Cyanomethylation of Substituted Fluorenes and Oxindoles with Alkyl Nitriles

Gang Hong, Pradip D. Nahide, and Marisa C. Kozlowski*

Department of Chemistry, Roy and Diana Vagelos Laboratories, University of Pennsylvania, Philadelphia, Pennsylvania 19104, United States

Supporting Information

Contents

Experimental Section S2
1.1 General Experimental Procedures S2
1.2 Optimization of the Reaction Conditions S3
1.3 Mechanistic Probes S5
1.4 Characterization Data of Products S11
1.5 Derivatization of Product **3aa** S29
References S30
Copies of ^{1}H NMR, ^{13}C NMR and ^{19}F NMR S31

Experimental Section

Caution: Di-*tert*-butyl peroxide is a strong oxidizer and can be explosive. Exposure inhalation or skin contact is harmful. All experiments involving peroxy compounds should be carried out behind a safety shield and in a fume hood.[1]

All non-aqueous reactions were carried out under an atmosphere of dry argon unless otherwise noted. Commercial reagents were used as received without additional purification unless otherwise noted. 3-Substituted oxindoles used in this study were prepared according to the literature.[2] 9-Substituted fluorenes were prepared according to the literature.[3] Reaction mixtures were heated in vials on thermostatted metal blocks using Ika plates. Reactions were monitored by thin layer chromatography (TLC) using Silicycle glass-backed TLC plates with 250 μm silica and F254 indicator. Visualization was accomplished by UV light.

^{1}H NMR, ^{13}C NMR, and ^{19}F NMR spectra were recorded on a AM-500 Fourier transform NMR spectrometer at 500 MHz, 125 MHz, 376 MHz respectively. Chemical shifts are reported relative to the solvent resonance peak δ 7.26 ($CDCl_3$) for ^{1}H and δ 77.16 ($CDCl_3$) for ^{13}C. Data are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, b = broad singlet, m = multiplet), coupling constants, and number of protons. High resolution mass spectra were obtained using a VG autospec with an ionization mode of EI or ESI-TOF. Infrared spectra are reported in cm^{-1}. Column chromatography was performed with silica gel (50-63 μm mesh particle size).

1.1 General Experimental Procedures

General procedure A – cyanomethylation of 3-substituted oxindoles in acetonitrile. Oxindole **1** (0.15 mmol) was added to a flame-dried 8 mL microwave vial equipped with stir bar and was

brought into the glovebox. Acetonitrile **2a** (0.10 M, 1.5 mL) and *t*-BuOO*t*-Bu (110 µL, 4.00 equiv) were added to the mixture sequentially. The microwave vial was sealed with a Teflon cap, removed from the glovebox, and placed in a 130 °C oil bath. After 24 h, the mixture was allowed to cool to ambient temperature and was concentrated. The residue was chromatographed (EtOAc/hexanes) to afford the product **3**.

General procedure B – cyanomethylation of 9-substituted fluorenes in neat alkyl nitriles. Fluorene **5** (0.15 mmol) was added to a flame-dried 8 mL microwave vial equipped with stir bar and was brought into the glovebox. PivOH (31 mg, 0.30 mmol, 2.0 equiv), alkyl nitrile **2** (0.10 M, 1.5 mL) and *t*-BuOO*t*-Bu (165 µL, 6.00 equiv) were added to the mixture sequentially. The microwave vial was sealed with a Teflon cap, removed from the glovebox, and placed in a 125 °C oil bath. After 23 h, the mixture was allowed to cool to ambient temperature and was concentrated. The residue was chromatographed (EtOAc/hexanes) to afford the desired product **6**.

1.2 Optimization of the Reaction Conditions

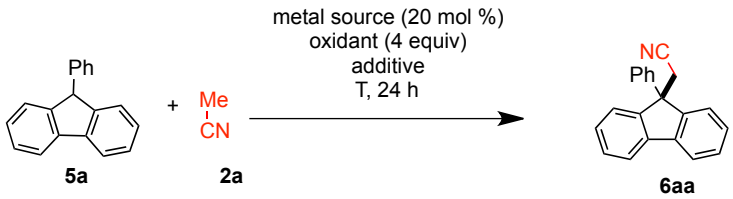
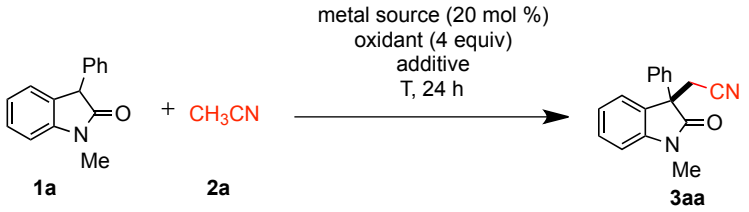


Table S1.

Entry	Metal source	Oxidant[a]	Additive (equiv)	T (°C)	Yield (%)[b]
1	CuBr	*t*-BuOO*t*-Bu	Phen (0.2)	130	0
2	$Cu(OTf)_2$	*t*-BuOO*t*-Bu	Phen (0.2)/Na_3PO_4 (2)	130	23
3	CuI	*t*-BuOO*t*-Bu	Phen (0.2)	130	0
4	$Cu(OAc)_2$	*t*-BuOO*t*-Bu	Phen (0.2)/PivOH (2)	130	0
5	CuCl	*t*-BuOO*t*-Bu		130	26
6	CuCN	*t*-BuOO*t*-Bu		130	46
7	$Pd(OAc)_2$	*t*-BuOO*t*-Bu		130	48
8	$Co(OAc)_2{\cdot}4H_2O$	*t*-BuOO*t*-Bu		130	36
9	$Mn(OAc)_3{\cdot}2H_2O$	*t*-BuOO*t*-Bu		130	0
10	Ferrocene	*t*-BuOO*t*-Bu		130	28
11	$FeCl_3$	Ag_2CO_3 (2)		130	13

12	$FeCl_3$	*t*-BuOO*t*-Bu	Ag_2CO_3 (2)	130	53[c]
13	$Sc(OTf)_3$	Ag_2O (2)		130	15
14		*t*-BuOO*t*-Bu	Ag_2CO_3 (0.2)	130	49[c]
15		*t*-BuOO*t*-Bu		130	54[c]
16		DCP		130	9
17		BzOOBz		130	46
18		TBPB		130	25
19		*t*-BuOOH		130	41
20		*t*-BuOO*t*-Bu	KO^{t}Bu (1)	130	0
21		*t*-BuOO*t*-Bu	Cs_2CO_3 (2)	130	0
22		*t*-BuOO*t*-Bu	DBU (2)	130	trace
23		*t*-BuOO*t*-Bu	PivOH (2)	130	60[c]
24		*t*-BuOO*t*-Bu	HOAc (1)	130	45
25		*t*-BuOO*t*-Bu	TsOH (2)	130	11
26		*t*-BuOO*t*-Bu	KI (0.3)	130	33
27		*t*-BuOO*t*-Bu	TBAI (0.2)	130	48
28		*t*-BuOO*t*-Bu	PivOH (1)	130	56[c]
29		***t*-BuOO*t*-Bu (6)**	**PivOH (2)**	**125**	**65[c,d]**
30		*t*-BuOO*t*-Bu (6)	PivOH (2)	125	46[e] (67)[c,f]

[a]CHP = cumene hydroperoxide, TBPB = *tert*-butyl peroxybenzoate, DCP = dicumylperoxide. [b]Reaction on 0.15 mmol scale and yields analyzed by ^{1}H NMR analysis using 4,4'-dimethoxybenzil as an internal standard. [c]Isolated yield. [d]23 h. [e]16 h. [f]36 h



1a **2a** **3aa**

Table S2.

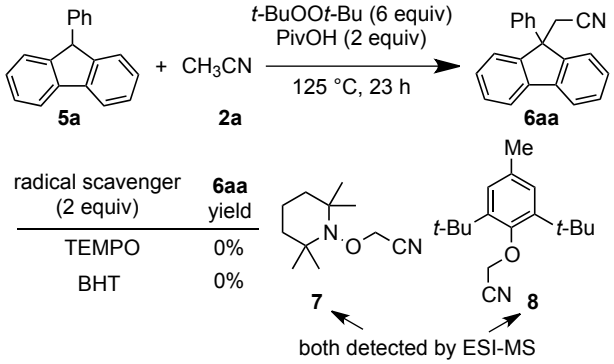
Entry	Metal source	Oxidant [a]	Additive (equiv)	T (°C)	Yield (%)[b]
1	$Cu(OTf)_2$	*t*-BuOO*t*-Bu	Phen (0.5)/Na_3PO_4 (2)	120	16
2	$Cu(OTf)_2$	*t*-BuOO*t*-Bu	Phen (0.5)	120	20
3	$Cu(OAc)_2$	*t*-BuOO*t*-Bu		120	16
4	Cu	*t*-BuOO*t*-Bu		120	22
5	Cu_2O	*t*-BuOO*t*-Bu		120	17
6	CuBr (1)	*t*-BuOO*t*-Bu		120	30
7	CuCl	*t*-BuOO*t*-Bu		120	23
8	$FeCl_3$	Ag_2CO_3		120	34[b]
9	$FeCl_3$	*t*-BuOO*t*-Bu		120	12
10	$Fe(acac)_3$	*t*-BuOO*t*-Bu		120	trace
11	Ferrocene	*t*-BuOO*t*-Bu		120	33
12	$Sc(OTf)_3$	Ag_2O (2)		120	30
13	$Sc(OTf)_3$	*t*-BuOO*t*-Bu		120	12

14	$Zn(OTf)_2$	*t*-BuOO*t*-Bu		120	trace
15	$Pd(OAc)_2$	*t*-BuOO*t*-Bu		120	34[b]
16	$PdCl_2$	*t*-BuOO*t*-Bu		120	22
17	$Pd(OAc)_2$	$K_2S_2O_8$		120	0
18	$CoCl_2{\cdot}6H_2O$	*t*-BuOO*t*-Bu		120	27
19	$Ni(OAc)_2$	*t*-BuOO*t*-Bu		120	8
20	$AlCl_3$	*t*-BuOO*t*-Bu		120	0
21		*t*-BuOO*t*-Bu		120	40[c]
22		TBPB		120	38
23		*t*-BuOOH		120	trace
24		CHP		120	0
25		BzOOBz		120	30
26		DCP		120	38
27		**t-BuOOt-Bu**		**130**	**48[c]**
28		*t*-BuOO*t*-Bu		100	14
29		*t*-BuOO*t*-Bu (2)		130	25
30		*t*-BuOO*t*-Bu (6)		130	41
31		*t*-BuOO*t*-Bu		130	46[c,d]
32		*t*-BuOO*t*-Bu		130	35[e](47)[f]
33		*t*-BuOO*t*-Bu	KOH (1)	130	0
34		*t*-BuOO*t*-Bu	Na_3PO_4 (2)	130	9
35		*t*-BuOO*t*-Bu	DBU (1)	130	0
36		*t*-BuOO*t*-Bu	Cs_2CO_3 (2)	130	0
37		*t*-BuOO*t*-Bu	PivOH (2)	130	29
38		*t*-BuOO*t*-Bu	AcOH (2)	130	33
39		*t*-BuOO*t*-Bu	TsOH (2)	130	0
40		*t*-BuOO*t*-Bu	TBAI (0.2)	130	39
41		*t*-BuOO*t*-Bu	I_2 (0.25)	130	0
42		*t*-BuOO*t*-Bu		130	27[g]

[a]CHP = cumene hydroperoxide, TBPB = *tert*-butyl peroxybenzoate, DCP = dicumylperoxide. [b]Reaction on 0.15 mmol scale and yields analyzed by ^{1}H NMR analysis using 4,4'-dimethoxybenzil as an internal standard. [c]Isolated yield. [d]t-BuOOt-Bu was added in two portions. [e]16 h. [f]36 h. [g]5 mL CH_3CN

1.3 Mechanistic Probes

Radical inhibitor/trap experiments.



Compound **5a** (36 mg, 0.15 mmol) was added to a flame-dried 8 mL microwave vial equipped with a stir bar and was brought into the glovebox. TEMPO (47 mg, 2.0 equiv), PivOH (31 mg, 0.30 mmol, 2.0 equiv), acetonitrile (0.10 M, 1.5 mL), and *t*-BuOO*t*-Bu (165 µL, 6.00 equiv) were added to the mixture sequentially. The microwave vial was sealed with a Teflon cap, removed from the glovebox, and placed in a 125 °C oil bath. After 23 h, the mixture was allowed to cool to ambient temperature. Part of the mixture was analyzed by UPLC-MS, and the TEMPO-adduct was observed.

Figure S1.

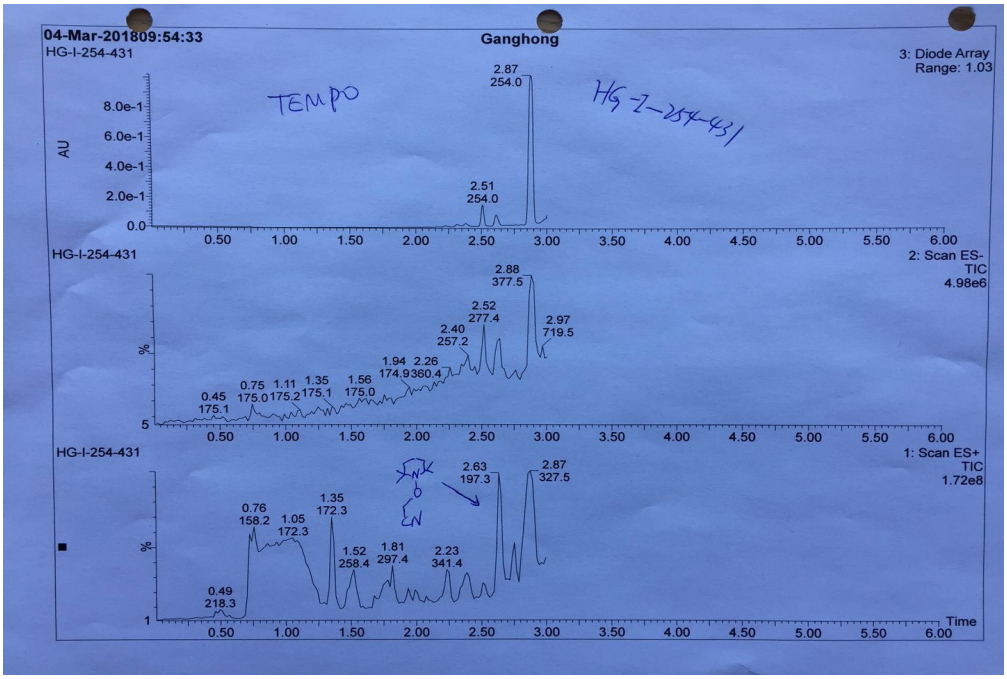
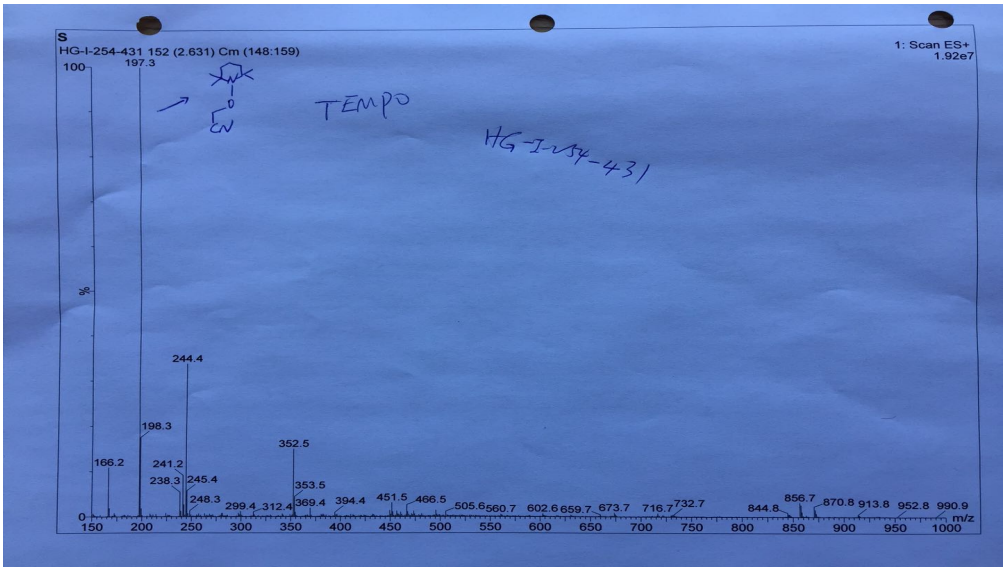


Figure S2.



When the BHT (66 mg, 2.0 equiv) was added to the reaction of **5a** with **2a** under the standard conditions, no desired product **6aa** was detected, and the BHT-adduct was also observed.

Figure S3.

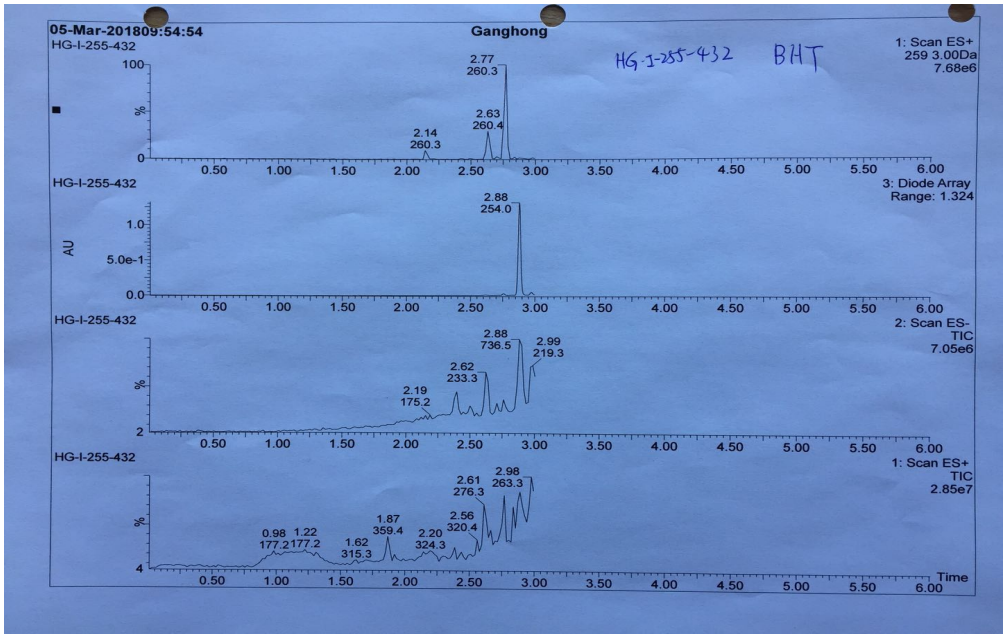
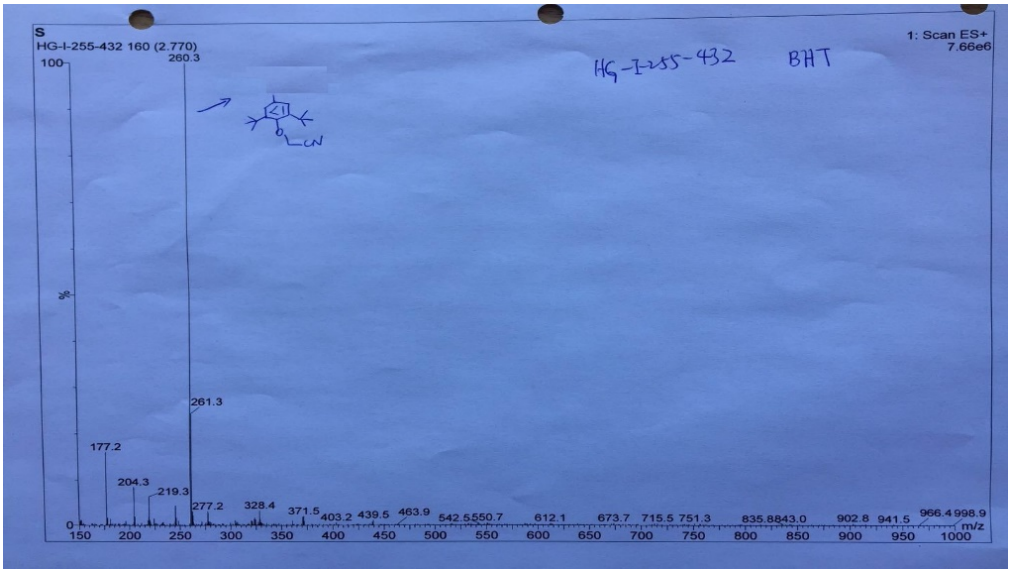
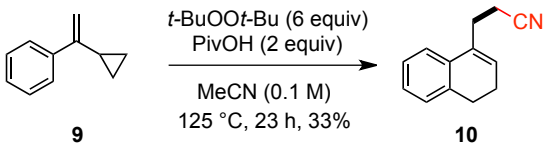


Figure S4.

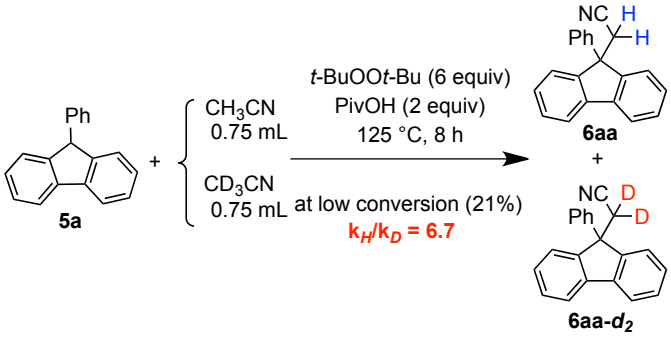


Radical clock experiment.



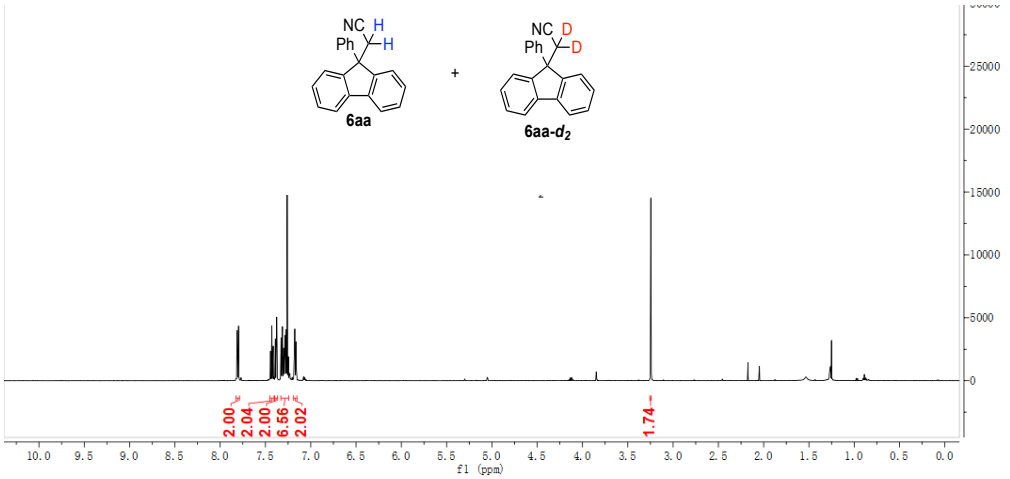
Starting material **9** was synthesized according to literature procedure.[4] Alkene **9** (22 mg, 0.15 mmol) was submitted to the general procedure A. Purification by flash chromatography (100:7 hexane/EtOAc) afforded compound **10** in 33% yield (9.1 mg) as a pale yellow oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.24-7.13 (m, 3H), 7.12 (d, J = 7.5 Hz, 1H), 6.00 (t, J = 1.5 Hz, 1H), 2.84-2.79 (m, 2H), 2.76 (t, J = 8.0 Hz, 2H), 2.57 (t, J = 7.5 Hz, 2H), 2.32-2.27 (m, 2H). Spectral data match those previously reported.[4]

Competitive KIE experiment.

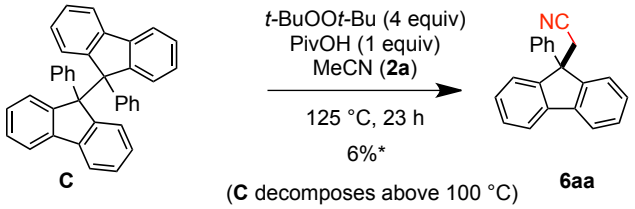


CD_3CN (99.9%) was purchased from Cambridge Isotope Laboratories and was used without further purification. Compound **5a** (36 mg, 0.15 mmol) was added to a flame-dried 8 mL microwave vial equipped with stir bar and was brought into the glovebox. PivOH (31 mg, 0.30 mmol, 2.0 equiv), acetonitrile/D_3-acetonitrile (1:1, 1.5 mL), and *t*-BuOO*t*-Bu (165 µL, 6.00 equiv) were added to the mixture sequentially. The microwave vial was sealed with a Teflon cap, removed from the glovebox, and placed in a 125 °C oil bath. After 8 h, the mixture was allowed to cool to ambient temperature, diluted with CH_2Cl_2 (1 mL), and concentrated. The residue was chromatographed (EtOAc/hexanes) to afford the corresponding product in 21% yield (8.8 mg). The product was analyzed by ^1H NMR (Figure S5):

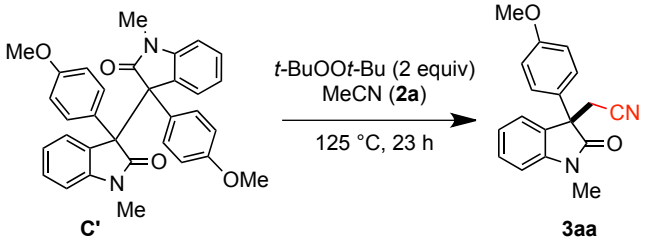
Figure S5.



Using dimer intermediates as substrates.



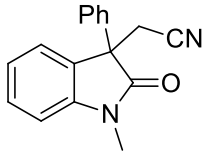
The dimer (**C**) of fuorene **5a** (34 mg, 0.07 mmol)[5] was added to a flame-dried 8 mL microwave vial equipped with stir bar and was brought into the glovebox. PivOH (7.0 mg, 0.07 mmol, 1.0 equiv), acetonitrile **2a** (0.05 M, 1.5 mL) and *t*-BuOO*t*-Bu (39 µL, 0.28 mmol, 4.00 equiv) were added to the mixture sequentially. The microwave vial was sealed with a Teflon cap, removed from the glovebox, and placed in a 125 °C oil bath. After 23 h, the mixture was allowed to cool to ambient temperature and was concentrated. The mixture was analyzed by ^{1}H NMR spectroscopy use CH_2Br_2 as an internal standard: 6% yield. Dimer **C** decomposed above 100 °C accounting for the low yield.



The dimer (**C'**) of oxindole **1a** (35 mg, 0.070 mmol)[6] was added to a flame-dried 8 mL microwave vial equipped with stir bar and was brought into the glovebox. Acetonitrile **2a** (0.10 M, 0.7 mL) and *t*-BuOO*t*-Bu (26 µL, 0.14 mmol, 2.00 equiv) were added to the mixture sequentially. The microwave vial was sealed with a Teflon cap, removed from the glovebox, and placed in a 130 °C oil bath. After 24 h, the mixture was allowed to cool to ambient temperature and was concentrated. The mixture was analyzed by ^{1}H NMR spectroscopy use CH_2Br_2 as an internal standard: 20% yield.

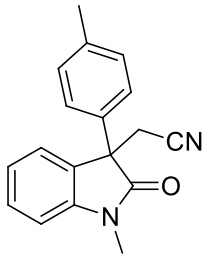
1.4 Characterization Data of Products

2-(1-Methyl-2-oxo-3-phenylindolin-3-yl)acetonitrile (3aa)



General procedure A was followed using **1a** (34 mg, 0.15 mmol), and *t*-BuOO*t*-Bu (110 μL, 4.00 equiv) in acetonitrile **2a** (1.5 mL, 0.10 M) at 130 °C for 24 h. Chromatography (12% EtOAc/hexanes) afforded **3aa** in 48% yield (19 mg) as an amorphous brown solid: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.53 (d, *J* = 7.5 Hz, 1H), 7.44 (td, *J* = 8.0, 1.5 Hz, 1H), 7.36-7.30 (m, 5H), 7.22 (t, *J* = 7.5 Hz, 1H), 6.98 (d, *J* = 8.0 Hz, 1H), 3.38 (d, *J* = 17.0 Hz, 1H), 3.25 (s, 3H), 3.05 (d, *J* = 17.0 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 175.6, 143.5, 136.4, 129.6, 129.3, 128.9, 128.3, 126.7, 125.2, 123.3, 116.3, 108.9, 52.6, 26.7, 26.3; IR (film) 2925, 2250, 1714, 1611, 1471, 1371, 755, 696 cm^{-1}; HRMS (EI-TOF) calcd for $C_{17}H_{14}N_2O$ $[M]^+$ m/z = 262.1106; found 262.1098.

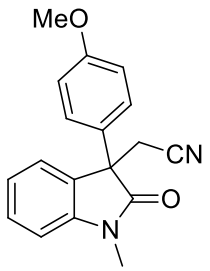
2-(1-Methyl-2-oxo-3-(p-tolyl)indolin-3-yl)acetonitrile (3ba)



General procedure A was followed using **1b** (36 mg, 0.15 mmol), and *t*-BuOO*t*-Bu (110 μL, 4.00 equiv) in acetonitrile **2a** (1.5 mL, 0.10 M) at 130 °C for 24 h. Chromatography (12% EtOAc/hexanes) afforded **3ba** in 38% yield (16 mg) as a colorless oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.52 (d, *J* = 7.5 Hz, 1H), 7.44 (td, *J* = 7.5, 1.0 Hz, 1H), 7.23-7.19 (m, 3H), 7.14 (d, *J* = 8.0 Hz, 2H), 6.97 (d, *J* = 8.0 Hz, 1H), 3.37 (d, *J* = 16.5 Hz, 1H), 3.24 (s, 3H), 3.02 (d, *J* = 16.5 Hz, 1H),

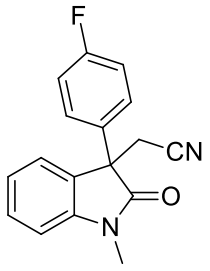
2.32 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 176.0, 143.7, 138.4, 133.6, 129.9, 129.8, 129.7, 126.8, 125.3, 123.5, 116.7, 109.1, 52.5, 26.9, 26.5, 21.1; IR (film) 2924, 2249, 1713, 1611, 1470, 1371, 754, 690 cm^{-1}; HRMS (EI-TOF) calcd for $C_{18}H_{16}N_2O$ $[M]^+$ m/z = 276.1263; found 276.1261.

2-(3-(4-Methoxyphenyl)-1-methyl-2-oxoindolin-3-yl)acetonitrile (3ca)



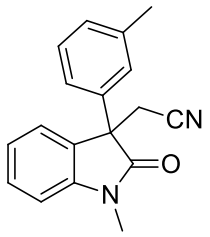
General procedure A was followed using **1c** (38 mg, 0.15 mmol), and *t*-BuOO*t*-Bu (110 μL, 4.00 equiv) in acetonitrile **2a** (1.5 mL, 0.10 M) at 130 °C for 24 h. Chromatography (16% EtOAc/hexanes) afforded **3ca** in 46% yield (20 mg) as a colorless oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.54 (d, *J* = 7.5 Hz, 1H), 7.43 (td, *J* = 7.5, 1.0 Hz, 1H), 7.29-7.26 (m, 2H), 7.22 (t, *J* = 7.0 Hz, 1H), 6.97 (d, *J* = 8.0 Hz, 1H), 6.86 (d, *J* = 9.0 Hz, 2H), 3.78 (s, 3H), 3.34 (d, *J* = 16.5 Hz, 1H), 3.23 (s, 3H), 2.98 (d, *J* = 16.5 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 176.1, 159.7, 143.7, 129.8, 129.7, 128.5, 128.2, 125.4, 123.5, 116.6, 114.5, 109.1, 55.4, 52.2, 26.8, 26.7; IR (film) 2958, 2249, 1713, 1610, 1470, 1371, 1254, 754 cm^{-1}; HRMS (EI-TOF) calcd for $C_{18}H_{16}N_2O_2$ $[M]^+$ m/z = 292.1212; found 292.1209.

2-(3-(4-Fluorophenyl)-1-methyl-2-oxoindolin-3-yl)acetonitrile (3da)



General procedure A was followed using **1d** (36 mg, 0.15 mmol), and *t*-BuO*t*-Bu (110 μL, 4.00 equiv) in acetonitrile **2a** (1.5 mL, 0.10 M) at 130 °C for 24 h. Chromatography (12% EtOAc/hexanes) afforded **3da** in 40% yield (17 mg) as a colorless oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.55 (d, *J* = 7.5 Hz, 1H), 7.45 (td, *J* = 8.0, 1.0 Hz, 1H), 7.37-7.34 (m, 2H), 7.24 (t, *J* = 7.5 Hz, 1H), 7.03 (t, *J* = 8.5 Hz, 2H), 6.98 (d, *J* = 7.5 Hz, 1H), 3.35 (d, *J* = 16.5 Hz, 1H), 3.24 (s, 3H), 2.98 (d, *J* = 16.5 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 175.9, 163.1 (d, *J* = 247 Hz), 143.9, 132.5 (d, *J* = 3.1 Hz), 130.3, 129.5, 129.1 (d, *J* = 8.3 Hz), 125.6, 123.9, 116.6, 116.3 (d, *J* = 21.6 Hz), 109.5, 52.4, 27.2, 27.1; ^{19}F NMR (376 MHz, $CDCl_3$) δ –113.5; IR (film) 2925, 2250, 1713, 1612, 1471, 1371, 1235, 754 cm^{-1}; HRMS (EI-TOF) calcd for $C_{17}H_{13}FN_2O$ $[M]^+$ m/z = 280.1012; found 280.1021.

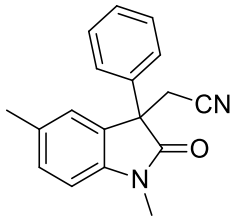
2-(1-Methyl-2-oxo-3-(m-tolyl)indolin-3-yl)acetonitrile (3ea)



General procedure A was followed using **1e** (36 mg, 0.15 mmol), and *t*-BuO*t*-Bu (110 μL, 4.00 equiv) in acetonitrile **2a** (1.5 mL, 0.10 M) at 130 °C for 24 h. Chromatography (12% EtOAc/hexanes) afforded **3ea i**n 47% yield (20 mg) as an amorphous white solid: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.51 (d, *J* = 7.5 Hz, 1H), 7.44 (td, *J* = 7.5, 1.0 Hz, 1H), 7.24-7.19 (m, 2H), 7.15-7.09 (m, 3H), 6.97 (d, *J* = 8.0 Hz, 1H), 3.36 (d, *J* = 17.0 Hz, 1H), 3.25 (s, 3H), 3.04 (d, *J* = 17.0 Hz, 1H), 2.32 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 176.0, 143.7, 138.9, 136.6, 129.7, 129.3, 128.9, 127.4, 125.3, 123.9, 123.5, 118. 0, 116.6, 109.1, 52.8, 26.9, 26.5, 21.7; IR (film) 2932, 2250,

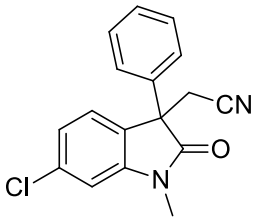
1713, 1611, 1470, 1370, 754, 732 cm^{-1}; HRMS (EI-TOF) calcd for $C_{18}H_{16}N_2O$ $[M]^+$ m/z = 276.1263; found 276.1279.

2-(1,5-Dimethyl-2-oxo-3-phenylindolin-3-yl)acetonitrile (3fa)



General procedure A was followed using **4f** (36 mg, 0.15 mmol), and *t*-BuOO*t*-Bu (110 μL, 4.00 equiv) in acetonitrile **2a** (1.5 mL, 0.10 M) at 130 °C for 24 h. Chromatography (12% EtOAc/hexanes) afforded **3fa** in 40% yield (17 mg) as a colorless oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35-7.30 (m, 6H), 7.23 (d, *J* = 8.0 Hz, 1H), 6.86 (d, *J* = 8.0 Hz, 1H), 3.36 (d, *J* = 16.5 Hz, 1H), 3.23 (s, 3H), 3.03 (d, *J* = 16.5 Hz, 1H), 2.41 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 175.8, 141.4, 136.8, 133.2, 130.1, 129.7, 129.1, 128.4, 126.9, 126.0, 116.6, 108.8, 52.9, 26.9, 26.5, 21.4; IR (film) 2923, 2250, 1712, 1619, 1499, 1355, 734, 697 cm^{-1}; HRMS (EI-TOF) calcd for $C_{18}H_{16}N_2O$ $[M]^+$ m/z = 276.1263; found 276.1265.

