

# Electronic Supplementary Information for Gold Catalyzed Spirocyclization of 1- Ene-4,9- and 3-Ene-1,7-diyne Esters to Azaspiro[4.4]nonenones and Azaspiro[4.5]decadienones

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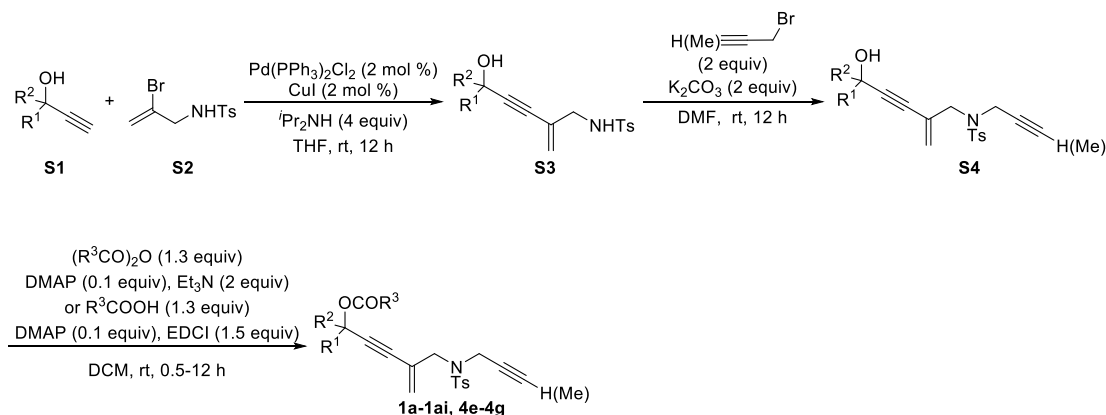
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## 1. General information

THF and toluene were dried using Na/benzophenone, DCE was dried using CaH<sub>2</sub>. Analytical thin layer chromatography (TLC) was performed using pre-coated silica gel plate. Visualization was achieved by UV light (254 nm). Flash chromatography was performed using silica gel and gradient solvent system (Petroleum ether: EtOAc as eluent). <sup>1</sup>H NMR, <sup>13</sup>C NMR and <sup>19</sup>F NMR spectra were recorded with either a Bruker AVQ-600 or 400 spectrometer instrument in CDCl<sub>3</sub>. Chemical shifts (ppm) were recorded with tetramethylsilane (TMS) as the internal reference standard. Multiplicities are given as: s (singlet), d (doublet), t (triplet), q (quartet), dd (doublet of doublets), td (triplet of doublets), dt (doublet of triplet) or m (multiplet). The number of protons (*n*) for a given resonance is indicated by *n*H and coupling constants are reported as a *J* value in Hz. High resolution mass spectra (HRMS) were obtained on a Finnigan MAT95XP LC/HRMS TOF spectrometer using simultaneous electrospray (ESI). Melting points were determined using a digital melting point apparatus (MPA-100).

## 2. Preparation and characterization of starting materials

### 2.1. General Procedure A



**Step 1:**<sup>S1</sup> To an oven-dried round-bottom flask equipped with a stirring bar were added S2 (3.3 mmol, 1.1 equiv), S1 (3.0 mmol, 1.0 equiv, if solid, added at this time), Pd(PPh<sub>3</sub>)<sub>2</sub>Cl<sub>2</sub> (0.06 mmol, 2 mol %) and CuI (0.06 mmol, 2 mol %) in anhydrous THF (15 mL, 0.2 M) was added diisopropylamine (*i*Pr<sub>2</sub>NH, 12.0 mmol, 4.0 equiv) under an argon atmosphere at 0 °C. S1 (if liquid, dissolved in THF and added at last by a syringe). The reaction mixture was stirred at room temperature for 12 h until full consumption of the starting material (monitored by TLC). Upon completion, the reaction mixture was quenched with saturated NH<sub>4</sub>Cl solution and extracted with EtOAc, the combined organic layers were washed with brine, dried over MgSO<sub>4</sub>. After filtration and concentration, the residue was purified by flash column chromatography on silica gel (eluent: petroleum ether/EtOAc) to afford S3.

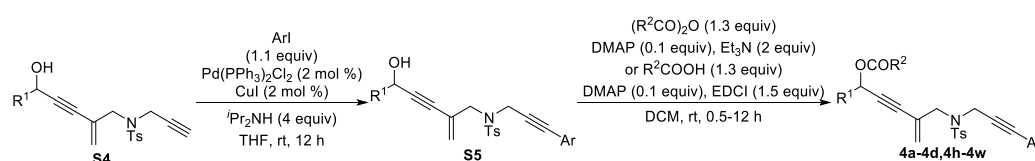
**Step 2:** To a 50 mL round-bottom flask equipped with a stirring bar were added S3 (1.5 mmol, 1.0 equiv) and K<sub>2</sub>CO<sub>3</sub> (3.0 mmol, 2.0 equiv) in dry DMF (7.5 mL, 0.2 M) was added 1-bromo-2-butyne or propargylic bromide (3.0 mmol, 2.0 equiv) under an argon atmosphere. The reaction mixture was stirred at room temperature for 12 h until full consumption of the starting material (monitored by TLC). Upon completion, the reaction mixture was quenched with saturated NaCl solution and extracted with EtOAc, the combined organic layers were washed with brine, dried over MgSO<sub>4</sub>. After filtration and concentration, the residue was purified by flash column chromatography on silica gel (eluent: petroleum ether/EtOAc) to afford S4.



**Step 3:** To a 25 mL oven-dried round-bottom flask equipped with a stirring bar were added **S4** (1.2 mmol, 1.0 equiv), DMAP (0.12 mmol, 0.1 equiv), Et<sub>3</sub>N (2.4 mmol, 2.0 equiv) and (R<sup>3</sup>CO)<sub>2</sub>O (1.56 mmol, 1.3 equiv) in DCM (5 mL) under an air atmosphere. The reaction mixture was stirred at room temperature for 0.5-4 h until full consumption of the starting material (monitored by TLC). Upon completion, the reaction mixture was quenched with saturated NH<sub>4</sub>Cl solution and extracted with DCM, the combined organic layers were washed with brine, dried over MgSO<sub>4</sub>. After filtration and concentration, the residue was purified by flash column chromatography on silica gel (eluent: petroleum ether/EtOAc) to afford **1a-1n**, **1ad** and **4e-4g**.

To a 25 mL oven-dried round-bottom flask equipped with a stirring bar were added **S4** (1.2 mmol, 1.0 equiv), R<sup>3</sup>COOH (1.56 mmol, 1.3 equiv) and DMAP (0.12 mmol, 0.1 equiv) in DCM (5 mL) was added EDCI (1.8 mmol, 1.5 equiv) under an air atmosphere at 0 °C. The reaction mixture was stirred at room temperature for 4-12 h until full consumption of the starting material (monitored by TLC). Upon completion, the reaction mixture was quenched with saturated NH<sub>4</sub>Cl solution and extracted with DCM, the combined organic layers were washed with brine, dried over MgSO<sub>4</sub>. After filtration and concentration, the residue was purified by flash column chromatography on silica gel (eluent: petroleum ether/EtOAc) to afford **1o-1ac** and **1ae-1ai**.

## 2.2. General Procedure B



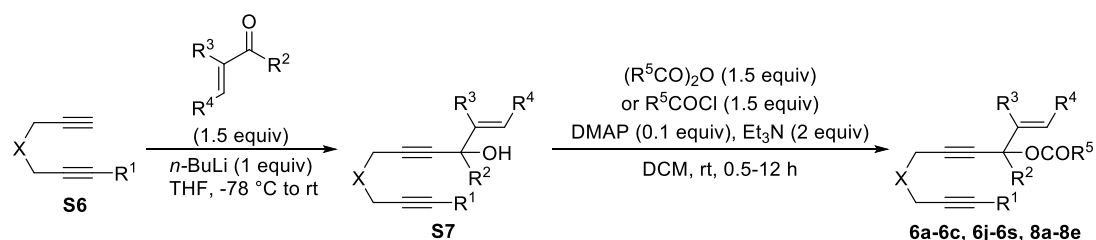
**Step 1:** To an oven-dried round-bottom flask equipped with a stirring bar were added ArI (1.65 mmol, 1.1 equiv), **S4** (1.5 mmol, 1.0 equiv, if solid, added at this time), Pd(PPh<sub>3</sub>)<sub>2</sub>Cl<sub>2</sub> (0.03 mmol, 2 mol %) and CuI (0.03 mmol, 2 mol %) in anhydrous THF (7.5 mL, 0.2 M) was added <sup>i</sup>Pr<sub>2</sub>NH (6.0 mmol, 4.0 equiv) under an argon atmosphere at 0 °C. **S4** (if liquid, dissolved in THF and added at last by a syringe). The reaction mixture was stirred at room temperature for 12 h until full consumption of the starting material (monitored by TLC). Upon completion, the reaction mixture was quenched with saturated NH<sub>4</sub>Cl solution and extracted with EtOAc, the combined organic layers

were washed with brine, dried over MgSO<sub>4</sub>. After filtration and concentration, the residue was purified by flash column chromatography on silica gel (eluent: petroleum ether/EtOAc) to afford **S5**.

**Step 2:** To a 25 mL oven-dried round-bottom flask equipped with a stirring bar were added **S5** (0.8 mmol, 1.0 equiv), DMAP (0.08 mmol, 0.1 equiv), Et<sub>3</sub>N (1.6 mmol, 2.0 equiv) and (R<sup>2</sup>CO)<sub>2</sub>O (1.04 mmol, 1.3 equiv) in DCM (4 mL) under an air atmosphere. The reaction mixture was stirred at room temperature for 0.5-4 h until full consumption of the starting material (monitored by TLC). Upon completion, the reaction mixture was quenched with saturated NH<sub>4</sub>Cl solution and extracted with DCM, the combined organic layers were washed with brine, dried over MgSO<sub>4</sub>. After filtration and concentration, the residue was purified by flash column chromatography on silica gel (eluent: petroleum ether/EtOAc) to afford **4a-4d**.

To a 25 mL oven-dried round-bottom flask equipped with a stirring bar were added **S5** (0.8 mmol, 1.0 equiv), R<sup>2</sup>COOH (1.04 mmol, 1.3 equiv) and DMAP (0.08 mmol, 0.1 equiv) in DCM (4 mL) was added EDCI (1.2 mmol, 1.5 equiv) under an air atmosphere at 0 °C. The reaction mixture was stirred at room temperature for 4-12 h until full consumption of the starting material (monitored by TLC). Upon completion, the reaction mixture was quenched with saturated NH<sub>4</sub>Cl solution and extracted with DCM, the combined organic layers were washed with brine, dried over MgSO<sub>4</sub>. After filtration and concentration, the residue was purified by flash column chromatography on silica gel (eluent: petroleum ether/EtOAc) to afford **4h-4w**.

### 2.3. General Procedure C

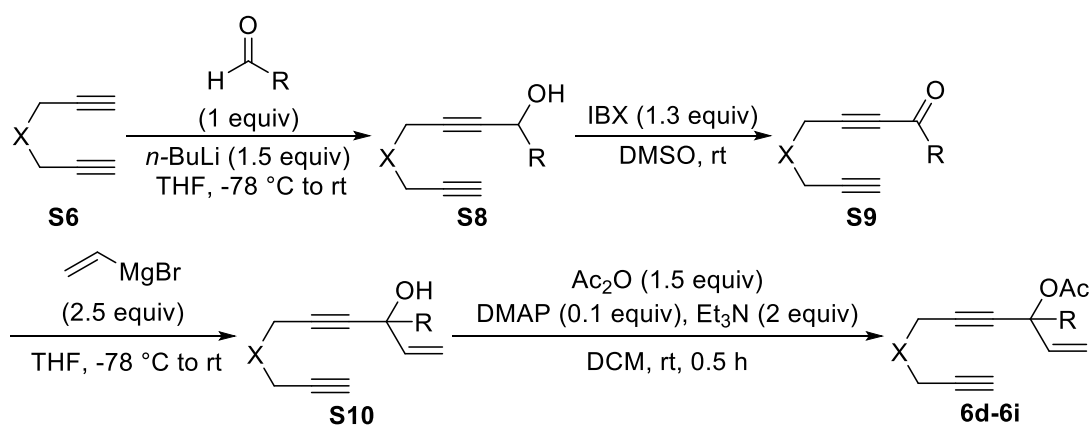


**Step 1:**<sup>S2</sup> To a stirring solution of diene **S6** (3.0 mmol, 1.5 equiv) in THF (10 mL, 0.2 M) at -78 °C was added *n*-butyllithium (3.0 mmol, 1.5 equiv.) in a dropwise manner. The resulting solution was stirred for 1 h, and the corresponding vinyl ketone

derivatives (2.0 mmol, 1.0 equiv.) was subsequently added dropwise at  $-78\text{ }^{\circ}\text{C}$  and stirred for 2 h. The reaction mixture was then allowed to warm to room temperature and stirred for 1 h. The reaction was quenched with saturated  $\text{NH}_4\text{Cl}$  solution and extracted with EtOAc. The combined organic layers were washed with brine, dried over  $\text{MgSO}_4$ . After filtration and concentration, the residue was purified by flash column chromatography on silica gel (eluent: petroleum ether/EtOAc) to afford **S7**.

**Step 2:** To a 25 mL oven-dried round-bottom flask equipped with a stirring bar were added **S7** (1.0 mmol, 1.0 equiv), DMAP (0.1 mmol, 0.1 equiv),  $\text{Et}_3\text{N}$  (2.0 mmol, 2.0 equiv) and  $(\text{R}^5\text{CO})_2\text{O}$  or  $\text{R}^5\text{COCl}$  (1.5 mmol, 1.5 equiv) in DCM (4 mL) under an air atmosphere. The reaction mixture was stirred at room temperature for 0.5-4 h until full consumption of the starting material (monitored by TLC). Upon completion, the reaction mixture was quenched with saturated  $\text{NH}_4\text{Cl}$  solution and extracted with DCM, the combined organic layers were washed with brine, dried over  $\text{MgSO}_4$ . After filtration and concentration, the residue was purified by flash column chromatography on silica gel (eluent: petroleum ether/EtOAc) to afford **6a–6c**, **6j–6s** and **8a–8e**.

#### 2.4. General Procedure D



**Step 1:** To a stirring solution of diyne **S6** (4.5 mmol, 1.5 equiv) in THF (15 mL, 0.2 M) at  $-78\text{ }^{\circ}\text{C}$  was added  $n$ -butyllithium (4.5 mmol, 1.5 equiv.) in a dropwise manner. The resulting solution was stirred for 1 h, and the corresponding aldehyde (3.0 mmol, 1.0 equiv.) was subsequently added dropwise at  $-78\text{ }^{\circ}\text{C}$  and stirred for 2 h. The reaction mixture was then allowed to warm to room temperature and stirred for 1 h (monitored by TLC). The reaction was then quenched with saturated  $\text{NH}_4\text{Cl}$  solution and extracted

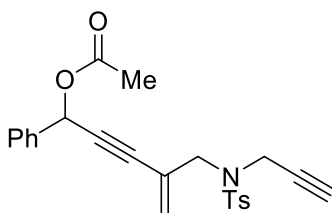
with EtOAc. The combined organic layers were washed with brine, dried over MgSO<sub>4</sub>, concentrated under reduced pressure, and purified by flash column chromatography on silica gel (eluent: petroleum benzene/EtOAc) to afford **S8**.

**Step 2:** To stirring solution of **S8** (2.0 mmol, 1.0 equiv) in DMSO (3.0 mL) was added IBX (2.6 mmol, 1.3 equiv.) portion-wise and the reaction mixture was stirred at for 2 h at room temperature (monitored by TLC). Subsequently, water (30 mL) and EtOAc (10 mL) were added, and the resulting solution was stirred for 15 min. After filtration through a layer of Celite, the filtrate was extracted with EtOAc. The combined organic layers were washed with water and brine, dried over MgSO<sub>4</sub>, concentrated under reduced pressure, and purified by flash column chromatography on silica gel (eluent: petroleum benzene/EtOAc) to afford **S9**.

**Step 3:** Dropwise at -78 °C, vinylmagnesium bromide solution (3.75 mmol, 2.5 equiv.) was added dropwise into a stirring solution of **S9** (1.5 mmol, 1.0 equiv) in THF (7.5 mL, 0.2 M), over 10 min. The resulting reaction mixture was then stirred at -78 °C for 3 h (monitored by TLC) Upon completion, the reaction was quenched with saturated NH<sub>4</sub>Cl solution in an ice bath and extracted with EtOAc. The combined organic layers were washed with brine, dried over MgSO<sub>4</sub>, concentrated under reduced pressure, and purified by flash column chromatography on silica gel (eluent: petroleum benzene/EtOAc) to afford **S10**.

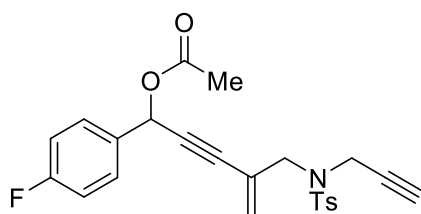
**Step 4:** To a 25 mL oven-dried round-bottom flask equipped with a stirring bar were added **S10** (1.0 mmol, 1.0 equiv), DMAP (0.1 mmol, 0.1 equiv), Et<sub>3</sub>N (2.0 mmol, 2.0 equiv) and Ac<sub>2</sub>O (1.5 mmol, 1.5 equiv) in DCM (4 mL) under an air atmosphere. The reaction mixture was stirred at room temperature for 0.5 h until full consumption of the starting material (monitored by TLC). Upon completion, the reaction mixture was quenched with saturated NH<sub>4</sub>Cl solution and extracted with DCM, the combined organic layers were washed with brine, dried over MgSO<sub>4</sub>. After filtration and concentration, the residue was purified by flash column chromatography on silica gel (eluent: petroleum ether/EtOAc) to afford **6d–6i**.

**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl acetate (1a)**



The title compound was prepared according to general procedure **A** in 43% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 6:1) to afford **1a** as a pale-yellow oil;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.73 (d,  $J = 8.3$  Hz, 2H), 7.55–7.53 (m, 2H), 7.41–7.35 (m, 3H), 7.27 (d,  $J = 8.3$  Hz, 2H), 6.55 (s, 1H), 5.63 (s, 1H), 5.59 (d,  $J = 0.9$  Hz, 1H), 4.11 (d,  $J = 2.0$  Hz, 2H), 3.96–3.86 (m, 2H), 2.40 (s, 3H), 2.10 (s, 3H), 2.02 (t,  $J = 2.3$  Hz, 1H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  169.7, 143.6, 136.5, 135.9, 129.4, 128.9, 128.6, 127.7, 127.6, 125.5, 124.9, 87.1, 84.7, 76.2, 74.0, 65.7, 50.5, 36.0, 21.4, 20.9; **HRMS (ESI)** calcd for  $\text{C}_{24}\text{H}_{23}\text{NNaO}_4\text{S}$   $[\text{M}+\text{Na}]^+$ : 444.1240; found: 444.1249.

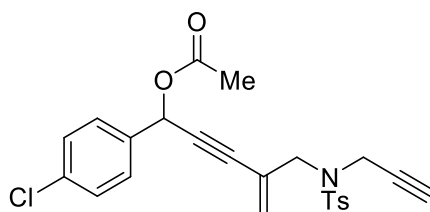
**1-(4-fluorophenyl)-4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)pent-4-en-2-yn-1-yl acetate (1b)**



The title compound was prepared according to general procedure **A** in 41% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 5:1) to afford **1b** as a yellow oil;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.72 (d,  $J = 8.3$  Hz, 2H), 7.50–7.46 (m, 2H), 7.36–7.33 (m, 2H), 7.28–7.23 (m, 2H), 6.51 (s, 1H), 5.62 (s, 1H), 5.59 (d,  $J = 1.0$  Hz, 1H), 4.09 (d,  $J = 1.3$  Hz, 2H), 3.96–3.86 (m, 2H), 2.39 (s, 3H), 2.09 (s, 3H), 2.01 (t,  $J = 2.4$  Hz, 1H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  169.7, 163.0 (d,  $J = 249.5$  Hz), 143.7, 136.0, 132.6, 129.9 (d,  $J = 8.7$  Hz), 129.5, 127.7, 125.9, 125.0, 115.6 (d,  $J = 21.7$  Hz), 87.0, 84.9, 76.2, 74.0, 65.1, 50.6,

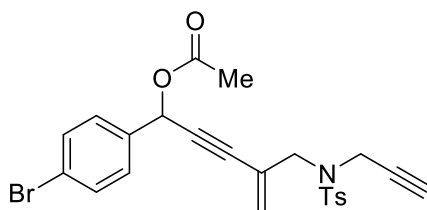
36.0, 21.5, 21.0;  $^{19}\text{F}$  NMR (565 MHz,  $\text{CDCl}_3$ )  $\delta$  -112.40 – -112.45 (m); HRMS (ESI) calcd for  $\text{C}_{24}\text{H}_{22}\text{FKNO}_4\text{S}$   $[\text{M}+\text{K}]^+$ : 478.0885; found: 478.0668.

**1-(4-chlorophenyl)-4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)pent-4-en-2-yn-1-yl acetate (1c)**



The title compound was prepared according to general procedure **A** in 47% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 6:1) to afford **1c** as a pale-yellow oil;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.72 (d,  $J$  = 8.3 Hz, 2H), 7.48 (m, 2H), 7.39–7.32 (m, 2H), 7.28–7.23 (m, 2H), 6.51 (s, 1H), 5.62 (s, 1H), 5.59 (d,  $J$  = 1.0 Hz, 1H), 4.09 (d,  $J$  = 1.3 Hz, 2H), 3.96–3.86 (m, 2H), 2.39 (s, 3H), 2.09 (s, 3H), 2.01 (t,  $J$  = 2.4 Hz, 1H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  169.5, 143.6, 135.8, 135.1, 134.8, 129.4, 129.2, 128.8, 127.6, 125.89, 124.8, 86.6, 84.9, 76.0, 74.1, 64.9, 50.5, 35.9, 21.4, 20.9; HRMS (ESI) calcd for  $\text{C}_{24}\text{H}_{22}\text{ClNNaO}_4\text{S}$   $[\text{M}+\text{Na}]^+$ : 478.0850; found: 478.0865.

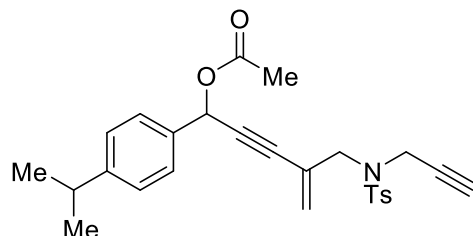
**1-(4-bromophenyl)-4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)pent-4-en-2-yn-1-yl acetate (1d)**



The title compound was prepared according to general procedure **A** in 40% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 6:1) to afford **1d** as a yellow oil;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.73 (d,  $J$  = 8.1 Hz, 2H), 7.52 (d,  $J$  = 8.3 Hz, 2H), 7.42 (d,  $J$  = 8.3 Hz, 2H), 7.28 (d,  $J$  = 8.0 Hz, 2H), 6.50 (s, 1H), 5.63 (s, 1H), 5.60 (s, 1H), 4.10 (s, 2H), 3.96–3.86 (m, 2H), 2.41 (s, 3H), 2.11 (s, 3H), 2.00 (s, 1H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  169.7, 143.7,

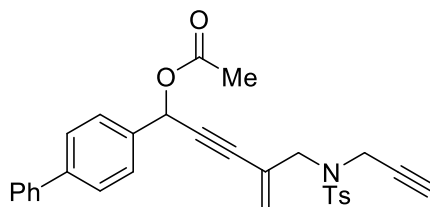
135.9, 135.6, 131.8, 129.6, 129.5, 127.7, 126.0, 124.9, 123.2, 86.6, 85.0, 76.2, 74.1, 65.1, 50.6, 36.0, 21.50 21.0; **HRMS (ESI)** calcd for C<sub>24</sub>H<sub>22</sub>BrNNaO<sub>4</sub>S [M+Na]<sup>+</sup>: 522.0345; found: 522.0353.

**1-(4-isopropylphenyl)-4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)pent-4-en-2-yn-1-yl acetate (1e)**



The title compound was prepared according to general procedure **A** in 47% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 5:1) to afford **1e** as a pale-yellow oil; **<sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>)** δ 7.74 (d, *J* = 8.2 Hz, 2H), 7.46 (d, *J* = 8.1 Hz, 2H), 7.28 (d, *J* = 8.2 Hz, 2H), 7.25 (d, *J* = 8.0 Hz, 2H), 6.52 (s, 1H), 5.63 (s, 1H), 5.60 (s, 1H), 4.12 (d, *J* = 2.3 Hz, 2H), 3.99–3.88 (m, 2H), 2.94–2.89 (m, 1H), 2.41 (s, 3H), 2.10 (s, 3H), 2.02 (t, *J* = 2.4 Hz, 1H), 1.25 (d, *J* = 6.9 Hz, 6H); **<sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>)** δ 169.8, 149.8, 143.6, 136.0, 134.0, 129.5, 127.9, 127.7, 126.7, 125.4, 125.0, 87.4, 84.6, 76.3, 74.0, 65.6, 50.5, 36.1, 33.9, 23.9, 23.8, 21.5, 21.1; **HRMS (ESI)** calcd for C<sub>27</sub>H<sub>29</sub>NNaO<sub>4</sub>S [M+Na]<sup>+</sup>: 486.1710; found: 486.1717.

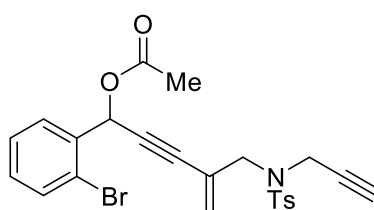
**1-([1,1'-biphenyl]-4-yl)-4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)pent-4-en-2-yn-1-yl acetate (1f)**



The title compound was prepared according to general procedure **A** in 32% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 5:1) to afford **1f** as a pale-yellow oil; **<sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>)** δ 7.75 (d, *J* = 8.3 Hz, 2H), 7.62 (s, 4H), 7.61–7.58 (m, 2H), 7.45 (t, *J* = 7.7 Hz,

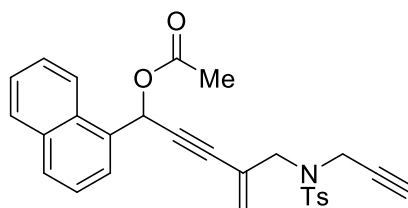
2H), 7.36 (t,  $J = 7.4$  Hz, 1H), 7.28 (d,  $J = 8.1$  Hz, 2H), 6.60 (s, 1H), 5.66 (s, 1H), 5.62 (d,  $J = 1.1$  Hz, 1H), 4.14 (d,  $J = 2.0$  Hz, 2H), 4.00–3.90 (m, 2H), 2.41 (s, 3H), 2.14 (s, 3H), 2.02 (t,  $J = 2.4$  Hz, 1H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  169.8, 143.6, 142.0, 140.5, 136.0, 135.6, 129.5, 128.8, 128.3, 127.7, 127.5, 127.4, 127.2, 125.6, 125.0, 87.2, 84.8, 76.3, 74.0, 65.6, 50.6, 36.1, 21.5, 21.1; HRMS (ESI) calcd for  $\text{C}_{30}\text{H}_{27}\text{NNaO}_4\text{S}$   $[\text{M}+\text{Na}]^+$ : 520.1553; found: 520.1565.

**1-(2-bromophenyl)-4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)pent-4-en-2-yn-1-yl acetate (1g)**



The title compound was prepared according to general procedure **A** in 45% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 16:1 to 6:1) to afford **1g** as a pale-yellow oil;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.84 (dd,  $J = 7.8, 1.5$  Hz, 1H), 7.73 (d,  $J = 8.3$  Hz, 2H), 7.57 (dd,  $J = 8.0, 0.9$  Hz, 1H), 7.44–7.38 (m, 1H), 7.27 (d,  $J = 8.1$  Hz, 2H), 7.25–7.21 (m, 1H), 6.77 (s, 1H), 5.64 (s, 1H), 5.60 (d,  $J = 0.9$  Hz, 1H), 4.12 (s, 2H), 3.98–3.88 (m, 2H), 2.41 (s, 3H), 2.12 (s, 3H), 2.01 (t,  $J = 2.4$  Hz, 1H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  169.4, 143.7, 136.1, 135.6, 133.0, 130.6, 130.2, 129.5, 128.0, 127.8, 125.9, 125.1, 123.3, 86.4, 85.2, 76.3, 74.1, 65.3, 50.7, 36.3, 21.5, 20.8; HRMS (ESI) calcd for  $\text{C}_{24}\text{H}_{22}\text{BrNNaO}_4\text{S}$   $[\text{M}+\text{Na}]^+$ : 522.0345; found: 522.0352.

**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-(naphthalen-1-yl)pent-4-en-2-yn-1-yl acetate (1h)**

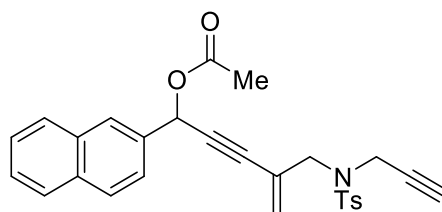


The title compound was prepared according to general procedure **A** in 43% yield over



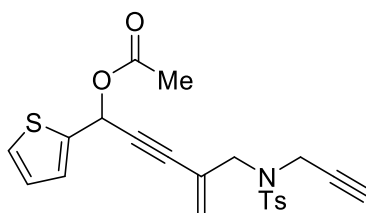
3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 5:1) to afford **1h** as a pale-yellow oil; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 8.19 (d, *J* = 8.5 Hz, 1H), 7.93–7.88 (m, 2H), 7.86 (d, *J* = 7.0 Hz, 1H), 7.74 (d, *J* = 8.3 Hz, 2H), 7.63–7.57 (m, 1H), 7.57–7.39 (m, 2H), 7.28–7.25 (m, 2H), 7.18 (s, 1H), 5.62 (s, 1H), 5.60 (d, *J* = 1.0 Hz, 1H), 4.18–4.05 (m, 2H), 3.97–3.90 (m, 2H), 2.40 (s, 3H), 2.14 (s, 3H), 2.00 (t, *J* = 2.4 Hz, 1H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 169.9, 143.6, 136.0, 133.2, 131.8, 130.5, 130.0, 129.4, 128.8, 127.7, 126.9, 126.7, 126.0, 125.6, 125.2, 125.1, 123.6, 87.3, 85.1, 76.3, 74.0, 64.1, 50.6, 36.1, 21.5, 21.0; HRMS (ESI) calcd for C<sub>28</sub>H<sub>25</sub>NNaO<sub>4</sub>S [M+Na]<sup>+</sup>: 494.1397; found: 494.1409.

**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-(naphthalen-2-yl)pent-4-en-2-yn-1-yl acetate (1i)**



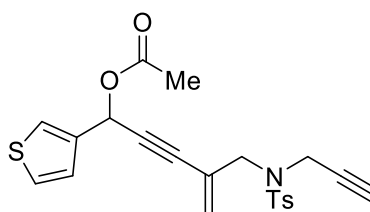
The title compound was prepared according to general procedure **A** in 39% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 8:1 to 4:1) to afford **1i** as a yellow oil; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 8.04 (s, 1H), 7.94–7.91 (m, 1H), 7.88 (d, *J* = 8.5 Hz, 1H), 7.85–7.83 (m, 1H), 7.75 (d, *J* = 8.2 Hz, 2H), 7.63 (dd, *J* = 8.5, 1.7 Hz, 1H), 7.53–7.49 (m, 2H), 7.29–7.23 (m, 2H), 6.73 (s, 1H), 5.67 (s, 1H), 5.62 (s, 1H), 4.14 (s, 2H), 4.01–3.91 (m, 2H), 2.39 (s, 3H), 2.14 (s, 3H), 2.02 (t, *J* = 2.4 Hz, 1H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 169.8, 143.6, 136.0, 133.9, 133.4, 133.0, 129.5, 128.6, 128.4, 127.7, 127.6, 127.3, 126.6, 126.4, 125.8, 125.1, 125.0, 87.2, 85.0, 76.3, 74.0, 65.9, 50.6, 36.1, 21.5, 21.1; HRMS (ESI) calcd for C<sub>28</sub>H<sub>26</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 472.1577; found: 472.1583.

**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-(thiophen-2-yl)pent-4-en-2-yn-1-yl acetate (1j)**



The title compound was prepared according to general procedure **A** in 41% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 5:1) to afford **1j** as a yellow oil;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.73 (d,  $J = 8.2$  Hz, 2H), 7.35–7.30 (m, 1H), 7.30–7.23 (m, 3H), 7.01–6.90 (m, 1H), 6.75 (s, 1H), 5.66 (s, 1H), 5.63 (s, 1H), 4.13 (d,  $J = 2.3$  Hz, 2H), 3.93 (s, 2H), 2.40 (s, 3H), 2.10 (s, 3H), 2.03 (t,  $J = 2.4$  Hz, 1H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  169.5, 143.6, 139.4, 136.0, 129.4, 127.9, 127.7, 127.0, 126.7, 125.9, 124.8, 86.4, 84.2, 76.3, 74.0, 60.8, 50.4, 36.1, 21.4, 20.9; **HRMS (ESI)** calcd for  $\text{C}_{22}\text{H}_{21}\text{NNaO}_4\text{S}_2$   $[\text{M}+\text{Na}]^+$ : 450.0804; found: 450.0815.

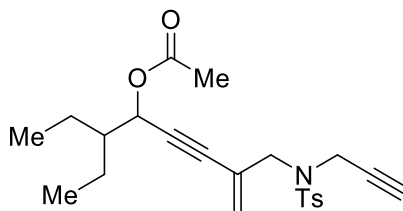
**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-(thiophen-3-yl)pent-4-en-2-yn-1-yl acetate (1k)**



The title compound was prepared according to general procedure **A** in 40% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 5:1) to afford **1k** as a pale-yellow oil;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.73 (d,  $J = 8.3$  Hz, 2H), 7.51 (d,  $J = 2.9$  Hz, 1H), 7.31 (dd,  $J = 5.0, 3.0$  Hz, 1H), 7.28 (d,  $J = 8.2$  Hz, 2H), 7.19 (dd,  $J = 5.0, 1.1$  Hz, 1H), 6.60 (s, 1H), 5.64 (s, 1H), 5.60 (d,  $J = 1.0$  Hz, 1H), 4.12 (d,  $J = 2.3$  Hz, 2H), 3.92 (s, 2H), 2.41 (s, 3H), 2.10 (s, 3H), 2.02 (t,  $J = 2.4$  Hz, 1H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  169.7, 143.6, 137.3, 135.9, 129.5, 127.7, 126.8, 126.4, 125.8, 125.0, 124.9, 86.9, 83.9, 76.2, 74.0, 61.2, 50.5, 36.01,

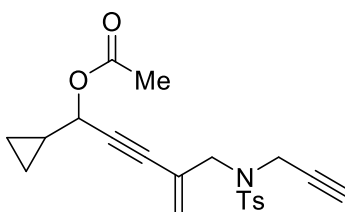
21.5, 21.0; **HRMS (ESI)** calcd for C<sub>22</sub>H<sub>21</sub>NNaO<sub>4</sub>S<sub>2</sub> [M+Na]<sup>+</sup>: 450.0804; found: 450.0810.

**3-ethyl-7-(((4-methyl-N-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)oct-7-en-5-yn-4-yl acetate (1l)**



The title compound was prepared according to general procedure **A** in 43% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 6:1) to afford **1l** as a pale-yellow oil; **<sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>)** δ 7.72 (d, *J* = 8.3 Hz, 2H), 7.28 (d, *J* = 8.0 Hz, 2H), 5.55 (s, 1H), 5.53–5.51 (m, 2H), 4.11 (d, *J* = 2.4 Hz, 2H), 3.87 (s, 2H), 2.41 (s, 3H), 2.07 (s, 3H), 1.99 (t, *J* = 2.4 Hz, 1H), 1.59–1.52 (m, 2H), 1.51–1.38 (m, 3H), 0.92 (td, *J* = 7.4, 2.7 Hz, 6H); **<sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>)** δ 170.0, 143.5, 136.1, 129.4, 127.7, 125.3, 124.8, 87.5, 83.5, 76.3, 73.9, 66.6, 50.2, 45.3, 36.0, 22.4, 22.1, 21.5, 21.0, 11.5, 11.4; **HRMS (ESI)** calcd for C<sub>23</sub>H<sub>30</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>:416.1890; found: 416.1899.

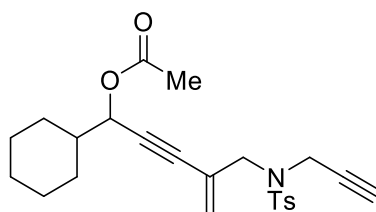
**1-cyclopropyl-4-(((4-methyl-N-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl) pent-4-en-2-yn-1-yl acetate (1m)**



The title compound was prepared according to general procedure **A** in 46% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 6:1) to afford **1m** as a pale-yellow oil; **<sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>)** δ 7.72 (d, *J* = 8.2 Hz, 2H), 7.28 (d, *J* = 8.1 Hz, 2H), 5.56 (s, 1H), 5.54 (s, 1H), 5.30 (d, *J* = 6.9 Hz, 1H), 4.10 (d, *J* = 2.3 Hz, 2H), 3.86 (s, 2H), 2.40 (s, 3H), 2.09 (s, 3H), 2.01 (t, *J* = 2.4 Hz, 1H), 1.29–1.22 (m, 1H), 0.61–0.54 (m, 2H), 0.54–0.44 (m, 2H);

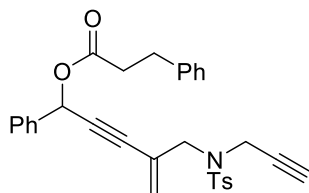
$^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  170.0, 143.6, 136.0, 129.4, 127.7, 125.1, 125.0, 86.3, 83.0, 76.3, 74.0, 67.6, 50.5, 36.0, 21.5, 21.0, 14.3, 3.5, 2.2; HRMS (ESI) calcd for  $\text{C}_{21}\text{H}_{24}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ :386.1421; found: 386.1432.

**1-cyclohexyl-4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)pent-4-en-2-yn-1-yl acetate (1n)**



The title compound was prepared according to general procedure **A** in 47% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 7:1) to afford **1n** as a pale-yellow oil;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.73 (d,  $J$  = 8.3 Hz, 2H), 7.28 (d,  $J$  = 8.0 Hz, 2H), 5.56 (s, 1H), 5.53 (d,  $J$  = 1.2 Hz, 1H), 5.29 (d,  $J$  = 6.2 Hz, 1H), 4.11 (d,  $J$  = 2.4 Hz, 2H), 3.87 (s, 2H), 2.41 (s, 3H), 2.08 (s, 3H), 1.99 (t,  $J$  = 2.4 Hz, 1H), 1.84 (d,  $J$  = 12.4 Hz, 1H), 1.78–1.73 (m, 3H), 1.71–1.63 (m, 2H), 1.28–1.06 (m, 6H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  170.0, 143.5, 136.1, 129.4, 127.7, 125.2, 124.9, 87.5, 83.5, 76.3, 73.9, 68.4, 50.6, 41.8, 36.0, 28.5, 28.0, 26.1, 25.7, 25.6, 21.5, 20.9; HRMS (ESI) calcd for  $\text{C}_{24}\text{H}_{30}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ :428.1890; found: 428.1899.

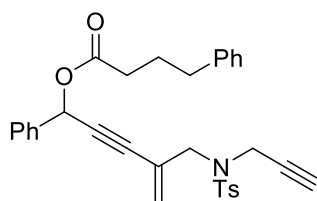
**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl 3-phenylpropanoate (1o)**



The title compound was prepared according to general procedure **A** in 44% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 20:1 to 10:1) to afford **1o** as a pale-yellow oil;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.76 (d,  $J$  = 8.2 Hz, 2H), 7.51 (d,  $J$  = 6.8 Hz, 2H), 7.44–7.35 (m, 3H), 7.30–7.25 (m, 4H), 7.24–7.16 (m, 3H), 6.59 (s, 1H), 5.65 (s, 1H), 5.62 (s, 1H), 4.13 (d,  $J$  =

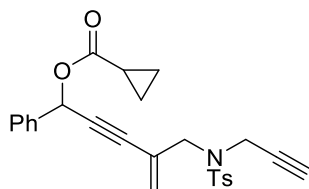
1.4 Hz, 2H), 4.01–3.90 (m, 2H), 2.99 (t,  $J = 7.7$  Hz, 2H), 2.79–2.65 (m, 2H), 2.43 (s, 3H), 2.03 (t,  $J = 2.3$  Hz, 1H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  171.6, 143.6, 140.2, 136.5, 136.0, 129.5, 128.9, 128.6, 128.4, 128.3, 127.8, 127.7, 126.2, 125.5, 125.0, 87.1, 84.8, 76.3, 74.0, 65.7, 50.5, 36.1, 35.8, 30.7, 21.5; HRMS (ESI) calcd for  $\text{C}_{31}\text{H}_{29}\text{NNaO}_4\text{S}$   $[\text{M}+\text{Na}]^+$ : 534.1710; found: 534.1717.

**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpen-4-en-2-yn-1-yl 4-phenylbutanoate (1p)**



The title compound was prepared according to general procedure **A** in 42% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 20:1 to 10:1) to afford **1p** as a pale-yellow oil;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.74 (d,  $J = 8.2$  Hz, 2H), 7.54 (d,  $J = 7.1$  Hz, 2H), 7.43–7.35 (m, 3H), 7.29–7.25 (m, 4H), 7.21–7.17 (m, 1H), 7.15 (d,  $J = 7.3$  Hz, 2H), 6.59 (s, 1H), 5.64 (s, 1H), 5.61 (d,  $J = 0.9$  Hz, 1H), 4.11 (d,  $J = 1.8$  Hz, 2H), 3.99–3.88 (m, 2H), 2.64 (t,  $J = 7.6$  Hz, 2H), 2.48–2.32 (m, 5H), 2.02–1.91 (m, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  172.2, 143.6, 141.2, 136.7, 136.0, 129.5, 129.0, 128.7, 128.5, 128.3, 127.8, 127.7, 125.9, 125.5, 125.0, 87.2, 84.8, 76.3, 74.00, 65.6, 50.5, 36.1, 34.9, 33.5, 26.4, 21.5; HRMS (ESI) calcd for  $\text{C}_{32}\text{H}_{31}\text{NNaO}_4\text{S}$   $[\text{M}+\text{Na}]^+$ : 548.1866; found: 548.1872.

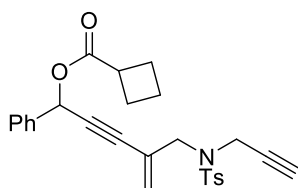
**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl cyclopropanecarboxylate (1q)**



The title compound was prepared according to general procedure **A** in 44% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 20:1 to 10:1) to afford **1q** as a pale-yellow solid, mp 58–60 °C;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.74 (d,  $J = 8.3$  Hz, 2H), 7.56–7.51 (m, 2H), 7.43–7.32 (m, 3H),

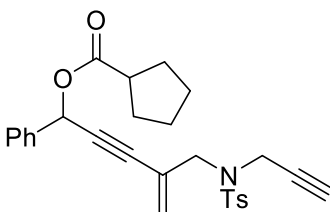
7.27 (d,  $J = 8.0$  Hz, 2H), 6.57 (s, 1H), 5.63 (s, 1H), 5.60 (d,  $J = 1.2$  Hz, 1H), 4.12 (d,  $J = 2.2$  Hz, 2H), 3.97–3.88 (m, 2H), 2.41 (s, 3H), 2.02 (t,  $J = 2.4$  Hz, 1H), 1.70–1.64 (m, 1H), 1.10–0.99 (m, 2H), 0.95–0.83 (m, 2H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  173.7, 143.6, 136.8, 136.0, 129.5, 128.9, 128.7, 127.8, 125.5, 125.1, 87.3, 84.7, 76.4, 74.0, 65.7, 50.5, 36.1, 21.52 13.0, 8.9, 8.9; HRMS (ESI) calcd for  $\text{C}_{26}\text{H}_{25}\text{NNaO}_4\text{S}$   $[\text{M}+\text{Na}]^+$ : 470.1397; found: 470.1403.

**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl cyclobutanecarboxylate (1r)**



The title compound was prepared according to general procedure **A** in 36% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 20:1 to 12:1) to afford **1r** as a pale-yellow oil;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.74 (d,  $J = 8.3$  Hz, 2H), 7.54–7.49 (m, 2H), 7.42–7.32 (m, 3H), 7.28–7.26 (m, 2H), 6.56 (s, 1H), 5.62 (s, 1H), 5.59 (d,  $J = 1.1$  Hz, 1H), 4.11 (d,  $J = 2.3$  Hz, 2H), 3.97–3.87 (m, 2H), 3.23–3.14 (m, 1H), 2.41 (s, 3H), 2.37–2.25 (m, 2H), 2.25–2.15 (m, 2H), 2.01 (t,  $J = 2.4$  Hz, 1H), 1.99–1.94 (m, 1H), 1.94–1.87 (m, 1H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  174.2, 143.6, 136.2, 136.0, 129.5, 128.9, 128.6, 127.7, 127.7, 125.5, 125.1, 87.3, 84.7, 76.3, 74.0, 65.5, 50.5, 37.9, 36.1, 25.1, 25.1, 21.5, 18.3; HRMS (ESI) calcd for  $\text{C}_{27}\text{H}_{27}\text{NNaO}_4\text{S}$   $[\text{M}+\text{Na}]^+$ : 484.1553; found: 484.1559.

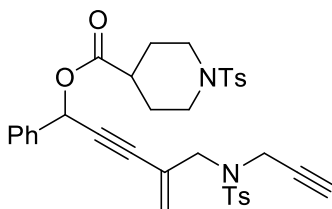
**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl cyclopentanecarboxylate (1s)**



The title compound was prepared according to general procedure **A** in 46% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum

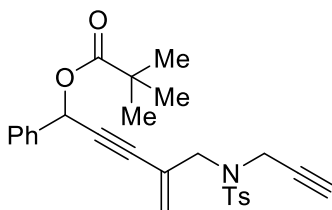
ether/EtOAc = 20:1 to 12:1) to afford **1s** as a pale-yellow oil; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.74 (d, *J* = 8.3 Hz, 2H), 7.52 (d, *J* = 7.1 Hz, 2H), 7.42–7.36 (m, 2H), 7.37–7.34 (m, 1H), 7.27 (d, *J* = 8.9 Hz, 2H), 6.56 (s, 1H), 5.62 (s, 1H), 5.59 (d, *J* = 1.0 Hz, 1H), 4.11 (d, *J* = 2.3 Hz, 2H), 3.92 (s, 2H), 2.84–2.74 (m, 1H), 2.40 (s, 3H), 2.02 (t, *J* = 2.4 Hz, 1H), 1.95–1.81 (m, 3H), 1.80–1.74 (m, 1H), 1.73–1.66 (m, 2H), 1.60–1.53 (m, 2H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 175.4, 143.6, 136.2, 136.0, 129.4, 128.8, 128.6, 127.7, 127.5, 125.4, 125.0, 87.3, 84.6, 76.3, 74.0, 65.4, 50.5, 43.6, 36.1, 29.8, 29.7, 25.7, 25.7, 21.5; HRMS (ESI) calcd for C<sub>28</sub>H<sub>29</sub>NNaO<sub>4</sub>S [M+Na]<sup>+</sup>: 498.1710; found: 498.1718.

**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl 1-tosylpiperidine-4-carboxylate (**1t**)**



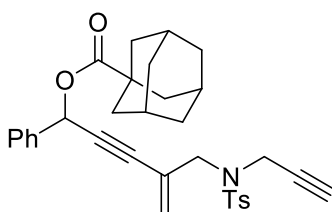
The title compound was prepared according to general procedure **A** in 41% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 20:1 to 8:1) to afford **1t** as a pale-yellow oil; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.72 (d, *J* = 8.2 Hz, 2H), 7.61 (d, *J* = 8.2 Hz, 2H), 7.49–7.45 (m, 2H), 7.39–7.33 (m, 3H), 7.32–7.25 (m, 4H), 6.51 (s, 1H), 5.59 (s, 1H), 5.57 (d, *J* = 0.7 Hz, 1H), 4.09 (d, *J* = 2.3 Hz, 2H), 3.89 (s, 2H), 3.69–3.52 (m, 2H), 2.48–2.44 (m, 2H), 2.41 (d, *J* = 5.4 Hz, 6H), 2.35–2.27 (m, 1H), 2.04–1.98 (m, 2H), 1.97–1.93 (m, 1H), 1.89–1.75 (m, 2H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 172.6, 143.7, 143.5, 136.4, 135.9, 133.1, 129.6, 129.5, 129.0, 128.7, 127.7, 127.6, 127.6, 125.7, 125.0, 86.9, 84.9, 76.1, 74.1, 66.0, 50.6, 45.3, 45.2, 39.9, 36.0, 27.2, 27.2, 21.5, 21.5; HRMS (ESI) calcd for C<sub>35</sub>H<sub>36</sub>N<sub>2</sub>NaO<sub>6</sub>S<sub>2</sub> [M+Na]<sup>+</sup>: 667.1907; found: 667.1919.

**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl pivalate (1u)**



The title compound was prepared according to general procedure **A** in 41% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 40:1 to 18:1) to afford **1u** as a pale-yellow oil;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.74 (d,  $J = 8.3$  Hz, 2H), 7.53–7.48 (m, 2H), 7.41–7.37 (m, 2H), 7.36–7.34 (m, 1H), 7.28–7.26 (m, 2H), 6.53 (s, 1H), 5.61 (s, 1H), 5.59 (d,  $J = 1.2$  Hz, 1H), 4.12 (d,  $J = 2.4$  Hz, 2H), 3.92 (s, 2H), 2.41 (s, 3H), 2.01 (t,  $J = 2.4$  Hz, 1H), 1.22 (s, 9H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  177.1, 143.6, 136.9, 136.0, 129.5, 128.7, 128.6, 127.7, 127.4, 125.3, 125.1, 87.4, 84.5, 76.3, 74.0, 65.5, 50.5, 38.7, 36.1, 26.9, 21.5; **HRMS** (ESI) calcd for  $\text{C}_{27}\text{H}_{29}\text{NNaO}_4\text{S}$   $[\text{M}+\text{Na}]^+$ : 486.1710; found: 486.1719.

**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl-adamantane-1-carboxylate (1v)**

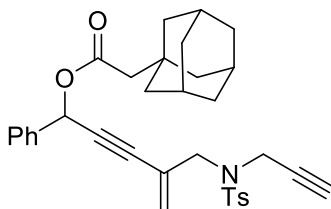


The title compound was prepared according to general procedure **A** in 44% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 20:1 to 8:1) to afford **1v** as a pale-yellow oil;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.74 (d,  $J = 8.2$  Hz, 2H), 7.50 (d,  $J = 7.3$  Hz, 2H), 7.38 (t,  $J = 7.3$  Hz, 2H), 7.36–7.32 (m, 1H), 7.27 (d,  $J = 8.6$  Hz, 2H), 6.54 (s, 1H), 5.61 (s, 1H), 5.58 (s, 1H), 4.12 (d,  $J = 2.0$  Hz, 2H), 3.92 (s, 2H), 2.40 (s, 3H), 2.01 (d,  $J = 2.3$  Hz, 4H), 1.91 (s, 6H), 1.74–1.65 (m, 6H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  176.2, 143.6, 137.0, 136.0, 129.4, 128.6, 128.5, 127.7, 127.3, 125.3, 125.1, 87.5, 84.5, 76.3, 74.0, 65.1, 50.5, 40.7,



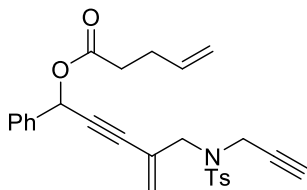
38.5, 36.4, 36.1, 27.8, 21.5; **HRMS (ESI)** calcd for C<sub>33</sub>H<sub>35</sub>NNaO<sub>4</sub>S [M+Na]<sup>+</sup>: 564.2179; found: 564.2187.

**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl 2-(adamantan-1-yl)acetate (1w)**



The title compound was prepared according to general procedure **A** in 43% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 20:1 to 8:1) to afford **1w** as a pale-yellow oil; **<sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>)** δ 7.73 (d, *J* = 8.2 Hz, 2H), 7.54 (d, *J* = 7.2 Hz, 2H), 7.39 (t, *J* = 7.3 Hz, 2H), 7.37–7.33 (m, 1H), 7.27 (d, *J* = 7.9 Hz, 2H), 6.55 (s, 1H), 5.61 (s, 1H), 5.60 (d, *J* = 0.9 Hz, 1H), 4.11 (d, *J* = 2.3 Hz, 2H), 3.95–3.88 (m, 2H), 2.41 (s, 3H), 2.10–2.12 (m, 2H), 2.02 (t, *J* = 2.4 Hz, 1H), 1.93 (s, 3H), 1.69–1.64 (m, 4H), 1.59 (s, 8H); **<sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>)** δ 170.5, 143.6, 136.7, 136.0, 129.4, 128.8, 128.6, 127.8, 127.7, 125.2, 125.0, 87.4, 84.6, 76.3, 74.0, 65.2, 50.4, 48.6, 42.3, 36.6, 36.1, 33.2, 28.5, 21.5; **HRMS (ESI)** calcd for C<sub>34</sub>H<sub>37</sub>NNaO<sub>4</sub>S [M+Na]<sup>+</sup>: 578.2336; found: 578.2348.

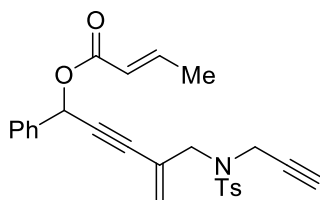
**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl pent-4-enoate (1x)**



The title compound was prepared according to general procedure **A** in 48% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 20:1 to 8:1) to afford **1x** as a pale-yellow oil; **<sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>)** δ 7.74 (d, *J* = 8.1 Hz, 2H), 7.53 (d, *J* = 7.4 Hz, 2H), 7.41–7.33 (m, 3H), 7.27 (d, *J* = 8.0 Hz, 2H), 6.57 (s, 1H), 5.85–5.76 (m, 1H), 5.63 (s, 1H), 5.60 (s, 1H), 5.03 (d, *J* = 17.1 Hz, 1H), 4.98 (d, *J* = 10.2 Hz, 1H), 4.12 (d, *J* = 1.6 Hz, 2H), 3.97–3.87 (m,

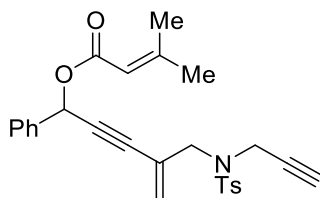
2H), 2.53–2.44 (m, 2H), 2.43–2.37 (m, 5H), 2.01 (s, 1H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  171.8, 143.6, 136.6, 136.3, 136.0, 129.5, 128.9, 128.6, 127.8, 127.7, 125.5, 125.0, 115.6, 87.2, 84.8, 76.3, 74.0, 65.7, 50.5, 36.1, 33.4, 28.7, 21.5; HRMS (ESI) calcd for  $\text{C}_{27}\text{H}_{27}\text{NNaO}_4\text{S}$   $[\text{M}+\text{Na}]^+$ : 484.1553; found: 484.1564.

**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl (E)-but-2-enoate (1y)**



The title compound was prepared according to general procedure **A** in 18% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 20:1 to 8:1) to afford **1y** as a yellow oil;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.73 (d,  $J = 8.2$  Hz, 2H), 7.54 (d,  $J = 7.2$  Hz, 2H), 7.39 (t,  $J = 7.3$  Hz, 2H), 7.37–7.33 (m, 1H), 7.27 (d,  $J = 8.6$  Hz, 2H), 7.11–7.00 (m, 1H), 6.62 (s, 1H), 5.88 (dd,  $J = 15.5$ , 1.7 Hz, 1H), 5.63 (s, 1H), 5.60 (d,  $J = 0.7$  Hz, 1H), 4.11 (d,  $J = 1.8$  Hz, 2H), 3.97–3.87 (m, 2H), 2.40 (s, 3H), 2.02 (t,  $J = 2.4$  Hz, 1H), 1.88 (dd,  $J = 6.9$ , 1.6 Hz, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  165.1, 146.1, 143.6, 136.7, 135.9, 129.4, 128.8, 128.6, 127.7, 127.7, 125.5, 125.0, 122.0, 87.2, 84.7, 76.3, 74.0, 65.4, 50.5, 36.1, 21.5, 18.0; HRMS (ESI) calcd for  $\text{C}_{26}\text{H}_{25}\text{NNaO}_4\text{S}$   $[\text{M}+\text{Na}]^+$ : 470.1397; found: 470.1405.

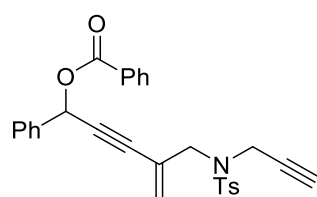
**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl 3-methylbut-2-enoate (1z)**



The title compound was prepared according to general procedure **A** in 46% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 20:1 to 10:1) to afford **1z** as a pale-yellow oil;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.74 (d,  $J = 8.2$  Hz, 2H), 7.54 (d,  $J = 7.4$  Hz, 2H), 7.38 (t,  $J = 7.3$  Hz, 2H), 7.34 (t,  $J = 7.2$  Hz, 1H), 7.27 (d,  $J = 8.1$  Hz, 2H), 6.60 (s, 1H), 5.73 (s, 1H), 5.62 (s,

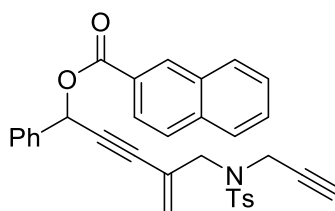
1H), 5.59 (s, 1H), 4.12 (d,  $J = 2.1$  Hz, 2H), 3.99–3.86 (m, 2H), 2.40 (s, 3H), 2.19 (s, 3H), 2.02 (t,  $J = 2.0$  Hz, 1H), 1.90 (s, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  165.0, 158.4, 143.6, 137.1, 136.1, 129.4, 128.7, 128.6, 127.7, 127.6, 125.3, 125.1, 115.4, 87.7, 84.5, 76.4, 73.2, 64.7, 50.5, 36.1, 27.4, 21.5, 20.4; HRMS (ESI) calcd for  $\text{C}_{27}\text{H}_{27}\text{NNaO}_4\text{S}$   $[\text{M}+\text{Na}]^+$ : 484.1553; found: 484.1559.

**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl benzoate (1aa)**



The title compound was prepared according to general procedure **A** in 45% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 20:1 to 10:1) to afford **1aa** as a yellow oil;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  8.09 (dd,  $J = 8.3, 1.2$  Hz, 2H), 7.74 (d,  $J = 8.3$  Hz, 2H), 7.63 (d,  $J = 7.3$  Hz, 2H), 7.60–7.54 (m, 1H), 7.46–7.40 (m, 4H), 7.40–7.36 (m, 1H), 7.28–7.23 (m, 2H), 6.81 (s, 1H), 5.65 (s, 1H), 5.62 (d,  $J = 1.1$  Hz, 1H), 4.13 (d,  $J = 1.7$  Hz, 2H), 4.00–3.90 (m, 2H), 2.40 (s, 3H), 2.01 (t,  $J = 2.4$  Hz, 1H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  165.4, 143.6, 136.7, 136.0, 133.3, 129.9, 129.7, 129.5, 129.0, 128.7, 128.4, 127.8, 127.7, 125.6, 125.0, 87.2, 85.0, 76.4, 74.0, 66.3, 50.5, 36.2, 21.5; HRMS (ESI) calcd for  $\text{C}_{29}\text{H}_{25}\text{NNaO}_4\text{S}$   $[\text{M}+\text{Na}]^+$ : 506.1397; found: 506.1404.

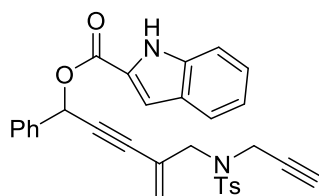
**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl 2-naphthoate (1ab)**



The title compound was prepared according to general procedure **A** in 36% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 20:1 to 12:1) to afford **1ab** as a yellow oil;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )

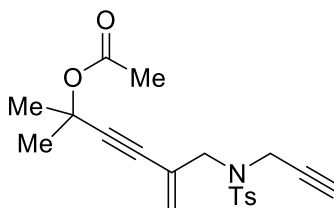
$\delta$  8.67 (s, 1H), 8.10 (dd,  $J = 8.6, 1.6$  Hz, 1H), 7.96 (d,  $J = 8.1$  Hz, 1H), 7.90–7.84 (m, 2H), 7.75 (d,  $J = 8.2$  Hz, 2H), 7.70 (d,  $J = 7.4$  Hz, 2H), 7.62–7.57 (m, 1H), 7.54 (t,  $J = 7.5$  Hz, 1H), 7.45 (t,  $J = 7.5$  Hz, 2H), 7.40 (t,  $J = 7.4$  Hz, 1H), 7.29–7.22 (m, 2H), 6.90 (s, 1H), 5.68 (s, 1H), 5.63 (d,  $J = 0.8$  Hz, 1H), 4.15 (s, 2H), 4.03–3.89 (m, 2H), 2.39 (s, 3H), 2.02 (t,  $J = 2.4$  Hz, 1H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  165.5, 143.6, 136.7, 136.0, 135.6, 132.4, 131.5, 129.5, 129.4, 129.0, 128.7, 128.4, 128.1, 127.9, 127.7, 126.8, 126.6, 125.7, 125.3, 125.0, 87.2, 85.1, 76.3, 74.0, 66.4, 50.6, 36.1, 21.5; HRMS (ESI) calcd for  $\text{C}_{33}\text{H}_{27}\text{NNaO}_4\text{S}$   $[\text{M}+\text{Na}]^+$ : 556.1553; found: 556.1566.

**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl 1H-indole-2-carboxylate (1ac)**



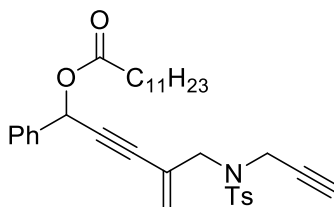
The title compound was prepared according to general procedure **A** in 36% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 6:1) to afford **1ac** as a pale-yellow oil;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  9.31–9.26 (m, 1H), 7.77 (d,  $J = 8.2$  Hz, 2H), 7.68 (d,  $J = 7.7$  Hz, 3H), 7.48–7.41 (m, 3H), 7.39 (t,  $J = 7.2$  Hz, 1H), 7.34–7.30 (m, 2H), 7.30–7.26 (m, 2H), 7.14 (t,  $J = 7.5$  Hz, 1H), 6.86–6.84 (m, 1H), 5.65 (s, 1H), 5.61 (s, 1H), 4.15 (d,  $J = 2.1$  Hz, 2H), 4.14–3.93 (m, 2H), 2.41 (s, 3H), 2.01 (t,  $J = 2.3$  Hz, 1H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  160.5, 143.7, 137.1, 136.5, 136.1, 129.5, 129.1, 128.7, 127.9, 127.6, 127.3, 126.5, 125.6, 125.6, 125.1, 122.5, 120.8, 112.0, 109.9, 87.2, 85.3, 76.2, 74.0, 66.4, 50.7, 36.0, 21.5; HRMS (ESI) calcd for  $\text{C}_{31}\text{H}_{26}\text{NNaO}_4\text{S}$   $[\text{M}+\text{Na}]^+$ : 545.1505; found: 545.1513.

**2-methyl-5-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)hex-5-en-3-yn-2-yl acetate (1ad)**



The title compound was prepared according to general procedure **A** in 32% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 8:1 to 4:1) to afford **1ad** as a pale-yellow oil;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.72 (d,  $J = 8.1$  Hz, 2H), 7.27 (d,  $J = 8.2$  Hz, 2H), 5.51 (s, 1H), 5.48 (s, 1H), 4.12 (d,  $J = 2.1$  Hz, 2H), 3.86 (s, 2H), 2.40 (s, 3H), 2.00 (s, 4H), 1.65 (s, 6H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  169.2, 143.5, 136.2, 129.4, 127.6, 125.3, 124.2, 92.0, 81.8, 76.5, 73.8, 72.0, 50.6, 36.0, 28.8, 21.8, 21.5; **HRMS (ESI)** calcd for  $\text{C}_{20}\text{H}_{23}\text{NNaO}_4\text{S}$   $[\text{M}+\text{Na}]^+$ : 396.1240; found: 396.1254.

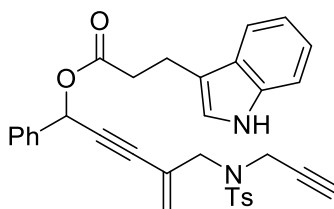
**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl dodecanoate (1ae)**



The title compound was prepared according to general procedure **A** in 46% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 20:1 to 12:1) to afford **1ae** as a pale-yellow oil;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.74 (d,  $J = 8.2$  Hz, 2H), 7.52 (d,  $J = 7.2$  Hz, 2H), 7.38 (t,  $J = 7.2$  Hz, 2H), 7.37–7.33 (m, 1H), 7.27 (d,  $J = 8.2$  Hz, 2H), 6.57 (s, 1H), 5.62 (s, 1H), 5.59 (s, 1H), 4.11 (d,  $J = 1.9$  Hz, 2H), 3.99–3.84 (m, 2H), 2.41 (s, 3H), 2.38–2.32 (m, 2H), 2.01 (t,  $J = 2.3$  Hz, 1H), 1.67–1.60 (m, 2H), 1.28–1.23 (m, 16H), 0.88 (t,  $J = 7.0$  Hz, 3H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  172.5, 143.6, 136.8, 136.1, 129.5, 128.9, 128.6, 127.7, 125.4, 125.1, 87.4, 84.7, 76.4, 73.9, 65.5, 50.5, 36.1, 34.2, 31.9, 29.6, 29.5, 29.4, 29.3,

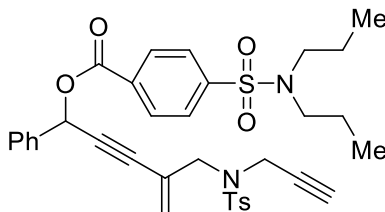
29.2, 29.0, 24.8, 22.6, 21.5, 14.1; **HRMS (ESI)** calcd for  $C_{34}H_{43}NNaO_4S$   $[M+Na]^+$ : 584.2805; found: 584.2811.

**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl 3-(1H-indol-3-yl)propanoate (1af)**



The title compound was prepared according to general procedure **A** in 41% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 20:1 to 10:1) to afford **1af** as a yellow oil;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  8.14 (s, 1H), 7.75 (d,  $J = 7.9$  Hz, 2H), 7.59 (d,  $J = 7.9$  Hz, 1H), 7.55–7.47 (m, 2H), 7.40–7.33 (m, 4H), 7.28 (d,  $J = 8.1$  Hz, 2H), 7.19 (t,  $J = 7.5$  Hz, 1H), 7.13–7.09 (m, 1H), 6.98 (s, 1H), 6.61–6.56 (m, 1H), 5.63 (s, 1H), 5.61 (d,  $J = 0.9$  Hz, 1H), 4.12 (s, 2H), 3.93 (s, 2H), 3.18–3.09 (m, 2H), 2.88–2.70 (m, 2H), 2.42 (s, 3H), 2.03–1.98 (m, 1H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  172.1, 143.7, 136.6, 136.2, 135.9, 129.5, 128.9, 128.6, 127.8, 127.7, 127.1, 125.6, 125.0, 121.9, 121.7, 119.2, 118.6, 114.4, 111.1, 87.3, 84.7, 76.3, 74.1, 65.7, 50.6, 36.2, 34.9, 21.5, 20.5; **HRMS (ESI)** calcd for  $C_{33}H_{30}N_2NaO_4S$   $[M+Na]^+$ : 573.1818; found: 573.1825.

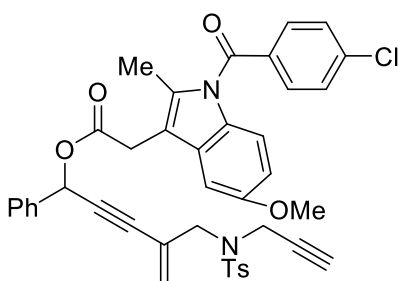
**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl 4-(*N,N*-dipropylsulfamoyl)benzoate (1ag)**



The title compound was prepared according to general procedure **A** in 45% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 14:1 to 8:1) to afford **1ag** as a colorless oil;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  8.19 (d,  $J = 8.5$  Hz, 2H), 7.86 (d,  $J = 8.5$  Hz, 2H), 7.73 (d,  $J = 8.2$  Hz, 2H), 7.64 (d,  $J$

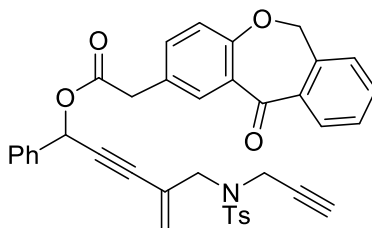
= 7.1 Hz, 2H), 7.43 (t,  $J = 7.2$  Hz, 2H), 7.41–7.37 (m, 1H), 7.27 (d,  $J = 8.2$  Hz, 2H), 6.80 (s, 1H), 5.65 (s, 1H), 5.61 (s, 1H), 4.17–4.06 (m, 2H), 3.99–3.89 (m, 2H), 3.11–3.04 (m, 4H), 2.40 (s, 3H), 1.99 (t,  $J = 2.1$  Hz, 1H), 1.59–1.47 (m, 4H), 0.85 (t,  $J = 7.4$  Hz, 6H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  164.1, 144.4, 143.7, 136.3, 136.0, 133.0, 130.5, 129.5, 129.2, 128.8, 128.0, 127.7, 127.0, 125.9, 125.0, 86.7, 85.4, 76.2, 74.0, 67.1, 50.6, 49.9, 36.1, 21.889 21.5, 11.1; HRMS (ESI) calcd for  $\text{C}_{35}\text{H}_{38}\text{N}_2\text{NaO}_6\text{S}_2$   $[\text{M}+\text{Na}]^+$ : 669.2063; found: 669.2069.

**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl 2-(1-(4-chlorobenzoyl)-5-methoxy-2-methyl-1*H*-indol-3-yl)acetate (1ah)**



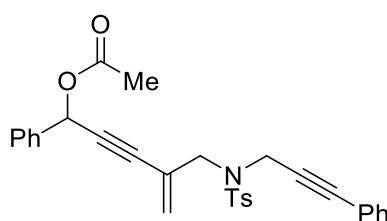
The title compound was prepared according to general procedure **A** in 38% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 6:1) to afford **1ah** as a yellow solid, mp 70–72 °C;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.72 (d,  $J = 8.3$  Hz, 2H), 7.64–7.61 (m, 2H), 7.51–7.47 (m, 2H), 7.45–7.43 (m, 2H), 7.37–7.34 (m, 2H), 7.27–7.25 (m, 2H), 6.92 (d,  $J = 2.4$  Hz, 1H), 6.90 (d,  $J = 9.0$  Hz, 1H), 6.66 (dd,  $J = 9.0, 2.5$  Hz, 1H), 6.56 (s, 1H), 5.58 (s, 2H), 4.08 (t,  $J = 1.8$  Hz, 2H), 3.95–3.87 (m, 2H), 3.77–3.70 (m, 5H), 2.40 (s, 3H), 2.34 (s, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  169.6, 168.2, 156.0, 143.6, 139.2, 136.4, 136.0, 136.0, 133.9, 131.1, 130.7, 130.5, 129.5, 129.1, 129.0, 128.6, 127.8, 127.7, 125.7, 125.0, 114.9, 112.2, 111.9, 101.1, 86.9, 85.1, 76.3, 74.0, 66.4, 55.6, 50.6, 36.0, 30.4, 21.5, 13.4; HRMS (ESI) calcd for  $\text{C}_{41}\text{H}_{35}\text{ClN}_2\text{NaO}_6\text{S}$   $[\text{M}+\text{Na}]^+$ : 741.1797; found: 741.1804.

**4-(((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl 2-(11-oxo-6,11-dihydrodibenzo[*b,e*]oxepin-2-yl)acetate (1ai)**



The title compound was prepared according to general procedure **A** in 43% yield over 3 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 14:1 to 8:1) to afford **1ai** as a colorless oil;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  8.11 (d,  $J = 2.3$  Hz, 1H), 7.88 (dd,  $J = 7.7, 0.9$  Hz, 1H), 7.73 (d,  $J = 8.3$  Hz, 2H), 7.57–7.55 (m, 1H), 7.53–7.50 (m, 2H), 7.47 (t,  $J = 7.6, 1.0$  Hz, 1H), 7.42 (dd,  $J = 8.4, 2.4$  Hz, 1H), 7.40–7.34 (m, 4H), 7.27 (d,  $J = 6.6$  Hz, 3H), 7.02 (d,  $J = 8.4$  Hz, 1H), 6.57 (s, 1H), 5.63 (s, 1H), 5.60 (d,  $J = 1.0$  Hz, 1H), 5.18 (s, 2H), 4.11 (d,  $J = 2.3$  Hz, 2H), 3.98–3.88 (m, 2H), 3.76 – 3.64 (m, 2H), 2.40 (s, 3H), 2.01 (t,  $J = 2.4$  Hz, 1H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  190.7, 170.2, 160.5, 143.6, 140.4, 136.4, 136.0, 135.5, 132.7, 132.5, 129.5, 129.4, 129.2, 129.0, 128.7, 127.80, 127.76, 127.7, 127.3, 125.6, 125.1, 125.0, 121.0, 86.9, 85.1, 76.3, 74.0, 73.6, 66.3, 50.5, 40.0, 36.1, 21.5; HRMS (ESI) calcd for  $\text{C}_{38}\text{H}_{31}\text{NNaO}_6\text{S}$   $[\text{M}+\text{Na}]^+$ : 652.1764; found: 652.1776.

**4-(((4-methyl-*N*-(3-phenylprop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl acetate (4a)**

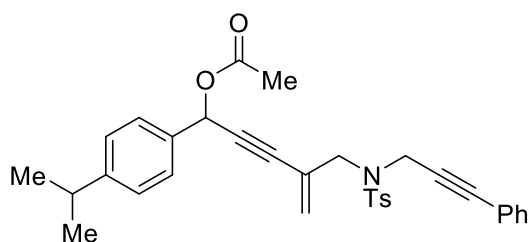


The title compound was prepared according to general procedure **B** in 59% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 7:1) to afford **4a** as a pale-yellow solid, mp 76–78 °C;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.79 (d,  $J = 8.1$  Hz, 2H), 7.57 (d,  $J = 7.2$  Hz, 2H), 7.42–7.35 (m, 3H), 7.30 – 7.27 (m, 1H), 7.26–7.22 (m, 4H), 7.06 (d,  $J = 7.4$  Hz, 2H), 6.59 (s, 1H),



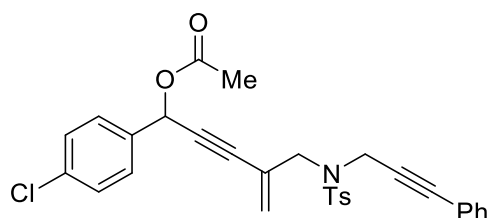
5.68 (s, 1H), 5.66 (s, 1H), 4.34 (s, 2H), 4.05–3.93 (m, 2H), 2.34 (s, 3H), 2.11 (s, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  169.7, 143.5, 136.6, 136.0, 131.4, 129.5, 128.9, 128.6, 128.4, 128.1, 127.8, 127.7, 125.4, 125.1, 122.0, 87.18, 85.8, 84.9, 81.4, 65.7, 50.8, 37.0, 21.3, 21.0; HRMS (ESI) calcd for  $\text{C}_{30}\text{H}_{27}\text{NNaO}_4\text{S}$   $[\text{M}+\text{Na}]^+$ : 520.1553; found: 520.1559.

**1-(4-isopropylphenyl)-4-(((4-methyl-*N*-(3-phenylprop-2-yn-1-yl)phenyl)sulfonamido)methyl)pent-4-en-2-yn-1-yl acetate (4b)**



The title compound was prepared according to general procedure **B** in 48% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 12:1 to 7:1) to afford **4b** as a pale-yellow oil;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.80 (d,  $J = 8.1$  Hz, 2H), 7.49 (d,  $J = 8.1$  Hz, 2H), 7.29 (t,  $J = 7.4$  Hz, 1H), 7.27–7.22 (m, 6H), 7.07 (d,  $J = 7.3$  Hz, 2H), 6.57 (s, 1H), 5.67 (s, 1H), 5.66 (s, 1H), 4.35 (s, 2H), 4.05–3.93 (m, 2H), 2.92 (dt,  $J = 13.8, 6.9$  Hz, 1H), 2.34 (s, 3H), 2.10 (s, 3H), 1.26 (d,  $J = 6.9$  Hz, 6H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  169.8, 149.8, 143.5, 136.0, 134.0, 131.5, 129.5, 128.4, 128.1, 127.9, 127.7, 126.7, 125.3, 125.2, 122.0, 87.4, 85.8, 84.7, 81.5, 65.7, 50.8, 37.0, 33.8, 23.9, 23.8, 21.4, 21.1; HRMS (ESI) calcd for  $\text{C}_{33}\text{H}_{34}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 540.2203; found: 540.2217.

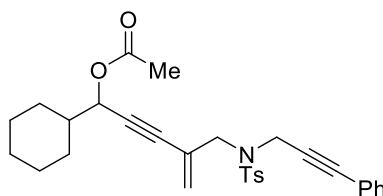
**1-(4-chlorophenyl)-4-(((4-methyl-*N*-(3-phenylprop-2-yn-1-yl)phenyl)sulfonamido)methyl)pent-4-en-2-yn-1-yl acetate (4c)**



The title compound was prepared according to general procedure **B** in 60% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum

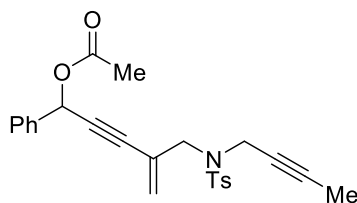
ether/EtOAc = 12:1 to 7:1) to afford **4c** as a yellow oil; **<sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>)** δ 7.78 (d, *J* = 8.3 Hz, 2H), 7.53–7.47 (m, 2H), 7.37–7.32 (m, 2H), 7.31–7.27 (m, 1H), 7.27–7.21 (m, 4H), 7.07–7.02 (m, 2H), 6.54 (s, 1H), 5.67 (s, 1H), 5.65 (d, *J* = 1.1 Hz, 1H), 4.32 (s, 2H), 4.03–3.93 (m, 2H), 2.34 (s, 3H), 2.11 (s, 3H); **<sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>)** δ 169.7, 143.6, 136.0, 135.2, 135.0, 131.5, 129.6, 129.3, 128.9, 128.5, 128.1, 127.7, 125.9, 125.1, 122.0, 86.8, 85.9, 85.2, 81.3, 65.1, 50.9, 37.0, 21.4, 21.0; **HRMS (ESI)** calcd for C<sub>30</sub>H<sub>26</sub>ClNNaO<sub>4</sub>S [M+Na]<sup>+</sup>: 554.1163; found: 554.1173.

**1-cyclohexyl-4-(((4-methyl-N-(3-phenylprop-2-yn-1-yl)phenyl)sulfonamido)methyl)pent-4-en-2-yn-1-yl acetate (4d)**



The title compound was prepared according to general procedure **B** in 49% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 14:1 to 7:1) to afford **4d** as a pale-yellow solid, mp 67–69 °C; **<sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>)** δ 7.77 (d, *J* = 8.2 Hz, 2H), 7.31–7.20 (m, 5H), 7.08–7.02 (m, 2H), 5.60 (d, *J* = 6.6 Hz, 2H), 5.33 (d, *J* = 6.1 Hz, 1H), 4.33 (s, 2H), 3.94 (s, 2H), 2.33 (s, 3H), 2.09 (s, 3H), 1.79–1.76 (m, 1H), 1.77 (d, *J* = 9.0 Hz, 3H), 1.73–1.63 (m, 2H), 1.30–1.08 (m, 5H); **<sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>)** δ 170.1, 143.5, 136.1, 131.4, 129.5, 128.4, 128.1, 127.7, 125.3, 124.8, 122.1, 87.5, 85.8, 83.6, 81.4, 68.5, 51.0, 41.8, 36.9, 28.5, 28.0, 26.1, 25.7, 25.7, 21.4, 21.0; **HRMS (ESI)** calcd for C<sub>30</sub>H<sub>34</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 504.2203; found: 504.2208.

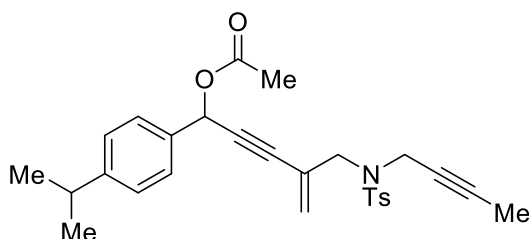
**4-(((N-(but-2-yn-1-yl)-4-methylphenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl acetate (4e)**



The title compound was prepared according to general procedure **A** in 54% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum

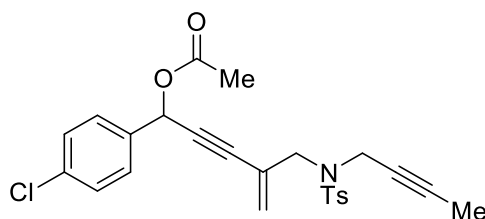
ether/EtOAc = 10:1 to 6:1) to afford **4e** as a pale-yellow oil;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.74 (d,  $J = 8.2$  Hz, 1H), 7.56–7.52 (m, 2H), 7.42–7.34 (m, 3H), 7.28 (d,  $J = 8.3$  Hz, 2H), 6.56 (s, 1H), 5.62 (s, 1H), 5.60 (d,  $J = 1.0$  Hz, 1H), 4.04 (d,  $J = 2.2$  Hz, 2H), 3.92–3.85 (m, 2H), 2.41 (s, 3H), 2.11 (s, 3H), 1.53 (t,  $J = 2.3$  Hz, 3H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  169.8, 143.3, 136.7, 136.3, 129.2, 129.0, 128.7, 127.8, 125.3, 125.1, 87.0, 85.0, 81.8, 71.5, 65.8, 50.5, 36.7, 21.5, 21.1, 3.2; **HRMS (ESI)** calcd for  $\text{C}_{25}\text{H}_{26}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 436.1577; found: 436.1586.

**4-(((N-(but-2-yn-1-yl)-4-methylphenyl)sulfonamido)methyl)-1-(4-isopropylphenyl)pent-4-en-2-yn-1-yl acetate (4f)**



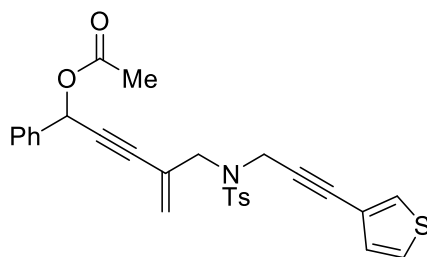
The title compound was prepared according to general procedure **A** in 58% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 16:1 to 8:1) to afford **4f** as a yellow oil;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.75 (d,  $J = 8.2$  Hz, 2H), 7.47 (d,  $J = 8.1$  Hz, 2H), 7.28 (d,  $J = 8.1$  Hz, 2H), 7.25 (d,  $J = 8.2$  Hz, 2H), 6.54 (s, 1H), 5.61 (s, 1H), 5.59 (s, 1H), 4.05 (d,  $J = 2.1$  Hz, 2H), 3.96–3.84 (m, 2H), 2.94–2.89 (m, 1H), 2.41 (s, 3H), 2.10 (s, 3H), 1.53 (t,  $J = 2.3$  Hz, 3H), 1.25 (d,  $J = 7.0$  Hz, 6H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  169.7, 149.7, 143.2, 136.2, 134.0, 129.2, 127.9, 127.8, 126.7, 125.3, 124.9, 87.1, 84.7, 81.8, 71.5, 65.6, 50.4, 36.7, 33.8, 23.8, 23.8, 21.4, 21.0, 3.1; **HRMS (ESI)** calcd for  $\text{C}_{28}\text{H}_{32}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 478.2047; found: 478.2055.

**4-(((*N*-(but-2-yn-1-yl)-4-methylphenyl)sulfonamido)methyl)-1-(4-chlorophenyl)pent-4-en-2-yn-1-yl acetate (4g)**



The title compound was prepared according to general procedure **A** in 62% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 6:1) to afford **4g** as a yellow solid, mp 92–94 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.73 (d, *J* = 8.3 Hz, 2H), 7.49 (d, *J* = 8.5 Hz, 2H), 7.37–7.34 (m, 1H), 7.28 (d, *J* = 8.1 Hz, 2H), 6.52 (s, 1H), 5.62 (s, 1H), 5.59 (d, *J* = 0.9 Hz, 1H), 4.03 (s, 2H), 3.92–3.83 (m, 2H), 2.41 (s, 3H), 2.10 (s, 3H), 1.51 (t, *J* = 2.3 Hz, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 169.6, 143.3, 136.2, 135.2, 134.9, 129.3, 129.2, 128.8, 127.8, 125.5, 125.2, 86.5, 85.2, 81.9, 71.3, 65.0, 50.6, 36.6, 21.4, 21.0, 3.2; HRMS (ESI) calcd for C<sub>25</sub>H<sub>24</sub>ClNNaO<sub>4</sub>S [M+Na]<sup>+</sup>: 492.1007; found: 492.1014.

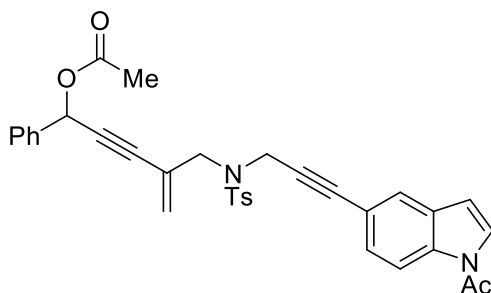
**4-(((4-methyl-*N*-(3-(thiophen-3-yl)prop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl acetate (4h)**



The title compound was prepared according to general procedure **B** in 60% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 12:1 to 7:1) to afford **4h** as a yellow solid, mp 95–97 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.78 (d, *J* = 8.2 Hz, 2H), 7.55 (d, *J* = 7.4 Hz, 2H), 7.41–7.34 (m, 3H), 7.27–7.24 (m, 2H), 7.21–7.18 (m, 1H), 7.13 (d, *J* = 2.3 Hz, 1H), 6.78 (dd, *J* = 5.0, 0.8 Hz, 1H), 6.58 (s, 1H), 5.66 (s, 1H), 5.64 (s, 1H), 4.31 (s, 2H), 4.03–3.92 (m, 2H), 2.36 (s, 3H), 2.11 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 169.7, 143.5, 136.6, 136.2, 129.5, 129.5, 128.9, 128.9, 128.6, 127.8, 127.7, 125.3, 125.2, 125.1, 121.1, 87.2, 84.9, 81.2,

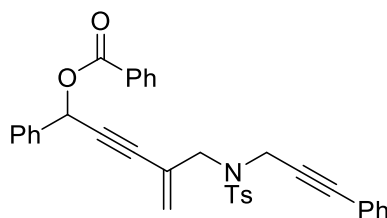
81.0, 65.8, 50.8, 37.1, 21.4, 21.0; **HRMS (ESI)** calcd for  $C_{28}H_{25}NNaO_4S_2$   $[M+Na]^+$ : 526.1117; found: 526.1124.

**4-(((N-(3-(1-acetyl-1H-indol-5-yl)prop-2-yn-1-yl)-4-methylphenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl acetate (4i)**



The title compound was prepared according to general procedure **B** in 58% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 6:1 to 3:1) to afford **4i** as a yellow oil;  **$^1H$  NMR (600 MHz,  $CDCl_3$ )**  $\delta$  8.31 (d,  $J = 8.5$  Hz, 1H), 7.79 (d,  $J = 8.2$  Hz, 2H), 7.58–7.54 (m, 2H), 7.43 (d,  $J = 3.7$  Hz, 1H), 7.41–7.33 (m, 3H), 7.28 (d,  $J = 0.6$  Hz, 1H), 7.27–7.23 (m, 2H), 7.01 (dd,  $J = 8.6, 1.3$  Hz, 1H), 6.59 (s, 1H), 6.55 (d,  $J = 3.7$  Hz, 1H), 5.67 (d,  $J = 3.8$  Hz, 2H), 4.35 (s, 2H), 4.05–3.96 (m, 2H), 2.61 (s, 3H), 2.32 (s, 3H), 2.10 (s, 3H);  **$^{13}C$  NMR (150 MHz,  $CDCl_3$ )**  $\delta$  169.7, 168.5, 143.5, 136.5, 136.0, 135.0, 130.0, 129.5, 128.9, 128.6, 128.3, 127.8, 127.7, 126.2, 125.4, 125.1, 124.1, 117.1, 116.2, 108.5, 87.1, 86.2, 84.9, 80.3, 65.7, 50.8, 37.1, 23.8, 21.4, 21.0; **HRMS (ESI)** calcd for  $C_{34}H_{30}N_2NaO_5S$   $[M+Na]^+$ : 601.1768; found: 601.1774.

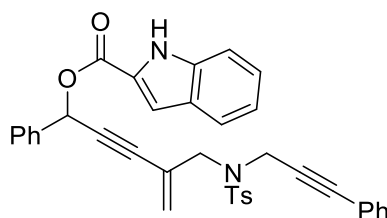
**4-(((4-methyl-N-(3-phenylprop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl benzoate (4j)**



The title compound was prepared according to general procedure **B** in 57% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 14:1 to 10:1) to afford **4j** as a pale-yellow oil;  **$^1H$  NMR (600 MHz,**

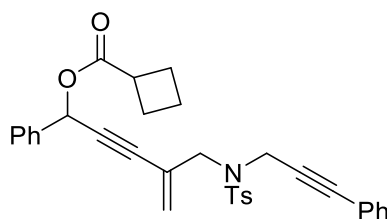
**CDCl<sub>3</sub>**)  $\delta$  8.10 (d,  $J = 7.4$  Hz, 2H), 7.79 (d,  $J = 8.2$  Hz, 2H), 7.66 (d,  $J = 7.4$  Hz, 2H), 7.56 (t,  $J = 7.4$  Hz, 1H), 7.46–7.40 (m, 4H), 7.38 (t,  $J = 7.3$  Hz, 1H), 7.28 (t,  $J = 7.4$  Hz, 1H), 7.26–7.21 (m, 4H), 7.06 (d,  $J = 7.3$  Hz, 2H), 6.85 (s, 1H), 5.69 (s, 1H), 5.68 (s, 1H), 4.35 (s, 2H), 4.07–3.96 (m, 2H), 2.33 (s, 3H); **<sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>)**  $\delta$  165.4, 143.5, 136.7, 136.0, 133.2, 131.5, 129.9, 129.7, 129.5, 129.0, 128.7, 128.4, 128.3, 128.2, 127.8, 127.7, 125.5, 125.2, 122.0, 87.2, 85.9, 85.2, 81.5, 66.3, 50.8, 37.1, 21.4; **HRMS (ESI)** calcd for C<sub>35</sub>H<sub>29</sub>NNaO<sub>4</sub>S [M+Na]<sup>+</sup>: 582.1710; found: 582.1716.

**4-(((4-methyl-*N*-(3-phenylprop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl 1H-indole-2-carboxylate (4k)**



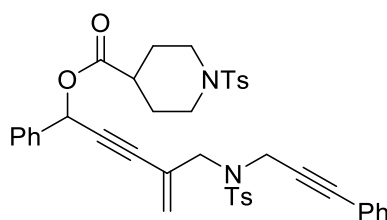
The title compound was prepared according to general procedure **B** in 60% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 6:1) to afford **4k** as a pale-yellow solid, mp 60–62 °C; **<sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>)**  $\delta$  9.24 (s, 1H), 7.81 (d,  $J = 8.2$  Hz, 2H), 7.70 (d,  $J = 7.3$  Hz, 2H), 7.68 (d,  $J = 8.1$  Hz, 1H), 7.45–7.41 (m, 3H), 7.41–7.38 (m, 1H), 7.33–7.29 (m, 2H), 7.29–7.25 (m, 3H), 7.22 (t,  $J = 7.5$  Hz, 2H), 7.14 (t,  $J = 7.5$  Hz, 1H), 7.08–7.04 (m, 2H), 6.87 (s, 1H), 5.68 (s, 1H), 5.66 (s, 1H), 4.37 (s, 2H), 4.09–4.02 (m, 2H), 2.34 (s, 3H); **<sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>)**  $\delta$  160.5, 143.6, 137.1, 136.5, 136.1, 131.5, 129.6, 129.1, 128.7, 128.4, 128.1, 128.0, 127.7, 127.3, 126.6, 125.6, 125.5, 125.3, 122.5, 122.0, 120.8, 112.0, 109.9, 87.3, 85.9, 85.5, 81.4, 66.4, 51.1, 37.0, 21.4; **HRMS (ESI)** calcd for C<sub>37</sub>H<sub>31</sub>N<sub>2</sub>O<sub>4</sub>S [M+H]<sup>+</sup>: 599.1999; found: 599.2006.

**4-(((4-methyl-*N*-(3-phenylprop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl cyclobutanecarboxylate (4l)**



The title compound was prepared according to general procedure **B** in 59% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 15:1 to 10:1) to afford **4l** as a yellow oil;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.79 (d,  $J = 8.2$  Hz, 2H), 7.55 (d,  $J = 7.2$  Hz, 2H), 7.40–7.37 (m, 2H), 7.36–7.33 (m, 1H), 7.28 (t,  $J = 7.4$  Hz, 1H), 7.27–7.22 (m, 4H), 7.07 (d,  $J = 7.3$  Hz, 2H), 6.61 (s, 1H), 5.66 (d,  $J = 5.4$  Hz, 2H), 4.34 (s, 2H), 4.03–3.94 (m, 2H), 3.19 (p,  $J = 8.5$  Hz, 1H), 2.38–2.24 (m, 5H), 2.24–2.15 (m, 2H), 2.01–1.93 (m, 1H), 1.93–1.87 (m, 1H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  174.1, 143.5, 136.8, 136.1, 131.4, 129.5, 128.8, 128.6, 128.4, 128.1, 127.7, 127.6, 125.3, 125.2, 122.1, 87.4, 85.8, 84.80 81.5, 65.5, 50.8, 37.9, 37.1, 25.1, 21.3, 18.3; **HRMS (ESI)** calcd for  $\text{C}_{33}\text{H}_{31}\text{NNaO}_4\text{S}$   $[\text{M}+\text{Na}]^+$ : 560.1866; found: 560.1871.

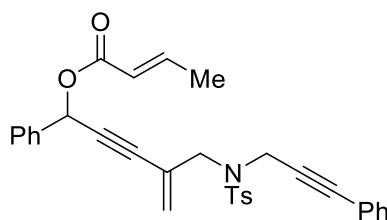
**4-(((4-methyl-*N*-(3-phenylprop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl 1-tosylpiperidine-4-carboxylate (4m)**



The title compound was prepared according to general procedure **B** in 57% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 8:1 to 5:1) to afford **4m** as a yellow solid, mp 100–102 °C;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.76 (d,  $J = 8.3$  Hz, 2H), 7.62 (d,  $J = 8.2$  Hz, 2H), 7.50–7.47 (m, 2H), 7.39–7.34 (m, 3H), 7.32–7.28 (m, 2H), 7.28–7.21 (m, 5H), 7.05–7.01 (m, 2H), 6.53 (s, 1H), 5.62 (s, 2H), 4.30 (s, 2H), 3.96 (s, 2H), 3.64–3.55 (m, 2H), 2.48–2.40 (m,

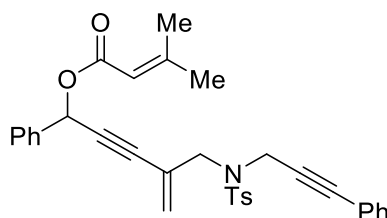
5H), 2.35–2.28 (m, 4H), 2.04–1.99 (m, 1H), 1.98–1.92 (m, 1H), 1.88–1.75 (m, 2H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 172.6, 143.6, 143.5, 136.4, 136.0, 133.1, 131.4, 129.6, 129.5, 129.0, 128.7, 128.4, 128.1, 127.7, 127.6, 127.6, 125.6, 125.1, 122.0, 86.9, 85.9, 85.0, 81.3, 66.0, 50.9, 45.3, 45.2, 39.9, 36.9, 27.2, 21.5, 21.6; HRMS (ESI) calcd for C<sub>41</sub>H<sub>40</sub>N<sub>2</sub>NaO<sub>6</sub>S<sub>2</sub> [M+Na]<sup>+</sup>: 743.2220; found: 743.2234.

**4-(((4-methyl-*N*-(3-phenylprop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl (*E*)-but-2-enoate (4n)**



The title compound was prepared according to general procedure **B** in 60% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 15:1 to 10:1) to afford **4n** as a yellow oil; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.78 (d, *J* = 8.3 Hz, 2H), 7.60–7.55 (m, 2H), 7.42–7.32 (m, 3H), 7.30–7.26 (m, 1H), 7.26–7.22 (m, 4H), 7.11–7.00 (m, 3H), 6.66 (s, 1H), 5.88 (dd, *J* = 15.5, 1.7 Hz, 1H), 5.67 (s, 1H), 5.66 (d, *J* = 1.1 Hz, 1H), 4.34 (s, 2H), 4.04–3.93 (m, 2H), 2.33 (s, 3H), 1.87 (dd, *J* = 6.9, 1.6 Hz, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 165.1, 146.1, 143.5, 136.8, 136.0, 131.5, 129.5, 128.8, 128.6, 128.4, 128.1, 127.8, 127.7, 125.4, 125.2, 122.1, 122.1, 87.3, 85.8, 84.8, 81.5, 65.4, 50.8, 37.1, 21.4, 18.0; HRMS (ESI) calcd for C<sub>32</sub>H<sub>29</sub>NNaO<sub>4</sub>S [M+Na]<sup>+</sup>: 546.1710; found: 546.1717.

**4-(((4-methyl-*N*-(3-phenylprop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl 3-methylbut-2-enoate (4o)**

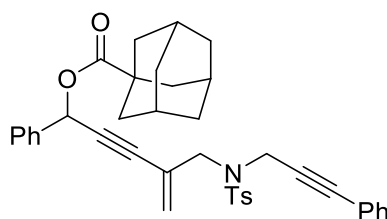


The title compound was prepared according to general procedure **B** in 59% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum



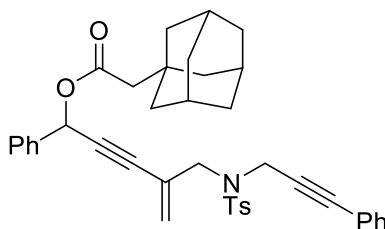
ether/EtOAc = 15:1 to 10:1) to afford **4o** as a yellow oil; **<sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>)** δ 7.79 (d, *J* = 8.1 Hz, 2H), 7.57 (d, *J* = 7.4 Hz, 2H), 7.38 (t, *J* = 7.2 Hz, 2H), 7.36–7.32 (m, 1H), 7.30–7.22 (m, 5H), 7.08 (d, *J* = 7.4 Hz, 2H), 6.64 (s, 1H), 5.73 (s, 1H), 5.66 (d, *J* = 6.1 Hz, 2H), 4.34 (s, 2H), 4.03–3.93 (m, 2H), 2.33 (s, 3H), 2.19 (s, 3H), 1.89 (s, 3H); **<sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>)** δ 165.1, 158.4, 143.5, 137.1, 136.1, 131.5, 129.5, 128.7, 128.6, 128.4, 128.1, 127.8, 127.7, 125.3, 125.2, 122.1, 115.4, 87.7, 85.8, 84.6, 81.6, 64.7, 50.8, 37.1, 27.4, 21.4, 20.4; **HRMS (ESI)** calcd for C<sub>33</sub>H<sub>31</sub>NNaO<sub>4</sub>S [M+Na]<sup>+</sup>: 560.1866; found: 560.1875.

**4-(((4-methyl-*N*-(3-phenylprop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl-adamantane-1-carboxylate (4p)**



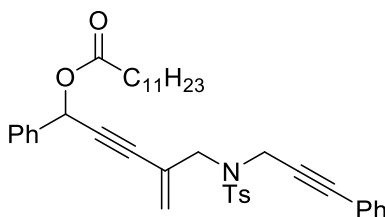
The title compound was prepared according to general procedure **B** in 47% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 20:1 to 12:1) to afford **4p** as a yellow oil; **<sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>)** δ 7.78 (d, *J* = 8.2 Hz, 2H), 7.52 (d, *J* = 7.4 Hz, 2H), 7.41–7.31 (m, 3H), 7.31–7.20 (m, 5H), 7.09–7.03 (m, 2H), 6.57 (s, 1H), 5.65 (d, *J* = 1.3 Hz, 2H), 4.34 (s, 2H), 3.98 (s, 2H), 2.33 (s, 3H), 2.01 (s, 3H), 1.95–1.90 (m, 6H), 1.75–1.66 (m, 6H); **<sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>)** δ 176.2, 143.5, 137.0, 136.1, 131.5, 129.5, 128.6, 128.6, 128.4, 128.1, 127.7, 127.4, 125.2, 125.1, 122.1, 87.6, 85.8, 84.6, 81.5, 65.2, 50.8, 40.7, 38.5, 37.1, 36.4, 27.8, 21.4; **HRMS (ESI)** calcd for C<sub>39</sub>H<sub>39</sub>NNaO<sub>4</sub>S [M+Na]<sup>+</sup>: 640.2492; found: 640.2503.

**4-(((4-methyl-*N*-(3-phenylprop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl 2-(adamantan-1-yl)acetate (4q)**



The title compound was prepared according to general procedure **B** in 60% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 15:1 to 10:1) to afford **4q** as a pale-yellow oil;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.78 (d,  $J = 8.2$  Hz, 2H), 7.56 (d,  $J = 7.1$  Hz, 2H), 7.41–7.33 (m, 3H), 7.30–7.26 (m, 1H), 7.26–7.21 (m, 4H), 7.06 (d,  $J = 7.2$  Hz, 2H), 6.58 (s, 1H), 5.65 (d,  $J = 1.6$  Hz, 2H), 4.33 (s, 2H), 4.02–3.92 (m, 2H), 2.33 (s, 3H), 2.14–2.08 (m, 2H), 1.92 (s, 3H), 1.69–1.64 (m, 3H), 1.61–1.56 (m, 9H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  170.5, 143.5, 136.8, 136.1, 131.5, 129.5, 128.9, 128.6, 128.4, 128.1, 127.9, 127.8, 125.2, 125.1, 122.1, 87.5, 85.8, 84.8, 81.5, 65.3, 50.7, 48.6, 42.3, 37.1, 36.7, 33.2, 28.6, 21.4; **HRMS (ESI)** calcd for  $\text{C}_{40}\text{H}_{41}\text{NNaO}_4\text{S}$   $[\text{M}+\text{Na}]^+$ : 654.2649; found: 654.2654.

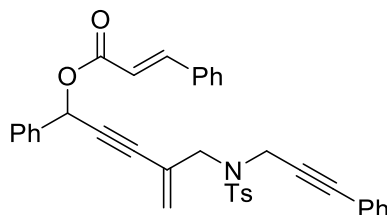
**4-(((4-methyl-*N*-(3-phenylprop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl dodecanoate (4r)**



The title compound was prepared according to general procedure **B** in 49% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 15:1 to 10:1) to afford **4r** as a yellow oil;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.78 (d,  $J = 8.2$  Hz, 2H), 7.55 (d,  $J = 7.3$  Hz, 2H), 7.41–7.35 (m, 3H), 7.30–7.27 (m, 1H), 7.26–7.21 (m, 4H), 7.08–7.05 (m, 2H), 6.60 (s, 1H), 5.66 (d,  $J = 5.4$  Hz, 2H), 4.33 (s, 2H), 4.02–3.94 (m, 2H), 2.41–2.34 (m, 2H), 2.33 (s, 3H), 1.66–1.60 (m, 2H), 1.35–1.21 (m, 16H), 0.88 (t,  $J = 7.0$  Hz, 3H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  172.6, 143.5,

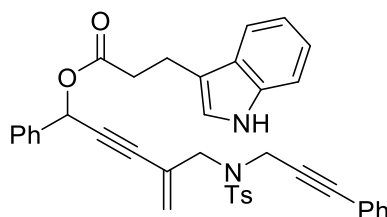
136.8, 136.1, 131.5, 129.5, 128.9, 128.6, 128.4, 128.1, 127.8, 127.8, 125.3, 125.2, 122.1, 87.3, 85.9, 84.8, 81.5, 65.5, 50.8, 37.1, 34.2, 31.9, 29.6, 29.5, 29.4, 29.3, 29.2, 29.0, 24.8, 22.6, 21.4, 14.1; **HRMS (ESI)** calcd for C<sub>40</sub>H<sub>47</sub>NNaO<sub>4</sub>S [M+Na]<sup>+</sup>:660.3118; found: 660.3123.

**4-(((4-methyl-N-(3-phenylprop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl cinnamate (4s)**



The title compound was prepared according to general procedure **B** in 56% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 15:1 to 7:1) to afford **4s** as a yellow oil; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.80 (d, *J* = 8.3 Hz, 2H), 7.78–7.75 (m, 1H), 7.67–7.62 (m, 2H), 7.55–7.48 (m, 2H), 7.45–7.40 (m, 2H), 7.40–7.36 (m, 4H), 7.30–7.21 (m, 5H), 7.10–7.05 (m, 2H), 6.76 (s, 1H), 6.50–6.47 (m, 1H), 5.71 (s, 1H), 5.69 (d, *J* = 1.2 Hz, 1H), 4.40–4.32 (m, 2H), 4.07–3.97 (m, 2H), 2.33 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 165.6, 145.8, 143.5, 136.7, 136.0, 134.2, 131.4, 130.4, 129.5, 128.9, 128.8, 128.7, 128.4, 128.1, 128.0, 127.8, 127.7, 125.5, 125.1, 122.0, 117.4, 87.2, 85.8, 85.0, 81.5, 65.8, 50.8, 37.1, 21.3; **HRMS (ESI)** calcd for C<sub>37</sub>H<sub>31</sub>NNaO<sub>4</sub>S [M+Na]<sup>+</sup>:608.1866; found: 608.1874.

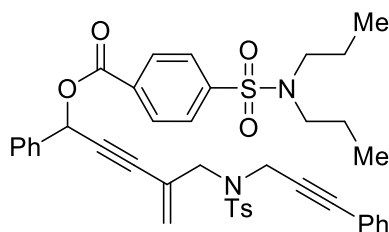
**4-(((4-methyl-N-(3-phenylprop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl 3-(1H-indol-3-yl)propanoate (4t)**



The title compound was prepared according to general procedure **B** in 57% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 5:1) to afford **4t** as a pale-yellow oil; <sup>1</sup>H NMR (600 MHz,

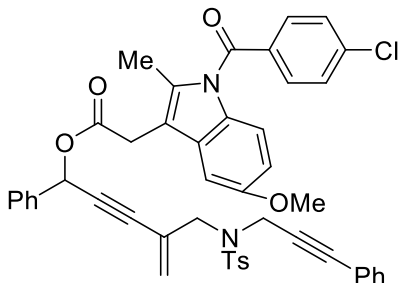
$\text{CDCl}_3$ )  $\delta$  8.17 (s, 1H), 7.80 (d,  $J = 8.2$  Hz, 2H), 7.60 (d,  $J = 7.9$  Hz, 1H), 7.53–7.49 (m, 2H), 7.40–7.33 (m, 4H), 7.29 (t,  $J = 7.4$  Hz, 1H), 7.27–7.22 (m, 4H), 7.19 (t,  $J = 7.5$  Hz, 1H), 7.11 (t,  $J = 7.5$  Hz, 1H), 7.06 (d,  $J = 7.3$  Hz, 2H), 6.99 (d,  $J = 1.6$  Hz, 1H), 6.62 (s, 1H), 5.67 (s, 2H), 4.38–4.30 (m, 2H), 4.03 – 3.96 (m, 2H), 3.20–3.09 (m, 2H), 2.86–2.73 (m, 2H), 2.34 (s, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  172.1, 143.7, 136.7, 136.2, 135.9, 131.5, 129.6, 128.9, 128.6, 128.4, 128.1, 127.8, 127.7, 127.1, 125.6, 125.2, 122.0, 121.9, 121.7, 119.2, 118.6, 114.4, 111.1, 87.3, 85.9, 84.8, 81.4, 65.7, 50.9, 37.1, 34.8, 21.4, 20.5; HRMS (ESI) calcd for  $\text{C}_{39}\text{H}_{35}\text{N}_2\text{O}_4\text{S}$   $[\text{M}+\text{H}]^+$ :627.2312; found: 627.2319.

**4-(((4-methyl-*N*-(3-phenylprop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl 4-(*N,N*-dipropylsulfamoyl)benzoate (4u)**



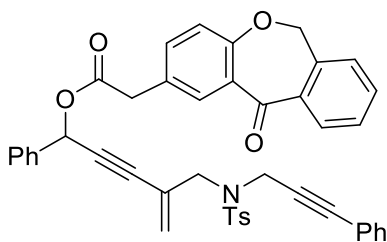
The title compound was prepared according to general procedure **B** in 60% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 20:1 to 6:1) to afford **4u** as a yellow oil;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  8.20 (d,  $J = 8.5$  Hz, 2H), 7.86 (d,  $J = 8.5$  Hz, 2H), 7.78 (d,  $J = 8.2$  Hz, 2H), 7.66 (d,  $J = 7.1$  Hz, 2H), 7.43 (t,  $J = 7.3$  Hz, 2H), 7.39 (t,  $J = 7.2$  Hz, 1H), 7.30–7.20 (m, 5H), 7.05–7.02 (m, 2H), 6.84 (s, 1H), 5.69 (s, 1H), 5.67 (s, 1H), 4.38–4.29 (m, 2H), 4.04–3.97 (m, 2H), 3.09–3.06 (m, 4H), 2.33 (s, 3H), 1.57–1.50 (m, 4H), 0.86 (t,  $J = 7.4$  Hz, 6H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  164.1, 144.4, 143.6, 136.2, 136.0, 132.9, 131.4, 130.5, 129.5, 129.2, 128.8, 128.4, 128.1, 127.9, 127.7, 126.9, 125.8, 125.1, 121.9, 86.7, 85.9, 85.5, 81.3, 67.1, 50.9, 49.9, 37.0, 21.9, 21.3, 11.1; HRMS (ESI) calcd for  $\text{C}_{41}\text{H}_{43}\text{N}_2\text{O}_6\text{S}_2$   $[\text{M}+\text{H}]^+$ :723.2557; found: 723.2568.

**4-(((4-methyl-*N*-(3-phenylprop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl 2-(1-(4-chlorobenzoyl)-5-methoxy-2-methyl-1*H*-indol-3-yl)acetate (4v)**



The title compound was prepared according to general procedure **B** in 62% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 6:1) to afford **4v** as a pale-yellow solid, mp 72–74 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.77 (d, *J* = 7.9 Hz, 2H), 7.62 (d, *J* = 8.2 Hz, 2H), 7.53–7.49 (m, 2H), 7.44 (d, *J* = 8.2 Hz, 2H), 7.35 (d, *J* = 3.6 Hz, 3H), 7.28 (t, *J* = 7.4 Hz, 1H), 7.25–7.21 (m, 4H), 7.05 (d, *J* = 7.7 Hz, 2H), 6.93 (s, 1H), 6.91 (d, *J* = 9.0 Hz, 1H), 6.66 (d, *J* = 8.9 Hz, 1H), 6.59 (s, 1H), 5.63 (s, 1H), 5.62 (s, 1H), 4.30 (s, 2H), 4.01–3.93 (m, 2H), 3.78–3.69 (m, 5H), 2.33 (d, *J* = 5.2 Hz, 6H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 169.6, 168.2, 156.0, 143.5, 139.2, 136.2, 136.2, 136.0, 133.9, 131.5, 131.1, 130.8, 130.5, 129.5, 129.1, 129.0, 128.7, 128.4, 128.1, 127.8, 127.7, 125.6, 125.2, 122.1, 114.9, 112.3, 111.9, 101.2, 87.0, 85.9, 85.2, 81.5, 66.5, 55.6, 50.9, 37.0, 30.4, 21.4, 13.4; HRMS (ESI) calcd for C<sub>47</sub>H<sub>40</sub>ClN<sub>2</sub>O<sub>6</sub>S [M+H]<sup>+</sup>:795.2290; found: 795.2299.

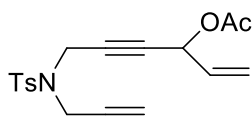
**4-(((4-methyl-*N*-(3-phenylprop-2-yn-1-yl)phenyl)sulfonamido)methyl)-1-phenylpent-4-en-2-yn-1-yl 2-(11-oxo-6,11-dihydrodibenzo[b,e]oxepin-2-yl)acetate (4w)**



The title compound was prepared according to general procedure **B** in 49% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum

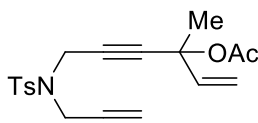
ether/EtOAc = 10:1 to 5:1) to afford **4w** as a pale-yellow solid, mp 62–64 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 8.13 (s, 1H), 7.89 (d, *J* = 7.7 Hz, 1H), 7.78 (d, *J* = 8.1 Hz, 2H), 7.57–7.52 (m, 3H), 7.46 (t, *J* = 7.6 Hz, 1H), 7.43 (dd, *J* = 8.4, 1.9 Hz, 1H), 7.40–7.33 (m, 4H), 7.30–7.26 (m, 1H), 7.25–7.21 (m, 4H), 7.07 (d, *J* = 7.7 Hz, 2H), 7.02 (d, *J* = 8.4 Hz, 1H), 6.61 (s, 1H), 5.66 (d, *J* = 8.2 Hz, 2H), 5.17 (s, 2H), 4.33 (s, 2H), 4.03–3.96 (m, 2H), 3.71 (q, *J* = 15.9 Hz, 2H), 2.33 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 190.6, 170.2, 160.5, 143.5, 140.4, 136.4, 136.3, 136.1, 135.5, 132.7, 132.5, 131.5, 129.5, 129.4, 129.2, 129.0, 128.7, 128.4, 128.1, 128.0, 127.7, 127.3, 125.5, 125.2, 125.1, 122.1, 121.0, 87.0, 85.9, 85.2, 81.5, 73.7, 66.4, 50.9, 40.0, 37.0, 21.6; HRMS (ESI) calcd for C<sub>44</sub>H<sub>35</sub>NNaO<sub>6</sub>S [M+Na]<sup>+</sup>:728.2077; found: 728.2083.

**6-((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)hex-1-en-4-yn-3-yl acetate (6a)**



The title compound was prepared according to general procedure C in 71% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 14:1 to 7:1) to afford **6a** as a pale-yellow oil; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.76–7.66 (m, 2H), 7.32–7.28 (m, 2H), 5.79–5.64 (m, 2H), 5.41–5.31 (m, 1H), 5.30–5.20 (m, 1H), 4.23 (d, *J* = 1.4 Hz, 2H), 4.13 (d, *J* = 2.4 Hz, 2H), 2.42 (s, 3H), 2.14 (t, *J* = 2.5 Hz, 1H), 2.07 (s, 3H); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 169.4, 143.9, 135.2, 132.4, 129.6, 127.9, 119.0, 81.2, 79.6, 76.2, 74.0, 64.0, 36.5, 36.4, 21.6, 20.9; HRMS (ESI) calcd. for C<sub>18</sub>H<sub>19</sub>NO<sub>4</sub>SNa [M+Na]<sup>+</sup>: 368.0927, found: 368.0933.

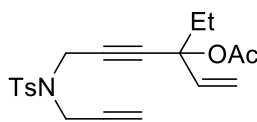
**3-methyl-6-((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)hex-1-en-4-yn-3-yl acetate (6b)**



The title compound was prepared according to general procedure C in 61% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum

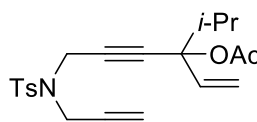
ether/EtOAc = 15:1 to 8:1) to afford **6b** as a pale-yellow oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.75–7.70 (m, 2H), 7.31–7.26 (m, 2H), 5.88–5.78 (m, 1H), 5.35 (d,  $J = 17.1$  Hz, 1H), 5.18–5.11 (m, 1H), 4.24 (s, 2H), 4.17 (d,  $J = 2.3$  Hz, 2H), 2.41 (s, 3H), 2.12 (t,  $J = 2.5$  Hz, 1H), 2.00–1.96 (m, 3H), 1.53–1.49 (m, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  168.7, 143.8, 138.3, 135.4, 129.6, 127.9, 115.5, 84.5, 79.2, 76.4, 73.8, 36.6, 36.2, 28.0, 21.7, 21.5; **HRMS (ESI)** calcd. for  $\text{C}_{19}\text{H}_{21}\text{NO}_4\text{SNa}$   $[\text{M}+\text{Na}]^+$ : 382.1089, found: 382.1097.

**3-ethyl-6-((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)hex-1-en-4-yn-3-yl acetate (6c)**



The title compound was prepared according to general procedure **C** in 66% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 16:1 to 9:1) to afford **6c** as a pale-yellow oil;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.74–7.68 (m, 2H), 7.32–7.26 (m, 2H), 5.77–5.67 (m, 1H), 5.34 (dd,  $J = 17.1$ , 0.8 Hz, 1H), 5.19 (dd,  $J = 10.4$ , 0.8 Hz, 1H), 4.26 (s, 2H), 4.18 (d,  $J = 2.4$  Hz, 2H), 2.41 (s, 3H), 2.12 (t,  $J = 2.5$  Hz, 1H), 1.99 (s, 3H), 1.89–1.80 (m, 1H), 1.76–1.63 (m, 1H), 0.86 (t,  $J = 7.4$  Hz, 3H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  168.6, 143.7, 137.1, 135.5, 129.6, 127.8, 116.6, 83.4, 80.2, 77.9, 76.4, 73.8, 36.6, 36.2, 33.7, 21.6, 21.5, 8.1; **HRMS (ESI)** calcd. for  $\text{C}_{20}\text{H}_{23}\text{NO}_4\text{SNa}$   $[\text{M}+\text{Na}]^+$ : 396.1245, found: 396.1256.

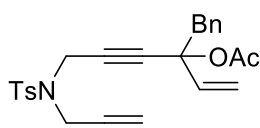
**3-isopropyl-6-((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)hex-1-en-4-yn-3-yl acetate (6d)**



The title compound was prepared according to general procedure **D** in 27% yield over 4 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 16:1 to 9:1) to afford **6d** as a pale-yellow oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.75–7.69 (m, 2H), 7.33–7.27 (m, 2H), 5.72–5.62 (m, 1H), 5.35 (dd,  $J = 17.2$ ,

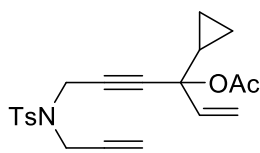
1.0 Hz, 1H), 5.24 (dd,  $J = 10.4, 1.0$  Hz, 1H), 4.27 (s, 2H), 4.21 (d,  $J = 2.3$  Hz, 2H), 2.41 (s, 3H), 2.12 (t,  $J = 2.5$  Hz, 1H), 2.04–2.00 (m, 1H), 1.99 (s, 3H), 0.93 (d,  $J = 6.7$  Hz, 3H), 0.83 (d,  $J = 6.8$  Hz, 3H);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  168.6, 143.7, 136.0, 135.4, 129.7, 127.8, 117.6, 82.3, 81.3, 80.8, 76.4, 73.9, 37.0, 36.6, 36.2, 21.7, 21.5, 17.1, 16.9; HRMS (ESI) calcd. for  $\text{C}_{21}\text{H}_{26}\text{NO}_4$   $[\text{M} + \text{H}]^+$ : 388.1577, found: 388.1583.

**3-benzyl-6-((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)hex-1-en-4-yn-3-yl acetate (6e)**



The title compound was prepared according to general procedure **D** in 25% yield over 4 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 15:1 to 8:1) to afford **6e** as a pale-yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.71–7.66 (m, 2H), 7.31–7.22 (m, 5H), 7.21–7.16 (m, 2H), 5.79–5.71 (m, 1H), 5.29 (dd,  $J = 17.1, 0.6$  Hz, 1H), 5.18 (dd,  $J = 10.4, 0.6$  Hz, 1H), 4.28–4.17 (m, 2H), 4.13–3.99 (m, 2H), 3.11 (d,  $J = 13.5$  Hz, 1H), 3.02 (d,  $J = 13.5$  Hz, 1H), 2.39 (s, 3H), 2.10 (t,  $J = 2.5$  Hz, 1H), 1.99 (s, 3H);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  168.5, 143.7, 136.9, 135.4, 134.7, 131.0, 129.6, 127.8, 127.8, 127.0, 116.9, 83.1, 81.5, 77.1, 76.4, 73.8, 46.8, 36.5, 36.1, 21.7, 21.5; HRMS (ESI) calcd. for  $\text{C}_{25}\text{H}_{25}\text{NO}_4\text{SNa}$   $[\text{M} + \text{Na}]^+$ : 458.1396, found: 458.1402.

**3-cyclopropyl-6-((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)hex-1-en-4-yn-3-yl acetate (6f)**

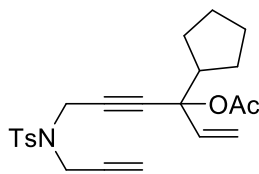


The title compound was prepared according to general procedure **D** in 22% yield over 4 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 16:1 to 9:1) to afford **6f** as a pale-yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.72–7.68 (m, 2H), 7.31–7.27 (m, 2H), 5.88–5.79 (m, 1H), 5.34 (dd,  $J = 17.1, 0.8$  Hz, 1H), 5.16 (dd,  $J = 10.4, 0.8$  Hz, 1H), 4.23 (s, 2H), 4.17 (d,  $J = 2.4$  Hz, 2H), 2.41



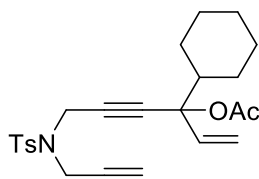
(s, 3H), 2.12 (t,  $J = 2.5$  Hz, 1H), 2.00 (s, 3H), 1.34–1.27 (m, 1H), 0.58–0.40 (m, 3H), 0.36–0.28 (m, 1H);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  168.7, 143.8, 136.8, 135.3, 129.6, 127.8, 116.1, 81.4, 80.3, 79.3, 76.3, 73.9, 36.5, 36.2, 21.7, 21.5, 19.1, 2.71, 2.0; HRMS (ESI) calcd. for  $\text{C}_{21}\text{H}_{25}\text{NO}_3\text{S}$   $[\text{M}+\text{H}]^+$ : 387.1399, found: 387.1405.

