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Oxidative Dearomatization of Indoles via Pd-Catalyzed C–H Oxygenation: An Entry to C2-Quaternary Indolin-3-ones

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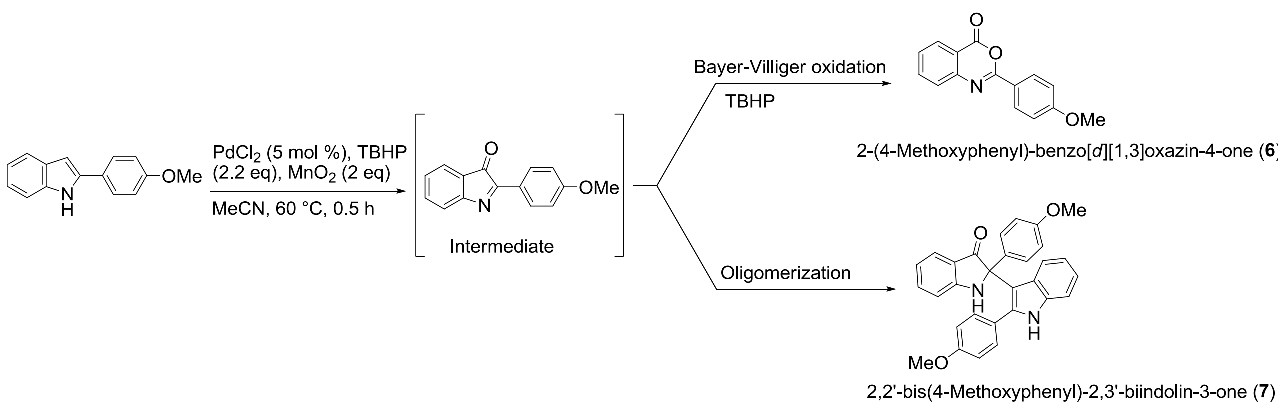
Contents

1. General Information

All reactants and reagents were obtained from the commercial source and used without further purification. 2-arylindole precursors (**4**) were prepared according to the literature known method.[1] The NMR spectra were recorded on a Bruker Avance DPX 400 MHz spectrometer in $CDCl_3$/DMSO–d_6/CD_3OD solvents using TMS as an internal standard. *J* values are given in Hz. HRMS (ESI) were recorded with Bruker–Maxis mass spectrometers. IR spectra were recorded on a Nicolet FT–IR Impact 410 instrument as thin film (neat). The reactions were monitored by TLC (Merck®, Silica gel 60 F254). Column chromatography was carried out through silica gel (60-120 mesh) using EtOAc/hexane as an eluent.

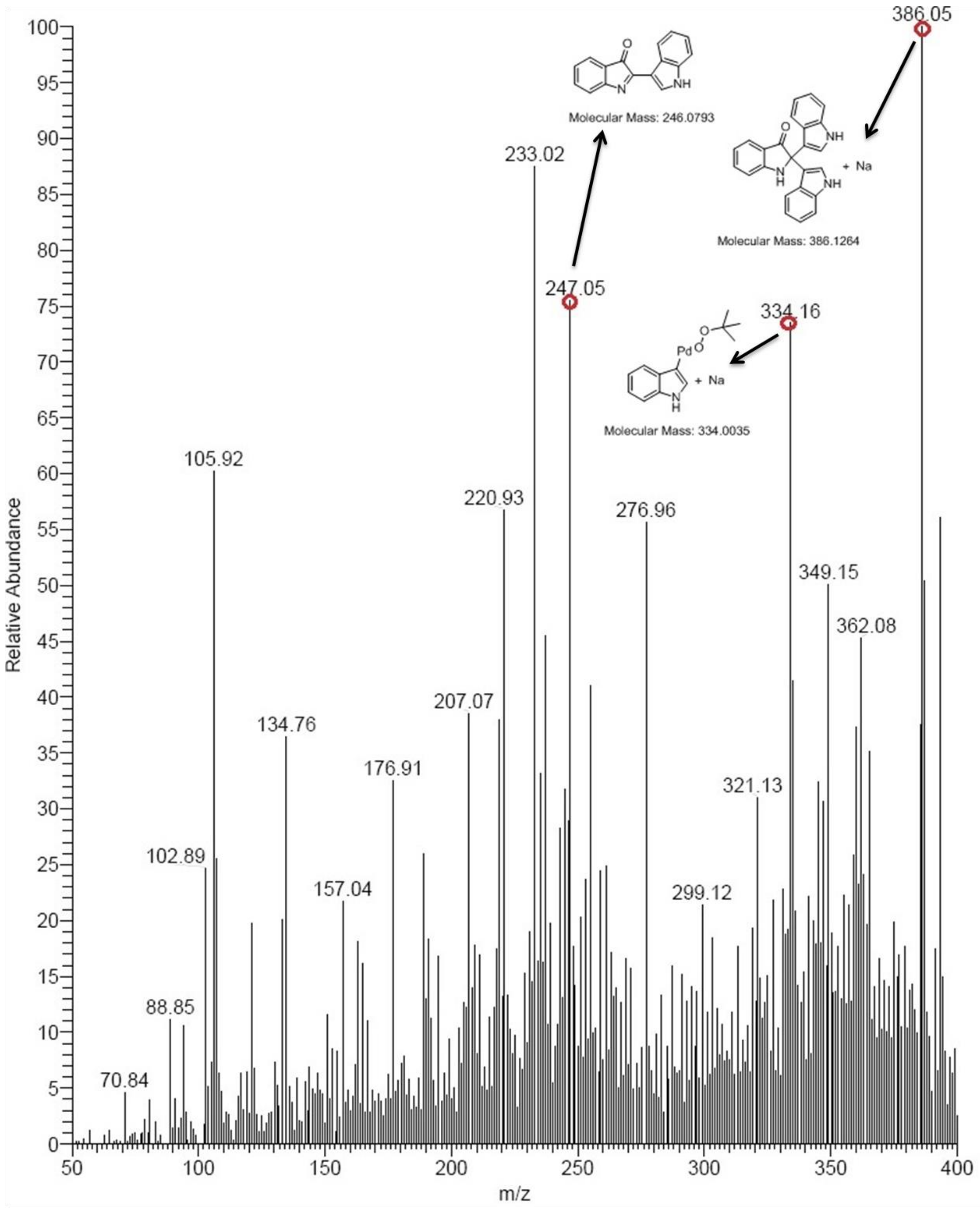
2. Mechanistic Investigation

2.1 Isolation of products (6) and (7) generated from the intermediate 2-(4-Methoxyphenyl)-3*H*-indol-3-one

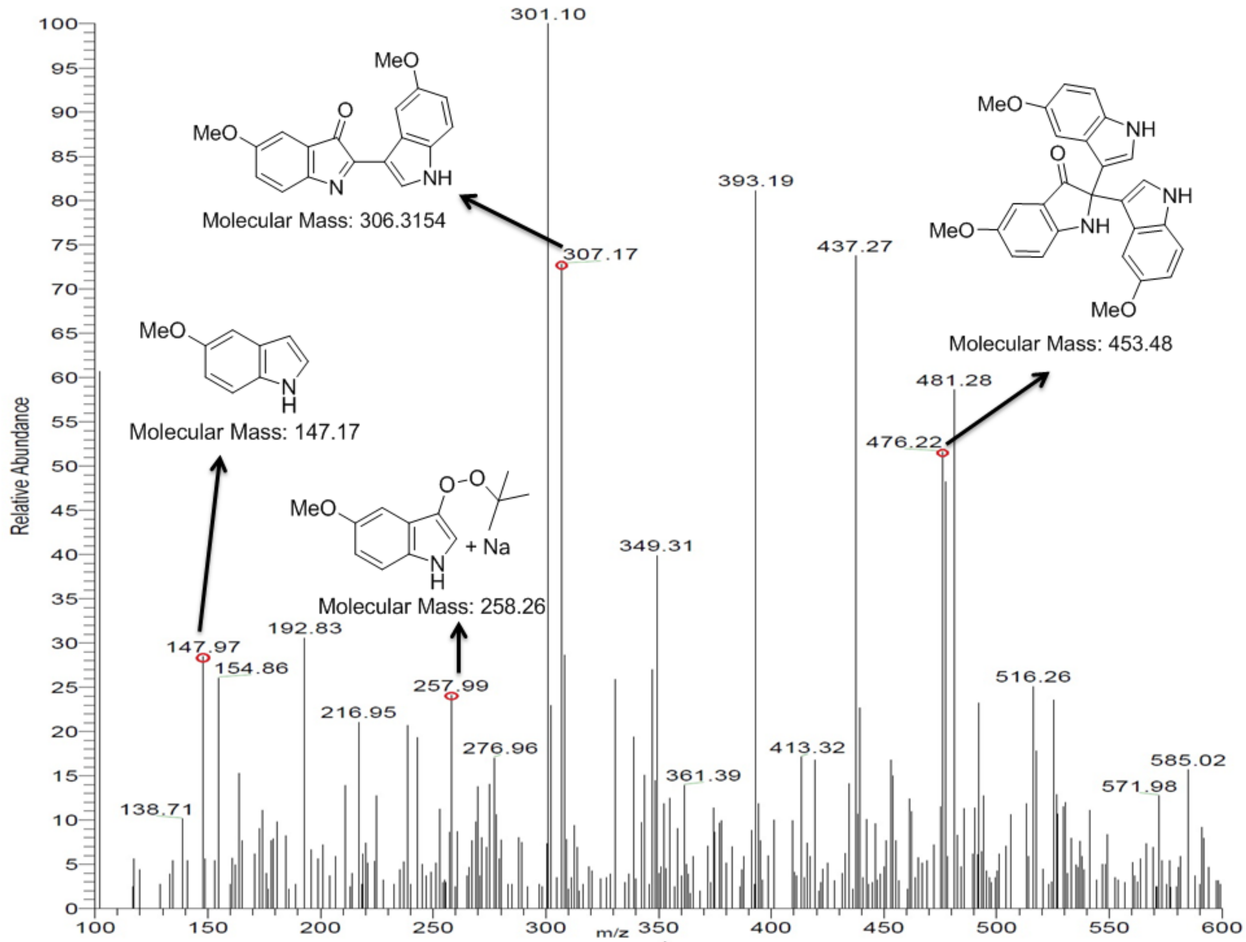


2.2 ESI-MS of crude mixtures after 15 min of the onset of reaction for identifiying the possible intermediates

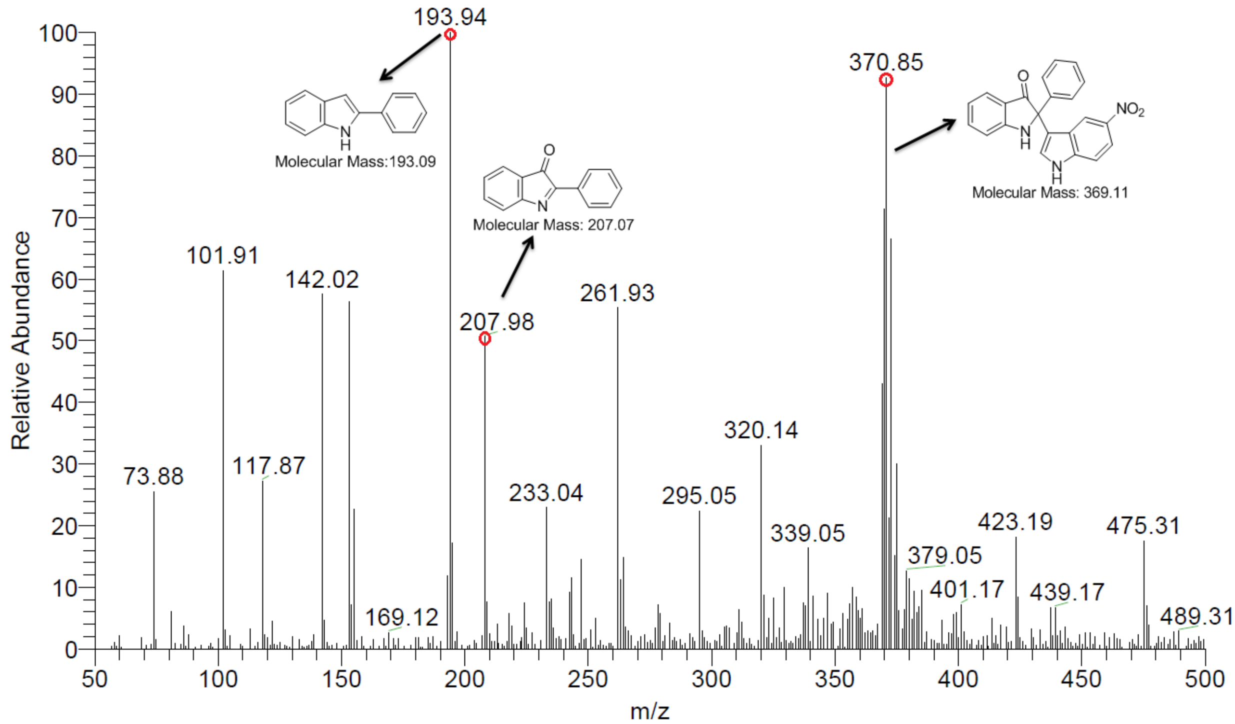
2.2.1 For a reaction of Indole



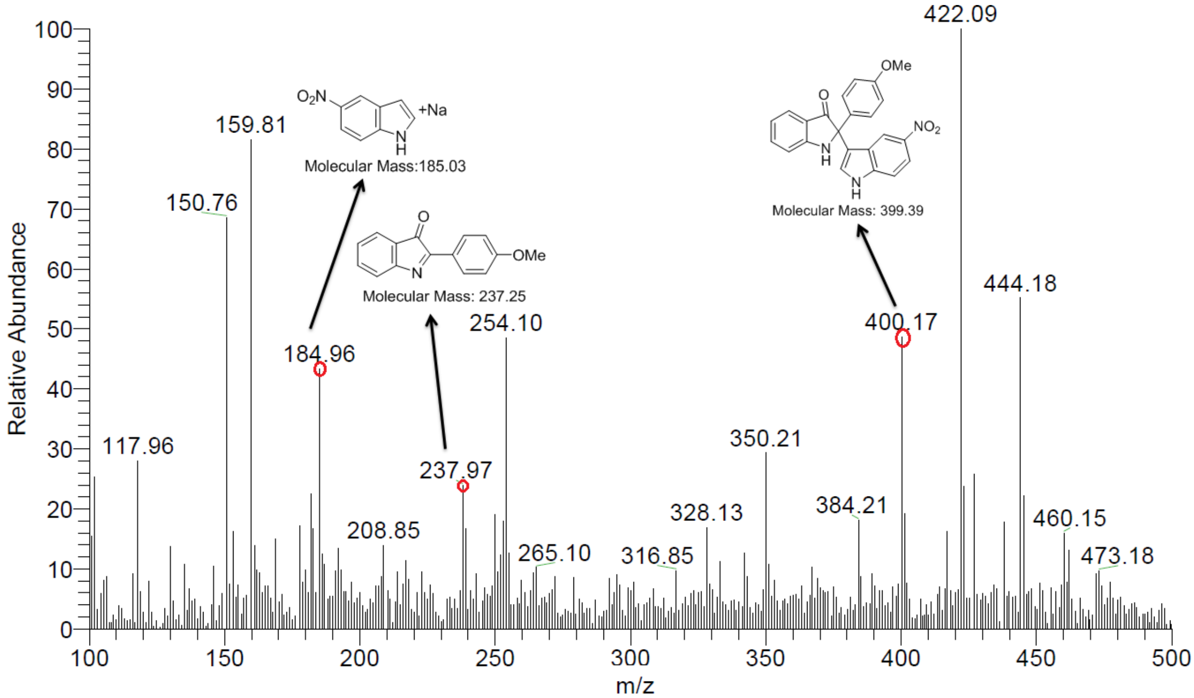
2.2.2 For a reaction of 5-Methoxyindole



2.2.3 For a reaction of 2-Phenylindole with 5-Nitroindole



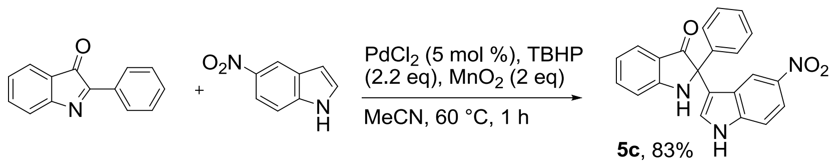
2.2.4 For a reaction of 2-(4-Methoxyphenyl)-1*H*-indole with 5-Nitroindole



2.3 Synthesis of 2-Phenyl-3*H*-indol-3-one (8) for using as substrate in the optimized reaction conditions: It was synthesized following literature reported method.[2]

Red solid, m.p. 98-100 °C; IR (ATR): ν_{max} 1761, 1725, 1540, 1263 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.38-8.35 (m, 2H), 7.58-7.46 (m, 5H), 7.41 (d, J = 7.4 Hz, 1H), 7.26 (dd, J = 6.9, 7.8 Hz, 1H), ppm; $^{13}C\{^{1}H\}$NMR (100 MHz, $CDCl_3$): δ 193.5, 161.2, 159.8, 136.8, 132.2, 130.0, 129.3, 128.8, 128.4, 124.7, 123.1, 122.0 ppm; HRMS (ESI) m/z: calcd. for $C_{14}H_{10}NO$ $[M+H]^+$ 208.0764, found: 208.0783.

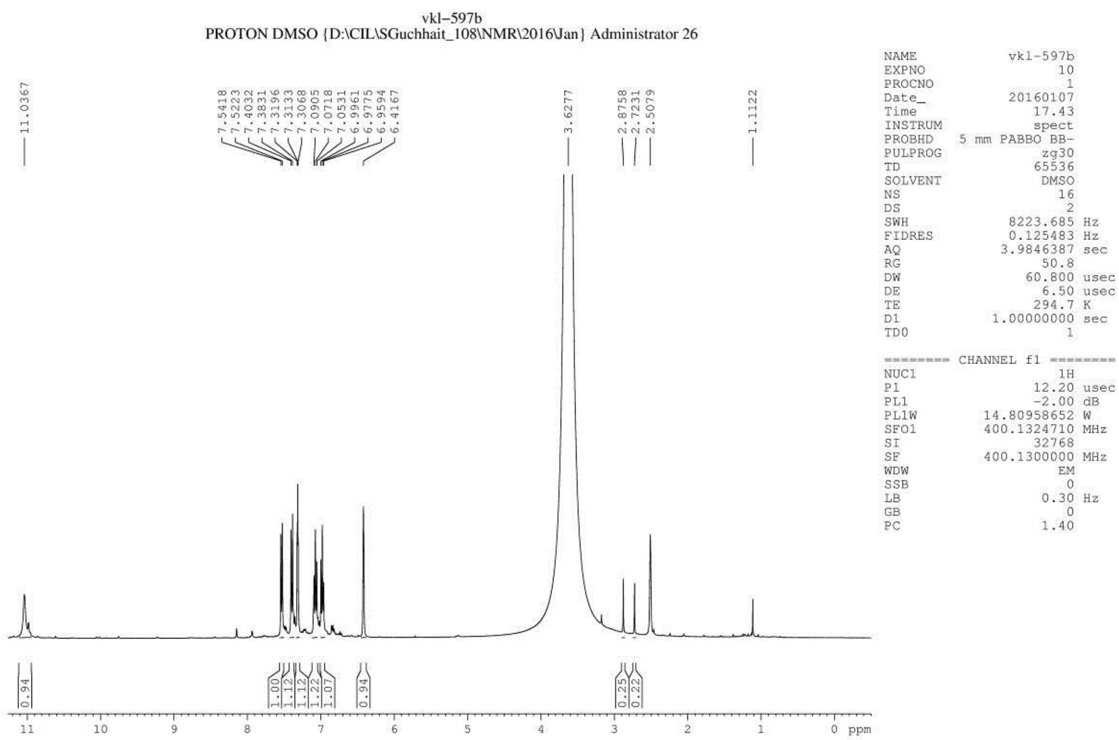
It was reacted with 5-nitroindole under optimized conditions to give the product **5c** in 83% isolated yield.



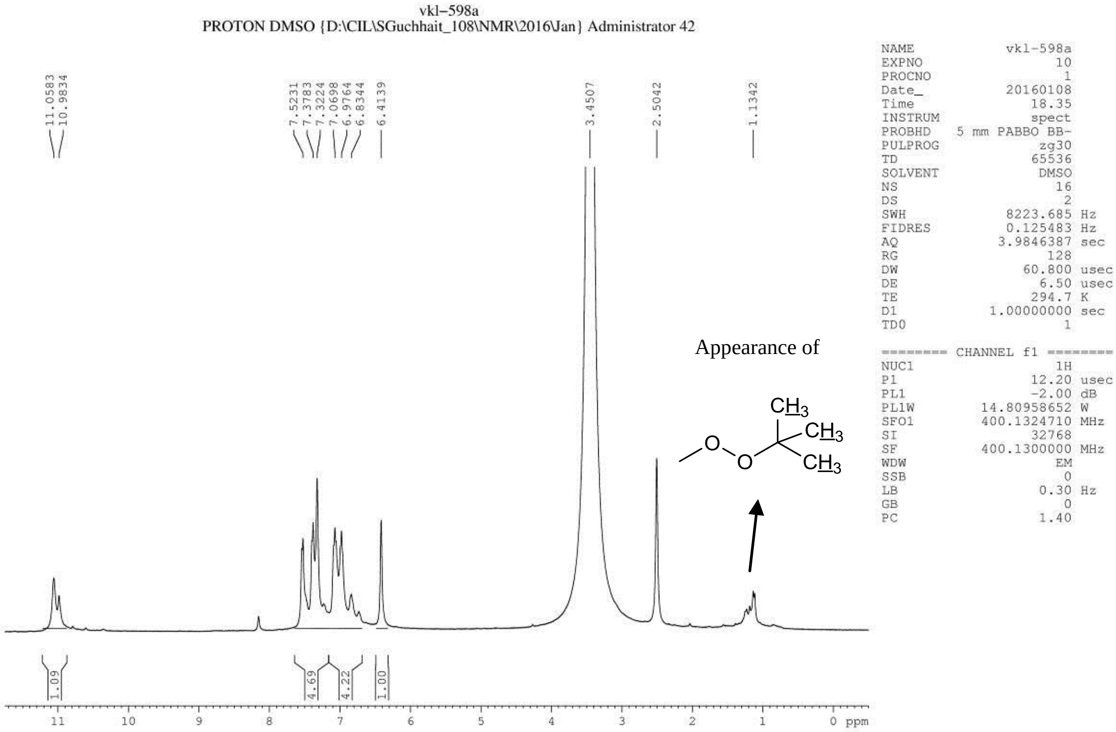
2.4 ^{1}H NMR study

2.4.1 ^{1}H NMR studies of crude reaction mixtures at different time intervals from the onset of reaction for identifiying the possible intermediates: Indole (**1**, 1 mmol), $PdCl_2$ (8.8 mg, 0.05 mmol) and MnO_2 (174 mg, 2 equiv) were loaded in a sealed tube under air. MeCN (1 mL, as received from commercial source) and then TBHP (70% aq. solution, 0.29 mL, 2.2 equiv) were added to the mixture. The tube was sealed and placed into a preheated oil bath at 60°C. Aliquots were withdrawn after 15 min, 30 min and 1.5 h and filtered through celite bed. The solvent and volatiles were completely evaporated under rotary evaporator and NMR spectra were recorded.

After 15 min



After 30 min


vkl-598a
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7.5231
7.3783
7.3224
7.0698
6.9764
6.8344
6.4139
3.4507
2.5042
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Appearance of
CH3
CH3
CH3
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1.09
4.69
4.22
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11 10 9 8 7 6 5 4 3 2 1 0 ppm
NAME vkl-598a
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PROCNO 1
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Time 18.35
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PULPROG zg30
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DE 6.50 usec
TE 294.7 K
D1 1.00000000 sec
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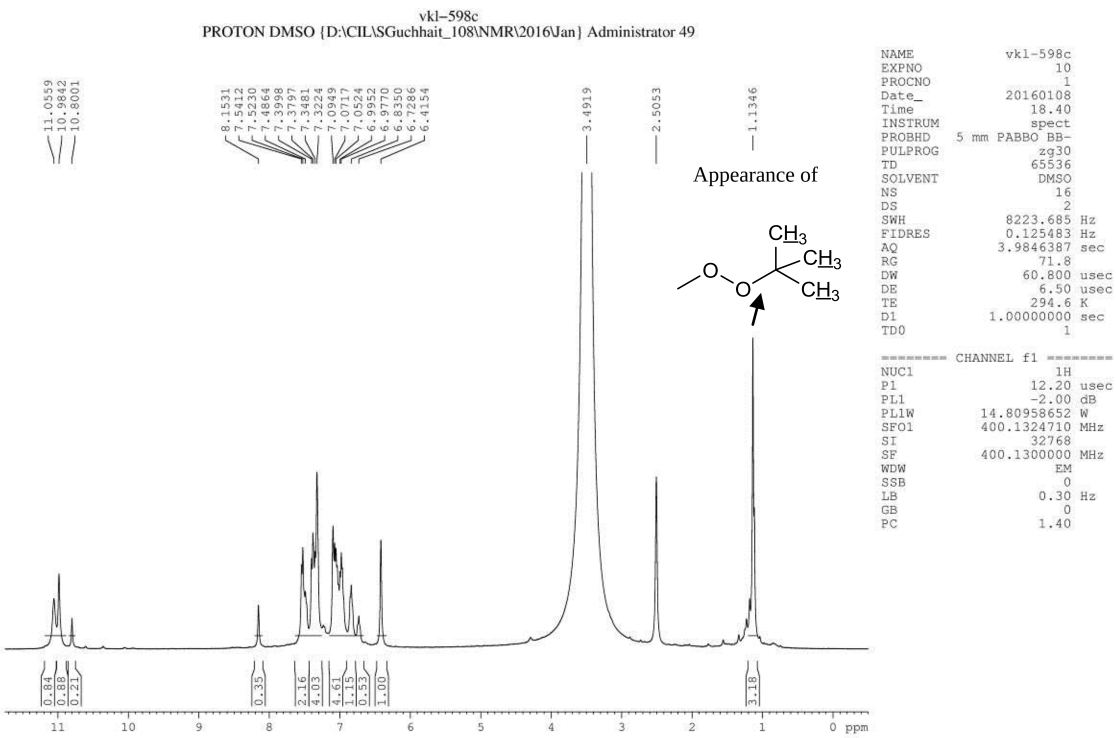
After 1.5 h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CH3
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TD0 1
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PL1 -2.00 dB
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SFO1 400.1324710 MHz
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GB 0
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7.4864
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2.5053
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0.88
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0.35
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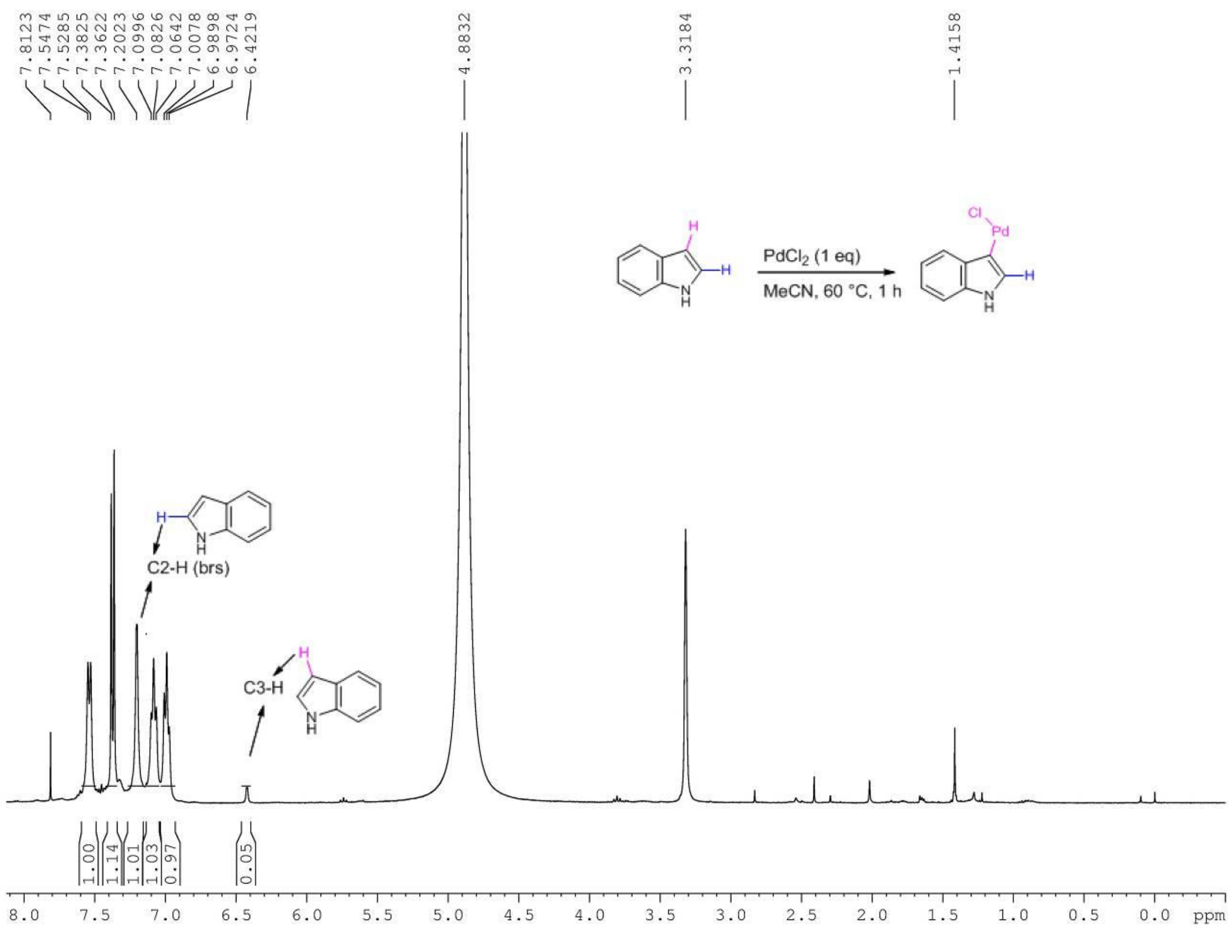
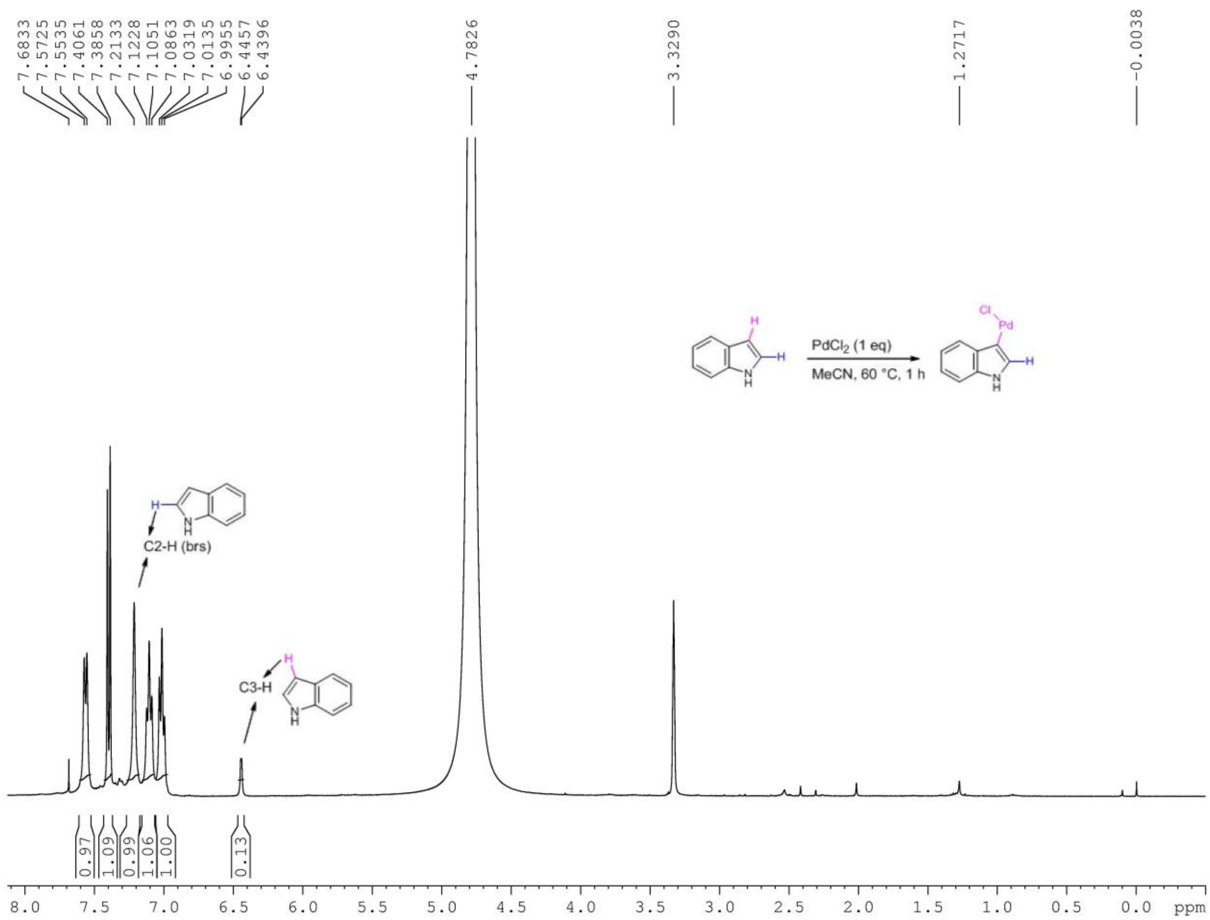
4.03
4.61
1.15
0.53
1.00
3.18
11
10
9
8
7
6
5
4
3
2
1
0 ppm

