Palladium-Catalyzed Direct C(sp3)-H Arylation of Indole-3-ones with Aryl Halides: A Novel and Efficient Method for the Synthesis of Nucleophilic 2-Monoarylated Indole-3-ones

Yong-Long Zhao,[a,*] Yong-Qin Tang,[a] Xing-Hai Fei,[a] Tao Xiao,[a] Ya-Dong Lu,[a] Xiao-Zhong Fu,[a] Bin He,[a] Meng Zhou,[a] Chun Li,[a] Peng-Fei Xu,[b,*] and Yuan-Yong Yang [a],*

[a] State Key Laboratory of Functions and Applications of Medicinal Plants, School of Pharmacy, Engineering Research Center for the Development and Application of Ethnic Medicine and TCM (Ministry of Education), Guizhou Medical University, Guiyang 550004, P.R. China.

[b] State Key Laboratory of Applied Organic Chemistry and College of Chemistry & Chemical Engineering, Lanzhou University, Lanzhou 730000, P.R. China.

*Corresponding authors: E-mail addresses: zhaoyl05@126.com; xupf@lzu.edu.cn; 312854015@qq.com

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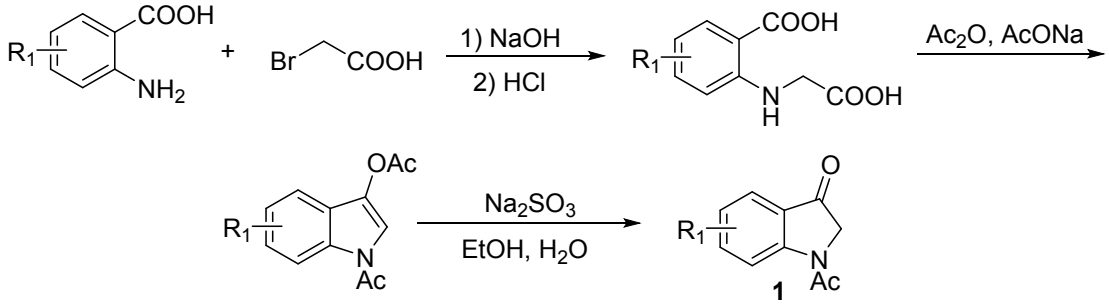
1. General Information

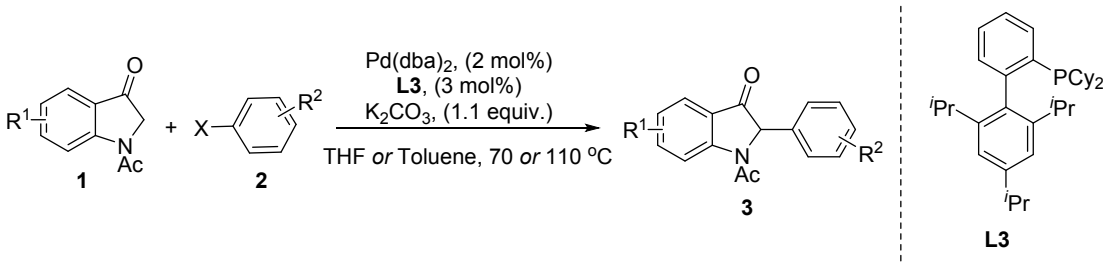
Chemicals and solvents were either purchased from commercial suppliers or purified by standard procedures as specified in Purification of Laboratory Chemicals, 4th Ed (Armarego, W. L. F.; Perrin, D. D. Butterworth Heinemann: 1997). Analytical thin-layer chromatography (TLC) was performed on silica gel plates with F-254 indicator and compounds were visualized by irradiation with UV light and/or by treatment with a solution of phosphomolybdic acid in ethanol followed by heating. Flash chromatography was carried out utilizing silica gel (200-300 mesh). ^{1}H NMR, ^{13}C NMR spectra were recorded on a Varain Mercury 400 spectrometer (400 MHz ^{1}H, 100 MHz ^{13}C). The spectra were recorded in $CDCl_3$ as the solvent at room temperature, ^{1}H and ^{13}C NMR chemical shifts are reported in ppm relative to either the residual solvent peak (^{13}C) (δ = 77.00 ppm) or TMS (^{1}H) (δ = 0 ppm) as an internal standard. Data for ^{1}H NMR are reported as follows: chemical shift (δ ppm), multiplicity (s = singlet, d = doublet, t = triplet, m = multiplet, dd = doublet), integration，coupling constant (Hz) and assignment. Data for ^{13}C NMR are reported as chemical shift. HRMS were performed on a Thermofisher (Vanquish（UPLC）— Q-Exactive Plus) mass instrument (ESI).

2. Preparation of Substrates

Substrates **1** were prepared by following the publish procedures [1-3]



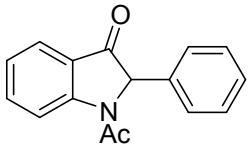
3. General procedure for the Direct C(sp3)-H Arylation of Indole-3-ones with Aryl Halides



Indole-3-ones **1** (0.25 mmol), $Pd(dba)_2$ (0.005 mmol, 4.6 mg), K_2CO_3 (0.275 mmol, 38 mg, 1.1 equiv.) and 2-dicyclohexylphosphino-2′,4′,6′-triisopropylbiphenyl **L3** (0.07 mmol, 3.3 mg) were added to a Schlenk tube equipped with a stir bar.. Then sealed with a rubber septum and vacuum purged five times with high pure nitrogen to remove air. To these solids, aryl halides **2** (0.275 mmol, 1.1 equiv.) and fresh distilled degassed THF (2 ml) or Toluene (1 ml) was added consecutively under a positive

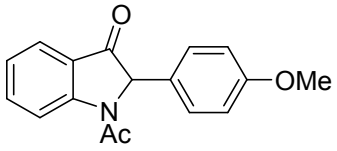
flow of high pure nitrogen. The reaction mixture was stirred at 70 °C or 110 °C. After the required period of time, the reaction was complete (as judged by TLC analysis). The reaction mixture was directly purified by flash column chromatography (eluted with petroleum ether/EtOAc = 15:1 to 10:1) to afford the C-2 aryl indole-3-ones **3**.

4. Analytical data of 3a–p



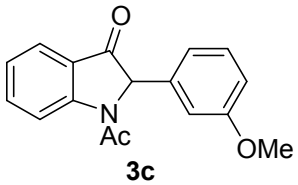
3a

1-Acetyl-2-phenylindolin-3-one (3a). White solid; Reaction time: 14 h; Yield: 87%; m. p.: 125-126 °C; ^{1}HNMR (400 MHz, $CDCl_3$): δ 8.62 (d, *J* = 8.8 Hz, 1H), 7.90 – 7.50 (m, 2H), 7.30 – 7.25 (m, 3H), 7.23 – 7.10 (m, 3H), 5.12 (s, 1H), 1.99 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.2, 169.6, 154.1, 137.9, 134.7, 129.8, 129.0, 126.0, 125.0, 123.0, 118.8, 69.8, 24.9; HRMS (ESI): calculated $[M+H]^+$ for $C_{16}H_{14}NO_2$: 252.10191, found $[M+H]^+$: 252.10171.



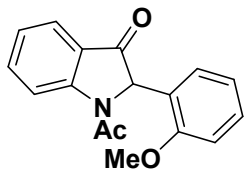
3b

1-Acetyl-2-(4-methoxyphenyl)indolin-3-one (3b). White solid; Reaction time: 14 h; Yield: 95%; m. p.: 138-139 °C; ^{1}HNMR (400 MHz, $CDCl_3$): δ 8.68 (d, *J* = 8.8 Hz, 1H), 7.80 – 7.60 (m, 2H), 7.35 – 7.20 (m, 2H), 6.90 – 6.78 (m, 3H), 5.16 (s, 1H), 3.78 (s, 3H), 2.08 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.0, 169.6, 154.0, 137.8, 136.1, 130.8, 124.9, 123.0, 118.7, 118.0, 114.0, 111.9, 69.7, 55.5, 24.8; HRMS (ESI): calculated $[M+H]^+$ for $C_{17}H_{16}NO_3$: 282.11247, found $[M+H]^+$: 282.11228.



3c

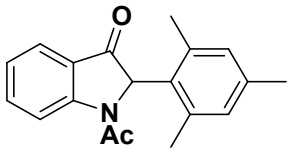
1-Acetyl-2-(3-methoxyphenyl)indolin-3-one (3c). Pale yellow solid; Reaction time: 14 h; Yield: 49%; m. p.: 135-136 °C; ^{1}HNMR (400 MHz, $CDCl_3$): δ 8.61 (d, *J* = 8.4 Hz, 1H), 7.70 – 7.60 (m, 2H), 7.25 – 7.14 (m, 2H), 6.88 – 6.68 (m, 3H), 5.09 (s, 1H), 3.71 (s, 3H), 2.01 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.0, 169.6,160.6, 154.0, 137.8, 133.2, 130.8, 125.0, 118.7, 118.1, 114.1, 112.0, 69.8, 55.5, 24.8; HRMS (ESI): calculated $[M+H]^+$ for $C_{17}H_{16}NO_3$: 282.11247, found $[M+H]^+$: 282.11224.



3d

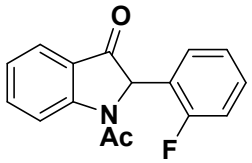
1-Acetyl-2-(2-methoxyphenyl)indolin-3-one (3d). White solid;

Reaction time: 14 h; Yield: 50%; m. p.: 152-153 °C; ^{1}HNMR (400 MHz, $CDCl_3$): δ 8.66 (d, *J* = 6.8 Hz, 1H), 7.85 – 7.65 (m, 2H), 7.35 – 7.18 (m, 2H), 7.08 – 6.77 (m, 3H), 5.72 (s, 1H), 3.83 (s, 3H), 2.03 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 196.5, 169.6, 157.4, 154.2, 137.4, 130.2, 127.3, 124.6, 124.5, 124.0, 121.5, 118.6, 112.1, 64.5, 56.2, 24.5; HRMS (ESI): calculated $[M+H]^+$ for $C_{17}H_{16}NO_3$: 282.11247, found $[M+H]^+$: 282.11225.



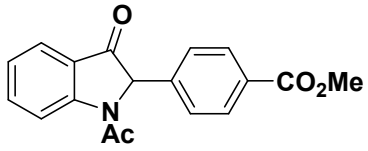
3e

1-Acetyl-2-mesitylindolin-3-one (3e). Yellow solid; Reaction time: 14 h; Yield: 26%; m. p.: 120-121 °C; ^{1}HNMR (400 MHz, $CDCl_3$): δ 8.59 (s, 1H), 7.74-7.60 (m, 2H), 7.24 – 7.15 (m, 1H), 6.90 (s, 1H), 6.69 (s, 1H), 5.59 (s, 1H), 2.47 (s, 3H), 2.19 (s, 3H), 1.89 (s, 3H), 1.72 (s, 3H).; ^{13}C NMR (100 MHz, $CDCl_3$): δ 196.3, 169.7, 153.7, 153.6, 137.6, 131.4, 130.1, 129.4, 124.5, 124.3, 123.7, 66.6, 24.3, 21.2, 21.0, 20.0; HRMS (ESI): calculated $[M+H]^+$ for $C_{19}H_{20}NO_2$: 294.14886, found $[M+H]^+$: 294.14877.



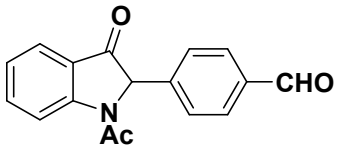
3f

1-Acetyl-2-(2-fluorophenyl)indolin-3-one (3f). White solid; Reaction time: 14 h; Yield: 43%; m. p.: 140-141 °C; ^{1}HNMR (400 MHz, $CDCl_3$): δ 8.60 (d, *J* = 8.0 Hz, 1H), 7.82 – 7.53 (m, 2H), 7.32 – 7.23 (m, 1H), 7.23 – 7.17 (m, 1H), 7.16 – 7.07 (m, 1H), 7.06 – 7.00 (m, 1H), 6.99-6.89 (m, 1H), 5.53 (s, 1H), 1.99 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 194.9, 169.2, 161.9, 159.4, 154.2, 147.7, 147.2, 137.8, 125.2, 125.1, 124.9, 124.8, 124.6, 122.7, 122.5, 118.7, 116.8, 116.6, 63.5, 24.4; HRMS (ESI): calculated $[M+H]^+$ for $C_{15}H_{13}FNO_2$: 270.09248, found $[M+H]^+$: 270.09270.



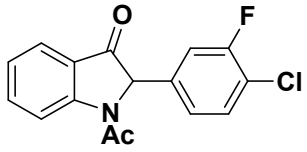
3g

Methyl 4-(1-acetyl-3-oxoindolin-2-yl)benzoate (3g). White solid; Reaction time: 14 h; Yield: 88%; m. p.: 147-148 °C; ^{1}HNMR (400 MHz, $CDCl_3$): δ 8.67 (d, *J* = 7.6 Hz, 1H), 8.04 (d, *J* = 8.2 Hz, 2H), 7.73 (t, *J* = 8.2 Hz, 2H), 7.35 (d, *J* = 8.3 Hz, 2H), 7.29 – 7.24 (m, 1H), 5.24 (s, 1H), 3.89 (s, 3H), 2.02 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 194.3, 169.4, 166.6, 154.0, 139.5, 138.1, 131.0, 126.1, 125.3, 125.2, 125.1, 122.8, 118.9, 69.5, 52.6, 24.8; HRMS (ESI): calculated $[M+H]^+$ for $C_{18}H_{16}NO_4$: 310.10738, found $[M+H]^+$: 310.10714.



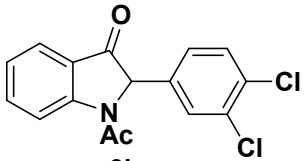
3h

4-(1-Acetyl-3-oxoindolin-2-yl)benzaldehyde (3h). White solid; Reaction time: 14 h; Yield: 63%; m. p.: 157-158 ^{o}C; ^{1}HNMR (400 MHz, $CDCl_3$): δ 10.01 (s, 1H), 8.70 (d, *J* = 7.6 Hz, 1H), 7.92 (d, *J* = 8.4 Hz, 2H), 7.80-7.70 (m, 2H), 7.49 (d, *J* = 8.4 Hz, 2H), 7.40 – 7.17 (m, 1H), 5.33 (s, 1H), 2.06 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 194.0, 191.6, 169.2, 154.0, 141.1, 138.2, 136.7, 131.0, 130.6, 126.7, 125.3, 125.1, 122.7, 118.8, 69.4, 24.8; HRMS (ESI): calculated $[M+H]^+$ for $C_{17}H_{14}NO_3$: 280.09682, found $[M+H]^+$: 280.09641.



