Water-Mediated C-H Activation of Arenes with Secure Carbene Precursors: the Reaction and its Application

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Contents

1.General Information

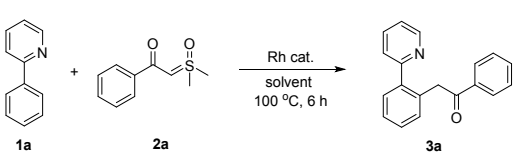
Unless otherwise noted, all reactions were carried out in reaction vessels in sealed tubes. Reactions were carried out without any precautions to extrude moisture or air unless otherwise noted. Solvents used were of analytical purity. All reactions were monitored by thin-layer chromatography (TLC) and were visualized using UV light. Product purification was done using silica gel column chromatography. Thin layer chromatography (TLC) characterization was performed with precoated silica gel GF254 (0.2mm), while column chromatography characterization was performed with silica gel (100-200mesh). ^{1}H NMR, ^{13}C NMR and ^{19}F NMR spectra were recorded with tetramethylsilane (TMS, δ = 0.00 ppm) as the internal standard. ^{1}H NMR spectra were recorded at 400 or 600 MHz (Varian), ^{13}C NMR spectra were recorded at 100 or 150 MHz (Varian) and ^{19}F NMR spectra were recorded at 376 MHz (Varian). Chemical shifts are reported in ppm downfield from $CDCl_3$ (δ = 7.26 ppm) or DMSO-d_6 (δ = 2.54 ppm) for ^{1}H NMR and chemical shifts for ^{13}C NMR spectra are reported in ppm relative to the central $CDCl_3$ (δ = 77.0 ppm) or DMSO-d_6 (δ = 39.6 ppm). Coupling constants were given in Hz. HRMS spectra were recorded on a Waters Q-TOF Premier. Melting points were measured with YRT-3 melting point apparatus (Shantou Keyi Instrument & Equipment Co., Ltd., Shantou, China). Commercial reagents were from Best-reagent (Homepage: http://www.best-reagent.com) or Astatech Chemical Technology Co, Ltd. (Homepage:http://www.astabio-chem.com). All reagents were used without further purification.

2. Preparation of sulfoxonium ylides[1]

To a stirred solution of potassium tert-butoxide (1.0 g, 9.1 mmol) in THF (10 mL) was added trimethylsulfoxonium iodide (1.5 g, 6.9 mmol) at room temperature. The resulting mixture was refluxed for 2 h. Then the reaction mixture was cooled to 0 ^{o}C, followed by addition of acylchlorides (2.3 mmol) in THF (2 mL). The reaction was allowed to room temperature and stirred for 3 h. After the solvent was evaporated, water (20 mL) and ethyl acetate (20 mL) were added to the residual crude product. The aqueous layer was separated and washed with ethylacetate (3 × 20 mL) and the organic layers were combined. The organic solution was dried over anhydrous Na_2SO_4 , and evaporated under vacuum. The residue was purified by column chromatography on silica gel to afford the sulfoxonium ylide.

3. Optimization of the reaction conditions (Table S1)

Table S1. Reaction optimization[a]



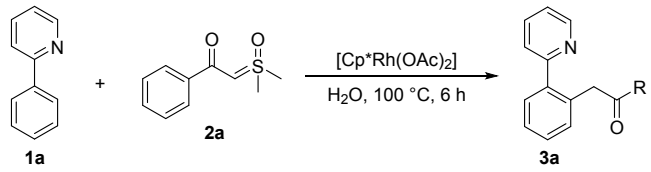
1a 2a 3a

Entry	Catalyst	Solvent[b]	Yield[c] (%)
1	$[Cp^*RhCl_2]_2/AgSbF_6$	$[BMIM]BF_4$	49%
2	$[Cp^*RhCl_2]_2/AgSbF_6$	$[BMIM]NTf_2$	53%
3	$[Cp^*RhCl_2]_2/AgSbF_6$	$[BTMG]PF_6$	62%

4	$[Cp^*RhCl_2]_2/AgSbF_6$	PEG400	61%
5	$[Cp^*RhCl_2]_2/AgSbF_6$	Tween-80	trace
6	$[Cp^*RhCl_2]_2/AgSbF_6$	ChCl-EG	trace
7	$[Cp^*RhCl_2]_2/AgSbF_6$	ChCl-H_2O	trace
8	$[Cp^*RhCl_2]_2/AgSbF_6$	H_2O	82%

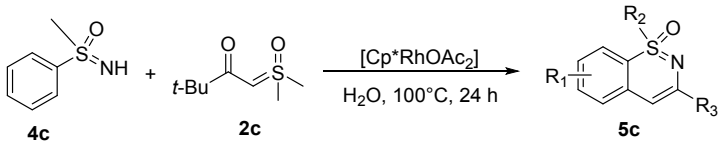
[a] Unless otherwise noted, all the reactions were carried out using: 2-phenylpyridine **1a** (0.2 mmol), dimethyloxosulfonium benzoylmethylide **2a** (0.4 mmol), Rh cat. (5 mol%), $AgSbF_6$ (20 mol%), solvent(1.5 ml), under air. [b] [BMIM] = 1-butyl-3-methylimidazolium; [BTMG] = *N,N,N′,N′*-tetramethyl-*N″*-butylhydrazine; PEG = polyethylene glycol; ChCl = choline chloride; EG = ethylene glycol. [c] Isolated yields.

4. General procedures for the acylmethylation (3a as an example)



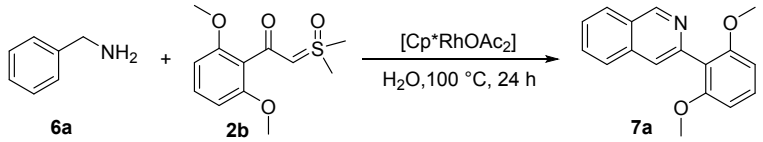
A mixture of 2-phenylpyridines **1a** (0.2 mmol), dimethyloxosulfonium benzoylmethylide **2a** (0.4mmol), $[Cp^*Rh(OAc)_2]$ (0.05 mmol) were weighted in a Schlenk tube equipped with a stir bar. Water (1.5 mL) was added and the mixture was stirred at 100 °C for 6 h under air. After completion, the reaction mixture was extracted with dichloromethane. The organic phase was evaporated under reduced pressure. The oily residue was purified by chromatography on a silica gel column (eluent: PE/EA = 50/1) and product **3a** was obtained with a 86% yield.

5. General procedure for C-H activation/annulation of sulfoximines and sulfoxonium ylides (5c as an example)



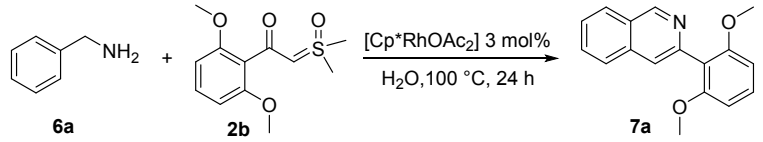
A mixture of the S-phenyl-S-methylsulfoximines **4c** (0.2 mmol), dimethyloxosulfonium tertbutylmethylide **2c** (0.4mmol), $[Cp^*Rh(OAc)_2]$ (0.05 mmol) were weighted in a Schlenk tube equipped with a stir bar. Water (1.5 mL) was added and the mixture was stirred at 100 °C for 24 h under air. After completion, the reaction mixture was extracted with dichloromethane. The organic phase was evaporated under reduced pressure. The oily residue was purified by chromatography on a silica gel column (eluent: PE/EA = 50/1) and product **5c** was obtained with a 91% yield.

6. General procedure for C-H activation/annulation of benzylamines and sulfoxonium ylides (7a as an example)



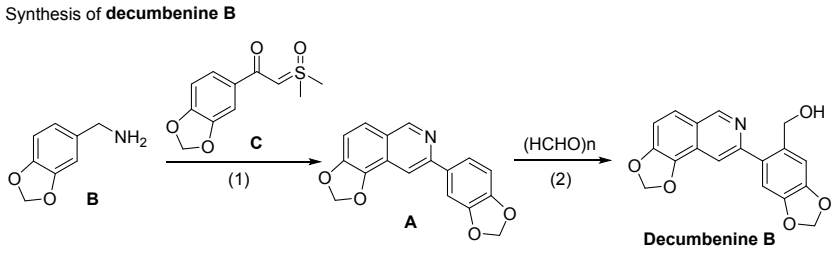
A mixture of benzylamine **6a** (0.2 mmol), dimethyloxosulfonium 2,6-dimethoxyl-1-benzoylmethylide **2b** (0.4 mmol), [Cp*Rh(OAc)$_2$] (0.05 mmol) were weighted in a Schlenk tube equipped with a stir bar. Water (1.5 mL) was added and the mixture was stirred at 100 °C for 24 h under air. After completion, the reaction mixture was extracted with dichloromethane. The organic phase was evaporated under reduced pressure. The oily residue was purified by chromatography on a silica gel column (eluent: PE/EA = 20/1) and product **7a** was obtained with a 81% yield.

7. A large scale of the reactions (7a as an example)



A mixture of benzylamine **6a** (5 mmol), dimethyloxosulfonium 2,6-dimethoxyl-1-benzoylmethylide **2b** (10 mmol), [Cp*Rh(OAc)$_2$] (0.15 mmol) were weighted in a Schlenk tube equipped with a stir bar. Water (25 mL) was added and the mixture was stirred at 100 °C for 24 h under air. After completion, the reaction mixture was extracted with dichloromethane. The organic phase was evaporated under reduced pressure. The oily residue was purified by chromatography on a silica gel column (eluent: PE/EA = 20/1) and product **7a** was obtained with a 75% yield.

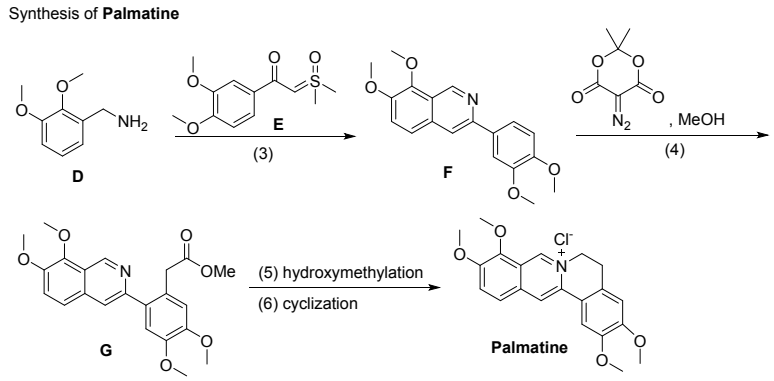
8. The synthesis of natural products



Synthesis of decumbenine B

(1) To a 75 ml tube was added benzo[d][1,3]dioxol-5-ylmethanamine **B** (907.2 mg, 6 mmol), sulfonium ylide **C** (721 mg, 3 mmol), [Cp*Rh(OAc)$_2$] 5 mol% (100 mg, 5 mol%) in H_2O (15 mL). The tube was sealed and stirred at 100 ^oC for 24 h. Afterwards, the reaction mixture was extracted with dichloromethane. After extraction and evaporation of the solvents under reduced pressure, the crude product was purified by column chromatography on silica gel (PE/EtOAc) to get yellow solid (compound **A**) in 30% yield. (264 mg).

(2) To a 75 ml oven-dried tube was added $ZnBr_2$ (0.045 mmol, 10 mg), $RuCl_3 \cdot xH2O$ (0.09 mmol, 22.8 mg), THF (5.0 mL), compound **A** (0.9 mmol, 264 mg), paraformaldehyde (4.5 mmol,135.5 mg) and $ZnMe_2$ (3.2 mmol, 1.0 M in toluene, 3.2 mL) sequentially under argon. The tube was sealed and stirred at 60 °C for 24 h. After completion, the reaction mixture was diluted with saturated. aq. NH_4Cl (30 mL) and extracted with ethylacetate (3 x 30 mL). Then the oganic layer was dried with anhydrous sodium sulfate, concentrated in vacuo and purified by silica gel column chromatography (5:1 PE/DCM to 200:1 DCM/MeOH) to provide decumbenine B (198 mg, 68%).



Synthesis of Palmatine

(3) To a 75 ml tube was added (2,3-dimethoxyphenyl)methanamine (1 g, 6 mmol), sulfonium ylide **E** (768.9 mg, 3 mmol), $[Cp^*Rh(OAc)_2]$ 5 mol% (100 mg, 5 mol%) in H_2O (15 mL). The tube was sealed and stirred at 100 °C for 24 h. Afterwards, the reaction mixture was extracted with dichloromethane. After extraction and evaporation of the solvents under reduced pressure, the crude product was purified by column chromatography on silica gel (PE/EtOAc) to get yellow solid (compound **F**) in 37% yield.

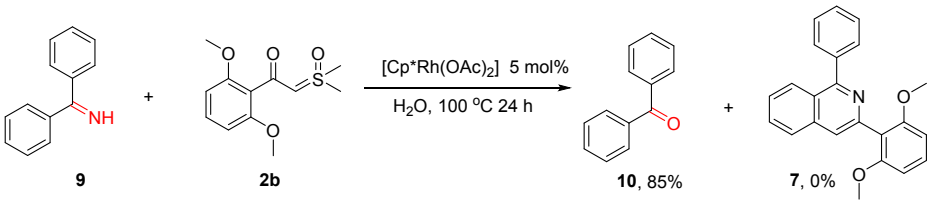
(4) A mixture of compound F (361 mg, 1.1mmol), 5-Diazo-2,2-dimethyl-1,3-dioxane-4,6-dione (224.6mg, 1.32 mmol) and $[Cp^*IrCl_2]_2$ (43.8 mg, 5 mol %) was added in one-pot and stirred in MeOH (5 mL) at 100 °C for 2 h, The mixture was cooled to room temperature, filtered through a pad of Celite, and concentrated under reduced pressure. The residue was then purified by flash column chromatography to give compound **G** in 42% yield.

(5) Under Ar, compound **G** (183.6 mg) was suspended in dry THF. $LiAlH_4$ (2eq) in THF was added to the mixture dropwise at 0 °C. the mixture was stirred for half an hour and then diluted with EtOAc, and quenched with water. aq. NaOH (4M) was added and the mixture was stirred at room temperature for half an hour and then filtered through a plug of celite. After extraction and evaporation of the solvents under reduced pressure, the crude product was purified by column chromatography on silica gel to get yellow solid.

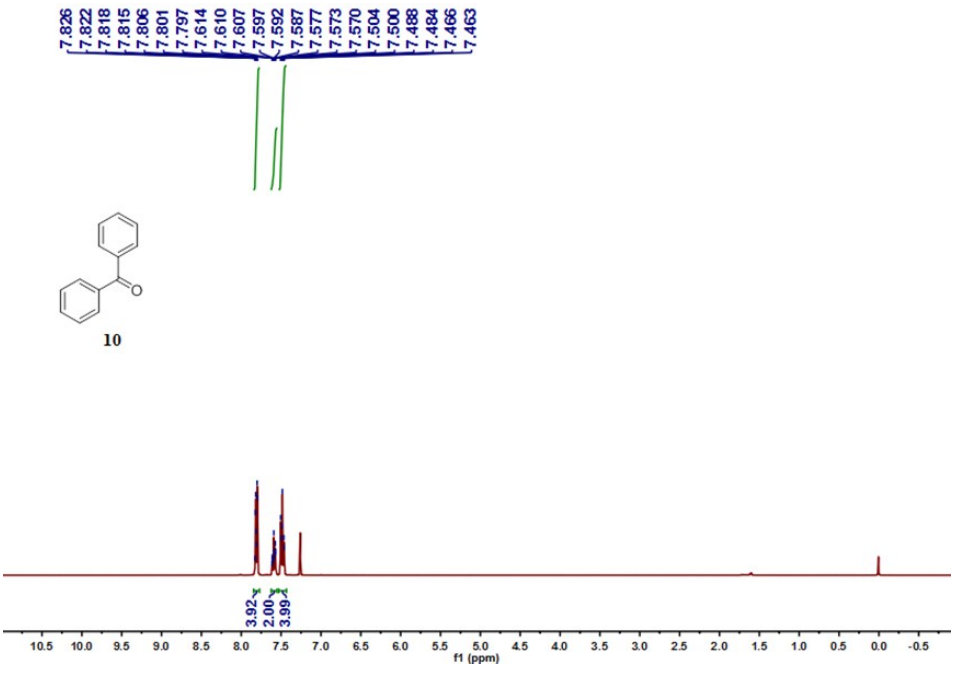
(6) Then this yellow solid was dissolved in $SOCl_2$ and stirred at room temperature for 1h. The reaction mixture was concentrated under reduced pressure, and water was added. After extraction with EtOAc for 4 times, the oil layer was discarded and the aqueous layer was extracted with DCM. Then the combined oganic layer was dried with anhydrous sodium sulfate and concentrated in vacuo to provide Palmatine (129.2 mg).

9. Mechanistic study

On the basis of the previously reported examples of the rhodium-catalyzed C-H activation with sulfoxonium ylides, the mechanism of acylmethylation and 1,2-benzothiazines formation was widely recognized.[1,2] However, benzylamines as C-H activation substrates had two possible paths according to previous related studies.[3,4] In order to gain the insight into the reaction mechanism, some experiments for the mechanistic study was conducted. First, using α-phenylbenzenemethanimine **9** with sulfoxonium ylide **2b** under the standard reaction conditions was carried out (Scheme S1). α-Phenylbenzenemethanimine **9** was hydrolyzed completely, only affording diphenylmethanone **10** with a 85% yield (Schem S2, ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 – 7.77 (m, 4H), 7.59 (td, J = 7.2, 1.4 Hz, 2H), 7.53 – 7.43 (m, 4H)). This result indicated that aryl imine is extremely sensitive in water, and aryl amine is more likely as a directing group rather than imine.

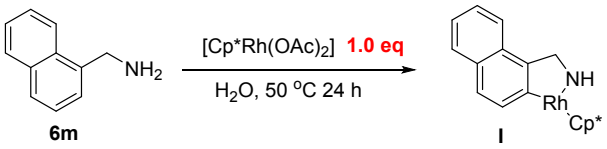


Scheme S1. The reaction of α-phenylbenzenemethanimine

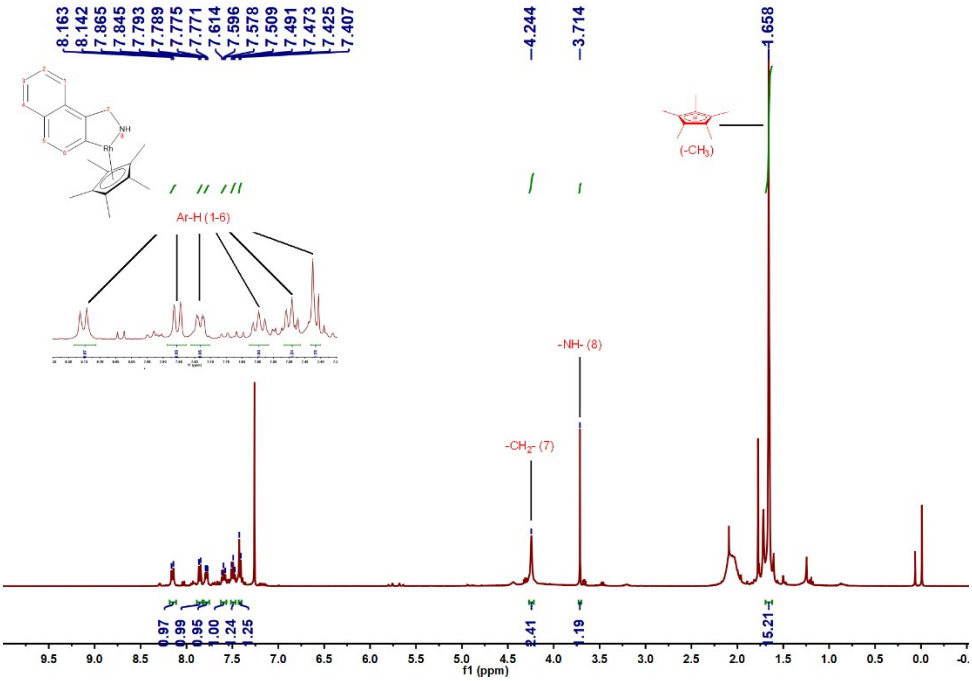


Scheme S2. The ^{1}H NMR Spectra of diphenylmethanone

Then, we used **6m** with [Cp*Rh(OAc)$_2$] to obtained the intermediate **I** (Scheme S3). Unfortunately, we failed to isolated the intermediate **I** after trying our best. Therefore, the ^{1}H NMR spectrum of the reaction mixture was confirmed (Scheme S4). The characteristic peaks showed that the intermediate **I** is possibly a amine complex, which stability is inferior to the imine complex.

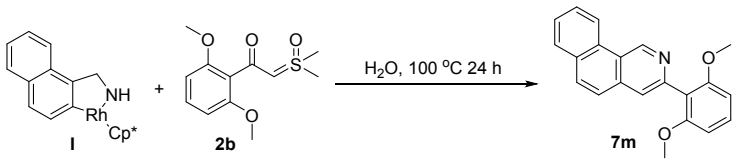


Scheme S3. The intermediate **I** formation



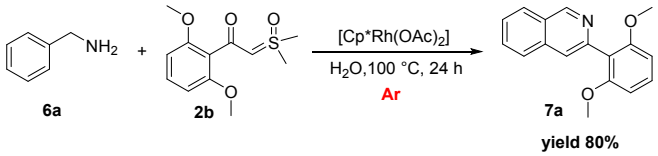
Scheme S4. In situ ^{1}H NMR spectrum of the reaction mixture

The mixture was then recovered for the next reaction with sulfoxonium ylide **2b**. The reaction still performed well affording the desired product **7m** successfully (Scheme S5).



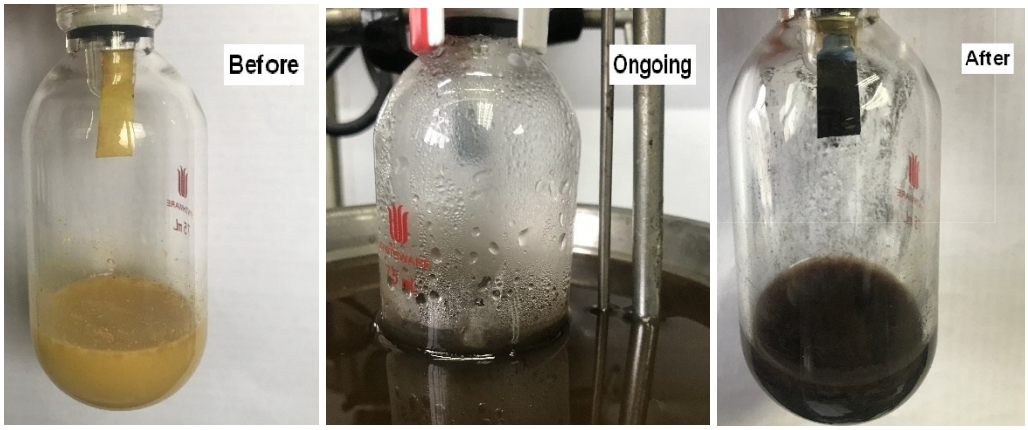
Scheme S5. The reaction of intermediate **I** with sulfoxonium ylide **2b**

To further probe the pathway of this protocol, the reaction of benzylamine **6a** and dimethyloxosulfonium 2,6-dimethoxyl-1-benzoylmethylide **2b** was carried out under Ar (Scheme S6).

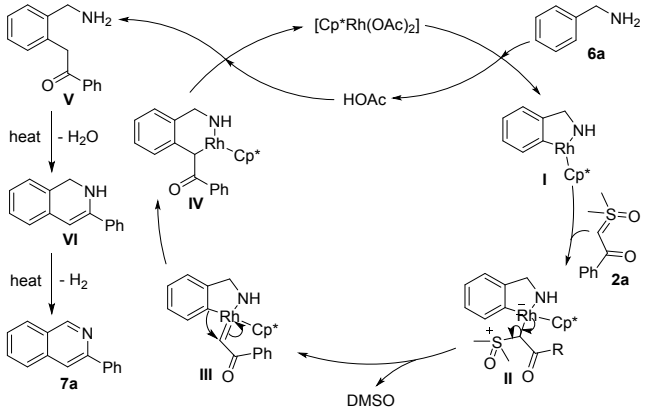


Scheme S6. The key experiment for the mechanistic study

The reaction proceeded successfully affording the desired product **7a** with a 80% yield. This result indicated that benzylamine **6a** may occur C-H activation directly without an amine oxidation to imine. According to the relevant research,[3b] the extrusion of H_2 was also detected by phosphomolybdic acid/$PdCl_2$ testing paper (Scheme S7). Based on the results above, the possible mechanism for this protocol was more likely to be as shown in Scheme S8.



Schem S7. The test paper changing as the reaction proceeding



Scheme S8. The possible mechanism

10. Reference

[1] Barday, M.; Janot, C.; Halcovitch, N. R.; Muir, J.; Aïssa, C. *Angew. Chem., Int. Ed.* **2017**, *56*, 13117-13121.

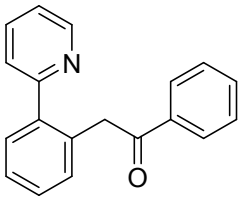
[2] Zheng, G.; Tian, M.; Xu, Y.; Chen, X.; Li, X. *Org. Chem. Front.* **2018**, *5*, 998-1002.

[3] (a) Villuendas, P.; Urriolabeitia, E. P. *J. Org. Chem.* **2013**, *78*, 5254-5263. (b) Chu, H.; Xue, P.; Yu, J.-T.; Cheng, J. *J. Org. Chem.* **2016**, *81*, 8009-8013. (c) Ruiz, S.; Villuendas, P.; Ortuño, M. A.; Lledós, A.; Urriolabeitia, E. P. *Chem. Eur. J.* **2015**, *21*, 8626-8636.

[4] (a) Wang, Q.; Li, X. *Org. Chem. Front.* **2016**, *3*, 1159-1162. (b) Lin, X.; Chauvin, R.; Yu, Y.; Wang, L.; Xu, L.; Cui, X. *ChemistrySelect* **2017**, *2*, 2383-2387. (c) Morimoto, K.; Hirano, K.; Satoh, T.; Miura, M. *Chem. Lett.* **2011**, *40*, 600-602.

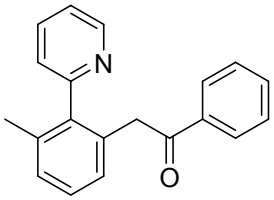
11. Characterization data for the products

1-phenyl-2-(2-(pyridin-2-yl)phenyl)ethan-1-one (3a)



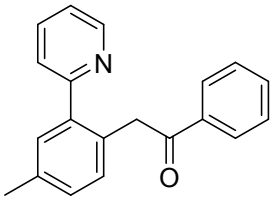
Yield 88% (48.0 mg). Yellow solid, m.p. 95-96 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.39 (d, *J* = 4.2 Hz, 1H), 7.90 (d, *J* = 7.4 Hz, 2H), 7.69 (td, *J* = 7.8, 1.6 Hz, 1H), 7.56 – 7.36 (m, 7H), 7.35 – 7.30 (m, 1H), 7.16 – 7.10 (m, 1H), 4.53 (s, 2H); ^{13}C NMR (100MHz, $CDCl_3$) δ 197.8, 159.4, 148.6, 139.9, 137.1, 136.7, 133.4, 132.7, 131.9, 129.8, 128.6, 128.5 (2C), 128.3 (2C), 127.3, 123.8, 121.8, 43.6. HRMS (ESI): *m/z* calculated for $C_{19}H_{15}NOH^+$:274.1226, found: 274.1224.

2-(3-methyl-2-(pyridin-2-yl)phenyl)-1-phenylethan-1-one (3b)



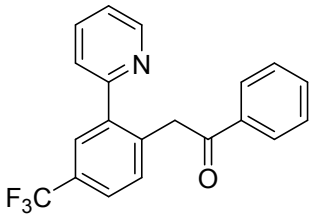
Yield 76% (43.7 mg). Yellow solid, m.p. 99-100 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.64 (d, *J* = 4.4 Hz, 1H), 7.76 (d, *J* = 7.6 Hz, 2H), 7.63 (td, *J* = 7.6, 2.0 Hz, 1H), 7.47 (t, *J* = 7.2 Hz, 1H), 7.35 (t, *J* = 7.6 Hz, 2H), 7.28 – 7.14 (m, 4H), 7.11 (d, *J* = 7.4 Hz, 1H), 4.07 (s, 2H), 2.07 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.1, 159.1, 149.4, 140.3, 136.7, 136.4, 136.2, 133.2, 132.9, 129.0, 128.5 (2C), 128.3, 128.2 (2C), 128.1, 125.3, 122.0, 43.4, 20.4. HRMS (ESI): *m/z* calculated for $C_{20}H_{17}NOH^+$:288.1383, found: 288.1381.

2-(4-methyl-2-(pyridin-2-yl)phenyl)-1-phenylethan-1-one (3c)



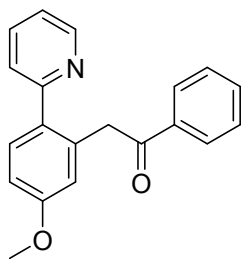
Yield 80% (46.0 mg). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.42 (d, *J* = 4.2 Hz, 1H), 7.89 (d, *J* = 7.4 Hz, 2H), 7.68 (td, *J* = 7.8, 1.7 Hz, 1H), 7.52 (t, *J* = 7.4 Hz, 1H), 7.47 – 7.37 (m, 3H), 7.32 (s, 1H), 7.21 (s, 2H), 7.14 (ddd, *J* = 7.6, 4.8, 1.2 Hz, 1H), 4.47 (s, 2H), 2.40 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.2, 159.5, 148.6, 139.7, 137.1, 136.9, 136.7, 132.7, 131.6, 130.6, 130.2, 129.4, 128.4 (2C), 128.3 (2C), 123.9, 121.8, 43.1, 21.1. HRMS (ESI): *m/z* calculated for $C_{20}H_{17}NOH^+$:288.1383, found: 288.1381.

1-phenyl-2-(2-(pyridin-2-yl)-4-(trifluoromethyl)phenyl)ethan-1-one (3d)



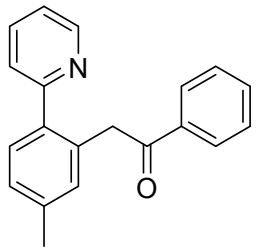
Yield 79% (53.9 mg). Yellow solid, m.p. 74-75 °C. ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.48 – 8.38 (m, 1H), 7.92 – 7.84 (m, 2H), 7.75 (td, *J* = 7.8, 1.8 Hz, 1H), 7.69 (d, *J* = 1.8 Hz, 1H), 7.65 (dd, *J* = 8.0, 1.8 Hz, 1H), 7.58 – 7.51 (m, 1H), 7.51 – 7.39 (m, 4H), 7.21 (ddd, *J* = 7.6, 5.0, 1.2 Hz, 1H), 4.56 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.3, 159.3, 153.6 (d, 1C), 137.4, 137.1, 132.8, 132.5, 130.4 (q, 1C), 128.4, 128.4 (2C), 128.2 (2C), 127.9, 125.3, 123.8, 121.9, 115.4, 114.2, 42.7. ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.5. HRMS (ESI): *m/z* calculated for $C_{20}H_{14}F_3NOH^+$:342.1100, found: 342.1102.

2-(5-methoxy-2-(pyridin-2-yl)phenyl)-1-phenylethan-1-one (3e)



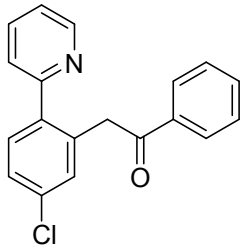
Yield 85% (51.6 mg). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.33 (d, *J* = 4.2 Hz, 1H), 7.90 (d, *J* = 7.4 Hz, 2H), 7.66 (td, *J* = 7.7, 1.9 Hz, 1H), 7.53 (t, *J* = 7.4 Hz, 1H), 7.43 (q, *J* = 8.4, 7.3 Hz, 4H), 7.12 – 7.05 (m, 1H), 6.92 (dd, *J* = 8.5, 2.7 Hz, 1H), 6.86 (d, *J* = 2.4 Hz, 1H), 4.52 (s, 2H), 3.84 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ197.8, 159.7, 148.4, 137.1, 136.7, 134.9, 132.7, 131.1, 130.0, 128.4 (2C), 128.3 (2C), 123.6, 121.3, 117.3, 112.7, 55.3, 43.9. HRMS (ESI): *m/z* calculated for $C_{20}H_{17}NO_2H^+$:304.1332, found: 304.1334.

2-(5-methyl-2-(pyridin-2-yl)phenyl)-1-phenylethan-1-one (3f)



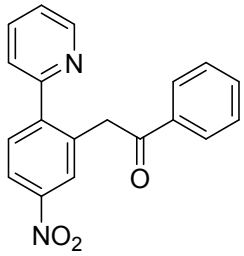
Yield 86% (49.4 mg). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.36 (d, *J* = 4.0 Hz, 1H), 7.90 (d, *J* = 7.4 Hz, 2H), 7.72 – 7.62 (m, 1H), 7.53 (t, *J* = 7.4 Hz, 1H), 7.48 – 7.34 (m, 4H), 7.19 (d, *J* = 7.8 Hz, 1H), 7.16 – 7.05 (m, 2H), 4.50 (s, 2H), 2.39 (s, 3H); ^{13}C NMR (100 MHz, CDCl3) δ 198.0, 159.4, 148.4, 138.4, 137.2, 136.9, 136.6, 133.1, 132.6, 129.7, 128.4 (2C), 128.3, 128.2 (2C), 128.0, 123.7, 121.5, 43.5, 21.2. HRMS (ESI): *m/z* calculated for $C_{20}H_{17}NOH^+$:288.1383, found: 288.1381.

2-(5-chloro-2-(pyridin-2-yl)phenyl)-1-phenylethan-1-one (3g)



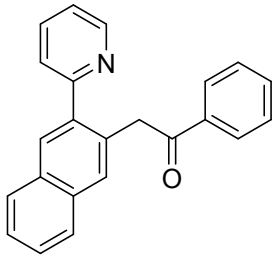
Yield 86% (52.9 mg). Yellow solid, m.p. 55-56 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.36 (d, *J* = 4.8 Hz, 1H), 7.88 (d, *J* = 7.8 Hz, 2H), 7.70 (td, *J* = 7.8, 2.0 Hz, 1H), 7.54 (t, *J* = 7.4 Hz, 1H), 7.48 – 7.39 (m, 4H), 7.38 – 7.31 (m, 2H), 7.14 (dd, *J* = 7.6, 4.8 Hz, 1H), 4.51 (s, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 197.0, 158.0, 148.3, 137.2, 136.8, 135.3, 132.9, 131.9, 131.0, 130.1, 128.5 (2C), 128.4, 128.1 (2C), 127.5, 123.9, 122.2, 43.3. HRMS (ESI): *m/z* calculated for $C_{19}H_{14}ClNOH^+$:308.0837, found: 308.0835.

2-(5-nitro-2-(pyridin-2-yl)phenyl)-1-phenylethan-1-one (3h)



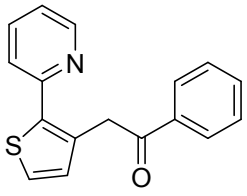
Yield 56% (35.7 mg). Yellow solid, m.p. 111-112 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.38 (d, *J* = 4.2 Hz, 1H), 8.31 – 8.15 (m, 2H), 7.90 (d, *J* = 7.6 Hz, 2H), 7.75 (t, *J* = 7.6 Hz, 1H), 7.67 (d, *J* = 8.4 Hz, 1H), 7.57 (t, *J* = 7.2 Hz, 1H), 7.47 (dt, *J* = 15.0, 7.6 Hz, 3H), 7.24 – 7.14 (m, 1H), 4.65 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.4, 157.3, 148.9, 147.6, 146.0, 137.1, 136.6, 135.6, 133.2, 130.7, 128.7 (2C), 128.1 (2C), 127.2, 124.0, 122.9, 122.3, 43.5. HRMS (ESI): *m/z* calculated for $C_{19}H_{14}N_2O_3H^+$:319.1077, found: 319.1075.

1-phenyl-2-(3-(pyridin-2-yl)naphthalen-2-yl)ethan-1-one (3i)



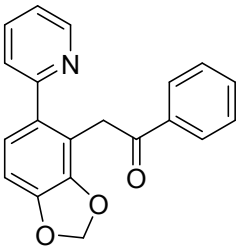
Yield 94% (60.8 mg). Brown solid, m.p. 98-99 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.42 (d, *J* = 4.4 Hz, 1H), 7.97 (s, 1H), 7.94 – 7.86 (m, 3H), 7.86 – 7.78 (m, 2H), 7.74 (t, *J* = 7.8 Hz, 1H), 7.60 (d, *J* = 7.8 Hz, 1H), 7.55 – 7.47 (m, 3H), 7.46 – 7.36 (m, 2H), 7.20 – 7.11 (m, 1H), 4.72 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.9, 159.5, 148.4, 138.1, 137.1, 137.0, 133.3, 132.7, 132.5, 131.3, 130.8, 129.4, 128.5 (2C), 128.3 (2C), 128.0, 127.4, 126.6, 126.1, 124.2, 121.9, 43.9. HRMS (ESI): *m/z* calculated for $C_{23}H_{17}NOH^+$:324.1388, found: 324.1387.

1-phenyl-2-(2-(pyridin-2-yl)thiophen-3-yl)ethan-1-one (3j)



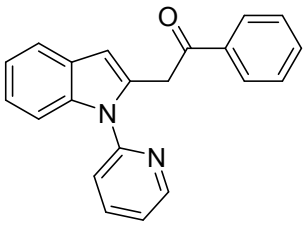
Yield 77% (43.0 mg). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.45 (q, *J* = 1.7 Hz, 1H), 8.04 (d, *J* = 7.3 Hz, 2H), 7.65 (td, *J* = 7.7, 1.9 Hz, 1H), 7.54 (t, *J* = 7.8 Hz, 2H), 7.46 (d, *J* = 7.8 Hz, 2H), 7.33 (d, *J* = 5.1 Hz, 1H), 7.16 – 7.06 (m, 1H), 7.02 (d, *J* = 5.1 Hz, 1H), 4.75 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.7, 153.1, 149.1, 138.1, 137.1, 136.9, 133.4, 132.9, 131.7, 128.6 (2C), 128.5 (2C), 125.3, 122.1, 121.6, 39.8. HRMS (ESI): *m/z* calculated for $C_{17}H_{13}NOSH^+$:280.0791, found: 280.0792.

1-phenyl-2-(5-(pyridin-2-yl)benzo[d][1,3]dioxol-4-yl)ethan-1-one (3k)



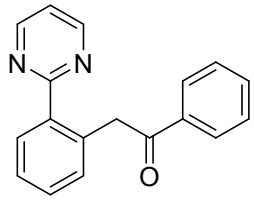
Yield 77% (48.9 mg). Yellow solid, m.p. 100-101 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.33 (d, *J* = 4.2 Hz, 1H), 7.94 (d, *J* = 7.6 Hz, 2H), 7.65 (t, *J* = 7.5 Hz, 1H), 7.55 (t, *J* = 7.4 Hz, 1H), 7.44 (t, *J* = 7.8 Hz, 3H), 7.09 (dd, *J* = 7.6, 4.8 Hz, 1H), 7.04 (d, *J* = 8.2 Hz, 1H), 6.85 (d, *J* = 8.0 Hz, 1H), 6.01 (s, 2H), 4.53 (s, 2H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 196.6, 158.6, 148.2, 147.6, 137.0, 136.9, 133.3, 132.7, 130.1, 128.4 (2C), 128.1 (2C), 123.6, 123.5, 121.5, 115.6, 107.1, 101.3, 37.1. HRMS (ESI): *m/z* calculated for $C_{20}H_{15}NO_3H^+$:381.1125, found: 381.1123.

1-phenyl-2-(1-(pyridin-2-yl)-1H-indol-2-yl)ethan-1-one (3l)



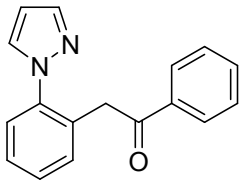
Yield 54% (33.7 mg). Amorphous light yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.37 (dd, *J* = 5.2, 1.8 Hz, 1H), 7.91 (d, *J* = 7.6 Hz, 2H), 7.84 (td, *J* = 7.6, 1.8 Hz, 1H), 7.61 – 7.51 (m, 3H), 7.46 – 7.40 (m, 3H), 7.20 – 7.13 (m, 3H), 6.57 (s, 1H), 4.69 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.1, 151.4, 149.2, 138.4, 136.9, 136.7, 133.9, 133.0, 128.7, 128.5 (2C), 128.3 (2C), 122.3, 121.6, 120.9, 120.5, 120.2, 110.3, 106.0, 38.4. HRMS (ESI): *m/z* calculated for $C_{21}H_{16}N_2OH^+$:313.1335, found: 313.1332.

1-phenyl-2-(2-(pyrimidin-2-yl)phenyl)ethan-1-one (3m)



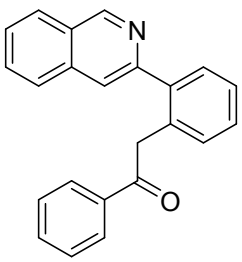
Yield 78% (42.8 mg). Yellow solid, m.p. 115-116 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.51 (d, *J* = 4.8 Hz, 2H), 8.30 – 8.22 (m, 1H), 8.02 (d, *J* = 7.4 Hz, 2H), 7.57 (t, *J* = 7.4 Hz, 1H), 7.51 – 7.43 (m, 4H), 7.38 – 7.33 (m, 1H), 7.04 (t, *J* = 4.8 Hz, 1H), 4.69 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.7, 156.5, 137.7, 136.6, 135.0, 133.4, 132.9, 132.4, 130.9, 130.2, 130.1, 128.5 (2C), 128.1 (2C), 127.4, 118.6, 45.1. HRMS (ESI): *m/z* calculated for $C_{18}H_{14}N_2OH^+$:275.1179, found: 275.1182.

2-(2-(1H-pyrazol-1-yl)phenyl)-1-phenylethan-1-one (3n)



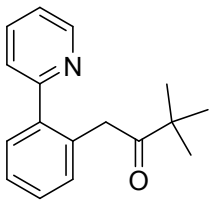
Yield 55% (28.9 mg). Yellow solid, m.p. 72-73 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88 (d, *J* = 7.6 Hz, 2H), 7.61 (d, *J* = 2.0 Hz, 2H), 7.54 (t, *J* = 7.4 Hz, 1H), 7.45 – 7.33 (m, 6H), 6.34 (s, 1H), 4.40 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.1, 140.6, 140.0, 136.6, 133.1, 132.1, 131.0, 130.9, 128.6 (2C), 128.5, 128.3 (2C), 128.0, 126.0, 106.5, 41.7. HRMS (ESI): *m/z* calculated for $C_{17}H_{14}N_2OH^+$:263.1179, found: 263.1182.

2-(2-(isoquinolin-3-yl)phenyl)-1-phenylethan-1-one (3o)



Yield 52% (33.6mg). Yellow wax. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.11 (s, 1H), 7.93 (d, *J* = 8.2 Hz, 1H), 7.87 (d, *J* = 7.3 Hz, 2H), 7.82 – 7.75 (m, 2H), 7.71 – 7.64 (m, 1H), 7.59 (td, *J* = 4.3, 2.1 Hz, 2H), 7.50 – 7.45 (m, 1H), 7.44 – 7.32 (m, 5H), 4.55 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 198.1, 153.1, 151.4, 137.1, 136.5, 133.6, 133.3, 132.6, 131.7, 130.6, 130.3, 130.1, 128.4, 128.4, 128.4 (2C), 128.3 (2C), 127.5, 127.2, 126.8, 120.3, 43.6. HRMS (ESI): *m/z* calculated for $C_{23}H_{17}NOH^+$:324.1383, found: 324.1382.

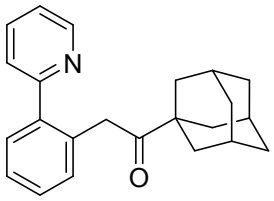
3,3-dimethyl-1-(2-(pyridin-2-yl)phenyl)butan-2-one (3p)



Yield 31% (15.2 mg). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.62 (d, *J* = 4.4 Hz, 1H), 7.73 (td, *J* = 7.7, 1.8 Hz, 1H), 7.43 – 7.37 (m, 2H), 7.37 – 7.33 (m,

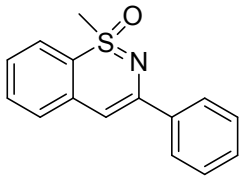
2H), 7.24 – 7.17 (m, 2H), 4.12 (s, 2H), 1.04 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 212.0, 159.1, 147.5, 139.5, 135.6, 132.3, 130.6, 128.7, 127.3, 126.0, 123.2, 120.7, 43.2, 40.5, 25.6 (3C). HRMS (ESI): *m/z* calculated for $C_{17}H_{19}NOH^+$:254.1539, found: 254.1542.

1-((3r,5r,7r)-adamantan-1-yl)-2-(2-(pyridin-2-yl)phenyl)ethan-1-one (3q)



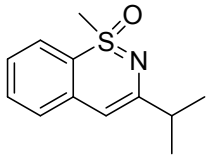
Yield 85% (56.3 mg). Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.63 (ddd, *J* = 4.9, 1.9, 1.0 Hz, 1H), 7.72 (td, *J* = 7.7, 1.9 Hz, 1H), 7.41 – 7.37 (m, 2H), 7.36 – 7.32 (m, 2H), 7.22 (ddd, *J* = 7.5, 4.9, 1.2 Hz, 1H), 7.19 – 7.14 (m, 1H), 4.05 (s, 2H), 1.98 (s, 3H), 1.72 – 1.67 (m, 9H), 1.66 – 1.60 (m, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 212.7, 160.0, 148.5, 140.4, 136.7, 133.4, 131.7, 129.8, 128.4, 126.9, 124.3, 121.8, 41.2, 38.7, 38.4 (3C), 36.5 (3C), 28.0 (3C). HRMS (ESI): *m/z* calculated for $C_{23}H_{25}NOH^+$:332.2009, found: 332.2011.

1-methyl-3-phenylbenzo[*e*][1,2]thiazine 1-oxide (5a)



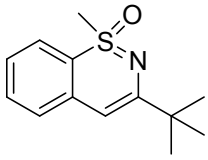
Yield 35% (17.9 mg). Yellow solid, m.p. 94-95 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 (d, *J* = 7.2 Hz, 2H), 7.80 (d, *J* = 8.0 Hz, 1H), 7.57 (t, *J* = 7.6 Hz, 1H), 7.44 – 7.34 (m, 5H), 6.68 (s, 1H), 3.62 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 147.1, 138.5, 136.7, 132.6, 128.9, 128.3 (2C), 127.2 (2C), 126.5, 126.3, 123.4, 118.7, 98.2, 45.4. HRMS (ESI): *m/z* calculated for $C_{15}H_{13}NOSH^+$:256.0791, found: 256.0795.

3-isopropyl-1-methylbenzo[*e*][1,2]thiazine 1-oxide (5b)



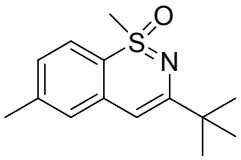
Yield 90% (39.8 mg). White solid, m.p. 85-86 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70 (d, *J* = 8.1 Hz, 1H), 7.48 (t, *J* = 7.5 Hz, 1H), 7.30 (t, *J* = 7.8 Hz, 1H), 7.24 (d, *J* = 8.0 Hz, 1H), 5.95 (s, 1H), 3.48 (s, 3H), 2.60 (q, *J* = 6.8 Hz, 1H), 1.23 (s, 3H), 1.21 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.5, 136.9, 132.4, 126.4, 125.6, 123.3, 117.9, 96.2, 45.1, 36.3, 21.3 (2C). HRMS (ESI): *m/z* calculated for $C_{12}H_{15}NOSH^+$:222.0947, found: 222.0949.

3-(tert-butyl)-1-methylbenzo[*e*][1,2]thiazine 1-oxide (5c)



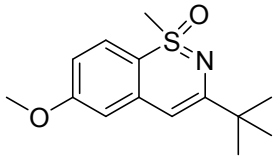
Yield 91% (42.4 mg). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71 (d, *J* = 8.0 Hz, 1H), 7.49 (t, *J* = 7.6 Hz, 1H), 7.37 – 7.23 (m, 2H), 6.06 (s, 1H), 3.47 (s, 3H), 1.27 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.8, 137.0, 132.3, 126.8, 125.7, 123.2, 117.7, 95.2, 45.1, 37.3, 28.9 (3C). HRMS (ESI): *m/z* calculated for $C_{13}H_{17}NOSH^+$:236.1104, found: 236.1108.

3-(tert-butyl)-1,6-dimethylbenzo[*e*][1,2]thiazine 1-oxide (5d)



Yield 91% (45.4 mg). White solid, m.p. 98-99 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60 (d, *J* = 8.1 Hz, 1H), 7.13 (dd, *J* = 8.2, 1.6 Hz, 1H), 7.07 (s, 1H), 5.98 (s, 1H), 3.43 (s, 3H), 2.39 (s, 3H), 1.26 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.7, 142.8, 137.2, 127.1, 126.4, 123.2, 115.3, 94.9, 45.2, 37.2, 28.9(3C), 21.7. HRMS (ESI): *m/z* calculated for $C_{14}H_{19}NOSH^+$:250.1260, found: 250.1262.

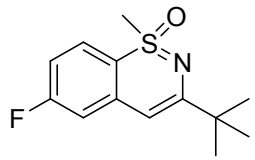
3-(tert-butyl)-6-methoxy-1-methylbenzo[*e*][1,2]thiazine 1-oxide (5e)



Yield 89% (47.2 mg). White solid, m.p. 109-110 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.63 (d, *J* = 8.8 Hz, 1H), 6.88 (dd, *J* = 8.8, 2.4 Hz, 1H), 6.65 (d,

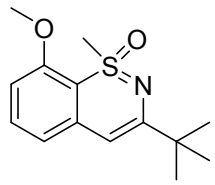
J = 2.3 Hz, 1H), 5.96 (s, 1H), 3.86 (s, 3H), 3.41 (s, 3H), 1.26 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.6, 160.7, 139.8, 125.5, 115.2, 110.9, 107.6, 95.0, 55.6, 45.9, 37.4, 29.0 (3C). HRMS (ESI): *m/z* calculated for $C_{14}H_{19}NO_2SH^+$:266.1209, found: 266.1206.

3-(tert-butyl)-6-fluoro-1-methylbenzo[*e*][1,2]thiazine 1-oxide (5f)



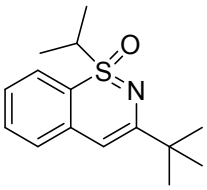
Yield 70% (35.5 mg). Light yellow solid, m.p. 95-96 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 (dd, *J* = 8.8, 5.4 Hz, 1H), 7.03 (td, *J* = 8.4, 2.5 Hz, 1H), 6.92 (dd, *J* = 10.0, 2.5 Hz, 1H), 6.00 (s, 1H), 3.45 (s, 3H), 1.26 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.0, 163.4, 161.5, 140.2, 140.0, 126.4, 126.3, 114.3, 114.1, 113.9, 113.9, 111.6, 111.4, 94.9, 94.9, 45.5, 37.4, 28.8 (3C). ^{19}F NMR (376 MHz, $CDCl_3$) δ -105.9. HRMS (ESI): *m/z* calculated for $C_{13}H_{16}FNOSH^+$:254.1009, found: 254.1011.

3-(tert-butyl)-8-methoxy-1-methylbenzo[*e*][1,2]thiazine 1-oxide (5g)



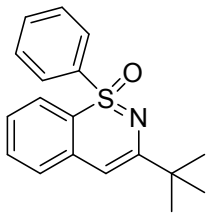
Yield 85% (45.1 mg). White solid, m.p. 155-156 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 (t, *J* = 8.1 Hz, 1H), 6.89 (d, *J* = 8.0 Hz, 1H), 6.75 (d, *J* = 8.0 Hz, 1H), 6.04 (s, 1H), 4.01 (s, 3H), 3.66 (s, 3H), 1.27 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.0, 155.7, 139.1, 132.8, 119.5, 107.9, 106.2, 94.8, 56.2, 48.2, 37.2, 29.0(3C). HRMS (ESI): *m/z* calculated for $C_{14}H_{19}NO_2SH^+$:266.1209, found: 266.1206.

3-(tert-butyl)-1-isopropylbenzo[*e*][1,2]thiazine 1-oxide (5h)



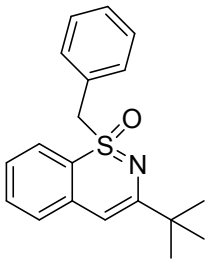
Yield 30% (15.8 mg). Light Yellow solid, m.p. 60-61 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 (d, *J* = 7.9 Hz, 1H), 7.45 (t, *J* = 7.5 Hz, 1H), 7.33 – 7.13 (m, 2H), 5.88 (s, 1H), 3.71 (hept, *J* = 7.1, 6.2 Hz, 1H), 1.47 (d, *J* = 6.4 Hz, 3H), 1.26 (s, 9H), 1.07 (d, *J* = 6.3 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.1, 139.3, 132.5, 126.5, 125.3, 124.3, 113.5, 93.8, 58.0, 37.7, 29.0(3C), 17.1,13.5. HRMS (ESI): *m/z* calculated for $C_{15}H_{21}NOSH^+$:264.1417, found: 264.1414.

3-(tert-butyl)-1-phenylbenzo[*e*][1,2]thiazine 1-oxide (5i)



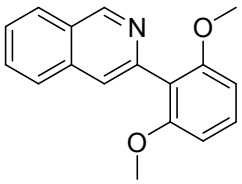
Yield 91% (54.1 mg). Yellow solid, m.p. 87 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 – 7.85 (m, 2H), 7.64 – 7.51 (m, 3H), 7.41 (ddd, *J* = 8.2, 7.0, 1.3 Hz, 1H), 7.32 – 7.24 (m, 2H), 7.15 (ddd, *J* = 8.1, 6.9, 1.2 Hz, 1H), 6.19 (s, 1H), 1.34 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.8, 141.1, 136.7, 133.1, 131.7, 129.1 (2C), 128.9 (2C), 125.7, 124.8, 118.7, 95.0, 37.6, 29.0 (3C). HRMS (ESI): *m/z* calculated for $C_{18}H_{19}NOSH^+$:298.1260, found: 298.1264.

1-benzyl-3-(tert-butyl) benzo[*e*][1,2]thiazine 1-oxide (5j)



Yield 62% (38.6 mg). Amorphous yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58 (d, *J* = 7.9 Hz, 1H), 7.41 (t, *J* = 7.5 Hz, 1H), 7.26 – 7.18 (m, 2H), 7.16 (t, *J* = 7.4 Hz, 2H), 7.09 (d, *J* = 7.5 Hz, 3H), 5.72 (s, 1H), 4.76 – 4.50 (m, 2H), 1.21 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.6, 139.1, 132.7, 131.2 (2C), 128.5, 128.4, 128.2 (2C), 126.4, 125.2, 124.9, 114.3, 94.2, 64.1, 37.5, 29.0 (3C). HRMS (ESI): *m/z* calculated for $C_{19}H_{21}NOSH^+$: 312.1417, found: 312.1414.