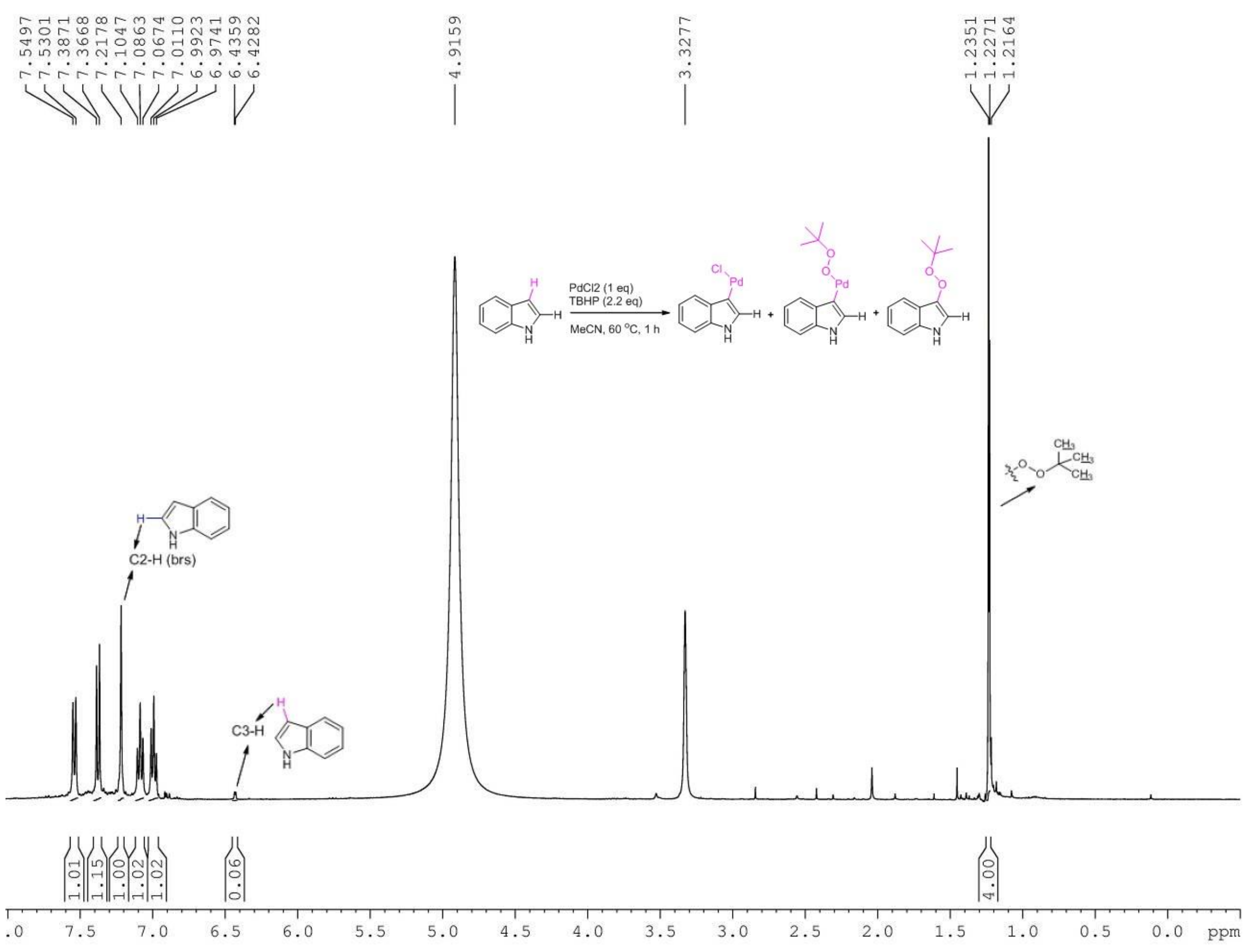
2.4.2 For a reaction of indole (1 eq) and $PdCl_2$ (1 eq): Indole (117 mg, 1 eq) and $PdCl_2$ (177 mg, 1 eq) were loaded under air in a sealed tube in MeCN (1 mL). The tube was sealed and placed into a preheated oil bath at 60 °C for 1 h. It was filtered through celite bed without water workup. The solvent and volatiles were completely evaporated under rotary evaporator and NMR spectrum was recorded. After 1 h of the onset of reaction, the ^{1}H NMR spectrum showed signal for C-3 H in trace while the signal for C-2 H shows broad singlet suggesting C-3 electropalladation[3] of indole. ^{1}H NMR spectrum is appended below.



2.4.3 For a reaction of indole (1 eq) and $PdCl_2$ (1 eq) (without filtration): Indole (117 mg, 1 eq) and $PdCl_2$ (177 mg, 1 eq) were loaded under air in a sealed tube in MeCN (1 mL). The tube was sealed and placed into a preheated oil bath at 60 °C for 1 h. The reaction mixture was directly subjected for evaporation of solvent and volatiles completely under rotary evaporator, without water workup and filtration, and NMR spectrum was recorded. After 1 h of the onset of reaction, the ^{1}H NMR spectrum showed signal for C-3 H in trace while the signal for C-2 H shows broad singlet suggesting C-3 electropalladation of indole. ^{1}H NMR spectrum is appended below.

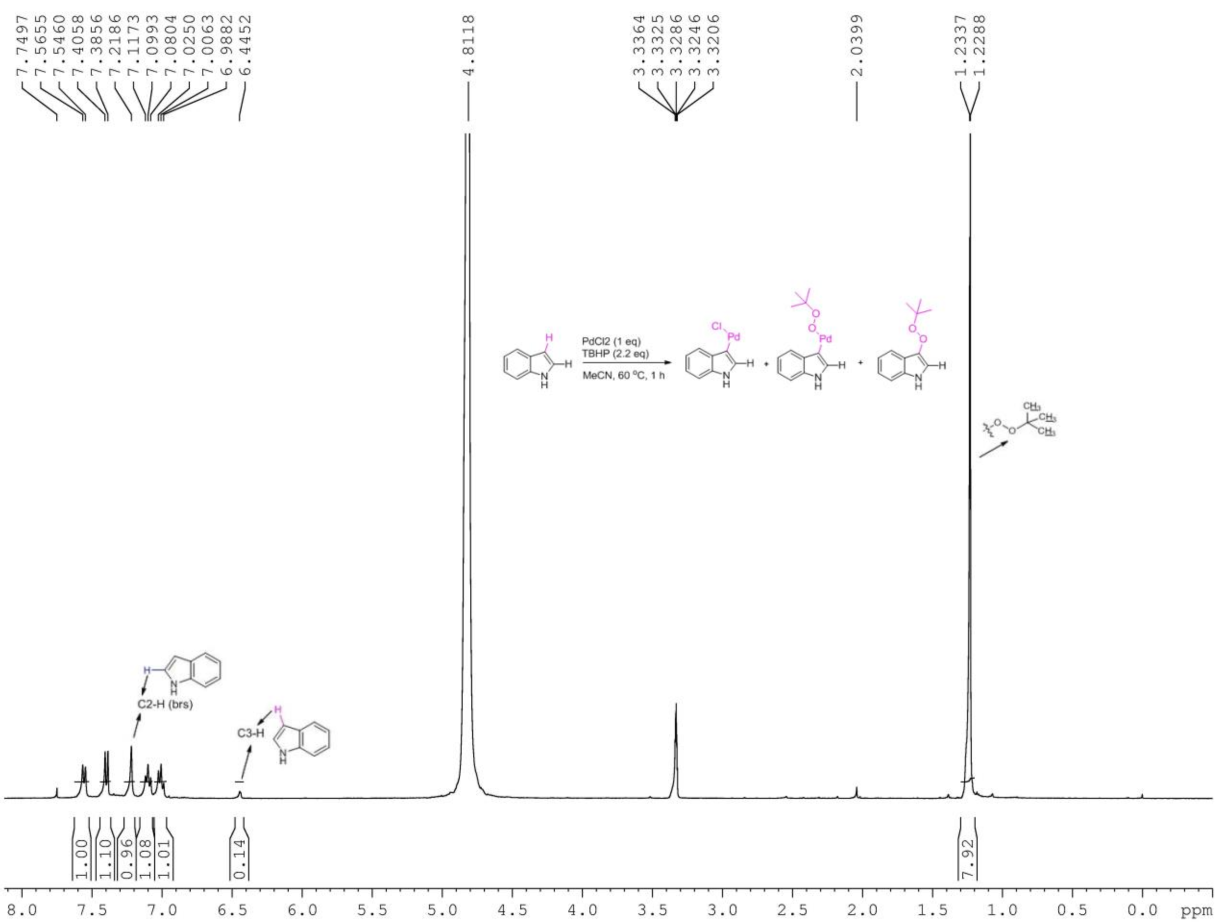


2.4.4 For the reaction of Indole (1 eq), $PdCl_2$ (1 eq) and TBHP (2.2 eq): Indole (117 mg, 1 eq) and $PdCl_2$ (177 mg, 1 eq) and TBHP (70% aq. solution, 0.29 mL, 2.2 equiv.) were loaded in a sealed tube under air in MeCN (1 mL). The tube was sealed and placed into a preheated oil bath at 60 °C for 1 h. It was filtered through celite bed without water workup. The solvent and volatiles were completely evaporated under rotary evaporated and NMR spectra were recorded. After 1 h of the onset of reaction, the ^{1}H NMR spectra showed signal for C-3 H in trace while the signal for C-2 H shows broad singlet as well as signal for *tert*-butyl peroxide side chain. This indicates C-3 electropalladation of indole followed by nucleophilic displacement of chloride of C-3 palladated indole by *tert*-butylperoxide moiety. This intermediate with *tert*-butyl peroxide moiety attached to the Pd also supported by mass spectrum. ^{1}H NMR spectrum is appended below.



2.4.5 For the reaction of Indole (1 eq), $PdCl_2$ (1 eq) and TBHP (2.2 eq) (without filtration):

Indole (117 mg, 1 eq) and $PdCl_2$ (177 mg, 1 eq) and TBHP (70% aq. solution, 0.29 mL, 2.2 equiv.) were loaded in a sealed tube under air in MeCN (1 mL). The tube was sealed and placed into a preheated oil bath at 60 °C for 1 h. The reaction mixture was directly subjected for evaporation of solvent and volatiles completely under rotary evaporator, without water workup and filtration, and NMR spectra were recorded. After 1 h of the onset of reaction, the ^{1}H NMR spectra showed signal for C-3 H in trace while the signal for C-2 H shows singlet as well as signal for tert-butyl peroxide side chain. This indicates C-3 electropalladation of indole followed by nucleophilic displacement of chloride of C-3 palladated indole by tert-butylperoxide moiety. This intermediate with tert-butyl peroxide moiety attached to the Pd also supported by mass spectrum. ^{1}H NMR spectrum is appended below.



3. General procedure for synthesis of 2,2-bis(1*H*-Indol-3-yl)indolin-3-one derivatives (2)

Indole derivative (**1**, 1 mmol), $PdCl_2$ (8.8 mg, 0.05 mmol) and MnO_2 (174 mg, 2 equiv.) were loaded in a sealed tube under air. MeCN (1 mL, as received from commercial source) and then TBHP (70% aq. solution, 0.29 mL, 2.2 equiv.) were added to the mixture. The tube was sealed and placed into a preheated oil bath at 60°C and stirred for 4-5 hours. After completion of reaction as indicated by TLC, the reaction was allowed to cool to room temperature and diluted with 60 mL of EtOAc. The diluted solution was filtered through celite. The organic layer was washed with water (3 × 10 mL) and then with brine (1 × 10 mL), dried over anhyd. Na_2SO_4 and concentrated under reduced pressure. The column chromatographic purification of crude mass was performed on silica gel (60-120 mesh) using EtOAc-hexane (25-40%) as eluting solvent to provide the products (**2a-f**, Table 3). Utilizing this general procedure, products (**5a-m**, Table 2) were also prepared. Both 2-aryl indole (1 mmol, **4**) and indole derivative (1 eq, **1**) were added from the beginning of the reaction.

4. Spectral data of the synthesized compounds:

2-(5-Bromo-1*H*-indol-3-yl)-2-phenylindolin-3-one (5a)[4]

Yellow solid, 257 mg, 64%, m.p. 130-132 °C; IR (ATR): ν_{max} 3343, 2925, 1684, 1615, 734, 699 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 8.35 (s, NH), 7.69 (d, *J* = 7.8 Hz, 1H), 7.55-7.50 (m, 3H), 7.34-7.30 (m, 4H), 7.25-7.22 (m, 2H), 7.18 (d, *J* = 2.6 Hz, 1H), 6.97 (d, *J* = 8.2 Hz, 1H), 6.91 (dd, *J* = 7.5, 7.4 Hz, 1H), 5.38 (s, NH) ppm; $^{13}C\{^1H\}$NMR (100 MHz, $CDCl_3$): δ 200.4, 160.5, 139.2, 137.7, 135.6, 128.6, 128.0, 127.4, 126.7, 125.6, 125.5, 124.9, 122.3, 119.8, 119.4, 115.2, 113.3, 113.1, 112.9, 71.1 ppm; HRMS (ESI) *m/z*: calcd. for $C_{22}H_{15}{}^{79}BrN_2ONa$ $[M+Na]^+$ 425.0260, found: 425.0266 and calcd. for $C_{22}H_{15}{}^{81}BrN_2ONa$ $[M+Na]^+$ 427.0245, found 427.0243.

2-(5-Methoxy-1*H*-indol-3-yl)-2-phenylindolin-3-one (5b)

Yellow solid; 234 mg, 66%; mp: 91-93˚C; IR (KBr) ν_{max} 3336, 2925, 1687, 1616, 1485, 1089 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 8.14 (s, *N*H), 7.71 (d, *J* = 7.7 Hz, 1H), 7.61 (dd, *J* = 8.2, 1.8 Hz, 2H), 7.52 (dt, *J* = 8.3, 1.2 Hz, 1H), 7.35-7.27 (m, 3H), 7.25 (d, *J* = 8.8 Hz, 1H), 7.09 (d, *J* = 2.6 Hz, 1H), 6.95 (d, *J* = 8.2 Hz, 1H), 6.90 (dd, *J* = 7.7, 7.2 Hz, 1H), 6.83 (dd, *J* = 8.8, 2.4 Hz, 1H), 6.57 (d, *J* = 2.3 Hz, 1H), 5.38 (s, *N*H), 3.62 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$); δ 200.9, 160.6, 154.0, 139.4, 137.6, 132.0, 128.5, 127.8, 126.9, 126.1, 125.6, 124.5, 119.8, 119.7, 115.4, 112.9, 112.35, 112.31, 101.9, 71.3, 55.6 ppm; HRMS (ESI) *m/z*: calcd. for $C_{23}H_{18}N_2O_2$ $[M+H]^+$ 355.1446, found 355.1445.

2-(5-Nitro-1*H*-indol-3-yl)-2-phenylindolin-3-one (5c)

Yellow solid, 314 mg, 85%, m.p. >200 °C; IR (ATR): ν_{max} 3414, 3308, 2924, 1673, 1622, 1465, 1314, 1278 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ 11.85 (s, NH), 8.55 (s, 1H), 8.14 (s, 1H), 7.97 (d, J = 8.5 Hz, 1H), 7.58-7.49 (m, 3H), 7.43-7.33 (m, 6H), 7.00 (d, J = 8.0 Hz, 1H), 6.78 (dd, J = 7.1, 7.2 Hz, 1H) ppm; $^{13}C\{^1H\}$NMR (100 MHz, DMSO-d_6): δ 200.4, 161.5, 140.8, 140.6, 140.1, 138.5, 128.9, 128.2, 126.9, 125.25, 125.18, 118.4, 117.8, 117.5, 117.3, 112.9, 112.5, 70.7 ppm; HRMS (ESI) *m/z*: calcd. for $C_{22}H_{15}N_3O_3Na$ $[M+Na]^+$ 392.1011, found: 392.1004.

2-(5-Fluoro-1*H*-indol-3-yl)-2-phenylindolin-3-one (5d)[4]

Yellow solid, 209 mg, 61%, m.p. >200 °C; IR (ATR): ν_{max} 3328, 2925, 1682, 1614, 1484, 1466 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 8.27 (s, NH), 7.70 (d, J = 7.7 Hz, 1H), 7.56-7.51 (m, 3H), 7.35-7.27 (m, 4H), 7.20 (d, J = 2.6 Hz, 1H), 6.96 (d, J = 8.3 Hz, 1H), 6.94-6.90 (m, 2H), 6.81 (dd, J = 9.6, 2.3 Hz, 1H), 5.35 (s, 1H) ppm; $^{13}C\{^1H\}$NMR (100 MHz, $CDCl_3$): δ 200.5, 160.4, 157.7 (d, $J_{C\text{-}F}$ = 235 Hz), 139.2, 137.7, 133.4, 128.6, 127.9, 126.8, 125.9 (d, $J_{C\text{-}C\text{-}C\text{-}F}$ = 10 Hz), 125.6, 125.5, 119.7 (d, $J_{C\text{-}C\text{-}F}$ = 21 Hz), 115.9 (d, $J_{C\text{-}C\text{-}C\text{-}C\text{-}F}$ = 5 Hz), 112.9, 112.3 (d, $J_{C\text{-}C\text{-}C\text{-}F}$ = 10 Hz), 111.2, 110.9, 104.9 (d, $J_{C\text{-}C\text{-}F}$ = 24 Hz), 71.1 ppm; HRMS (ESI) *m/z*: calcd. for $C_{22}H_{15}FN_2ONa$ $[M+Na]^+$ 365.1066, found: 365.1061.

3-(3-Oxo-2-phenylindolin-2-yl)-1*H*-indole-5-carbonitrile (5e)

Yellow solid, 202 mg, 58%, m.p. >200°C; IR (ATR): ν_{max} 3258, 2224, 1678, 1618 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ 11.71 (s, NH), 8.52 (s, 1H), 7.58-7.48 (m, 4H), 7.44-7.29 (m, 7H), 6.99 (d, J = 8.2 Hz, 1H), 6.77 (dd, J = 7.4, 7.4 Hz, 1H) ppm; $^{13}C\{^1H\}$NMR (100 MHz, DMSO-d_6): δ 200.3, 161.4, 140.1, 139.2, 138.5, 128.9, 128.2, 127.0, 126.9, 126.1, 125.7, 125.3, 124.5, 121.1, 118.3, 117.5, 115.7, 113.7, 112.4, 101.2, 70.7 ppm; HRMS (ESI) *m/z*: calcd. for $C_{23}H_{15}N_3ONa$ $[M+Na]^+$ 372.1113, found: 372.1109.

2-(5-Bromo-1*H*-indol-3-yl)-2-(4-methoxyphenyl)indolin-3-one (5f)

Yellow solid, 259 mg, 60%, m.p. >200 °C; IR (ATR): ν_{max} 3446, 3342, 1683, 1611, 1464, 1250, 1030, 758 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ 11.29 (s, NH), 8.35 (s, 1H), 7.52 (dt, J = 8.2, 1.2 Hz, 1H), 7.47 (d, *J* = 7.7 Hz, 1H), 7.36 (d, *J* = 8.6 Hz, 1H), 7.30-7.27 (m, 3H), 7.19-7.16 (m, 2H), 6.97 (d, *J* = 8.3 Hz, 1H), 6.89 (d, *J* = 8.8 Hz, 2H), 6.74 (dd, *J* = 7.2, 7.4 Hz, 1H), 3.72 (s, 3H) ppm; $^{13}C\{^{1}H\}$NMR (100 MHz, DMSO-d_6): δ 200.8, 161.3, 159.2, 138.3, 136.1, 132.1, 128.2, 127.8, 125.9, 125.1, 124.3, 122.7, 118.0, 117.7, 114.7, 114.3, 114.1, 112.3, 111.8, 70.4, 55.5 ppm; HRMS (ESI) *m/z*: calcd. for $C_{23}H_{17}{}^{79}BrN_2O_2Na$ $[M+Na]^+$ 455.0371, found: 455.0405.

3-(2-(4-Methoxyphenyl)-3-oxoindolin-2-yl)-1*H*-indole-5-carbonitrile (5g)

Yellow solid, 231 mg, 61%, m.p. 125-127 °C; IR (ATR): ν_{max} 3325, 2926, 2221, 1679, 1608, 1466, 1247, 1032 cm^{-1}; ^{1}H NMR (400 MHz, CD_3OD): δ 7.57-7.49 (m, 4H), 7.37-7.30 (m, 4H), 6.99 (d, *J* = 8.2 Hz, 1H), 6.87 (d, *J* = 8.8 Hz, 2H), 6.80 (dd, *J* = 7.4, 7.4 Hz, 1H), 3.77 (s, 3H) ppm; $^{13}C\{^{1}H\}$NMR (100 MHz, CD_3OD): δ 202.5, 161.5, 159.5, 139.2, 138.1, 131.4, 127.8, 126.0, 125.9, 125.6, 124.6, 124.0, 120.3, 118.1, 117.7, 116.2, 113.5, 112.4, 111.9, 101.2, 70.6, 54.3 ppm; HRMS (ESI) *m/z*: calcd. for $C_{24}H_{18}N_3O_2$ $[M+H]^+$ 380.1401, found: 380.1398.

2-(4-Methoxyphenyl)-2-(5-nitro-1*H*-indol-3-yl)indolin-3-one (5h)

Yellow solid, 283 mg, 71%, m.p. >200 °C; IR (ATR): ν_{max} 3363, 2925, 1683, 1617, 1467, 1332, 1250 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ 11.81 (s, NH), 8.45 (s, 1H), 8.14 (d, *J* = 1.7 Hz, 1H), 7.97 (dd, *J* = 9.0, 2.1 Hz, 1H), 7.57-7.47 (m, 3H), 7.38 (d, *J* = 2.1 Hz, 1H), 7.28 (d, *J* = 8.7 Hz, 2H), 6.98 (d, *J* = 8.3 Hz, 1H), 6.90 (d, *J* = 8.8 Hz, 2H), 6.76 (dd, *J* = 7.4, 7.4 Hz, 1H), 3.70 (s, 3H) ppm; $^{13}C\{^{1}H\}$NMR (100 MHz, DMSO-d_6): δ 200.8, 161.3, 159.3, 140.8, 140.6, 138.6, 131.8, 128.2, 128.1, 125.2, 125.1, 118.4, 117.85, 117.80, 117.5, 117.4, 114.3, 112.8, 112.4, 70.3, 55.5 ppm; HRMS (ESI) *m/z*: calcd. for $C_{23}H_{17}N_3O_4Na[M+Na]^+$ 422.1117, found: 422.1107.

3-(2-(4-Chlorophenyl)-3-oxoindolin-2-yl)-1*H*-indole-5-carbonitrile (5i)

Yellow solid, 241 mg, 63%, m.p. 132-134 °C; IR (ATR): ν_{max} 3325, 2924, 2222, 1680, 1615, 1487, 736 cm^{-1}; ^{1}H NMR (400 MHz, CD_3OD): δ 7.47-7.39 (m, 4H), 7.33 (d, *J* = 8.6 Hz, 2H), 7.26 (dd, *J* = 8.5, 1.4 Hz, 1H), 7.23-7.19 (m, 3H), 6.89 (d, *J* = 8.3 Hz, 1H), 6.71 (dd, *J* = 7.5, 7.3 Hz, 1H) ppm; $^{13}C\{^{1}H\}$NMR (100 MHz, CD_3OD): δ 201.5, 161.6, 139.2, 138.5, 138.2, 133.5, 128.2, 126.2, 125.5, 125.4, 124.6, 124.2, 120.2, 118.4, 117.6, 115.6, 112.6, 112.1, 101.5, 70.4 ppm; HRMS (ESI) m/z: calcd. for $C_{23}H_{14}{}^{35}ClN_3ONa[M+Na]^+$ 406.0723, found: 406.0733.

2-(4-Chlorophenyl)-2-(5-nitro-1*H*-indol-3-yl)indolin-3-one (5j)

Yellow solid, 282 mg, 70%, m.p. >200 °C; IR (ATR): ν_{max} 3313, 2922, 1678, 1615, 1465, 1323, 737 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ 11.90 (s, NH), 8.60 (s, 1H), 8.12 (d, *J* = 2.0 Hz, 1H), 7.99 (dd, *J* = 9.0, 2.2 Hz, 1H), 7.59-7.50 (m, 3H), 7.44-7.39 (m, 5H), 7.00 (d, *J* = 8.3 Hz, 1H), 6.79 (dd, *J* = 7.4, 7.4 Hz, 1H) ppm; ^{13}C{^{1}H}NMR (100 MHz, DMSO-d_6): δ 199.9, 161.5, 140.9, 140.6, 139.1, 138.7, 133.0, 128.97, 128.88, 128.4, 125.3, 124.9, 118.6, 117.5, 117.45, 117.40, 117.1, 112.9, 112.6, 70.2 ppm; HRMS (ESI) *m/z*: calcd. for $C_{22}H_{14}{}^{35}ClN_3O_3Na[M+Na]^+$ 426.0622, found: 426.0600.

2-(5-Nitro-1*H*-indol-3-yl)-2-(4-(trifluoromethyl)phenyl)indolin-3-one (5k)

Yellow solid, 271 mg, 62%, m.p. >200 °C; IR (ATR): ν_{max} 3343, 2924, 1683, 1615, 1466, 1322 cm^{-1}; ^{1}H NMR (400 MHz, CD_3OD): δ 8.14 (d, *J* = 2.2 Hz, 1H), 8.04 (dd, *J* = 9.0, 2.2 Hz, 1H), 7.71 (d, *J* = 8.4 Hz, 2H), 7.66 (d, *J* = 8.5 Hz, 2H), 7.61-7.56 (m, 2H), 7.51 (d, *J* = 9.0 Hz, 1H), 7.36 (s, 1H), 7.05 (d, *J* = 8.3 Hz, 1H), 6.87 (ddd, *J* = 7.4, 7.5, 0.7 Hz, 1H) ppm; ^{13}C{^{1}H}NMR (100 MHz, CD_3OD): δ 202.4, 163.1, 145.6, 142.6, 141.8, 139.7, 131.1 (q, $J_{C\text{-}C\text{-}F}$ = 32 Hz), 128.7, 126.4 (q, $J_{C\text{-}C\text{-}C\text{-}F}$ = 4 Hz), 126.2, 126.1, 125.7 (q, $J_{C\text{-}F}$ = 269 Hz), 120.0, 119.0, 118.45, 118.40, 118.3, 113.7, 112.9, 71.9 ppm; HRMS (ESI) *m/z*: calcd. for $C_{23}H_{14}F_3N_3O_3Na[M+Na]^+$ 438.1067, found: 438.1052.

3-(3-Oxo-2-(4-(trifluoromethoxy)phenyl)indolin-2-yl)-1*H*-indole-5-carbonitrile (5l)

Yellow solid, 229 mg, 53%, m.p. 114-116 °C; IR (ATR): ν_{max} 3326, 2222, 1683, 1615, 1467, 1256, 1160 cm^{-1}; ^{1}H NMR (400 MHz, CD_3OD): δ 7.60-7.52 (m, 6H), 7.39 (dd, *J* = 8.6, 1.4 Hz, 1H), 7.32 (s, 1H), 7.25 (d, *J* = 8.2 Hz, 2H), 7.03 (d, *J* = 8.3 Hz, 1H), 6.85 (dd, *J* = 7.7, 7.1 Hz, 1H) ppm; ^{13}C{^{1}H}NMR (100 MHz, CD_3OD): δ 202.8, 163.0, 150.2, 140.6, 140.3, 139.6, 129.8, 127.7, 126.9, 126.8, 126.1, 125.7, 121.95, 121.92 (q, $J_{C\text{-}F}$ = 254 Hz), 121.6, 119.9, 119.0, 117.0, 114.0, 113.5, 102.9, 71.8 ppm; HRMS (ESI) *m/z*: calcd. for $C_{24}H_{14}F_3N_3O_2Na[M+Na]^+$ 456.0936, found: 456.0921.

2-Methyl-2-(5-nitro-1*H*-indol-3-yl)indolin-3-one (5m)

Yellow solid, 92 mg, 30%, m.p. >200 °C; IR (ATR): ν_{max} 3383, 2931, 1685, 1610, 1467, 1323 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ 11.79 (s, NH), 8.25 (d, *J* = 2.0 Hz, 1H), 7.95 (dd, *J* = 9.0, 2.2 Hz, 1H), 7.87 (s, 1H), 7.65 (d, *J* = 2.2 Hz, 1H), 7.58-7.52 (m, 2H), 7.48 (d, *J* = 7.7 Hz, 1H), 6.99 (d, J = 8.3 Hz, 1H), 6.78 (dd, J = 7.4, 7.4 Hz, 1H), 1.67 (s, 3H) ppm; $^{13}C\{^1H\}$NMR (100 MHz, DMSO-d_6): δ 203.4, 161.2, 140.8, 140.4, 138.5, 127.7, 125.1, 124.4, 118.3, 117.9, 117.8, 117.3, 117.1, 112.70, 112.66, 65.4, 23.9 ppm; HRMS (ESI) *m/z*: calcd. for $C_{17}H_{14}N_3O_3$ $[M+H]^+$ 308.1037, found: 308.1034.

2,2-Bis(1*H*-Indol-3-yl)indolin-3-one (2a)[5]

Yellow solid; 109 mg, 90%; mp: >200 ˚C; IR (KBr) ν_{max} 3369, 2923, 1674, 1610, 1456 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ 10.97 (s, 2*N*H), 8. 14 (s, 1H), 7.51-7.46 (m, 2H), 7.35 (d, J = 8.1 Hz, 2H), 7.31 (d, J = 8.0 Hz, 2H), 7.09 (d, J = 2.4 Hz, 2H), 7.03 (dd, J = 7.6, 7.3 Hz, 2H), 6.94 (d, J = 8.3 Hz, 1H), 6.83 (dd, J = 7.8, 7.3 Hz, 2H), 6.72 (dd, J = 7.4, 7.4 Hz, 1H) ppm; $^{13}C\{^1H\}$NMR (100 MHz, DMSO-d_6); δ 200.8, 160.5, 137.4, 136.9, 125.6, 124.4, 123.9, 121.0, 120.5, 118.3, 117.7, 117.1, 113.9, 111.8, 111.6, 67.6 ppm; HRMS (ESI) *m/z*: calcd. for $C_{24}H_{17}N_3ONa$ $[M+Na]^+$ 386.1270, found 386.1274.

5-Methoxy-2,2-bis(5-methoxy-1*H*-indol-3-yl)indolin-3-one (2b)[5]

Yellow solid; 130 mg, 86%; mp: >200 ˚C; IR (KBr) ν_{max} 3390, 2924, 1644, 1489, 1213, 1028 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ 10.80 (s, *N*H), 10.79 (s, *N*H), 7.80 (s, 1H), 7.26 (d, J = 8.6 Hz, 2H), 7.22 (d, J = 2.7 Hz, 1H), 7.05 (d, J = 2.4 Hz, 2H), 6.99-6.95 (m, 2H), 6.82 (d, J = 2.3 Hz, 2H), 6.71 (dd, J = 8.8, 2.4 Hz, 2H), 3.72 (s, 3H), 3.55 (s, 6H) ppm; $^{13}C\{^1H\}$NMR (100 MHz, DMSO-d_6); δ 201.7, 157.3, 153.0, 152.2, 132.6, 128.2, 126.5, 125.2, 118.5, 114.1, 113.9, 112.6, 111.0, 104.9, 103.5, 68.9, 56.0, 55.5 ppm; HRMS (ESI) *m/z*: calcd. for $C_{27}H_{23}N_3O_4Na$ $[M+Na]^+$ 476.1587, found 476.1587.

