

## Supporting Information

### Synthesis of Tetracyclic Indenopyrazolopyrazolones through Cascade Reactions of Aryl Azomethine Imines with Propargyl Alcohols

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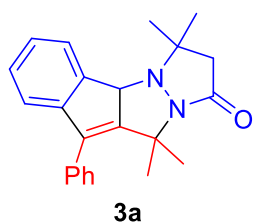
## I. General experimental information

Commercial reagents were used without further purification. 2-Benzylidene-3,3-dimethyl-5-oxopyrazolidin-2-ium-1-ide (**1**)<sup>[1]</sup> and propargyl alcohols (**2**)<sup>[2,3]</sup> were prepared based on literature procedures. [Ru(*p*-cymene)Cl<sub>2</sub>]<sub>2</sub> were from commercial sources. Melting points were recorded with a micro melting point apparatus and uncorrected. The <sup>1</sup>H NMR spectra were recorded at 400 MHz or 600 MHz. The <sup>13</sup>C NMR spectra were recorded at 100 MHz or 150 MHz. The <sup>19</sup>F NMR spectra were recorded at 376 MHz or 565 MHz. Chemical shifts were expressed in parts per million ( $\delta$ ), and were reported as s (singlet), d (doublet), t (triplet), dd (doublet of doublets), m (multiplet), br s (broad singlet), etc. The coupling constants *J* were given in Hz. High resolution mass spectra (HRMS) were obtained *via* ESI mode by using a MicrOTOF mass spectrometer. All reactions were monitored by thin layer chromatography (TLC) using silica gel plates (silica gel 60 F254 0.25 mm), and components were visualized by observation under UV light (254 and 365 nm).

## II. Experimental procedures and spectroscopic data

### 1. Typical procedure for the synthesis of 3a and spectroscopic data of 3a-3hh

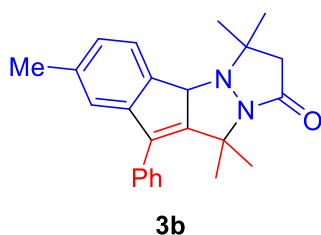
To a reaction tube equipped with a stir bar were charged with 2-benzylidene-3,3-dimethyl-5-oxopyrazolidin-2-ium-1-ide (**1a**, 60.6 mg, 0.3 mmol), HFIP (2 mL), [Ru(*p*-cymene)Cl<sub>2</sub>]<sub>2</sub> (4.6 mg, 0.0075 mmol), AgSbF<sub>6</sub> (10.7 mg, 0.03 mmol) and 2-methyl-4-phenylbut-3-yn-2-ol (**2a**, 48.1 mg, 0.3 mmol). The mixture was stirred at 60 °C for 2 h under air. Upon completion, it was cooled to room temperature, filtered through a pad of celite and concentrated under reduced pressure. The residue was purified by silica gel chromatography using petroleum ether/ethyl acetate (1:1) as eluent to afford **3a**. **3b-3hh** were obtained in a similar manner.



#### 3,3,10,10-Tetramethyl-9-phenyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one

(**3a**)

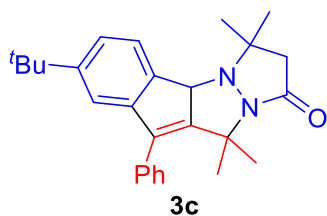
Eluent: petroleum ether/ethyl acetate (1:1). White solid (89.8 mg, 87%), mp 212.3-213.6 °C. <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.48-7.39 (m, 6H), 7.33 (t, *J* = 7.6 Hz, 1H), 7.27-7.23 (m, 2H), 4.70 (s, 1H), 2.78 (d, *J* = 15.6 Hz, 1H), 2.41 (d, *J* = 15.6 Hz, 1H), 1.96 (s, 3H), 1.56 (s, 3H), 1.54 (s, 3H), 1.35 (s, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (100 MHz, CDCl<sub>3</sub>): δ 162.8, 154.6, 148.6, 139.7, 137.1, 133.5, 128.9, 128.7, 128.6, 128.5, 125.9, 125.3, 121.4, 65.7, 60.3, 58.7, 50.1, 27.7, 27.4, 22.5, 21.1 HRMS (ESI) *m/z*: [M+H]<sup>+</sup> Calcd for C<sub>23</sub>H<sub>25</sub>N<sub>2</sub>O 345.1961; found 345.1960.



**3,3,7,10,10-Pentamethyl-9-phenyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one**

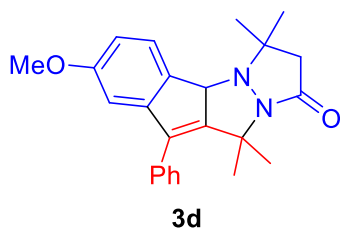
**(3b)**

Eluent: petroleum ether/ethyl acetate (1:1). White solid (90.3 mg, 84%), mp 221.5-222.1 °C. <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.48-7.40 (m, 5H), 7.34 (d, *J* = 8.0 Hz, 1H), 7.06-7.04 (m, 2H), 4.66 (s, 1H), 2.77 (d, *J* = 15.6 Hz, 1H), 2.40 (d, *J* = 15.6 Hz, 1H), 2.35 (s, 3H), 1.94 (s, 3H), 1.54 (s, 3H), 1.52 (s, 3H), 1.33 (s, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (150 MHz, CDCl<sub>3</sub>): δ 162.9, 155.0, 148.9, 138.7, 137.2, 136.9, 133.8, 129.0, 128.8, 128.5, 126.6, 125.1, 122.2, 65.4, 60.3, 58.8, 50.2, 27.8, 27.5, 22.6, 21.7, 21.1. HRMS (ESI) *m/z*: [M+H]<sup>+</sup> Calcd for C<sub>24</sub>H<sub>27</sub>N<sub>2</sub>O 359.2118; found 359.2106.



**7-(tert-Butyl)-3,3,10,10-tetramethyl-9-phenyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3c)**

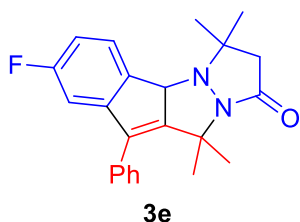
Eluent: petroleum ether/ethyl acetate (1:1). White solid (110.5 mg, 92%), mp 205.5-206.0 °C. <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.50-7.38 (m, 6H), 7.29-7.26 (m, 2H), 4.67 (s, 1H), 2.77 (d, *J* = 15.6 Hz, 1H), 2.40 (d, *J* = 15.6 Hz, 1H), 1.94 (s, 3H), 1.55 (s, 3H), 1.53 (s, 3H), 1.32 (s, 3H), 1.29 (s, 9H). <sup>13</sup>C{<sup>1</sup>H} NMR (150 MHz, CDCl<sub>3</sub>): δ 162.8, 154.9, 152.2, 148.5, 137.4, 136.8, 133.7, 128.9, 128.7, 128.4, 124.8, 122.8, 118.4, 65.2, 60.2, 58.7, 50.1, 34.9, 31.5, 27.7, 27.4, 22.5, 21.0. HRMS (ESI) *m/z*: [M+H]<sup>+</sup> Calcd for C<sub>27</sub>H<sub>33</sub>N<sub>2</sub>O 401.2587; found 401.2573.



**7-Methoxy-3,3,10,10-tetramethyl-9-phenyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one**

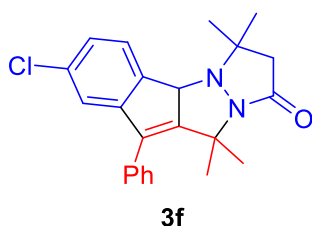
### ol-1-one (3d)

Eluent: petroleum ether/ethyl acetate (1:1). White solid (87.6 mg, 78%), mp 206.5-207.7 °C.  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.47-7.45 (m, 2H), 7.43-7.40 (m, 3H), 7.35 (d,  $J = 8.4$  Hz, 1H), 6.79 (d,  $J = 2.4$  Hz, 1H), 6.76 (dd,  $J_1 = 8.4$  Hz,  $J_2 = 2.4$  Hz, 1H), 4.65 (s, 1H), 3.78 (s, 3H), 2.78 (d,  $J = 15.6$  Hz, 1H), 2.40 (d,  $J = 15.6$  Hz, 1H), 1.94 (s, 3H), 1.54 (s, 3H), 1.52 (s, 3H), 1.33 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (150 MHz,  $\text{CDCl}_3$ ):  $\delta$  163.0, 160.6, 156.2, 150.4, 137.1, 133.6, 131.9, 129.0, 128.8, 128.6, 126.0, 111.1, 107.7, 65.1, 60.4, 58.8, 55.7, 50.2, 27.8, 27.4, 22.6, 21.2. HRMS (ESI)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{24}\text{H}_{27}\text{N}_2\text{O}_2$  375.2067; found:375.2053.



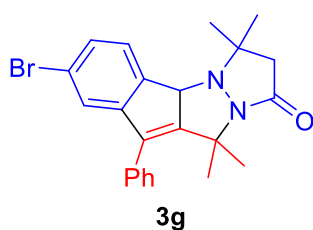
### 7-Fluoro-3,3,10,10-tetramethyl-9-phenyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3e)

Eluent: petroleum ether/ethyl acetate (1:1). White solid (84.7 mg, 78%), mp 193.2-194.5 °C.  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.49-7.38 (m, 6H), 6.96-6.91 (m, 2H), 4.66 (s, 1H), 2.78 (d,  $J = 15.6$  Hz, 1H), 2.41 (d,  $J = 15.6$  Hz, 1H), 1.95 (s, 3H), 1.55 (s, 3H), 1.52 (s, 3H), 1.34 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  163.6 (d,  $^1J_{\text{C-F}} = 244.9$  Hz), 162.8, 156.9, 151.0 (d,  $^3J_{\text{C-F}} = 8.7$  Hz), 136.6 (d,  $^4J_{\text{C-F}} = 2.9$  Hz), 135.2 (d,  $^4J_{\text{C-F}} = 2.9$  Hz), 132.9, 128.83, 128.78, 128.7, 126.2 (d,  $^3J_{\text{C-F}} = 9.4$  Hz), 112.4 (d,  $^2J_{\text{C-F}} = 22.4$  Hz), 108.9 (d,  $^2J_{\text{C-F}} = 23.8$  Hz), 65.0, 60.3, 58.7, 50.0, 27.6, 27.4, 22.4, 21.1.  $^{19}\text{F}$  NMR (376 MHz,  $\text{CDCl}_3$ ):  $\delta$  -112.65 (td,  $J_1 = 8.3$  Hz,  $J_2 = 4.1$  Hz). HRMS (ESI)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{23}\text{H}_{24}\text{FN}_2\text{O}$  363.1867; found 363.1857.



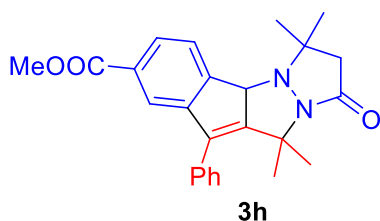
**7-Chloro-3,3,10,10-tetramethyl-9-phenyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3f)**

Eluent: petroleum ether/ethyl acetate (1:1). White solid (80.5 mg, 71%), mp 199.1-200.2 °C. <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.50-7.42 (m, 3H), 7.41-7.36 (m, 3H), 7.23-7.21 (m, 2H), 4.66 (s, 1H), 2.77 (d, *J* = 15.6 Hz, 1H), 2.41 (d, *J* = 15.6 Hz, 1H), 1.94 (s, 3H), 1.55 (s, 3H), 1.51 (s, 3H), 1.33 (s, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (100 MHz, CDCl<sub>3</sub>): δ 162.8, 156.5, 150.5, 137.9, 136.4, 134.9, 132.8, 128.9, 128.8, 128.7, 126.1, 125.7, 121.6, 65.1, 60.3, 58.7, 50.0, 27.6, 27.4, 22.5, 21.1. HRMS (ESI) *m/z*: [M+H]<sup>+</sup> Calcd for C<sub>23</sub>H<sub>24</sub>ClN<sub>2</sub>O 379.1572; found 379.1561.



**7-Bromo-3,3,10,10-tetramethyl-9-phenyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3g)**

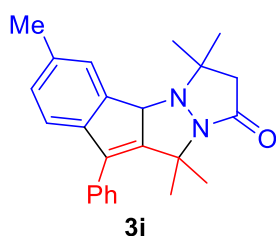
Eluent: petroleum ether/ethyl acetate (1:1). White solid (73.4 mg, 58%), mp 189.5-190.2 °C. <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.50-7.43 (m, 3H), 7.40-7.37 (m, 4H), 7.31 (d, *J* = 8.0 Hz, 1H), 4.64 (s, 1H), 2.77 (d, *J* = 15.6 Hz, 1H), 2.40 (d, *J* = 15.6 Hz, 1H), 1.94 (s, 3H), 1.54 (s, 3H), 1.51 (s, 3H), 1.33 (s, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (150 MHz, CDCl<sub>3</sub>): δ 162.8, 156.4, 150.7, 138.4, 136.4, 132.8, 128.9, 128.8, 128.7, 128.6, 126.5, 124.5, 123.0, 65.2, 60.3, 58.7, 49.9, 27.6, 27.4, 22.5, 21.1. HRMS (ESI) *m/z*: [M+H]<sup>+</sup> Calcd for C<sub>23</sub>H<sub>24</sub>BrN<sub>2</sub>O 423.1067; found 423.1060.



**Methyl 3,3,10,10-tetramethyl-1-oxo-9-phenyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]-**

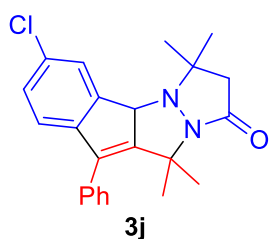
### pyrazole-7-carboxylate (3h)

Eluent: petroleum ether/ethyl acetate (1:1). White solid (57.9 mg, 48%), mp 185.6-186.7 °C.  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.97 (dd,  $J_1 = 8.0$  Hz,  $J_2 = 1.2$  Hz, 1H), 7.90 (d,  $J = 1.2$  Hz, 1H), 7.53 (d,  $J = 7.8$  Hz, 1H), 7.50-7.48 (m, 2H), 7.46-7.42 (m, 3H), 4.73 (s, 1H), 3.90 (s, 3H), 2.79 (d,  $J = 15.6$  Hz, 1H), 2.42 (d,  $J = 15.6$  Hz, 1H), 1.96 (s, 3H), 1.57 (s, 3H), 1.54 (s, 3H), 1.35 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  166.9, 162.8, 155.7, 149.1, 144.4, 136.8, 132.9, 130.7, 128.9, 128.80, 128.77, 127.6, 125.1, 122.1, 65.5, 60.4, 58.7, 52.3, 50.0, 27.6, 27.4, 22.5, 21.1. HRMS (ESI)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{25}\text{H}_{27}\text{N}_2\text{O}_3$  403.2016; found 403.2012.



### 3,3,6,10,10-Pentamethyl-9-phenyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3i)

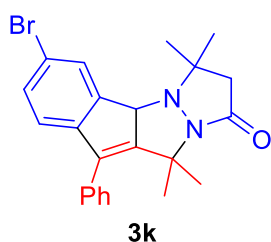
Eluent: petroleum ether/ethyl acetate (1:1). White solid (90.3 mg, 84%), mp 185.6-186.7°C.  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.46-7.38 (m, 5H), 7.27 (s, 1H), 7.15-7.14 (m, 2H), 4.67 (s, 1H), 2.78 (d,  $J = 15.6$  Hz, 1H), 2.42-2.39 (m, 4H), 1.95 (s, 3H), 1.55 (s, 3H), 1.54 (s, 3H), 1.34 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (150 MHz,  $\text{CDCl}_3$ ):  $\delta$  162.8, 153.6, 145.9, 139.9, 137.1, 135.7, 133.7, 129.2, 128.9, 128.6, 128.4, 126.3, 121.0, 65.5, 60.3, 58.6, 50.1, 27.7, 27.5, 22.6, 21.5, 21.0. HRMS (ESI)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{24}\text{H}_{27}\text{N}_2\text{O}$  359.2118; found 359.2106.



### 6-Chloro-3,3,10,10-tetramethyl-9-phenyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol

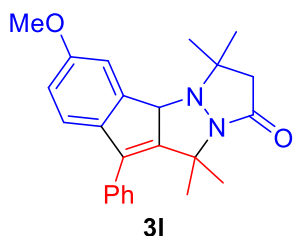
### -1-one (3j)

Eluent: petroleum ether/ethyl acetate (1:1). White solid (86.2 mg, 76%), mp 198.6-200.2 °C.  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.48-7.39 (m, 6H), 7.35-7.31(m, 1H), 7.27-7.22 (m, 2H), 4.70 (s, 1H), 2.78 (d,  $J = 15.6$  Hz, 1H), 2.41 (d,  $J = 15.6$  Hz, 1H), 1.96 (s, 3H), 1.56 (s, 3H), 1.54 (s, 3H), 1.35 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (150 MHz,  $\text{CDCl}_3$ ):  $\delta$  162.8, 156.5, 150.5, 137.9, 136.4, 134.9, 132.8, 128.9, 128.8, 128.7, 126.1, 125.7, 121.6, 65.1, 60.3, 58.7, 50.0, 27.6, 27.4, 22.5, 21.1. HRMS (ESI)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{23}\text{H}_{24}\text{ClN}_2\text{O}$  379.1572; found 379.1565.



### 6-Bromo-3,3,10,10-tetramethyl-9-phenyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3k)

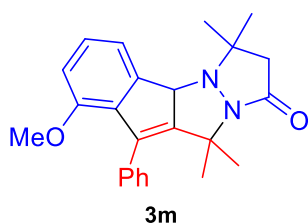
Eluent: petroleum ether/ethyl acetate (1:1). Light yellow solid (98.8 mg, 78%), mp 202.4-204.1 °C.  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.57 (d,  $J = 1.6$  Hz, 1H), 7.48-7.42 (m, 4H), 7.41-7.38 (m, 2H), 7.12 (d,  $J = 8.4$  Hz, 1H), 4.67 (s, 1H), 2.78 (d,  $J = 16.0$  Hz, 1H), 2.41 (d,  $J = 15.6$  Hz, 1H), 1.94 (s, 3H), 1.55 (s, 3H), 1.53 (s, 3H), 1.33 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  162.9, 155.0, 147.5, 141.6, 136.6, 132.9, 131.7, 128.80, 128.76, 128.6, 122.5, 119.8, 65.4, 60.4, 58.6, 50.0, 27.56, 27.52, 22.5, 21.1. HRMS (ESI)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{23}\text{H}_{24}\text{BrN}_2\text{O}$  423.1067; found 423.1055.



### 6-Methoxy-3,3,10,10-tetramethyl-9-phenyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3l)

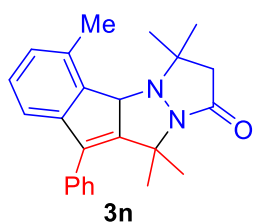


Eluent: petroleum ether/ethyl acetate (1:1). White solid (85.3 mg, 76%), mp 191.9-193.2 °C.  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.46-7.39 (m, 5H), 7.16 (d,  $J = 8.4$  Hz, 1H), 7.05 (d,  $J = 2.4$  Hz, 1H), 6.86 (dd,  $J_1 = 8.4$  Hz,  $J_2 = 2.4$  Hz, 1H), 4.67 (s, 1H), 3.84 (s, 3H), 2.78 (d,  $J = 16.2$  Hz, 1H), 2.40 (d,  $J = 15.6$  Hz, 1H), 1.94 (s, 3H), 1.54 (s, 6H), 1.33 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  162.8, 158.5, 152.2, 141.42, 141.35, 137.0, 133.7, 128.8, 128.6, 128.4, 121.7, 113.3, 112.7, 65.4, 60.3, 58.6, 55.7, 50.1, 27.7, 27.5, 22.6, 21.0. HRMS (ESI)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{24}\text{H}_{27}\text{N}_2\text{O}_2$  375.2067 ;found 375.2063.



**8-Methoxy-3,3,10,10-tetramethyl-9-phenyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3m)**

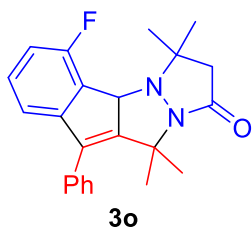
Eluent: petroleum ether/ethyl acetate (1:1). White solid (18.0 mg, 16%), mp 175.5-176.1 °C.  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.352-7.347 (m, 5H), 7.21 (t,  $J = 7.8$  Hz, 1H), 7.09 (d,  $J = 7.8$  Hz, 1H), 6.87 (d,  $J = 8.4$  Hz, 1H), 4.66 (s, 1H), 3.56 (s, 3H), 2.77 (d,  $J = 15.6$  Hz, 1H), 2.40 (d,  $J = 15.6$  Hz, 1H), 1.88 (s, 3H), 1.54 (s, 6H), 1.20 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (100 MHz,  $\text{CDCl}_3$ ):  $\delta$  162.8, 154.9, 153.6, 141.7, 136.9, 135.34, 135.28, 127.7, 127.3, 127.2, 118.2, 112.5, 65.8, 60.3, 58.8, 55.5, 50.2, 27.7, 27.5, 22.54, 21.0. HRMS (ESI)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{24}\text{H}_{27}\text{N}_2\text{O}_2$  375.2067; found 375.2063.



**3,3,5,10,10-Pentamethyl-9-phenyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3n)**

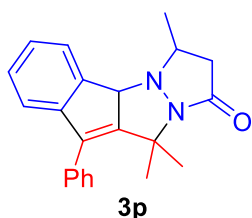
Eluent: petroleum ether/ethyl acetate (1:1). White solid (83.8 mg, 78%), mp 202.4-203.2 °C.  $^1\text{H}$  NMR (600

MHz, CDCl<sub>3</sub>):  $\delta$  7.46-7.40 (m, 5H), 7.24 (t,  $J = 7.8$  Hz, 1H), 7.06 (d,  $J = 7.8$  Hz, 2H), 4.69 (s, 1H), 2.72 (d,  $J = 15.6$  Hz, 1H), 2.56 (s, 3H), 2.37 (d,  $J = 15.6$  Hz, 1H), 1.89 (s, 3H), 1.65 (s, 3H), 1.50 (s, 3H), 1.34 (s, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (100 MHz, CDCl<sub>3</sub>):  $\delta$  163.1, 153.0, 149.2, 138.3, 137.4, 135.2, 133.9, 129.2, 129.1, 128.6, 128.4, 119.1, 64.5, 60.8, 57.3, 51.5, 27.8, 25.7, 22.5, 21.8, 20.0. HRMS (ESI)  $m/z$ : [M+H]<sup>+</sup> Calcd for C<sub>24</sub>H<sub>27</sub>N<sub>2</sub>O 359.2118; found 359.2108.



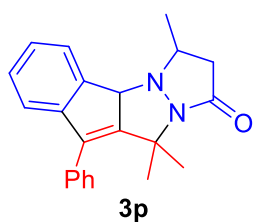
**5-Fluoro-3,3,10,10-tetramethyl-9-phenyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3o)**

Eluent: petroleum ether/ethyl acetate (1:1). White solid (71.7 mg, 66%), mp 198.2-198.8 °C. <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>):  $\delta$  7.48-7.41 (m, 5H), 7.34-7.31 (m, 1H), 7.05 (d,  $J = 7.8$  Hz, 1H), 6.96-6.93 (m, 1H), 4.77 (s, 1H), 2.77 (d,  $J = 15.6$  Hz, 1H), 2.42 (d,  $J = 16.2$  Hz, 1H), 1.95 (s, 3H), 1.58 (s, 3H), 1.50 (s, 3H), 1.35 (s, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (100 MHz, CDCl<sub>3</sub>):  $\delta$  163.0, 159.6 (d, <sup>1</sup> $J_{C-F} = 246.3$  Hz), 155.1, 151.9 (d, <sup>3</sup> $J_{C-F} = 5.8$  Hz), 136.9 (d, <sup>4</sup> $J_{C-F} = 2.9$  Hz), 133.1, 131.3 (d, <sup>3</sup> $J_{C-F} = 8.0$  Hz), 128.8, 128.73, 128.71, 124.4 (d, <sup>2</sup> $J_{C-F} = 16.6$  Hz), 117.5 (d, <sup>4</sup> $J_{C-F} = 2.9$  Hz), 113.7 (d, <sup>2</sup> $J_{C-F} = 22.4$  Hz), 63.0, 60.6, 58.2, 50.6, 27.6, 25.7 (d,  $J_{C(H3)-F} = 8.6$  Hz), 22.4, 20.5 (d,  $J_{C(H3)-F} = 2.1$  Hz). <sup>19</sup>F NMR (565 MHz, CDCl<sub>3</sub>)  $\delta$  -112.29 (dd,  $J_1 = 10.2$  Hz,  $J_2 = 4.0$  Hz). HRMS (ESI)  $m/z$ : [M+H]<sup>+</sup> Calcd for C<sub>23</sub>H<sub>24</sub>FN<sub>2</sub>O 363.1867; found 363.1860.



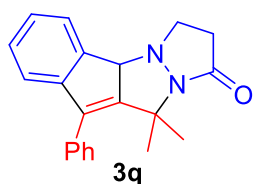
**3,10,10-Trimethyl-9-phenyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3p, isomer 1)**

Eluent: petroleum ether/ethyl acetate (1:1). White solid (42.0 mg, 42%), mp 191.8-192.1 °C.  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.53 (d,  $J = 7.2$  Hz, 1H), 7.47-7.41 (m, 5H), 7.34 (t,  $J = 7.2$  Hz, 1H), 7.27-7.24 (m, 2H), 4.35 (s, 1H), 3.56-3.51 (m, 1H), 2.74 (dd,  $J_1 = 15.6$  Hz,  $J_2 = 7.2$  Hz, 1H), 2.60 (dd,  $J_1 = 15.6$  Hz,  $J_2 = 13.2$  Hz, 1H), 1.99 (s, 3H), 1.55 (d,  $J = 6.0$  Hz, 3H), 1.31 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (150 MHz,  $\text{CDCl}_3$ ):  $\delta$  163.3, 154.2, 148.6, 139.0, 137.6, 133.4, 128.8, 128.7, 128.6, 126.0, 125.5, 121.3, 75.3, 63.1, 59.1, 44.4, 27.9, 23.0, 18.7. HRMS (ESI)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{22}\text{H}_{23}\text{N}_2\text{O}$  331.1805; found 331.1801.



**3,10,10-Trimethyl-9-phenyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3p, isomer 2)**

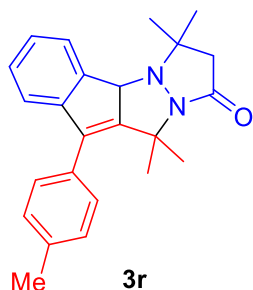
Eluent: petroleum ether/ethyl acetate (1:1). White solid (44.2 mg, 45%), mp 196.4-197.5 °C.  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.47-7.41 (m, 6H), 7.35 (t,  $J = 7.2$  Hz, 1H), 7.29-7.24 (m, 2H), 4.73 (s, 1H), 4.07-4.02 (m, 1H), 3.12 (dd,  $J_1 = 16.2$  Hz,  $J_2 = 7.8$  Hz, 1H), 2.35 (d,  $J = 16.2$  Hz, 1H), 1.95 (s, 3H), 1.52 (d,  $J = 7.2$  Hz, 3H), 1.33 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (150 MHz,  $\text{CDCl}_3$ ):  $\delta$  162.7, 154.7, 148.4, 139.6, 137.7, 133.6, 128.9, 128.8, 128.7, 128.5, 126.0, 124.2, 121.5, 65.3, 59.0, 53.1, 43.7, 27.5, 22.5, 14.9. HRMS (ESI)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{22}\text{H}_{23}\text{N}_2\text{O}$  331.1805; found 331.1801.



**10,10-Dimethyl-9-phenyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3q)**

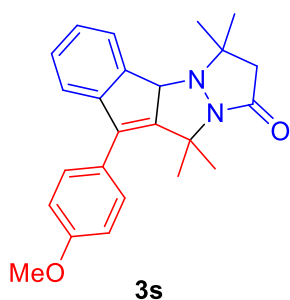
Eluent: petroleum ether/ethyl acetate (1:2). Yellow solid (79.7 mg, 84%), mp 176.9-178.0 °C.  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.49-7.41 (m, 6H), 7.37-7.33 (m, 1H), 7.28-7.23 (m, 2H), 4.26 (s, 1H), 3.88 (t,  $J = 8.4$  Hz, 1H), 3.23-3.16 (m, 1H), 2.99-2.90 (m, 1H), 2.70 (dd,  $J_1 = 15.6$  Hz,  $J_2 = 7.8$  Hz, 1H), 2.00 (s, 3H), 1.30 (s,

3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (150 MHz,  $\text{CDCl}_3$ ):  $\delta$  163.4, 154.3, 148.2, 139.2, 137.9, 133.5, 129.0, 128.7, 128.6, 126.1, 124.4, 121.4, 75.4, 59.6, 53.8, 37.2, 27.7, 23.0. HRMS (ESI)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{21}\text{H}_{21}\text{N}_2\text{O}$  317.1648; found 317.1647.



**3,3,10,10-Tetramethyl-9-(*p*-tolyl)-2,3,4a,10-tetrahydro-1*H*-indeno[1,2-*c*]pyrazolo[1,2-*a*]pyrazol-1-one (3r)**

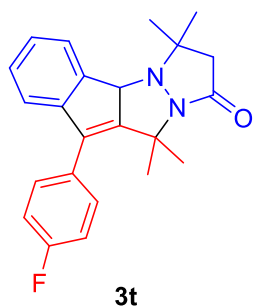
Eluent: petroleum ether/ethyl acetate (1:1). White solid (81.7 mg, 76%), mp 203.6-204.7 °C.  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.46 (d,  $J = 7.6$  Hz, 1H), 7.33-7.35 (m, 3H), 7.28-7.22 (m, 4H), 4.69 (s, 1H), 2.78 (d,  $J = 15.6$  Hz, 1H), 2.42-2.38 (m, 4H), 1.95 (s, 3H), 1.56 (s, 3H), 1.54 (s, 3H), 1.36 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$ : 162.8, 154.1, 148.7, 139.7, 138.4, 137.1, 130.5, 129.4, 128.8, 128.6, 125.8, 125.3, 121.4, 65.6, 60.3, 58.7, 50.1, 27.7, 27.4, 22.5, 21.4, 21.1. HRMS (ESI)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{24}\text{H}_{27}\text{N}_2\text{O}$  359.2118; found 359.2119.



**9-(4-Methoxyphenyl)-3,3,10,10-tetramethyl-2,3,4a,10-tetrahydro-1*H*-indeno[1,2-*c*]pyrazolo[1,2-*a*]pyrazol-1-one (3s)**

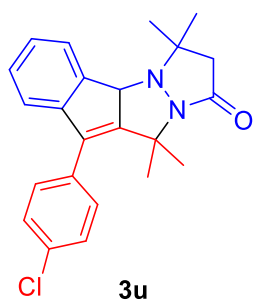
Eluent: petroleum ether/ethyl acetate (1:1). White solid (83.1 mg, 74%), mp 214.8-215.2 °C.  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.46 (d,  $J = 7.6$  Hz, 1H), 7.37-7.34 (m, 2H), 7.33 (d,  $J = 7.2$  Hz, 1H), 7.28-7.22 (m, 2H),

6.99 (d,  $J = 8.8$  Hz, 2H), 4.68 (s, 1H), 3.87 (s, 3H), 2.78 (d,  $J = 16.0$  Hz, 1H), 2.40 (d,  $J = 15.6$  Hz, 1H), 1.95 (s, 3H), 1.56 (s, 3H), 1.53 (s, 3H), 1.37 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (150 MHz,  $\text{CDCl}_3$ ):  $\delta$  162.8, 159.8, 153.6, 148.7, 139.7, 136.8, 130.1, 128.6, 125.8, 125.7, 125.3, 121.3, 114.1, 65.5, 60.3, 58.7, 55.3, 50.1, 27.7, 27.4, 22.5, 21.0. HRMS (ESI)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{24}\text{H}_{27}\text{N}_2\text{O}_2$  375.2067; found: 375.2053.



**9-(4-Fluorophenyl)-3,3,10,10-tetramethyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazo-1-one (3t)**

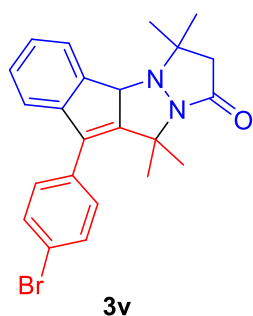
Eluent: petroleum ether/ethyl acetate (1:1). White solid (93.4 mg, 86%), mp 191.6-192.4 °C.  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.47 (d,  $J = 7.2$  Hz, 1H), 7.41-7.39 (m, 2H), 7.35-7.33 (m, 1H), 7.27-7.24 (m, 1H), 7.22 (d,  $J = 7.2$  Hz, 1H), 7.17-7.15 (m, 2H), 4.69 (s, 1H), 2.78 (d,  $J = 15.6$  Hz, 1H), 2.41 (d,  $J = 16.2$  Hz, 1H), 1.94 (s, 3H), 1.56 (s, 3H), 1.53 (s, 3H), 1.35 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (150 MHz,  $\text{CDCl}_3$ ):  $\delta$  162.9, 162.8 (d,  $^1J_{\text{C-F}} = 246.2$  Hz), 154.9, 148.4, 139.6, 136.1, 130.6 (d,  $^3J_{\text{C-F}} = 7.7$  Hz), 129.5 (d,  $^4J_{\text{C-F}} = 3.3$  Hz), 128.7, 126.0, 125.3, 121.1, 115.8 (d,  $^2J_{\text{C-F}} = 21.9$  Hz), 65.7, 60.3, 58.5, 50.0, 27.7, 27.4, 22.5, 21.0.  $^{19}\text{F}$  NMR (565 MHz,  $\text{CDCl}_3$ ):  $\delta$  -112.58 – -112.63 (m). HRMS (ESI)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{23}\text{H}_{24}\text{FN}_2\text{O}$  363.1867; found 363.1858.



**9-(4-Chlorophenyl)-3,3,10,10-tetramethyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazo-1-one**

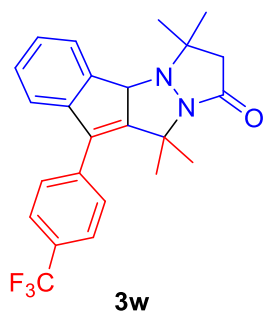
### **l-1-one (3u)**

Eluent: petroleum ether/ethyl acetate (1:1). White solid (82.8 mg, 73%), mp 199.4-200.4 °C.  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.47-7.39 (m, 6H), 7.32 (t,  $J = 7.8$  Hz, 1H), 7.25-7.23 (m, 1H), 4.69 (s, 1H), 2.78 (d,  $J = 15.6$  Hz, 1H), 2.41 (d,  $J = 15.6$  Hz, 1H), 1.95 (s, 3H), 1.55 (s, 3H), 1.53 (s, 3H), 1.35 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (150 MHz,  $\text{CDCl}_3$ ):  $\delta$  162.8, 154.7, 148.6, 139.7, 137.1, 133.5, 128.9, 128.7, 128.6, 128.5, 125.9, 125.3, 121.4, 65.7, 60.3, 58.7, 50.1, 27.7, 27.4, 22.5, 21.1. HRMS (ESI)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{23}\text{H}_{24}\text{ClN}_2\text{O}$  379.1572; found 379.1565.



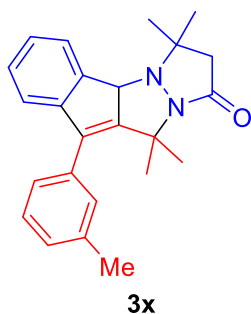
### **9-(4-Bromophenyl)-3,3,10,10-tetramethyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3v)**

Eluent: petroleum ether/ethyl acetate (1:1). White solid (95.0 mg, 75%), mp 206.5-207.7 °C.  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.61-7.59 (m, 2H), 7.47 (d,  $J = 7.2$  Hz, 1H), 7.36-7.33 (m, 1H), 7.32-7.29 (m, 2H), 7.27-7.25 (m, 1H), 7.21 (d,  $J = 7.2$  Hz, 1H), 4.69 (s, 1H), 2.78 (d,  $J = 16.2$  Hz, 1H), 2.41 (d,  $J = 15.6$  Hz, 1H), 1.94 (s, 3H), 1.56 (s, 3H), 1.53 (s, 3H), 1.36 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (150 MHz,  $\text{CDCl}_3$ ):  $\delta$  162.9, 155.3, 148.1, 139.6, 136.0, 132.4, 132.0, 130.5, 128.7, 126.1, 125.4, 122.6, 121.1, 65.8, 60.3, 58.6, 50.0, 27.7, 27.4, 22.6, 21.1. HRMS (ESI)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{23}\text{H}_{24}\text{BrN}_2\text{O}$  423.1067; found 423.1048.



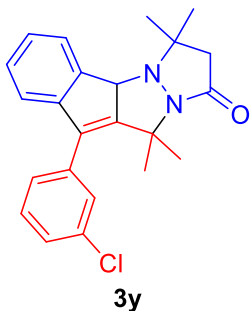
**3,3,10,10-Tetramethyl-9-(4-(trifluoromethyl)phenyl)-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3w)**

Eluent: petroleum ether/ethyl acetate (1:1). White solid (94.0 mg, 76%), mp 209.6-210.4 °C. <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>): δ 7.74 (d, *J* = 7.8 Hz, 2H), 7.56 (d, *J* = 7.8 Hz, 2H), 7.49 (d, *J* = 7.8 Hz, 1H), 7.37-7.34 (m, 1H), 7.28 (td, *J*<sub>1</sub> = 7.8 Hz, *J*<sub>2</sub> = 1.2 Hz, 1H), 7.20 (d, *J* = 7.2 Hz, 1H), 4.73 (s, 1H), 2.79 (d, *J* = 15.6 Hz, 1H), 2.42 (d, *J* = 15.6 Hz, 1H), 1.96 (s, 3H), 1.57 (s, 3H), 1.54 (s, 3H), 1.34 (s, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (150 MHz, CDCl<sub>3</sub>): δ 162.9, 156.3, 148.0, 139.6, 137.4, 135.8, 130.6 (q, <sup>2</sup>*J*<sub>C-F</sub> = 32.7 Hz), 129.2, 128.8, 126.2, 125.7 (q, <sup>3</sup>*J*<sub>C-F</sub> = 3.2 Hz), 125.5, 124.0 (q, <sup>1</sup>*J*<sub>C-F</sub> = 270.2 Hz), 121.1, 65.9, 60.3, 58.5, 50.0, 27.6, 27.4, 22.7, 21.1. <sup>19</sup>F NMR (565 MHz, CDCl<sub>3</sub>): δ -62.61 (s). HRMS (ESI) *m/z*: [M+H]<sup>+</sup> Calcd for C<sub>24</sub>H<sub>24</sub>F<sub>3</sub>N<sub>2</sub>O 413.1835; found 413.1823.



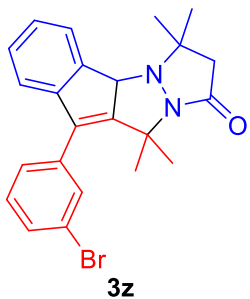
**3,3,10,10-Tetramethyl-9-(*m*-tolyl)-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3x)**

Eluent: petroleum ether/ethyl acetate (1:1). White solid (98.9 mg, 92%), mp 199.5-200.4 °C. <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>): δ 7.46 (d, *J* = 7.2 Hz, 1H), 7.35-7.32 (m, 2H), 7.27-7.21 (m, 5H), 4.69 (s, 1H), 2.78 (d, *J* = 15.6 Hz, 1H), 2.42-2.39 (m, 4H), 1.95 (s, 3H), 1.56 (s, 3H), 1.53 (s, 3H), 1.36 (s, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (150 MHz, CDCl<sub>3</sub>): δ 162.8, 154.4, 148.7, 139.7, 138.3, 137.3, 133.4, 129.4, 129.3, 128.61, 128.56, 126.0, 125.8, 125.3, 121.4, 65.6, 60.3, 58.7, 50.1, 27.7, 27.4, 22.5, 21.5, 21.1. HRMS (ESI) *m/z*: [M+H]<sup>+</sup> Calcd for C<sub>24</sub>H<sub>27</sub>N<sub>2</sub>O 359.2118; found 359.2106.