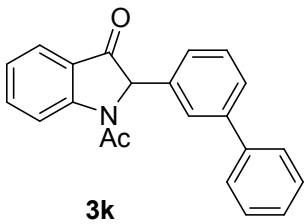
3i

1-Acetyl-2-(4-chloro-3-fluorophenyl)indolin-3-one (3i). White solid; Reaction time: 14 h; Yield: 42%; m. p.: 141-142 ^{o}C; ^{1}HNMR (400 MHz, $CDCl_3$): δ8.68 (s, 1H), 7.80 – 7.60 (m, 2H), 7.38 – 7.24 (m, 2H), 7.24 – 7.08 (m, 2H), 5.15 (s, 1H), 2.09 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 194.4, 169.2, 159.8, 157.3, 138.2, 131.9, 128.3, 128.0, 125.9, 125.3, 118.1, 117.9, 68.5, 24.9; HRMS (ESI): calculated $[M+H]^+$ for $C_{16}H_{12}ClFNO_2$: 304.05351, found $[M+H]^+$: 304.05351.



3j

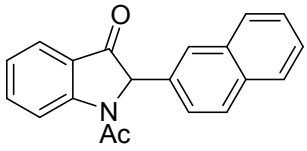
1-Acetyl-2-(3,4-dichlorophenyl)indolin-3-one (3j). White solid; Reaction time: 14 h; Yield: 28%; m. p.: 112-113 ^{o}C; ^{1}HNMR (400 MHz, $CDCl_3$): δ 8.61 (s, 1H), 7.75 – 7.60 (m, 2H), 7.50-7.35 (m, 1H), 7.34 – 7.25 (m, 1H), 7.23 – 7.16 (m, 1H), 7.13 – 6.98 (m, 1H), 5.08 (s, 1H), 2.02 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 194.1, 169.2, 147.9, 147.3, 138.3, 133.5, 125.3, 124.2, 119.3,118.9, 68.5, 24.9; HRMS (ESI): calculated $[M+H]^+$ for $C_{16}H_{12}Cl_2NO_2$: 320.02396, found $[M+H]^+$: 320.02396.



3k

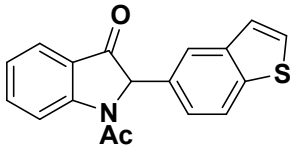
2-([1,1'-biphenyl]-3-yl)-1-acetylindolin-3-one (3k). White solid; Reaction time: 14 h; Yield: 72%; m. p.: 160-161 ^{o}C; ^{1}HNMR (400 MHz, $CDCl_3$): δ 8.55 (d, *J* = 6.8 Hz, 1H), 7.91 – 7.47 (m, 4H), 7.47 – 7.26 (m, 5H), 7.25 – 7.15 (m, 2H), 6.86 (d, *J* = 6.8 Hz, 1H), 5.36 (s, 1H), 1.60 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 196.7, 169.6, 154.4, 142.9, 140.0, 137.8, 133.0, 128.7, 128.4, 127.9, 124.8, 124.5, 123.4, 118.6, 65.7, 24.6; HRMS (ESI): calculated $[M+H]^+$ for $C_{22}H_{18}NO_2$:

328.13321, found $[M+H]^+$: 328.13318.



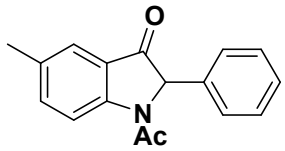
3l

1-Acetyl-2-(naphthalen-2-yl)indolin-3-one (3l). White solid; Reaction time: 14 h; Yield: 53%; m. p.: 130-131 °C; ^{1}HNMR (400 MHz, $CDCl_3$): δ 8.72 (d, *J* = 8.4 Hz, 1H), 7.87 – 7.73 (m, 5H), 7.52 – 7.45 (m, 2H), 7.40 – 7.25 (m, 2H), 5.34 (s, 1H), 2.07 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.2, 169.8, 154.0, 137.9, 133.6, 133.5, 132.0, 130.0, 128.6, 128.2, 128.1, 128.0, 127.0, 126.8, 125.5, 125.1, 124.9, 118.8, 69.9, 24.9; HRMS (ESI): calculated $[M+H]^+$ for $C_{20}H_{16}NO_2$: 302.11756, found $[M+H]^+$: 302.11730.



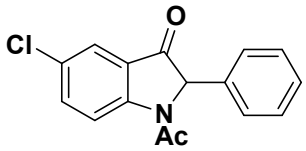
3m

1-Acetyl-2-(benzo[b]thiophen-5-yl)indolin-3-one (3m). Yellow solid; Reaction time: 14 h; Yield: 41%; m. p.: 160-161 °C; ^{1}HNMR (400 MHz, $CDCl_3$): δ 8.66 (d, *J* = 8.0 Hz, 1H), 7.81 (d, *J* = 8.4 Hz, 1H), 7.75 – 7.60 (m, 3H), 7.41 (d, *J* = 5.2 Hz, 1H), 7.28 – 7.13 (m, 3H), 5.24 (s, 1H), 2.00 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 196.3, 169.7, 154.1, 140.4, 140.3, 137.9, 130.9, 129.0, 128.2, 125.1, 124.0, 123.9, 121.8, 121.1, 118.8, 69.8, 24.9; HRMS (ESI): calculated $[M+H]^+$ for $C_{18}H_{14}NO_2S$: 308.07398, found $[M+H]^+$: 308.07397.



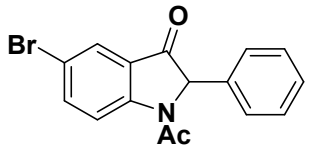
3n

1-Acetyl-5-methyl-2-phenylindolin-3-one (3n). White solid; Reaction time: 14 h; Yield: 32%; m. p.: 155-156 °C; ^{1}HNMR (400 MHz, $CDCl_3$): δ 8.50 (d, *J* = 8.4 Hz, 1H), 7.51 – 7.42 (m, 2H), 7.33 – 7.25 (m, 3H), 7.21 – 7.14 (m, 2H), 5.11 (s, 1H), 2.32 (s, 3H), 1.97 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 195.2, 169.3, 152.3, 147.3, 139.0, 135.0, 134.9, 129.7, 129.0, 126.0, 124.2, 123.2, 119.3, 118.5, 70.1, 24.7, 21.0; HRMS (ESI): calculated $[M+H]^+$ for $C_{17}H_{16}NO_2$: 266.11756, found $[M+H]^+$: 266.11743.



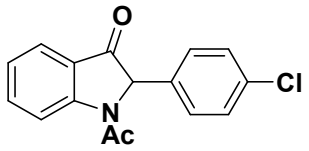
3o

1-Acetyl-5-chloro-2-phenylindolin-3-one (3o). White solid; Reaction time: 14 h; Yield: 91%; m. p.: 155-156 °C; ^{1}HNMR (400 MHz, $CDCl_3$): δ 8.59 (d, *J* = 8.4 Hz, 1H), 7.69 – 7.53 (m, 2H), 7.39 – 7.24 (m, 3H), 7.24 – 7.15 (m, 2H), 5.16 (s, 1H), 1.98 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 194.0, 169.5, 152.4,137.6, 134.2, 130.6, 129.9, 125.9, 124.4, 120.0, 70.2, 24.7; HRMS (ESI): calculated $[M+H]^+$ for $C_{16}H_{13}ClNO_2$: 286.06293, found $[M+H]^+$: 286.06286.



3p

1-Acetyl-5-bromo-2-phenylindolin-3-one (3p). White solid; Reaction time: 14 h; Yield: 53%; m. p.: 155-156 ^{o}C; ^{1}HNMR (400 MHz, $CDCl_3$): δ 8.61 (d, *J* = 8.0 Hz, 1H), 7.90 – 7.75 (m, 2H), 7.45 – 7.30 (m, 3H), 7.28 – 7.15 (d, *J* = 6.9 Hz, 2H), 5.22 (s, 1H), 2.06 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 193.8, 169.5, 147.3, 140.4, 134.2, 130.3, 129.9, 129.6, 127.6, 126.0, 124.2, 120.4, 118.0, 70.1, 24.8; HRMS (ESI): calculated $[M+H]^+$ for $C_{16}H_{13}BrNO_2$: 330.01242, found $[M+H]^+$: 330.01256.



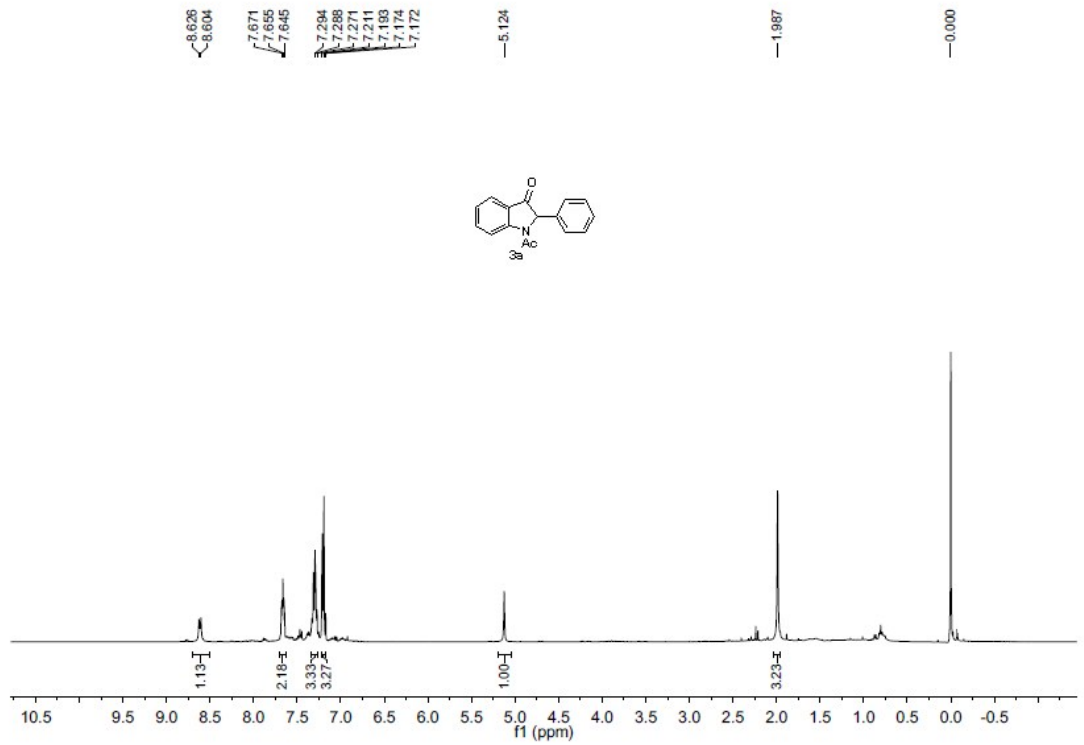
3q

1-Acetyl-2-(4-chlorophenyl)indolin-3-one (3q). White solid; Reaction time: 14 h; Yield: 40%; m. p.: 120-121 ^{o}C; ^{1}HNMR (400 MHz, $CDCl_3$): δ 8.68 (d, *J* = 5.4 Hz, 1H), 7.77 – 7.60 (m, 2H), 7.36 (d, *J* = 8.4 Hz, 2H), 7.28 – 7.20 (m, 3H), 5.17 (s, 1H), 2.07 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 194.7, 169.3, 154.0, 138.0, 135.1, 133.3, 130.0, 127.4, 125.2, 122.9, 118.9, 69.2, 24.8; HRMS (ESI): calculated $[M+H]^+$ for $C_{16}H_{13}ClNO_2$: 286.06293, found $[M+H]^+$: 286.06286.

References

1) Y. Z. Liu, J. Zhang, P. F. Xu and Y. C. Luo, *J. Org. Chem.* **2011**, *76*, 7551–7555.
2) Y. Z. Liu, R. L. Chen and P. F. Xu, *J. Org. Chem.* **2011**, *76*, 2884 – 2887.
3) W. S. Shun, L. Hong and R. Wang, *Chem. Eur. J.* **2011**, *17*, 6030 – 6033.