5-Fluoro-2,2-bis(5-fluoro-1*H*-indol-3-yl)indolin-3-one (2c)[5]

Yellow solid; 116 mg, 83%; mp: 91-93 ˚C; IR (KBr) ν_{max} 3406, 2924, 1687, 1627, 1487 cm^{-1}; ^1H NMR (400 MHz, DMSO-d_6): δ 11.16 (s, *N*H), 11.15 (s, *N*H), 8.18 (s, 1H), 7.46 (ddd, J = 9.0, 9.0, 2.8 Hz, 1H), 7.38-7.35 (m, 2H), 7.27 (dd, J = 7.6, 2.7 Hz, 1H), 7.23 (d, J = 2.6 Hz, 2H), 6.99 (dd, J = 8.9, 3.9 Hz, 1H), 6.94-6.86 (m, 4H) ppm; $^{13}C\{^1H\}$NMR (100 MHz, DMSO-d_6); δ 200. 9, 158.1, 156.8 (d, J_{C-F} = 229 Hz), 155.5 (d, J_{C-F} = 234 Hz), 134.1, 126.5, 126.3, 126.2, 126.1 (d, J_{C-F} = 11 Hz), 117.9 (d, J_{C-F} = 7 Hz), 114.1 (d, J_{C-F} = 5 Hz), 113.9 (d, J_{C-F} = 8 Hz), 113.2 (d, J_{C-F} = 10 Hz), 109.9 (d, J_{C-F} = 26 Hz), 109.5 (d, J_{C-F} = 22 Hz), 105.3 (d, J_{C-F} = 24 Hz), 68.7 ppm; HRMS (ESI) *m/z*: calcd. for $C_{24}H_{15}F_3N_3O$ $[M+H]^+$ 418.1169, found 418.1170.

5-Nitro-2,2-bis(5-nitro-1*H*-indol-3-yl)indolin-3-one (2d)[5]

Yellow solid; 135 mg, 81%; mp: >200 ˚C, IR (KBr) ν_{max} 3324, 2923, 1694, 1618, 1467, 1322 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ 11.99 (s, 2*N*H), 9.97 (s, 1H), 8.43 (dd, *J* = 9.2, 2.4 Hz, 1H), 8.37 (d, *J* = 2.3 Hz, 1H), 8.22 (d, *J* = 2.1 Hz, 2H), 7.97 (dd, *J* = 9.0, 2.2 Hz, 2H), 7.61-7.58 (m, 4H), 7.12 (d, *J* = 9.2 Hz, 1H) ppm; ^{13}C{^{1}H}NMR (100 MHz, DMSO-d_6); δ 198.6, 162.9, 140.9, 140.7, 138.8, 133.8, 128.4, 124.7, 122.8, 117.5, 117.4, 116.7, 115.1, 113.1, 112.3, 68.9 ppm; HRMS (ESI) *m/z*: calcd. for $C_{24}H_{14}N_6O_7Na$ $[M+Na]^+$ 521.0822, found 521.0819.

5-Phenyl-2,2-bis(5-phenyl-1*H*-indol-3-yl)indolin-3-one (2e)

Yellow solid; 166 mg, 84%; mp: >200˚C; IR (KBr) ν_{max} 3300, 2924, 1687, 1621 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ 11.13 (s, *N*H), 11.10 (s, *N*H), 8.57 (s, 1H), 7.93 (d, *J* = 8.6 Hz, 1H), 7.77 (d, *J* = 6.8 Hz, 1H), 7.66-7.64 (m, 4H), 7.57 (d, *J* = 9.4 Hz, 1H), 7.46-7.42 (m, 7H), 7.38-7.28 (m, 7H), 7.24-7.20 (m, 3H), 7.17 (d, *J* = 7.2 Hz, 1H), 7.10 (dd, *J* = 8.5, 3.2 Hz, 1H) ppm; ^{13}C{^{1}H}NMR (100 MHz, DMSO-d_6); δ 201.6, 160.7, 142.2, 140.2, 137.2, 137.1, 131.3, 130.1, 129.4, 129.2, 127.9, 127.1, 126.9, 126.6, 126.4, 125.3, 122.3, 120.9, 119.2, 119.0, 114.7, 112.9, 112.6, 68.7 ppm; HRMS (ESI) *m/z*: calcd. for $C_{42}H_{30}N_3O$ $[M+H]^+$ 592.2391, found 592.2384.

5-Cyano-2,2-bis(5-cyano-1*H*-indol-3-yl)indolin-3-one (2f)[5]

Yellow solid; 116 mg, 79%; mp: 147-149 ˚C; IR (KBr) ν_{max} 3309, 2923, 2221, 1699, 1621, 1495 cm^{-1} ^{1}H NMR (400 MHz, DMSO-d_6): δ 11.79 (s, 2*N*H), 9.43 (s, 1H), 8.04 (s, 1H), 7.89 (dd, *J* = 8.6, 1.4 Hz, 1H), 7.64 (s, 2H), 7.59 (d, *J* = 8.5 Hz, 2H), 7.48 (d, *J* = 2.3 Hz, 2H), 7.43 (dd, *J* = 8.6, 0.7 Hz, 2H), 7.09 (d, *J* = 8.6 Hz, 1H) ppm; ^{13}C{^{1}H}NMR (100 MHz, DMSO-d_6); δ 198.5, 161.7, 141.1, 139.3, 131.3, 127.1, 125.8, 125.4, 124.6, 120.9, 119.7, 117.5, 113.9, 113.8, 113.0, 101.4, 99.4, 67.9 ppm;; HRMS (ESI) *m/z*: calcd. for $C_{27}H_{14}N_6O$ $[M+H]^+$ 439.1309, found 439.1307.

3,3-Bis(1*H*-indol-3-yl)indolin-2-one (3)[6]

Yellow solid; 102 mg, 28%; mp: >200 ˚C; IR (KBr) ν_{max} 3429, 2923, 1706, 1614, 1468 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ 10.96 (s, 1*N*H), 10.95 (s, 1*N*H), 10.59 (s, *N*H), 7.35 (d, *J* = 8.1 Hz, 2H), 7.25-7.21 (m, 4H), 7.03-6.98 (m, 3H), 6.93 (ddd, *J* = 7.5, 7.5, 0.8 Hz, 2H), 6.85 (d, *J* = 2.5 Hz, 2H), 6.80 (ddd, *J* = 7.6, 7.5, 0.8 Hz, 2H) ppm; ^{13}C{^{1}H}NMR (100 MHz, DMSO-d_6); 179.2, 141.8, 137.4, 135.1, 128.3, 126.2, 125.4, 124.7, 121.9, 121.4, 121.2, 118.7, 114.8, 112.0, 110.0, 53.0 ppm; ESI-MS, *m/z*: $[M+Na]^+$ 386.09.

2-(4-Methoxy-phenyl)-benzo[*d*][1,3]oxazin-4-one (6)[7]

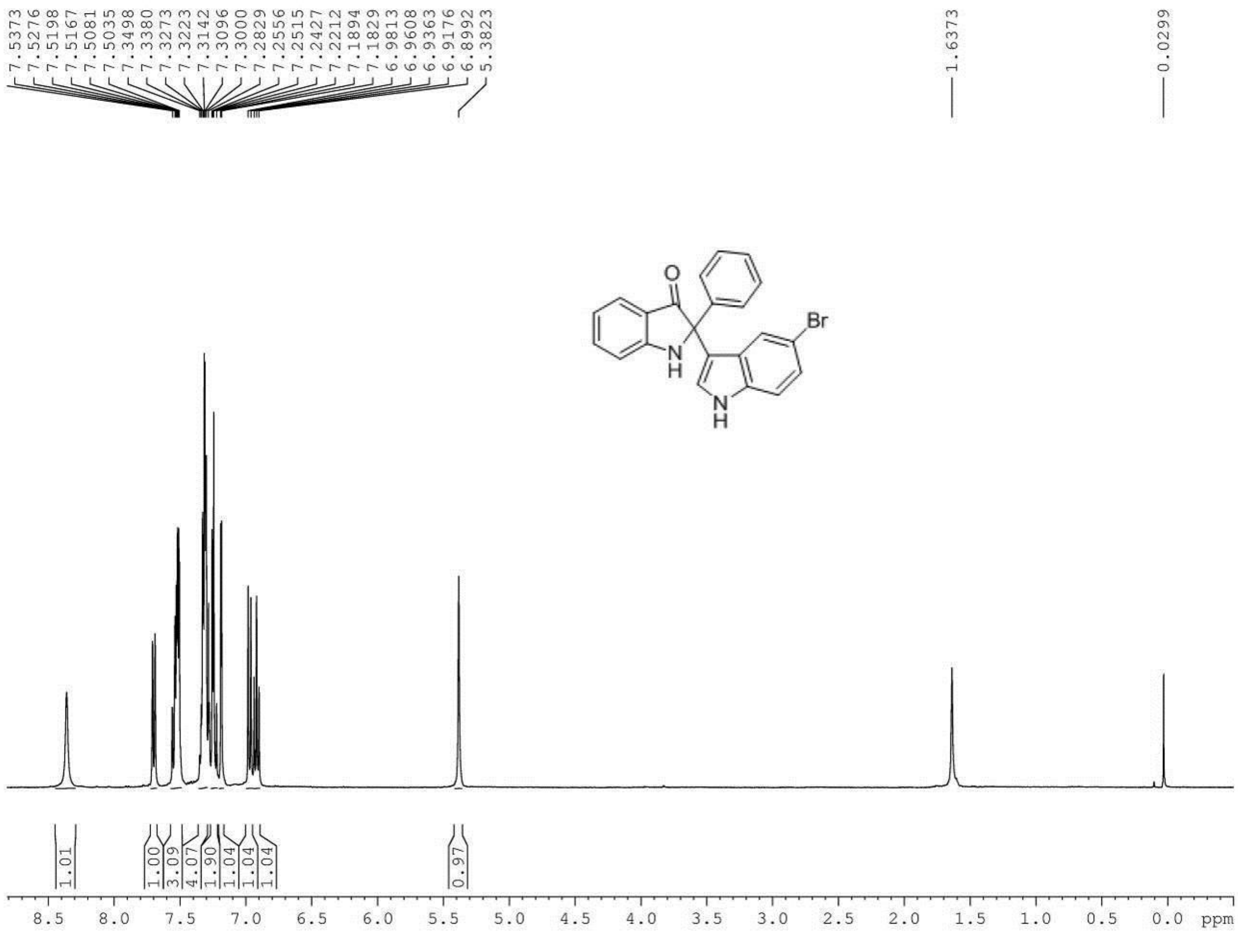
White solid; 30 mg, 12%; mp: 142-144 ˚C; IR (KBr) ν_{max} 2922, 1755, 1605, 1259, 1172, 768 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.28 (d, J = 8.2 Hz, 2H), 8.24 (d, J = 7.6 Hz, 1H), 7.82 (dd, J = 6.9, 7.1 Hz, 1H), 7.67 (d, J = 7.8 Hz, 1H), 7.50 (dd, J = 7.2, 7.1 Hz, 1H), 7.02 (d, J = 8.2 Hz, 2H), 3.92 (s, 3H) ppm; $^{13}C\{^{1}H\}$NMR (100 MHz, $CDCl_3$); 163.3, 159.8, 157.2, 147.4, 136.5, 130.3, 128.6, 127.7, 126.9, 122.6, 116.7, 114.2, 55.5 ppm; HRMS (ESI) *m/z*: calcd. for $C_{15}H_{12}NO_3$ $[M+H]^+$ 254.0819, found 254.0826.

2,2'-Bis(4-methoxyphenyl)-2,3-biindolin-3-one (7)

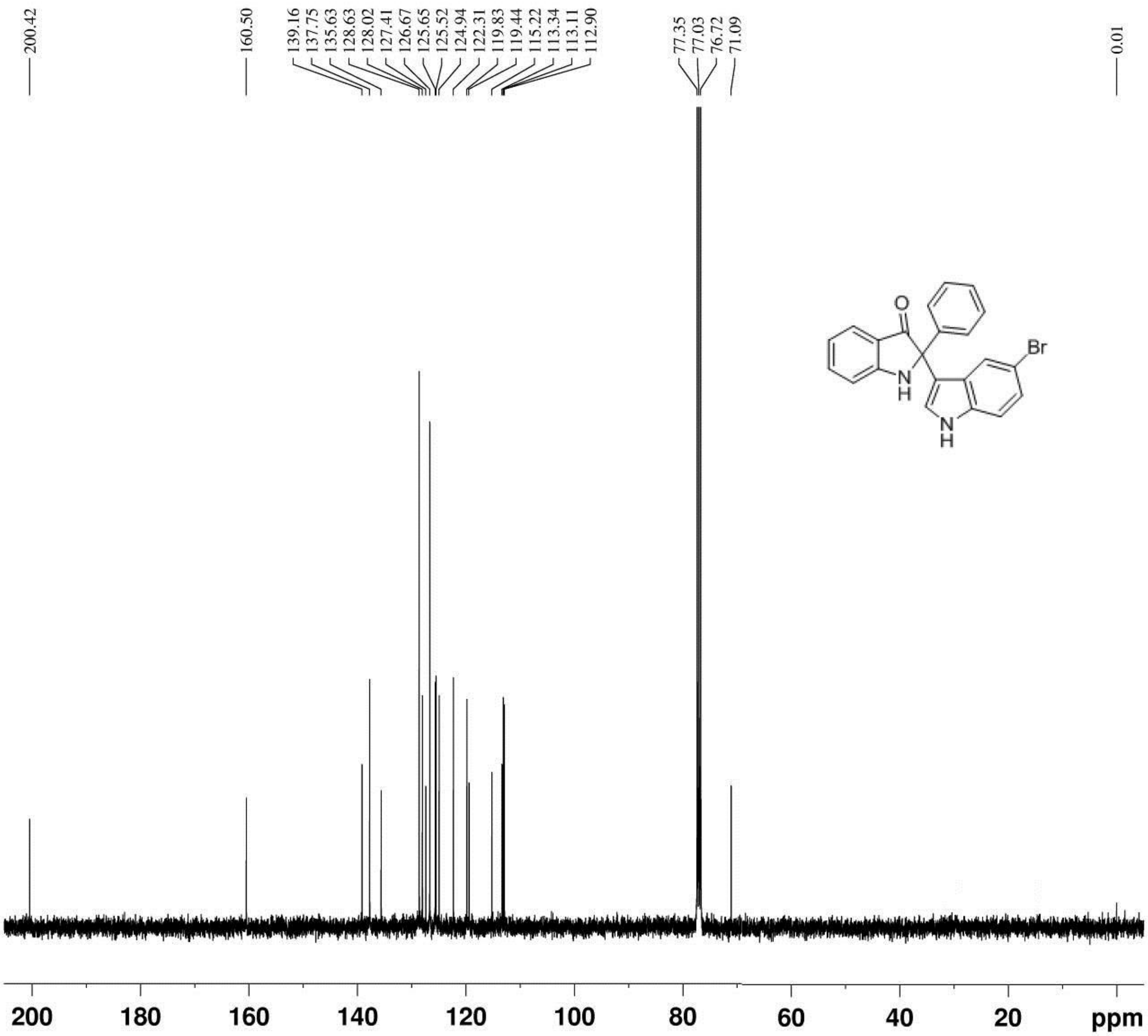
Yellow solid, 64 mg, 14%; m.p. 102-104 °C; IR (ATR): ν_{max} 3339, 2917, 1708, 1617, 1505, 1248 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.14 (s, *N*H), 7.45 (m, 4H), 7.31 (d, J = 8.6 Hz, 1H), 7.15 (dd, J = 7.1, 6.8 Hz, 1H), 7.05-6.99 (m, 3H), 6.93 (dd, J = 7.5, 7.2 Hz, 1H), 6.79 (dd, J = 7.4, 7.4 Hz, 1H), 6.76-6.73 (m, 3H), 6.66 (d, J = 8.6 Hz, 2H), 5.21 (s, *N*H), 3.79 (s, 3H), 3.75 (s, 3H) ppm; $^{13}C\{^{1}H\}$NMR (100 MHz, $CDCl_3$): δ 200.7, 159.5, 159.2, 159.1, 137.0, 136.9, 135.5, 132.5, 130.9, 128.4, 127.5, 125.5, 125.4, 122.1, 121.5, 120.5, 119.9, 119.0, 113.7, 113.1, 112.23, 112.20, 110.6, 71.67, 55.3, 55.2 ppm; HRMS (ESI) m/z: calcd. for $C_{30}H_{25}N_2O_3$ $[M+H]^+$ 461.1867, found: 461.1864.

5. NMR spectra of compounds (5a-m, 2a-f, 3, 6, 7 and 8)

5a: ^{1}H NMR



5a: ^{13}C NMR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76.72
71.09
0.01
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H
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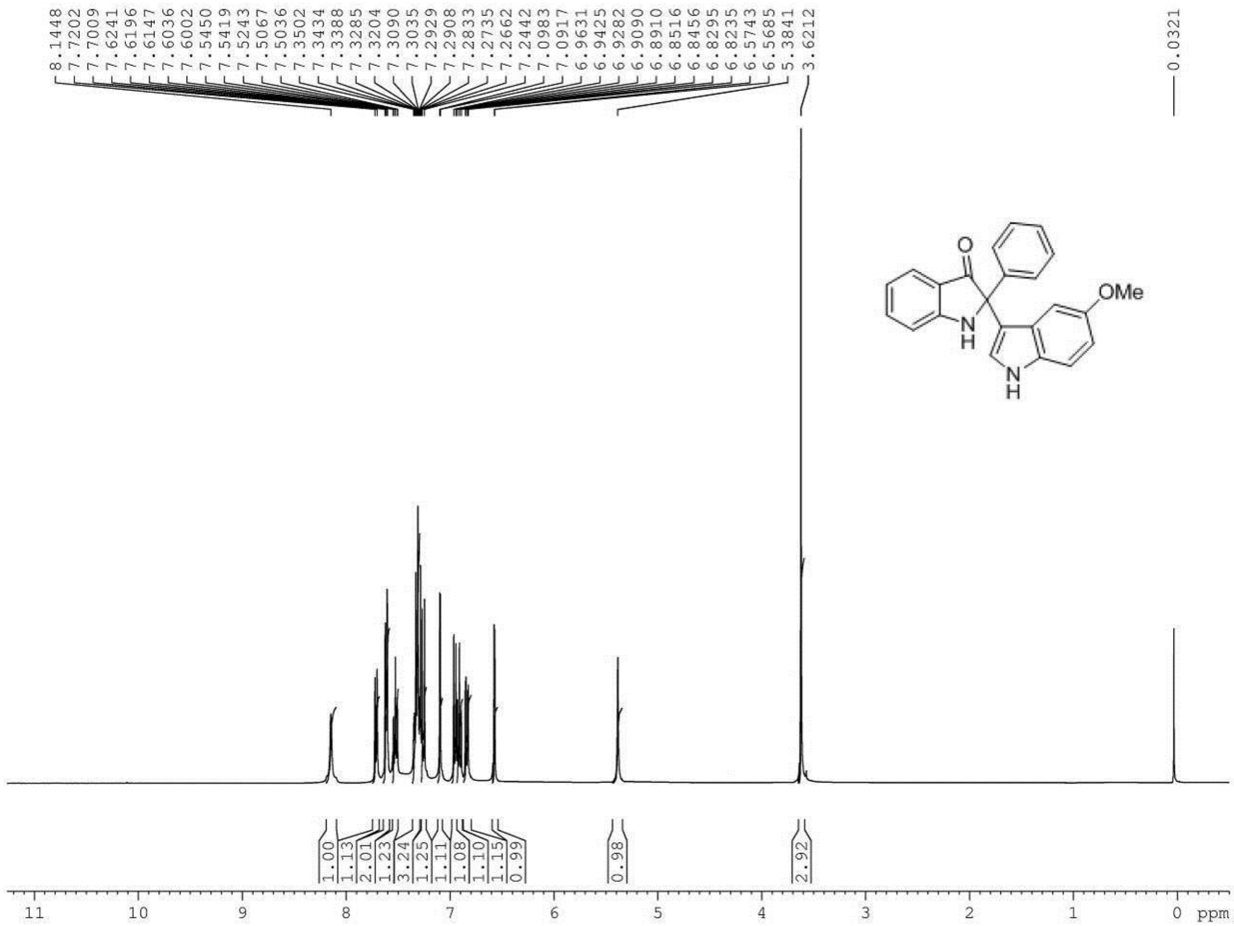
20
ppm

5b: ^{1}H NMR



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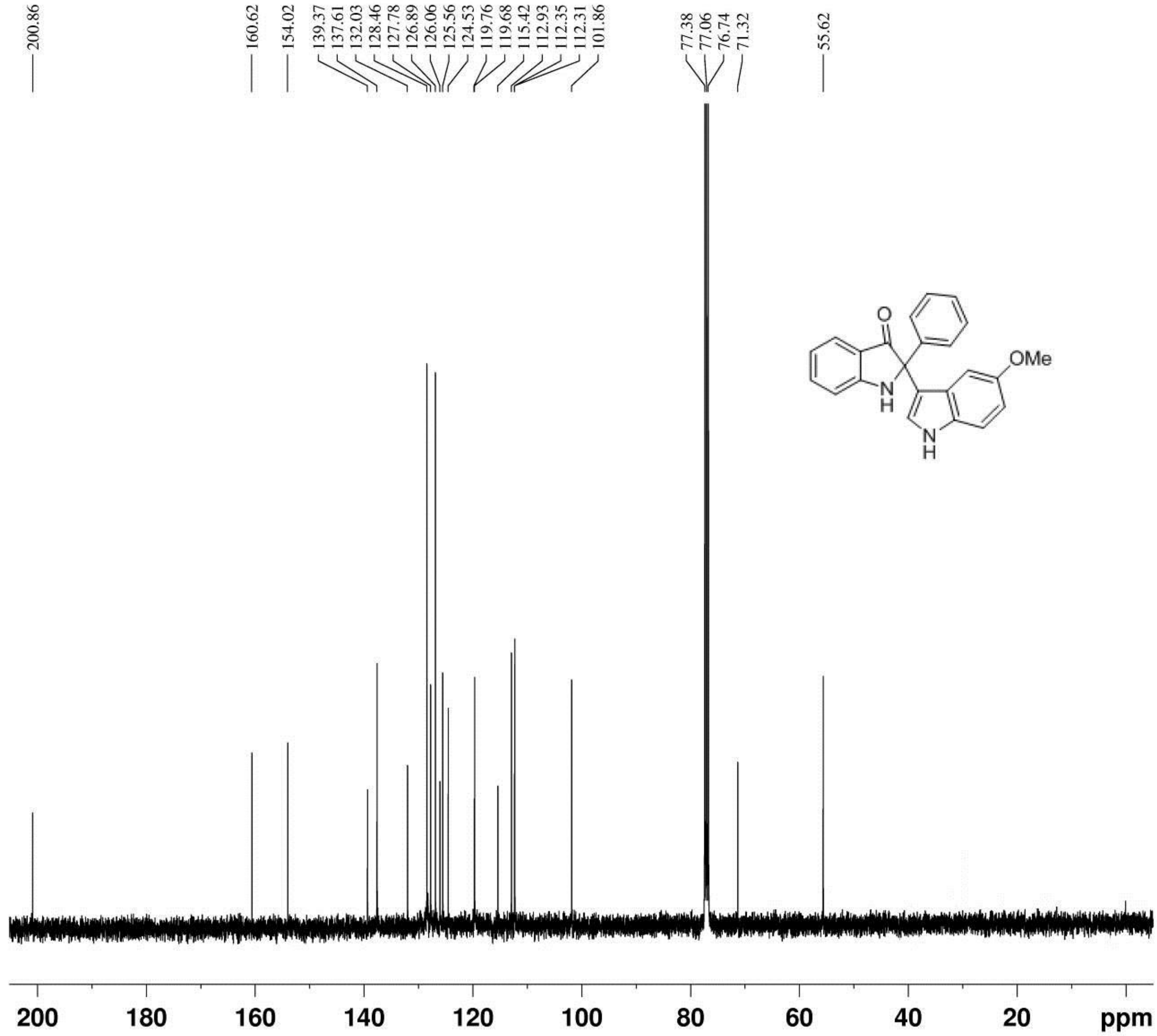
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71.32
55.62
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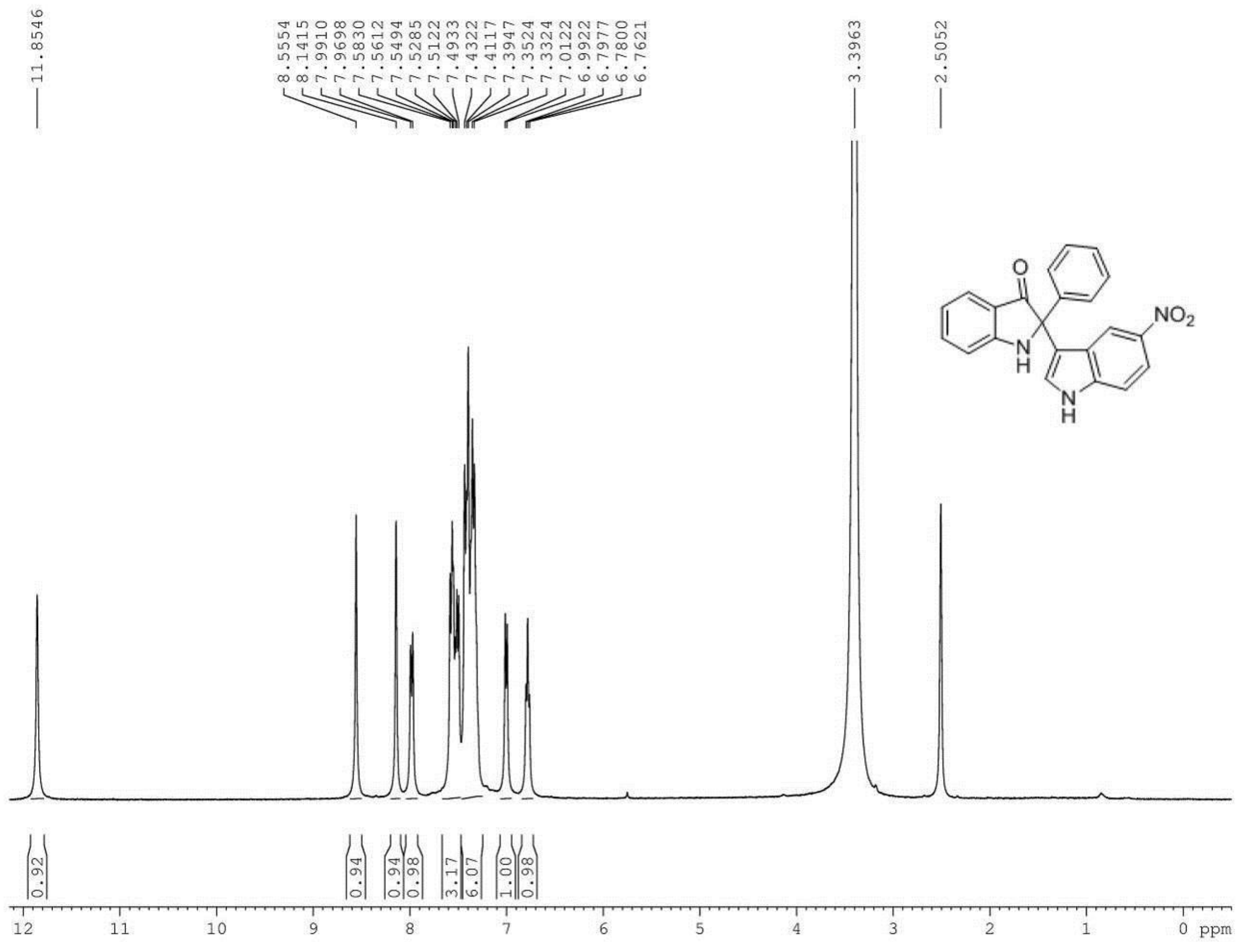
ppm

5c: ^{1}H NMR



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6.7977
6.7800
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NH
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0.94
0.98
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6.07
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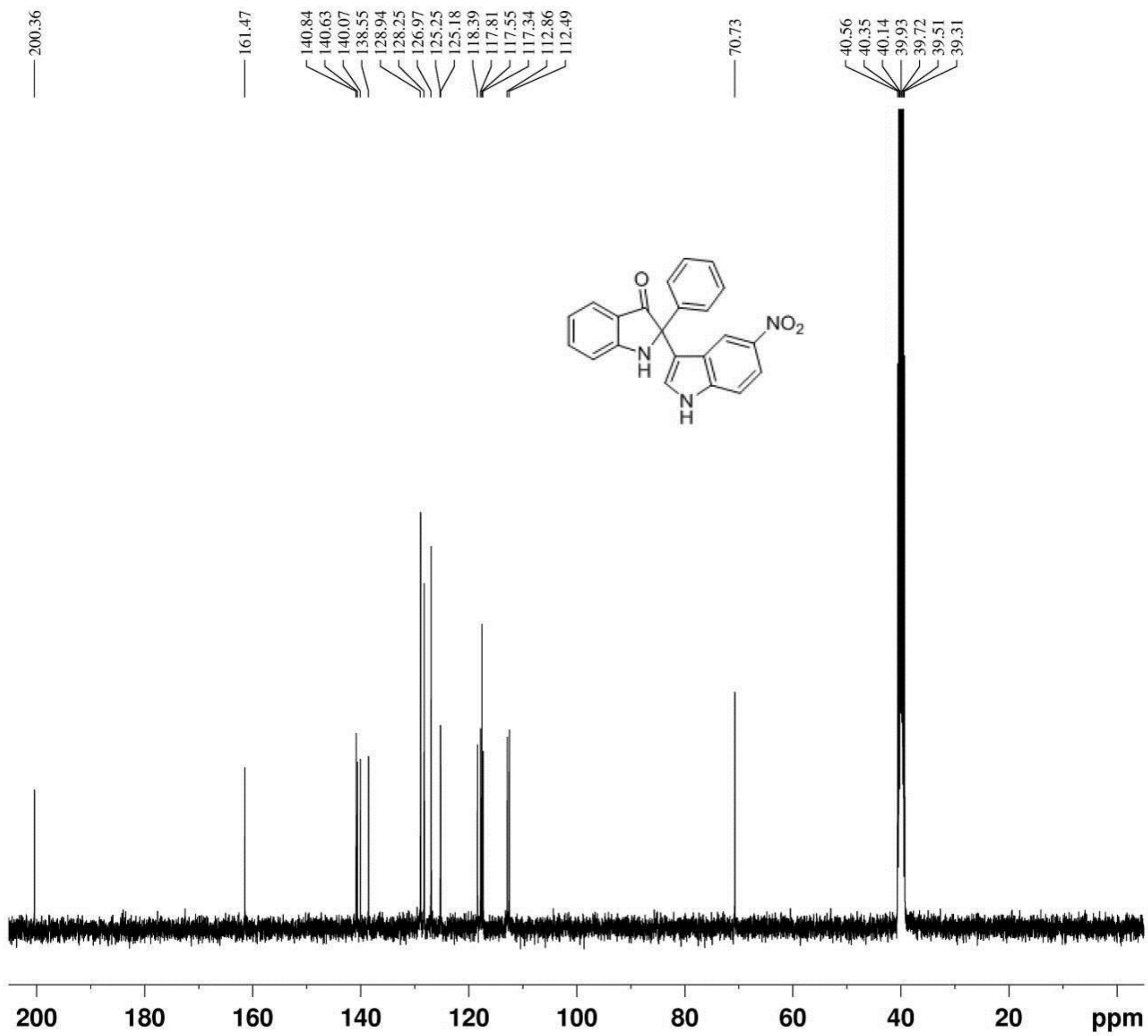
5c: ^{13}C NMR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39.51
39.31
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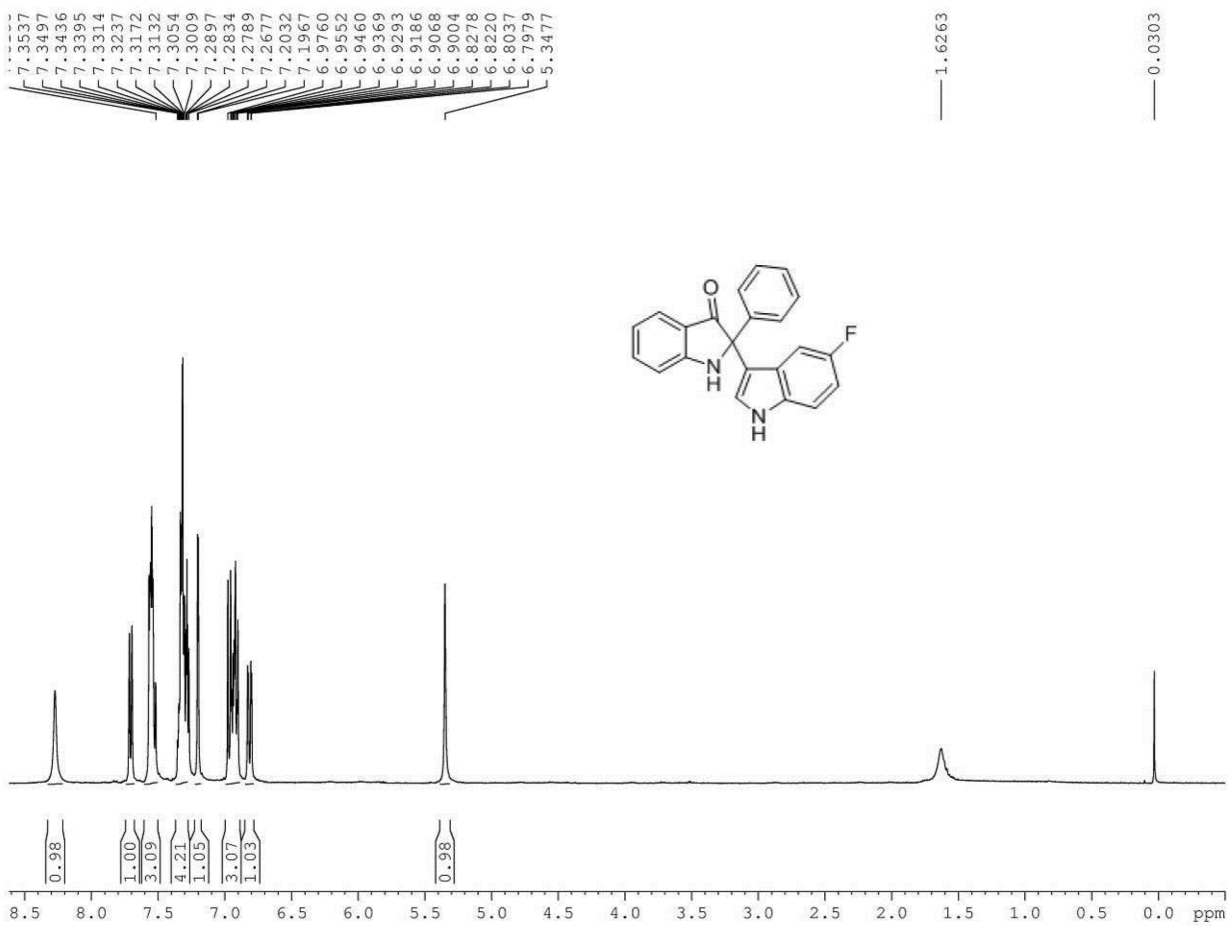
20
ppm