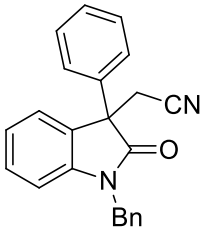
2-(6-Chloro-1-methyl-2-oxo-3-phenylindolin-3-yl)acetonitrile (3ga)



General procedure A was followed using **1g** (39 mg, 0.15 mmol), and *t*-BuOO*t*-Bu (110 μL, 4.00 equiv) in acetonitrile **2a** (1.5 mL, 0.10 M) at 130 °C for 24 h. Chromatography (11% EtOAc/hexanes) afforded **3ga** in 63% yield (28 mg) as an amorphous white solid: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.44 (d, *J* = 8.0 Hz, 1H), 7.37-7.30 (m, 5H), 7.20 (dd, *J* = 8.0, 2.0 Hz, 1H), 6.98

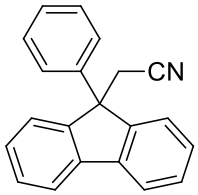
(d, J = 1.5 Hz, 1H), 3.36 (d, J = 17.0 Hz, 1H), 3.23 (s, 3H), 3.05 (d, J = 17.0 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 175.8, 144.9, 136.1, 135.9, 129.2, 128.8, 127.8, 126.7, 126.3, 123.4, 116.3, 109.9, 52.6, 27.0, 26.5; IR (film) 2948, 2250, 1719, 1608, 1494, 1367, 729, 695 cm^{-1}; HRMS (EI-TOF) calcd for $C_{17}H_{13}ClN_2O$ $[M]^+$ m/z = 296.0716; found 296.0719.

2-(1-Benzyl-2-oxo-3-phenylindolin-3-yl)acetonitrile (3ha)



General procedure A was followed using **1h** (45 mg, 0.15 mmol), and *t*-BuOO*t*-Bu (110 μL, 4.00 equiv) in acetonitrile **2a** (1.5 mL, 0.10 M) at 130 °C for 24 h. Chromatography (13% EtOAc/hexanes) afforded **3ha** in 52% yield (26 mg) as a colorless oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.50 (d, J = 7.5 Hz, 1H), 7.38-7.24 (m, 11H), 7.17 (td, J = 7.5, 1.0 Hz, 1H), 6.85 (d, J = 8.0 Hz, 1H), 4.96 (d, J = 16.0 Hz, 1H), 4.92 (d, J = 16.0 Hz, 1H), 3.44 (d, J = 16.5 Hz, 1H), 3.15 (d, J = 16.5 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 176.1, 142.9, 136.8, 135.3, 129.7 (2C), 129.2, 129.0, 128.6, 127.9, 127.3, 126.8, 125.3, 123.6, 116.5, 110.2, 52.9, 44.4, 26.4; IR (film) 3032, 2925, 2250, 1713, 1612, 1487, 1362, 732, 696 cm^{-1}; HRMS (EI-TOF) calcd for $C_{23}H_{18}N_2O$ $[M]^+$ m/z = 338.1419; found 338.1433.

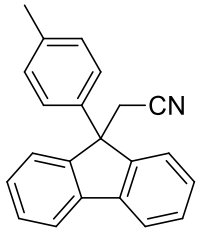
2-(9-Phenyl-9H-fluoren-9-yl)acetonitrile (6aa)



General procedure B was followed using **5a** (36 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 μL, 6.00 equiv) in acetonitrile (1.5 mL, 0.10 M) at 125 °C for 23 h.

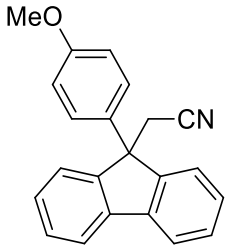
Chromatography (4% EtOAc/hexanes) afforded **6aa** (27 mg) in 65% yield as a colorless oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (d, *J* = 7.5 Hz, 2H), 7.43 (td, *J* = 7.5, 1.0 Hz, 2H), 7.39 (d, *J* = 7.5 Hz, 2H), 7.34-7.23 (m, 5H), 7.17 (d, *J* = 7.0 Hz, 2H), 3.25 (s, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 149.4, 140.9, 140.1, 129.0, 128.7, 128.3, 127.6, 126.4, 124.6, 120.7, 117.7, 55.5, 27.7; IR (film) 3061, 2926, 2250, 1698, 1449, 754, 733 cm^{-1}; HRMS (EI-TOF) calcd for $C_{21}H_{15}N$ $[M]^+$ m/z = 281.1204; found 281.1195.

2-(9-(*p*-Tolyl)-9H-fluoren-9-yl)acetonitrile (6ba)



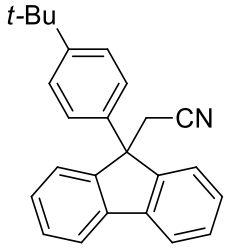
General procedure B was followed using **5b** (38.5 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 μL, 6.00 equiv) in acetonitrile (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (4% EtOAc/hexanes) afforded **6ba** in 61% yield (27.0 mg) as a colorless oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (d, *J* = 7.5 Hz, 2H), 7.42 (td, *J* = 7.5, 1.0 Hz, 2H), 7.38 (d, *J* = 7.5 Hz, 2H), 7.31 (td, *J* = 7.5, 1.0 Hz, 2H), 7.08 (d, *J* = 8.0 Hz, 2H), 7.05 (d, *J* = 8.5 Hz, 2H), 3.22 (s, 2H), 2.30 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 149.5, 140.1, 137.9, 137.3, 129.7, 128.6, 128.3, 126.3, 124.5, 120.6, 117.7, 55.3, 27.8, 21.1; IR (film) 3024, 2922, 2248, 1512, 1448, 748, 734 cm^{-1}; HRMS (EI-TOF) calcd for $C_{22}H_{17}N$ $[M]^+$ m/z = 295.1361; found 295.1364.

2-(9-(4-Methoxyphenyl)-9H-fluoren-9-yl)acetonitrile (6ca)



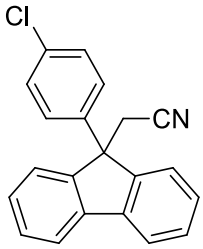
General procedure B was followed using **5c** (41 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 μL, 6.00 equiv) in acetonitrile (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (7% EtOAc/hexanes) afforded **6ca** in 55% yield (26 mg) as a colorless oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.79 (d, *J* = 7.5 Hz, 2H), 7.44-7.37 (m, 4H), 7.31 (td, *J* = 7.5, 1.0 Hz, 2H), 7.09 (d, *J* = 9.0 Hz, 2H), 6.81 (d, *J* = 9.0 Hz, 2H), 3.77 (s, 3H), 3.21 (s, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 158.9, 149.6, 140.0, 132.8, 128.6, 128.3, 127.5, 124.5, 120.6, 117.7, 114.3, 55.4, 54.9, 27.9; IR (film) 3031, 2932, 2249, 1580, 1448, 1185, 749, 735 cm^{-1}; HRMS (EI-TOF) calcd for $C_{22}H_{17}NO$ $[M]^+$ m/z = 311.1310; found 311.1310.

2-(9-(4-(*tert*-Butyl)phenyl)-9H-fluoren-9-yl)acetonitrile (6da)



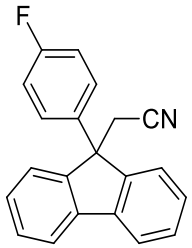
General procedure B was followed using **5d** (45 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 μL, 6.00 equiv) in acetonitrile (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (6% EtOAc/hexanes) afforded **6da** in 62% yield (31 mg) as a colorless oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (d, *J* = 7.5 Hz, 2H), 7.44-7.39 (m, 4H), 7.33-7.26 (m, 4H), 7.09 (d, *J* = 8.5 Hz, 2H), 3.24 (s, 2H), 1.27 (s, 9H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 150.4, 149.4, 140.1, 137.7, 128.6, 128.2, 126.0, 125.9, 124.6, 120.6, 117.7, 55.2, 34.5, 31.4, 27.8; IR (film) 3025, 2962, 2248, 1448, 758, 734 cm^{-1}; HRMS (EI-TOF) calcd for $C_{25}H_{23}N$ $[M]^+$ m/z = 337.1830; found 337.1830.

2-(9-(4-Chlorophenyl)-9H-fluoren-9-yl)acetonitrile (6ea)



General procedure B was followed using **5e** (42 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 μL, 6.00 equiv) in acetonitrile (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (5% EtOAc/hexanes) afforded **6ea** in 55% yield (26 mg) as a colorless oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (d, *J* = 7.5 Hz, 2H), 7.44 (td, *J* = 7.5, 1.0 Hz, 2H), 7.37-7.30 (m, 4H), 7.25 (d, *J* = 7.5 Hz, 2H), 7.10 (d, *J* = 8.5 Hz, 2H), 3.20 (s, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 148.9, 140.0, 139.5, 133.6, 129.2, 128.9, 128.5, 127.9, 124.4, 120.8, 117.4, 55.1, 27.7; IR (film) 3065, 2925, 2250, 1492, 1448, 1094, 758, 735 cm^{-1}; HRMS (EI-TOF) calcd for $C_{21}H_{14}ClN$ $[M]^+$ m/z = 315.0815; found 315.0796.

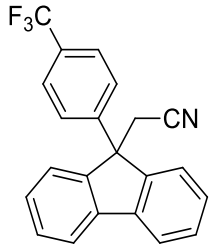
2-(9-(4-Fluorophenyl)-9H-fluoren-9-yl)acetonitrile (6fa)



General procedure B was followed using **5f** (39 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 μL, 6.00 equiv) in acetonitrile (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (4% EtOAc/hexanes) afforded **6fa** in 45% yield (20 mg) as a colorless oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.79 (d, *J* = 7.5 Hz, 2H), 7.42 (td, *J* = 7.5, 1.0 Hz, 2H), 7.37-7.34 (m, 2H), 7.30 (td, *J* = 7.5, 1.0 Hz, 2H), 7.15-7.11 (m, 2H), 6.95 (t, *J* = 8.5 Hz, 2H), 3.19 (s, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 161.9 (d, *J* = 246 Hz), 148.9, 139.8, 136.5 (d, *J* = 3.5 Hz), 128.6, 128.2, 127.9 (d, *J* = 8.3 Hz), 124.2, 120.5, 117.2, 115.6 (d, *J* = 21.4 Hz), 54.8, 27.7; ^{19}F NMR (376 MHz,

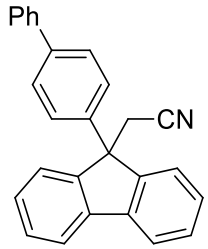
$CDCl_3$) δ -114.9; IR (film) 3065, 2923, 2249, 1508, 1449, 750, 734 cm^{-1}; HRMS (EI-TOF) calcd for $C_{21}H_{14}FN$ $[M]^+$ m/z = 299.1110; found 299.1115.

2-(9-(4-(Trifluoromethyl)phenyl)-9H-fluoren-9-yl)acetonitrile (6ga)



General procedure B was followed using **5g** (46 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 μL, 6.00 equiv) in acetonitrile (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (4% EtOAc/hexanes) afforded **6ga** in 46% yield (24 mg) as a white solid: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.83 (d, *J* = 7.5 Hz, 2H), 7.54 (d, *J* = 8.5 Hz, 2H), 7.46 (td, *J* = 7.0, 1.5 Hz, 2H), 7.38-7.31 (m, 4H), 7.29 (d, *J* = 8.5 Hz, 2H), 3.25 (s, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 148.5, 145.1, 139.9, 129.9 (q, *J* = 32.4 Hz), 128.9, 128.4, 126.8, 125.8 (q, *J* = 3.6 Hz), 124.9 (q, *J* = 271 Hz), 124.3, 120.7, 117.2, 55.3, 27.4; ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.7; IR (film) 3066, 2926, 2249, 1618, 1328, 1119, 750, 733 cm^{-1}; HRMS (EI-TOF) calcd for $C_{22}H_{14}F_3N$ $[M]^+$ m/z = 349.1078; found 349.1093.

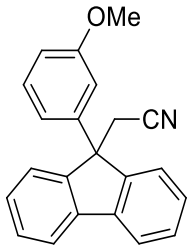
2-(9-([1,1'-Biphenyl]-4-yl)-9H-fluoren-9-yl)acetonitrile (6ha)



General procedure B was followed using **5h** (48 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 μL, 6.00 equiv) in acetonitrile (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (5% EtOAc/hexanes) afforded **6ha** in 47% yield (25 mg) as a white solid: ^{1}H

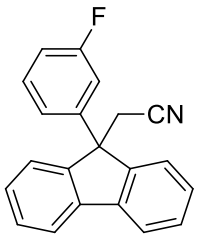
NMR (500 MHz, $CDCl_3$) δ 7.80 (d, *J* = 7.5 Hz, 2H), 7.53-7.47 (m, 4H), 7.45-7.38 (m, 6H), 7.34-7.29 (m, 3H), 7.22 (d, *J* = 8.5 Hz, 2H), 3.26 (s, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 149.1, 140.3, 140.2, 139.9, 137.9, 128.7, 128.5, 128.2, 127.5, 127.3, 126.9, 126.6, 124.4, 120.5, 117.4, 55.1, 27.6; IR (film) 3030, 2924, 2248, 1486, 1448, 762, 735 cm^{-1}; HRMS (EI-TOF) calcd for $C_{27}H_{19}N$ $[M]^+$ m/z = 357.1517; found 357.1502.

2-(9-(3-methoxyphenyl)-9H-fluoren-9-yl)acetonitrile (6ia)



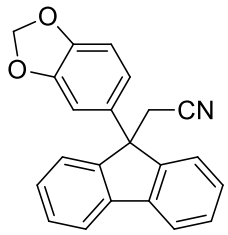
General procedure B was followed using **5i** (41 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 μL, 6.00 equiv) in acetonitrile (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (7% EtOAc/hexanes) afforded **6ia** in 51% yield (24 mg) as a colorless oil: ^1H NMR (500 MHz, $CDCl_3$) δ 7.79 (d, *J* = 7.5 Hz, 2H), 7.44-7.39 (m, 4H), 7.31 (td, *J* = 7.5, 1.0 Hz, 2H), 7.22 (t, *J* = 8.0 Hz, 1H), 6.79 (td, *J* = 7.0, 1.5 Hz, 2H), 6.67 (t, *J* = 2.5 Hz, 1H), 3.71 (s, 3H), 3.22 (s, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 159.9, 149.1, 142.6, 140.1, 129.9, 128.7, 128.3, 124.5, 120.6, 118.7, 117.6, 113.3, 112.0, 55.5, 55.3, 27.8; IR (film) 3067, 2948, 2247, 1490, 1449, 766, 734 cm^{-1}; HRMS (EI-TOF) calcd for $C_{22}H_{17}NO$ $[M]^+$ m/z = 311.1310; found 311.1298.

2-(9-(3-Fluorophenyl)-9H-fluoren-9-yl)acetonitrile (5ja)



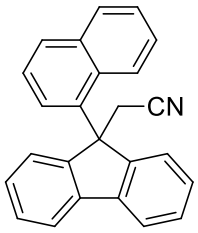
General procedure B was followed using **5j** (39 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 μL, 6.00 equiv) in acetonitrile (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (3% EtOAc/hexanes) afforded **5ja** in 61% yield (27 mg) as a colorless oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.81 (d, *J* = 7.5 Hz, 2H), 7.45 (td, *J* = 7.5, 1.0 Hz, 2H), 7.39 (d, *J* = 7.5 Hz, 2H), 7.35-7.27 (m, 3H), 7.05-7.02 (m, 1H), 6.98-6.93 (m, 1H), 6.80 (dt, *J* = 10.0, 2.5 Hz, 1H), 3.22 (s, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.1 (d, *J* = 245 Hz), 148.7, 143.6 (d, *J* = 6.9 Hz), 140.1, 130.5 (d, *J* = 8.4 Hz), 128.9, 128.5, 124.5, 121.9 (d, *J* = 2.8 Hz), 120.8, 117.3, 114.6 (d, *J* = 21.0 Hz), 113.8 (d, *J* = 22.8 Hz), 55.3 (d, *J* = 1.8 Hz), 28.8 (d, *J* = 269 Hz); ^{19}F NMR (376 MHz, $CDCl_3$) δ -111.7; IR (film) 2923, 2852, 2249, 1588, 1449, 764, 748 cm^{-1}; HRMS (EI-TOF) calcd for $C_{21}H_{14}FN$ $[M]^+$ m/z = 299.1110; found 299.1118.

2-(9-(Benzo[d][1,3]dioxol-5-yl)-9H-fluoren-9-yl)acetonitrile (6ka)



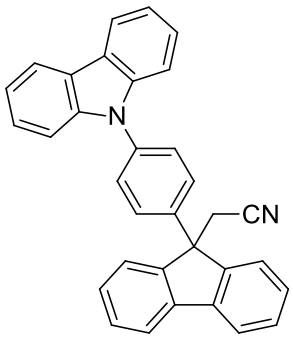
General procedure B was followed using **5k** (43 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 μL, 6.00 equiv) in acetonitrile (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (7% EtOAc/hexanes) afforded **6ka** in 34% yield (17 mg) as a colorless oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.78 (d, *J* = 8.0 Hz, 2H), 7.44-7.38 (m, 4H), 7.31 (td, *J* = 8.5, 1.0 Hz, 2H), 6.82 (dd, *J* = 8.5, 2.0 Hz, 1H), 6.75 (d, *J* = 8.5 Hz, 1H), 6.43 (d, *J* = 2.0 Hz, 1H), 5.89 (s, 2H), 3.17 (s, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 149.3, 148.3, 147.1, 139.9, 134.7, 128.7, 128.3, 124.4, 120.7, 119.3, 117.6, 108.4, 107.4, 101.3, 55.3, 27.9; IR (film) 3062, 2919, 2249, 1488, 1448, 1240, 1040, 752, 735 cm^{-1}; HRMS (EI-TOF) calcd for $C_{22}H_{15}NO_2$ $[M]^+$ m/z = 325.1103; found 325.1122.

2-(9-(Naphthalen-1-yl)-9H-fluoren-9-yl)acetonitrile (6la)



General procedure B was followed using **5l** (44 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 μL, 6.00 equiv) in acetonitrile (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (5% EtOAc/hexanes) afforded **6la** in 36% yield (18 mg) as an amorphous white solid: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.99 (d, *J* = 7.5 Hz, 1H), 7.95 (d, *J* = 7.5 Hz, 2H), 7.86 (d, *J* = 8.5 Hz, 1H), 7.75 (d, *J* = 8.0 Hz, 1H), 7.63 (t, *J* = 7.5 Hz, 1H), 7.46 (t, *J* = 7.5 Hz, 2H), 7.22 (t, *J* = 7.5 Hz, 3H), 7.14 (d, *J* = 7.5 Hz, 2H), 6.84 (t, *J* = 8.5 Hz, 1H), 6.57 (d, *J* = 9.0 Hz, 1H), 3.14 (s, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 150.5, 139.5, 134.8, 130.8, 129.7, 128.9, 128.7, 128.5, 127.6, 127.5, 125.9, 125.8, 125.5, 125.3, 124.9, 124.1, 121.3, 56.3, 31.9; IR (film) 3051, 2923, 2249, 1448, 775, 736 cm^{-1}; HRMS (EI-TOF) calcd for $C_{25}H_{17}N$ $[M]^+$ m/z = 331.1361; found 331.1367.

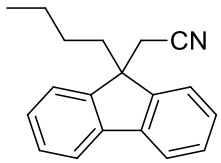
2-(9-(4-(9H-Carbazol-9-yl)phenyl)-9H-fluoren-9-yl)acetonitrile (5ma)



General procedure B was followed using **5m** (61 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 μL, 6.00 equiv) in acetonitrile (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (6% EtOAc/hexanes) afforded **5ma** in 49% yield (33 mg) an amorphous white

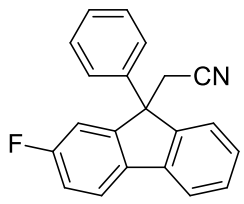
solid: ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.12 (d, *J* = 8.0 Hz, 2H), 7.85 (d, *J* = 7.5 Hz, 2H), 7.53-7.47 (m, 6H), 7.43-7.36 (m, 8H), 7.30-7.26 (m, 2H), 3.32 (s, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 149.1, 140.8, 140.2, 140.1, 137.2, 128.9, 128.5, 127.9, 127.4, 126.1, 124.6, 123.6, 120.8, 120.4, 120.2, 117.5, 109.9, 55.4, 27.9; IR (film) 3061, 2925, 2249, 1514, 1451, 1229, 750, 735 cm^{-1}; HRMS (EI-TOF) calcd for $C_{33}H_{22}N_2$ $[M]^+$ m/z = 446.1783; found 446.1793.

2-(9-Butyl-9H-fluoren-9-yl)acetonitrile (6na)



General procedure B was followed using **5n** (33 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 μL, 6.00 equiv) in acetonitrile (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (4% EtOAc/hexanes) afforded **6na** in 51% yield (20 mg) as a colorless oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.74 (d, *J* = 7.5 Hz, 2H), 7.54 (d, *J* = 7.5 Hz, 2H), 7.41 (td, *J* = 7.5, 1.0 Hz, 2H), 7.35 (td, *J* = 7.5, 1.5 Hz, 2H), 2.72 (s, 2H), 2.23-2.19 (m, 2H), 1.14 (q, *J* = 7.5 Hz, 2H), 0.70 (t, *J* = 7.5 Hz, 3H), 0.67-0.60 (m, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 147.5, 140.5, 128.4, 127.9, 123.1, 120.4, 117.9, 51.0, 37.2, 29.3, 26.0, 22.8, 13.8; IR (film) 2956, 2930, 2860, 2247, 1449, 761, 736 cm^{-1}; HRMS (EI-TOF) calcd for $C_{19}H_{19}N$ $[M]^+$ m/z = 261.1517; found 261.1542.

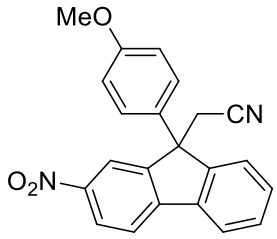
2-(2-Fluoro-9-phenyl-9H-fluoren-9-yl)acetonitrile (6oa)



General procedure B was followed using **5o** (39 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 μL, 6.00 equiv) in acetonitrile (1.5 mL, 0.10 M) at 125 °C for 23 h.

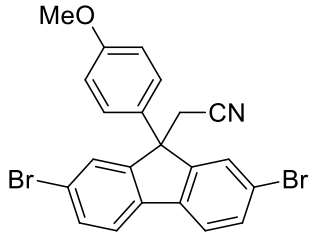
Chromatography (4% EtOAc/hexanes) afforded **6oa** in 34% yield (15 mg) as a colorless oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.77-7.73 (m, 2H), 7.43 (t, *J* = 7.5 Hz, 1H), 7.36 (d, *J* = 7.5 Hz, 1H), 7.32-7.26 (m, 4H), 7.17-7.11 (m, 3H), 7.07 (dd, *J* = 8.5, 2.5 Hz, 1H), 3.25 (s, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 163.0 (d, *J* = 246 Hz), 151.5 (d, *J* = 7.6 Hz), 149.3, 140.3, 139.3, 136.2, 129.1, 128.9, 128.0, 127.8, 126.3, 124.5, 121.8 (d, *J* = 8.8 Hz), 120.4, 117.2, 116.0 (d, *J* = 23.0 Hz), 112.1 (d, *J* = 23.3 Hz), 55.6, 27.6; ^{19}F NMR (376 MHz, $CDCl_3$) δ –112.4; IR (film) 3052, 2248, 1592, 1454, 1265, 757, 732 cm^{-1}; HRMS (EI-TOF) calcd for $C_{21}H_{14}FN$ $[M]^+$ m/z = 299.1110; found 299.1120.

2-(9-(4-Methoxyphenyl)-2-nitro-9H-fluoren-9-yl)acetonitrile (6pa)



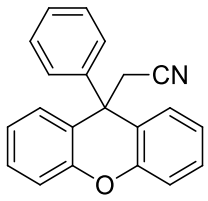
General procedure B was followed using **5p** (48 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuO*O*t*-Bu (165 μL, 6.00 equiv) in acetonitrile (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (12% EtOAc/hexanes) afforded **6pa** in 55% yield (29 mg) an amorphous white solid: ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.33 (dd, *J* = 8.0, 2.0 Hz, 1H), 8.16 (d, *J* = 1.0 Hz, 1H), 7.92-7.88 (m, 2H), 7.54-7.45 (m, 3H), 7.06 (d, *J* = 9.0 Hz, 2H), 6.83 (d, *J* = 9.0 Hz, 2H), 3.78 (s, 3H), 3.42 (d, *J* = 16.5 Hz, 1H), 3.25 (d, *J* = 16.5 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 159.5, 150.8, 150.7, 147.8, 146.4, 137.9, 131.1, 130.5, 129.3, 127.4, 124.9, 124.8, 122.1, 120.9, 119.9, 116.7, 114.8, 55.4, 55.4, 27.7; IR (film) 3062, 2250, 1592, 1454, 1265, 757, 732 cm^{-1}; HRMS (EI-TOF) calcd for $C_{22}H_{16}N_2O_3$ $[M]^+$ m/z = 356.1161; found 356.1176.

2-(2,7-Dibromo-9-(4-methoxyphenyl)-9H-fluoren-9-yl)acetonitrile (6qa)



General procedure B was followed using **5q** (64 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 μL, 6.00 equiv) in acetonitrile (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (5% EtOAc/hexanes) afforded **6qa** in 64% yield (45 mg) as an amorphous white solid: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.62 (d, *J* = 8.0 Hz, 2H), 7.55 (dd, *J* = 8.0, 1.5 Hz, 2H), 7.46 (d, *J* = 1.5 Hz, 2H), 7.02 (d, *J* = 9.0 Hz, 2H), 6.84 (d, *J* = 9.0 Hz, 2H), 3.79 (s, 3H), 3.23 (s, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 159.4, 151.2, 138.1, 132.2, 131.2, 127.8, 127.4, 122.5, 122.1, 116.8, 114.7, 55.4, 55.2, 27.7; IR (film) 2931, 2836, 2249, 1512, 1253, 735 cm^{-1}; HRMS (EI-TOF) calcd for $C_{22}H_{15}Br_2NO$ $[M]^+$ m/z = 466.9520; found 466.9534.

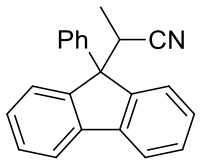
2-(9-Phenyl-9H-xanthen-9-yl)acetonitrile (6ra)



General procedure B was followed using **5r** (39 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 μL, 6.00 equiv) in acetonitrile (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (6% EtOAc/hexanes) afforded **6ra** in 20% yield (8.9 mg) as a colorless oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.38 (t, *J* = 7.5 Hz, 2H), 7.34-7.26 (m, 5H), 7.19 (dd, *J* = 8.0, 1.0 Hz, 2H), 7.01-6.97 (m, 2H), 6.84 (dd, *J* = 8.0, 1.5 Hz, 2H), 3.22 (s, 2H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 150.9, 144.9, 129.2, 129.1, 128.7, 128.6, 127.4, 125.8, 123.7, 117.2, 116.9, 45.8, 33.1; IR (film)

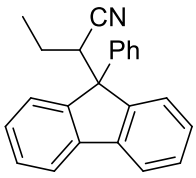
3051, 3025, 2249, 1600, 1479, 1443, 1276, 1255, 753, 699 cm^{-1}; HRMS (EI-TOF) calcd for $C_{21}H_{15}NO$ $[M]^+$ m/z = 297.1154; found 297.1140.

2-(9-Phenyl-9H-fluoren-9-yl)propanenitrile (6ab)



General procedure B was followed using **5a** (36 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 µL, 6.00 equiv) in propiononitrile **2b** (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (4% EtOAc/hexanes) afforded **6ab** in 66% yield (29 mg) as an amorphous white solid: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (d, *J* = 8.0 Hz, 1H), 7.75-7.71 (m, 2H), 7.49 (dd, *J* = 7.5, 1.0 Hz, 1H), 7.40 (dd, *J* = 7.5, 1.5 Hz, 1H), 7.35 (dd, *J* = 7.5, 1.5 Hz, 1H), 7.31-7.18 (m, 7H), 4.00 (q, *J* = 7.0 Hz, 1H), 0.78 (d, *J* = 7.0 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 148.2, 146.6, 141.9, 141.5, 140.5, 128.9, 128.8, 128.4, 128.3, 128.2, 127.6, 126.6, 125.8, 123.7, 121.9, 120.4, 120.3, 59.8, 32.9, 13.4; IR (film) 3061, 2940, 2239, 1450, 754, 732, 697 cm^{-1}; HRMS (EI-TOF) calcd for $C_{22}H_{17}N$ $[M]^+$ m/z = 295.1361; found 295.1363.

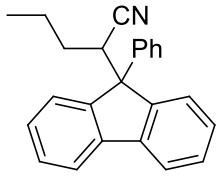
2-(9-Phenyl-9H-fluoren-9-yl)butanenitrile (6ac)



General procedure B was followed using **5a** (36 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 µL, 6.00 equiv) in butyronitrile **2c** (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (4% EtOAc/hexanes) afforded **6ac** in 75% yield (35 mg) as an amorphous white solid: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (d, *J* = 8.0 Hz, 1H), 7.73 (dd, *J* = 8.0, 3.5 Hz, 2H),

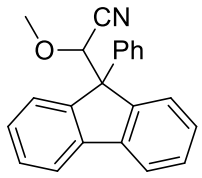
7.48 (t, J = 7.5 Hz, 1H), 7.41-7.33 (m, 2H), 7.30-7.20 (m, 7H), 3.74 (t, J = 3.5 Hz, 1H), 1.05-0.92 (m, 5H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 148.5, 147.1, 141.7, 140.4, 128.9, 128.7, 128.4, 128.3, 128.2, 127.5, 126.5, 125.7, 123.7, 120.9, 120.4, 120.3, 119.8, 59.7, 41.7, 20.9, 12.4; IR (film) 3061, 2969, 2240, 1450, 747, 734, 697 cm^{-1}; HRMS (EI-TOF) calcd for $C_{23}H_{19}N$ $[M]^+$ m/z = 309.1517; found 309.1523.

2-(9-Phenyl-9H-fluoren-9-yl)pentanenitrile (6ad)



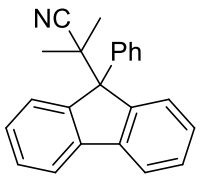
General procedure B was followed using **5a** (36 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 μL, 6.00 equiv) in pentanenitrile **2d** (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (5% EtOAc/hexanes) afforded **6ad** in 72% yield (35 mg) as an amorphous white solid: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.80 (d, J = 7.5 Hz, 1H), 7.74 (dd, J = 8.0, 4.5 Hz, 2H), 7.49 (t, J = 7.0 Hz, 1H), 7.42-7.33 (m, 2H), 7.30-7.21 (m, 7H), 3.85 (dd, J = 11.5, 3.5 Hz, 1H), 1.58-1.50 (m, 1H), 1.35-1.27 (m, 1H), 1.09-0.98 (m, 1H), 0.87-0.80 (m, 1H), 0.75 (t, J = 7.5 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 148.4, 147.1, 141.7, 141.6, 140.4, 128.9, 128.7, 128.4, 128.3, 128.1, 127.5, 126.6, 125.7, 123.7, 121.2, 120.4, 120.3, 59.6, 39.4, 29.2, 21.0, 13.5; IR (film) 3060, 2960, 2245, 1450, 755, 733, 697 cm^{-1}; HRMS (EI-TOF) calcd for $C_{24}H_{21}N$ $[M]^+$ m/z = 323.1674; found 323.1685.

2-Methoxy-2-(9-phenyl-9H-fluoren-9-yl)acetonitrile (6ae)



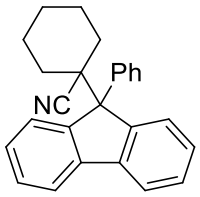
General procedure B was followed using **5a** (36 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuO*t*-Bu (165 μL, 6.00 equiv) in 2-methoxyacetonitrile **2e** (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (6% EtOAc/hexanes) afforded **6ae** in 42% yield (20 mg) as an amorphous white solid: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.82 (d, *J* = 7.6 Hz, 1H), 7.80 (d, *J* = 7.6 Hz, 1H), 7.57 (d, *J* = 7.5 Hz, 1H), 7.47 (td, *J* = 7.0, 1.0 Hz, 1H), 7.42 (td, *J* = 7.0, 1.0 Hz, 1H), 7.37 (d, *J* = 7.5 Hz, 1H), 7.33 (td, *J* = 8.0, 1.0 Hz, 1H), 7.29-7.20 (m, 6H), 4.80 (s, 1H), 3.55 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 146.9, 146.4, 141.4, 140.8, 139.8, 129.0, 128.9, 128.8, 128.0, 127.9, 127.5, 127.1, 126.9, 125.5, 120.6, 120.4, 116.5, 76.5, 61.1, 59.1; IR (film) 3061, 2930, 2250, 1450, 1099, 756, 736 cm^{-1}; HRMS (EI-TOF) calcd for $C_{22}H_{17}NO$ $[M]^+$ m/z = 311.1310; found 311.1310 (masses identical).

2-Methyl-2-(9-phenyl-9H-fluoren-9-yl)propanenitrile (6af)



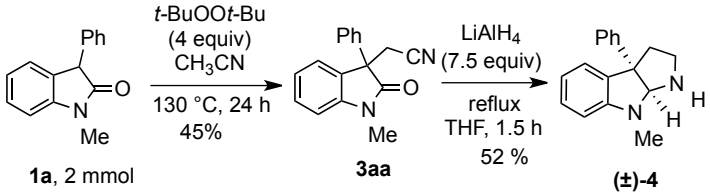
General procedure B was followed using **5a** (36 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuO*t*-Bu (165 μL, 6.00 equiv) in isobutyronitrile **2f** (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (4% EtOAc/hexanes) afforded **6af** in 42% yield (20 mg) as a colorless oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.76 (d, *J* = 7.5 Hz, 2H), 7.59-7.55 (m, 4H), 7.42 (t, *J* = 7.5 Hz, 2H), 7.32-7.20 (m, 5H), 1.27 (s, 6H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 147.9, 141.4, 140.7, 128.6, 128.5, 128.1, 127.7, 127.1, 126.5, 126.4, 120.1, 63.0, 38.2, 24.7; IR (film) 3060, 2229, 1448, 744, 728 cm^{-1}; HRMS (EI-TOF) calcd for $C_{23}H_{19}N$ $[M]^+$ m/z = 309.1517; found 309.1529.

1-(9-Phenyl-9H-fluoren-9-yl)cyclohexanecarbonitrile (6ag)



General procedure B was followed using **5a** (36 mg, 0.15 mmol), PivOH (31 mg, 0.30 mmol, 2.0 equiv), and *t*-BuOO*t*-Bu (165 μL, 6.00 equiv) in cyclohexanecarbonitrile **2g** (1.5 mL, 0.10 M) at 125 °C for 23 h. Chromatography (4% EtOAc/hexanes) afforded **6ag** in 61% yield (32 mg) as an amorphous white solid: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.75 (d, *J* = 7.5 Hz, 2H), 7.61-7.58 (m, 4H), 7.41 (t, *J* = 7.5 Hz, 2H), 7.30 (td, *J* = 7.5, 1.0 Hz, 2H), 7.27-7.18 (m, 3H), 1.85-1.39 (m, 7H), 1.30-1.25 (m, 2H), 0.97-0.88 (m, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 148.1, 141.6, 140.4, 128.6, 128.4, 128.3, 127.6, 127.1, 126.9, 123.7, 119.9, 63.7, 45.9, 31.3, 25.1, 22.9; IR (film) 3058, 2937, 2227, 1449, 743, 699 cm^{-1}; HRMS (EI-TOF) calcd for $C_{26}H_{23}N$ $[M]^+$ m/z = 349.1830; found 349.1831.

1.5 Derivatization of Product 3aa



Large scale cyanomethylation and derivatization to 8-methyl-3a-phenyl-1,2,3,3a,8,8a-hexahydropyrrolo[2,3-b]indole (4). Oxindole **1a** (446 mg, 2.00 mmol) was submitted to the General procedure A. Purification by chromatography (100:12 hexane/EtOAc) afforded compound **3aa** in 45% yield (236 mg) as a brown solid. To a precooled (5 °C) stirred suspension of $LiAlH_4$ (256 mg, 6.75 mmol) in anhydrous THF (10 mL) and under argon atmosphere was added the oxindole **3aa** (236 mg, 0.900 mmol) in THF (10 mL), and the mixture was heated at

reflux for 1.5 h. After cooling, the reaction mixture in an ice/water bath, the reaction was quenched by adding, in sequence, EtOAc (10 mL) and water (5 mL). The solids were removed by filtration and washed with EtOAc (2 × 10 mL). The combined organic phases were washed with brine, dried, and concentrated under reduced pressure. The resulting pyrroloindoline was purified by chromatography on silica gel (100:1 CH_2Cl_2/MeOH) affording compound **4** in 52% yield (117 mg) as a colorless oil: ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.35-7.28 (m, 4H), 7.20 (t, *J* = 7.0 Hz, 1H), 7.09 (t, *J* = 7.5 Hz, 1H), 6.89 (d, *J* = 7.0 Hz, 1H), 6.60 (t, *J* = 7.5 Hz, 1H), 6.39 (d, *J* = 8.0 Hz, 1H), 4.94 (s, 1H), 3.24-3.19 (m, 1H), 2.91 (s, 3H), 2.79-2.72 (m, 1H), 2.53-2.47 (m, 1H), 2.42-2.37 (m, 1H), 2.03 (s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 151.3, 146.2, 134.2, 128.4, 128.1, 126.3, 126.2, 124.2, 116.8, 105.1, 92.9, 61.3, 46.8, 41.8, 31.3; IR (film) 2933, 2875, 1603, 1492, 1296, 738, 699 cm^{-1}; HRMS (EI-TOF) calcd for $C_{17}H_{18}N_2$ $[M]^+$ m/z = 250.1470; found 250.1482.

References

(1) Heaney, H.; Cardona, F.; Goti, A.; Frederick, A. L. **2013**. Hydrogen Peroxide–Urea. e-EROS Encyclopedia of Reagents for Organic Synthesis.