NMR spectrogram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7.671
7.655
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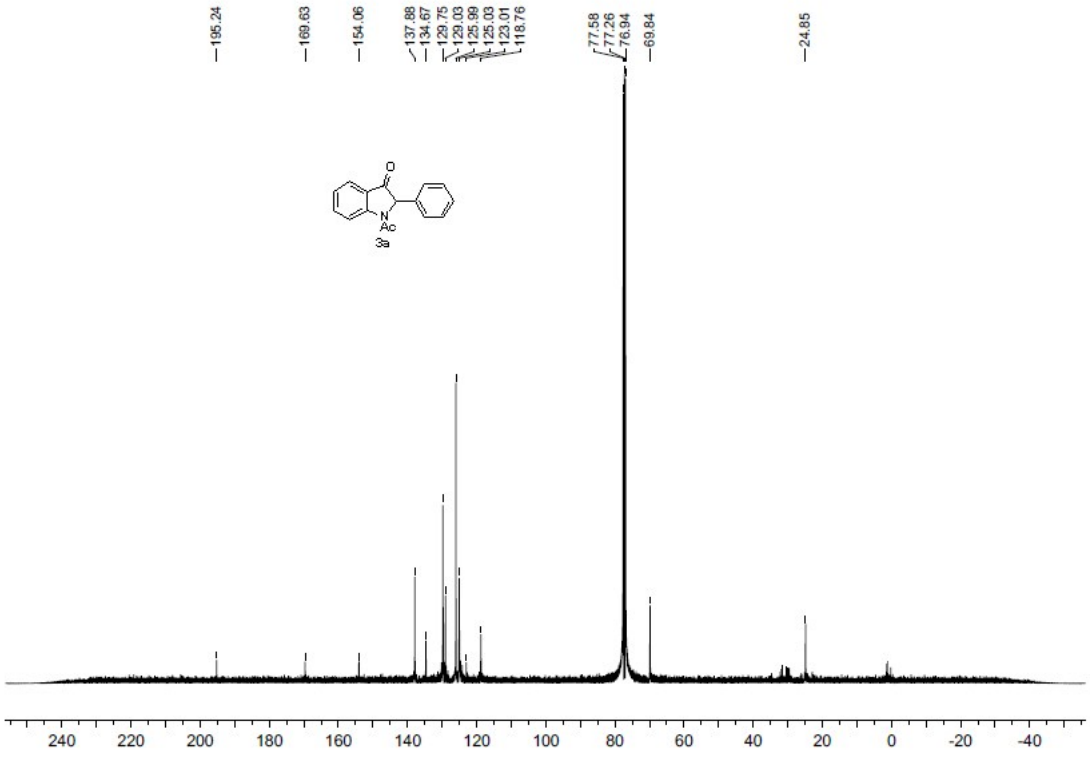
7.294
7.288
7.271
7.211
7.193
7.174
7.172
5.124
1.987
0.000
O
N
Ac
3a
1.13
2.18
3.33
3.27
1.00
3.23
10.5
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)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125.99
125.03
123.01
118.76
77.58
77.26
76.94
69.84
24.85
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N
Ac
3a
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220
200
180
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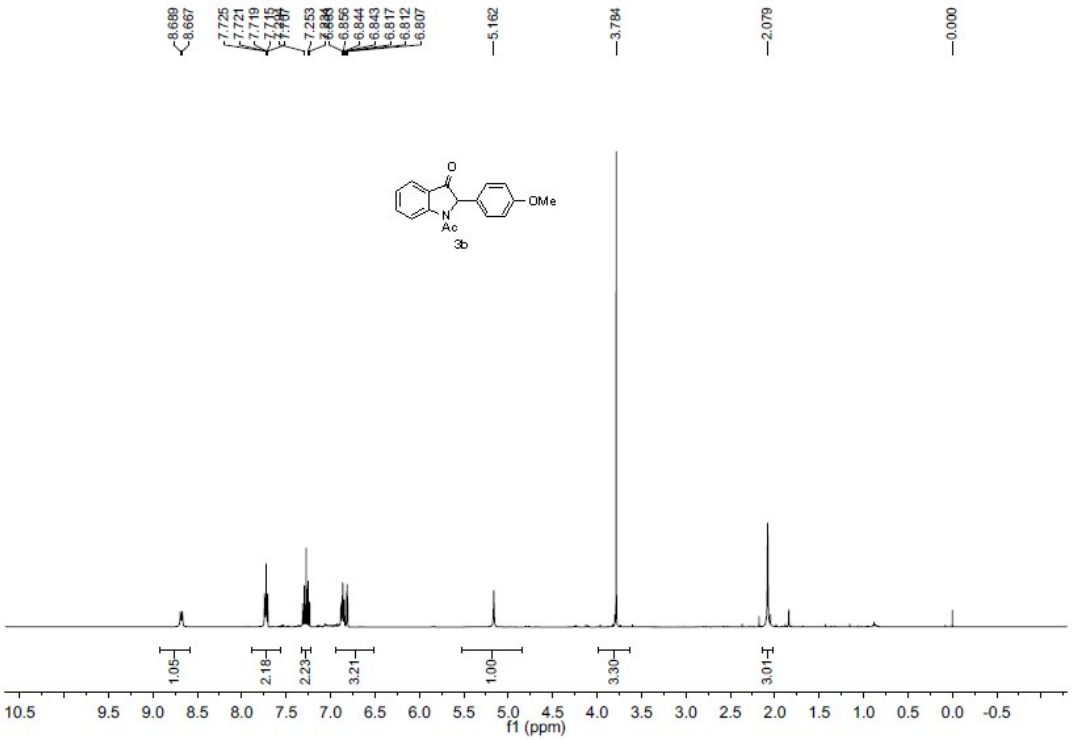
140
120
100
80
60
40
20
0
-20
-40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7.253
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6.844
6.843
6.817
6.812
6.807
5.162
3.784
2.079
0.000
OMe
N
Ac
3b
1.05
2.18
2.23
3.21
1.00
3.30
3.01
10.5
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
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0.5
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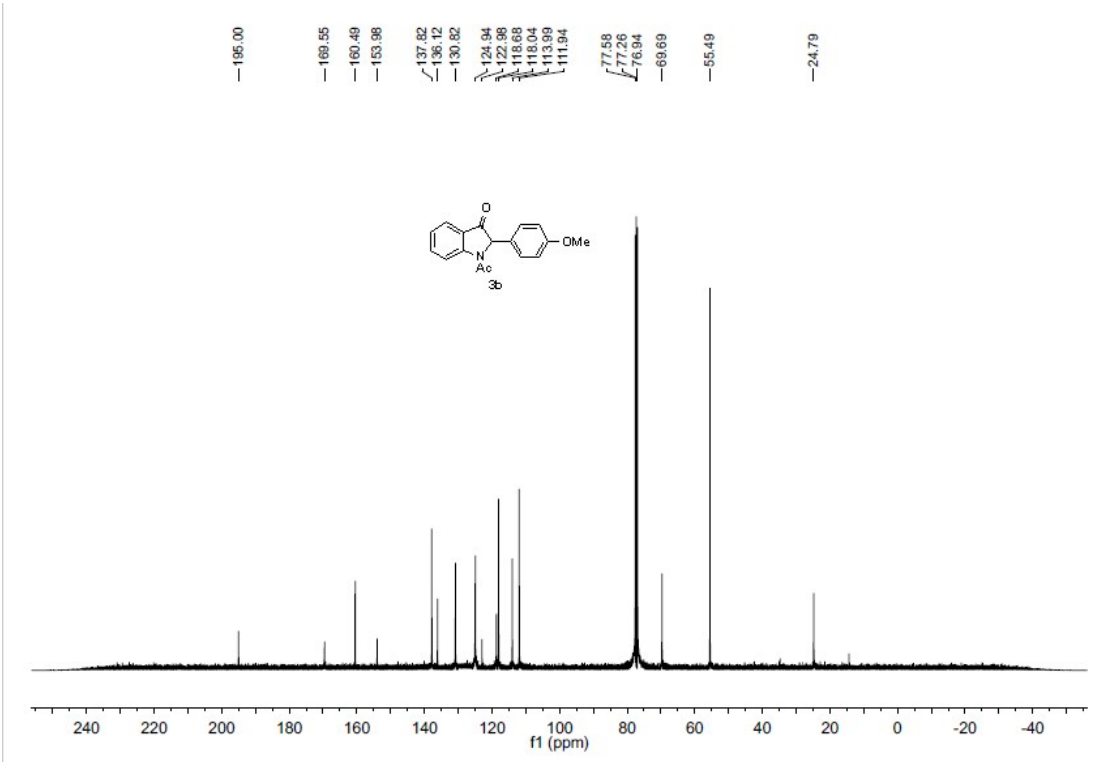
f1 (ppm)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124.94
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118.68
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111.94
77.58
77.26
76.94
69.69
55.49
24.79
OMe
N
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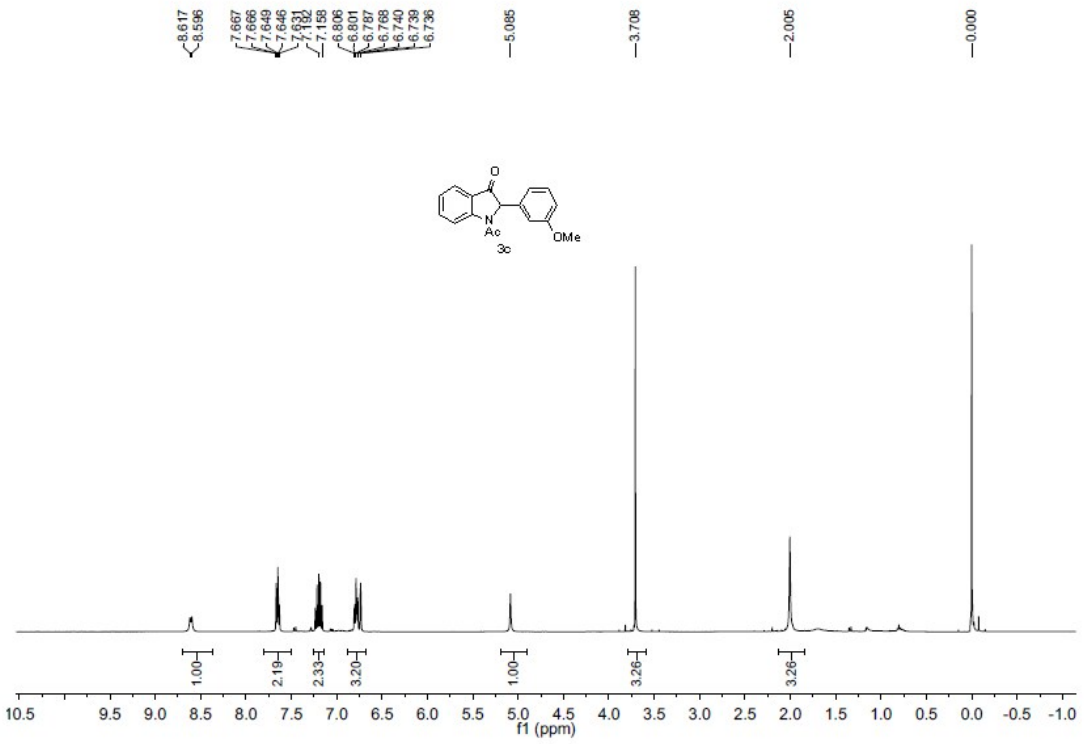
-40
f1 (ppm)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7.667
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7.192
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6.801
6.787
6.768
6.740
6.739
6.736
5.085
3.708
2.005
0.000
O
N
Ac
OMe
3c
1.00
2.19
2.33
3.20
1.00
3.26
3.26
10.5
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