5d: ^{1}H NMR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F
N
H
N
H
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1.00
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4.21
1.05
3.07
1.03
0.98
8.5
8.0
7.5
7.0
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6.0
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5.0
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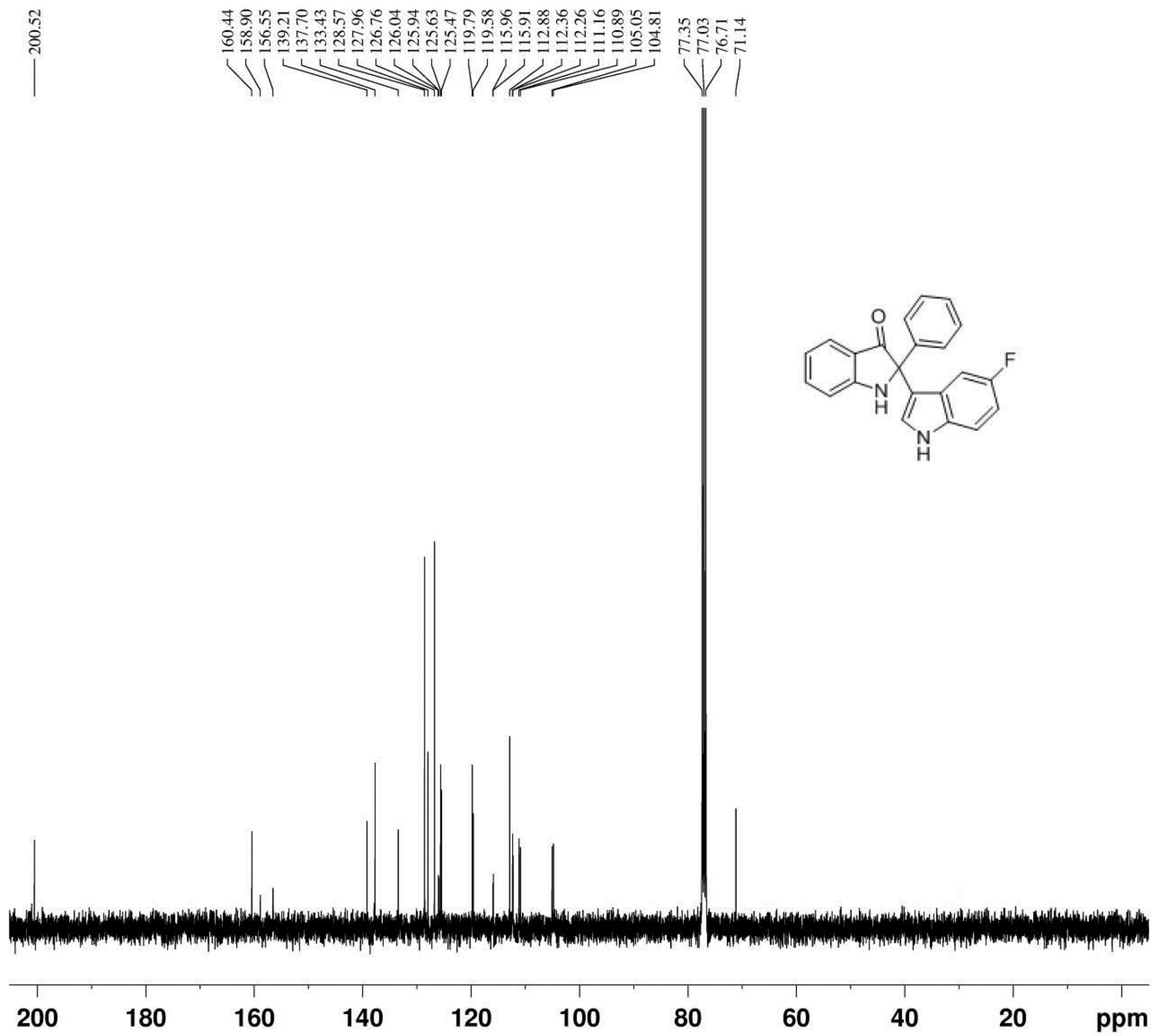
ppm

5d: ^{13}C NMR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115.96
115.91
112.88
112.36
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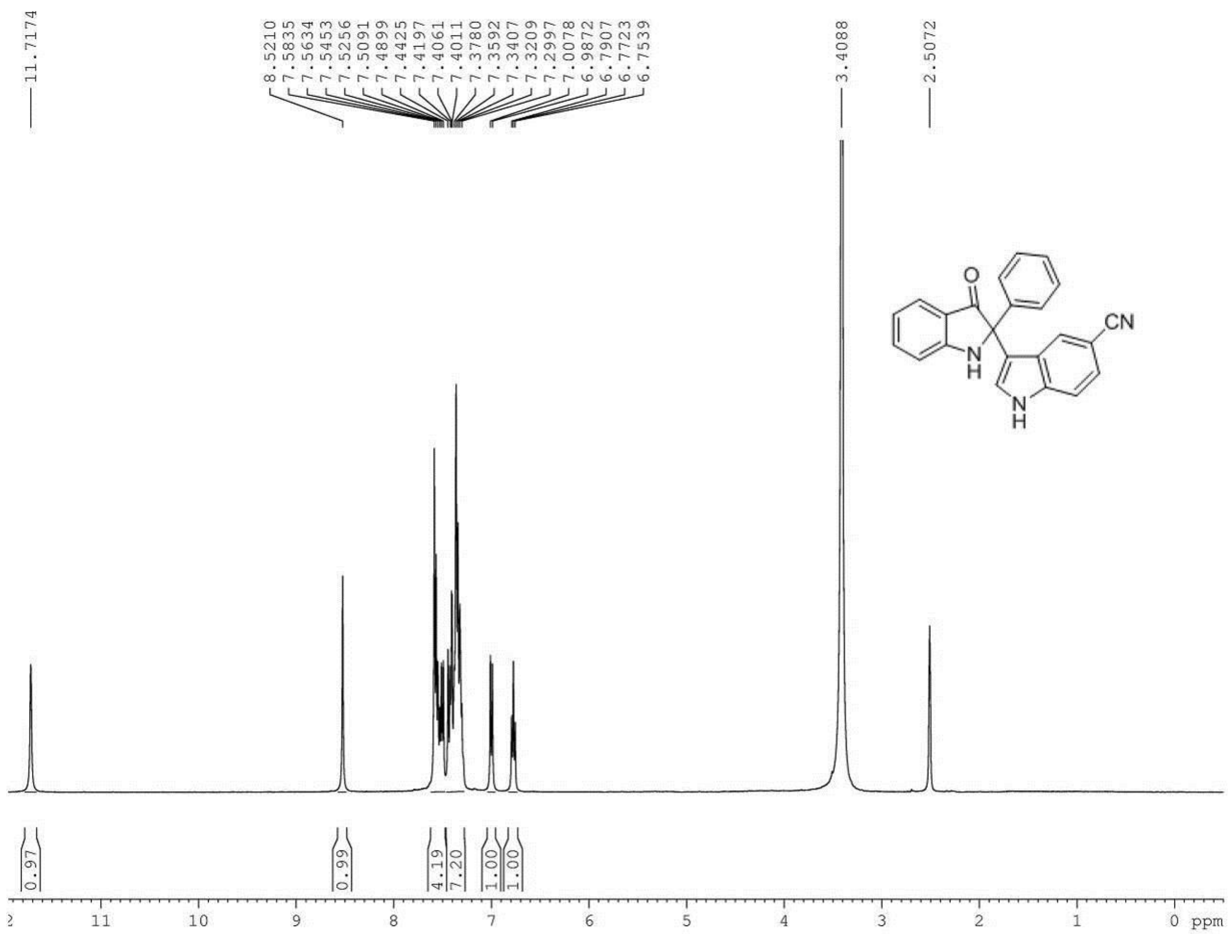
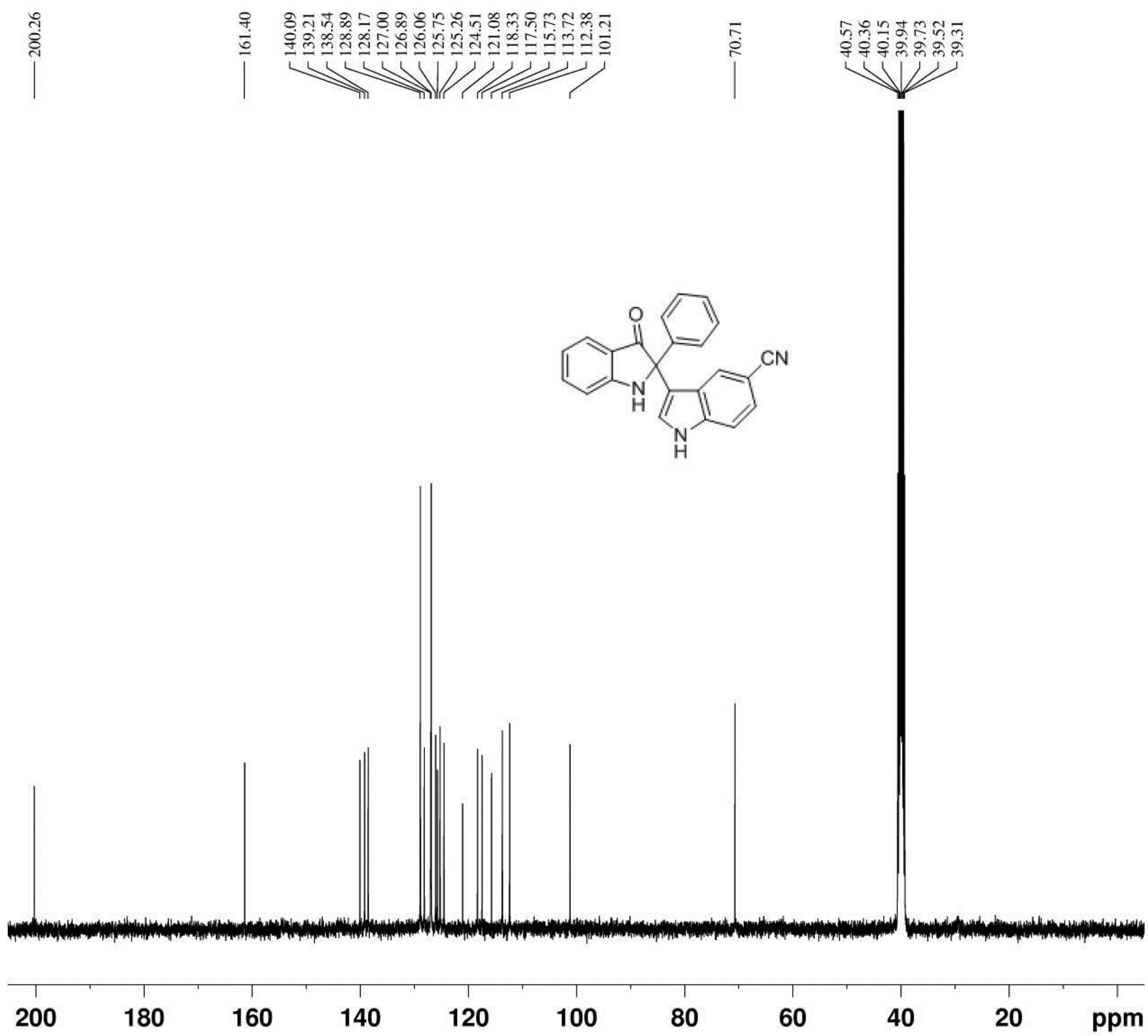
111.16
110.89
105.05
104.81
77.35
77.03
76.71
71.14
O
F
N
H
N
H
200
180
160
140
120
100
80
60
40
20
ppm

5e: ^{1}H NMR

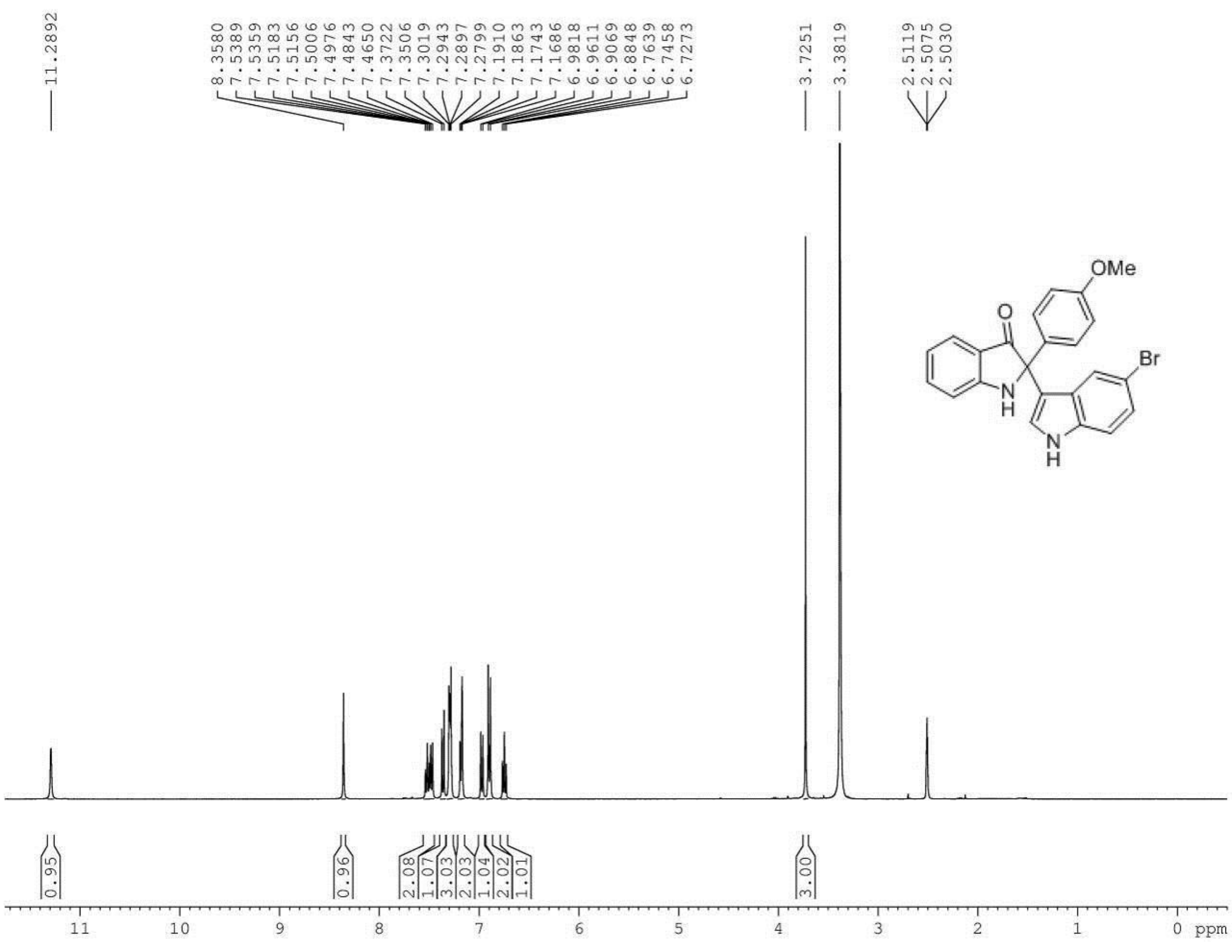


11.7174
8.5210
7.5835
7.5634
7.5453
7.5256
7.5091
7.4899
7.4425
7.4197
7.4061
7.4011
7.3780
7.3592
7.3407
7.3209
7.2997
7.0078
6.9872
6.7907
6.7723
6.7539
3.4088
2.5072
CN
O
NH
NH
0.97
0.99
4.19
7.20
1.00
1.00
11
10
9
8
7
6
5
4
3
2
1
0 ppm

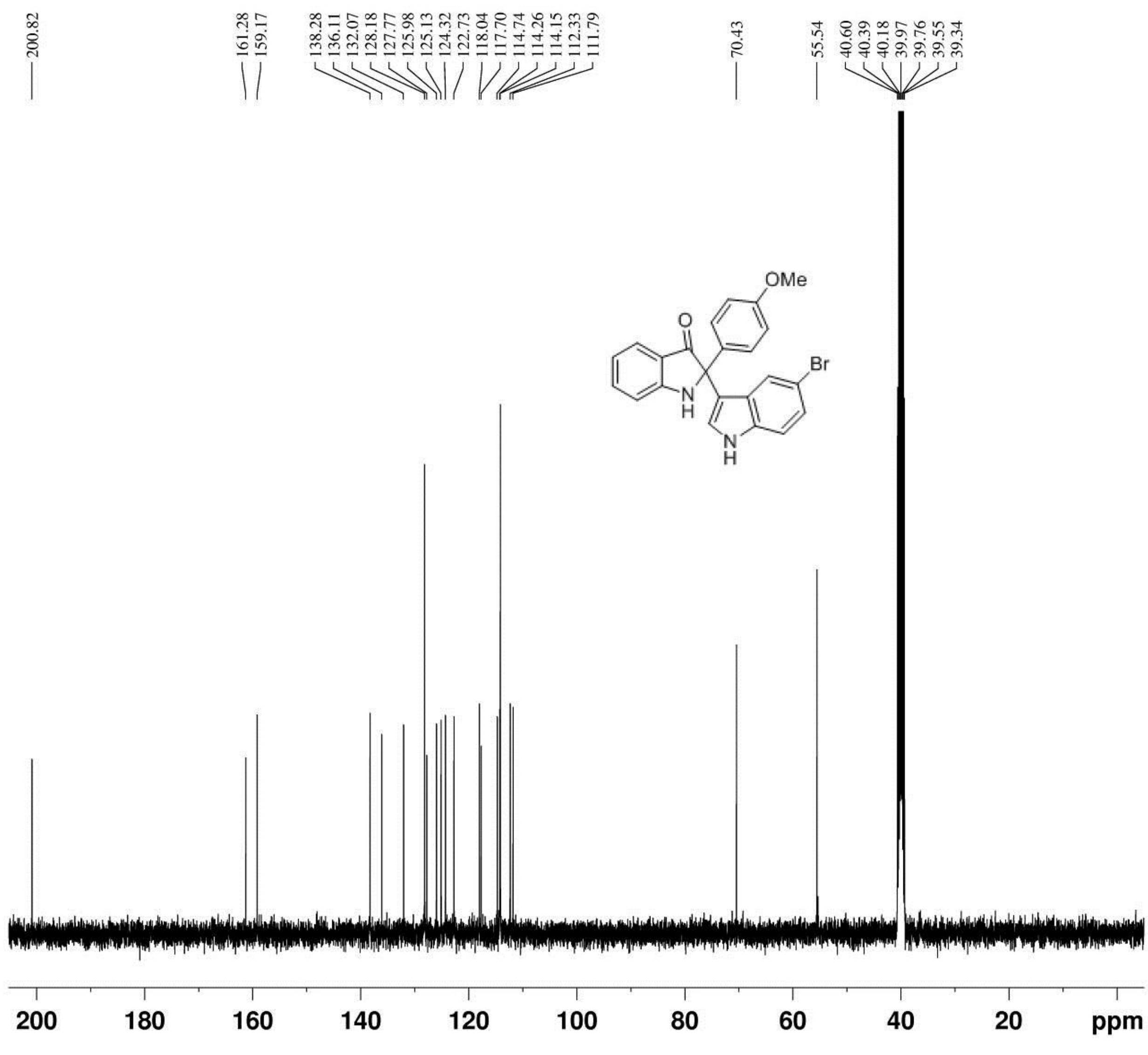
5e: ^{13}C NMR


200.26
161.40
140.09
139.21
138.54
128.89
128.17
127.00
126.89
126.06
125.75
125.26
124.51
121.08
118.33
117.50
115.73
113.72
112.38
101.21
70.71
40.57
40.36
40.15
39.94
39.73
39.52
39.31
O
N
H
CN
N
H
200
180
160
140
120
100
80
60
40
20
ppm

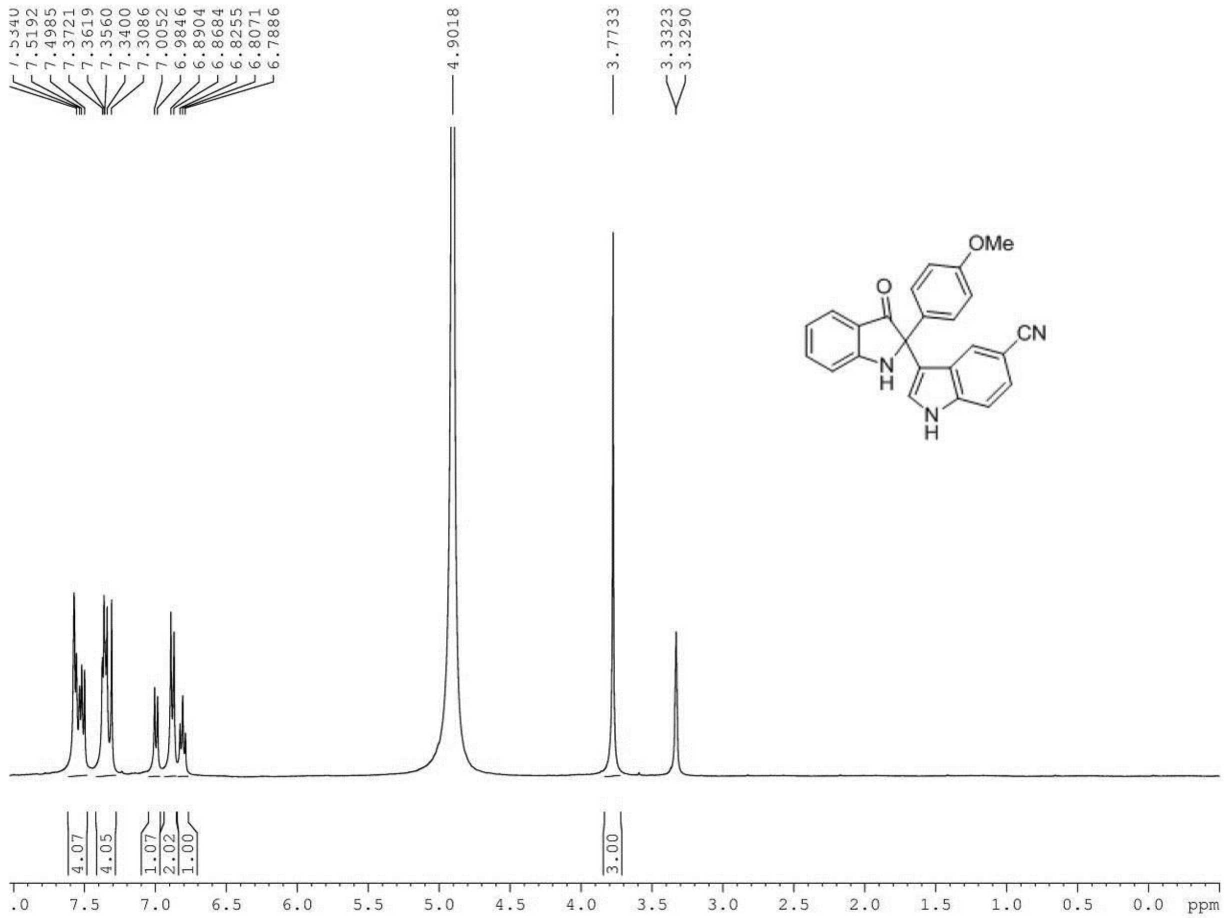
5f: ^{1}H NMR


11.2892
8.3580
7.5389
7.5359
7.5183
7.5156
7.5006
7.4976
7.4843
7.4650
7.3722
7.3506
7.3019
7.2943
7.2897
7.2799
7.1910
7.1863
7.1743
7.1686
6.9818
6.9611
6.9069
6.8848
6.7639
6.7458
6.7273
3.7251
3.3819
2.5119
2.5075
2.5030
OMe
O
Br
N
H
N
H
0.95
0.96
2.08
1.07
3.03
2.03
1.04
2.02
1.01
3.00
11
10
9
8
7
6
5
4
3
2
1
0 ppm

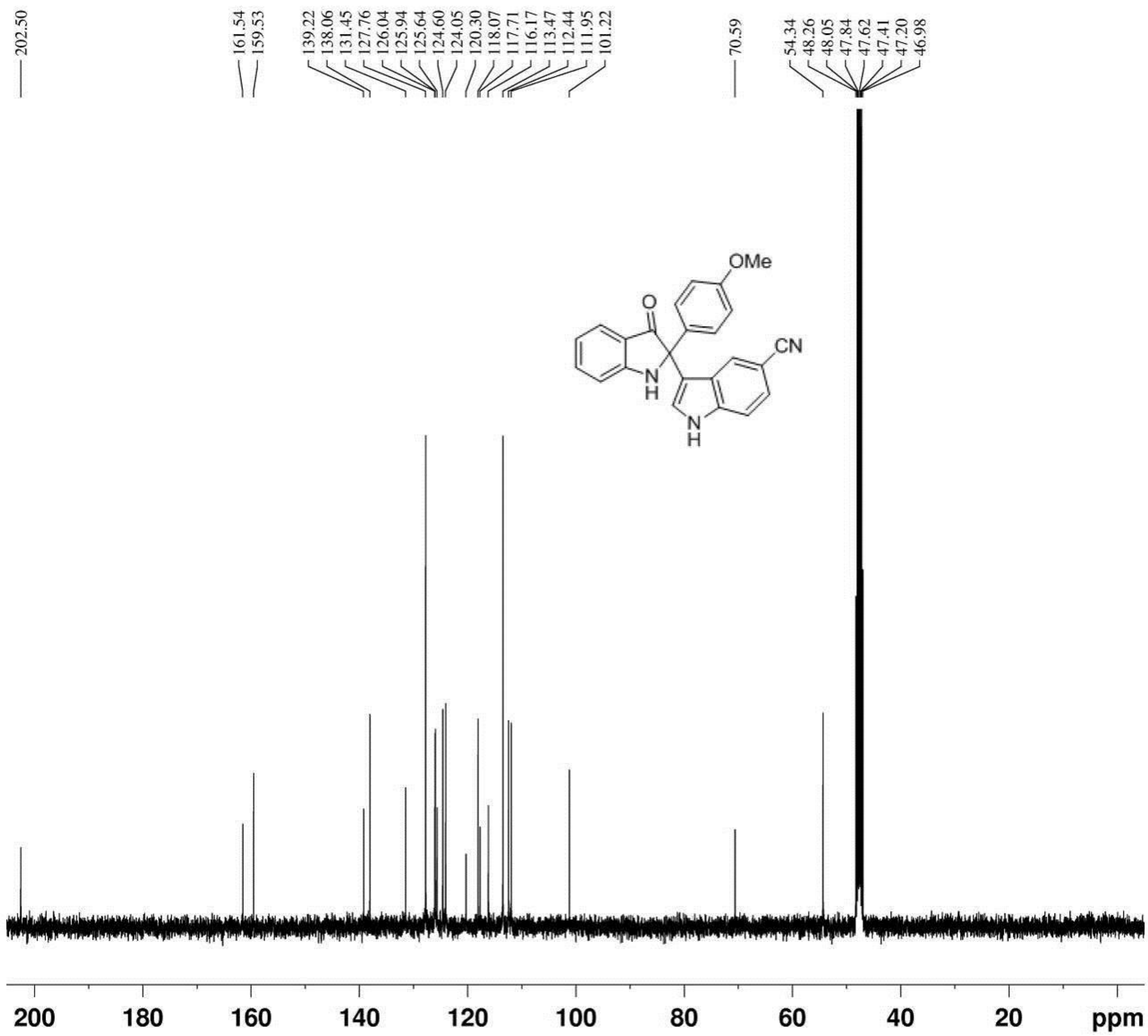
5f: ^{13}C NMR


200.82
161.28
159.17
138.28
136.11
132.07
128.18
127.77
125.98
125.13
124.32
122.73
118.04
117.70
114.74
114.26
114.15
112.33
111.79
70.43
55.54
40.60
40.39
40.18
39.97
39.76
39.55
39.34
OMe
O
Br
N
H
N
H
200
180
160
140
120
100
80
60
40
20
ppm

