Supporting Information

[4+2]-Annulation of Prop-2-ynylsulfonium Salts and *N*-substituted pyrrole-2-carboxaldehydes: Access to Indolizines Containing a Thioether Group

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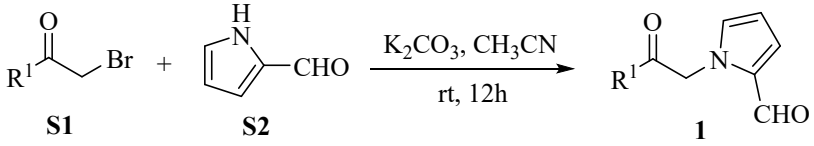
1. Experimental

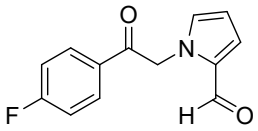
General. All reactions were carried out in test tube under air atmosphere. Chemicals were purchased from commercial suppliers and used without further purification. Purification of reaction products were carried out by chromatography using silica gel (200-300 mesh). High resolution MS data were recorded on Agilent 6200 Series TOF spectrometer. NMR spectra were recorded on AVIII for ^{1}H NMR at 500/400 MHz and for ^{13}C NMR at 125/100 MHz. For ^{1}H NMR, tetramethylsilane (TMS) was served as internal standard (δ). The spectra data presented here are reported as follows: chemical shift, integration, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), and coupling constant(s) in Hertz. For ^{13}C NMR TMS was used as internal standard and spectra were obtained with complete proton decoupling.

General procedure for the synthesis of *N*-substituted pyrrole-2-carboxaldehydes 1



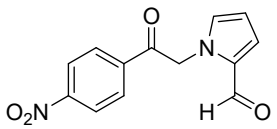
S1 **S2** **1**

To a mixture of **S2** (5 mmol, 0.48 g) and K_2CO_3 (6 mmol, 0.83 g) in 40 mL of CH_3CN were added corresponding α-bromo-substituted ketone (5.5 mmol), and the reaction was proceeded at room temperature for 12 h. After completion, the mixture was filtered and dried under reduced pressure. Then the residue was diluted with 30 ml of ethyl acetate and washed with water for 3 times. The organic layer was dried with sodium sulfate, concentrated and purified by silica gel chromatography to obtain **1**.



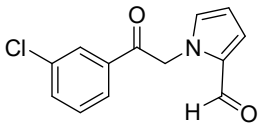
1-(2-(4-fluorophenyl)-2-oxoethyl)-1H-pyrrole-2-carbaldehyde (**1d**)

^{1}H NMR (500 MHz, $CDCl_3$) δ 9.51 (1H, d, *J* = 1.0 Hz), 8.06 – 8.02 (2H, m), 7.21 – 7.17 (2H, m), 7.04 (1H, dd, *J* = 4.0, 1.5 Hz), 6.96 (1H, t, *J* = 1.0 Hz), 6.36 (1H, dd, *J* = 4.0, 2.5 Hz), 5.77 (2H, s). HRMS calcd for $C_{13}H_{10}FNO_2+H^+$: 232.0876, found: 232.0874.



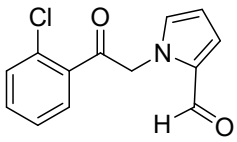
1-(2-(4-nitrophenyl)-2-oxoethyl)-1H-pyrrole-2-carbaldehyde (**1e**)

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.50 (1H, d, J = 1.0 Hz), 8.39 – 8.36 (2H, m), 7.58 – 7.55 (2H, m), 7.07 (1H, dd, J = 4.0, 1.6 Hz), 6.98 (1H, t, J = 1.0 Hz), 6.39 (1H, dd, J = 4.0, 2.8 Hz), 5.78 (2H, s). HRMS calcd for $C_{13}H_{10}N_2O_4$+H^+: 259.0713, found: 259.0715.



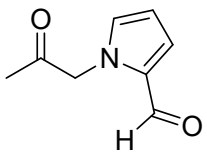
1-(2-(3-chlorophenyl)-2-oxoethyl)-1H-pyrrole-2-carbaldehyde (**1h**)

^{1}H NMR (500 MHz, $CDCl_3$) δ 9.51 (1H, d, J = 1.0 Hz), 7.97 (1H, t, J = 1.5 Hz), 7.89 (1H, dt, J = 7.5, 1.0 Hz), 7.62-7.59 (1H, m), 7.47 (1H, t, J = 8.0 Hz), 7.05 (1H, dd, J = 4.0, 1.5 Hz), 6.95 (1H, t, J = 1.0 Hz), 6.37 (1H, dd, J = 4.0, 2.5 Hz), 5.76 (2H, s). HRMS calcd for $C_{13}H_{10}ClNO_2$+H^+: 248.0473, found: 248.0470.



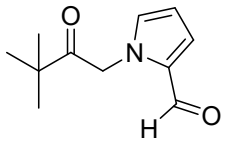
1-(2-(2-chlorophenyl)-2-oxoethyl)-1H-pyrrole-2-carbaldehyde (**1j**)

^{1}H NMR (500 MHz, $CDCl_3$) δ 9.51 (1H, d, J = 1.0 Hz), 7.77 (1H, dt, J = 7.5, 1.0 Hz), 7.46 (1H, d, J = 1.0 Hz) ,7.45 (1H, d, J = 1.0 Hz), 7.41- 7.38 (1H, m), 7.04 (1H, dd, J = 4.0, 2.0 Hz), 7.00 (1H, t, J = 1.0 Hz), 6.36 (1H, dd, J = 4.0, 2.5 Hz), 5.65 (2H, s). HRMS calcd for $C_{13}H_{10}ClNO_2$+H^+: 248.0473, found: 248.0470.



1-(2-oxopropyl)-1H-pyrrole-2-carbaldehyde (**1p**)

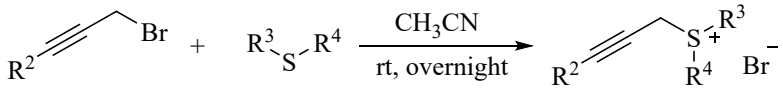
^{1}H NMR (500 MHz, $CDCl_3$) δ 9.50 (1H, d, J = 1.0 Hz), 7.00 (1H, dd, J = 4.0, 2.0 Hz), 6.87 (1H, t, J = 1.0 Hz), 6.32 (1H, dd, J = 4.0, 2.5 Hz), 5.10 (2H, s), 2.24 (3H, s). HRMS calcd for $C_8H_9NO_2$+H^+: 152.0706, found: 152.0708.



1-(3,3-dimethyl-2-oxobutyl)-1H-pyrrole-2-carbaldehyde (**1q**)

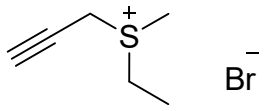
^{1}H NMR (500 MHz, $CDCl_3$) δ 9.47 (1H, d, J = 1.0Hz), 6.98 (1H, dd, J = 4.0, 1.5 Hz), 6.83 (1H, t, J = 1.0 Hz), 6.30 (1H, dd, J = 4.0, 2.5 Hz), 5.36 (2H, s), 1.28 (9H, s). HRMS calcd for $C_{11}H_{15}NO_2$+H^+: 194.1176, found: 194.1174.

General procedure for the synthesis of prop-2-ynyl-substituted sulfonium salt 2



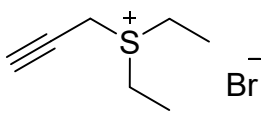
S3 **S4** **2**

A mixture of bromopropyne (20 mmol) and corresponding thioether (40 mmol) was stirred in 50 mL of CH_3CN at room temperature overnight. The reaction mixture was filtered, and the filter cake was washed with 30 ml of petroleum ether which was dried under vacuum to obtain **2** as white solid.



ethyl(methyl)(prop-2-yn-1-yl)sulfonium bromide(**2b**)

^{1}H NMR (400 MHz, DMSO) δ 4.80 (2H, d, J = 2.0 Hz), 3.98 (1H, s), 3.45 (2H, q, J = 8.0 Hz), 3.01 (3H, s), 1.35 (3H, t, J = 7.2 Hz). HRMS calcd for $C_6H_{11}S^+$: 115.0576, found: 115.0574.



diethyl(prop-2-yn-1-yl)sulfonium bromide(**2c**)

^{1}H NMR (400 MHz, DMSO) δ 4.57 (2H, d, J = 2.0 Hz), 3.93 (1H, s), 3.45 (4H, q, J = 8.0 Hz), 1.33(6H, t, J = 7.2 Hz). HRMS calcd for $C_7H_{13}S^+$: 129.0732, found: 129.0730.

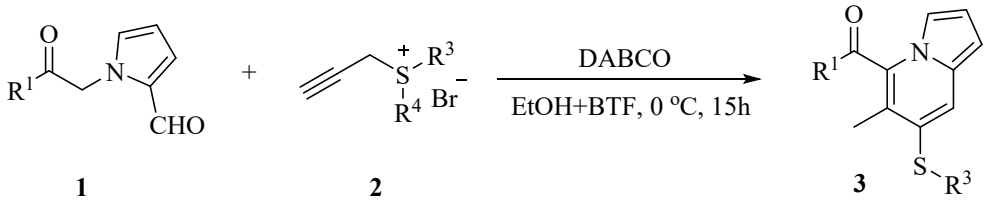
Additional reaction optimization

Supplementary Table 1. Additional optimization of reaction conditions[a]

Entry	Solvent	Base	Temp (℃)	Ratio (**1a**: **2a**: base)	Yield (%)[b]
1	i-PrOH	DABCO	0	1: 2: 3	14%
2	MeOH: BTF (8:2)	DABCO	0	1: 2: 3	4%
3	EtOH: H_2O (8:2)	DABCO	0	1: 2: 3	6%
4	EtOH: BTF (8:2)	Cs_2CO_3	0	1: 2: 3	Trace
5	EtOH: BTF (8:2)	Et_3N	0	1: 2: 3	Trace
6	EtOH: BTF (8:2)	t-BuOK	0	1: 2: 3	Trace
7	EtOH	DABCO	0	1: 5: 7	49%

[a]Reaction conditions unless otherwise specified: 1.0 mmol of **1a**, portionwise addition of **2a** (0.5 equiv per 0.5 h), 10 mL of solvent, 12 h, air. [b]Isolated yields.

General procedure for the synthesis of target compounds 3

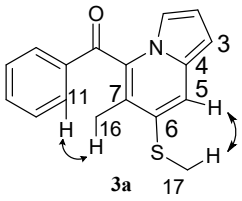


1 **2** **3**

To a solution of corresponding *N*-substituted pyrrole-2-carboxaldehyde **1** (1.0 mmol) in 10 mL of mixed solvent (ethanol : benzotrifluoride = 8:2) was added DABCO (7.0 mmol, 0.78 g) at 0 ℃. Then sulfonium salt **2** (5.0 mmol) was successively added (once per 0.5 h, each time for 0.5 equiv), and the reaction was stirred for 12h. After completion, the reaction was filtered. The filtrate was concentrated under reduced pressure to obtain crude residue, which was purified by silica gel column chromatography (petroleum ether: ethyl acetate=100:1) to obtain product **3**.

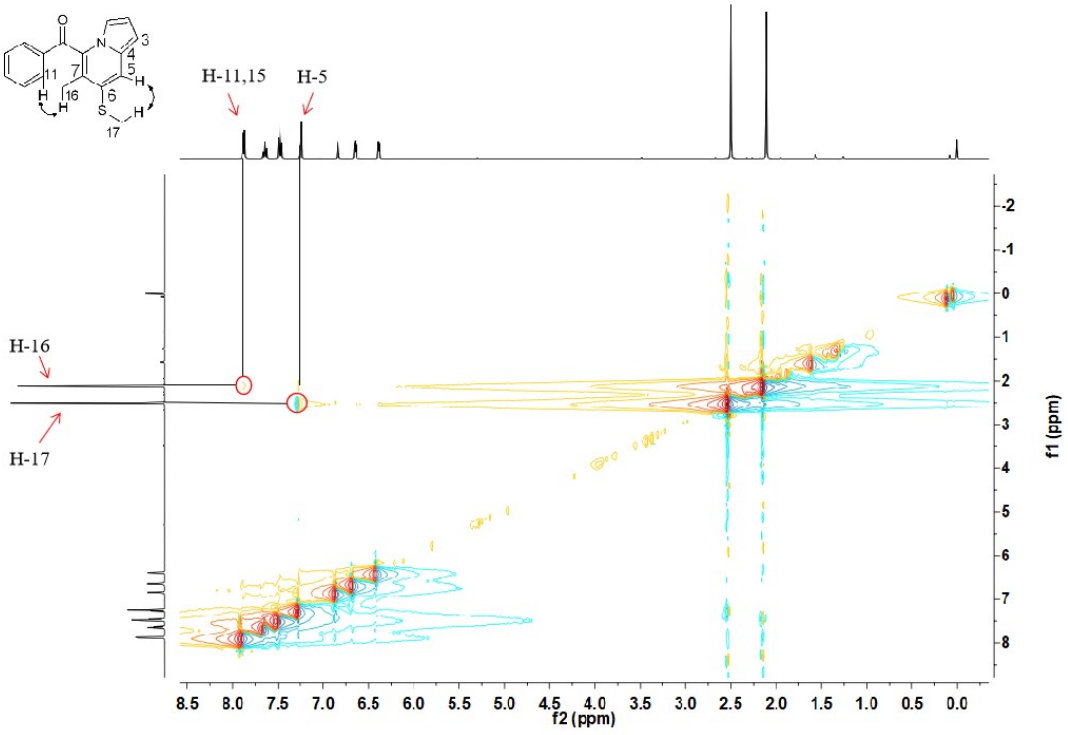
The 2D NMR for confirmation of compounds of 3a and 3g

According to the chemical shifts and the coupling constants in ^{1}H NMR spectra, the signals of the key H-5, H-17, H-16 and H-11 can be identified. As shown in NOESY spectra of **3a**, correlations between H-11 and H-16, H-5 and H-17 were observed, instead of H-11 with H-17 and H-5 with H-16, which indicated that the structure can't be **3a'**. Therefore, the structure of representative product should be **3a**.

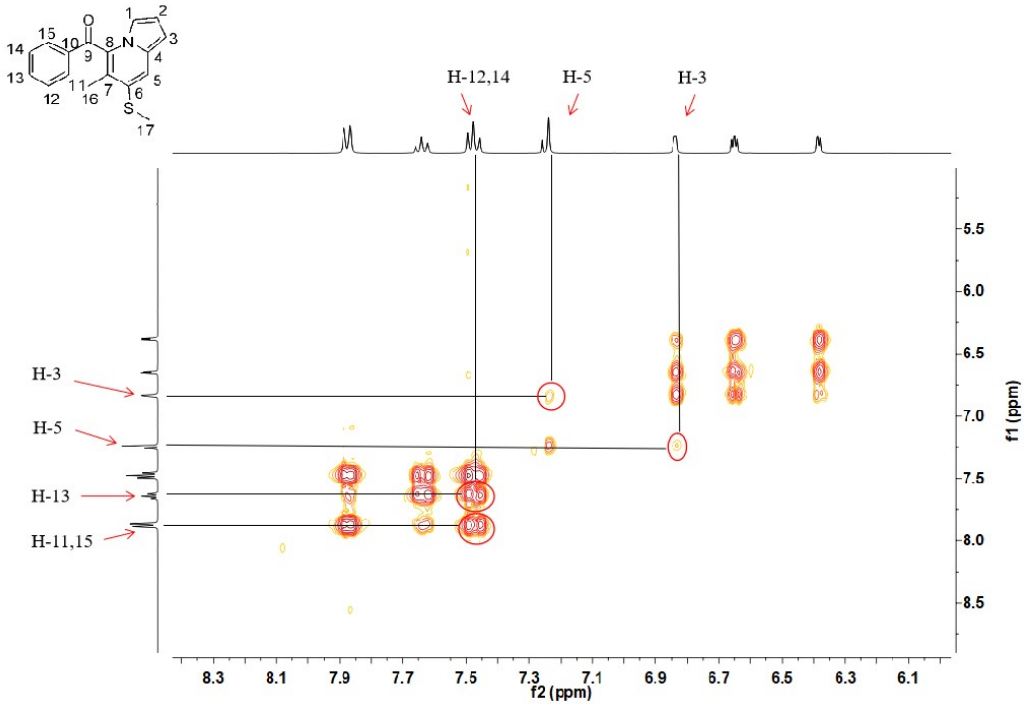


3a

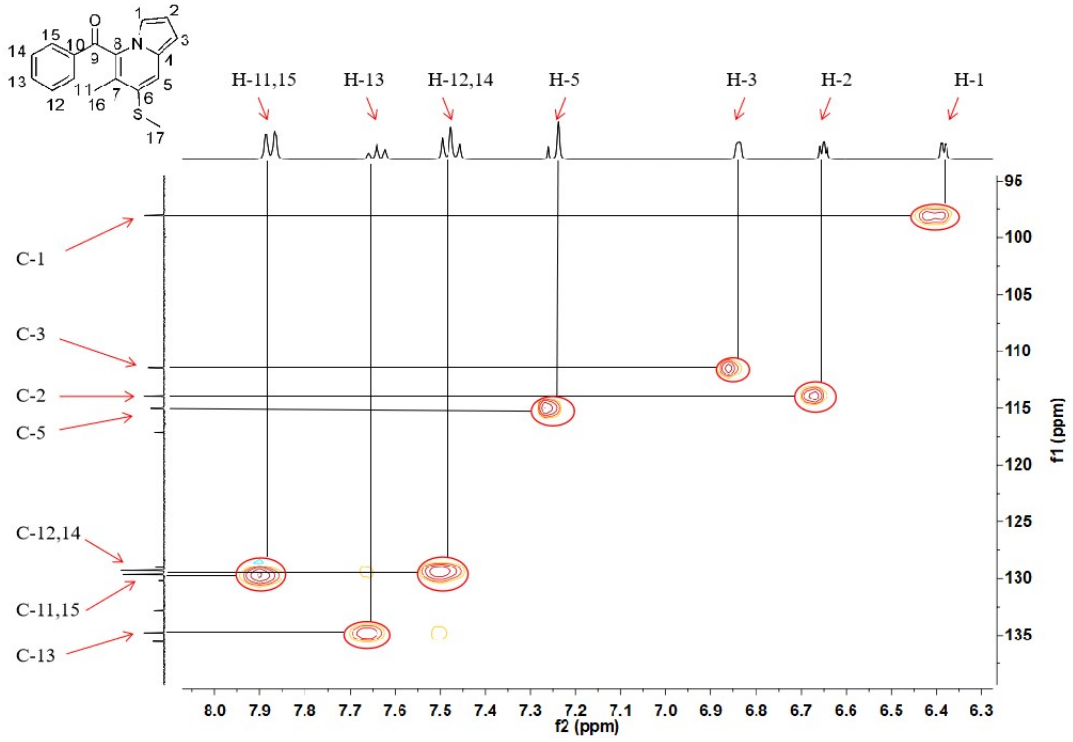
3a'



