Supporting Information

Synthesis of diarylsulphide/diarylselenide embedded pyrazole-fused isocoumarins and isatin/ninhydrin hydrazones via acid catalyzed solvent and temperature controlled reactions

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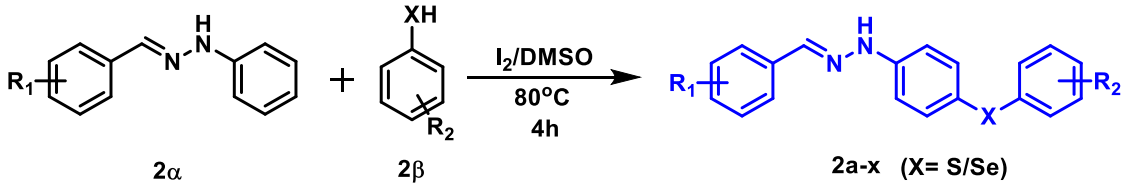
Experimental section:

General information: Solvents and chemicals were sourced from commercial chemical suppliers and used without additional purification. The starting materials, specifically diaryl sulfide/selenide embedded arylhydrazones **2**, were synthesized following a previously reported procedure.[1,2] Melting points were recorded in open capillary tubes and remained uncorrected. Column chromatography was carried out using silica gel (60-120 mesh) and neutral alumina (Merck) with hexane/ethyl acetate solvent system. Additionally, ^{1}H (300 & 400 MHz), ^{13}C (75 & 101 MHz) and ^{19}F (377 MHz) spectra were acquired using Bruker instrument in $CDCl_3$ and DMSO-d_6 NMR solvents. High-resolution mass spectra (HRMS) were obtained using the Xevo G2-S QTof instrument. Lastly, X-ray diffraction data for the crystallized compound were collected at 296 K using MoK_α radiation and the Bruker APEX-II CCD System.

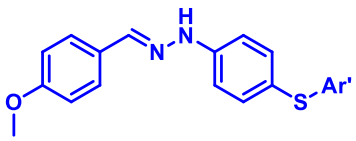
Experimental procedure for the synthesis of starting material sulphenylated/selenylated arylhydrazones 2[1,2]



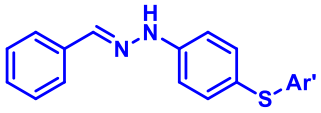
2α 2β 2a-x (X= S/Se)

Initially, arylhydrazone **2α** was synthesized following a previously reported procedure using differently substituted benzaldehydes and phenylhydrazines in ethanol solvent.[1] Subsequently, a mixture of compounds **2α** (1.0 mmol, 1.0 equiv) and diversely substituted arylthiols/arylselenols **2β** (1.5 mmol, 1.5 equiv) was dissolved in 2.0 ml dimethyl sulfoxide (DMSO) in a 25 ml round-bottom flask. To this pot iodine (10 mol %, 0.1 equiv) was added and then the entire reaction mixture was heated at 80°C for 4 h under N_2 atmosphere in an oil bath (monitored by TLC). After completion of the reaction, the crude mixture was quenched with 10 ml of saturated sodium thiosulfate solution and extracted twice with ethyl acetate. The collected organic layer was then dried over anhydrous Na_2SO_4. Evaporation under reduced pressure yielded a crude mass, which was subsequently purified by column chromatography using silica gel (hexane/ethyl acetate as solvent system) to obtain starting materials **2a-x** in 60-86% yield (Table S1).[2]

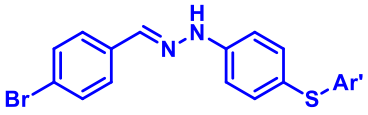
Table S1: Starting materials diarylsulfide and diarylselenide containing arylhydrazones **2** utilized in the synthesis of compounds **3** & **4**.[2]



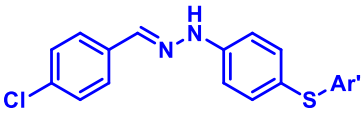
2a: Ar'= -C_6H_5 (86%)
2b: Ar'= -*p*-Me-C_6H_4 (78%)
2c: Ar'= -*p*-Cl-C_6H_4 (85%)
2d: Ar'= -*p*-Br-C_6H_4 (80%)
2e: Ar'= -*o*-Br-C_6H_4 (60%)
2f: Ar'= -*p*-F-C_6H_4 (74%)



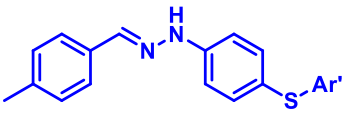
2g: Ar'= -*p*-Cl-C_6H_4 (84%)
2h: Ar'= -*p*-Br-C_6H_4 (83%)



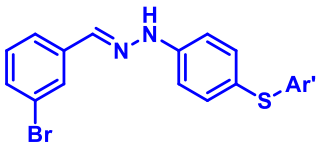
2i: Ar'= -*p*-Cl-C_6H_4 (78%)
2j: Ar'= -*p*-Br-C_6H_4 (83%)



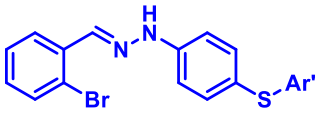
2k: Ar'= -C_6H_5 (82%)
2l: Ar'= -*p*-Cl-C_6H_4 (75%)
2m: Ar'= -*p*-Br-C_6H_4 (83%)



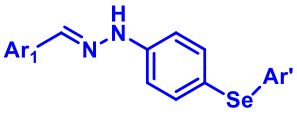
2n: Ar'= -C_6H_5 (77%)
2o: Ar'= -*p*-Cl-C_6H_4 (85%)
2p: Ar'= -*p*-Br-C_6H_4 (84%)



2q: Ar'= -*p*-Br-C_6H_4 (82%)



2r: Ar'= -*p*-Br-C_6H_4 (58%)



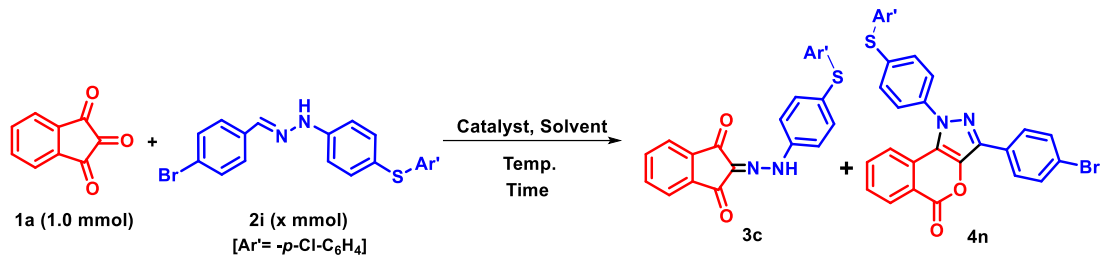
2s: Ar'= -C_6H_5, Ar_1= -*p*-Me-C_6H_4 (75%)
2t: Ar'= -C_6H_5, Ar_1= -*p*-OMe-C_6H_4 (82%)
2u: Ar'= -C_6H_5, Ar_1= -*p*-Cl-C_6H_4 (85%)
2v: Ar'= -C_6H_5, Ar_1= -*p*-Br-C_6H_4 (83%)
2w: Ar'= -*p*-Cl-C_6H_4, Ar_1= -C_6H_5 (80%)
2x: Ar'= -*p*-Br-C_6H_4, Ar_1= -C_6H_5 (84%)

References:

1 Z. T. G. Maz, S. Turanli, H. B. Caliskan, *J. Fac. Pharm. Ankara.*, 2023, **47**, 111-119.

2 A. Dhurey, S. Mandal, A. Pramanik, *J. Org. Chem.*, 2023, **88**, 5377-5390.

Table S2. Optimization of the reaction conditions for compound **3** and **4** (full studies).[a,b]



Entry	**2i** (x mmol)	Catalyst (y mol%)	Solvent (2.0 mL)	Temp (°C)	Time (hr)	Yield[b] (%) of **3c**	Yield[b] (% of **4n**
1	1.0	*p*-TSA (5.0)	EtOH	r.t.	1.0	-	<10
2	1.0	HCl (5.0)	EtOH	r.t.	1.0	-	12
3	1.0	HCl (5.0)	EtOH	78	1.0	15	-
4	1.0	$Cu(OAc)_2$ (5.0)	EtOH	78	1.0	28	-
5	1.0	$FeCl_3$ (5.0)	EtOH	78	1.0	trace	-
6	1.0	CSA (5.0)	EtOH	78	1.0	45	-
7	1.0	AcOH (5.0)	EtOH	78	1.0	30	-
8	1.0	*p*-TSA (5.0)	EtOH	78	1.0	62	-
9	1.2	*p*-TSA (5.0)	EtOH	78	1.0	67	-
10	1.2	*p*-TSA (10.0)	EtOH	78	1.0	70	-
11	1.5	*p*-TSA (20.0)	EtOH	78	1.0	74	
12	1.5	*p*-TSA (20.0)	EtOH	78	2.0	82	-
13	**1.5**	***p*-TSA (20.0)**	**EtOH**	**78**	**3.0**	**85**	**-**
14	1.5	*p*-TSA (20.0)	EtOH	78	4.0	81	-
15	1.5	*p*-TSA (30.0)	EtOH	78	4.0	79	-
16	2.0	*p*-TSA (40.0)	EtOH	78	5.0	65	-
17	1.5	-	EtOH	78	2.0	-	-
18	1.5	HCl (0.1)	DCM	r.t.	1.0	-	76
19	**1.5**	**H_2SO_4 (0.1)**	**DCM**	**r.t.**	**1.0**	**-**	**89**
20	1.5	H_2SO_4 (0.1)	CH_3CN	r.t.	1.0	-	74
21	1.5	H_2SO_4 (0.1)	$CHCl_3$	r.t.	1.0	-	63
22	1.5	H_2SO_4 (0.1)	Acetone	r.t.	1.0	-	60

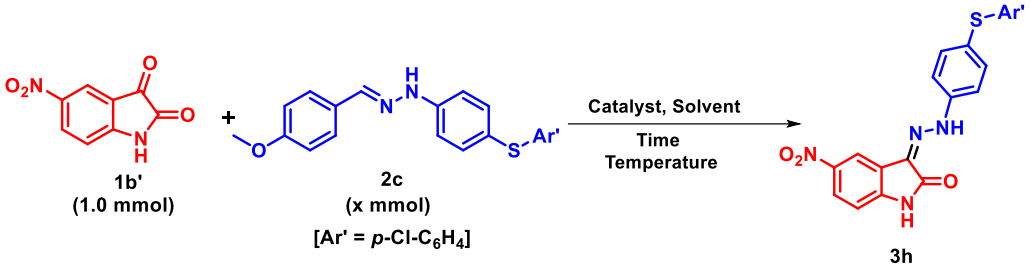
[a]Reaction conditions: **1a** (1.0 mmol) and **2i** (x mol%) were dissolved in solvent (2.0 mL) and then catalyst (y mol%) was added to the same pot. The entire reaction mixture was stirred for 1-5 h at r.t.-78°C in open-air. [b]Isolated yields. Bold row 13 & 19 indicate the optimal conditions for **3c** and **4n** respectively.

Optimization studies for the formation of isatin hydrazones 3.

To achieve the maximum yield of isatin derived sulphenylated hydrazone **3h**, 5-nitroisatin **1b'** and (*E*)-1-(4-((4-chloromophenyl)thio)phenyl)-2-(4-methoxybenzylidene)hydrazine **2c** were taken as model substrates in the optimization study. The starting material **1b'** (1.0 mmol) and hydrazone **2c** (x mmol) were dissolved in 2.0 mL solvent and then the entire reaction mixture was stirred with different acid catalysts (y mol %) in open air for different time and temperatures (Table S3). Initially, the use of strong mineral acids such as conc. HCl & H_2SO_4 (5 mol % each) as catalyst in EtOH (2.0 mL) at r.t. and 78°C for 1.0 h stirring resulted very low yield of the product **3h** due to charring of the reaction mixture (Table S3, entries 1-3). Thus we employed other Lewis/organic acids such as $Cu(OAc)_2$, $FeCl_3$, CSA, AcOH and *p*-TsOH (5 mol % each) successively for 1.0 h reflux (78°C) to further maximize the yield of **3h** (entries 4-8). From the above screening experiments it was observed that *p*-TsOH was the most efficient catalyst to deliver **3h** in ~68% yields (entry 8). Then to improve the yield of **3h** further, the amount of hydrazone **2c** was increased from 1.0 to 1.5 mmol. The results showed minimal improvement in the yield of **3h** if the other reaction parameters were kept constant (Table S3, entries 9 & 10). Subsequently, upon increasing the mol % of *p*-TsOH and reaction time simultaneously (Table S3, entries 11-13), the best possible outcome of **3h** with ~92% yield was isolated when the reaction mixture was refluxed for 3.0 h in presence of 20 mol% *p*-TsOH (entry 13). The extended period of heating and use of excess amount of *p*-TsOH showed sudden decline in the yield of **3h** from 92% to 71%, presumably due to thermal decomposition of hydrazone **2c** (entries 14-17). Expectedly, the reaction failed to generate **3h** in the absence of catalyst, thus implying the role of *p*-TsOH for this reaction to occur (entry 18). Several aprotic solvents such as acetone, DCM, CH_3CN, DMF and DMSO were also examined but none of these solvents were effective enough for the production of **3h** in satisfactory yield (Table S3, entries 19-23). Therefore, refluxing the mixture of 5-nitroisatin **1b'** (1.0 mmole) and arylhydrazone **2c** (1.5 mmol) in EtOH (2.0 mL) in open air

for 3.0 h at 78°C in presence of *p*-TsOH (20 mol %) afforded the desired product **3h** in ~92% yield (Table S3, entry 13).

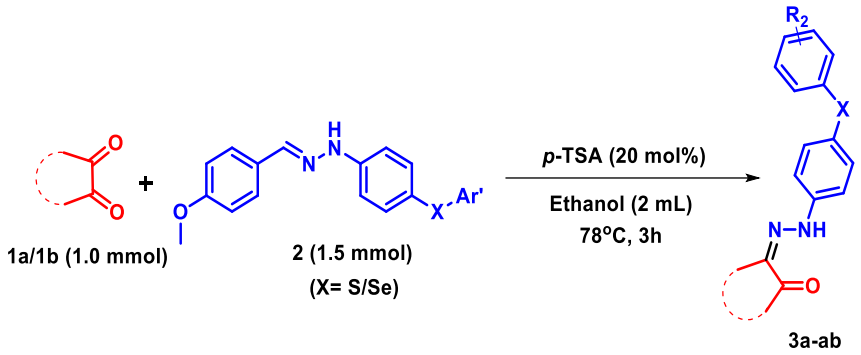
Table S3 Optimization of the reaction conditions for formation of isatin hydrazones.[a,b]

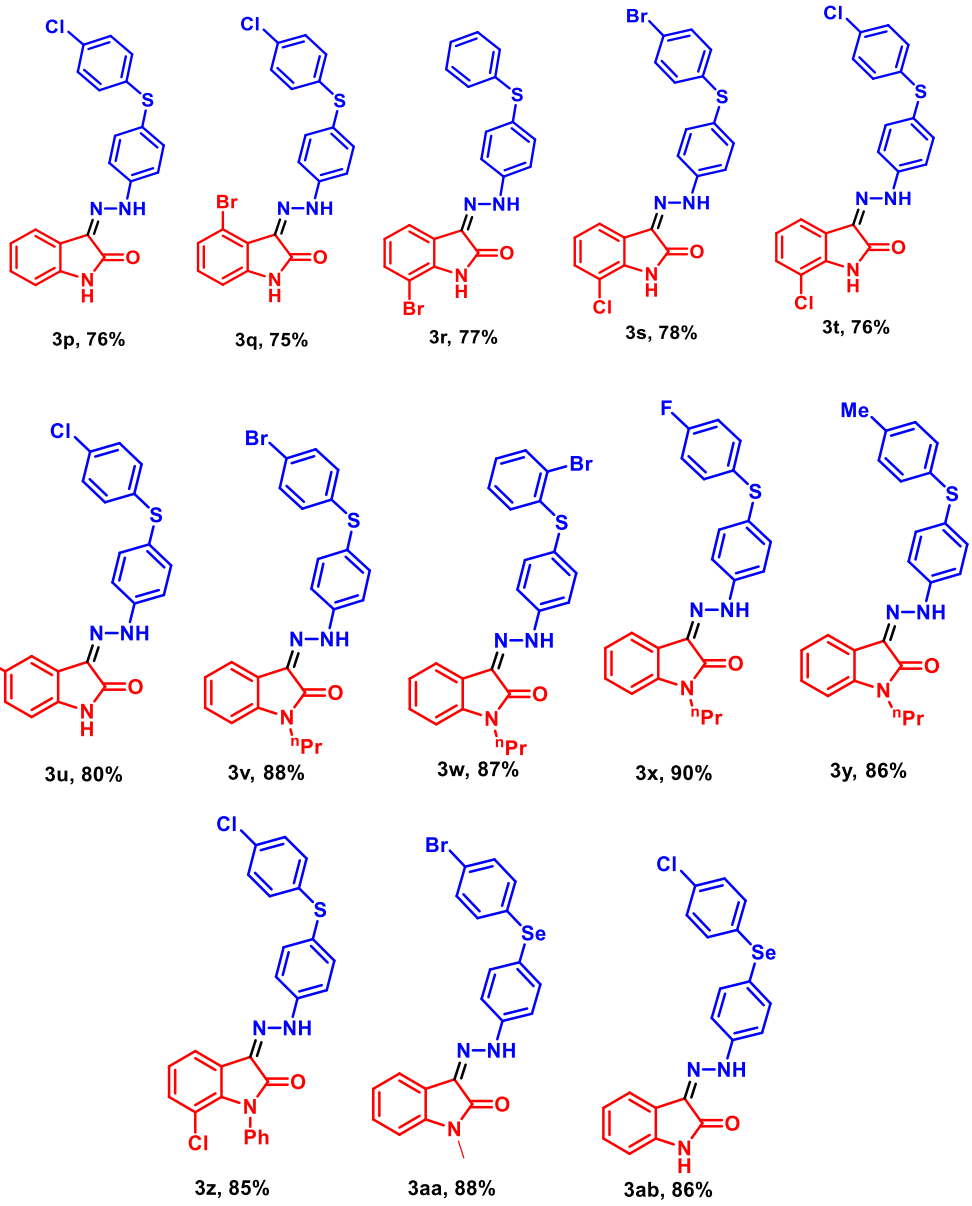


Entry	**2c** (x mmol)	Catalyst (y mol %)	Solvent (2.0 mL)	Time (h)	Temp. (°C)	Yield[b](%) of **3h**
1	1.0	HCl (5.0)	EtOH	1.0	r.t.	-
2	1.0	HCl (5.0)	EtOH	1.0	78	<20
3	1.0	H_2SO_4 (5.0)	EtOH	1.0	78	22
4	1.0	$Cu(OAc)_2$ (5.0)	EtOH	1.0	78	31
5	1.0	$FeCl_3$ (5.0)	EtOH	1.0	78	trace
6	1.0	CSA (5.0)	EtOH	1.0	78	43
7	1.0	AcOH (5.0)	EtOH	1.0	78	32
8	1.0	*p*-TsOH (5.0)	EtOH	1.0	78	68
9	1.2	*p*-TsOH (5.0)	EtOH	1.0	78	72
10	1.5	*p*-TsOH (5.0)	EtOH	1.0	78	74
11	1.5	*p*-TsOH (10.0)	EtOH	1.5	78	80
12	1.5	*p*-TsOH (15.0)	EtOH	2.0	78	83
13	**1.5**	***p*-TsOH (20.0)**	**EtOH**	**3.0**	**78**	**92**
14	1.5	*p*-TsOH (20.0)	EtOH	4.0	78	90
15	1.5	*p*-TsOH (20.0)	EtOH	5.0	78	87
16	1.5	*p*-TsOH (30.0)	EtOH	3.0	78	78
17	1.5	*p*-TsOH (40.0)	EtOH	3.0	78	71
18	1.5	-	EtOH	3.0	78	-
19	1.5	*p*-TsOH (20.0)	Acetone	3.0	78	44
20	1.5	*p*-TsOH (20.0)	DCM	3.0	78	25
21	1.5	*p*-TsOH (20.0)	CH_3CN	3.0	78	31
22	1.5	*p*-TsOH (20.0)	DMF	3.0	78	-
23	1.5	*p*-TsOH (20.0)	DMSO	3.0	78	-

[a]Reaction conditions: Substrate **1b'** (1.0 mmol) & **2c** (x mmol) were dissolved in solvent (2.0 mL) and then catalyst (y mol %) was added to this pot. Then the entire reaction mixture was stirred at r.t.-78°C for 1.0-5.0 h. [b]Yield of isolated product **3h**. Bold row 13 indicates the optimal conditions for **3h**.

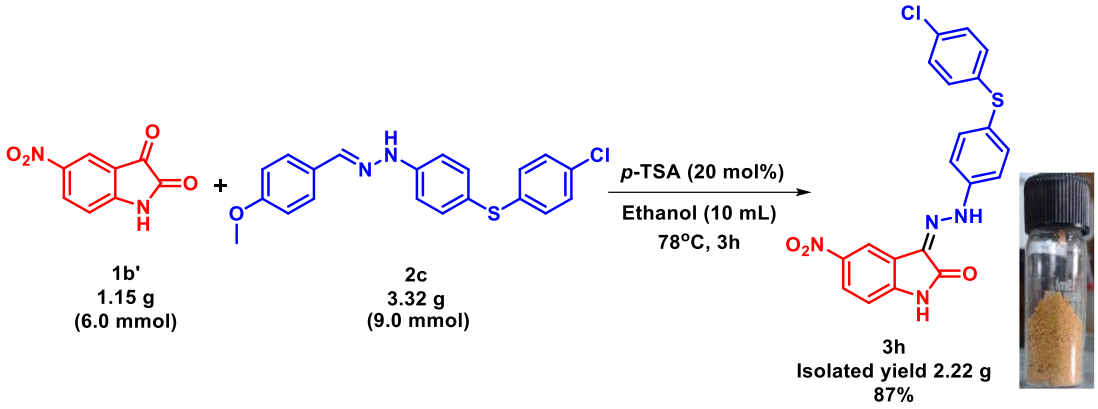
Table S4 Synthesis of diarylsulphide/diarylselenide substituted ninhydrin/isatin hydrazones **3**.[a]





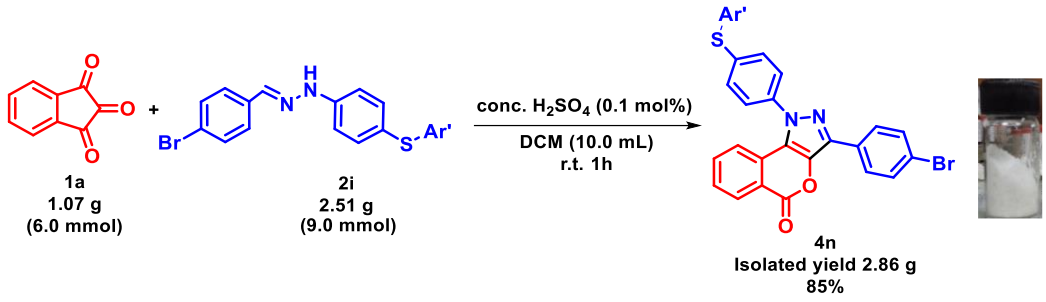
[a]Reaction conditions: ninhydrin **1a**/isatin **1b** (1.0 mmol) and hydrazone **2** (1.5 mmol) were dissolved in ethanol (2.0 mL) and then 20 mol% *p*-TSA was added to the same pot. The entire reaction mixture was refluxed at 78°C for 3 h in open-air.

Gram-scale synthesis of compound 3h.

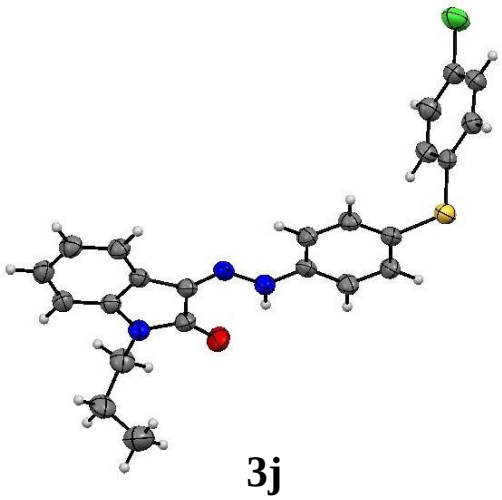


Upon confirming the efficacy of the method through the preparation of a series of ninhydrin/isatin derived hydrazones (**3**) substituted with diarylsulphide/diarylselenide unit, a gram-scale synthesis was undertaken to demonstrate its practical usefulness. The desired product **3h** was obtained in 87% yield (~ 2.22 g) after heating a mixture of 5-nitroisatin **1b'** (~1.15 g, 6.0 mmol) and hydrazone **2c** (~3.32 g, 9.0 mmol) in 10 mL ethanol in presence of *p*-TSA at 78ºC for 3 h.

Gram-scale synthesis of compound 4n.



Upon confirming the efficacy of the method through the preparation of a series of pyrazole-fused isocoumarins integrated with diarylsulphide/diarylselenide unit, a gram-scale synthesis was undertaken to demonstrate its practical usefulness. The desired product **4n** was obtained in 85% yield (~ 2.86 g) after stirring a mixture of ninhydrin **1a** (~1.06 g, 6.0 mmol) and hydrazone **2i** (~2.51 g, 9.0 mmol) in presence of conc. H_2SO_4 (0.1 mol%) in 10 mL DCM at r.t. for 1 h.



3j

Figure S1. ORTEP diagram of X-ray crystal structure of compound **3j** (CCDC No. 2371891). The thermal ellipsoids are shown at 50% probability. Color code: blue, nitrogen; red, oxygen; yellow, sulphur; green, chlorine; grey, carbon; white, hydrogen. The crystal was grown from $CHCl_3$ at room temperature through slow evaporation.

Table S5. Single crystal X-ray analysis data of compound **3j**

Compound	**3j**
Formula	$C_{23}H_{20}ClN_3OS$
Formula weight	421.93
Temperature (K)	175.29
Crystal colour	Yellow
Crystal system	Triclinic
Space group	P-1
a(Å)	5.4212(11)
b(Å)	12.849(3)
c(Å)	15.183(3)
α(°)	82.858(8)
β(°)	81.299(8)
γ(°)	87.732(9)
V(Å^3)	1037.1(4)
Z	2
D_c/gcm^{-3}	1.351
Radiation type	MoK_α
Radiation wave length	0.71073

μ/mm^{-1}	0.304
F(000)	440.0
Crystal size/mm^3	0.18 × 0.1 × 0.03
R*(int)*	0.0665
R*(sigma)*	0.0761
Total reflections	11618
Independent reflections	4541
2Θ range for data collection/°	5.994 to 54.496
Index ranges	-6 ≤ h ≤ 6, -16 ≤ k ≤ 16, -19 ≤ l ≤ 19
R_1,wR_2(I>2σ(I))	0.0597, 0.1629
R_1,wR_2(for all data)	0.0730, 0.1782
Goodness-of-fitonF^2	1.056
Largest diff. peak/hole / e Å^{-3}	0.41/-0.34

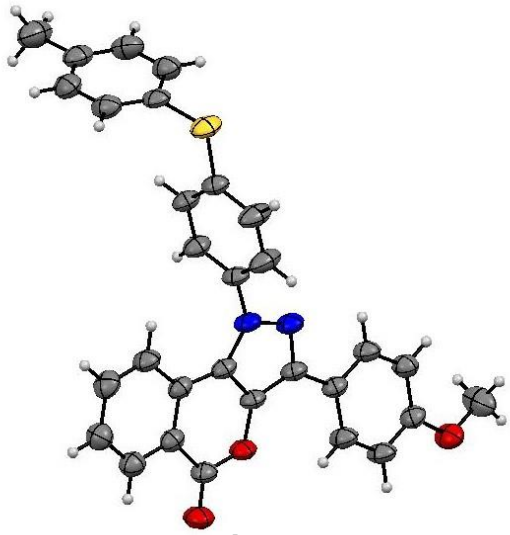


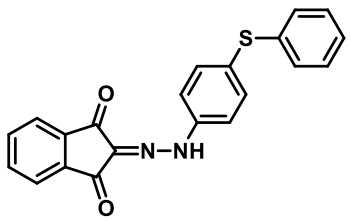
Figure S2. ORTEP diagram of X-ray crystal structure of compound **4p** (CCDC No. 2371892). The thermal ellipsoids are shown at 50% probability. Color code: blue, nitrogen; red, oxygen; yellow, sulphur; grey, carbon; white, hydrogen. The crystal was grown from CH_3CN+$CHCl_3$+Hexane at room temperature through slow evaporation.

Table S6. Single crystal X-ray analysis data of compound **4p**

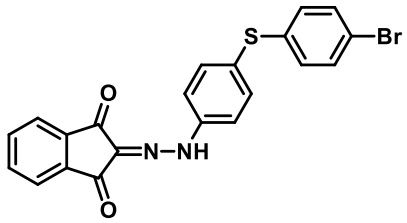
Compound	**4p**
Formula	$C_{30}H_{22}N_2O_3S$
Formula weight	490.55
Temperature (K)	298.95
Crystal colour	White
Crystal system	Triclinic
Space group	P-1
a(Å)	7.8820(11)
b(Å)	10.6903(15)
c(Å)	15.608(2)
α(°)	81.608(5)
β(°)	82.326(5)
γ(°)	68.920(5)
V(Å^3)	1209.3(3)
Z	2
D_c/gcm^{-3}	1.347
Radiation type	MoK_α
Radiation wavelength	0.71073
μ/mm^{-1}	0.170
F(000)	512.0
Crystal size/mm^3	0.15 × 0.1 × 0.08
R(int)	0.0824
R*(sigma)*	0.1006
Total reflections	15750
Independent reflections	6425
2Θ range for data collection/°	5.296 to 58.278
Index ranges	$-8 \le h \le 10$, $-13 \le k \le 14$, $-21 \le l \le 21$
R_1,wR_2 (I>2σ(I))	0.0722, 0.1890
R_1,wR_2 (for all data)	0.1222, 0.2350
Goodness-of-fitonF^2	1.046
Largest diff. peak/hole / e Å^{-3}	0.40/-0.40

Spectral data of compounds 3:

2-(2-(4-(phenylthio)phenyl)hydrazono)-1H-indene-1,3(2H)-dione (3a): The compound was purified by column chromatography as red solid (294 mg, 82% yield) using 10% ethylacetate in hexane; m.p. 175°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.31 (t, J = 4.4 Hz, 3H), 7.43-7.54 (m, 6H), 7.60-7.83 (m, 2H), 7.84-7.91 (m, 1H), 7.95-7.82 (s, 1H), 13.46 (s, 1H) ppm; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 117.0, 121.0, 122.9, 123.2, 127.6, 128.9, 129.4, 131.0, 132.9, 134.2, 135.0, 135.4, 138.8, 140.3, 140.6, 186.0, 188.7 ppm; HRMS (ESI-TOF): Calcd for $[C_{21}H_{15}O_2N_2S]^+$ *m/z* 359.0855. Found 359.0880.



2-(2-(4-((4-bromophenyl)thio)phenyl)hydrazono)-1H-indene-1,3(2H)-dione (3b): The compound was purified by column chromatography as red solid (380 mg, 87%yield) using 15% ethylacetate in hexane; m.p. 189°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.19 (d, J = 10.8 Hz, 2H), 7.36-7.52 (m, 6H), 7.76-7.84 (m, 2H), 7.90 (t, J = 7.2 Hz, 1H), 7.98 (t, J = 6.8 Hz, 1H), 13.46 (s, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 117.1, 121.1, 122.9, 123.3, 131.9, 132.3, 132.4, 132.9, 135.1, 135.2, 135.5, 138.8, 140.5, 140.7, 186.0, 188.7 ppm.; HRMS (ESI-TOF): Calcd for $[C_{21}H_{14}O_2N_2BrS]^+$ *m/z* 436.9960. Found 436.9997.

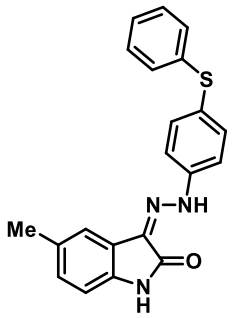


2-(2-(4-((4-chlorophenyl)thio)phenyl)hydrazono)-1H-indene-1,3(2H)-dione (3c): The compound was purified by column chromatography as red solid (334 mg, 85% yield) using 10% ethylacetate in hexane; m.p. 185°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.26-7.31 (m, 4H), 7.40 (d, J = 8.0 Hz, 2H), 7.49 (d, J = 8.4 Hz, 2H), 7.77-7.83 (m, 2H), 7.91 (d, J = 6.4 Hz, 1H), 7.97 (d, J = 8.0 Hz, 1H), 13.46 (s, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 117.0, 122.9, 123.3, 129.4, 131.2, 131.9, 132.7, 132.8, 133.2, 134.3, 135.1, 135.5, 138.8, 140.4, 140.7, 185.9, 188.7 ppm.; HRMS (ESI-TOF): Calcd for $[C_{21}H_{14}O_2N_2ClS]^+$ *m/z* 393.0465. Found 393.0493.

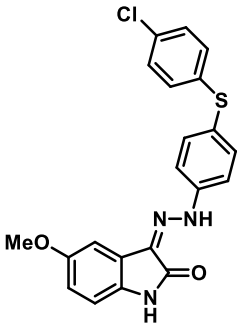
(Z)-3-(2-(4-((4-bromophenyl)thio)phenyl)hydrazono)indolin-2-one (3d): The compound was purified by column chromatography as orange solid (322 mg, 76% yield) using 10% ethylacetate in hexane; m.p. 205°C; ^{1}H NMR (400 MHz, DMSO-d_6): δ 6.92 (d, J = 8.0 Hz, 1H), 7.03-7.11 (m, 3H), 7.25 (t, J = 8.0 Hz, 1H), 7.43-7.56 (m, 7H), 11.06 (s, 1H), 12.76 (s, 1H)

ppm.; $^{13}C\{^{1}H\}$NMR (101 MHz, DMSO-d_6): δ 111.0, 115.8, 119.3, 119.6, 121.4, 122.4, 125.2, 129.2, 129.4, 130.3, 132.5, 135.3, 137.7, 140.6, 143.6, 165.7 ppm.; HRMS (ESI-TOF): Calcd for $[C_{20}H_{15}ON_3BrS]^+$ *m/z* 424.0120. Found 424.0164.

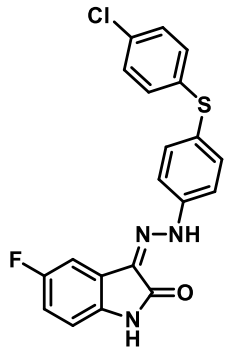
(Z)-5-methyl-3-(2-(4-(phenylthio)phenyl)hydrazono)indolin-2-one (3e): The compound was purified by column chromatography as yellow solid (223 mg, 62% yield) using 10% ethylacetate in hexane; m.p. 192°C; ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.39 (s, 3H), 6.82 (d, *J* = 7.8 Hz, 1H), 7.07 (d, *J* = 7.8 Hz, 1H), 7.17 (t, *J* = 6.6 Hz, 2H), 7.23-7.26 (m, 3H), 7.37 (d, *J* = 8.7 Hz, 2H), 7.46 (t, *J* = 8.1 Hz, 3H), 7.85 (brs, 1H), 12.73 (s, 1H) ppm.; $^{13}C\{^{1}H\}$NMR (101 MHz, $CDCl_3$): δ 21.1, 110.0, 115.2, 119.9, 121.8, 127.0, 127.1, 127.9, 129.1, 130.0, 132.0, 132.3, 134.6, 136.1, 136.5, 142.7, 163.6 ppm.; HRMS (ESI-TOF): Calcd for $[C_{21}H_{18}ON_3S]^+$ *m/z* 360.1108. Found 360.1143.



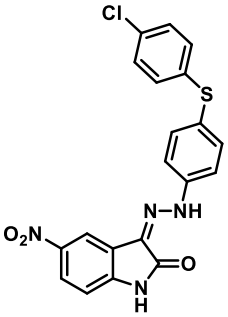
(Z)-3-(2-(4-((4-chlorophenyl)thio)phenyl)hydrazono)-5-methoxyindolin-2-one (3f): The compound was purified by column chromatography as orange solid (246 mg, 60% yield) using 15% ethylacetate in hexane; m.p. 228°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.87 (s, 3H), 6.83 (s, 2H), 7.18 (d, *J* = 8.4 Hz, 2H), 7.24 (t, *J* = 9.2 Hz, 3H), 7.38 (d, *J* = 8.4 Hz, 2H), 7.45 (d, *J* = 8.4 Hz, 2H), 7.64 (brs, 1H), 12.79 (s, 1H) ppm.; $^{13}C\{^{1}H\}$NMR (101 MHz, $CDCl_3$): δ 55.92, 104.5, 111.0, 115.0, 115.3, 122.6, 127.3, 128.0, 129.1, 130.1, 132.1, 134.5, 136.4, 142.6, 156.0, 163.7 ppm.; HRMS (ESI-TOF): Calcd for $[C_{21}H_{17}O_2N_3ClS]^+$ *m/z* 410.0731. Found 410.0783.



(Z)-3-(2-(4-((4-chlorophenyl)thio)phenyl)hydrazono)-5-fluoroindolin-2-one (3g): The compound was purified by column chromatography as orange solid (358 mg, 90% yield) using 10% ethylacetate in hexane; m.p. 172°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.86 (t, *J* = 6.8 Hz, 1H), 6.97 (t, *J* = 10.0 Hz, 1H), 7.20 (t, *J* = 17.6 Hz, 3H), 7.36-7.46 (m, 6H), 7.63 (brs, 1H), 12.81 (s, 1H) ppm.; $^{13}C\{^{1}H\}$NMR (101 MHz, DMSO-d_6): δ 111.1 (d, $^{2}J_{C\text{-}F}$ = 25.5 Hz), 116.7, 116.8, 120.4, 120.9, 127.5 (d, $^{3}J_{C\text{-}F}$ = 8.9 Hz), 130.9, 134.5, 135.1, 136.2, 139.8, 141.5, 141.6, 148.0, 163.2 (d, $^{1}J_{C\text{-}F}$ = 190.8 Hz), 168.4 ppm.; $^{19}F\{^{13}C\}$NMR (377 MHz, DMSO-d_6): δ 120.2 ppm.; HRMS (ESI-TOF): Calcd for $[C_{20}H_{14}ON_3ClFS]^+$ *m/z* 398.0531. Found 398.0579.

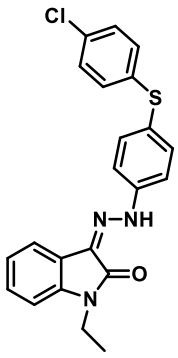


(Z)-3-(2-(4-((4-chlorophenyl)thio)phenyl)hydrazono)-5-nitroindolin-2-one (3h): The



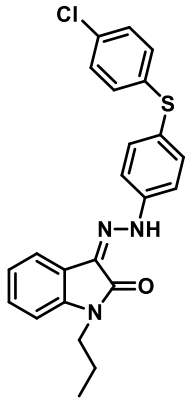
compound was purified by column chromatography as orange solid (391 mg, 92% yield) using 25% ethylacetate in hexane; m.p. above 250°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.90-7.03 (m, 1H), 7.10-7.21 (m, 3H), 7.29-7.40 (m, 4H), 8.06-8.21 (m, 2H), 8.39 (t, J = 8.4 Hz, 1H), 10.92 (s, 1H), 12.83 (s, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 110.5, 110.7, 114.6, 115.6, 120.7, 124.2, 125.8, 127.3, 128.5, 129.1, 130.5, 134.0, 135.8, 141.9, 143.2, 164.3 ppm.; HRMS (ESI-TOF): Calcd for $[C_{20}H_{14}O_3N_4ClS]^+$ *m/z* 425.0938. Found 425.0962.

(Z)-3-(2-(4-((4-chlorophenyl)thio)phenyl)hydrazono)-1-ethylindolin-2-one (3i): The

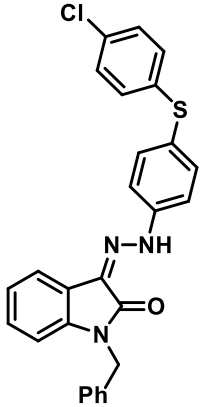


compound was purified by column chromatography as yellow solid (347 mg, 85% yield) using 5% ethylacetate in hexane; m.p. 135°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.26 (t, J = 7.2 Hz, 3H), 3.76-3.82 (m, 2H), 6.85 (d, J = 8.0 Hz, 1H), 7.02-7.09 (m, 3H), 7.15 (d, J = 8.4 Hz, 2H), 7.21-7.28 (m, 3H), 7.35 (d, J = 8.4 Hz, 2H), 7.58 (d, J = 7.6 Hz, 1H), 12.77 (s, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 13.1, 34.2, 108.6, 115.2, 119.2, 121.1, 122.5, 126.8, 128.0, 128.4, 129.1, 130.0, 132.0, 134.6, 136.6, 140.3, 142.8, 161.9 ppm.; HRMS (ESI-TOF): Calcd for $[C_{22}H_{19}ON_3ClS]^+$ *m/z* 408.0938. Found 408.0973.

(Z)-3-(2-(4-((4-chlorophenyl)thio)phenyl)hydrazono)-1-propylindolin-2-one (3j): The



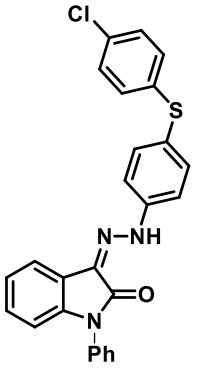
compound was purified by column chromatography as yellow solid (354 mg, 84% yield) using 5% ethylacetate in hexane; m.p. 142°C; ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.02 (t, J = 10.5 Hz, 3H), 1.75-1.84 (m, 2H), 3.81 (t, J = 3.6 Hz, 2H), 6.93 (d, J = 7.2 Hz, 1H), 7.11-7.18 (m, 4H), 7.24 (d, J = 8.1 Hz, 2H), 7.29-7.38 (m, 2H), 7.45 (d, J = 6.0 Hz, 2H), 7.67 (d, J = 5.4 Hz, 1H), 12.88 (s, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 11.4, 21.1, 41.1, 108.8, 115.2, 119.2, 121.0, 122.5, 126.8, 128.0, 128.4, 129.1, 129.3, 130.0, 132.0, 134.6, 140.7, 142.8, 162.3 ppm.; HRMS (ESI-TOF): Calcd for $[C_{23}H_{21}ON_3ClS]^+$ *m/z* 422.1095. Found 422.1133.



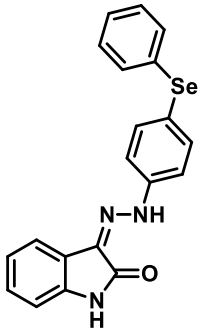
(Z)-1-benzyl-3-(2-(4-((4-chlorophenyl)thio)phenyl)hydrazono)indolin-2-one (3k): The compound was purified by column chromatography as yellow solid (400 mg, 85% yield) using 5% ethylacetate in hexane; m.p. 138°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.02 (s, 2H), 6.83 (d, J = 8.0 Hz,

1H), 7.12 (t, *J* = 7.6 Hz, 1H), 7.19 (t, *J* = 8.8 Hz, 2H), 7.24 (t, *J* = 8.4 Hz, 3H), 7.32-7.39 (m, 7H), 7.46 (d, *J* = 8.4 Hz, 2H), 7.68 (d, *J* = 7.2 Hz, 1H), 12.88 (s, 1H) ppm.; $^{13}C\{^{1}H\}$NMR (101 MHz, $CDCl_3$): δ 43.2, 109.4, 115.2, 119.2, 121.1, 122.8, 127.1, 127.3, 127.7, 127.8, 128.4, 128.9, 129.1, 130.1, 132.1, 134.5, 135.6, 136.5, 140.4, 142.7, 162.2 ppm.; HRMS (ESI-TOF): Calcd for $[C_{27}H_{21}ON_3ClS]^+$ *m/z* 470.1095. Found 470.1123.

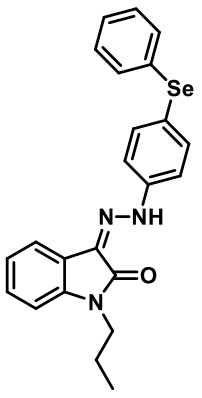
(Z)-3-(2-(4-((4-chlorophenyl)thio)phenyl)hydrazono)-1-phenylindolin-2-one (3l): The compound was purified by column chromatography as yellow solid (392 mg, 86% yield) using 10% ethylacetate in hexane; m.p. 132°C; ^{1}H NMR (300 MHz, DMSO-d_6): δ 6.88 (d, *J* = 7.8 Hz, 1H), 7.21 (d, *J* = 8.7 Hz, 3H), 7.30 (t, *J* = 7.8 Hz, 1H), 7.39 (d, *J* = 8.7 Hz, 2H), 7.46-7.63 (m, 9H), 7.69 (d, *J* = 6.3 Hz, 1H), 12.73 (s, 1H) ppm.; $^{13}C\{^{1}H\}$NMR (101 MHz, DMSO-d_6): δ 110.1, 116.2, 119.4, 120.9, 123.5, 126.1, 127.0, 127.8, 128.7, 129.3, 129.7, 130.0, 130.3, 131.4, 133.8, 135.1, 136.8, 141.5, 143.4, 160.8 ppm.; HRMS (ESI-TOF): Calcd for $[C_{26}H_{19}ON_3ClS]^+$ *m/z* 456.0938. Found 456.0970.



(Z)-3-(2-(4-(phenylselanyl)phenyl)hydrazono)indolin-2-one (3m): The compound was purified by column chromatography as orange solid (341 mg, 87% yield) using 10% ethylacetate in hexane; m.p. 205°C;^{1}H NMR (400 MHz, $CDCl_3$+DMSO-d_6): δ 6.85 (t, *J* = 7.2 Hz, 1H), 6.92-7.00 (m, 1H),7.11-7.18 (m, 4H), 7.23 (d, *J* = 5.2 Hz, 1H), 7.28-7.32 (m, 3H), 7.43-7.47 (m, 2H), 7.51 (t, *J* = 6.8 Hz, 1H), 9.92 (s, 1H), 12.75 (s, 1H) ppm.; $^{13}C\{^{1}H\}$NMR (101 MHz, DMSO-d_6): δ 114.5, 120.7, 123.8, 125.3, 127.7, 130.3, 133.1, 134.1, 134.4, 134.9, 136.1, 140.0, 141.7, 146.6, 148.2, 166.3 ppm.; HRMS (ESI-TOF): Calcd for $[C_{20}H_{16}ON_3Se]^+$ *m/z* 394.0460. Found 394.0513.

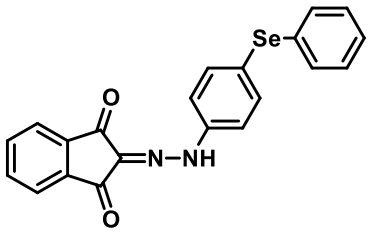


(Z)-3-(2-(4-(phenylselanyl)phenyl)hydrazono)-1-propylindolin-2-one (3n): The compound was purified by column chromatography as yellow solid (386 mg, 89% yield) using 5% ethylacetate in hexane; m.p. 135°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.01 (t, *J* = 7.6 Hz, 3H), 1.76-1.82 (m, 2H), 3.79 (t, *J* = 7.2 Hz, 2H), 6.92 (d, *J* = 8.0 Hz, 1H), 7.13 (t, *J* = 7.6 Hz, 1H), 7.25-7.34 (m, 6H), 7.42 (d, *J* = 6.8 Hz, 2H), 7.56 (d, *J* = 8.4 Hz, 2H), 7.66 (d, *J* = 7.6 Hz, 1H), 12.86 (s, 1H) ppm.; $^{13}C\{^{1}H\}$NMR (101 MHz, $CDCl_3$): δ 11.5, 21.2, 41.1, 108.8, 115.2, 119.1, 121.1, 122.5, 123.2, 126.7, 127.7, 128.2,

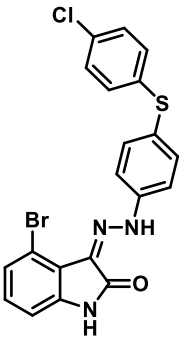


129.2, 131.5, 132.6, 135.7, 140.6, 142.5, 162.3 ppm.; HRMS (ESI-TOF): Calcd for $[C_{23}H_{22}ON_3Se]^+$ *m/z* 436.0929. Found 436.0955.

2-(2-(4-(phenylselanyl)phenyl)hydrazono)-1H-indene-1,3(2H)-dione (3o): The compound was purified by column chromatography as red solid (365 mg, 90% yield) using 10% ethylacetate in hexane; m.p. 197°C;^{1}H NMR (400 MHz, $CDCl_3$): δ 7.31 (d, *J* = 2.8 Hz, 2H), 7.38-7.41 (m, 1H), 7.44-7.54 (m, 6H), 7.61 (d, *J* = 8.0 Hz, 1H), 7.80 (t, *J* = 4.4 Hz, 1H), 7.90 (d, *J* = 6.0 Hz, 1H), 7.97 (d, *J* = 7.6 Hz, 1H),13.46 (s, 1H) ppm.; $^{13}C\{^1H\}$NMR (101 MHz, $CDCl_3$): δ 117.0, 122.9, 123.2, 127.2, 127.6, 129.4, 131.0, 132.9, 134.2, 134.5, 135.0, 135.4, 138.8, 140.3, 140.6, 186.0, 188.7 ppm.; HRMS (ESI-TOF): Calcd for $[C_{21}H_{15}O_2N_2Se]^+$ *m/z* 408.0299. Found 408.0354.

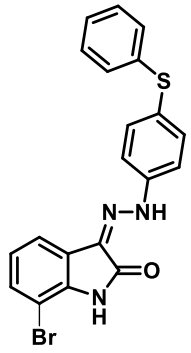


(Z)-3-(2-(4-((4-chlorophenyl)thio)phenyl)hydrazono)indolin-2-one (3p): The compound was purified by column chromatography as orange solid (288 mg, 76% yield) using 10% ethylacetate in hexane; m.p. 198°C; ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.93 (d, *J* = 6.0 Hz, 1H), 7.13 (t, *J* = 6.0 Hz, 1H), 7.18 (d, *J* = 6.3 Hz, 2H), 7.24-7.27 (m, 3H), 7.38 (d, *J* = 6.6 Hz, 2H), 7.45 (d, *J* = 6.3 Hz, 2H), 7.66 (d, *J* = 5.7 Hz, 1H), 7.90 (brs, 1H), 12.75 (s, 1H) ppm.; $^{13}C\{^1H\}$NMR (101 MHz, DMSO-d_6): δ 111.0, 115.8, 119.3, 121.4, 122.4, 125.4, 129.4, 129.7, 130.2, 131.3, 135.3, 137.0, 140.6, 143.6, 145.3, 163.5 ppm.; HRMS (ESI-TOF): Calcd for $[C_{20}H_{15}ON_3ClS]^+$ *m/z* 380.0625. Found 380.0659.

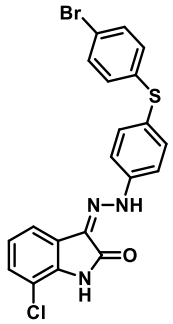


(Z)-4-bromo-3-(2-(4-((4-chlorophenyl)thio)phenyl)hydrazono)indolin-2-one (3q): The compound was purified by column chromatography as orange solid (344 mg, 75% yield) using 10% ethylacetate in hexane; m.p. 220°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.93 (d, *J* = 8.0 Hz, 1H), 7.11-7.19 (m, 3H), 7.24-7.26 (m, 2H), 7.38 (d, *J* = 8.4 Hz, 2H), 7.45 (d, *J* = 8.4 Hz, 2H), 7.66 (d, *J* = 7.6 Hz, 1H), 7.78 (brs, 1H), 12.76 (s, 1H) ppm.; $^{13}C\{^1H\}$NMR (101 MHz, $CDCl_3$): δ 110.3, 115.3, 119.4, 121.8, 122.8, 127.3, 127.6, 128.5, 129.1, 130.1, 132.1, 134.5, 136.4, 138.2, 142.6, 163.3 ppm.; HRMS (ESI-TOF): Calcd for $[C_{20}H_{14}ON_3ClBrS]^+$ *m/z* 457.9730. Found 457.9764.

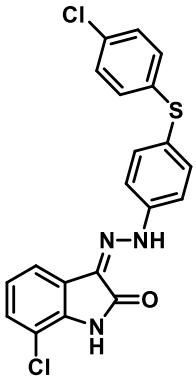
(Z)-7-bromo-3-(2-(4-(phenylthio)phenyl)hydrazono)indolin-2-one (3r): The compound was purified by column chromatography as orange solid (327 mg, 77% yield) using 15% ethylacetate in hexane; m.p. 210°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.93 (d, J = 7.6 Hz, 1H), 7.13 (t, J = 7.6 Hz, 1H), 7.19-7.27(m, 3H), 7.29-7.31 (m, 2H), 7.37 (d, J = 8.8 Hz, 2H), 7.46 (d, J = 8.8 Hz, 2H), 7.66 (d, J = 7.6 Hz, 1H), 7.85 (brs, 1H), 12.76 (s, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 110.2, 115.2, 119.3, 121.8, 122.8, 126.2, 127.4, 128.1, 128.4, 129.0, 129.1, 134.2, 137.6, 138.2, 142.3, 163.4 ppm.; HRMS (ESI-TOF): Calcd for $[C_{20}H_{15}ON_3BrS]^+$ *m/z* 424.0120. Found 424.0175.



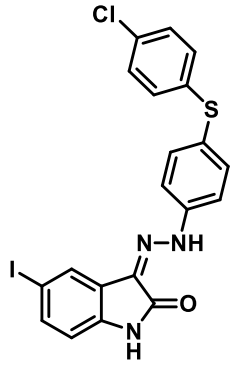
(Z)-3-(2-(4-((4-bromophenyl)thio)phenyl)hydrazono)-7-chloroindolin-2-one (3s): The compound was purified by column chromatography as orange solid (358 mg, 78% yield) using 15% ethylacetate in hexane; m.p. 214°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 6.97-7.04 (m, 2H), 7.23-7.37 (m, 6H), 7.42-7.49 (m, 2H), 7.54 (d, J = 6.0 Hz, 1H),7.68 (s, 1H), 12.72 (s, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 115.5, 117.5, 123.2, 123.6, 127.0, 127.9, 128.3, 129.2, 130.5, 132.3, 134.2, 135.4, 136.0, 142.1, 162.5ppm.; HRMS (ESI-TOF): Calcd for $[C_{20}H_{14}ON_3ClBrS]^+$ *m/z* 457.9730. Found 457.9777.



(Z)-7-chloro-3-(2-(4-((4-chlorophenyl)thio)phenyl)hydrazono)indolin-2-one (3t): The compound was purified by column chromatography as orange solid (315 mg, 76% yield) using 15% ethylacetate in hexane; m.p. 208°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.08 (t, J = 7.8 Hz, 1H), 7.19 (d, J = 8.4 Hz, 2H), 7.25 (s, 3H), 7.37-7.45 (m, 4H), 7.56 (d, J = 7.6 Hz, 1H), 7.86 (brs, 1H), 12.81 (s, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 114.6, 115.5, 117.5, 123.2, 123.5, 127.0, 127.9, 128.3, 129.2, 130.5, 132.3, 134.2, 135.4, 136.0, 142.1, 162.5 ppm.; HRMS (ESI-TOF): Calcd for $[C_{20}H_{14}ON_3Cl_2S]^+$ *m/z* 414.0235. Found 414.0272.

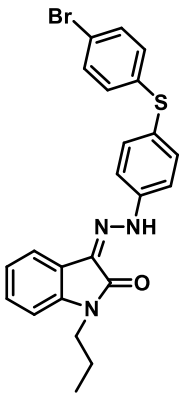


(Z)-3-(2-(4-((4-chlorophenyl)thio)phenyl)hydrazono)-5-iodoindolin-2-one (3u): The compound was purified by column chromatography as orange solid (405 mg, 80% yield) using 10% ethylacetate in hexane; m.p. 235°C; ^{1}H NMR (300 MHz, DMSO-d_6): 6.96-6.77 (m, 3H), 7.17 (d, J = 8.7 Hz, 1H), 7.32-7.42 (m, 2H), 7.53 (t, J = 10.5 Hz, 1H), 7.62-7.65 (m, 4H), 10.66 (s, 1H), 12.70 (brs, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, DMSO-



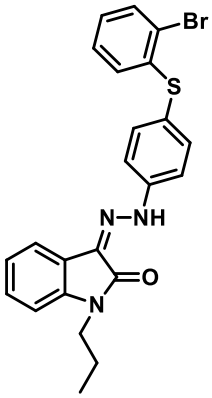
d_6): δ 101.3, 118.2, 120.9, 132.4, 132.8, 134.4, 135.1, 138.2, 138.3, 139.6, 144.3, 144.4, 146.4, 146.5, 167.6, 176.3 ppm.; HRMS (ESI-TOF): Calcd for $[C_{20}H_{14}ON_3ClIS]^+$ *m/z* 505.9592. Found 505.9645.

(Z)-3-(2-(4-((4-bromophenyl)thio)phenyl)hydrazono)-1-propylindolin-2-one (3v): The



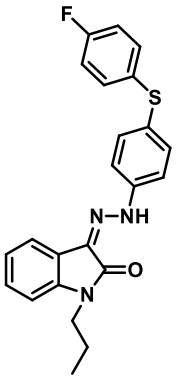
compound was purified by column chromatography as yellow solid (410 mg, 88% yield) using 5% ethylacetate in hexane; m.p. 138°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.02 (t, *J* = 7.6 Hz, 3H), 1.75-1.84 (m, 2H), 3.79 (t, *J* = 7.2 Hz, 2H), 6.93 (d, *J* = 8.0 Hz, 1H), 7.09-7.17 (m, 3H), 7.31 (t, *J* = 7.6 Hz, 1H),7.38 (t, *J* = 8.4 Hz, 4H), 7.45 (d, *J* = 8.4 Hz, 2H),7.67 (d, *J* = 7.6 Hz, 1H), 12.88 (s, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 11.5, 21.1, 41.1, 108.8, 115.2, 119.2, 119.8, 121.0, 122.5, 126.5, 128.0, 128.4, 130.1, 132.0, 134.8, 137.4, 140.7, 142.9, 162.3 ppm.; HRMS (ESI-TOF): Calcd for $[C_{23}H_{21}ON_3BrS]^+$ *m/z* 466.0589. Found 466.0639.

(Z)-3-(2-(4-((2-bromophenyl)thio)phenyl)hydrazono)-1-propylindolin-2-one (3w): The compound was purified by column chromatography as yellow solid (406 mg, 87% yield)



using 5% ethylacetate in hexane; m.p. 148°C; ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.02 (t, *J* = 7.5 Hz, 3H), 1.74-1.83 (m, 2H), 3.80 (t, *J* = 7.2 Hz, 2H), 6.81 (d, *J* = 9.0 Hz, 1H), 6.92-7.02 (m, 2H), 7.14 (t, *J* = 7.5 Hz, 2H), 7.32 (t, *J* = 8.1 Hz, 1H), 7.42 (d, *J* = 8.7 Hz, 2H), 7.52-7.56 (m, 3H), 7.68 (d, *J* = 7.2 Hz, 1H), 12.91 (s, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 6.7, 16.4, 36.4, 104.1, 110.6, 114.5, 116.2, 116.5, 117.8, 120.0, 121.7, 122.9, 123.2, 123.5, 123.7, 128.0, 131.6, 135.6, 136.0, 138.7, 157.5 ppm.; HRMS (ESI-TOF): Calcd for $[C_{23}H_{21}ON_3BrS]^+$ *m/z* 466.0589. Found 466.0651.

