Supporting information

Cu-Catalyzed Direct C7-Sulfonylation of Indolines with Arylsulfonyl Chlorides

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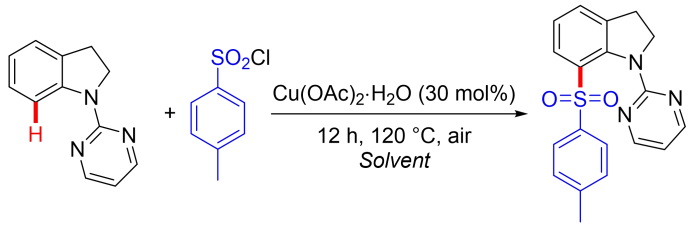
Experimental Section

1. Optimization of reaction conditions

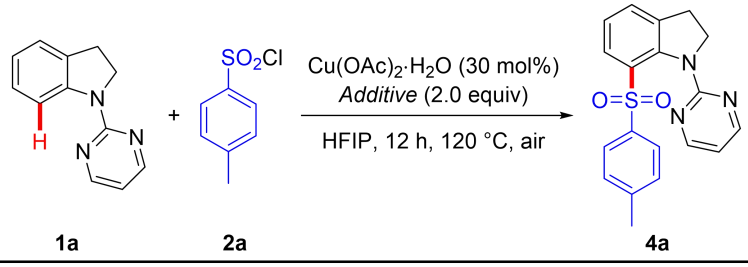
Table S1. Optimization of solvents[a]



Solvent	Yield(%)	Solvent	Yield(%)
DCE	trace	**HFIP**	**19**
CH_3CN	trace	MeOH	trace
1,4-Dioxane	7	EtOH	trace
toluene	7	TFE	trace
DMSO	trace	PEG400	trace
AcOH	N.D.	^{t}AmOH	trace

[a]Reaction conditions:**1a** (0.2 mmol), **2a** (2.0 equiv), $Cu(OAc)_2·H_2O$ (30 mol%), solvent (1 mL), 12 h, 120 °C, under air. Isolated yield. DCE = 1,2-Dichloroethane; DMSO = Dimethyl sulfoxide; HFIP = 1,1,1,3,3,3-Hexafluoroisopropanol; TFE = 2,2,2-Trifluoroethanol; ^{t}AmOH = *tert*-Amyl alcohol.

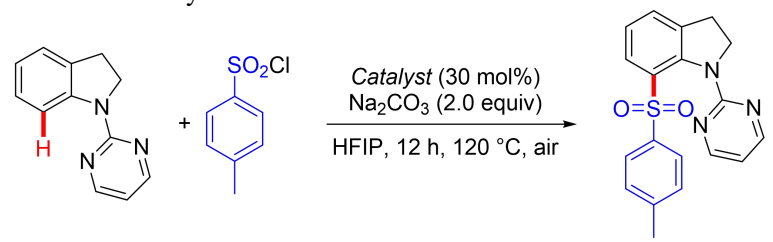
Table S2. Optimization of additive[a]



Additive	Yield(%)	Additive	Yield(%)
1-AdCOOH	trace	NaOH	35
MesCOOH	trace	$NaHCO_3$	18
DABCO	N.D.	**Na_2CO_3**	**79**
K_3PO_4	N.R.	Li_2CO_3	35
NaOAc	10	K_2CO_3	10
CH_3ONa	12	Cs_2CO_3	trace
PivONa • H_2O	19		

[a]Reaction conditions:**1a** (0.2 mmol), **2a** (2.0 equiv), $Cu(OAc)_2·H_2O$ (30 mol%), Additive(2.0 equiv), HFIP (1 mL), 12 h, 120 °C, under air. Isolated yield.

Table S3. Optimization of catalyst[a]

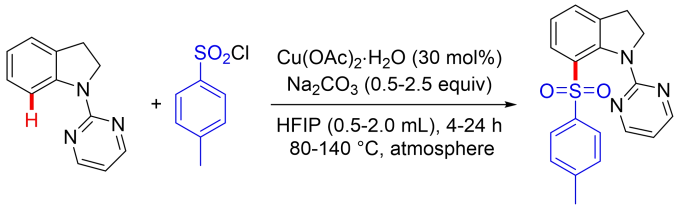


1a **2a** **4a**

Entry	Catalyst(30 mol%)	Yield(%)
1	CuCl	trace
2	Cu_2O	8
3	CuI	trace
4	CuOAc	18
5	$CuCl_2 \cdot 2H_2O$	trace
6	CuO	trace
7	$CuBr_2$	trace
8	$Cu(OAc)_2$	72
9	$Cu(OTf)_2$	trace
10	**$Cu(OAc)_2 \cdot H_2O$**	**79**

[a]Reaction conditions:**1a** (0.2 mmol), **2a** (2.0 equiv), Cat. (30 mol%) , Na_2CO_3 (2.0 equiv), HFIP (1 mL), 120 ℃, 12 h, under air. Isolated yield.

Table S4. Optimization of dosages of **2a** and base, temperature and time[a]



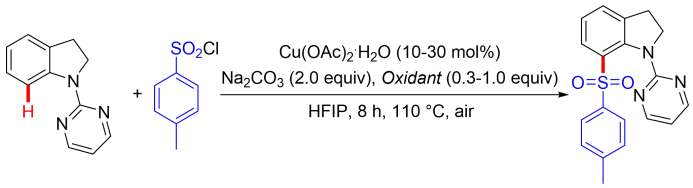
1a **2a** **4a**

Entry	**2a** (equiv)	Na_2CO_3 (equiv)	T (ºC)	t (h)	Yield (%)
1	1.5	2.0	120	12	77
2	2.0	2.0	120	12	79
3	3.0	2.0	120	12	52
4	2.0	0.5	120	12	18
5	2.0	1.0	120	12	11
6	2.0	2.5	120	12	77
7	2.0	2.0	80	12	31
8	2.0	2.0	90	12	39
9	2.0	2.0	100	12	77
10	2.0	2.0	110	12	80
11	2.0	2.0	140	12	65
12	2.0	2.0	110	4	77

13	**2.0**	**2.0**	**110**	**8**	**80**
14	2.0	2.0	110	16	78
15	2.0	2.0	110	24	78
16[b]	2.0	2.0	110	8	23
17[c]	2.0	2.0	110	8	80
18[d]	2.0	2.0	110	8	48
19[e]	2.0	2.0	110	8	50

[a]Reaction conditions:**1a** (0.2 mmol), **2a** (1.5-3.0 equiv), $Cu(OAc)_2 \cdot H_2O$ (30 mol%), Na_2CO_3 (0.5-2.5 equiv), HFIP (1 mL), 4-24 h, 80-140 °C, under air. Isolated yield. [b]HFIP (0.5 mL). [c]HFIP (2 mL). [d]**1a** was replaced by 5-methoxy-1-(pyrimidin-2-yl)indoline. [e]**1a** was replaced by 5-fluoro-1-(pyrimidin-2-yl)indoline.

Table S5. Optimization of oxidant[a]



1a **2a** **4a**

Entry	$Cu(OAc)_2 \cdot H_2O$(mol%)	Oxidant(equiv)	Yield(%)
1	30	TBHP(1.0)	11
2	30	MnO_2(1.0)	62
3	30	Ag_2CO_3(1.0)	76
4	30	$PhI(OAc)_2$(1.0)	11
5	30	$K_2S_2O_8$(1.0)	72
6	30	MnO_2(0.5)	62
7	30	$K_2S_2O_8$(0.5)	72
8	30	Ag_2CO_3(0.5)	75
9	**20**	**Ag_2CO_3(0.5)**	**82**
10	10	Ag_2CO_3(0.5)	30
11	20	Ag_2CO_3 (0.3)	62
12	20	Ag_2CO_3 (1.0)	76

[a]Reaction conditions:**1a** (0.2 mmol), **2a** (2.0 equiv), $Cu(OAc)_2 \cdot H_2O$ (10-30 mol%), Na_2CO_3 (2.0 equiv), Oxidant(0.3-1.0 equiv), HFIP (1 mL), under air, 8 h, 110 °C. Isolated yield.

2. Mechanistic studies

Reaction in the presence of radical scavengers

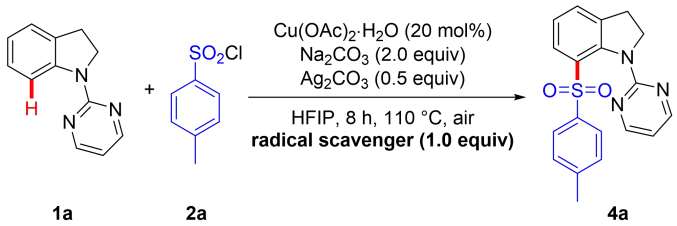
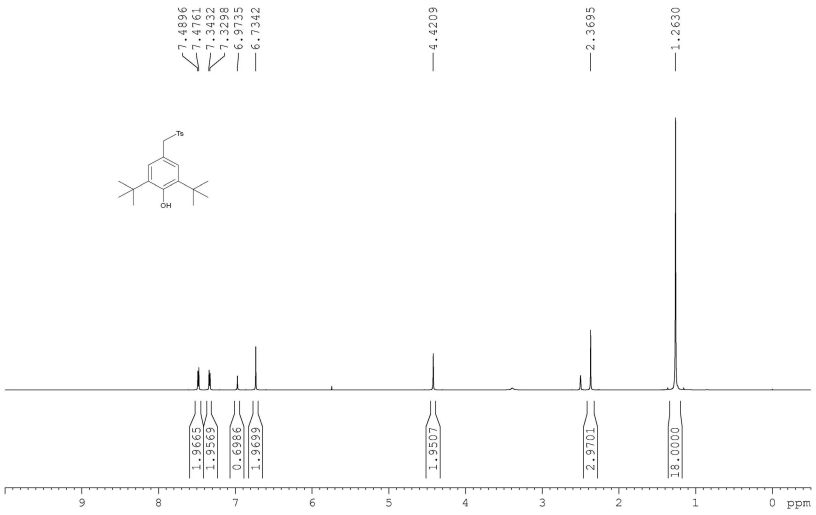


Table S6 Effect of radical scavenger[a]

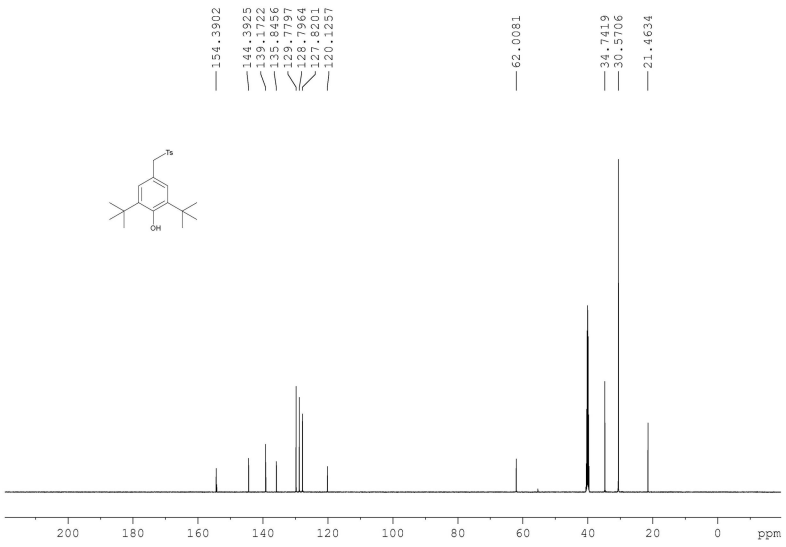
Entry	Radical scavenger	Yield of **4a** (%)
1	--	82
2	TEMPO	trace
3	BHT	22
4	BQ	7

[a]Reaction conditions:**1a** (0.2 mmol), **2a** (2 equiv), $Cu(OAc)_2 \cdot H_2O$(20 mol%), Na_2CO_3 (2.0 equiv), Ag_2CO_3 (0.5 equiv.), radical scavenger (1.0 equiv), HFIP (1 mL), 8 h, 110 °C, under air. Isolated yield. TEMPO = (2,2,6,6-Tetramethylpiperidin-1-yl)oxidanyl. BHT = 2,6-Di-*tert*-butyl-4-methylphenol. BQ = Benzoquinone.

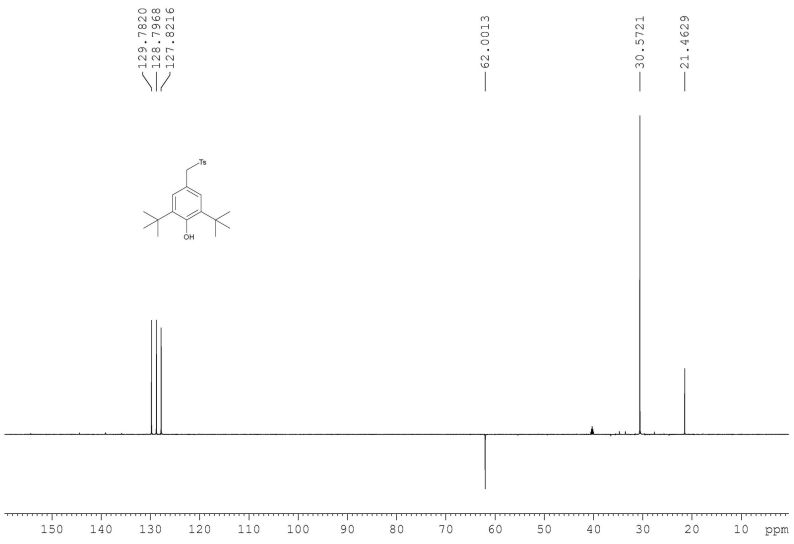
^{1}H NMR spectrum of compound **8**



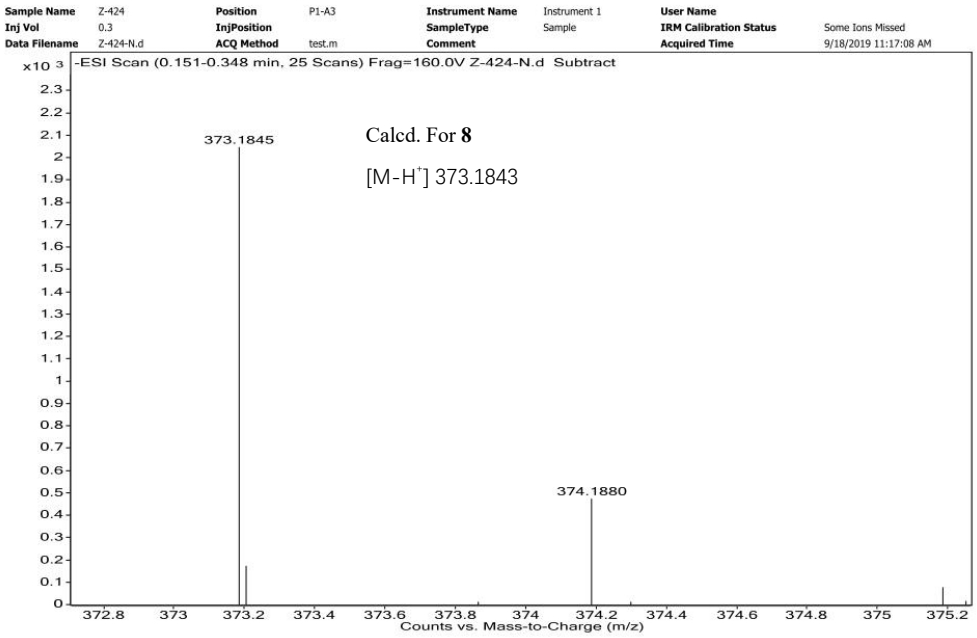
^{13}C NMR spectrum of compound **8**



DEPT(135°) spectrum of compound **8**



HRMS(negative or positive ESI) for **8**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Instrument Name Instrument 1
User Name
Inj Vol 0.3
InjPosition
SampleType Sample
IRM Calibration Status Some Ions Missed
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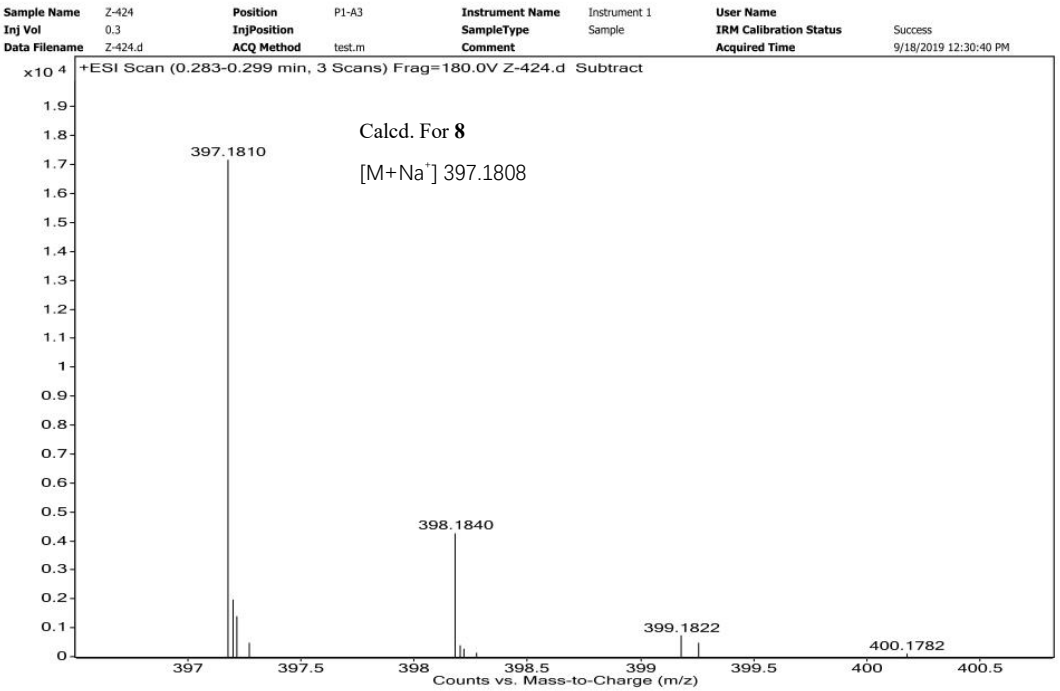
ACQ Method test.m
Comment
Acquired Time 9/18/2019 11:17:08 AM
-ESI Scan (0.151-0.348 min, 25 Scans) Frag=160.0V Z-424-N.d Subtract
x10 3
373.1845
374.1880
Calcd. For 8
[M-H+] 373.1843
Counts vs. Mass-to-Charge (m/z)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IRM Calibration Status Success
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ACQ Method test.m
Comment
Acquired Time 9/18/2019 12:30:40 PM
+ESI Scan (0.283-0.299 min, 3 Scans) Frag=180.0V Z-424.d Subtract
x10 4
397.1810
398.1840
399.1822
400.1782
Calcd. For 8
[M+Na+] 397.1808
Counts vs. Mass-to-Charge (m/z)

3. X-ray crystal structure of 4a and 4i

X-ray diffraction data for all studied compounds were collected using a Xcalibur, Eos, Gemini diffractometer, at the temperature of 120(2)K, using graphite-monochromated Cu Kα radiation. Using Olex2,[1] the structure was solved with the ShelXS[2] structure solution program using direct methods and refined with the ShelXL[3] refinement package using Least Squares minimisation. Crystal data, data collection and structure refinement details are summarized in Table S7 and Table S8.

Crystals of compounds **4a** and **4i** were groune from DCM/Hexane.

1. Dolomanov, O. V. Bourhis, L. J. Gildea, R. J, Howard, J. A. K. Puschmann, H. OLEX2: a complete structure solution, refinement and analysis program. *J. Appl. Cryst.* **2009***, 42*, 339-341.

2. Sheldrick, G.M. A short history of SHELX. *Acta Cryst., Sect. A* **2008**, *A64*, 112-122.

3. Sheldrick, G.M. Crystal structure refinement with SHELXL. *Acta Cryst.* **2015**, *C71*, 3-8.

Table S7. Crystal data and structure refinement for **4a**

Structure	**4a**
Identification code	1962623
Empirical formula	$C_{19}H_{17}N_3O_2S$
Formula weight	351.41
Temperature/K	293(2)
Crystal system	monoclinic
Space group	$P2_1/n$
a/Å	14.3930(4)
b/Å	7.2772(2)
c/Å	16.8277(5)
α/°	90
β/°	107.223(3)
γ/°	90
Volume/Å^3	1683.50(9)
Z	4
ρ_{calc}g/cm^3	1.387
μ/mm^{-1}	1.857
F(000)	736.0
Crystal size/mm^3	0.14 × 0.11 × 0.1
Radiation	CuKα (λ = 1.54184)
2Θ range for data collection/°	7.116 to 134.15
Index ranges	-15 ≤ h ≤ 17, -5 ≤ k ≤ 8, -20 ≤ l ≤ 15
Reflections collected	6233
Independent reflections	3002 [R_{int} = 0.0272, R_{sigma} = 0.0357]
Data/restraints/parameters	3002/0/228
Goodness-of-fit on F^2	1.036
Final R indexes [I>=2σ (I)]	R_1 = 0.0425, wR_2 = 0.1186
Final R indexes [all data]	R_1 = 0.0506, wR_2 = 0.1278
Largest diff. peak/hole / e Å^{-3}	0.30/-0.27

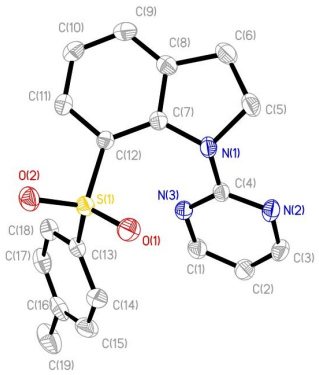


Figure S1. the structure of **4a** (thermal ellipsoids at the 30% probability level)

Table S8 Crystal data and structure refinement for **4i**

Structure	**4i**
Identification code	1962624
Empirical formula	$C_{19}H_{14}N_4O_2S$
Formula weight	362.40
Temperature/K	293(2)
Crystal system	triclinic
Space group	P-1
a/Å	7.3315(4)
b/Å	10.8147(8)
c/Å	11.6977(9)
α/°	111.608(7)
β/°	93.223(6)
γ/°	100.174(6)
Volume/Å^3	841.26(11)
Z	2
ρ_{calc}g/cm^3	1.431
μ/mm^{-1}	1.899
F(000)	376.0
Crystal size/mm^3	0.13 × 0.12 × 0.1
Radiation	CuKα (λ = 1.54184)
2Θ range for data collection/°	8.202 to 134.164
Index ranges	-7 ≤ h ≤ 8, -12 ≤ k ≤ 12, -13 ≤ l ≤ 11
Reflections collected	5800
Independent reflections	2983 [R_{int} = 0.0210, R_{sigma} = 0.0300]
Data/restraints/parameters	2983/0/236
Goodness-of-fit on F^2	1.051
Final R indexes [I>=2σ (I)]	R_1 = 0.0413, wR_2 = 0.1167
Final R indexes [all data]	R_1 = 0.0477, wR_2 = 0.1252
Largest diff. peak/hole / e Å^{-3}	0.31/-0.28