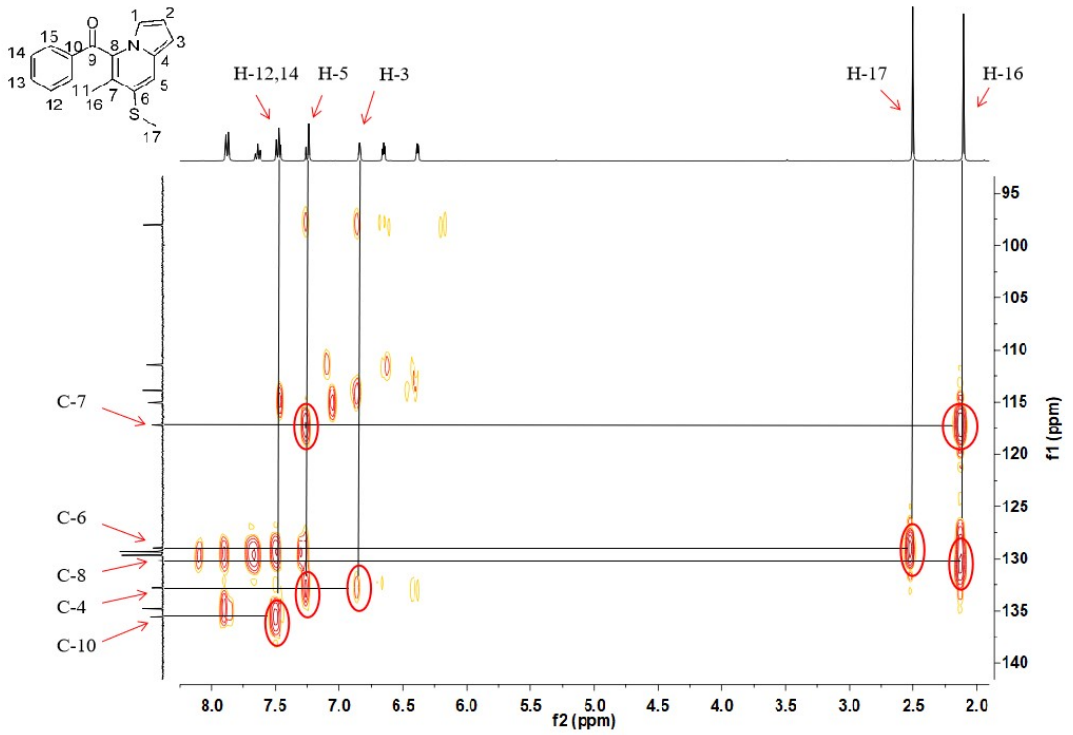
3a ^{1}H-^{1}H-COSY



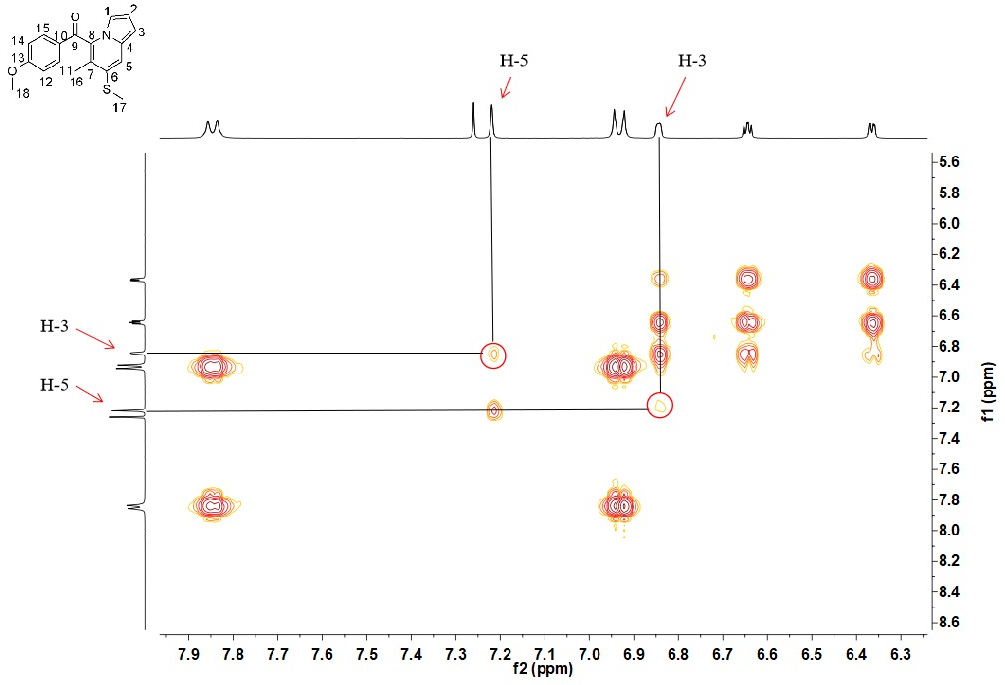
3a ^{1}H-^{13}C-HSQC



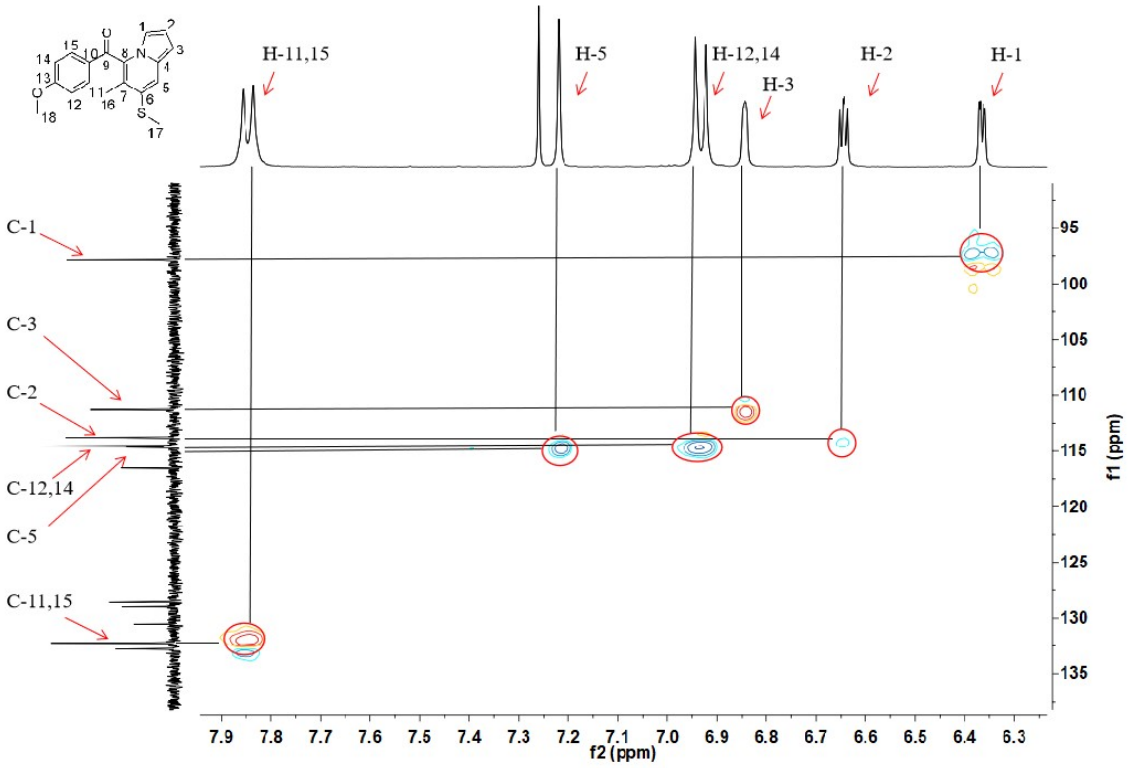
3a ^{1}H-^{13}C-HMBC



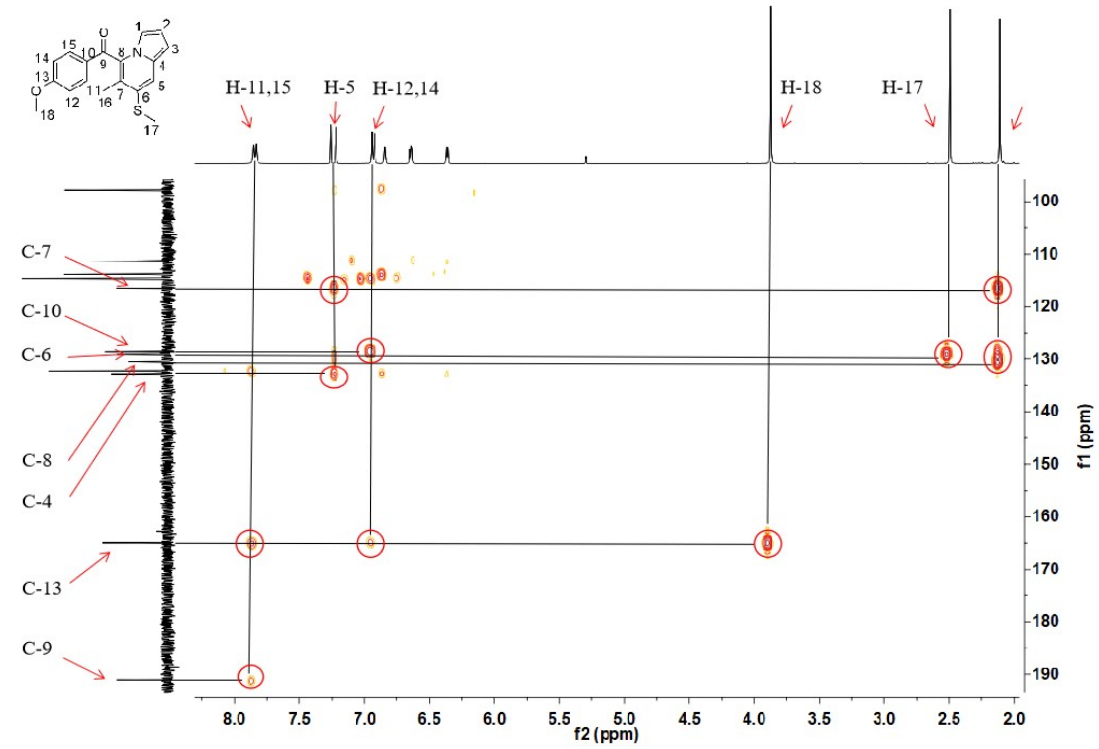
3g ^{1}H-^{1}H-COSY



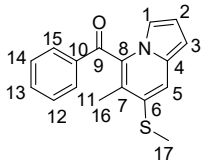
3g ^{1}H-^{13}C-HSQC



3g ^{1}H-^{13}C-HMBC



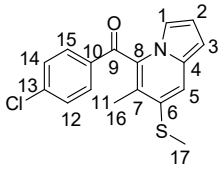
Characterization data for target compounds 3



(6-methyl-7-(methylthio)indolizin-5-yl)(phenyl)methanone (**3a**)

Red oil, yield:188mg, 67%.

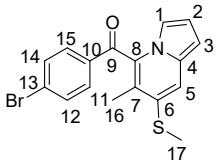
^{1}H NMR (400MHz, $CDCl_3$): δ 7.88 (2H, d, *J*=7.2Hz, H-11,15), 7.64 (1H, t, *J*=7.4Hz, H-13), 7.47 (2H, t, *J*=7.8Hz, H-12,14), 7.24 (1H, s, H-5), 6.84 (1H, s, H-3), 6.65 (1H, t, *J*=3.4Hz, H-2), 6.39 (1H, dd, *J*=4.0, 1.2Hz, H-1), 2.50 (3H, s, H-17), 2.11 (3H, s, H-16); ^{13}C NMR (100MHz, $CDCl_3$): δ 192.9(C-9), 135.8(C-10), 135.0(C-13), 133.0(C-4), 130.4(C-8), 129.9(C-11,15), 129.5(C-12,14), 129.2(C-6), 117.4(C-7), 115.4(C-5), 114.1(C-2), 111.6(C-3), 98.3(C-1), 16.1(C-17), 15.29(C-16); HRMS calcd for $C_{17}H_{15}NOS+H^+$: 282.0947, found: 282.0943.



(4-chlorophenyl)(6-methyl-7-(methylthio)indolizin-5-yl)methanone (**3b**)

Red oil, yield: 205mg, 65%.

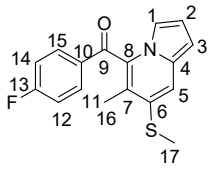
^{1}H NMR (500MHz, $CDCl_3$): δ 7.80 (2H, d, *J*=8.5Hz, H-11,15), 7.45 (2H, t, *J*=9.0Hz, H-12,14), 7.23 (1H, s, H-5), 6.80 (1H, m, H-3), 6.66 (1H, dd, *J*=4.0, 2.5Hz, H-2), 6.39 (1H, dd, *J*=4.0, 1.0Hz, H-1), 2.50 (3H, s, H-17), 2.09 (3H, s, H-16); ^{13}C NMR (125MHz, $CDCl_3$): δ191.6(C-9),141.7(C-13), 134.2(C-4), 133.1(C-11,15), 131.3(C-8), 130.0(C-6), 129.3(C-10), 117.7(C-7), 115.5(C-5), 114.3(C-12,14), 111.6(C-2), 100.2(C-3), 98.5(C-1), 16.1(C-17), 15.3(C-16); HRMS calcd for $C_{17}H_{14}ClNOS+H^+$: 316.0557, found: 316.0553.



(4-bromophenyl)(6-methyl-7-(methylthio)indolizin-5-yl)methanone (**3c**)

Red oil, yield: 201mg, 56%.

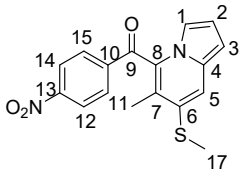
^{1}H NMR (500MHz, $CDCl_3$): δ 7.73 (2H, d, *J*=8.0Hz, H-11,15), 7.62 (2H, d, *J*=8.0Hz, H-12,14),7.25 (1H, s, H-5), 6.79 (1H, s, H-3), 6.66 (1H, s, H-2), 6.40 (1H, s, H-1), 2.50 (3H, s, H-17), 2.09 (3H, s, H-16); ^{13}C NMR (125MHz, $CDCl_3$): δ 191.8(C-9), 138.8(C-13), 135.5(C-4), 134.51(C-11,15), 133.0(C-8), 131.3(C-6), 130.6(C-10), 130.0(C-7), 117.8(C-5), 115.5(C-12,14), 114.5(C-2), 111.6(C-3), 98.7(C-1), 16.1(C-17), 15.3(C-16); HRMS calcd for $C_{17}H_{14}BrNOS+H^+$: 360.0052, found: 360.0054.



(4-fluorophenyl)(6-methyl-7-(methylthio)indolizin-5-yl)methanone (**3d**)

Yellow oil, yield: 144mg, 48%.

^{1}H NMR (400MHz, $CDCl_3$): *δ* 7.90 (2H, dd, *J*=8.8, 5.2Hz, H-11,15), 7.23 (1H, s, H-5), 7.14 (2H, m, H-12,14), 6.81 (1H, s, H-3), 6.66 (1H, dd, *J*=3.6, 2.8Hz, H-2), 6.38 (1H, dd, *J*=3.6, 1.2Hz, H-1), 2.50 (3H, s, H-17), 2.10 (3H, s, H-16). ^{13}C NMR (100MHz, $CDCl_3$) *δ* 191.3(C-9), 167.0 (168.3,165.7, d, *J*=256Hz, C-13), 133.0(C-4), 132.7 (132.8,132.7, d, *J*=10Hz,C-11,15), 132.2 (132.3,132.2, d, *J*=3Hz, C-8), 130.1(C-6), 129.3(C-10), 117.4(C-7), 116.9 (117.0,116.8, d, *J*=22Hz, C-5), 115.3(C-12,14), 114.3(C-2), 111.6(C-3), 98.4(C-1), 16.0(C-17), 15.2(C-16). HRMS calcd for $C_{17}H_{14}FNOS+H^+$: 300.0853, found: 300.0850.

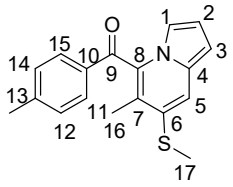


(5-methyl-7-(methylthio)indolizin-5-yl)(4-nitrophenyl)methanone (**3e**)

Red oil, yield: 49mg, 15%.

^{1}H NMR (400MHz, $CDCl_3$): δ 7.89 (1H, t, *J*=2.0Hz, H-14), 7.67 (1H, d, *J*=8.0Hz, H-12), 7.61 (1H, dd, *J* =8.0, 1.2Hz, H-15), 7.40 (1H, t, *J*=8.0Hz, H-11), 7.25 (1H, s, H-5), 6.82 (1H,

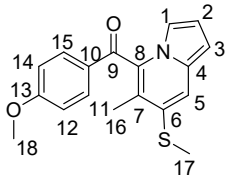
d, *J*=1.2Hz, H-3), 6.66 (1H, dd, *J*= 4.0, 2.8Hz, H-2), 6.40 (1H, dd, *J*=3.8, 1.2Hz, H-1), 2.50 (3H, s, H-17), 2.10 (3H, s, H-16); ^{13}C NMR (100MHz, $CDCl_3$): δ 191.4(C-9), 137.3(C-13), 135.7(C-4), 134.7(C-11,15), 132.8(C-8), 130.7(C-6), 129.2(C-10), 127.9(C-7), 117.7(C-5), 115.5(C-12,14), 114.2(C-2), 111.4(C-3), 98.4(C-1), 15.9(C-17), 15.1(C-16); HRMS calcd for $C_{17}H_{14}N_2O_3S+H^+$: 327.0798, found: 327.0795.



(6-methyl-7-(methylthio)indolizin-5-yl)(p-tolyl)methanone (**3f**)

Red oil, yield: 180mg, 61%.

^{1}H NMR (500MHz, $CDCl_3$): δ 7.79 (2H, d, *J*=8.0Hz, H-11,15), 7.29 (2H, d, *J*=7.5Hz, H-12,14), 7.25 (1H, s, H-5), 6.86 (1H, s, H-3), 6.67 (1H, t, *J*=3.5Hz, H-2), 6.40 (1H, d, *J*=4.0Hz, H-1), 2.52 (3H, s, H-17), 2.45 (3H, s, CH_3-C13), 2.13 (3H, s, H-16); ^{13}C NMR (125MHz, $CDCl_3$): δ 192.5(C-9), 146.3(C-13), 133.3(C-4), 133.0(C-11,15), 130.7(C-8), 130.3(C-6), 130.0(C-10), 129.2(C-7), 117.1(C-5), 115.1(C-12,14), 114.1(C-2), 111.6(C-3), 98.2(C-1), 22.1(C-13), 16.1(C-17), 15.2(C-16); HRMS calcd for $C_{18}H_{17}NOS+H^+$: 296.1104, found: 296.1103.