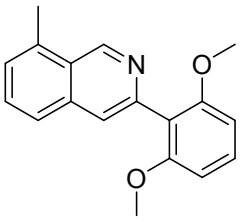
3-(2,6-dimethoxyphenyl)isoquinoline (7a)



Yield 81% (43.0 mg). White solid, m.p. 148 °C. ^{1}H NMR (400 MHz, $CDCL_3$)

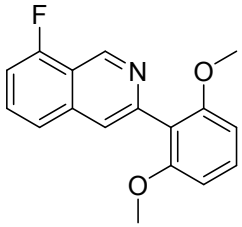
δ 9.39 (s, 1H), 8.00 (d, *J* = 8.1 Hz, 1H), 7.83 (d, *J* = 8.2 Hz, 1H), 7.71 (s, 1H), 7.67 (t, *J* = 7.6 Hz, 1H), 7.58 (t, *J* = 7.4 Hz, 1H), 7.35 (t, *J* = 8.4 Hz, 1H), 6.69 (d, *J* = 8.4 Hz, 2H), 3.73 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.3 (2C), 150.8, 146.4, 135.2, 129.0, 128.6, 126.5, 126.4, 125.9, 125.7, 121.4, 117.9 , 103.1 (2C), 54.9 (2C). HRMS (ESI): *m/z* calculated for $C_{17}H_{15}NO_2H^+$: 266.1176, found: 266.1171.

3-(2,6-dimethoxyphenyl)-8-methylisoquinoline (7b)



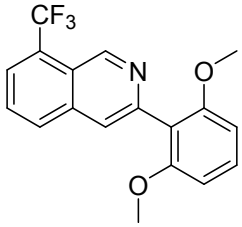
Yield 80% (44.7 mg). White solid, m.p.:158-160 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.59 (s, 1H), 7.69 (s, 1H), 7.67 (d, *J* = 8.3 Hz, 1H), 7.54 (t, *J* = 8.0 Hz, 1H), 7.35 (m, 2H), 6.69 (d, *J* = 8.4 Hz, 2H), 3.73 (s, 6H), 2.81 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 158.3 (2C), 148.8, 147.3, 136.6, 135.3, 129.9, 129.6, 127.6, 126.4, 125.1, 122.8, 119.1, 104.21 (2C), 56.0 (2C), 18.5. HRMS (ESI): *m/z* calculated for $C_{18}H_{17}NO_2H^+$: 280.1332, found: 280.1336.

3-(2,6-dimethoxyphenyl)-8-fluoroisoquinoline (7c)



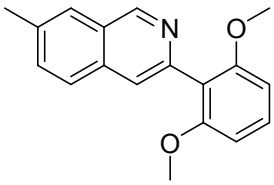
Yield 40% (22.7 mg). Light yellow solid, m.p. 68-69 °C. ^{1}H NMR (400 MHz, $CDCL_3$) δ 9.65 (s, 1H), 7.71 (s, 1H), 7.60 (t, *J* = 4.0 Hz, 2H), 7.35 (t, *J* = 8.4 Hz, 1H), 7.24 – 7.16 (m, 1H), 6.69 (d, *J* = 8.4 Hz, 2H), 3.73 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.30(d, *J* = 256.9 Hz), 157.2 (2C), 147.6, 144.6 (d, *J* = 4.6 Hz), 136.6 (d, *J* = 3.6 Hz), 129.4 (d, *J* = 8.5 Hz), 128.8, 121.6 (d, *J* = 4.5 Hz), 120.8 (d, *J* = 2.8 Hz), 117.6, 116.9 (d, *J* = 15.9 Hz), 109.6 (d, *J* = 19.1 Hz), 103.1 (2C), 54.9 (2C). ^{19}F NMR (376 MHz, $CDCl_3$) δ -123.3. HRMS (ESI): *m/z* calculated for $C_{17}H_{14}FNO_2H^+$: 284.1081, found: 284.1062.

3-(2,6-dimethoxyphenyl)-8-(trifluoromethyl)isoquinoline (7d)



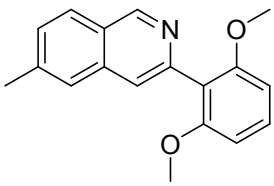
Yield 89% (59.3 mg). Yellow solid, m.p. 101-102 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.46 (s, 1H), 8.12 (d, *J* = 12.0 Hz, 2H), 7.80 (s, 1H), 7.75 (dd, *J* = 8.4, 1.2 Hz, 1H), 7.37 (t, *J* = 8.4 Hz, 1H), 6.70 (d, *J* = 8.4 Hz, 2H), 3.73 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.2 (2C), 150.8, 148.1, 134.2, 130.6 (q, *J* = 32.6 Hz), 129.0, 127.7, 127.0, 124.2, 123.6(q, *J* = 4.5 Hz), 122.0, 121.5 (q, *J* = 3.1 Hz), 117.3, 103.1 (2C), 54.9 (2C). ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.90. HRMS (ESI): *m/z* calculated for $C_{18}H_{14}FNO_2H^+$: 334.1049, found: 334.1046.

3-(2,6-dimethoxyphenyl)-7-methylisoquinoline (7e)



Yield 67% (37.4 mg). Light yellow solid, m.p. 98-99 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.29 (s, 1H), 7.75 (s, 1H), 7.72 (d, *J* = 8.4 Hz, 1H), 7.66 (s, 1H), 7.50 (dd, *J* = 8.4, 1.6 Hz, 1H), 7.34 (t, *J* = 8.4 Hz, 1H), 6.68 (d, *J* = 8.4 Hz, 2H), 3.72 (s, 6H), 2.55 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 158.3 (2C), 151.2, 146.7, 136.7, 134.6, 132.3, 129.5, 127.6, 126.5, 126.2, 122.1, 119.2, 104.2 (2C), 56.0 (2C), 21.8. HRMS (ESI): *m/z* calculated for $C_{18}H_{17}NO_2H^+$: 280.1332, found: 280.1334.

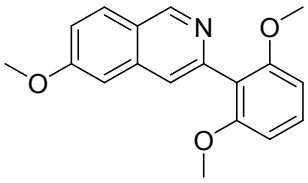
3-(2,6-dimethoxyphenyl)-7-methylisoquinoline (7f)



Yield 56% (31.3 mg). Brown oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.31 (s, 1H), 7.89 (d, *J* = 8.4 Hz, 1H), 7.60 (d, *J* = 9.7 Hz, 2H), 7.42 (dd, *J* = 8.4, 1.2 Hz, 1H), 7.34 (t, *J* = 8.4 Hz, 1H), 6.68 (d, *J* = 8.4 Hz, 2H), 3.73 (s, 6H), 2.54 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.3 (2C), 150.3, 146.3, 139.4, 135.6, 128.5, 128.2, 126.3, 124.8, 124.6, 120.9, 118.0, 103.1 (2C),

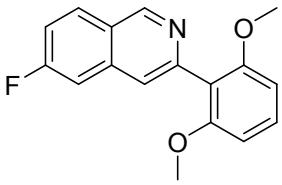
54.9 (2C), 21.1. HRMS (ESI): *m/z* calculated for $C_{18}H_{17}NO_2H^+$: 280.1332, found: 280.1333.

3-(2,6-dimethoxyphenyl)-6-methoxyisoquinoline (7g)



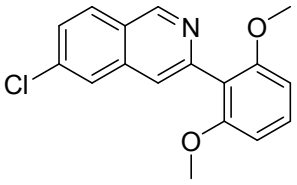
Yield 43% (25.4 mg). Amorphous yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.25 (s, 1H), 7.89 (d, *J* = 9.0 Hz, 1H), 7.60 (s, 1H), 7.34 (t, *J* = 8.4 Hz, 1H), 7.22 (dd, *J* = 9.0, 2.4 Hz, 1 H), 7.07 (d, *J* = 2.4 Hz, 1H), 6.68 (d, *J* = 8.4 Hz, 2H), 3.94 (s, 3H), 3.73 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.9 (2C), 157.3, 156.3, 149.7, 146.5, 137.3, 128.6, 128.3, 122.2, 120.8, 119.2, 103.2, 103.1 (2C), 55.0 (2C), 54.4. HRMS (ESI): *m/z* calculated for $C_{18}H_{17}NO_3H^+$: 296.1281, found: 296.1277.

3-(2,6-dimethoxyphenyl)-6-fluoroisoquinoline (7h)



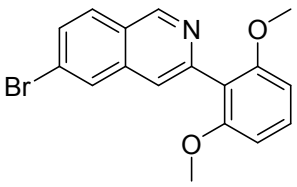
Yield 30% (17.0 mg). Amorphous yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.38 (s, 1H), 8.03 (dd, *J* = 8.0, 4.0 Hz, 1H), 7.68 (s, 1H), 7.43 (dd, *J* = 8.0, 4.0 Hz, 1H), 7.36 (t, *J* = 8.4 Hz, 2H), 6.69 (d, *J* = 8.4 Hz, 2H), 3.74 (s, 6H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 162.3 (d, *J* = 253.0 Hz), 157.2 (2C), 150.3, 147.0, 136.8 (d, *J* = 10.7 Hz), 129.7 (d, *J* = 9.9 Hz), 128.9, 123.6, 121.2 (d, *J* = 5.4 Hz), 117.2, 116.6 (d, *J* = 25.9 Hz), 109.0 (d, *J* = 20.9 Hz), 103.1 (2C), 54.9 (2C). ^{19}F NMR (376 MHz, $CDCl_3$) δ -106.8. HRMS (ESI): *m/z* calculated for $C_{17}H_{14}FNO_2H^+$: 284.1081, found: 284.1067.

6-chloro-3-(2,6-dimethoxyphenyl)isoquinoline (7i)



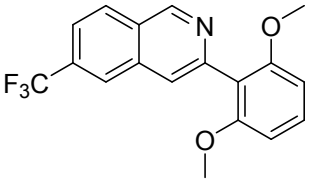
Yield 40% (24.0 mg). Light yellow solid, m.p.: 97-98 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.34 (s, 1H), 7.93 (d, *J* = 8.7 Hz, 1H), 7.81 (d, *J* = 2 Hz, 1H), 7.62 (s, 1H), 7.52 (dd, *J* = 8.7, 2.0 Hz, 1H), 7.35 (t, *J* = 8.4 Hz, 1H), 6.68 (d, *J* = 8.4 Hz, 2H), 3.73 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.2 (2C), 150.5, 147.6, 135.9, 135.2, 128.8, 128.2, 127.0, 124.5, 120.5, 117.5, 103.1 (2C), 54.9 (2C). HRMS (ESI): *m/z* calculated for $C_{17}H_{14}ClNO_2H^+$: 300.0786, found: 300.0788.

6- bromo-3-(2,6-dimethoxyphenyl)isoquinoline (7j)



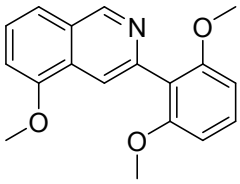
Yield 71% (48.9 mg). White solid, m.p. 68-69 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.34 (s, 1H), 7.99 (d, *J* = 1.6 Hz, 1H), 7.86 (d, *J* = 8.8 Hz, 1H), 7.65 (dd, *J* = 8.8, 1.6 Hz, 1H), 7.61 (s, 1H), 7.35 (t, *J* = 8.4 Hz, 1H), 6.68 (d, *J* = 8.4 Hz, 2H), 3.73 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.2 (2C), 151.7, 148.7, 137.3, 130.5, 129.9 129.2, 128.9, 125.7, 124.9, 121.5, 118.5, 104.2 (2C), 56.0 (2C). HRMS (ESI): *m/z* calculated for $C_{17}H_{14}BrNO_2H^+$: 344.0281, found: 344.0279.

3-(2,6-dimethoxyphenyl)-6-(trifluoromethyl)isoquinoline (7k)



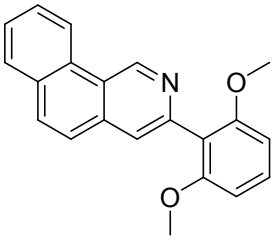
Yield 89% (24.0 mg). White solid, m.p. 98-99 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.73 (s, 1H), 8.00 (d, *J* = 8.4 Hz, 1H), 7.91 (d, *J* = 7.2 Hz, 1H), 7.78 (s, 1H), 7.68 (t, *J* = 7.8 Hz, 1H), 7.37 (t, *J* = 8.4 Hz, 1H), 6.70 (d, *J* = 8.4 Hz, 2H), 3.74 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.2 (2C), 147.6, 147.3 (q, *J* = 3.1 Hz), 135.8, 130.6, 129.6, 129.0, 127.3, 125.57 (q, *J* = 31.6 Hz), 124.3 (q, *J* = 6.1 Hz), 121.8, 121.7, 117.2, 103.1 (2C),54.9 (2C). ^{19}F NMR (376 MHz, $CDCl_3$) δ -58.7. HRMS (ESI): *m/z* calculated for $C_{18}H_{14}F_3NO_2H^+$: 334.1049, found: 344.1052.

3-(2,6-dimethoxyphenyl)-5-methoxyisoquinoline (7l)



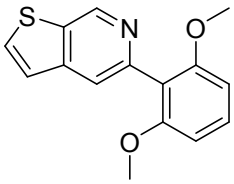
Yield 74% (43.7 mg). Yellow solid, m.p. 138-139 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.33 (s, 1H), 8.06 (s, 1H), 7.56 (d, *J* = 8.2 Hz, 1H), 7.48 (t, *J* = 8.0 Hz, 1H), 7.33 (t, *J* = 8.4 Hz, 1H), 6.96 (d, *J* = 7.6 Hz, 1H), 6.67 (d, *J* = 8.4 Hz, 2H), 3.97 (s, 3H), 3.72 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.3 (2C), 157.2, 149.2, 144.3, 131.0, 128.5, 127.5, 127.2, 122.4, 121.3, 117.8, 103.6, 103.1 (2C), 54.9 (2C), 54.4. HRMS (ESI): *m/z* calculated for $C_{18}H_{17}NO_3H^+$: 296.1281, found: 296.1279.

3-(2,6-dimethoxyphenyl)benzo[h]isoquinoline (7m)



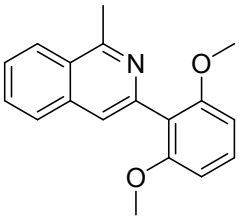
Yield 73% (46.0 mg). White solid, m.p. 202-203 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.16 (s, 1H), 8.81 (d, *J* = 8.2 Hz, 1H), 7.89 (d, *J* = 8.8 Hz, 2H), 7.77 (s, 1H), 7.75 – 7.59 (m, 3H), 7.37 (t, *J* = 8.4 Hz, 1H), 6.71 (d, *J* = 8.4 Hz, 2H), 3.75 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.3 (2C), 148.6, 145.1, 135.2, 131.1, 130.3, 128.7, 128.5, 127.8, 126.7, 126.1, 124.2, 122.6, 122.3, 121.0, 117.8, 103.2 (2C), 55.0 (2C). HRMS (ESI): *m/z* calculated for $C_{21}H_{17}NO_2H^+$: 316.1332, found: 316.1331.

5-(2,6-dimethoxyphenyl)thieno[2,3-*c*]pyridine (7n)



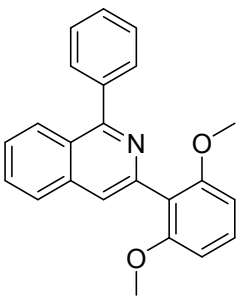
Yield 30% (43.7 mg). Yellow solid, m.p. 170-171 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.28 (s, 1H), 7.75 (s, 1H), 7.71 (d, *J* = 5.4 Hz, 1H), 7.40 – 7.31 (m, 2H), 6.68 (d, *J* = 8.3 Hz, 2H), 3.73 (s, 6H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 158.2, 147.5, 145.4, 144.0, 134.8, 131.8, 129.6, 123.2, 120.1, 118.9, 104.1 (2C), 56.0 (2C). HRMS (ESI): *m/z* calculated for $C_{15}H_{13}NO_2SH^+$: 272.0740, found: 272.0742.

3-(2,6-dimethoxyphenyl)-1-methylisoquinoline (7o)



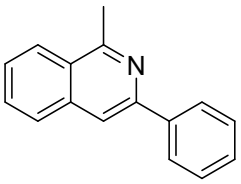
Yield 95% (53.1 mg). White solid, m.p. 196-197 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.13 (d, *J* = 8.4 Hz, 1H), 7.80 (d, *J* = 8.0 Hz, 1H), 7.63 (t, *J* = 7.2 Hz, 1H), 7.55 (t, *J* = 7.2 Hz, 2H), 7.33 (t, *J* = 8.4 Hz, 1H), 6.68 (d, *J* = 8.4 Hz, 2H), 3.72 (s, 6H), 3.03 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 158.4 (2C), 158.0, 146.5, 136.4, 129.6, 129.4, 127.4, 126.6, 126.3, 125.6, 120.9, 119.5, 104.4 (2C), 56.0 (2C), 22.5. HRMS (ESI): *m/z* calculated for $C_{18}H_{17}NO_2H^+$: 280.1332, found: 280.1335.

3-(2,6-dimethoxyphenyl)-1-phenylisoquinoline (7p)



Yield 95% (64.9 mg). White solid, m.p. 142-143 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.11 (d, *J* = 8.4 Hz, 1H), 7.89 (d, *J* = 8.2 Hz, 1H), 7.76 (d, *J* = 7.6 Hz, 2H), 7.72 (s, 1H), 7.68 – 7.62 (m, 1H), 7.56 – 7.43 (m, 4H), 7.32 (t, *J* = 8.4 Hz, 1H), 6.68 (d, *J* = 8.4 Hz, 2H), 3.77 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.0 (2C), 158.5, 146.9, 139.9, 137.3, 130.3 (2C), 129.6, 129.5, 128.3, 128.2 (2C), 127.5, 127.2, 126.8, 125.6, 121.8, 104.5 (2C), 56.1 (2C). HRMS (ESI): *m/z* calculated for $C_{23}H_{19}NO_2H^+$:342.1489, found: 342.1487.

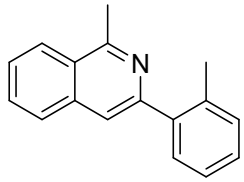
1-methyl-3-phenylisoquinoline (8a)



Yield 56% (24.6 mg). Yellow wax. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.14 (t, *J* = 6.8 Hz, 3H), 7.92 (s, 1H), 7.86 (d, *J* = 8.2 Hz, 1H), 7.67 (t, *J* = 7.4 Hz, 1H),

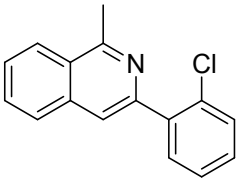
7.57 (t, *J* = 7.6 Hz, 1H), 7.51 (t, *J* = 7.6 Hz, 2H), 7.41 (t, *J* = 7.4 Hz, 1H), 3.05 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.5, 148.9, 138.7, 135.7, 129.0, 127.7 (2C), 127.3, 126.6, 126.0 (2C), 125.8, 125.5, 124.6, 114.3, 21.6. HRMS (ESI): *m/z* calculated for $C_{16}H_{13}NH^+$:220.1121, found: 220,1122.

1-methyl-3-(*o*-tolyl)isoquinoline (8b)



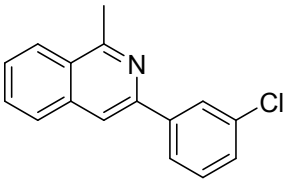
Yield 68% (24.6 mg). Yellow wax. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.17 (d, *J* = 8.4 Hz, 1H), 7.84 (d, *J* = 8.0 Hz, 1H), 7.70 (t, *J* = 7.4 Hz, 1H), 7.65 – 7.56 (m, 2H), 7.53 – 7.46 (m, 1H), 7.39 – 7.24 (m, 3H), 3.04 (s, 3H), 2.43 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 158.0, 152.5, 140.8, 136.4, 136.2, 130.8, 130.1, 130.0, 128.0, 127.4, 126.9, 126.1, 125.9, 125.7, 118.8, 22.5, 20.5. HRMS (ESI): *m/z* calculated for $C_{17}H_{15}NH^+$:234.1283, found: 234.1282.

3-(2-chlorophenyl)-1-methylisoquinoline(8c)



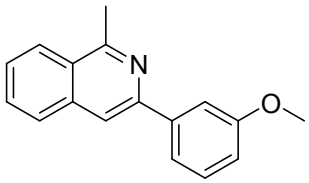
Yield 66% (33.5 mg). Yellow wax. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.17 (d, *J* = 8.4 Hz, 1H), 7.91 – 7.81 (m, 2H), 7.74 – 7.66 (m, 2H), 7.62 (t, *J* = 7.6 Hz, 1H), 7.54 – 7.44 (m, 1H), 7.42 – 7.28 (m, 2H), 3.04 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.4, 148.0, 138.5, 134.9, 131.5, 130.9, 129.1, 129.1, 128.1, 126.6, 126.2, 125.9, 125.4, 124.6, 118.9, 21.4. HRMS (ESI): *m/z* calculated for $C_{16}H_{12}ClNH^+$:254.0731, found: 254.0729.

3-(3-chlorophenyl)-1-methylisoquinoline (8d)



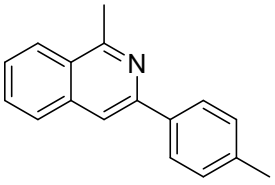
Yield 52% (26.4 mg). Yellow wax. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.22 – 8.08 (m, 2H), 8.01 (d, *J* = 7.6 Hz, 1H), 7.92 (s, 1H), 7.87 (d, *J* = 8.2 Hz, 1H), 7.70 (t, *J* = 7.6 Hz, 1H), 7.60 (t, *J* = 7.6 Hz, 1H), 7.47 – 7.32 (m, 2H), 3.05 (s, 3H); ^{13}C NMR (150 MHz, $CDCl_3$) δ 158.8, 148.3, 141.5, 136.6, 134.8, 130.3, 129.9, 128.3, 127.7, 127.2, 127.1, 126.8, 125.7, 125.0, 115.6, 29.7. HRMS (ESI): *m/z* calculated for $C_{16}H_{12}ClNH^+$:254.0731, found: 254.0733.

3-(3-methoxyphenyl)-1-methylisoquinoline (8e)



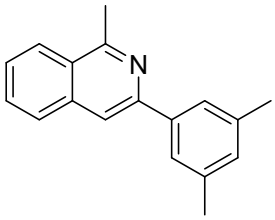
Yield 57% (28.4 mg). Yellow solid, m.p. 66-67 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.12 (d, *J* = 8.4 Hz, 1H), 7.91 (s, 1H), 7.85 (d, *J* = 8.0 Hz, 1H), 7.74 (s, 1H), 7.68 (dd, *J* = 17.4, 7.6 Hz, 2H), 7.57 (ddd, *J* = 8.2, 6.8, 1.2 Hz, 1H), 7.41 (t, *J* = 8.0 Hz, 1H), 6.96 (dd, *J* = 8.4, 2.8 Hz, 1H), 3.93 (s, 3H), 3.04 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.0, 157.5, 148.7, 140.3, 135.7, 129.0, 128.6, 126.6, 125.8, 125.6, 124.6, 118.7, 114.4, 113.2, 111.3, 54.3, 21.6. HRMS (ESI): *m/z* calculated for $C_{17}H_{15}NOH^+$:250.1226, found: 250.1228.

1-methyl-3-(*p*-tolyl)isoquinoline (8f)



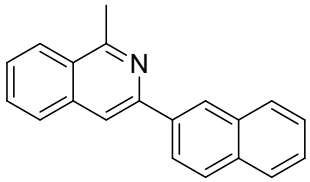
Yield 49% (22.9 mg). Yellow oil. ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.11 (d, *J* = 8.4 Hz, 1H), 8.05 (d, *J* = 7.8 Hz, 2H), 7.89 (s, 1H), 7.84 (d, *J* = 8.2 Hz, 1H), 7.65 (t, *J* = 7.4 Hz, 1H), 7.55 (t, *J* = 7.4 Hz, 1H), 7.31 (d, *J* = 7.8 Hz, 2H), 3.04 (s, 3H), 2.43 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 157.4, 149.0, 137.1, 136.0, 135.8, 128.9, 128.4 (2C), 126.5, 125.8 (2C), 125.5, 125.4, 124.6, 113.7, 21.6, 20.2. HRMS (ESI): *m/z* calculated for $C_{17}H_{15}NH^+$:234.1277, found: 234.1279.

3-(3,5-dimethylphenyl)-1-methylisoquinoline (8g)



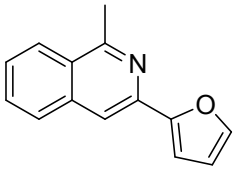
Yield 46% (22.8 mg). White solid, m.p. 92-93 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.13 (dd, *J* = 8.4, 1.0 Hz, 1H), 7.91 (s, 1H), 7.85 (d, *J* = 8.2 Hz, 1H), 7.76 (s, 2H), 7.67 (ddd, *J* = 8.2, 6.8, 1.2 Hz, 1H), 7.56 (ddd, *J* = 8.2, 6.8, 1.2 Hz, 1H), 7.05 (s, 1H), 3.06 (s, 3H), 2.44 (s, 6H). ^{13}C NMR (150 MHz, $CDCl_3$) δ 158.4, 150.3, 139.6, 138.2 (2C), 136.8, 130.0, 130.0, 127.6, 126.6, 126.5, 125.6, 124.8 (2C), 115.3, 29.7, 21.5 (2C). HRMS (ESI): *m/z* calculated for $C_{18}H_{17}NH^+$:248.1434, found: 248.1432.

1-methyl-3-(naphthalen-2-yl)isoquinoline(8h)



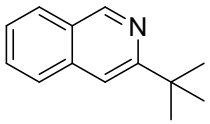
Yield 75% (40.4 mg). Brown solid, m.p. 98-99 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.68 (s, 1H), 8.27 (d, *J* = 8.4 Hz, 1H), 8.16 (d, *J* = 8.4 Hz, 1H), 8.08 (s, 1H), 7.98 (t, *J* = 9.6 Hz, 2H), 7.94 – 7.84 (m, 2H), 7.70 (t, *J* = 7.6 Hz, 1H), 7.60 (t, *J* = 7.6 Hz, 1H), 7.55 – 7.45 (m, 2H), 3.11 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.7, 148.6, 135.8, 135.8, 132.7, 132.4, 129.2, 127.7, 127.3, 126.7, 126.6, 125.9, 125.6, 125.2, 125.2, 125.1, 124.7, 123.8, 114.6, 21.6. HRMS (ESI): *m/z* calculated for $C_{20}H_{15}NH^+$:270.1277, found: 270.1278.

3-(furan-2-yl)-1-methylisoquinoline (8i)



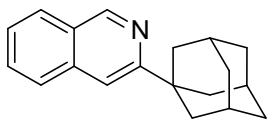
Yield 33% (13.8 mg). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09 (d, *J* = 8.2 Hz, 1H), 7.88 (s, 1H), 7.82 (d, *J* = 8.2 Hz, 1H), 7.65 (ddd, *J* = 8.2, 6.8, 1.2 Hz, 1H), 7.59 – 7.51 (m, 2H), 7.13 (d, *J* = 3.6 Hz, 1H), 6.55 (dd, *J* = 3.4, 1.8 Hz, 1H), 3.00 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.9, 153.2, 141.9, 141.1, 135.5, 129.3, 126.6, 125.7, 125.6, 124.7, 112.0, 110.9, 107.1, 21.5. HRMS (ESI): *m/z* calculated for $C_{14}H_{11}NOH^+$:210.0913, found: 210.0915.

3-(tert-butyl)isoquinoline (8j)



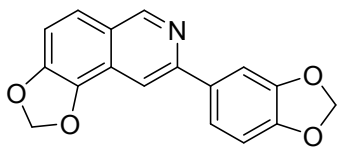
Yield 32% (11.9 mg). Yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.24 (s, 1H), 7.93 (d, *J* = 8.4 Hz, 1H), 7.78 (d, *J* = 8.2 Hz, 1H), 7.69 – 7.58 (m, 2H), 7.53 (t, *J* = 7.6 Hz, 1H), 1.47 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.8, 150.4, 135.5, 129.1, 126.3, 125.8, 125.5, 125.4, 113.2, 36.0, 29.2 (3C). HRMS (ESI): *m/z* calculated for $C_{13}H_{15}NH^+$:186.1277, found: 186.1272.

3-((3r,5r,7r)-adamantan-1-yl)isoquinoline (8k)



Yield 46% (24.2 mg). Yellow solid, m.p. 63-64 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.24 (s, 1H), 7.92 (d, *J* = 8.2 Hz, 1H), 7.77 (d, *J* = 8.2 Hz, 1H), 7.63 (t, *J* = 7.6 Hz, 1H), 7.52 (d, *J* = 7.6 Hz, 2H), 2.17 – 2.13 (m, 3H), 2.09 (d, *J* = 2.8 Hz, 6H), 1.82 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.7, 150.5, 135.6, 129.0, 126.3, 125.9, 125.6, 125.3, 113.4, 40.9 (3C), 37.2, 35.9 (3C), 27.8 (3C). HRMS (ESI): *m/z* calculated for $C_{19}H_{21}NH^+$:264.1747, found: 264.1751.

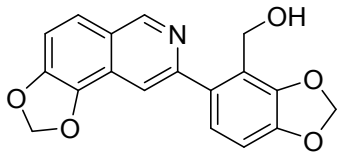
8-(benzo[d][1,3]dioxol-5-yl)-[1,3]dioxolo[4,5-f]isoquinoline (A)



Total yield 21% (12.3 mg). Yellow solid, m.p. 160-162 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 9.27 (s, 1H), 7.98 (s, 1H), 7.81 – 7.71 (m, 3H), 7.45 (d, *J* = 8.6 Hz, 1H), 7.03 (d, *J* = 8.2 Hz, 1H), 6.33 (d, *J* = 1.3 Hz, 2H), 6.10 (d, *J* = 1.3 Hz, 2H); ^{13}C NMR (150 MHz, DMSO-d_6) δ 153.1, 149.7, 148.4, 148.4, 147.4, 140.3, 133.4, 124.0, 123.4, 122.2, 121.2, 111.9, 108.9, 107.2, 107.0, 102.9, 101.7. HRMS (ESI): *m/z* calculated for $C_{17}H_{11}NO_4H^+$:294.0761, found:

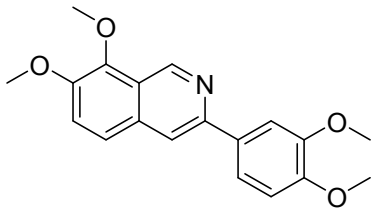
294.0763.

Decumbenine B



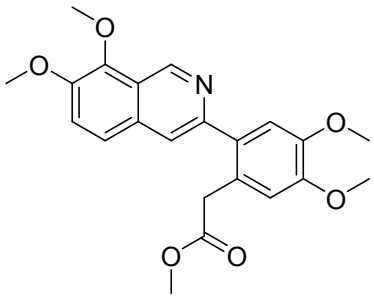
Total yield 68% (44.0 mg). White solid, m.p. 224-225 °C. ^{1}H NMR (400 MHz, DMSO-d_6) δ 9.29 (s, 1H), 7.87 (s, 1H), 7.81 (d, J = 8.6 Hz, 1H), 7.50 (d, J = 8.5 Hz, 1H), 7.20 (d, J = 8.1 Hz, 1H), 6.97 (d, J = 8.0 Hz, 1H), 6.32 (s, 2H), 6.12 (s, 2H), 5.54 (t, J = 5.7 Hz, 1H), 4.42 (d, J = 5.5 Hz, 2H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 152.1, 151.1, 147.2, 147.1, 146.6, 139.9, 134.5, 124.0, 123.2, 121.6, 121.3, 112.0, 111.1, 111.1, 107.6, 102.6, 101.3, 55.2. HRMS (ESI): *m/z* calculated for $C_{18}H_{13}NO_5Na^+$:346.0686; found: 346.0688.

3-(3,4-dimethoxyphenyl)-7,8-dimethoxyisoquinoline (F)



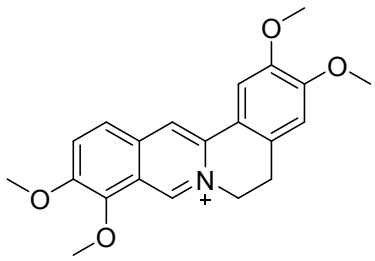
Yield 37% (24.1 mg). Yellow solid, m.p. 122-123 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.60 (s, 1H), 7.93 (s, 1H), 7.76 (d, J = 2.0 Hz, 1H), 7.66–7.58 (m, 2H), 7.50 (d, J = 9.2 Hz, 1H), 6.99 (d, J = 8.4 Hz, 1H), 4.08 (s, 3H), 4.04 (s, 3H), 4.02 (s, 3H), 3.95 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 149.5, 149.3, 149.1, 148.6, 147.0, 144.0, 132.7, 132.4, 122.9, 122.9, 120.5, 119.1, 115.2, 111.3, 109.9, 61.8, 57.1, 56.0, 56.0. HRMS (ESI): *m/z* calculated for $C_{19}H_{19}NO_4H^+$: 326.1387, found: 326.1372.

methyl 2-(2-(7,8-dimethoxyisoquinolin-3-yl)-4,5-dimethoxyphenyl)acetate (G)



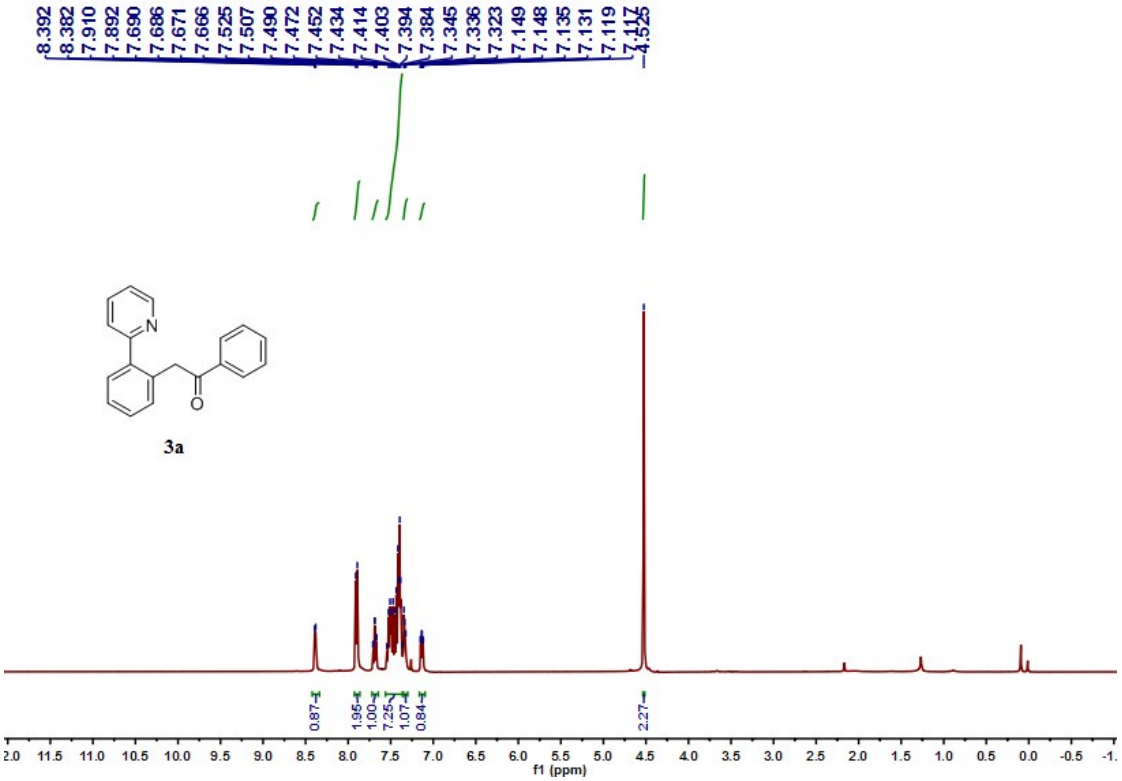
Yield 35% (27.8 mg). Yellow oil. ^{1}H NMR (400 MHz, DMSO-d_6) δ 9.37 (s, 1H), 7.90 (s, 1H), 7.76 (s, 2H), 7.14 (s, 1H), 6.98 (s, 1H), 3.99 (d, J = 5.9 Hz, 6H), 3.82 (d, J = 5.1 Hz, 6H), 3.80 (s, 2H), 3.48 (s, 3H). ^{13}C NMR (100MHz, DMSO-d_6) δ 172.3, 151.0, 149.0, 148.8, 148.1, 145.8, 143.2, 133.0, 132.1, 125.7, 123.5, 122.3, 121.3, 119.3, 115.8, 114.0, 61.7, 57.3, 56.2, 56.2, 51.8, 38.9. HRMS (ESI): *m/z* calculated for $C_{22}H_{23}NO_6H^+$: 398.1598, found: 398.1599.

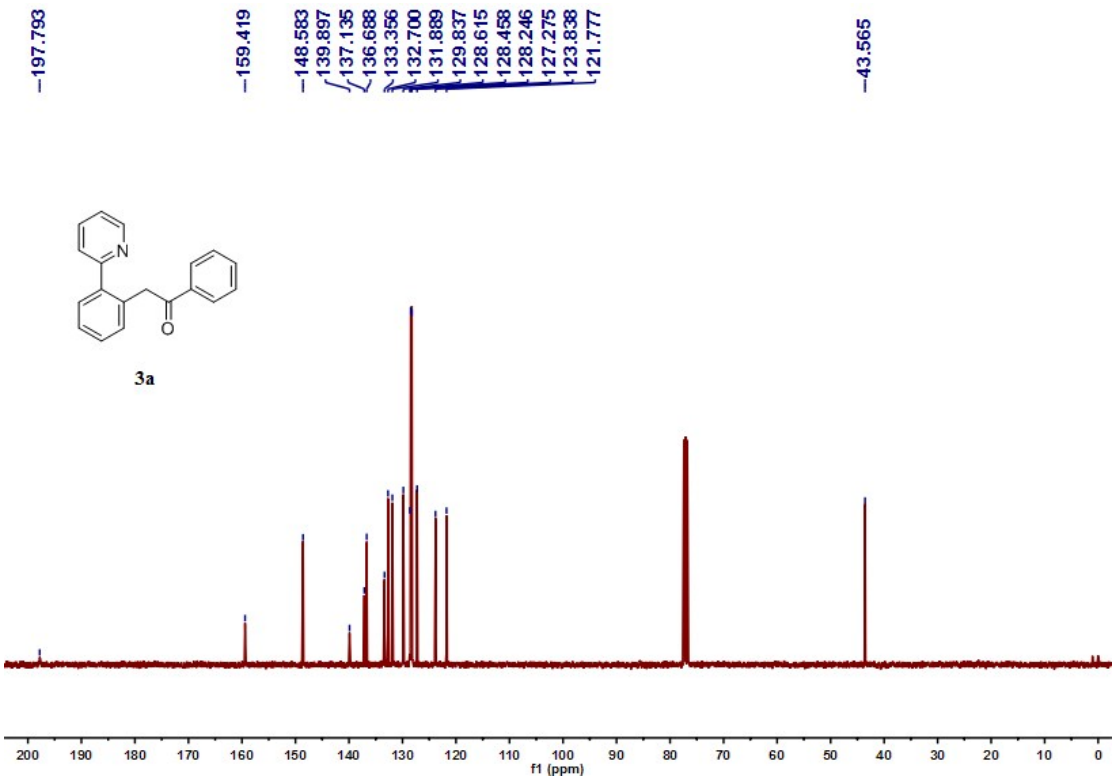
Palmatine

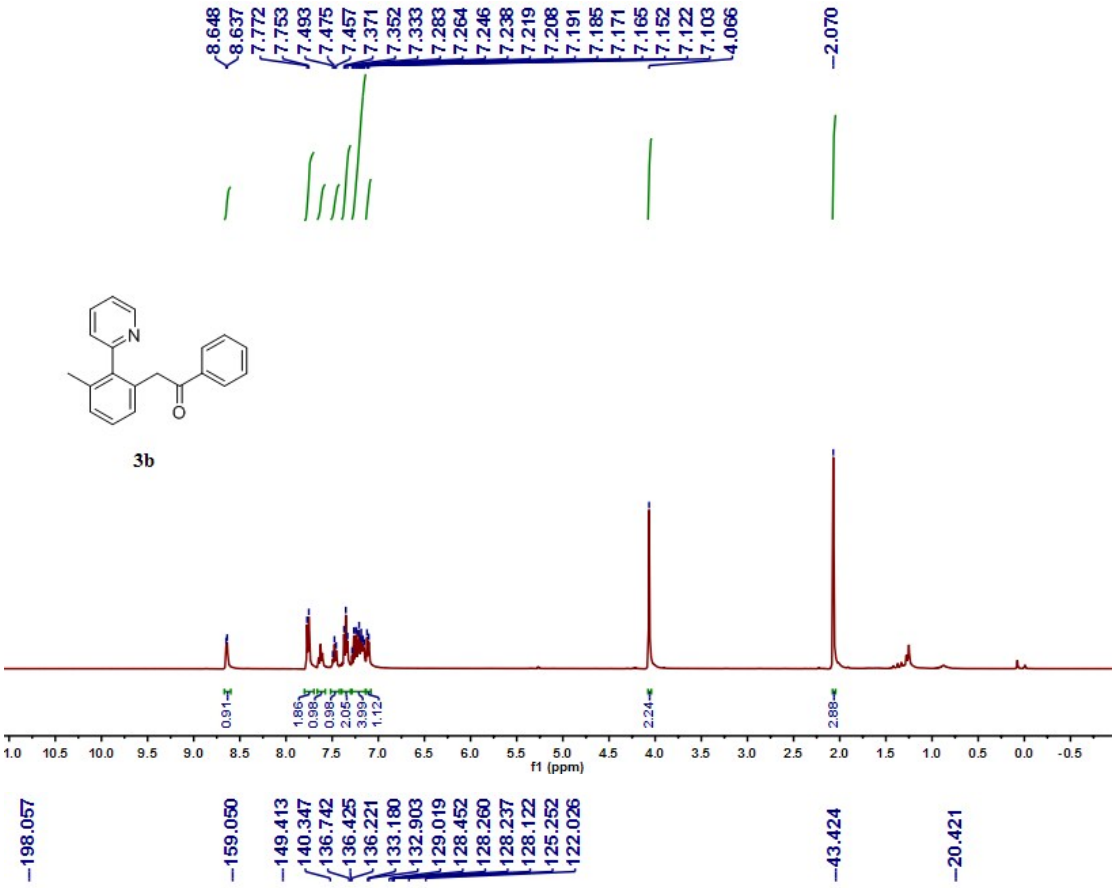


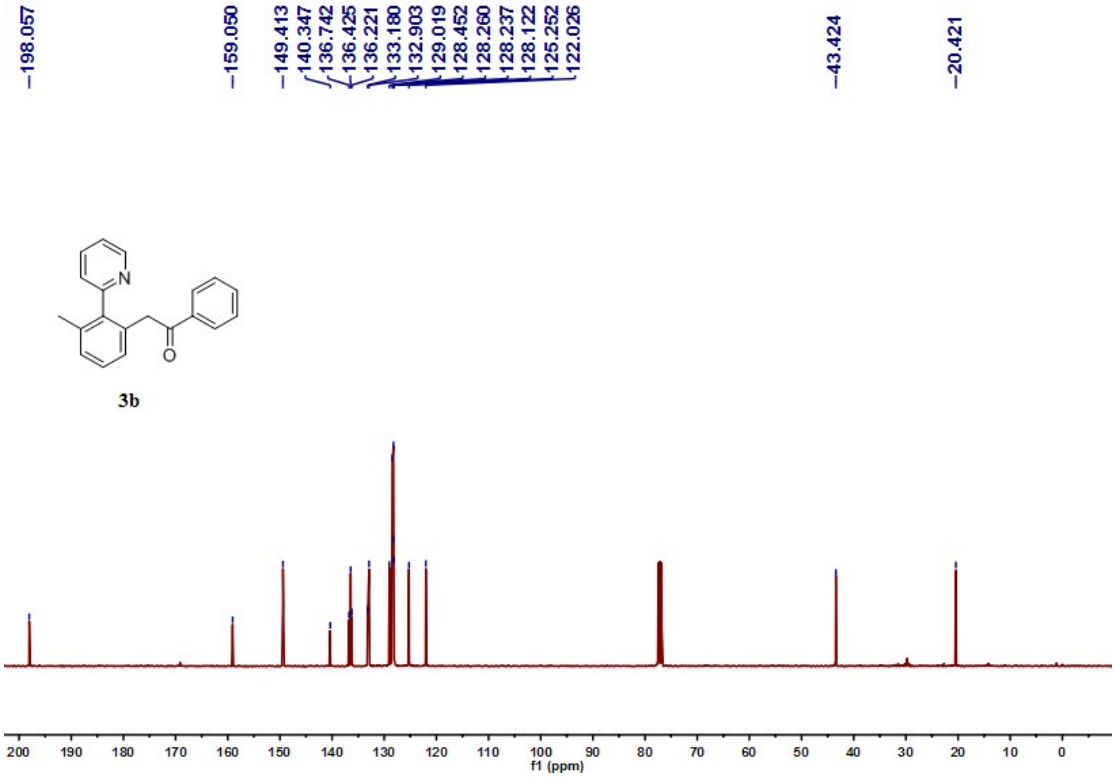
Yellow solid, m.p. 173-174 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 10.19 (s, 1H), 8.73 (s, 1H), 8.00 (d, J = 8.6 Hz, 1H), 7.69 (d, J = 8.5 Hz, 1H), 7.46 (s, 1H), 6.72 (s, 1H), 5.24 – 5.15 (m, 2H), 4.25 (s, 3H), 4.08 (s, 3H), 4.02 (s, 3H), 3.95 (s, 3H), 3.29 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 152.1, 150.3, 149.4, 146.0, 144.6, 137.8, 133.7, 128.1, 125.9, 123.8, 121.9, 120.3, 118.9, 110.7, 108.7, 62.6, 57.2, 57.0, 56.3, 29.8, 27.3. HRMS (ESI): *m/z* calculated for $C_{21}H_{22}NO_4^+$ [M-Cl$^-$]:352.1543, found: 352.1540.

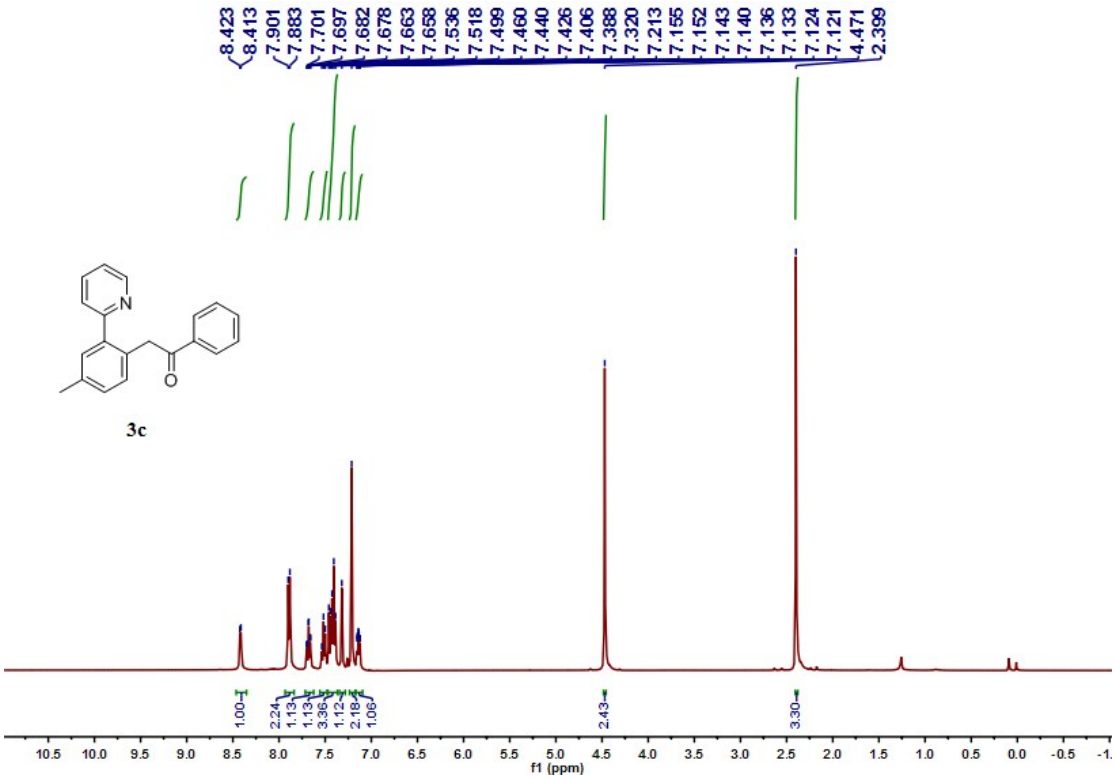
12. ^{1}H NMR, ^{13}C NMR and ^{19}F NMR Spectra of Products

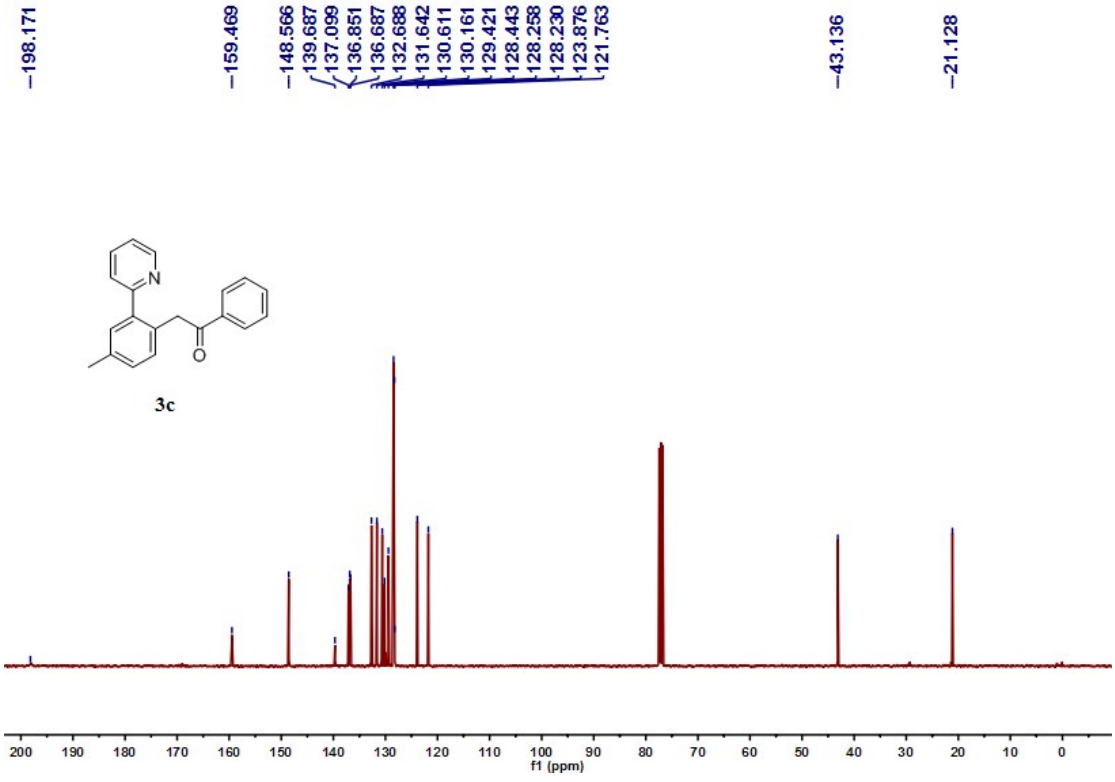


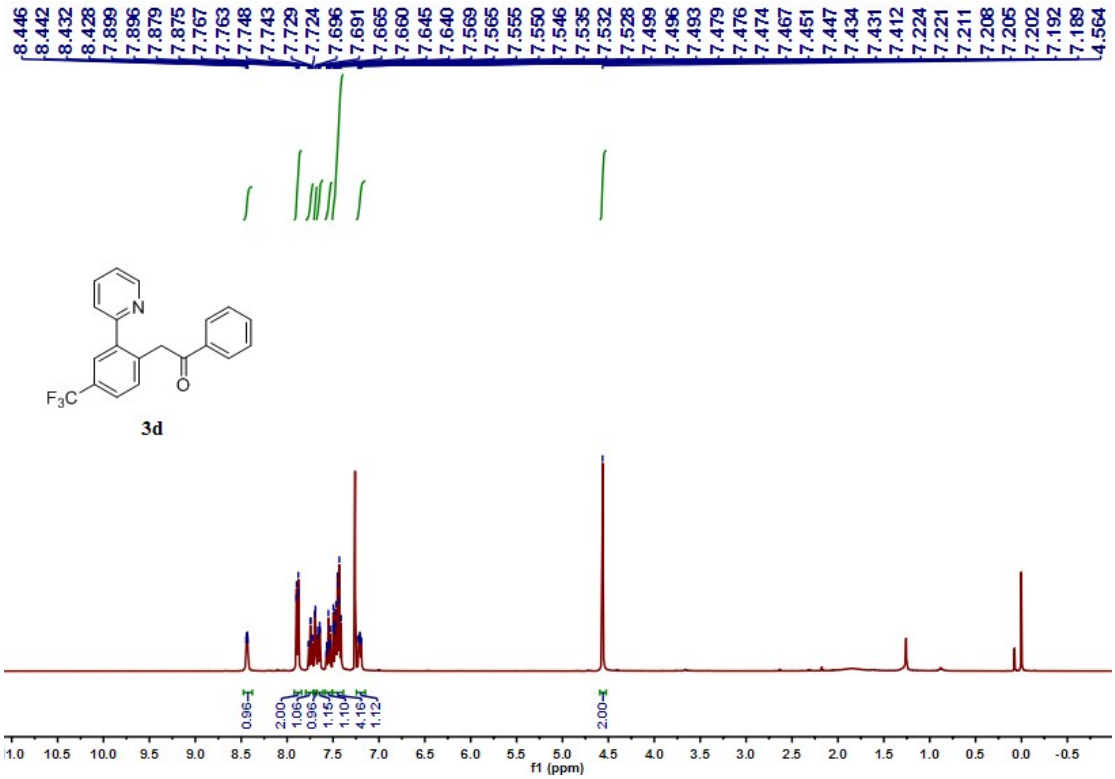


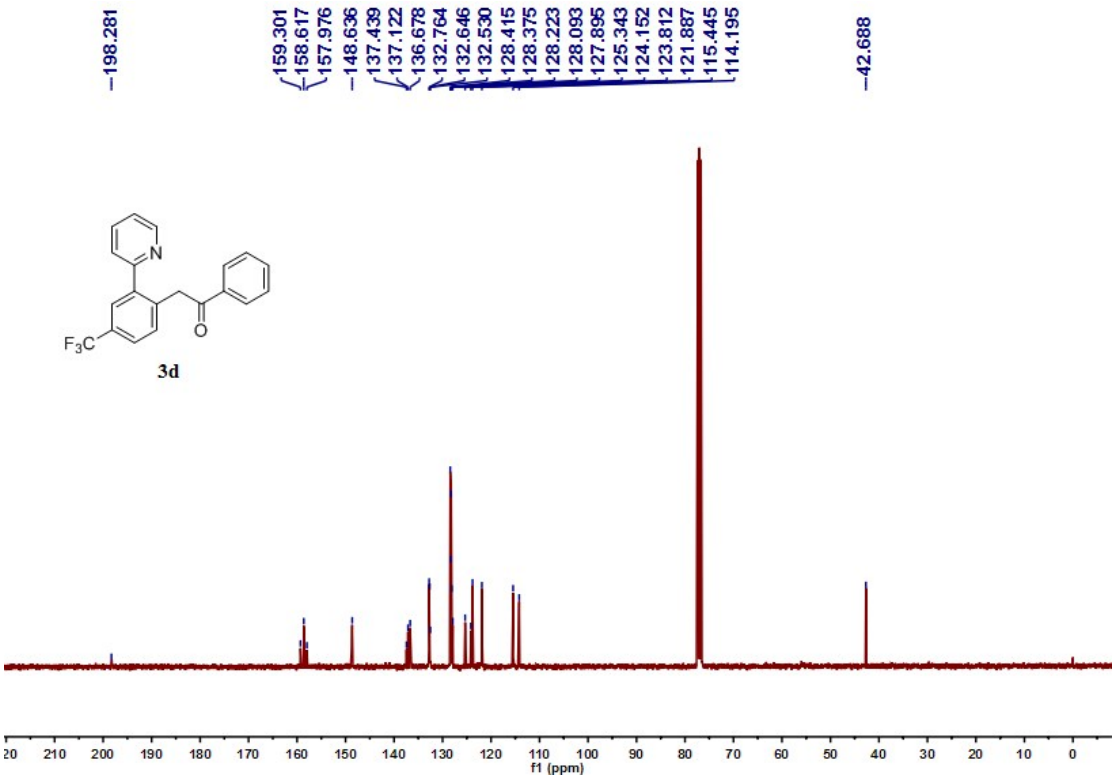

8.648
8.637
7.772
7.753
7.493
7.475
7.457
7.371
7.352
7.333
7.283
7.264
7.246
7.238
7.219
7.208
7.191
7.185
7.171
7.165
7.152
7.122
7.103
4.066
2.070
3b
0.91
1.86
0.98
0.98
2.05
3.99
1.12
2.24
2.88
f1 (ppm)