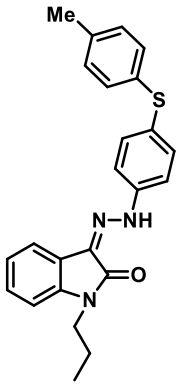
(Z)-3-(2-(4-((4-fluorophenyl)thio)phenyl)hydrazono)-1-propylindolin-2-one (3x): The compound was purified by column chromatography as yellow solid (365 mg, 90% yield)



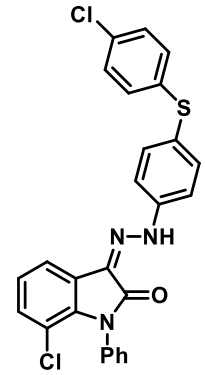
using 5% ethylacetate in hexane; m.p. 126°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 1.01 (t, *J* = 7.6 Hz, 3H), 1.74-1.84 (m, 2H), 3.79 (t, *J* = 7.2 Hz, 2H), 6.92 (d, *J* = 8.0 Hz, 1H), 7.01 (t, *J* = 8.4 Hz, 2H), 7.13 (t, *J* = 7.6 Hz, 1H), 7.28-7.32 (m, 5H), 7.39 (d, *J* = 8.4 Hz, 2H), 7.66 (d, *J* = 7.6 Hz, 1H), 12.86 (s, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 11.5, 21.2, 41.1, 108.8, 115.1,116.2 (d, $^2J_{C\text{-}F}$ = 22.0 Hz), 119.1, 121.1, 122.5, 127.7, 128.4 (d, $^3J_{C\text{-}F}$ = 8.1 Hz), 131.9, 132.0, 132.2, 133.4, 140.6, 142.3, 161.8 (d, $^1J_{C\text{-}F}$ = 247.2 Hz), 162.2 ppm.;

$^{19}F\{^{13}C\}$NMR (377 MHz, $CDCl_3$): δ 115.3 ppm.; HRMS (ESI-TOF): Calcd for $[C_{23}H_{21}ON_3FS]^+$ *m/z* 406.1390. Found 406.1435.

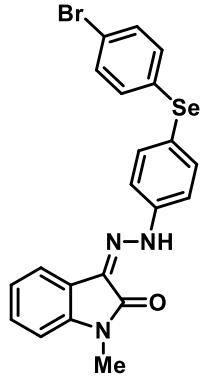
(Z)-1-propyl-3-(2-(4-(p-tolylthio)phenyl)hydrazono)indolin-2-one (3y): The compound was purified by column chromatography as orange solid (345 mg, 86% yield) using 5% ethylacetate in hexane; m.p. 120°C; ^1H NMR (400 MHz, $CDCl_3$): δ 1.01 (t, *J* = 7.6 Hz, 3H), 1.76-1.84 (m, 2H), 2.34 (s, 3H), 3.79 (t, *J* = 7.2 Hz, 2H), 6.92 (d, *J* = 7.6 Hz, 1H), 7.11-7.14 (m, 3H),7.23 (d, *J* = 8.0 Hz, 2H), 7.31 (t, *J* = 8.4 Hz, 3H), 7.39 (d, *J* = 8.4 Hz, 2H), 7.66 (d, *J* = 7.6 Hz, 1H), 12.86 (s, 1H) ppm.; $^{13}C\{^1H\}$NMR (101 MHz, $CDCl_3$): δ 11.5, 21.070, 21.071, 41.1, 108.8, 115.0, 119.1, 121.1, 122.5, 127.5, 128.1, 129.1, 129.9, 130.3, 133.1, 133.3, 136.6, 140.5, 142.0, 162.3 ppm.; HRMS (ESI-TOF): Calcd for $[C_{24}H_{24}ON_3S]^+$ *m/z* 402.1641. Found 402.1678.



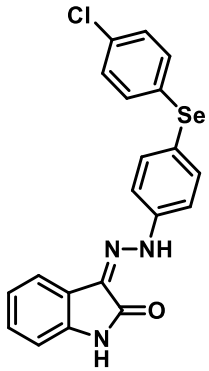
(Z)-7-chloro-3-(2-(4-((4-chlorophenyl)thio)phenyl)hydrazono)-1-phenylindolin-2-one (3z): The compound was purified by column chromatography as yellow solid (417 mg, 85% yield) using 5% ethylacetate in hexane; m.p. 128°C; ^1H NMR (400 MHz, $CDCl_3$): δ 6.97 (d, *J* = 8.8 Hz, 1H), 7.19 (d, *J* = 13.2 Hz, 2H), 7.25 (s, 1H), 7.39 (t, *J* = 8.4 Hz, 3H), 7.44-7.50 (m, 6H), 7.59 (t, *J* = 11.2 Hz, 2H), 7.75 (d, *J* = 12.0 Hz, 1H), 12.95 (s, 1H) ppm.; $^{13}C\{^1H\}$NMR (101 MHz, $CDCl_3$):δ 109.9, 115.3, 119.2, 121.0, 123.2, 126.3, 127.4, 127.5, 128.3, 129.1, 129.4, 129.7, 130.2, 132.1, 133.6, 134.4, 136.4, 141.0, 142.6, 161.6 ppm.; HRMS (ESI-TOF): Calcd for $[C_{26}H_{17}ON_3Cl_2S]^+$ *m/z* 490.0548. Found 490.0583.



(Z)-3-(2-(4-((4-bromophenyl)selanyl)phenyl)hydrazono)-1-methylindolin-2-one (3aa): The compound was purified by column chromatography as yellow solid (427 mg, 88% yield) using 10% ethylacetate in hexane; m.p. 142°C; ^1H NMR (400 MHz, $CDCl_3$): δ 3.36 (s, 3H), 6.91 (d, *J* = 7.6 Hz, 1H), 7.09-7.16 (m, 3H), 7.30-7.39 (m, 5H), 7.45 (d, *J* = 8.4 Hz, 2H), 6.91 (d, *J* = 7.6 Hz, 1H), 7.65 (d, *J* = 7.6 Hz, 1H), 12.83 (s, 1H) ppm.; $^{13}C\{^1H\}$NMR (101 MHz, $CDCl_3$): δ 25.5, 108.5, 115.2, 119.1, 119.8, 120.9, 122.7, 126.5, 127.9, 128.5, 130.1, 132.0, 134.8, 137.4, 141.2, 142.9, 162.2 ppm.; HRMS (ESI-TOF): Calcd for $[C_{21}H_{17}ON_3BrSe]^+$ *m/z* 485.9721. Found 485.9763.



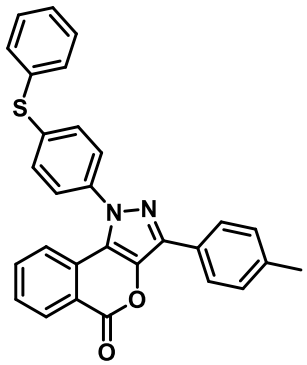
(Z)-3-(2-(4-((4-chlorophenyl)selanyl)phenyl)hydrazono)indolin-2-one (3ab): The



compound was purified by column chromatography as yellow solid (367 mg, 86% yield) using 15% ethylacetate in hexane; m.p. 138°C;^{1}H NMR (400 MHz, $CDCl_3$): δ 6.83-6.95 (m, 1H), 6.97-7.11 (m, 1H), 7.14-7.30 (m, 7H), 7.44-7.51 (m, 3H), 9.92 (s, 1H), 12.79 (s, 1H) ppm.; $^{13}C\{^{1}H\}$NMR (101 MHz, $CDCl_3$): δ 110.6, 112.5, 115.0, 119.0, 121.5, 122.1, 122.7, 126.7, 128.3, 129.2, 131.3, 132.5, 135.7, 139.5, 142.6, 164.0 ppm.; HRMS (ESI-TOF): Calcd for $[C_{20}H_{15}ON_3ClSe]^{+}$*m/z* 428.0070. Found 428.0123.

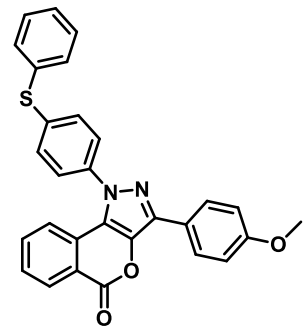
Spectral data of compounds 4:

1-(4-(phenylthio)phenyl)-3-(p-tolyl)isochromeno[4,3-c]pyrazol-5(1*H*)-one (4a): The compound was purified by column chromatography as white solid (405 mg, 88% yield) using

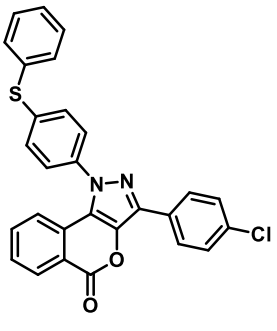


7% ethylacetate in hexane; m.p. 172°C; ^{1}H NMR (400 MHz, $CDCl_3$+DMSO-d_6): δ 2.31 (s, 3H), 7.17-7.19 (m, 3H), 7.29-7.36 (m, 4H), 7.41-7.45 (m, 5H), 7.51-7.55 (m, 2H), 7.92-7.96 (m, 2H), 8.34 (d, *J* = 7.6 Hz, 1H) ppm.; $^{13}C\{^{1}H\}$NMR (101 MHz, $CDCl_3$+DMSO-d_6): δ 21.3, 119.5, 120.9, 123.5, 126.2, 127.1, 127.3, 127.9, 128.3, 128.5, 129.3, 129.6, 129.9, 132.0, 132.9, 133.1, 134.7, 136.6, 137.6, 138.2, 138.3, 139.4, 161.4 ppm.; HRMS (ESI-TOF): Calcd for $[C_{29}H_{21}O_2N_2S]^{+}$ *m/z* 461.1324. Found 461.1371.

3-(4-methoxyphenyl)-1-(4-(phenylthio)phenyl)isochromeno[4,3-c]pyrazol-5(1*H*)-one



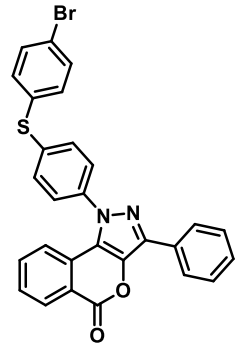
(4b): The compound was purified by column chromatography as white solid (386 mg, 81% yield) using 7% ethylacetate in hexane; m.p. 198°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.86 (s, 3H), 6.98 (d, *J* = 8.8 Hz, 2H), 7.27 (d, *J* = 8.0 Hz, 1H), 7.38-7.46 (m, 5H), 7.51-7.55 (m, 5H), 7.60 (t, *J* = 7.6 Hz, 1H), 8.07 (d, *J* = 8.4 Hz, 2H), 8.42 (d, *J* = 8.0 Hz, 1H) ppm.;$^{13}C\{^{1}H\}$NMR (101 MHz, $CDCl_3$): δ 55.3, 114.1, 116.9, 119.6, 121.0, 122.8, 123.5, 127.2, 127.8, 128.4, 129.6, 130.1, 131.0, 132.1, 132.9, 133.3, 134.7, 136.5, 137.6, 138.4, 139.3, 159.8, 161.4 ppm.; HRMS (ESI-TOF): Calcd for $[C_{29}H_{21}O_3N_2S]^{+}$ *m/z* 477.1274. Found 477.1309.



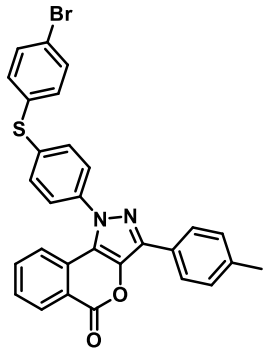
3-(4-chlorophenyl)-1-(4-(phenylthio)phenyl)isochromeno[4,3-c]pyrazol-5(1*H*)-one (4c): The compound was purified by column chromatography as white solid (408 mg, 85% yield) using 5%

ethylacetate in hexane; m.p. >250°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ7.284 (d, J = 1.6 Hz, 1H), 7.40-7.45 (m, 7H), 7.50-7.57 (m, 5H), 7.62 (t, J = 6.4 Hz, 1H), 8.08 (d, J = 16.4 Hz, 2H), 8.45 (d, J = 8.0 Hz, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ119.6, 121.0, 123.8, 127.1, 127.6, 127.8, 128.5, 128.7, 128.8, 128.9, 129.7, 129.9, 132.3, 133.10, 133.2, 134.3, 134.8, 136.6, 136.8, 138.1, 139.9, 161.2 ppm.; HRMS (ESI-TOF): Calcd for $[C_{28}H_{18}O_2N_2ClS]^+$ *m/z* 480.0699. Found 480.0754.

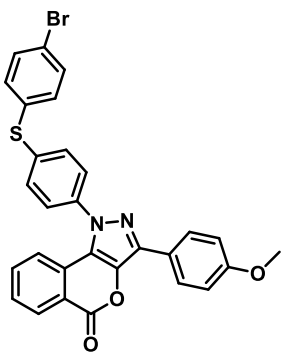
1-(4-((4-bromophenyl)thio)phenyl)-3-phenylisochromeno[4,3-c]pyrazol-5(1*H*)-one (4d): The compound was purified by column chromatography as white solid (462 mg, 88% yield) using 7% ethylacetate in hexane; m.p. 191°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.30 (d, J = 7.2 Hz, 1H), 7.37-7.43 (m, 3H), 7.47-7.52 (m, 4H), 7.54-7.58 (m, 5H), 7.64 (t, J = 8.0 Hz, 1H),8.18 (d, J = 7.6 Hz, 2H), 8.48 (d, J = 7.6 Hz, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 119.8, 120.9, 122.5, 123.7, 126.5, 127.3, 127.9, 128.6, 128.73, 128.79, 130.1, 130.6, 132.3, 132.7, 132.9, 134.0, 134.7, 137.0, 137.9, 138.5, 138.7, 161.4 ppm.; HRMS (ESI-TOF): Calcd for $[C_{28}H_{18}O_2N_2BrS]^+$ *m/z* 525.0273. Found 525.0309.



1-(4-((4-bromophenyl)thio)phenyl)-3-(p-tolyl)isochromeno[4,3-c]pyrazol-5(1*H*)-one (4e): The compound was purified by column chromatography as white solid (442 mg, 82% yield) using 7% ethylacetate in hexane; m.p. 227°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 2.48 (s, 3H), 7.29-7.31 (m, 3H), 7.38 (d, J = 8.0 Hz, 2H), 7.48 (d, J = 7.2 Hz, 2H), 7.56 (t, J = 8.4 Hz, 5H), 7.63 (t, J = 7.6 Hz, 1H), 8.07 (d, J = 7.6 Hz, 2H), 8.48 (d, J = 7.6 Hz, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 21.4, 119.8, 120.9, 122.5, 123.6, 126.4, 127.2, 127.3, 128.0, 128.6, 129.4, 130.7, 132.3, 132.7, 133.0, 134.0, 134.7, 136.9, 138.0, 138.4, 138.6, 138.8, 161.4 ppm.; HRMS (ESI-TOF): Calcd for $[C_{29}H_{20}O_2N_2BrS]^+$ *m/z* 539.0351. Found 539.0397.

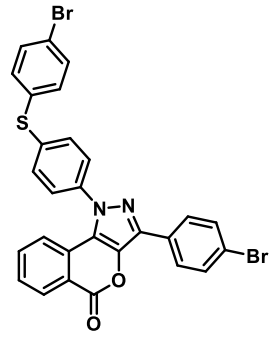


1-(4-((4-bromophenyl)thio)phenyl)-3-(4-methoxyphenyl)isochromeno[4,3-c]pyrazol-5(1H)-one (4f): The compound was purified by column chromatography as white solid (466 mg, 84% yield) using 7% ethylacetate in hexane; m.p. 192°C; ^{1}H NMR (400 MHz, DMSO-d_6): δ 3.81 (s, 3H), 7.10 (d, J = 11.6 Hz, 2H), 7.20 (d, J = 10.4 Hz, 1H), 7.45 (d, J = 11.2 Hz, 2H), 7.54 (d, J = 11.2 Hz, 2H), 7.63-7.71 (m, 5H), 7.80 (t, J = 9.6 Hz, 1H), 7.94 (d, J = 11.6 Hz, 2H), 8.33 (d, J = 9.6 Hz, 1H) ppm.; ^{13}C{^{1}H}NMR (101

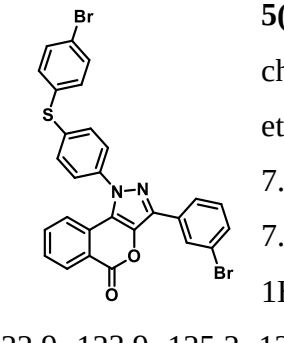


MHz, DMSO-d_6): δ 55.6, 114.9, 119.6, 121.3, 122.0, 122.9, 124.0, 127.7, 127.8, 128.1, 129.5, 131.3, 132.0, 133.2, 133.4, 134.2, 135.9, 136.3, 136.8, 137.4, 139.1, 159.9, 161.1 ppm.; HRMS (ESI-TOF): Calcd for $[C_{29}H_{20}O_3N_2BrS]^+$ *m/z* 555.0379. Found 555.0434.

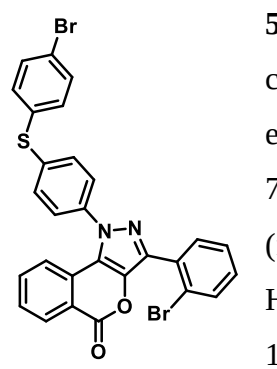
3-(4-bromophenyl)-1-(4-((4-bromophenyl)thio)phenyl)isochromeno[4,3-c]pyrazol-5(1*H*)-one (4g): The compound was purified by column chromatography as white solid (538 mg, 89% yield) using 7% ethylacetate in hexane; m.p. 185°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.28 (d, *J* = 8.0 Hz, 1H), 7.40 (t, *J* = 8.4 Hz, 2H), 7.46 (t, *J* = 12.4 Hz, 2H), 7.53-7.57 (m, 3H),7.60-7.68 (m, 4H), 7.76 (d, *J* = 8.4 Hz, 1H), 8.05 (d, *J* = 8.4 Hz, 2H), 8.47 (d, *J* = 6.4 Hz, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 119.7, 120.9, 122.6, 123.8, 127.2, 127.8, 127.9, 128.6, 128.8, 129.1, 130.4, 131.1, 131.9, 132.3, 132.7, 132.8, 133.3, 134.2, 134.8, 138.5, 138.9, 161.2 ppm.; HRMS (ESI-TOF): Calcd for $[C_{28}H_{17}O_2N_2Br_2S]^+$ *m/z* 604.9358. Found 604.9402.

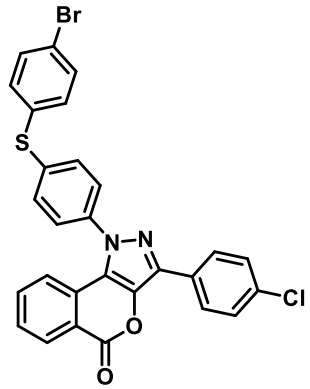


3-(3-bromophenyl)-1-(4-((4-bromophenyl)thio)phenyl)isochromeno[4,3-c]pyrazol-5(1*H*)-one (4h): The compound was purified by column chromatography as white solid (508 mg, 84% yield) using 7% ethylacetate in hexane; m.p. 182°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.29-7.30 (m, 1H), 7.35-7.43 (m, 3H), 7.45-7.60 (m, 8H), 7.64 (t, *J* = 7.6 Hz, 1H), 8.14 (d, *J* = 7.6 Hz, 1H), 8.31 (s, 1H), 8.49 (d, *J* = 7.6 Hz, 1H)ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 119.8, 120.9, 122.6, 122.9, 123.9, 125.2, 127.1, 127.2, 127.8, 128.5, 128.84, 128.89, 129.0, 129.7, 129.9, 130.3, 130.4, 131.5, 132.4, 132.8, 133.1, 134.2, 134.8, 161.1 ppm.; HRMS (ESI-TOF): Calcd for $[C_{28}H_{17}O_2N_2Br_2S]^+$ *m/z* 604.9279. Found 604.9318.

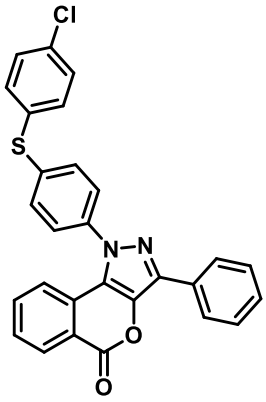


3-(2-bromophenyl)-1-(4-((4-bromophenyl)thio)phenyl)isochromeno[4,3-c]pyrazol-5(1*H*)-one (4i): The compound was purified by column chromatography as white solid (483 mg, 80% yield) using 5% ethylacetate in hexane; m.p. 170°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.28-7.37 (m, 4H), 7.42-7.49 (m, 2H), 7.52-7.58 (m, 4H), 7.60-7.66 (m, 3H), 7.75 (t, *J* = 8.4 Hz, 1H), 7.82-7.85 (m, 1H), 8.48 (t, *J* = 8.0 Hz, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 120.0, 121.0, 123.4, 127.2, 127.3, 127.9, 128.2, 128.8, 128.9, 129.2, 130.2, 130.5, 130.6, 130.9, 131.9, 132.3, 132.7, 133.4, 133.9, 134.7, 138.5, 138.7, 138.9, 161.2 ppm.; HRMS (ESI-TOF): Calcd for $[C_{28}H_{17}O_2N_2Br_2S]^+$ *m/z* 604.9279. Found 604.9335.

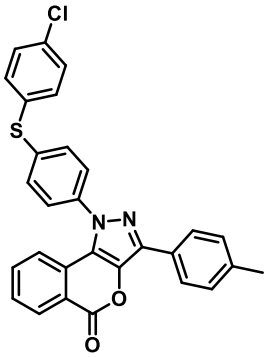


1-(4-((4-bromophenyl)thio)phenyl)-3-(4-chlorophenyl)isochromeno[4,3-c]pyrazol-5(1*H*)-one (4j): 

The compound was purified by column chromatography as white solid (492 mg, 88% yield) using 7% ethylacetate in hexane; m.p. 240°C; ^{1}H NMR (400 MHz, $CDCl_3$+DMSO-d_6): δ 7.21-7.28 (m, 2H), 7.34-7.41 (m, 7H), 7.47-7.49 (m, 3H), 7.51-7.58 (m, 1H), 8.02-8.06 (m, 2H), 8.38-8.40 (m, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$+DMSO-d_6): δ 119.6, 120.9, 123.8, 127.1, 127.6, 127.7, 128.7, 128.8, 128.9, 129.8, 130.1, 131.8, 132.2, 134.1, 134.3, 134.6, 134.8, 136.6, 136.7, 138.4, 139.1, 161.1 ppm.; HRMS (ESI-TOF): Calcd for $[C_{28}H_{17}O_2N_2BrClS]^+$ *m/z* 558.9883. Found 558.9926.

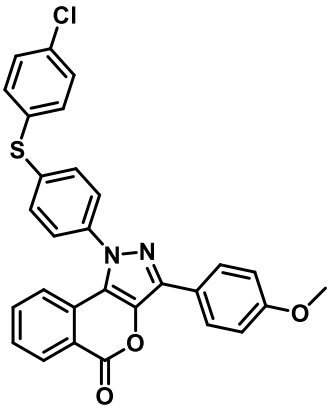
1-(4-((4-chlorophenyl)thio)phenyl)-3-phenylisochromeno[4,3-c]pyrazol-5(1*H*)-one (4k): 

The compound was purified by column chromatography as white solid (418 mg, 87% yield) using 7% ethylacetate in hexane; m.p. 182°C; ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.16-7.20 (m, 1H), 7.28-7.40 (m, 9H), 7.46-7.52 (m, 3H), 7.59 (t, *J* = 10.8 Hz, 1H), 7.97 (d, *J* = 6.6 Hz, 2H), 8.28 (d, *J* = 7.8 Hz, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 124.2, 125.7, 128.4, 131.1, 131.9, 132.1, 132.5, 133.3, 133.4, 133.5, 134.5, 134.9, 135.0, 136.8, 138.7, 139.1, 139.7, 141.5, 142.2, 143.2, 143.5, 166.0 ppm.; HRMS (ESI-TOF): Calcd for $[C_{28}H_{18}O_2N_2ClS]^+$ *m/z* 481.0778. Found 481.0811.

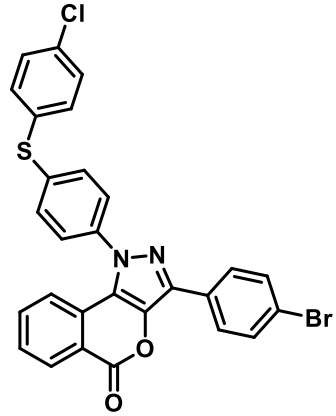
1-(4-((4-bromophenyl)thio)phenyl)-3-(p-tolyl)isochromeno[4,3-c]pyrazol-5(1*H*)-one (4l): 

The compound was purified by column chromatography as white solid (415 mg, 77% yield) using 7% ethylacetate in hexane; m.p. 213°C; ^{1}H NMR (400 MHz, DMSO-d_6): δ 2.36 (s, 3H), 7.20 (d, *J* = 8.0 Hz, 1H), 7.34 (d, *J* = 8.0 Hz, 2H), 7.45 (d, *J* = 8.0 Hz, 2H), 7.54 (d, *J* = 8.0 Hz, 2H), 7.68 (t, *J* = 9.6 Hz, 5H),7.80 (t, *J* = 8.0 Hz, 1H), 7.90 (d, *J* = 8.0 Hz, 2H), 8.32 (d, *J* = 8.4 Hz, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, DMSO-d_6): δ 21.4, 119.6, 121.2, 122.0, 124.0, 126.1, 127.6, 127.8, 128.1, 129.5, 129.9, 131.2, 131.9, 133.2, 133.4, 134.2, 135.8, 136.5, 136.8, 137.4, 138.5, 139.1, 161.0 ppm.; HRMS (ESI-TOF): Calcd for $[C_{29}H_{20}O_2N_2BrS]^+$ *m/z* 539.0430. Found 539.0471.

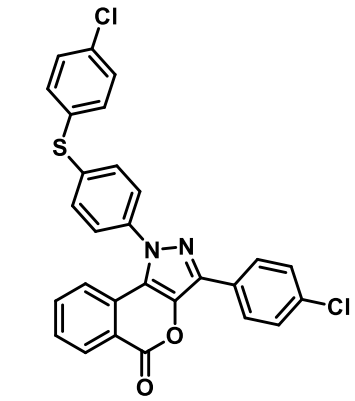
1-(4-((4-chlorophenyl)thio)phenyl)-3-(4-methoxyphenyl)isochromeno[4,3-c]pyrazol-5(1H)-one (4m): The compound was purified by column chromatography as white solid (419 mg, 82% yield) using 7% ethylacetate in hexane; m.p. 187°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.85 (s, 3H), 6.97 (d, J = 8.4 Hz, 2H), 7.26 (d, J = 8.0 Hz, 1H), 7.38 (d, J = 8.4 Hz, 2H),7.43-7.45 (m, 3H),7.48-7.61 (m, 5H), 8.06 (d, J = 8.4 Hz, 2H), 8.40 (d, J = 7.6 Hz, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 55.3, 114.1, 119.6, 120.9, 122.7, 123.5, 127.3, 127.8, 127.9, 128.5, 129.8, 130.4, 132.1, 132.2, 133.8, 134.4, 134.6, 136.6, 137.7, 138.4, 138.7, 159.8, 161.3 ppm.; ^{13}C{^{1}H} DEPT- 135 NMR (101 MHz, $CDCl_3$): δ 55.3, 114.1, 120.9, 127.2, 127.8, 128.5, 129.8, 130.4, 132.1, 133.8, 134.6 ppm.;HRMS (ESI-TOF): Calcd for $[C_{29}H_{20}O_3N_2ClS]^+$ *m/z* 511.0884. Found 511.0942.



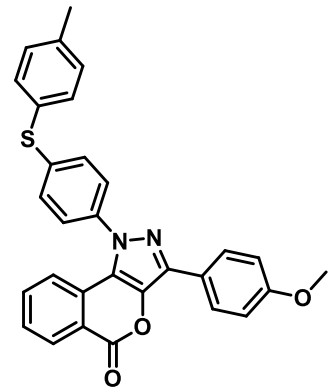
3-(4-bromophenyl)-1-(4-((4-chlorophenyl)thio)phenyl)isochromeno[4,3-c]pyrazol-5(1*H*)-one (4n): The compound was purified by column chromatography as white solid (498 mg, 89% yield) using 7% ethylacetate in hexane; m.p. 233°C; ^{1}H NMR (400 MHz, DMSO-d_6): δ 7.16 (d, J = 8.0 Hz, 1H), 7.44-7.59 (m, 8H), 7.66 (d, J = 8.0 Hz, 3H), 7.78 (t, J = 7.2 Hz, 1H), 7.98 (d, J = 8.4 Hz, 2H), 8.30 (d, J = 8.0 Hz, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, DMSO-d_6): δ 121.2, 124.2, 124.3, 127.7, 127.90, 127.97, 128.0, 129.1, 129.5, 129.6, 129.7, 130.40, 130.49, 132.0, 133.0, 133.6, 135.9, 136.5, 138.4, 139.0, 157.5, 161.0 ppm.; HRMS (ESI-TOF): Calcd for $[C_{28}H_{17}O_2N_2BrClS]^+$ *m/z* 578.9883. Found 578.9951.



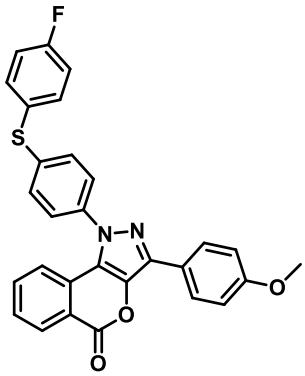
3-(4-chlorophenyl)-1-(4-((4-chlorophenyl)thio)phenyl)isochromeno[4,3-c]pyrazol-5(1*H*)-one (4o): The compound was purified by column chromatography as white solid (438 mg, 85% yield) using 7% ethylacetate in hexane; m.p. 177°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.27 (d, J = 6.4 Hz, 1H), 7.40 (d, J = 8.4 Hz, 2H), 7.45-7.48 (m, 5H),7.53-7.58 (m, 3H), 7.64 (t, J = 8.4 Hz, 2H), 8.10 (d, J = 8.4 Hz, 2H), 8.46 (d, J = 7.6 Hz, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ119.7, 121.0, 123.8, 127.2, 127.7, 127.8, 128.7, 128.8, 128.9, 129.9, 130.2, 131.9, 132.3, 134.1, 134.4, 134.7, 134.8, 136.7, 136.8, 138.4, 139.1, 161.2 ppm.; HRMS (ESI-TOF): Calcd for $[C_{28}H_{17}O_2N_2Cl_2S]^+$ *m/z* 515.0389. Found 515.0424.



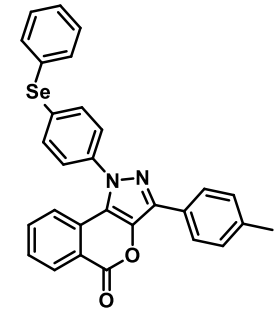
3-(4-methoxyphenyl)-1-(4-(p-tolylthio)phenyl)isochromeno[4,3-c]pyrazol-5(1*H*)-one (4p): The compound was purified by column chromatography as white solid (382 mg, 78% yield) using 7% ethylacetate in hexane; m.p. 203°C;^{1}H NMR (400 MHz, $CDCl_3$): δ 2.42 (s, 3H), 3.88 (s, 3H), 7.01 (d, J = 8.0 Hz, 2H), 7.27 (t, J = 9.2 Hz, 3H), 7.38 (d, J = 8.0 Hz, 2H), 7.46-7.56 (m, 5H), 7.62 (t, J = 9.2 Hz, 1H), 8.10 (d, J = 8.4 Hz, 2H), 8.46 (d, J = 8.0 Hz, 1H)ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 20.7, 55.3, 114.1, 119.7, 121.0, 122.9, 123.6, 127.1, 127.9, 128.0, 128.5, 129.03, 129.06, 130.5, 132.2, 133.8, 134.7, 136.5, 137.6, 137.9, 139.0, 140.6, 159.8, 161.5 ppm.; HRMS (ESI-TOF): Calcd for $[C_{30}H_{23}O_3N_2S]^+$ *m/z* 491.1351. Found 491.1384.



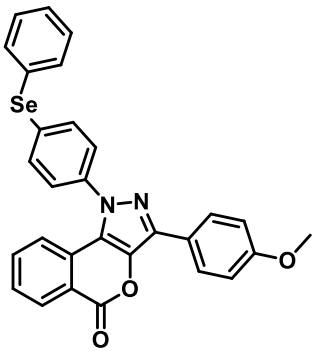
1-(4-((4-fluorophenyl)thio)phenyl)-3-(4-methoxyphenyl)isochromeno[4,3-c]pyrazol-5(1*H*)-one (4q): The compound was purified by column chromatography as white solid (425 mg, 86% yield) using 7% ethylacetate in hexane; m.p. 189°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.87 (s, 3H), 6.99-7.06 (m, 2H), 7.14 (t, J = 8.8 Hz, 2H), 7.28 (t, J = 16.4 Hz, 2H), 7.39 (d, J = 8.8 Hz, 2H), 7.50-7.61 (m, 5H), 8.09 (d, J = 6.4 Hz, 2H), 8.45 (d, J = 8.0 Hz, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 55.3, 114.1, 116.6 (d, $^{2}J_{C\text{-}F}$ = 22.2 Hz), 117.0, 119.7, 120.9, 122.8, 123.5, 127.2, 127.8, 128.6 (d, $^{3}J_{C\text{-}F}$ = 8.7 Hz), 129.2, 131.2, 132.2, 134.7, 135.8, 136.6, 137.7, 138.2, 139.9, 159.8, 161.4, 163.0 (d, $^{1}J_{C\text{-}F}$ = 250.2 Hz) ppm.; ^{19}F{^{13}C}NMR (377 MHz, $CDCl_3$): δ 111.8 ppm.; HRMS (ESI-TOF): Calcd for $[C_{29}H_{20}O_3N_2FS]^+$ *m/z* 495.1179. Found 495.1239.



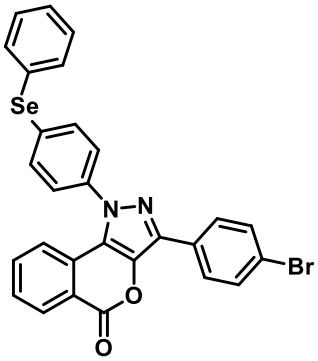
1-(4-(phenylselanyl)phenyl)-3-(p-tolyl)isochromeno[4,3-c]pyrazol-5(1*H*)-one (4r): The compound was purified by column chromatography as white solid (406 mg, 80% yield) using 7% ethylacetate in hexane; m.p. 220°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 2.42 (s, 3H), 7.29 (t, J = 7.6 Hz, 3H), 7.39-7.47 (m, 5H), 7.52-7.57 (m, 5H), 7.63 (t, J = 7.6 Hz, 1H), 8.07 (d, J = 7.6 Hz, 2H), 8.47 (d, J = 7.6 Hz, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 21.4, 119.7, 121.0, 123.6, 126.4, 127.2, 127.3, 128.0, 128.4, 128.6, 129.4, 129.6, 130.1, 132.2, 132.9, 133.3, 134.7, 136.8, 137.9, 138.3, 138.5, 139.5, 161.5 ppm.; ^{13}C{^{1}H} DEPT- 135 NMR (101 MHz, $CDCl_3$): δ 21.4, 121.0, 126.4, 127.2, 128.4, 128.6, 129.4, 129.6, 130.1, 132.2, 132.9, 134.7 ppm.; HRMS (ESI-TOF): Calcd for $[C_{29}H_{21}O_2N_2Se]^+$ *m/z* 509.0690. Found 509.0743.



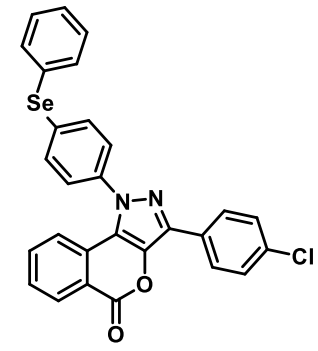
3-(4-methoxyphenyl)-1-(4-(phenylselanyl)phenyl)isochromeno[4,3-c]pyrazol-5(1*H*)-one (4s): The compound was purified by column chromatography as white solid (429 mg, 82% yield) using 7% ethylacetate in hexane; m.p. 205°C; ^{1}H NMR (400 MHz, $CDCl_3$+ DMSO-d_6): δ3.81 (s, 3H), 7.05 (d, J = 8.4 Hz, 2H), 7.21-7.53 (m, 9H),7.73-7.94 (m, 5H), 8.23-8.33 (m, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$+DMSO-d_6): δ 55.5, 114.6, 117.7, 119.6, 121.2, 123.0, 123.8, 127.5, 127.7, 128.8, 129.3, 129.8, 130.2, 130.5, 131.9, 132.9, 135.7, 135.8, 138.7, 140.5, 141.6, 159.9, 161.0 ppm.; HRMS (ESI-TOF): Calcd for $[C_{29}H_{21}O_3N_2Se]^+$ *m/z* 525.0718. Found 525.0757.



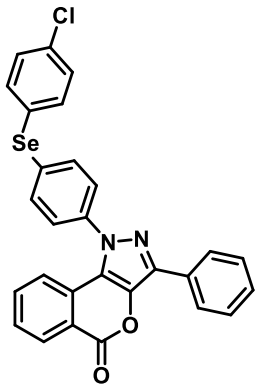
3-(4-bromophenyl)-1-(4-(phenylselanyl)phenyl)isochromeno[4,3-c]pyrazol-5(1*H*)-one (4t): The compound was purified by column chromatography as white solid (504 mg, 88% yield) using 7% ethylacetate in hexane; m.p. 187°C; ^{1}H NMR (400 MHz, DMSO-d_6): δ 7.20 (d, J = 8.0 Hz, 1H), 7.41-7.47 (m, 3H), 7.54 (t, J = 8.0 Hz, 4H), 7.64-7.72 (m, 5H), 7.81 (d, J = 8.0 Hz, 1H), 8.01 (d, J = 7.6 Hz, 2H), 8.32 (d, J = 8.0 Hz, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, DMSO-d_6): δ 119.6, 121.3, 122.1, 124.1, 126.3, 127.8, 128.1, 129.1, 129.4, 129.6, 130.3, 130.5, 131.2, 132.0, 133.2, 134.3, 135.9, 136.7, 136.8, 137.6, 139.0, 161.0 ppm.; HRMS (ESI-TOF): Calcd for $[C_{28}H_{18}O_2N_2BrSe]^+$ *m/z* 572.9718. Found 572.9766.



3-(4-chlorophenyl)-1-(4-(phenylselanyl)phenyl)isochromeno[4,3-c]pyrazol-5(1*H*)-one (4u): The compound was purified by column chromatography as white solid (470 mg, 89% yield) using 7% ethylacetate in hexane; m.p. 178°C; ^{1}H NMR (400 MHz, $CDCl_3$+DMSO-d_6): δ 7.27-7.31 (m, 1H), 7.36-7.44 (m, 7H), 7.48-7.56 (m, 5H), 7.62 (t, J = 7.6 Hz, 1H), 8.08 (d, J = 8.4 Hz, 2H), 8.44 (d, J = 8.0 Hz, 1H) ppm.; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$+DMSO-d_6): δ 119.6, 121.0, 123.8, 127.1, 127.6, 127.8, 128.5, 128.7, 128.8, 128.9, 129.7, 129.8, 130.5, 132.2, 133.1, 134.3, 134.8, 136.6, 136.7, 138.0, 140.0, 161.2 ppm.; HRMS (ESI-TOF): Calcd for $[C_{28}H_{18}O_2N_2ClSe]^+$ *m/z* 529.0223. Found 529.0268.

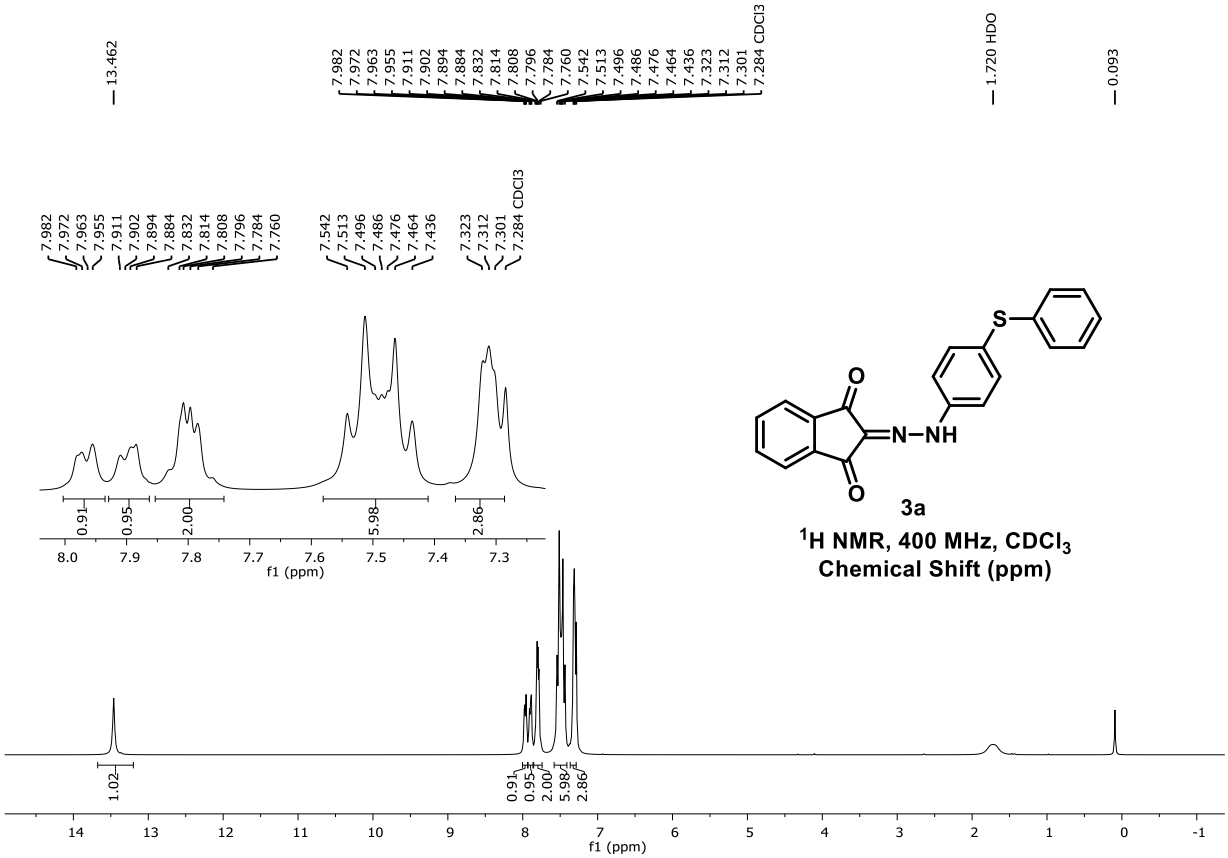


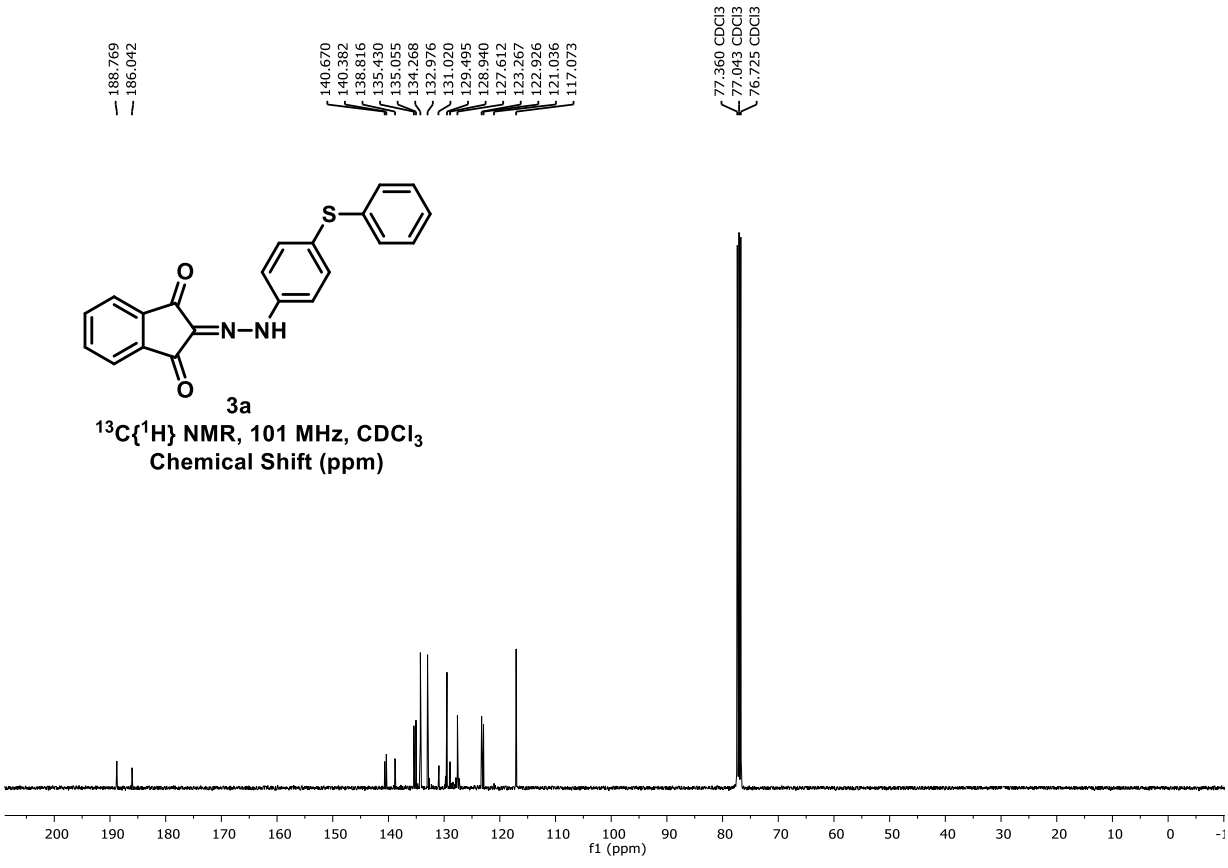
1-(4-((4-chlorophenyl)selanyl)phenyl)-3-phenylisochromeno[4,3-c]pyrazol-5(1*H*)-one

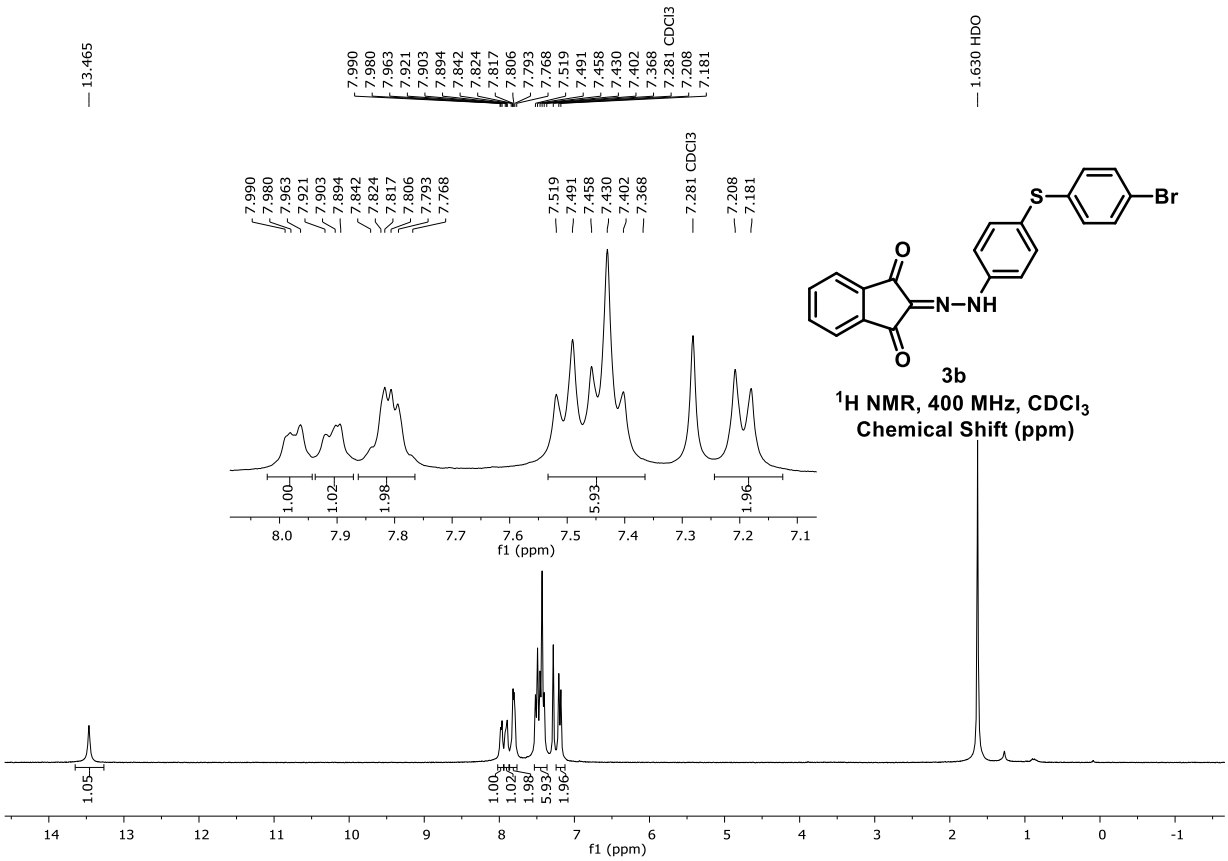


(4v): The compound was purified by column chromatography as white solid (459 mg, 87% yield) using 10% ethylacetate in hexane; m.p. 170°C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.28 (d, J = 8.0 Hz, 1H), 7.38-7.41 (m, 3H), 7.45-7.51 (m, 6H), 7.54-7.57 (m, 3H), 7.62 (t, J = 8.0 Hz, 1H), 8.16 (d, J = 7.6 Hz, 1H), 8.46 (d, J = 7.6 Hz, 1H) ppm; ^{13}C{^{1}H}NMR (101 MHz, $CDCl_3$): δ 119.7, 120.9, 123.7, 126.5, 127.3, 127.9, 128.6, 128.71, 128.77, 129.8, 130.1, 130.3, 132.0, 132.3, 133.9, 134.5, 134.7, 137.0, 137.8, 138.6, 138.8, 161.3 ppm; HRMS (ESI-TOF): Calcd for $[C_{28}H_{18}O_2N_2ClSe]^+$ *m/z* 529.0223. Found 529.0211.