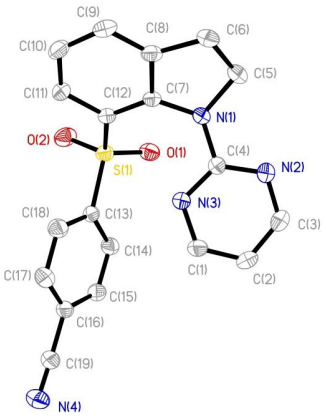
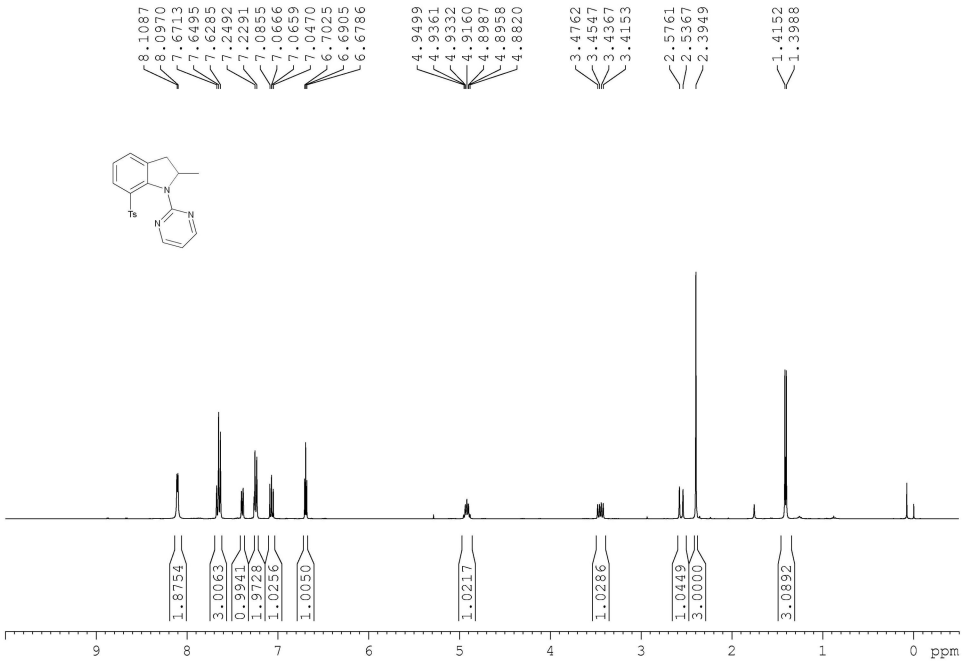


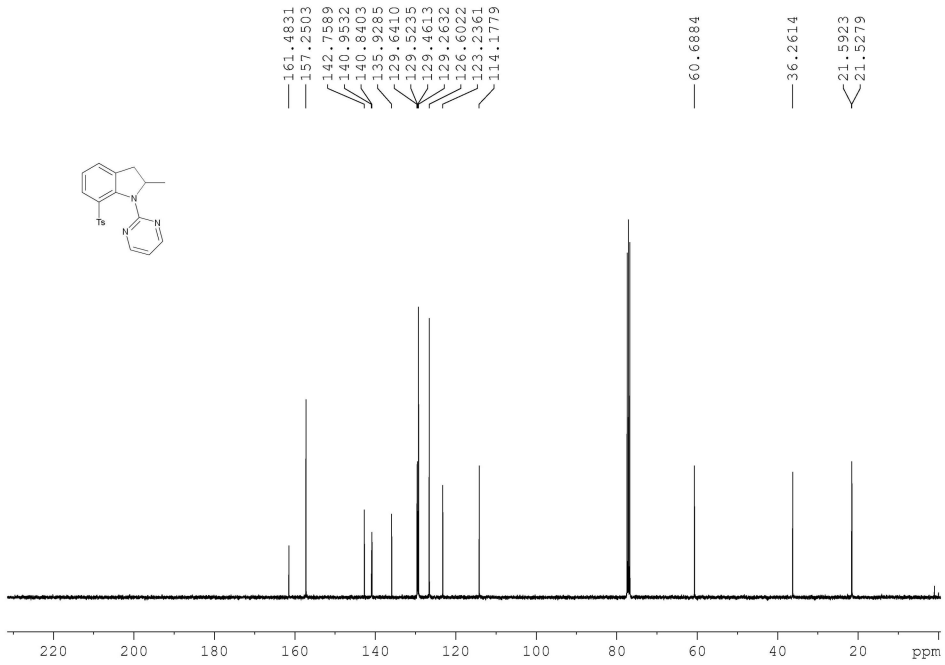
Figure S2. the structure of **4i** (thermal ellipsoids at the 30% probability level)