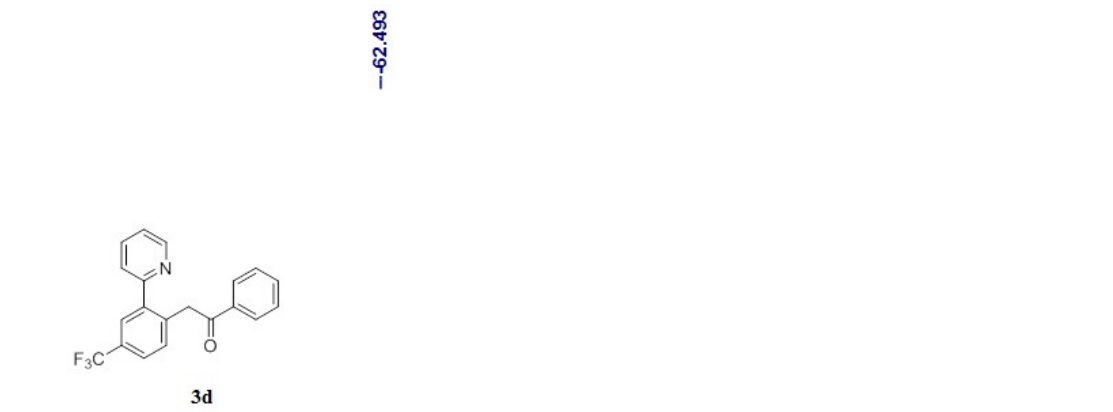

198.057
159.050
149.413
140.347
136.742
136.425
136.221
133.180
132.903
129.019
128.452
128.260
128.237
128.122
125.252
122.026
43.424
20.421
3b
f1 (ppm)


8.423
8.413
7.901
7.883
7.701
7.697
7.682
7.678
7.663
7.658
7.536
7.518
7.499
7.460
7.440
7.426
7.406
7.388
7.320
7.213
7.155
7.152
7.143
7.140
7.136
7.133
7.124
7.121
4.471
2.399
3c
1.00
2.24
1.13
1.13
3.36
1.12
2.18
1.06
2.43
3.30
f1 (ppm)

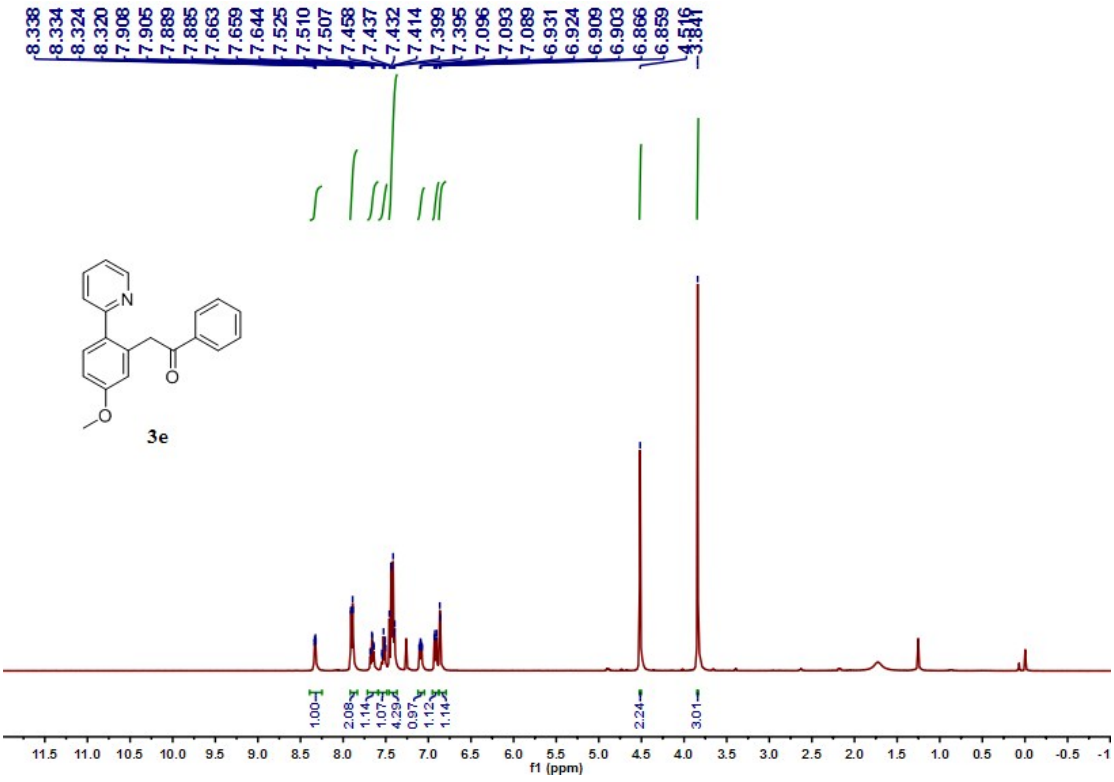

198.171
159.469
148.566
139.687
137.099
136.851
136.687
132.688
131.642
130.611
130.161
129.421
128.443
128.258
128.230
123.876
121.763
43.136
21.128
3c
f1 (ppm)


8.446
8.442
8.432
8.428
7.899
7.896
7.879
7.875
7.767
7.763
7.748
7.743
7.729
7.724
7.696
7.691
7.665
7.660
7.645
7.640
7.569
7.565
7.555
7.550
7.546
7.535
7.532
7.528
7.499
7.496
7.493
7.479
7.476
7.474
7.467
7.451
7.447
7.434
7.431
7.412
7.224
7.221
7.211
7.208
7.205
7.202
7.192
7.189
4.564
N
O
F3C
3d
0.96
2.00
1.06
0.96
1.15
1.10
4.16
1.12
2.00
f1 (ppm)

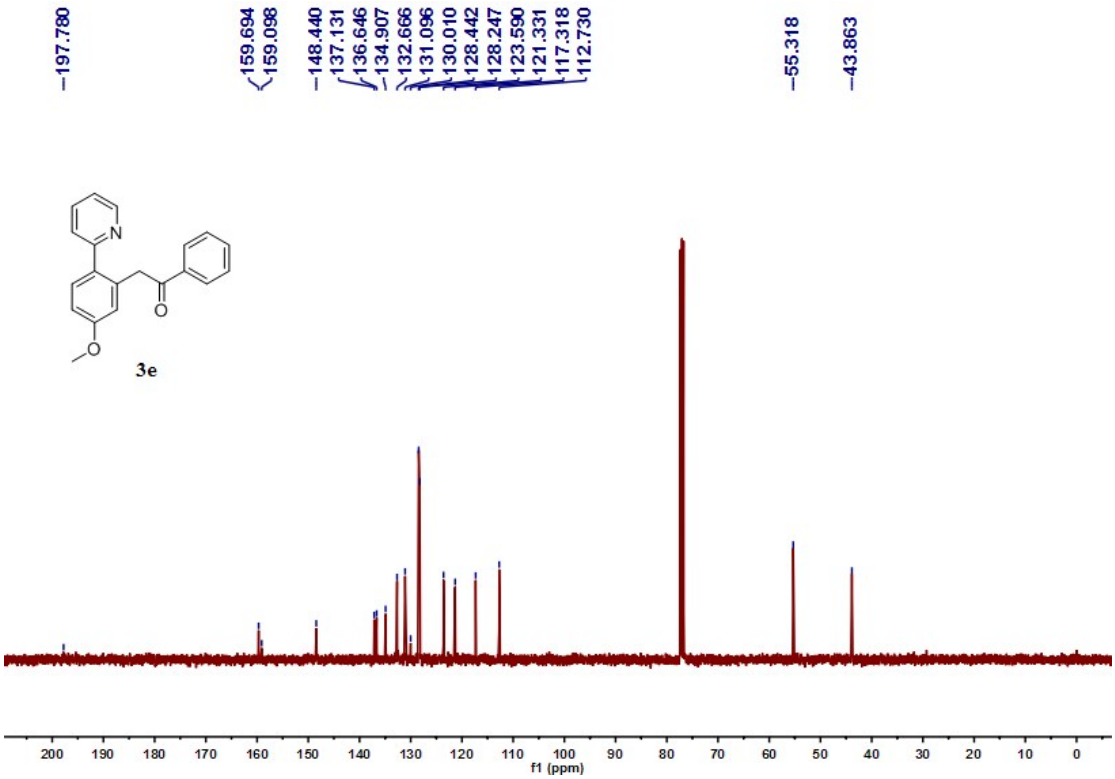

198.281
159.301
158.617
157.976
148.636
137.439
137.122
136.678
132.764
132.646
132.530
128.415
128.375
128.223
128.093
127.895
125.343
124.152
123.812
121.887
115.445
114.195
42.688
N
O
F3C
3d
f1 (ppm)

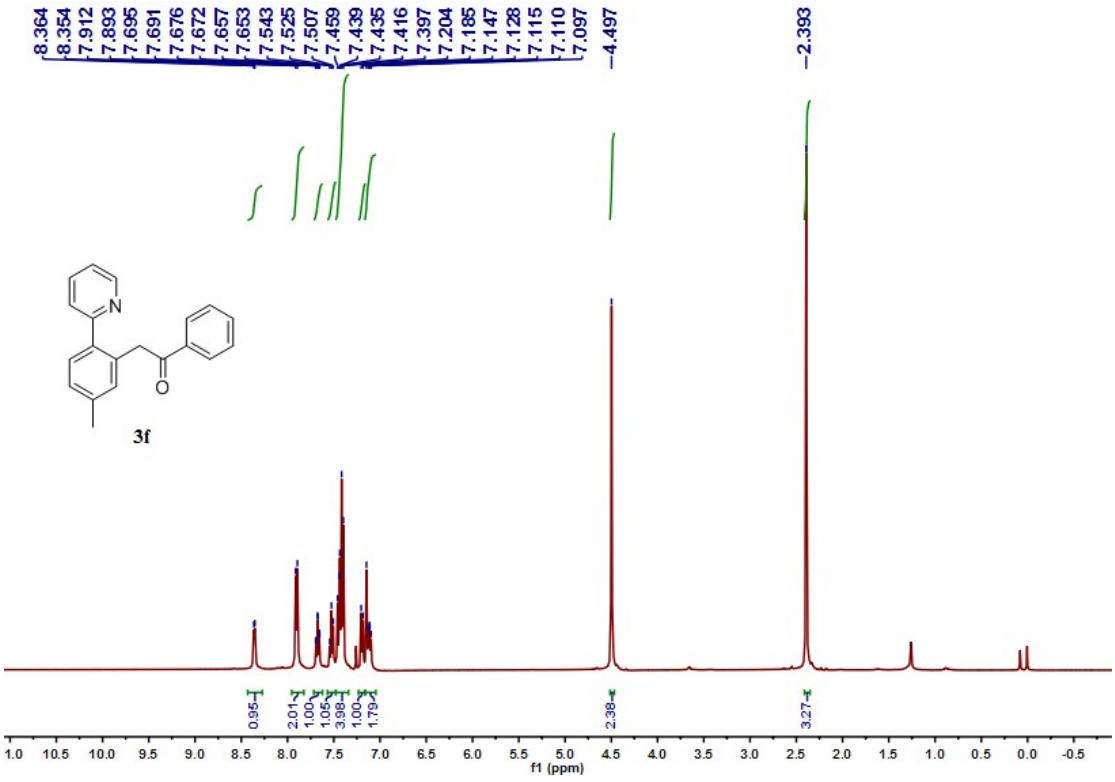

-62.493
N
O
F3C
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

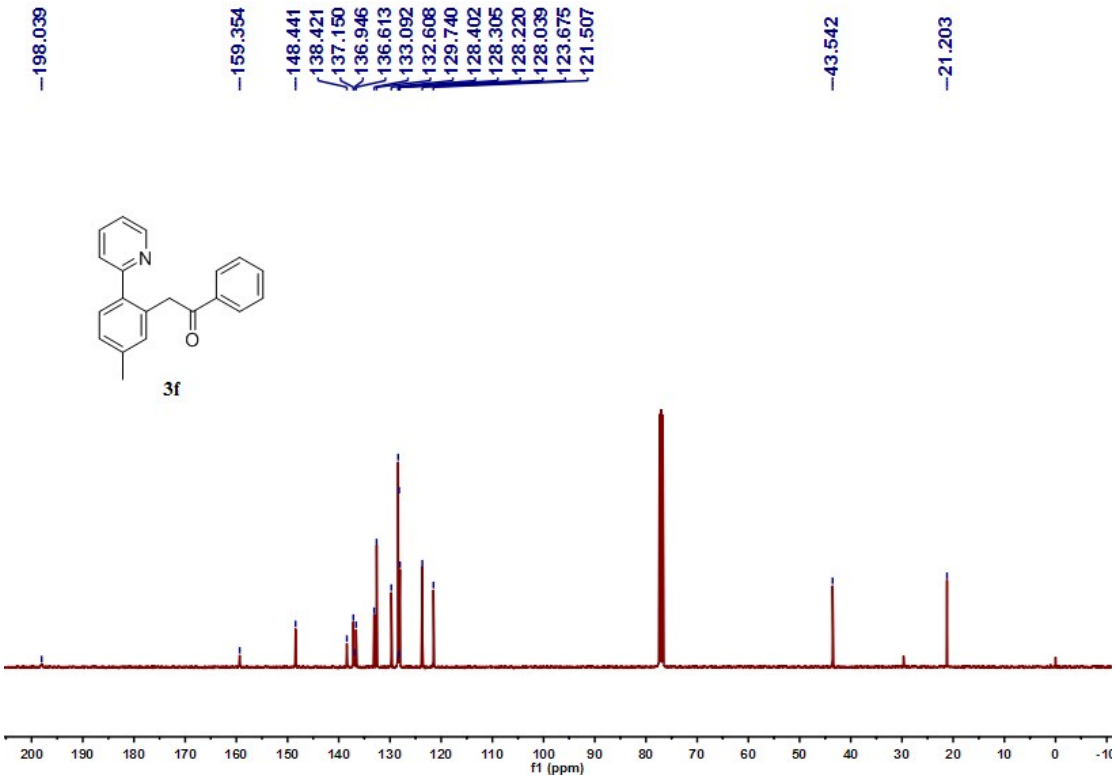
3d

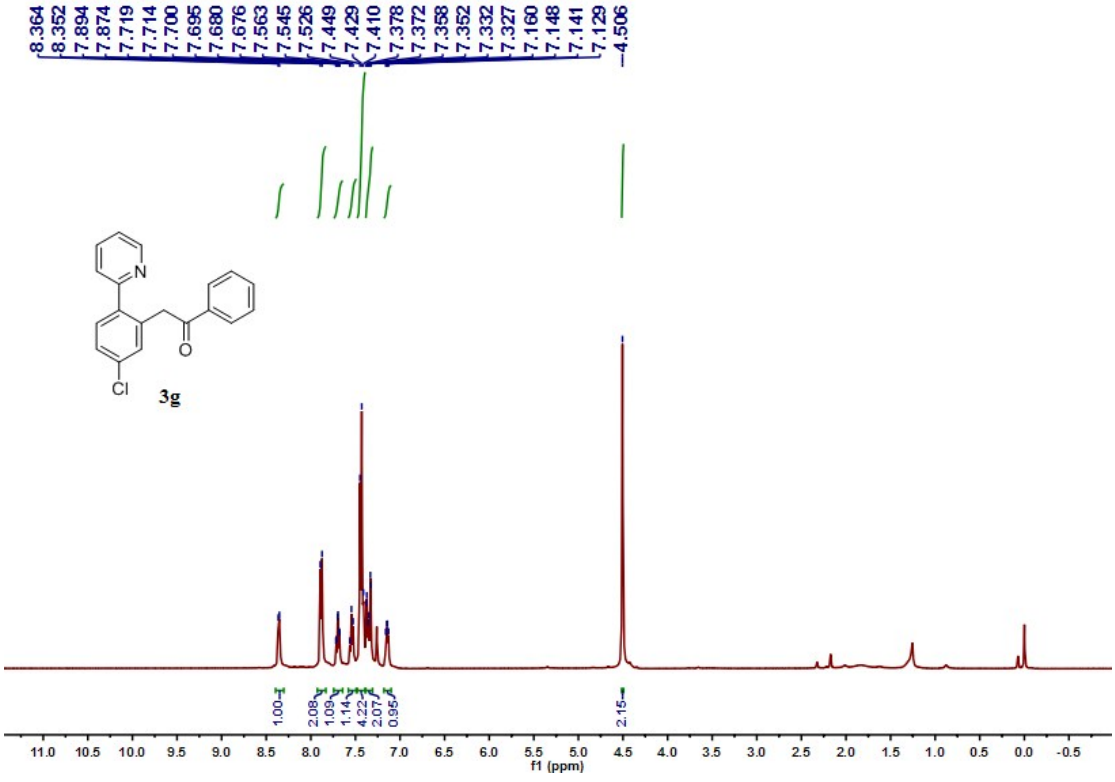

8.338
8.334
8.324
8.320
7.908
7.905
7.889
7.885
7.663
7.659
7.644
7.525
7.510
7.507
7.458
7.437
7.432
7.414
7.399
7.395
7.096
7.093
7.089
6.931
6.924
6.909
6.903
6.866
6.859
4.516
3.841
N
O
O
1.00
2.08
1.14
1.07
4.29
0.97
1.12
1.14
2.24
3.01
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1
f1 (ppm)

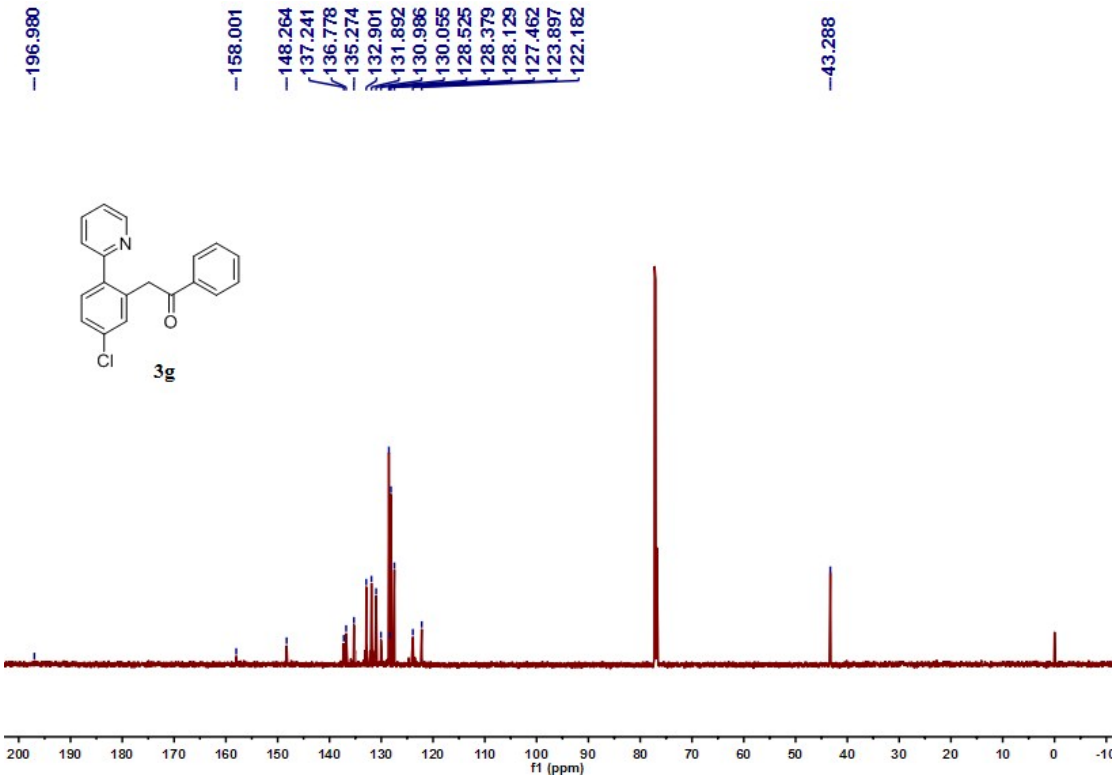
3e

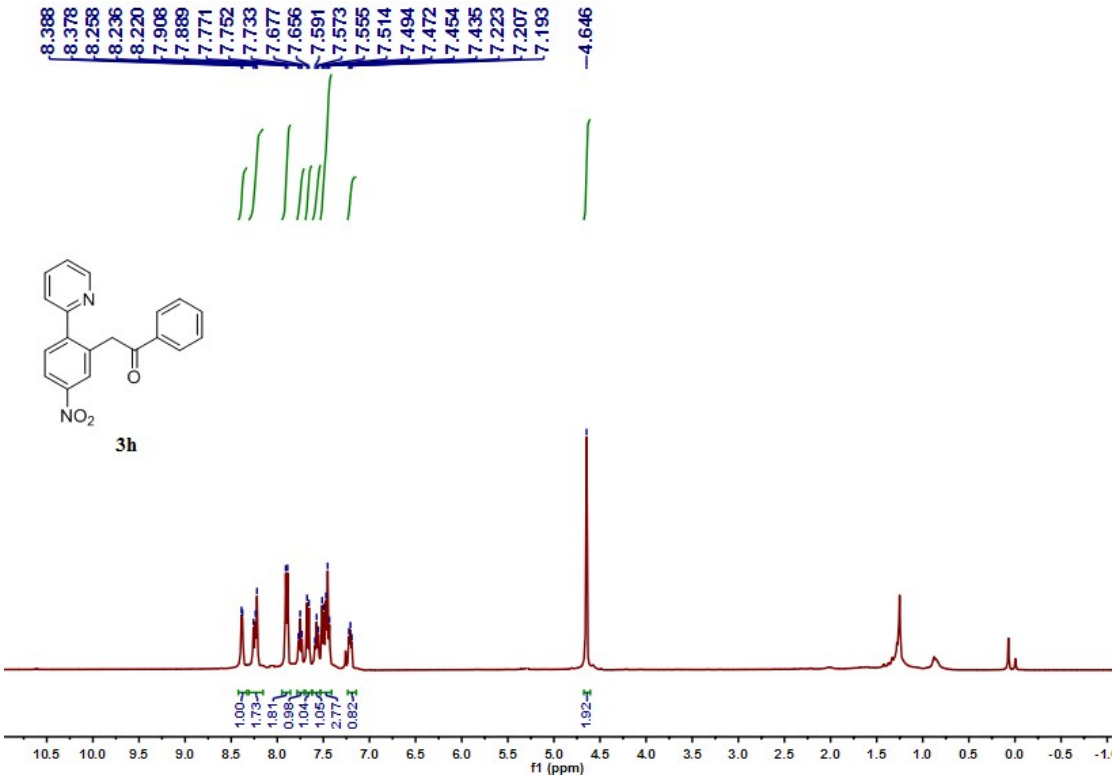

197.780
159.694
159.098
148.440
137.131
136.646
134.907
132.666
131.096
130.010
128.442
128.247
123.590
121.331
117.318
112.730
55.318
43.863
3e
f1 (ppm)


8.364
8.354
7.912
7.893
7.695
7.691
7.676
7.672
7.657
7.653
7.543
7.525
7.507
7.459
7.439
7.435
7.416
7.397
7.204
7.185
7.147
7.128
7.115
7.110
7.097
4.497
2.393
3f
0.95
2.01
1.00
1.05
3.98
1.00
1.79
2.38
3.27
f1 (ppm)


198.039
159.354
148.441
138.421
137.150
136.946
136.613
133.092
132.608
129.740
128.402
128.305
128.220
128.039
123.675
121.507
43.542
21.203
N
O
3f
f1 (ppm)


8.364
8.352
7.894
7.874
7.719
7.714
7.700
7.695
7.680
7.676
7.563
7.545
7.526
7.449
7.429
7.410
7.378
7.372
7.358
7.352
7.332
7.327
7.160
7.148
7.141
7.129
4.506
N
O
Cl
3g
1.00
2.08
1.09
1.14
4.22
2.07
0.95
2.15
f1 (ppm)


196.980
158.001
148.264
137.241
136.778
135.274
132.901
131.892
130.986
130.055
128.525
128.379
128.129
127.462
123.897
122.182
43.288
N
O
Cl
3g
f1 (ppm)


8.388
8.378
8.258
8.236
8.220
7.908
7.889
7.771
7.752
7.733
7.677
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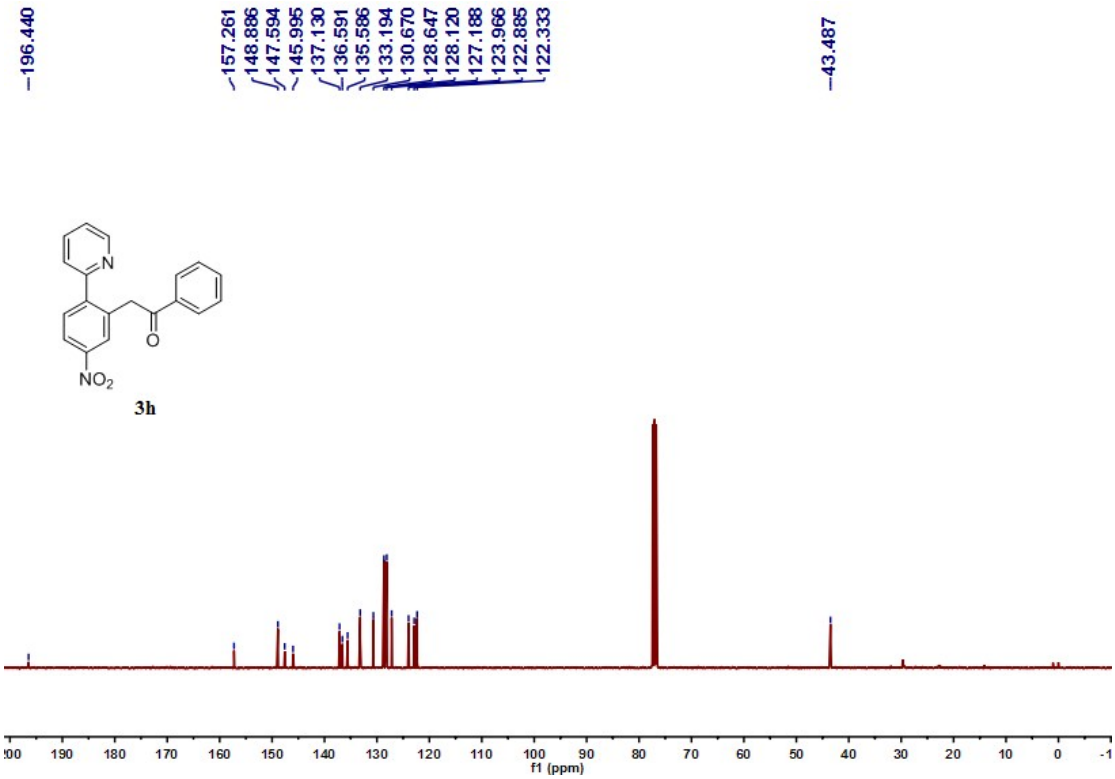
7.573
7.555
7.514
7.494
7.472
7.454
7.435
7.223
7.207
7.193
4.646
N
O
NO2
3h
1.00
1.73
1.81
0.98
1.04
1.05
2.77
0.82
1.92
f1 (ppm)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147.594
145.995
137.130
136.591
135.586
133.194
130.670
128.647
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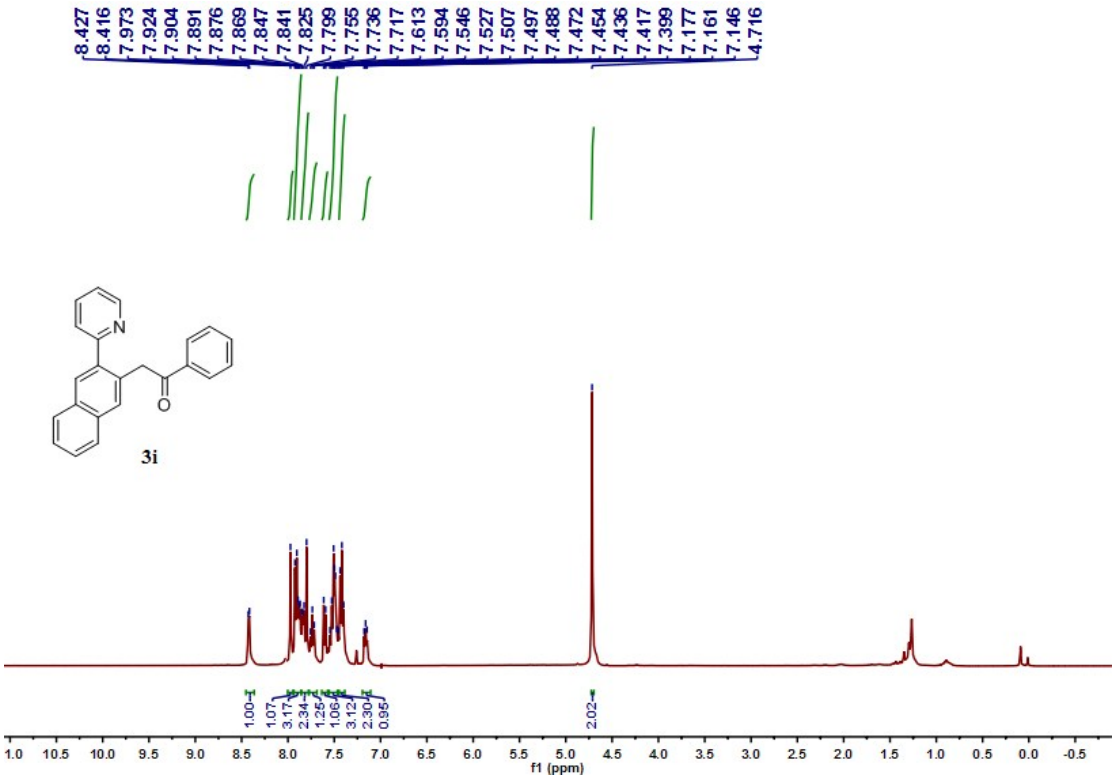
127.188
123.966
122.885
122.333
43.487
N
O
NO2
3h
f1 (ppm)


8.427
8.416
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7.904
7.891
7.876
7.869
7.847
7.841
7.825
7.799
7.755
7.736
7.717
7.613
7.594
7.546
7.527
7.507
7.497
7.488
7.472
7.454
7.436
7.417
7.399
7.177
7.161
7.146
4.716
N
O
3i
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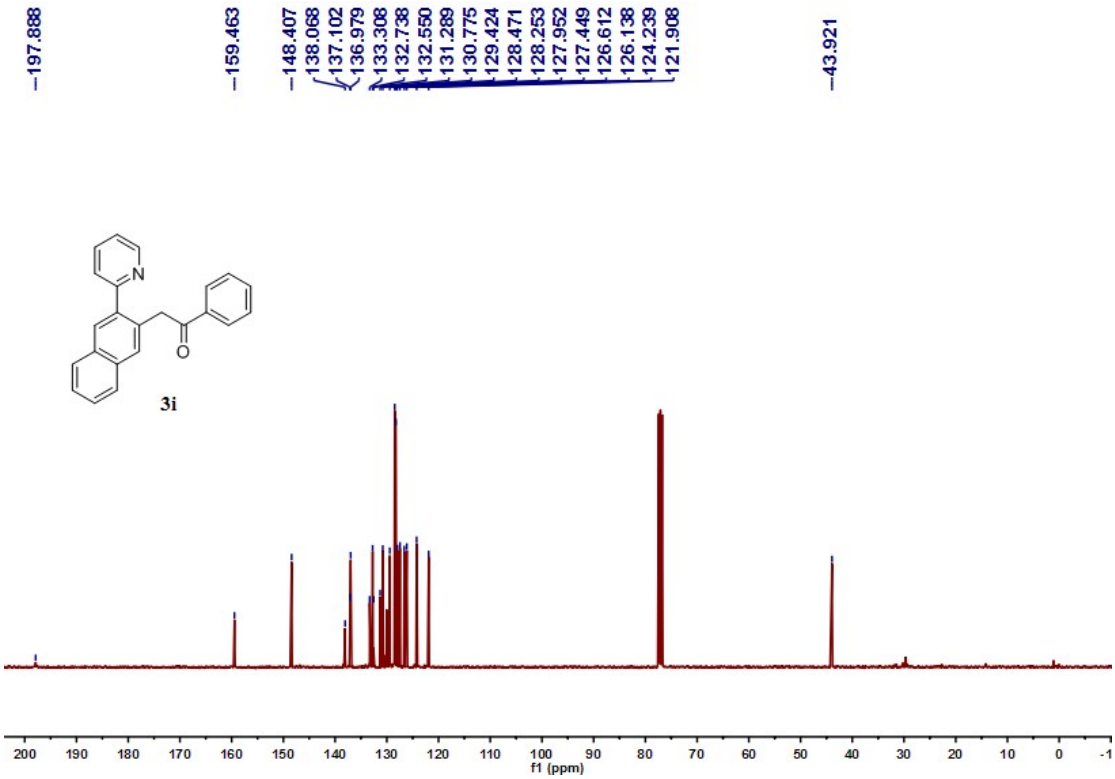
1.07
3.17
2.34
1.25
1.06
3.12
2.30
0.96
2.02
f1 (ppm)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137.102
136.979
133.308
132.738
132.550
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129.424
128.471
128.253
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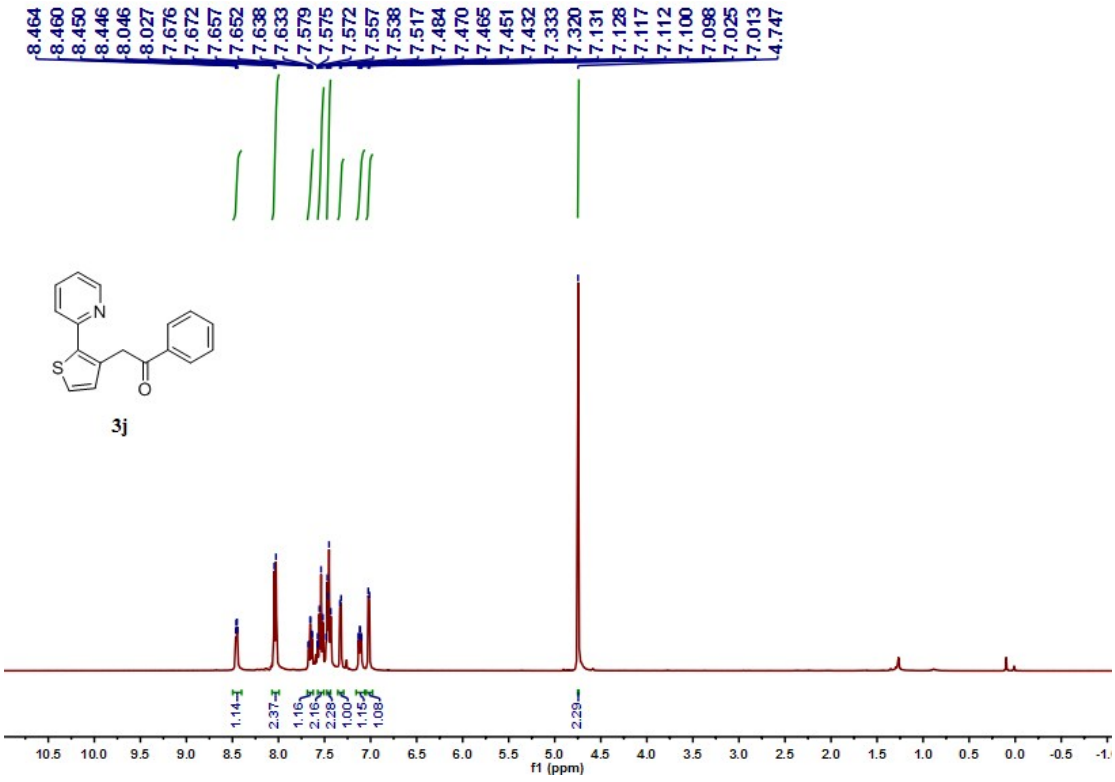
127.449
126.612
126.138
124.239
121.906
43.921
N
O
3i
f1 (ppm)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8.446
8.046
8.027
7.676
7.672
7.657
7.652
7.638
7.633
7.579
7.575
7.572
7.557
7.538
7.517
7.484
7.470
7.465
7.451
7.432
7.333
7.320
7.131
7.128
7.117
7.112
7.100
7.098
7.025
7.013
4.747
N
S
O
3j
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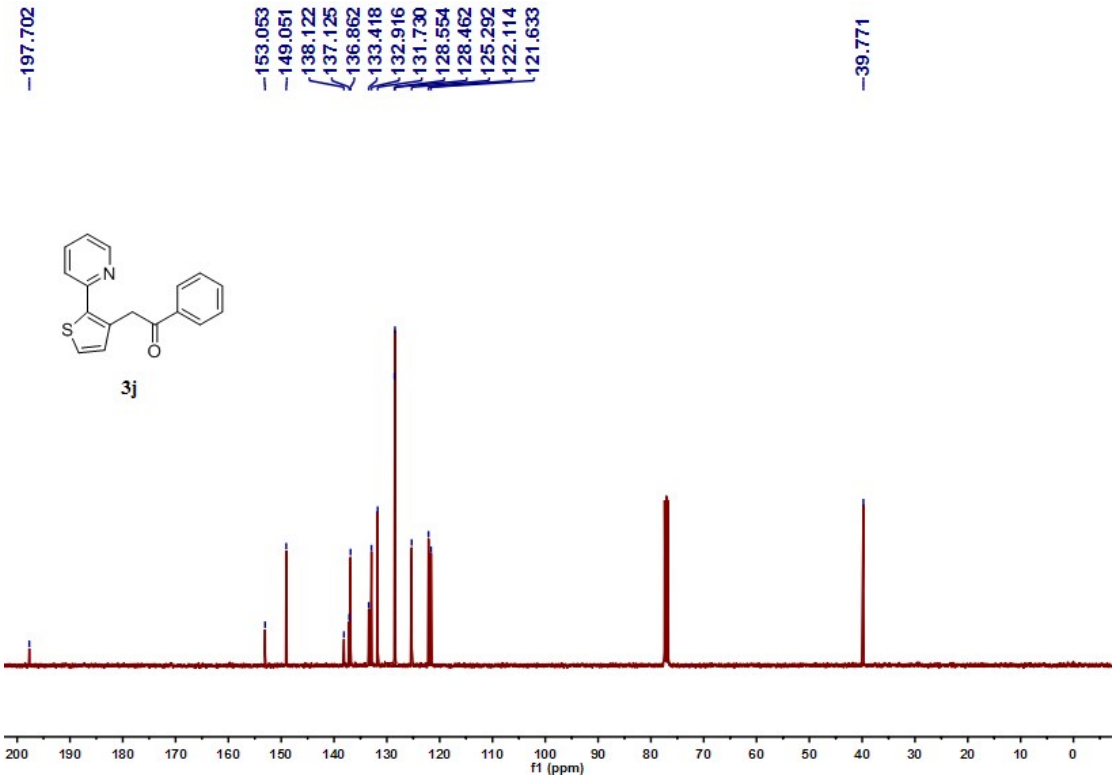
2.37
1.16
2.16
2.28
1.00
1.15
1.08
2.29
f1 (ppm)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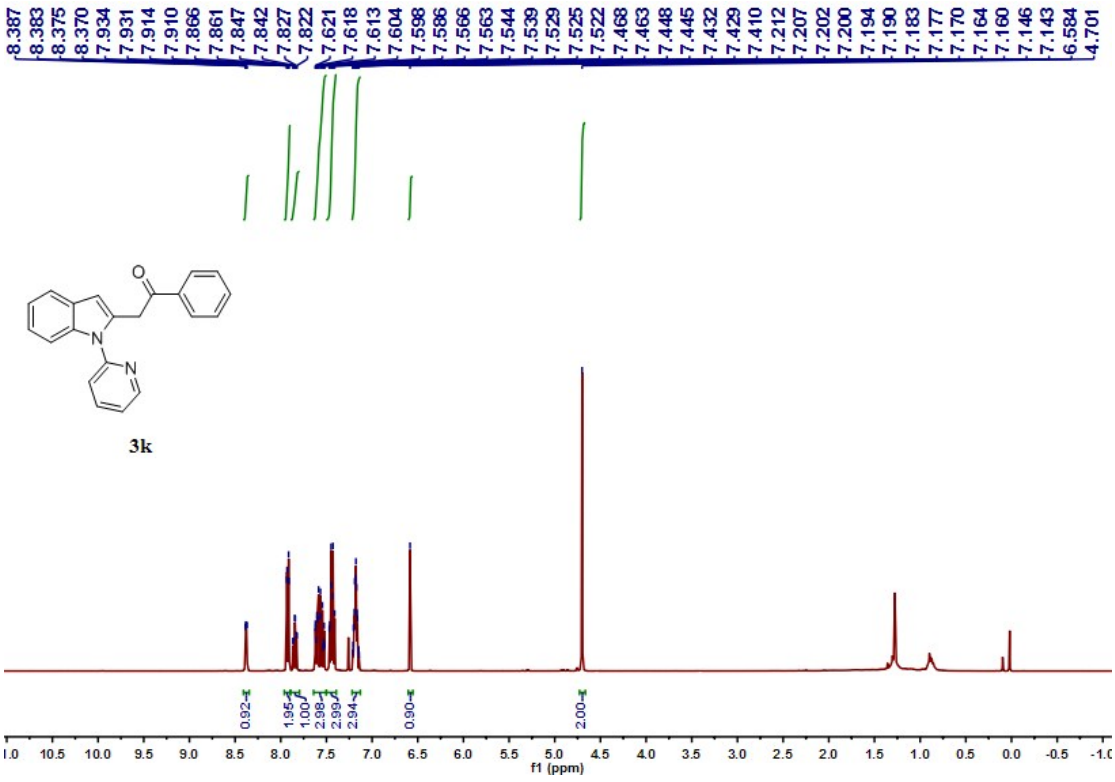
137.125
136.862
133.418
132.916
131.730
128.554
128.462
125.292
122.114
121.633
39.771
N
S
O
3j
f1 (ppm)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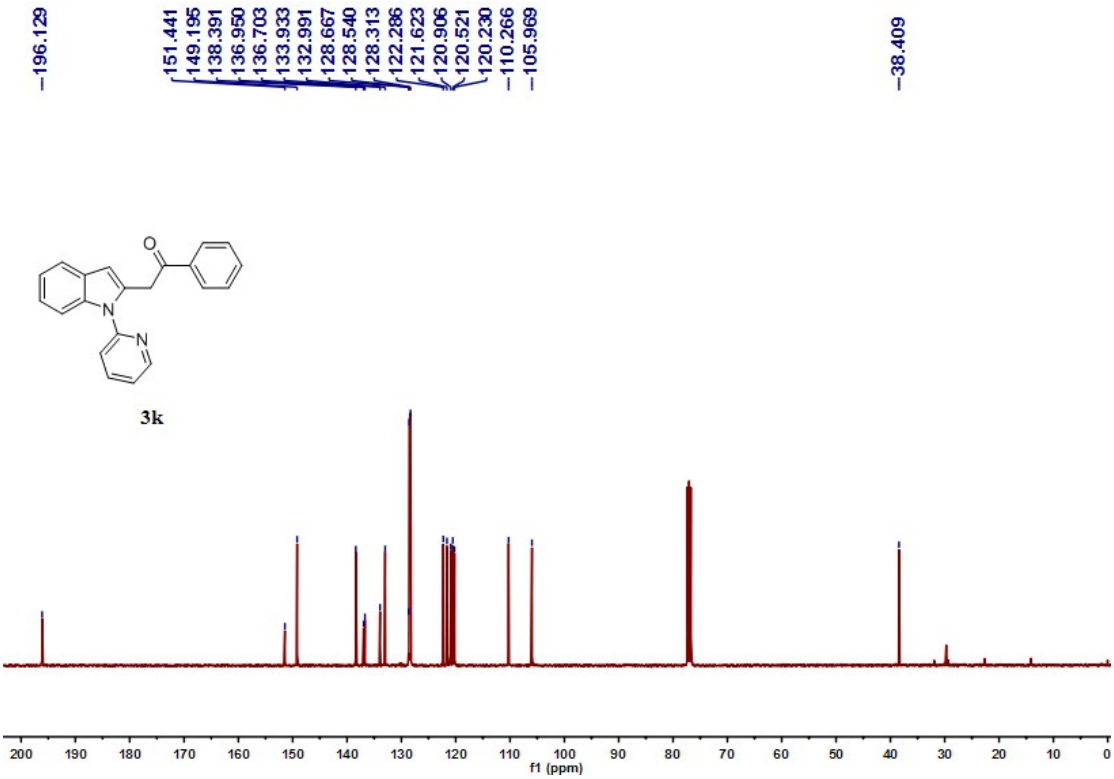
7.934
7.931
7.914
7.910
7.866
7.861
7.847
7.842
7.827
7.822
7.621
7.618
7.613
7.604
7.598
7.586
7.566
7.563
7.544
7.539
7.529
7.525
7.522
7.468
7.463
7.448
7.445
7.432
7.429
7.410
7.212
7.207
7.202
7.200
7.194
7.190
7.183
7.177
7.170
7.164
7.160
7.146
7.143
6.584
4.701
O
N
N
3k
0.92
1.95
1.00
2.98
2.99
2.94
0.90
2.00
f1 (ppm)


196.129
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149.195
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136.950
136.703
133.933
132.991
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128.540
128.313
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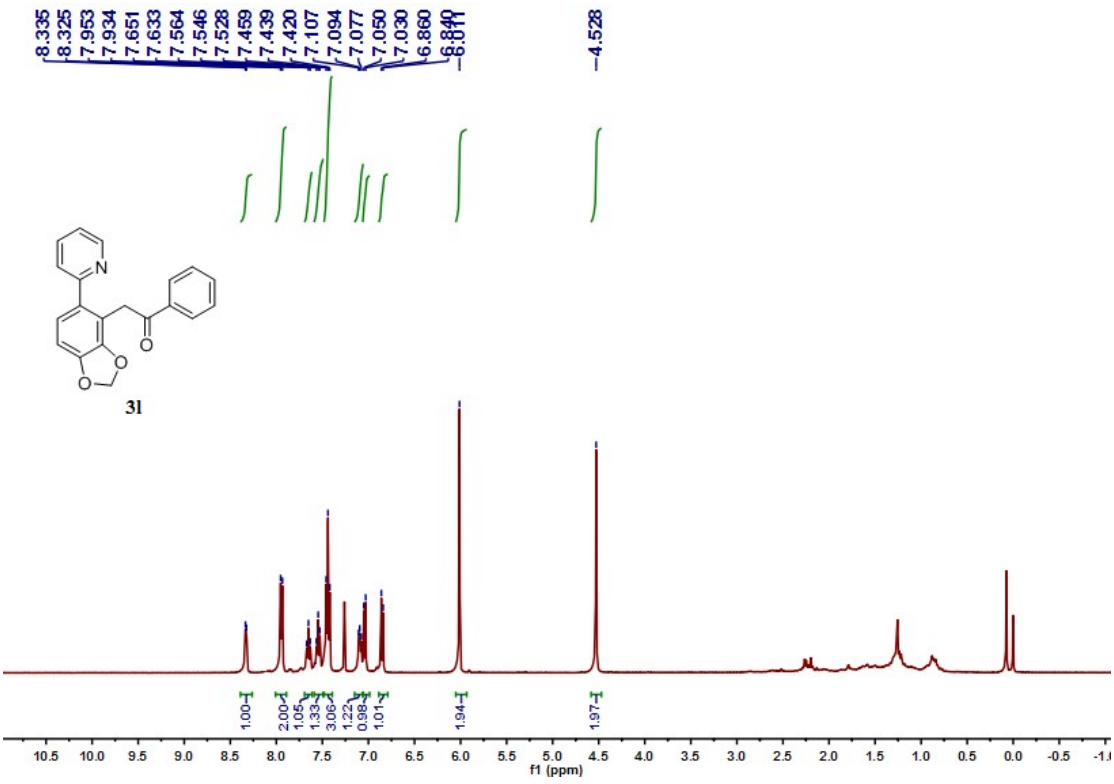
121.623
120.906
120.521
120.230
110.266
105.969
38.409
3k
f1 (ppm)


