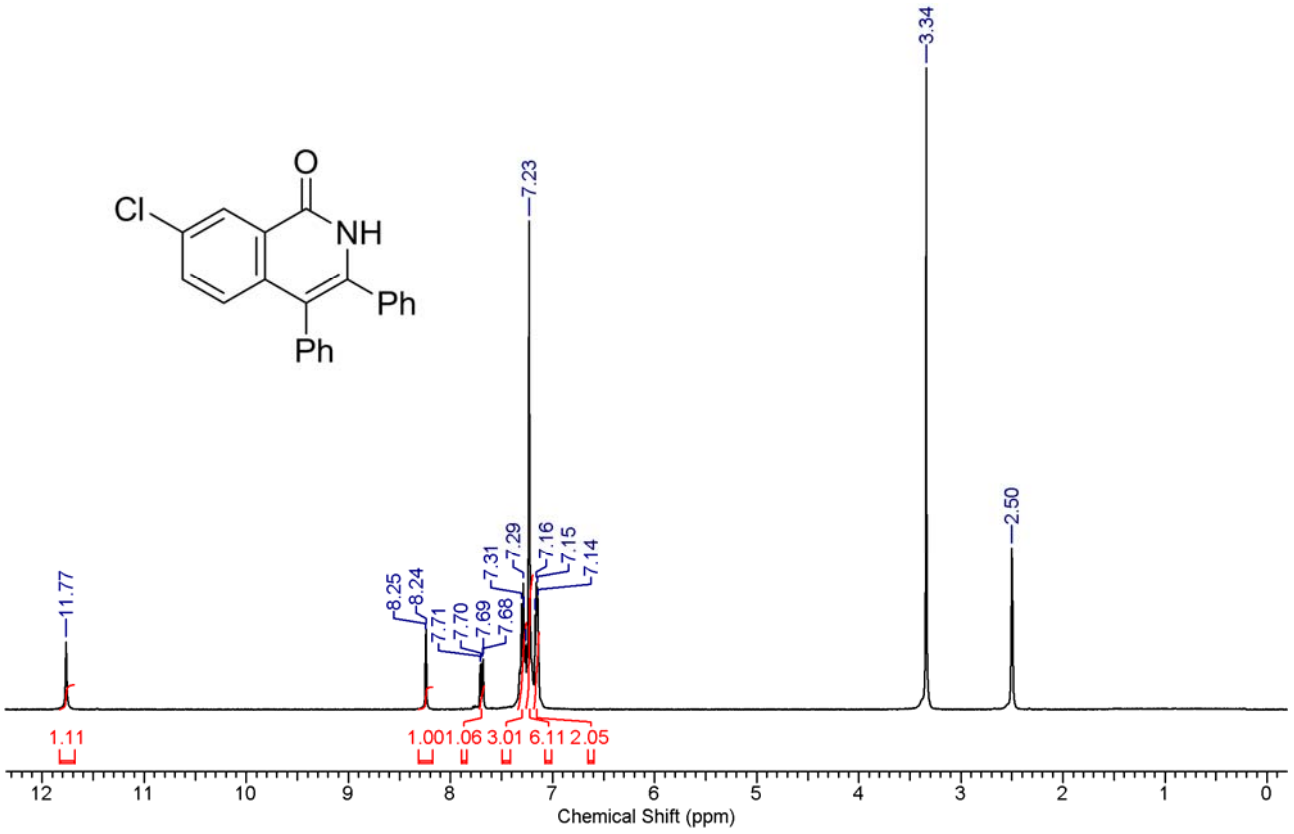


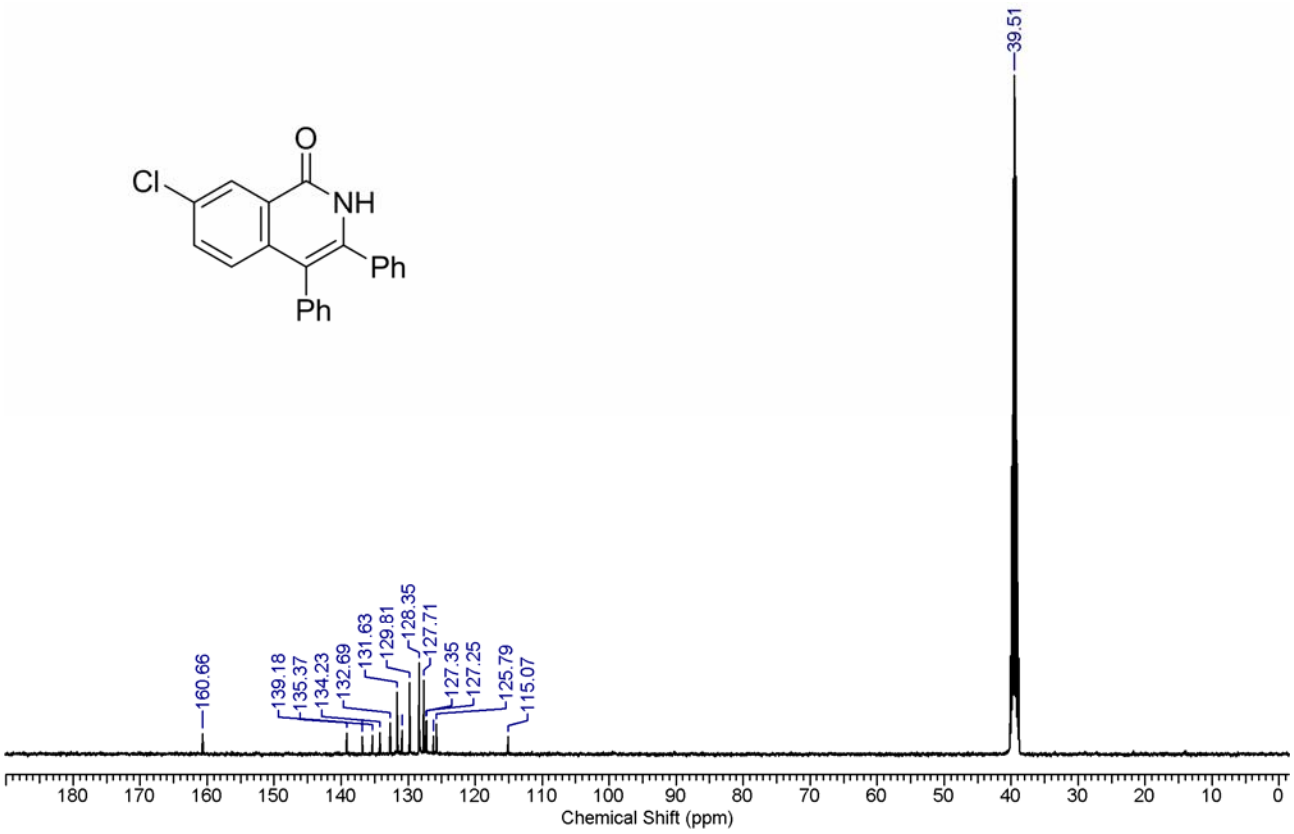


DEPT (135) NMR Spectrum of Compound **3o.**

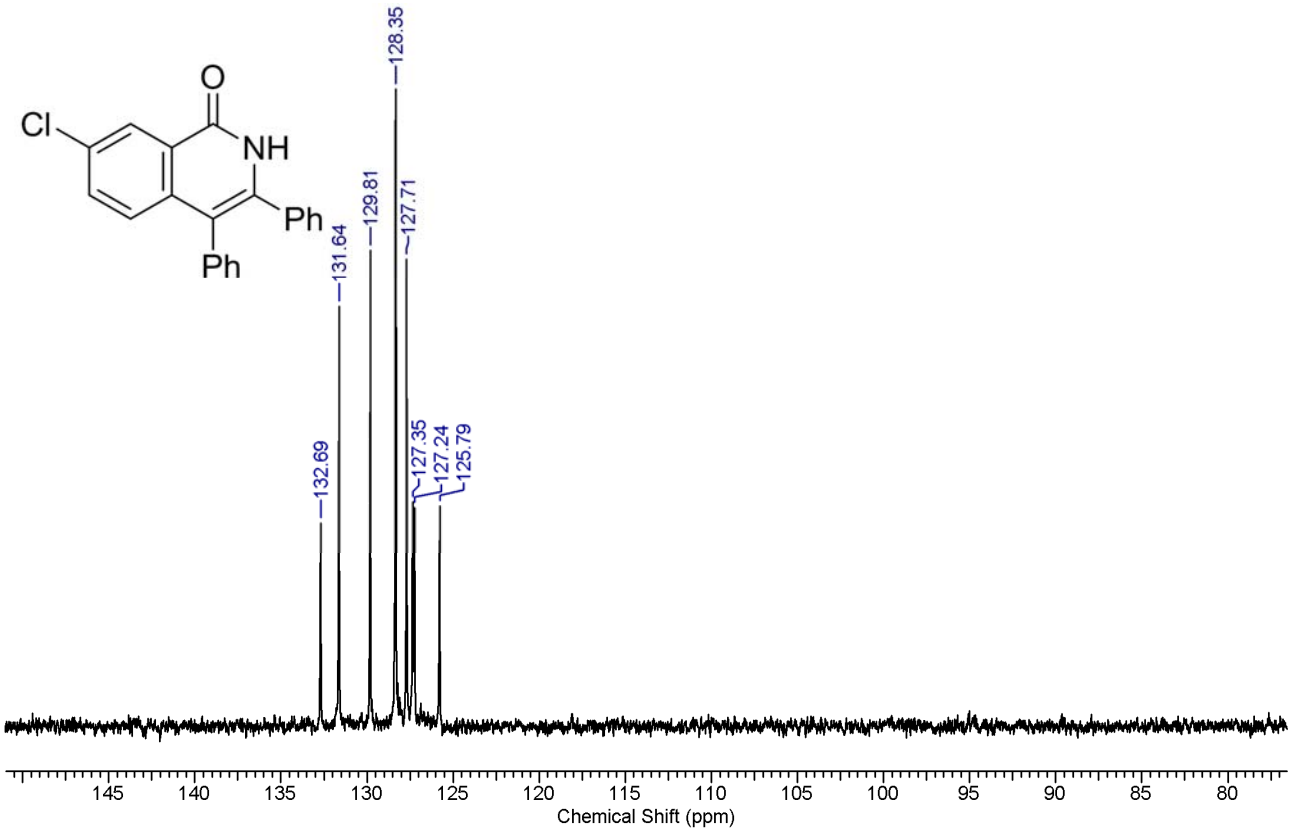


^{1}H and ^{13}C NMR Spectra of Compound **3p.**

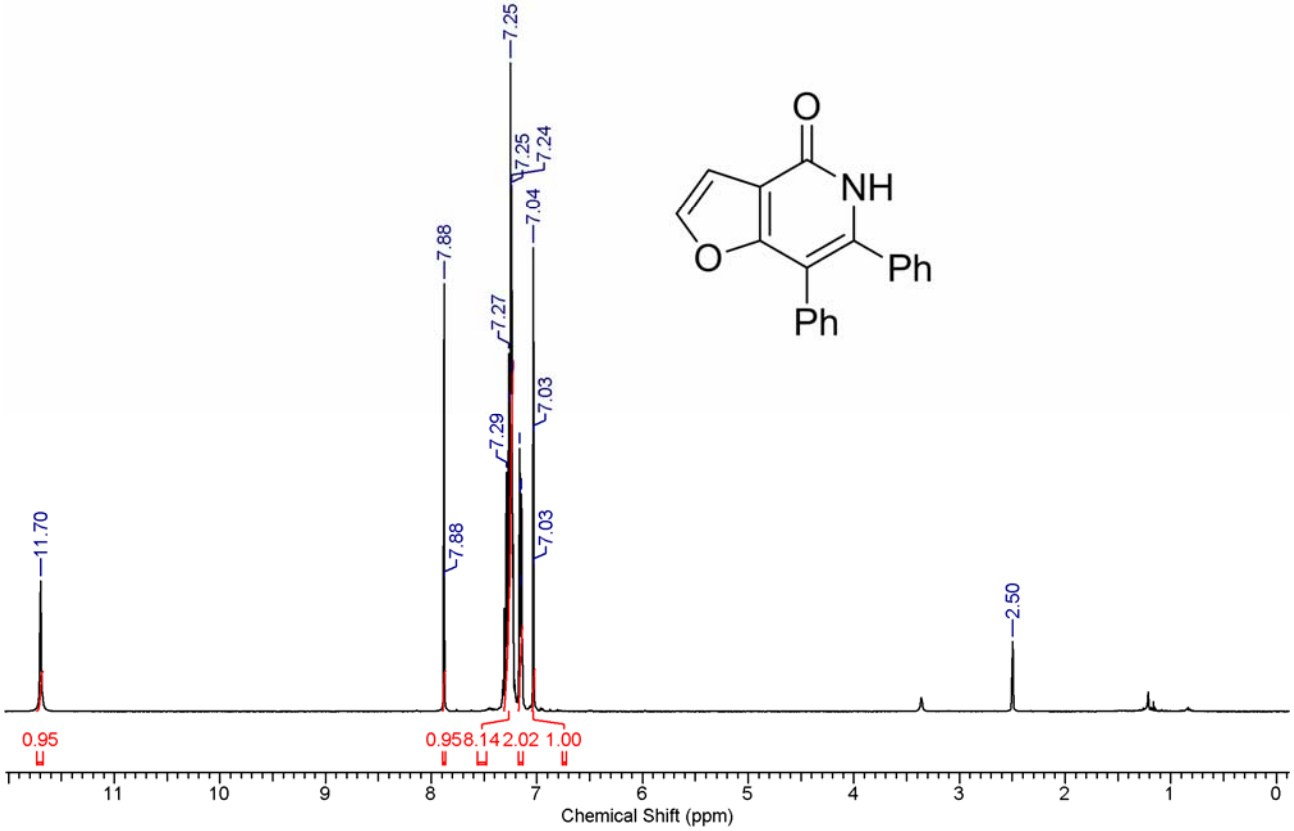


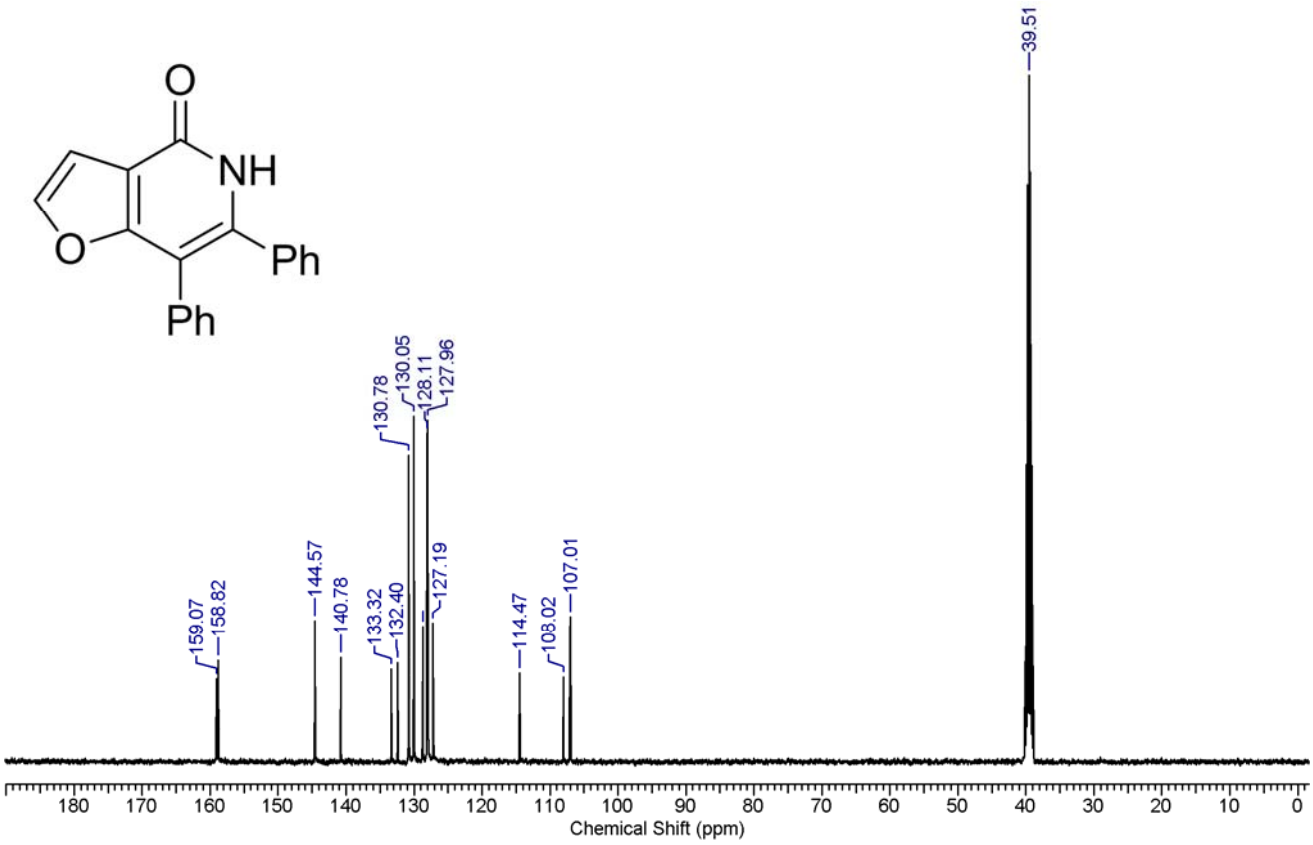


DEPT (135) NMR Spectrum of Compound **3p.**

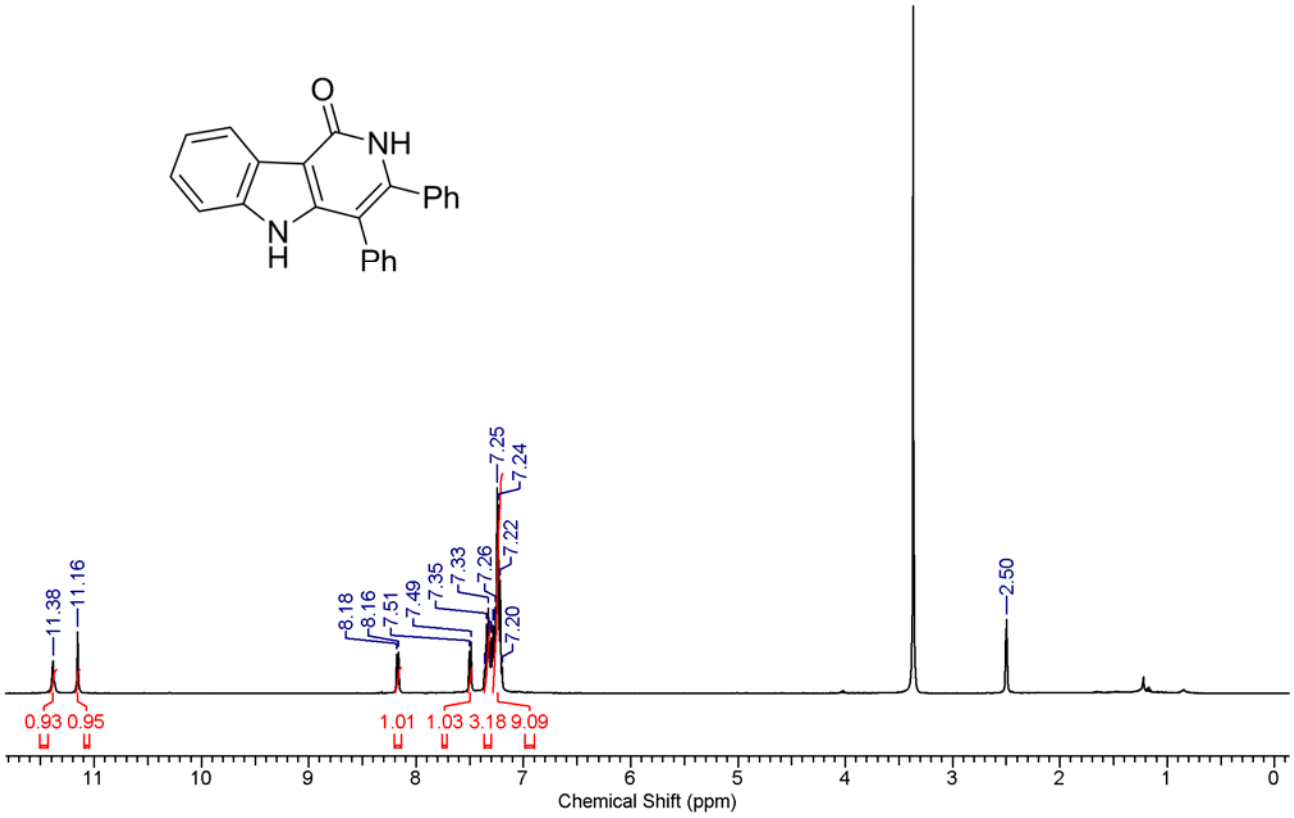


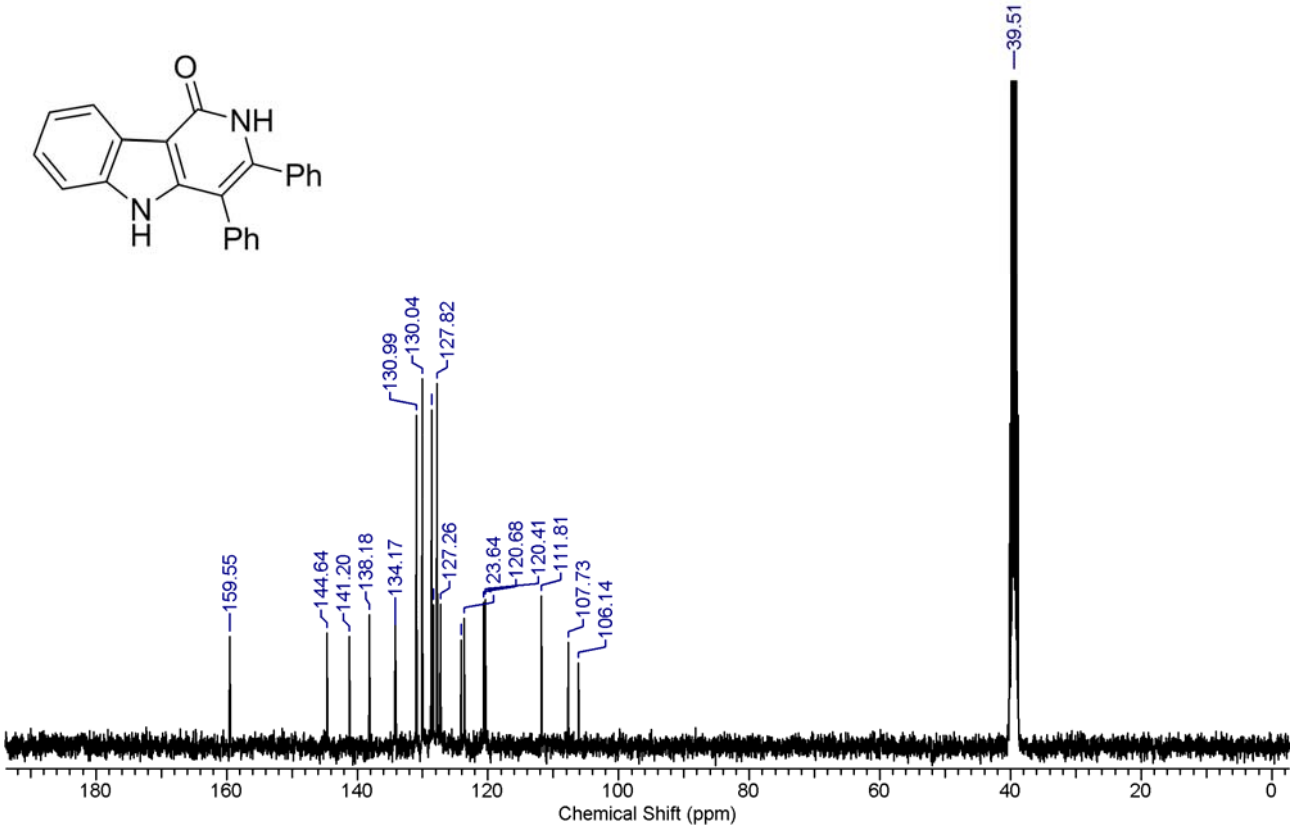
^{1}H and ^{13}C NMR Spectra of Compound **3q.**