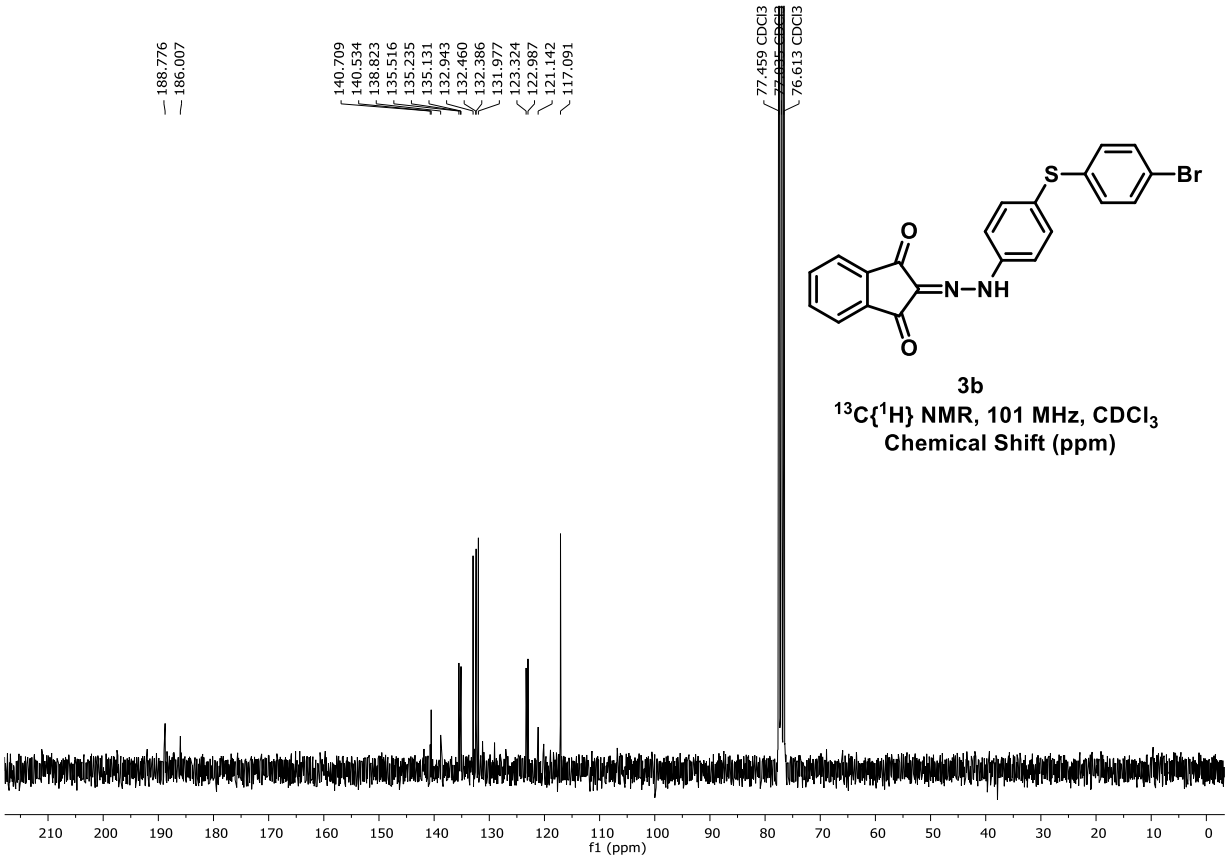
^{1}H and ^{13}C NMR Spectra of compounds 3a-ab:



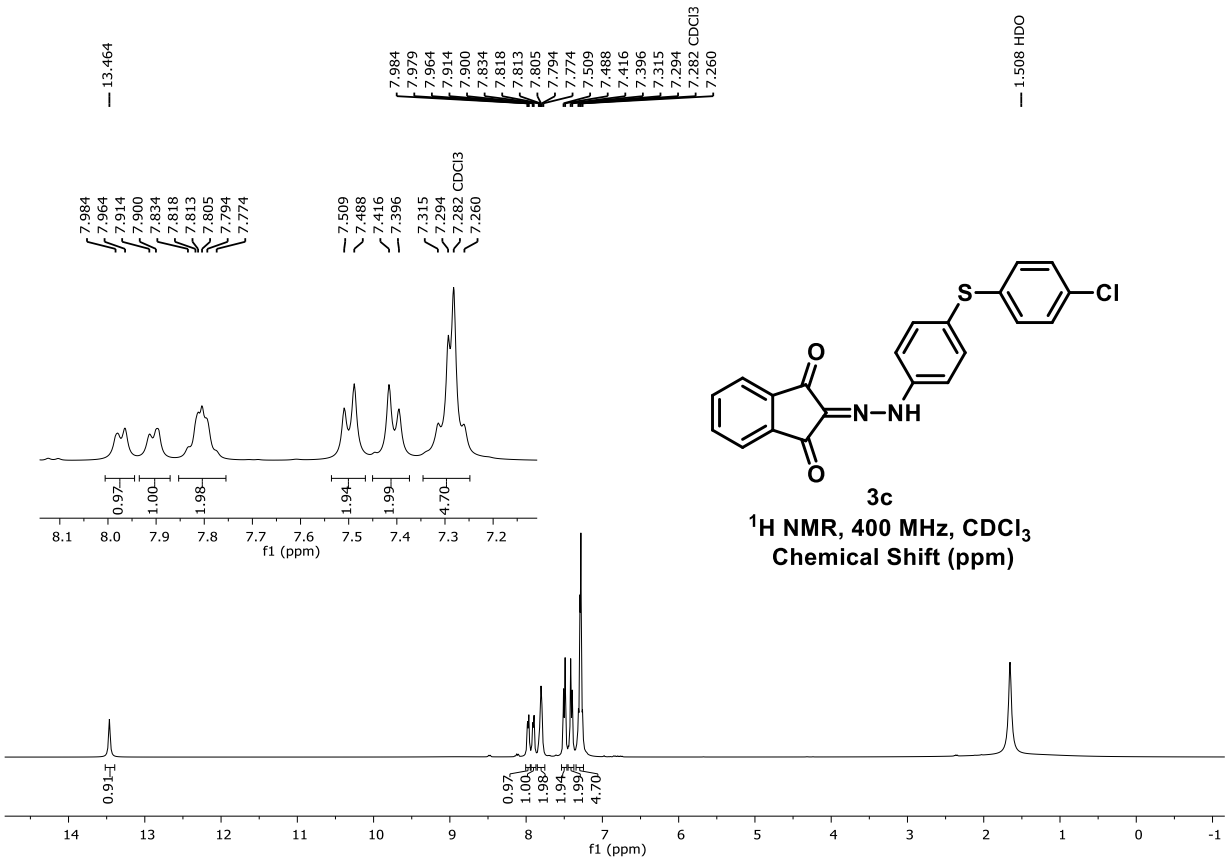


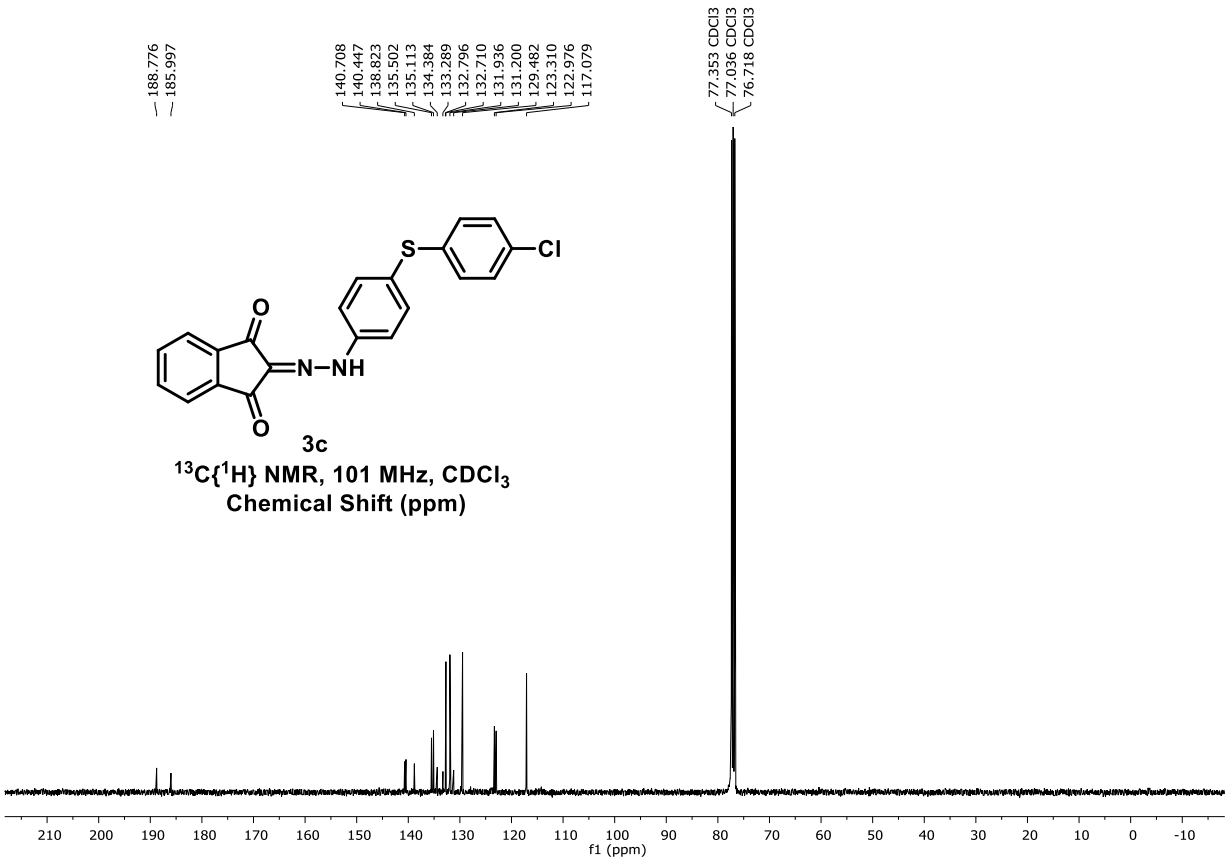


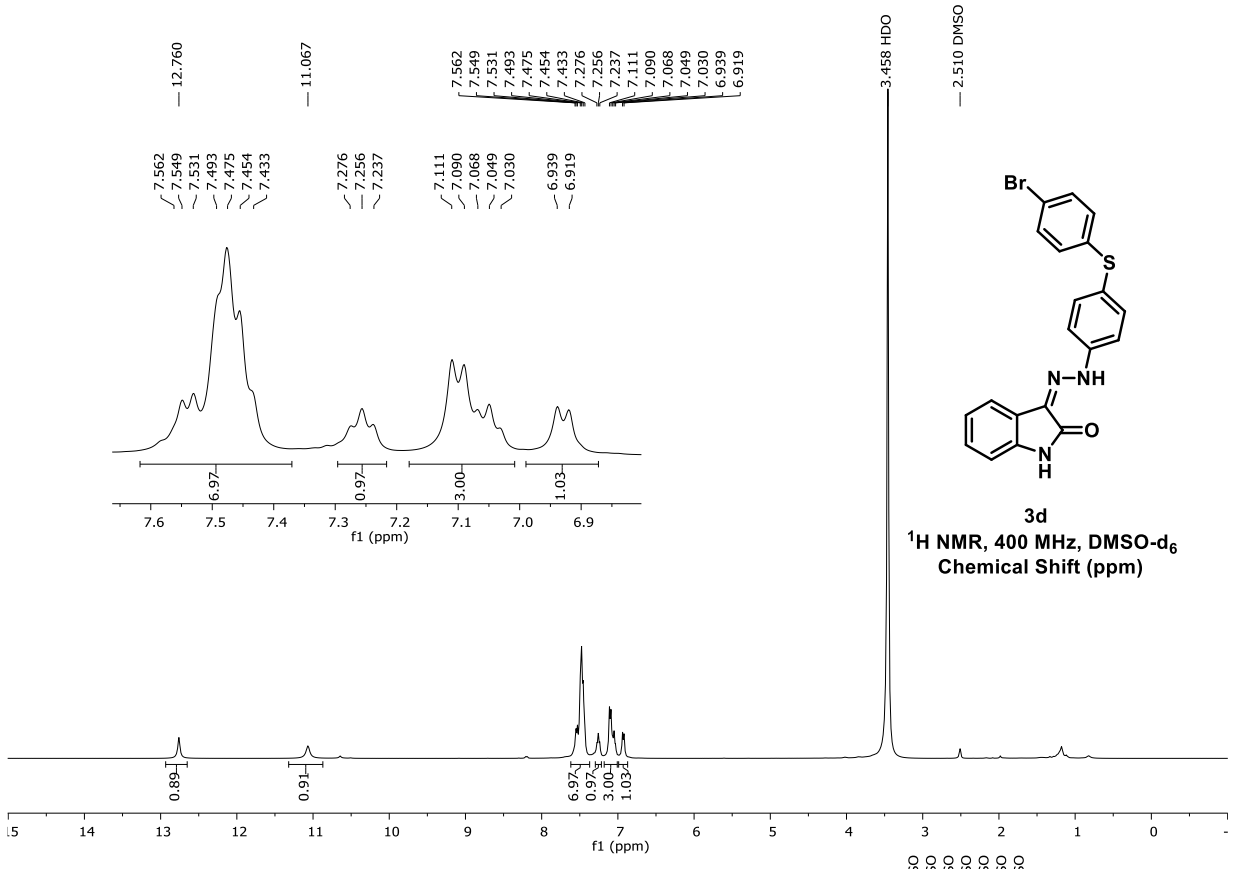
3b
^{1}H NMR, 400 MHz, $CDCl_3$
Chemical Shift (ppm)



3b
$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$
Chemical Shift (ppm)


13.464
7.984
7.979
7.964
7.914
7.900
7.834
7.818
7.813
7.805
7.794
7.774
7.509
7.488
7.416
7.396
7.315
7.294
7.282 CDCl3
7.260
1.508 HDO
0.97
1.00
1.98
1.94
1.99
4.70
f1 (ppm)
S
Cl
O
N–NH
O
3c
^{1}H NMR, 400 MHz, CDCl$_3$
Chemical Shift (ppm)

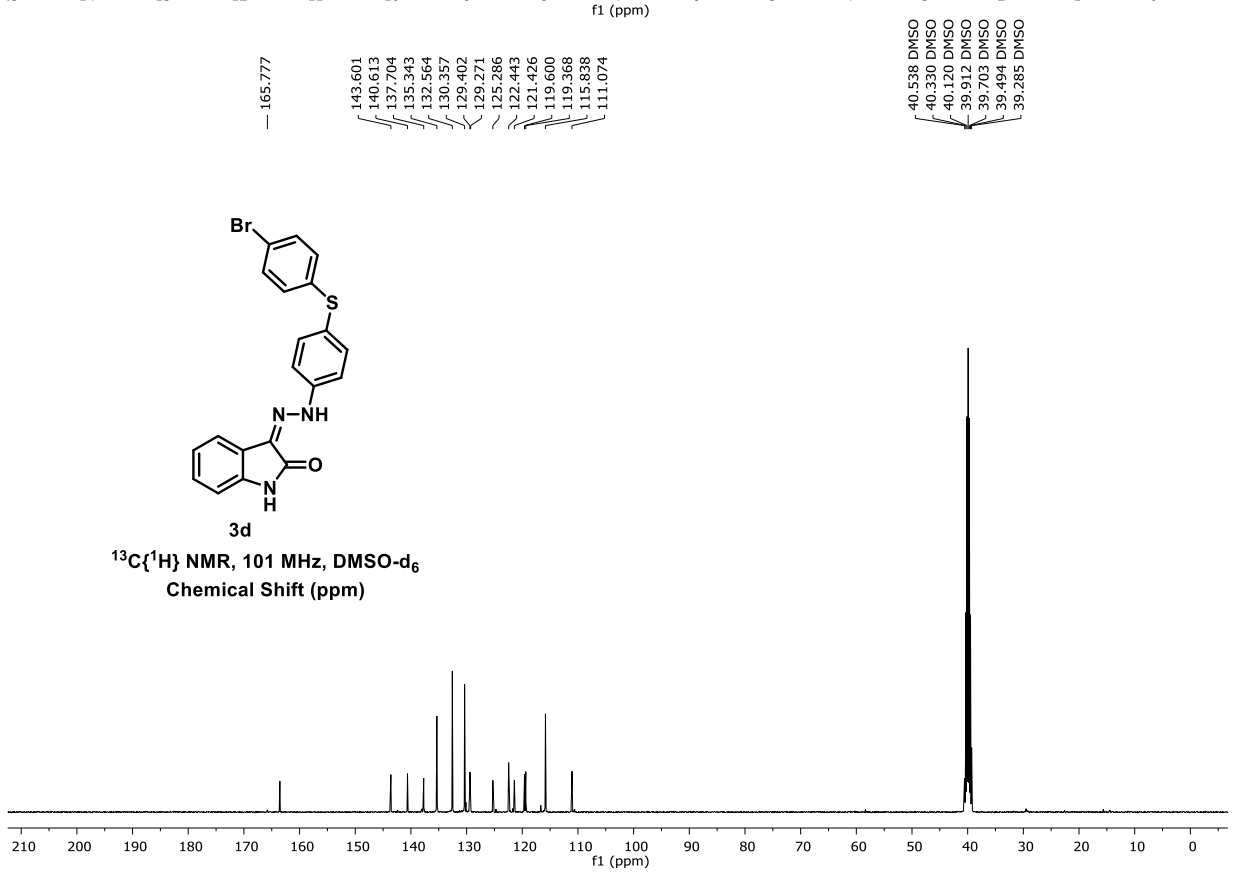

188.776
185.997
140.708
140.447
138.823
135.502
135.113
134.384
133.289
132.796
132.710
131.936
131.200
129.482
123.310
122.976
117.079
77.353 CDCl3
77.036 CDCl3
76.718 CDCl3
f1 (ppm)
S
Cl
O
N–NH
O
3c
^{13}C{^{1}H} NMR, 101 MHz, CDCl$_3$
Chemical Shift (ppm)



3d

^{1}H NMR, 400 MHz, DMSO-d_6

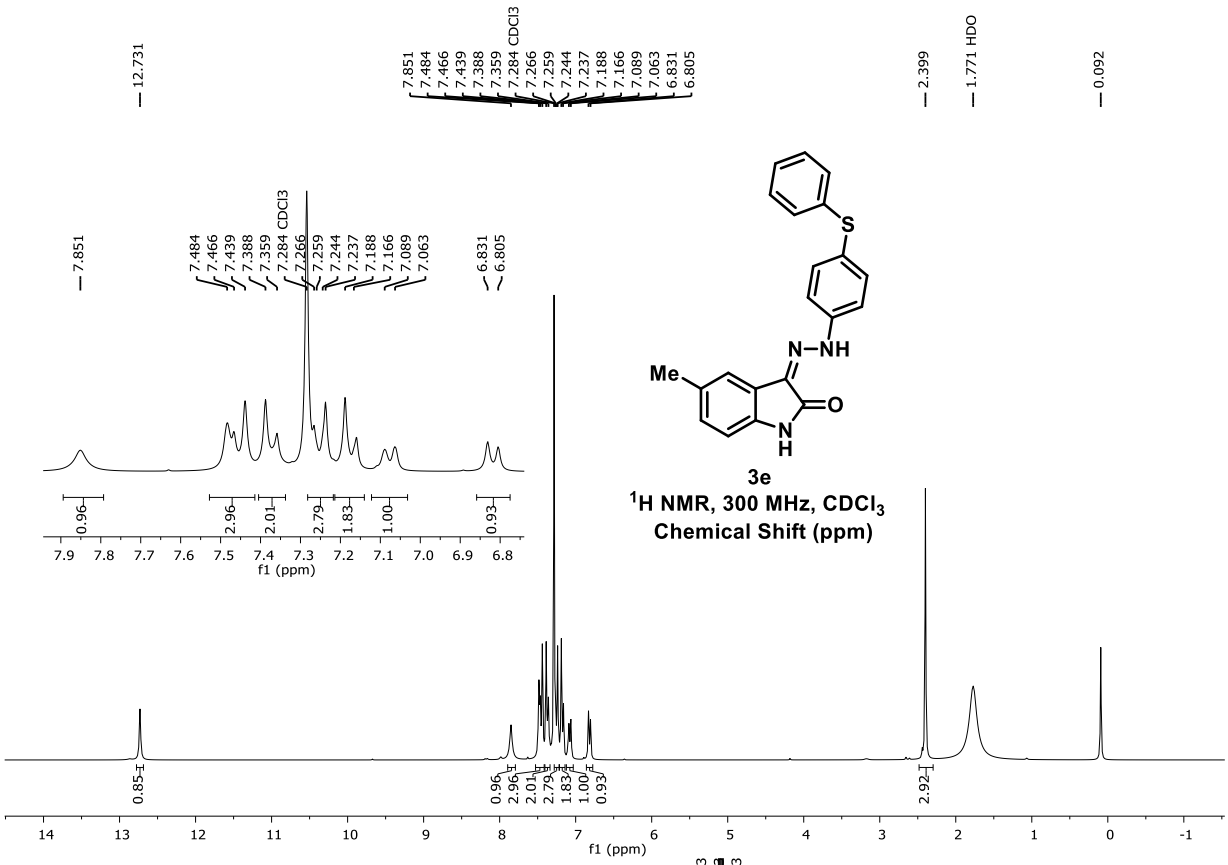
Chemical Shift (ppm)



3d

^{13}C{^{1}H} NMR, 101 MHz, DMSO-d_6

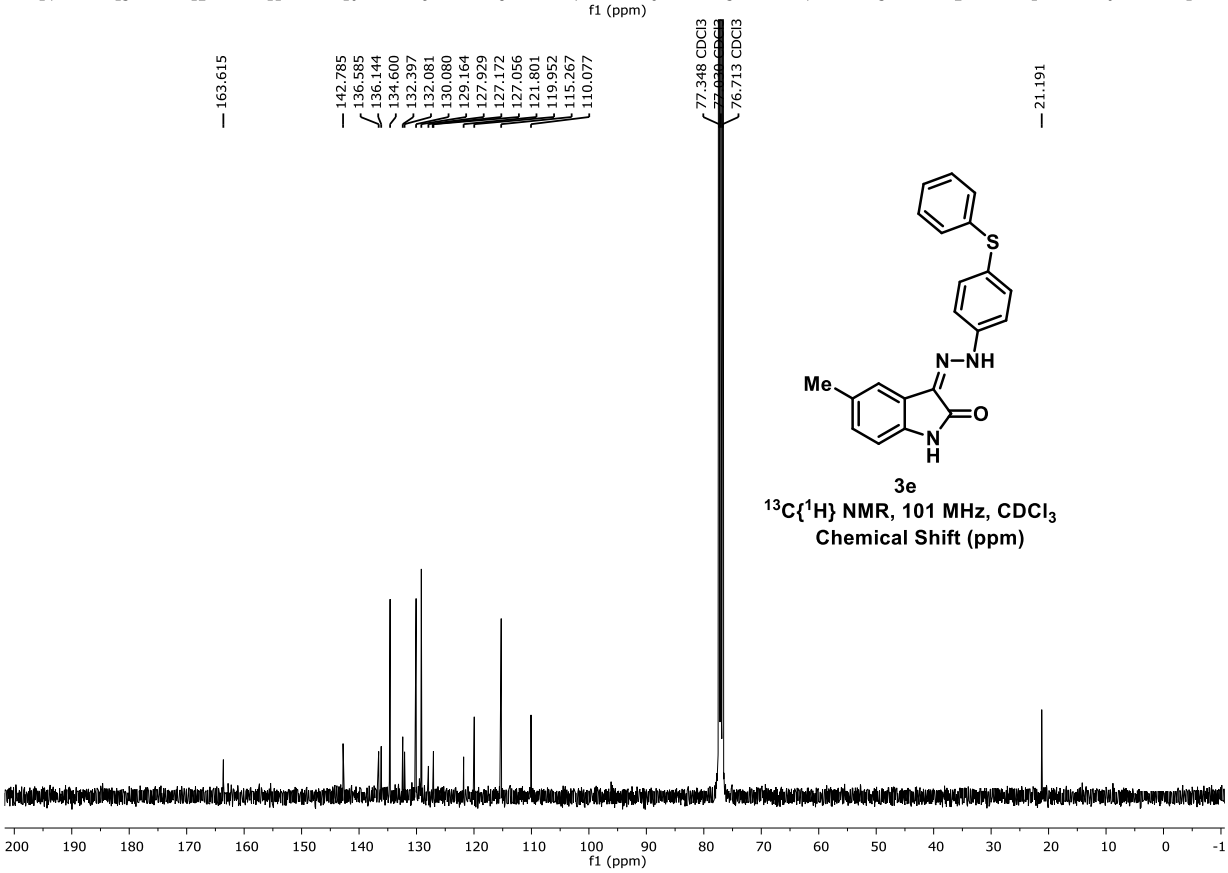
Chemical Shift (ppm)



3e

^{1}H NMR, 300 MHz, $CDCl_3$

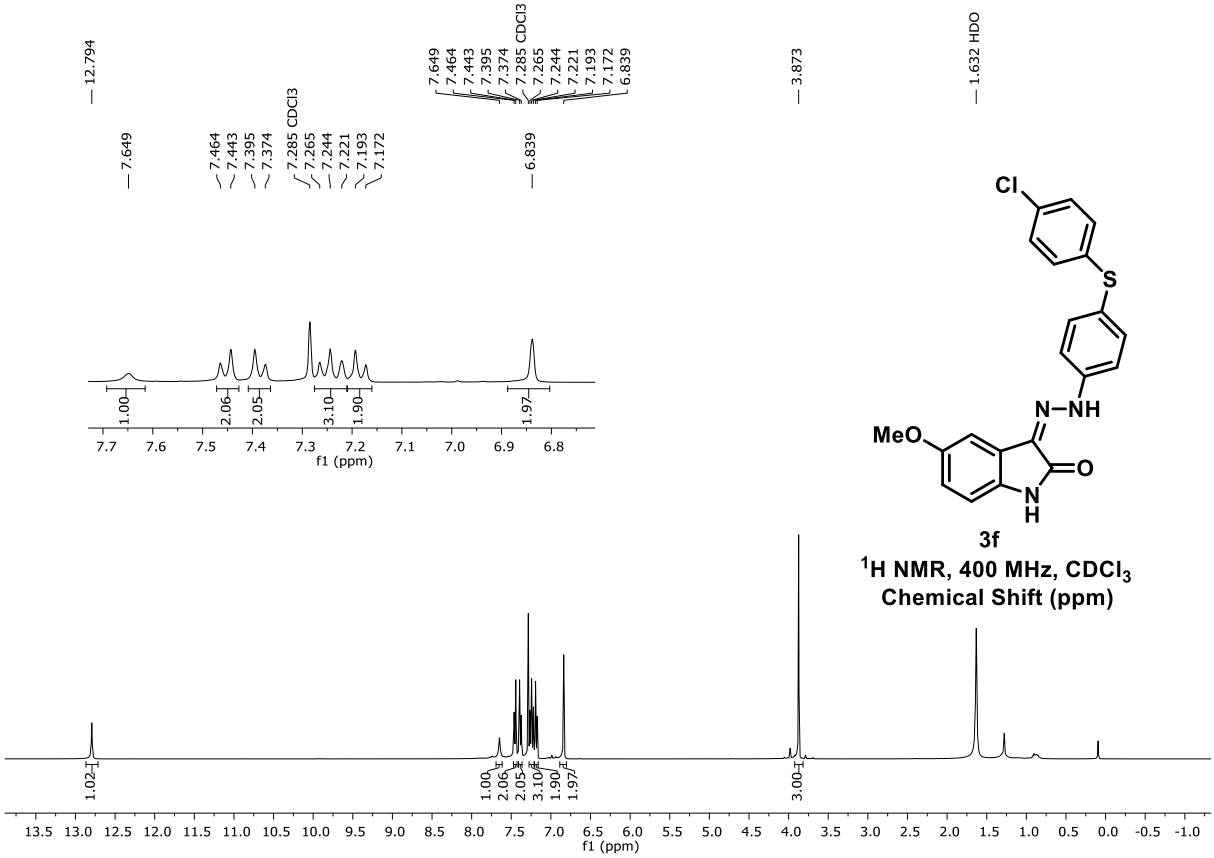
Chemical Shift (ppm)

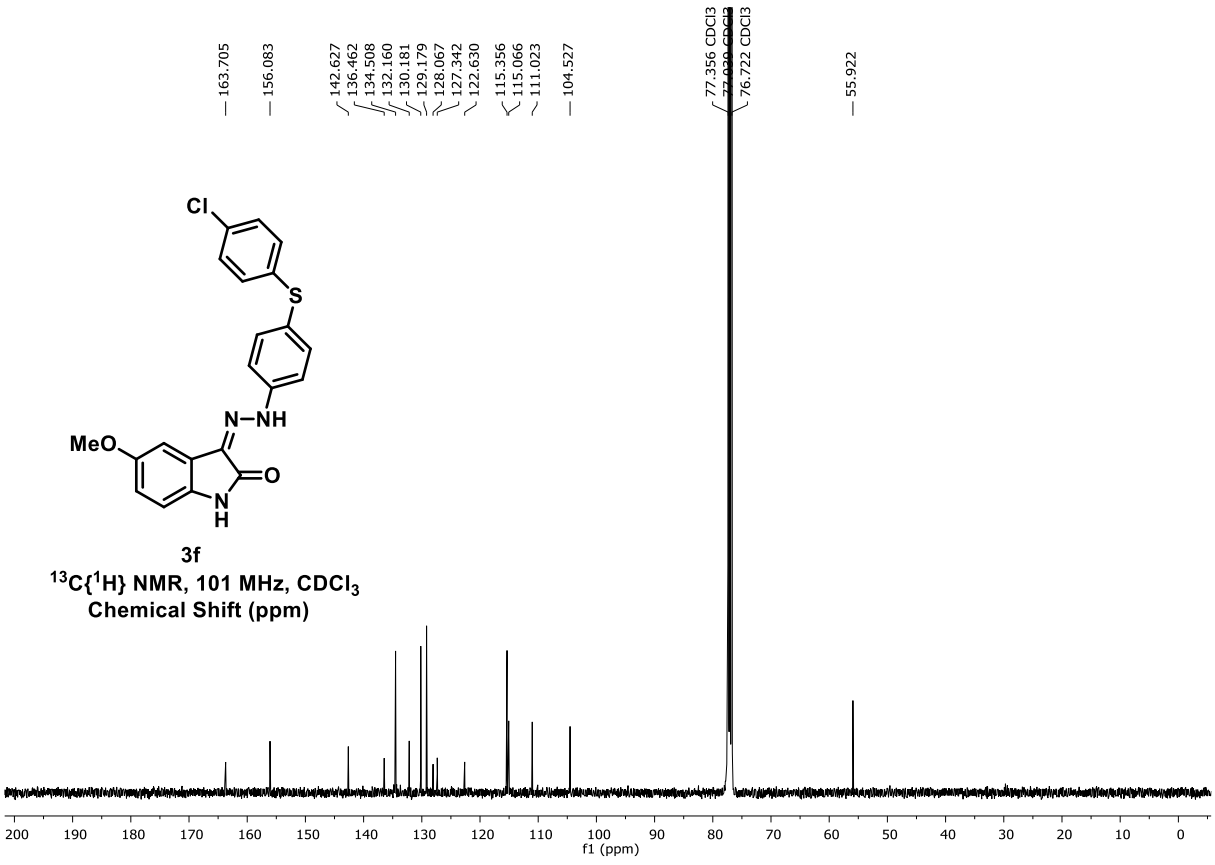


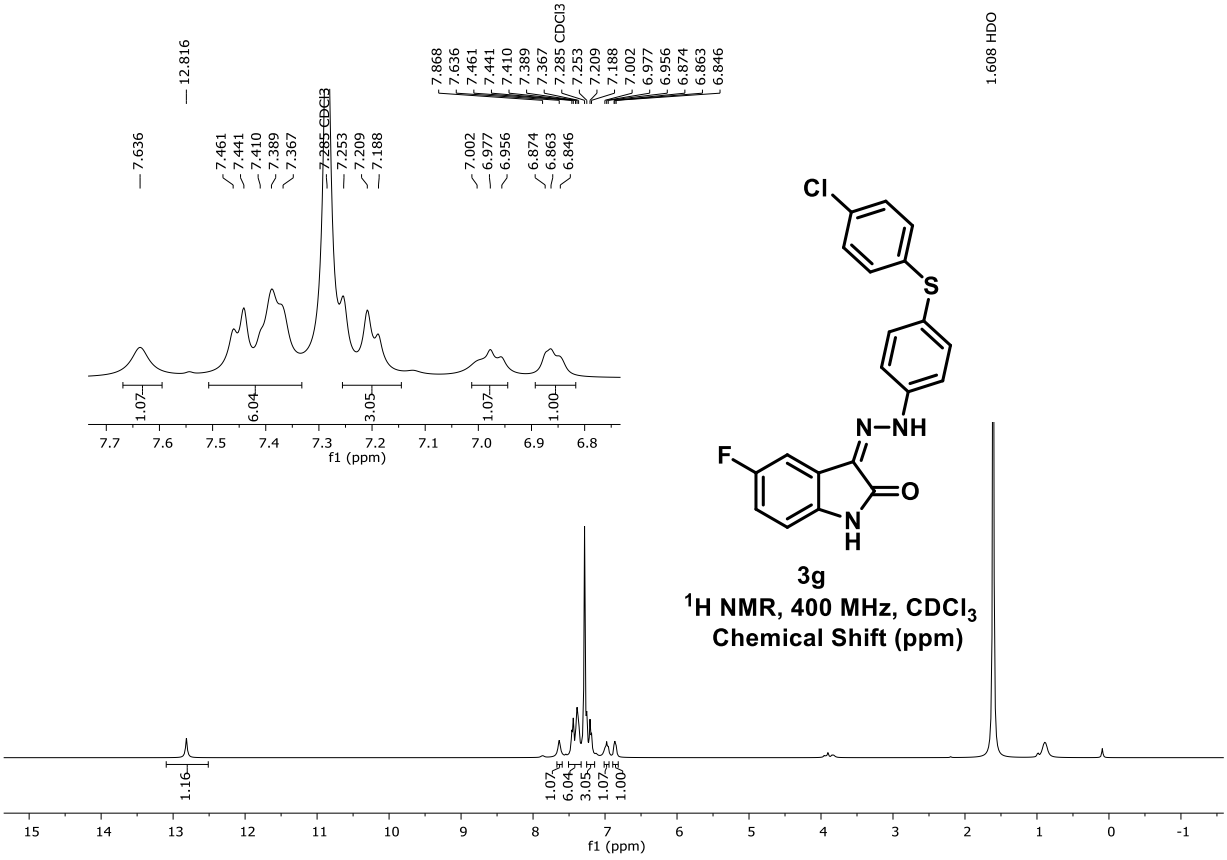
3e

$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$

Chemical Shift (ppm)


12.794
7.649
7.464
7.443
7.395
7.374
7.285 CDCl3
7.265
7.244
7.221
7.193
7.172
6.839
3.873
1.632 HDO
1.00
2.06
2.05
3.10
1.90
1.97
f1 (ppm)
Cl
S
N–NH
MeO
O
N
H
3f
1H NMR, 400 MHz, CDCl3
Chemical Shift (ppm)
1.02
1.00
2.06
2.05
3.10
1.90
1.97
3.00
f1 (ppm)

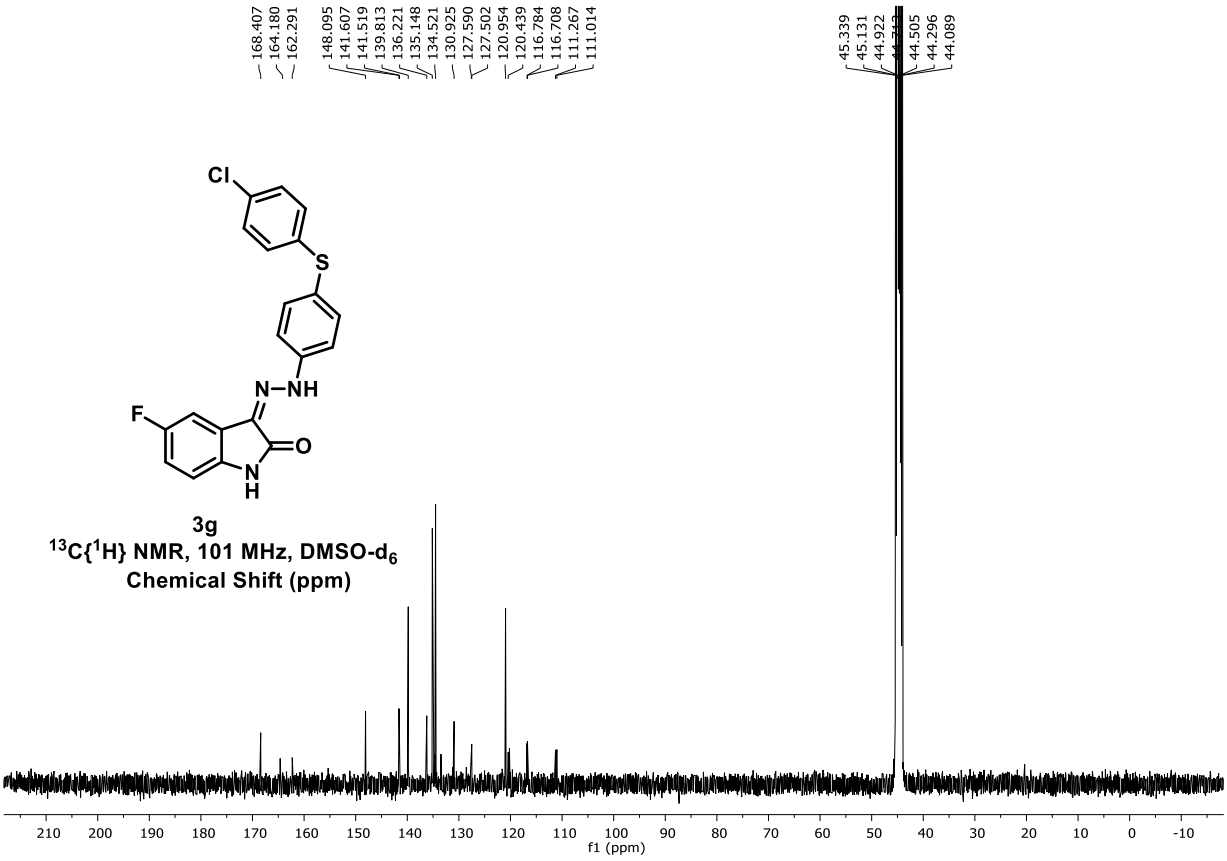

163.705
156.083
142.627
136.462
134.508
132.160
130.181
129.179
128.067
127.342
122.630
115.356
115.066
111.023
104.527
77.356 CDCl3
77.030 CDCl3
76.722 CDCl3
55.922
Cl
S
N–NH
MeO
O
N
H
3f
13C{1H} NMR, 101 MHz, CDCl3
Chemical Shift (ppm)
f1 (ppm)



3g

^{1}H NMR, 400 MHz, $CDCl_3$

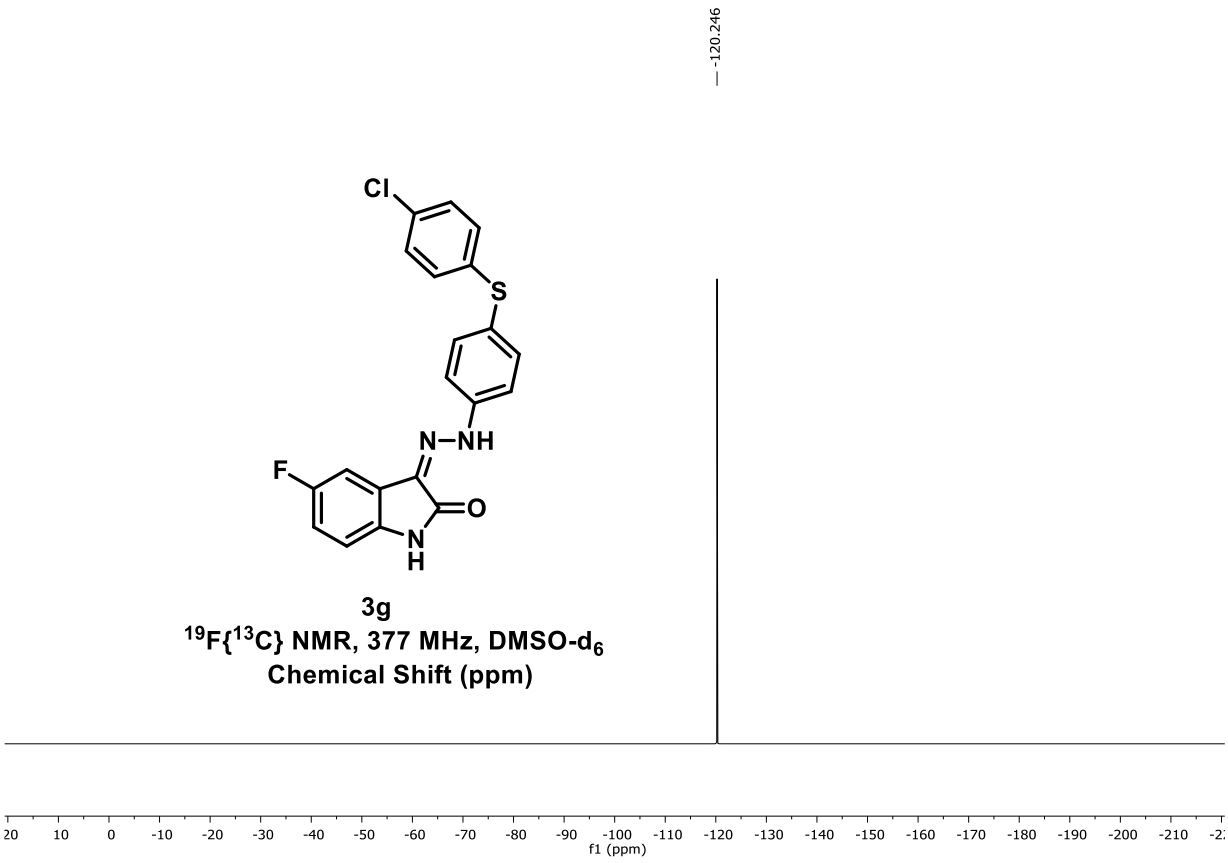
Chemical Shift (ppm)



3g

$^{13}C\{^{1}H\}$ NMR, 101 MHz, DMSO-d_6

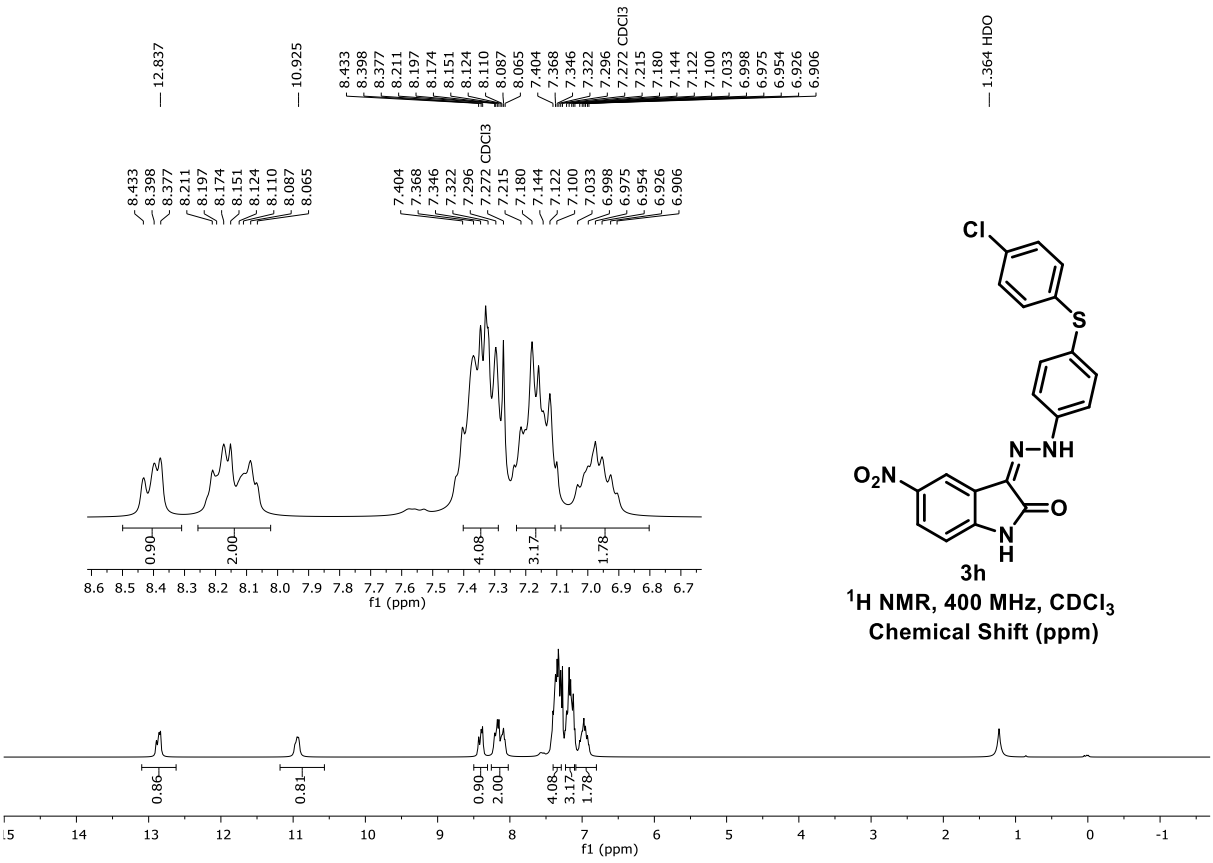
Chemical Shift (ppm)



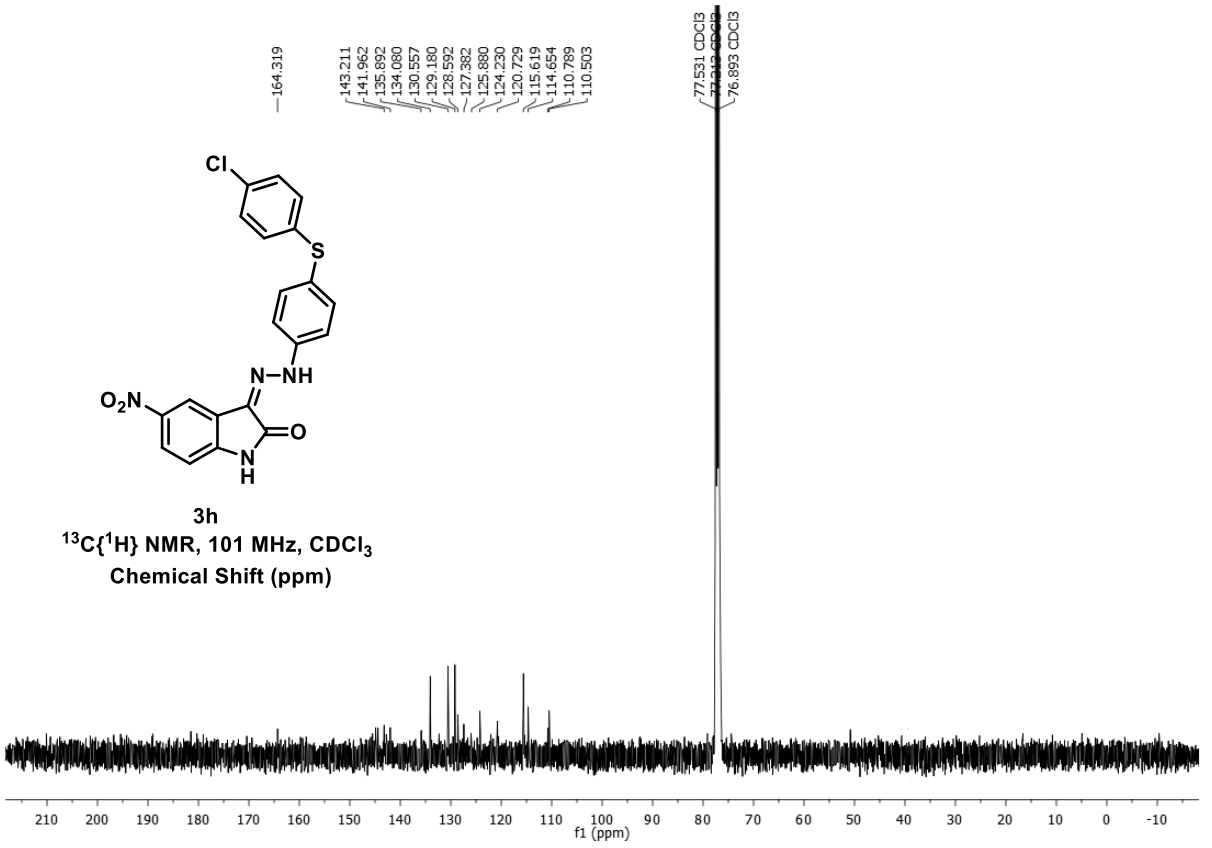
3g

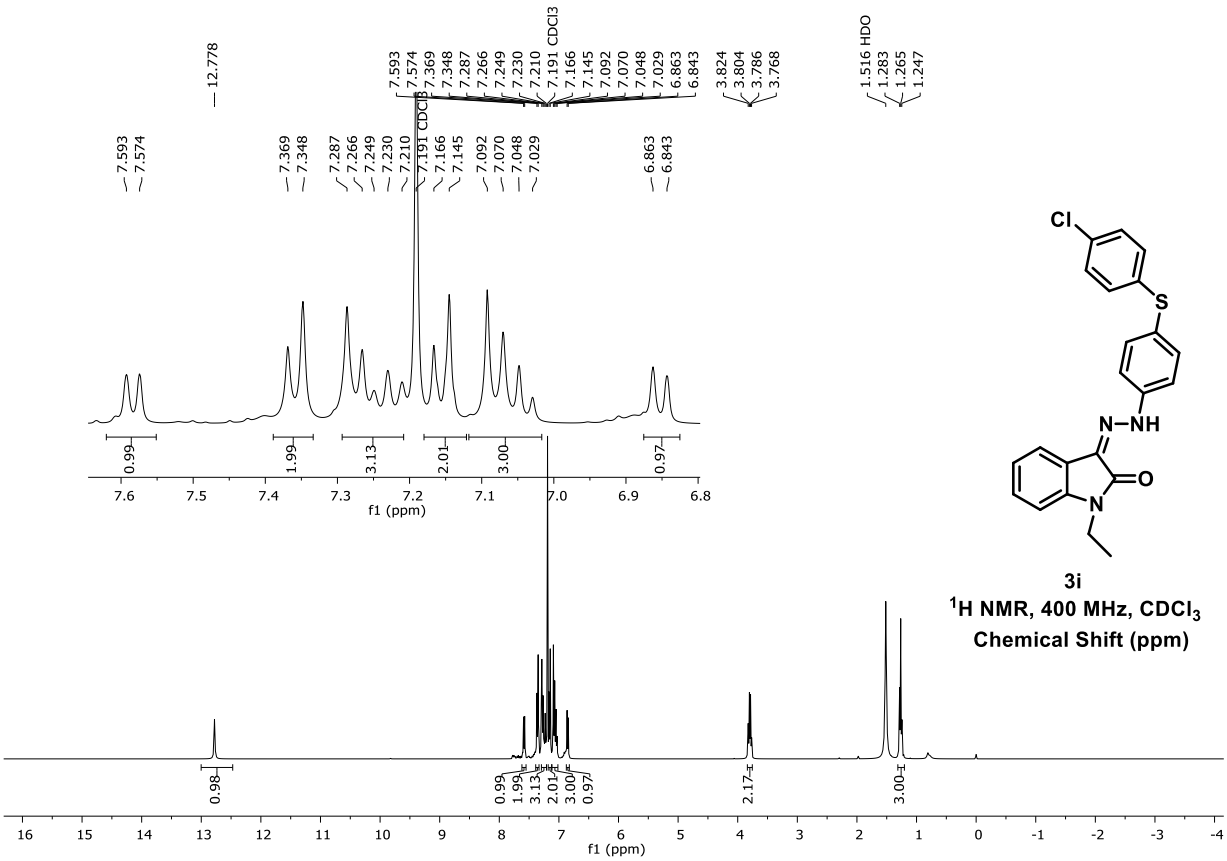
$^{19}F\{^{13}C\}$ NMR, 377 MHz, DMSO-d_6

Chemical Shift (ppm)

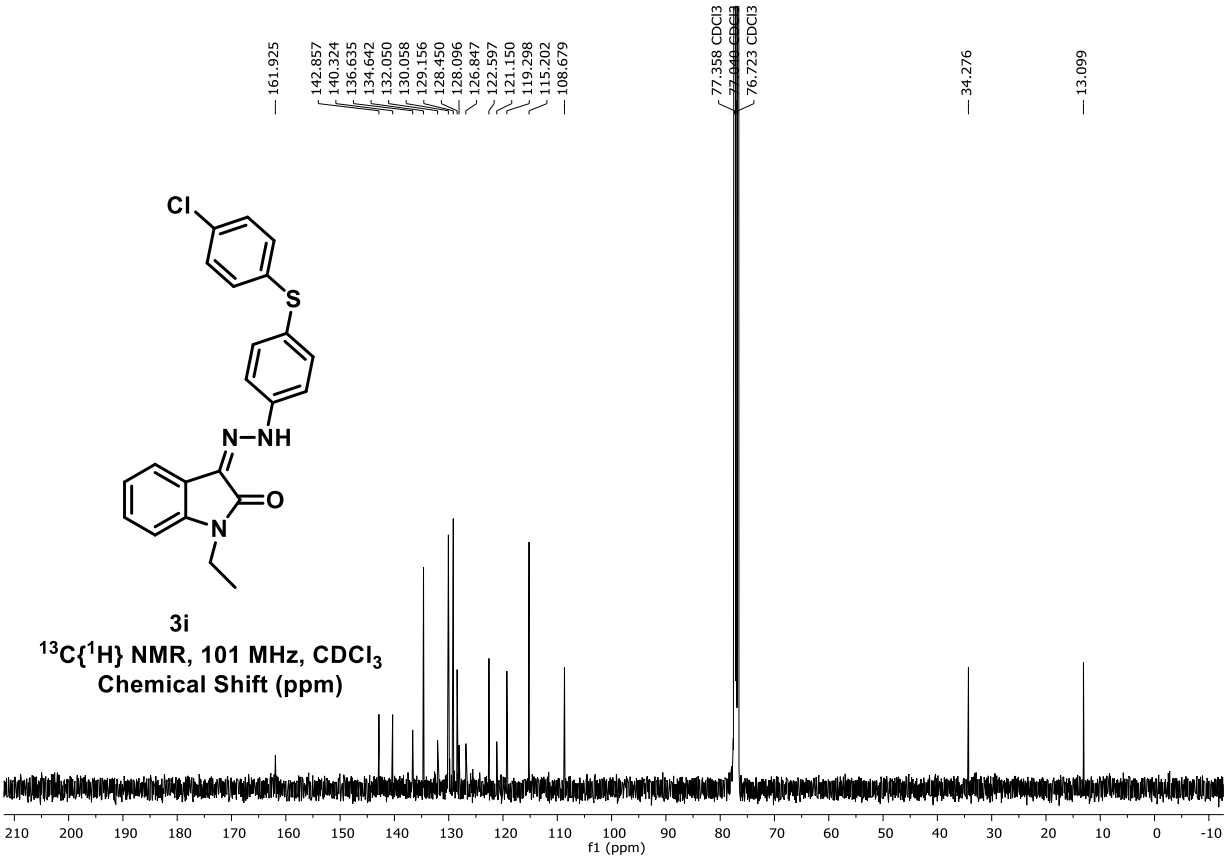

12.837
10.925
8.433
8.398
8.377
8.211
8.197
8.174
8.151
8.124
8.110
8.087
8.065
7.404
7.368
7.346
7.322
7.296
7.272 CDCl3
7.215
7.180
7.144
7.122
7.100
7.033
6.998
6.975
6.954
6.926
6.906
1.364 HDO
0.90
2.00
4.08
3.17
1.78
f1 (ppm)
Cl
S
N–NH
O2N
O
N
H
3h
1H NMR, 400 MHz, CDCl3
Chemical Shift (ppm)

0.86
0.81
0.90
2.00
4.08
3.17
1.78
f1 (ppm)

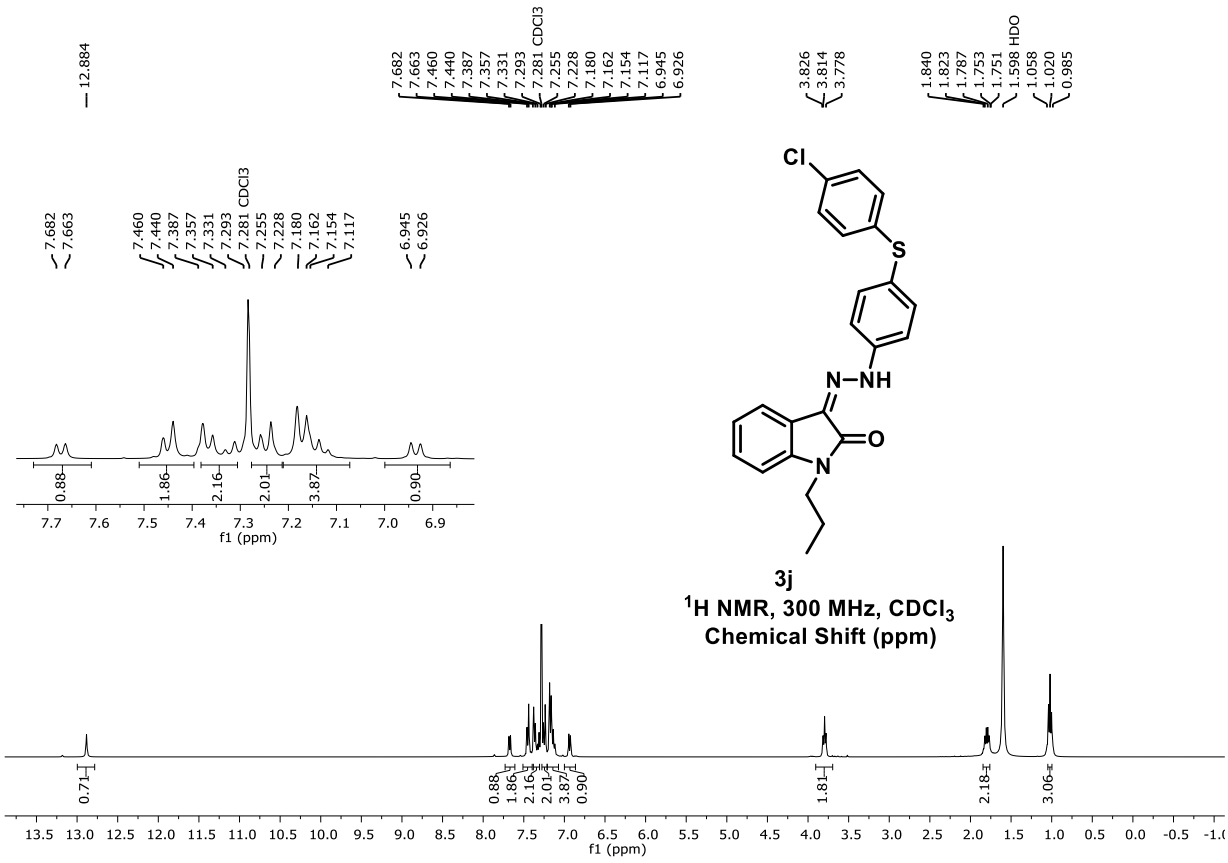

164.319
143.211
141.962
135.892
134.080
130.557
129.180
128.592
127.382
125.880
124.230
120.729
115.619
114.654
110.789
110.503
77.531 CDCl3
77.212 CDCl3
76.893 CDCl3
f1 (ppm)
Cl
S
N–NH
O2N
O
N
H
3h
13C{1H} NMR, 101 MHz, CDCl3
Chemical Shift (ppm)

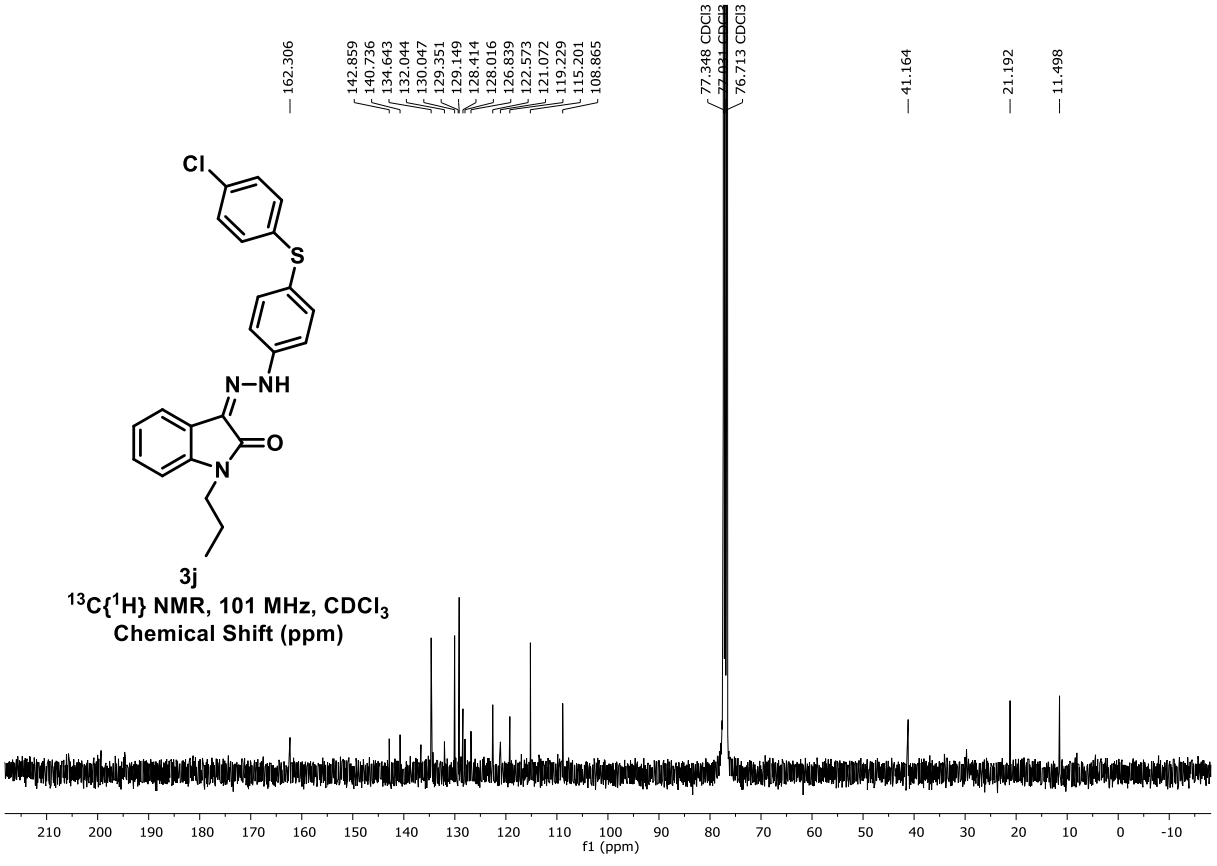


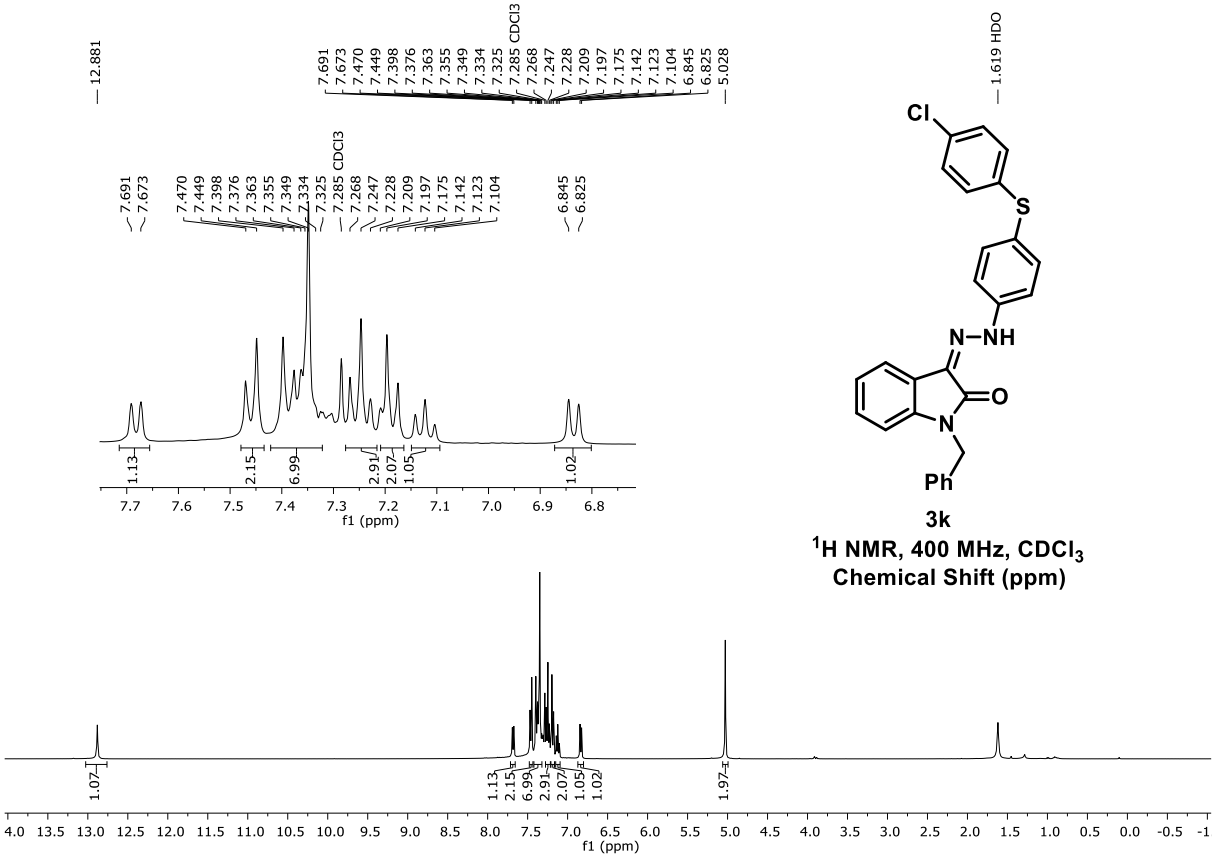
3i
^{1}H NMR, 400 MHz, $CDCl_3$
Chemical Shift (ppm)



3i
$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$
Chemical Shift (ppm)


12.884
7.682
7.663
7.460
7.440
7.387
7.357
7.331
7.293
7.281 CDCl3
7.255
7.228
7.180
7.162
7.154
7.117
6.945
6.926
3.826
3.814
3.778
1.840
1.823
1.787
1.753
1.751
1.598 HDO
1.058
1.020
0.985
Cl
S
N–NH
O
N
3j
^{1}H NMR, 300 MHz, CDCl$_3$
Chemical Shift (ppm)
f1 (ppm)