NMR Spectra of compounds

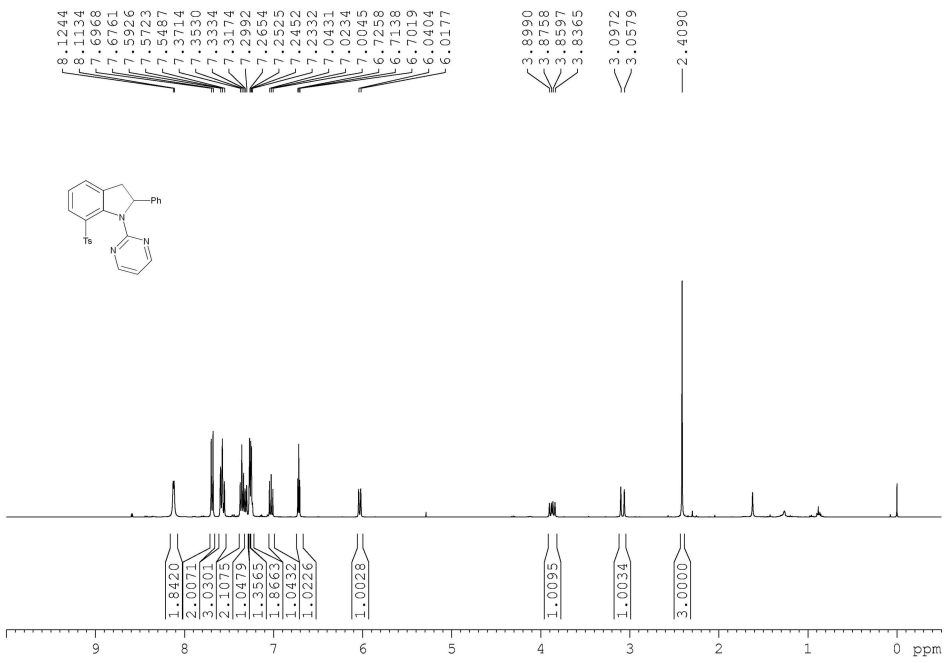
^{1}H NMR spectrum of compound **3a**



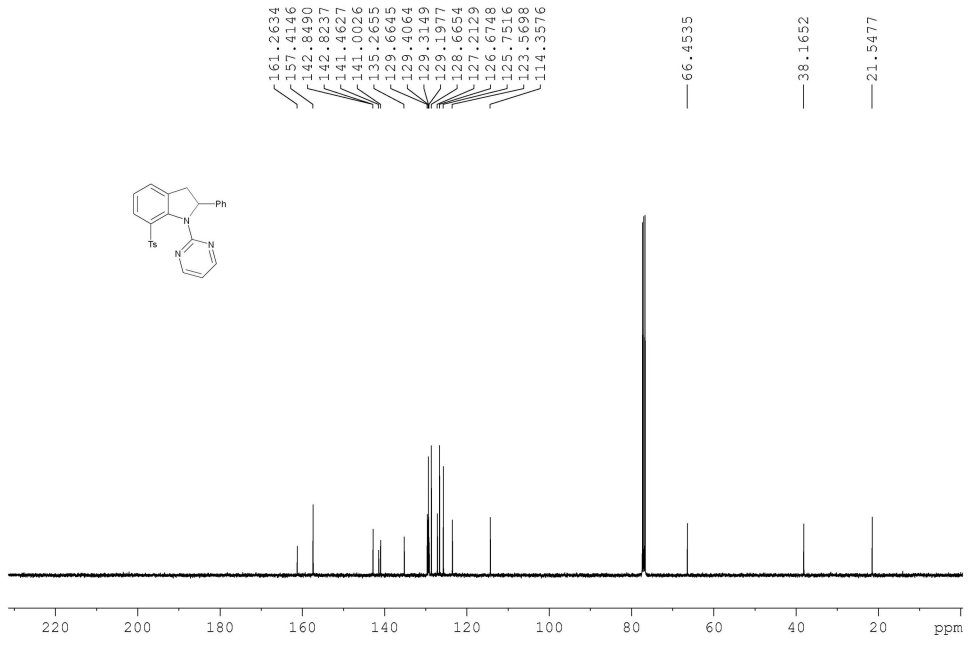
^{13}C NMR spectrum of compound **3a**



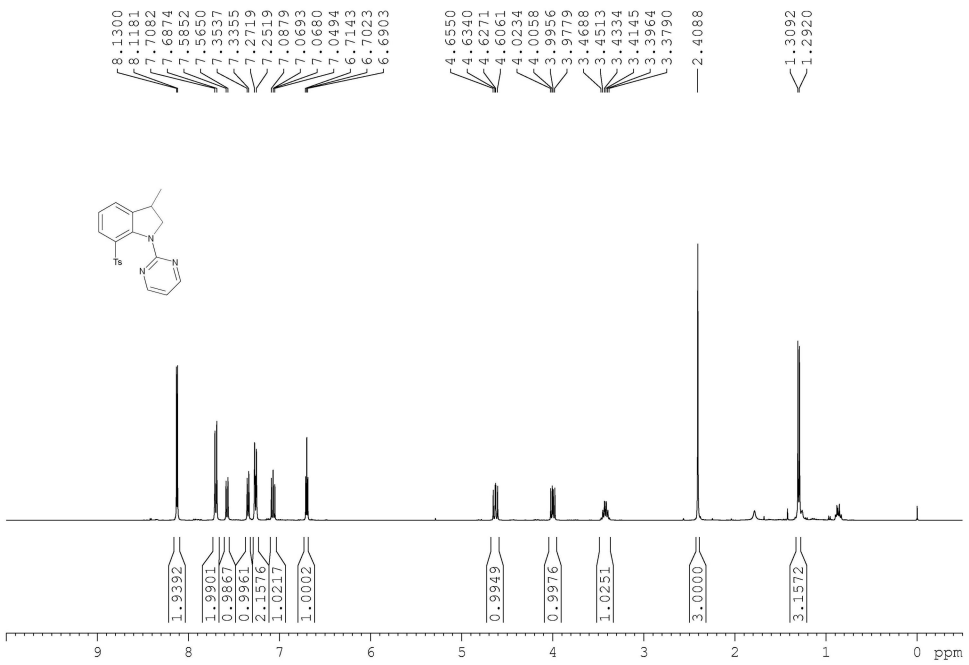
^{1}H NMR spectrum of compound **3b**



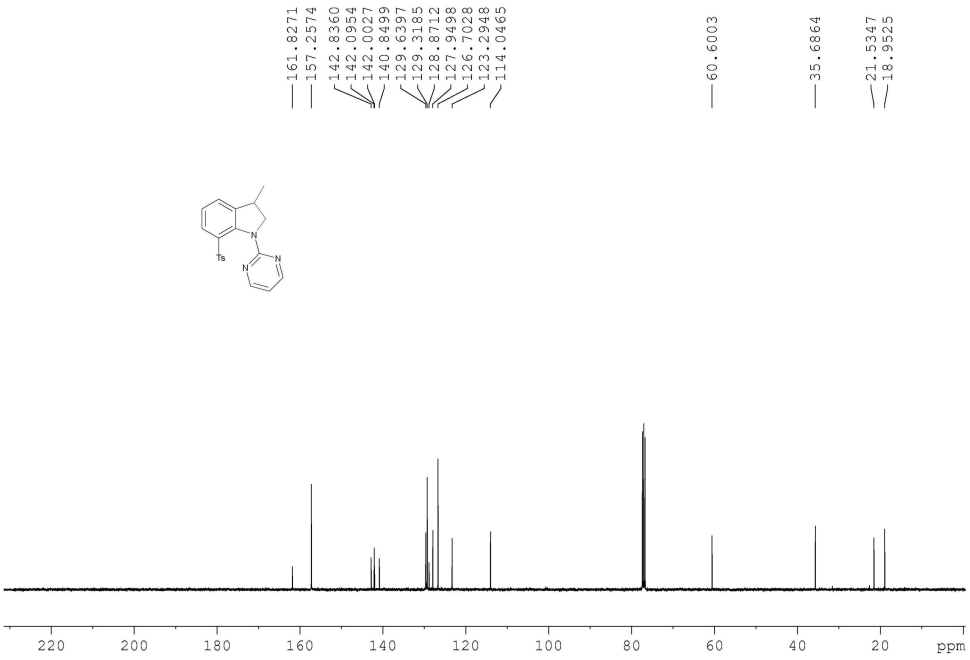
^{13}C NMR spectrum of compound **3b**



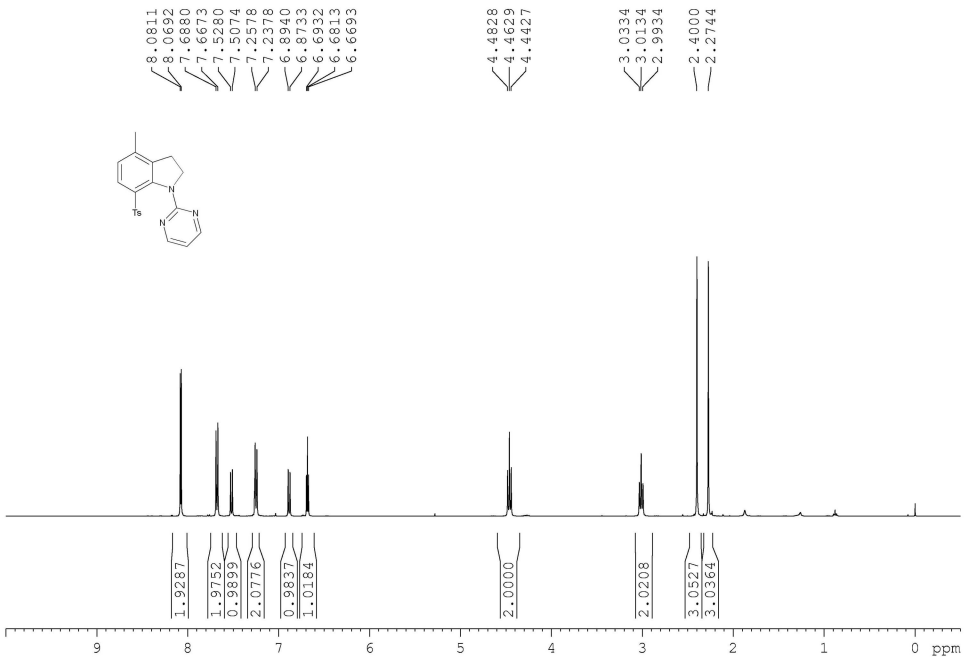
^{1}H NMR spectrum of compound **3c**



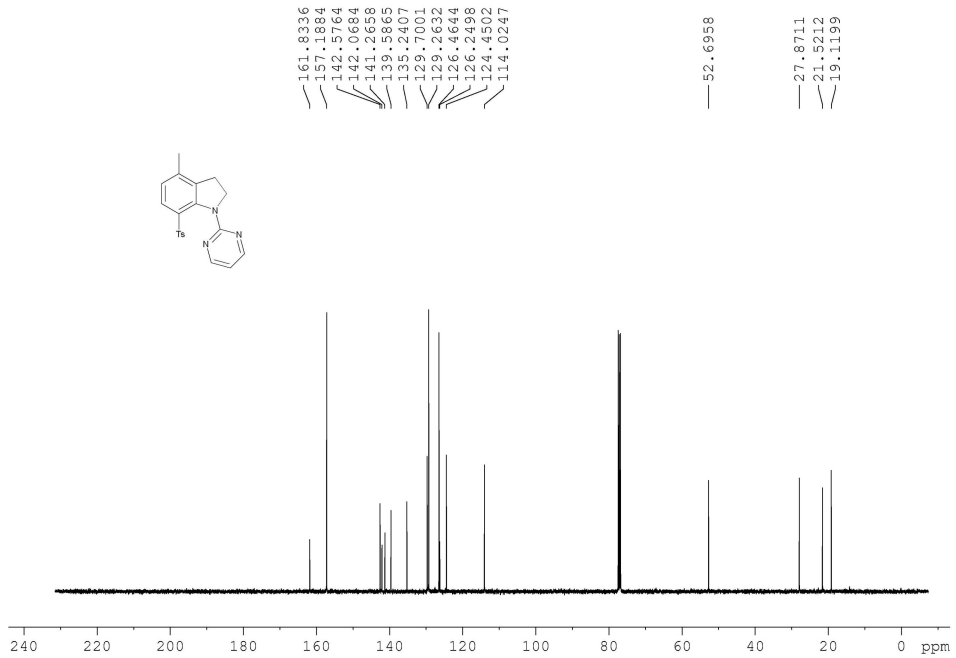
^{13}C NMR spectrum of compound **3c**



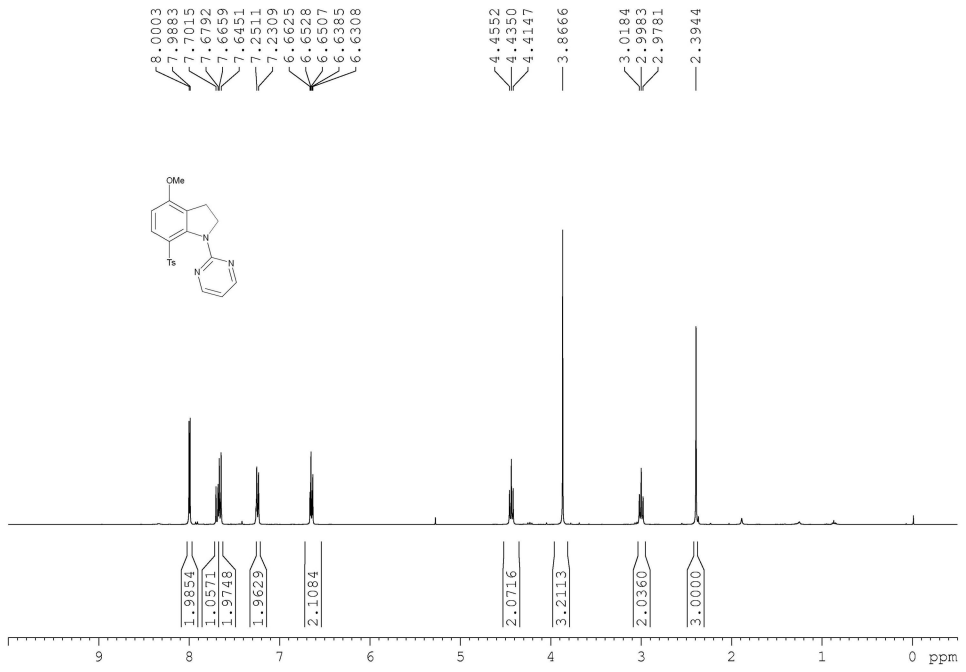
^{1}H NMR spectrum of compound **3d**



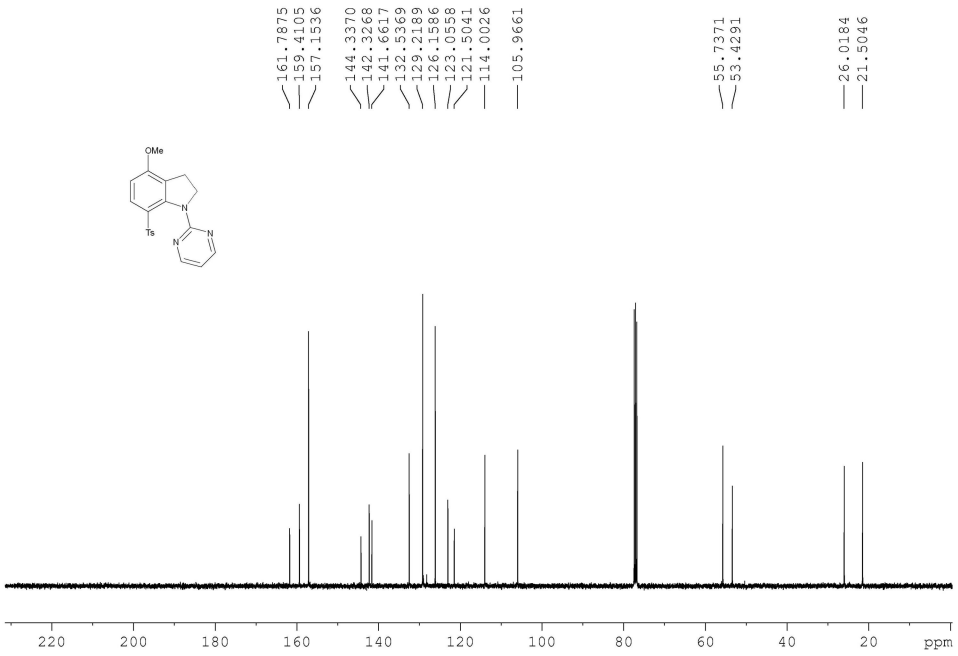
^{13}C NMR spectrum of compound **3d**



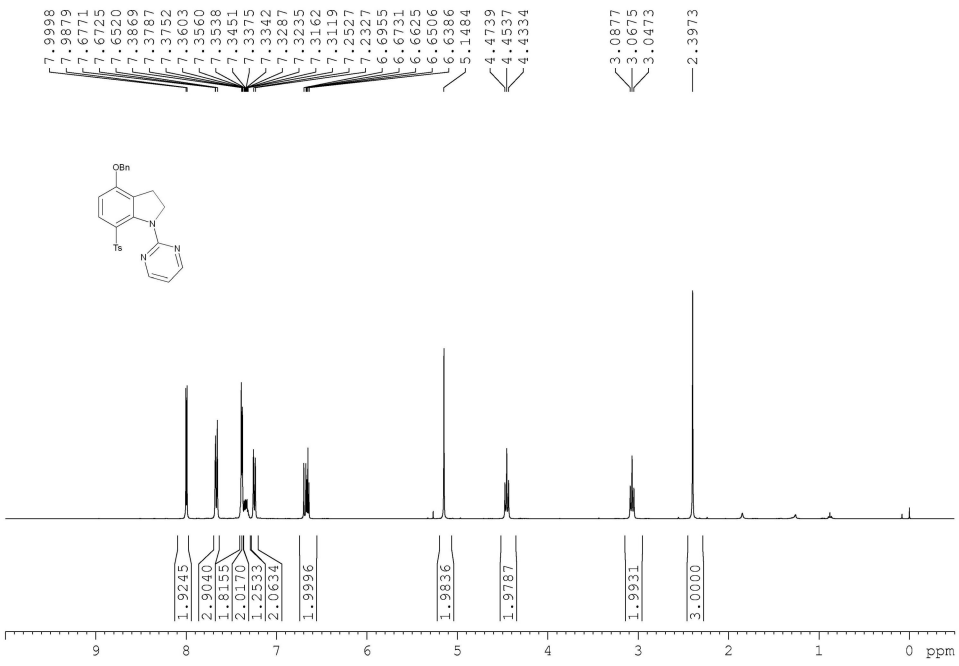
^{1}H NMR spectrum of compound **3e**



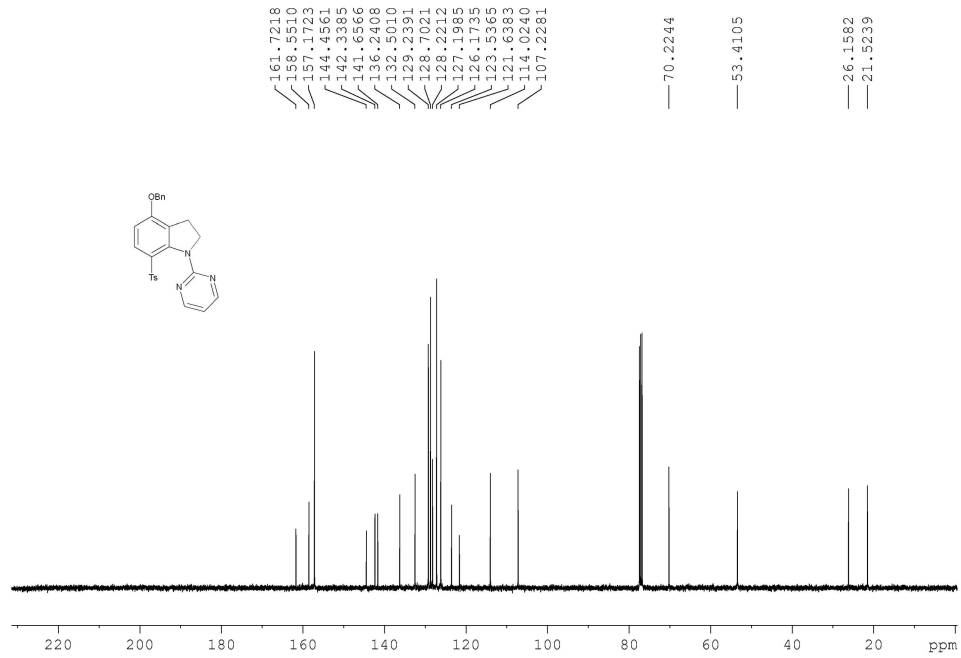
^{13}C NMR spectrum of compound **3e**



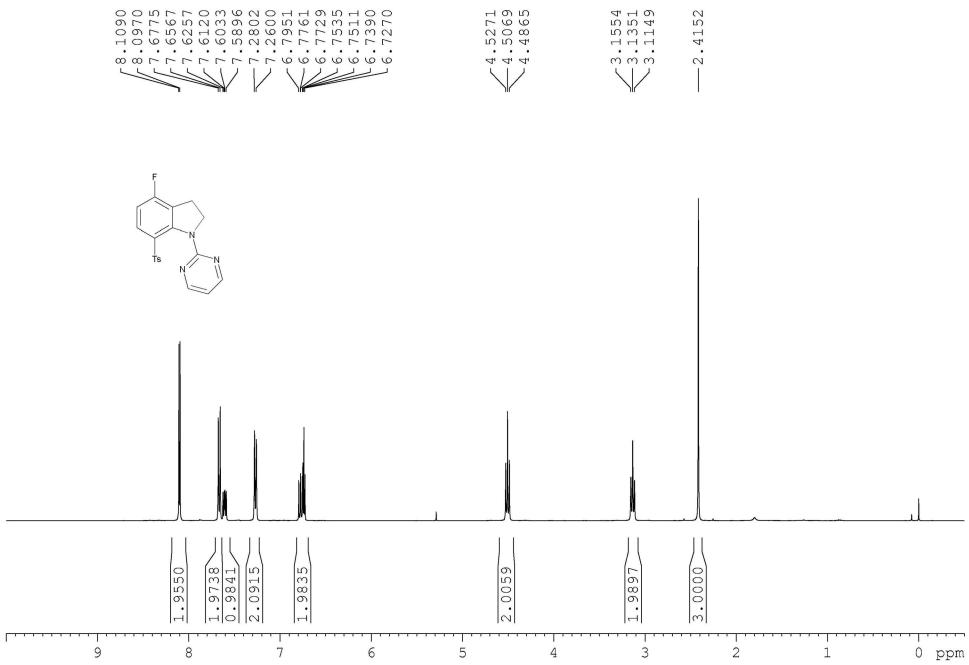
^{1}H NMR spectrum of compound **3f**



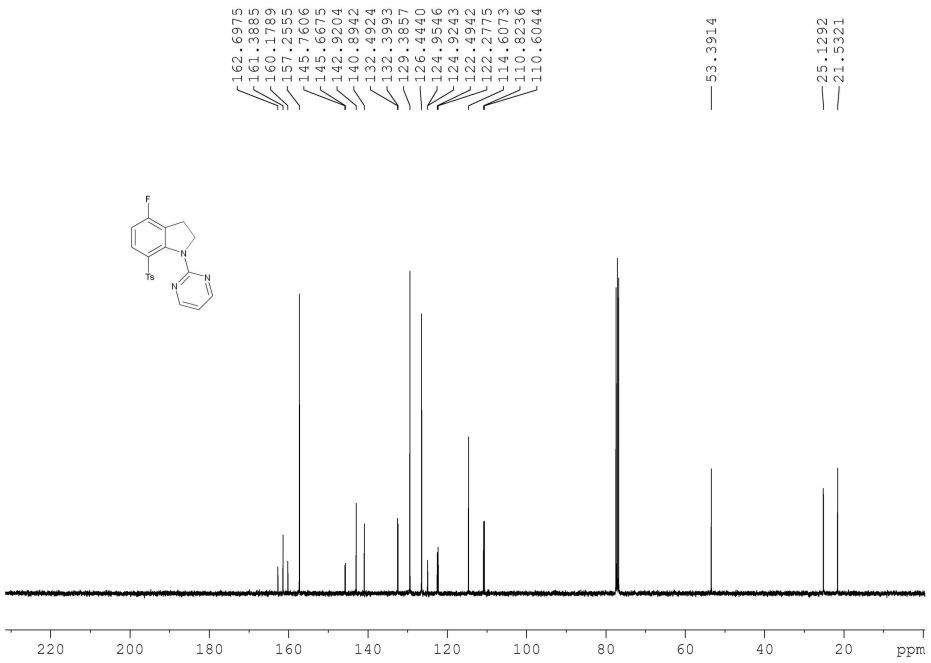
^{13}C NMR spectrum of compound **3f**



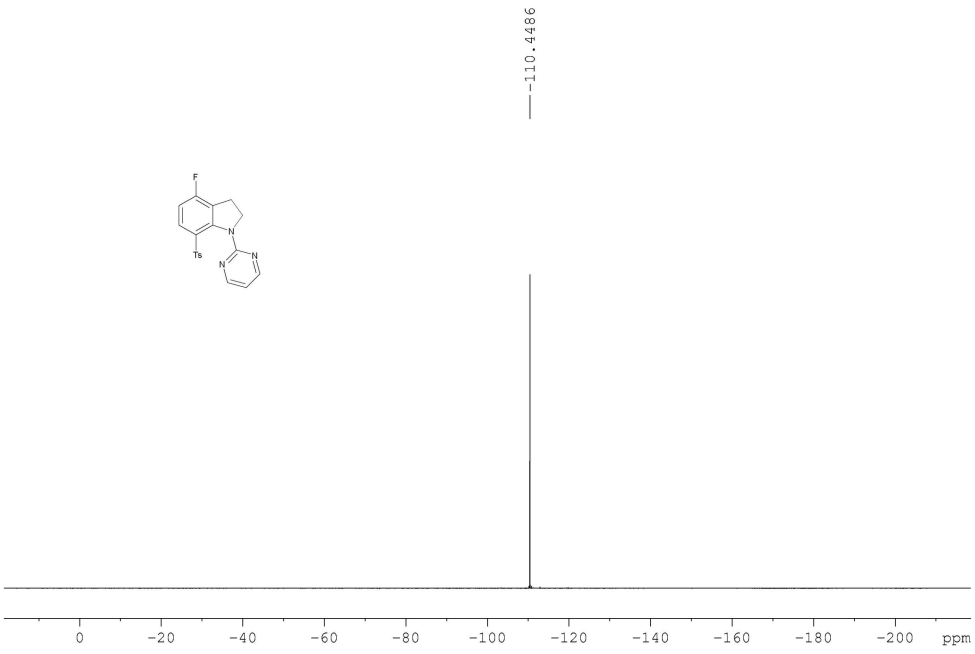
^{1}H NMR spectrum of compound **3g**