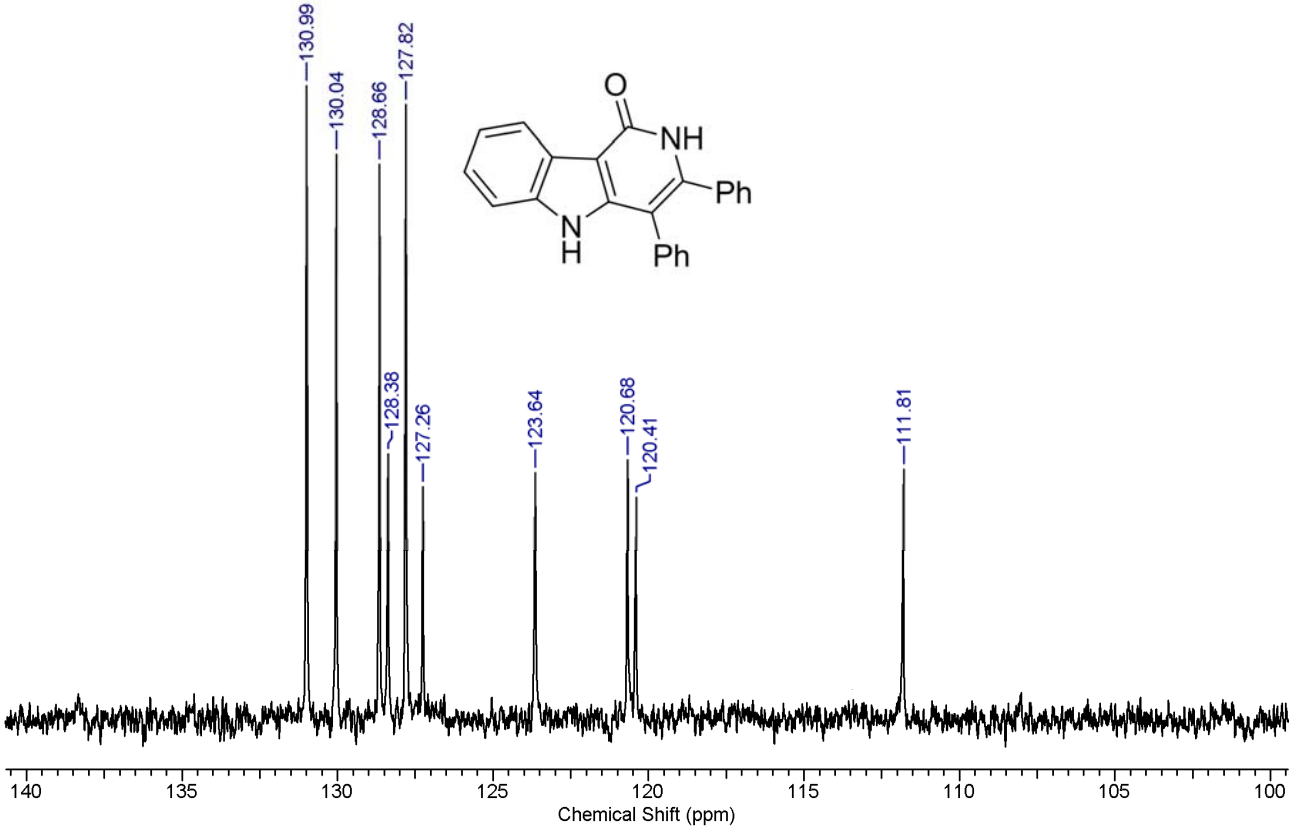


^{1}H and ^{13}C NMR Spectra of Compound **3r.**

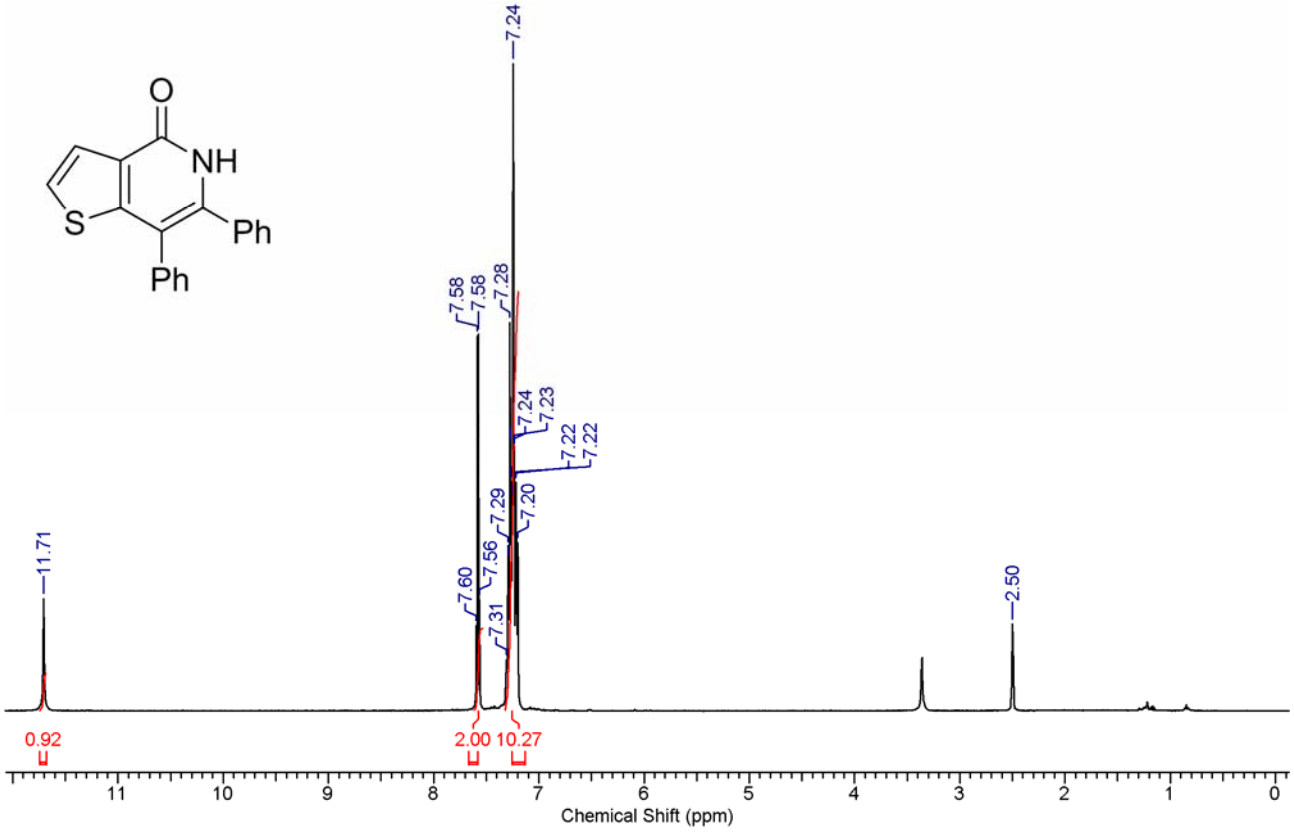


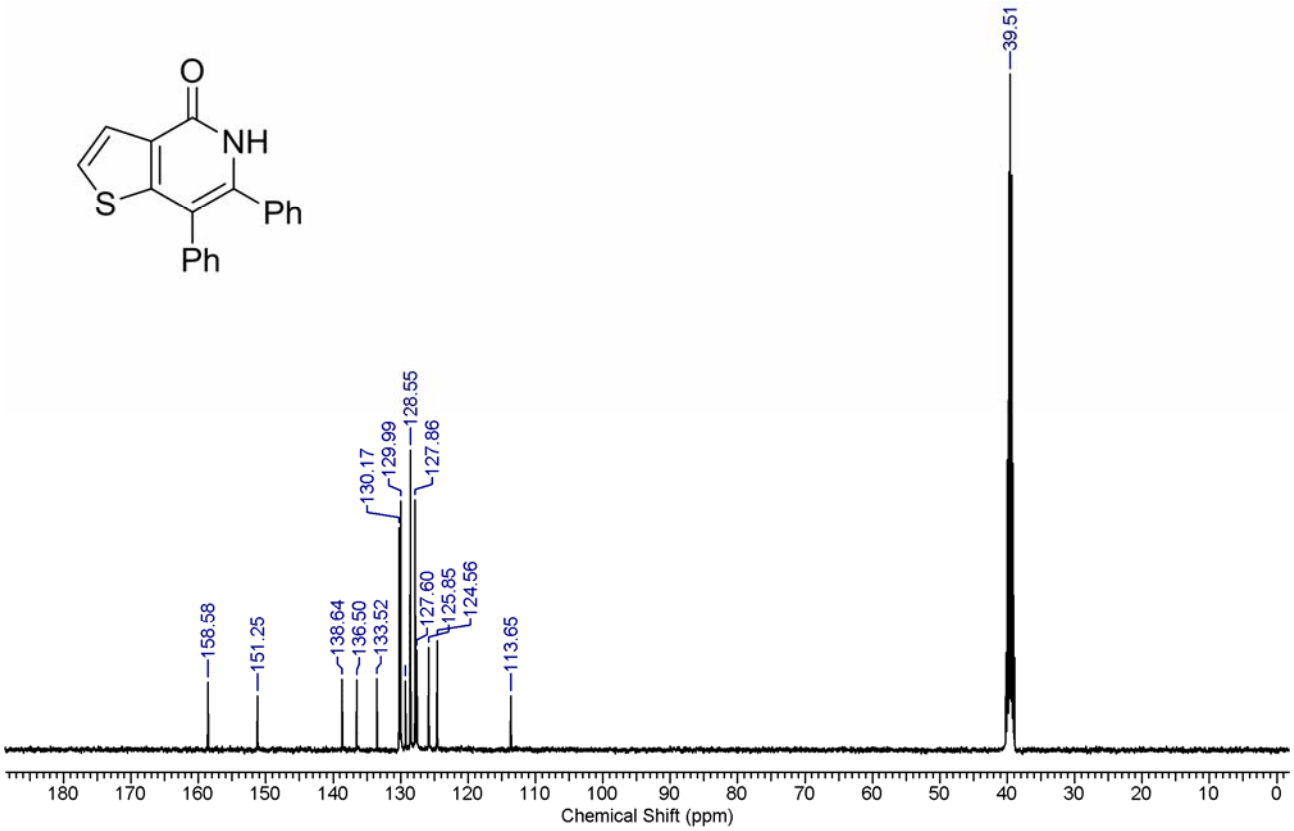


DEPT (135) NMR Spectrum of Compound **3r.**

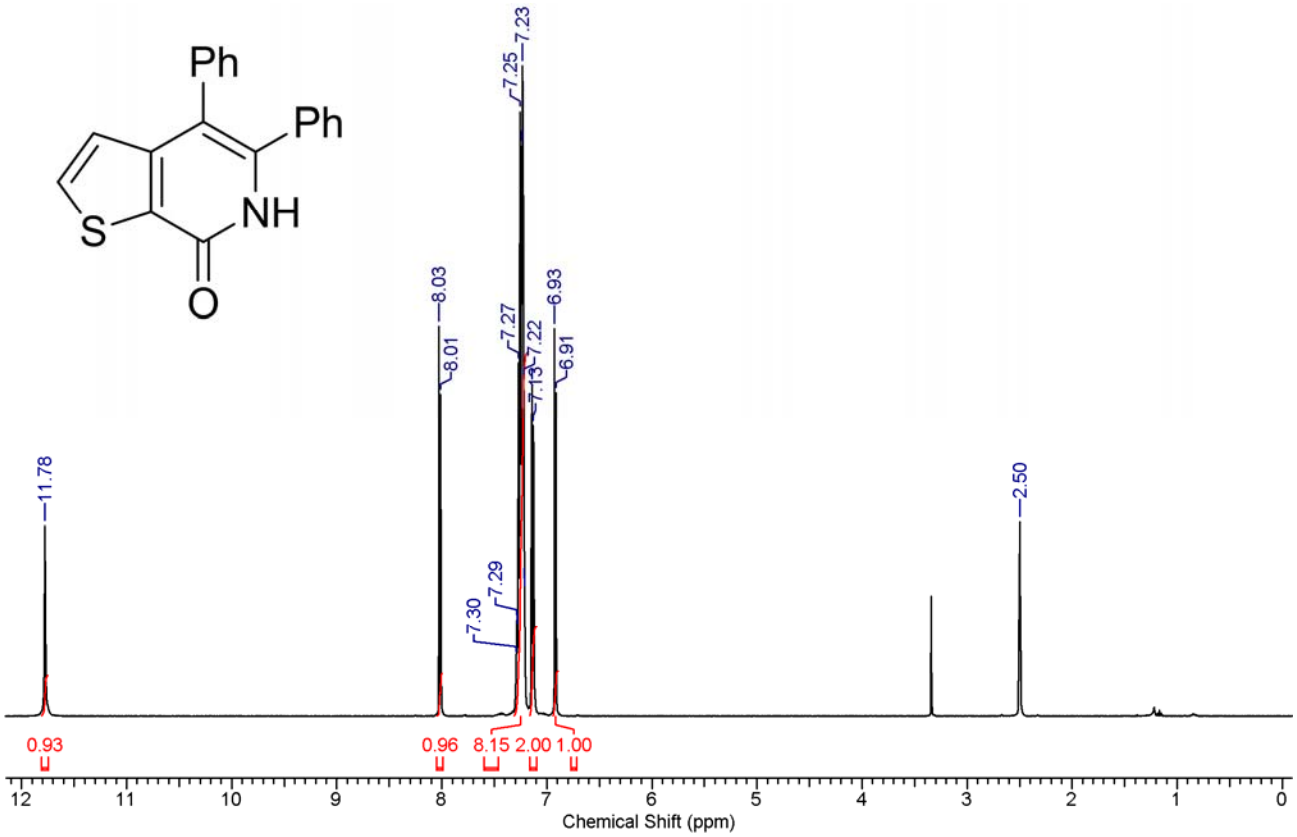


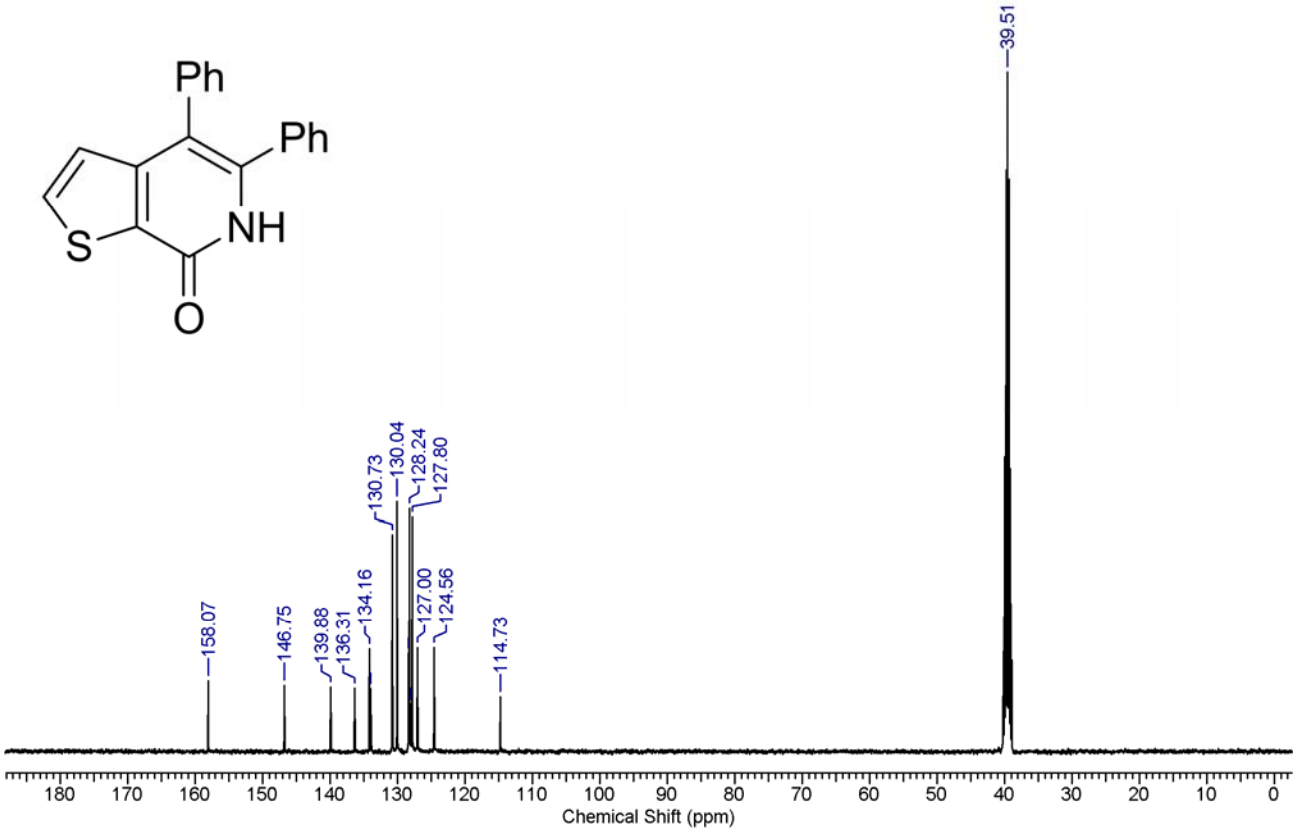
^{1}H and ^{13}C NMR Spectra of Compound **3s.**



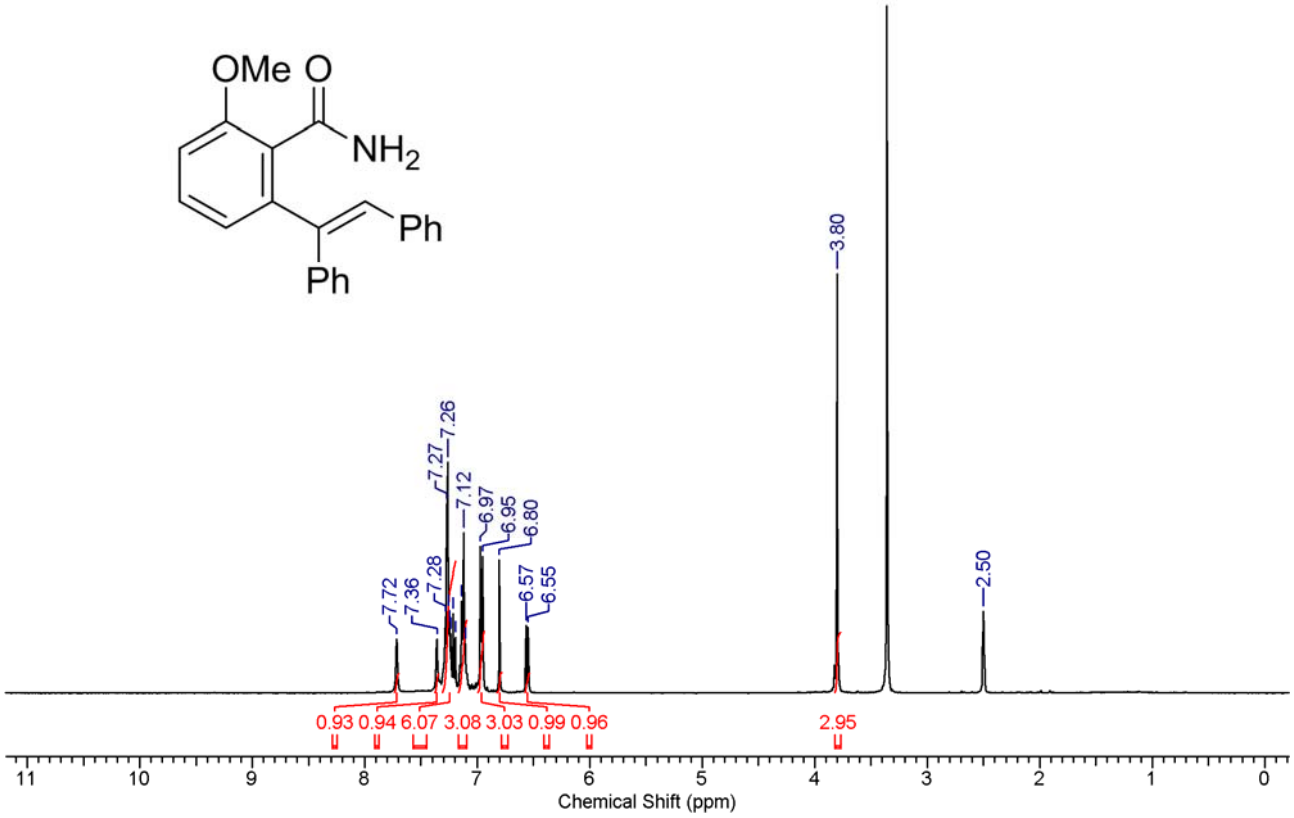


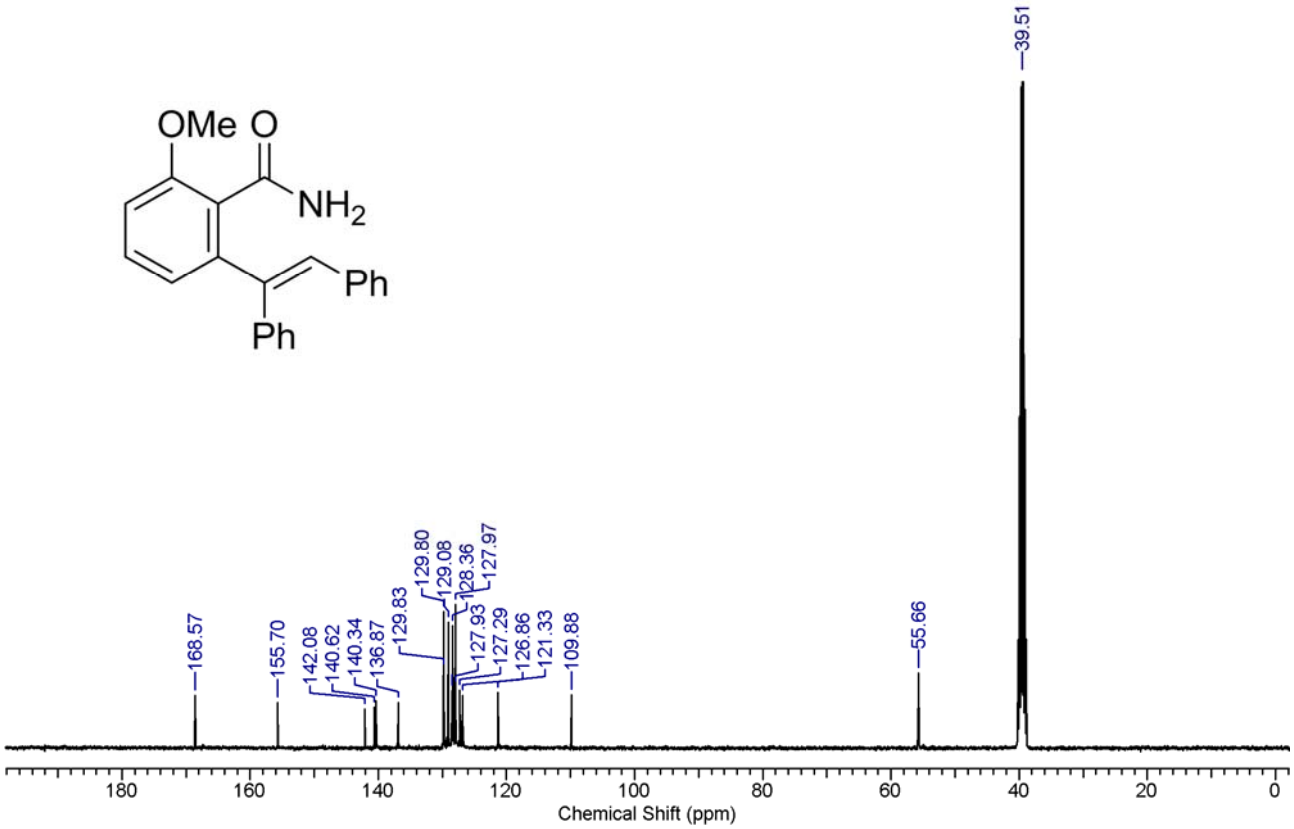
^{1}H and ^{13}C NMR Spectra of Compound **3t.**