**3-cyclopentyl-6-((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)hex-1-en-4-yn-3-yl acetate (6g)**



The title compound was prepared according to general procedure **D** in 26% yield over 4 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 17:1 to 9:1) to afford **6g** as a Yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.74–7.69 (m, 2H), 7.32–7.27 (m, 2H), 5.77–5.68 (m, 1H), 5.34 (dd,  $J = 17.1, 0.9$  Hz, 1H), 5.18 (dd,  $J = 10.4, 0.9$  Hz, 1H), 4.26 (d,  $J = 1.0$  Hz, 2H), 4.19 (d,  $J = 2.5$  Hz, 2H), 2.42 (s, 3H), 2.29–2.19 (m, 1H), 2.11 (t,  $J = 2.5$  Hz, 1H), 1.98 (s, 3H), 1.72–1.40 (m, 8H);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  168.7, 143.7, 136.9, 135.4, 129.6, 127.8, 116.7, 82.9, 80.5, 80.3, 76.3, 73.8, 48.8, 36.6, 36.1, 27.7, 27.7, 25.8, 25.6, 21.7, 21.6; HRMS (ESI) calcd. for  $\text{C}_{23}\text{H}_{28}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 414.1734, found: 414.1742.

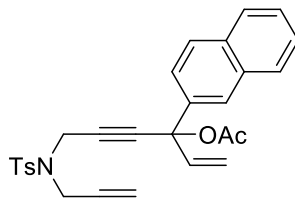
**3-cyclohexyl-6-((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)hex-1-en-4-yn-3-yl acetate (6h)**



The title compound was prepared according to general procedure **D** in 25% yield over 4 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 18:1 to 9:1) to afford **6h** as a yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.74–7.70 (m, 2H), 7.31–7.27 (m, 2H), 5.71–5.63 (m, 1H), 5.32 (dd,  $J = 17.2, 0.9$  Hz, 1H), 5.22 (dd,  $J = 10.4, 0.9$  Hz, 1H), 4.27 (s, 2H), 4.20 (d,  $J = 2.4$  Hz, 2H), 2.42 (s, 3H), 2.12 (t,  $J = 2.5$  Hz, 1H), 1.99 (s, 3H), 1.83–1.68 (m, 3H), 1.68–1.61 (m, 3H), 1.21–0.91

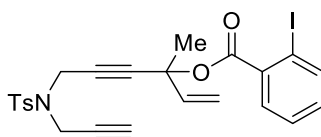
(m, 5H);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  168.6, 143.7, 136.3, 135.4, 129.6, 127.8, 117.4, 82.7, 80.9, 80.8, 76.4, 73.8, 46.6, 36.6, 36.2, 27.1, 26.9, 26.2, 26.2, 26.0, 21.7, 21.6; HRMS (ESI) calcd. for  $\text{C}_{24}\text{H}_{30}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 428.1890, found: 428.1898.

**6-((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)-3-(naphthalen-2-yl)hex-1-en-4-yn-3-yl acetate (6i)**



The title compound was prepared according to general procedure **D** in 21% yield over 4 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 14:1 to 7:1) to afford **6i** as a yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.94 (d,  $J$  = 1.9 Hz, 1H), 7.84–7.78 (m, 3H), 7.75–7.71 (m, 2H), 7.51–7.45 (m, 3H), 7.23–7.20 (m, 2H), 6.05–5.97 (m, 1H), 5.40 (dd,  $J$  = 17.0, 0.6 Hz, 1H), 5.22 (dd,  $J$  = 10.3, 0.6 Hz, 1H), 4.39 (d,  $J$  = 0.9 Hz, 2H), 4.22 (d,  $J$  = 2.4 Hz, 2H), 2.32 (s, 3H), 2.17 (t,  $J$  = 2.5 Hz, 1H), 2.10 (s, 3H);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  168.1, 143.8, 138.1, 137.2, 135.3, 133.0, 132.8, 129.7, 128.4, 128.2, 127.8, 127.6, 126.5, 126.44, 125.1, 123.4, 116.0, 83.1, 82.6, 78.1, 76.4, 74.0, 36.8, 36.4, 21.7, 21.5; HRMS (ESI) calcd. for  $\text{C}_{28}\text{H}_{25}\text{NO}_4\text{SNa}$   $[\text{M}+\text{Na}]^+$ : 494.1397, found: 494.1402.

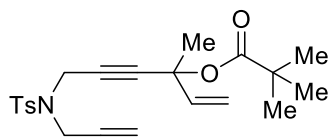
**3-methyl-6-((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)hex-1-en-4-yn-3-yl 2-iodobenzoate (6j)**



The title compound was prepared according to general procedure **C** in 42% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 12:1 to 6:1) to afford **6j** as a yellow oil;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.97 (dd,  $J$  = 8.0, 1.0 Hz, 1H), 7.73–7.70 (m, 2H), 7.69 (dd,  $J$  = 7.8, 1.7 Hz, 1H), 7.39 (td,  $J$  = 7.6, 1.2 Hz, 1H), 7.25–7.22 (m, 2H), 7.16–7.12 (m, 1H), 6.03–5.96 (m, 1H), 5.48 (dd,  $J$  = 17.1, 0.5 Hz, 1H), 5.23 (dd,  $J$  = 10.4, 0.5 Hz, 1H), 4.30 (s, 2H), 4.22 (d,  $J$

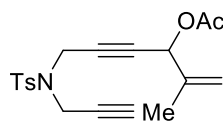
= 2.5 Hz, 2H), 2.33 (s, 3H), 2.14 (t,  $J = 2.5$  Hz, 1H), 1.68 (s, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  164.3, 143.7, 141.2, 137.9, 135.7, 135.4, 132.5, 130.8, 129.6, 127.9, 127.8, 116.2, 93.8, 84.1, 80.0, 76.6, 75.5, 73.9, 36.6, 36.4, 28.1, 21.4; HRMS (ESI) calcd. for  $\text{C}_{24}\text{H}_{22}\text{INO}_4\text{SNa}$   $[\text{M}+\text{Na}]^+$ : 570.0206, found: 570.0212.

**3-methyl-6-((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)hex-1-en-4-yn-3-yl pivalate (6k)**



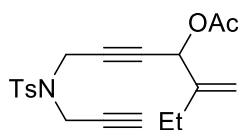
The title compound was prepared according to general procedure C in 48% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 16:1 to 8:1) to afford **6k** as a colorless oil;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.73–7.70 (m, 2H), 7.30–7.28 (m, 2H), 5.84–5.78 (m, 1H), 5.34 (dd,  $J = 17.1, 0.6$  Hz, 1H), 5.12 (dd,  $J = 10.4, 0.7$  Hz, 1H), 4.23 (s, 2H), 4.18 (d,  $J = 2.2$  Hz, 2H), 2.41 (s, 3H), 2.10 (t,  $J = 2.5$  Hz, 1H), 1.51 (s, 3H), 1.15 (s, 9H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  176.1, 143.7, 138.6, 135.5, 129.6, 127.9, 115.1, 84.9, 78.8, 76.5, 73.7, 73.4, 39.0, 36.6, 36.1, 28.0, 27.0, 21.5; HRMS (ESI) calcd. for  $\text{C}_{22}\text{H}_{27}\text{NO}_4\text{SNa}$   $[\text{M}+\text{Na}]^+$ : 424.1553, found: 424.1565.

**2-methyl-6-((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)hex-1-en-4-yn-3-yl acetate (6l)**



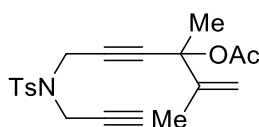
The title compound was prepared according to general procedure C in 69% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 16:1 to 8:1) to afford **6l** as a colorless oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.72–7.69 (m, 2H), 7.31–7.27 (m, 2H), 5.63 (s, 1H), 5.06 (s, 1H), 4.94 (s, 1H), 4.22 (d,  $J = 1.6$  Hz, 2H), 4.12 (d,  $J = 2.4$  Hz, 2H), 2.42 (s, 3H), 2.14 (t,  $J = 2.5$  Hz, 1H), 2.08–2.06 (m, 3H), 1.71 (s, 3H);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  169.4, 143.9, 139.7, 135.2, 129.6, 127.8, 115.0, 81.7, 78.9, 76.2, 74.0, 66.8, 36.5, 36.3, 21.6, 20.9, 18.2; HRMS (ESI) calcd. for  $\text{C}_{19}\text{H}_{22}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 360.1264, found: 360.1270.

**1-((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)-5-methylenehept-2-yn-4-yl acetate (6m)**



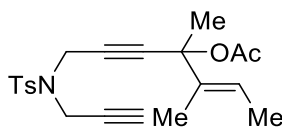
The title compound was prepared according to general procedure **C** in 72% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 11:1 to 6:1) to afford **6m** as a colorless oil;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.70 (d,  $J = 8.3$  Hz, 2H), 7.29 (d,  $J = 8.0$  Hz, 2H), 5.68 (s, 1H), 5.14 (s, 1H), 4.95 (s, 1H), 4.22 (d,  $J = 1.5$  Hz, 2H), 4.12 (d,  $J = 2.4$  Hz, 2H), 2.42 (s, 3H), 2.13 (t,  $J = 2.5$  Hz, 1H), 2.07 (s, 3H), 2.07–2.00 (m, 2H), 1.04 (t,  $J = 7.4$  Hz, 3H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  169.4, 145.3, 143.8, 135.1, 129.5, 127.8, 112.8, 81.9, 78.8, 76.1, 74.0, 66.3, 36.5, 36.3, 24.5, 21.5, 20.8, 11.8; **HRMS (ESI)** calcd. for  $\text{C}_{20}\text{H}_{24}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 374.1421, found: 374.1432.

**2,3-dimethyl-6-((4-methyl-*N*-(prop-2-yn-1-yl)phenyl)sulfonamido)hex-1-en-4-yn-3-yl acetate (6n)**



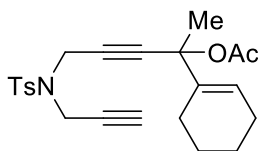
The title compound was prepared according to general procedure **C** in 75% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 17:1 to 8:1) to afford **6n** as a pale-yellow oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.73–7.70 (m, 2H), 7.31–7.27 (m, 2H), 5.13–5.11 (m, 1H), 4.90–4.87 (m, 1H), 4.24 (s, 2H), 4.17 (d,  $J = 2.4$  Hz, 2H), 2.42 (s, 3H), 2.11 (t,  $J = 2.5$  Hz, 1H), 2.01 (s, 3H), 1.72–1.69 (m, 3H), 1.53 (s, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  168.6, 144.2, 143.7, 135.4, 129.6, 127.8, 112.4, 85.3, 78.9, 76.4, 76.1, 73.8, 36.6, 36.2, 27.6, 21.5, 21.5, 17.9; **HRMS (ESI)** calcd. for  $\text{C}_{20}\text{H}_{25}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 374.1421, found: 374.1435.

**(E)-3,4-dimethyl-7-((4-methyl-N-(prop-2-yn-1-yl)phenyl)sulfonamido)hept-2-en-5-yn-4-yl acetate (6o)**



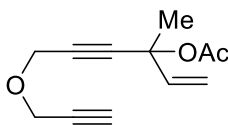
The title compound was prepared according to general procedure C in 58% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 18:1 to 9:1) to afford **6o** as a pale-yellow oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.73–7.69 (m, 2H), 7.30–7.26 (m, 2H), 5.79–5.72 (m, 1H), 4.23 (s, 2H), 4.17 (d,  $J = 2.4$  Hz, 2H), 2.41 (s, 3H), 2.11 (t,  $J = 2.5$  Hz, 1H), 1.98 (s, 3H), 1.62–1.58 (m, 3H), 1.57–1.56 (m, 3H), 1.49 (s, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  168.6, 143.7, 135.4, 134.7, 129.6, 127.8, 121.2, 85.6, 79.1, 77.2, 76.4, 73.7, 36.7, 36.2, 27.5, 21.6, 21.5, 13.4, 11.4; **HRMS (ESI)** calcd. for  $\text{C}_{21}\text{H}_{26}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 388.1577, found: 388.1583.

**2-(cyclohex-1-en-1-yl)-5-((4-methyl-N-(prop-2-yn-1-yl)phenyl)sulfonamido)pent-3-yn-2-yl acetate (6p)**



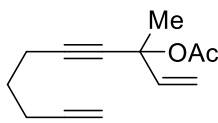
The title compound was prepared according to general procedure C in 62% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 18:1 to 9:1) to afford **6p** as a colorless oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.73–7.70 (m, 2H), 7.31–7.28 (m, 2H), 5.90–5.86 (m, 1H), 4.24 (s, 2H), 4.17 (d,  $J = 2.4$  Hz, 2H), 2.41 (s, 3H), 2.11 (t,  $J = 2.5$  Hz, 1H), 2.06–2.01 (m, 2H), 1.98 (s, 3H), 1.89–1.79 (m, 1H), 1.63–1.52 (m, 5H), 1.50 (s, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  168.6, 143.7, 136.8, 135.4, 129.6, 127.8, 123.6, 85.7, 78.9, 77.2, 76.5, 73.7, 36.7, 36.2, 27.4, 25.0, 23.5, 22.7, 22.0, 21.6, 21.6; **HRMS (ESI)** calcd. for  $\text{C}_{23}\text{H}_{27}\text{NO}_4\text{SNa}$   $[\text{M}+\text{Na}]^+$ : 436.1553, found: 436.1559.

### 3-methyl-6-(prop-2-yn-1-yloxy)hex-1-en-4-yn-3-yl acetate (6q)



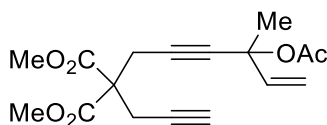
The title compound was prepared according to general procedure **C** in 49% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 50:1 to 20:1) to afford **6q** as a colorless oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  6.03–5.93 (m, 1H), 5.53 (dd,  $J = 17.1, 0.4$  Hz, 1H), 5.23 (dd,  $J = 10.4, 0.5$  Hz, 1H), 4.34 (s, 2H), 4.26 (d,  $J = 2.4$  Hz, 2H), 2.44 (t,  $J = 2.4$  Hz, 1H), 2.04 (s, 3H), 1.70 (s, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  168.9, 138.5, 115.5, 85.5, 81.8, 79.0, 74.9, 74.1, 56.8, 56.4, 28.3, 21.8; **HRMS (ESI)** calcd. for  $\text{C}_{12}\text{H}_{15}\text{O}_3$   $[\text{M}+\text{H}]^+$ : 207.1016, found: 207.1025.

### 3-methyldeca-1-en-4,9-diyn-3-yl acetate (6r)



The title compound was prepared according to general procedure **C** in 42% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 50:1 to 30:1) to afford **6r** as a colorless oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  6.04–5.94 (m, 1H), 5.52 (dd,  $J = 17.1, 0.8$  Hz, 1H), 5.19 (dd,  $J = 10.3, 0.9$  Hz, 1H), 2.39 (t,  $J = 7.0$  Hz, 2H), 2.31 (td,  $J = 7.1, 2.6$  Hz, 2H), 2.03 (s, 3H), 1.95 (t,  $J = 2.6$  Hz, 1H), 1.80–1.71 (m, 2H), 1.67 (s, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  169.0, 139.3, 115.0, 86.1, 83.5, 79.5, 74.8, 68.8, 28.6, 27.4, 21.9, 17.9, 17.5; **HRMS (ESI)** calcd. for  $\text{C}_{13}\text{H}_{16}\text{O}_2\text{Na}$   $[\text{M}+\text{Na}]^+$ : 227.1043, found: 227.1048.

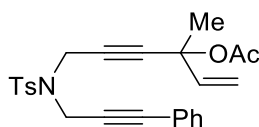
### dimethyl 2-(4-acetoxy-4-methylhex-5-en-2-yn-1-yl)-2-(prop-2-yn-1-yl)malonate (6s)



The title compound was prepared according to general procedure **C** in 48% yield over

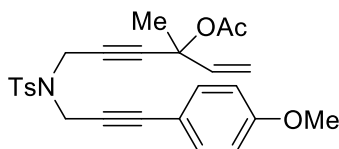
2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 20:1 to 8:1) to afford **6s** as a colorless oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  5.98–5.88 (m, 1H), 5.48 (dd,  $J = 17.1, 0.7$  Hz, 1H), 5.19 (dd,  $J = 10.4, 0.8$  Hz, 1H), 3.76 (s, 6H), 3.05 (s, 2H), 2.99 (d,  $J = 2.6$  Hz, 2H), 2.04–1.99 (m, 4H), 1.64 (s, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  169.1, 168.7, 138.8, 115.4, 82.1, 81.3, 78.5, 74.3, 71.6, 56.8, 53.1, 28.6, 23.0, 22.8, 21.8; **HRMS (ESI) calcd.** for  $\text{C}_{17}\text{H}_{20}\text{O}_6\text{Na}$   $[\text{M}+\text{Na}]^+$ : 343.1152, found: 343.1158.

**3-methyl-6-((4-methyl-*N*-(3-phenylprop-2-yn-1-yl)phenyl)sulfonamido)hex-1-en-4-yn-3-yl acetate (**8a**)**



The title compound was prepared according to general procedure **C** in 73% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 20:1 to 7:1) to afford **8a** as a pale-yellow oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.77–7.74 (m, 2H), 7.29–7.22 (m, 5H), 7.20–7.15 (m, 2H), 5.91–5.82 (m, 1H), 5.40 (dd,  $J = 17.1, 0.6$  Hz, 1H), 5.15 (dd,  $J = 10.4, 0.7$  Hz, 1H), 4.41 (s, 2H), 4.28 (s, 2H), 2.35 (s, 3H), 2.00–1.98 (m, 3H), 1.55 (s, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  168.7, 143.7, 138.4, 135.4, 131.6, 129.6, 128.4, 128.1, 127.9, 122.3, 115.5, 85.7, 84.4, 81.6, 79.5, 73.9, 37.2, 36.9, 28.1, 21.7, 21.4; **HRMS (ESI) calcd.** for  $\text{C}_{25}\text{H}_{26}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 436.1577, found: 436.1584.

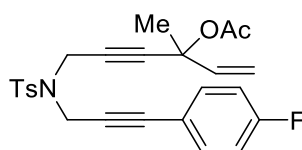
**6-((*N*-(3-(4-methoxyphenyl)prop-2-yn-1-yl)-4-methylphenyl)sulfonamido)-3-methylhex-1-en-4-yn-3-yl acetate (**8b**)**



The title compound was prepared according to general procedure **C** in 56% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 30:1 to 6:1) to afford **8b** as a yellow oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.77–7.73 (m, 2H), 7.29–7.26 (m, 2H), 7.15–7.10 (m, 2H), 6.81–6.74 (m, 2H), 5.92–

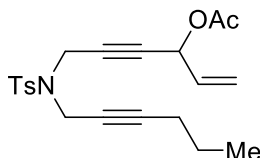
5.81 (m, 1H), 5.40 (d,  $J = 17.1$  Hz, 1H), 5.15 (d,  $J = 10.4$  Hz, 1H), 4.39 (s, 2H), 4.27 (s, 2H), 3.80 (s, 2H), 2.37 (s, 3H), 1.99 (s, 3H), 1.55 (s, 3H);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  168.7, 159.7, 143.6, 138.4, 135.5, 133.1, 129.6, 127.9, 115.5, 114.4, 113.8, 85.6, 84.3, 80.1, 79.6, 74.0, 55.3, 37.3, 36.8, 28.1, 21.7, 21.5; HRMS (ESI) calcd. for  $\text{C}_{26}\text{H}_{28}\text{NO}_5\text{S}$   $[\text{M}+\text{H}]^+$ : 466.1683, found: 466.1688.

**6-((*N*-(3-(4-fluorophenyl)prop-2-yn-1-yl)-4-methylphenyl)sulfonamido)-3-methylhex-1-en-4-yn-3-yl acetate (8c)**



The title compound was prepared according to general procedure **C** in 61% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 30:1 to 7:1) to afford **8c** as a Yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.77–7.74 (m, 2H), 7.29–7.25 (m, 2H), 7.20–7.14 (m, 2H), 6.95 (t,  $J = 8.6$  Hz, 2H), 5.90–5.81 (m, 1H), 5.39 (d,  $J = 17.1$  Hz, 1H), 5.15 (d,  $J = 10.4$  Hz, 1H), 4.39 (s, 2H), 4.27 (s, 2H), 2.37 (s, 3H), 1.99 (s, 3H), 1.54 (s, 3H);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  168.7, 162.5 (d,  $J = 249.9$  Hz), 143.7, 138.3, 135.4, 133.6 (d,  $J = 8.4$  Hz), 129.6, 127.9, 118.3, 115.5 (d,  $J = 3.1$  Hz), 115.3, 84.5, 84.5, 81.6, 79.4, 73.9, 37.1, 36.9, 28.1, 21.7, 21.5; HRMS (ESI) calcd. for  $\text{C}_{25}\text{H}_{25}\text{FNO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 454.1483, found: 454.1489.

**6-((*N*-(hex-2-yn-1-yl)-4-methylphenyl)sulfonamido)hex-1-en-4-yn-3-yl acetate (8d)**

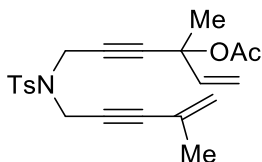


The title compound was prepared according to general procedure **C** in 68% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 30:1 to 8:1) to afford **8d** as a pale-yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.73–7.69 (m, 2H), 7.30–7.27 (m, 2H), 5.79–5.69 (m, 2H), 5.42–5.35 (m, 1H), 5.27–5.22 (m, 1H), 4.21 (d,  $J = 1.4$  Hz, 2H), 4.11 (t,  $J = 2.1$  Hz, 2H), 2.42 (s, 3H), 2.07 (s, 3H), 2.02–1.95 (m, 2H), 1.42–1.31 (m, 2H), 0.87 (t,  $J = 7.4$  Hz, 3H);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  169.4, 143.6, 135.4, 132.4, 129.5, 127.9, 119.0, 86.5, 80.8, 80.0,



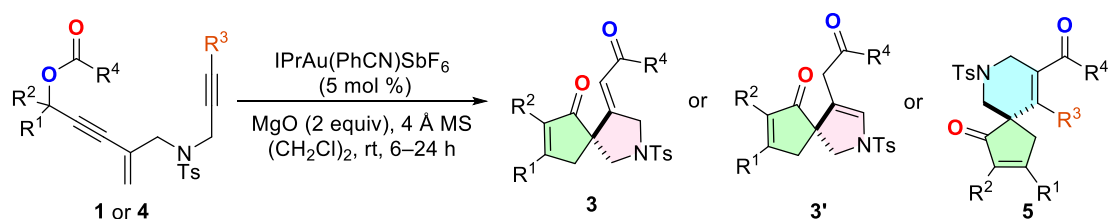
72.2, 64.0, 36.9, 36.4, 21.8, 21.5, 20.9, 20.5, 13.4; **HRMS (ESI)** calcd. for C<sub>21</sub>H<sub>26</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 388.1577, found: 388.1596.

**3-methyl-6-((4-methyl-N-(4-methylpent-4-en-2-yn-1-yl)phenyl)sulfonamido)hex-1-en-4-yn-3-yl acetate (8e)**



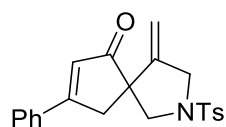
The title compound was prepared according to general procedure **C** in 52% yield over 2 steps. It was purified by column chromatography on silica gel (petroleum ether/EtOAc = 30:1 to 7:1) to afford **8e** as a pale-yellow oil; **<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)** δ 7.74–7.69 (m, 2H), 7.31–7.27 (m, 2H), 5.90–5.81 (m, 1H), 5.39 (d, *J* = 17.1 Hz, 1H), 5.17–5.13 (m, 2H), 5.07 (s, 1H), 4.30 (s, 2H), 4.21 (s, 2H), 2.40 (s, 3H), 1.99 (s, 3H), 1.73–1.69 (m, 3H), 1.54 (s, 3H); **<sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>)** δ 168.7, 143.6, 138.4, 135.5, 129.6, 127.9, 126.0, 122.3, 115.5, 86.8, 84.3, 80.6, 79.5, 73.9, 37.0, 36.7, 28.1, 23.1, 21.7, 21.5; **HRMS (ESI)** calcd. for C<sub>22</sub>H<sub>26</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 400.1577, found: 400.1597.

### 3. General procedure for IPrAu(PhCN)SbF<sub>6</sub>-catalyzed spirocyclization of 3-ene-1,7-diyne esters **1a–ai** and **4a–w**



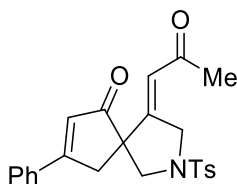
To a solution of **1** or **4** (0.2 mmol), MgO (0.4 mmol), and 4 Å MS (100 mg) in anhydrous DCE (2 mL) was added IPrAu(PhCN)SbF<sub>6</sub> (5 mol %) under an argon atmosphere. The reaction mixture was stirred at room temperature for 6–24 h. Upon completion, filtered through celite, washed with CH<sub>2</sub>Cl<sub>2</sub> and the solvent was removed under reduced pressure. The residue was purified by flash column chromatography on silica gel (eluent: petroleum ether: EtOAc) to afford the product **3** or **3'** or **5**.

#### 4-methylene-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (**2a**)



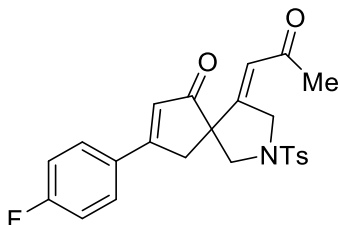
Column chromatography (petroleum ether/EtOAc = 20:1 to 5:1) to afford **2a** in 30% yield (22.8 mg; Table 1, entry 1); pale-yellow solid, mp 104–106 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.73 (d, *J* = 8.2 Hz, 2H), 7.65–7.59 (m, 2H), 7.54–7.42 (m, 3H), 7.35 (d, *J* = 8.1 Hz, 2H), 6.55 (t, *J* = 1.5 Hz, 1H), 4.96 (s, 1H), 4.76 (s, 1H), 4.24 (dt, *J* = 13.9, 1.7 Hz, 1H), 3.72 (dt, *J* = 13.9, 2.4 Hz, 1H), 3.57 (d, *J* = 9.6 Hz, 1H), 3.35 (d, *J* = 9.6 Hz, 1H), 3.23 (dd, *J* = 18.2, 1.6 Hz, 1H), 3.15 (dd, *J* = 18.2, 1.6 Hz, 1H), 2.45 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 205.8, 172.5, 148.9, 144.0, 133.1, 132.3, 131.9, 129.8, 129.0, 128.0, 127.0, 125.4, 107.2, 58.0, 57.6, 52.6, 45.3, 21.5; HRMS (ESI) calcd for C<sub>22</sub>H<sub>22</sub>NO<sub>3</sub>S [M+H]<sup>+</sup>: 380.1315; found: 380.1322.

**(Z)-4-(2-oxopropylidene)-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3a)**



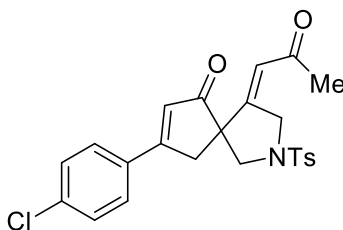
Column chromatography (petroleum ether/EtOAc = 20:1 to 4:1) to afford **3a** in 83% yield (70.0 mg); colorless solid, mp 162–164 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.73 (d, *J* = 8.2 Hz, 2H), 7.65 (d, *J* = 7.2 Hz, 2H), 7.54 (t, *J* = 7.3 Hz, 1H), 7.49 (t, *J* = 7.4 Hz, 2H), 7.34 (d, *J* = 8.0 Hz, 2H), 6.65 (s, 1H), 5.87 (t, *J* = 2.4 Hz, 1H), 4.79 (dd, *J* = 18.8, 2.3 Hz, 1H), 3.95 (dd, *J* = 18.8, 2.6 Hz, 1H), 3.59 (d, *J* = 9.5 Hz, 1H), 3.38 (dd, *J* = 18.4, 1.2 Hz, 1H), 3.19 (d, *J* = 9.5 Hz, 1H), 3.16 (dd, *J* = 18.5, 1.3 Hz, 1H), 2.44 (s, 3H), 2.11 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 204.7, 197.0, 173.1, 160.4, 144.2, 132.7, 132.4, 131.7, 129.9, 129.2, 128.0, 127.1, 126.0, 119.0, 59.3, 56.5, 53.7, 45.9, 31.2, 21.5; HRMS (ESI) calcd for C<sub>24</sub>H<sub>24</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 422.1421; found: 422.1427.

**(Z)-8-(4-fluorophenyl)-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3b)**



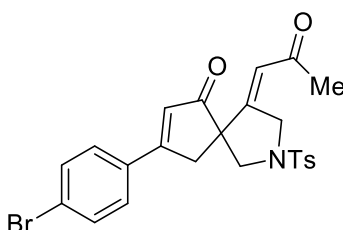
Column chromatography (petroleum ether/EtOAc = 15:1 to 3:1) to afford **3b** in 88% yield (77.4 mg); pale-yellow oil; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.74 (d, *J* = 8.1 Hz, 2H), 7.69–7.64 (m, 2H), 7.35 (d, *J* = 8.0 Hz, 2H), 7.19 (t, *J* = 8.5 Hz, 2H), 6.60 (s, 1H), 5.87 (t, *J* = 2.4 Hz, 1H), 4.79 (dd, *J* = 18.8, 2.3 Hz, 1H), 3.94 (dd, *J* = 18.8, 2.6 Hz, 1H), 3.59 (d, *J* = 9.4 Hz, 1H), 3.38 (d, *J* = 18.3 Hz, 1H), 3.20–3.12 (m, 2H), 2.45 (s, 3H), 2.12 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 204.5, 197.0, 171.7, 165.03 (d, *J* = 255.3 Hz), 160.3, 144.2, 131.7, 129.9, 129.42 (d, *J* = 8.9 Hz), 129.1, 128.0, 125.8, 119.1, 116.5 (d, *J* = 22.1 Hz), 59.4, 56.5, 53.6, 46.0, 31.2, 21.5; <sup>19</sup>F NMR (565 MHz, CDCl<sub>3</sub>) δ -105.66–-105.71 (m); HRMS (ESI) calcd for C<sub>24</sub>H<sub>23</sub>FNO<sub>4</sub>S [M+H]<sup>+</sup>: 440.1326; found: 440.1333.

**(Z)-8-(4-chlorophenyl)-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3c)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 4:1) to afford **3c** in 79% yield (72.0 mg); yellow solid, mp 166–168 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.71 (d, *J* = 8.1 Hz, 2H), 7.58 (d, *J* = 8.5 Hz, 2H), 7.45 (d, *J* = 8.5 Hz, 2H), 7.33 (d, *J* = 8.0 Hz, 2H), 6.62 (s, 1H), 5.86 (t, *J* = 2.3 Hz, 1H), 4.76 (dd, *J* = 18.8, 2.2 Hz, 1H), 3.93 (dd, *J* = 18.8, 2.6 Hz, 1H), 3.57 (d, *J* = 9.5 Hz, 1H), 3.35 (dd, *J* = 18.4, 1.0 Hz, 1H), 3.17 (d, *J* = 9.5 Hz, 1H), 3.12 (dd, *J* = 18.4, 1.2 Hz, 1H), 2.43 (s, 3H), 2.11 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 204.5, 196.9, 171.5, 160.1, 144.2, 138.5, 131.7, 131.2, 129.9, 129.5, 128.4, 128.0, 126.3, 119.1, 59.3, 56.4, 53.6, 45.7, 31.1, 21.5; HRMS (ESI) calcd for C<sub>24</sub>H<sub>23</sub>ClNO<sub>4</sub>S [M+H]<sup>+</sup>: 456.1031; found: 456.1038.

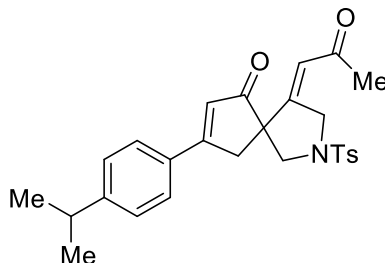
**(Z)-8-(4-bromophenyl)-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3d)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 4:1) to afford **3d** in 81% yield (81.1 mg); colorless solid, mp 176–178 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.72 (d, *J* = 8.2 Hz, 2H), 7.62 (d, *J* = 8.6 Hz, 2H), 7.51 (d, *J* = 8.6 Hz, 2H), 7.34 (d, *J* = 8.0 Hz, 2H), 6.64 (s, 1H), 5.86 (t, *J* = 2.5 Hz, 1H), 4.76 (dd, *J* = 18.8, 2.4 Hz, 1H), 3.93 (dd, *J* = 18.8, 2.7 Hz, 1H), 3.58 (d, *J* = 9.5 Hz, 1H), 3.35 (dd, *J* = 18.4, 1.4 Hz, 1H), 3.17 (d, *J* = 9.5 Hz, 1H), 3.13 (dd, *J* = 18.4, 1.5 Hz, 1H), 2.44 (s, 3H), 2.11 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 204.5, 196.9, 171.6, 160.1, 144.2, 132.5, 131.7, 131.6, 129.9, 128.5, 128.0, 127.0, 126.4, 119.1, 59.3, 56.5, 53.6, 45.7, 31.2, 21.5; HRMS (ESI) calcd

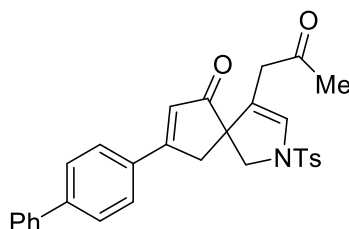
for C<sub>24</sub>H<sub>23</sub>BrNO<sub>4</sub>S [M+H]<sup>+</sup>: 500.0526; found: 500.0536.

**(Z)-8-(4-isopropylphenyl)-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3e)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 4:1) to afford **3e** in 73% yield (67.7 mg); yellow solid, mp 153–155 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.73 (d, *J* = 8.2 Hz, 2H), 7.59 (d, *J* = 8.3 Hz, 2H), 7.35 (d, *J* = 3.5 Hz, 2H), 7.34 (d, *J* = 3.3 Hz, 2H), 6.62 (s, 1H), 5.86 (t, *J* = 2.5 Hz, 1H), 4.79 (dd, *J* = 18.8, 2.3 Hz, 1H), 3.94 (dd, *J* = 18.8, 2.7 Hz, 1H), 3.58 (d, *J* = 9.5 Hz, 1H), 3.36 (dd, *J* = 18.4, 1.4 Hz, 1H), 3.20 (d, *J* = 9.5 Hz, 1H), 3.14 (dd, *J* = 18.4, 1.4 Hz, 1H), 3.00–2.95 (m, 1H), 2.44 (s, 3H), 2.11 (s, 3H), 1.28 (d, *J* = 6.9 Hz, 6H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 204.7, 197.0, 173.1, 160.6, 154.1, 144.1, 131.7, 130.4, 129.9, 128.0, 127.33, 127.28, 125.1, 118.9, 59.2, 56.5, 53.7, 45.9, 34.2, 31.1, 23.6, 21.5; HRMS (ESI) calcd for C<sub>27</sub>H<sub>30</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>:464.1890; found: 464.1898.

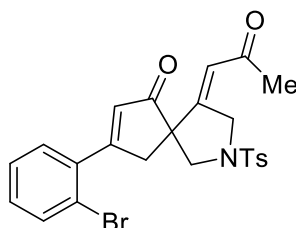
**8-([1,1'-biphenyl]-4-yl)-4-(2-oxopropyl)-2-tosyl-2-azaspiro[4.4]nona-3,7-dien-6-one (3f')**



Column chromatography (petroleum ether/EtOAc = 15:1 to 3:1) to afford **3f** in 72% yield (71.7 mg); yellow solid, mp 156–158 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.75 (d, *J* = 8.2 Hz, 2H), 7.67 (d, *J* = 8.3 Hz, 2H), 7.62 (d, *J* = 7.5 Hz, 2H), 7.58 (d, *J* = 8.4 Hz, 2H), 7.48 (t, *J* = 7.6 Hz, 2H), 7.44–7.38 (m, 3H), 6.62 (s, 1H), 6.54 (s, 1H), 3.79 (d, *J* = 11.0 Hz, 1H), 3.59 (d, *J* = 11.1 Hz, 1H), 2.95 (d, *J* = 17.6 Hz, 1H), 2.90 (dd, *J* = 18.5, 1.4 Hz, 1H), 2.84 (d, *J* = 17.5 Hz, 1H), 2.64 (dd, *J* = 18.6, 1.2 Hz, 1H), 2.51 (s, 3H),

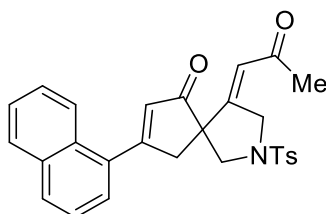
2.06 (s, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  206.9, 204.5, 171.7, 144.8, 144.2, 139.5, 132.6, 131.7, 130.8, 129.8, 129.0, 128.3, 127.9, 127.6, 127.5, 127.0, 125.6, 120.8, 60.6, 57.8, 42.3, 39.4, 29.4, 21.6; HRMS (ESI) calcd for  $\text{C}_{30}\text{H}_{28}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 498.1734; found: 498.1740.

**(Z)-8-(2-bromophenyl)-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3g)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 3:1) to afford **3g** in 83% yield (83.1 mg); colorless solid, mp 145–147 °C;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.73 (d,  $J$  = 8.2 Hz, 2H), 7.69 (d,  $J$  = 8.0 Hz, 1H), 7.43–7.39 (m, 1H), 7.35–7.32 (m, 3H), 7.32–7.28 (m, 1H), 6.61 (d,  $J$  = 1.5 Hz, 1H), 6.00 (t,  $J$  = 2.5 Hz, 1H), 4.75 (dd,  $J$  = 18.7, 2.3 Hz, 1H), 3.96 (dd,  $J$  = 18.7, 2.7 Hz, 1H), 3.61 (d,  $J$  = 9.5 Hz, 1H), 3.35 (dd,  $J$  = 18.8, 1.7 Hz, 1H), 3.24 (d,  $J$  = 9.5 Hz, 1H), 3.18 (dd,  $J$  = 18.8, 1.6 Hz, 1H), 2.43 (s, 3H), 2.15 (s, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  204.8, 196.9, 173.8, 159.8, 144.2, 135.4, 134.2, 132.0, 131.9, 131.4, 129.9, 128.9, 128.0, 127.8, 121.4, 119.0, 59.3, 56.1, 53.6, 48.5, 31.2, 21.5; HRMS (ESI) calcd for  $\text{C}_{24}\text{H}_{23}\text{BrNO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 500.0526; found: 500.0531.

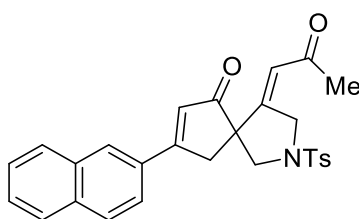
**(Z)-8-(naphthalen-1-yl)-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3h)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 3:1) to afford **3h** in 83% yield (78.3 mg); yellow solid, mp 131–133 °C;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  8.11–8.06 (m, 1H), 7.96 (dd,  $J$  = 7.5, 1.5 Hz, 1H), 7.94 (dd,  $J$  = 7.0, 2.4 Hz, 1H), 7.75 (d,  $J$  = 8.2 Hz, 2H), 7.63–7.51 (m, 4H), 7.34 (d,  $J$  = 8.0 Hz, 2H), 6.62 (s, 1H), 6.02 (t,  $J$  = 2.5

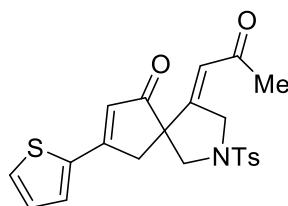
Hz, 1H), 4.80 (dd,  $J = 18.7, 2.4$  Hz, 1H), 4.01 (dd,  $J = 18.8, 2.7$  Hz, 1H), 3.68 (d,  $J = 9.5$  Hz, 1H), 3.49 (dd,  $J = 18.8, 1.5$  Hz, 1H), 3.29 (d,  $J = 9.5$  Hz, 1H), 3.26 (dd,  $J = 18.8, 1.6$  Hz, 1H), 2.43 (s, 3H), 2.17 (s, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  204.7, 196.9, 173.9, 160.1, 144.2, 133.9, 132.4, 131.9, 131.7, 131.4, 129.9, 129.9, 129.1, 128.0, 127.4, 126.6, 125.3, 125.0, 124.3, 118.9, 59.1, 56.5, 53.7, 49.2, 31.2, 21.5; HRMS (ESI) calcd for  $\text{C}_{28}\text{H}_{26}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 472.1577; found: 472.1584.

**(Z)-8-(naphthalen-2-yl)-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3i)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 3:1) to afford **3i** in 80% yield (75.05mg); yellow solid, mp 177–179 °C;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  8.11 (s, 1H), 7.95–7.91 (m, 2H), 7.88 (d,  $J = 7.9$  Hz, 1H), 7.75 (d,  $J = 8.0$  Hz, 3H), 7.65–7.54 (m, 2H), 7.35 (d,  $J = 8.0$  Hz, 2H), 6.77 (s, 1H), 5.92 (t,  $J = 2.4$  Hz, 1H), 4.83 (dd,  $J = 18.8, 2.2$  Hz, 1H), 3.97 (dd,  $J = 18.8, 2.6$  Hz, 1H), 3.64 (d,  $J = 9.5$  Hz, 1H), 3.54 (d,  $J = 18.2$  Hz, 1H), 3.32 (dd,  $J = 18.2, 1.0$  Hz, 1H), 3.22 (d,  $J = 9.5$  Hz, 1H), 2.45 (s, 3H), 2.12 (s, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  204.7, 197.0, 172.8, 160.5, 144.2, 135.0, 132.9, 131.7, 130.1, 129.9, 129.2, 129.0, 128.4, 128.1, 127.9, 127.8, 127.3, 126.3, 123.6, 119.0, 59.4, 56.6, 53.7, 46.0, 31.2, 21.5; HRMS (ESI) calcd for  $\text{C}_{28}\text{H}_{26}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 472.1577; found: 472.1583.

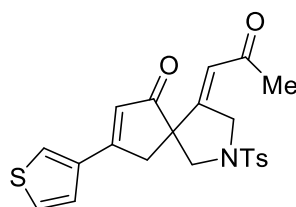
**(Z)-4-(2-oxopropylidene)-8-(thiophen-2-yl)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3j)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 3:1) to afford **3j** in 40%

yield (34.2 mg); yellow solid, mp 150–152 °C;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.73 (d,  $J = 8.0$  Hz, 2H), 7.65 (d,  $J = 5.0$  Hz, 1H), 7.47 (d,  $J = 3.6$  Hz, 1H), 7.35 (d,  $J = 8.0$  Hz, 2H), 7.19 (t,  $J = 4.3$  Hz, 1H), 6.42 (s, 1H), 5.89 (s, 1H), 4.78 (dd,  $J = 18.8, 1.9$  Hz, 1H), 3.93 (dd,  $J = 18.8, 2.5$  Hz, 1H), 3.59 (d,  $J = 9.5$  Hz, 1H), 3.38 (d,  $J = 18.1$  Hz, 1H), 3.18 (d,  $J = 9.5$  Hz, 1H), 3.15 (d,  $J = 18.3$  Hz, 1H), 2.44 (s, 3H), 2.13 (s, 3H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  203.8, 197.0, 165.6, 160.4, 144.2, 137.5, 132.0, 131.8, 130.0, 129.9, 128.8, 128.1, 124.3, 119.1, 59.3, 56.6, 53.7, 46.4, 31.2, 21.5; **HRMS (ESI)** calcd for  $\text{C}_{22}\text{H}_{22}\text{NO}_4\text{S}_2$   $[\text{M}+\text{H}]^+$ : 428.0985; found: 428.0994.

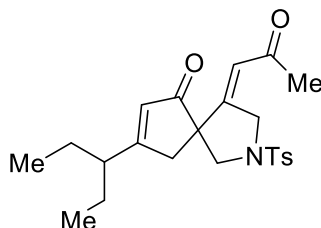
**(Z)-4-(2-oxopropylidene)-8-(thiophen-3-yl)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3k)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 3:1) to afford **3k** in 57% yield (48.7 mg); colorless solid, mp 165–167 °C;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.75–7.71 (m, 3H), 7.46 (dd,  $J = 5.1, 2.9$  Hz, 1H), 7.38 (dd,  $J = 5.1, 1.2$  Hz, 1H), 7.37 (d,  $J = 8.1$  Hz, 2H), 6.44 (s, 1H), 5.87 (t,  $J = 2.6$  Hz, 1H), 4.78 (dd,  $J = 18.8, 2.4$  Hz, 1H), 3.93 (dd,  $J = 18.8, 2.7$  Hz, 1H), 3.58 (d,  $J = 9.4$  Hz, 1H), 3.36 (dd,  $J = 18.3, 1.5$  Hz, 1H), 3.17 (d,  $J = 9.4$  Hz, 1H), 3.13 (dd,  $J = 18.3, 1.5$  Hz, 1H), 2.44 (s, 3H), 2.12 (s, 3H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  204.7, 197.0, 167.1, 160.4, 144.2, 136.1, 131.6, 129.9, 128.3, 128.0, 127.6, 125.9, 125.2, 119.0, 59.1, 56.5, 53.6, 46.3, 31.1, 21.5; **HRMS (ESI)** calcd for  $\text{C}_{22}\text{H}_{22}\text{NO}_4\text{S}_2$   $[\text{M}+\text{H}]^+$ : 428.0985; found: 428.0993.

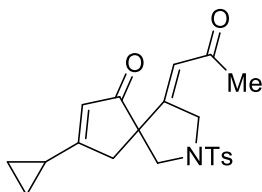


**(Z)-4-(2-oxopropylidene)-8-(pentan-3-yl)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one**  
**(3l)**



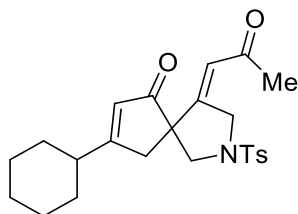
Column chromatography (petroleum ether/EtOAc = 20:1 to 4:1) to afford **3l** in 71% yield (59.0 mg); colorless solid, mp 145–147 °C;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.70 (d,  $J = 8.2$  Hz, 2H), 7.32 (d,  $J = 8.1$  Hz, 2H), 6.03 (s, 1H), 5.78 (t,  $J = 2.5$  Hz, 1H), 4.70 (dd,  $J = 18.8, 2.3$  Hz, 1H), 3.88 (dd,  $J = 18.8, 2.7$  Hz, 1H), 3.45 (d,  $J = 9.4$  Hz, 1H), 3.10 (d,  $J = 9.4$  Hz, 1H), 2.85 (dd,  $J = 18.9, 1.0$  Hz, 1H), 2.65 (dd,  $J = 18.9, 1.0$  Hz, 1H), 2.41 (s, 3H), 2.40–2.35 (m, 1H), 2.10 (s, 3H), 1.65–1.56 (m, 2H), 1.53–1.44 (m, 2H), 0.85 (t,  $J = 7.4$  Hz, 6H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  205.1, 196.8, 185.9, 160.6, 144.1, 131.7, 129.8, 128.0, 118.4, 58.9, 56.4, 53.6, 46.7, 46.2, 31.1, 25.8, 25.8, 21.5, 11.7, 11.6; **HRMS (ESI)** calcd for  $\text{C}_{23}\text{H}_{30}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 416.1890; found: 416.1899.

**(Z)-8-cyclopropyl-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one**  
**(3m)**



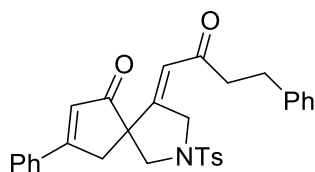
Column chromatography (petroleum ether/EtOAc = 15:1 to 3:1) to afford **3m** in 41% yield (31.6 mg); colorless solid, mp 147–149 °C;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.70 (d,  $J = 8.2$  Hz, 2H), 7.32 (d,  $J = 8.0$  Hz, 2H), 6.01 (s, 1H), 5.80 (t,  $J = 2.5$  Hz, 1H), 4.70 (dd,  $J = 18.7, 2.4$  Hz, 1H), 3.86 (dd,  $J = 18.8, 2.7$  Hz, 1H), 3.46 (d,  $J = 9.4$  Hz, 1H), 3.06 (d,  $J = 9.4$  Hz, 1H), 2.77 (dd,  $J = 18.6, 1.1$  Hz, 1H), 2.53 (dd,  $J = 18.6, 1.2$  Hz, 1H), 2.43 (s, 3H), 2.13 (s, 3H), 1.96–1.88 (m, 1H), 1.18 (dd,  $J = 8.2, 2.6$  Hz, 2H), 0.96–0.88 (m, 2H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  204.2, 197.0, 185.4, 160.4, 144.2, 131.6, 129.9, 128.0, 126.3, 118.8, 58.9, 56.4, 53.6, 45.8, 31.2, 21.5, 15.4, 10.9, 10.8; **HRMS (ESI)** calcd for  $\text{C}_{21}\text{H}_{34}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 386.1421; found: 386.1432.

**(Z)-8-cyclohexyl-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3n)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 4:1) to afford **3n** in 47% yield (40.2 mg); colorless solid, mp 153–155 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.70 (d, *J* = 8.2 Hz, 2H), 7.32 (d, *J* = 8.0 Hz, 2H), 5.99 (d, *J* = 1.0 Hz, 1H), 5.77 (t, *J* = 2.5 Hz, 1H), 4.70 (dd, *J* = 18.7, 2.4 Hz, 1H), 3.88 (dd, *J* = 18.7, 2.7 Hz, 1H), 3.45 (d, *J* = 9.3 Hz, 1H), 3.09 (d, *J* = 9.4 Hz, 1H), 2.93 (dd, *J* = 18.8, 0.8 Hz, 1H), 2.71 (dd, *J* = 18.8, 0.9 Hz, 1H), 2.42 (s, 3H), 2.38–2.31 (m, 1H), 2.12 (s, 3H), 1.89 (d, *J* = 12.1 Hz, 2H), 1.85–1.80 (m, 2H), 1.74 (dd, *J* = 9.8, 3.3 Hz, 1H), 1.37–1.31 (m, 2H), 1.30–1.20 (m, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 205.4, 197.0, 187.3, 160.4, 144.1, 131.7, 129.9, 128.0, 127.1, 118.5, 59.0, 56.3, 53.6, 47.1, 41.9, 31.1, 31.1, 31.1, 25.8, 25.8, 25.7, 21.5; HRMS (ESI) calcd for C<sub>24</sub>H<sub>30</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 428.1890; found: 428.1898.

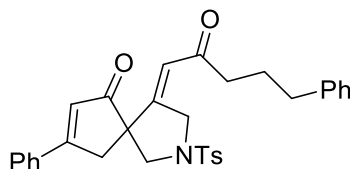
**(Z)-4-(2-oxo-4-phenylbutylidene)-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3o)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 4:1) to afford **3o** in 76% yield (77.8 mg); pale-yellow solid, mp 128–130 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.75 (d, *J* = 8.2 Hz, 2H), 7.67–7.62 (m, 2H), 7.57–7.52 (m, 1H), 7.50 (t, *J* = 7.4 Hz, 2H), 7.36 (d, *J* = 8.0 Hz, 2H), 7.21 (t, *J* = 7.6 Hz, 2H), 7.14–7.07 (m, 3H), 6.64 (s, 1H), 5.81 (t, *J* = 2.6 Hz, 1H), 4.81 (dd, *J* = 18.8, 2.3 Hz, 1H), 3.96 (dd, *J* = 18.8, 2.7 Hz, 1H), 3.59 (d, *J* = 9.5 Hz, 1H), 3.37 (dd, *J* = 18.4, 1.4 Hz, 1H), 3.19 (d, *J* = 9.5 Hz, 1H), 3.11 (dd, *J* = 18.4, 1.5 Hz, 1H), 2.90–2.79 (m, 2H), 2.74–2.67 (m, 2H), 2.45 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 204.7, 198.5, 173.1, 160.4, 144.2, 140.6, 132.7, 132.4, 131.7, 129.9, 129.2, 128.4, 128.2, 128.1, 127.2, 126.1, 126.0, 118.6, 59.3, 56.5, 53.7,

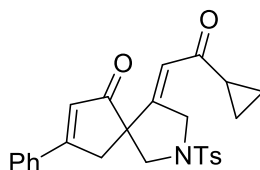
45.9, 45.3, 29.6, 21.5; **HRMS (ESI)** calcd for C<sub>31</sub>H<sub>30</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 512.1890; found: 512.1899.

**(Z)-4-(2-oxo-5-phenylpentylidene)-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3p)**



Column chromatography (petroleum ether/EtOAc = 20:1 to 5:1) to afford **3p** in 82% yield (86.2 mg); colorless solid, mp 139–141 °C; **<sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>)** δ 7.74 (d, *J* = 8.2 Hz, 2H), 7.68–7.63 (m, 2H), 7.56–7.52 (m, 1H), 7.50 (t, *J* = 7.4 Hz, 2H), 7.35 (d, *J* = 8.1 Hz, 2H), 7.23 (t, *J* = 7.5 Hz, 2H), 7.14 (t, *J* = 7.4 Hz, 1H), 7.11 (d, *J* = 7.2 Hz, 2H), 6.65 (s, 1H), 5.82 (t, *J* = 2.6 Hz, 1H), 4.80 (dd, *J* = 18.7, 2.3 Hz, 1H), 3.96 (dd, *J* = 18.7, 2.7 Hz, 1H), 3.59 (d, *J* = 9.4 Hz, 1H), 3.38 (dd, *J* = 18.4, 1.4 Hz, 1H), 3.19 (d, *J* = 9.4 Hz, 1H), 3.14 (dd, *J* = 18.4, 1.5 Hz, 1H), 2.56 (t, *J* = 7.2 Hz, 2H), 2.44 (s, 3H), 2.37 (td, *J* = 7.1, 2.0 Hz, 2H), 1.89–1.81 (m, 2H); **<sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>)** δ 204.7, 199.2, 173.1, 160.1, 144.2, 141.3, 132.7, 132.3, 131.7, 129.9, 129.2, 128.4, 128.3, 128.1, 127.1, 126.0, 125.9, 118.7, 59.3, 56.6, 53.7, 46.0, 43.0, 34.9, 24.9, 21.5; **HRMS (ESI)** calcd for C<sub>32</sub>H<sub>32</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 526.2047; found: 526.2052.

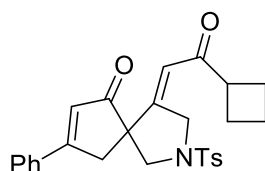
**(Z)-4-(2-cyclopropyl-2-oxoethylidene)-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3q)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 4:1) to afford **3q** in 82% yield (73.4 mg); colorless solid, mp 155–157 °C; **<sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>)** δ 7.73 (d, *J* = 7.9 Hz, 2H), 7.67 (d, *J* = 7.7 Hz, 2H), 7.56–7.52 (m, 1H), 7.50 (t, *J* = 7.3 Hz, 2H), 7.34 (d, *J* = 7.9 Hz, 2H), 6.68 (s, 1H), 6.03 (s, 1H), 4.79 (d, *J* = 18.7 Hz, 1H), 3.94 (dd, *J* = 18.7, 2.5 Hz, 1H), 3.60 (d, *J* = 9.4 Hz, 1H), 3.40 (d, *J* = 18.4 Hz, 1H), 3.24–3.17 (m, 2H), 2.44 (s, 3H), 1.86–1.80 (m, 1H), 1.03–0.96 (m, 2H), 0.85 (dd, *J* = 7.7, 2.9

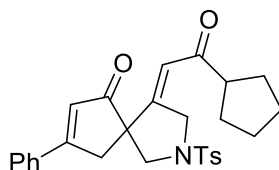
Hz, 2H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  204.9, 199.3, 173.1, 159.5, 144.1, 132.8, 132.3, 131.7, 129.9, 129.2, 128.1, 127.2, 126.1, 119.2, 59.4, 56.6, 53.8, 46.1, 22.2, 21.5, 11.8, 11.8; HRMS (ESI) calcd for  $\text{C}_{26}\text{H}_{26}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 448.1577; found: 448.1586.

**(Z)-4-(2-cyclobutyl-2-oxoethylidene)-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3r)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 4:1) to afford **3r** in 96% yield (88.6 mg); colorless solid, mp 156–158 °C;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.74 (d,  $J$  = 8.2 Hz, 2H), 7.67–7.64 (m, 2H), 7.54 (t,  $J$  = 7.3 Hz, 1H), 7.50 (t,  $J$  = 7.3 Hz, 2H), 7.35 (d,  $J$  = 8.0 Hz, 2H), 6.65 (s, 1H), 5.77 (t,  $J$  = 2.6 Hz, 1H), 4.83 (dd,  $J$  = 18.7, 2.3 Hz, 1H), 3.98 (dd,  $J$  = 18.7, 2.7 Hz, 1H), 3.59 (d,  $J$  = 9.4 Hz, 1H), 3.40 (dd,  $J$  = 18.4, 1.4 Hz, 1H), 3.18 (d,  $J$  = 9.5 Hz, 2H), 3.16–3.13 (m, 1H), 2.45 (s, 3H), 2.16–2.09 (m, 2H), 2.09–2.02 (m, 2H), 1.93–1.86 (m, 1H), 1.80–1.73 (m, 1H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  204.8, 200.5, 173.1, 160.6, 144.2, 132.8, 132.3, 131.7, 129.9, 129.2, 128.1, 127.2, 126.1, 117.3, 59.4, 56.7, 53.8, 46.1, 46.1, 24.1, 23.9, 21.6, 17.5; HRMS (ESI) calcd for  $\text{C}_{27}\text{H}_{28}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 462.1734; found: 462.1746.

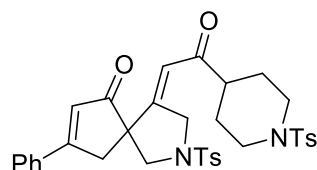
**(Z)-4-(2-cyclopentyl-2-oxoethylidene)-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3s)**



Column chromatography (petroleum ether/EtOAc = 10:1 to 5:1) to afford **3s** in 97% yield (92.3 mg); colorless solid, mp 164–166 °C;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.73 (d,  $J$  = 8.2 Hz, 2H), 7.69–7.63 (m, 2H), 7.56–7.52 (m, 1H), 7.50 (t,  $J$  = 7.4 Hz, 2H), 7.34 (d,  $J$  = 8.1 Hz, 2H), 6.66 (s, 1H), 5.89 (t,  $J$  = 2.6 Hz, 1H), 4.80 (dd,  $J$  = 18.6, 2.3 Hz, 1H), 3.96 (dd,  $J$  = 18.6, 2.7 Hz, 1H), 3.58 (d,  $J$  = 9.4 Hz, 1H), 3.40 (dd,  $J$  = 18.4, 1.4 Hz, 1H), 3.20–3.12 (m, 2H), 2.83–2.75 (m, 1H), 2.44 (s, 3H), 1.73–1.62 (m, 4H),

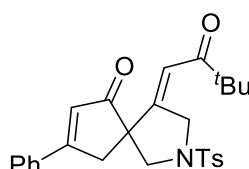
1.60–1.54 (m, 2H), 1.53–1.48 (m, 2H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 204.8, 201.8, 173.0, 160.2, 144.1, 132.8, 132.3, 131.7, 129.9, 129.2, 128.1, 127.1, 126.0, 118.6, 59.4, 56.7, 53.8, 52.0, 46.1, 28.6, 28.5, 25.9, 25.9, 21.5; HRMS (ESI) calcd for C<sub>28</sub>H<sub>30</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 476.1890; found: 476.1897.

**(Z)-4-(2-oxo-2-(1-tosylpiperidin-4-yl)ethylidene)-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3t)**



Column chromatography (petroleum ether/EtOAc = 8:1 to 2:1) to afford **3t** in 97% yield (125.1 mg); colorless solid, mp 120–123 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.72 (d, *J* = 8.2 Hz, 2H), 7.66–7.63 (m, 2H), 7.59 (d, *J* = 8.2 Hz, 2H), 7.56–7.53 (m, 1H), 7.50 (t, *J* = 7.4 Hz, 2H), 7.35 (d, *J* = 8.1 Hz, 2H), 7.29 (d, *J* = 8.1 Hz, 2H), 6.63 (s, 1H), 5.84 (t, *J* = 2.5 Hz, 1H), 4.76 (dd, *J* = 18.9, 2.3 Hz, 1H), 3.91 (dd, *J* = 18.9, 2.7 Hz, 1H), 3.68–3.62 (m, 2H), 3.59 (d, *J* = 9.4 Hz, 1H), 3.40 (dd, *J* = 18.4, 1.4 Hz, 1H), 3.16 (d, *J* = 9.5 Hz, 1H), 3.13 (dd, *J* = 18.4, 1.5 Hz, 1H), 2.45 (s, 3H), 2.41 (s, 3H), 2.33 (td, *J* = 11.7, 9.0, 2.9 Hz, 2H), 2.22–2.17 (m, 1H), 1.79–1.73 (m, 2H), 1.64–1.61 (m, 2H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 204.5, 199.8, 173.1, 162.3, 144.2, 143.6, 132.9, 132.6, 132.4, 131.7, 129.9, 129.6, 129.2, 128.0, 127.5, 127.1, 125.8, 116.9, 59.5, 56.5, 53.8, 47.7, 45.9, 45.3, 45.3, 26.7, 26.6, 21.5, 21.4; HRMS (ESI) calcd for C<sub>35</sub>H<sub>37</sub>N<sub>2</sub>O<sub>6</sub>S<sub>2</sub> [M+H]<sup>+</sup>: 645.2088; found: 645.2098.

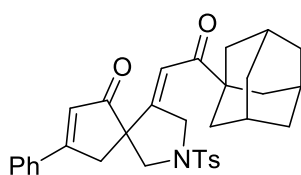
**(Z)-4-(3,3-dimethyl-2-oxobutylidene)-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3u)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 4:1) to afford **3u** in 63% yield (58.4 mg); colorless solid, mp 150–152 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.73 (d, *J* = 8.0 Hz, 2H), 7.66 (d, *J* = 7.7 Hz, 2H), 7.54 (t, *J* = 7.2 Hz, 1H), 7.50 (t, *J* = 7.5

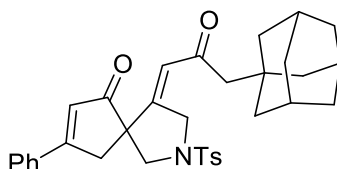
Hz, 2H), 7.34 (d,  $J = 8.0$  Hz, 2H), 6.66 (s, 1H), 6.12 (t,  $J = 2.3$  Hz, 1H), 4.79 (dd,  $J = 18.6, 2.1$  Hz, 1H), 3.95 (dd,  $J = 18.6, 2.6$  Hz, 1H), 3.58 (d,  $J = 9.4$  Hz, 1H), 3.42 (d,  $J = 18.4$  Hz, 1H), 3.19–3.13 (m, 2H), 2.44 (s, 3H), 1.04 (s, 9H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  204.8, 204.5, 173.0, 161.1, 144.1, 132.8, 132.3, 131.7, 129.9, 129.20, 128.1, 127.1, 126.1, 115.0, 59.6, 56.8, 53.9, 46.2, 43.6, 26.1, 21.5; HRMS (ESI) calcd for  $\text{C}_{27}\text{H}_{30}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ :464.1890; found: 464.1997.

**(Z)-4-(2-(adamantan-1-yl)-2-oxoethylidene)-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3v)**



Column chromatography (petroleum ether/EtOAc = 10:1 to 5:1) to afford **3v** in 74% yield (80.2 mg); colorless solid, mp 128–130 °C;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.73 (d,  $J = 8.2$  Hz, 2H), 7.69–7.65 (m, 2H), 7.56–7.53 (m, 1H), 7.50 (t,  $J = 7.3$  Hz, 2H), 7.34 (d,  $J = 8.0$  Hz, 2H), 6.68 (s, 1H), 6.13 (t,  $J = 2.5$  Hz, 1H), 4.78 (dd,  $J = 18.6, 2.3$  Hz, 1H), 3.94 (dd,  $J = 18.7, 2.7$  Hz, 1H), 3.57 (d,  $J = 9.3$  Hz, 1H), 3.42 (dd,  $J = 18.4, 1.2$  Hz, 1H), 3.16–3.13 (m, 2H), 2.44 (s, 3H), 1.97 (s, 3H), 1.71–1.64 (m, 9H), 1.64–1.56 (m, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  205.0, 204.1, 173.0, 161.0, 144.1, 132.8, 132.3, 131.6, 129.9, 129.2, 128.1, 127.2, 126.2, 114.6, 59.7, 56.9, 54.0, 46.3, 45.8, 37.7, 36.3, 27.7, 21.5; HRMS (ESI) calcd for  $\text{C}_{33}\text{H}_{36}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ :542.2360; found: 542.2375.

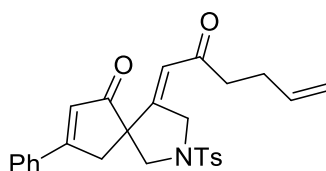
**(Z)-4-(3-(adamantan-1-yl)-2-oxopropylidene)-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3w)**



Column chromatography (petroleum ether/EtOAc = 10:1 to 4:1) to afford **3w** in 92% yield (102.3 mg); colorless solid, mp 108–110 °C;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.74 (d,  $J = 8.2$  Hz, 2H), 7.65 (d,  $J = 7.2$  Hz, 2H), 7.54 (t,  $J = 7.3$  Hz, 1H), 7.49 (t,  $J = 7.3$

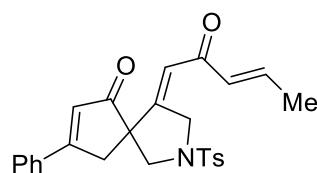
Hz, 2H), 7.34 (d,  $J = 8.0$  Hz, 2H), 6.65 (s, 1H), 5.81 (t,  $J = 2.5$  Hz, 1H), 4.79 (dd,  $J = 18.7, 2.2$  Hz, 1H), 3.95 (dd,  $J = 18.7, 2.6$  Hz, 1H), 3.58 (d,  $J = 9.4$  Hz, 1H), 3.38 (dd,  $J = 18.4, 1.1$  Hz, 1H), 3.19 (d,  $J = 9.4$  Hz, 1H), 3.14 (dd,  $J = 18.4, 1.3$  Hz, 1H), 2.44 (s, 3H), 2.15–2.08 (m, 2H), 1.88 (s, 3H), 1.66–1.61 (m, 3H), 1.58–1.53 (m, 3H), 1.52–1.47 (m, 6H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  204.72, 199.41, 173.0, 159.2, 144.1, 132.8, 132.3, 131.8, 129.9, 129.2, 128.1, 127.1, 126.0, 120.7, 59.3, 57.5, 56.5, 53.7, 46.1, 42.4, 36.6, 34.0, 28.5, 21.5; HRMS (ESI) calcd for  $\text{C}_{34}\text{H}_{38}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ :556.2516; found: 556.2528.

**(Z)-4-(2-oxohex-5-en-1-ylidene)-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3x)**



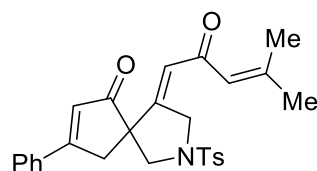
Column chromatography (petroleum ether/EtOAc = 15:1 to 5:1) to afford **3x** in 80% yield (73.9 mg); colorless solid, mp 130–132 °C;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.73 (d,  $J = 7.9$  Hz, 2H), 7.65 (d,  $J = 7.4$  Hz, 2H), 7.53 (t,  $J = 6.9$  Hz, 1H), 7.49 (t,  $J = 7.5$  Hz, 2H), 7.34 (d,  $J = 7.9$  Hz, 2H), 6.65 (s, 1H), 5.86 (t,  $J = 2.4$  Hz, 1H), 5.78–5.67 (m, 1H), 4.95 (d,  $J = 17.1$  Hz, 1H), 4.91 (d,  $J = 10.2$  Hz, 1H), 4.79 (d,  $J = 18.8$  Hz, 1H), 3.96 (dd,  $J = 18.7, 2.6$  Hz, 1H), 3.59 (d,  $J = 9.5$  Hz, 1H), 3.38 (d,  $J = 18.4$  Hz, 1H), 3.19 (d,  $J = 9.5$  Hz, 1H), 3.16 (d,  $J = 18.4$  Hz, 1H), 2.47 (t,  $J = 7.4$  Hz, 2H), 2.44 (s, 3H), 2.28–2.21 (m, 2H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  204.7, 198.6, 173.1, 160.3, 144.1, 136.7, 132.7, 132.3, 131.70, 129.9, 129.2, 128.0, 127.1, 126.0, 118.5, 115.2, 59.3, 56.5, 53.7, 45.9, 42.8, 27.5, 21.5; HRMS (ESI) calcd for  $\text{C}_{27}\text{H}_{28}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ :462.1734; found: 462.1745.

**(Z)-4-((E)-2-oxopent-3-en-1-ylidene)-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3y)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 4:1) to afford **3y** in 65% yield (58.2 mg); yellow oil;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.74 (d,  $J = 8.2$  Hz, 2H), 7.66 (d,  $J = 7.2$  Hz, 2H), 7.54 (t,  $J = 7.3$  Hz, 1H), 7.52–7.48 (m, 2H), 7.34 (d,  $J = 8.1$  Hz, 2H), 6.83–6.72 (m, 1H), 6.67 (s, 1H), 6.09 (dd,  $J = 15.6, 1.5$  Hz, 1H), 6.04 (t,  $J = 2.5$  Hz, 1H), 4.86 (dd,  $J = 18.8, 2.3$  Hz, 1H), 4.01 (dd,  $J = 18.8, 2.7$  Hz, 1H), 3.60 (d,  $J = 9.4$  Hz, 1H), 3.40 (dd,  $J = 18.4, 1.2$  Hz, 1H), 3.22–3.16 (m, 2H), 2.44 (s, 3H), 1.83 (dd,  $J = 6.9, 1.4$  Hz, 3H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  204.9, 188.4, 173.1, 160.9, 144.2, 143.7, 132.8, 132.4, 132.3, 131.8, 129.9, 129.2, 128.1, 127.2, 126.1, 117.5, 59.6, 56.6, 53.8, 46.0, 21.5, 18.3; **HRMS (ESI)** calcd for  $\text{C}_{26}\text{H}_{26}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ :448.1577; found: 448.1589.

**(Z)-4-(4-methyl-2-oxopent-3-en-1-ylidene)-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3z)**

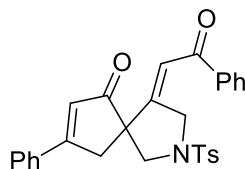


Column chromatography (petroleum ether/EtOAc = 15:1 to 4:1) to afford **3z** in 83% yield (76.6 mg); pale-yellow solid, mp 71–73 °C;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.75 (d,  $J = 8.2$  Hz, 2H), 7.66–7.63 (m, 2H), 7.54–7.51 (m, 1H), 7.51–7.47 (m, 2H), 7.34 (d,  $J = 8.0$  Hz, 2H), 6.64 (s, 1H), 5.96 (d,  $J = 1.1$  Hz, 1H), 5.84 (t,  $J = 2.6$  Hz, 1H), 4.88 (dd,  $J = 18.5, 2.4$  Hz, 1H), 4.04 (dd,  $J = 18.5, 2.6$  Hz, 1H), 3.58 (d,  $J = 9.5$  Hz, 1H), 3.36 (dd,  $J = 18.4, 1.5$  Hz, 1H), 3.22 (d,  $J = 9.5$  Hz, 1H), 3.16 (dd,  $J = 18.4, 1.5$  Hz, 1H), 2.44 (s, 3H), 2.13–2.11 (m, 3H), 1.83 (s, 3H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  204.9, 189.1, 173.0, 159.7, 157.4, 144.0, 132.9, 132.2, 132.1, 129.7, 129.2, 128.1, 127.1, 126.0, 125.0, 121.0, 59.4, 56.5, 53.5, 46.1, 27.70, 21.5, 20.7; **HRMS (ESI)** calcd for



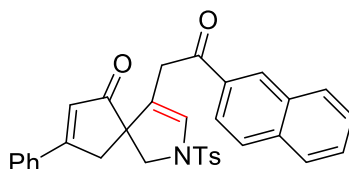
C<sub>27</sub>H<sub>28</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>:462.1734; found: 462.1743.

**(Z)-4-(2-oxo-2-phenylethylidene)-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one**  
**(3aa)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 5:1) to afford **3aa** in 67% yield (64.8 mg); yellow solid, mp 149–151 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.80–7.76 (m, 4H), 7.68 (d, *J* = 7.2 Hz, 2H), 7.57–7.53 (m, 1H), 7.50 (t, *J* = 7.4 Hz, 3H), 7.40 (t, *J* = 7.8 Hz, 2H), 7.36 (d, *J* = 8.1 Hz, 2H), 6.72 (s, 1H), 6.64 (t, *J* = 2.5 Hz, 1H), 4.97 (dd, *J* = 18.8, 2.3 Hz, 1H), 4.12 (dd, *J* = 18.8, 2.7 Hz, 1H), 3.65 (d, *J* = 9.4 Hz, 1H), 3.46 (dd, *J* = 18.5, 1.0 Hz, 1H), 3.28–3.24 (m, 2H), 2.44 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 204.8, 189.4, 173.2, 162.5, 144.2, 137.8, 133.0, 132.8, 132.4, 131.8, 130.0, 129.2, 128.6, 128.1, 128.1, 127.2, 126.2, 115.7, 59.9, 56.8, 54.0, 46.1, 21.5; HRMS (ESI) calcd for C<sub>29</sub>H<sub>25</sub>NNaO<sub>4</sub>S [M+Na]<sup>+</sup>:506.1397; found: 506.1409.

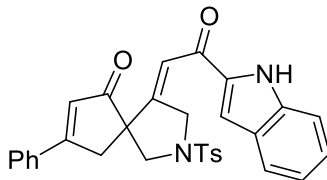
**4-(2-(naphthalen-2-yl)-2-oxoethyl)-8-phenyl-2-tosyl-2-azaspiro[4.4]nona-3,7-dien-6-one (3ab')**



Column chromatography (petroleum ether/EtOAc = 15:1 to 4:1) to afford **3ab** in 69% yield (73.6 mg); pale-yellow solid, mp 97–99 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 8.30 (s, 1H), 7.91–7.83 (m, 4H), 7.62 (t, *J* = 7.7 Hz, 1H), 7.55 (d, *J* = 8.1 Hz, 3H), 7.49–7.44 (m, 3H), 7.43–7.39 (m, 2H), 7.12 (d, *J* = 8.0 Hz, 2H), 6.55 (s, 1H), 6.49 (s, 1H), 3.77 (d, *J* = 11.0 Hz, 1H), 3.70 (d, *J* = 17.3 Hz, 1H), 3.59 (d, *J* = 11.1 Hz, 1H), 3.31 (dd, *J* = 16.7, 1.1 Hz, 1H), 2.94 (dd, *J* = 18.6, 1.2 Hz, 1H), 2.63 (dd, *J* = 18.6, 0.9 Hz, 1H), 2.38 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 207.2, 196.2, 172.4, 144.0, 135.6, 133.1, 132.8, 132.4, 132.2, 132.0, 130.9, 130.7, 129.7, 129.6, 129.0, 128.8, 128.5, 127.8, 127.7, 126.9, 126.8, 125.9, 123.8, 122.2, 60.9, 58.0, 42.2, 34.8, 21.5; HRMS (ESI) calcd for

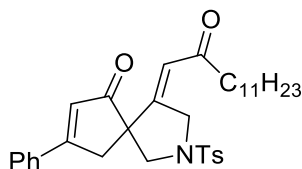
C<sub>33</sub>H<sub>28</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>:534.1734; found: 534.1740.

**(Z)-4-(2-(1H-indol-2-yl)-2-oxoethylidene)-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3ac)**



Column chromatography (petroleum ether/EtOAc = 10:1 to 4:1) to afford **3ac** in 64% yield (66.9 mg); yellow solid, mp 171–173 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 9.12 (s, 1H), 7.78 (d, *J* = 7.8 Hz, 2H), 7.70 (d, *J* = 7.3 Hz, 2H), 7.62 (d, *J* = 7.9 Hz, 1H), 7.58–7.50 (m, 3H), 7.41 (d, *J* = 8.1 Hz, 1H), 7.38–7.32 (m, 3H), 7.11 (t, *J* = 7.4 Hz, 1H), 7.02 (s, 1H), 6.75 (s, 1H), 6.54 (s, 1H), 5.03 (d, *J* = 18.3 Hz, 1H), 4.18 (d, *J* = 18.6 Hz, 1H), 3.65 (d, *J* = 9.3 Hz, 1H), 3.45 (d, *J* = 18.6 Hz, 1H), 3.29–3.23 (m, 2H), 2.44 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 204.8, 180.8, 173.3, 161.2, 144.3, 137.7, 136.2, 132.8, 132.5, 131.8, 130.0, 129.3, 128.1, 127.6, 127.3, 126.7, 126.2, 123.2, 121.1, 115.8, 112.2, 109.4, 59.8, 56.8, 54.0, 46.1, 21.6; HRMS (ESI) calcd for C<sub>31</sub>H<sub>27</sub>N<sub>2</sub>O<sub>4</sub>S [M+H]<sup>+</sup>: 523.1686; found: 523.1698.

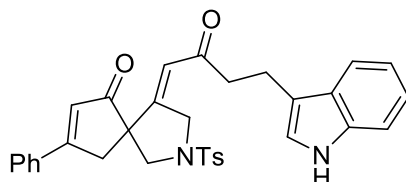
**(Z)-4-(2-oxotridecylidene)-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3ae)**



Column chromatography (petroleum ether/EtOAc = 20:1 to 6:1) to afford **3ae** in 76% yield (85.4 mg); pale-yellow oil; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.74 (d, *J* = 8.2 Hz, 2H), 7.68–7.63 (m, 2H), 7.56–7.52 (m, 1H), 7.52–7.48 (m, 2H), 7.34 (d, *J* = 7.9 Hz, 2H), 6.65 (t, *J* = 1.6 Hz, 1H), 5.85 (t, *J* = 2.6 Hz, 1H), 4.80 (dd, *J* = 18.7, 2.4 Hz, 1H), 3.97 (dd, *J* = 18.7, 2.7 Hz, 1H), 3.59 (d, *J* = 9.5 Hz, 1H), 3.39 (dd, *J* = 18.4, 1.6 Hz, 1H), 3.20 (d, *J* = 9.5 Hz, 1H), 3.16 (dd, *J* = 18.4, 1.6 Hz, 1H), 2.44 (s, 3H), 2.36 (td, *J* = 7.0, 1.1 Hz, 2H), 1.53–1.44 (m, 2H), 1.32–1.25 (m, 3H), 1.24–1.20 (m, 13H), 0.87 (t, *J* = 7.1 Hz, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 204.8, 199.7, 173.0, 156.0, 144.1, 132.8, 132.3, 131.9, 129.9, 129.2, 128.1, 127.1, 126.1, 118.7, 59.4, 56.6, 53.7, 46.0,

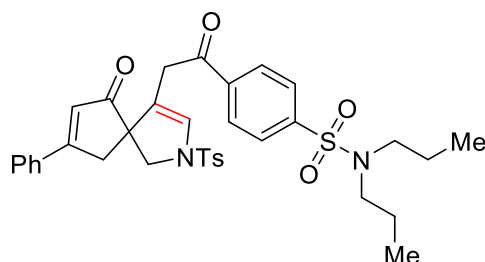
44.0, 31.8, 29.5, 29.5, 29.4, 29.3, 29.3, 29.1, 23.6, 22.6, 21.5, 14.1; **HRMS (ESI)** calcd for C<sub>34</sub>H<sub>44</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>:562.2986; found: 562.2993.

**(Z)-4-(4-(1*H*-indol-3-yl)-2-oxobutylidene)-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3af)**



Column chromatography (petroleum ether/EtOAc = 10:1 to 3:1) to afford **3af** in 78% yield (85.9 mg); yellow solid, mp 151–153 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.98 (s, 1H), 7.74 (d, *J* = 8.0 Hz, 2H), 7.60 (d, *J* = 7.5 Hz, 2H), 7.54 (t, *J* = 7.3 Hz, 1H), 7.49 (t, *J* = 7.5 Hz, 3H), 7.34 (d, *J* = 8.0 Hz, 2H), 7.28 (d, *J* = 8.1 Hz, 1H), 7.13 (t, *J* = 7.6 Hz, 1H), 7.05 (t, *J* = 7.5 Hz, 1H), 6.90 (s, 1H), 6.58 (s, 1H), 5.78 (s, 1H), 4.80 (dd, *J* = 18.7, 1.7 Hz, 1H), 3.98 (dd, *J* = 18.7, 2.4 Hz, 1H), 3.56 (d, *J* = 9.5 Hz, 1H), 3.29 (d, *J* = 18.4 Hz, 1H), 3.20 (d, *J* = 9.5 Hz, 1H), 3.10–2.91 (m, 3H), 2.88–2.67 (m, 2H), 2.45 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 204.7, 199.3, 173.1, 159.9, 144.2, 136.2, 132.7, 132.3, 131.8, 129.9, 129.2, 128.1, 127.2, 127.0, 125.9, 122.0, 121.8, 119.2, 118.8, 118.5, 114.8, 111.1, 59.3, 56.5, 53.7, 45.8, 44.2, 21.6, 19.4; **HRMS (ESI)** calcd for C<sub>33</sub>H<sub>31</sub>N<sub>2</sub>O<sub>4</sub>S [M+H]<sup>+</sup>:551.1999; found: 551.2007.

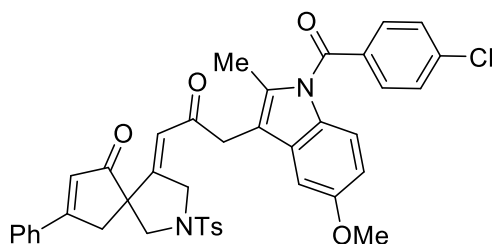
**4-(2-(6-oxo-8-phenyl-2-tosyl-2-azaspiro[4.4]nona-3,7-dien-4-yl)acetyl)-*N,N*-dipropylbenzenesulfonamide (3ag')**



Column chromatography (petroleum ether/EtOAc = 8:1 to 4:1) to afford **3ag** in 43% yield (55.6 mg); yellow solid, mp 123–125 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.92 (d, *J* = 8.5 Hz, 2H), 7.83 (d, *J* = 8.5 Hz, 2H), 7.63 (d, *J* = 8.2 Hz, 2H), 7.52–7.48 (m, 3H), 7.47–7.42 (m, 2H), 7.36 (d, *J* = 8.0 Hz, 2H), 6.53 (s, 1H), 6.48 (s, 1H), 3.76 (d, *J* = 11.0

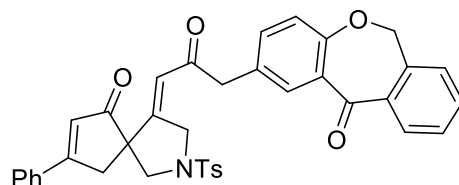
Hz, 1H), 3.60 (d,  $J = 11.0$  Hz, 1H), 3.56 (dd,  $J = 17.2, 1.3$  Hz, 1H), 3.25 (dd,  $J = 17.2, 1.5$  Hz, 1H), 3.12–3.05 (m, 4H), 2.94 (dd,  $J = 18.6, 1.6$  Hz, 1H), 2.68 (dd,  $J = 18.7, 1.4$  Hz, 1H), 2.51 (s, 3H), 1.59–1.49 (m, 4H), 0.86 (t,  $J = 7.4$  Hz, 6H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  207.1, 195.1, 172.5, 144.5, 144.4, 138.5, 132.8, 132.4, 132.2, 131.1, 129.9, 129.1, 129.1, 127.9, 127.3, 127.0, 125.9, 120.9, 60.8, 58.0, 50.0, 42.2, 35.0, 22.0, 21.6, 11.1; HRMS (ESI) calcd for  $\text{C}_{35}\text{H}_{39}\text{N}_2\text{O}_6\text{S}_2$   $[\text{M}+\text{H}]^+$ :647.2244; found: 647.2253.

**(Z)-4-(3-(1-(4-chlorobenzoyl)-5-methoxy-2-methyl-1H-indol-3-yl)-2-oxopropylidene)-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3ah)**



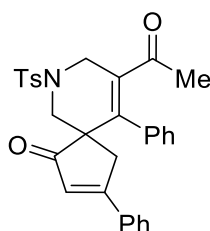
Column chromatography (petroleum ether/EtOAc = 10:1 to 3:1) to afford **3ah** in 90% yield (129.5 mg); pale-yellow solid, mp 180–182 °C;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.72 (d,  $J = 8.1$  Hz, 2H), 7.60–7.56 (m, 4H), 7.53 (t,  $J = 7.3$  Hz, 1H), 7.47 (t,  $J = 7.5$  Hz, 2H), 7.43 (d,  $J = 8.4$  Hz, 2H), 7.33 (d,  $J = 8.1$  Hz, 2H), 6.81 (d,  $J = 9.0$  Hz, 1H), 6.71 (d,  $J = 2.4$  Hz, 1H), 6.61 (dd,  $J = 9.0, 2.5$  Hz, 1H), 6.58 (s, 1H), 5.97 (t,  $J = 2.5$  Hz, 1H), 4.79 (dd,  $J = 18.9, 2.2$  Hz, 1H), 3.96 (dd,  $J = 18.9, 2.7$  Hz, 1H), 3.74 (s, 3H), 3.67 (d,  $J = 1.7$  Hz, 2H), 3.58 (d,  $J = 9.6$  Hz, 1H), 3.31 (d,  $J = 18.4$  Hz, 1H), 3.23 (d,  $J = 9.6$  Hz, 1H), 3.06 (dd,  $J = 18.3, 1.2$  Hz, 1H), 2.43 (s, 3H), 2.21 (s, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  204.4, 195.5, 173.1, 168.1, 161.7, 156.1, 144.2, 139.2, 135.9, 133.7, 132.7, 132.3, 131.9, 131.1, 130.8, 130.5, 129.9, 129.2, 129.1, 128.1, 127.1, 125.8, 117.6, 115.0, 112.0, 111.8, 100.8, 59.5, 56.3, 55.6, 53.7, 45.8, 39.52, 21.5, 13.3; HRMS (ESI) calcd for  $\text{C}_{41}\text{H}_{36}\text{ClN}_2\text{O}_6\text{S}$   $[\text{M}+\text{H}]^+$ :719.1977; found: 719.1989.

**(Z)-4-(2-oxo-3-(11-oxo-6,11-dihydrodibenzo[b,e]oxepin-2-yl)propylidene)-8-phenyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (3ai)**



Column chromatography (petroleum ether/EtOAc = 10:1 to 3:1) to afford **3ai** in 83% yield (104.5 mg); pale-yellow solid, mp 149–151 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.93 (d, *J* = 2.2 Hz, 1H), 7.84 (d, *J* = 7.6 Hz, 1H), 7.71 (d, *J* = 8.2 Hz, 2H), 7.67–7.62 (m, 2H), 7.57–7.50 (m, 2H), 7.50–7.43 (m, 3H), 7.34 (t, *J* = 7.5 Hz, 3H), 7.21 (dd, *J* = 8.4, 2.3 Hz, 1H), 6.98 (d, *J* = 8.4 Hz, 1H), 6.65 (s, 1H), 5.96 (t, *J* = 2.5 Hz, 1H), 5.13 (s, 2H), 4.78 (dd, *J* = 19.0, 2.3 Hz, 1H), 3.95 (dd, *J* = 19.0, 2.7 Hz, 1H), 3.70 (s, 2H), 3.59 (d, *J* = 9.5 Hz, 1H), 3.38 (dd, *J* = 18.4, 1.2 Hz, 1H), 3.20 (d, *J* = 9.5 Hz, 1H), 3.15 (dd, *J* = 18.4, 1.3 Hz, 1H), 2.43 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 206.9, 203.8, 190.5, 172.2, 160.4, 144.3, 140.3, 136.3, 135.5, 132.8, 132.5, 132.5, 132.0, 131.2, 129.8, 129.4, 129.2, 129.0, 127.9, 127.8, 127.2, 126.9, 125.7, 125.1, 121.1, 120.5, 120.4, 73.5, 60.6, 57.8, 47.8, 42.2, 38.0, 21.6; HRMS (ESI) calcd for C<sub>38</sub>H<sub>32</sub>NNaO<sub>6</sub>S [M+Na]<sup>+</sup>:652.1764; found: 652.1778.

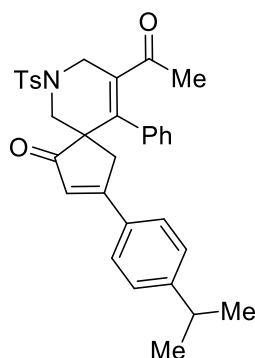
**9-acetyl-3,10-diphenyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5a)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 4:1) to afford **5a** in 90% yield (89.6 mg); pale-yellow solid, mp 222–224 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.67 (d, *J* = 8.2 Hz, 2H), 7.59–7.54 (m, 2H), 7.49–7.45 (m, 1H), 7.44–7.41 (m, 2H), 7.35 (d, *J* = 8.0 Hz, 2H), 7.28–7.22 (m, 3H), 7.11–7.07 (m, 2H), 6.40 (t, *J* = 1.4 Hz, 1H), 4.62 (dd, *J* = 16.6, 1.4 Hz, 1H), 3.67 (dd, *J* = 11.5, 1.4 Hz, 1H), 3.45 (dd, *J* = 18.8, 1.3 Hz, 1H), 3.27 (d, *J* = 16.6 Hz, 1H), 3.25 (d, *J* = 18.8 Hz, 1H), 2.84 (d, *J* = 11.5 Hz, 1H), 2.44 (s, 3H), 1.52 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 206.6, 200.8, 173.8,

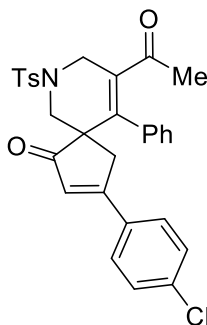
145.3, 144.2, 137.0, 136.6, 132.9, 132.3, 132.0, 130.0, 129.5, 129.0, 128.7, 127.7, 127.1, 126.3, 55.8, 52.7, 46.1, 41.7, 30.6, 21.5; **HRMS (ESI)** calcd for C<sub>30</sub>H<sub>28</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 498.1734; found: 498.1745.

**9-acetyl-3-(4-isopropylphenyl)-10-phenyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5b)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 5:1) to afford **5b** in 61% yield (65.8 mg); yellow solid, mp 180–182 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.69 (d, *J* = 8.2 Hz, 2H), 7.53 (d, *J* = 8.3 Hz, 2H), 7.36 (d, *J* = 8.1 Hz, 2H), 7.32–7.27 (m, 3H), 7.27–7.23 (m, 3H), 7.11 (d, *J* = 6.8 Hz, 2H), 6.39 (s, 1H), 4.64 (d, *J* = 16.6 Hz, 1H), 3.68 (dd, *J* = 11.5, 0.8 Hz, 1H), 3.46 (d, *J* = 18.8 Hz, 1H), 3.29–3.23 (m, 2H), 2.98–2.92 (m, 1H), 2.85 (d, *J* = 11.5 Hz, 1H), 2.46 (s, 3H), 1.54 (s, 3H), 1.27 (d, *J* = 6.9 Hz, 6H); <sup>13</sup>C NMR (150MHz, CDCl<sub>3</sub>) δ 206.6, 200.8, 173.8, 153.7, 145.4, 144.1, 137.0, 136.7, 132.3, 130.5, 129.9, 129.5, 128.9, 128.6, 127.7, 127.3, 127.1, 125.5, 55.7, 52.7, 46.1, 41.7, 34.2, 30.6, 23.6, 21.5; **HRMS (ESI)** calcd for C<sub>33</sub>H<sub>34</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 540.2203; found: 540.2212.

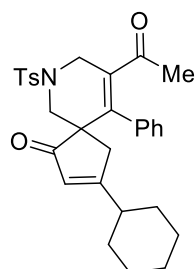
**9-acetyl-3-(4-chlorophenyl)-10-phenyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5c)**



Column chromatography (petroleum ether/EtOAc = 12:1 to 6:1) to afford **5c** in 73%

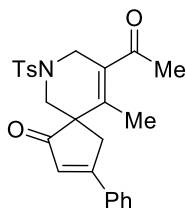
yield (77.7 mg); colorless solid, mp 201–203 °C;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.68 (d,  $J = 8.2$  Hz, 2H), 7.52–7.47 (m, 2H), 7.40 (d,  $J = 8.6$  Hz, 2H), 7.36 (d,  $J = 8.0$  Hz, 2H), 7.30–7.23 (m, 3H), 7.11–7.07 (m, 2H), 6.38 (s, 1H), 4.62 (dd,  $J = 16.6, 1.3$  Hz, 1H), 3.68 (dd,  $J = 11.5, 1.3$  Hz, 1H), 3.42 (dd,  $J = 18.8, 1.2$  Hz, 1H), 3.28 (d,  $J = 16.6$  Hz, 1H), 3.22 (d,  $J = 18.8$  Hz, 1H), 2.85 (d,  $J = 11.5$  Hz, 1H), 2.45 (s, 3H), 1.53 (s, 3H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  206.4, 200.7, 172.1, 145.0, 144.2, 138.2, 137.0, 136.5, 132.3, 131.3, 130.0, 129.5, 129.3, 129.0, 128.9, 128.3, 127.7, 126.6, 55.8, 52.5, 46.0, 41.7, 30.6, 21.5; **HRMS (ESI)** calcd for  $\text{C}_{30}\text{H}_{27}\text{ClNO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 532.1344; found: 532.1356.

**9-acetyl-3-cyclohexyl-10-phenyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5d)**



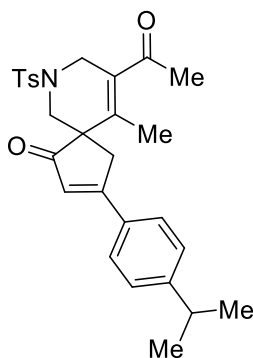
Column chromatography (petroleum ether/EtOAc = 15:1 to 6:1) to afford **5d** in 42% yield (42.3 mg); colorless solid, mp 190–192 °C;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.66 (d,  $J = 8.2$  Hz, 2H), 7.33 (d,  $J = 8.0$  Hz, 2H), 7.31–7.28 (m, 1H), 7.27–7.23 (m, 2H), 7.06–7.01 (m, 2H), 5.73 (d,  $J = 1.0$  Hz, 1H), 4.57 (dd,  $J = 16.5, 1.4$  Hz, 1H), 3.55 (dd,  $J = 11.5, 1.4$  Hz, 1H), 3.20 (d,  $J = 16.5$  Hz, 1H), 2.93 (d,  $J = 19.4$  Hz, 1H), 2.95–2.82 (m, 2H), 2.78 (d,  $J = 11.5$  Hz, 1H), 2.43 (s, 3H), 2.22–2.13 (m, 1H), 1.68–1.63 (m, 3H), 1.50 (s, 3H), 1.27–1.22 (m, 3H), 1.16–1.08 (m, 2H), 1.02–0.94 (m, 1H), 0.89–0.81 (m, 1H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  207.4, 200.6, 188.0, 145.8, 144.1, 136.5, 136.4, 132.4, 129.0, 129.5, 128.8, 128.4, 127.7, 127.4, 55.3, 52.3, 45.9, 42.9, 41.7, 31.1, 30.77, 30.8, 25.8, 25.7, 25.7, 21.5; **HRMS (ESI)** calcd for  $\text{C}_{30}\text{H}_{34}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 504.2203; found: 504.2216.

**9-acetyl-10-methyl-3-phenyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5e)**



Column chromatography (petroleum ether/EtOAc = 10:1 to 4:1) to afford **5e** in 67% yield (58.4 mg); colorless solid, mp 146–148 °C;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.71 (d,  $J = 7.2$  Hz, 2H), 7.63 (d,  $J = 8.2$  Hz, 2H), 7.53 (t,  $J = 7.2$  Hz, 1H), 7.49 (t,  $J = 7.3$  Hz, 2H), 7.33 (d,  $J = 8.0$  Hz, 2H), 6.63 (s, 1H), 4.35 (d,  $J = 15.6$  Hz, 1H), 3.58 (d,  $J = 11.4$  Hz, 1H), 3.45 (d,  $J = 18.9$  Hz, 1H), 3.23 (dd,  $J = 15.7, 2.1$  Hz, 1H), 3.11 (d,  $J = 18.9$  Hz, 1H), 2.57 (d,  $J = 11.4$  Hz, 1H), 2.43 (s, 3H), 2.28 (s, 3H), 1.78 (s, 3H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  207.1, 199.6, 174.6, 144.2, 140.9, 132.9, 132.4, 132.2, 132.2, 129.9, 129.1, 127.6, 127.2, 126.3, 55.5, 51.7, 46.0, 41.9, 30.6, 21.5, 16.6; HRMS (ESI) calcd for  $\text{C}_{25}\text{H}_{26}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 436.1577; found: 436.1590.

**9-acetyl-3-(4-isopropylphenyl)-10-methyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5f)**

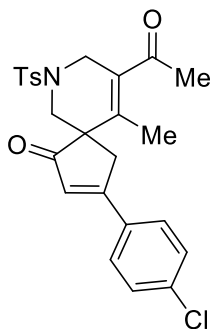


Column chromatography (petroleum ether/EtOAc = 10:1 to 4:1) to afford **5f** in 58% yield (55.4 mg); pale-yellow solid, mp 82–84 °C;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.67–7.61 (m, 4H), 7.37–7.31 (m, 4H), 6.59 (s, 1H), 4.35 (d,  $J = 15.6$  Hz, 1H), 3.56 (d,  $J = 11.4$  Hz, 1H), 3.43 (d,  $J = 18.8$  Hz, 1H), 3.23 (dd,  $J = 15.7, 2.1$  Hz, 1H), 3.09 (d,  $J = 18.8$  Hz, 1H), 3.00–2.95 (m, 1H), 2.56 (d,  $J = 11.4$  Hz, 1H), 2.43 (s, 3H), 2.28 (s, 3H), 1.77 (s, 3H), 1.28 (d,  $J = 6.9$  Hz, 6H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  207.1, 199.5, 174.5, 153.9, 144.2, 141.1, 132.3, 132.2, 130.6, 129.9, 127.6, 127.4, 127.2, 125.5, 55.4,



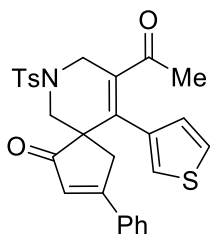
51.7, 46.0, 41.9, 34.2, 30.6, 23.7, 21.5, 16.6; **HRMS (ESI)** calcd for C<sub>28</sub>H<sub>32</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 478.2047; found: 478.2056.

**9-acetyl-3-(4-chlorophenyl)-10-methyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5g)**



Column chromatography (petroleum ether/EtOAc = 8:1 to 4:1) to afford **5g** in 65% yield (61.1 mg); yellow solid, mp 110–112 °C; **<sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>)** δ 7.66–7.60 (m, 4H), 7.49–7.45 (m, 2H), 7.33 (d, *J* = 8.0 Hz, 2H), 6.60 (t, *J* = 1.5 Hz, 1H), 4.39–4.30 (m, 1H), 3.57 (dd, *J* = 11.4, 1.1 Hz, 1H), 3.41 (dd, *J* = 18.8, 1.2 Hz, 1H), 3.25–3.20 (m, 1H), 3.07 (d, *J* = 18.9 Hz, 1H), 2.56 (d, *J* = 11.3 Hz, 1H), 2.43 (s, 3H), 2.28 (s, 3H), 1.77 (t, *J* = 1.9 Hz, 3H); **<sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>)** δ 206.8, 199.5, 172.8, 144.3, 140.6, 138.4, 132.5, 132.2, 131.4, 130.0, 129.4, 128.5, 127.6, 126.6, 55.5, 51.6, 45.9, 41.8, 30.6, 21.5, 16.6; **HRMS (ESI)** calcd for C<sub>25</sub>H<sub>25</sub>ClNO<sub>4</sub>S [M+H]<sup>+</sup>: 470.1187; found: 470.1198.

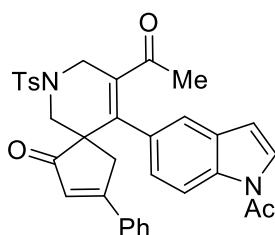
**9-acetyl-3-phenyl-10-(thiophen-3-yl)-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5h)**



Column chromatography (petroleum ether/EtOAc = 10:1 to 5:1) to afford **5h** in 63% yield (63.5 mg); pale-yellow solid, mp 205–207 °C; **<sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>)** δ 7.65 (d, *J* = 8.1 Hz, 2H), 7.59 (d, *J* = 7.4 Hz, 2H), 7.48 (t, *J* = 7.2 Hz, 1H), 7.43 (t, *J* = 7.5 Hz, 2H), 7.33 (d, *J* = 8.1 Hz, 2H), 7.24–7.20 (m, 1H), 7.05 (d, *J* = 1.9 Hz, 1H), 6.84

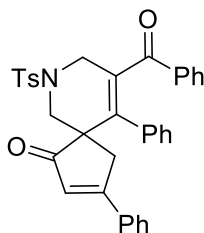
(d,  $J = 5.0$  Hz, 1H), 6.47 (s, 1H), 4.61 (d,  $J = 16.6$  Hz, 1H), 3.68 (d,  $J = 11.5$  Hz, 1H), 3.46 (d,  $J = 18.7$  Hz, 1H), 3.20 (d,  $J = 16.7$  Hz, 1H), 3.15 (d,  $J = 18.7$  Hz, 1H), 2.78 (d,  $J = 11.5$  Hz, 1H), 2.43 (s, 3H), 1.63 (s, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  206.9, 201.0, 174.1, 144.2, 140.4, 137.6, 136.3, 132.9, 132.2, 132.1, 129.9, 129.0, 128.4, 127.7, 127.1, 126.6, 126.2, 126.1, 55.6, 52.5, 46.1, 42.0, 29.8, 21.5; HRMS (ESI) calcd for  $\text{C}_{28}\text{H}_{26}\text{NO}_4\text{S}_2$   $[\text{M}+\text{H}]^+$ : 504.1298; found: 504.1309.

**9-acetyl-10-(1-acetyl-1H-indol-5-yl)-3-phenyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5i)**



Column chromatography (petroleum ether/EtOAc = 10:1 to 2:1) to afford **5i** in 65% yield (75.2 mg); colorless solid, mp 152–154 °C;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  8.30 (d,  $J = 8.5$  Hz, 1H), 7.67 (d,  $J = 8.2$  Hz, 2H), 7.52 (d,  $J = 7.4$  Hz, 2H), 7.43 (t,  $J = 7.3$  Hz, 1H), 7.40–7.36 (m, 3H), 7.34 (d,  $J = 8.1$  Hz, 2H), 7.30 (s, 1H), 7.09 (d,  $J = 8.6$  Hz, 1H), 6.55 (d,  $J = 3.8$  Hz, 1H), 6.40 (s, 1H), 4.66 (d,  $J = 16.7$  Hz, 1H), 3.68 (d,  $J = 11.5$  Hz, 1H), 3.45 (d,  $J = 18.9$  Hz, 1H), 3.27 (d,  $J = 16.6$  Hz, 1H), 3.25 (d,  $J = 18.8$  Hz, 1H), 2.87 (d,  $J = 11.5$  Hz, 1H), 2.57 (s, 3H), 2.44 (s, 3H), 1.47 (s, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  206.8, 201.0, 173.8, 168.5, 145.6, 144.1, 137.3, 135.5, 132.8, 132.3, 132.0, 130.4, 129.9, 128.9, 127.7, 127.1, 126.3, 126.2, 126.2, 122.3, 116.7, 109.1, 56.0, 52.8, 46.2, 41.8, 30.6, 23.8, 21.5; HRMS (ESI) calcd for  $\text{C}_{34}\text{H}_{31}\text{N}_2\text{O}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 579.1948; found: 579.1964.

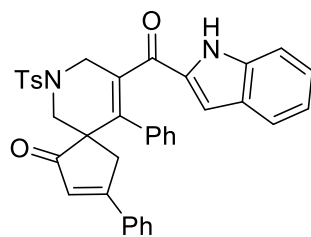
**9-benzoyl-3,10-diphenyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5j)**



Column chromatography (petroleum ether/EtOAc = 14:1 to 8:1) to afford **5j** in 63%

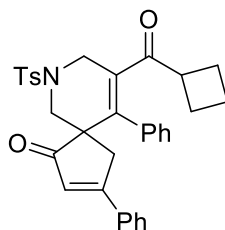
yield (70.5 mg); colorless solid, mp 181–183 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.71–7.63 (m, 4H), 7.58 (d, *J* = 7.3 Hz, 2H), 7.47 (t, *J* = 7.3 Hz, 1H), 7.42 (t, *J* = 7.4 Hz, 2H), 7.35 (d, *J* = 8.0 Hz, 2H), 7.31 (t, *J* = 7.4 Hz, 1H), 7.19 (t, *J* = 7.7 Hz, 2H), 6.90 (d, *J* = 1.6 Hz, 5H), 6.48 (s, 1H), 4.59 (d, *J* = 16.4 Hz, 1H), 3.70 (d, *J* = 11.6 Hz, 1H), 3.54 (d, *J* = 16.4 Hz, 1H), 3.45 (d, *J* = 18.7 Hz, 1H), 3.22 (d, *J* = 18.7 Hz, 1H), 3.11 (d, *J* = 11.6 Hz, 1H), 2.44 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 206.8, 196.8, 173.5, 144.2, 140.6, 136.4, 135.9, 135.1, 133.0, 132.9, 132.4, 131.9, 130.0, 129.7, 129.2, 128.9, 128.1, 128.0, 127.9, 127.7, 127.1, 126.2, 55.0, 53.0, 47.0, 41.5, 21.5; HRMS (ESI) calcd for C<sub>35</sub>H<sub>30</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 560.1890; found: 560.1897.

**9-(1*H*-indole-2-carbonyl)-3,10-diphenyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5k)**



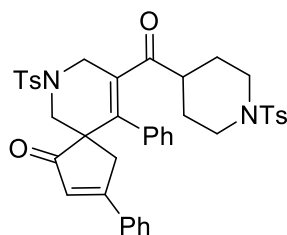
Column chromatography (petroleum ether/EtOAc = 10:1 to 4:1) to afford **5k** in 73% yield (87.4 mg); pale-yellow solid, mp 244–246 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 9.01–8.83 (m, 1H), 7.67 (d, *J* = 8.2 Hz, 2H), 7.59 (t, *J* = 7.5 Hz, 3H), 7.48 (t, *J* = 7.3 Hz, 1H), 7.43 (t, *J* = 7.4 Hz, 2H), 7.33 (d, *J* = 8.1 Hz, 2H), 7.26 (d, *J* = 5.9 Hz, 2H), 7.10 (s, 1H), 7.09–7.04 (m, 3H), 6.99–6.89 (m, 3H), 6.54 (s, 1H), 4.59 (d, *J* = 16.3 Hz, 1H), 3.73 (d, *J* = 11.7 Hz, 1H), 3.54 (d, *J* = 16.3 Hz, 1H), 3.47 (d, *J* = 18.7 Hz, 1H), 3.23 (d, *J* = 18.7 Hz, 1H), 3.10 (d, *J* = 11.7 Hz, 1H), 2.43 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 207.1, 187.5, 173.8, 144.2, 139.7, 137.8, 136.0, 135.0, 134.3, 133.0, 132.4, 132.0, 130.0, 129.7, 129.0, 128.2, 128.1, 127.7, 127.2, 127.2, 126.7, 126.2, 123.4, 120.9, 113.7, 112.1, 55.1, 53.2, 47.2, 41.4, 21.5; HRMS (ESI) calcd for C<sub>37</sub>H<sub>31</sub>N<sub>2</sub>O<sub>4</sub>S [M+H]<sup>+</sup>: 599.1999; found: 599.2013.

**9-(cyclobutanecarbonyl)-3,10-diphenyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5l)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 5:1) to afford **5l** in 83% yield (89.3 mg); colorless solid, mp 181–183 °C;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.66 (d,  $J = 8.2$  Hz, 2H), 7.57–7.53 (m, 2H), 7.46 (t,  $J = 7.3$  Hz, 1H), 7.41 (t,  $J = 7.4$  Hz, 2H), 7.34 (d,  $J = 8.1$  Hz, 2H), 7.23–7.18 (m, 3H), 7.06–7.02 (m, 2H), 6.41 (s, 1H), 4.57 (dd,  $J = 16.5, 0.9$  Hz, 1H), 3.64 (dd,  $J = 11.5, 0.9$  Hz, 1H), 3.43 (dd,  $J = 18.8, 0.9$  Hz, 1H), 3.27 (d,  $J = 16.5$  Hz, 1H), 3.18 (d,  $J = 18.8$  Hz, 1H), 2.83 (d,  $J = 11.5$  Hz, 1H), 2.65–2.57 (m, 1H), 2.43 (s, 3H), 1.97–1.85 (m, 2H), 1.69–1.62 (m, 1H), 1.61–1.53 (m, 2H), 1.32–1.26 (m, 1H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  206.7, 206.5, 173.6, 144.1, 142.5, 136.7, 136.6, 132.9, 132.3, 132.0, 129.9, 129.5, 128.9, 128.7, 128.5, 127.7, 127.1, 126.3, 55.3, 52.7, 46.6, 45.3, 41.8, 25.8, 24.9, 21.5, 17.2; **HRMS (ESI)** calcd for  $\text{C}_{33}\text{H}_{32}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 538.2047; found: 538.2054.

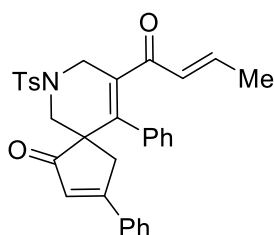
**3,10-diphenyl-7-tosyl-9-(1-tosylpiperidine-4-carbonyl)-7-azaspiro[4.5]deca-2,9-dien-1-one (5m)**



Column chromatography (petroleum ether/EtOAc = 8:1 to 2:1) to afford **5m** in 70% yield (100.9 mg); colorless solid, mp 223–225 °C;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.63 (d,  $J = 8.1$  Hz, 2H), 7.53 (t,  $J = 8.1$  Hz, 4H), 7.45 (t,  $J = 7.3$  Hz, 1H), 7.40 (t,  $J = 7.5$  Hz, 2H), 7.34 (d,  $J = 8.0$  Hz, 2H), 7.27 (d,  $J = 8.0$  Hz, 2H), 7.18–7.09 (m, 3H), 6.99 (d,  $J = 7.1$  Hz, 2H), 6.42 (s, 1H), 4.47 (d,  $J = 16.5$  Hz, 1H), 3.62 (d,  $J = 11.6$  Hz, 1H), 3.54 (d,  $J = 11.7$  Hz, 1H), 3.48 (d,  $J = 11.9$  Hz, 1H), 3.39 (d,  $J = 18.8$  Hz, 1H), 3.19 (d,  $J =$

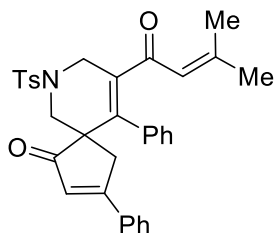
16.5 Hz, 1H), 3.12 (d,  $J = 18.8$  Hz, 1H), 2.85 (d,  $J = 11.6$  Hz, 1H), 2.43 (d,  $J = 11.0$  Hz, 6H), 1.95–1.86 (m, 1H), 1.79–1.69 (m, 1H), 1.58–1.49 (m, 2H), 1.46–1.39 (m, 1H), 1.35–1.25 (m, 1H), 1.07 (d,  $J = 13.3$  Hz, 1H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  206.5, 205.9, 173.8, 144.3, 143.4, 142.1, 136.6, 136.3, 133.3, 132.7, 132.3, 132.1, 130.0, 129.5, 129.4, 128.9, 128.6, 127.6, 127.4, 127.1, 126.1, 55.2, 52.6, 47.1, 46.6, 45.4, 45.1, 41.5, 27.9, 26.3, 21.5, 21.4; HRMS (ESI) calcd for  $\text{C}_{41}\text{H}_{41}\text{N}_2\text{O}_6\text{S}_2$   $[\text{M}+\text{H}]^+$ : 721.2401; found: 721.2414.

**(E)-9-(but-2-enoyl)-3,10-diphenyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5n)**



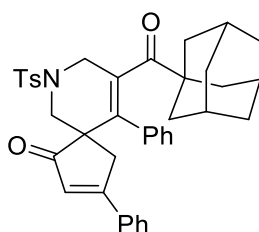
Column chromatography (petroleum ether/EtOAc = 10:1 to 4:1) to afford **5n** in 83% yield (87.0 mg); colorless solid, mp 202–204 °C;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.66 (d,  $J = 8.2$  Hz, 2H), 7.60–7.54 (m, 2H), 7.48 – 7.45 (m, 1H), 7.41 (dd,  $J = 10.2, 4.6$  Hz, 2H), 7.33 (d,  $J = 8.0$  Hz, 2H), 7.19–7.12 (m, 3H), 7.05–7.89 (m, 2H), 6.66–6.59 (m, 1H), 6.47 (s, 1H), 5.53 (dd,  $J = 15.5, 1.6$  Hz, 1H), 4.55 (dd,  $J = 16.5, 0.9$  Hz, 1H), 3.64 (dd,  $J = 11.5, 0.9$  Hz, 1H), 3.42 (dd,  $J = 18.8, 1.0$  Hz, 1H), 3.34 (d,  $J = 16.5$  Hz, 1H), 3.18 (d,  $J = 18.8$  Hz, 1H), 2.93 (d,  $J = 11.5$  Hz, 1H), 2.43 (s, 3H), 1.51 (dd,  $J = 6.9, 1.5$  Hz, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  206.9, 194.2, 173.6, 144.5, 144.1, 141.9, 136.6, 136.22, 132.9, 132.4, 132.0, 130.9, 129.9, 129.6, 128.9, 128.6, 128.3, 127.7, 127.1, 126.2, 55.2, 52.8, 46.4, 41.7, 21.5, 17.9; HRMS (ESI) calcd for  $\text{C}_{32}\text{H}_{30}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 524.1890; found: 524.1899.

**9-(3-methylbut-2-enoyl)-3,10-diphenyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5o)**



Column chromatography (petroleum ether/EtOAc = 14:1 to 6:1) to afford **5o** in 87% yield (93.6 mg); colorless solid, mp 233–235 °C;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.66 (d,  $J = 8.2$  Hz, 2H), 7.59–7.55 (m, 2H), 7.48–7.45 (m, 1H), 7.44–7.41 (m, 2H), 7.33 (d,  $J = 8.0$  Hz, 2H), 7.17–7.14 (m, 3H), 7.07–7.03 (m, 2H), 6.43 (s, 1H), 5.45–5.42 (m, 1H), 4.63 (dd,  $J = 16.5, 1.2$  Hz, 1H), 3.66 (dd,  $J = 11.5, 1.2$  Hz, 1H), 3.44 (dd,  $J = 18.8, 1.2$  Hz, 1H), 3.31 (d,  $J = 16.5$  Hz, 1H), 3.22 (d,  $J = 18.8$  Hz, 1H), 2.87 (d,  $J = 11.4$  Hz, 1H), 2.43 (s, 3H), 1.84 (d,  $J = 0.7$  Hz, 3H), 1.39 (d,  $J = 0.6$  Hz, 3H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  207.0, 193.5, 173.7, 154.6, 144.1, 142.1, 138.0, 136.8, 133.0, 132.4, 131.9, 129.9, 129.7, 128.9, 128.6, 128.2, 127.7, 127.1, 126.3, 125.5, 55.3, 52.8, 46.2, 41.8, 27.1, 21.5, 20.5; HRMS (ESI) calcd for  $\text{C}_{33}\text{H}_{32}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 538.2047; found: 538.2059.

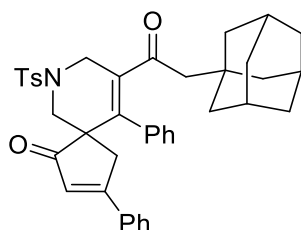
**9-(adamantane-1-carbonyl)-3,10-diphenyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5p)**



Column chromatography (petroleum ether/EtOAc = 10:1 to 4:1) to afford **5p** in 55% yield (102.6 mg); colorless solid, mp 194–196 °C;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.65 (d,  $J = 7.9$  Hz, 2H), 7.61 (d,  $J = 7.6$  Hz, 2H), 7.51–7.47 (m, 1H), 7.44 (t,  $J = 7.4$  Hz, 2H), 7.35 (d,  $J = 7.9$  Hz, 2H), 7.15 (d,  $J = 6.0$  Hz, 3H), 7.04 (d,  $J = 5.9$  Hz, 2H), 6.44 (s, 1H), 4.14 (d,  $J = 16.0$  Hz, 1H), 3.56 (d,  $J = 11.5$  Hz, 1H), 3.43 (d,  $J = 16.6$  Hz, 2H), 3.27 (d,  $J = 18.9$  Hz, 1H), 2.96 (d,  $J = 11.5$  Hz, 1H), 2.45 (s, 3H), 1.82 (s, 3H), 1.60–

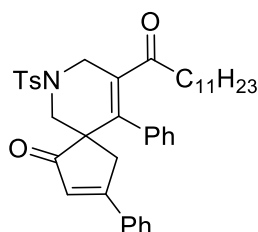
1.53 (m, 4H), 1.48–1.44 (m, 3H), 1.43–1.39 (m, 3H), 1.37–1.33 (m, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  213.9, 206.8, 172.9, 144.2, 136.7, 136.6, 133.6, 133.2, 132.6, 131.9, 130.0, 129.0, 128.3, 128.2, 127.6, 127.1, 126.4, 54.0, 52.5, 47.0, 46.4, 42.0, 38.4, 36.1, 27.8, 21.6; HRMS (ESI) calcd for  $\text{C}_{39}\text{H}_{40}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 618.2673; found: 618.2691.

**9-(2-(adamantan-1-yl)acetyl)-3,10-diphenyl-7-tosyl-7-azaspiro[4.5] deca-2,9-dien-1-one (5q)**



Column chromatography (petroleum ether/EtOAc = 12:1 to 5:1) to afford **5q** in 84% yield (110.0 mg); colorless solid, mp 152–154 °C;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.67 (d,  $J$  = 8.2 Hz, 2H), 7.60–7.55 (m, 2H), 7.49–7.45 (m, 1H), 7.44–7.41 (m, 2H), 7.34 (d,  $J$  = 8.0 Hz, 2H), 7.25–7.18 (m, 3H), 7.06–7.02 (m, 2H), 6.42 (s, 1H), 4.50 (dd,  $J$  = 16.4, 1.0 Hz, 1H), 3.63 (dd,  $J$  = 11.5, 1.0 Hz, 1H), 3.45 (dd,  $J$  = 18.8, 1.2 Hz, 1H), 3.35 (d,  $J$  = 16.5 Hz, 1H), 3.22 (d,  $J$  = 18.9 Hz, 1H), 2.86 (d,  $J$  = 11.5 Hz, 1H), 2.44 (s, 3H), 1.82 (s, 3H), 1.64 (s, 1H), 1.62–1.47 (m, 3H), 1.54 (s, 1H), 1.52–1.48 (m, 3H), 1.34–1.30 (m, 3H), 1.29–1.24 (m, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  206.7, 204.7, 173.4, 144.1, 141.5, 138.3, 136.7, 133.0, 132.5, 131.9, 129.9, 129.6, 129.0, 128.8, 128.6, 127.7, 127.1, 126.6, 56.0, 55.1, 52.6, 45.9, 42.2, 41.9, 36.6, 33.8, 28.4, 21.5; HRMS (ESI) calcd for  $\text{C}_{40}\text{H}_{42}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 632.2829; found: 632.2842.

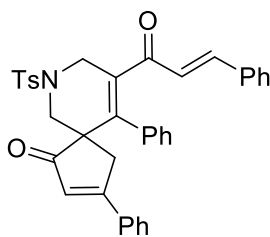
**9-dodecanoyl-3,10-diphenyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5r)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 7:1) to afford **5r** in 80% yield (102.1 mg); colorless solid, mp 139–141 °C;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.66

(d,  $J = 8.2$  Hz, 2H), 7.59–7.55 (m, 2H), 7.49–7.45 (m, 1H), 7.42 (t,  $J = 7.4$  Hz, 2H), 7.34 (d,  $J = 8.0$  Hz, 2H), 7.25–7.19 (m, 3H), 7.09–7.05 (m, 2H), 6.41 (s, 1H), 4.54 (dd,  $J = 16.5, 1.1$  Hz, 1H), 3.66 (dd,  $J = 11.5, 1.1$  Hz, 1H), 3.44 (dd,  $J = 18.8, 1.1$  Hz, 1H), 3.28 (d,  $J = 16.5$  Hz, 1H), 3.23 (d,  $J = 18.8$  Hz, 1H), 2.85 (d,  $J = 11.5$  Hz, 1H), 2.44 (s, 3H), 1.84–1.77 (m, 1H), 1.75–1.68 (m, 1H), 1.31–1.25 (m, 3H), 1.24–1.20 (m, 6H), 1.17–1.12 (m, 3H), 1.11–1.06 (m, 2H), 1.01–0.95 (m, 2H), 0.89–0.81 (m, 5H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  206.7, 204.8, 173.6, 144.1, 142.3, 137.2, 136.6, 132.9, 132.3, 132.0, 129.9, 129.5, 128.9, 128.8, 128.5, 127.7, 127.1, 126.3, 55.3, 52.7, 46.3, 42.9, 41.8, 31.8, 29.5, 29.5, 29.3, 29.0, 28.8, 23.85, 22.6, 21.5, 14.1; HRMS (ESI) calcd for  $\text{C}_{40}\text{H}_{48}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 638.3299; found: 638.3313.

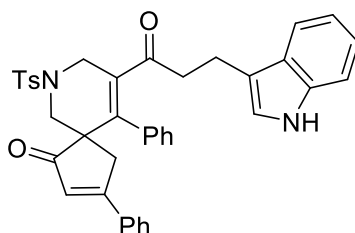
**9-cinnamoyl-3,10-diphenyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5s)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 5:1) to afford **5s** in 85% yield (99.6 mg); pale-yellow solid, mp 220–222 °C;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.69 (d,  $J = 8.2$  Hz, 2H), 7.60–7.56 (m, 2H), 7.49–7.45 (m, 1H), 7.42 (t,  $J = 7.4$  Hz, 2H), 7.36–7.30 (m, 3H), 7.29–7.25 (m, 1H), 7.22 (t,  $J = 7.4$  Hz, 2H), 7.19–7.12 (m, 5H), 7.12–7.09 (m, 2H), 6.50 (s, 1H), 6.14 (d,  $J = 15.8$  Hz, 1H), 4.72 (dd,  $J = 16.5, 0.9$  Hz, 1H), 3.70 (dd,  $J = 11.5, 1.0$  Hz, 1H), 3.47 (dd,  $J = 18.8, 1.0$  Hz, 1H), 3.40 (d,  $J = 16.5$  Hz, 1H), 3.22 (d,  $J = 18.8$  Hz, 1H), 2.97 (d,  $J = 11.5$  Hz, 1H), 2.43 (s, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  206.9, 192.9, 173.8, 144.1, 143.6, 142.9, 137.0, 136.7, 134.4, 132.9, 132.3, 132.0, 130.2, 129.9, 129.8, 129.0, 128.9, 128.6, 128.6, 128.1, 127.7, 127.1, 126.3, 125.6, 55.55, 52.9, 46.5, 41.8, 21.5; HRMS (ESI) calcd for  $\text{C}_{37}\text{H}_{32}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 586.2047; found: 586.2059.