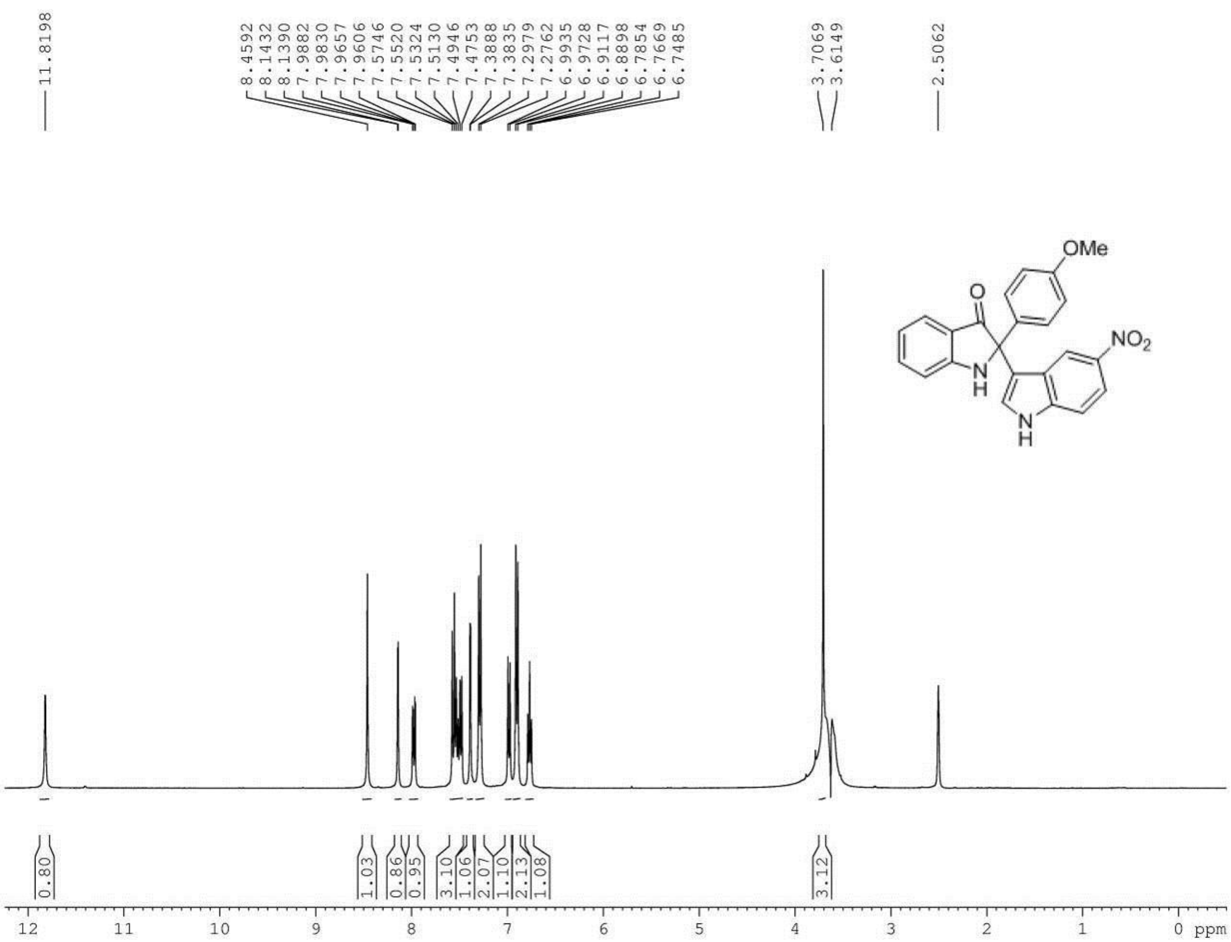
5g: ¹H NMR


7.5340
7.5192
7.4985
7.3721
7.3619
7.3560
7.3400
7.3086
7.0052
6.9846
6.8904
6.8684
6.8255
6.8071
6.7886
4.9018
3.7733
3.3323
3.3290
OMe
O
CN
N
H
N
H
4.07
4.05
1.07
2.02
1.00
3.00
.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
ppm

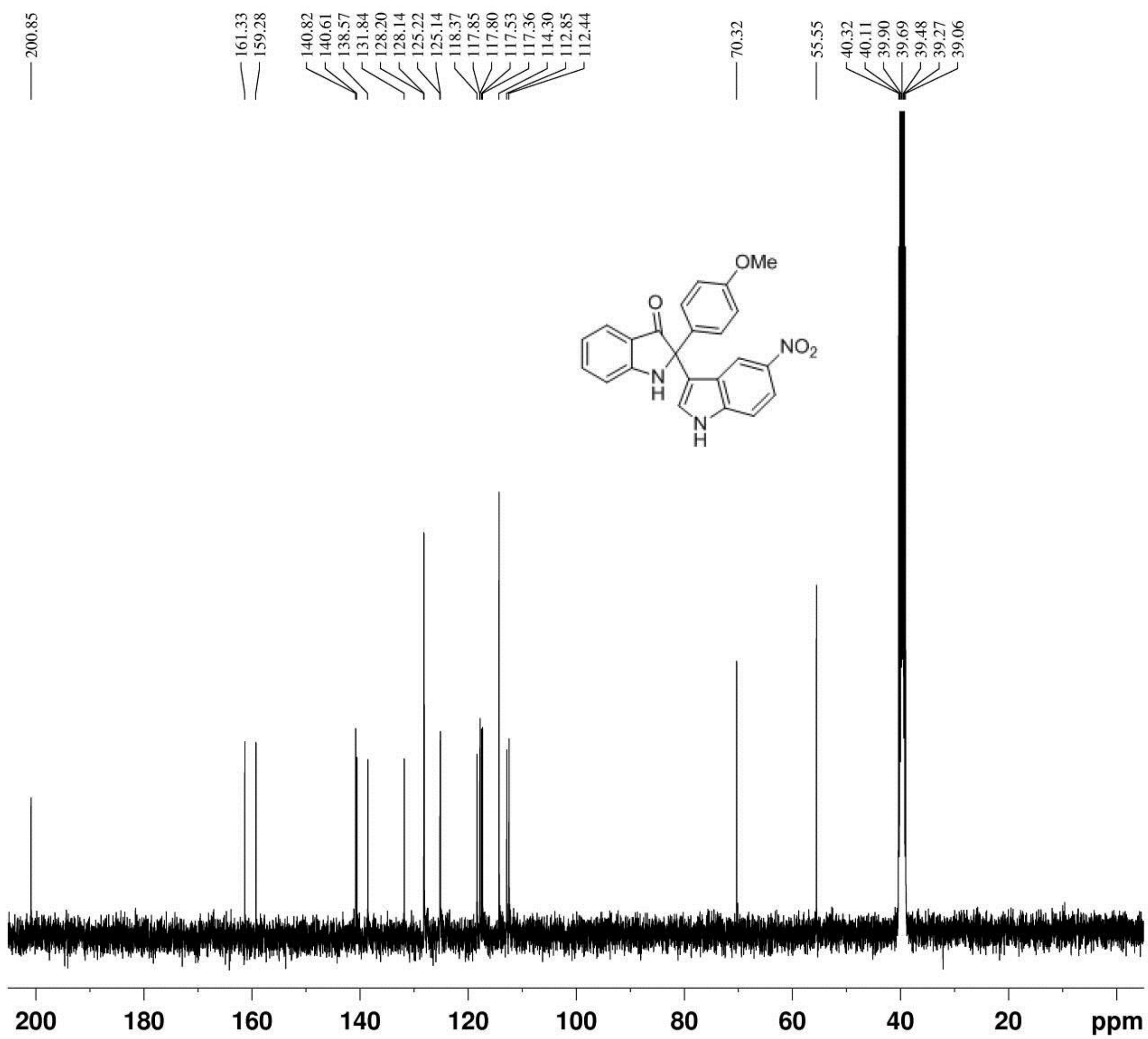
5g: ^{13}C NMR


202.50
161.54
159.53
139.22
138.06
131.45
127.76
126.04
125.94
125.64
124.60
124.05
120.30
118.07
117.71
116.17
113.47
112.44
111.95
101.22
70.59
54.34
48.26
48.05
47.84
47.62
47.41
47.20
46.98
OMe
O
CN
N
H
N
H
200
180
160
140
120
100
80
60
40
20
ppm

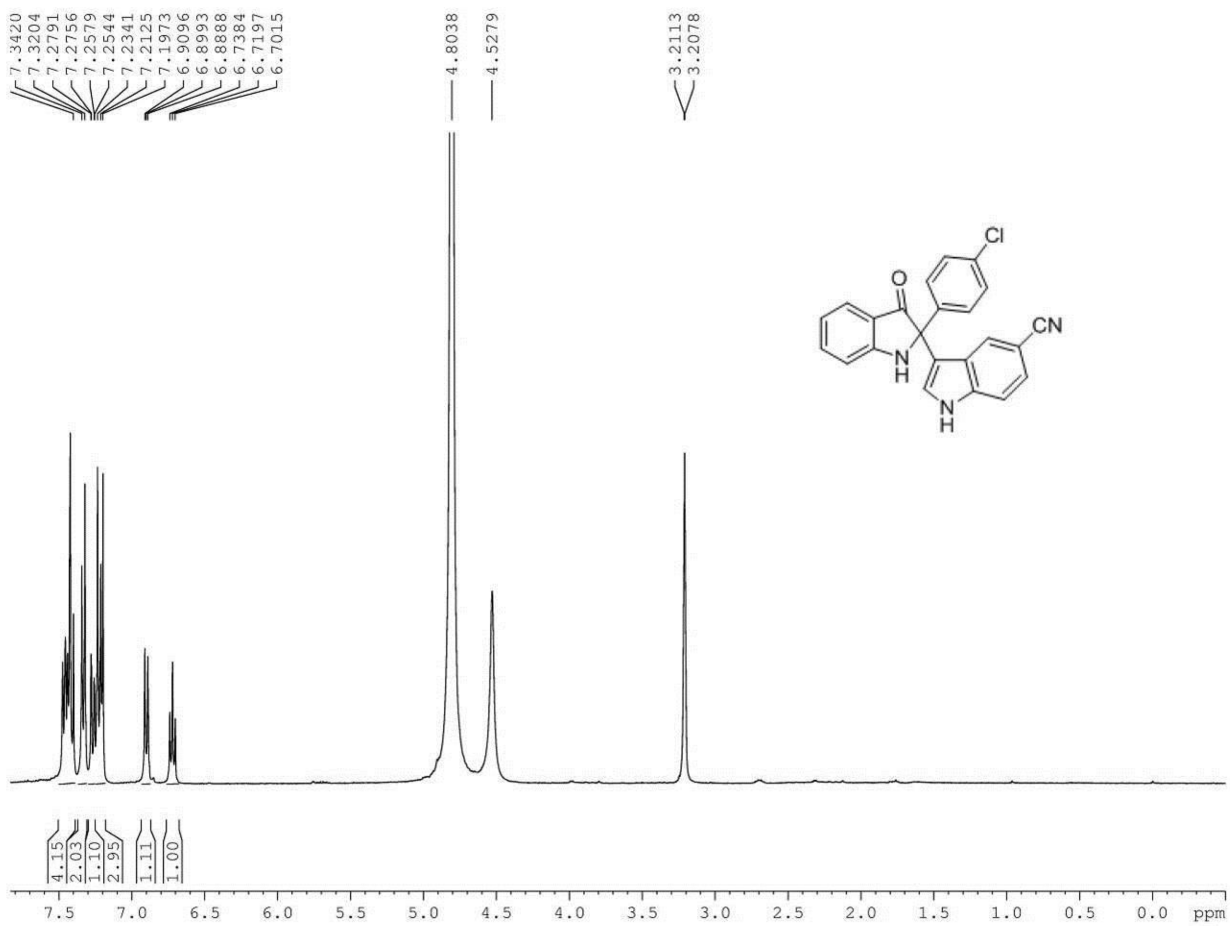
5h: ^{1}H NMR


11.8198
8.4592
8.1432
8.1390
7.9882
7.9830
7.9657
7.9606
7.5746
7.5520
7.5324
7.5130
7.4946
7.4753
7.3888
7.3835
7.2979
7.2762
6.9935
6.9728
6.9117
6.8898
6.7854
6.7669
6.7485
3.7069
3.6149
2.5062
OMe
O
NO2
N
H
N
H
0.80
1.03
0.86
0.95
3.10
1.06
2.07
1.10
2.13
1.08
3.12
12
11
10
9
8
7
6
5
4
3
2
1
0 ppm

5h: ^{13}C NMR

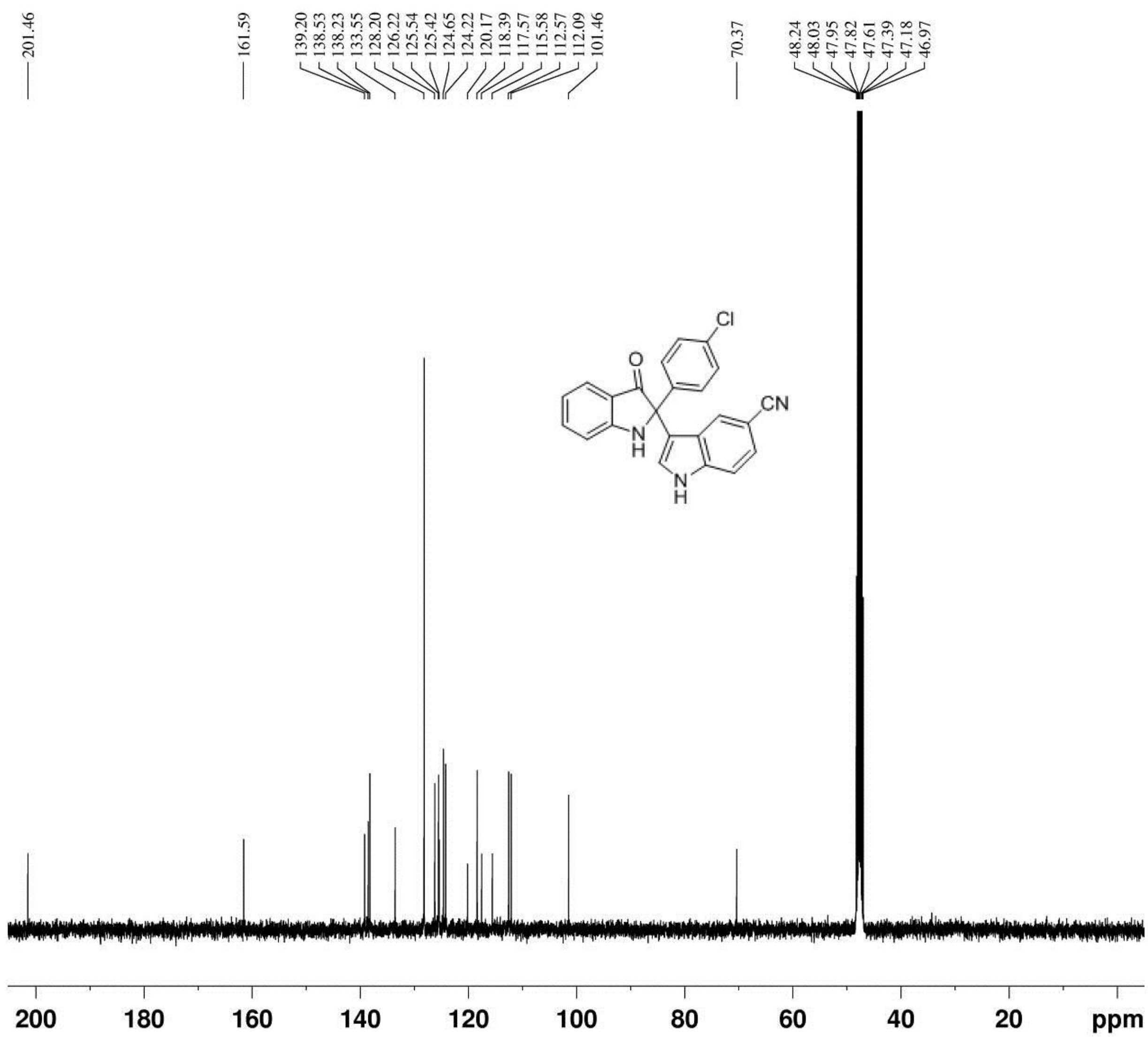

200.85
161.33
159.28
140.82
140.61
138.57
131.84
128.20
128.14
125.22
125.14
118.37
117.85
117.80
117.53
117.36
114.30
112.85
112.44
70.32
55.55
40.32
40.11
39.90
39.69
39.48
39.27
39.06
OMe
O
NO2
N
H
N
H
200
180
160
140
120
100
80
60
40
20
ppm

5i: ^{1}H NMR

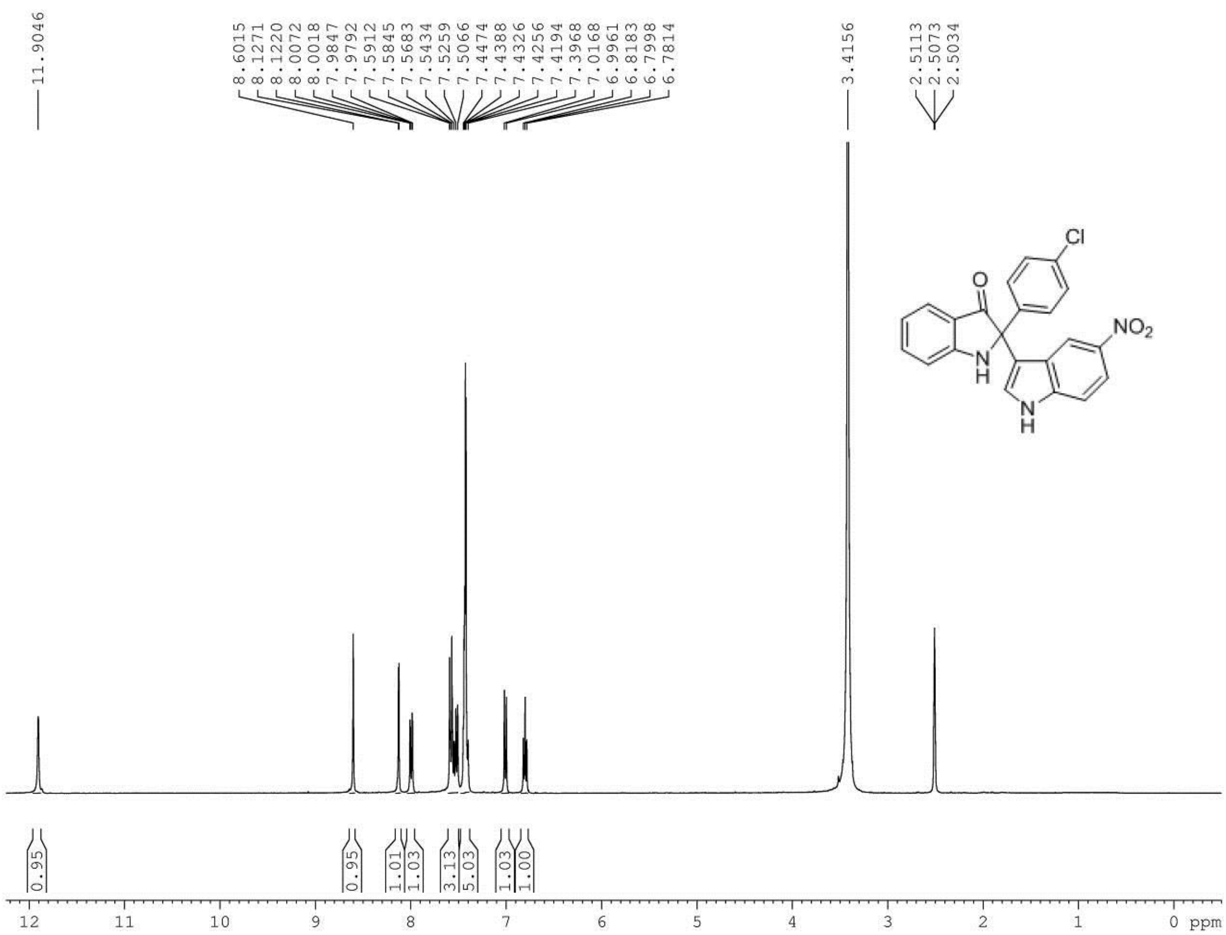


7.3420
7.3204
7.2791
7.2756
7.2579
7.2544
7.2341
7.2125
7.1973
6.9096
6.8993
6.8888
6.7384
6.7197
6.7015
4.8038
4.5279
3.2113
3.2078
Cl
O
CN
N
H
N
H
4.15
2.03
1.10
2.95
1.11
1.00
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 ppm

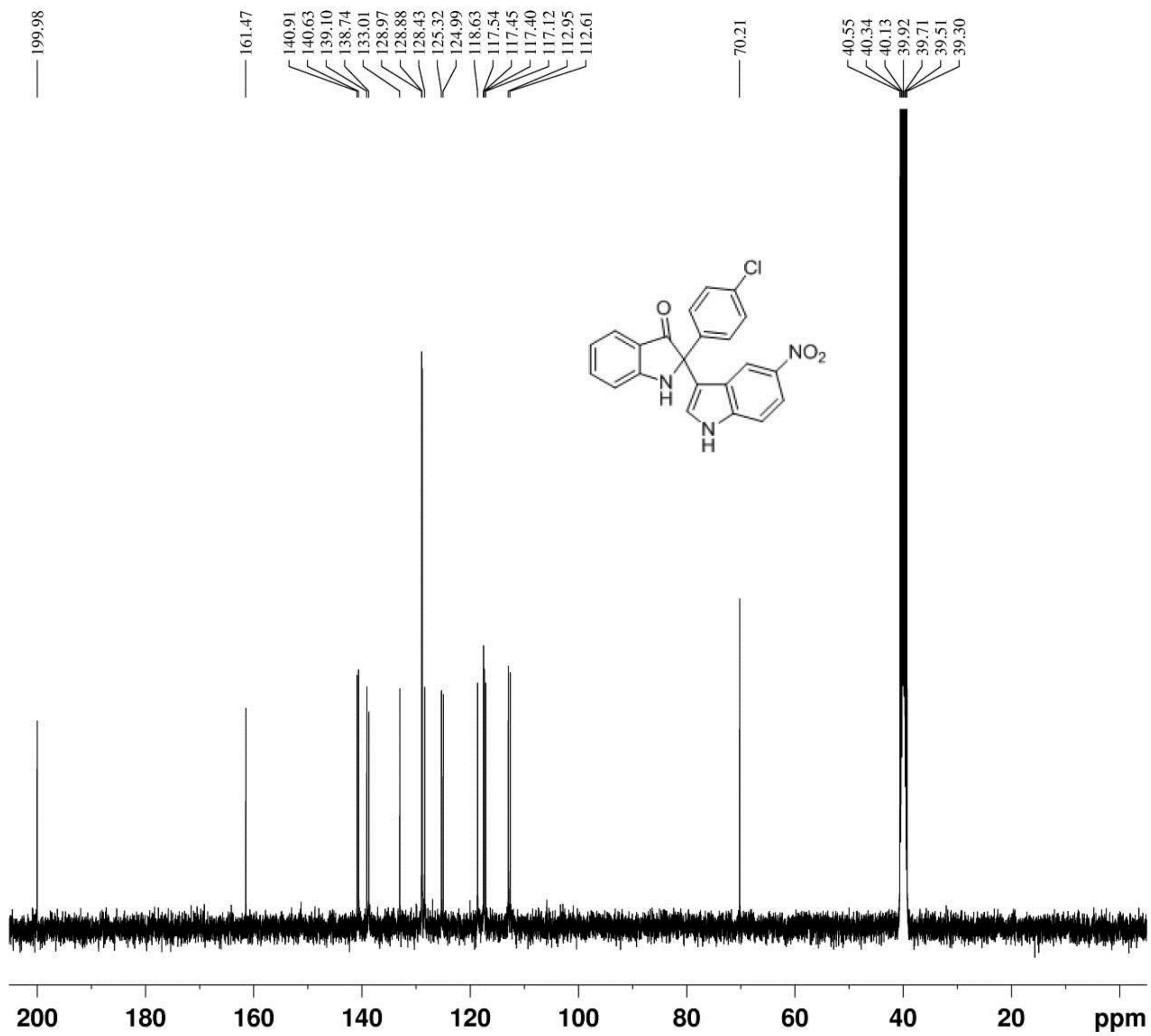
5i: ^{13}C NMR


201.46
161.59
139.20
138.53
138.23
133.55
128.20
126.22
125.54
125.42
124.65
124.22
120.17
118.39
117.57
115.58
112.57
112.09
101.46
70.37
48.24
48.03
47.95
47.82
47.61
47.39
47.18
46.97
Cl
O
CN
N
H
N
H
200
180
160
140
120
100
80
60
40
20
ppm

5j: ^{1}H NMR

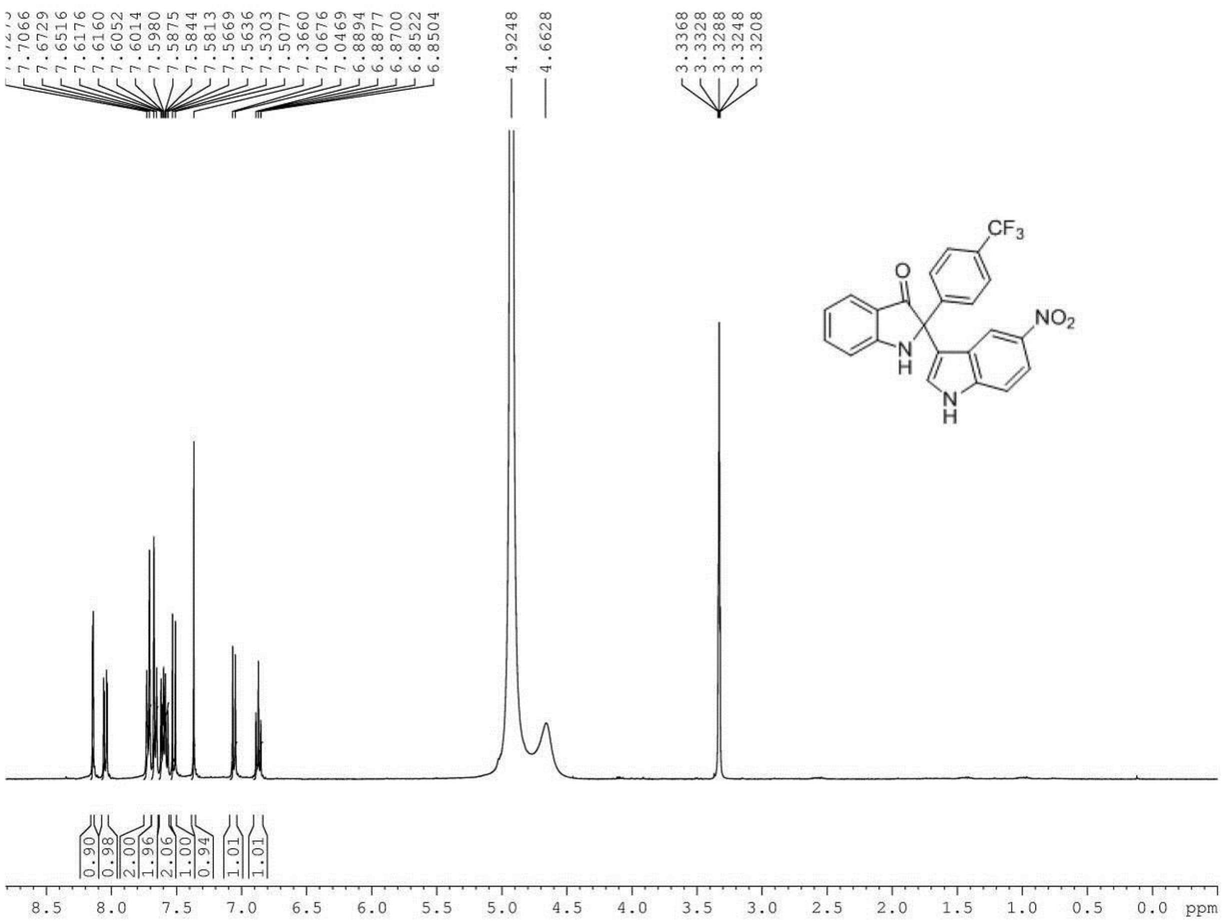

11.9046
8.6015
8.1271
8.1220
8.0072
8.0018
7.9847
7.9792
7.5912
7.5845
7.5683
7.5434
7.5259
7.5066
7.4474
7.4388
7.4326
7.4256
7.4194
7.3968
7.0168
6.9961
6.8183
6.7998
6.7814
3.4156
2.5113
2.5073
2.5034
Cl
O
NO2
N
H
N
H
0.95
0.95
1.01
1.03
3.13
5.03
1.03
1.00
12
11
10
9
8
7
6
5
4
3
2
1
0 ppm

5j: ^{13}C NMR

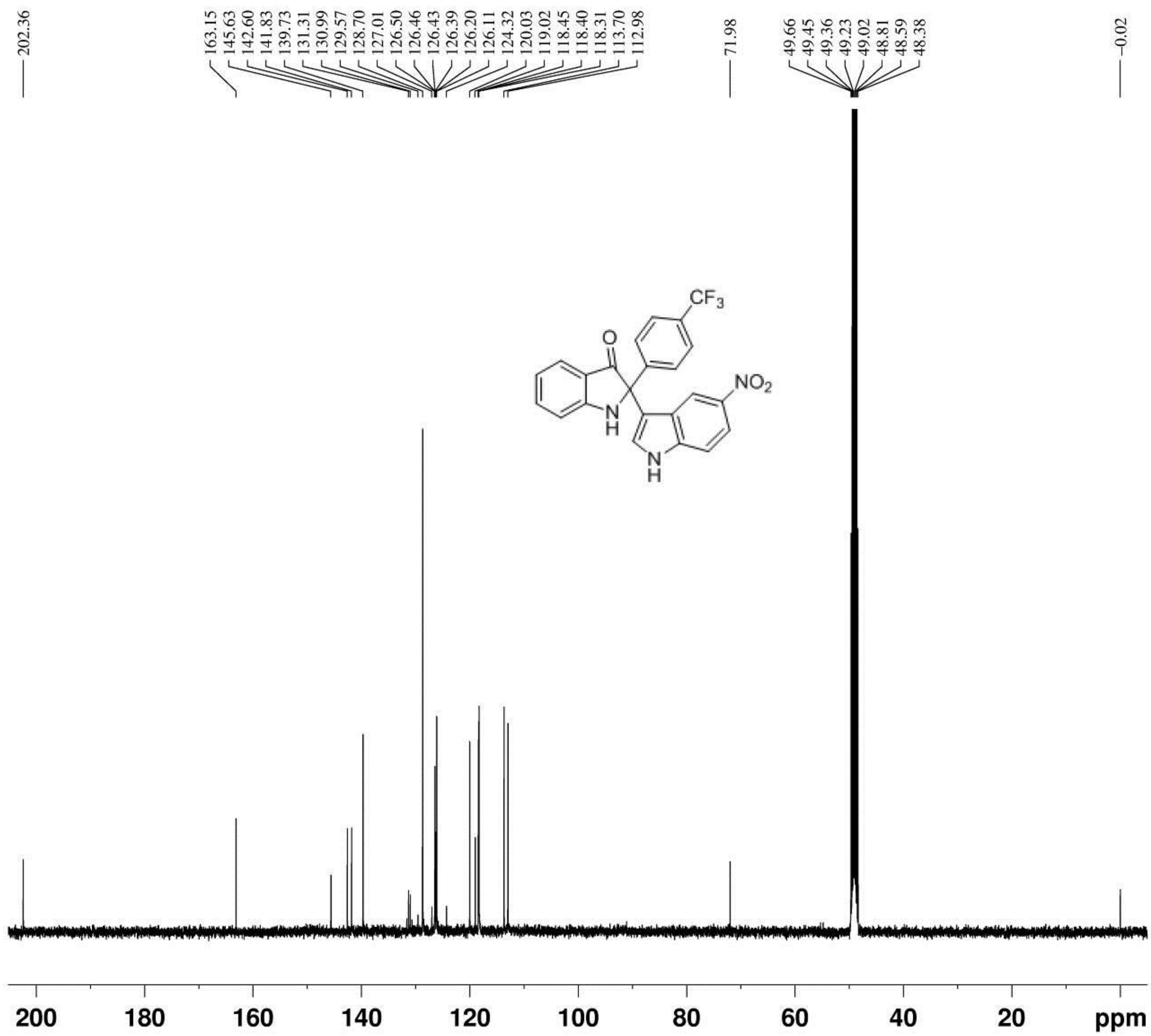


199.98
161.47
140.91
140.63
139.10
138.74
133.01
128.97
128.88
128.43
125.32
124.99
118.63
117.54
117.45
117.40
117.12
112.95
112.61
70.21
40.55
40.34
40.13
39.92
39.71
39.51
39.30
Cl
O
NO2
N
H
N
H
200
180
160
140
120
100
80
60
40
20
ppm