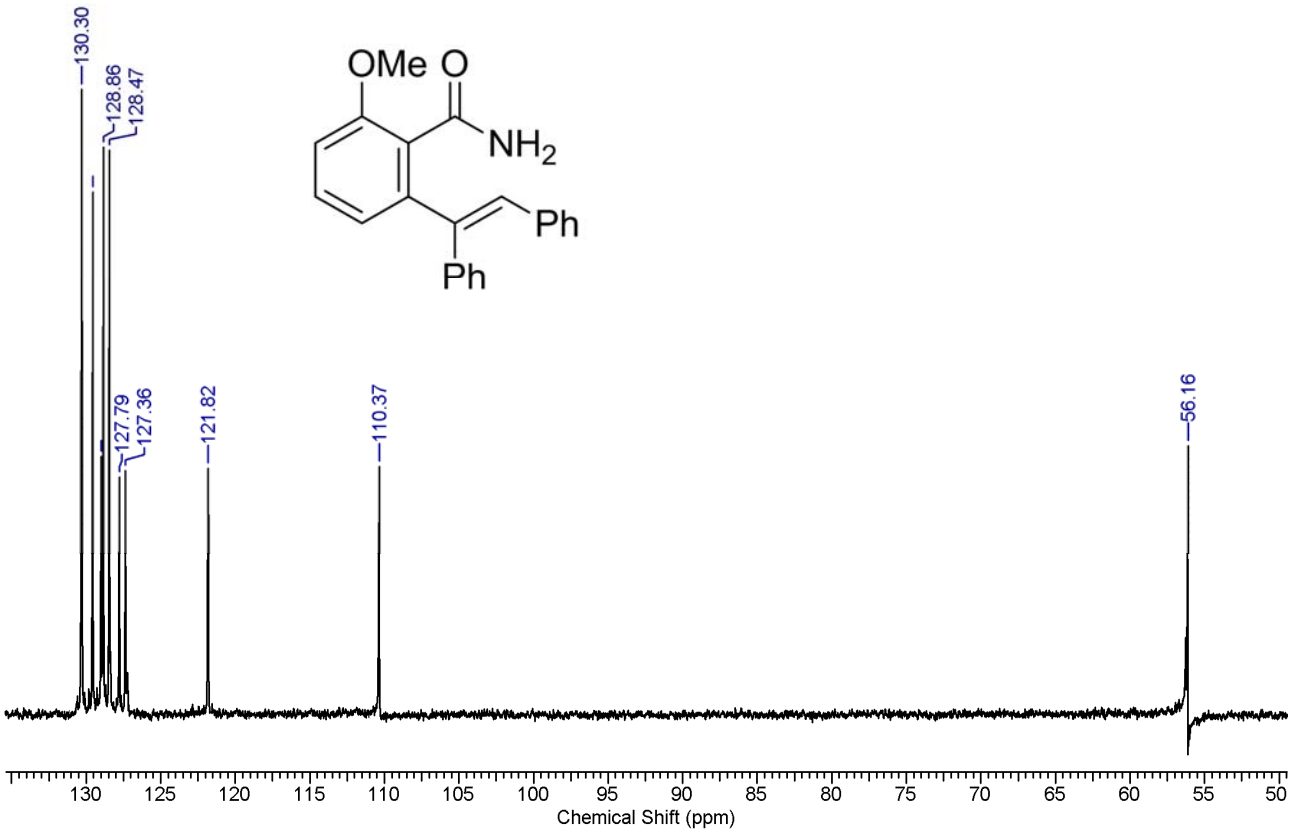


^{1}H and ^{13}C NMR Spectra of Compound **3u.**

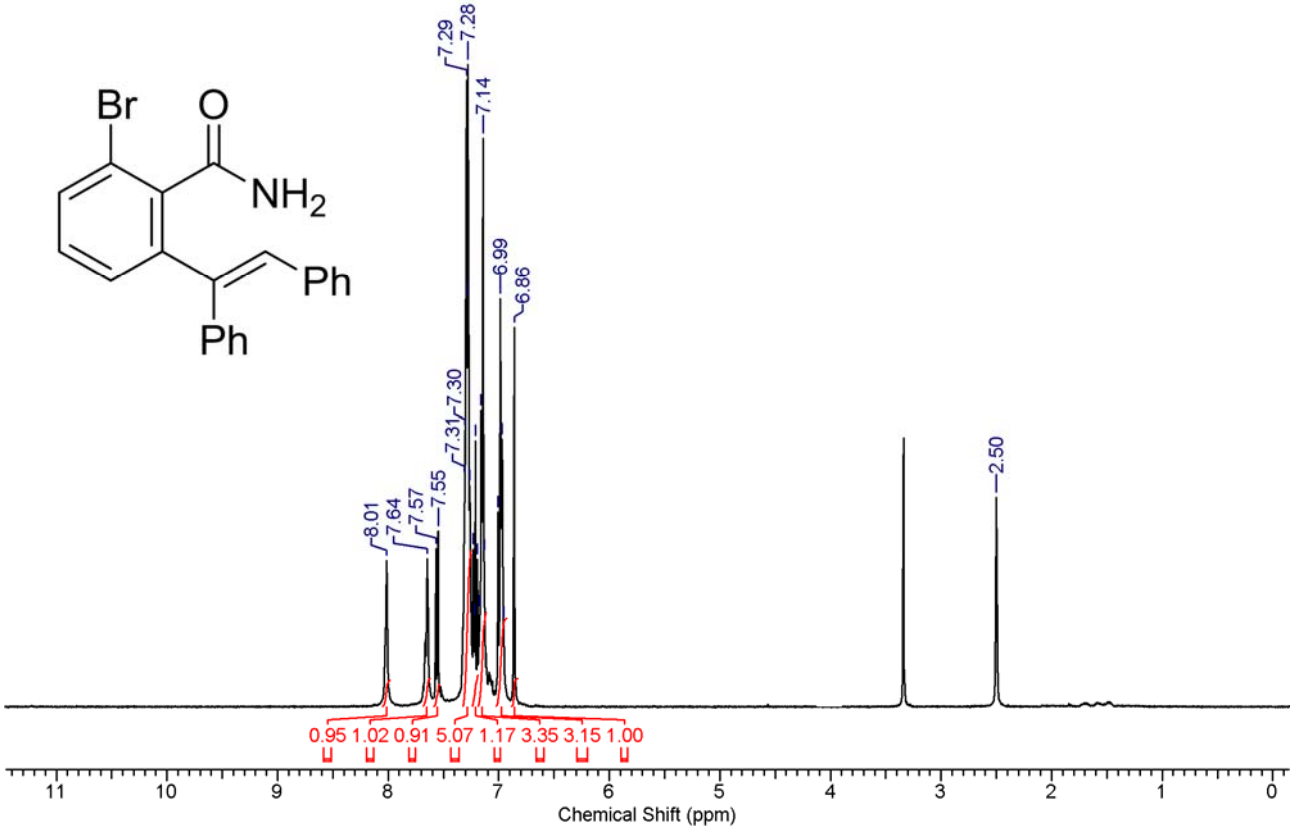


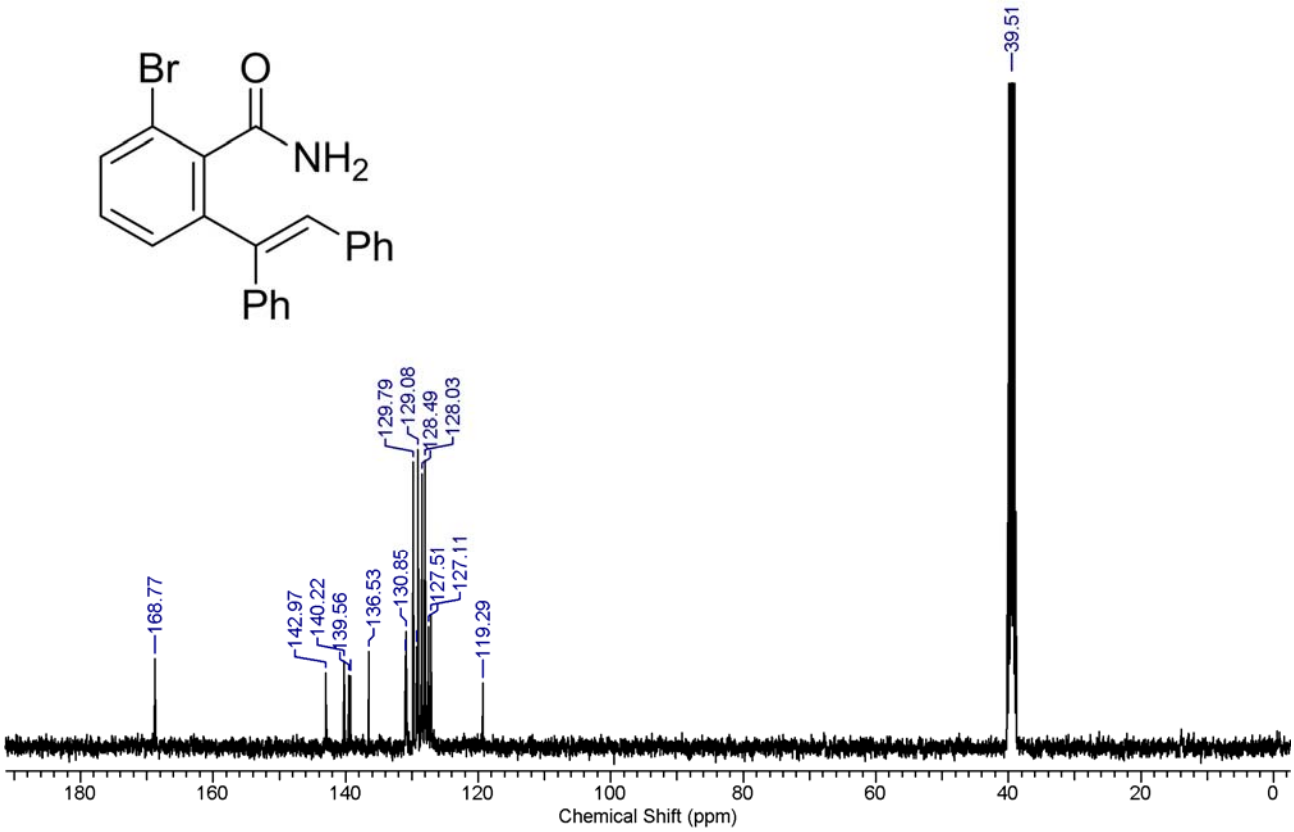


DEPT (135) NMR Spectrum of Compound **3u.**

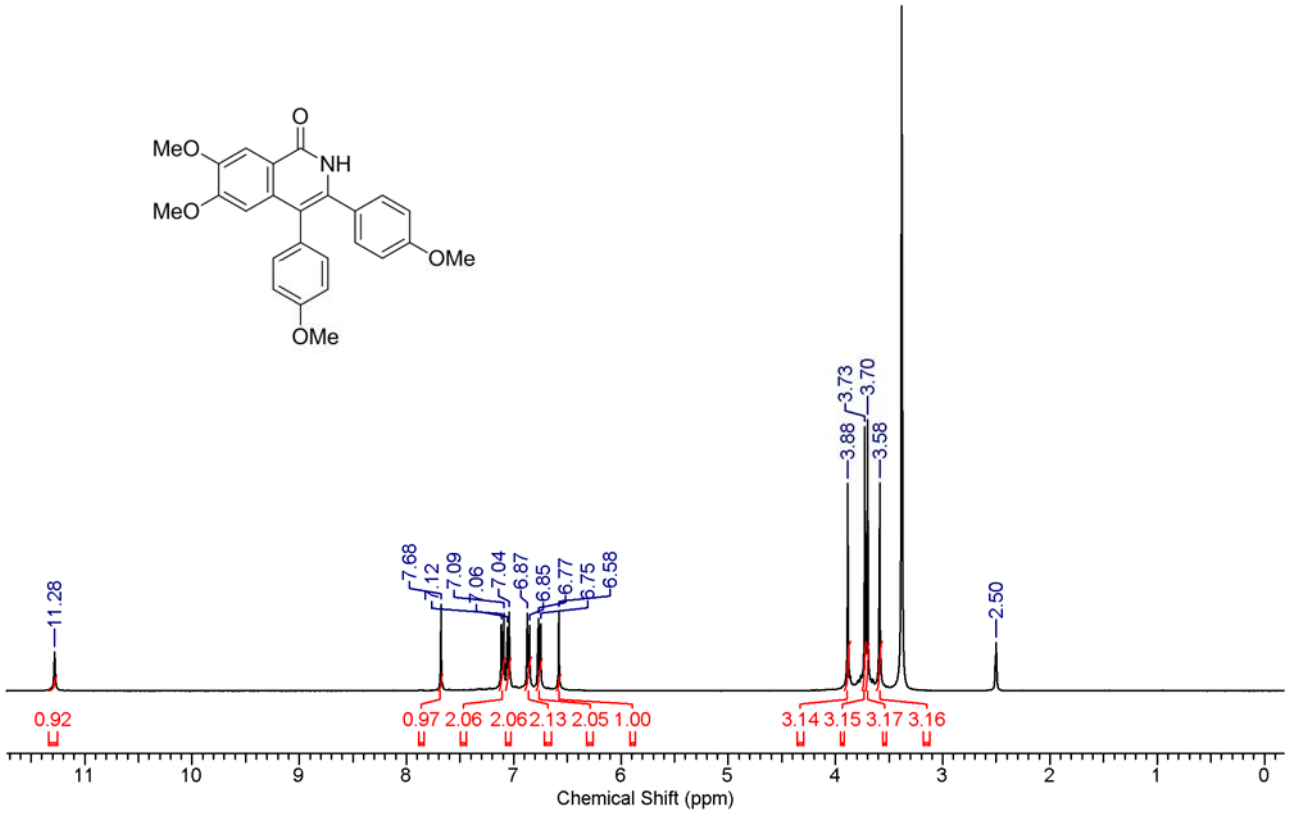


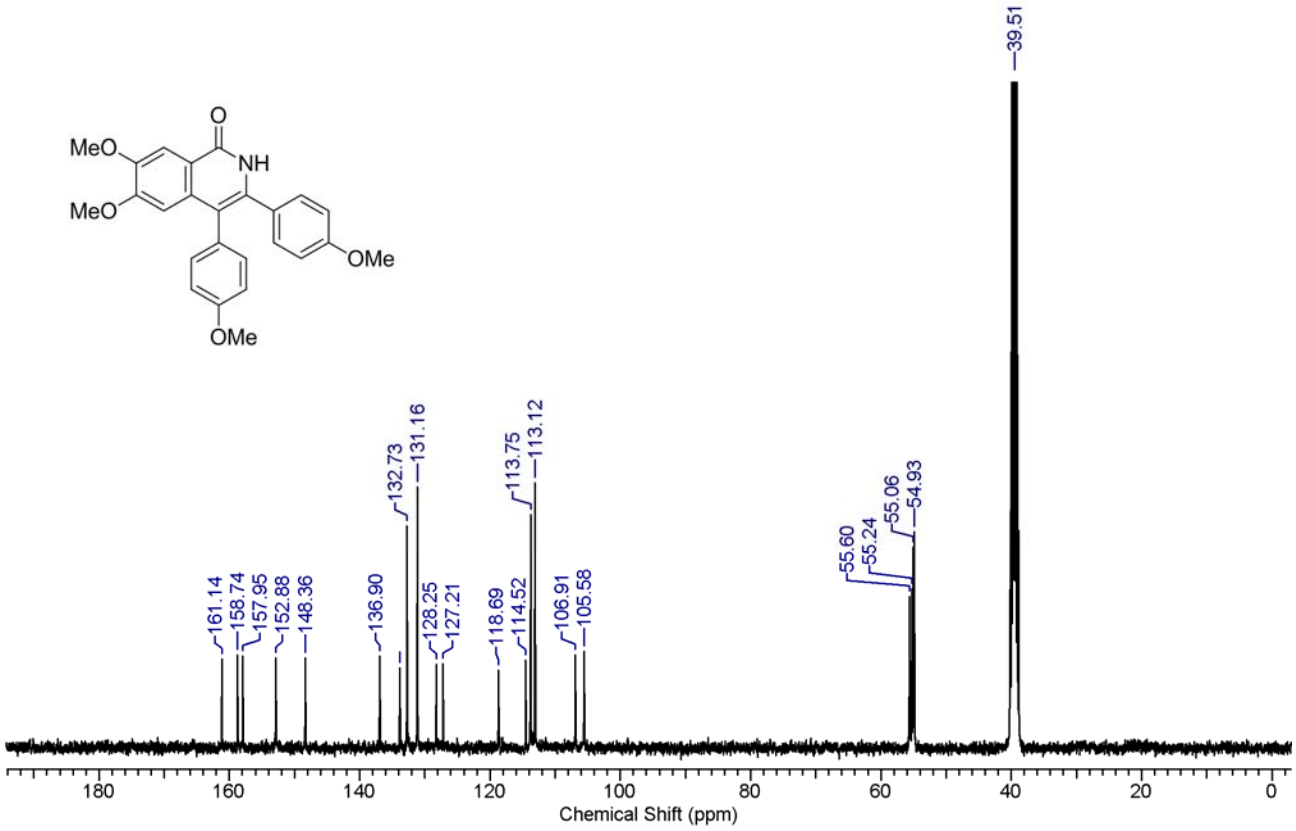
^{1}H and ^{13}C NMR Spectra of Compound **3v.**