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2.5
2.0
1.5
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0.0
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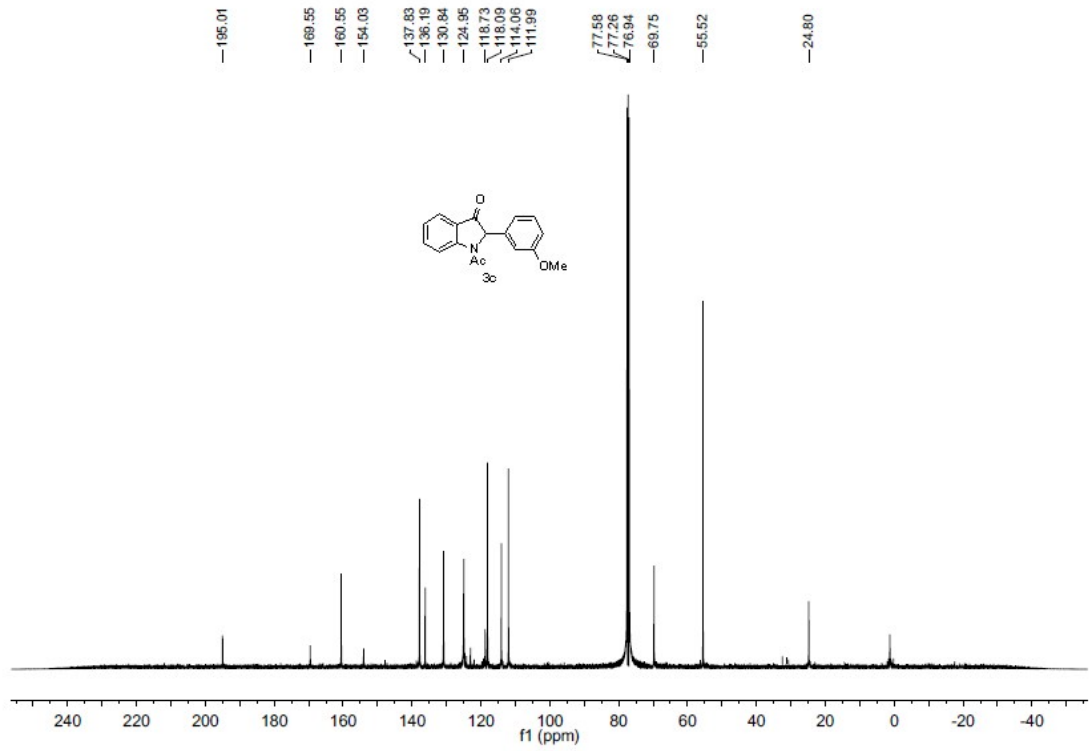
f1 (ppm)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124.95
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114.06
111.99
77.58
77.26
76.94
69.75
55.52
24.80
O
N
Ac
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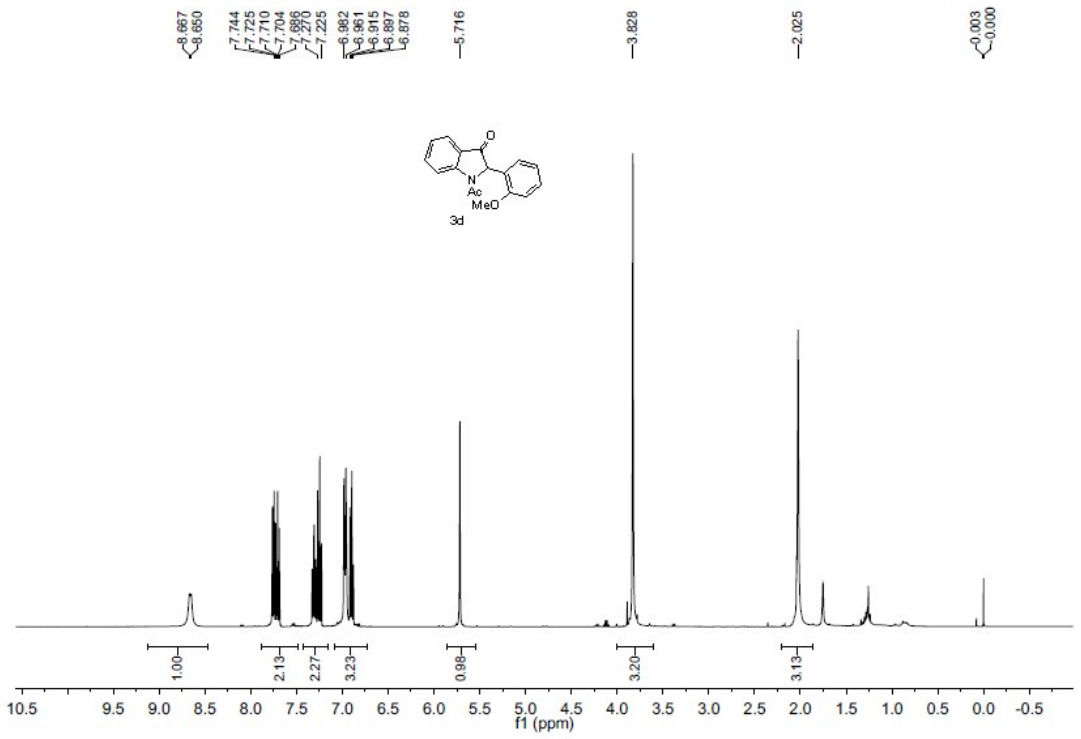
f1 (ppm)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7.270
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6.897
6.878
5.716
3.828
2.025
0.003
0.000
O
N
Ac
MeO
3d
1.00
2.13
2.27
3.23
0.98
3.20
3.13
10.5
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
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3.0
2.5
2.0
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0.5
0.0
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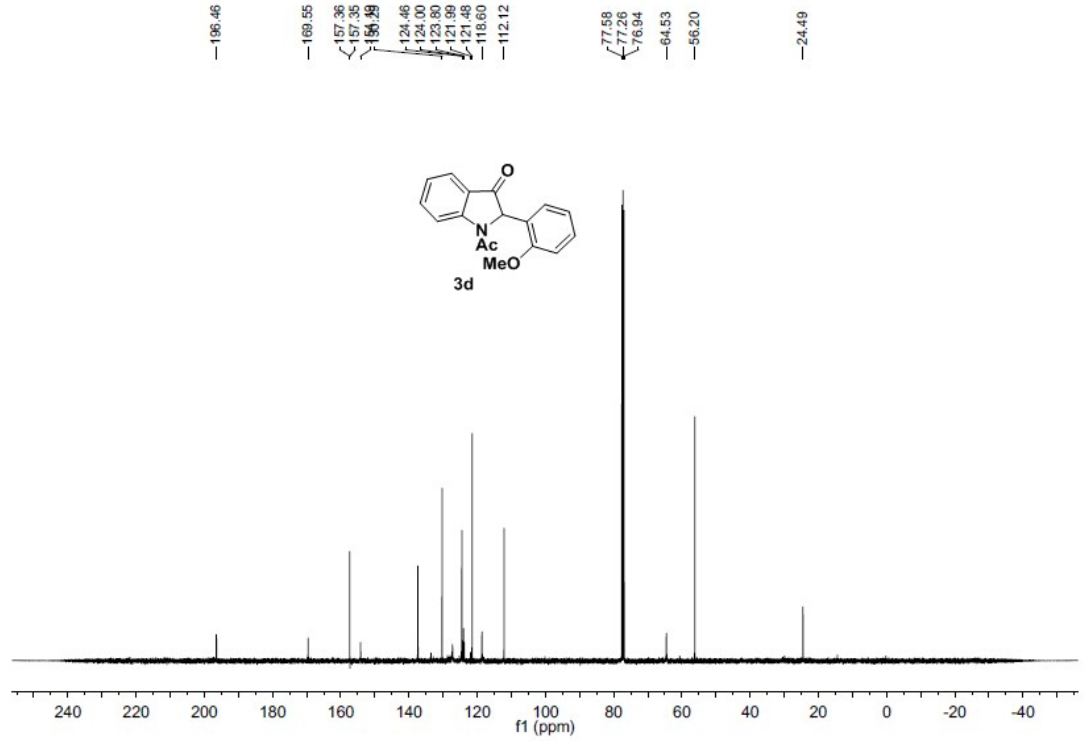
f1 (ppm)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121.99
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77.26
76.94
64.53
56.20
24.49
O
N
Ac
MeO
3d
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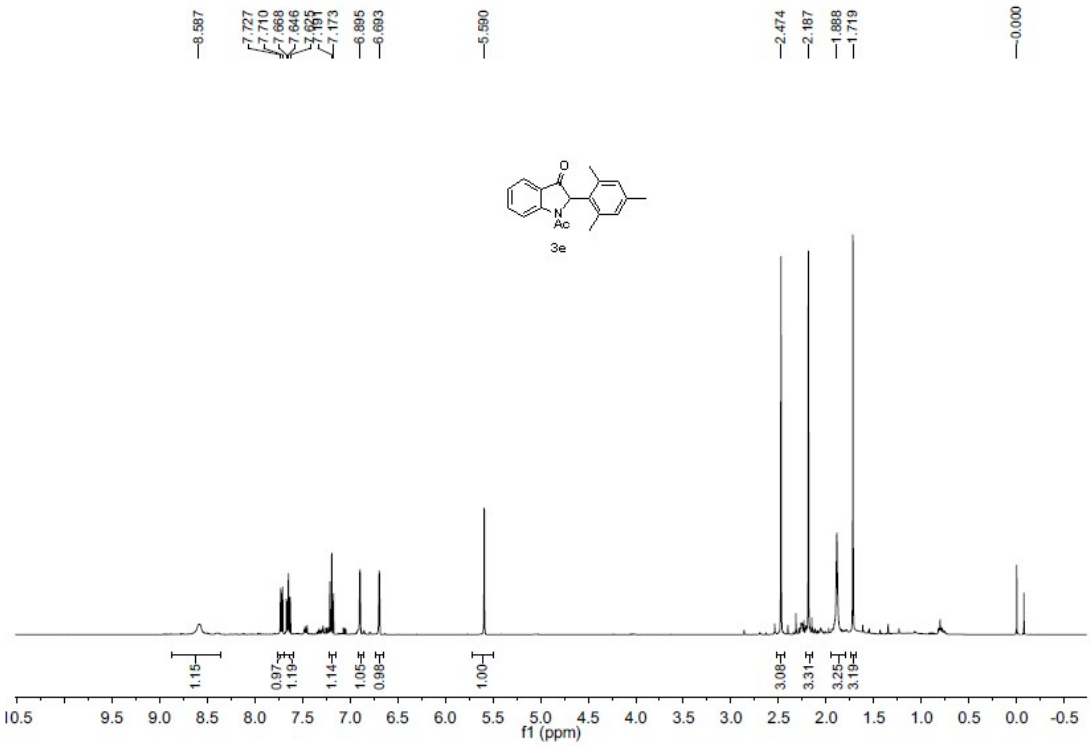
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
f1 (ppm)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7.173
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2.187
1.888
1.719
0.000
3e
1.15
0.97
1.19
1.14
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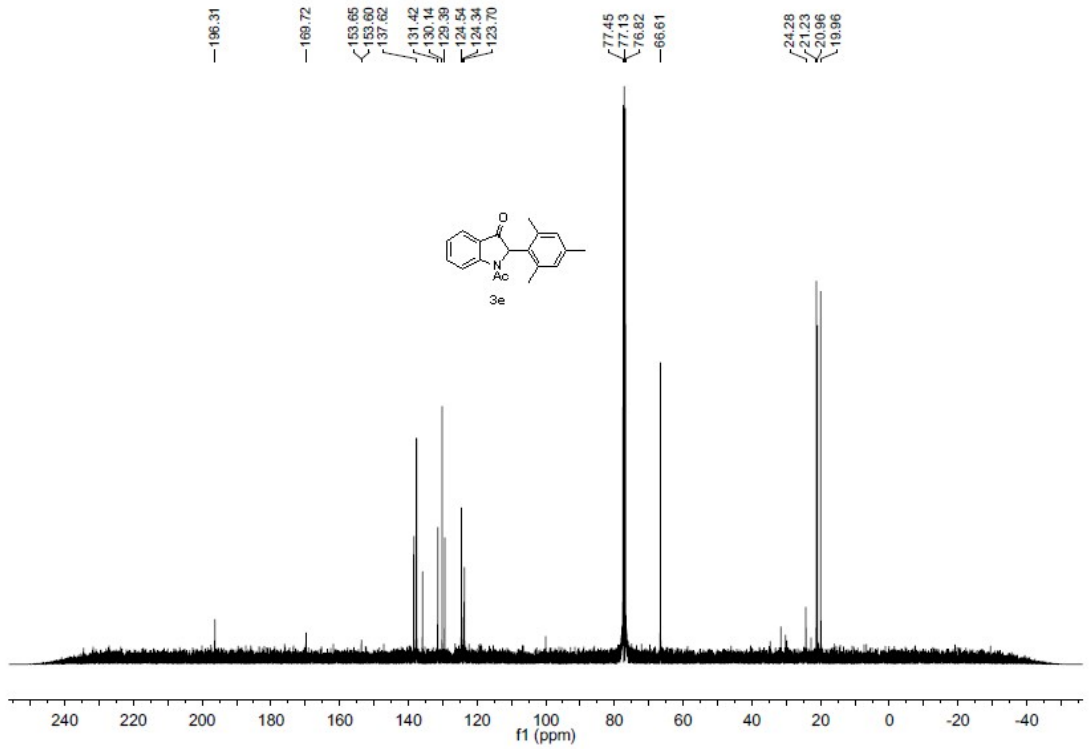
3.25
3.19
f1 (ppm)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129.39
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77.13
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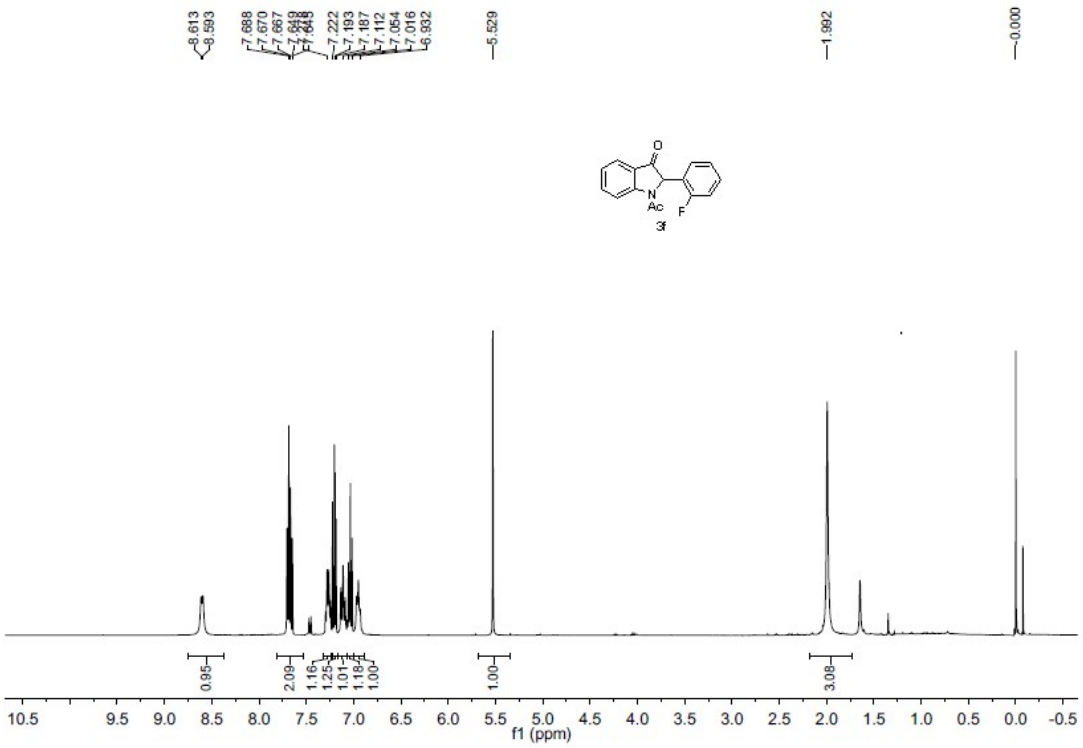