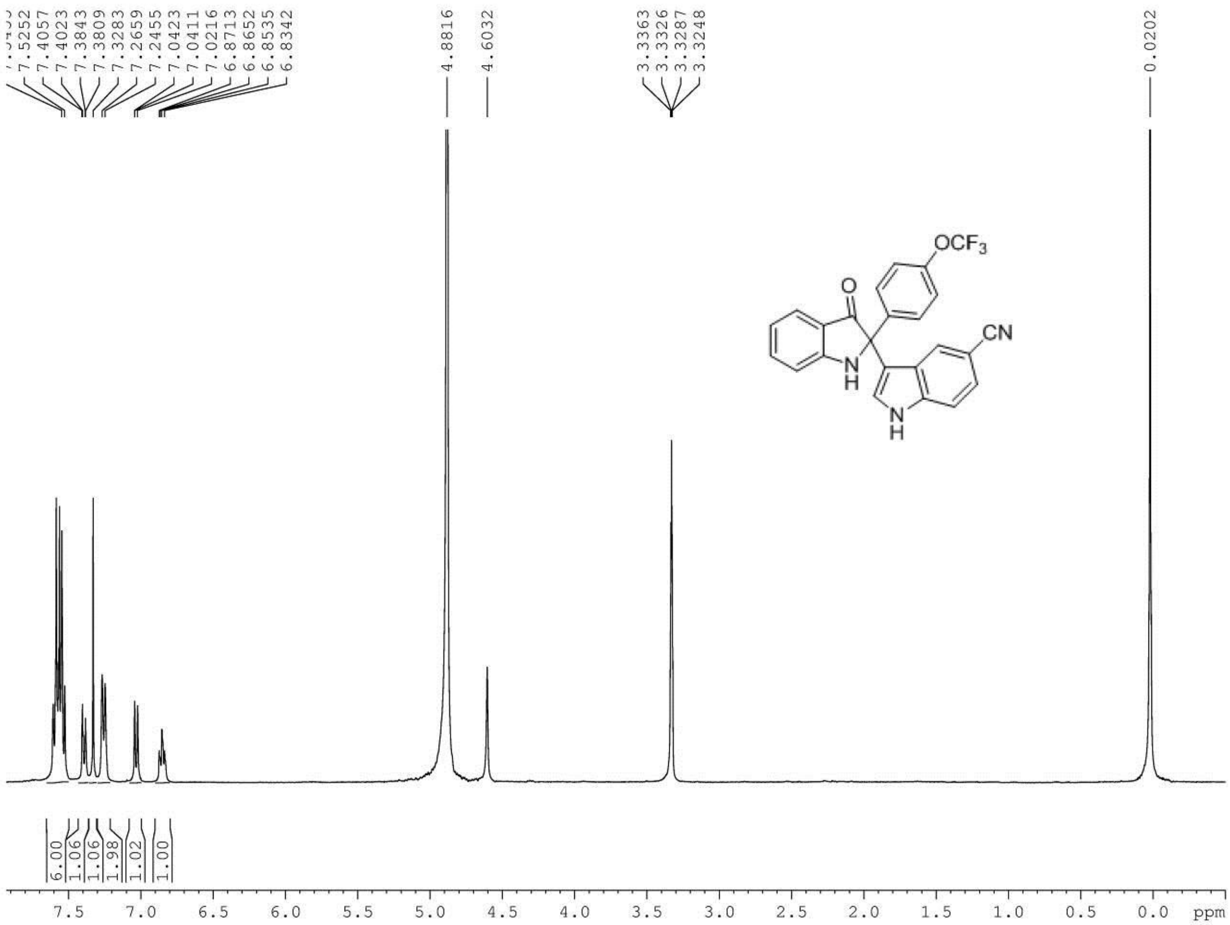
5k: ^{1}H NMR



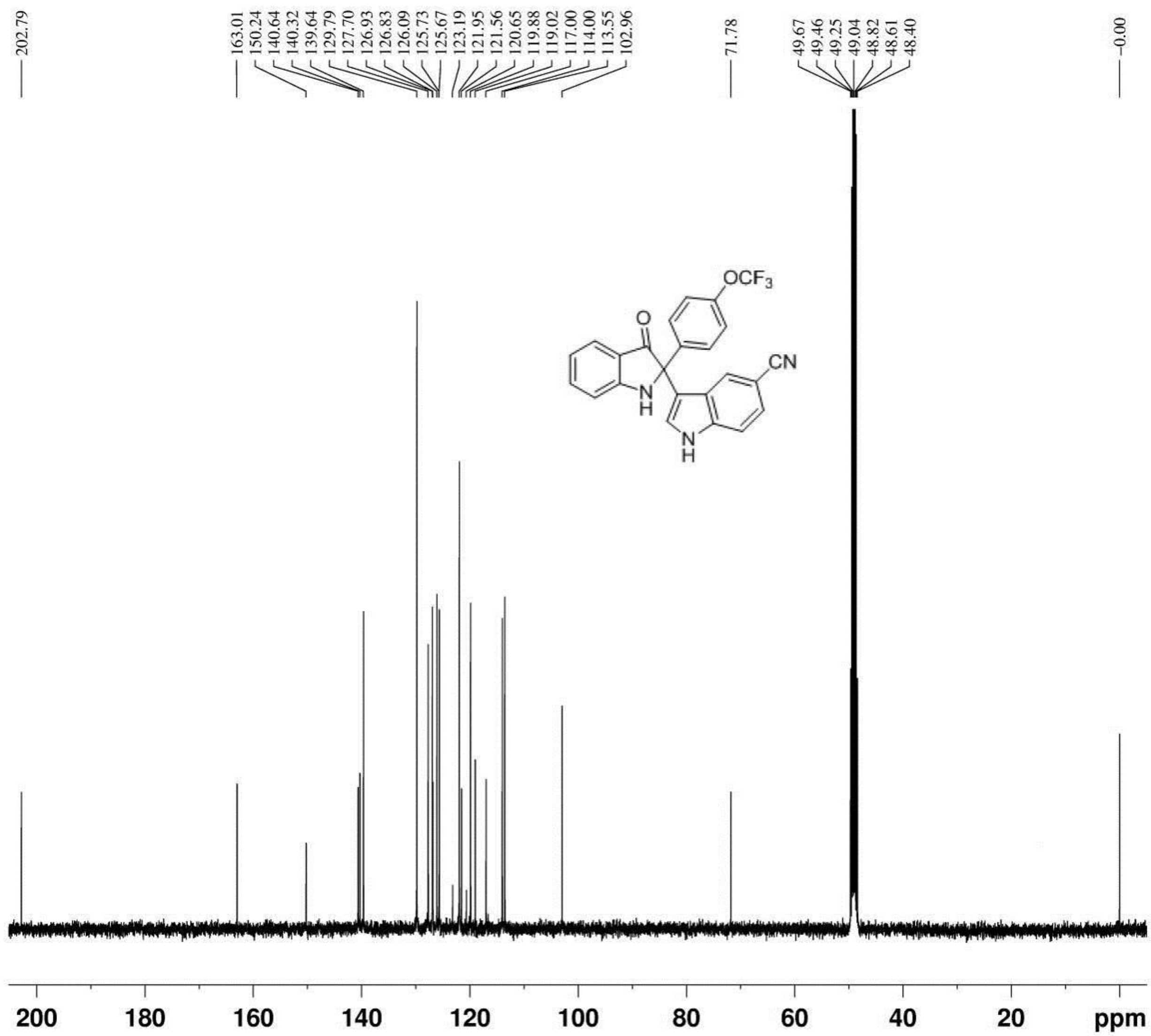
5k: ^{13}C NMR


202.36
163.15
145.63
142.60
141.83
139.73
131.31
130.99
129.57
128.70
127.01
126.50
126.46
126.43
126.39
126.20
126.11
124.32
120.03
119.02
118.45
118.40
118.31
113.70
112.98
71.98
49.66
49.45
49.36
49.23
49.02
48.81
48.59
48.38
-0.02
CF3
O
NO2
N H
N H
200
180
160
140
120
100
80
60
40
20
ppm

5l: ^{1}H NMR

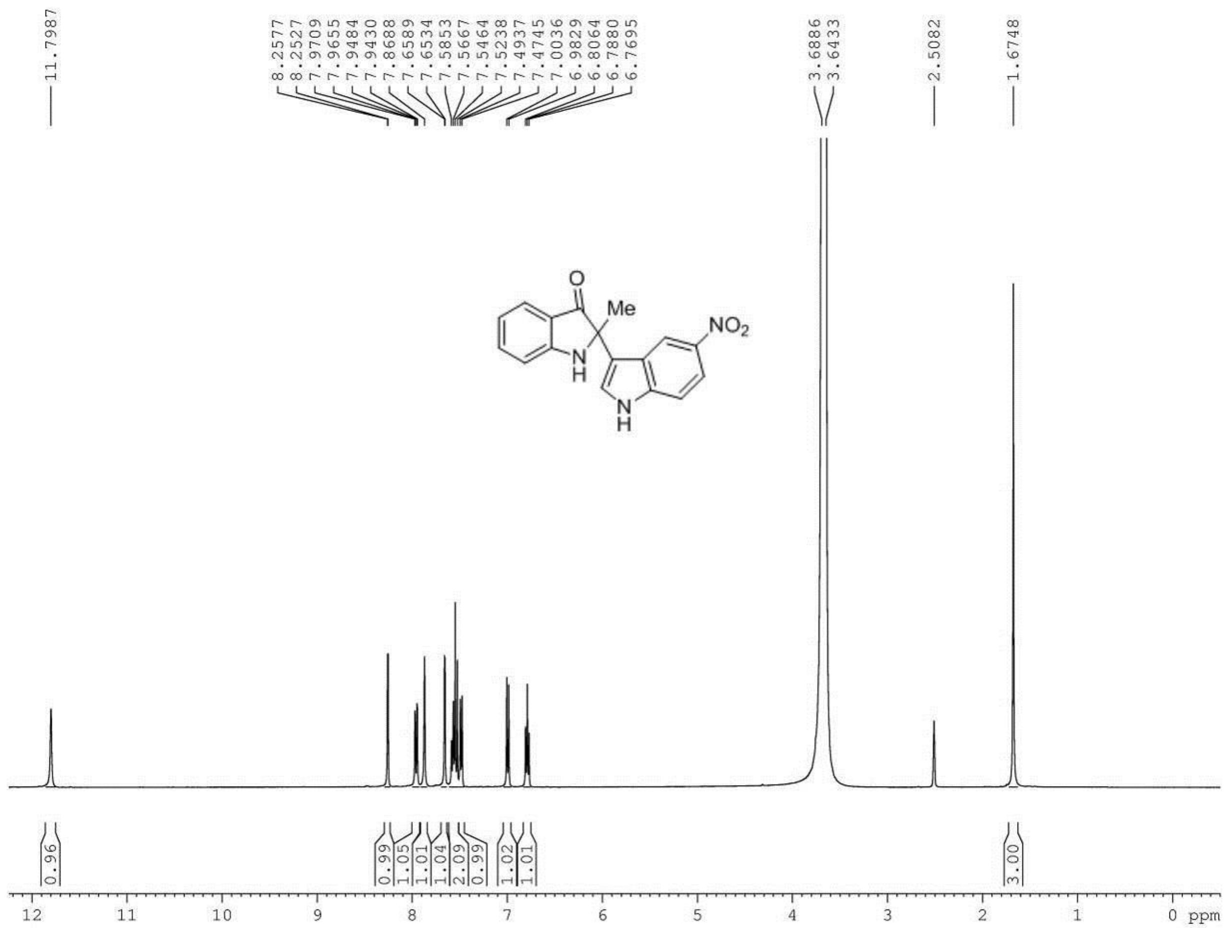

7.5252
7.4057
7.4023
7.3843
7.3809
7.3283
7.2659
7.2455
7.0423
7.0411
7.0216
6.8713
6.8652
6.8535
6.8342
4.8816
4.6032
3.3363
3.3326
3.3287
3.3248
0.0202
OCF3
O
CN
N
H
N
H
6.00
1.06
1.06
1.98
1.02
1.00
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ppm

5l: ^{13}C NMR



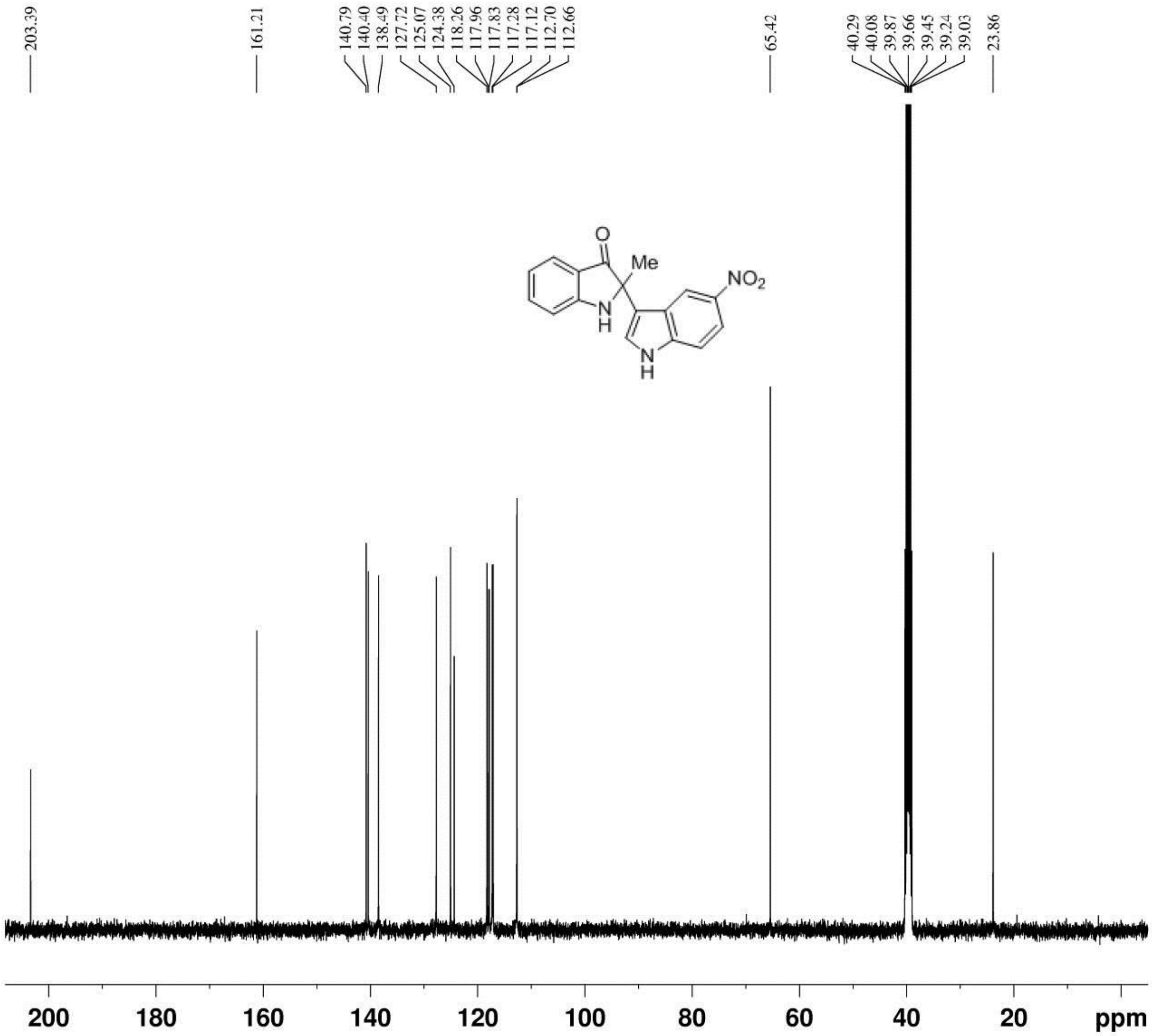
202.79
163.01
150.24
140.64
140.32
139.64
129.79
127.70
126.93
126.83
126.09
125.73
125.67
123.19
121.95
121.56
120.65
119.88
119.02
117.00
114.00
113.55
102.96
71.78
49.67
49.46
49.25
49.04
48.82
48.61
48.40
-0.00
OCF3
O
CN
N
H
N
H
200
180
160
140
120
100
80
60
40
20
ppm

5m: ¹H NMR

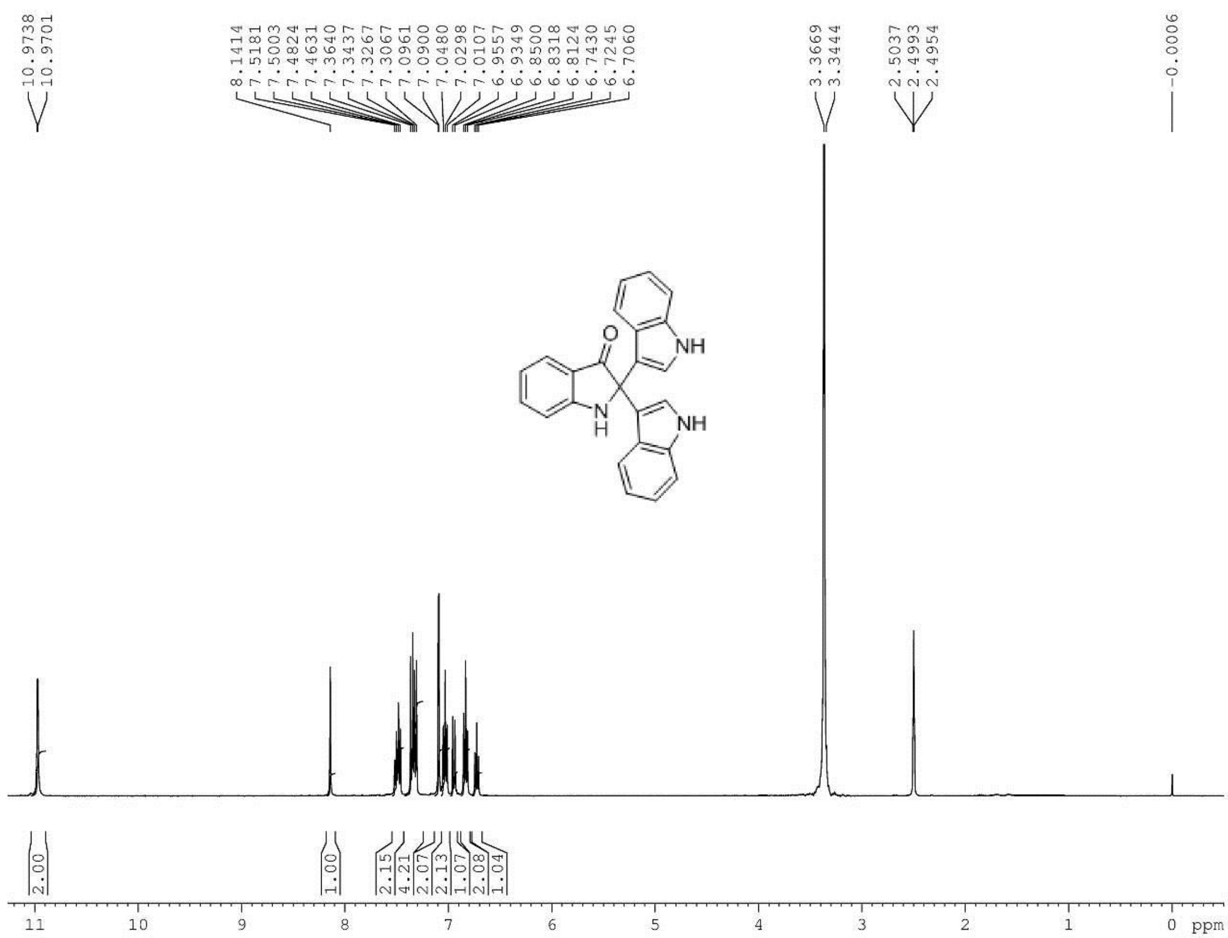


11.7987
8.2577
8.2527
7.9709
7.9655
7.9484
7.9430
7.8688
7.6589
7.6534
7.5853
7.5667
7.5464
7.5238
7.4937
7.4745
7.0036
6.9829
6.8064
6.7880
6.7695
3.6886
3.6433
2.5082
1.6748
O
Me
NO2
N
H
N
H
0.96
0.99
1.05
1.01
1.04
2.09
0.99
1.02
1.01
3.00
12
11
10
9
8
7
6
5
4
3
2
1
0 ppm

5m: ^{13}C NMR

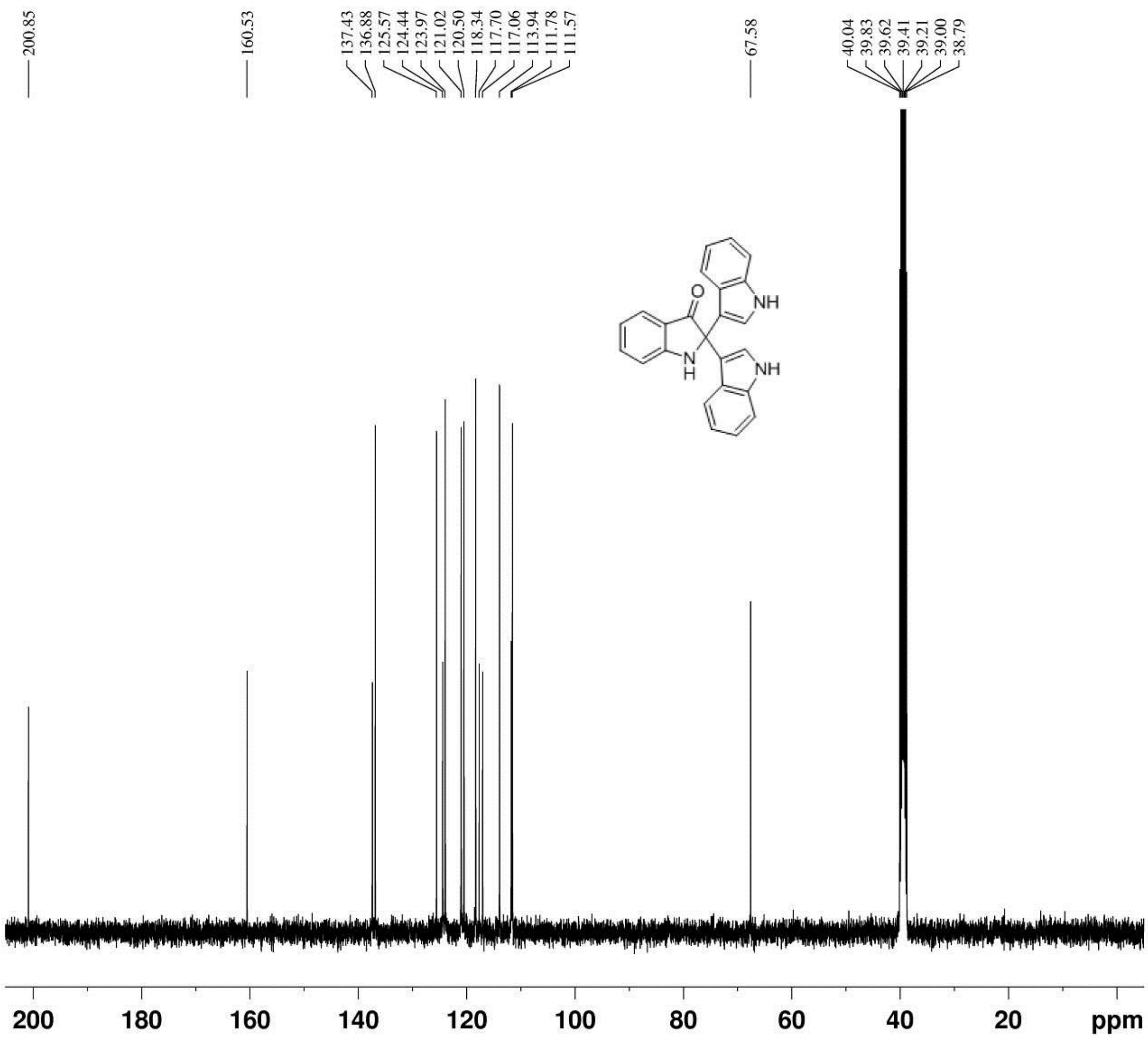

203.39
161.21
140.79
140.40
138.49
127.72
125.07
124.38
118.26
117.96
117.83
117.28
117.12
112.70
112.66
65.42
40.29
40.08
39.87
39.66
39.45
39.24
39.03
23.86
O
Me
NO2
N
H
N
H
200
180
160
140
120
100
80
60
40
20
ppm

2a: ^{1}H NMR

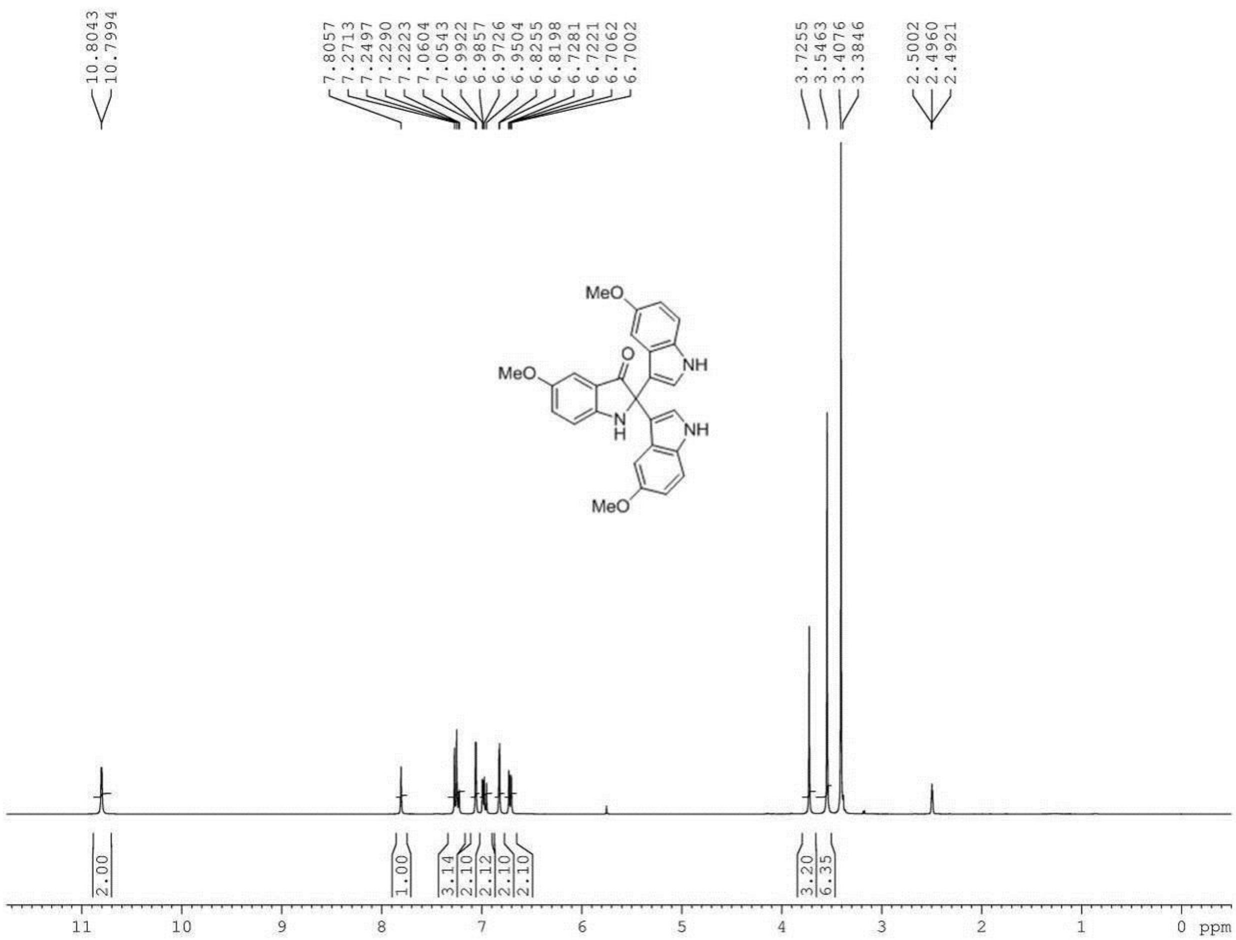


10.9738
10.9701
8.1414
7.5181
7.5003
7.4824
7.4631
7.3640
7.3437
7.3267
7.3067
7.0961
7.0900
7.0480
7.0298
7.0107
6.9557
6.9349
6.8500
6.8318
6.8124
6.7430
6.7245
6.7060
3.3669
3.3444
2.5037
2.4993
2.4954
-0.0006
O
NH
NH
N
H
2.00
1.00
2.15
4.21
2.07
2.13
1.07
2.08
1.04
11
10
9
8
7
6
5
4
3
2
1
0 ppm

2a: ^{13}C NMR

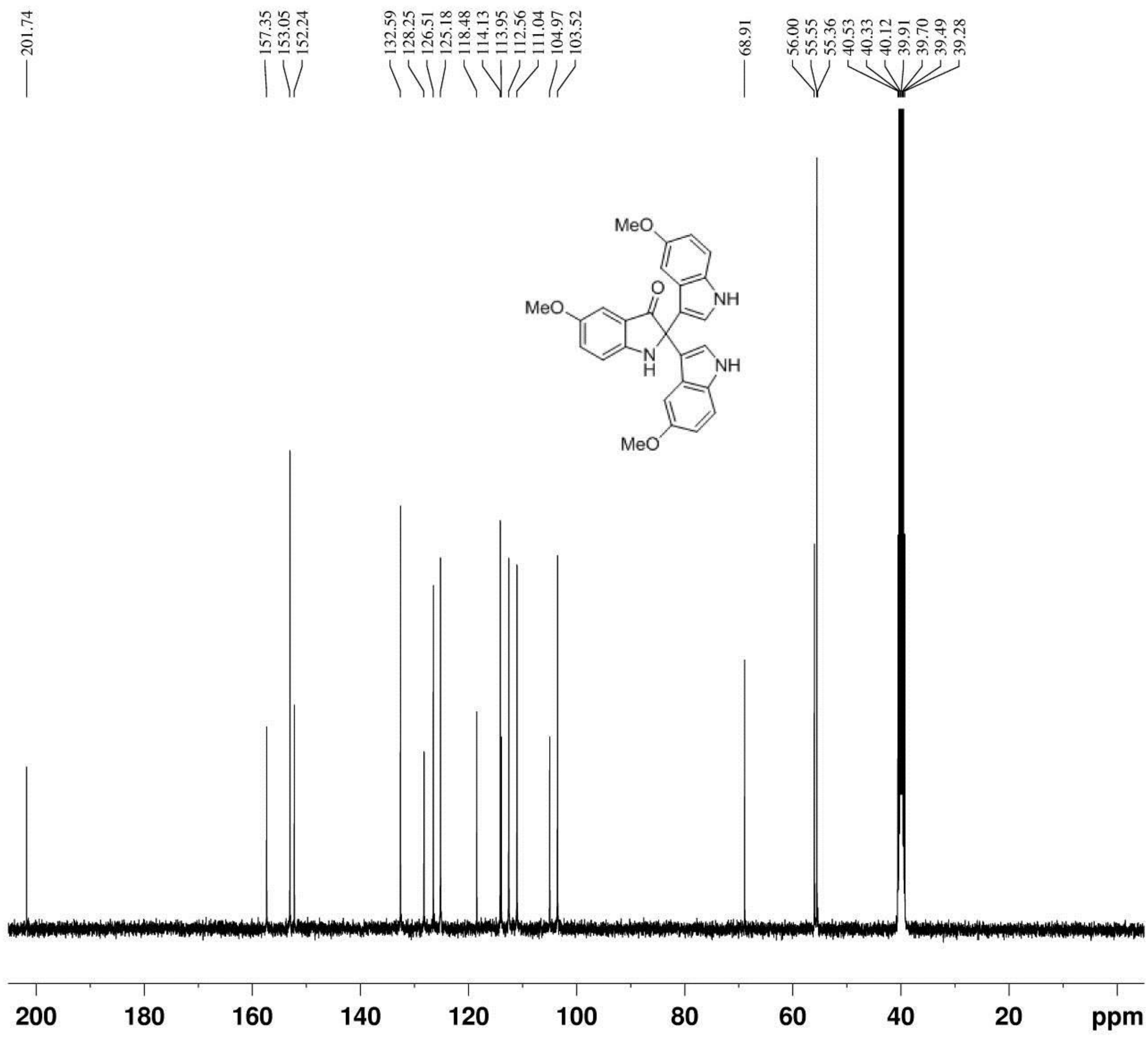

200.85
160.53
137.43
136.88
125.57
124.44
123.97
121.02
120.50
118.34
117.70
117.06
113.94
111.78
111.57
67.58
40.04
39.83
39.62
39.41
39.21
39.00
38.79
O
NH
N
H
NH
200
180
160
140
120
100
80
60
40
20
ppm