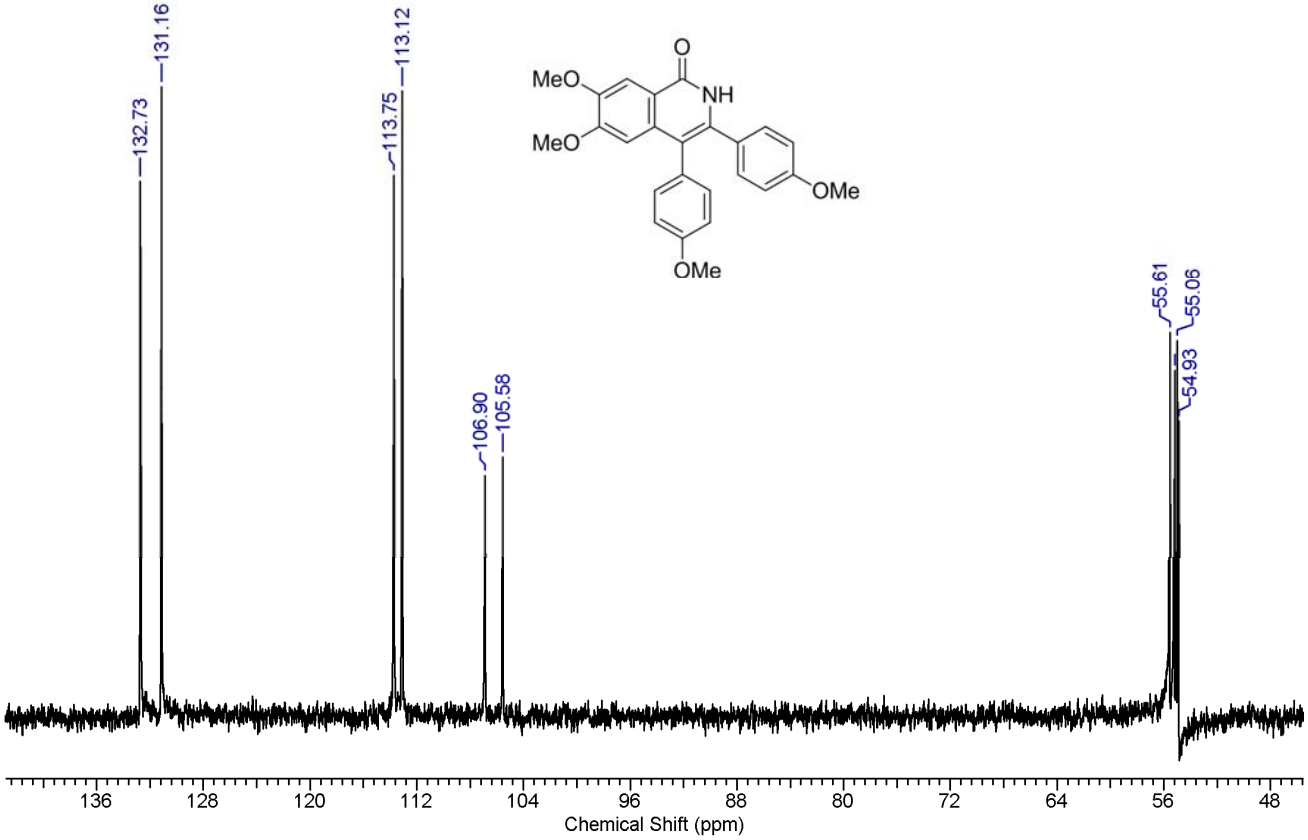


^{1}H and ^{13}C NMR Spectra of Compound **4a.**

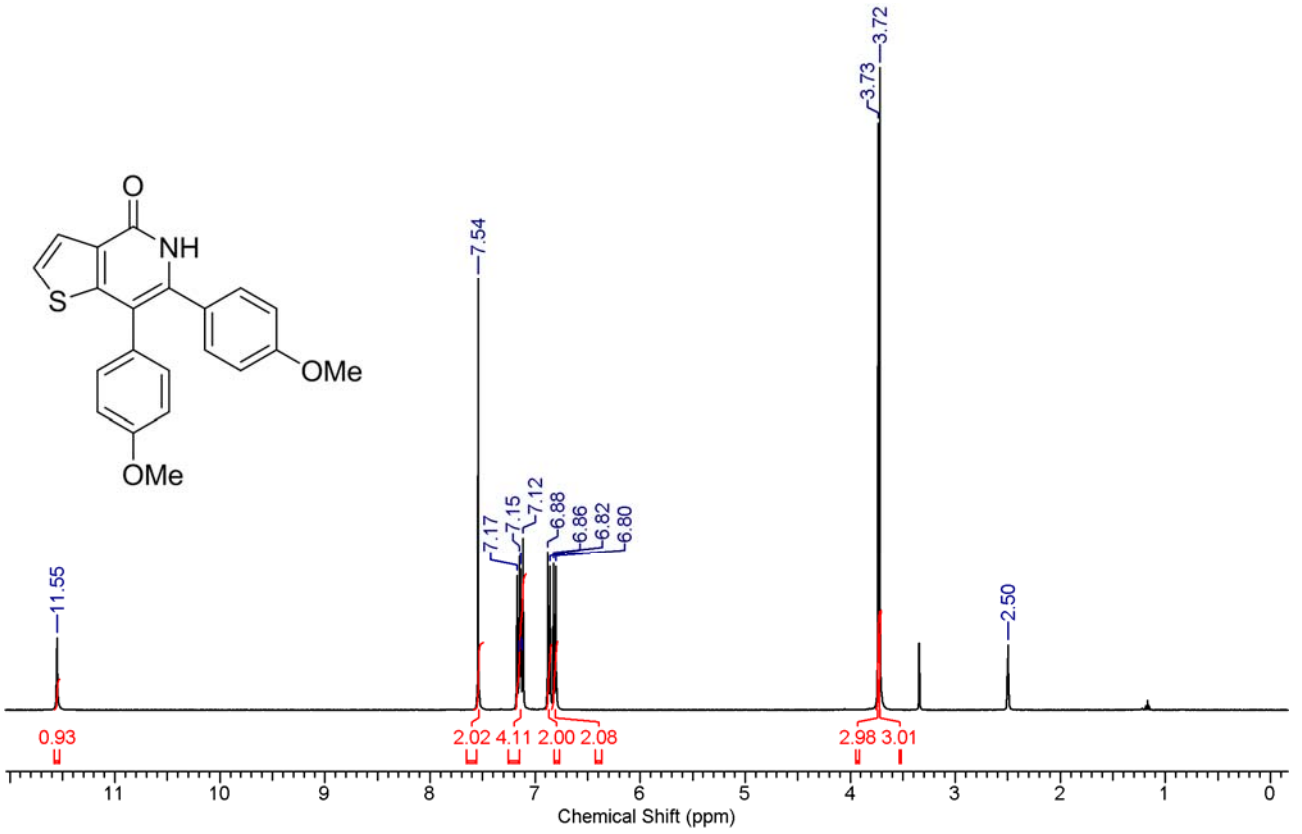


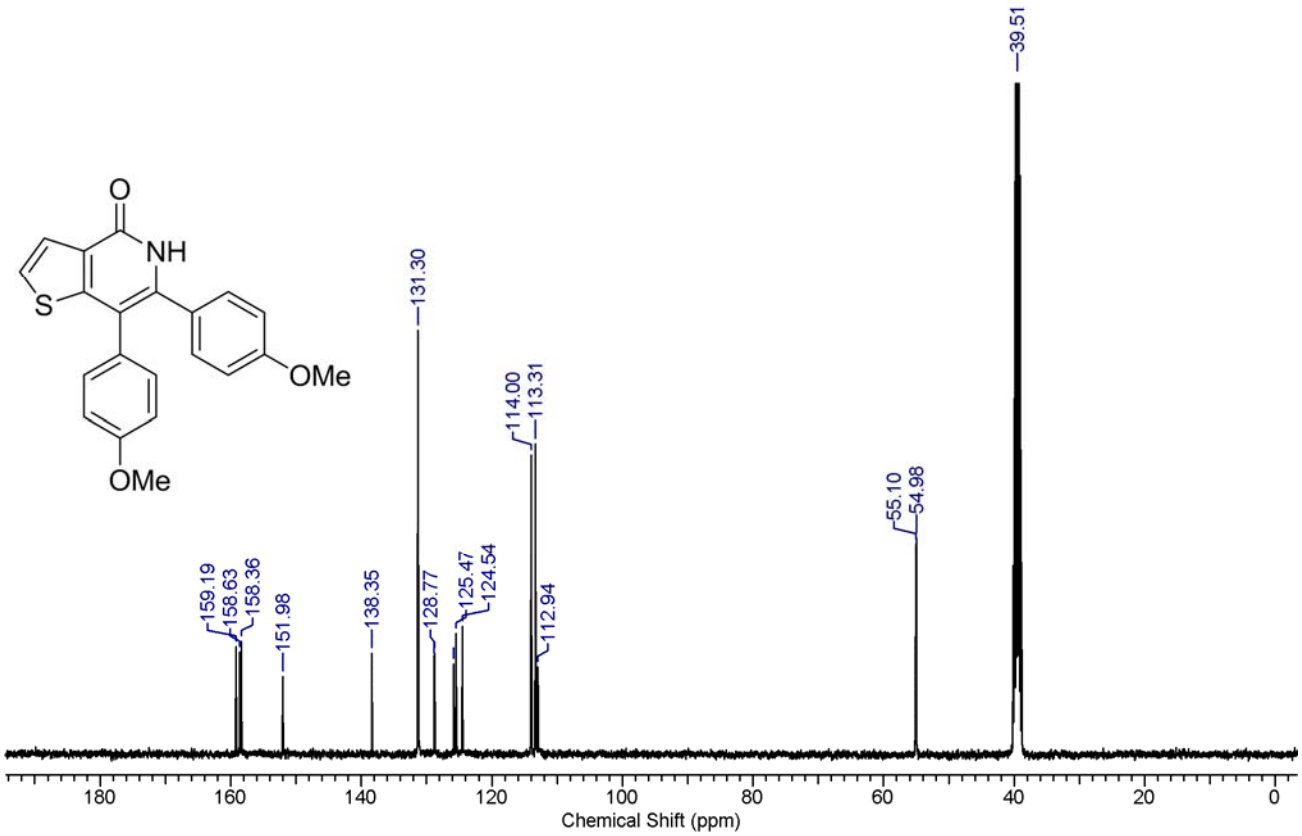


DEPT (135) NMR Spectrum of Compound **4a.**

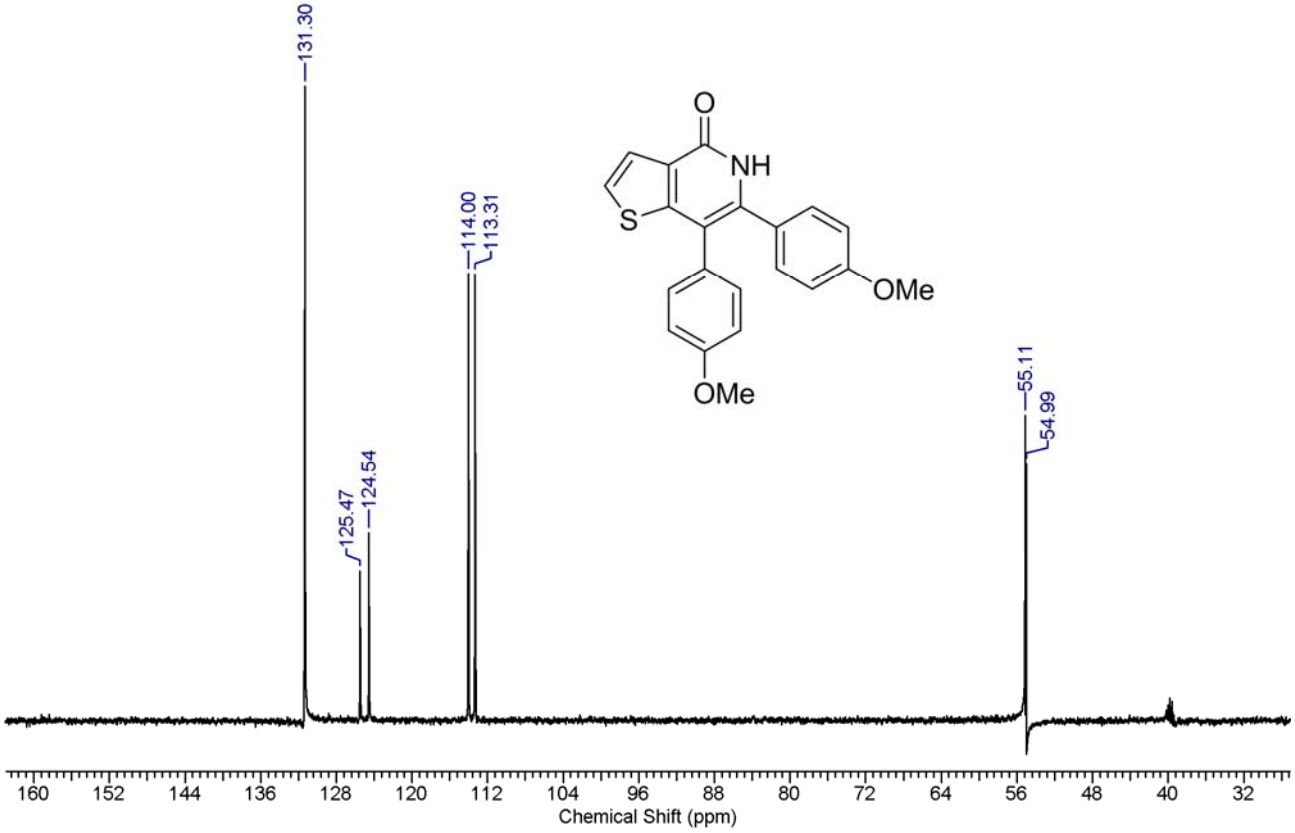


^{1}H and ^{13}C NMR Spectra of Compound **4b.**

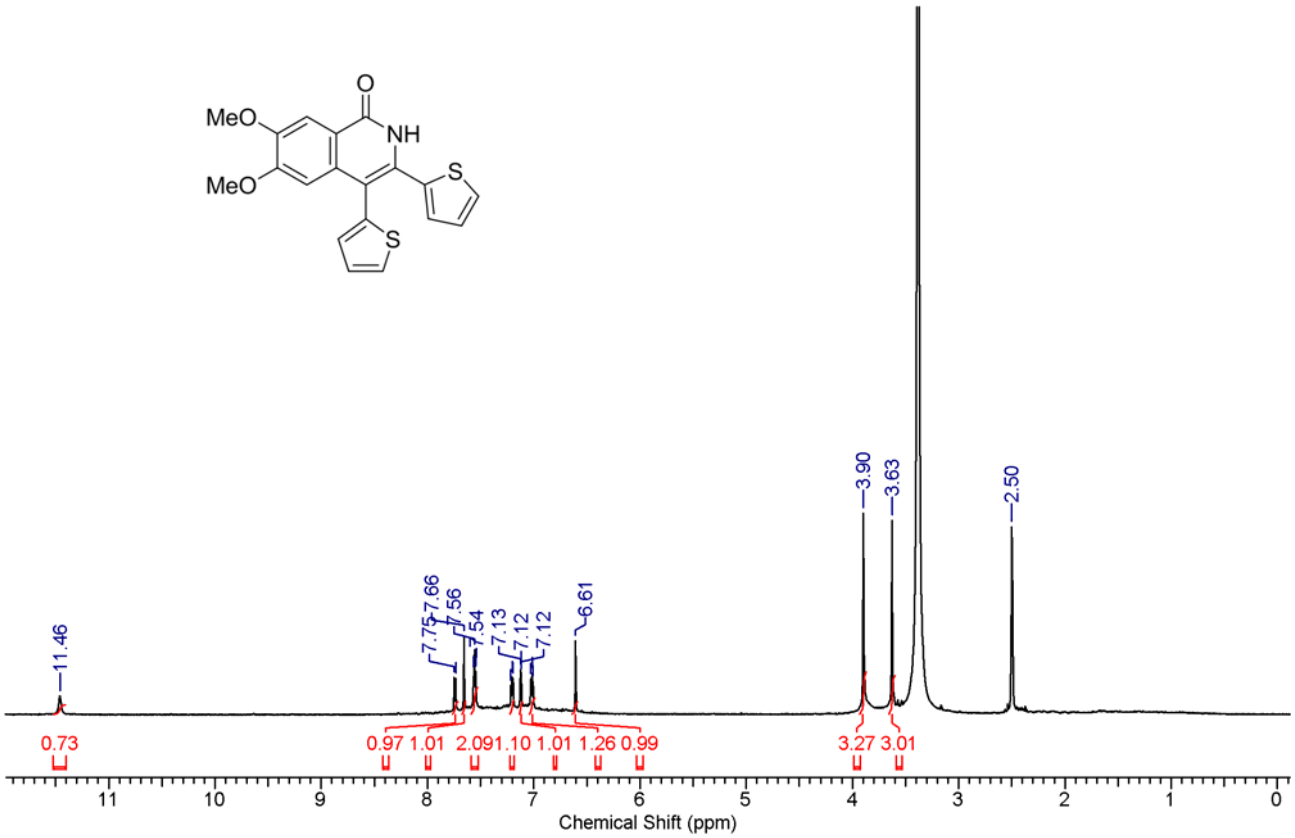


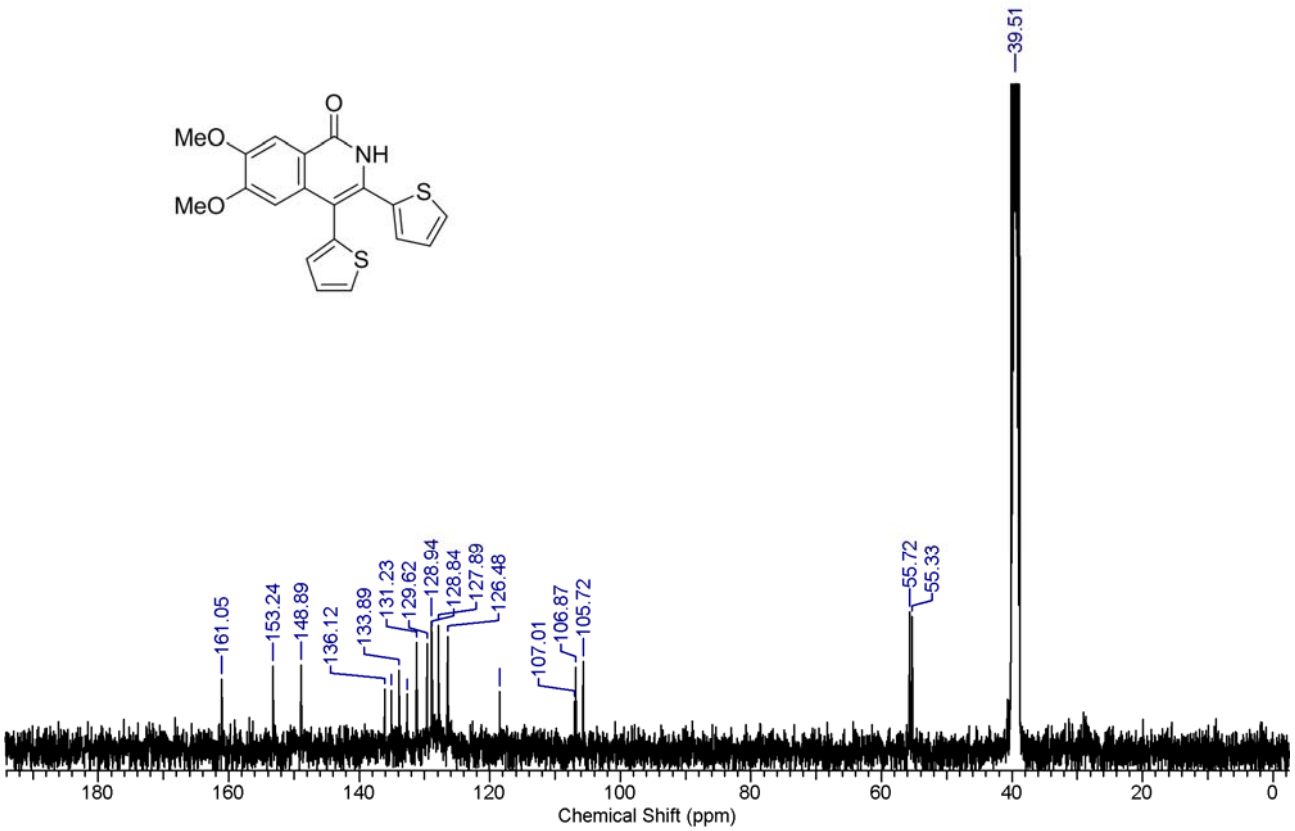


DEPT (135) NMR Spectrum of Compound **4b.**

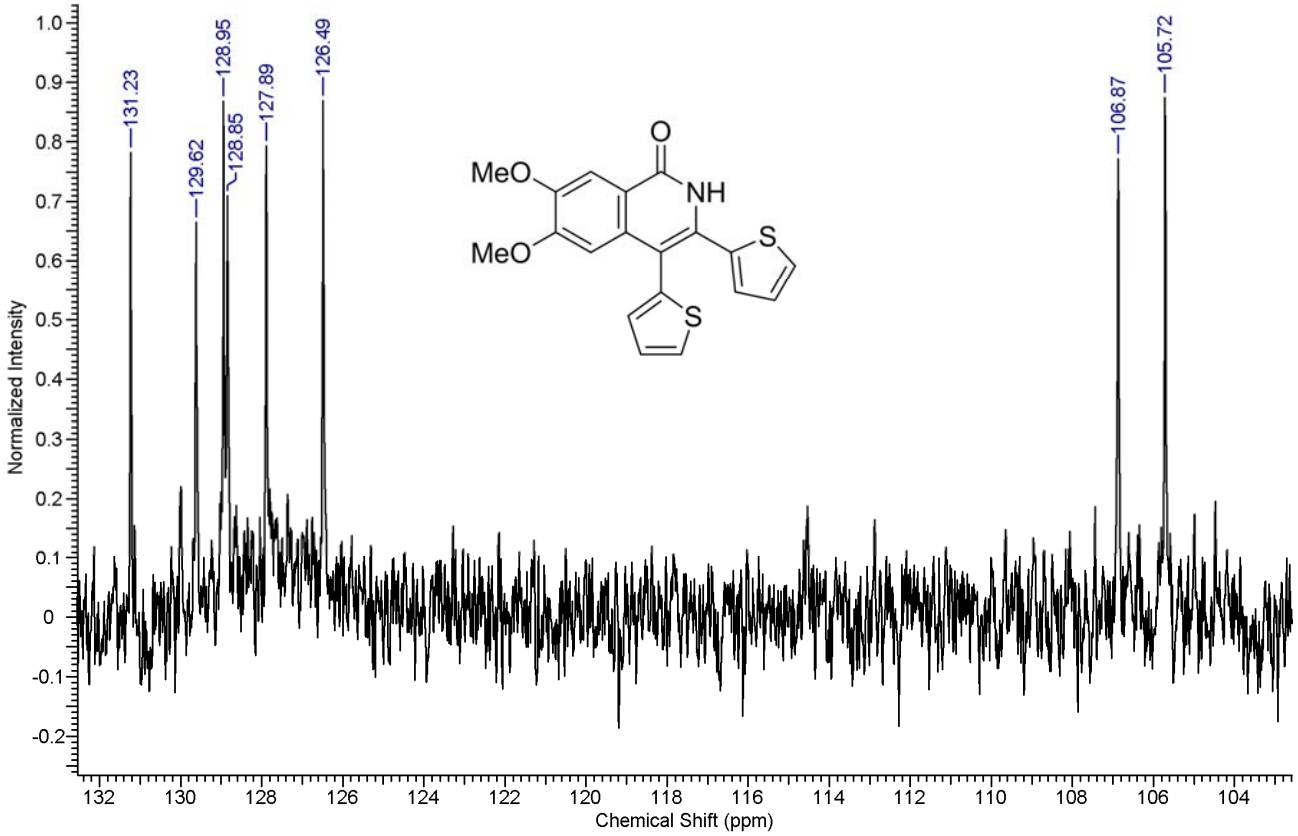