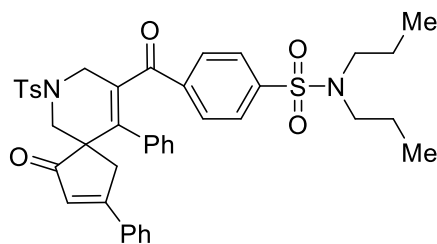


**9-(3-(1*H*-indol-3-yl)propanoyl)-3,10-diphenyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5t)**



Column chromatography (petroleum ether/EtOAc = 10:1 to 4:1) to afford **5t** in 83% yield (104.0 mg); pale-yellow solid, mp 184–186 °C;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  8.01 (s, 1H), 7.62 (d,  $J = 8.2$  Hz, 2H), 7.56 (d,  $J = 7.5$  Hz, 2H), 7.49 (t,  $J = 7.3$  Hz, 1H), 7.44 (t,  $J = 7.5$  Hz, 2H), 7.34–7.30 (m, 3H), 7.28 (d,  $J = 7.9$  Hz, 1H), 7.24–7.13 (m, 4H), 7.06–7.02 (m, 3H), 6.71 (d,  $J = 1.9$  Hz, 1H), 6.39 (s, 1H), 4.37 (d,  $J = 16.4$  Hz, 1H), 3.58 (d,  $J = 11.5$  Hz, 1H), 3.33 (d,  $J = 19.0$  Hz, 1H), 3.19 (d,  $J = 16.4$  Hz, 1H), 3.05 (d,  $J = 19.0$  Hz, 1H), 2.80–2.74 (m, 2H), 2.73–2.68 (m, 1H), 2.45 (s, 3H), 2.30–2.15 (m, 2H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  206.6, 205.1, 173.5, 144.1, 142.5, 137.1, 136.7, 136.2, 132.9, 132.3, 132.0, 129.9, 129.2, 128.9, 128.9, 128.6, 127.6, 127.1, 126.9, 126.2, 121.9, 121.5, 119.0, 118.8, 114.5, 111.1, 55.1, 52.6, 46.1, 43.2, 41.8, 21.5, 20.5; HRMS (ESI) calcd for  $\text{C}_{39}\text{H}_{35}\text{N}_2\text{O}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 627.2312; found: 627.2330.

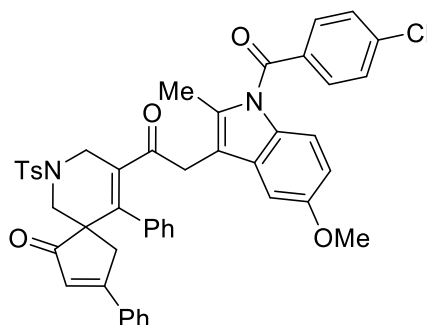
**4-(1-oxo-3,10-diphenyl-7-tosyl-7-azaspiro[4.5]deca-2,9-diene-9-carbonyl)-*N,N*-dipropylbenzenesulfonamide (5u)**



Column chromatography (petroleum ether/EtOAc = 10:1 to 4:1) to afford **5u** in 41% yield (62.2 mg); colorless solid, mp 194–196 °C;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.71–7.65 (m, 4H), 7.57 (t,  $J = 8.7$  Hz, 4H), 7.48 (t,  $J = 7.3$  Hz, 1H), 7.43 (t,  $J = 7.5$  Hz, 2H), 7.36 (d,  $J = 8.1$  Hz, 2H), 6.93–6.84 (m, 5H), 6.53 (s, 1H), 4.66 (d,  $J = 16.5$  Hz, 1H), 3.70 (d,  $J = 11.7$  Hz, 1H), 3.53 (d,  $J = 16.5$  Hz, 1H), 3.43 (d,  $J = 18.7$  Hz, 1H), 3.15–3.09 (m, 2H), 3.01–2.91 (m, 4H), 2.46 (s, 3H), 1.50–1.41 (m, 4H), 0.84 (t,  $J = 7.4$  Hz,

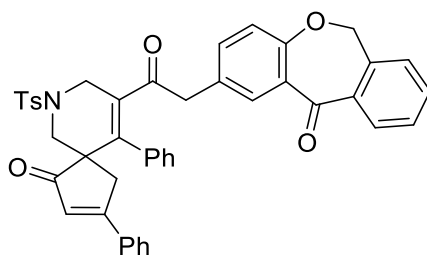
6H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  206.6, 195.8, 173.8, 144.3, 143.3, 143.3, 139.8, 135.9, 134.8, 132.8, 132.4, 132.1, 130.0, 129.8, 129.5, 129.0, 128.6, 128.2, 127.7, 127.1, 126.5, 126.1, 55.3, 53.1, 49.8, 47.0, 41.4, 21.8, 21.5, 11.1; HRMS (ESI) calcd for  $\text{C}_{41}\text{H}_{43}\text{N}_2\text{O}_6\text{S}_2$   $[\text{M}+\text{H}]^+$ : 723.2557; found: 723.2571.

**9-(2-(1-(4-chlorobenzoyl)-5-methoxy-2-methyl-1*H*-indol-3-yl)acetyl)-3,10-diphenyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5v)**



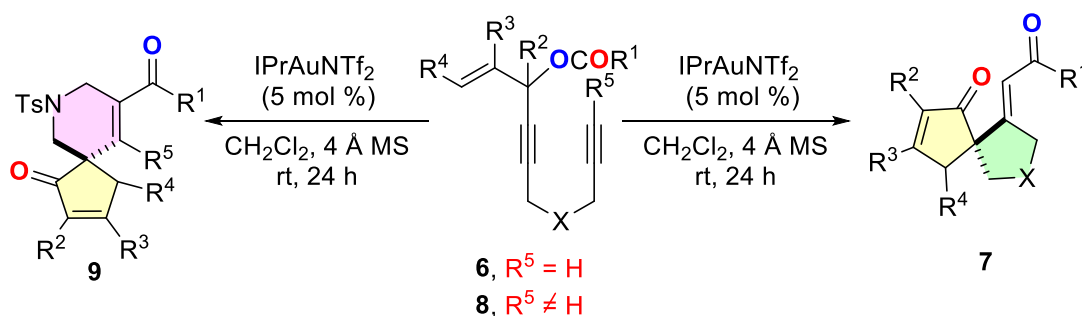
Column chromatography (petroleum ether/EtOAc = 10:1 to 5:1) to afford **5v** in 83% yield (132.0 mg); pale-yellow solid, mp 144–146 °C;  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.63–7.55 (m, 6H), 7.49 (t,  $J$  = 7.2 Hz, 1H), 7.46–7.42 (m, 4H), 7.30 (d,  $J$  = 7.2 Hz, 5H), 7.23–7.18 (m, 2H), 6.95 (d,  $J$  = 9.0 Hz, 1H), 6.66 (dd,  $J$  = 9.0, 2.4 Hz, 1H), 6.58 (d,  $J$  = 2.3 Hz, 1H), 6.46 (s, 1H), 4.43 (d,  $J$  = 16.5 Hz, 1H), 3.82 (s, 3H), 3.66 (d,  $J$  = 11.6 Hz, 1H), 3.45 (d,  $J$  = 18.8 Hz, 1H), 3.25 (d,  $J$  = 18.9 Hz, 1H), 3.24 (dd,  $J$  = 16.5, 2.5 Hz, 1H), 3.07 (d,  $J$  = 16.5 Hz, 1H), 2.87 (d,  $J$  = 11.6 Hz, 1H), 2.41 (s, 3H), 2.03 (s, 3H);  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ )  $\delta$  206.3, 200.6, 173.5, 168.1, 156.0, 144.2, 141.9, 139.1, 137.3, 136.6, 135.8, 133.9, 132.9, 132.3, 132.0, 131.1, 130.8, 130.4, 129.9, 129.5, 129.2, 129.0, 129.0, 128.9, 127.6, 127.1, 126.3, 114.9, 112.0, 111.6, 101.2, 55.7, 55.2, 52.7, 46.7, 41.7, 38.5, 21.5, 13.4; HRMS (ESI) calcd for  $\text{C}_{47}\text{H}_{39}\text{ClN}_2\text{NaO}_6\text{S}$   $[\text{M}+\text{Na}]^+$ : 817.2110; found: 817.2127.

**9-(2-(11-oxo-6,11-dihydrodibenzo[*b,e*]oxepin-2-yl)acetyl)-3,10-diphenyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (5w)**



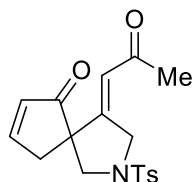
Column chromatography (petroleum ether/EtOAc = 10:1 to 4:1) to afford **5w** in 73% yield (103.1 mg); colorless solid, mp 198–200 °C;  $^1\text{H NMR}$  (600 MHz,  $\text{CDCl}_3$ )  $\delta$  7.87 (d,  $J = 7.6$  Hz, 1H), 7.63 (d,  $J = 8.2$  Hz, 2H), 7.60 (d,  $J = 7.3$  Hz, 2H), 7.57 (d,  $J = 1.8$  Hz, 1H), 7.56–7.52 (m, 1H), 7.50–7.45 (m, 2H), 7.45–7.41 (m, 2H), 7.36–7.28 (m, 6H), 7.17 (d,  $J = 7.2$  Hz, 2H), 6.94–6.87 (m, 2H), 6.45 (s, 1H), 5.13 (s, 2H), 4.47 (d,  $J = 16.5$  Hz, 1H), 3.67 (d,  $J = 11.5$  Hz, 1H), 3.47 (d,  $J = 18.9$  Hz, 1H), 3.29 (d,  $J = 18.7$  Hz, 1H), 3.27 (d,  $J = 16.5$  Hz, 1H), 3.18 (d,  $J = 16.9$  Hz, 1H), 3.08 (d,  $J = 16.9$  Hz, 1H), 2.87 (d,  $J = 11.5$  Hz, 1H), 2.42 (s, 3H);  $^{13}\text{C NMR}$  (150 MHz,  $\text{CDCl}_3$ )  $\delta$  206.5, 201.6, 190.5, 173.7, 160.3, 144.2, 143.0, 140.4, 137.1, 136.5, 136.5, 135.6, 133.0, 132.7, 132.6, 132.3, 132.0, 129.9, 129.6, 129.4, 129.3, 129.2, 129.0, 129.0, 127.7, 127.7, 127.3, 127.2, 126.3, 125.0, 120.7, 73.6, 55.4, 52.7, 48.2, 46.6, 41.9, 21.5; **HRMS (ESI)** calcd for  $\text{C}_{44}\text{H}_{36}\text{NO}_6\text{S}$   $[\text{M}+\text{H}]^+$ :706.2258; found: 706.2266.

#### 4. General procedure for IPrAuNTf<sub>2</sub>-catalyzed spirocyclization of 1-ene-4,9-diyne esters **6a–s** and **8a–e**



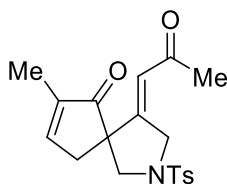
To a solution of **6** or **8** (0.2 mmol) and 4 Å MS (100 mg) in anhydrous DCM (2 mL) was added IPrAuNTf<sub>2</sub> (5 mol%) under an argon atmosphere. The reaction mixture was stirred at room temperature for 24 h. Upon completion, filtered through celite, washed with CH<sub>2</sub>Cl<sub>2</sub> and the solvent was removed under reduced pressure. The residue was purified by flash column chromatography on silica gel (eluent: petroleum ether: EtOAc) to give the product **7** or **9**.

#### (*Z*)-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (**7a**)



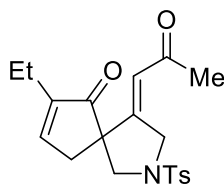
Column chromatography (petroleum ether/EtOAc = 15:1 to 5:1) to afford **7a** in 77% yield (53.2 mg); yellow oil; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.88–7.83 (m, 1H), 7.72–7.67 (m, 2H), 7.34–7.30 (m, 2H), 6.30–6.26 (m, 1H), 5.79 (t, *J* = 2.6 Hz, 1H), 4.68 (dd, *J* = 18.7, 2.5 Hz, 1H), 3.92 (dd, *J* = 18.7, 2.8 Hz, 1H), 3.45 (d, *J* = 9.4 Hz, 1H), 3.12 (d, *J* = 9.4 Hz, 1H), 3.01 (dt, *J* = 19.7, 2.4 Hz, 1H), 2.82 (dt, *J* = 19.7, 2.5 Hz, 1H), 2.41 (s, 3H), 2.11 (s, 3H); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 205.9, 197.0, 164.2, 159.8, 144.2, 133.4, 131.6, 129.8, 127.9, 118.7, 57.7, 56.1, 53.5, 46.1, 31.1, 21.5; HRMS (ESI) calcd. for C<sub>18</sub>H<sub>19</sub>NO<sub>4</sub>SNa [M+Na]<sup>+</sup>: 368.0927, found: 368.0933.

**(Z)-7-methyl-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (7b)**



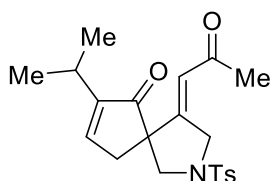
Column chromatography (petroleum ether/EtOAc = 15:1 to 5:1) to afford **7b** in 75% yield (53.9 mg); yellow oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.75–7.70 (m, 2H), 7.47–7.43 (m, 1H), 7.36–7.31 (m, 2H), 5.73 (t,  $J = 2.6$  Hz, 1H), 4.72 (dd,  $J = 18.7, 2.5$  Hz, 1H), 3.92 (dd,  $J = 18.7, 2.8$  Hz, 1H), 3.47 (d,  $J = 9.3$  Hz, 1H), 3.10 (d,  $J = 9.3$  Hz, 1H), 2.96–2.88 (m, 1H), 2.74–2.66 (m, 1H), 2.44 (s, 3H), 2.13 (s, 3H), 1.86–1.83 (m, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  205.9, 196.9, 160.4, 157.4, 144.2, 141.6, 131.8, 129.9, 128.1, 118.7, 58.2, 56.6, 53.7, 44.4, 31.2, 21.6, 10.5; **HRMS (ESI)** calcd. for  $\text{C}_{19}\text{H}_{21}\text{NO}_4\text{SNa}$   $[\text{M}+\text{Na}]^+$ : 382.1083, found: 382.1089.

**(Z)-7-ethyl-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (7c)**



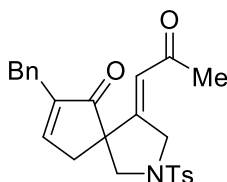
Column chromatography (petroleum ether/EtOAc = 14:1 to 6:1) to afford **7c** in 78% yield (58.3 mg); yellow oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.73–7.68 (m, 2H), 7.42–7.39 (m, 1H), 7.35–7.31 (m, 2H), 5.72 (t,  $J = 2.6$  Hz, 1H), 4.70 (dd,  $J = 18.7, 2.4$  Hz, 1H), 3.92 (dd,  $J = 18.7, 2.8$  Hz, 1H), 3.45 (d,  $J = 9.3$  Hz, 1H), 3.11 (d,  $J = 9.3$  Hz, 1H), 2.95–2.86 (m, 1H), 2.74–2.64 (m, 1H), 2.42 (s, 3H), 2.26–2.18 (m, 2H), 2.12 (s, 3H), 1.12 (t,  $J = 7.5$  Hz, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  205.5, 196.9, 160.4, 155.8, 147.5, 144.1, 131.8, 129.9, 128.0, 118.5, 58.5, 56.4, 53.6, 44.3, 31.1, 21.5, 18.4, 11.8; **HRMS (ESI)** calcd. for  $\text{C}_{20}\text{H}_{23}\text{NO}_4\text{SNa}$   $[\text{M}+\text{Na}]^+$ : 396.1240, found: 396.1245.

**(Z)-7-isopropyl-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (7d)**



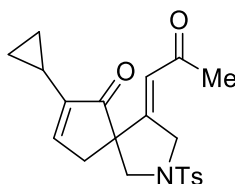
Column chromatography (petroleum ether/EtOAc = 13:1 to 5:1) to afford **7d** in 83% yield (64.3 mg); pale-yellow oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CD}_2\text{Cl}_2$ )  $\delta$  7.65–7.61 (m, 2H), 7.32–7.28 (m, 2H), 5.66 (t,  $J = 2.6$  Hz, 1H), 5.26–5.23 (m, 1H), 4.51 (dd,  $J = 18.5, 2.5$  Hz, 1H), 3.89 (dd,  $J = 18.5, 2.8$  Hz, 1H), 3.30 (d,  $J = 9.5$  Hz, 1H), 3.11 (d,  $J = 9.5$  Hz, 1H), 2.76–2.69 (m, 1H), 2.62–2.55 (m, 1H), 2.53–2.48 (m, 1H), 2.36 (s, 3H), 2.02 (s, 3H), 1.03 (s, 3H), 1.02 (s, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CD}_2\text{Cl}_2$ )  $\delta$  191.2, 183.5, 146.4, 140.9, 138.0, 130.9, 118.7, 116.4, 114.5, 104.9, 45.1, 42.6, 30.2, 17.5, 11.8, 7.9, 7.9, 7.4, 7.3; **HRMS (ESI)** calcd. for  $\text{C}_{21}\text{H}_{26}\text{NO}_4$   $[\text{M}+\text{H}]^+$ : 388.1577, found: 388.1583.

**(Z)-7-benzyl-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (7e)**



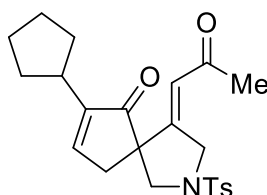
Column chromatography (petroleum ether/EtOAc = 12:1 to 5:1) to afford **7e** in 82% yield (71.24 mg); colorless oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.73–7.67 (m, 2H), 7.35–7.27 (m, 5H), 5.60 (t,  $J = 2.6$  Hz, 1H), 4.68 (dd,  $J = 18.7, 2.2$  Hz, 1H), 3.90 (dd,  $J = 18.7, 2.8$  Hz, 1H), 3.52 (s, 2H), 3.47 (d,  $J = 9.4$  Hz, 1H), 3.15 (d,  $J = 9.4$  Hz, 1H), 2.92–2.84 (m, 1H), 2.72–2.65 (m, 1H), 2.43 (s, 3H), 2.04 (s, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  204.8, 196.8, 160.2, 157.6, 145.7, 144.1, 137.8, 131.7, 129.8, 128.8, 128.7, 128.0, 126.6, 118.4, 58.3, 56.0, 53.5, 44.2, 31.6, 31.1, 21.5; **HRMS (ESI)** calcd. for  $\text{C}_{25}\text{H}_{25}\text{NO}_4\text{SNa}$   $[\text{M}+\text{Na}]^+$ : 458.1397, found: 458.1402.

**(Z)-7-cyclopropyl-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (7f)**



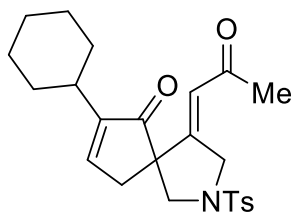
Column chromatography (petroleum ether/EtOAc = 15:1 to 5:1) to afford **7f** in 68% yield (52.4 mg); colorless oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.72–7.67 (m, 2H), 7.35–7.30 (m, 2H), 7.10 (t,  $J = 2.7$  Hz, 1H), 5.74 (t,  $J = 2.6$  Hz, 1H), 4.69 (dd,  $J = 18.6, 2.5$  Hz, 1H), 3.91 (dd,  $J = 18.7, 2.8$  Hz, 1H), 3.44 (d,  $J = 9.3$  Hz, 1H), 3.11 (d,  $J = 9.3$  Hz, 1H), 2.84 (dd,  $J = 19.3, 2.4$  Hz, 1H), 2.64 (dd,  $J = 19.3, 2.4$  Hz, 1H), 2.42 (s, 3H), 2.12 (s, 3H), 1.65–1.55 (m, 1H), 0.88 (dd,  $J = 8.5, 2.3$  Hz, 2H), 0.69–0.64 (m, 2H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  204.9, 196.9, 160.3, 152.1, 147.9, 144.1, 131.8, 129.8, 128.0, 118.6, 58.9, 56.4, 53.6, 43.8, 31.1, 21.5, 8.0, 7.8, 6.7; **HRMS (ESI)** calcd. for  $\text{C}_{21}\text{H}_{25}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 386.1421, found: 386.1399.

**(Z)-7-cyclopentyl-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (7g)**



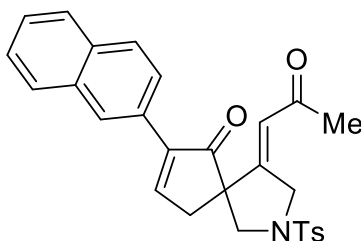
Column chromatography (petroleum ether/EtOAc = 15:1 to 5:1) to afford **7g** in 71% yield (58.7 mg); yellow oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.74–7.70 (m, 2H), 7.38–7.35 (m, 1H), 7.33 (d,  $J = 7.9$  Hz, 2H), 5.71 (t,  $J = 2.6$  Hz, 1H), 4.71 (dd,  $J = 18.7, 2.4$  Hz, 1H), 3.92 (dd,  $J = 18.7, 2.8$  Hz, 1H), 3.47 (d,  $J = 9.3$  Hz, 1H), 3.13 (d,  $J = 9.3$  Hz, 1H), 2.89 (dt,  $J = 4.5, 2.1$  Hz, 1H), 2.74–2.65 (m, 2H), 2.43 (s, 3H), 2.12 (s, 3H), 2.01–1.89 (m, 2H), 1.75–1.67 (m, 2H), 1.67–1.59 (m, 2H), 1.46–1.35 (m, 2H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  205.3, 196.9, 160.6, 154.4, 150.1, 144.1, 131.9, 129.9, 128.0, 118.4, 58.7, 56.3, 53.7, 44.2, 36.3, 31.6, 31.5, 31.1, 25.0; **HRMS (ESI)** calcd. for  $\text{C}_{23}\text{H}_{28}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 414.1734, found: 414.1717.

**(Z)-7-cyclohexyl-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (7h)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 5:1) to afford **7h** in 83% yield (71.0 mg); yellow oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.74–7.70 (m, 2H), 7.37–7.32 (m, 3H), 5.70 (t,  $J = 2.6$  Hz, 1H), 4.72 (dd,  $J = 18.7, 2.5$  Hz, 1H), 3.91 (dd,  $J = 18.7, 2.8$  Hz, 1H), 3.46 (d,  $J = 9.3$  Hz, 1H), 3.12 (d,  $J = 9.3$  Hz, 1H), 2.93–2.85 (m, 1H), 2.73–2.63 (m, 1H), 2.44 (s, 3H), 2.36–2.27 (m, 1H), 2.12 (s, 3H), 1.89–1.69 (m, 6H), 1.42–1.27 (m, 4H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  205.1, 196.9, 160.7, 154.8, 151.2, 144.1, 131.9, 129.9, 128.0, 118.4, 58.7, 56.3, 53.7, 44.3, 34.6, 31.8, 31.6, 31.2, 26.2, 26.2, 26.0, 21.6; **HRMS (ESI)** calcd. for  $\text{C}_{24}\text{H}_{30}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 428.1890, found: 428.1877.

**(Z)-7-(naphthalen-2-yl)-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (7i)**

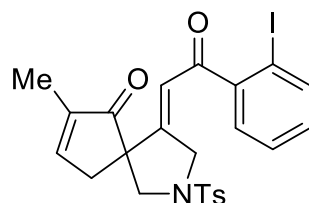


Column chromatography (petroleum ether/EtOAc = 10:1 to 4:1) to afford **7i** in 65% yield (61.3 mg); pale-ellow solid, mp 131–133 °C;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  8.40 (s, 1H), 8.09 (t,  $J = 3.0$  Hz, 1H), 7.90–7.86 (m, 2H), 7.85–7.81 (m, 1H), 7.78–7.74 (m, 2H), 7.72 (dd,  $J = 8.6, 1.7$  Hz, 1H), 7.54–7.49 (m, 2H), 7.36 (d,  $J = 7.9$  Hz, 2H), 5.88 (t,  $J = 2.6$  Hz, 1H), 4.79 (dd,  $J = 18.7, 2.4$  Hz, 1H), 4.00 (dd,  $J = 18.7, 2.8$  Hz, 1H), 3.62 (d,  $J = 9.4$  Hz, 1H), 3.28 (d,  $J = 9.4$  Hz, 1H), 3.13 (dd,  $J = 20.0, 3.0$  Hz, 1H), 2.92 (dd,  $J = 20.0, 3.1$  Hz, 1H), 2.45 (s, 3H), 2.13 (s, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  203.8, 197.0, 160.3, 157.5, 144.2, 142.3, 133.4, 133.1, 131.8, 129.9, 128.6, 128.4, 128.1, 127.6, 126.8, 126.7, 126.5, 124.2, 118.9, 59.6, 56.6, 53.7, 43.9, 31.2, 21.6; **HRMS (ESI)** calcd.



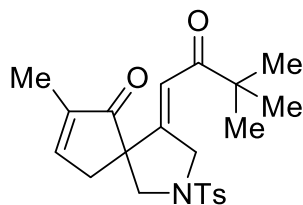
for C<sub>28</sub>H<sub>25</sub>NO<sub>4</sub>SNa [M+Na]<sup>+</sup>: 494.1397, found: 494.1402.

**(Z)-4-(2-(2-iodophenyl)-2-oxoethylidene)-7-methyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (7j)**



Column chromatography (petroleum ether/EtOAc = 7:1 to 4:1) to afford **7j** in 74% yield (81.0 mg); yellow solid, mp 144-146 °C; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.85 (d, *J* = 7.9 Hz, 1H), 7.78–7.73 (m, 2H), 7.47–7.45 (m, 1H), 7.40–7.33 (m, 3H), 7.30–7.27 (m, 1H), 7.13–7.07 (m, 1H), 6.17 (t, *J* = 2.6 Hz, 1H), 4.86 (dd, *J* = 18.8, 2.2 Hz, 1H), 4.05 (dd, *J* = 18.9, 2.8 Hz, 1H), 3.52 (d, *J* = 9.4 Hz, 1H), 3.22 (d, *J* = 9.4 Hz, 1H), 2.96 – 2.80 (m, 2H), 2.44 (s, 3H), 1.83–1.80 (m, 3H); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 205.4, 192.9, 162.0, 157.4, 144.5, 144.2, 141.5, 140.2, 131.9, 131.8, 129.9, 129.0, 128.2, 128.1, 118.1, 91.7, 58.6, 56.4, 54.0, 43.8, 21.6, 10.5; HRMS (ESI) calcd. for C<sub>24</sub>H<sub>22</sub>INO<sub>4</sub>SNa [M+Na]<sup>+</sup>: 570.0206, found: 570.0212.

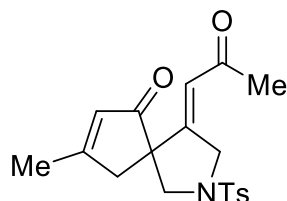
**(Z)-4-(3,3-dimethyl-2-oxobutylidene)-7-methyl-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (7k)**



Column chromatography (petroleum ether/EtOAc = 15:1 to 4:1) to afford **7k** in 74% yield (59.4 mg); colorless oil; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.74–7.70 (m, 2H), 7.47–7.44 (m, 1H), 7.35–7.31 (m, 2H), 5.98 (t, *J* = 2.6 Hz, 1H), 4.72 (dd, *J* = 18.5, 2.4 Hz, 1H), 3.93 (dd, *J* = 18.5, 2.8 Hz, 1H), 3.46 (d, *J* = 9.3 Hz, 1H), 3.11 (d, *J* = 9.3 Hz, 1H), 2.99–2.88 (m, 1H), 2.75–2.65 (m, 1H), 2.44 (s, 3H), 1.89–1.82 (m, 3H), 1.05 (s, 9H); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 205.9, 204.4, 161.2, 157.3, 144.2, 141.6, 131.9, 129.9, 128.1, 114.5, 58.4, 56.7, 53.9, 44.6, 43.6, 26.1, 21.6, 10.5; HRMS (ESI) calcd. for

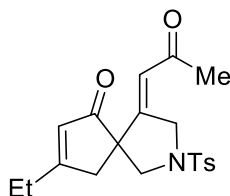
C<sub>22</sub>H<sub>27</sub>NO<sub>4</sub>SNa [M+Na]<sup>+</sup>: 424.1553, found: 424.1568.

**(Z)-8-methyl-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (71)**



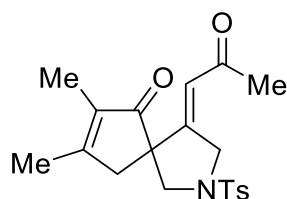
Column chromatography (petroleum ether/EtOAc = 10:1 to 5:1) to afford **71** in 70% yield (50.3 mg); yellow solid, mp 89-91 °C; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 7.72–7.67 (m, 2H), 7.34–7.29 (m, 2H), 6.04–6.00 (m, 1H), 5.80 (t, *J* = 2.6 Hz, 1H), 4.69 (dd, *J* = 18.7, 2.5 Hz, 1H), 3.88 (dd, *J* = 18.7, 2.8 Hz, 1H), 3.47 (d, *J* = 9.3 Hz, 1H), 3.08 (d, *J* = 9.3 Hz, 1H), 2.93 (d, *J* = 18.7 Hz, 1H), 2.70 (d, *J* = 19.0 Hz, 1H), 2.41 (s, 3H), 2.19 (d, *J* = 1.1 Hz, 3H), 2.12 (s, 3H); <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) δ 205.3, 197.0, 178.6, 160.2, 144.1, 131.7, 129.9, 129.8, 128.0, 118.7, 59.7, 56.3, 53.6, 50.1, 31.1, 21.5, 19.6; HRMS (ESI) calcd. for C<sub>19</sub>H<sub>22</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 360.1264, found: 360.1270.

**(Z)-8-ethyl-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (7m)**



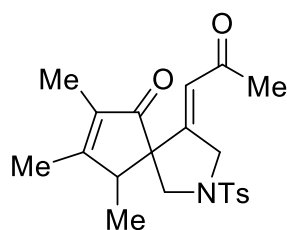
Column chromatography (petroleum ether/EtOAc = 10:1 to 4:1) to afford **7m** in 88% yield (0.986 g, 3 mmol scale); yellow oil; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.71 (d, *J* = 8.2 Hz, 2H), 7.33 (d, *J* = 8.1 Hz, 2H), 6.04 (s, 1H), 5.80 (t, *J* = 2.5 Hz, 1H), 4.72 (dd, *J* = 18.7, 2.3 Hz, 1H), 3.88 (dd, *J* = 18.7, 2.7 Hz, 1H), 3.49 (d, *J* = 9.3 Hz, 1H), 3.08 (d, *J* = 9.3 Hz, 1H), 2.96 (d, *J* = 18.9 Hz, 1H), 2.72 (d, *J* = 18.9 Hz, 1H), 2.51–2.46 (m, 2H), 2.43 (s, 3H), 2.13 (s, 3H), 1.24–1.21 (m, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 205.2, 197.0, 184.2, 160.2, 144.1, 131.6, 129.8, 127.9, 127.8, 118.6, 59.2, 56.3, 53.5, 48.6, 31.1, 26.8, 21.5, 11.2; HRMS (ESI) calcd. for C<sub>20</sub>H<sub>24</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 374.1421, found: 374.1433.

**(Z)-7,8-dimethyl-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (7n)**



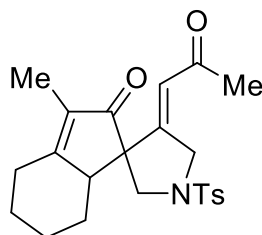
Column chromatography (petroleum ether/EtOAc = 15:1 to 5:1) to afford **7n** in 95% yield (71.0 mg); yellow oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.71–7.67 (m, 2H), 7.33–7.29 (m, 2H), 5.69 (t,  $J = 2.6$  Hz, 1H), 4.69 (dd,  $J = 18.7, 2.5$  Hz, 1H), 3.90 (dd,  $J = 18.7, 2.8$  Hz, 1H), 3.42 (d,  $J = 9.2$  Hz, 1H), 3.07 (d,  $J = 9.2$  Hz, 1H), 2.88–2.81 (m, 1H), 2.66–2.58 (m, 1H), 2.41 (s, 3H), 2.10 (s, 3H), 2.09 (d,  $J = 0.9$  Hz, 3H), 1.74–1.72 (m, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  205.2, 196.9, 169.8, 160.7, 144.1, 136.1, 131.9, 129.8, 128.0, 118.6, 58.3, 56.5, 53.6, 49.2, 31.1, 21.5, 17.2, 8.3; **HRMS (ESI)** calcd. for  $\text{C}_{20}\text{H}_{25}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 374.1421, found: 374.1415.

**(Z)-7,8,9-trimethyl-4-(2-oxopropylidene)-2-tosyl-2-azaspiro[4.4]non-7-en-6-one (7o)**



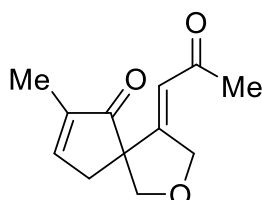
Column chromatography (petroleum ether/EtOAc = 15:1 to 6:1) to afford **7o** in 58% yield (44.9 mg); yellow oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.75–7.69 (m, 2H), 7.33 (d,  $J = 7.9$  Hz, 2H), 5.66 (t,  $J = 2.6$  Hz, 1H), 4.68 (dd,  $J = 18.5, 2.4$  Hz, 1H), 3.82 (dd,  $J = 18.6, 2.8$  Hz, 1H), 3.61 (d,  $J = 9.8$  Hz, 1H), 2.98 (d,  $J = 9.8$  Hz, 1H), 2.73–2.65 (m, 1H), 2.43 (s, 3H), 2.10 (s, 3H), 2.09 (s, 3H), 1.76–1.74 (m, 3H), 1.29 (d,  $J = 7.3$  Hz, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  204.8, 197.0, 174.9, 162.4, 144.1, 135.4, 131.4, 129.9, 128.1, 117.8, 61.5, 53.3, 51.2, 50.8, 31.2, 21.6, 15.6, 14.8, 8.4; **HRMS (ESI)** calcd. for  $\text{C}_{21}\text{H}_{26}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 388.1577, found: 388.1583.

**(Z)-3-methyl-4'-(2-oxopropylidene)-1'-tosyl-5,6,7,7a-tetrahydrospiro[indene-1,3'-pyrrolidin]-2(4H)-one (7p)**



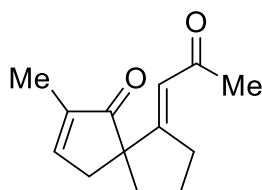
Column chromatography (petroleum ether/EtOAc = 10:1 to 5:1) to afford **7p** in 67% yield (55.4 mg); yellow oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.72–7.68 (m, 2H), 7.32 (d,  $J = 7.9$  Hz, 2H), 5.67 (t,  $J = 2.6$  Hz, 1H), 4.67 (dd,  $J = 18.5, 2.4$  Hz, 1H), 3.81 (dd,  $J = 18.6, 2.8$  Hz, 1H), 3.61 (d,  $J = 9.6$  Hz, 1H), 2.97–2.90 (m, 2H), 2.55–2.48 (m, 1H), 2.42 (s, 3H), 2.39–2.35 (m, 1H), 2.24–2.13 (m, 1H), 2.09 (s, 3H), 2.07–2.01 (m, 1H), 1.97–1.90 (m, 1H), 1.75–1.72 (m, 3H), 1.58–1.45 (m, 1H), 1.40–1.26 (m, 1H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  204.9, 197.0, 176.9, 162.4, 144.0, 132.2, 131.5, 129.8, 128.0, 117.8, 60.8, 54.3, 53.3, 50.4, 31.1, 30.9, 29.3, 26.9, 25.3, 21.5, 7.9; **HRMS (ESI)** calcd. for  $\text{C}_{23}\text{H}_{27}\text{NO}_4\text{SNa}$   $[\text{M}+\text{Na}]^+$ : 436.1553, found: 436.1558.

**(Z)-7-methyl-4-(2-oxopropylidene)-2-oxaspiro[4.4]non-7-en-6-one (7q)**



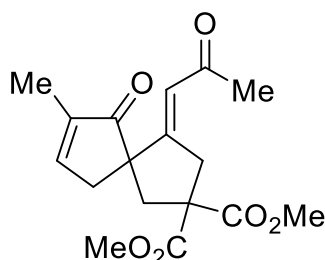
Column chromatography (petroleum ether/EtOAc = 10:1 to 5:1) to afford **7q** in 67% yield (27.6 mg); yellow oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.46–7.43 (m, 1H), 5.87 (t,  $J = 2.6$  Hz, 1H), 5.00 (dd,  $J = 18.1, 2.5$  Hz, 1H), 4.78 (dd,  $J = 18.2, 2.5$  Hz, 1H), 3.98 (d,  $J = 8.6$  Hz, 1H), 3.83 (d,  $J = 8.6$  Hz, 1H), 2.87–2.79 (m, 1H), 2.75–2.68 (m, 1H), 2.18 (s, 3H), 1.87–1.84 (m, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  206.6, 197.3, 165.4, 156.8, 141.4, 117.0, 76.2, 73.5, 59.5, 43.1, 31.0, 10.6; **HRMS (ESI)** calcd. for  $\text{C}_{12}\text{H}_{15}\text{O}_3$   $[\text{M}+\text{H}]^+$ : 207.1016, found: 207.0998.

**(E)-2-methyl-6-(2-oxopropylidene)spiro[4.4]non-2-en-1-one (7r)**



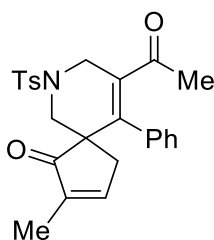
Column chromatography (petroleum ether/EtOAc = 30:1 to 5:1) to afford **7r** in 63% yield (25.7 mg); colorless oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.39–7.36 (m, 1H), 5.78 (s, 1H), 3.07–2.95 (m, 1H), 2.93–2.81 (m, 1H), 2.68–2.54 (m, 2H), 2.16–2.12 (m, 3H), 2.11–1.98 (m, 2H), 1.83–1.80 (m, 3H), 1.80–1.72 (m, 1H), 1.71–1.61 (m, 1H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  210.1, 198.0, 170.1, 156.4, 140.8, 118.9, 60.0, 44.5, 37.5, 34.0, 31.4, 24.3, 10.5; **HRMS (ESI)** calcd. for  $\text{C}_{13}\text{H}_{16}\text{O}_2\text{Na}$   $[\text{M}+\text{Na}]^+$ : 227.1043, found: 227.1048.

**dimethyl (E)-7-methyl-6-oxo-4-(2-oxopropylidene)spiro[4.4]non-7-ene-2,2-dicarboxylate (7s)**



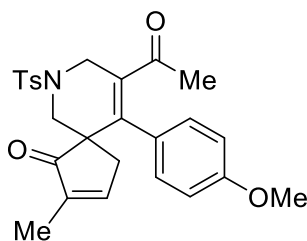
Column chromatography (petroleum ether/EtOAc = 10:1 to 5:1) to afford **7s** in 60% yield (38.4 mg); colorless oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.43–7.39 (m, 1H), 5.77 (t,  $J = 2.5$  Hz, 1H), 3.82 (dt,  $J = 19.9, 1.9$  Hz, 1H), 3.77 (s, 3H), 3.73 (s, 3H), 3.36 (dd,  $J = 19.8, 2.9$  Hz, 1H), 2.75 (d,  $J = 13.6$  Hz, 1H), 2.72–2.65 (m, 2H), 2.40 (dd,  $J = 13.6, 1.7$  Hz, 1H), 2.14 (s, 3H), 1.85–1.81 (m, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  208.2, 197.5, 172.1, 170.8, 165.3, 157.3, 140.6, 119.2, 59.7, 58.7, 53.0, 45.3, 42.8, 41.2, 31.5, 10.6; **HRMS (ESI)** calcd. for  $\text{C}_{17}\text{H}_{20}\text{O}_6\text{Na}$   $[\text{M}+\text{Na}]^+$ : 343.1152, found: 343.1158.

**9-acetyl-2-methyl-10-phenyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (9a)**



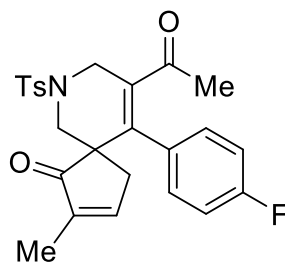
Column chromatography (petroleum ether/EtOAc = 15:1 to 4:1) to afford **9a** in 90% yield (78.4 mg); colorless solid, mp 179–181 °C;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.64–7.60 (m, 2H), 7.30 (d,  $J = 7.9$  Hz, 2H), 7.25–7.19 (m, 3H), 7.17–7.14 (m, 1H), 6.99–6.95 (m, 2H), 4.54 (dd,  $J = 16.5, 1.6$  Hz, 1H), 3.50 (dd,  $J = 11.5, 1.6$  Hz, 1H), 3.19 (d,  $J = 16.5$  Hz, 1H), 2.95–2.87 (m, 1H), 2.78–2.70 (m, 2H), 2.40 (s, 3H), 1.61–1.57 (m, 3H), 1.46 (s, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  207.8, 200.6, 158.0, 145.4, 144.1, 141.6, 136.6, 136.5, 132.4, 129.9, 129.3, 128.9, 128.4, 127.7, 54.5, 52.3, 45.9, 40.1, 30.6, 21.5, 10.2; **HRMS (ESI)** calcd. for  $\text{C}_{25}\text{H}_{25}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 436.1577, found: 436.1584.

**9-acetyl-10-(4-methoxyphenyl)-2-methyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (9b)**



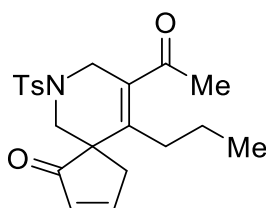
Column chromatography (petroleum ether/EtOAc = 10:1 to 3:1) to afford **9b** in 57% yield (53.1 mg); colorless solid, mp 185–187 °C;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.62–7.57 (m, 2H), 7.27 (d,  $J = 6.8$  Hz, 2H), 7.15 (s, 1H), 6.89–6.83 (m, 2H), 6.74–6.67 (m, 2H), 4.51 (d,  $J = 16.5$  Hz, 1H), 3.73–3.68 (m, 3H), 3.46 (d,  $J = 11.4$  Hz, 1H), 3.13 (d,  $J = 16.5$  Hz, 1H), 2.88 (d,  $J = 19.7$  Hz, 1H), 2.72–2.61 (m, 2H), 2.37 (s, 3H), 1.60 (s, 3H), 1.48–1.45 (m, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  208.1, 200.9, 160.0, 158.3, 145.4, 144.1, 141.7, 136.7, 132.5, 130.7, 129.9, 128.8, 127.7, 113.9, 55.2, 54.7, 52.4, 46.1, 40.3, 30.6, 21.5, 10.3; **HRMS (ESI)** calcd. for  $\text{C}_{26}\text{H}_{28}\text{NO}_5\text{S}$   $[\text{M}+\text{H}]^+$ : 466.1683, found: 466.1678.

**9-acetyl-10-(4-fluorophenyl)-2-methyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (9c)**



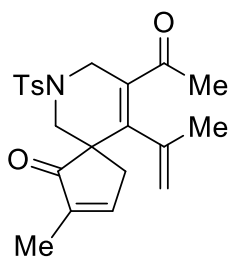
Column chromatography (petroleum ether/EtOAc = 15:1 to 4:1) to afford **9c** in 79% yield (71.7 mg); yellow oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.69–7.63 (m, 2H), 7.41–7.30 (m, 2H), 7.23 (s, 1H), 7.04–6.93 (m, 4H), 4.56 (d,  $J = 16.6$  Hz, 1H), 3.54 (d,  $J = 11.4$  Hz, 1H), 3.23 (dd,  $J = 16.5, 3.2$  Hz, 1H), 2.97 (d,  $J = 19.6$  Hz, 1H), 2.80–2.71 (m, 2H), 2.48–2.43 (m, 3H), 1.65 (s, 3H), 1.57–1.51 (m, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  207.8, 200.4, 158.2, 144.2, 144.0, 141.8, 137.3, 132.4, 131.2 (d,  $J = 8.3$  Hz), 130.0, 127.7, 115.7 (d,  $J = 21.5$  Hz), 54.6, 52.4, 46.0, 40.1, 30.7, 21.5, 10.2; **HRMS (ESI)** calcd. for  $\text{C}_{25}\text{H}_{25}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 454.1483, found: 436.1494.

**9-acetyl-10-propyl-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one (9d)**



Column chromatography (petroleum ether/EtOAc = 10:1 to 5:1) to afford **9d** in 71% yield (55.0 mg); colorless solid, mp 152–154 °C;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.90–7.86 (m, 1H), 7.64–7.59 (m, 2H), 7.35–7.31 (m, 2H), 6.28 (d,  $J = 5.6$  Hz, 1H), 4.19 (d,  $J = 15.5$  Hz, 1H), 3.40 (d,  $J = 11.3$  Hz, 1H), 3.28 (d,  $J = 15.5$  Hz, 1H), 3.08 (d,  $J = 20.2$  Hz, 1H), 2.84 (d,  $J = 20.2$  Hz, 1H), 2.48 (d,  $J = 11.4$  Hz, 1H), 2.43 (s, 3H), 2.25 (s, 3H), 2.15 (td,  $J = 12.9, 5.0$  Hz, 1H), 1.82 (td,  $J = 13.1, 4.7$  Hz, 1H), 1.41–1.21 (m, 2H), 0.80 (t,  $J = 7.2$  Hz, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  208.3, 200.2, 165.4, 144.3, 143.7, 133.9, 132.5, 132.1, 130.0, 127.6, 53.8, 51.8, 46.1, 43.0, 33.2, 29.9, 23.1, 21.5, 14.8; **HRMS (ESI)** calcd. for  $\text{C}_{21}\text{H}_{26}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 388.1577, found: 388.1583.

**9-acetyl-2-methyl-10-(prop-1-en-2-yl)-7-tosyl-7-azaspiro[4.5]deca-2,9-dien-1-one**  
**(9e)**

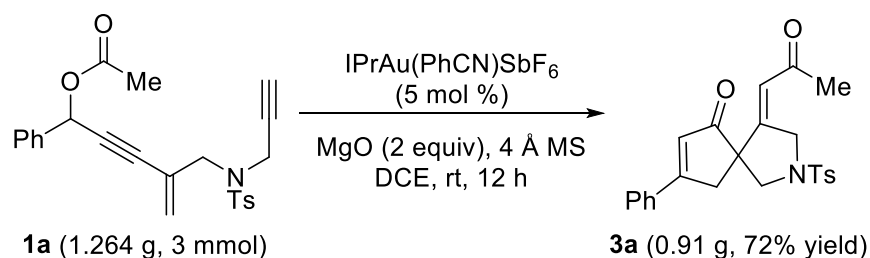


Column chromatography (petroleum ether/EtOAc = 10:1 to 5:1) to afford **9e** in 46% yield (36.8 mg); colorless oil;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.64–7.59 (m, 2H), 7.42–7.37 (m, 1H), 7.32 (d,  $J = 8.0$  Hz, 2H), 5.00 (s, 1H), 4.80 (s, 1H), 4.27 (d,  $J = 16.4$  Hz, 1H), 3.38 (d,  $J = 11.4$  Hz, 1H), 3.24 (d,  $J = 16.4$  Hz, 1H), 2.96–2.76 (m, 2H), 2.59 (d,  $J = 11.4$  Hz, 1H), 2.42 (s, 3H), 2.23 (s, 3H), 1.83–1.78 (m, 3H), 1.71 (s, 3H);  $^{13}\text{C NMR}$  (100 MHz,  $\text{CDCl}_3$ )  $\delta$  207.4, 201.9, 157.7, 145.3, 144.1, 141.9, 141.0, 135.2, 132.4, 129.9, 127.7, 121.0, 52.5, 45.8, 40.6, 30.4, 23.2, 21.5, 10.5; **HRMS (ESI)** calcd. for  $\text{C}_{22}\text{H}_{26}\text{NO}_4\text{S}$   $[\text{M}+\text{H}]^+$ : 400.1577, found: 400.1483.



## 5. Gram-scale synthesis of **3a**, **5a** and **7m** and further transformations

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



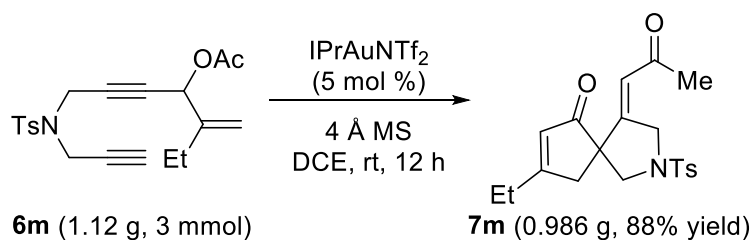
To a solution of **1a** (1.264 g, 3.0 mmol), MgO (0.242 g, 6.0 mmol), and 4 Å MS (1.5 g) in anhydrous DCE (30 mL) was added IPrAu(PhCN)SbF<sub>6</sub> (5 mol%) under an argon atmosphere. The reaction mixture was stirred at room temperature for 12 h. Upon completion, filtered through celite, washed with CH<sub>2</sub>Cl<sub>2</sub> and the solvent was removed under reduced pressure. The residue was purified by flash column chromatography on silica gel (petroleum ether/EtOAc = 20:1 to 4:1) to give the product **3a** (0.91 g, 72%).

### 5.2. Gram-scale synthesis of **5a**



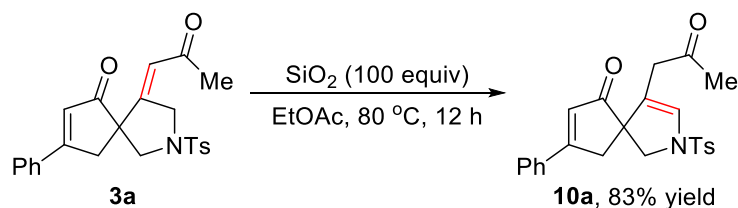
To a solution of **4a** (1.493 g, 3.0 mmol), MgO (0.242 g, 6.0 mmol), and 4 Å MS (1.5 g) in anhydrous DCE (30 mL) was added IPrAu(PhCN)SbF<sub>6</sub> (5 mol%) under an argon atmosphere. The reaction mixture was stirred at room temperature for 20 h. Upon completion, filtered through celite, washed with CH<sub>2</sub>Cl<sub>2</sub> and the solvent was removed under reduced pressure. The residue was purified by flash column chromatography on silica gel (petroleum ether/EtOAc = 15:1 to 4:1) to give the product **5a** (1.209g, 81%).

### 5.3. Gram-scale synthesis of **7m**



To a solution of **6m** (1.12 g, 3.0 mmol), and 4 Å MS (1.5 g) in anhydrous DCE (30 mL) was added IPrAuNTf<sub>2</sub> (5 mol%) under an argon atmosphere. The reaction mixture was stirred at room temperature for 12 h. Upon completion, filtered through celite, washed with CH<sub>2</sub>Cl<sub>2</sub> and the solvent was removed under reduced pressure. The residue was purified by flash column chromatography on silica gel (petroleum ether/EtOAc = 10:1 to 4:1) to give the product **7m** (0.986 g, 88%).

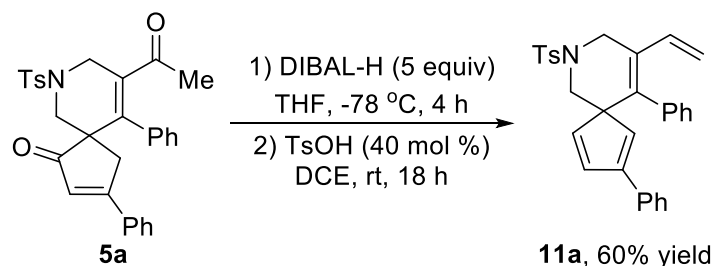
### 5.4. Synthetic transformation of **3a**



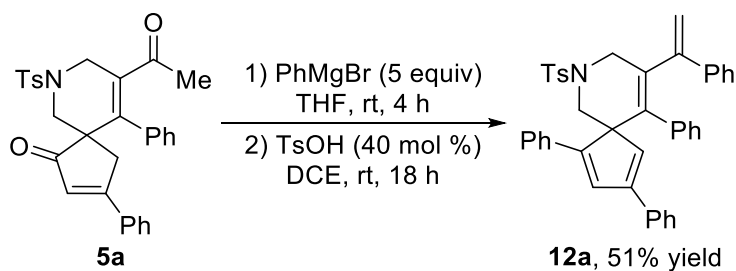
To a solution of **3a** (84.3 mg, 0.2 mmol) in EtOAc (4 mL) was added SiO<sub>2</sub> (1.2 g, 20.0 mmol) under an air atmosphere. The reaction mixture was stirred at 80 °C for 12 h. Upon completion, the reaction mixture was cooled down to room temperature and filtered through celite, washed with EtOAc and the solvent was removed under reduced pressure. The residue was purified by flash column chromatography on silica gel (eluent: petroleum ether: EtOAc = 15:1 to 3:1) to afford the product **10a** in 83% yield (70.0 mg) as a colorless solid, mp 115–117 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.73 (d, *J* = 8.0 Hz, 2H), 7.52–7.47 (m, 2H), 7.46–7.41 (m, 2H), 7.39 (d, *J* = 8.0 Hz, 2H), 6.60 (s, 1H), 6.50 (s, 1H), 3.76 (d, *J* = 11.0 Hz, 1H), 3.56 (d, *J* = 11.1 Hz, 1H), 2.92 (d, *J* = 17.5 Hz, 1H), 2.88–2.78 (m, 2H), 2.59 (d, *J* = 18.6 Hz, 1H), 2.49 (s, 3H), 2.04 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 207.0, 204.4, 172.2, 144.2, 132.8, 132.6, 132.0, 130.8, 129.9, 129.0, 127.9, 126.9, 125.8, 120.8, 60.6, 57.7, 42.2, 39.4, 29.4, 21.6; HRMS (ESI) calcd

for C<sub>24</sub>H<sub>24</sub>NO<sub>4</sub>S [M+H]<sup>+</sup>: 422.1421; found: 422.1429.

### 5.5. Synthetic transformation of **5a**



To a solution of **5a** (99.5 mg, 0.2 mmol) in anhydrous THF (4 mL) at -78 °C was added DIBAL-H (1.0 M in hexane, 1 mL, 5 equiv) dropwise and the reaction mixture was stirred -78 °C for 4 h, followed by addition of methanol and then warmed to room temperature. The reaction mixture was added saturated sodium potassium tartrate aqueous solution and stirred for 12 h. The mixture was extract with EtOAc, washed with brine and dried over MgSO<sub>4</sub>, then filtrated and concentrated under reduced pressure to give the crude diol product without further purification. The crude product was then dissolved in 2 mL DCE and added *p*-toluenesulfonic acid monohydrate (40 mol %) under an air atmosphere. The resulting reaction mixture was stirred at room temperature for 18 h. Upon completion, the reaction mixture was quenched with saturated NH<sub>4</sub>Cl solution and extracted with DCM, the combined organic layers were washed with brine, dried over MgSO<sub>4</sub>. After filtration and concentration, the residue was purified by flash column chromatography on silica gel (eluent: petroleum ether/EtOAc = 20:1 to 10:1) to afford **11a** (55.9 mg) in 60% yield as colorless solid, mp 187–189 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.74 (d, *J* = 8.2 Hz, 2H), 7.39–7.33 (m, 4H), 7.30 (t, *J* = 7.5 Hz, 2H), 7.26–7.22 (m, 1H), 7.16–7.09 (m, 3H), 6.94–6.90 (m, 2H), 6.57–6.54 (m, 2H), 6.44 (dd, *J* = 5.2, 2.3 Hz, 1H), 6.10 (dd, *J* = 17.9, 11.2 Hz, 1H), 5.09 (d, *J* = 17.8 Hz, 1H), 4.90 (d, *J* = 11.3 Hz, 1H), 4.00 (d, *J* = 15.3 Hz, 1H), 3.94 (d, *J* = 15.3 Hz, 1H), 3.30–3.25 (m, 2H), 2.46 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 146.0, 143.8, 141.4, 138.3, 136.9, 134.7, 133.8, 133.5, 133.0, 132.9, 129.8, 128.5, 128.5, 127.8, 127.8, 127.1, 127.0, 126.1, 112.2, 61.3, 49.5, 45.1, 21.6; HRMS (ESI) calcd for C<sub>30</sub>H<sub>28</sub>NO<sub>2</sub>S [M+H]<sup>+</sup>: 466,1835; found: 466,1846.



To a solution of **5a** (99.5 mg, 0.2 mmol) in anhydrous THF (4 mL) was added PhMgBr (1 mL, 1.0 mmol, 5 equiv) under an argon atmosphere at 0 °C. The reaction mixture was stirred at room temperature for 4 h. Upon completion, the reaction mixture was quenched with saturated NH<sub>4</sub>Cl solution and extracted with EtOAc, the combined organic layers were washed with brine, dried over MgSO<sub>4</sub>, then filtrated and concentrated under reduced pressure without further purification. The crude product was then added *p*-toluenesulfonic acid monohydrate (40 mol%) in DCE (2 mL) under an air atmosphere and stirred at room temperature for 18 h. Upon completion, the reaction mixture was quenched with saturated NH<sub>4</sub>Cl solution and extracted with DCM, the combined organic layers were washed with brine, dried over MgSO<sub>4</sub>. After filtration and concentration, the residue was purified by flash column chromatography on silica gel (eluent: petroleum ether/EtOAc = 15:1 to 7:1) to afford **12a** (55.9 mg) in 51% yield as pale-yellow solid, mp 190–192 °C; <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) δ 7.66–7.60 (m, 4H), 7.54–7.51 (m, 2H), 7.41–7.33 (m, 4H), 7.32–7.24 (m, 9H), 7.23–7.20 (m, 1H), 7.09 (d, *J* = 1.7 Hz, 1H), 7.06 (d, *J* = 1.7 Hz, 1H), 6.86 (t, *J* = 7.2 Hz, 1H), 6.80–6.78 (m, 2H), 6.75 (t, *J* = 7.6 Hz, 2H), 5.41 (s, 1H), 5.04 (s, 1H), 4.39 (dd, *J* = 16.5, 1.5 Hz, 1H), 3.67 (dd, *J* = 12.1, 1.5 Hz, 1H), 3.64 (d, *J* = 16.5 Hz, 1H), 3.35 (d, *J* = 12.0 Hz, 1H), 2.42 (s, 3H); <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) δ 148.7, 146.1, 144.2, 143.6, 139.1, 137.1, 136.7, 136.5, 134.6, 134.4, 133.9, 133.8, 130.3, 129.8, 128.6, 128.6, 128.4, 128.3, 127.8, 127.7, 127.6, 127.2, 126.6, 126.4, 126.3, 126.2, 126.0, 116.8, 61.2, 50.7, 48.9, 21.5; HRMS (ESI) calcd for C<sub>42</sub>H<sub>36</sub>NO<sub>2</sub>S [M+H]<sup>+</sup>: 618.2461; found: 618.2475.