**9-(3-Chlorophenyl)-3,3,10,10-tetramethyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazole-1-one (3y)**

Eluent: petroleum ether/ethyl acetate (1:1). White solid (91.9 mg, 81%), mp 203.0-204.2 °C. <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.47 (d, *J* = 8.4 Hz, 1H), 7.42-7.39 (m, 3H), 7.35-7.26 (m, 3H), 7.25-7.22 (m, 1H), 4.70 (s, 1H), 2.78 (d, *J* = 16.0 Hz, 1H), 2.41 (d, *J* = 15.6 Hz, 1H), 1.95 (s, 3H), 1.56 (s, 3H), 1.53 (s, 3H), 1.37 (s, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (150 MHz, CDCl<sub>3</sub>): δ 162.9, 155.8, 148.1, 139.6, 135.7, 135.4, 134.7, 130.0, 128.80, 128.78, 128.7, 127.1, 126.1, 125.4, 121.2, 65.8, 60.3, 58.6, 50.0, 27.7, 27.4, 22.6, 21.1. HRMS (ESI) *m/z*: [M+H]<sup>+</sup> Calcd for C<sub>23</sub>H<sub>24</sub>ClN<sub>2</sub>O 379.1572; found 379.1560.

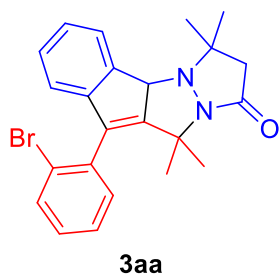


**9-(3-Bromophenyl)-3,3,10,10-tetramethyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazole-1-one (3z)**

Eluent: petroleum ether/ethyl acetate (1:1). White solid (110.2 mg, 87%), mp 189.8-191.2 °C. <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>): δ 7.58 (s, 1H), 7.55 (dt, *J*<sub>1</sub> = 7.2 Hz, *J*<sub>2</sub> = 1.8 Hz, 1H), 7.47 (d, *J* = 7.2 Hz, 1H), 7.36-7.32 (m, 3H), 7.28-7.25 (m, 1H), 7.22 (d, *J* = 7.2 Hz, 1H), 4.69 (s, 1H), 2.78 (d, *J* = 15.6 Hz, 1H), 2.41 (d, *J* = 15.6 Hz, 1H), 1.94 (s, 3H), 1.56 (s, 3H), 1.53 (s, 3H), 1.37 (s, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (150 MHz, CDCl<sub>3</sub>): δ 162.9, 155.8, 148.1, 139.6, 135.7, 135.6, 131.7, 131.6, 130.3, 128.8, 127.5, 126.1, 125.4, 122.8, 121.1, 65.8, 60.3,

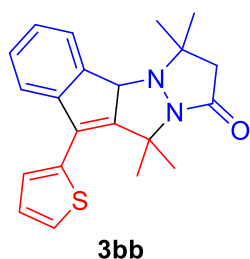


58.6, 50.0, 27.7, 27.4, 22.7, 21.1. HRMS (ESI)  $m/z$ :  $[M+H]^+$  Calcd for  $C_{23}H_{24}BrN_2O$  423.1067; found 423.1056.



**9-(2-Bromophenyl)-3,3,10,10-tetramethyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3aa)**

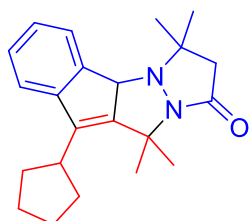
Eluent: petroleum ether/ethyl acetate (1:1). White solid (110.2 mg, 87%), mp 191.8-192.1 °C.  $^1H$  NMR (600 MHz,  $CDCl_3$ ):  $\delta$  7.70 (dd,  $J_1 = 7.8$  Hz,  $J_2 = 0.6$  Hz, 1H), 7.46 (d,  $J = 7.2$  Hz, 1H), 7.39-7.34 (m, 2H), 7.29-7.26 (m, 2H), 7.23 (td,  $J_1 = 7.8$  Hz,  $J_2 = 1.2$  Hz, 1H), 6.86 (d,  $J = 7.8$  Hz, 1H), 4.78 (s, 1H), 2.80 (d,  $J = 15.6$  Hz, 1H), 2.41 (d,  $J = 15.0$  Hz, 1H), 1.88 (s, 3H), 1.56 (s, 3H), 1.54 (s, 3H), 1.39 (s, 3H).  $^{13}C\{^1H\}$  NMR (150 MHz,  $CDCl_3$ ):  $\delta$  162.9, 155.5, 149.4, 139.6, 134.62, 134.57, 133.1, 131.0, 129.8, 128.7, 127.3, 125.8, 125.0, 123.5, 120.9, 65.6, 60.6, 58.7, 50.0, 27.4, 25.0, 23.5, 21.1. HRMS (ESI)  $m/z$ :  $[M+H]^+$  Calcd for  $C_{23}H_{24}BrN_2O$  423.1067; found 423.1060.



**3,3,10,10-Tetramethyl-9-(thiophen-2-yl)-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3bb)**

Eluent: petroleum ether/ethyl acetate (1:1). White solid (57.8 mg, 55%), mp 227.7-228.4 °C.  $^1H$  NMR (400 MHz,  $CDCl_3$ ):  $\delta$  7.48-7.46 (m, 2H), 7.43 (dd,  $J_1 = 5.2$  Hz,  $J_2 = 1.2$  Hz, 1H), 7.38 (t,  $J = 7.6$  Hz, 1H), 7.28-7.25 (m, 1H), 7.21 (dd,  $J_1 = 3.6$  Hz,  $J_2 = 1.2$  Hz, 1H), 7.16 (dd,  $J_1 = 5.2$  Hz,  $J_2 = 3.6$  Hz, 1H), 4.69 (s,

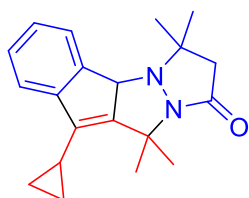
1H), 2.78 (d,  $J = 15.6$  Hz, 1H), 2.42 (d,  $J = 15.6$  Hz, 1H), 1.99 (s, 3H), 1.56 (s, 3H), 1.53 (s, 3H), 1.50 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (150 MHz,  $\text{CDCl}_3$ ):  $\delta$  162.9, 155.7, 148.0, 139.2, 133.8, 129.7, 128.8, 127.7, 127.6, 126.5, 126.2, 125.3, 121.4, 65.9, 60.1, 58.9, 50.1, 27.7, 27.5, 21.9, 21.0. HRMS (ESI)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{21}\text{H}_{23}\text{N}_2\text{OS}$  351.1526; found 351.1522.



**3cc**

**9-Cyclopentyl-3,3,10,10-tetramethyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3cc)**

Eluent: petroleum ether/ethyl acetate (1:1). White solid (70.6 mg, 70%), mp 185.2-186.5 °C.  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.40 (d,  $J = 7.2$  Hz, 1H), 7.33 (d,  $J = 7.2$  Hz, 1H), 7.29 (t,  $J = 7.2$  Hz, 1H), 7.17 (td,  $J_1 = 7.2$  Hz,  $J_2 = 1.2$  Hz, 1H), 4.48 (s, 1H), 3.22-3.16 (m, 1H), 2.78 (d,  $J = 15.6$  Hz, 1H), 2.40 (d,  $J = 15.0$  Hz, 1H), 2.02-1.87 (m, 6H), 1.83 (s, 3H), 1.81 (s, 3H), 1.77-1.73 (m, 2H), 1.504 (s, 3H), 1.496 (s, 3H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (150 MHz,  $\text{CDCl}_3$ ):  $\delta$  162.9, 153.5, 147.3, 140.1, 137.3, 128.0, 125.0, 124.8, 121.8, 65.5, 60.0, 58.5, 50.3, 38.4, 31.2, 30.2, 27.5, 26.80, 26.76, 26.2, 23.6, 21.0. HRMS (ESI)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{22}\text{H}_{29}\text{N}_2\text{O}$  337.2274; found 337.2264.

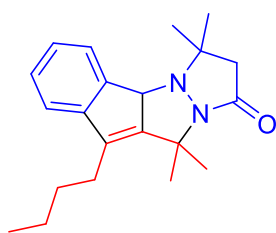


**3dd**

**9-Cyclopropyl-3,3,10,10-tetramethyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3dd)**

Eluent: petroleum ether/ethyl acetate (1:1). White solid (80.4 mg, 87%), mp 163.2-164.7 °C.  $^1\text{H}$  NMR (400

MHz, CDCl<sub>3</sub>):  $\delta$  7.46 (d,  $J = 7.6$  Hz, 1H), 7.39-7.33 (m, 2H), 7.19 (td,  $J_1 = 7.2$  Hz,  $J_2 = 0.8$  Hz, 1H), 4.48 (d,  $J = 1.2$  Hz, 1H), 2.77 (d,  $J = 15.6$  Hz, 1H), 2.40 (d,  $J = 15.6$  Hz, 1H), 1.92 (s, 3H), 1.82 (m, 3H), 1.70-1.65 (m, 1H), 1.50 (s, 3H), 1.48 (s, 3H), 1.00-0.93 (m, 2H), 0.76-0.70 (m, 1H), 0.54-0.49 (m, 1H). <sup>13</sup>C{<sup>1</sup>H} NMR (150 MHz, CDCl<sub>3</sub>):  $\delta$  162.8, 154.0, 149.5, 139.1, 136.8, 128.6, 125.5, 124.8, 121.0, 65.2, 60.1, 58.4, 50.1, 27.4, 25.5, 23.6, 21.0, 7.3, 5.7, 5.0. HRMS (ESI)  $m/z$ : [M+H]<sup>+</sup> Calcd for C<sub>20</sub>H<sub>25</sub>N<sub>2</sub>O 309.1961; found 309.1958.

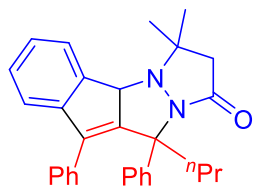


**3ee**

**9-Butyl-3,3,10,10-tetramethyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one**

(**3ee**)

Eluent: petroleum ether/ethyl acetate (1:1). Yellow syrup (73.9 mg, 76%). <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>):  $\delta$  7.39 (d,  $J = 7.2$  Hz, 1H), 7.34 (t,  $J = 7.6$  Hz, 1H), 7.28-7.26 (m, 1H), 7.18 (t,  $J = 7.6$  Hz, 1H), 4.51 (s, 1H), 2.78 (d,  $J = 15.6$  Hz, 1H), 2.62-2.52 (m, 2H), 2.39 (d,  $J = 15.6$  Hz, 1H), 1.83 (s, 6H), 1.64-1.56 (m, 2H), 1.50 (s, 3H), 1.49 (s, 3H), 1.47-1.39 (m, 2H), 0.96 (t,  $J = 7.6$  Hz, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (100 MHz, CDCl<sub>3</sub>):  $\delta$  162.8, 152.6, 149.2, 139.4, 135.1, 128.4, 125.2, 124.8, 120.1, 65.5, 60.1, 58.4, 50.2, 31.1, 27.4, 26.5, 25.5, 23.0, 22.99, 21.0, 13.9. HRMS (ESI)  $m/z$ : [M+H]<sup>+</sup> Calcd for C<sub>21</sub>H<sub>29</sub>N<sub>2</sub>O 325.2274; found 325.2274.

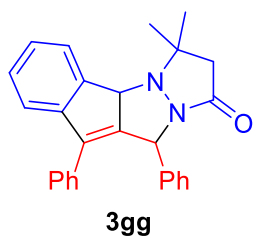


**3ff**

**3,3-Dimethyl-9,10-diphenyl-10-propyl-2,3,4a,10-tetrahydro-1H-indeno[1,2-c]pyrazolo[1,2-a]pyrazol-1-one (3ff)**

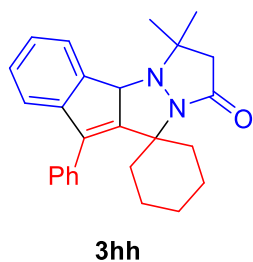
Eluent: petroleum ether/ethyl acetate (1:1). White solid (71.6 mg, 55%), mp 220.0-211.2 °C. <sup>1</sup>H NMR (600

MHz, CDCl<sub>3</sub>): δ 7.84 (d, *J* = 7.8 Hz, 2H), 7.49 (d, *J* = 7.2 Hz, 1H), 7.41-7.25 (m, 11H), 4.81 (s, 1H), 2.80 (d, *J* = 15.6 Hz, 1H), 2.66-2.62 (m, 1H), 2.41 (d, *J* = 15.6 Hz, 1H), 1.70-1.64 (m, 1H), 1.52 (s, 3H), 1.46 (s, 3H), 1.29-1.17 (m, 2H), 0.48 (t, *J* = 6.6 Hz, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (150 MHz, CDCl<sub>3</sub>): δ 163.4, 150.8, 148.6, 143.1, 140.2, 137.6, 133.1, 128.8, 128.61, 128.56, 128.5, 127.6, 127.3, 125.9, 125.5, 121.6, 67.7, 65.8, 60.3, 50.0, 35.3, 27.5, 20.8, 17.8, 13.3. HRMS (ESI) *m/z*: [M+H]<sup>+</sup> Calcd for C<sub>30</sub>H<sub>31</sub>N<sub>2</sub>O 435.2431; found 435.2428.



**3,3-Dimethyl-9,10-diphenyl-2,3,4a,10-tetrahydro-1*H*-indeno[1,2-*c*]pyrazolo[1,2-*a*]pyrazol-1-one (3gg)**

Eluent: petroleum ether/ethyl acetate (1:1). Light yellow solid (52.9 mg, 45%), mp 211.0-212.2 °C. <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.59-7.55 (m, 3H), 7.50 (d, *J* = 7.6 Hz, 1H), 7.44-7.40 (m, 3H), 7.37-7.35 (m, 4H), 7.33-7.31 (m, 1H), 7.29-7.27 (m, 2H), 5.38 (s, 1H), 5.00 (s, 1H), 2.77 (d, *J* = 15.6 Hz, 1H), 2.41 (d, *J* = 15.6 Hz, 1H), 1.61 (s, 3H), 1.56 (s, 3H). <sup>13</sup>C{<sup>1</sup>H} NMR (100 MHz, CDCl<sub>3</sub>): δ 163.7, 148.5, 147.2, 141.0, 139.9, 138.6, 132.8, 128.9, 128.8, 128.72, 128.68, 128.62, 128.57, 128.2, 126.2, 125.6, 122.2, 65.9, 60.7, 57.1, 49.7, 27.3, 21.1. HRMS (ESI) *m/z*: [M+H]<sup>+</sup> Calcd for C<sub>27</sub>H<sub>25</sub>N<sub>2</sub>O 393.1961; found 393.1958.

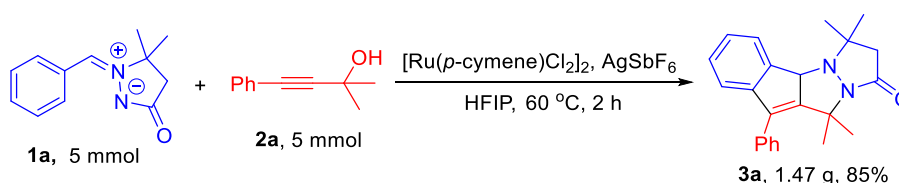


**3',3'-Dimethyl-9'-phenyl-2',3'-dihydro-1'*H*,4a'*H*-spiro[cyclohexane-1,10'-indeno[1,2-*c*]pyrazolo[1,2-*a*]pyrazol-1'-one (3hh)**

Eluent: petroleum ether/ethyl acetate (1:1). Yellow solid (92.2 mg, 80%), mp 155.6-156.4 °C. <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>): δ 7.46-7.43 (m, 3H), 7.42-7.39 (m, 1H), 7.36-7.35 (m, 2H), 7.26-7.24 (m, 1H), 7.21 (td, *J*<sub>1</sub> =

7.8 Hz,  $J_1 = 1.2$  Hz, 1H), 6.82 (d,  $J = 7.8$  Hz, 1H), 4.72 (s, 1H), 2.83 (d,  $J = 15.6$  Hz, 1H), 2.59 (td,  $J_1 = 12.6$  Hz,  $J_2 = 3.6$  Hz, 1H), 2.41-2.36 (m, 2H), 1.94-1.92 (m, 1H), 1.85-1.79 (m, 2H), 1.55 (s, 3H), 1.53 (s, 3H), 1.49-1.43 (m, 1H), 1.34-1.25 (m, 3H), 0.41-0.35 (m, 1H).  $^{13}\text{C}\{^1\text{H}\}$  NMR (150 MHz,  $\text{CDCl}_3$ ):  $\delta$  162.9, 153.6, 150.8, 138.5, 136.9, 135.0, 129.3, 128.64, 128.60, 128.1, 125.7, 124.7, 121.5, 65.9, 63.4, 60.5, 50.3, 35.9, 31.7, 27.3, 24.5, 23.0, 22.1, 21.0. HRMS (ESI)  $m/z$ :  $[\text{M}+\text{H}]^+$  Calcd for  $\text{C}_{26}\text{H}_{29}\text{N}_2\text{O}$  385.2274; found 385.2268.

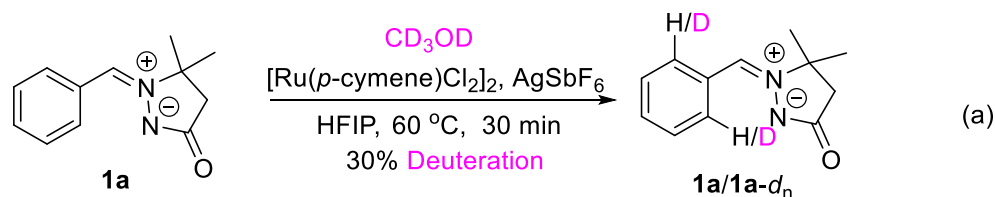
## 2. Gram-scale synthesis of **3a**



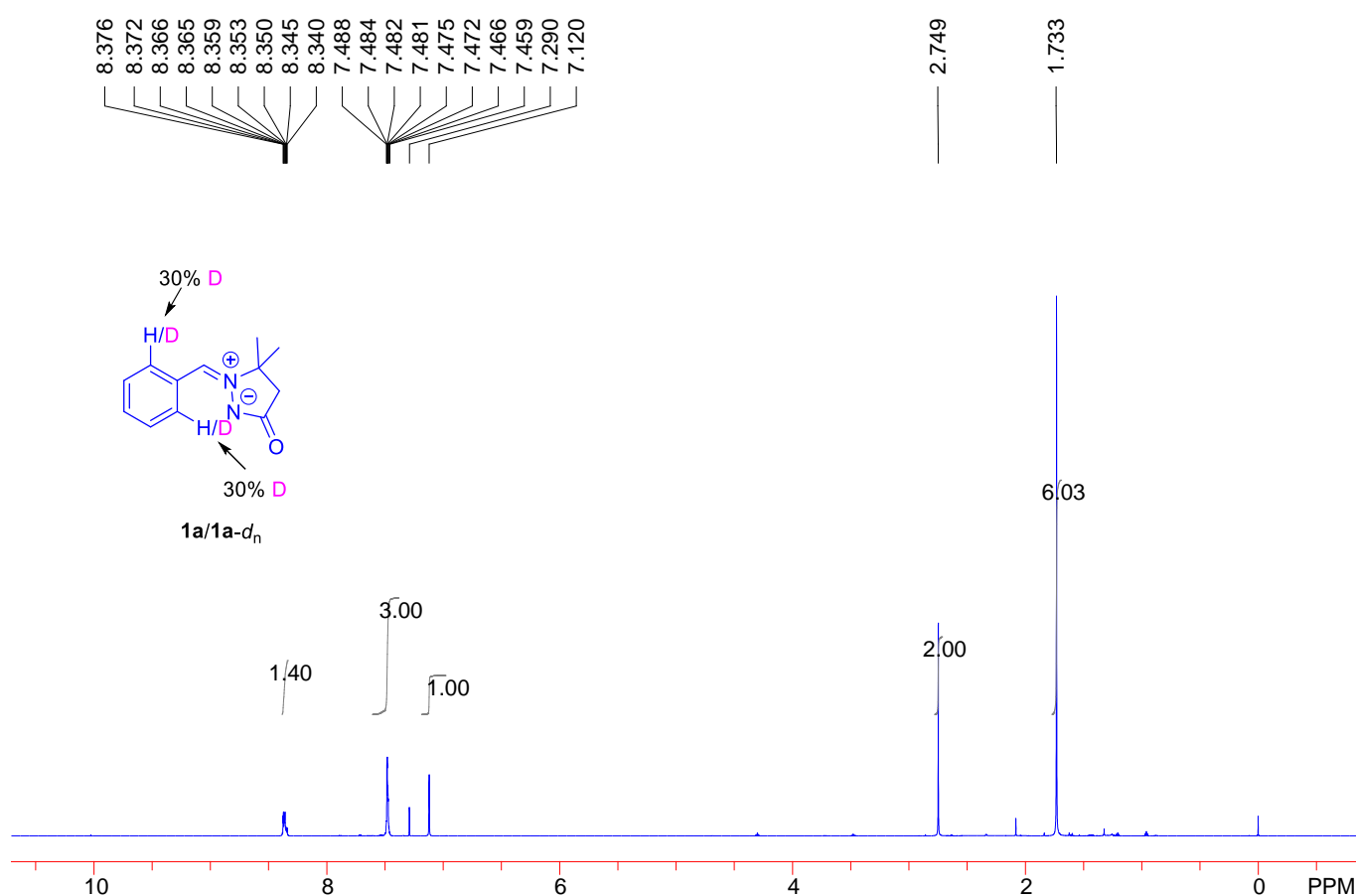
To a reaction tube equipped with a stir bar were charged with 2-Benzylidene-3,3-dimethyl-5-oxopyrazolidin-2-ium-1-ide (**1a**, 1.01 g, 5 mmol), HFIP (20 mL),  $[\text{Ru}(p\text{-cymene})\text{Cl}_2]_2$  (30.6 mg, 0.125 mmol),  $\text{AgSbF}_6$  (178.9 mg, 0.5 mmol), and 2-methyl-4-phenylbut-3-yn-2-ol (**2a**, 0.8 g, 5 mmol). The mixture was stirred at  $60\text{ }^\circ\text{C}$  for 2 h under air. Upon completion, it was cooled to room temperature, filtered through a pad of celite and concentrated under reduced pressure. The residue was purified by silica gel chromatography using petroleum ether/ethyl acetate (1:1) as eluent to afford **3a** (1.47 g, 85%).

### III. Mechanism studies

#### 1. H/D exchange experiment

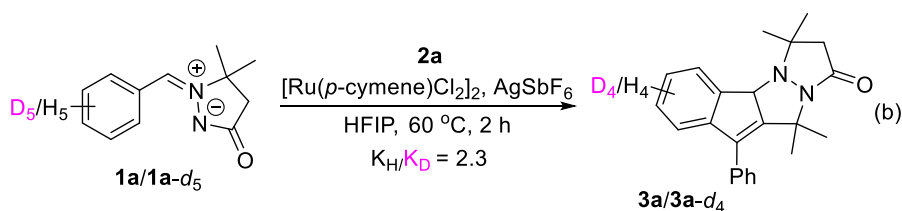


To a reaction tube equipped with a stir bar were charged with 2-benzylidene-3,3-dimethyl-5-oxopyrazolidin-2-ium-1-ide **1a** (40.4 mg, 0.2 mmol) HFIP (1 mL), CD<sub>3</sub>OD (0.16 mL, 4 mmol) [Ru(*p*-cymene)Cl<sub>2</sub>]<sub>2</sub> (3.1 mg, 0.005 mmol) and AgSbF<sub>6</sub> (7.16 mg, 0.02 mmol). The mixture was stirred at 60 °C for 30 min under air. Upon completion, it was cooled to room temperature, filtered through a pad of celite and concentrated under reduced pressure. The residue was purified by silica gel chromatography using ethyl acetate/MeOH (20:1) as eluent to give a mixture of **1a** and **1a-d<sub>n</sub>**. Upon analyzing the <sup>1</sup>H NMR spectrum of the mixture as shown in Fig. S1, the deuteration percentage was determined as 30%.

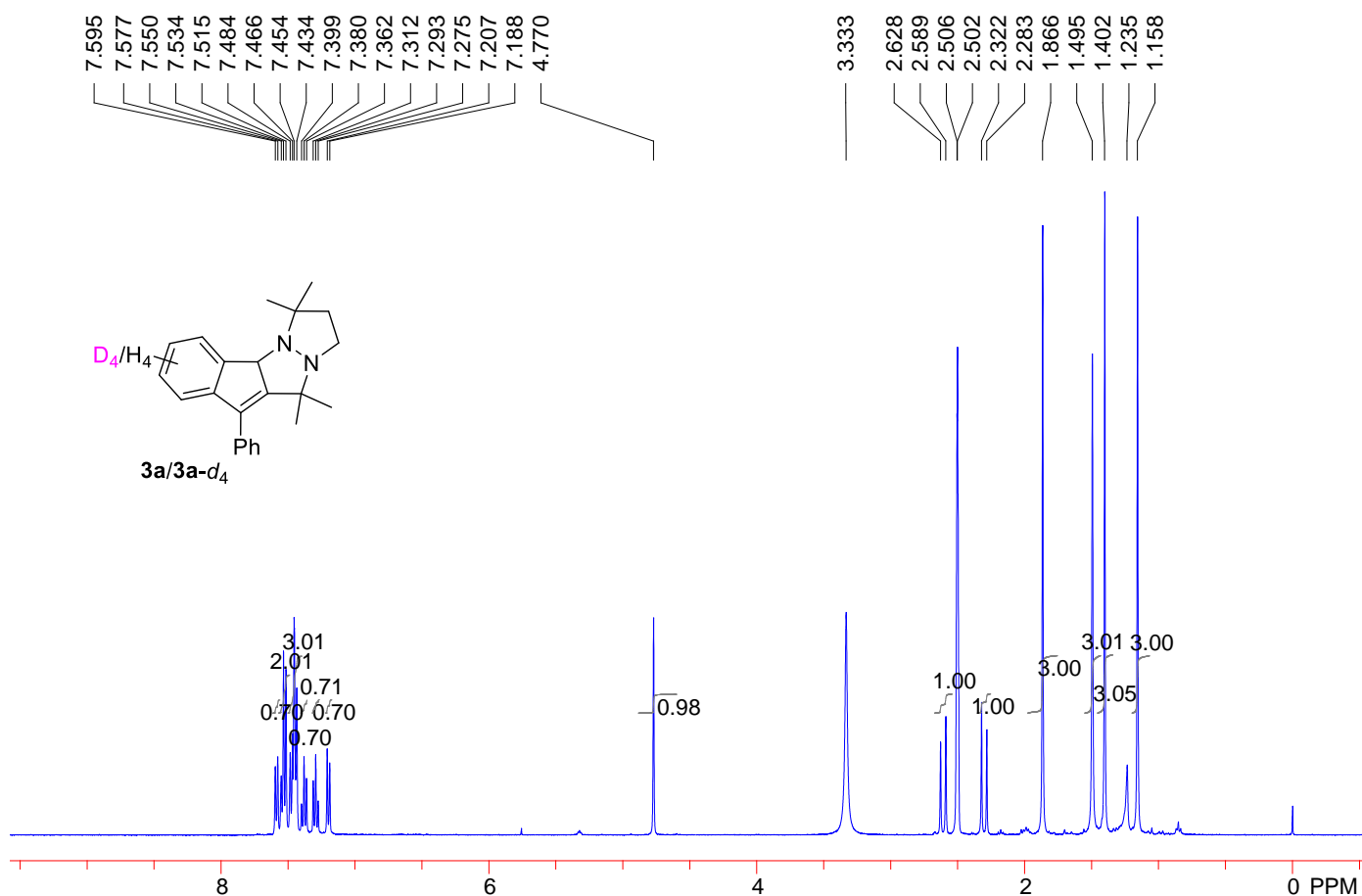


**Fig. S1** The <sup>1</sup>H NMR spectrum of the products obtained from the H/D exchange experiment

## 2. Intermolecular kinetic isotope effect study

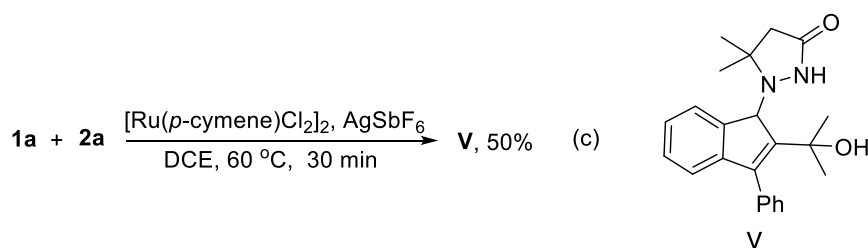


To a reaction tube equipped with a stir bar were charged with 2-benzylidene-3,3-dimethyl-5-oxopyrazolidin-2-ium-1-ide (**1a**, 40.4 mg, 0.2 mmol) and 2-(benzylidene-2,3,4,5,6-*d*<sub>5</sub>)-3,3-dimethyl-5-oxopyrazolidin-2-ium-1-ide (**1a-d<sub>5</sub>**, 41.4 mg, 0.2 mmol), HFIP (1 mL),  $[\text{Ru}(p\text{-cymene})\text{Cl}_2]_2$  (3.1 mg, 0.005 mmol),  $\text{AgSbF}_6$  (7.16 mg, 0.02 mmol) and 2-methyl-4-phenylbut-3-yn-2-ol (**2a**, 33.2 mg, 0.2 mmol). The mixture was stirred at 60 °C for 2 h under air. Upon completion, it was cooled to room temperature, filtered through a pad of celite and concentrated under reduced pressure. The residue was purified by silica gel chromatography using petroleum ether/ethyl acetate (1:1) as eluent to give a mixture of **3a** and **3a-d<sub>4</sub>**. Upon analyzing the <sup>1</sup>H NMR spectrum of the mixture as shown in Fig. S2, the ratio of **3a** and **3a-d<sub>4</sub>** was determined as 0.7:0.3. Accordingly, the intermolecular KIE ( $k_{\text{H}}/k_{\text{D}}$ ) was calculated as about 2.3.



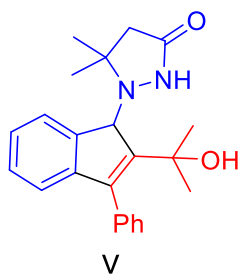
**Fig. S2** The  $^1\text{H}$  NMR spectrum of the products obtained from the intermolecular KIE experiment

### 3. Isolation and transformation of intermediate **V**



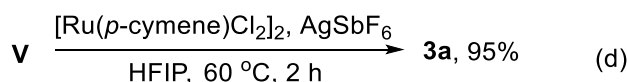
To a reaction tube equipped with a stir bar were charged with 2-benzylidene-3,3-dimethyl-5-oxopyrazolidin-2-ium-1-ide **1a** (40.4 mg, 0.2 mmol), DCE (1 mL),  $[\text{Ru}(p\text{-cymene})\text{Cl}_2]_2$  (3.1 mg, 0.005 mmol),  $\text{AgSbF}_6$  (7.16 mg, 0.02 mmol) and 2-methyl-4-phenylbut-3-yn-2-ol (**2a**, 32.1 mg, 0.3 mmol). The mixture was stirred at 60  $^\circ\text{C}$  for 30 min under air. Upon completion, it was cooled to room temperature, filtered through a pad of celite and concentrated under reduced pressure. The residue was purified by silica gel chromatography using petroleum ether/ethyl acetate (1:2) as eluent to afford **V** (36.2 mg, 50%).



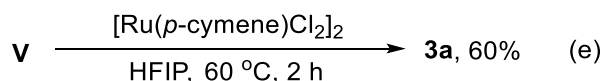


**1-(2-(2-Hydroxypropan-2-yl)-3-phenyl-1H-inden-1-yl)-5,5-dimethyl pyrazolidin-3-one (V)**

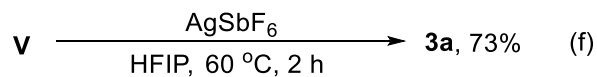
Eluent: petroleum ether/ethyl acetate (1:2). White solid (54.3 mg, 50%), mp 165.6-166.4 °C. <sup>1</sup>H NMR (400 MHz, DMSO-*d*<sub>6</sub>): δ 9.38 (br s, 1H), 7.60 (d, *J* = 6.8 Hz, 1H), 7.47-7.44 (m, 2H), 7.40-7.34 (m, 3H), 7.21-7.14 (m, 2H), 6.60-6.58 (m, 1H), 5.31 (br s, 1H), 5.10 (s, 1H), 2.61 (br s, 1H), 2.11 (d, *J* = 16.8 Hz, 1H), 1.59 (br s, 3H), 1.32 (s, 3H), 1.26 (s, 6H). <sup>13</sup>C{<sup>1</sup>H} NMR (100 MHz, DMSO-*d*<sub>6</sub>): δ 173.4, 149.8, 147.8, 140.9, 138.3, 136.9, 129.5, 128.54, 128.45, 127.7, 125.5, 124.3, 120.2, 71.9, 70.8, 62.8, 44.3, 32.6, 32.2. HRMS (ESI) *m/z*: [M+H]<sup>+</sup> Calcd for C<sub>23</sub>H<sub>27</sub>N<sub>2</sub>O<sub>2</sub> 363.2067; found 363.2065.



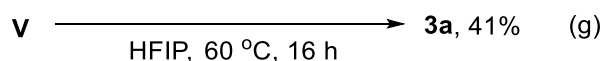
To a reaction tube equipped with a stir bar were charged with **V** (72.4 mg, 0.2 mmol), HFIP (1 mL), [Ru(*p*-cymene)Cl<sub>2</sub>]<sub>2</sub> (3.1 mg, 0.005 mmol) and AgSbF<sub>6</sub> (7.16 mg, 0.02 mmol). The mixture was stirred at 60 °C for 2 h under air. Upon completion, it was cooled to room temperature, filtered through a pad of celite and concentrated under reduced pressure. The residue was purified by silica gel chromatography using petroleum ether/ethyl acetate (1:1) as eluent to afford **3a** (65.4 mg, 95%).



To a reaction tube equipped with a stir bar were charged with **V** (36.2 mg, 0.1 mmol), HFIP (1 mL), [Ru(*p*-cymene)Cl<sub>2</sub>]<sub>2</sub> (1.6 mg, 0.0025 mmol). The mixture was stirred at 60 °C for 2 h under air. Upon completion, it was cooled to room temperature, filtered through a pad of celite and concentrated under reduced pressure. The residue was purified by silica gel chromatography using petroleum ether/ethyl acetate (1:1) as eluent to afford **3a** (20.7 mg, 60%).

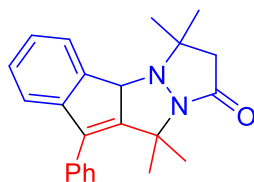
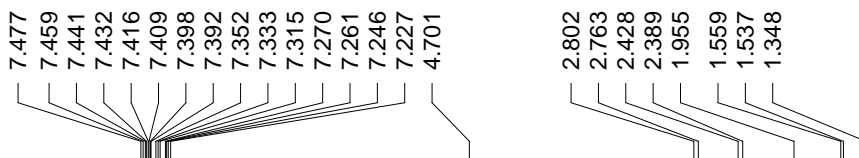


To a reaction tube equipped with a stir bar were charged with **V** (36.2 mg, 0.1 mmol), HFIP (1 mL), AgSbF<sub>6</sub> (3.6 mg, 0.01 mmol). The mixture was stirred at 60 °C for 2 h under air. Upon completion, it was cooled to room temperature, filtered through a pad of celite and concentrated under reduced pressure. The residue was purified by silica gel chromatography using petroleum ether/ethyl acetate (1:1) as eluent to afford **3a** (25.1 mg, 73%).



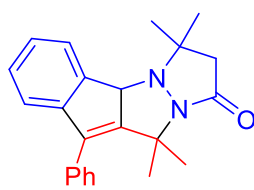
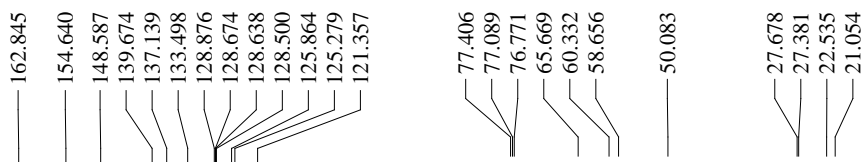
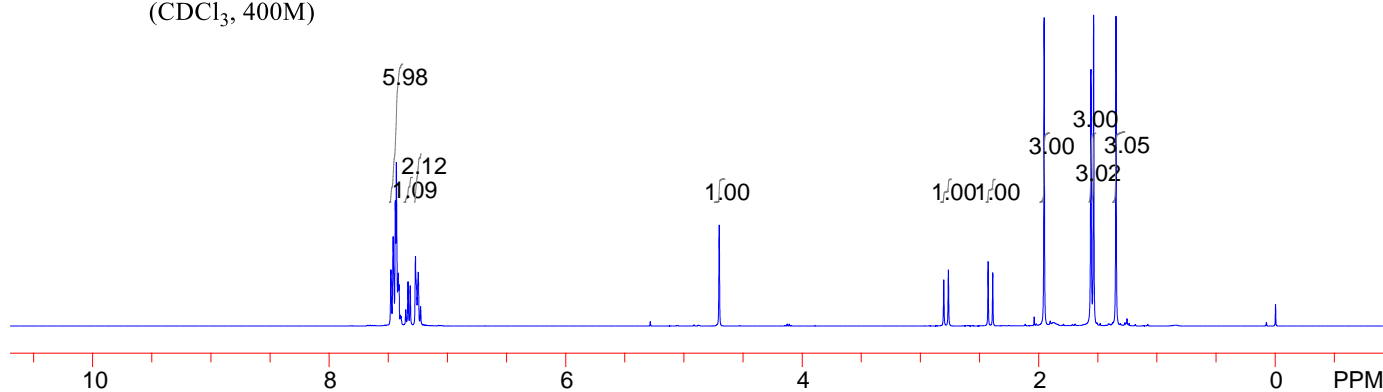
To a reaction tube equipped with a stir bar were charged with **V** (36.2 mg, 0.1 mmol), HFIP (1 mL). The mixture was stirred at 60 °C for 16 h under air. Upon completion, it was cooled to room temperature, filtered through a pad of celite and concentrated under reduced pressure. The residue was purified by silica gel chromatography using petroleum ether/ethyl acetate (1:1) as eluent to afford **3a** (14.1 mg, 41%).