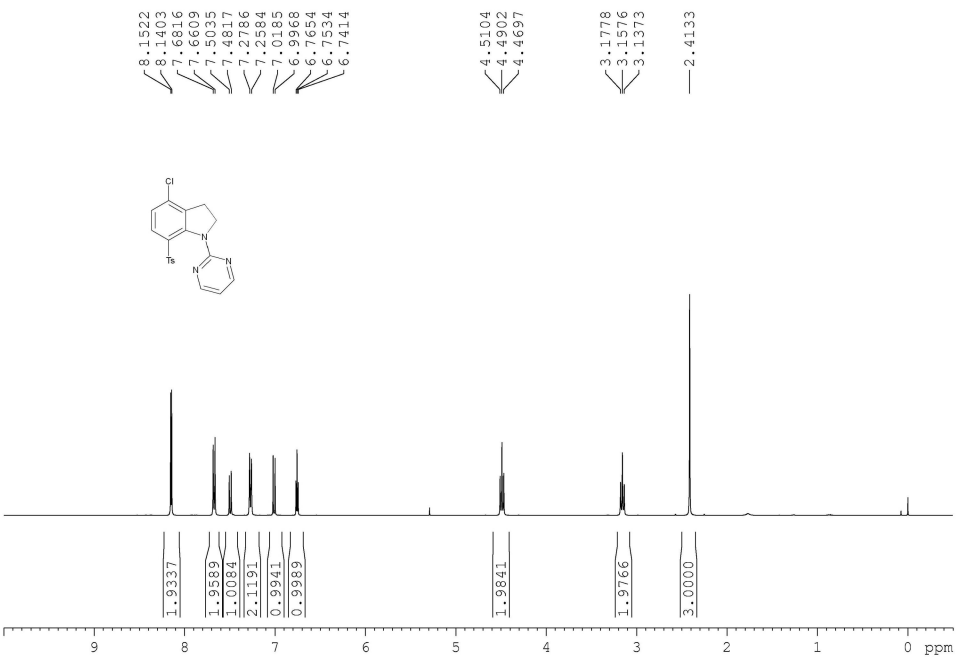
^{13}C NMR spectrum of compound **3g**



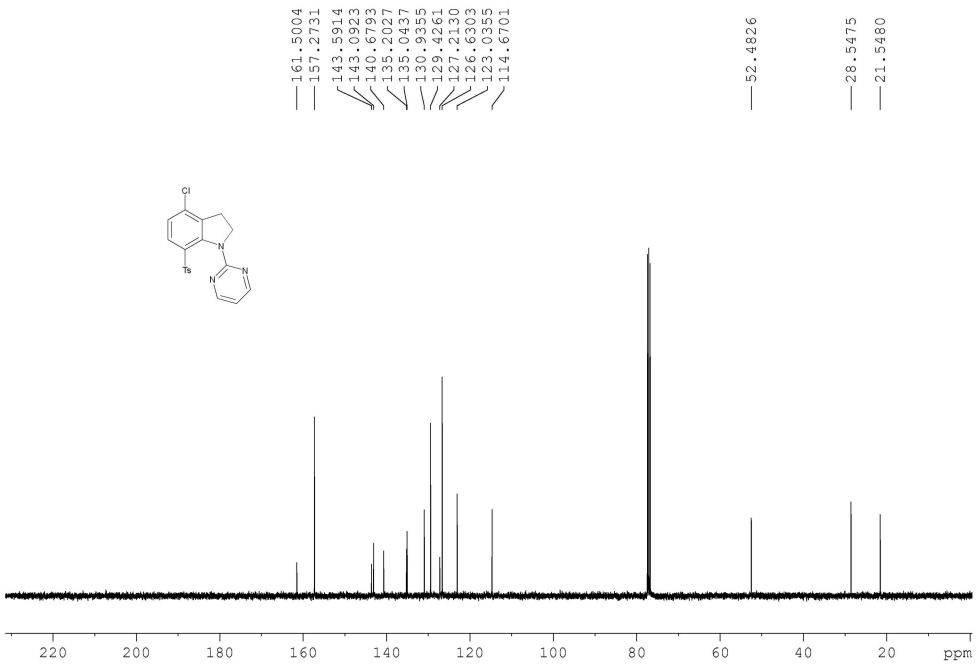
^{19}F NMR spectrum of compound **3g**



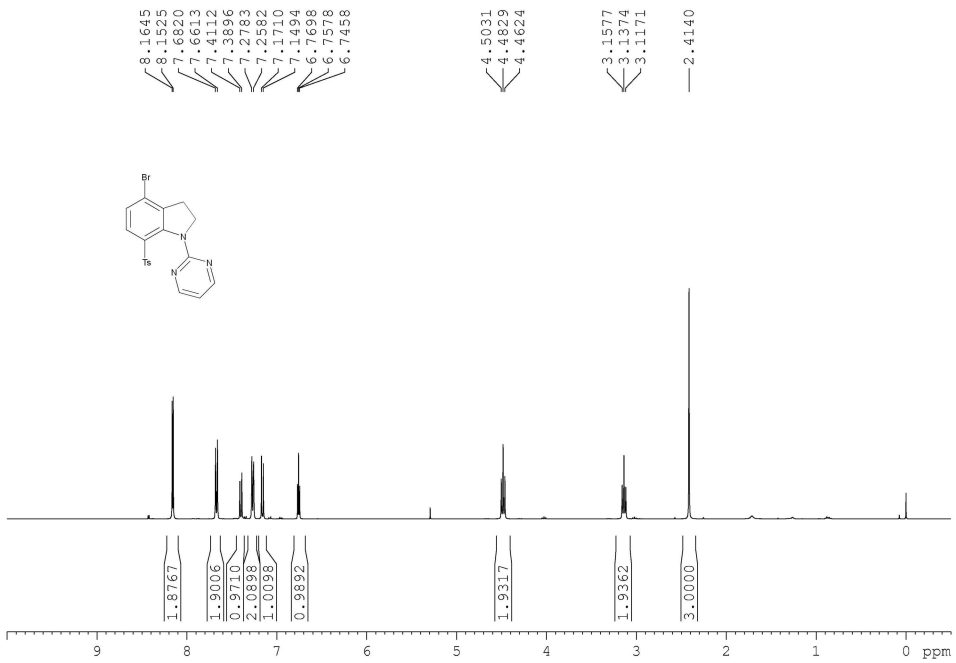
^{1}H NMR spectrum of compound **3h**



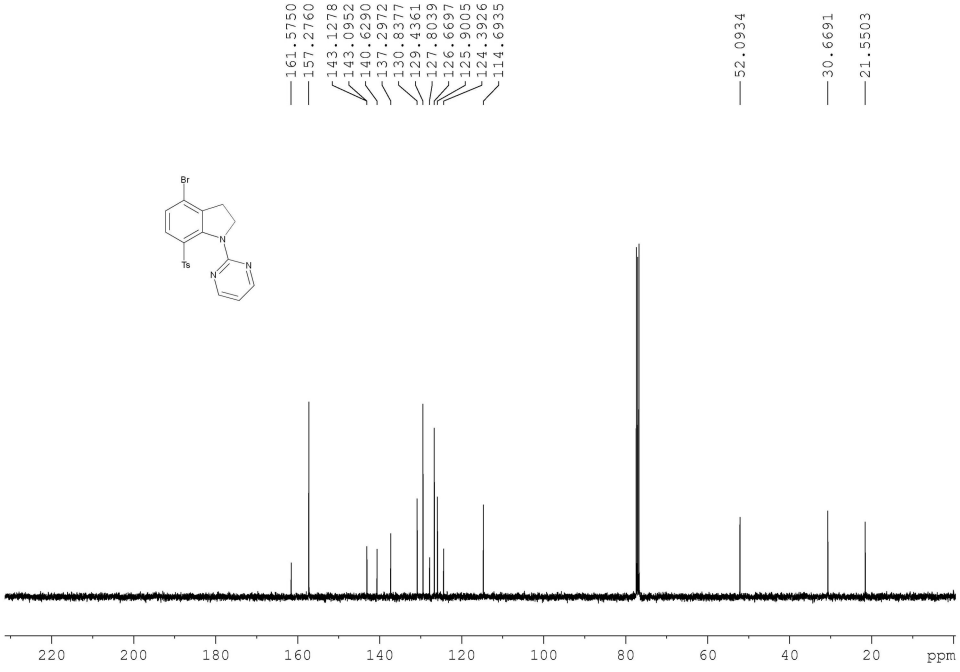
^{13}C NMR spectrum of compound **3h**



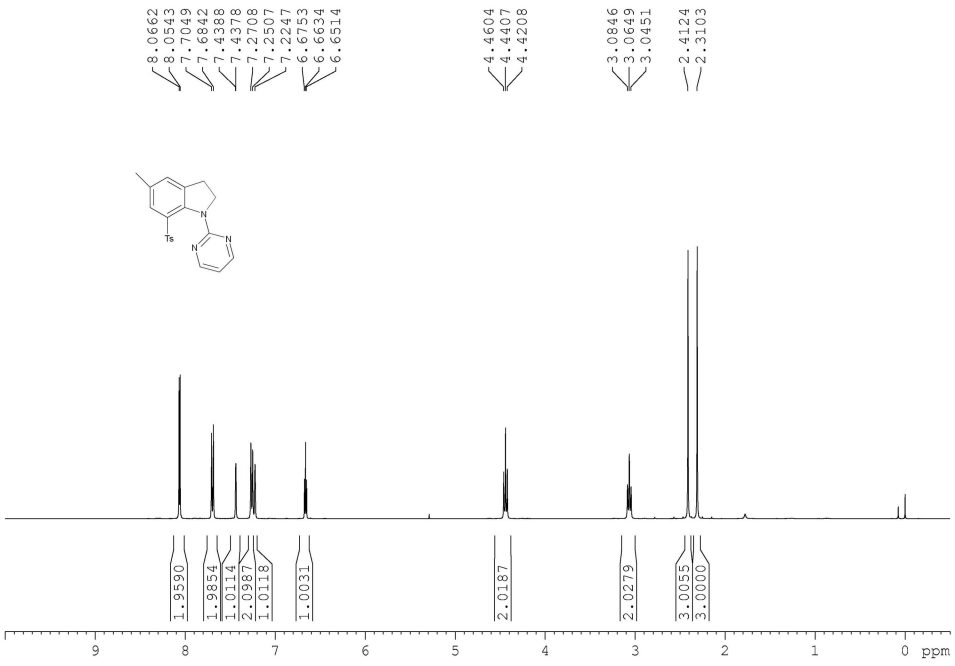
^{1}H NMR spectrum of compound **3i**



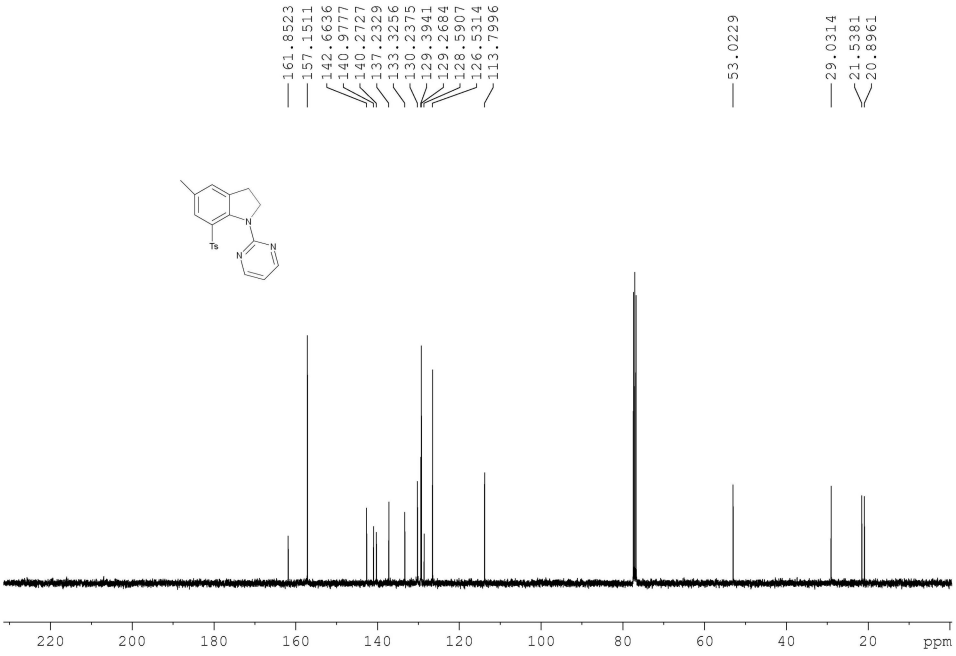
^{13}C NMR spectrum of compound **3i**



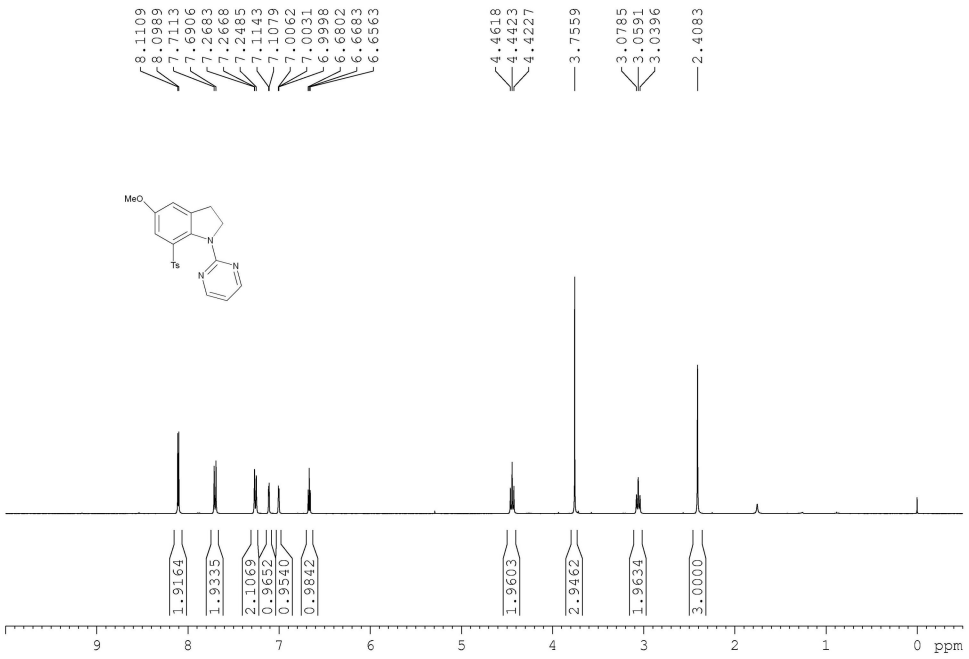
^{1}H NMR spectrum of compound **3j**



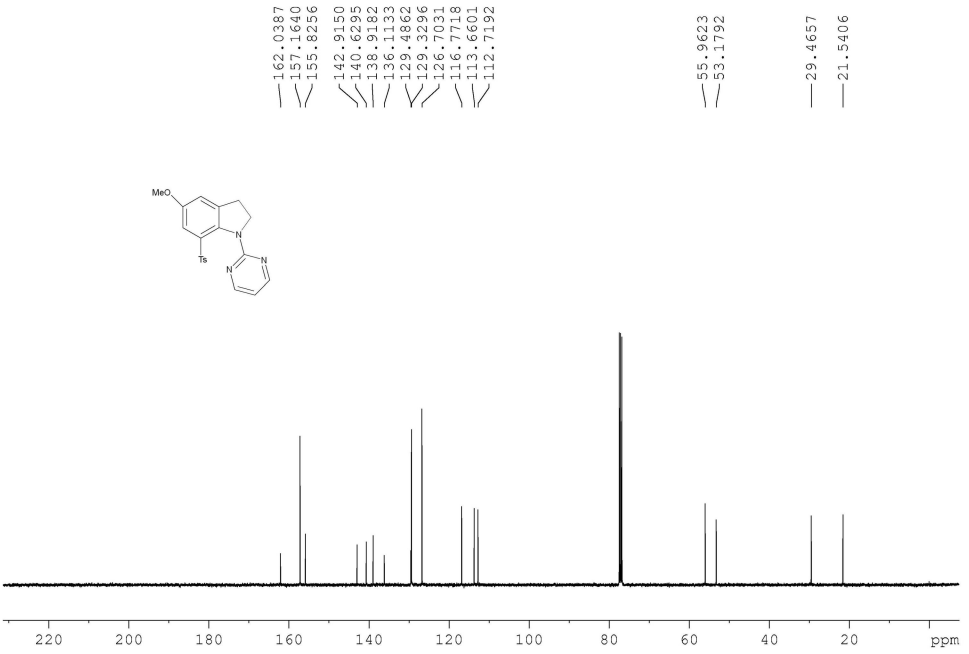
^{13}C NMR spectrum of compound **3j**



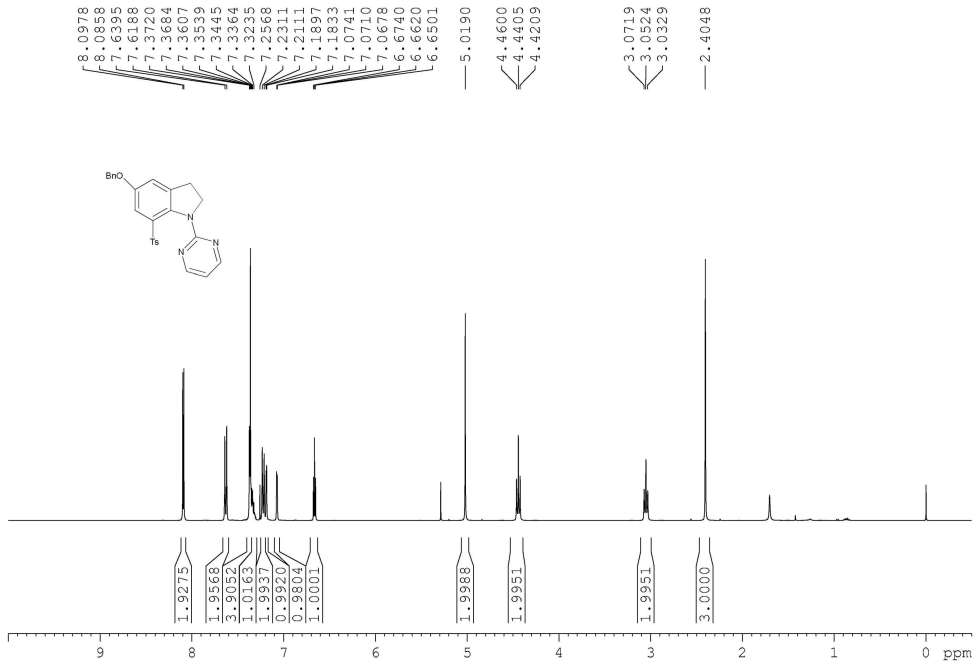
^{1}H NMR spectrum of compound **3k**



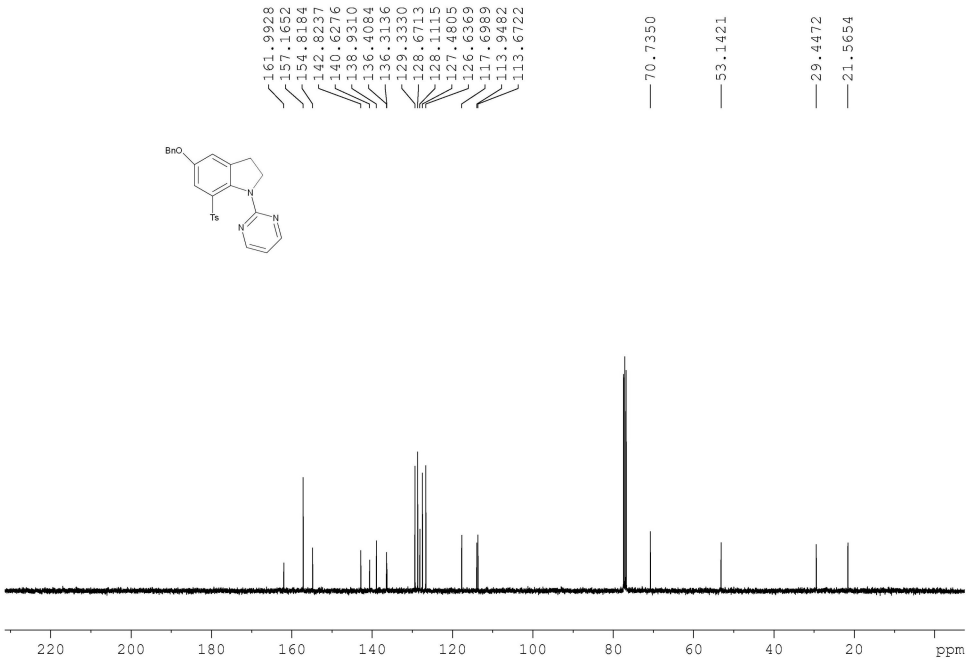
^{13}C NMR spectrum of compound **3k**



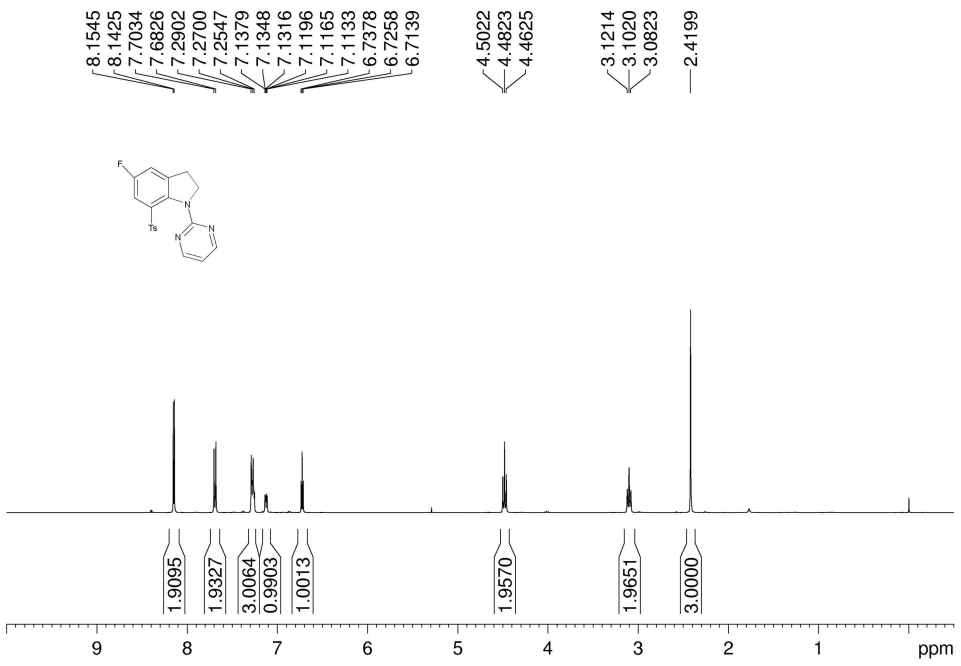
^{1}H NMR spectrum of compound **3l**



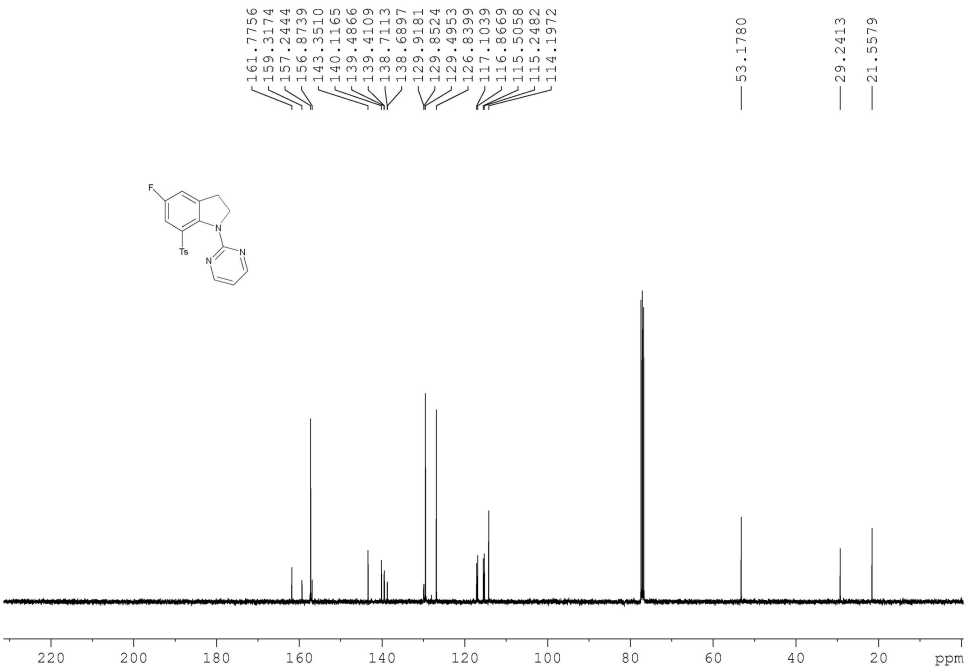
^{13}C NMR spectrum of compound **3l**



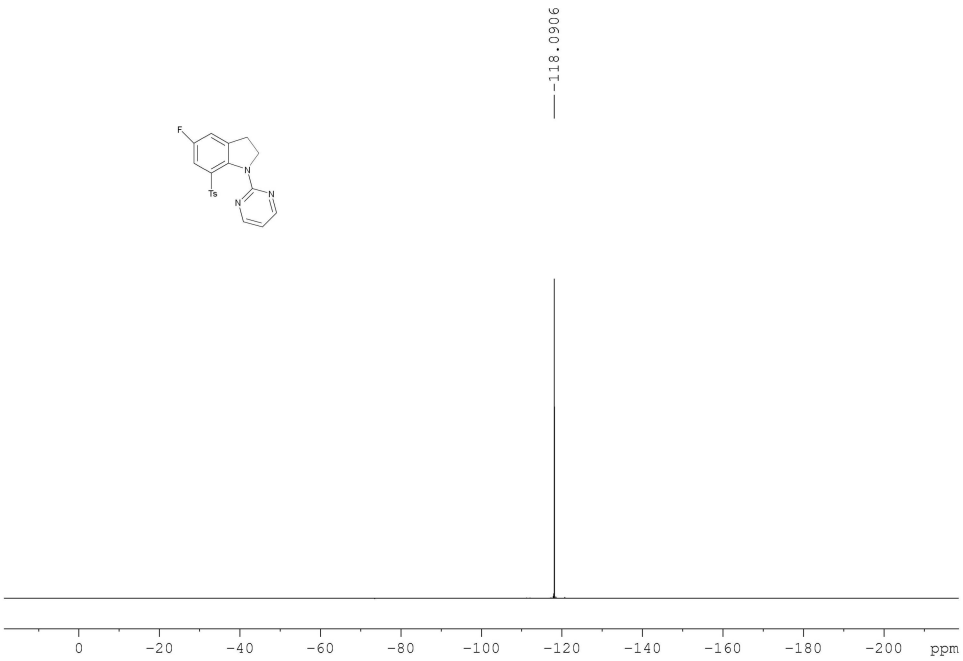
^{1}H NMR spectrum of compound **3m**



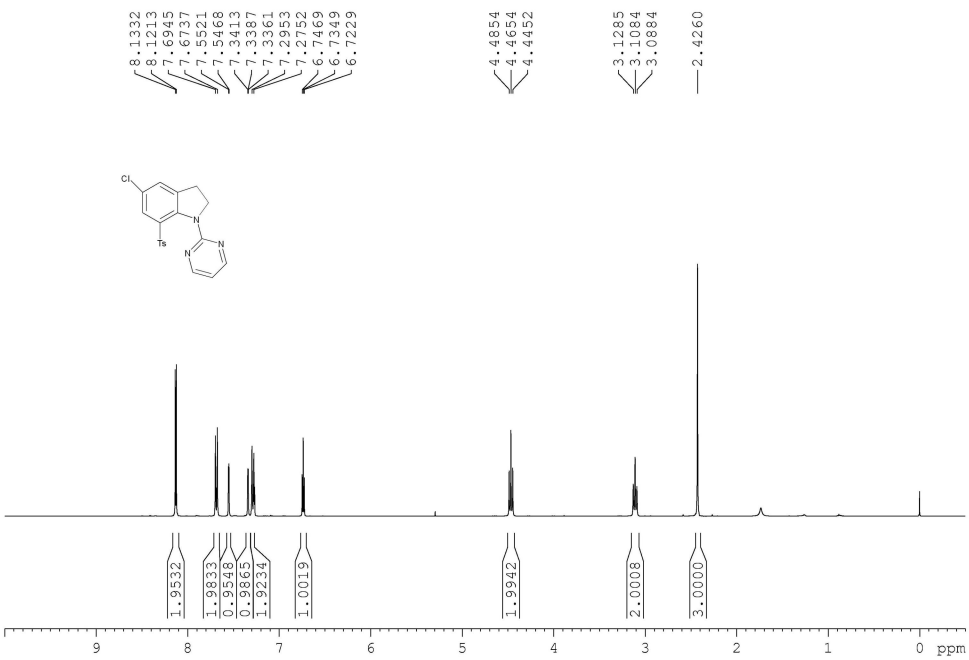