8.335
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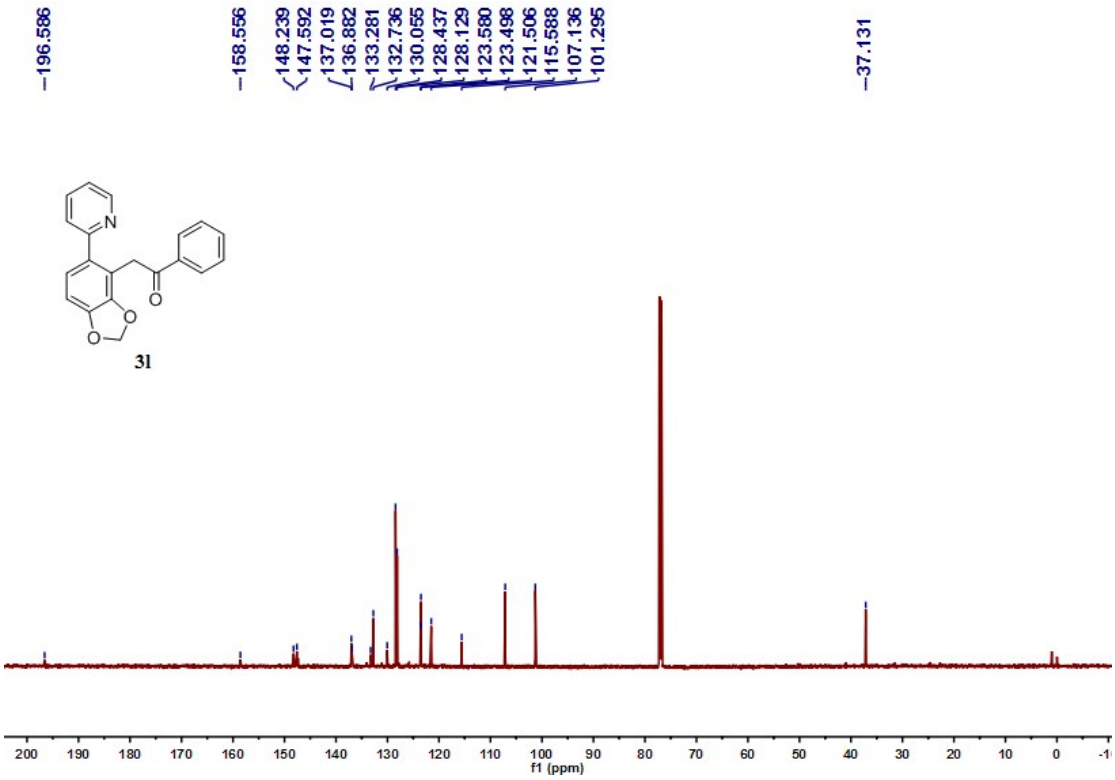
7.651
7.633
7.564
7.546
7.528
7.459
7.439
7.420
7.107
7.094
7.077
7.050
7.030
6.860
6.840
6.811
4.528
3l
1.00
2.00
1.05
1.33
3.06
1.22
0.98
1.01
1.94
1.97
f1 (ppm)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137.019
136.882
133.281
132.736
130.055
128.437
128.129
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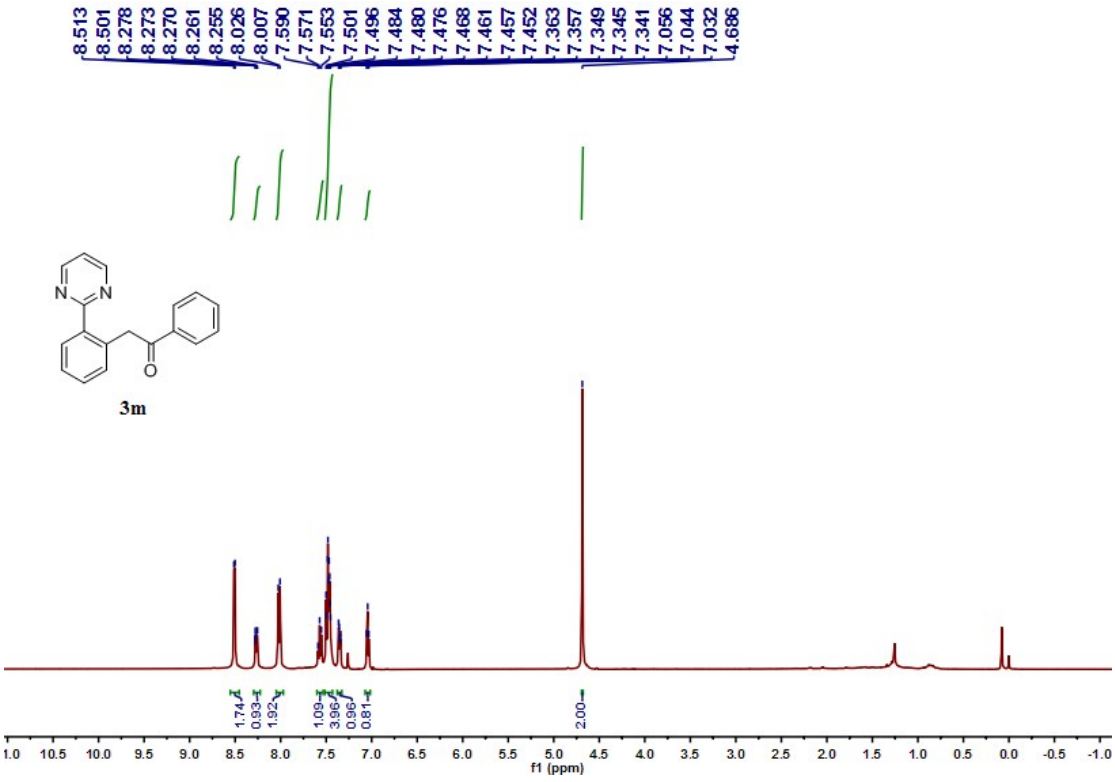
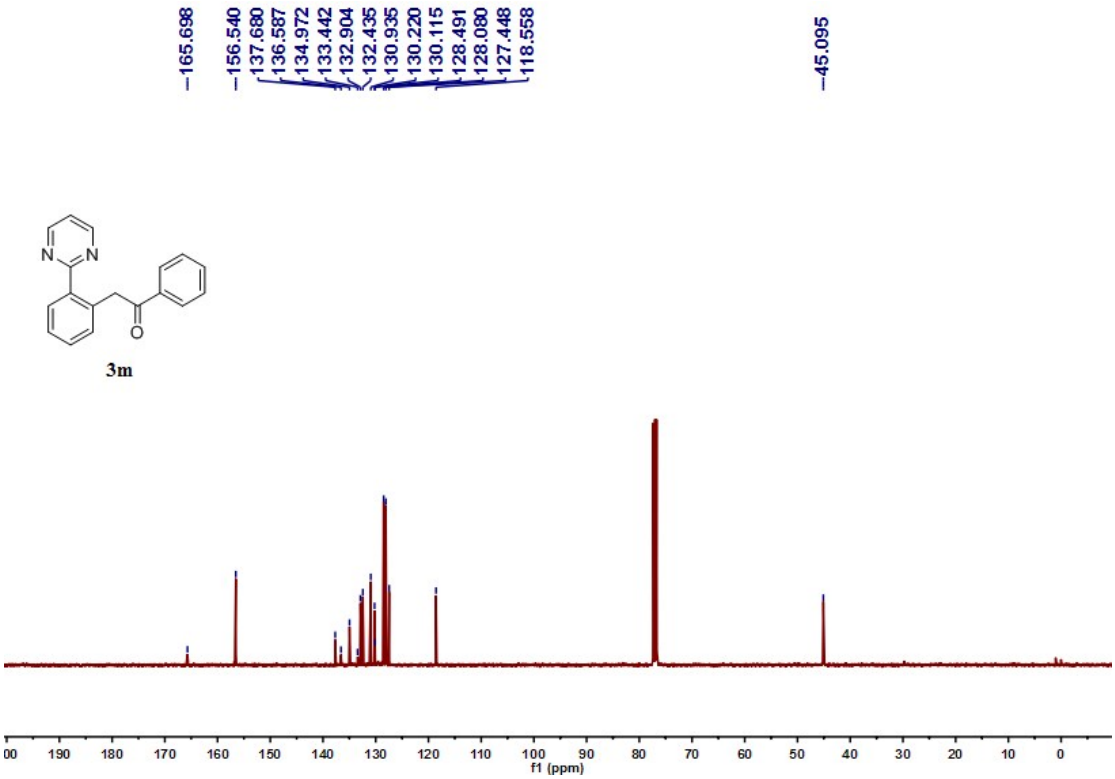
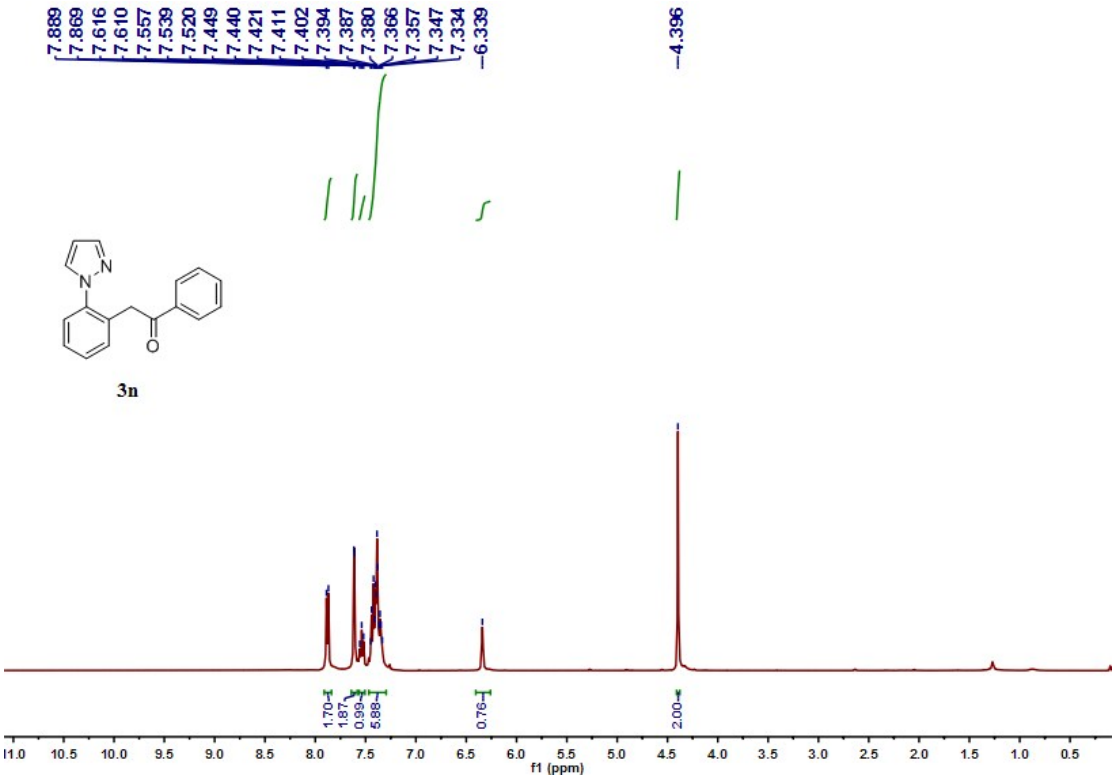
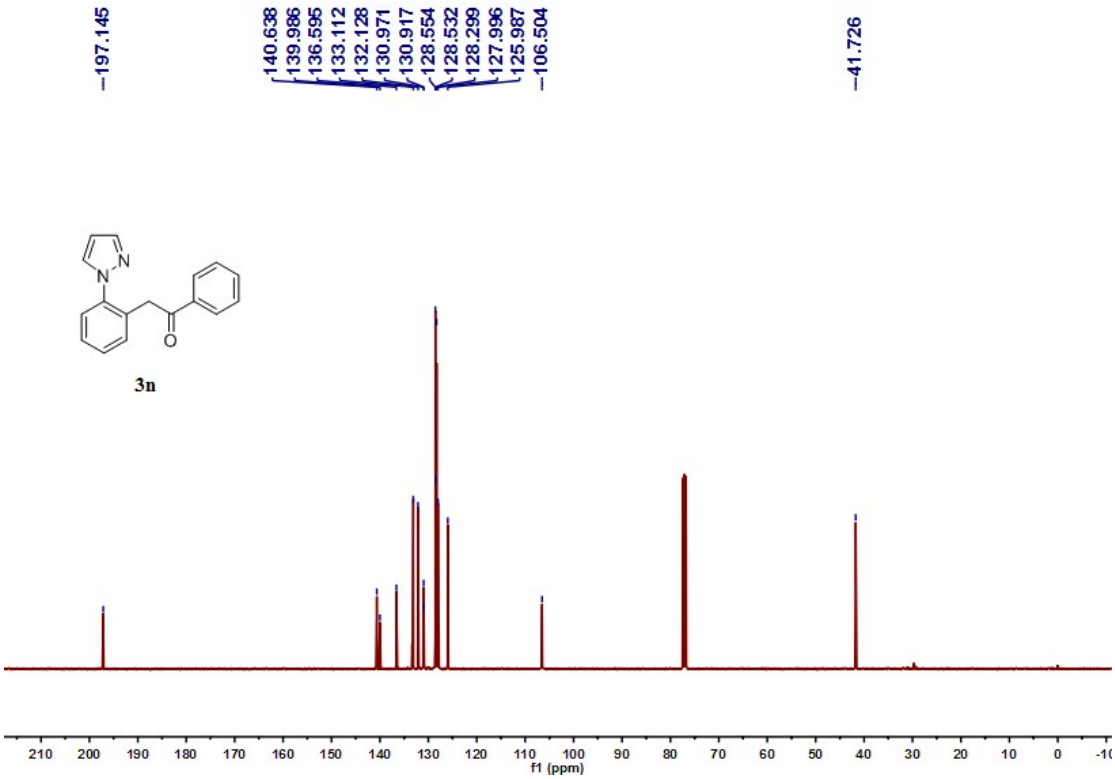
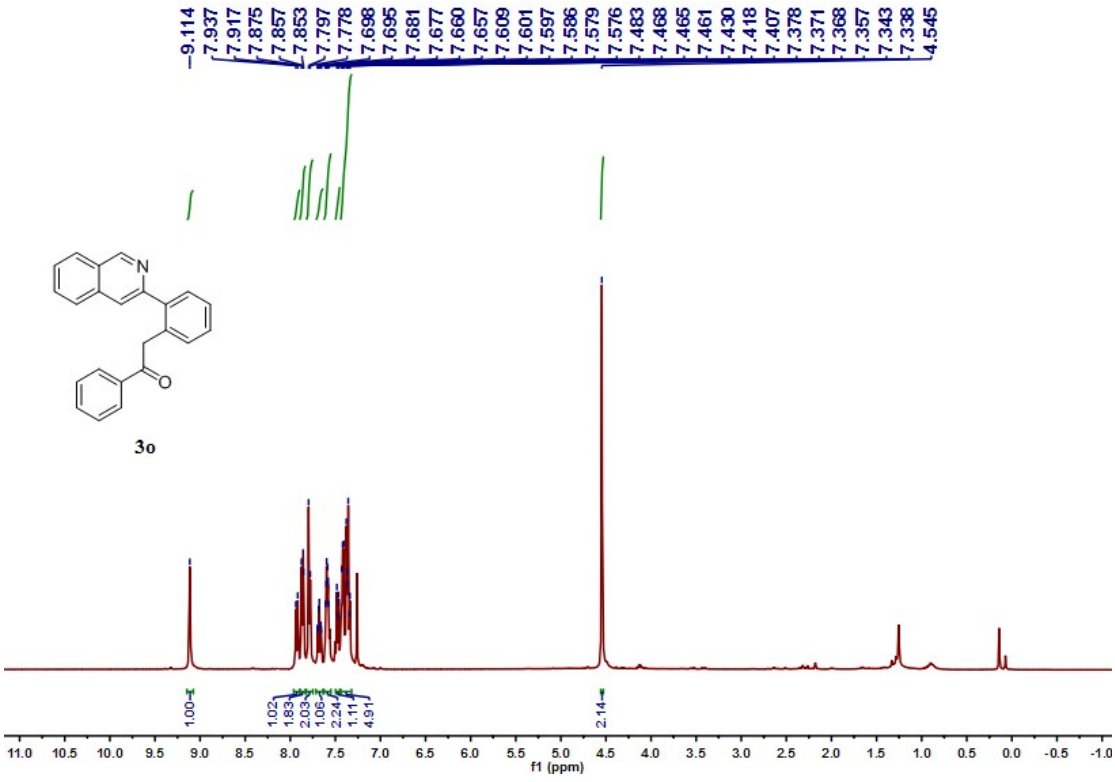
121.506
115.588
107.136
101.295
37.131
N
O
O
O
31
f1 (ppm)

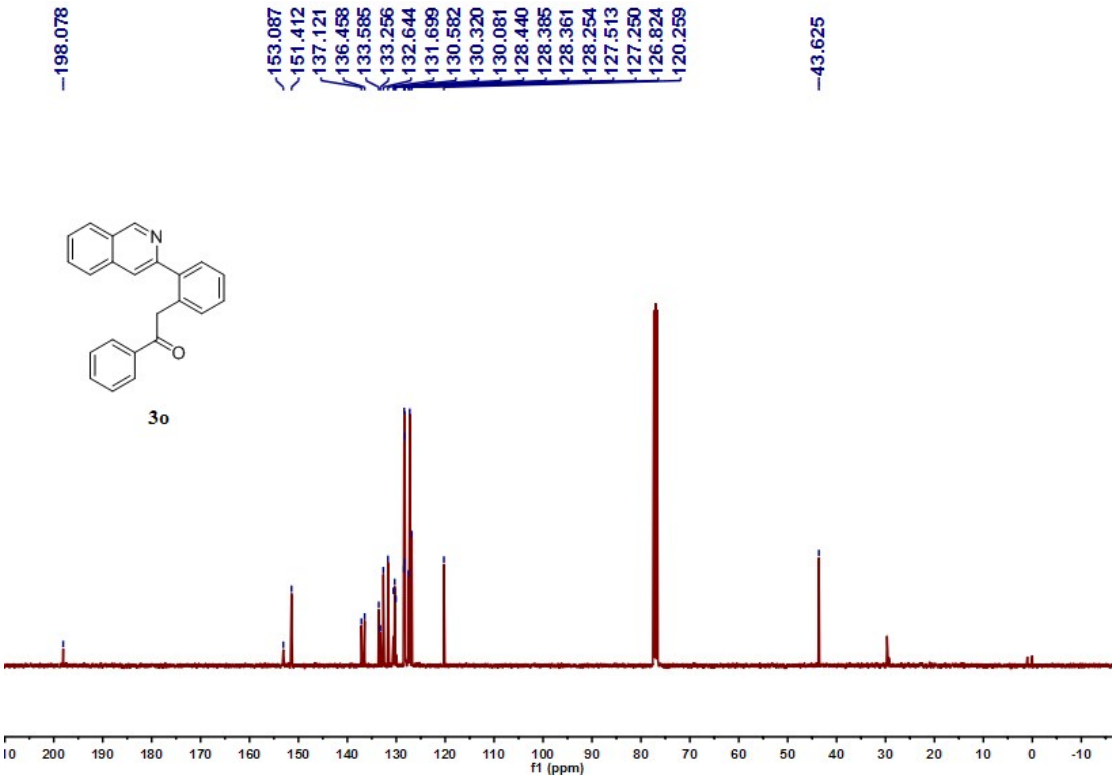

8.513
8.501
8.278
8.273
8.270
8.261
8.255
8.026
8.007
7.590
7.571
7.553
7.501
7.496
7.484
7.480
7.476
7.468
7.461
7.457
7.452
7.363
7.357
7.349
7.345
7.341
7.056
7.044
7.032
4.686
N
N
O
3m
1.74
0.93
1.92
1.09
3.96
0.96
0.81
2.00
f1 (ppm)


165.698
156.540
137.680
136.587
134.972
133.442
132.904
132.435
130.935
130.220
130.115
128.491
128.080
127.448
118.558
45.095
N
N
O
3m
f1 (ppm)

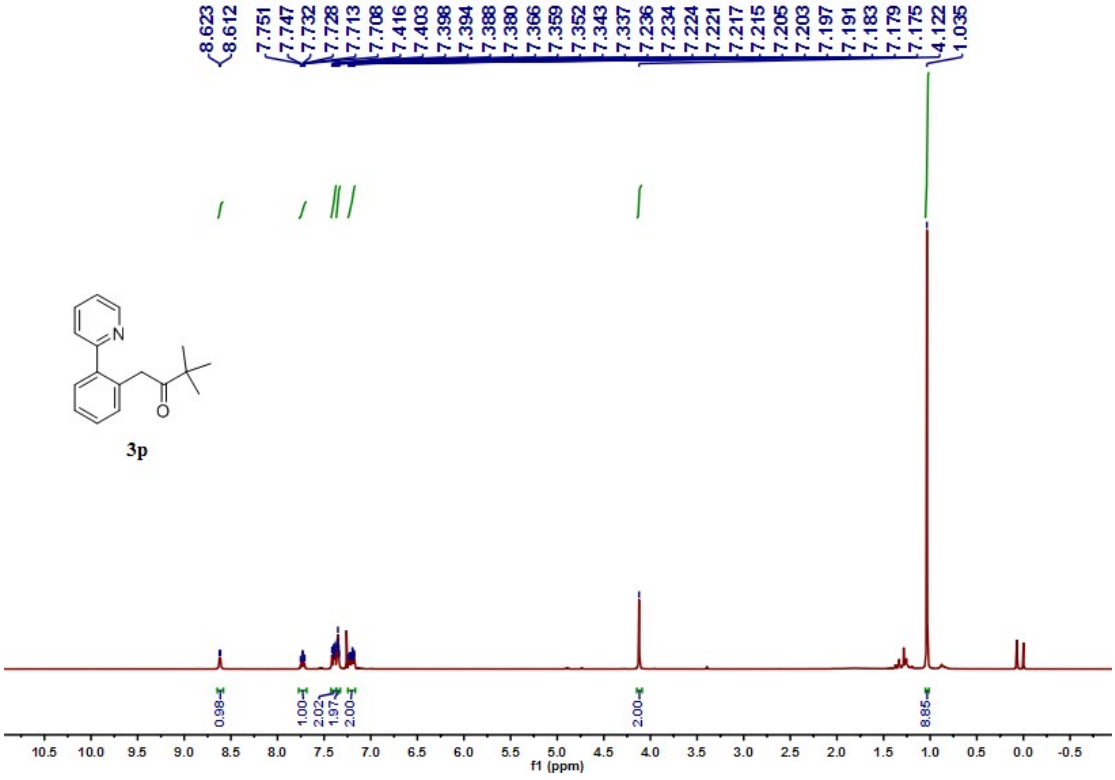

7.889
7.869
7.616
7.610
7.557
7.539
7.520
7.449
7.440
7.421
7.411
7.402
7.394
7.387
7.380
7.366
7.357
7.347
7.334
6.339
4.396
N
N
O
3n
1.70
1.87
0.99
5.88
0.76
2.00
f1 (ppm)


197.145
140.638
139.986
136.595
133.112
132.128
130.971
130.917
128.554
128.532
128.299
127.996
125.987
106.504
41.726
3n
f1 (ppm)

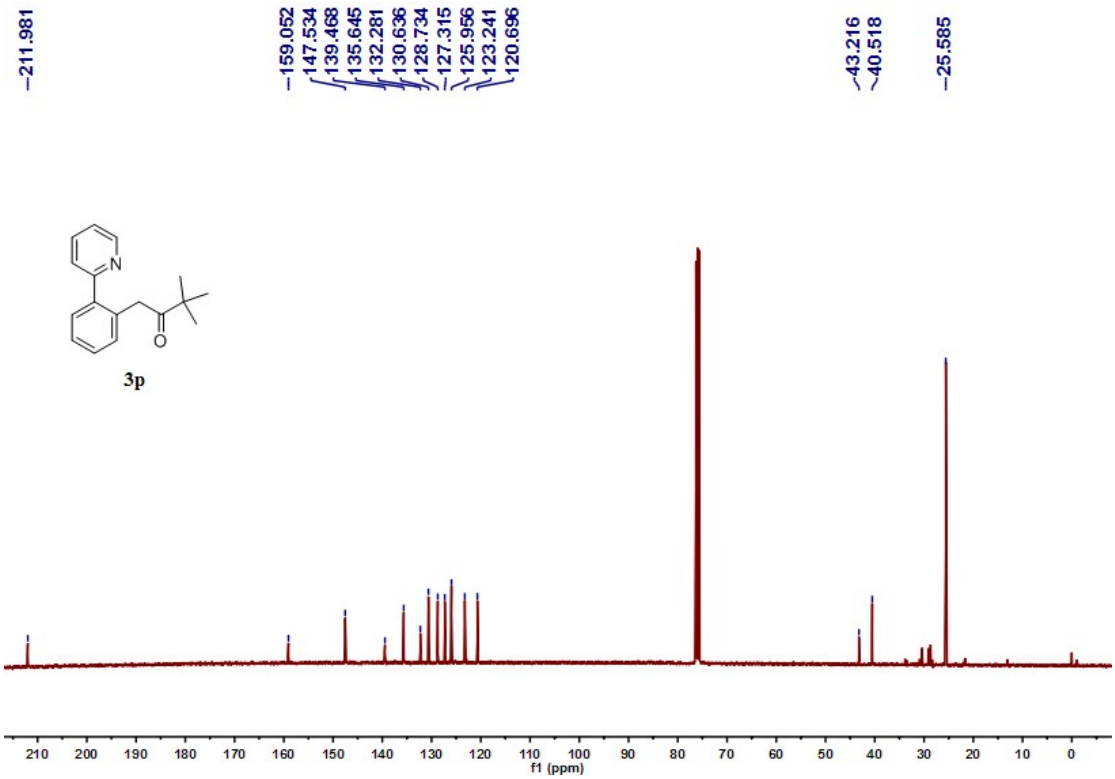

9.114
7.937
7.917
7.875
7.857
7.853
7.797
7.778
7.698
7.695
7.681
7.677
7.660
7.657
7.609
7.601
7.597
7.586
7.579
7.576
7.483
7.468
7.465
7.461
7.430
7.418
7.407
7.378
7.371
7.368
7.357
7.343
7.338
4.545
3o
1.00
1.02
1.83
2.03
1.06
2.24
1.11
4.91
2.14
f1 (ppm)

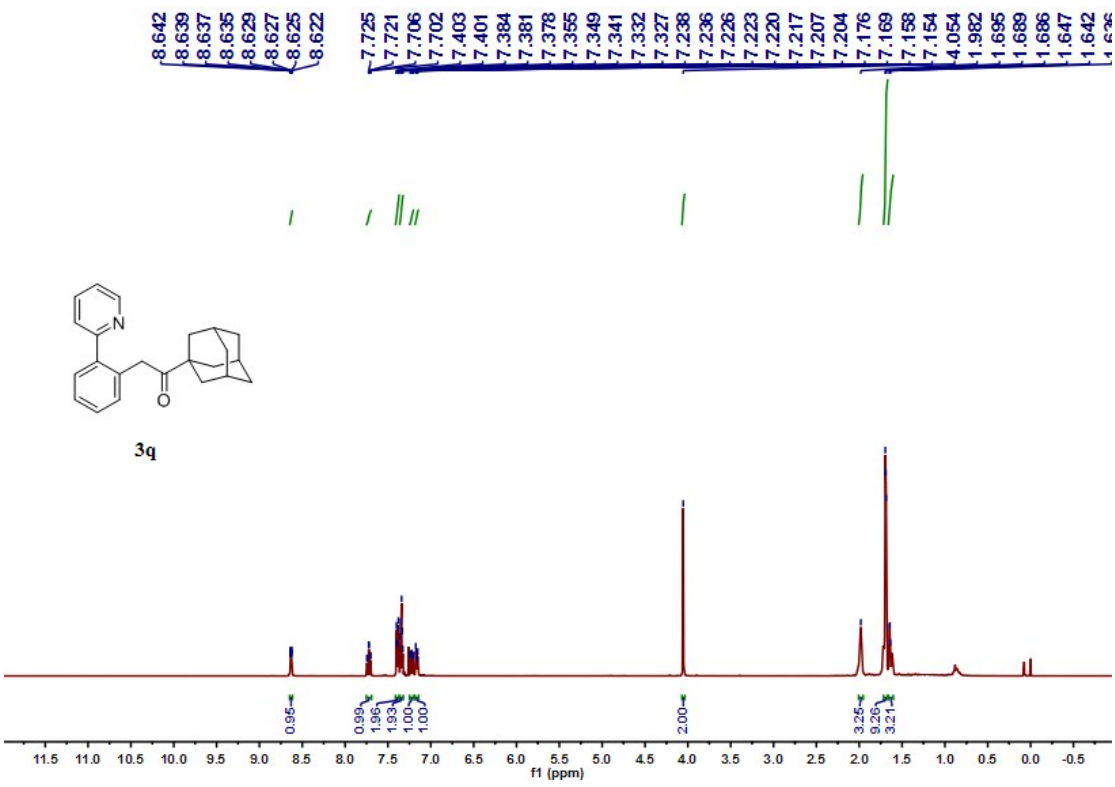

198.078
153.087
151.412
137.121
136.458
133.585
133.256
132.644
131.699
130.582
130.320
130.081
128.440
128.385
128.361
128.254
127.513
127.250
126.824
120.259
43.625
N
O
f1 (ppm)

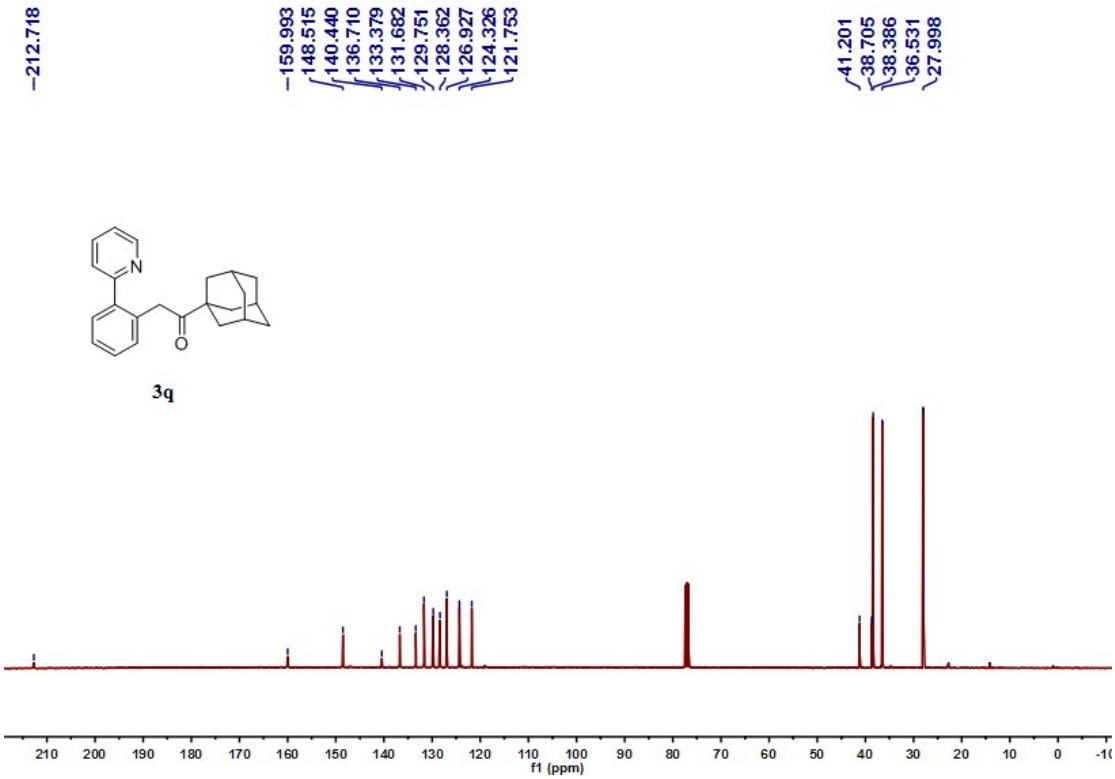
3o

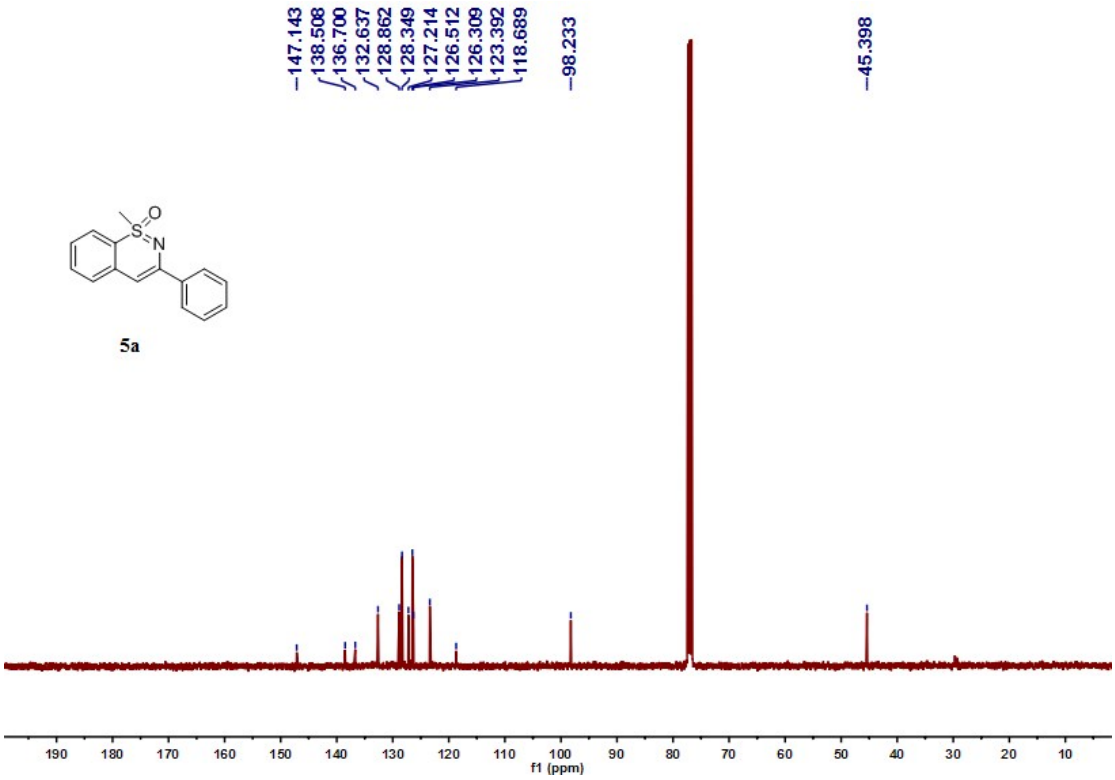

8.623
8.612
7.751
7.747
7.732
7.728
7.713
7.708
7.416
7.403
7.398
7.394
7.388
7.380
7.366
7.359
7.352
7.343
7.337
7.236
7.234
7.224
7.221
7.217
7.215
7.205
7.203
7.197
7.191
7.183
7.179
7.175
4.122
1.035
0.98
1.00
2.02
1.97
2.00
2.00
8.85
N
O
f1 (ppm)

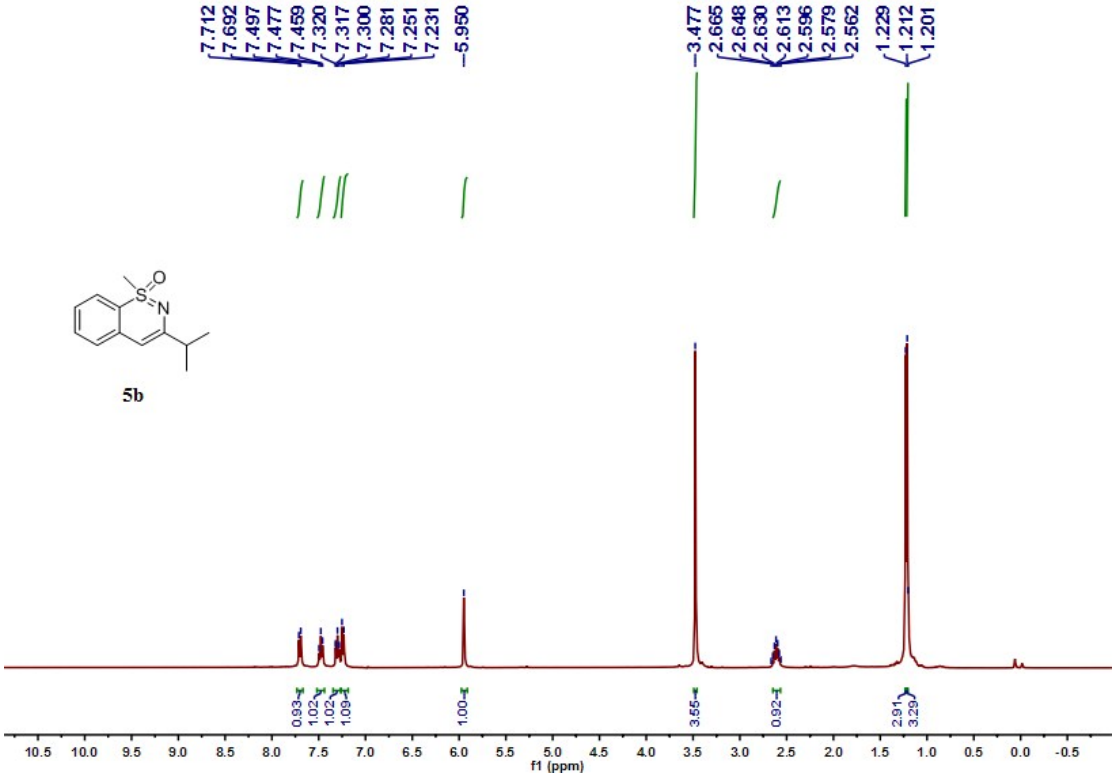
3p

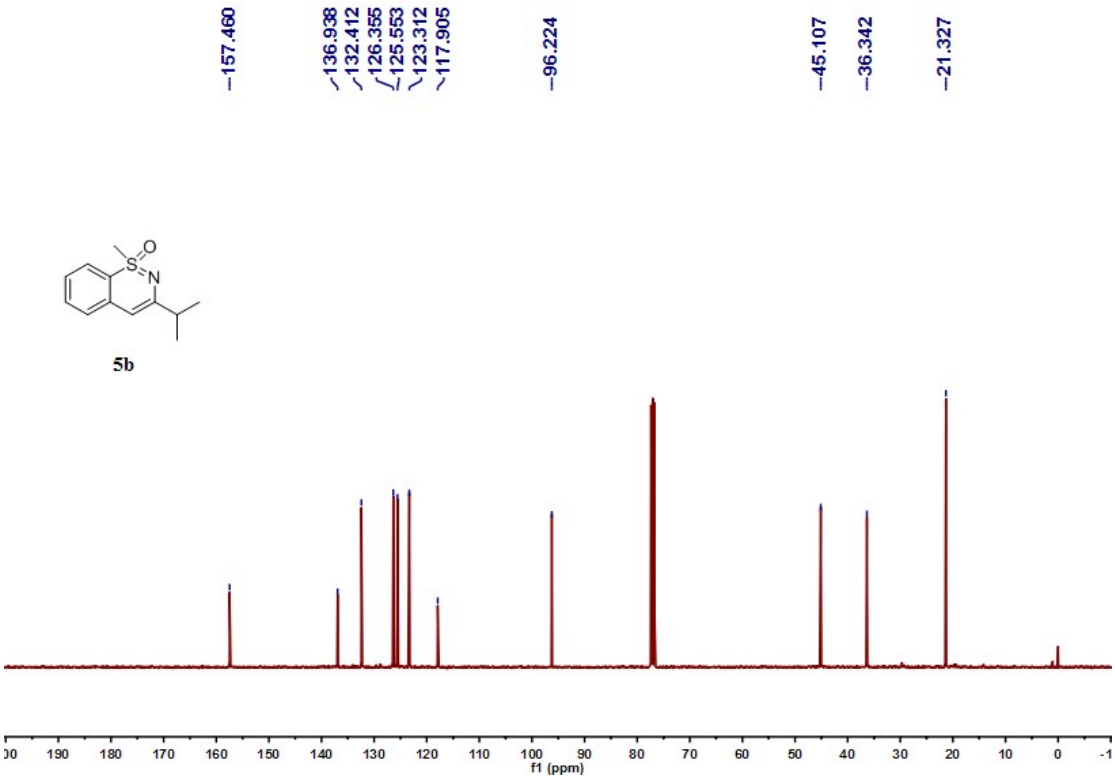

211.981
159.052
147.534
139.468
135.645
132.281
130.636
128.734
127.315
125.956
123.241
120.696
43.216
40.518
25.585
N
O
3p
f1 (ppm)


8.642
8.639
8.637
8.635
8.629
8.627
8.625
8.622
7.725
7.721
7.706
7.702
7.403
7.401
7.384
7.381
7.378
7.355
7.349
7.341
7.332
7.327
7.238
7.236
7.226
7.223
7.220
7.217
7.207
7.204
7.176
7.169
7.158
7.154
4.054
1.982
1.695
1.689
1.686
1.647
1.642
N
O
3q
0.95
0.99
1.96
1.93
1.00
1.00
2.00
3.25
9.26
3.21
f1 (ppm)

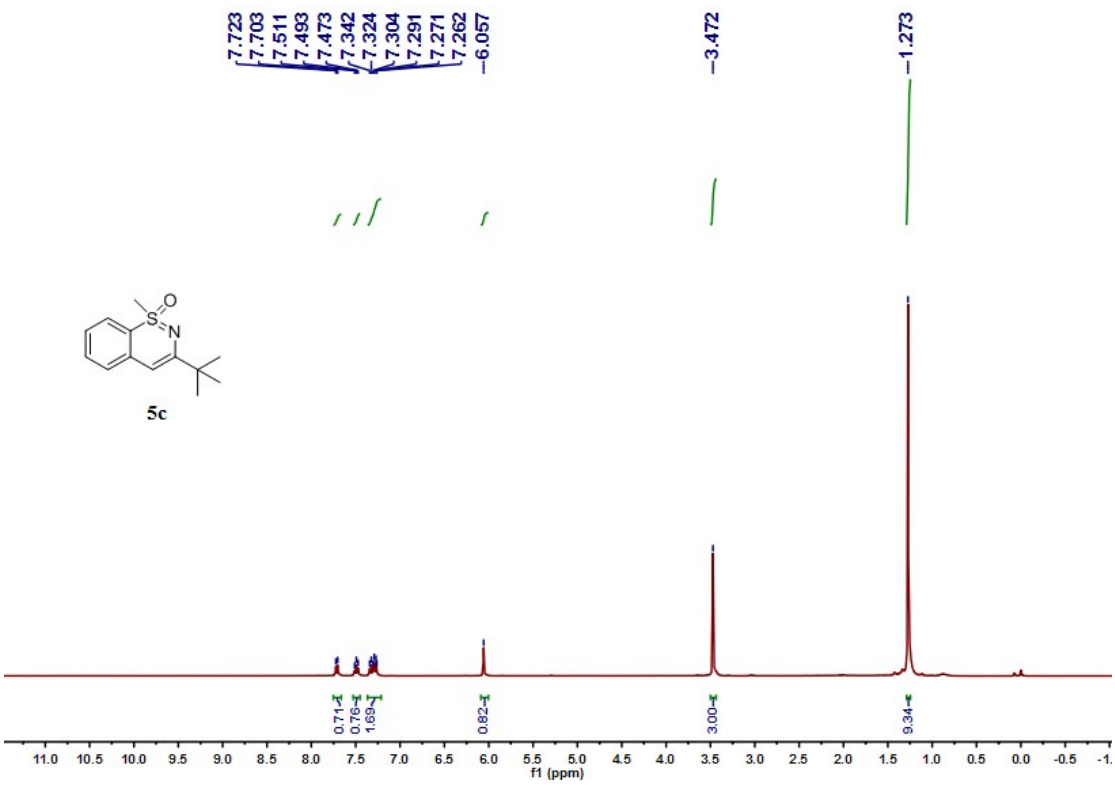

212.718
159.993
148.515
140.440
136.710
133.379
131.682
129.751
128.362
126.927
124.326
121.753
41.201
38.705
38.386
36.531
27.998
N
O
3q
f1 (ppm)
7.963
7.945
7.810
7.790
7.594
7.574
7.556
7.445
7.442
7.432
7.424
7.420
7.410
7.404
7.385
7.381
7.367
6.676
3.622
O
S
N
5a
2.06
1.18
1.16
4.97
1.00
3.15
f1 (ppm)


147.143
138.508
136.700
132.637
128.862
128.349
127.214
126.512
126.309
123.392
118.689
98.233
45.398
O
S
N
5a
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)

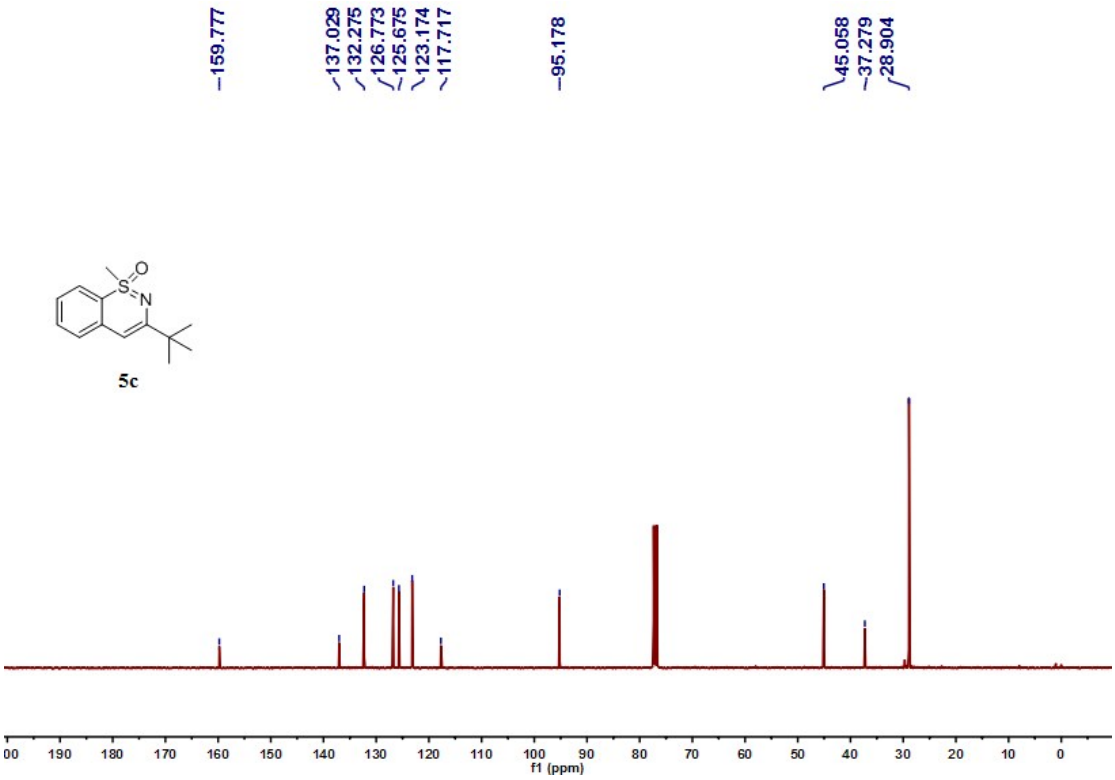

7.712
7.692
7.497
7.477
7.459
7.320
7.317
7.300
7.281
7.251
7.231
5.950
3.477
2.665
2.648
2.630
2.613
2.596
2.579
2.562
1.229
1.212
1.201
O
S
N
5b
0.93
1.02
1.02
1.09
1.00
3.55
0.92
2.91
3.29
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


157.460
136.938
132.412
126.355
125.553
123.312
117.905
96.224
45.107
36.342
21.327
f1 (ppm)

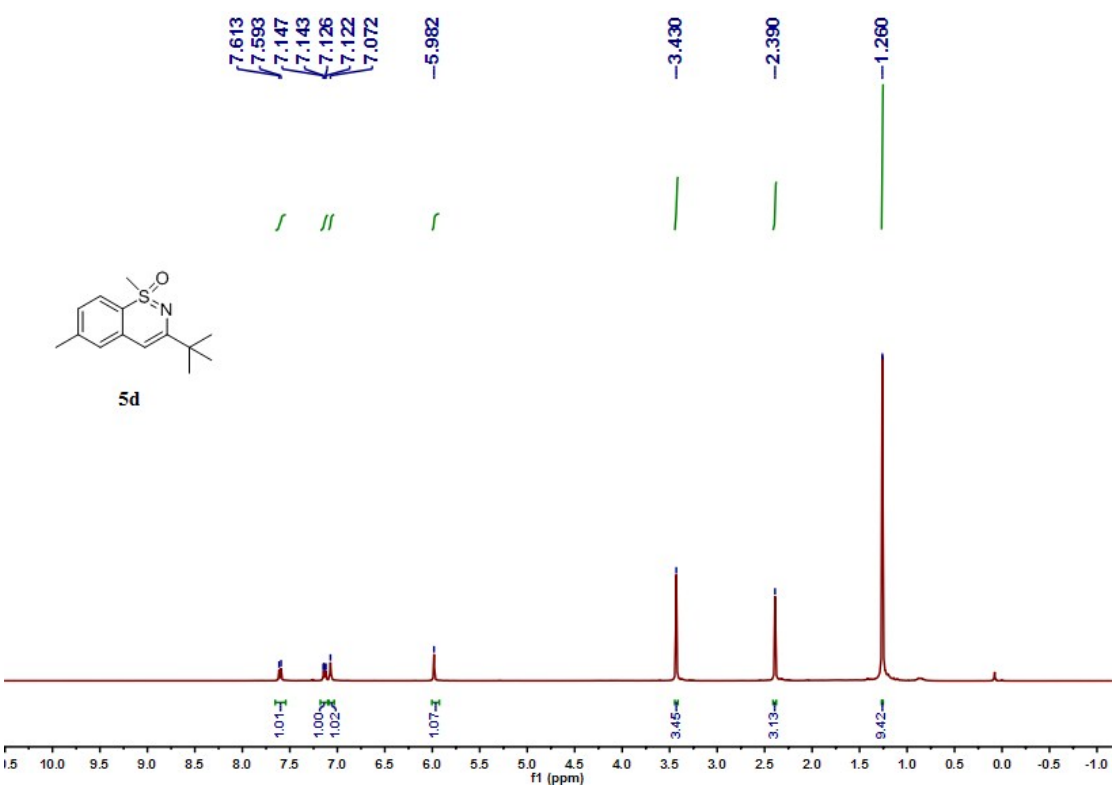
5b


7.723
7.703
7.511
7.493
7.473
7.342
7.324
7.304
7.291
7.271
7.262
6.057
3.472
1.273
0.71
0.76
1.69
0.82
3.00
9.34
f1 (ppm)

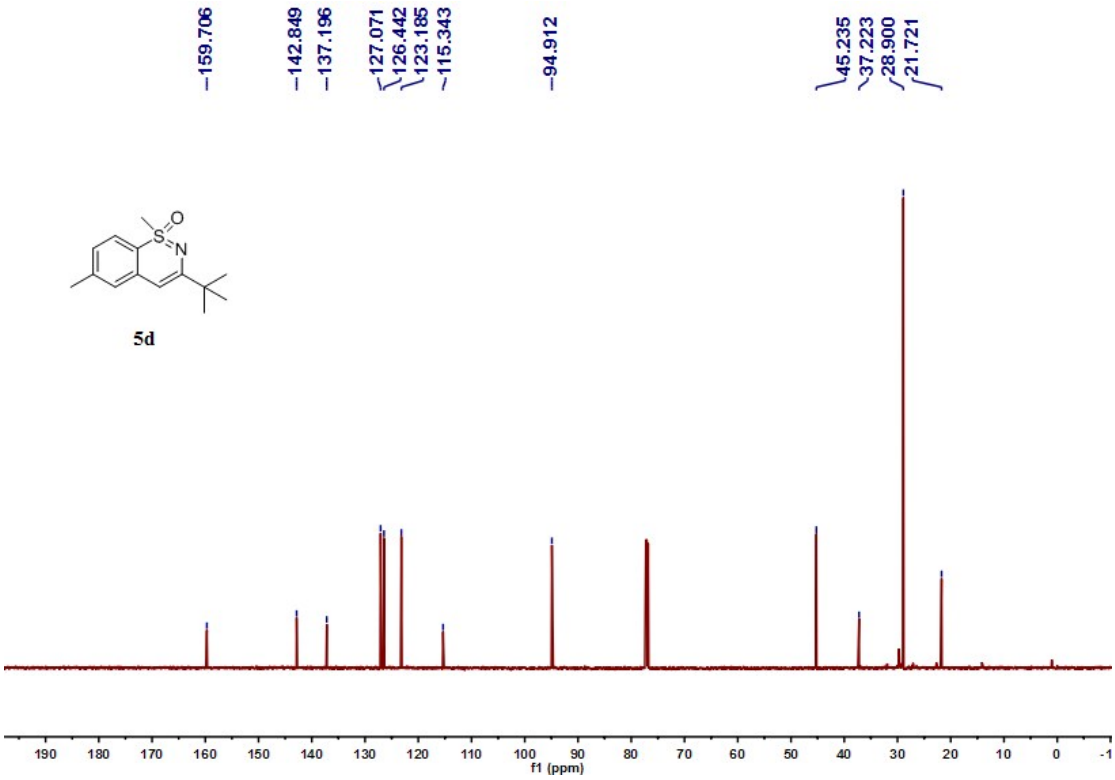
5c

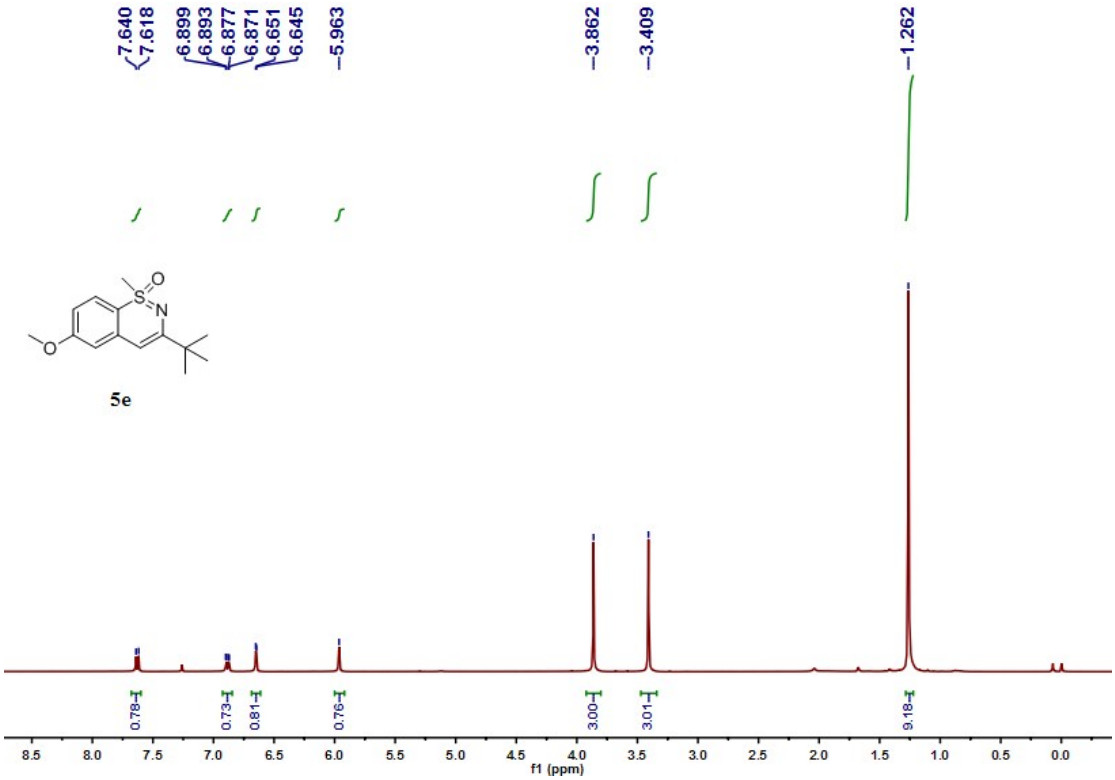

159.777
137.029
132.275
126.773
125.675
123.174
117.717
95.178
45.058
37.279
28.904
f1 (ppm)

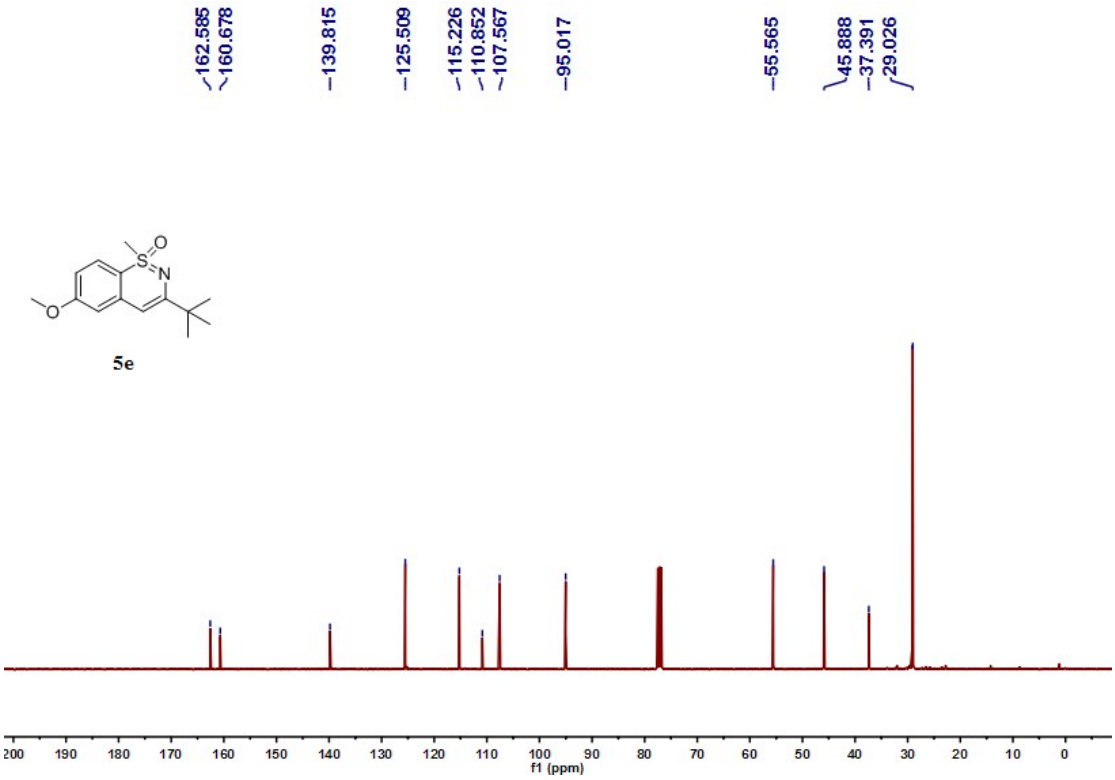
5c

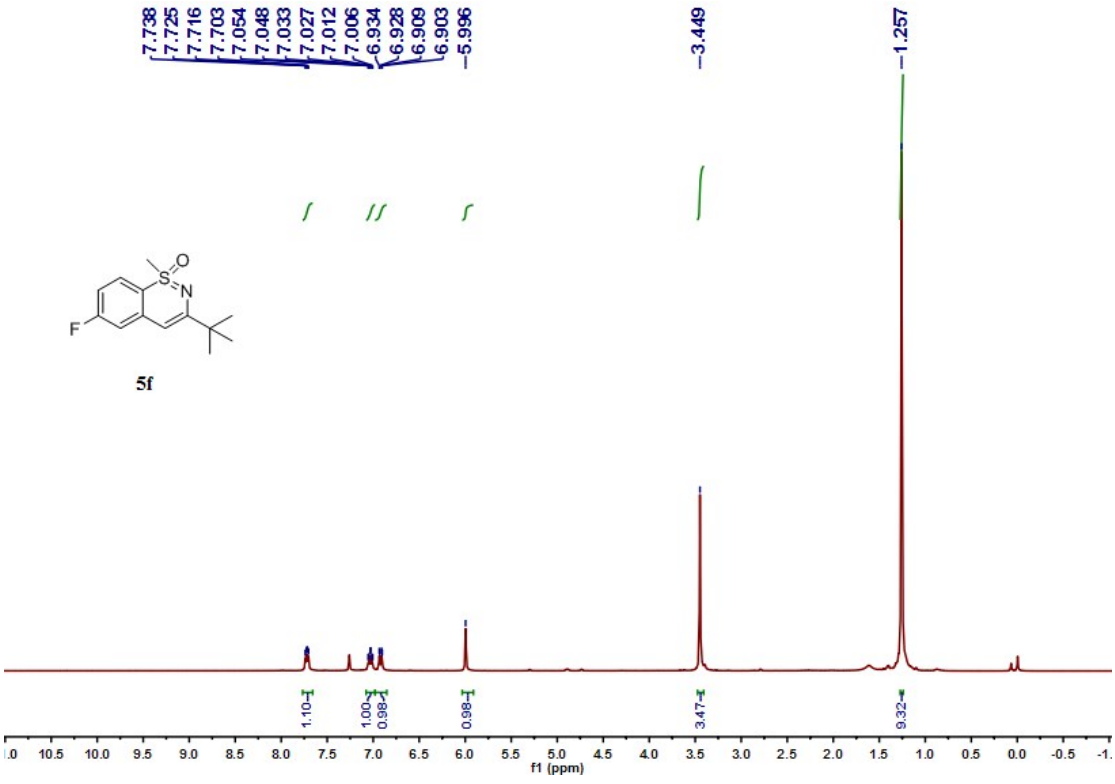

7.613
7.593
7.147
7.143
7.126
7.122
7.072
5.982
3.430
2.390
1.260
1.01
1.00
1.02
1.07
3.45
3.13
9.42
f1 (ppm)