## 6. $^1\text{H}$ , $^{13}\text{C}$ and $^{19}\text{F}$ NMR spectra

Figure S1  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1a

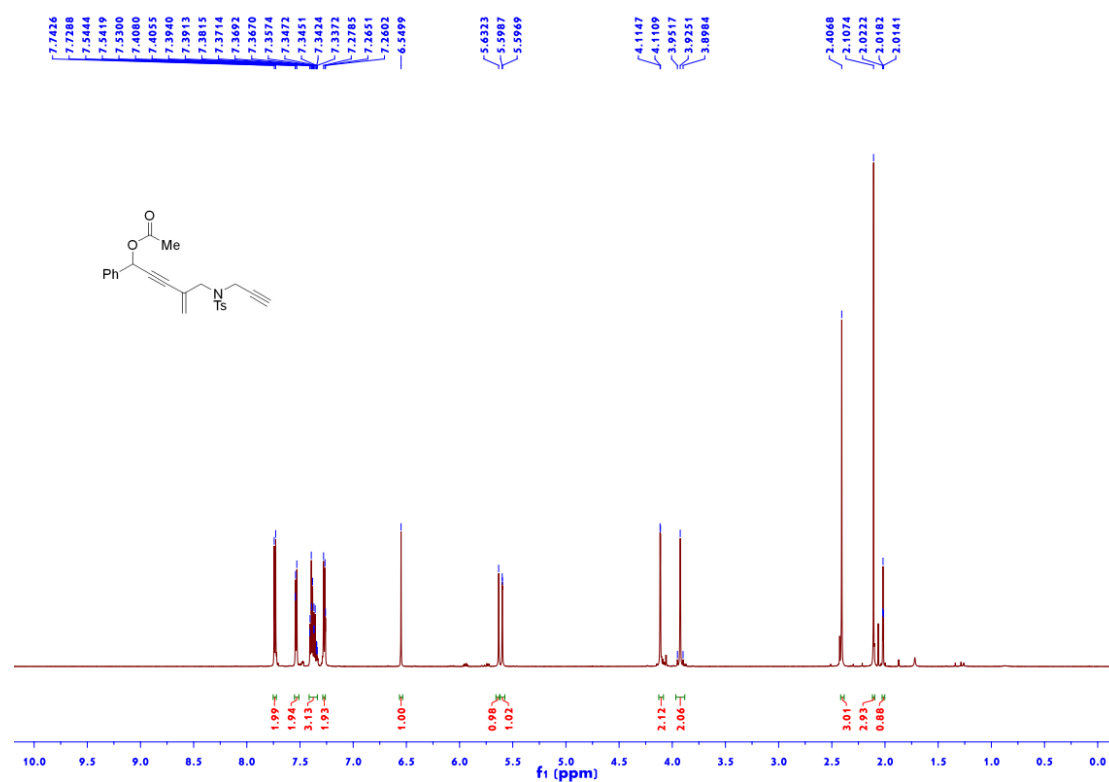


Figure S2  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1a

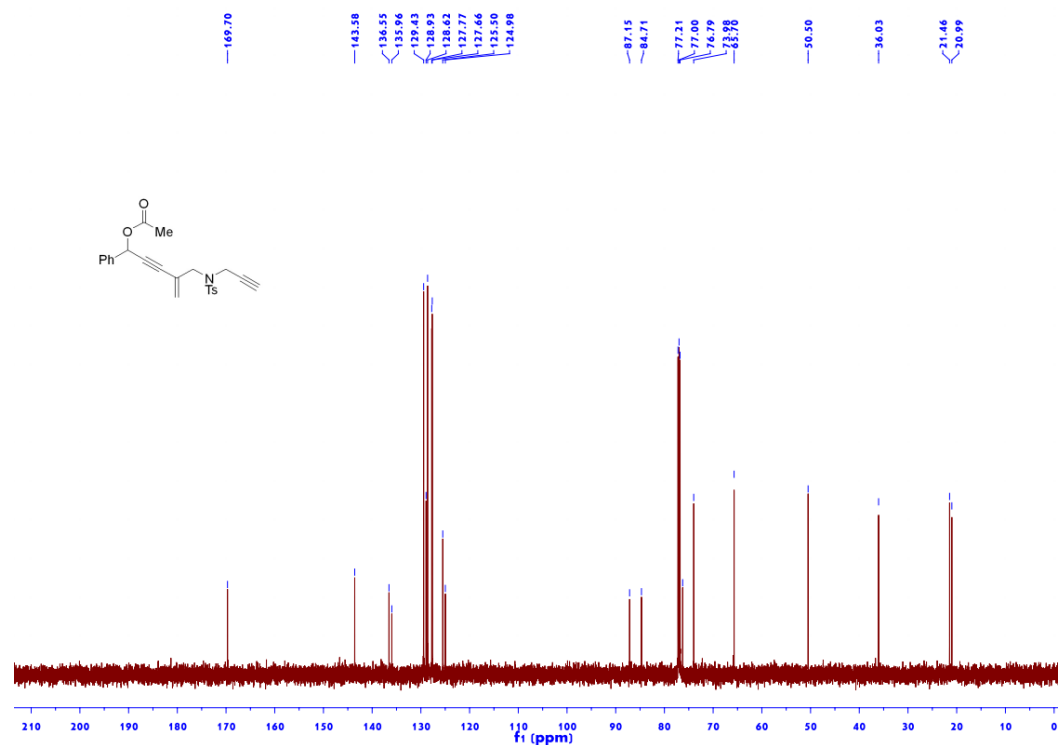


Figure S3 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 1b

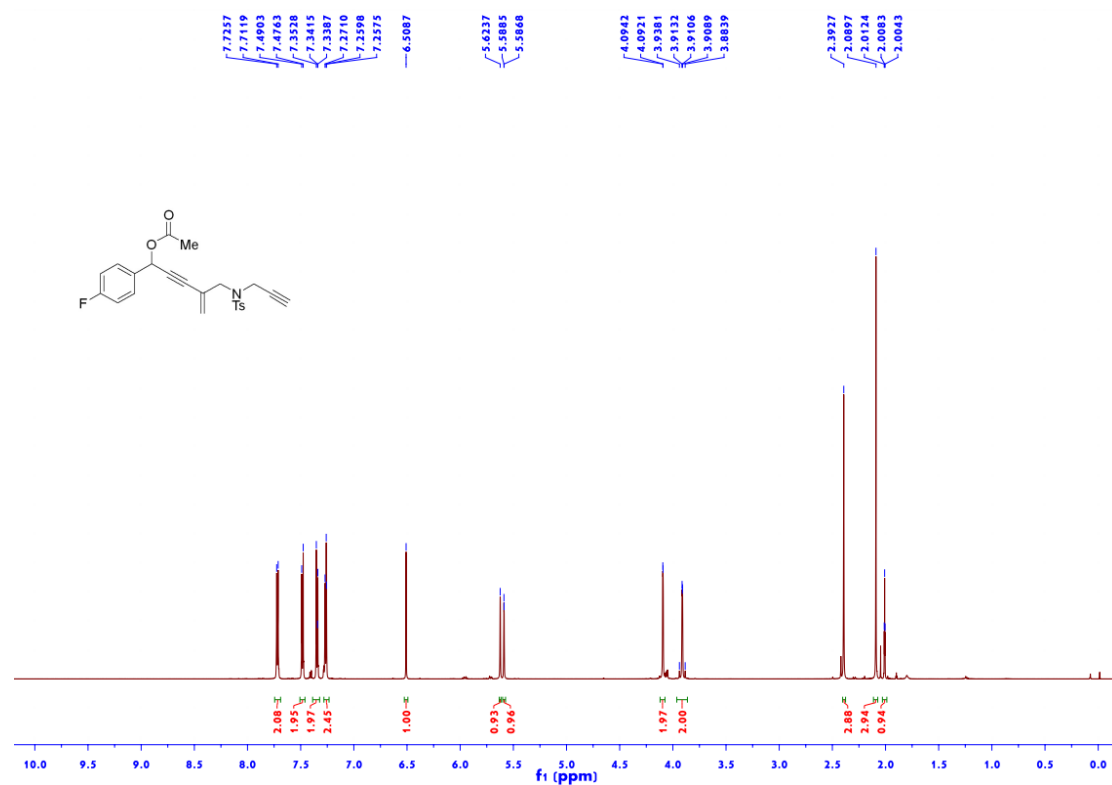


Figure S4 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 1b

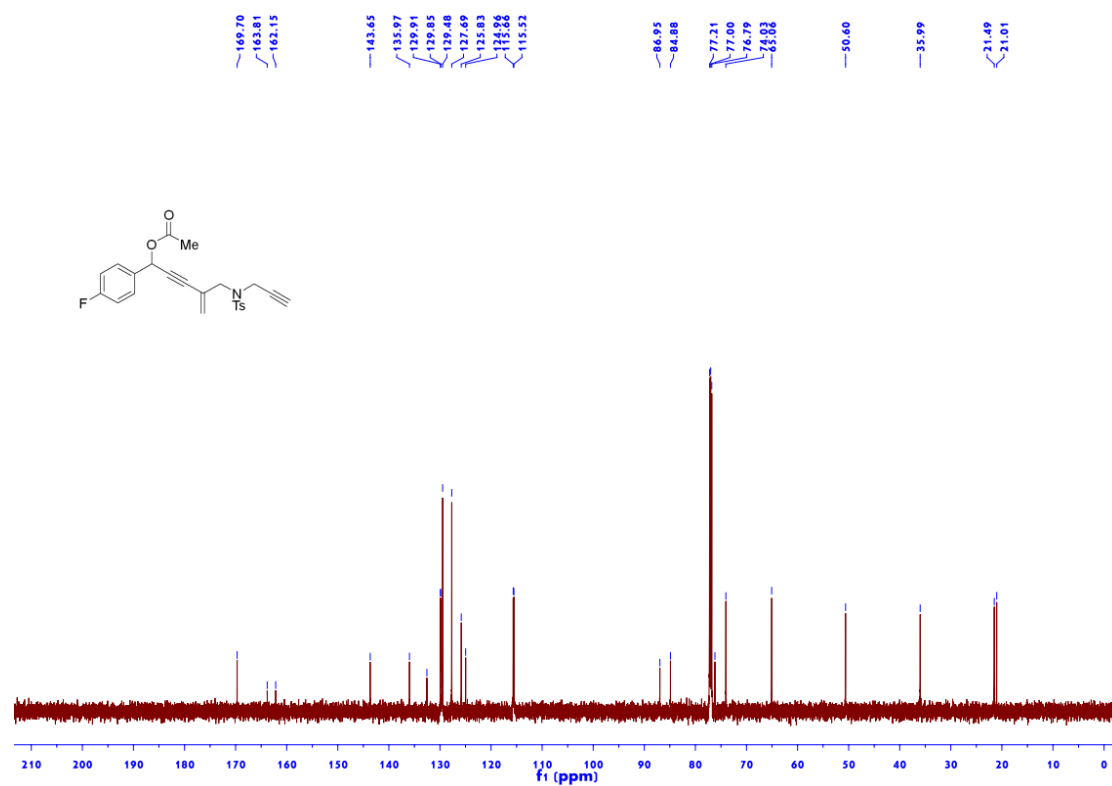


Figure S5  $^{19}\text{F}$  NMR (565 MHz,  $\text{CDCl}_3$ ) of 1b

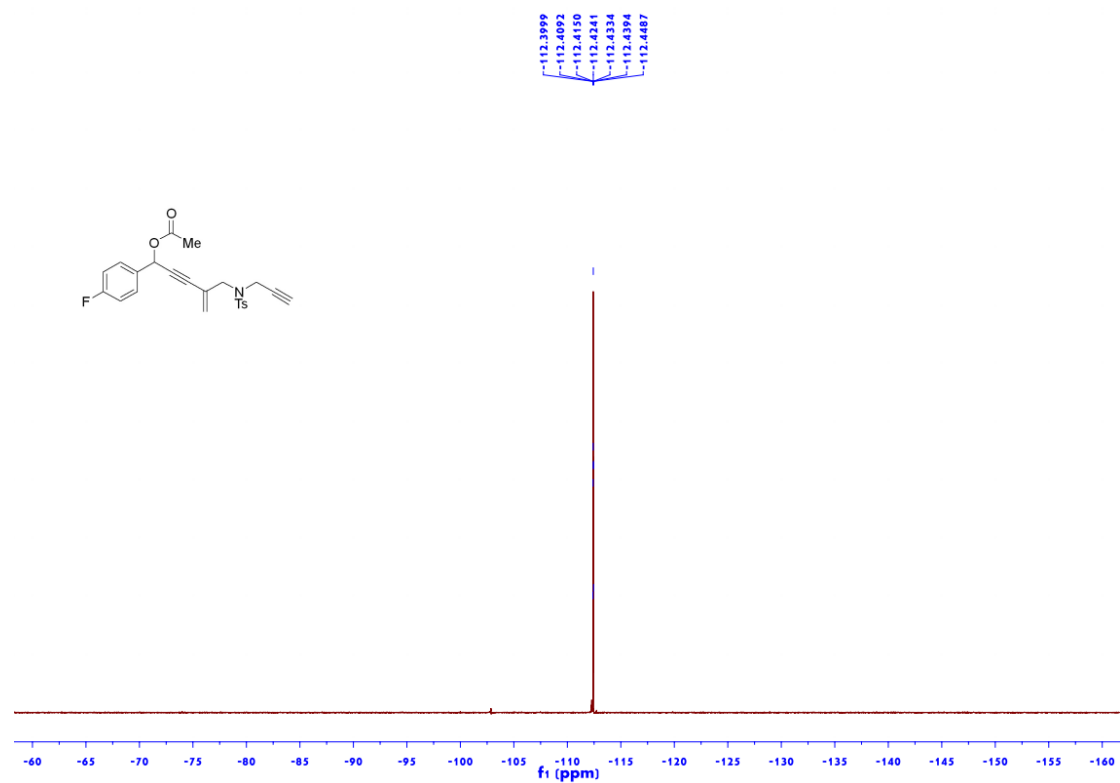


Figure S6  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1c

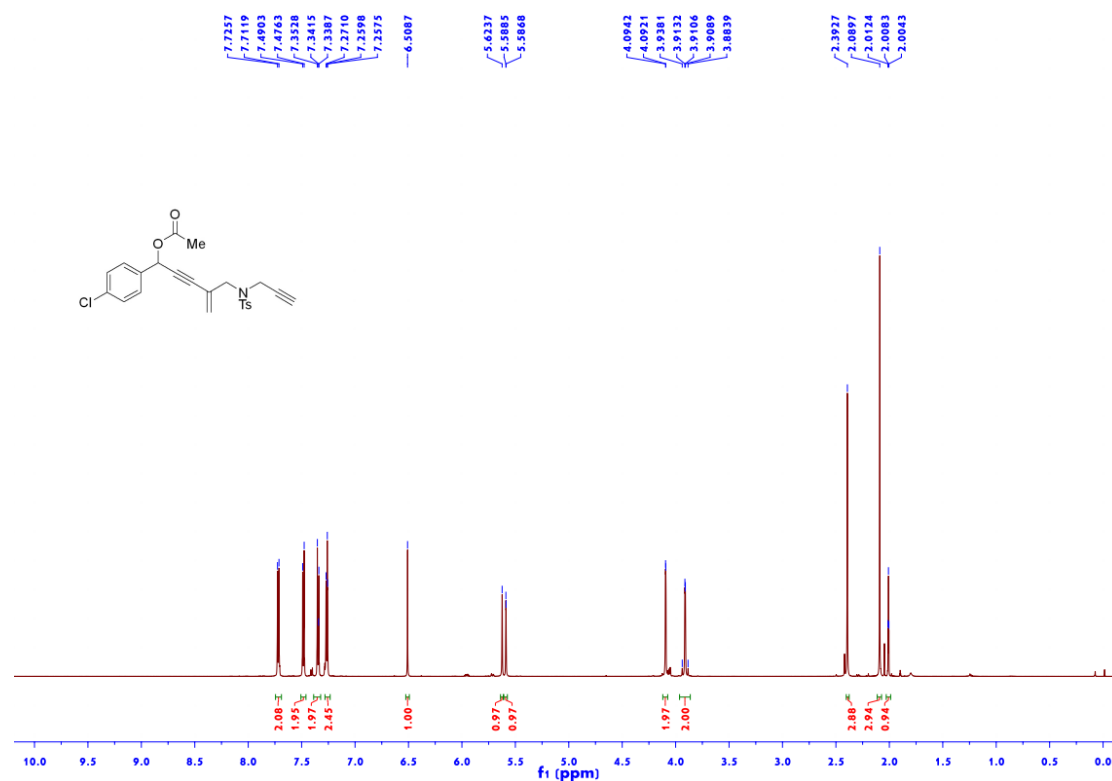


Figure S7  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1c

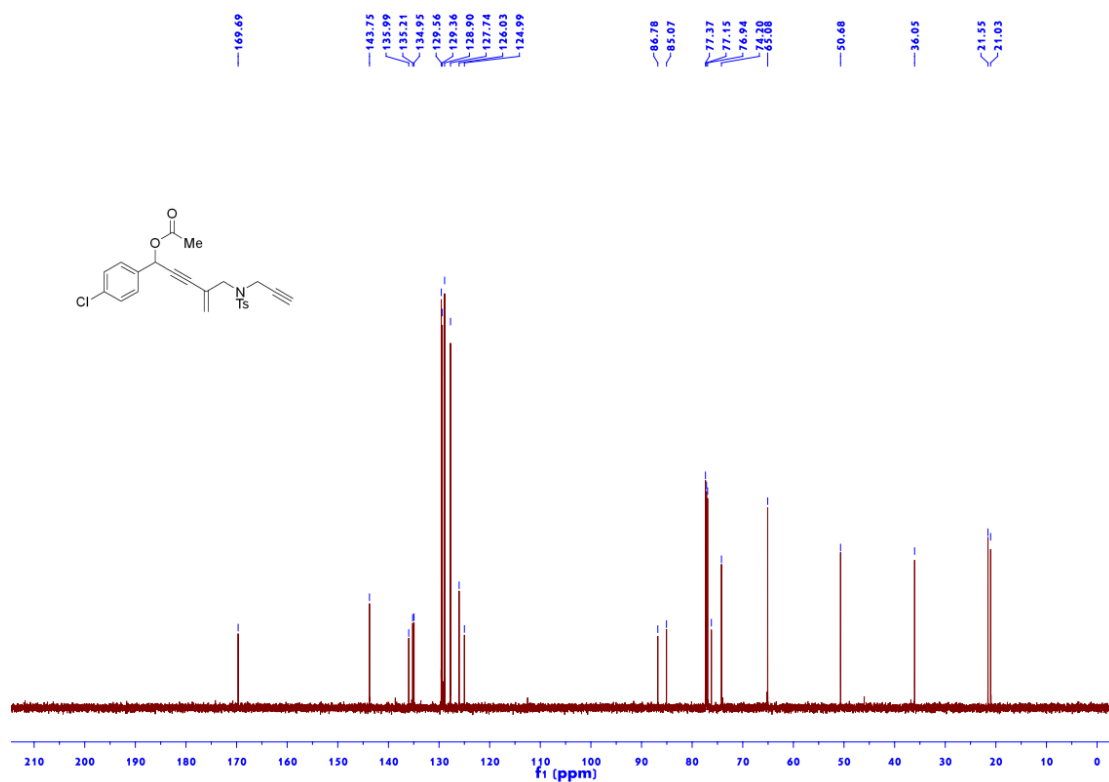


Figure S8  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1d

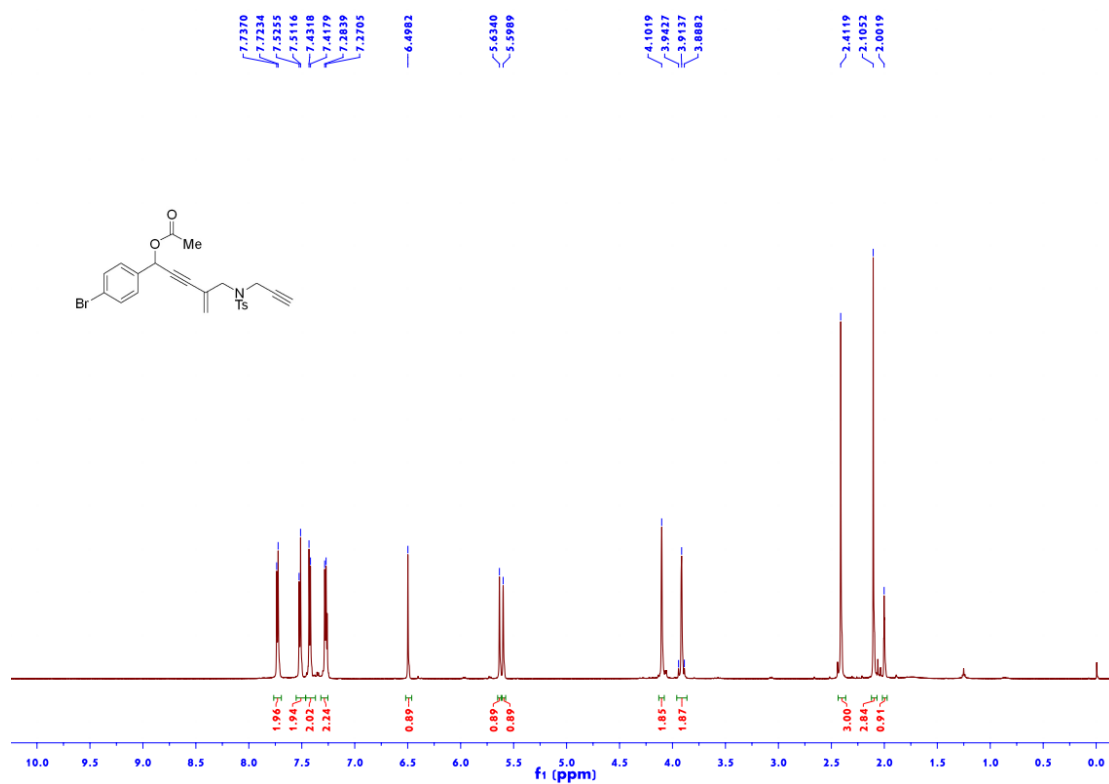




Figure S9 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 1d

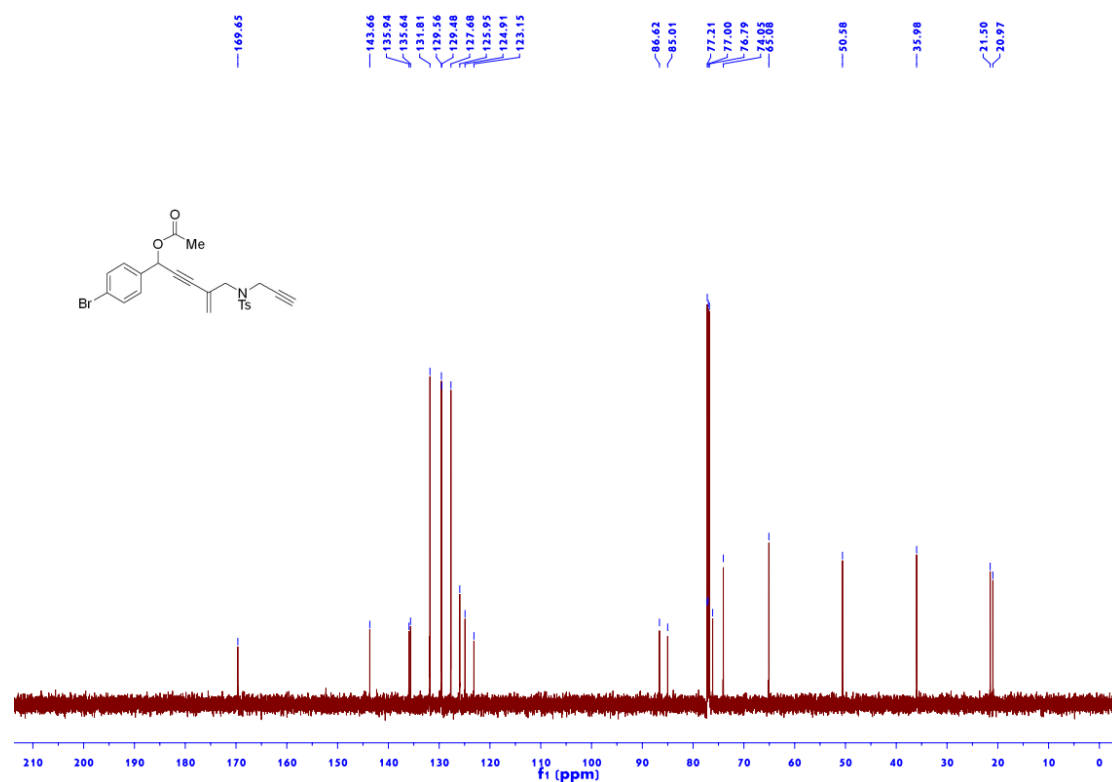


Figure S10 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 1e

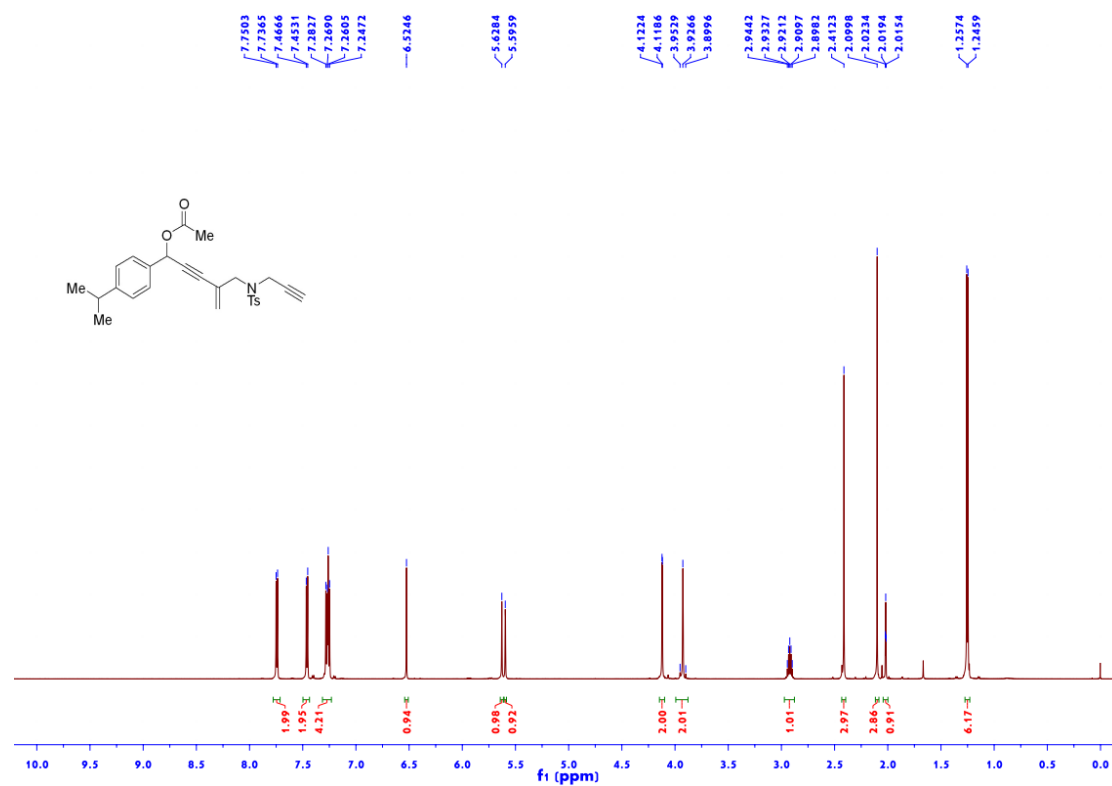


Figure S11  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1e

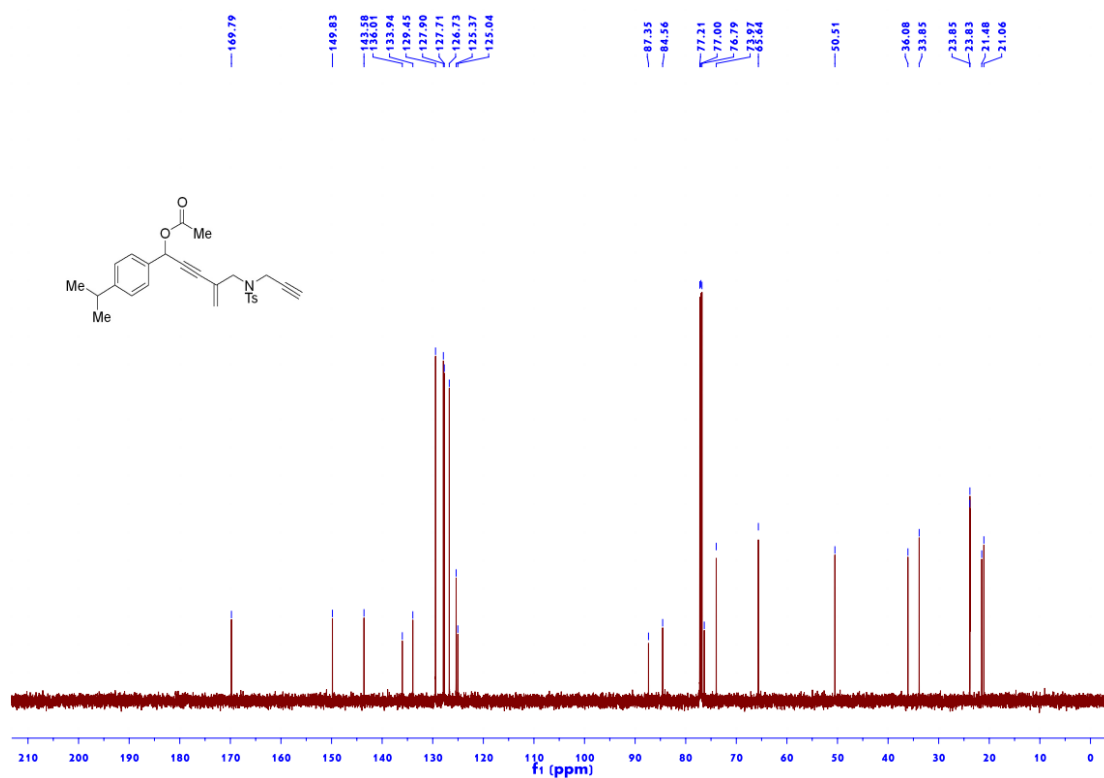


Figure S12  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1f

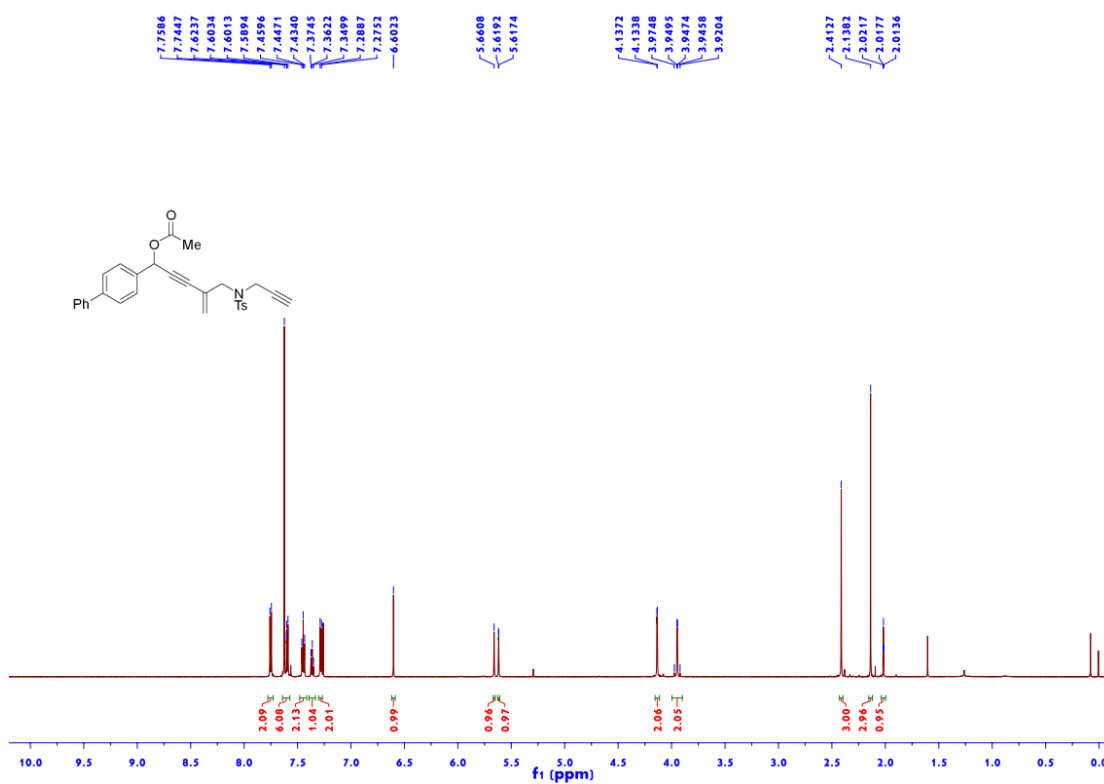


Figure S13  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of **1f**

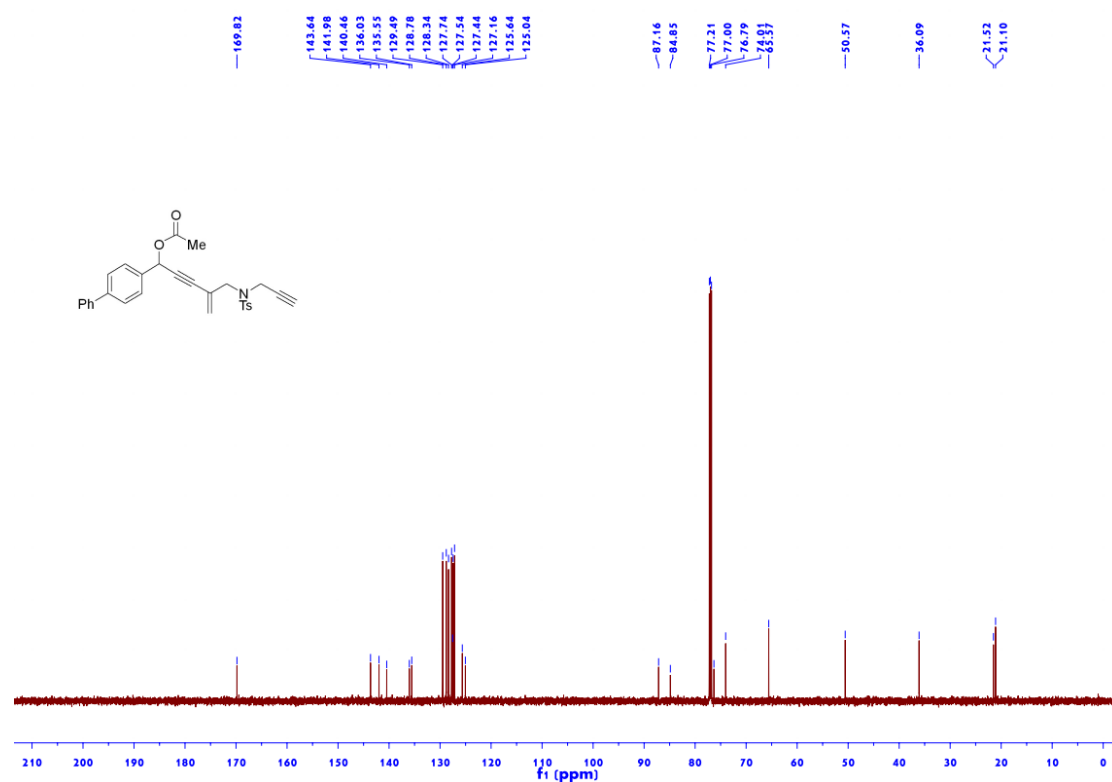


Figure S14  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of **1g**

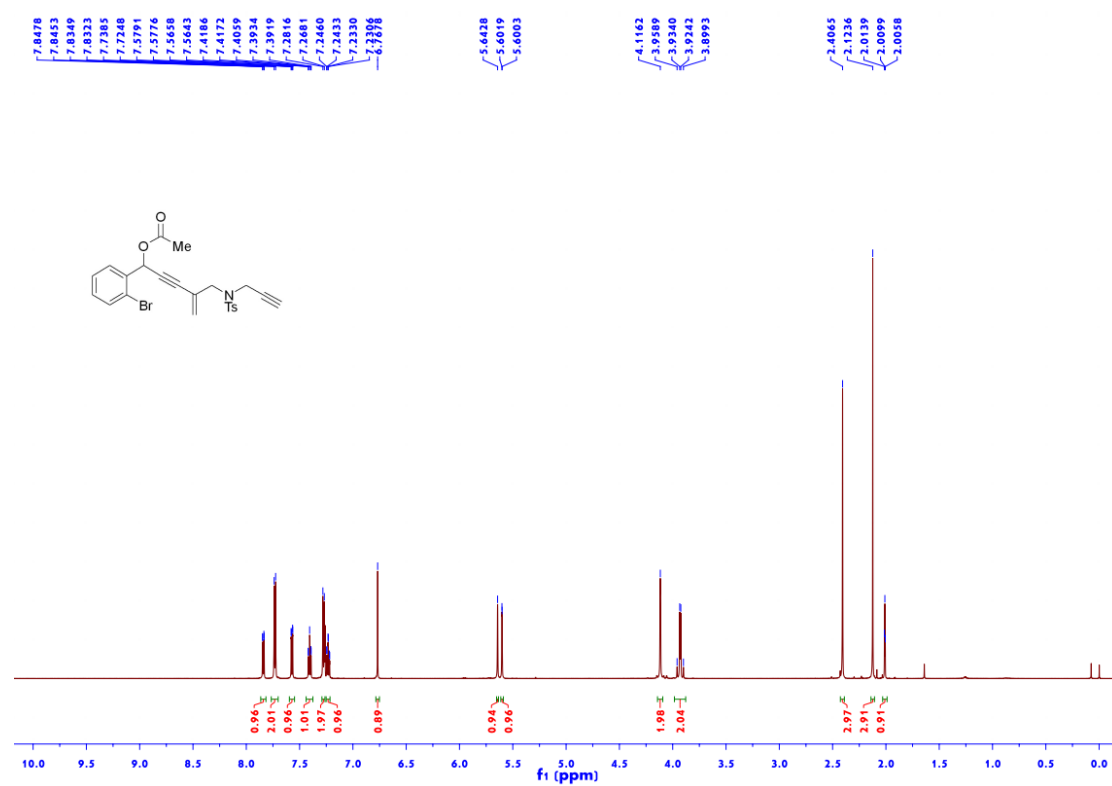


Figure S15  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1g

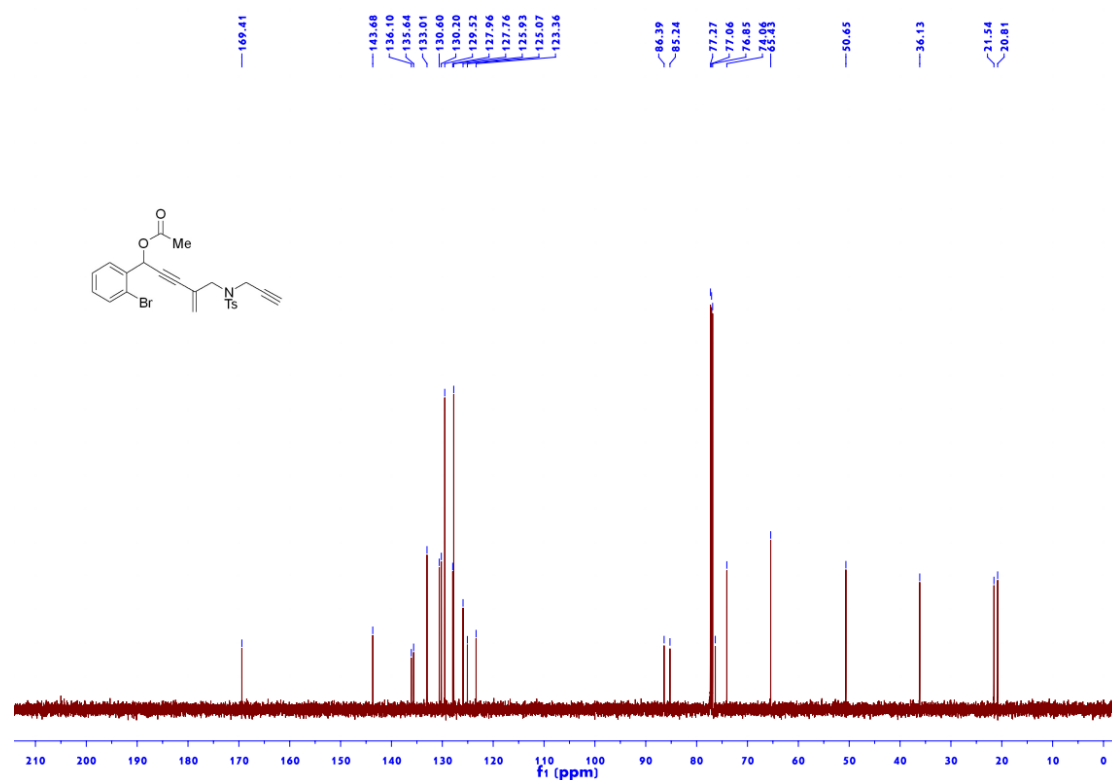


Figure S16  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1h

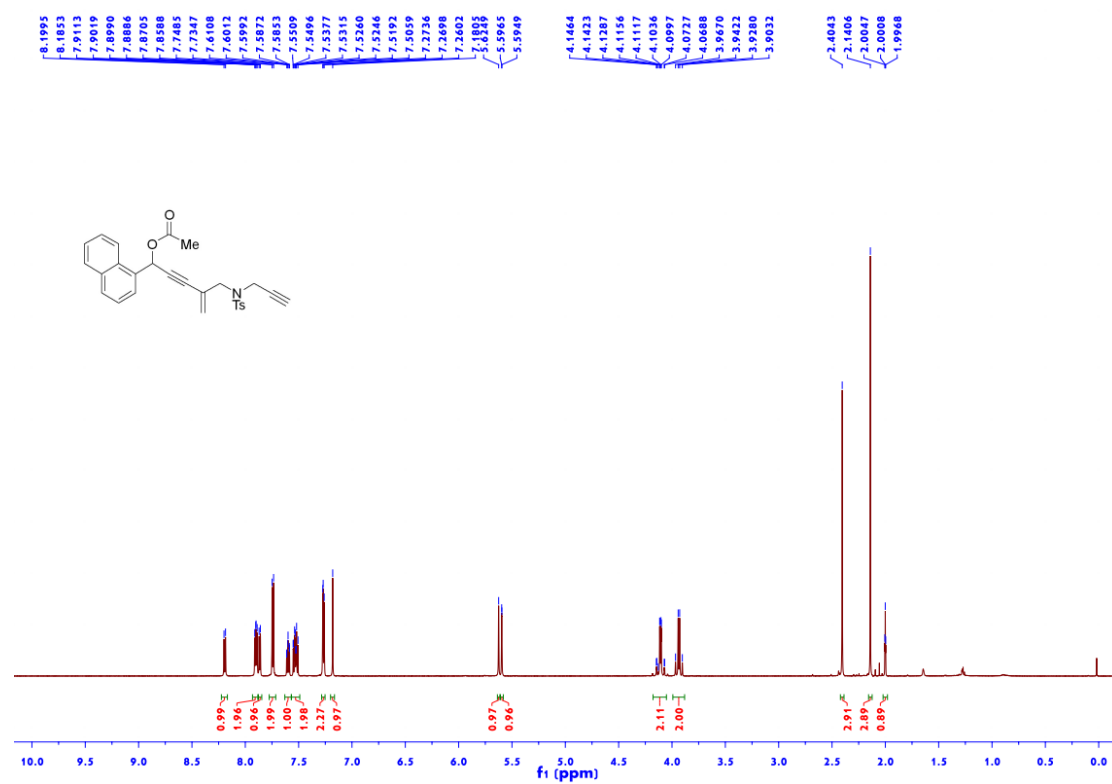


Figure S17  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1h

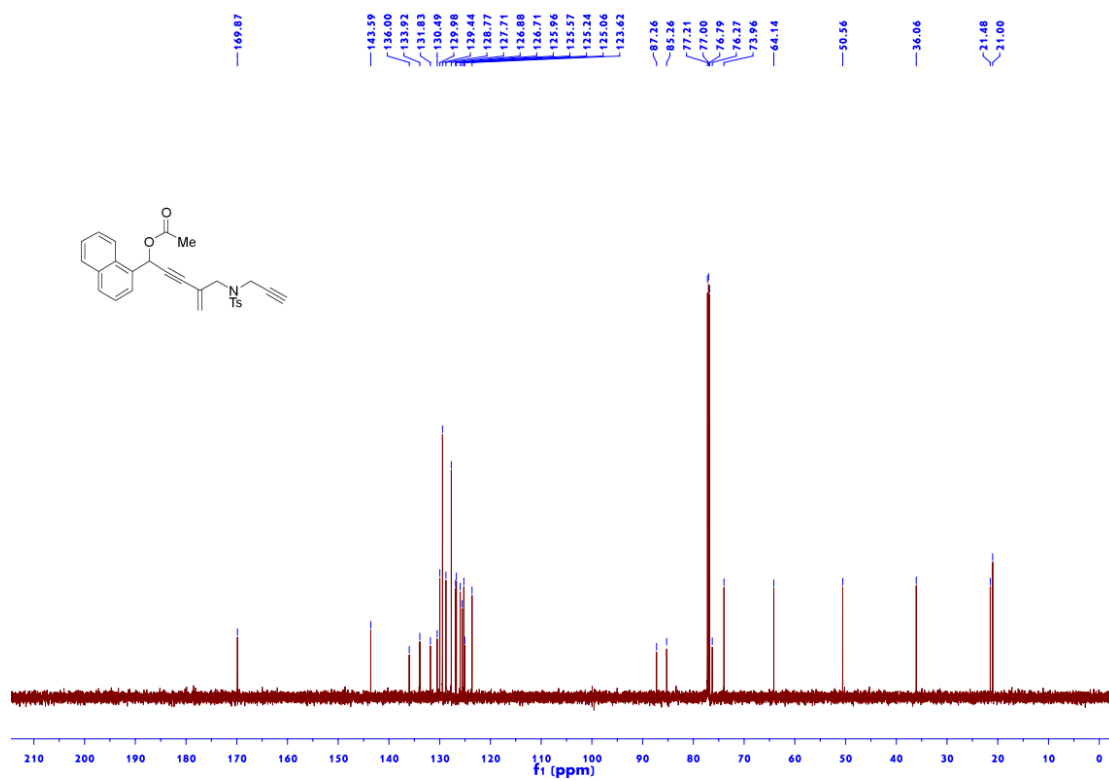


Figure S18  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1i

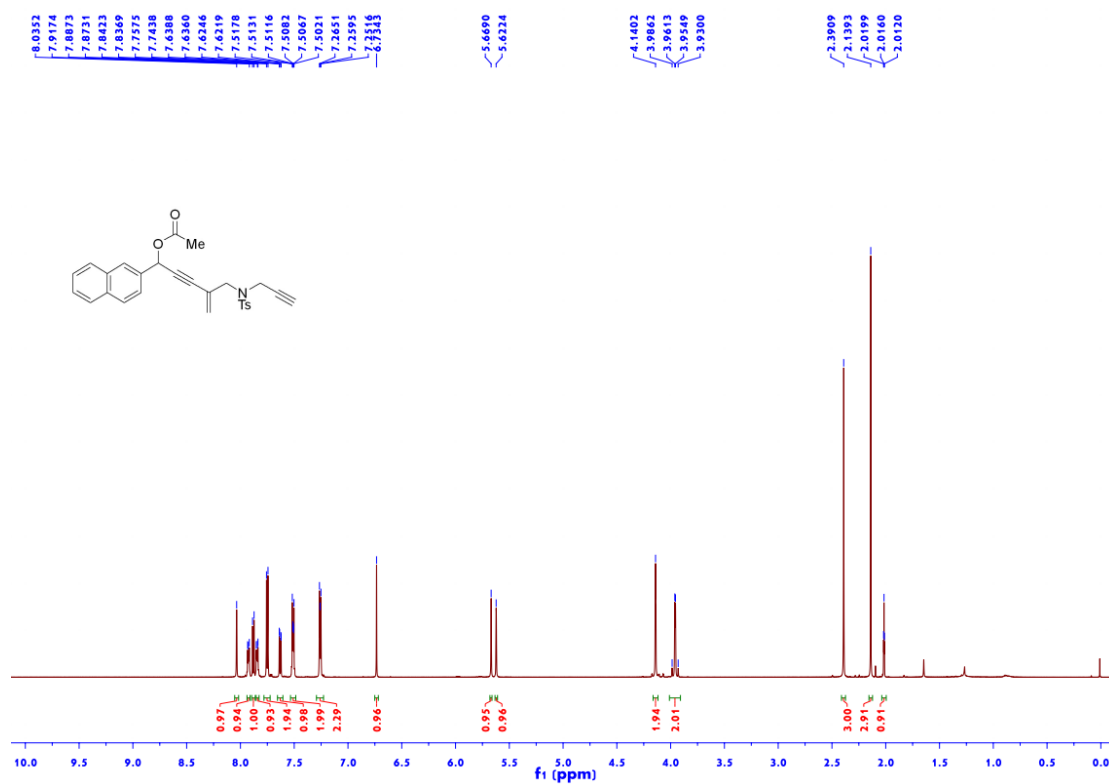


Figure S19  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of **1i**

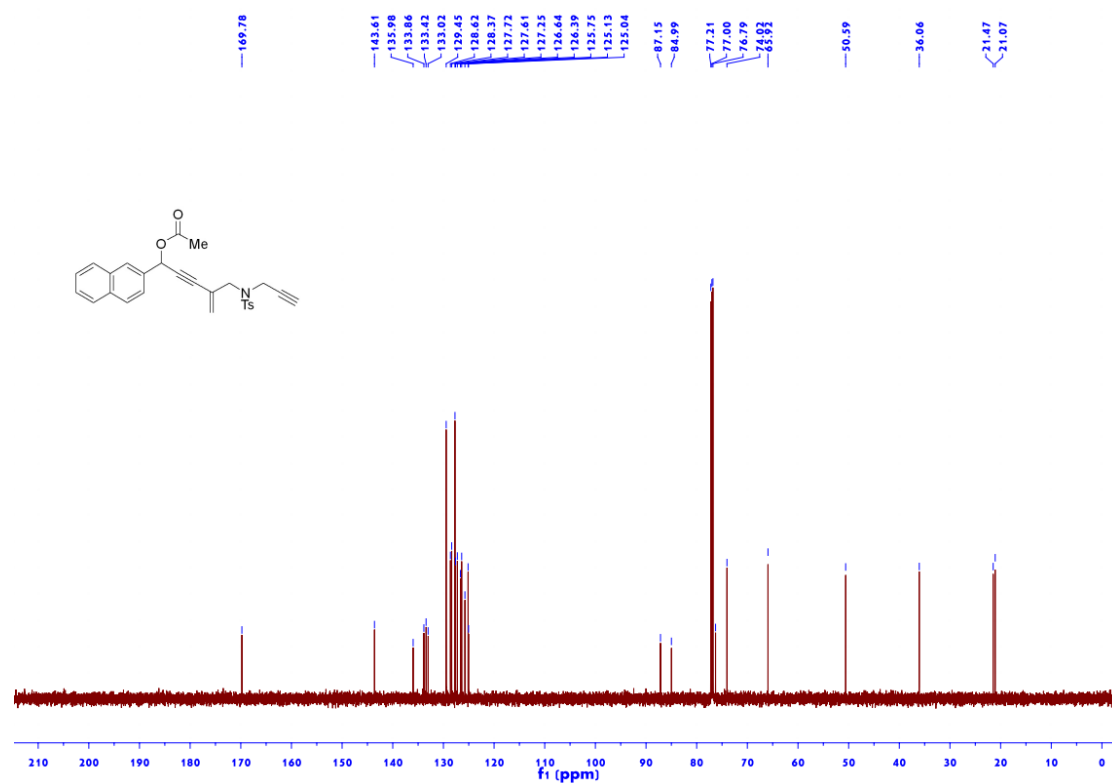


Figure S20  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of **1j**

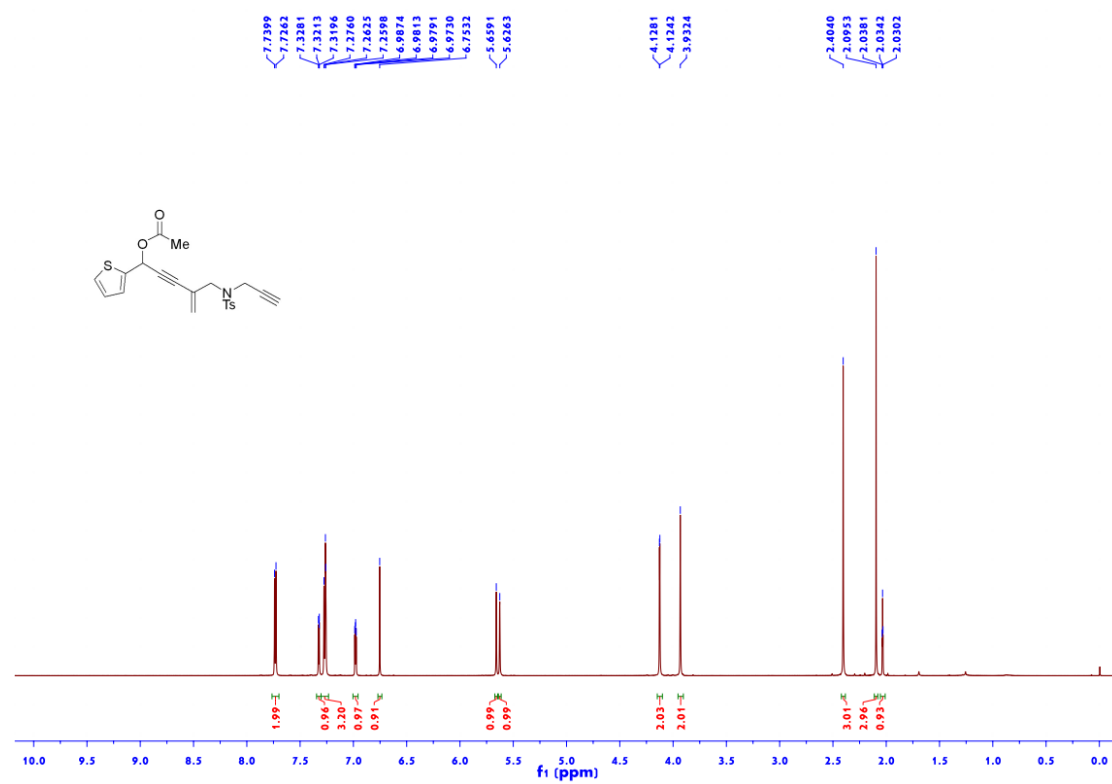


Figure S21  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1j

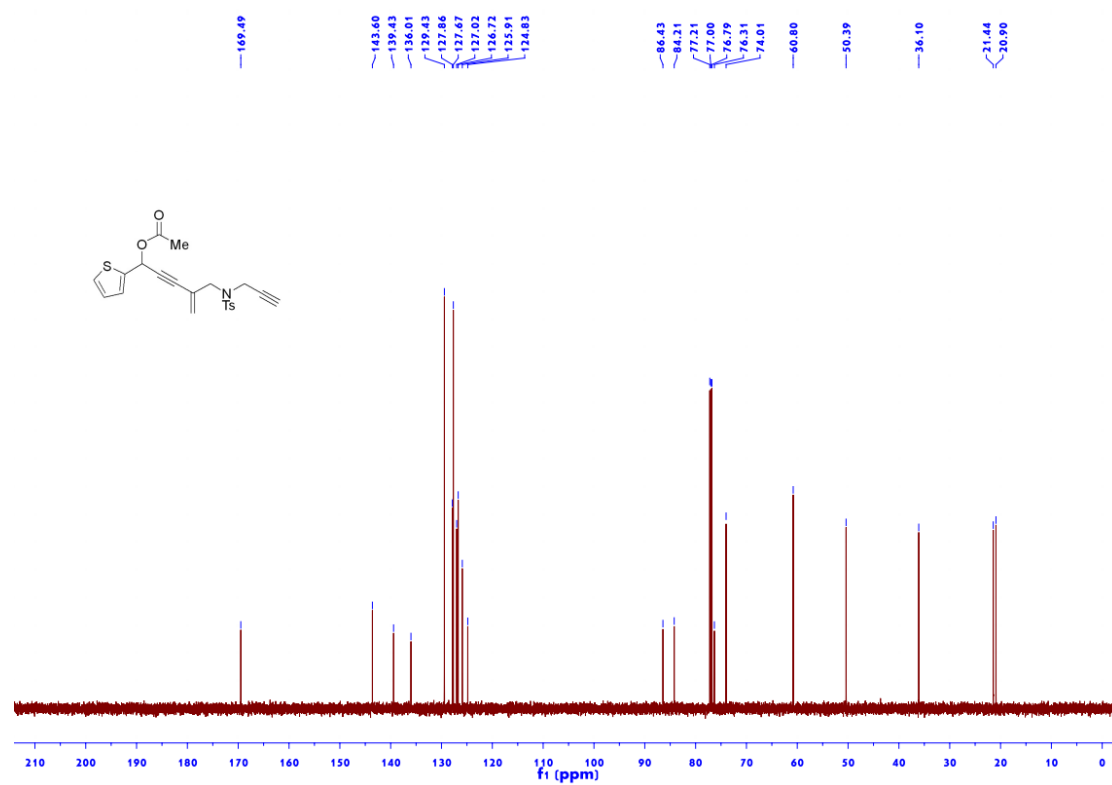


Figure S22  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1k

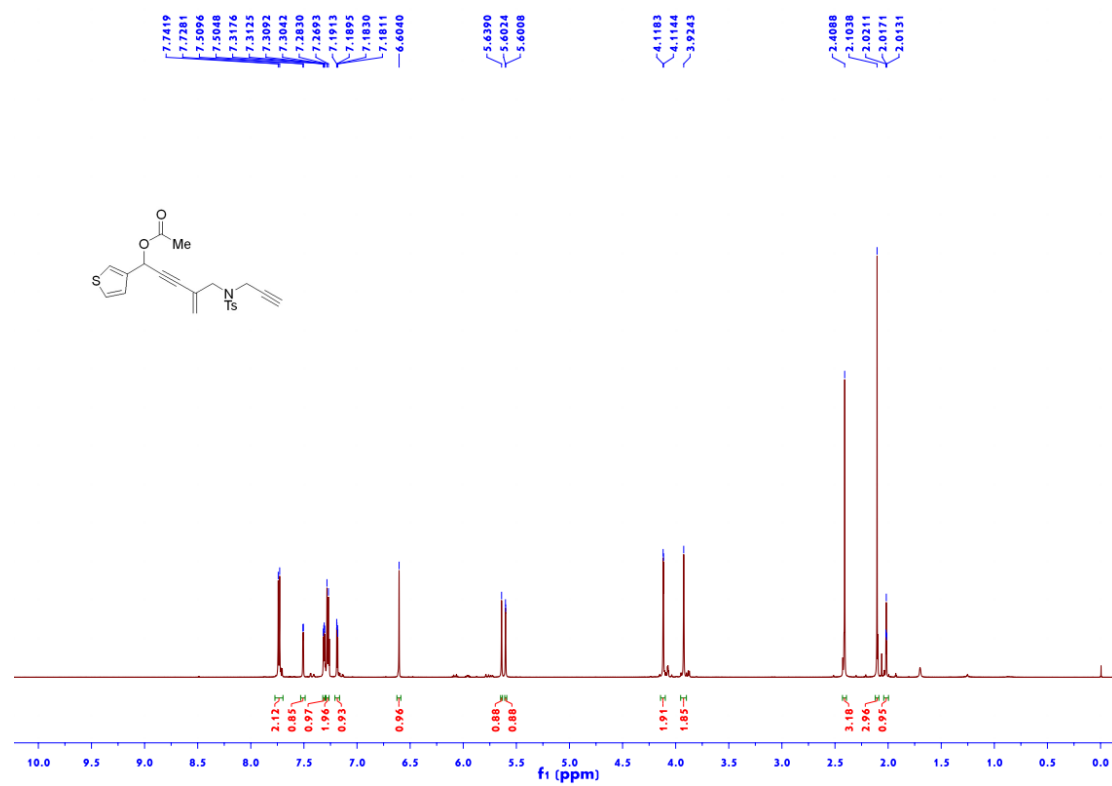


Figure S23  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1k

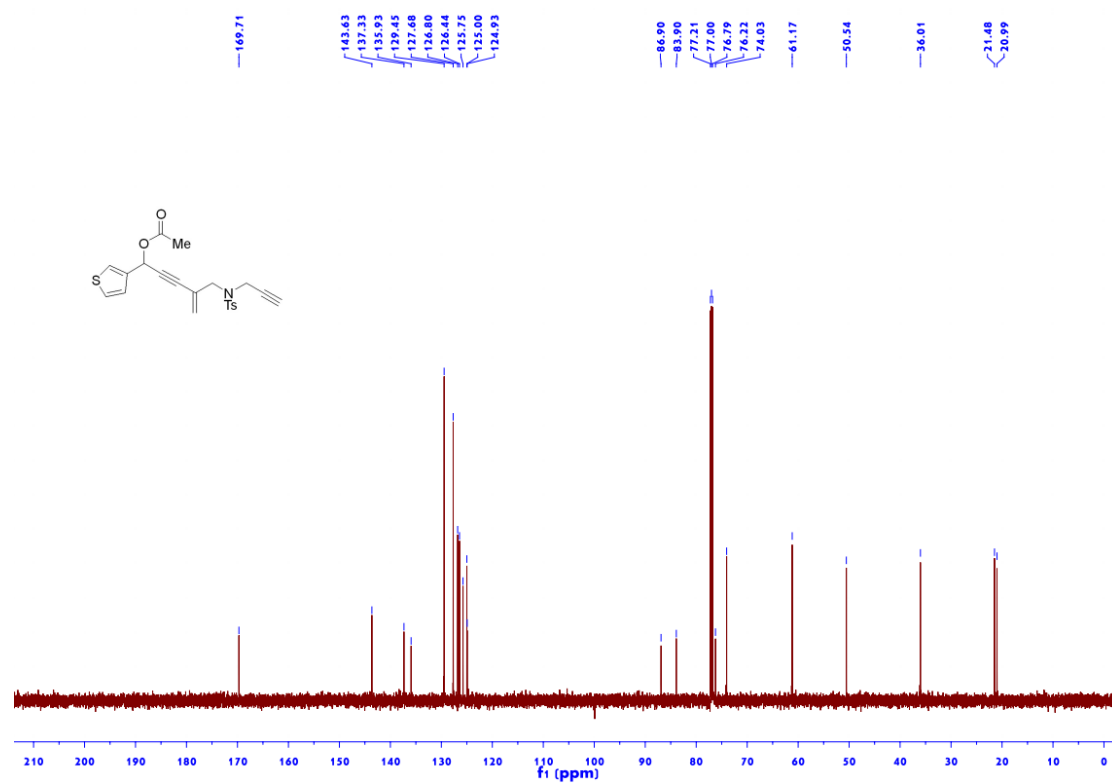


Figure S24  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1l

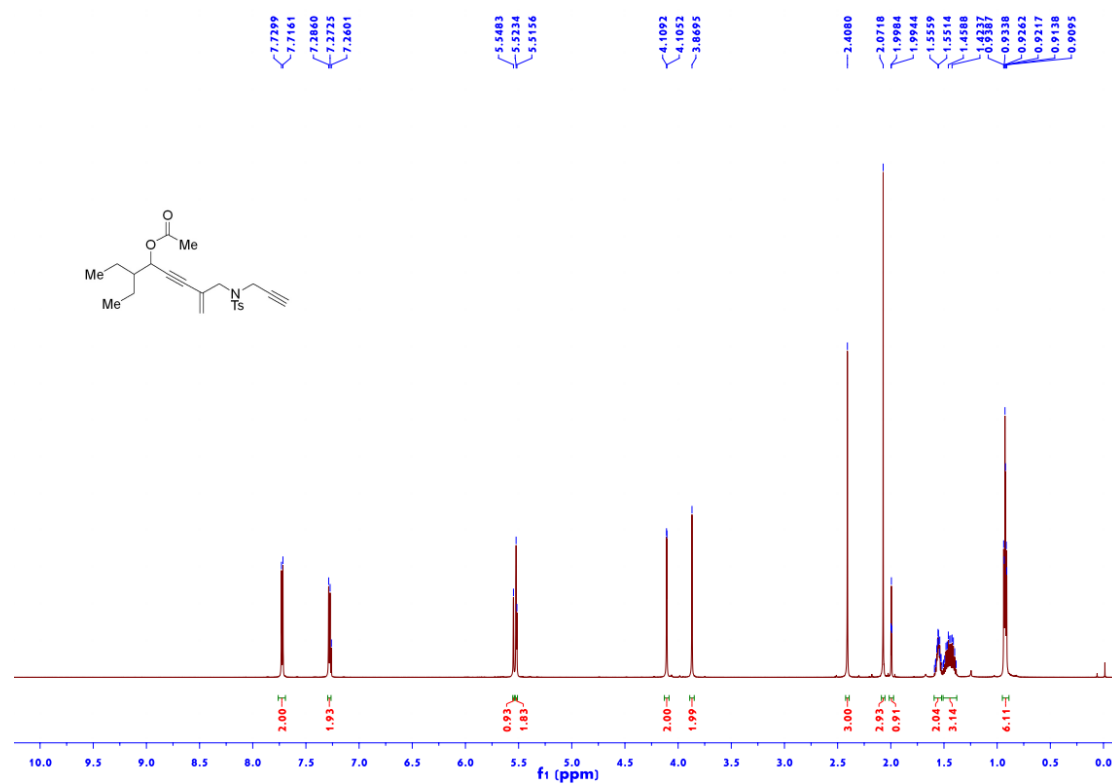




Figure S25  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1l

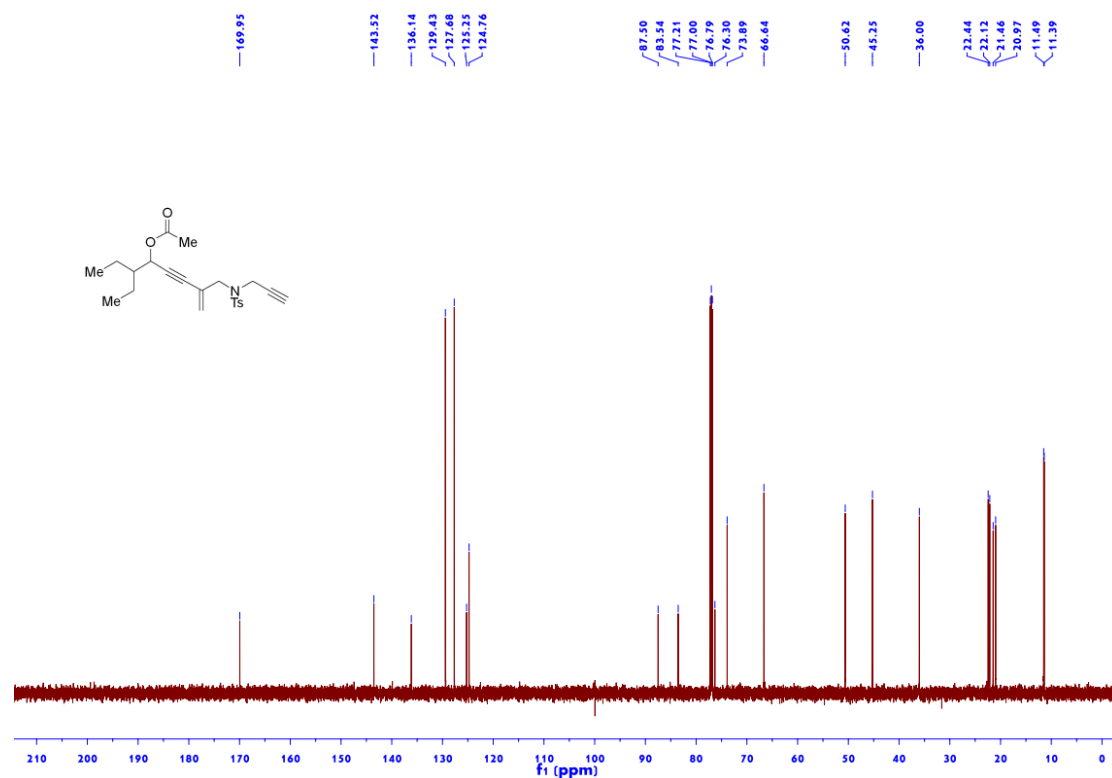


Figure S26  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1m

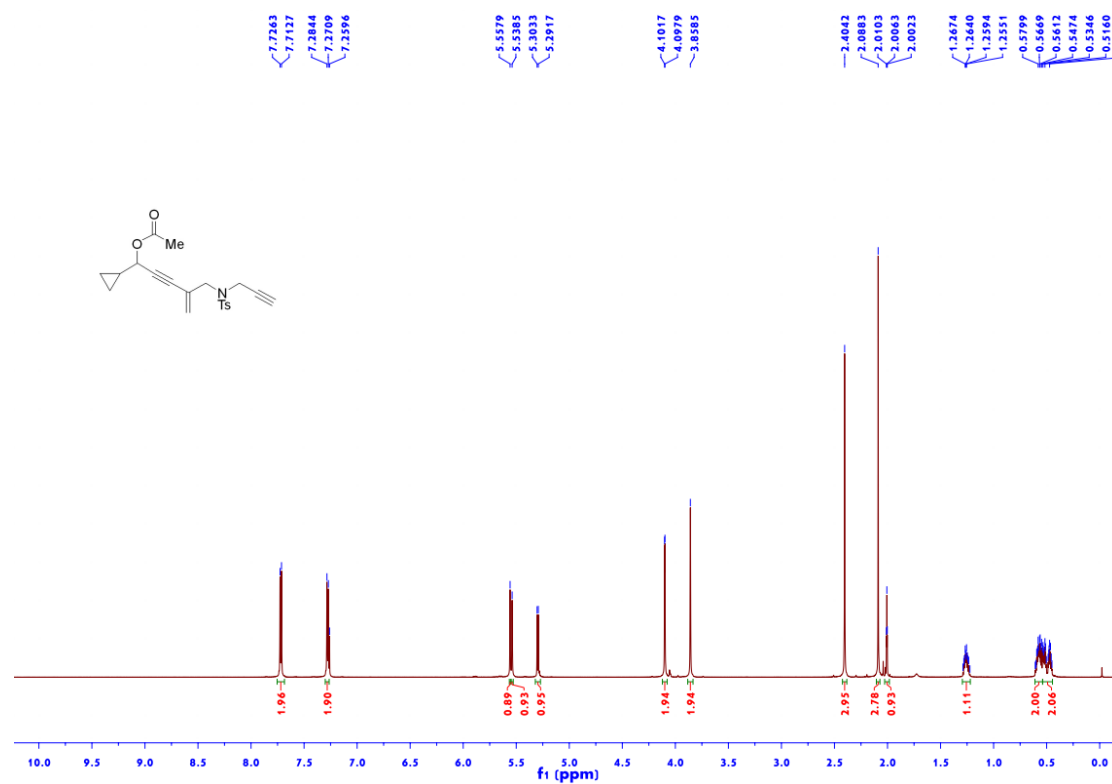


Figure S27 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 1m

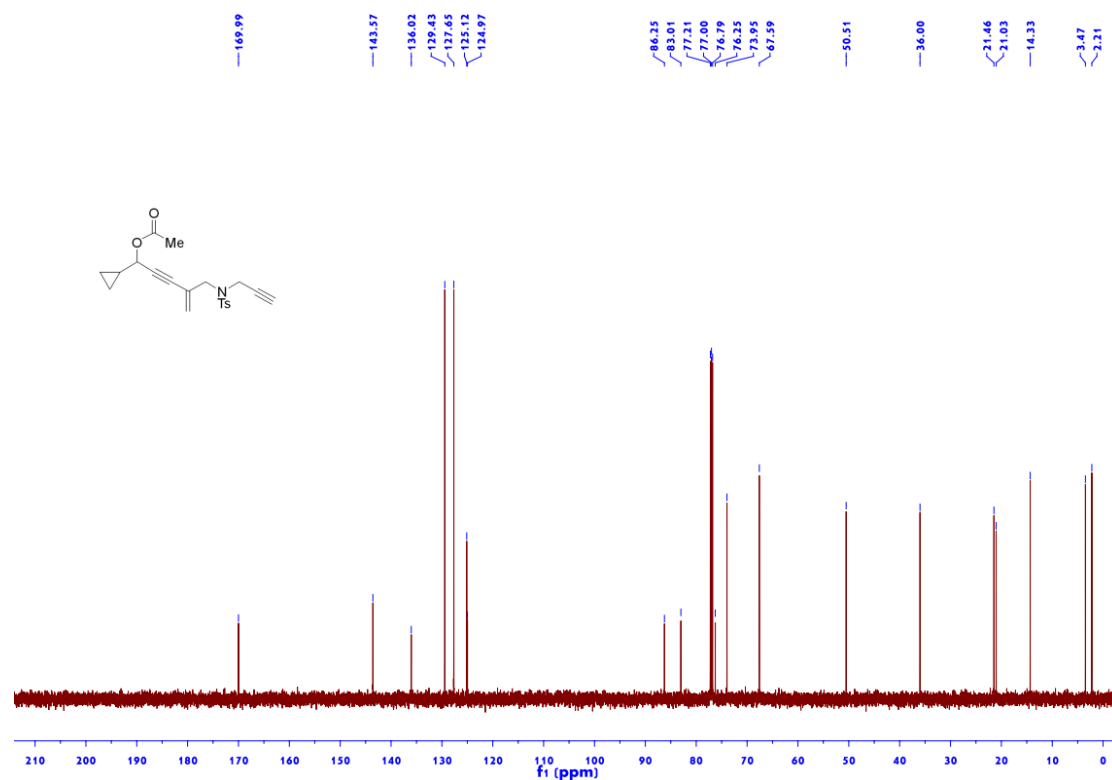


Figure S28 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 1n

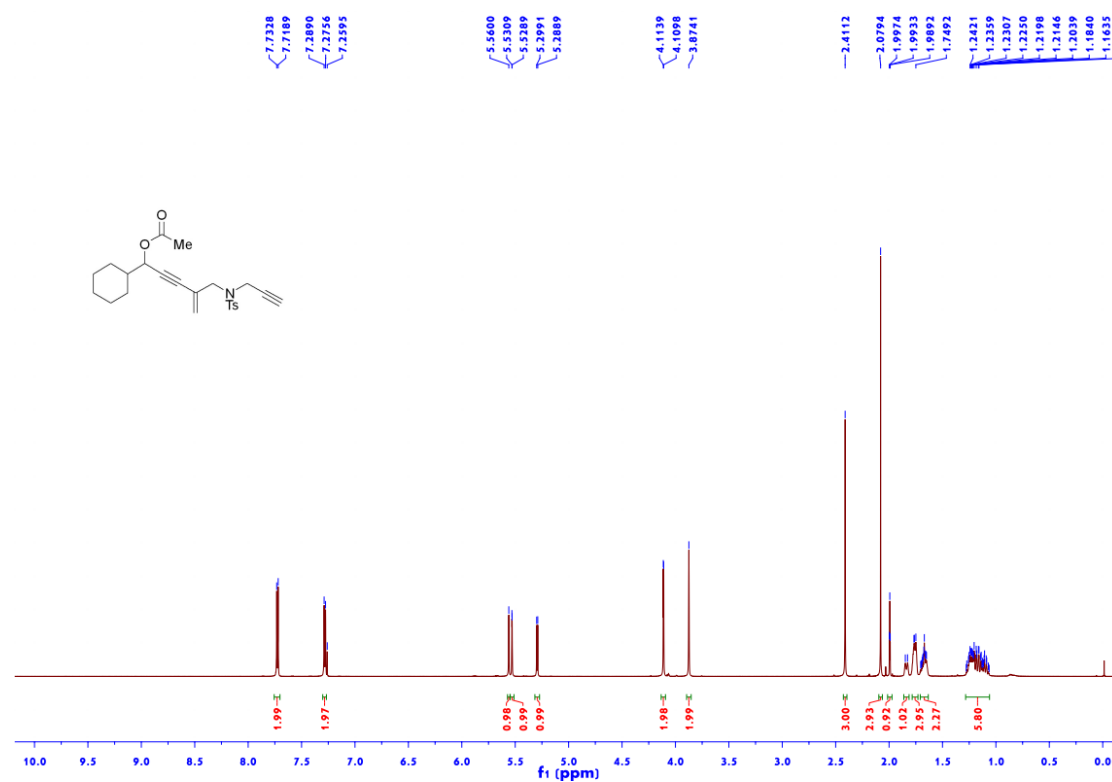


Figure S29  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1n

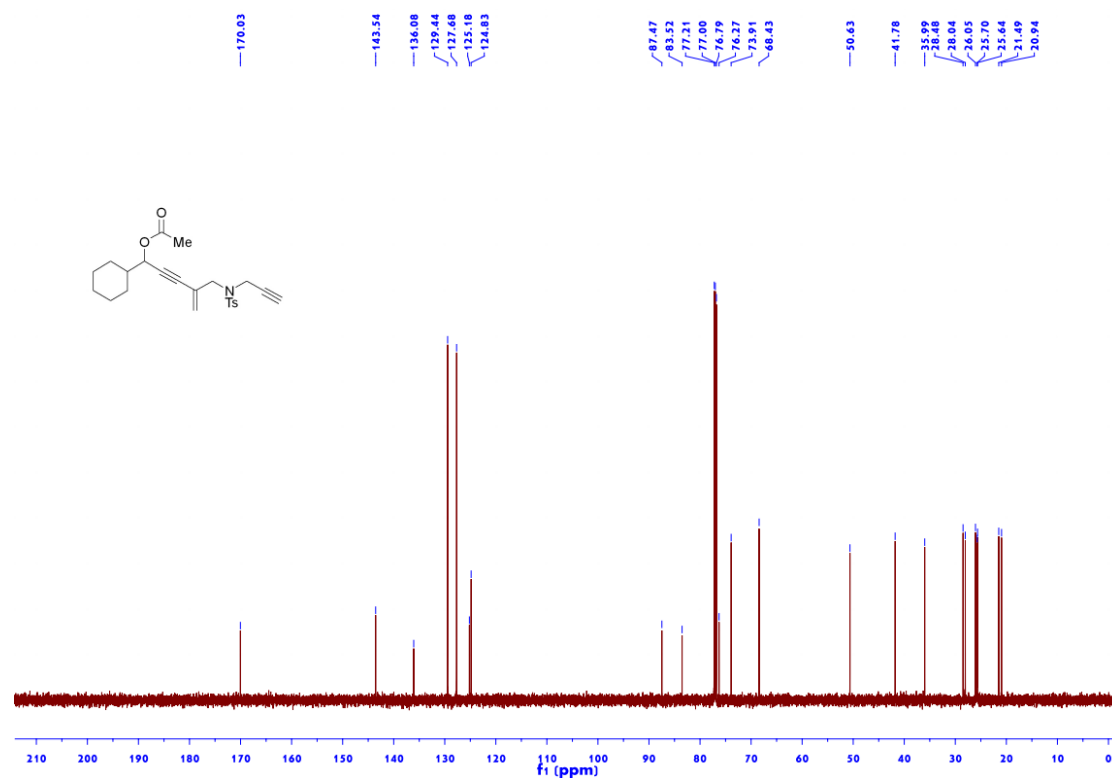


Figure S30  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1o

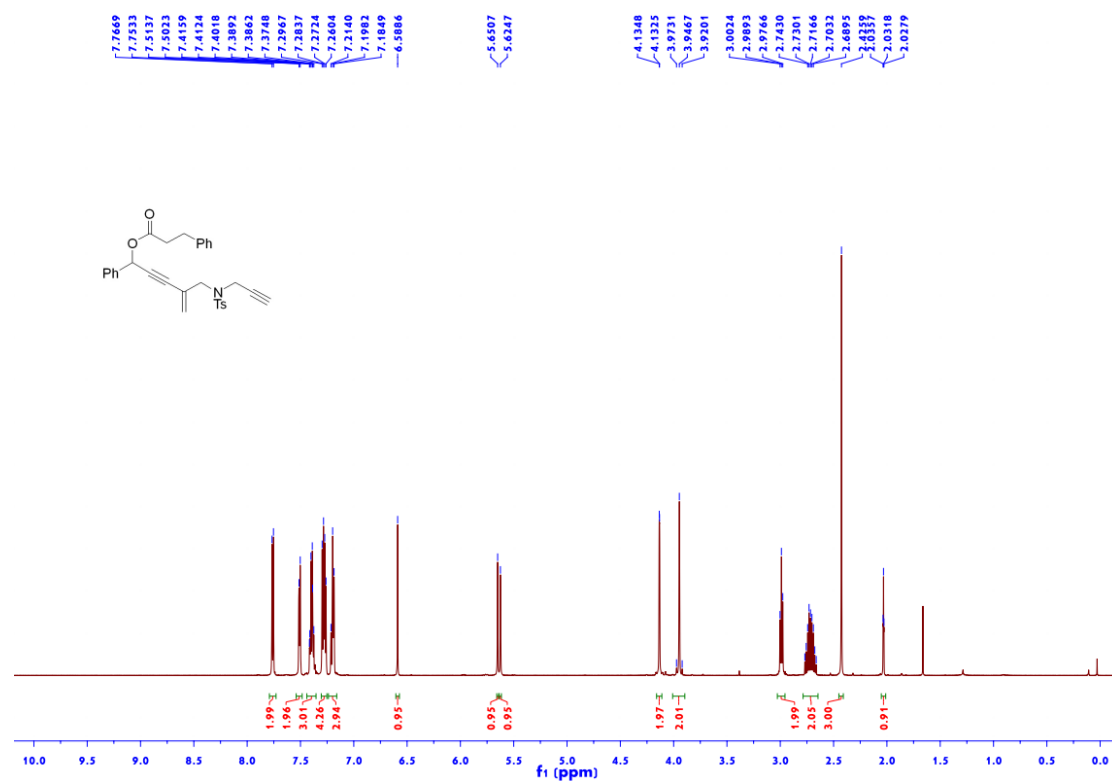


Figure S31  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1o

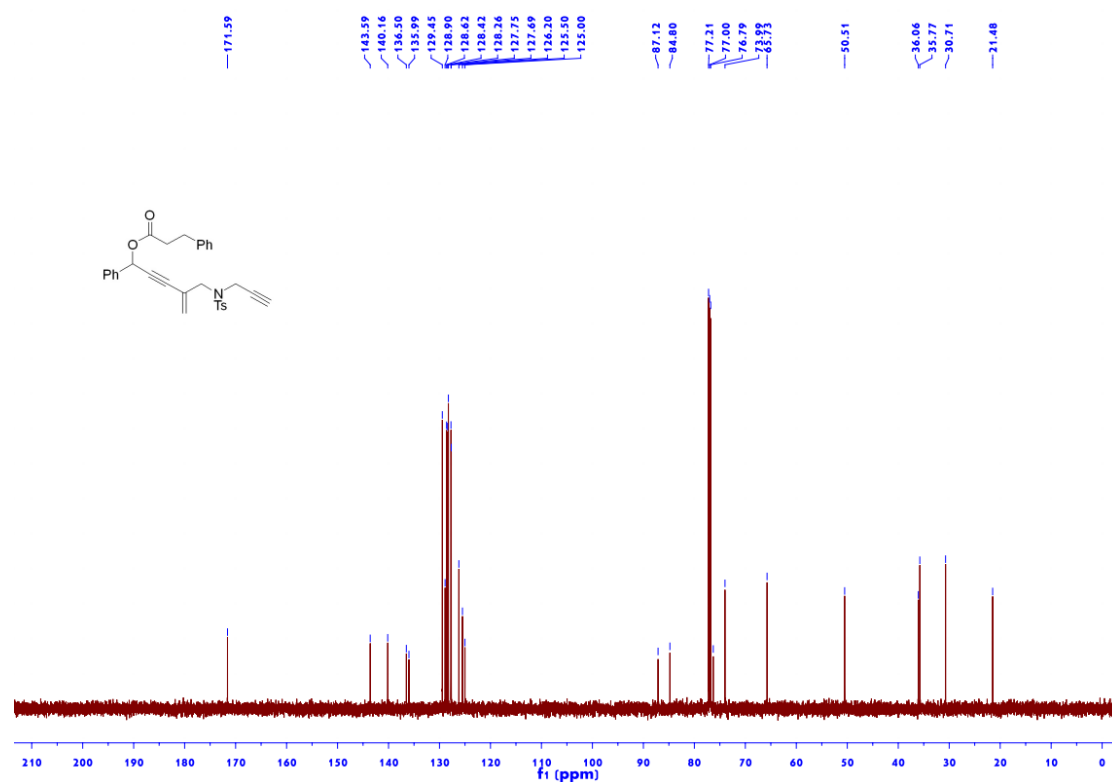


Figure S32  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1p

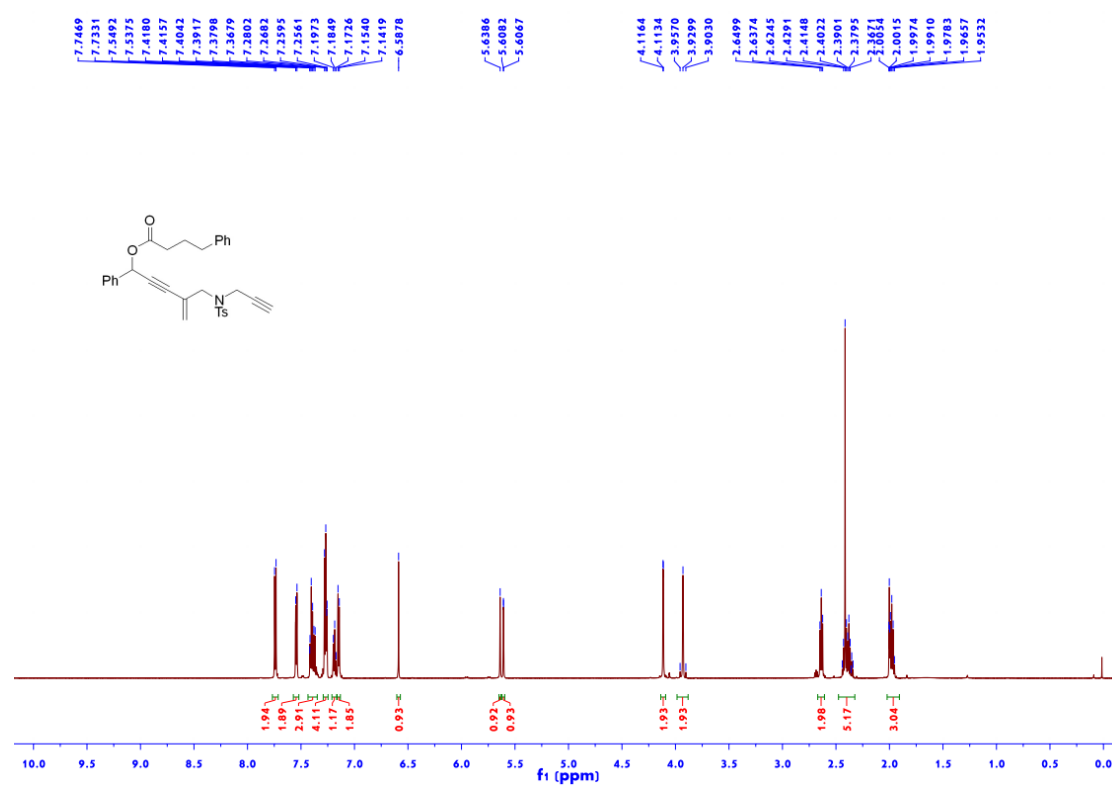


Figure S33  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1p

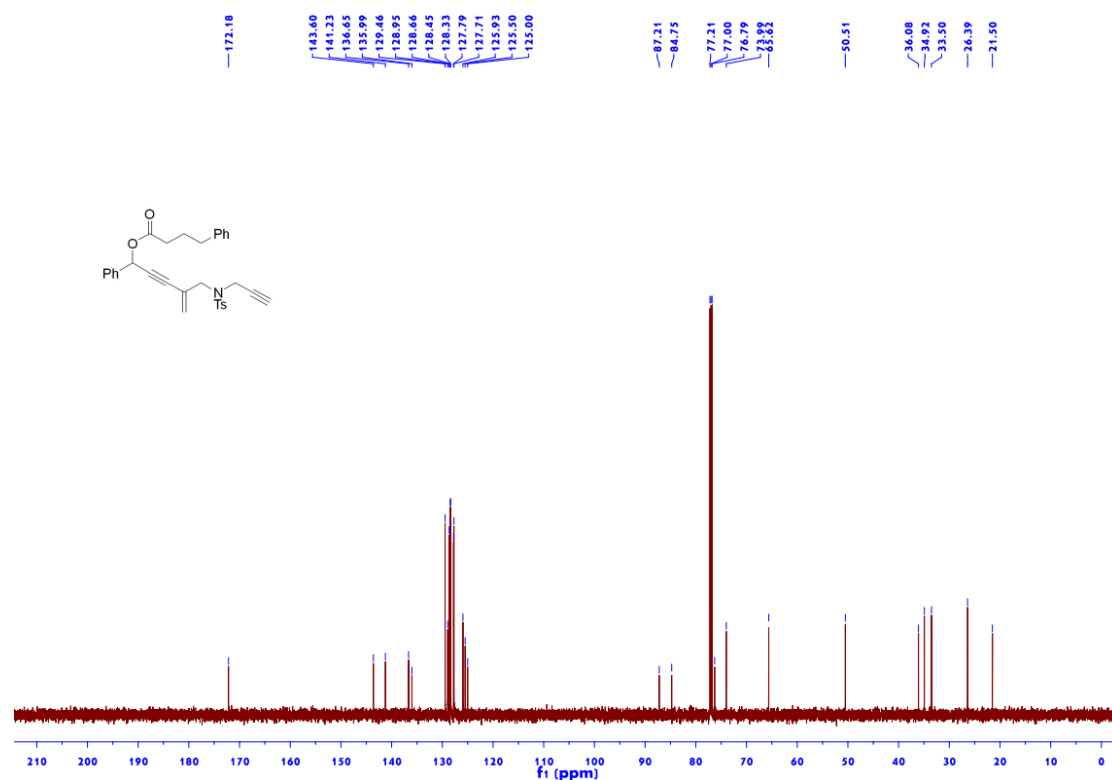


Figure S34  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1q

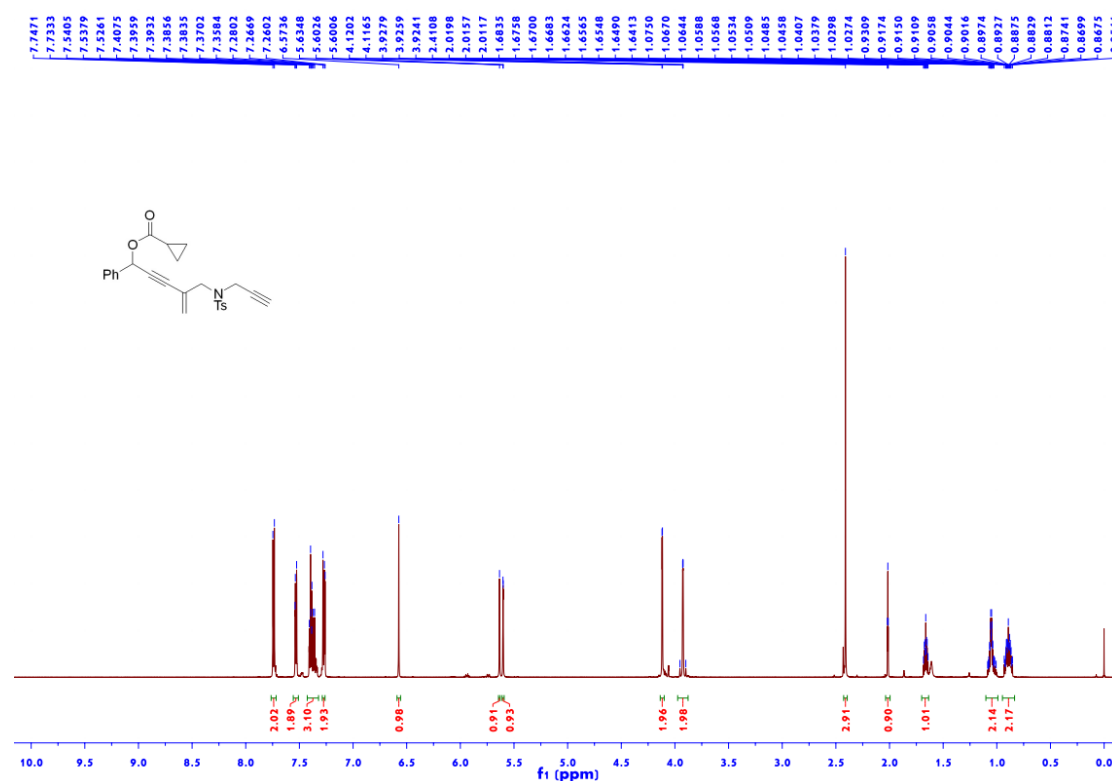


Figure S35  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1q

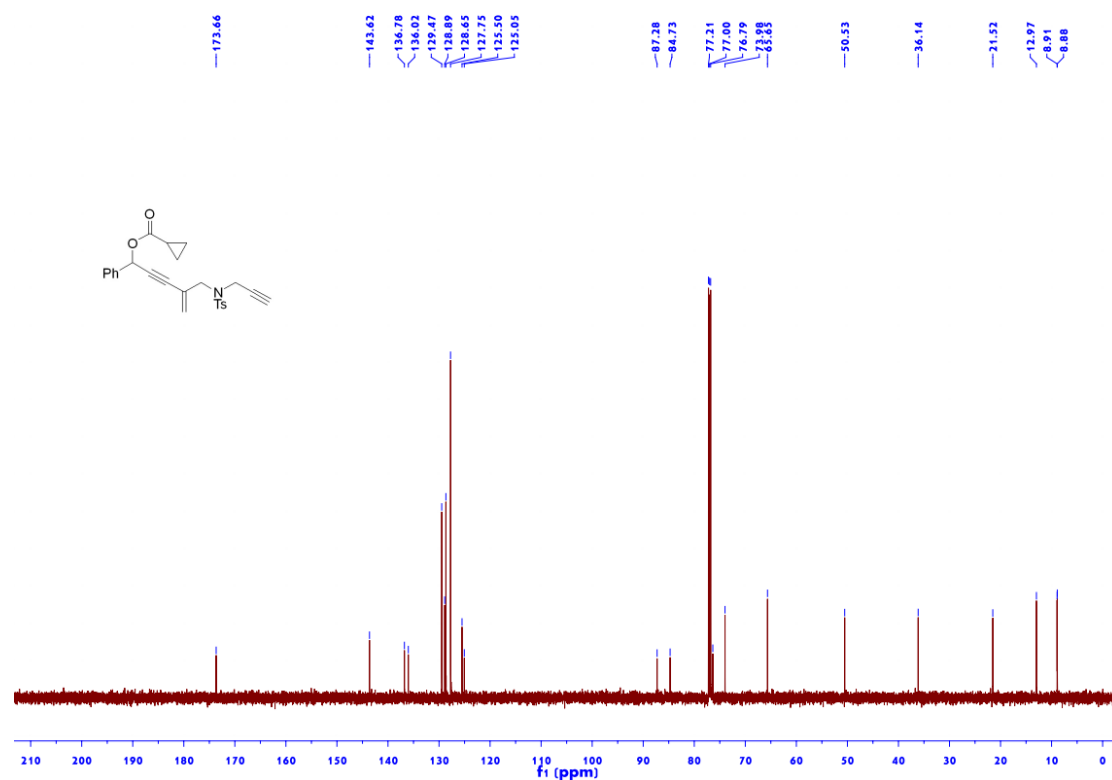


Figure S36  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1r

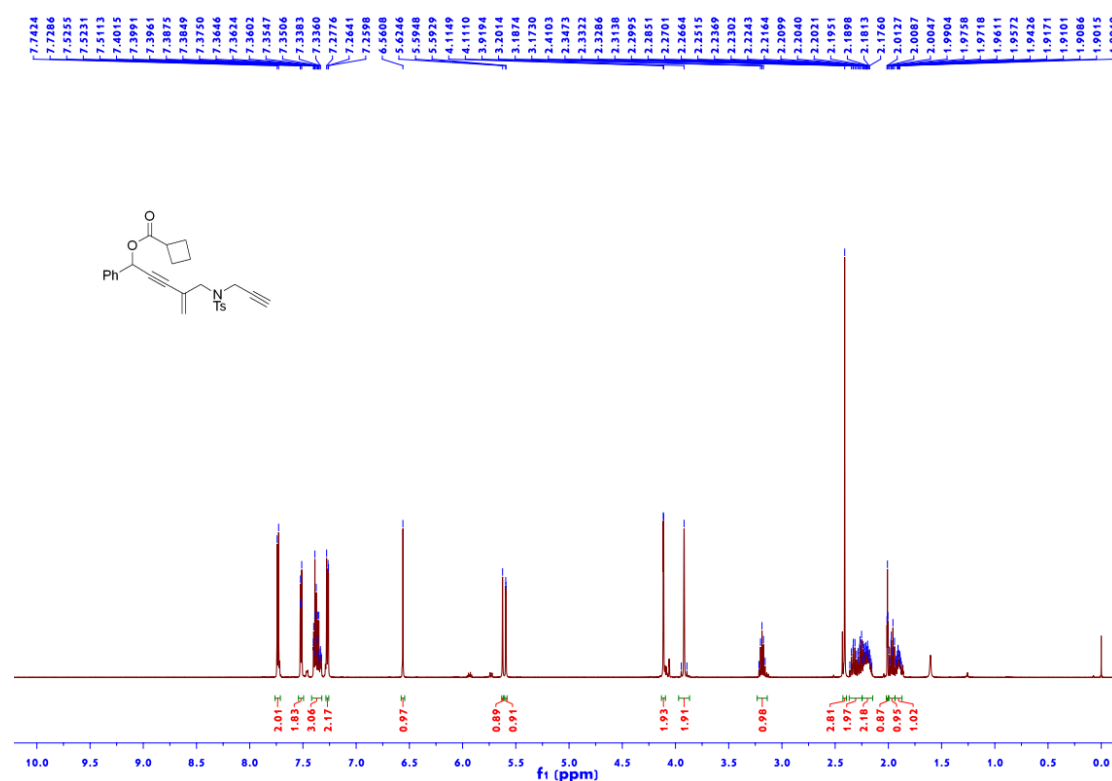


Figure S37  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1r

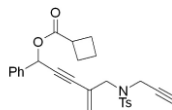
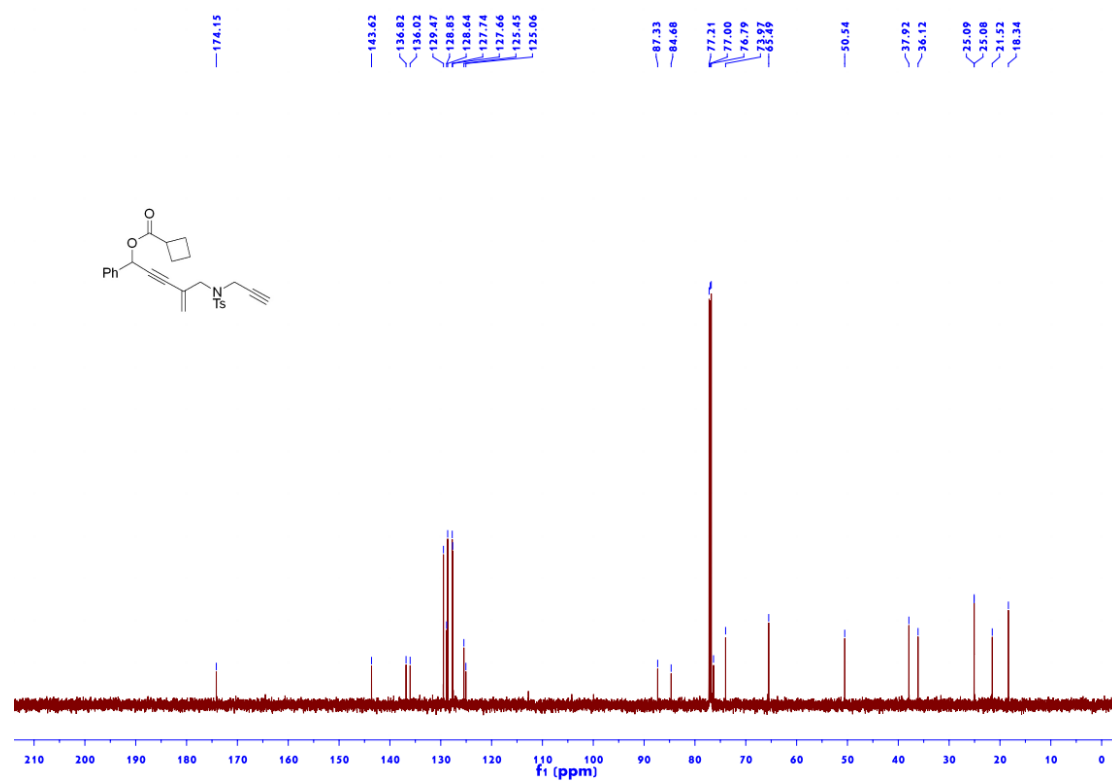


Figure S38  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1s

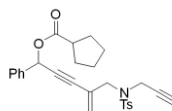
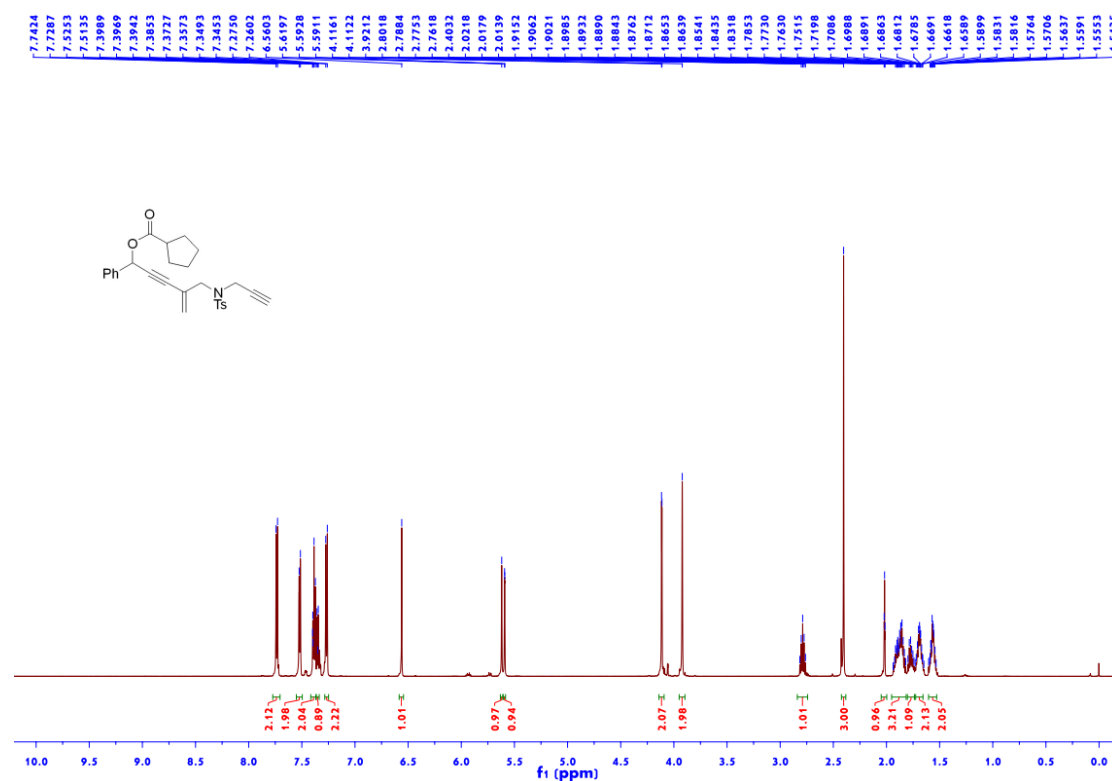


Figure S39  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1s

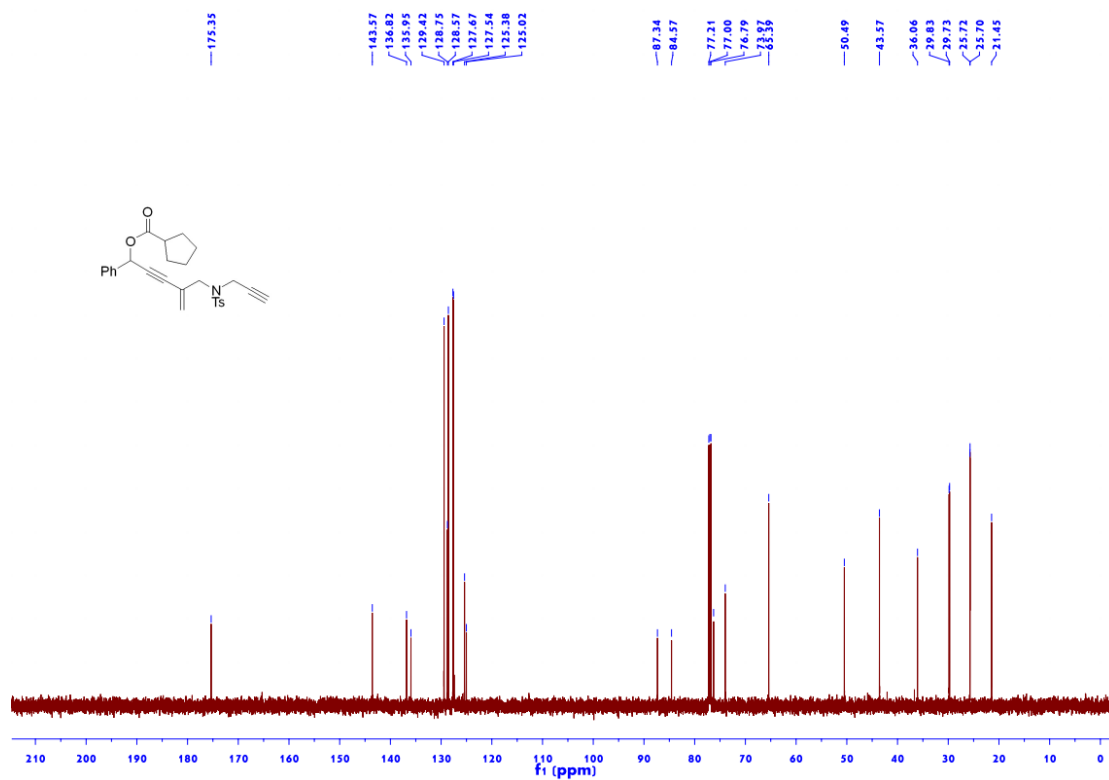


Figure S40  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1t

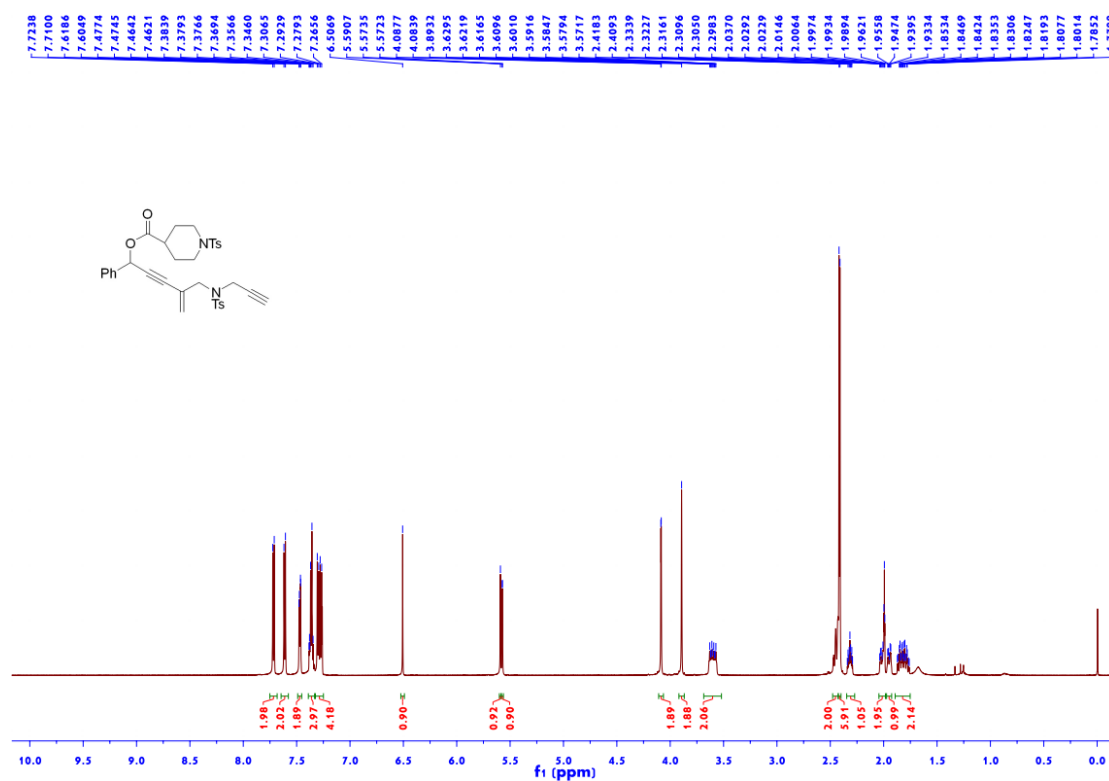




Figure S41  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1t

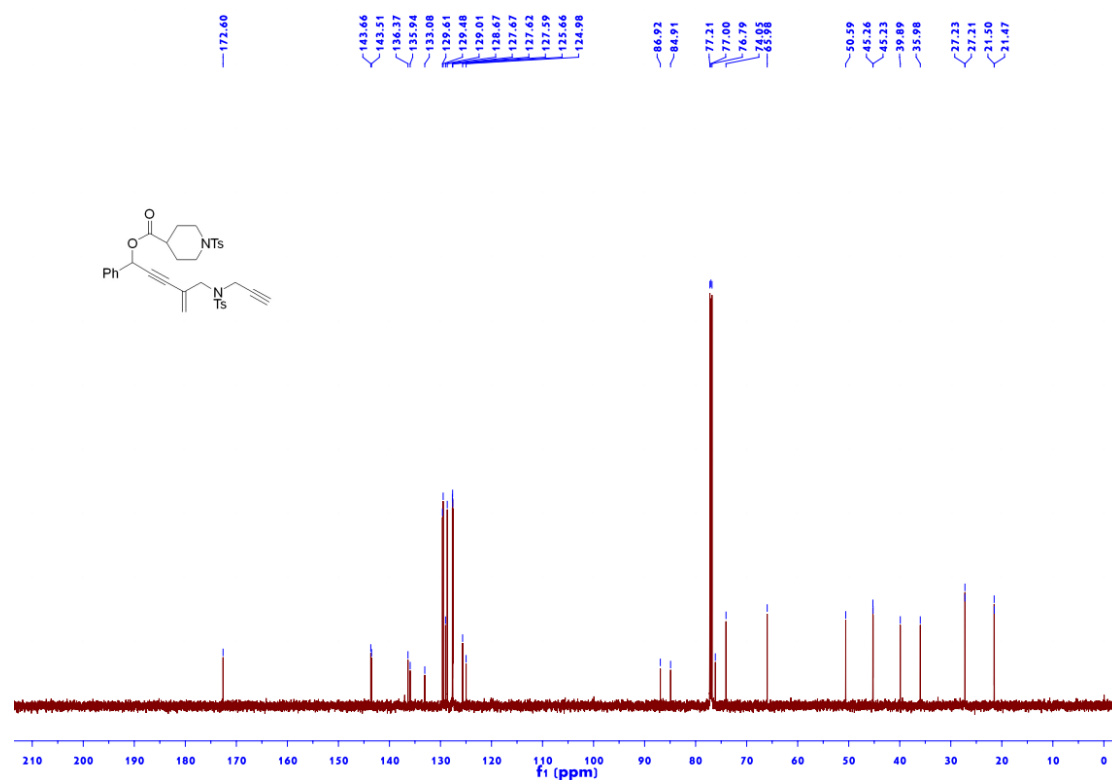


Figure S42  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1u

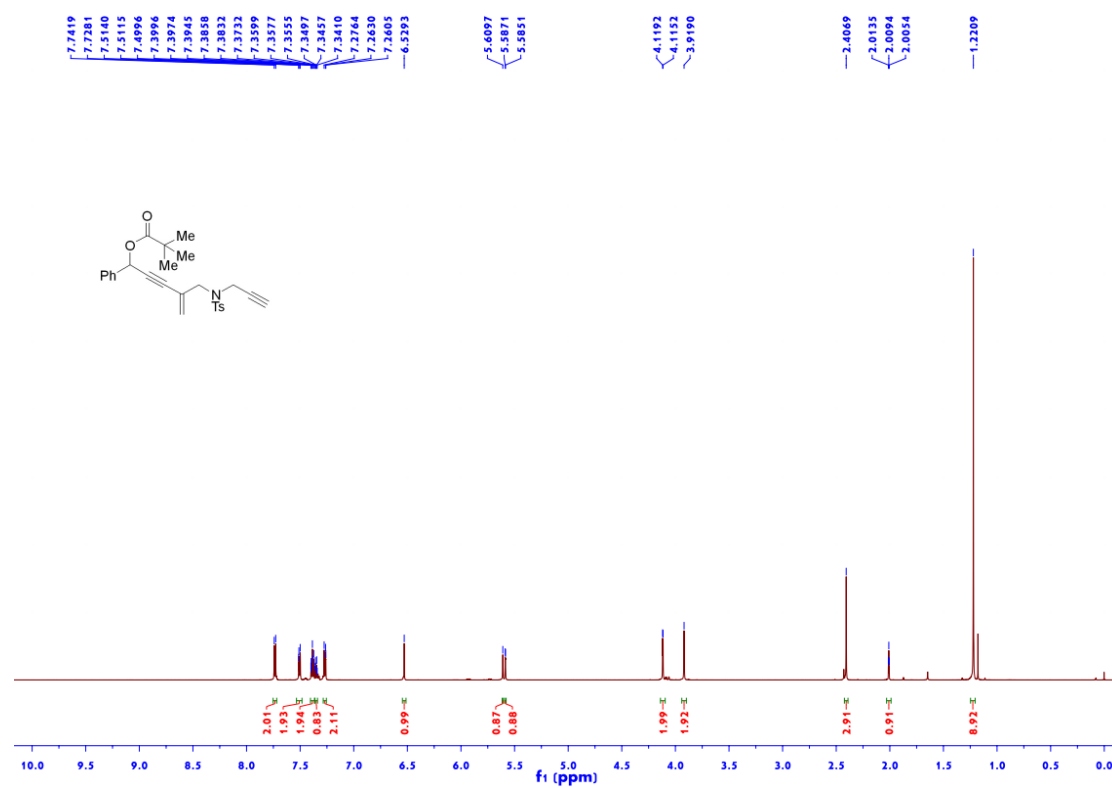


Figure S43  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1u

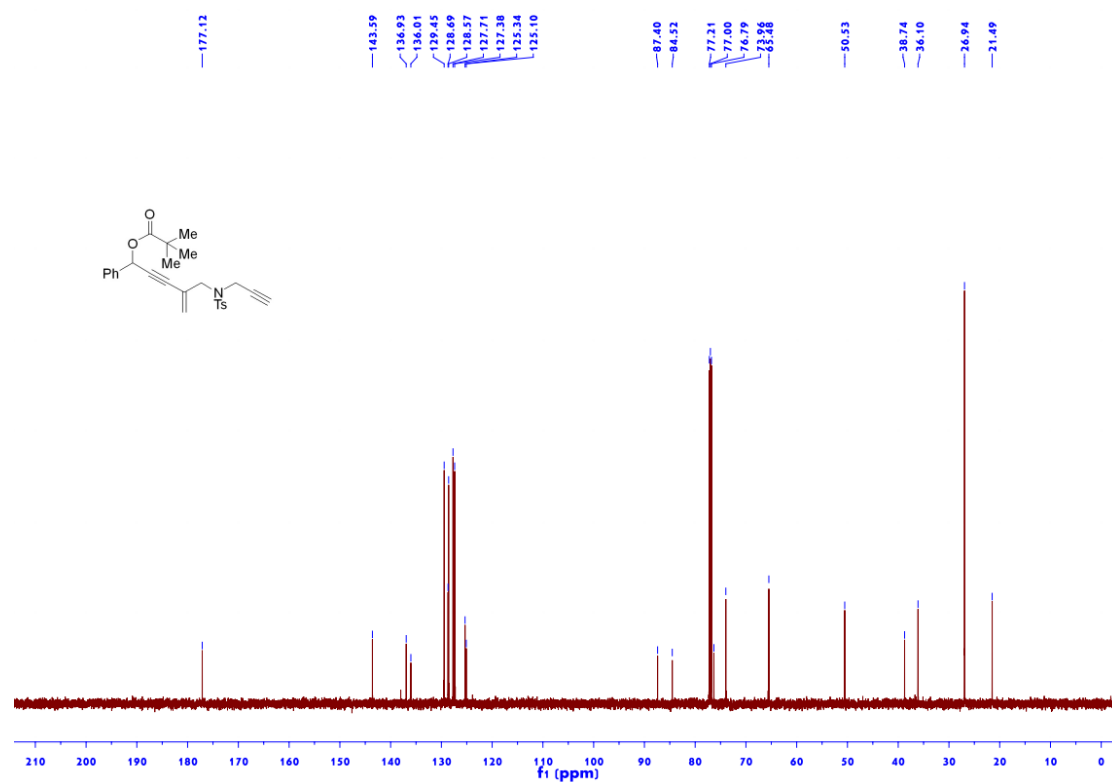


Figure S44  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1v

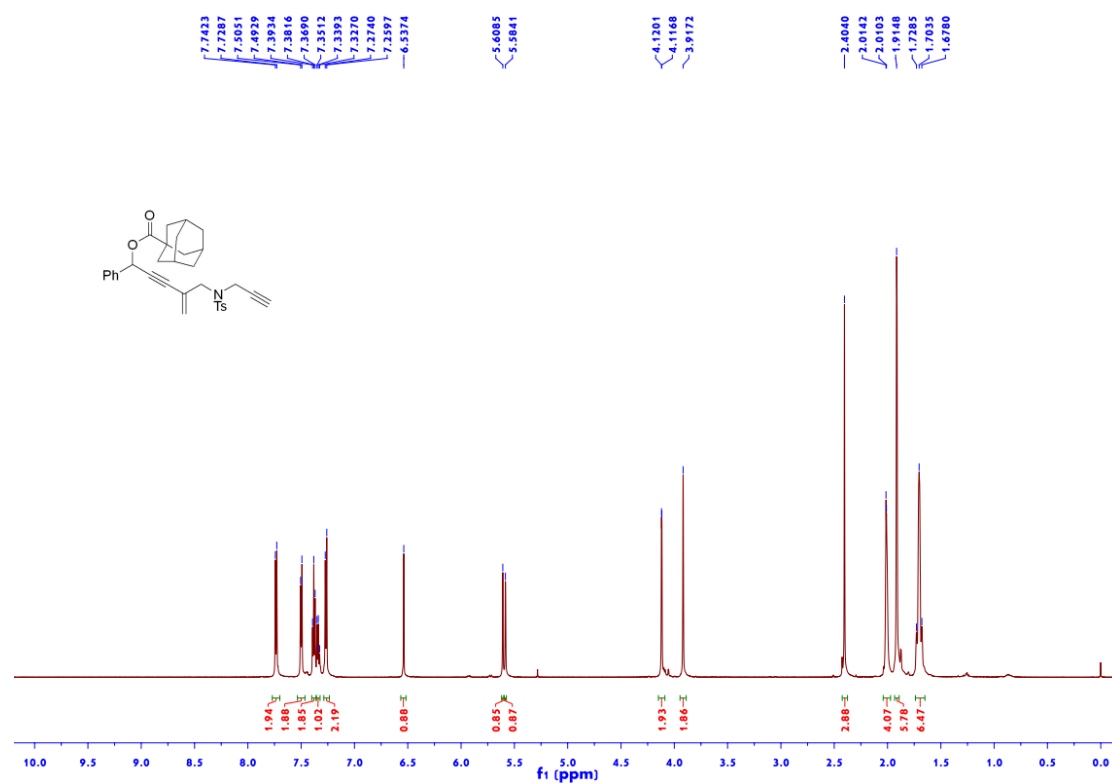


Figure S45  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1v

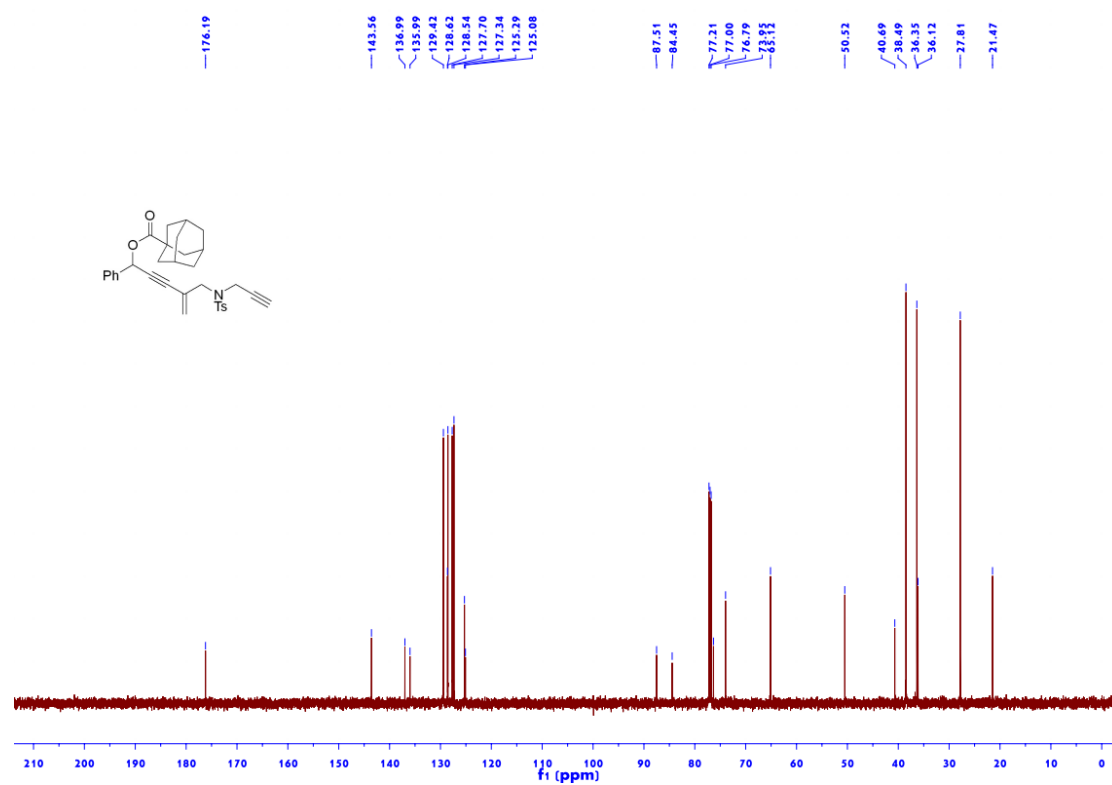


Figure S46  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1w

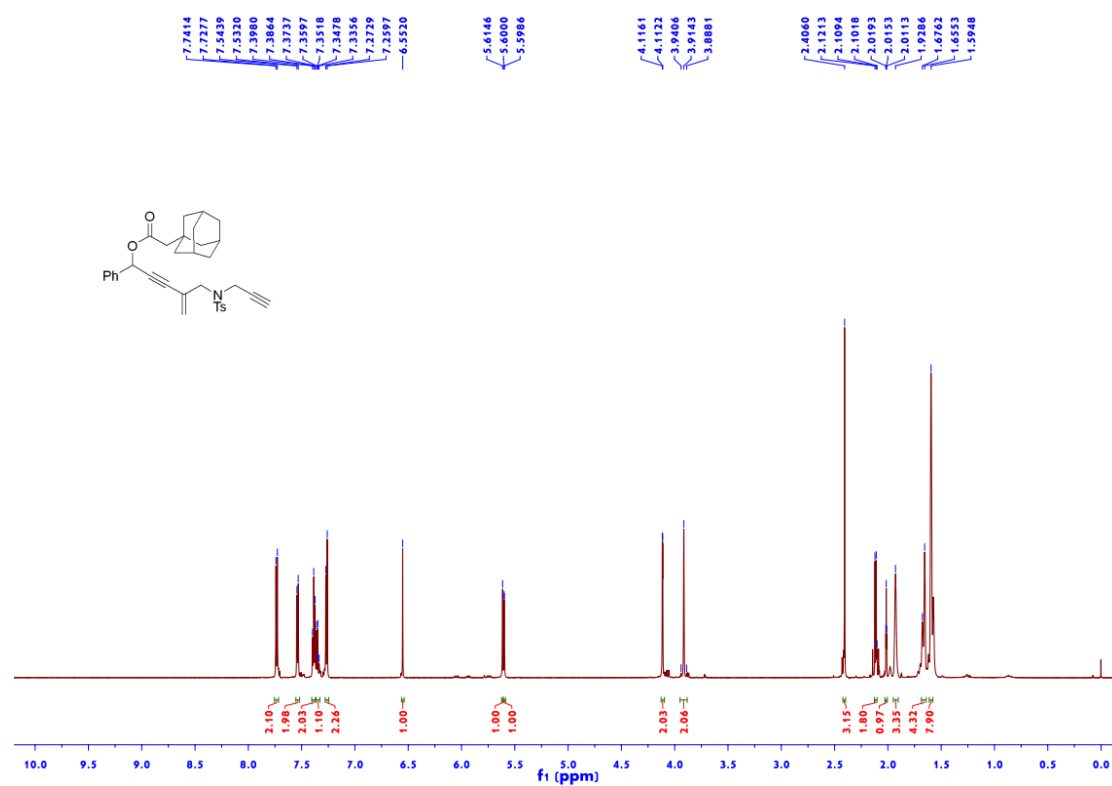


Figure S47 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 1w

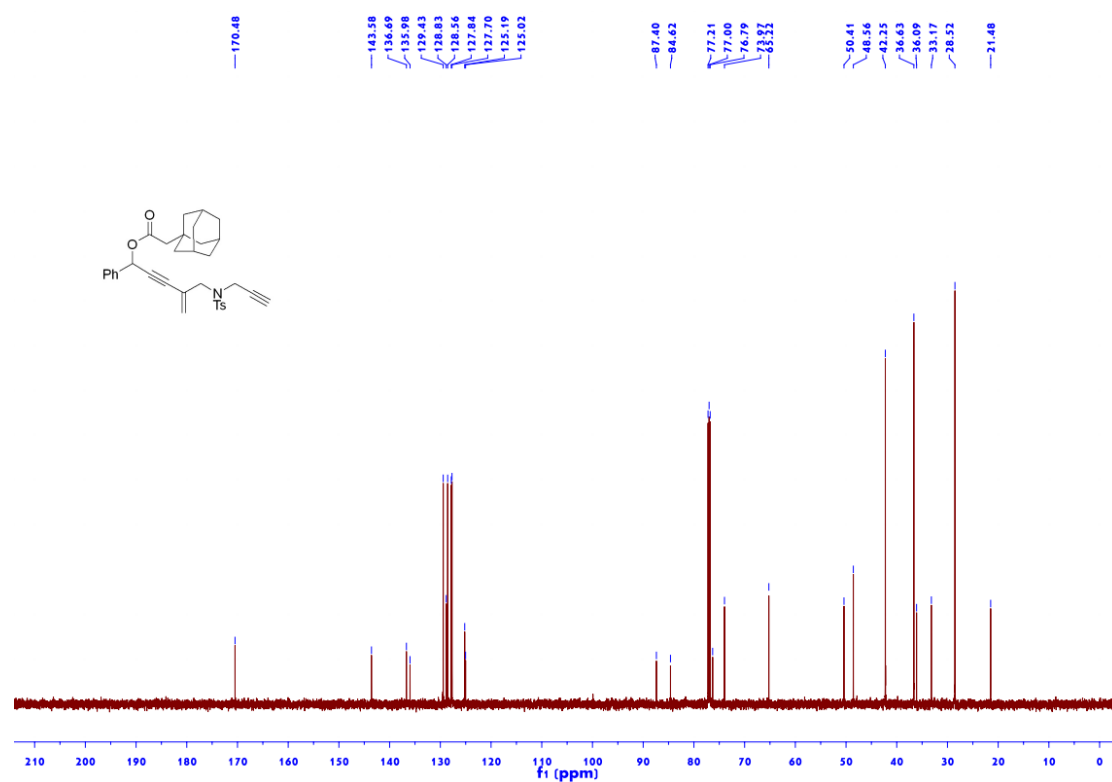


Figure S48 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 1x

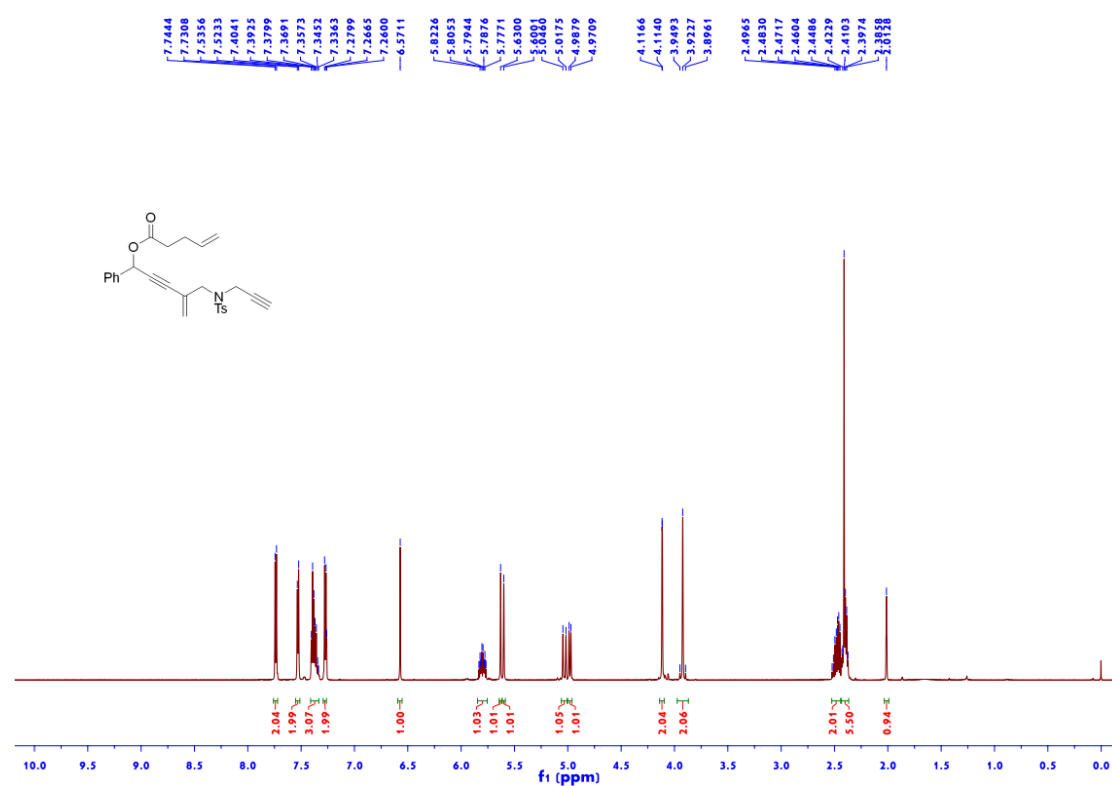


Figure S49 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 1x

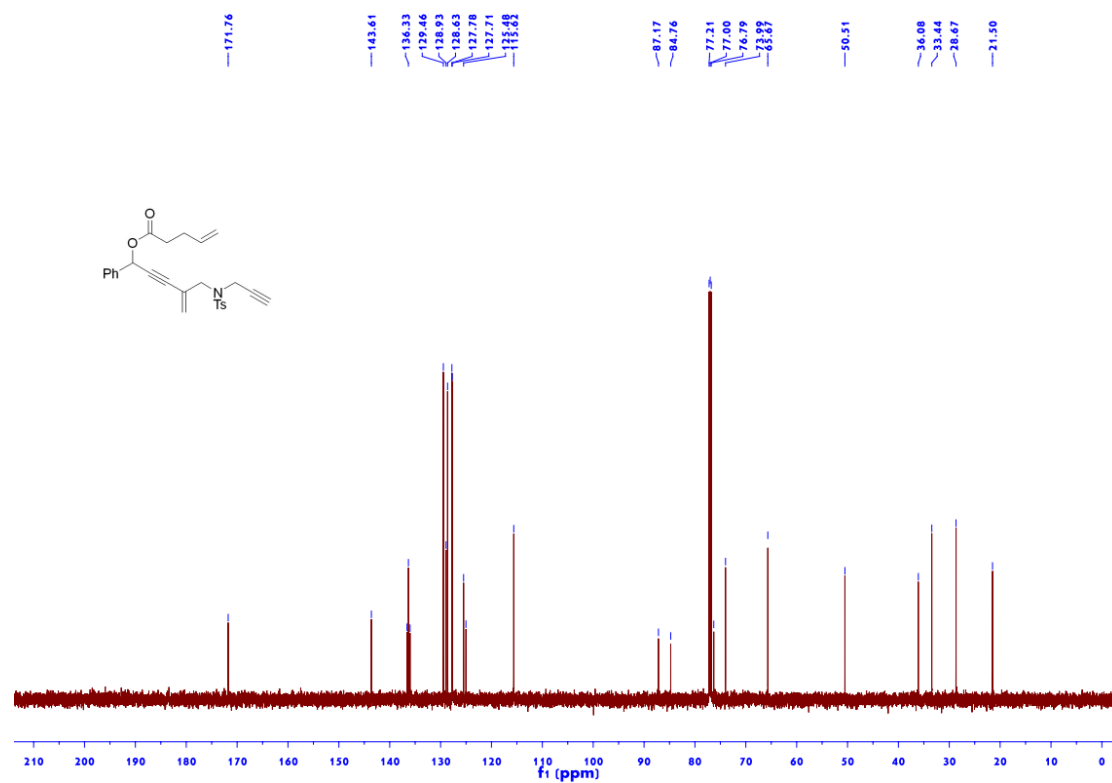


Figure S50 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 1y

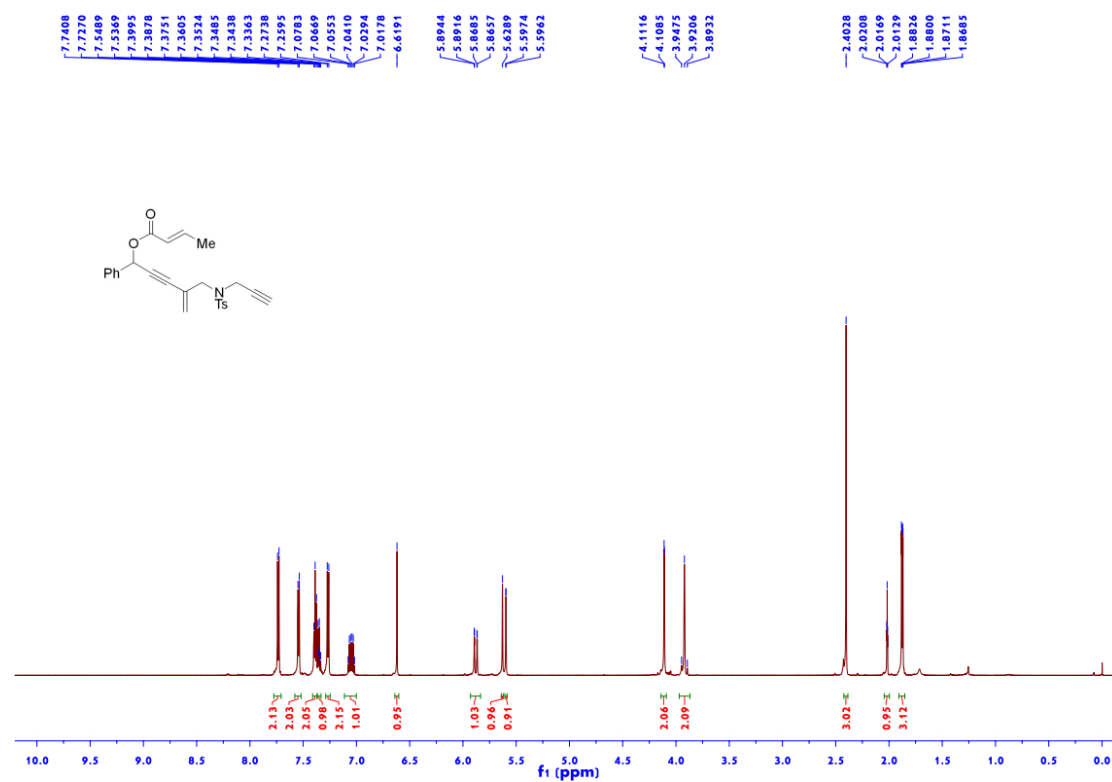


Figure S51  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1y

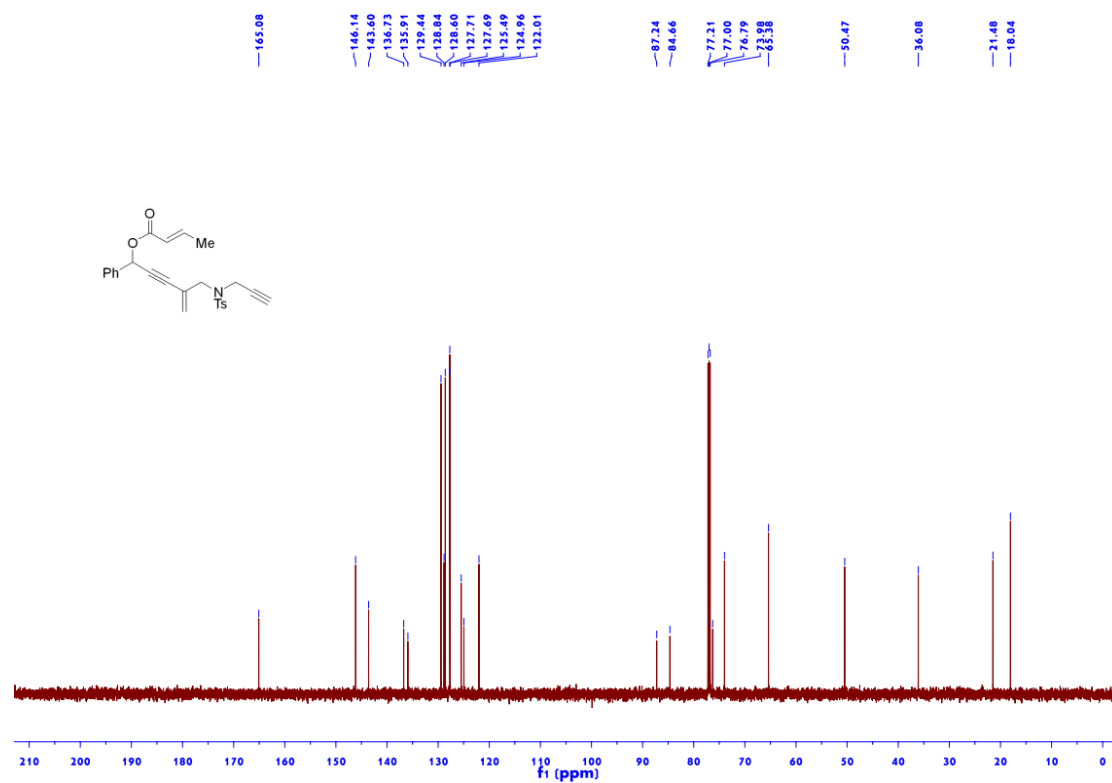


Figure S52  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1z

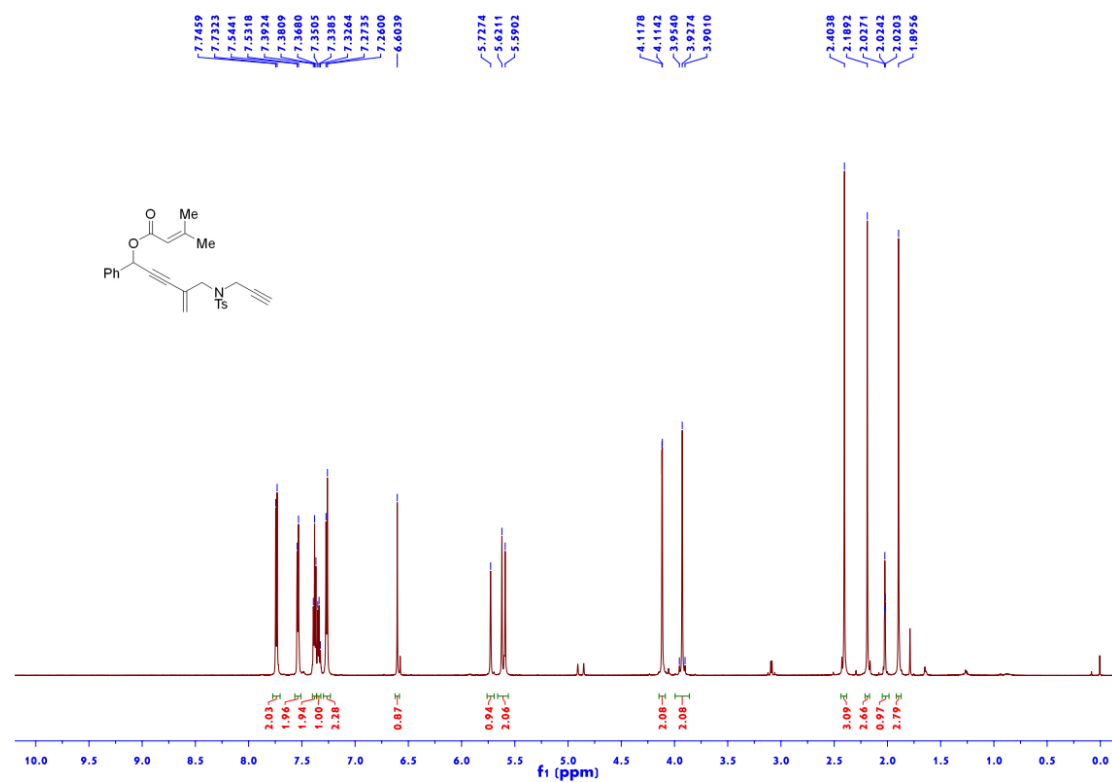


Figure S53  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1z

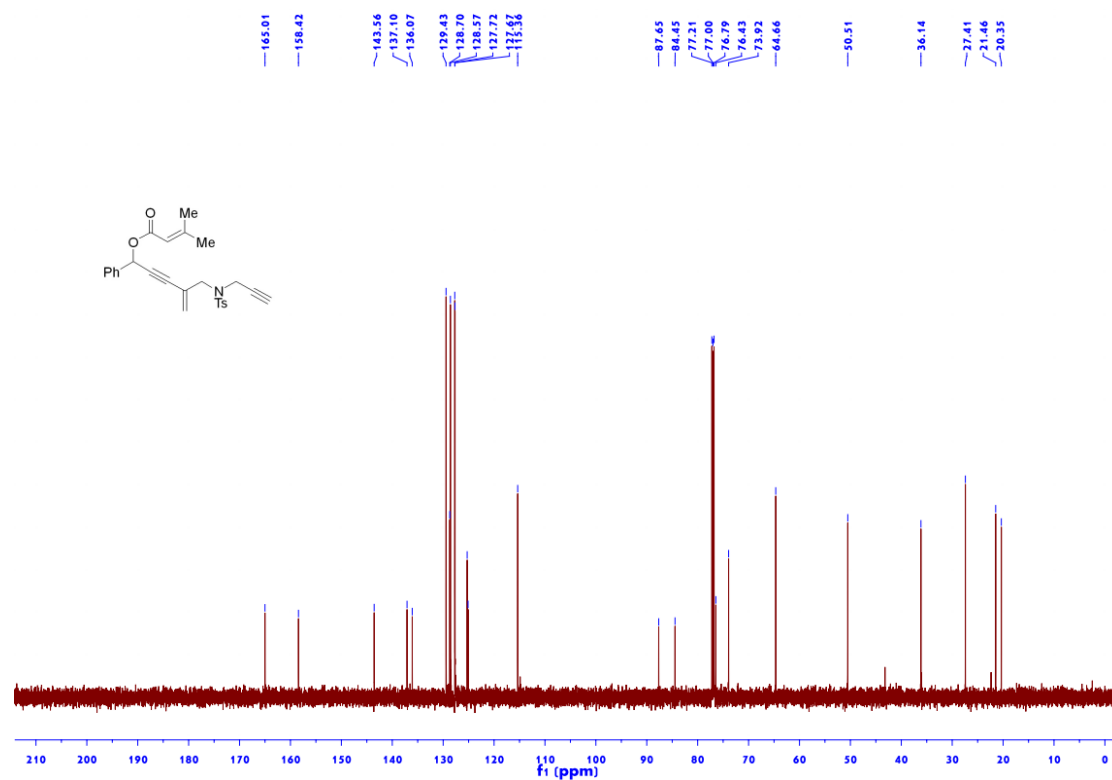


Figure S54  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1aa

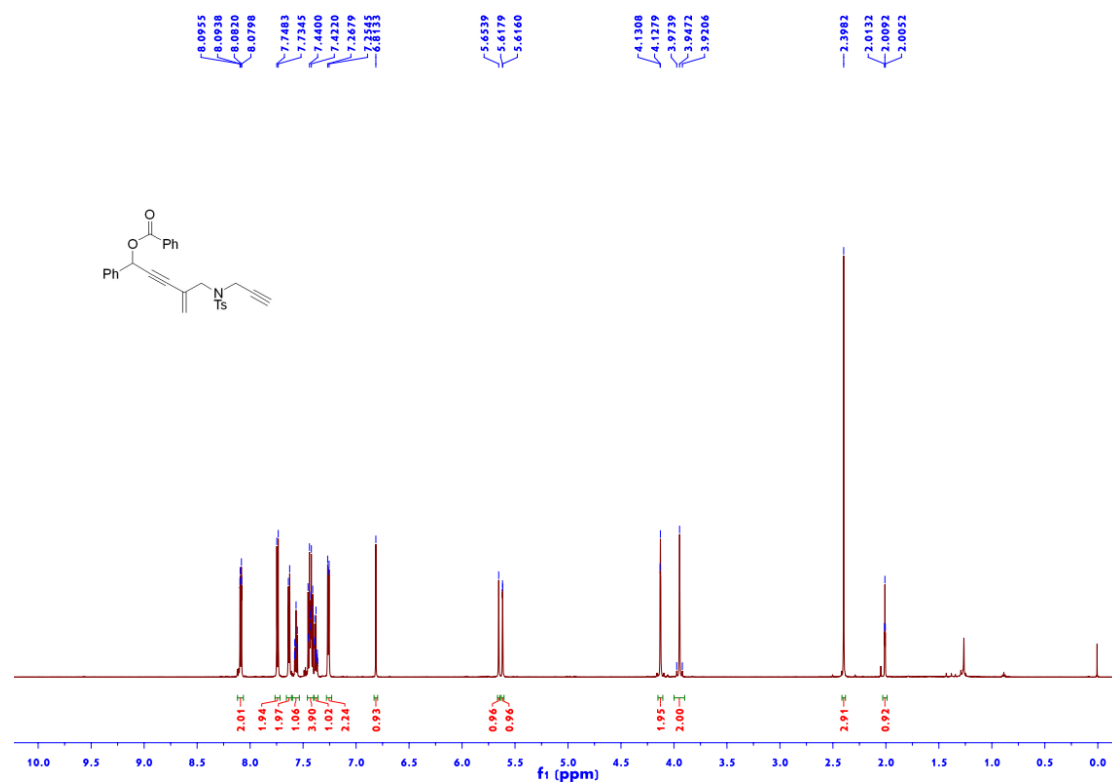


Figure S55  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1aa

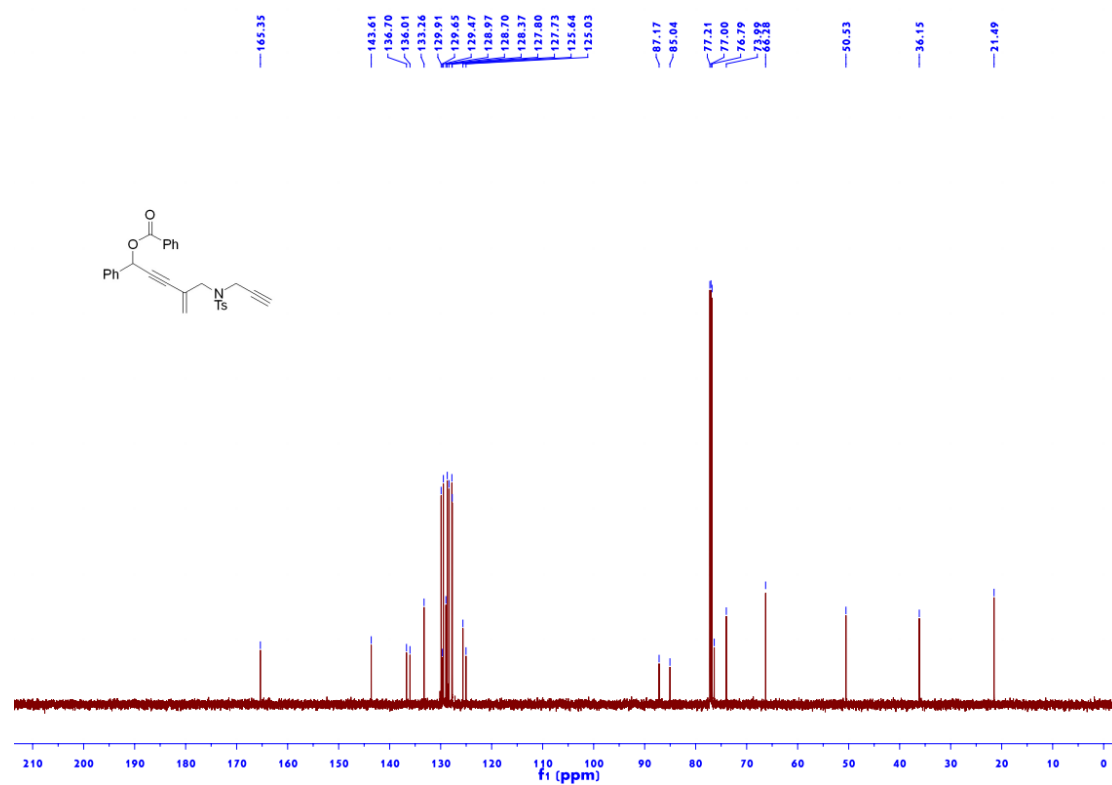


Figure S56  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1ab

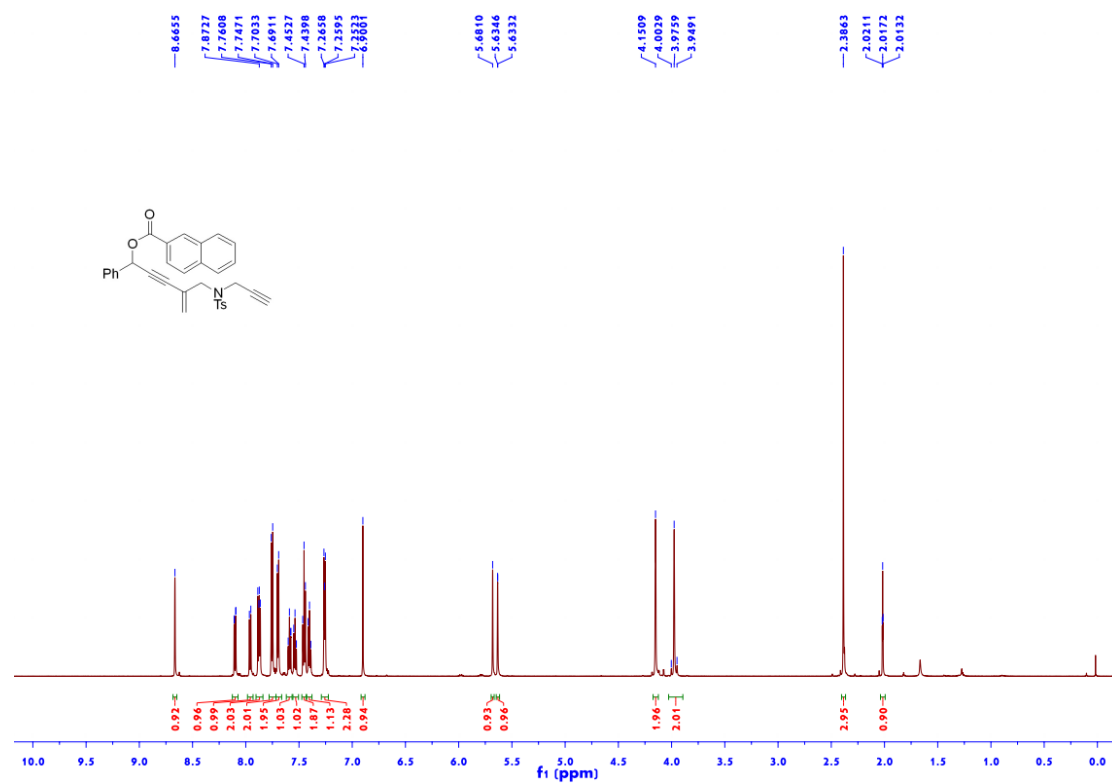




Figure S57 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 1ab

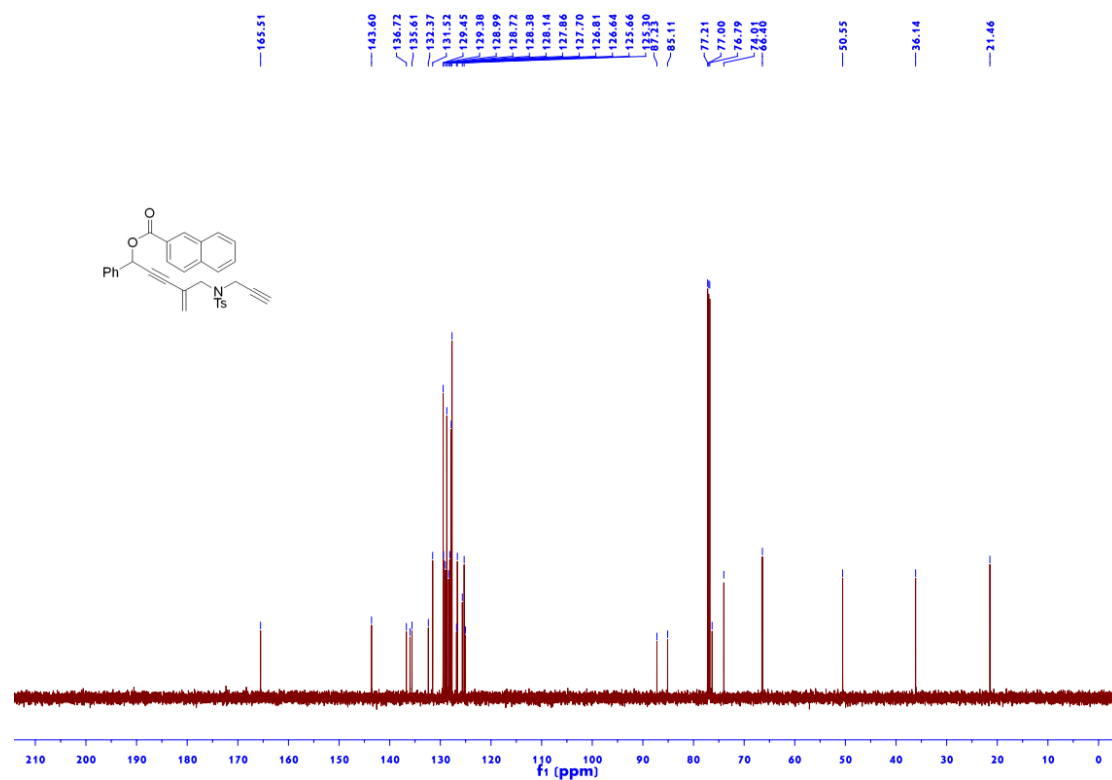


Figure S58 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 1ac

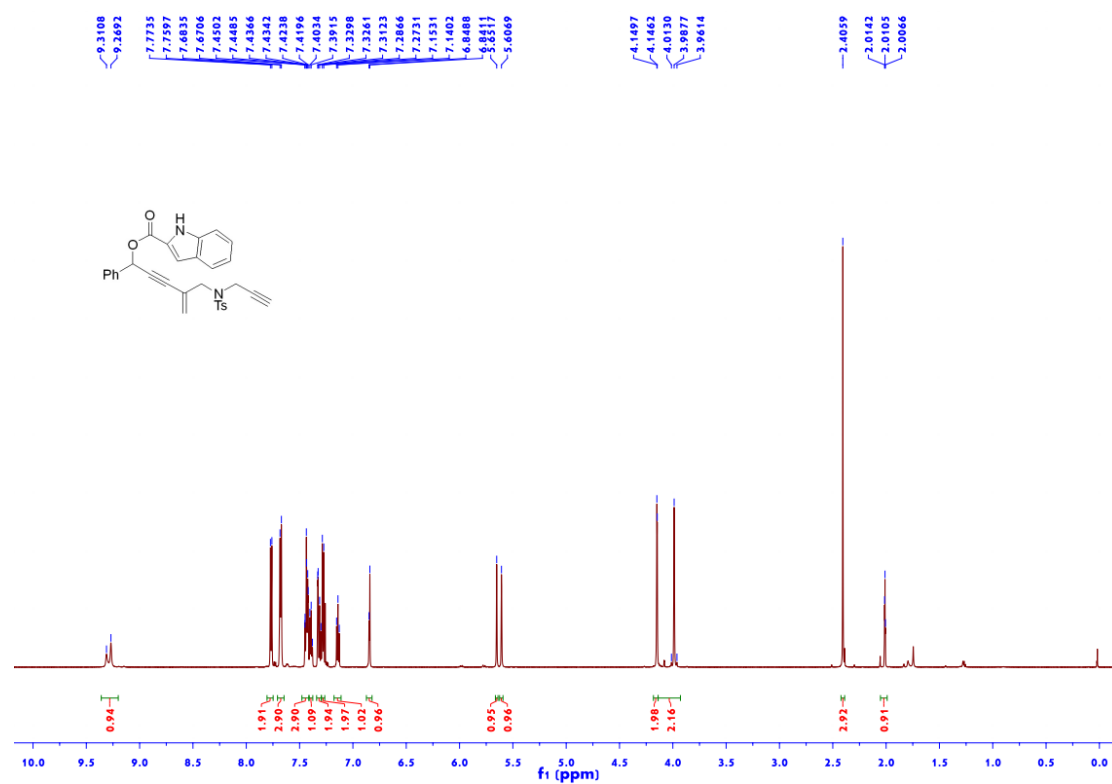


Figure S59  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1ac

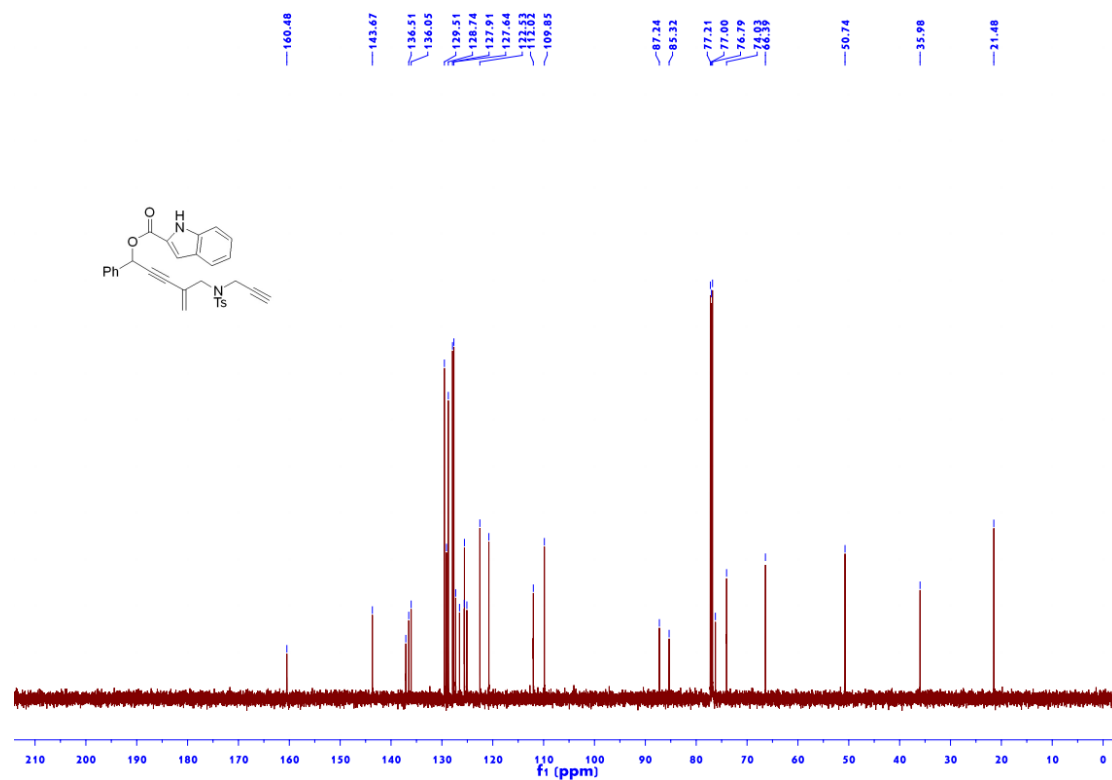


Figure S60  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1ad

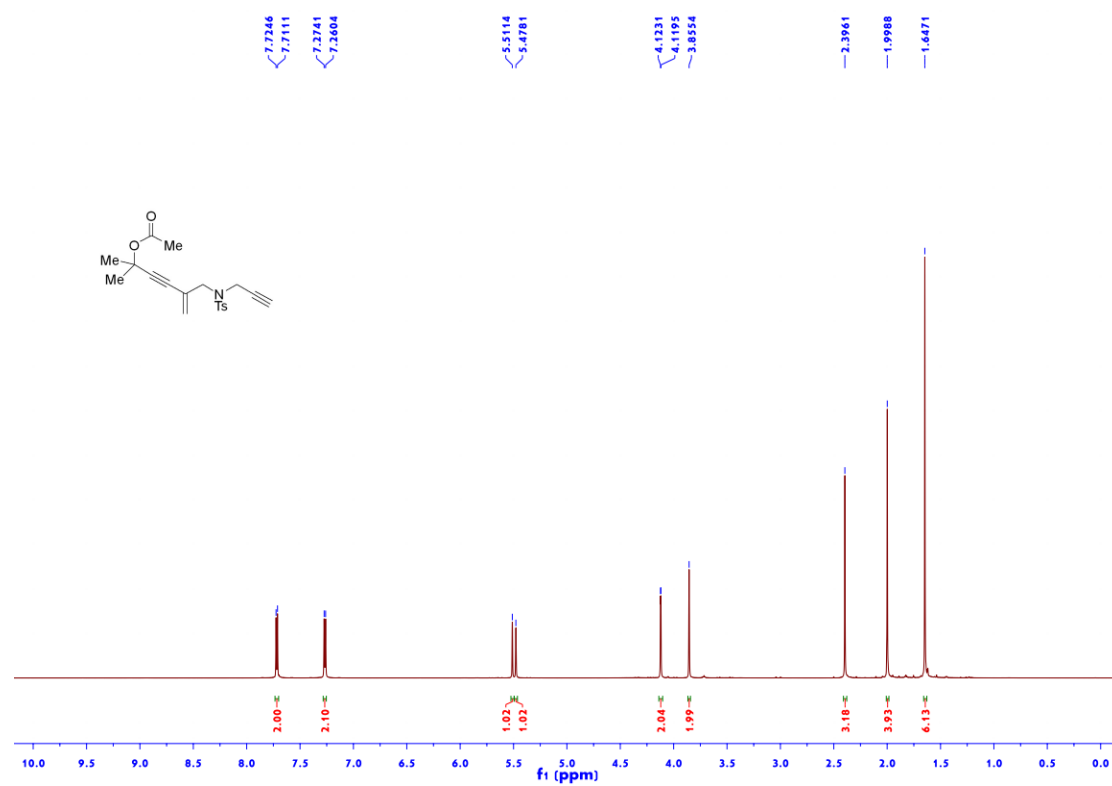


Figure S61  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1ad

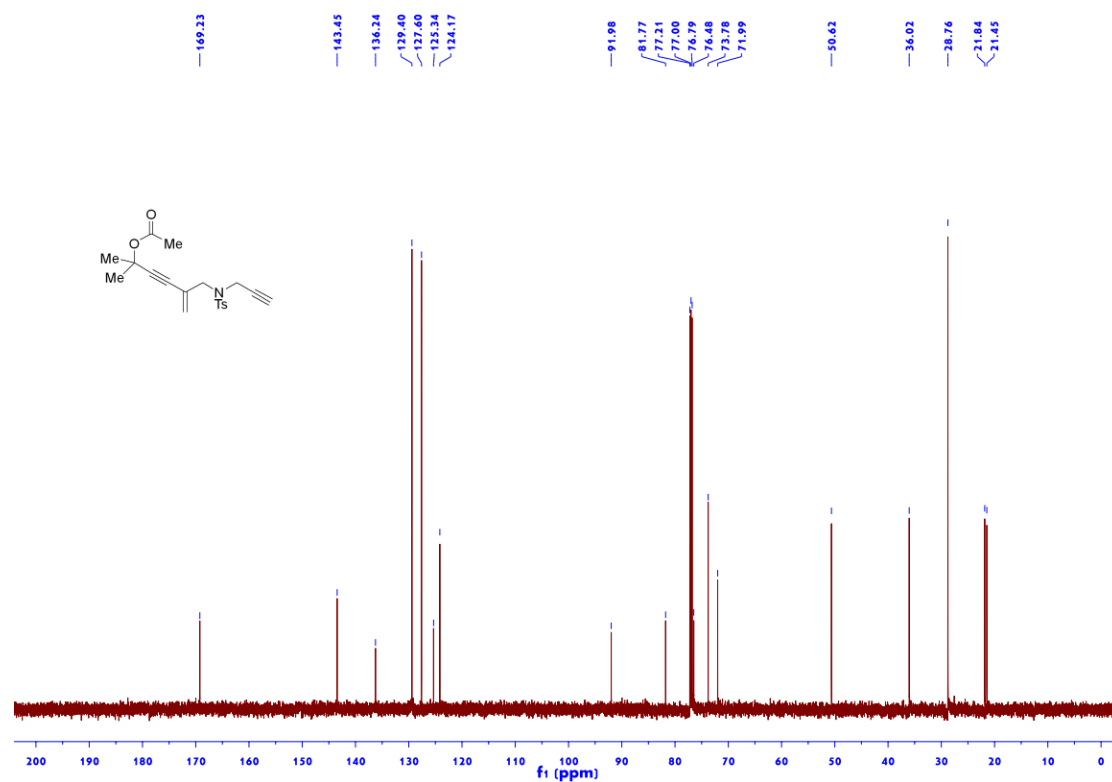


Figure S62  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1ae

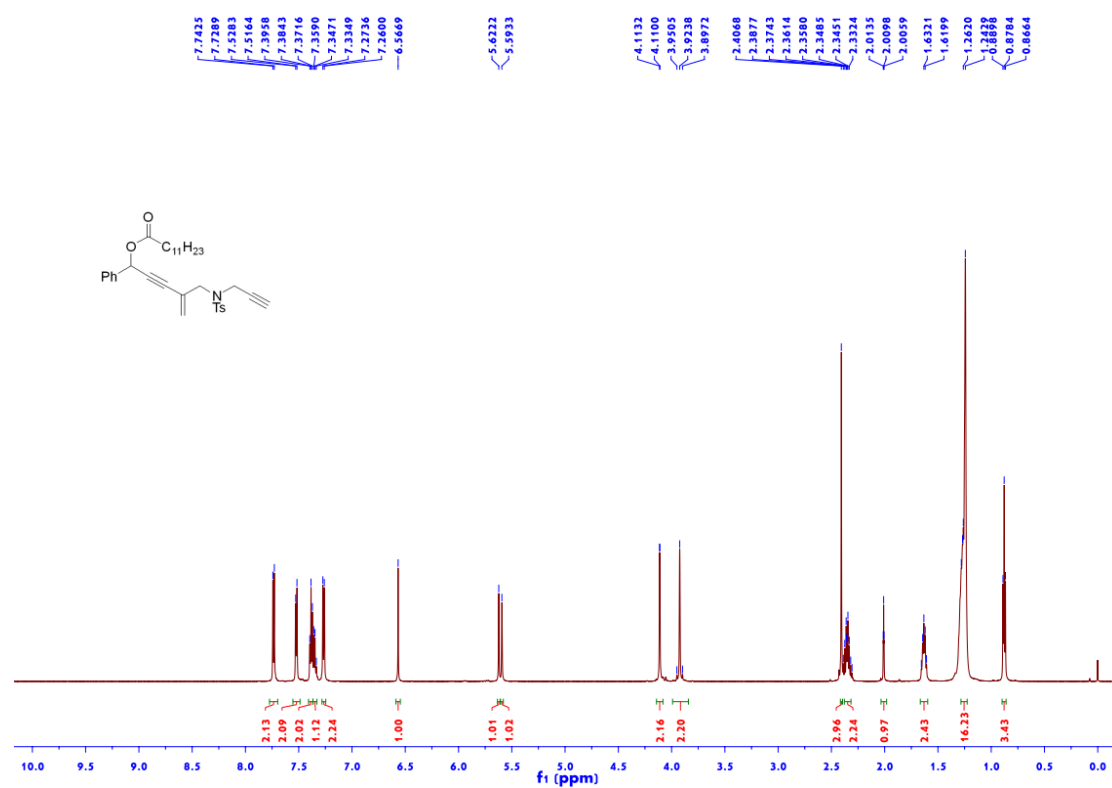




Figure S65  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 1af

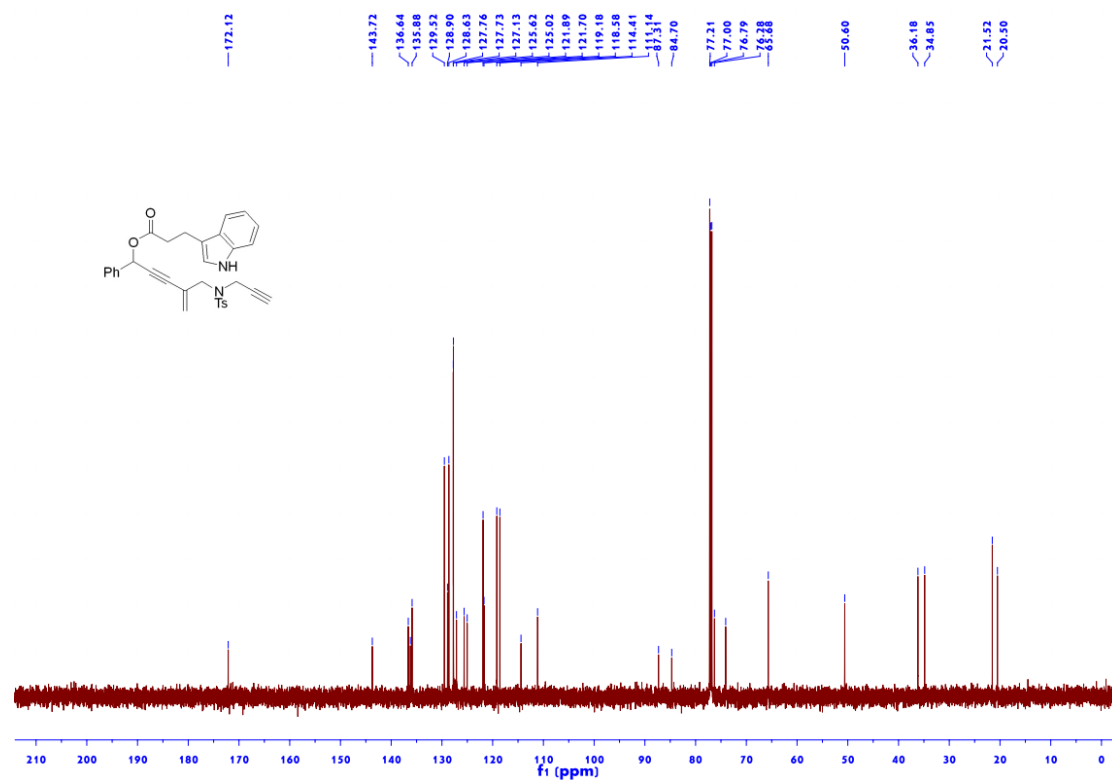


Figure S66  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 1ag

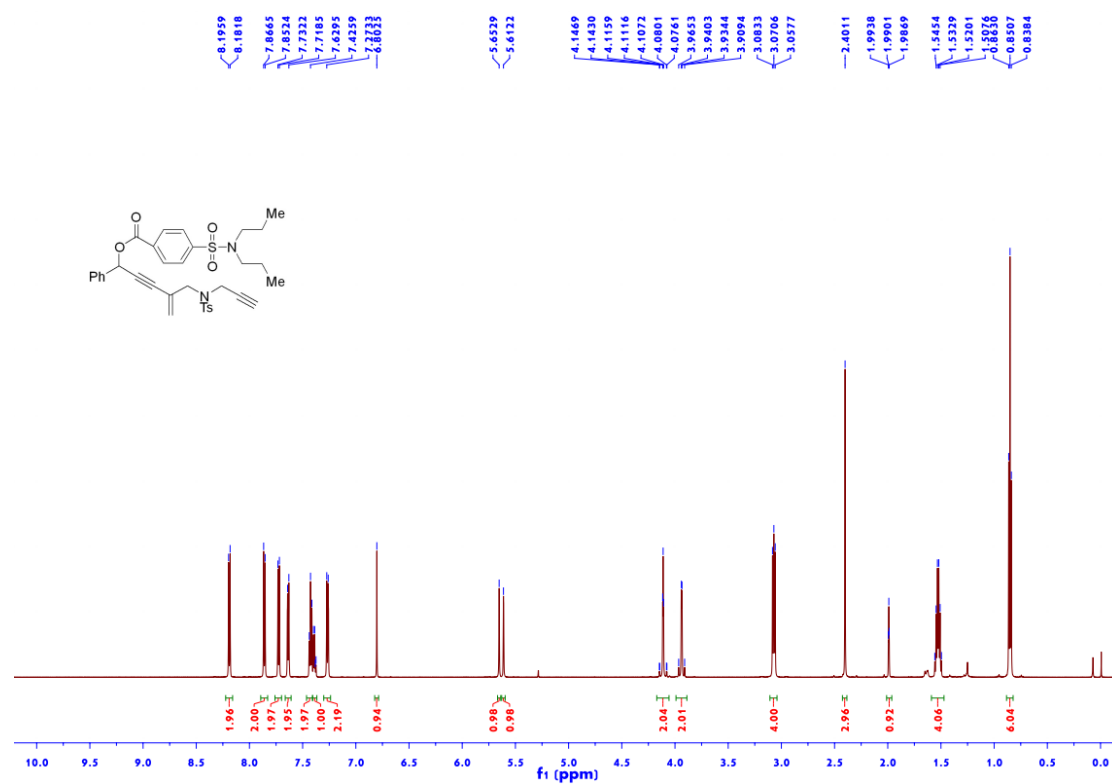


Figure S67 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 1ag

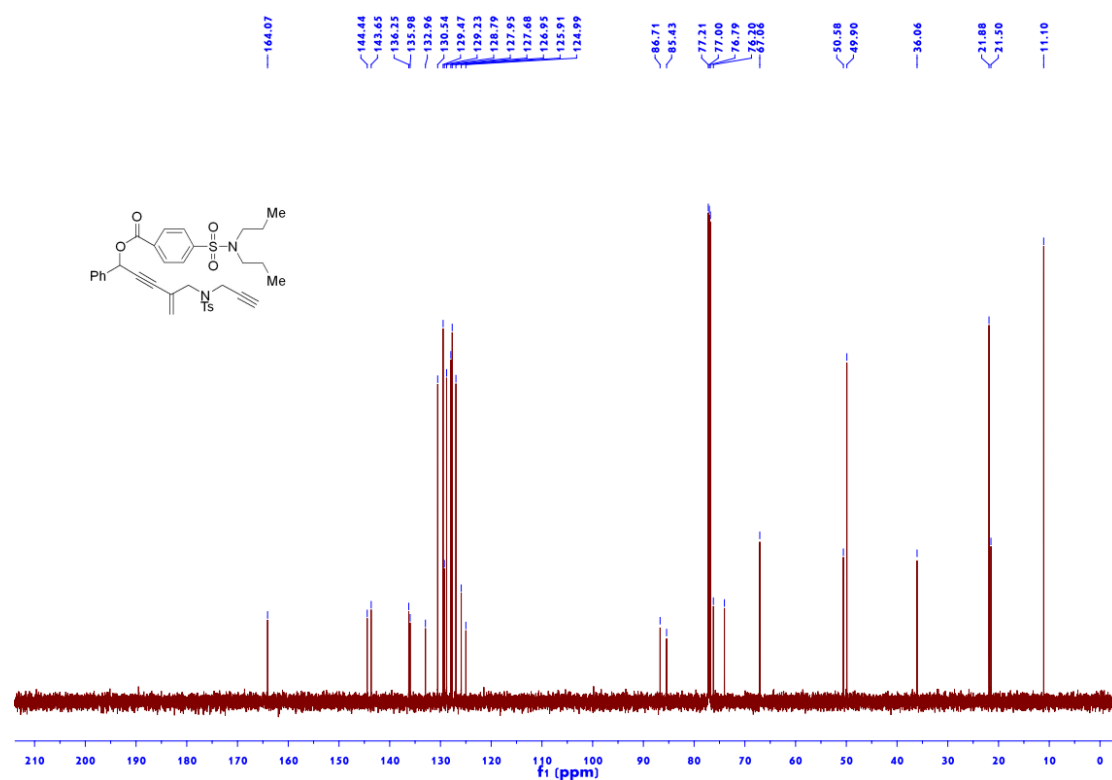


Figure S68 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 1ah

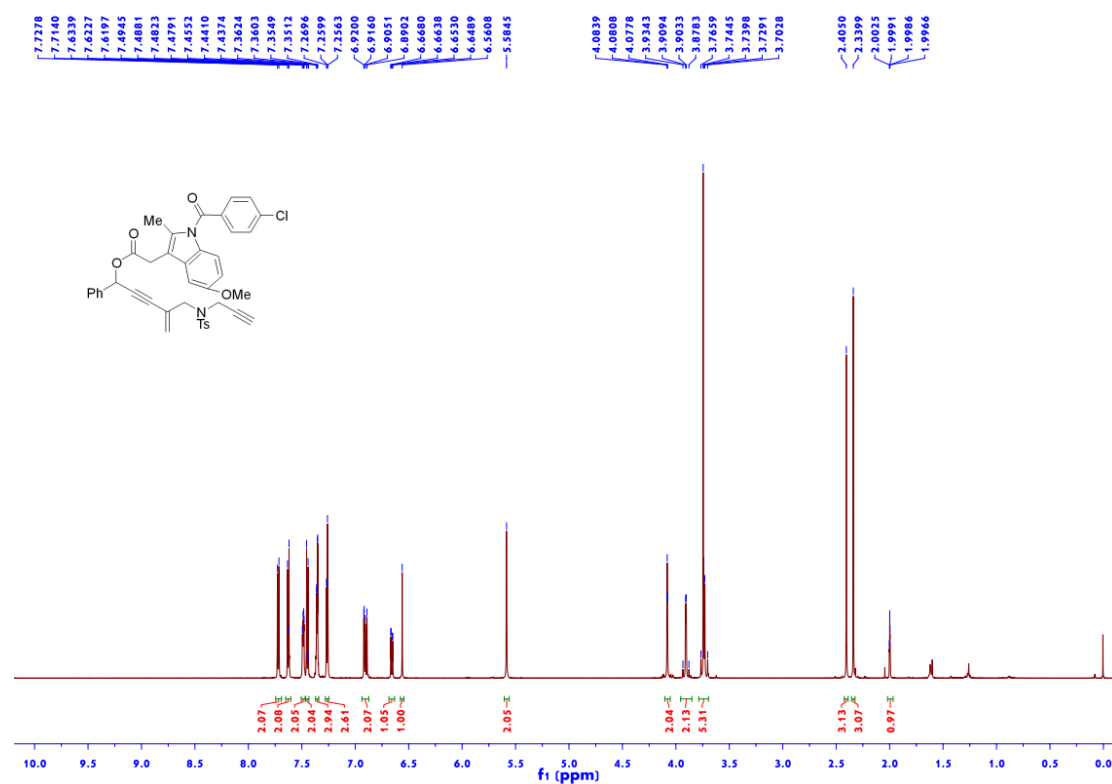


Figure S69 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 1ah

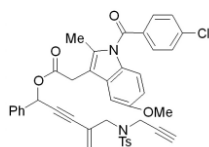
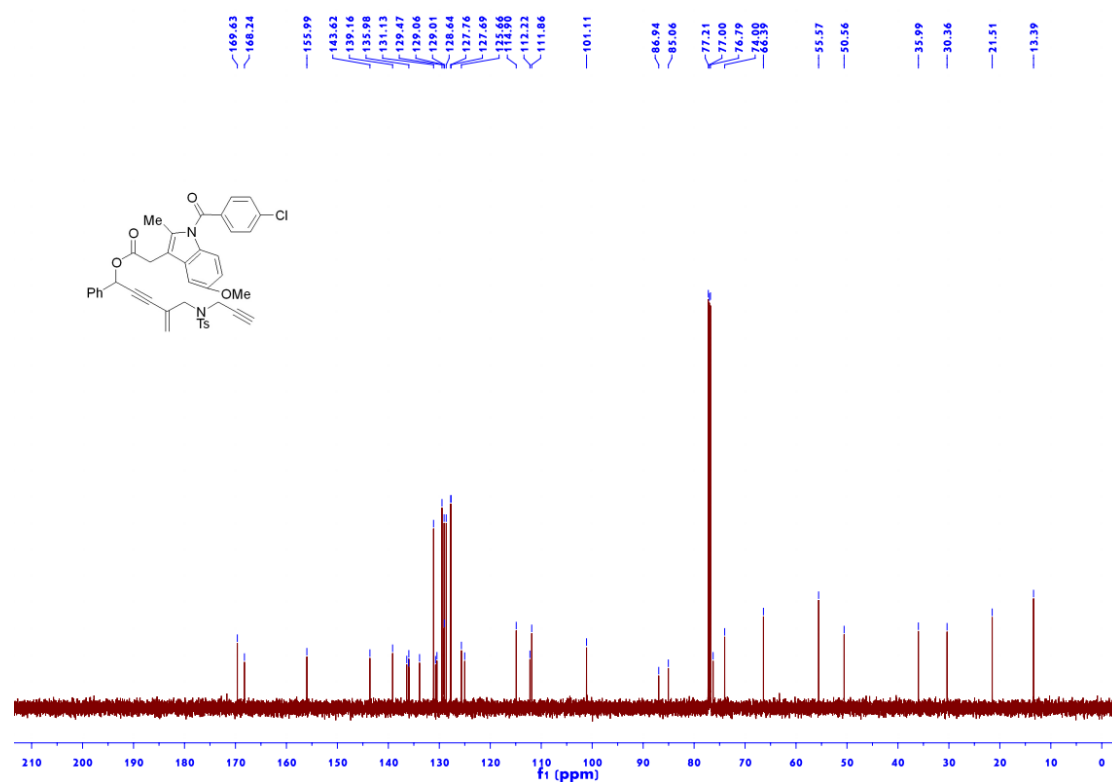