#### IV. Copies of NMR spectra of 3a-3hh



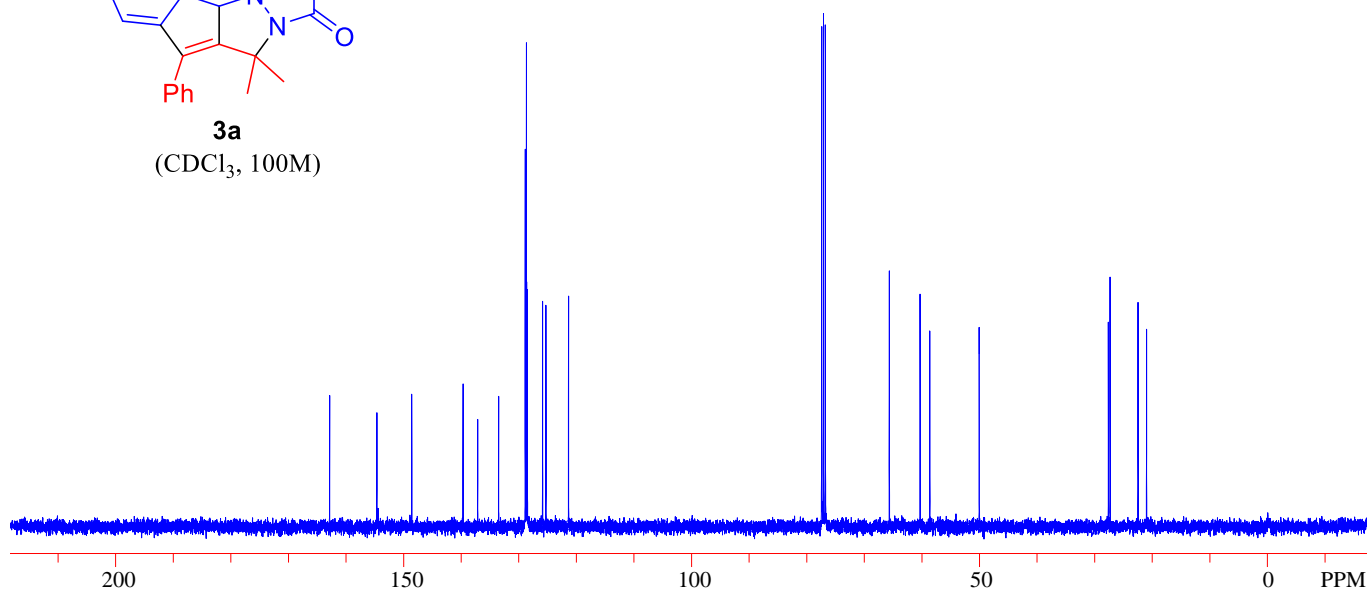
**3a**

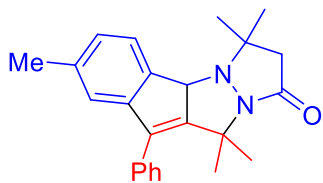
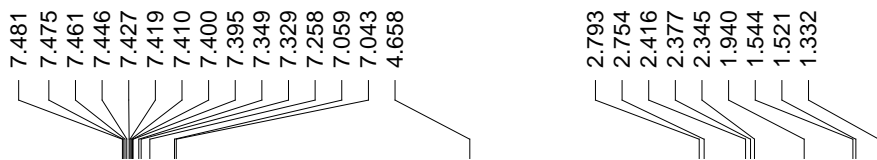
(CDCl<sub>3</sub>, 400M)



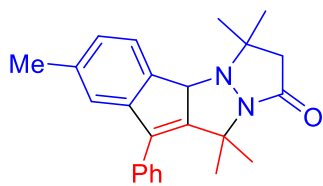
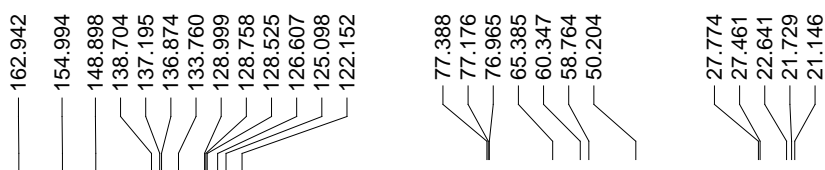
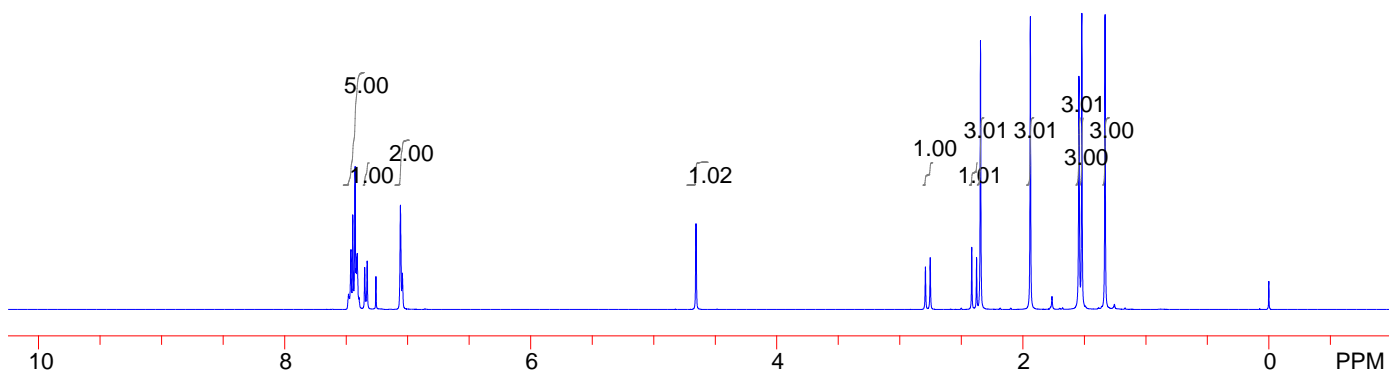
**3a**

(CDCl<sub>3</sub>, 100M)

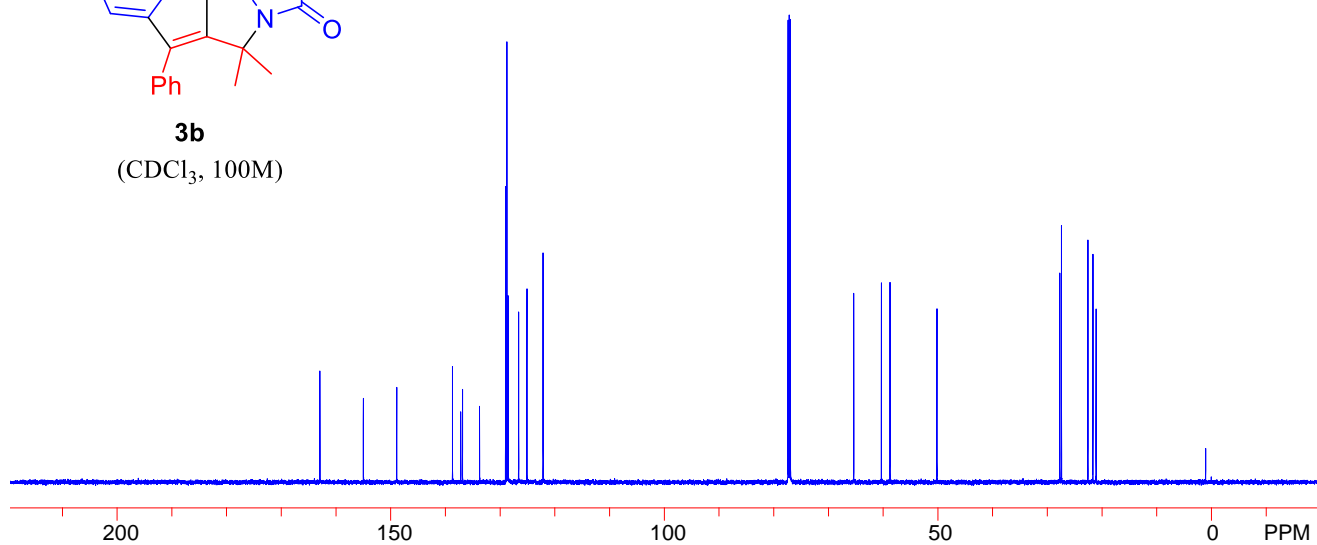


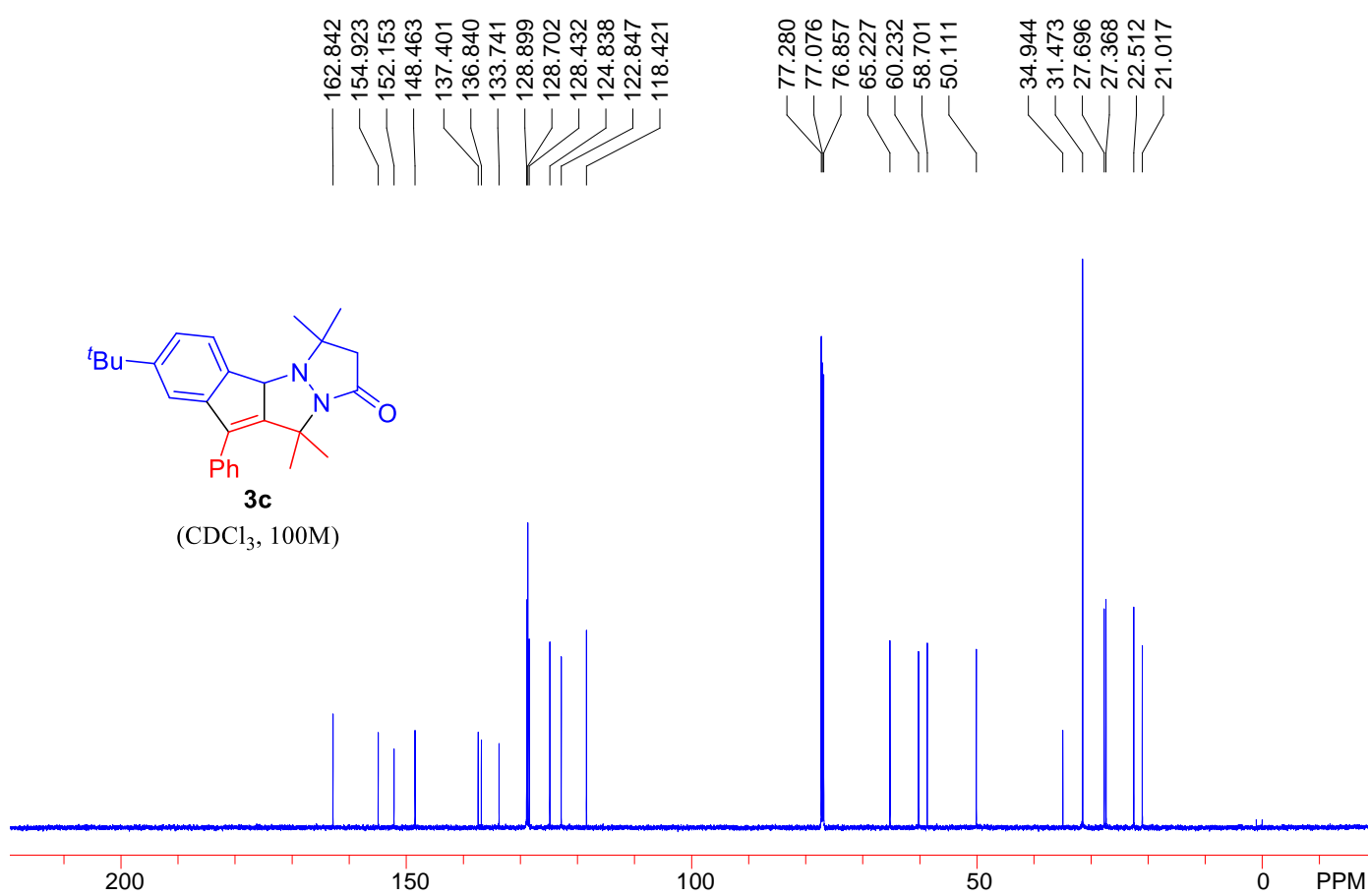
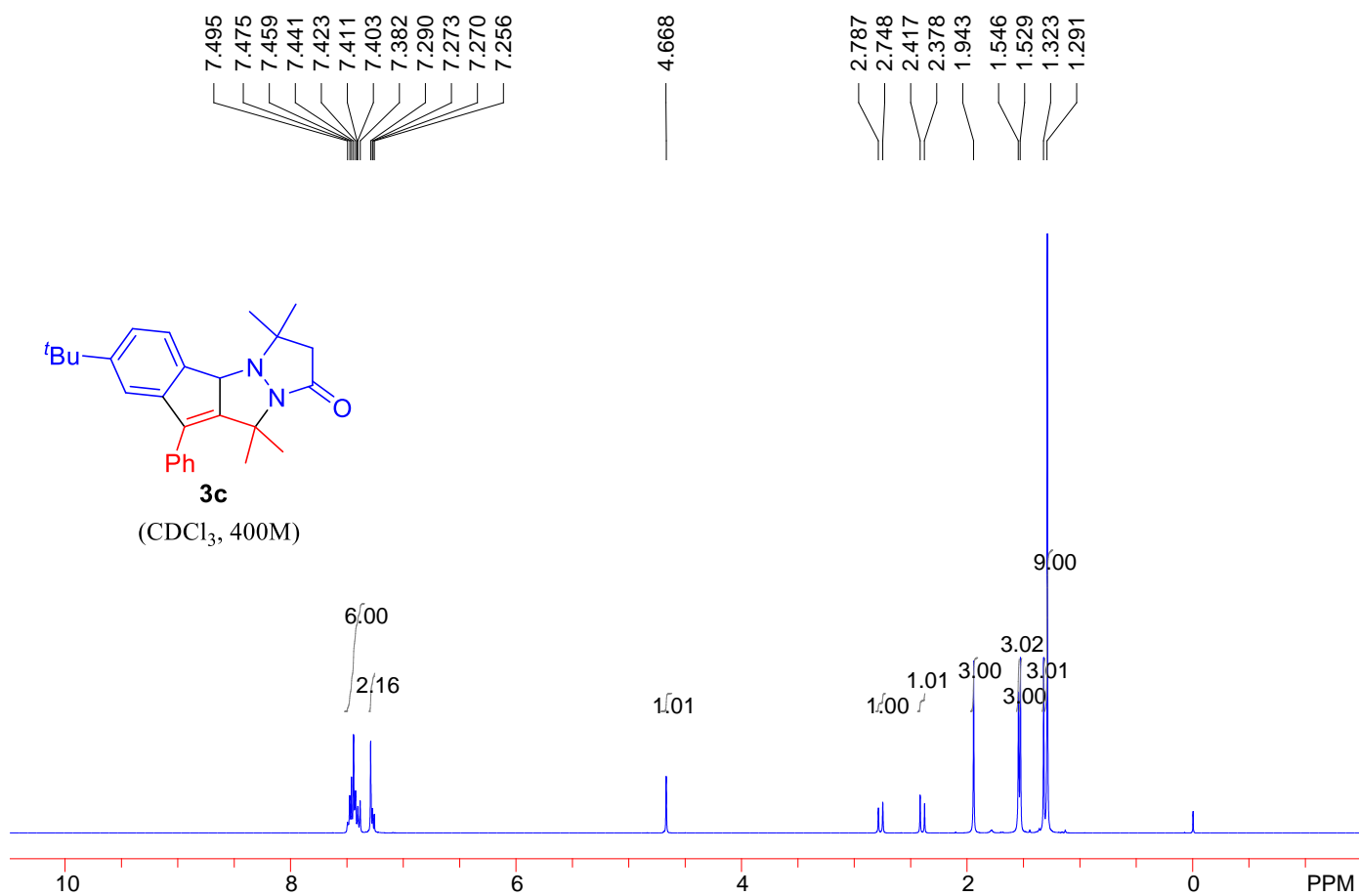


**3b**  
(CDCl<sub>3</sub>, 400M)

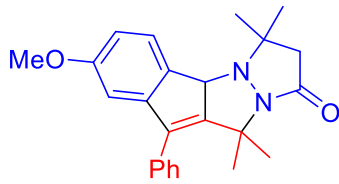


**3b**  
(CDCl<sub>3</sub>, 100M)

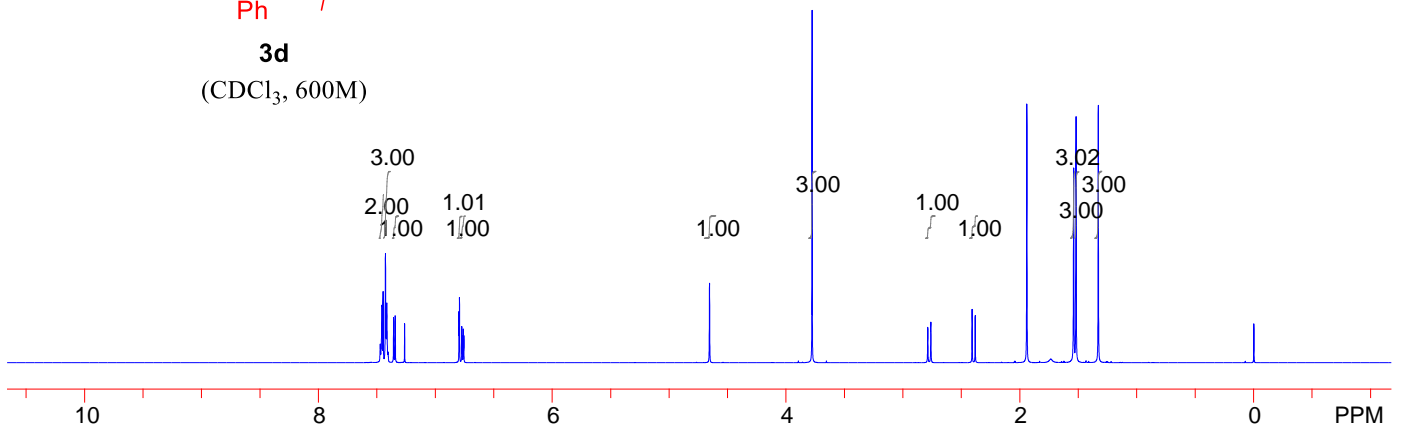




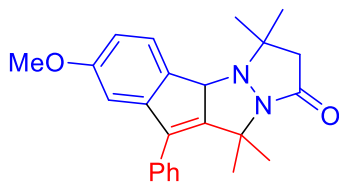
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7.457  
7.452  
7.446  
7.425  
7.419  
7.414  
7.406  
7.403  
7.356  
7.342  
7.262  
6.796  
6.792  
6.773  
6.769  
6.759  
6.755  
4.654  
3.777  
2.788  
2.762  
2.409  
2.383  
1.941  
1.541  
1.520  
1.330



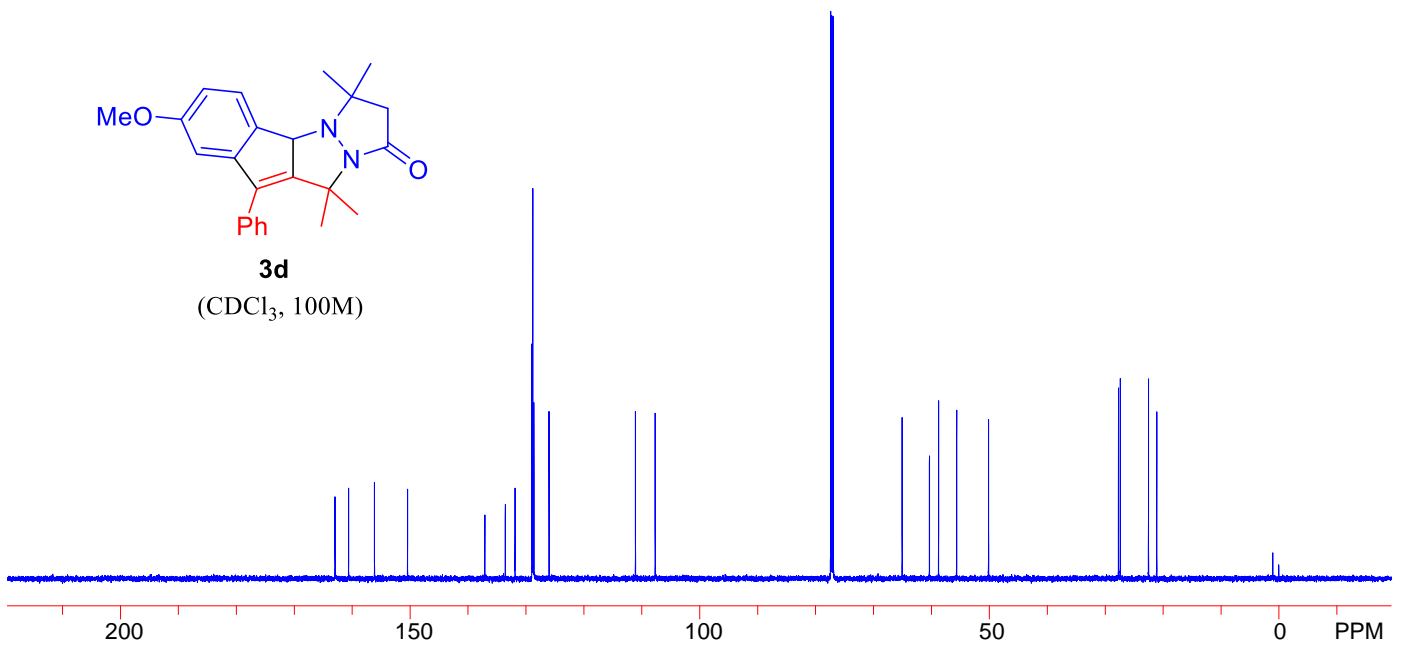
**3d**  
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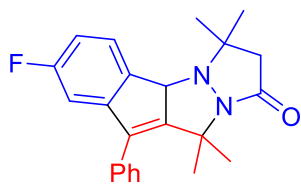
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156.154  
150.437  
137.093  
133.557  
131.879  
128.963  
128.824  
128.627  
126.010  
111.098  
107.685  
77.388  
77.176  
76.965  
65.072  
60.361  
58.786  
55.666  
50.168  
27.767  
27.446  
22.590  
21.161



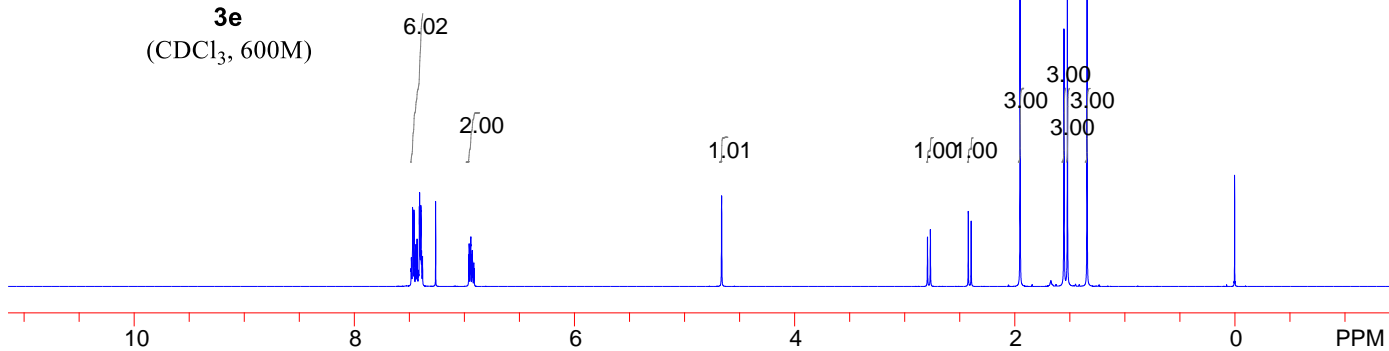
**3d**  
(CDCl<sub>3</sub>, 100M)



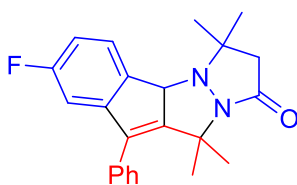
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7.471  
7.469  
7.459  
7.445  
7.443  
7.440  
7.435  
7.430  
7.426  
7.421  
7.418  
7.416  
7.410  
7.408  
7.403  
7.396  
7.394  
7.389  
7.381  
7.262  
6.961  
6.957  
6.945  
6.943  
6.942  
6.929  
6.926  
6.915  
6.911  
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2.791  
2.765  
2.420  
2.394  
1.950  
1.551  
1.519  
1.341



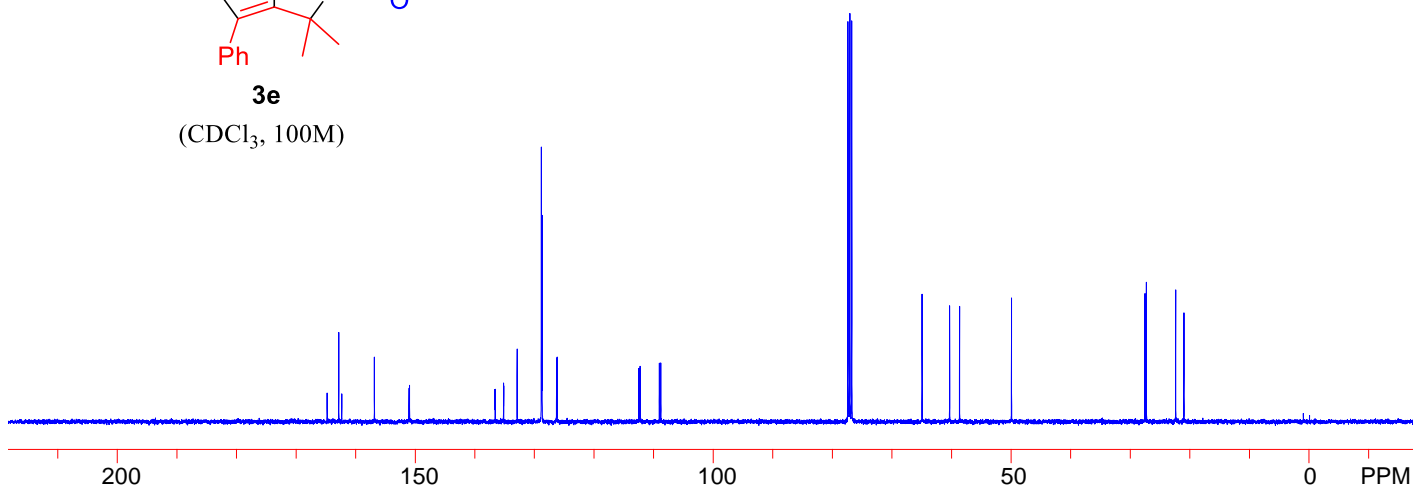
**3e**  
(CDCl<sub>3</sub>, 600M)

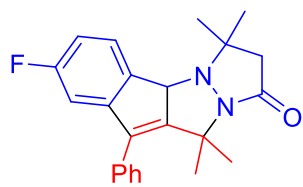


164.788  
162.845  
162.339  
156.857  
151.043  
150.956  
136.590  
136.561  
135.174  
135.145  
132.892  
128.833  
128.775  
128.710  
126.276  
126.182  
112.480  
112.256  
109.035  
108.797  
77.377  
77.060  
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49.967  
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22.448  
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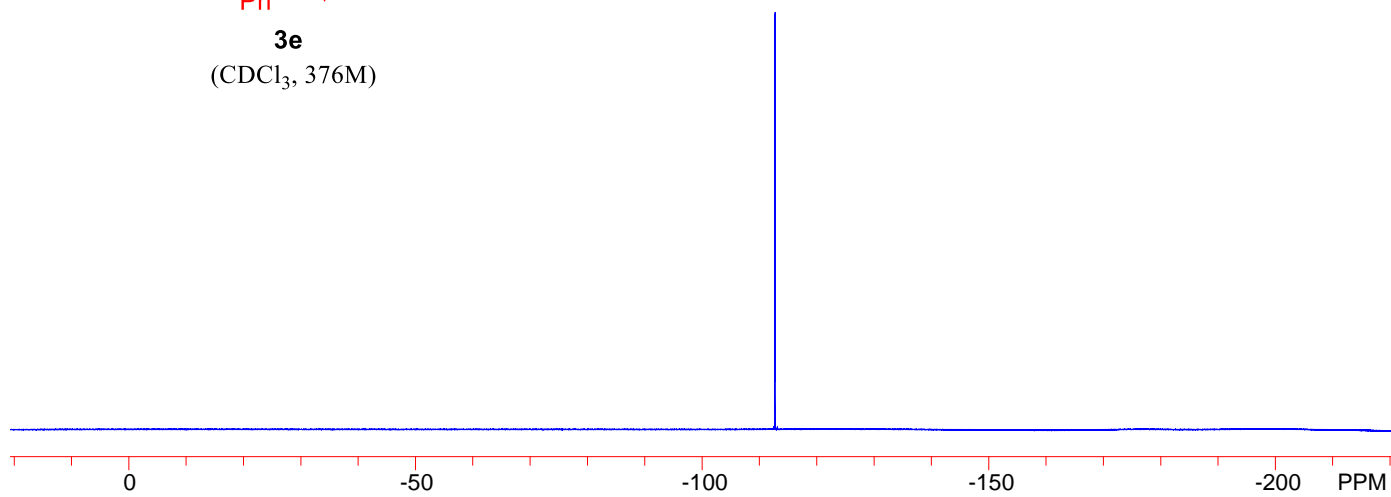
**3e**  
(CDCl<sub>3</sub>, 100M)



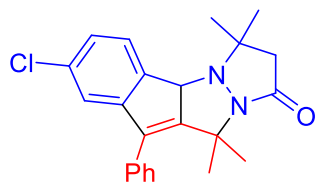
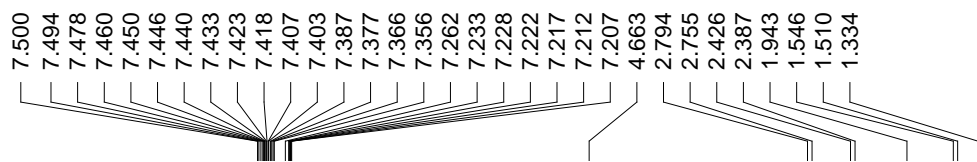


**3e**  
(CDCl<sub>3</sub>, 376M)

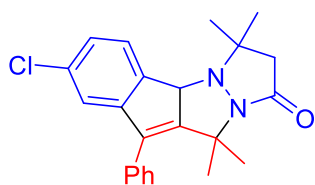
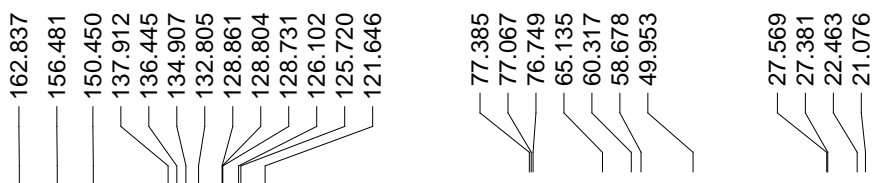
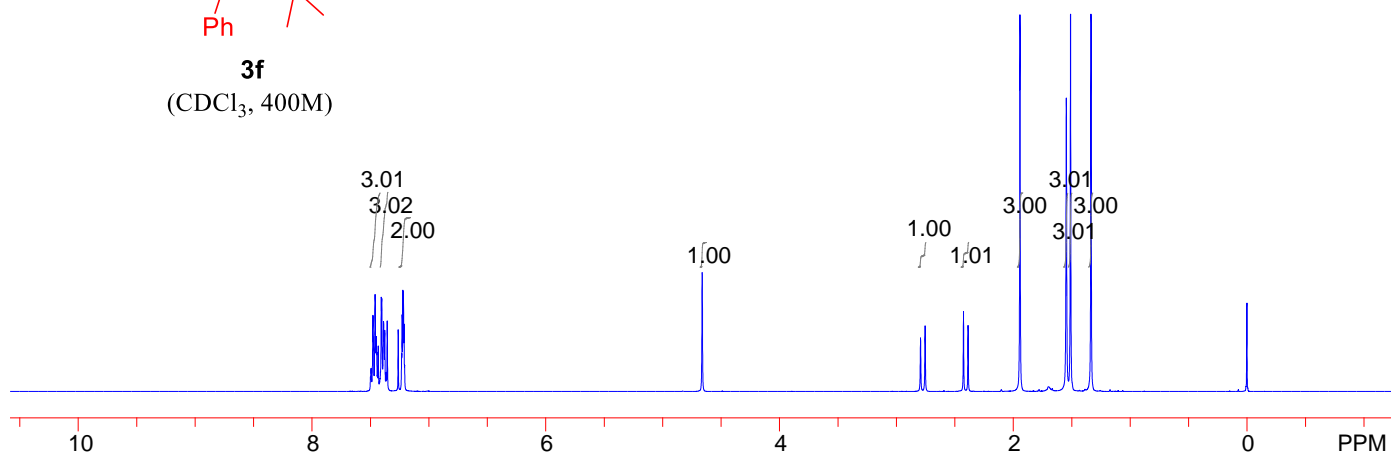
112.621  
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112.643  
112.658  
112.669  
112.680



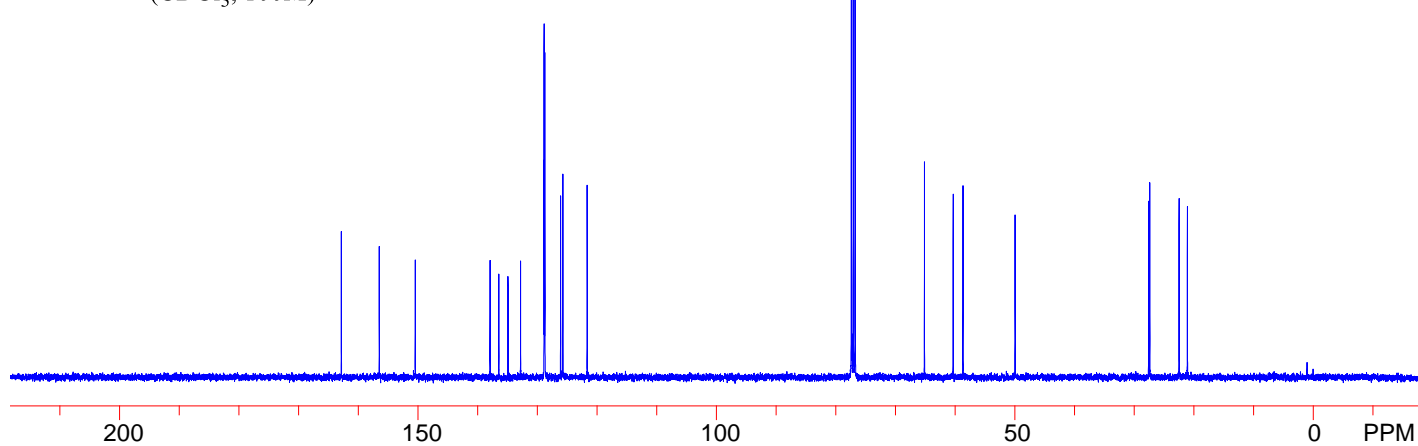


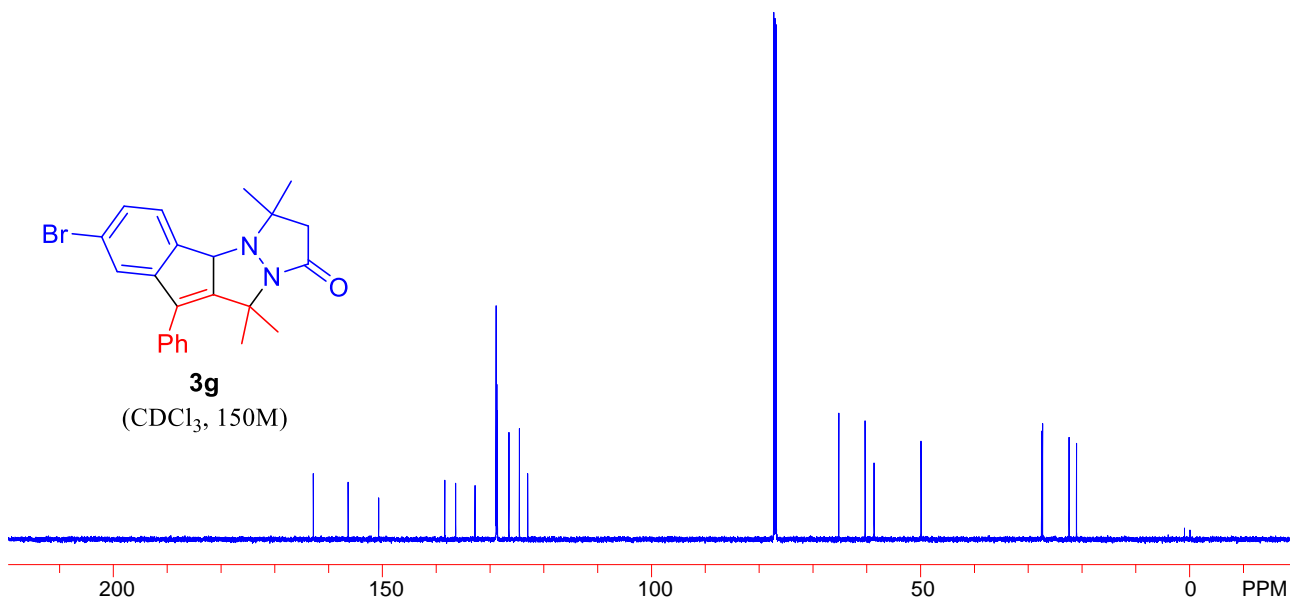
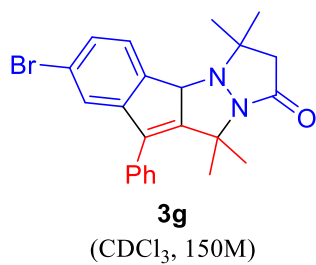
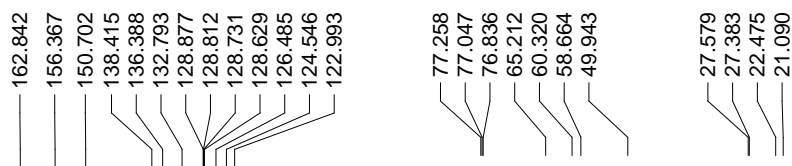
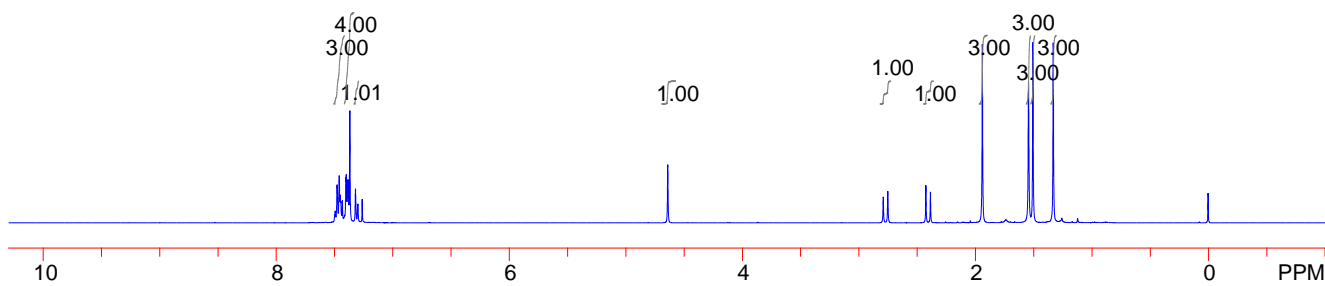
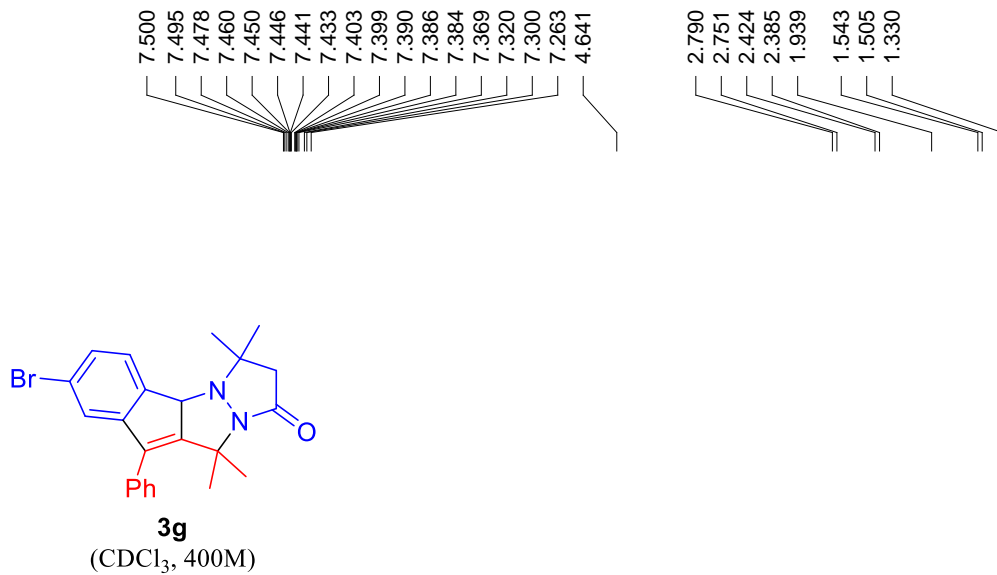