(2) (a) Trost, B. M.; Masters, J. T.; Burns, A. C. Palladium-Catalyzed Asymmetric Allylic Alkylation of 3-Aryloxindoles with Allylidene Dipivalate: A Useful Enol Pivalate Product. *Angew. Chem., Int. Ed.* **2013**, *52*, 2260. (b) Trost, B. M.; Xie, J.; Sieber, J. D. The Palladium Catalyzed Asymmetric Addition of Oxindoles and Allenes: An Atom-Economical Versatile Method for the Construction of Chiral Indole Alkaloids. *J. Am. Chem. Soc.* **2011**, *133*, 20611.

(3) (a) Shen, X.; Gu, N. N.; Liu, P.; Mao, X. W.; Xie, J. W.; Liu, Y.; Hen, L.; Dai, B. A Simple and Efficient Synthesis of 9-Arylfluorenes via Metal-Free Reductive Coupling of Arylboronic Acids and N-Tosylhydrazones in situ. *RSC Adv.* **2015**, *5*, 63726. (b) Vougioukalakis, G. C.; Roubelakis, M. M.; Orfanopoulos, M. Radical Reactivity of Aza[60]fullerene: Preparation of Monoadducts and Limitations. *J. Org. Chem.* **2010**, *75*, 4124.

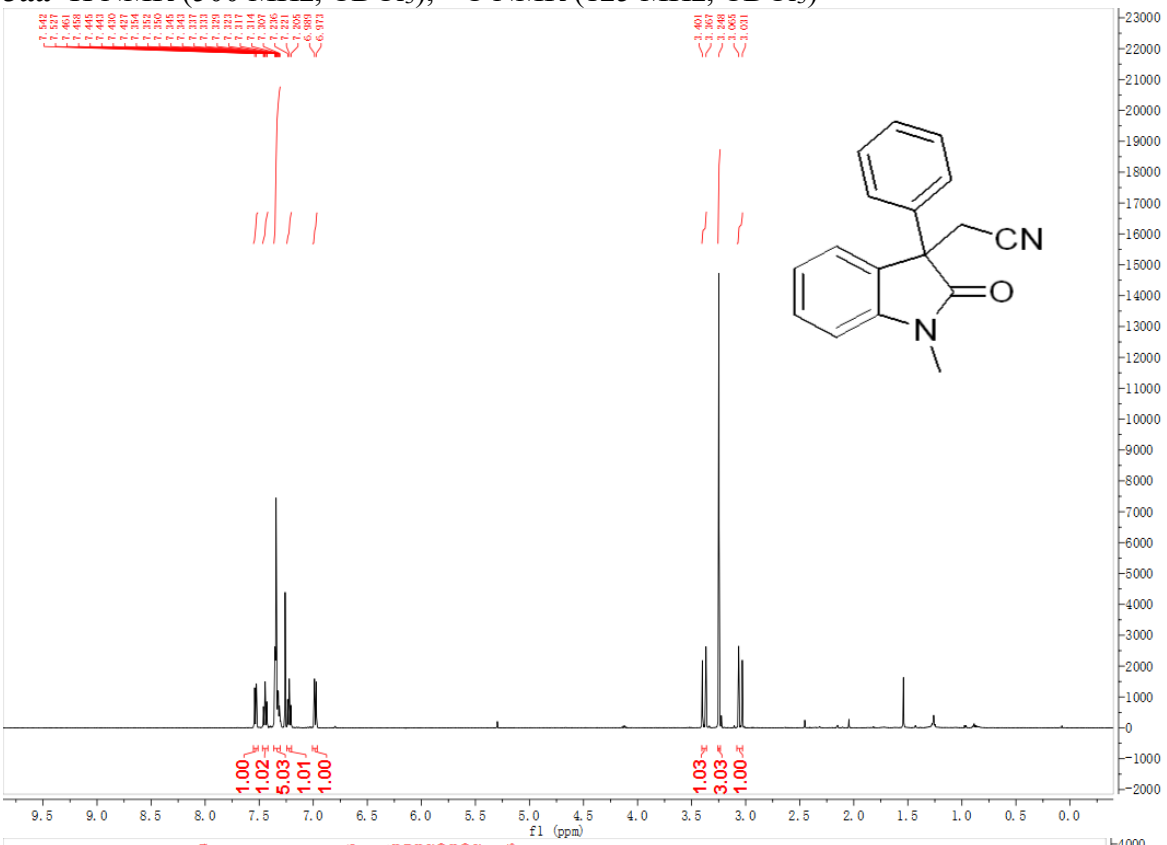
(4) Sazepin, C. C.; Wang, Q.; Sammis, G. M.; Zhu, J. P. Copper-Catalyzed Intermolecular Carboetherification of Unactivated Alkenes by Alkyl Nitriles and Alcohols. *Angew. Chem. Int. Ed.* **2015**, *54*, 5443.

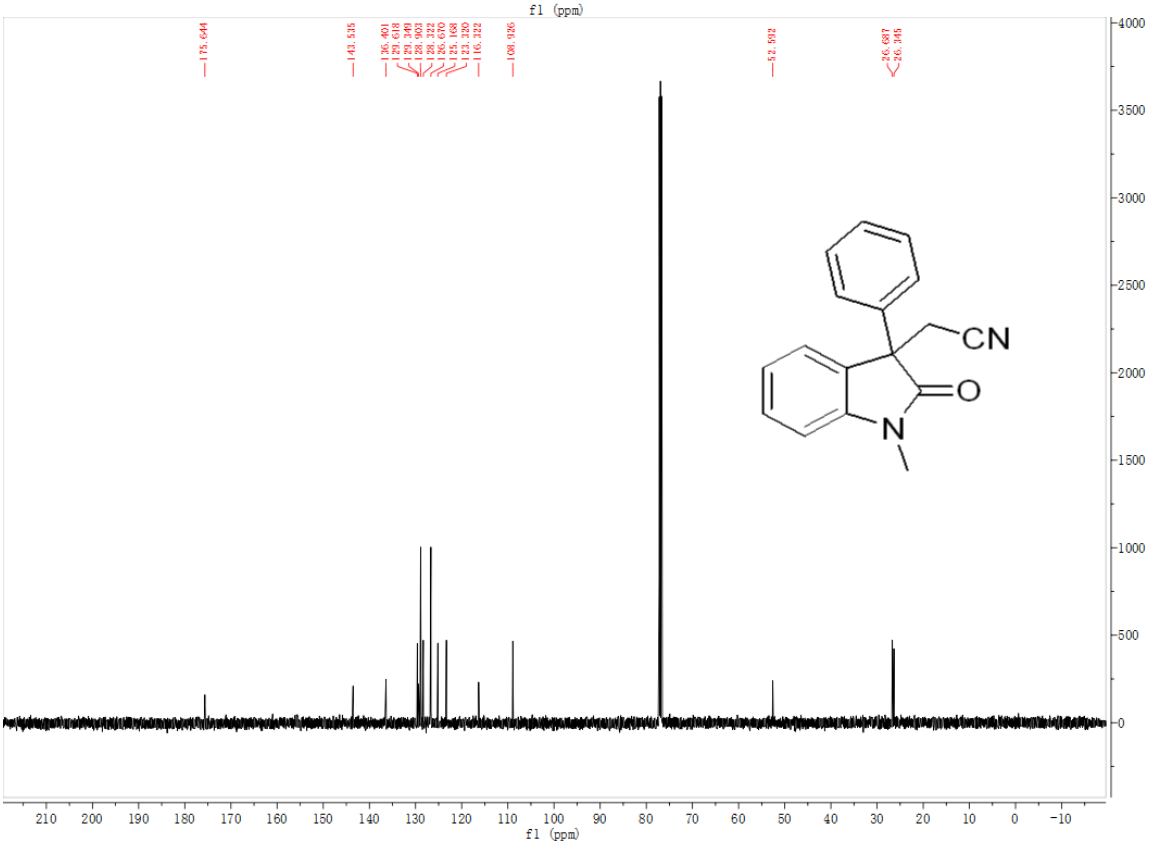
(5) Frenette, M.; Aliaga, C.; Font-Sanchis, E.; Scaiano, J. C. Bond Dissociation Energies for Radical- Dimers Derived from Highly Stabilized Carbon-Centered Radicals *Org. Lett.* **2004**, *6*, 2579-2582.

(6) Hong, G.; Nahide, P. D.; Neelam, U. K.; Amadeo, P.; Vijeta, A.; Curto, J. M.; Hendrick, C. E.; VanGelder, K. F.; Kozlowski, M. C. Palladium-Catalyzed Chemoselective Activation of sp^3 vs sp^2 C–H Bonds: Oxidative Coupling To Form Quaternary Centers *ACS Catal*. **2019**, *9*, 3716.

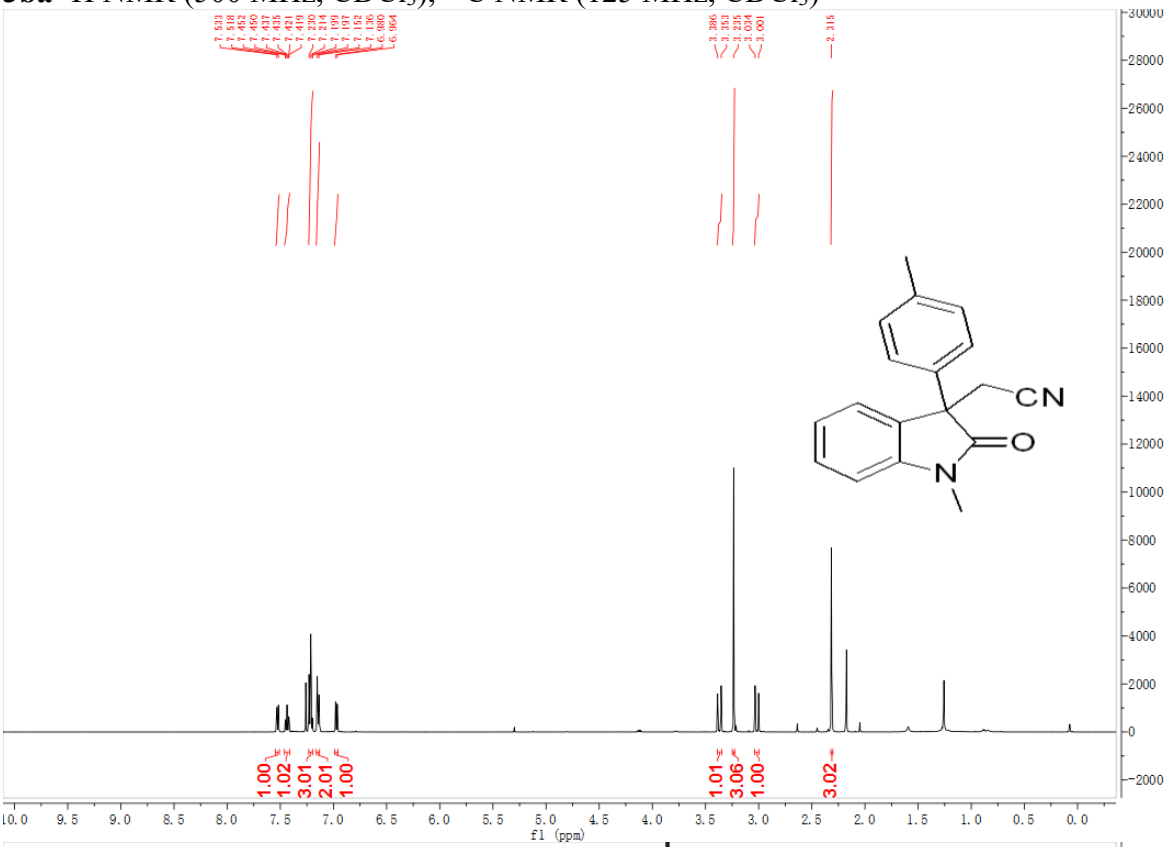
Copies of ^{1}H NMR, ^{13}C NMR and ^{19}F NMR

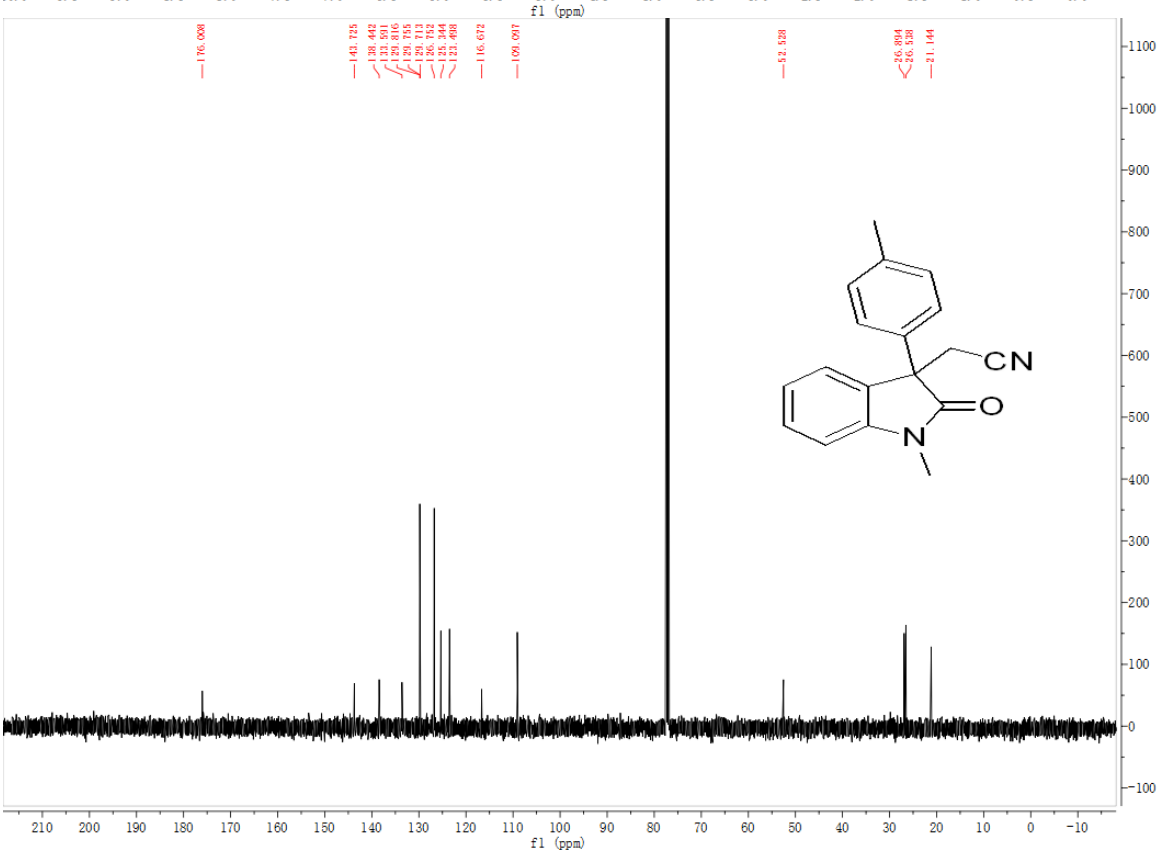
3aa ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)



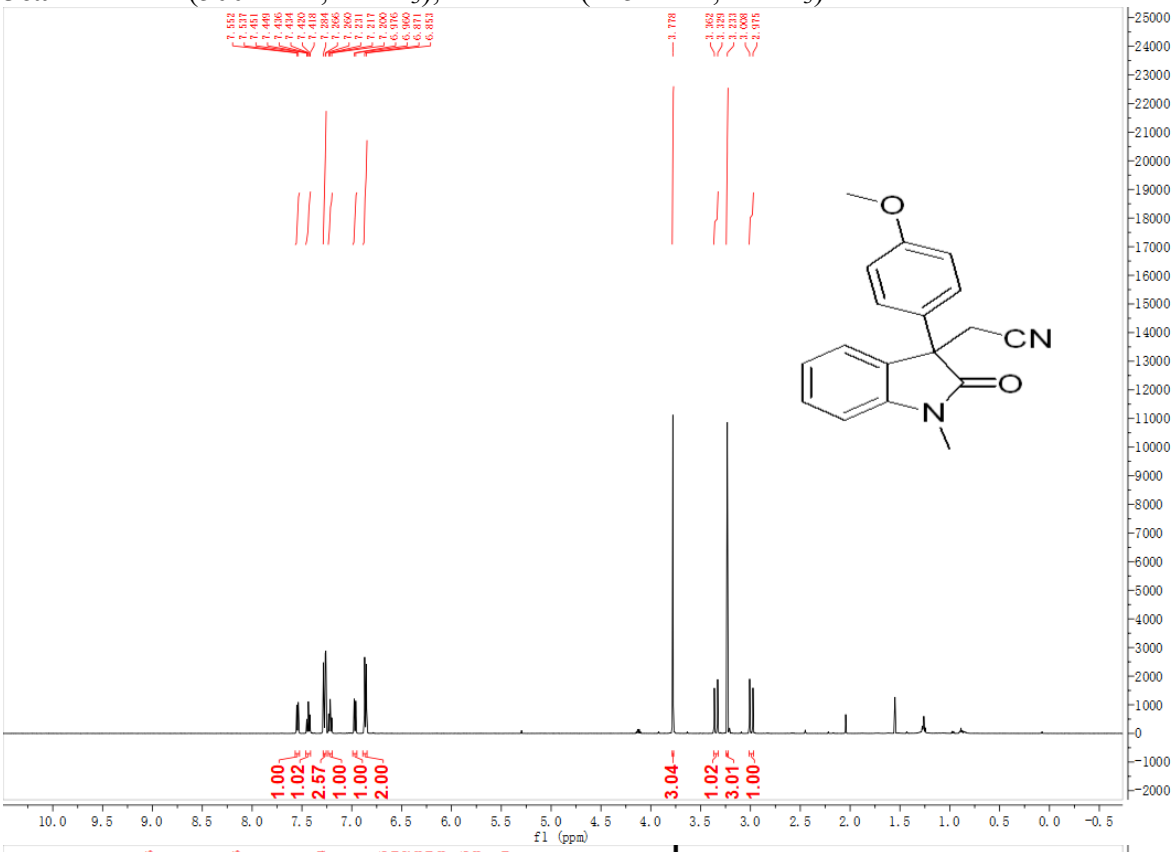


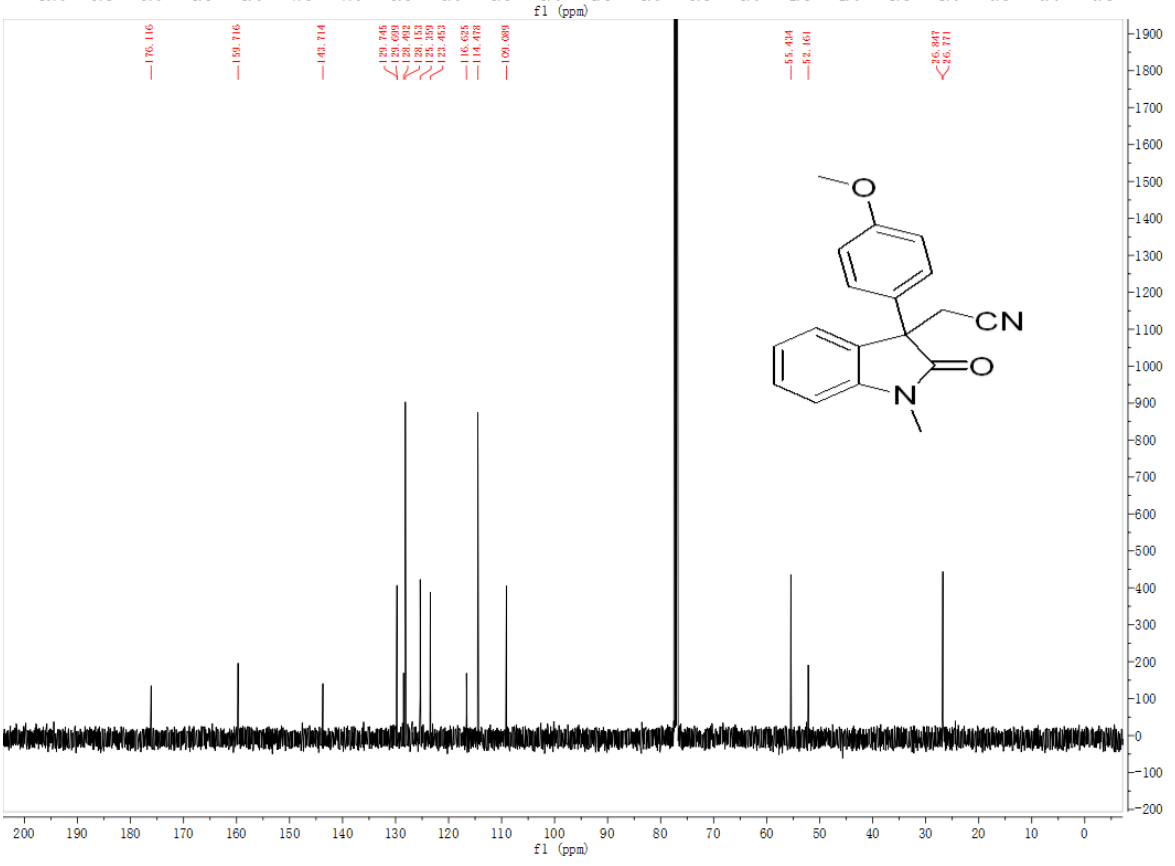
3ba ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)



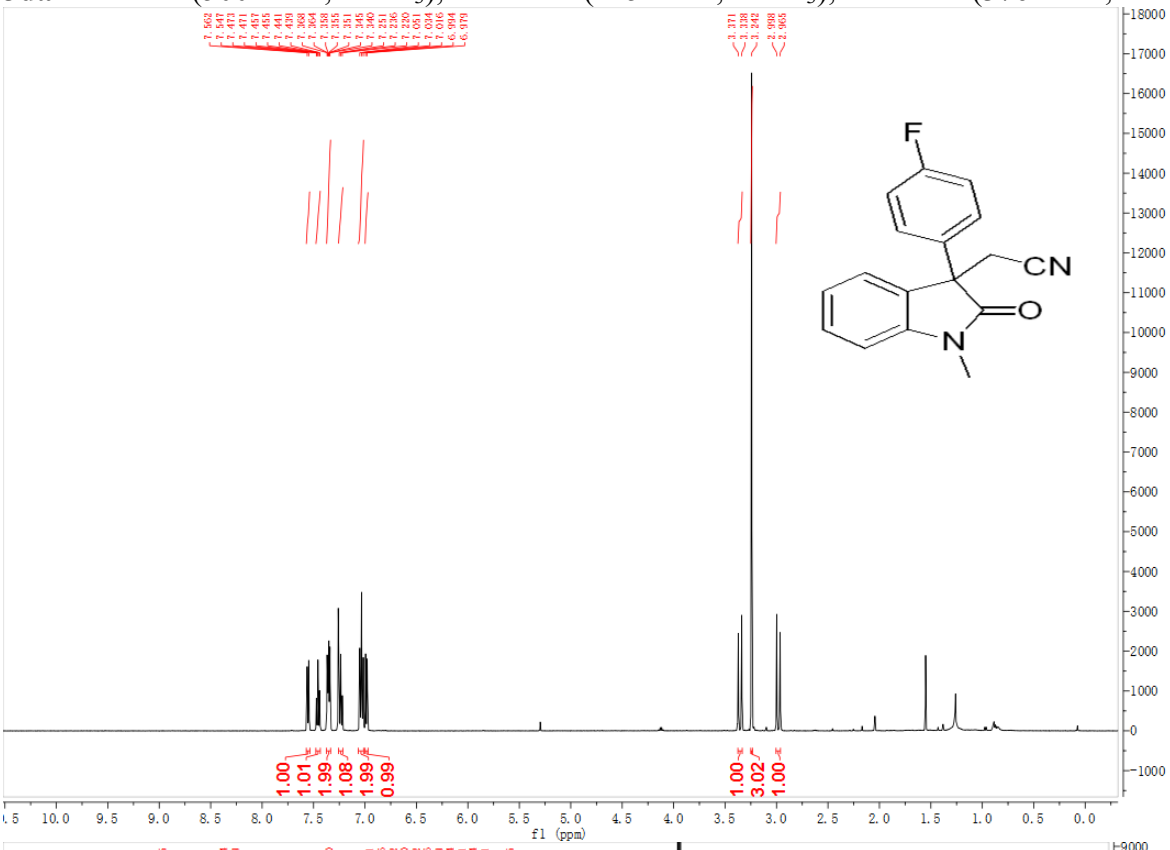


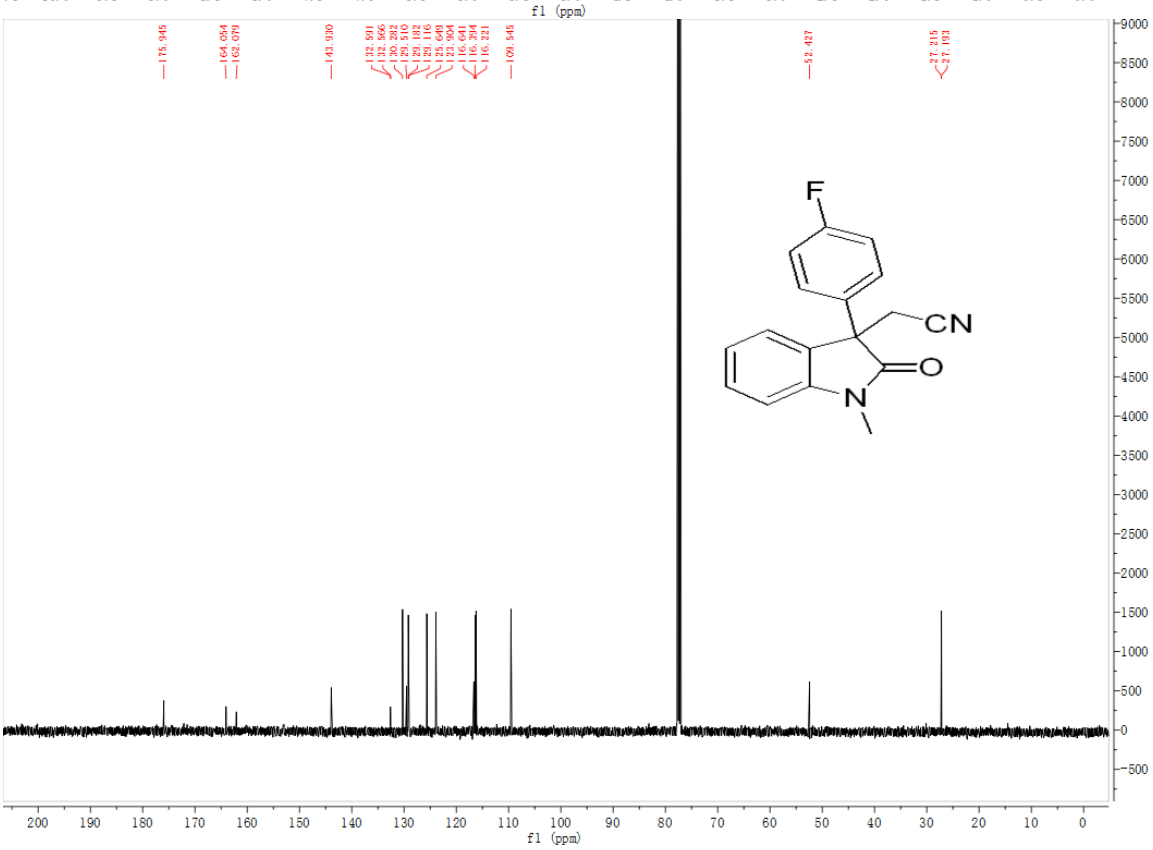
3ca ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)

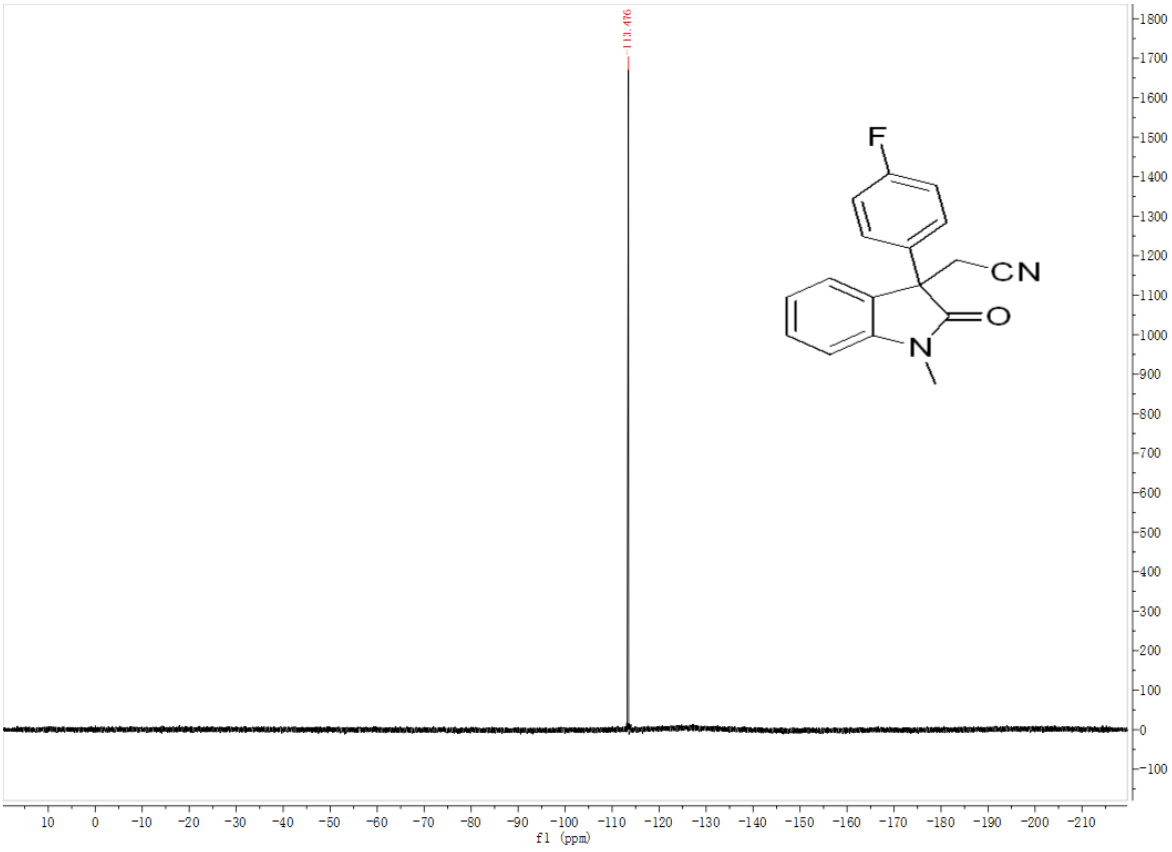




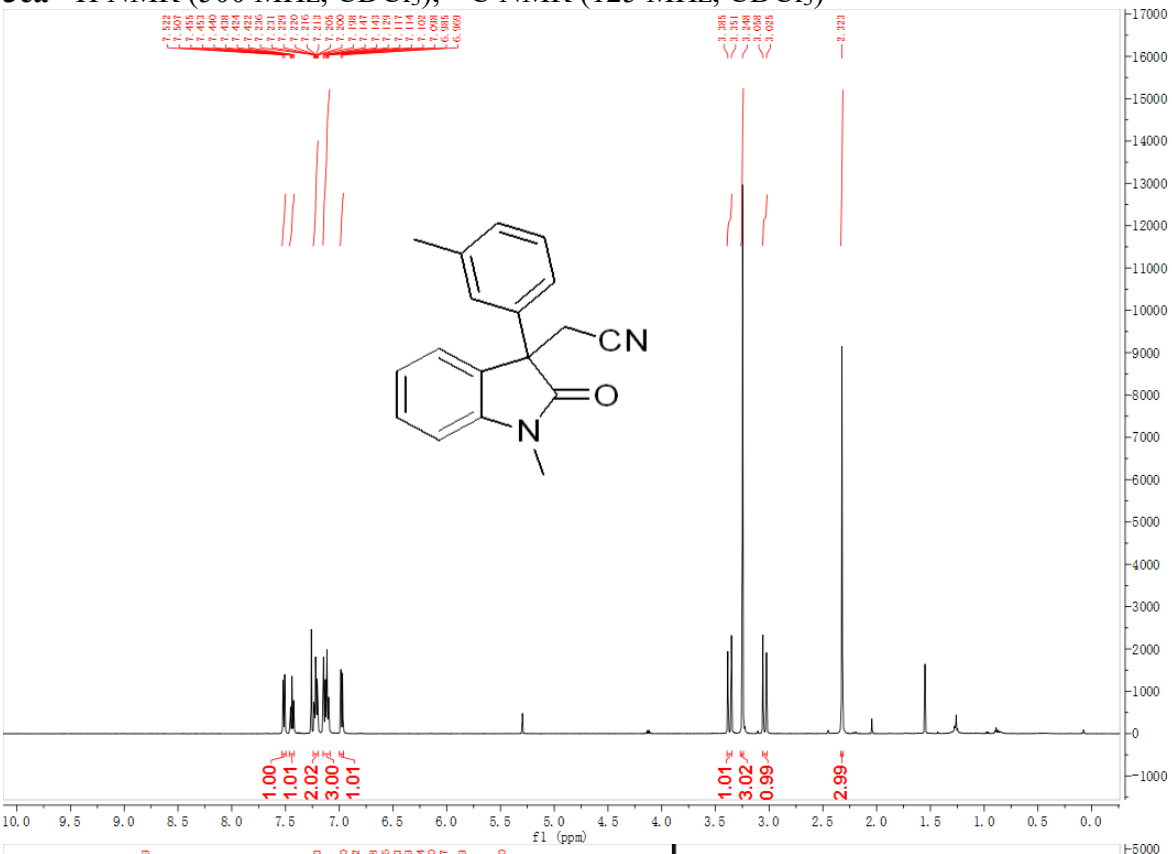
3da ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$), ^{19}F NMR (376 MHz, $CDCl_3$)

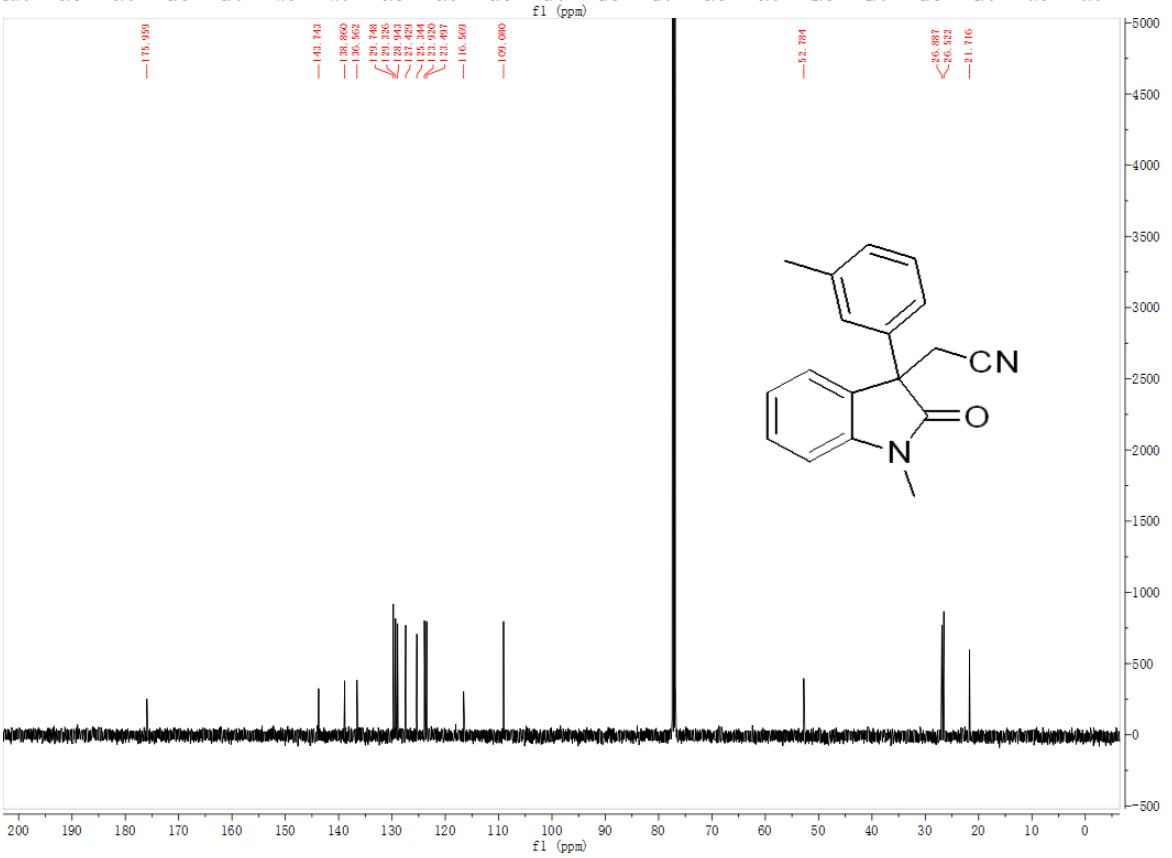




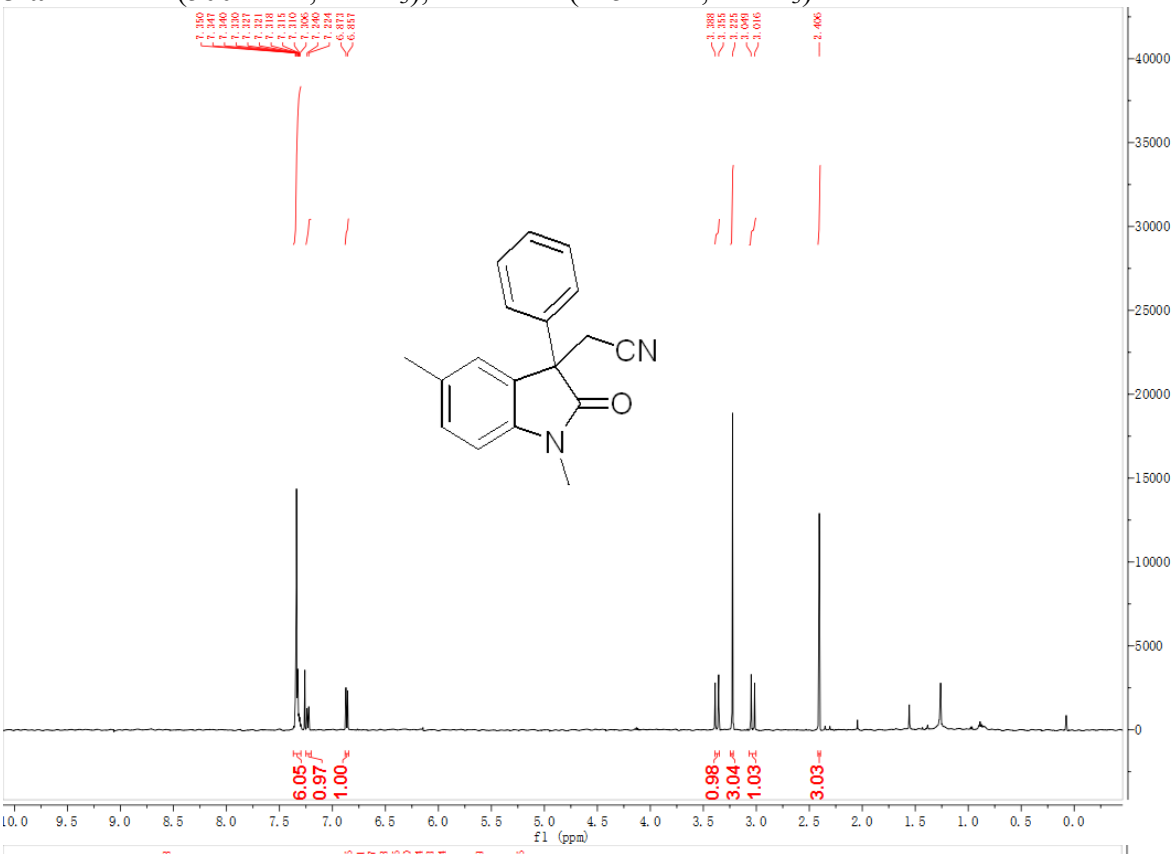

-113.476
F
CN
O
N
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
-100
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