Figure S70 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 1ai

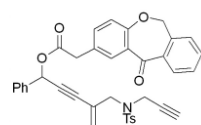
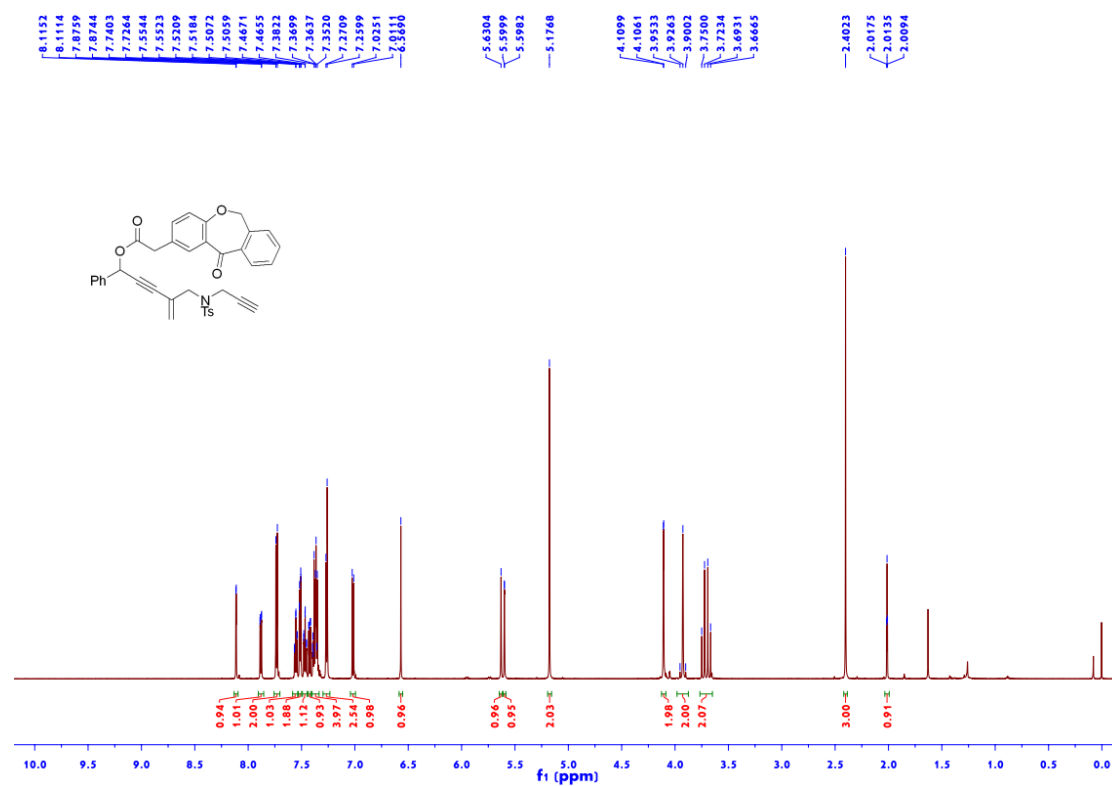