21.23
20.96
19.96
3e
f1 (ppm)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7.667
7.222
7.193
7.187
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7.054
7.016
6.932
5.529
1.992
0.000
O
N
Ac
F
3f
0.95
2.09
1.16
1.25
1.01
1.18
1.00
1.00
3.08
10.5
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
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2.0
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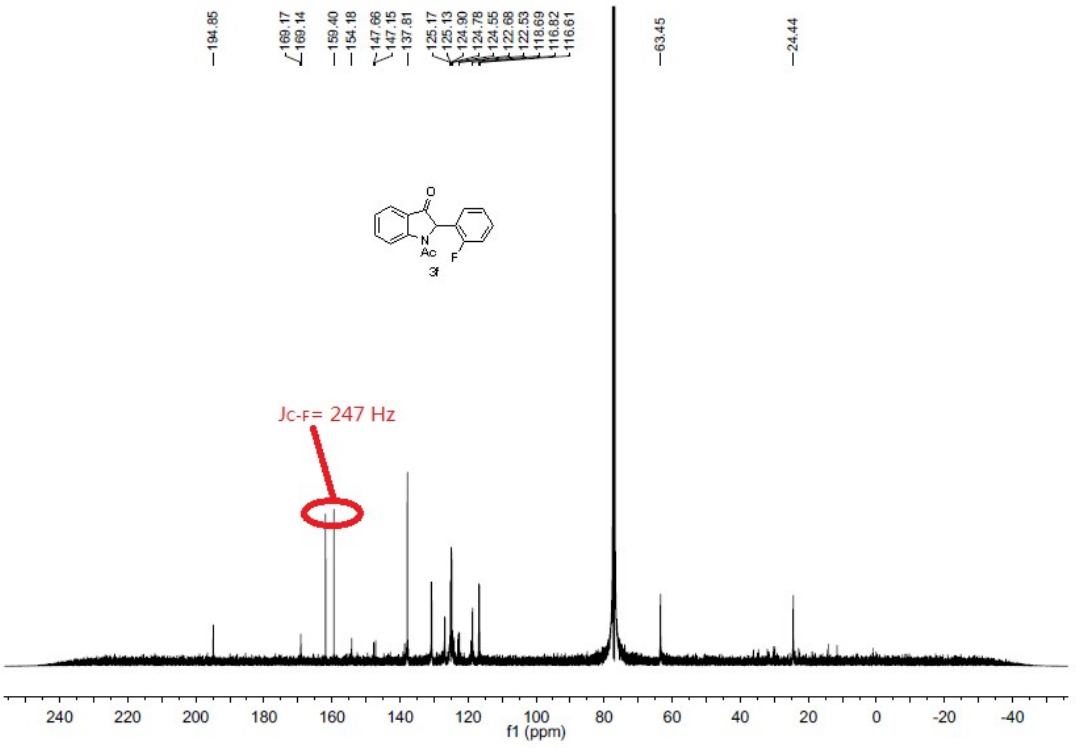
f1 (ppm)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169.14
159.40
154.18
147.66
147.15
137.81
125.17
125.13
124.90
124.78
124.55
122.68
122.53
118.69
116.82
116.61
63.45
24.44
O
N
Ac
F
3f
Jc-F= 247 Hz
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200
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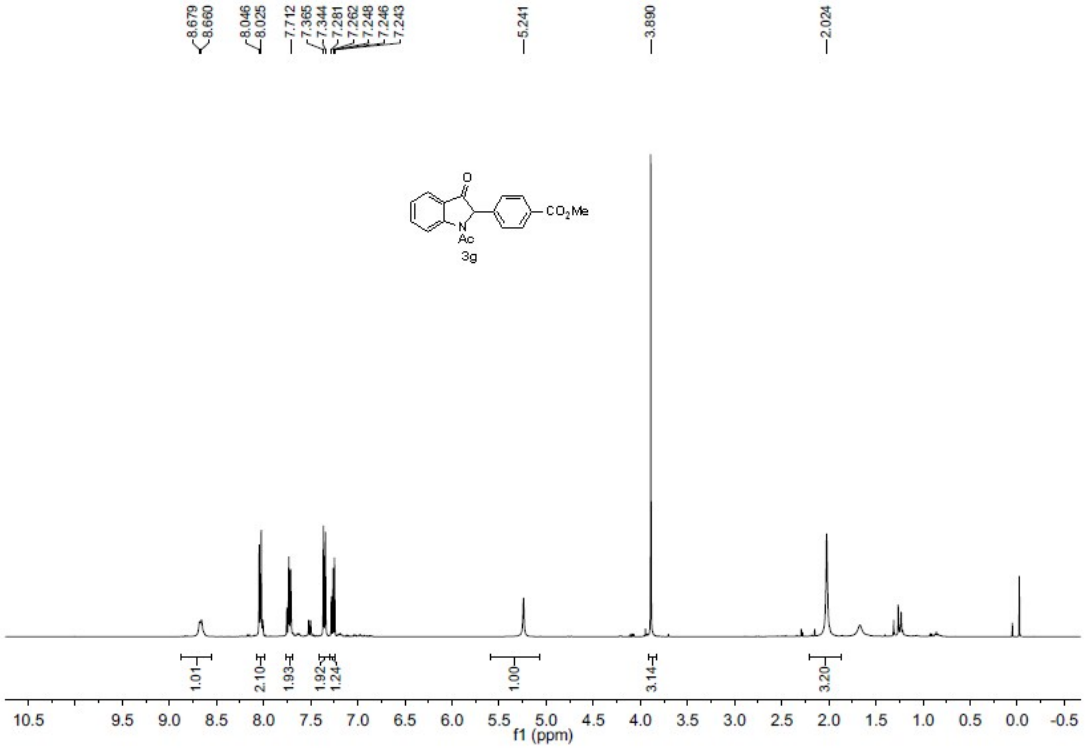
160
140
120
100
80
60
40
20
0
-20
-40
f1 (ppm)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7.246
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5.241
3.890
2.024
O
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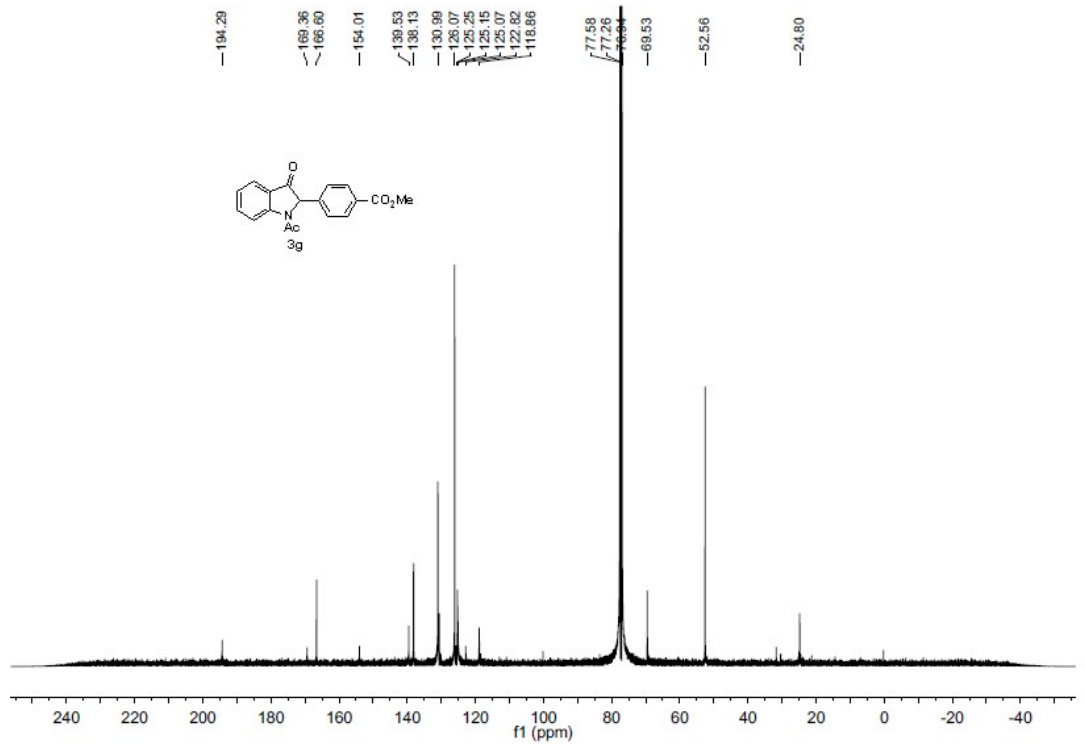
f1 (ppm)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76.94
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24.80
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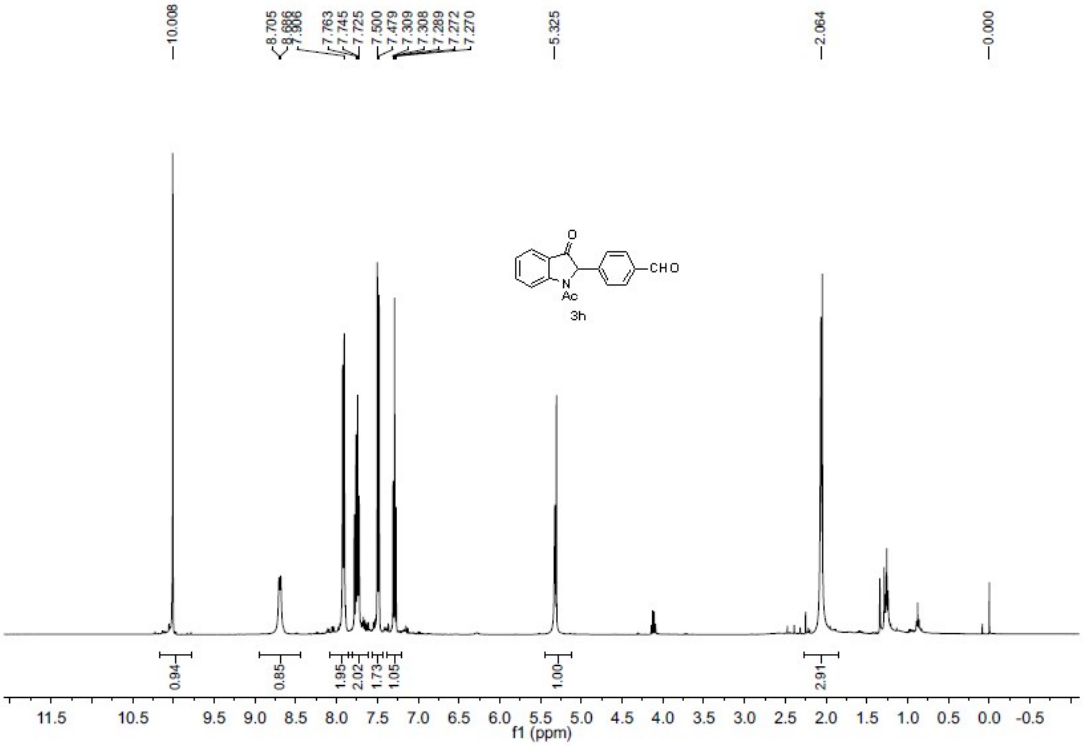
N
Ac
CO2Me
3g
f1 (ppm)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7.308
7.289
7.272
7.270
5.325
2.064
0.000
O
CHO
N
Ac
3h
0.94
0.85
1.95
2.02
1.73
1.05
1.00
2.91
11.5
10.5
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
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2.5
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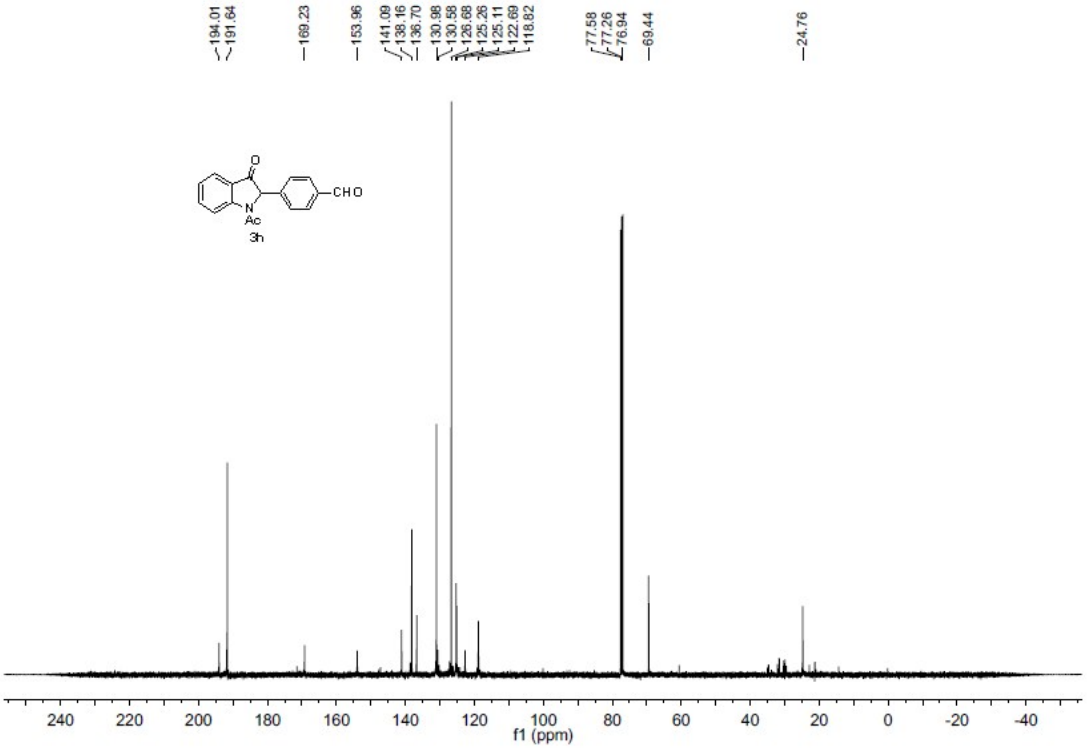
-0.5