^{1}H and ^{13}C NMR Spectra of Compound **4c.**

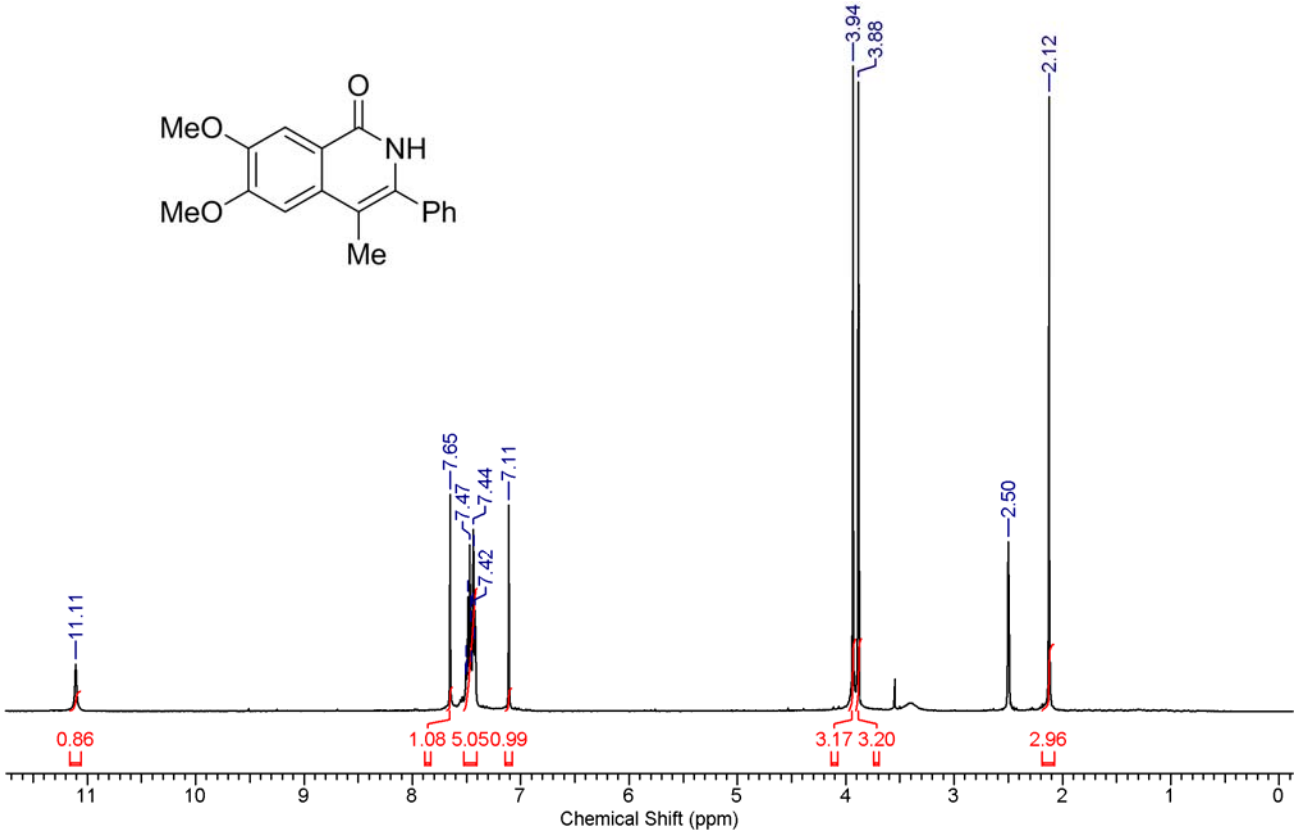


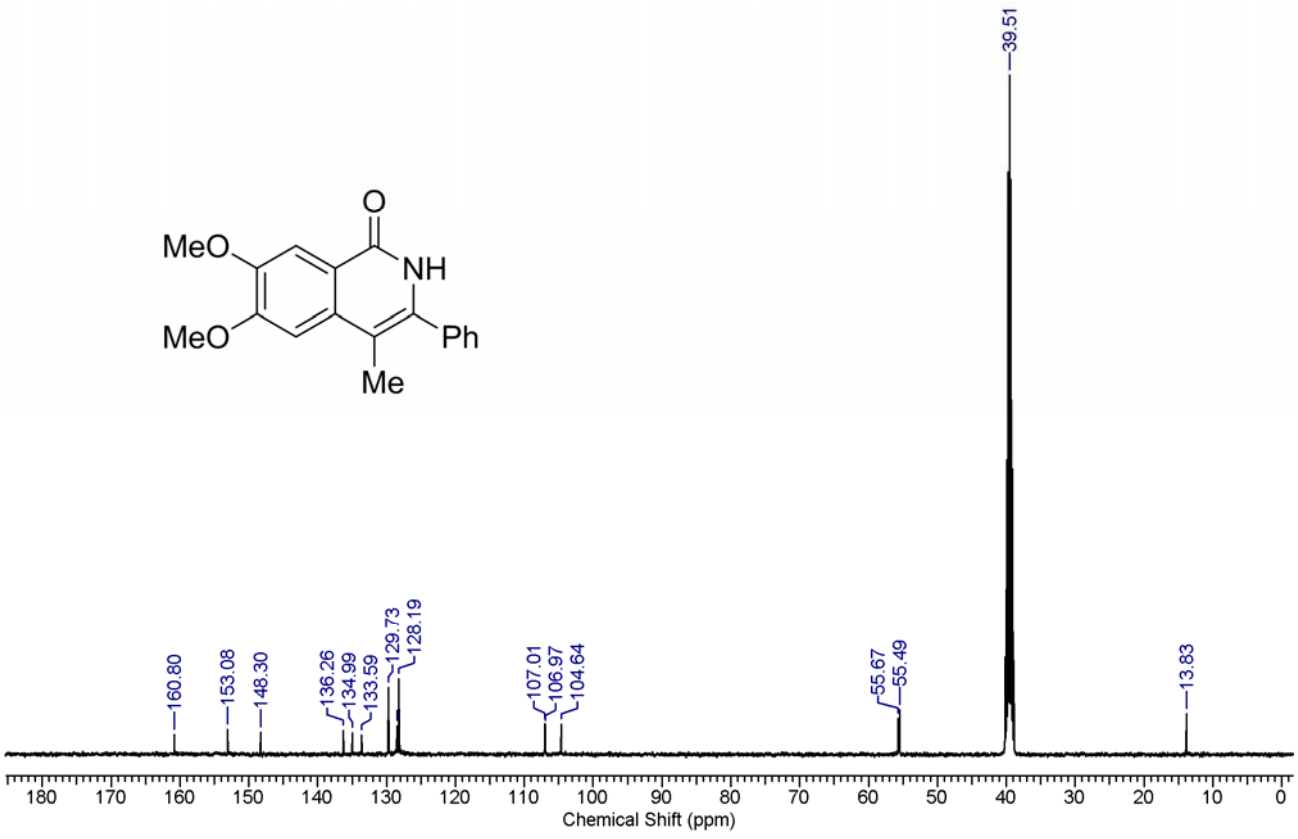


DEPT (135) NMR Spectrum of Compound **4c.**

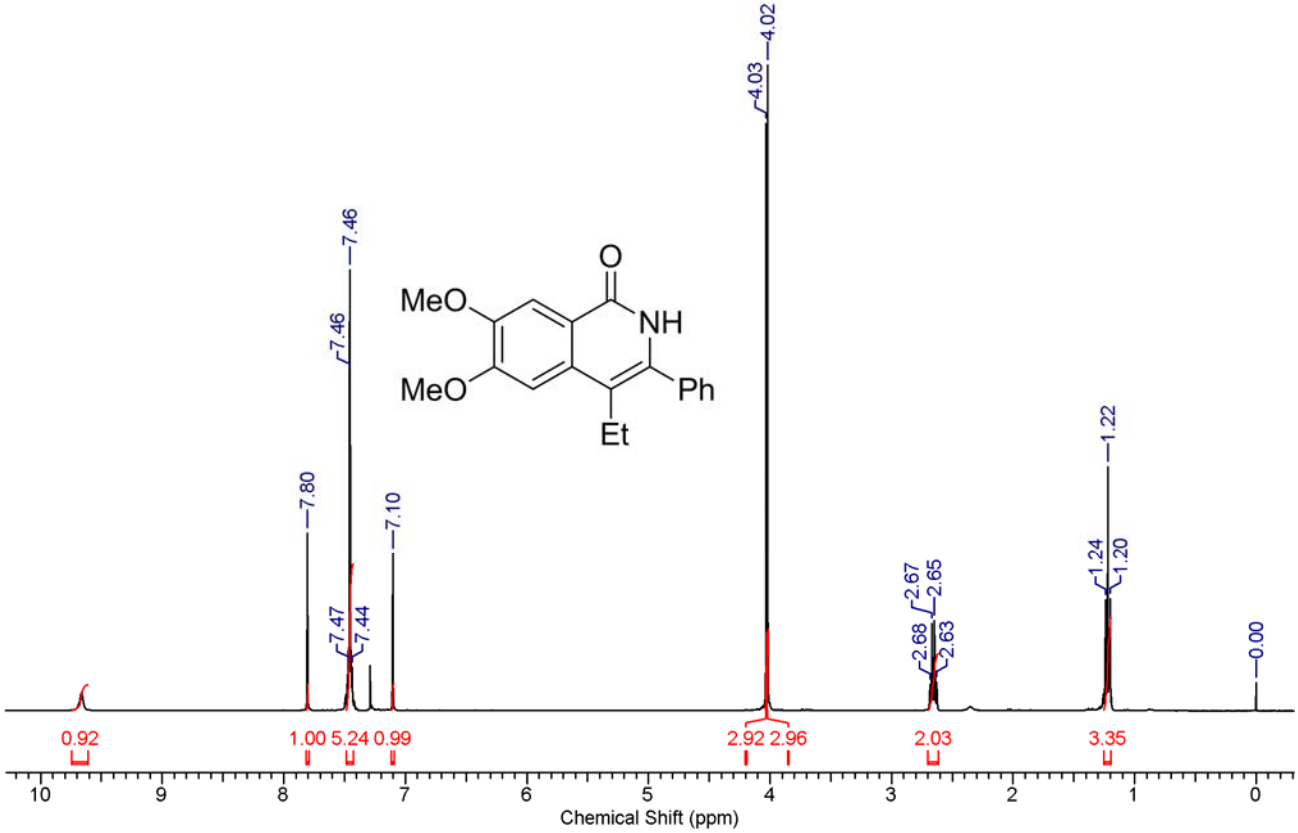


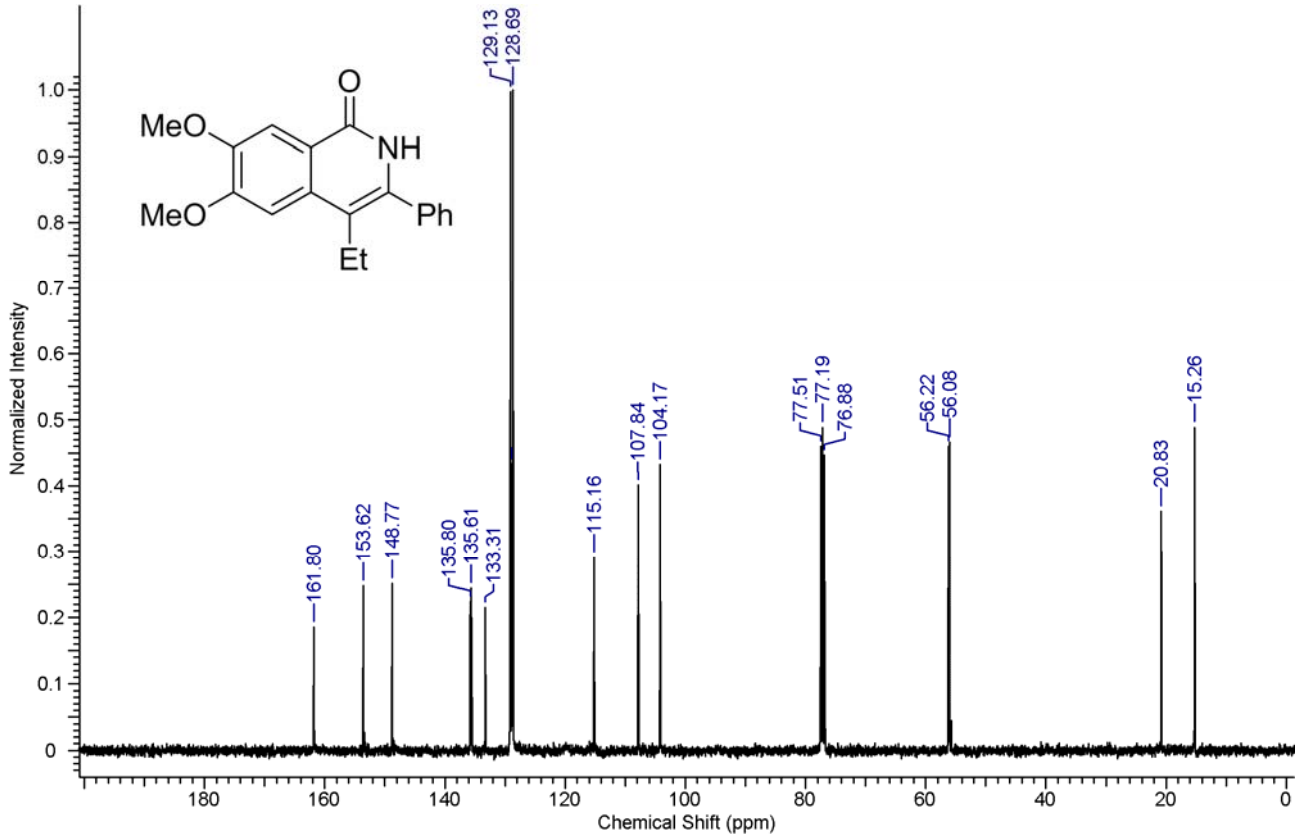
^{1}H and ^{13}C NMR Spectra of Compound **4d.**



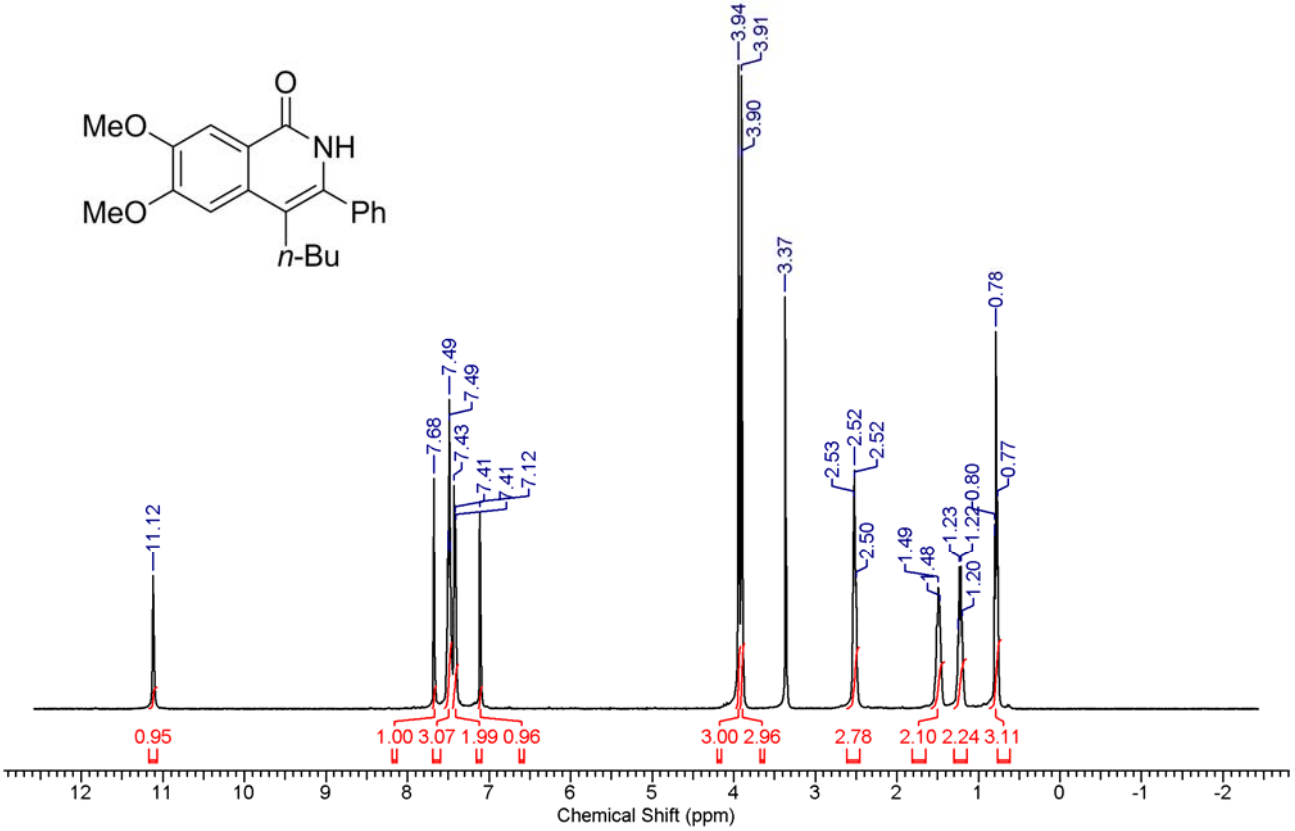


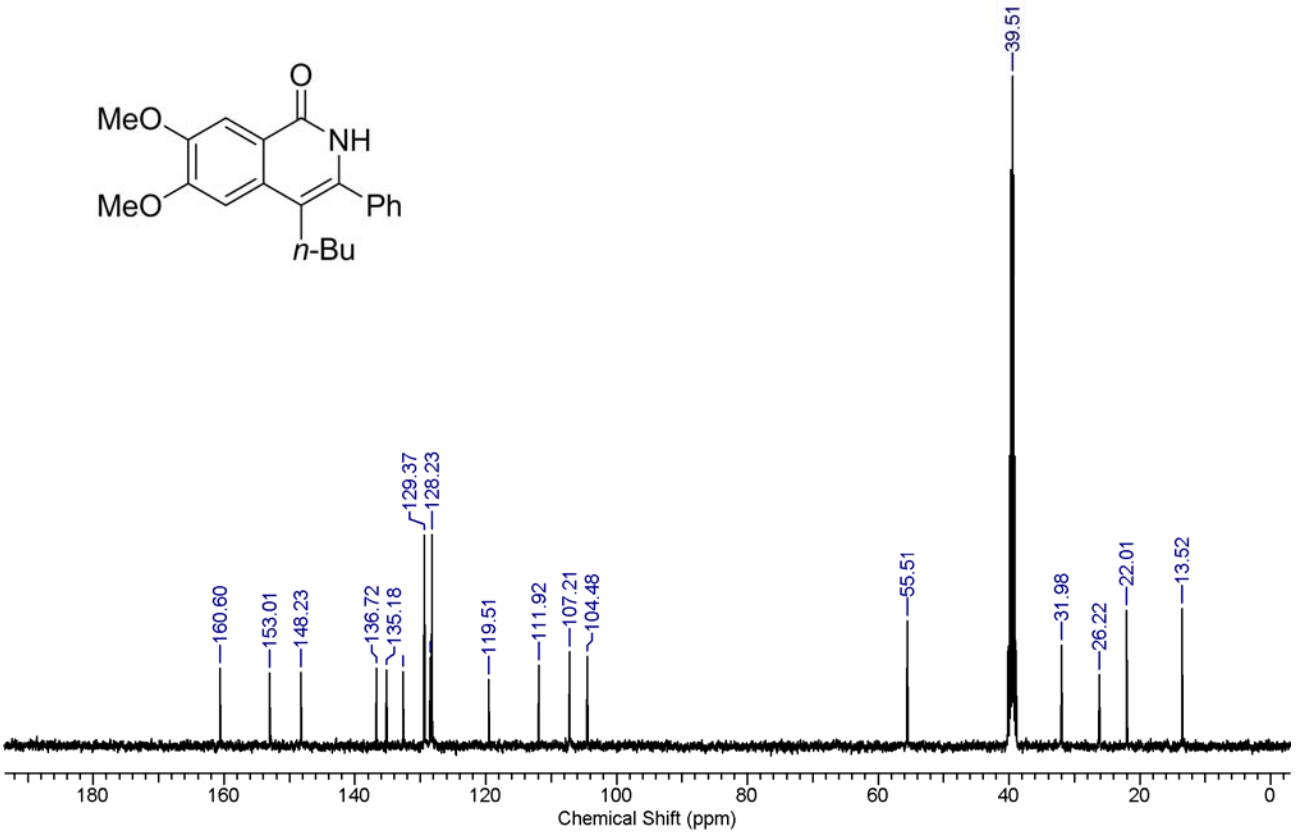
^{1}H and ^{13}C NMR Spectra of Compound **4e.**