Figure S71 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 1ai

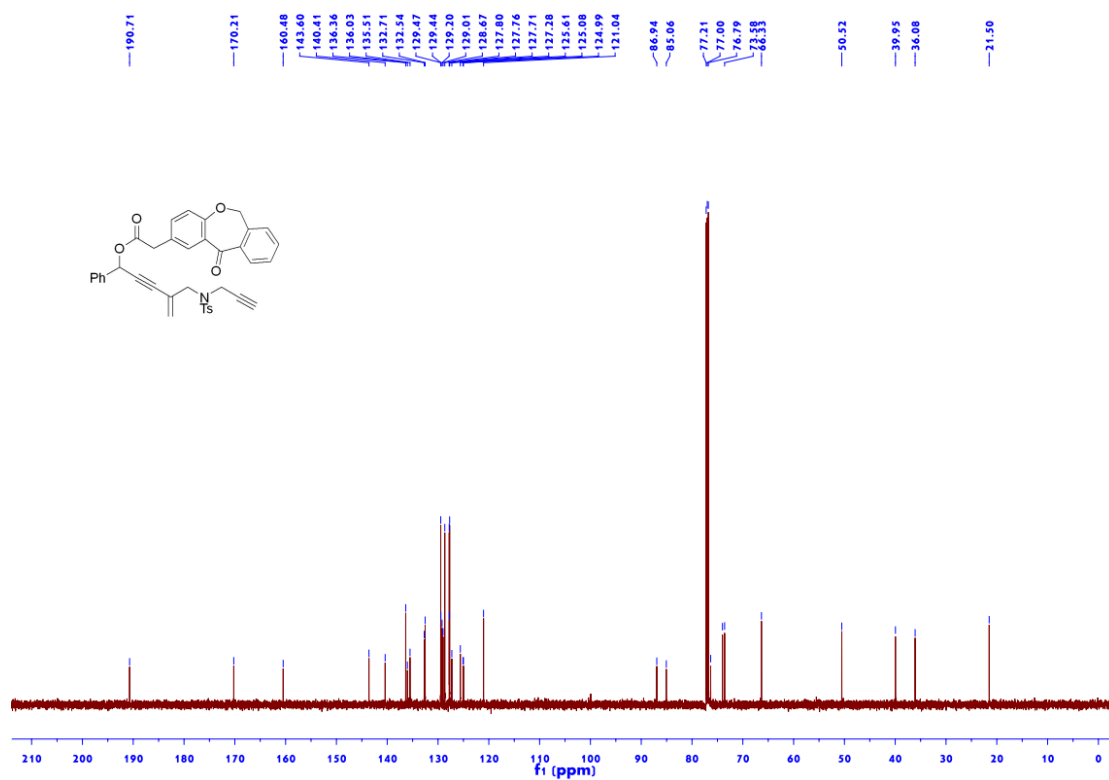


Figure S72 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 4a

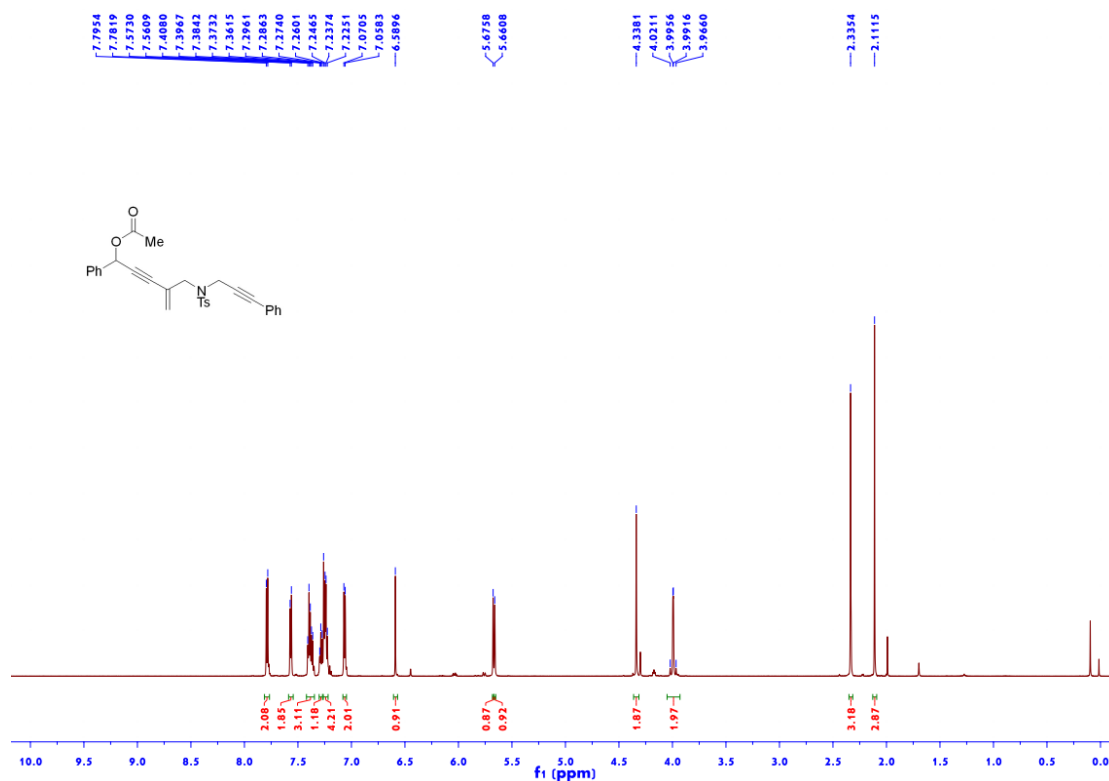




Figure S73 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 4a

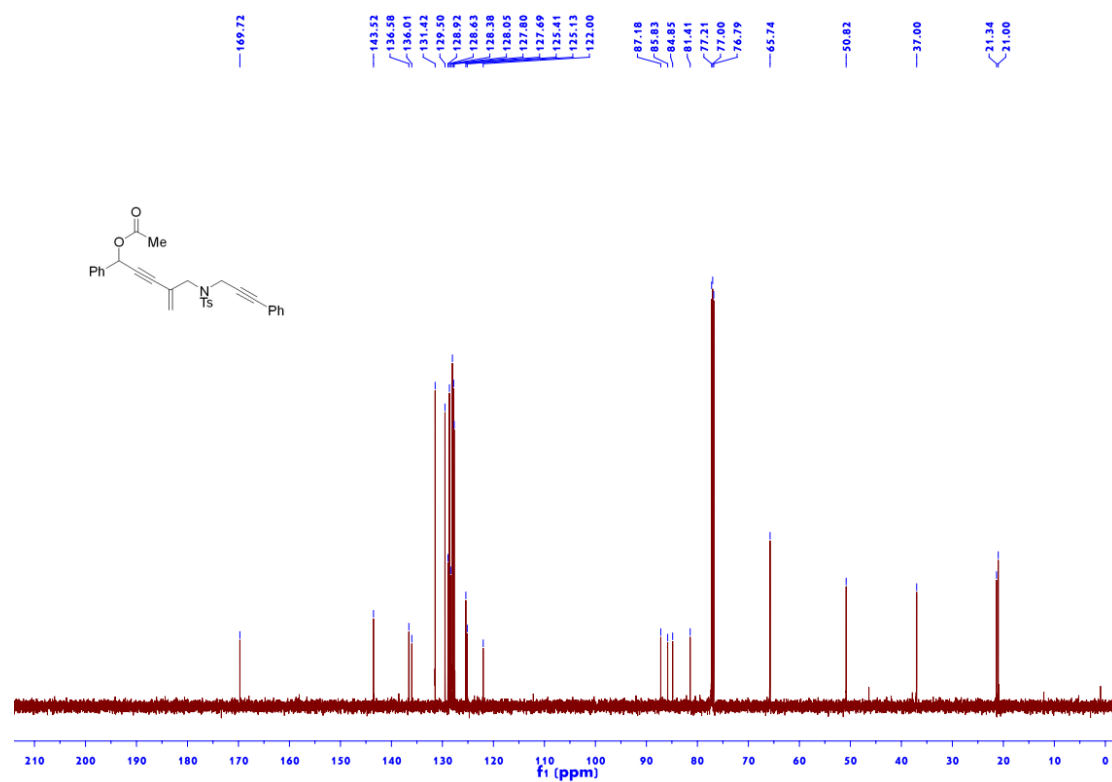


Figure S74 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 4b

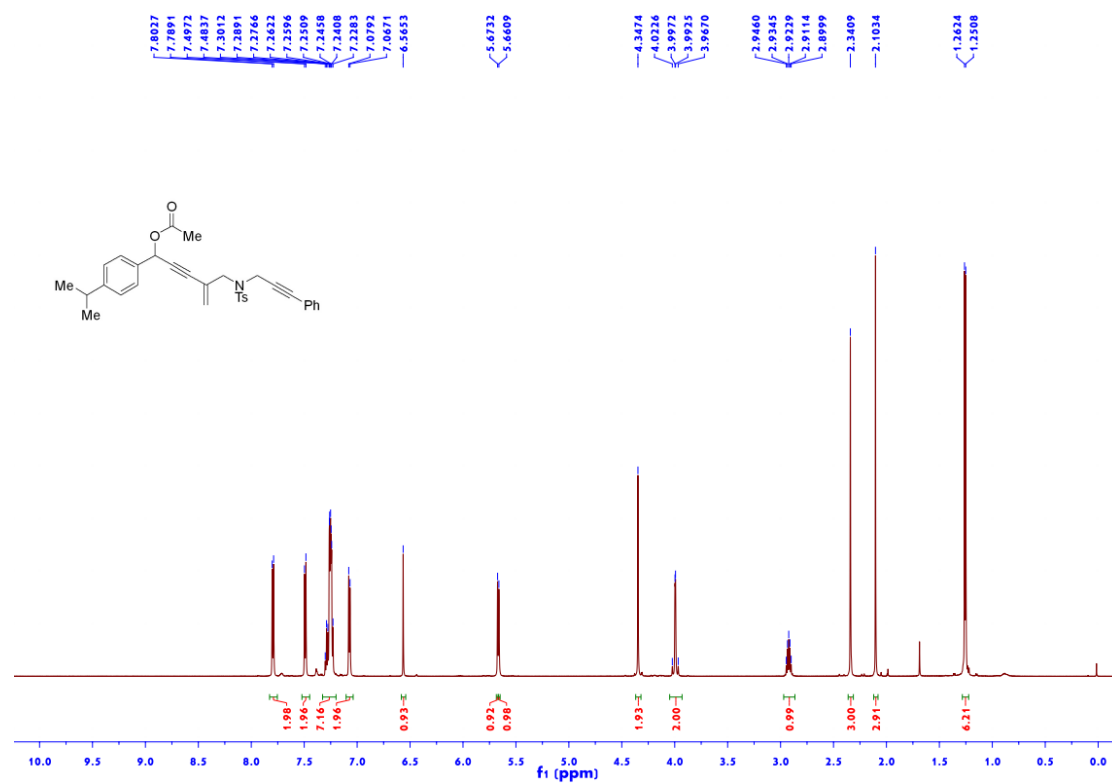


Figure S75 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 4b

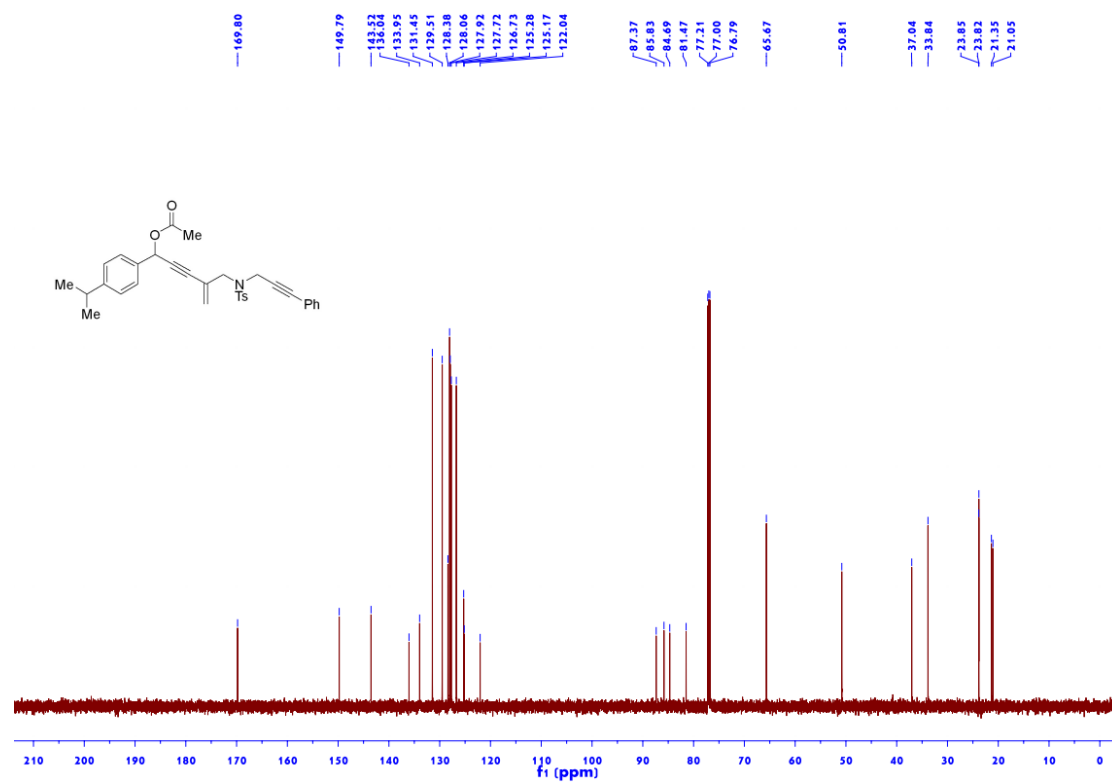


Figure S76 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 4c

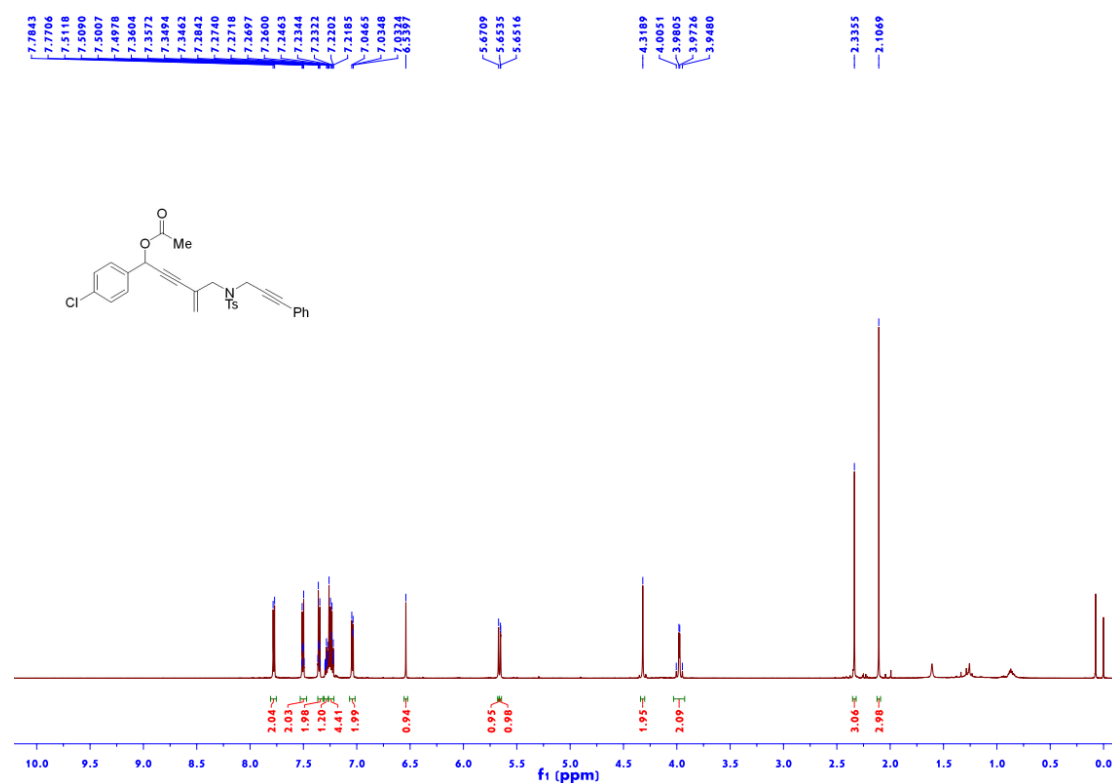


Figure S77 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 4c

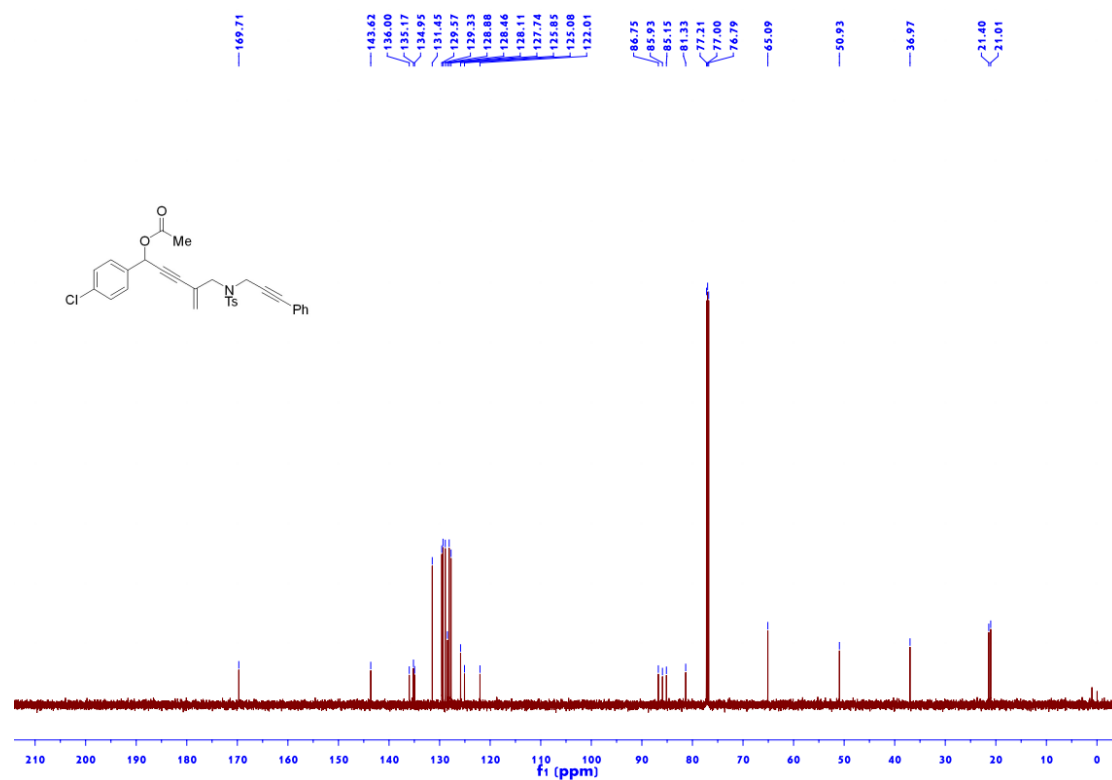


Figure S78 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 4d

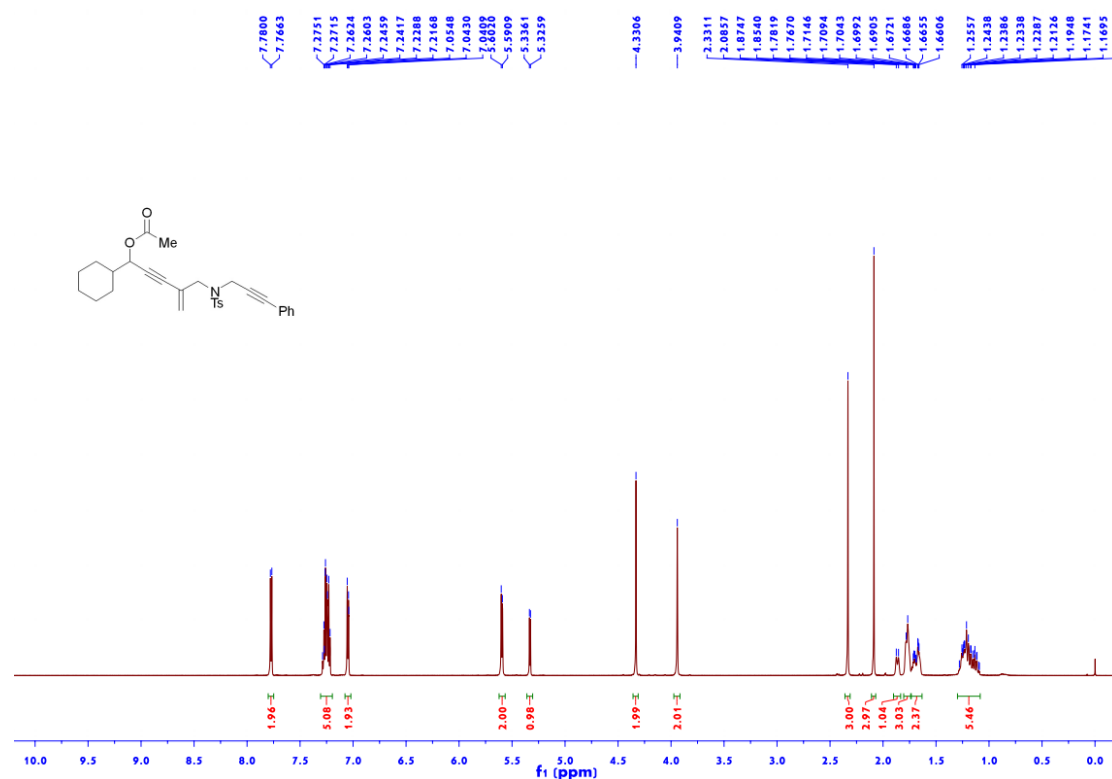


Figure S79  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 4d

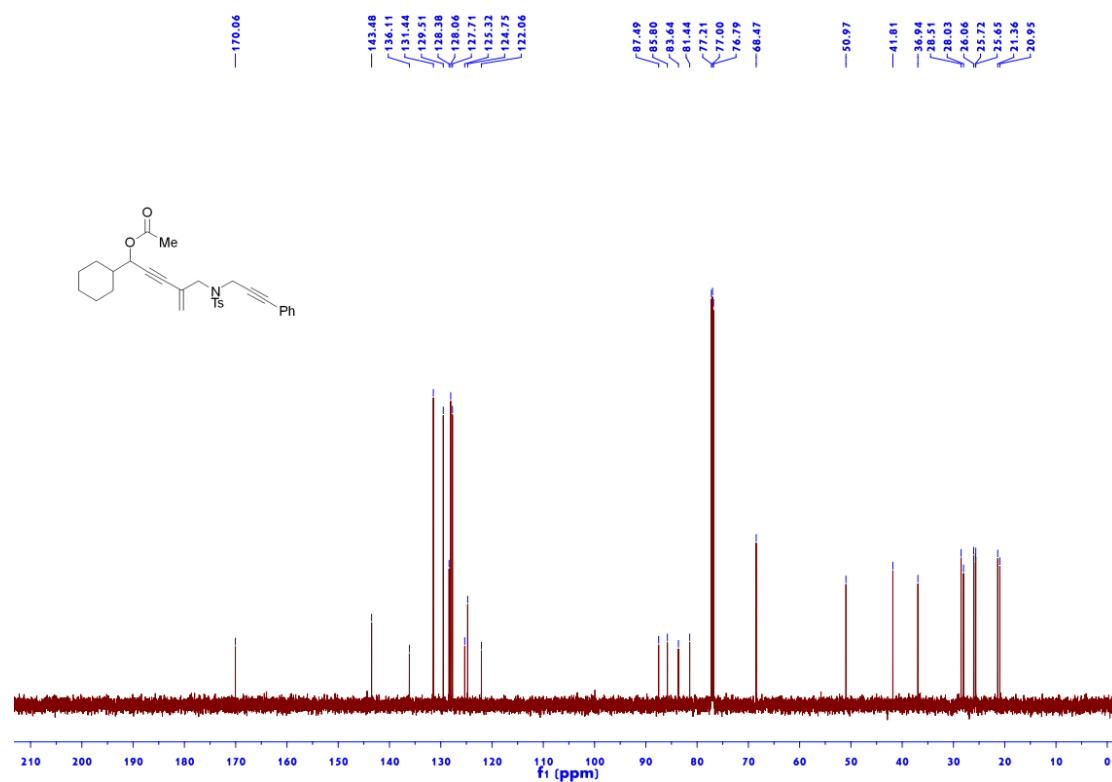


Figure S80  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 4e

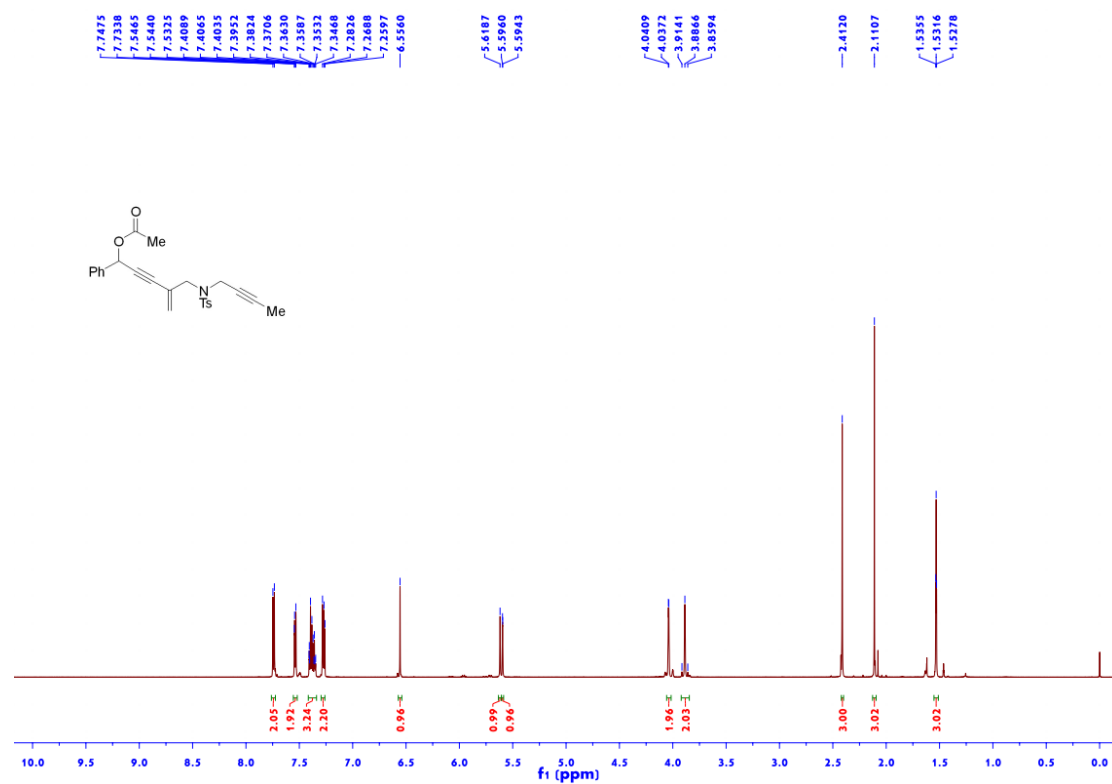


Figure S81  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 4e

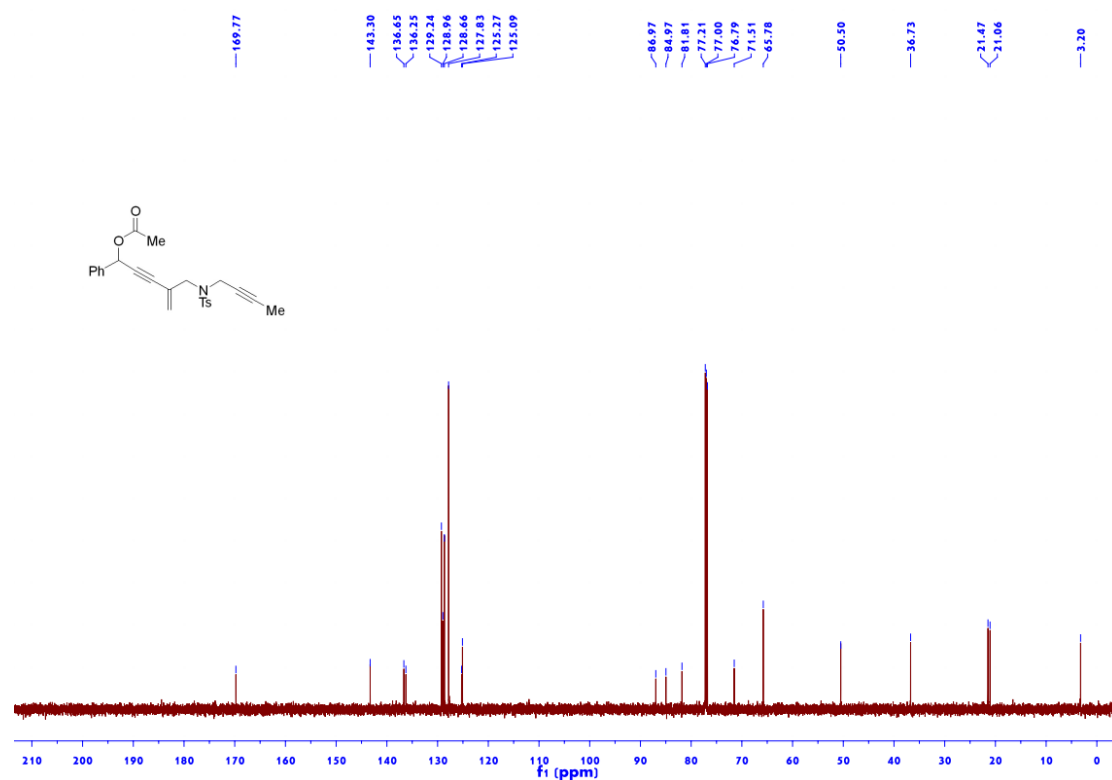


Figure S82  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 4f

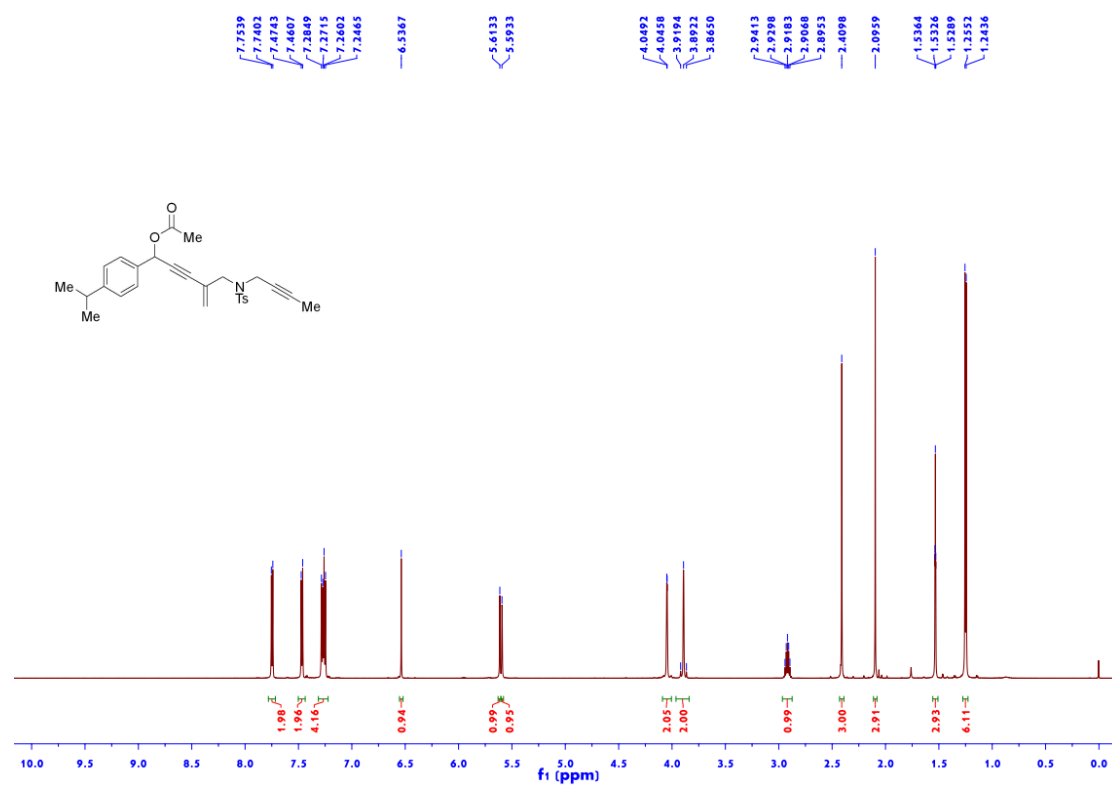


Figure S83 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 4f

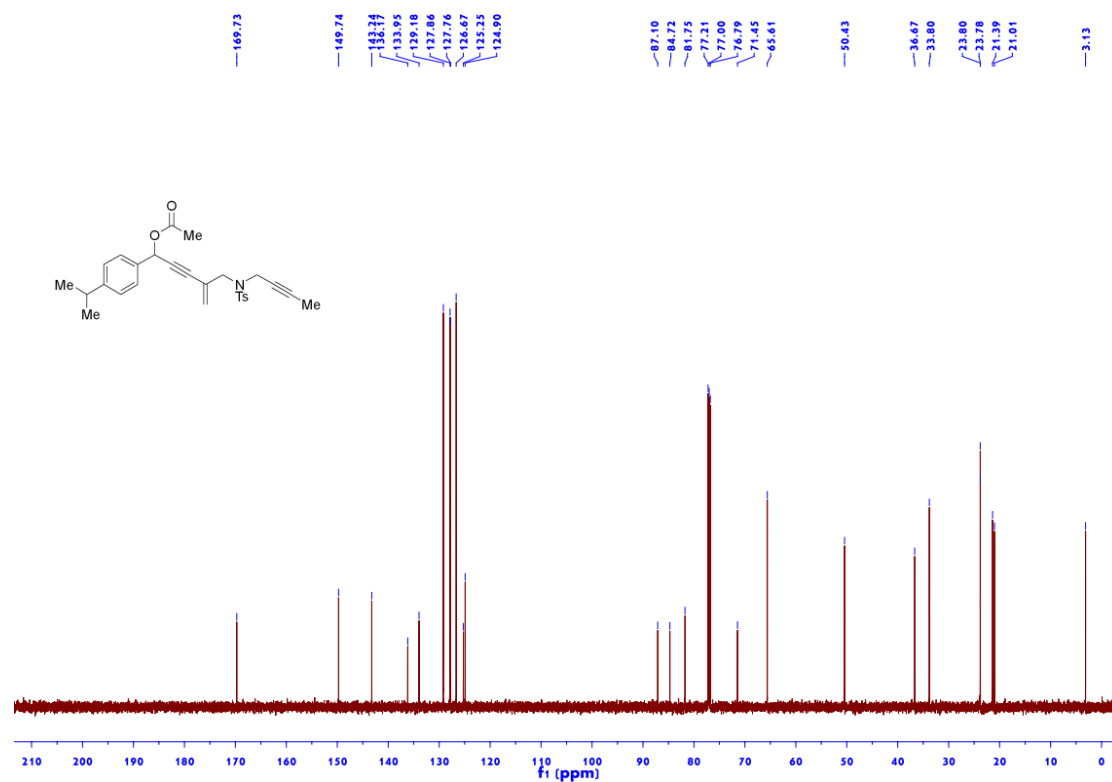


Figure S84 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 4g

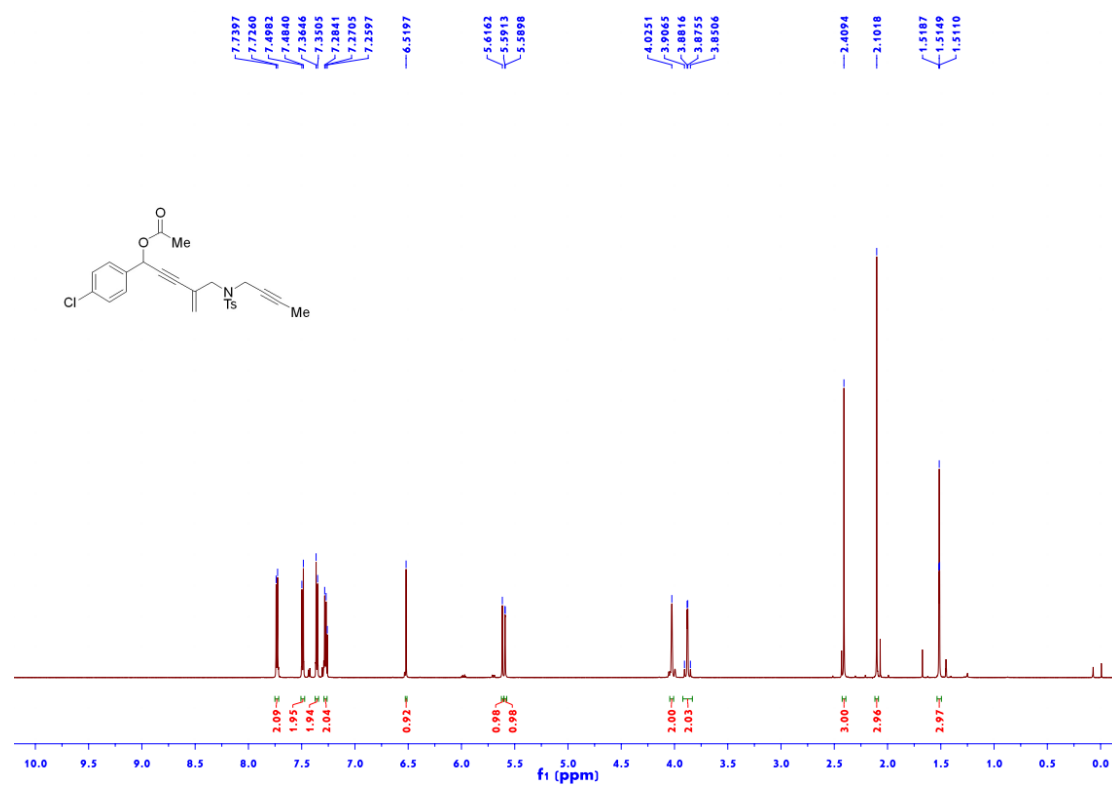


Figure S85 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 4g

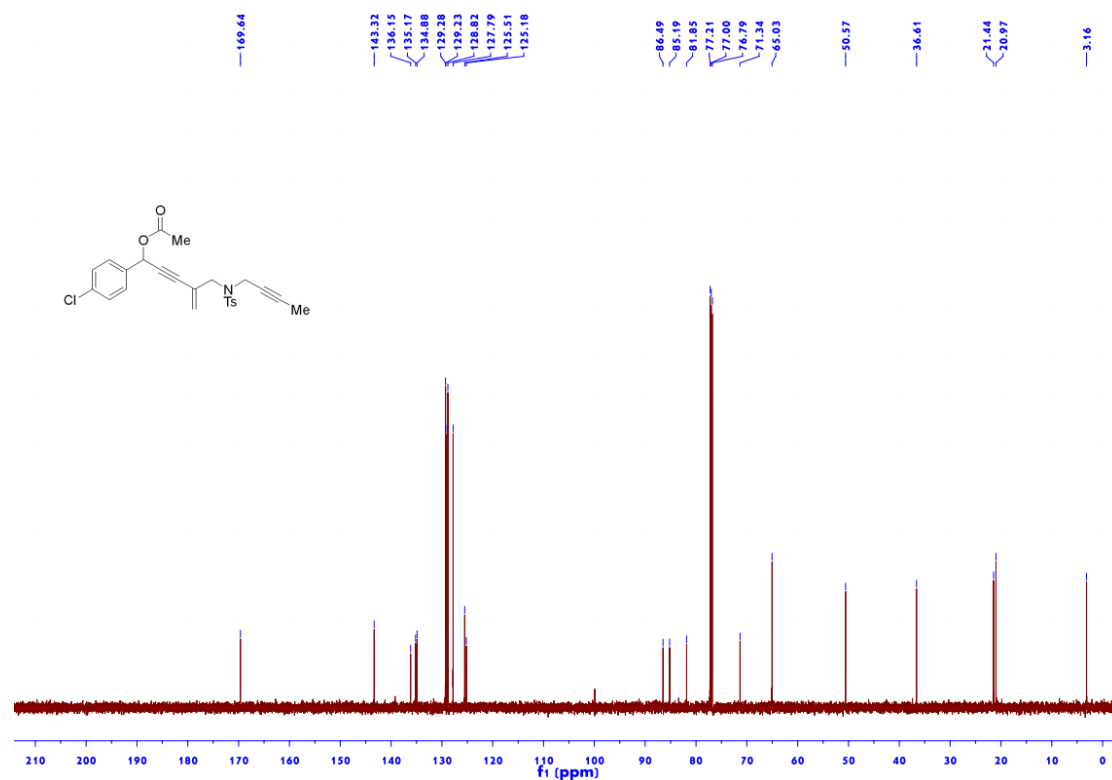


Figure S86 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 4h

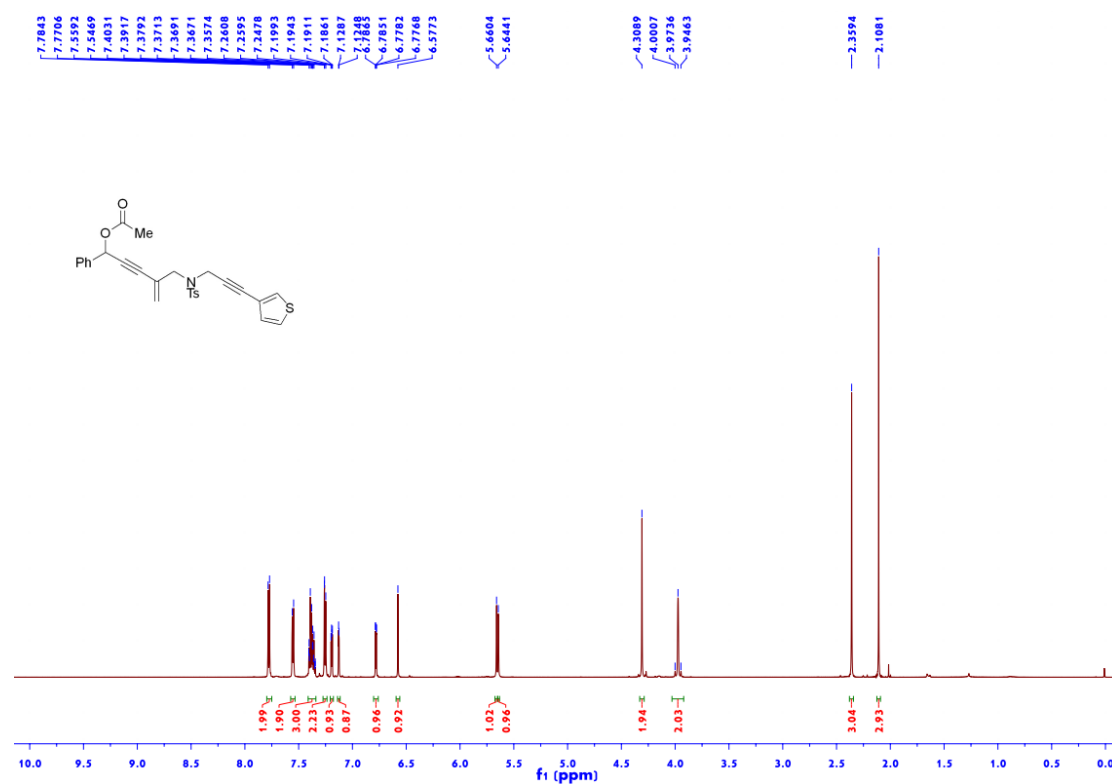


Figure S87 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 4h

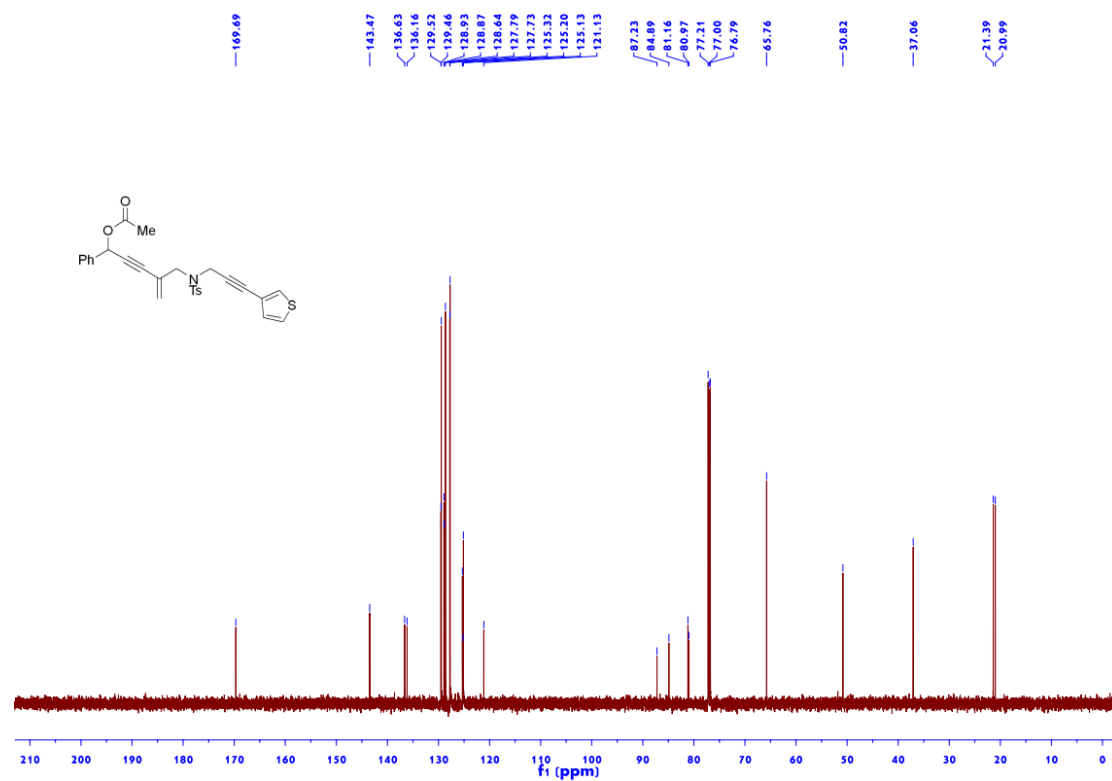


Figure S88 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 4i

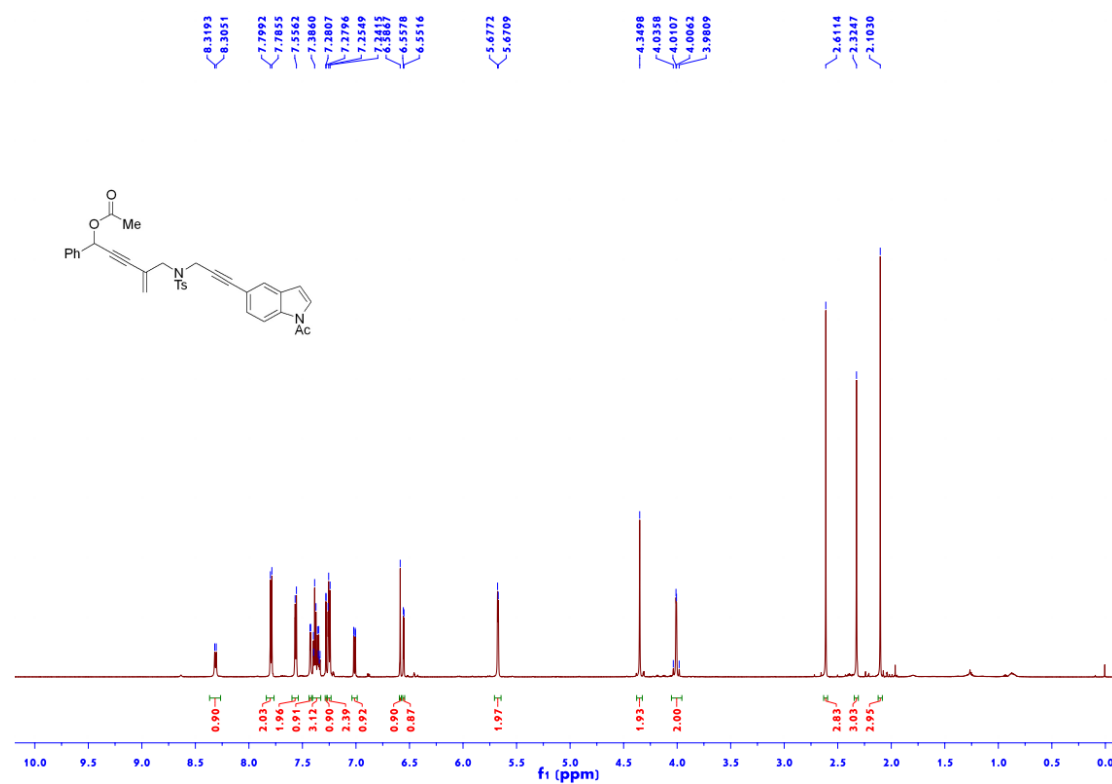




Figure S89 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 4i

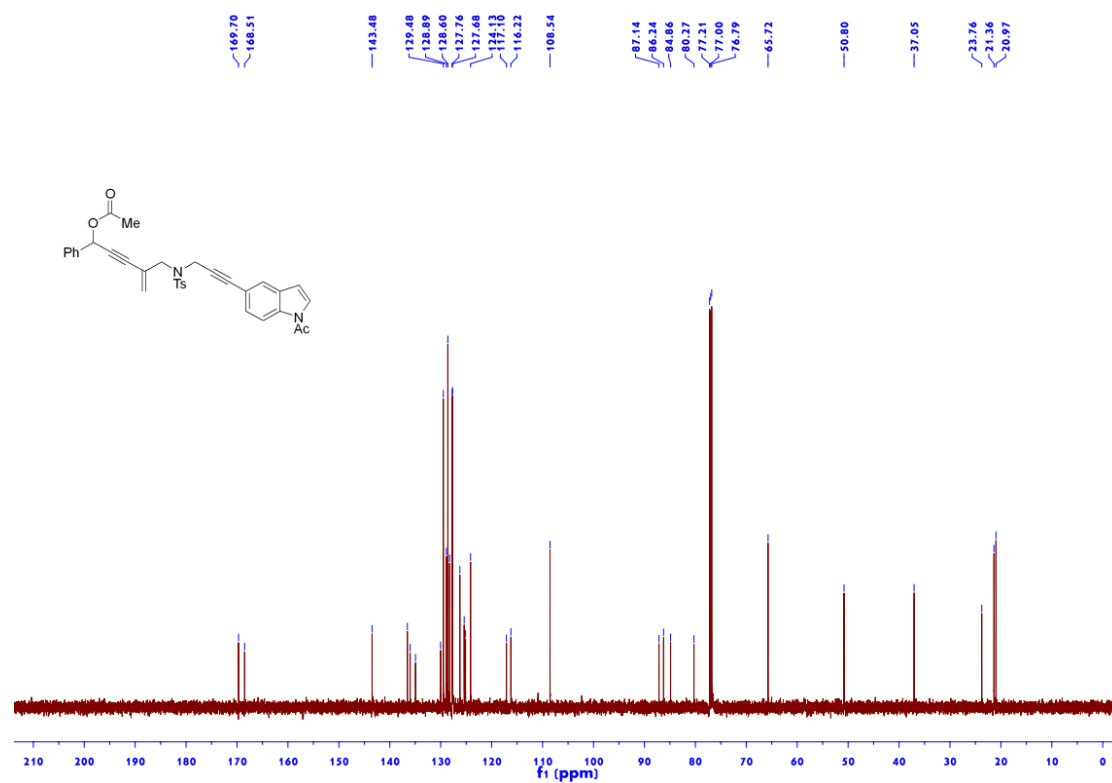


Figure S90 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 4j

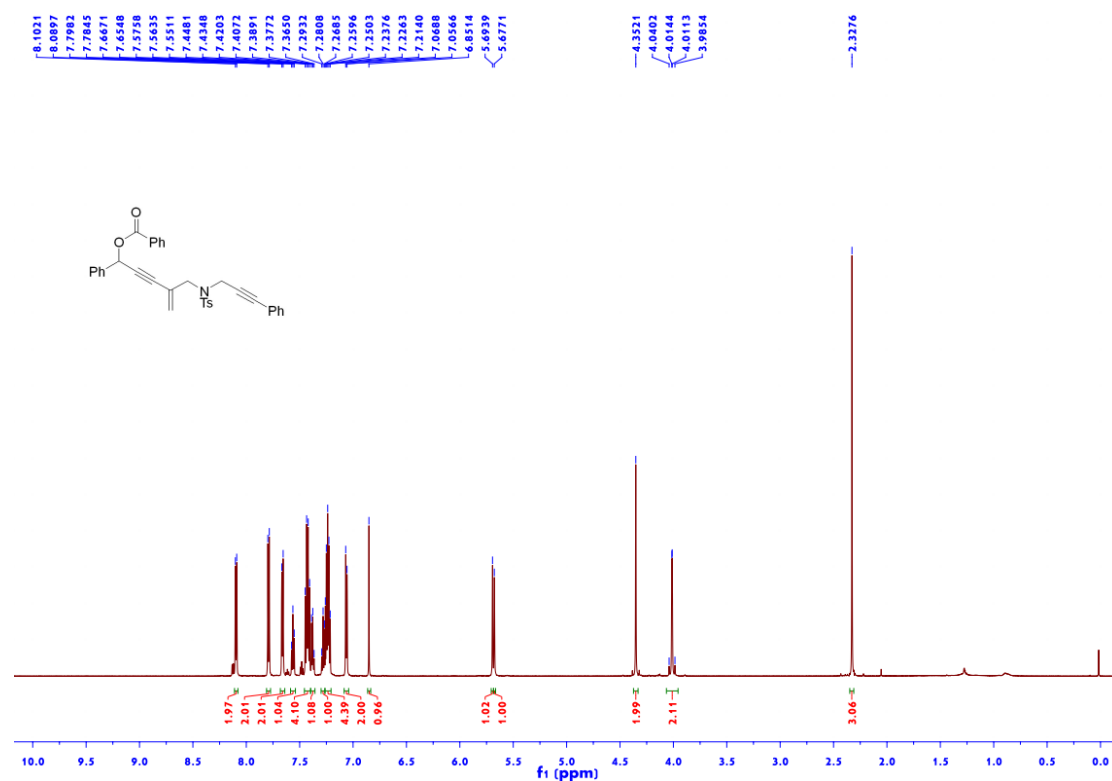


Figure S91 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 4j

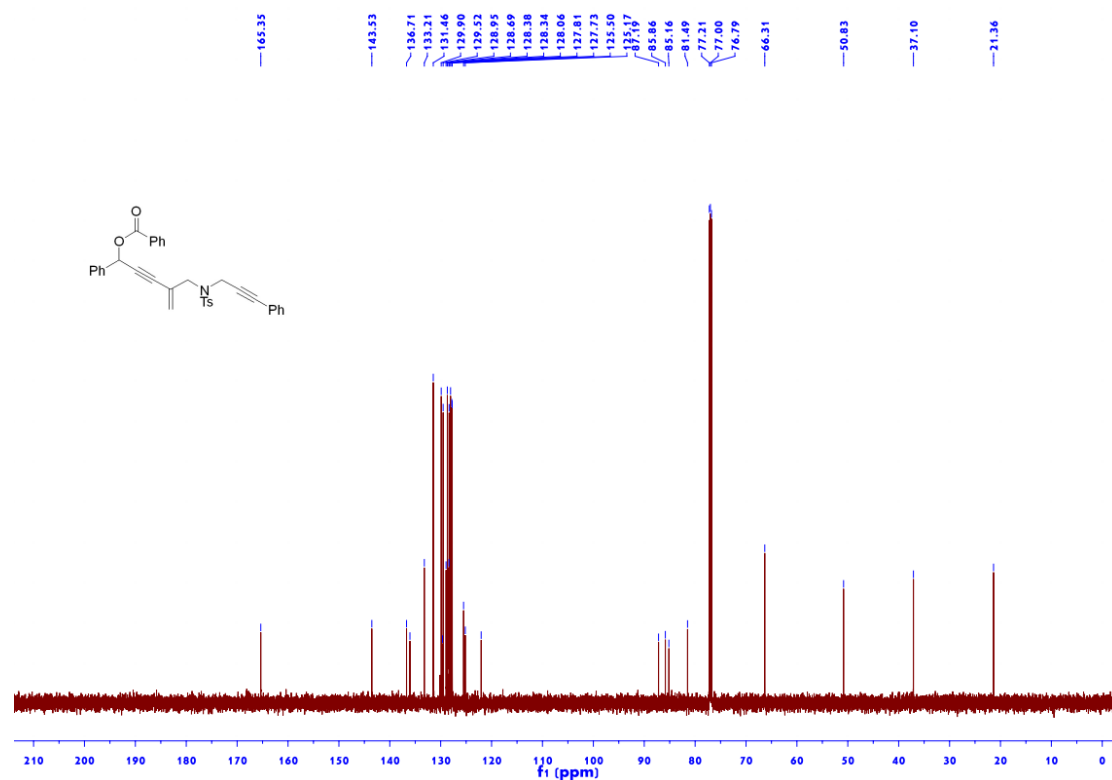


Figure S92 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 4k

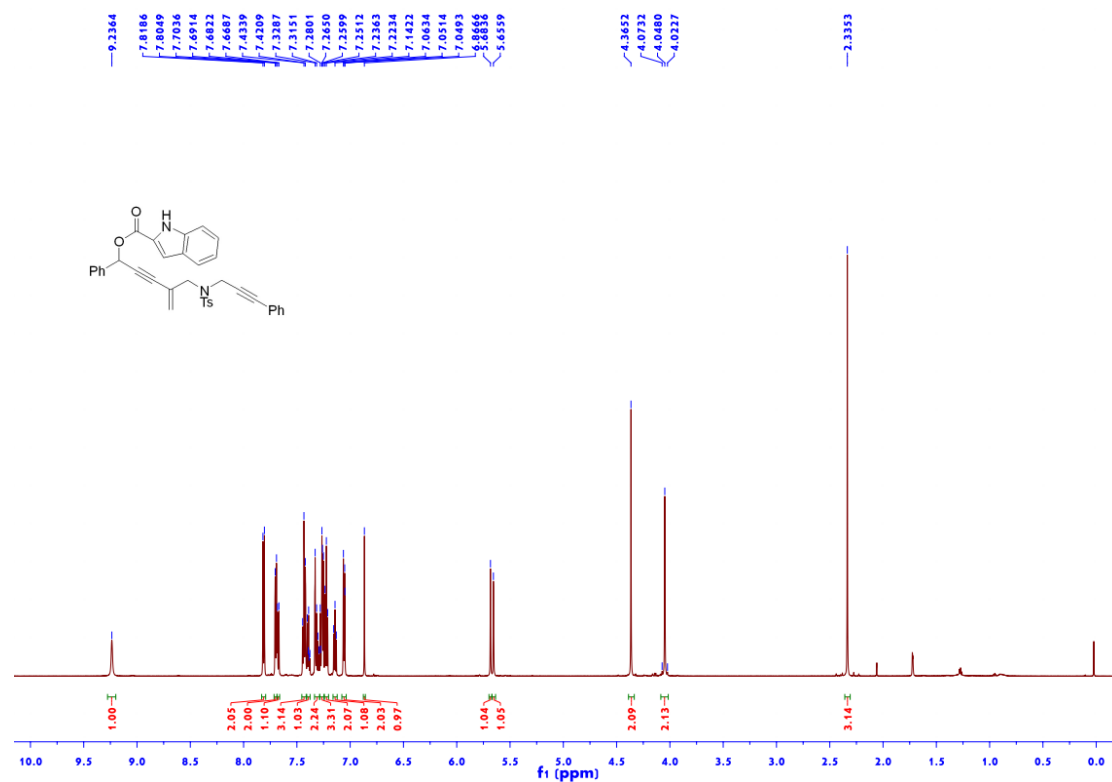


Figure S93  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 4k

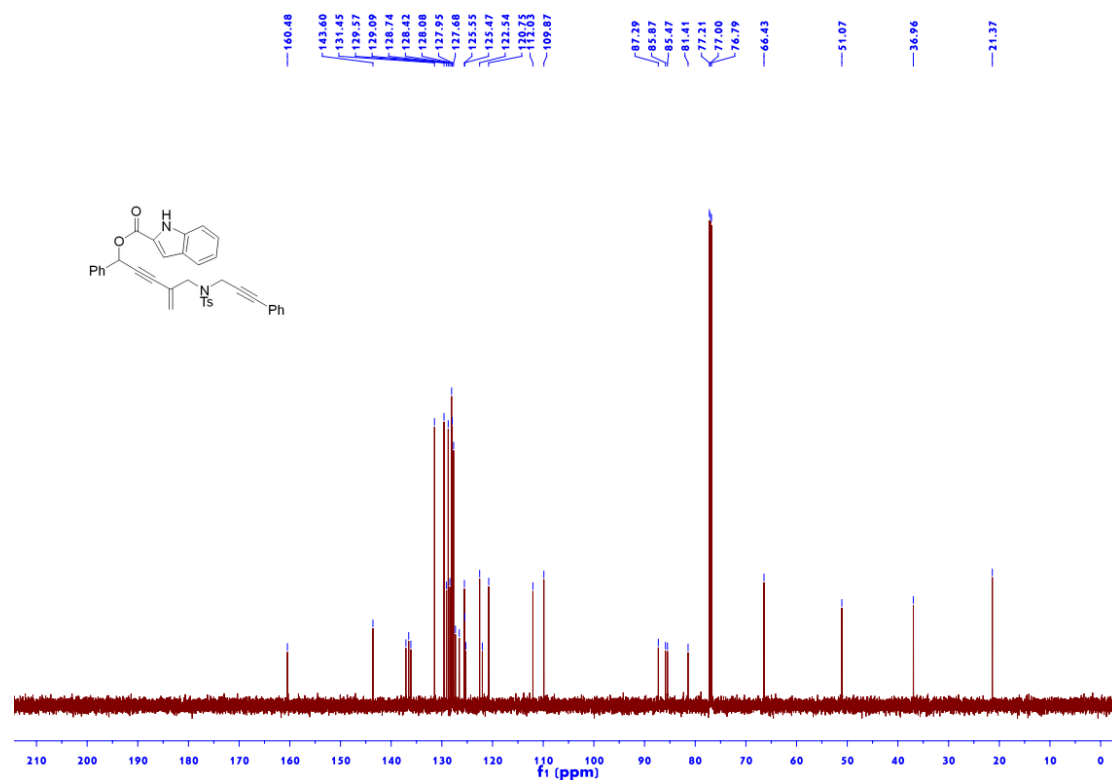


Figure S94  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 4l

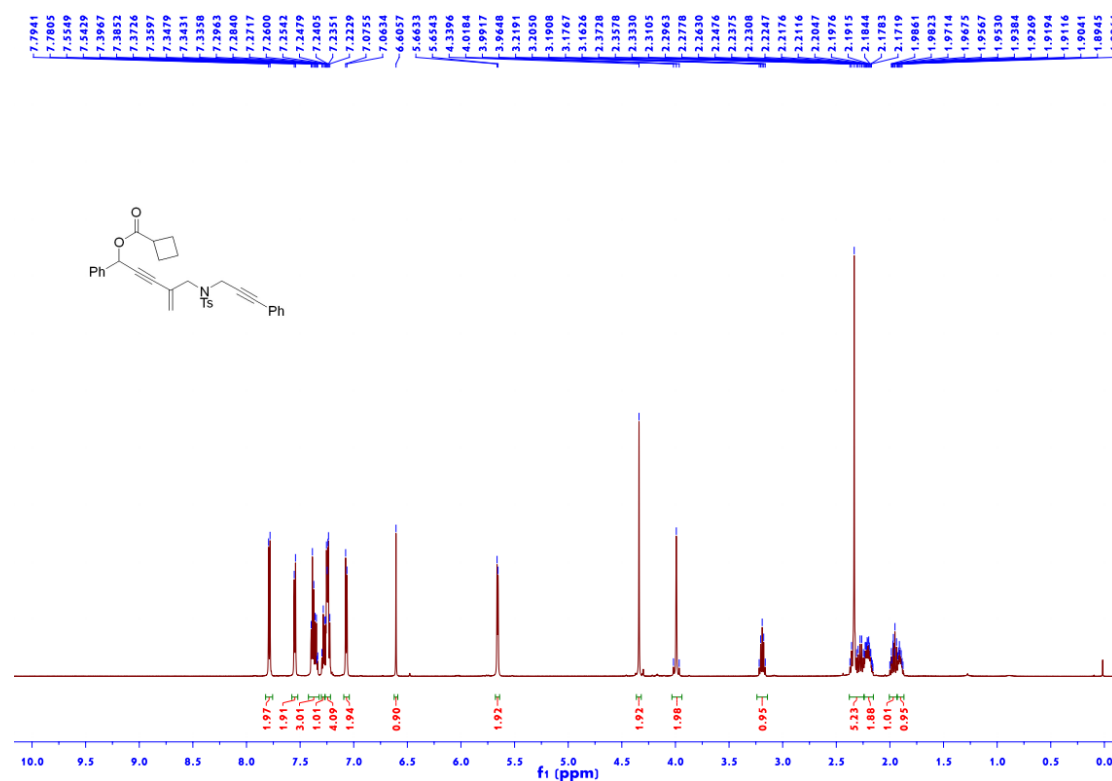


Figure S95 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 4l

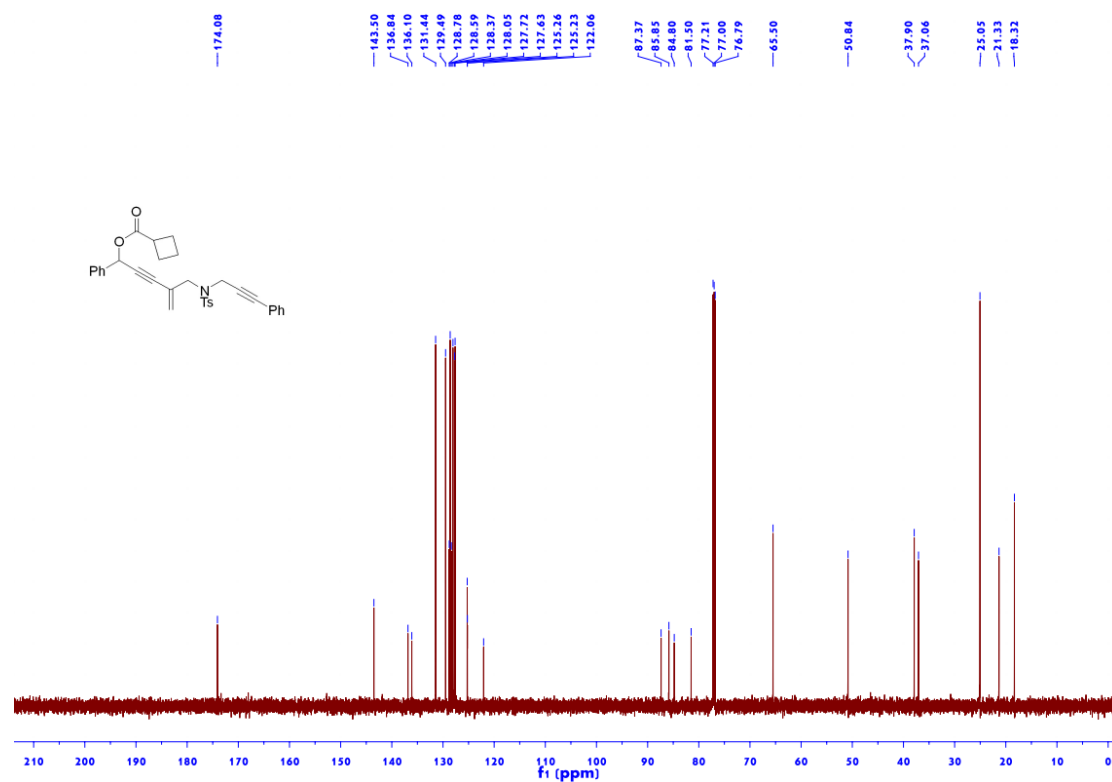


Figure S96 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 4m

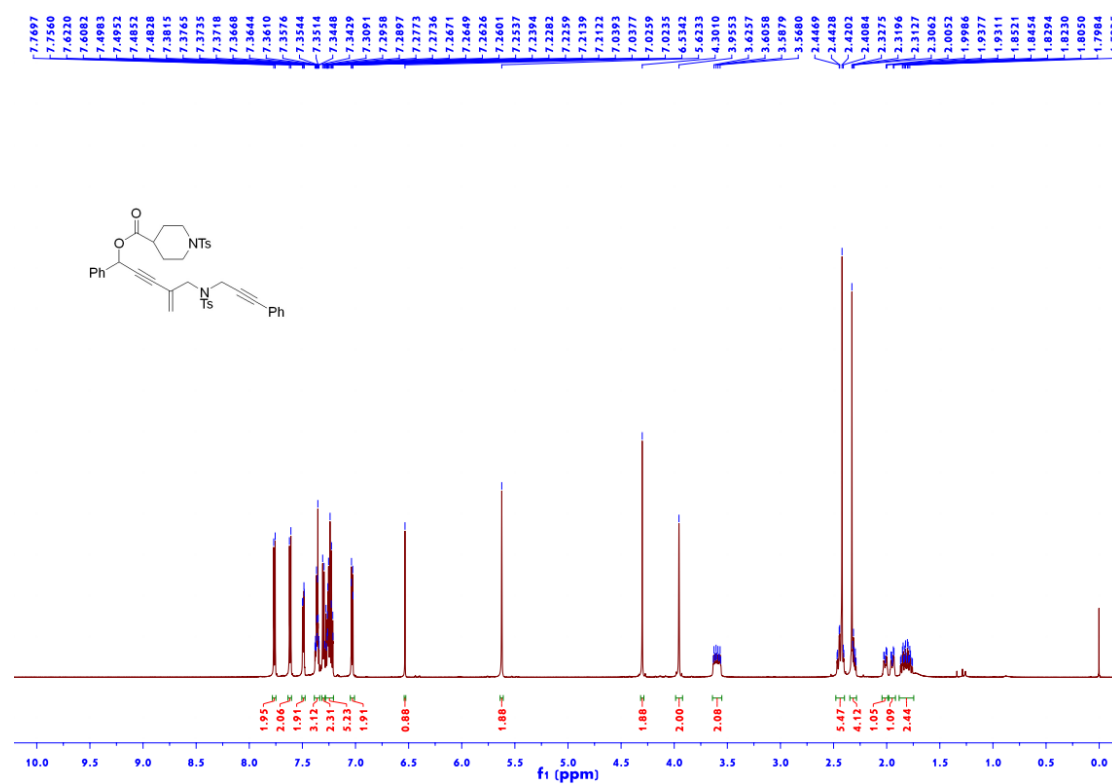


Figure S97 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 4m

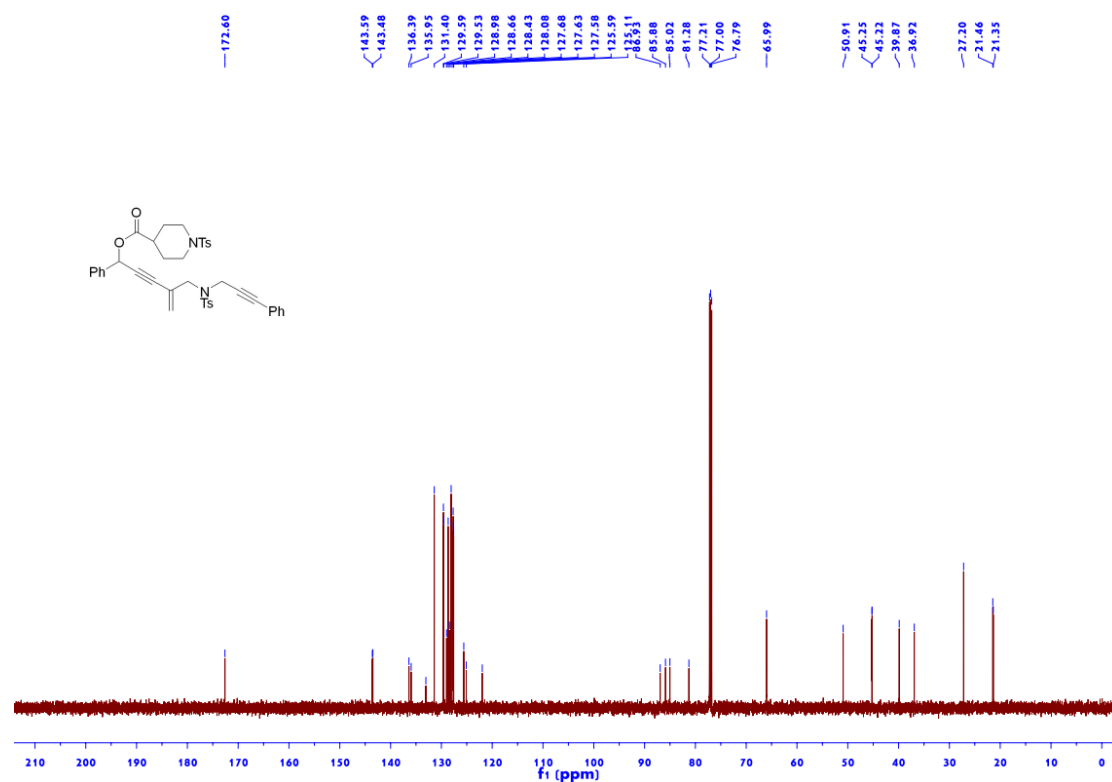


Figure S98 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 4n

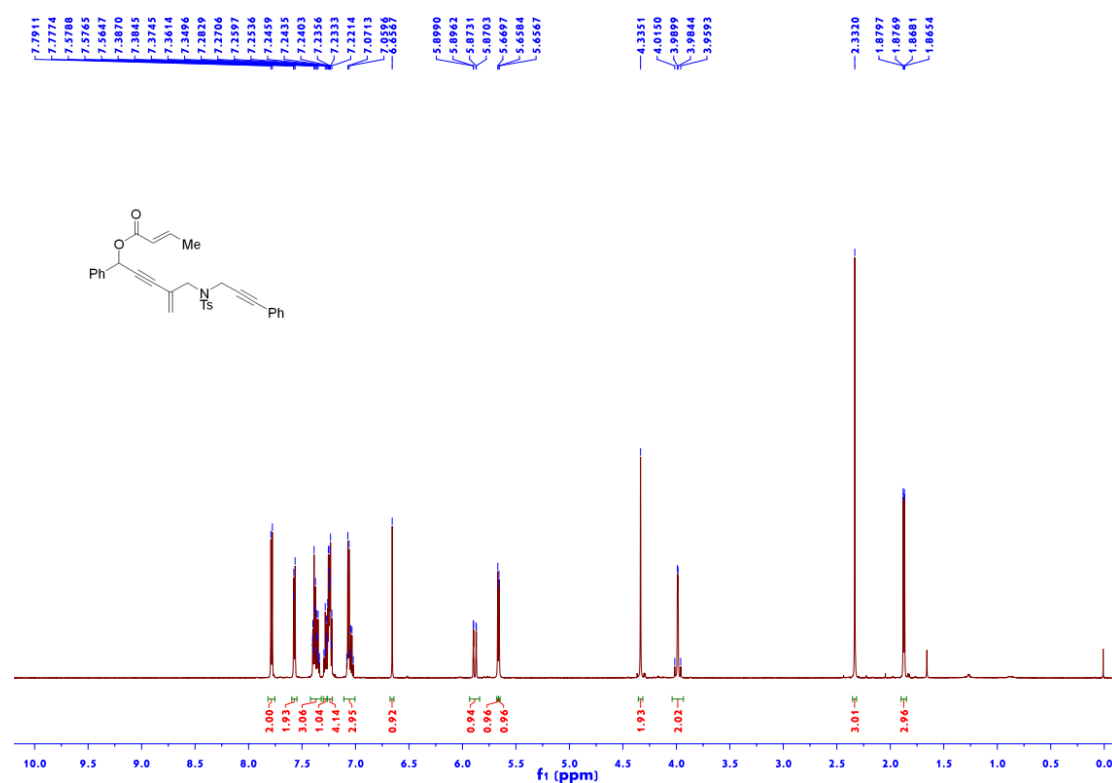




Figure S101  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 4o

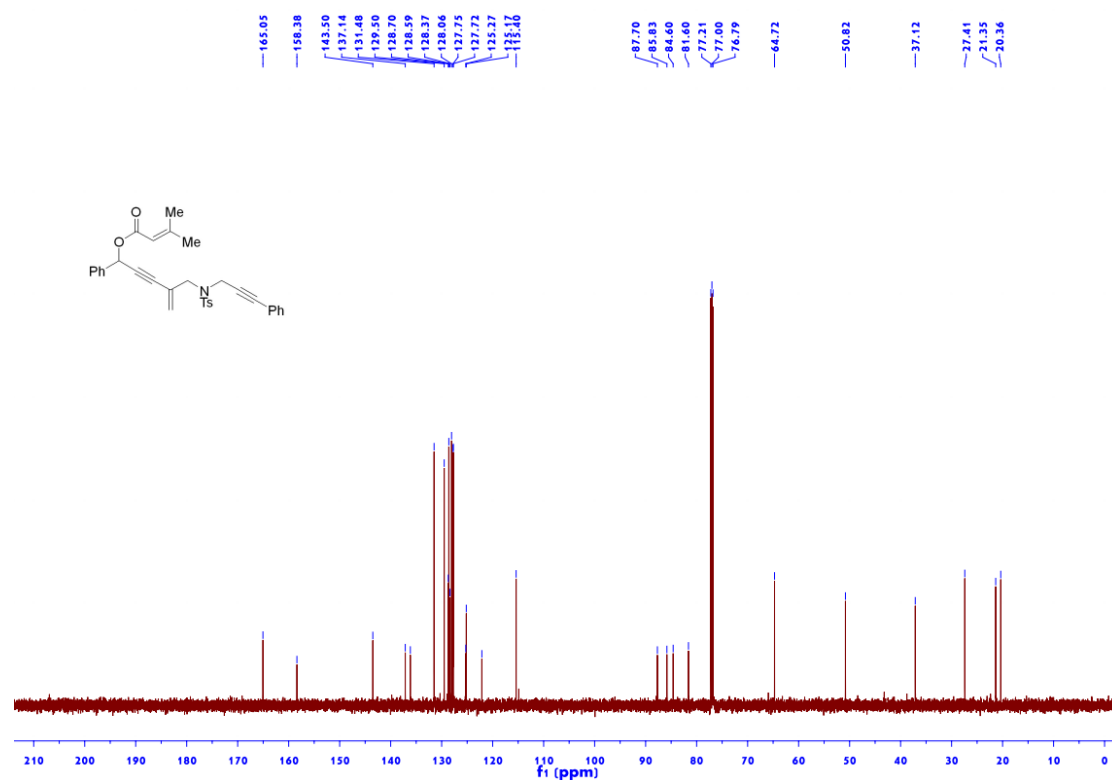


Figure S102  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 4p

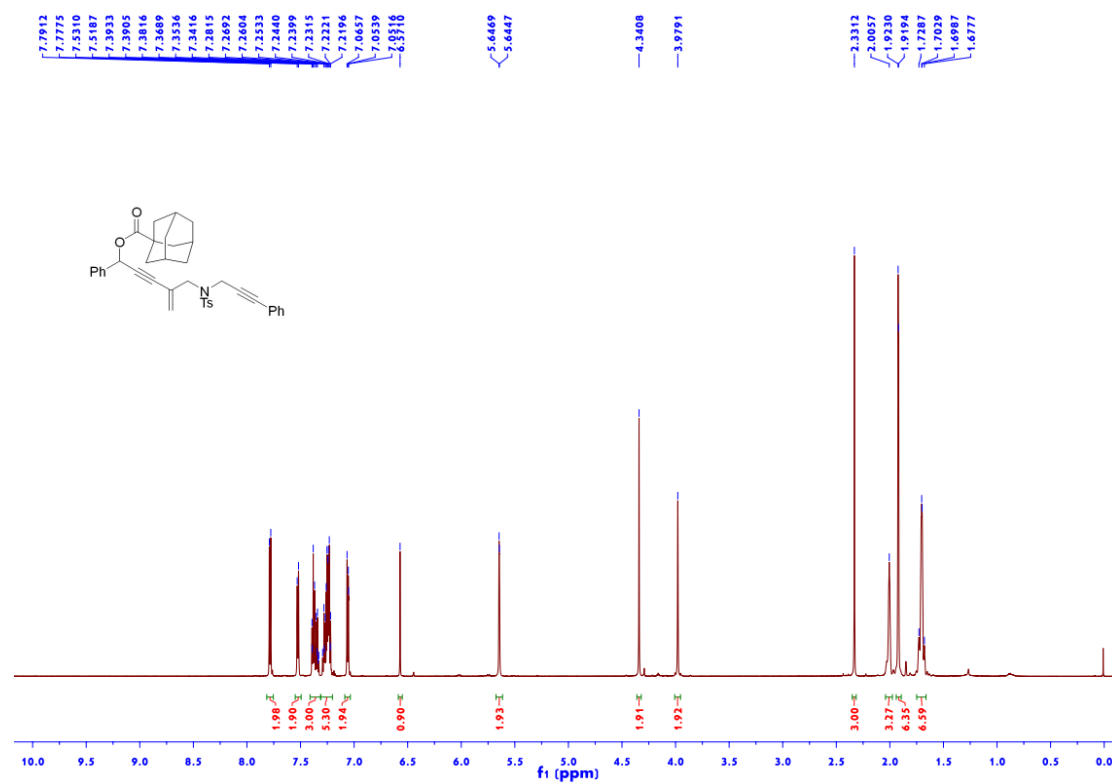


Figure S103  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 4p

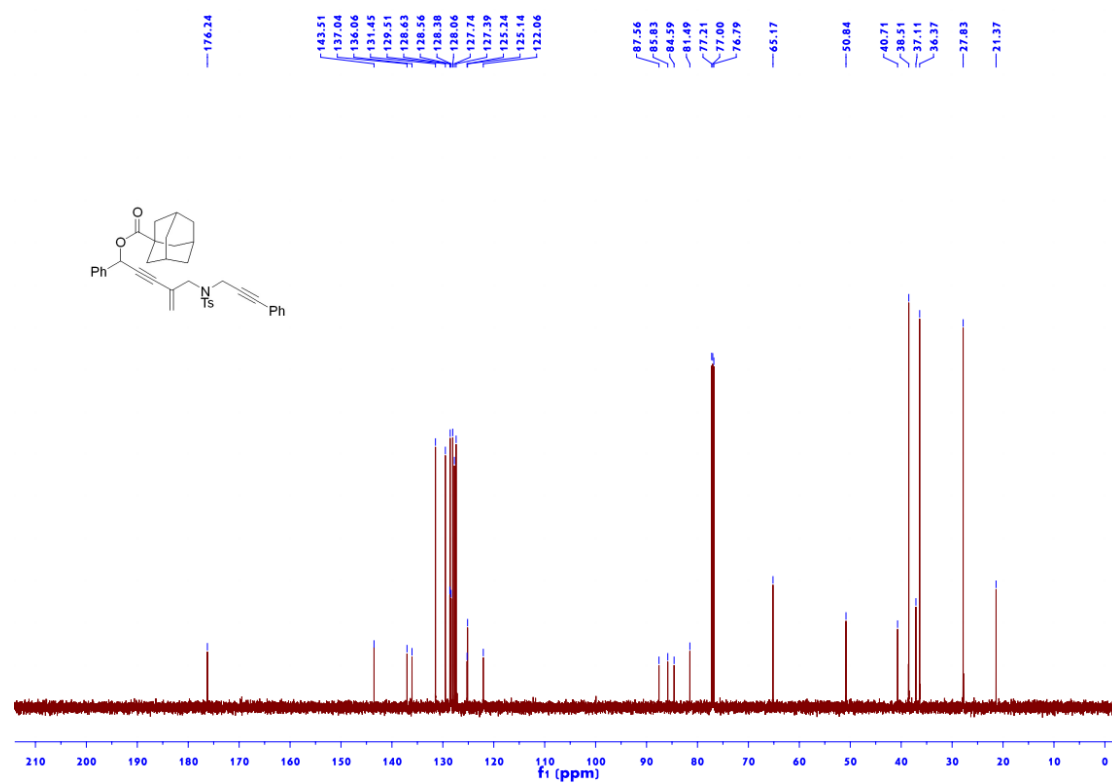


Figure S104  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 4q

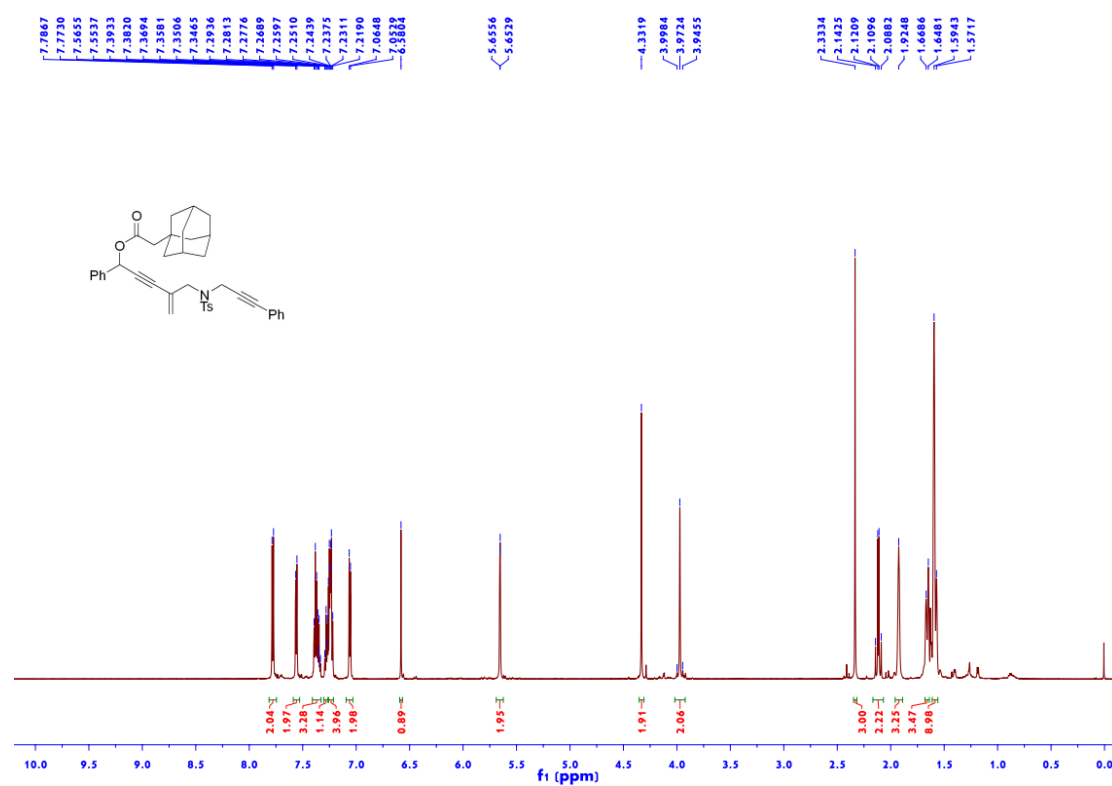




Figure S105  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 4q

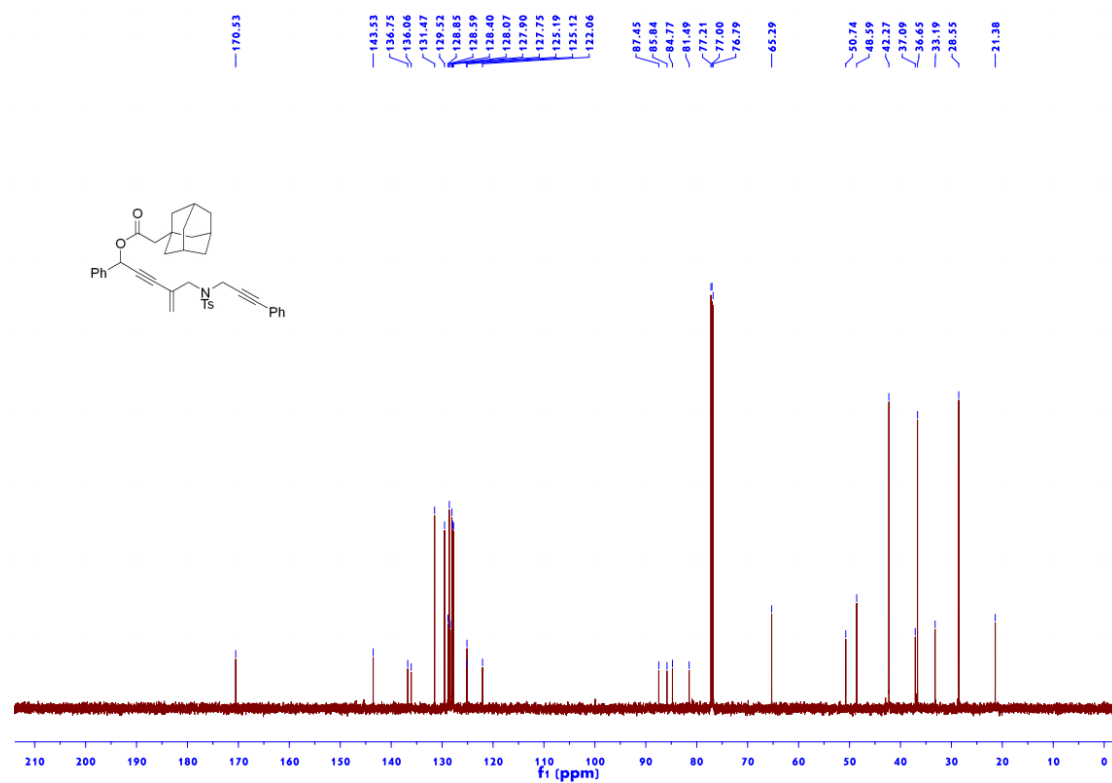


Figure S106  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 4r

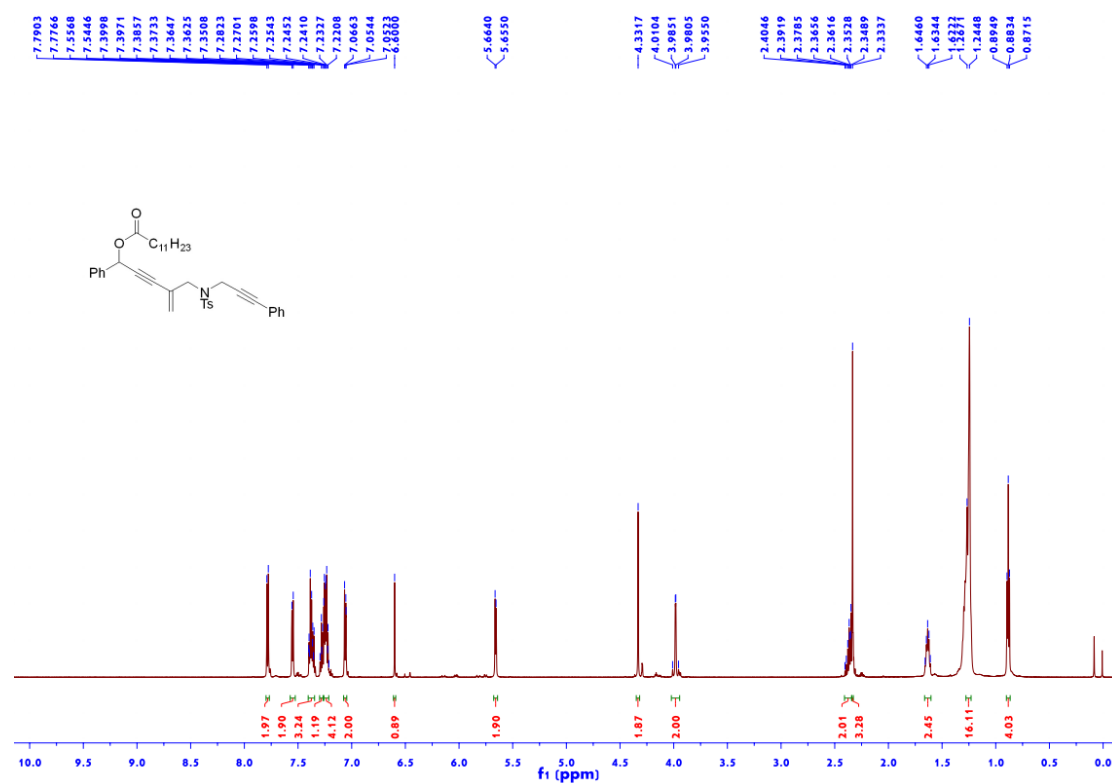


Figure S107 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 4r

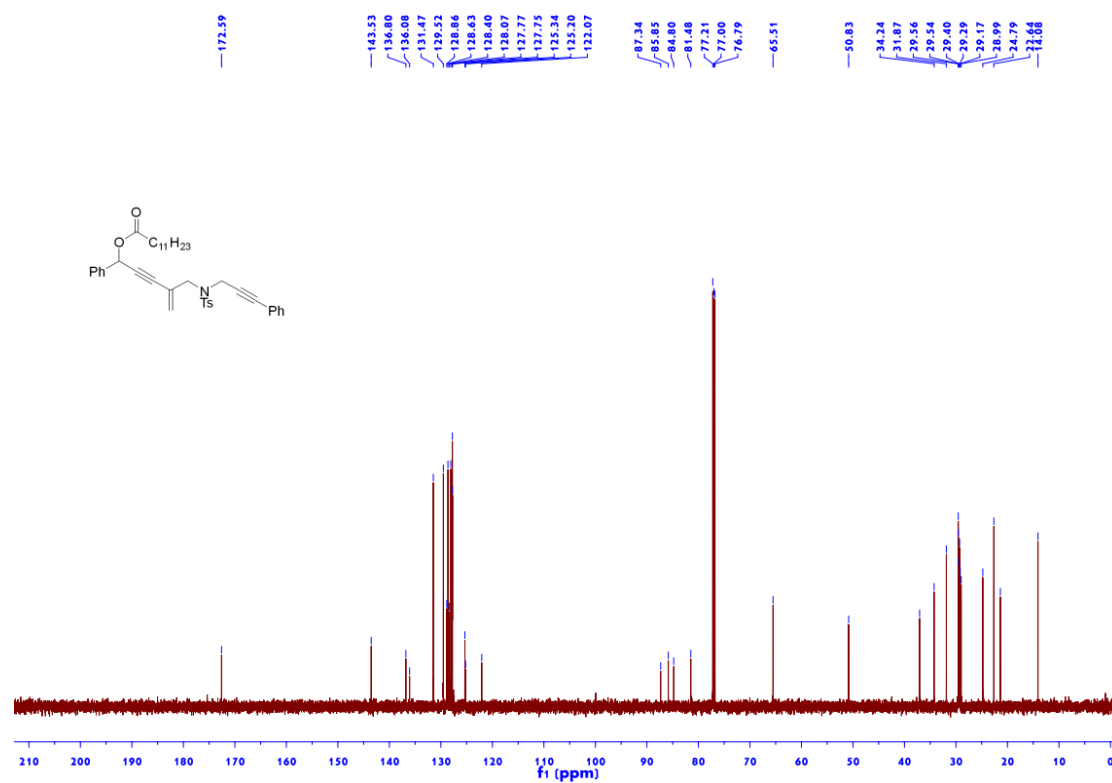


Figure S108 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 4s

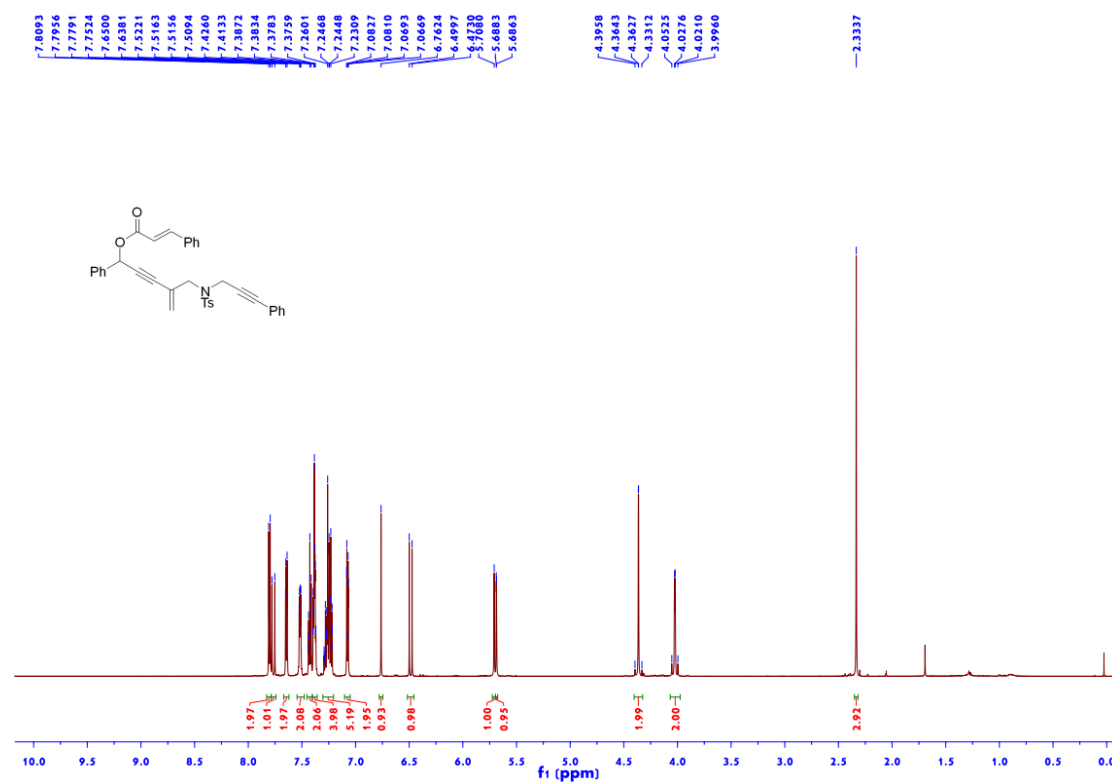


Figure S109  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 4s

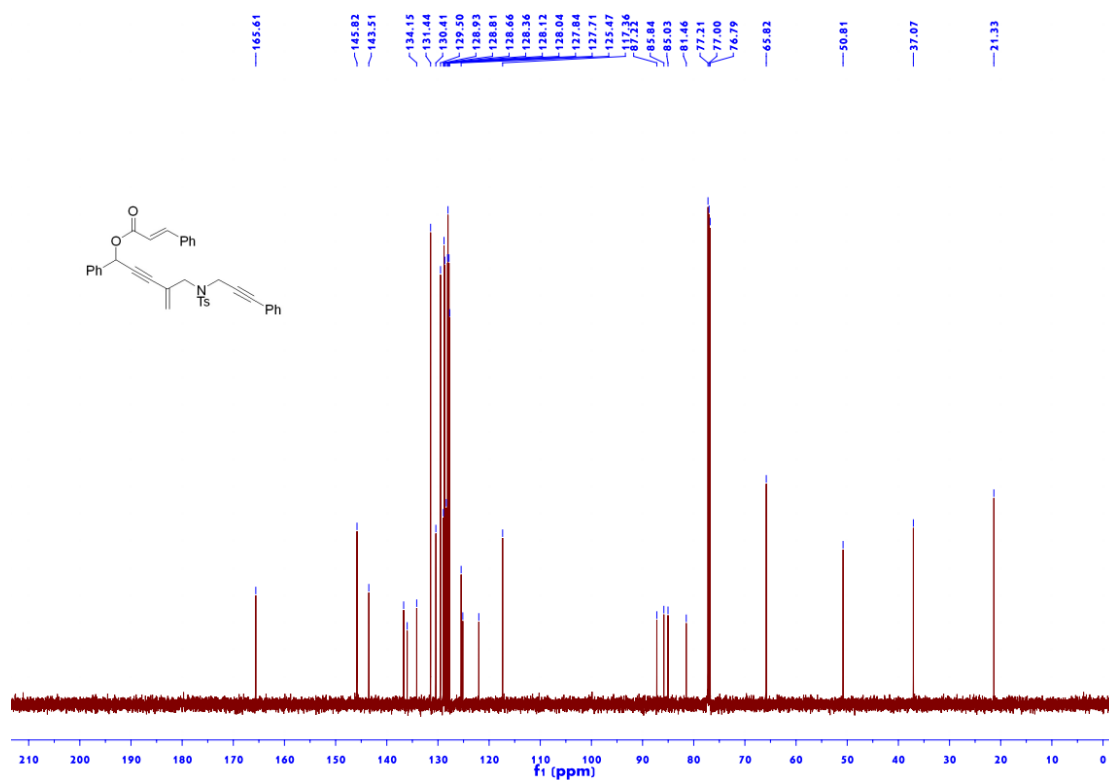


Figure S110  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 4t

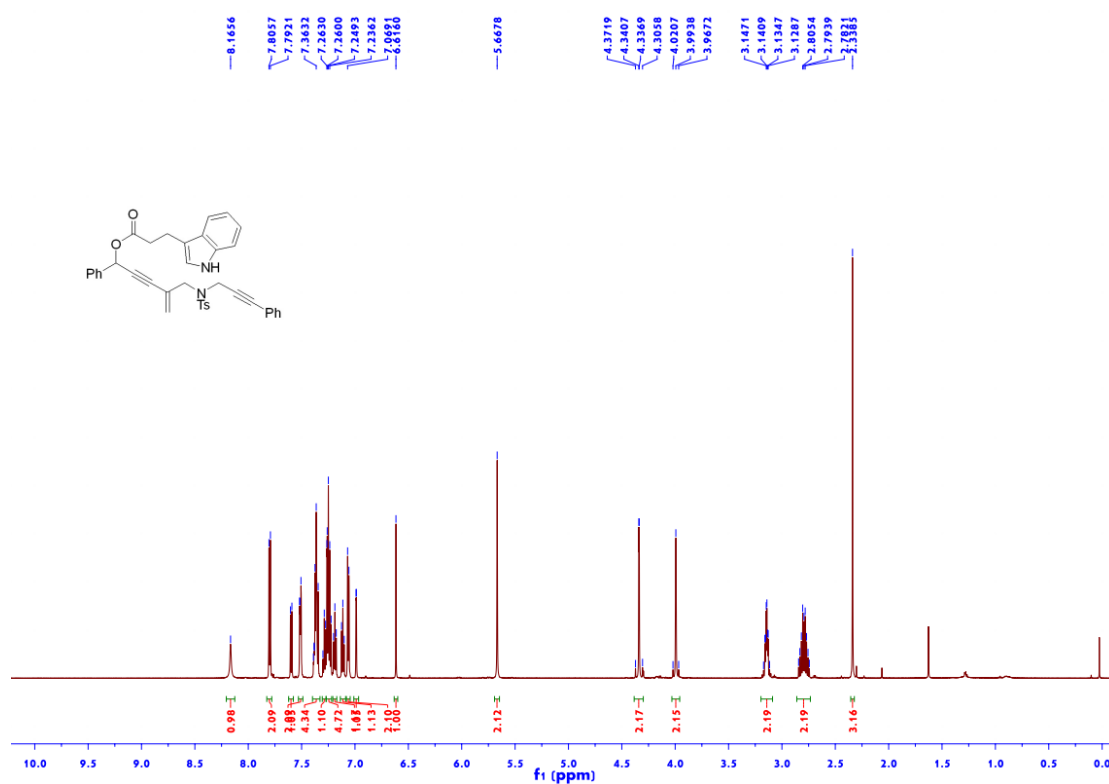


Figure S111  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 4t

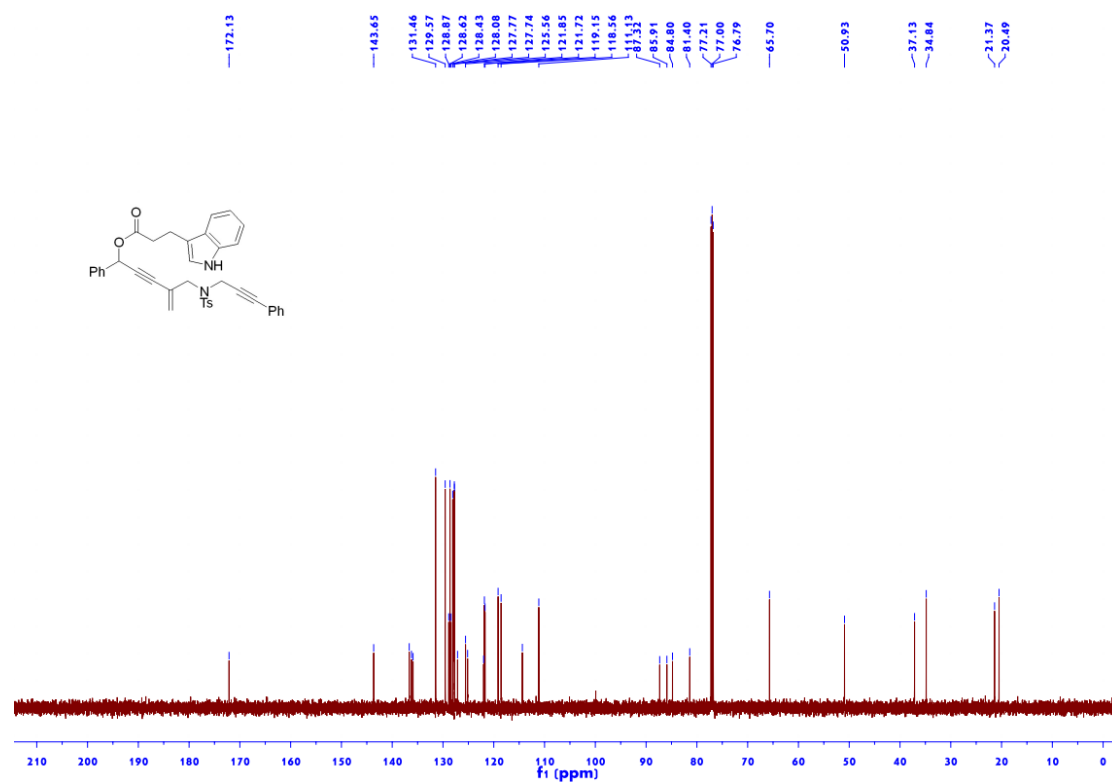


Figure S112  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 4u

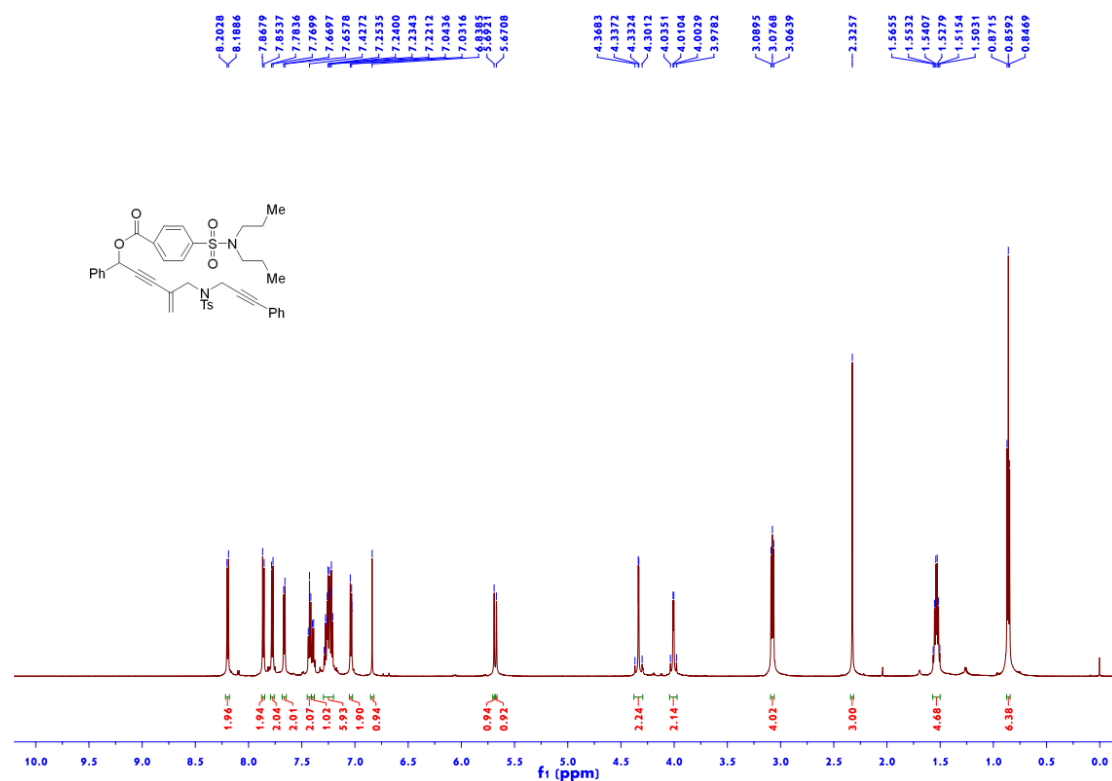


Figure S113 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 4u

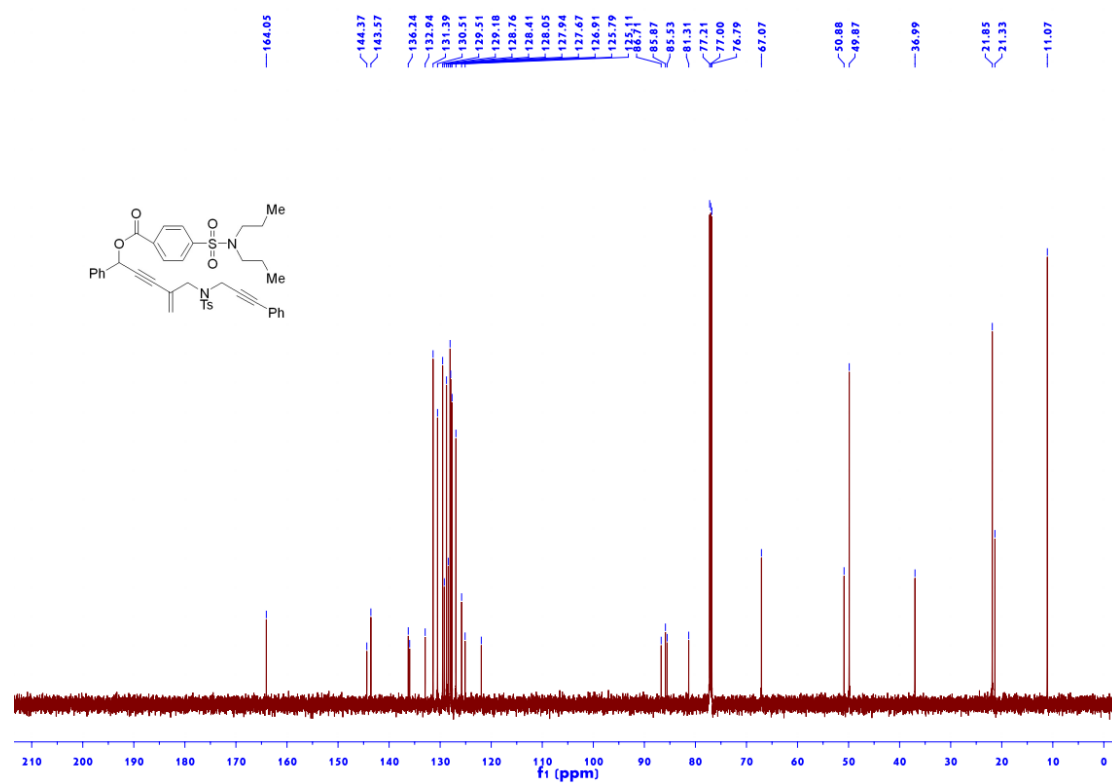


Figure S114 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 4v

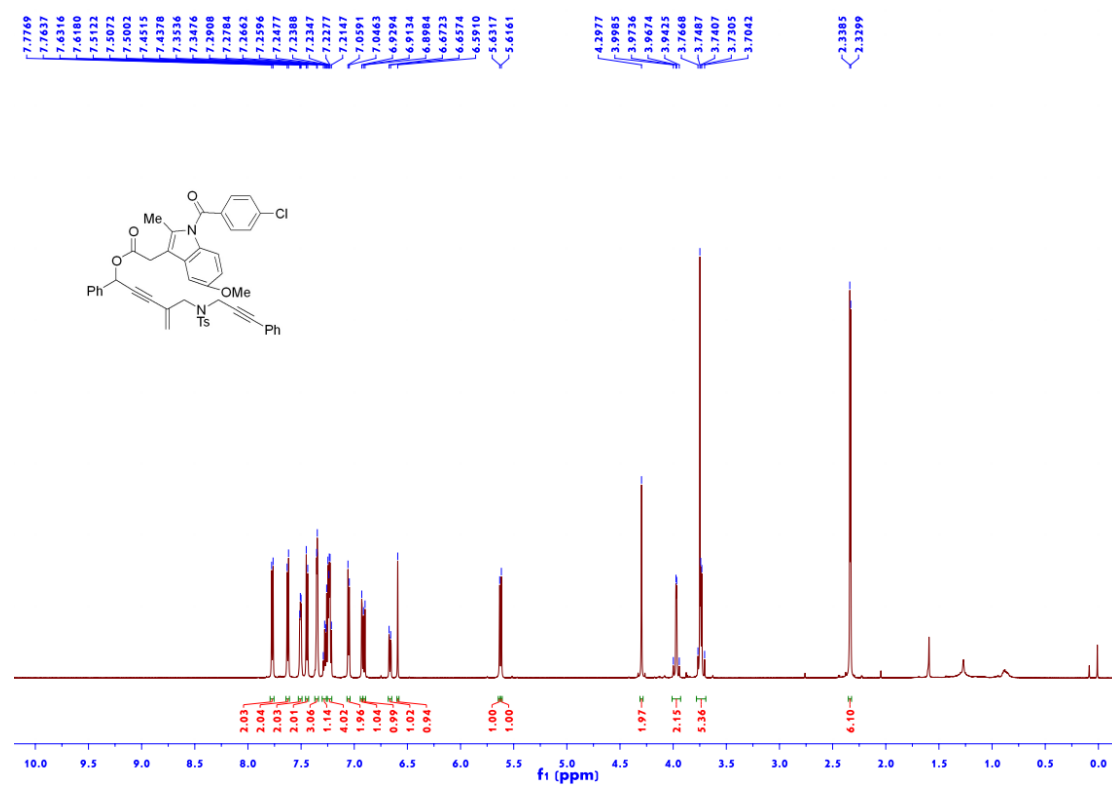


Figure S115  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 4v

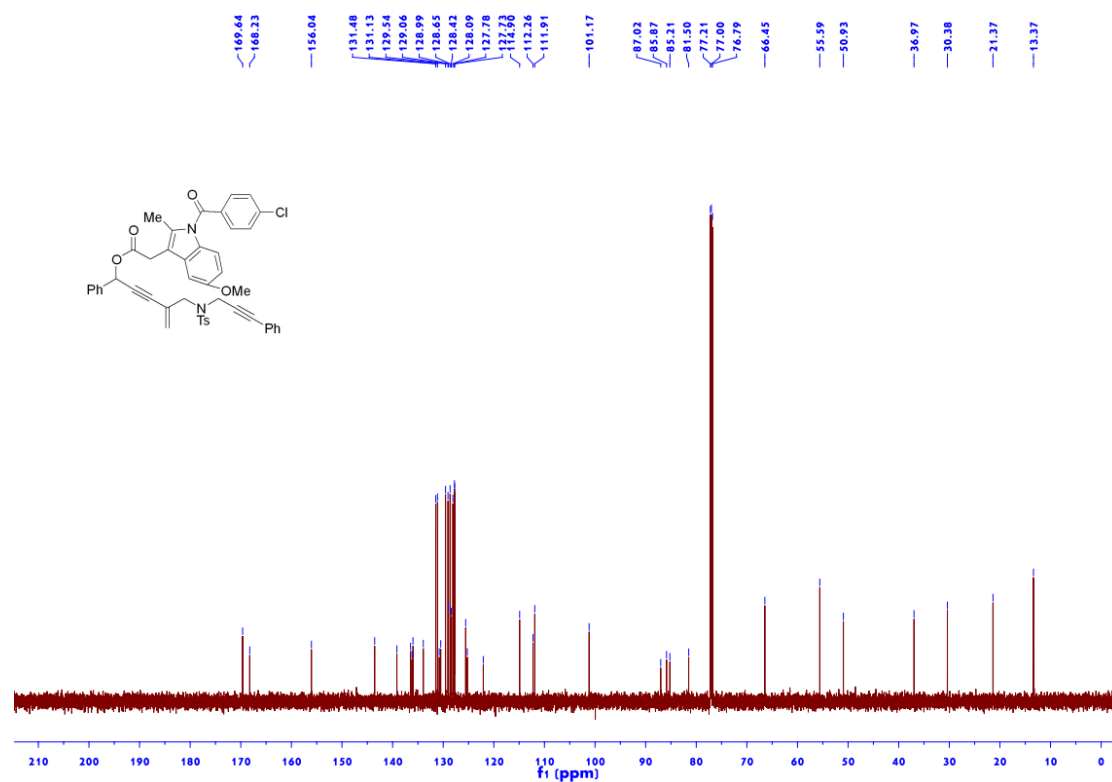


Figure S116  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 4w

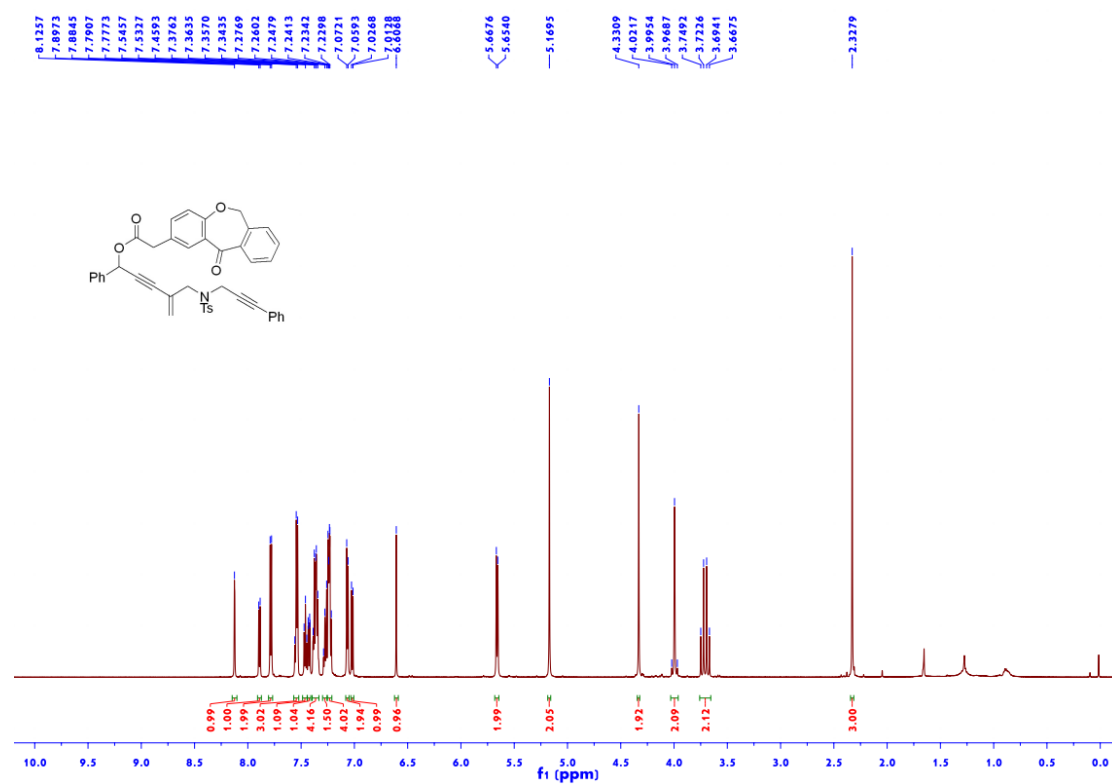


Figure S117  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 4w

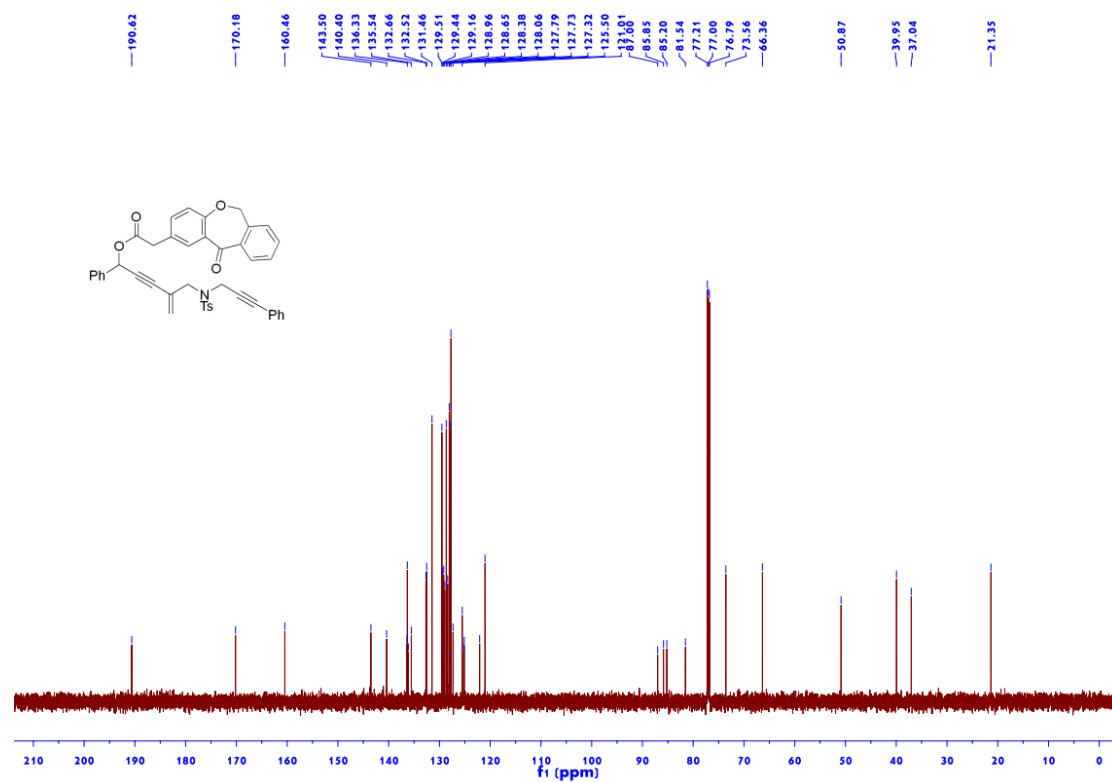


Figure S118  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) of 6a

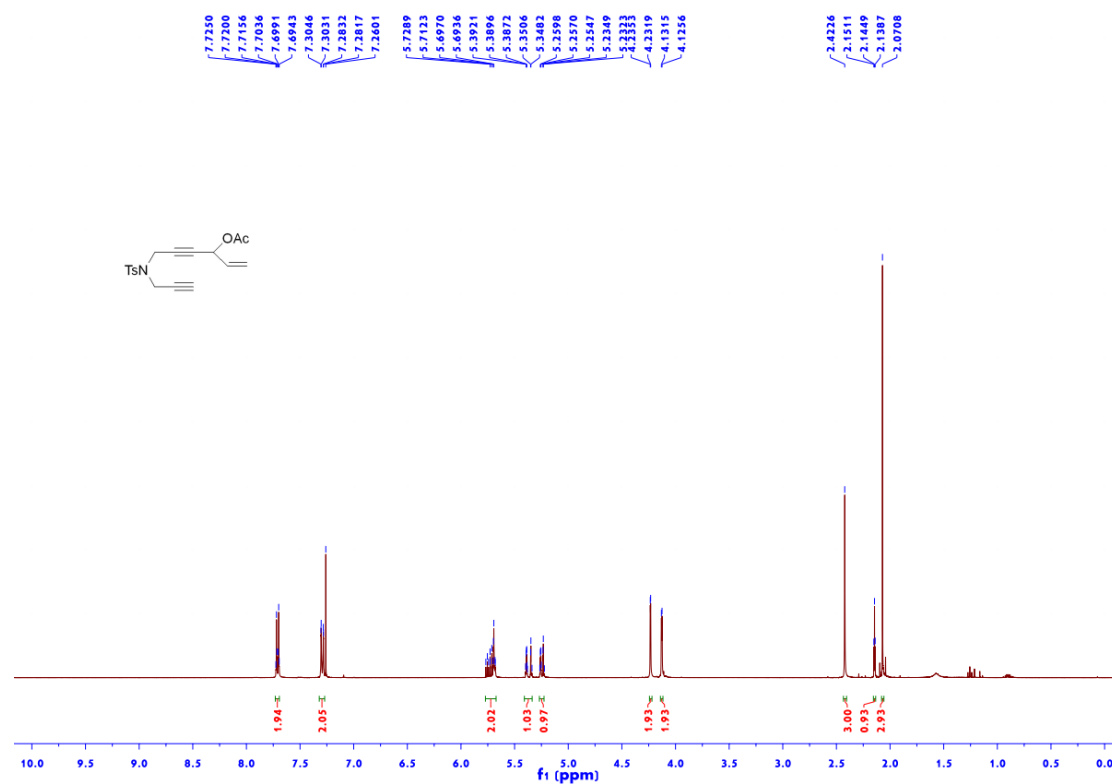






Figure S121 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 6b

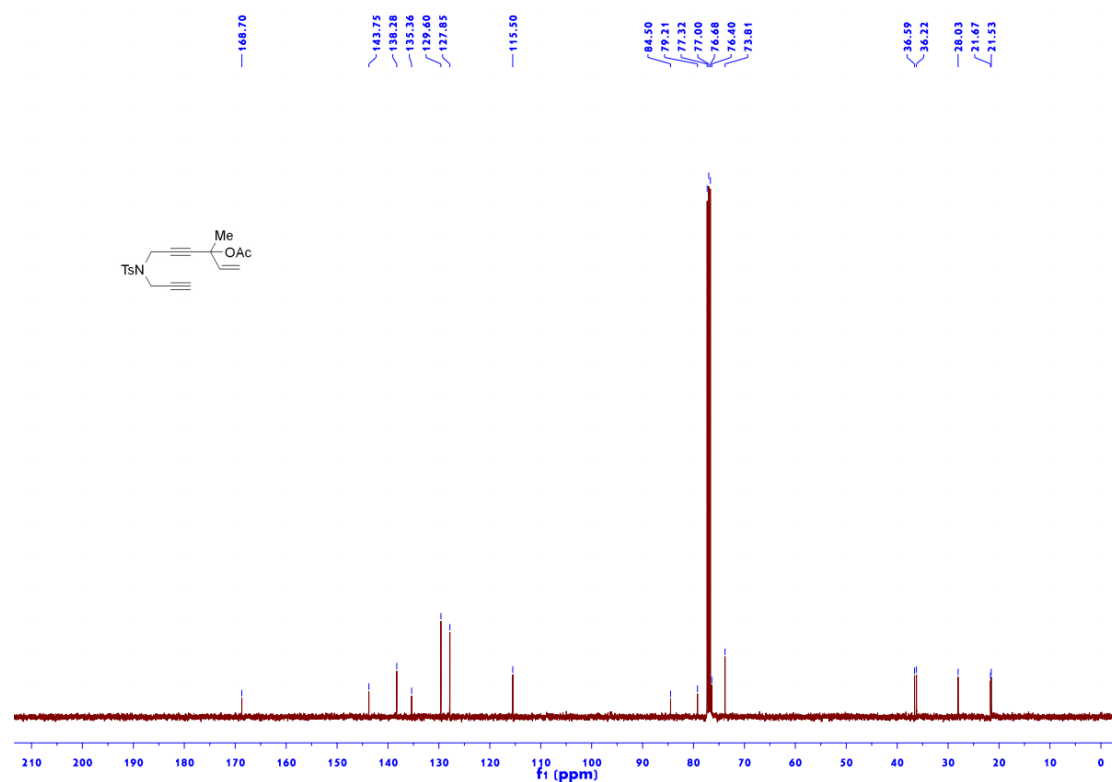


Figure S122 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 6c

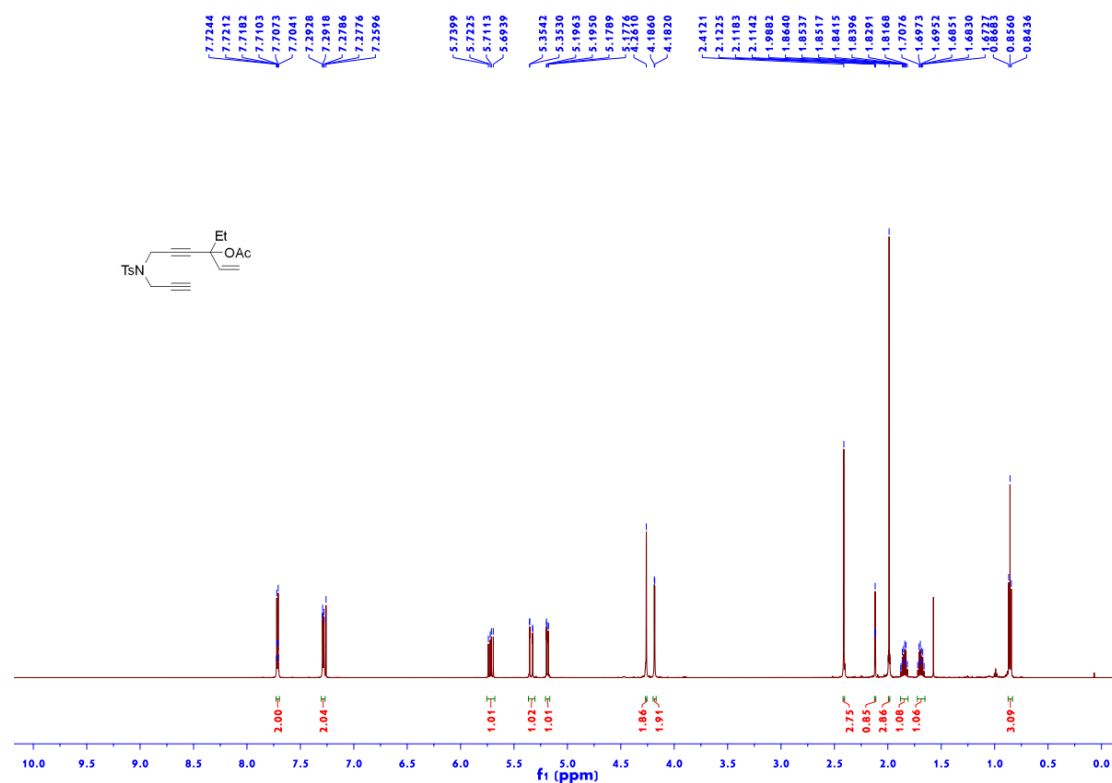


Figure S123 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 6c

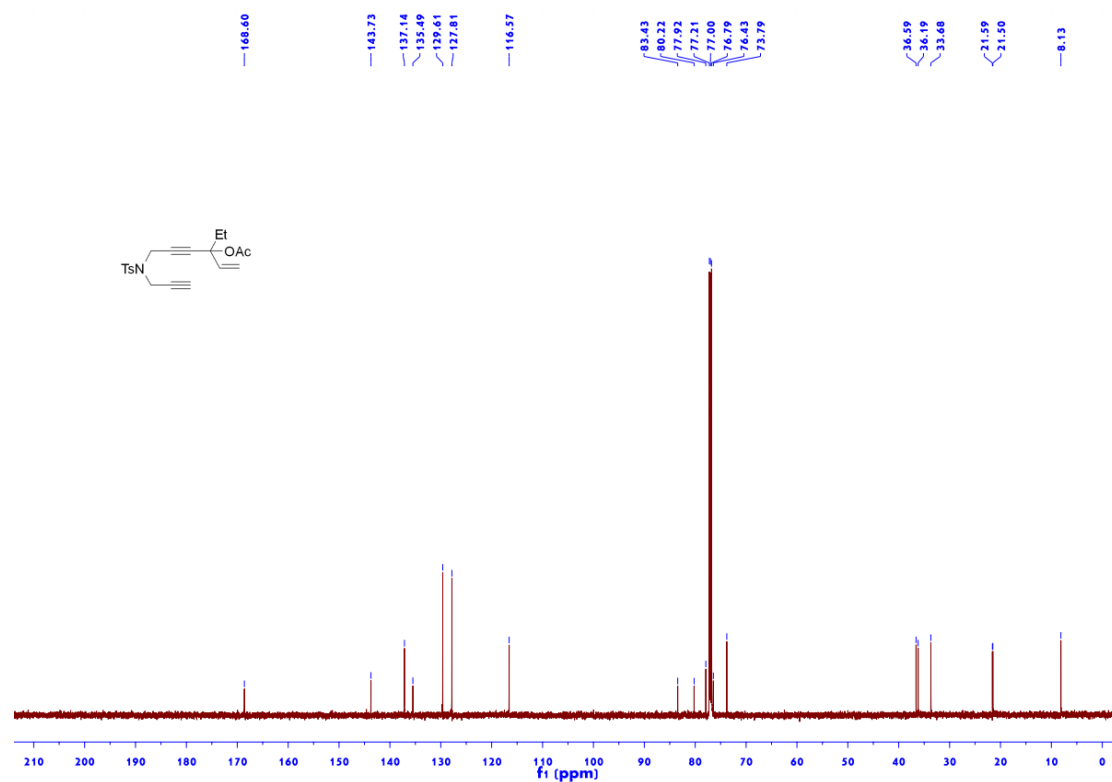


Figure S124 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 6d

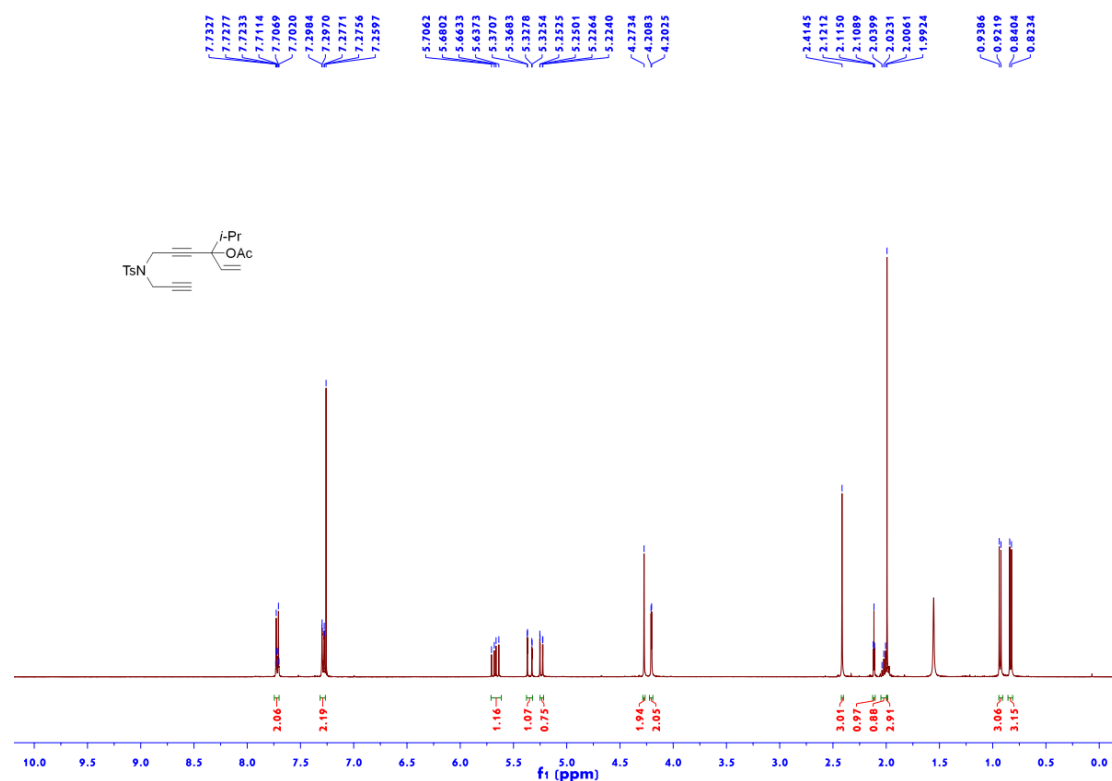




















Figure S141 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 6l

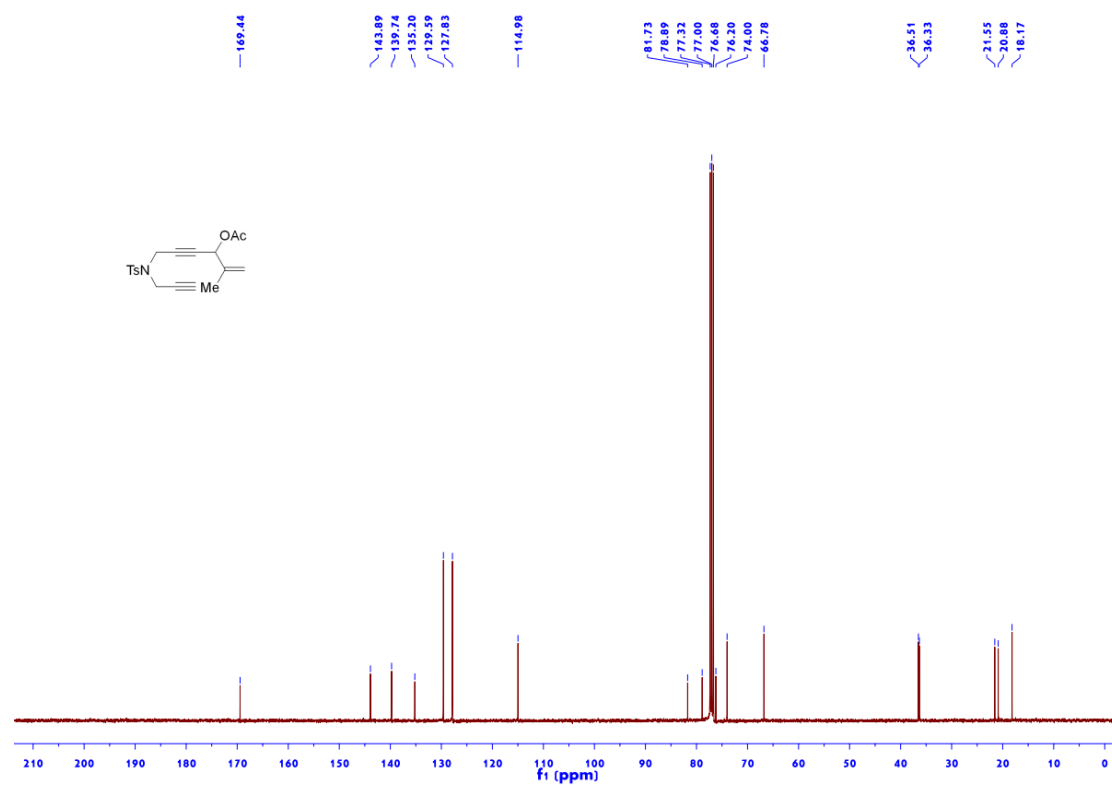


Figure S142 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 6m

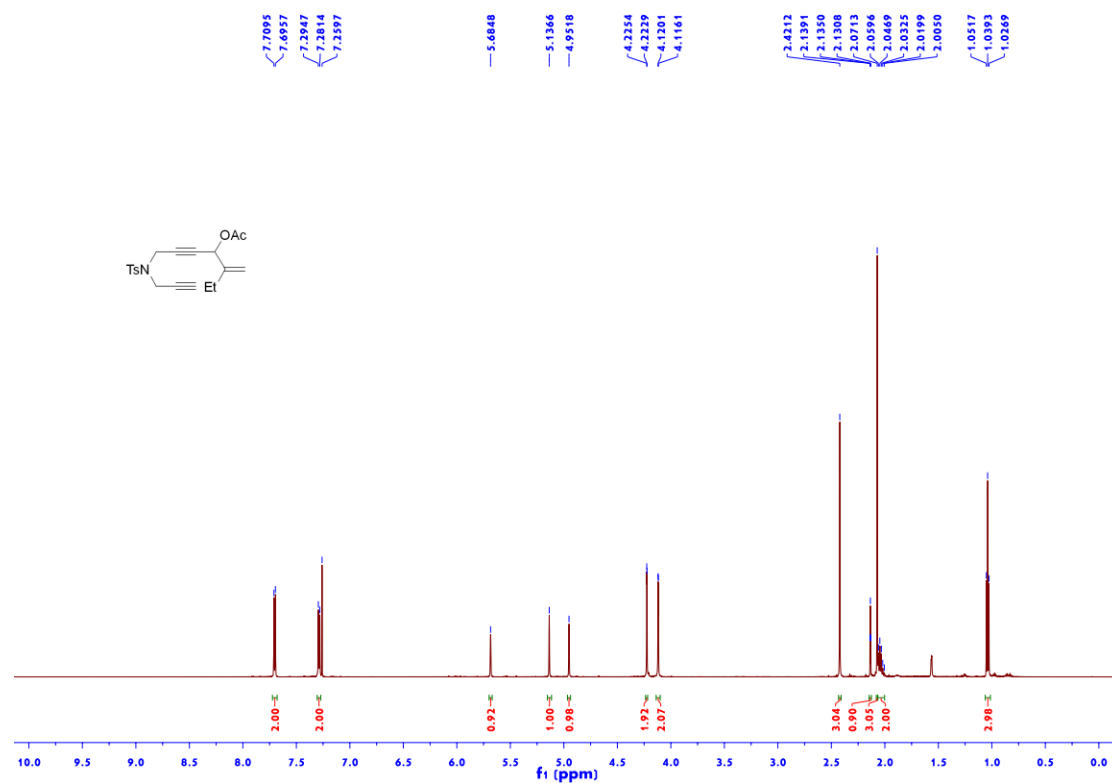


Figure S143 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 6m

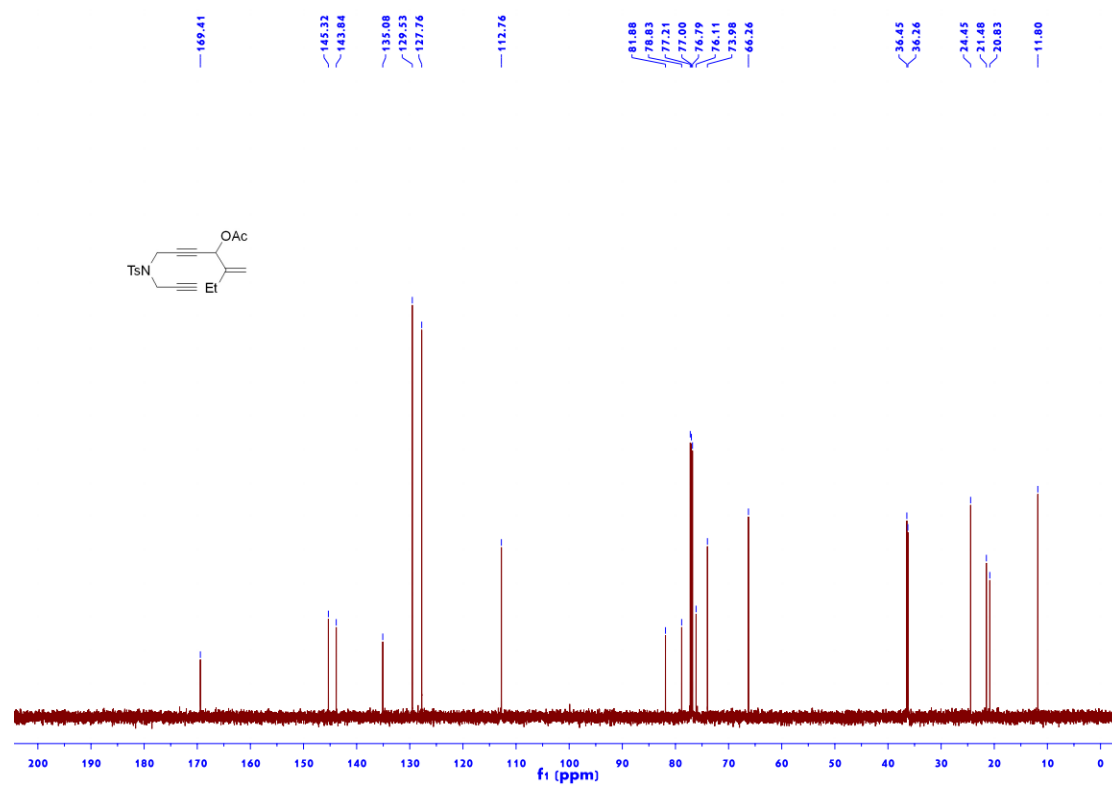


Figure S144 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 6n

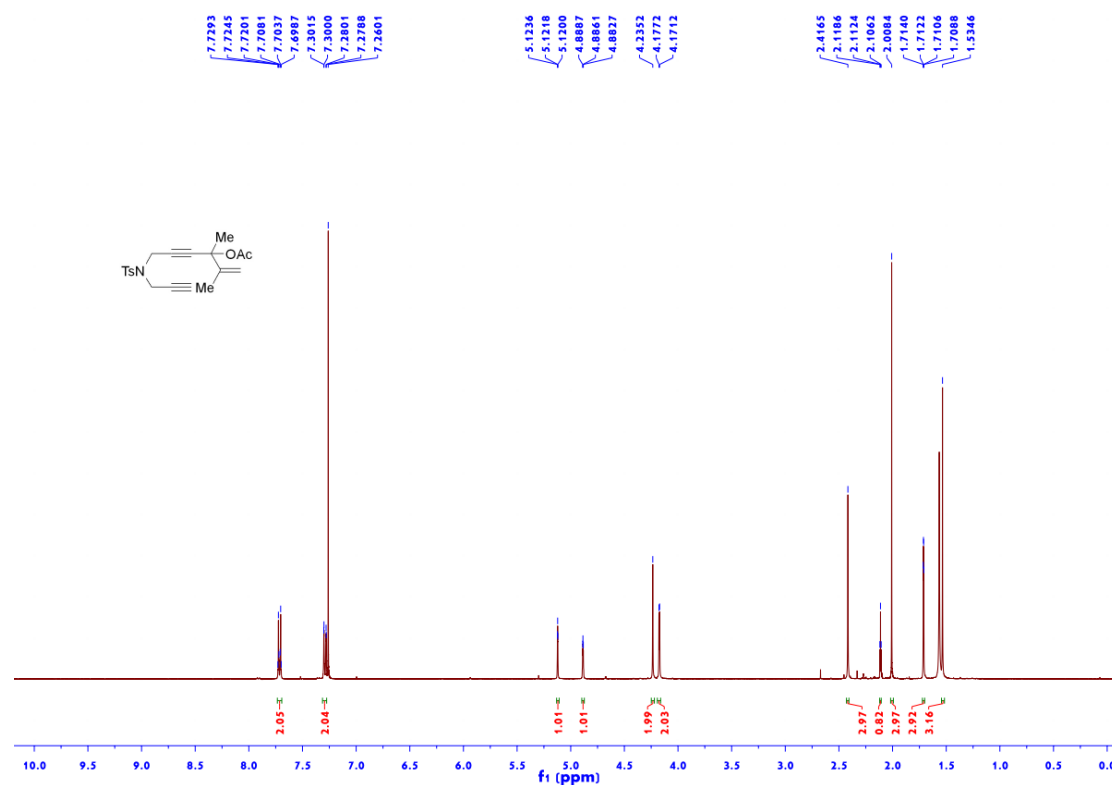








Figure S151  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ) of 6q

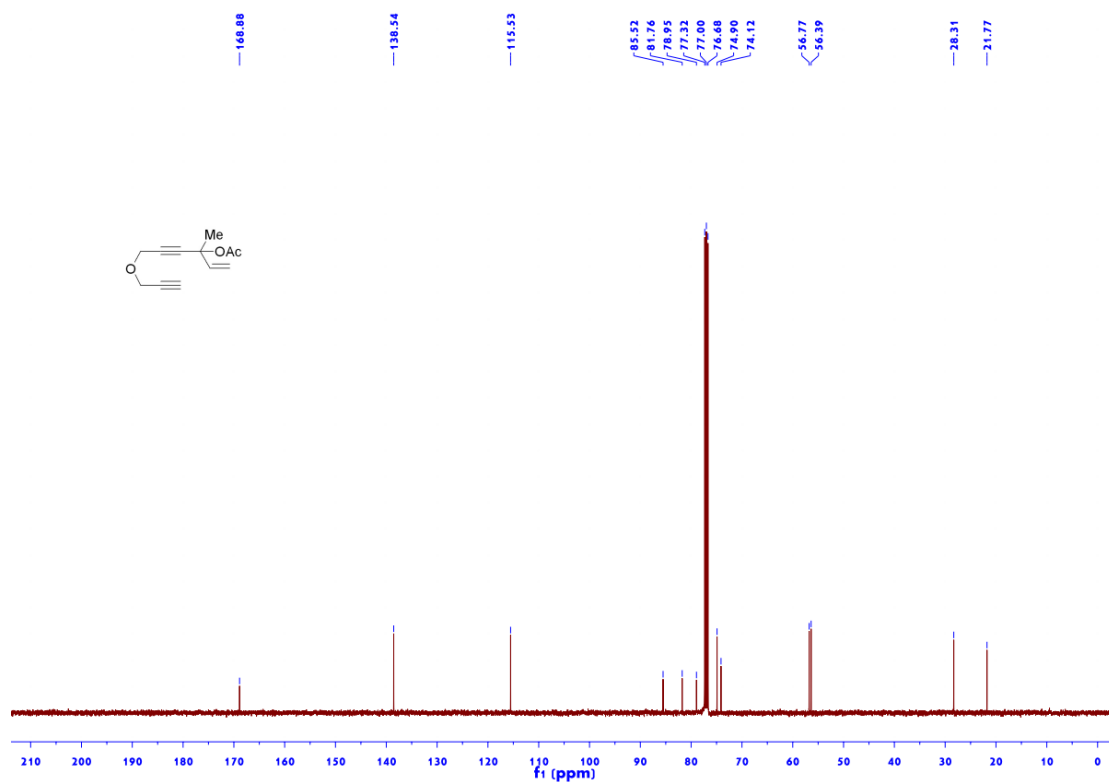


Figure S152  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) of 6r

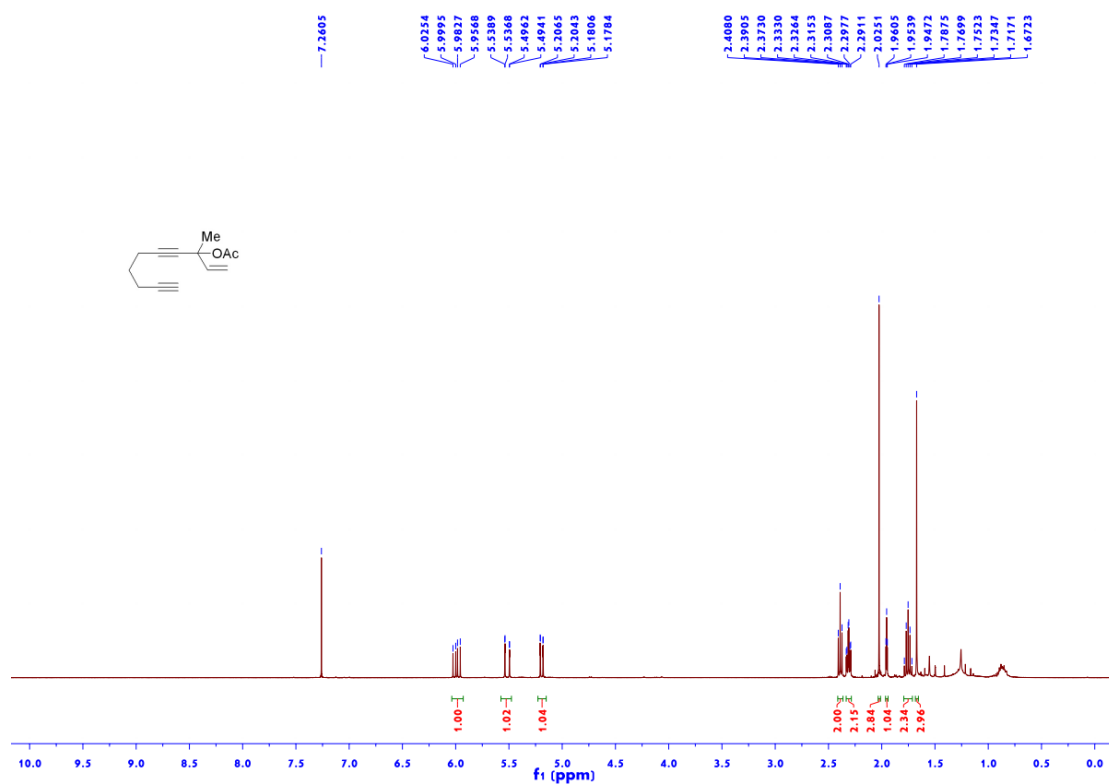




Figure S153 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 6r

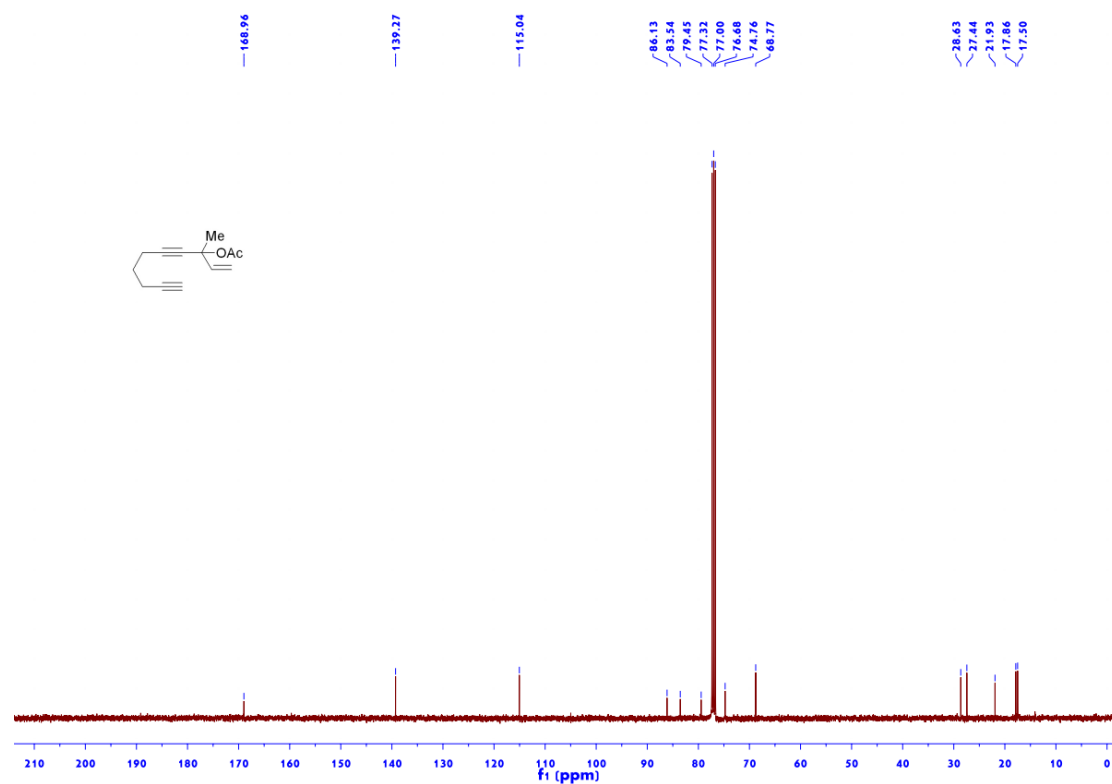


Figure S154 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 6s

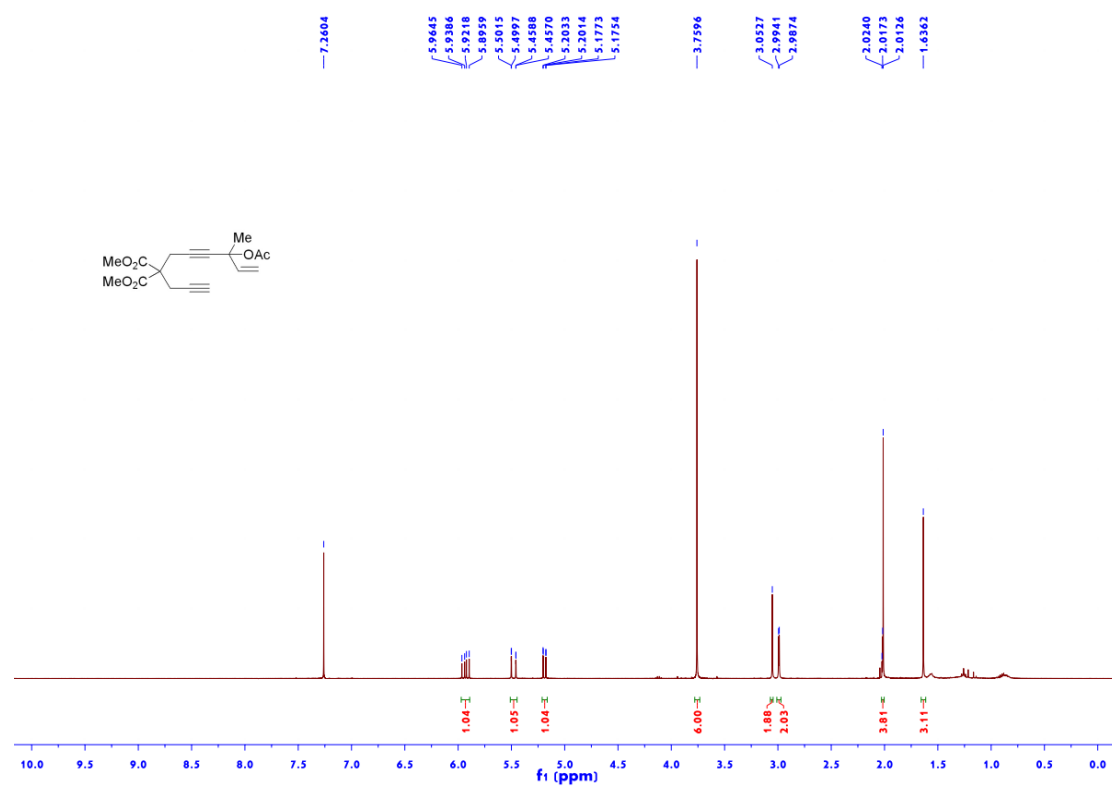


Figure S155  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ) of 6s

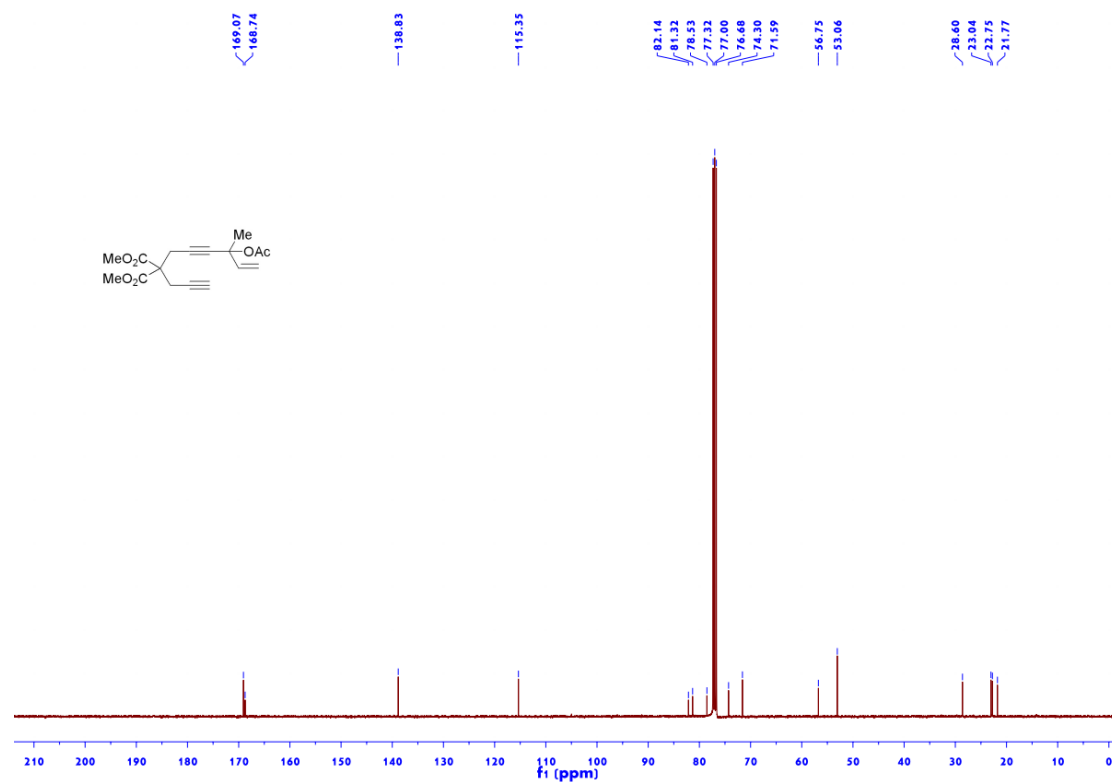


Figure S156  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) of 8a

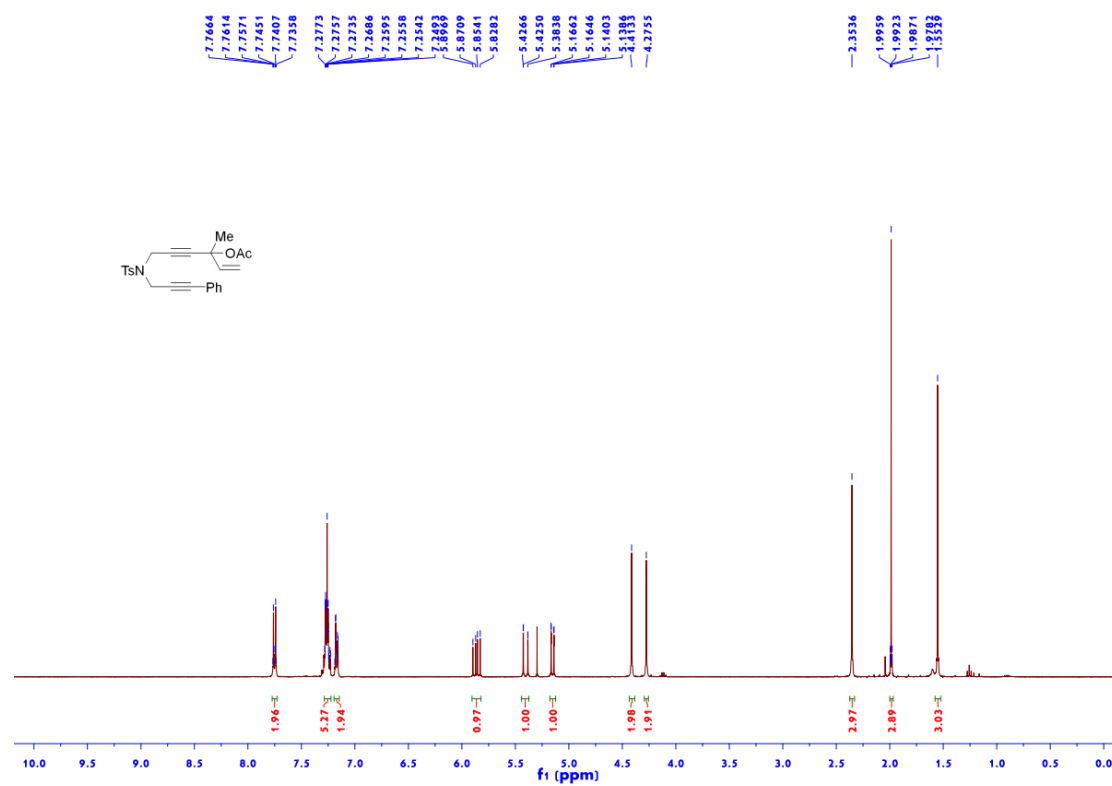


Figure S157  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ) of 8a

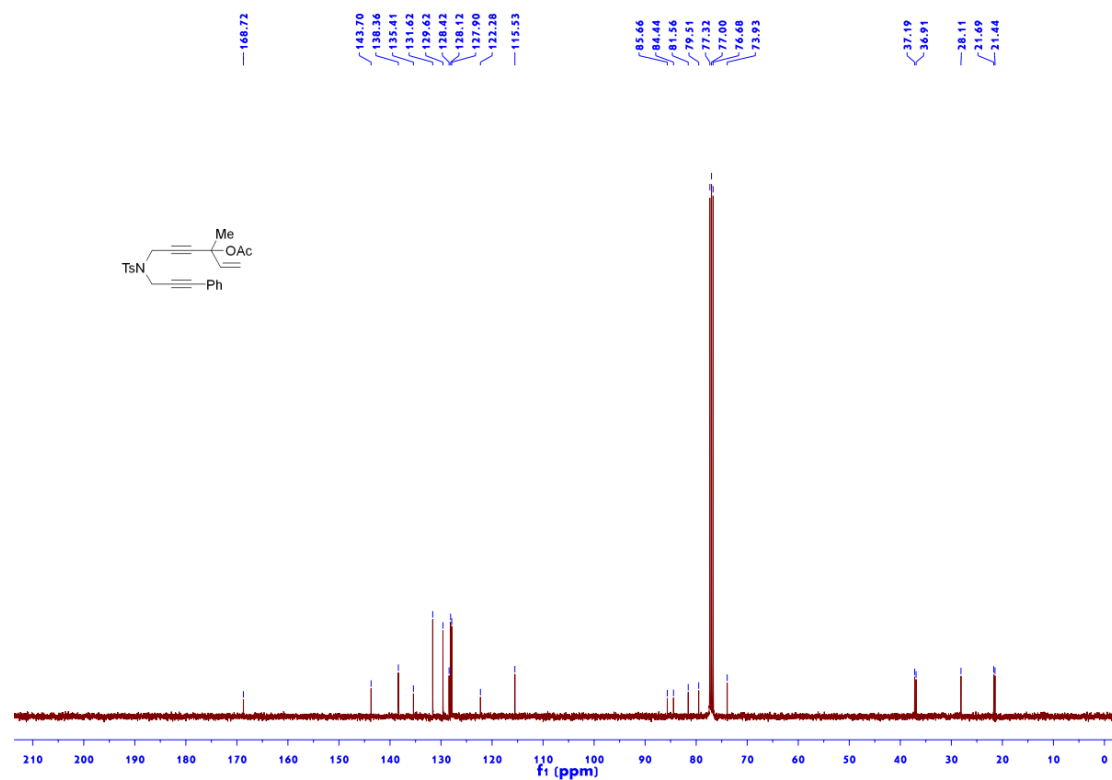


Figure S158  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) of 8b

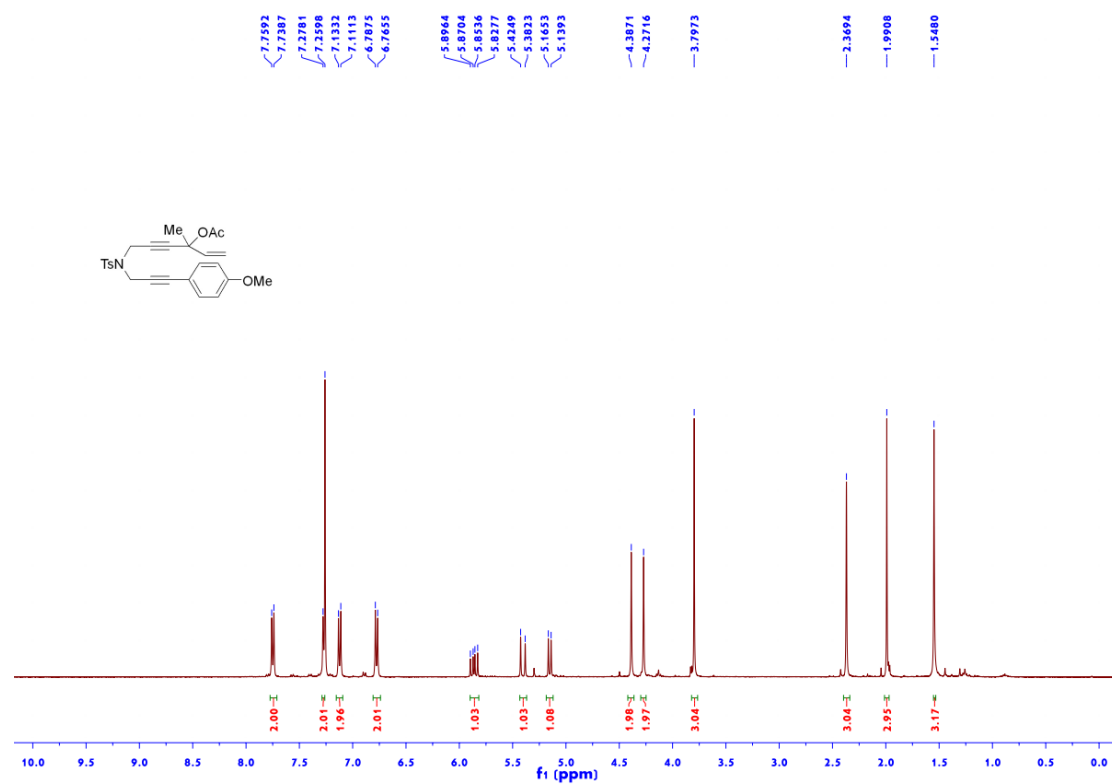




Figure S161 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 8c

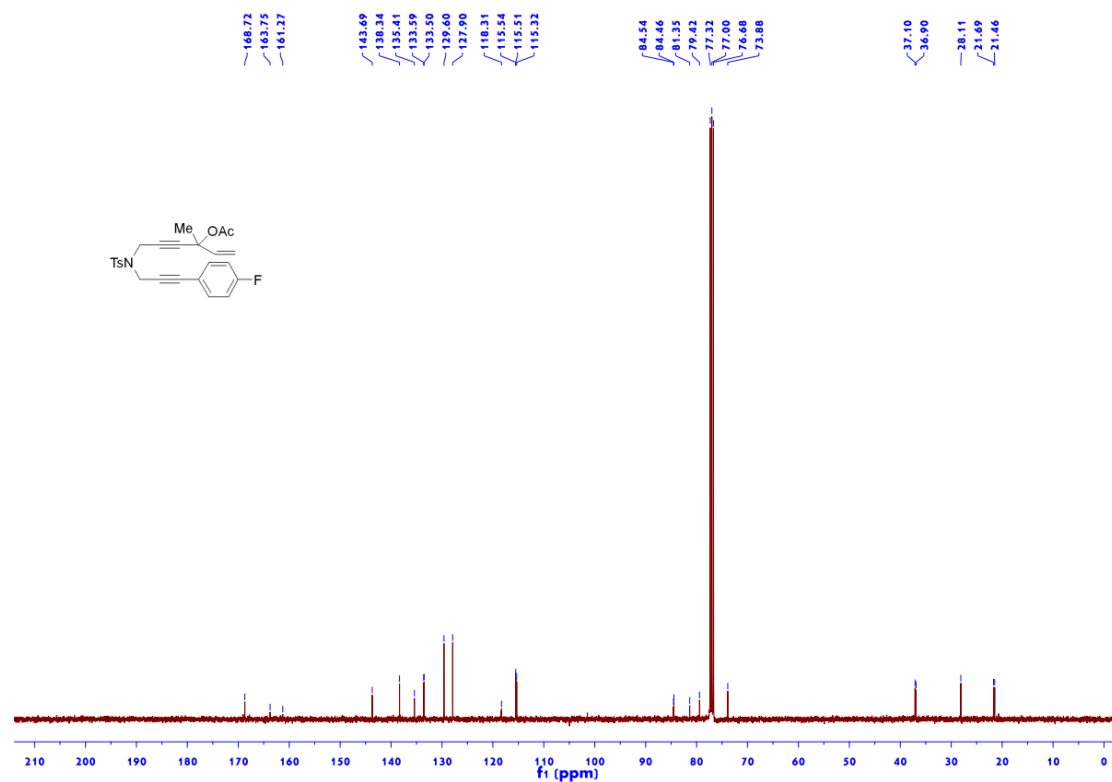


Figure S162 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 8d

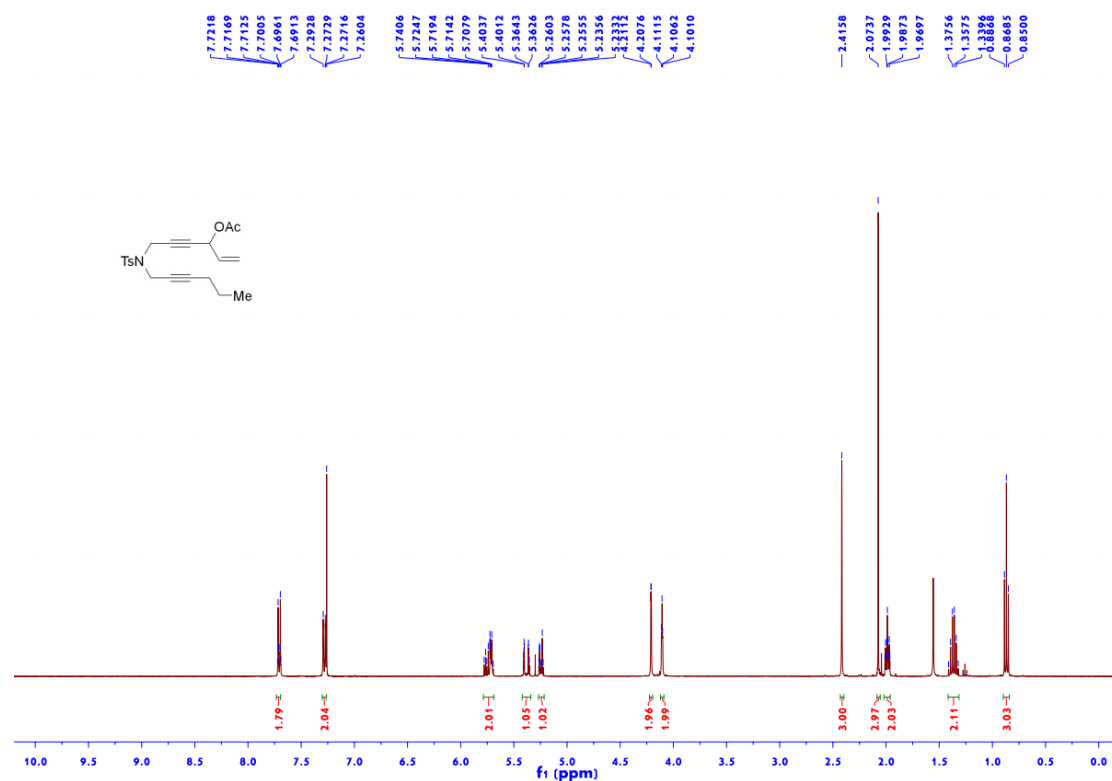


Figure S163 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 8d

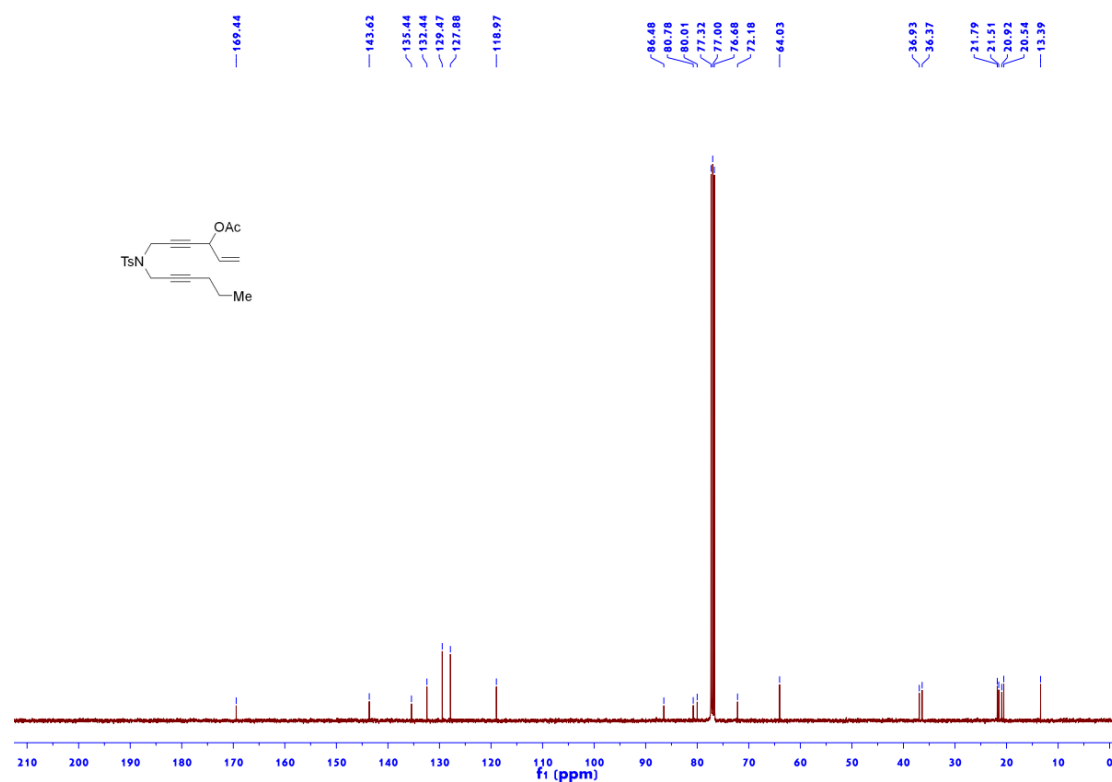


Figure S164 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 8e

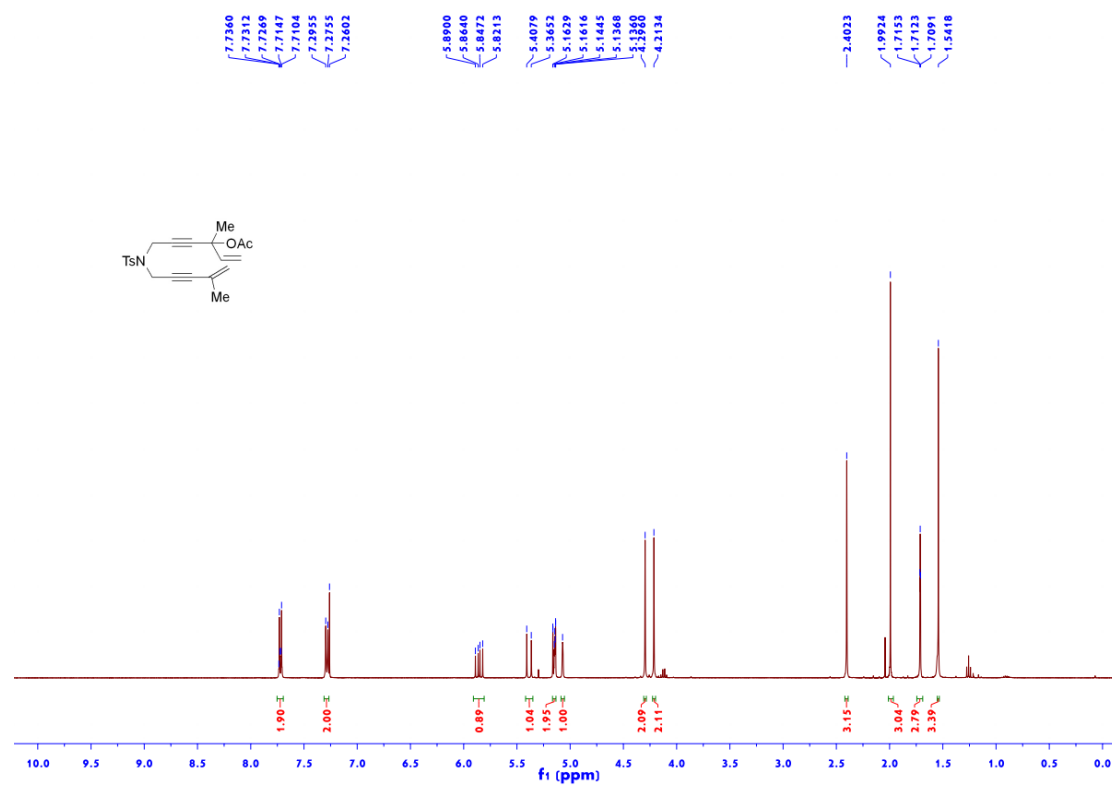


Figure S165  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ) of 8e

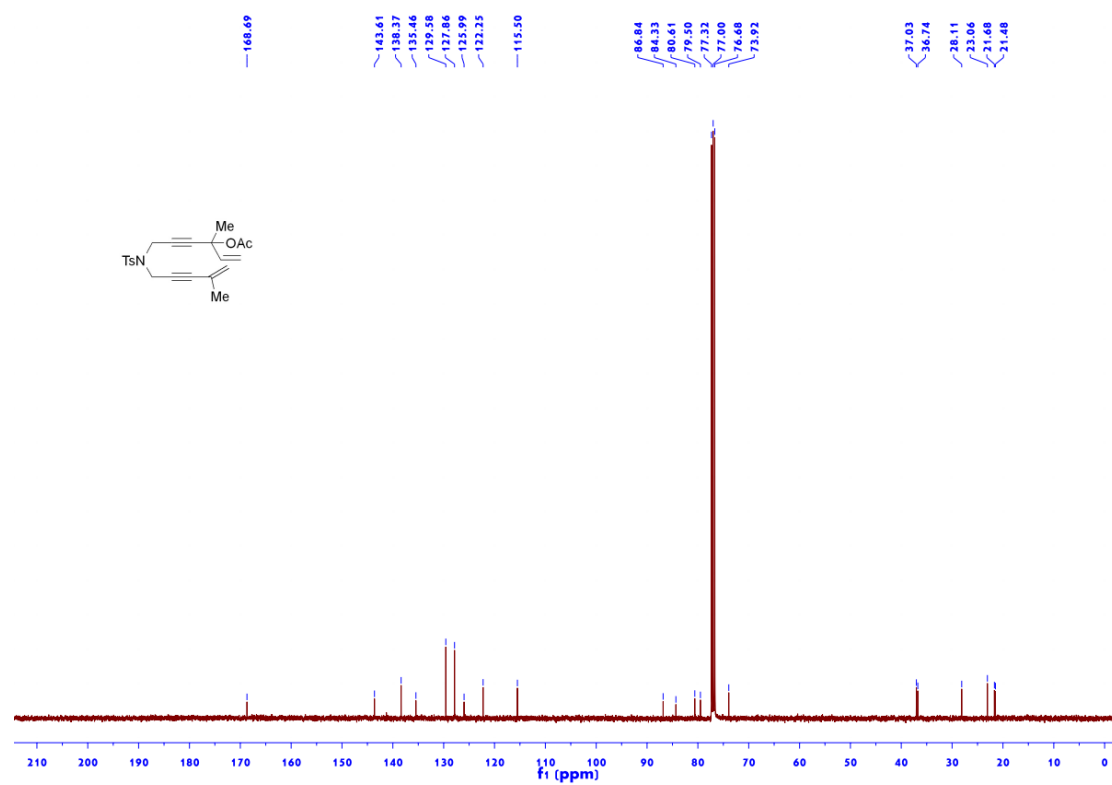


Figure S166  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 2a

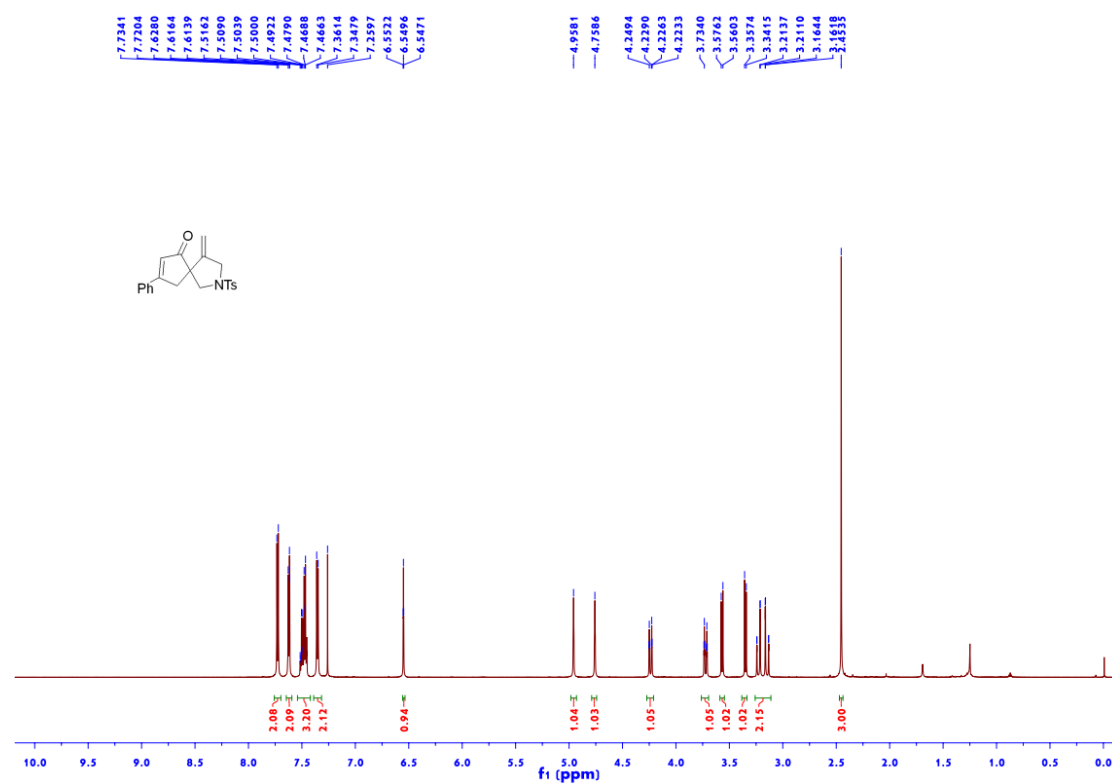






Figure S169  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 3a

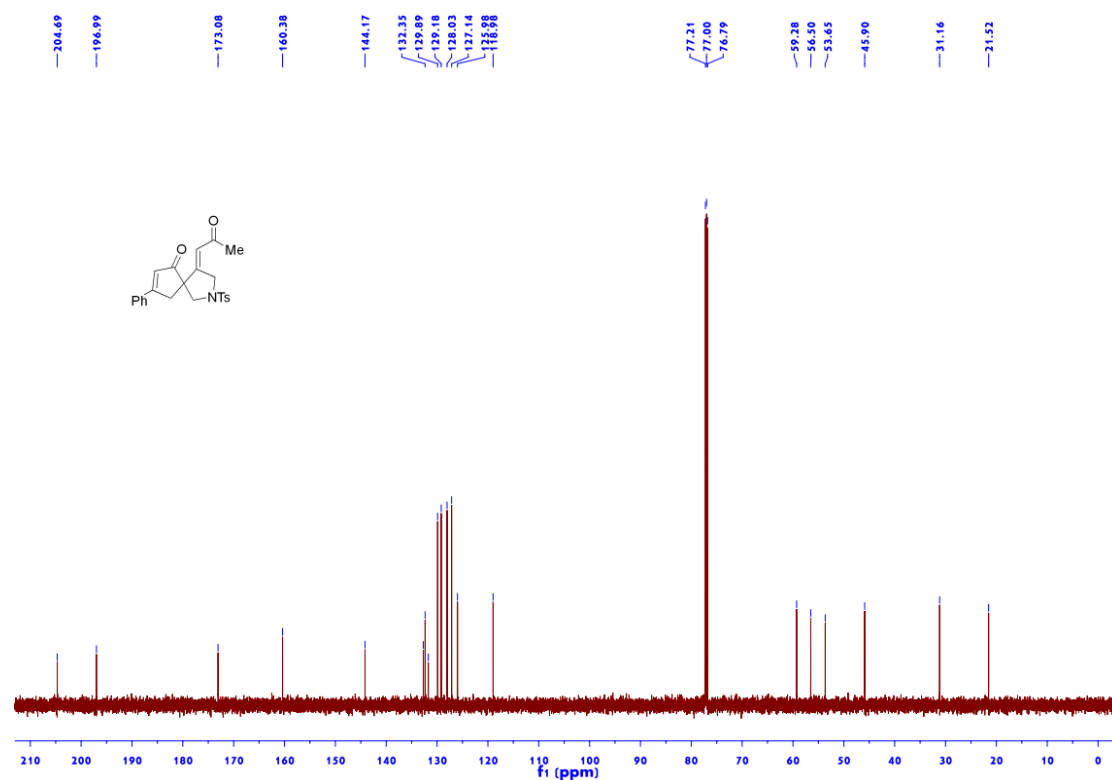


Figure S170  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 3b

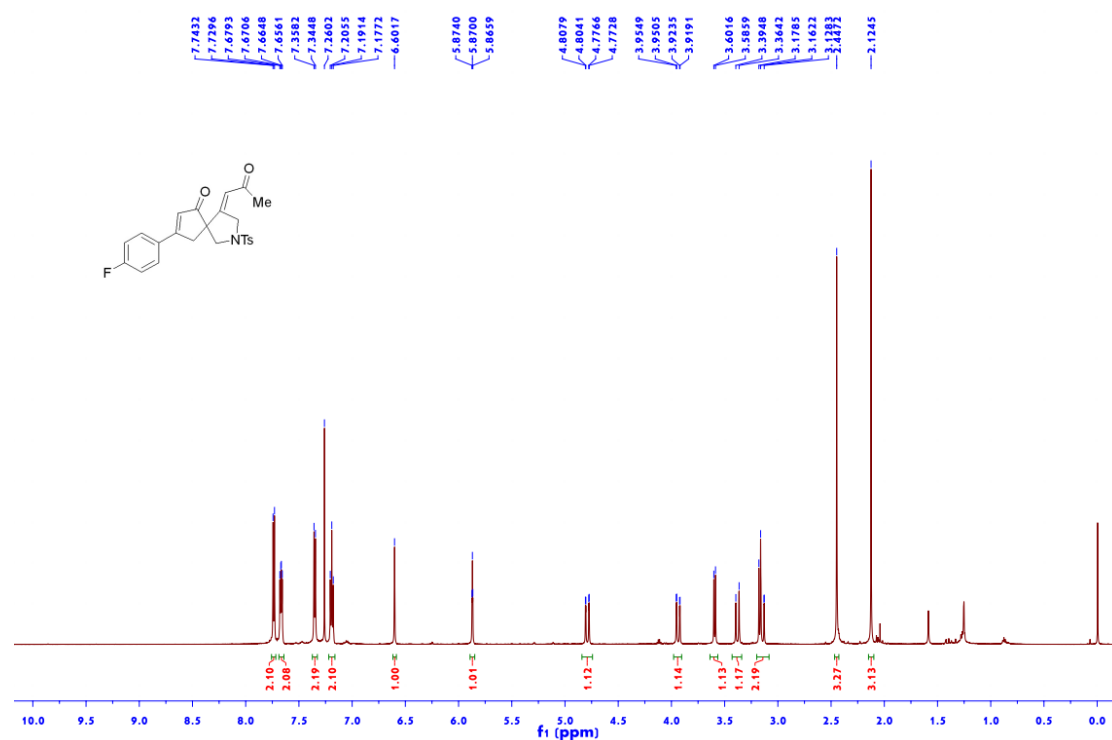


Figure S171 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3b

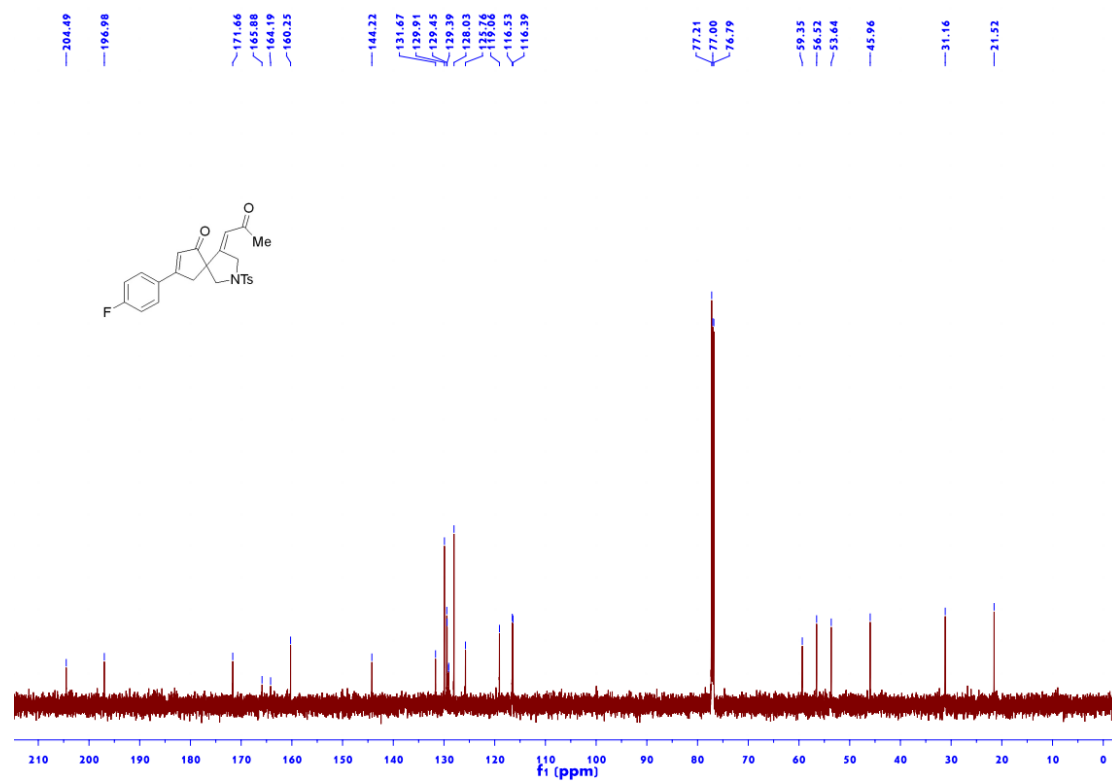


Figure S172 <sup>19</sup>F NMR (565 MHz, CDCl<sub>3</sub>) of 3b

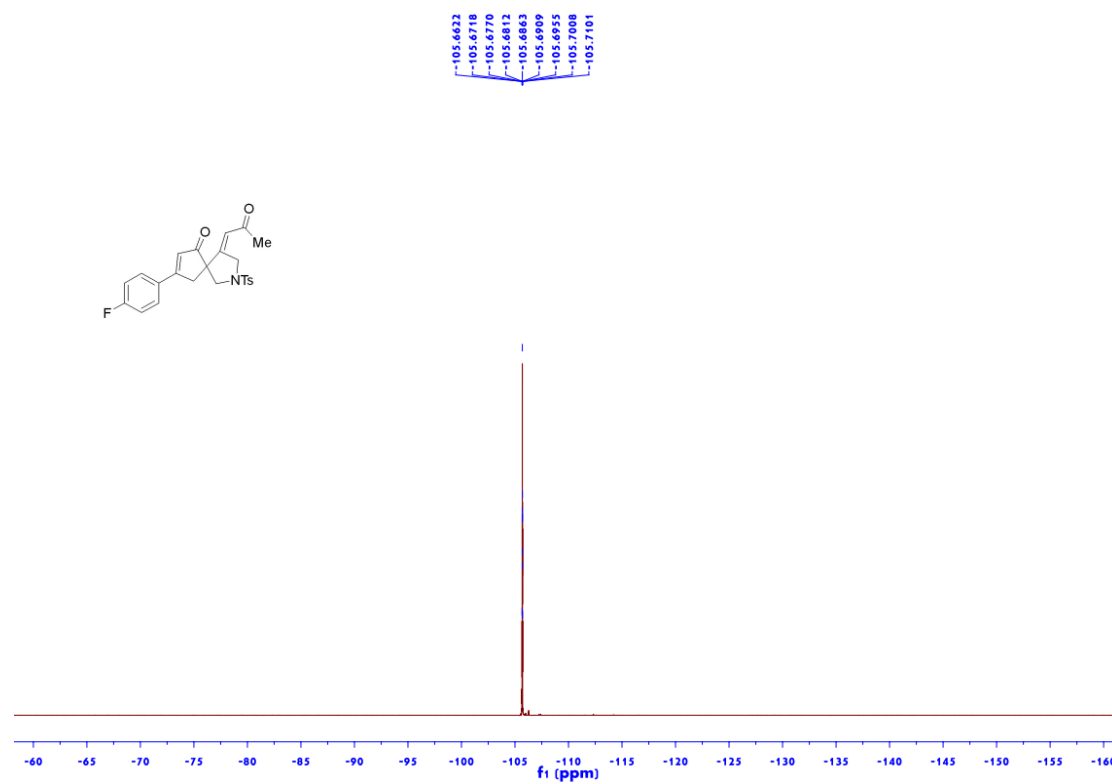


Figure S173 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3c

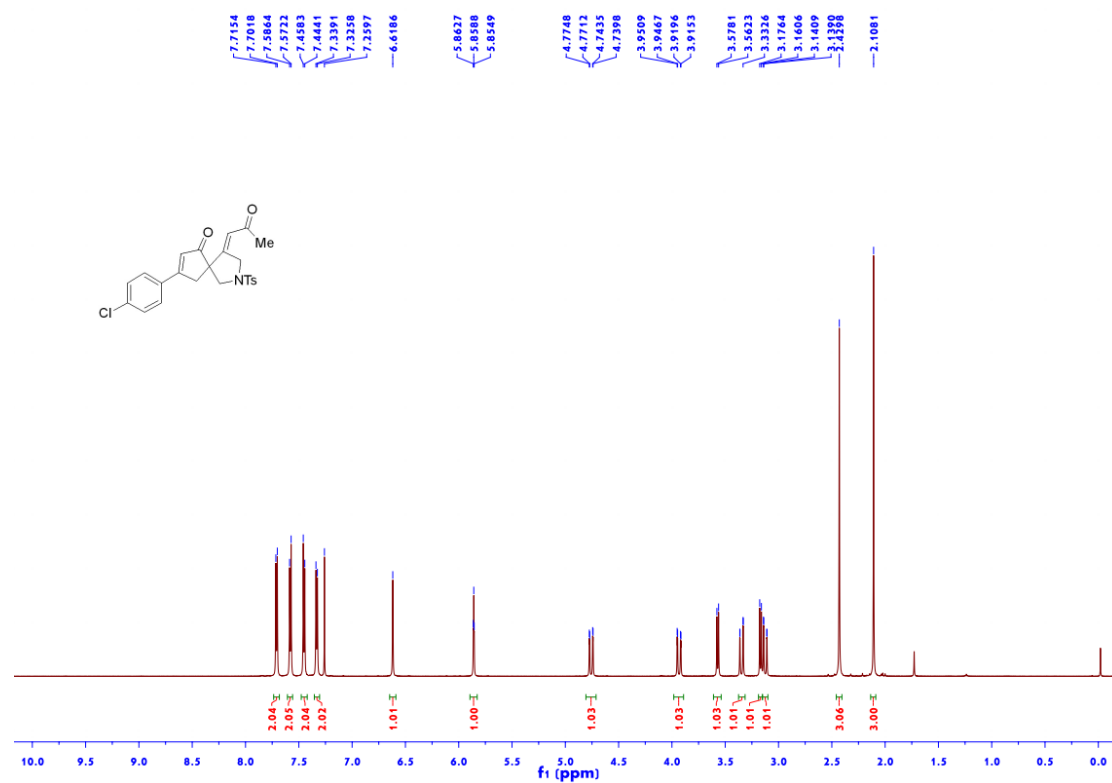


Figure S174 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3c

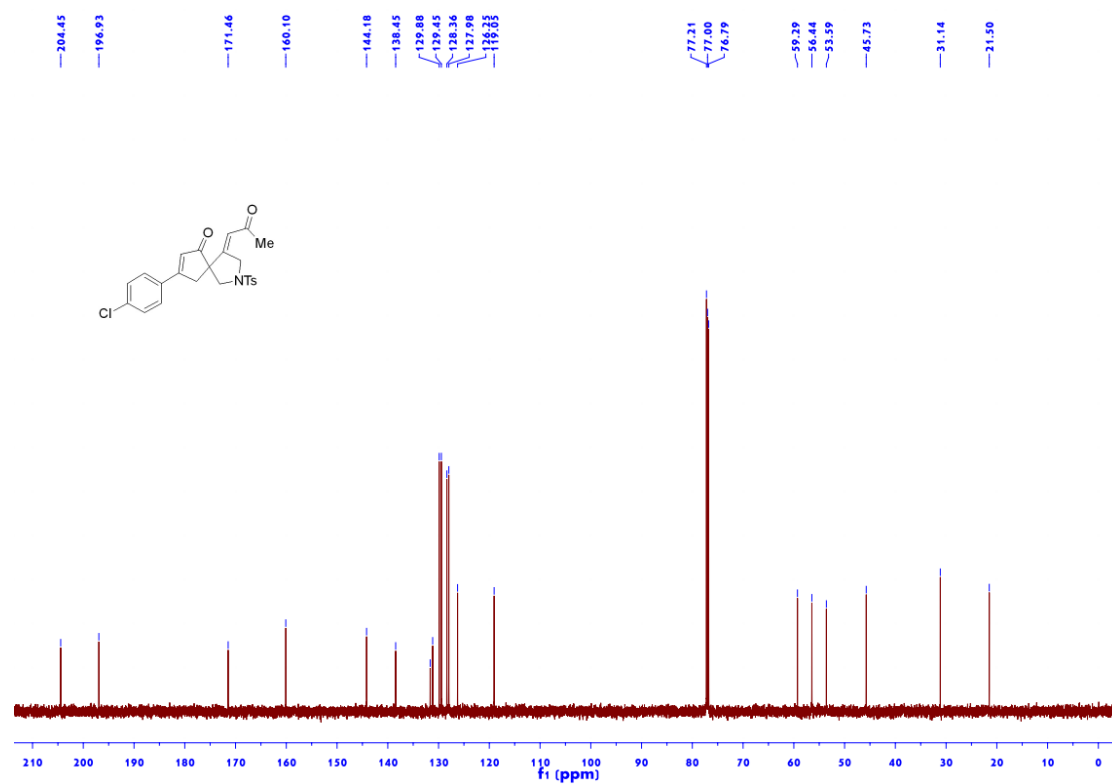


Figure S175 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3d

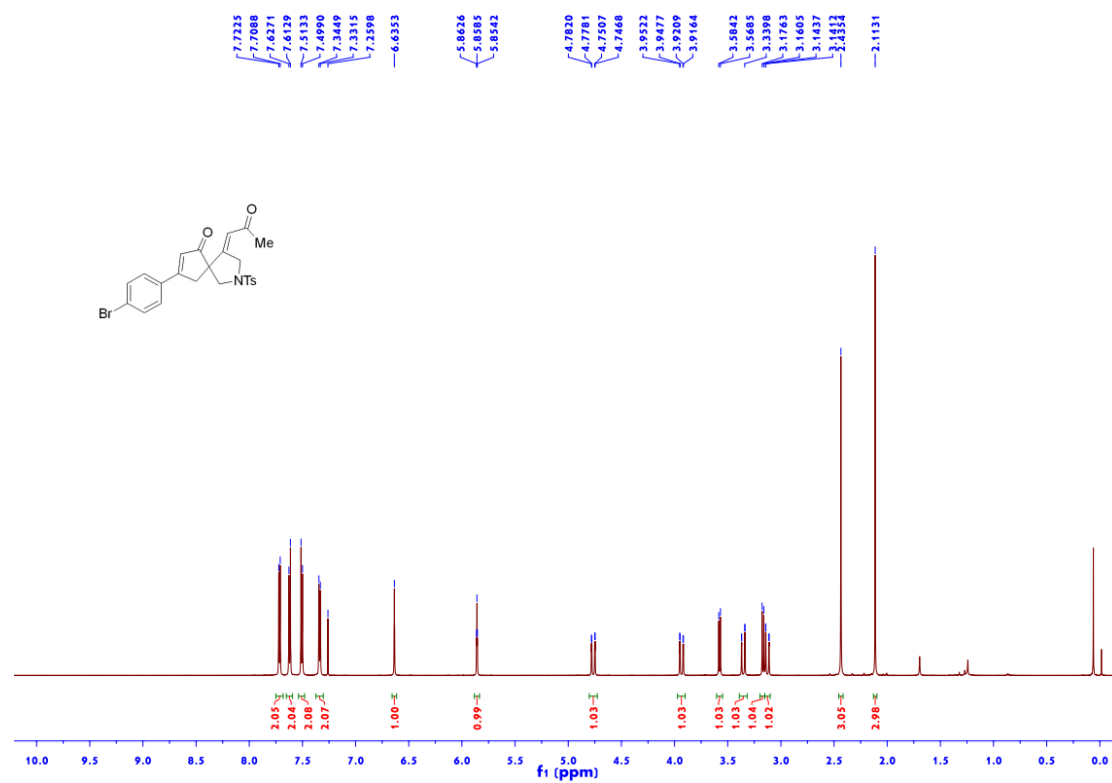


Figure S176 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3d

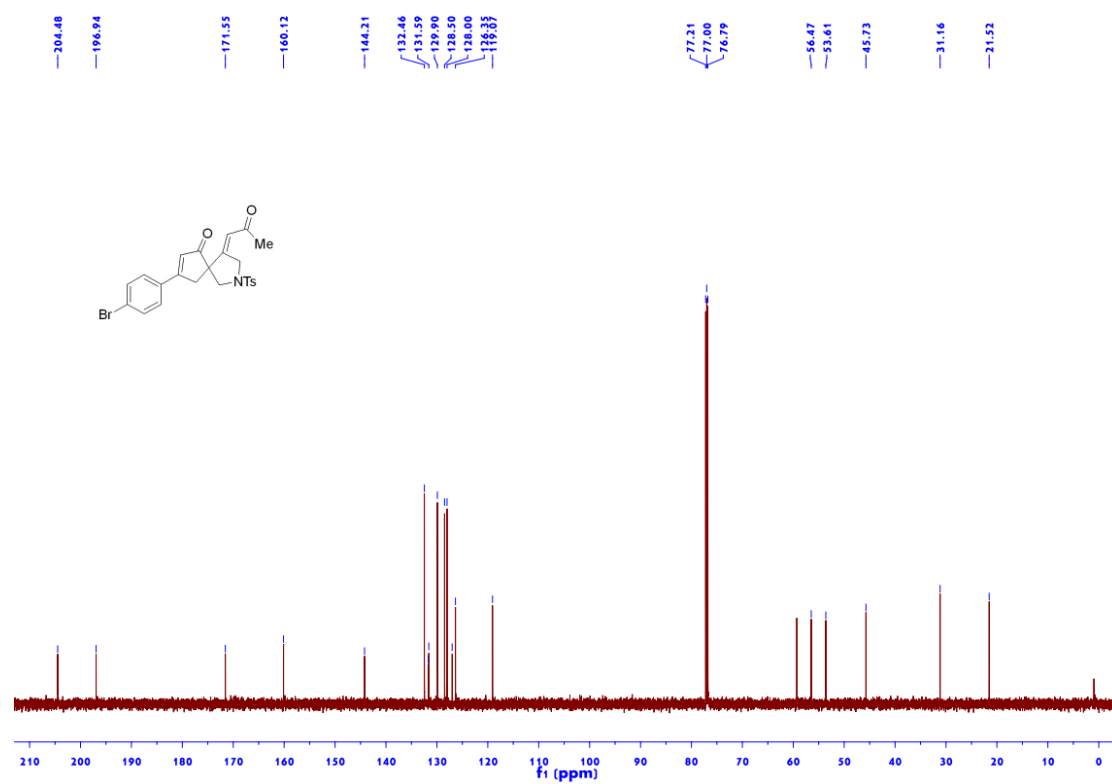


Figure S177 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3e

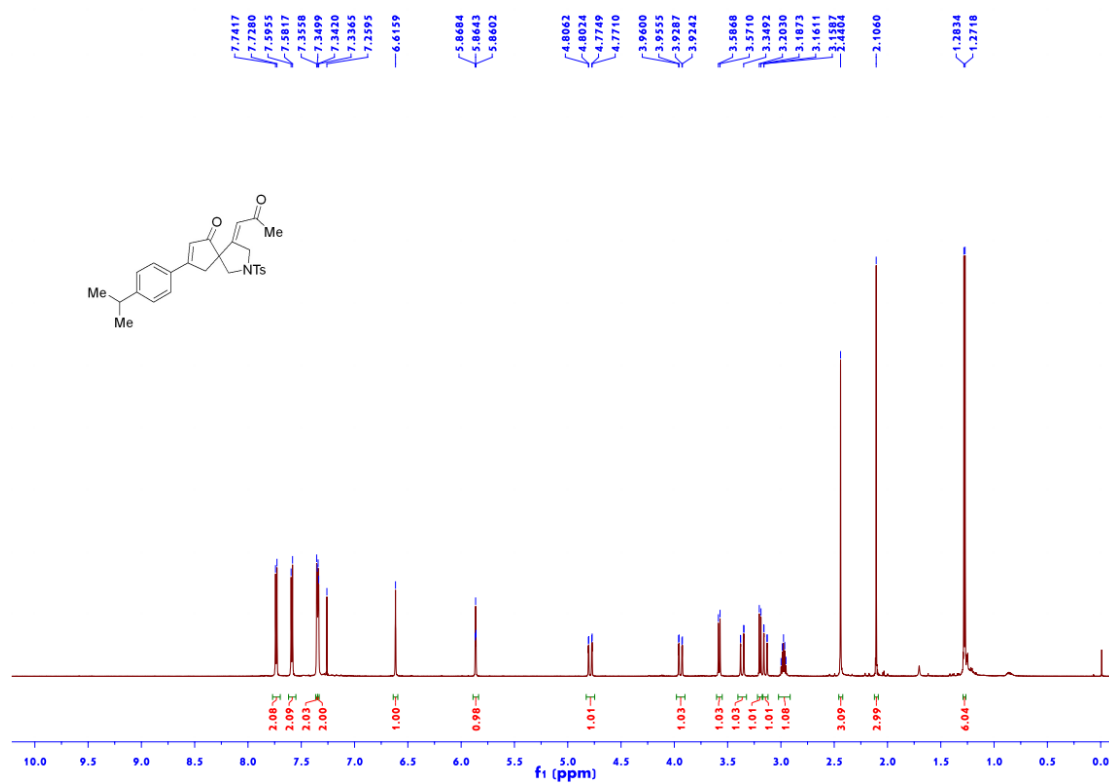


Figure S178 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3e

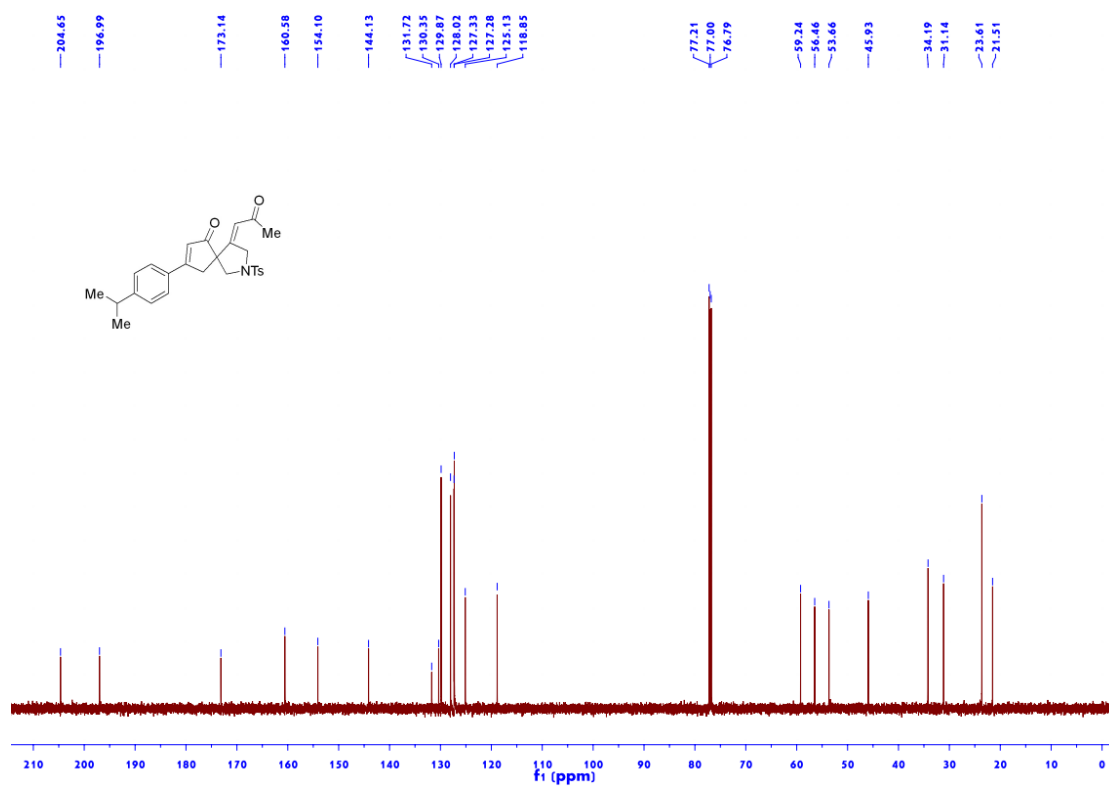


Figure S179 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3f'

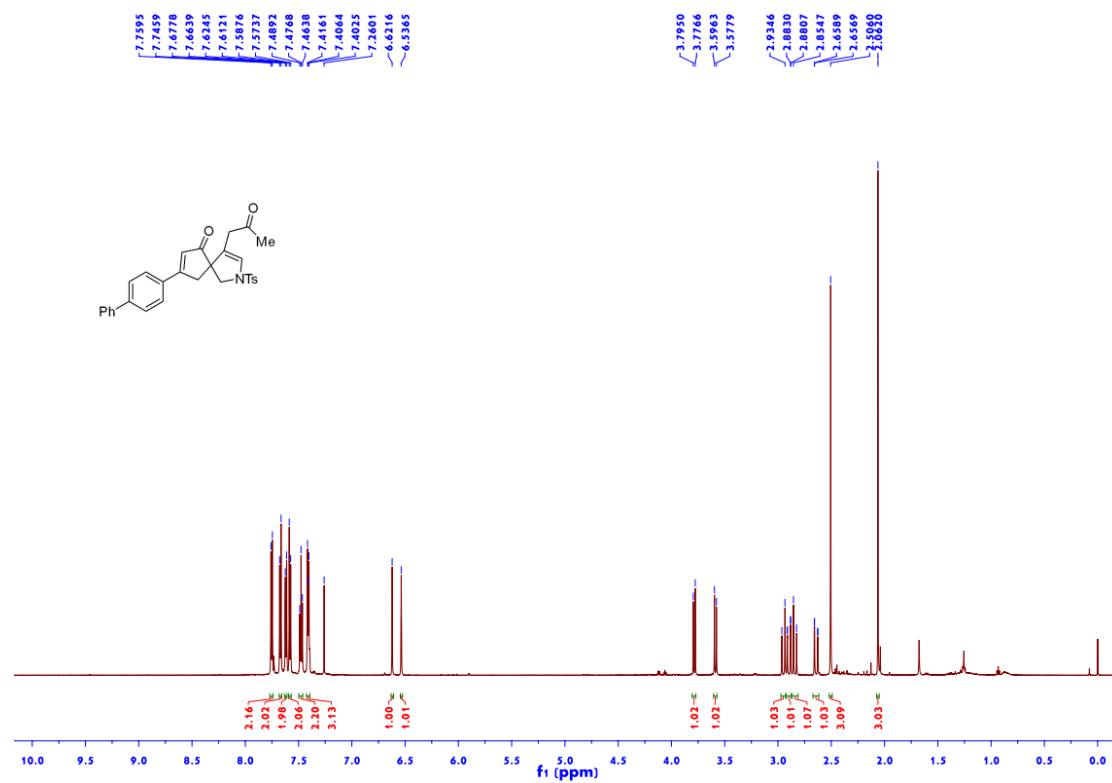


Figure S180 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3f'