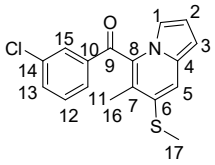


(4-methoxyphenyl)(6-methyl-7-(methylthio)indolizin-5-yl)methanone (**3g**)

Red oil, yield: 121mg, 39%.

^{1}H NMR (500MHz, $CDCl_3$): δ 7.85 (2H, d, *J*=8.0Hz, H-11,15), 7.21 (1H, s, H-5), 6.93 (2H, d, *J*=8.5Hz, H-12,14), 6.84 (1H, s, H-3), 6.64 (1H, t, *J*=3.5Hz, H-2), 6.36 (1H, d, *J*=3.5Hz, H-1), 3.87 (3H, s, H-18), 2.49 (3H, s, H-17), 2.10 (3H, s, H-16); ^{13}C NMR (125MHz, $CDCl_3$): δ 191.3(C-9), 165.2(C-13), 133.0(C-4), 132.5(C-11,15), 130.8(C-8), 129.3(C-6),

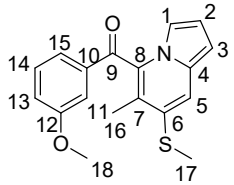
128.8(C-10), 116.8(C-7), 114.9(C-5), 114.8(C-12,14), 114.1(C-2), 111.6(C-3), 98.1(C-1), 55.9(C-18), 16.0(C-17), 15.2(C-16); HRMS calcd for $C_{18}H_{17}NO_2S+H^+$: 312.1053, found: 312.1050.



(3-chlorophenyl)(6-methyl-7-(methylthio)indolizin-5-yl)methanone (**3h**)

Red oil, yield: 123mg, 39%.

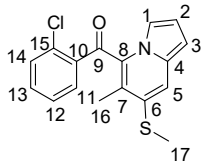
^{1}H NMR (500MHz, DMSO): δ 7.86 (1H, m, H-15), 7.84 (1H, d, *J* = 1.5Hz, H-11), 7.66 (1H, dt, *J* = 8.0, 1.5Hz, H-13), 7.62-7.59 (1H, m, H-12), 7.41 (1H, s, H-5), 6.90-6.89 (1H, m, H-3), 6.67 (1H, dd, *J* = 4.0, 3.0Hz, H-2), 6.42 (1H, dd, *J* = 4.0, 1.5 Hz, H-1), 2.53 (3H, s, H-17), 2.00 (3H, s, H-16); ^{13}C NMR (125MHz, $CDCl_3$): δ 191.4(C-9), 137.3(C-14), 135.7(C-10), 134.7(C-4), 130.7(C-13), 129.5(C-8), 129.2(C-15), 128.7(C-12), 127.9(C-11), 117.7(C-6), 115.5(C-7), 114.2(C-5), 111.4(C-2), 98.4(C-3), 97.4(C-1), 15.9(C-17), 15.1(C-16); HRMS calcd for $C_{17}H_{14}ClNOS+H^+$: 316.0557, found: 316.0554.



(3-methoxyphenyl)(6-methyl-7-(methylthio)indolizin-5-yl)methanone (**3i**)

Red oil, yield: 215mg, 69%.

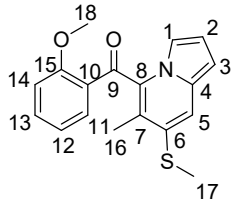
^{1}H NMR(400M Hz, $CDCl_3$): δ 7.52 (1H, d, *J*=1.2Hz, H-15), 7.36-7.32(2H, m, H-11,14), 7.23(1H, s, H-5), 7.19-7.17 (1H, m, H-13), 6.84 (1H, d, *J*=0.8Hz, H-3), 6.65 (1H, dd, *J*=3.6, 2.8Hz, H-2), 6.37 (1H, dd, *J*=4.0, 1.2Hz, H-1), 3.86 (3H, s, H-18), 2.49 (3H, s, H-17), 2.10 (3H, s, H-16); ^{13}C NMR (100MHz, $CDCl_3$): δ 192.8(C-9), 160.6(C-12), 137.2(C-10), 133.1(C-4), 130.6(C-8), 129.2(C-14), 123.0(C-15), 121.8(C-13), 117.4(C-11), 115.4(C-6), 114.2(C-7), 113.2(C-5), 111.7(C-2), 100.2(C-3), 98.3(C-1), 55.8(C-18), 16.1(C-17), 15.27(C-16); HRMS calcd for $C_{18}H_{17}NO_2S+H^+$: 312.1053, found: 312.1055.



(2-chlorophenyl)(6-methyl-7-(methylthio)indolizin-5-yl)methanone (**3j**)

Red oil, yield: 224mg, 71%.

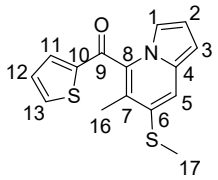
^{1}H NMR (500MHz, $CDCl_3$): δ 7.63 (1H, d, *J*=10.0Hz, H-11), 7.51-7.46 (2H, m, H-14), 7.35-7.31 (1H, m, H-13), 7.28 (1H, s, H-5), 7.07 (1H, d, *J*=1.5Hz, H-3), 6.68 (1H, dd, *J*=4.0, 3.5Hz, H-2), 6.40 (1H, dd, *J*=4.5,1.0Hz, H-1), 2.48 (3H, s, H-17), 2.13 (3H, s, H-16); ^{13}C NMR(125MHz, $CDCl_3$): δ 191.3(C-9), 136.6(C-15), 134.0(C-8), 133.9(C-13), 133.2(C-4), 131.9(C-10), 131.8(C-14), 131.1(C-11), 129.1(C-12), 127.7(C-6), 120.0(C-7), 116.8(C-5), 114.3(C-2), 112.2(C-3), 98.8(C-1), 16.2(C-17), 15.3(C-16); HRMS calcd for $C_{17}H_{14}ClNOS+H^+$: 316.0557, found: 316.0555.



(2-methoxyphenyl)(6-methyl-7-(methylthio)indolizin-5-yl)methanone (**3k**)

Red oil, yield: 149mg, 48%.

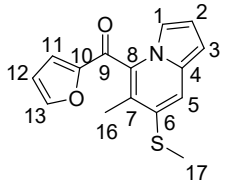
^{1}H NMR (400MHz, $CDCl_3$): δ 7.80 (1H, dd, *J*=8.0, 1.6Hz, H-11), 7.55 (1H, t, *J*=7.0Hz, H-13), 7.20 (1H, s, H-5), 7.03 (1H, t, *J*=7.6Hz, H-12), 6.95 (1H, d, *J*=8.4Hz, H-14), 6.91 (1H, d, *J*=1.2Hz, H-3), 6.62 (1H, dd, *J*=4.0, 2.8Hz, H-2), 6.34 (1H, dd, *J*=3.6,1.2Hz, H-1), 3.58 (3H, s, H-18), 2.47 (3H, s, H-17), 2.13 (3H, s, H-16); ^{13}C NMR (100MHz, $CDCl_3$): δ 191.1(C-9), 160.5(C-15), 135.8(C-13), 133.4(C-4), 133.0(C-8), 132.2(C-11), 129.3(C-12), 126.5(C-14), 121.3(C-10), 116.7(C-6), 115.3(C-7), 113.7(C-5), 112.7(C-2), 111.4(C-3), 98.0(C-1), 56.3(C-18), 16.3(C-17), 15.0(C-16); HRMS calcd for $C_{18}H_{17}NO_2S+H^+$: 312.1053, found: 312.1055.



(6-methyl-7-(methylthio)indolizin-5-yl)(thiophen-2-yl)methanone (**3l**)

Red oil, yield: 118mg, 41%.

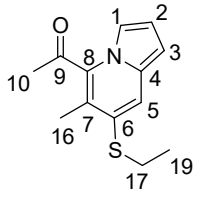
^{1}H NMR (500MHz, $CDCl_3$): δ 7.81 (1H, dd, *J*=5.0, 1.0Hz, H-13), 7.50 (1H, dd, *J*=3.5, 0.5Hz, H-11), 7.22 (1H, s, H-5), 7.11-7.09 (1H, m, H-12), 7.01 (1H, m, H-3), 6.70 (1H, dd, *J*=3.5, 2.5Hz, H-2), 6.40 (1H, dd, *J*=4.0, 1.5Hz, H-1), 2.52(3H, s, H-17), 2.20 (3H, s, H-16); ^{13}C NMR (125MHz, $CDCl_3$): δ 184.6(C-9), 143.1(C-10), 136.8(C-4), 135.7(C-13), 132.9(C-11), 130.2(C-8), 128.9(C-12), 128.9(C-6), 117.0(C-7), 115.3(C-5), 113.9(C-2), 111.4(C-3), 98.2(C-1), 15.9(C-17), 15.3(C-16); HRMS calcd for $C_{15}H_{13}NOS_2$+H^+: 288.0511, found: 288.0512.



furan-2-yl(6-methyl-7-(methylthio)indolizin-5-yl)methanone (**3m**)

Red oil, yield: 133mg, 49%.

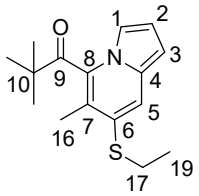
^{1}H NMR (400MHz, $CDCl_3$): δ 7.71 (s, 1H, H-13), 7.22 (s, 1H, H-5), 7.16 (d, *J*=3.6Hz, 1H, H-11), 7.00 (s, 1H, H-3), 6.70–6.67 (m, 1H, H-12), 6.57 (dd, *J*=3.6, 2.0Hz, 1H, H-2), 6.38 (dd, *J*=3.6, 0.8Hz, 1H, H-1), 2.48 (s, 3H, H-17), 2.16 (s, 3H, H-16); ^{13}C NMR (100MHz, $CDCl_3$): δ 179.2(C-9), 152.1(C-10), 148.8(C-4), 132.8(C-13), 129.5(C-8), 128.9(C-11), 121.9(C-12), 117.9(C-6), 115.7(C-7), 113.9(C-5), 113.1(C-2), 111.3(C-3), 98.3(C-1), 15.9(C-17), 15.2(C-16); HRMS calcd for $C_{15}H_{13}NO_2S$+H^+: 272.0740, found: 272.0735.



1-(6-methyl-7-(methylthio)indolizin-5-yl)ethenone (**3p**)

Yellow oil, yield: 72mg, 33%.

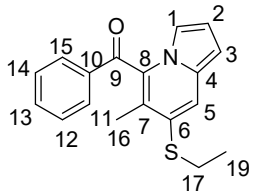
^{1}H NMR (500MHz, $CDCl_3$): δ 7.18 (1H, s, H-5), 7.04 (1H, m, H-3), 6.75 (1H, dd, *J*=3.5Hz, 2.5Hz, H-2), 6.39 (1H, dd, *J*=3.5, 1.0Hz, H-1), 2.63 (3H, s, H-COCH3), 2.46 (3H, s, H-17), 2.23 (3H, s, H-16); ^{13}C NMR (125MHz, $CDCl_3$): δ 199.5(C-9), 132.9(C-4), 132.5(C-8), 129.1(C-6), 116.0(C-7), 115.4(C-5), 114.3(C-2), 110.7(C-3), 98.5(C-1), 30.6(C-10), 16.0(C-17), 14.7(C-16); HRMS calcd for $C_{12}H_{13}NOS+H^+$: 220.0791, found: 220.0794.



2, 2-dimethyl-1-(6-methyl-7-(methylthio)indolizin-5-yl)propan-1-one (**3q**)

Yellow oil, yield: 76mg, 29%.

^{1}H NMR (500MHz, $CDCl_3$): δ 7.10 (1H, s, H-5), 6.80 (1H, m, H-3), 6.71 (1H, dd, *J*=4.0, 3.0Hz, H-2), 6.35 (1H, dd, *J*=3.5, 1.0Hz, H-1), 2.46 (3H, s, H-17), 2.13 (3H, s, H-16), 1.29 (9H, s, H-C_3H_9); ^{13}C NMR (125MHz, $CDCl_3$): δ 211.0(C-9), 132.9(C-4), 132.4(C-8), 129.4(C-6), 114.2(C-7), 114.1(C-5), 113.9(C-2), 111.1(C-3), 98.2(C-1), 46.0(C-10), 27.8(C-C_3H_9), 15.9(C-17), 15.8(C-16); HRMS calcd for $C_{15}H_{19}NOS+H^+$: 262.1260, found: 262.1265.



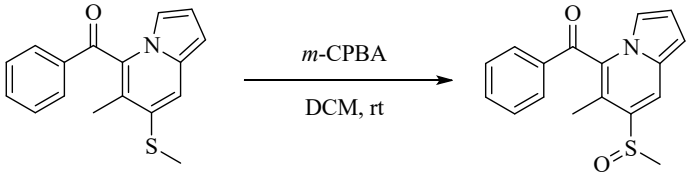
(7-(ethylthio)-6-methylindolizin-5-yl)(phenyl)methanone (**3r/3s**)

Red oil, yield: 150mg, 51%/127mg, 43%.

^{1}H NMR (500MHz, $CDCl_3$): δ 7.87 (2H, d, *J*=7.0Hz, H-11,15), 7.64 (1H, t, *J*=7.5Hz, H-13), 7.48 (2H, t, *J*=7.5Hz, H-12,14), 7.44 (1H, s, H-5), 6.86 (1H, s, H-3), 6.66 (1H, s, H-2), 6.42 (1H, s, H-1), 2.92 (2H, q, *J*=7.0Hz, H-17), 2.13 (3H, s, H-16), 1.38 (3H, t, *J*=7.5Hz, H-19); ^{13}C NMR (125MHz, $CDCl_3$): *δ* 192.7(C-9), 135.6(C-13), 134.8(C-4), 132.6(C-11,15), 130.3(C-8), 129.7(C-6), 129.3(C-10), 126.6(C-7), 119.3(C-5), 118.4(C-12,14), 114.1(C-2),

111.8(C-3), 98.7(C-1), 27.8(C-19), 15.5(C-17), 13.9(C-16); HRMS calcd for $C_{18}H_{17}NOS+H^+$: 296.1104, found: 296.1101.

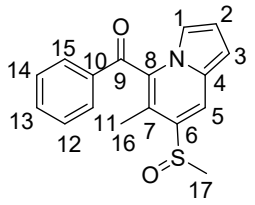
Procedure for the synthesis of derived compound (6-methyl-7-(methylsulfinyl)indolizin-5-yl)(phenyl)methanone (**4**)



3a **4**

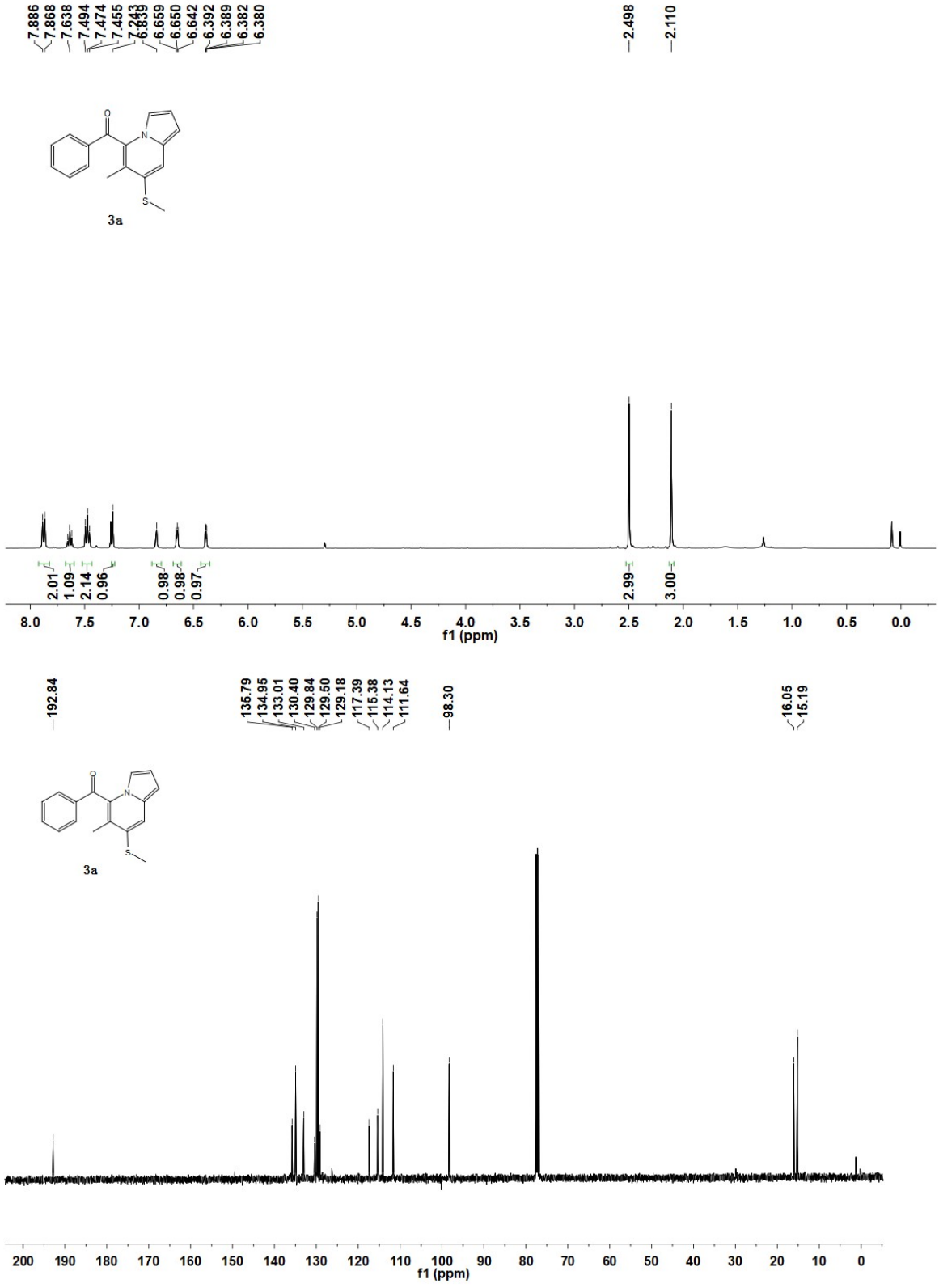
To a solution of **3a** (0.2 mmol, 50 mg) in 10 mL of dichloromethane, *m*-CPBA (0.8 mmol, 136mg) was added in portions (0.2 mmol each time) at 0° C, and then the reaction was stirred at room temperature for 2 h. After completion, the reaction solution was concentrated under reduced pressure to obtain a crude residue, which was purified by silica gel column chromatography (petroleum ether: dichloromethane=1:2) to obtain product **4**.