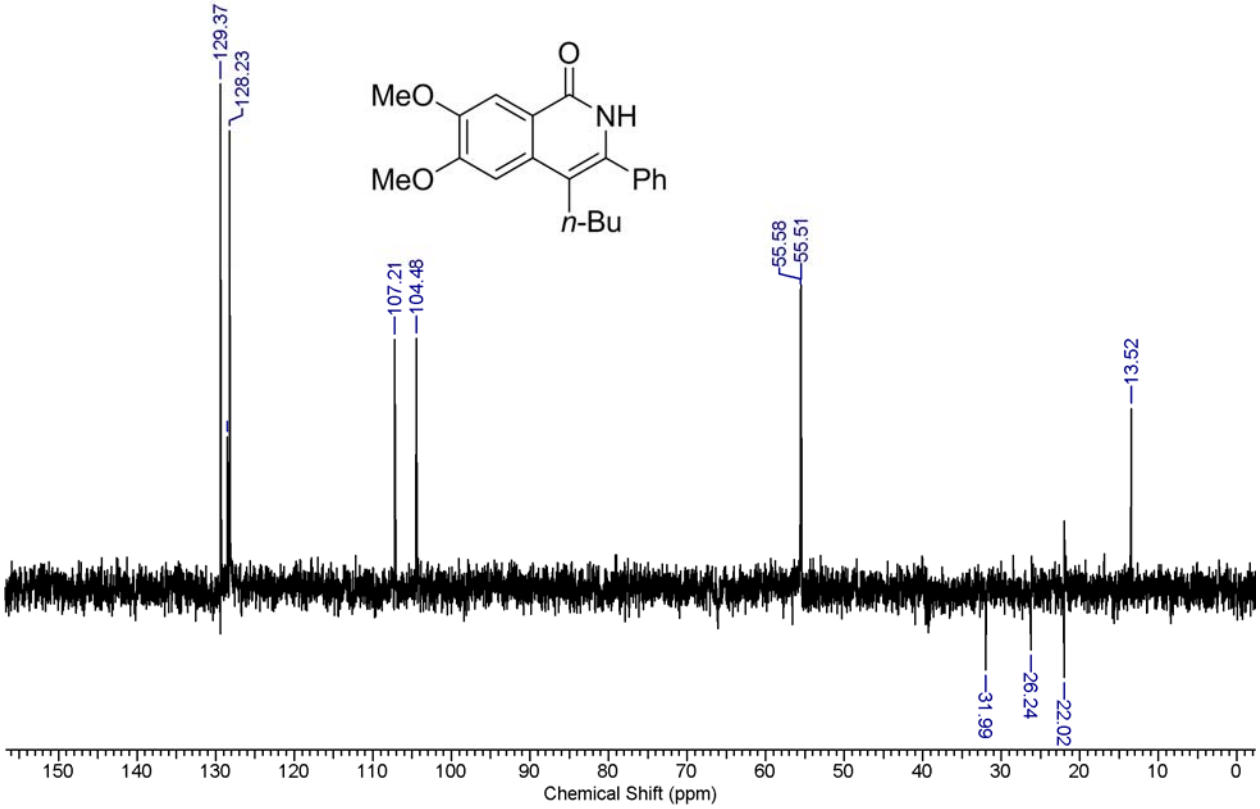


^{1}H and ^{13}C NMR Spectra of Compound **4f.**

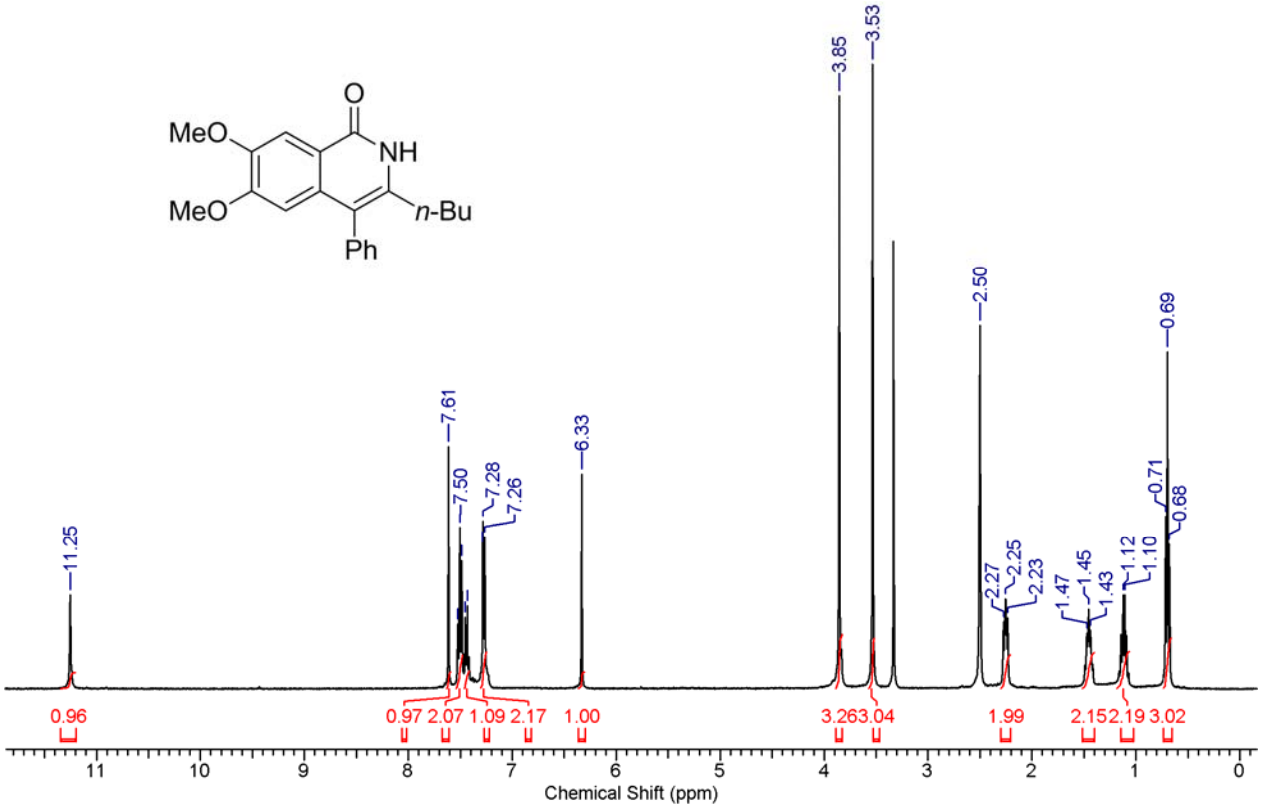




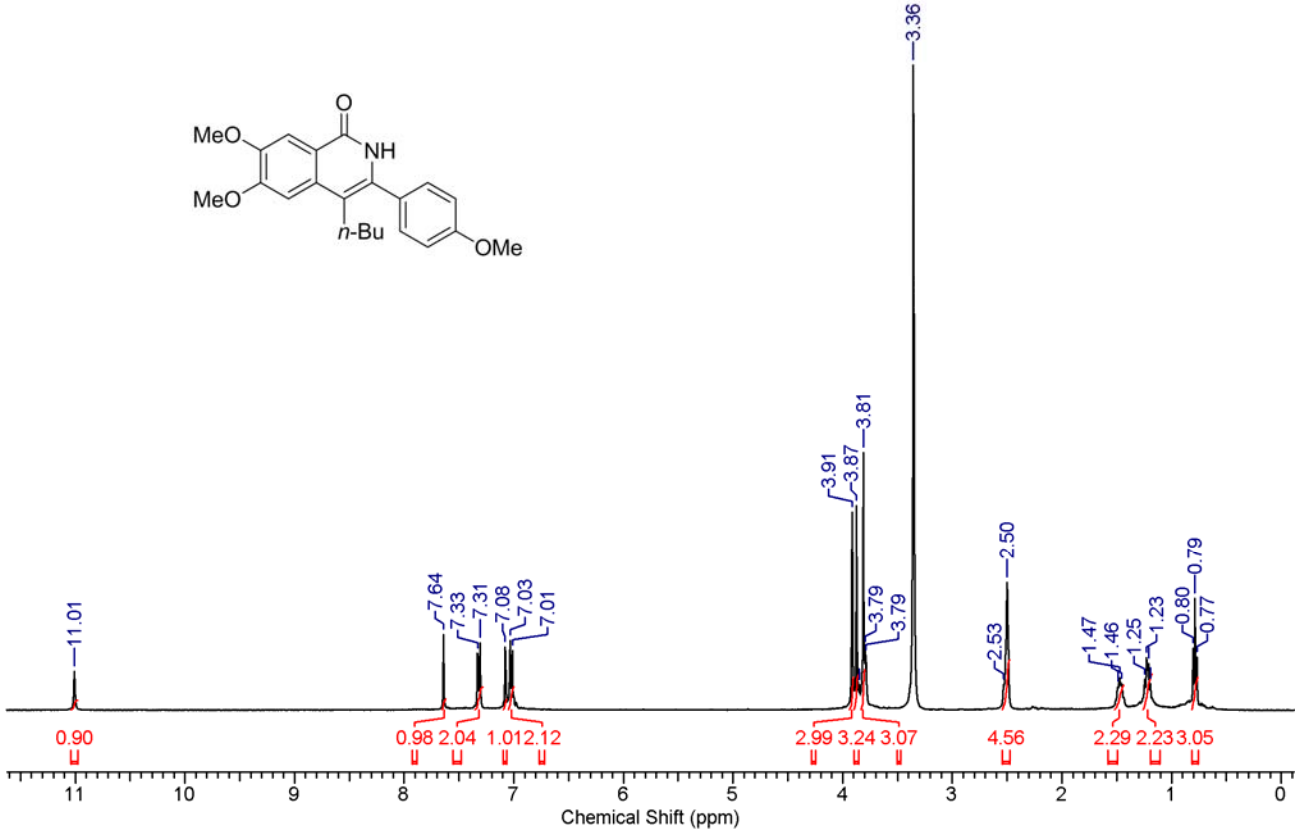
DEPT (135) NMR Spectrum of Compound **4f.**

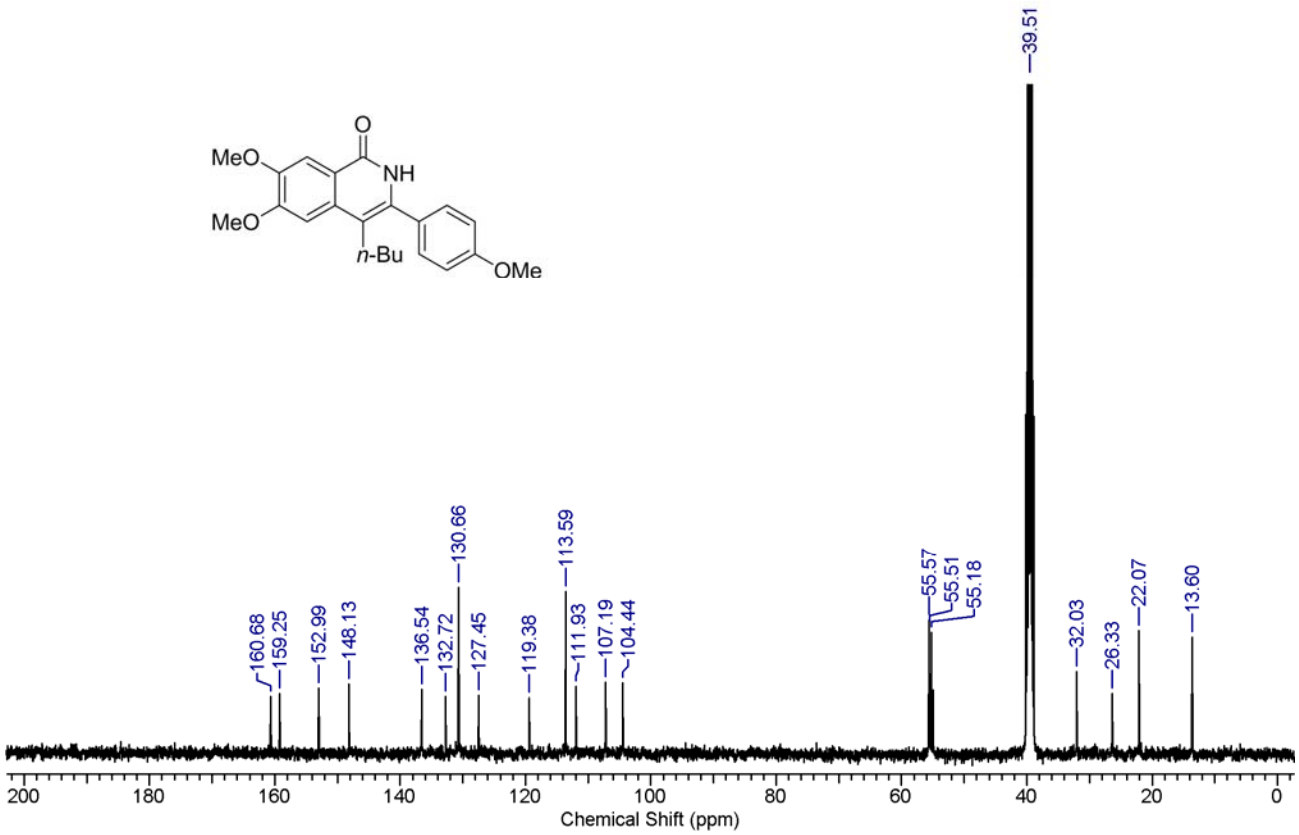


^{1}H Spectrum of Compound **4f'.**

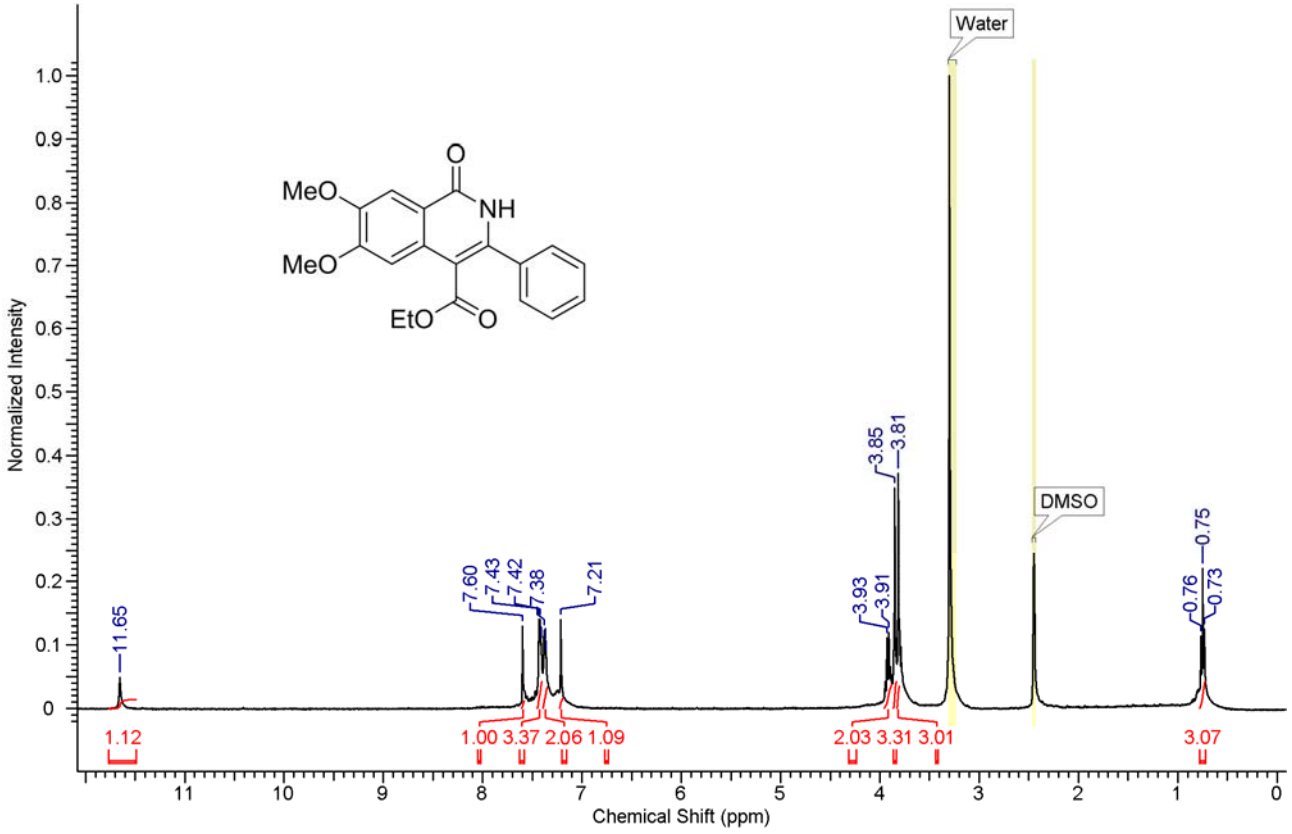


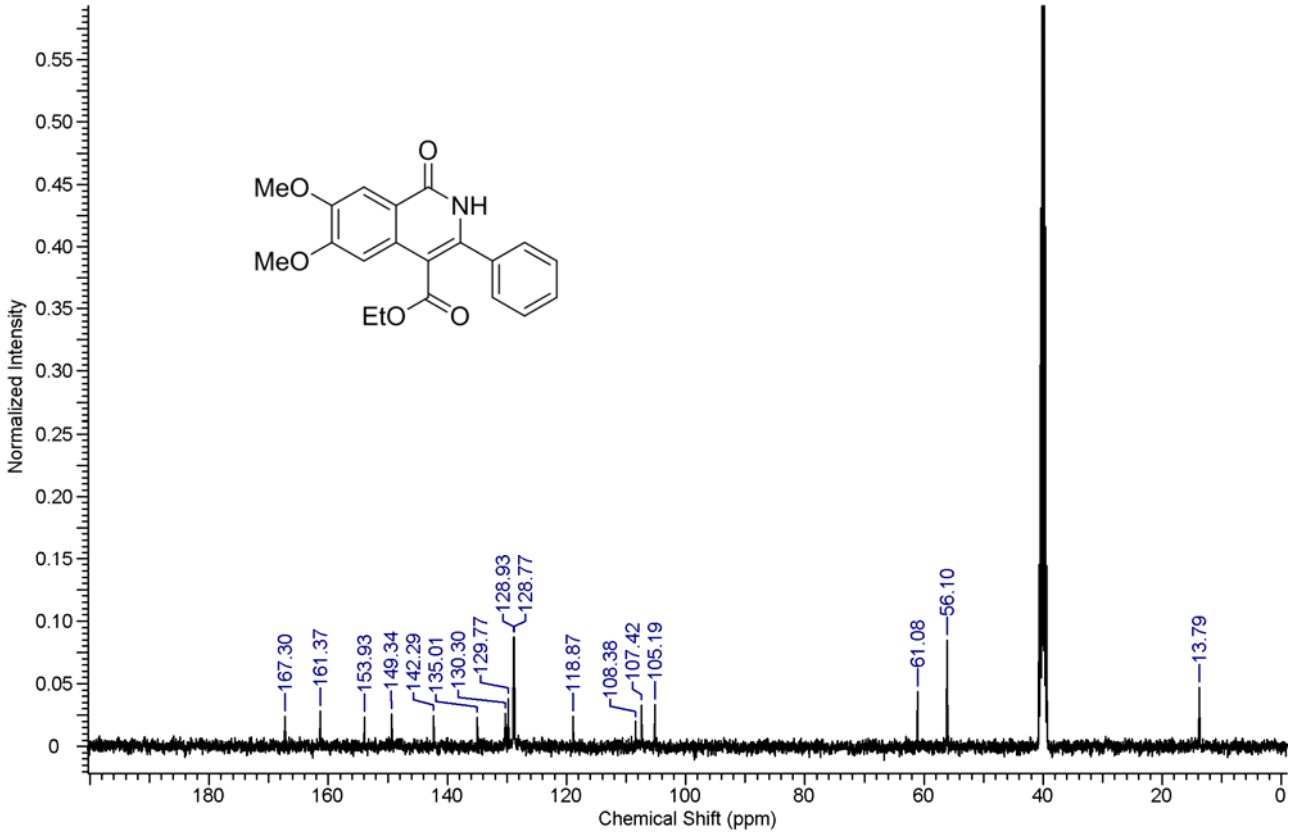
^{1}H and ^{13}C NMR Spectra of Compound **4g.**



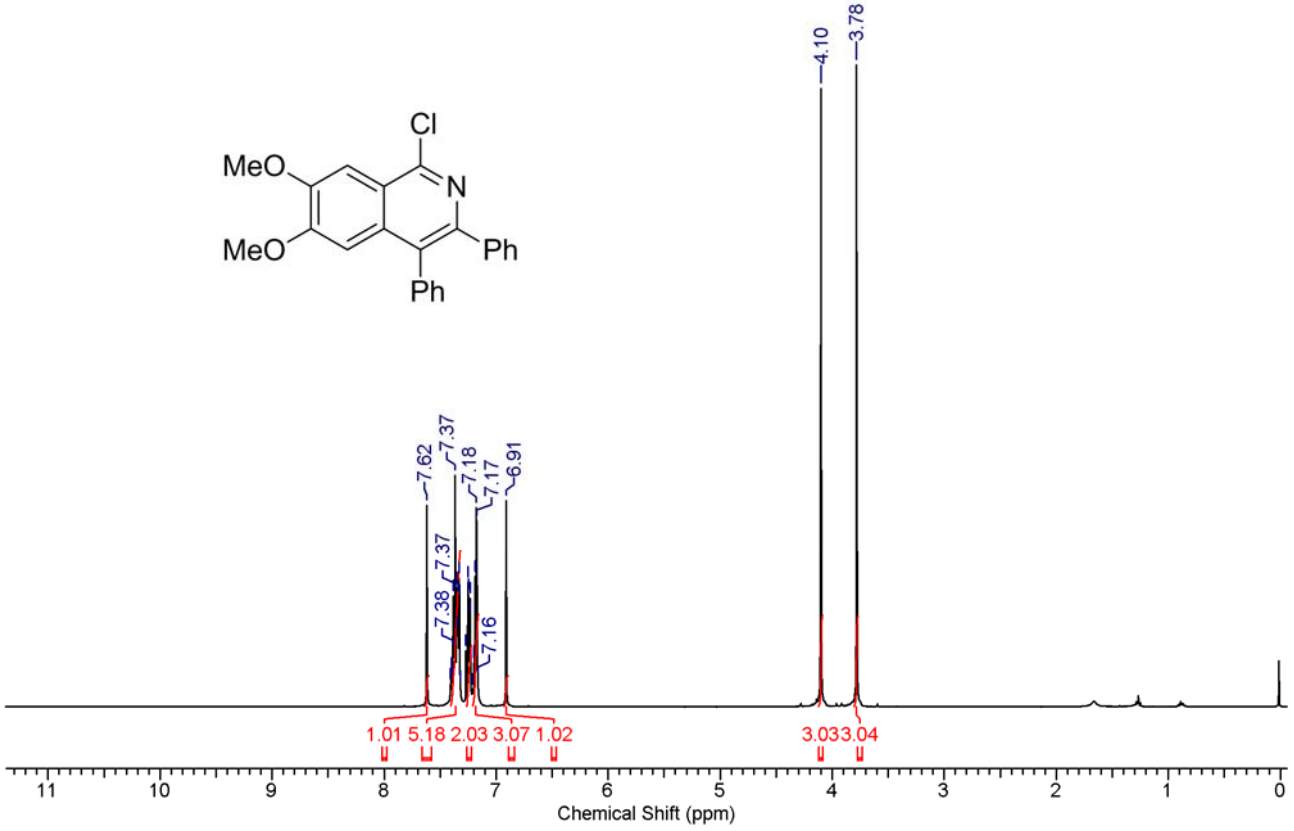


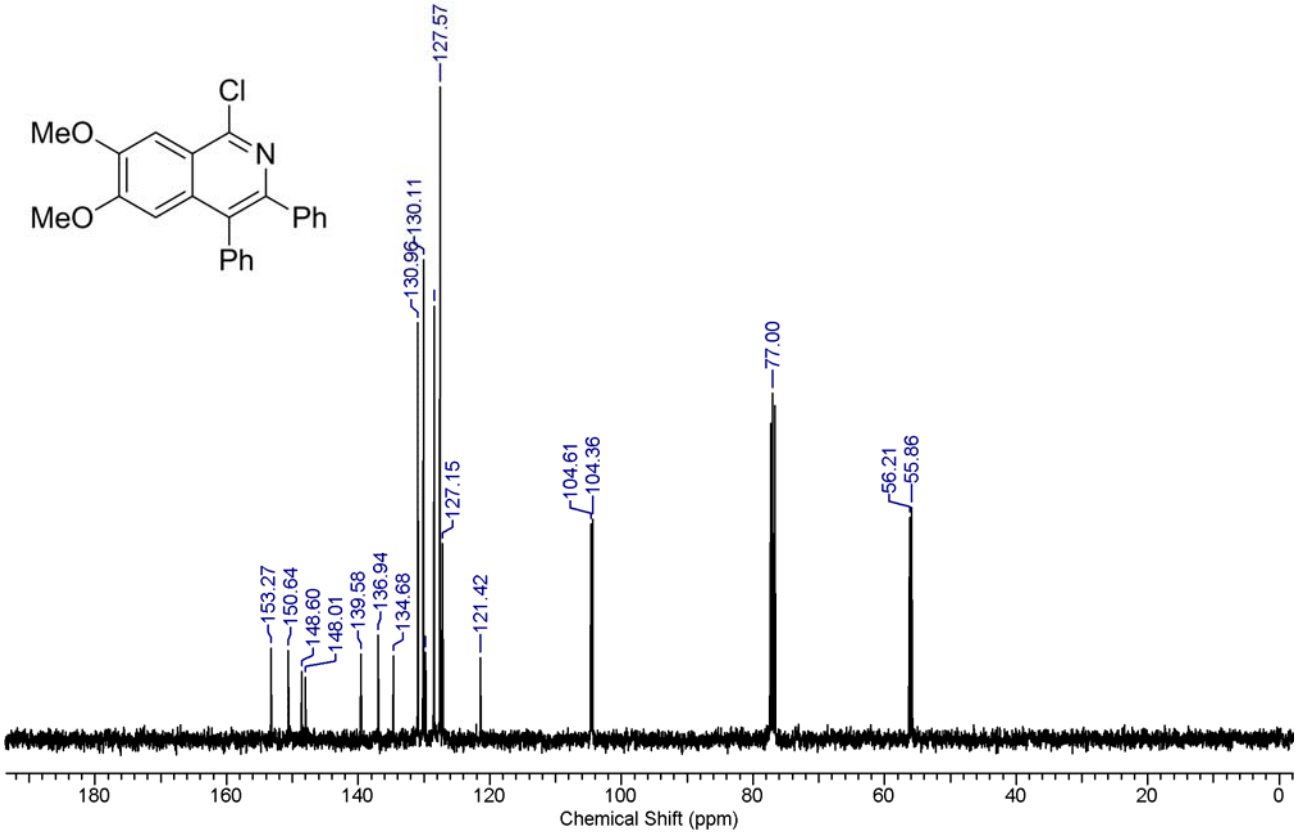
^{1}H and ^{13}C NMR Spectra of Compound **4h.**