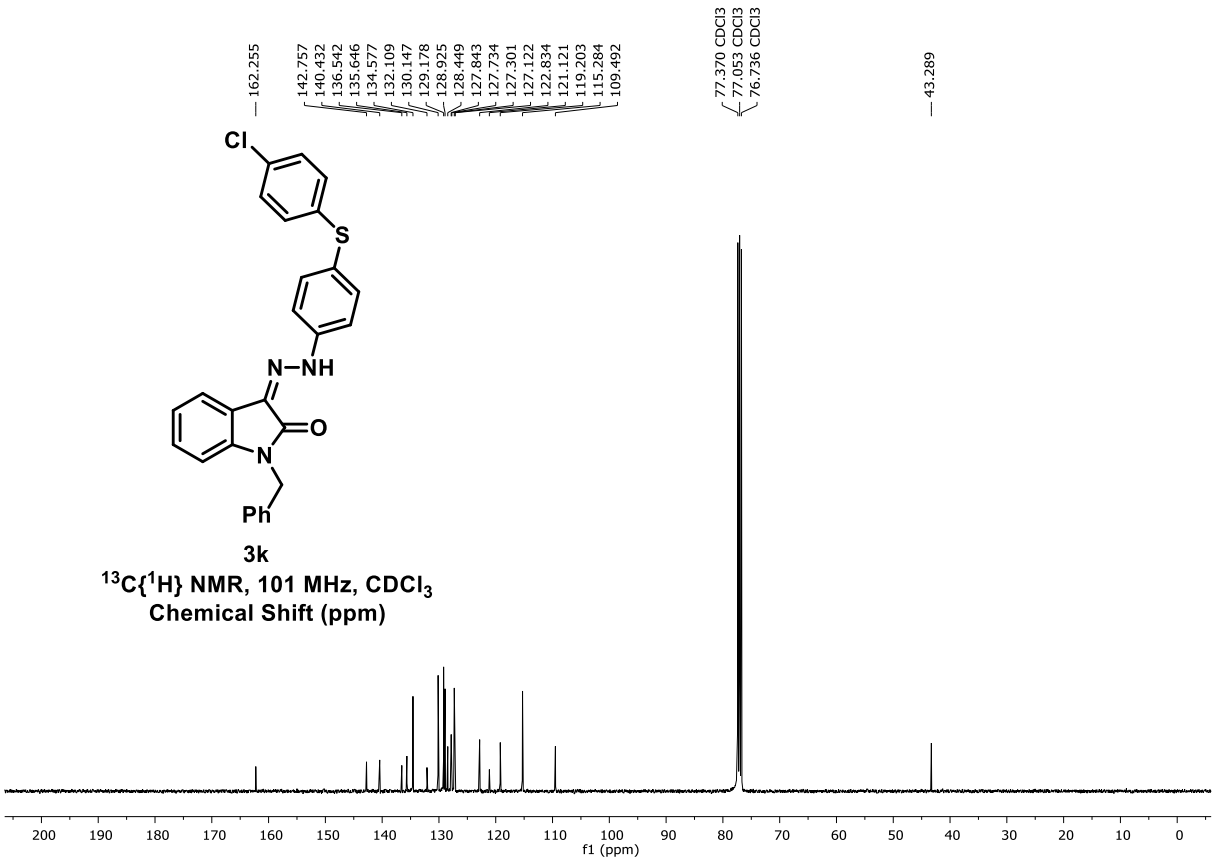

162.306
142.859
140.736
134.643
132.044
130.047
129.351
129.149
128.414
128.016
126.839
122.573
121.072
119.229
115.201
108.865
77.348 CDCl3
77.031 CDCl3
76.713 CDCl3
41.164
21.192
11.498
Cl
S
N–NH
O
N
3j
^{13}C{^{1}H} NMR, 101 MHz, CDCl$_3$
Chemical Shift (ppm)
f1 (ppm)



3k

^{1}H NMR, 400 MHz, $CDCl_3$

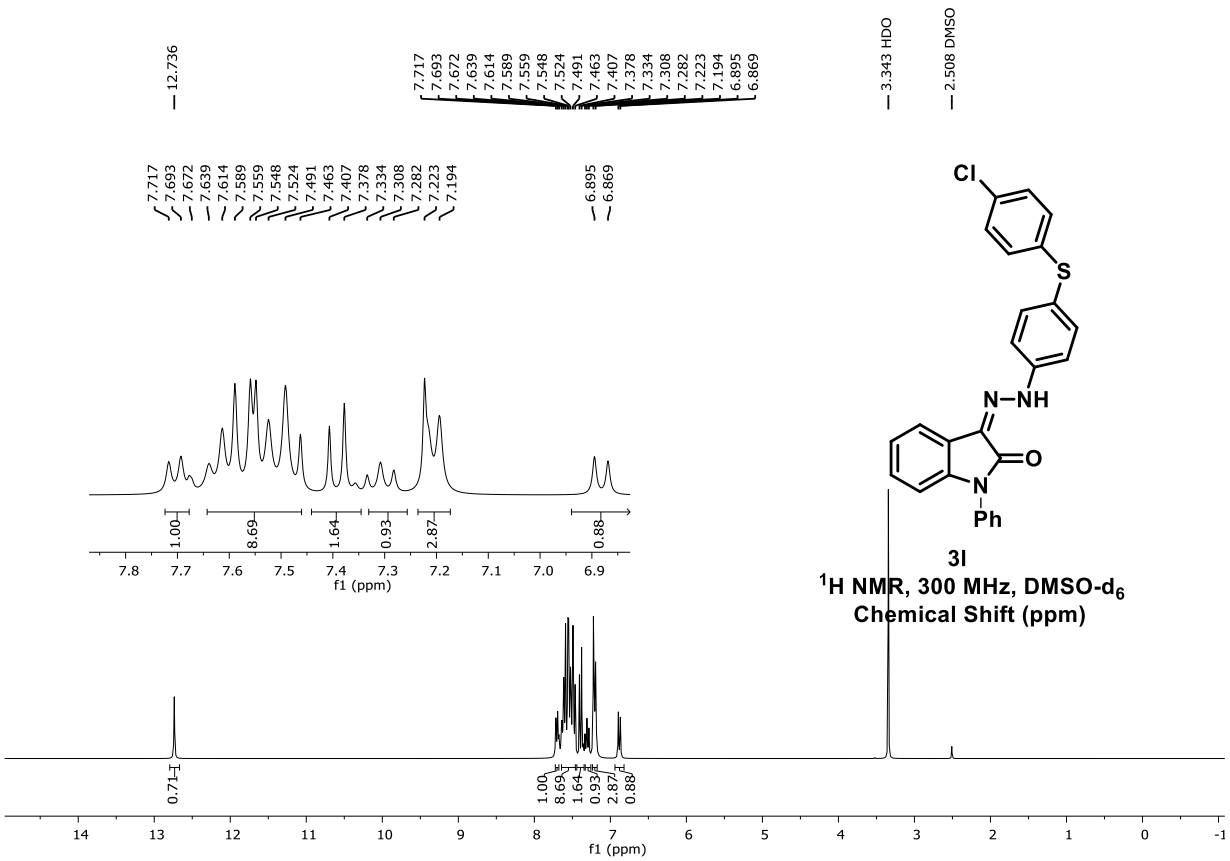
Chemical Shift (ppm)

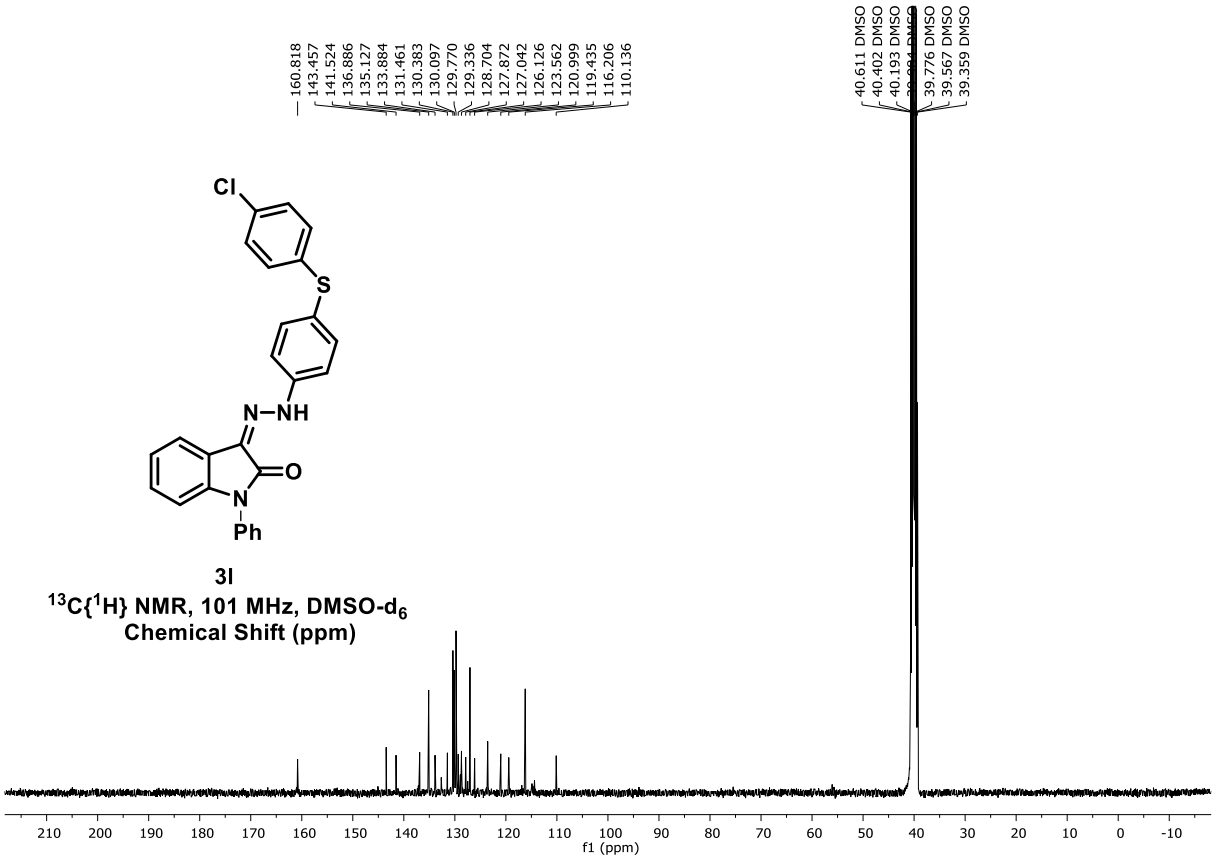


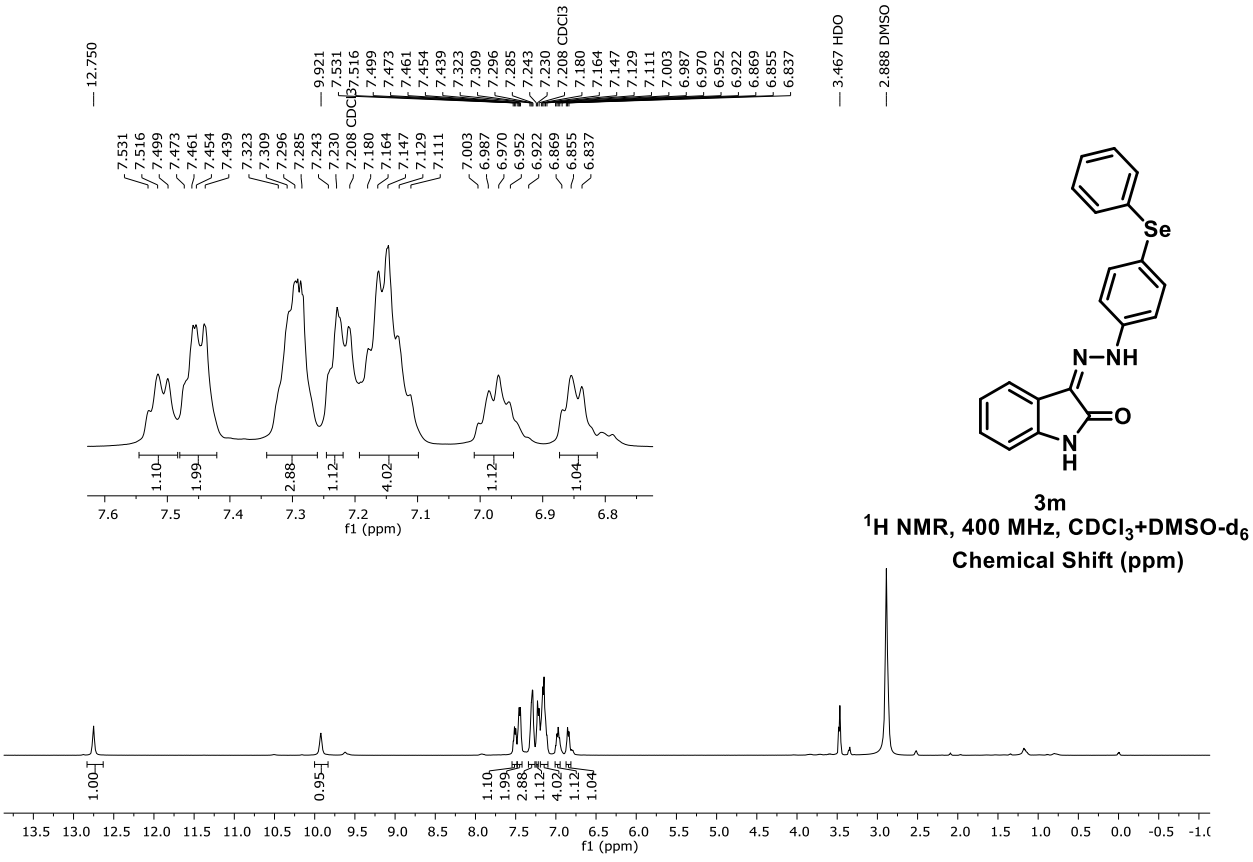
3k

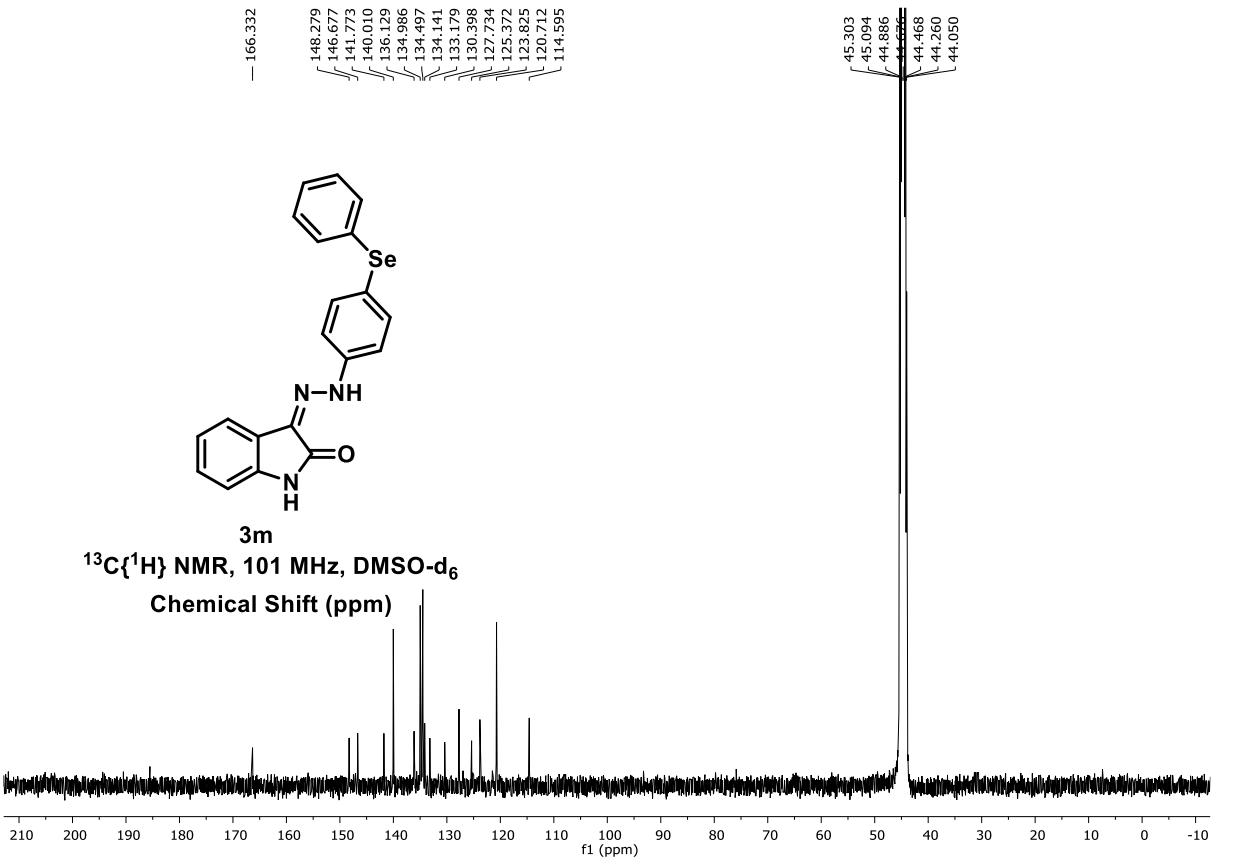
$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$

Chemical Shift (ppm)


12.736
7.717
7.693
7.672
7.639
7.614
7.589
7.559
7.548
7.524
7.491
7.463
7.407
7.378
7.334
7.308
7.282
7.223
7.194
6.895
6.869
3.343 HDO
2.508 DMSO
1.00
8.69
1.64
0.93
2.87
0.88
0.71
f1 (ppm)
Cl
S
N–NH
O
N
Ph
3l
^{1}H NMR, 300 MHz, DMSO-d$_6$
Chemical Shift (ppm)


160.818
143.457
141.524
136.886
135.127
133.884
131.461
130.383
130.097
129.770
129.336
128.704
127.872
127.042
126.126
123.562
120.999
119.435
116.206
110.136
40.611 DMSO
40.402 DMSO
40.193 DMSO
39.776 DMSO
39.567 DMSO
39.359 DMSO
Cl
S
N–NH
O
N
Ph
3l
^{13}C{^{1}H} NMR, 101 MHz, DMSO-d$_6$
Chemical Shift (ppm)
f1 (ppm)


12.750
9.921
7.531
7.516
7.499
7.473
7.461
7.454
7.439
7.323
7.309
7.296
7.285
7.243
7.230
7.208 CDCl3
7.180
7.164
7.147
7.129
7.111
7.003
6.987
6.970
6.952
6.922
6.869
6.855
6.837
3.467 HDO
2.888 DMSO
1.10
1.99
2.88
1.12
4.02
1.12
1.04
f1 (ppm)
Se
N–NH
O
N
H
3m
1H NMR, 400 MHz, CDCl3+DMSO-d6
Chemical Shift (ppm)
1.00
0.95
1.10
1.99
2.88
1.12
4.02
1.12
1.04
f1 (ppm)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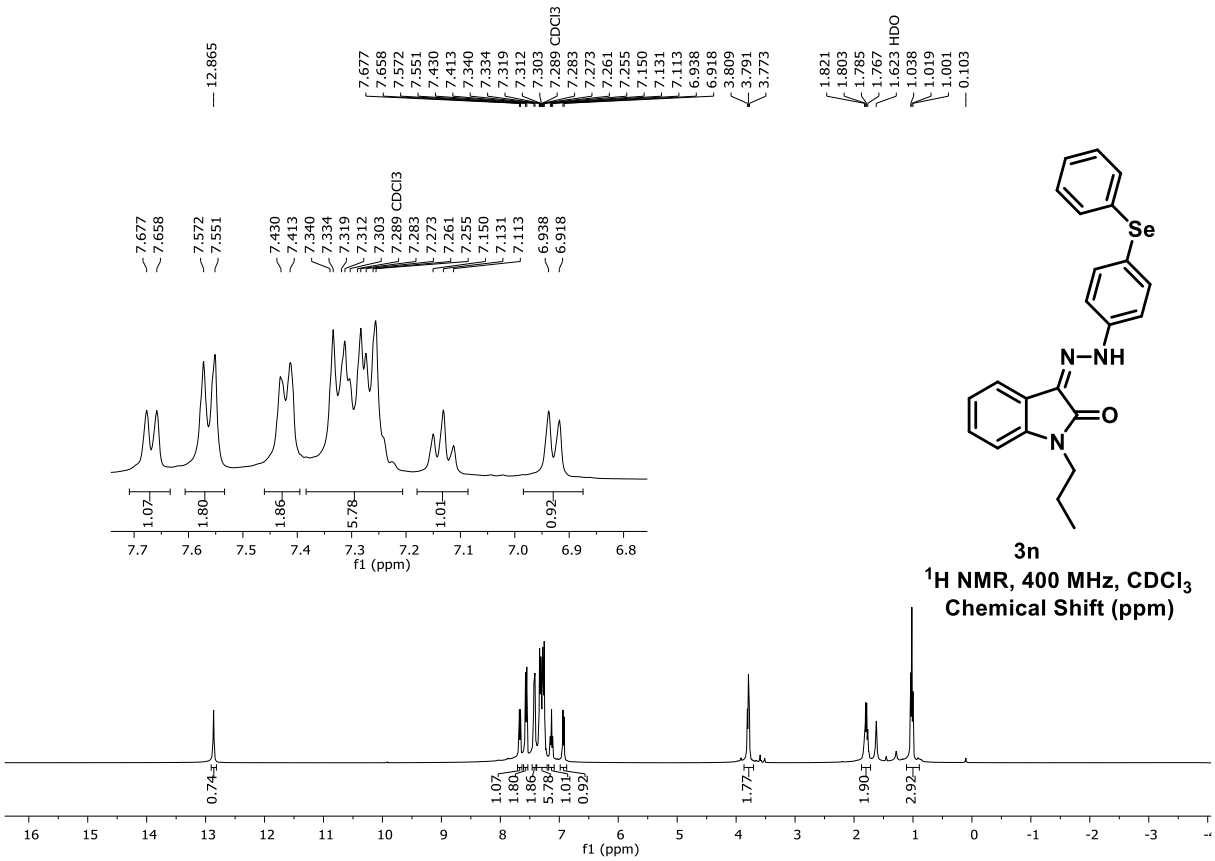
148.279
146.677
141.773
140.010
136.129
134.986
134.497
134.141
133.179
130.398
127.734
125.372
123.825
120.712
114.595
45.303
45.094
44.886
44.468
44.260
44.050
Se
N–NH
O
N
H
3m
13C{1H} NMR, 101 MHz, DMSO-d6
Chemical Shift (ppm)
f1 (ppm)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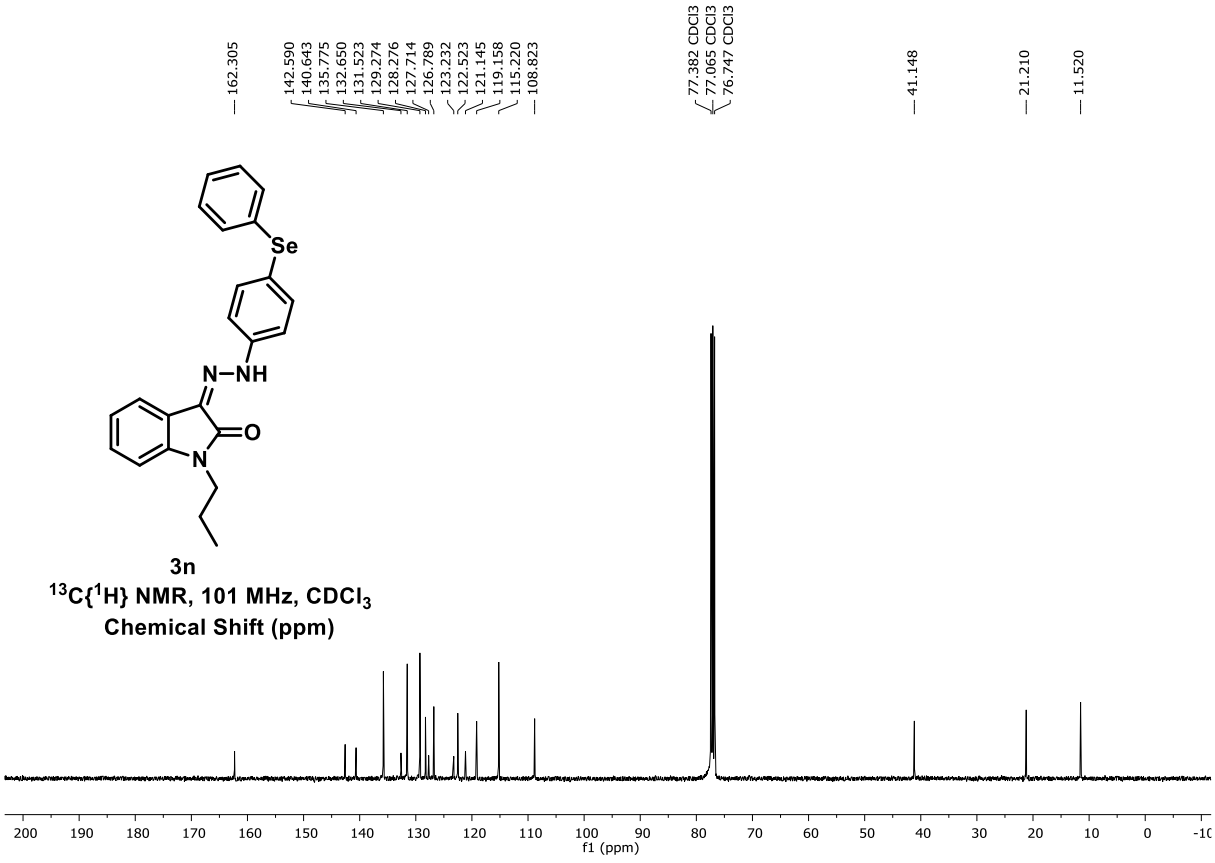
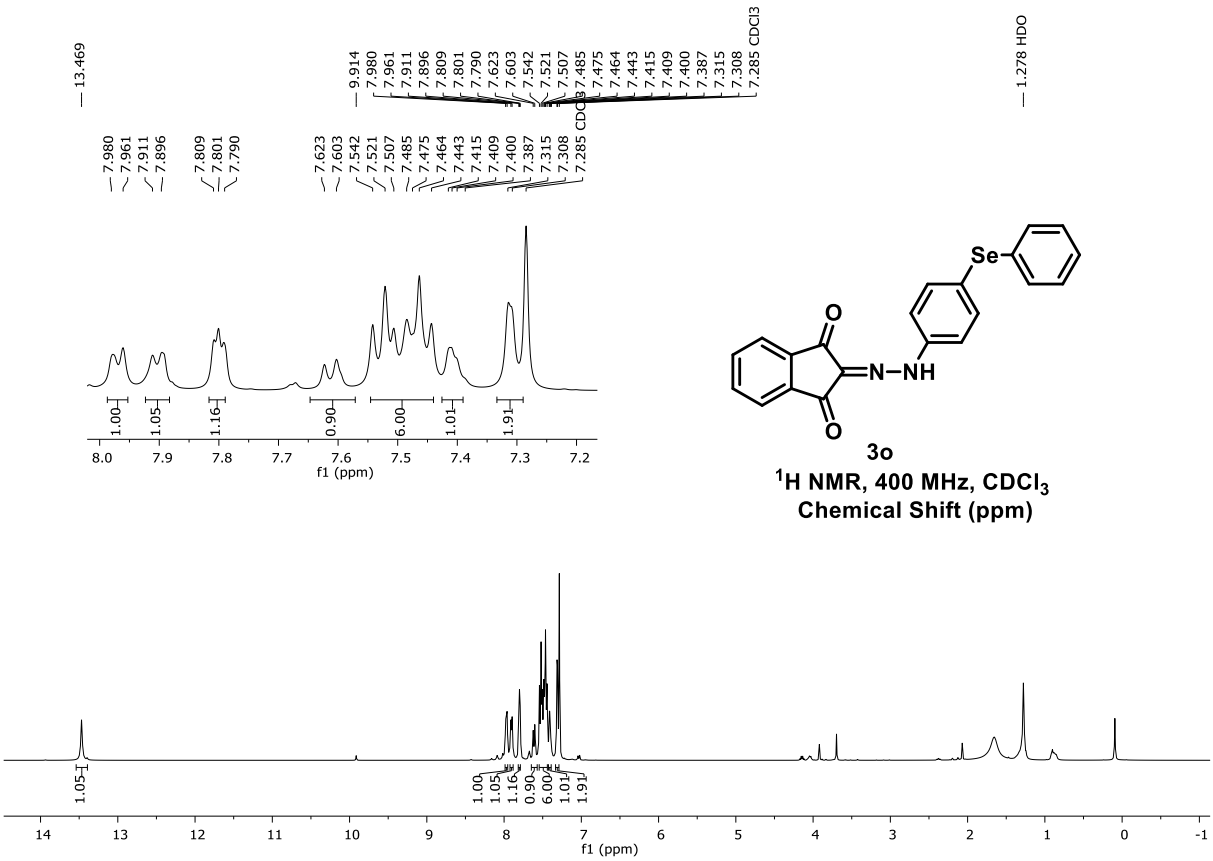
7.677
7.658
7.572
7.551
7.430
7.413
7.340
7.334
7.319
7.312
7.303
7.289 CDCl3
7.283
7.273
7.261
7.255
7.150
7.131
7.113
6.938
6.918
3.809
3.791
3.773
1.821
1.803
1.785
1.767
1.623 HDO
1.038
1.019
1.001
0.103
1.07
1.80
1.86
5.78
1.01
0.92
f1 (ppm)
Se
N–NH
O
N
3n
^{1}H NMR, 400 MHz, CDCl$_3$
Chemical Shift (ppm)
0.74
1.77
1.90
2.92
f1 (ppm)

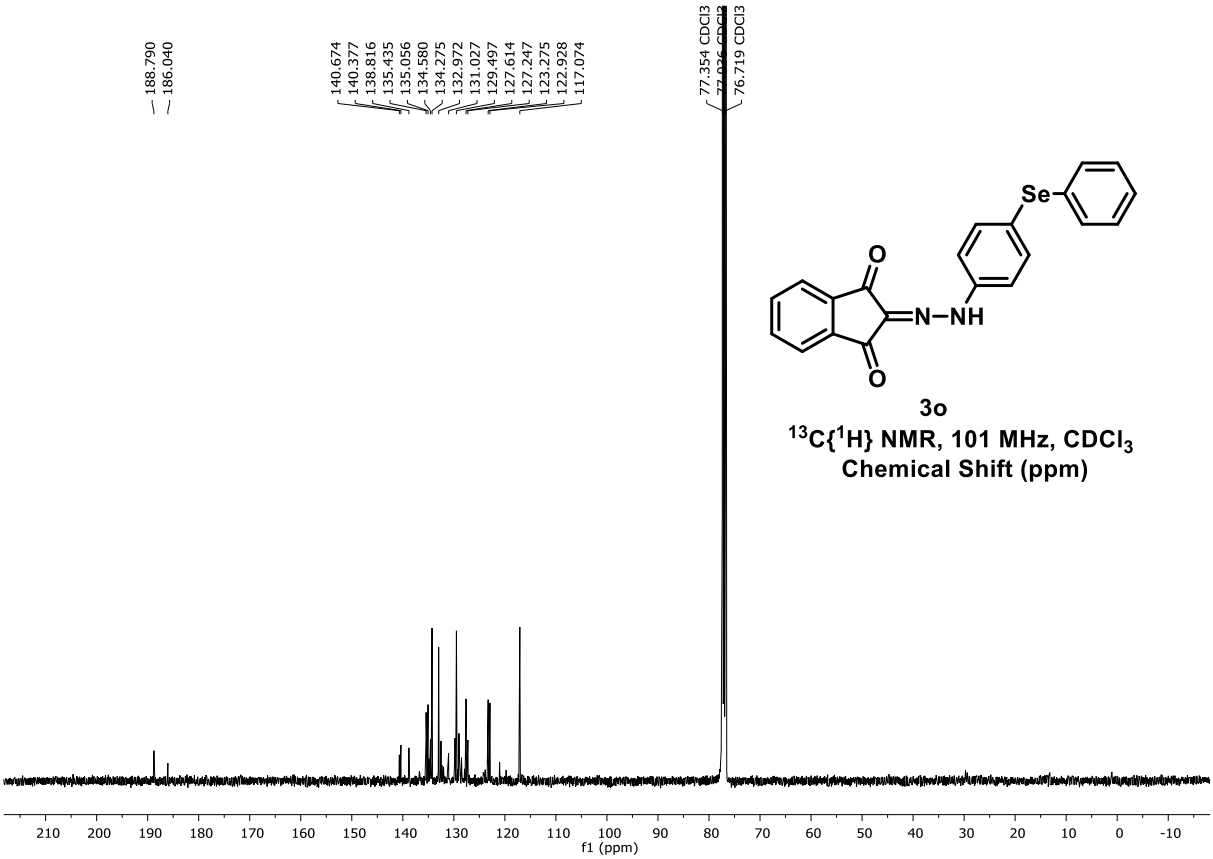

162.305
142.590
140.643
135.775
132.650
131.523
129.274
128.276
127.714
126.789
123.232
122.523
121.145
119.158
115.220
108.823
77.382 CDCl3
77.065 CDCl3
76.747 CDCl3
41.148
21.210
11.520
Se
N–NH
O
N
3n
^{13}C{^{1}H} NMR, 101 MHz, CDCl$_3$
Chemical Shift (ppm)
f1 (ppm)



3o

^{1}H NMR, 400 MHz, $CDCl_3$

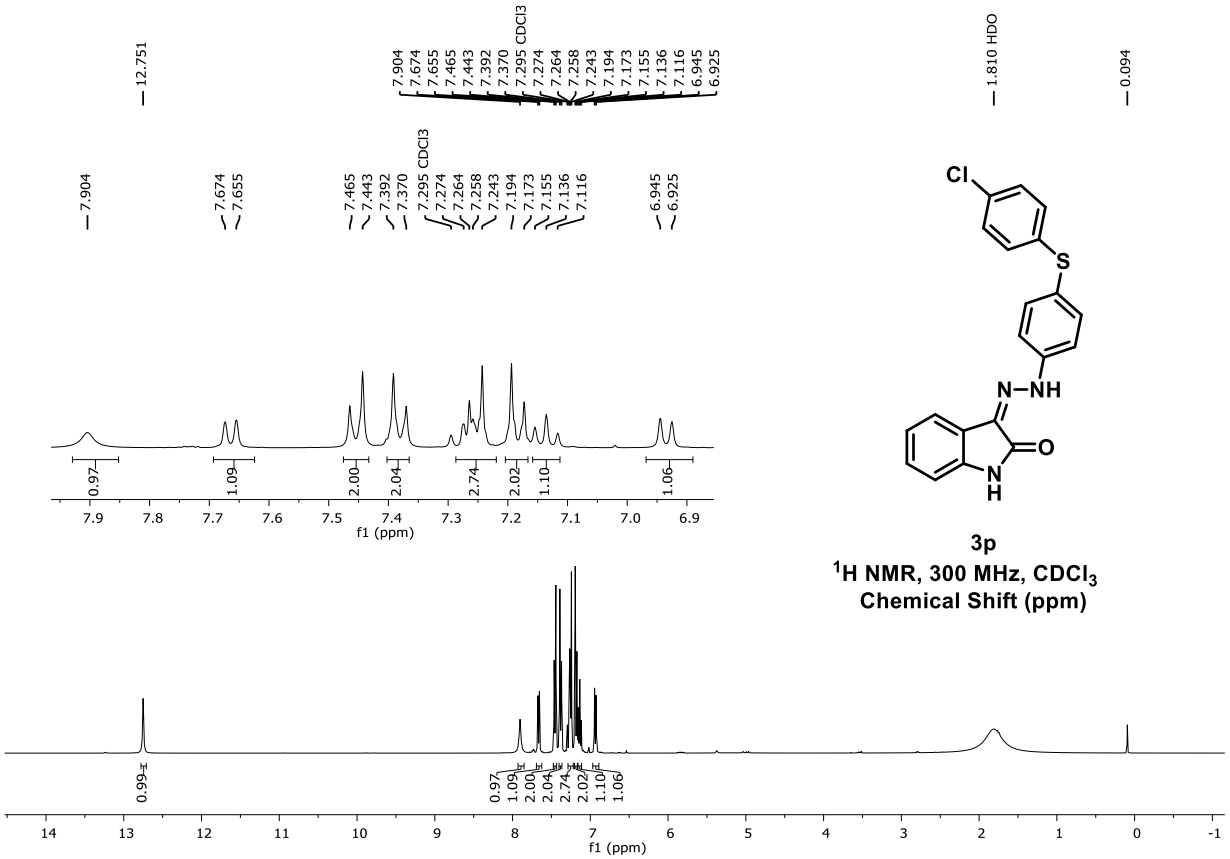
Chemical Shift (ppm)



3o

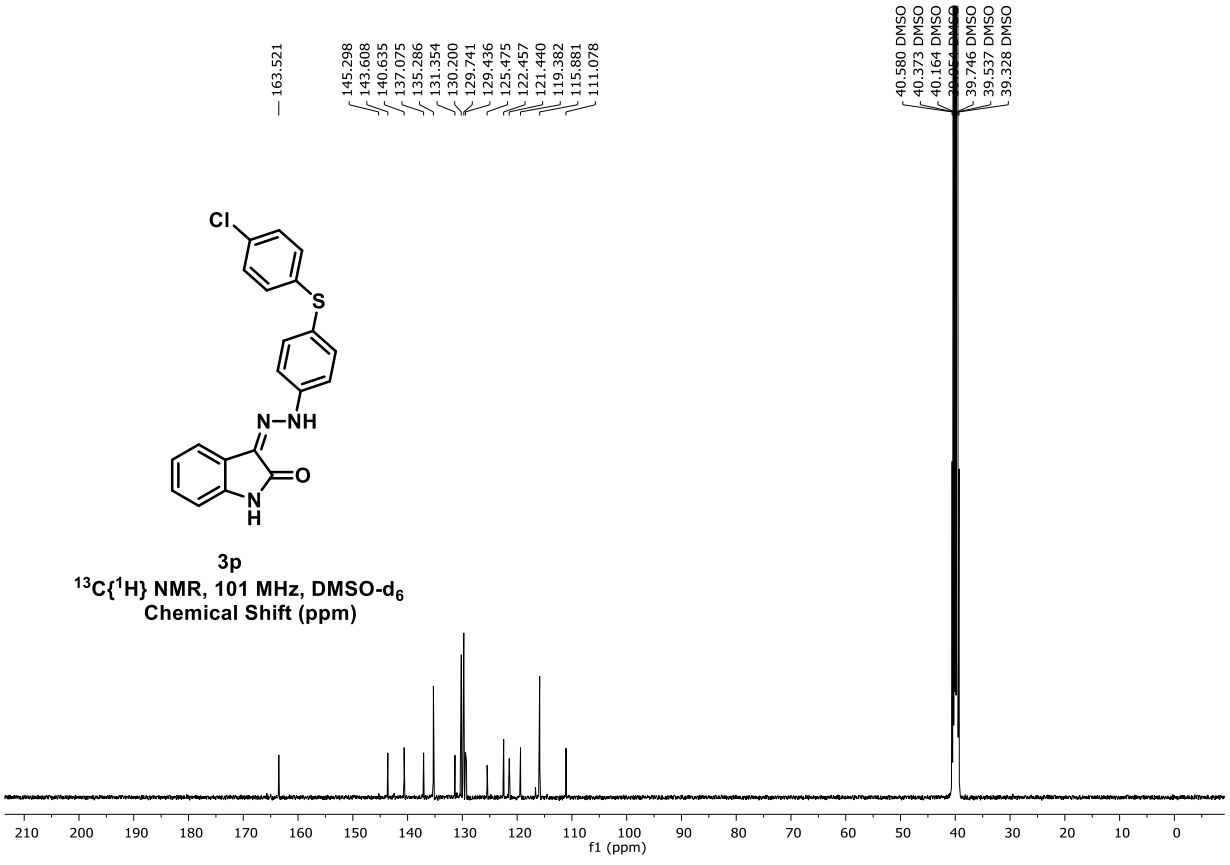
$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$

Chemical Shift (ppm)

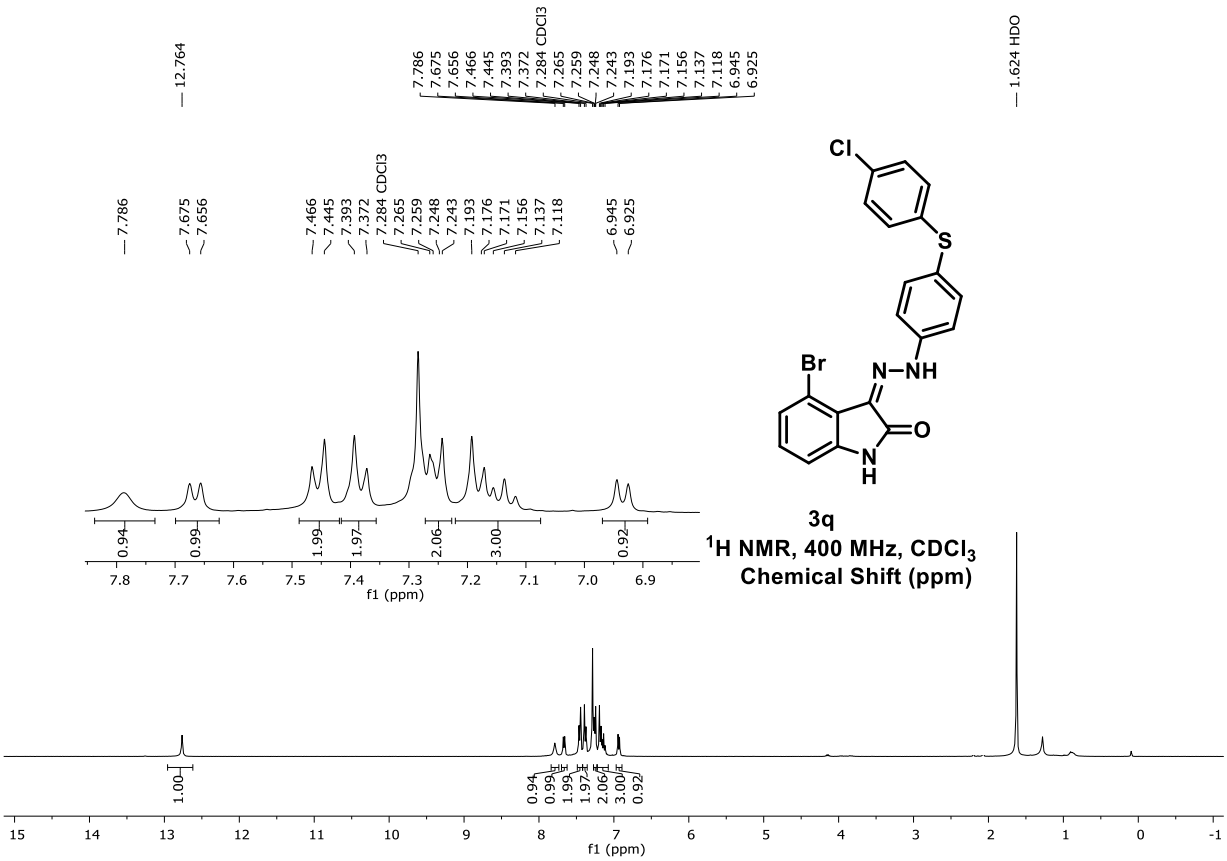


3p
^{1}H NMR, 300 MHz, $CDCl_3$
Chemical Shift (ppm)

f



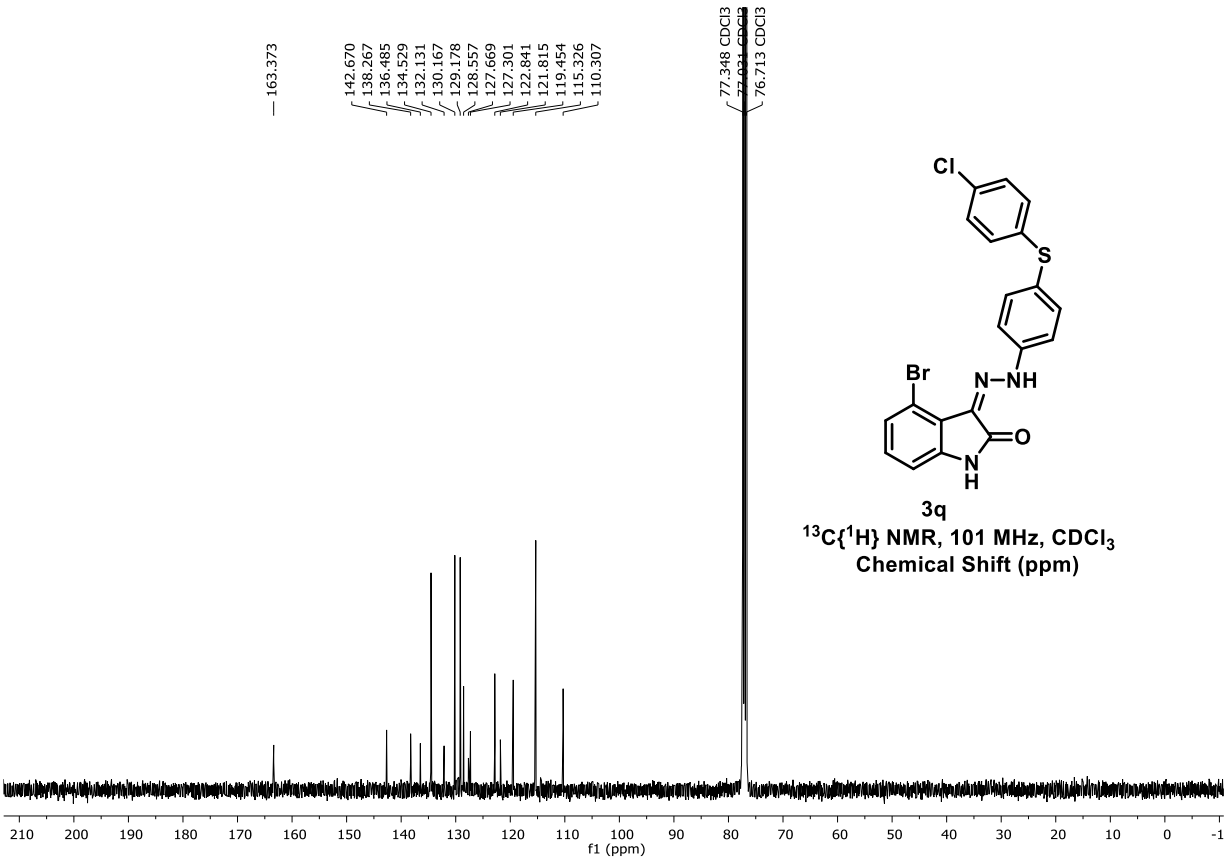
3p
$^{13}C\{^{1}H\}$ NMR, 101 MHz, DMSO-d_6
Chemical Shift (ppm)



3q

^{1}H NMR, 400 MHz, $CDCl_3$

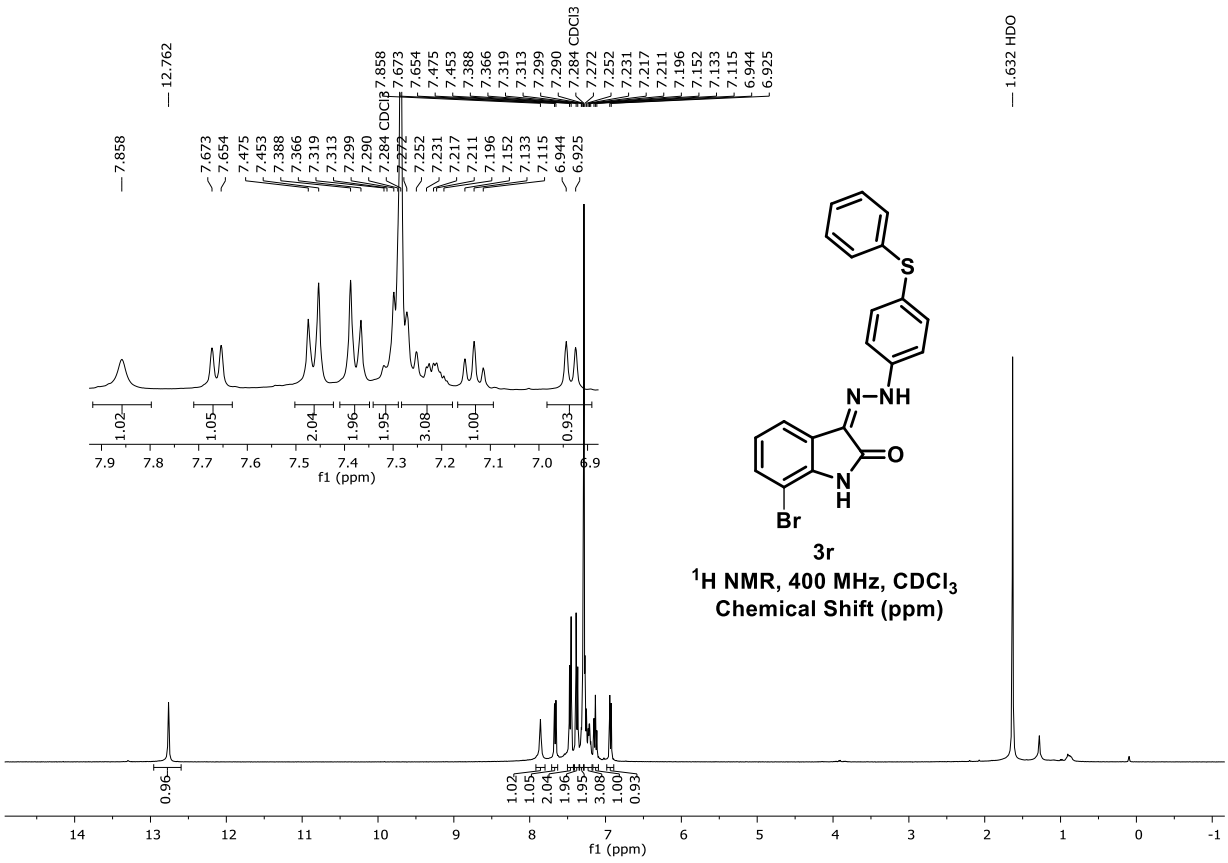
Chemical Shift (ppm)



3q

$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$

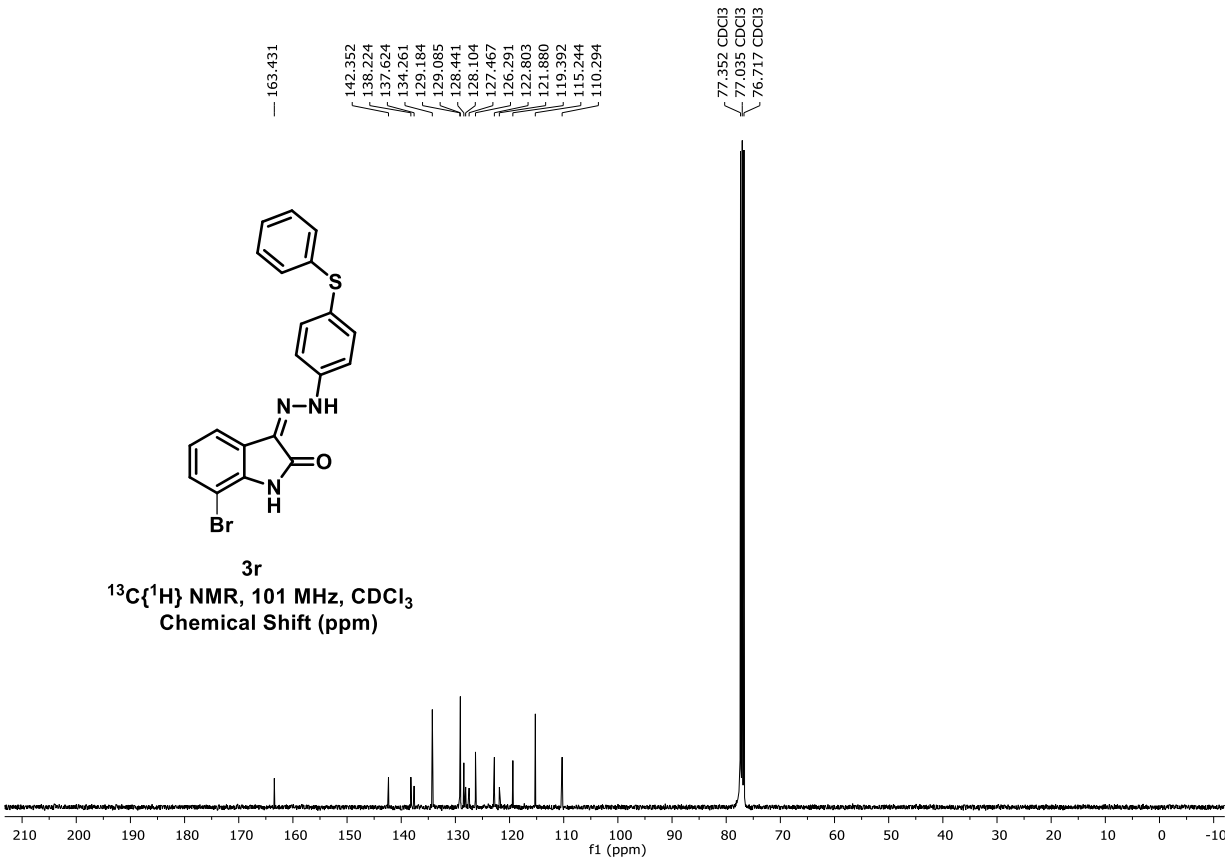
Chemical Shift (ppm)



3r

^{1}H NMR, 400 MHz, $CDCl_3$

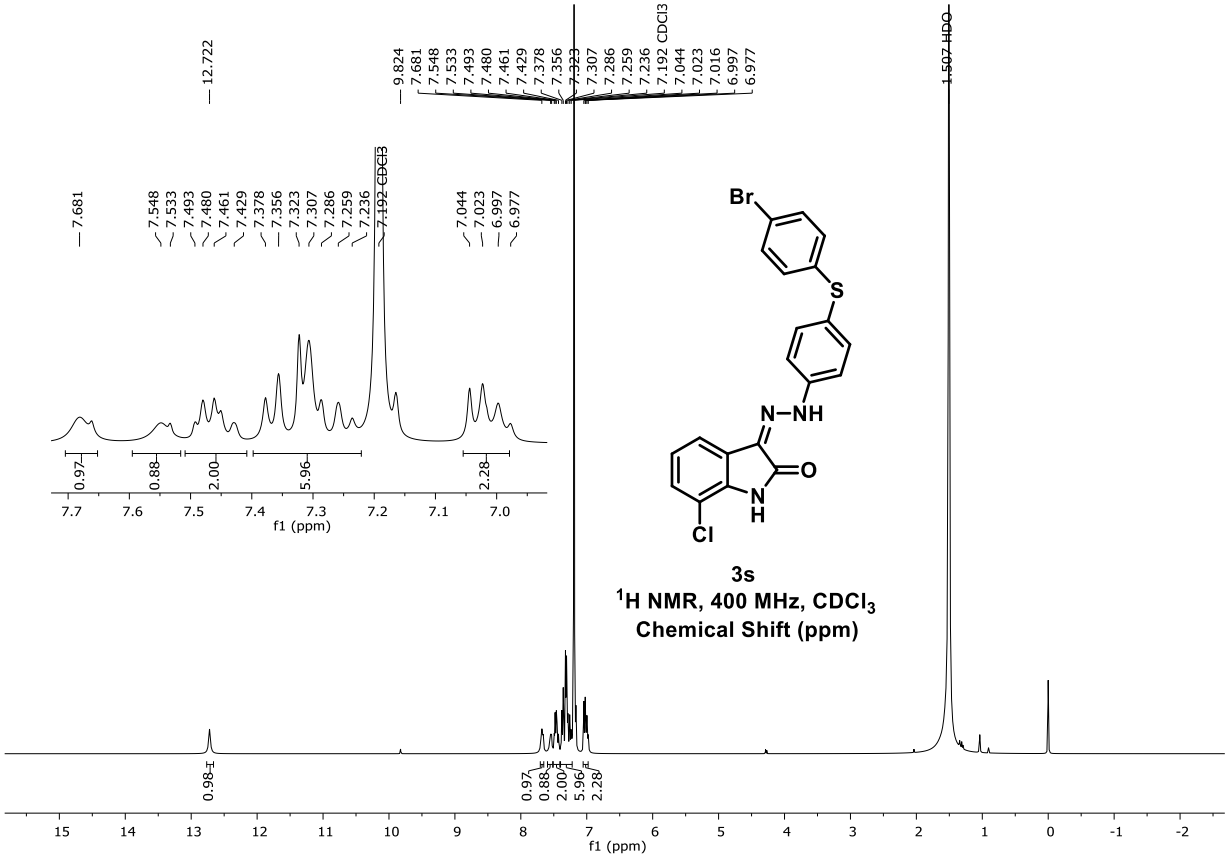
Chemical Shift (ppm)



3r

$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$

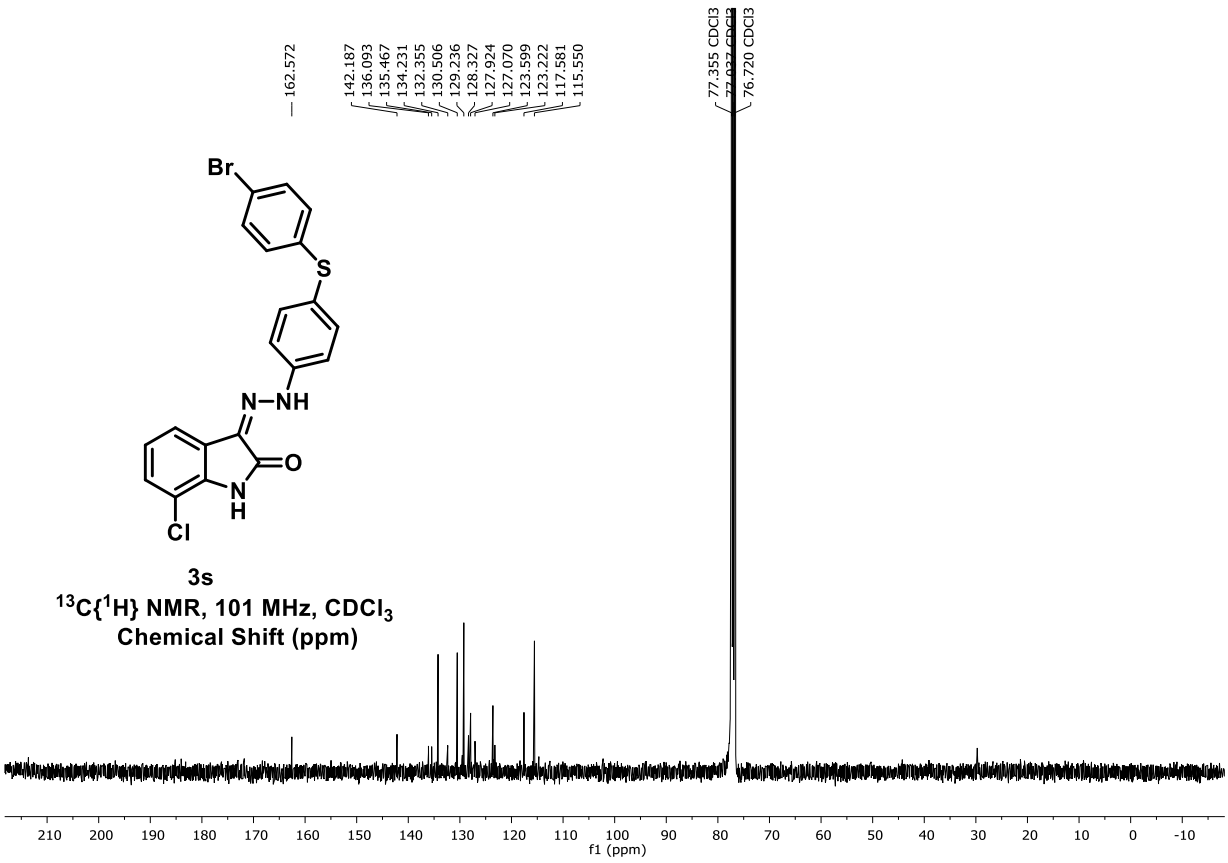
Chemical Shift (ppm)