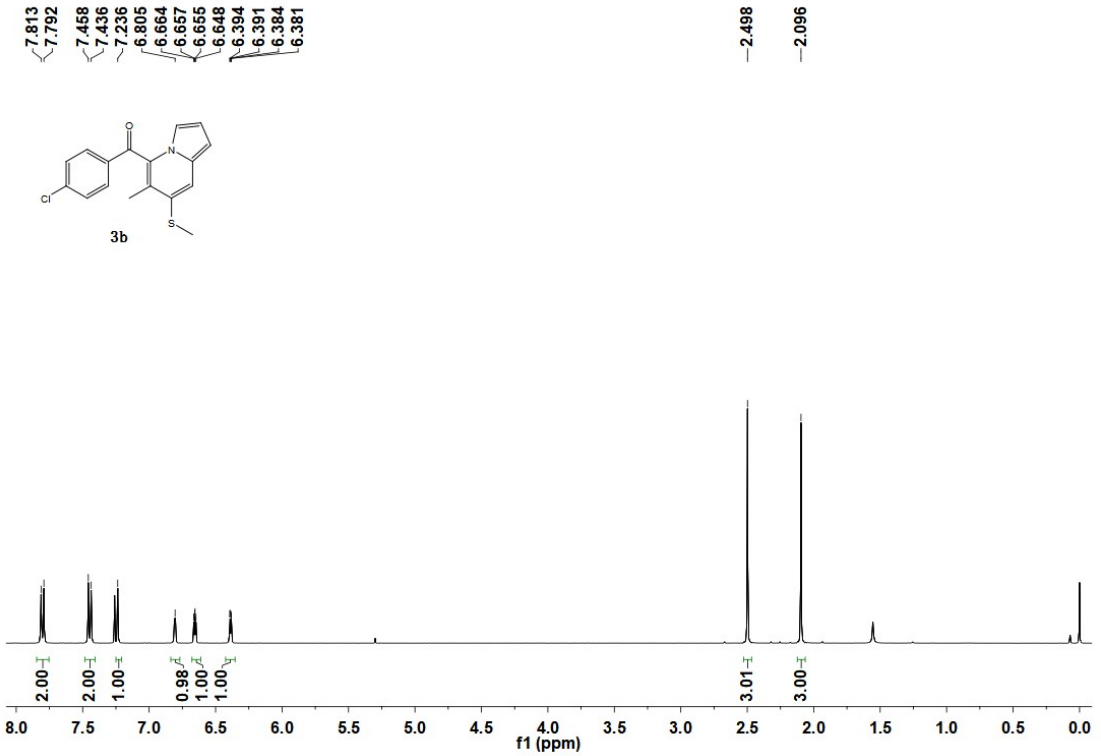
Yellow solid, yield: 38mg, 72%.



^{1}H NMR (400 MHz, $CDCl_3$) δ 8.17 (1H，s, H-5), 7.85 (2H, d, J = 7.3 Hz), 7.67 (1H, t, J = 7.4 Hz, H-11,15), 7.50 (2H, t, J = 7.8 Hz, H-12,14), 7.01 (1H, s, H-3), 6.80 – 6.78 (1H，m, H-2), 6.73 (1H，d, J = 3.2 Hz, H-1), 2.78 (3H，s, H-17), 2.11 (3H, s, H-16); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.0(C-9), 134.1(C-13), 133.1(C-4), 130.8(C-11,15), 129.7(C-8), 128.7(C-6), 128.5(C-10), 128.5(C-7), 116.0(C-5), 114.4(C-12,14), 112.9(C-2), 112.3(C-3), 102.2(C-1), 42.0(C-17), 12.6(C-16); HRMS calcd for $C_{17}H_{15}NO_2S+H^+$: 298.0896, found: 298.0899.

^{1}H and ^{13}C NMR Spectra of target compounds 3

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7.236
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6.664
6.657
6.655
6.648
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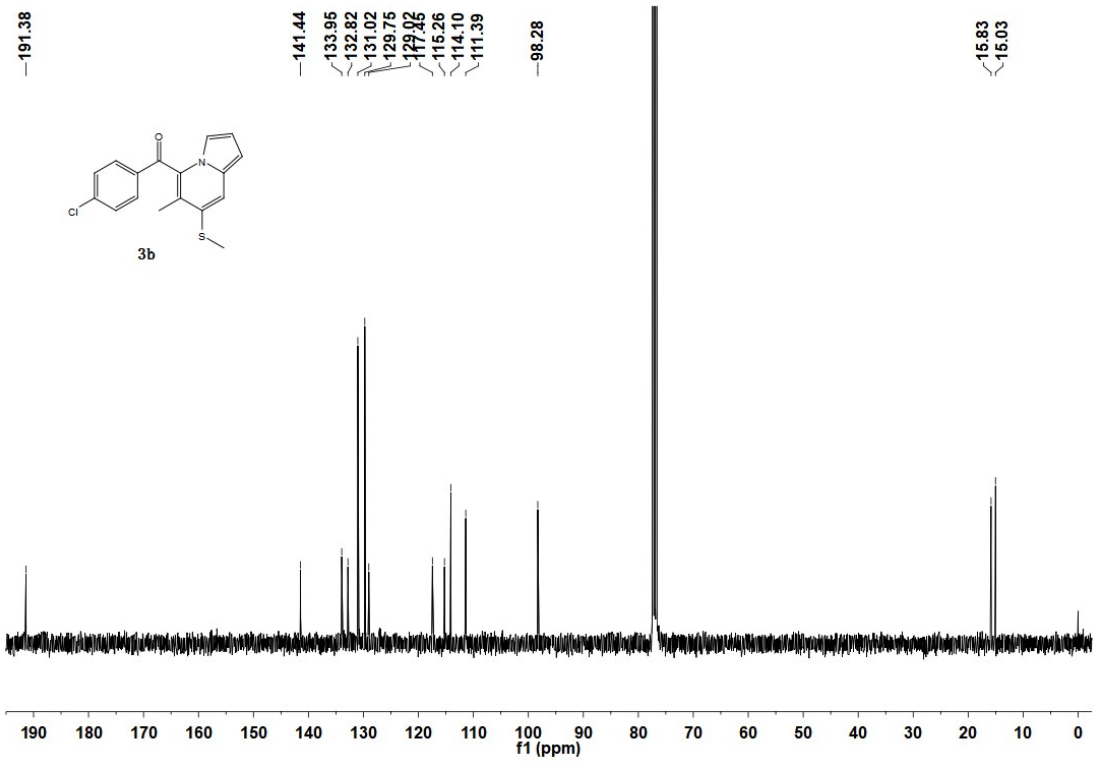
6.391
6.384
6.381
2.498
2.096
O
N
Cl
S
3b
2.00
2.00
1.00
0.98
1.00
1.00
3.01
3.00
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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129.75
129.02
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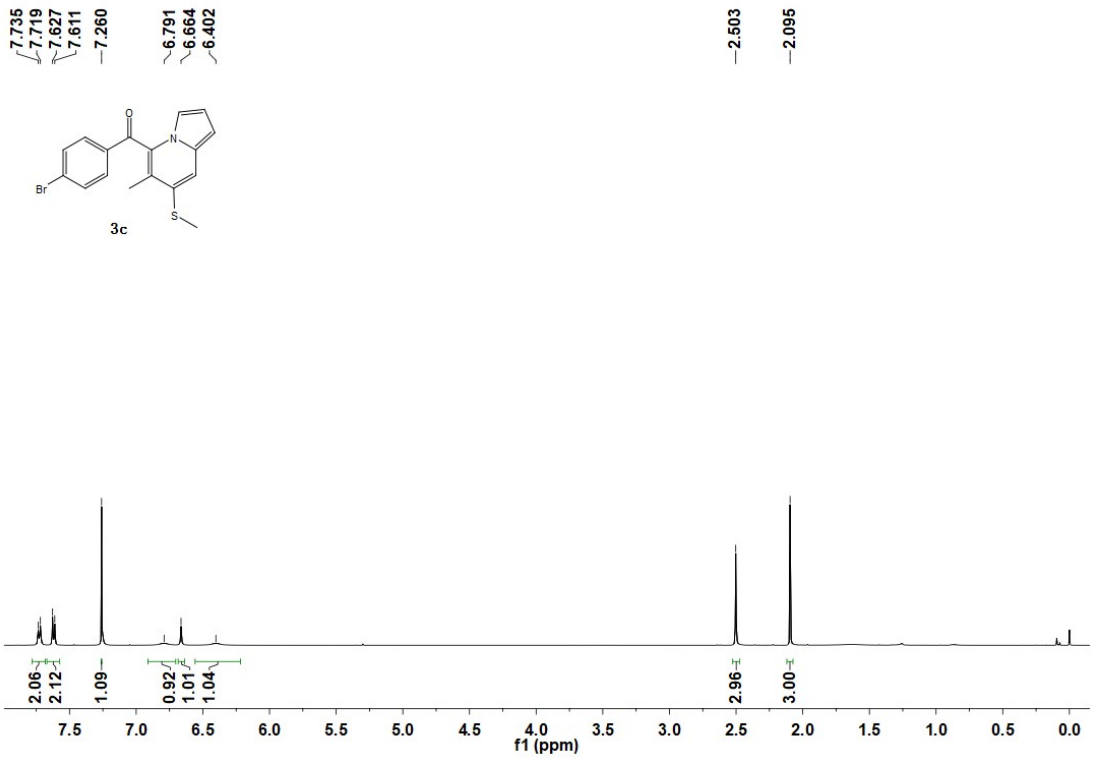
115.26
114.10
111.39
98.28
15.83
15.03
O
N
Cl
S
3b
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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6.791
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O
N
Br
S
3c
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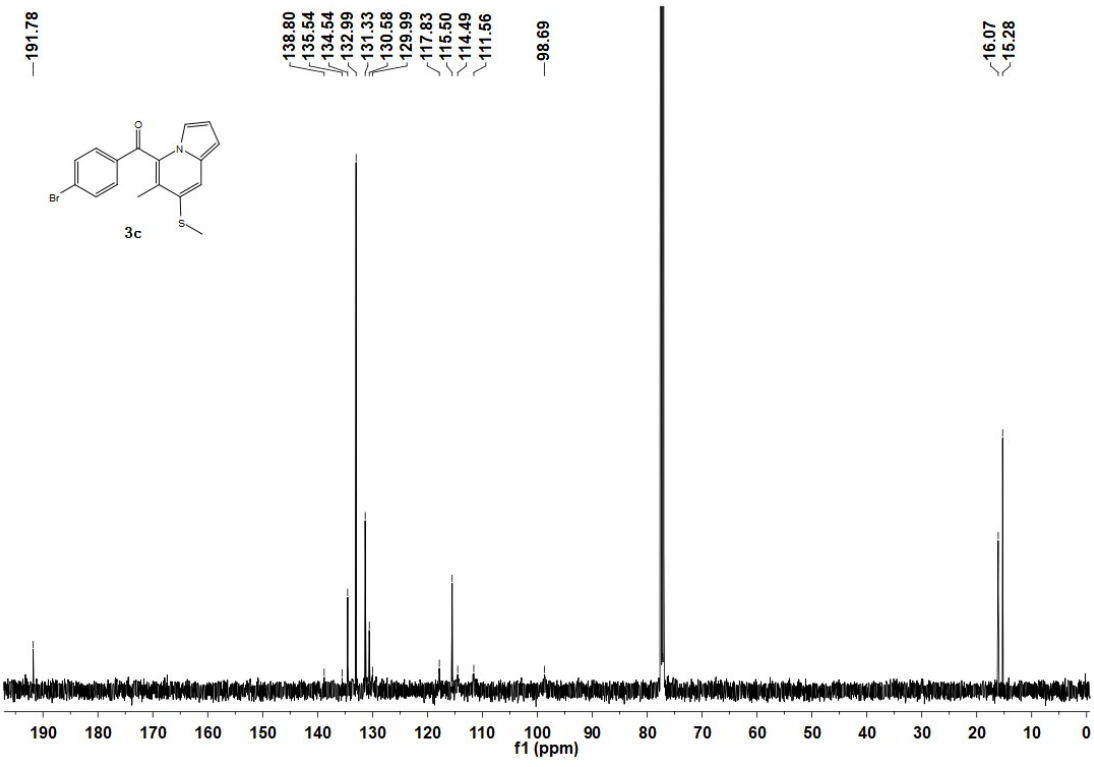
2.12
1.09
0.92
1.01
1.04
2.96
3.00
f1 (ppm)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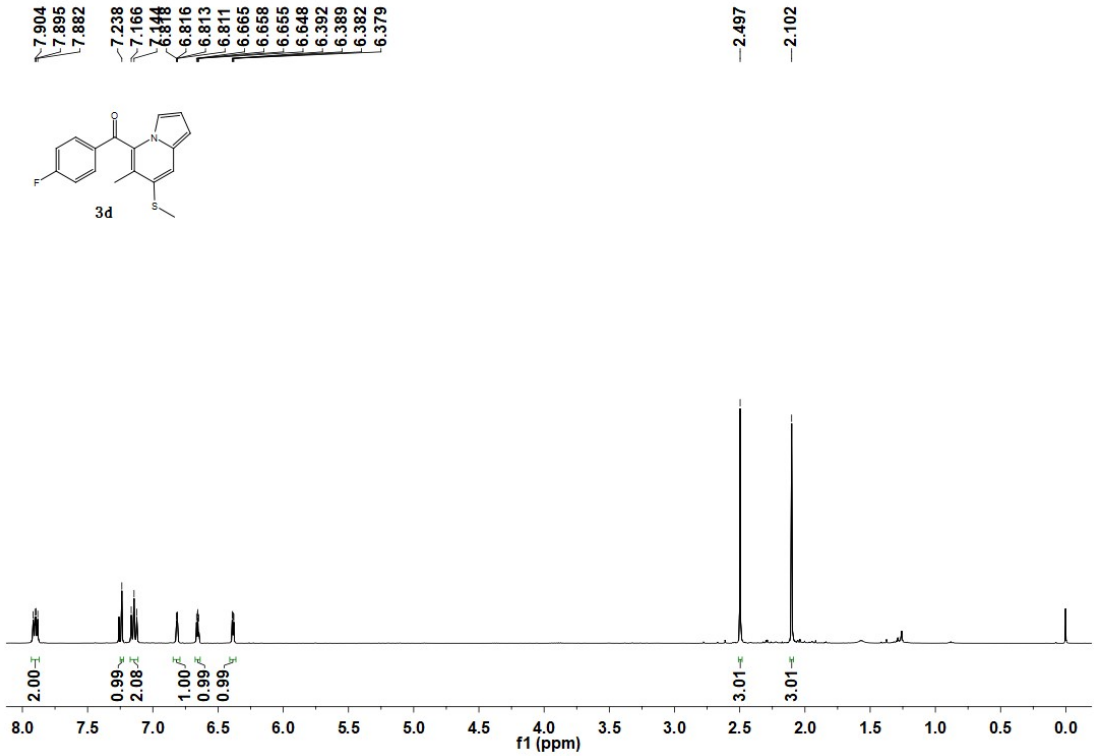
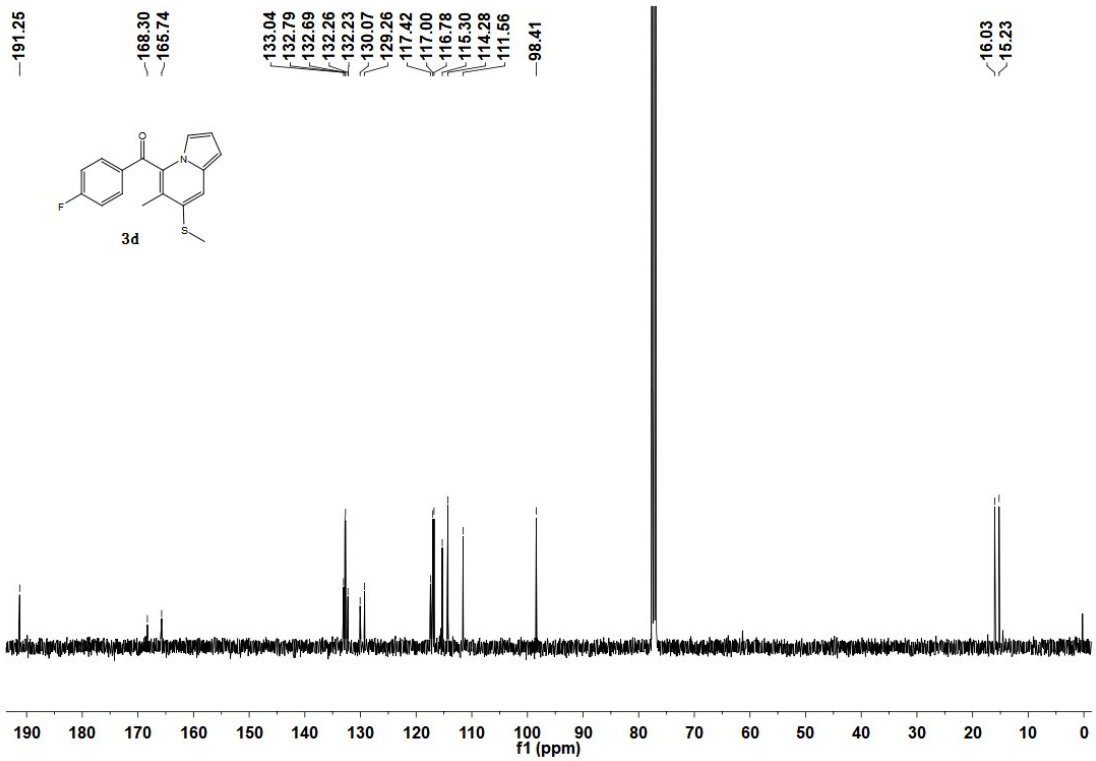
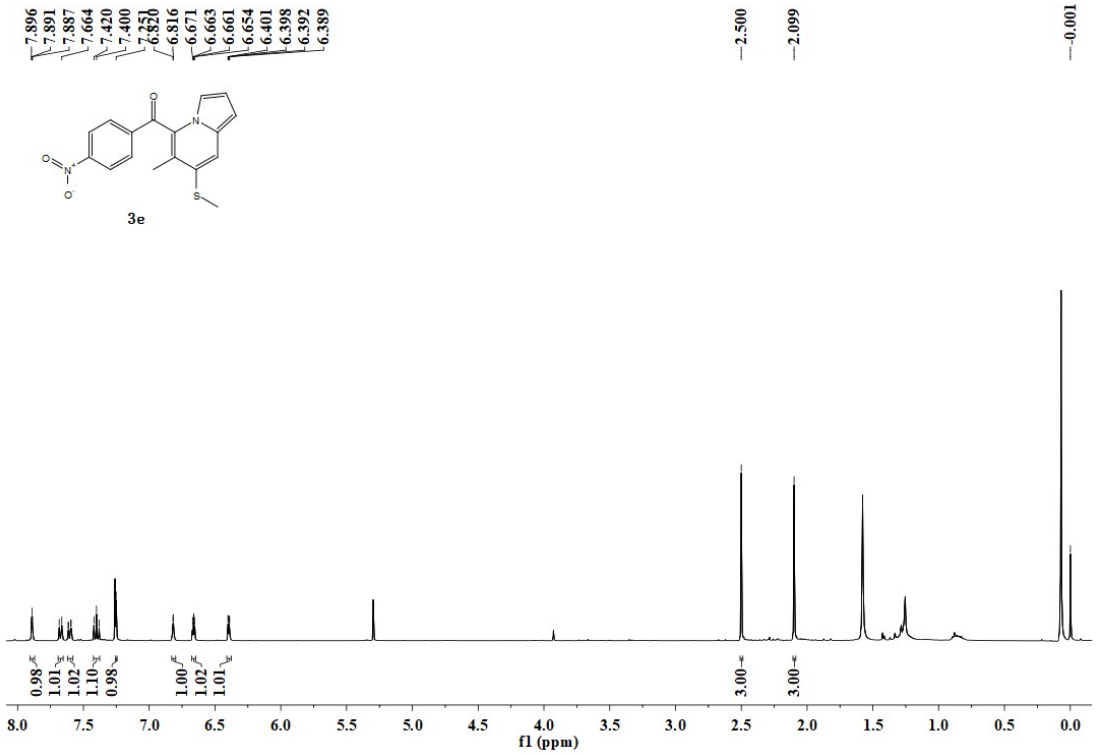
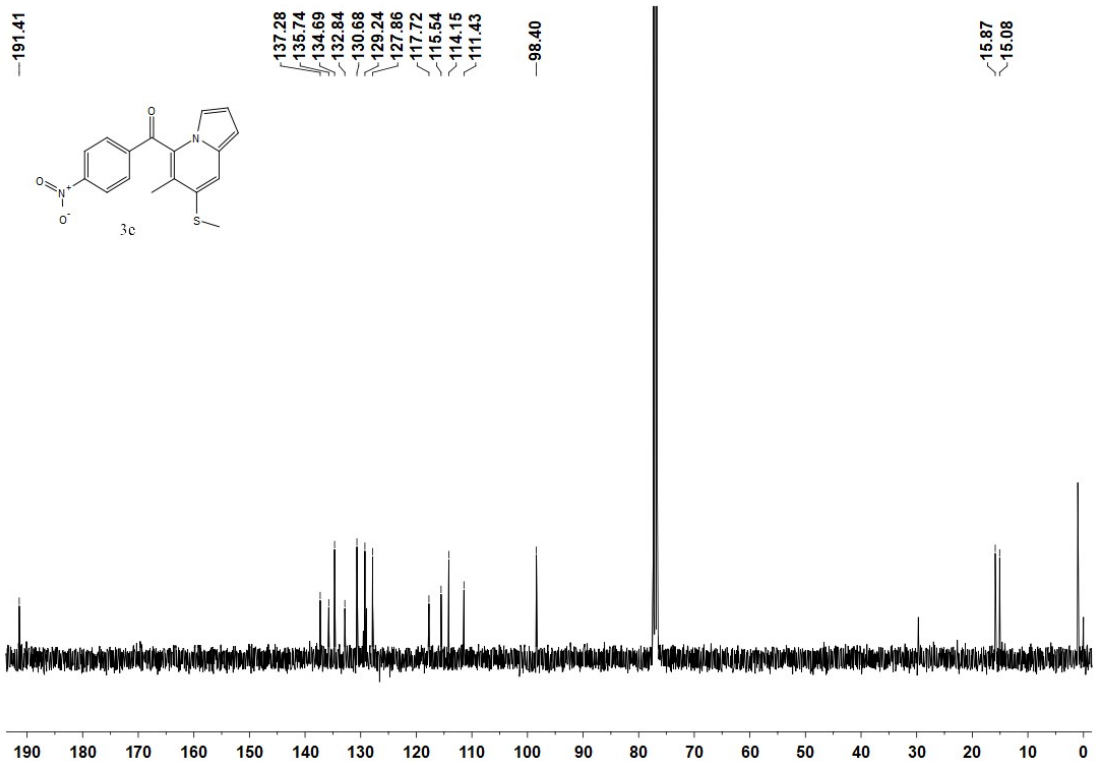
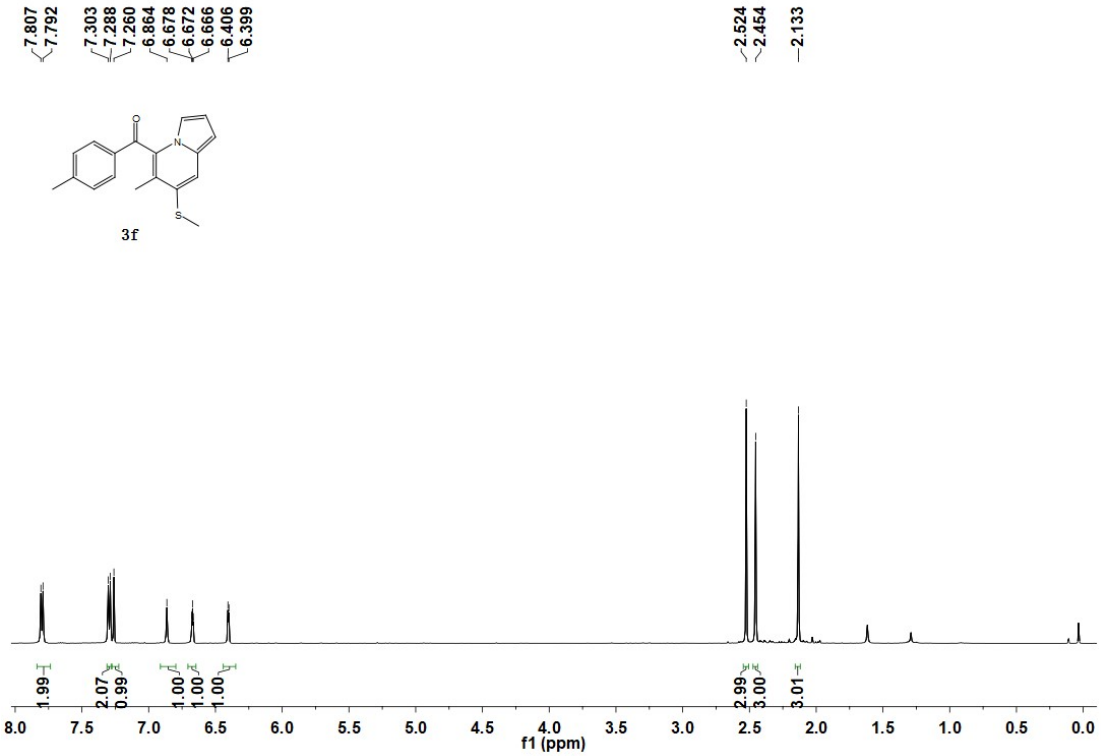
16.07
15.28
O
N
Br
S
3c
f1 (ppm)