f1 (ppm)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191.64
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141.09
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136.70
130.98
130.58
126.68
125.26
125.11
122.69
118.82
77.58
77.26
76.94
69.44
24.76
O
CHO
N
Ac
3h
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200
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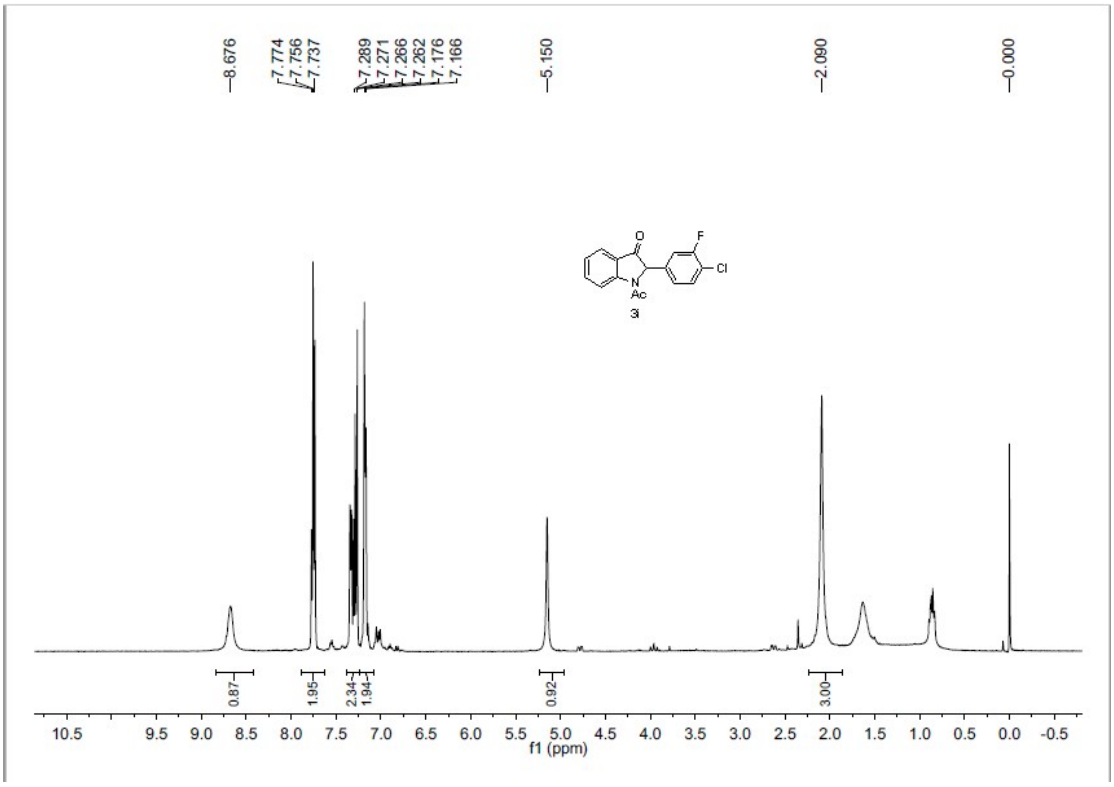
100
80
60
40
20
0
-20
-40
f1 (ppm)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7.262
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5.150
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0.000
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F
Cl
N
Ac
3i
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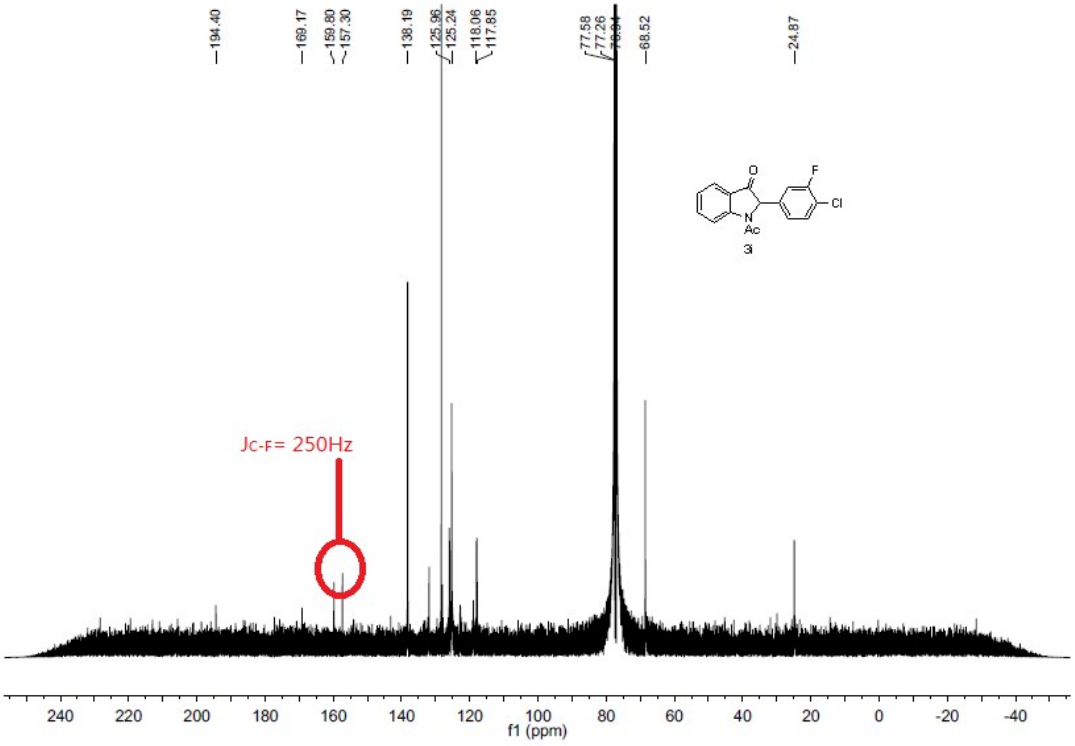
1.94
0.92
3.00
f1 (ppm)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138.19
125.96
125.24
118.06
117.85
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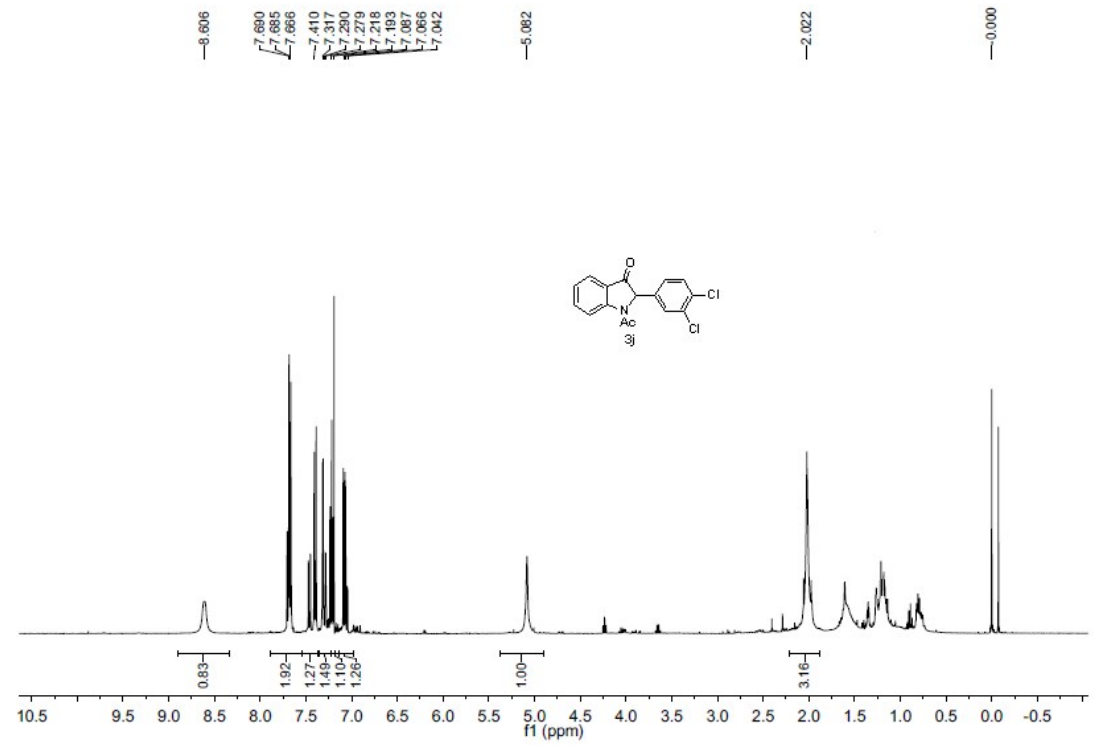
77.26
68.52
24.87
Jc-F= 250Hz
O
F
Cl
N
Ac
3i
f1 (ppm)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7.193
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7.042
5.062
2.022
0.000
O
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Cl
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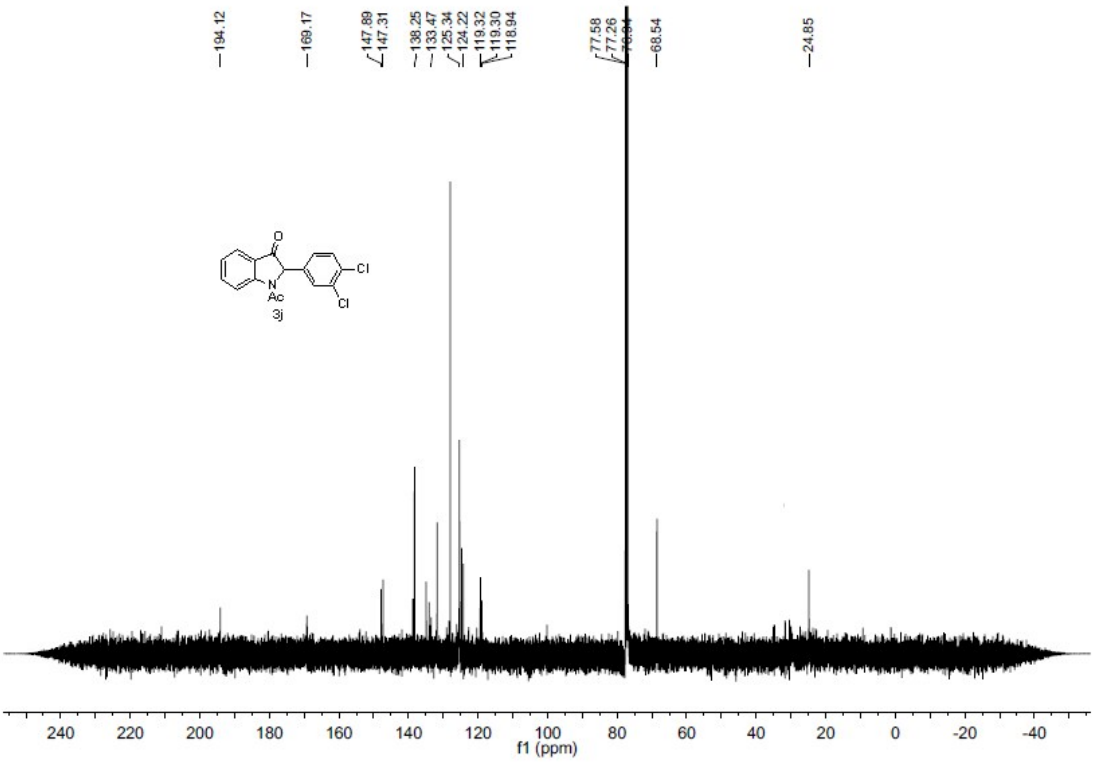
1.27
1.49
1.10
1.26
1.00
3.16
f1 (ppm)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133.47
125.34
124.22
119.32
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118.94
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77.26
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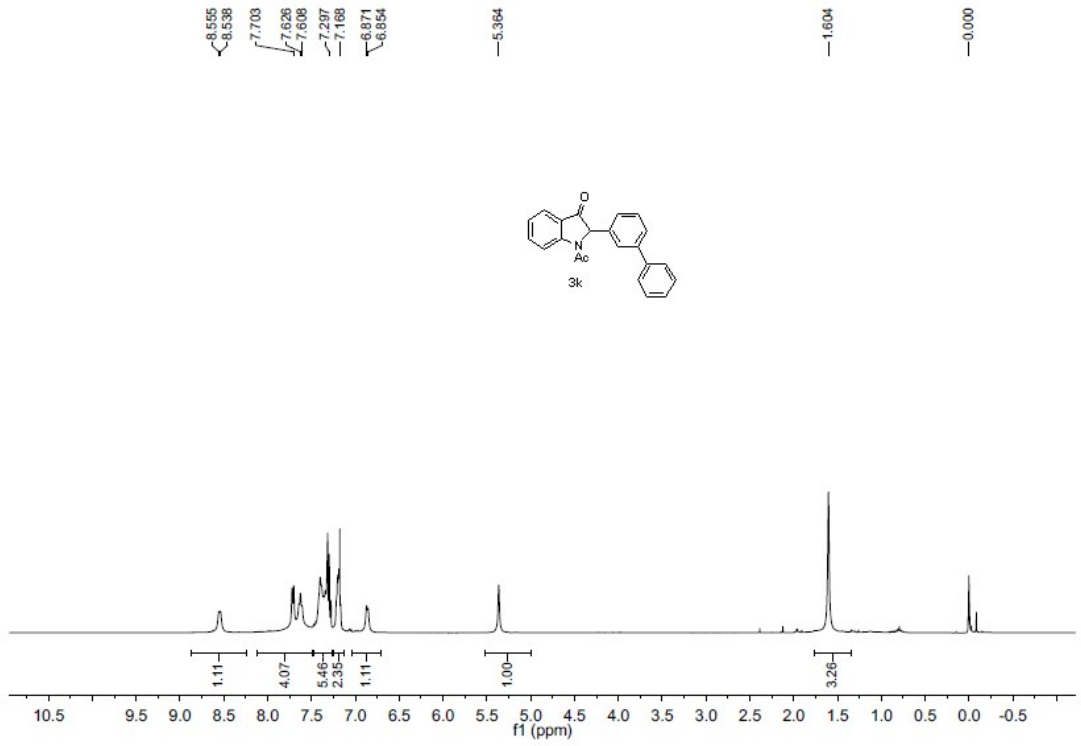
68.54
24.85
O
N
Ac
Cl
Cl
3j
f1 (ppm)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N
Ac
3k
1.11
4.07
5.46
2.35