3s

^{1}H NMR, 400 MHz, $CDCl_3$

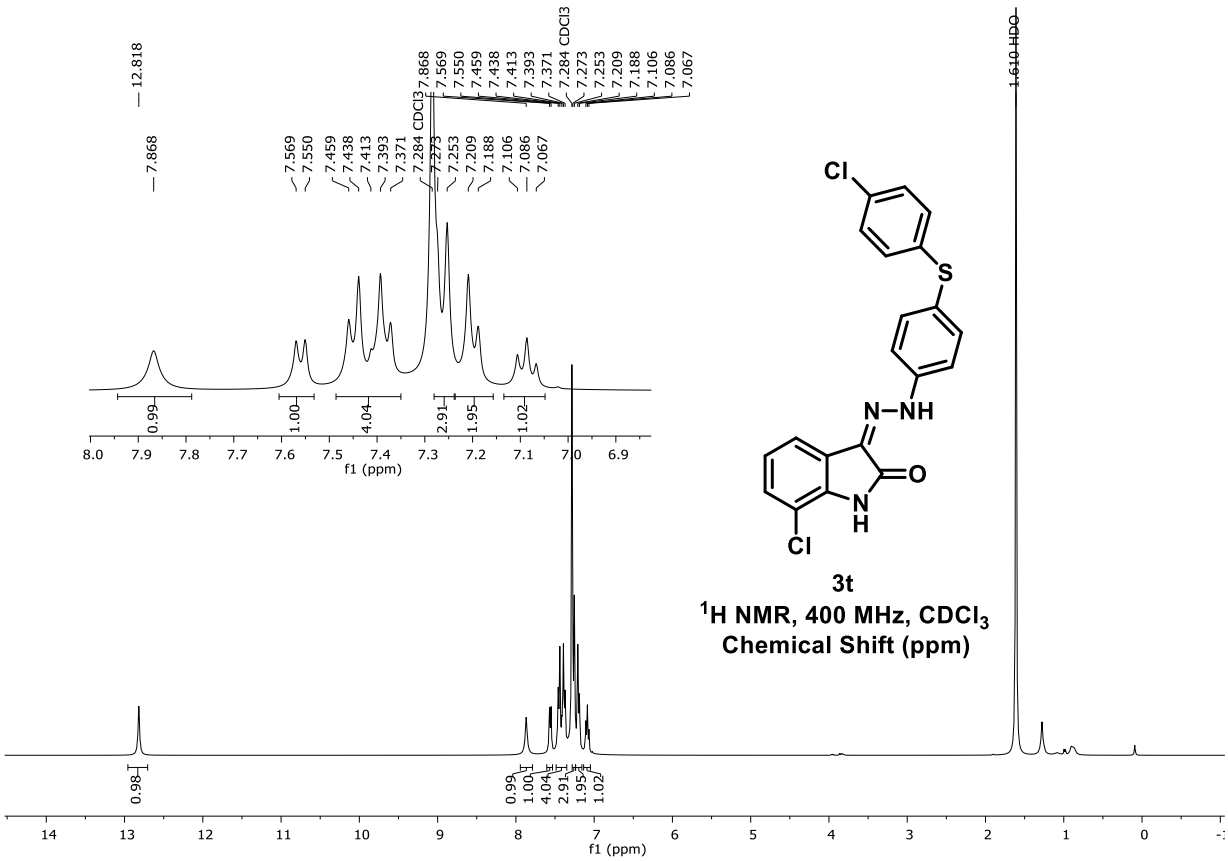
Chemical Shift (ppm)



3s

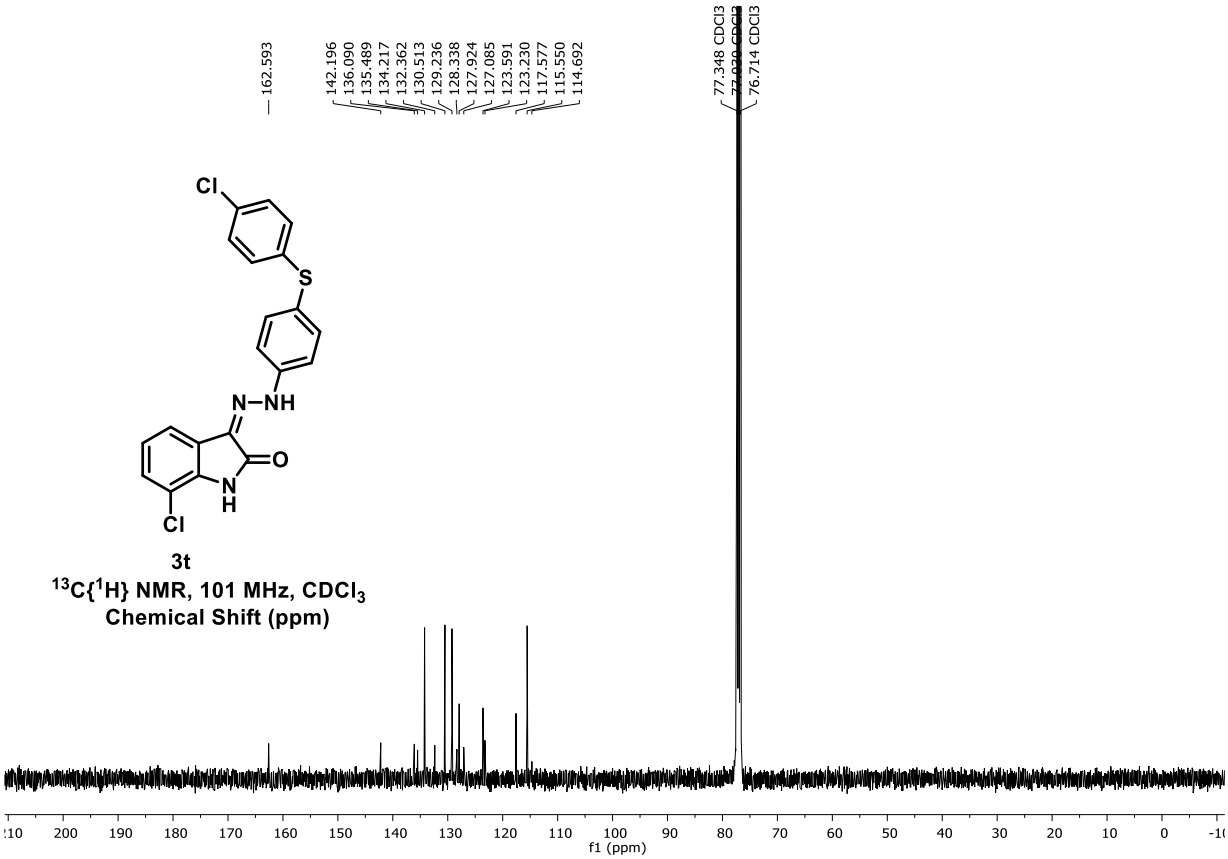
$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$

Chemical Shift (ppm)



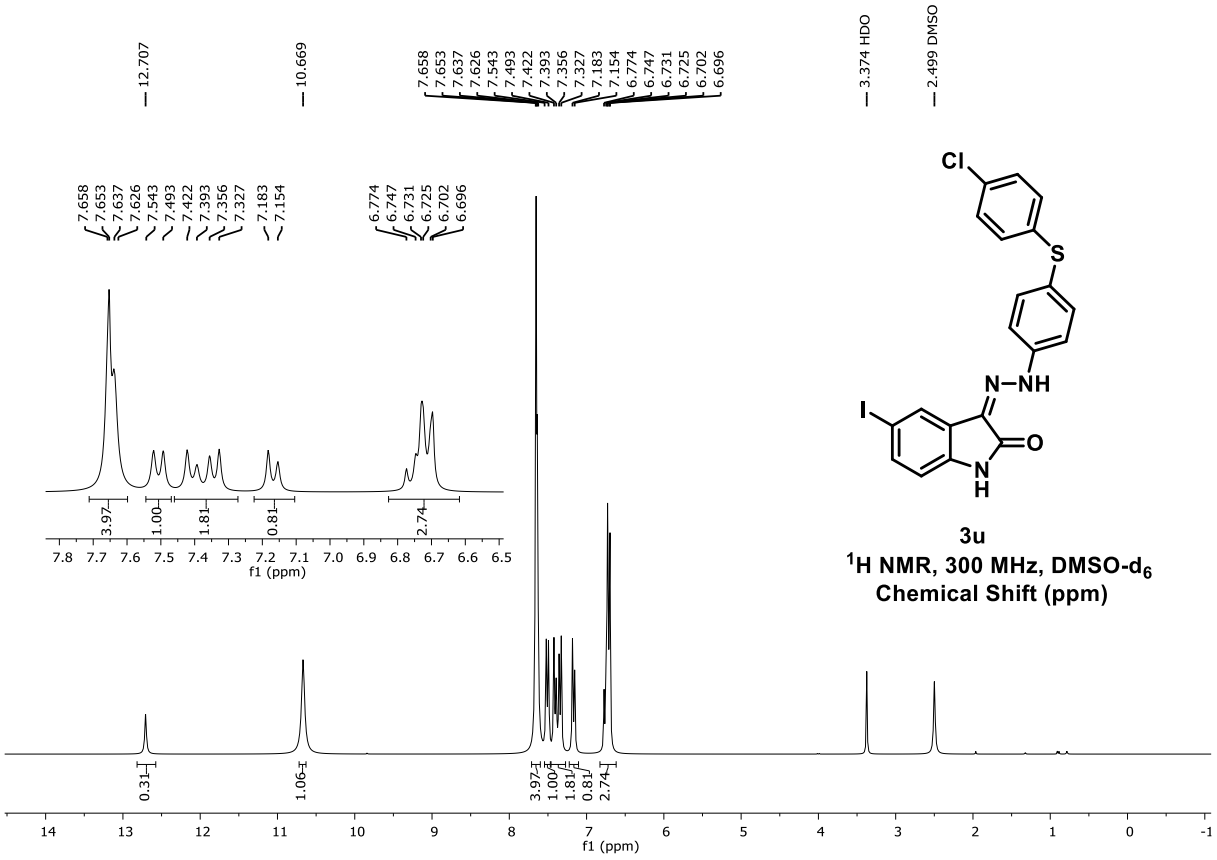
3t

^{1}H NMR, 400 MHz, $CDCl_3$
Chemical Shift (ppm)



3t

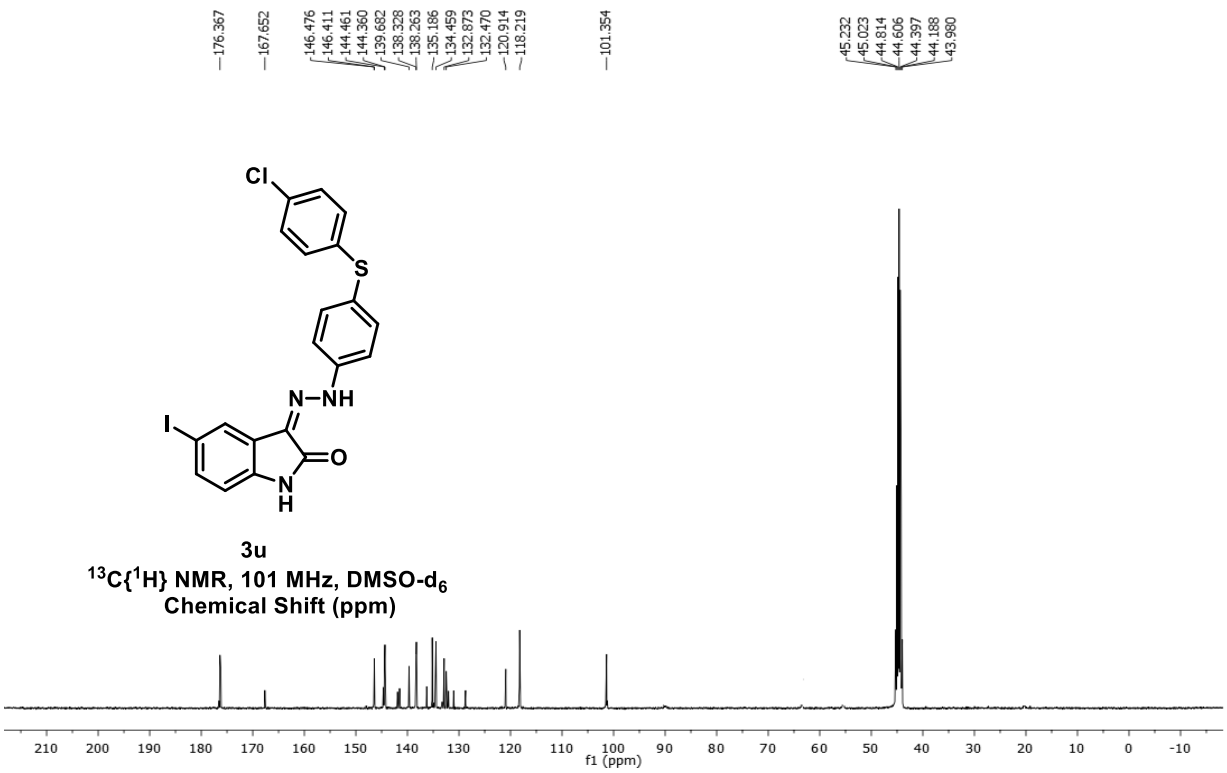
$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$
Chemical Shift (ppm)



3u

^{1}H NMR, 300 MHz, DMSO-d$_6$

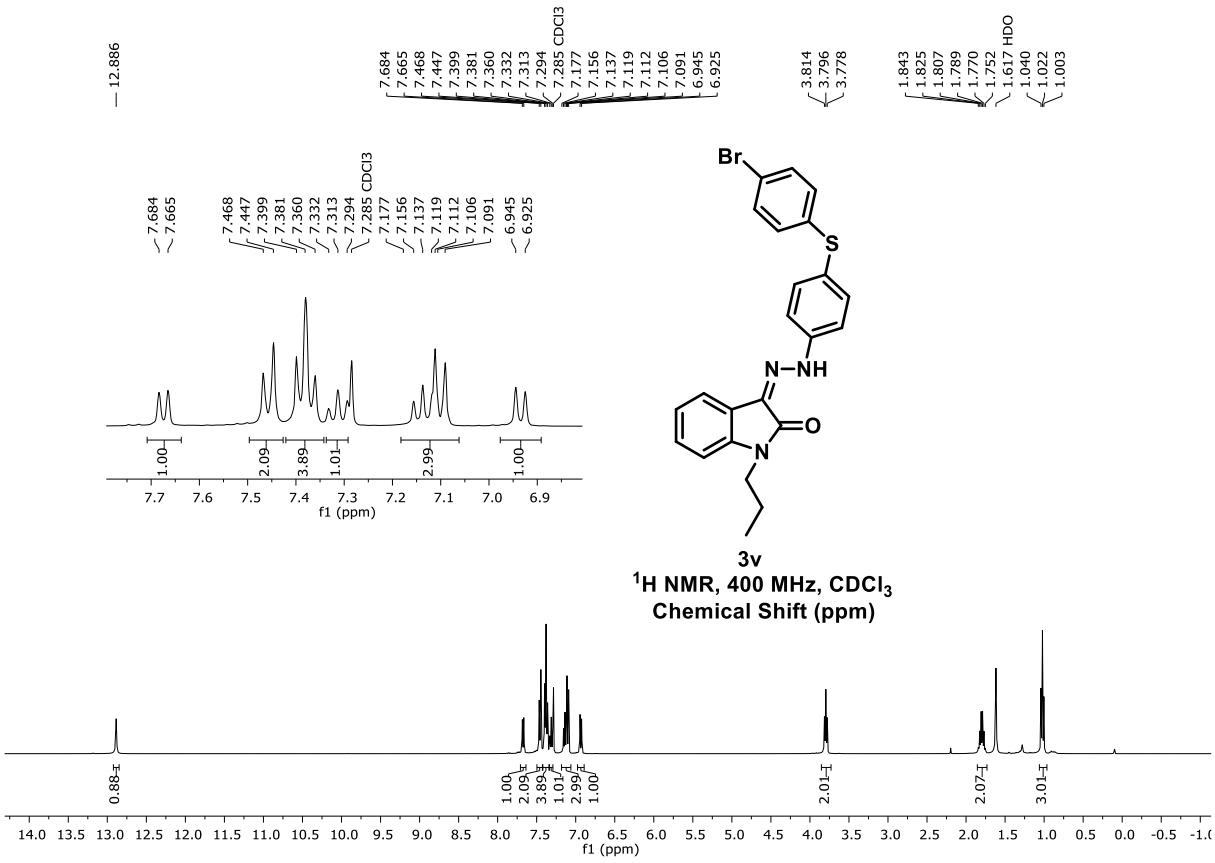
Chemical Shift (ppm)



3u

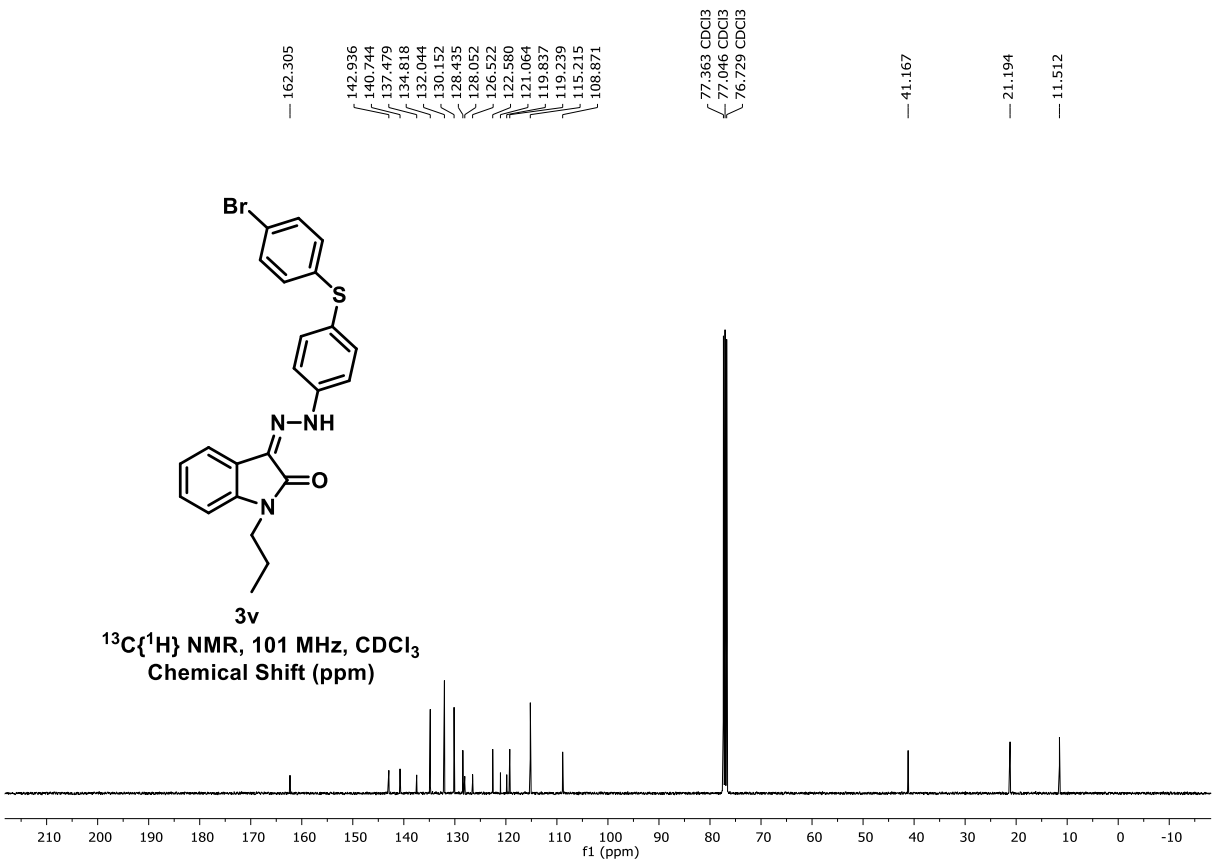
^{13}C{^{1}H} NMR, 101 MHz, DMSO-d$_6$

Chemical Shift (ppm)



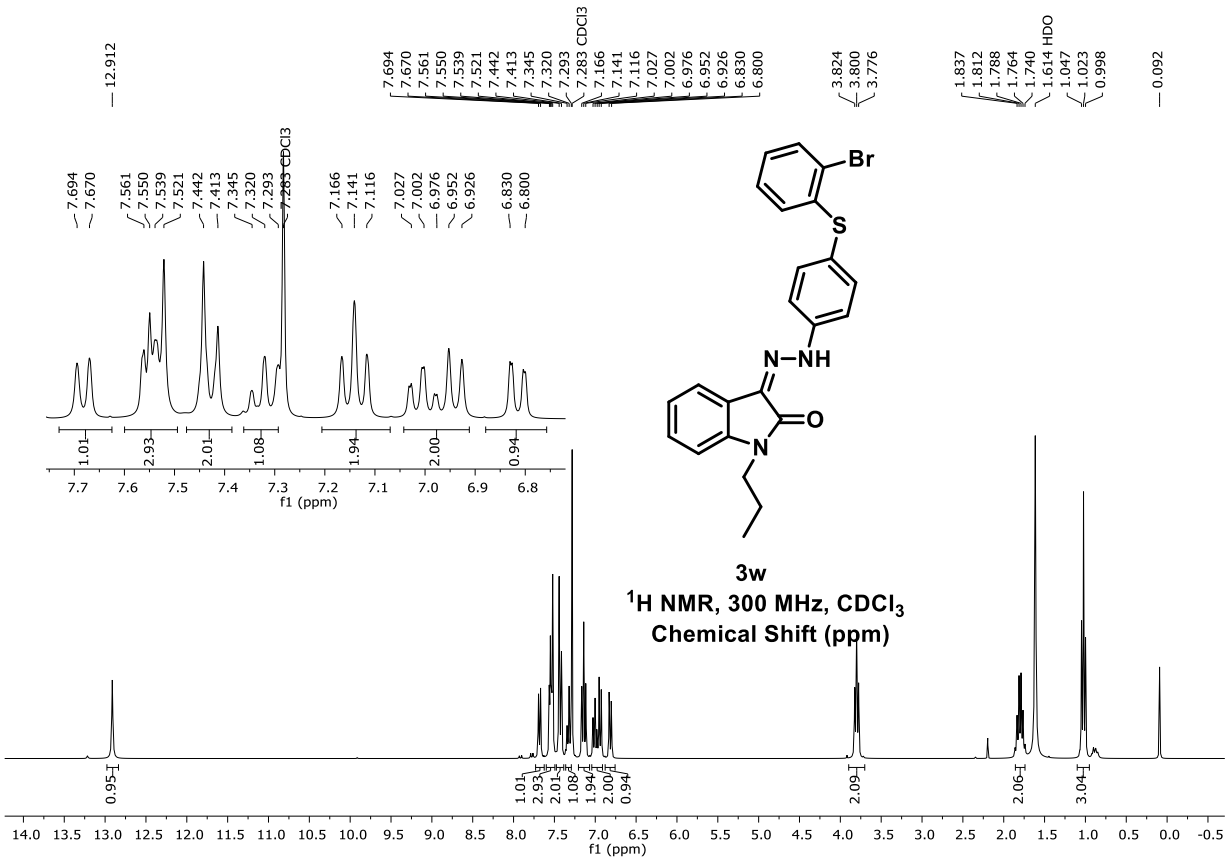
3v

^{1}H NMR, 400 MHz, $CDCl_3$
Chemical Shift (ppm)



3v

$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$
Chemical Shift (ppm)


12.912
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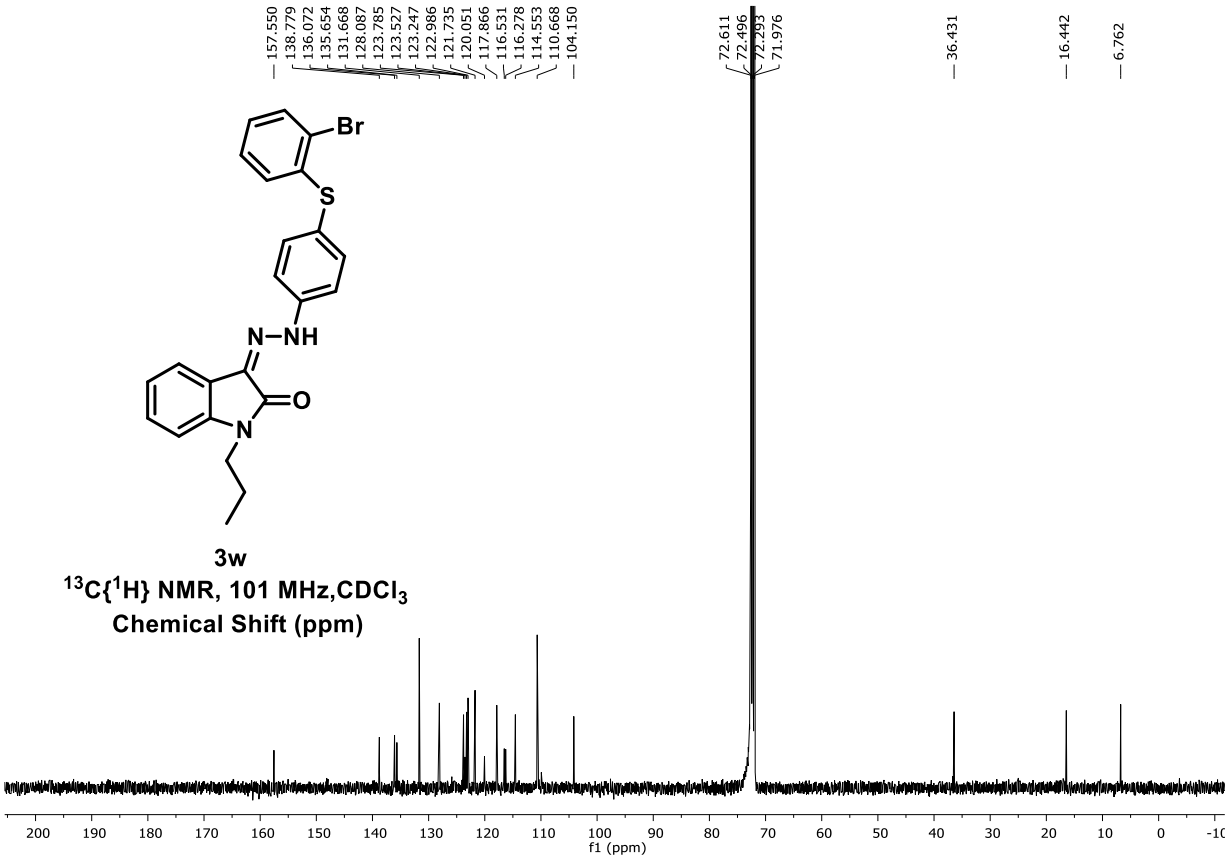
7.670
7.561
7.550
7.539
7.521
7.442
7.413
7.345
7.320
7.293
7.283 CDCl3
7.166
7.141
7.116
7.027
7.002
6.976
6.952
6.926
6.830
6.800
3.824
3.800
3.776
1.837
1.812
1.788
1.764
1.740
1.614 HDO
1.047
1.023
0.998
0.092
Br
S
N–NH
O
N
3w
^{1}H NMR, 300 MHz, CDCl$_3$
Chemical Shift (ppm)
f1 (ppm)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136.072
135.654
131.668
128.087
123.785
123.527
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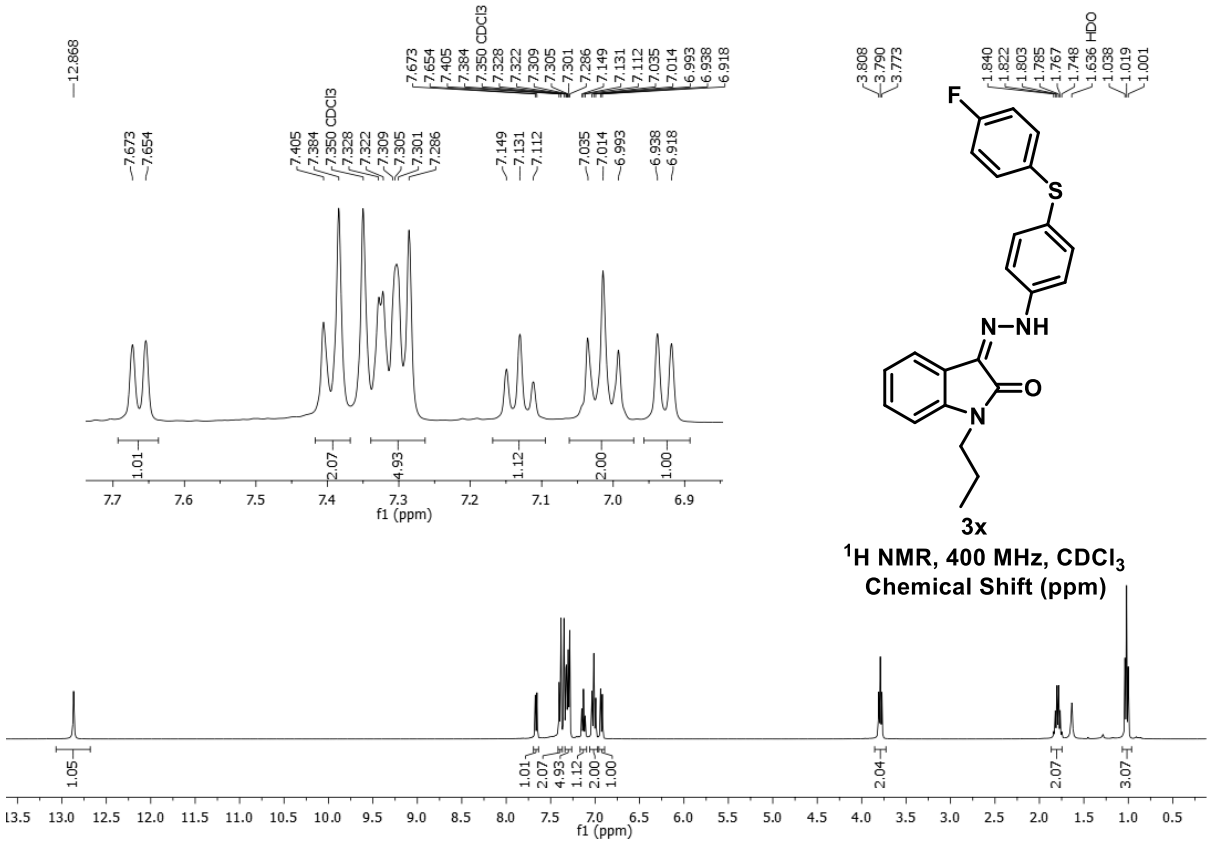
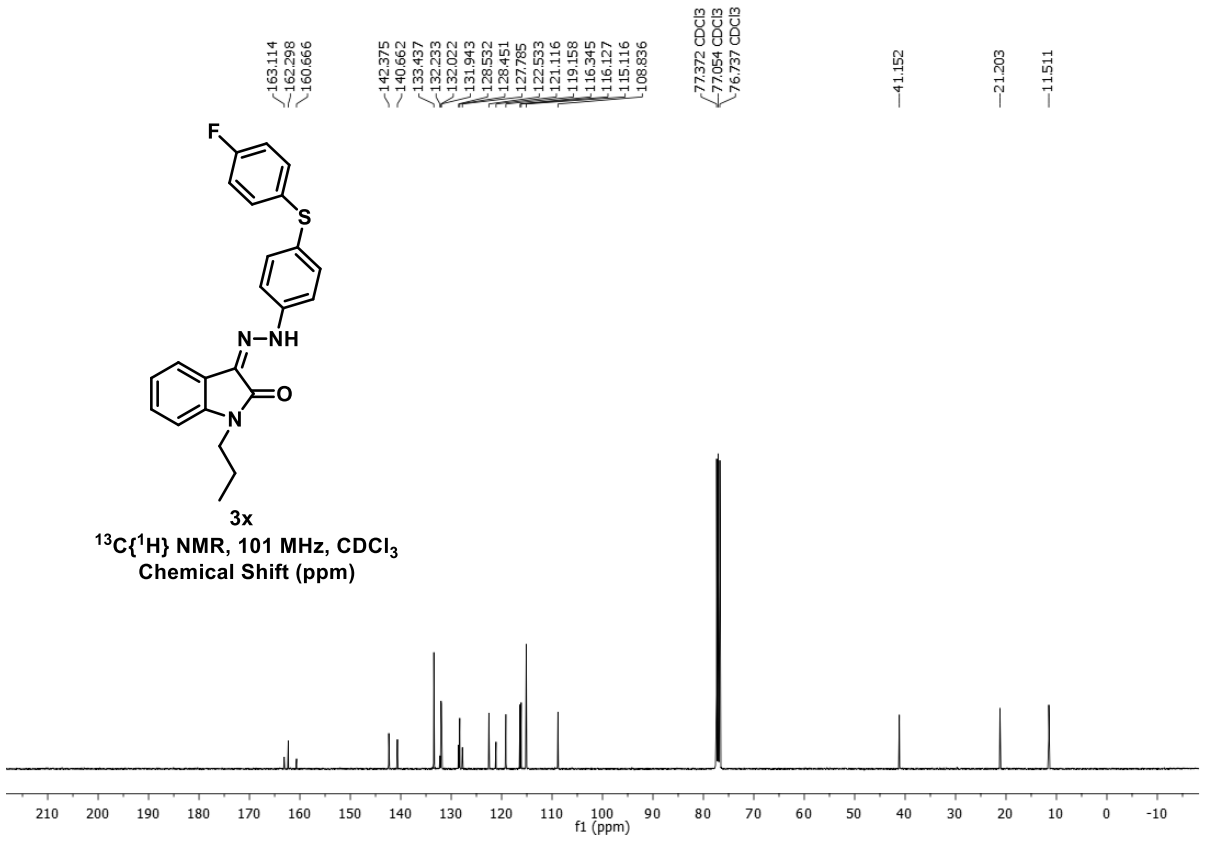
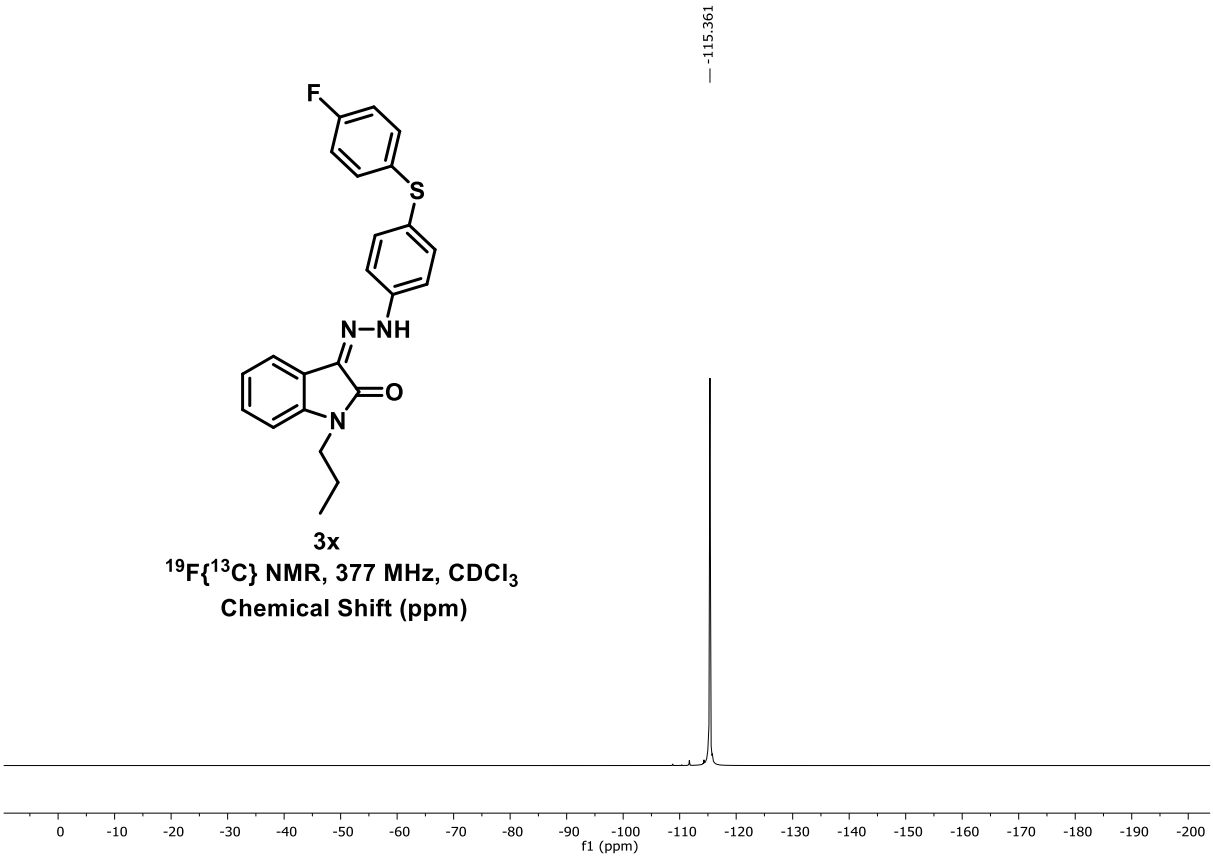
122.986
121.735
120.051
117.866
116.531
116.278
114.553
110.668
104.150
72.611
72.496
72.293
71.976
36.431
16.442
6.762
Br
S
N–NH
O
N
3w
^{13}C{^{1}H} NMR, 101 MHz,CDCl$_3$
Chemical Shift (ppm)
f1 (ppm)


12.868
7.673
7.654
7.405
7.384
7.350 CDCl3
7.328
7.322
7.309
7.305
7.301
7.286
7.149
7.131
7.112
7.035
7.014
6.993
6.938
6.918
3.808
3.790
3.773
1.840
1.822
1.803
1.785
1.767
1.748
1.636 HDO
1.038
1.019
1.001
1.01
2.07
4.93
1.12
2.00
1.00
f1 (ppm)
F
S
N–NH
O
N
3x
1H NMR, 400 MHz, CDCl3
Chemical Shift (ppm)
1.05
1.01
2.07
4.93
1.12
2.00
1.00
2.04
2.07
3.07
f1 (ppm)

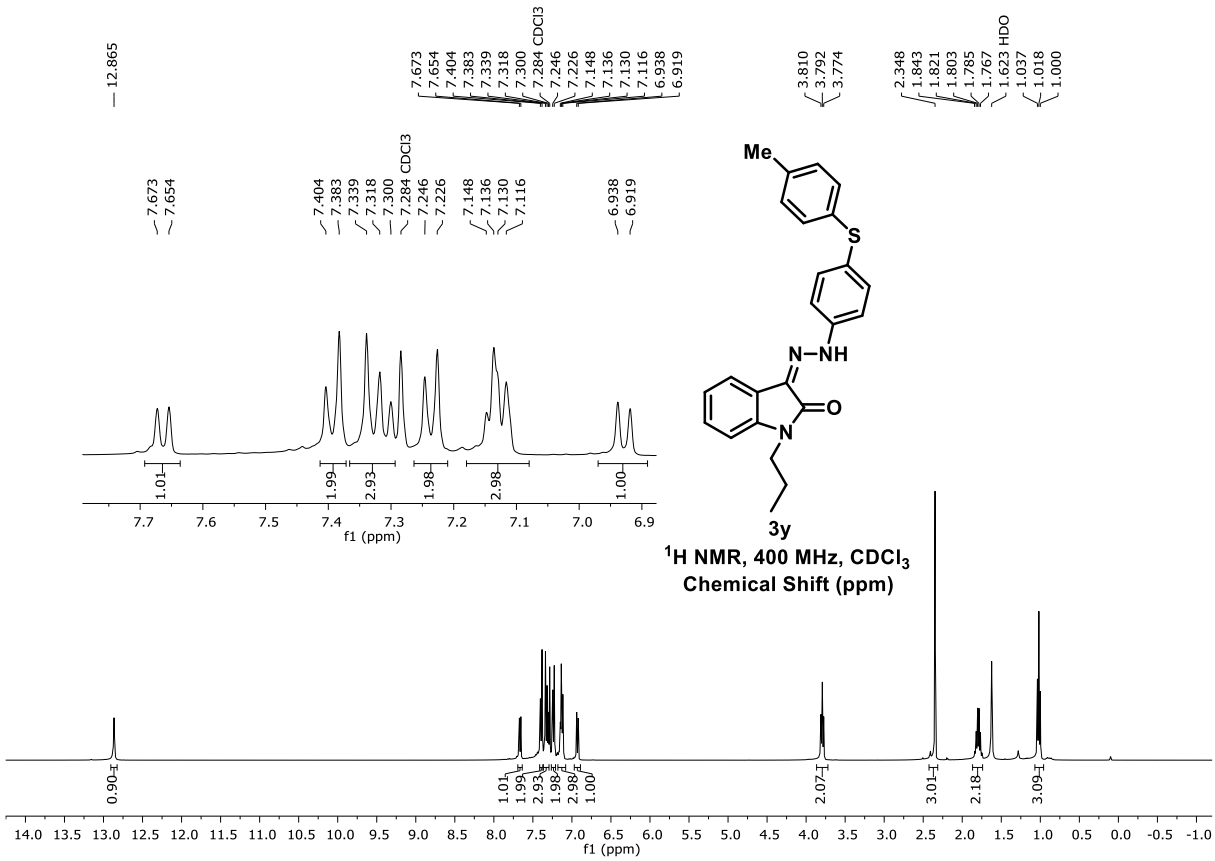

163.114
162.298
160.666
142.375
140.662
133.437
132.233
132.022
131.943
128.532
128.451
127.785
122.533
121.116
119.158
116.345
116.127
115.116
108.836
77.372 CDCl3
77.054 CDCl3
76.737 CDCl3
41.152
21.203
11.511
F
S
N–NH
O
N
3x
13C{1H} NMR, 101 MHz, CDCl3
Chemical Shift (ppm)
f1 (ppm)

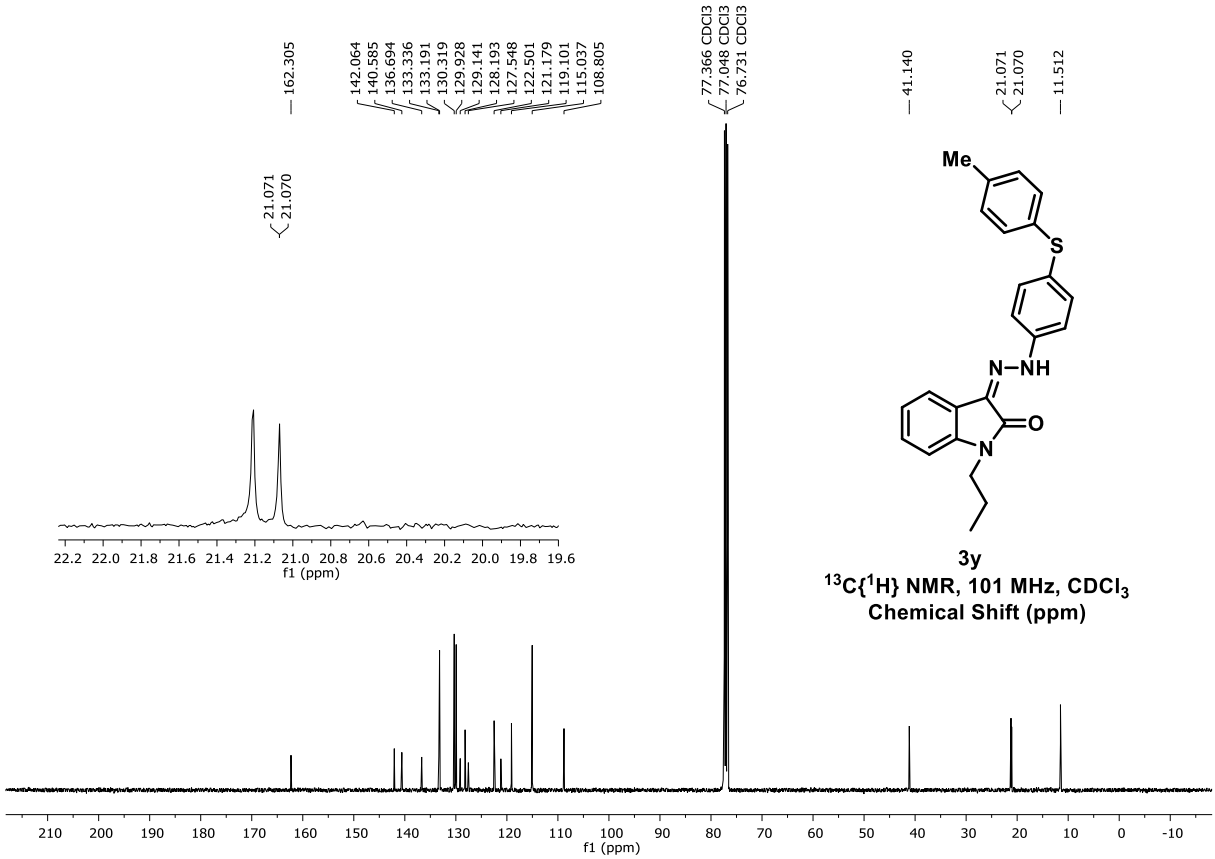


3x

$^{19}F\{^{13}C\}$ NMR, 377 MHz, $CDCl_3$

Chemical Shift (ppm)


12.865
7.673
7.654
7.404
7.383
7.339
7.318
7.300
7.284 CDCl3
7.246
7.226
7.148
7.136
7.130
7.116
6.938
6.919
3.810
3.792
3.774
2.348
1.843
1.821
1.803
1.785
1.767
1.623 HDO
1.037
1.018
1.000
Me
S
N–NH
O
N
3y
^{1}H NMR, 400 MHz, CDCl$_3$
Chemical Shift (ppm)
f1 (ppm)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142.064
140.585
136.694
133.336
133.191
130.319
129.928
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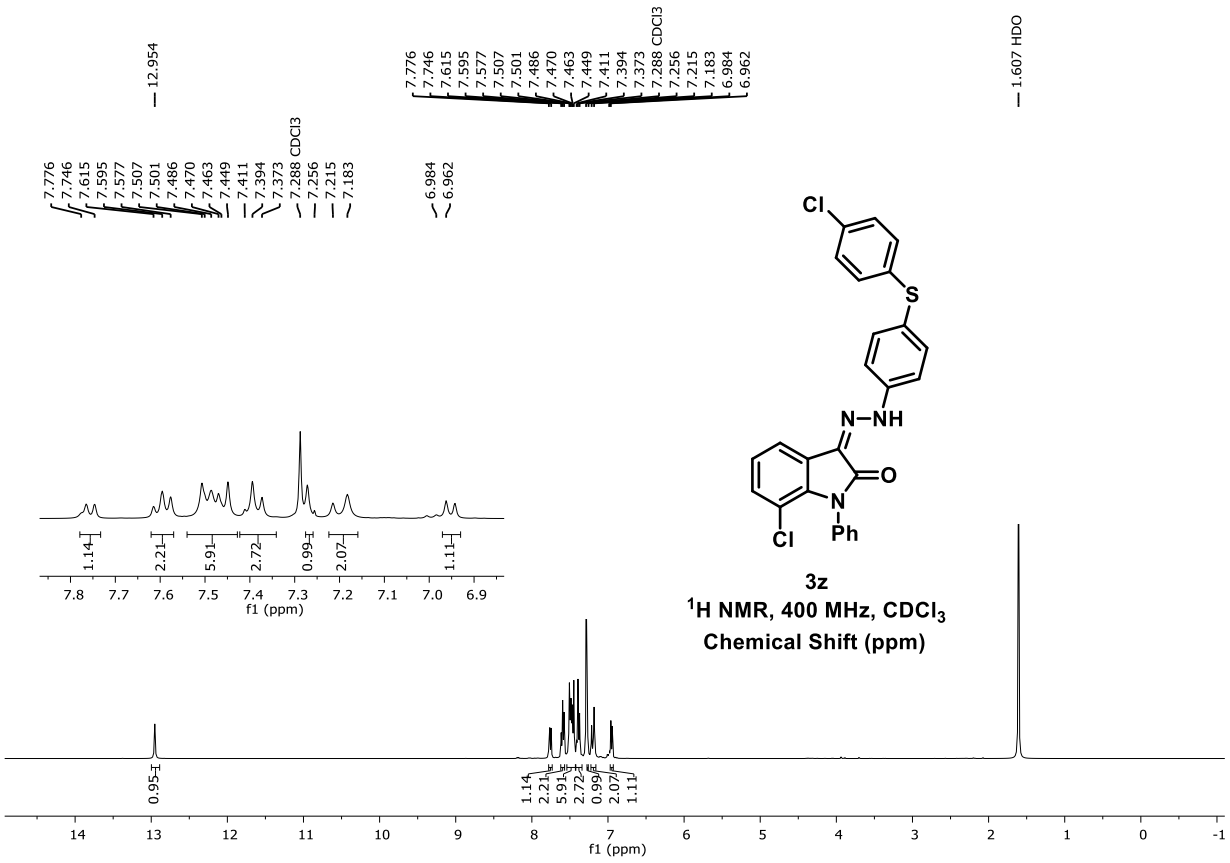
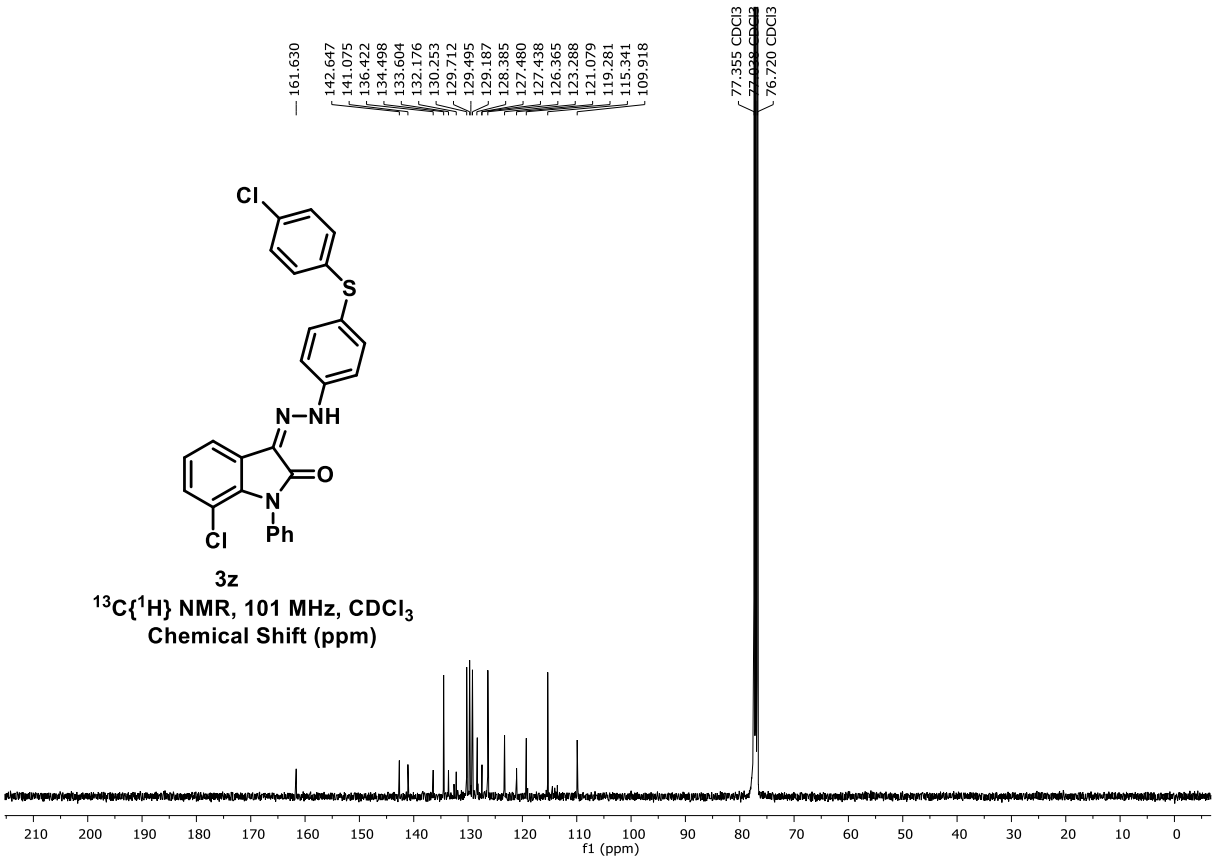
128.193
127.548
122.501
121.179
119.101
115.037
108.805
77.366 CDCl3
77.048 CDCl3
76.731 CDCl3
41.140
21.071
21.070
11.512
Me
S
N–NH
O
N
3y
^{13}C{^{1}H} NMR, 101 MHz, CDCl$_3$
Chemical Shift (ppm)
f1 (ppm)



3z

^{1}H NMR, 400 MHz, $CDCl_3$

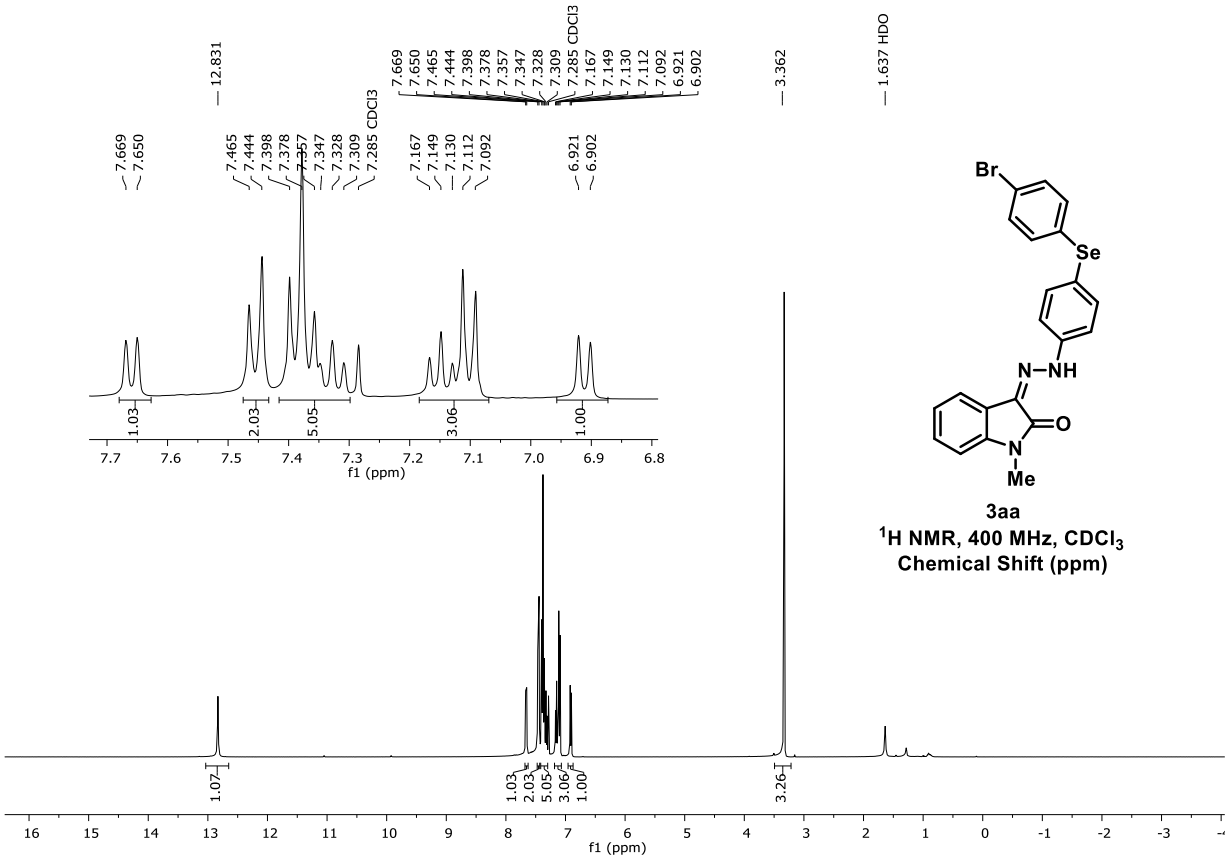
Chemical Shift (ppm)