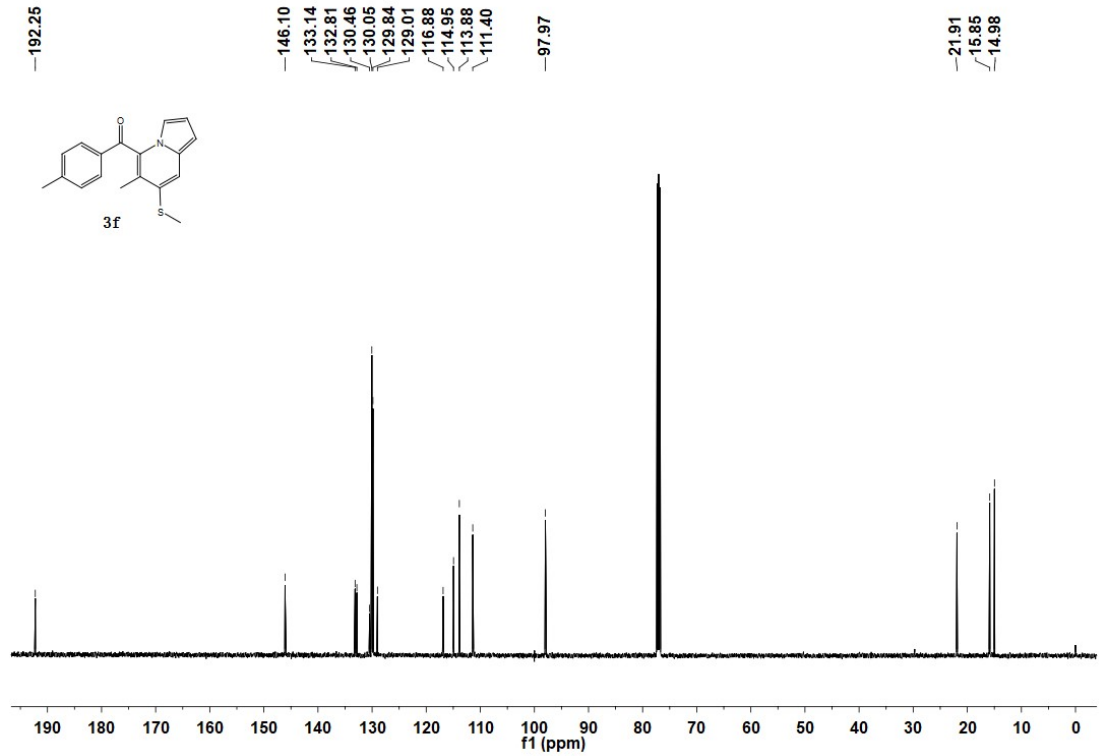

7.904
7.895
7.882
7.238
7.166
7.144
6.818
6.816
6.813
6.811
6.665
6.658
6.655
6.648
6.392
6.389
6.382
6.379
2.497
2.102
3d
2.00
0.99
2.08
1.00
0.99
0.99
3.01
3.01
f1 (ppm)

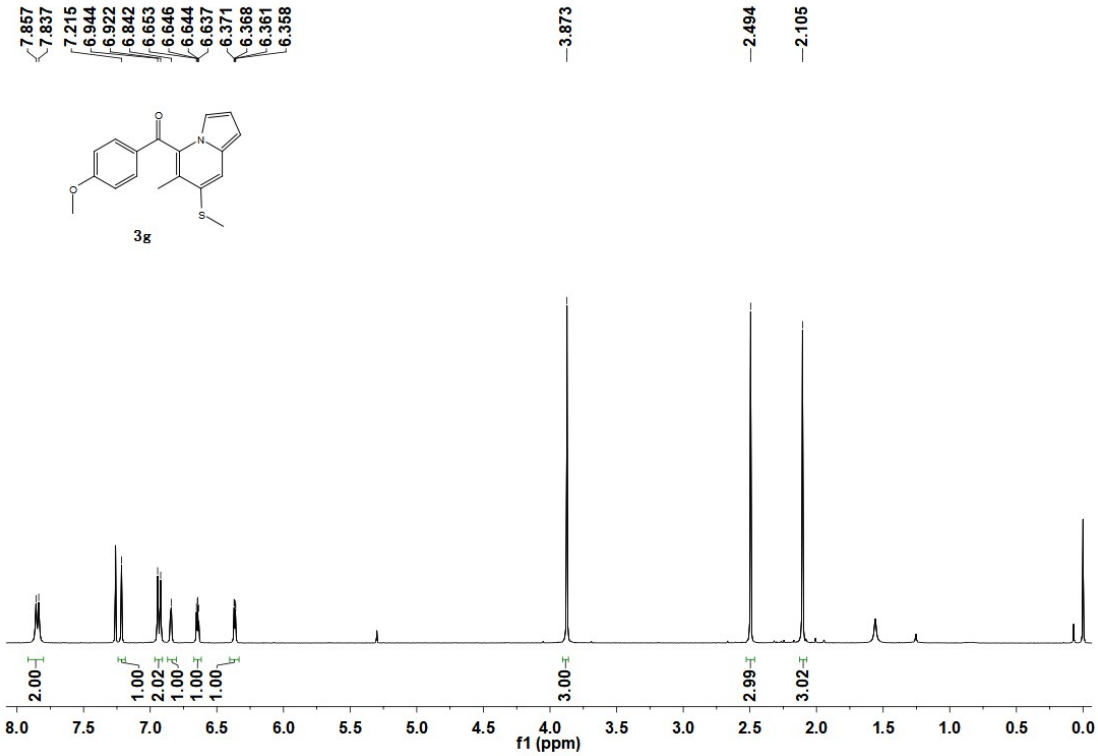

191.25
168.30
165.74
133.04
132.79
132.69
132.26
132.23
130.07
129.26
117.42
117.00
116.78
115.30
114.28
111.56
98.41
16.03
15.23
3d
f1 (ppm)


7.896
7.891
7.887
7.664
7.420
7.400
7.251
6.820
6.816
6.671
6.663
6.661
6.654
6.401
6.398
6.392
6.389
2.500
2.099
0.001
3e
0.98
1.01
1.02
1.10
0.98
1.00
1.02
1.01
3.00
3.00
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


191.41
137.28
135.74
134.69
132.84
130.68
129.24
127.86
117.72
115.54
114.15
111.43
98.40
15.87
15.08
3e
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0


7.807
7.792
7.303
7.288
7.260
6.864
6.678
6.672
6.666
6.406
6.399
2.524
2.454
2.133
3f
1.99
2.07
0.99
1.00
1.00
1.00
2.99
3.00
3.01
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


192.25
146.10
133.14
132.81
130.46
130.05
129.84
129.01
116.88
114.95
113.88
111.40
97.97
21.91
15.85
14.98
3f
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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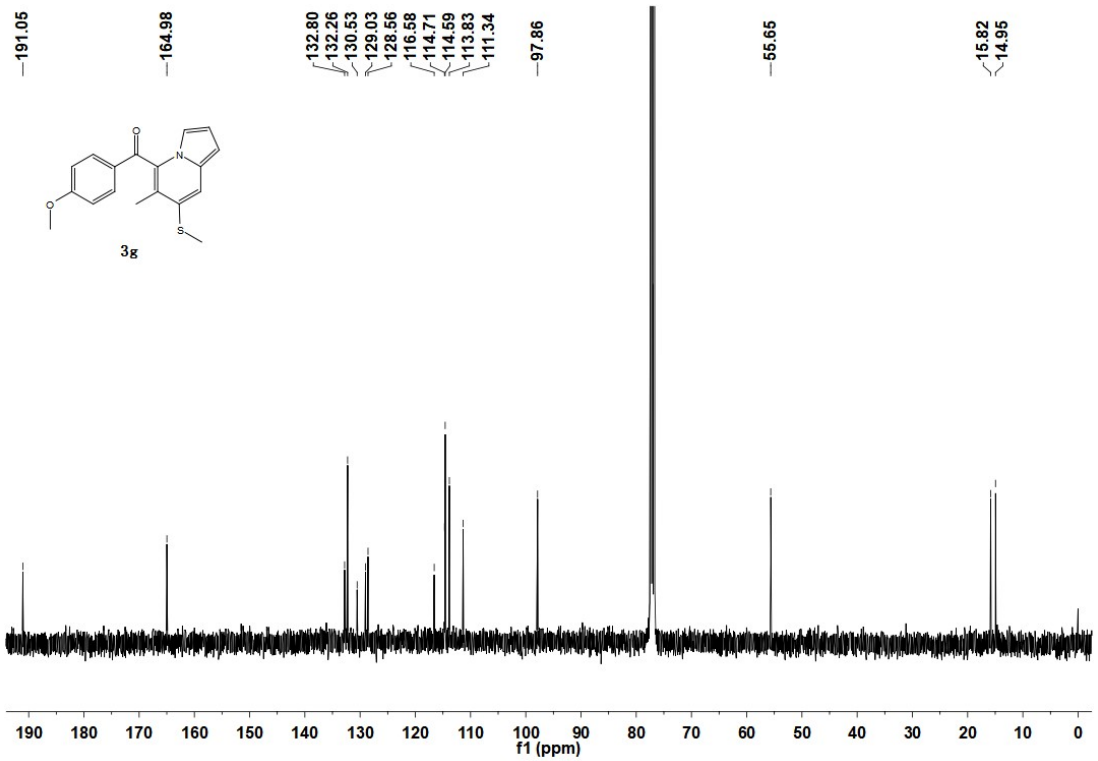
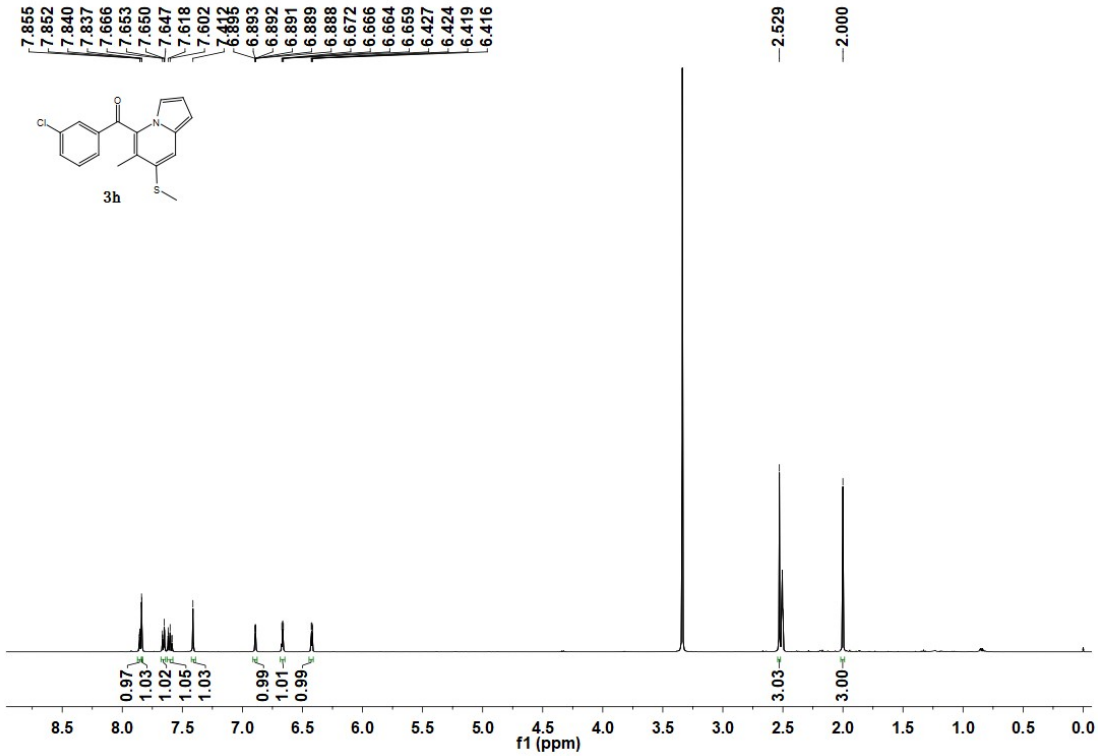
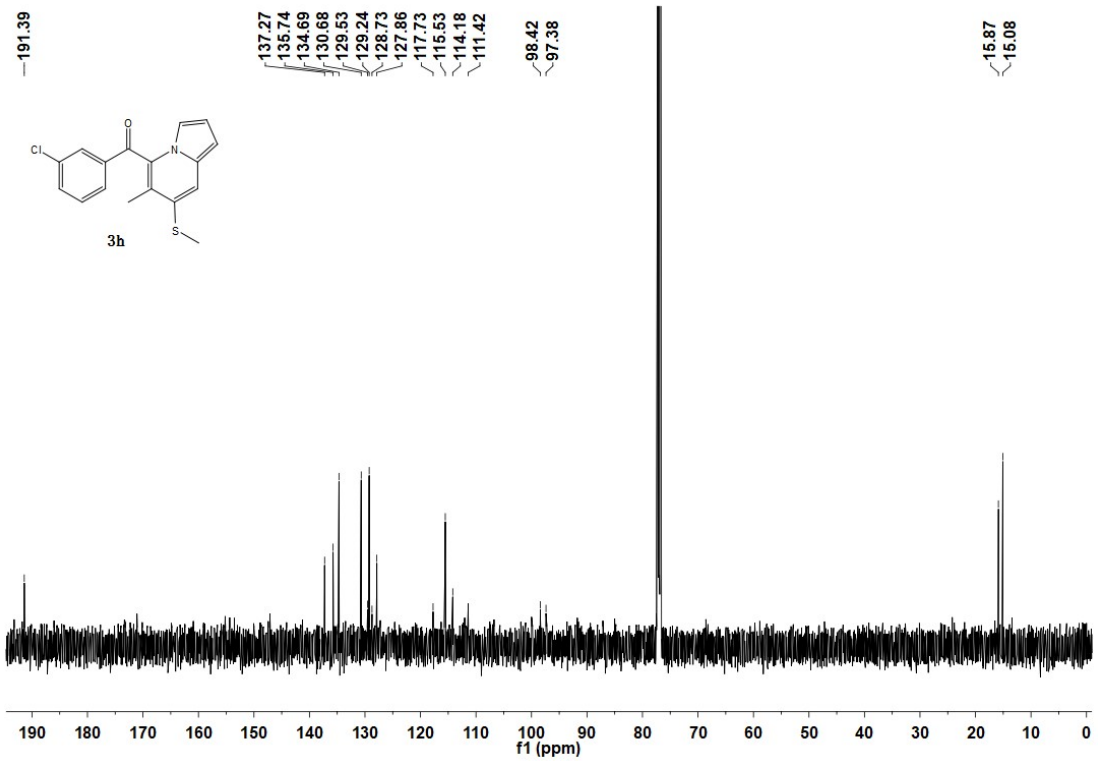
7.837
7.215
6.944
6.922
6.842
6.653
6.646
6.644
6.637
6.371
6.368
6.361
6.358
3.873
2.494
2.105
O
N
O
S
2.00
1.00
2.02
1.00
1.00
1.00
3.00
2.99
3.02
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