2b: ^{1}H NMR

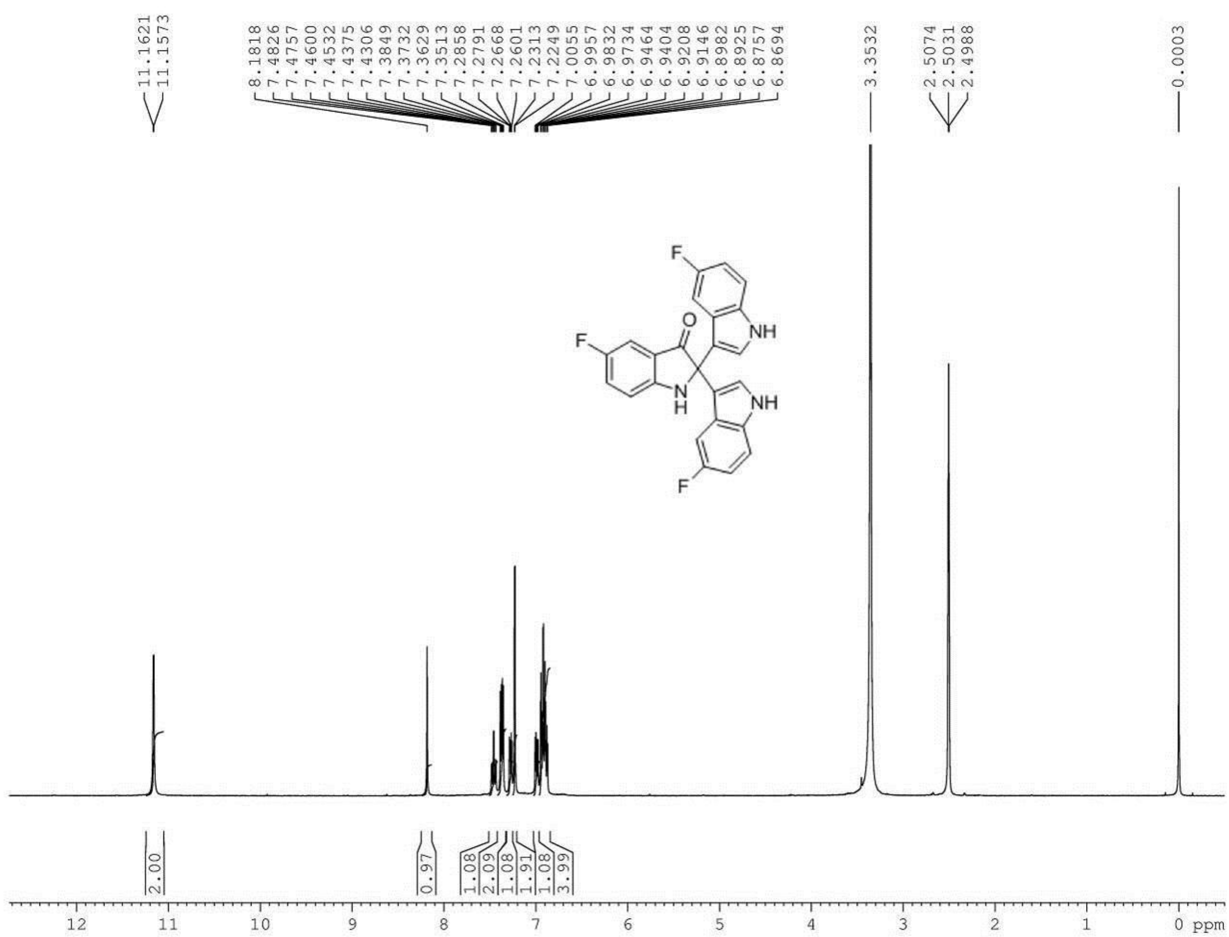


10.8043
10.7994
7.8057
7.2713
7.2497
7.2290
7.2223
7.0604
7.0543
6.9922
6.9857
6.9726
6.9504
6.8255
6.8198
6.7281
6.7221
6.7062
6.7002
3.7255
3.5463
3.4076
3.3846
2.5002
2.4960
2.4921
MeO
MeO
MeO
O
NH
NH
N
H
2.00
1.00
3.14
2.10
2.12
2.10
2.10
3.20
6.35
11
10
9
8
7
6
5
4
3
2
1
0 ppm

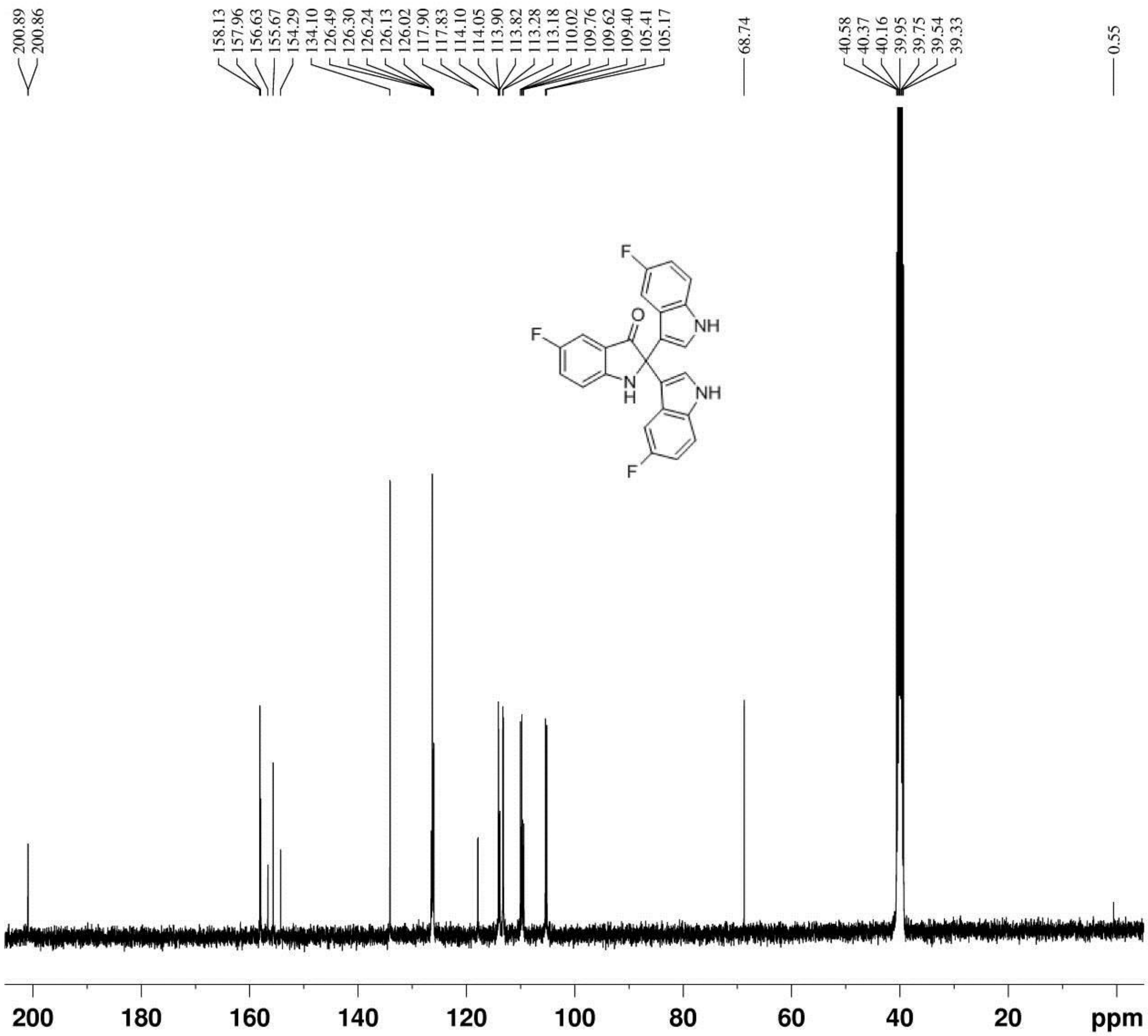
2b: ^{13}C NMR


201.74
157.35
153.05
152.24
132.59
128.25
126.51
125.18
118.48
114.13
113.95
112.56
111.04
104.97
103.52
68.91
56.00
55.55
55.36
40.53
40.33
40.12
39.91
39.70
39.49
39.28
MeO
MeO
O
NH
NH
N
H
MeO
200
180
160
140
120
100
80
60
40
20
ppm

2c: ^{1}H NMR

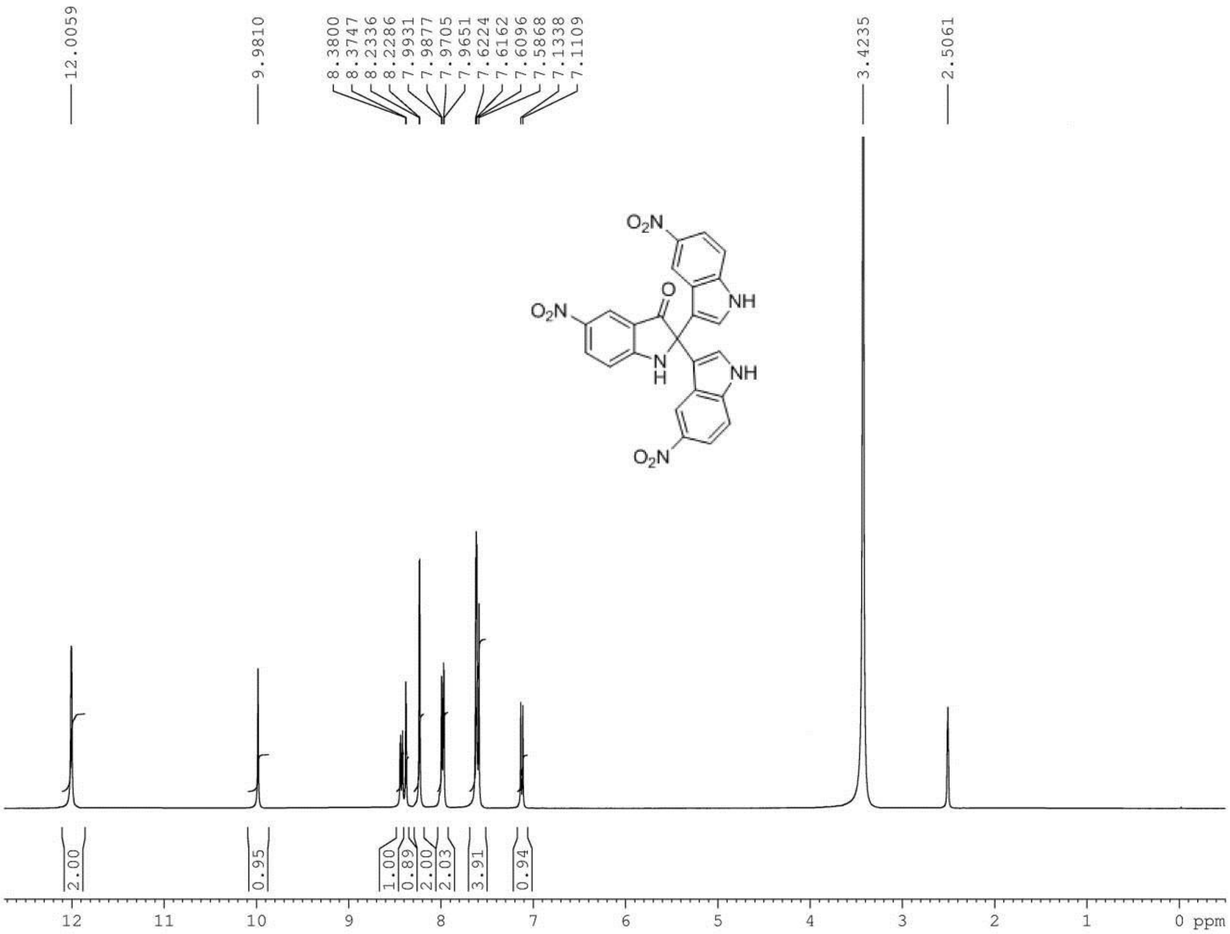


2c: ^{13}C NMR

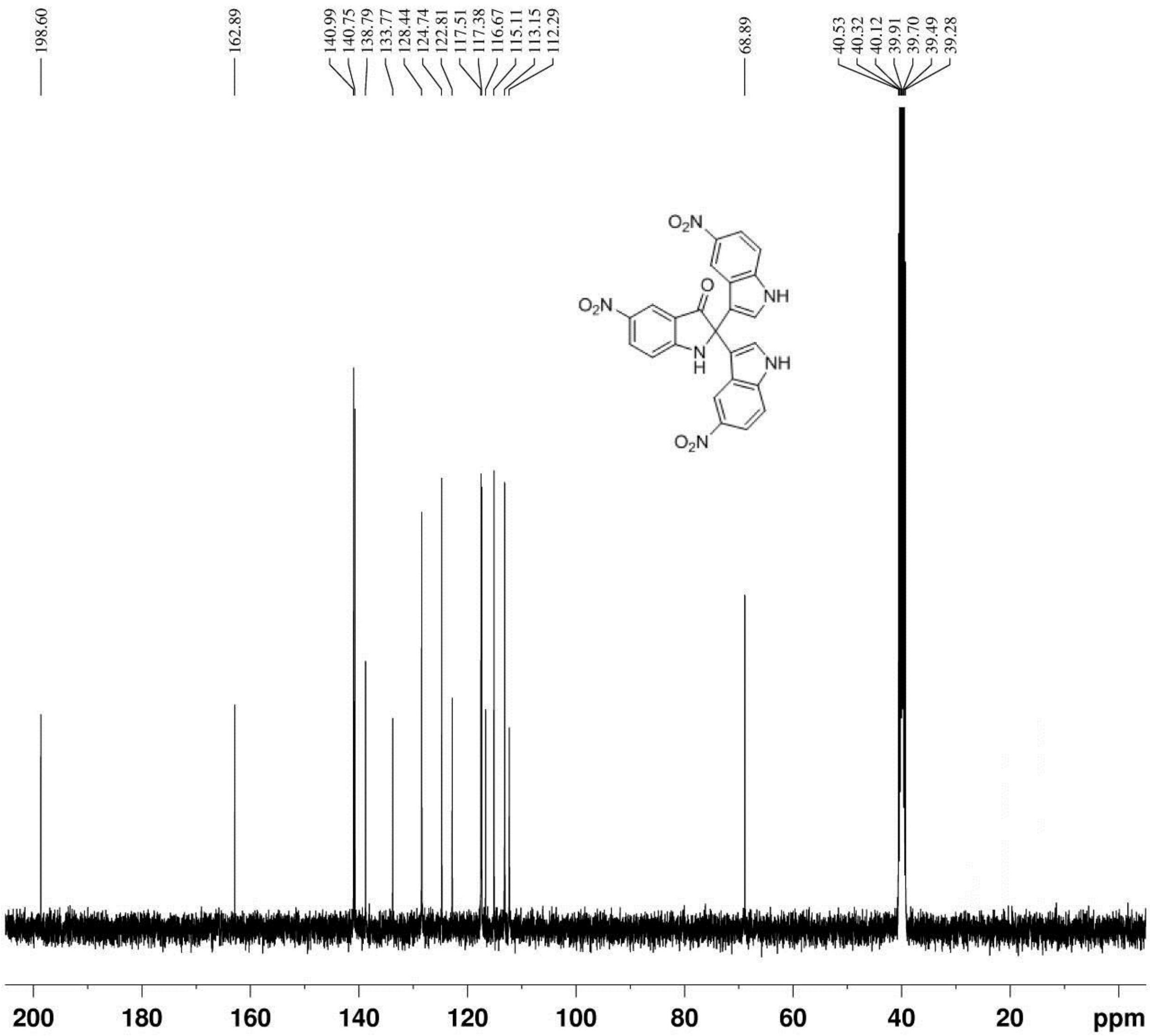


200.89
200.86
158.13
157.96
156.63
155.67
154.29
134.10
126.49
126.30
126.24
126.13
126.02
117.90
117.83
114.10
114.05
113.90
113.82
113.28
113.18
110.02
109.76
109.62
109.40
105.41
105.17
68.74
40.58
40.37
40.16
39.95
39.75
39.54
39.33
0.55
F
F
O
NH
N
H
NH
F
200
180
160
140
120
100
80
60
40
20
ppm

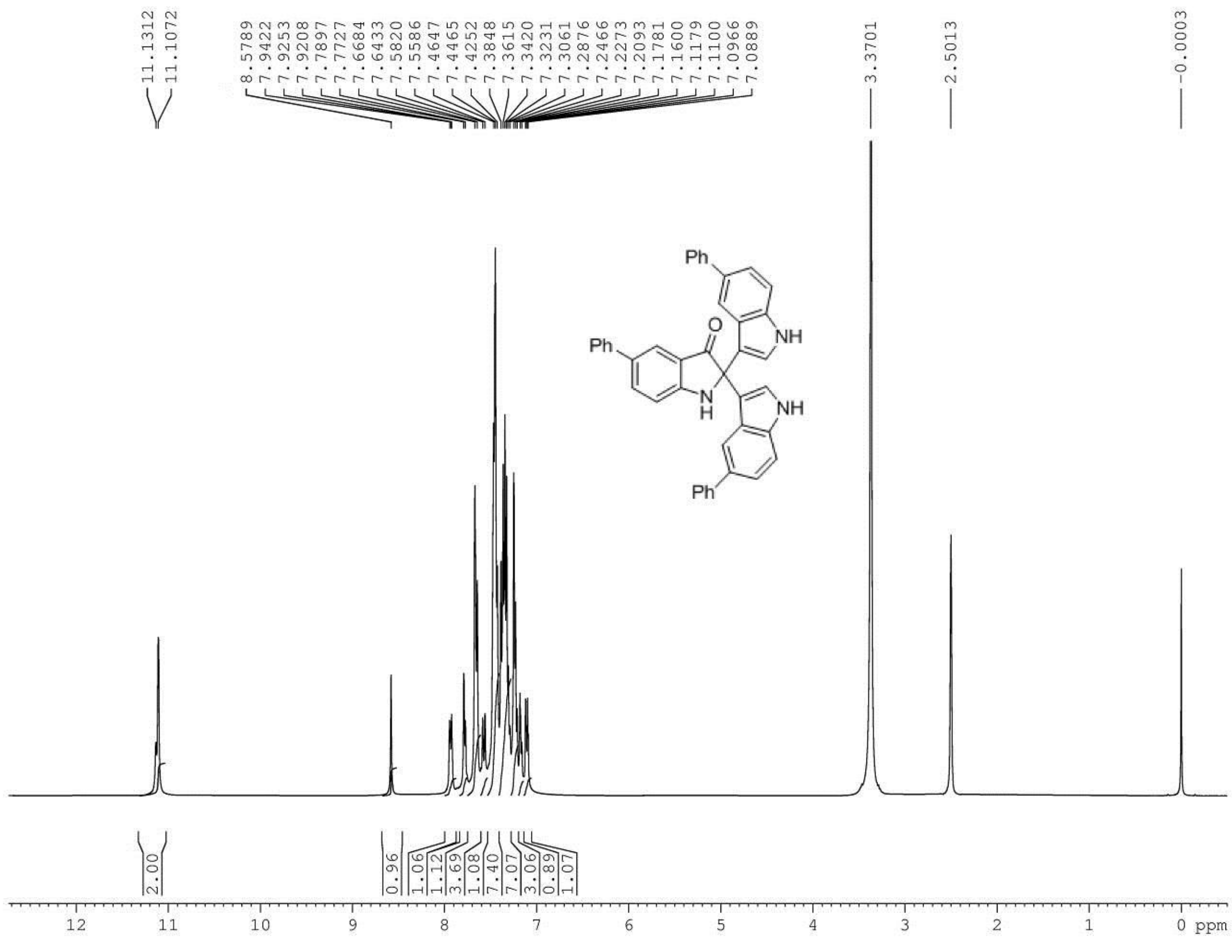
2d: ^{1}H NMR


12.0059
9.9810
8.3800
8.3747
8.2336
8.2286
7.9931
7.9877
7.9705
7.9651
7.6224
7.6162
7.6096
7.5868
7.1338
7.1109
3.4235
2.5061
O2N
O
NH
O2N
N
H
NH
O2N
2.00
0.95
1.00
0.89
2.00
2.03
3.91
0.94
12
11
10
9
8
7
6
5
4
3
2
1
0 ppm

2d: ^{13}C NMR

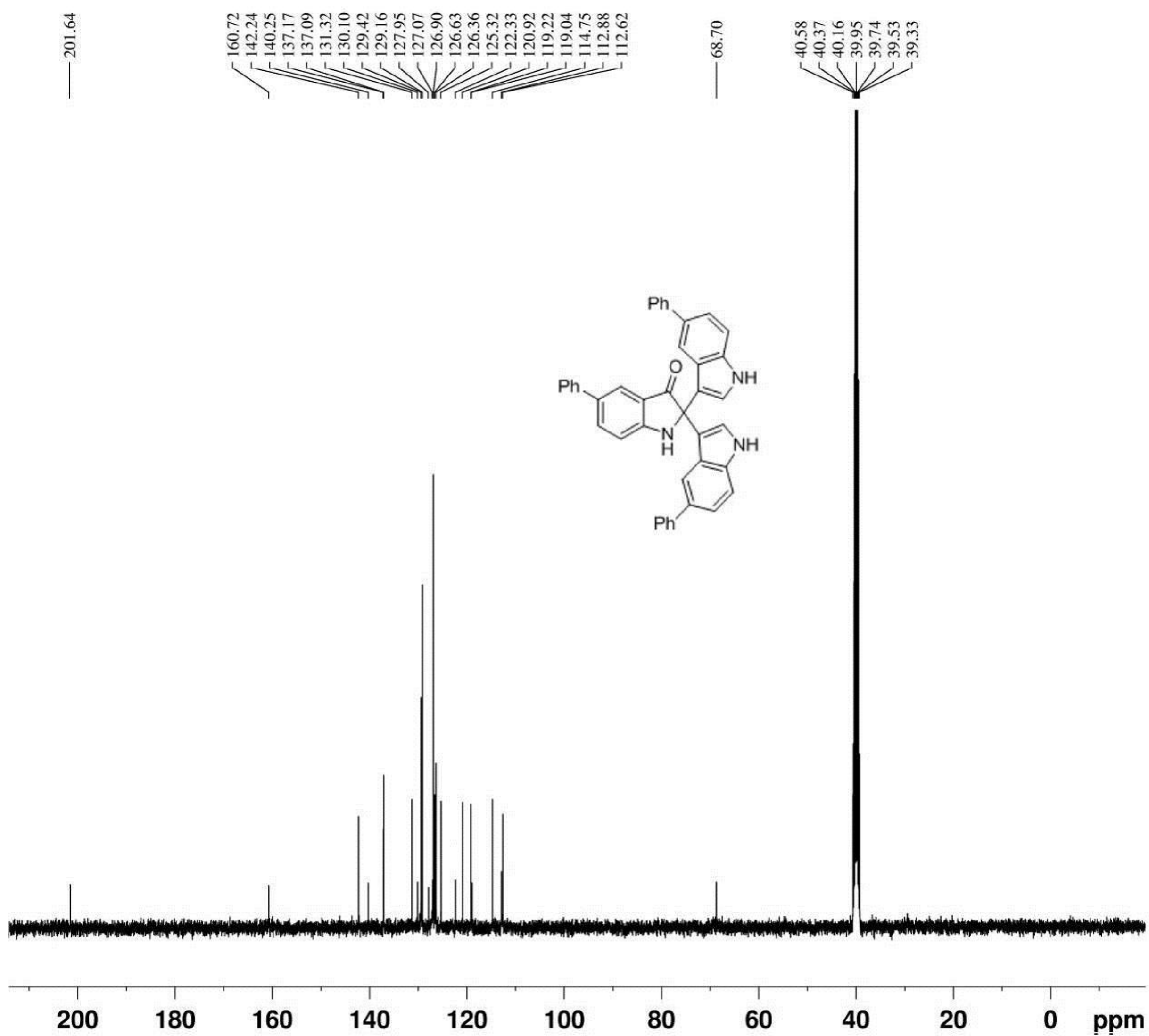

198.60
162.89
140.99
140.75
138.79
133.77
128.44
124.74
122.81
117.51
117.38
116.67
115.11
113.15
112.29
68.89
40.53
40.32
40.12
39.91
39.70
39.49
39.28
O_2N
O_2N
O_2N
O
NH
NH
N
H
200
180
160
140
120
100
80
60
40
20
ppm

2e: ^{1}H NMR



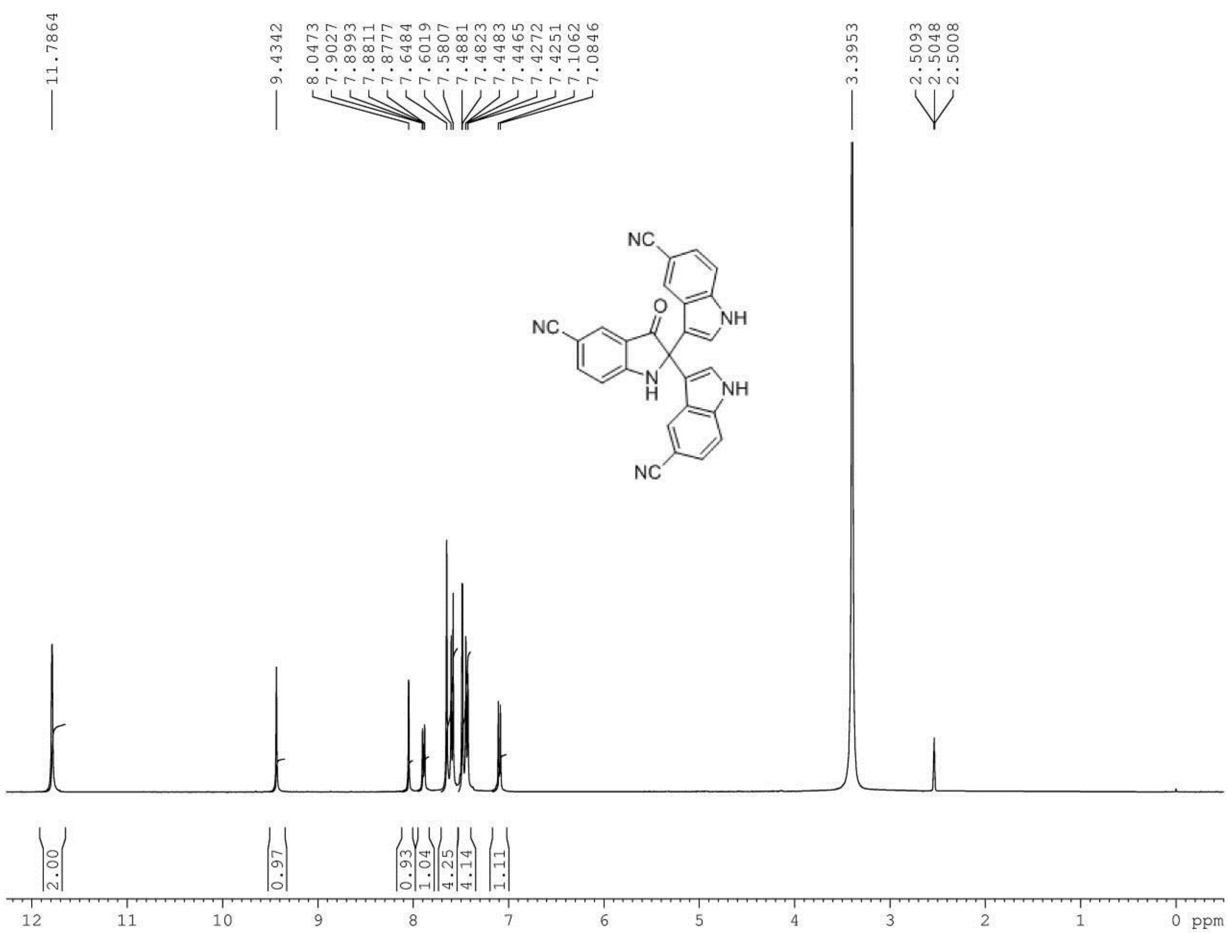
11.1312
11.1072
8.5789
7.9422
7.9253
7.9208
7.7897
7.7727
7.6684
7.6433
7.5820
7.5586
7.4647
7.4465
7.4252
7.3848
7.3615
7.3420
7.3231
7.3061
7.2876
7.2466
7.2273
7.2093
7.1781
7.1600
7.1179
7.1100
7.0966
7.0889
3.3701
2.5013
-0.0003
Ph
O
NH
N
H
2.00
0.96
1.06
1.12
3.69
1.08
7.40
7.07
3.06
0.89
1.07
12
11
10
9
8
7
6
5
4
3
2
1
0 ppm

2e: ^{13}C NMR

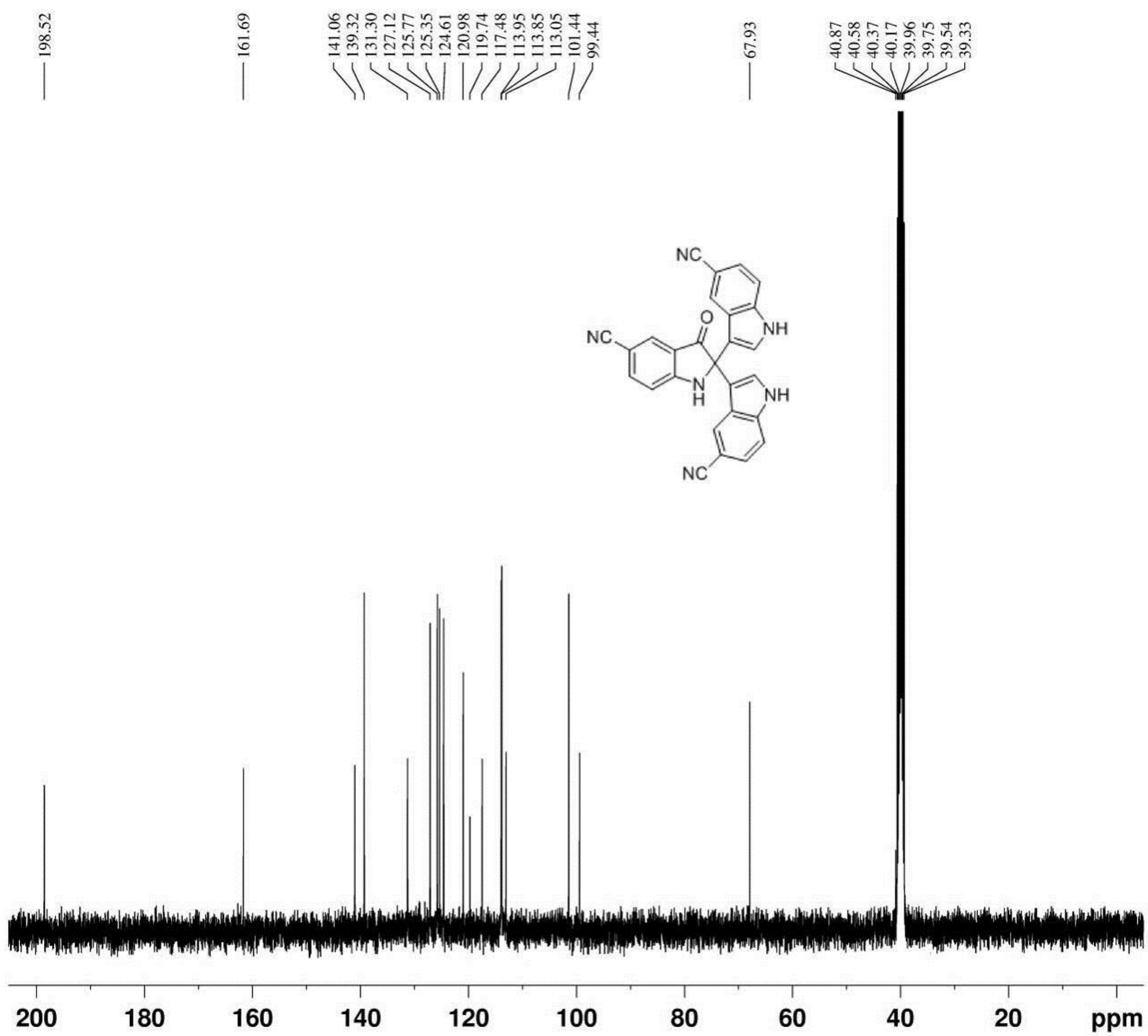


201.64
160.72
142.24
140.25
137.17
137.09
131.32
130.10
129.42
129.16
127.95
127.07
126.90
126.63
126.36
125.32
122.33
120.92
119.22
119.04
114.75
112.88
112.62
68.70
40.58
40.37
40.16
39.95
39.74
39.53
39.33
Ph
O
NH
H
200
180
160
140
120
100
80
60
40
20
0
ppm