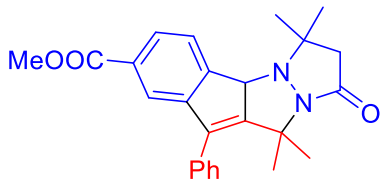
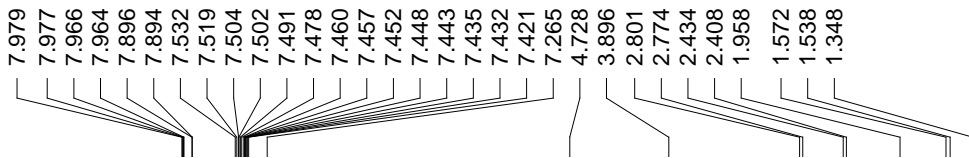
**3f**  
(CDCl<sub>3</sub>, 400M)



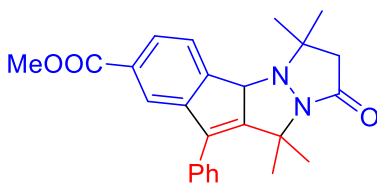
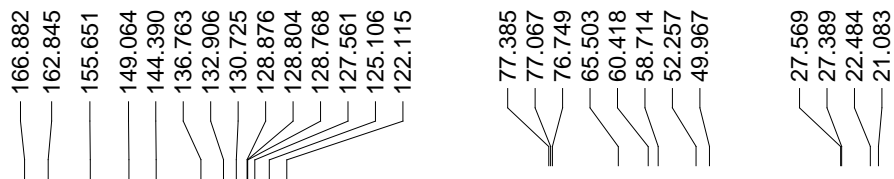
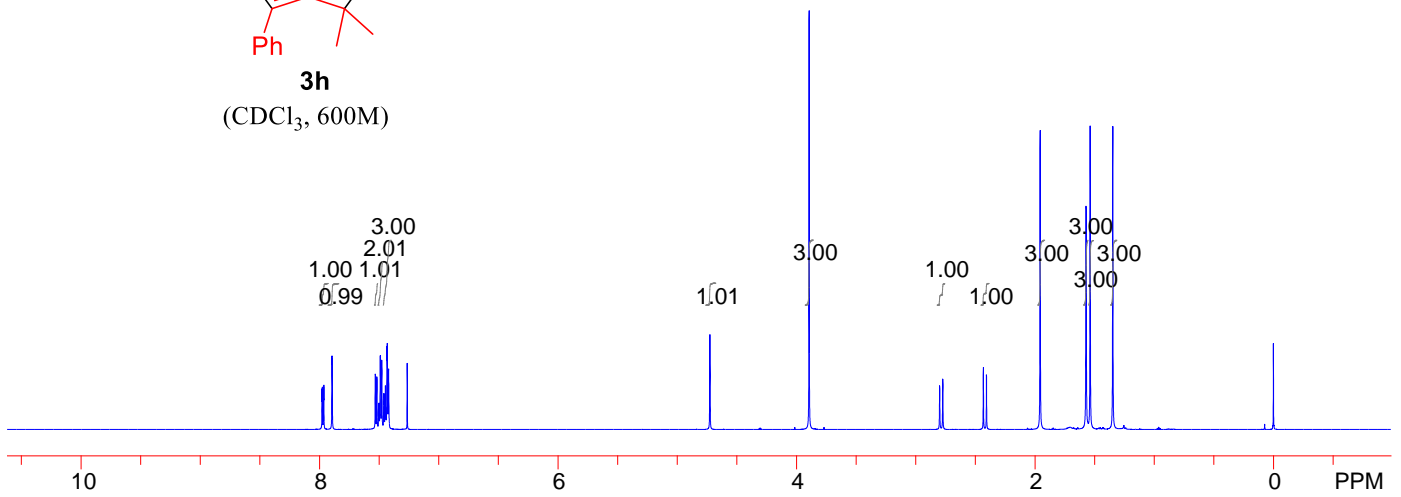
**3f**  
(CDCl<sub>3</sub>, 100M)



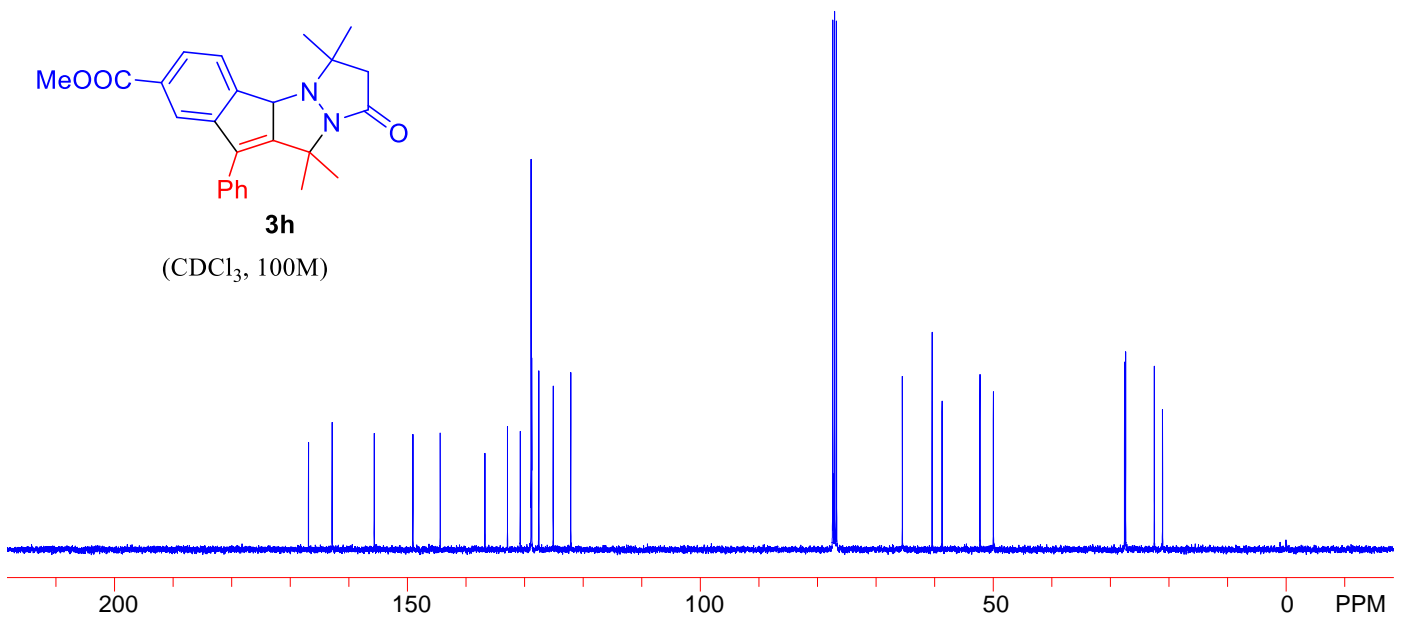


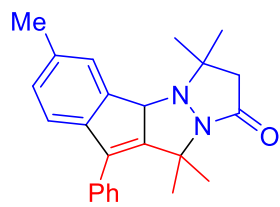
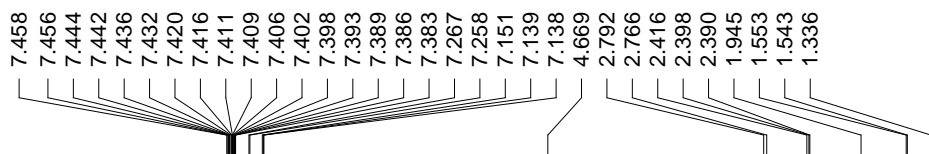


**3h**  
(CDCl<sub>3</sub>, 600M)

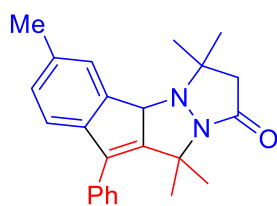
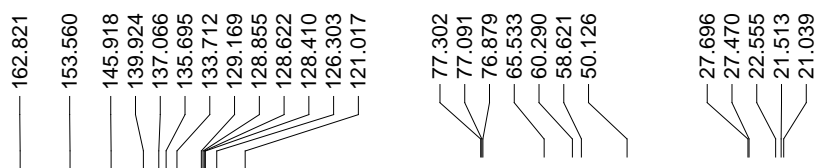
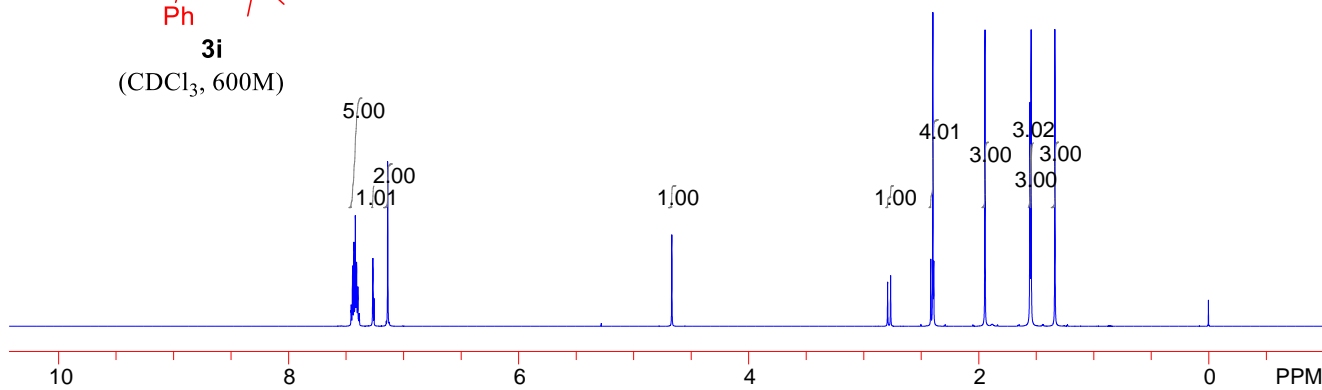


**3h**  
(CDCl<sub>3</sub>, 100M)

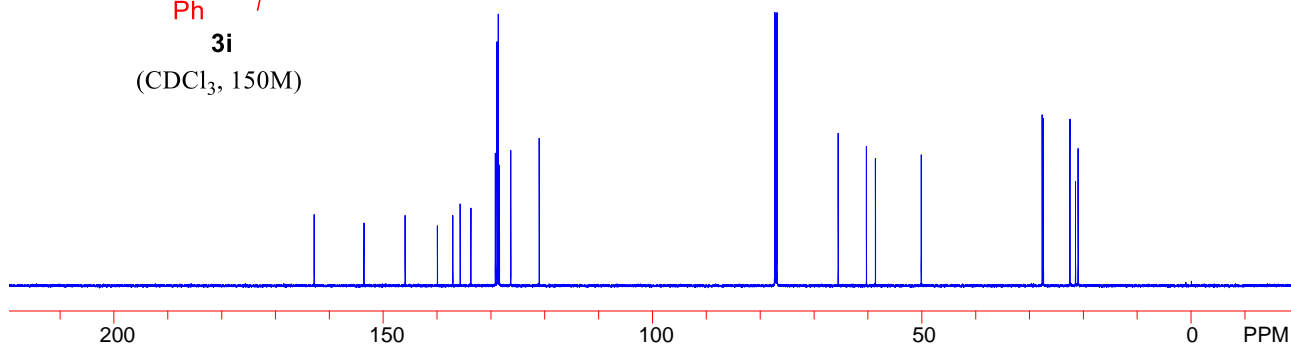


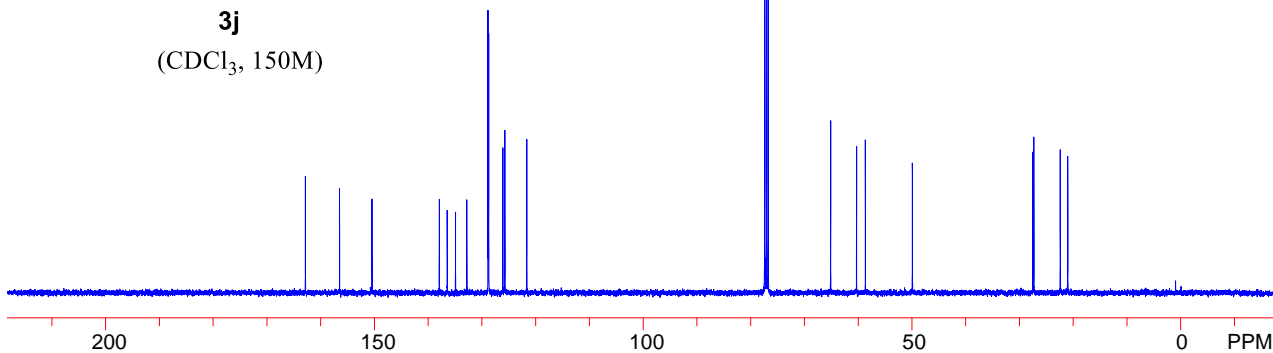
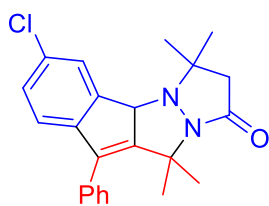
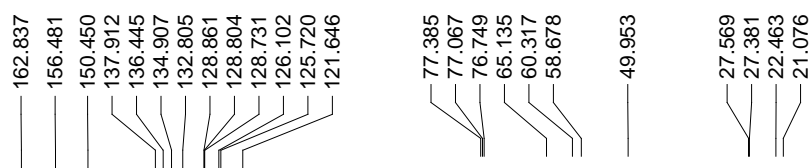
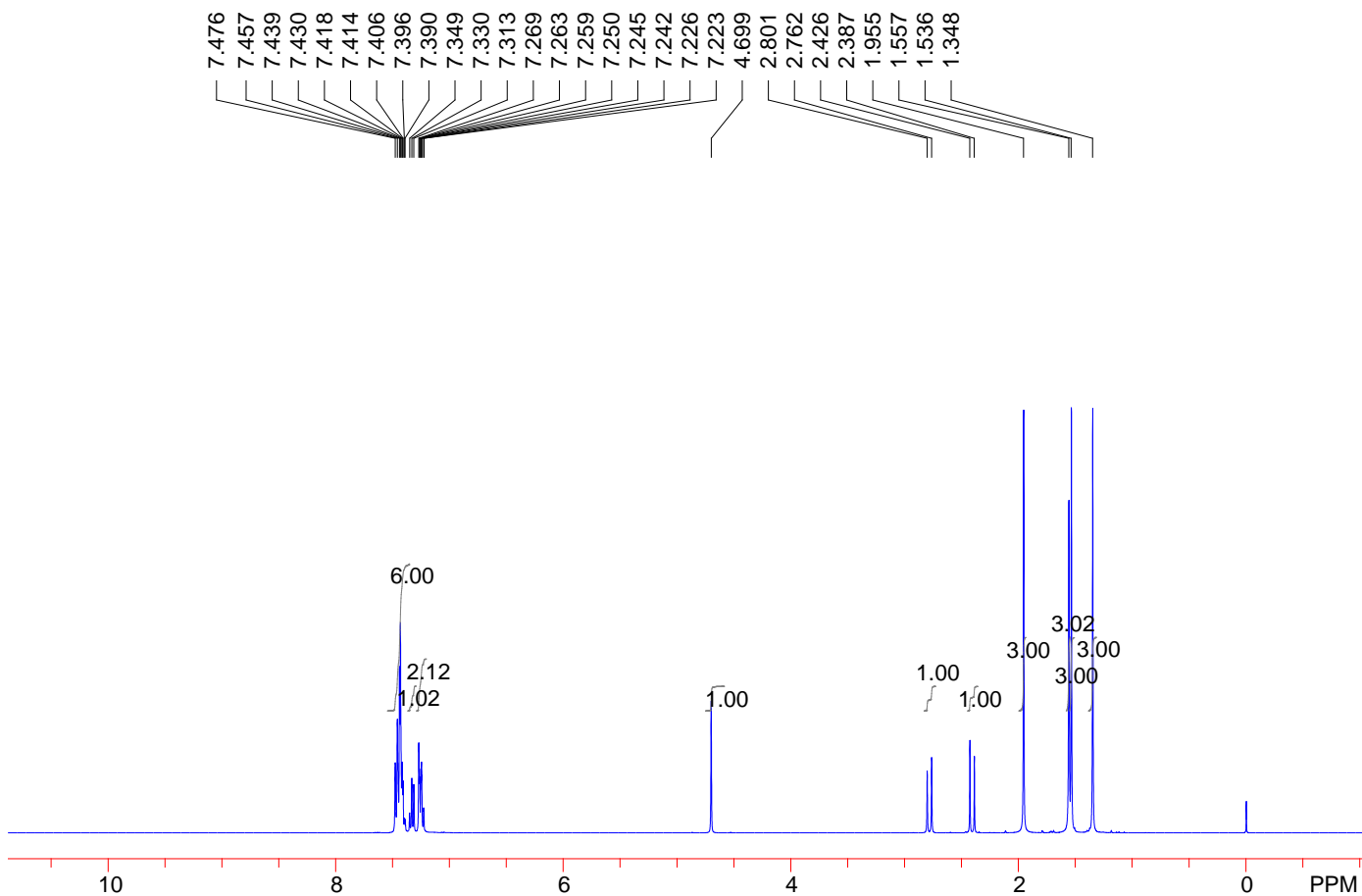


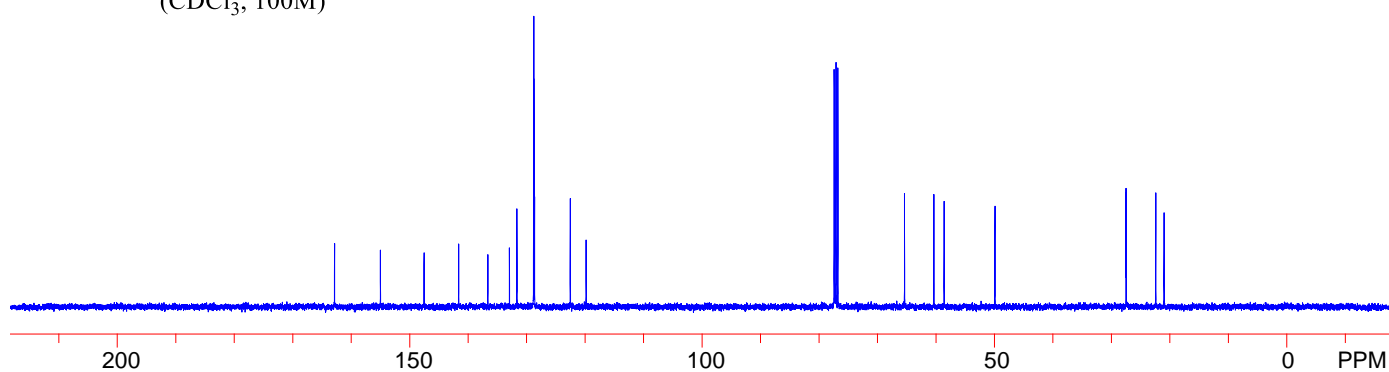
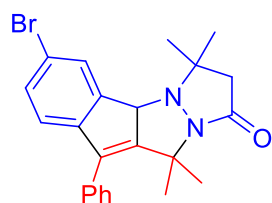
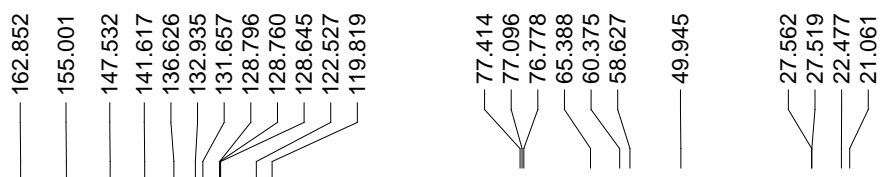
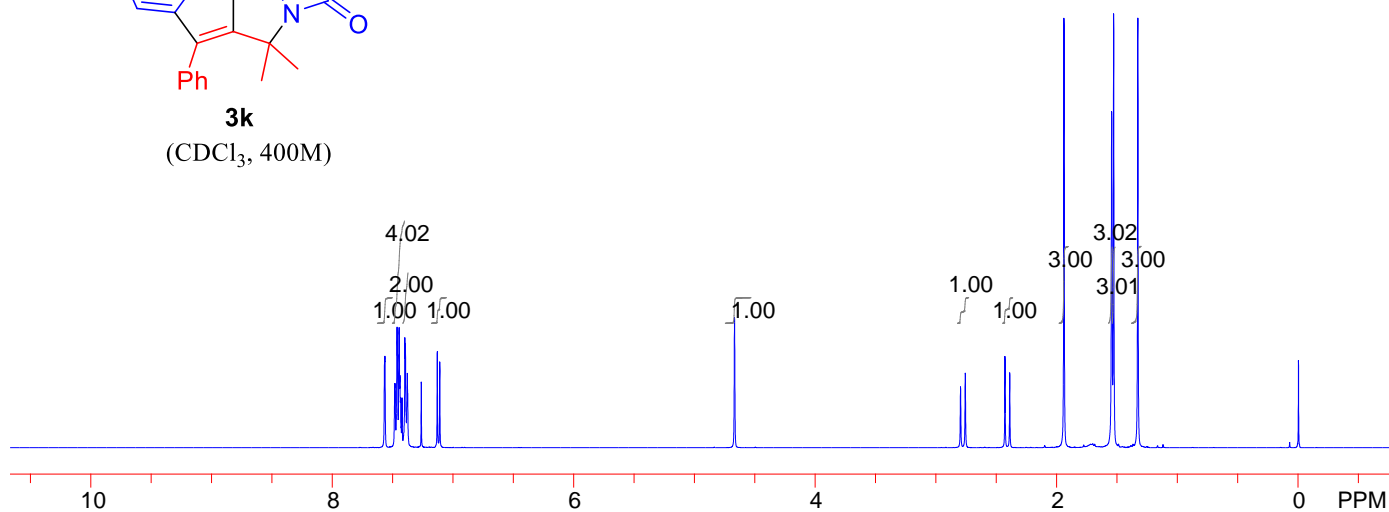
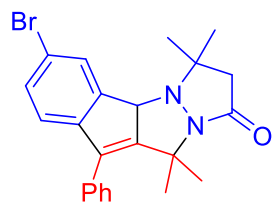
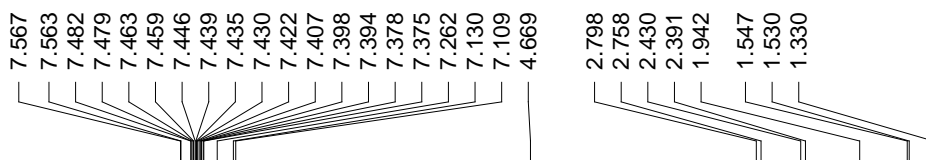
**3i**  
(CDCl<sub>3</sub>, 600M)

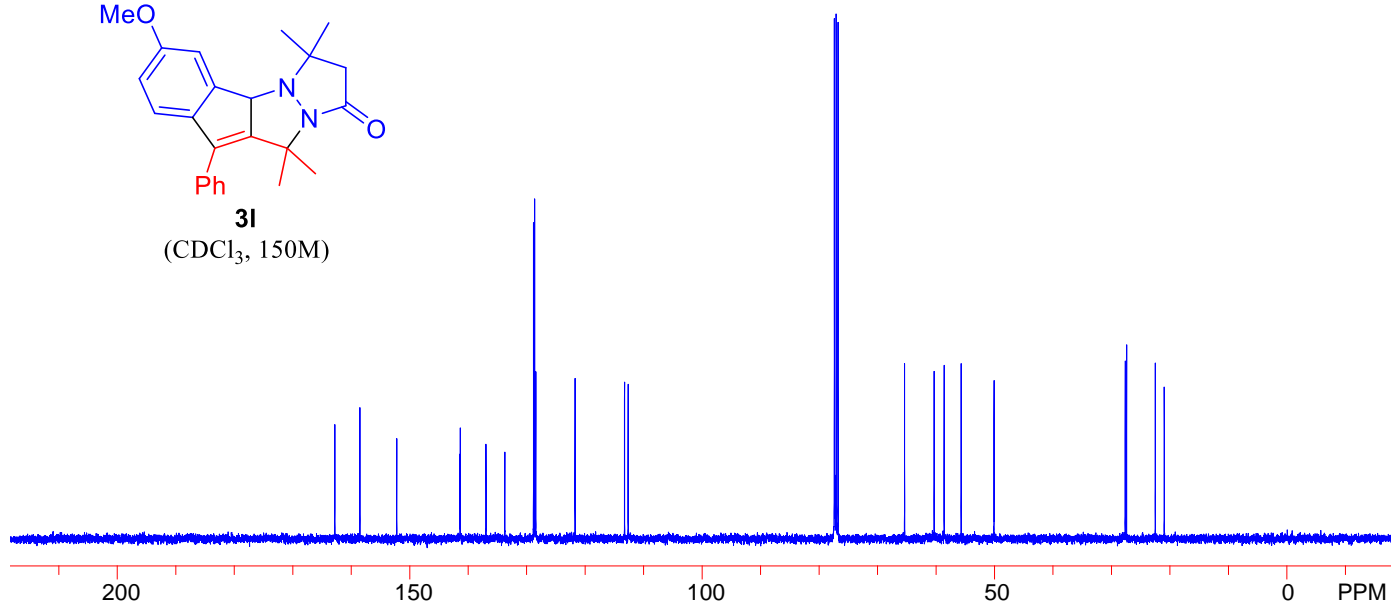
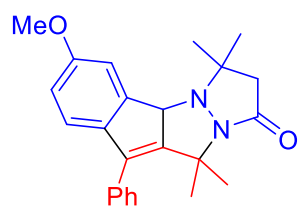
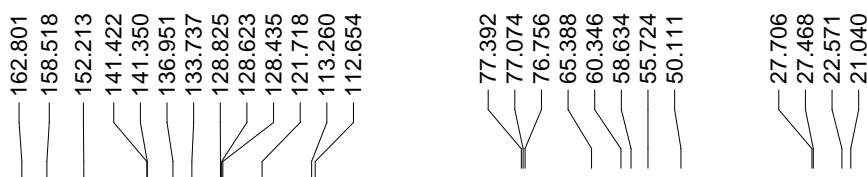
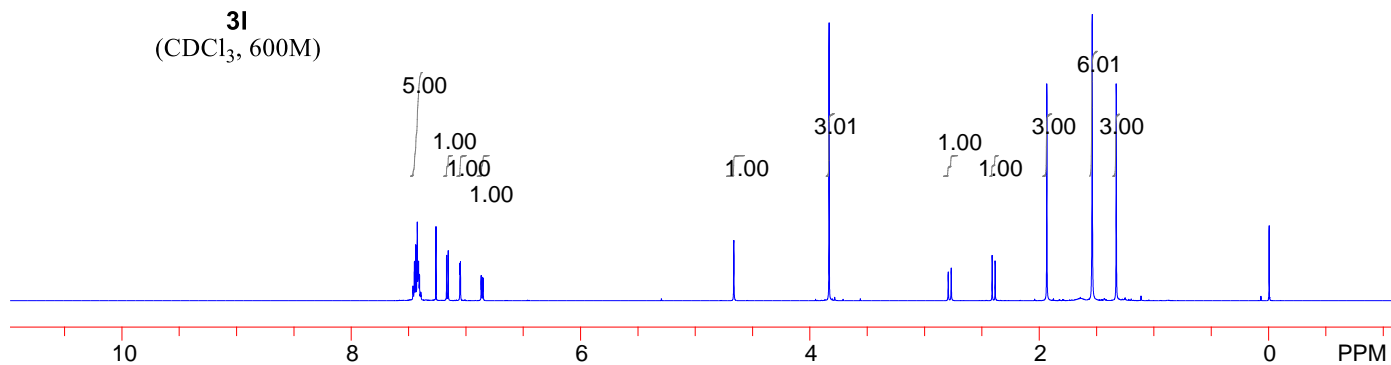
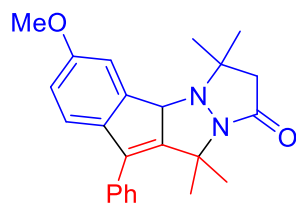
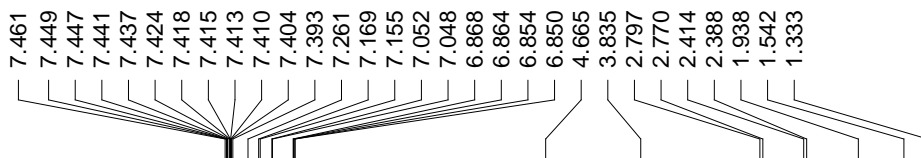


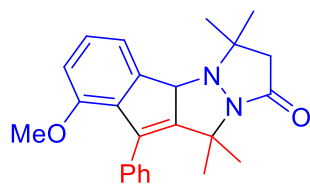
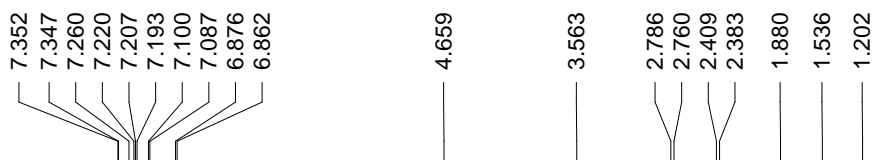
**3i**  
(CDCl<sub>3</sub>, 150M)



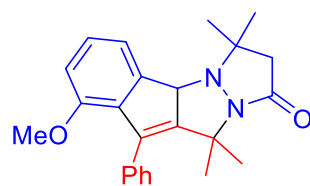
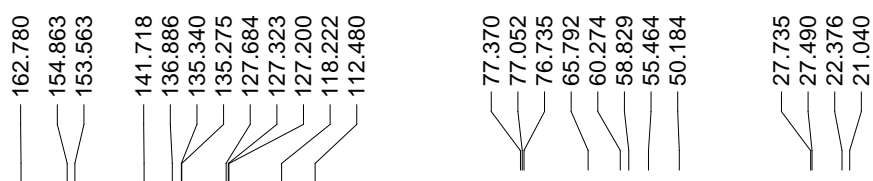
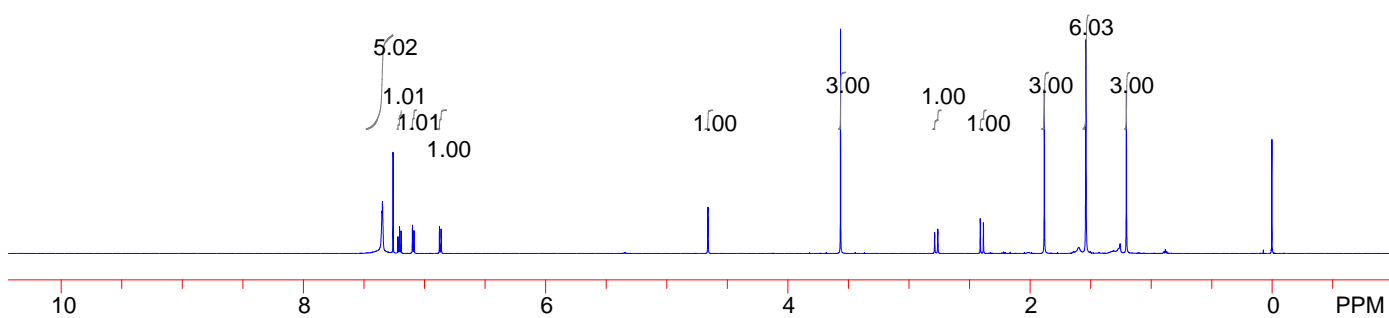




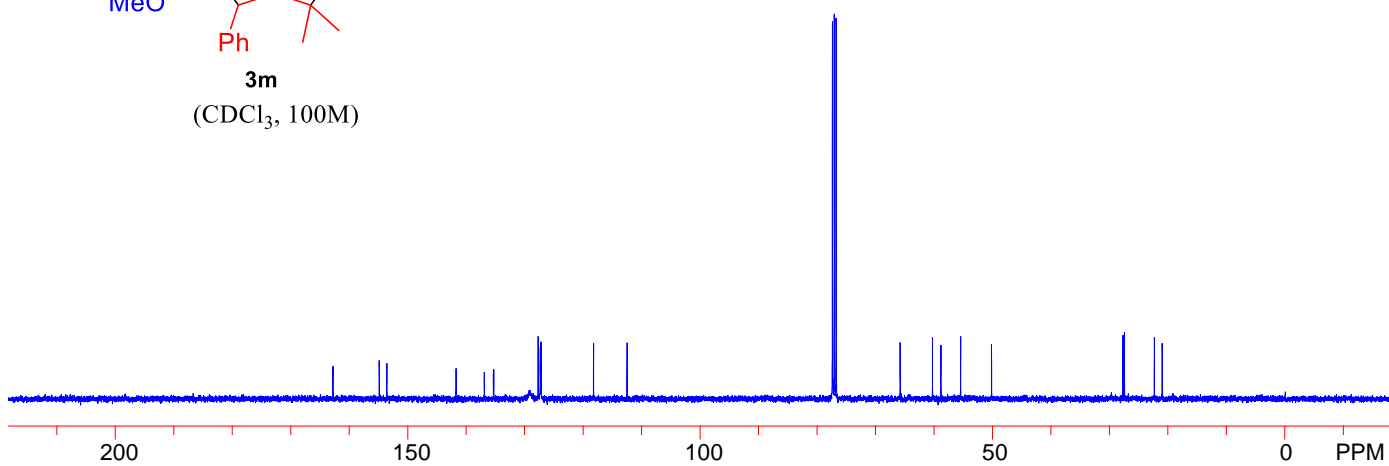




**3m**  
(CDCl<sub>3</sub>, 600M)



**3m**  
(CDCl<sub>3</sub>, 100M)

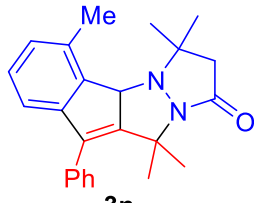




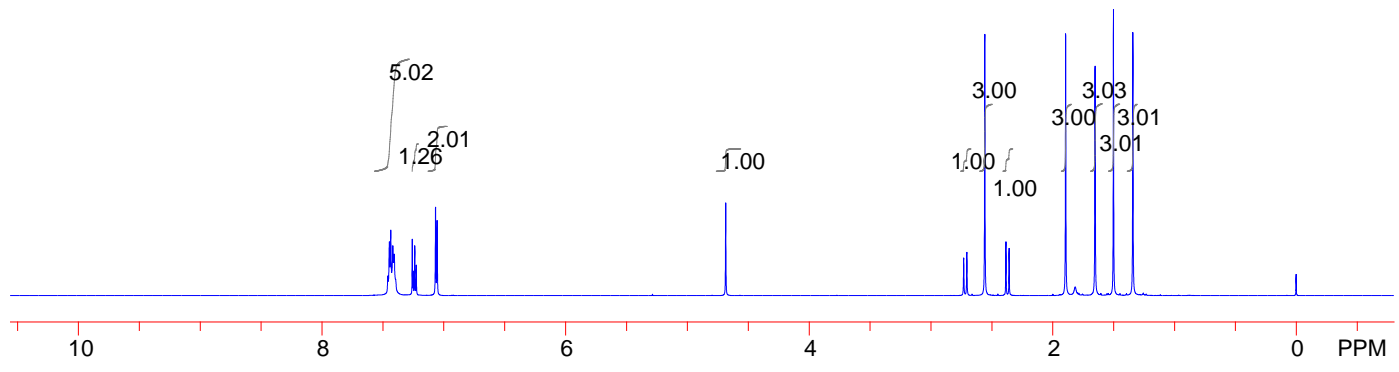
7.459  
7.447  
7.435  
7.419  
7.406  
7.395  
7.259  
7.251  
7.238  
7.226  
7.068  
7.055

4.686

2.731  
2.705  
2.558  
2.385  
2.359  
1.894  
1.652  
1.501  
1.341



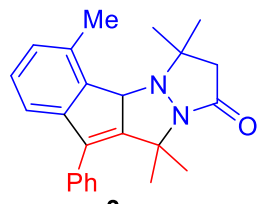
(CDCl<sub>3</sub>, 600M)



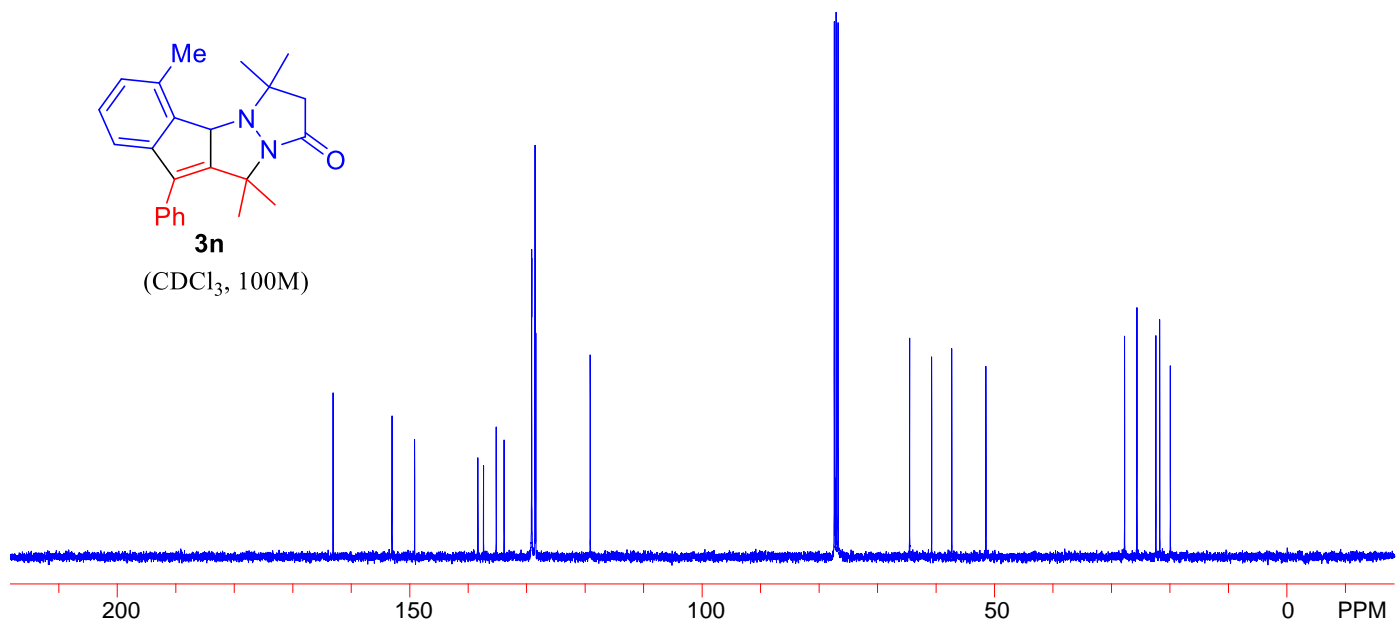
163.105  
153.022  
149.157  
138.338  
137.370  
135.203  
133.860  
129.150  
129.129  
128.565  
128.428  
119.140