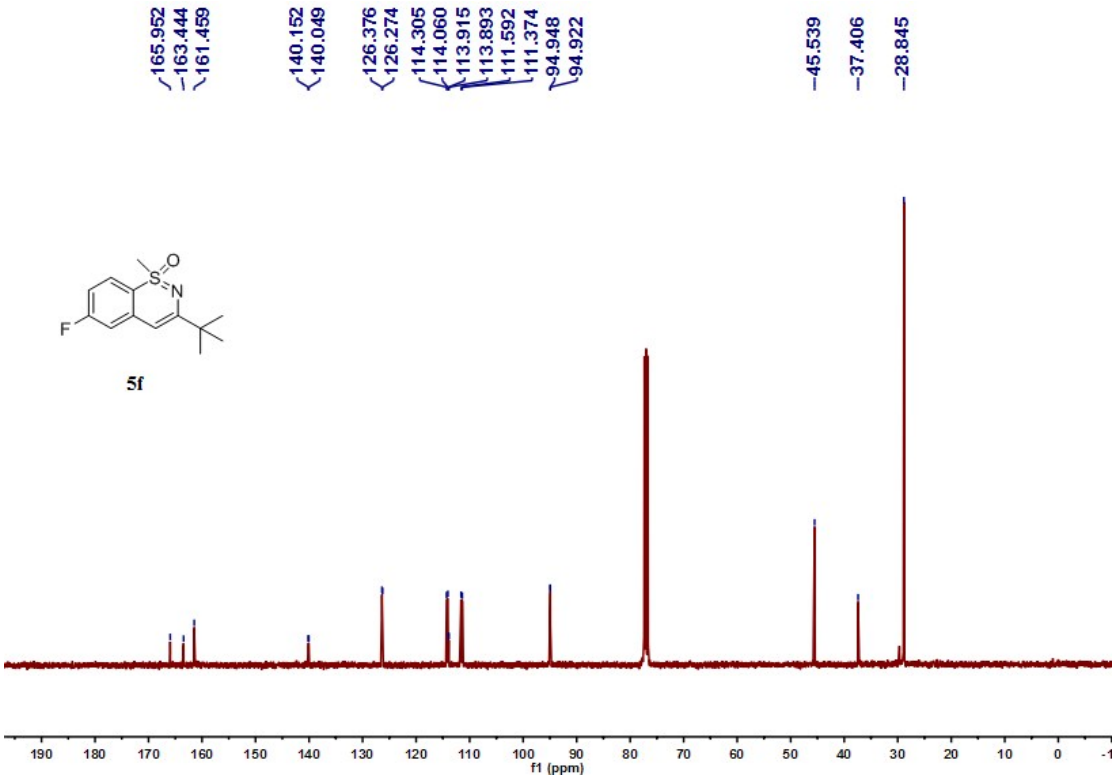
5d


159.706
142.849
137.196
127.071
126.442
123.185
115.343
94.912
45.235
37.223
28.900
21.721
5d
f1 (ppm)

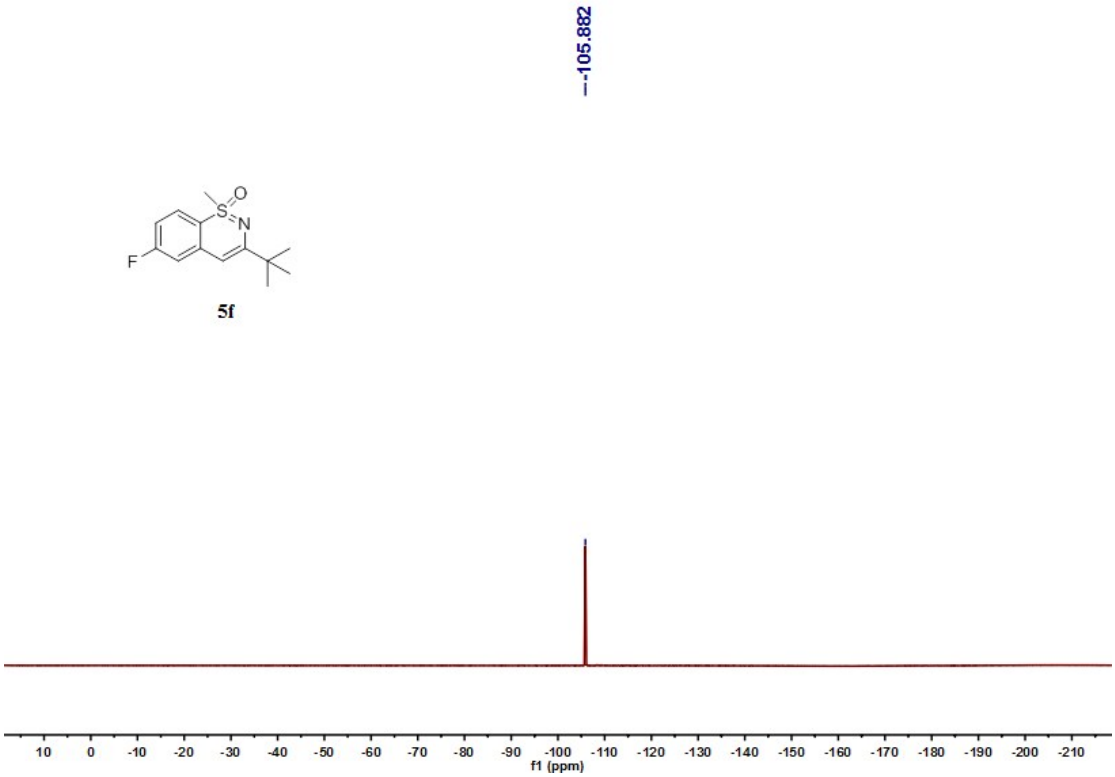

7.640
7.618
6.899
6.893
6.877
6.871
6.651
6.645
5.963
3.862
3.409
1.262
5e
0.78
0.73
0.81
0.76
3.00
3.01
9.18
f1 (ppm)


162.585
160.678
139.815
125.509
115.226
110.852
107.567
95.017
55.565
45.888
37.391
29.026
O
S
N
O
5e
f1 (ppm)

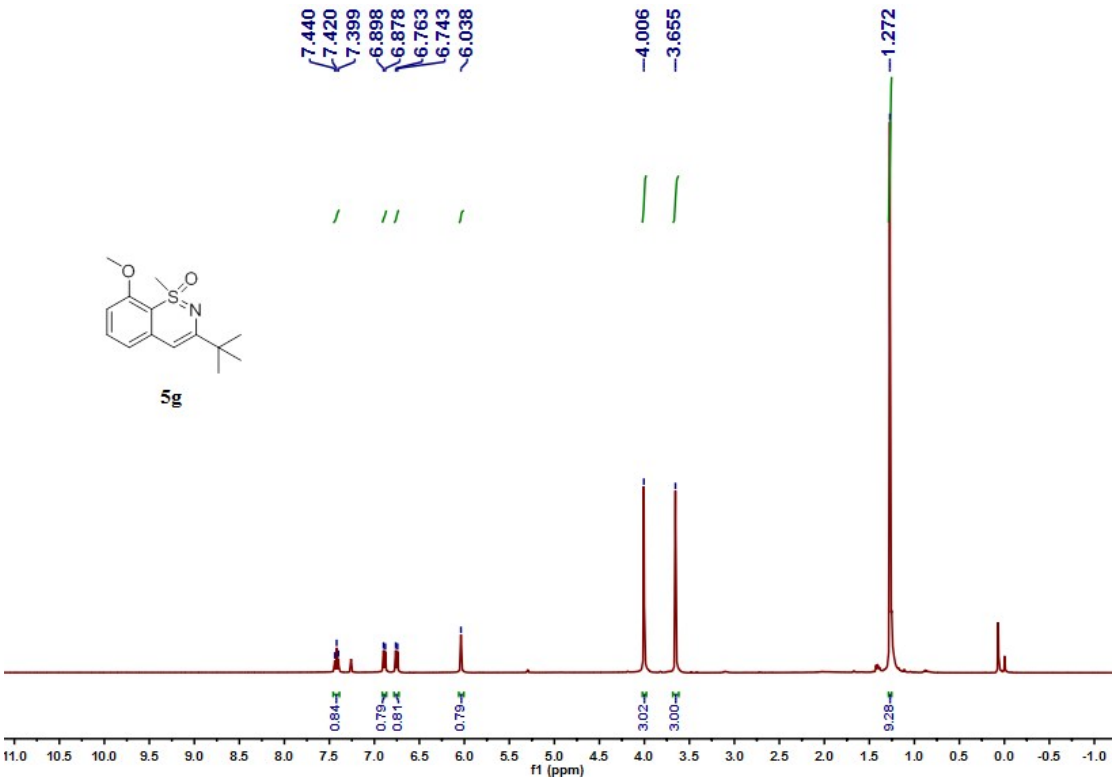

7.738
7.725
7.716
7.703
7.054
7.048
7.033
7.027
7.012
7.006
6.934
6.928
6.909
6.903
5.996
3.449
1.257
O
S
N
F
5f
1.10
1.00
0.98
0.98
3.47
9.32
f1 (ppm)


165.952
163.444
161.459
140.152
140.049
126.376
126.274
114.305
114.060
113.915
113.893
111.592
111.374
94.948
94.922
45.539
37.406
28.845
F
S
O
N
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

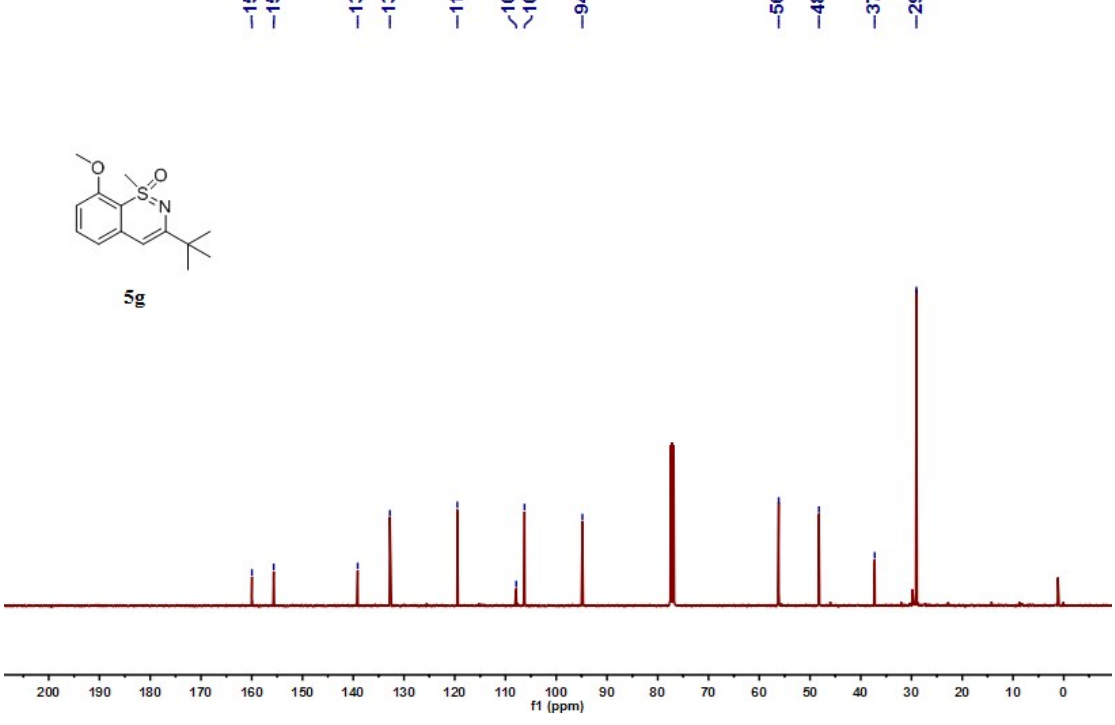
5f


-105.882
F
S
O
N
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

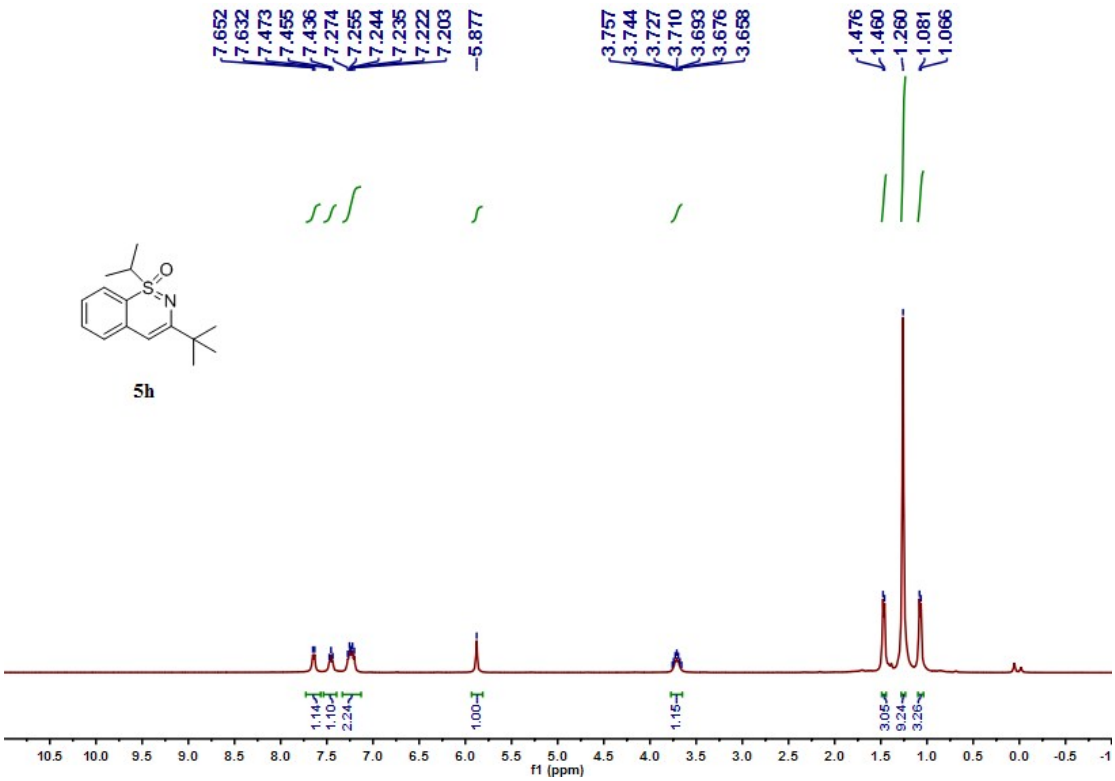
5f


7.440
7.420
7.399
6.898
6.878
6.763
6.743
6.038
4.006
3.655
1.272
0.84
0.79
0.81
0.79
3.02
3.00
9.28
f1 (ppm)

5g


159.962
155.673
139.118
132.777
119.487
107.881
106.242
94.847
56.161
48.238
37.239
29.035
f1 (ppm)

5g


7.652
7.632
7.473
7.455
7.436
7.274
7.255
7.244
7.235
7.222
7.203
5.877
3.757
3.744
3.727
3.710
3.693
3.676
3.658
1.476
1.460
1.260
1.081
1.066
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1.10
2.24
1.00
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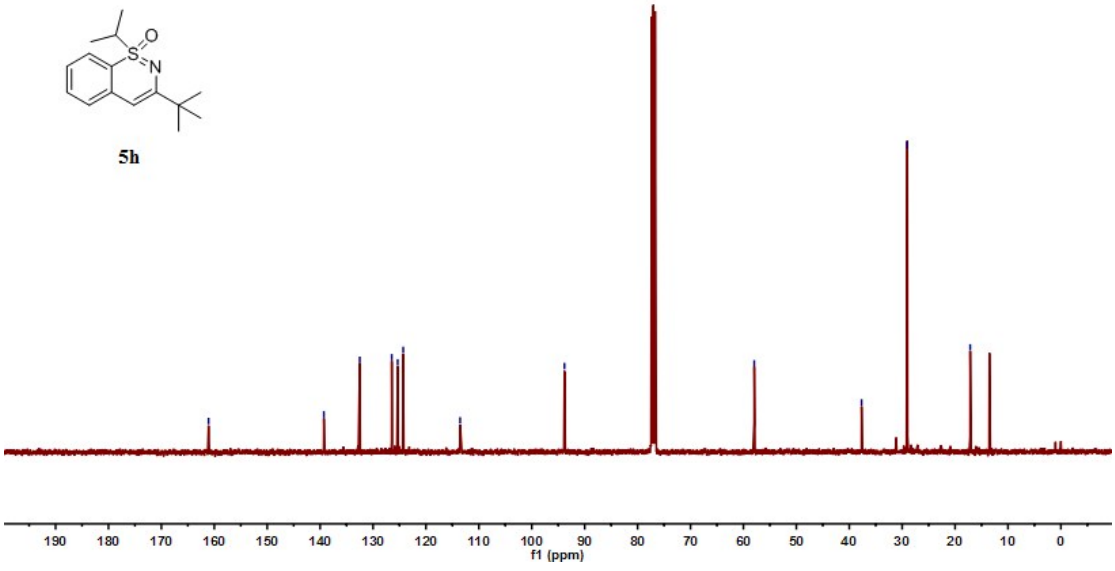
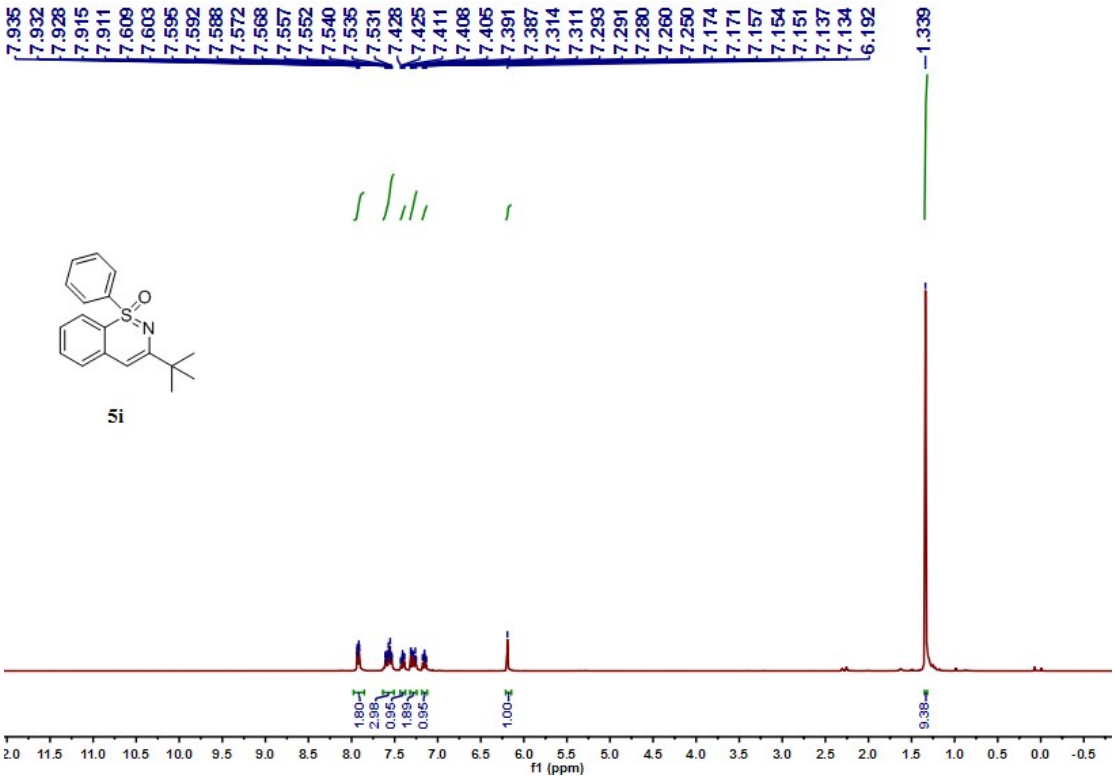
3.05
9.24
3.26
f1 (ppm)

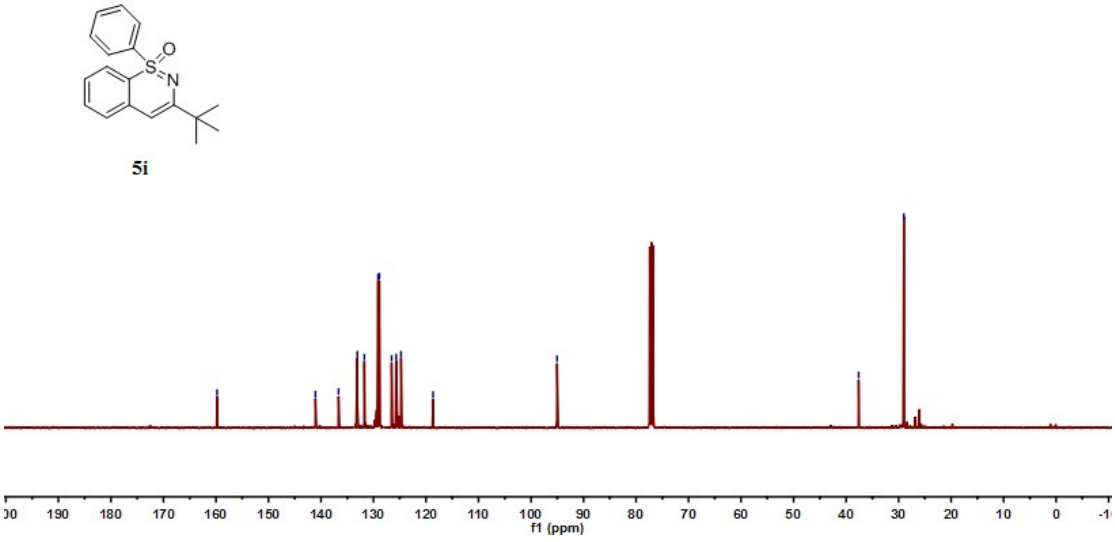
5h


161.089
139.296
132.516
126.464
125.346
124.296
113.538
93.826
57.955
37.671
29.021
17.147
f1 (ppm)

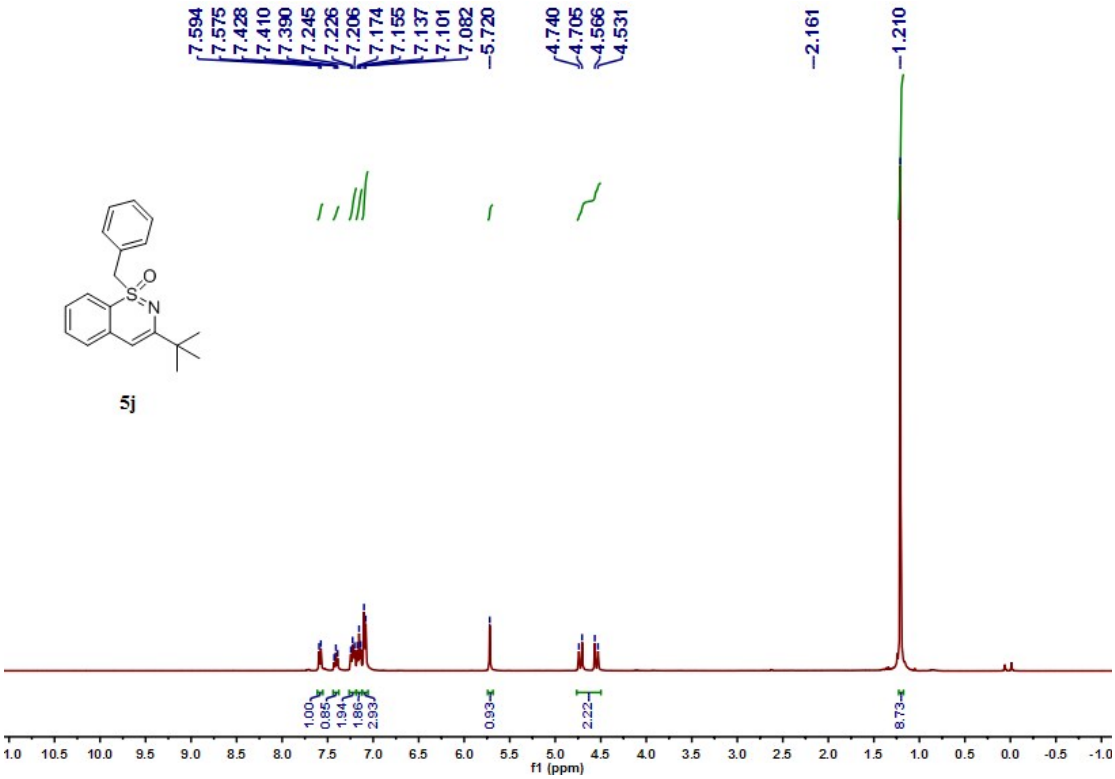
5h


7.935
7.932
7.928
7.915
7.911
7.609
7.603
7.595
7.592
7.588
7.572
7.568
7.557
7.552
7.540
7.535
7.531
7.428
7.425
7.411
7.408
7.405
7.391
7.387
7.314
7.311
7.293
7.291
7.280
7.260
7.250
7.174
7.171
7.157
7.154
7.151
7.137
7.134
6.192
1.339
1.80
2.98
0.95
1.89
0.95
1.00
9.38
f1 (ppm)

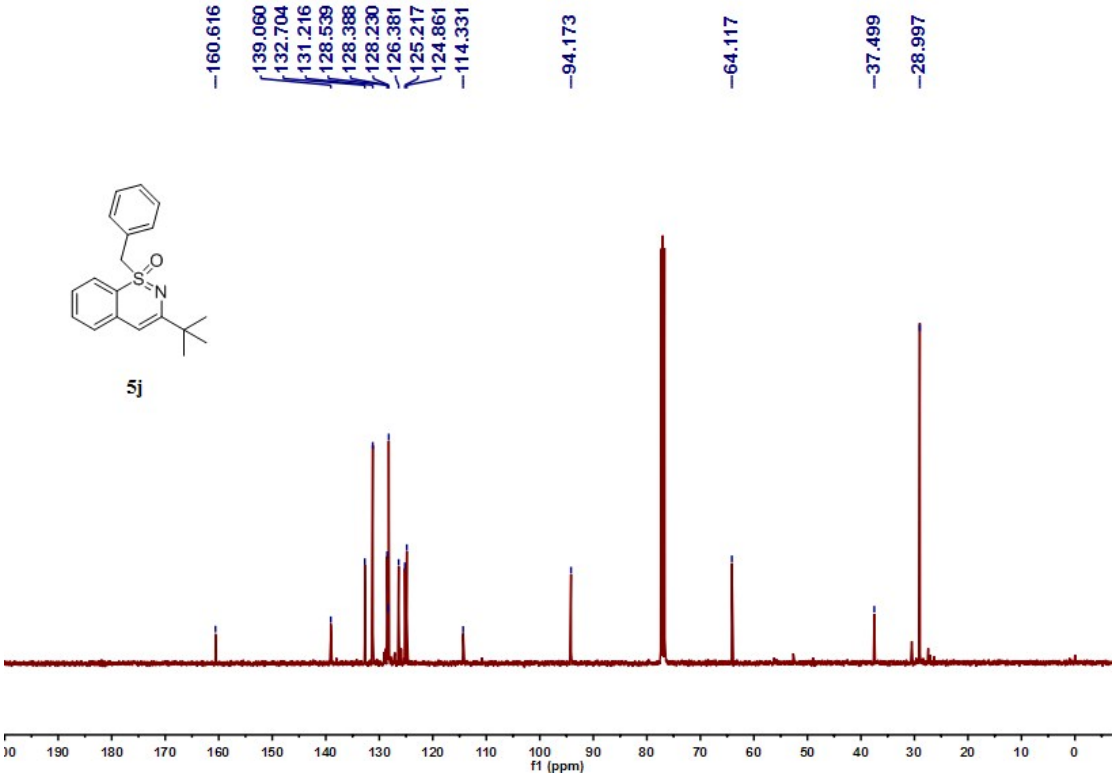
5i


159.786
141.053
136.653
133.081
131.742
129.127
128.890
126.548
125.675
124.752
118.654
95.043
37.601
29.006
f1 (ppm)

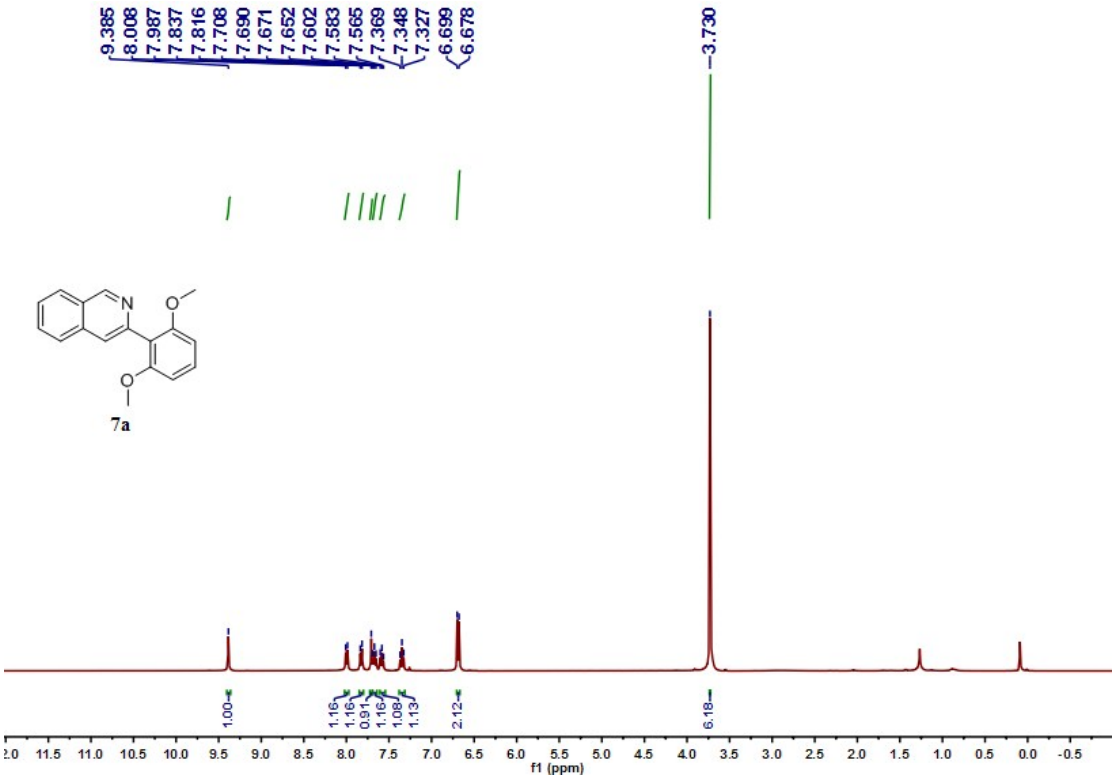
5i

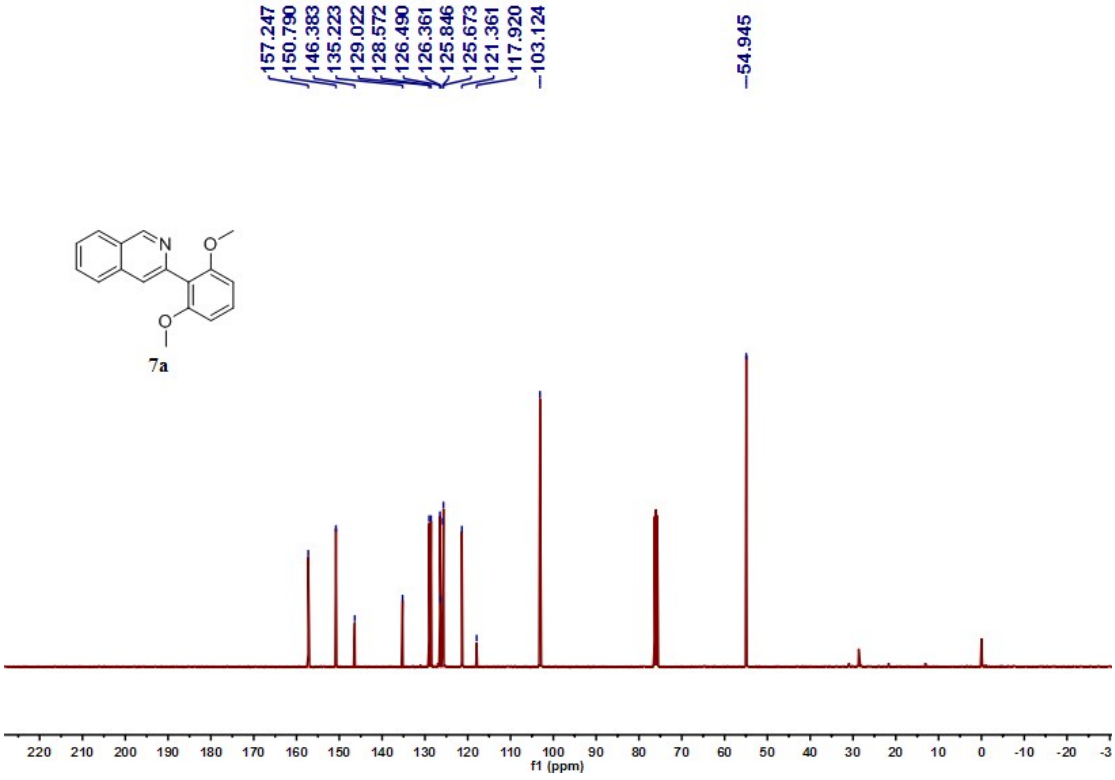

7.594
7.575
7.428
7.410
7.390
7.245
7.226
7.206
7.174
7.155
7.137
7.101
7.082
5.720
4.740
4.705
4.566
4.531
2.161
1.210
1.00
0.85
1.94
1.86
2.93
0.93
2.22
8.73
f1 (ppm)

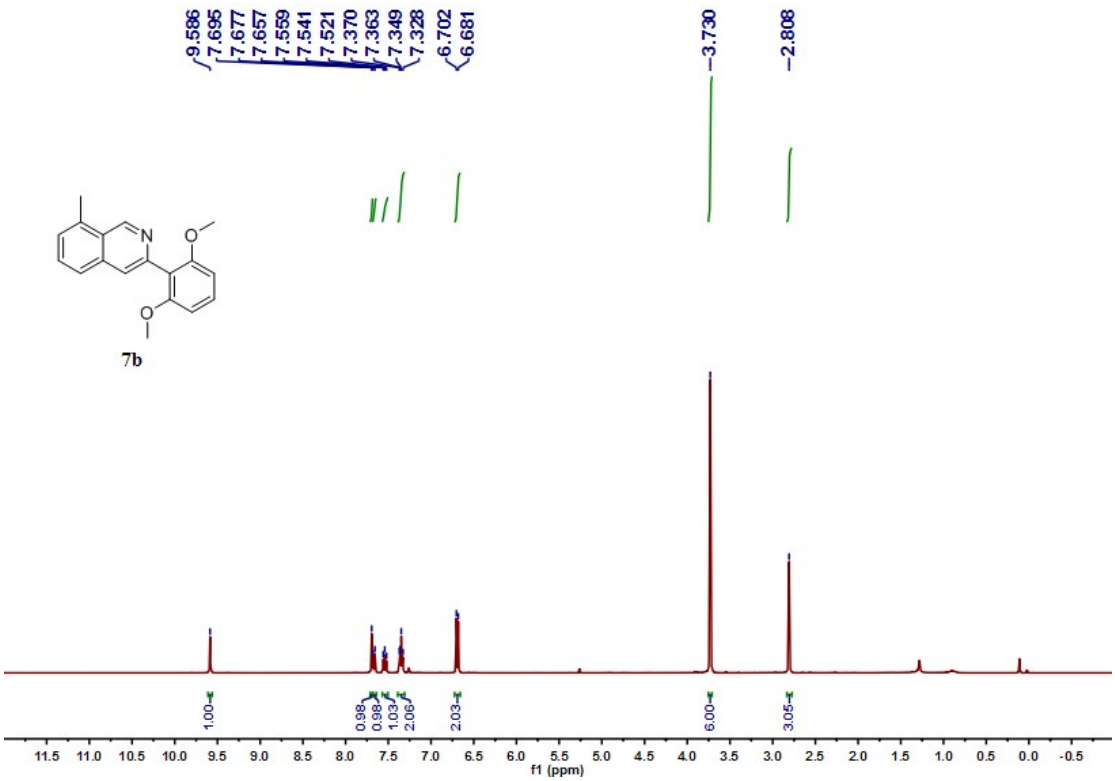
5j

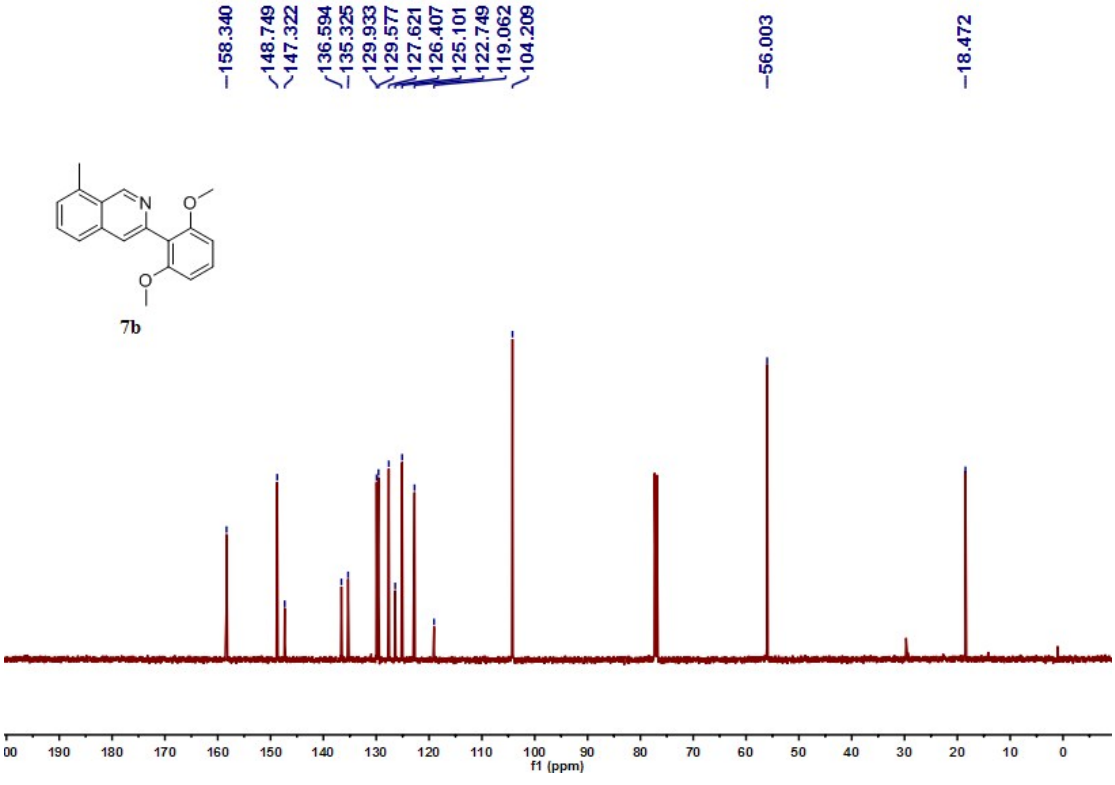

160.616
139.060
132.704
131.216
128.539
128.388
128.230
126.381
125.217
124.861
114.331
94.173
64.117
37.499
28.997
f1 (ppm)

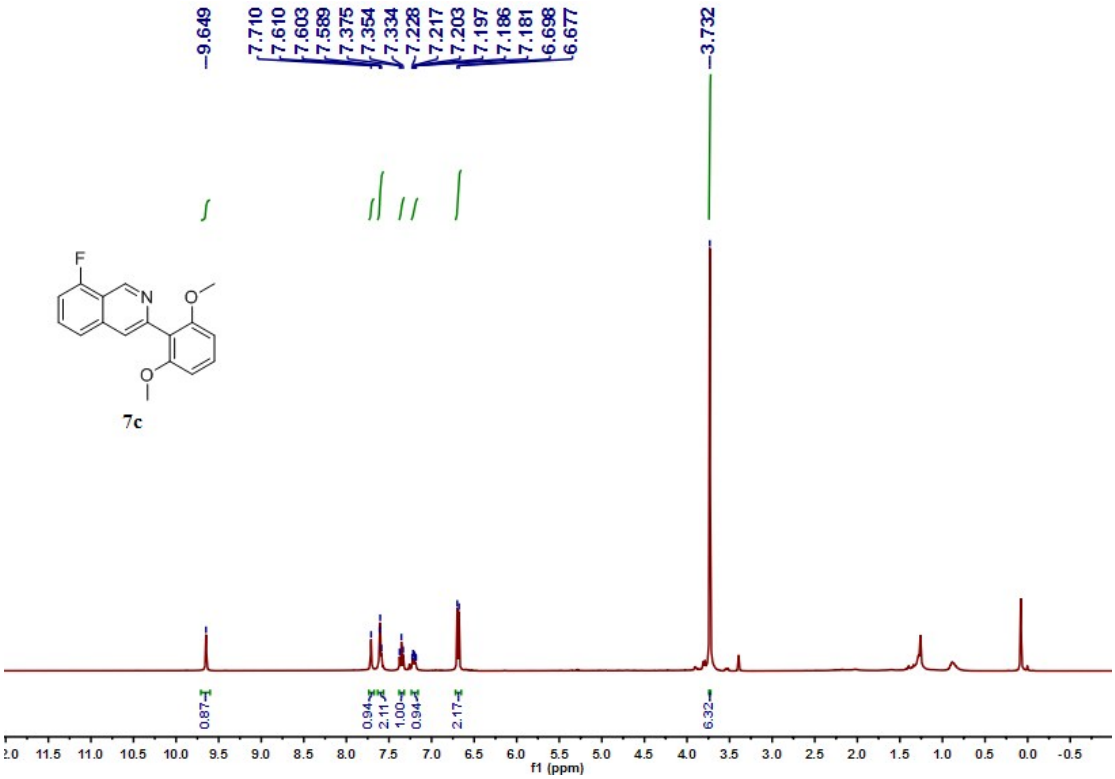
5j

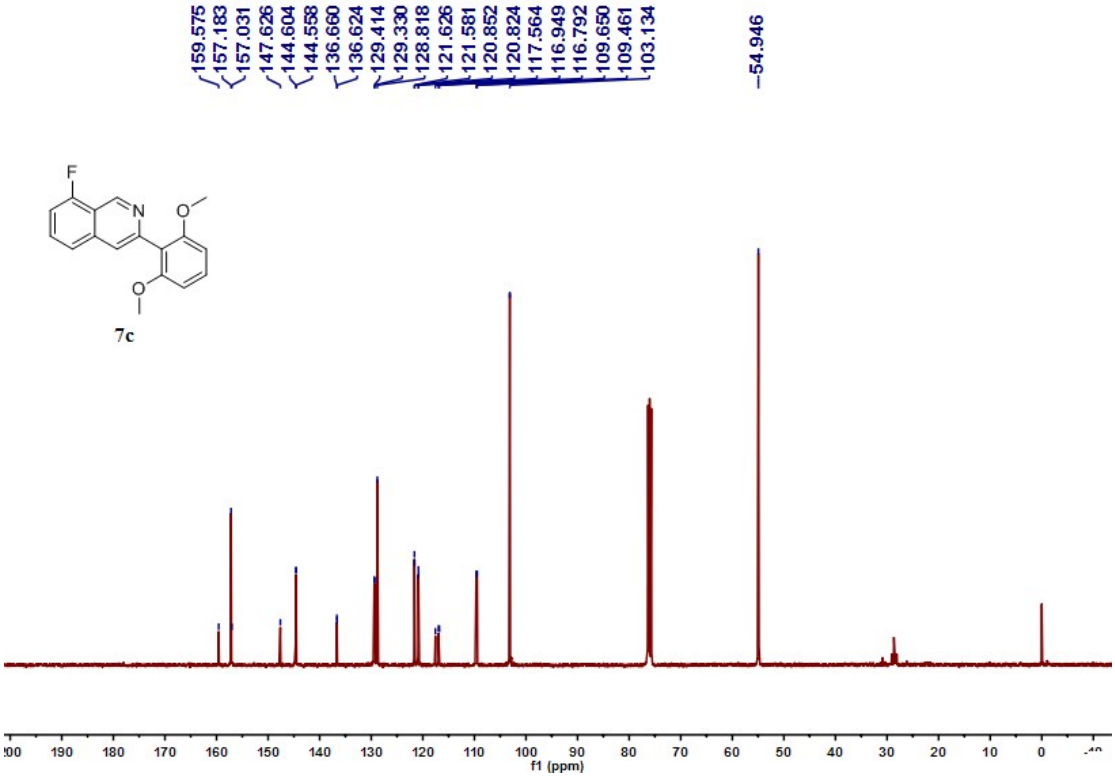

9.385
8.008
7.987
7.837
7.816
7.708
7.690
7.671
7.652
7.602
7.583
7.565
7.369
7.348
7.327
6.699
6.678
3.730
7a
1.00
1.16
1.16
0.91
1.16
1.08
1.13
2.12
6.18
f1 (ppm)

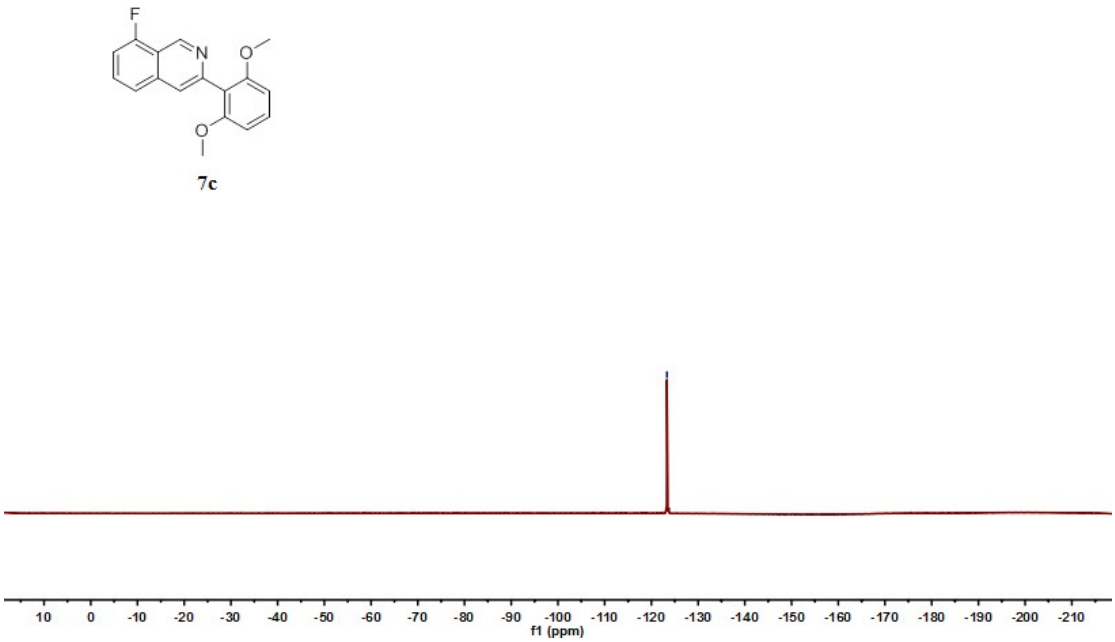

157.247
150.790
146.383
135.223
129.022
128.572
126.490
126.361
125.846
125.673
121.361
117.920
103.124
54.945
7a
f1 (ppm)

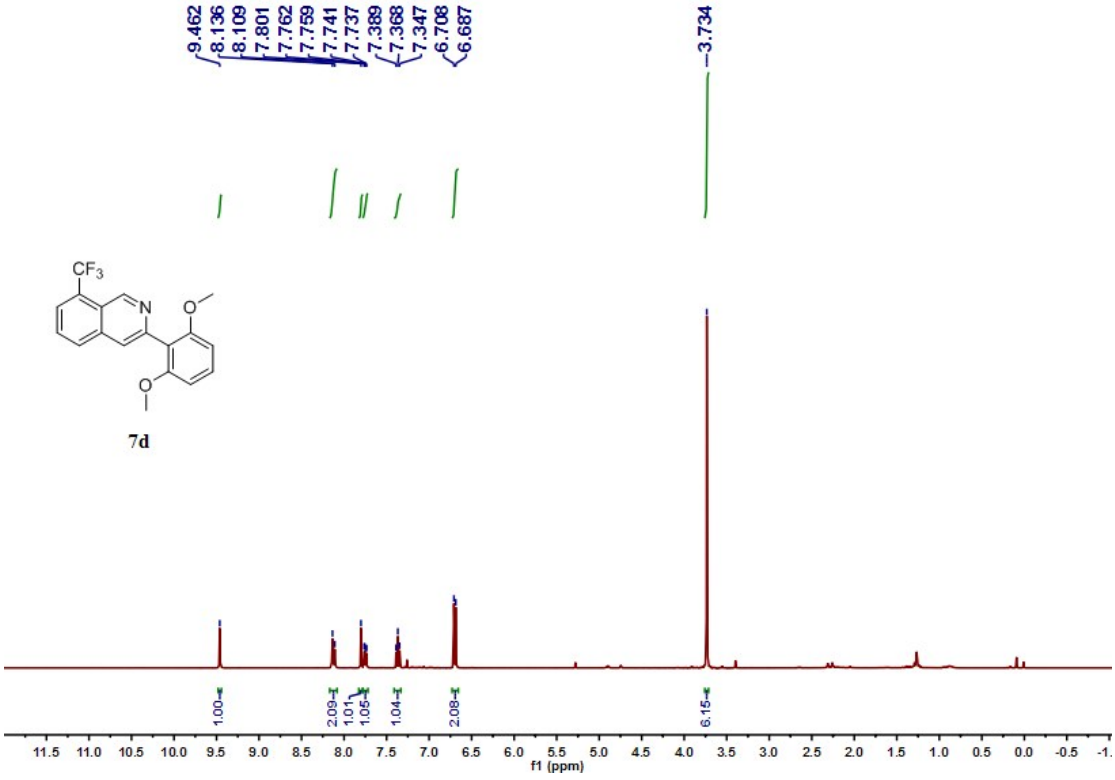

9.586
7.695
7.677
7.657
7.559
7.541
7.521
7.370
7.363
7.349
7.328
6.702
6.681
3.730
2.808
7b
1.00
0.98
0.98
1.03
2.06
2.03
6.00
3.05
f1 (ppm)

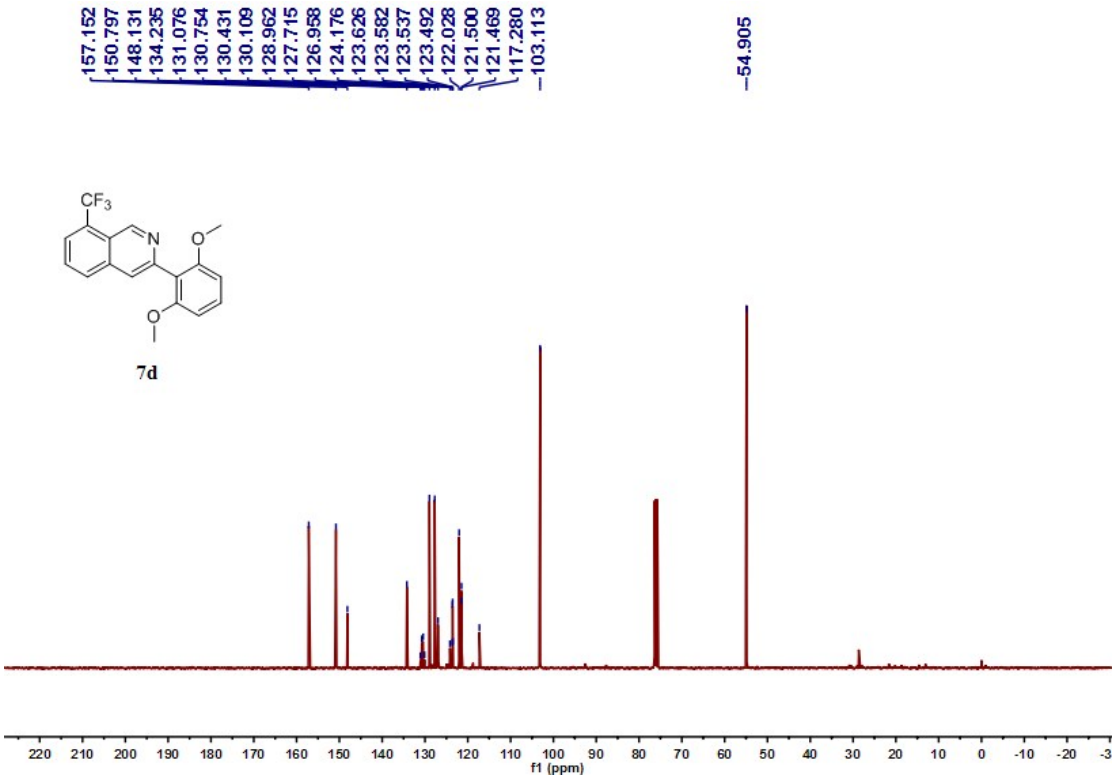

158.340
148.749
147.322
136.594
135.325
129.933
129.577
127.621
126.407
125.101
122.749
119.062
104.209
56.003
18.472
7b
f1 (ppm)