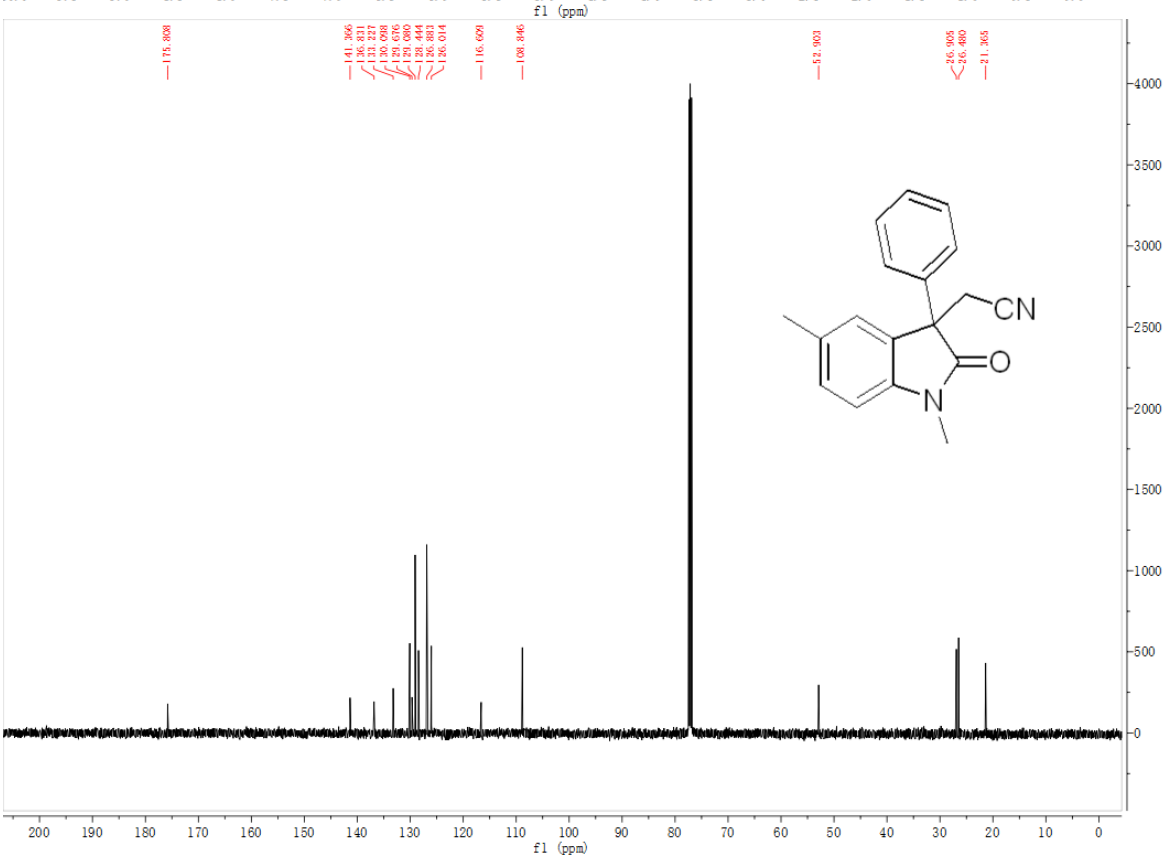
3ea ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)



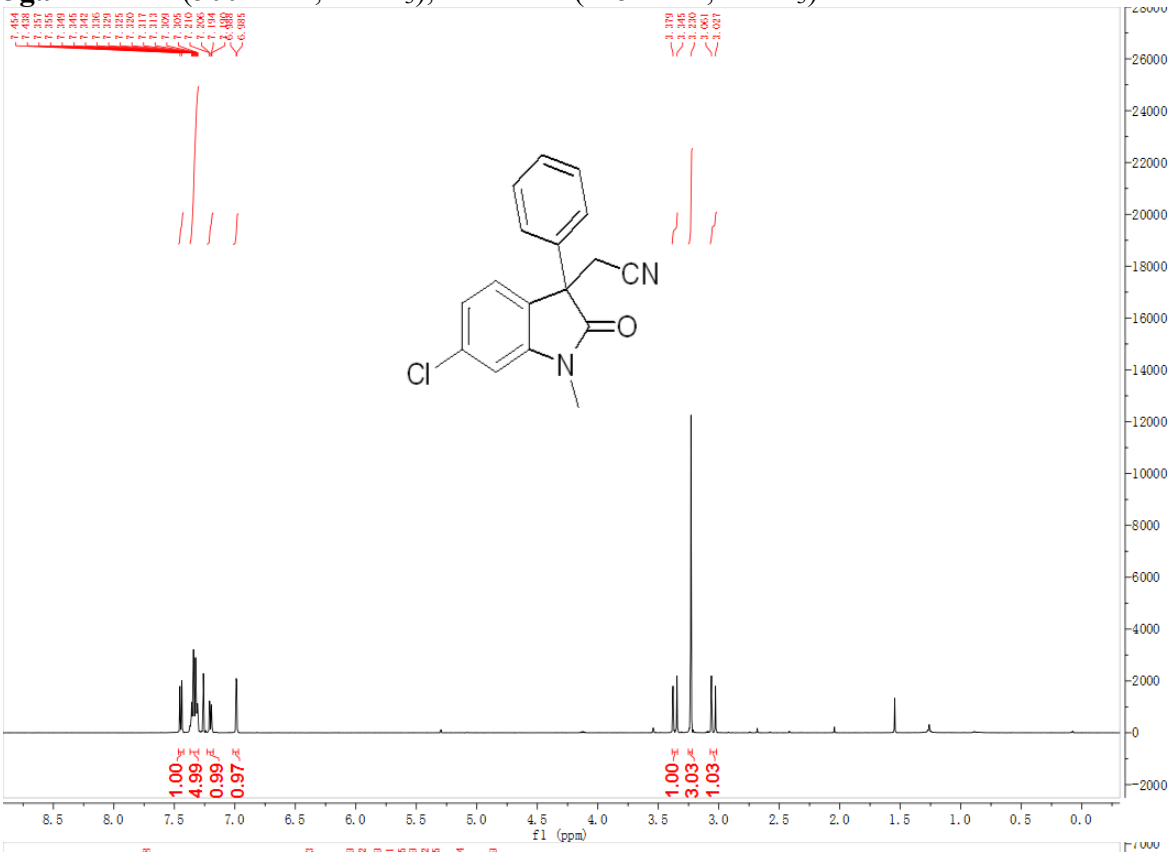


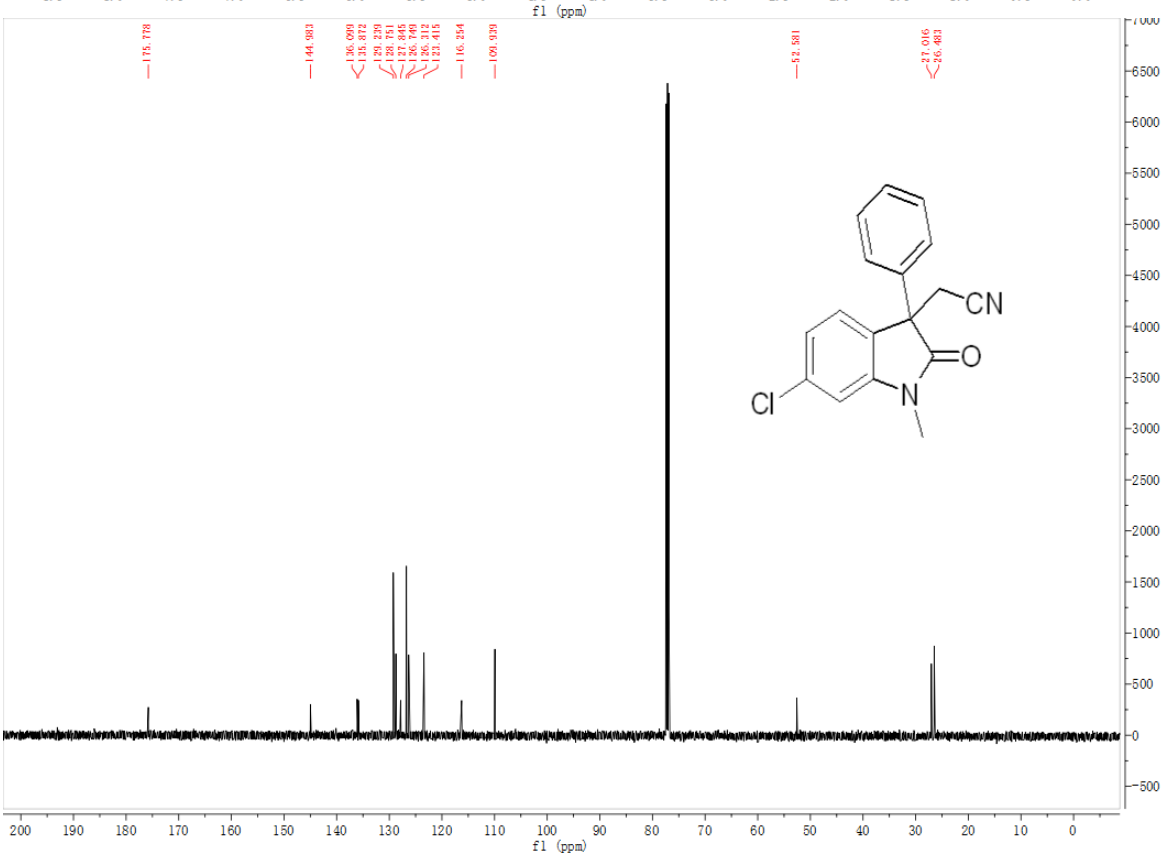
3fa ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)



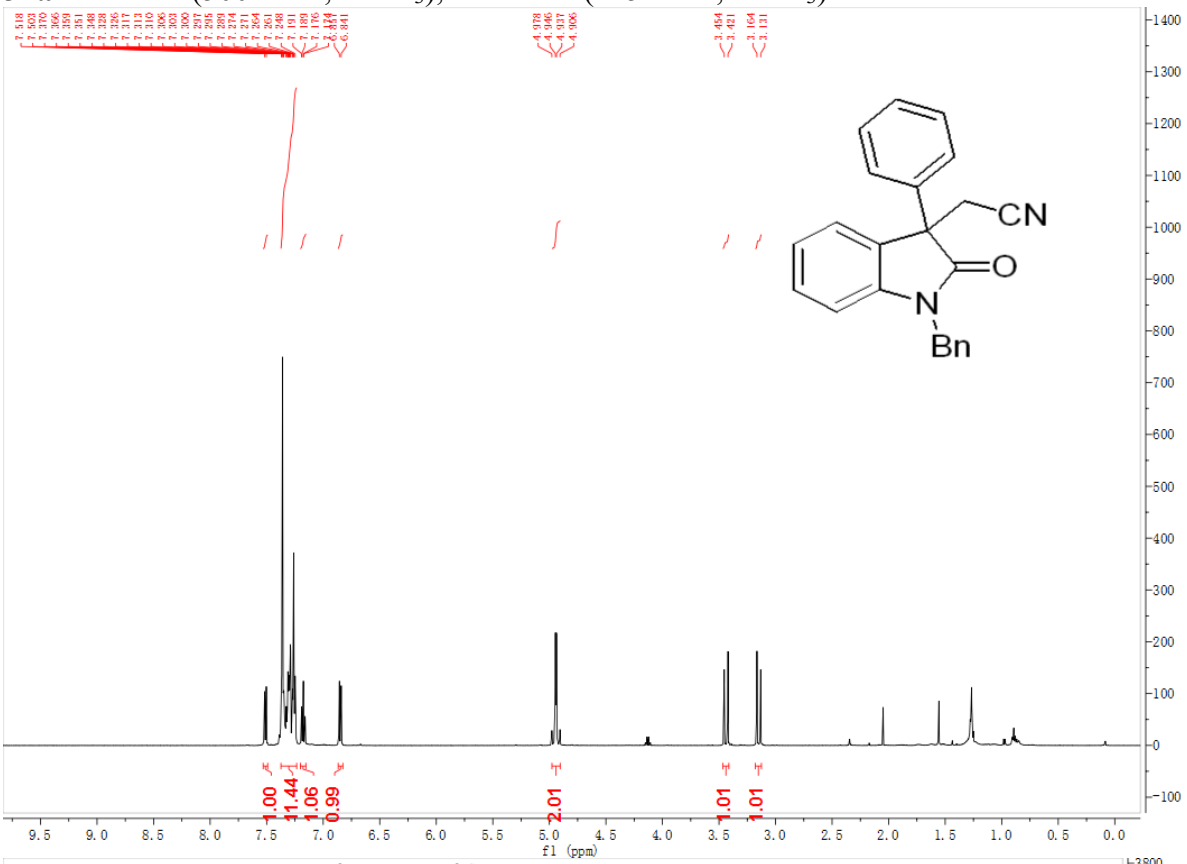


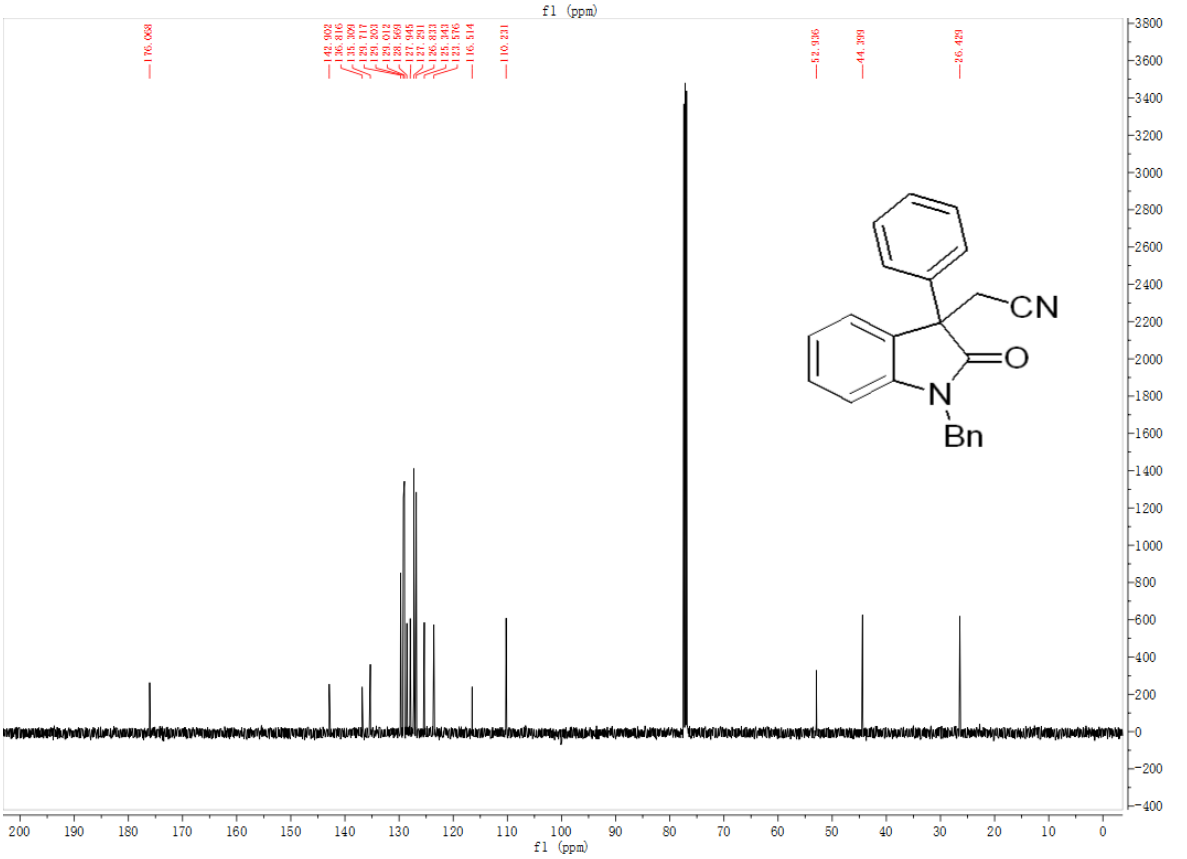
3ga ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)



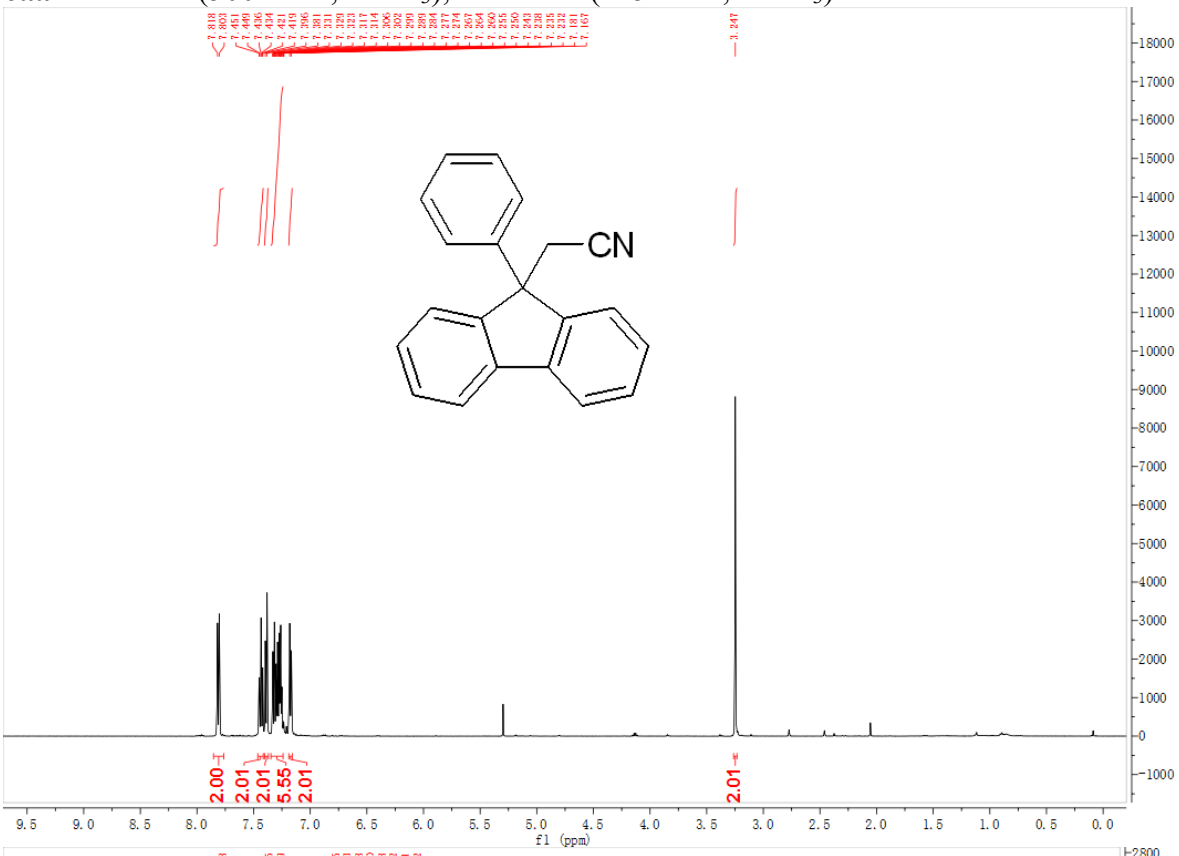


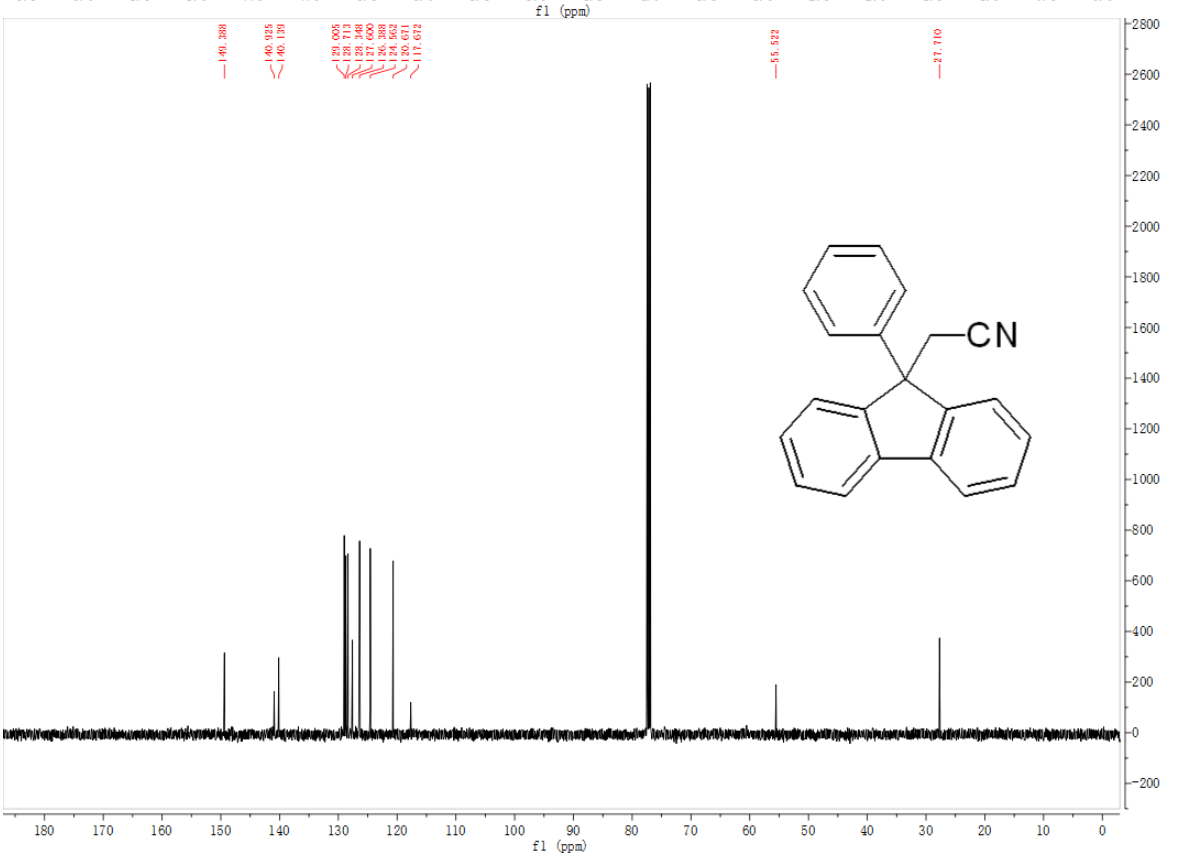
3ha ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)



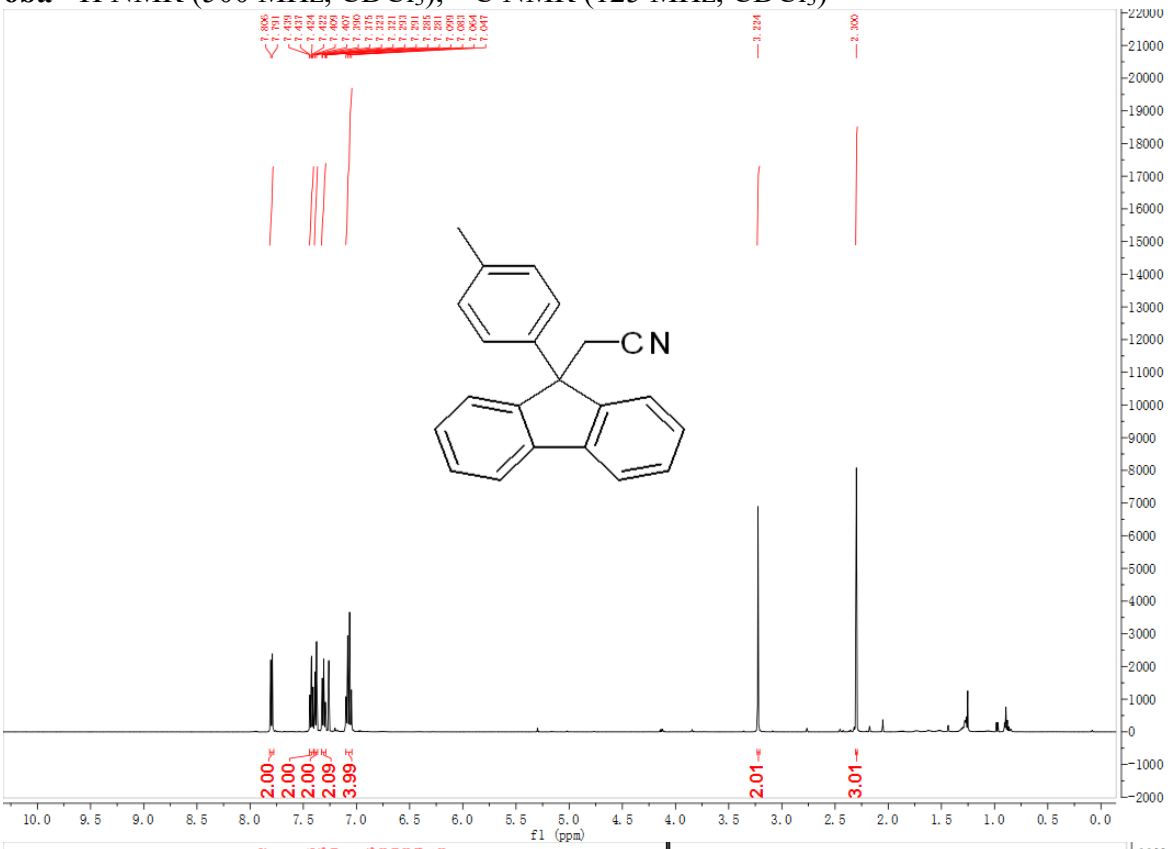


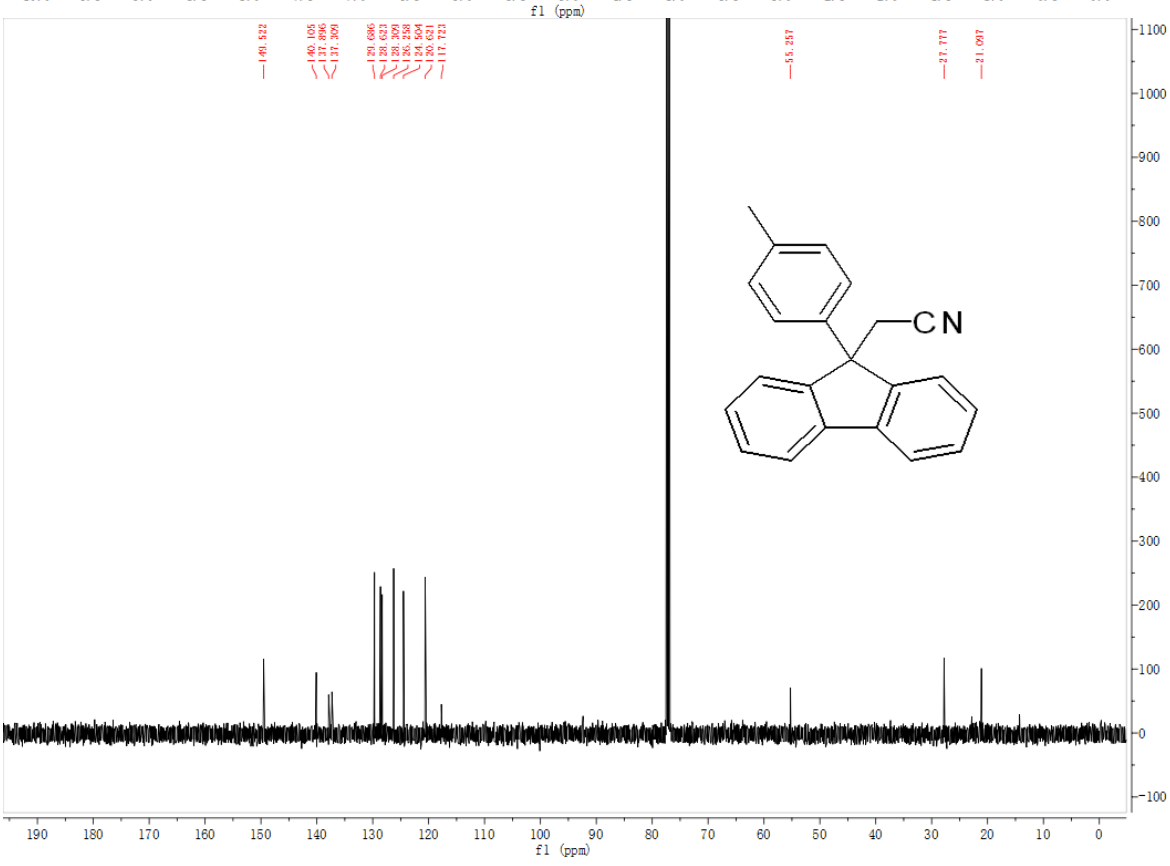
6aa ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)



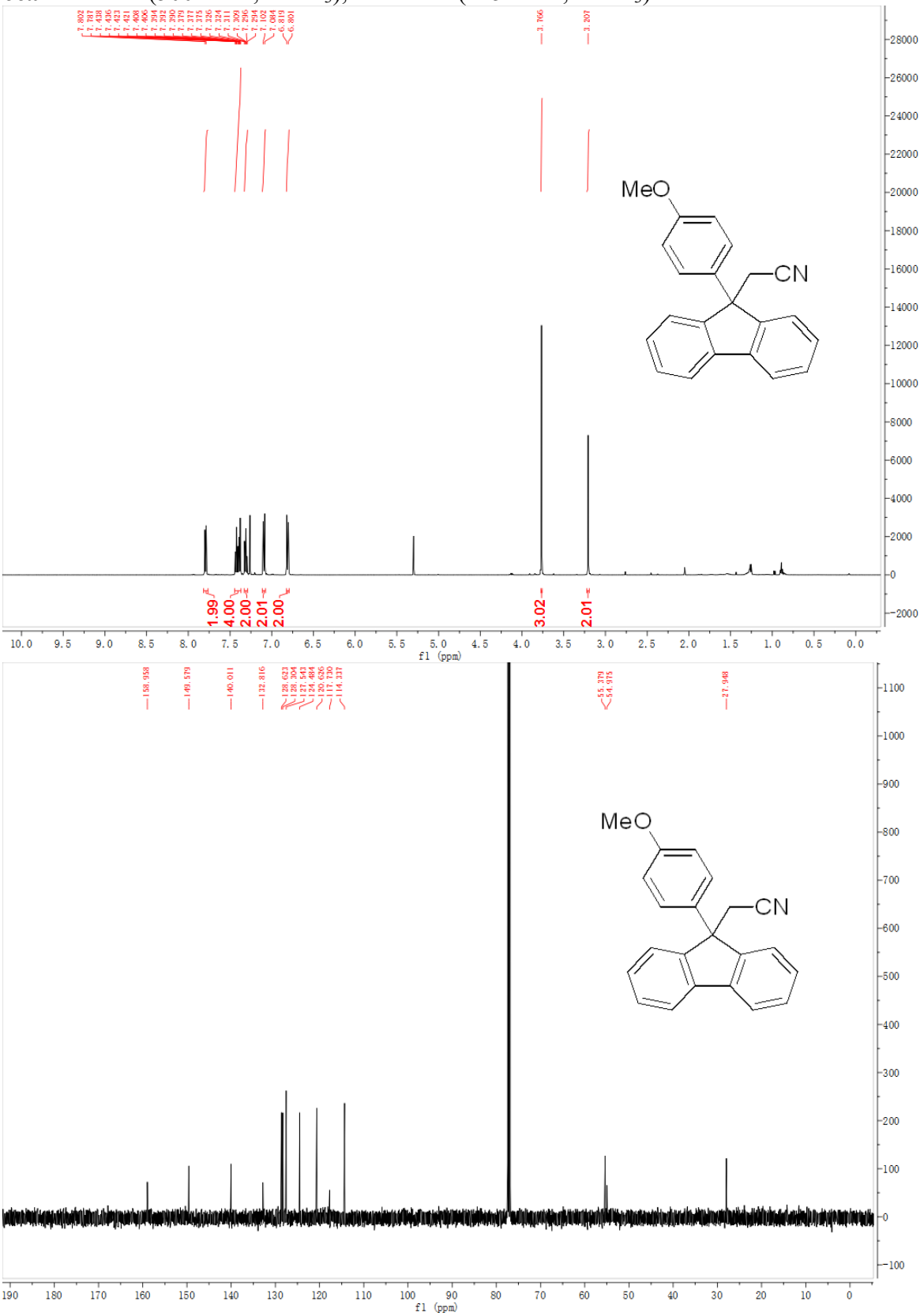


6ba ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)