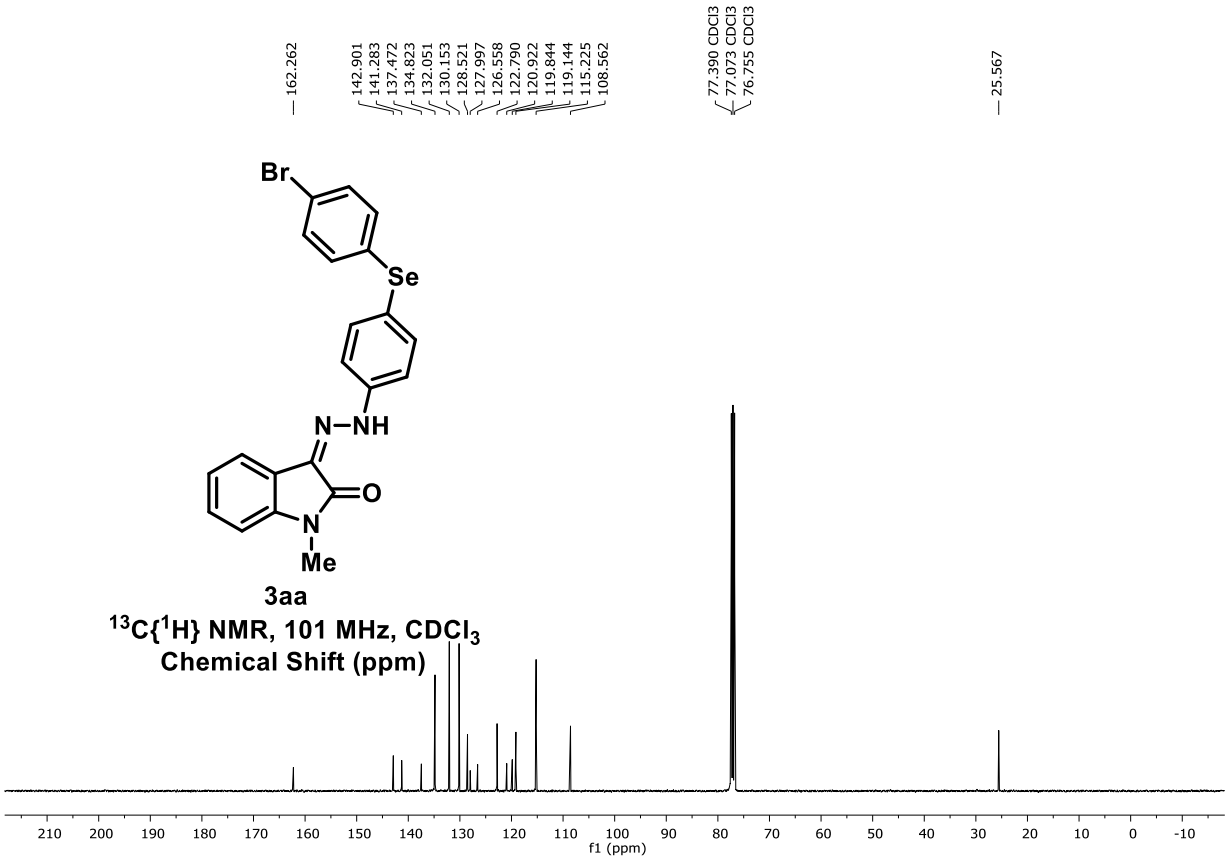
3z

$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$

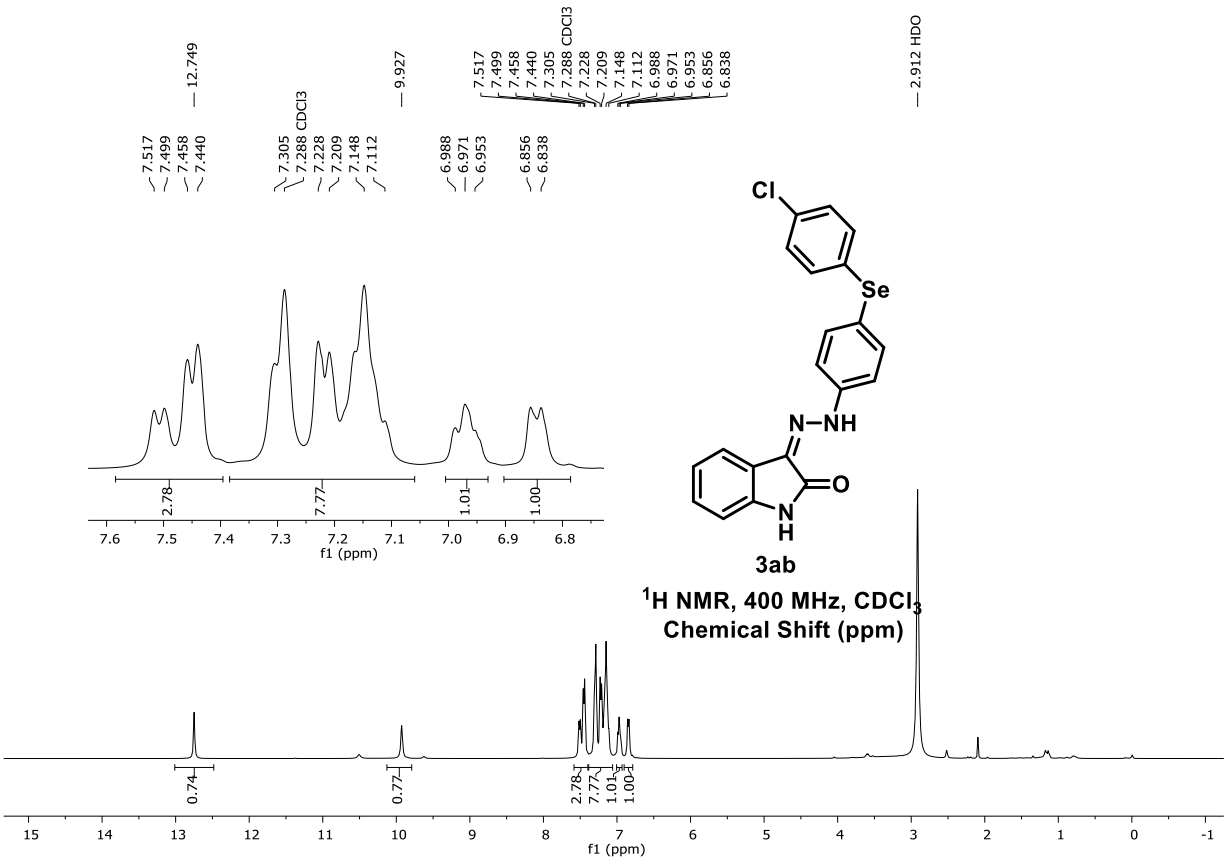
Chemical Shift (ppm)



3aa
^{1}H NMR, 400 MHz, $CDCl_3$
Chemical Shift (ppm)

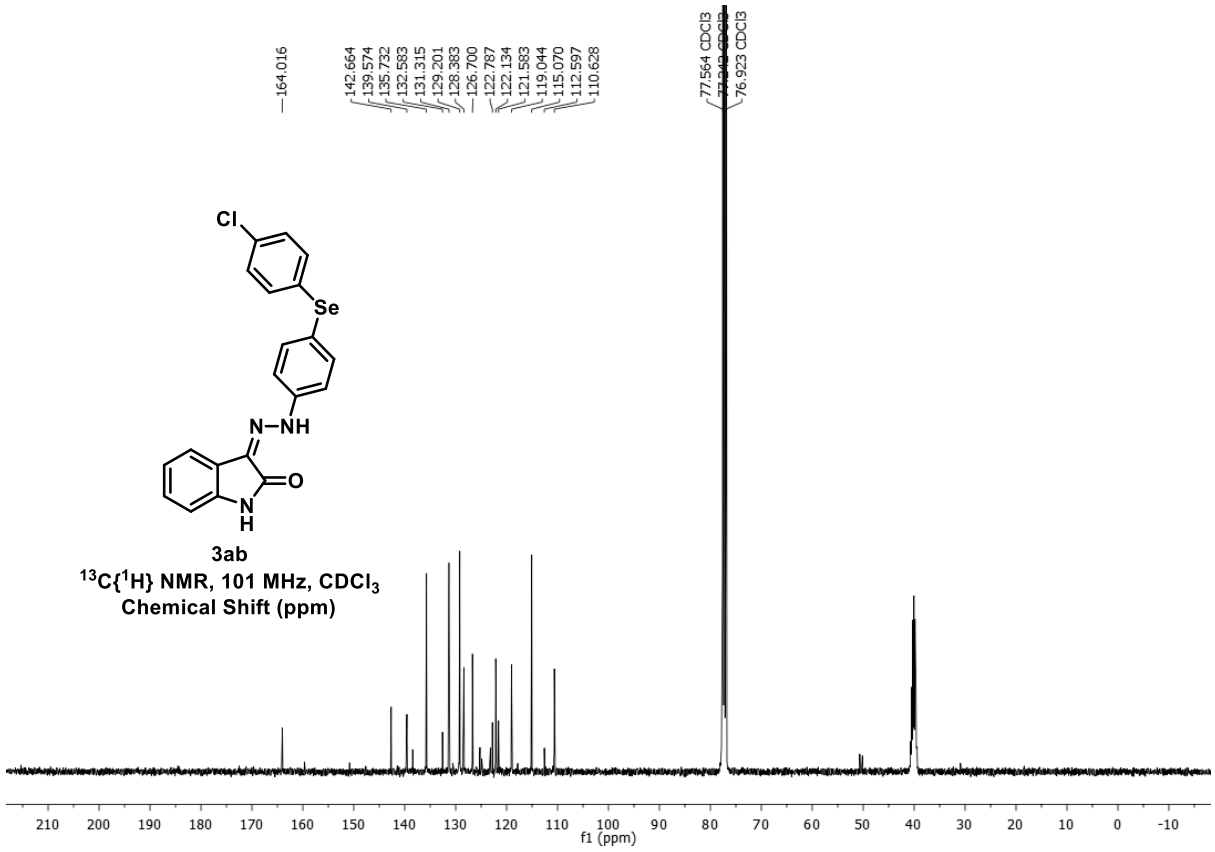


3aa
$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$
Chemical Shift (ppm)



3ab

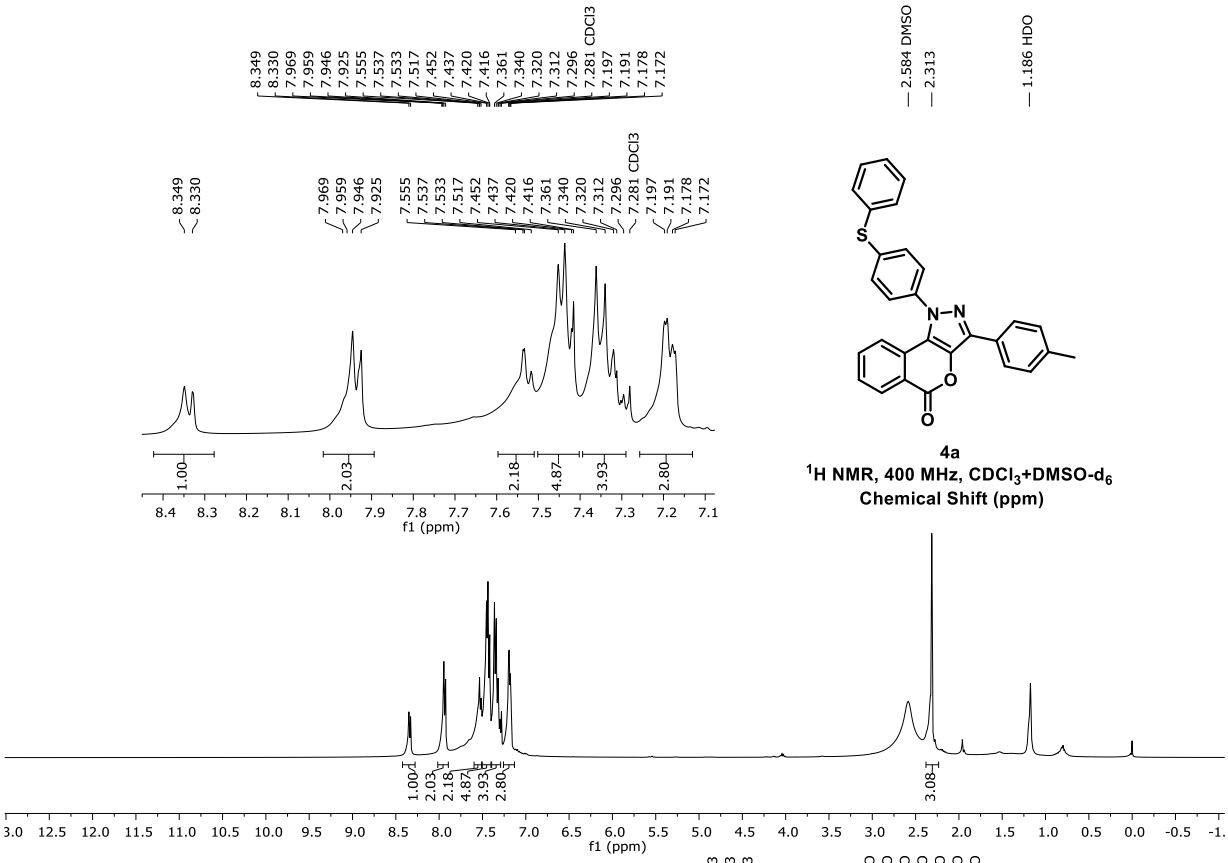
^{1}H NMR, 400 MHz, $CDCl_3$
Chemical Shift (ppm)



3ab

$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$
Chemical Shift (ppm)

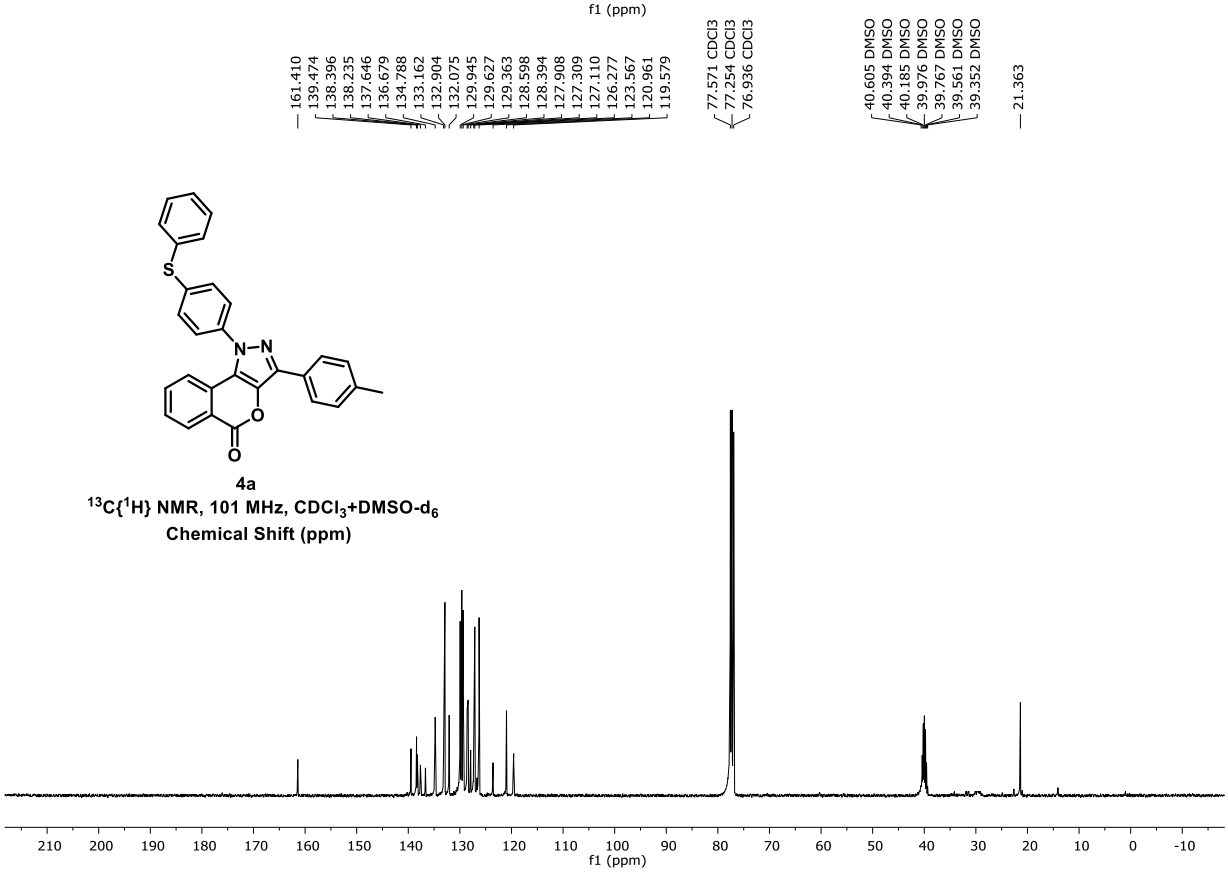
^{1}H and ^{13}C NMR Spectra of compounds 4a-v:



4a

^{1}H NMR, 400 MHz, $CDCl_3$+DMSO-d_6

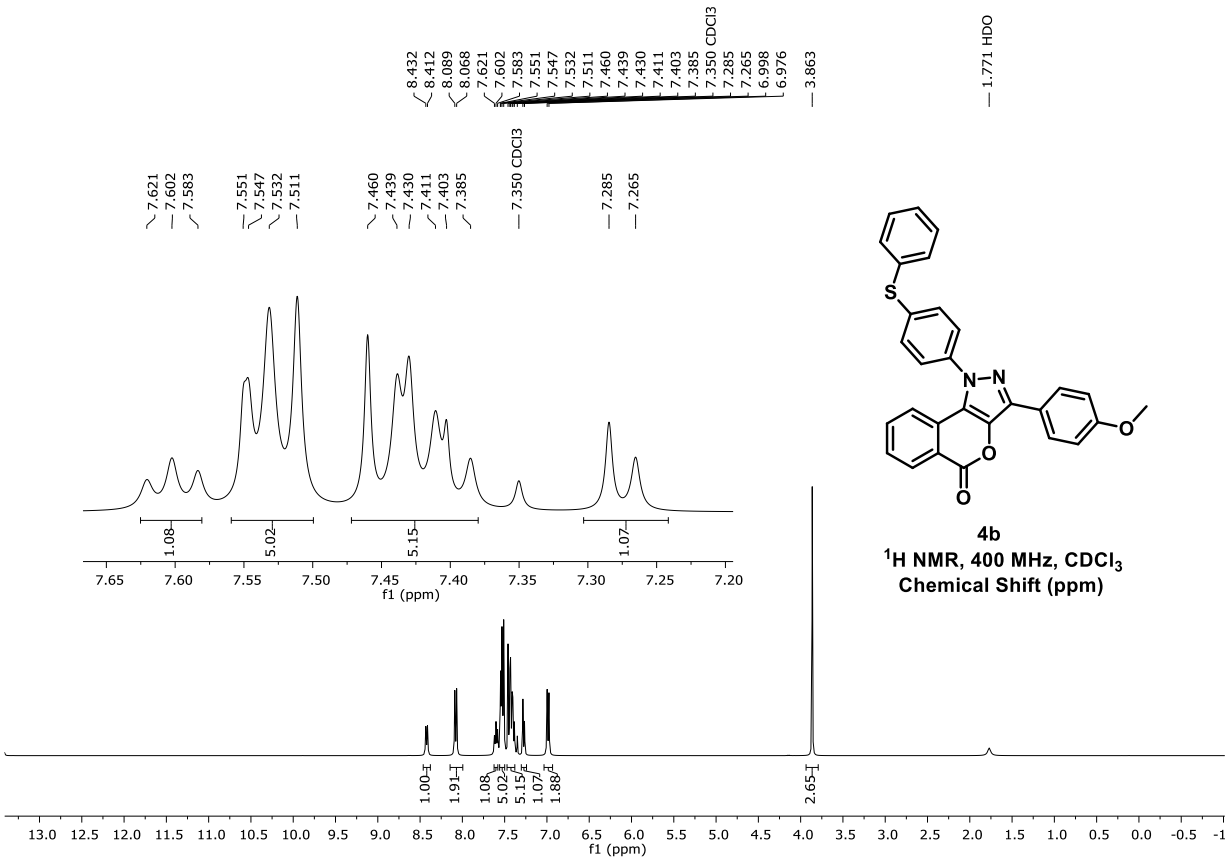
Chemical Shift (ppm)



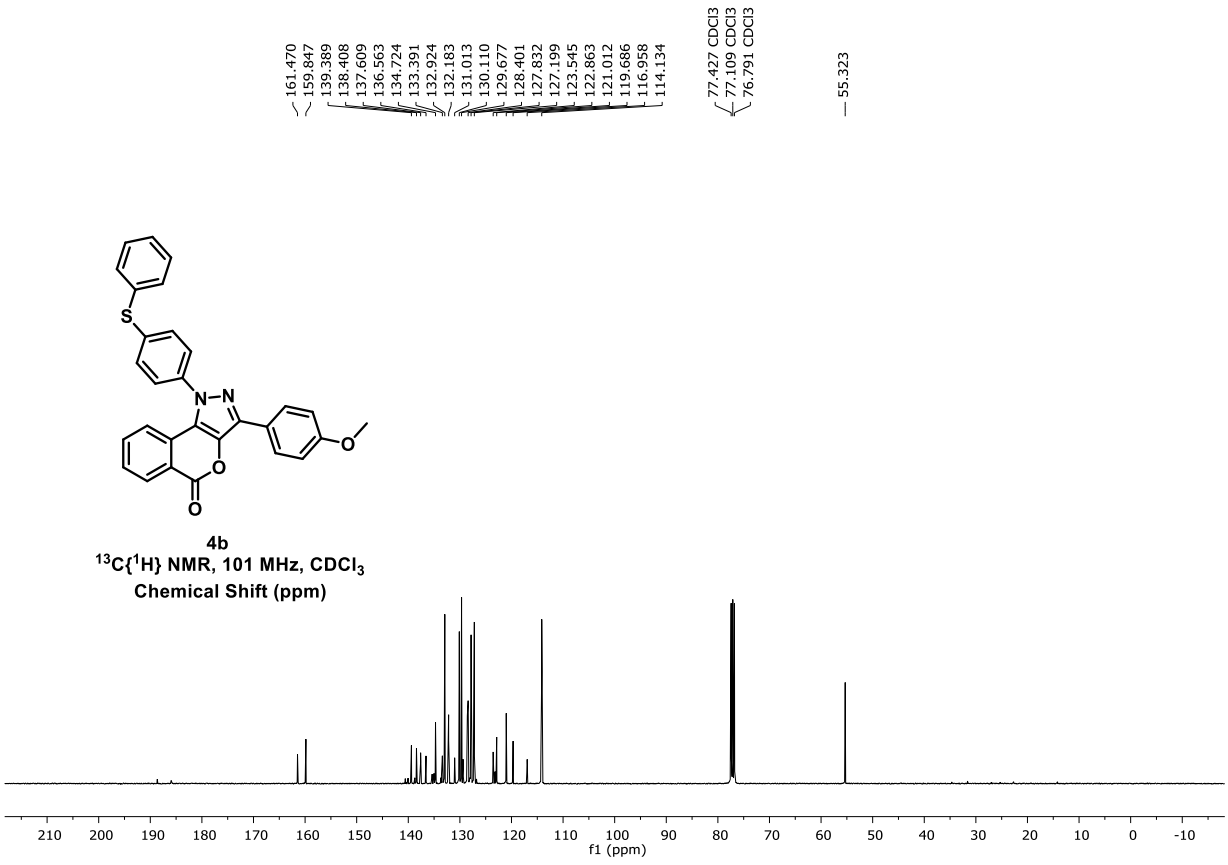
4a

^{13}C{^{1}H} NMR, 101 MHz, $CDCl_3$+DMSO-d_6

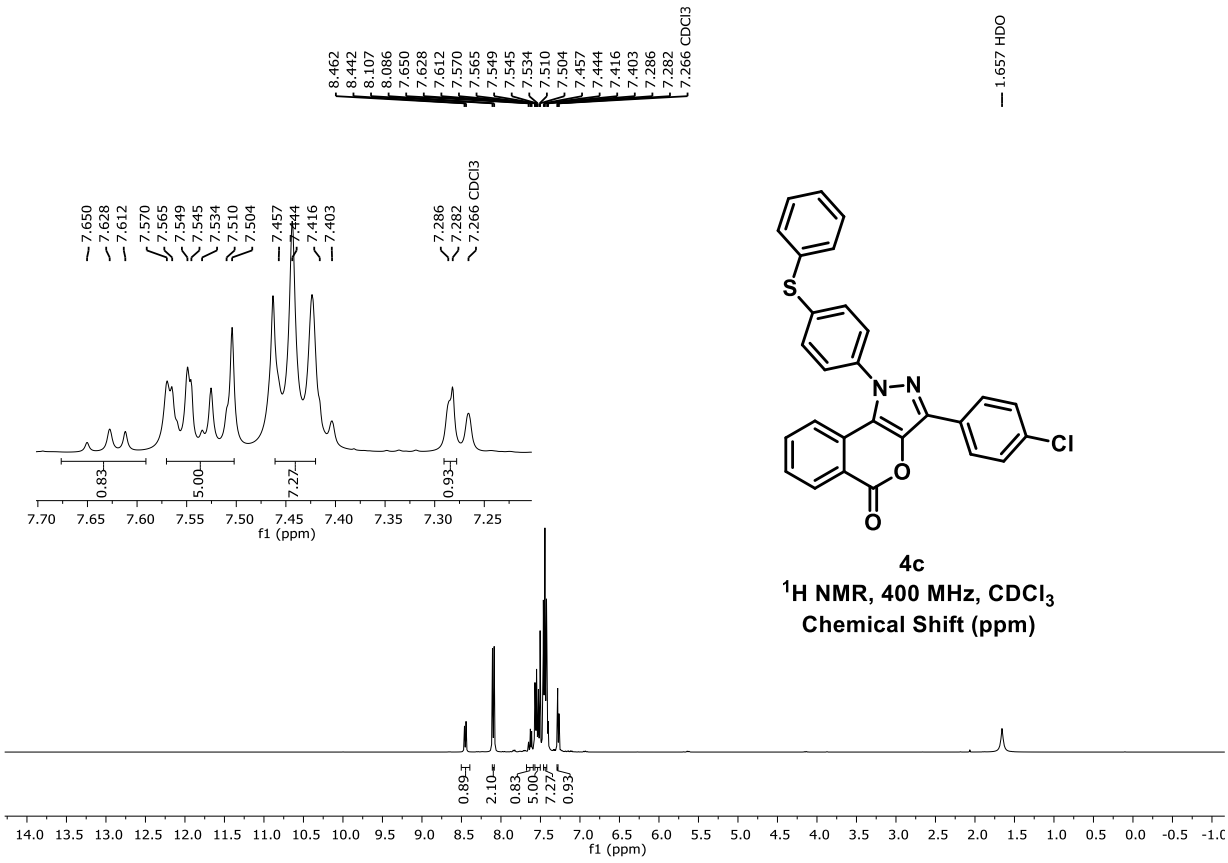
Chemical Shift (ppm)



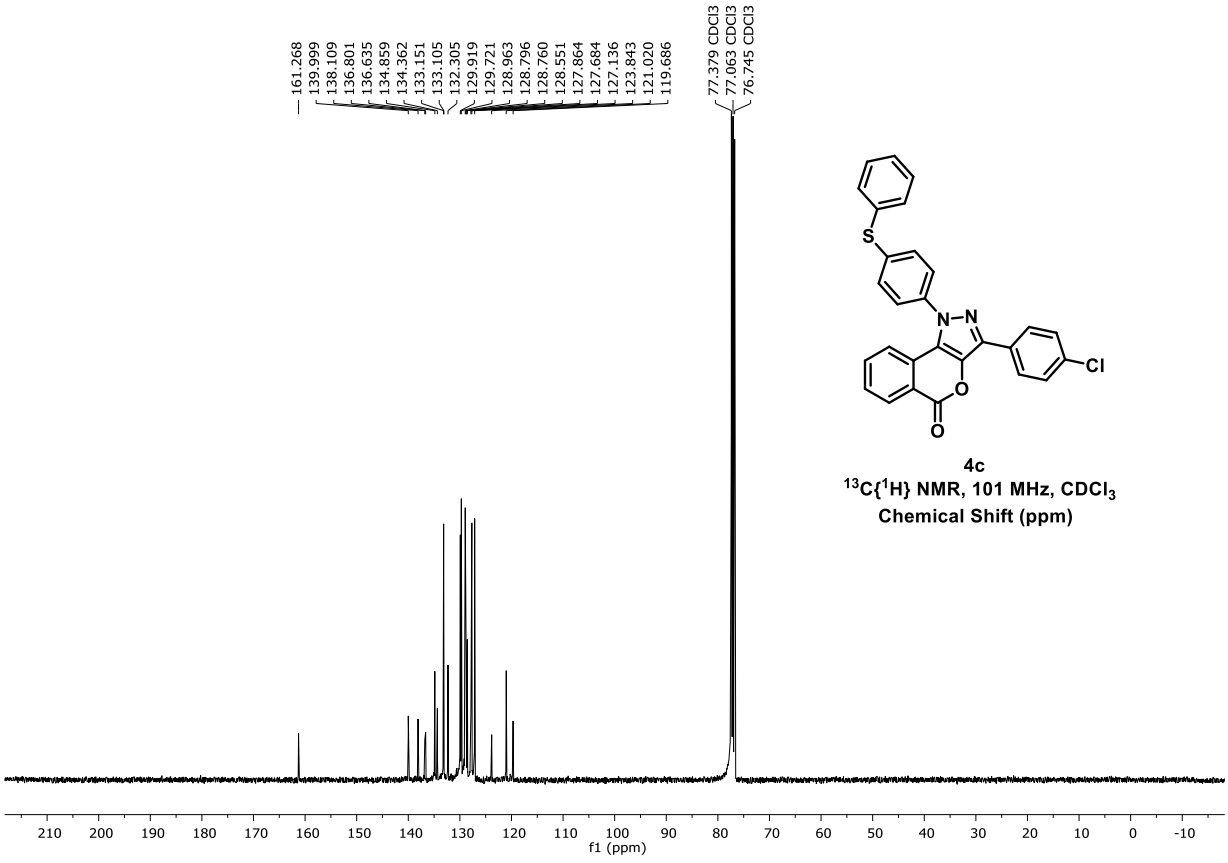
4b
^{1}H NMR, 400 MHz, $CDCl_3$
Chemical Shift (ppm)



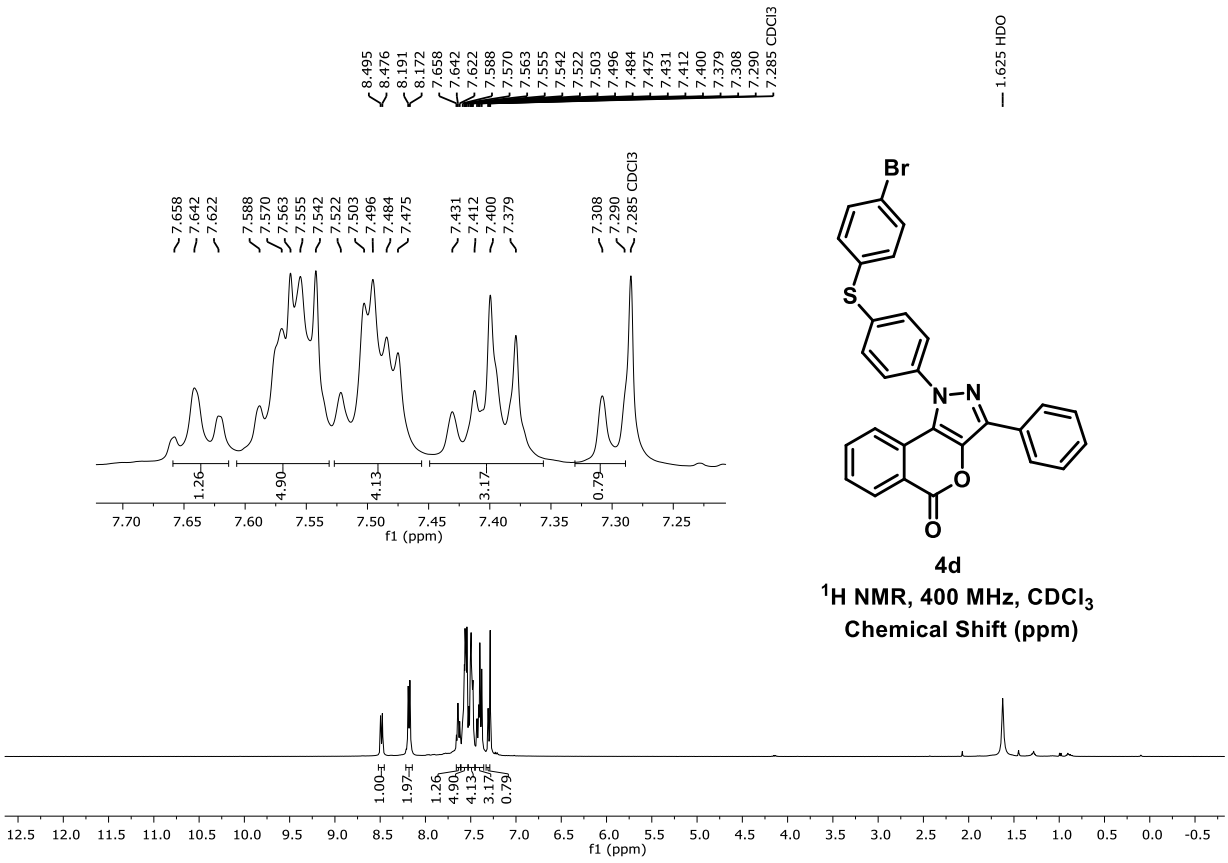
4b
$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$
Chemical Shift (ppm)



4c
^{1}H NMR, 400 MHz, $CDCl_3$
Chemical Shift (ppm)



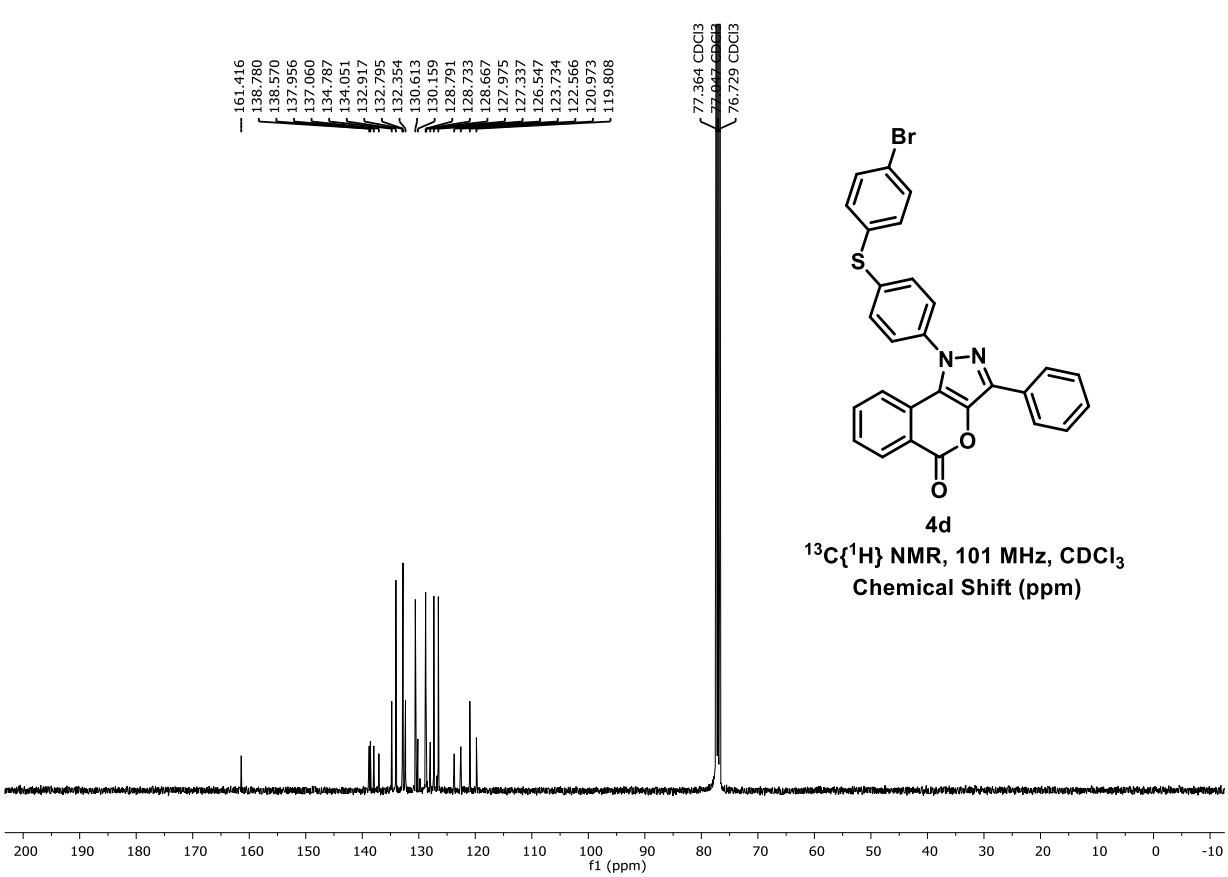
4c
$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$
Chemical Shift (ppm)



4d

^{1}H NMR, 400 MHz, $CDCl_3$

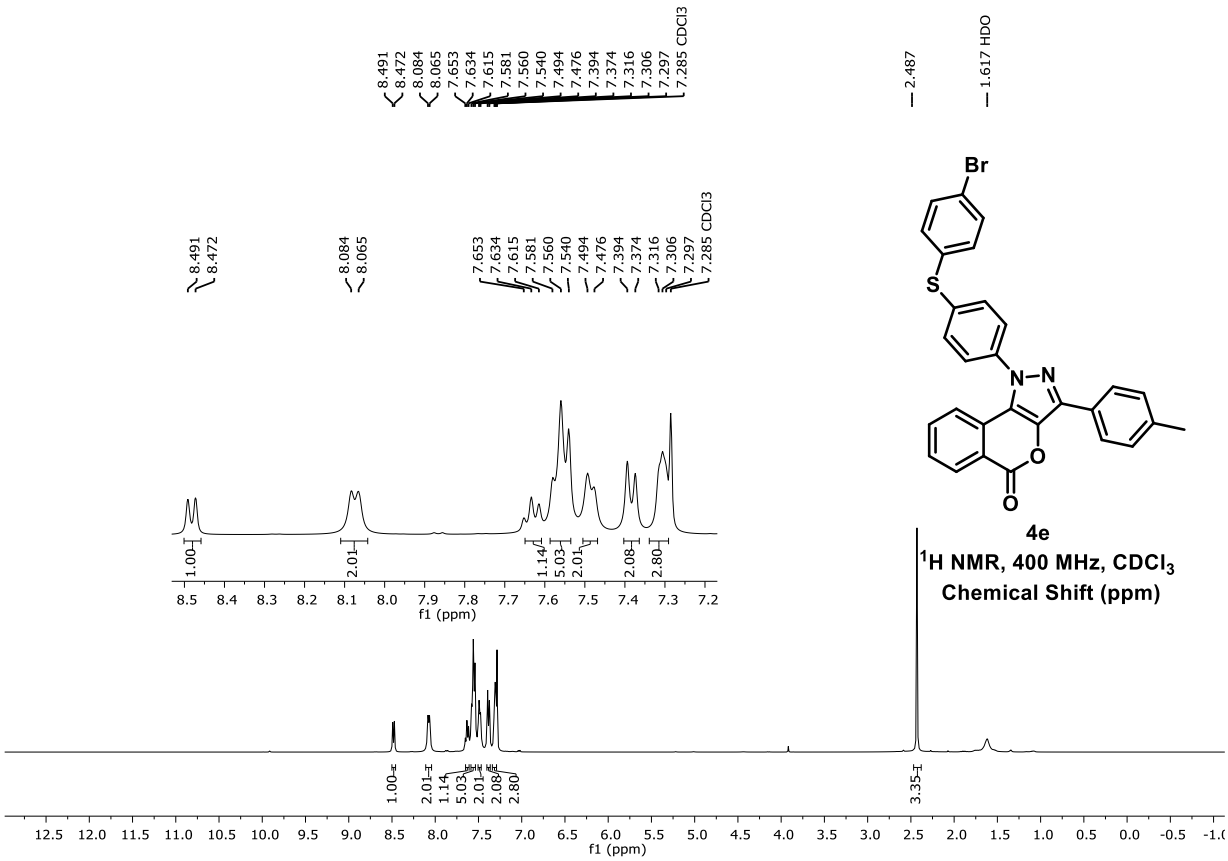
Chemical Shift (ppm)

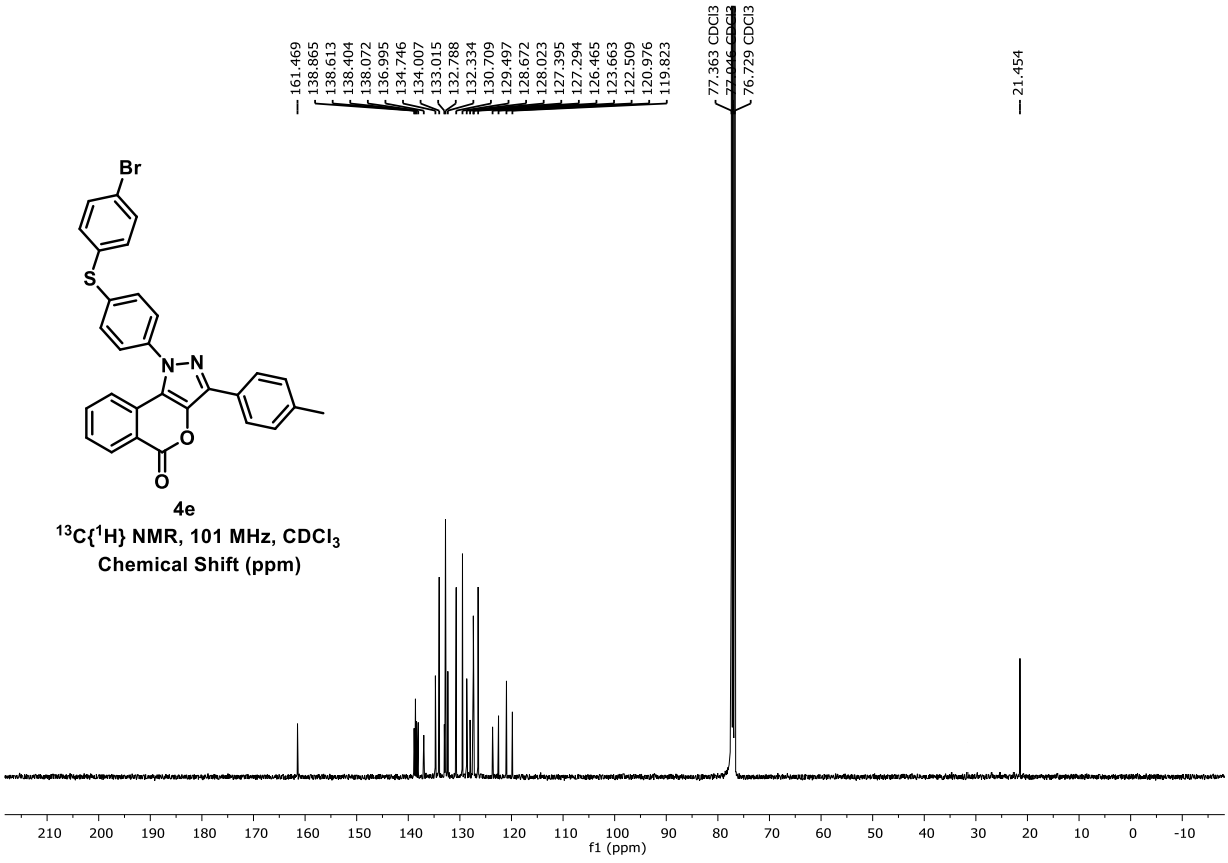


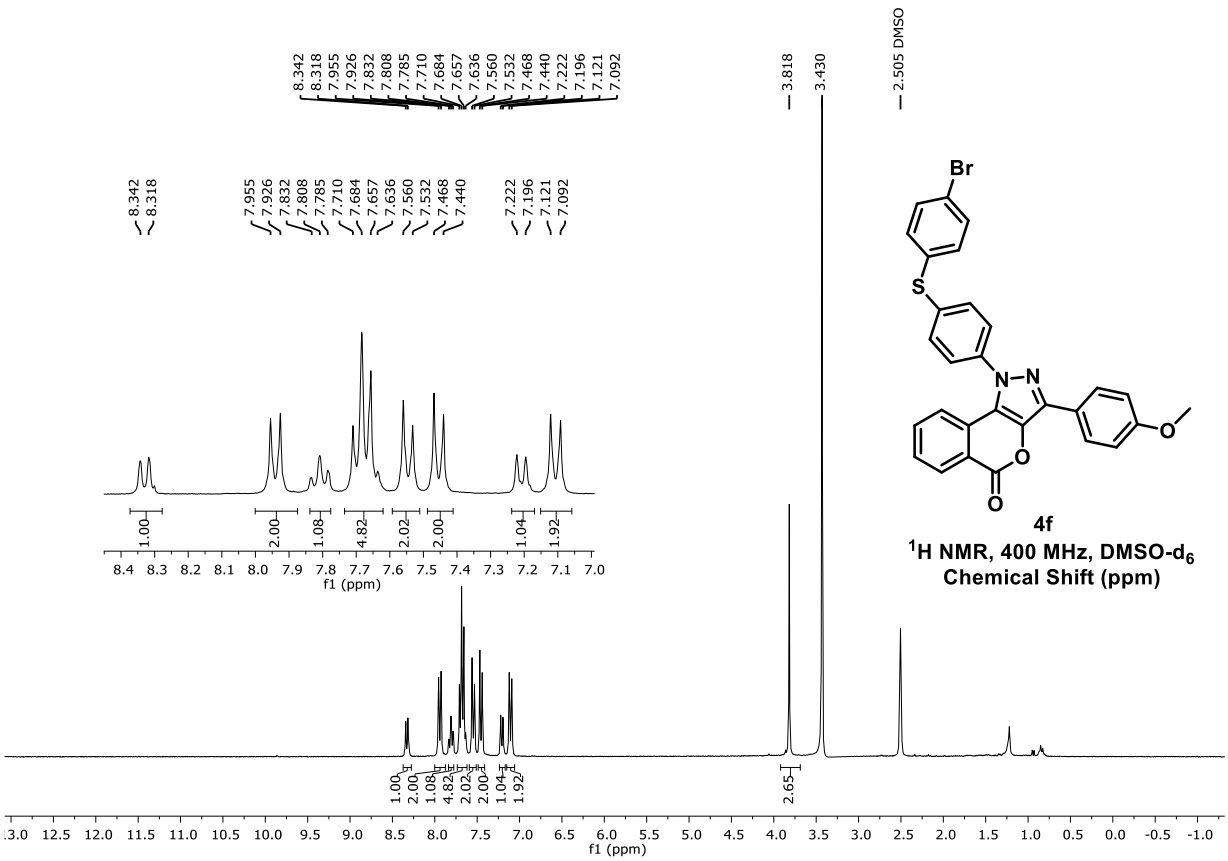
4d

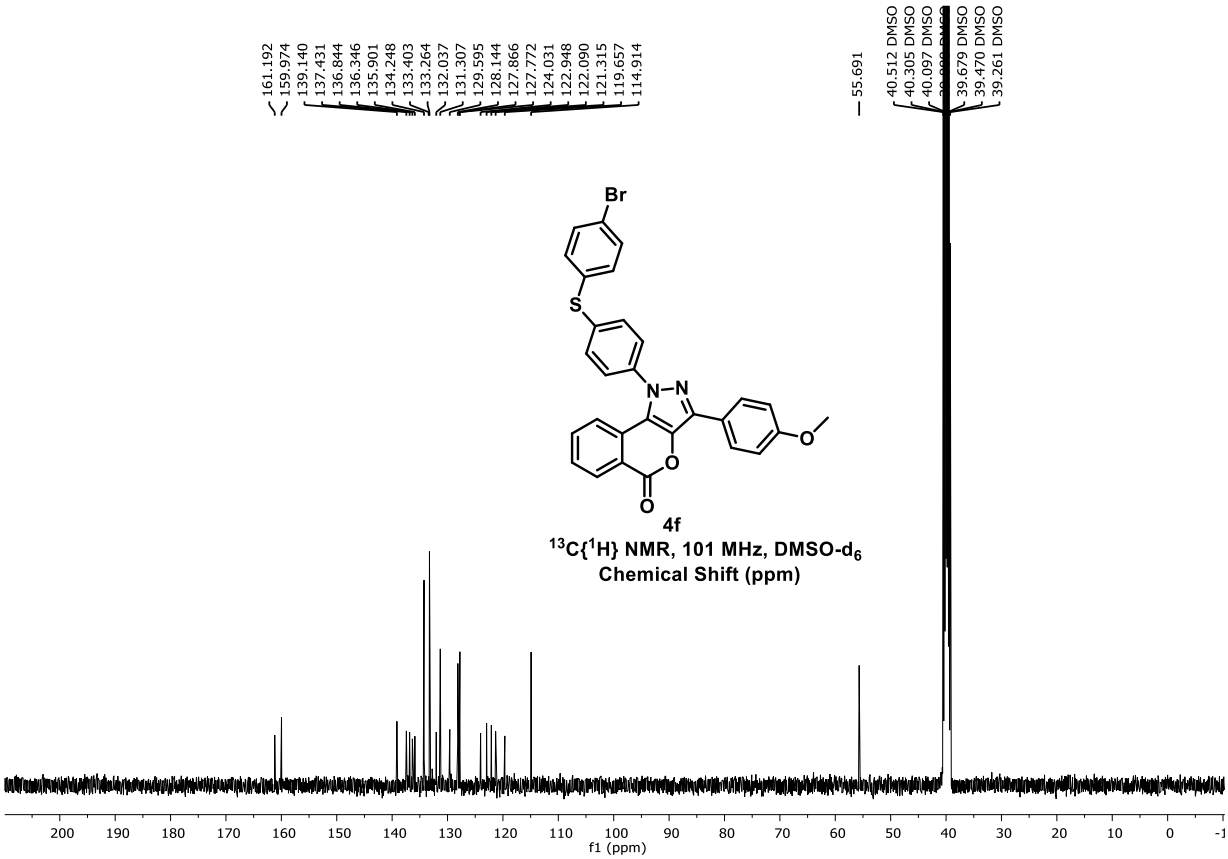
$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$

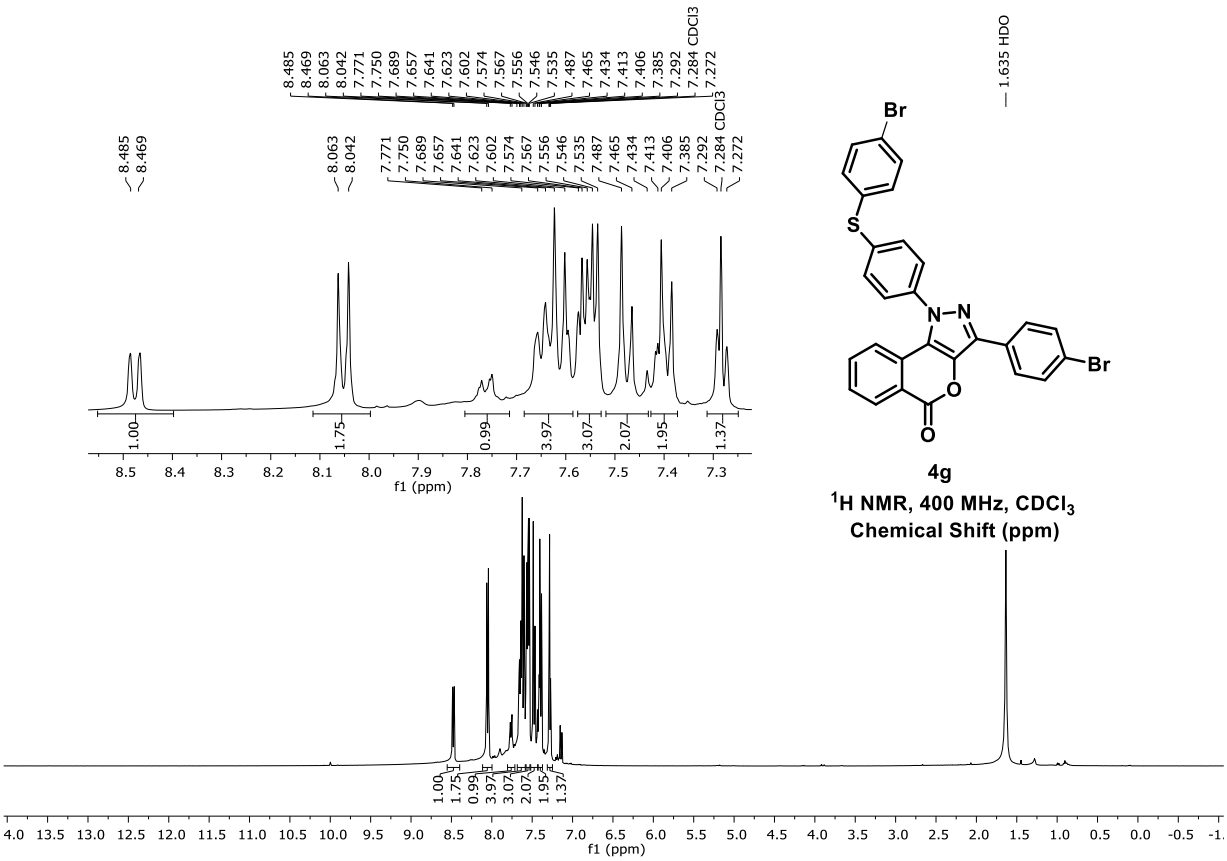
Chemical Shift (ppm)


8.491
8.472
8.084
8.065
7.653
7.634
7.615
7.581
7.560
7.540
7.494
7.476
7.394
7.374
7.316
7.306
7.297
7.285 CDCl3
2.487
1.617 HDO
Br
S
N–N
O
O
4e
^{1}H NMR, 400 MHz, CDCl$_3$
Chemical Shift (ppm)
1.00
2.01
1.14
5.03
2.01
2.08
2.80
3.35
f1 (ppm)


161.469
138.865
138.613
138.404
138.072
136.995
134.746
134.007
133.015
132.788
132.334
130.709
129.497
128.672
128.023
127.395
127.294
126.465
123.663
122.509
120.976
119.823
77.363 CDCl3
77.046 CDCl3
76.729 CDCl3
21.454
Br
S
N–N
O
O
4e
^{13}C{^{1}H} NMR, 101 MHz, CDCl$_3$
Chemical Shift (ppm)
f1 (ppm)


8.342
8.318
7.955
7.926
7.832
7.808
7.785
7.710
7.684
7.657
7.636
7.560
7.532
7.468
7.440
7.222
7.196
7.121
7.092
3.818
3.430
2.505 DMSO
Br
S
N–N
O
O
O
4f
^{1}H NMR, 400 MHz, DMSO-d$_6$
Chemical Shift (ppm)
1.00
2.00
1.08
4.82
2.02
2.00
1.04
1.92
2.65
f1 (ppm)

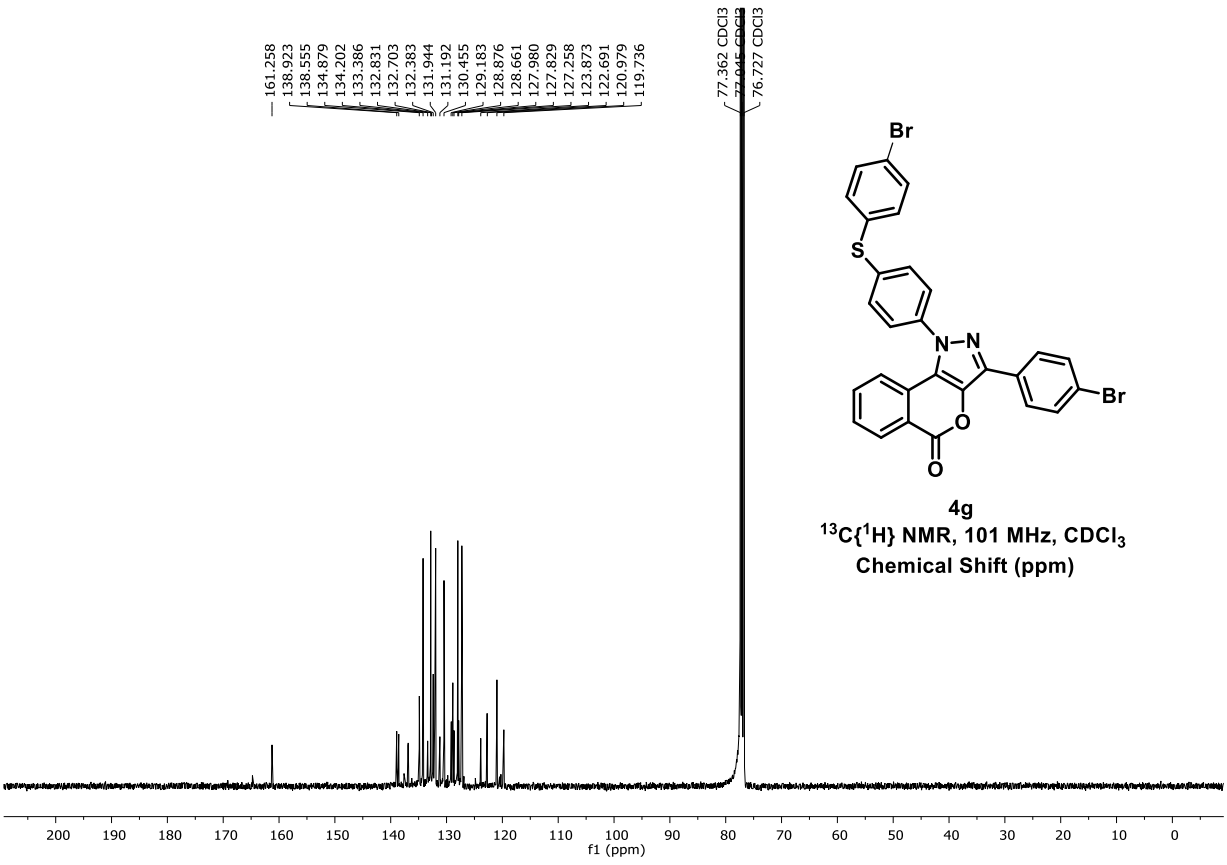

161.192
159.974
139.140
137.431
136.844
136.346
135.901
134.248
133.403
133.264
132.037
131.307
129.595
128.144
127.866
127.772
124.031
122.948
122.090
121.315
119.657
114.914
55.691
40.512 DMSO
40.305 DMSO
40.097 DMSO
39.679 DMSO
39.470 DMSO
39.261 DMSO
Br
S
N–N
O
O
O
4f
^{13}C{^{1}H} NMR, 101 MHz, DMSO-d$_6$
Chemical Shift (ppm)
f1 (ppm)



4g

^{1}H NMR, 400 MHz, $CDCl_3$

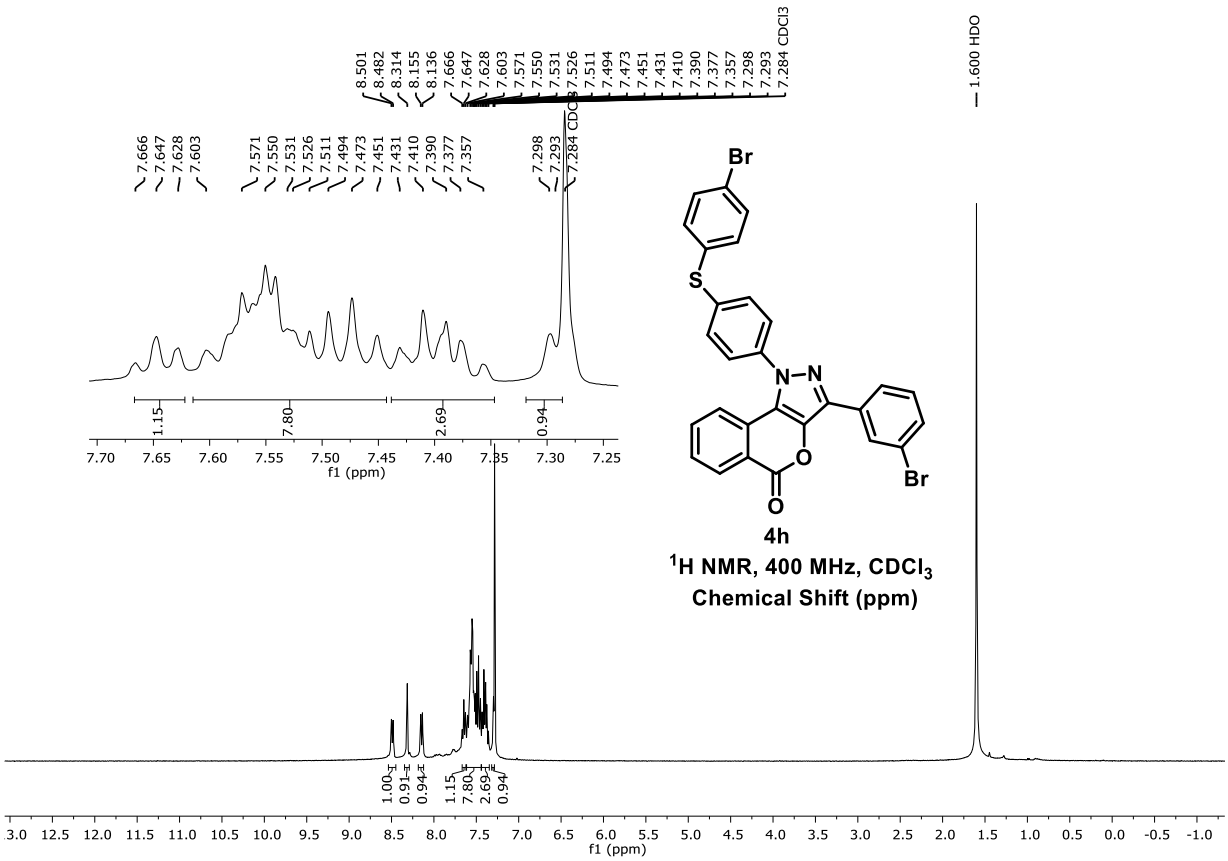
Chemical Shift (ppm)