3g


191.05
164.98
132.80
132.26
130.53
129.03
128.56
116.58
114.71
114.59
113.83
111.34
97.86
55.65
15.82
14.95
O
N
O
S
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

3g


7.855
7.852
7.840
7.837
7.666
7.653
7.650
7.647
7.618
7.602
6.893
6.892
6.891
6.889
6.888
6.672
6.666
6.664
6.659
6.427
6.424
6.419
6.416
2.529
2.000
3h
0.97
1.03
1.02
1.05
1.03
0.99
1.01
0.99
3.03
3.00
f1 (ppm)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137.27
135.74
134.69
130.68
129.53
129.24
128.73
127.86
117.73
115.53
114.18
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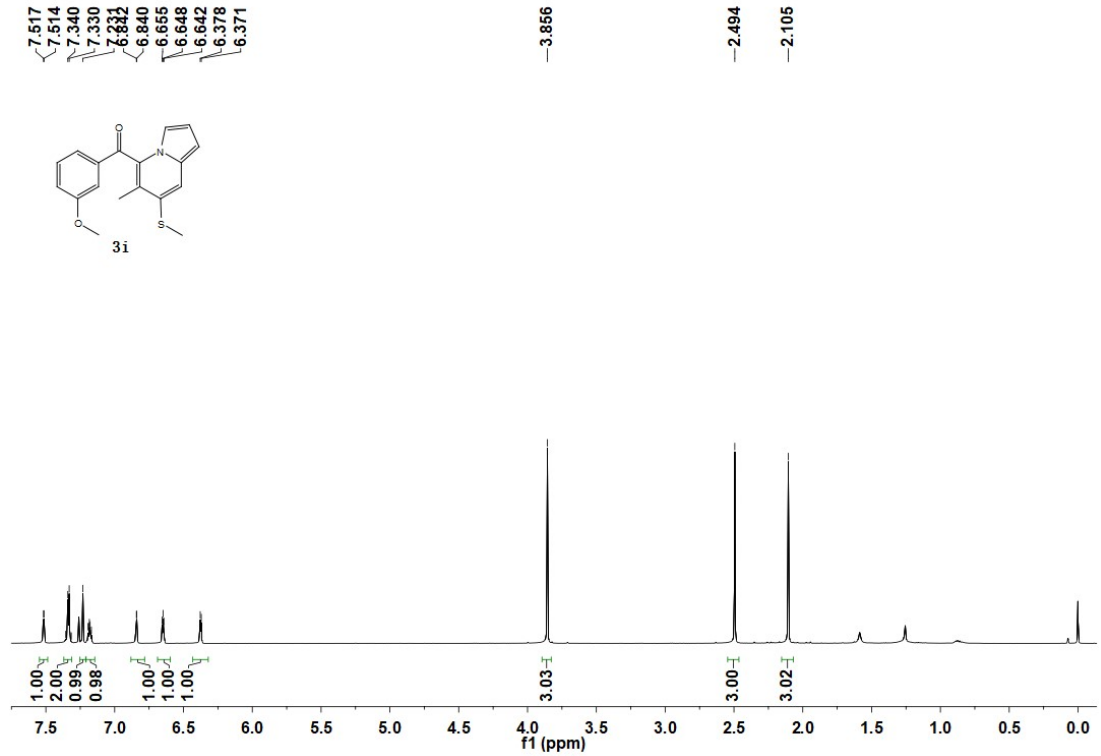
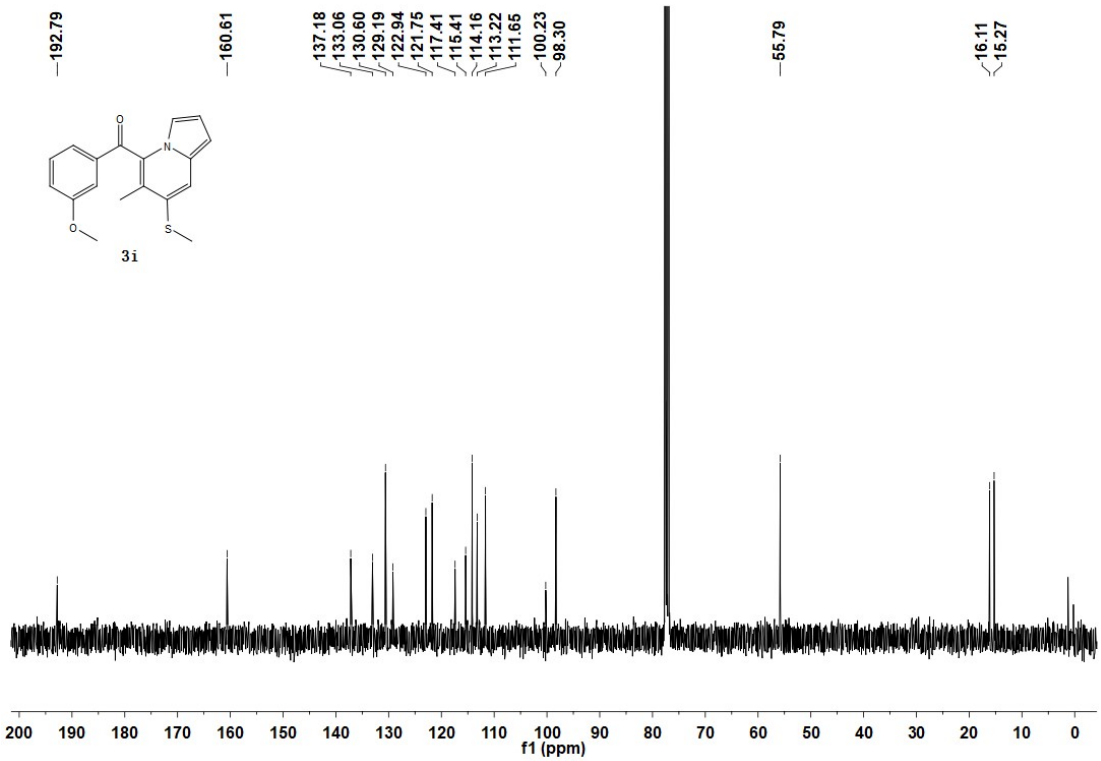
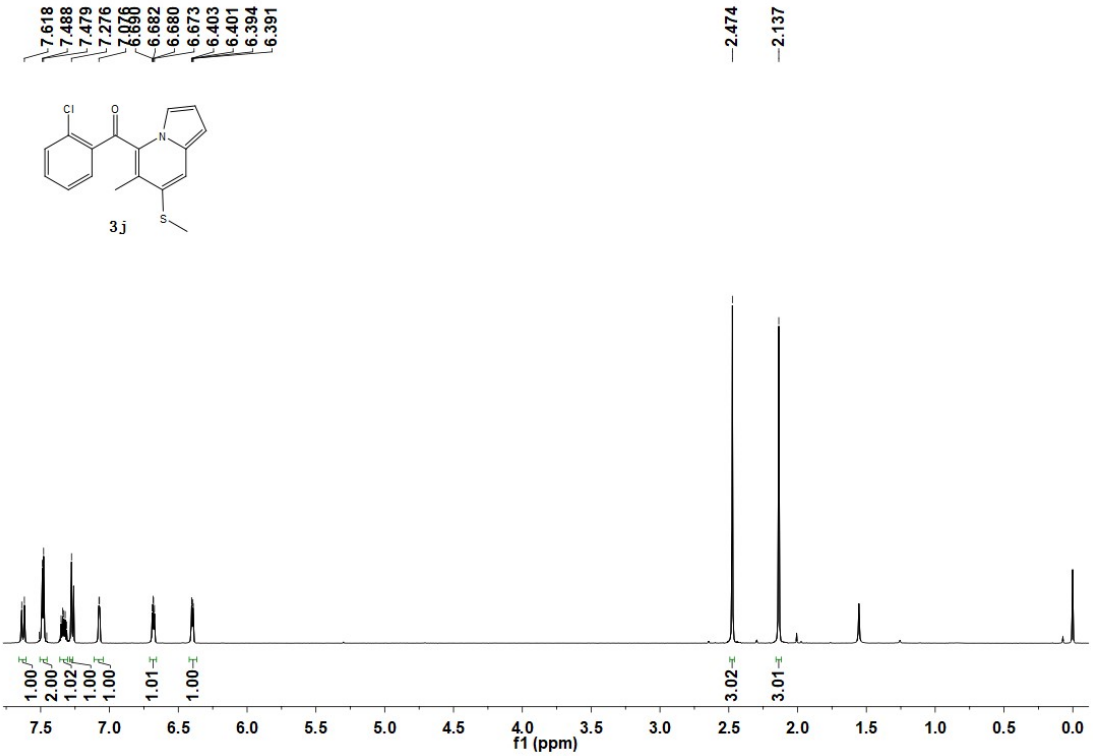
97.38
15.87
15.08
3h
f1 (ppm)


7.517
7.514
7.340
7.330
6.840
6.655
6.648
6.642
6.378
6.371
3.856
2.494
2.105
3i
1.00
2.00
0.99
0.98
1.00
1.00
1.00
3.03
3.00
3.02
f1 (ppm)


192.79
160.61
137.18
133.06
130.60
129.19
122.94
121.75
117.41
115.41
114.16
113.22
111.65
100.23
98.30
55.79
16.11
15.27
3i
f1 (ppm)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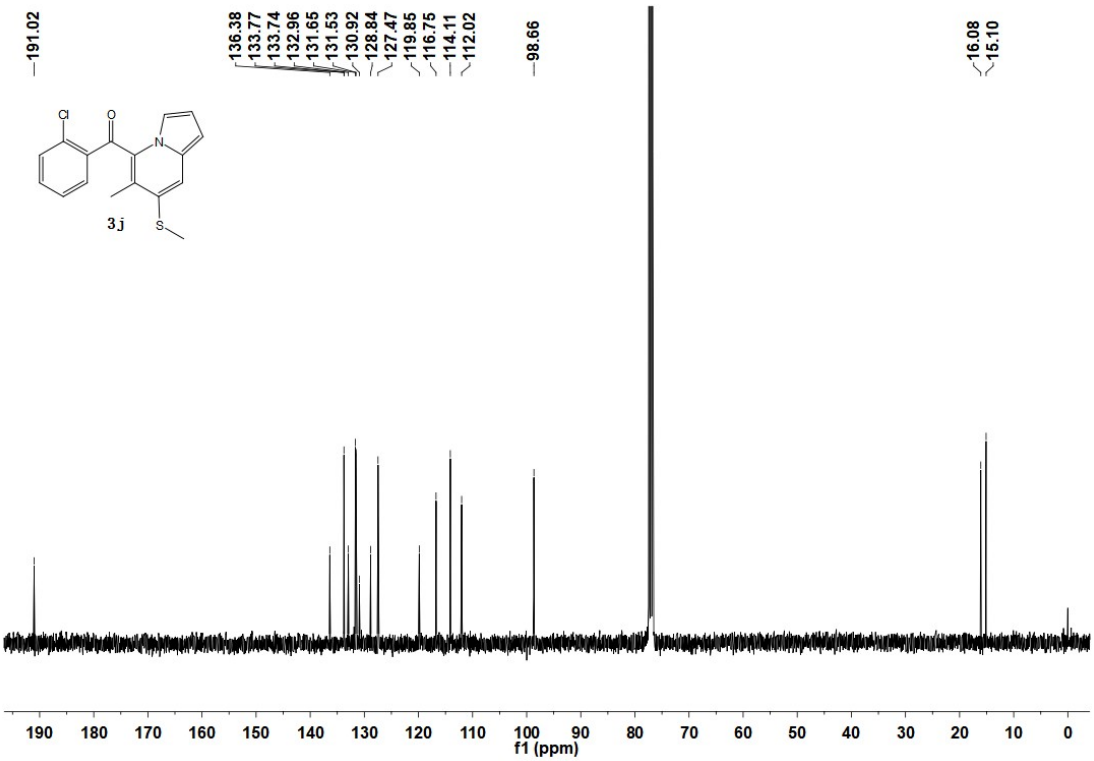
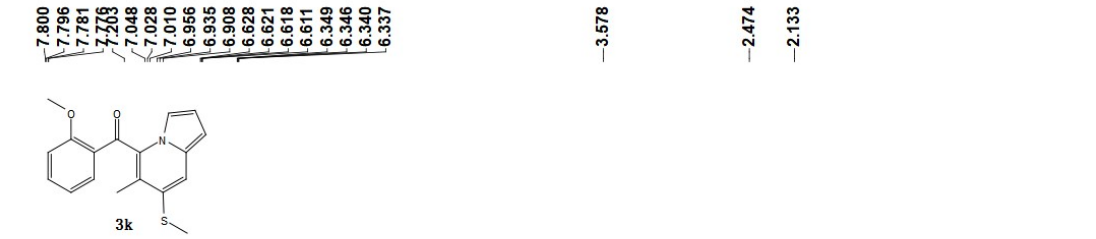
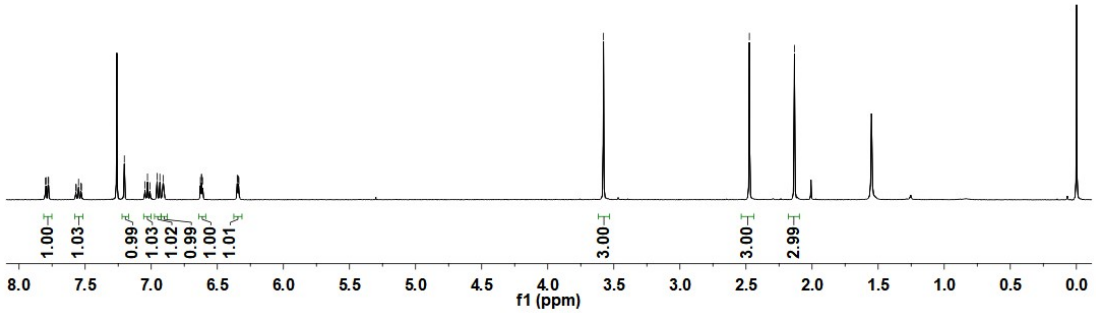
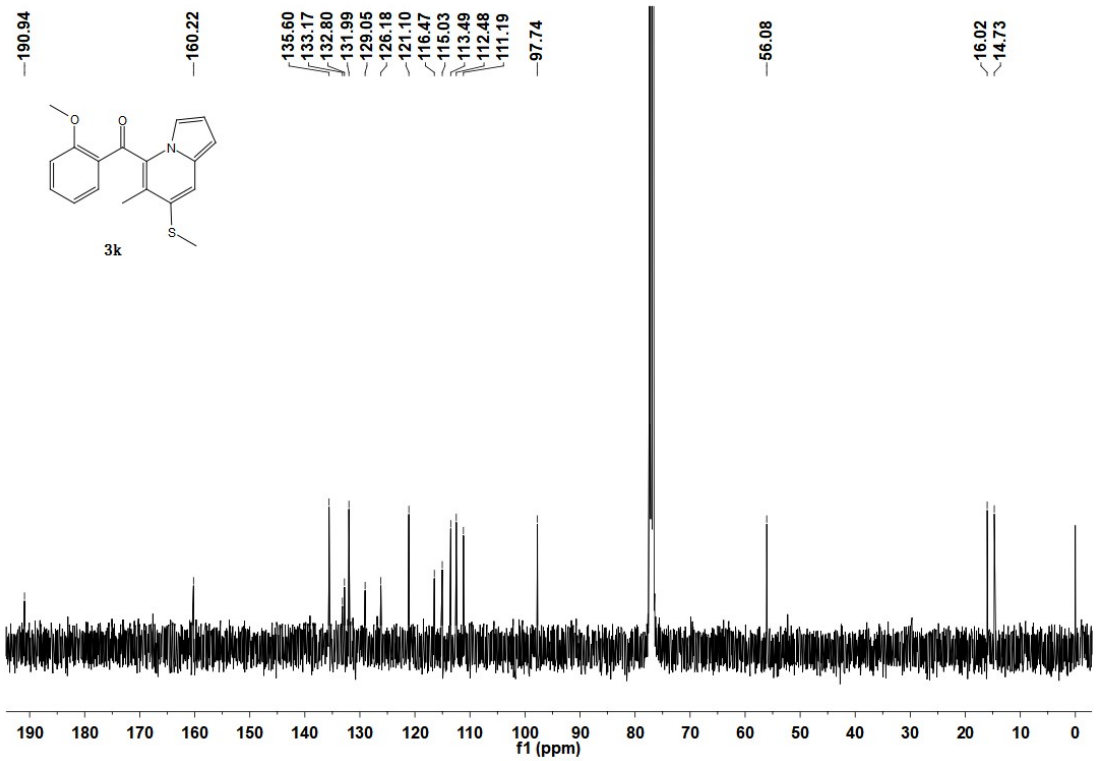
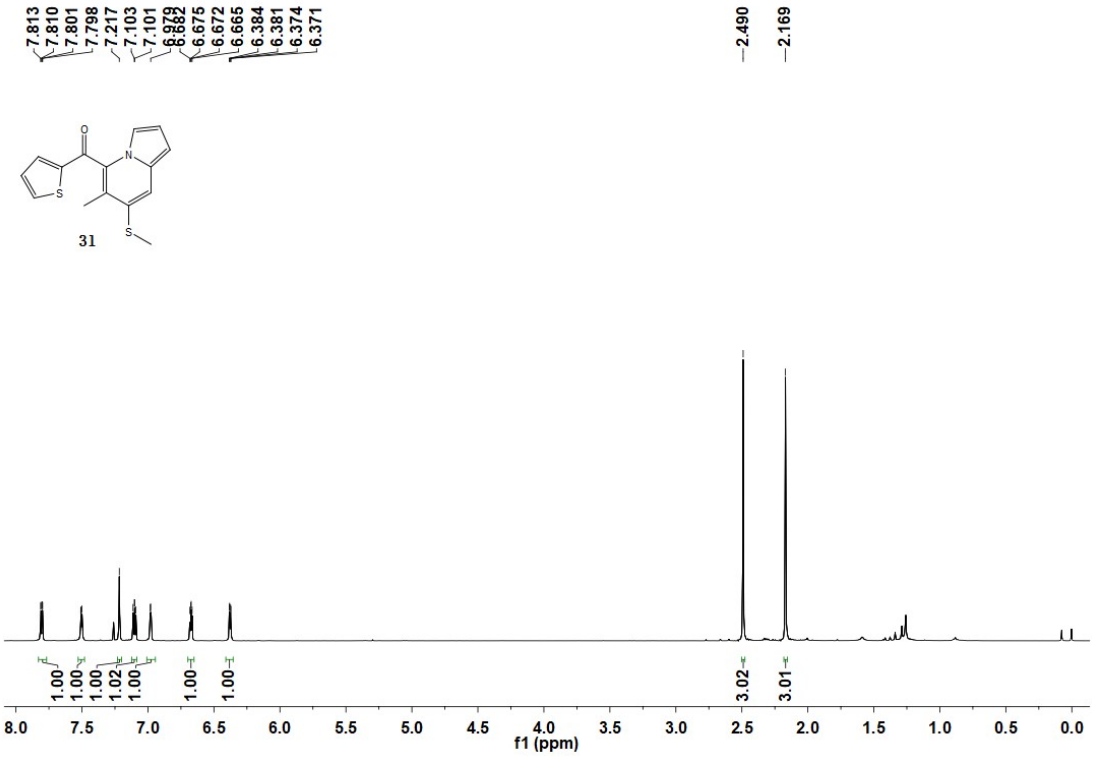
7.488
7.479
7.276
7.076
6.690
6.682
6.680
6.673
6.403
6.401
6.394
6.391
2.474
2.137
Cl
O
N
S
3j
1.00
2.00
1.02
1.00
1.00
1.01
1.00
3.02
3.01
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