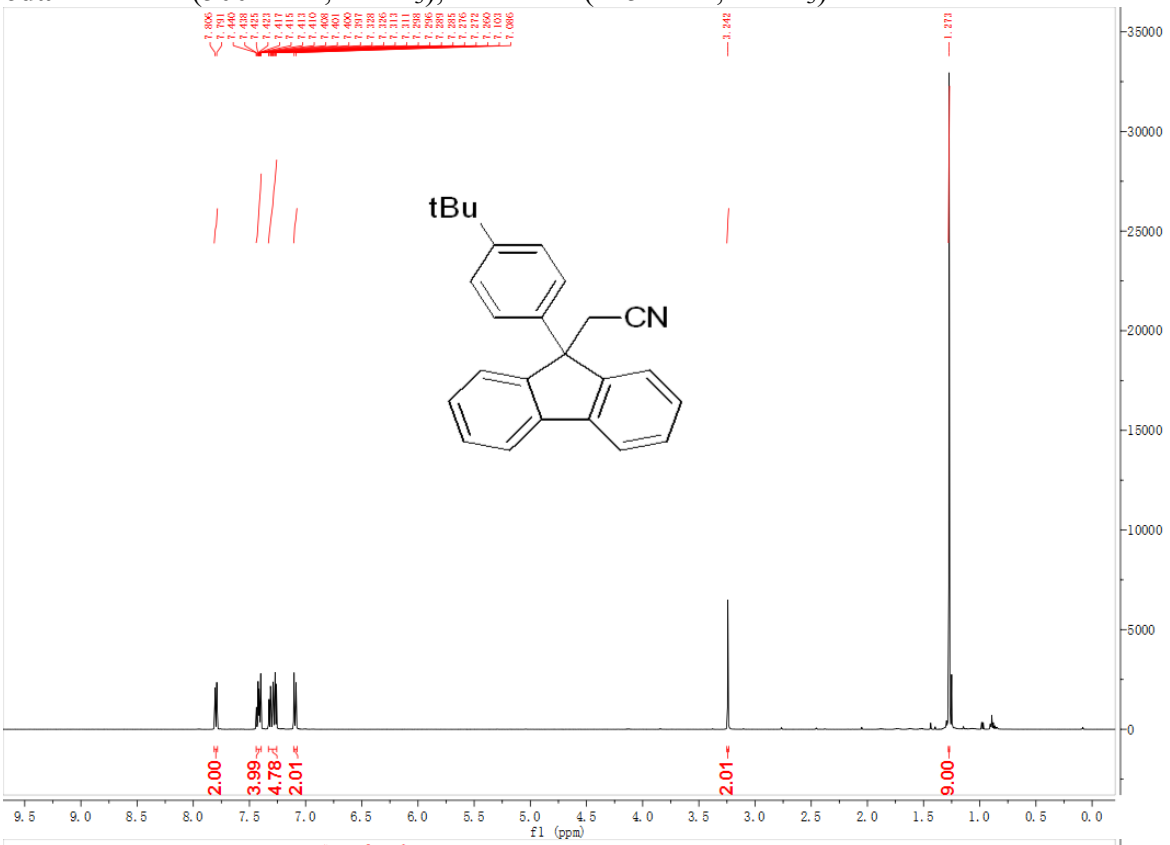


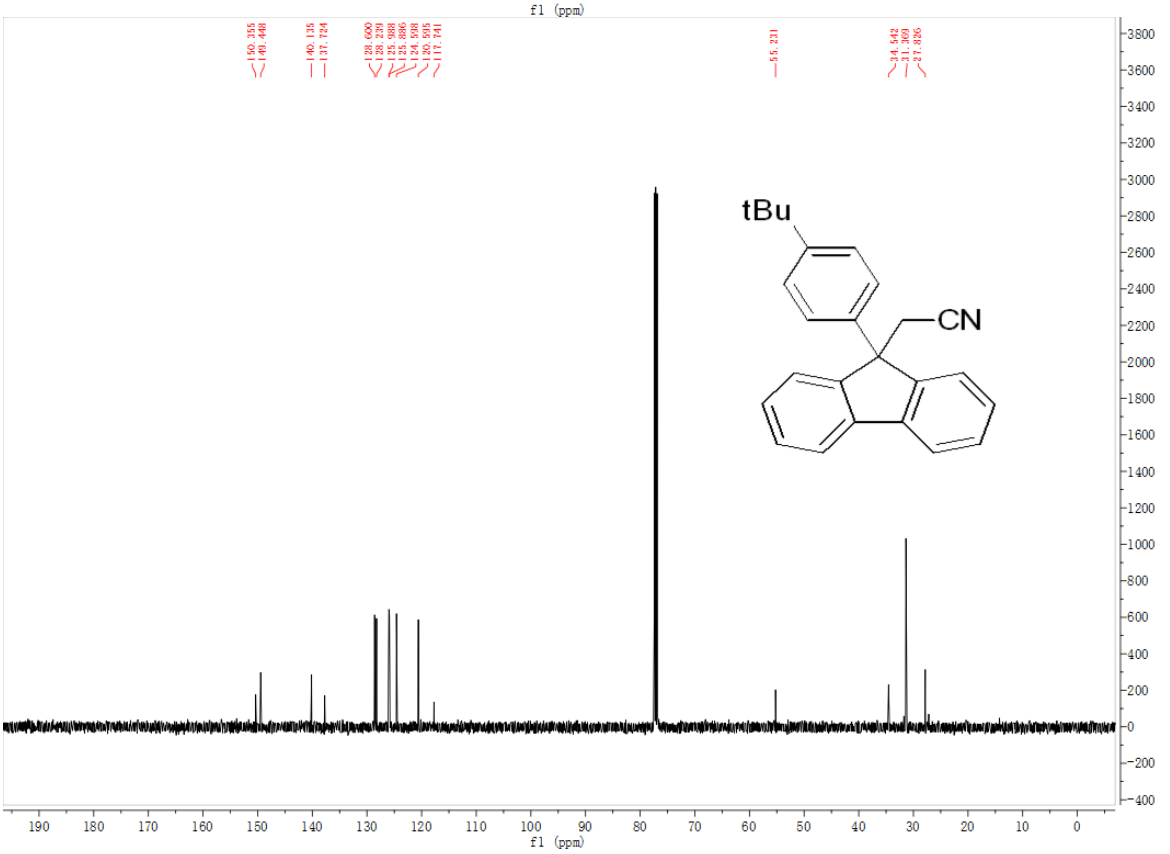


6ca ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)

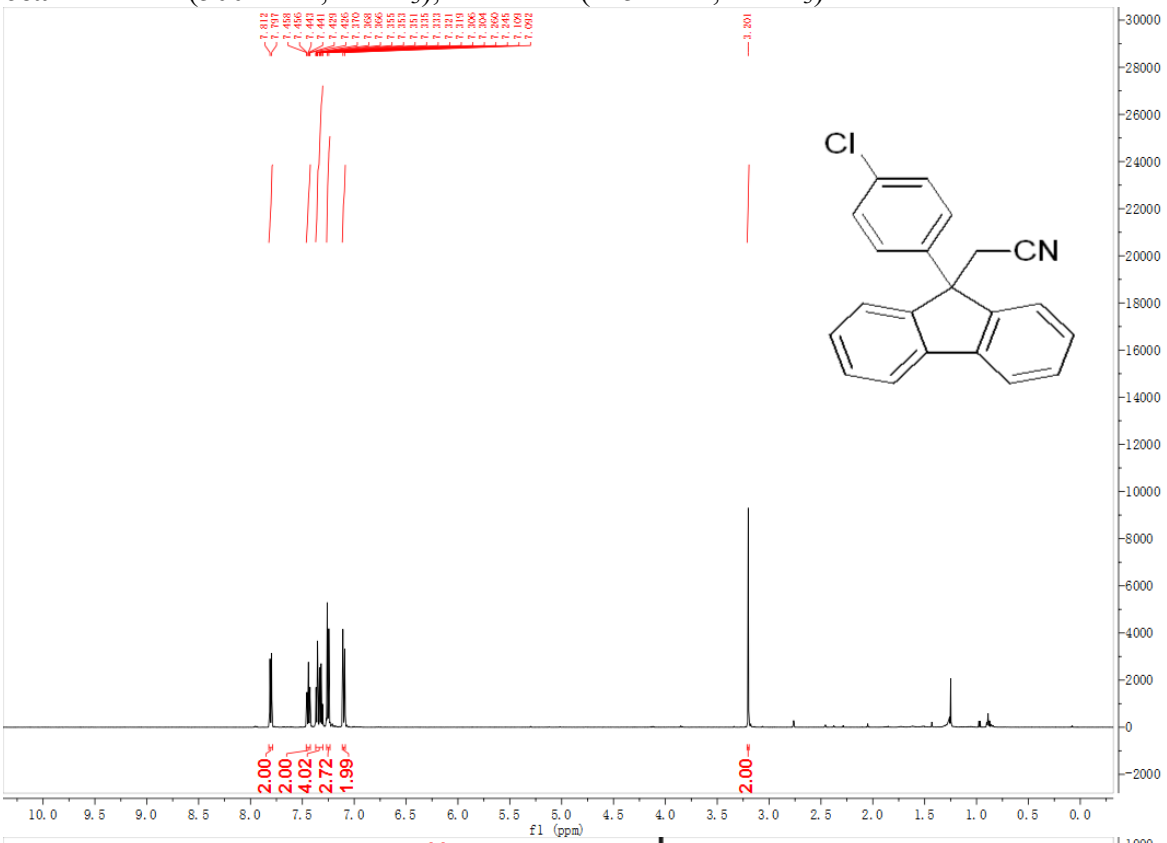


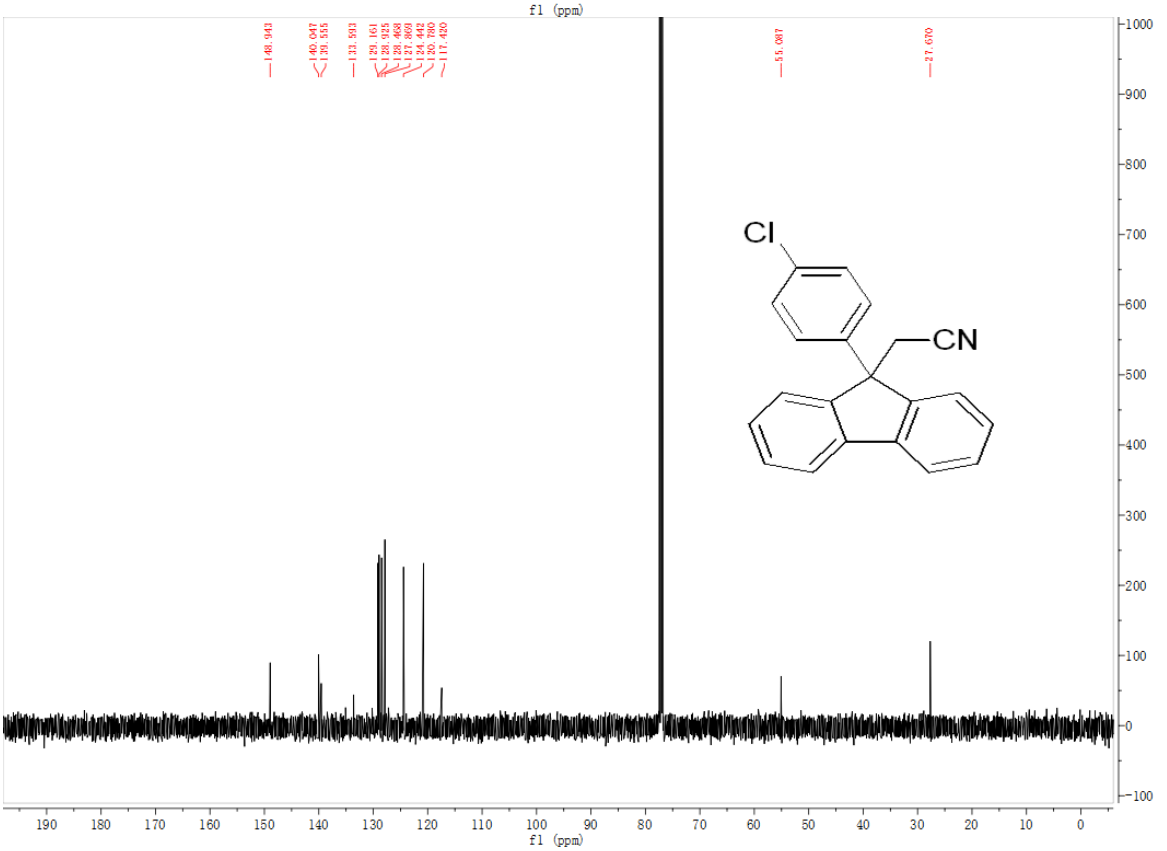
6da ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)



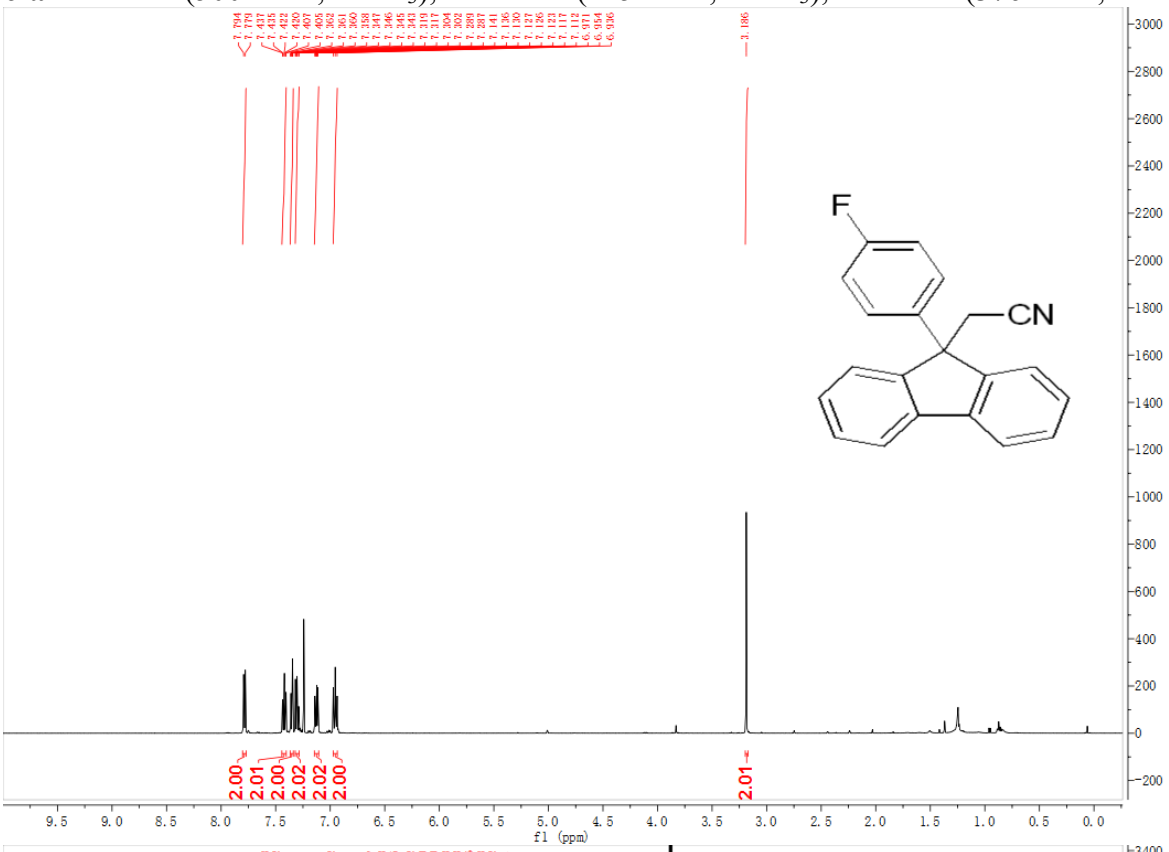


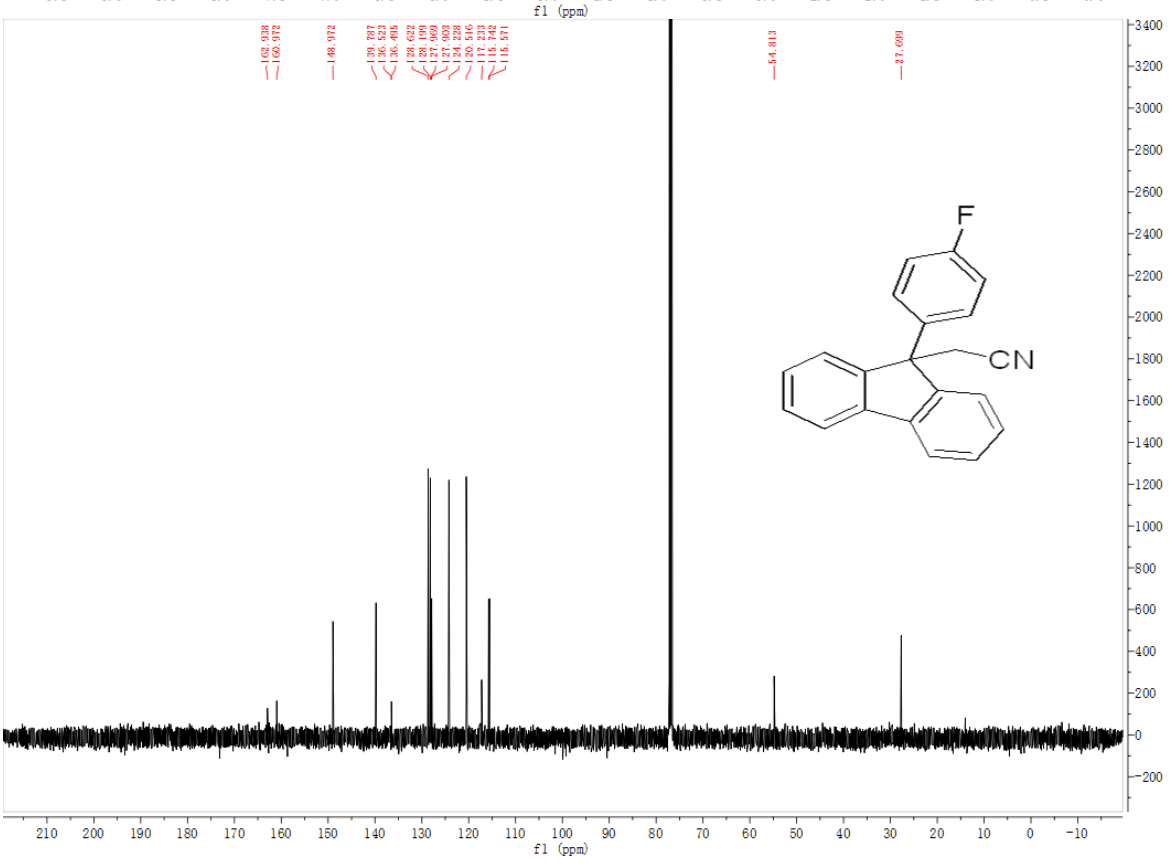
6ea ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)

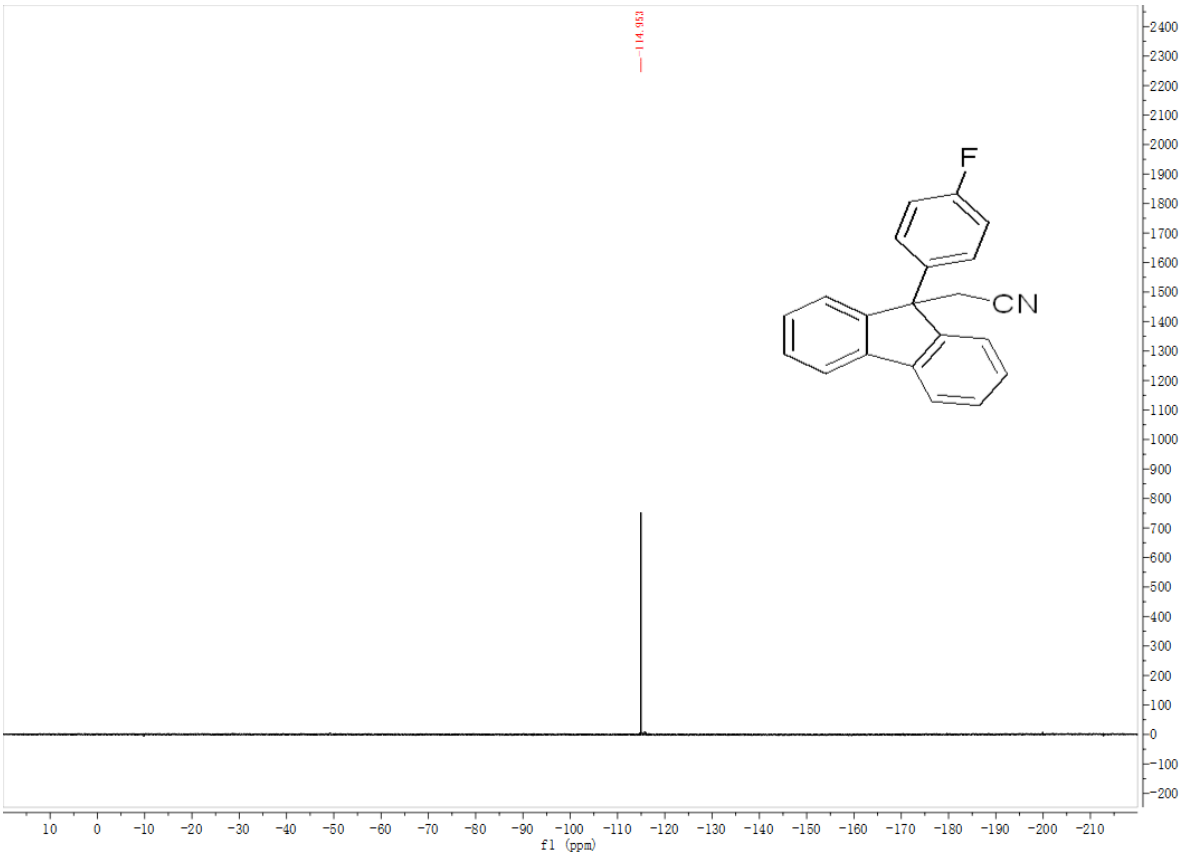




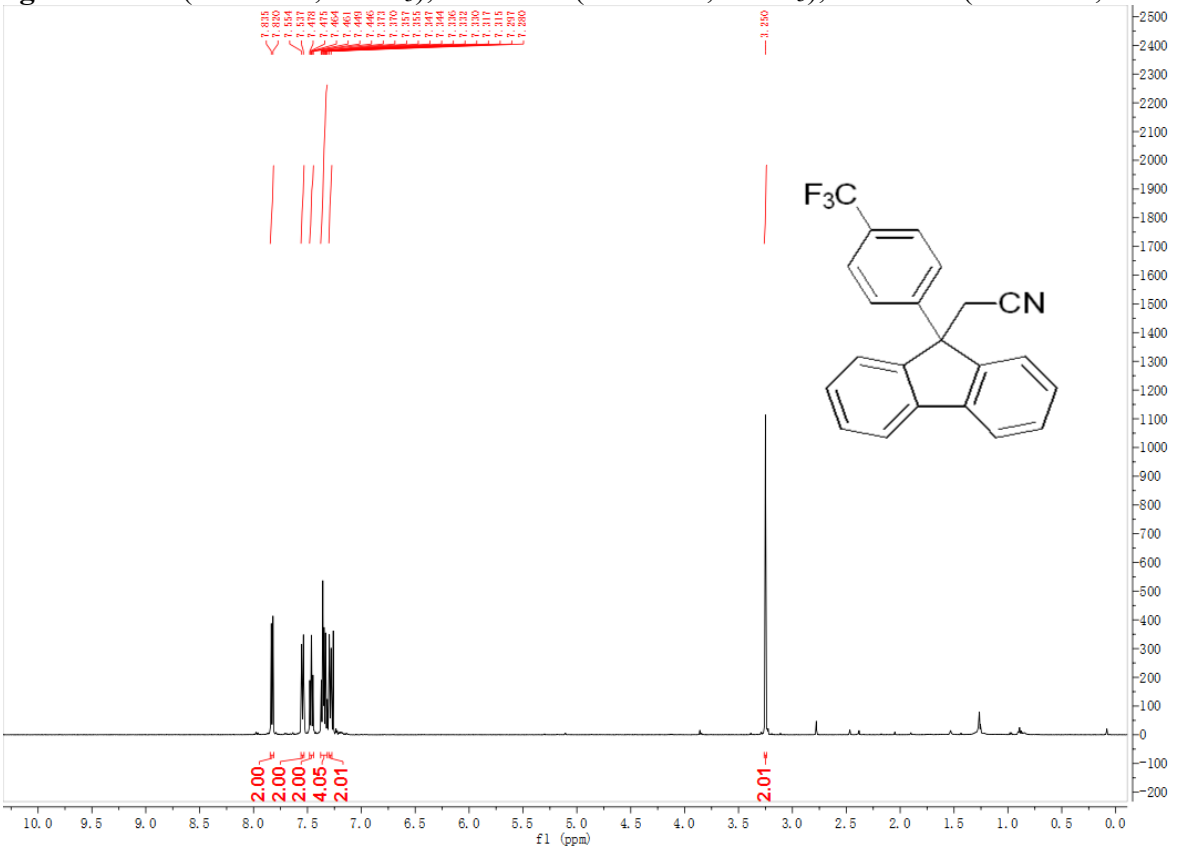
6fa ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$), ^{19}F NMR (376 MHz, $CDCl_3$)

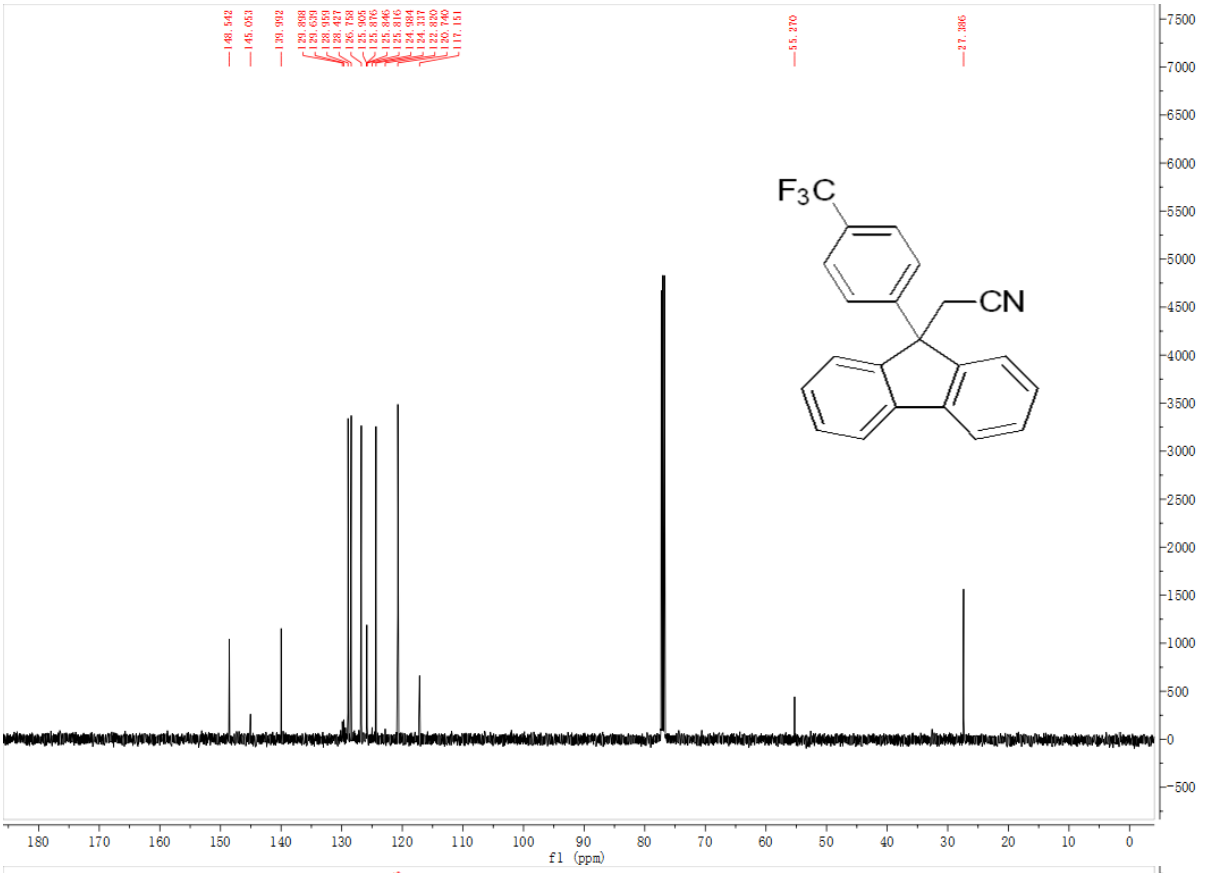


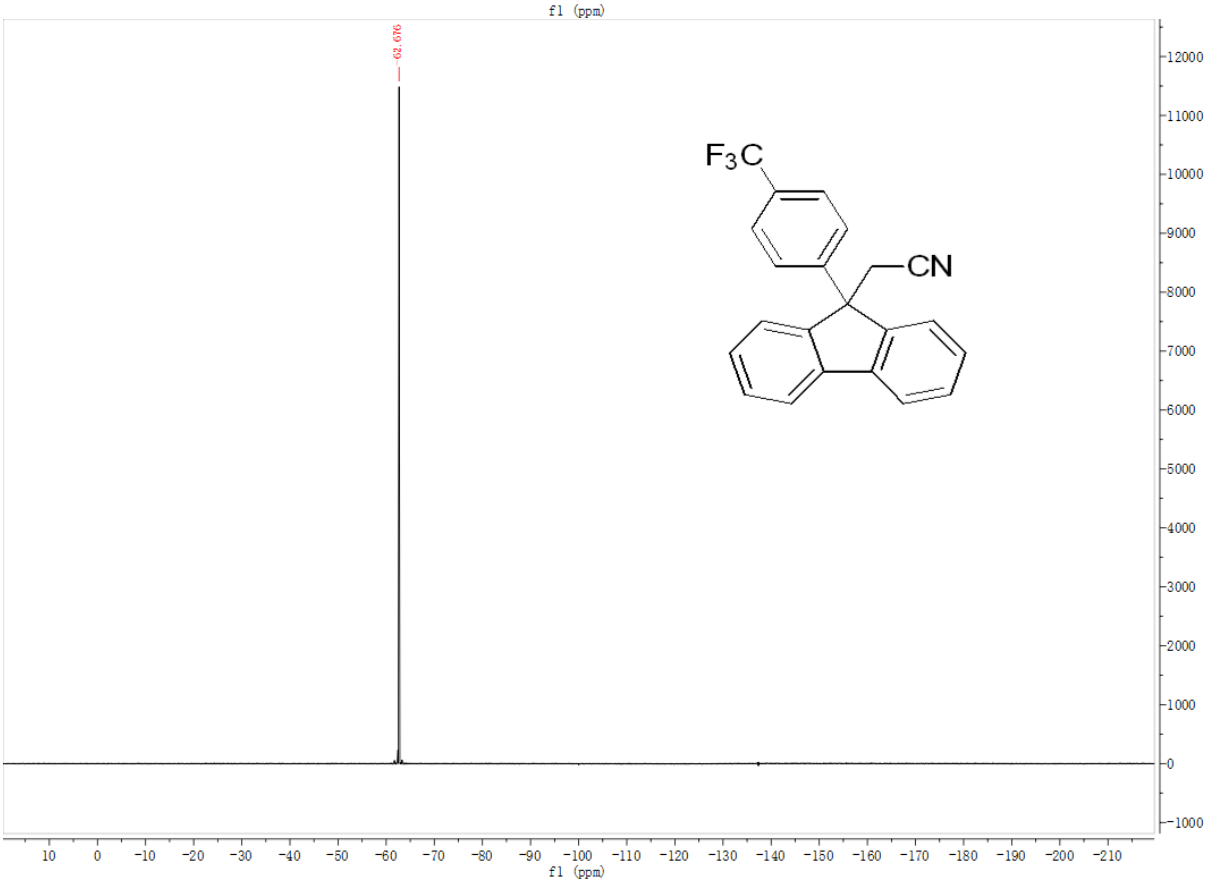




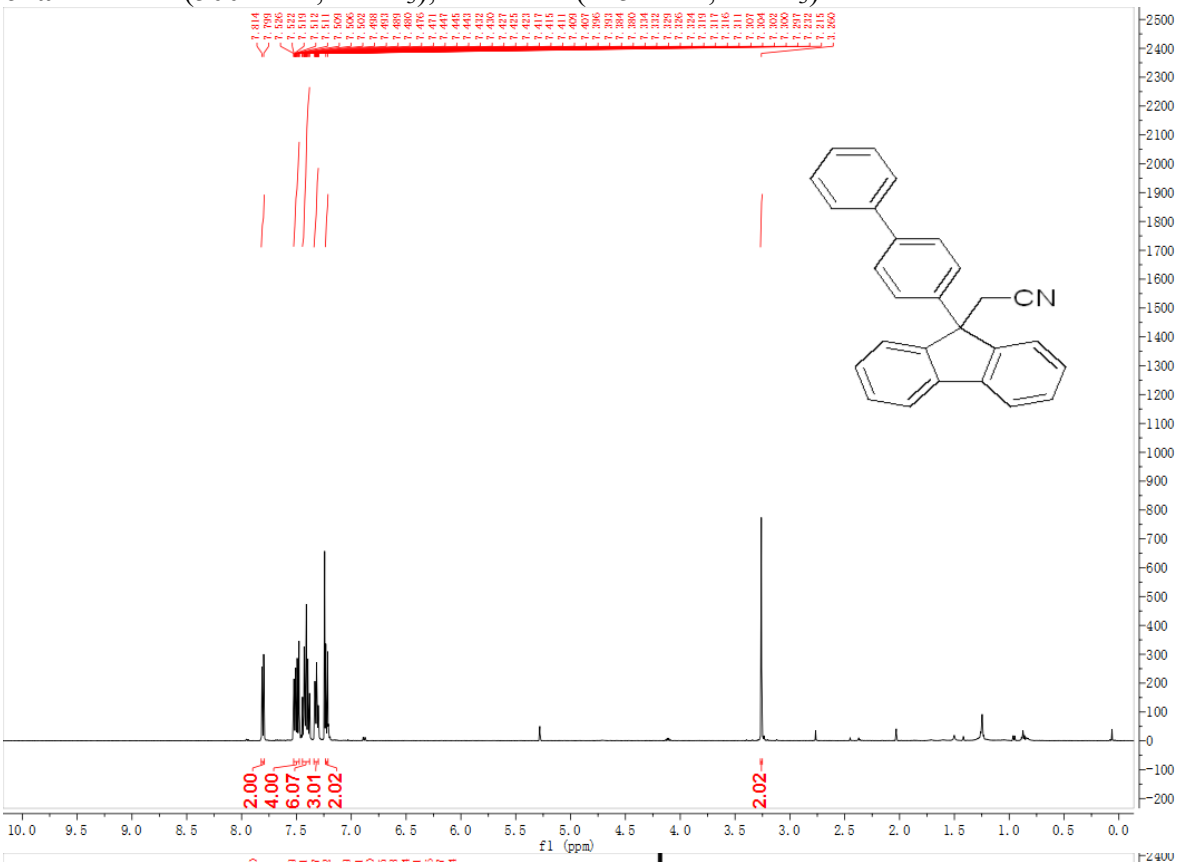
6ga ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$), ^{19}F NMR (376 MHz, $CDCl_3$)

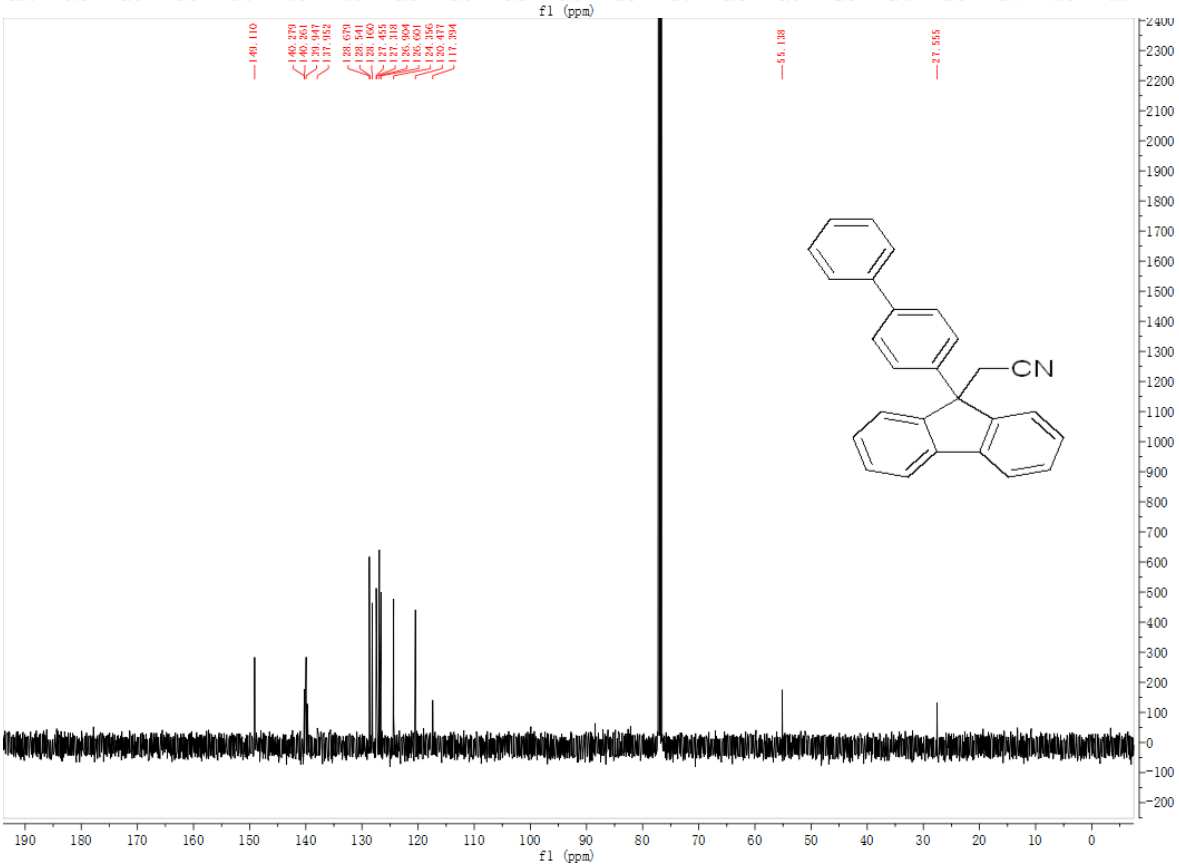



148.542
145.053
139.992
129.959
128.427
126.758
125.905
125.876
125.846
125.816
124.984
124.337
122.820
120.740
117.151
55.270
27.386
F3C
CN
f1 (ppm)