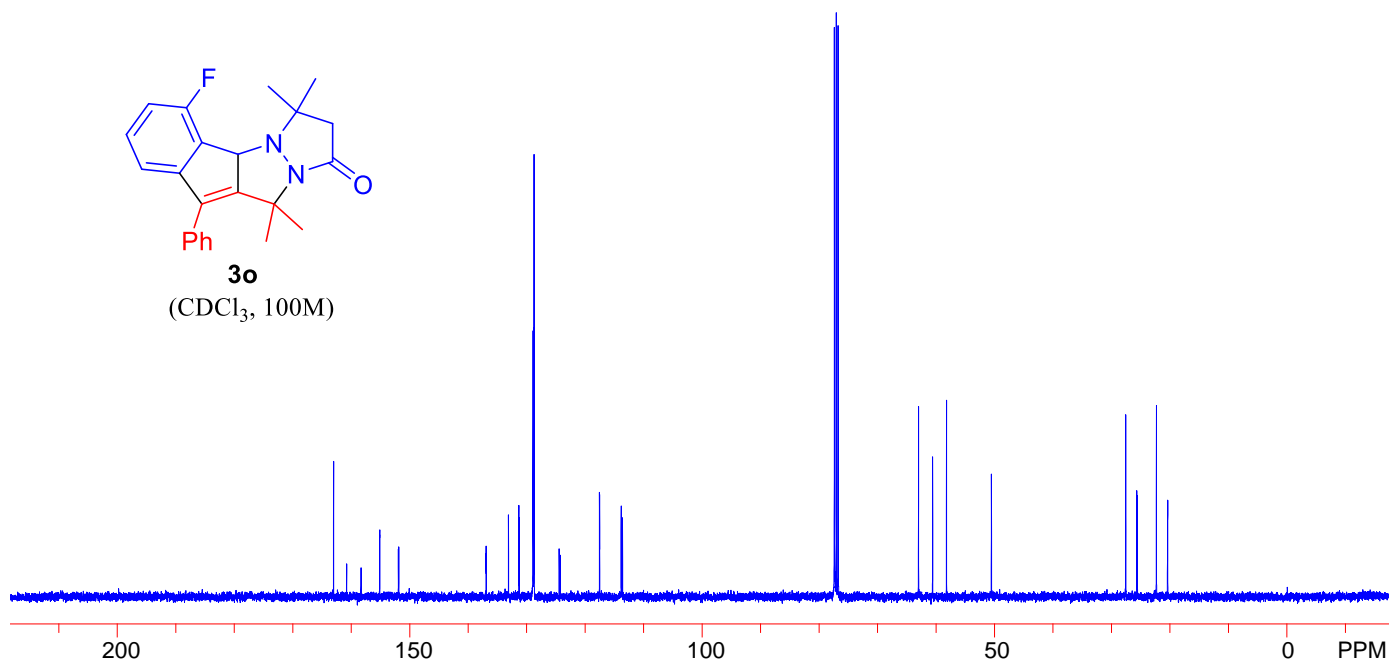
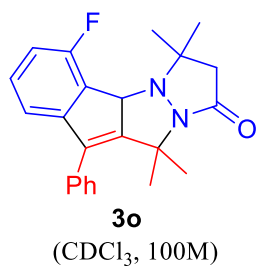
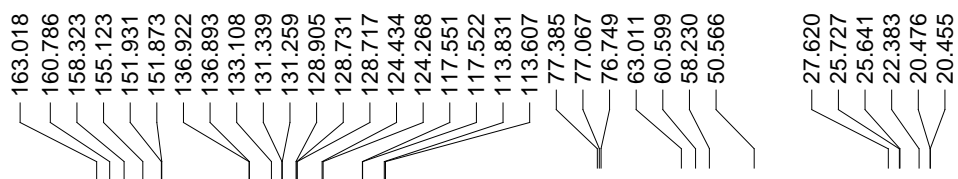
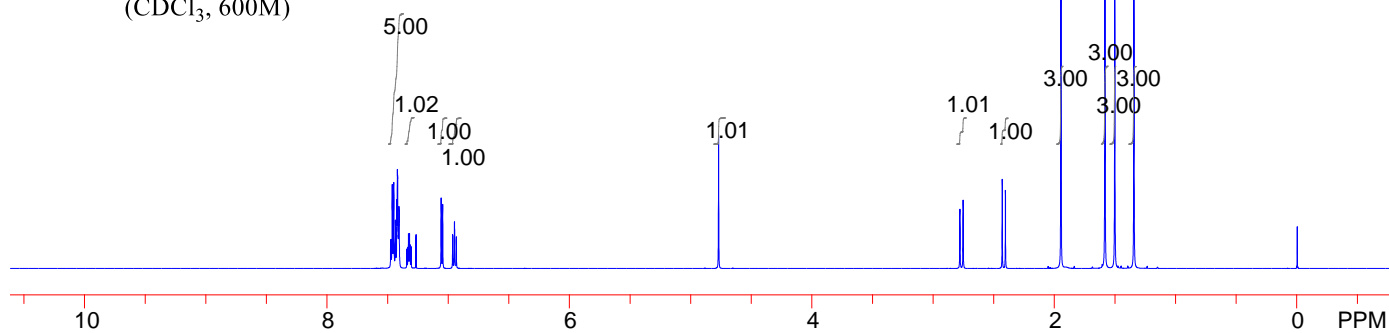
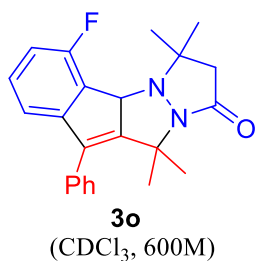
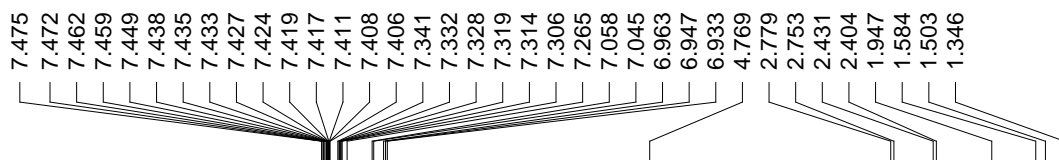
77.399  
77.081  
76.764  
64.535  
60.765  
57.327  
51.498

27.815  
25.706  
22.470  
21.813  
20.000

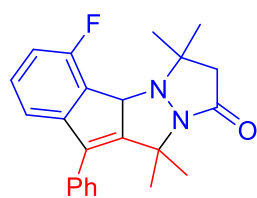


(CDCl<sub>3</sub>, 100M)

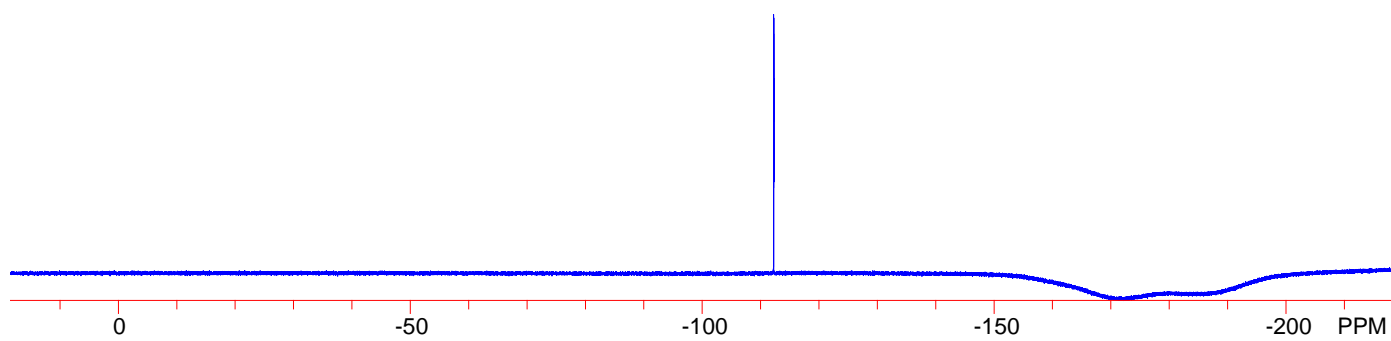


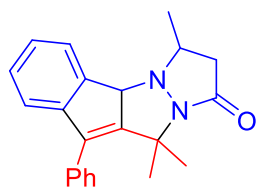
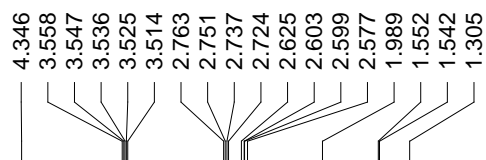
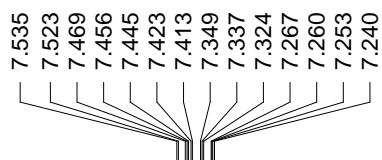


112.279  
112.286  
112.297  
112.304



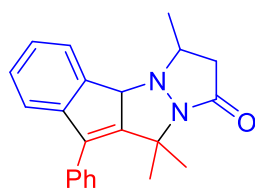
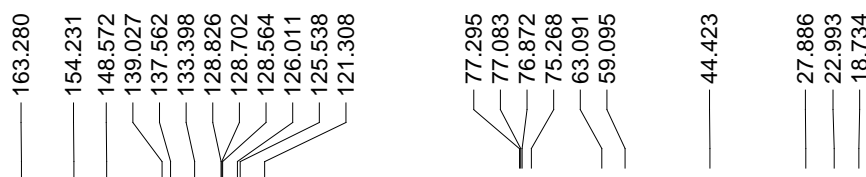
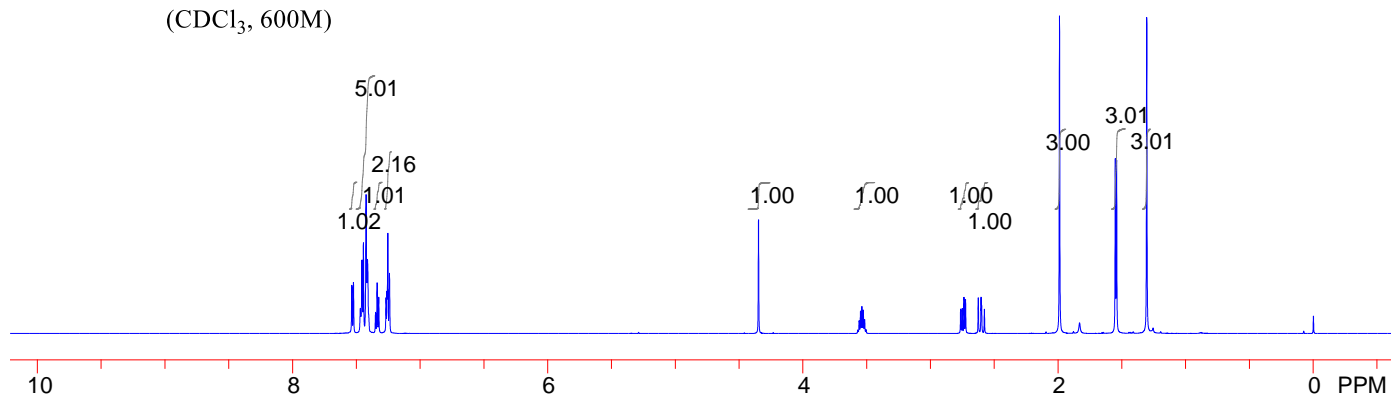
**3o**  
(CDCl<sub>3</sub>, 565M)





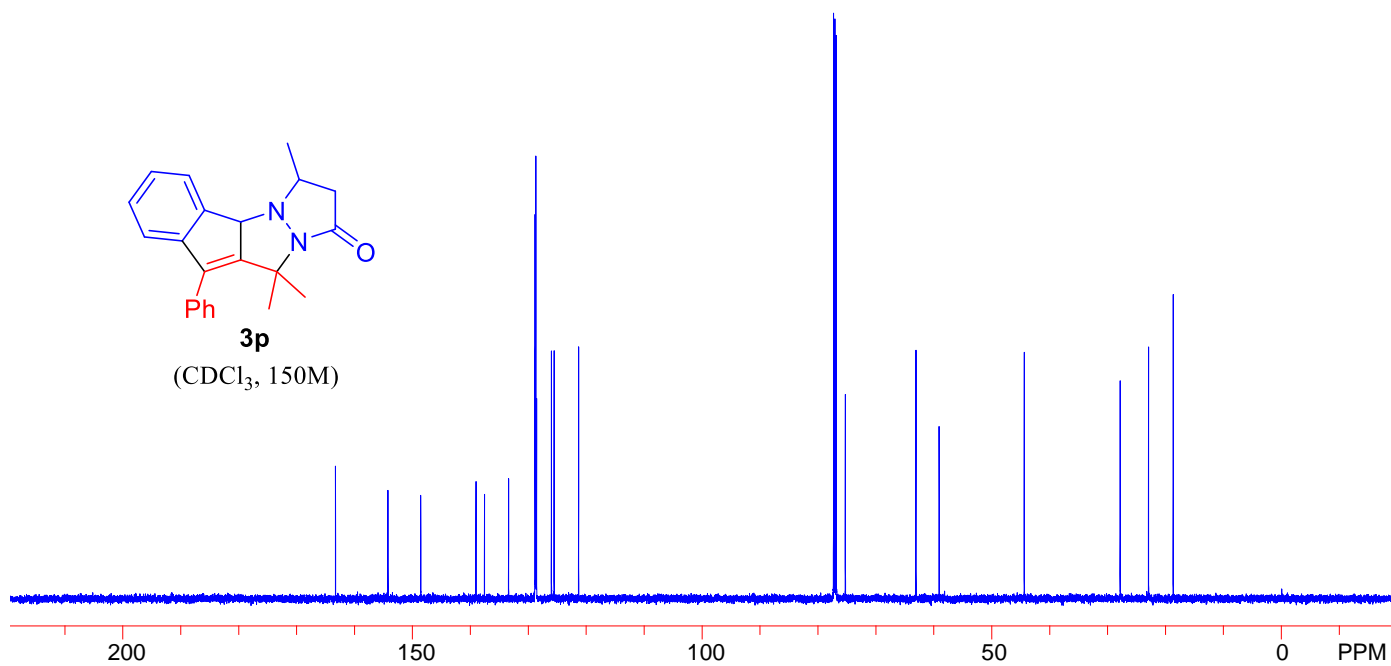
**3p**

(CDCl<sub>3</sub>, 600M)

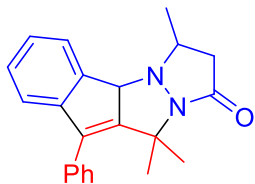


**3p**

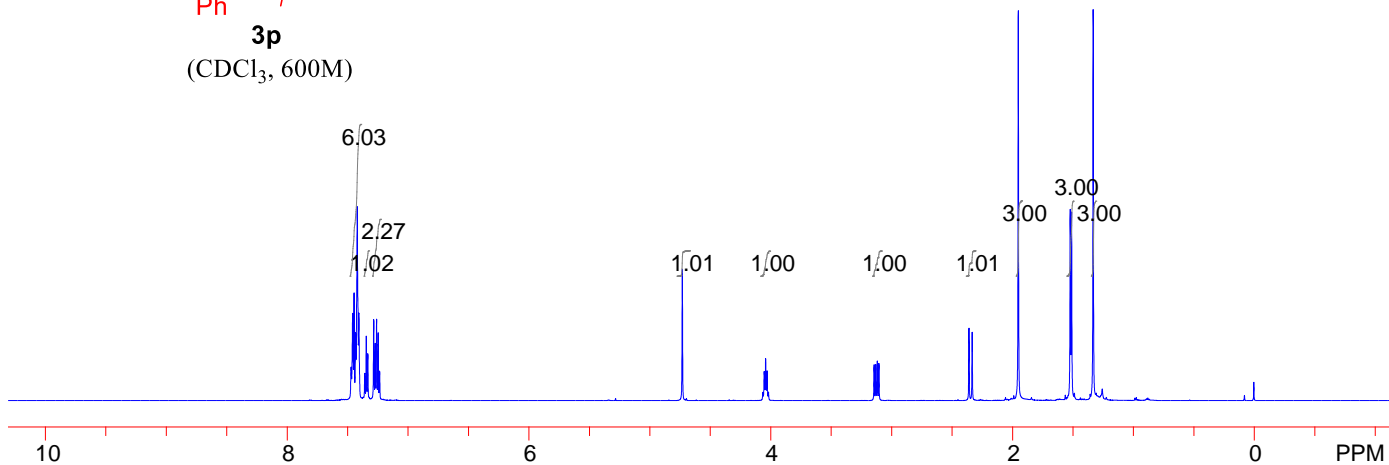
(CDCl<sub>3</sub>, 150M)



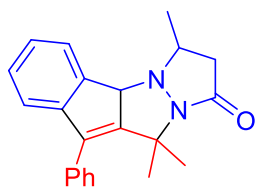
7.472  
7.459  
7.447  
7.435  
7.421  
7.407  
7.358  
7.346  
7.333  
7.285  
7.272  
7.261  
7.248  
7.235  
4.732  
4.066  
4.054  
4.043  
4.031  
4.019  
3.145  
3.131  
3.118  
3.105  
2.359  
2.332  
1.951  
1.521  
1.509  
1.331



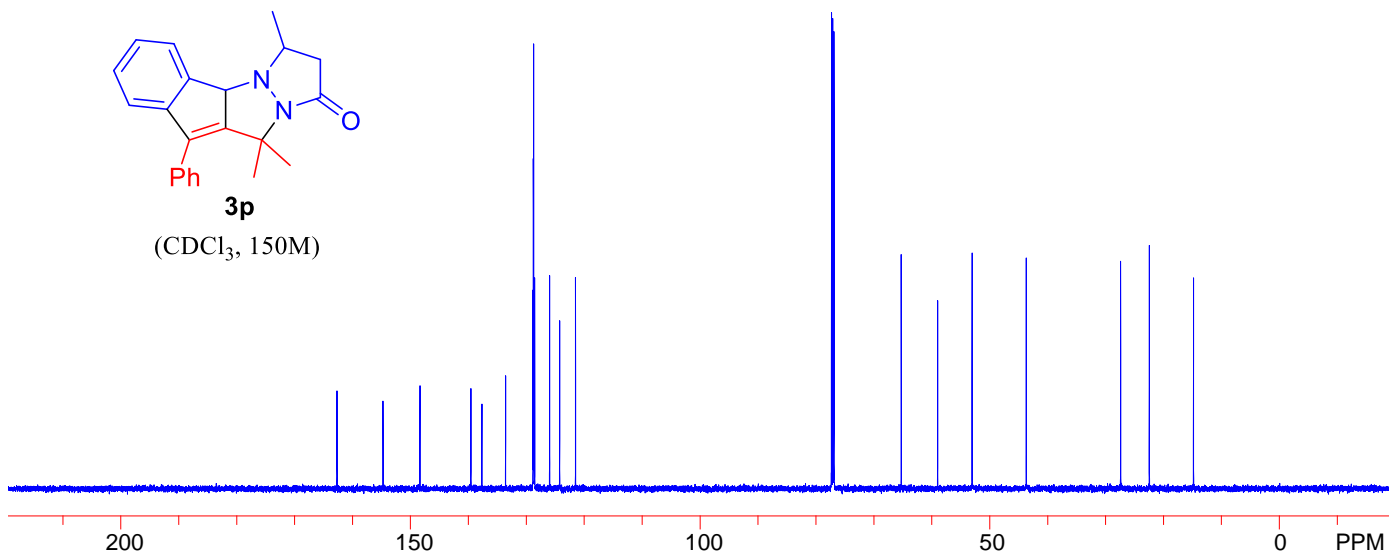
**3p**  
(CDCl<sub>3</sub>, 600M)

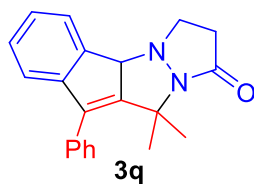
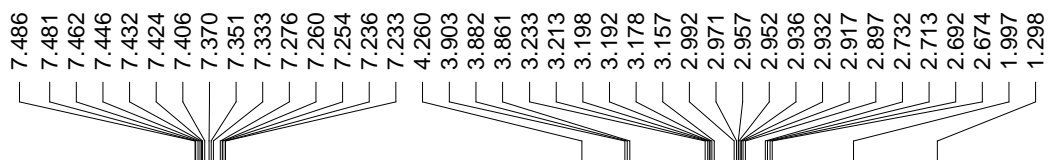


162.682  
154.734  
148.361  
139.560  
137.664  
133.573  
128.855  
128.782  
128.724  
128.542  
125.968  
124.232  
121.498  
77.310  
77.098  
76.887  
65.285  
59.007  
53.064  
43.731  
27.455  
22.512  
14.892

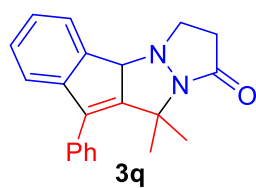
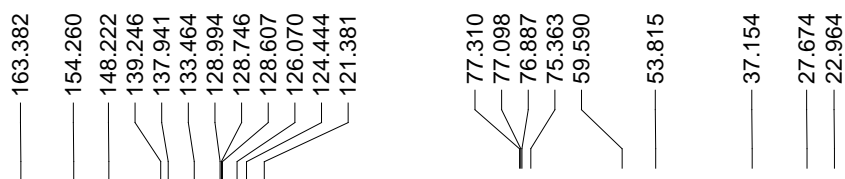
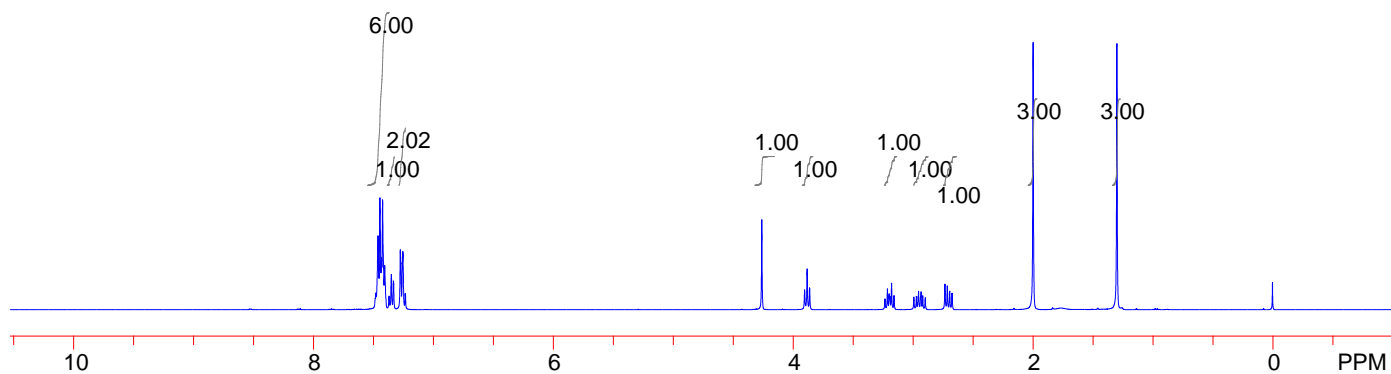


**3p**  
(CDCl<sub>3</sub>, 150M)

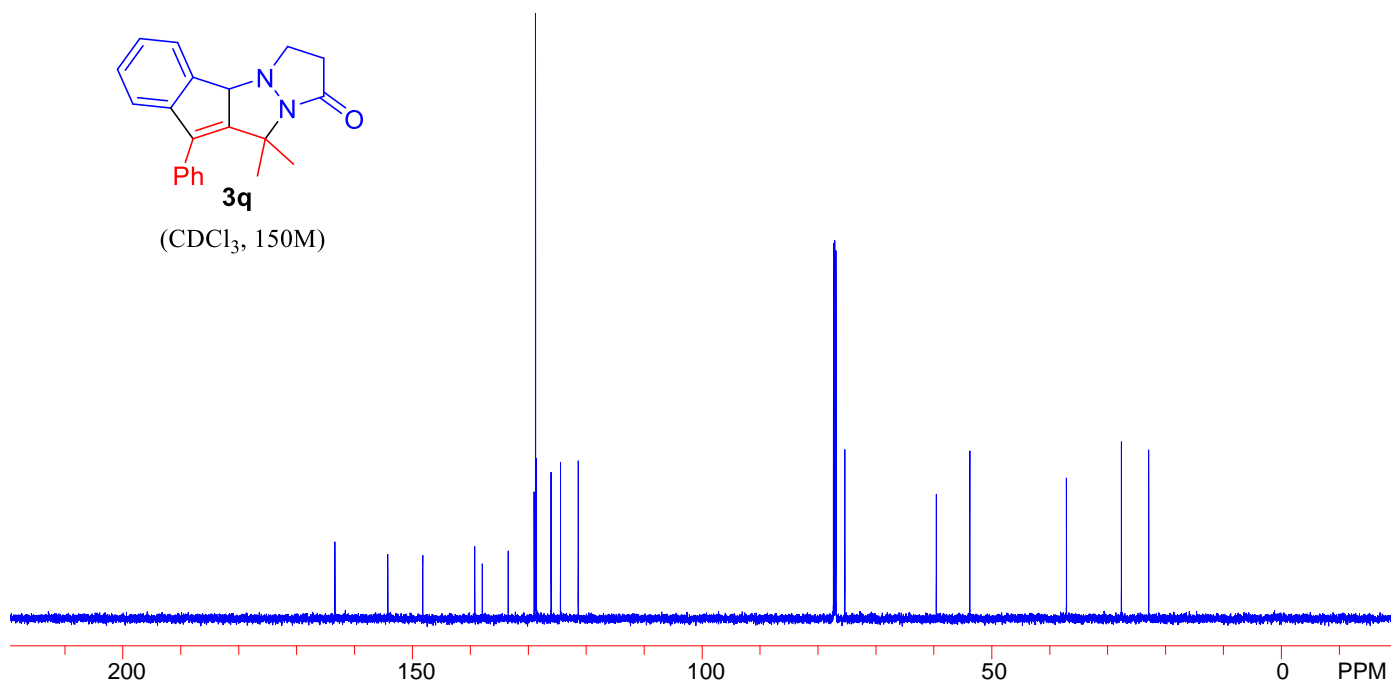


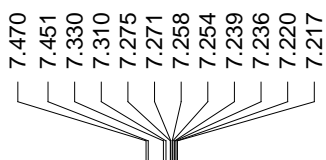


(CDCl<sub>3</sub>, 400M)

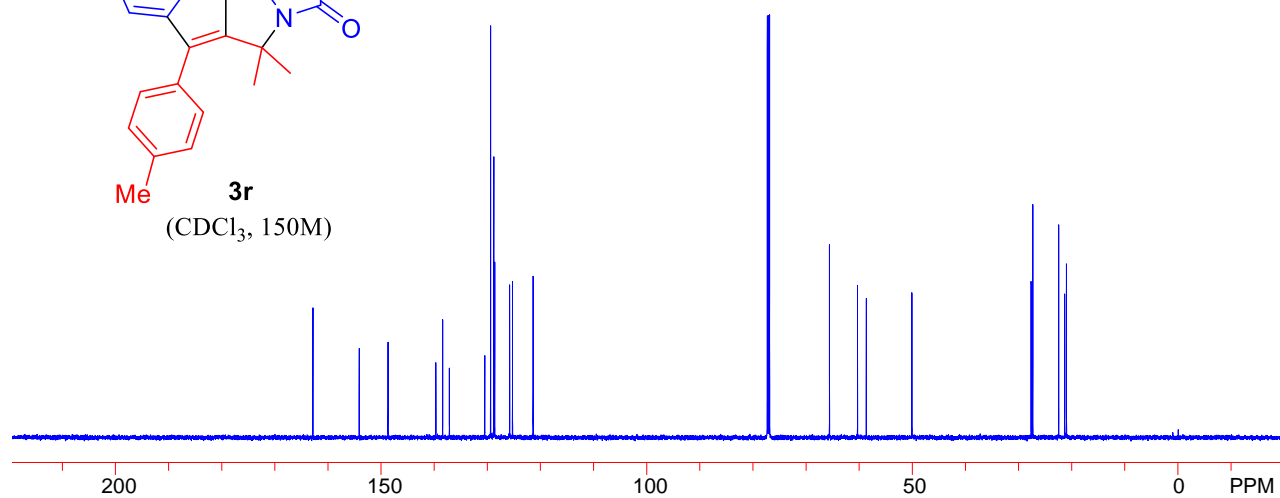
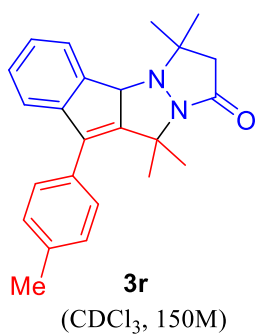
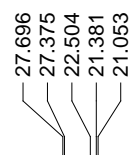
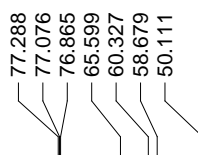
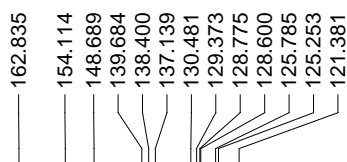
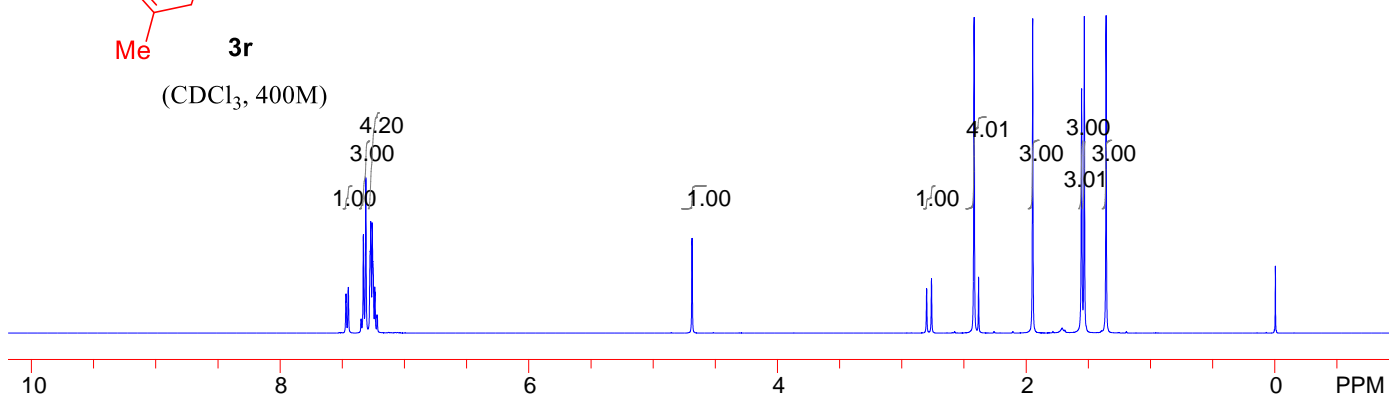
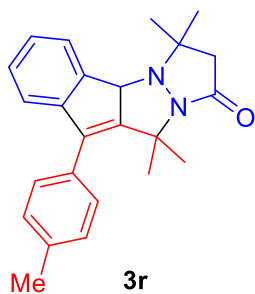
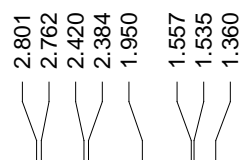


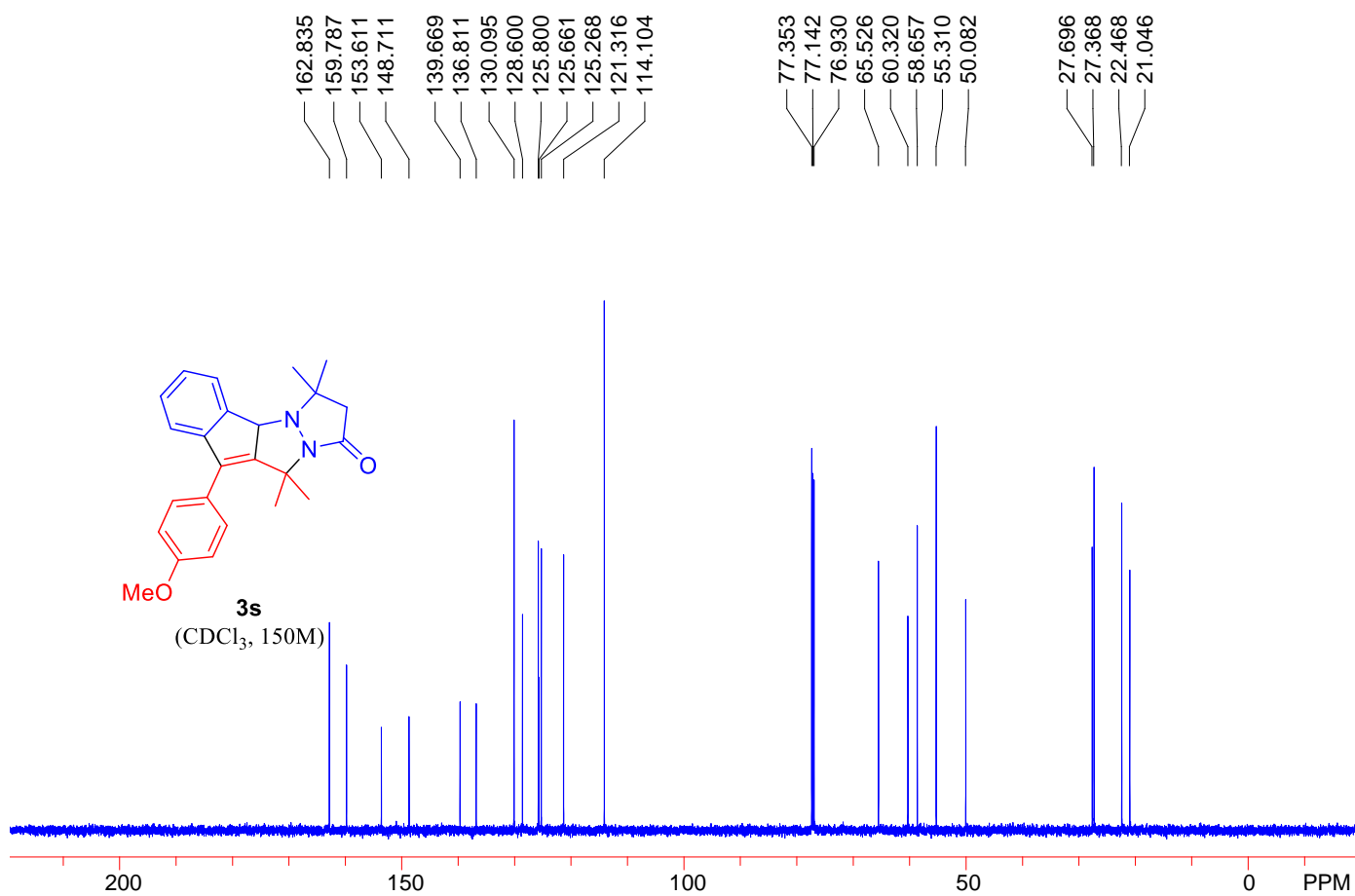
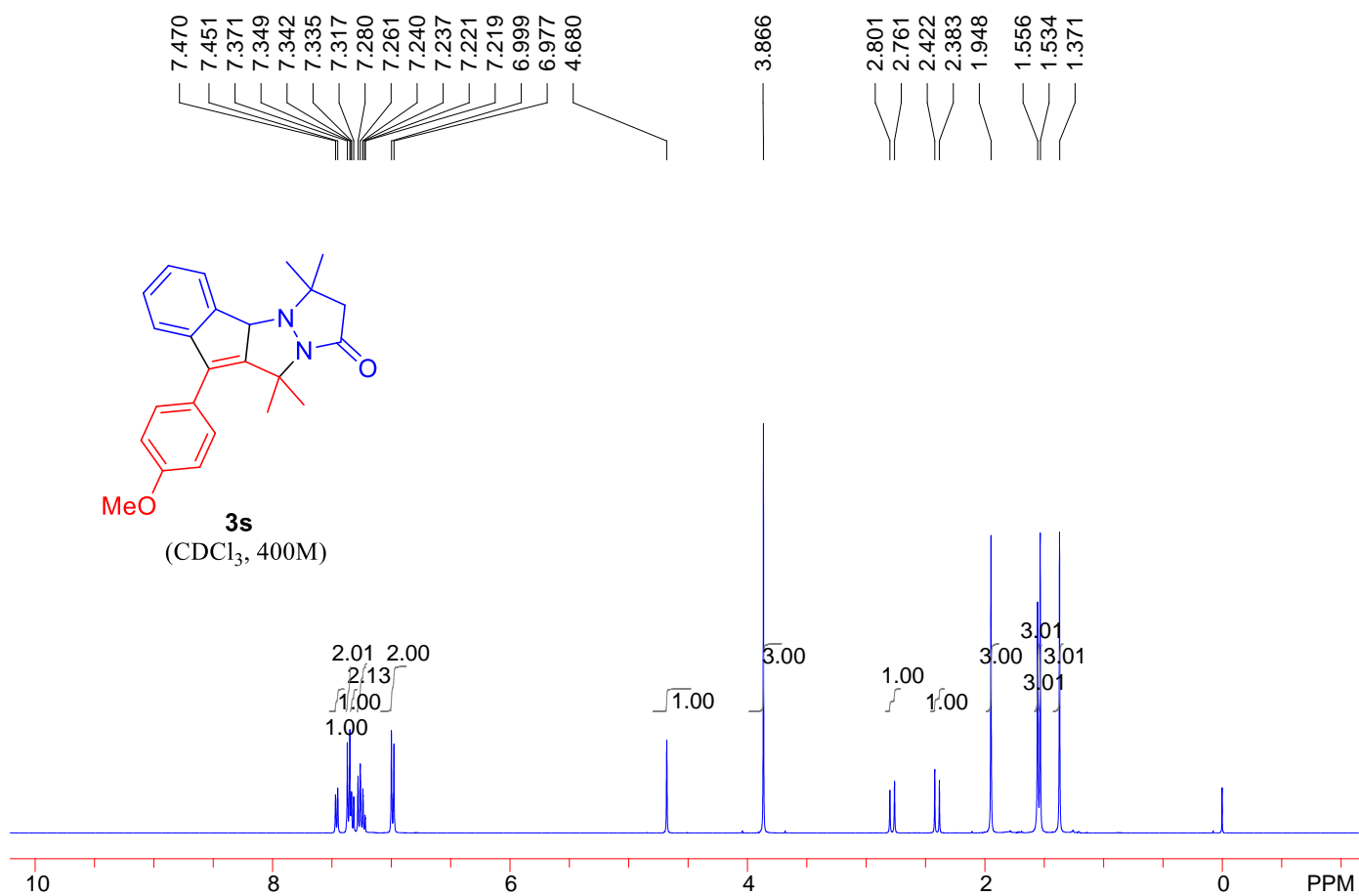
(CDCl<sub>3</sub>, 150M)





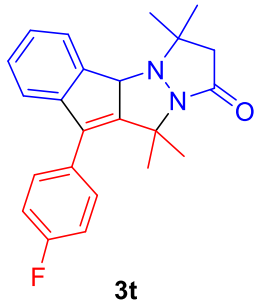
4.687



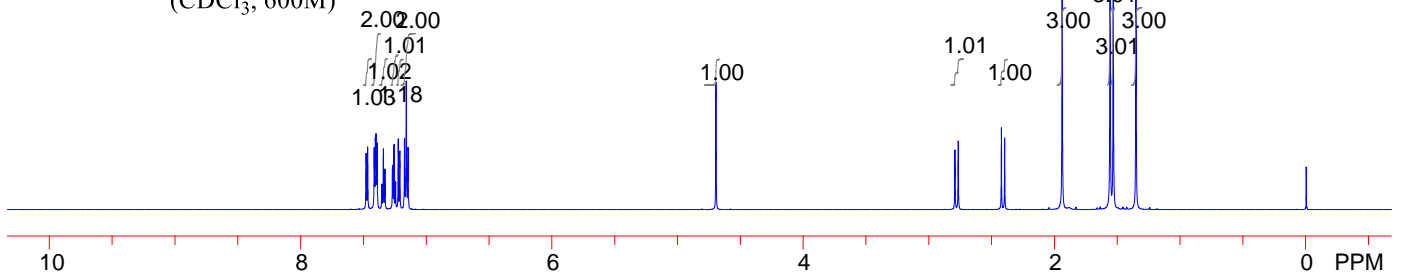




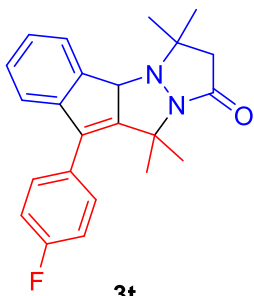
7.479  
7.467  
7.414  
7.411  
7.405  
7.400  
7.394  
7.391  
7.353  
7.342  
7.341  
7.329  
7.270  
7.268  
7.265  
7.257  
7.256  
7.245  
7.244  
7.223  
7.210  
7.174  
7.159  
7.145  
4.694  
2.793  
2.767  
2.424  
2.397  
1.940  
1.560  
1.534  
1.354