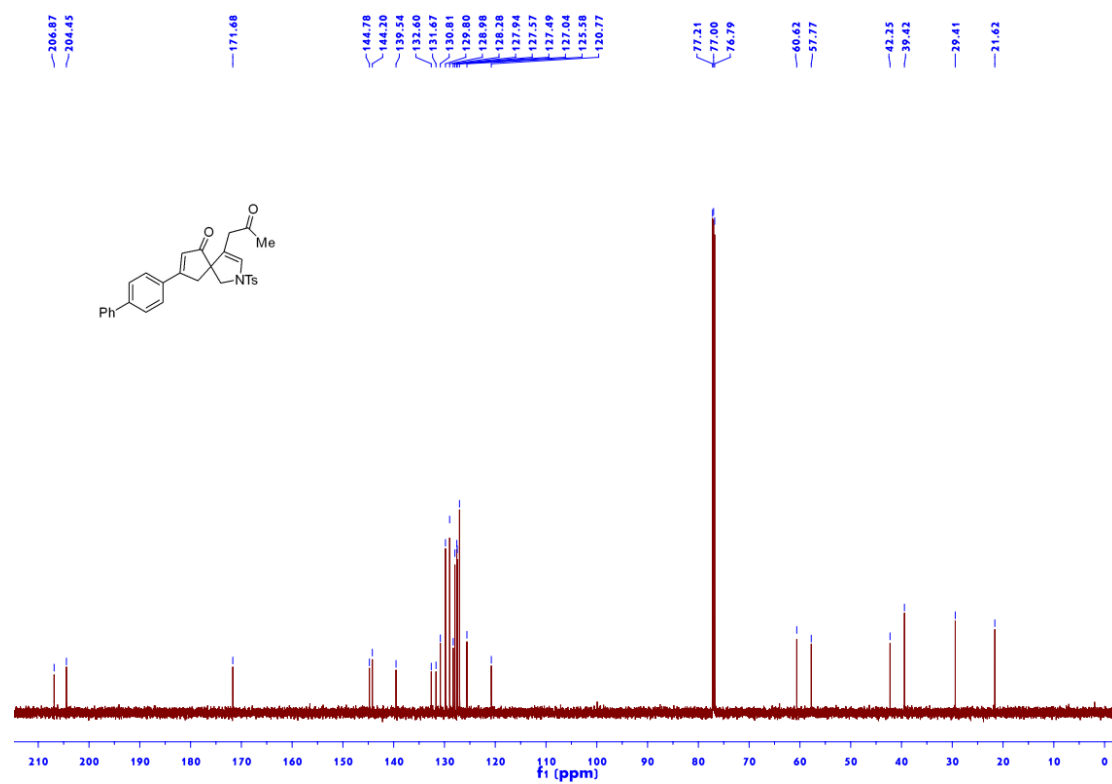


Figure S181 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3g

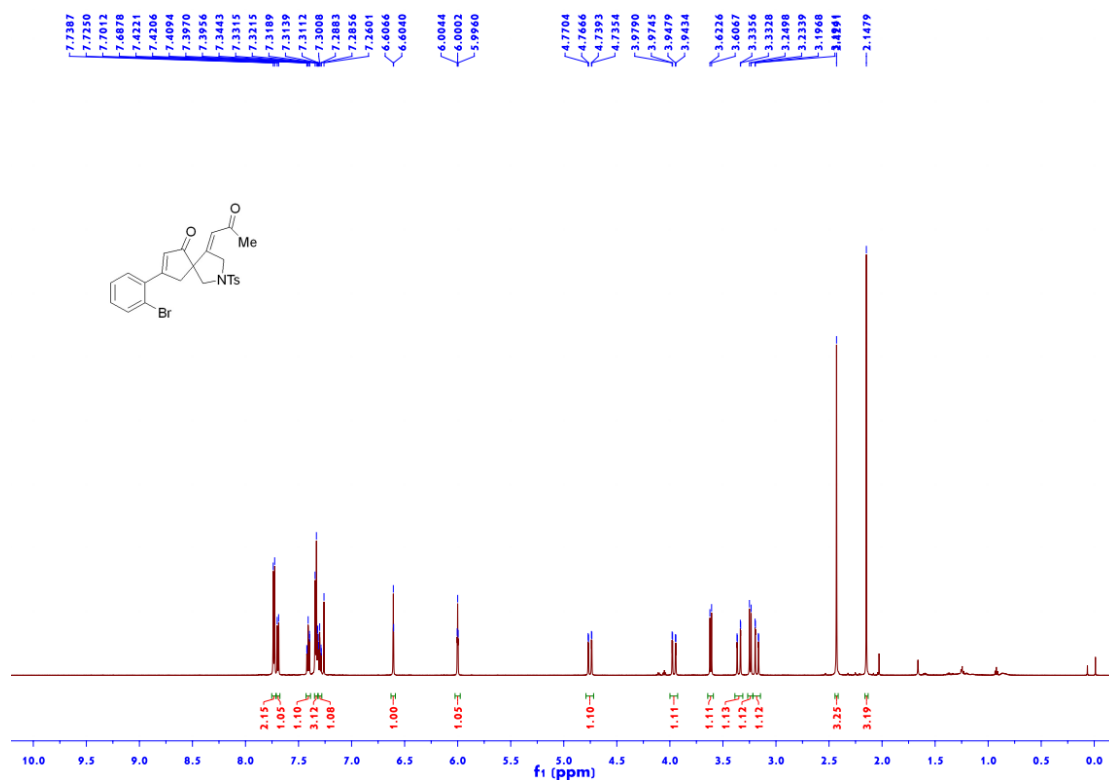


Figure S182 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3g

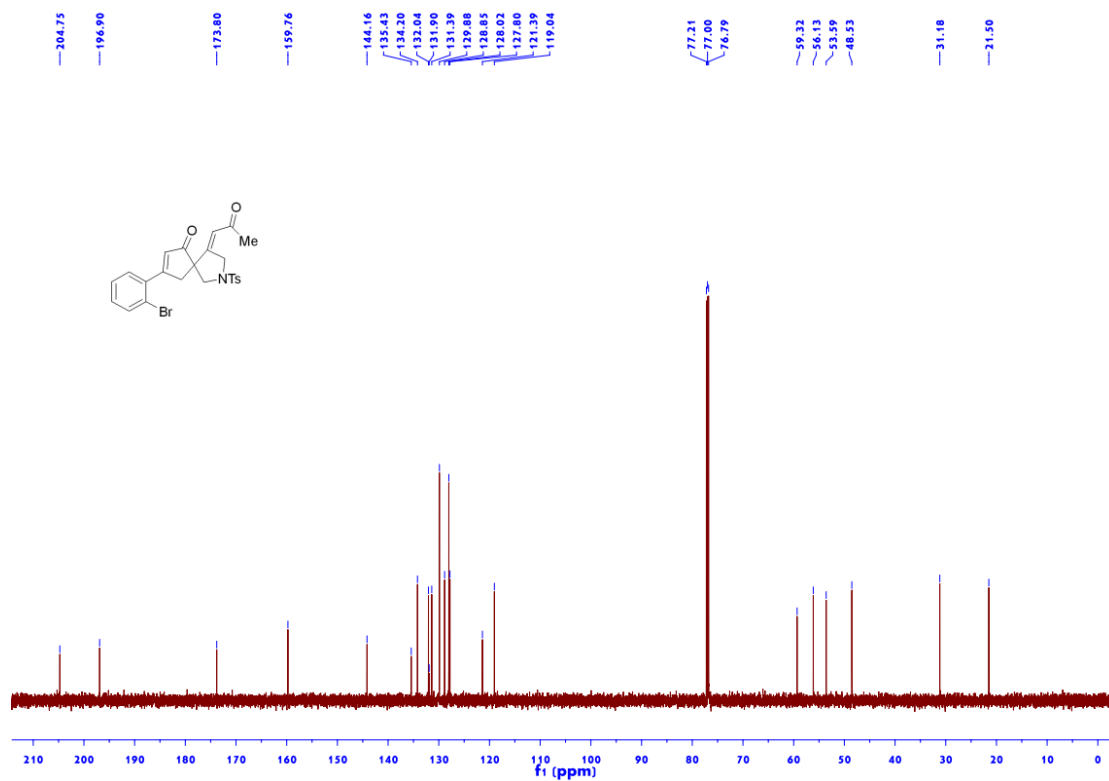


Figure S183 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3h

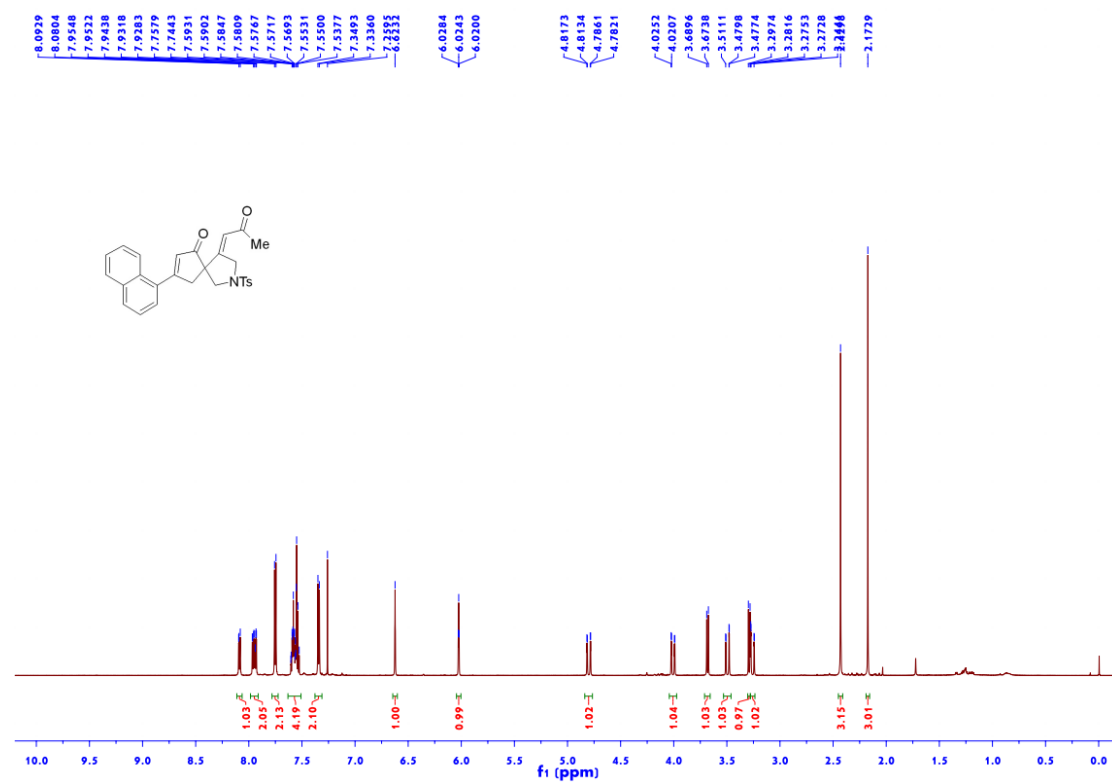


Figure S184 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3h

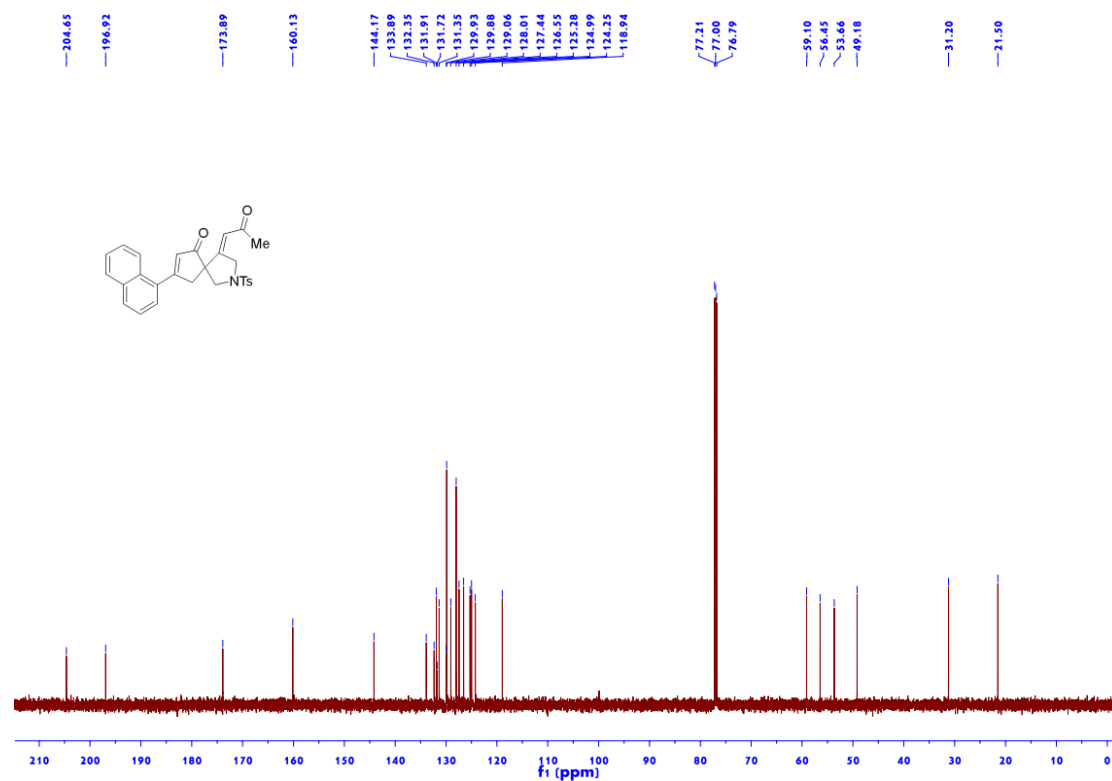




Figure S185 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3i

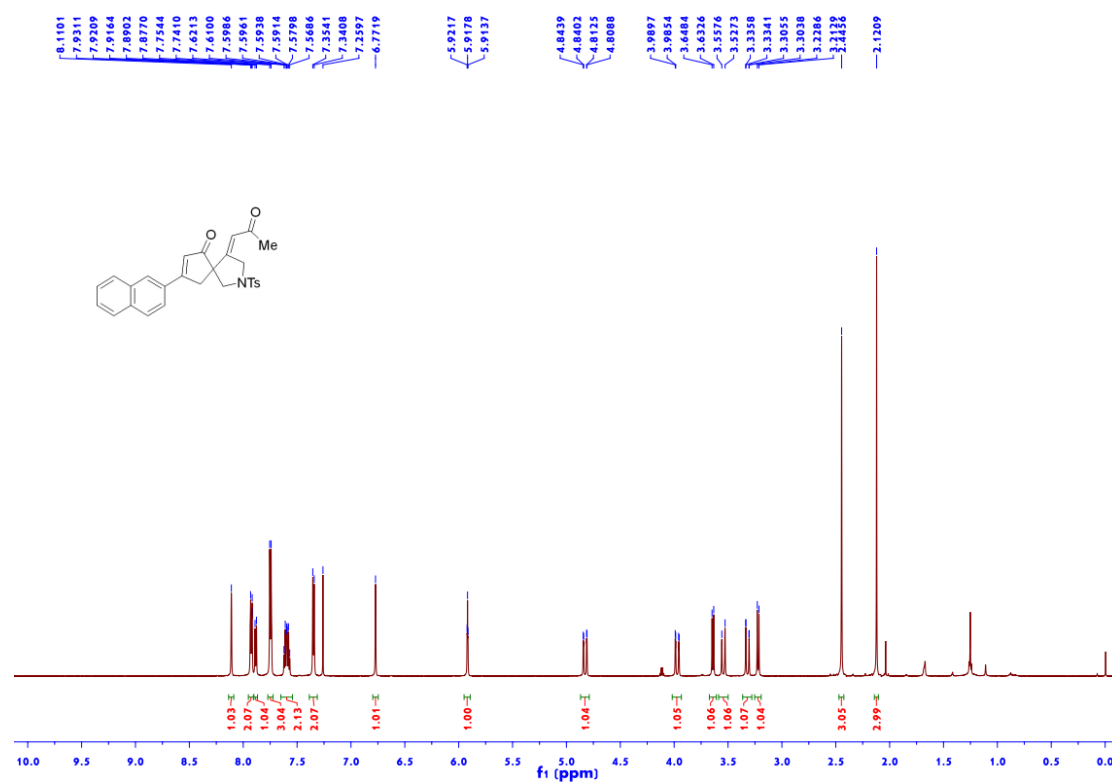


Figure S186 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3i

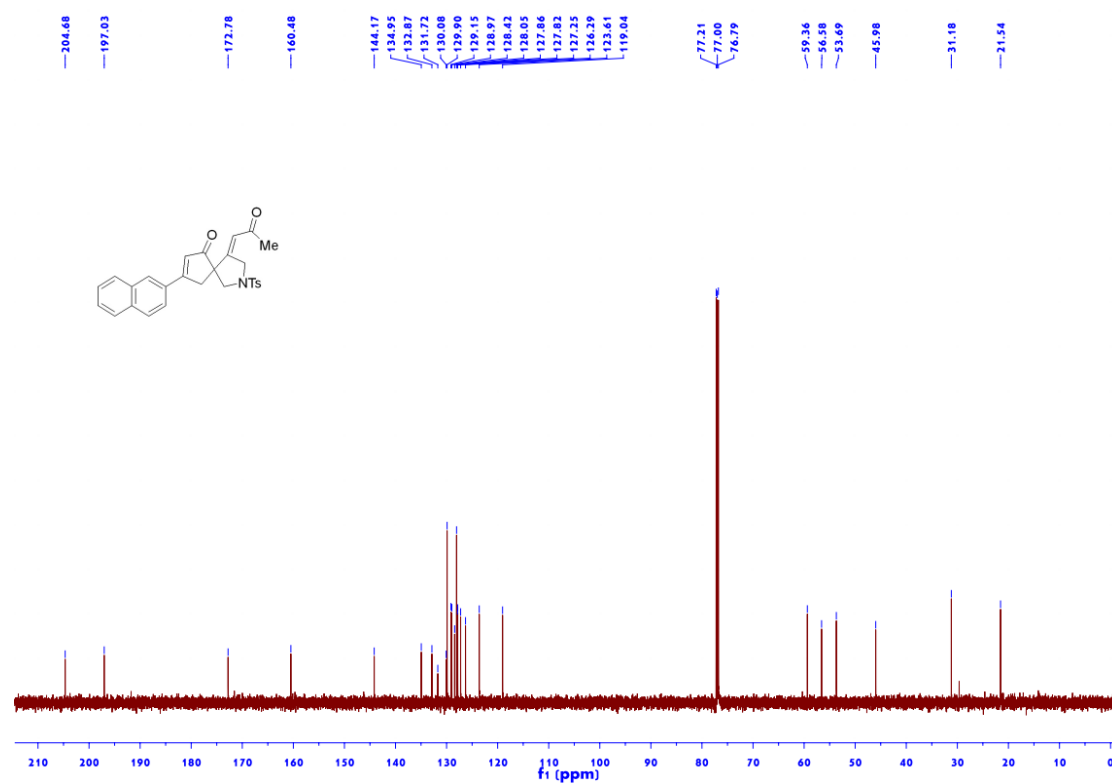


Figure S187 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3j

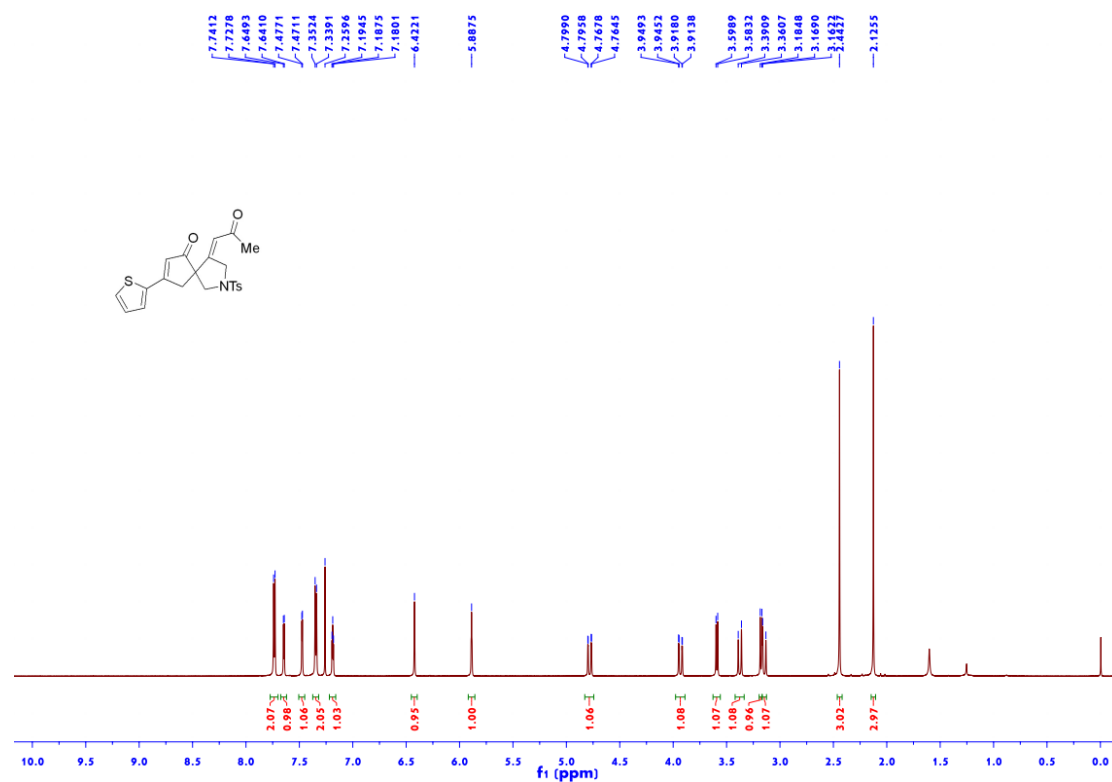


Figure S188 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3j

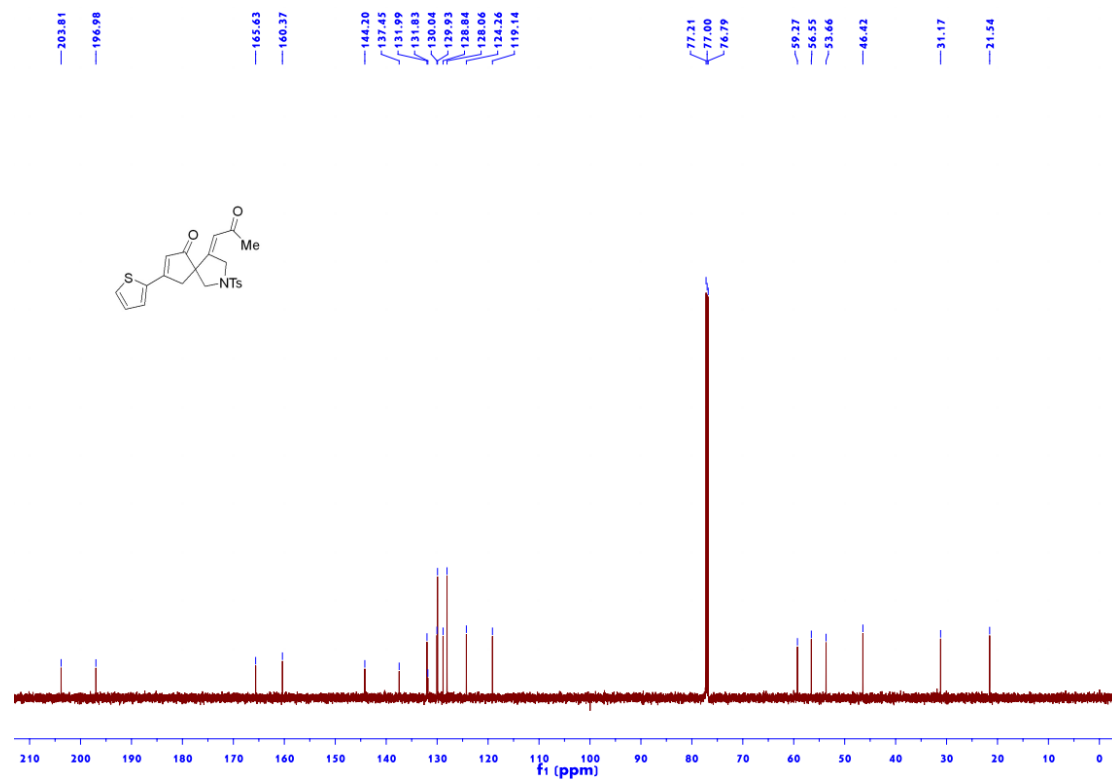


Figure S189 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3k

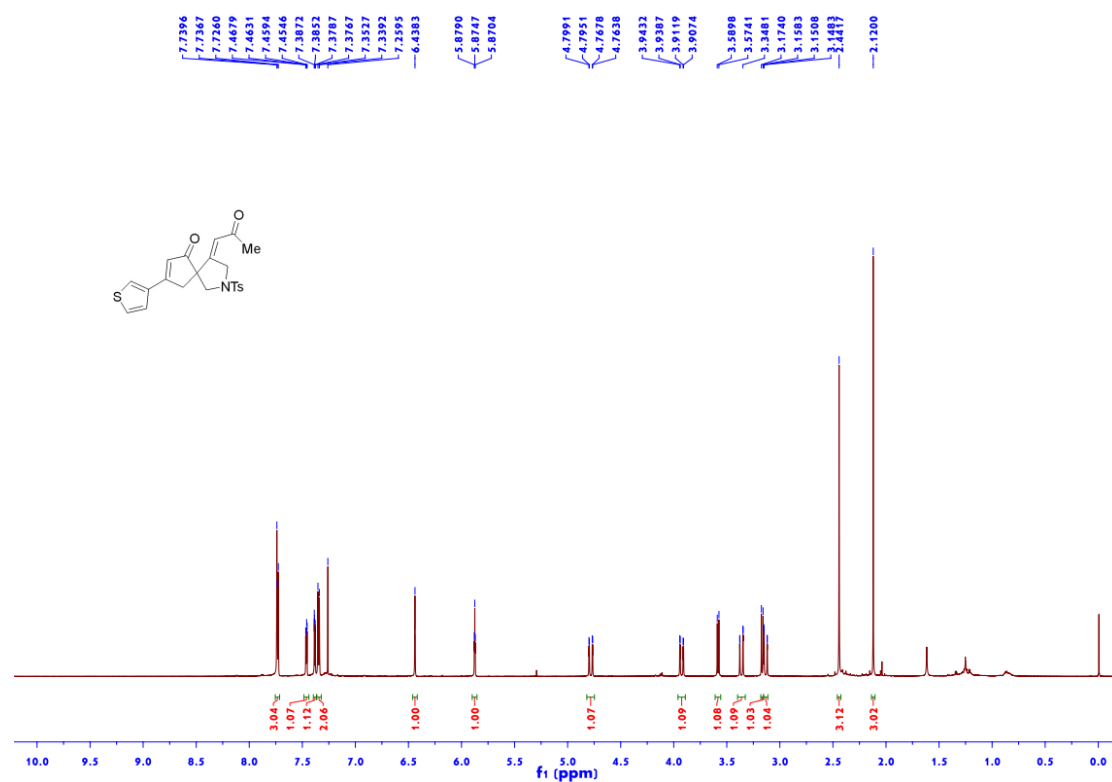


Figure S190 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3k

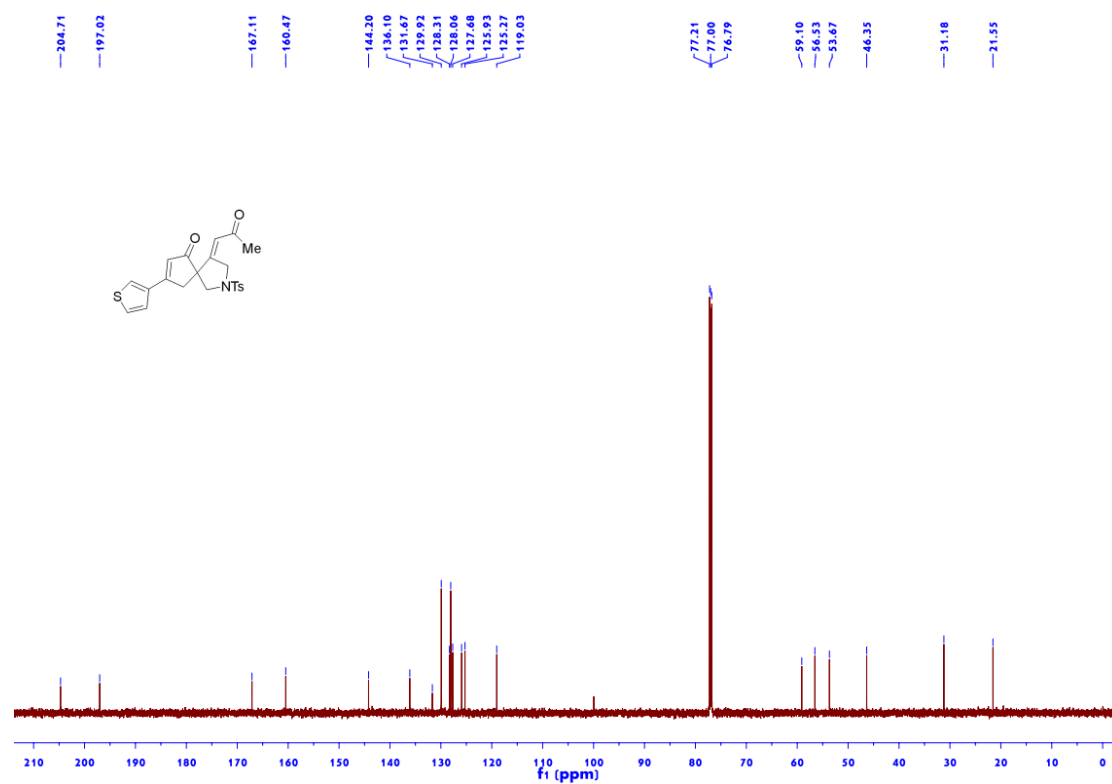


Figure S191 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3l

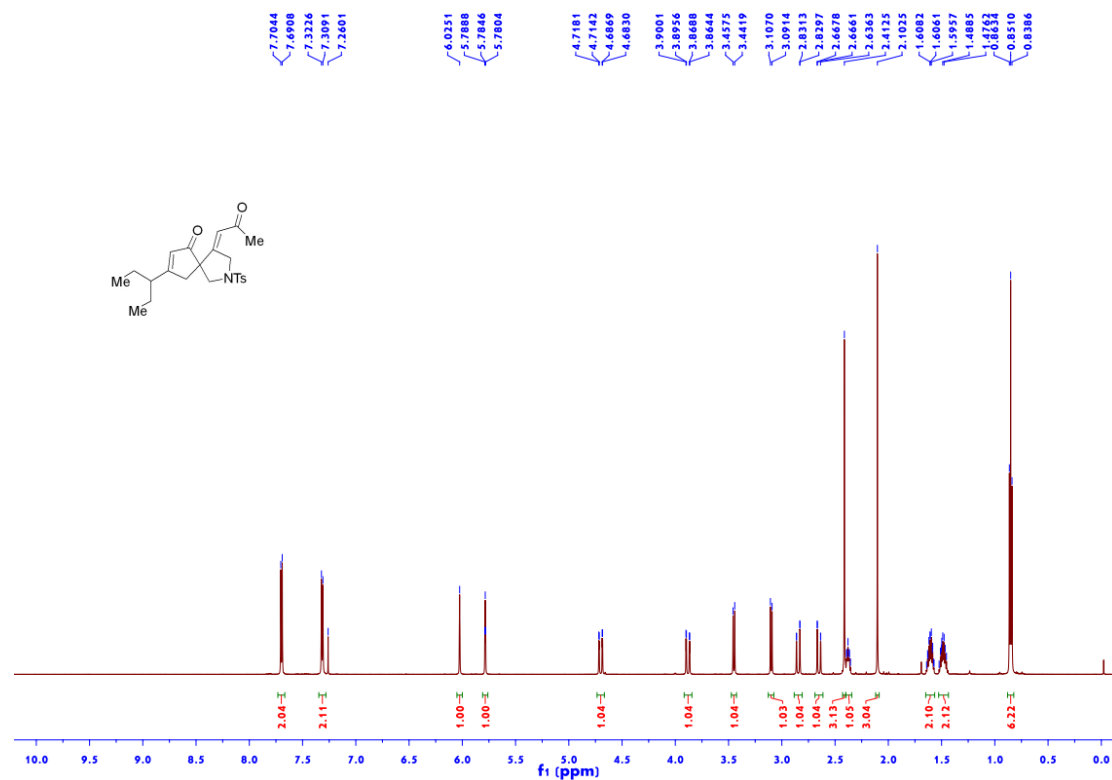


Figure S192 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3l

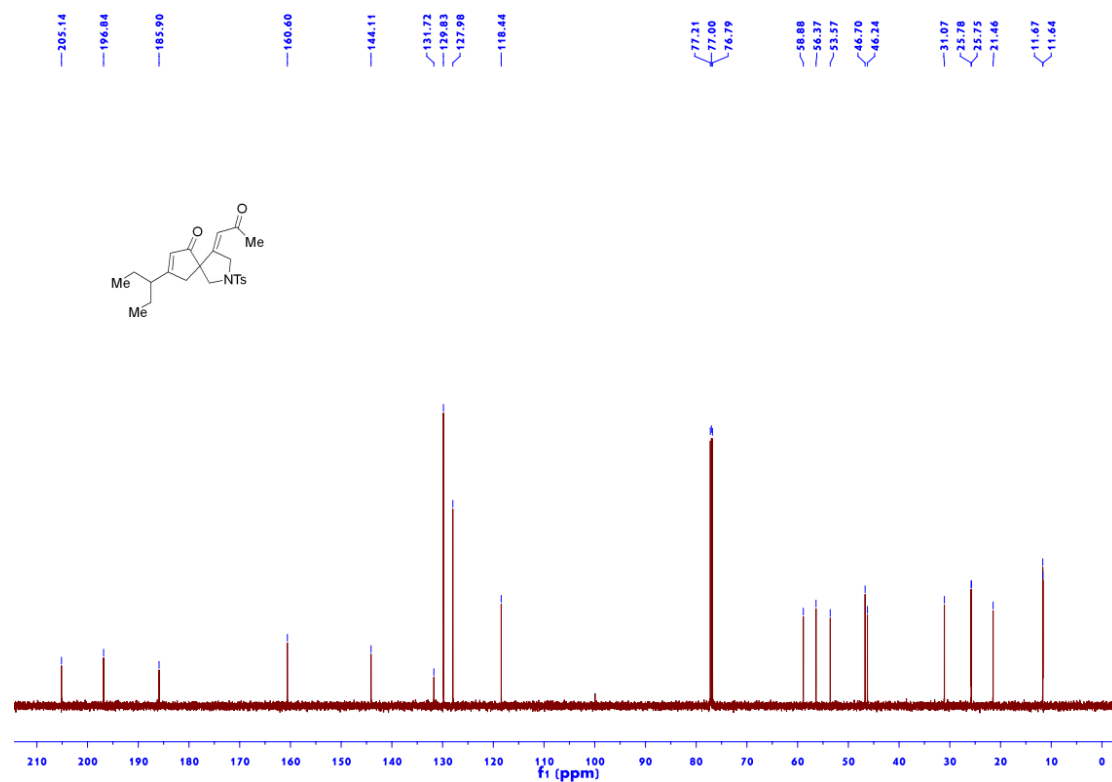


Figure S193 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3m

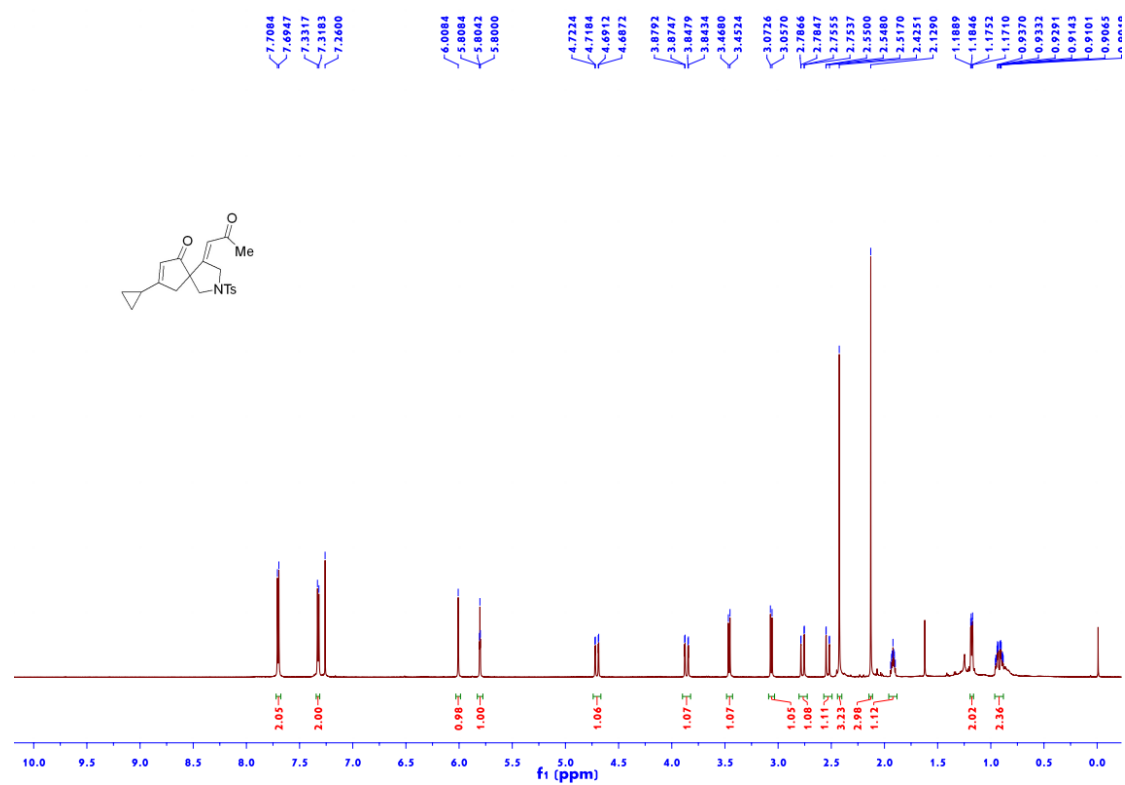


Figure S194 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3m

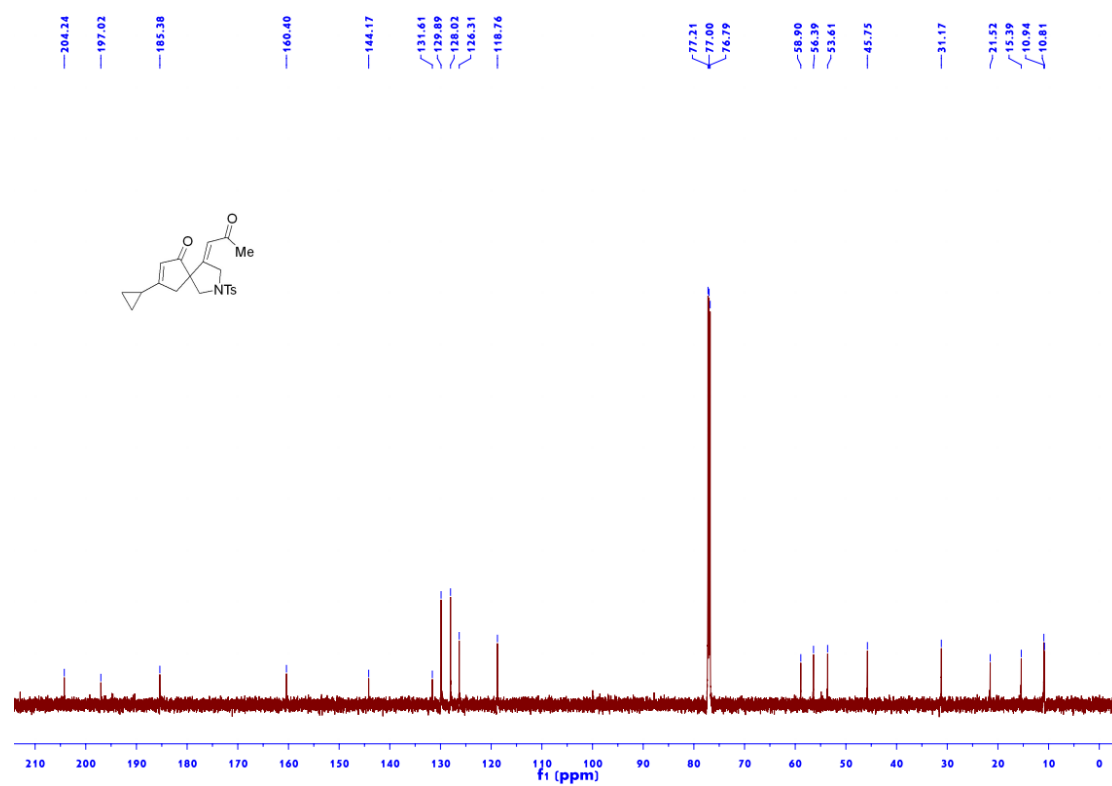


Figure S195 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3n

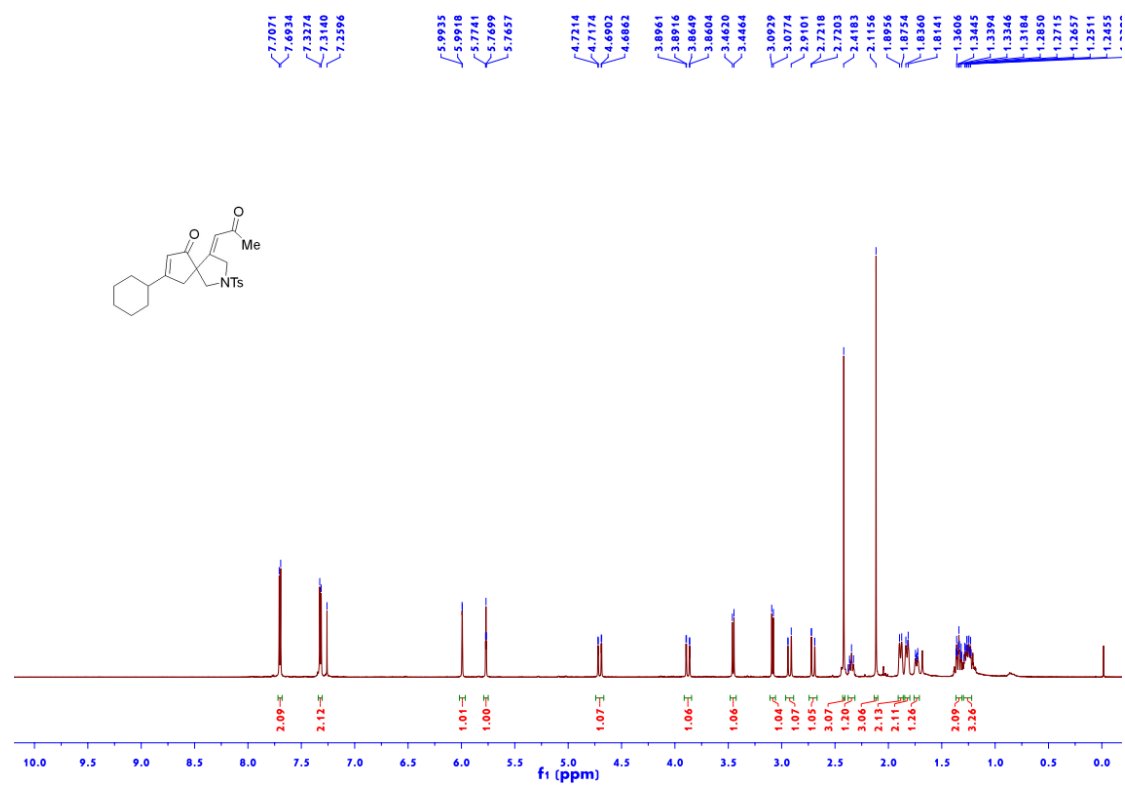


Figure S196 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3n

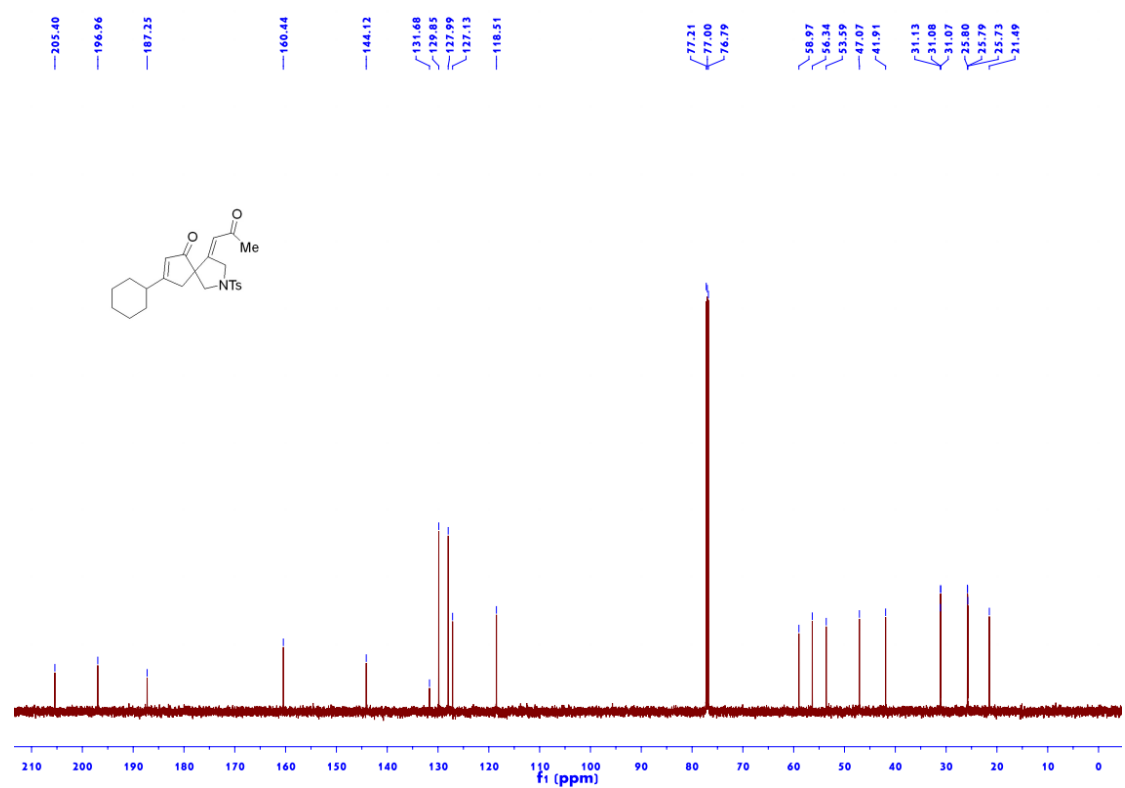


Figure S197 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3o

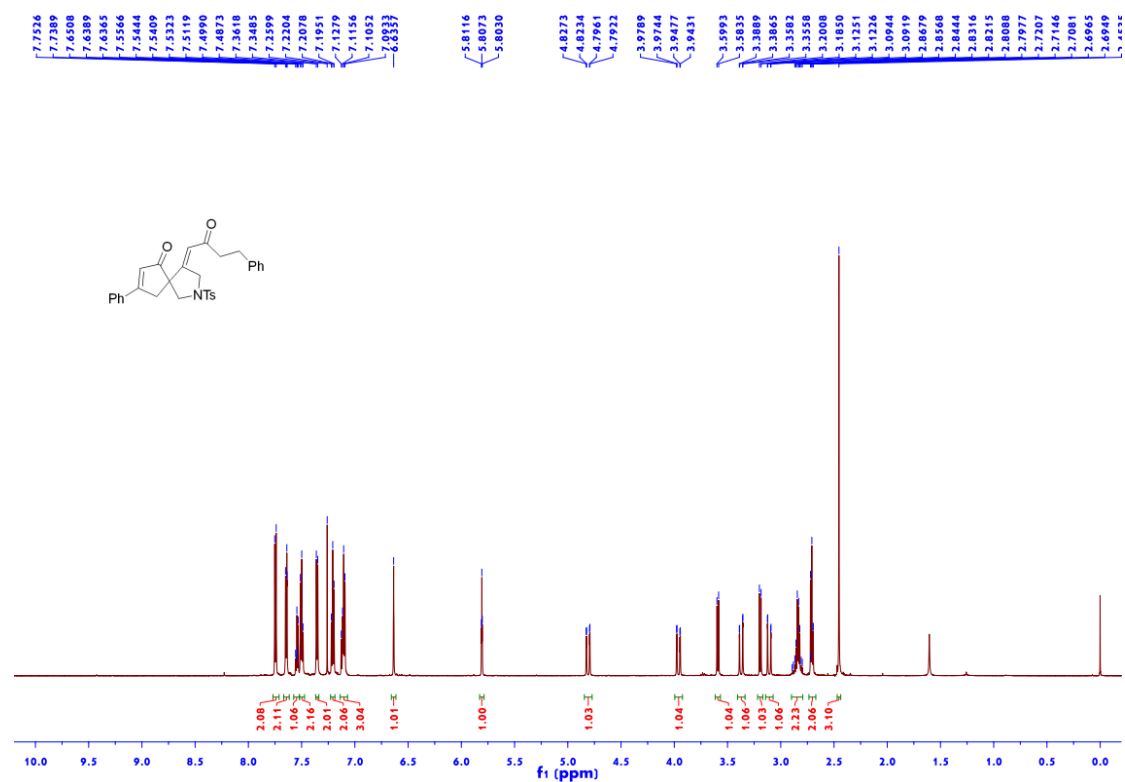


Figure S198 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3o

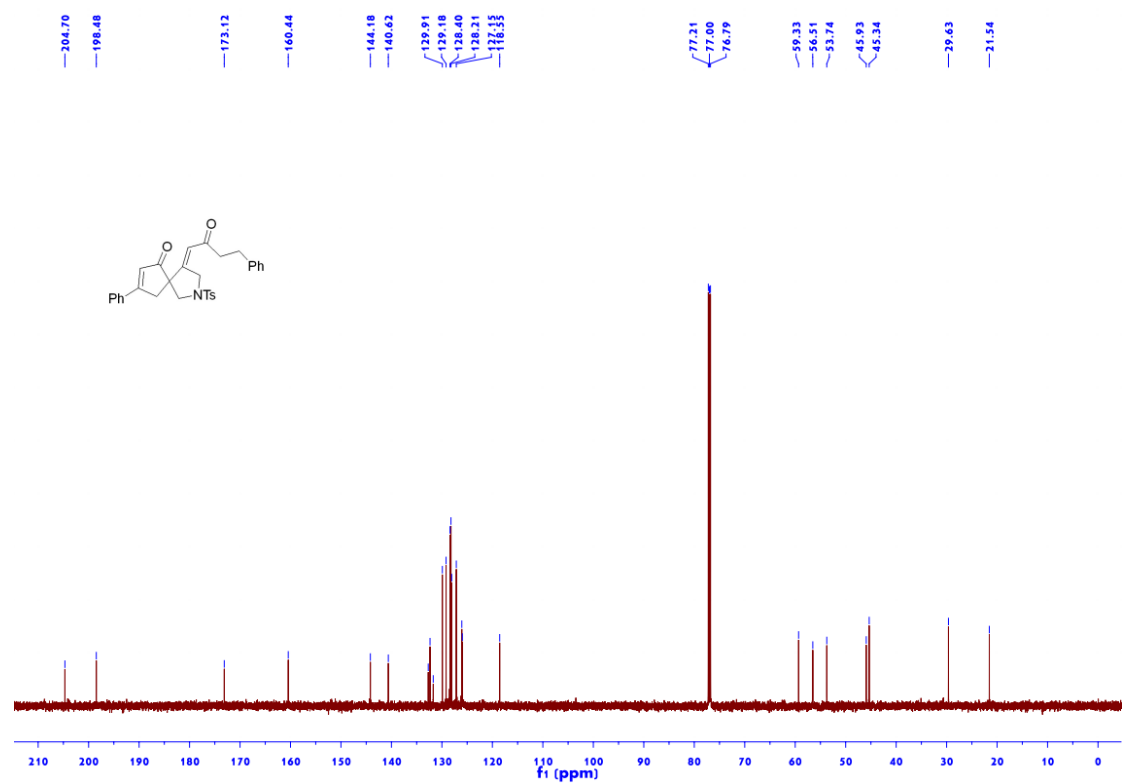


Figure S199 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3p

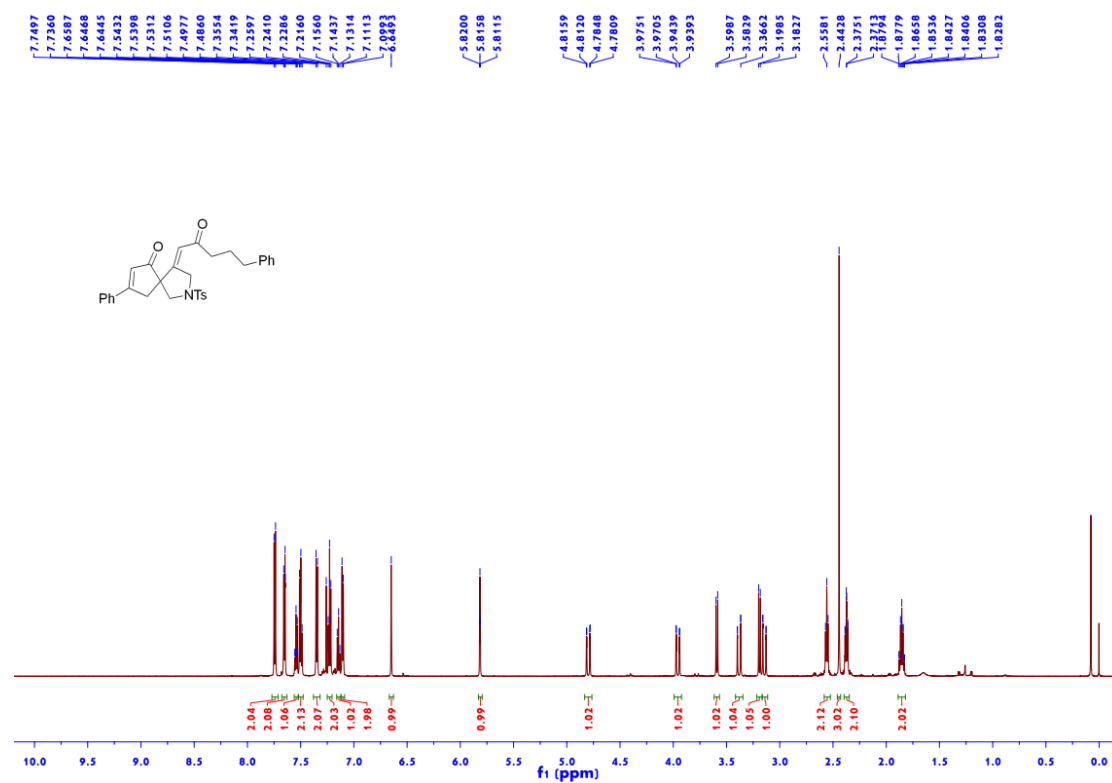


Figure S200 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3p

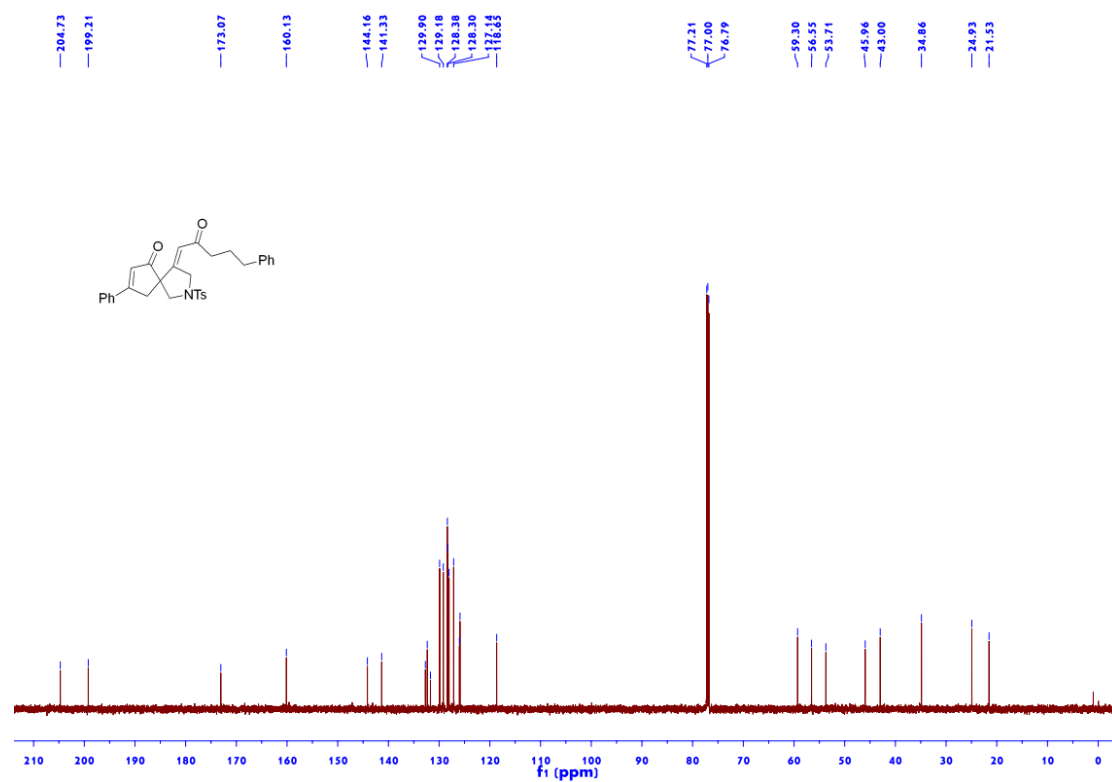




Figure S201 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3q

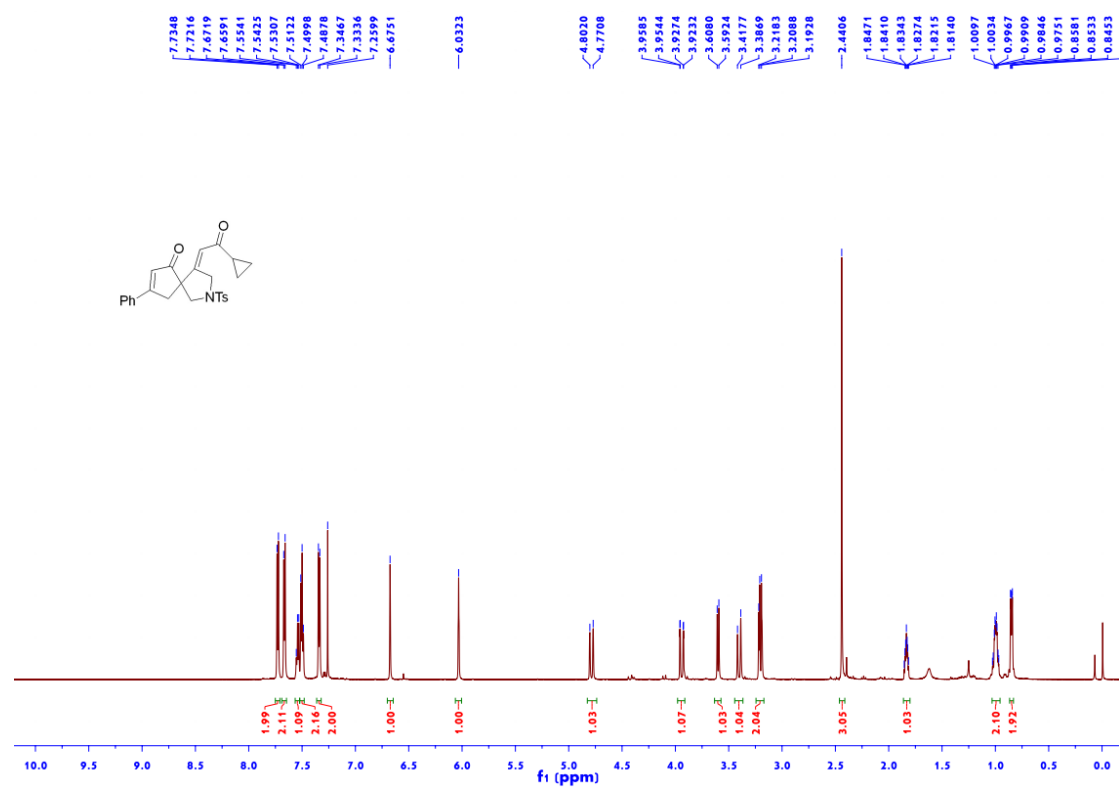


Figure S202 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3q

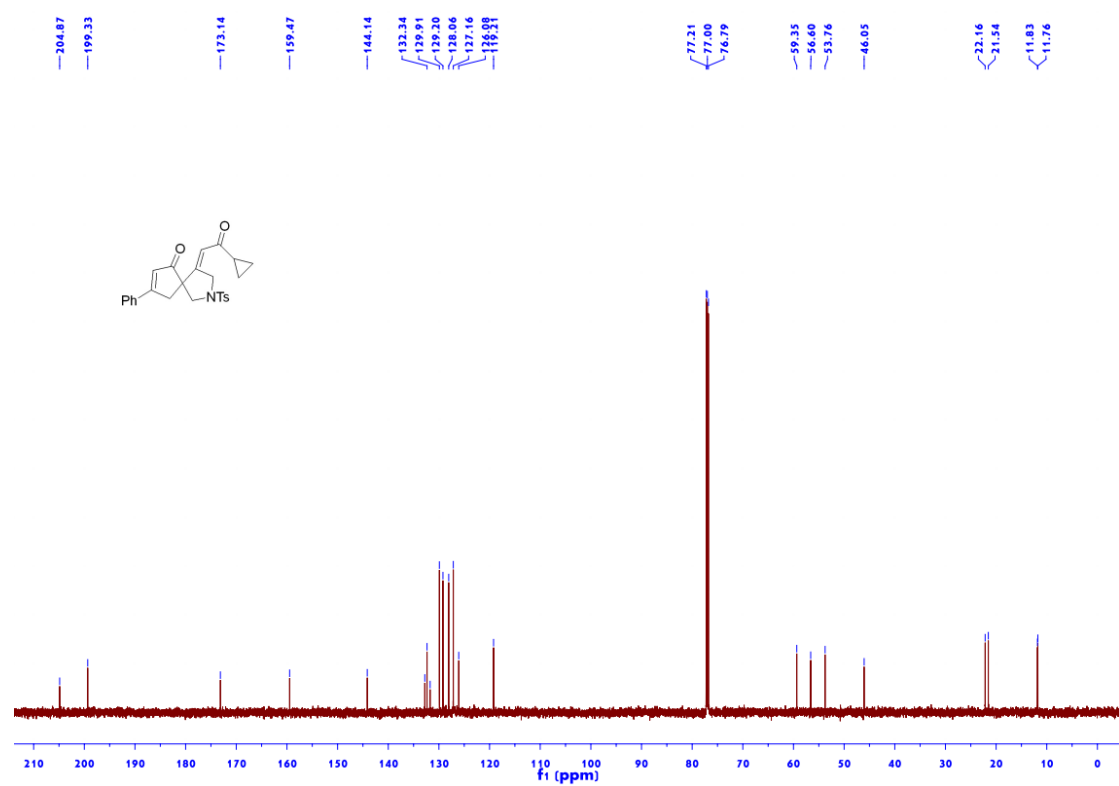


Figure S203 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3r

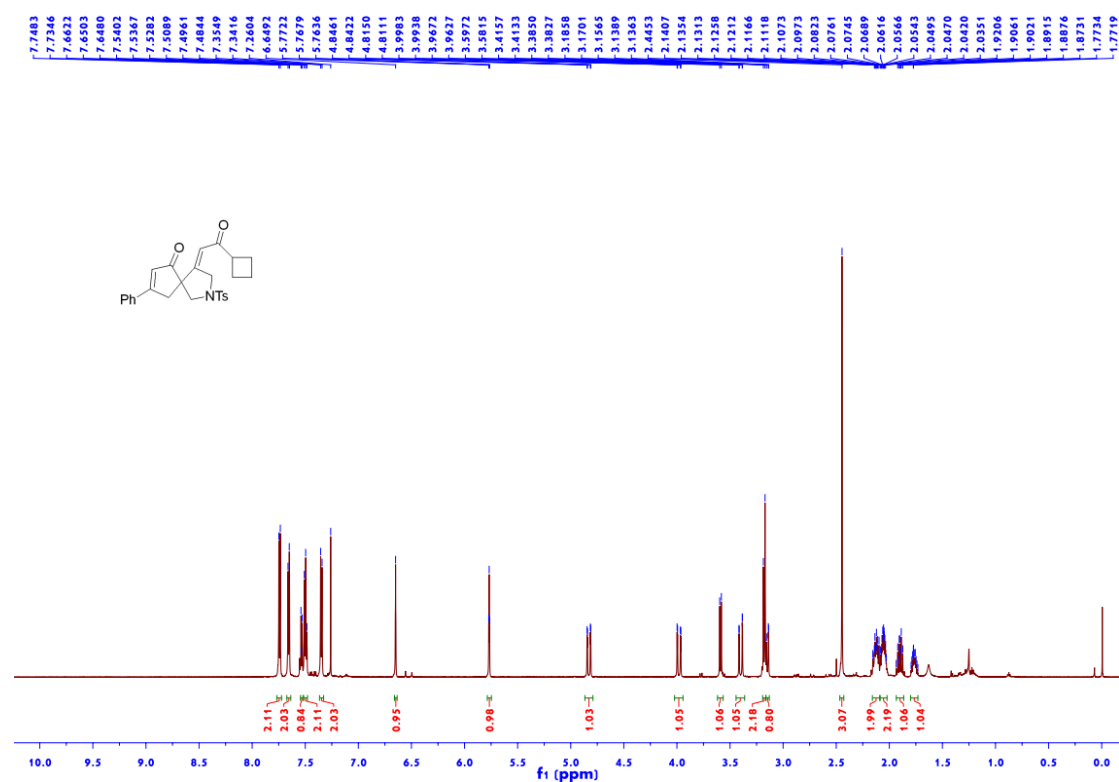


Figure S204 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3r

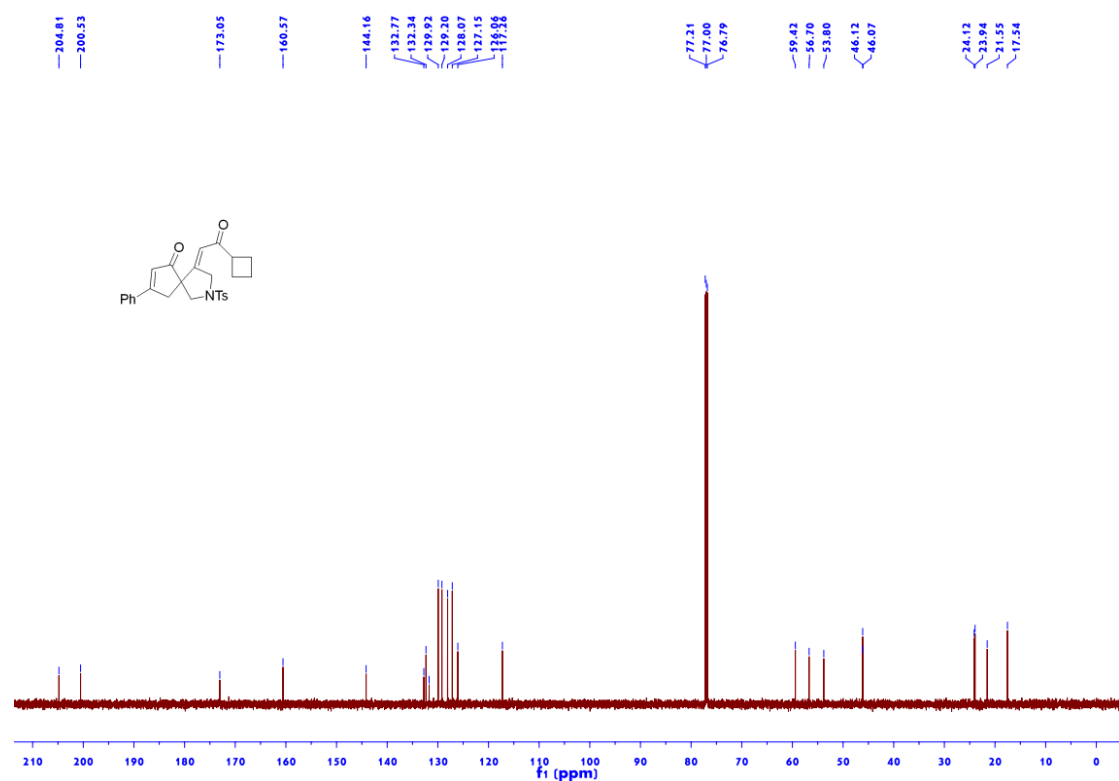


Figure S205 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3s

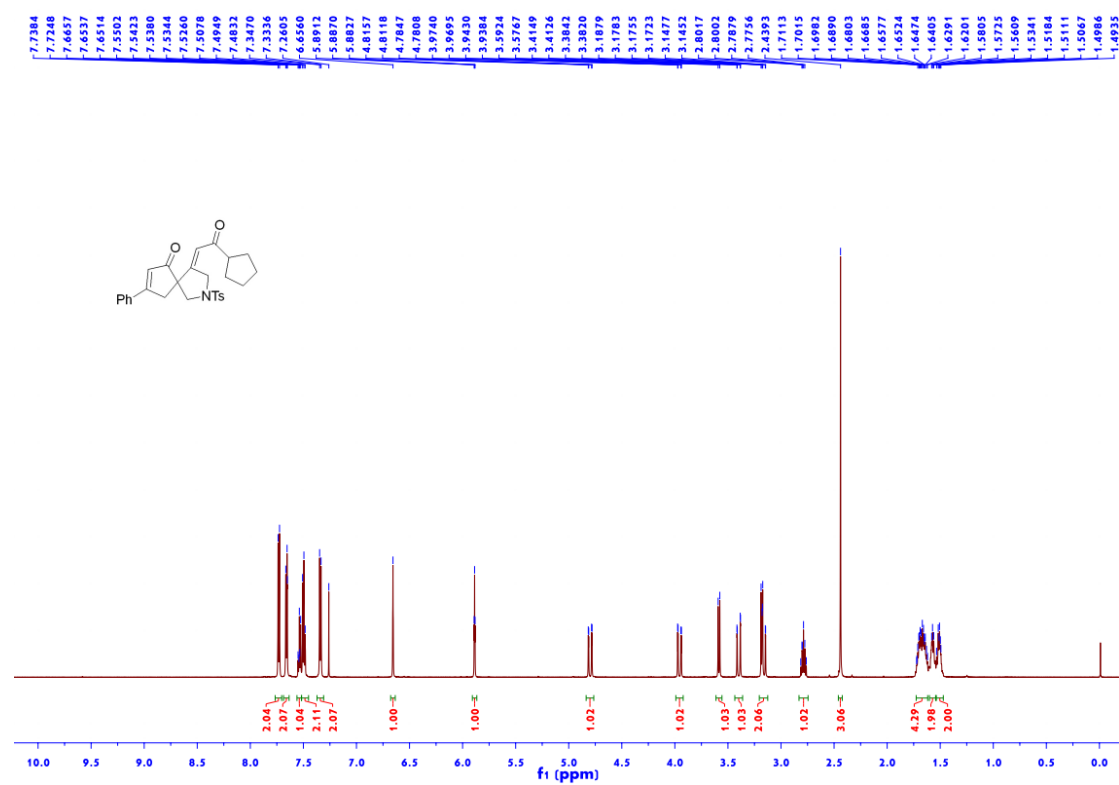


Figure S206 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3s

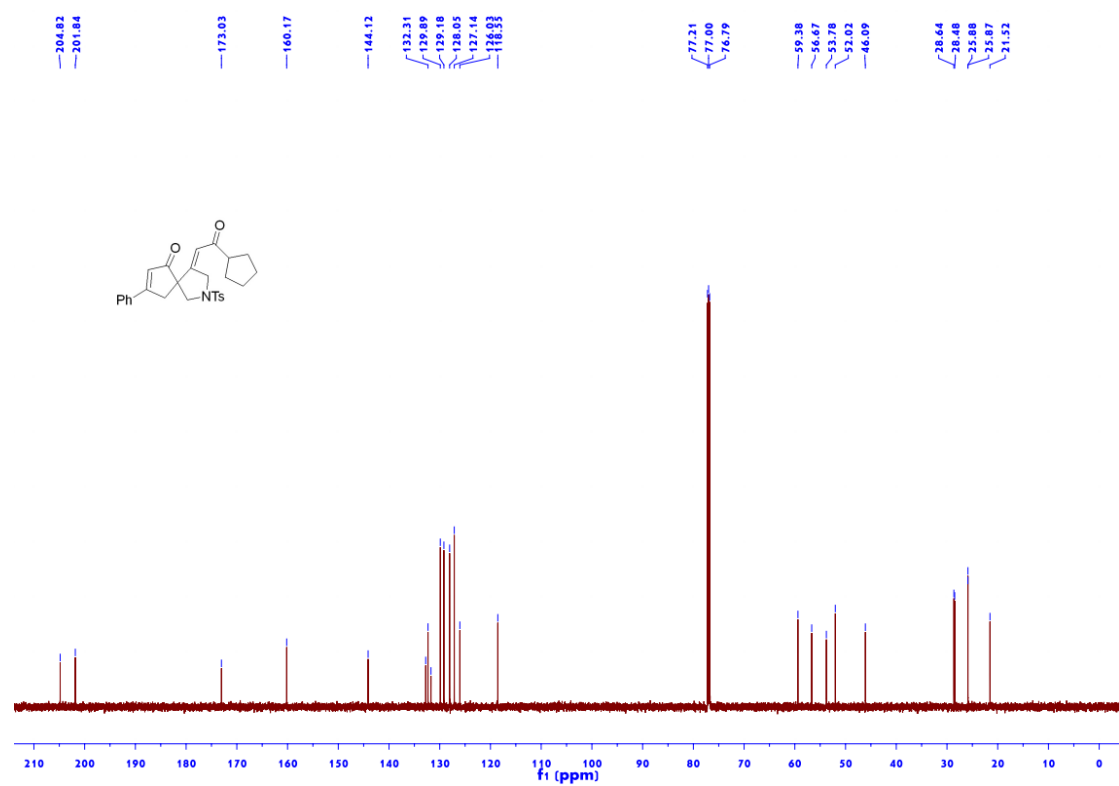


Figure S207 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3t

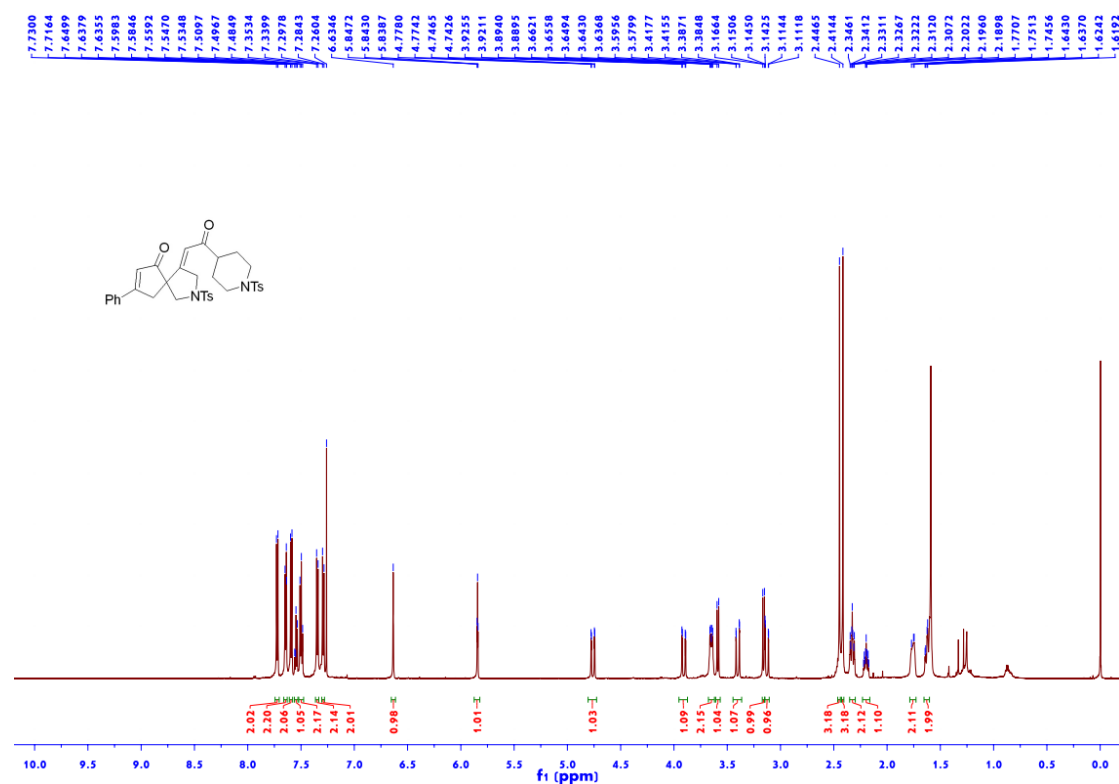


Figure S208 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3t

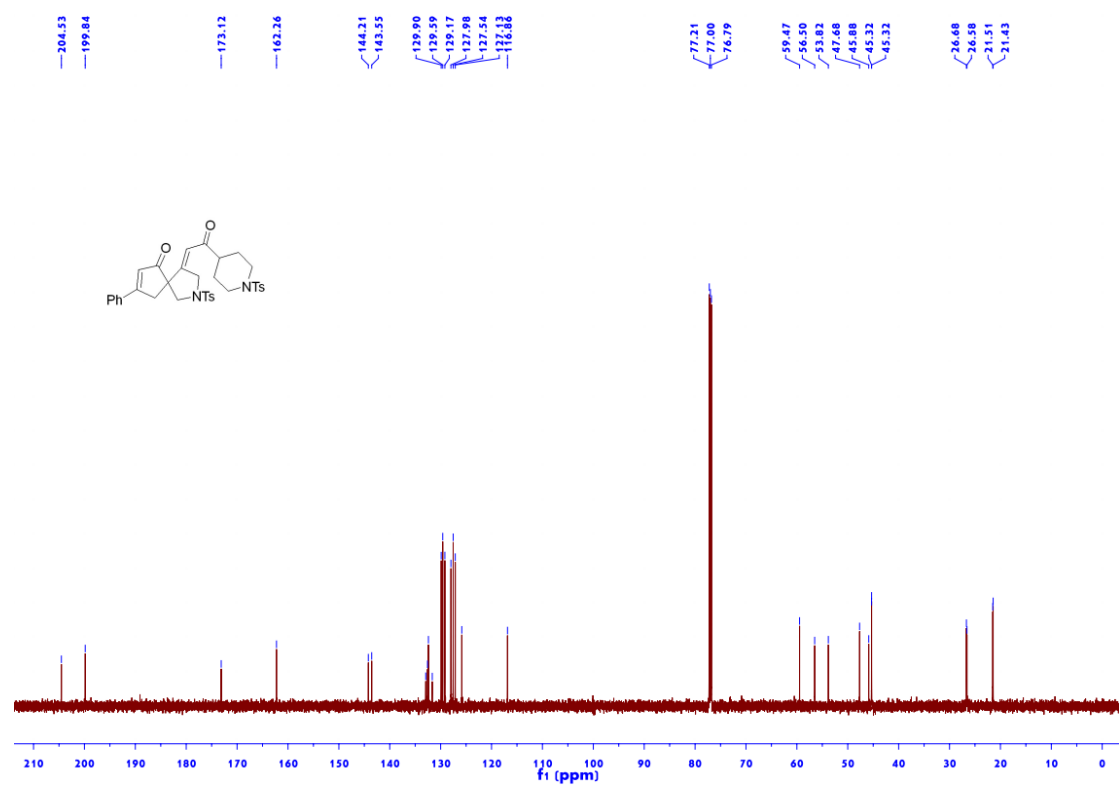


Figure S209 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3u

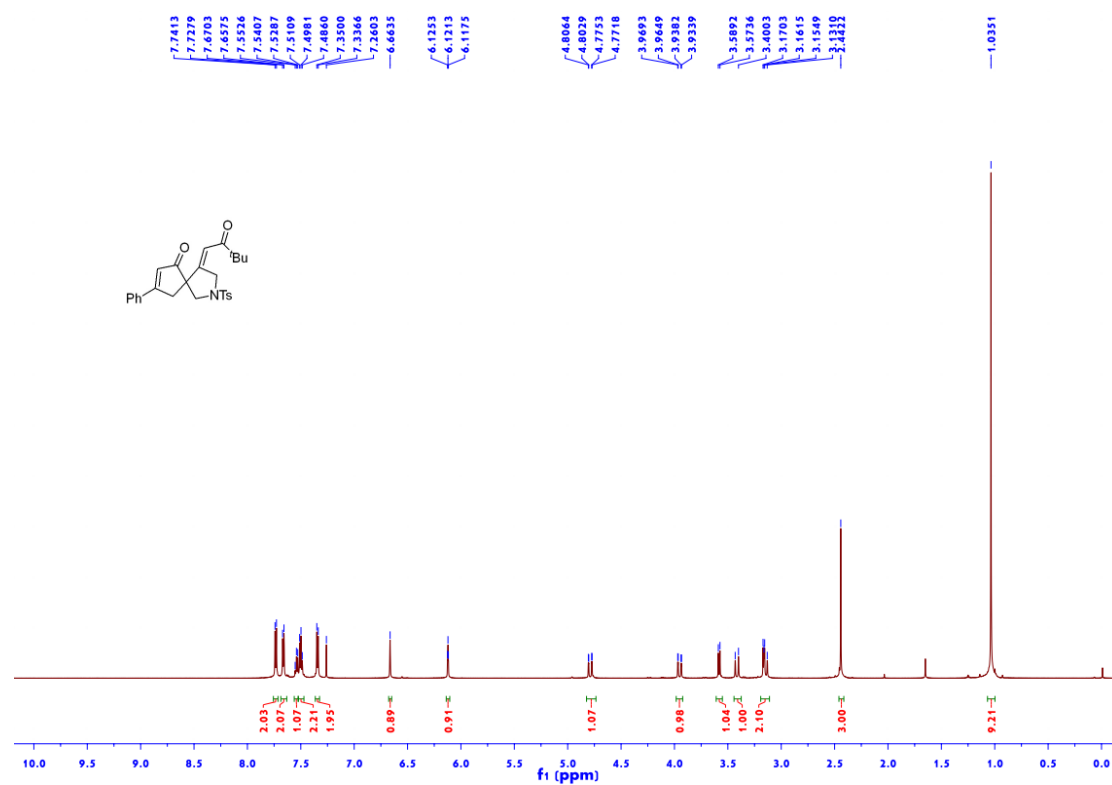


Figure S210 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3u

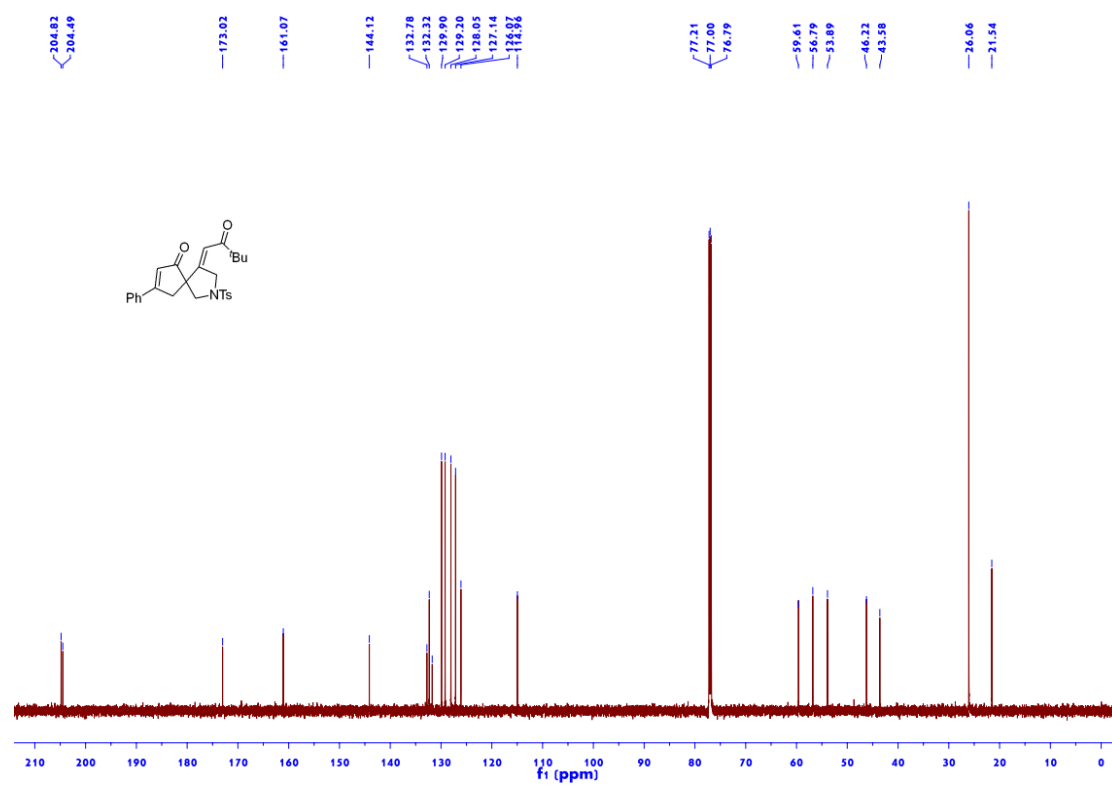


Figure S211 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3v

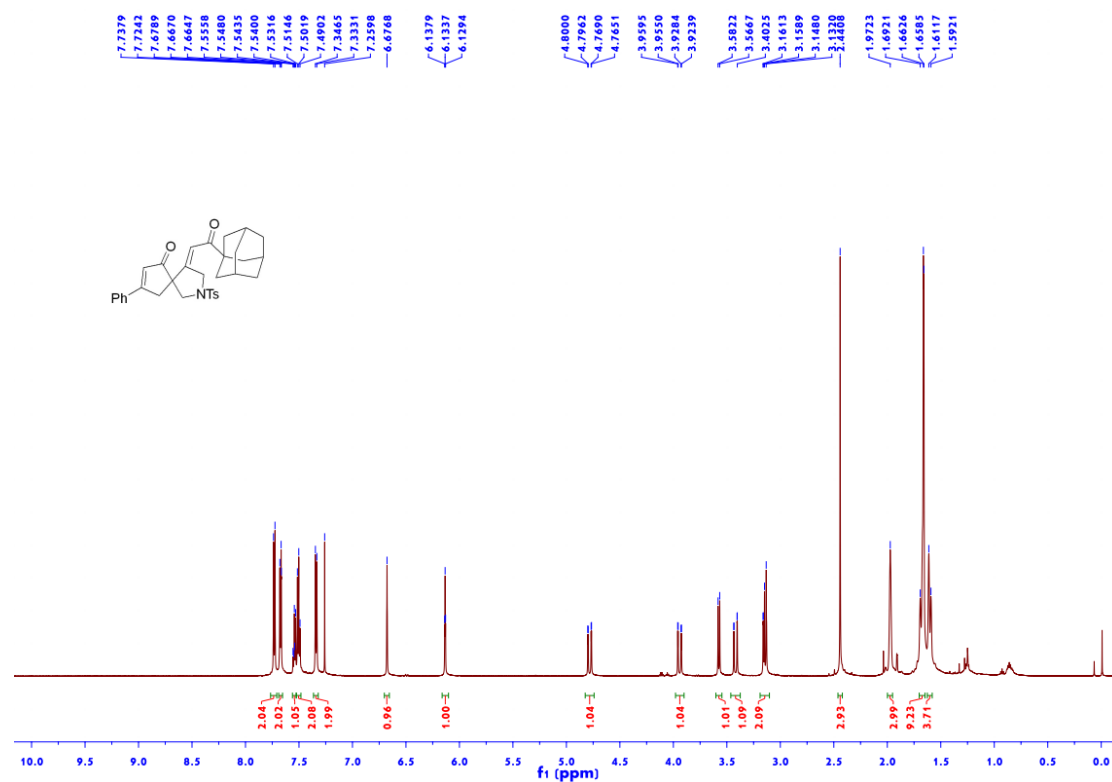


Figure S212 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3v

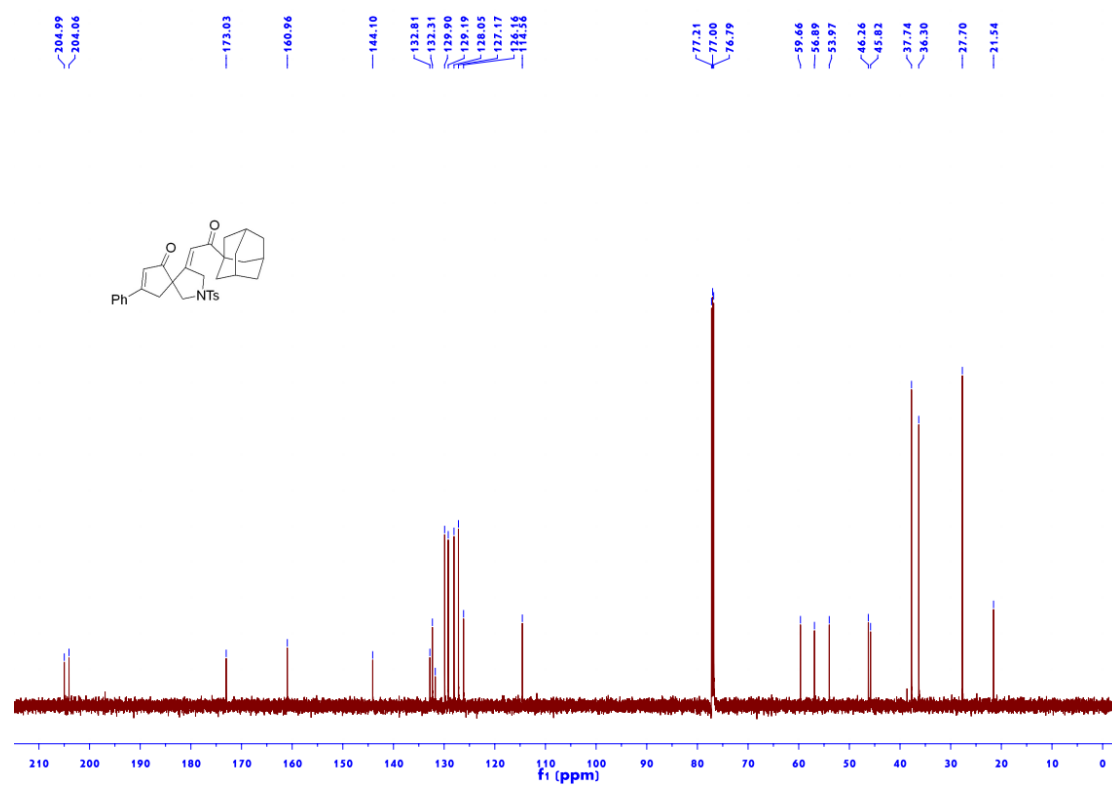


Figure S213 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3w

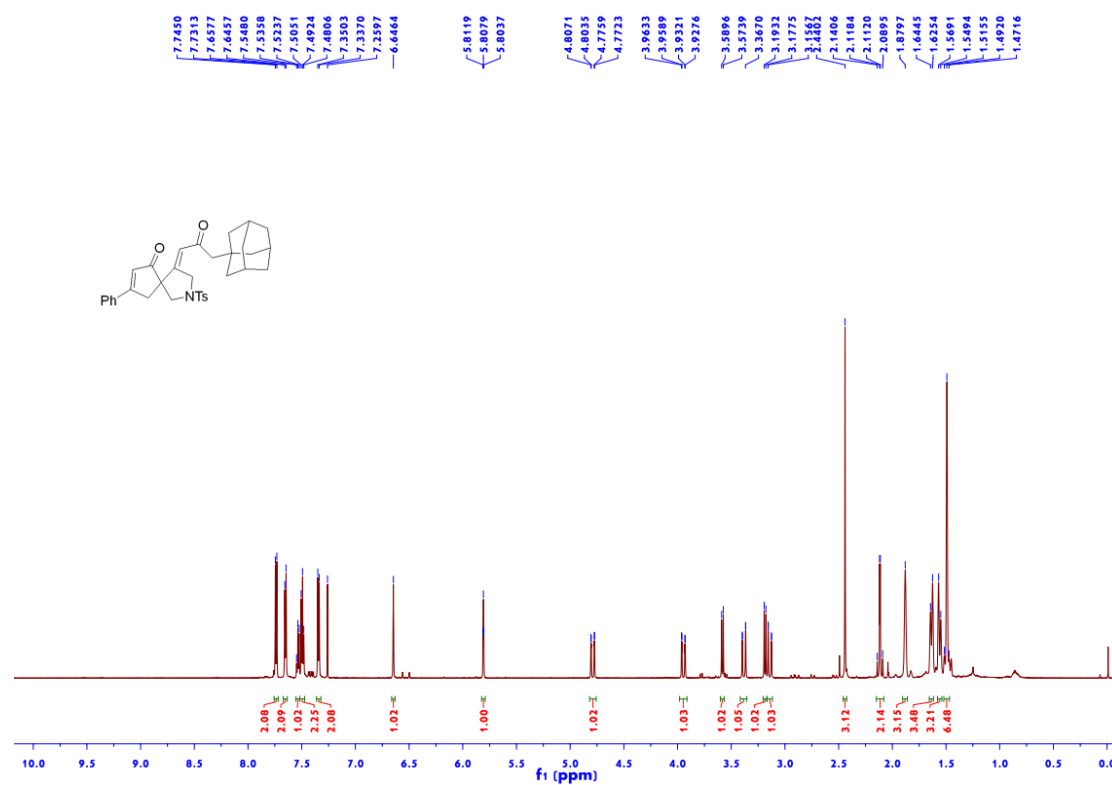


Figure S214 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3w

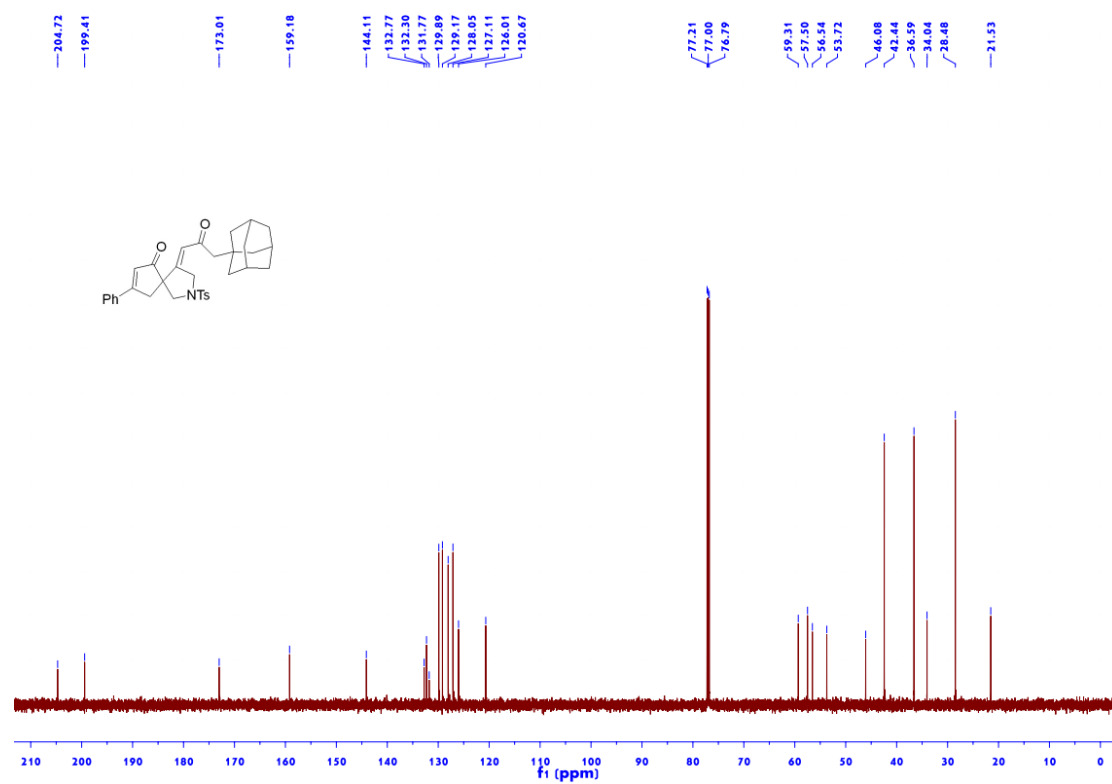


Figure S215 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3x

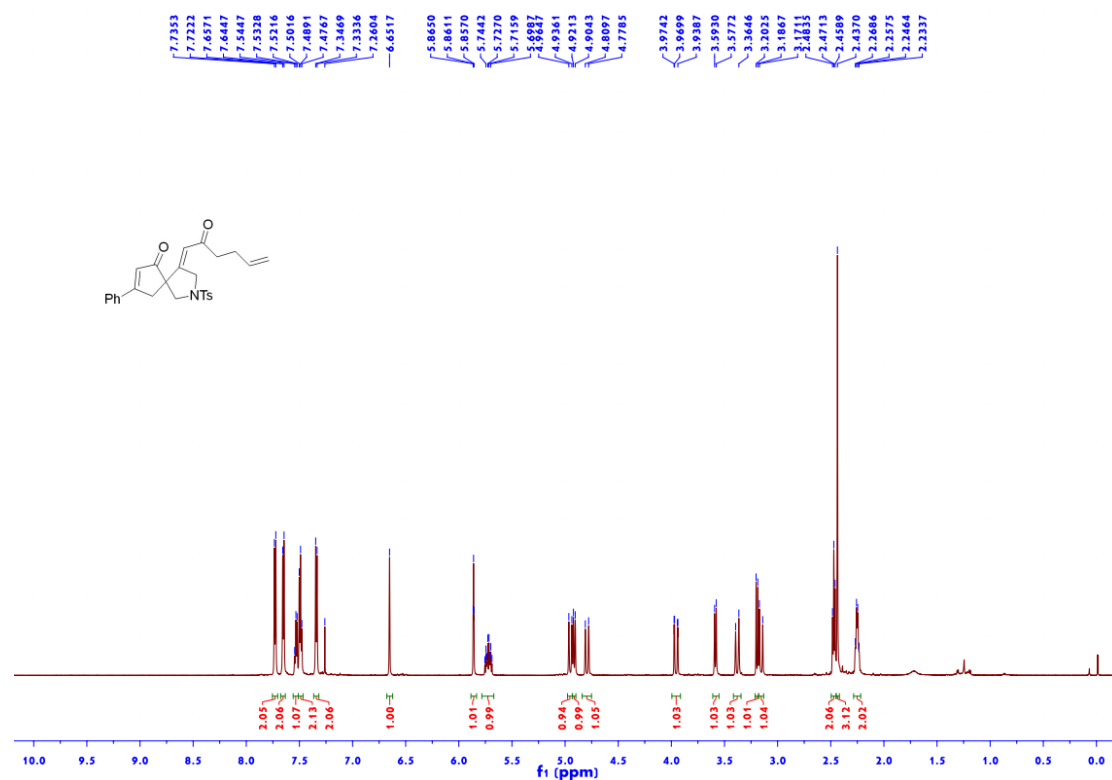


Figure S216 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3x

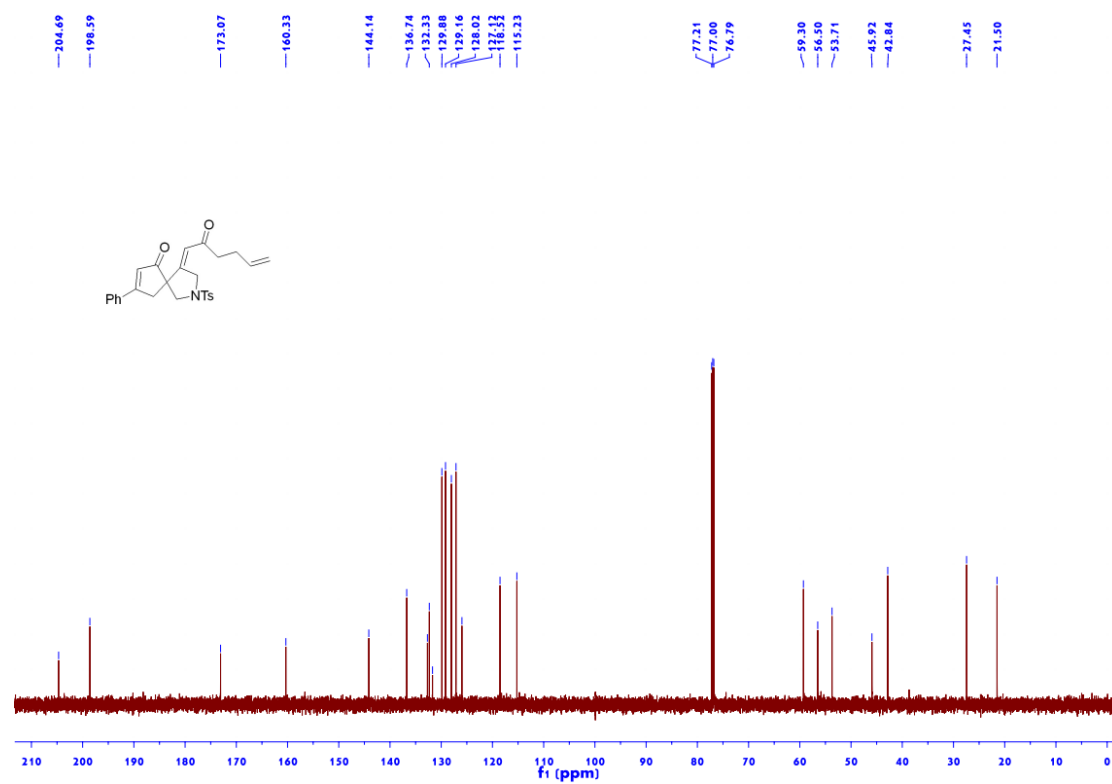




Figure S217 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3y

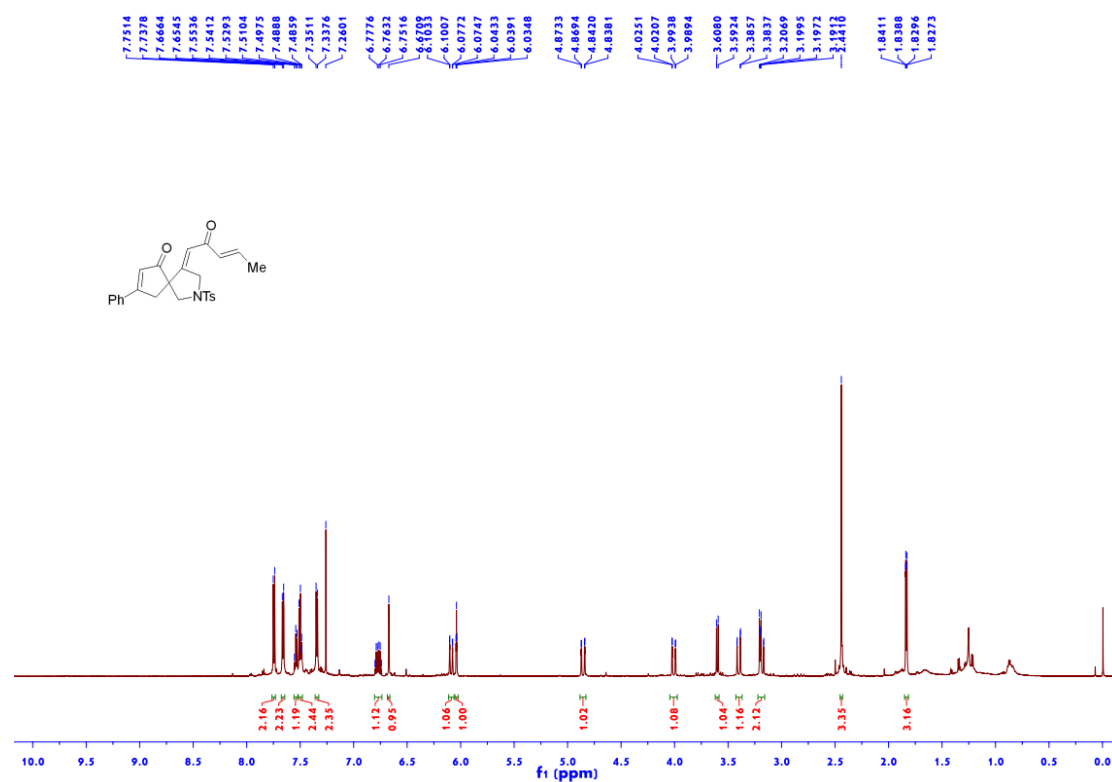


Figure S218 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3y

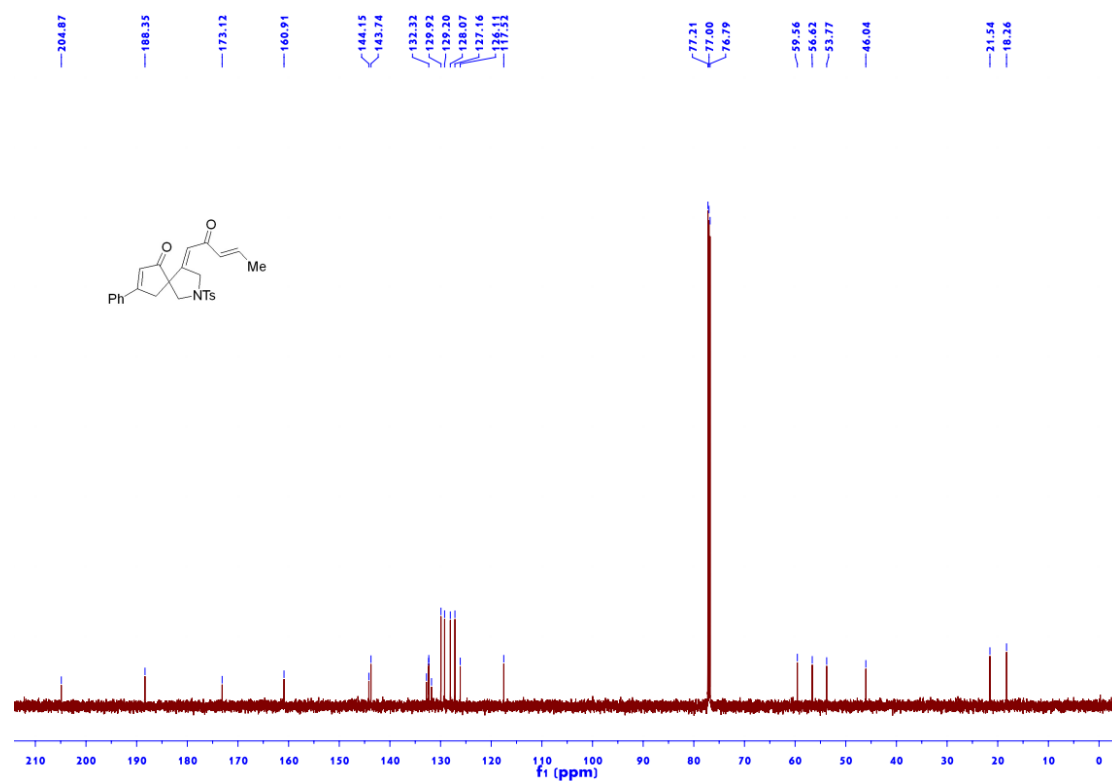


Figure S219 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3z

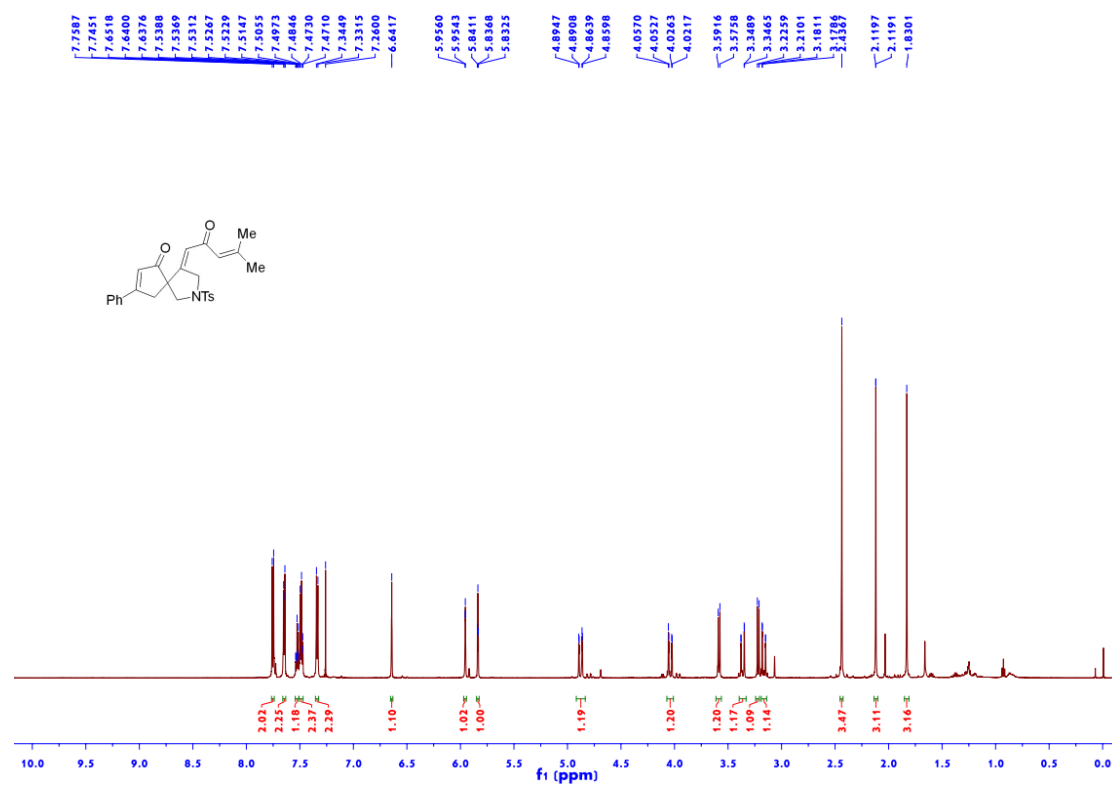


Figure S220 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3z

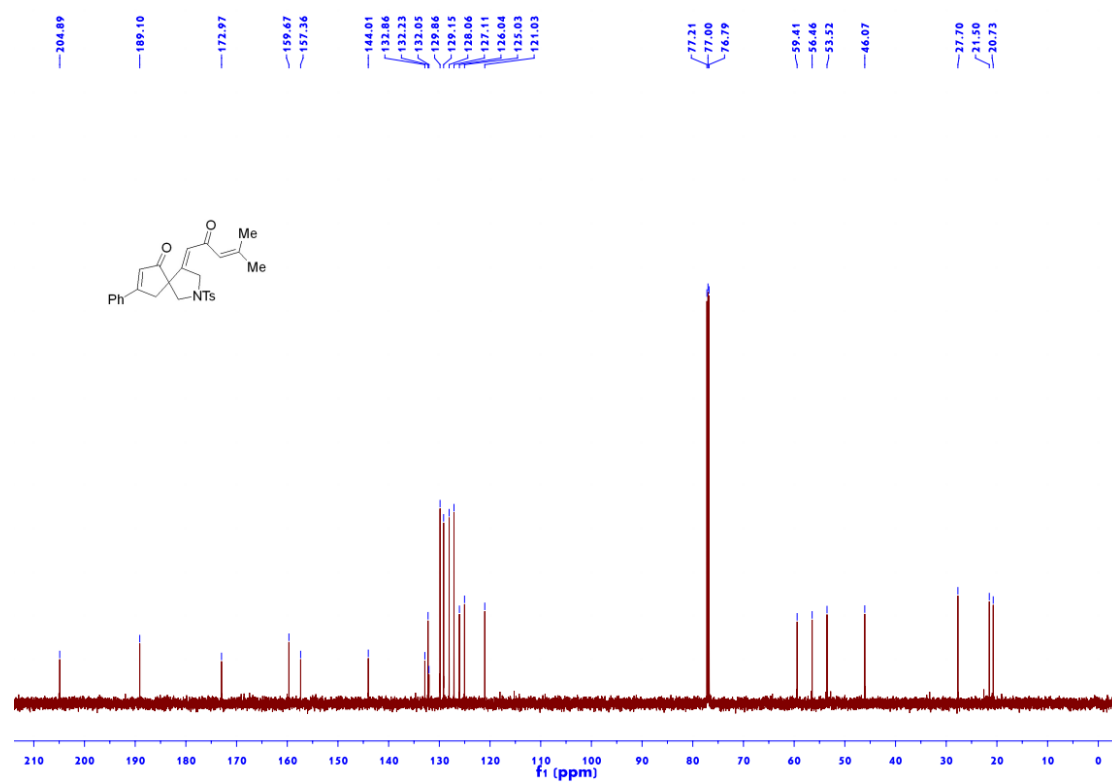


Figure S221 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3aa

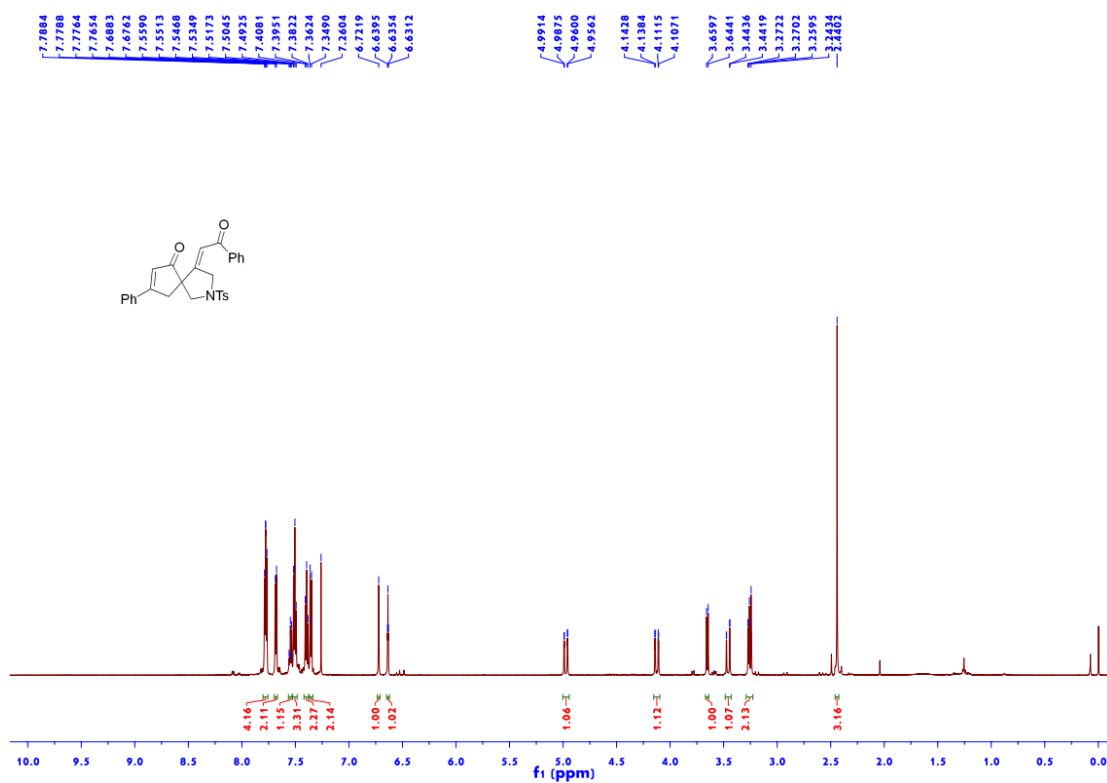


Figure S222 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3aa

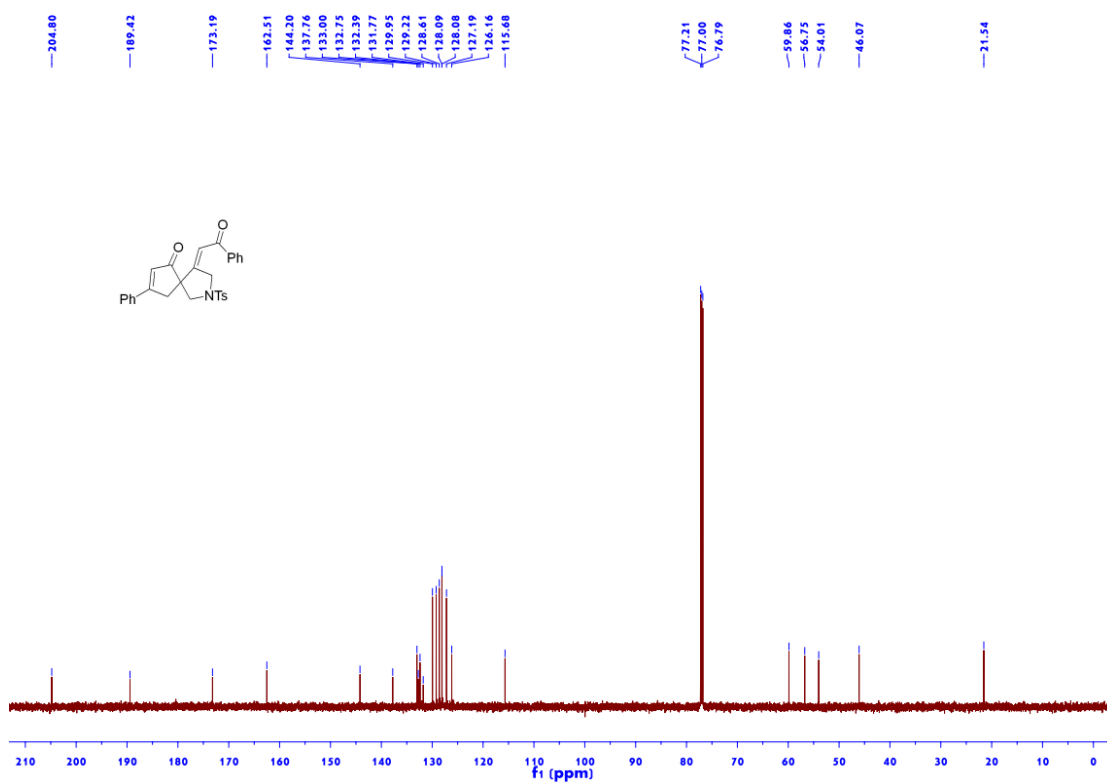


Figure S223 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3ab'

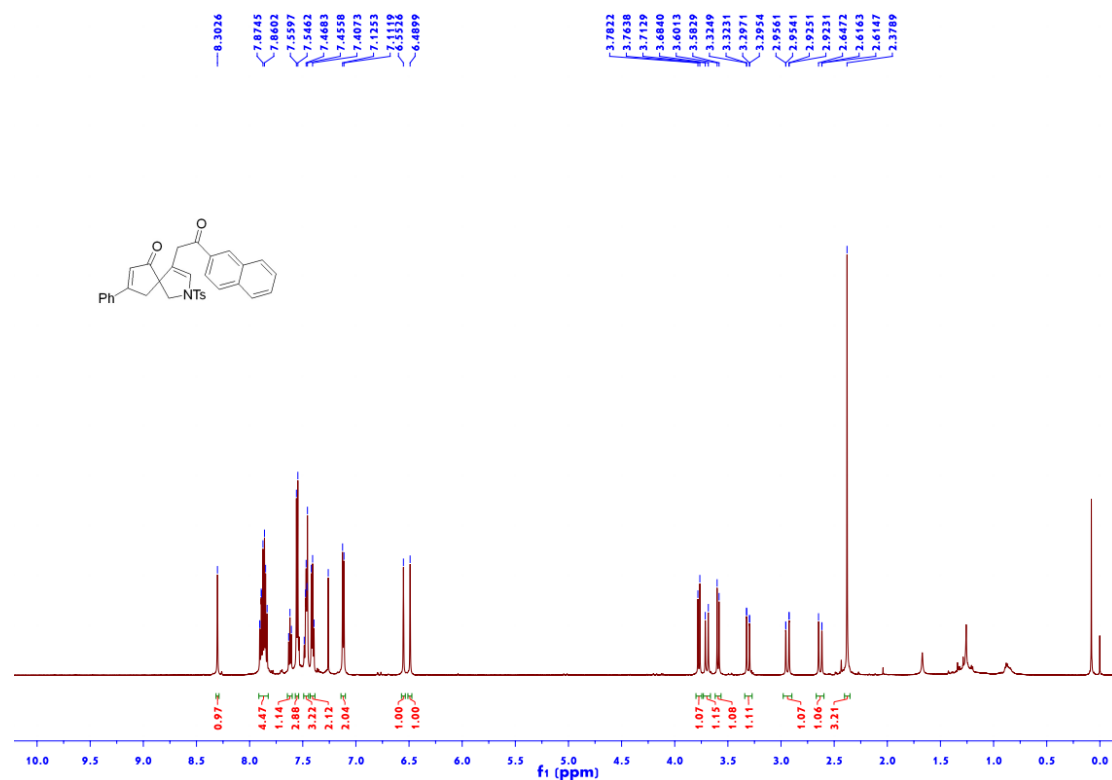


Figure S224 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3ab'

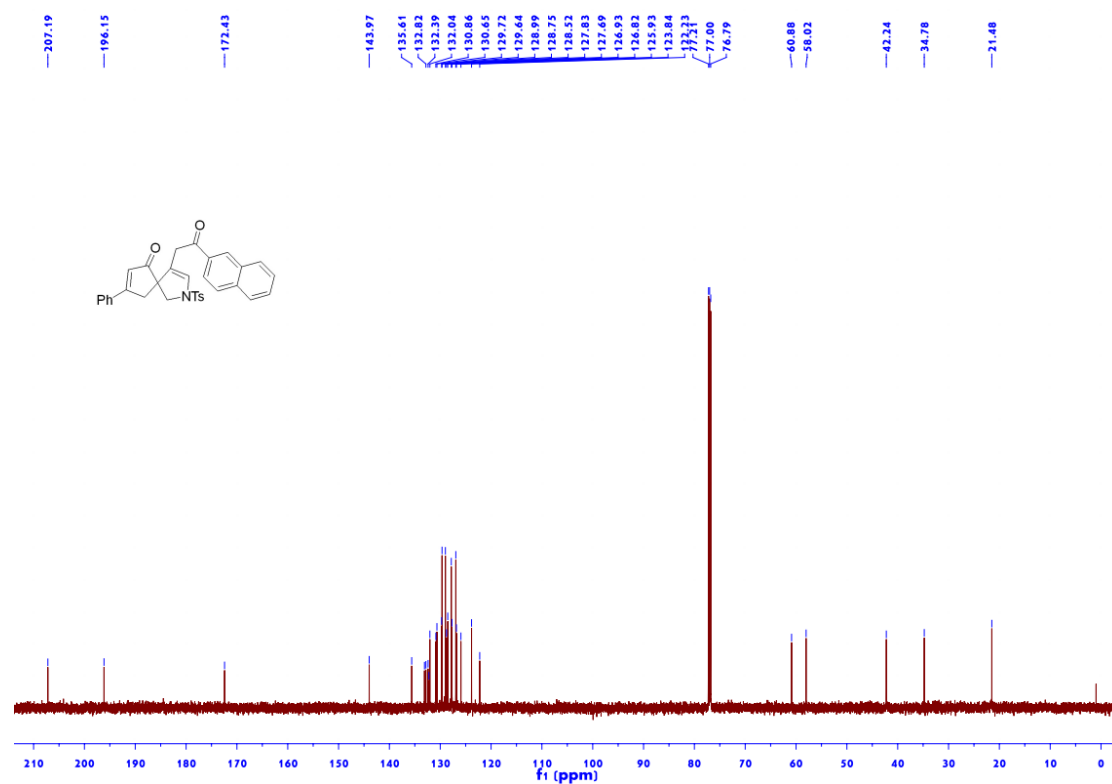


Figure S225 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3ac

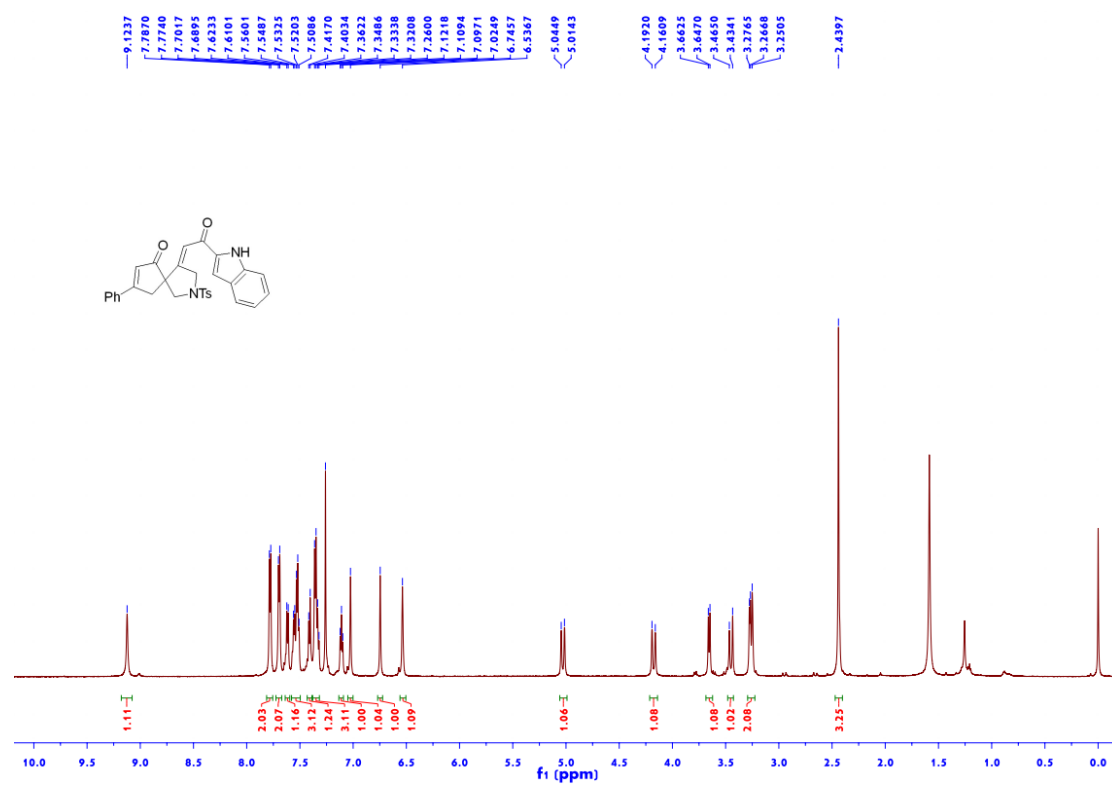


Figure S226 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3ac

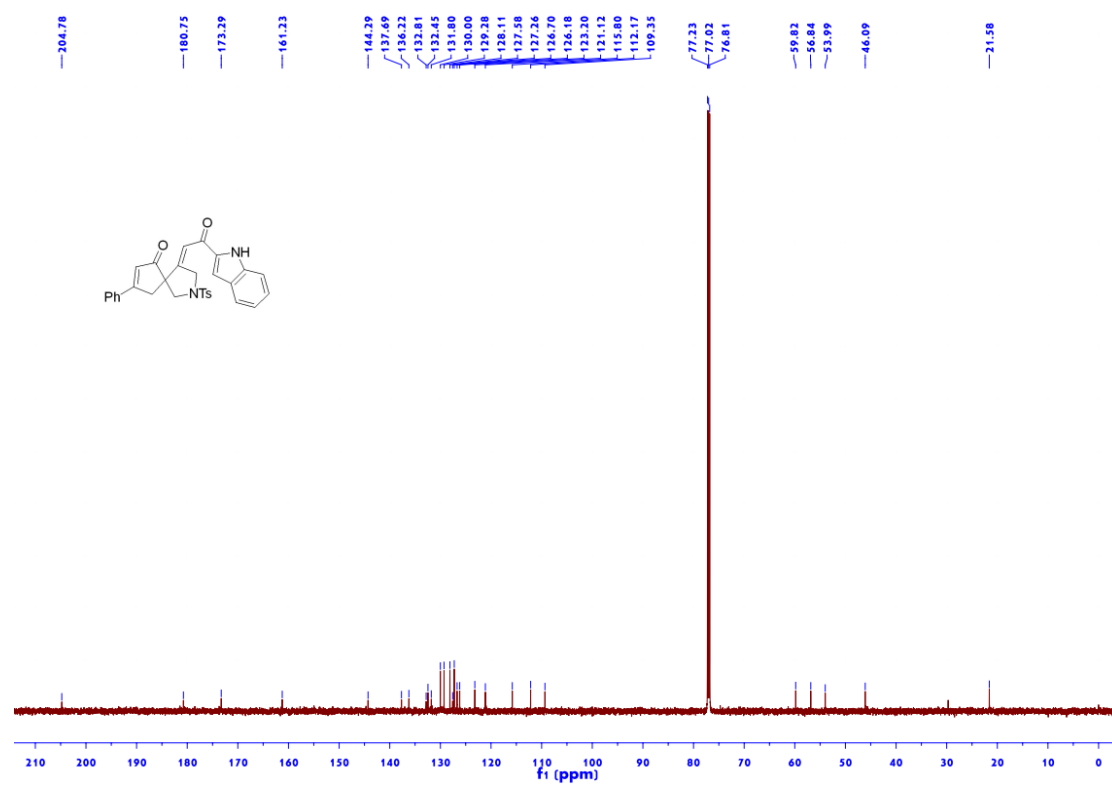


Figure S227 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3ae

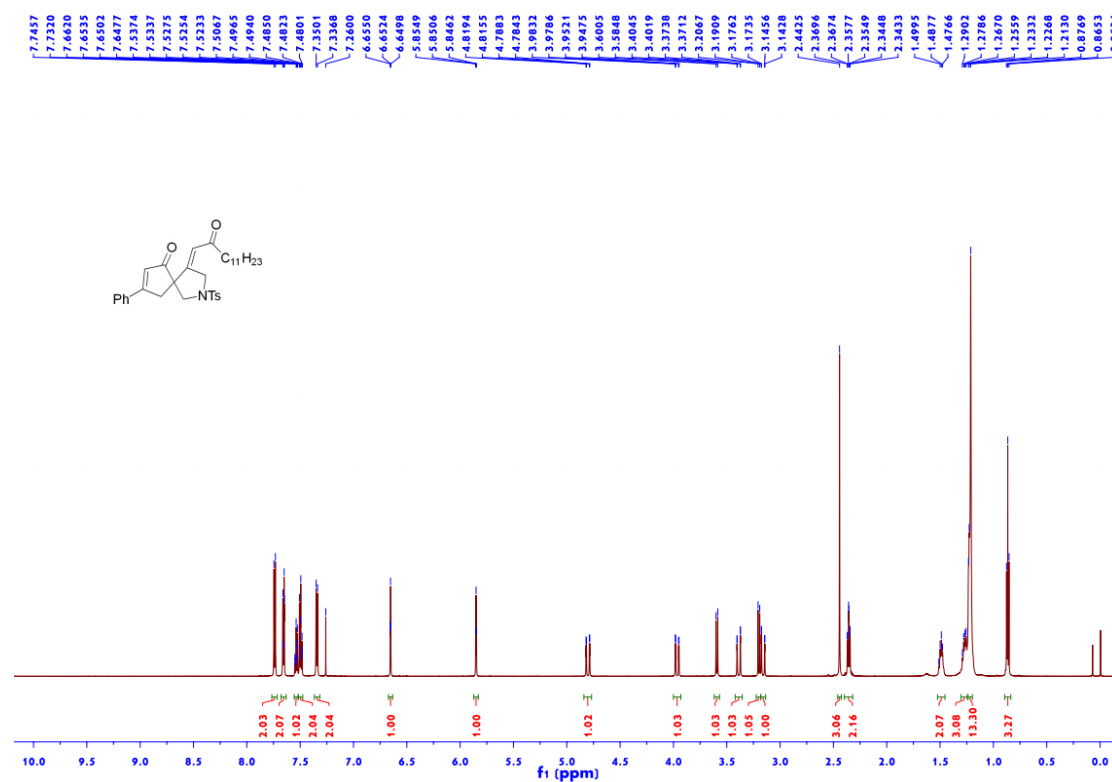


Figure S228 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3ae

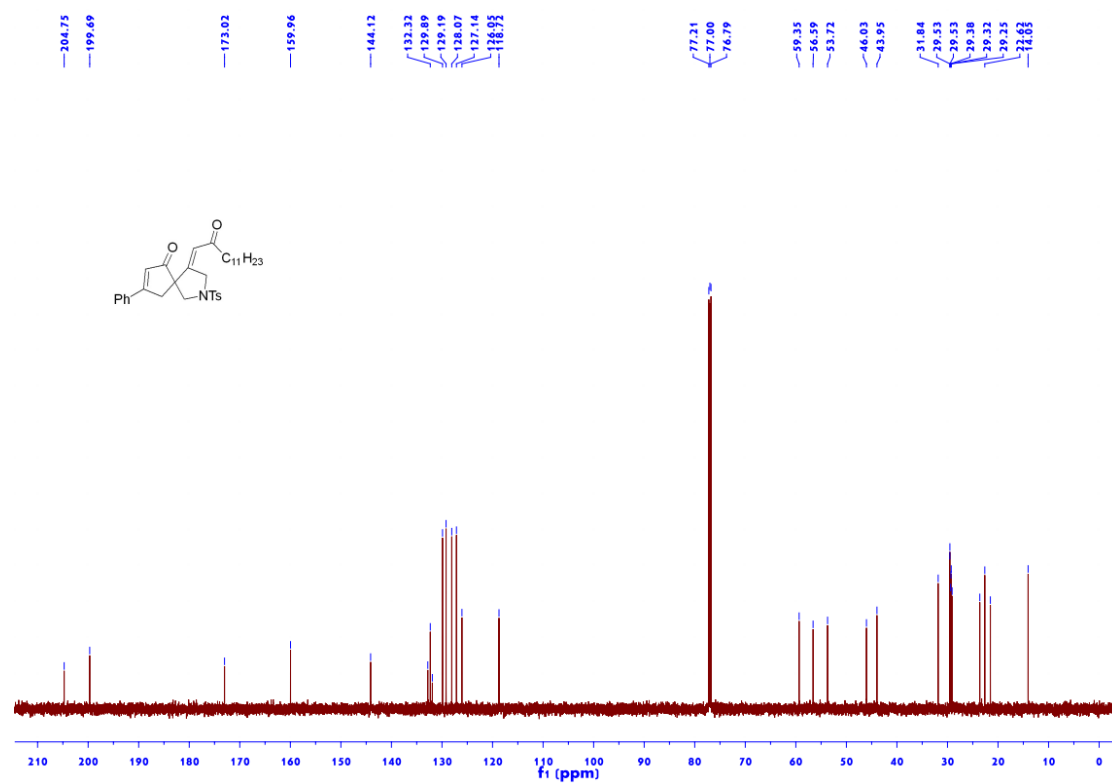


Figure S229 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3af

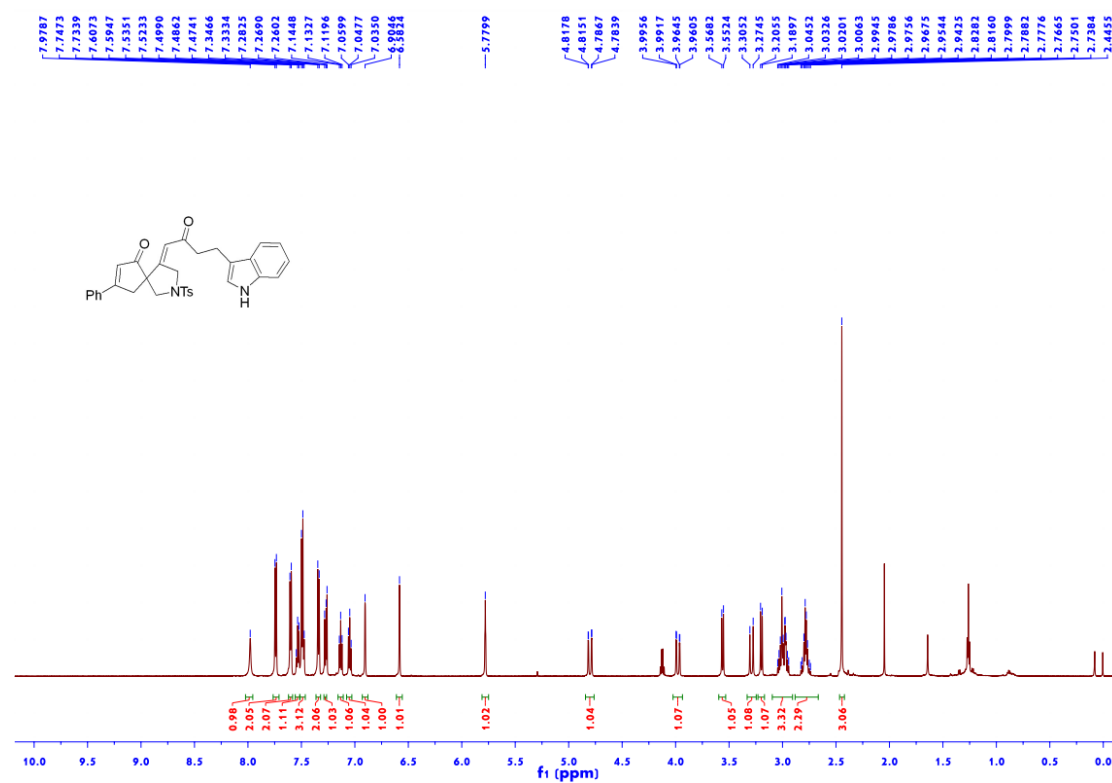


Figure S230 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3af

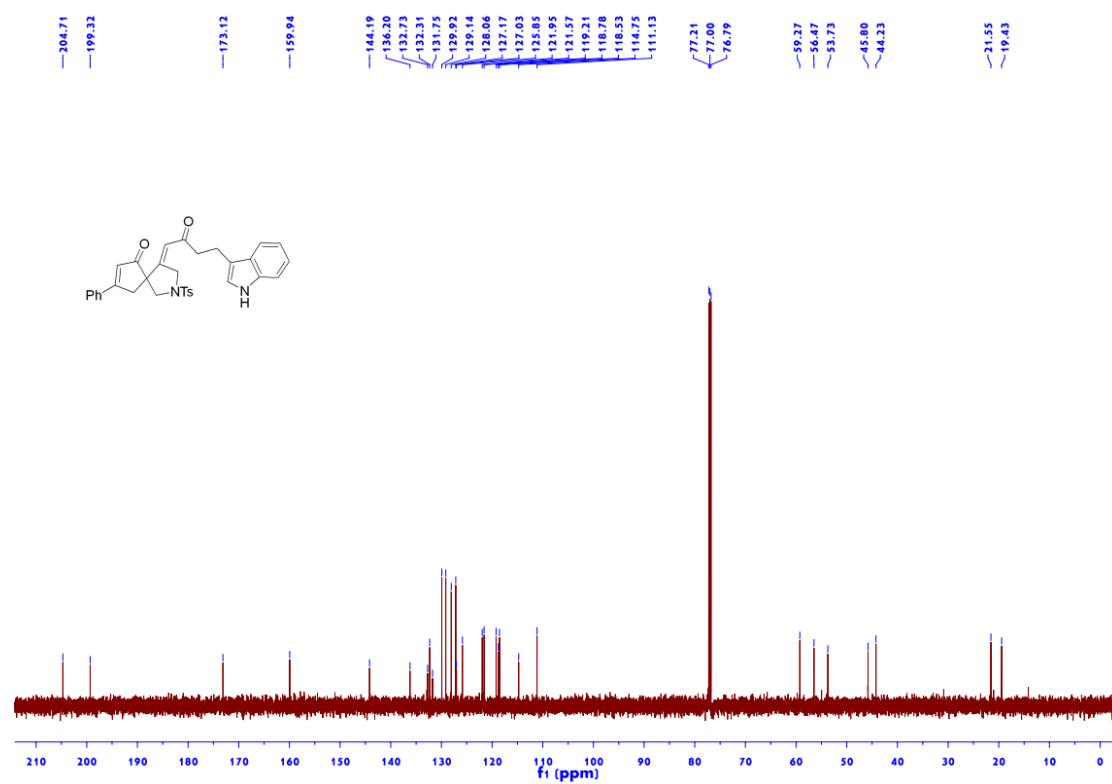


Figure S231 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3ag'

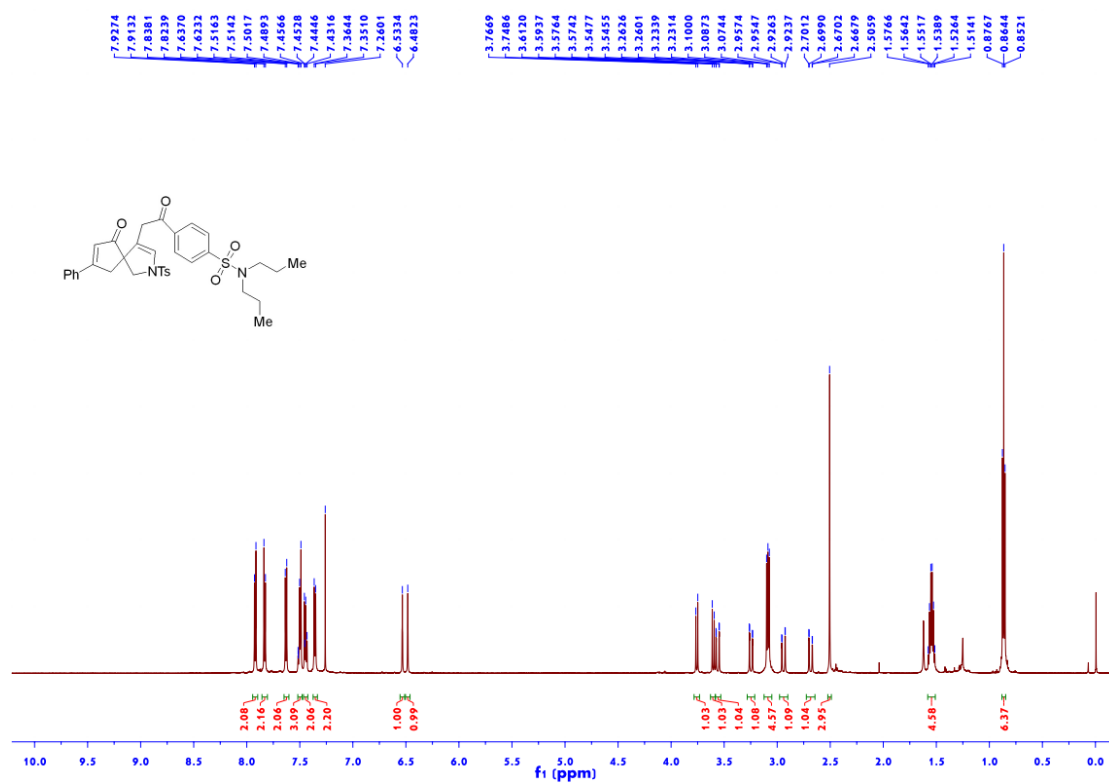


Figure S232 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3ag'