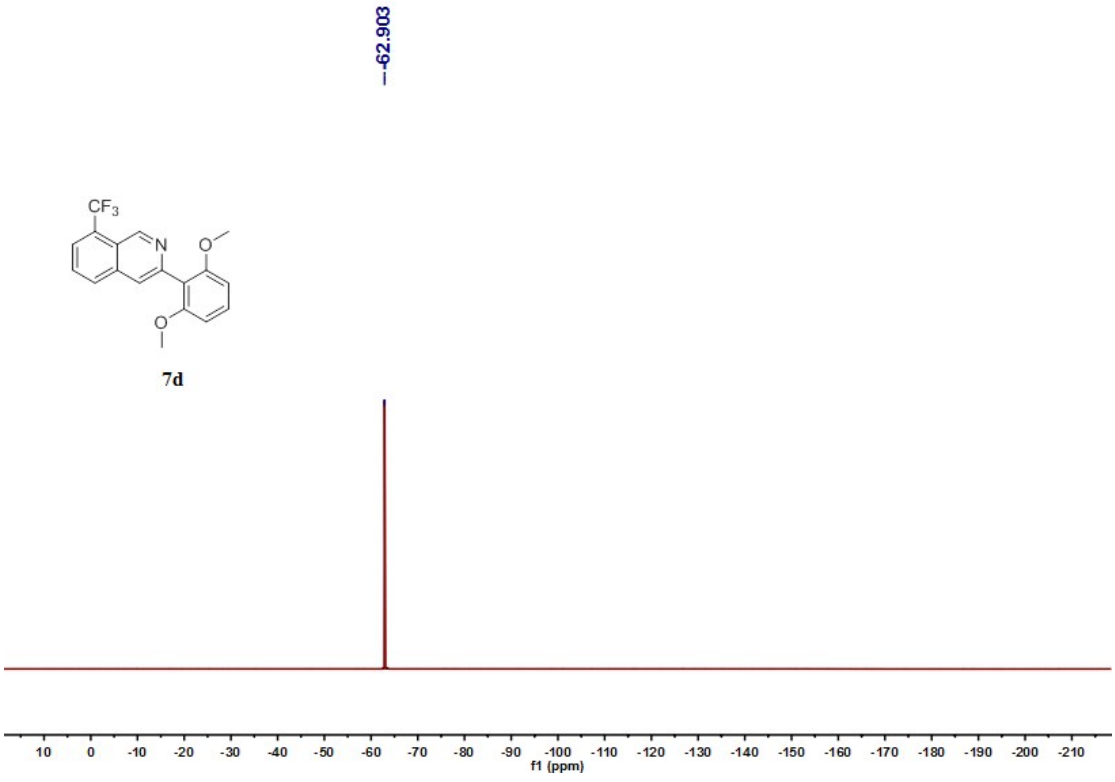

9.649
7.710
7.610
7.603
7.589
7.375
7.354
7.334
7.228
7.217
7.203
7.197
7.186
7.181
6.698
6.677
3.732
F
N
O
O
7c
0.87
0.94
2.11
1.00
0.94
2.17
6.32
f1 (ppm)

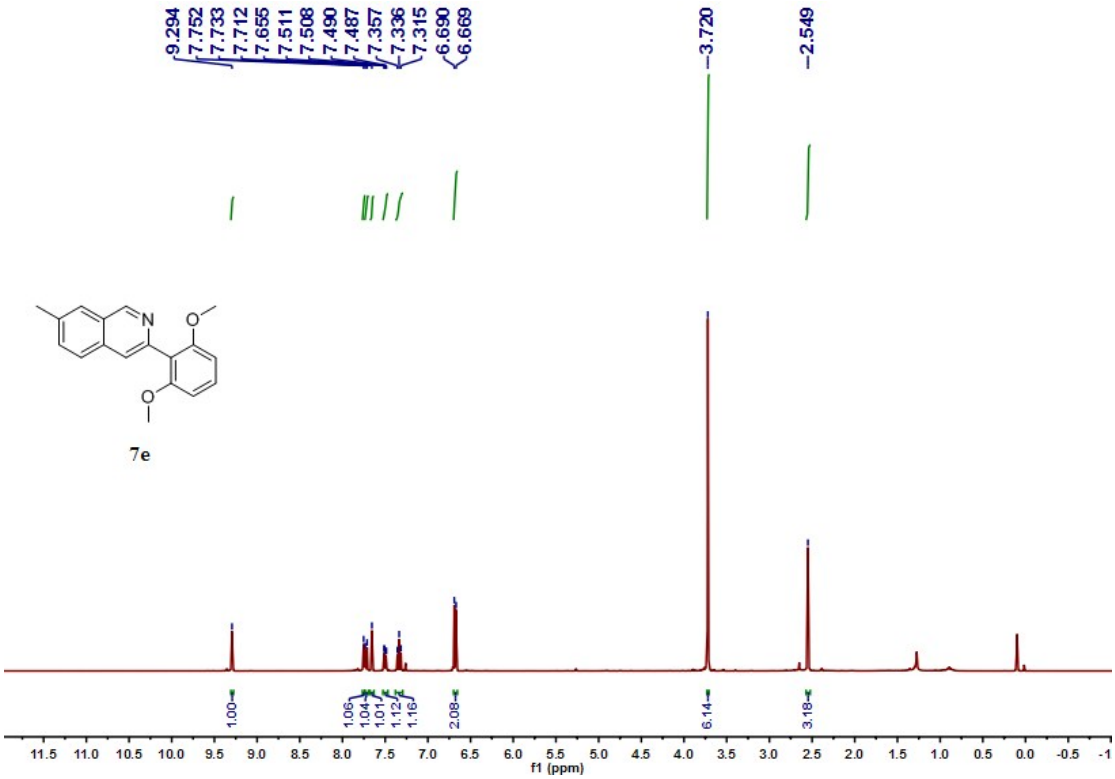

159.575
157.183
157.031
147.626
144.604
144.558
136.660
136.624
129.414
129.330
128.818
121.626
121.581
120.852
120.824
117.564
116.949
116.792
109.650
109.461
103.134
54.946
F
N
O
O
7c
f1 (ppm)


-123.329
F
N
O
O
7c
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

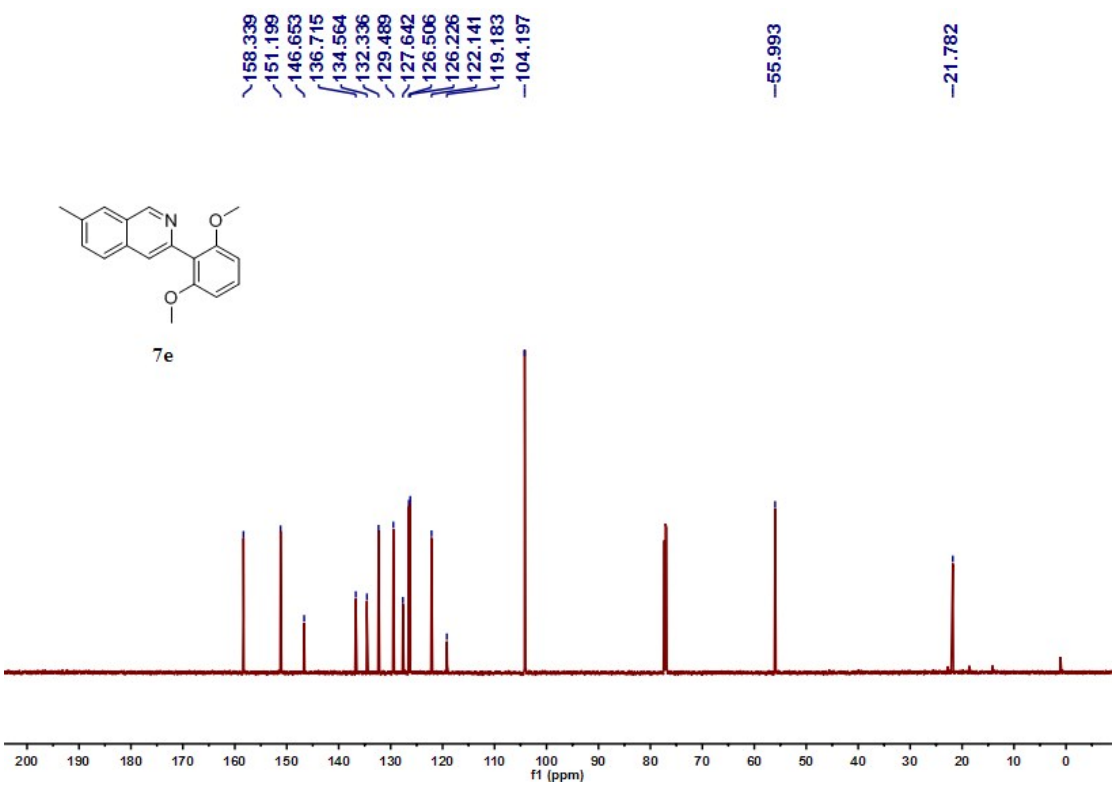

9.462
8.136
8.109
7.801
7.762
7.759
7.741
7.737
7.389
7.368
7.347
6.708
6.687
3.734
CF3
N
O
O
7d
1.00
2.09
1.01
1.05
1.04
2.08
6.15
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


157.152
150.797
148.131
134.235
131.076
130.754
130.431
130.109
128.962
127.715
126.958
124.176
123.626
123.582
123.537
123.492
122.028
121.500
121.469
117.280
103.113
54.905
CF3
N
O
O
7d
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20 -3
f1 (ppm)

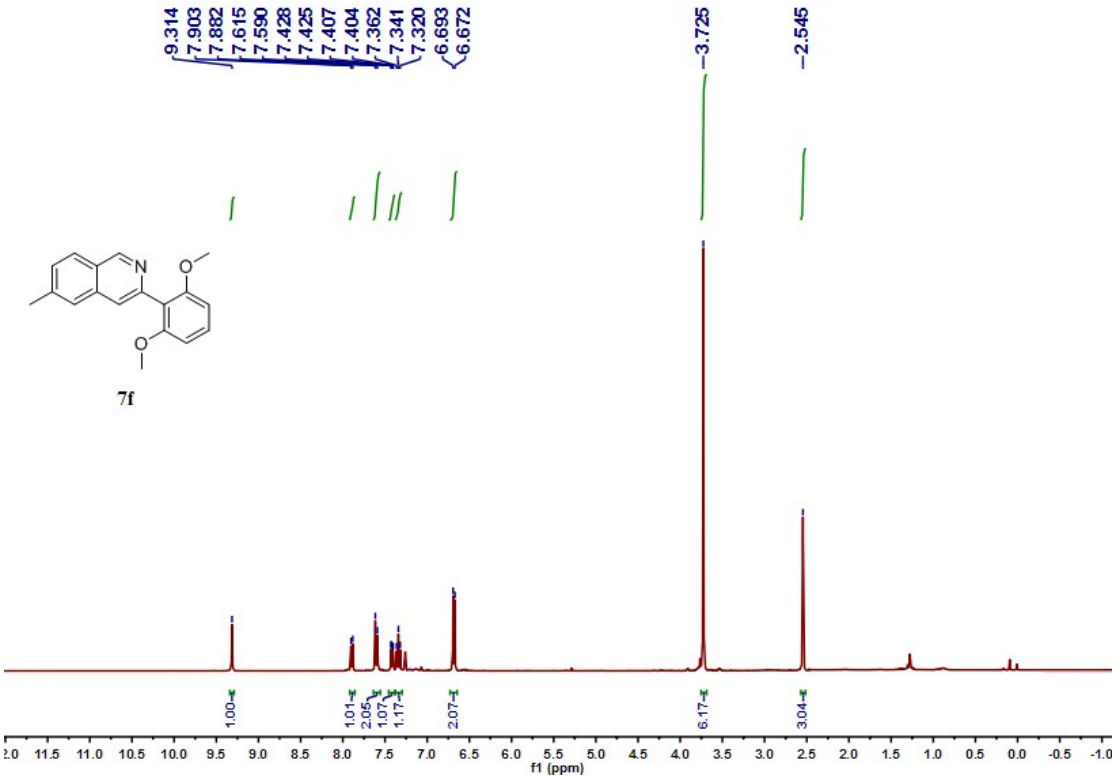

62.903
CF3
N
O
O
7d
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)


9.294
7.752
7.733
7.712
7.655
7.511
7.508
7.490
7.487
7.357
7.336
7.315
6.690
6.669
3.720
2.549
1.00
1.06
1.04
1.01
1.12
1.16
2.08
6.14
3.18
f1 (ppm)

7e


158.339
151.199
146.653
136.715
134.564
132.336
129.489
127.642
126.506
126.226
122.141
119.183
104.197
55.993
21.782
f1 (ppm)

7e


9.314
7.903
7.882
7.615
7.590
7.428
7.425
7.407
7.404
7.362
7.341
7.320
6.693
6.672
3.725
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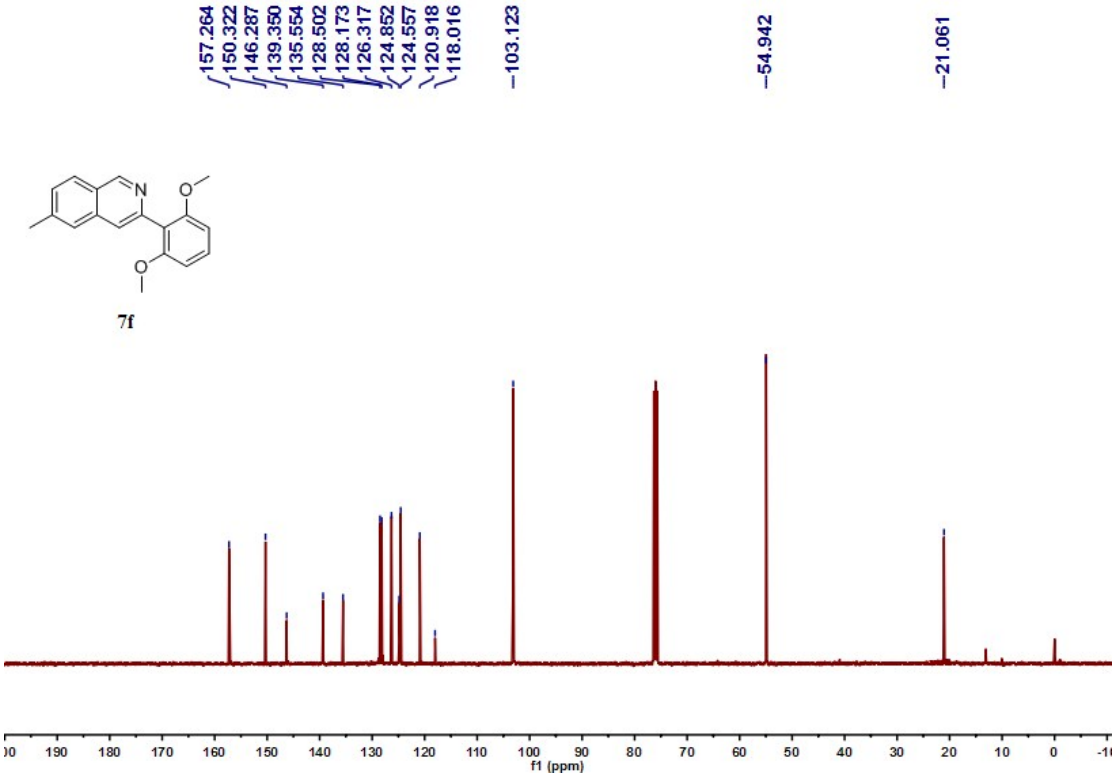
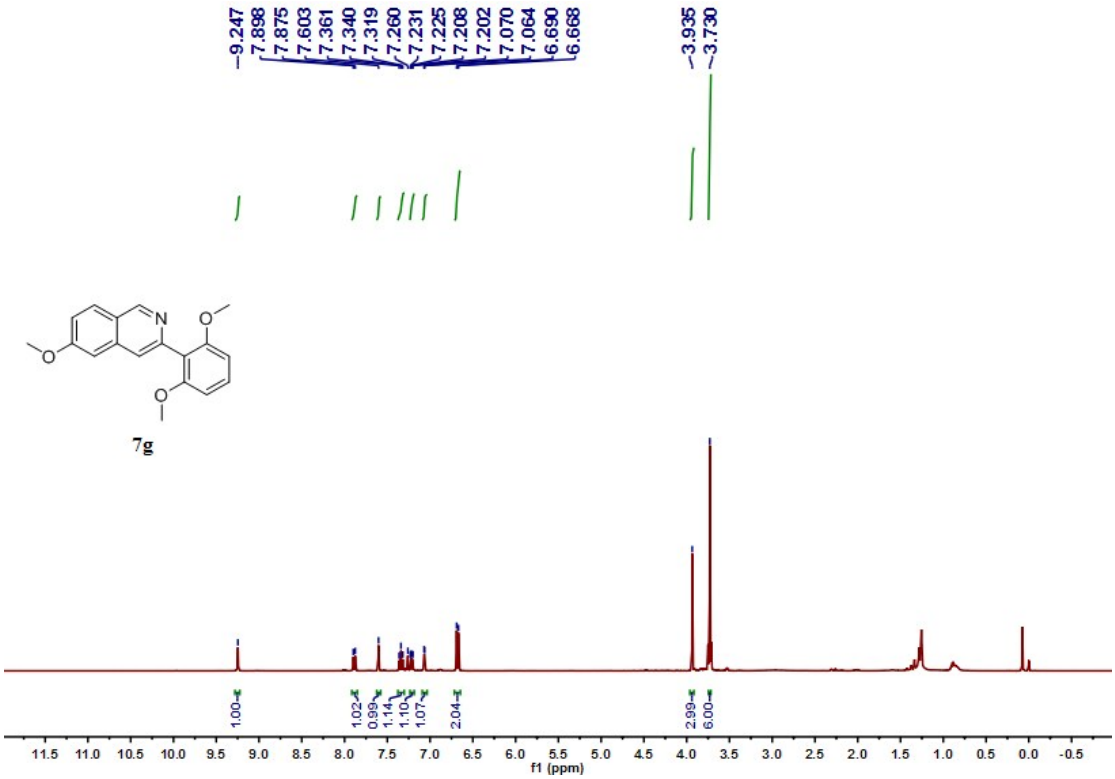
1.01
2.05
1.07
1.17
2.07
6.17
3.04
f1 (ppm)

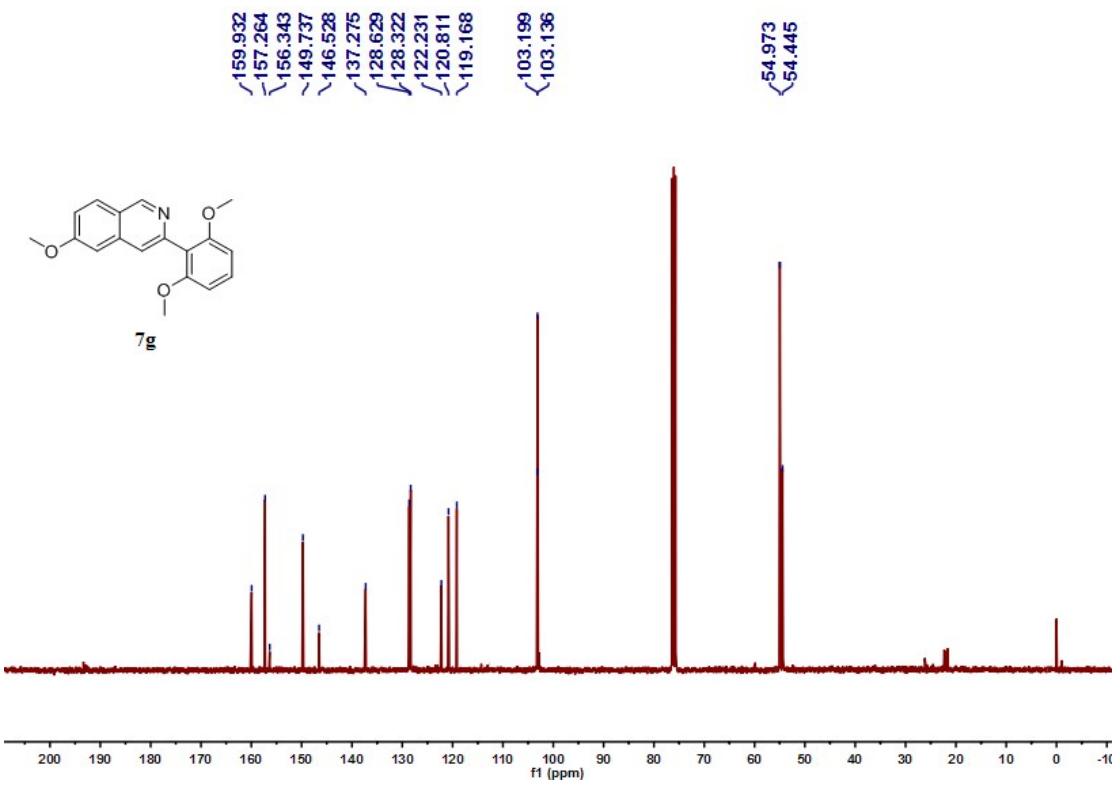
7f


157.264
150.322
146.287
139.350
135.554
128.502
128.173
126.317
124.852
124.557
120.918
118.016
103.123
54.942
21.061
f1 (ppm)

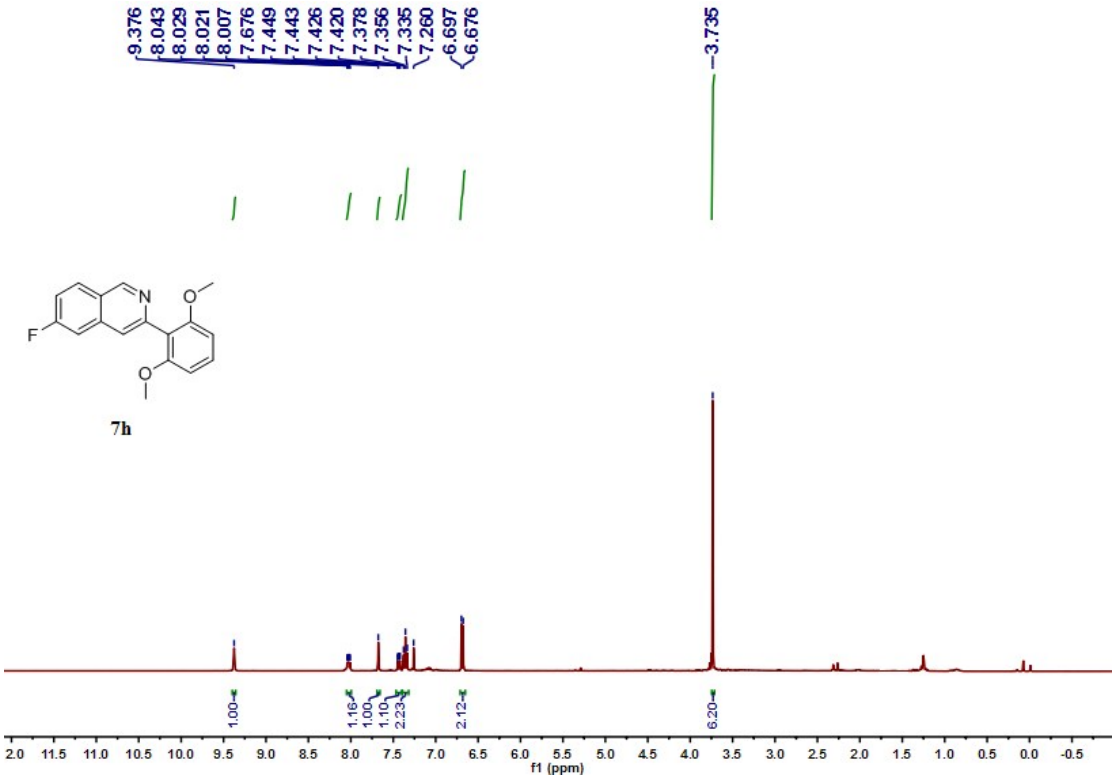
7f


9.247
7.898
7.875
7.603
7.361
7.340
7.319
7.260
7.231
7.225
7.208
7.202
7.070
7.064
6.690
6.668
3.935
3.730
1.00
1.02
0.99
1.14
1.10
1.07
2.04
2.99
6.00
f1 (ppm)

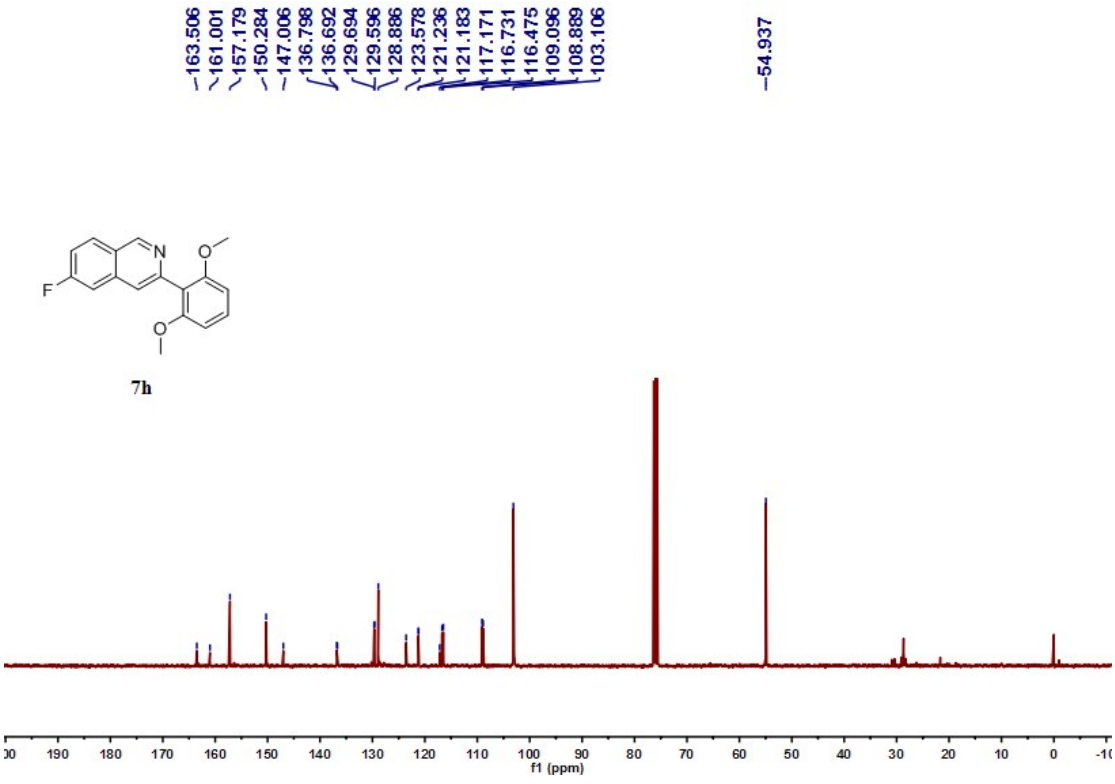
7g


159.932
157.264
156.343
149.737
146.528
137.275
128.629
128.322
122.231
120.811
119.168
103.199
103.136
54.973
54.445
f1 (ppm)

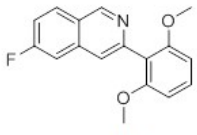
7g


9.376
8.043
8.029
8.021
8.007
7.676
7.449
7.443
7.426
7.420
7.378
7.356
7.335
7.260
6.697
6.676
3.735
1.00
1.16
1.00
1.10
2.23
2.12
6.20
f1 (ppm)

7h

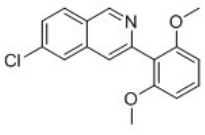

163.506
161.001
157.179
150.284
147.006
136.798
136.692
129.694
129.596
128.886
123.578
121.236
121.183
117.171
116.731
116.475
109.096
108.889
103.106
54.937
f1 (ppm)

7h



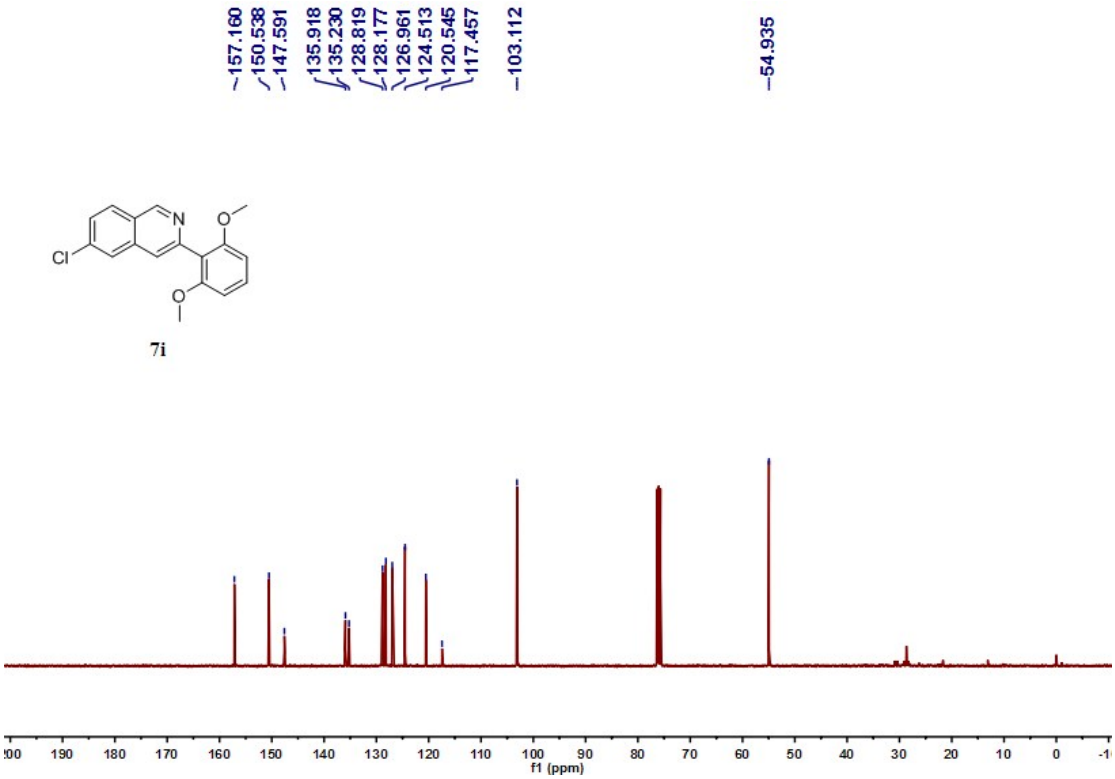
7h

-106.845
f1 (ppm)

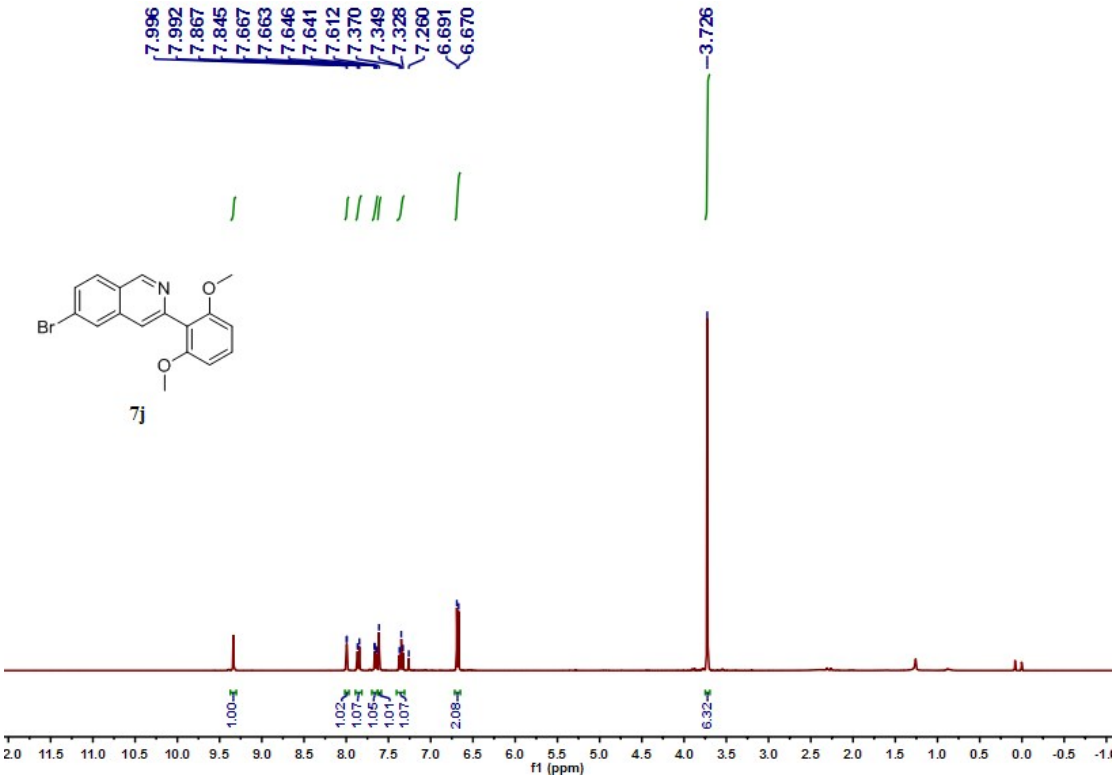


7i

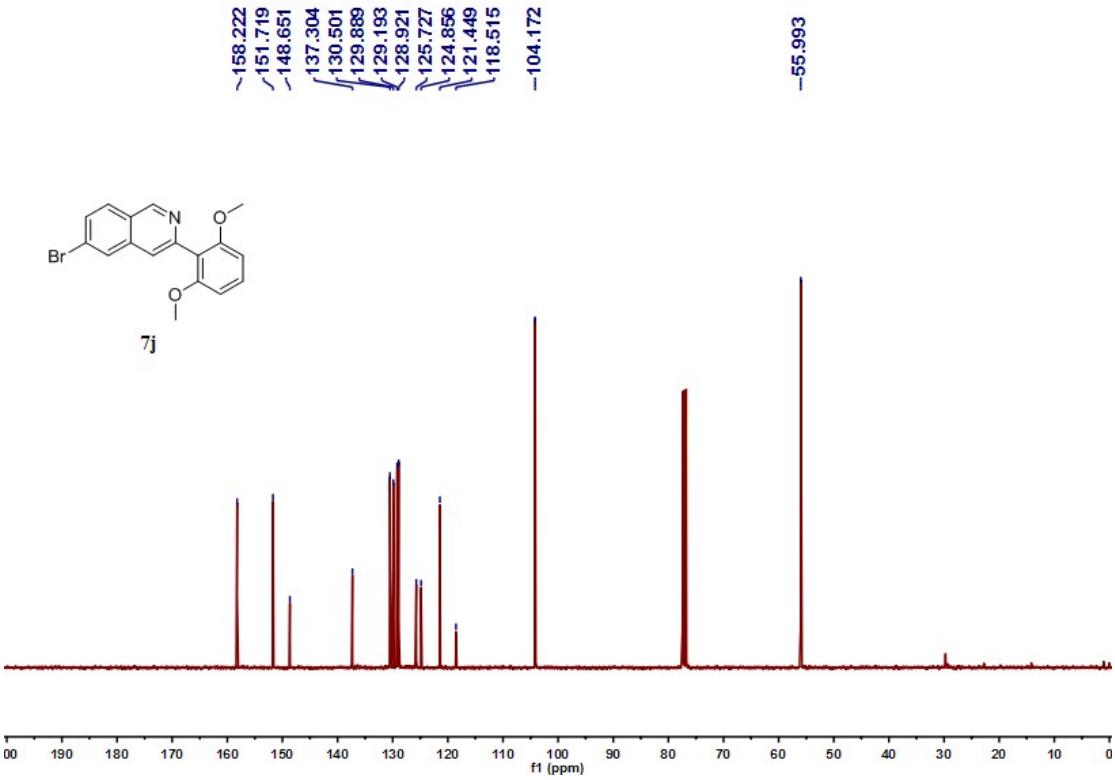
9.341
7.944
7.922
7.812
7.808
7.621
7.536
7.531
7.514
7.509
7.371
7.350
7.329
6.693
6.672
3.729
1.00
1.02
0.99
0.99
1.00
1.07
2.00
6.00
f1 (ppm)


157.160
150.538
147.591
135.918
135.230
128.819
128.177
126.961
124.513
120.545
117.457
103.112
54.935
Cl
N
O
O
f1 (ppm)

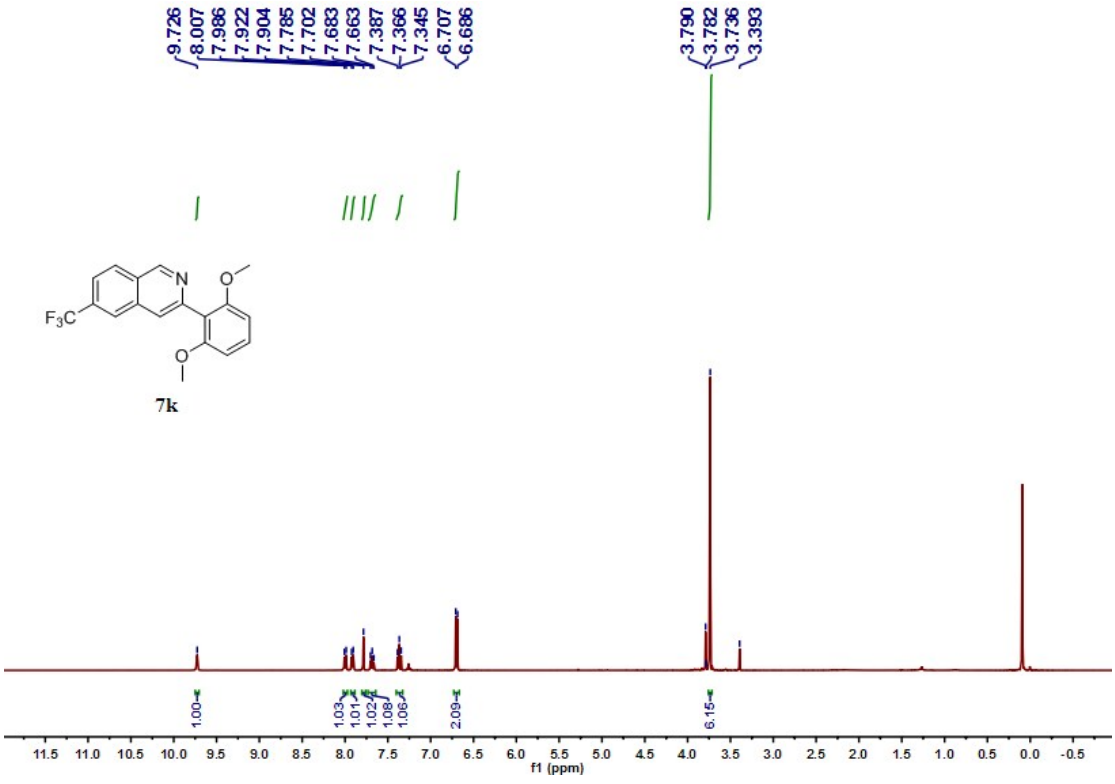
7i


7.996
7.992
7.867
7.845
7.667
7.663
7.646
7.641
7.612
7.370
7.349
7.328
7.260
6.691
6.670
3.726
Br
N
O
O
1.00
1.02
1.07
1.05
1.01
1.07
2.08
6.32
f1 (ppm)

7j


158.222
151.719
148.651
137.304
130.501
129.889
129.193
128.921
125.727
124.856
121.449
118.515
104.172
55.993
Br
N
O
O
f1 (ppm)

7j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7.986
7.922
7.904
7.785
7.702
7.683
7.663
7.387
7.366
7.345
6.707
6.686
3.790
3.782
3.736
3.393
F3C
N
O
O
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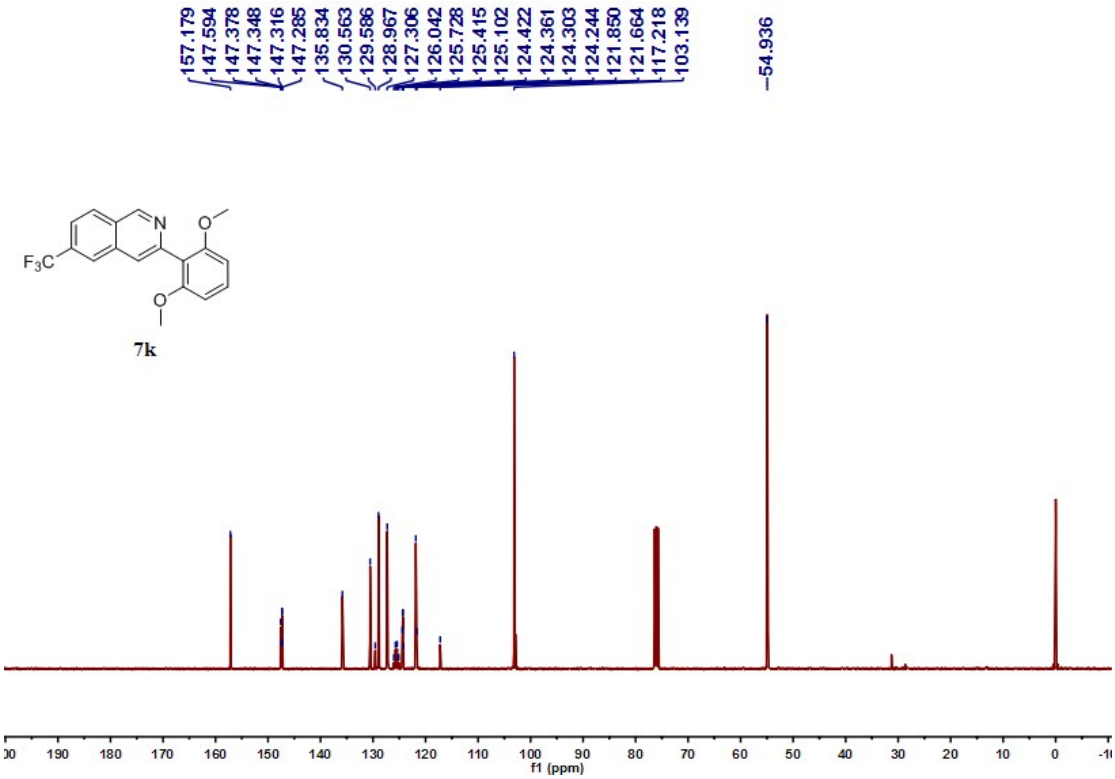
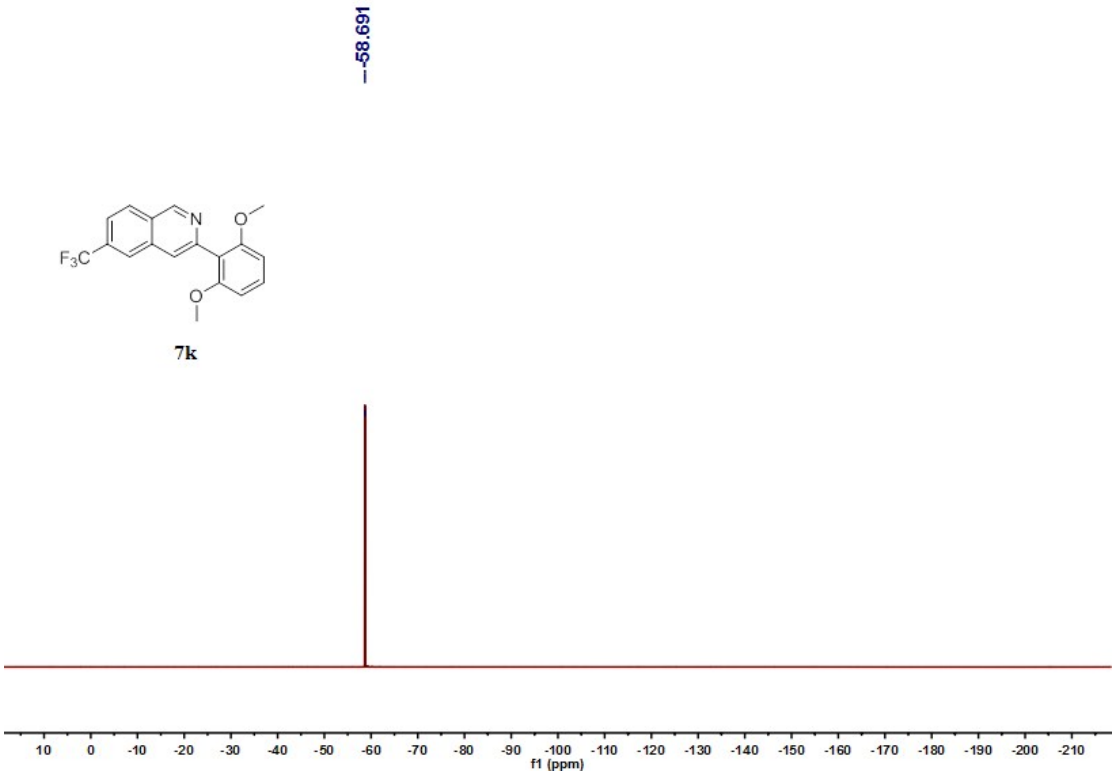
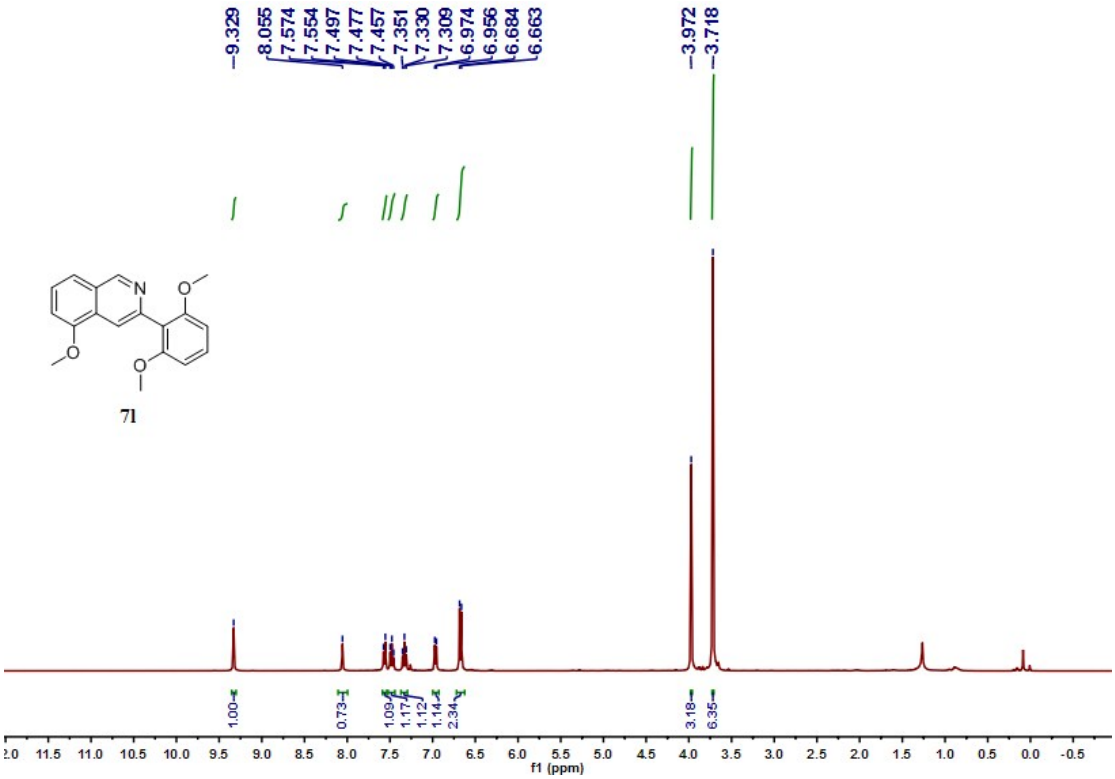
1.03
1.01
1.02
1.08
1.06
2.09
6.15
f1 (ppm)

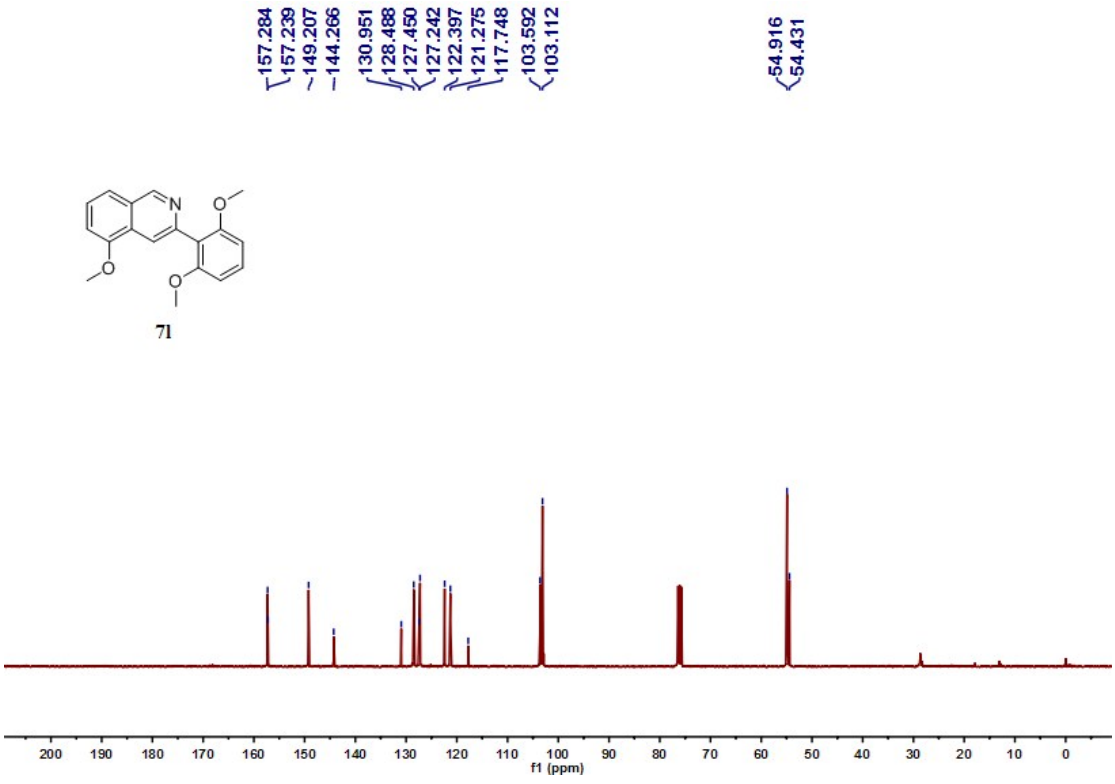
7k


157.179
147.594
147.378
147.348
147.316
147.285
135.834
130.563
129.586
128.967
127.306
126.042
125.728
125.415
125.102
124.422
124.361
124.303
124.244
121.850
121.664
117.218
103.139
54.936
F3C
N
O
O
7k
f1 (ppm)

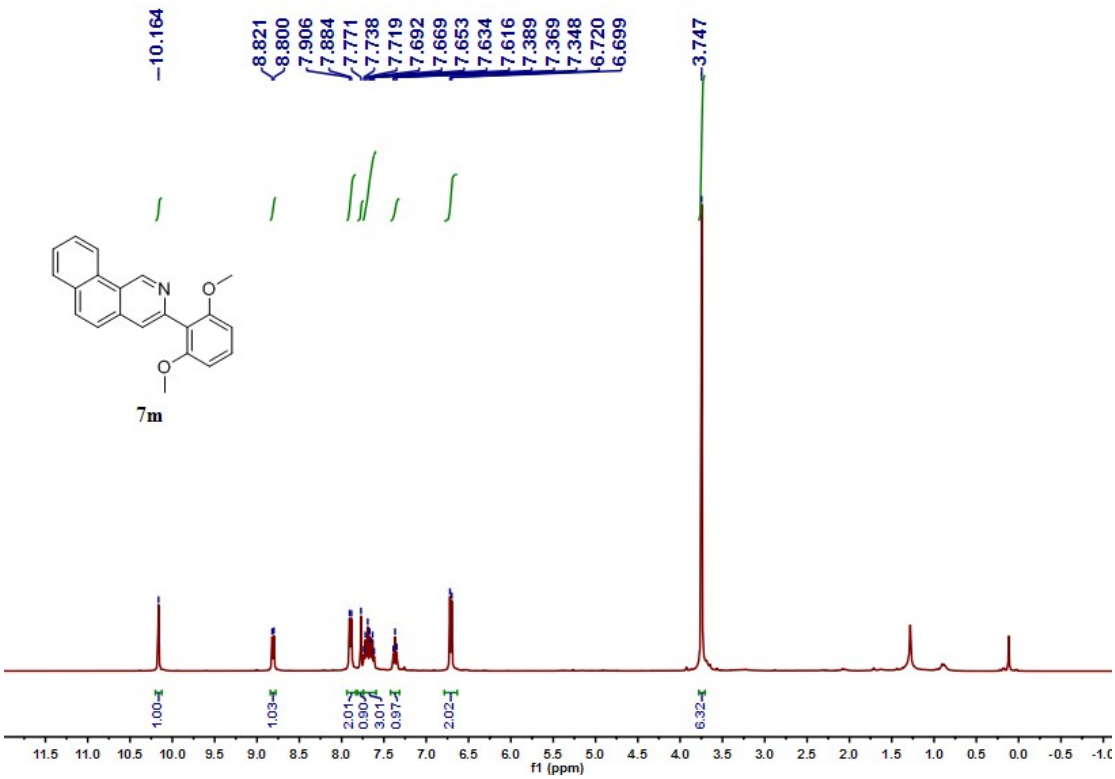

-58.691
F3C
N
O
O
7k
f1 (ppm)


9.329
8.055
7.574
7.554
7.497
7.477
7.457
7.351
7.330
7.309
6.974
6.956
6.684
6.663
3.972
3.718
1.00
0.73
1.09
1.17
1.12
1.14
2.34
3.18
6.35
f1 (ppm)

71


157.284
157.239
149.207
144.266
130.951
128.488
127.450
127.242
122.397
121.275
117.748
103.592
103.112
54.916
54.431
f1 (ppm)