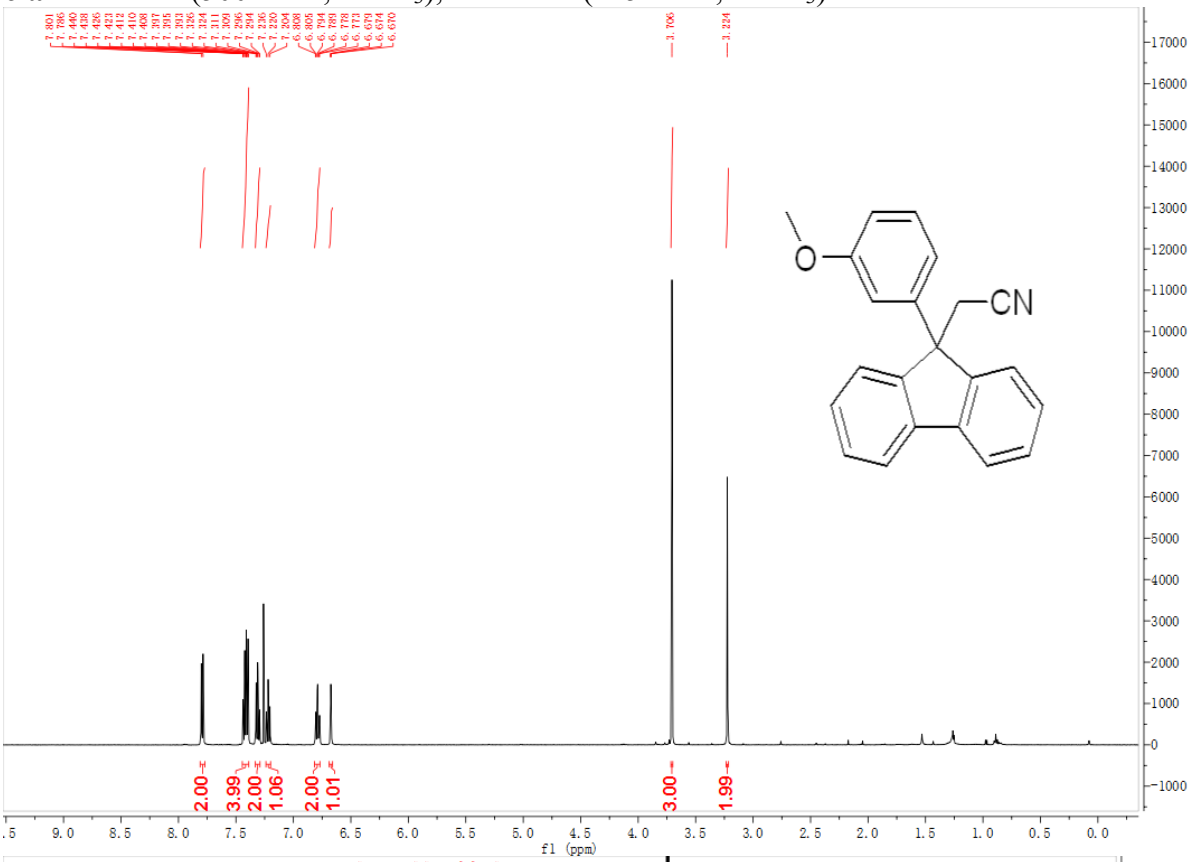

62.676
F3C
CN
f1 (ppm)

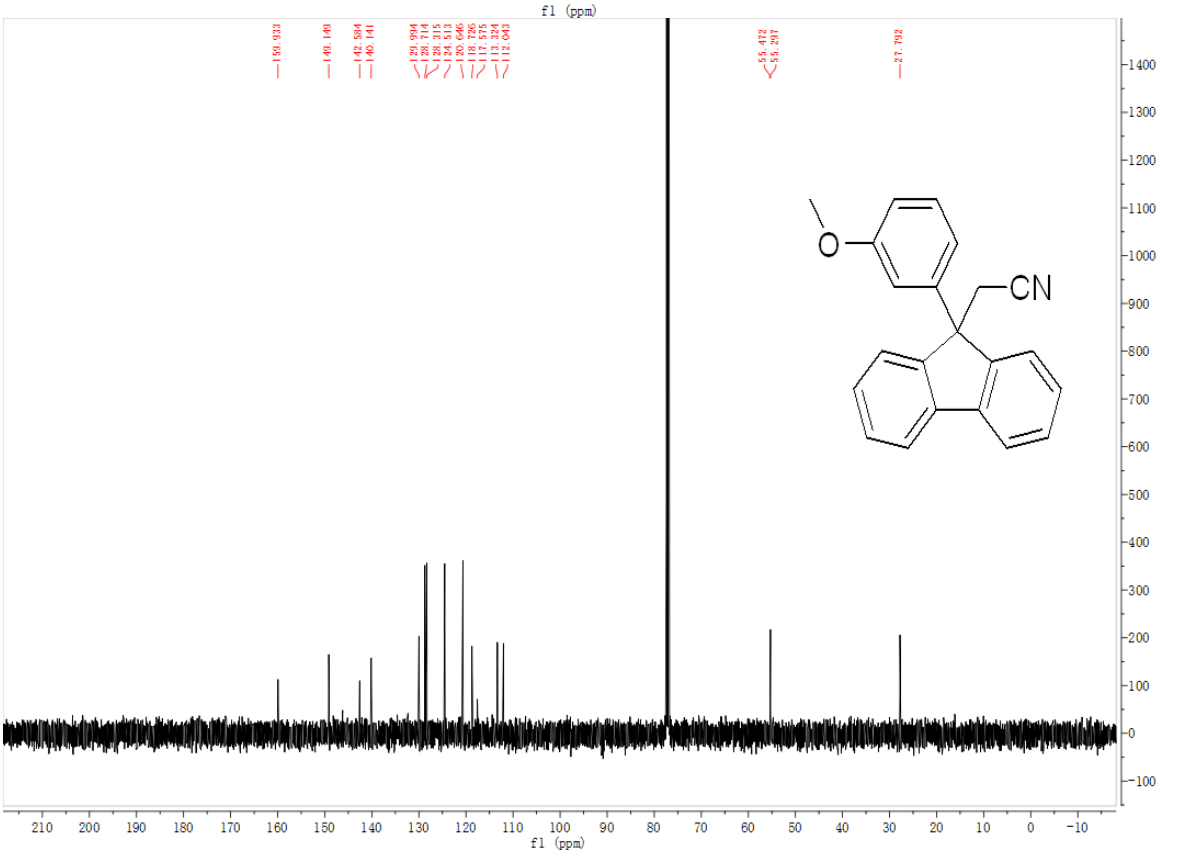
6ha ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)



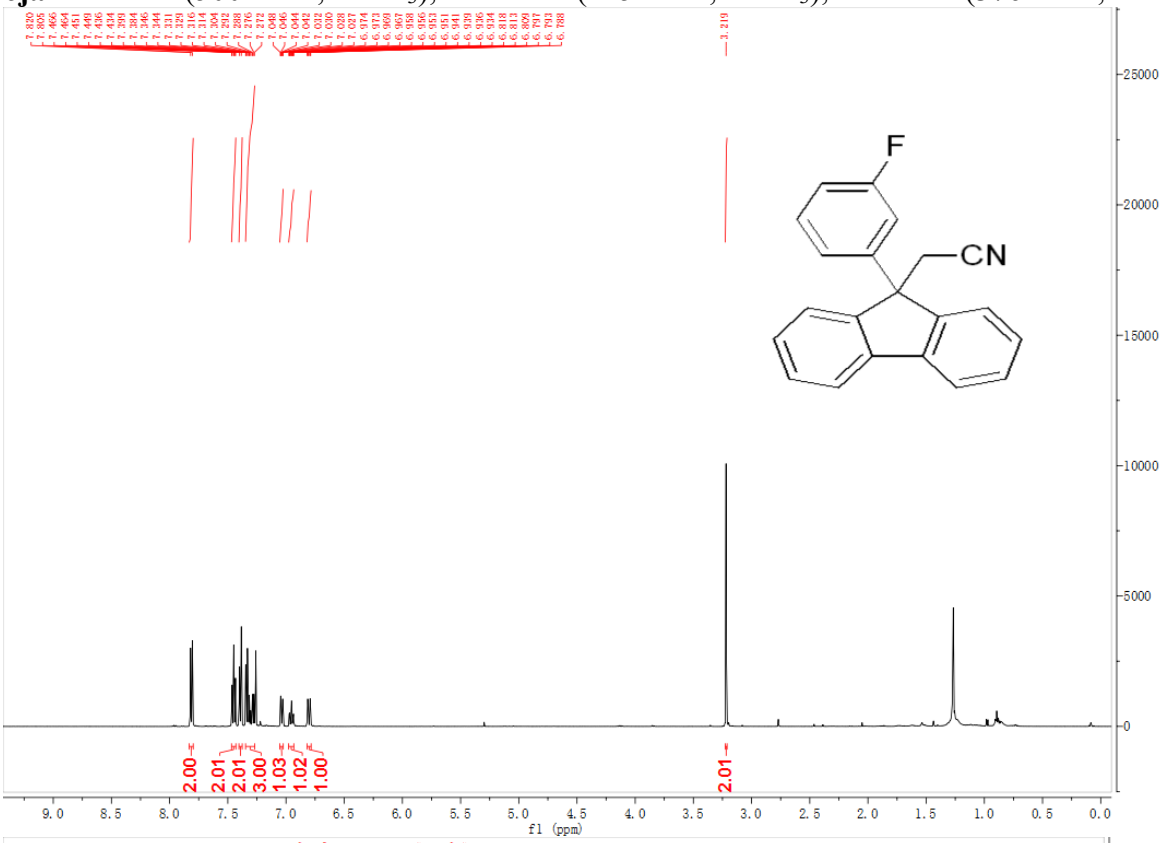


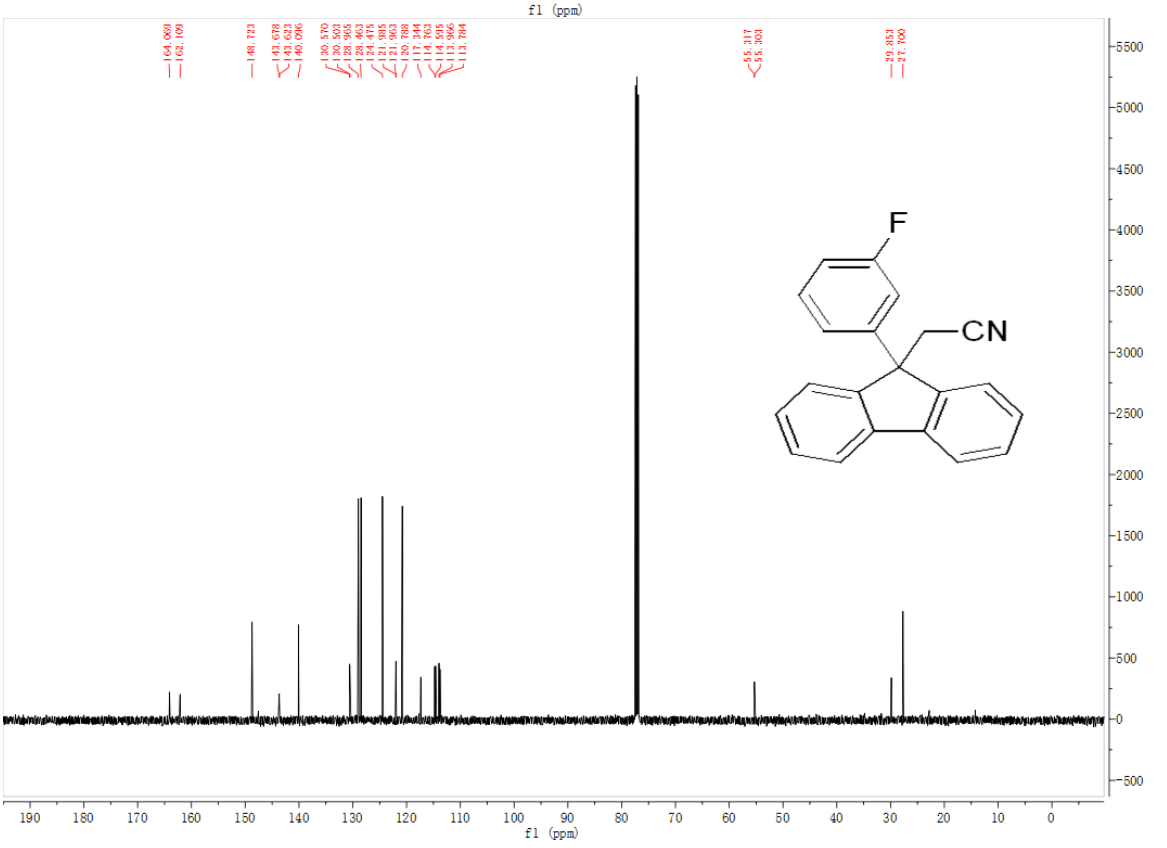
6ia ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)

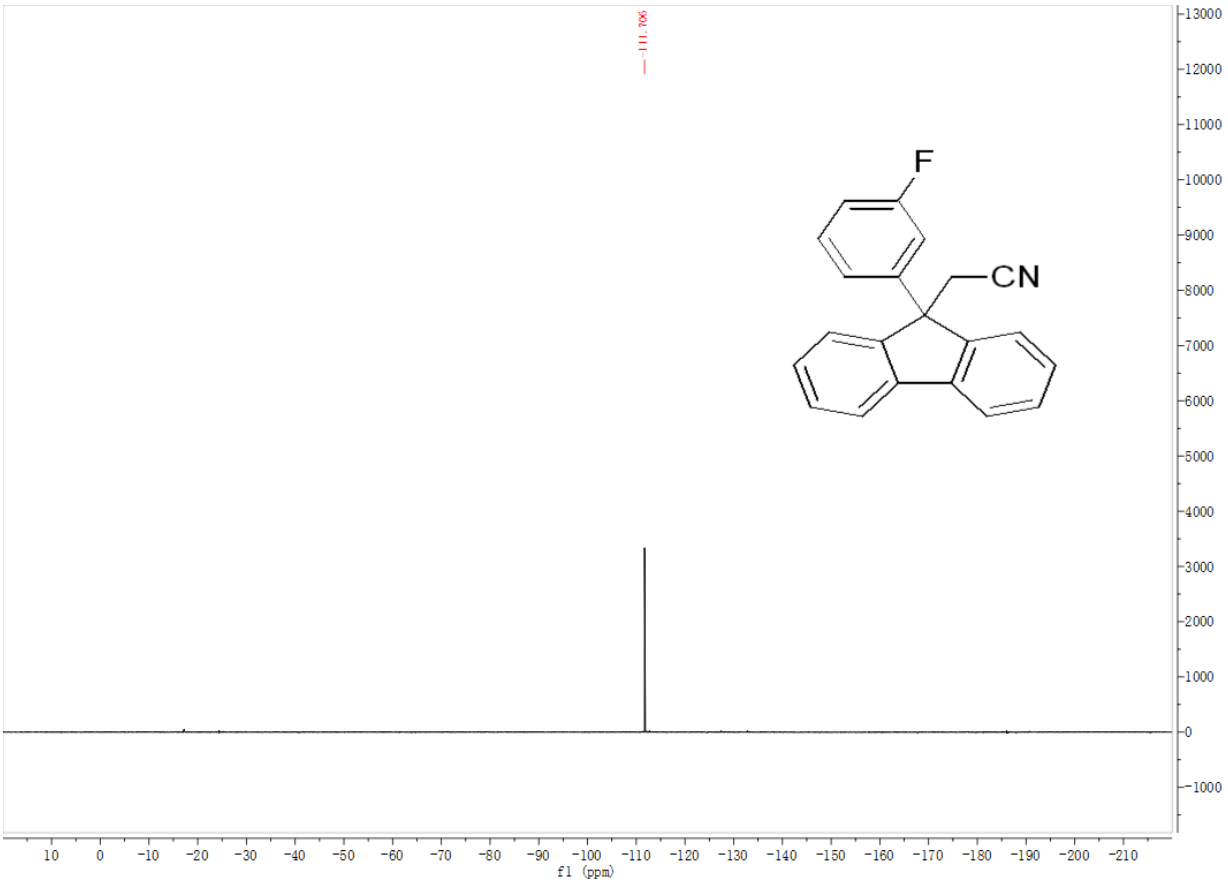




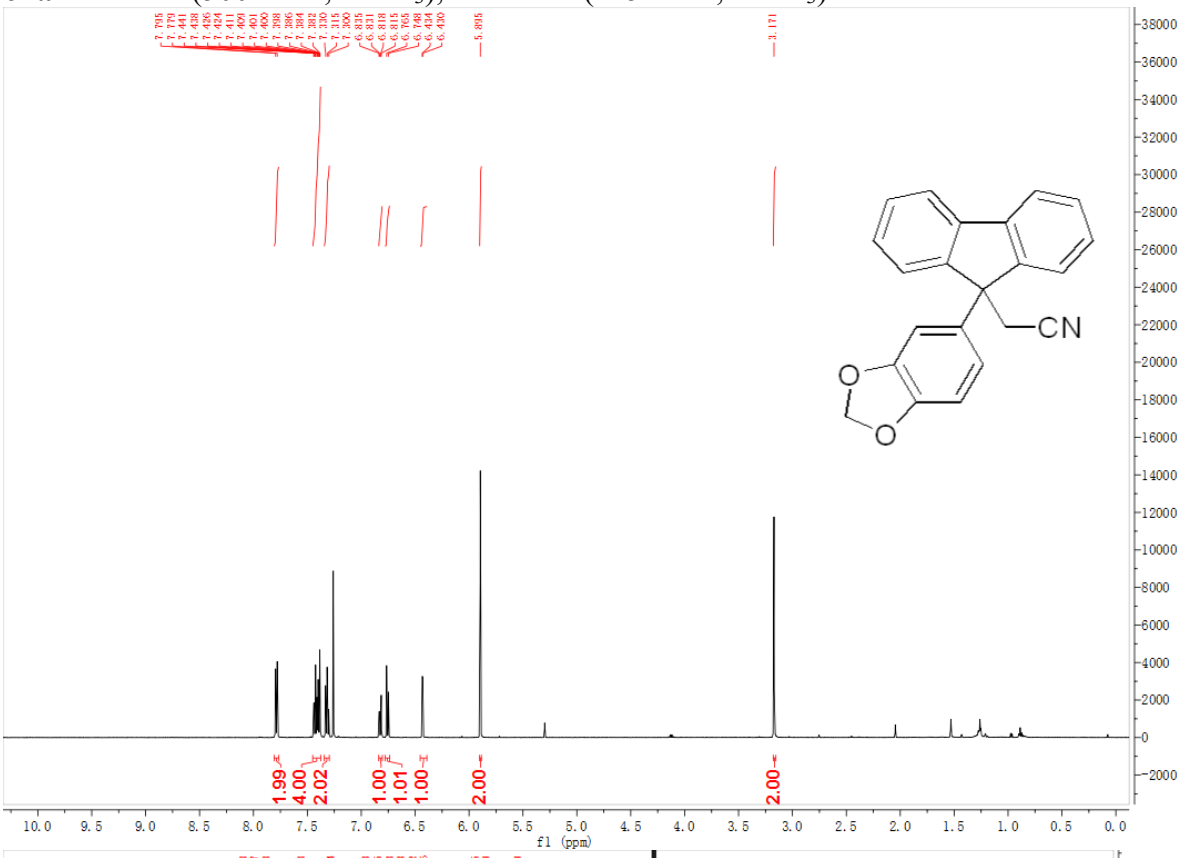
6ja ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$), ^{19}F NMR (376 MHz, $CDCl_3$)

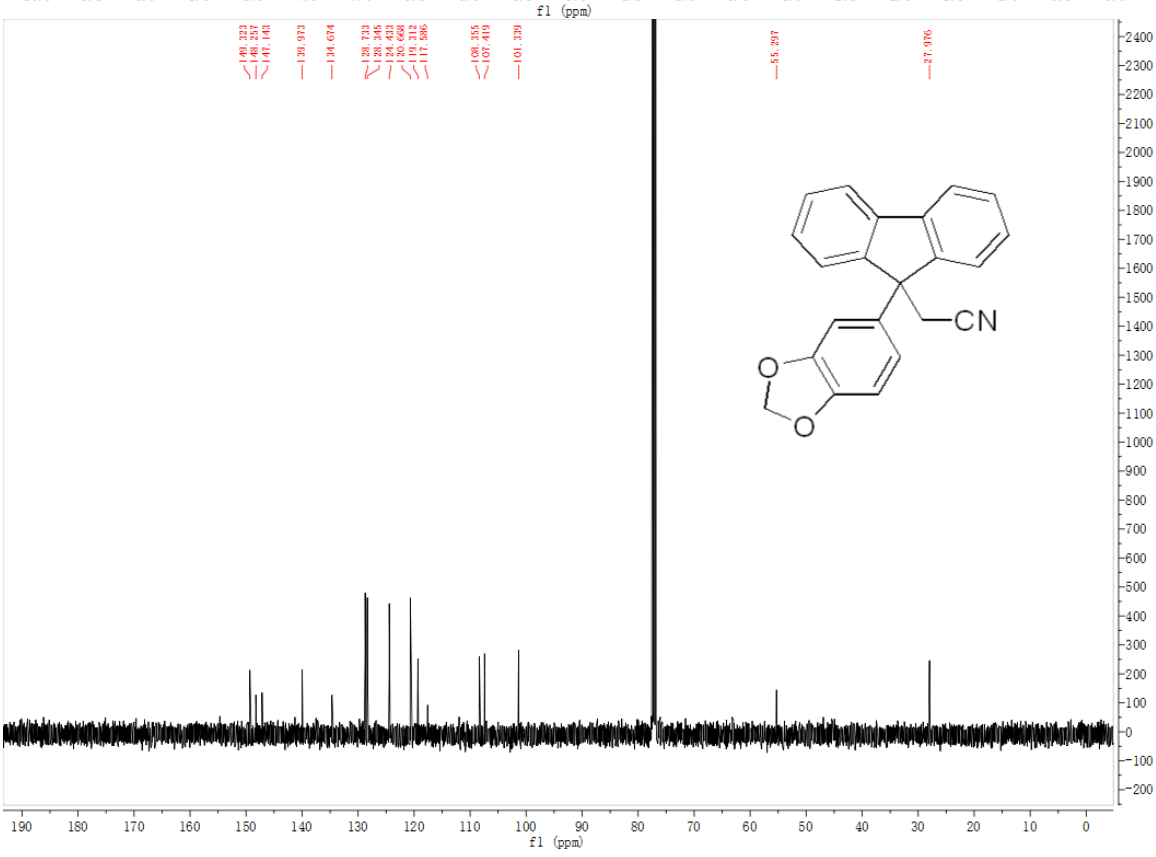




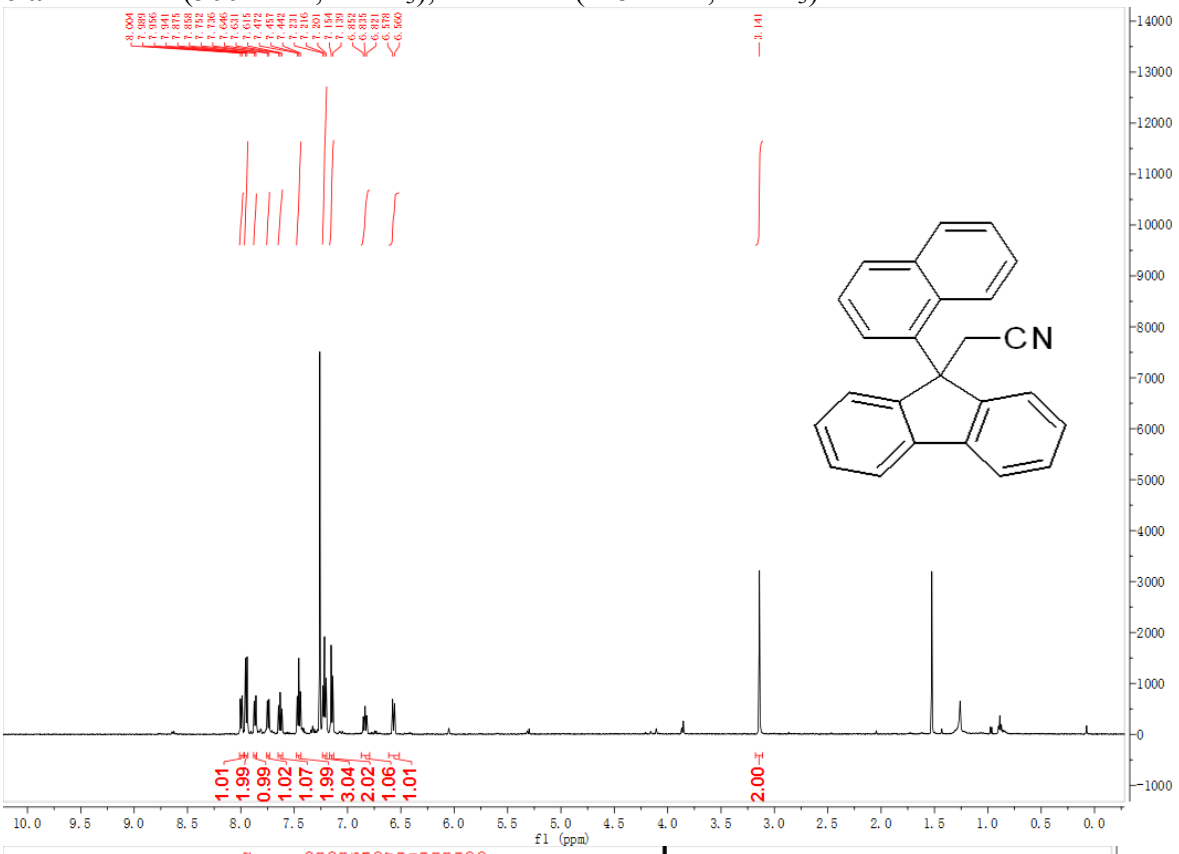

-111.706
F
CN
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

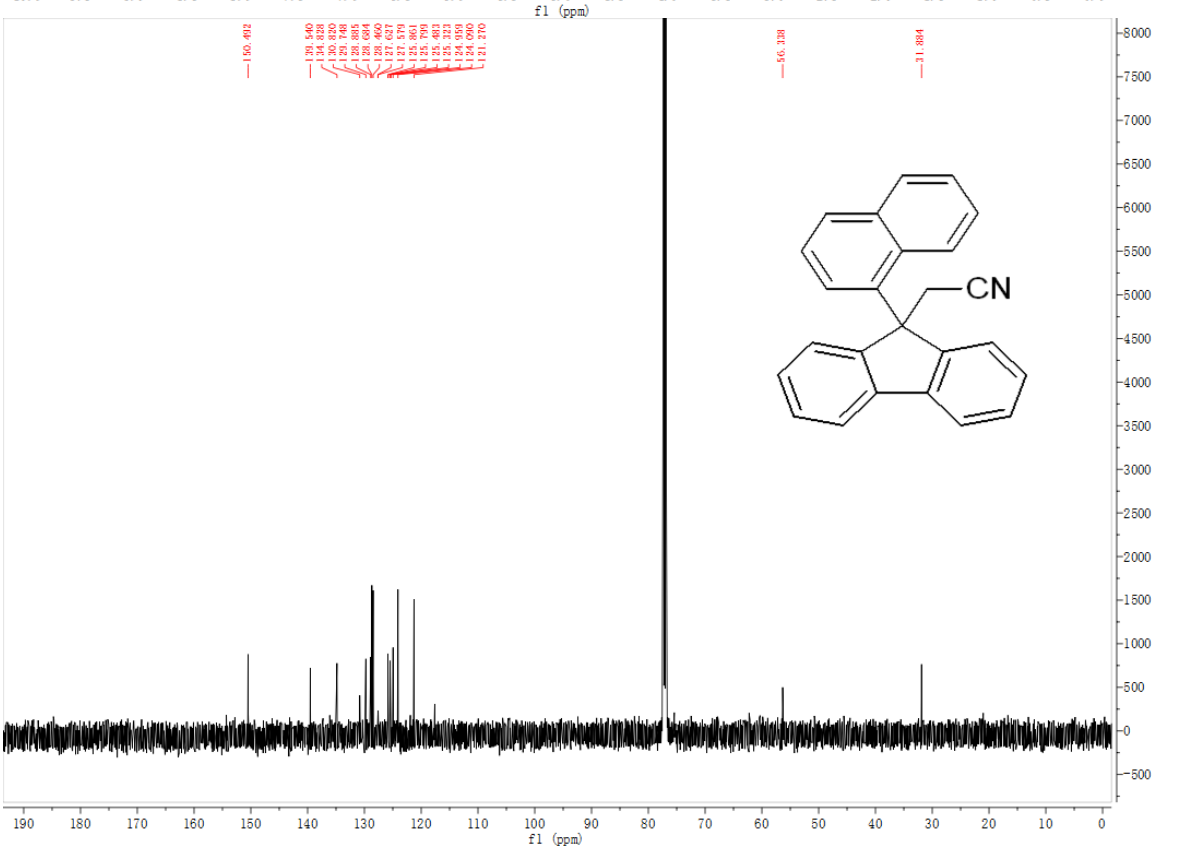
6ka ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)



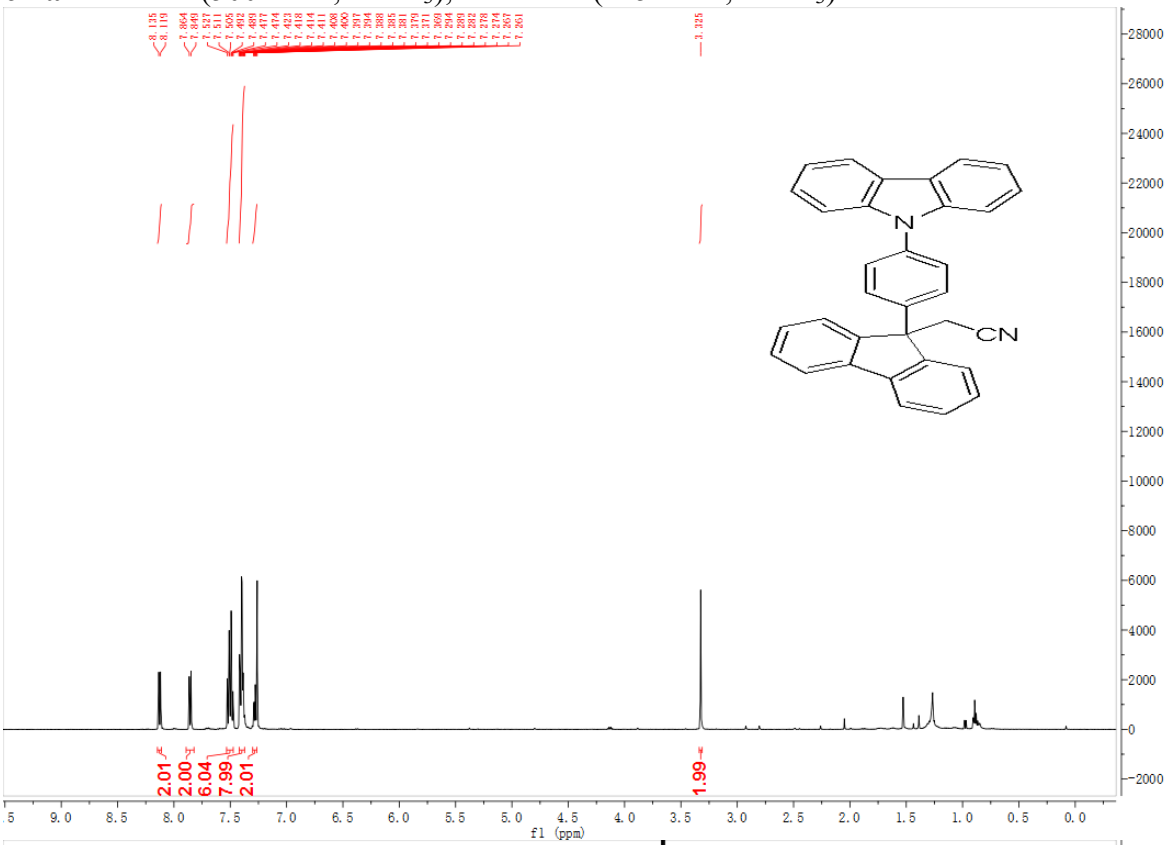


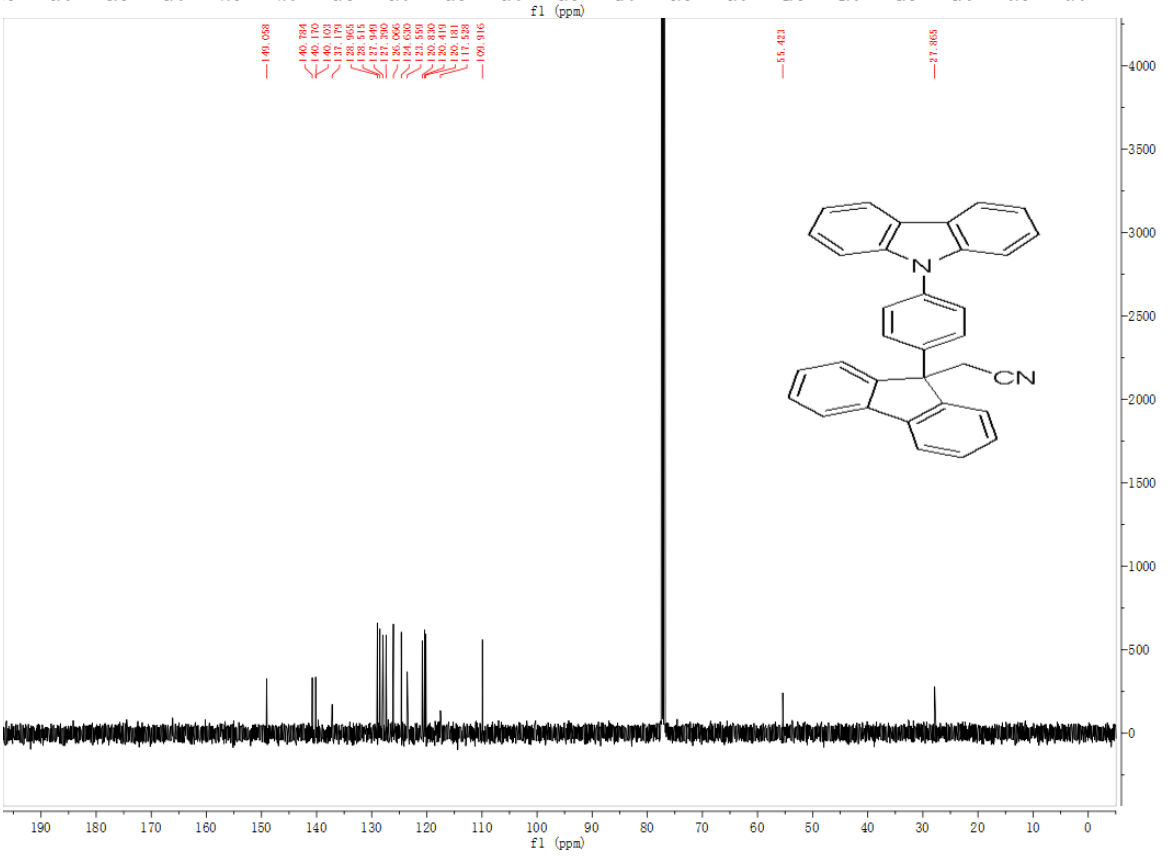
6la ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)