1.11
1.00
3.26
10.5
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
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3.0
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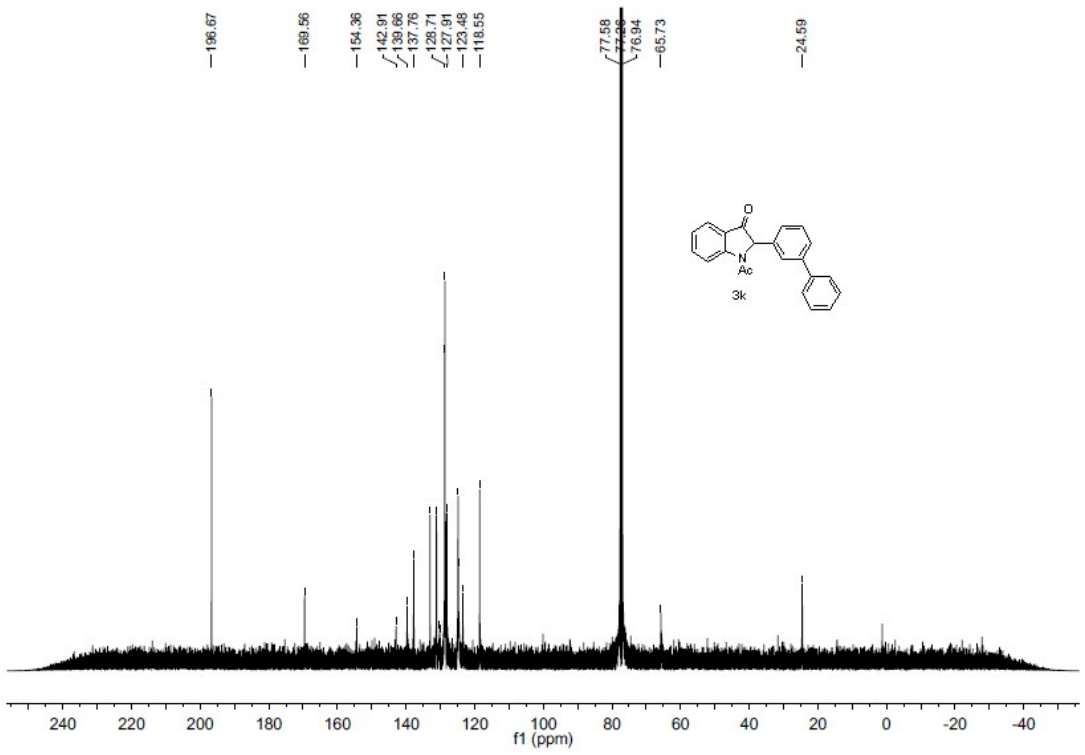
f1 (ppm)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127.91
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65.73
24.59
O
N
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120
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80
60
40
20
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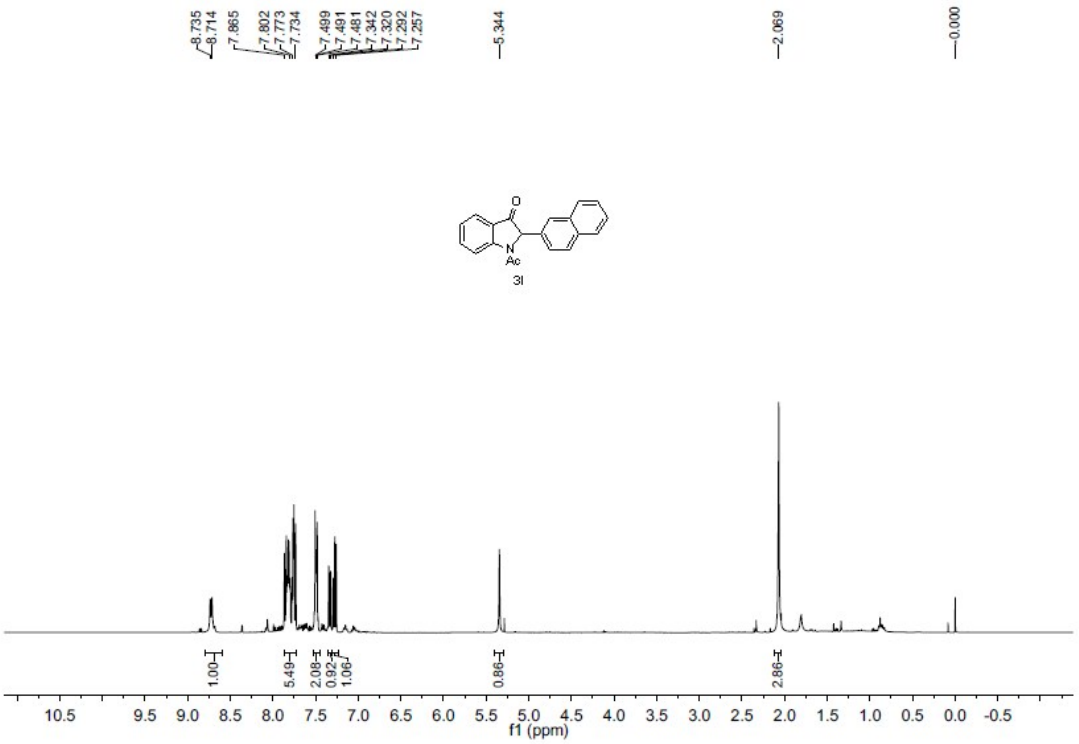
-20
-40
f1 (ppm)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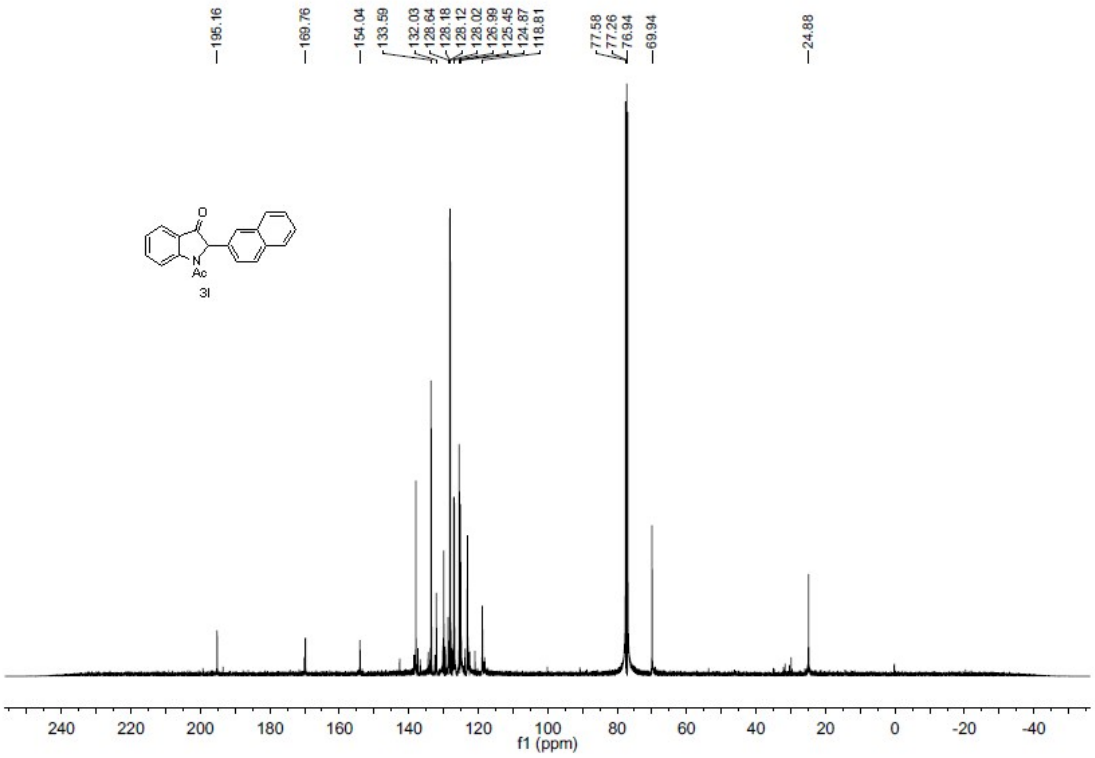
7.257
5.344
2.069
0.000
O
N
Ac
3l
1.00
5.49
2.08
0.92
1.06
0.86
2.86
10.5 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)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132.03
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128.18
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128.02
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125.45
124.87
118.81
77.58
77.26
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69.94
24.88
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N
Ac
3l
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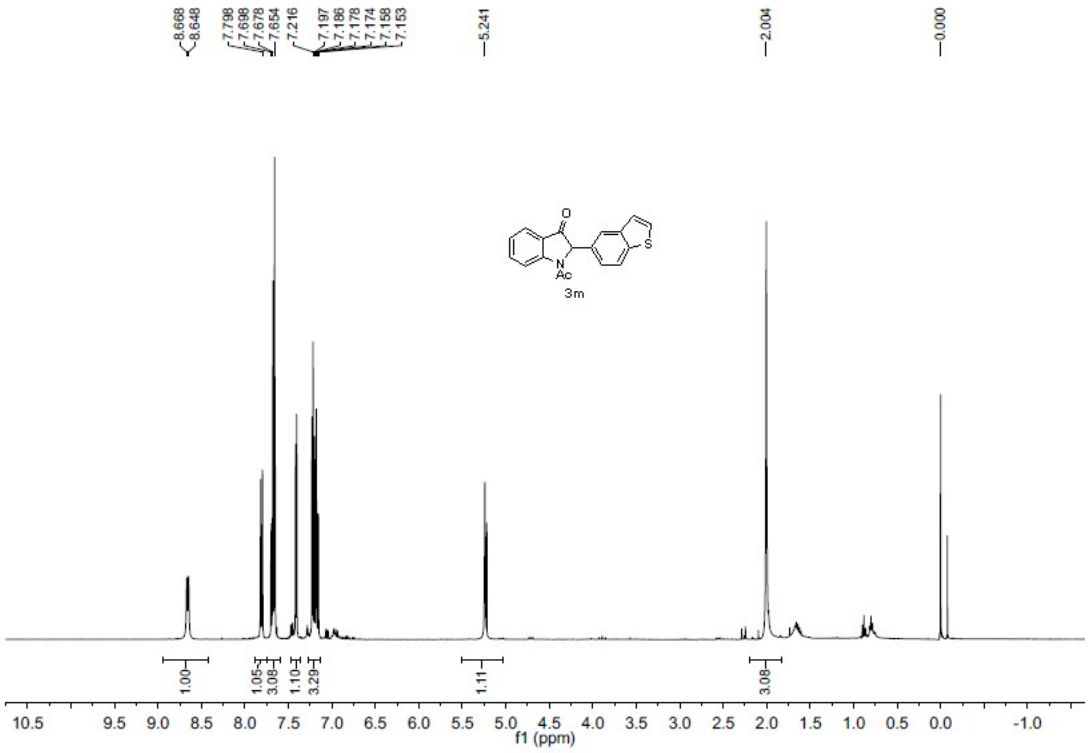
f1 (ppm)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7.174
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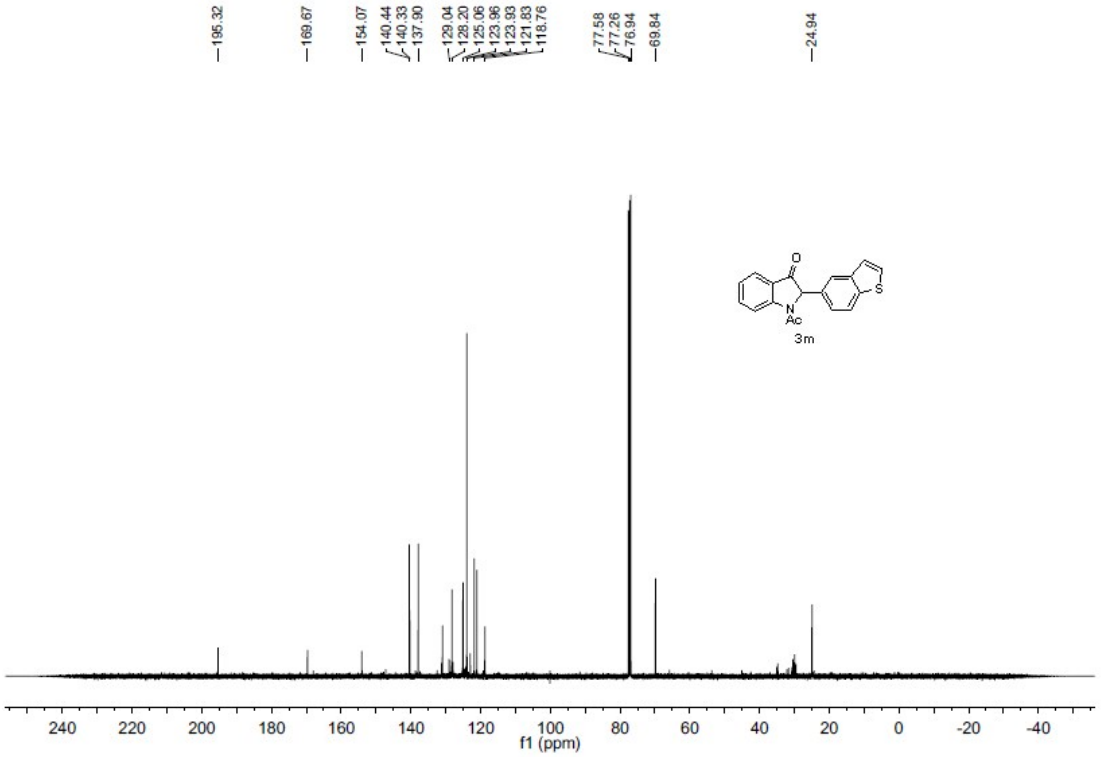
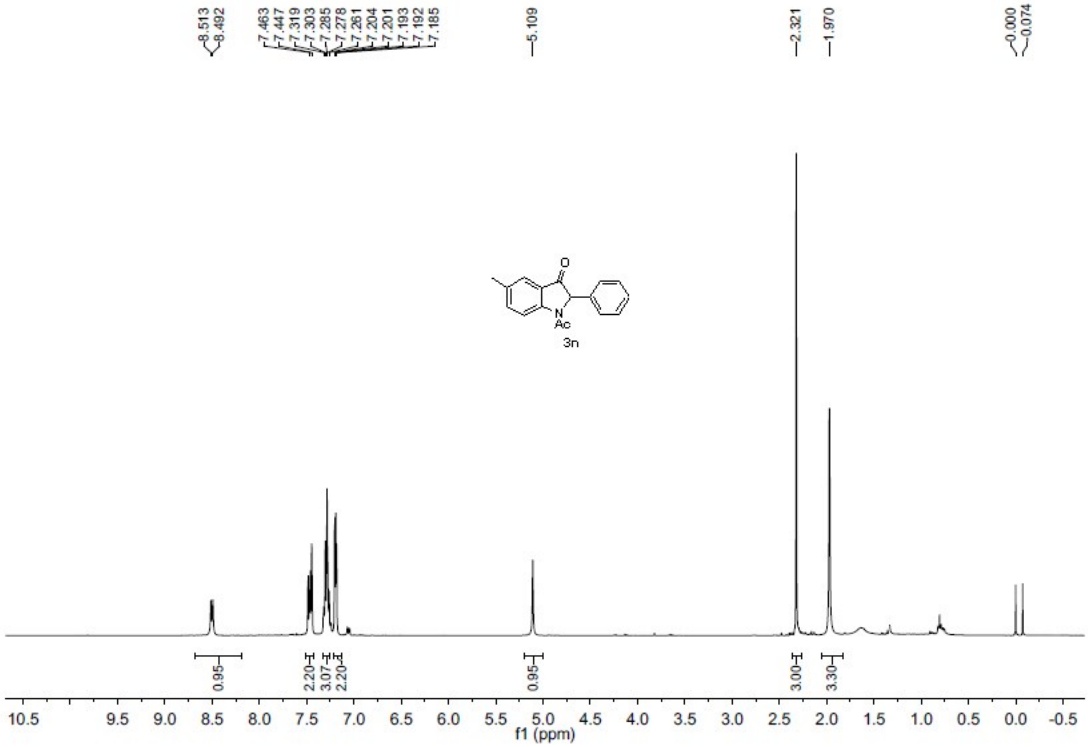
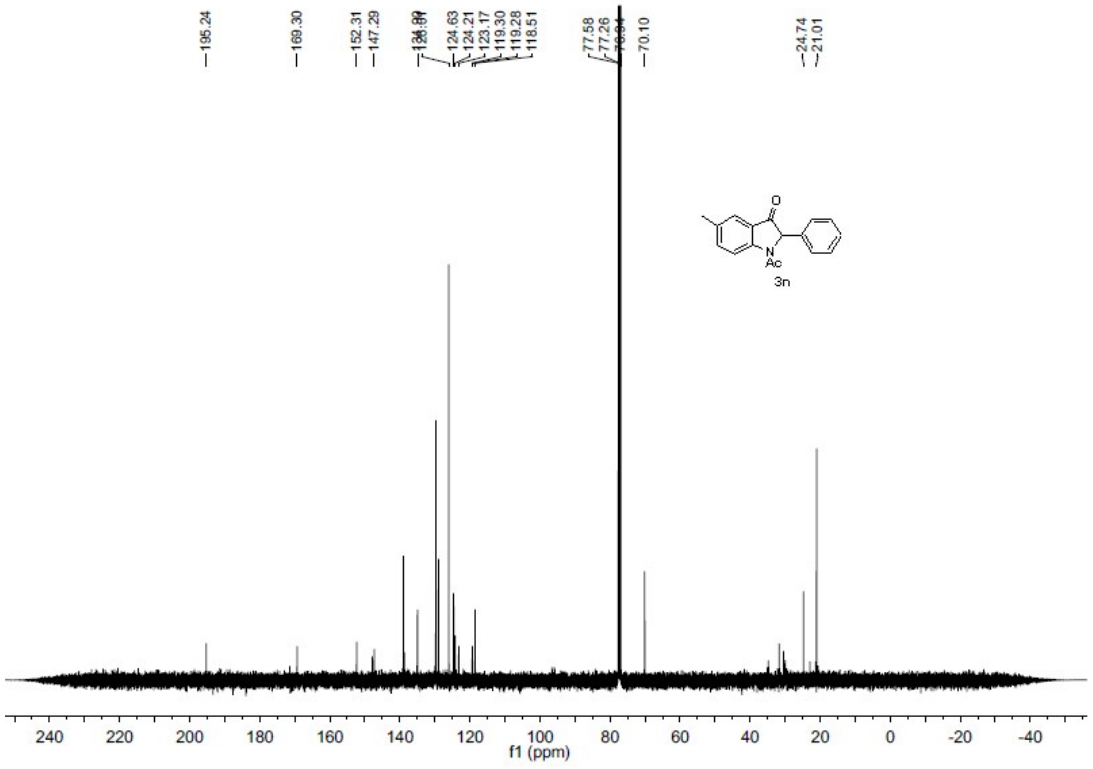
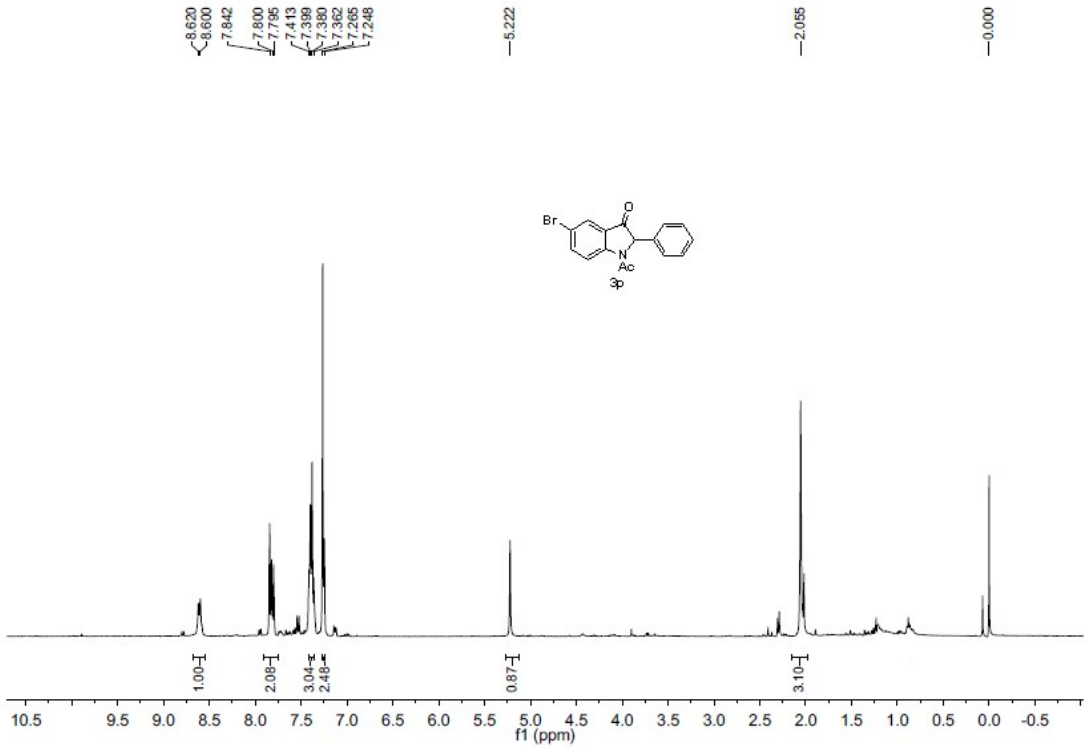
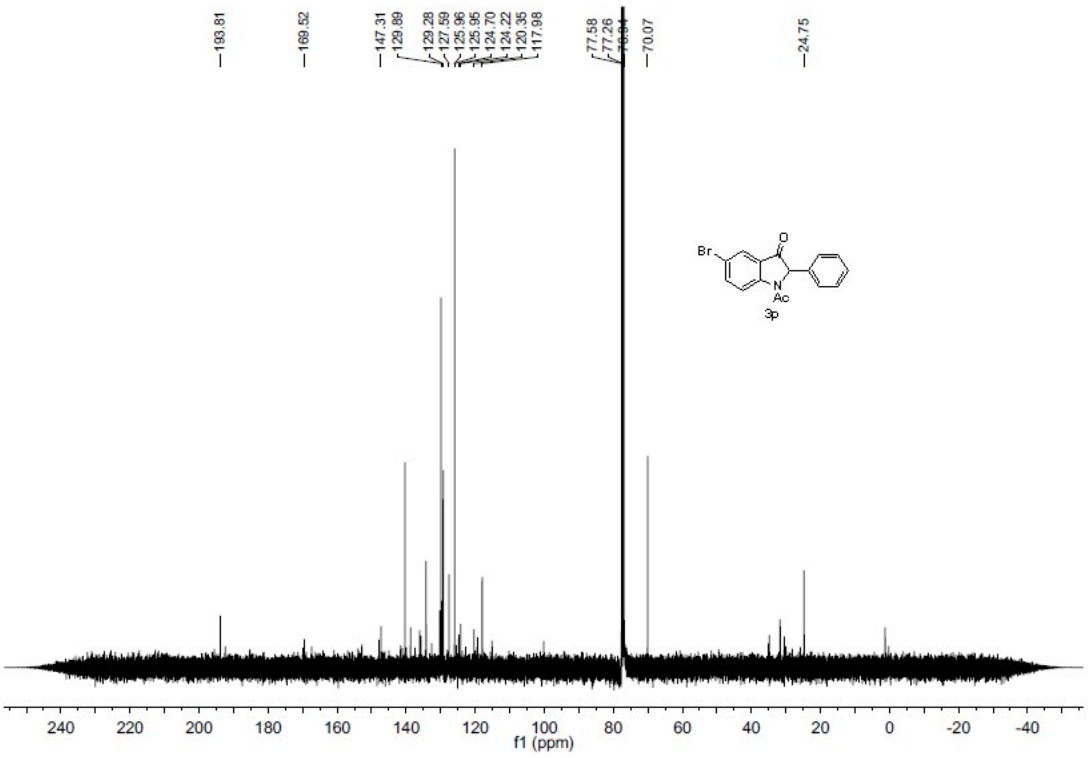
7.153
5.241
2.004
0.000
O
N
Ac
S
3m
1.00
1.05
3.08
1.10
3.29
1.11
3.08
10.5 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -1.0
f1 (ppm)