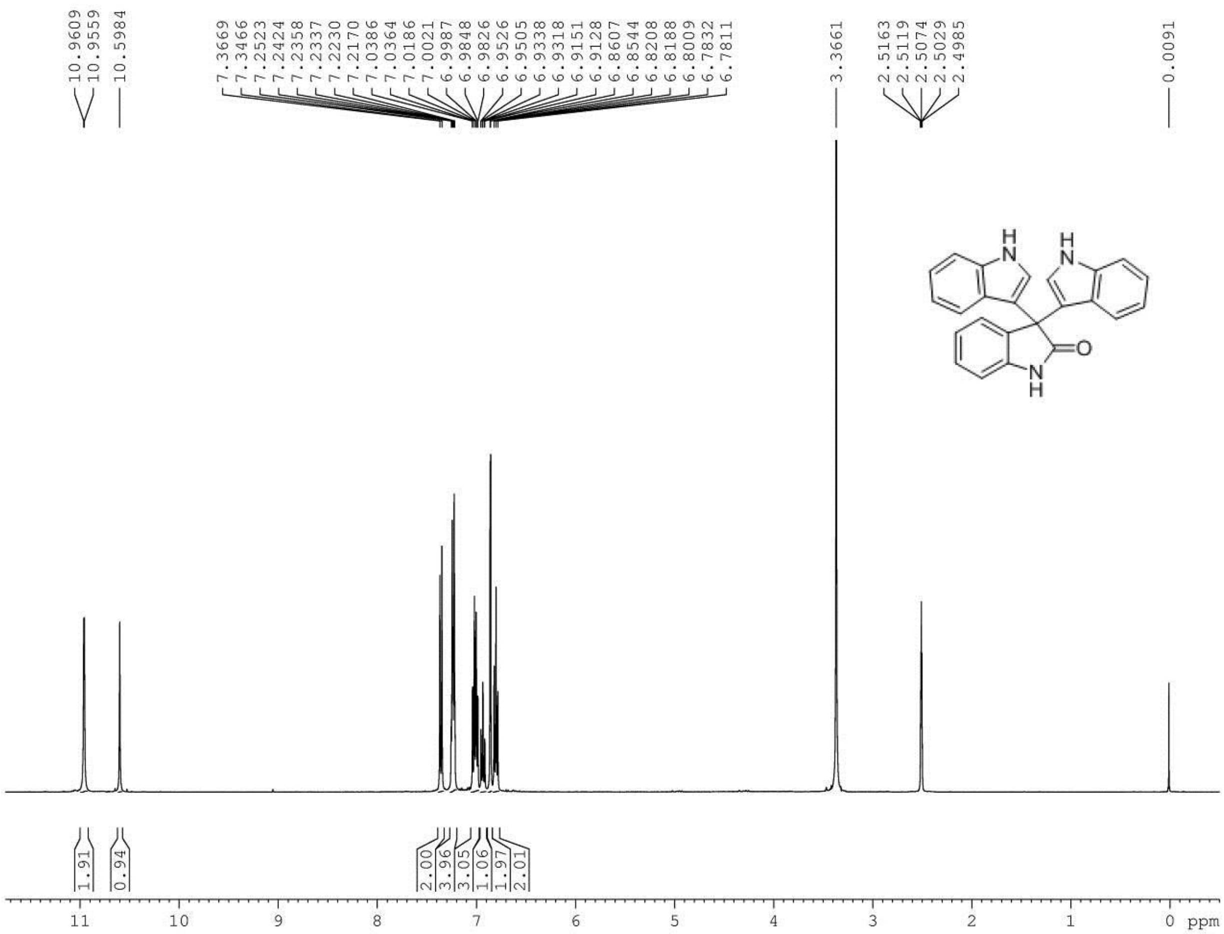
2f: ^{1}H NMR


11.7864
9.4342
8.0473
7.9027
7.8993
7.8811
7.8777
7.6484
7.6019
7.5807
7.4881
7.4823
7.4483
7.4465
7.4272
7.4251
7.1062
7.0846
3.3953
2.5093
2.5048
2.5008
NC
NC
O
NH
N
H
NH
NC
2.00
0.97
0.93
1.04
4.25
4.14
1.11
12
11
10
9
8
7
6
5
4
3
2
1
0 ppm

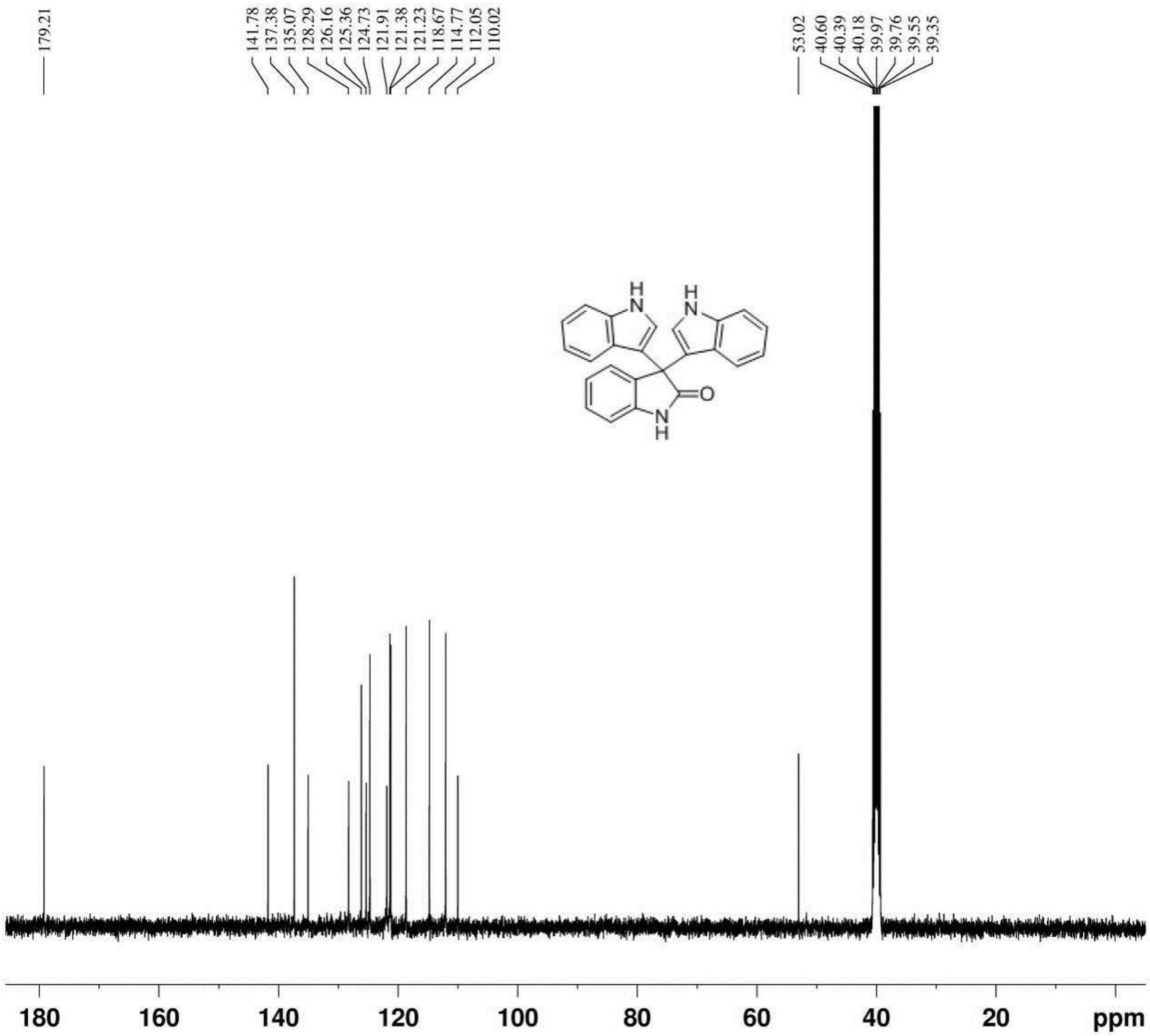
2f: ^{13}C NMR


198.52
161.69
141.06
139.32
131.30
127.12
125.77
125.35
124.61
120.98
119.74
117.48
113.95
113.85
113.05
101.44
99.44
67.93
40.87
40.58
40.37
40.17
39.96
39.75
39.54
39.33
NC
O
NH
NC
N
H
NH
NC
200
180
160
140
120
100
80
60
40
20
ppm

3: ^{1}H NMR

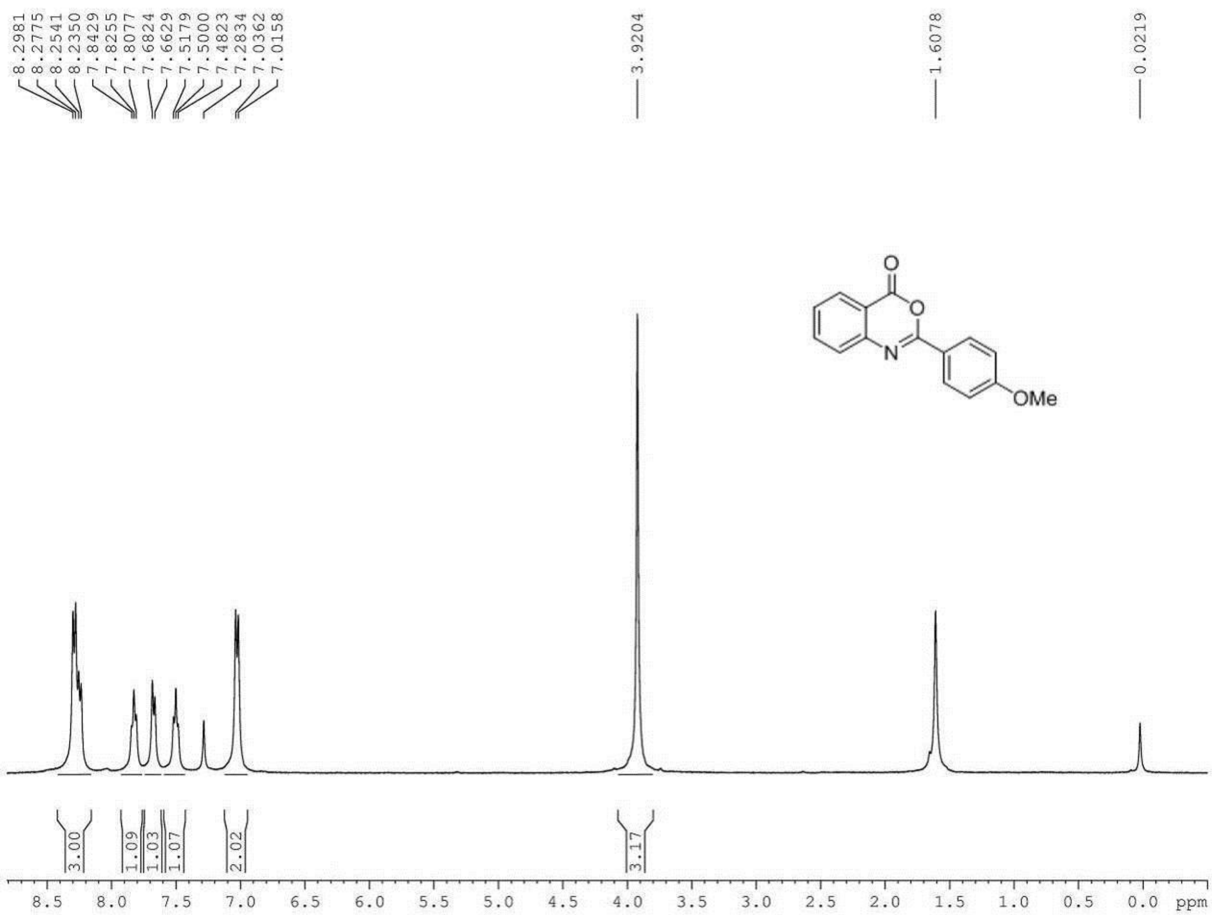

10.9609
10.9559
10.5984
7.3669
7.3466
7.2523
7.2424
7.2358
7.2337
7.2230
7.2170
7.0386
7.0364
7.0186
7.0021
6.9987
6.9848
6.9826
6.9526
6.9505
6.9338
6.9318
6.9151
6.9128
6.8607
6.8544
6.8208
6.8188
6.8009
6.7832
6.7811
3.3661
2.5163
2.5119
2.5074
2.5029
2.4985
0.0091
1.91
0.94
2.00
3.96
3.05
1.06
1.97
2.01
11
10
9
8
7
6
5
4
3
2
1
0 ppm

3: ^{13}C NMR

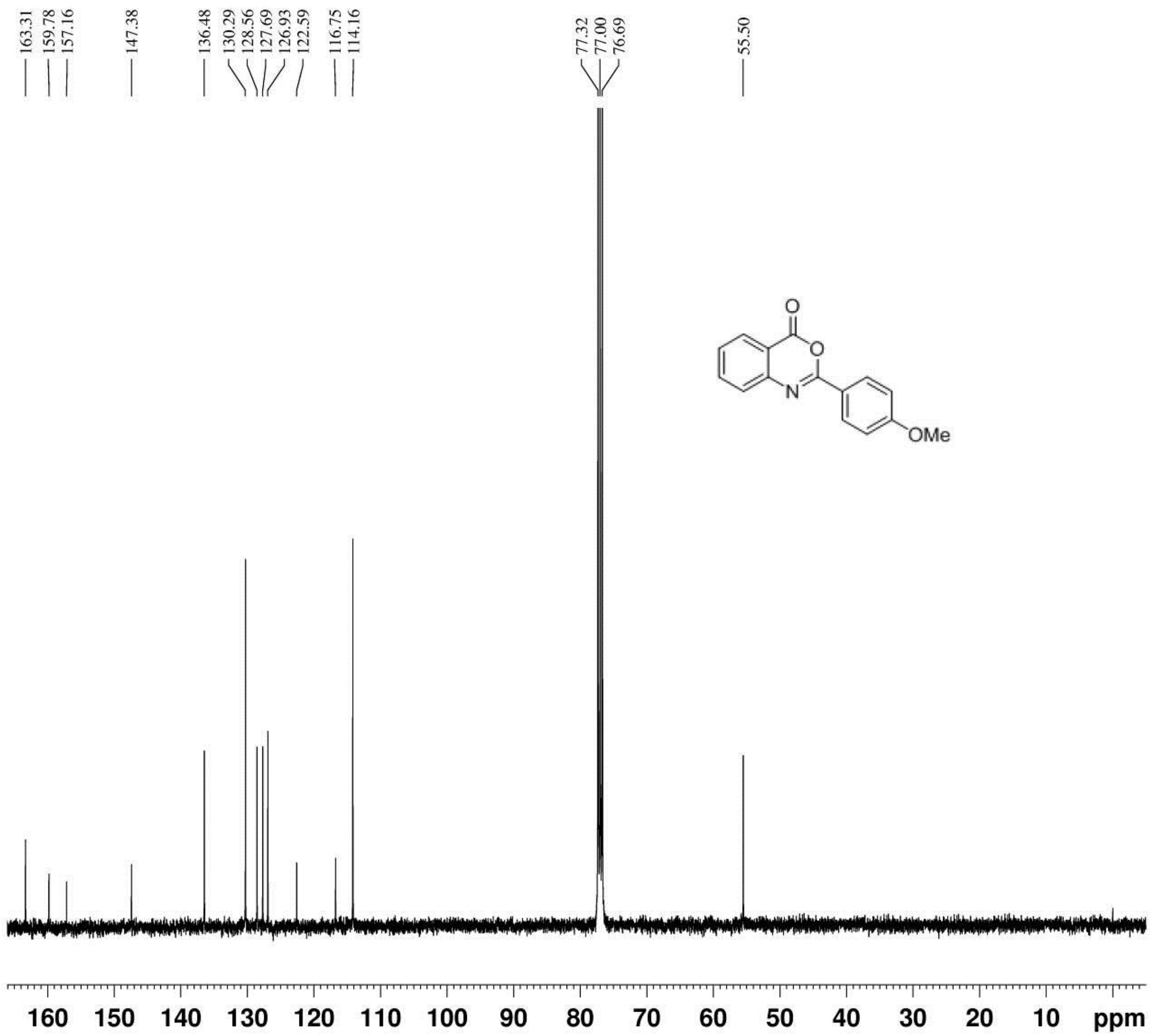


179.21
141.78
137.38
135.07
128.29
126.16
125.36
124.73
121.91
121.38
121.23
118.67
114.77
112.05
110.02
53.02
40.60
40.39
40.18
39.97
39.76
39.55
39.35
H
N
H
N
O
N
H
180
160
140
120
100
80
60
40
20
ppm

6: ^{1}H NMR

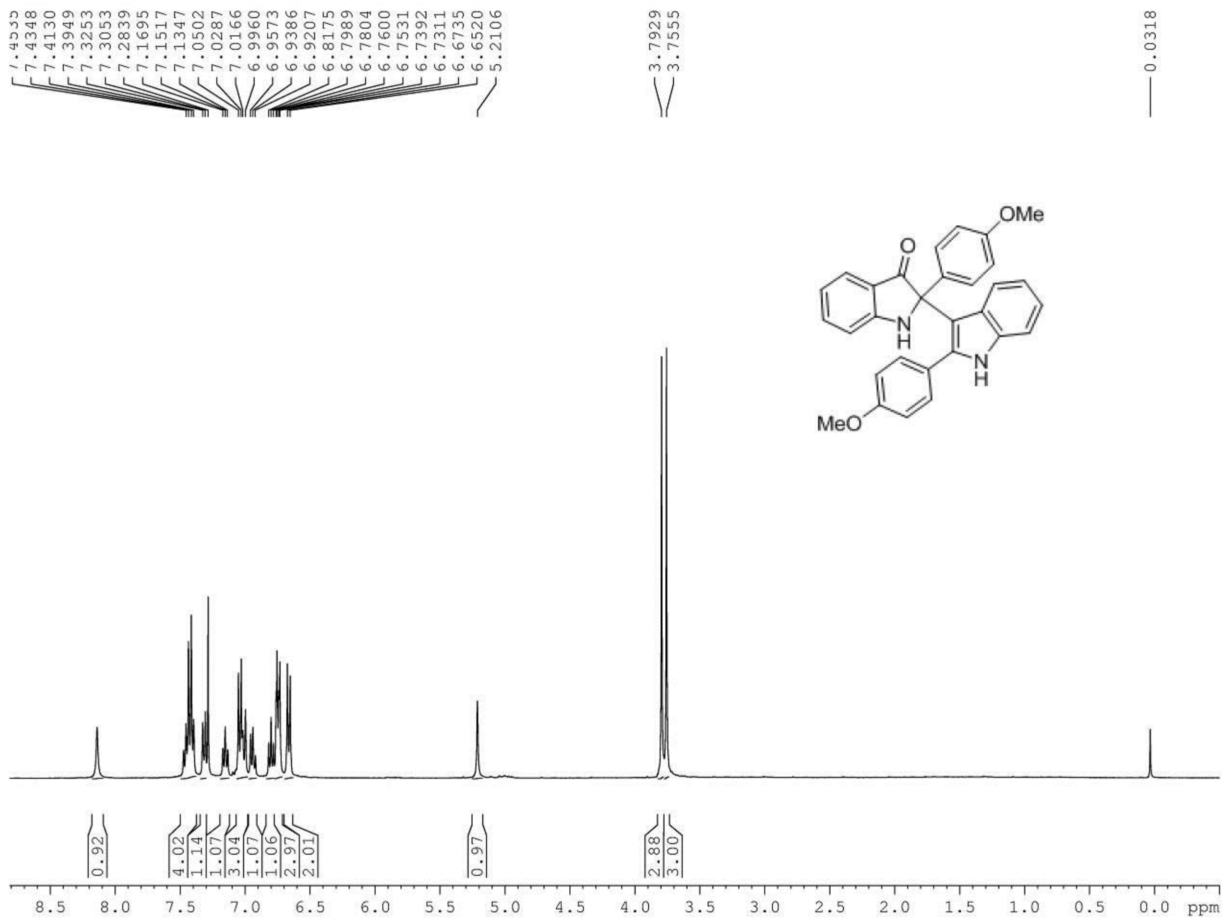

8.2981
8.2775
8.2541
8.2350
7.8429
7.8255
7.8077
7.6824
7.6629
7.5179
7.5000
7.4823
7.2834
7.0362
7.0158
3.9204
1.6078
0.0219
OMe
O
N
3.00
1.09
1.03
1.07
2.02
3.17
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 ppm

6: ^{13}C NMR



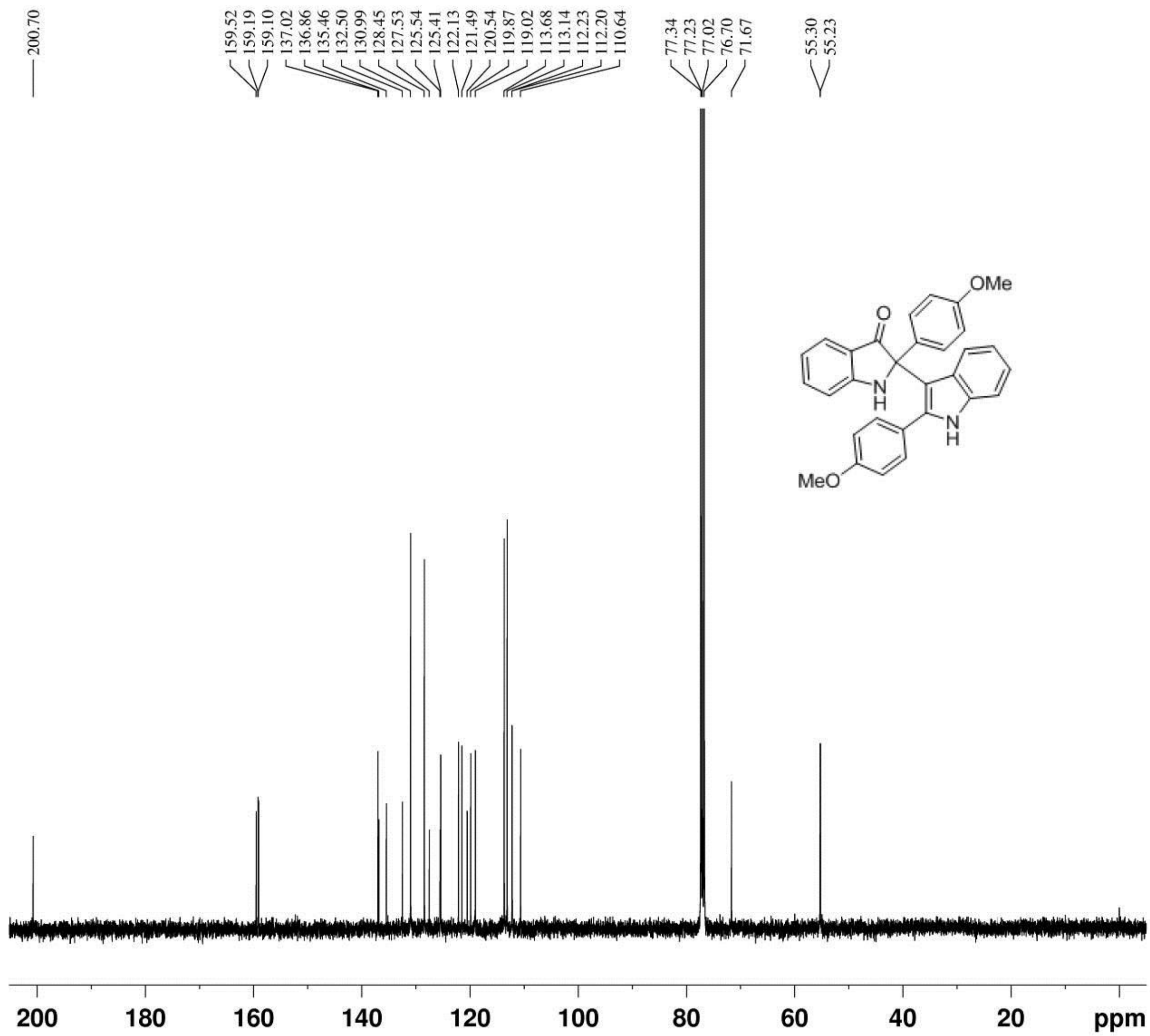
163.31
159.78
157.16
147.38
136.48
130.29
128.56
127.69
126.93
122.59
116.75
114.16
77.32
77.00
76.69
55.50
O
O
N
OMe
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm

7: ^{1}H NMR

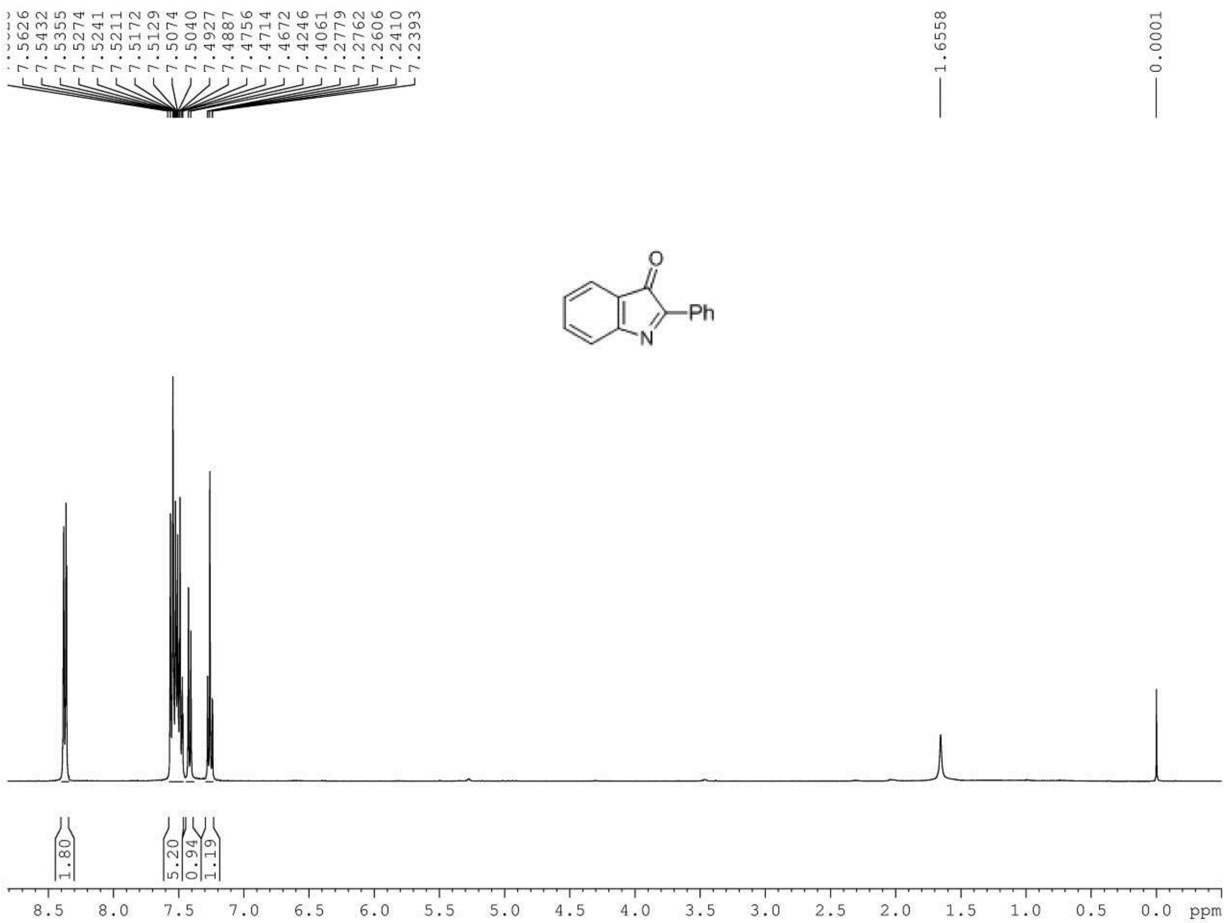


7.4555
7.4348
7.4130
7.3949
7.3253
7.3053
7.2839
7.1695
7.1517
7.1347
7.0502
7.0287
7.0166
6.9960
6.9573
6.9386
6.9207
6.8175
6.7989
6.7804
6.7600
6.7531
6.7392
6.7311
6.6735
6.6520
5.2106
3.7929
3.7555
0.0318
OMe
O
N
H
NH
MeO
0.92
4.02
1.14
1.07
3.04
1.07
1.06
2.97
2.01
0.97
2.88
3.00
8.5
8.0
7.5
7.0
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
ppm

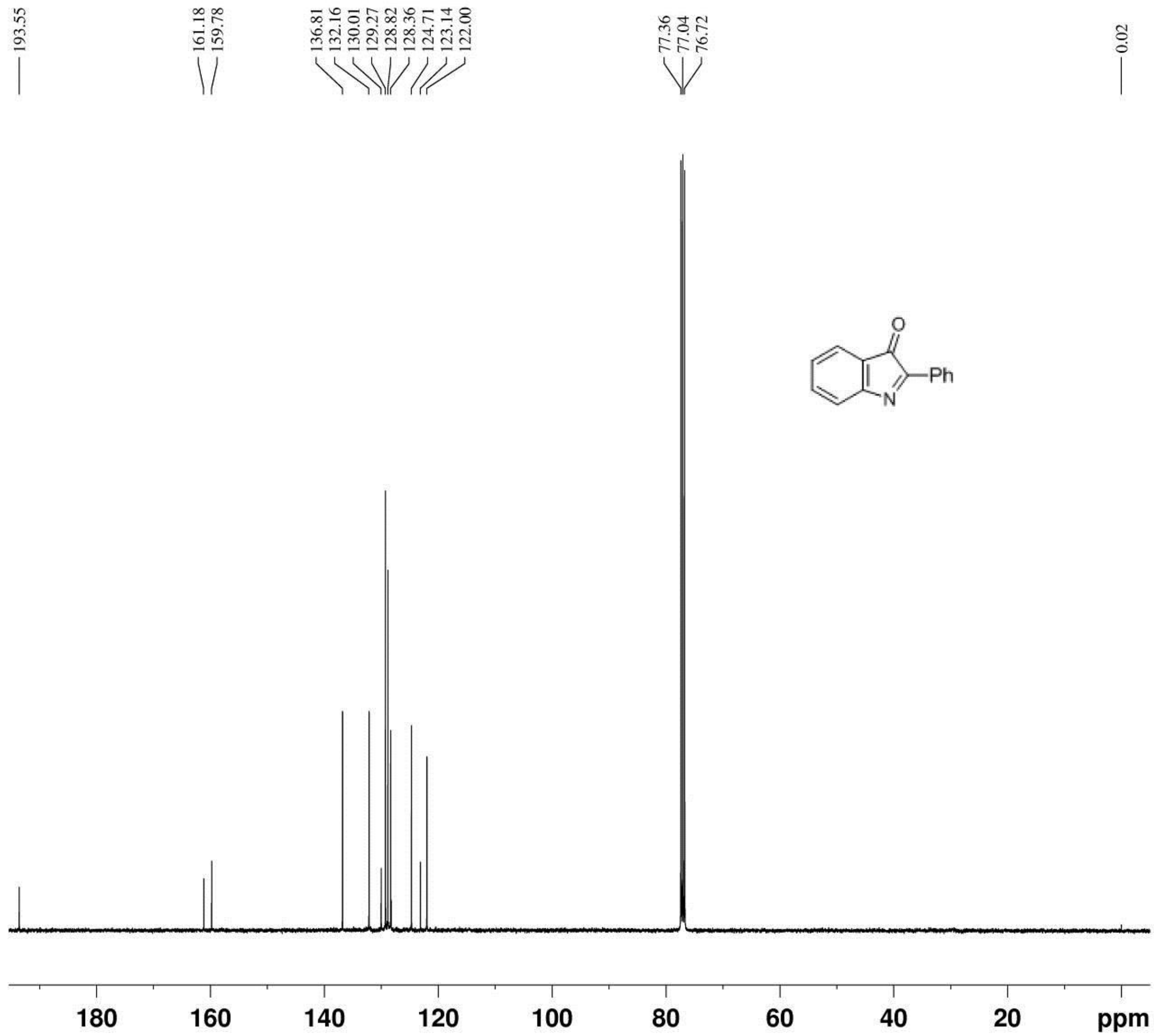
7: ^{13}C NMR


200.70
159.52
159.19
159.10
137.02
136.86
135.46
132.50
130.99
128.45
127.53
125.54
125.41
122.13
121.49
120.54
119.87
119.02
113.68
113.14
112.23
112.20
110.64
77.34
77.23
77.02
76.70
71.67
55.30
55.23
200
180
160
140
120
100
80
60
40
20
ppm
OMe
O
N
H
N
H
MeO

8: ^{1}H NMR



8: ^{13}C NMR



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