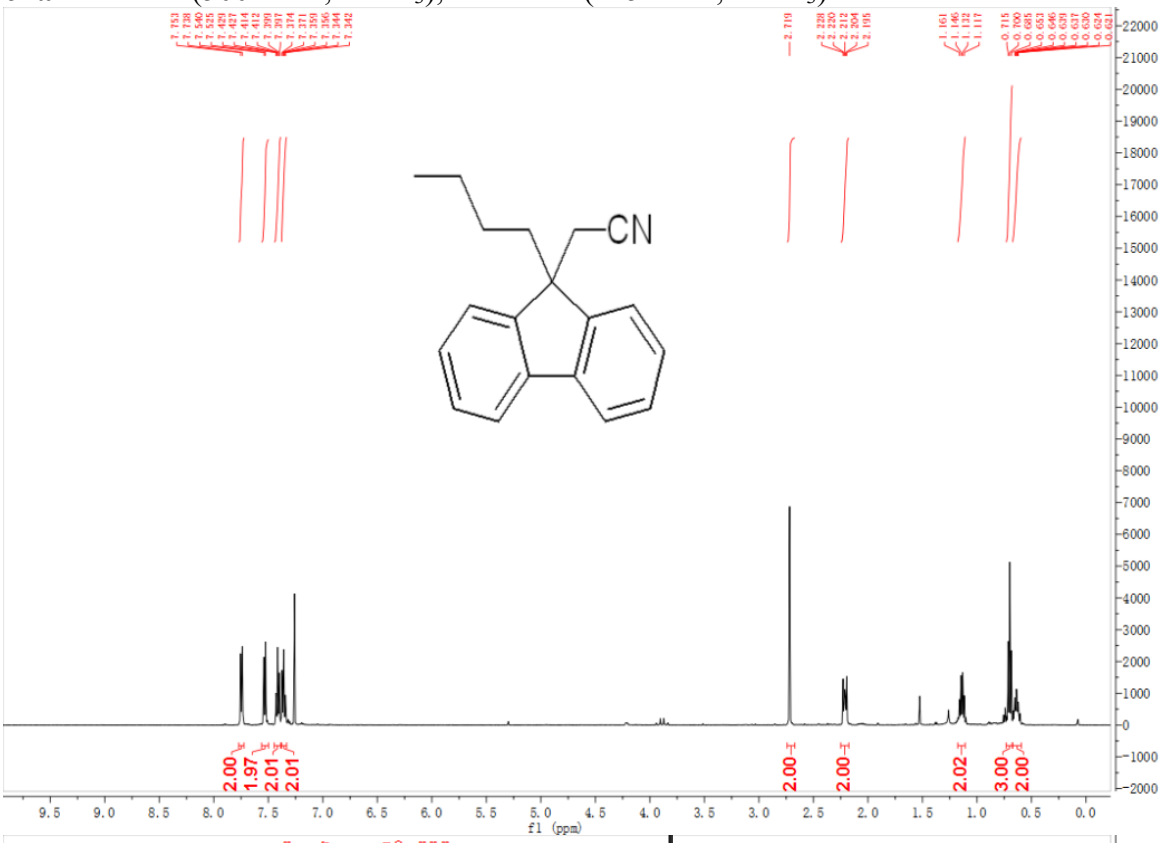


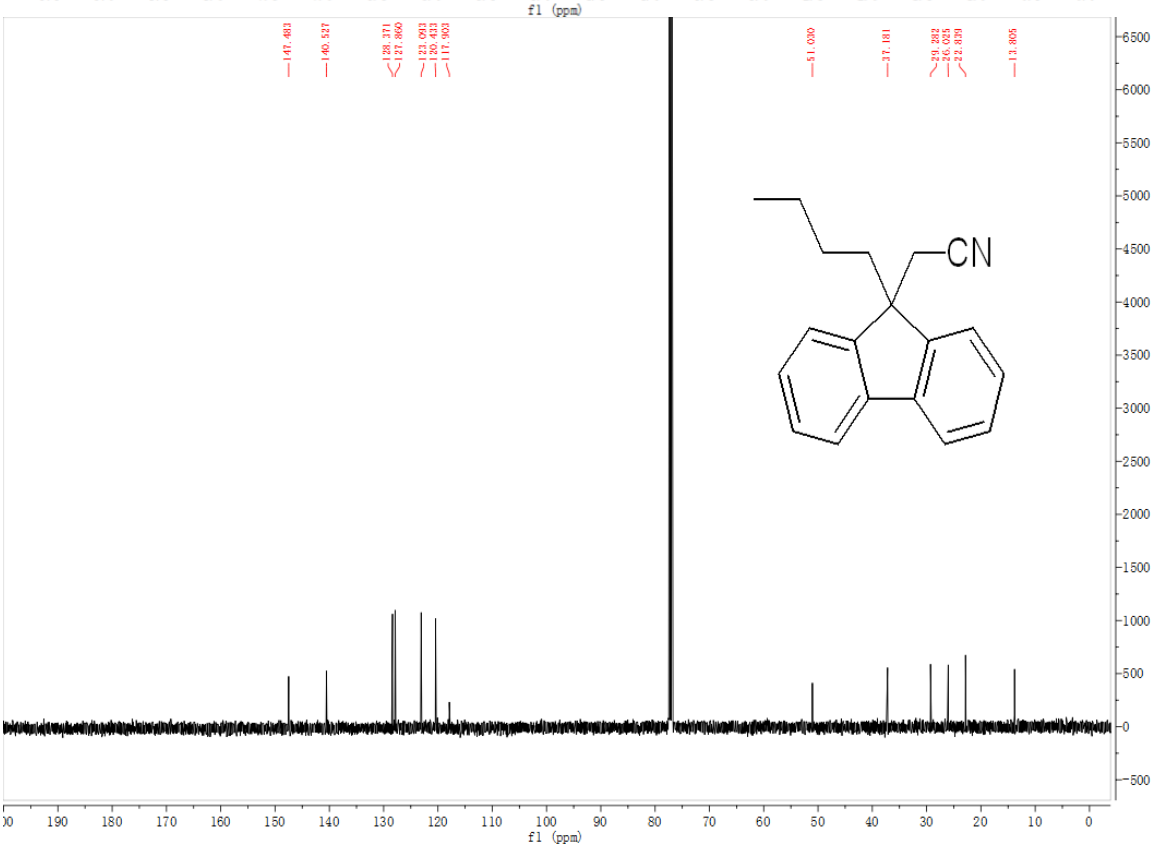
6ma ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)



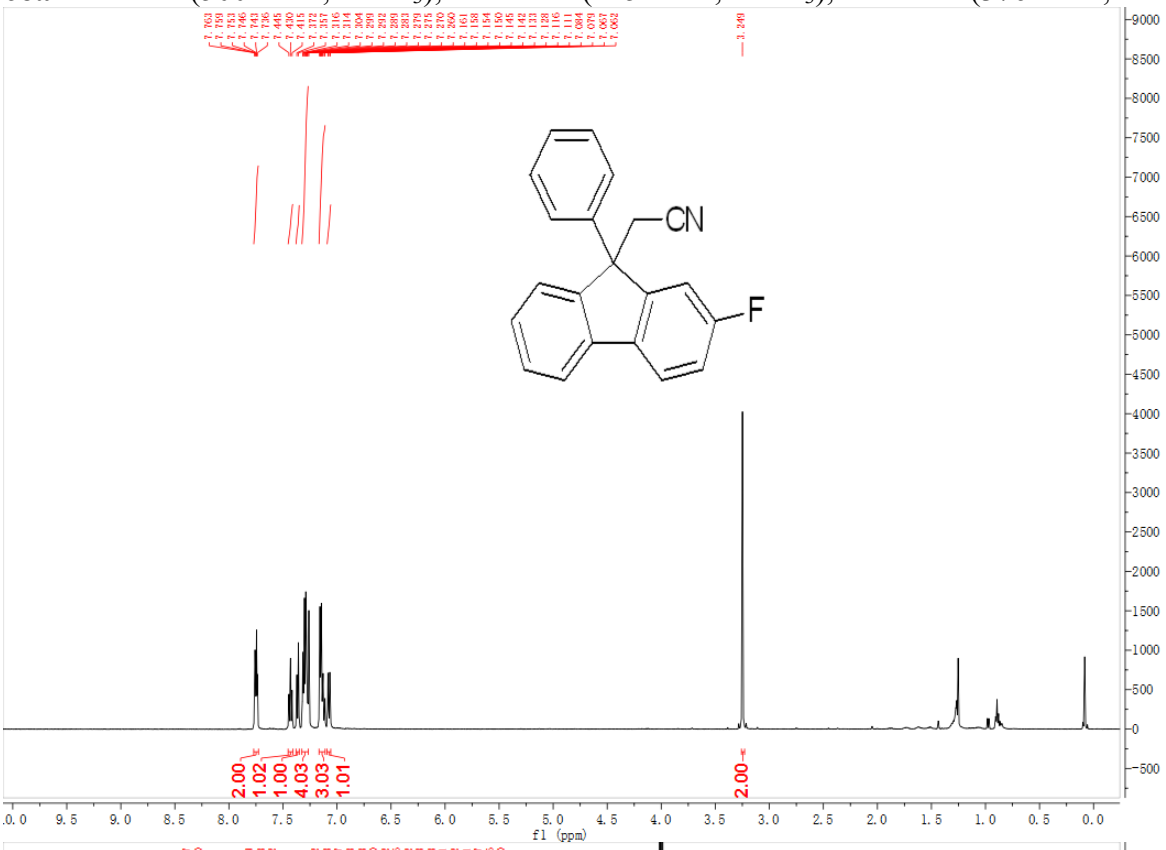


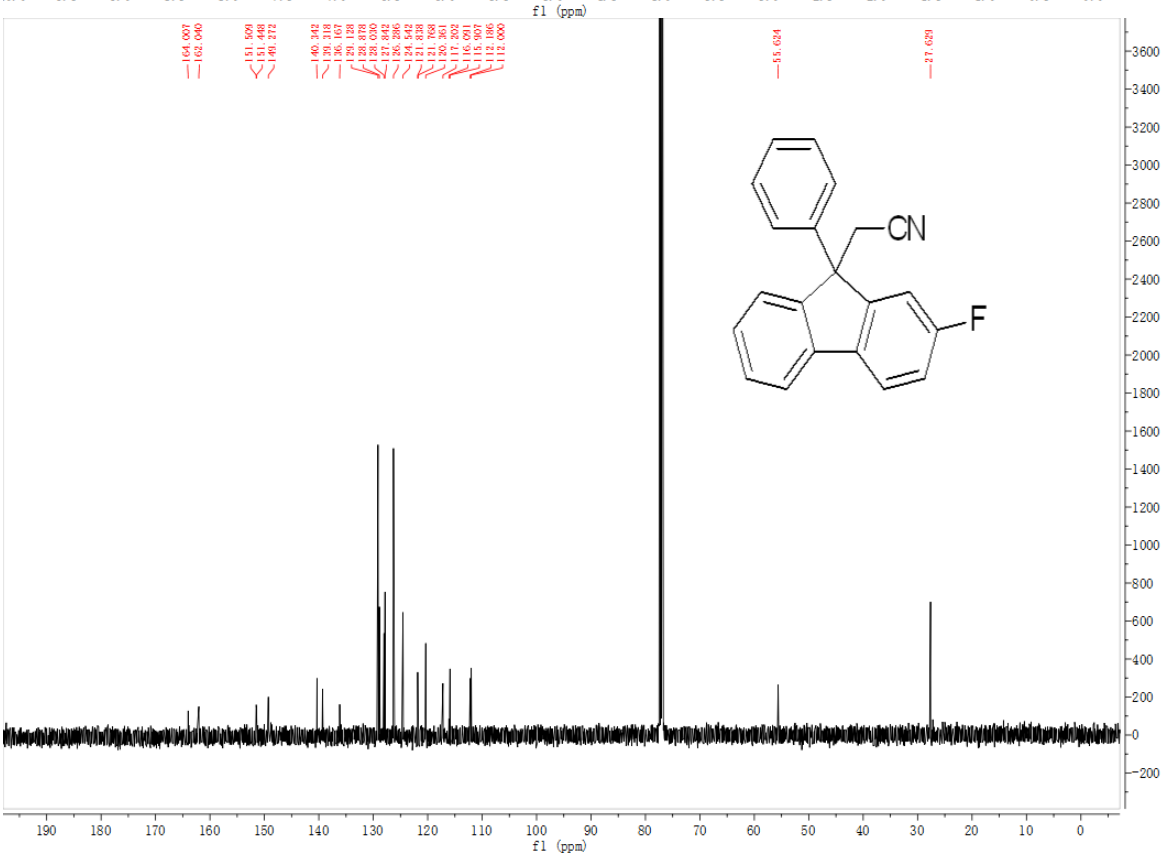
6na ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)

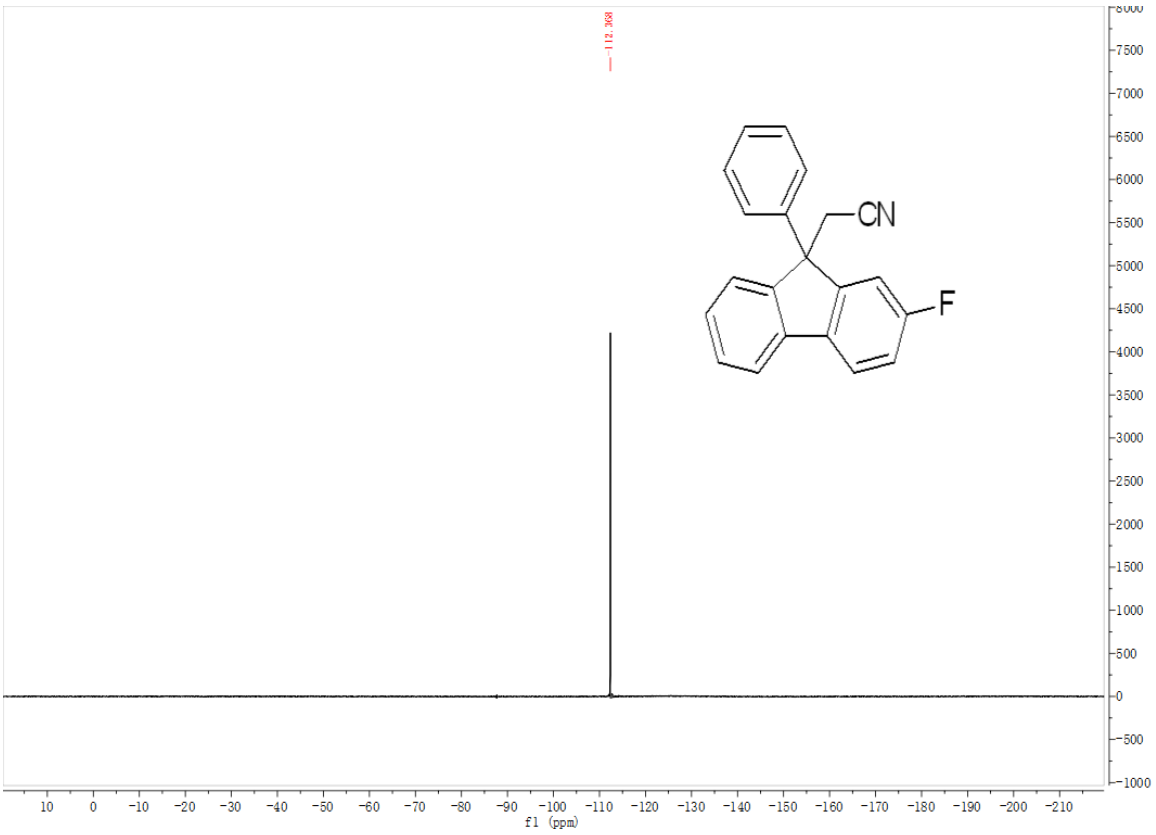




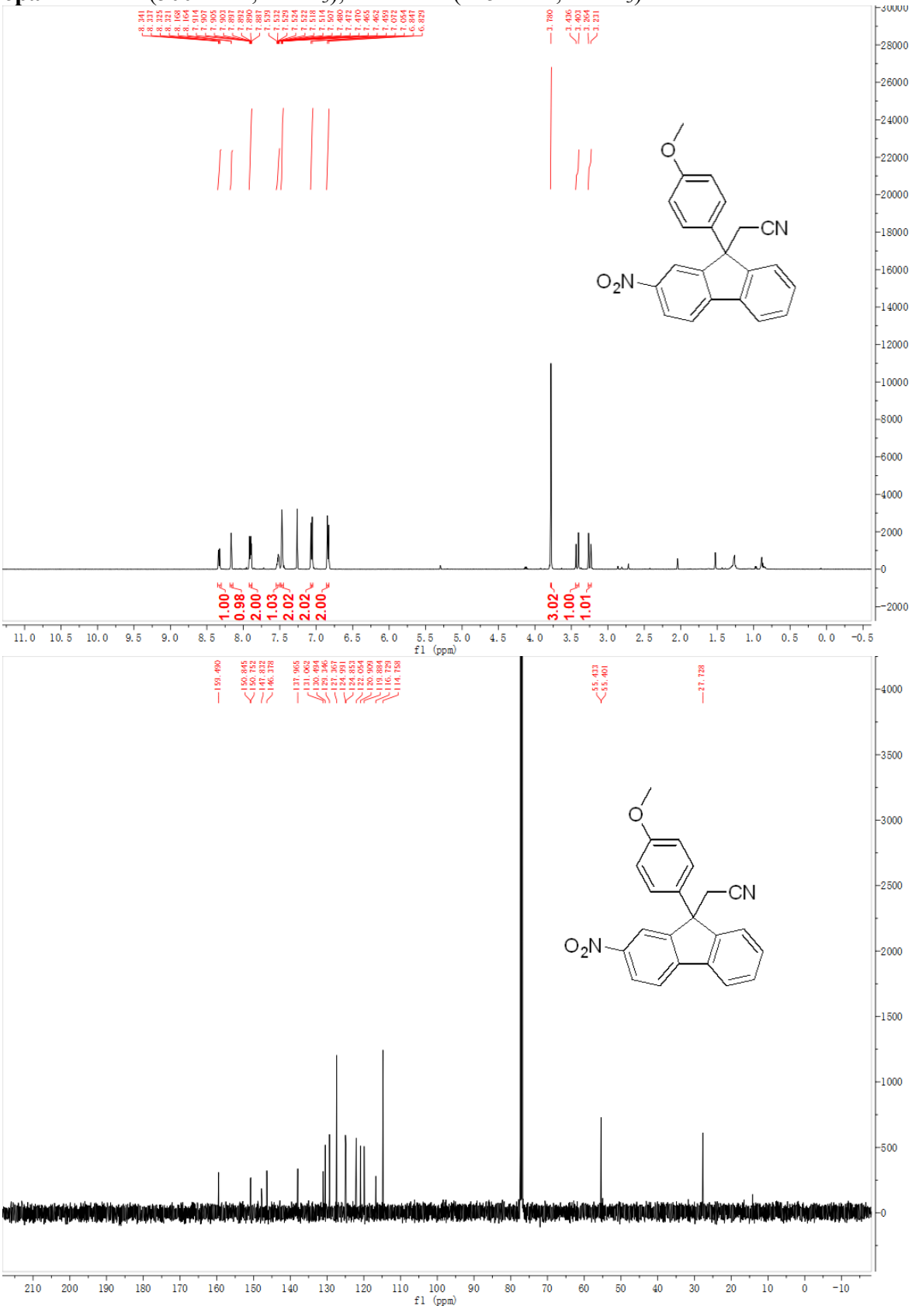
6oa ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$), ^{19}F NMR (376 MHz, $CDCl_3$)



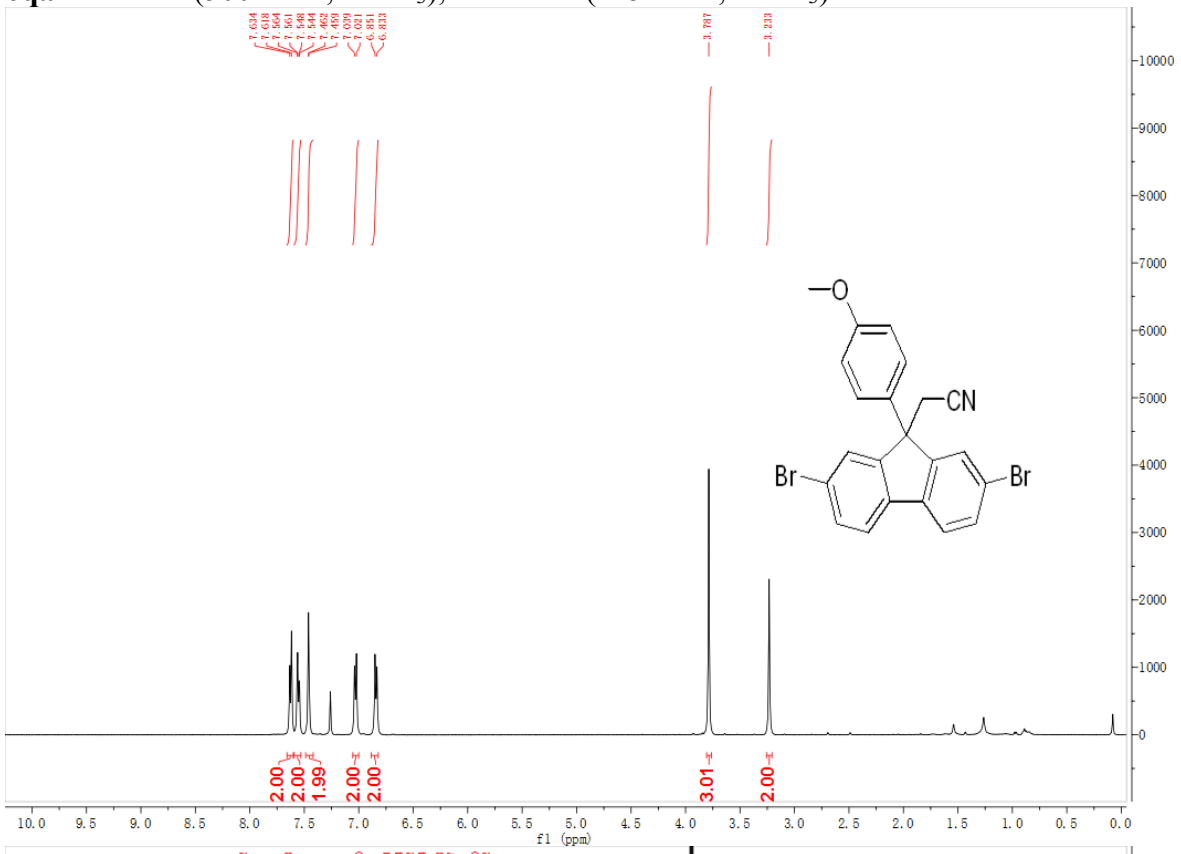


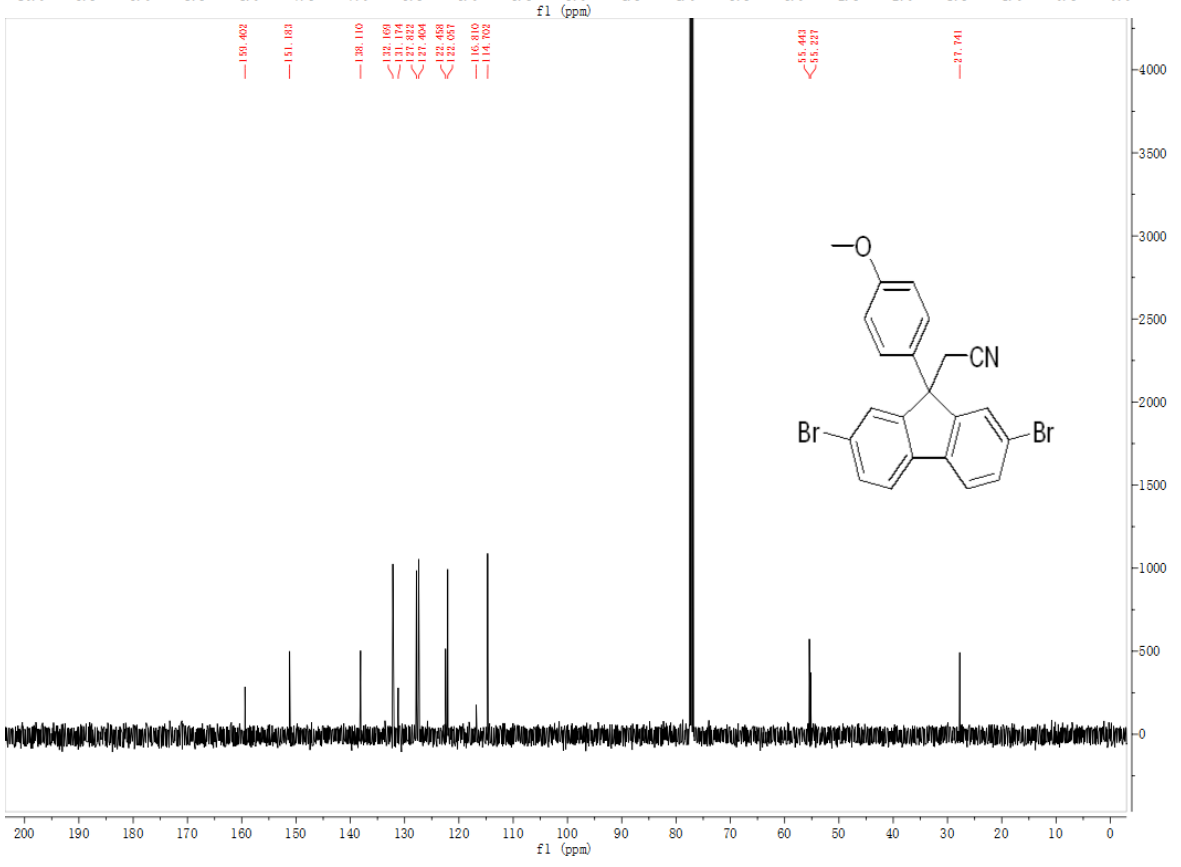

-112.368
CN
F
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)
7500 7000 6500 6000 5500 5000 4500 4000 3500 3000 2500 2000 1500 1000 500 0 -500 -1000

6pa ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)

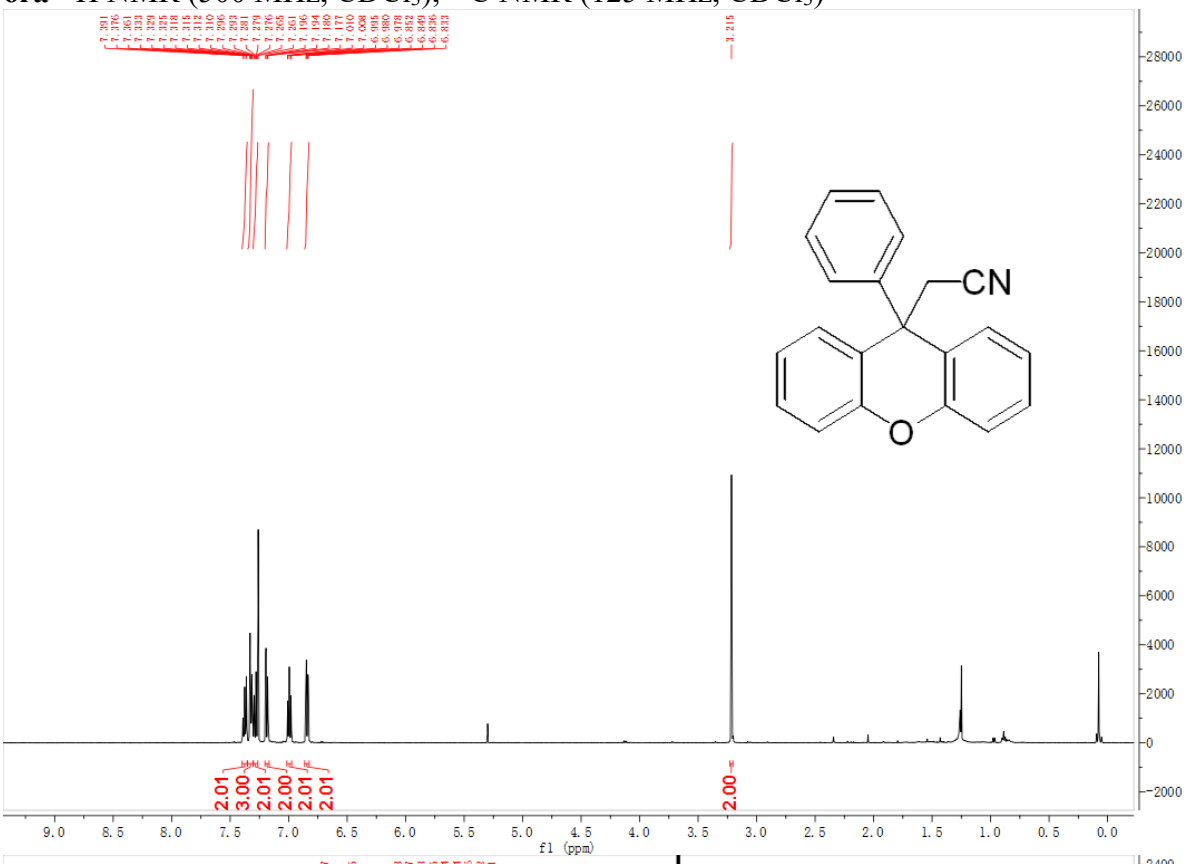


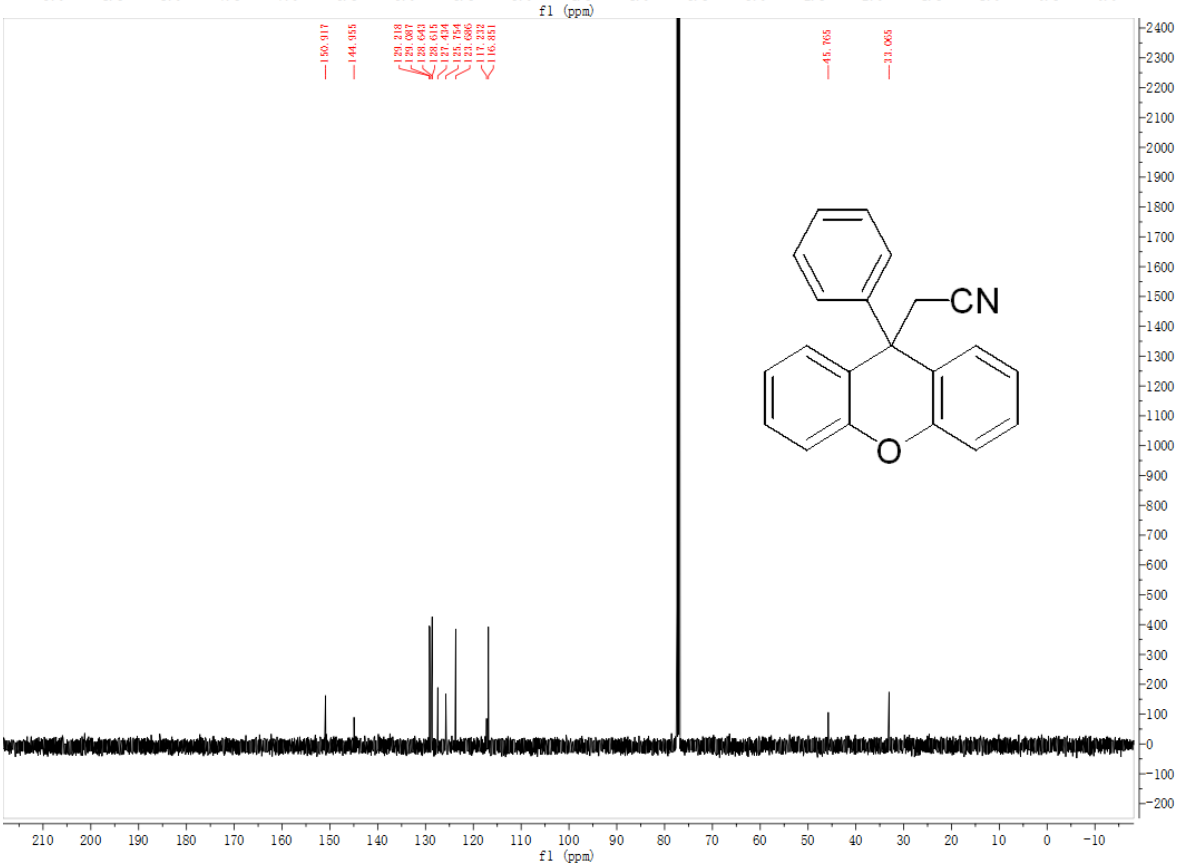
6qa ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)



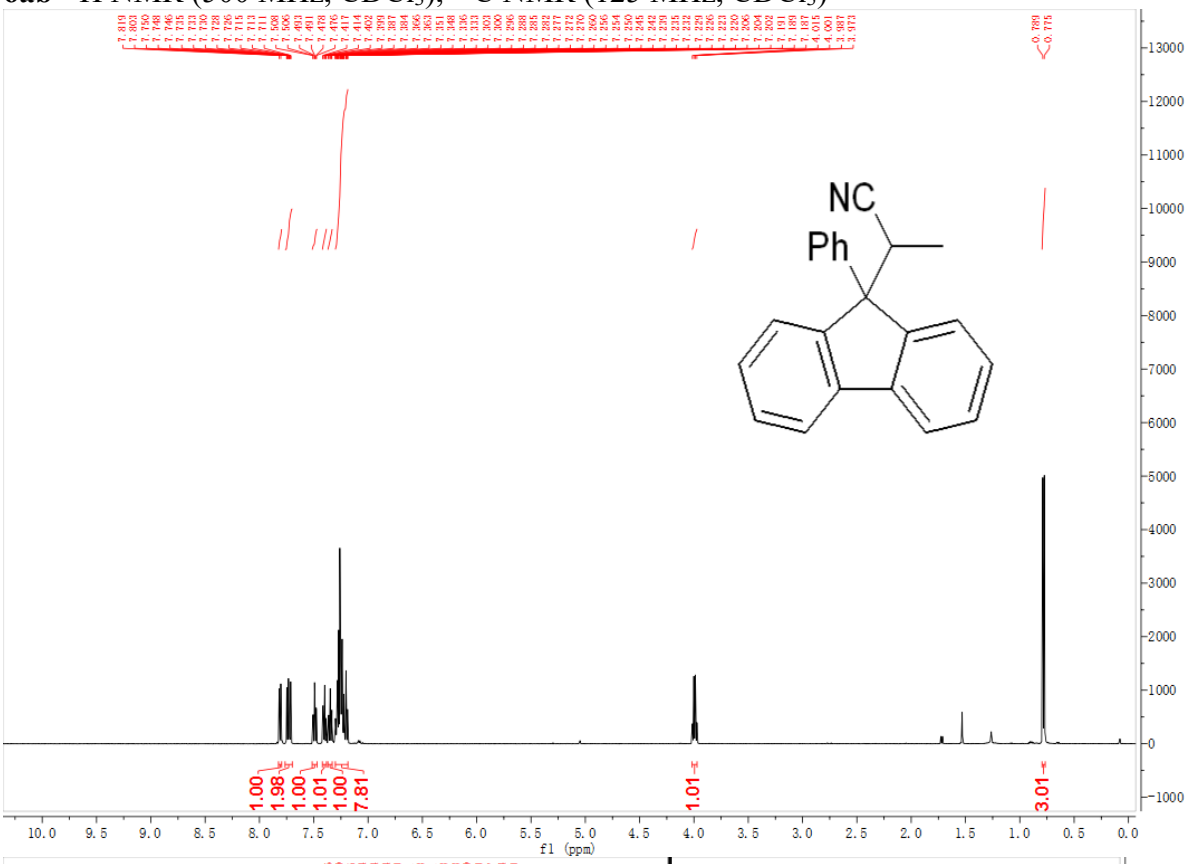


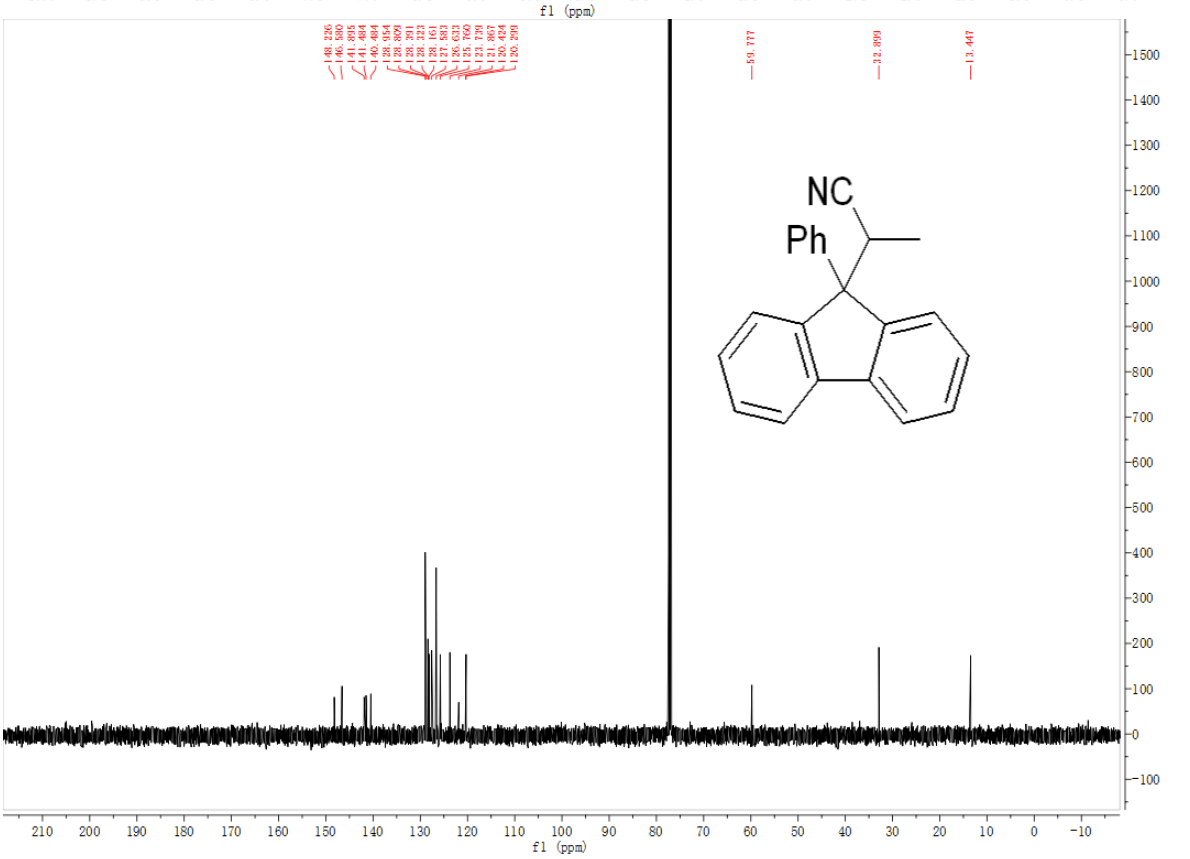
6ra ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)