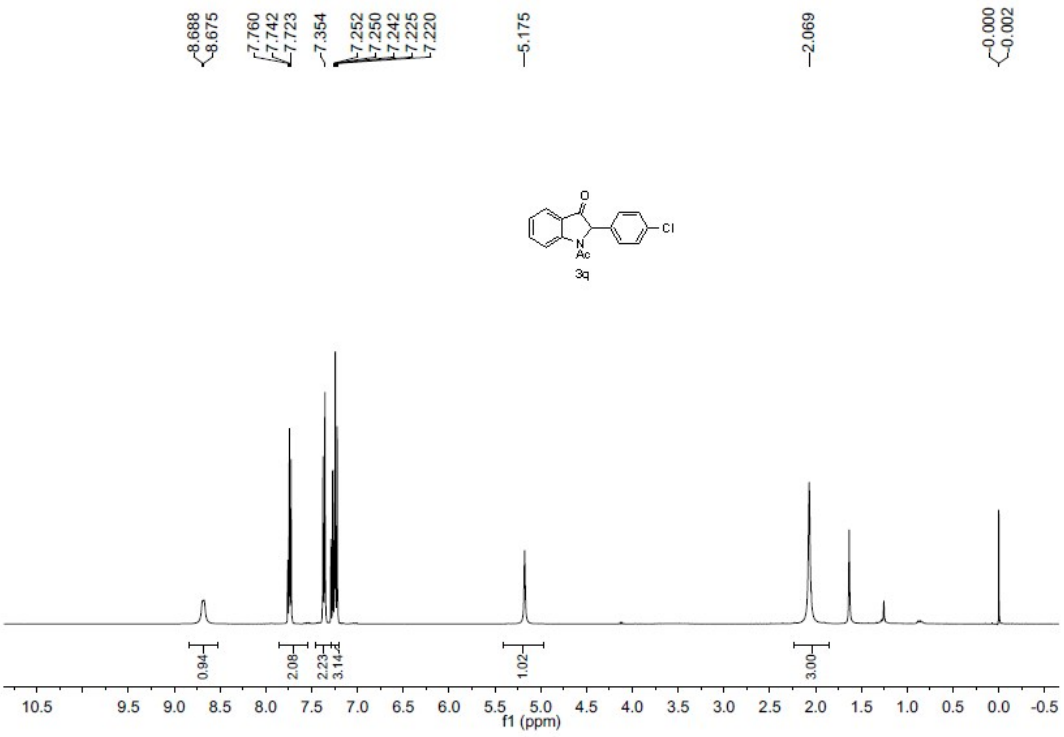

195.32
169.67
154.07
140.44
140.33
137.90
129.04
128.20
125.06
123.96
123.93
121.83
118.76
77.58
77.26
76.94
69.84
24.94
O
N
Ac
S
3m
240 220 200 180 160 140 120 100 80 60 40 20 0 -20 -40
f1 (ppm)

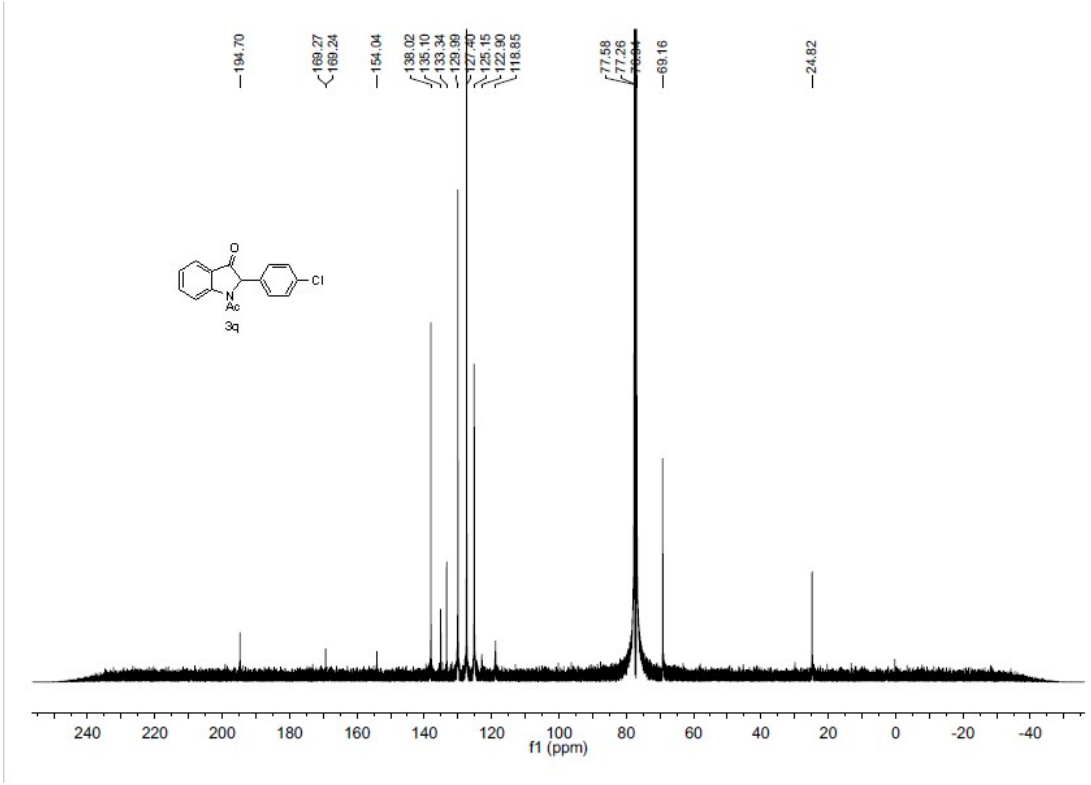

8.513
8.492
7.463
7.447
7.319
7.303
7.285
7.278
7.261
7.204
7.201
7.193
7.192
7.185
5.109
2.321
1.970
0.000
0.074
O
N
Ac
3n
0.95
2.20
3.07
2.20
0.95
3.00
3.30
10.5
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


195.24
169.30
152.31
147.29
124.63
124.21
123.17
119.30
119.28
118.51
77.58
77.26
76.94
70.10
24.74
21.01
O
N
Ac
3n
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
f1 (ppm)


8.620
8.600
7.842
7.800
7.795
7.413
7.399
7.380
7.362
7.265
7.248
5.222
2.055
0.000
Br
O
N
Ac
3p
1.00
2.08
3.04
2.48
0.87
3.10
10.5
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)


193.81
169.52
147.31
129.89
129.28
127.59
125.96
125.95
124.70
124.22
120.35
117.98
77.58
77.26
76.94
70.07
24.75
Br
O
N
Ac
3p
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
-40
f1 (ppm)


8.688
8.675
7.760
7.742
7.723
7.354
7.252
7.250
7.242
7.225
7.220
5.175
2.069
0.000
0.002
O
N
Ac
Cl
3q
0.94
2.08
2.23
3.14
1.02
3.00
f1 (ppm)


194.70
169.27
169.24
154.04
138.02
135.10
133.34
129.99
127.40
125.15
122.90
118.85
77.58
77.26
76.84
69.16
24.82
O
N
Ac
Cl
3q
f1 (ppm)