^{13}C NMR spectrum of compound **3m**



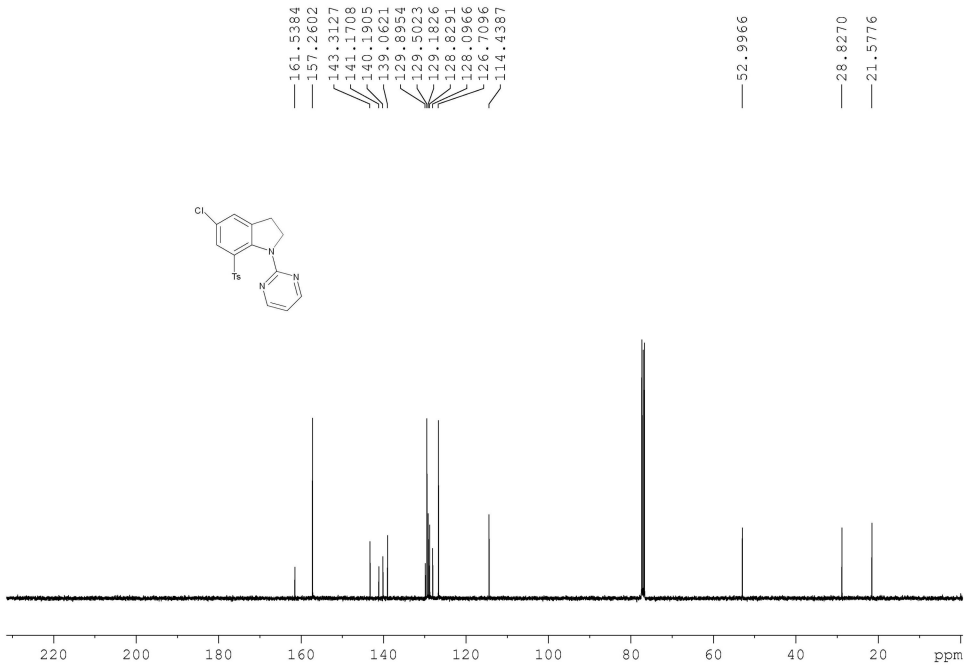
^{19}F NMR spectrum of compound **3m**



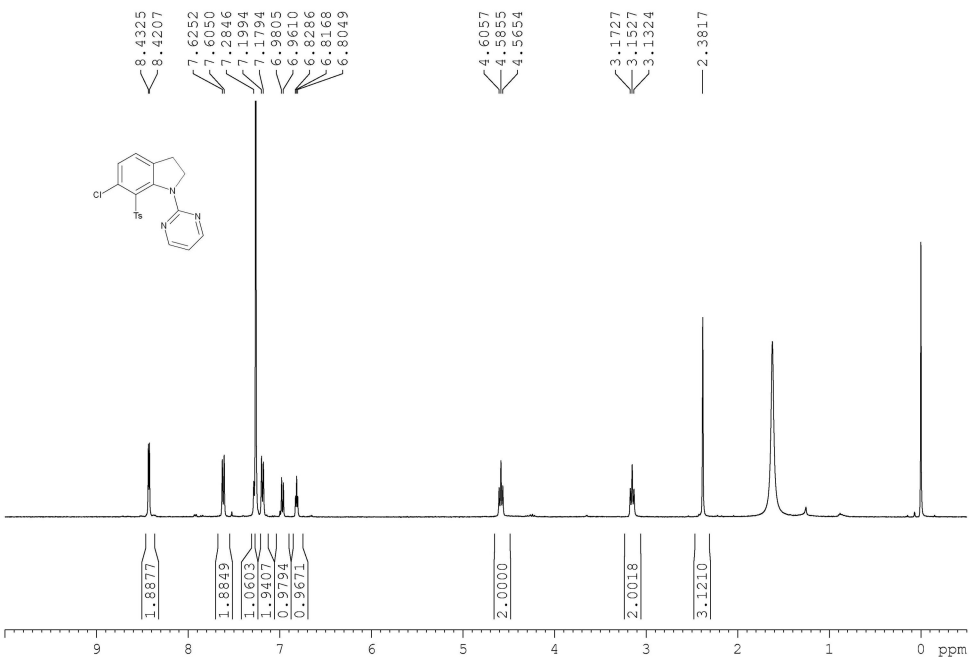
^{1}H NMR spectrum of compound **3n**



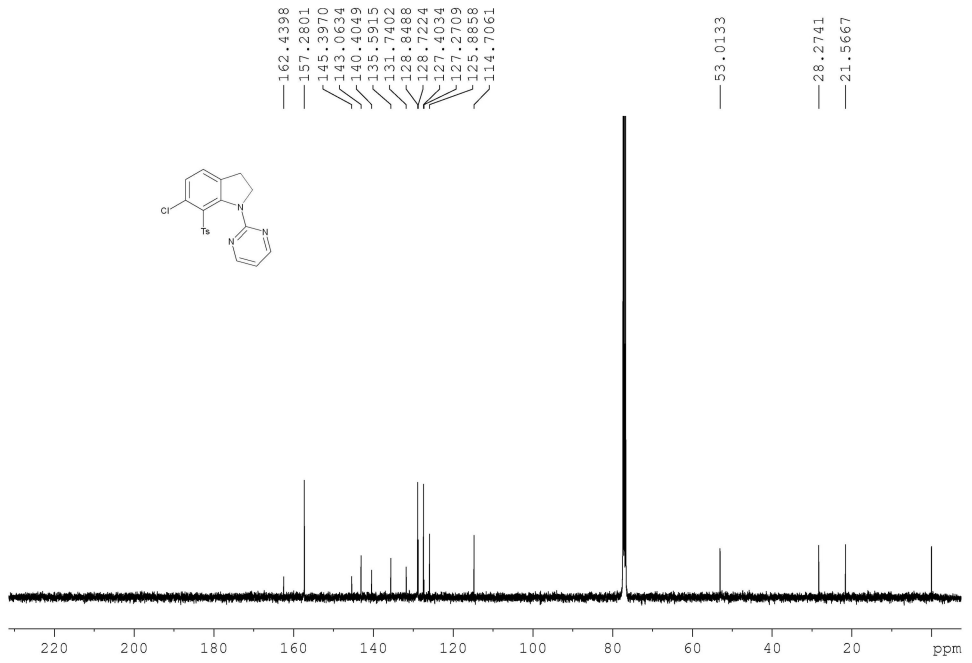
^{13}C NMR spectrum of compound **3n**



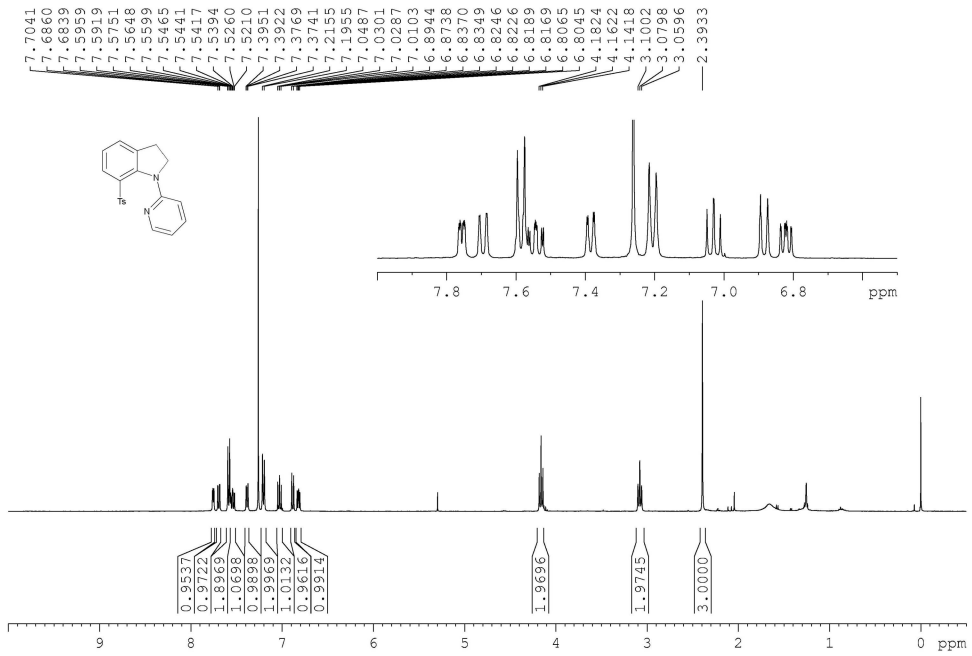
^{1}H NMR spectrum of compound **3o**



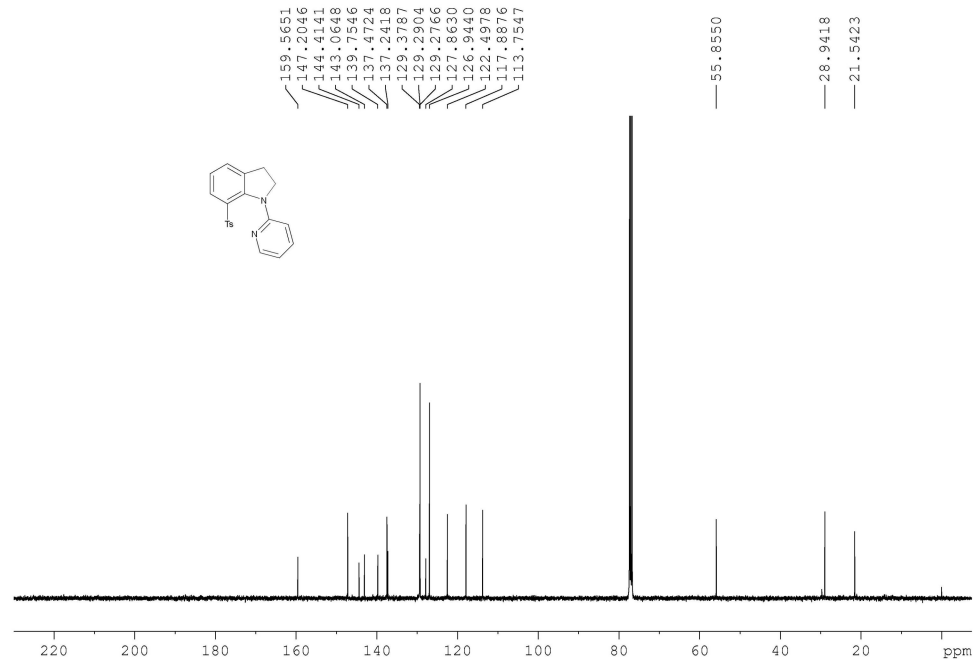
^{13}C NMR spectrum of compound **3o**



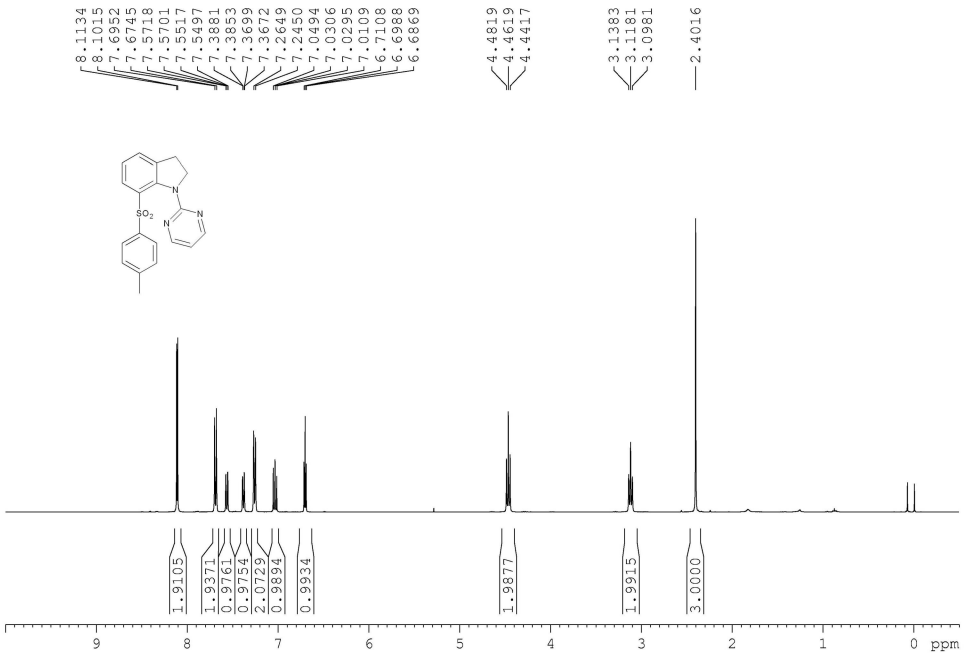
^{1}H NMR spectrum of compound **3p**



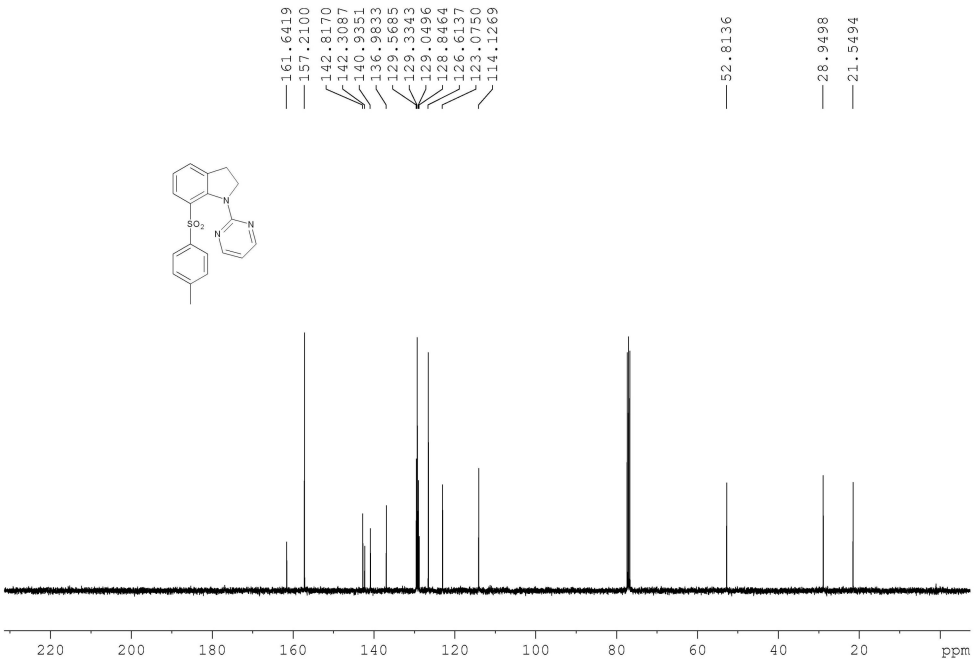
^{13}C NMR spectrum of compound **3p**



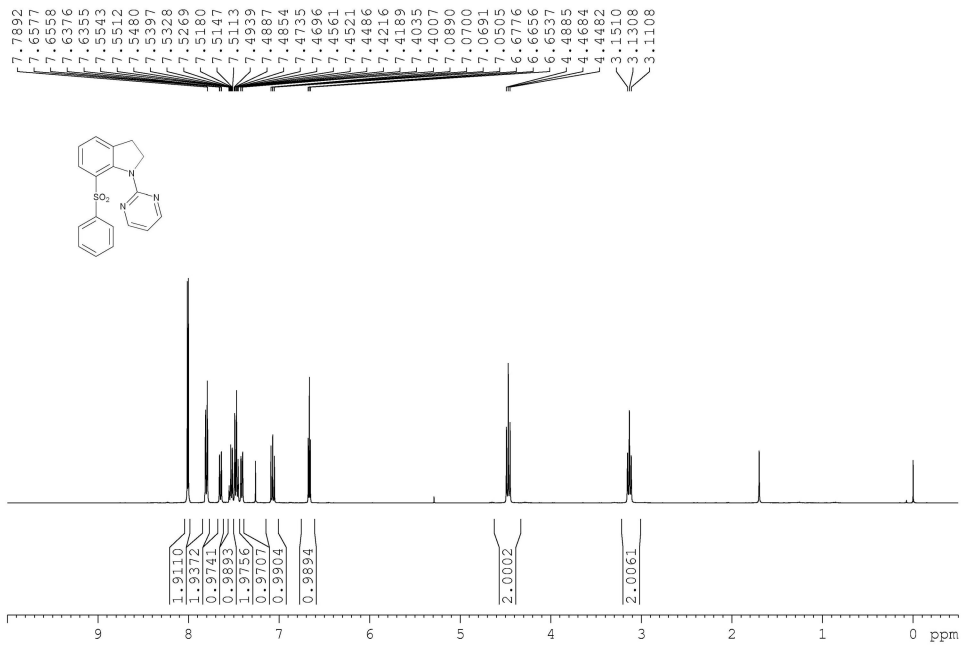
^{1}H NMR spectrum of compound **4a**



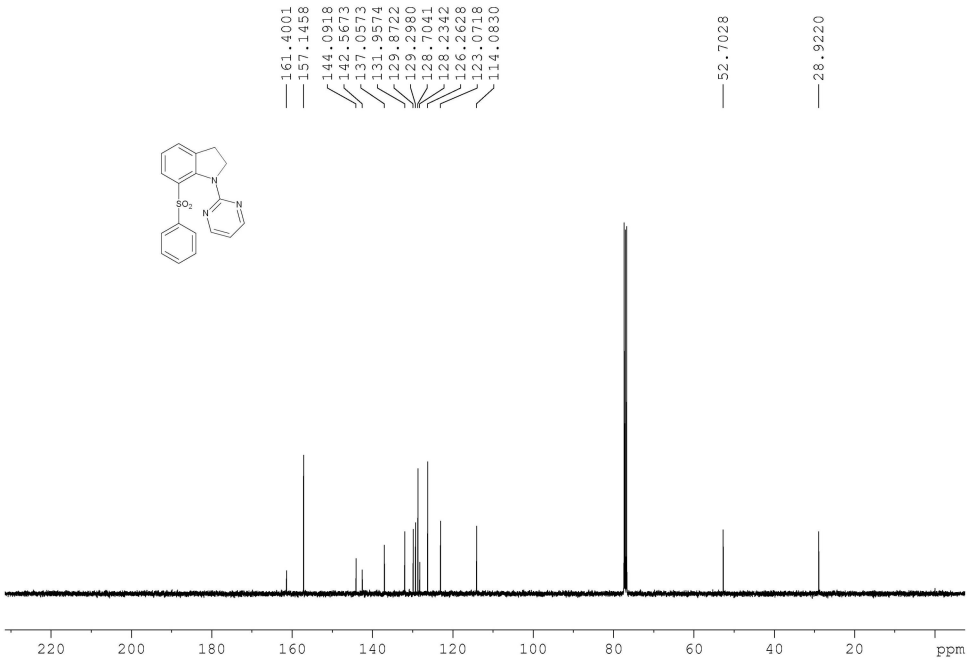
^{13}C NMR spectrum of compound **4a**



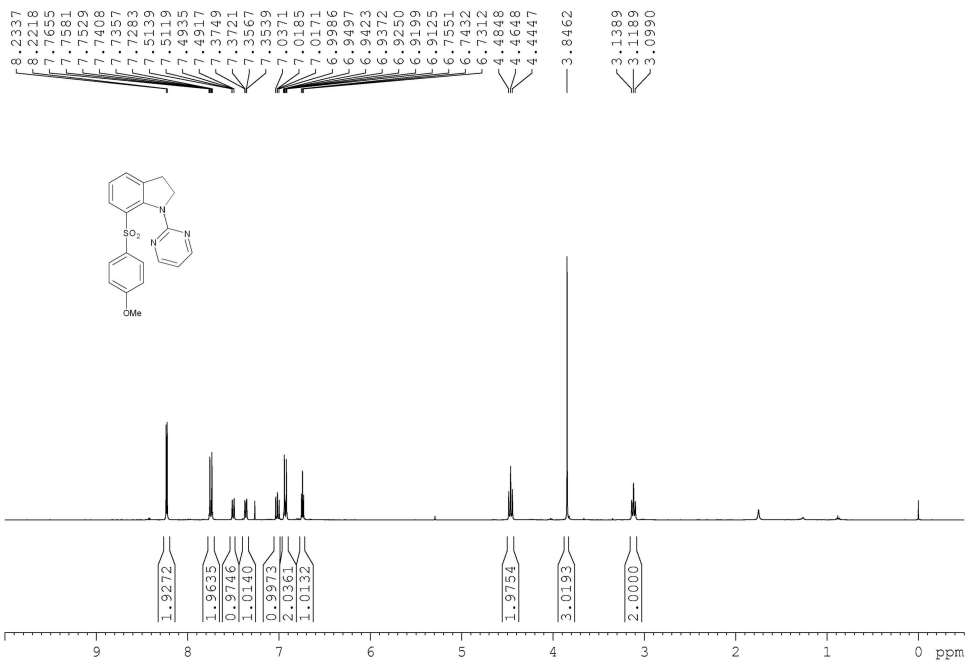
^{1}H NMR spectrum of compound **4b**



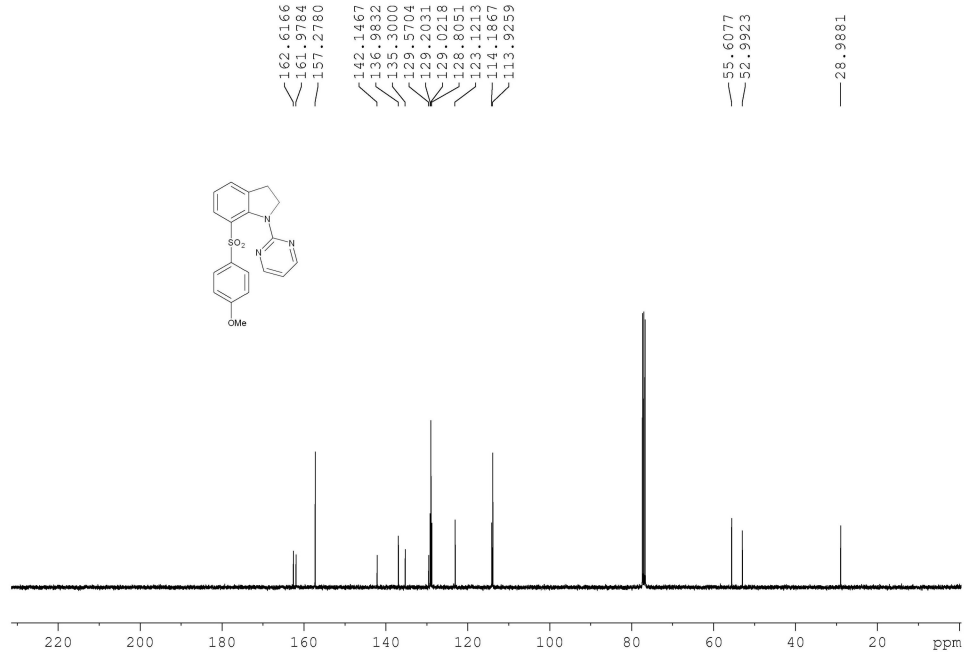
^{13}C NMR spectrum of compound **4b**



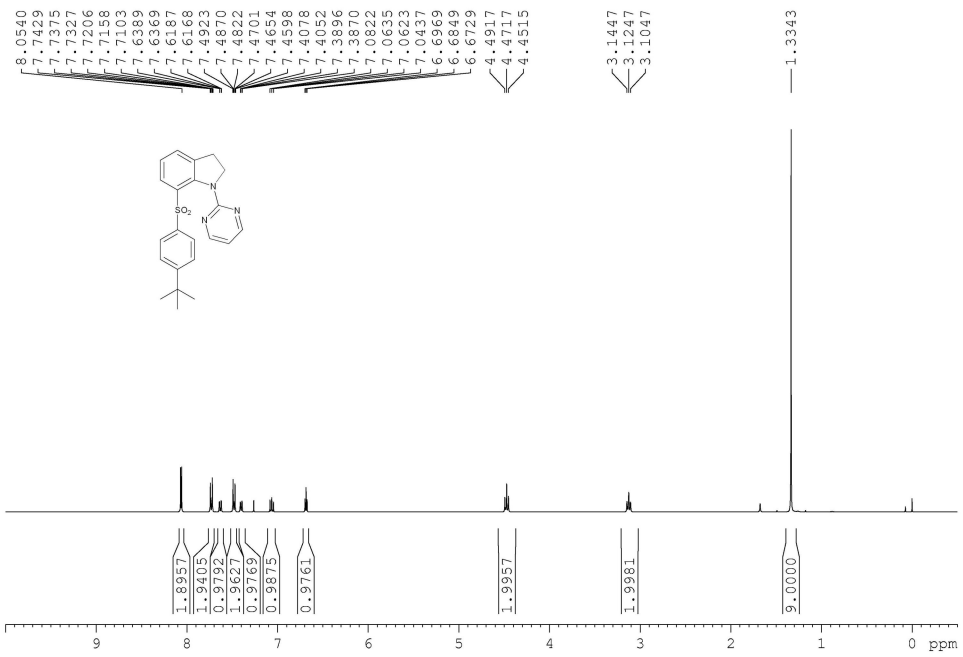
^{1}H NMR spectrum of compound **4c**



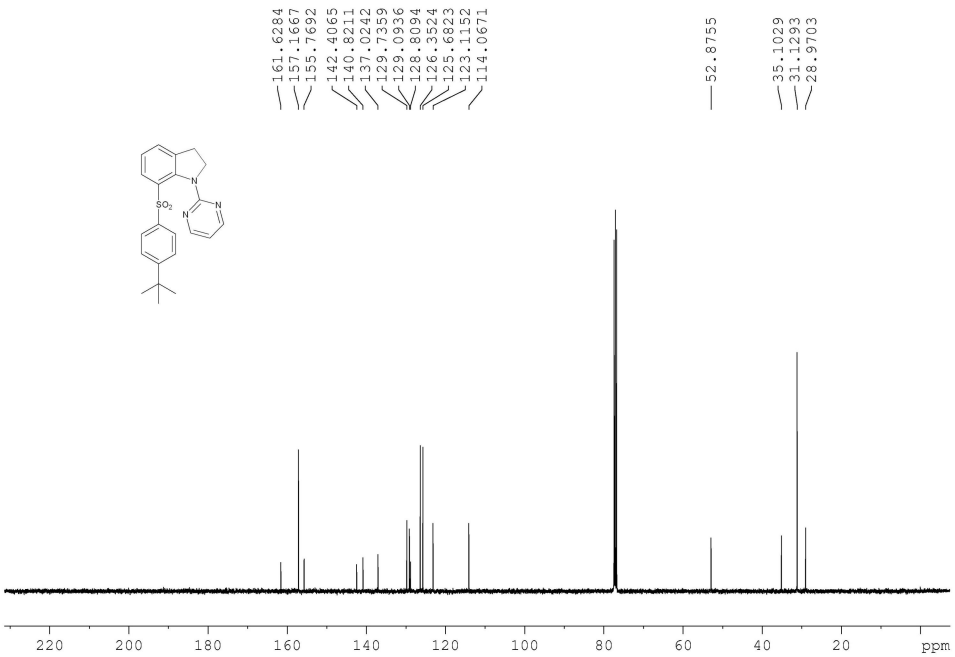