71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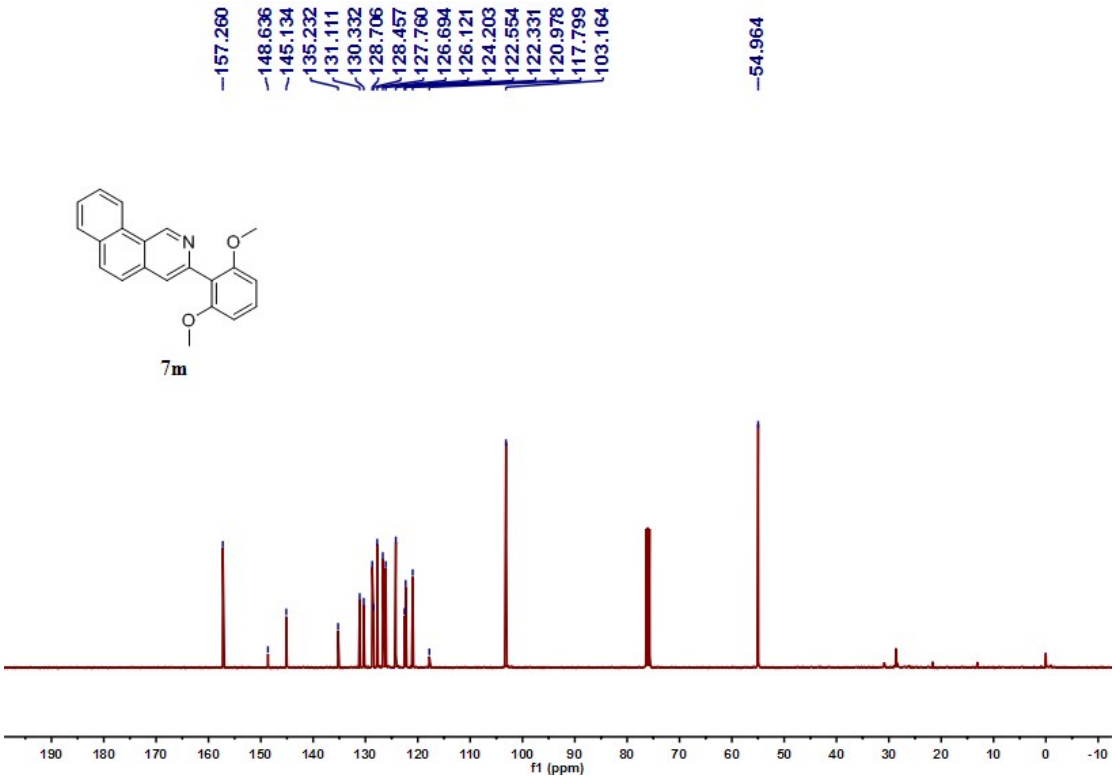
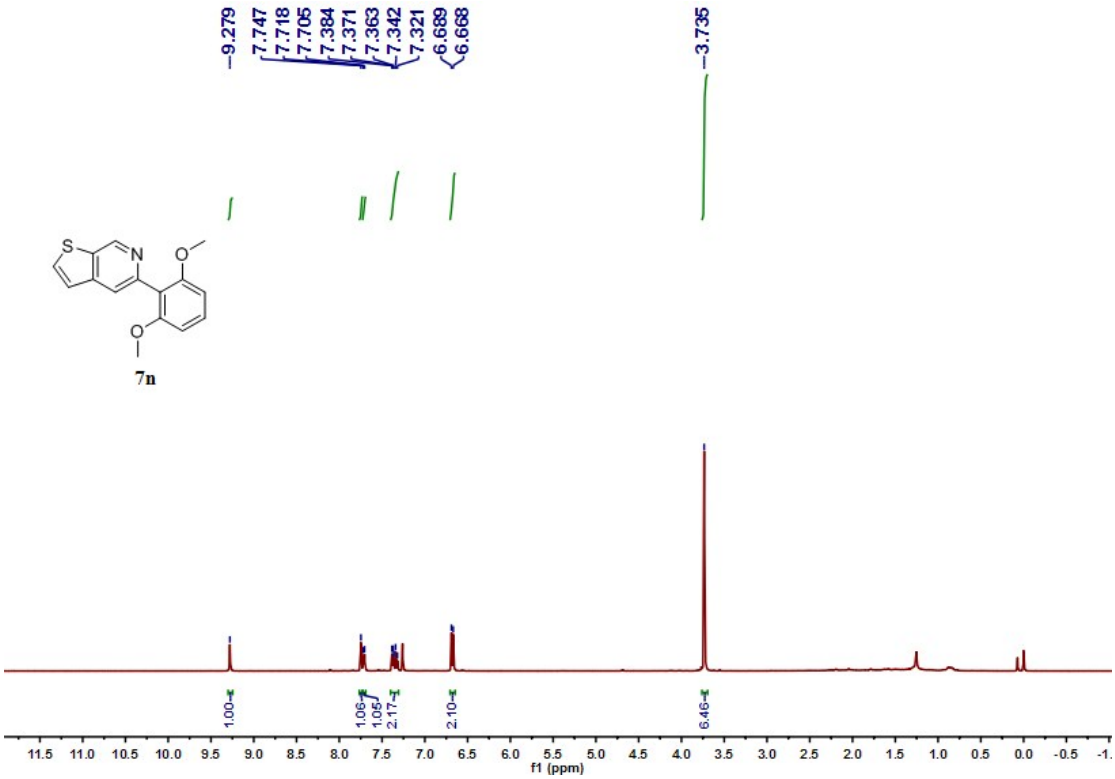
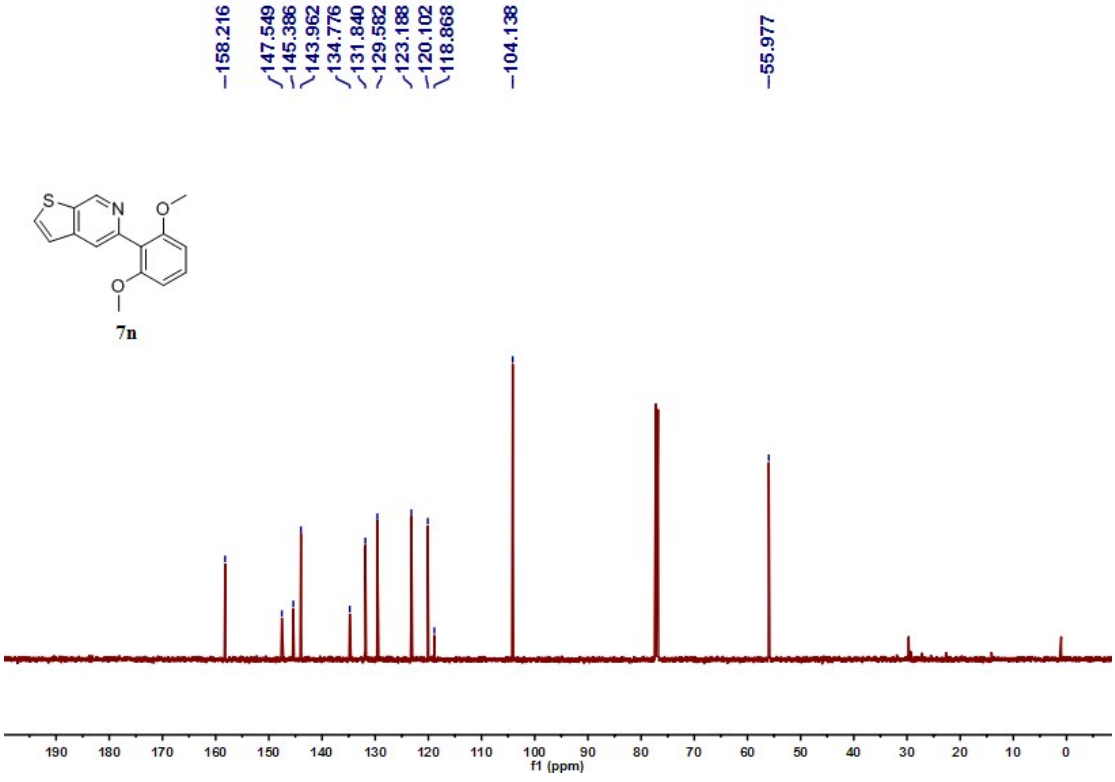
8.800
7.906
7.884
7.771
7.738
7.719
7.692
7.669
7.653
7.634
7.616
7.389
7.369
7.348
6.720
6.699
3.747
1.00
1.03
2.01
0.90
3.01
0.97
2.02
6.32
f1 (ppm)

7m


157.260
148.636
145.134
135.232
131.111
130.332
128.706
128.457
127.760
126.694
126.121
124.203
122.554
122.331
120.978
117.799
103.164
54.964
f1 (ppm)

7m


9.279
7.747
7.718
7.705
7.384
7.371
7.363
7.342
7.321
6.689
6.668
3.735
S
N
O
O
7n
1.00
1.06
1.05
2.17
2.10
6.46
f1 (ppm)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145.386
143.962
134.776
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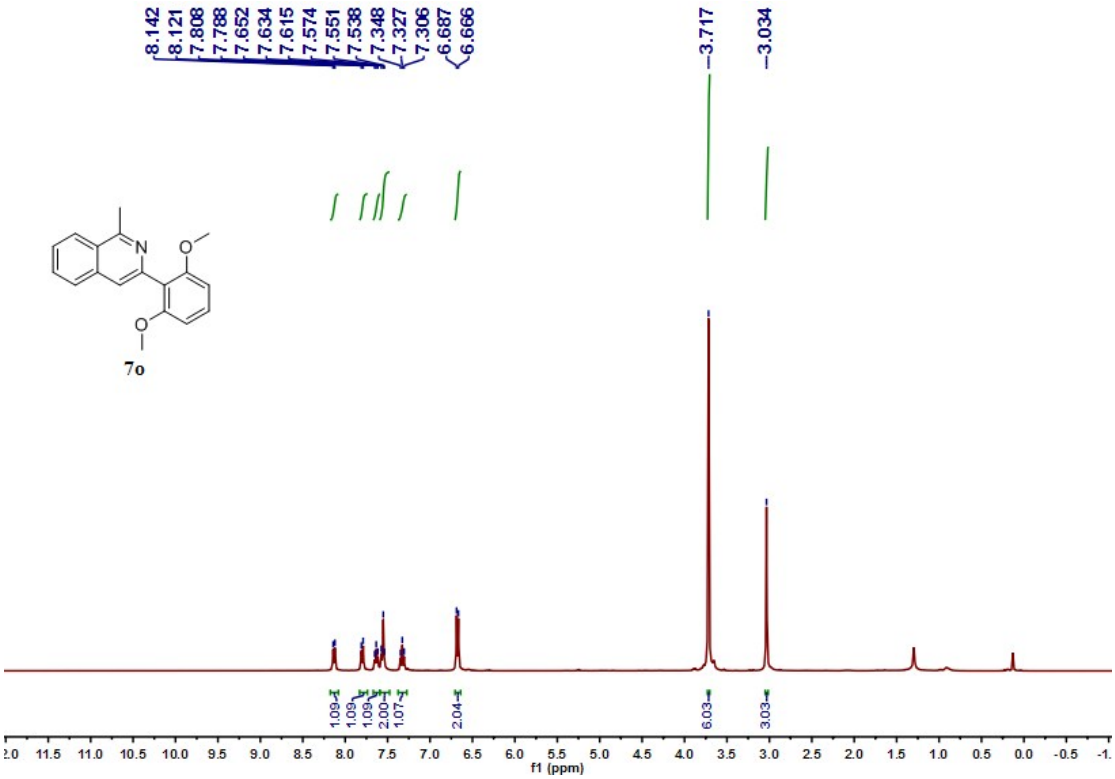
123.188
120.102
118.868
104.138
55.977
S
N
O
O
7n
f1 (ppm)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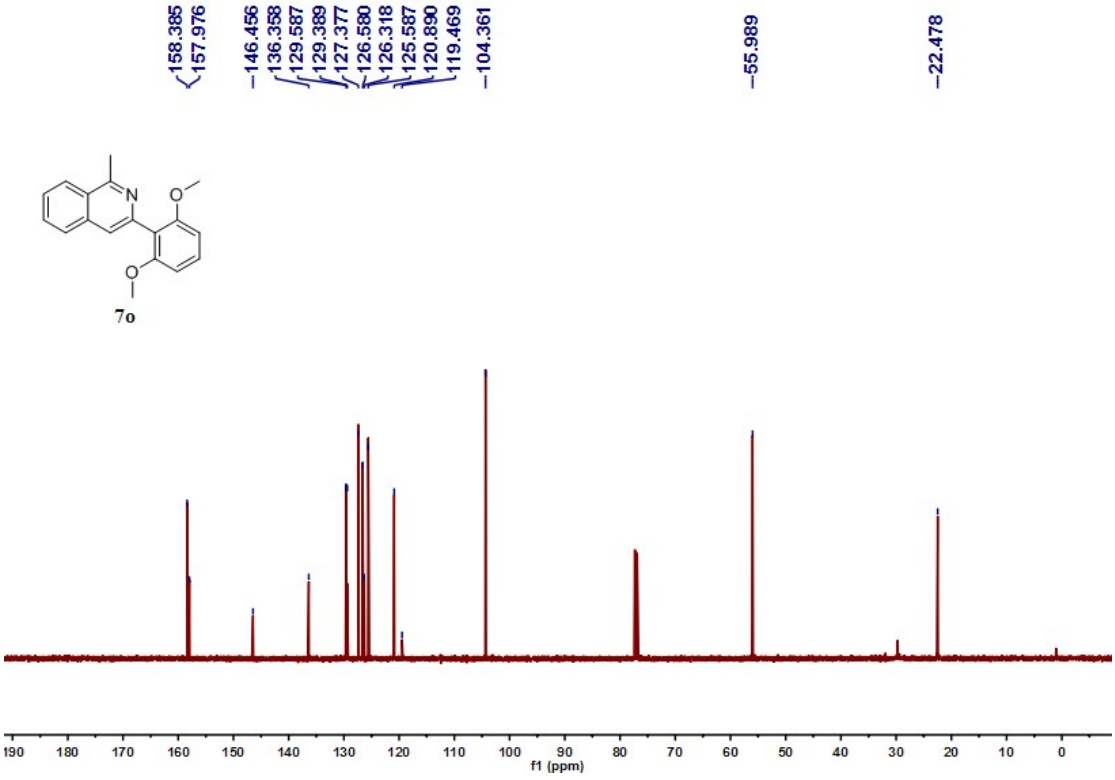
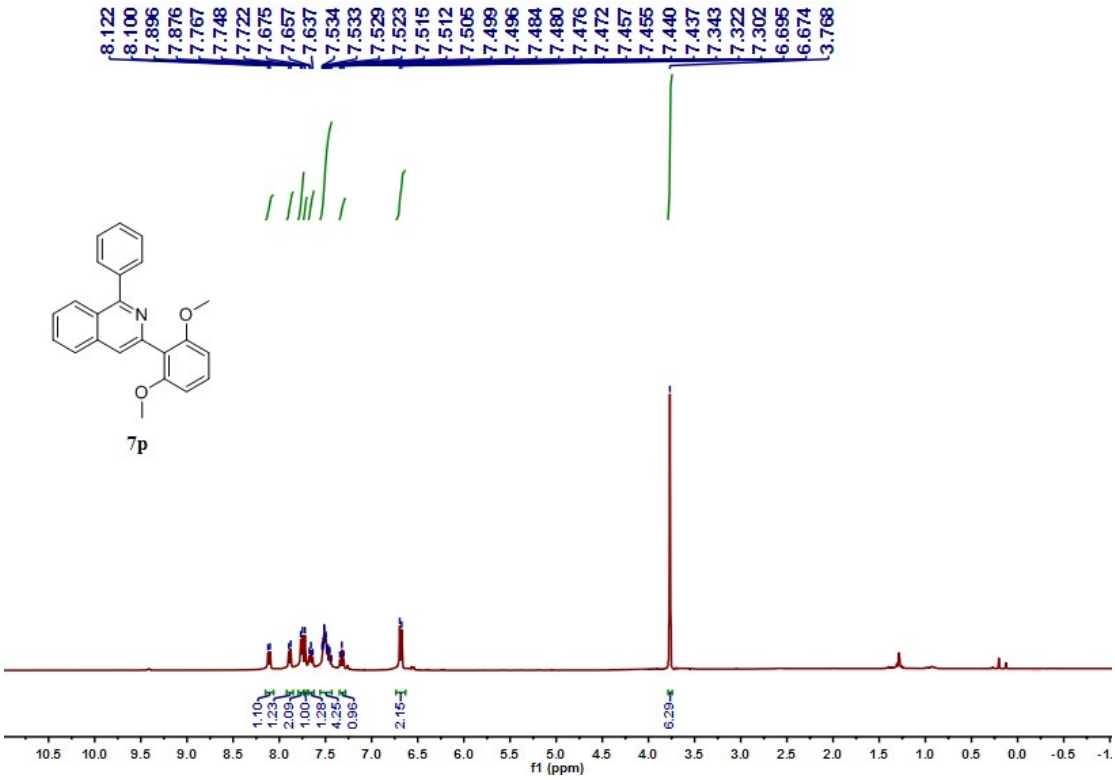
7.652
7.634
7.615
7.574
7.551
7.538
7.348
7.327
7.306
6.687
6.666
3.717
3.034
1.09
1.09
1.09
2.00
1.07
2.04
6.03
3.03
f1 (ppm)

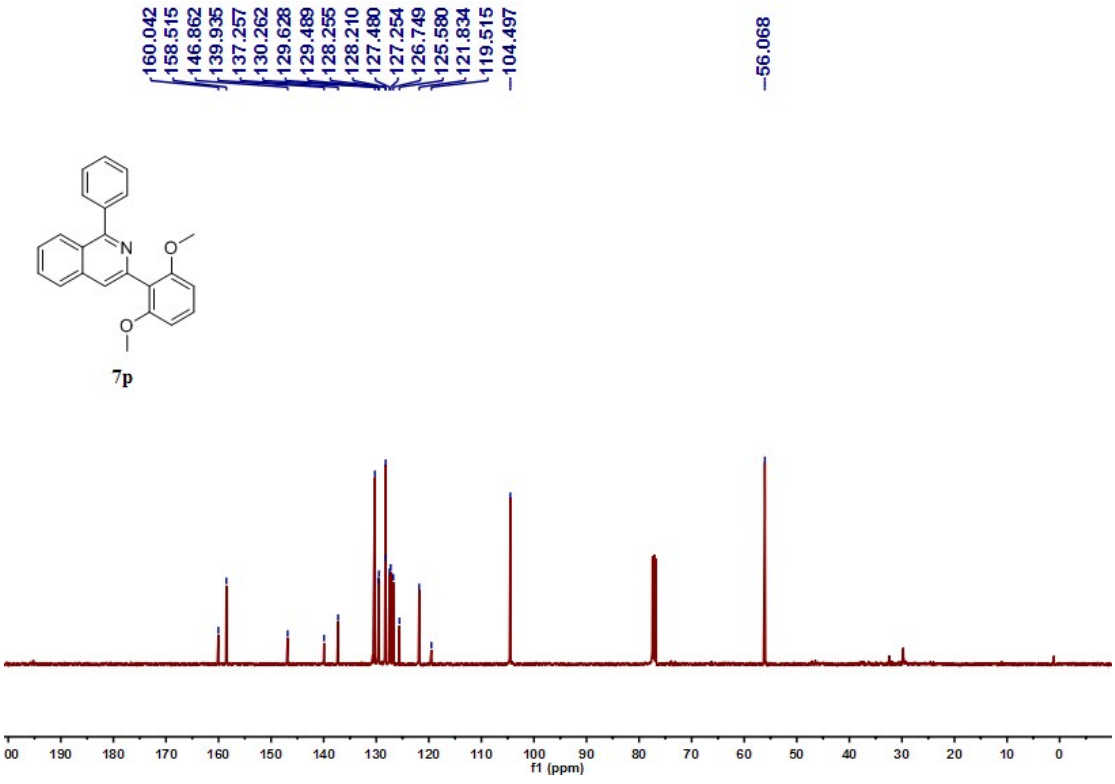
7o


158.385
157.976
146.456
136.358
129.587
129.389
127.377
126.580
126.318
125.587
120.890
119.469
104.361
55.989
22.478
f1 (ppm)

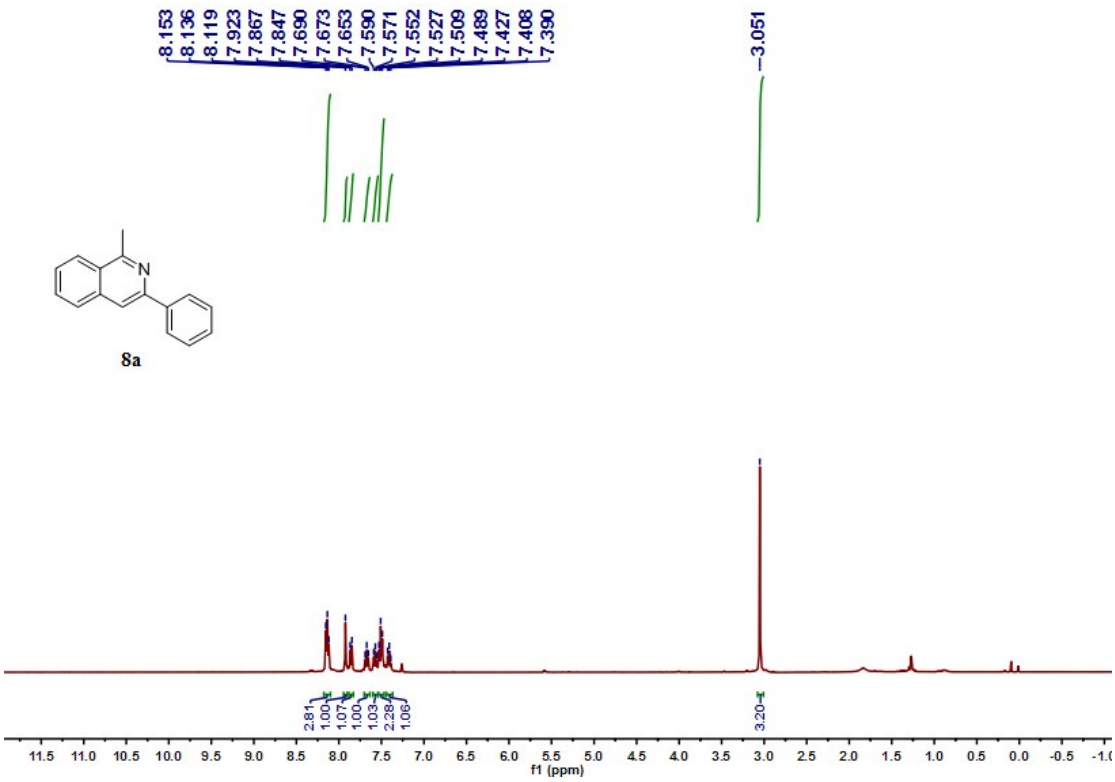
7o

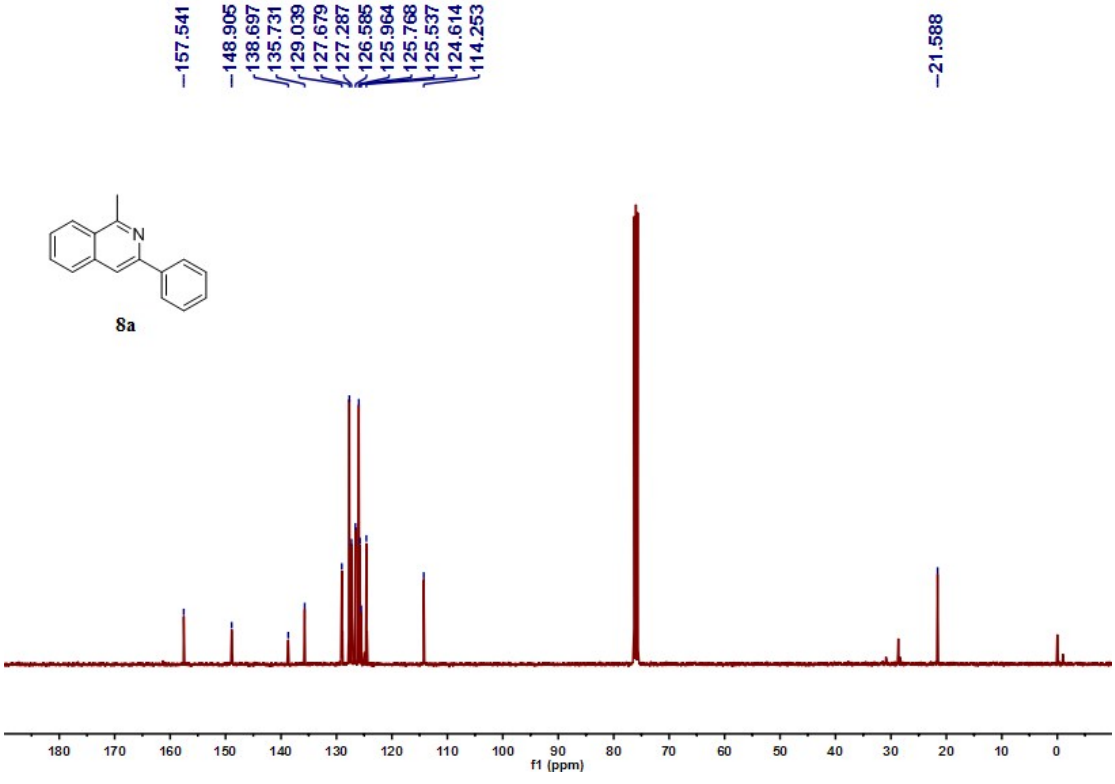

8.122
8.100
7.896
7.876
7.767
7.748
7.722
7.675
7.657
7.637
7.534
7.533
7.529
7.523
7.515
7.512
7.505
7.499
7.496
7.484
7.480
7.476
7.472
7.457
7.455
7.440
7.437
7.343
7.322
7.302
6.695
6.674
3.768
1.10
1.23
2.09
1.00
1.28
4.25
0.96
2.15
6.29
f1 (ppm)

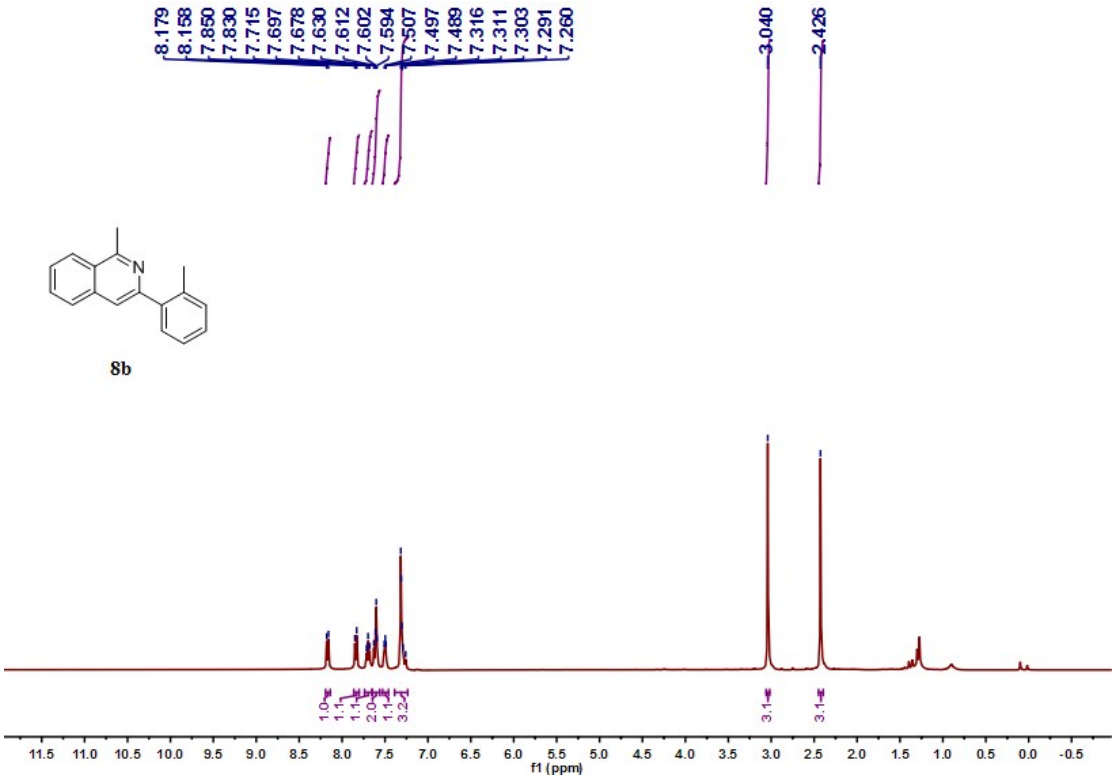
7p


160.042
158.515
146.862
139.935
137.257
130.262
129.628
129.489
128.255
128.210
127.480
127.254
126.749
125.580
121.834
119.515
104.497
56.068
f1 (ppm)

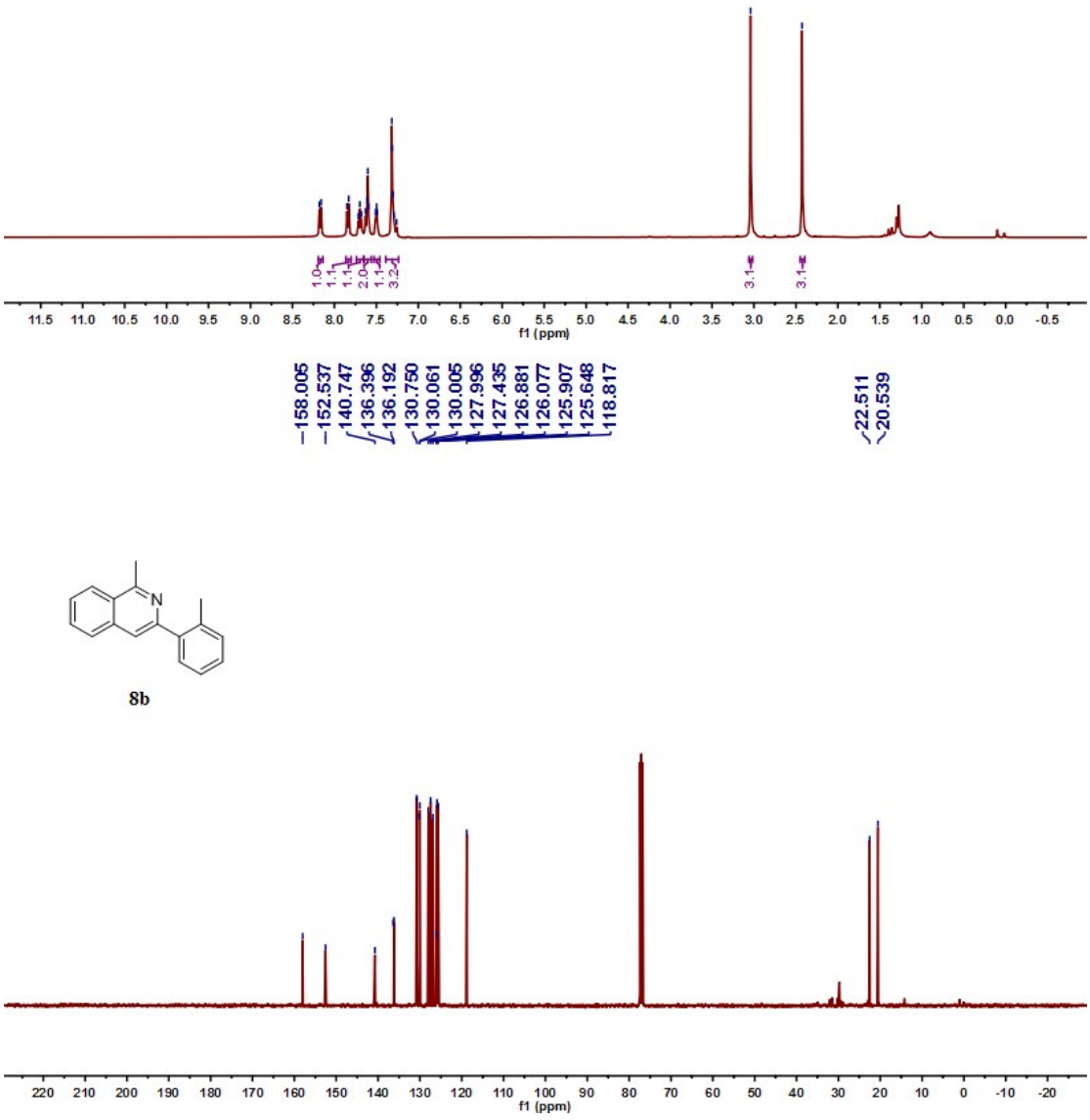
7p


8.153
8.136
8.119
7.923
7.867
7.847
7.690
7.673
7.653
7.590
7.571
7.552
7.527
7.509
7.489
7.427
7.408
7.390
3.051
N
8a
2.81
1.00
1.07
1.00
1.03
2.28
1.06
3.20
f1 (ppm)

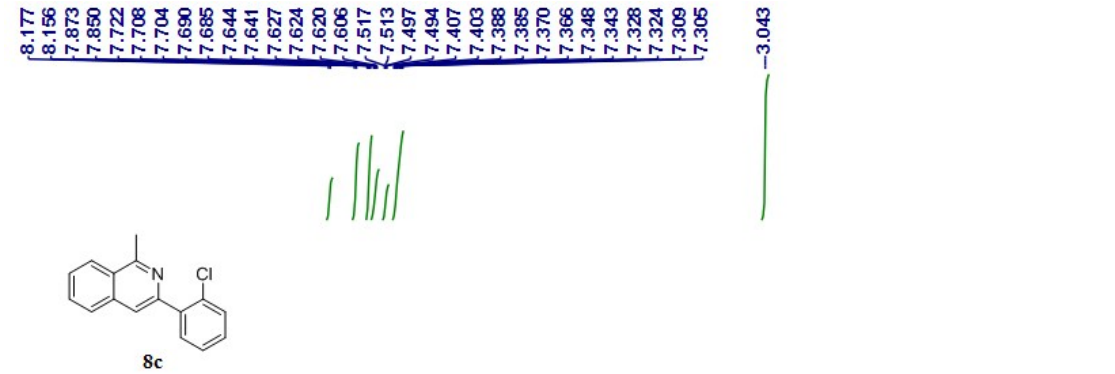

157.541
148.905
138.697
135.731
129.039
127.679
127.287
126.585
125.964
125.768
125.537
124.614
114.253
21.588
N
8a
f1 (ppm)


8.179
8.158
7.850
7.830
7.715
7.697
7.678
7.630
7.612
7.602
7.594
7.507
7.497
7.489
7.316
7.311
7.303
7.291
7.260
3.040
2.426
N
1.0
1.1
1.1
2.0
1.1
3.2
3.1
3.1
11.5 11.0 10.5 10.0 9.5 9.0 8.5 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 -0.5
f1 (ppm)

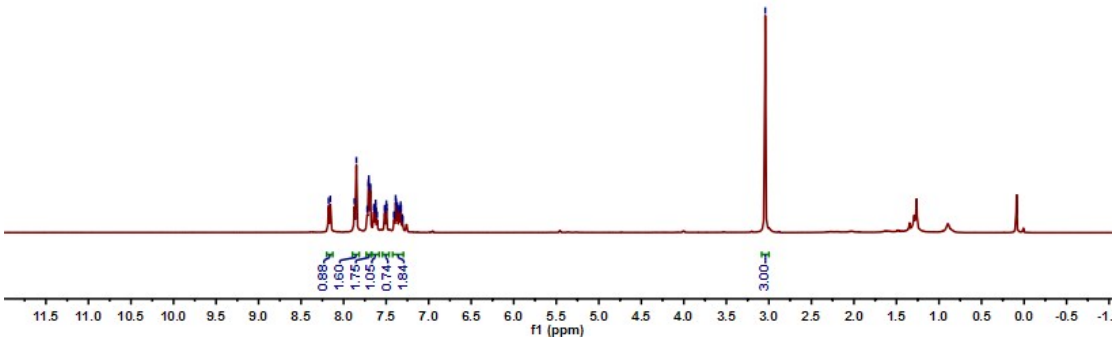
8b

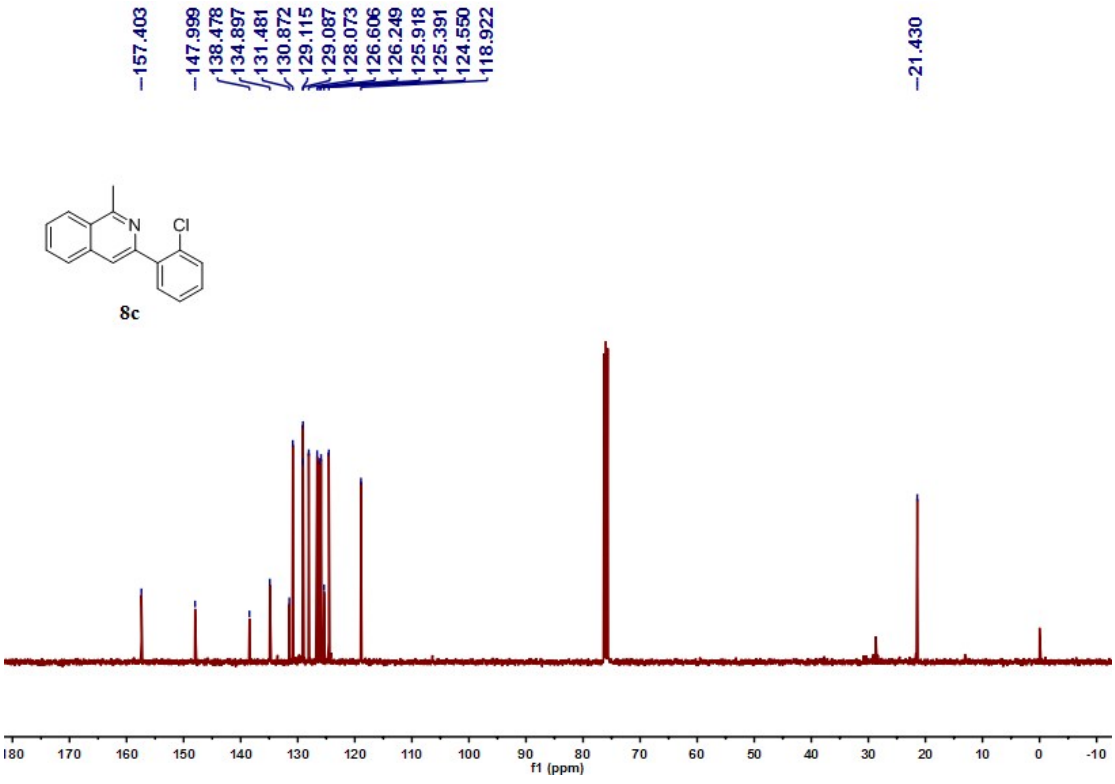

158.005
152.537
140.747
136.396
136.192
130.750
130.061
130.005
127.996
127.435
126.881
126.077
125.907
125.648
118.817
22.511
20.539
N
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
f1 (ppm)

8b

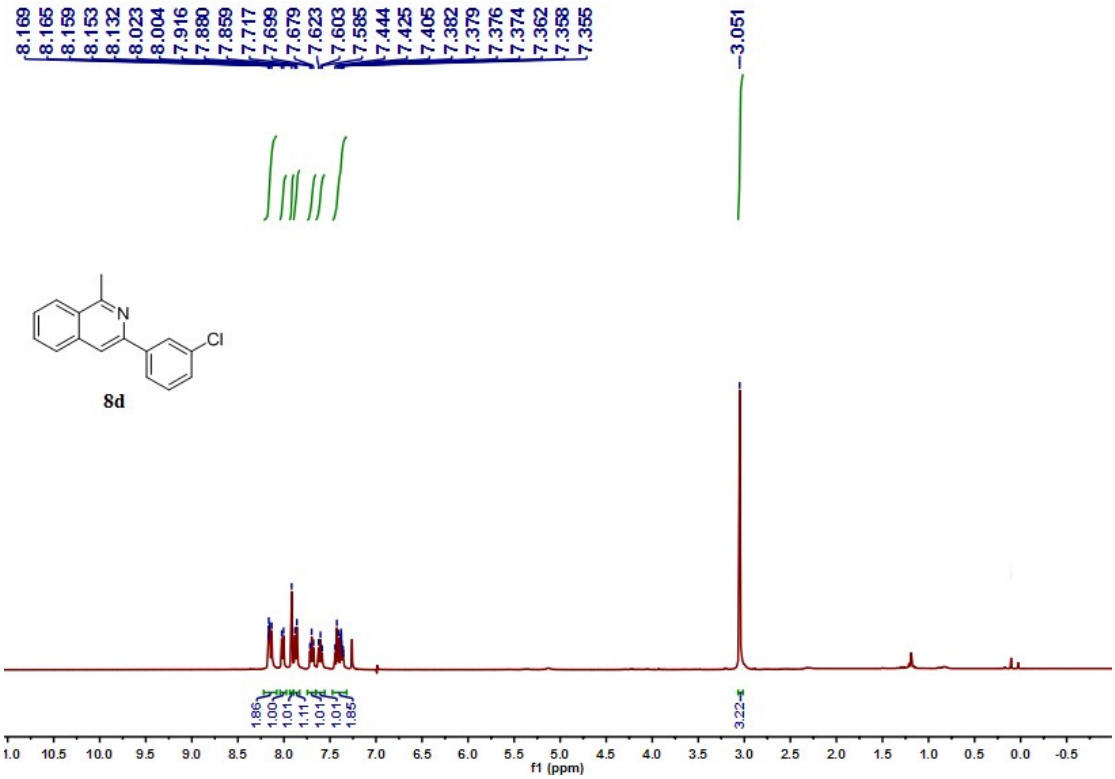

8.177
8.156
7.873
7.850
7.722
7.708
7.704
7.690
7.685
7.644
7.641
7.627
7.624
7.620
7.606
7.517
7.513
7.497
7.494
7.407
7.403
7.388
7.385
7.370
7.366
7.348
7.343
7.328
7.324
7.309
7.305
3.043
N
Cl

8c

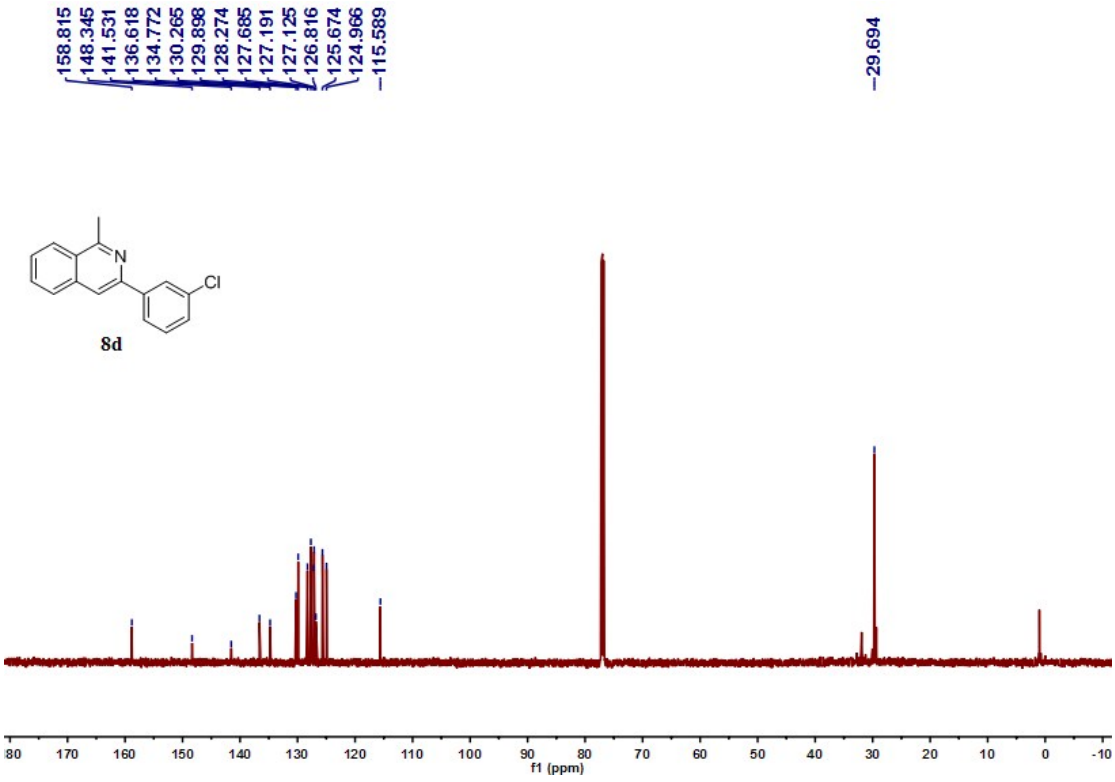

0.88
1.60
1.75
1.05
0.74
1.84
3.00
f1 (ppm)


157.403
147.999
138.478
134.897
131.481
130.872
129.115
129.087
128.073
126.606
126.249
125.918
125.391
124.550
118.922
21.430
N
Cl
f1 (ppm)

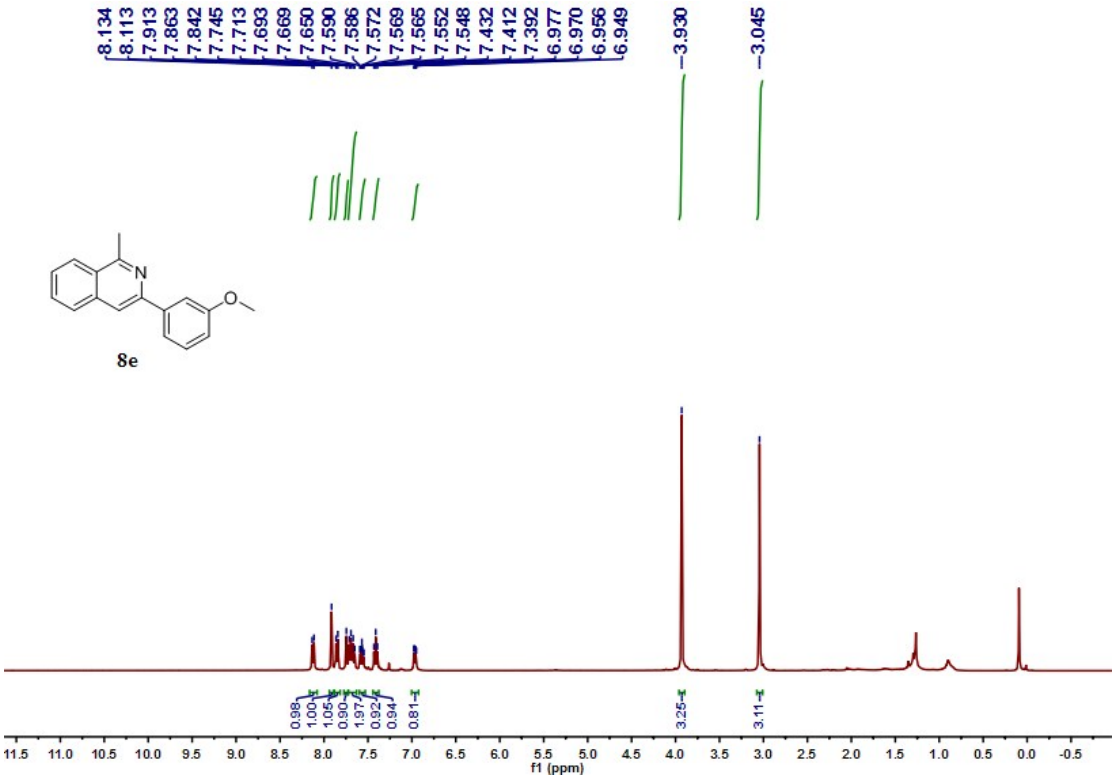
8c


8.169
8.165
8.159
8.153
8.132
8.023
8.004
7.916
7.880
7.859
7.717
7.699
7.679
7.623
7.603
7.585
7.444
7.425
7.405
7.382
7.379
7.376
7.374
7.362
7.358
7.355
3.051
N
Cl
1.86
1.00
1.01
1.11
1.01
1.01
1.85
3.22
f1 (ppm)

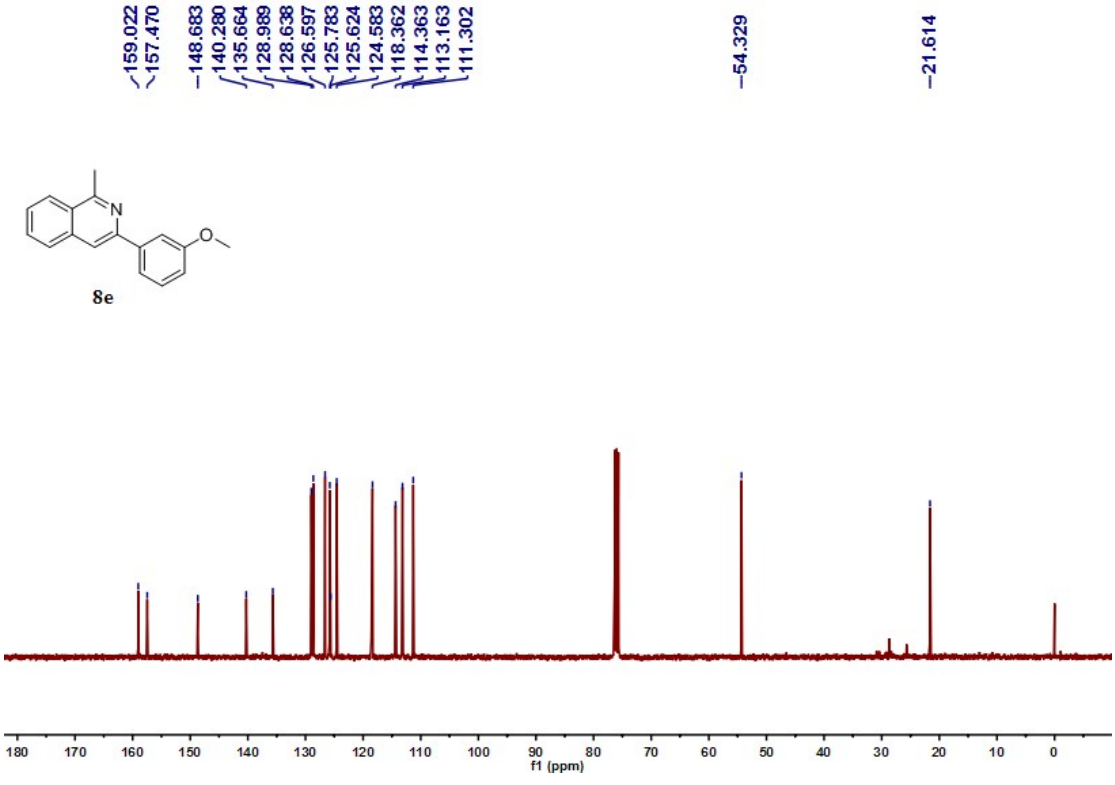
8d


158.815
148.345
141.531
136.618
134.772
130.265
129.898
128.274
127.685
127.191
127.125
126.816
125.674
124.966
115.589
29.694
N
Cl
f1 (ppm)

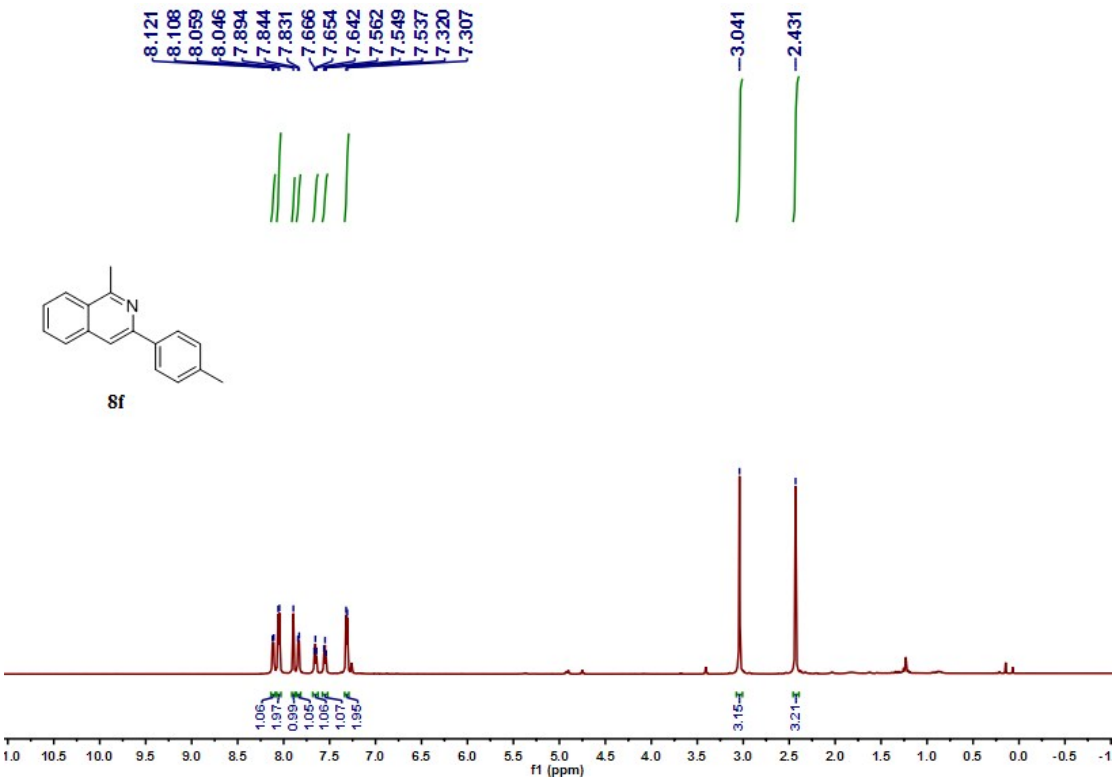
8d

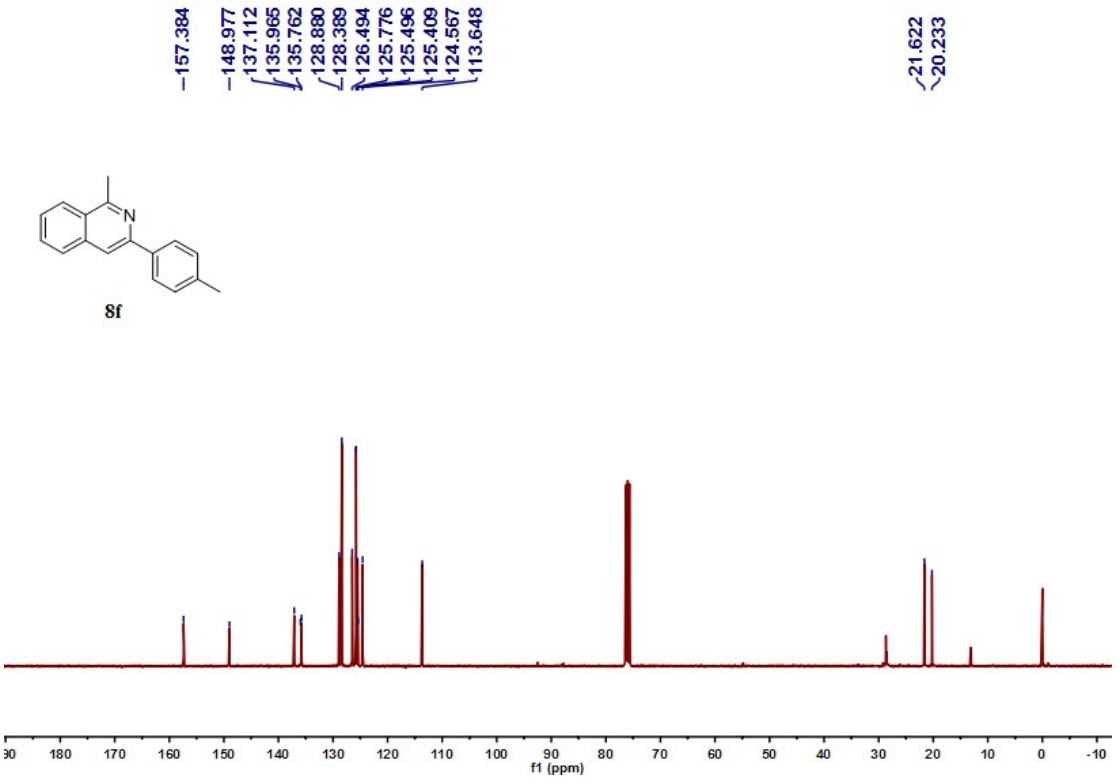

8.134
8.113
7.913
7.863
7.842
7.745
7.713
7.693
7.669
7.650
7.590
7.586
7.572
7.569
7.565
7.552
7.548
7.432
7.412
7.392
6.977
6.970
6.956
6.949
3.930
3.045
N
O
0.98
1.00
1.05
0.90
1.97
0.92
0.94
0.81
3.25
3.11
f1 (ppm)