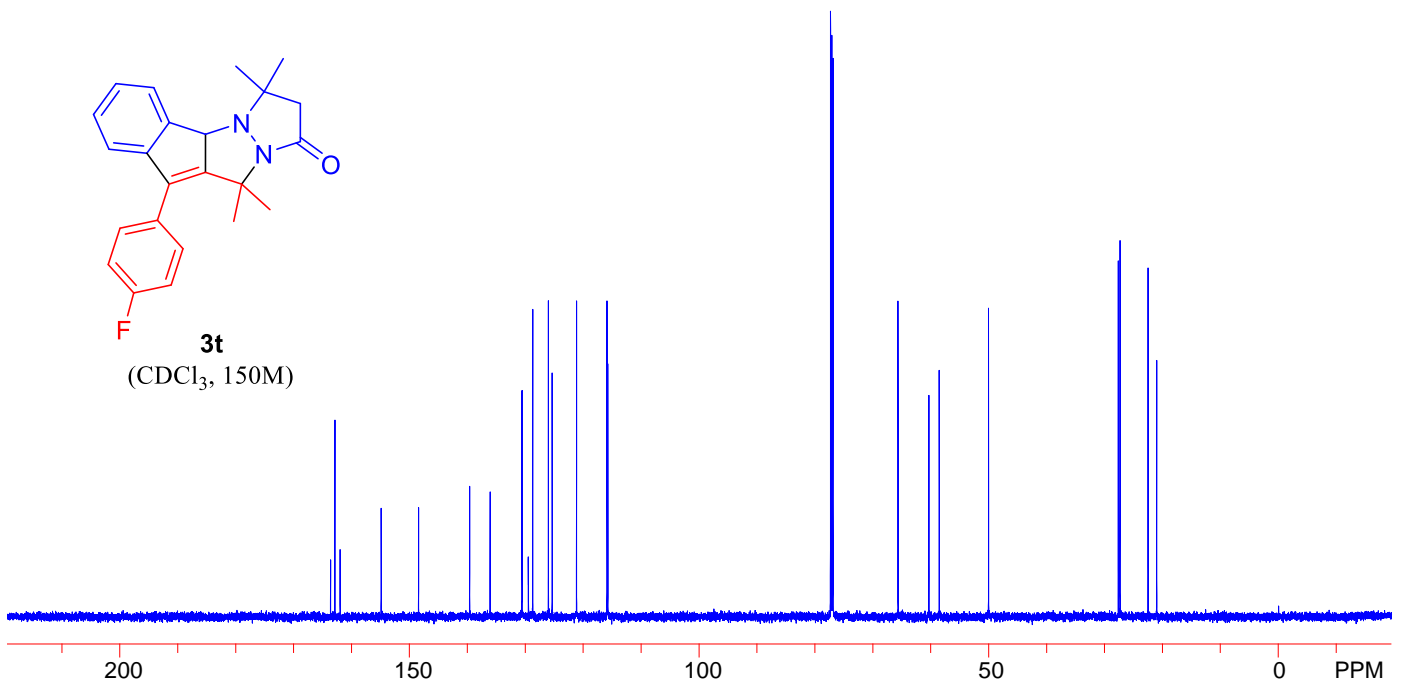
(CDCl<sub>3</sub>, 600M)



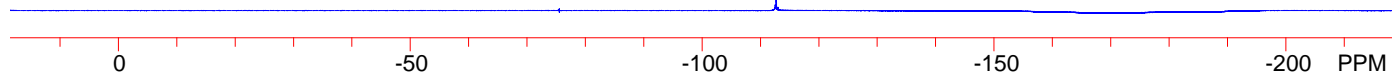
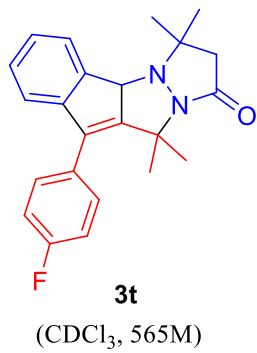
163.608  
162.864  
161.967  
154.872  
148.412  
139.596  
136.067  
130.583  
130.532  
129.468  
129.446  
128.709  
126.004  
125.348  
121.141  
115.883  
115.737  
77.295  
77.083  
76.872  
65.657  
60.327  
58.548  
50.045  
27.674  
27.375  
22.541  
21.046

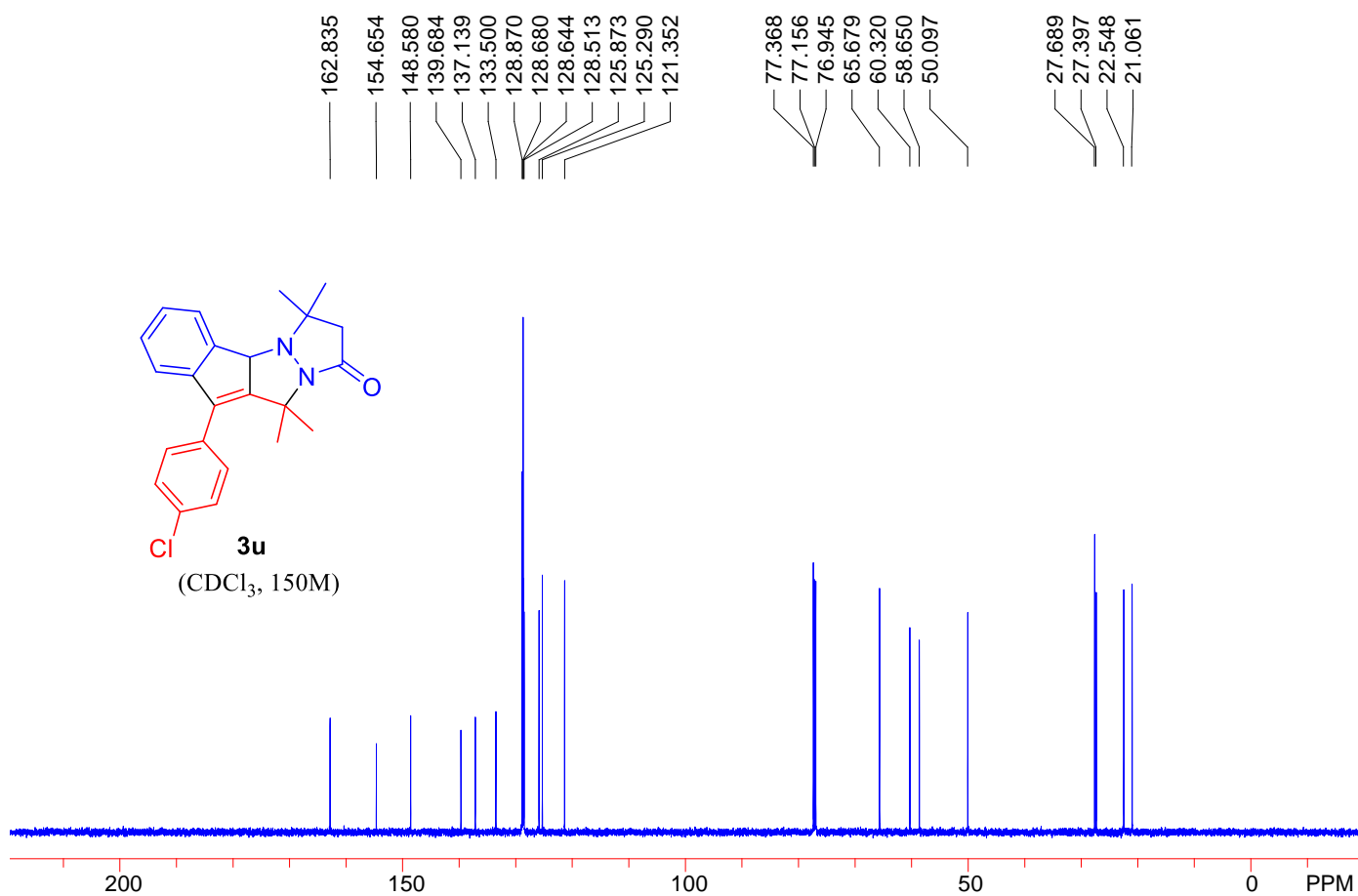
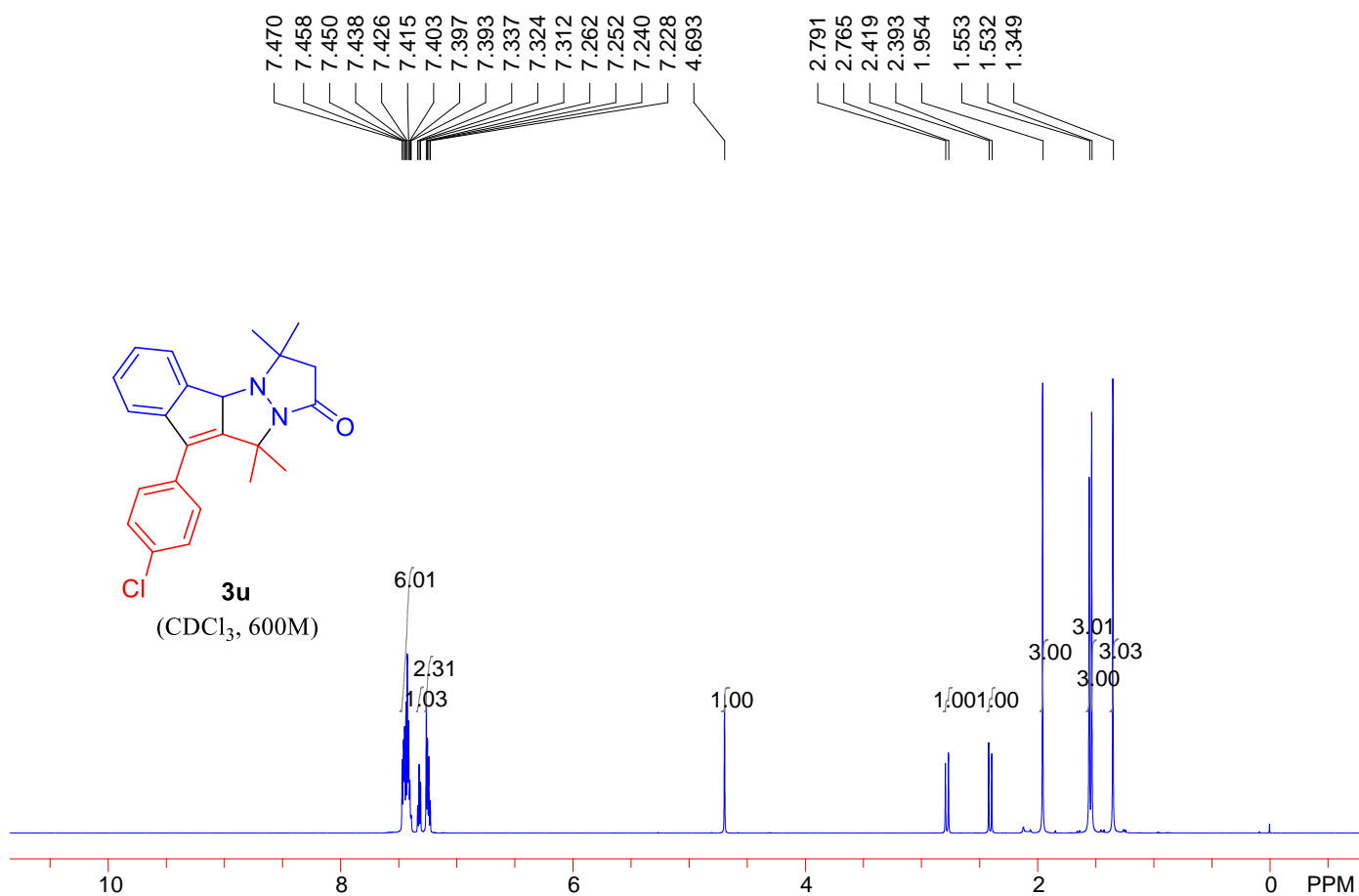


(CDCl<sub>3</sub>, 150M)

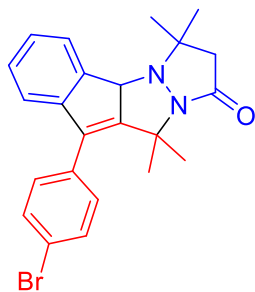


112.579  
112.594  
112.604  
112.612  
112.619  
112.626

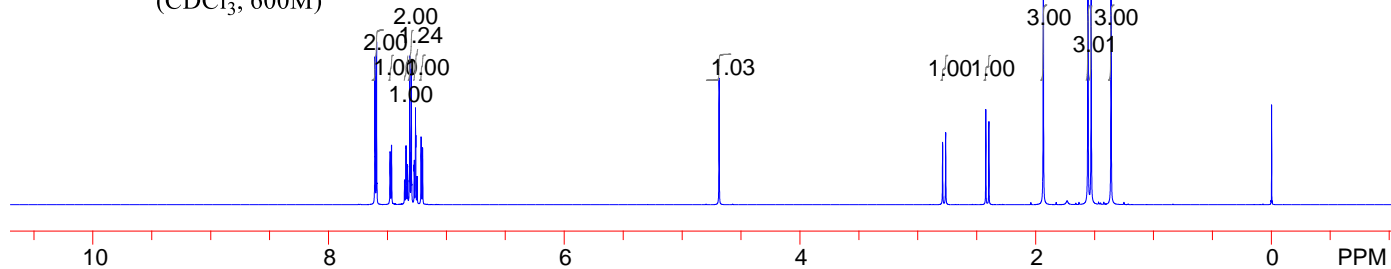




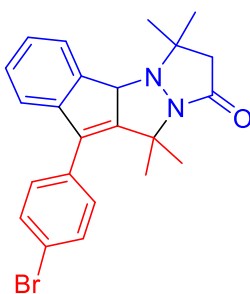
7.610  
7.606  
7.603  
7.595  
7.592  
7.588  
7.477  
7.465  
7.355  
7.354  
7.343  
7.341  
7.330  
7.329  
7.315  
7.311  
7.308  
7.300  
7.297  
7.293  
7.273  
7.272  
7.262  
7.259  
7.248  
7.247  
7.214  
7.202  
4.687  
2.791  
2.764  
2.424  
2.398  
1.936  
1.558  
1.530  
1.362



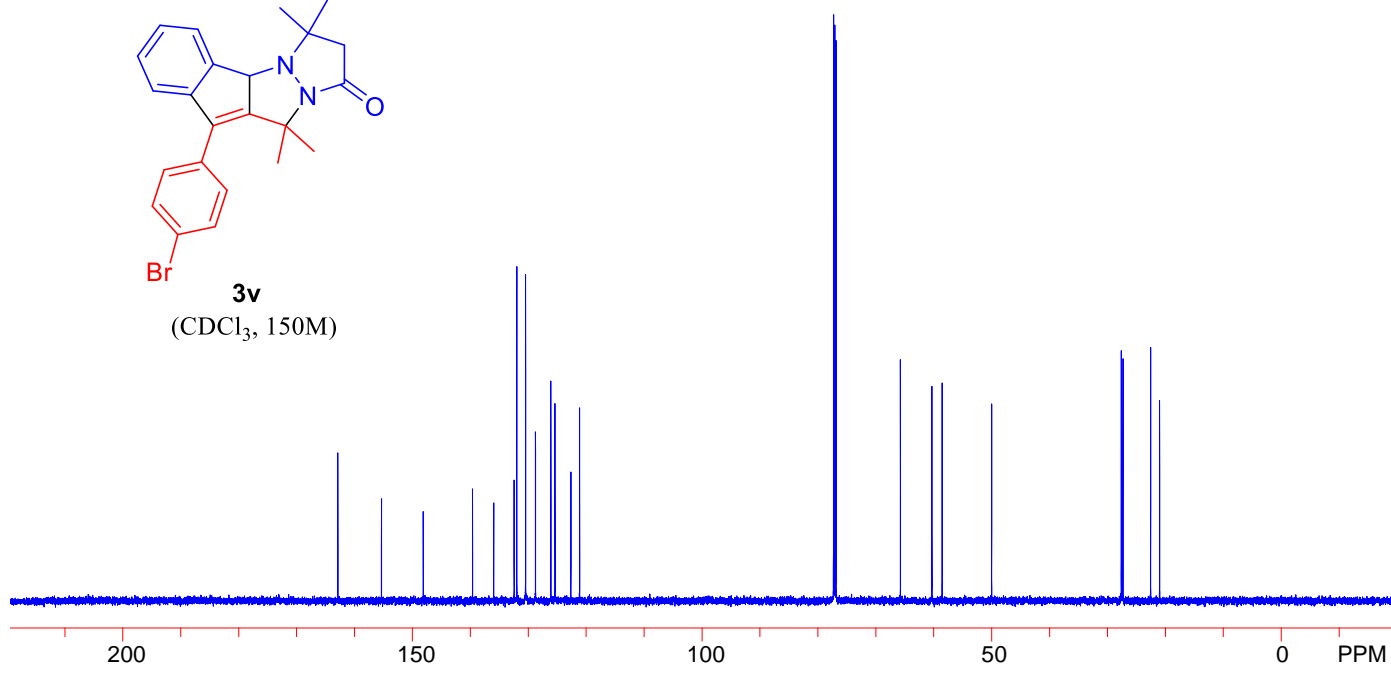
(CDCl<sub>3</sub>, 600M)

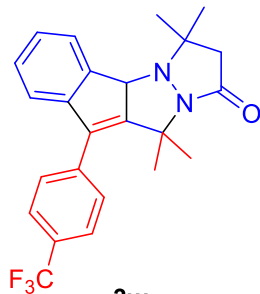
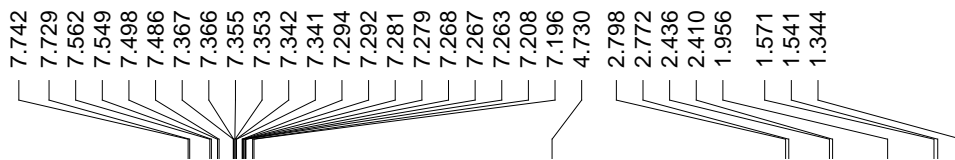


162.872  
155.339  
148.128  
139.611  
135.965  
132.436  
131.969  
130.452  
128.746  
126.092  
125.384  
122.635  
121.126  
77.288  
77.076  
76.865  
65.759  
60.327  
58.562  
50.031  
27.674  
27.383  
22.614  
21.061

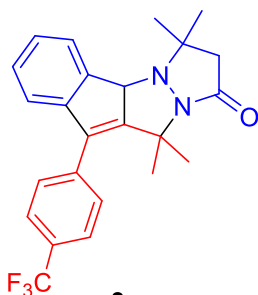
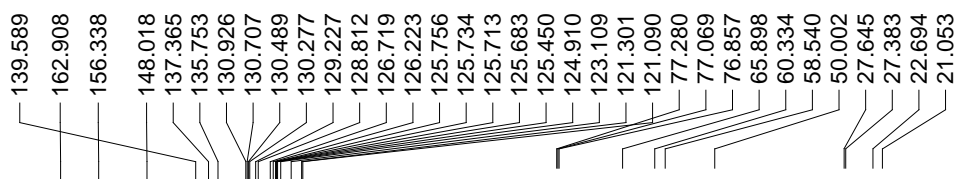
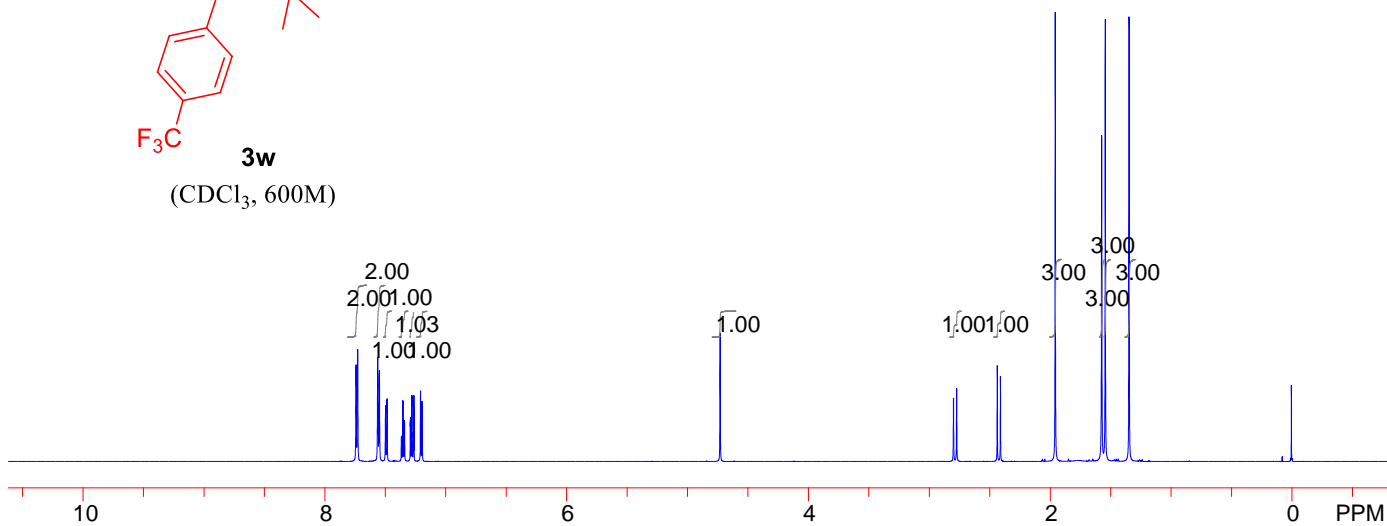


(CDCl<sub>3</sub>, 150M)

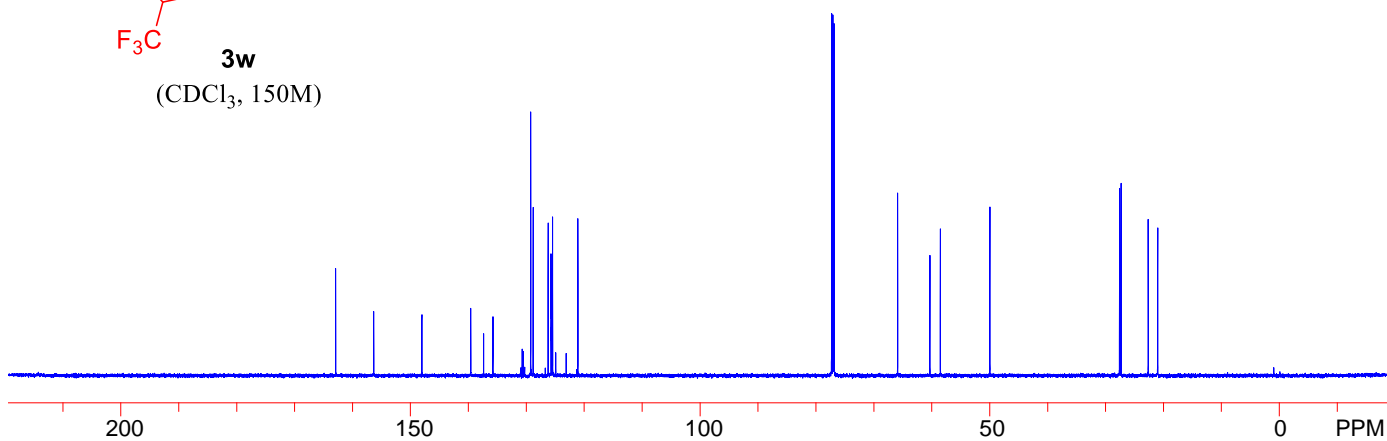


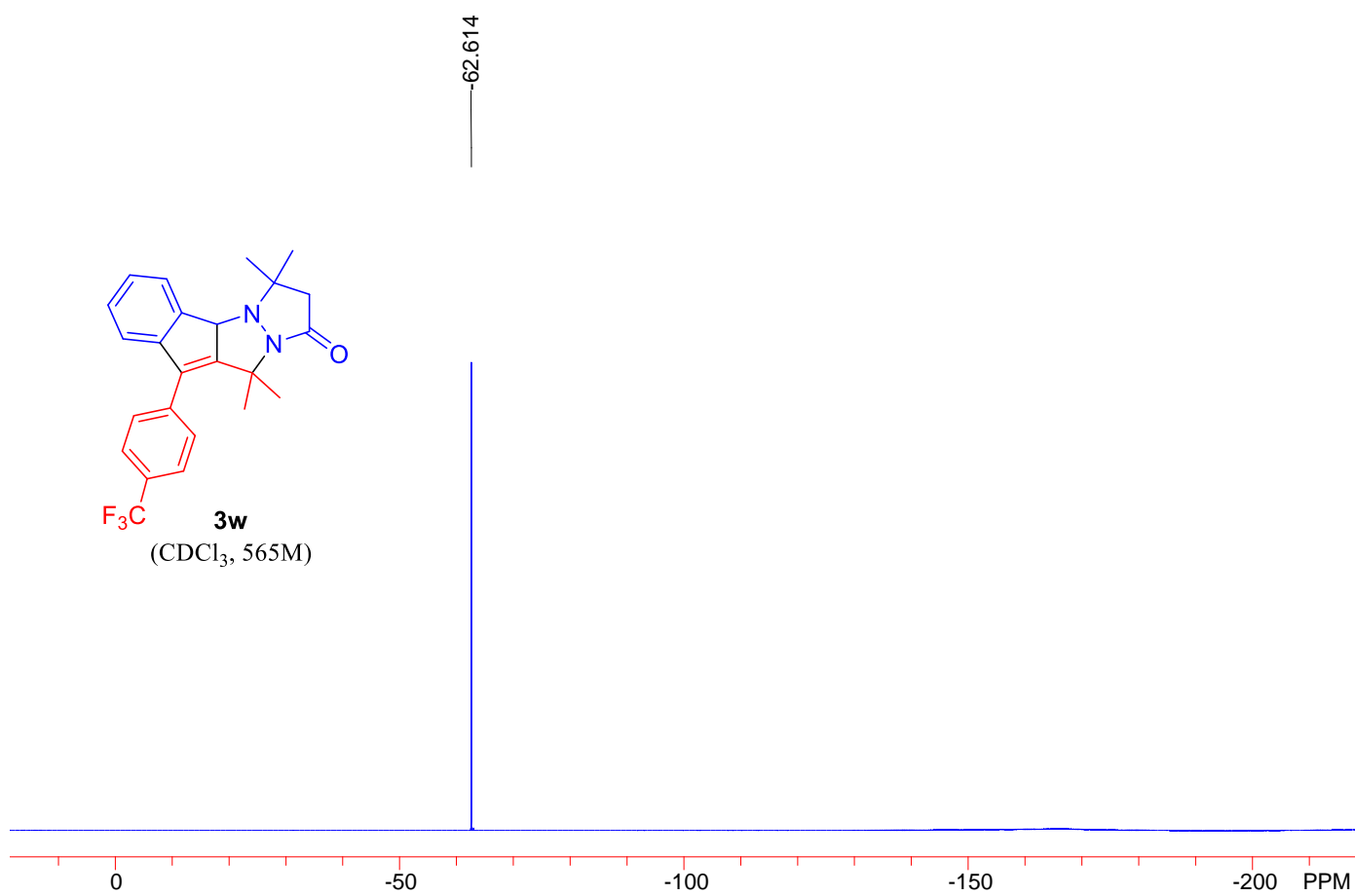


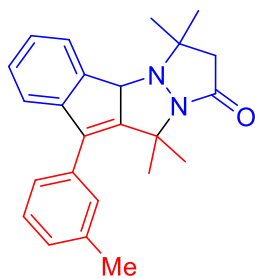
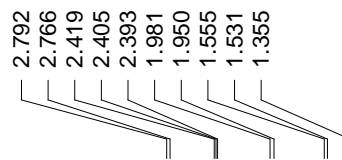
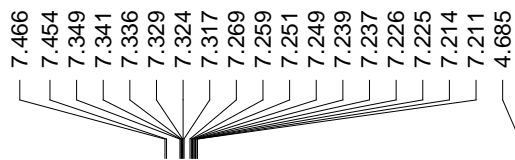
**3w**  
(CDCl<sub>3</sub>, 600M)



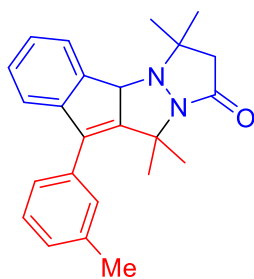
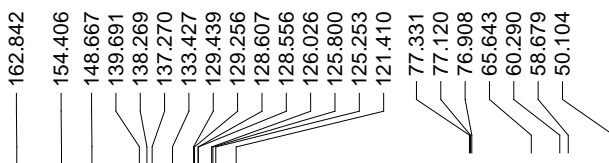
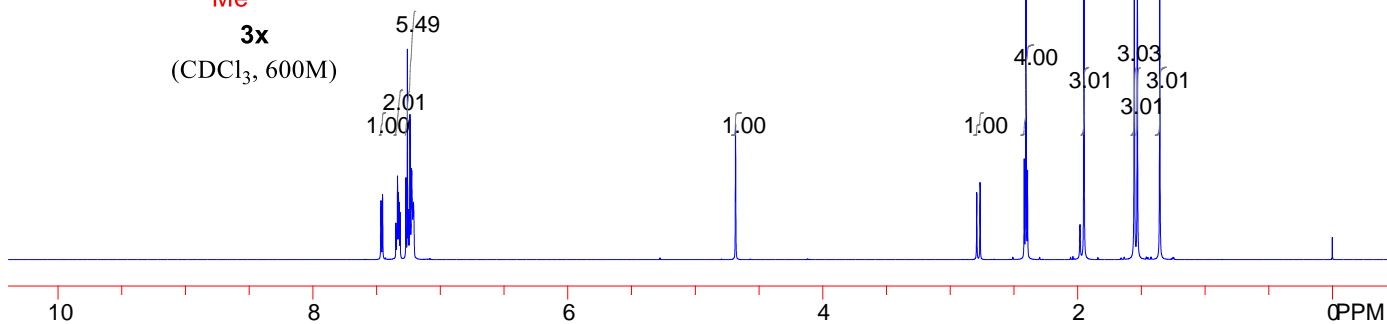
**3w**  
(CDCl<sub>3</sub>, 150M)



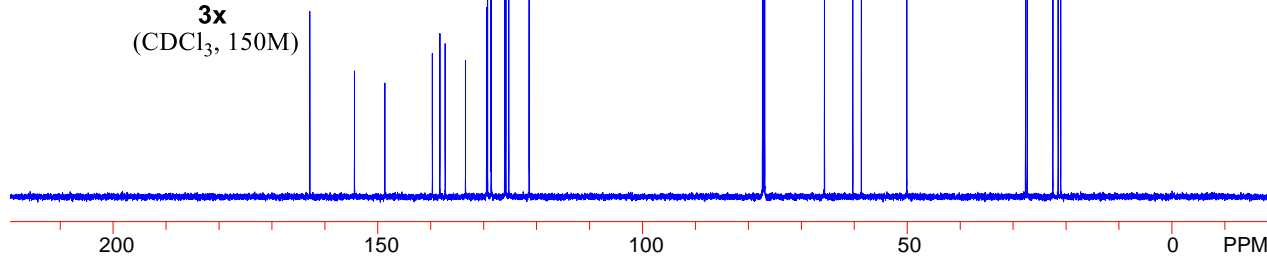


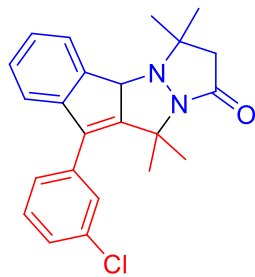
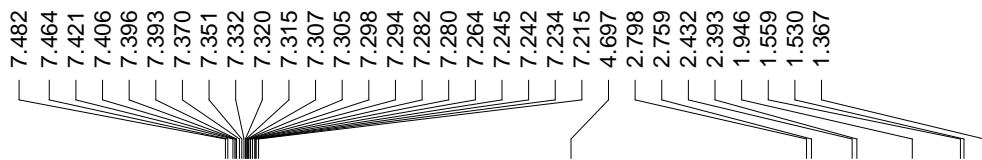


(CDCl<sub>3</sub>, 600M)

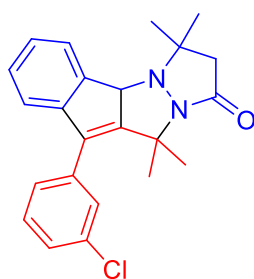
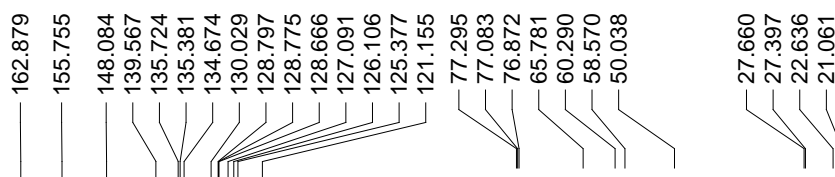
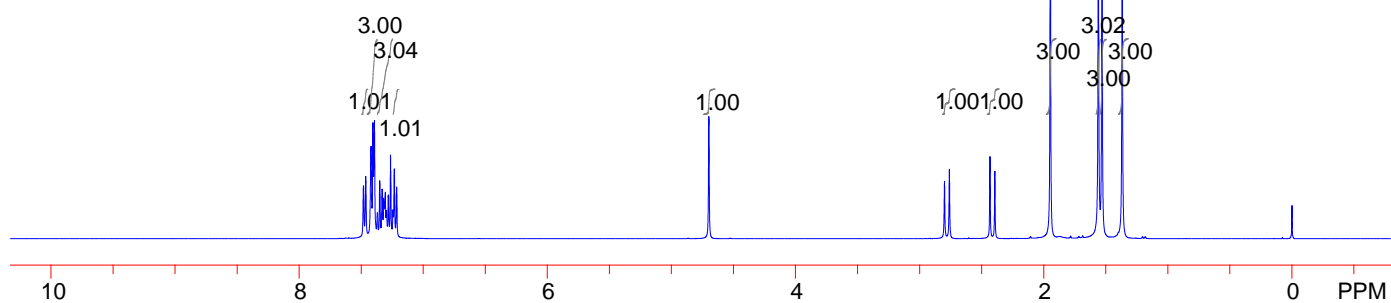


(CDCl<sub>3</sub>, 150M)

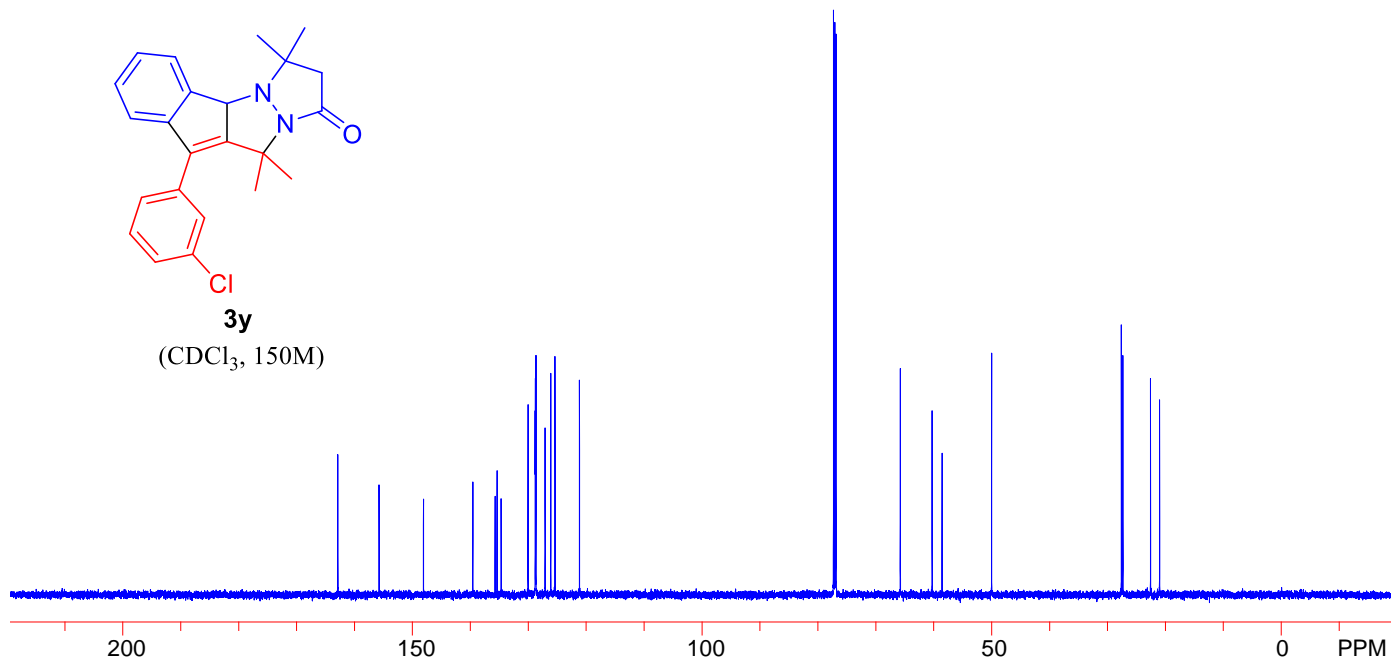




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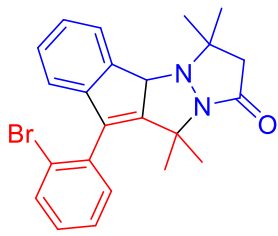
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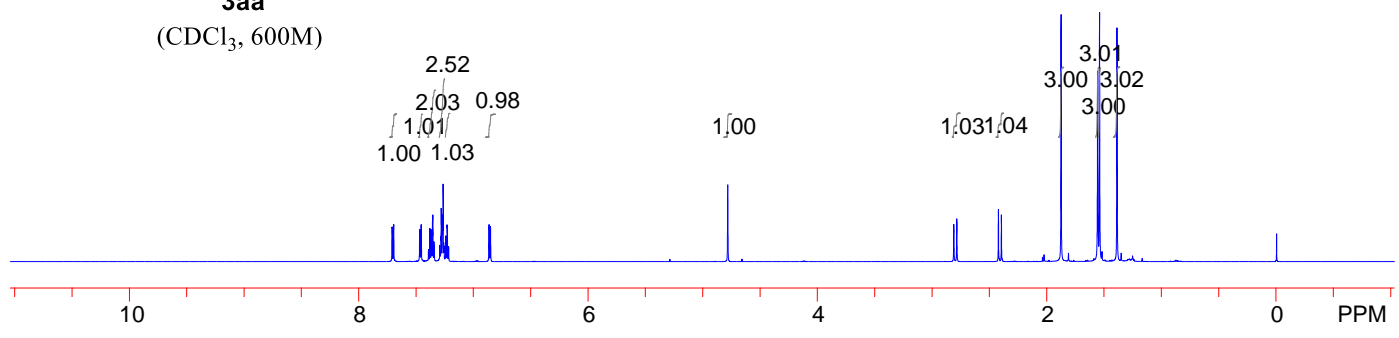




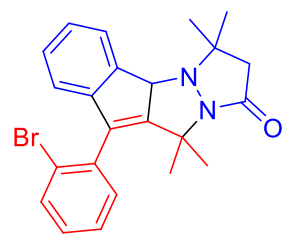
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7.357  
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7.284  
7.280  
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7.267  
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7.259  
7.255  
7.242  
7.240  
7.229  
7.228  
7.217  
7.215  
6.864  
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1.878  
1.559  
1.543  
1.391