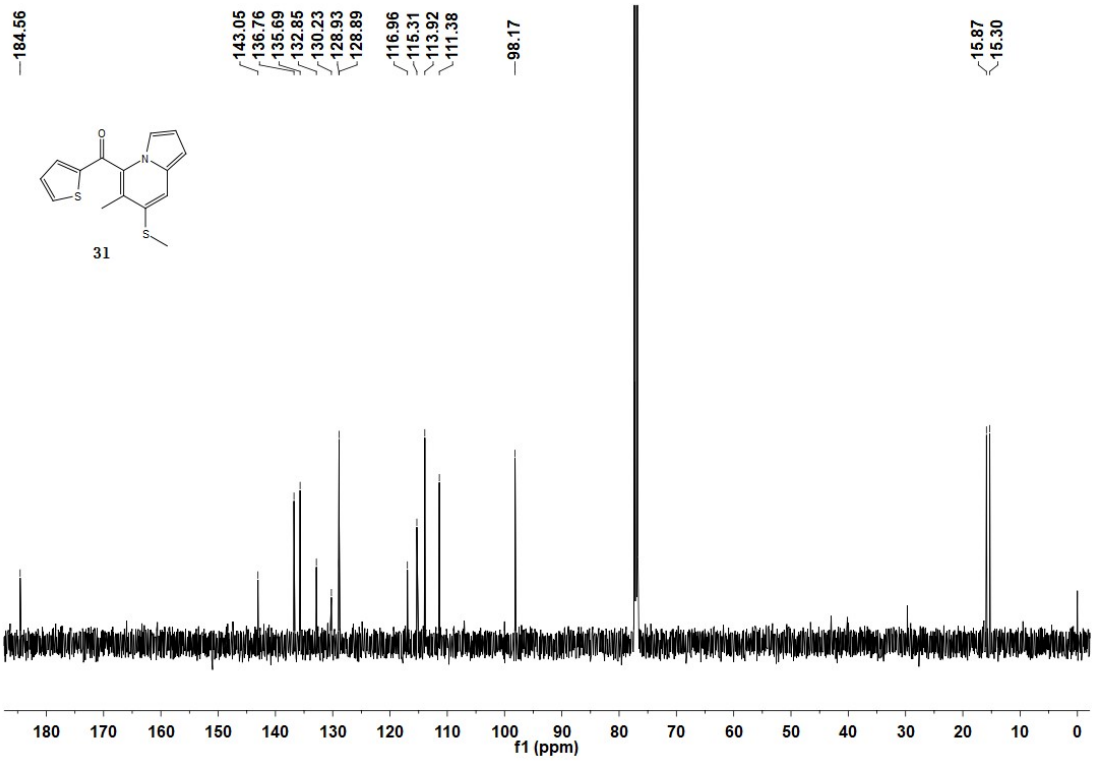

191.02
136.38
133.77
133.74
132.96
131.65
131.53
130.92
128.84
127.47
119.85
116.75
114.11
112.02
98.66
16.08
15.10
Cl
O
N
S
3j
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.800
7.796
7.781
7.776
7.203
7.048
7.028
7.010
6.956
6.935
6.908
6.628
6.621
6.618
6.611
6.349
6.346
6.340
6.337
3.578
2.474
2.133
O
O
N
S
3k


1.00
1.03
0.99
1.03
1.02
0.99
1.00
1.01
3.00
3.00
2.99
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


190.94
160.22
135.60
133.17
132.80
131.99
129.05
126.18
121.10
116.47
115.03
113.49
112.48
111.19
97.74
56.08
16.02
14.73
O
O
N
S
3k
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.813
7.810
7.801
7.798
7.217
7.103
7.101
6.679
6.675
6.672
6.665
6.384
6.381
6.374
6.371
2.490
2.169
O
N
S
S
31
1.00
1.00
1.00
1.02
1.00
1.00
1.00
3.02
3.01
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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132.85
130.23
128.93
128.89
116.96
115.31
113.92
111.38
98.17
15.87
15.30
O
N
S
S
31
180
170
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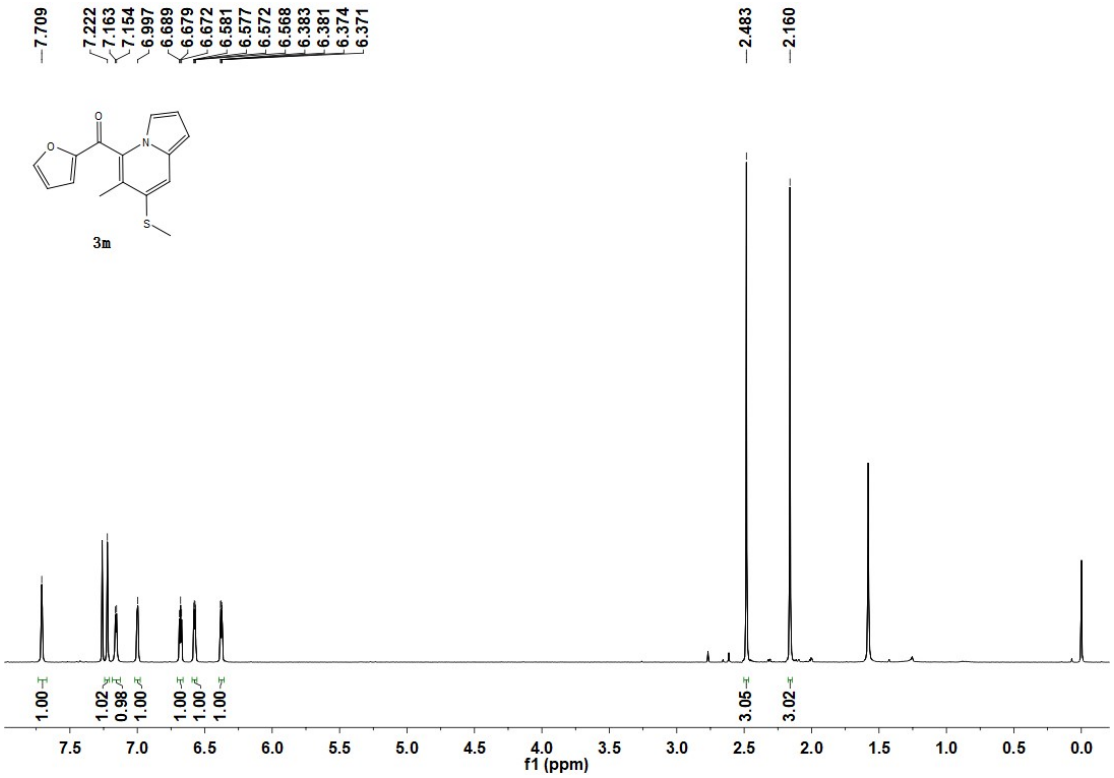
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.709
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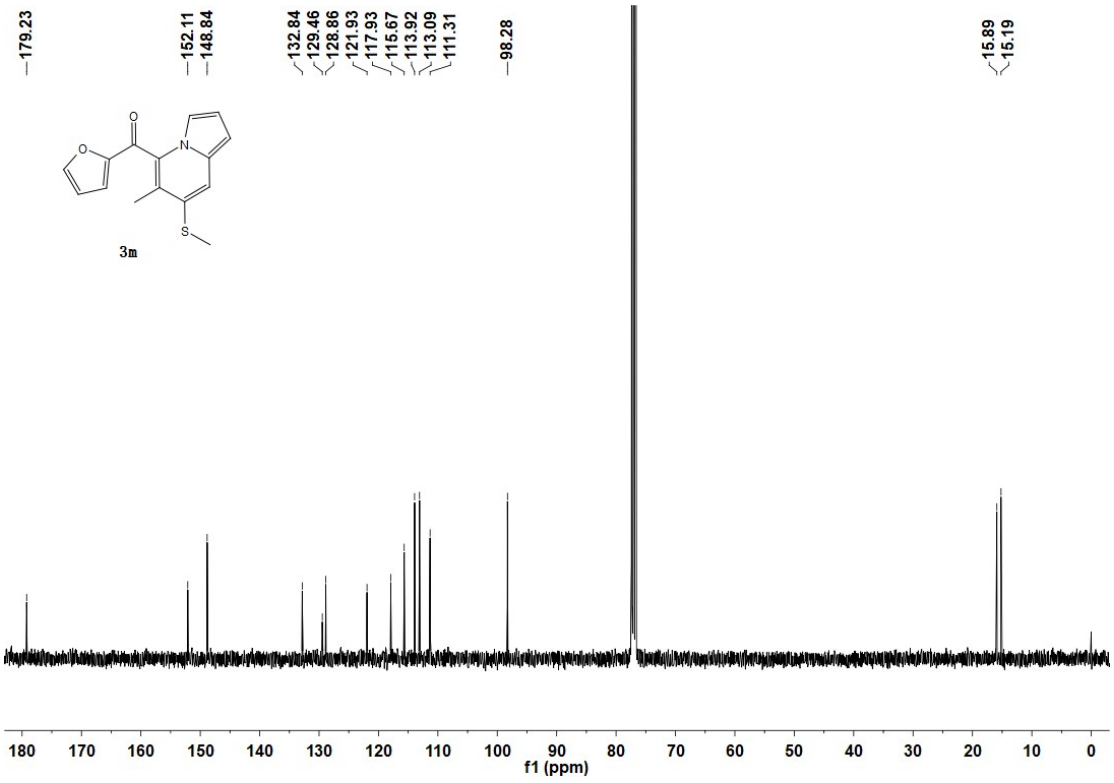
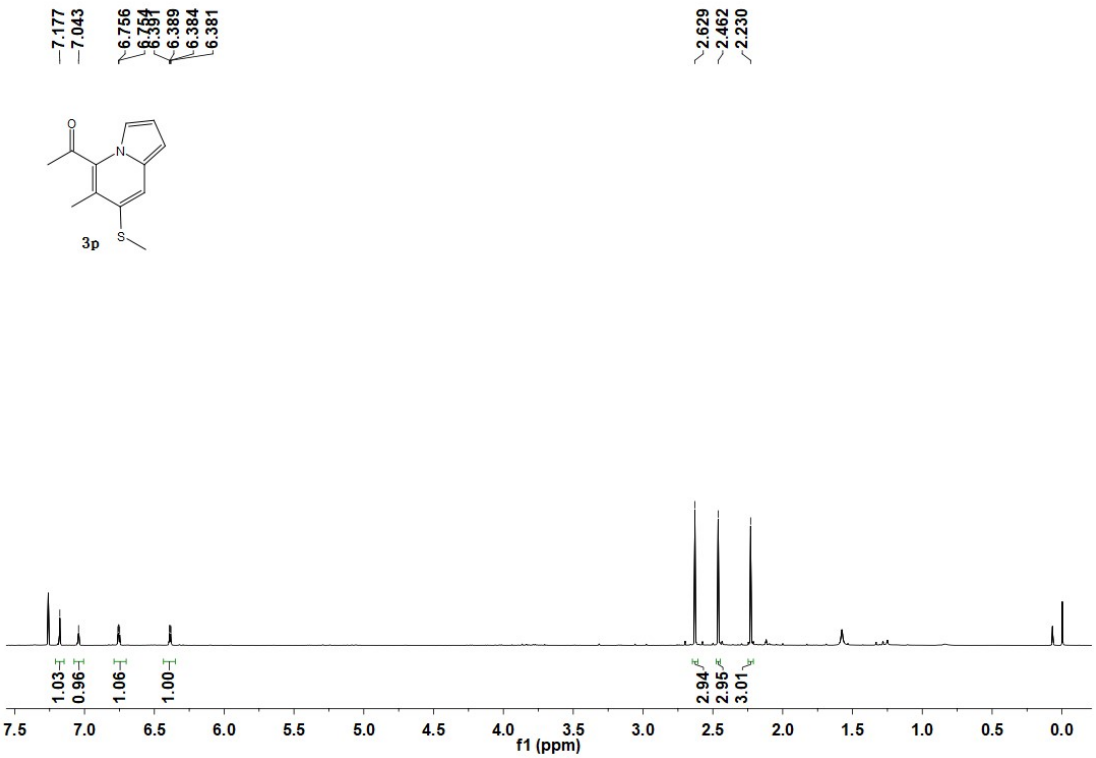
7.154
6.997
6.689
6.679
6.672
6.581
6.577
6.572
6.568
6.383
6.381
6.374
6.371
2.483
2.160
3m
1.00
1.02
0.98
1.00
1.00
1.00
1.00
3.05
3.02
f1 (ppm)