^{13}C NMR spectrum of compound **4c**



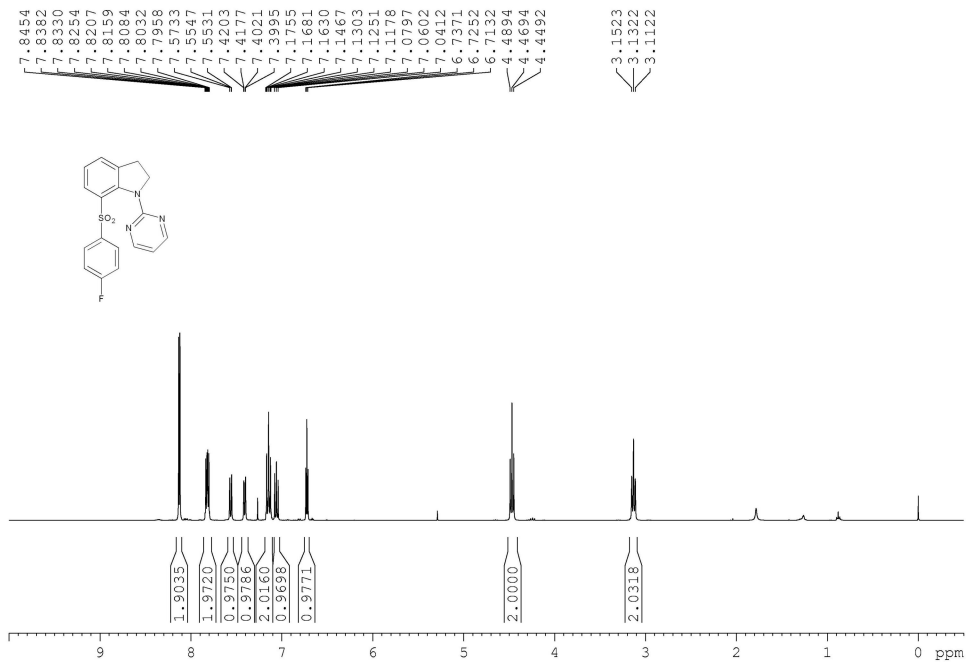
^{1}H NMR spectrum of compound **4d**



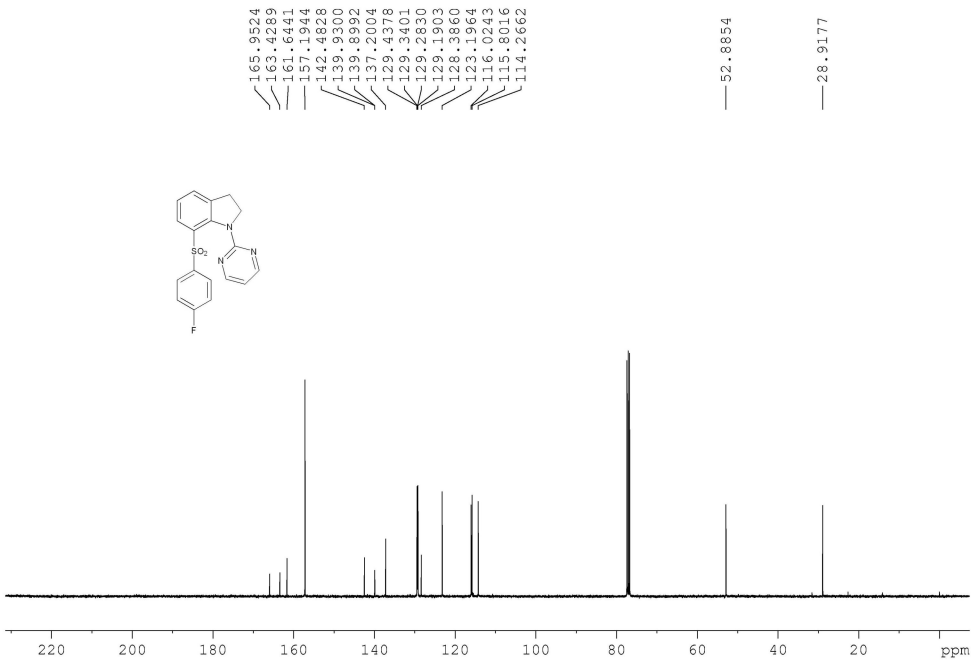
^{13}C NMR spectrum of compound **4d**



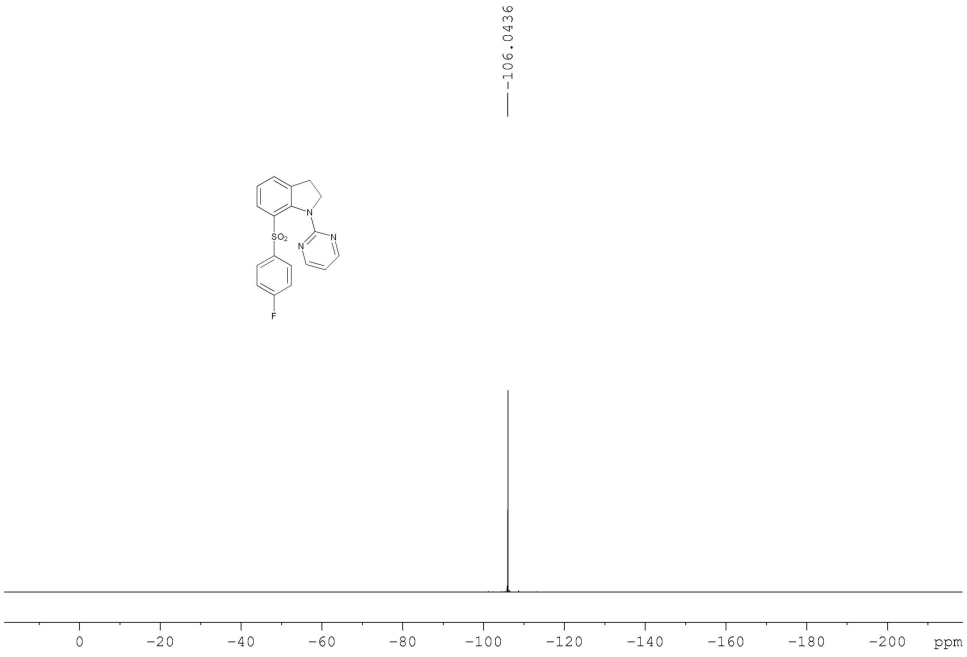
^{1}H NMR spectrum of compound **4e**



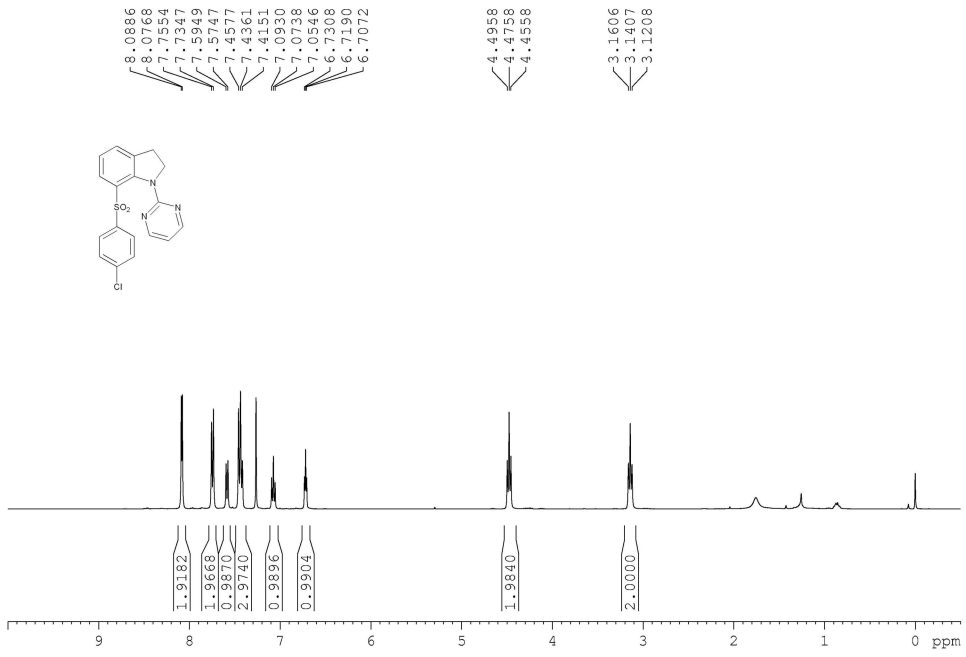
^{13}C NMR spectrum of compound **4e**



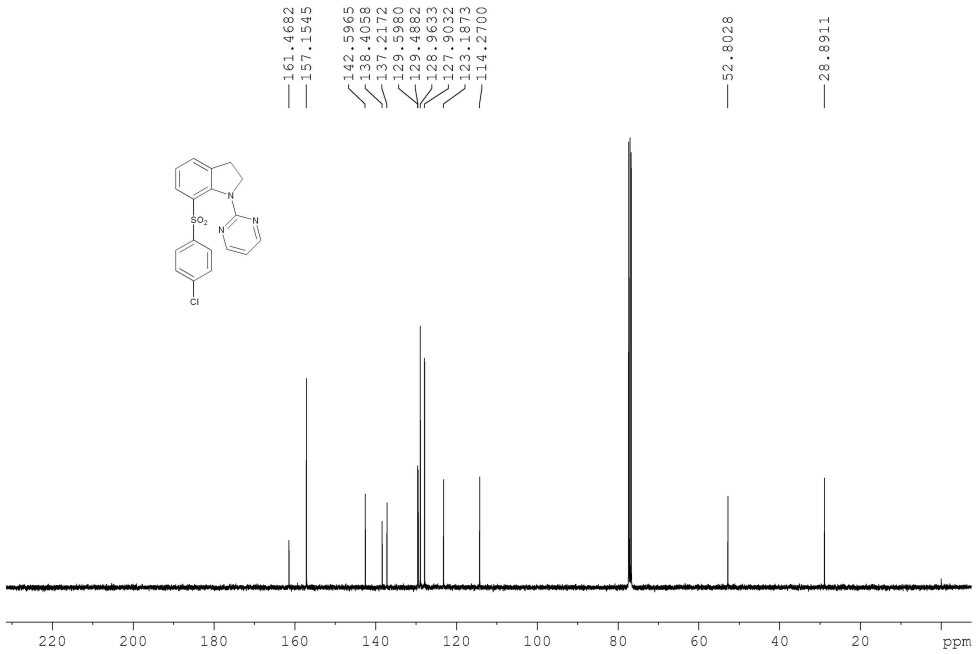
^{19}F NMR spectrum of compound **4e**



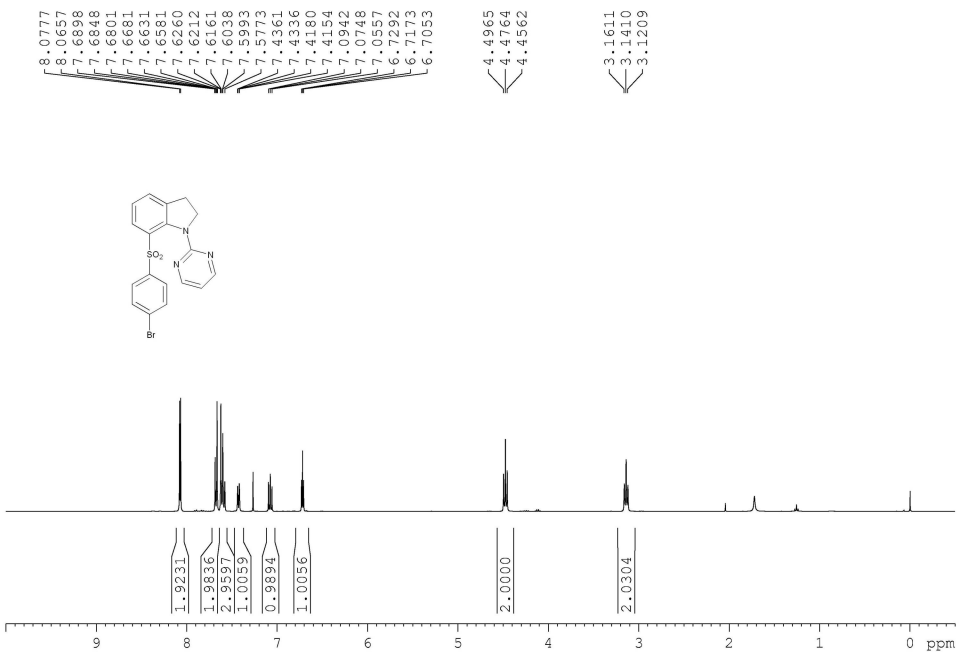
^{1}H NMR spectrum of compound **4f**



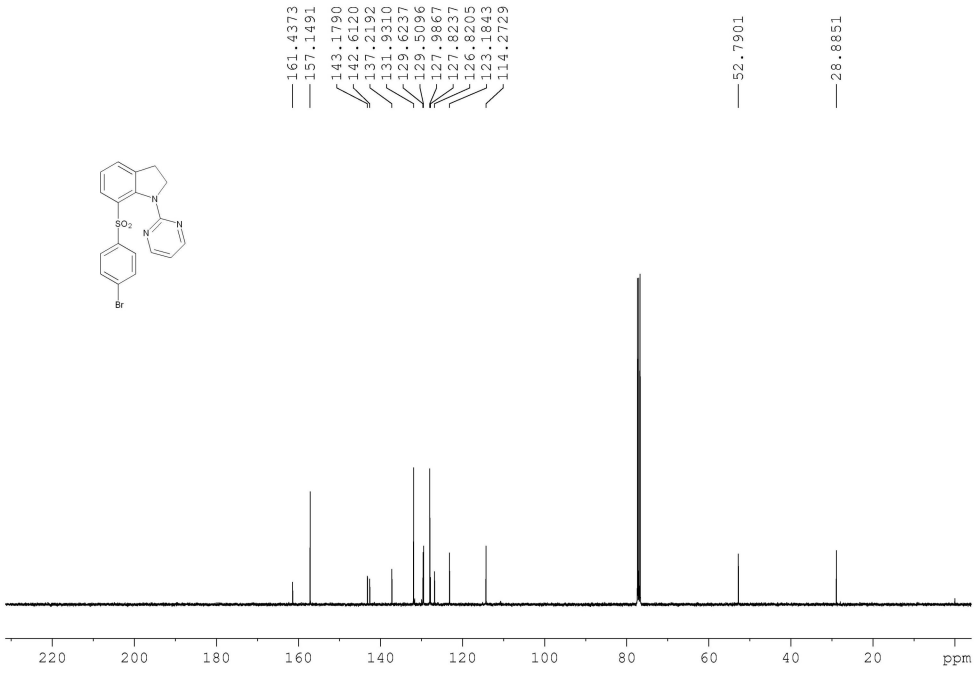
^{13}C NMR spectrum of compound **4f**



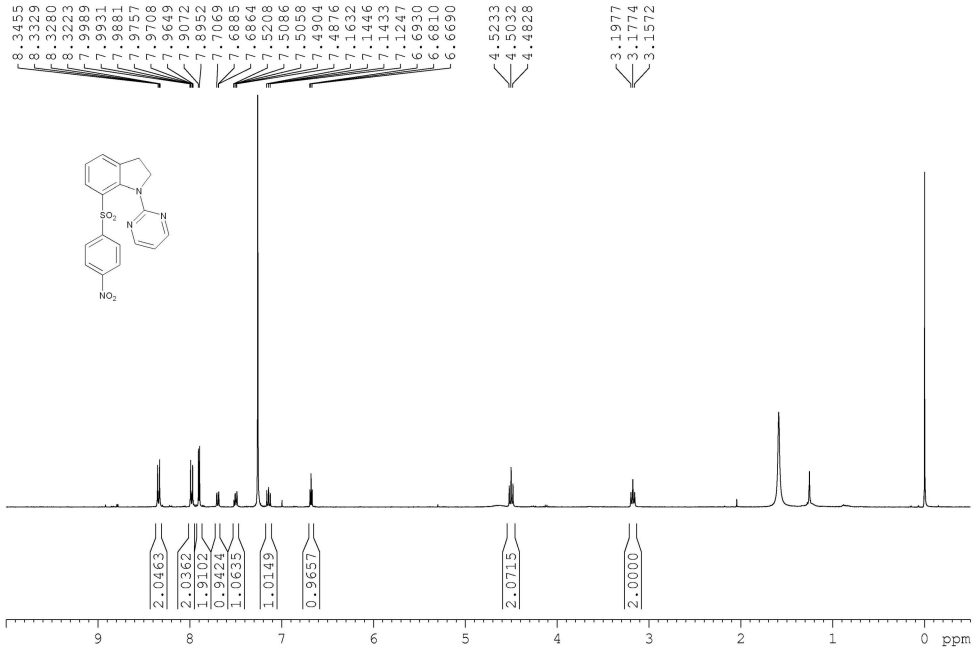
^{1}H NMR spectrum of compound **4g**



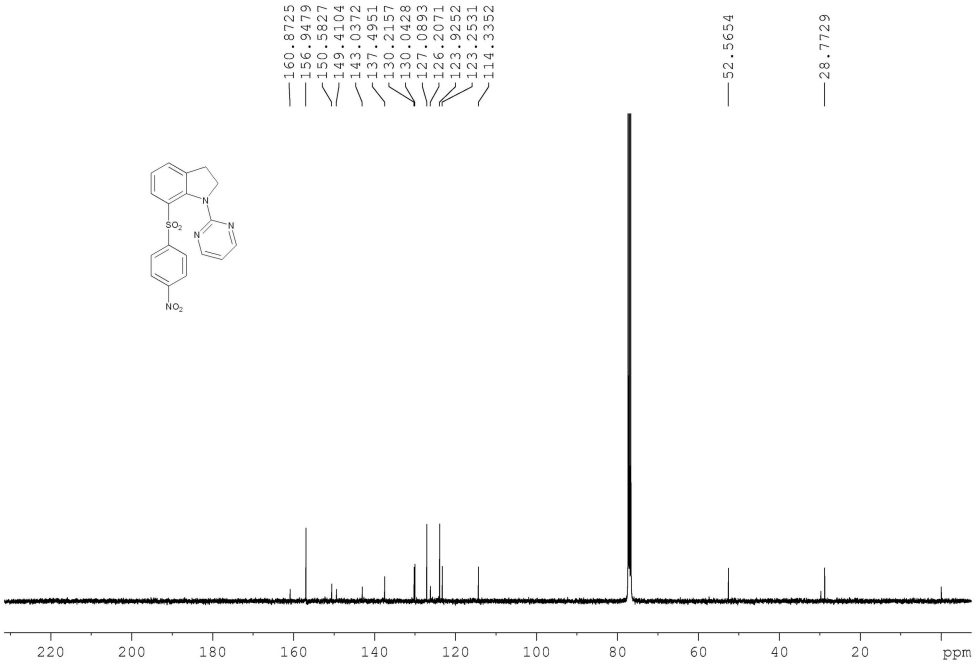
^{13}C NMR spectrum of compound **4g**



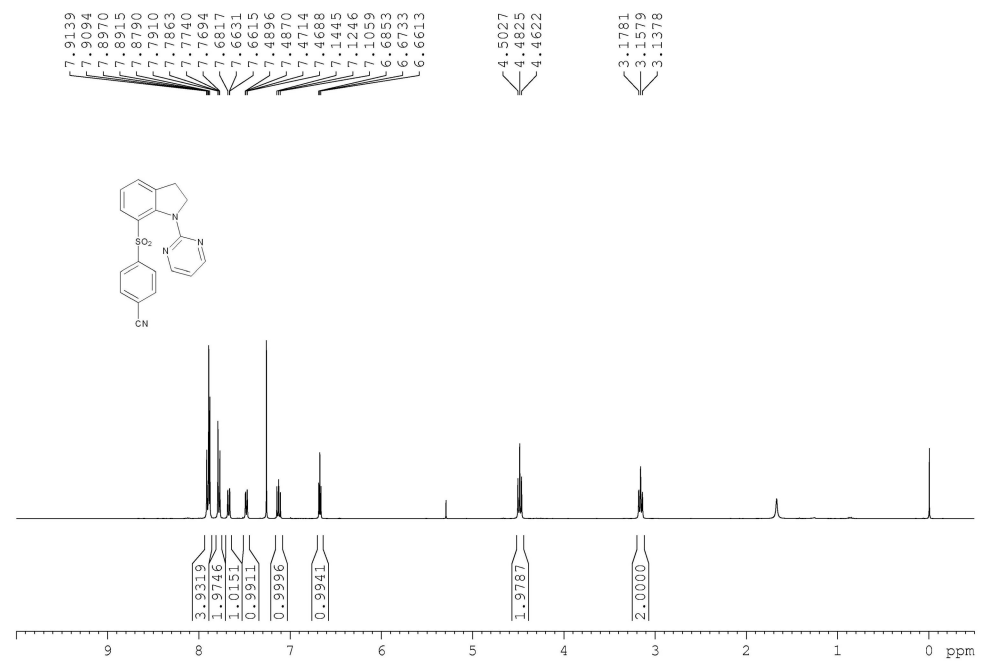
^{1}H NMR spectrum of compound **4h**



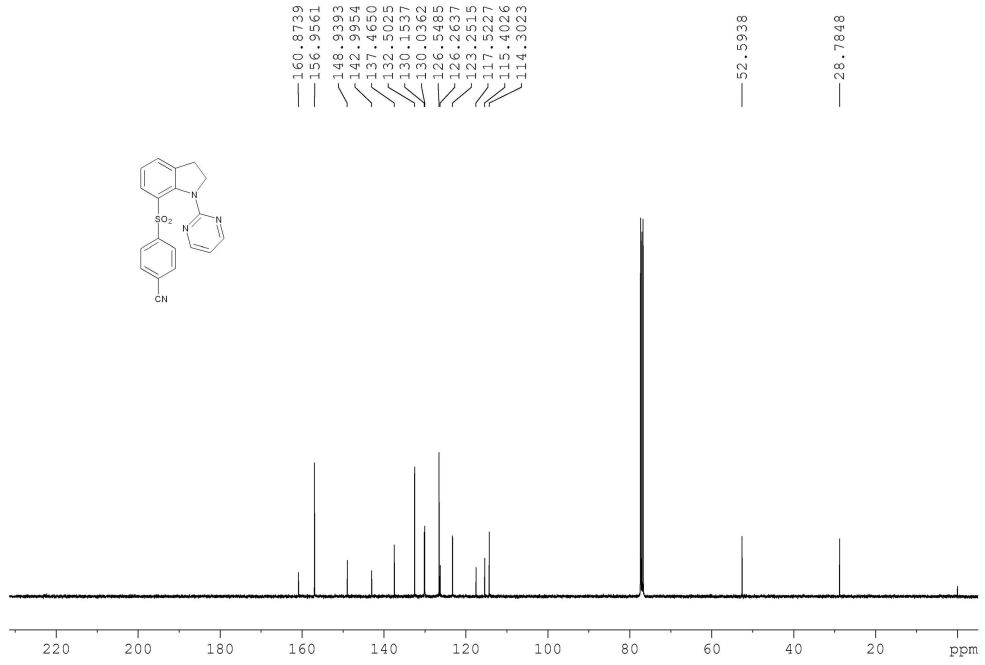
^{13}C NMR spectrum of compound **4h**



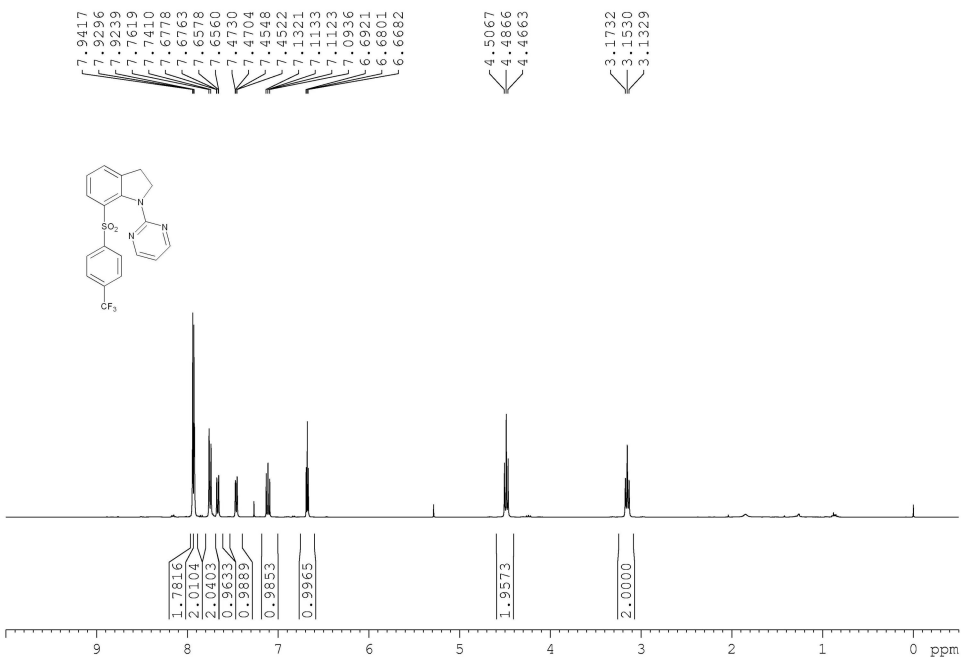
^{1}H NMR spectrum of compound **4i**



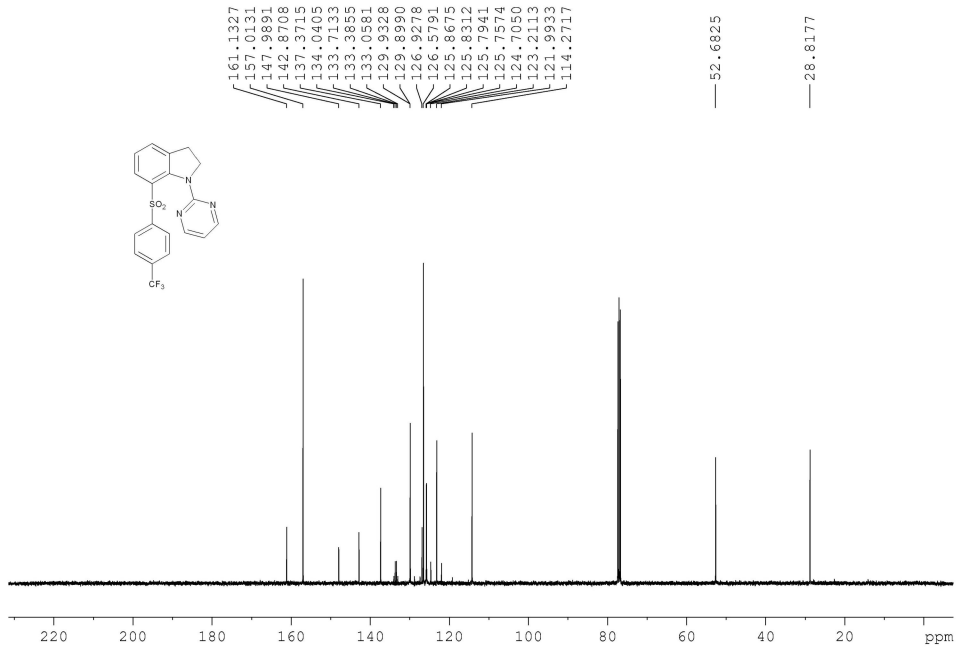
^{13}C NMR spectrum of compound **4i**