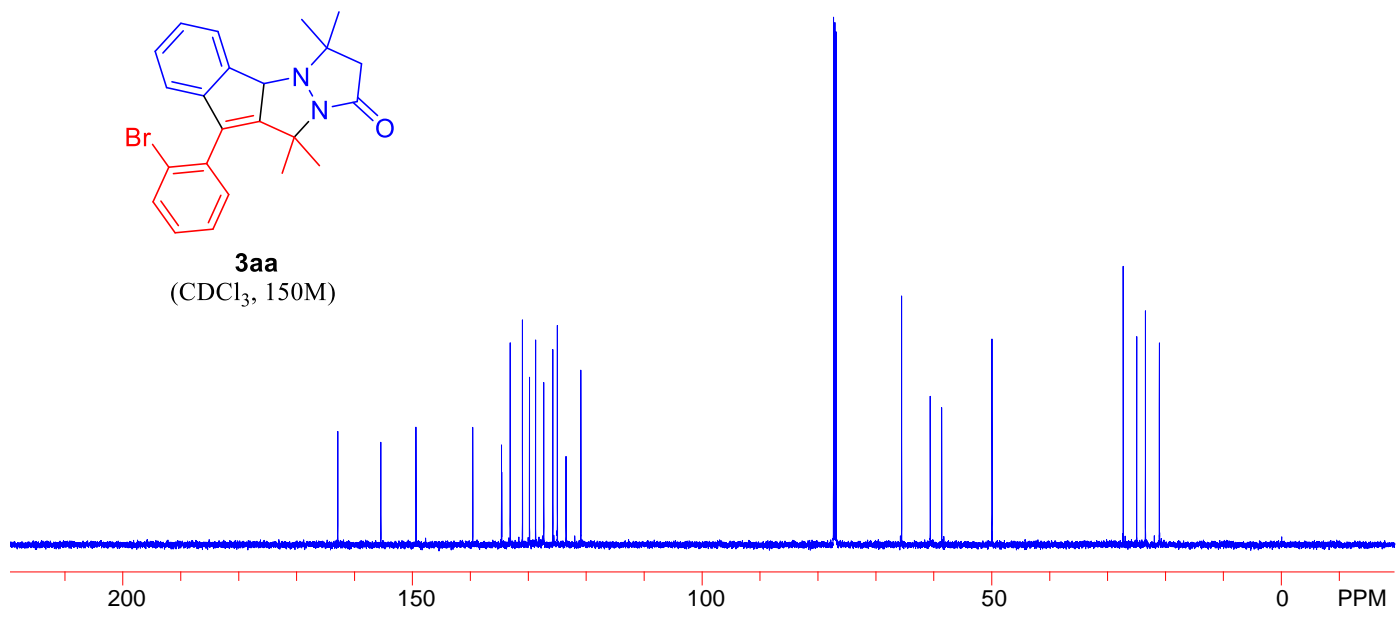
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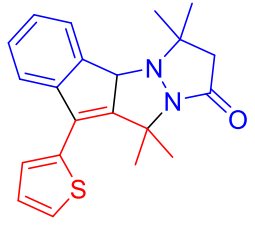
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123.474  
120.915  
77.295  
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23.532  
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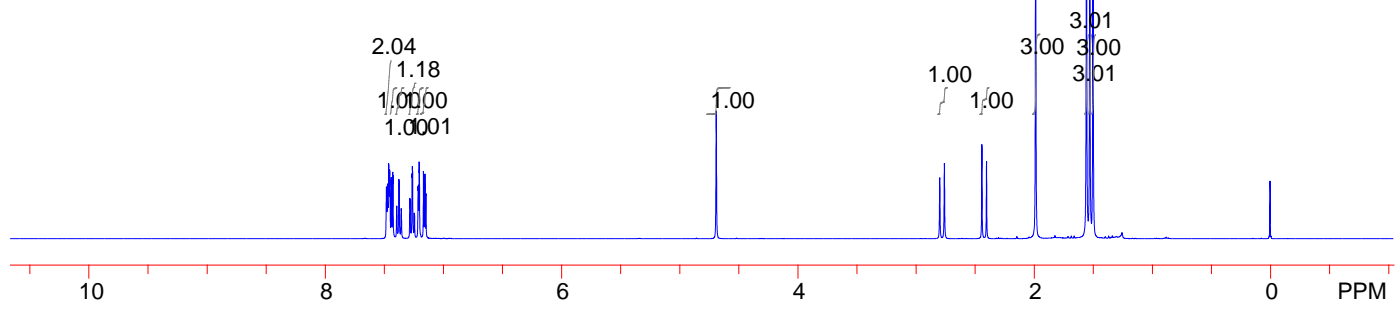
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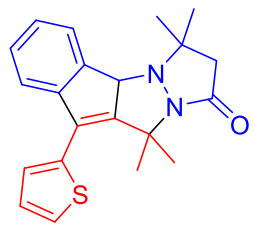
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7.281  
7.265  
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7.261  
7.247  
7.245  
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7.203  
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7.160  
7.156  
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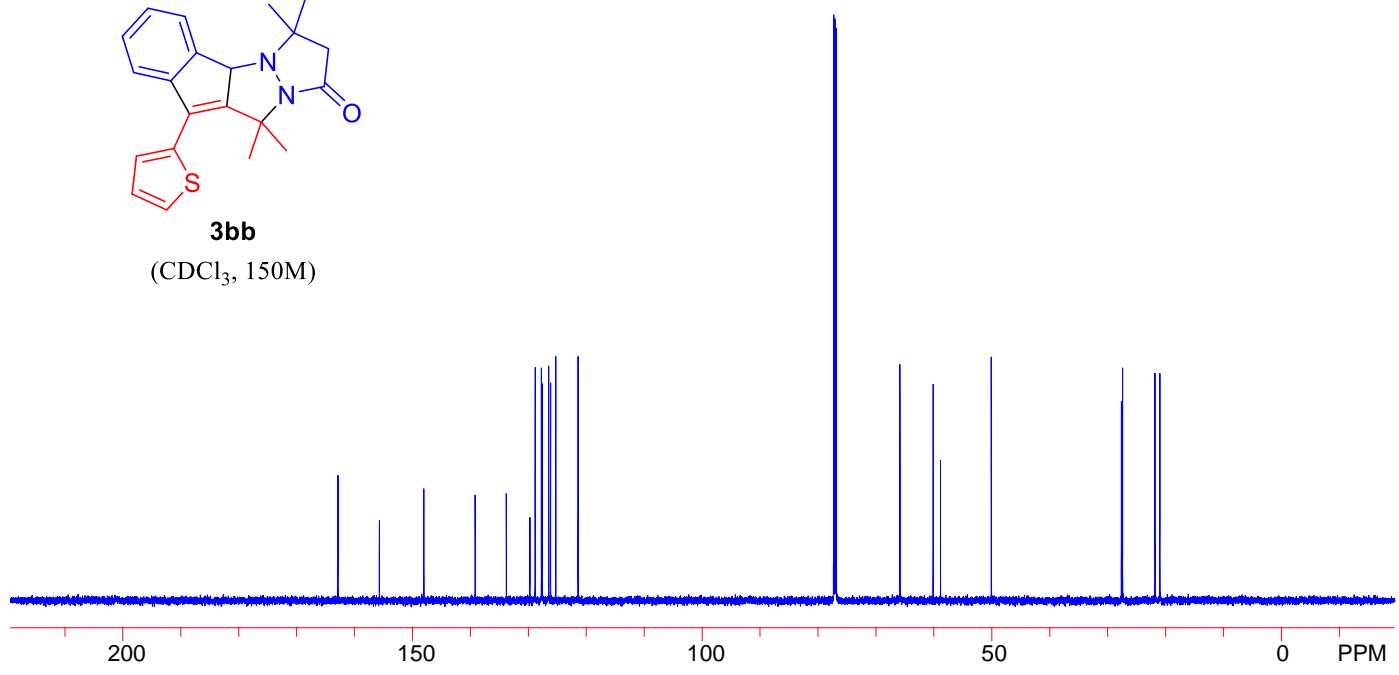
**3bb**  
(CDCl<sub>3</sub>, 400M)



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126.471  
126.150  
125.253  
121.410  
77.288  
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58.869  
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27.674  
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21.046

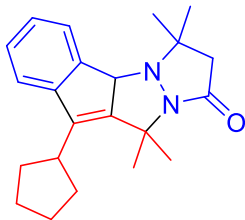


**3bb**  
(CDCl<sub>3</sub>, 150M)

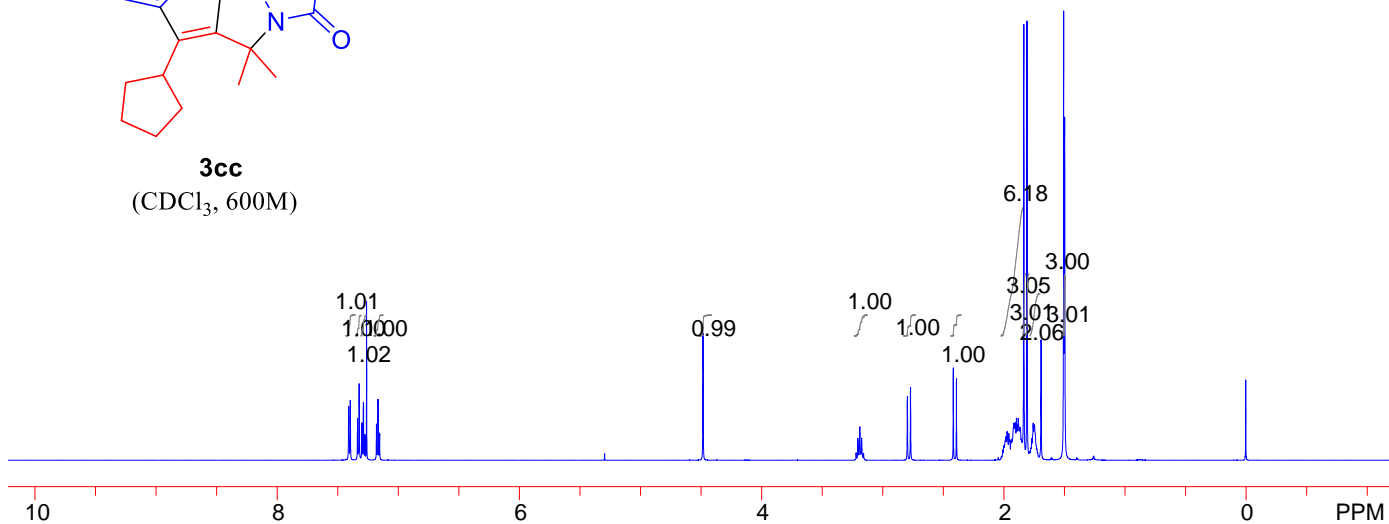


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7.156  
7.155

3.218  
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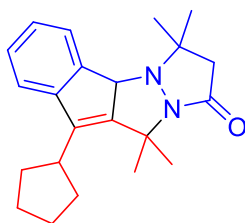


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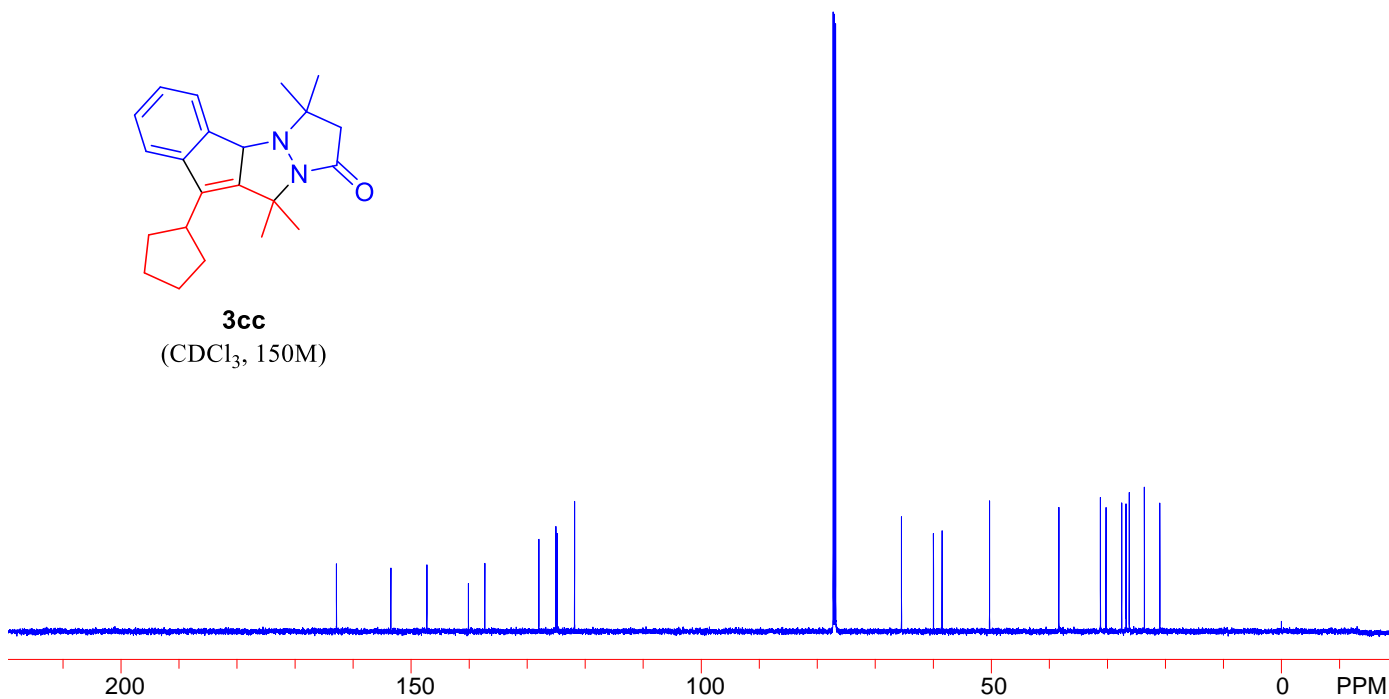


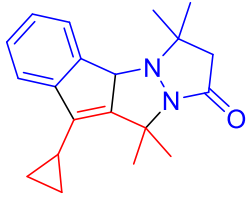
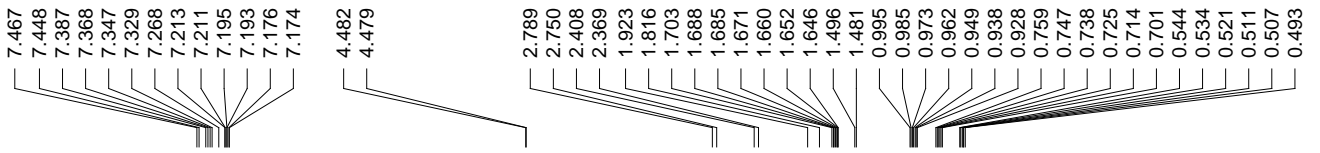
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76.836  
65.482  
59.970  
58.489  
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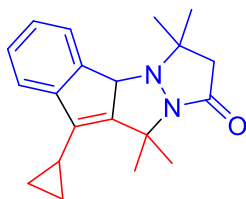
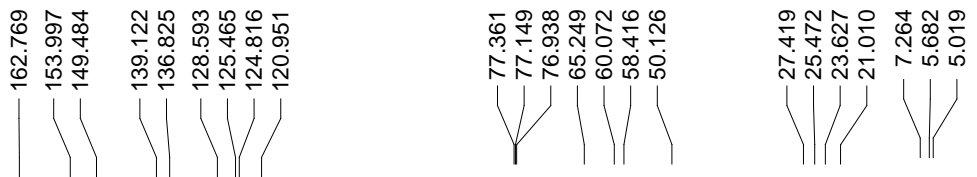
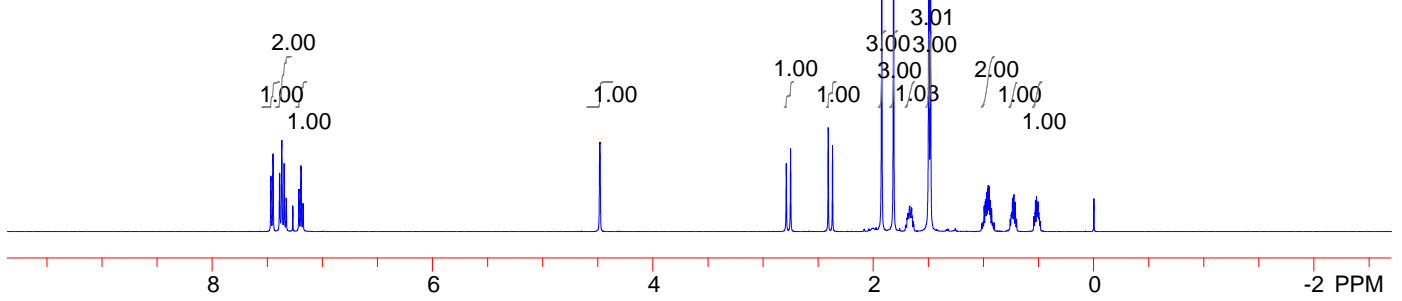


**3cc**  
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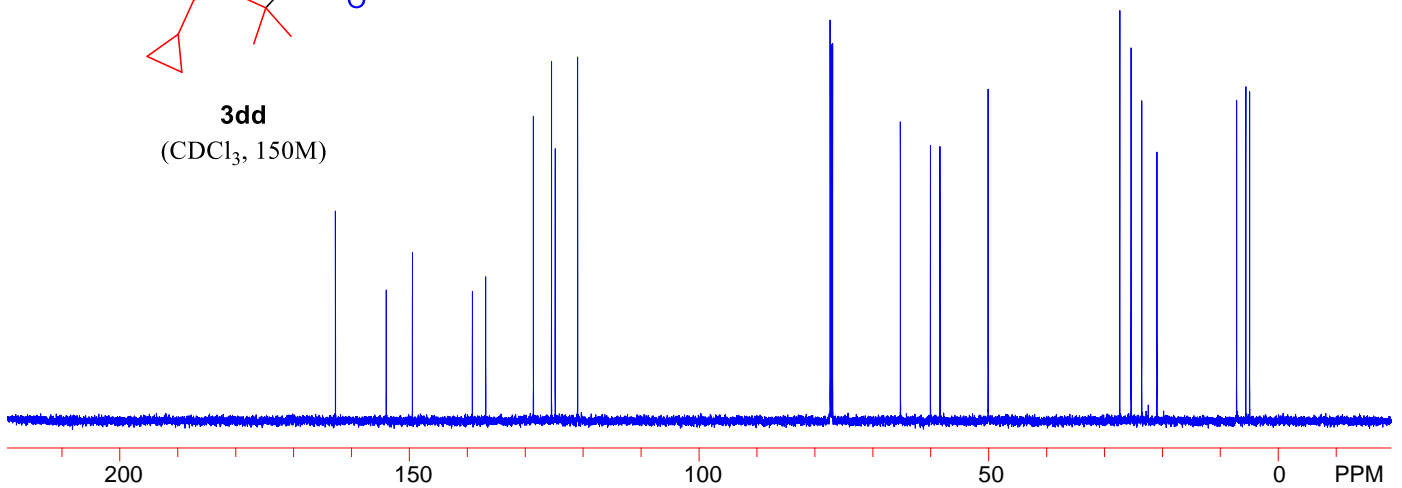




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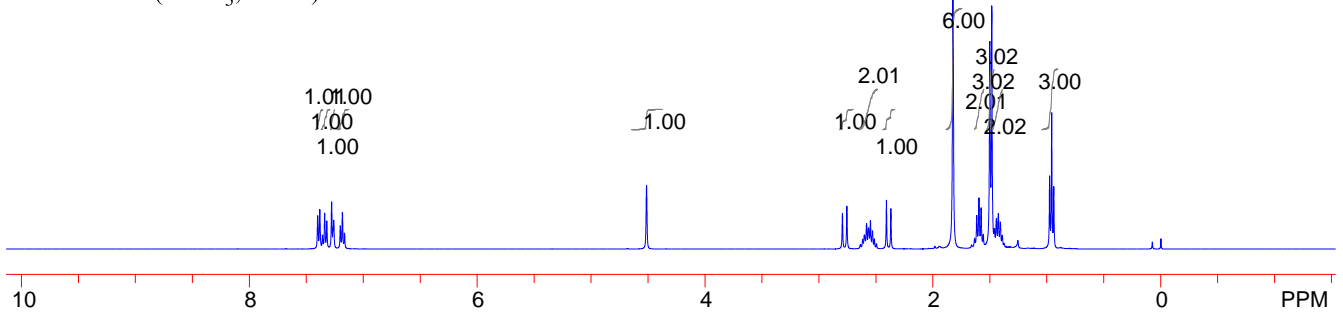
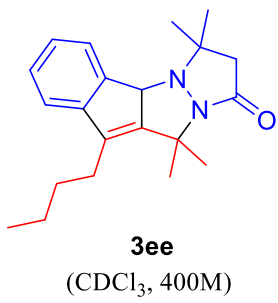


**3dd**  
(CDCl<sub>3</sub>, 150M)



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7.259  
7.202  
7.183  
7.165

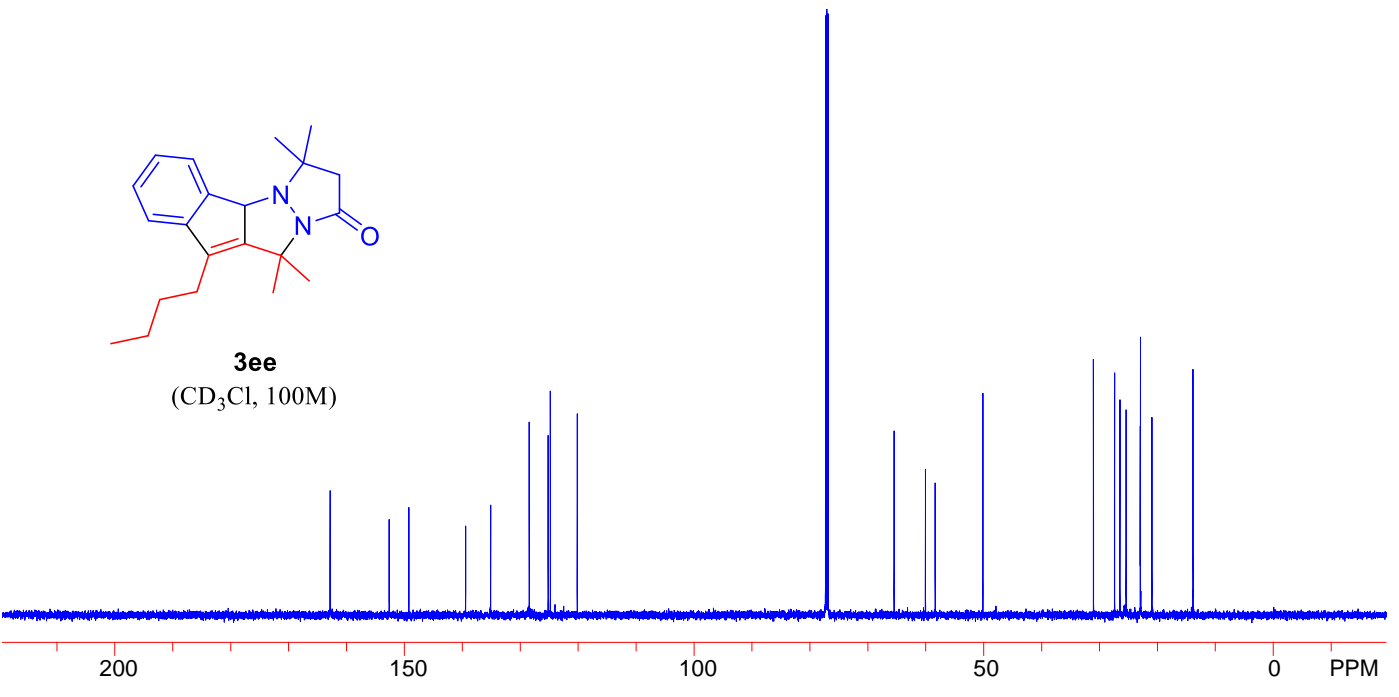
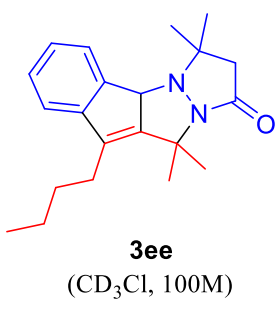
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2.370  
1.825  
1.635  
1.616  
1.597  
1.578  
1.559  
1.502  
1.484  
1.462  
1.444  
1.427  
1.409  
1.392  
0.977  
0.958  
0.940



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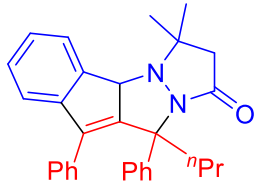
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22.993  
21.010  
13.929

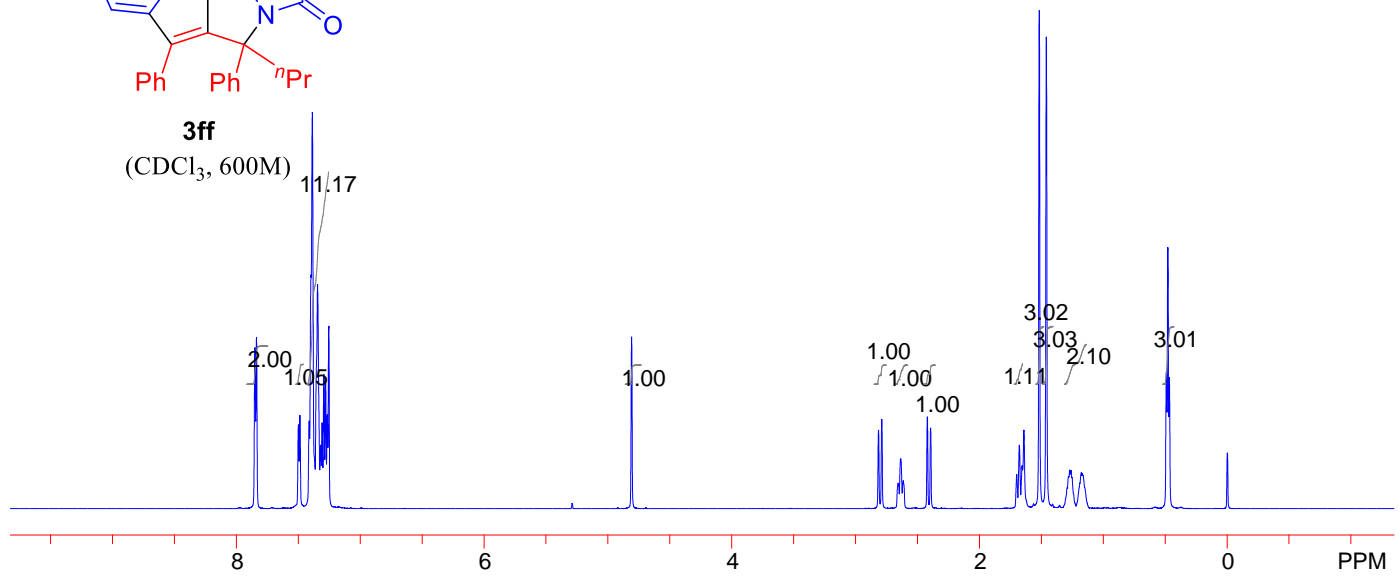


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7.398  
7.387  
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7.294  
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7.266  
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7.254  
4.809

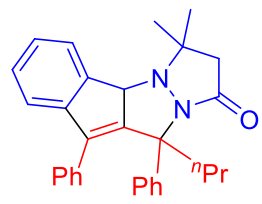
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0.469



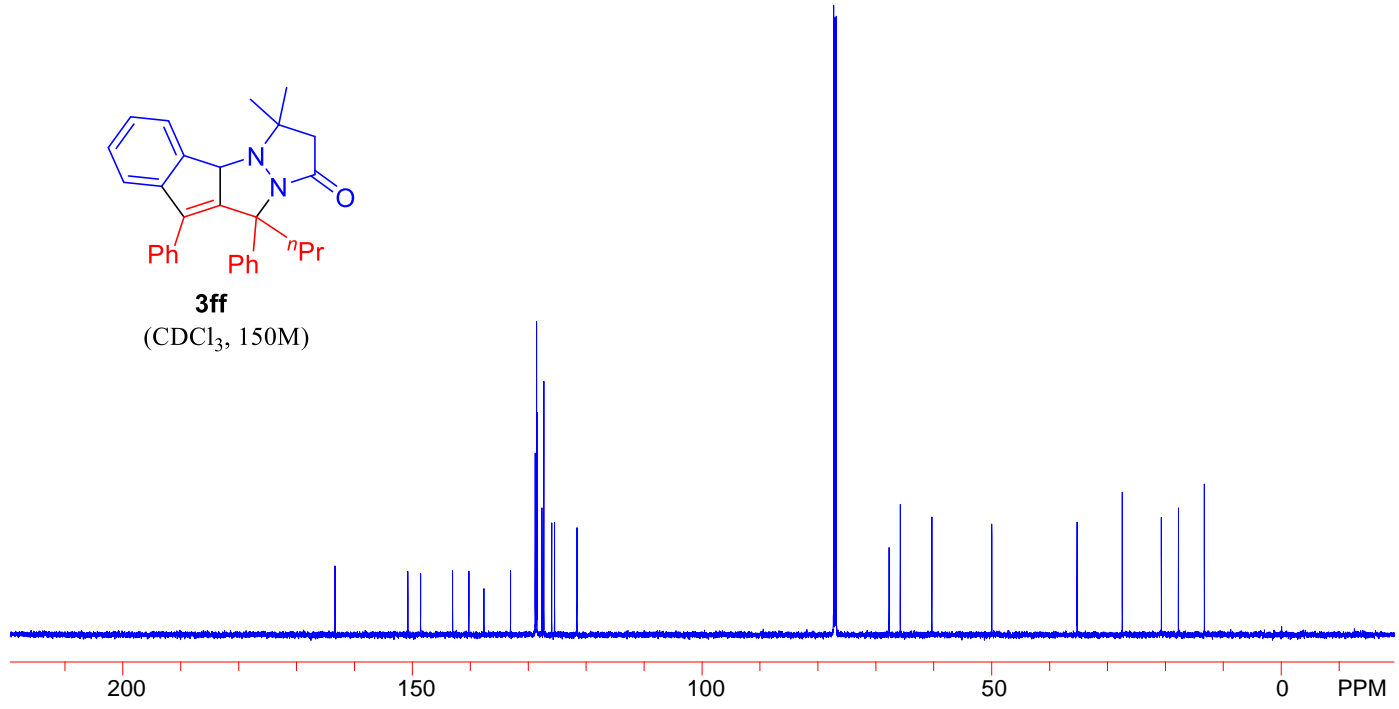
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(CDCl<sub>3</sub>, 600M)

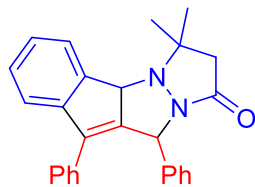
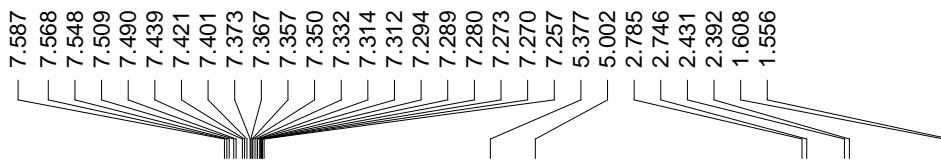


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77.054  
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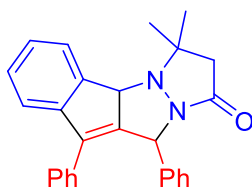
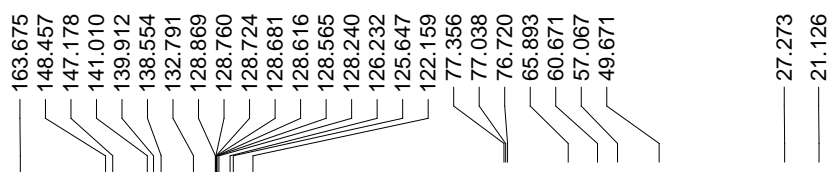
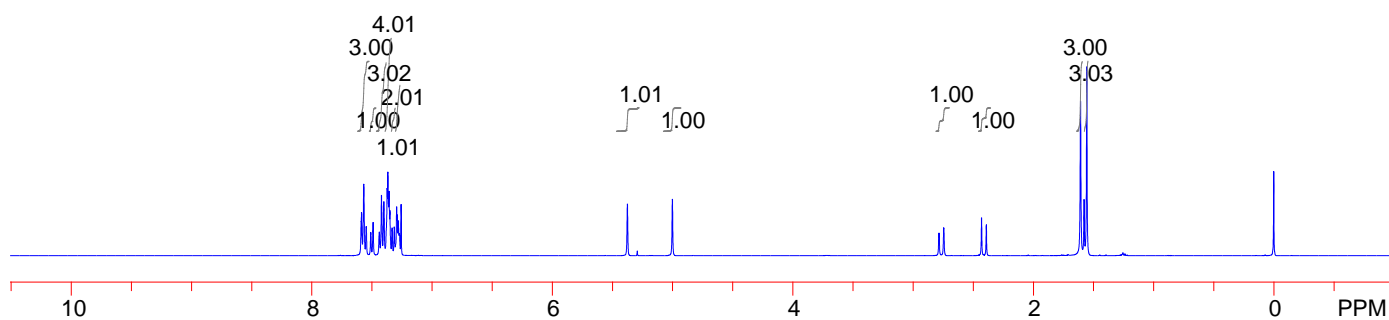
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(CDCl<sub>3</sub>, 150M)





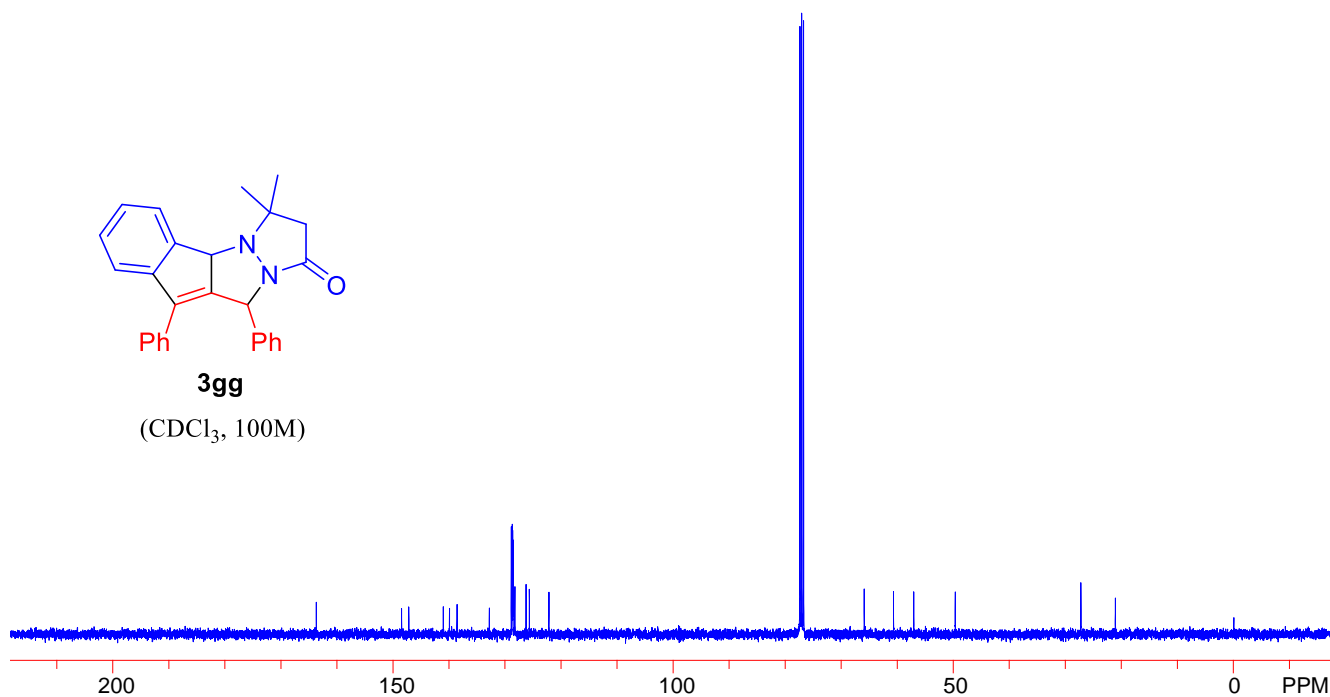
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(CDCl<sub>3</sub>, 400M)

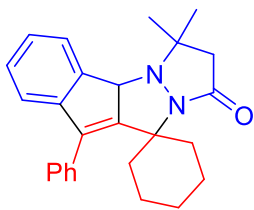
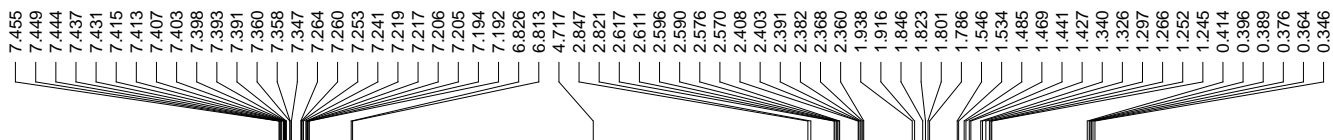


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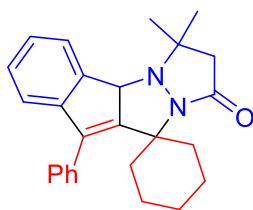
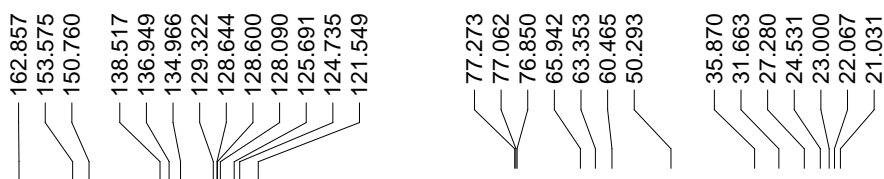
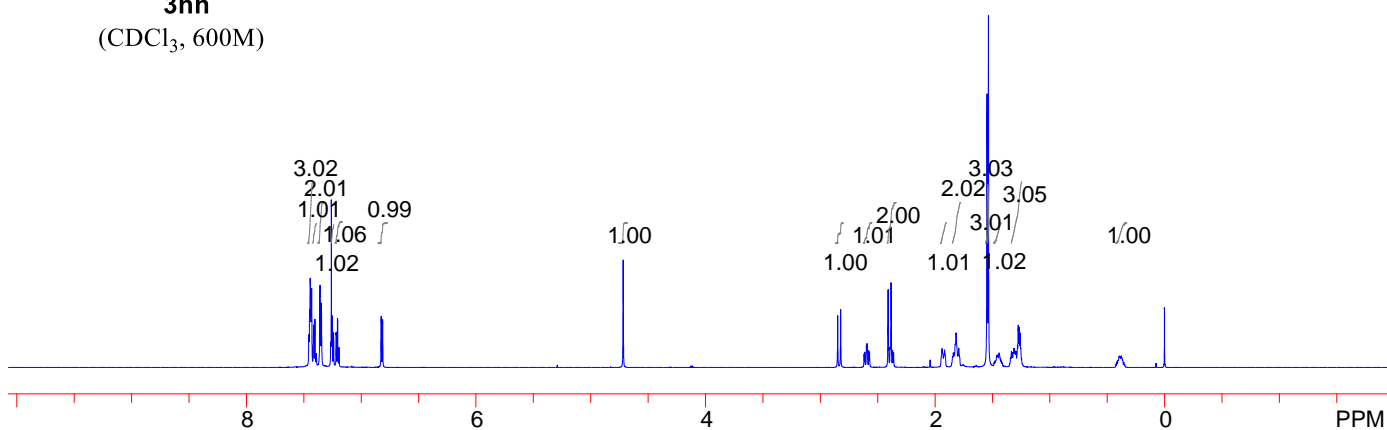
(CDCl<sub>3</sub>, 100M)