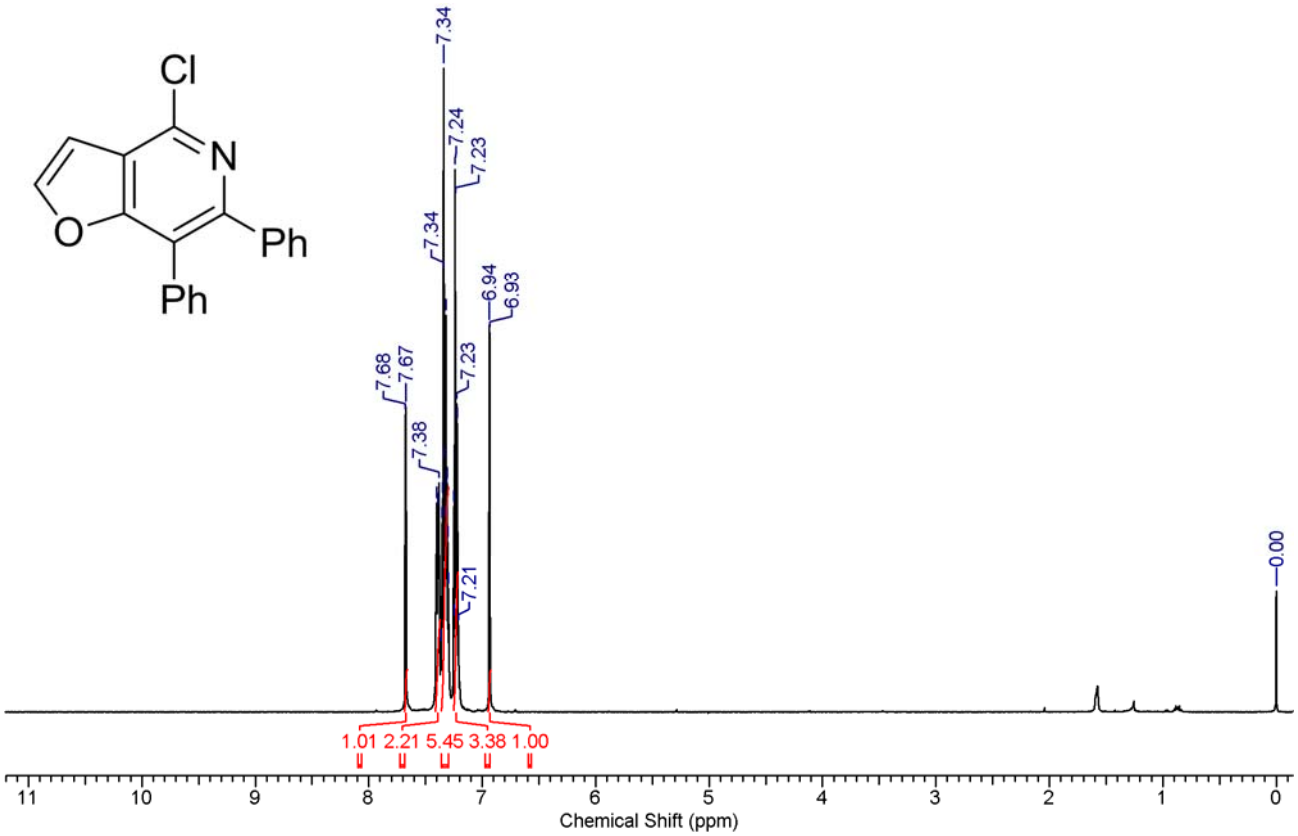


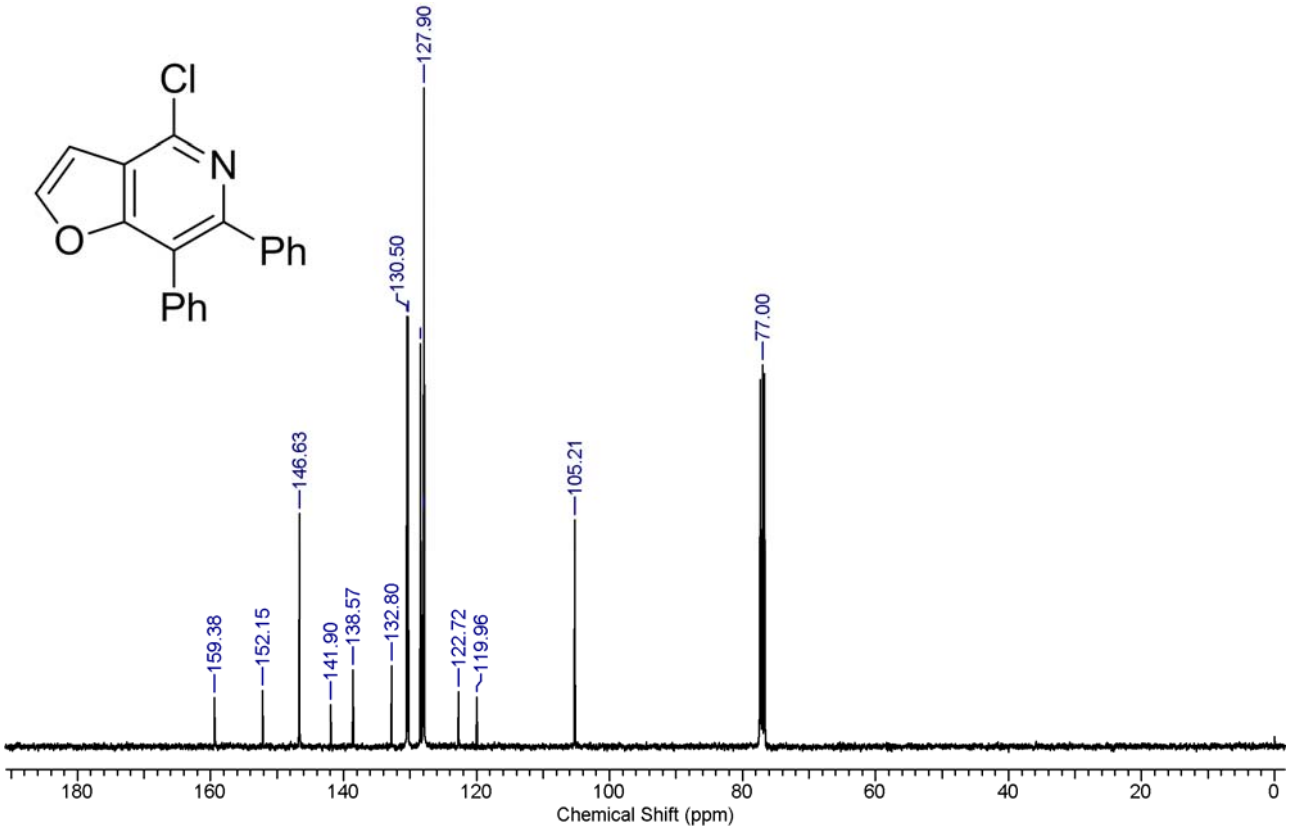
^{1}H and ^{13}C NMR Spectra of Compound **5a.**



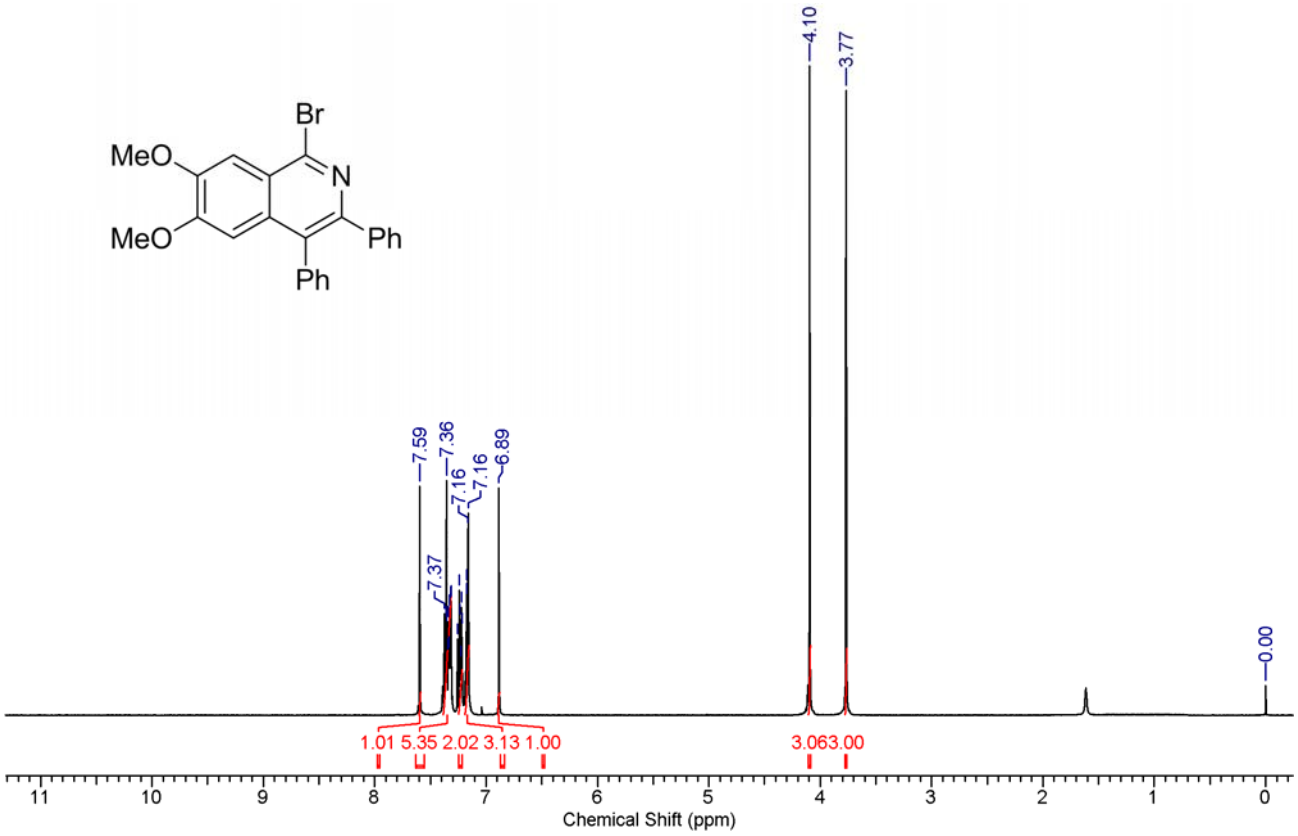


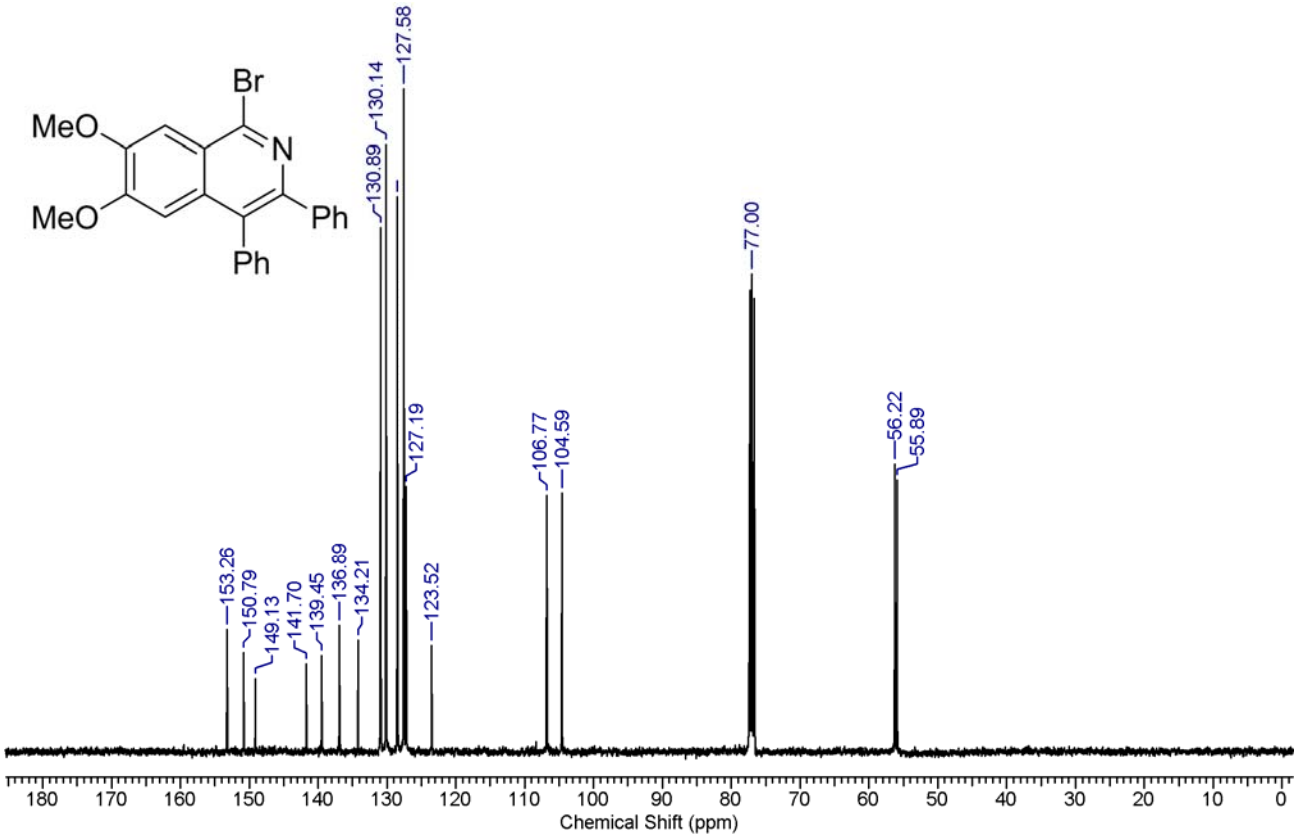
^{1}H and ^{13}C NMR Spectra of Compound **5b.**