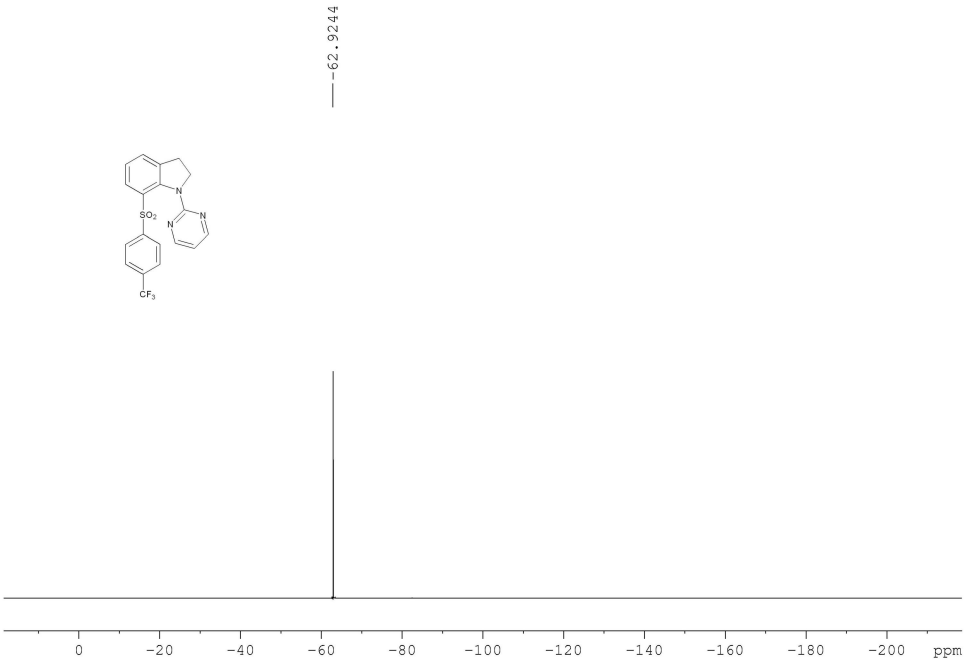
^{1}H NMR spectrum of compound **4j**



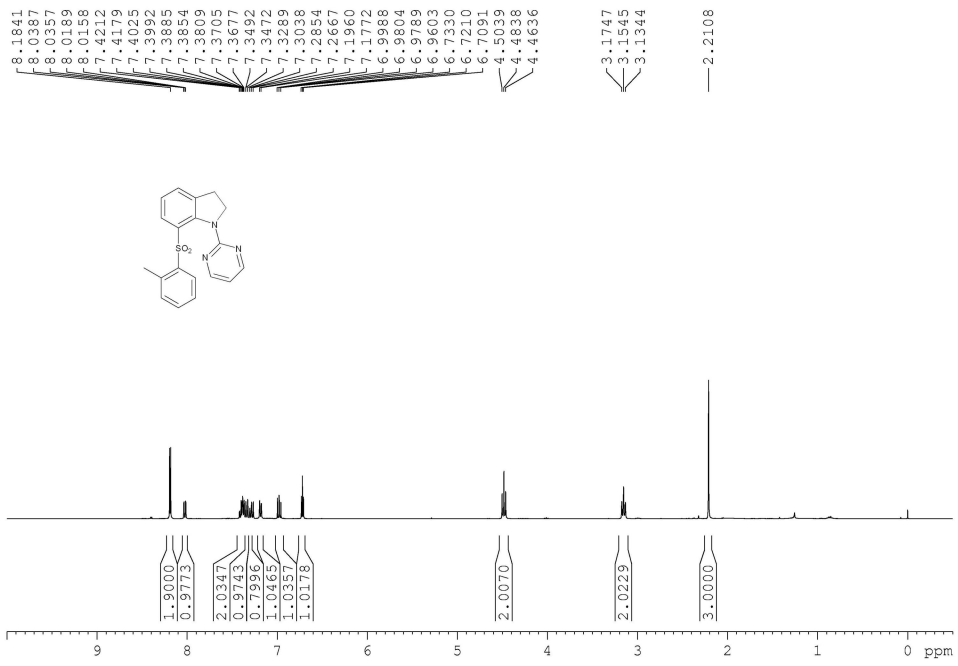
^{13}C NMR spectrum of compound **4j**



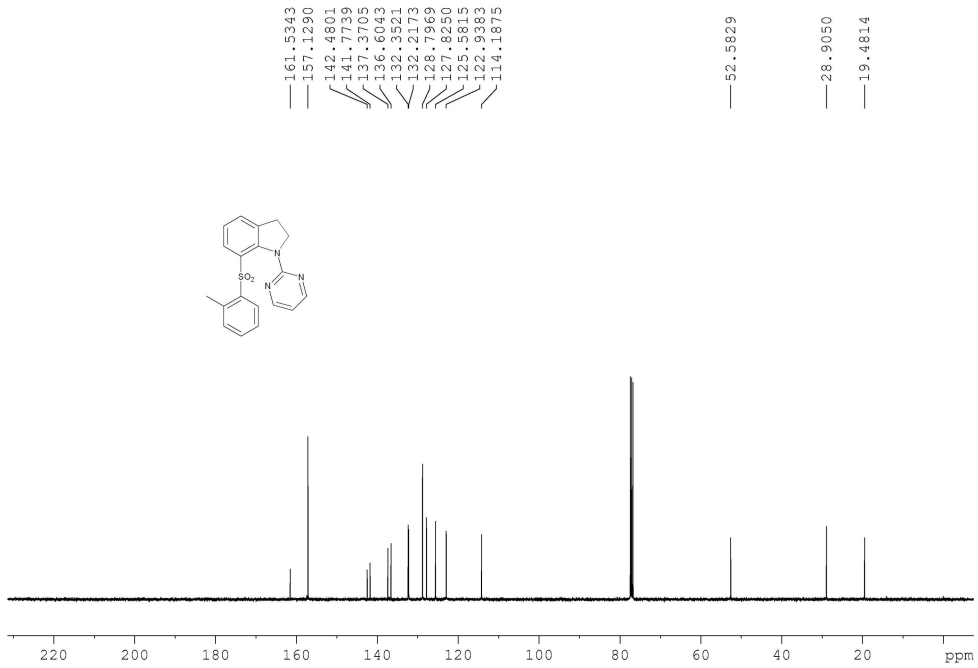
^{19}F NMR spectrum of compound **4j**



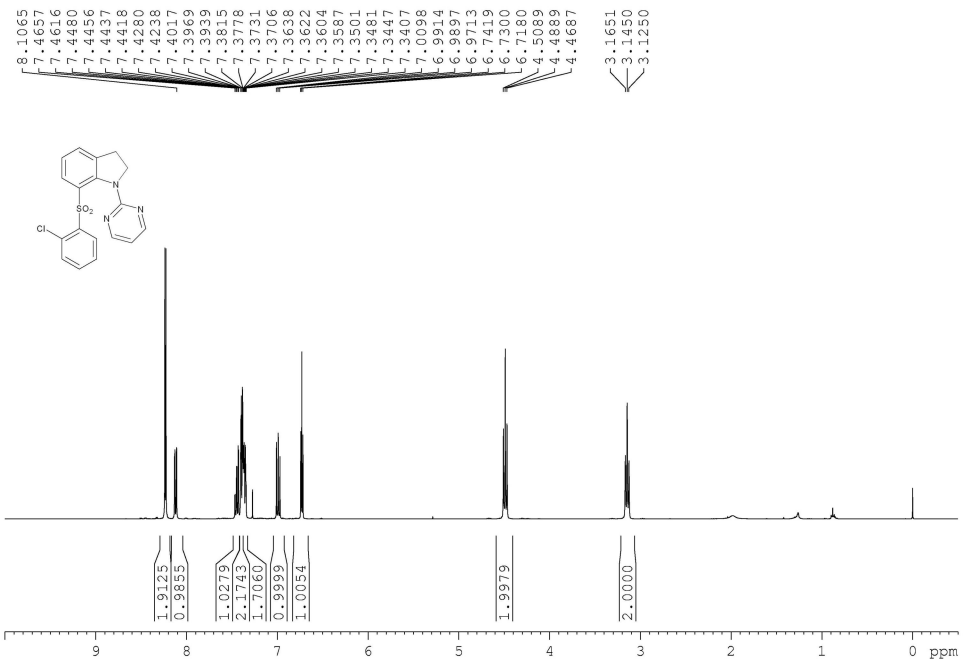
^{1}H NMR spectrum of compound **4k**



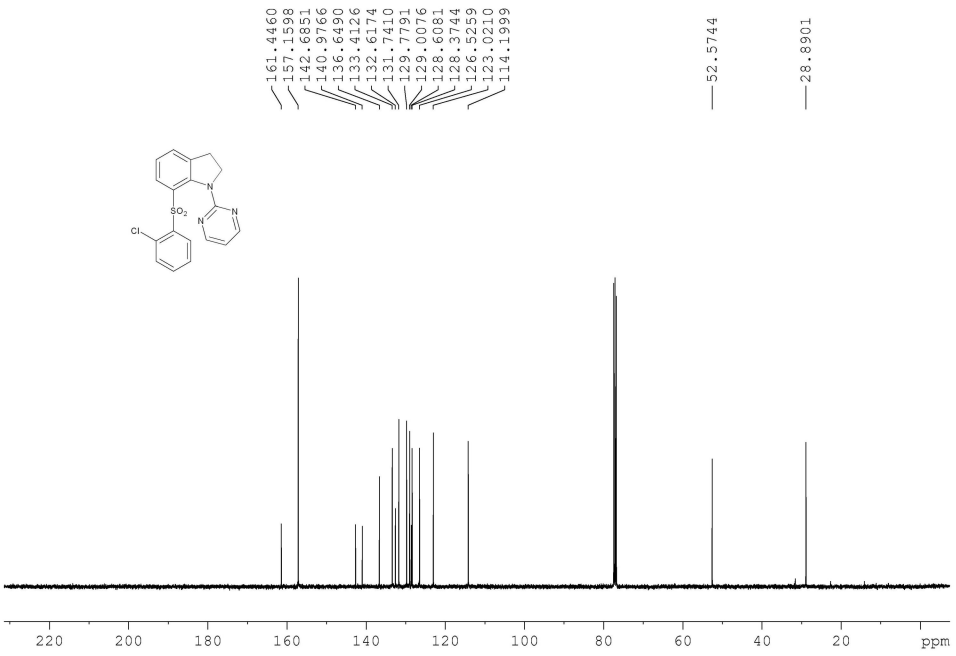
^{13}C NMR spectrum of compound **4k**



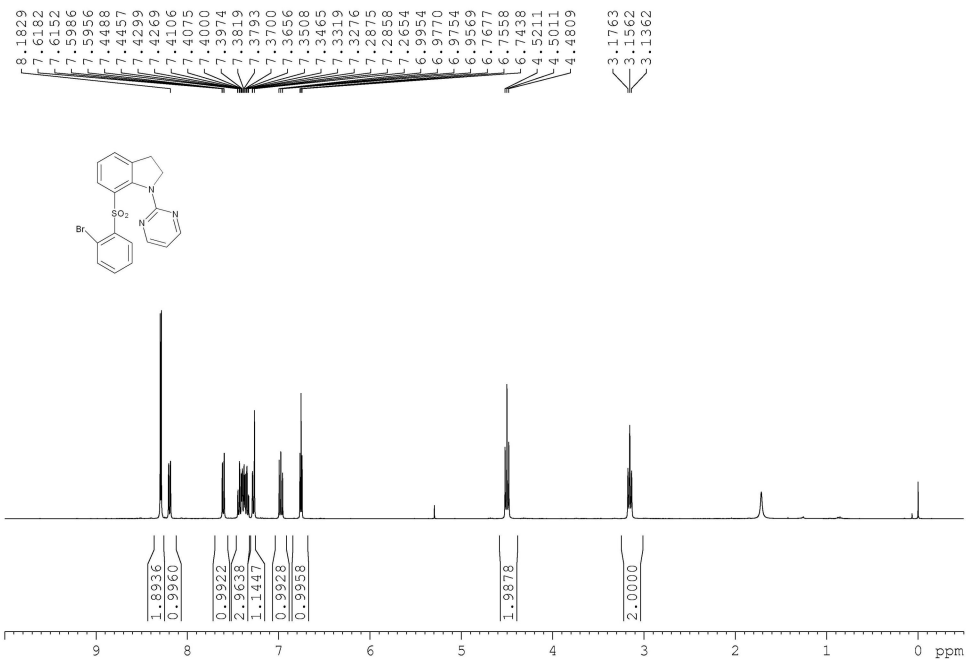
^{1}H NMR spectrum of compound **4l**



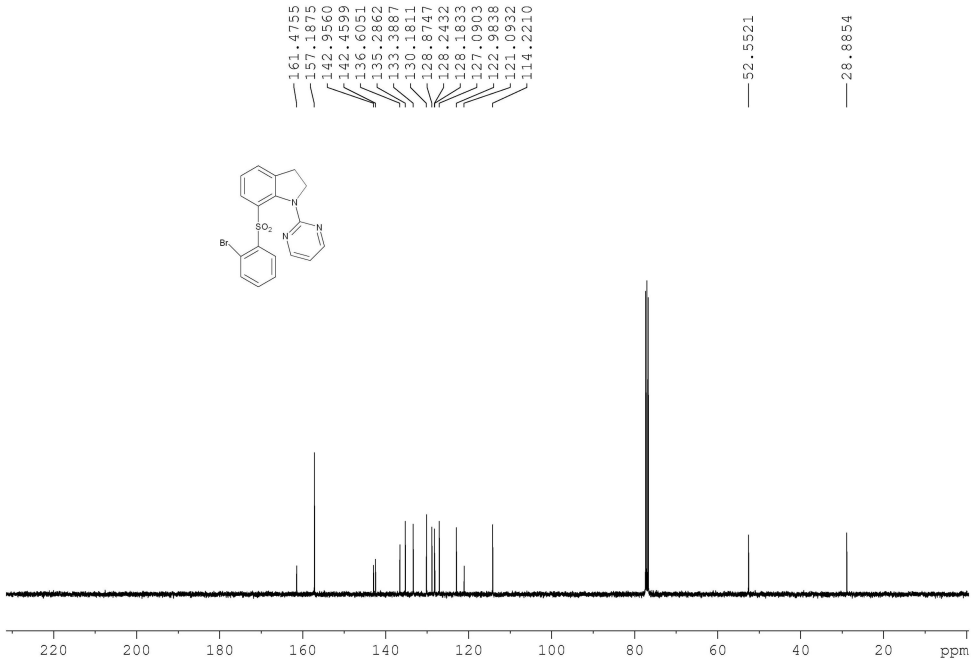
^{13}C NMR spectrum of compound **4l**



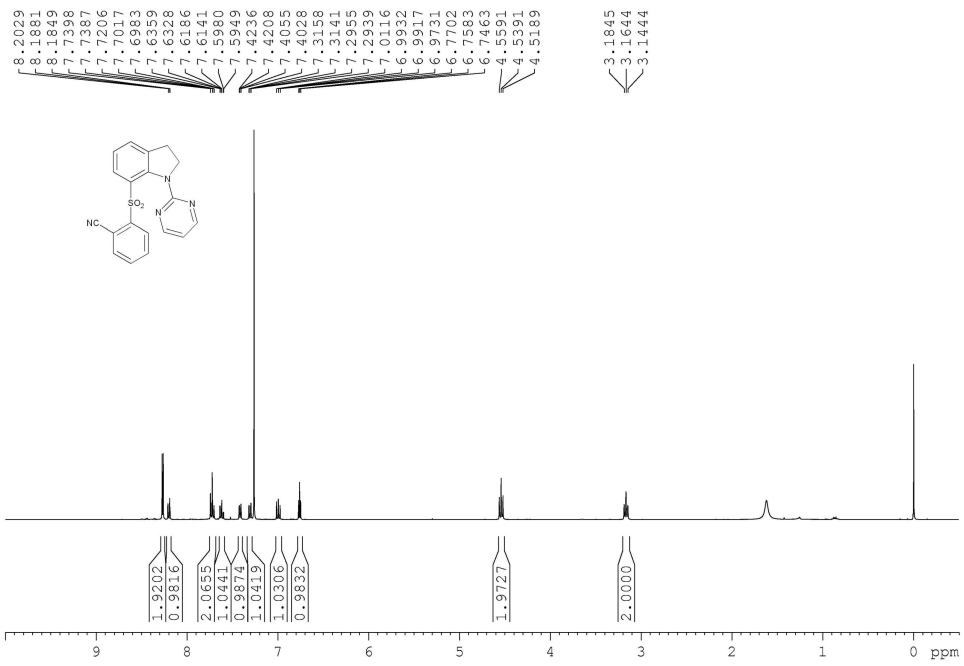
^{1}H NMR spectrum of compound **4m**



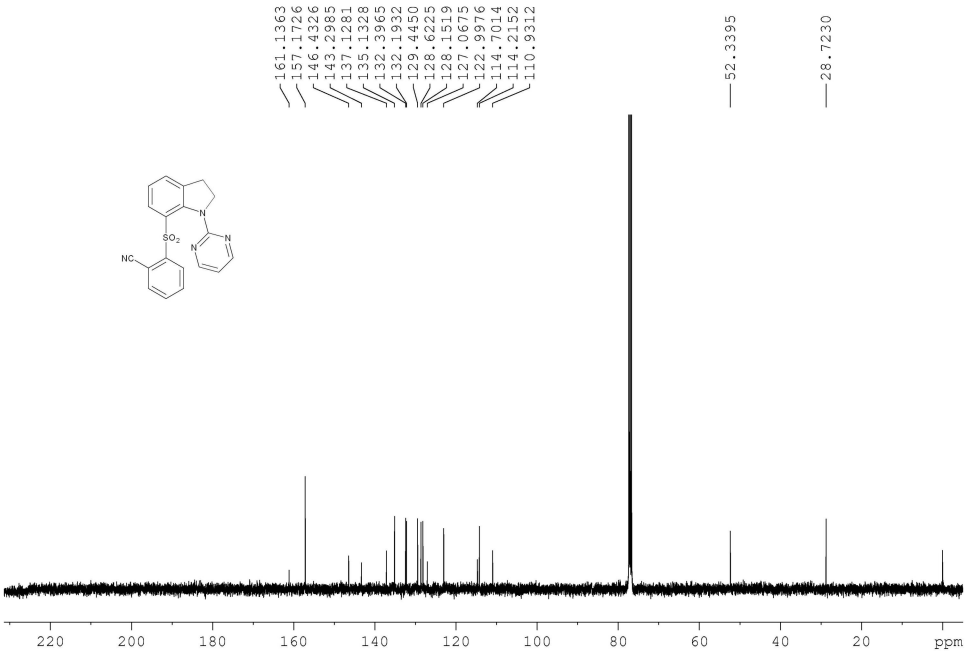
^{13}C NMR spectrum of compound **4m**



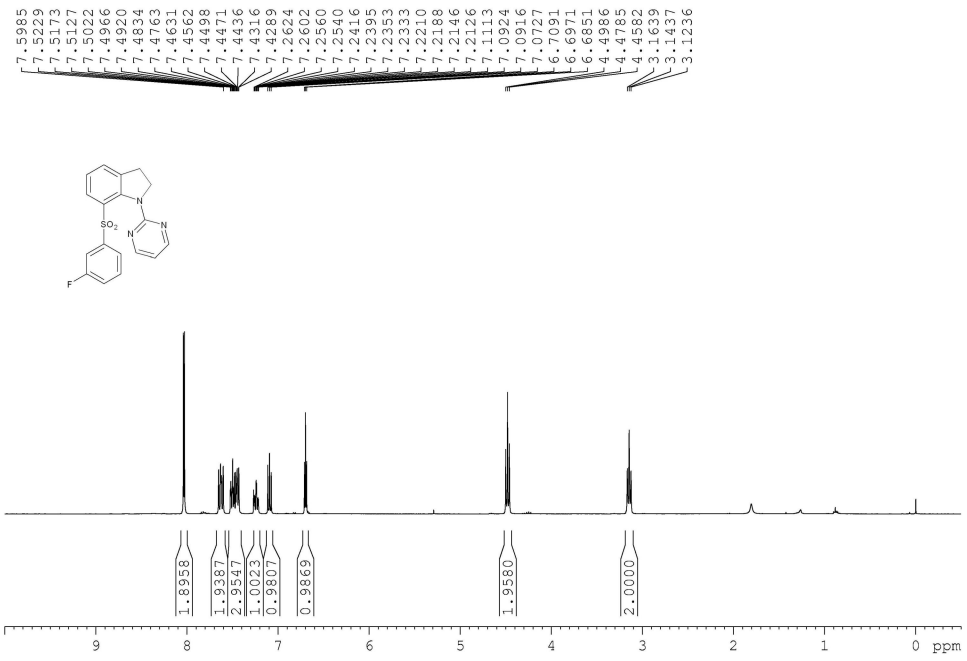
^{1}H NMR spectrum of compound **4n**



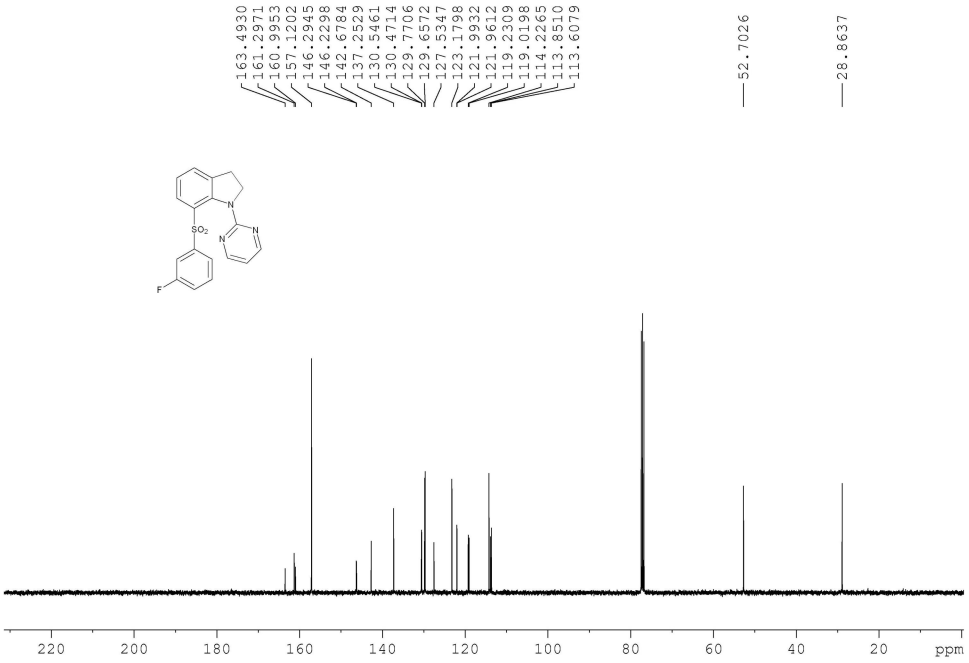
^{13}C NMR spectrum of compound **4n**



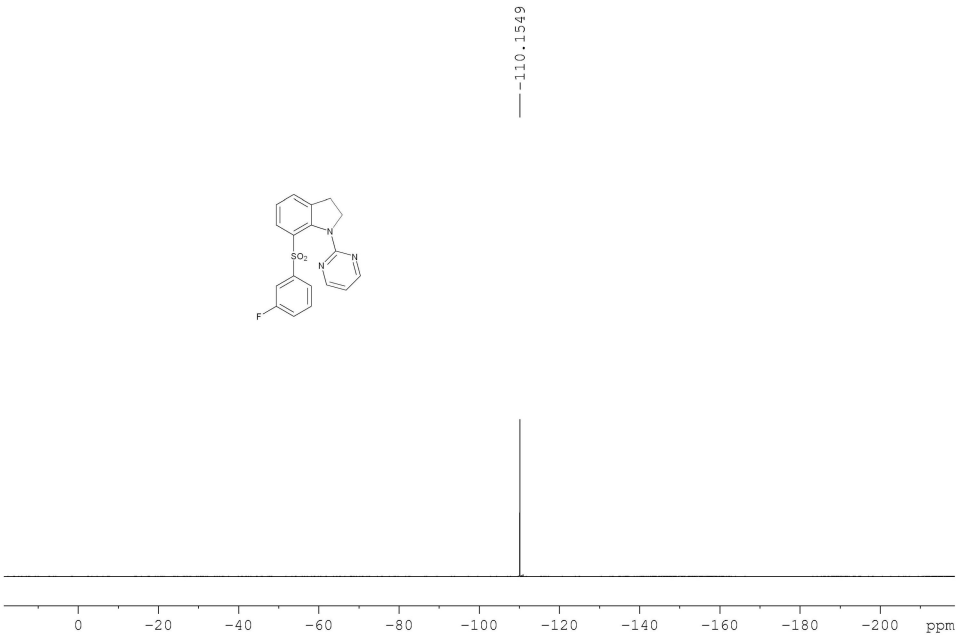
^{1}H NMR spectrum of compound **4o**



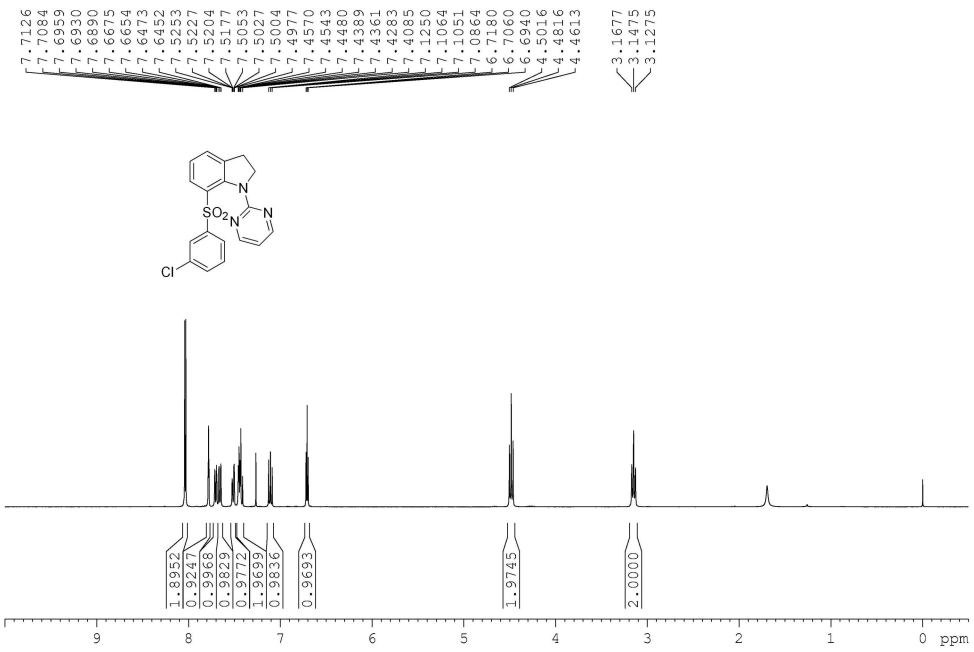
^{13}C NMR spectrum of compound **4o**