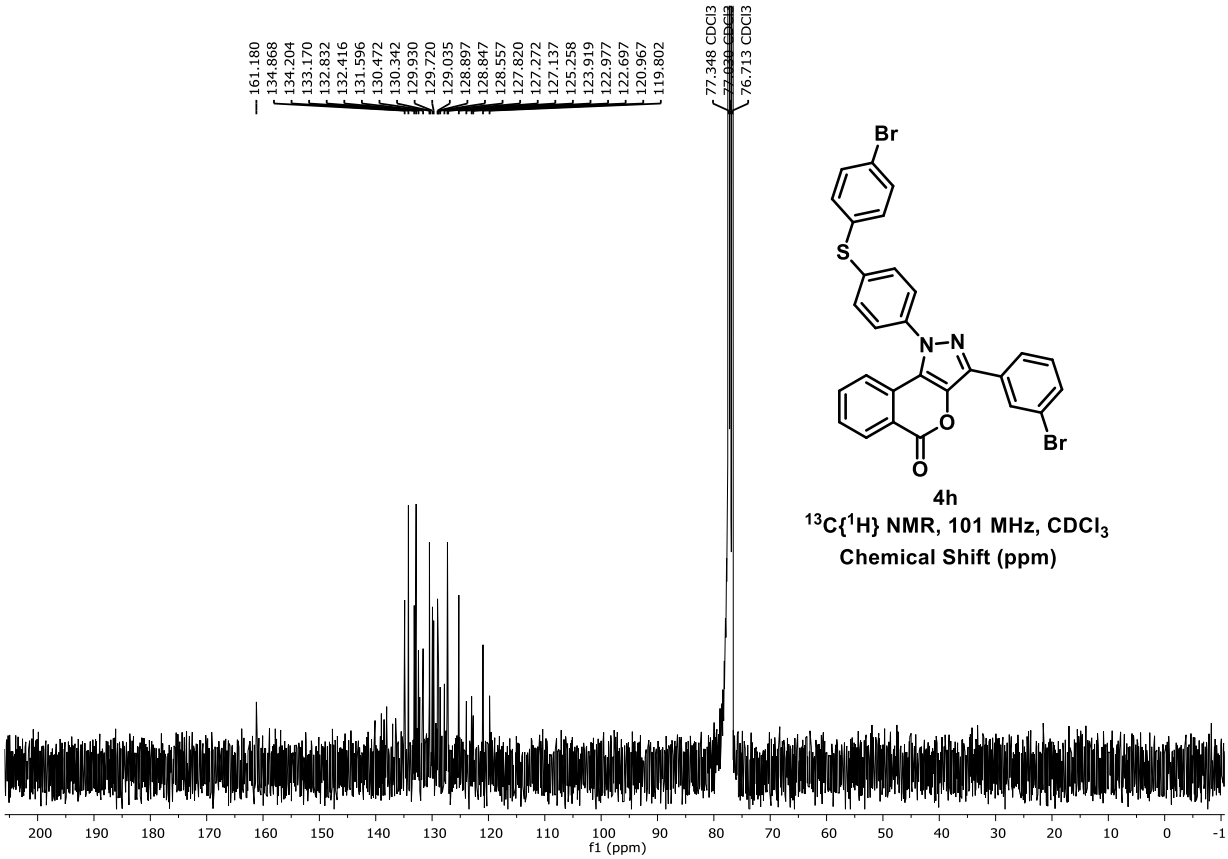


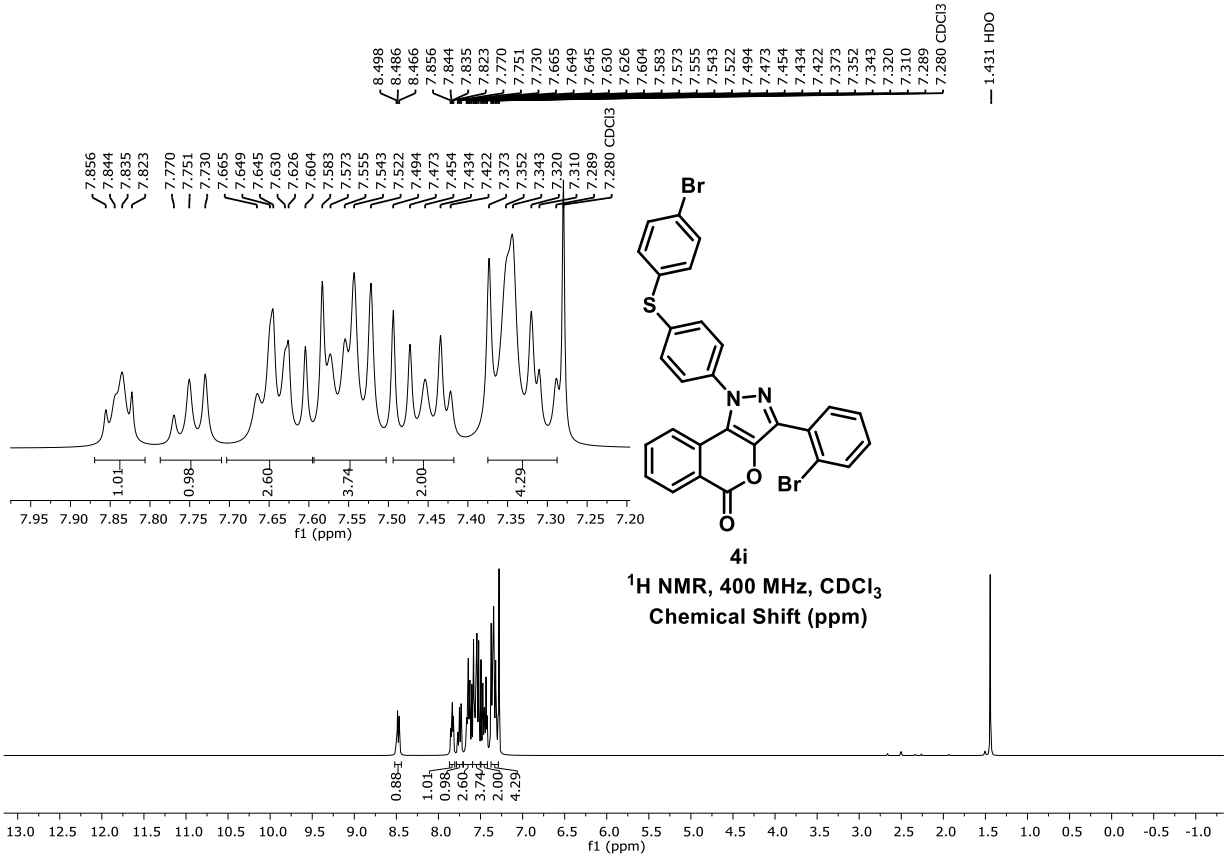
4g

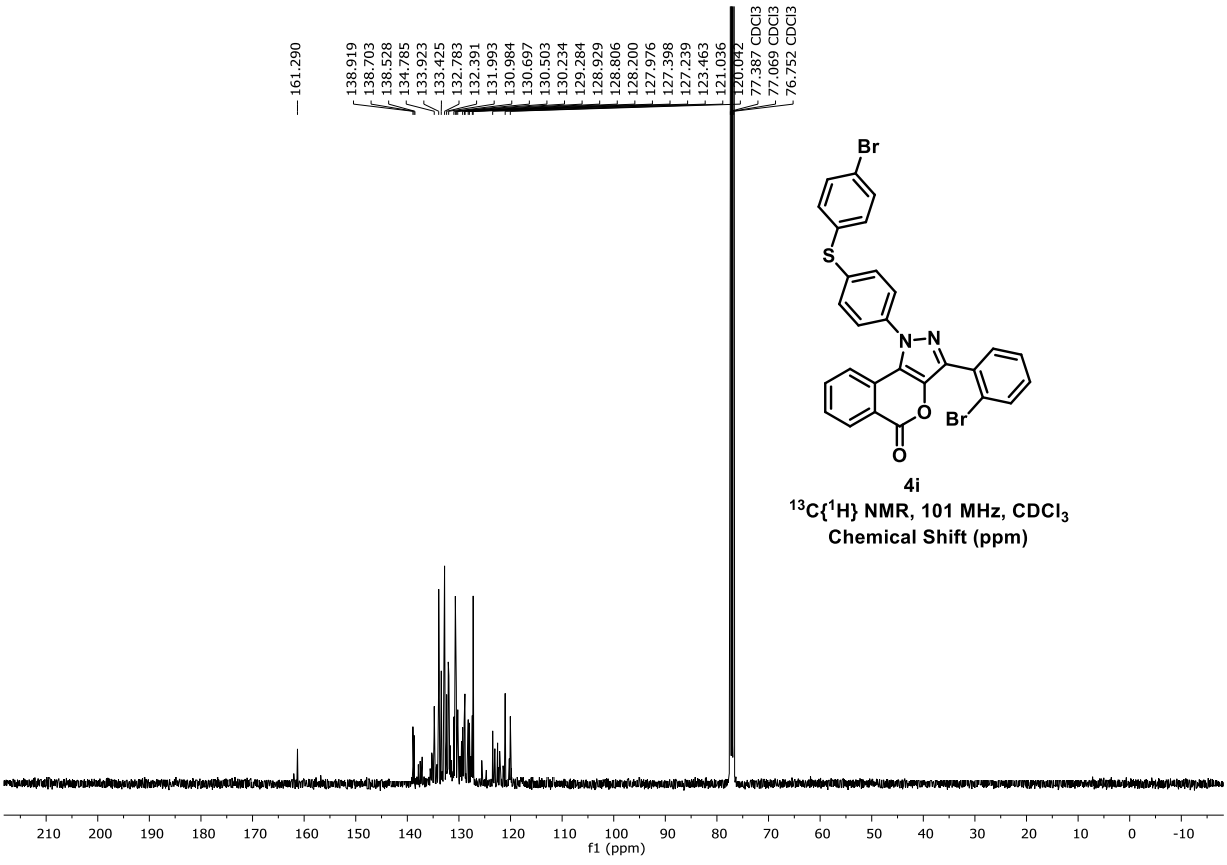
$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$

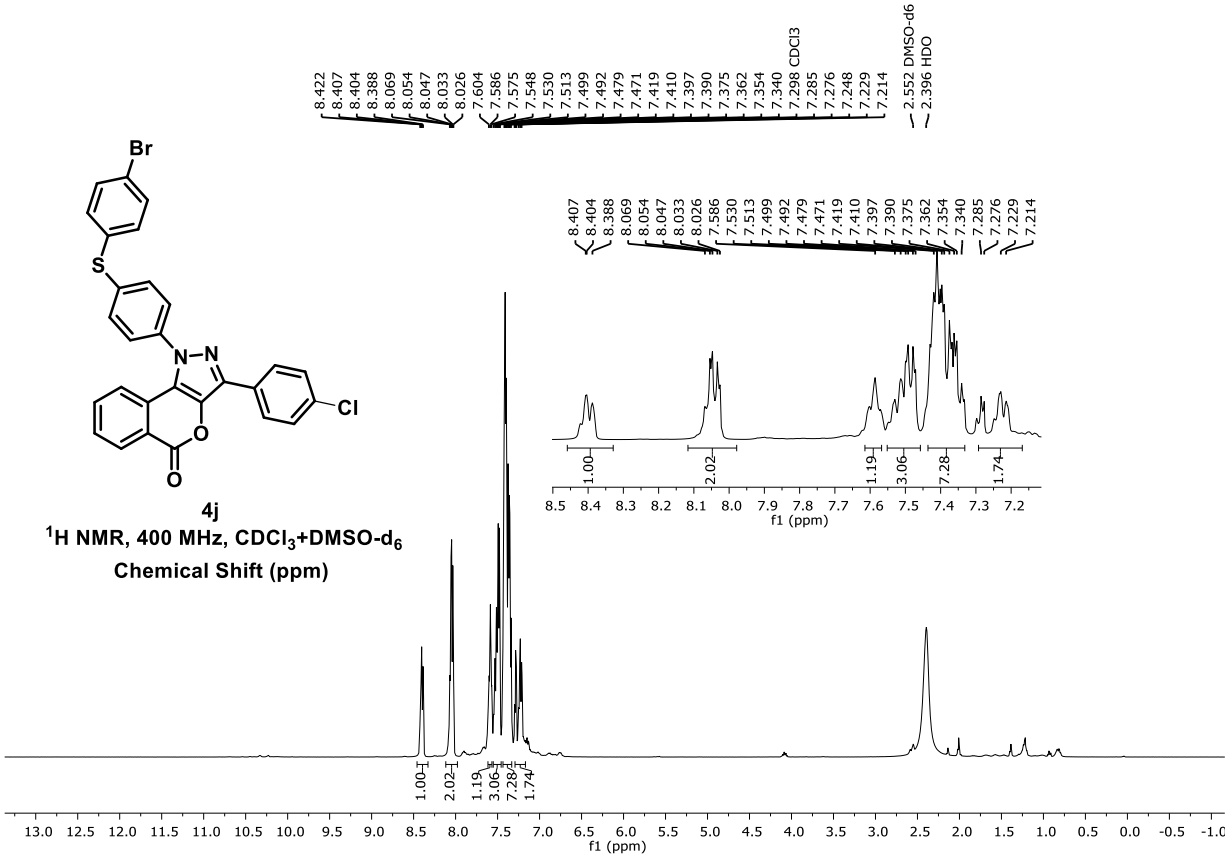
Chemical Shift (ppm)

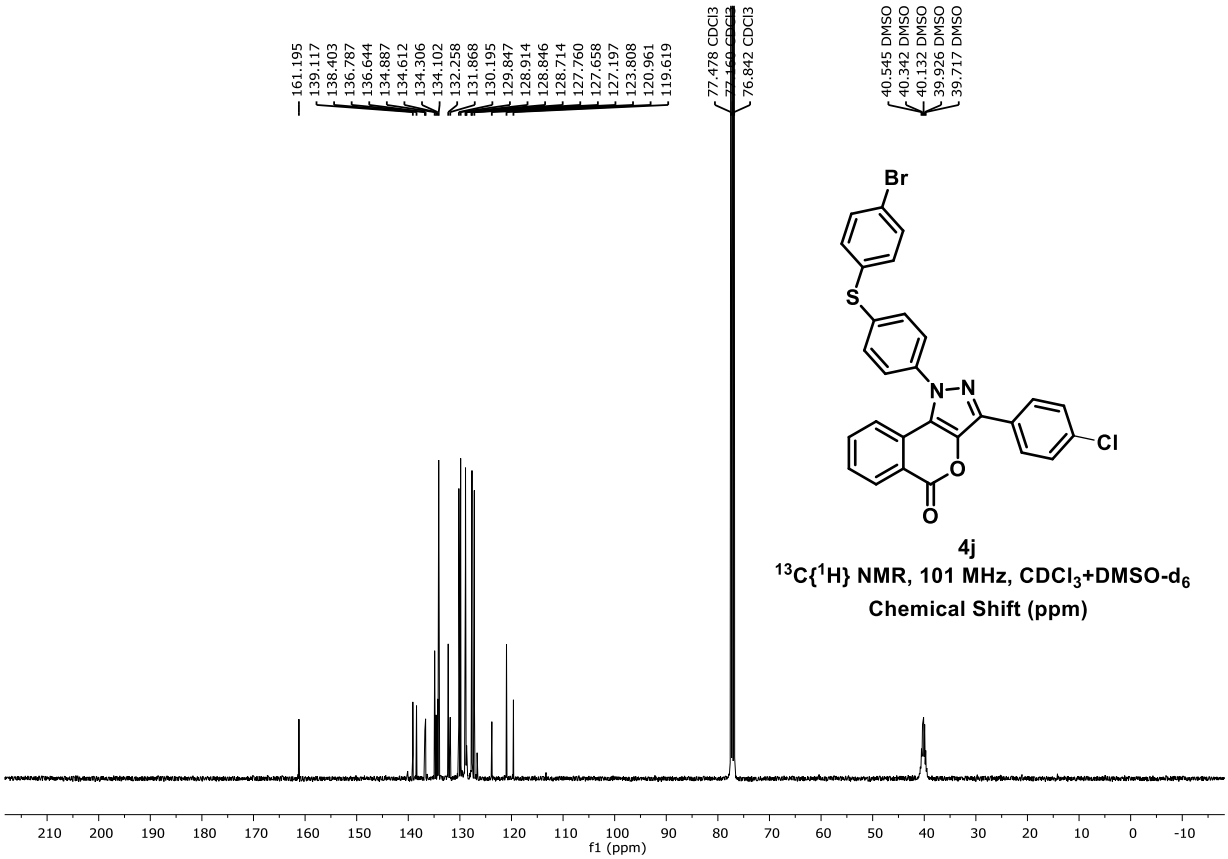

8.501
8.482
8.314
8.155
8.136
7.666
7.647
7.628
7.603
7.571
7.550
7.531
7.526
7.511
7.494
7.473
7.451
7.431
7.410
7.390
7.377
7.357
7.298
7.293
7.284 CDCl3
1.600 HDO
1.15
7.80
2.69
0.94
f1 (ppm)
Br
S
N–N
O
Br
O
4h
^{1}H NMR, 400 MHz, $CDCl_3$
Chemical Shift (ppm)

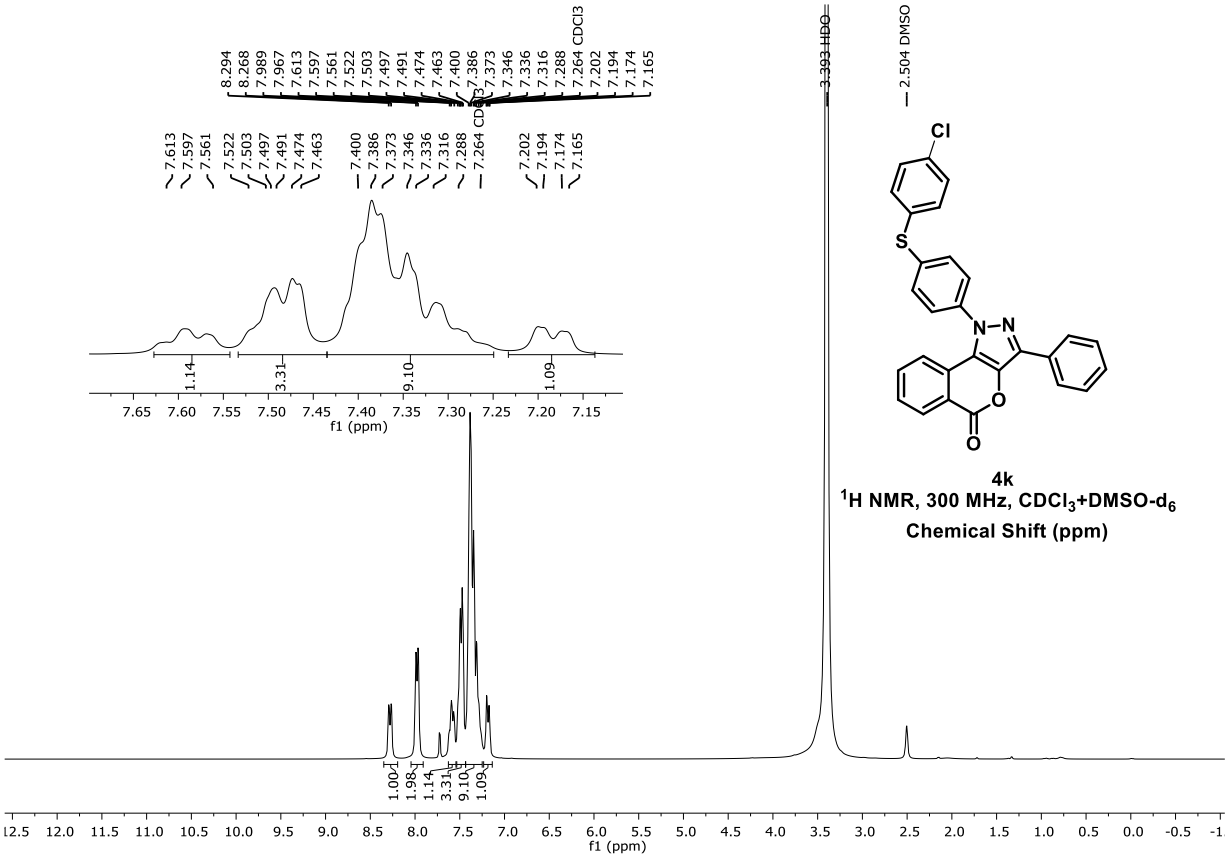

161.180
134.868
134.204
133.170
132.832
132.416
131.596
130.472
130.342
129.930
129.720
129.035
128.897
128.847
128.557
127.820
127.272
127.137
125.258
123.919
122.977
122.697
120.967
119.802
77.348 CDCl3
77.030 CDCl3
76.713 CDCl3
f1 (ppm)
Br
S
N–N
O
Br
O
4h
$^{13}C\{^1H\}$ NMR, 101 MHz, $CDCl_3$
Chemical Shift (ppm)


8.498
8.486
8.466
7.856
7.844
7.835
7.823
7.770
7.751
7.730
7.665
7.649
7.645
7.630
7.626
7.604
7.583
7.573
7.555
7.543
7.522
7.494
7.473
7.454
7.434
7.422
7.373
7.352
7.343
7.320
7.310
7.289
7.280 CDCl3
1.431 HDO
1.01
0.98
2.60
3.74
2.00
4.29
f1 (ppm)
Br
S
N–N
O
Br
O
4i
^{1}H NMR, 400 MHz, CDCl$_3$
Chemical Shift (ppm)
0.88
1.01
0.98
2.60
3.74
2.00
4.29
f1 (ppm)


161.290
138.919
138.703
138.528
134.785
133.923
133.425
132.783
132.391
131.993
130.984
130.697
130.503
130.234
129.284
128.929
128.806
128.200
127.976
127.398
127.239
123.463
121.036
120.042
77.387 CDCl3
77.069 CDCl3
76.752 CDCl3
f1 (ppm)
Br
S
N–N
O
Br
O
4i
^{13}C{^{1}H} NMR, 101 MHz, CDCl$_3$
Chemical Shift (ppm)


8.422
8.407
8.404
8.388
8.069
8.054
8.047
8.033
8.026
7.604
7.586
7.575
7.548
7.530
7.513
7.499
7.492
7.479
7.471
7.419
7.410
7.397
7.390
7.375
7.362
7.354
7.340
7.298 CDCl3
7.285
7.276
7.248
7.229
7.214
2.552 DMSO-d6
2.396 HDO
Br
S
N–N
Cl
O
O
4j
1H NMR, 400 MHz, CDCl3+DMSO-d6
Chemical Shift (ppm)
1.00
2.02
1.19
3.06
7.28
1.74
f1 (ppm)

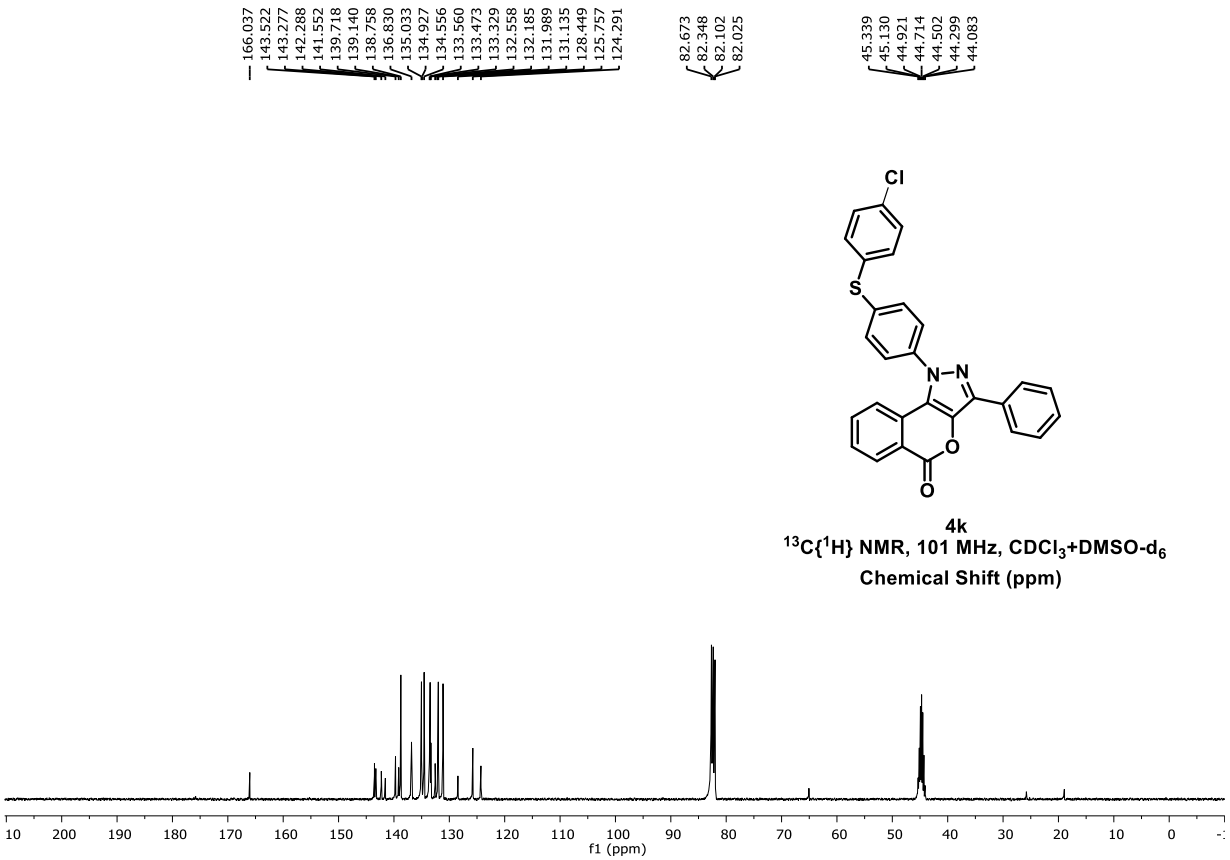

161.195
139.117
138.403
136.787
136.644
134.887
134.612
134.306
134.102
132.258
131.868
130.195
129.847
128.914
128.846
128.714
127.760
127.658
127.197
123.808
120.961
119.619
77.478 CDCl3
77.160 CDCl3
76.842 CDCl3
40.545 DMSO
40.342 DMSO
40.132 DMSO
39.926 DMSO
39.717 DMSO
Br
S
N–N
Cl
O
O
4j
13C{1H} NMR, 101 MHz, CDCl3+DMSO-d6
Chemical Shift (ppm)
f1 (ppm)



4k

^{1}H NMR, 300 MHz, $CDCl_3$+DMSO-d_6

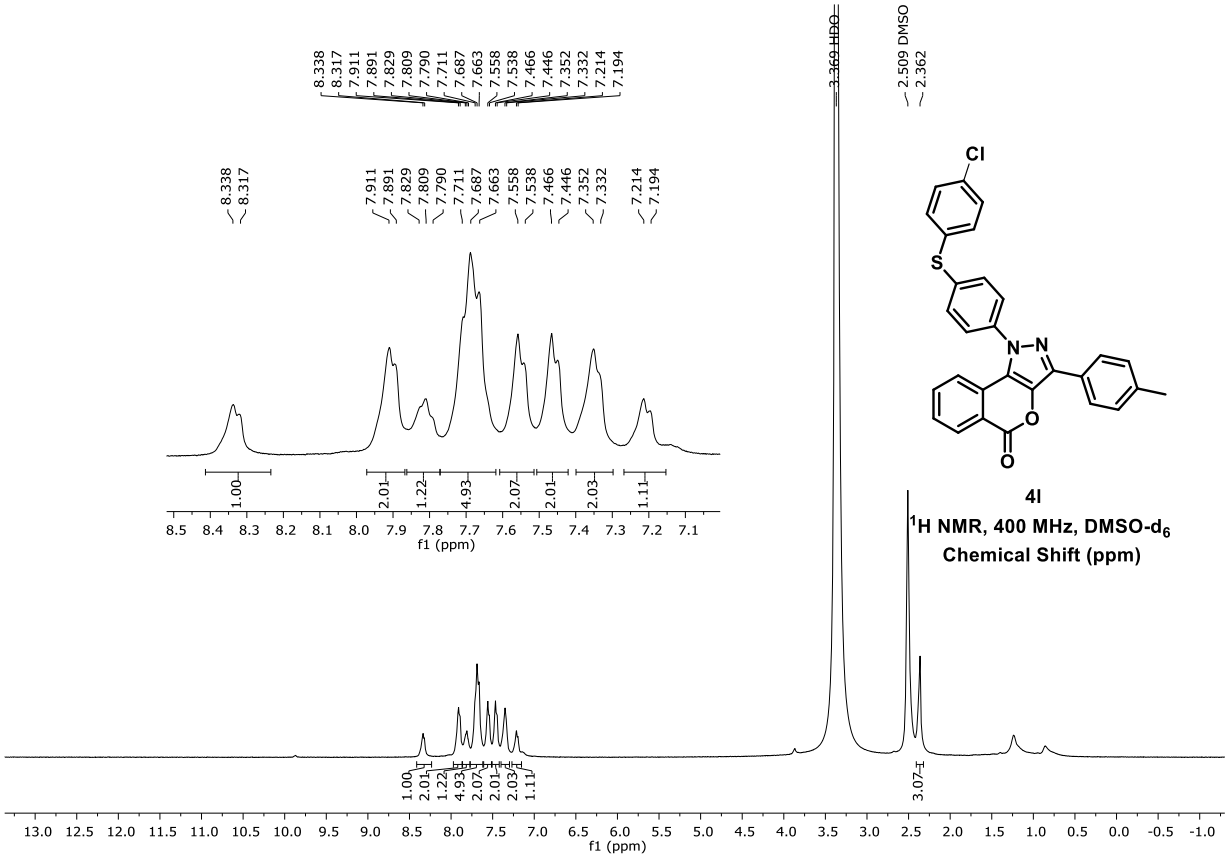
Chemical Shift (ppm)

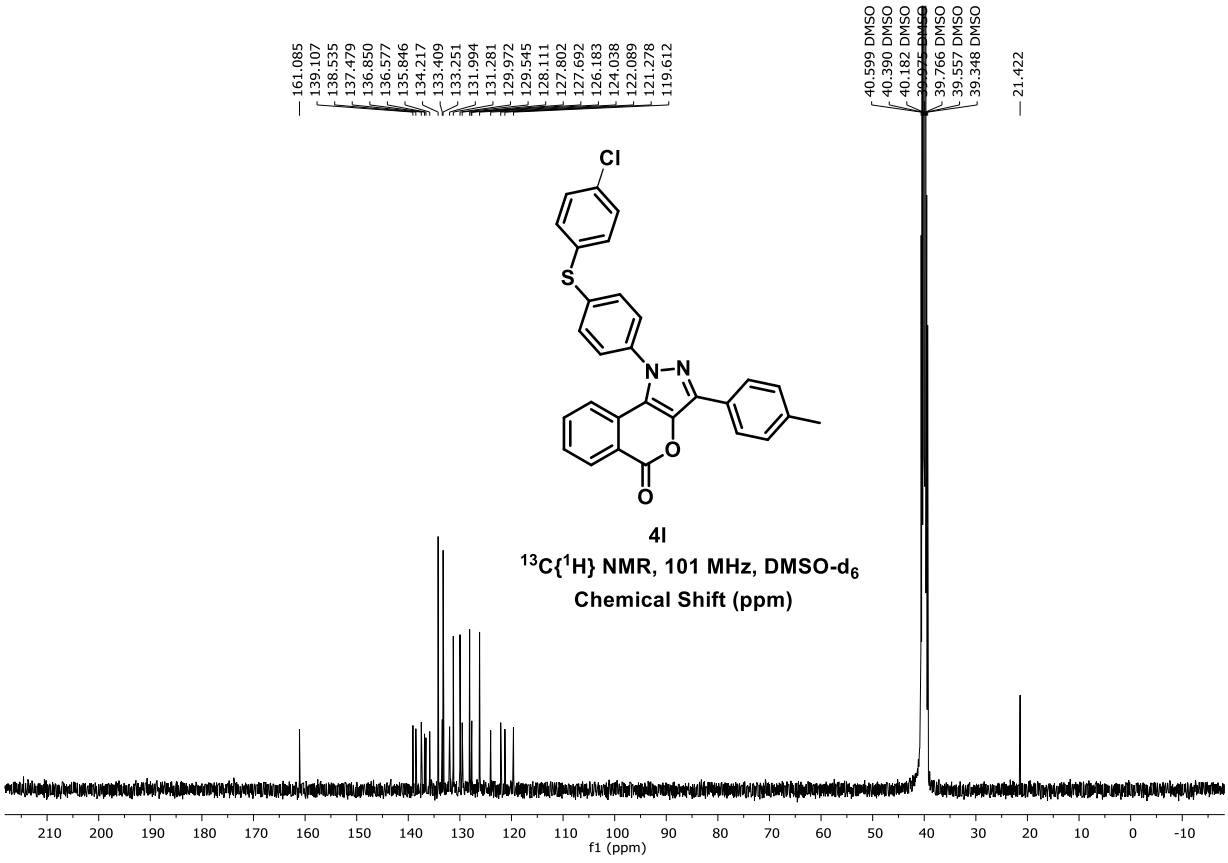


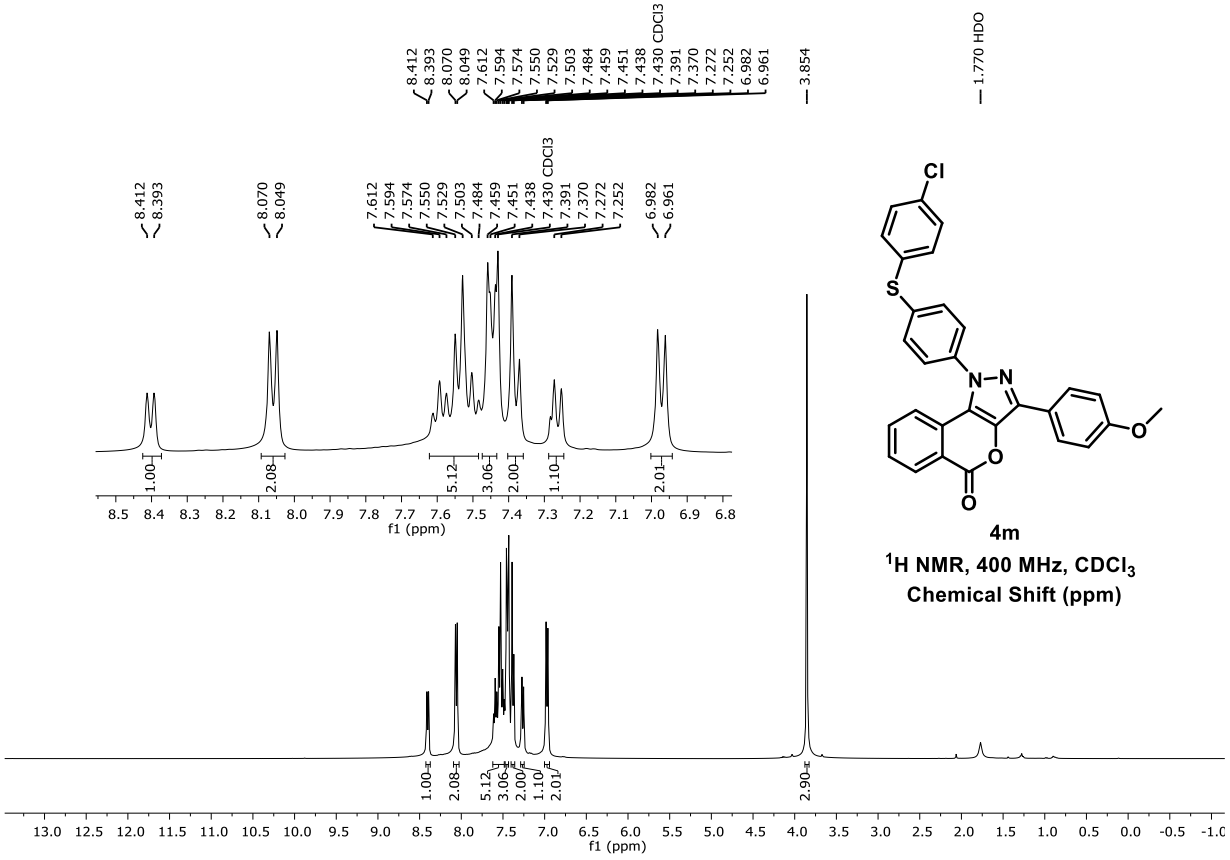
4k

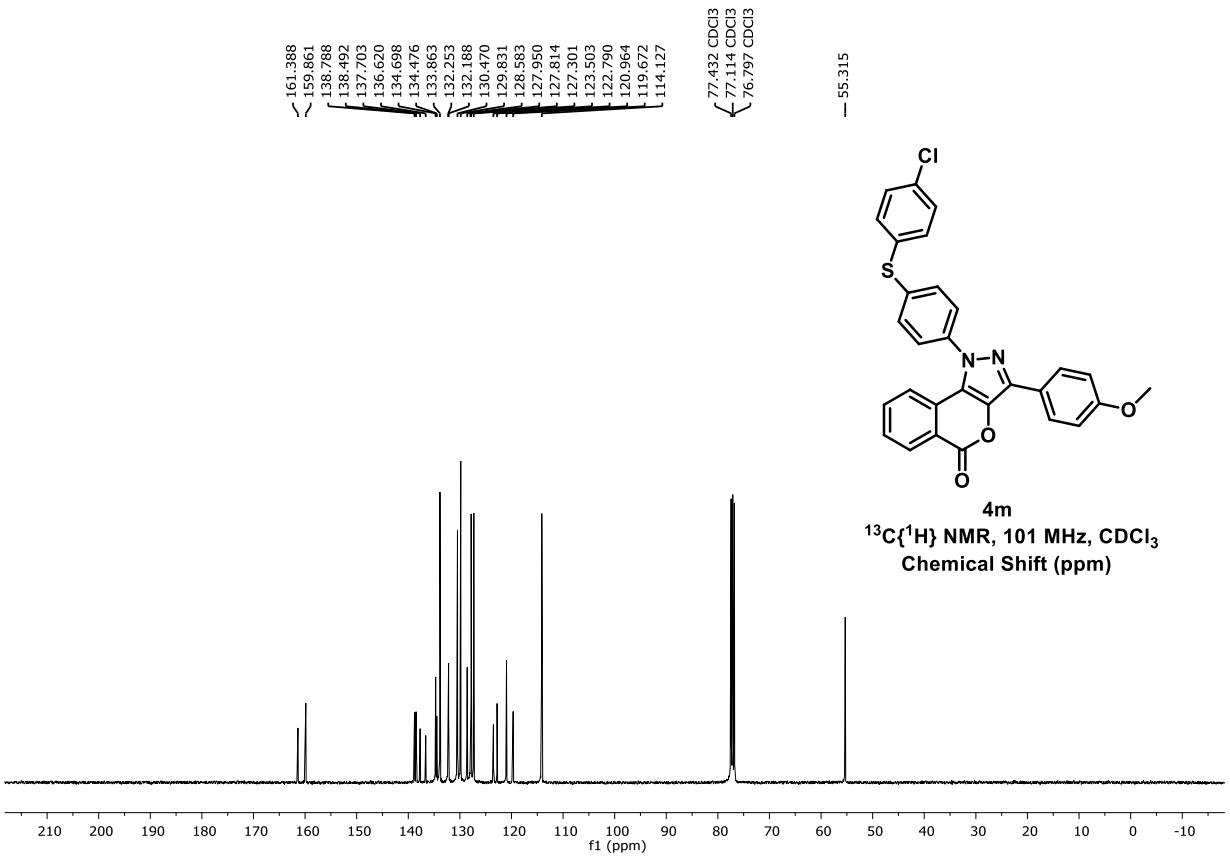
^{13}C{^{1}H} NMR, 101 MHz, $CDCl_3$+DMSO-d_6

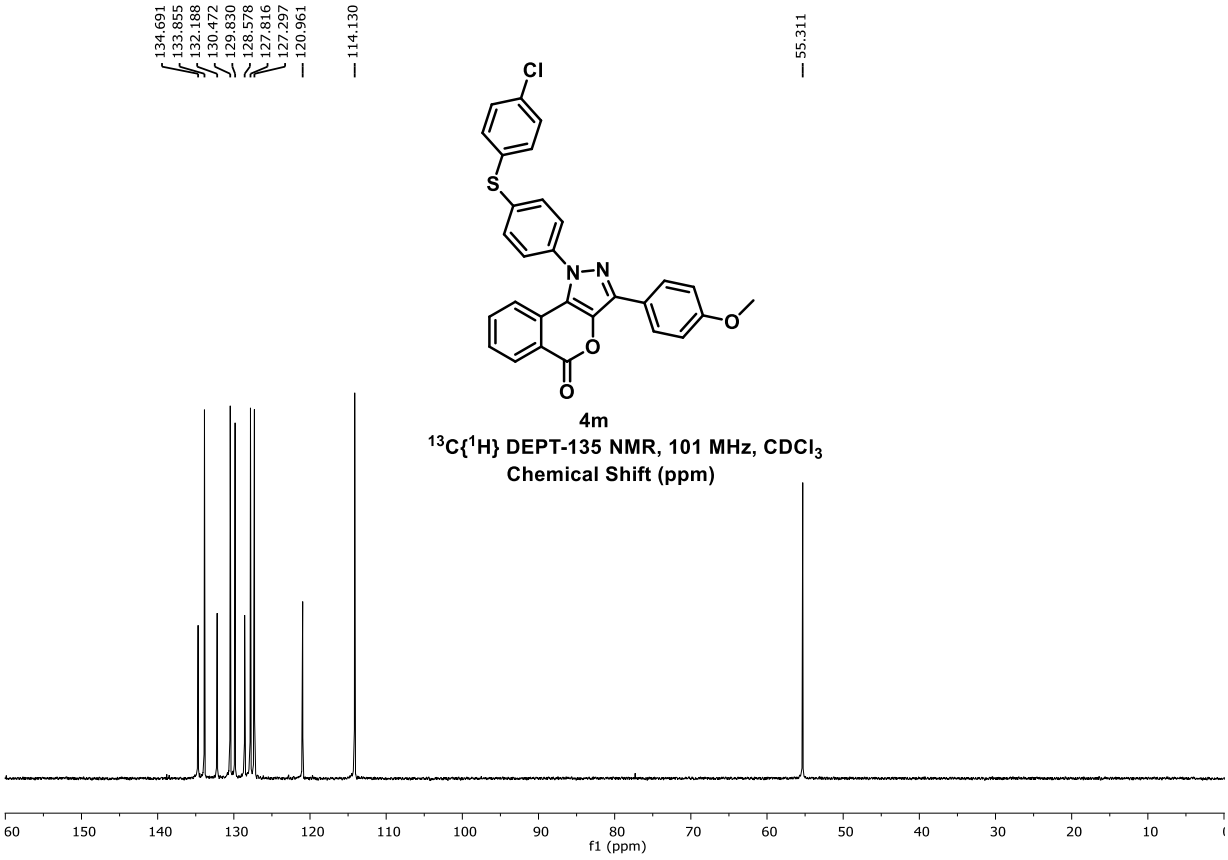
Chemical Shift (ppm)

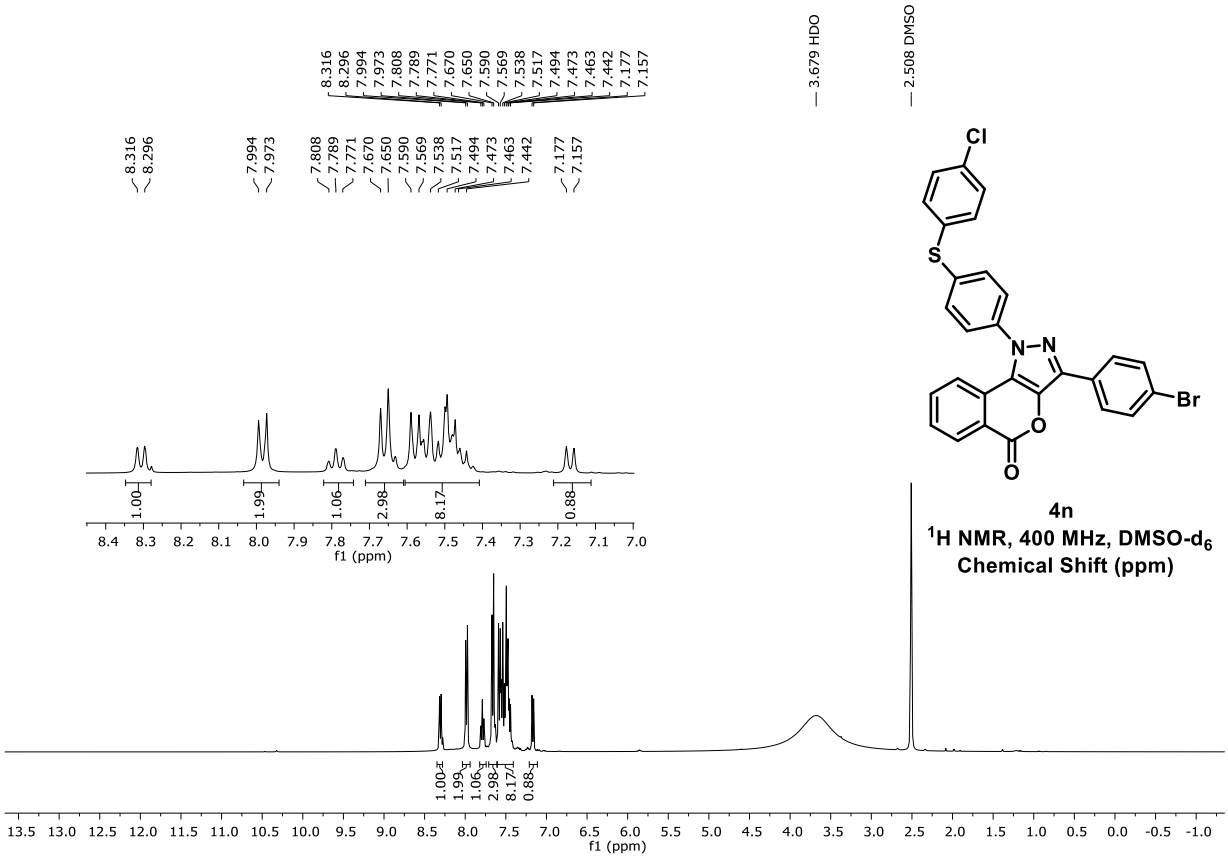

8.338
8.317
7.911
7.891
7.829
7.809
7.790
7.711
7.687
7.663
7.558
7.538
7.466
7.446
7.352
7.332
7.214
7.194
3.360 HDO
2.509 DMSO
2.362
1.00
2.01
1.22
4.93
2.07
2.01
2.03
1.11
3.07
f1 (ppm)
Cl
S
N–N
O
O
4l
^{1}H NMR, 400 MHz, DMSO-d$_6$
Chemical Shift (ppm)


161.085
139.107
138.535
137.479
136.850
136.577
135.846
134.217
133.409
133.251
131.994
131.281
129.972
129.545
128.111
127.802
127.692
126.183
124.038
122.089
121.278
119.612
40.599 DMSO
40.390 DMSO
40.182 DMSO
39.766 DMSO
39.557 DMSO
39.348 DMSO
21.422
f1 (ppm)
Cl
S
N–N
O
O
4l
^{13}C{^{1}H} NMR, 101 MHz, DMSO-d$_6$
Chemical Shift (ppm)

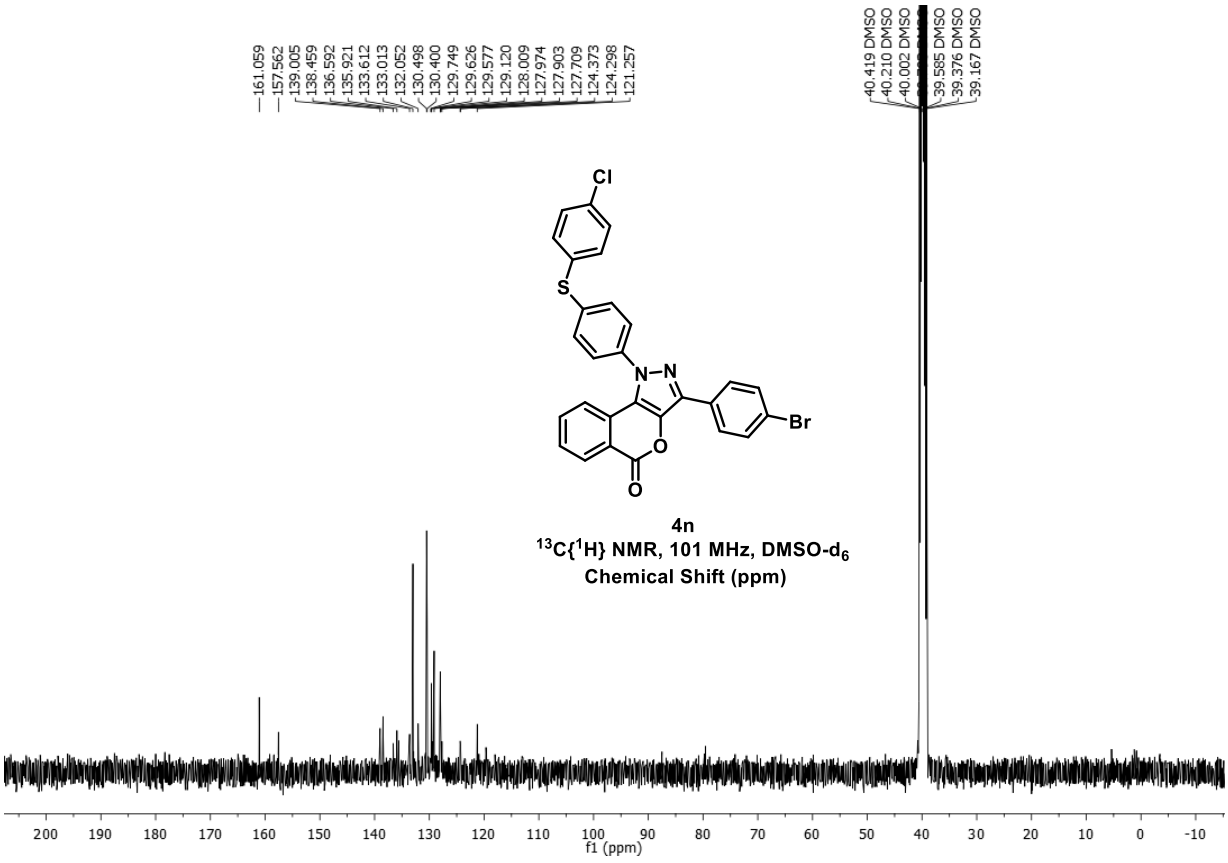

8.412
8.393
8.070
8.049
7.612
7.594
7.574
7.550
7.529
7.503
7.484
7.459
7.451
7.438
7.430 CDCl3
7.391
7.370
7.272
7.252
6.982
6.961
3.854
1.770 HDO
Cl
S
N–N
O
O
4m
^{1}H NMR, 400 MHz, CDCl$_3$
Chemical Shift (ppm)
f1 (ppm)


161.388
159.861
138.788
138.492
137.703
136.620
134.698
134.476
133.863
132.253
132.188
130.470
129.831
128.583
127.950
127.814
127.301
123.503
122.790
120.964
119.672
114.127
77.432 CDCl3
77.114 CDCl3
76.797 CDCl3
55.315
Cl
S
N–N
O
O
4m
^{13}C{^{1}H} NMR, 101 MHz, CDCl$_3$
Chemical Shift (ppm)
f1 (ppm)

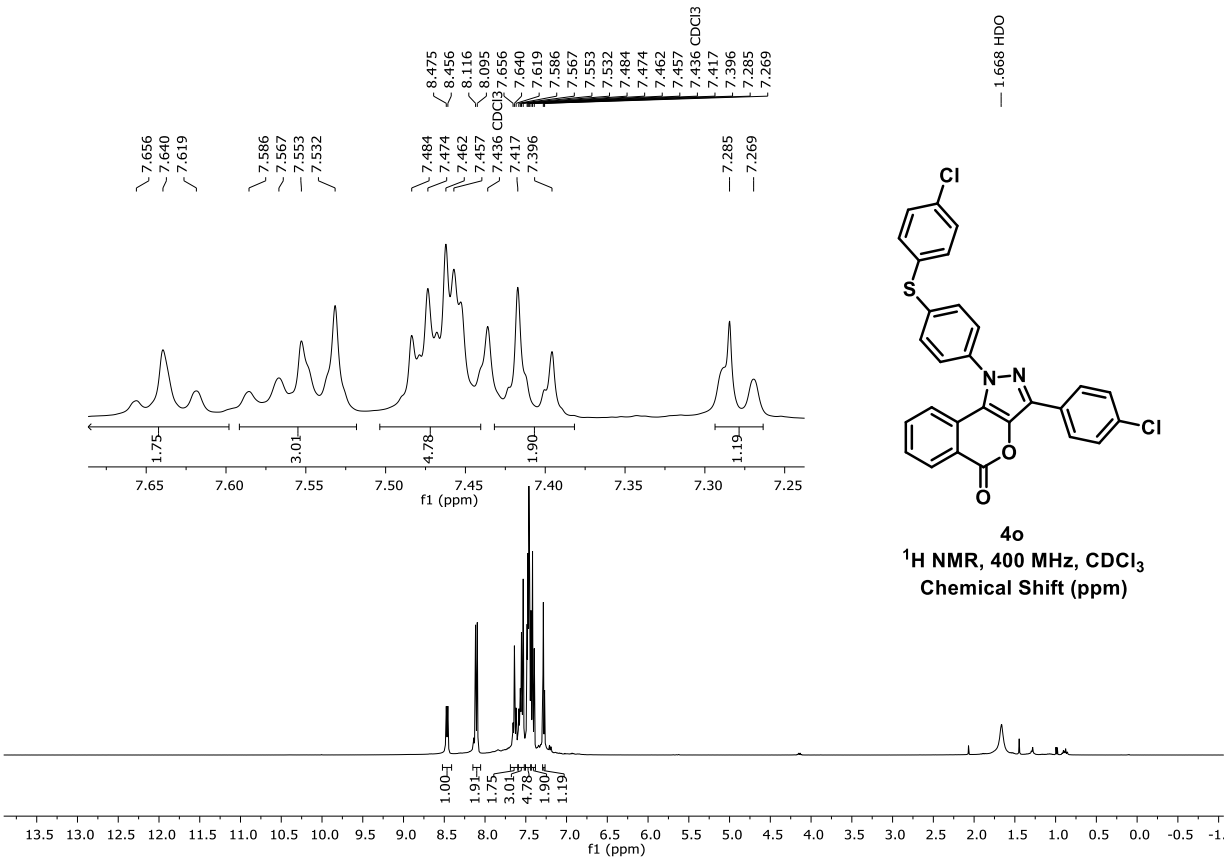

134.691
133.855
132.188
130.472
129.830
128.578
127.816
127.297
120.961
114.130
55.311
Cl
S
N–N
O
O
O
4m
$^{13}C\{^{1}H\}$ DEPT-135 NMR, 101 MHz, $CDCl_3$
Chemical Shift (ppm)
60
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)



4n
^{1}H NMR, 400 MHz, DMSO-d_6
Chemical Shift (ppm)



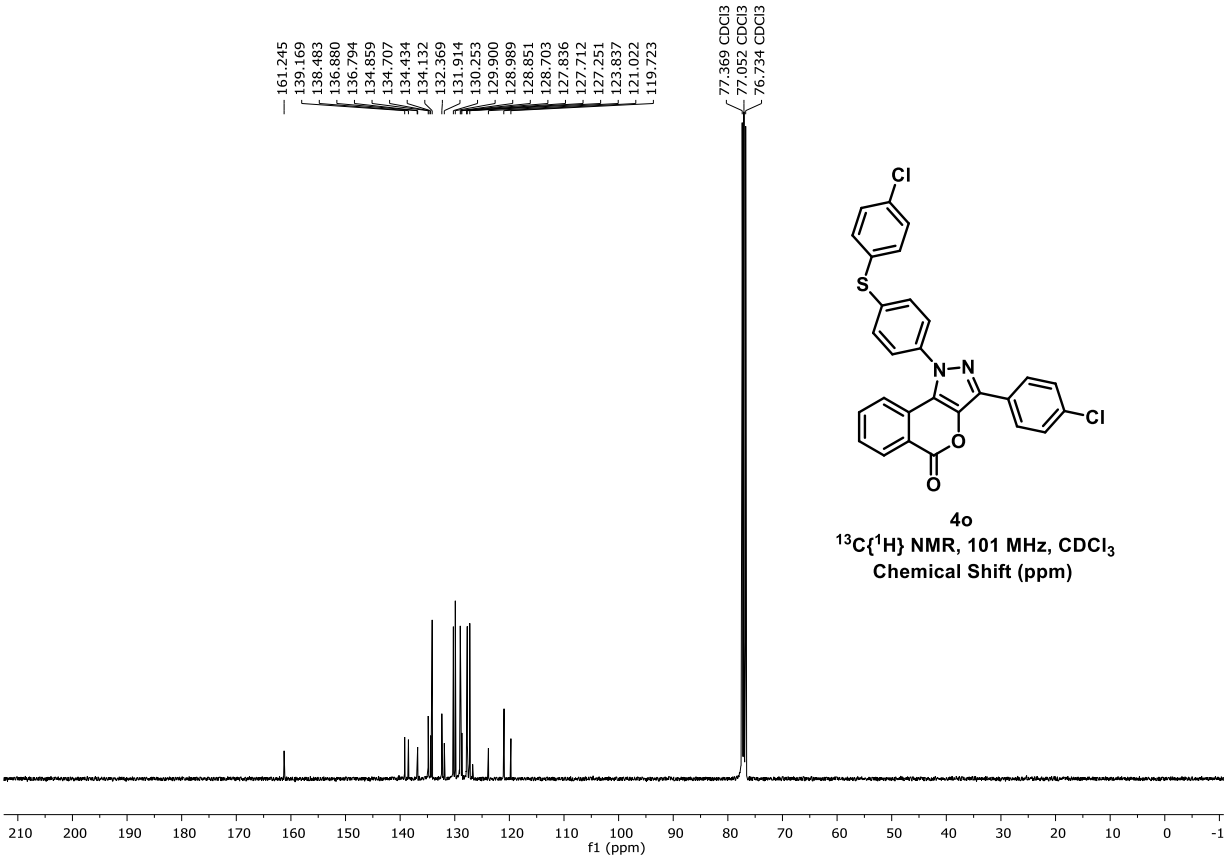
4n
^{13}C{^{1}H} NMR, 101 MHz, DMSO-d_6
Chemical Shift (ppm)