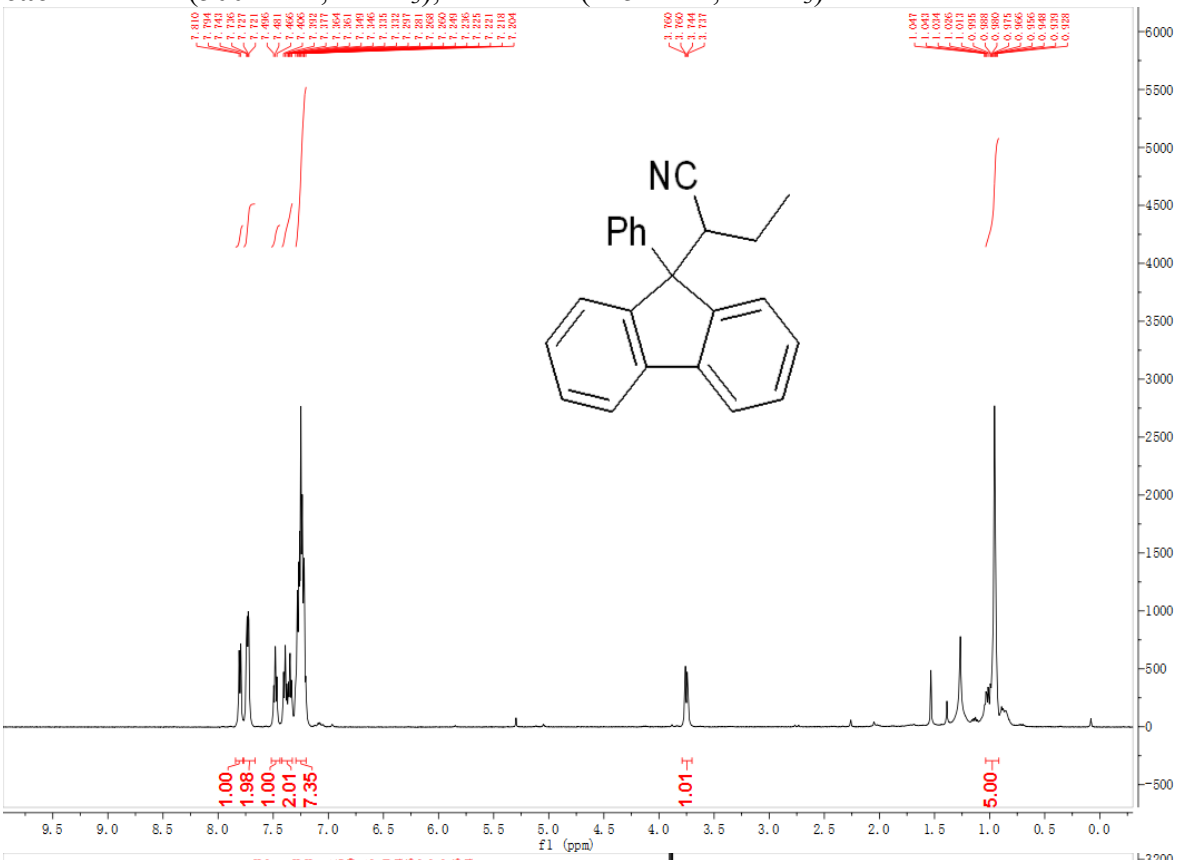


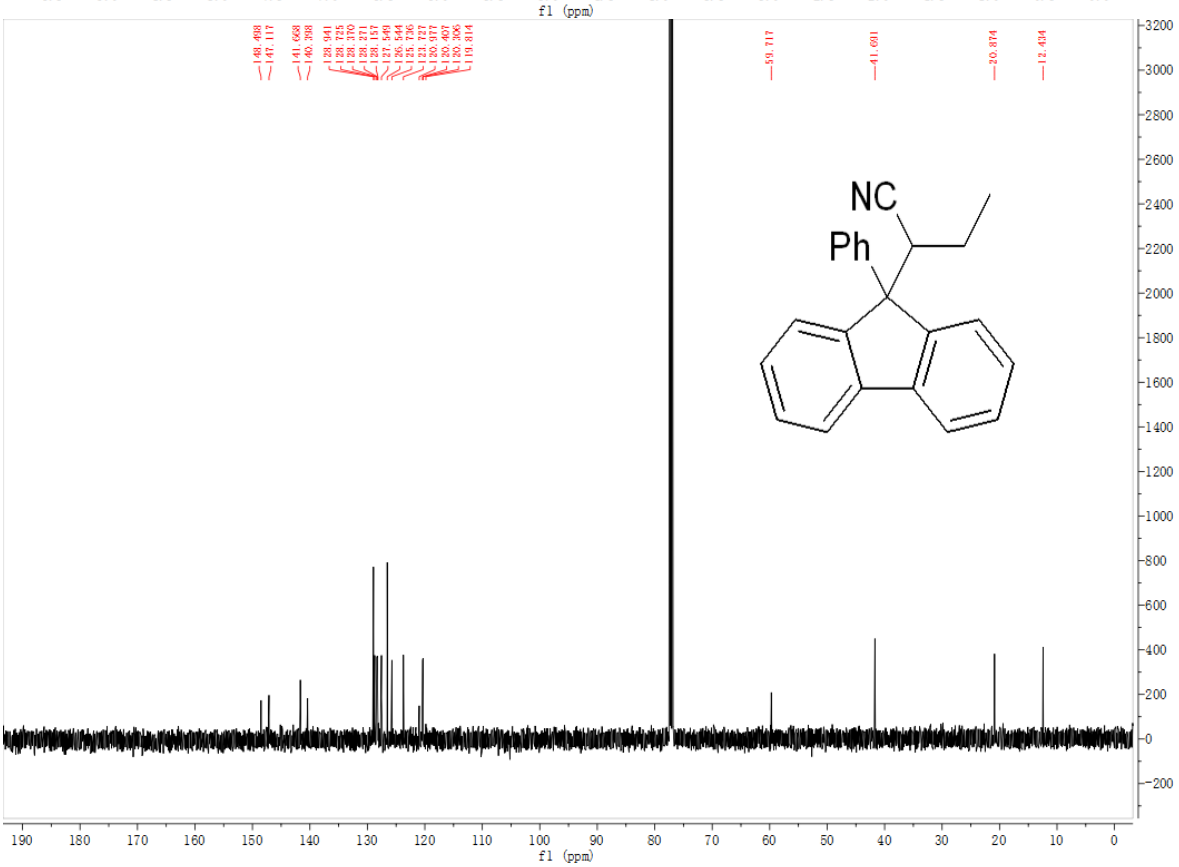
6ab ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)



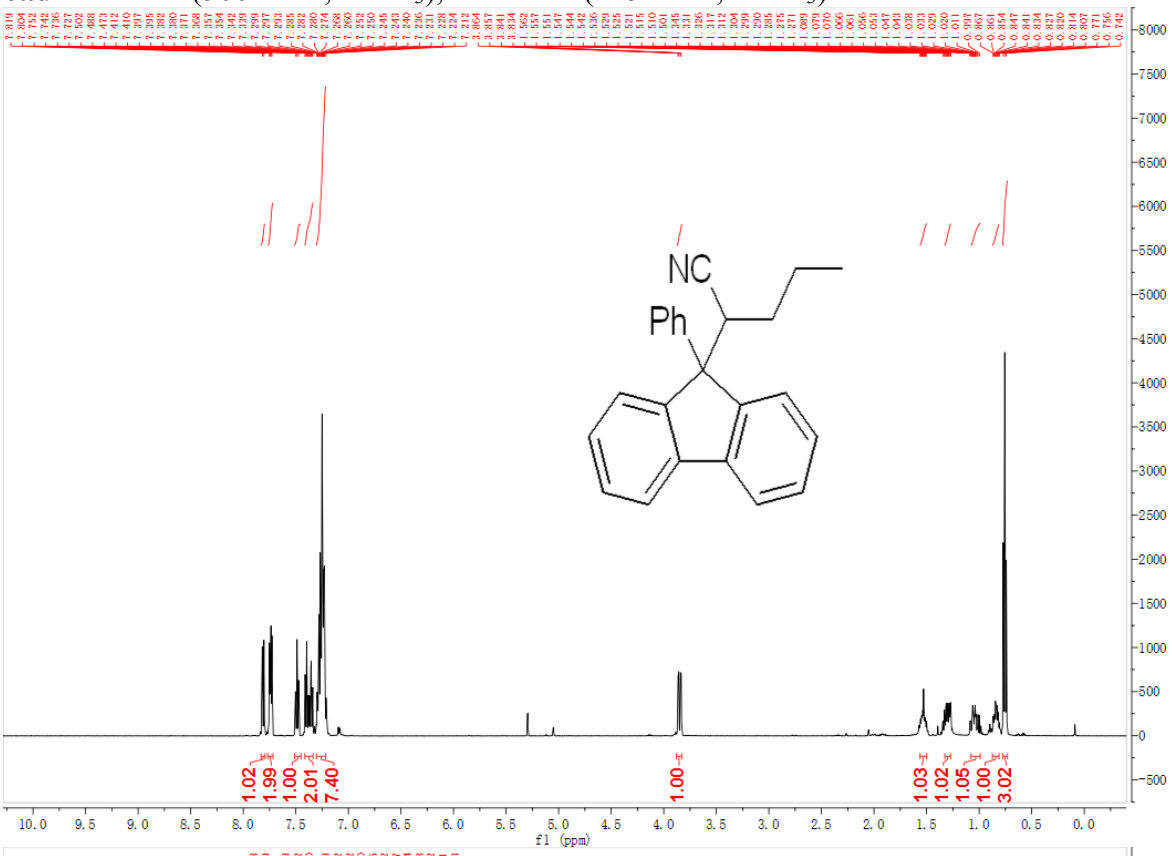


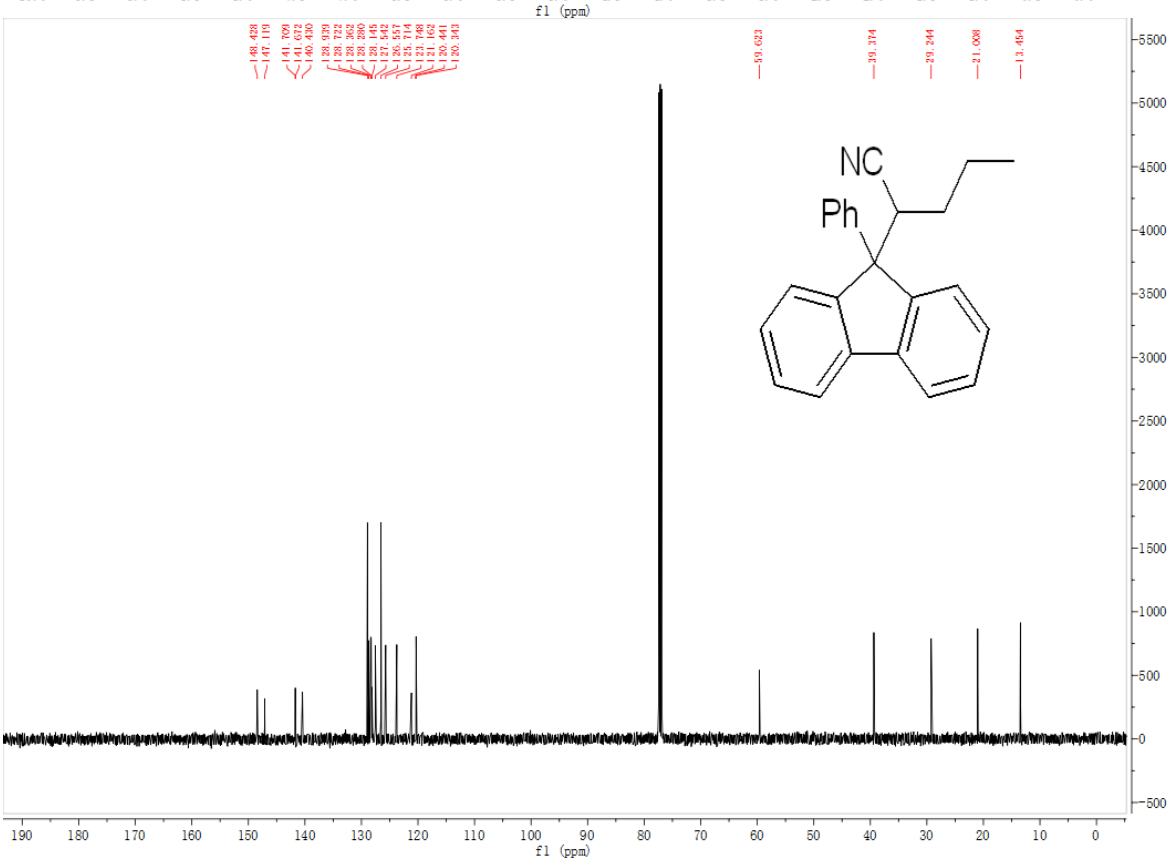
6ac ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)



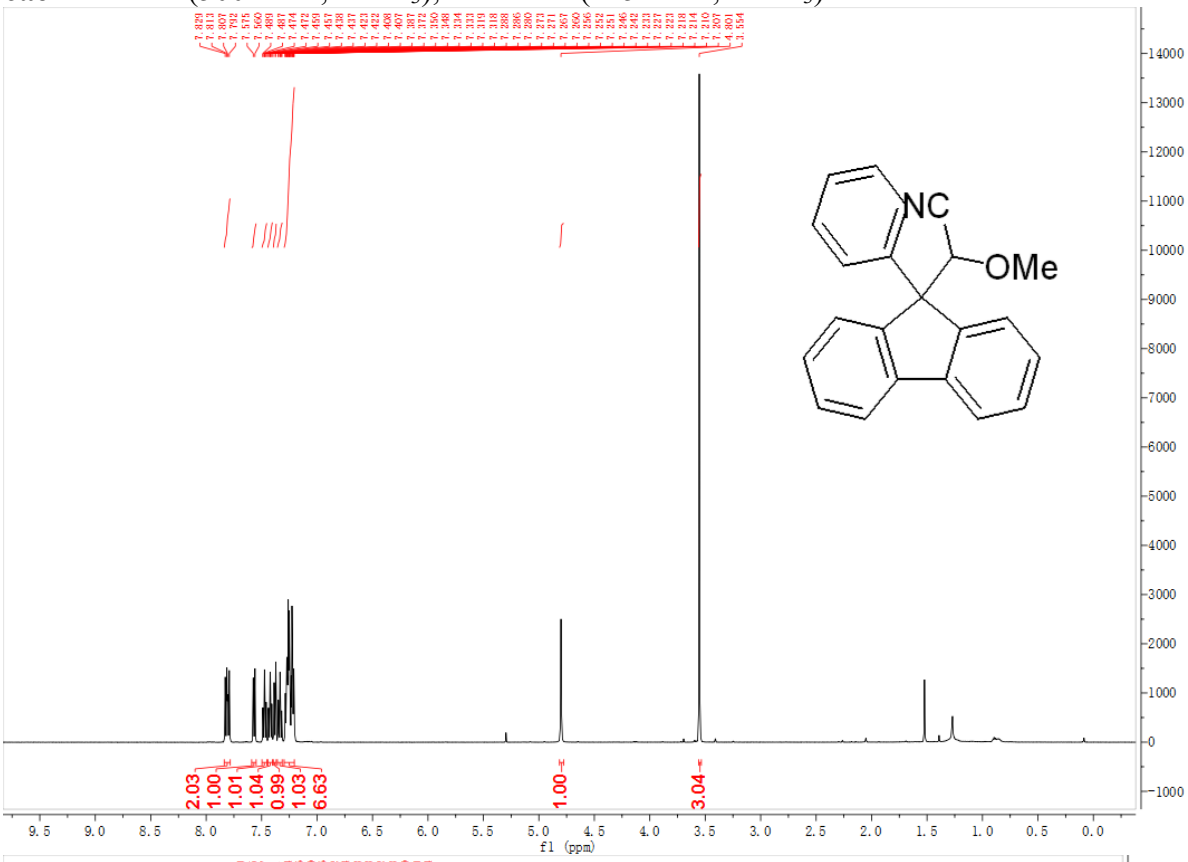


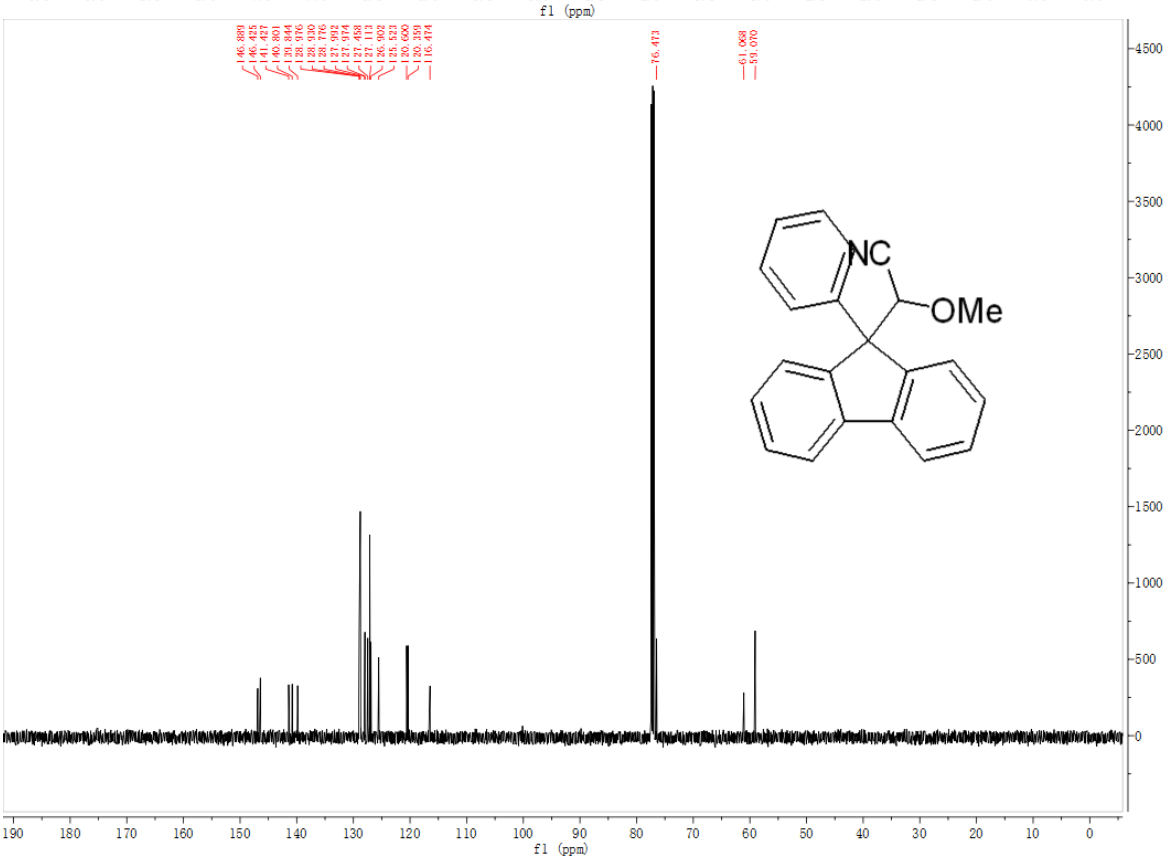
6ad ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)



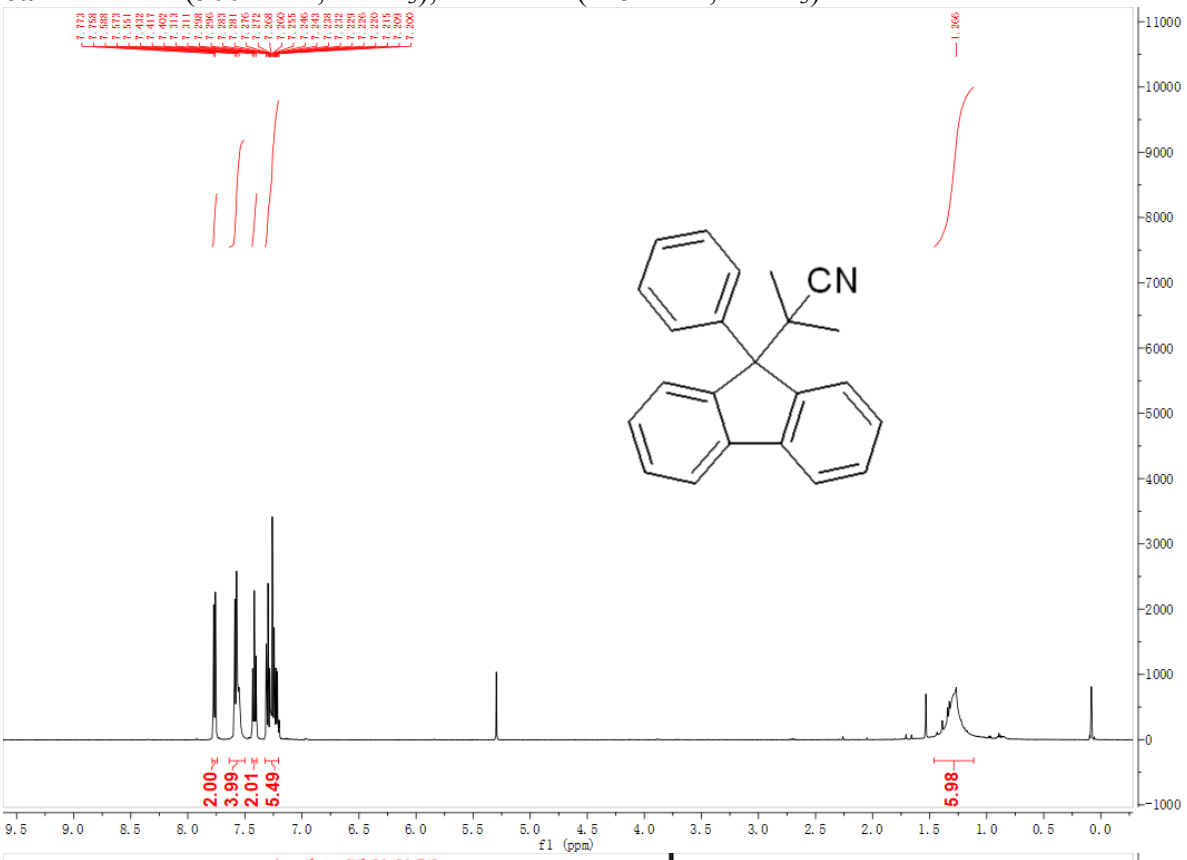


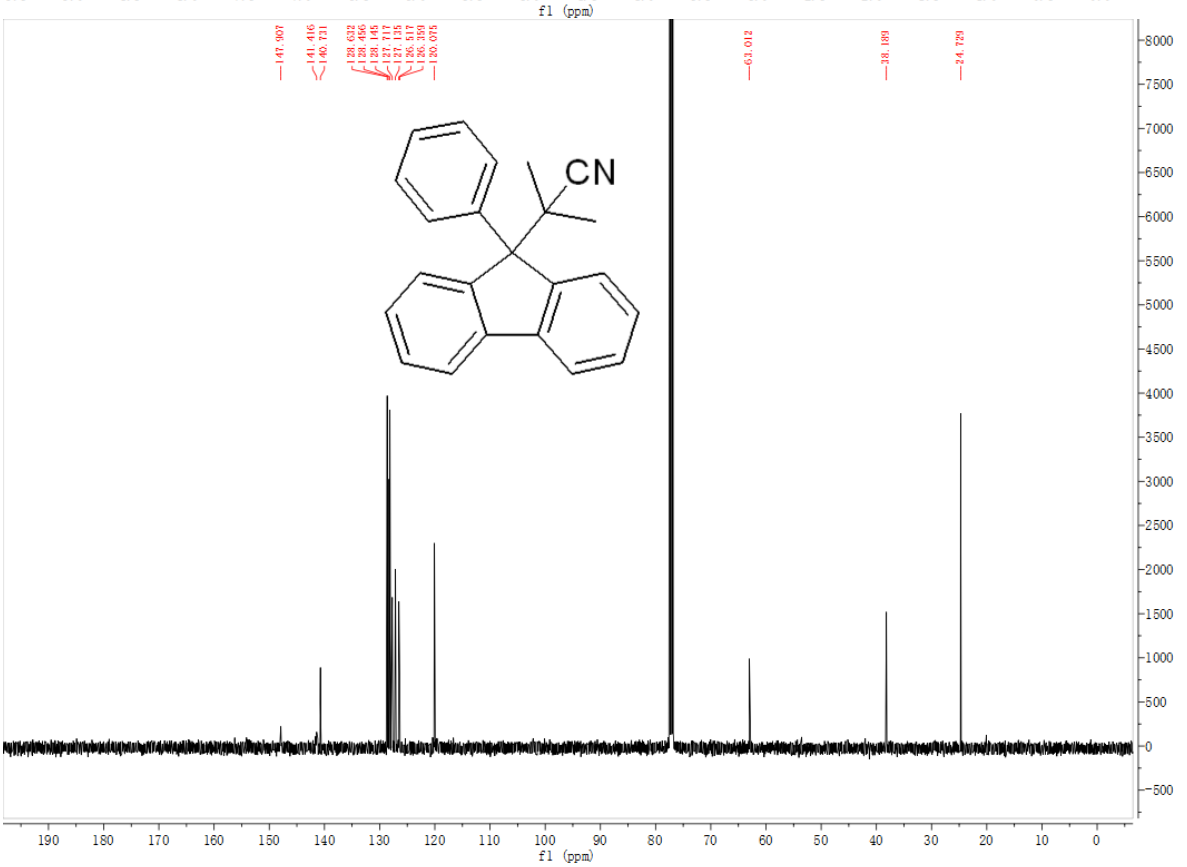
6ae ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)



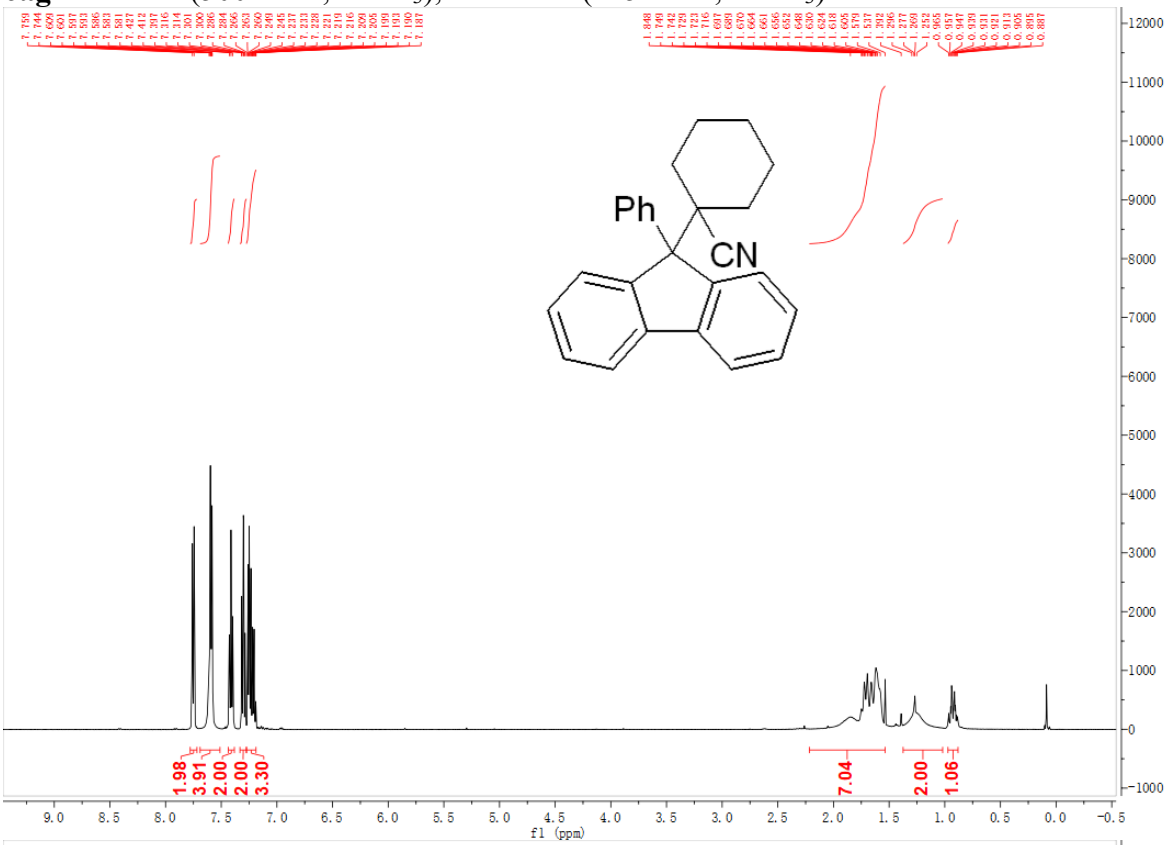


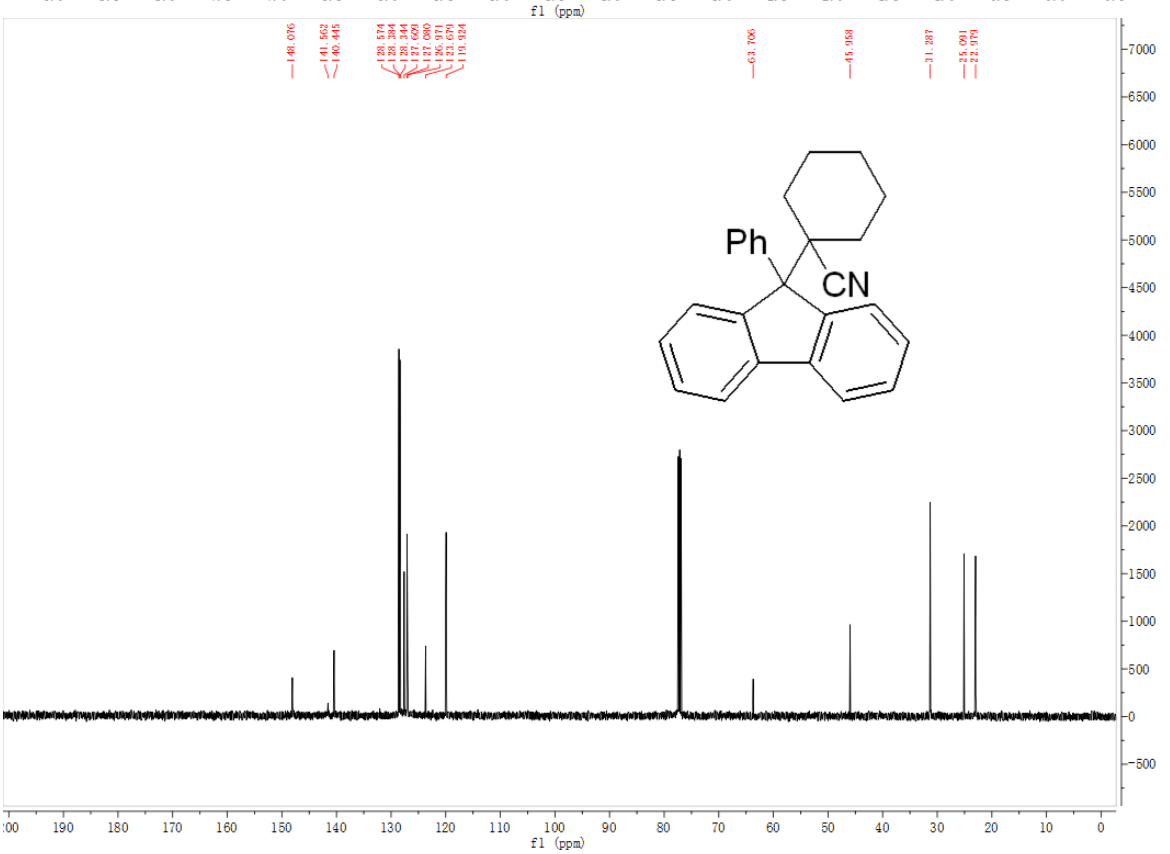
6af ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)



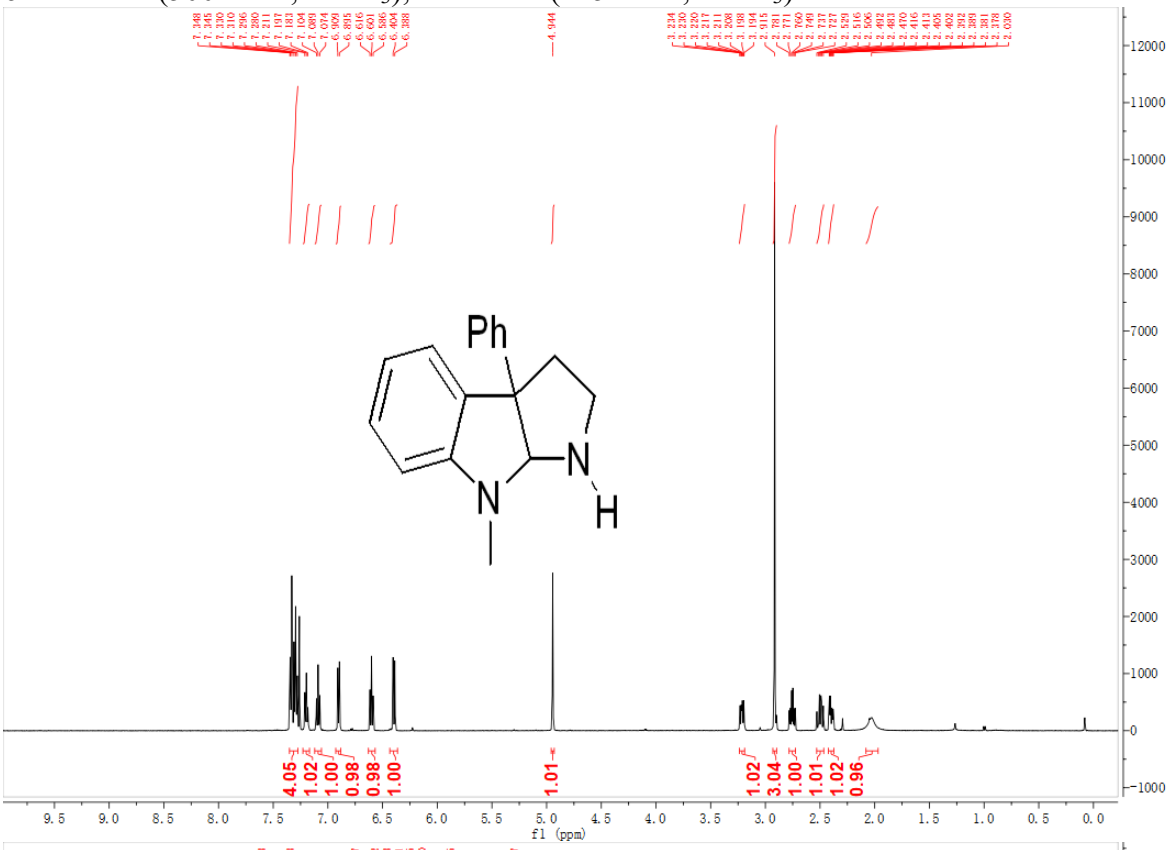


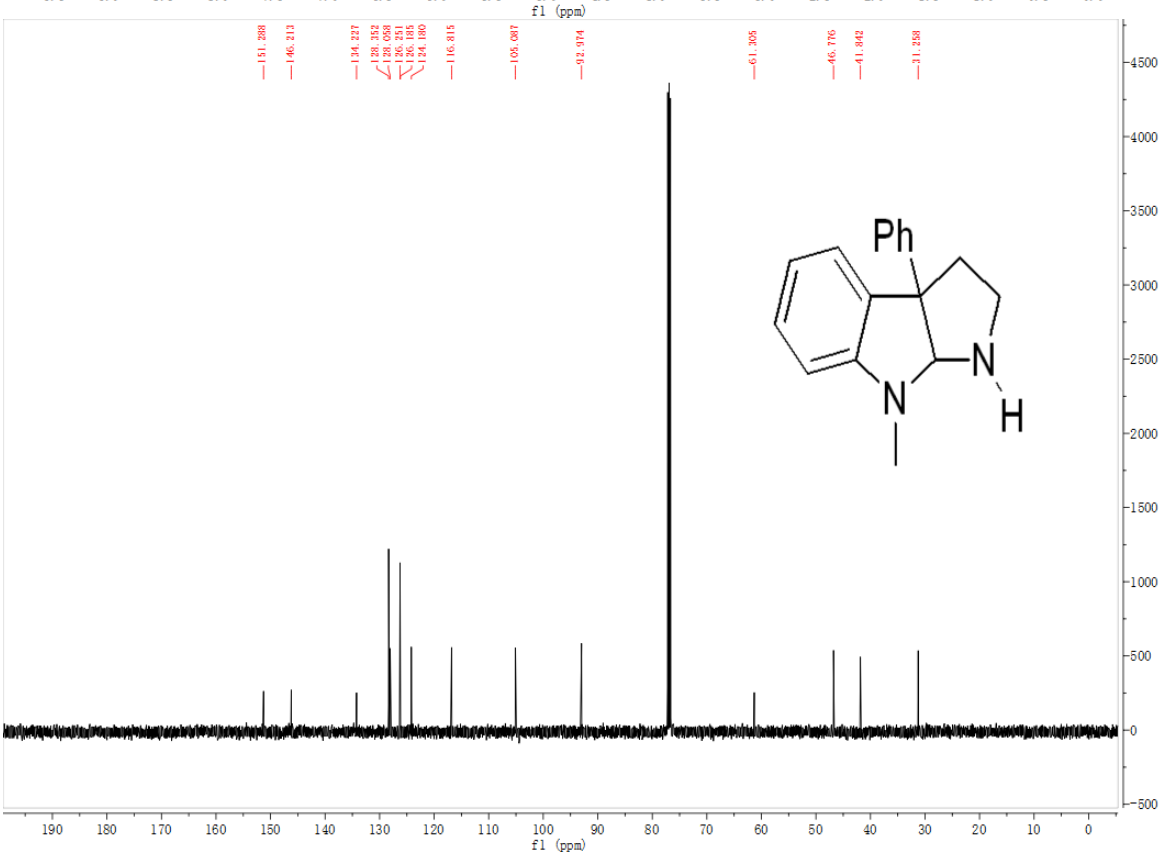
6ag ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)





6 ^{1}H NMR (500 MHz, $CDCl_3$), ^{13}C NMR (125 MHz, $CDCl_3$)





10 ^{1}H NMR (500 MHz, $CDCl_3$)