179.23
152.11
148.84
132.84
129.46
128.86
121.93
117.93
115.67
113.92
113.09
111.31
98.28
15.89
15.19
3m
f1 (ppm)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7.043
6.756
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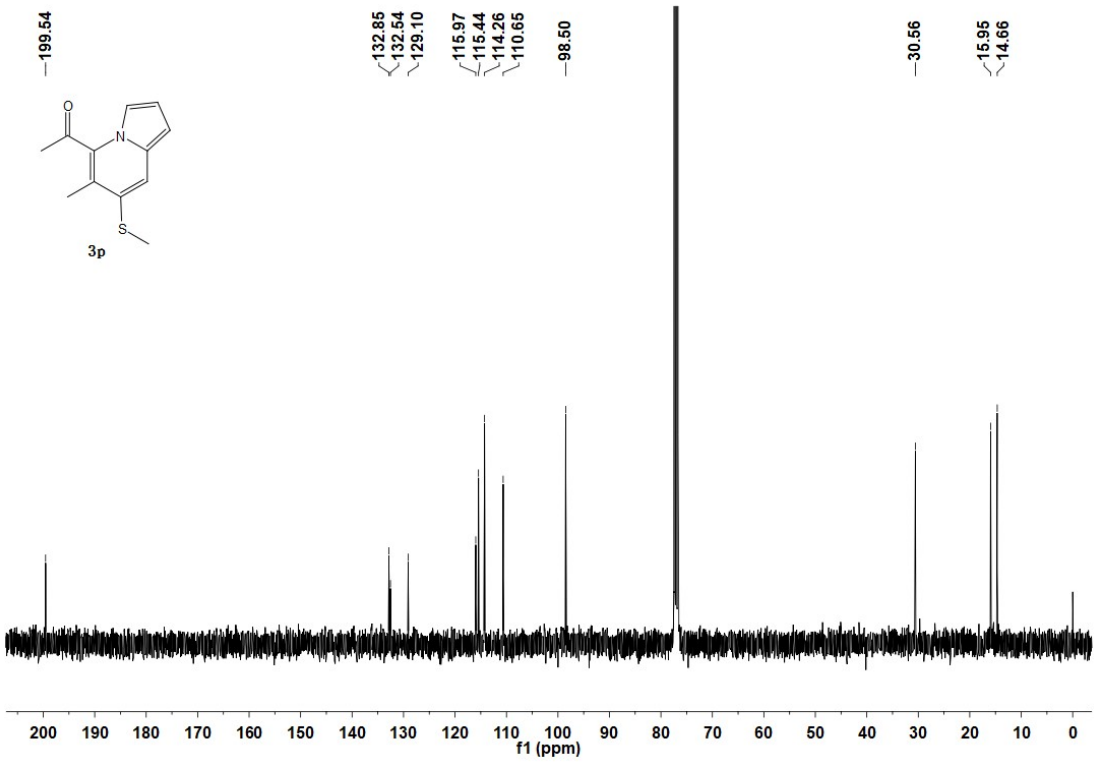
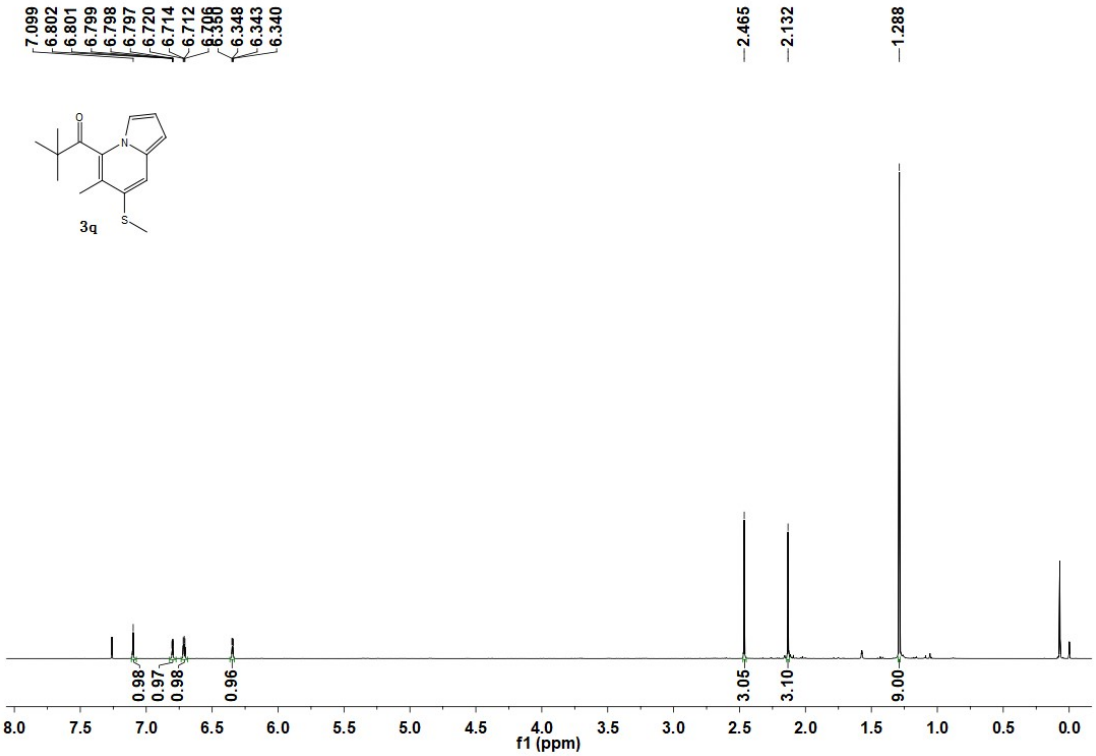
6.389
6.384
6.381
2.629
2.462
2.230
3p
1.03
0.96
1.06
1.00
2.94
2.95
3.01
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


199.54
132.85
132.54
129.10
115.97
115.44
114.26
110.65
98.50
30.56
15.95
14.66
3p
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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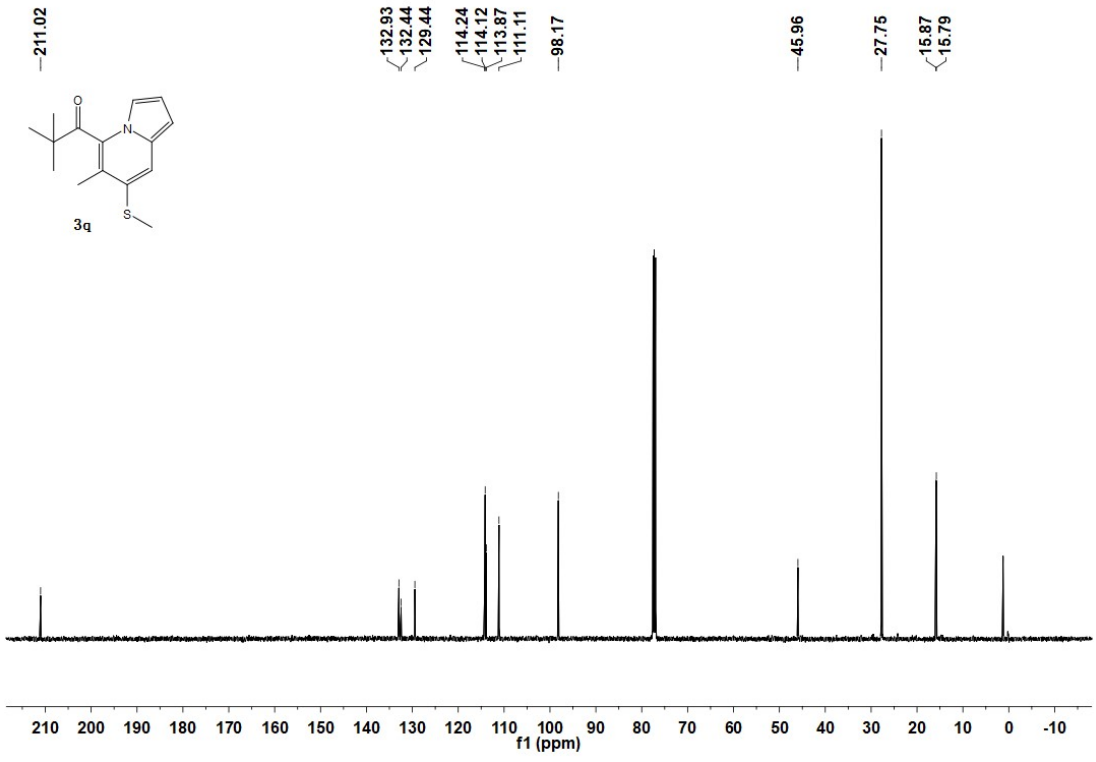
6.798
6.797
6.720
6.714
6.712
6.348
6.343
6.340
2.465
2.132
1.288
3q
0.98
0.97
0.98
0.96
3.05
3.10
9.00
f1 (ppm)


211.02
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132.44
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113.87
111.11
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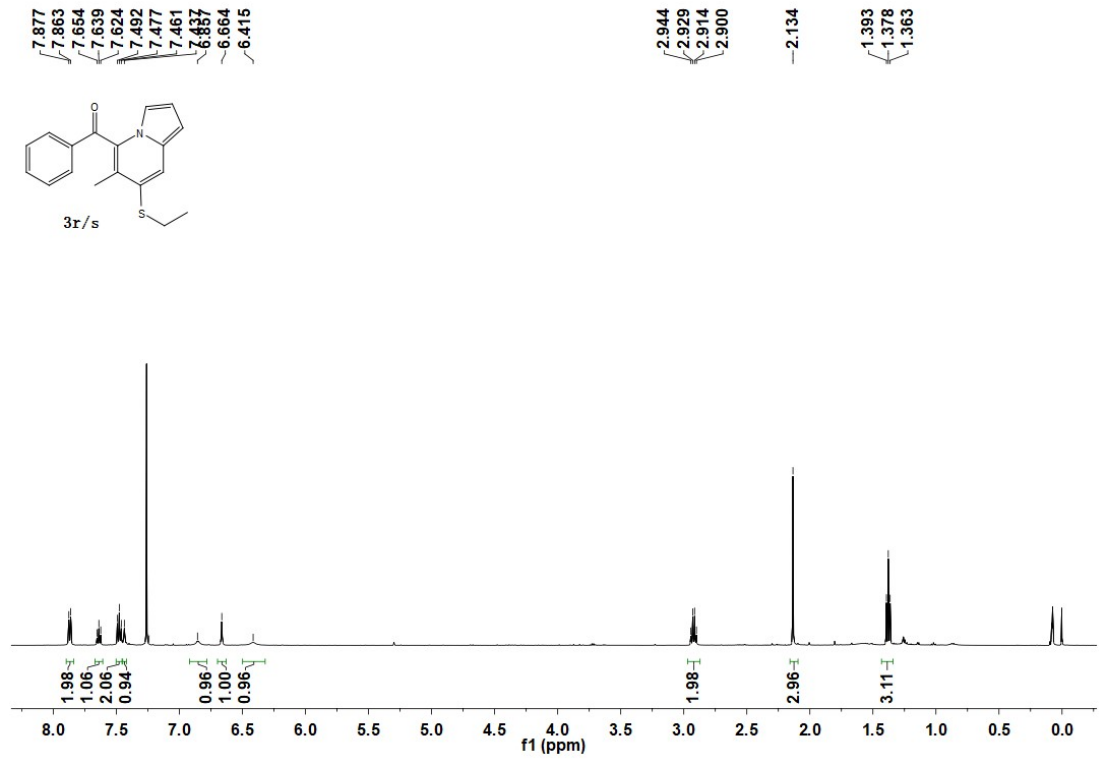
45.96
27.75
15.87
15.79
3q
f1 (ppm)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7.624
7.492
7.477
7.461
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6.415
2.944
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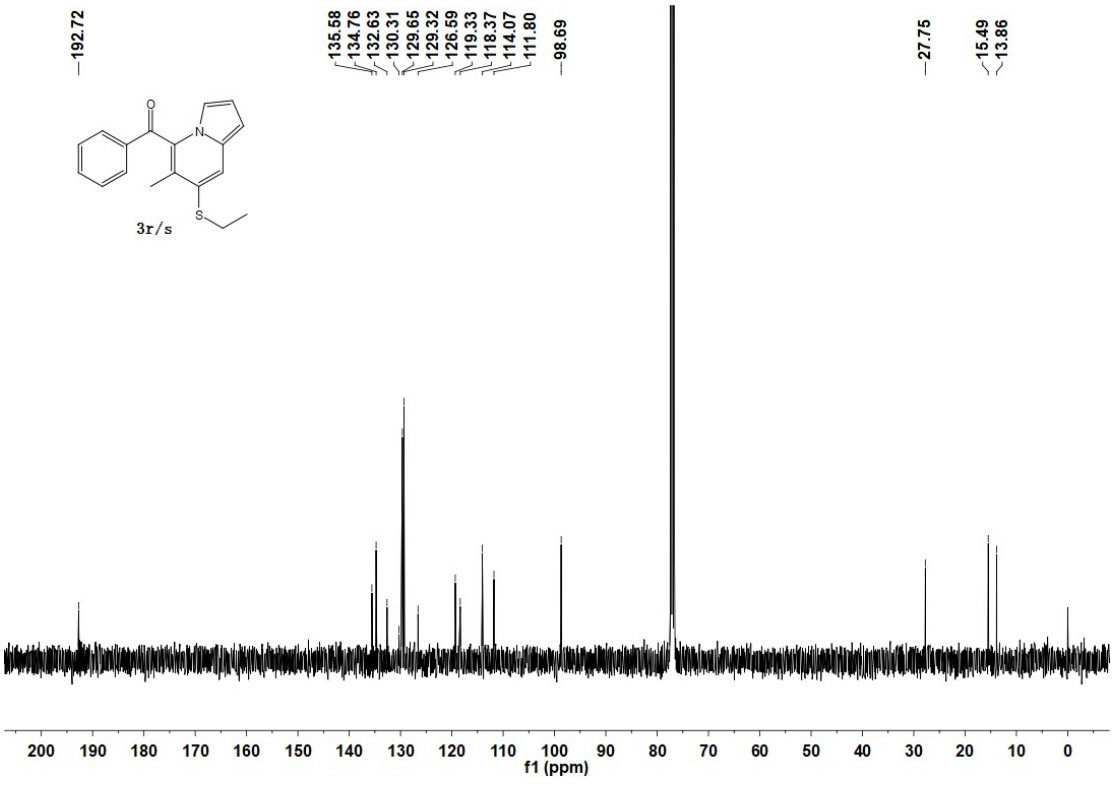
2.914
2.900
2.134
1.393
1.378
1.363
3r/s
1.98
1.06
2.06
0.94
0.96
1.00
0.96
1.98
2.96
3.11
f1 (ppm)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134.76
132.63
130.31
129.65
129.32
126.59
119.33
118.37
114.07
111.80
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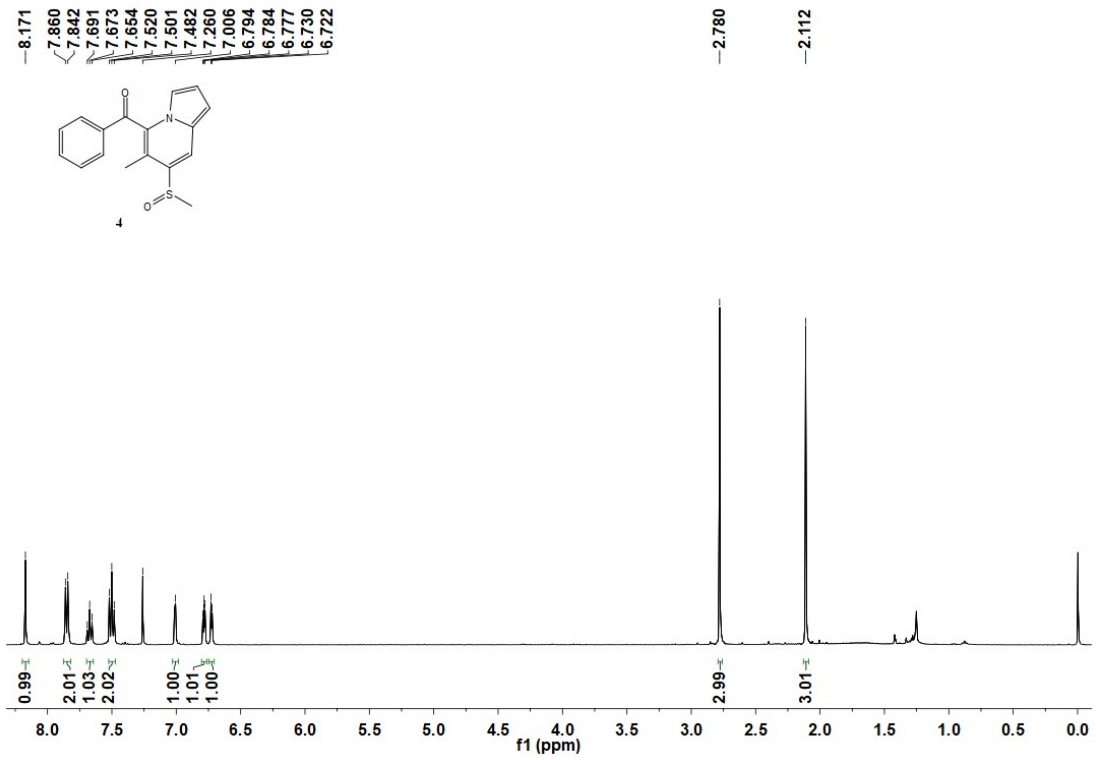
27.75
15.49
13.86
3r/s
f1 (ppm)


8.171
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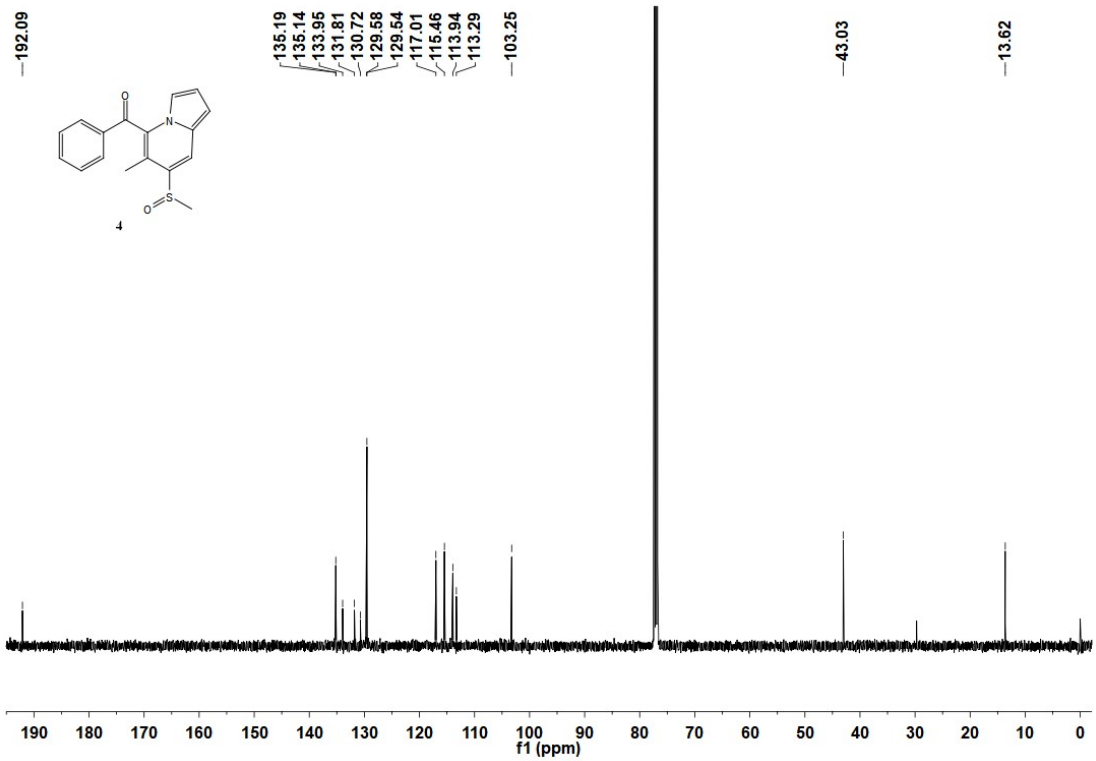
7.673
7.654
7.520
7.501
7.482
7.260
7.006
6.794
6.784
6.777
6.730
6.722
2.780
2.112
0.99
2.01
1.03
2.02
1.00
1.01
1.00
2.99
3.01
f1 (ppm)


192.09
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133.95
131.81
130.72
129.58
129.54
117.01
115.46
113.94
113.29
103.25
43.03
13.62
f1 (ppm)