4o

^{1}H NMR, 400 MHz, $CDCl_3$

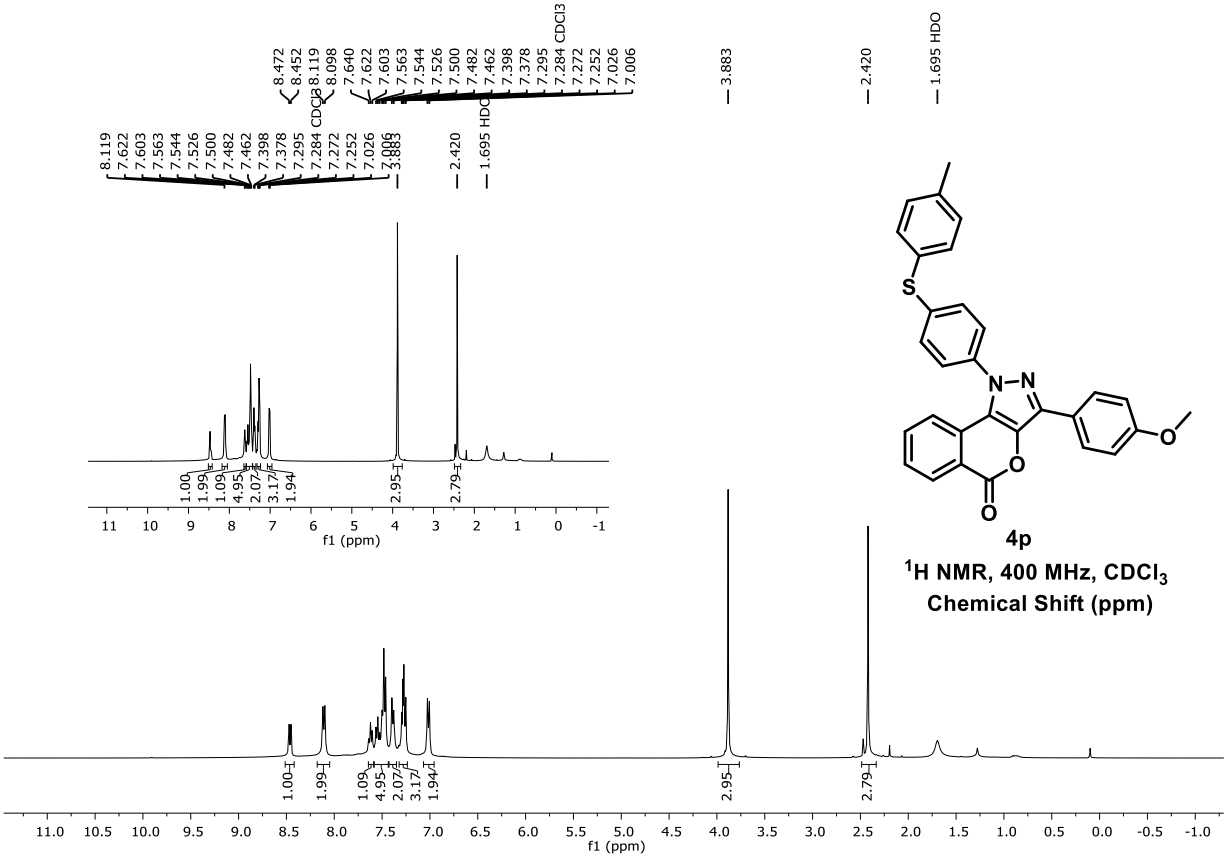
Chemical Shift (ppm)

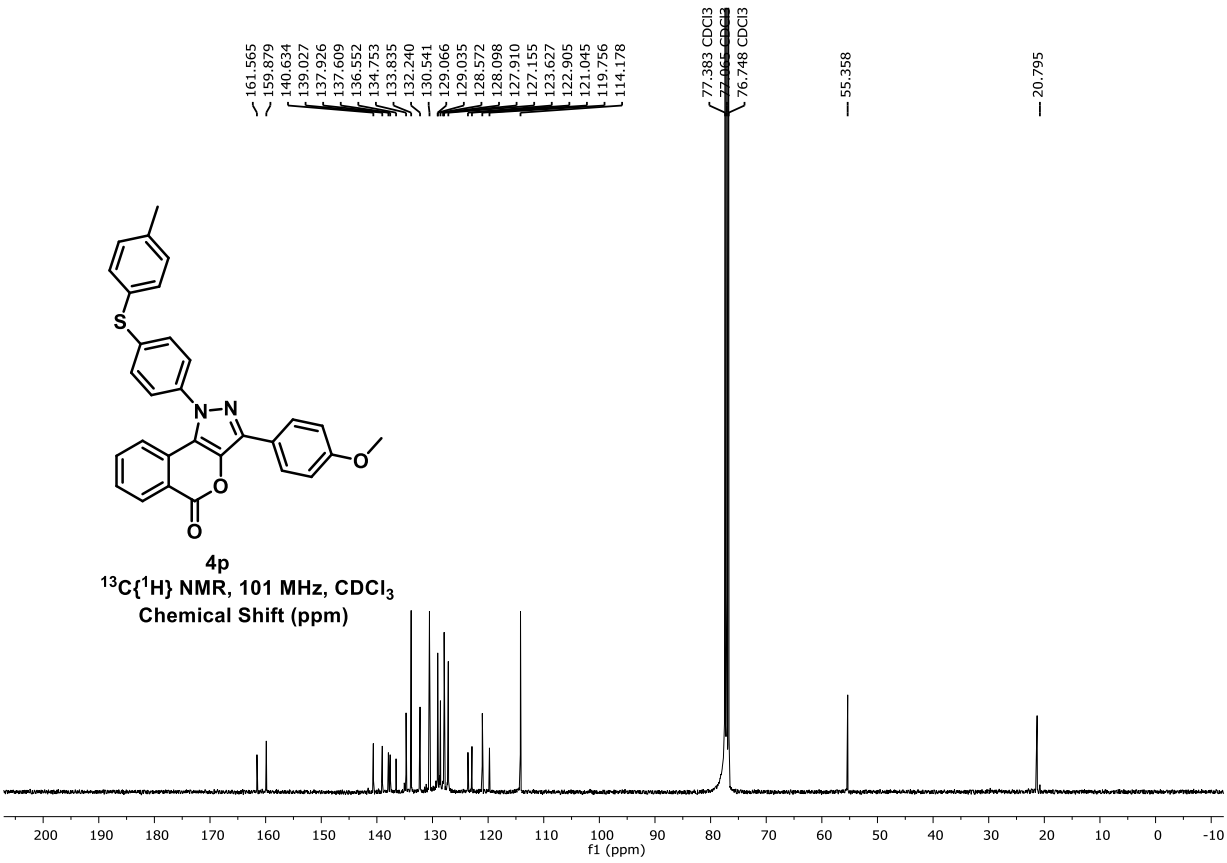


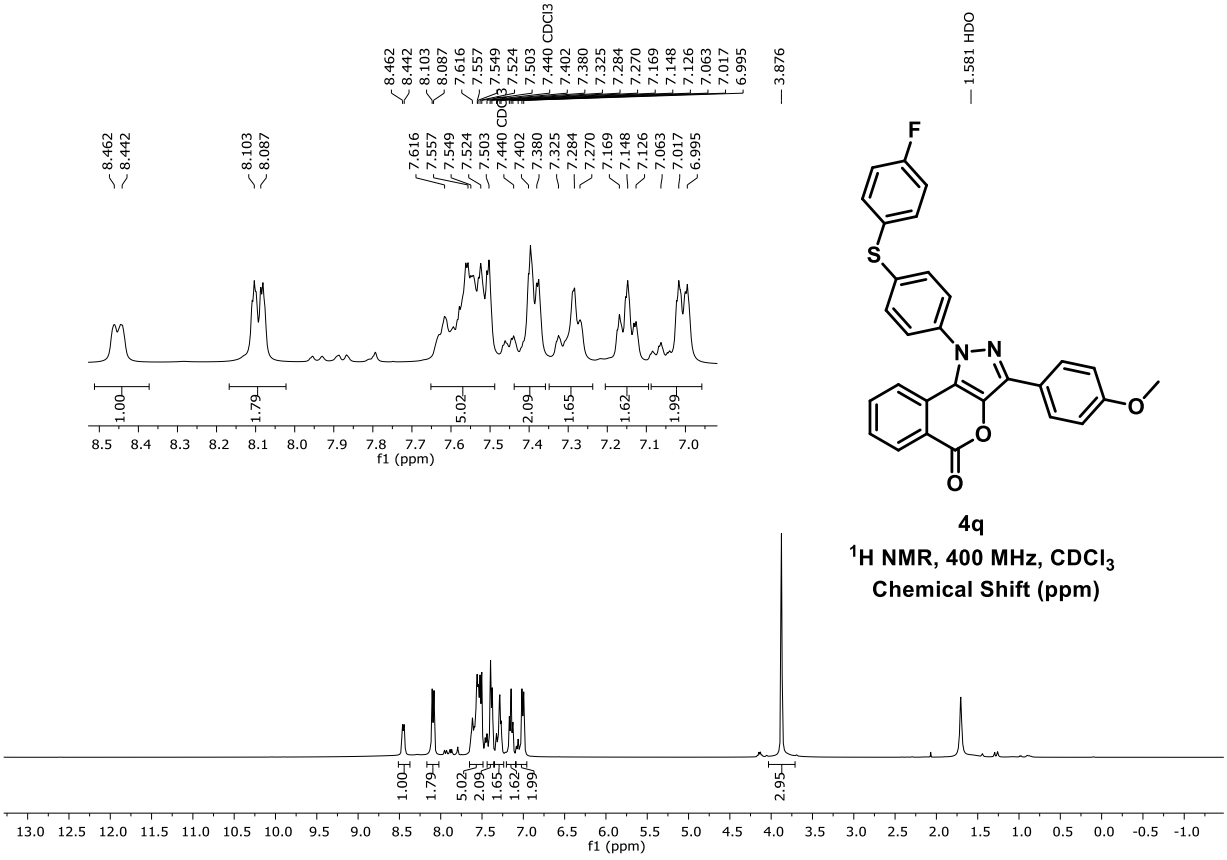
4o

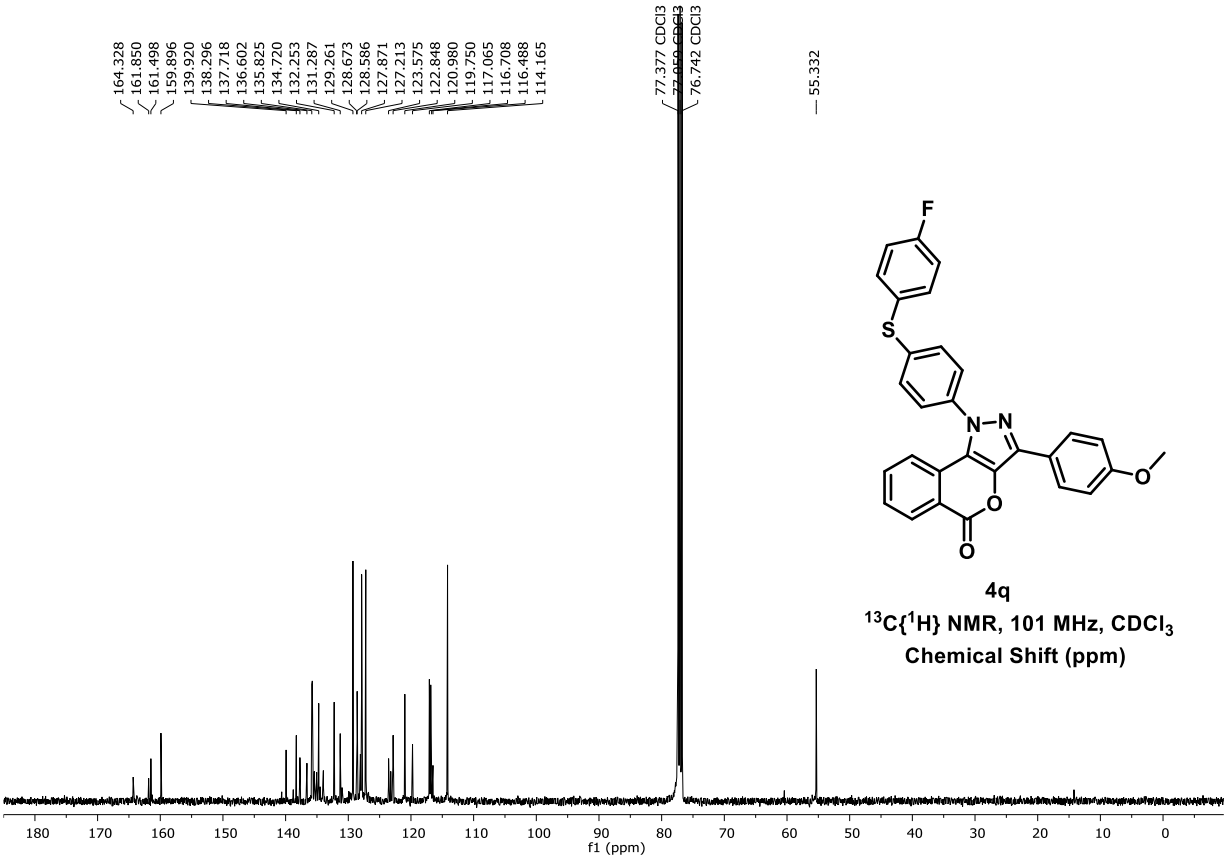
$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$

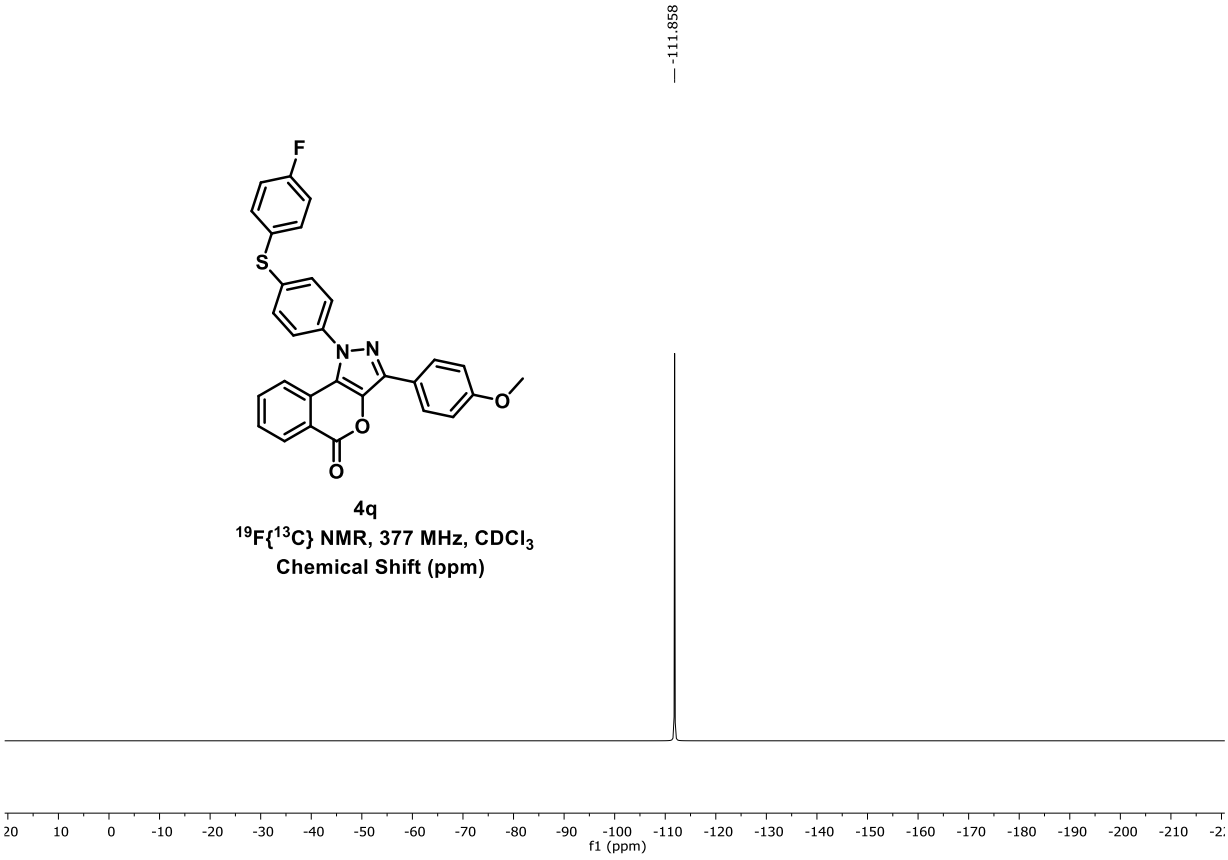
Chemical Shift (ppm)


8.472
8.452
8.119
8.098
7.640
7.622
7.603
7.563
7.544
7.526
7.500
7.482
7.462
7.398
7.378
7.295
7.284 CDCl3
7.272
7.252
7.026
7.006
3.883
2.420
1.695 HDO
1.00
1.99
1.09
4.95
2.07
3.17
1.94
2.95
2.79
f1 (ppm)
S
N–N
O
O
O
4p
1H NMR, 400 MHz, CDCl3
Chemical Shift (ppm)


161.565
159.879
140.634
139.027
137.926
137.609
136.552
134.753
133.835
132.240
130.541
129.066
129.035
128.572
128.098
127.910
127.155
123.627
122.905
121.045
119.756
114.178
77.383 CDCl3
77.065 CDCl3
76.748 CDCl3
55.358
20.795
f1 (ppm)
S
N–N
O
O
O
4p
13C{1H} NMR, 101 MHz, CDCl3
Chemical Shift (ppm)


8.462
8.442
8.103
8.087
7.616
7.557
7.549
7.524
7.503
7.440 CDCl3
7.402
7.380
7.325
7.284
7.270
7.169
7.148
7.126
7.063
7.017
6.995
3.876
1.581 HDO
1.00
1.79
5.02
2.09
1.65
1.62
1.99
f1 (ppm)
F
S
N–N
O
O
O
4q
^{1}H NMR, 400 MHz, CDCl$_3$
Chemical Shift (ppm)
1.00
1.79
5.02
2.09
1.65
1.62
1.99
2.95
f1 (ppm)

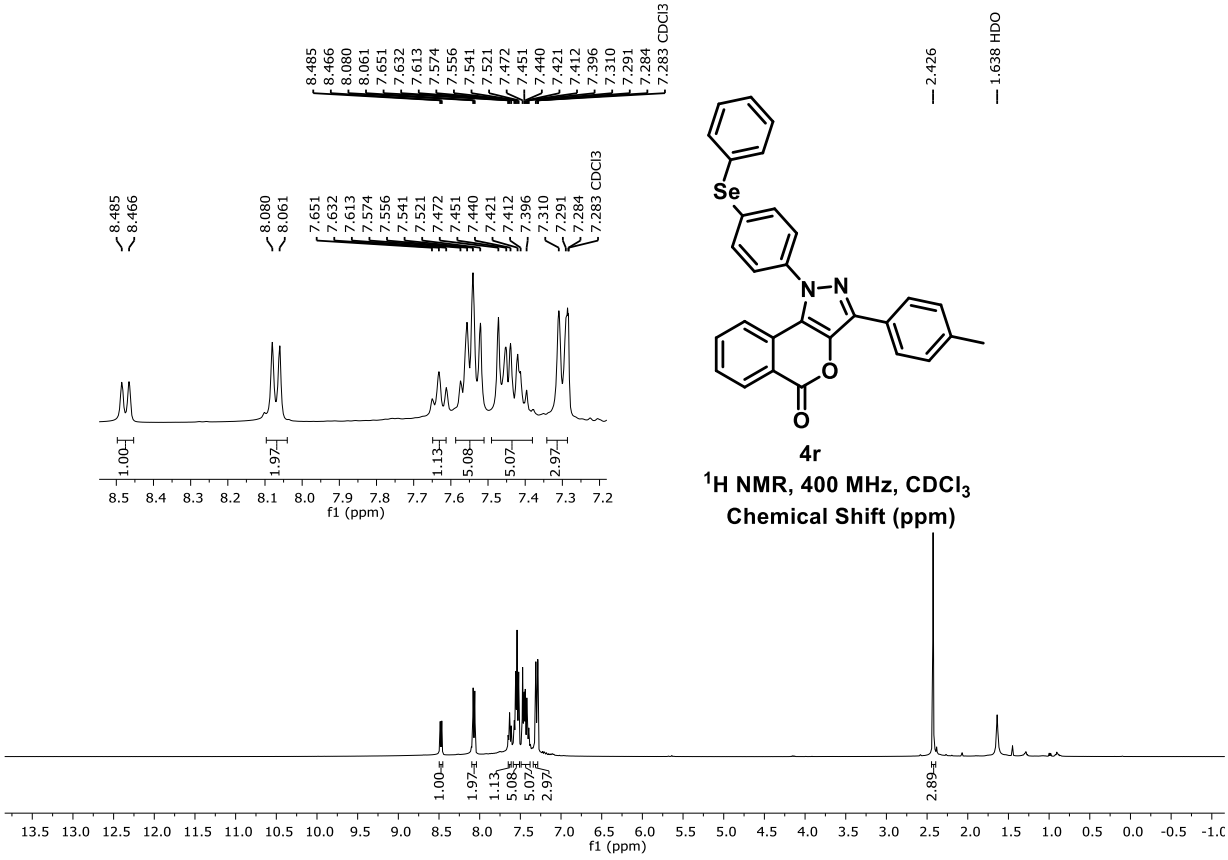

164.328
161.850
161.498
159.896
139.920
138.296
137.718
136.602
135.825
134.720
132.253
131.287
129.261
128.673
128.586
127.871
127.213
123.575
122.848
120.980
119.750
117.065
116.708
116.488
114.165
77.377 CDCl3
76.742 CDCl3
55.332
F
S
N–N
O
O
O
4q
^{13}C{^{1}H} NMR, 101 MHz, CDCl$_3$
Chemical Shift (ppm)
f1 (ppm)



4q

$^{19}F\{^{13}C\}$ NMR, 377 MHz, $CDCl_3$

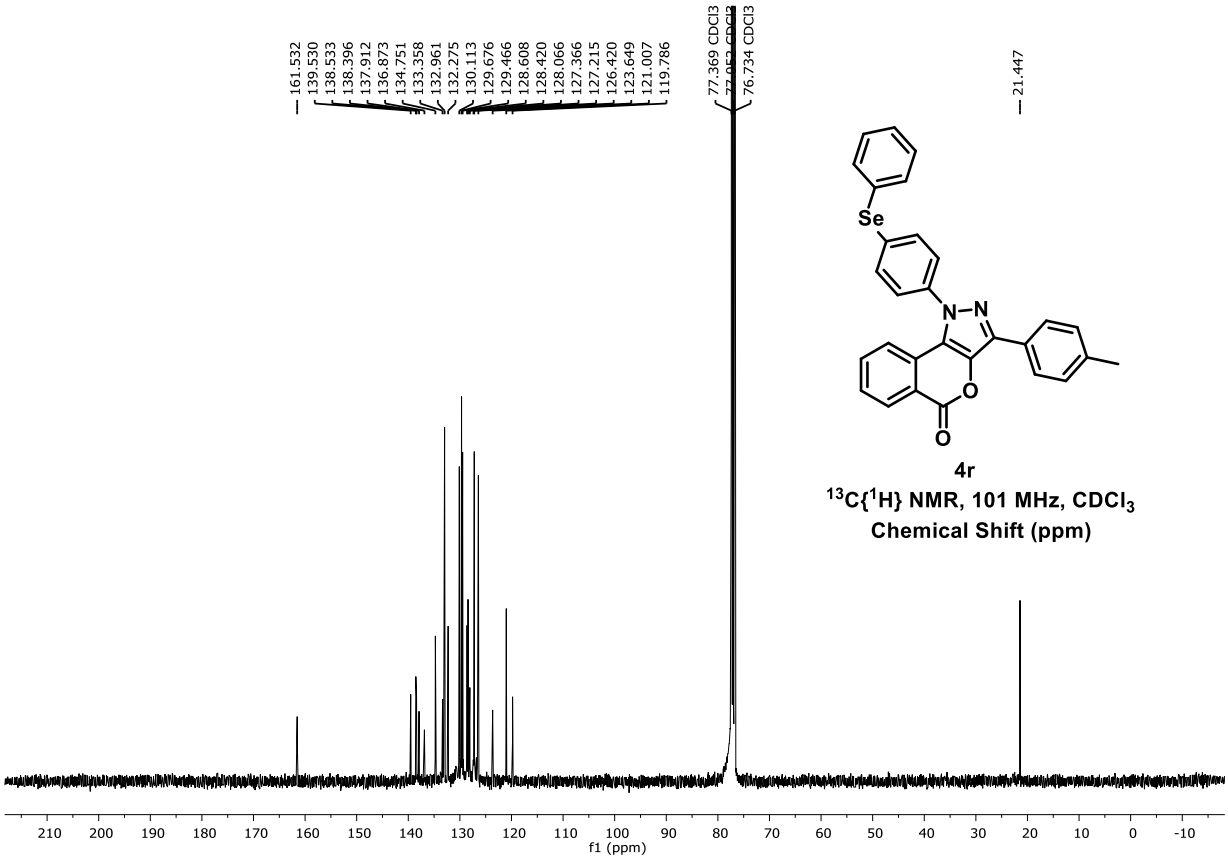
Chemical Shift (ppm)



4r

^{1}H NMR, 400 MHz, $CDCl_3$

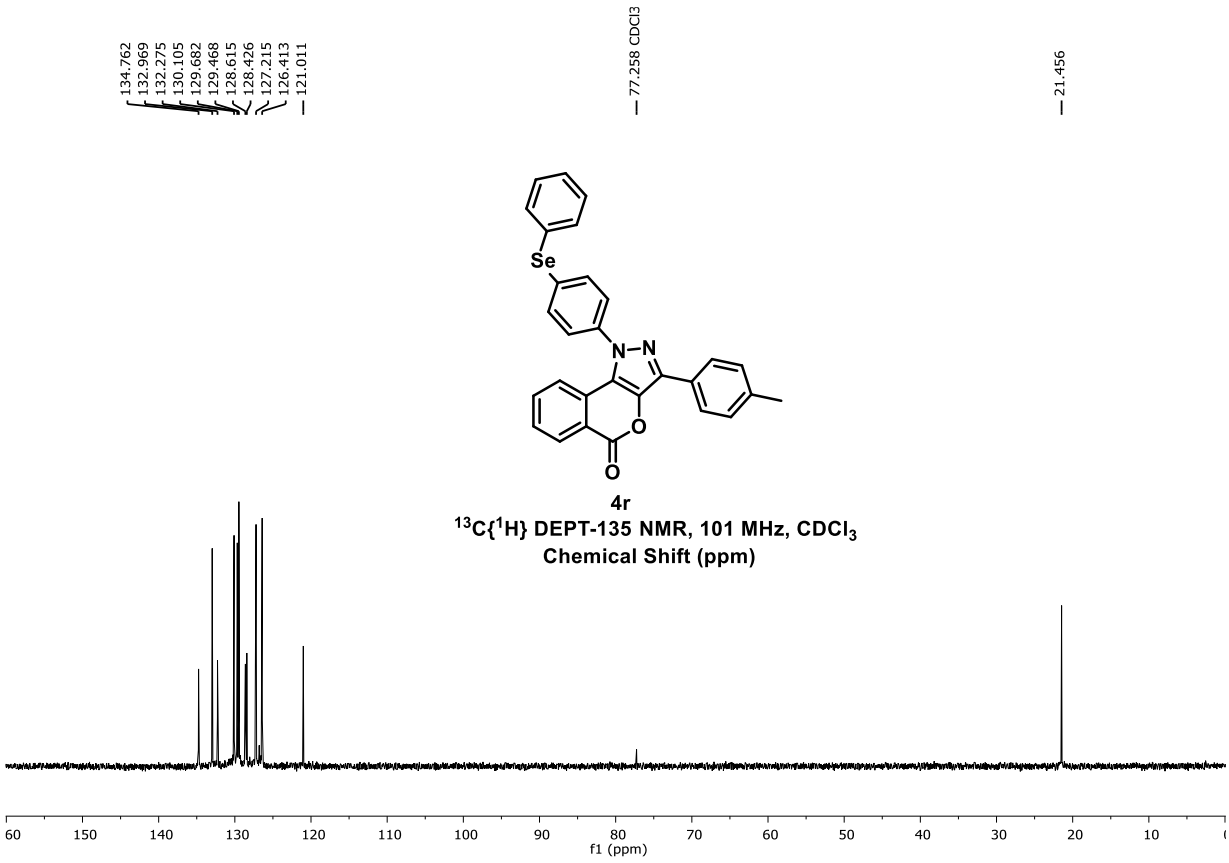
Chemical Shift (ppm)

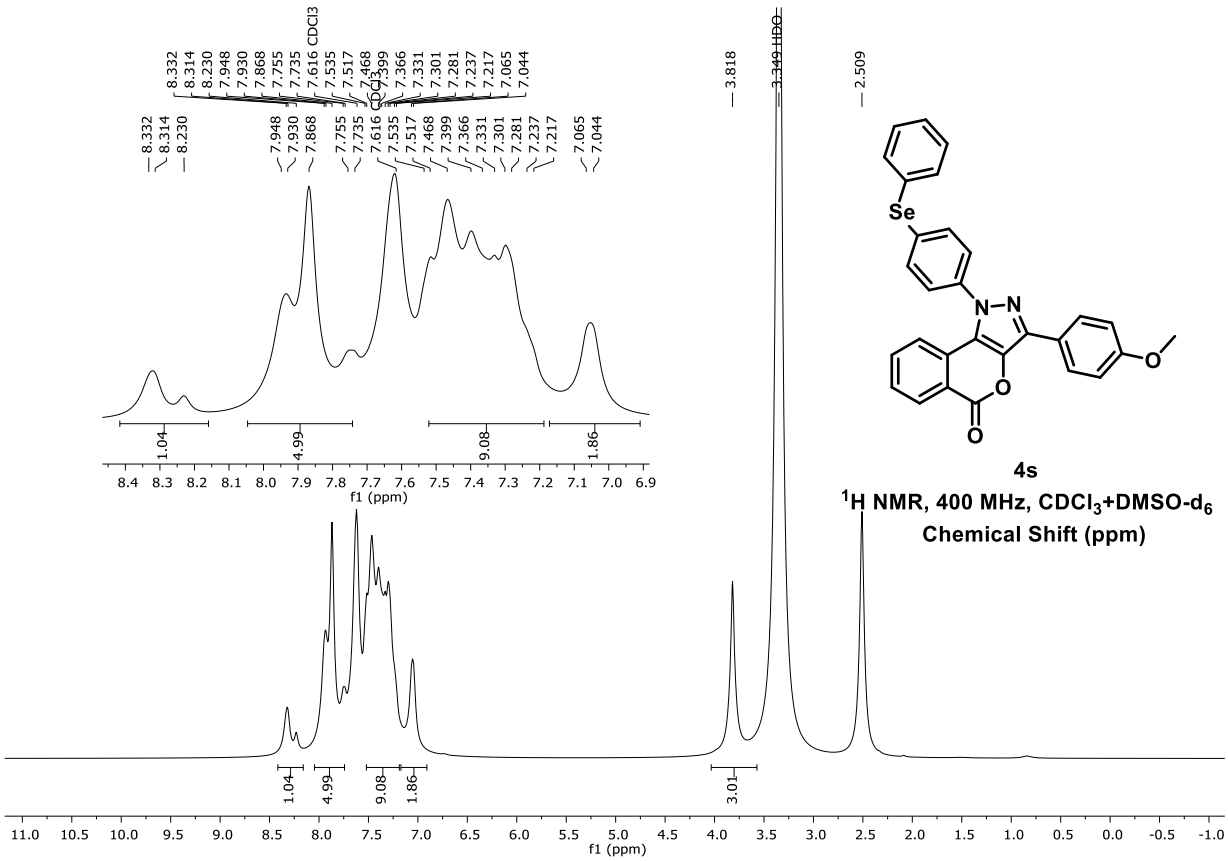


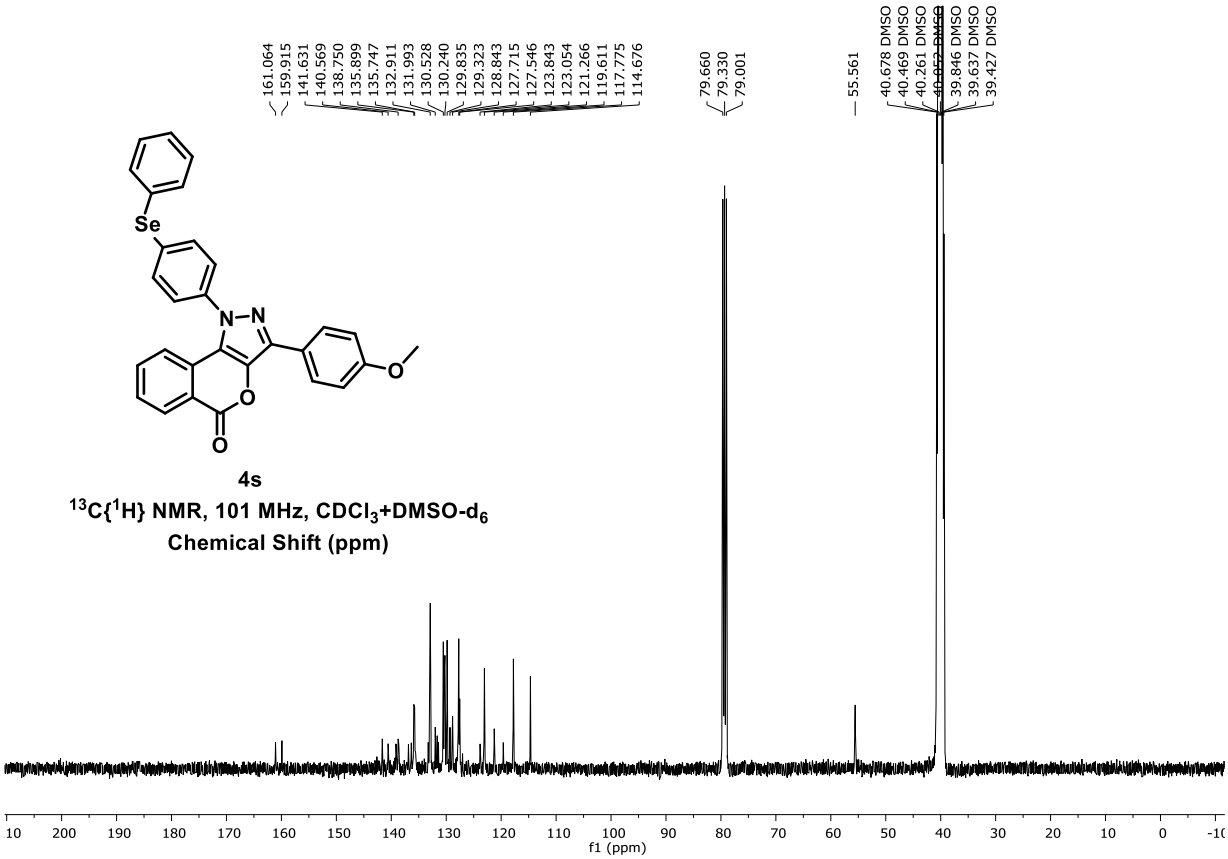
4r

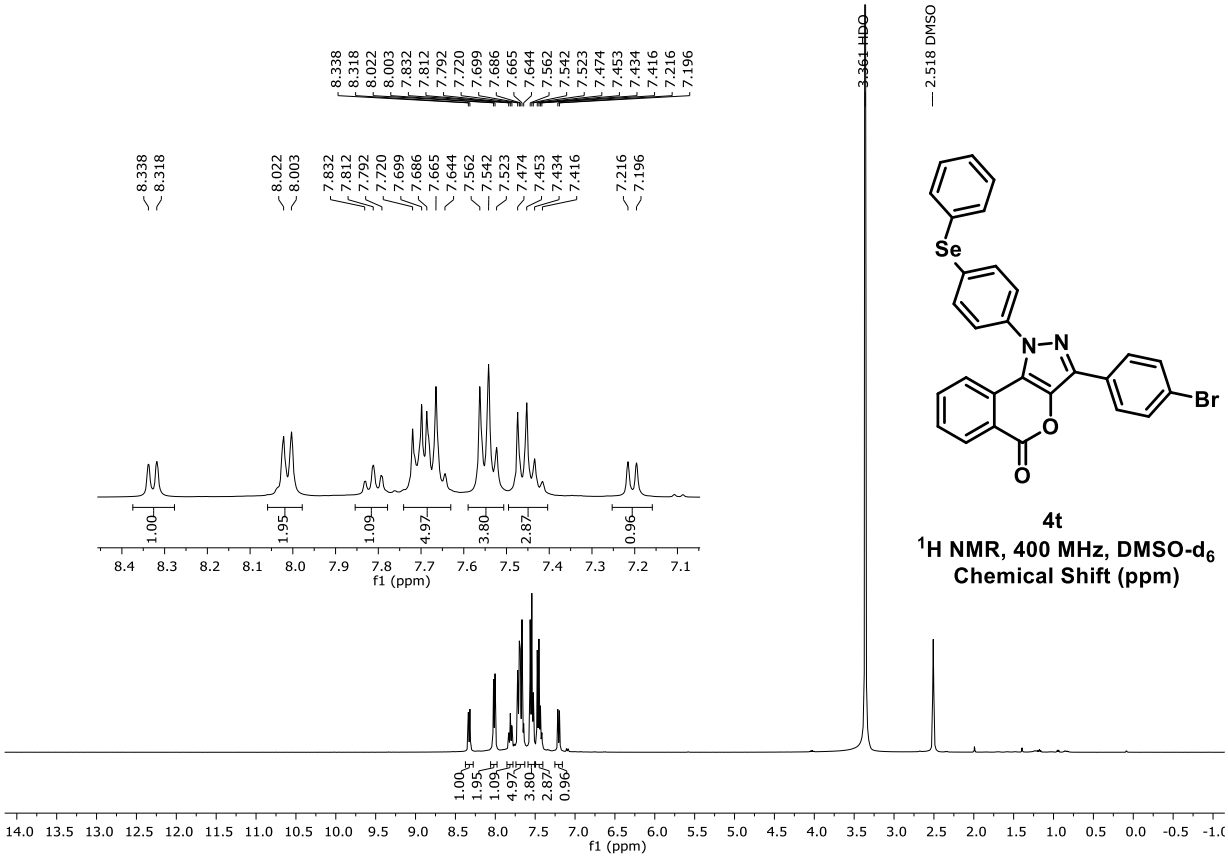
$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$

Chemical Shift (ppm)

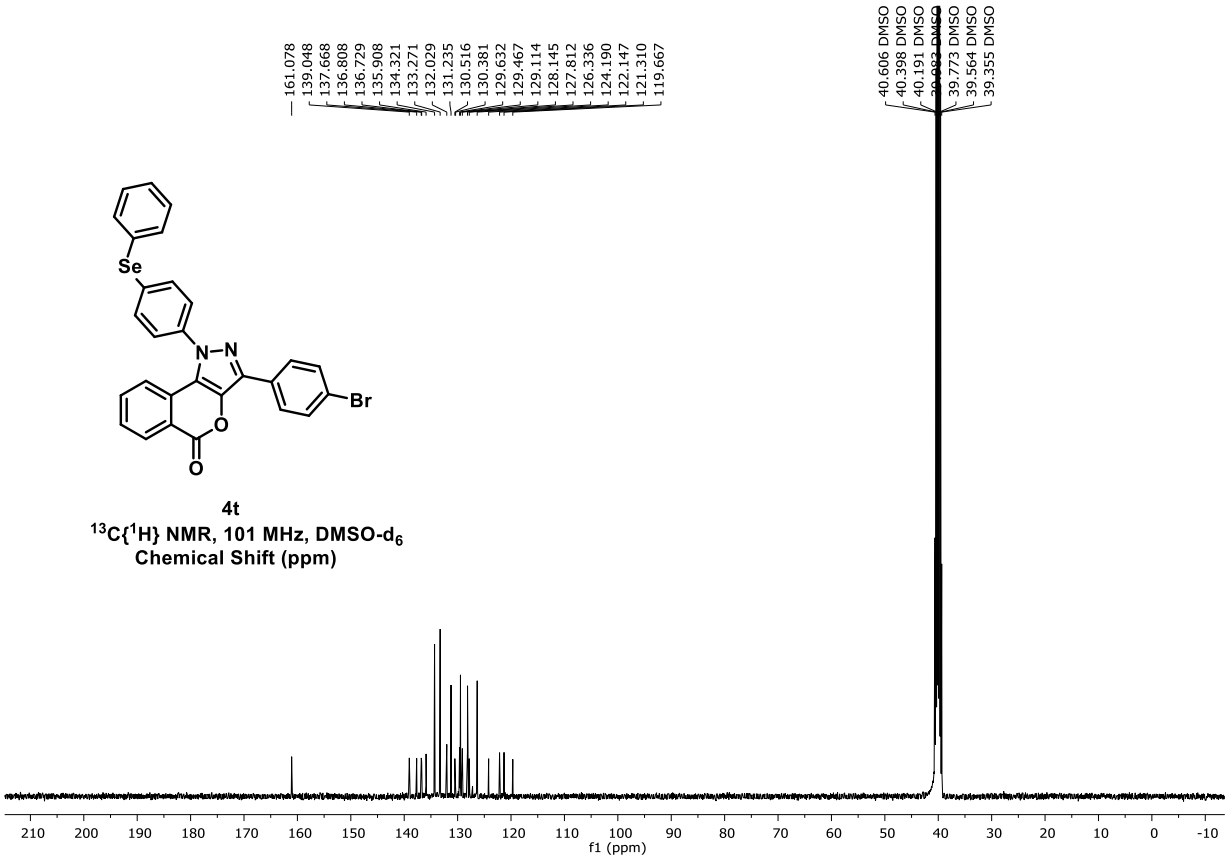

134.762
132.969
132.275
130.105
129.682
129.468
128.615
128.426
127.215
126.413
121.011
77.258 CDCl3
21.456
Se
N–N
O
O
4r
13C{1H} DEPT-135 NMR, 101 MHz, CDCl3
Chemical Shift (ppm)
60
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


8.332
8.314
8.230
7.948
7.930
7.868
7.755
7.735
7.616 CDCl3
7.535
7.517
7.468
7.399
7.366
7.331
7.301
7.281
7.237
7.217
7.065
7.044
3.818
3.349 HDO
2.509
1.04
4.99
9.08
1.86
3.01
f1 (ppm)
Se
N–N
O
O
O
4s
1H NMR, 400 MHz, CDCl3+DMSO-d6
Chemical Shift (ppm)

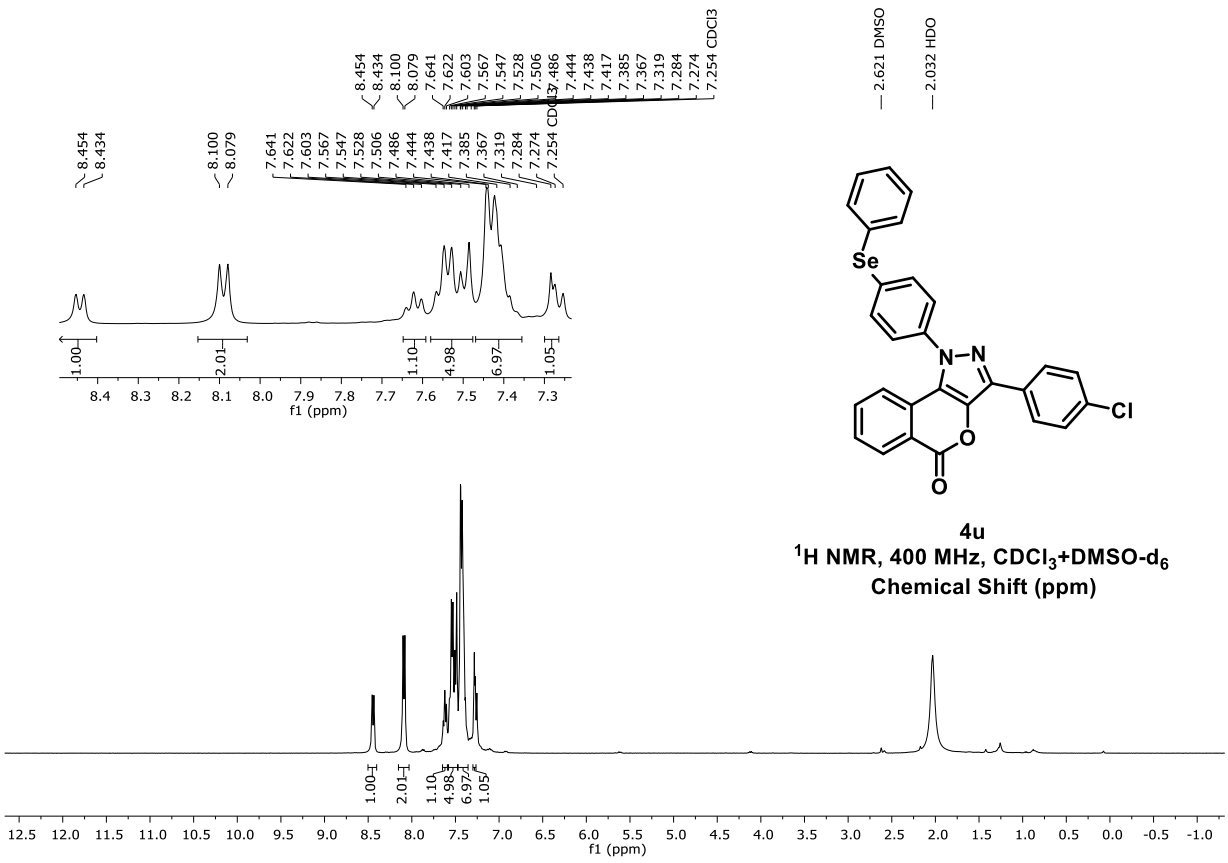

161.064
159.915
141.631
140.569
138.750
135.899
135.747
132.911
131.993
130.528
130.240
129.835
129.323
128.843
127.715
127.546
123.843
123.054
121.266
119.611
117.775
114.676
79.660
79.330
79.001
55.561
40.678 DMSO
40.469 DMSO
40.261 DMSO
39.846 DMSO
39.637 DMSO
39.427 DMSO
f1 (ppm)
Se
N–N
O
O
O
4s
13C{1H} NMR, 101 MHz, CDCl3+DMSO-d6
Chemical Shift (ppm)



4t
^{1}H NMR, 400 MHz, DMSO-d$_6$
Chemical Shift (ppm)



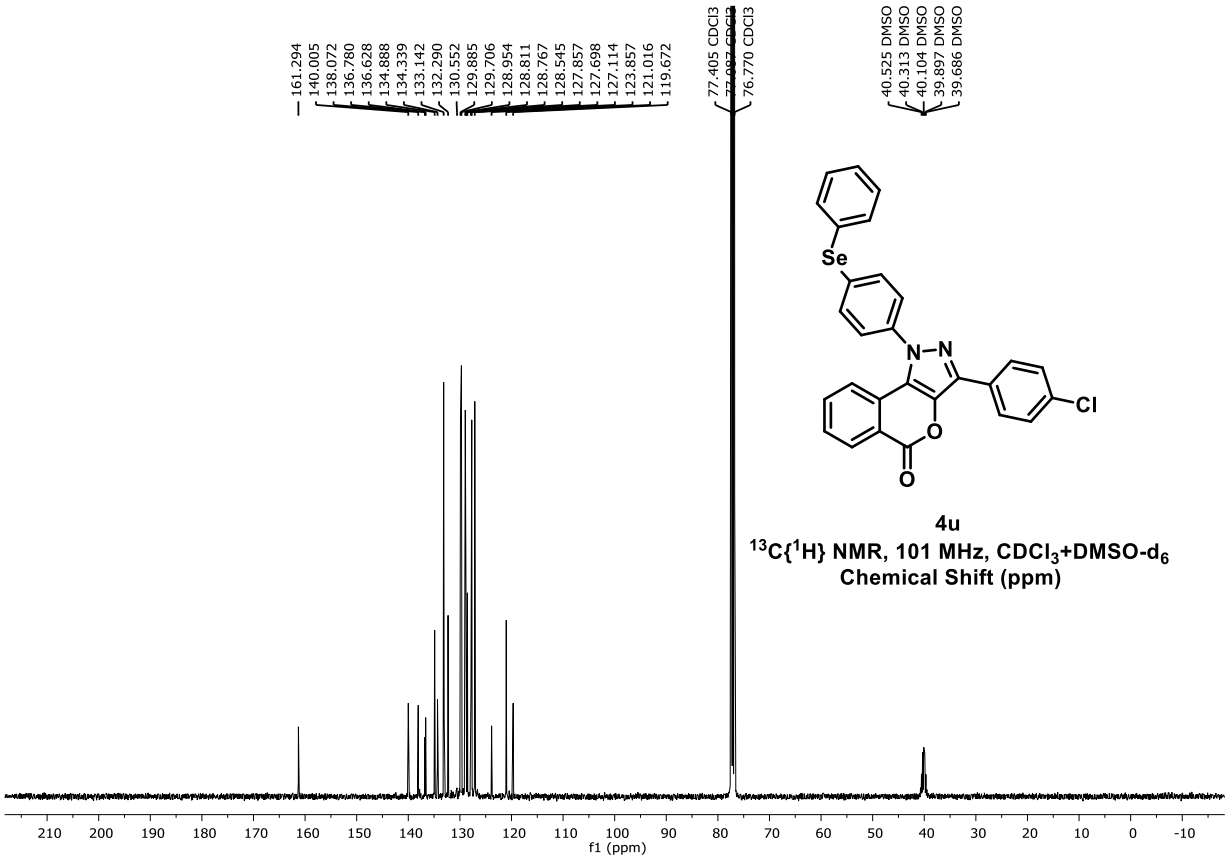
4t
^{13}C{^{1}H} NMR, 101 MHz, DMSO-d$_6$
Chemical Shift (ppm)



4u

^{1}H NMR, 400 MHz, $CDCl_3$+DMSO-d_6

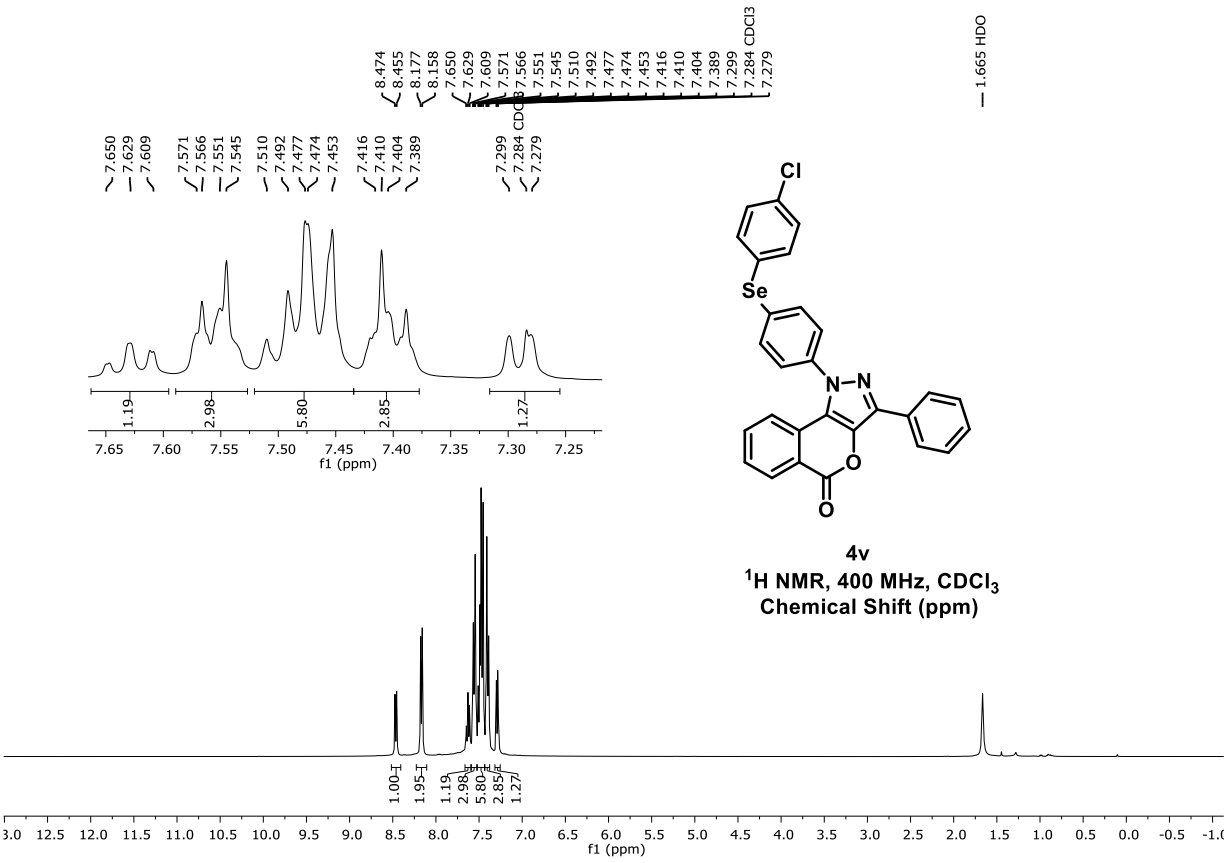
Chemical Shift (ppm)



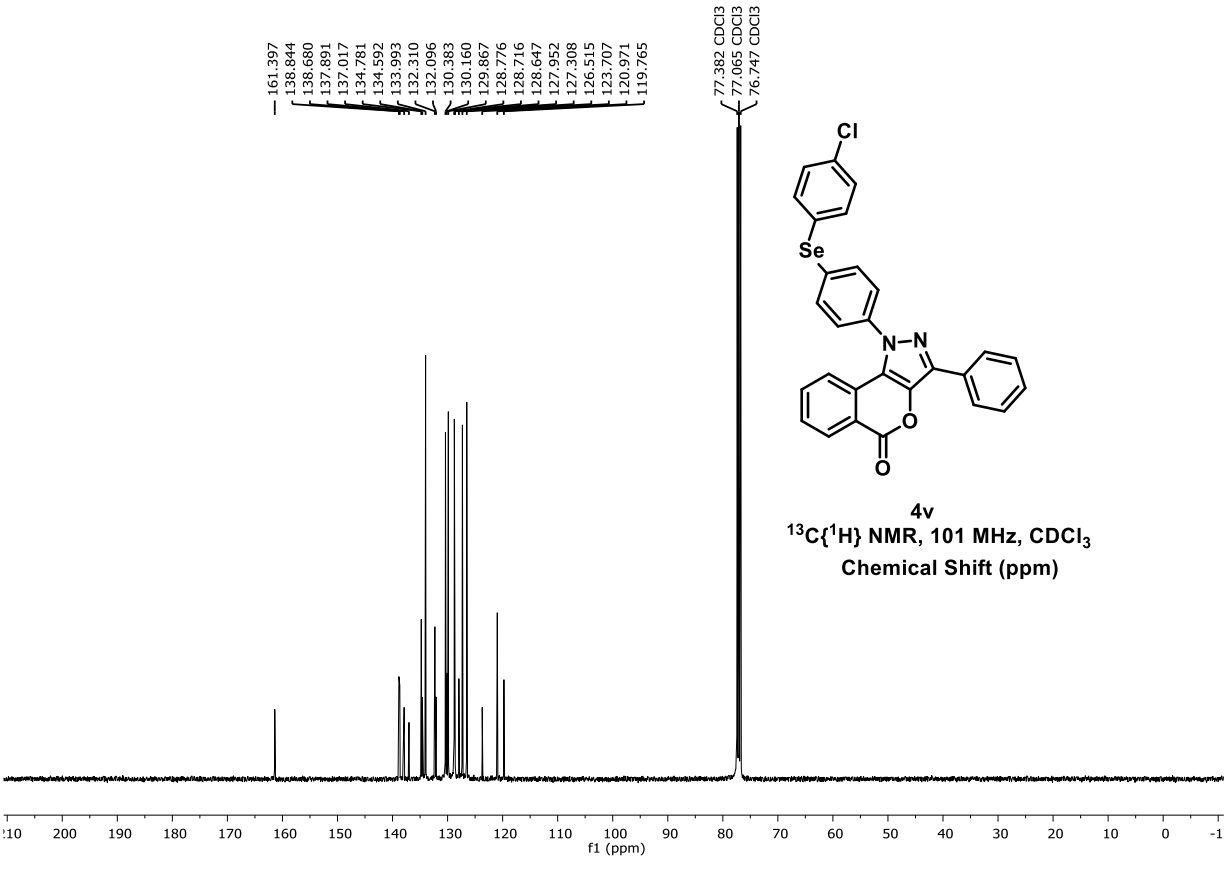
4u

^{13}C{^{1}H} NMR, 101 MHz, $CDCl_3$+DMSO-d_6

Chemical Shift (ppm)



4v
^{1}H NMR, 400 MHz, $CDCl_3$
Chemical Shift (ppm)



4v
$^{13}C\{^{1}H\}$ NMR, 101 MHz, $CDCl_3$
Chemical Shift (ppm)

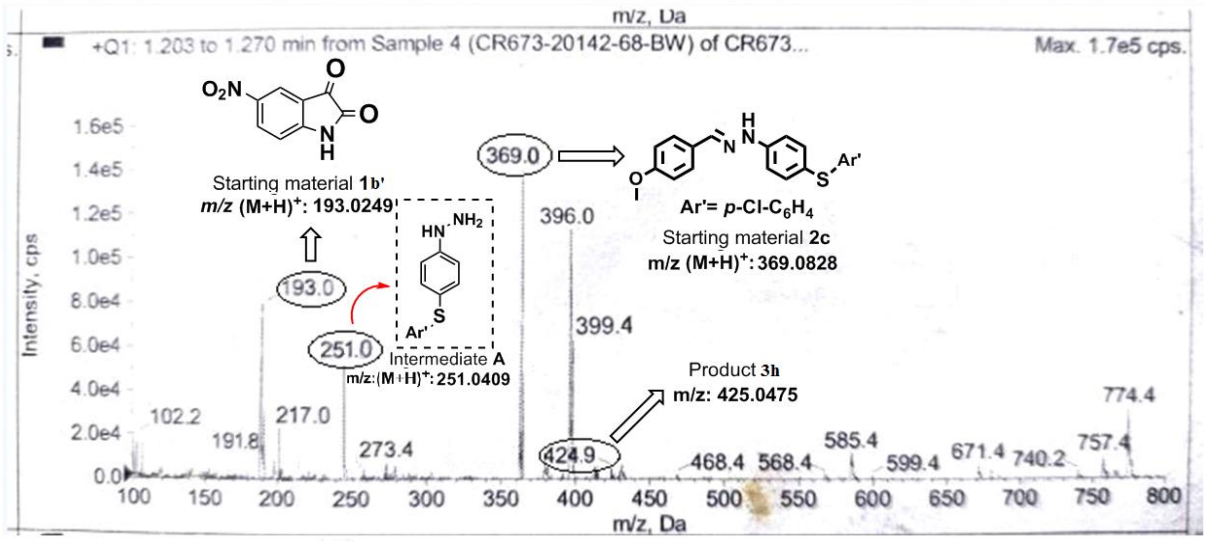


Figure S3. LC-MS Mass Spectrum of reaction mixture (**1b'**+**2c**) after 5 min.