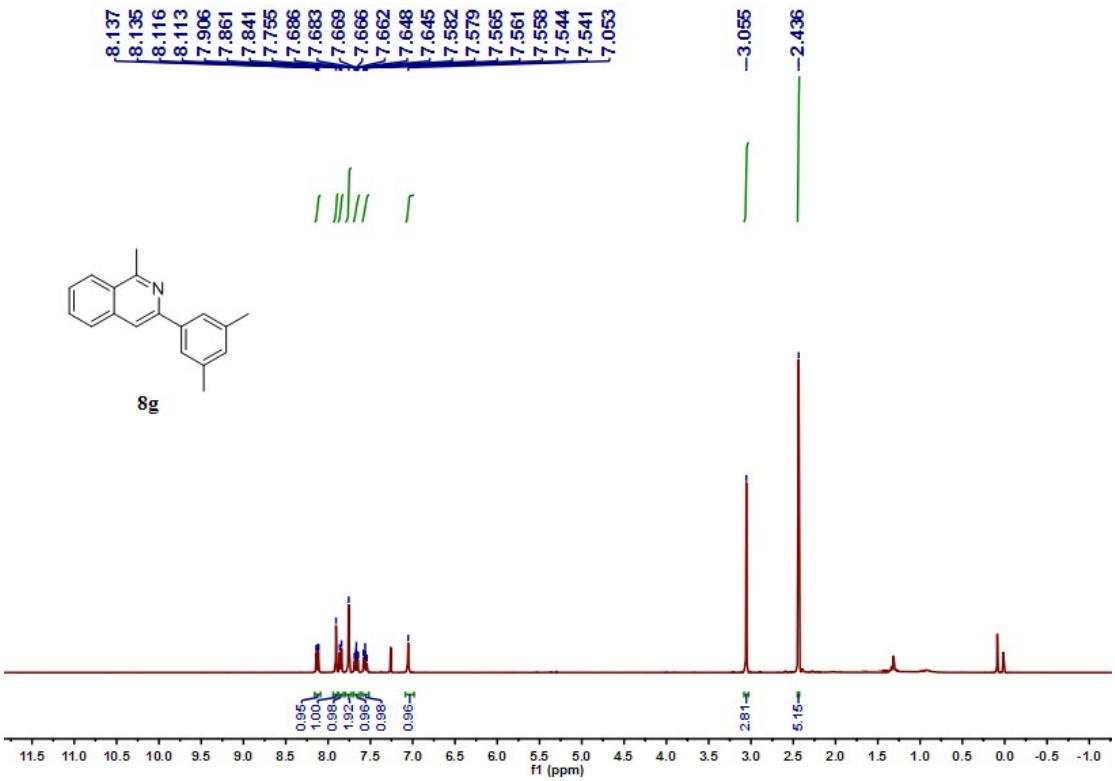
8e

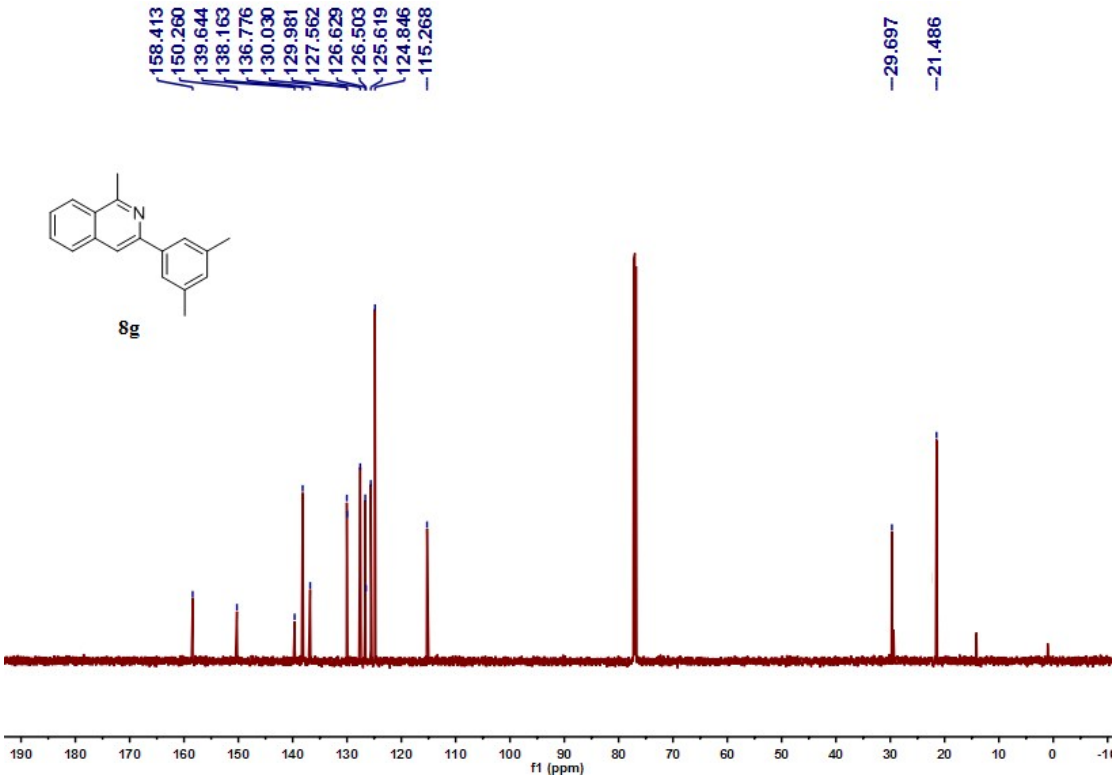

159.022
157.470
148.683
140.280
135.664
128.989
128.638
126.597
125.783
125.624
124.583
118.362
114.363
113.163
111.302
54.329
21.614
N
O
f1 (ppm)

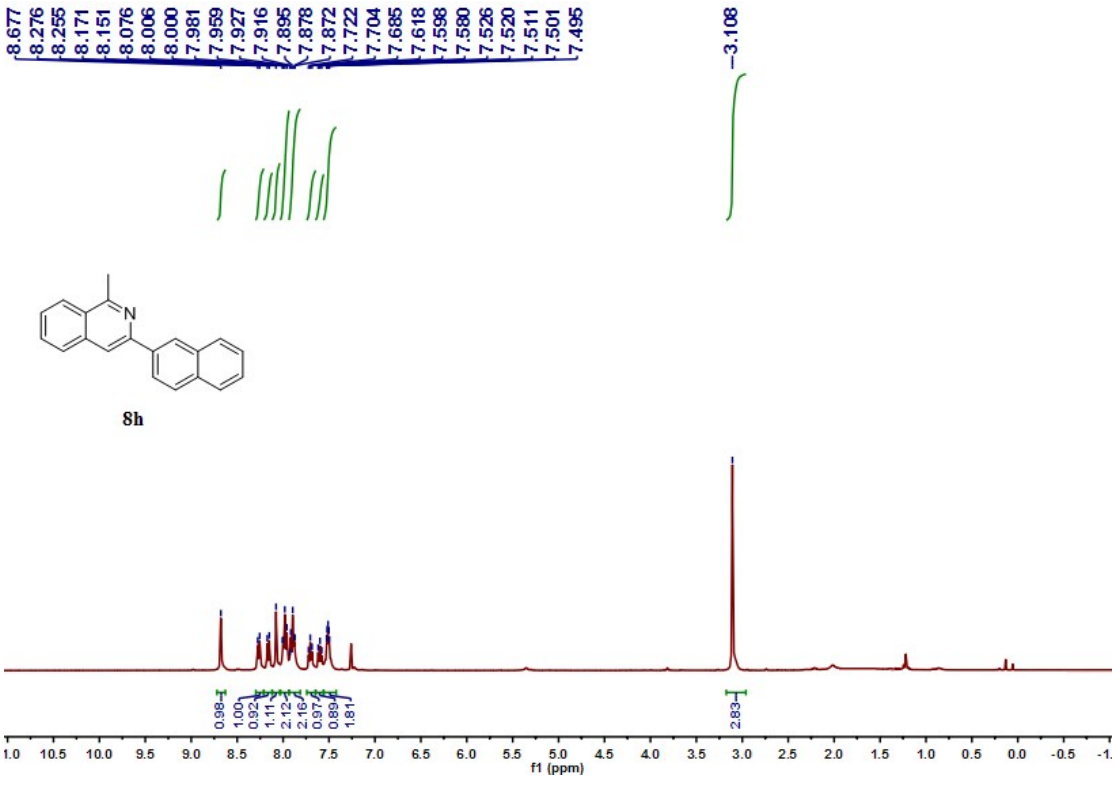
8e

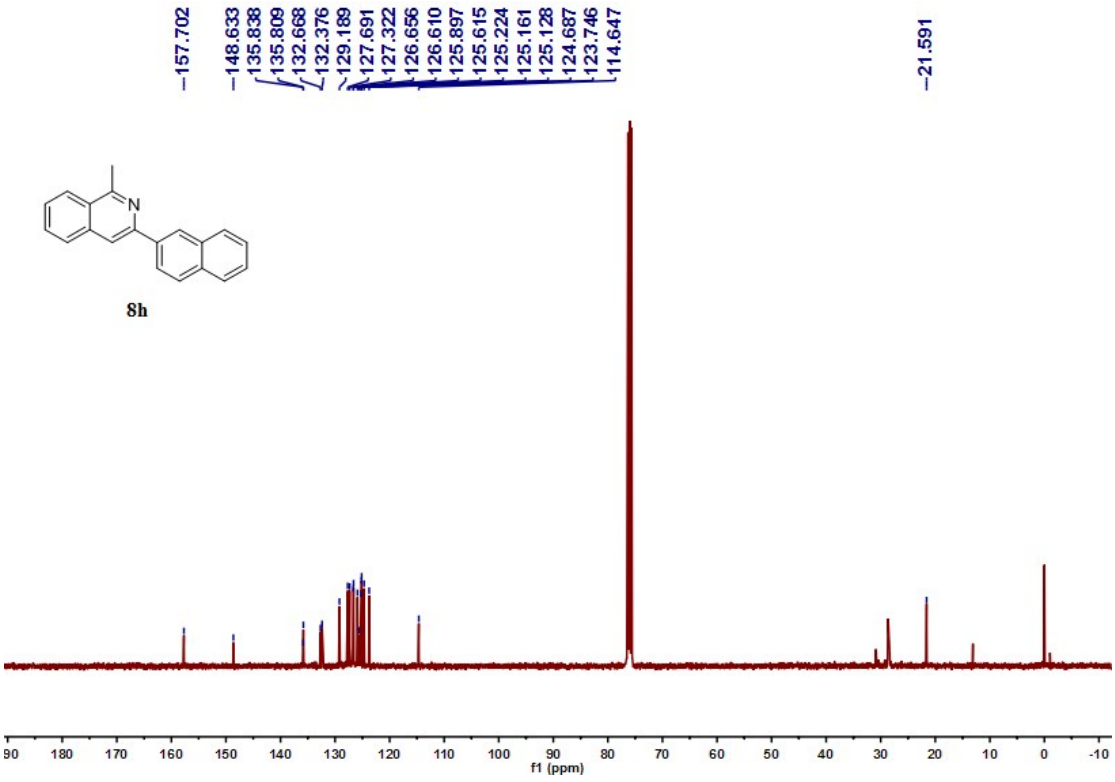

8.121
8.108
8.059
8.046
7.894
7.844
7.831
7.666
7.654
7.642
7.562
7.549
7.537
7.320
7.307
3.041
2.431
N
8f
1.06
1.97
0.99
1.05
1.06
1.07
1.95
3.15
3.21
f1 (ppm)

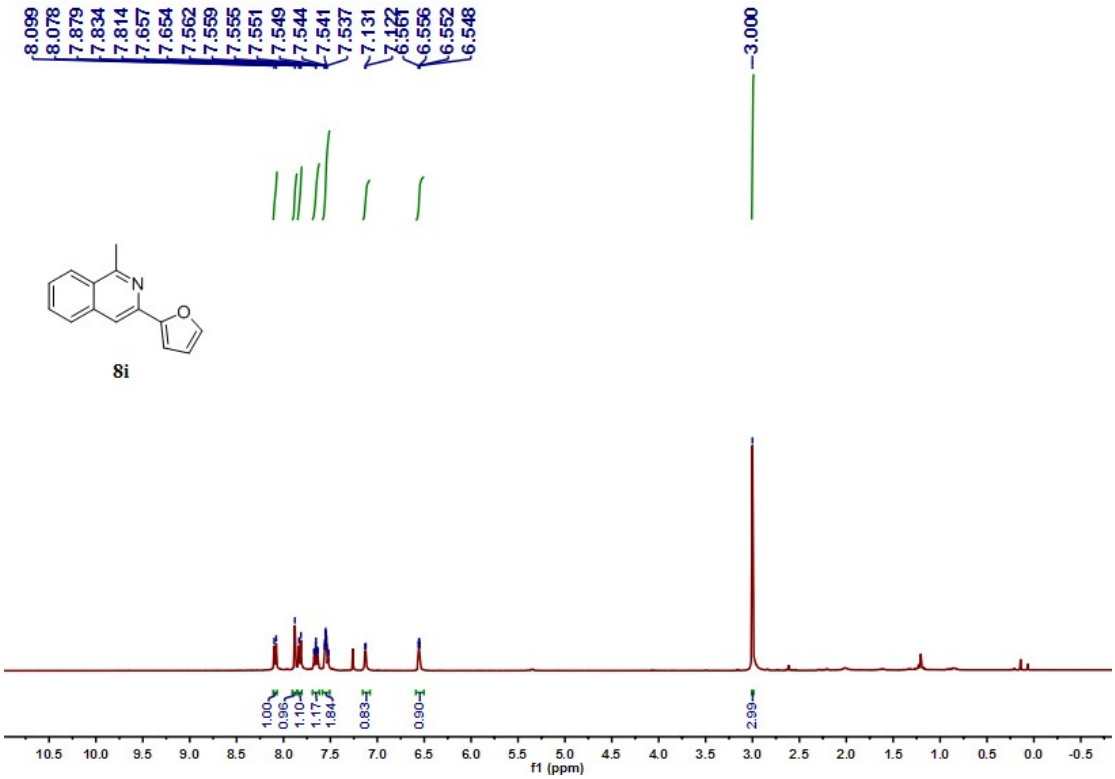

157.384
148.977
137.112
135.965
135.762
128.880
128.389
126.494
125.776
125.496
125.409
124.567
113.648
21.622
20.233
N
8f
f1 (ppm)


8.137
8.135
8.116
8.113
7.906
7.861
7.841
7.755
7.686
7.683
7.669
7.666
7.662
7.648
7.645
7.582
7.579
7.565
7.561
7.558
7.544
7.541
7.053
3.055
2.436
N
8g
0.95
1.00
0.98
1.92
0.96
0.98
0.96
2.81
5.15
11.5 11.0 10.5 10.0 9.5 9.0 8.5 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 -0.5 -1.0
f1 (ppm)

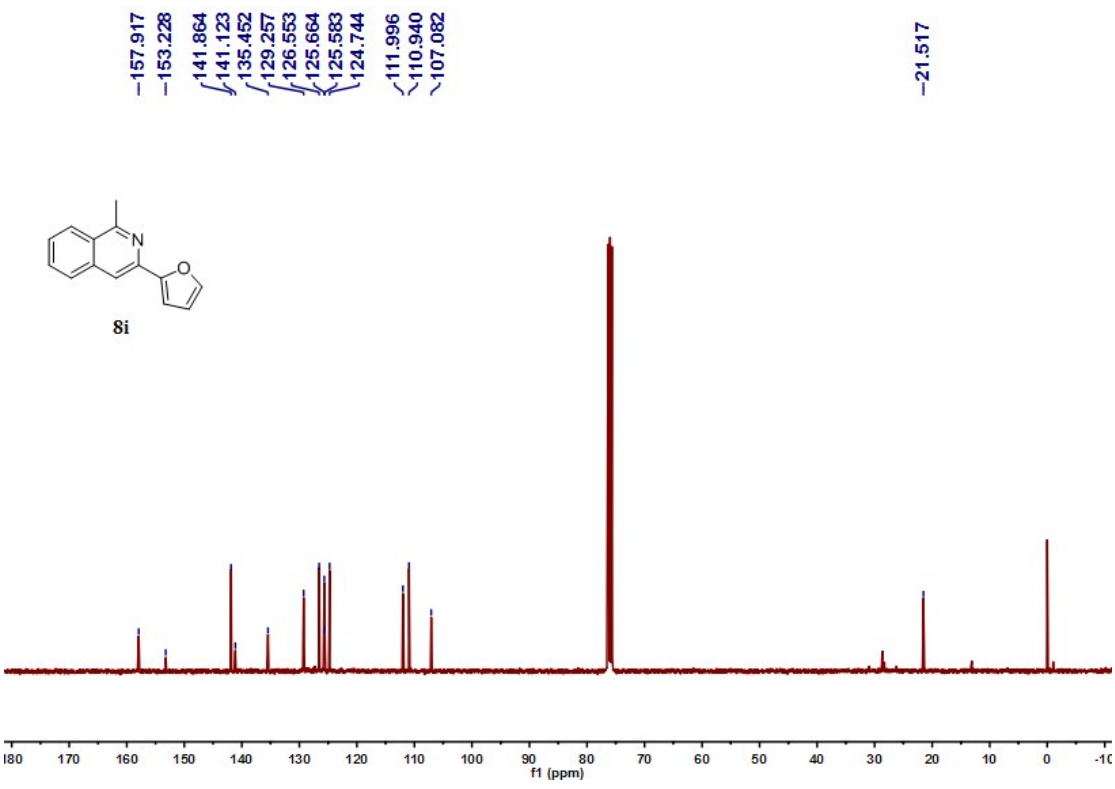

158.413
150.260
139.644
138.163
136.776
130.030
129.981
127.562
126.629
126.503
125.619
124.846
115.268
29.697
21.486
N
8g
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


8.677
8.276
8.255
8.171
8.151
8.076
8.006
8.000
7.981
7.959
7.927
7.916
7.895
7.878
7.872
7.722
7.704
7.685
7.618
7.598
7.580
7.526
7.520
7.511
7.501
7.495
3.108
N
8h
0.98
1.00
0.92
1.11
2.12
2.16
0.97
0.89
1.81
2.83
f1 (ppm)

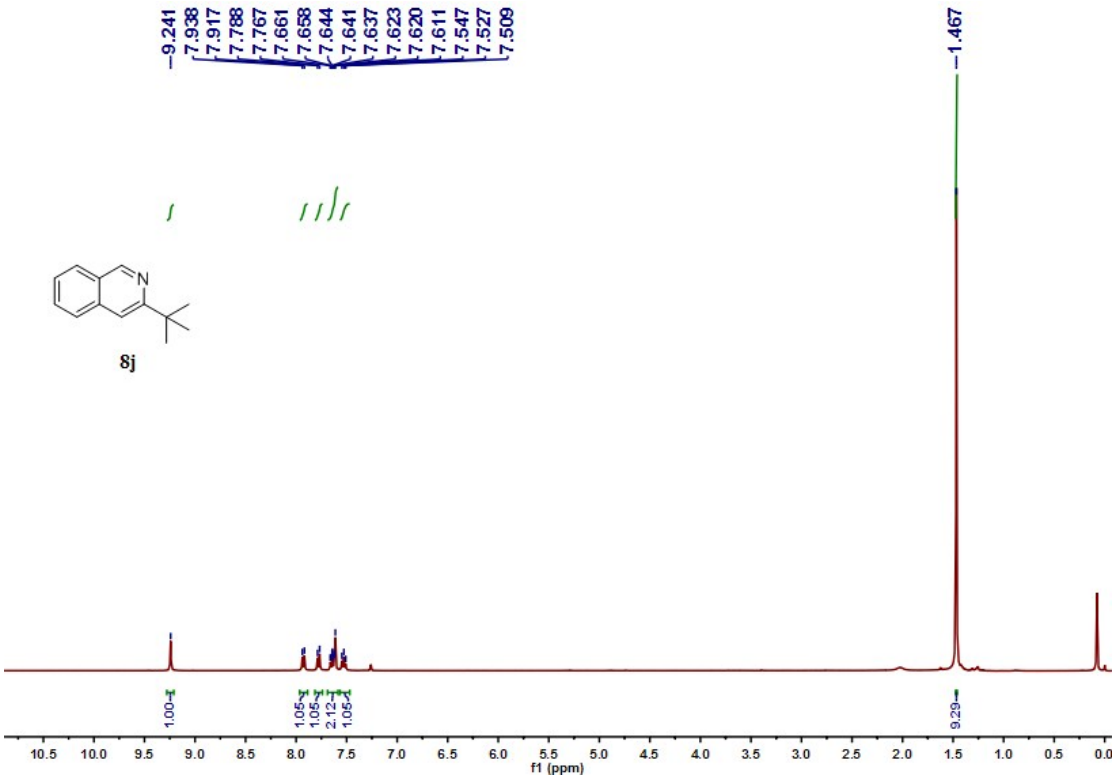

157.702
148.633
135.838
135.809
132.668
132.376
129.189
127.691
127.322
126.656
126.610
125.897
125.615
125.224
125.161
125.128
124.687
123.746
114.647
21.591
N
8h
f1 (ppm)


8.099
8.078
7.879
7.834
7.814
7.657
7.654
7.562
7.559
7.555
7.551
7.549
7.544
7.541
7.537
7.131
7.122
6.561
6.556
6.552
6.548
3.000
1.00
0.96
1.10
1.17
1.84
0.83
0.90
2.99
f1 (ppm)

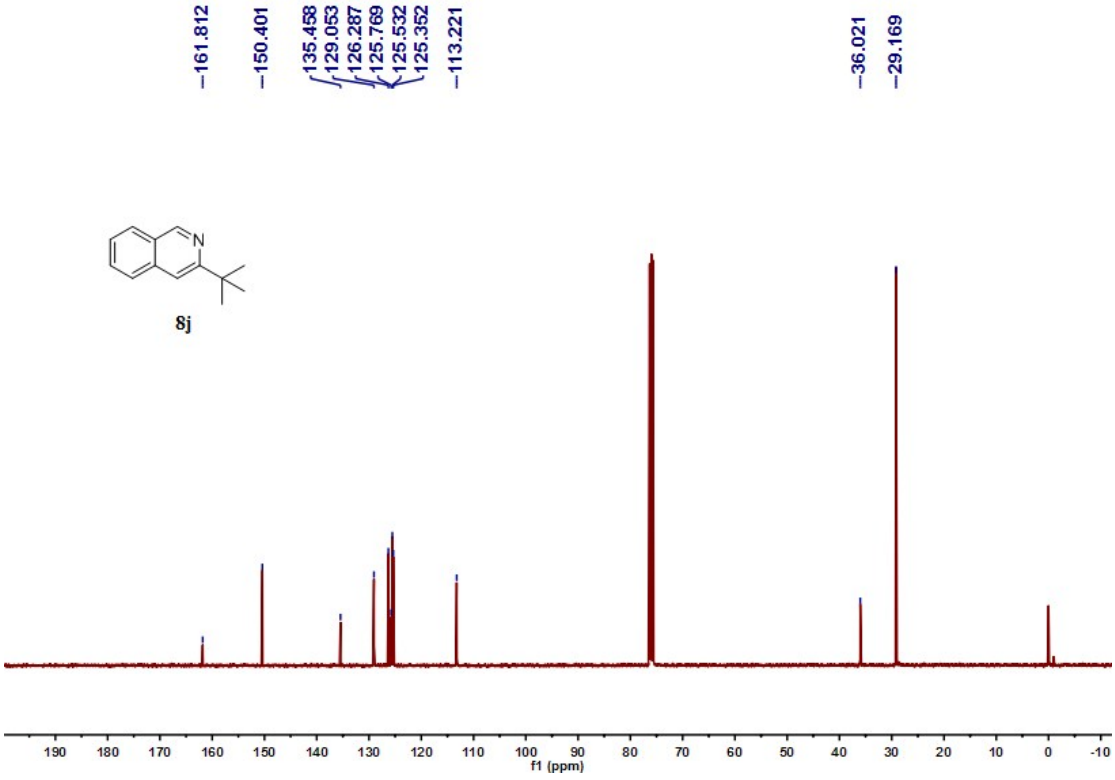
8i


157.917
153.228
141.864
141.123
135.452
129.257
126.553
125.664
125.583
124.744
111.996
110.940
107.082
21.517
f1 (ppm)

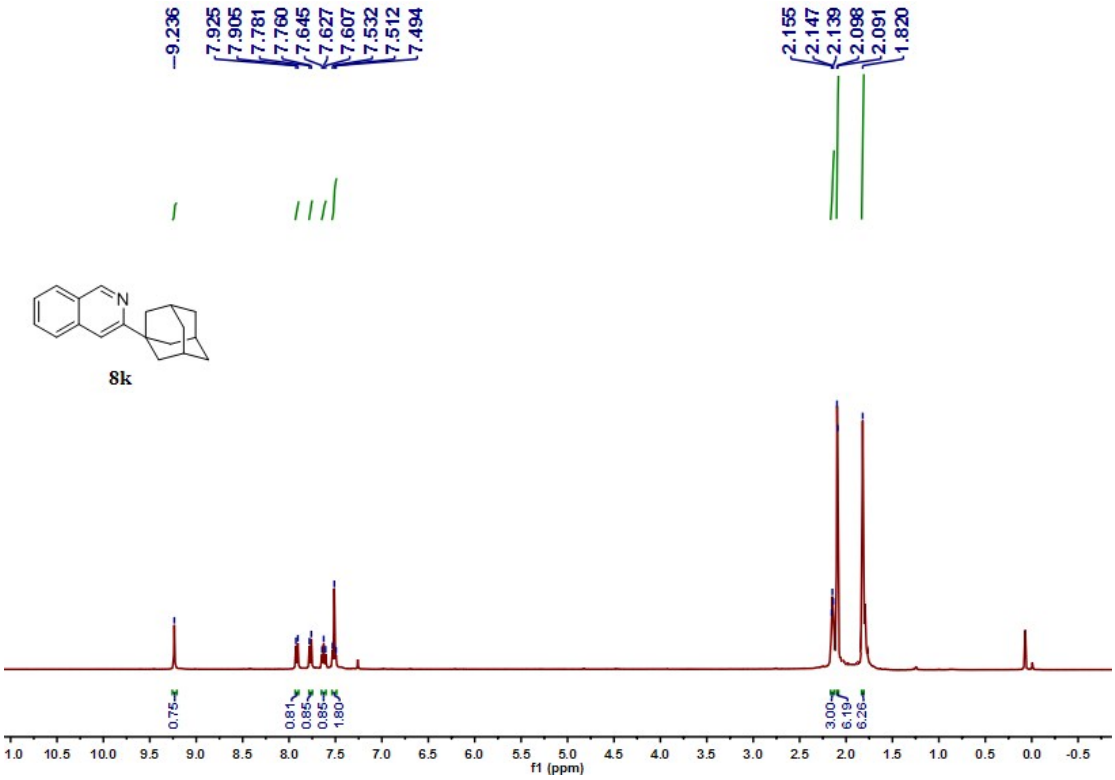
8i

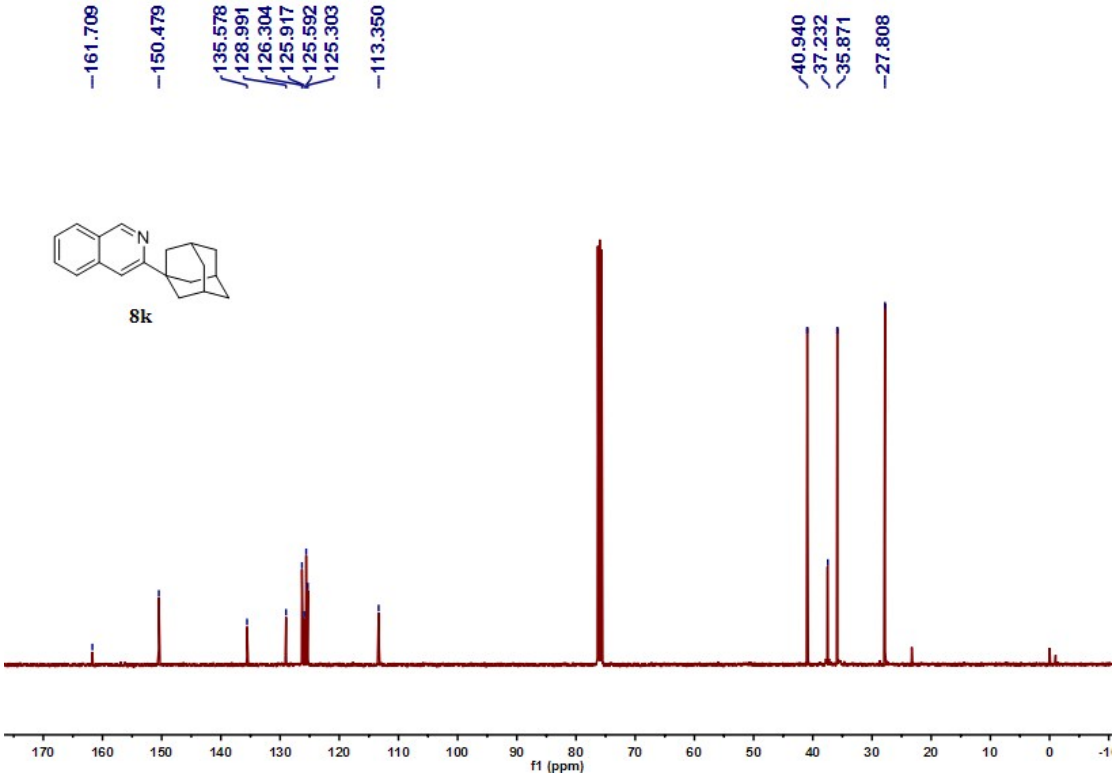

9.241
7.938
7.917
7.788
7.767
7.661
7.658
7.644
7.641
7.637
7.623
7.620
7.611
7.547
7.527
7.509
1.467
1.00
1.05
1.05
2.12
1.05
9.29
f1 (ppm)

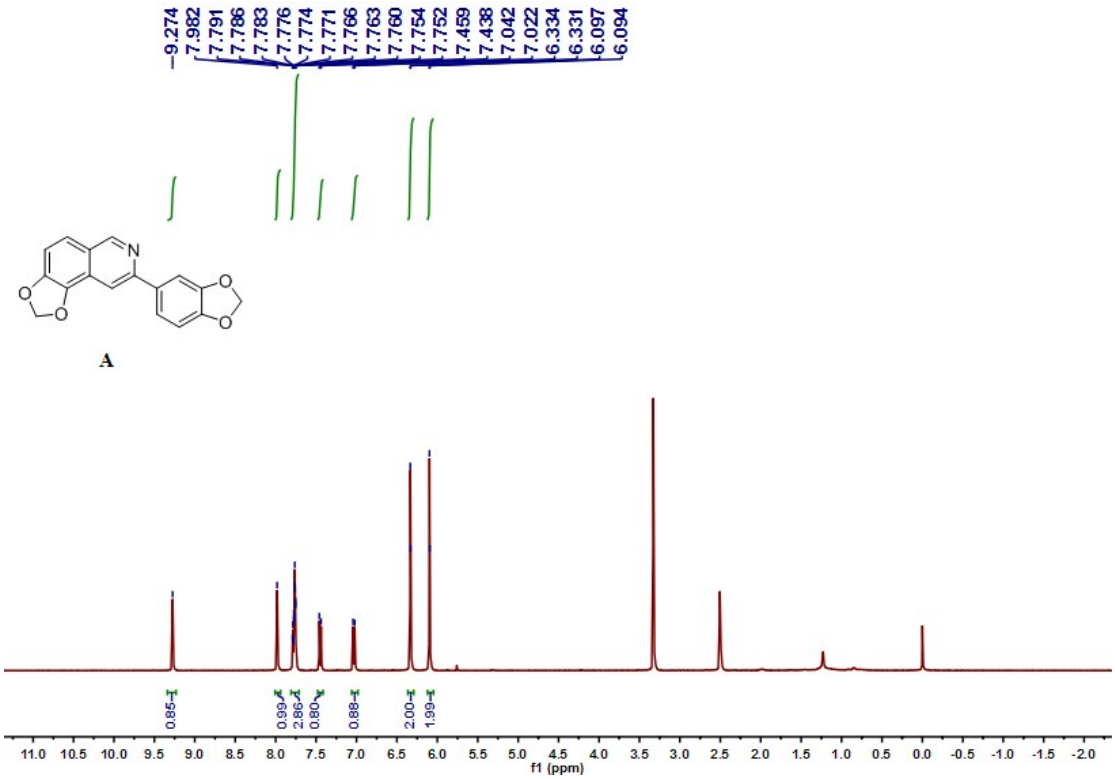
8j

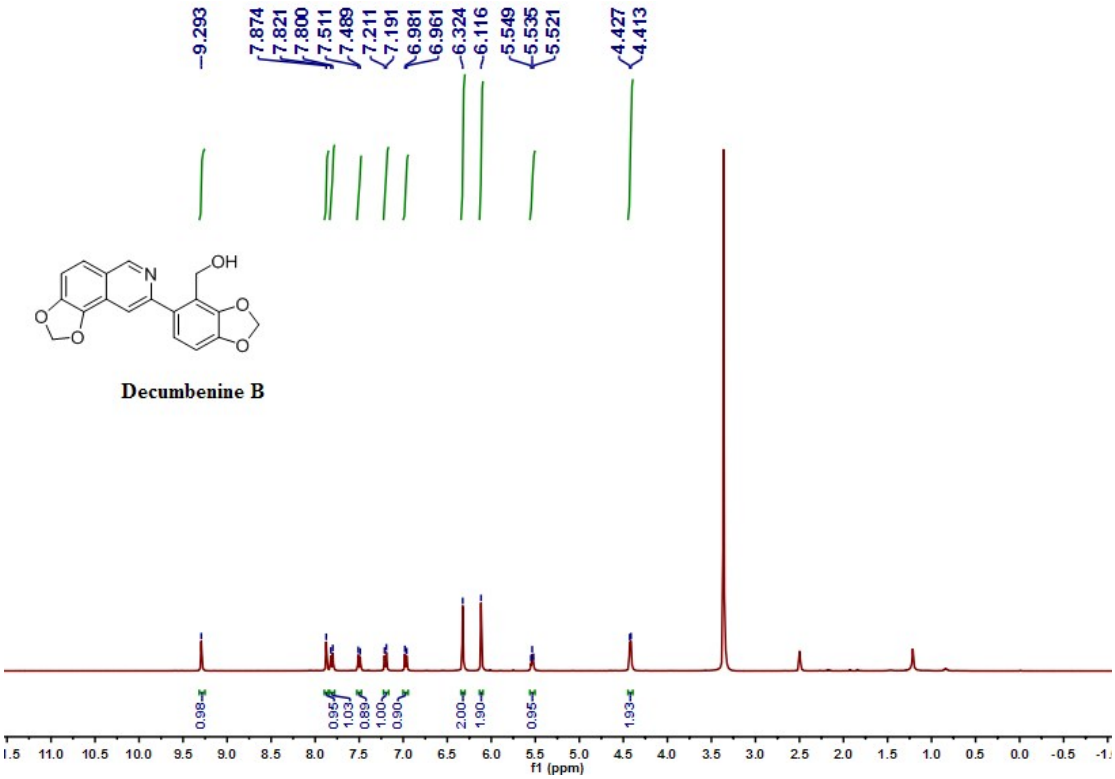

161.812
150.401
135.458
129.053
126.287
125.769
125.532
125.352
113.221
36.021
29.169
f1 (ppm)

8j

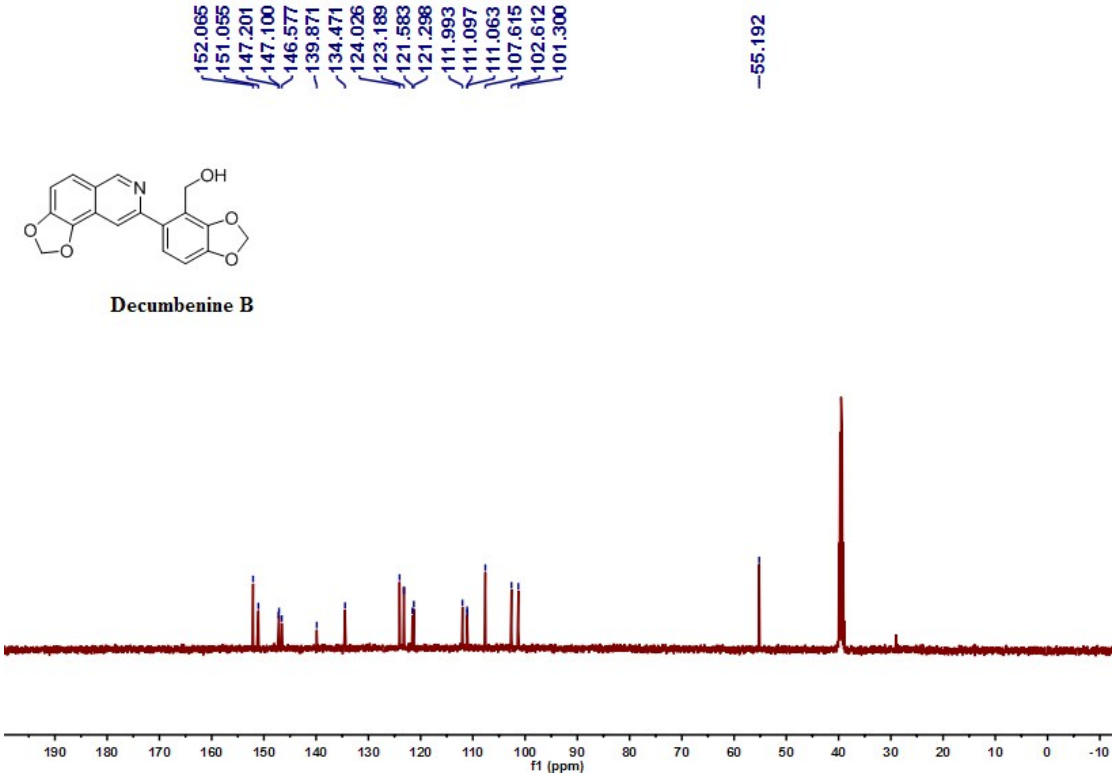

9.236
7.925
7.905
7.781
7.760
7.645
7.627
7.607
7.532
7.512
7.494
2.155
2.147
2.139
2.098
2.091
1.820
8k
0.75
0.81
0.85
0.85
1.80
3.00
6.19
6.26
f1 (ppm)


161.709
150.479
135.578
128.991
126.304
125.917
125.592
125.303
113.350
40.940
37.232
35.871
27.808
8k
f1 (ppm)

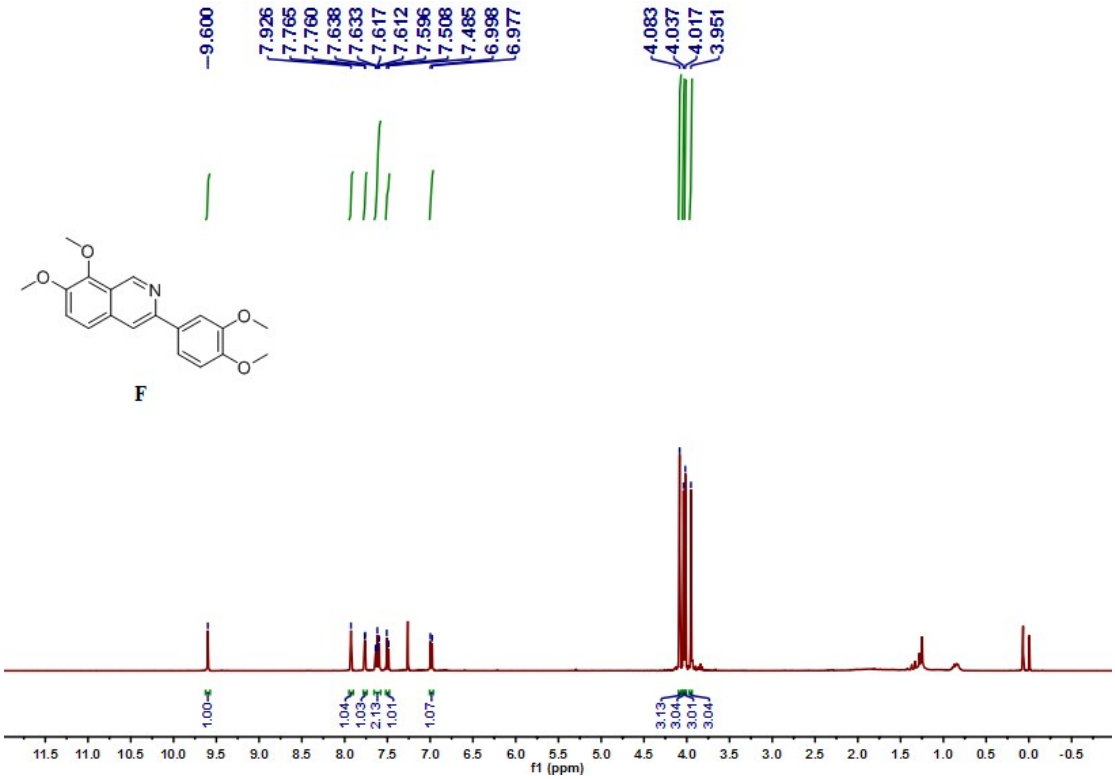

9.274
7.982
7.791
7.786
7.783
7.776
7.774
7.771
7.766
7.763
7.760
7.754
7.752
7.459
7.438
7.042
7.022
6.334
6.331
6.097
6.094
A
0.85
0.99
2.86
0.80
0.88
2.00
1.99
f1 (ppm)
153.054
149.661
148.401
148.355
147.390
140.342
133.422
124.037
123.424
122.205
121.173
111.946
108.899
107.153
106.968
102.891
101.728
A
f1 (ppm)



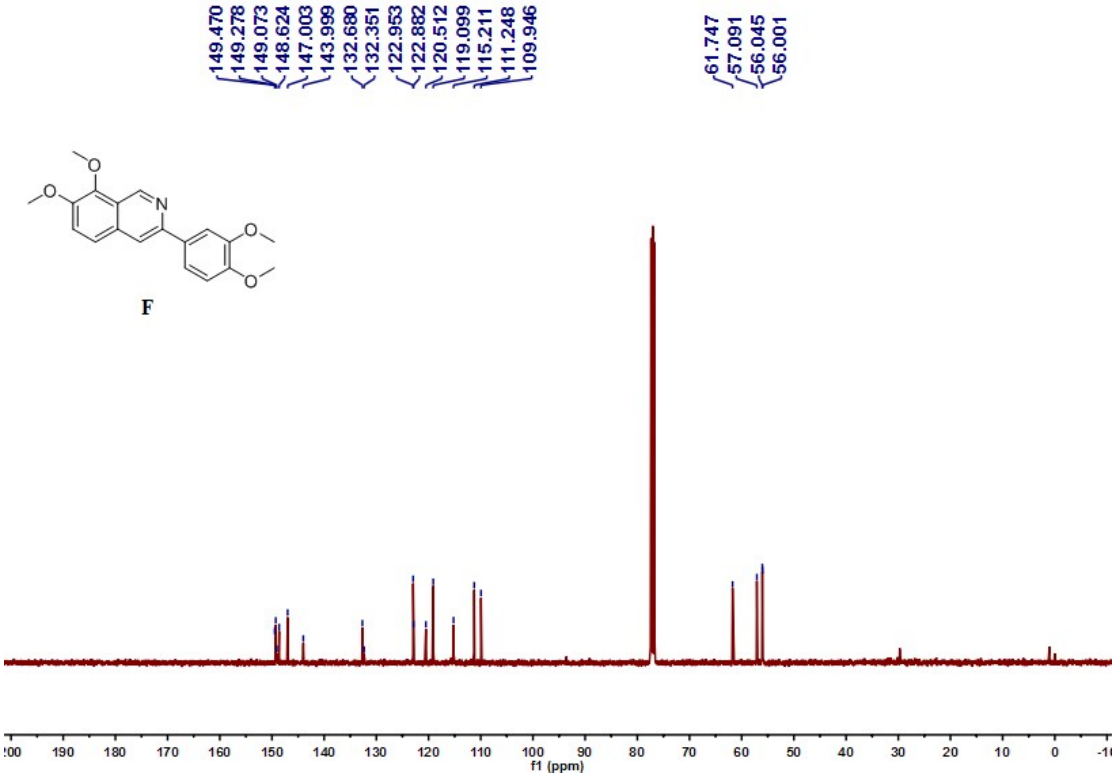
Decumbenine B



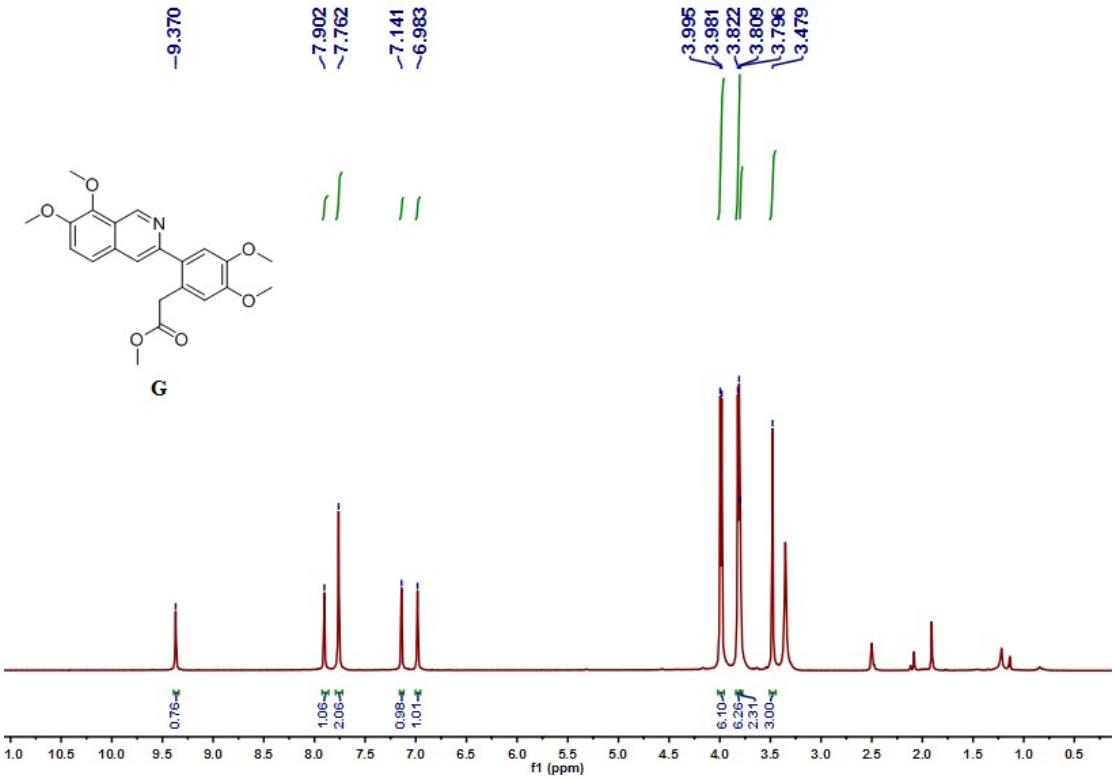
Decumbenine B


9.600
7.926
7.765
7.760
7.638
7.633
7.617
7.612
7.596
7.508
7.485
6.998
6.977
4.083
4.037
4.017
3.951
1.00
1.04
1.03
2.13
1.01
1.07
3.13
3.04
3.01
3.04
f1 (ppm)

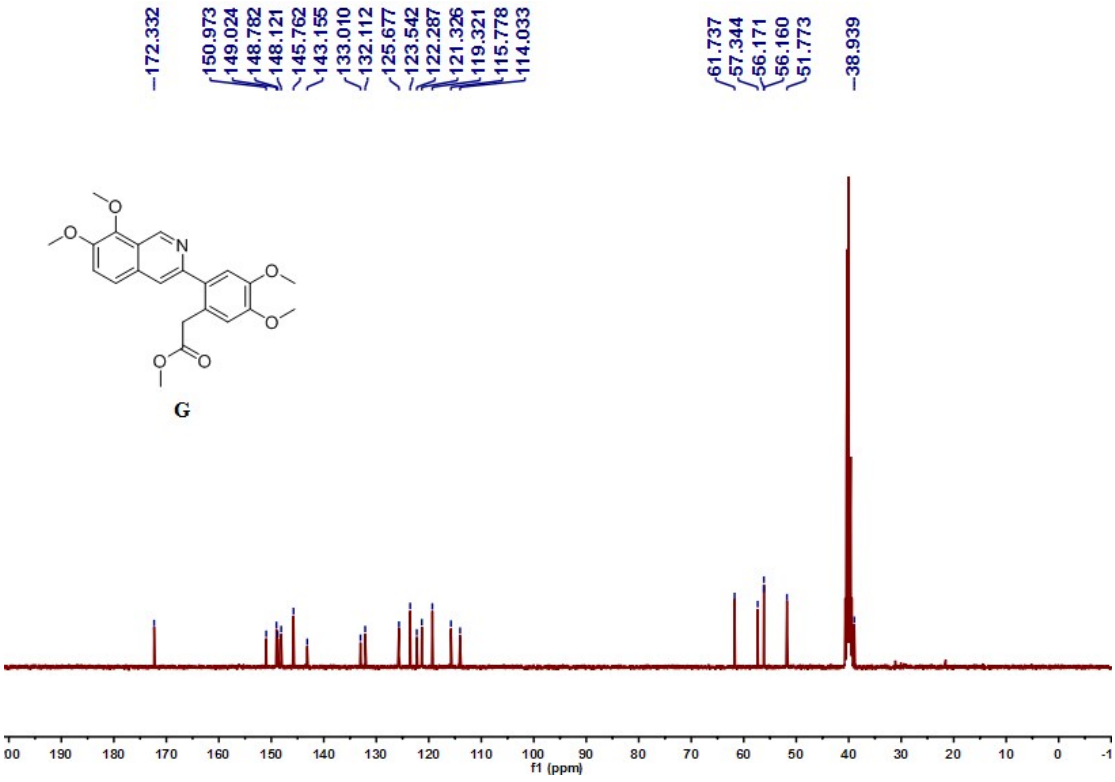
F


149.470
149.278
149.073
148.624
147.003
143.999
132.680
132.351
122.953
122.882
120.512
119.099
115.211
111.248
109.946
61.747
57.091
56.045
56.001
f1 (ppm)

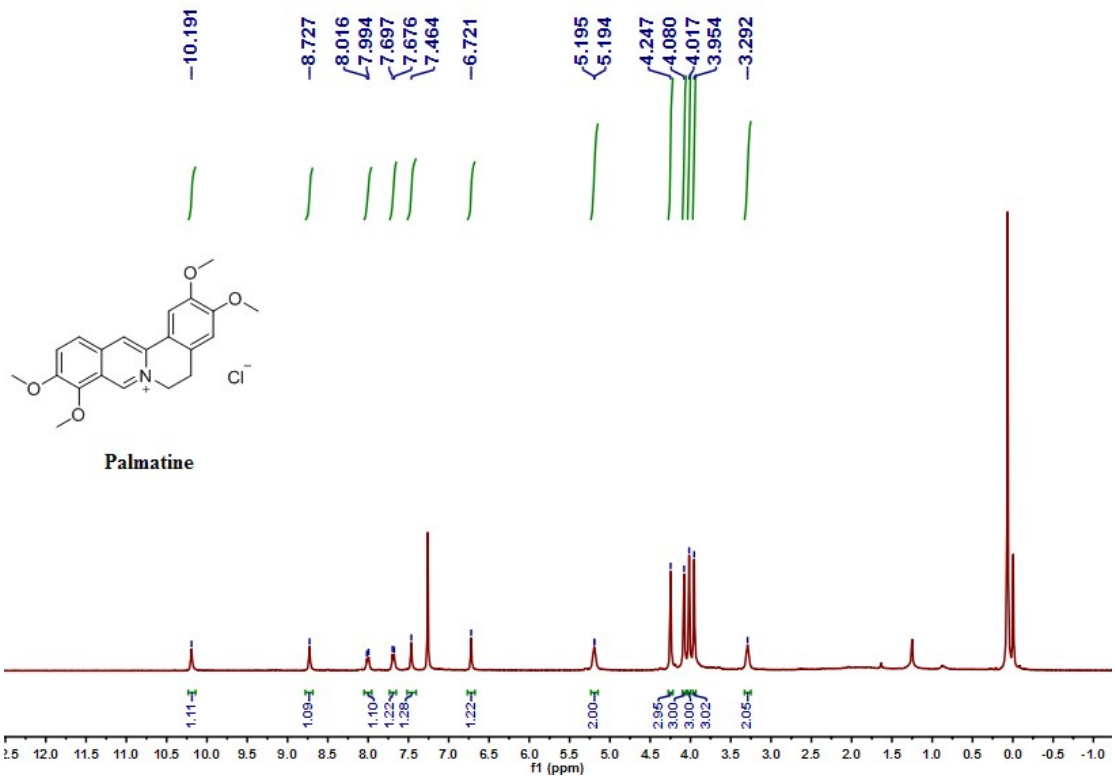
F


9.370
7.902
7.762
7.141
6.983
3.995
3.981
3.822
3.809
3.796
3.479
0.76
1.06
2.06
0.98
1.01
6.10
6.26
2.31
3.00
f1 (ppm)

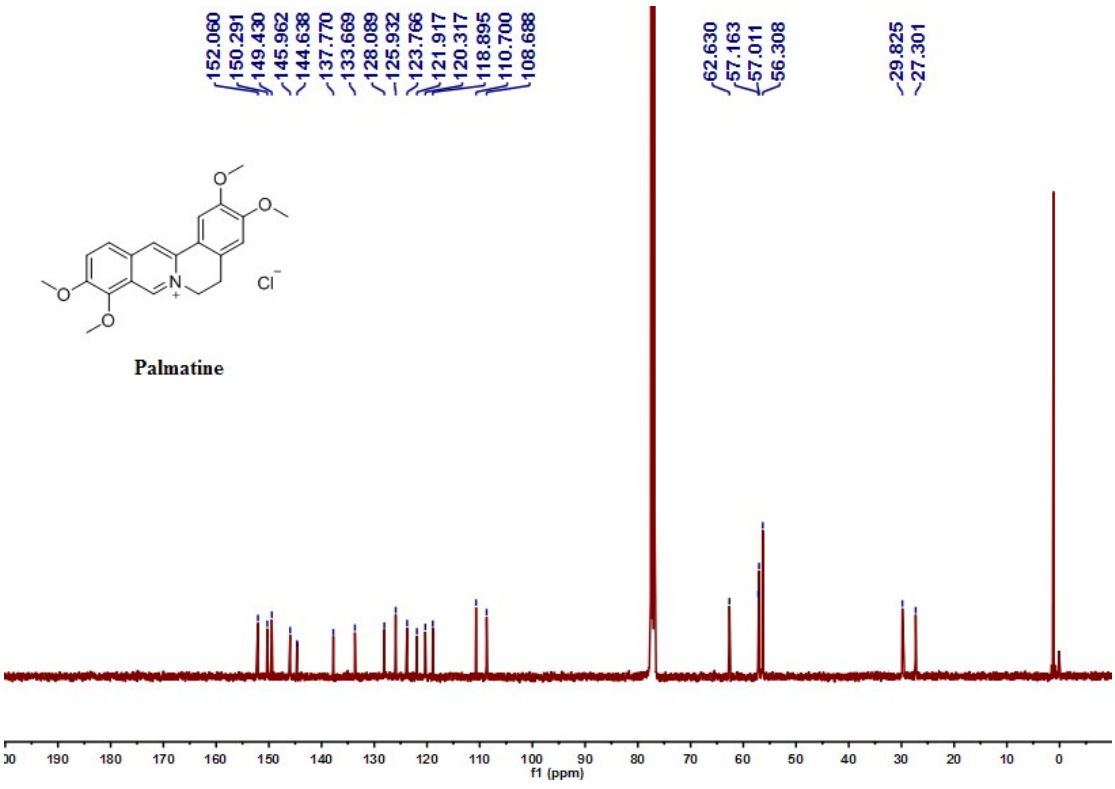
G


172.332
150.973
149.024
148.782
148.121
145.762
143.155
133.010
132.112
125.677
123.542
122.287
121.326
119.321
115.778
114.033
61.737
57.344
56.171
56.160
51.773
38.939
f1 (ppm)

G



Palmatine



Palmatine