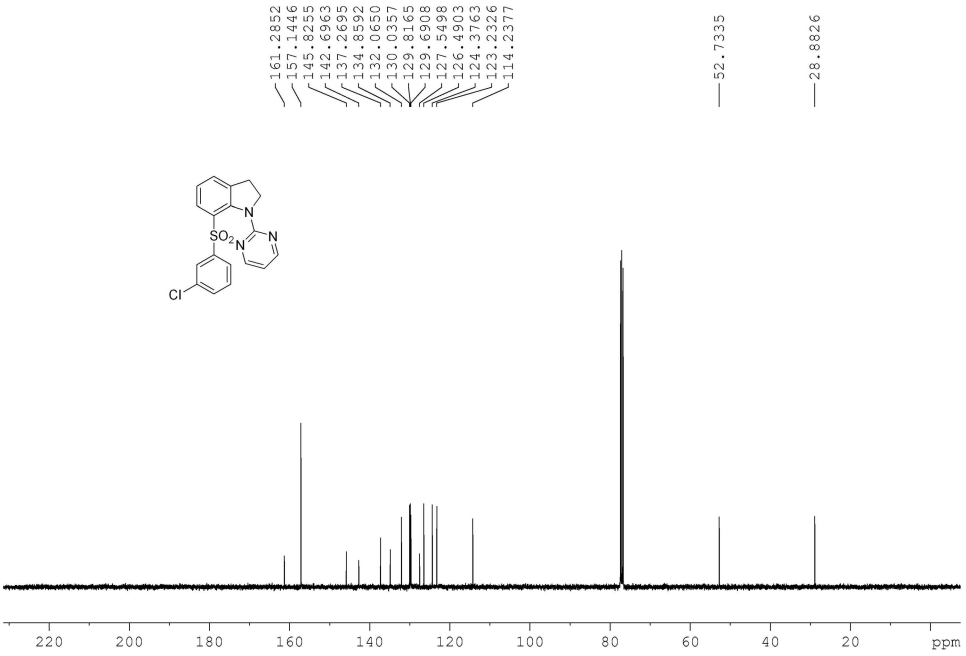
^{19}F NMR spectrum of compound **4o**



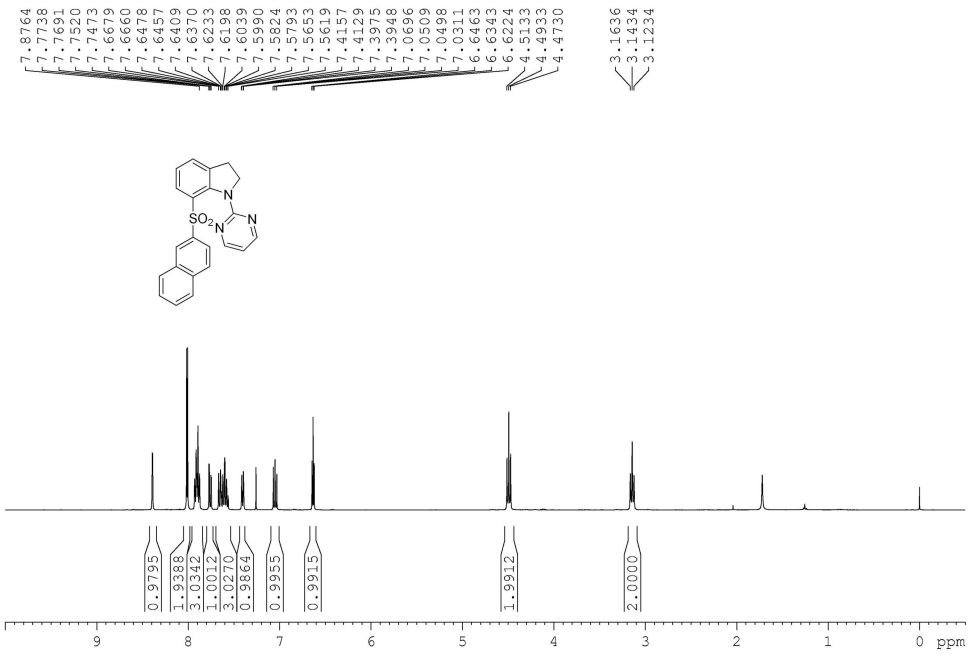
^{1}H NMR spectrum of compound **4p**



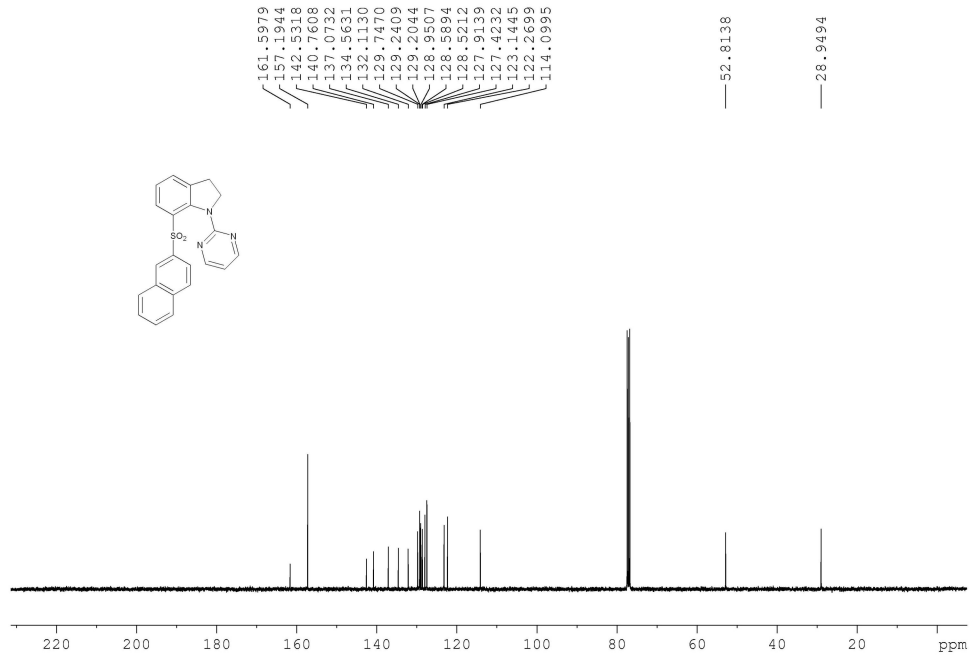
^{13}C NMR spectrum of compound **4p**



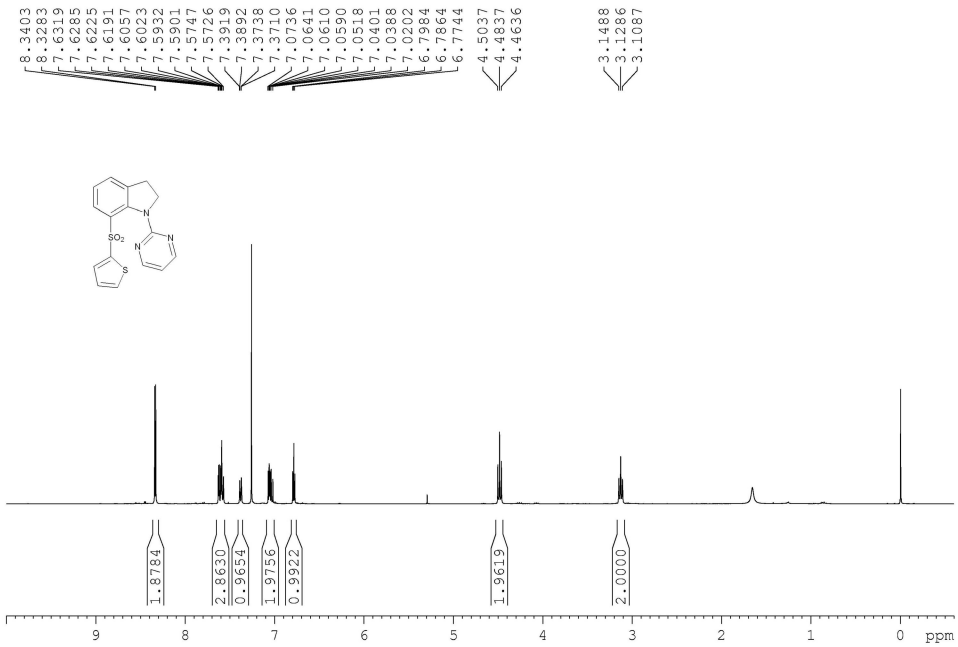
^{1}H NMR spectrum of compound **4q**



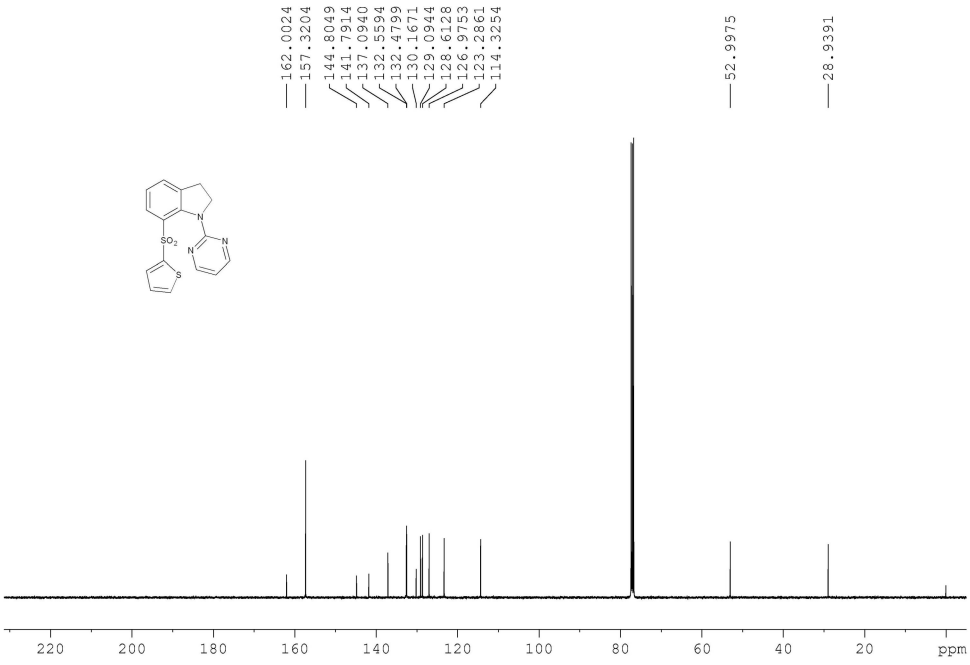
^{13}C NMR spectrum of compound **4q**



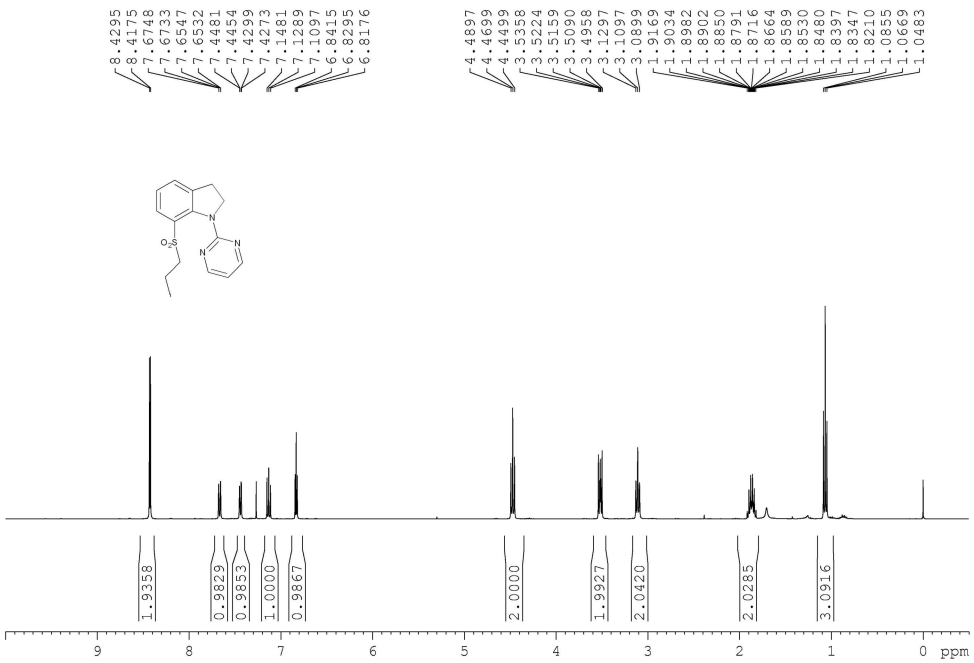
^{1}H NMR spectrum of compound **4r**



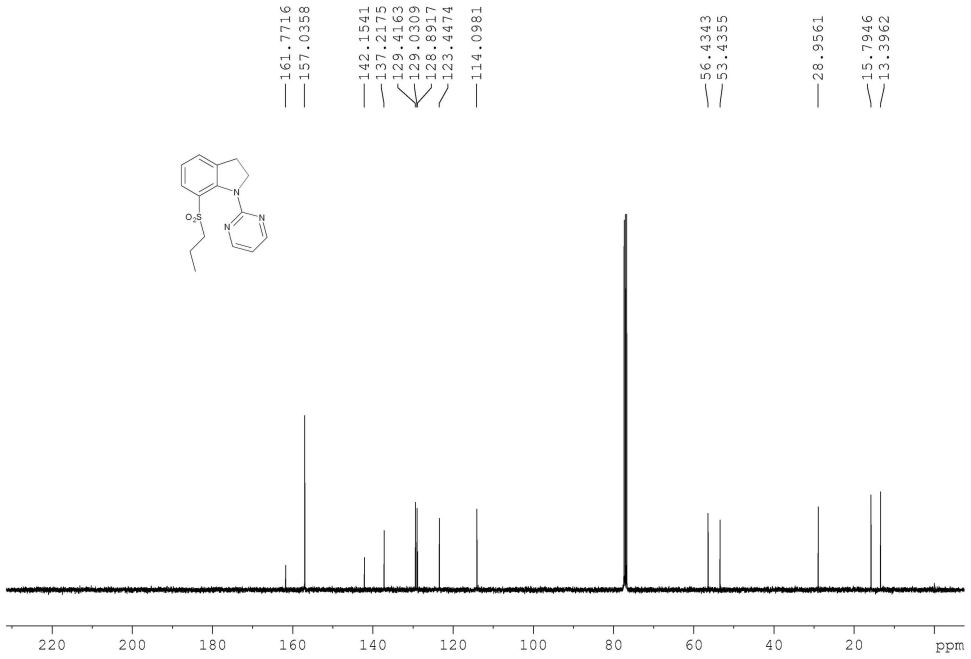
^{13}C NMR spectrum of compound **4r**



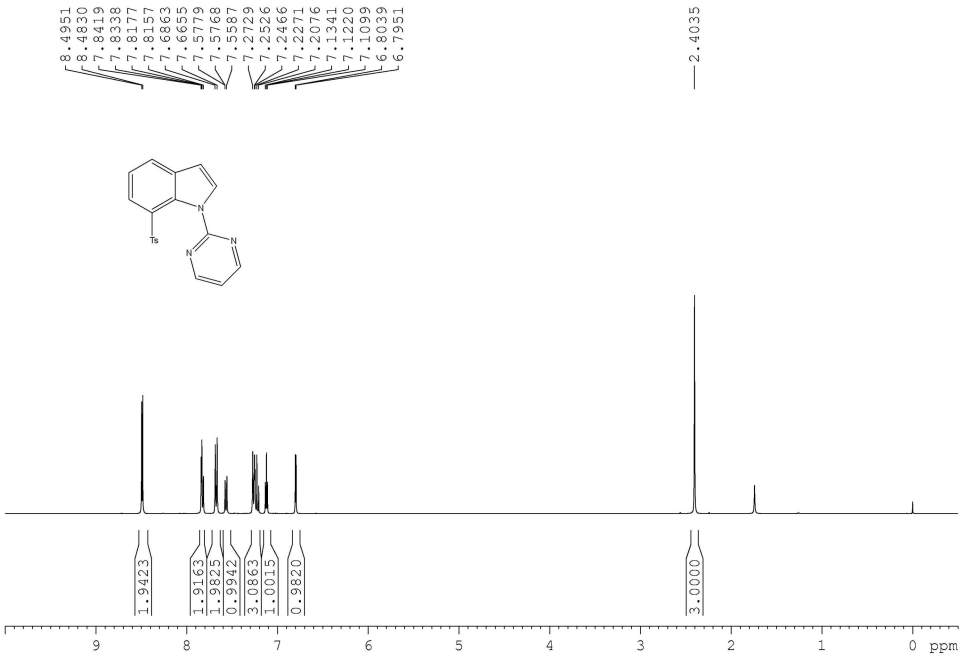
^{1}H NMR spectrum of compound **4s**



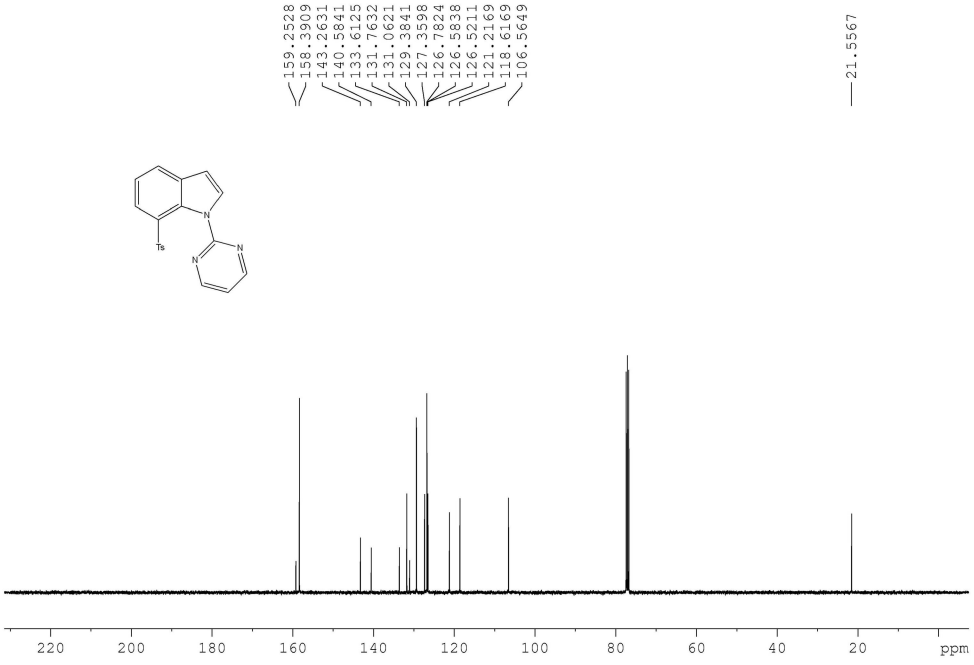
^{13}C NMR spectrum of compound **4s**



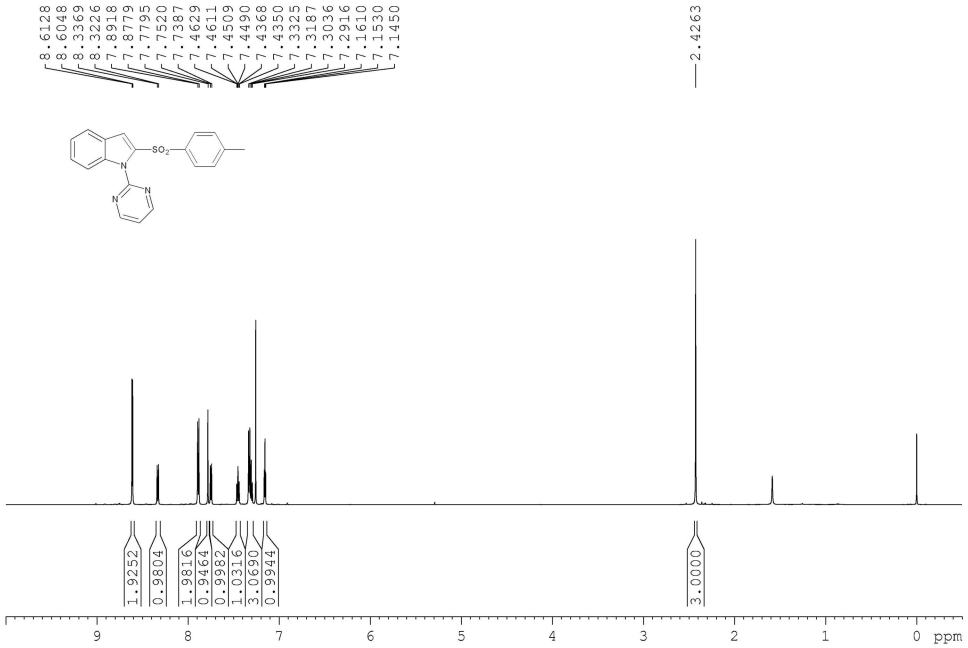
^{1}H NMR spectrum of compound **5**



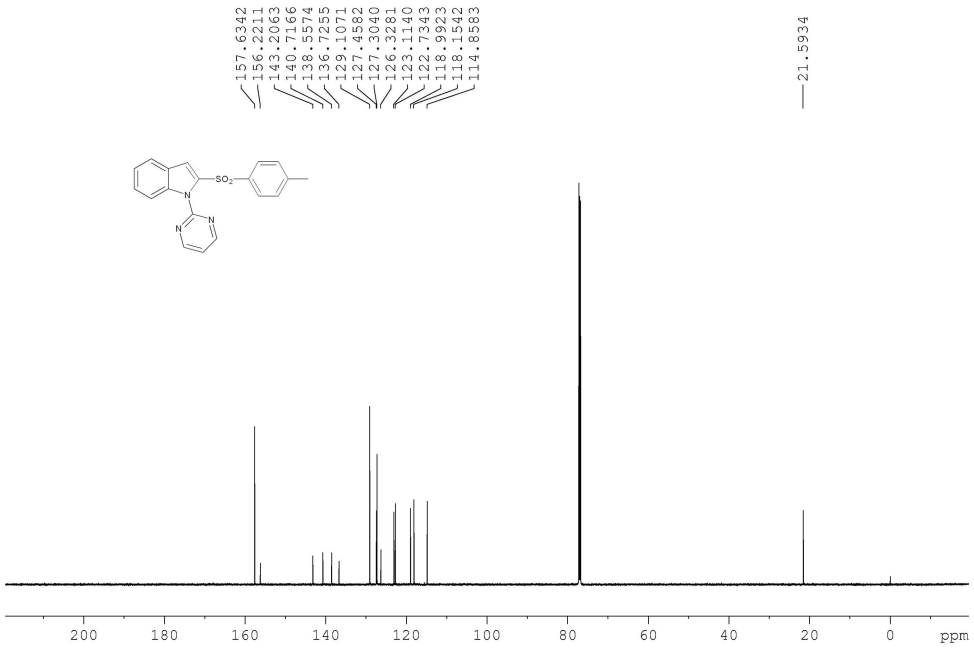
^{13}C NMR spectrum of compound **5**



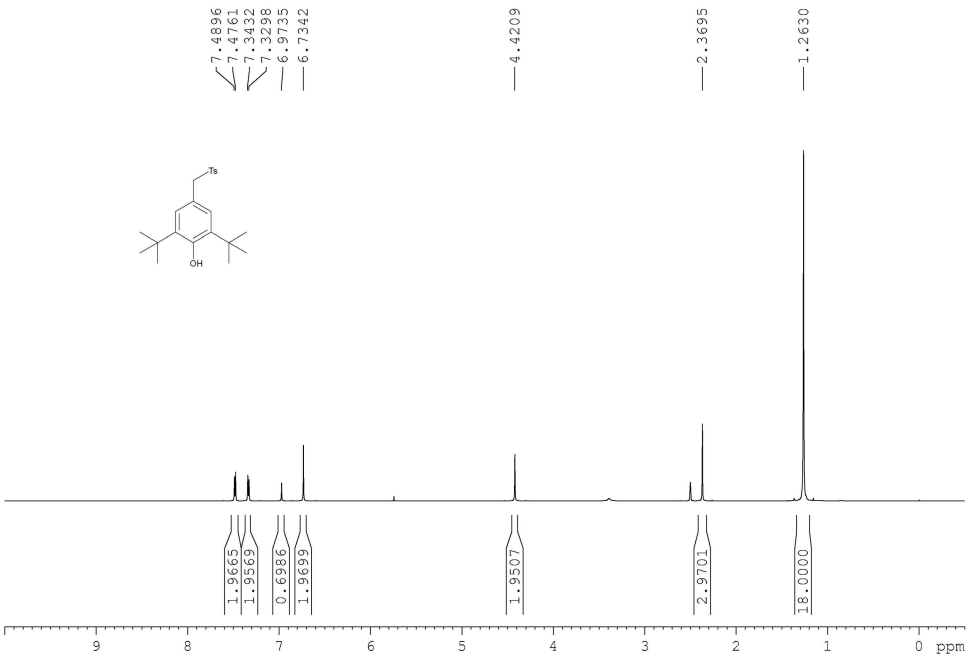
^{1}H NMR spectrum of compound **7**



^{13}C NMR spectrum of compound **7**



^{1}H NMR spectrum of compound **8**



^{13}C NMR spectrum of compound **8**