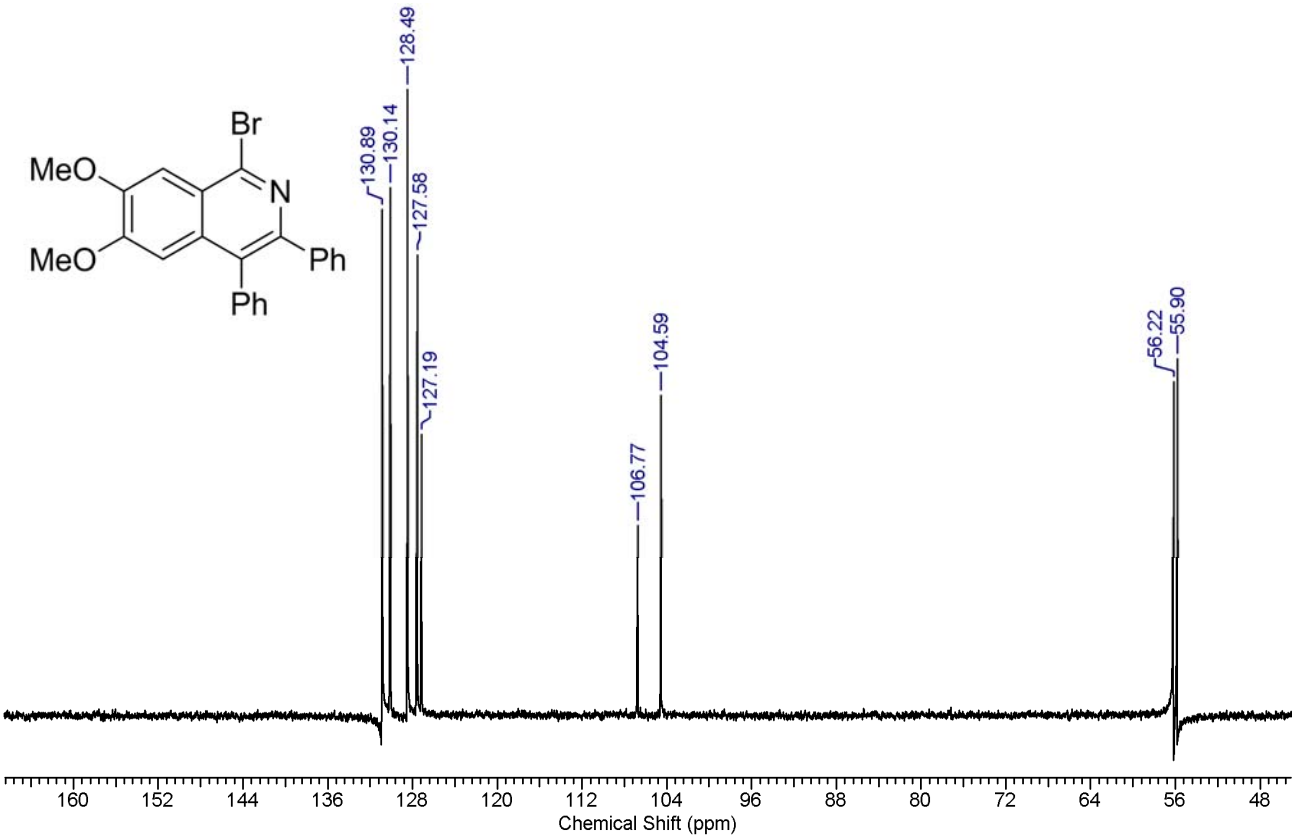


^{1}H and ^{13}C NMR Spectra of Compound **5c.**

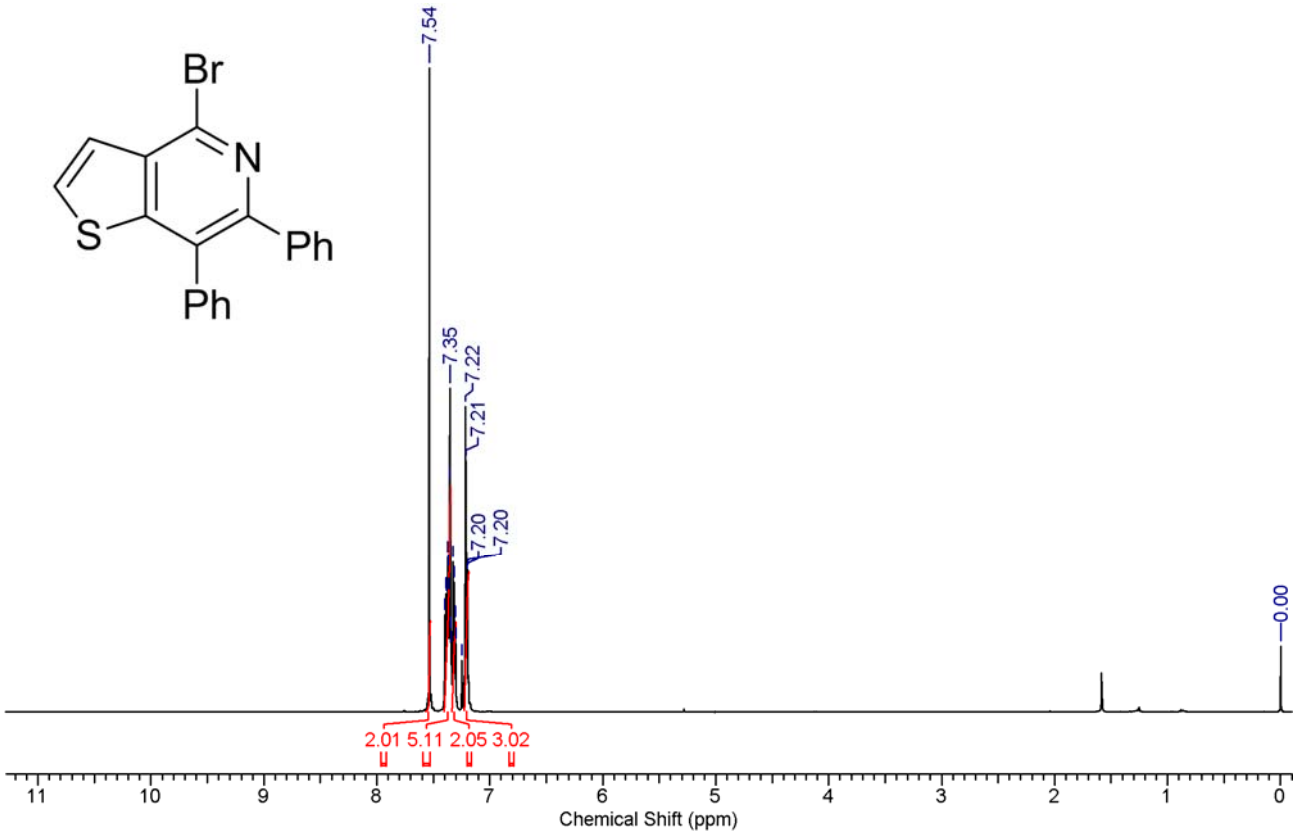


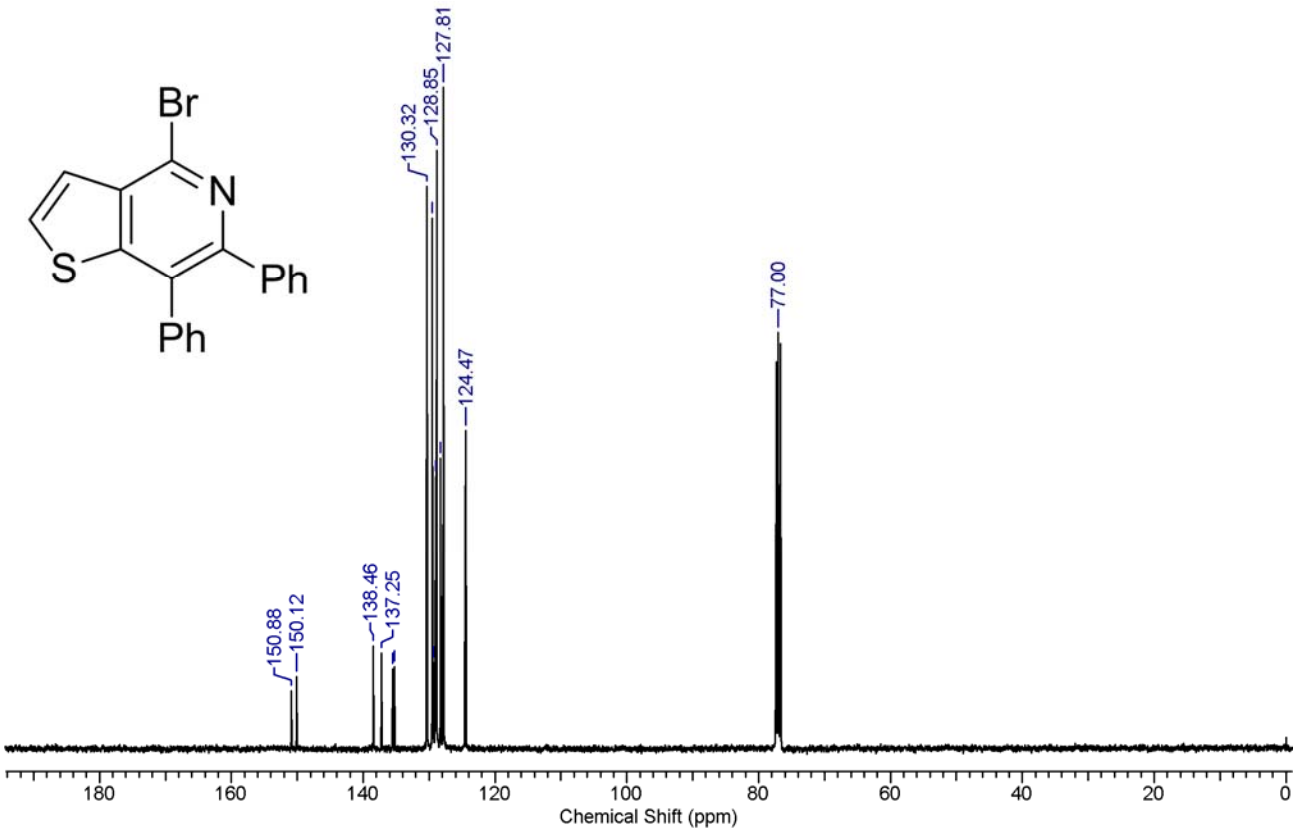


DEPT (135) NMR Spectrum of Compound **5c.**

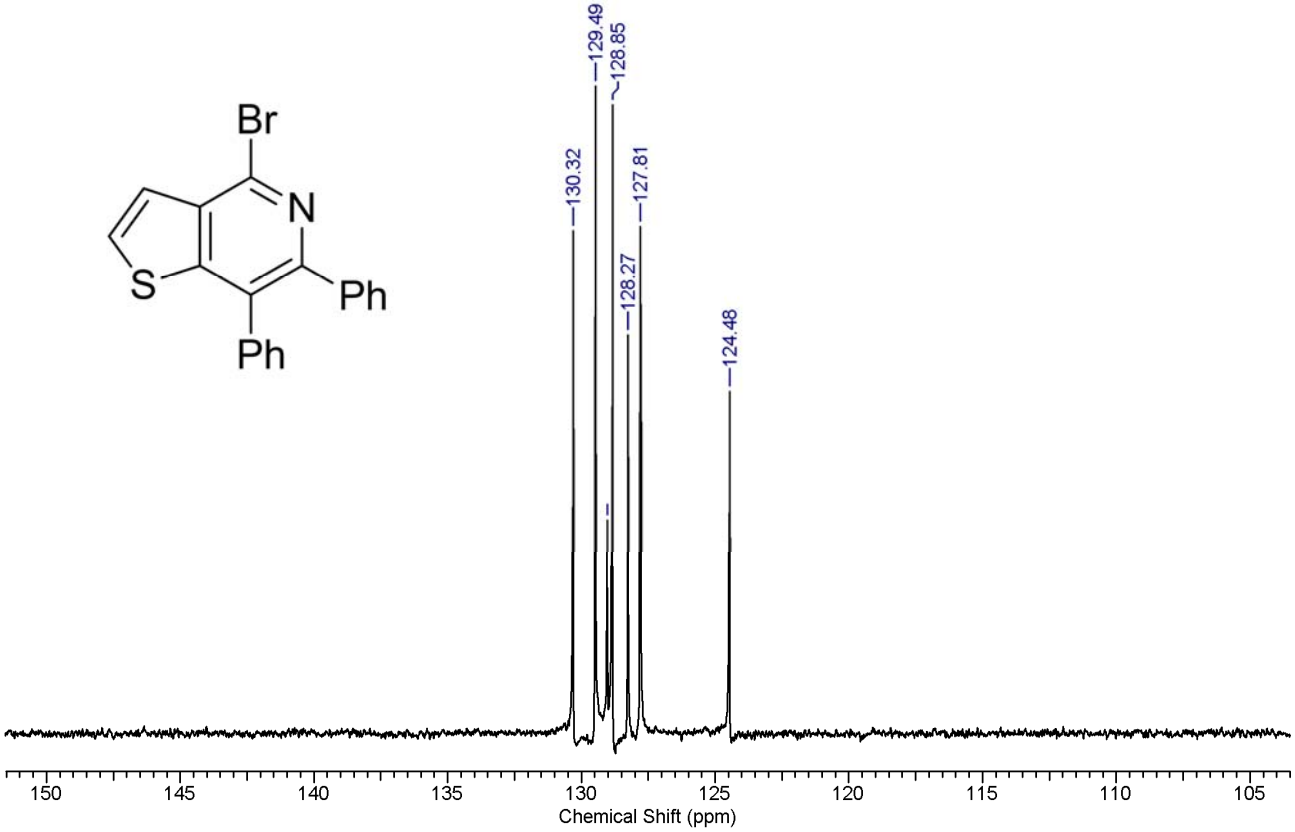


^{1}H and ^{13}C NMR Spectra of Compound **5d.**

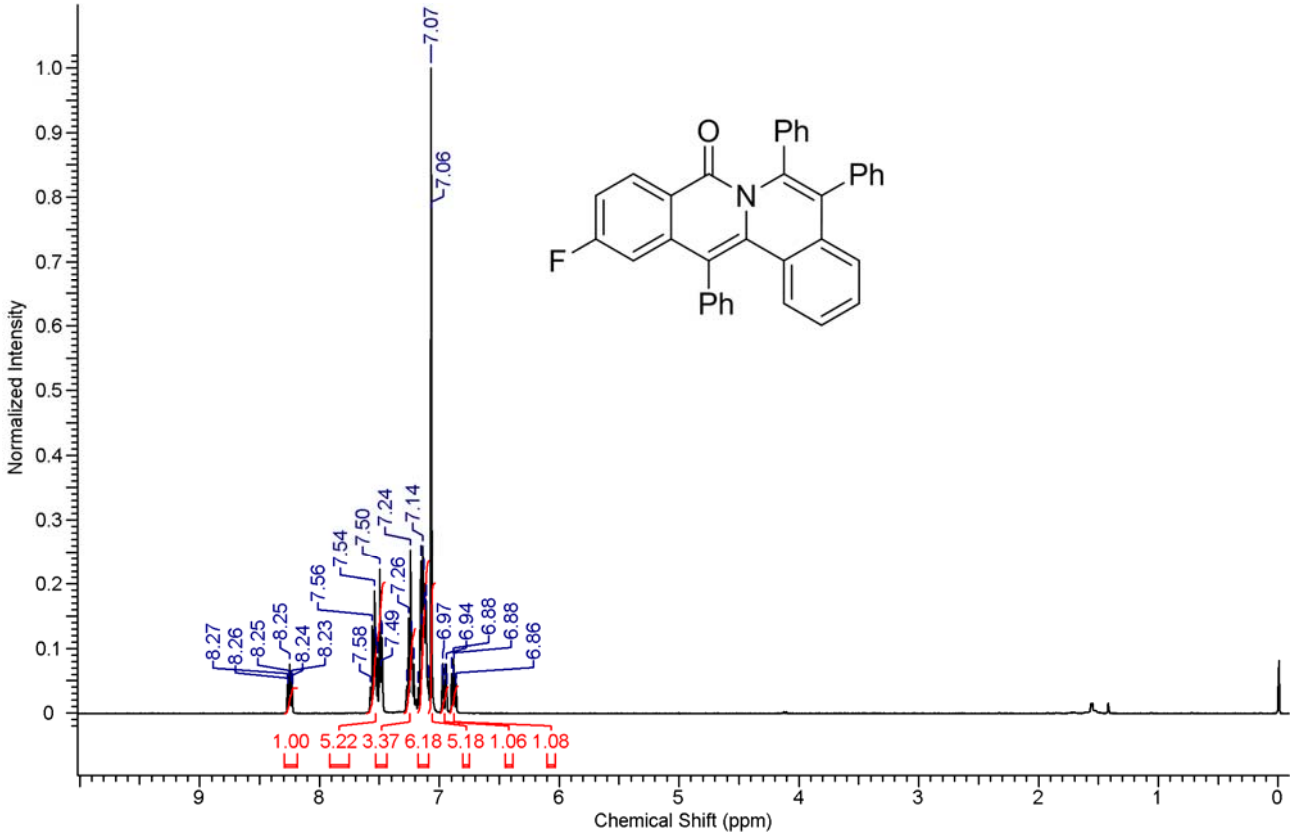


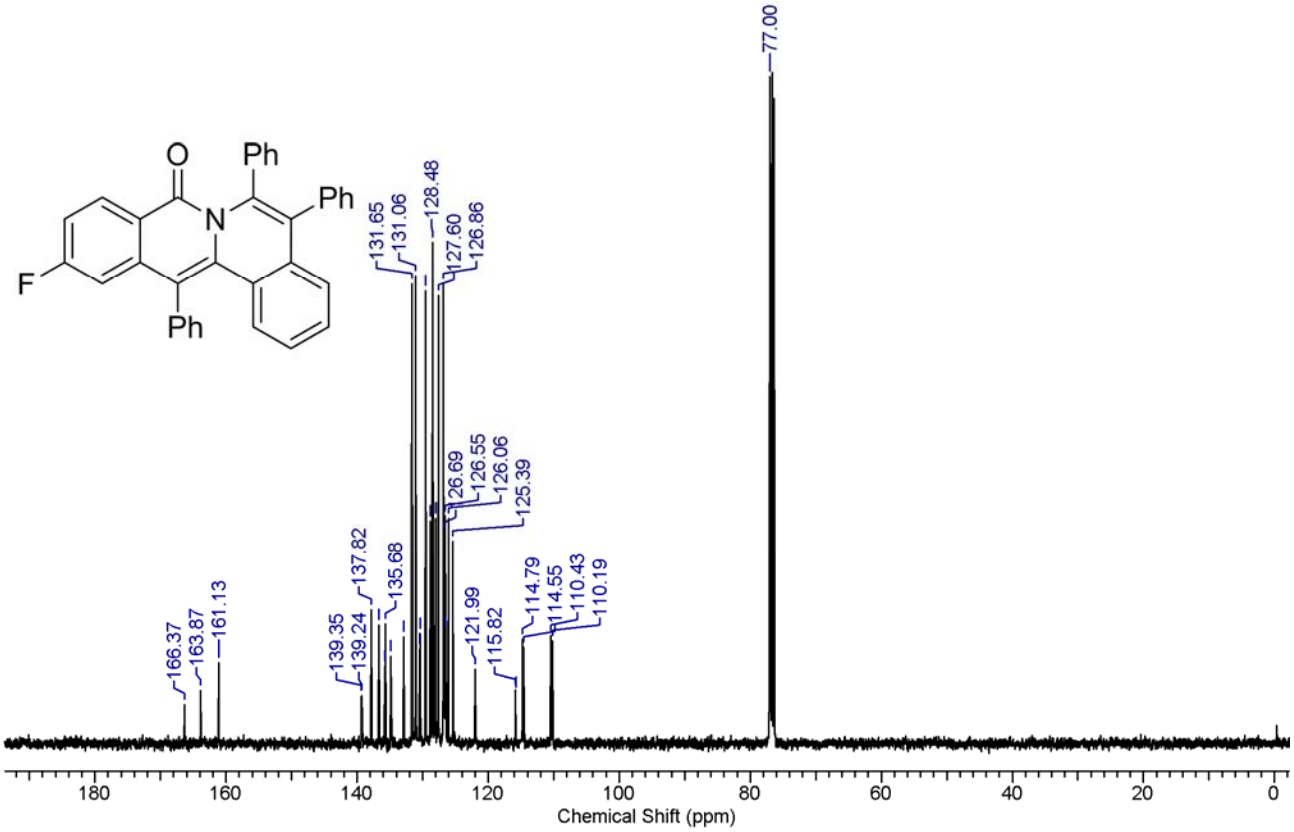


DEPT (135) NMR Spectrum of Compound **5d.**

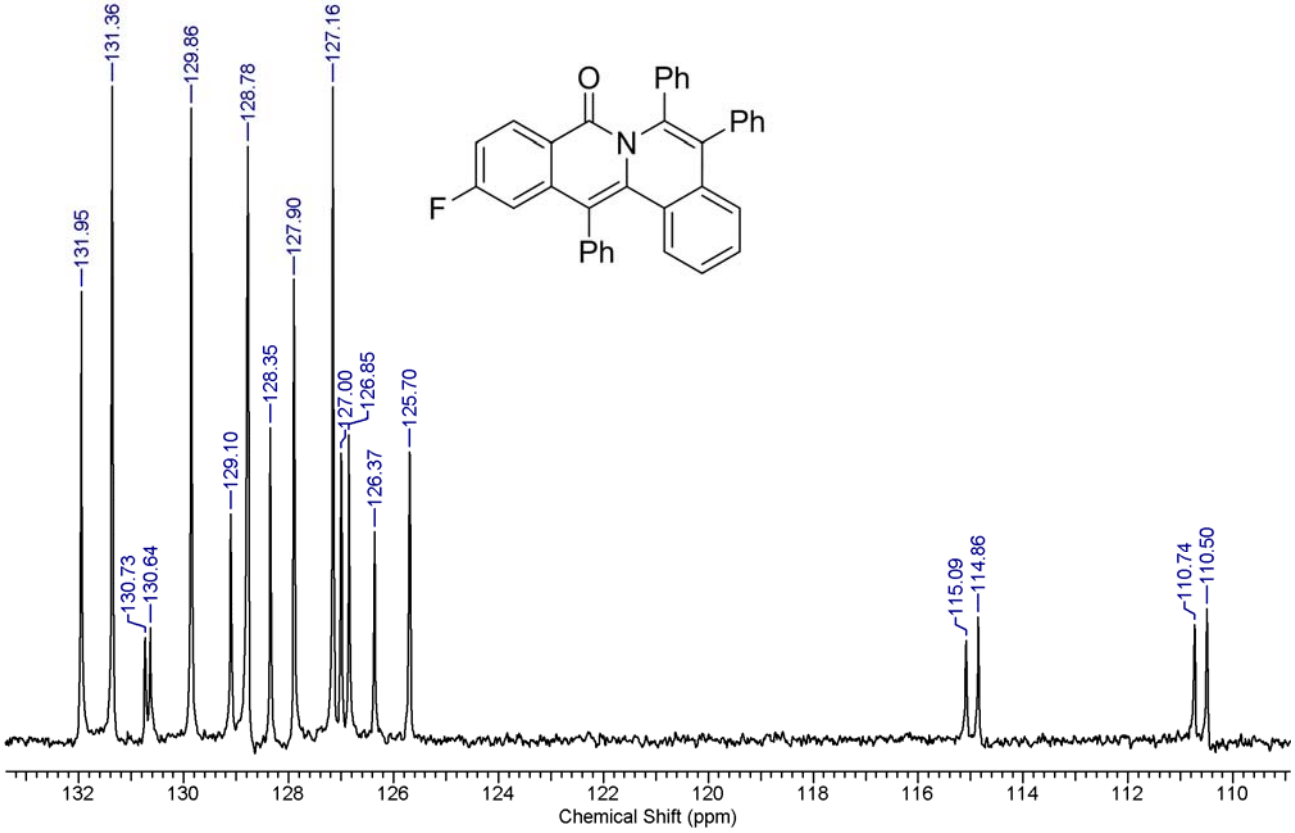


^{1}H and ^{13}C NMR Spectra of Compound **5e.**

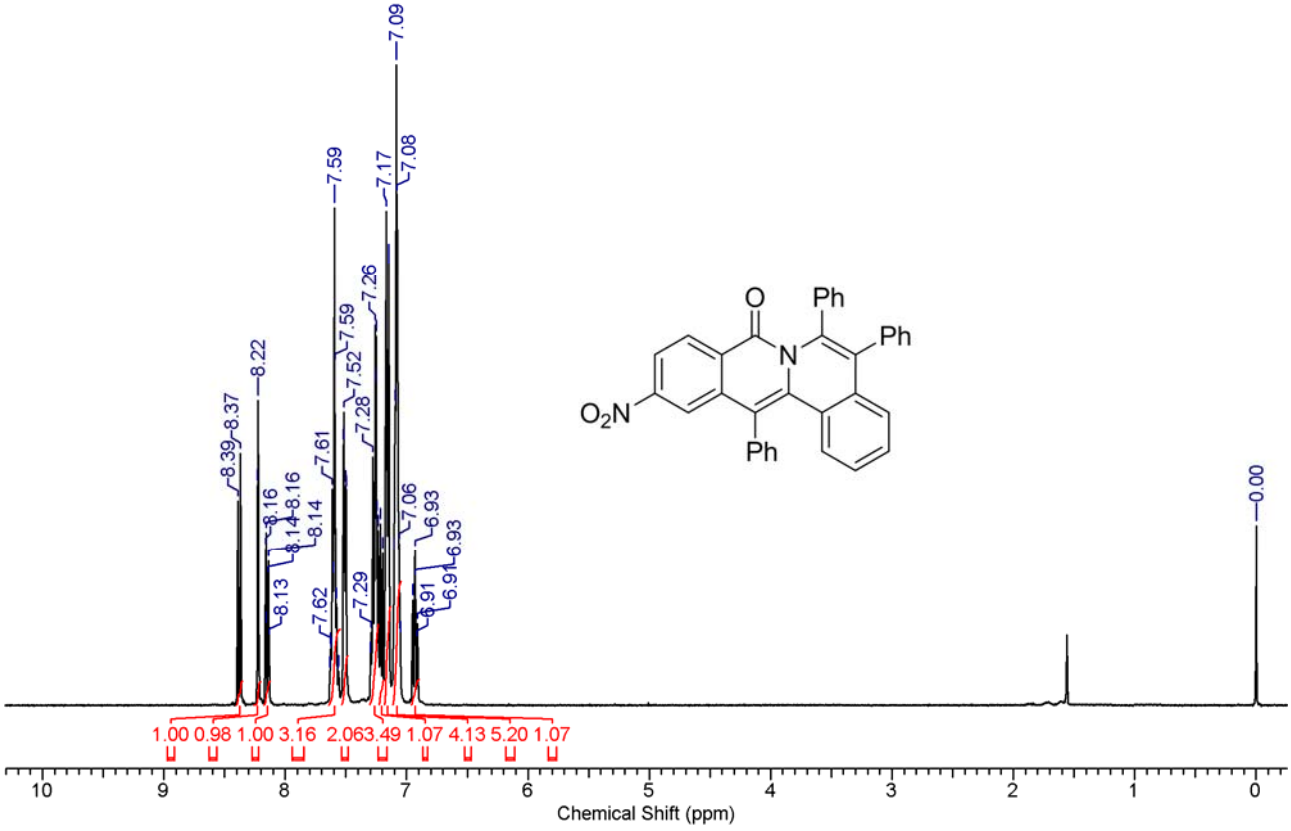


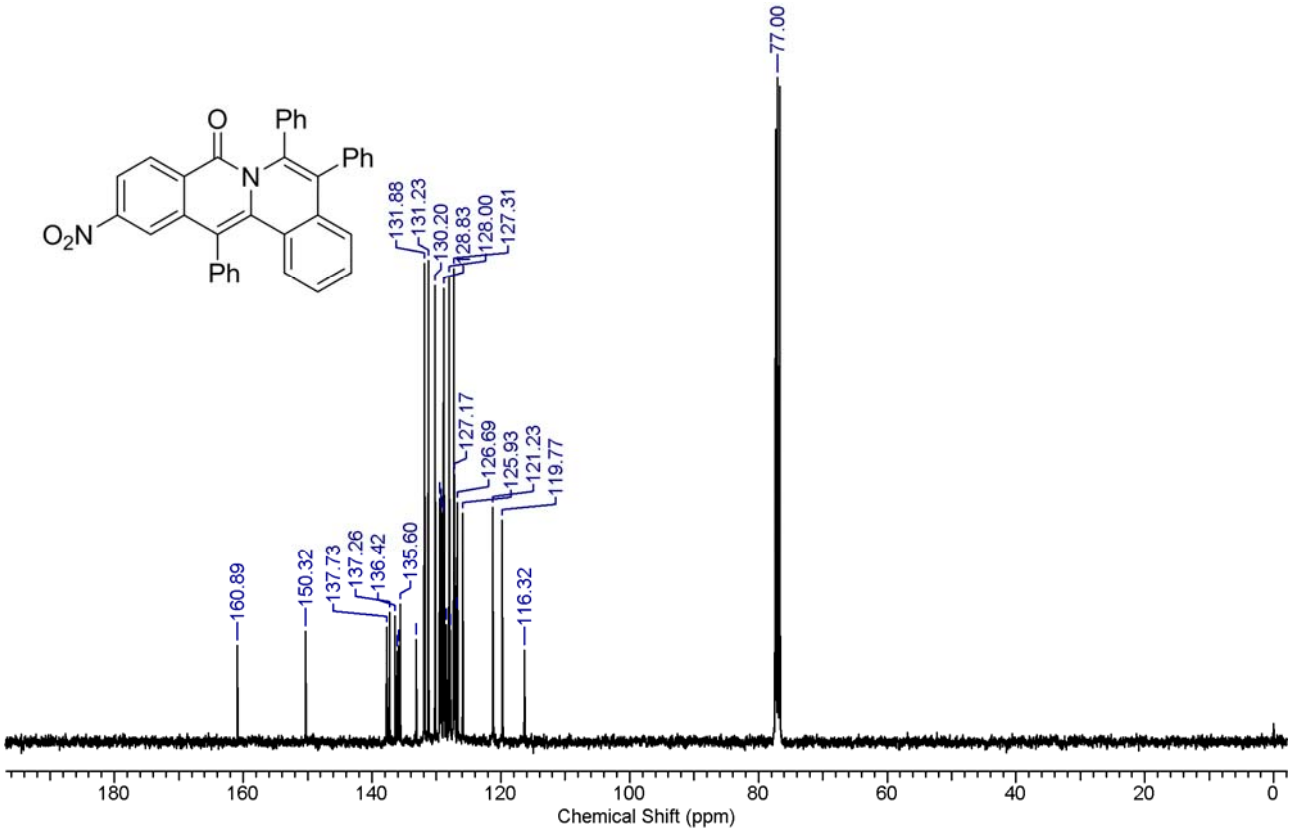


DEPT (135) NMR Spectrum of Compound **5e.**

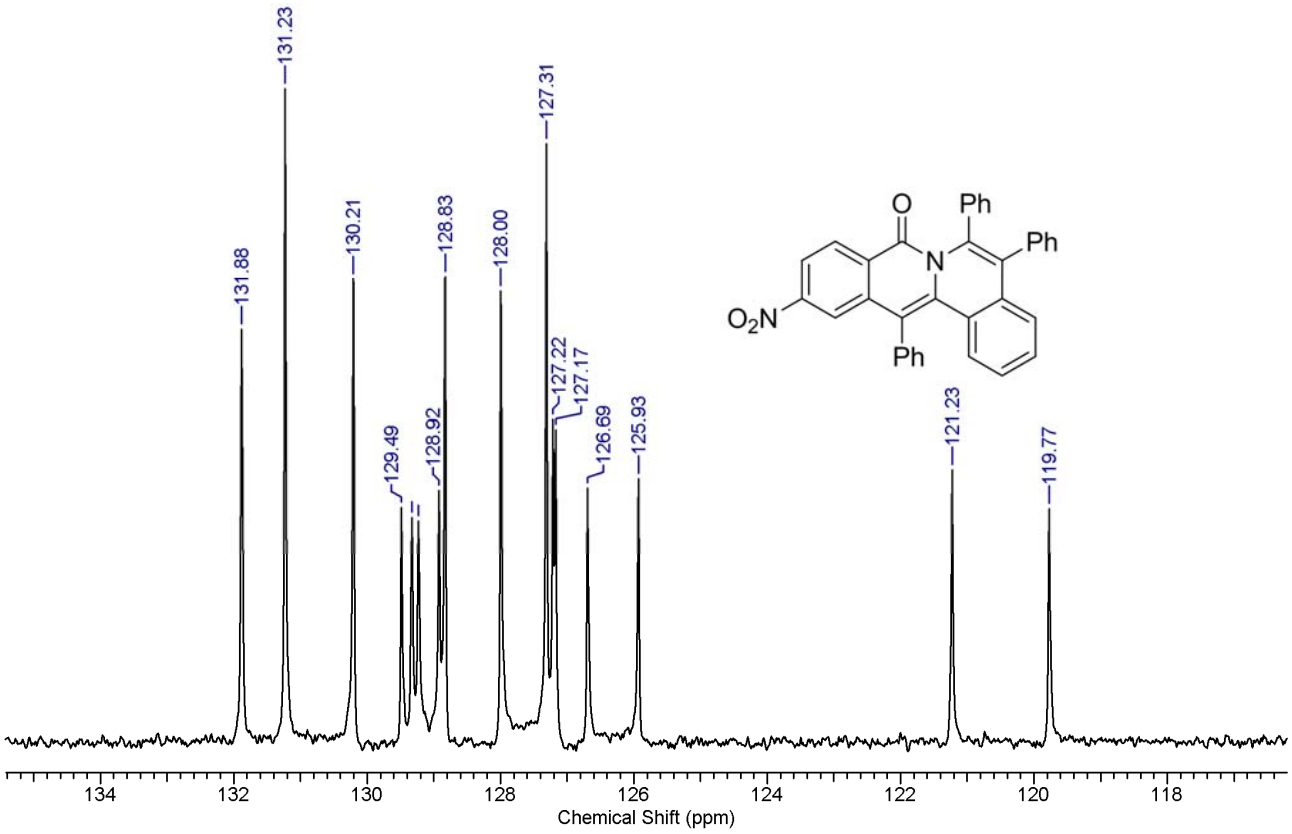


^{1}H and ^{13}C NMR Spectra of Compound **5f.**





DEPT (135) NMR Spectrum of Compound **5f.**



^{1}H NMR Spectrum of Compound **11a**.