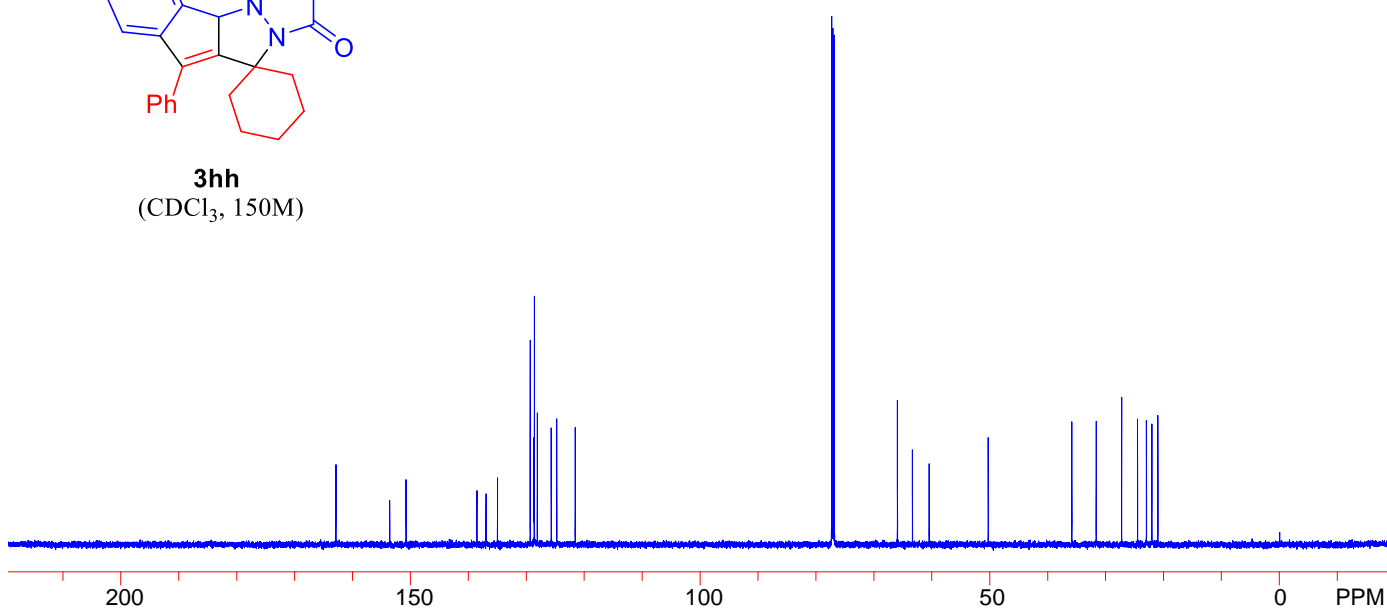




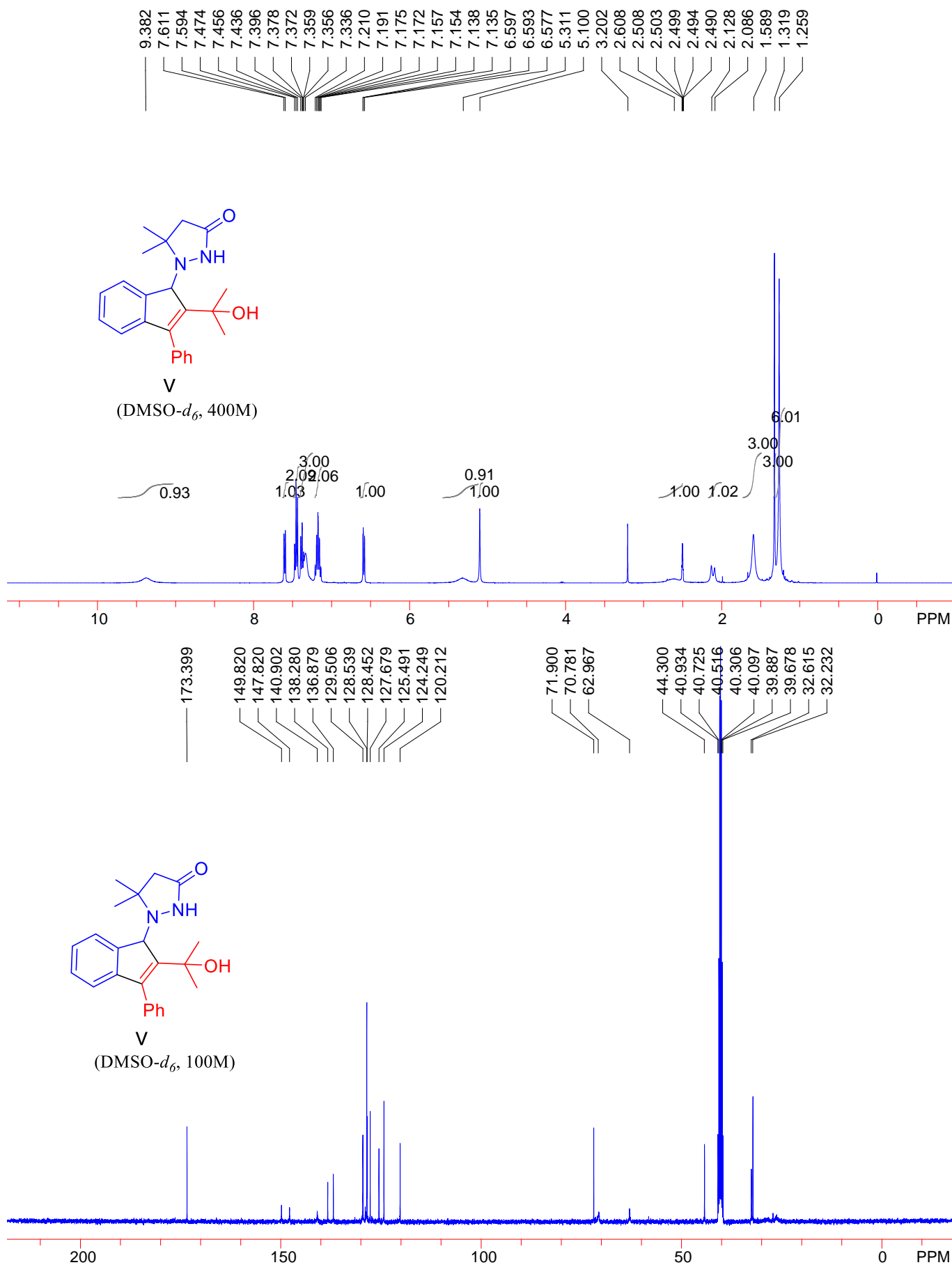
**3hh**  
(CDCl<sub>3</sub>, 600M)



**3hh**  
(CDCl<sub>3</sub>, 150M)



## V. Copis of the NMR spectra of V



## VI. X-ray crystal structure and data of **3a**

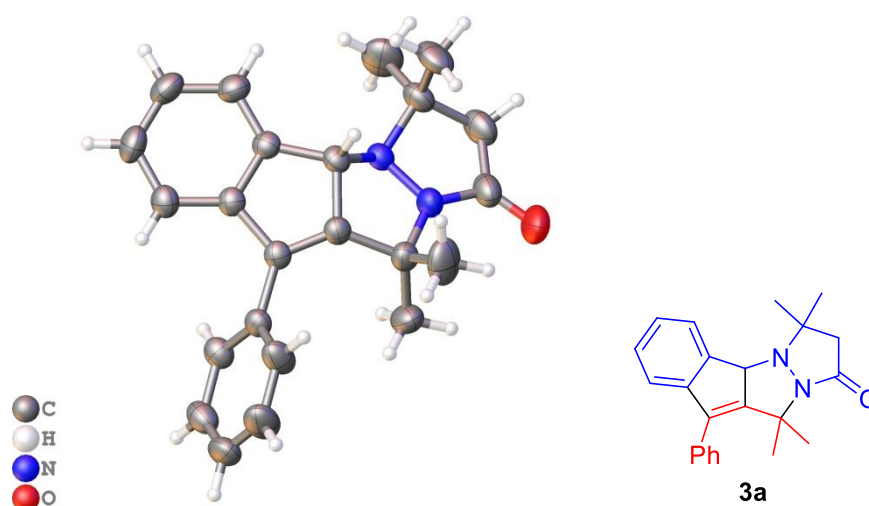


Fig. S3 X-ray crystal structure of **3a** with 50% ellipsoid probability

**X-ray structure determination.** Single crystals suitable for X-ray diffraction were obtained by slow evaporation of the solvent from a dichloromethane/ethyl acetate (2:1) solution of **3a**. Crystal data collection and refinement parameters of **3a** are summarized in Table S1. Intensity data were collected at 296 K on a SuperNova Dual diffractometer using mirror-monochromated Cu K $\alpha$  radiation,  $\lambda = 1.54184$  Å. The data were corrected for decay, Lorentz, and polarization effects as well as absorption and beam corrections based on the multi-scan technique. The structure was solved by a combination of direct methods in SHELXS and the difference Fourier technique, and refined by full-matrix least-squares procedures. Nonhydrogen atoms were refined with anisotropic displacement parameters. The H-atoms were either located or calculated and subsequently treated with a riding model.

**Table S1** Crystallographic data and structure refinement results of **3a**

Empirical formula	C <sub>23</sub> H <sub>24</sub> N <sub>2</sub> O
Formula weight	344.44
Temp, K	296.2 (4)
Crystal system	monoclinic
Space group	P2 <sub>1</sub> /c
<i>a</i> , Å	15.2849(6)
<i>b</i> , Å	7.3266(3)
<i>c</i> , Å	18.6240(8)
$\alpha$ (°)	90

$\beta$ (°)	110.556(5)
$\gamma$ (°)	90
Volume, Å <sup>3</sup>	1952.84(15)
Z	4
$d_{\text{calc}}$ , g cm <sup>-3</sup>	1.172
$\lambda$ , Å	1.54184
$\mu$ , mm <sup>-1</sup>	0.560
No. of data collected	8198
No. of unique data	3702
$R_{\text{int}}$	0.0282
Goodness-of-fit on $F^2$	1.086
$R_1$ , $wR_2$ ( $I > 2\sigma(I)$ )	0.0519, 0.1303
$R_1$ , $wR_2$ (all data)	0.0652, 0.1408

## VII. X-ray crystal structure and data of V

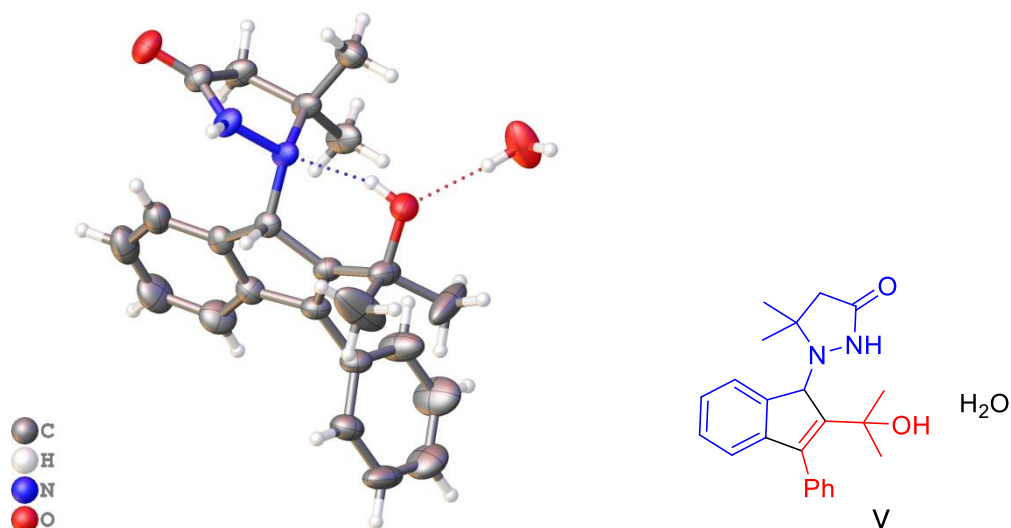


Fig. S4 X-ray crystal structure of **V** with H<sub>2</sub>O with 50% ellipsoid probability

**X-ray structure determination.** Single crystals suitable for X-ray diffraction were obtained by slow evaporation of the solvent from an ethyl acetate solution of **V**. Crystal data collection and refinement parameters of **V** are summarized in Table S2. Intensity data were collected at 295 K on a SuperNova Dual diffractometer using mirror-monochromated Cu K $\alpha$  radiation,  $\lambda = 1.54184$  Å. The data were corrected for decay, Lorentz, and polarization effects as well as absorption and beam corrections based on the multi-scan technique. The structure was solved by a combination of direct methods in SHELXS and the difference Fourier technique, and refined by full-matrix least-squares procedures. Nonhydrogen atoms were refined with anisotropic displacement parameters. The H-atoms were either located or calculated and subsequently treated with a riding model.

**Table S2** Crystallographic data and structure refinement results of **V** with H<sub>2</sub>O

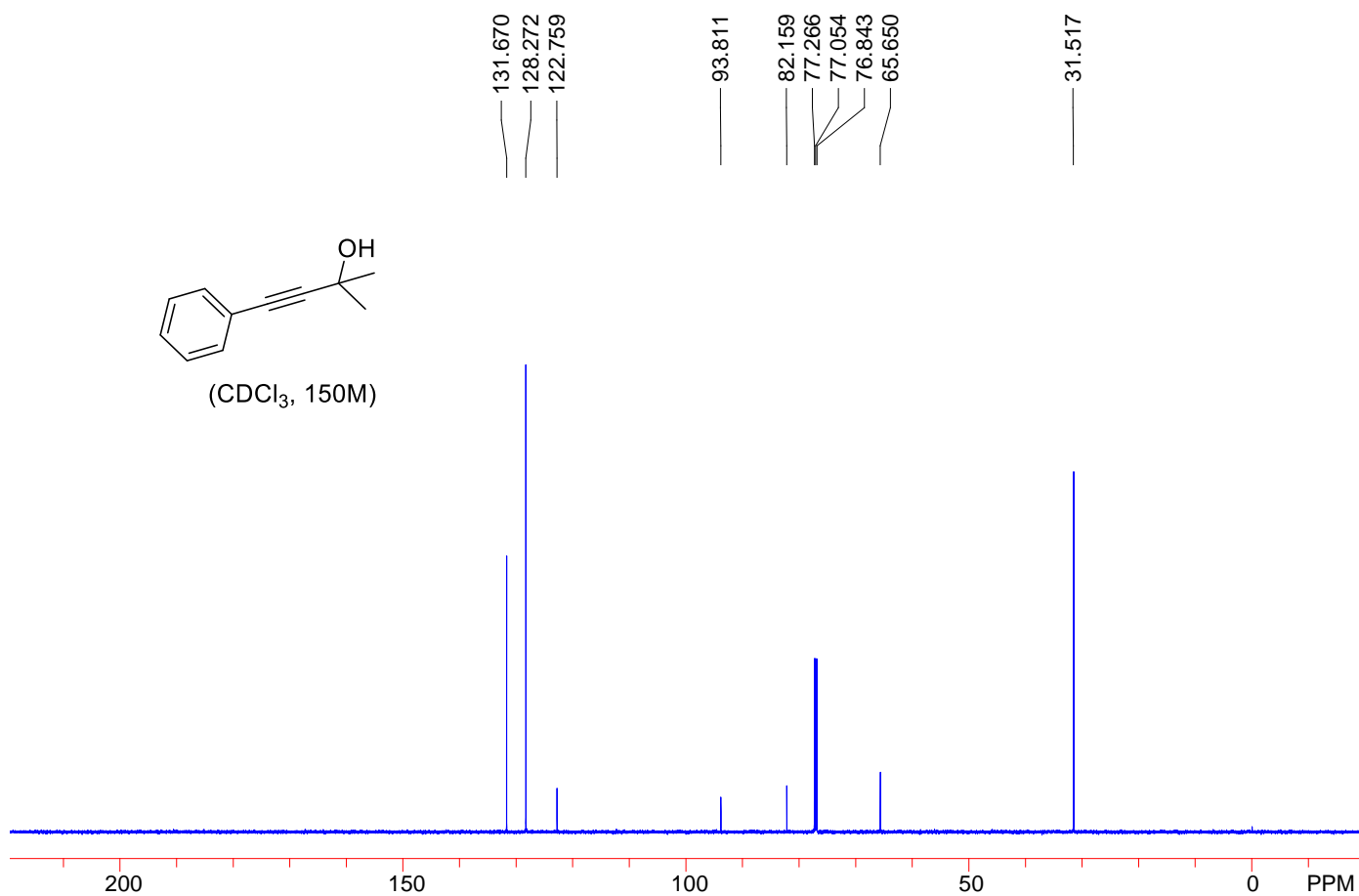
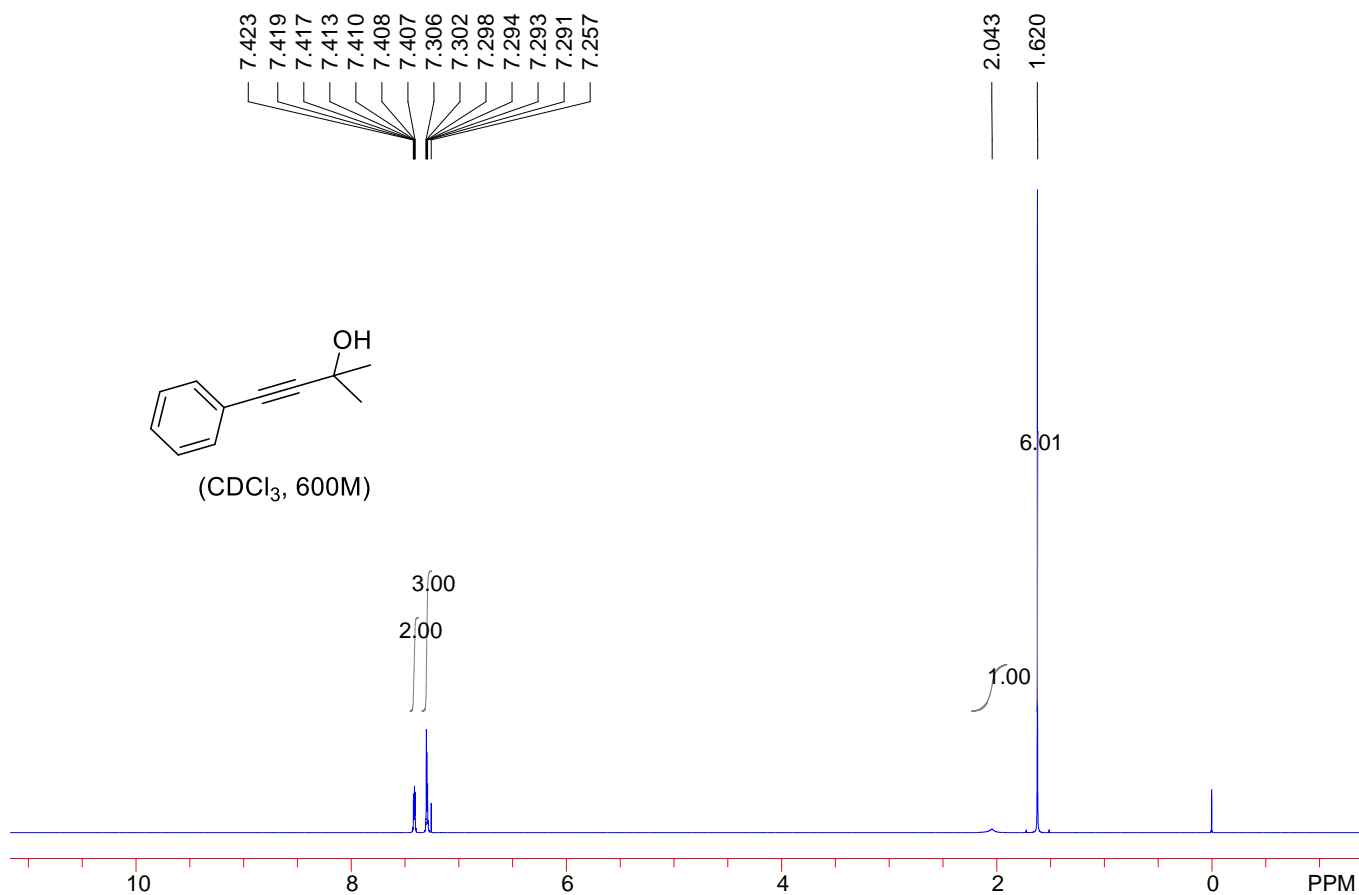
Empirical formula	C <sub>23</sub> H <sub>28</sub> N <sub>2</sub> O <sub>3</sub>
Formula weight	380.47
Temp, K	294.98(11)
Crystal system	monoclinic
Space group	P2 <sub>1</sub> /c
<i>a</i> , Å	7.0249(3)
<i>b</i> , Å	24.9828(10)
<i>c</i> , Å	12.0067(5)

$\alpha$ (°)	90
$\beta$ (°)	91.724(4)
$\gamma$ (°)	90
Volume, Å <sup>3</sup>	2106.24(15)
Z	4
$d_{\text{calc}}$ , g cm <sup>-3</sup>	1.200
$\lambda$ , Å	1.54184
$\mu$ , mm <sup>-1</sup>	0.635
No. of data collected	9870
No. of unique data	4019
$R_{\text{int}}$	0.0352
Goodness-of-fit on $F^2$	1.220
$R_1$ , $wR_2$ ( $I > 2\sigma(I)$ )	0.0785, 0.2362
$R_1$ , $wR_2$ (all data)	0.0958, 0.2420

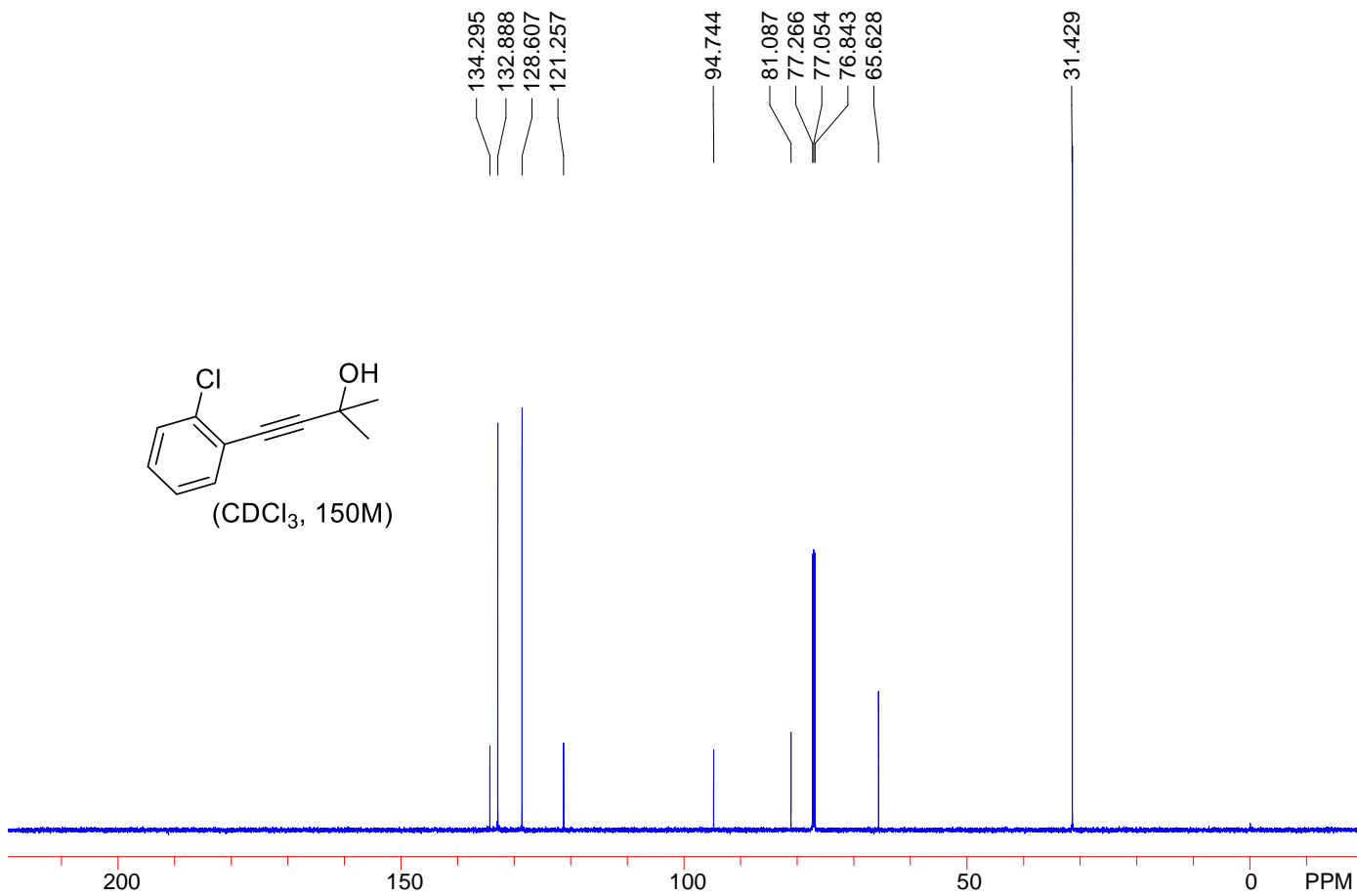
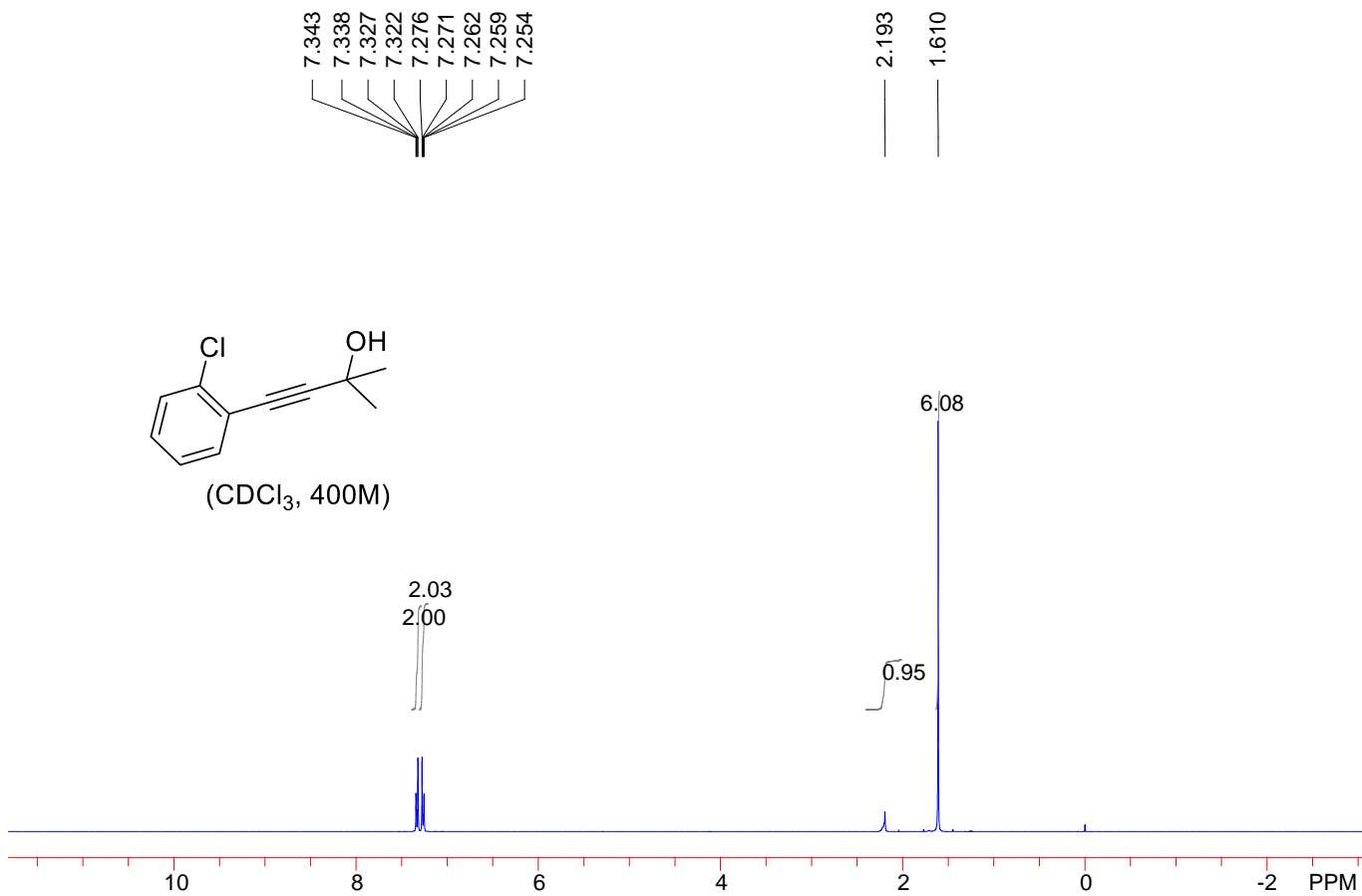
## VIII. Cell antiproliferative activity assay

Cell antiproliferative activity was evaluated by the CellTiter-Glo (Promega, USA) assay. Make 1000× compounds solution in DMSO, Add 1 μl 1000× compounds to 49 μl growth medium to make 20× compounds. Dilute cell suspensions in growth medium to desired density and 95 μl were taken to 96-well plate. Add 5 μl 20× compounds into 96-well plate according to the plate map. Final DMSO concentration in each well was 0.1%. Then the cell was incubated at 37 °C, 5% CO<sub>2</sub> for 72 h. Equilibrate the assay plate to room temperature before measurement. Add 20 μl of CellTiter-Glo® Reagent into each well. Mix contents for 2 minutes on an orbital shaker to induce cell lysis. Incubate at room temperature for 10 minutes to stabilize luminescent signal. Record luminescence using EnVision Multilabel Reader (PerkinElmer). Cell viability (CV%) was calculated relative to vehicle (DMSO) treated control wells using following formula: 
$$\text{Cell viability(\%)} = (\text{RLU compound} - \text{RLU blank}) / (\text{RLU control} - \text{RLU blank}) * 100\%.$$
 The IC<sub>50</sub> values were calculated using GraphPad Prism 6.0 software, fitting to a 4-parameter equation to generate concentration response curves. All assays were conducted with three parallel samples and three repetitions, and 5-fluorouracil (5-FU) was used as the positive control.

# IX. Copies of NMR spectra of selected propargyl alcohols

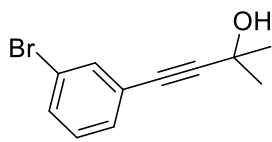






7.571  
7.568  
7.565  
7.442  
7.441  
7.439  
7.437  
7.429  
7.427  
7.426  
7.424  
7.342  
7.340  
7.338  
7.329  
7.327  
7.325  
7.261  
7.176  
7.171  
7.163  
7.150

2.038  
1.610



(CDCl<sub>3</sub>, 600M)

1.00 1.00  
1.00 1.00

0.94

6.00

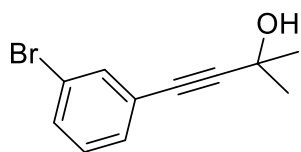
8 6 4 2 0 PPM

134.426  
131.422  
130.197  
129.716  
124.779  
122.074

95.189

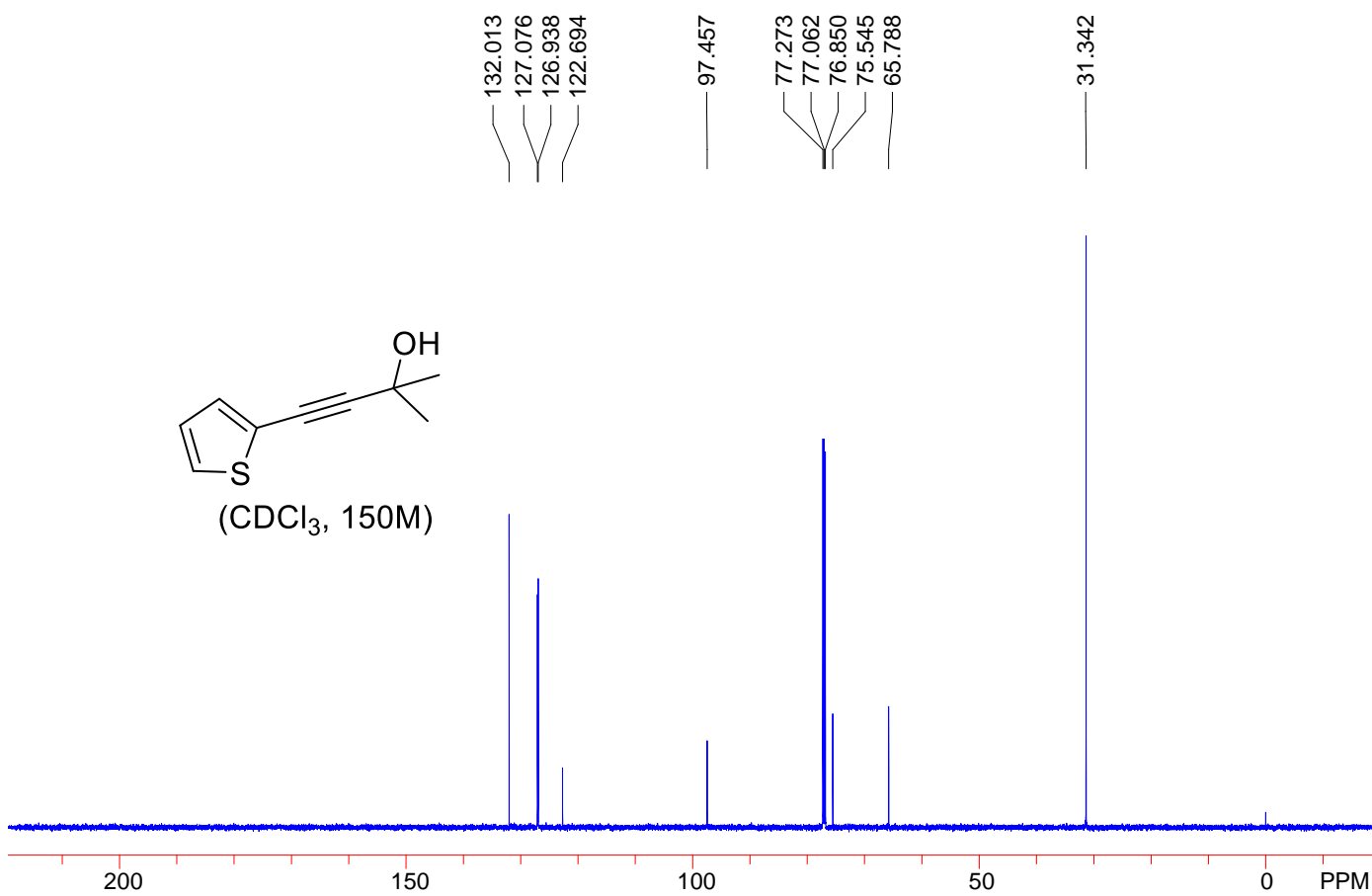
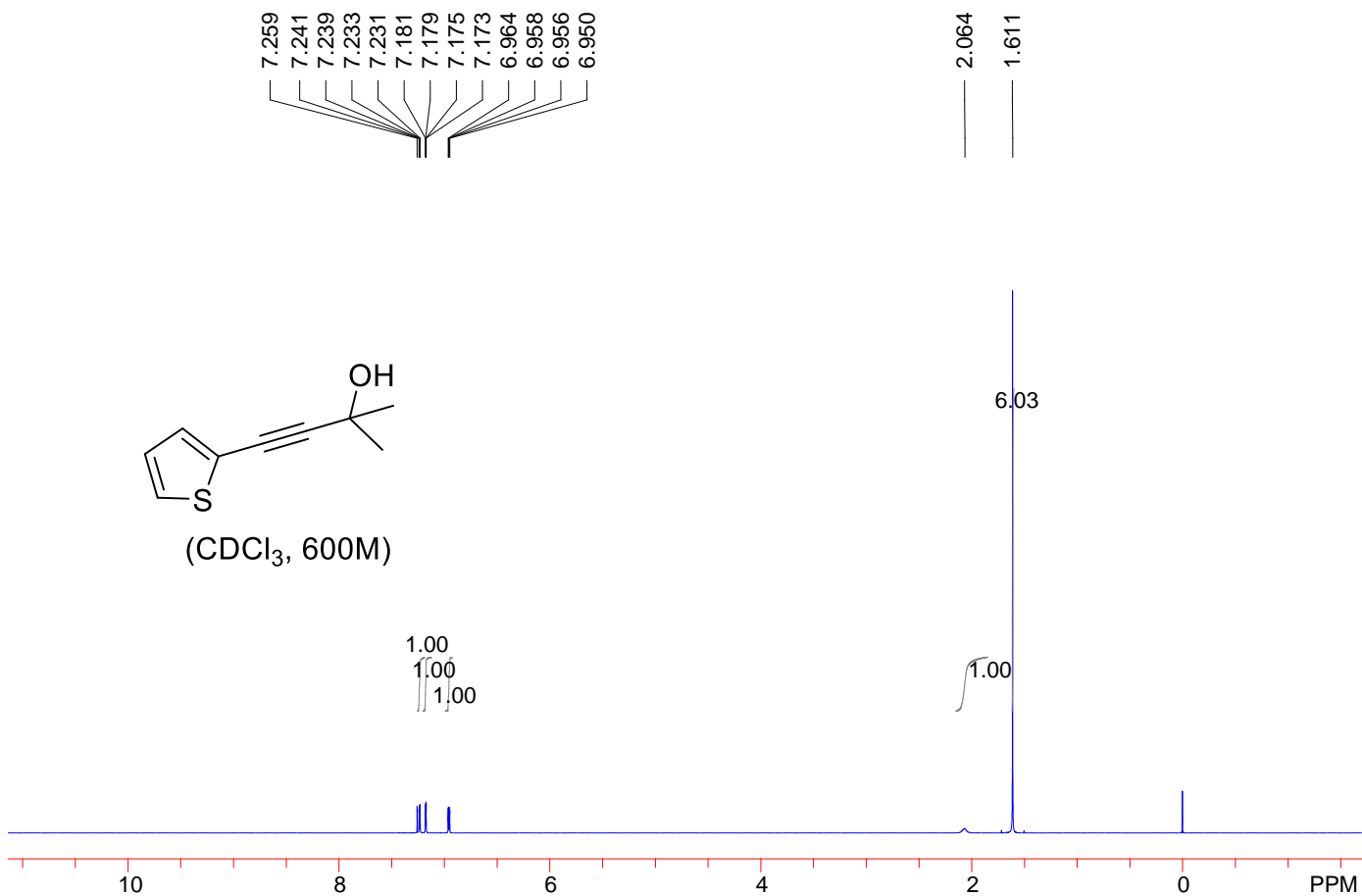
80.686  
77.310  
77.098  
76.887  
65.577

31.400



(CDCl<sub>3</sub>, 150M)

200 150 100 50 0 PPM



## X. References

- (1) M. Zhang, F. F. Wu, H. H. Wang, J. S. Wu, and W. Z. Chen, *Adv. Synth. Catal.* 2017, **359**, 2768.
- (2) P. K. R. Panyam, and T. Gandhi, *Adv. Synth. Catal.* 2017, **359**, 1144.
- (3) K.W. Feng, Y. L. Ban, P. F. Yuan, W. L. Lei, Q. Liu, and R. Fang, *Org. Lett.* 2019, **21**, 3131.