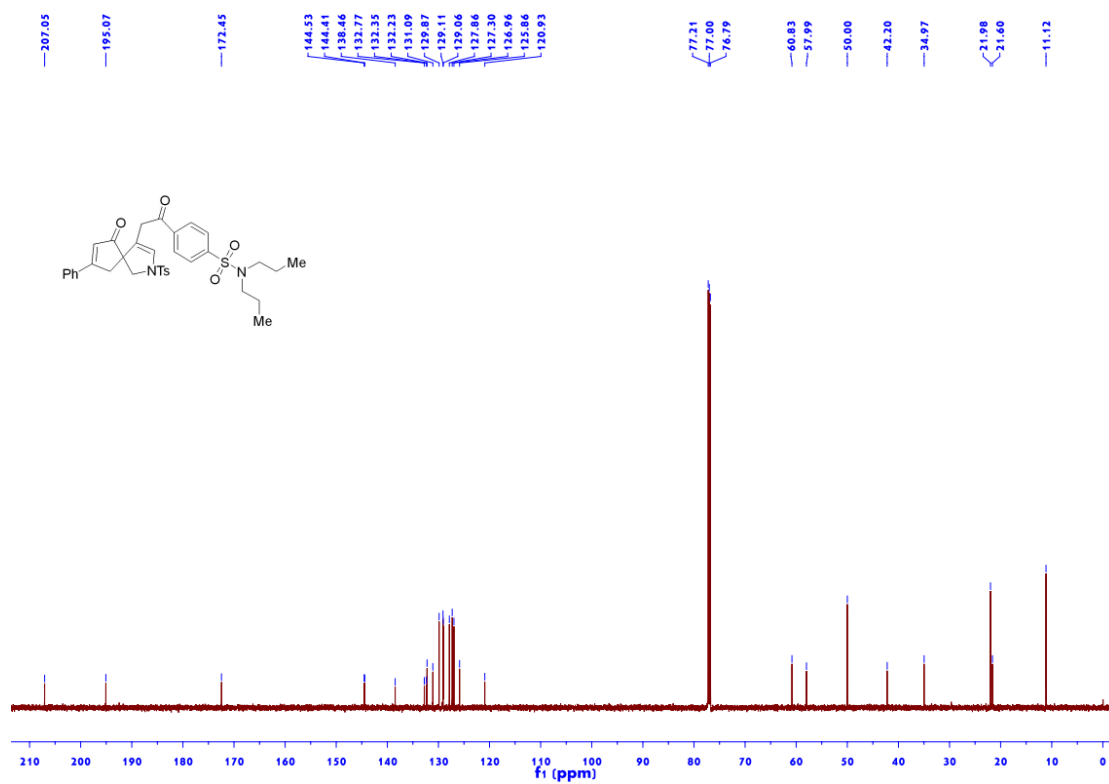




Figure S233 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3ah

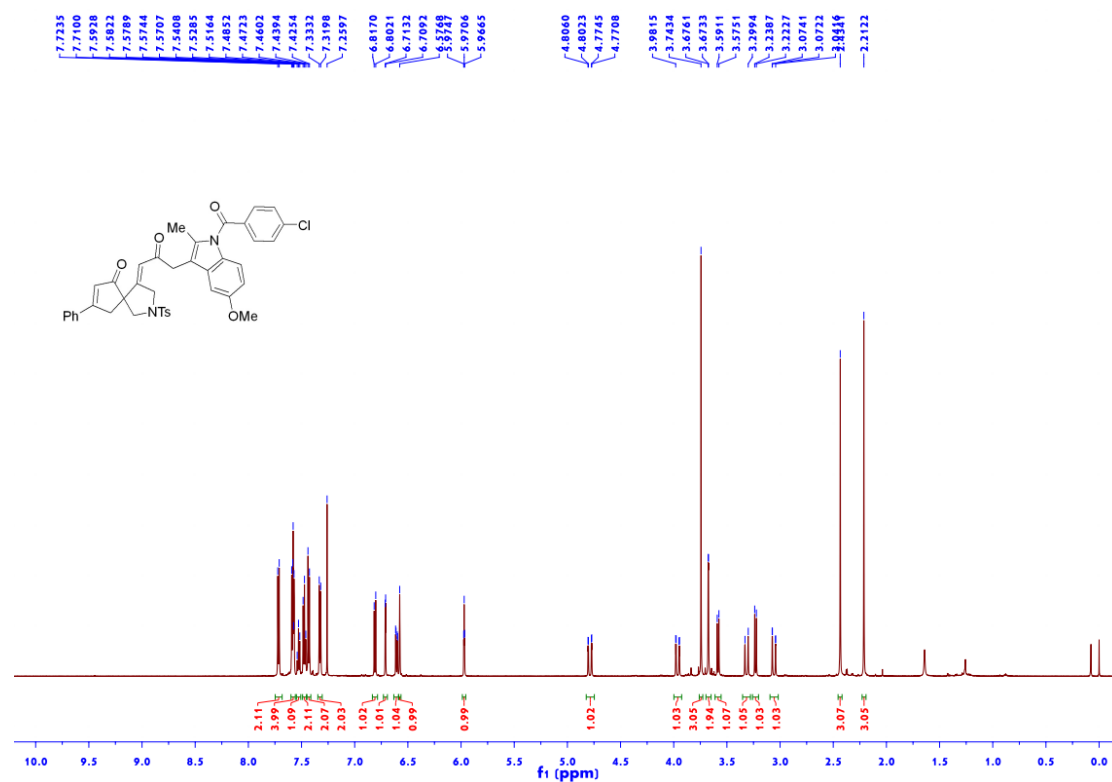


Figure S234 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3ah

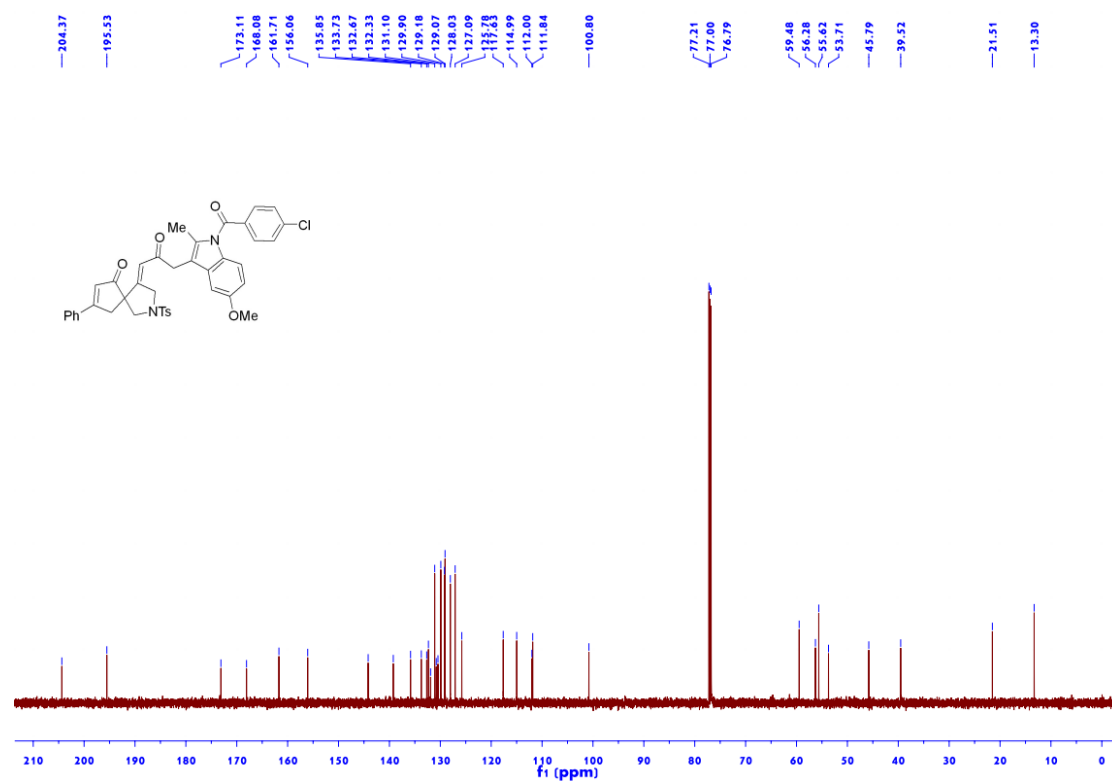


Figure S235 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 3ai

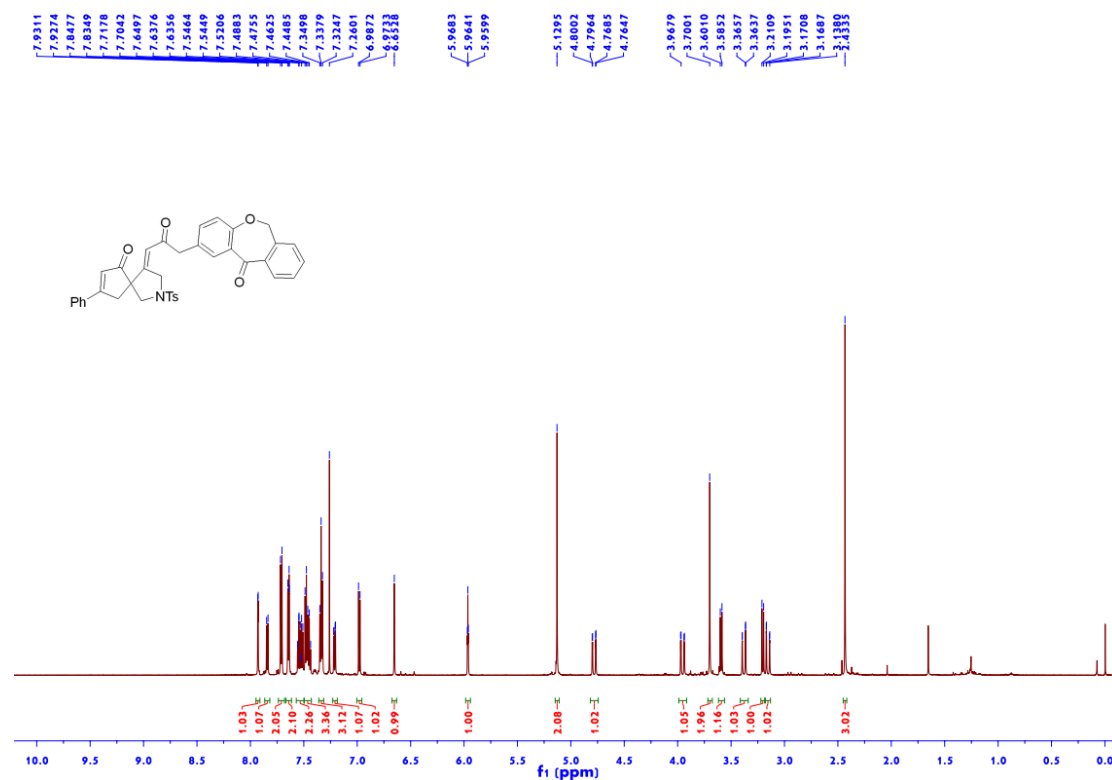


Figure S236 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 3ai

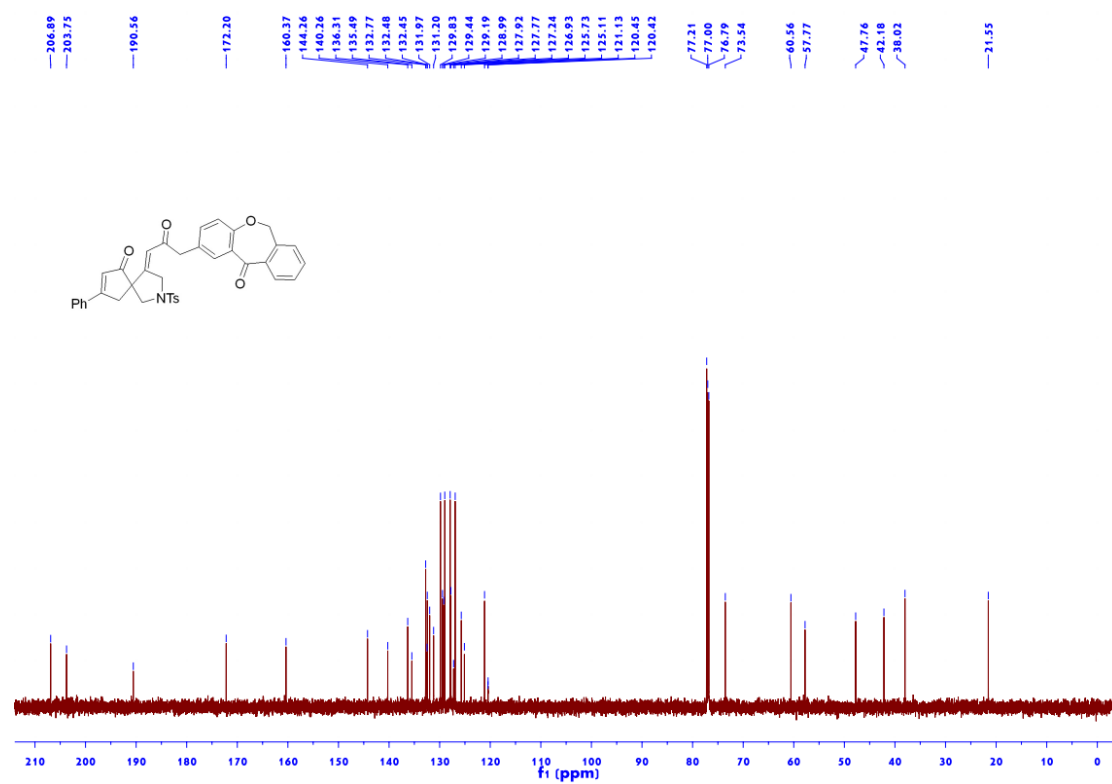


Figure S237 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5a

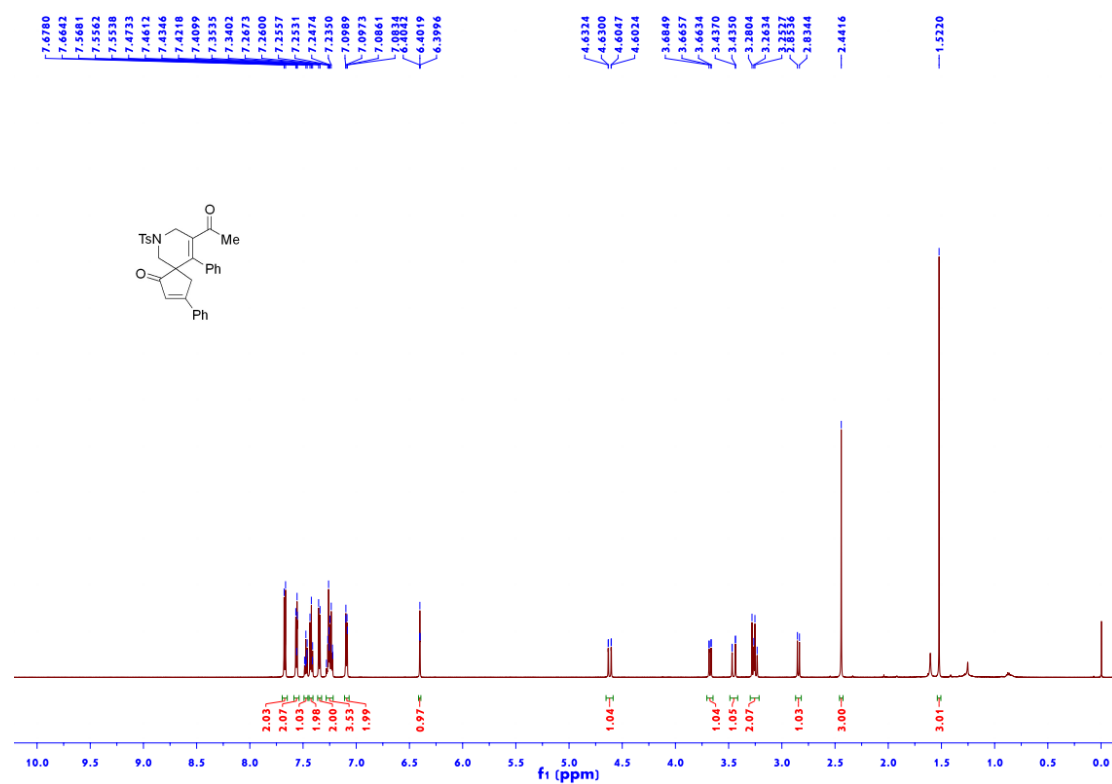


Figure S238 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5a

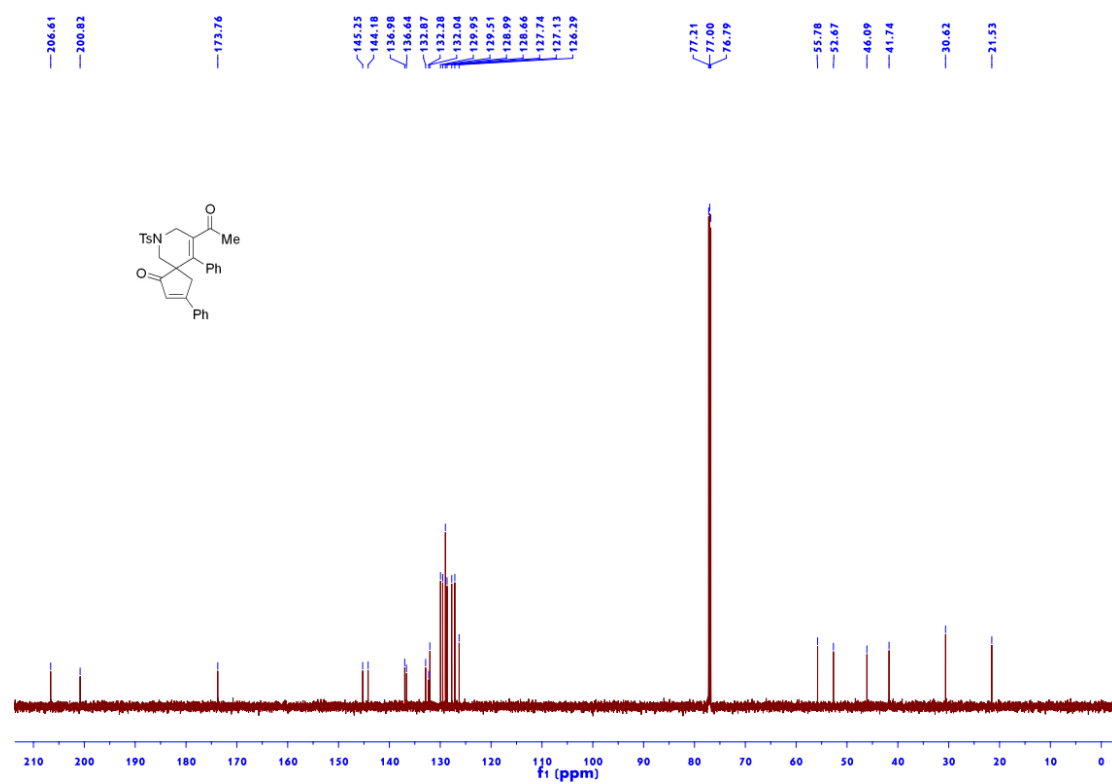


Figure S239 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5b

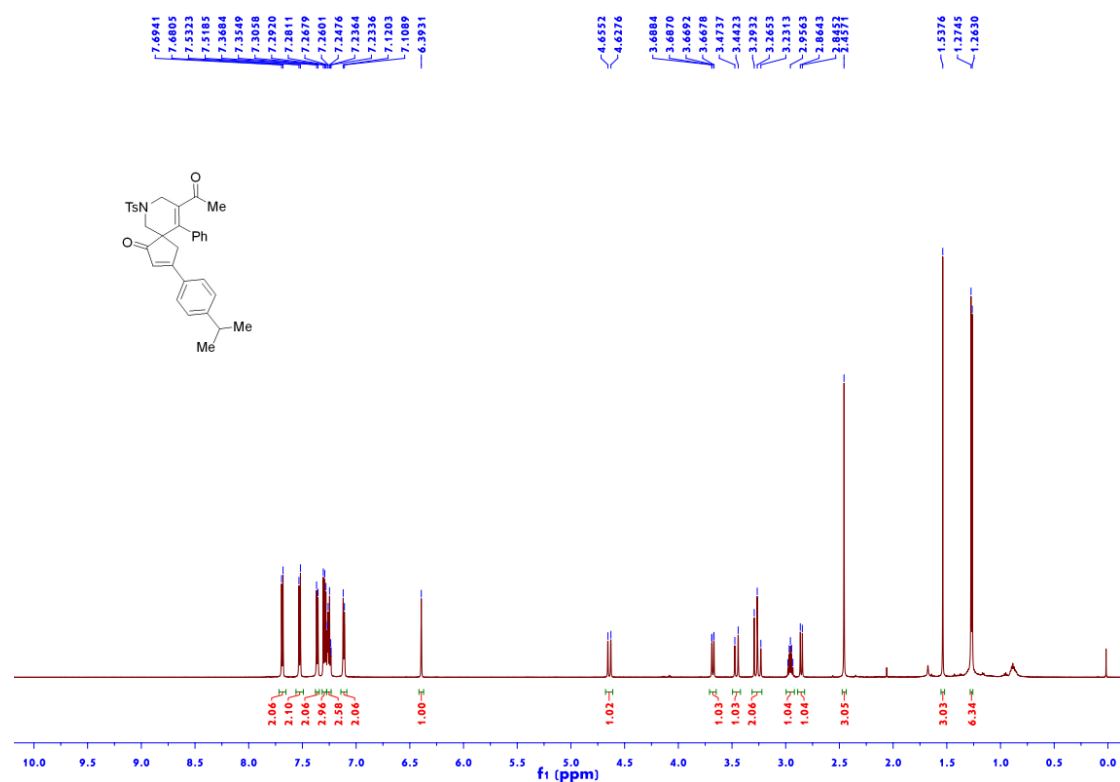


Figure S240 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5b

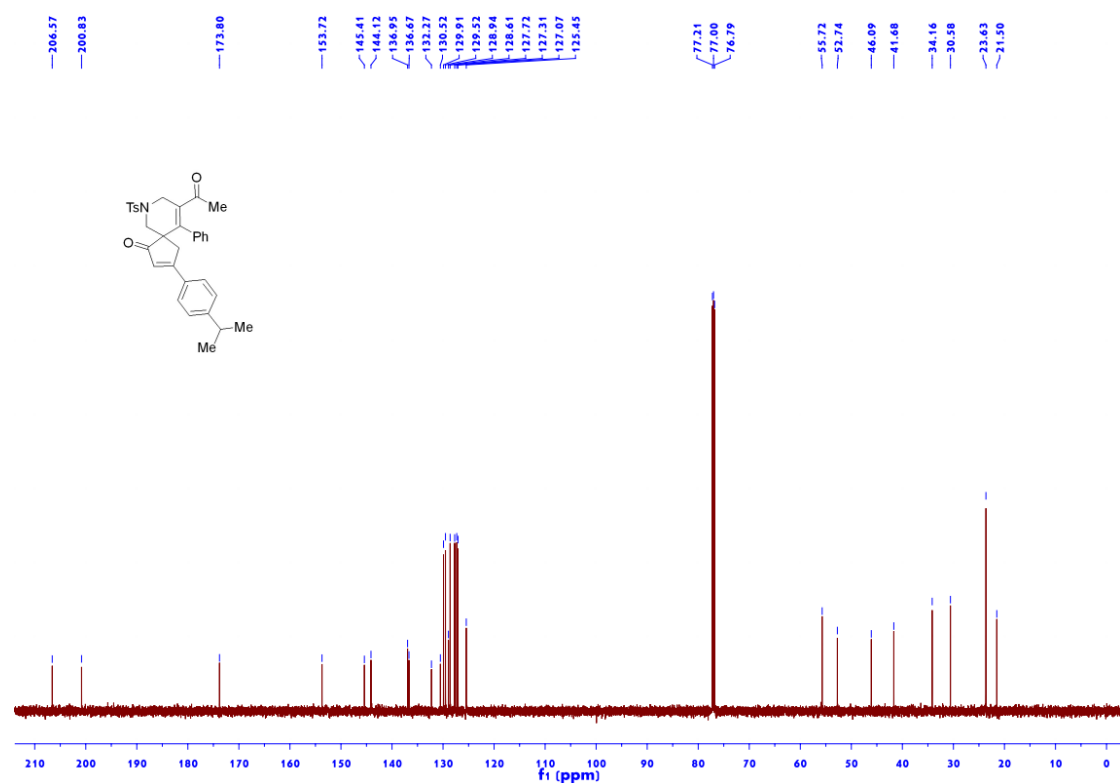


Figure S241 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5c

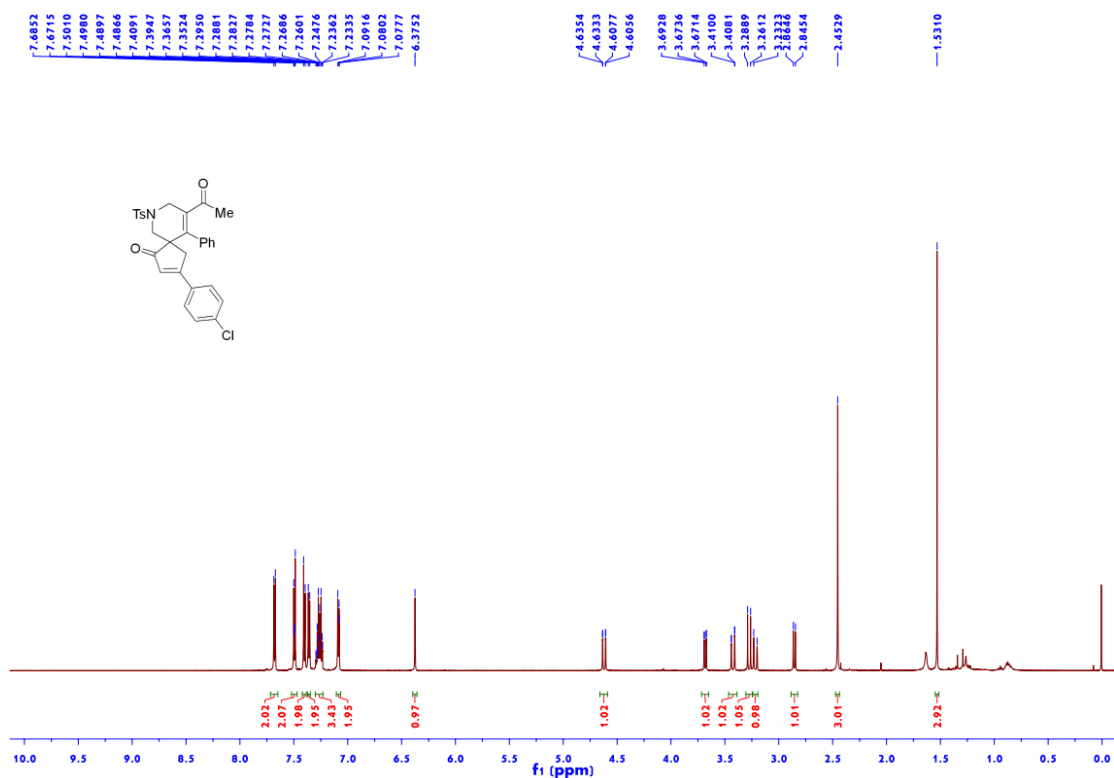


Figure S242 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5c

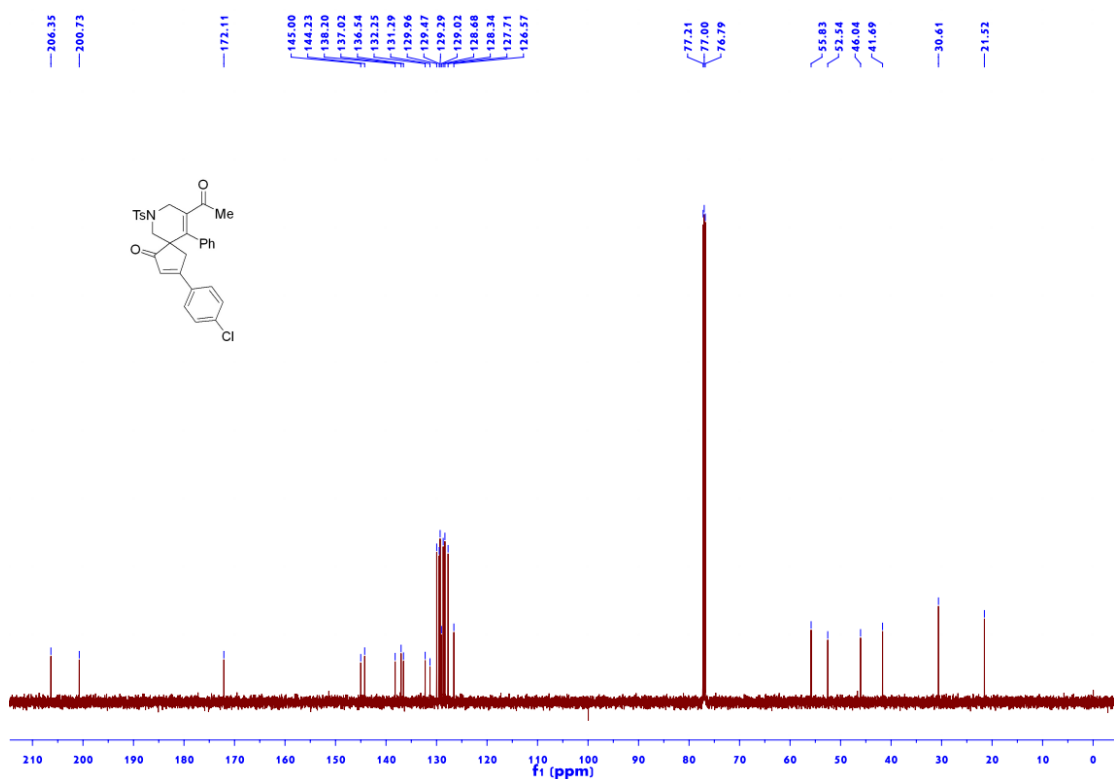


Figure S243 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5d

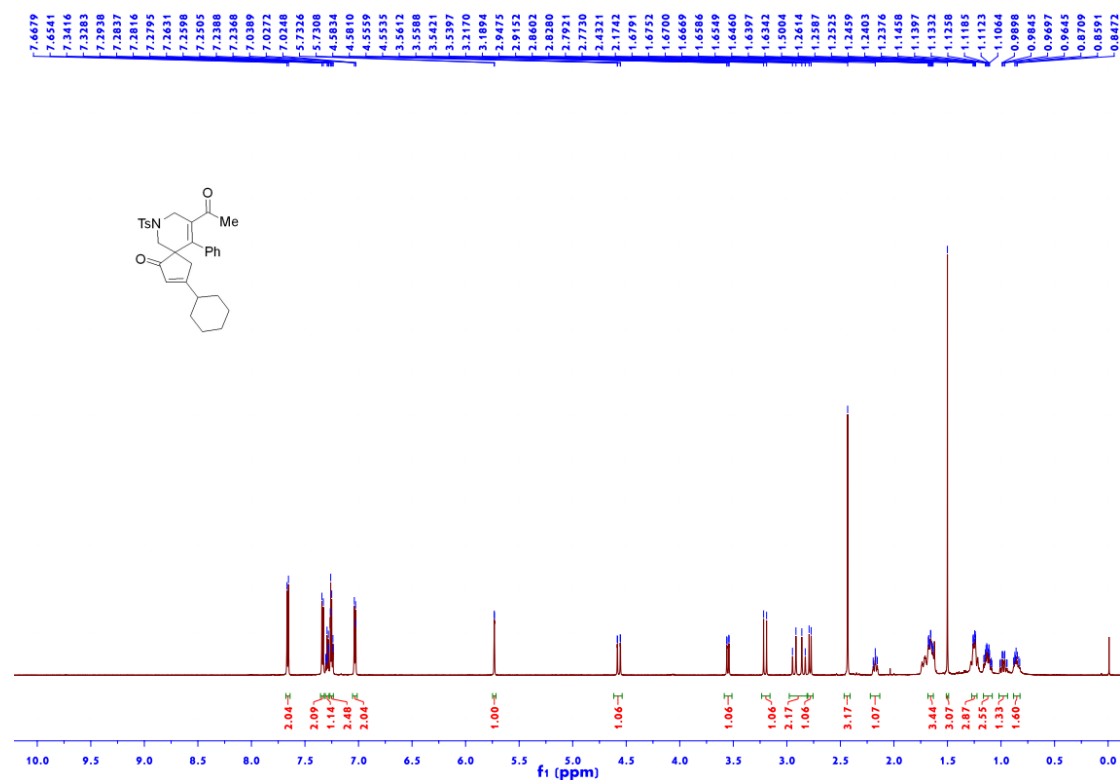


Figure S244 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5d

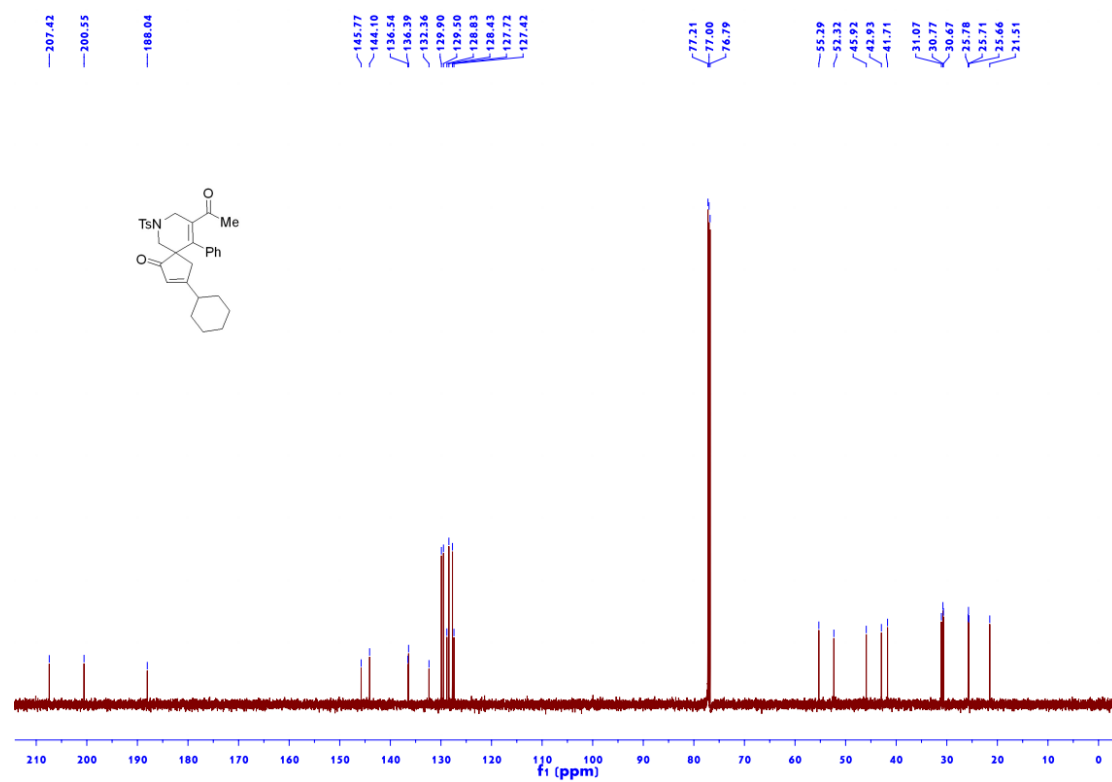


Figure S245 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5e

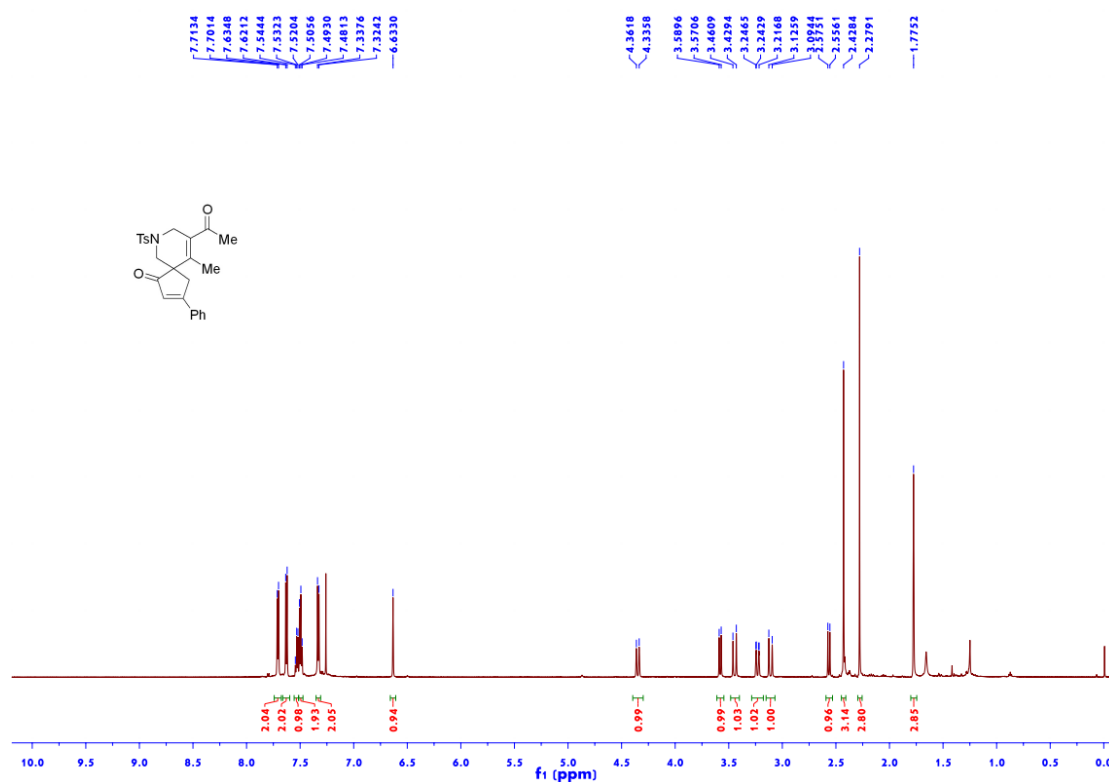


Figure S246 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5e

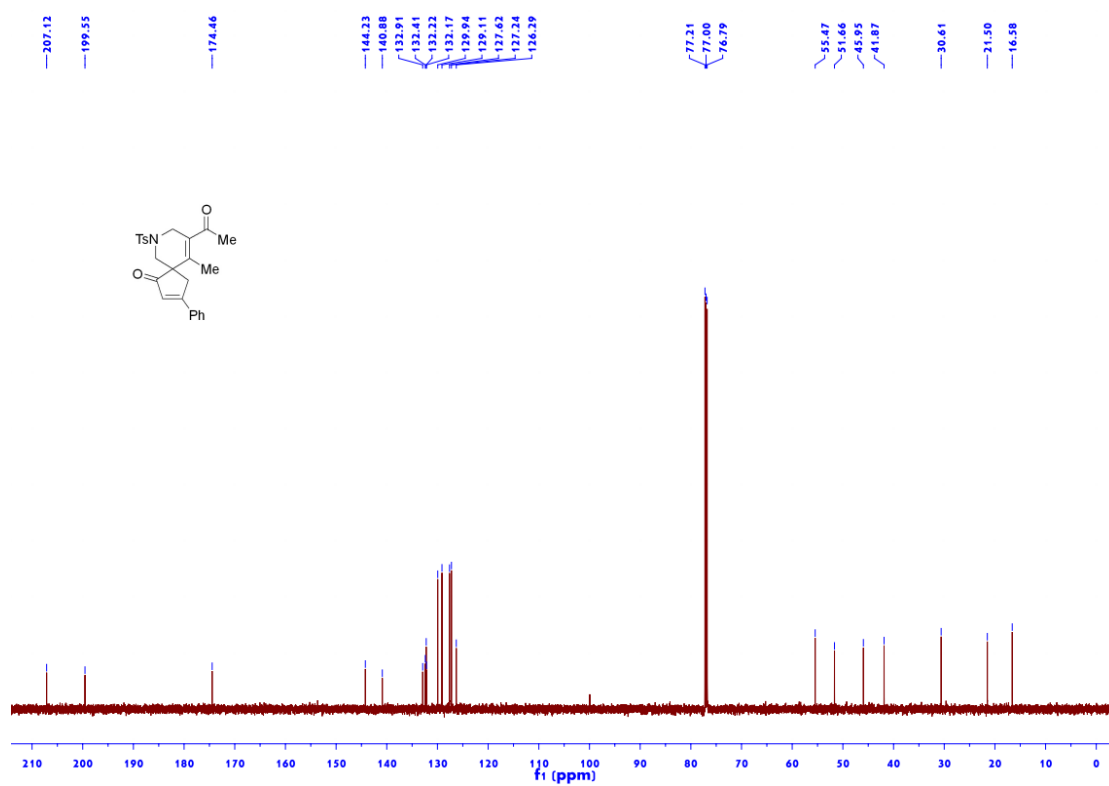


Figure S247 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5f

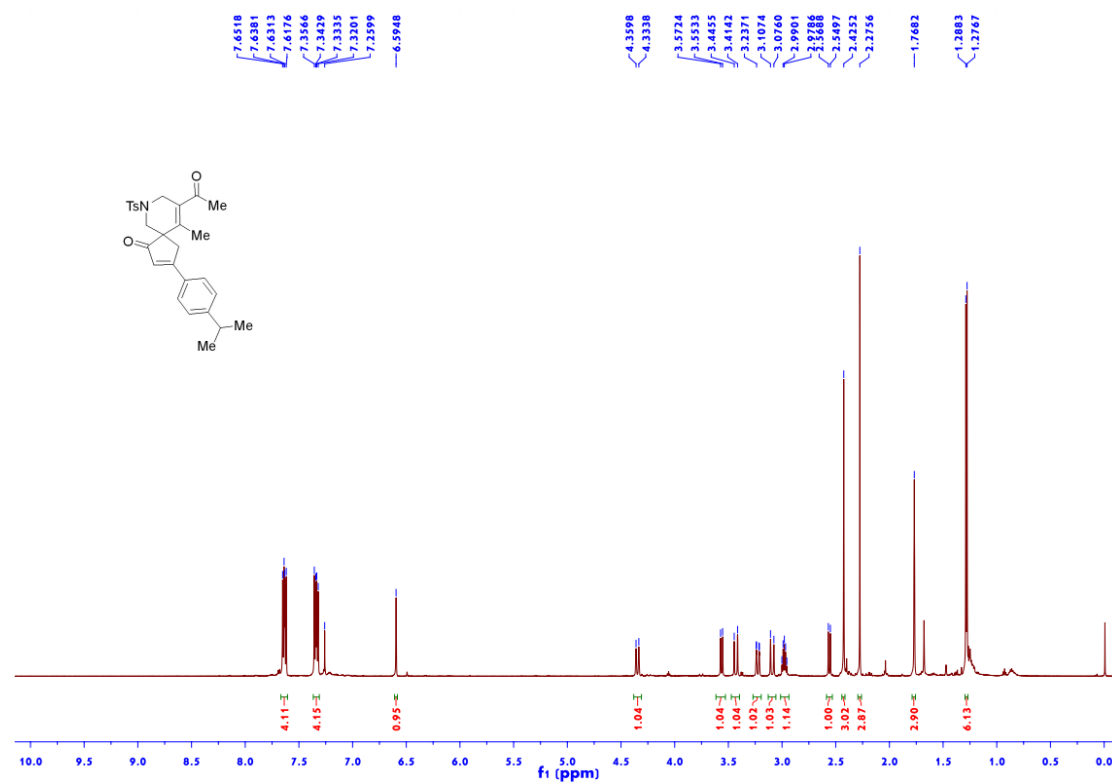


Figure S248 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5f

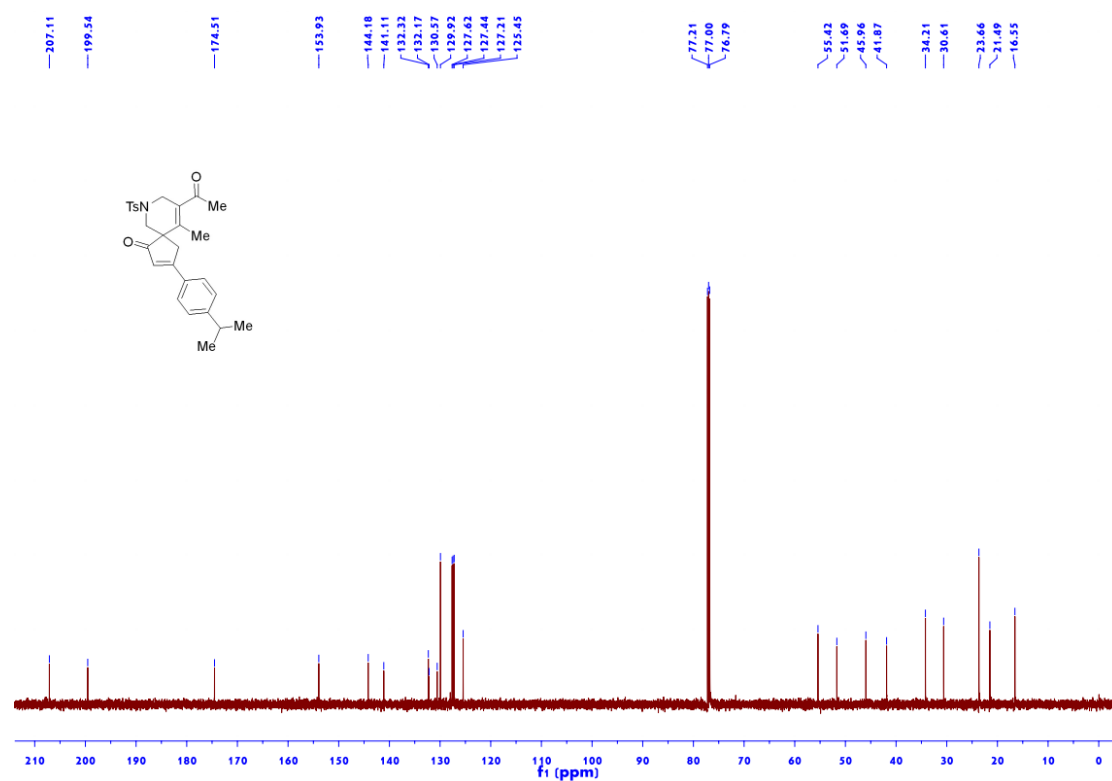




Figure S249 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5g

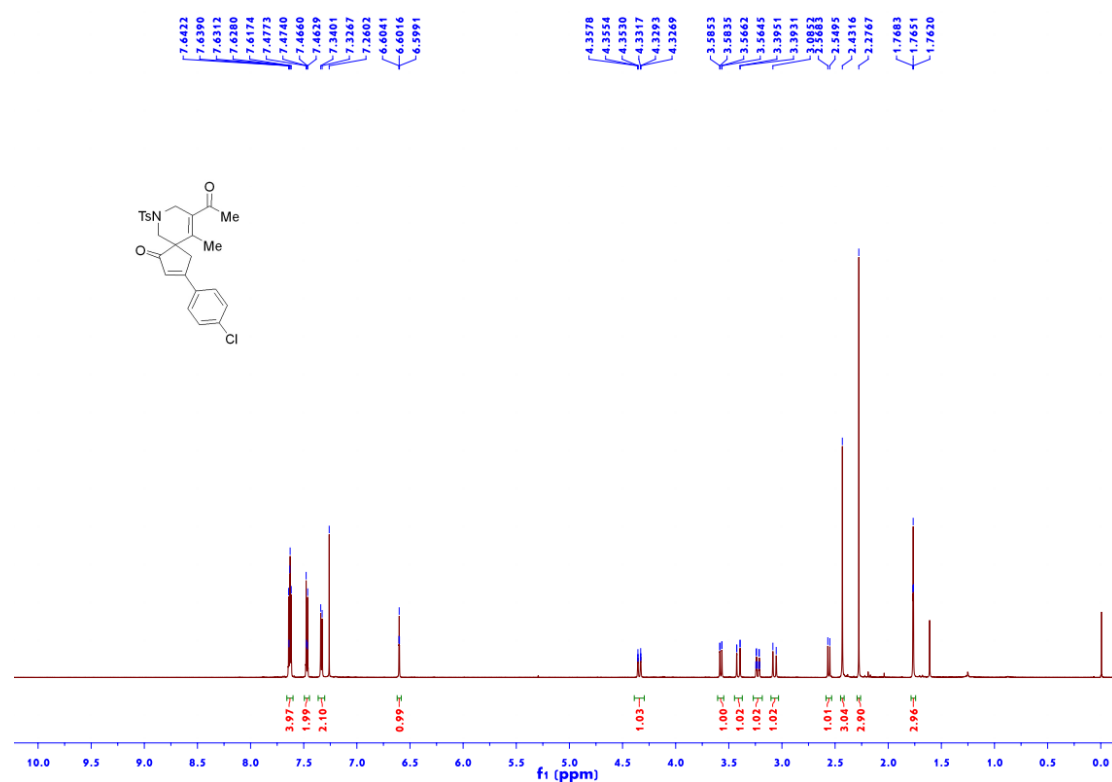


Figure S250 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5g

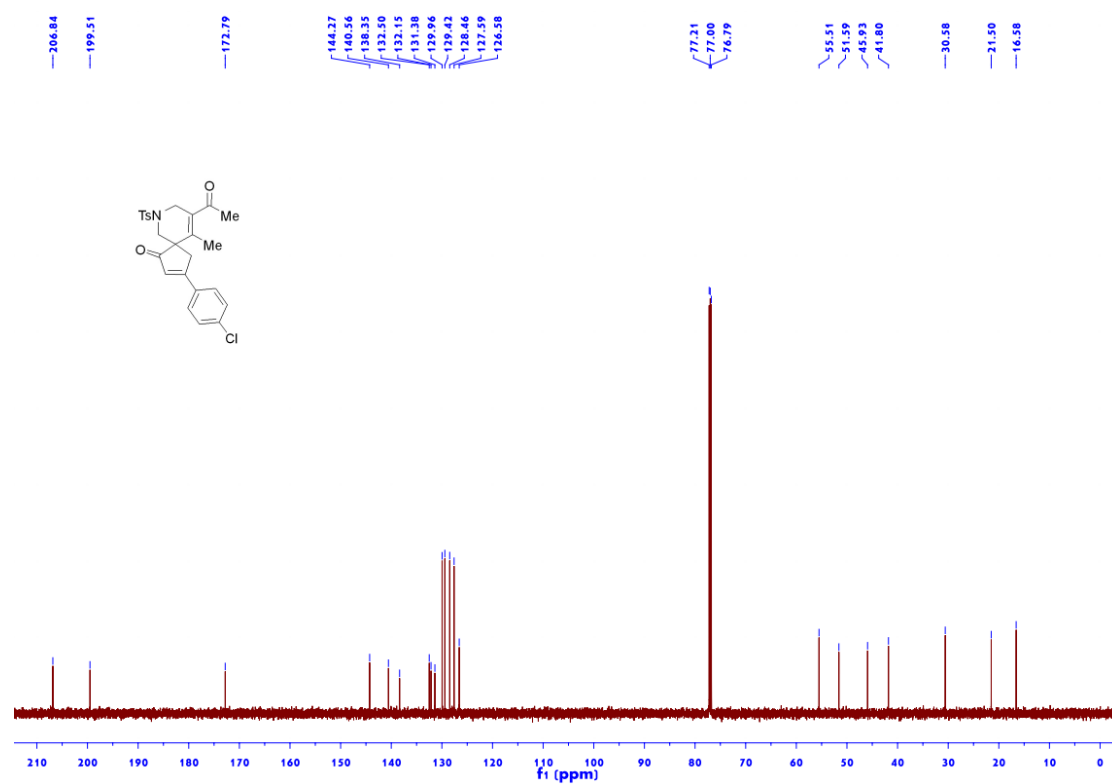


Figure S251 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5h

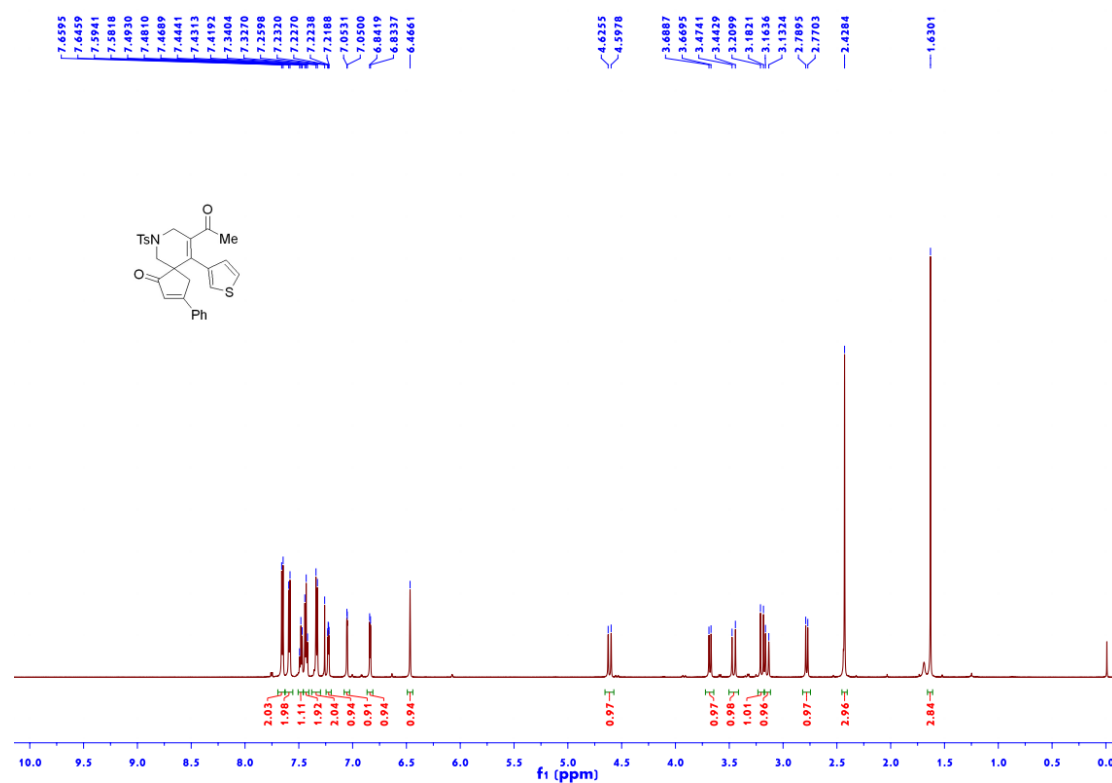


Figure S252 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5h

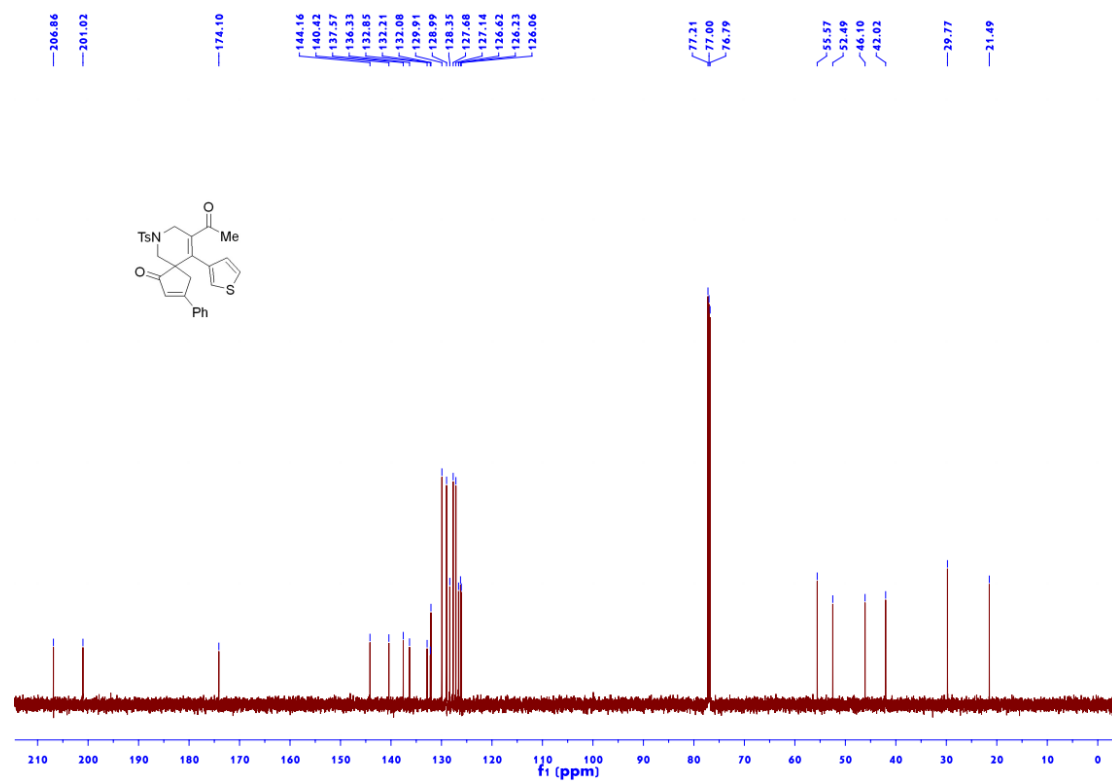


Figure S253 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5i

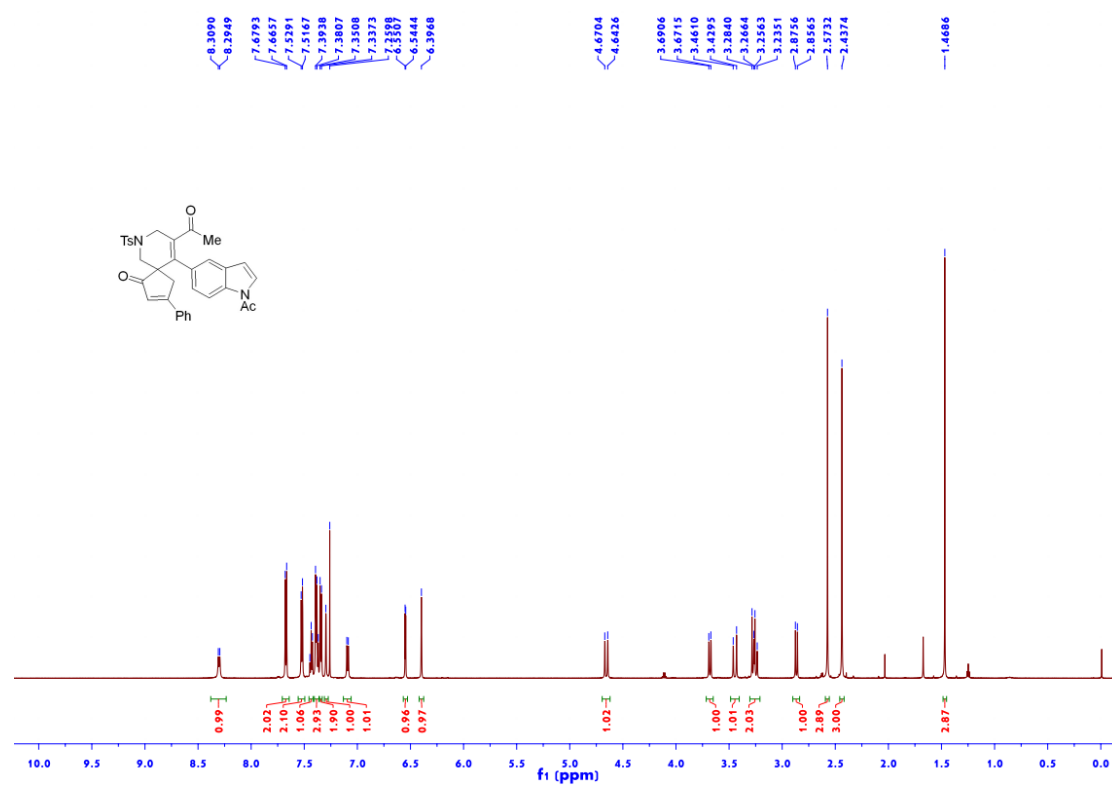


Figure S254 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5i

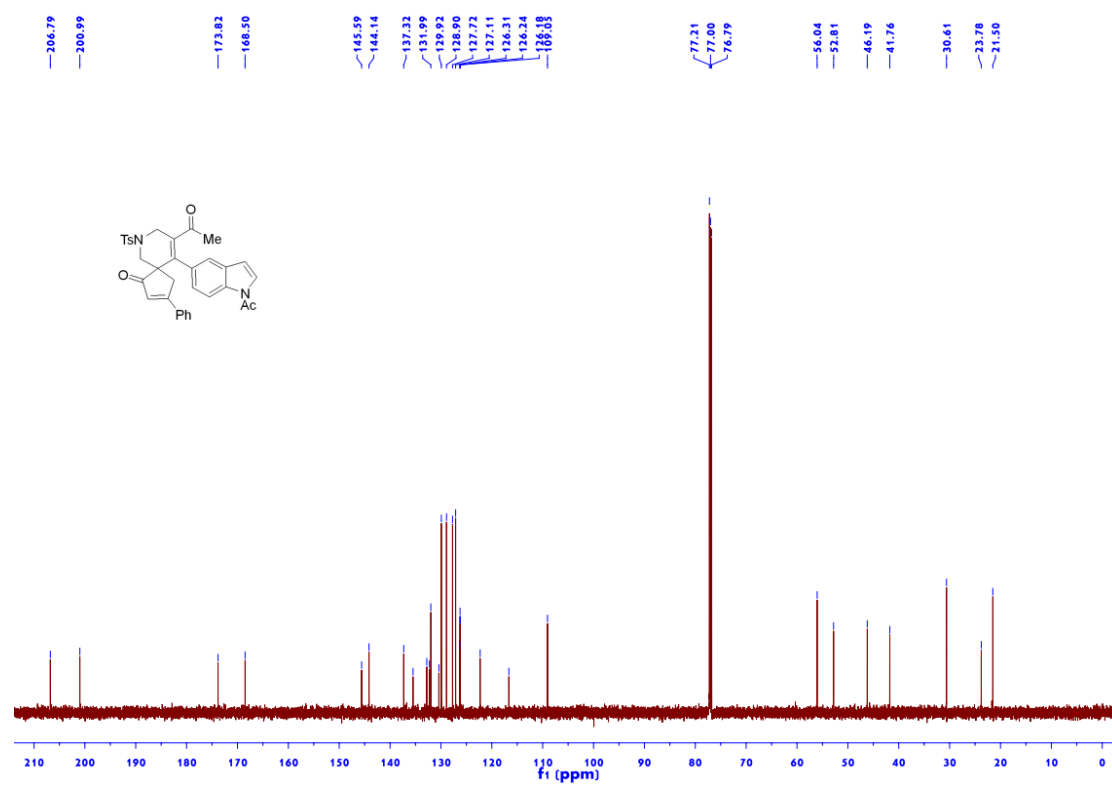


Figure S255 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5j

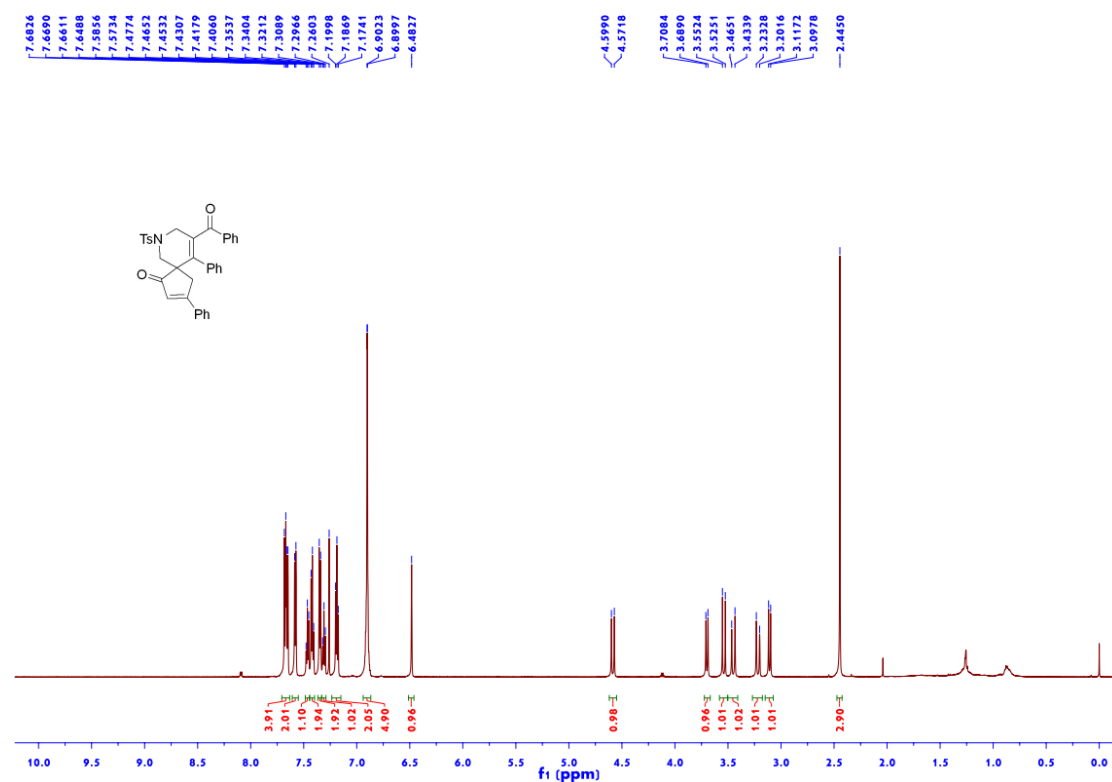


Figure S256 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5j

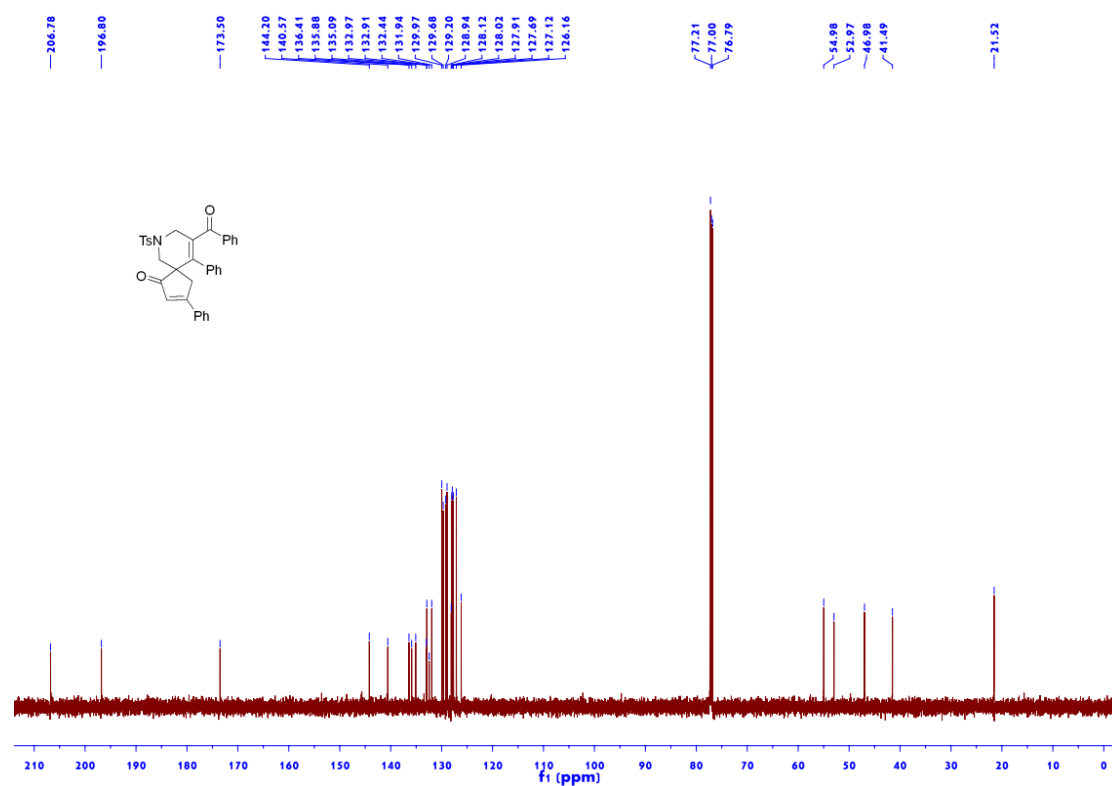


Figure S257 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5k

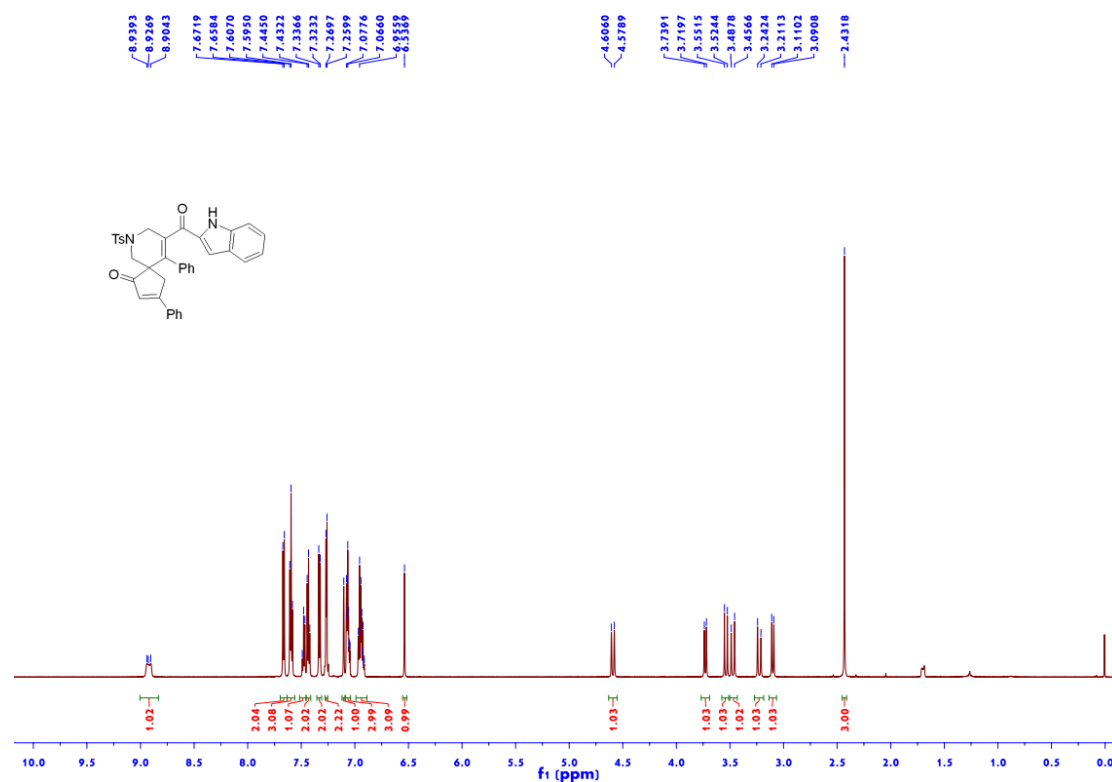


Figure S258 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5k

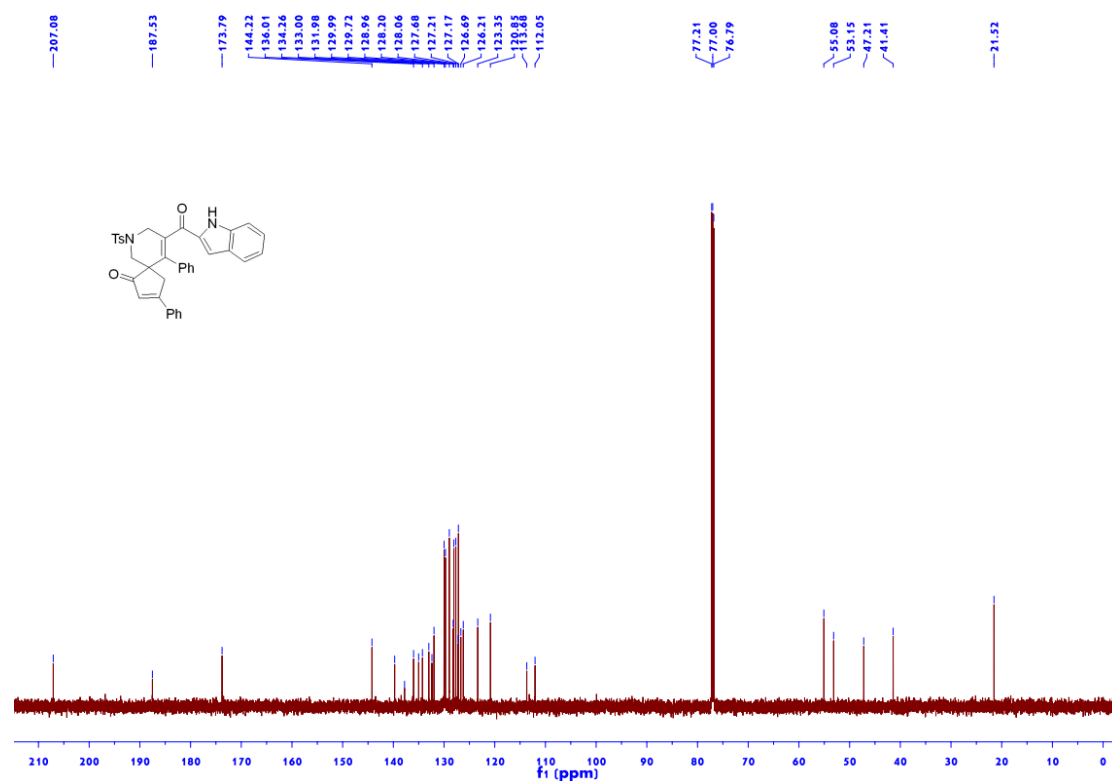


Figure S259 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5l

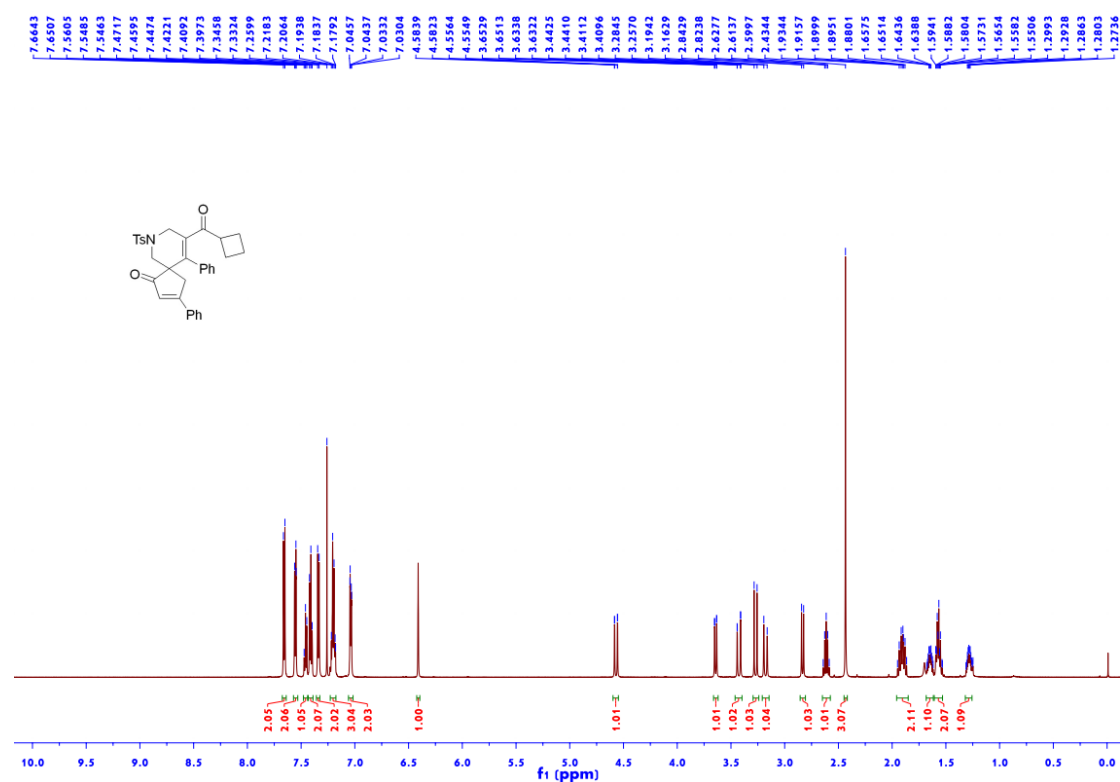


Figure S260 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5l

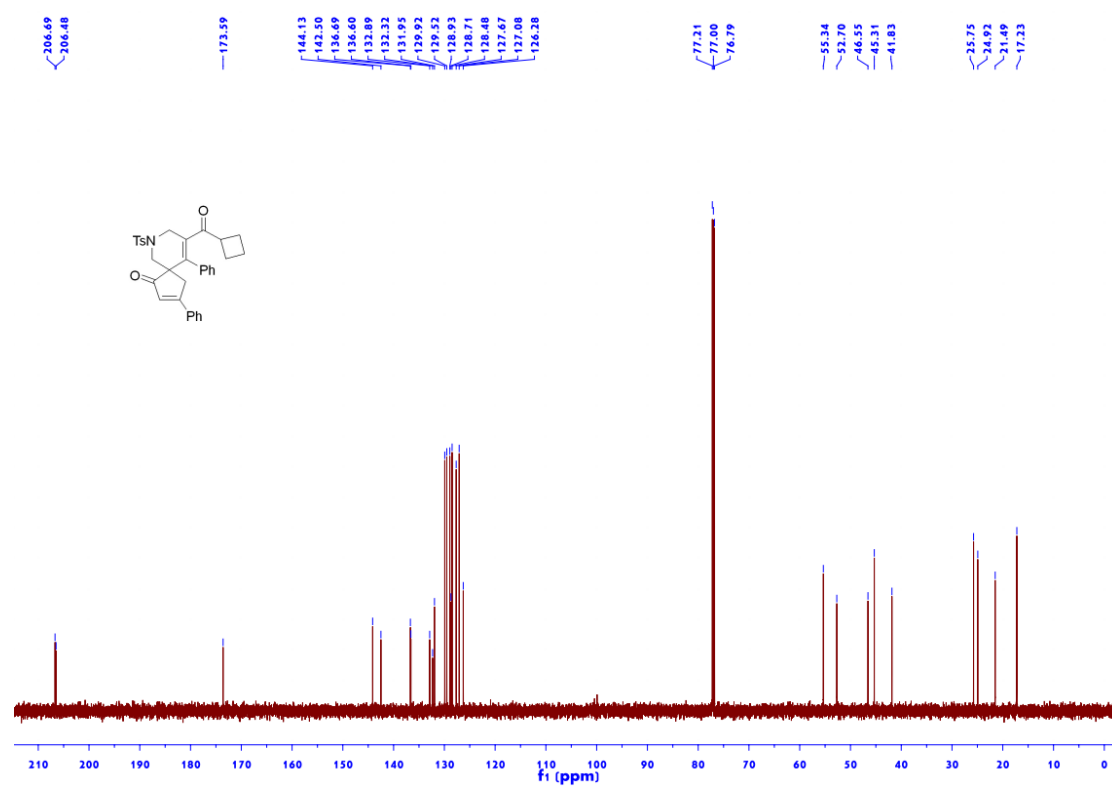


Figure S261 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5m

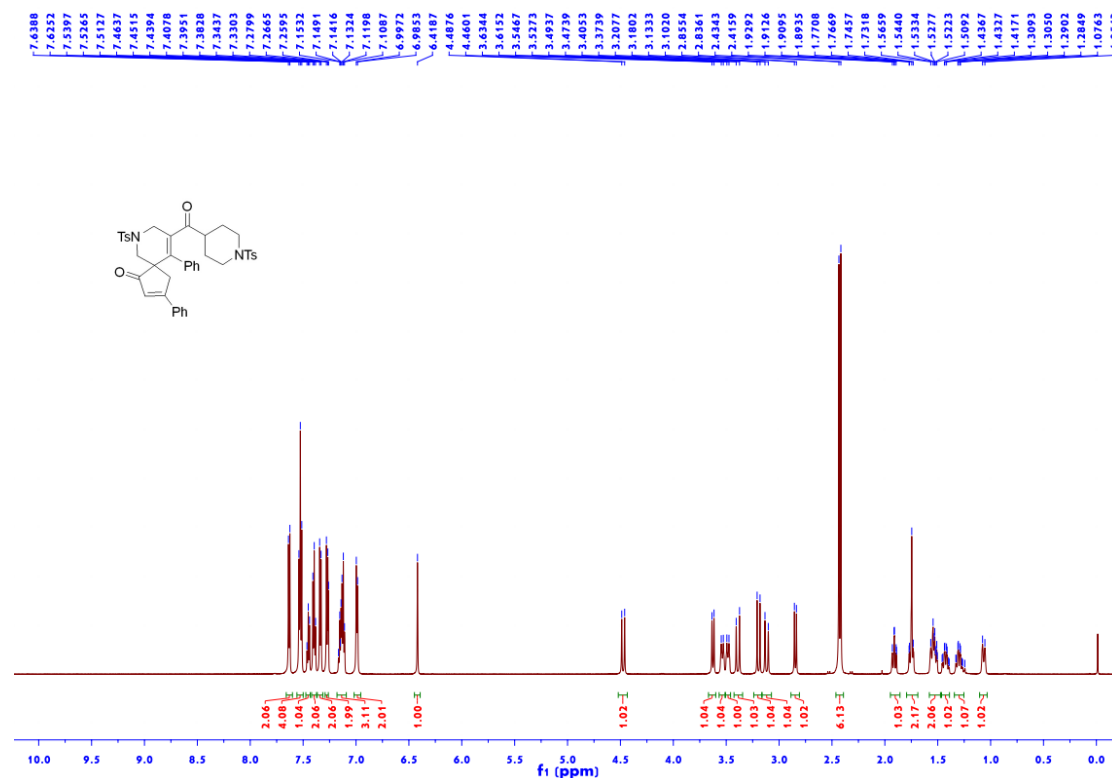


Figure S262 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5m

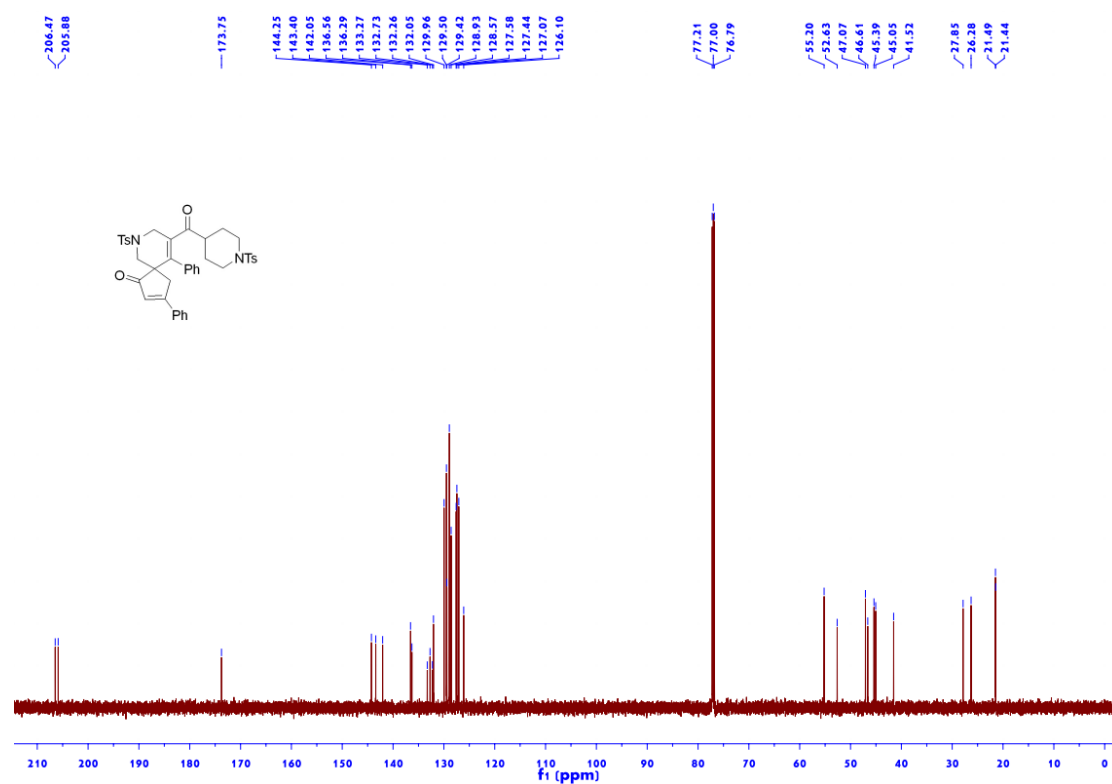


Figure S263 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5n

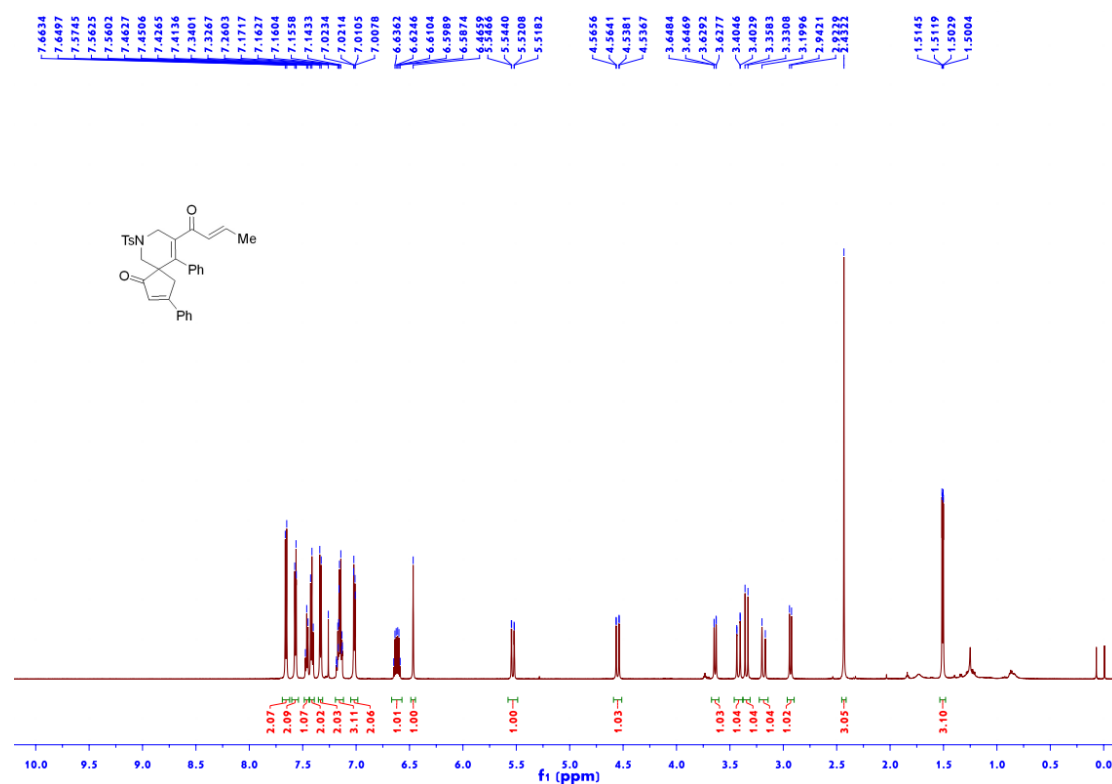


Figure S264 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5n

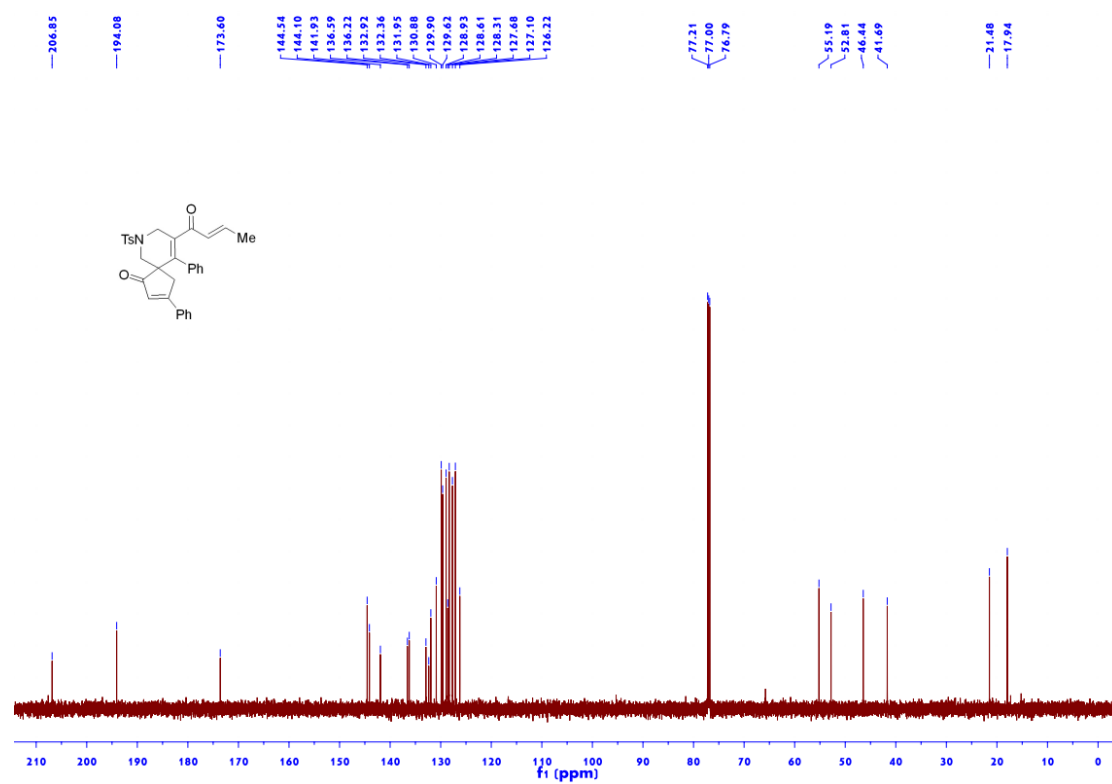




Figure S265  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 5o

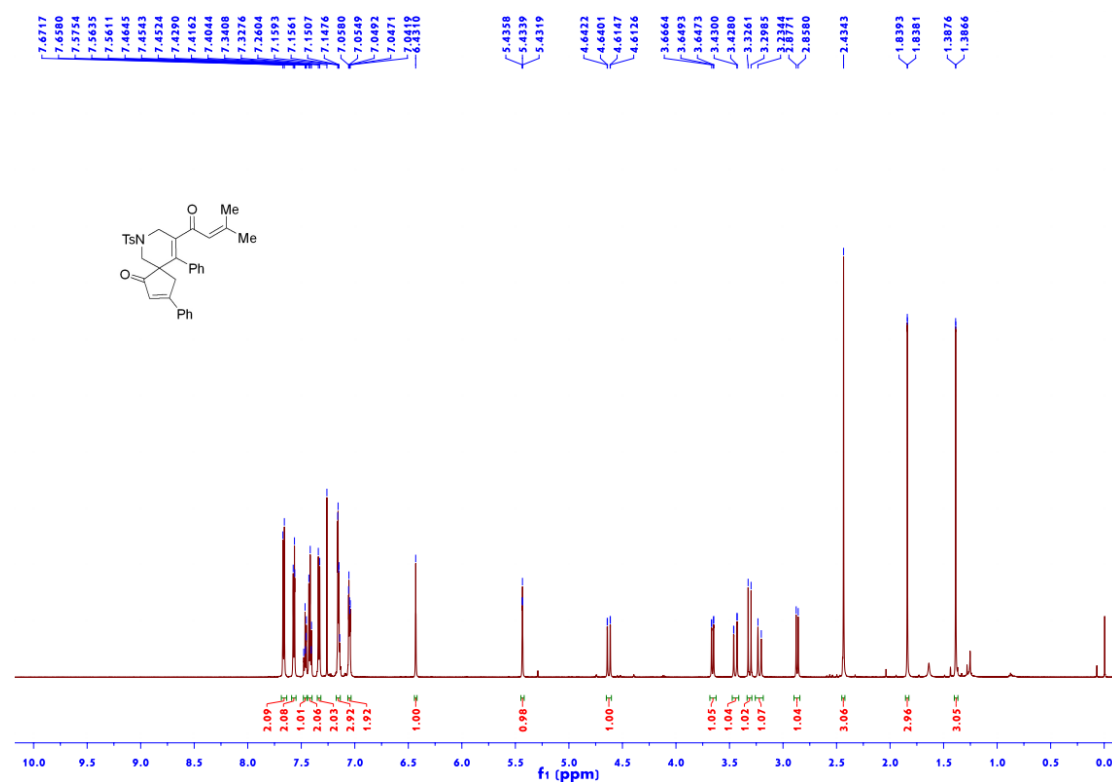


Figure S266  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 5o

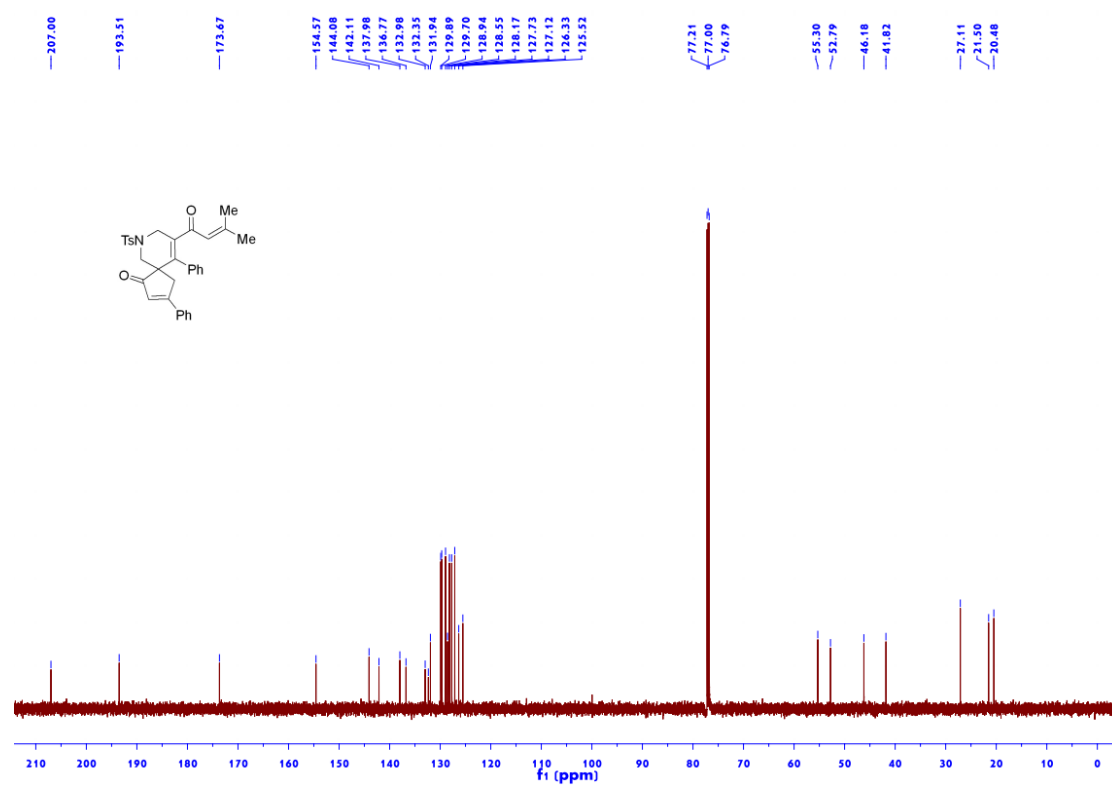


Figure S267 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5p

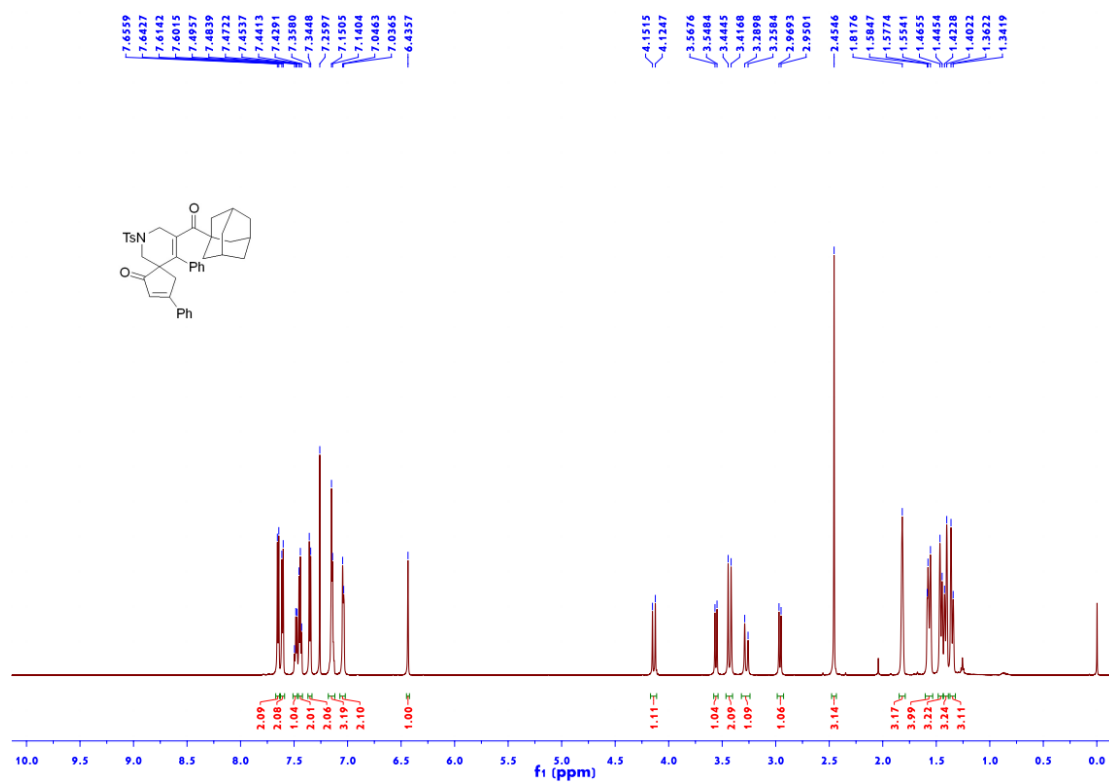


Figure S268 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5p

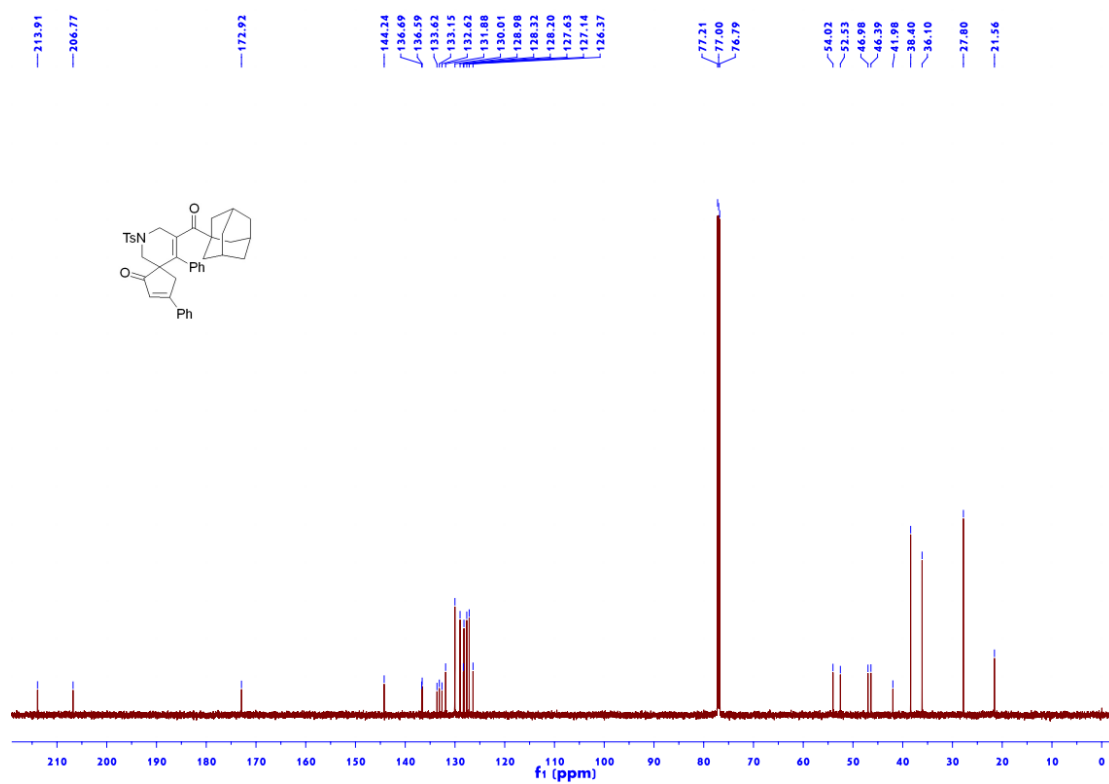


Figure S269 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5q

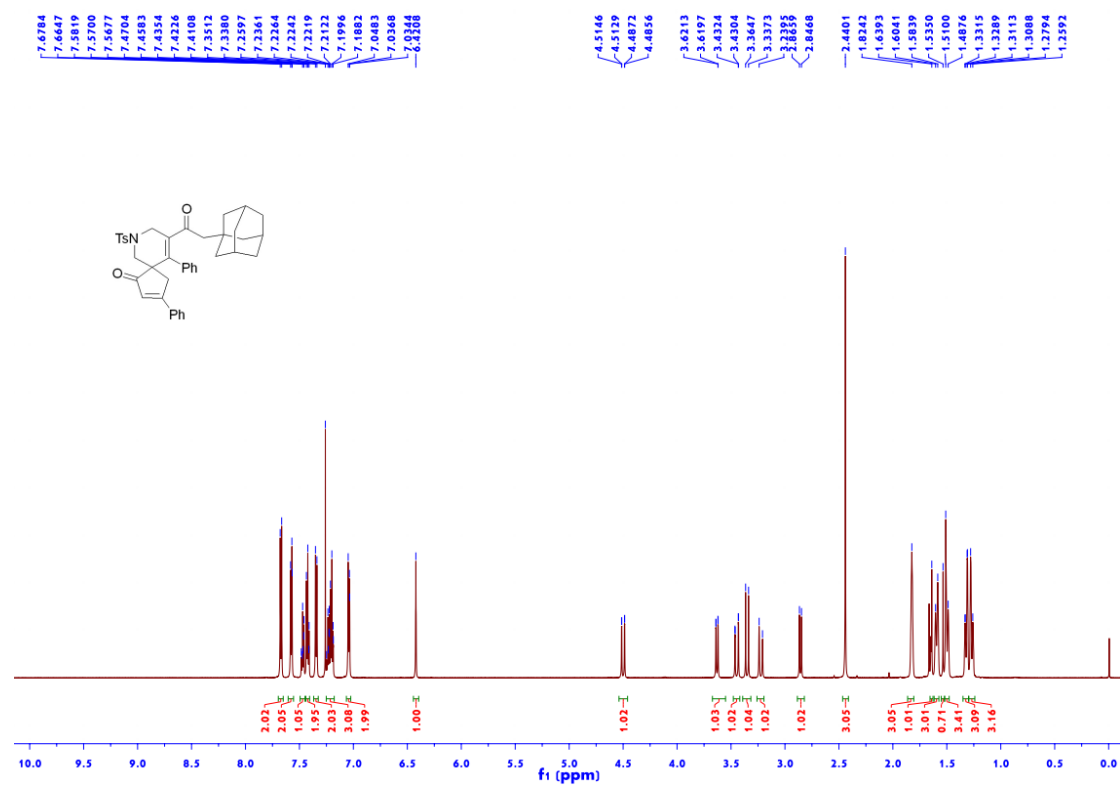


Figure S270 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5q

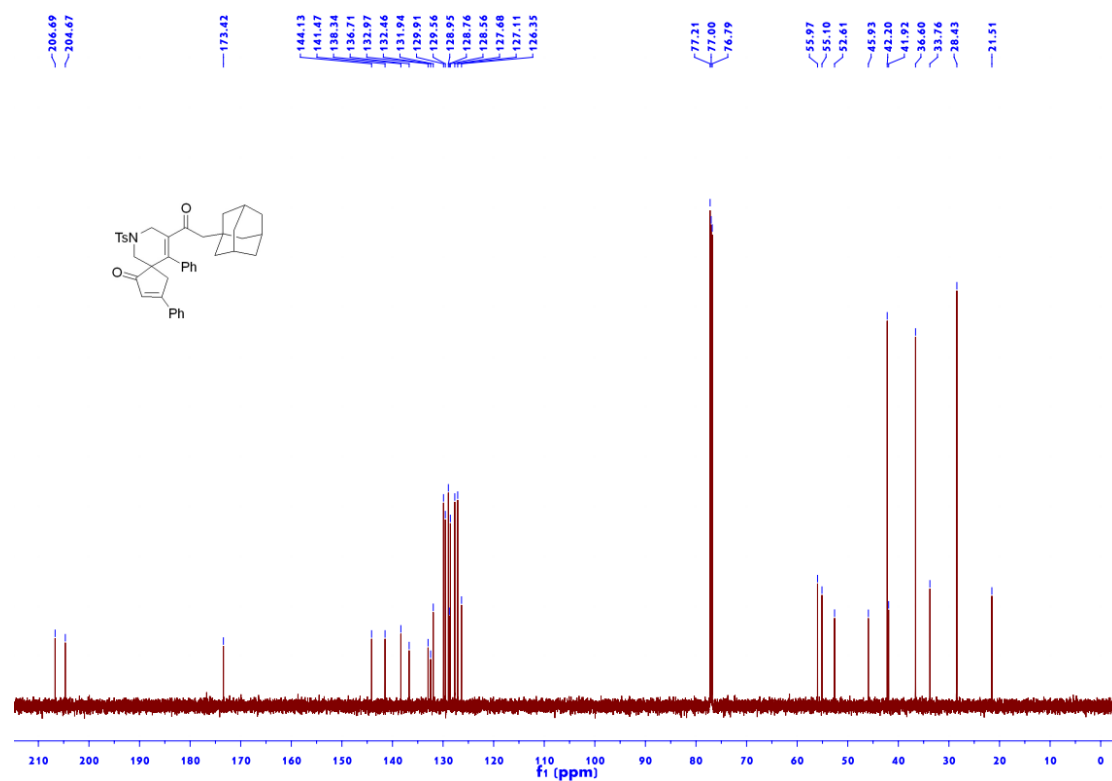


Figure S271 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5r

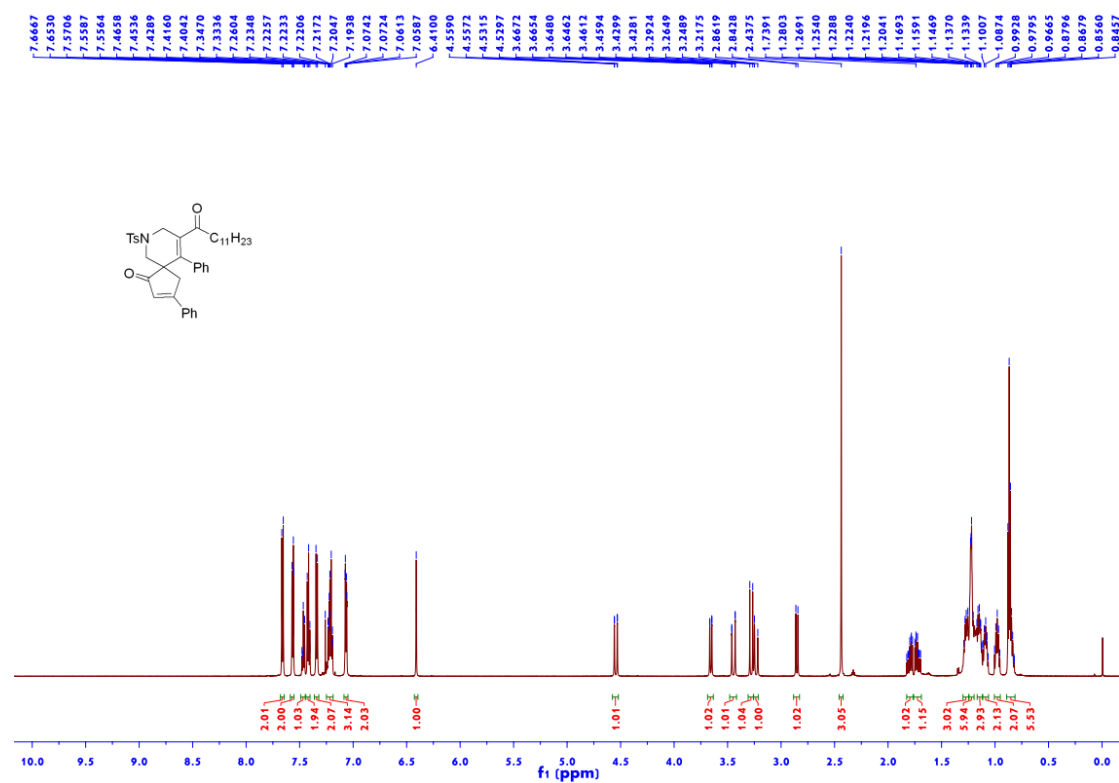


Figure S272 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5r

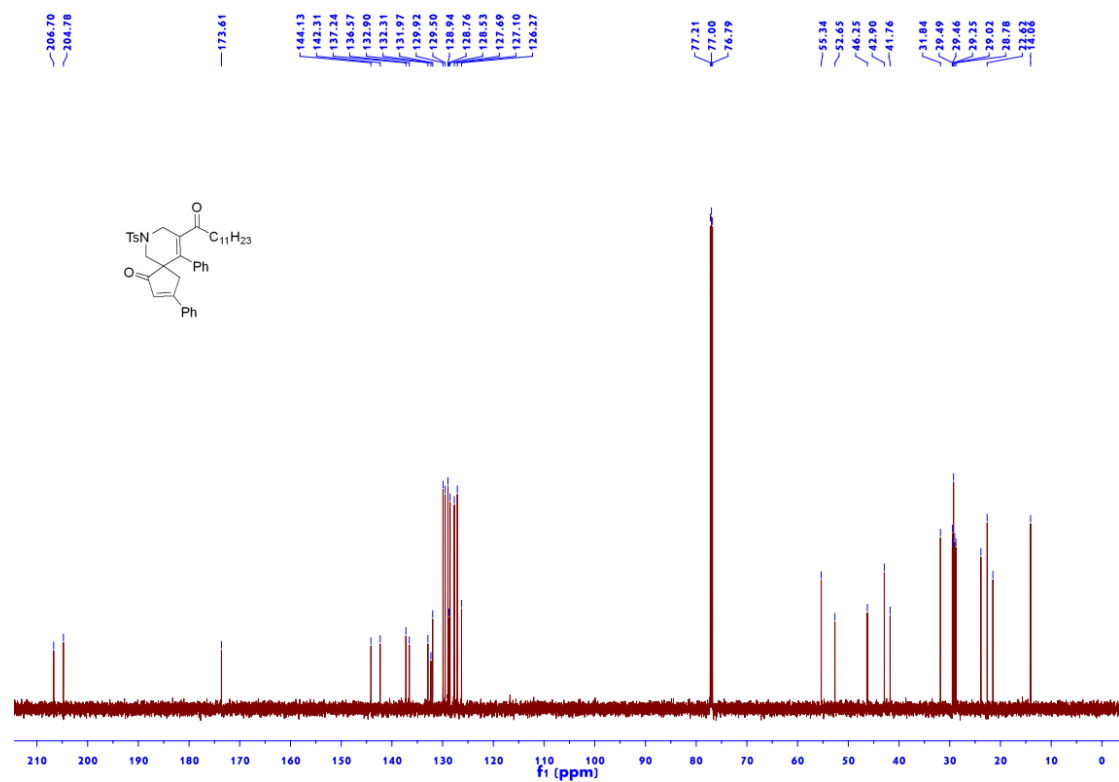


Figure S273 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5s

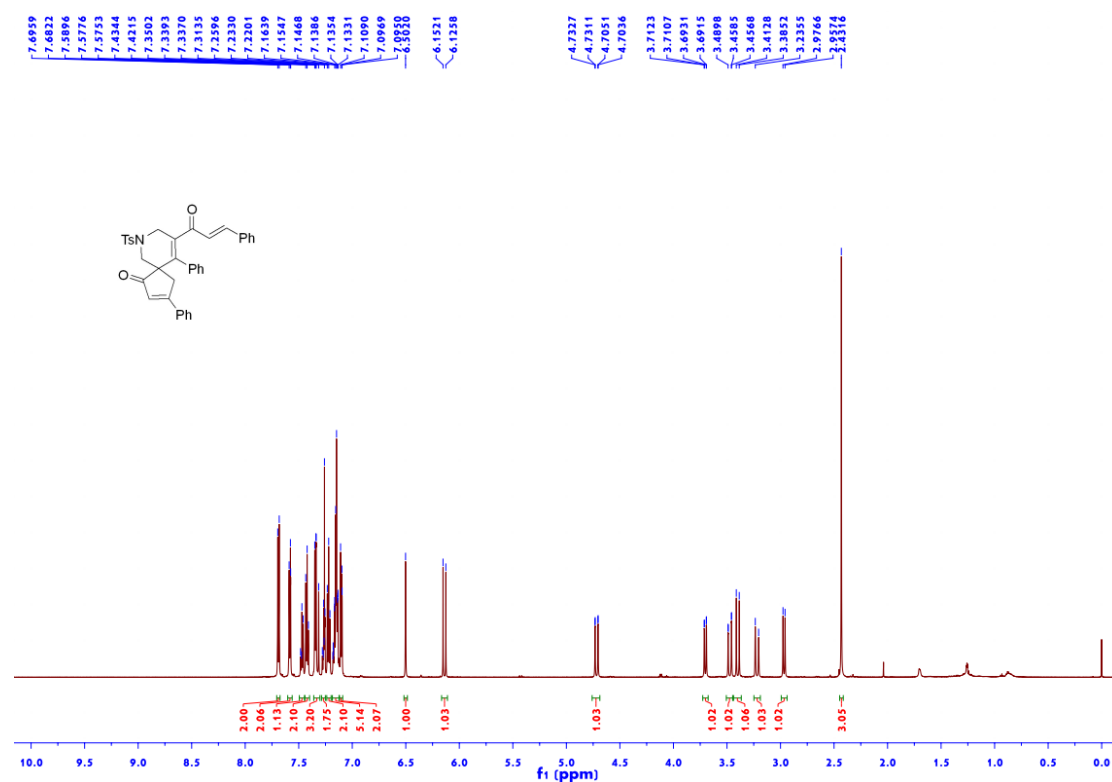


Figure S274 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5s

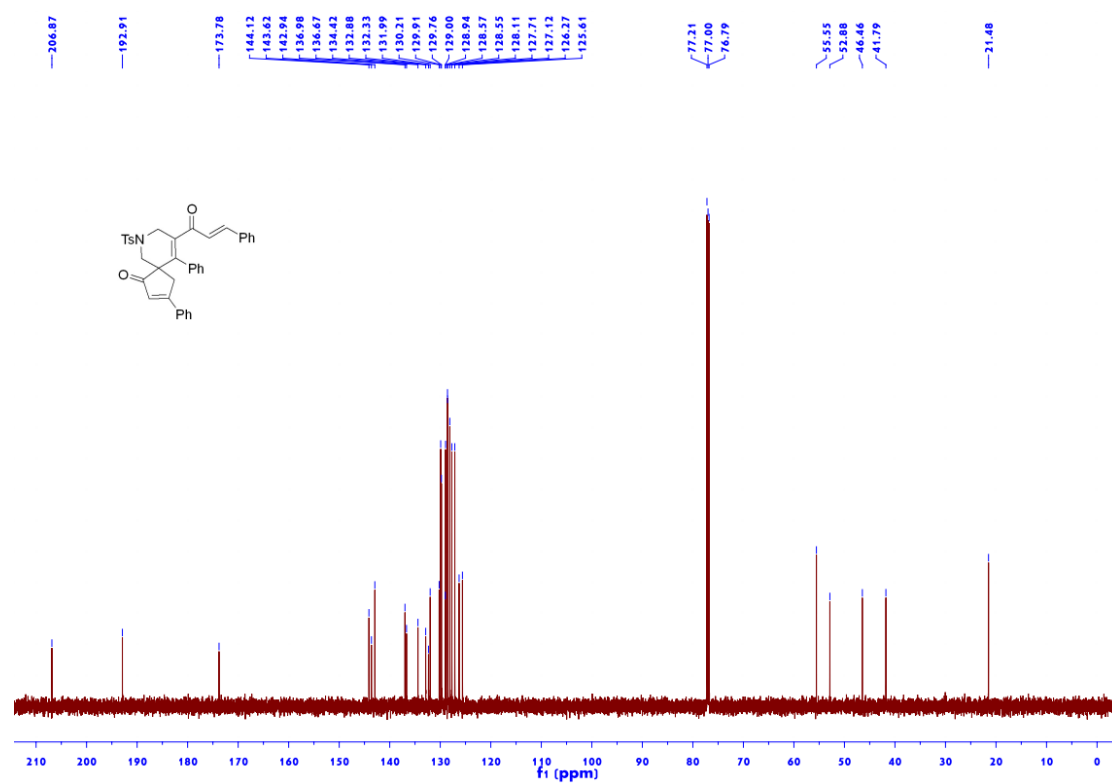




Figure S277 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5u

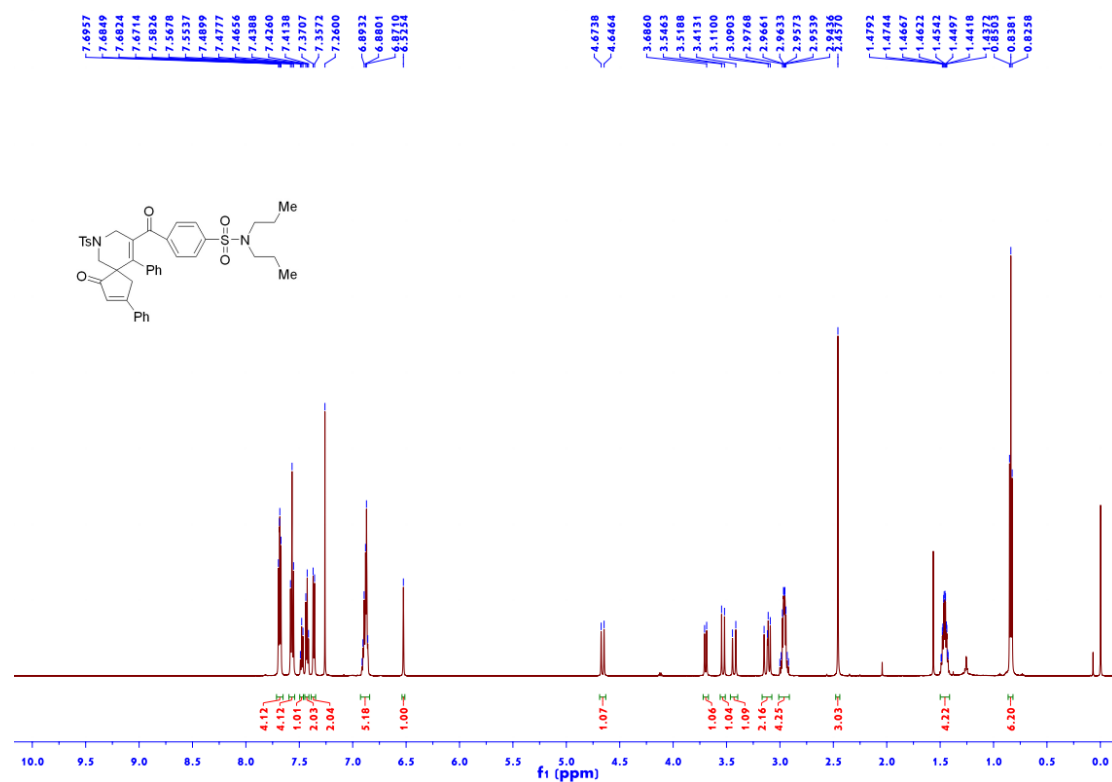


Figure S278 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5u

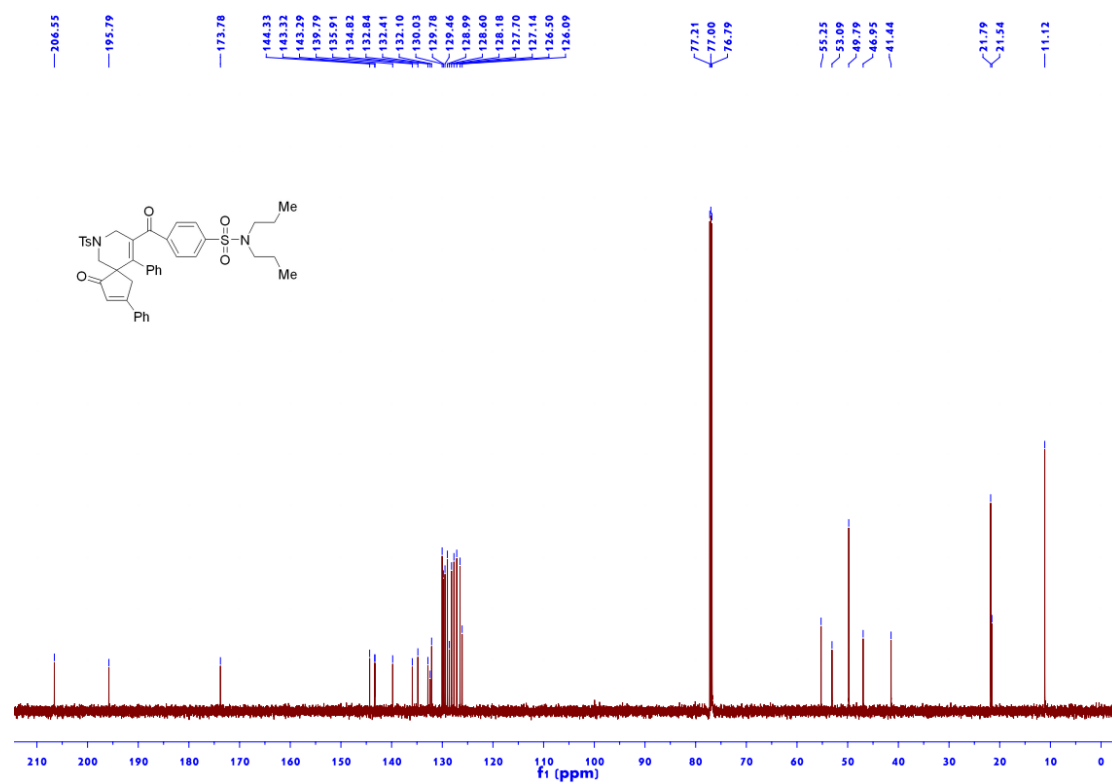






Figure S281 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 5w

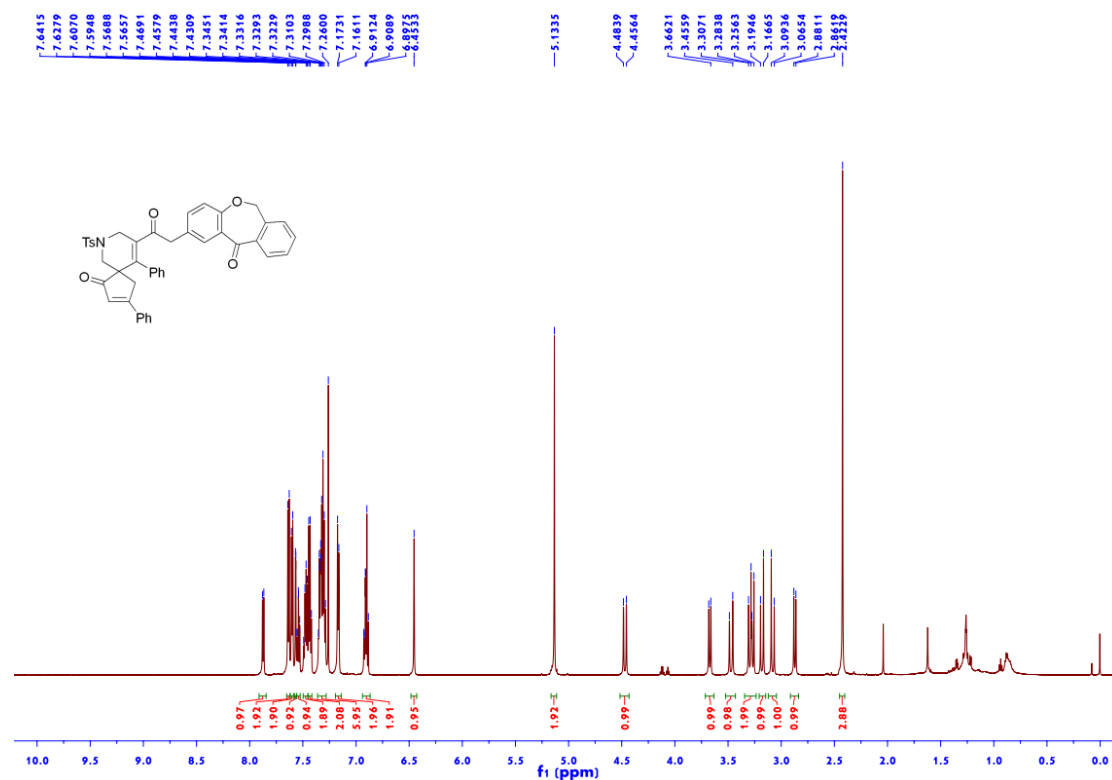


Figure S282 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 5w

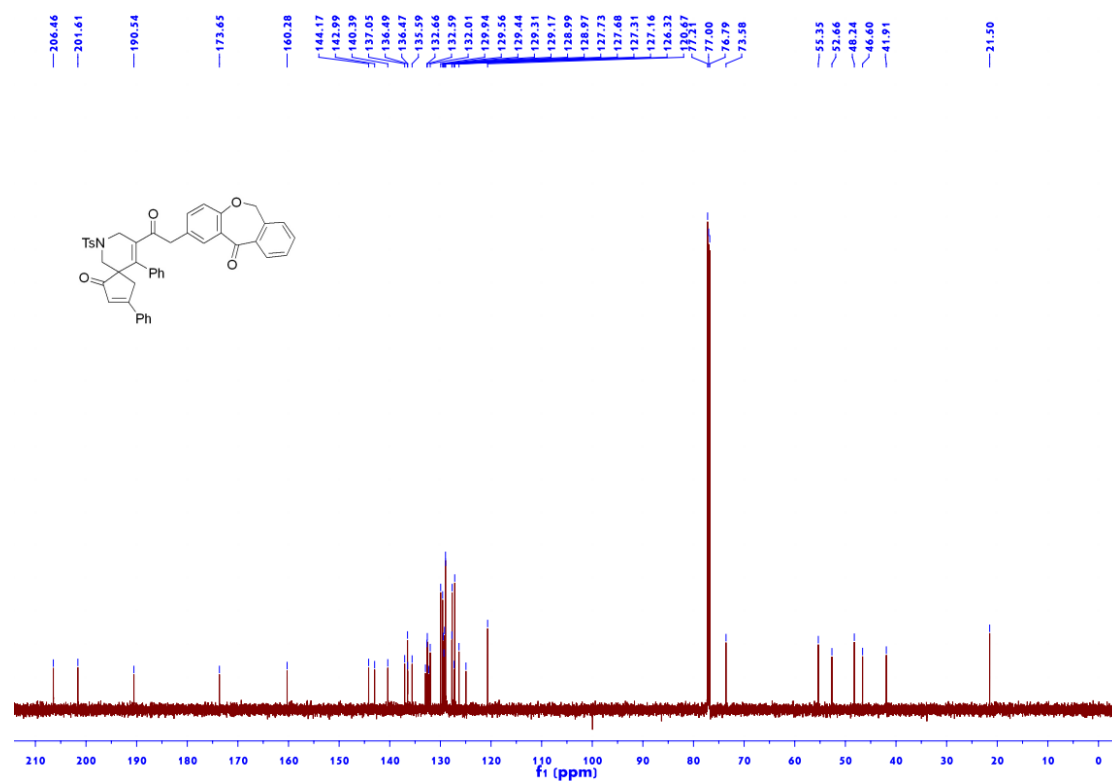


Figure S283 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 7a

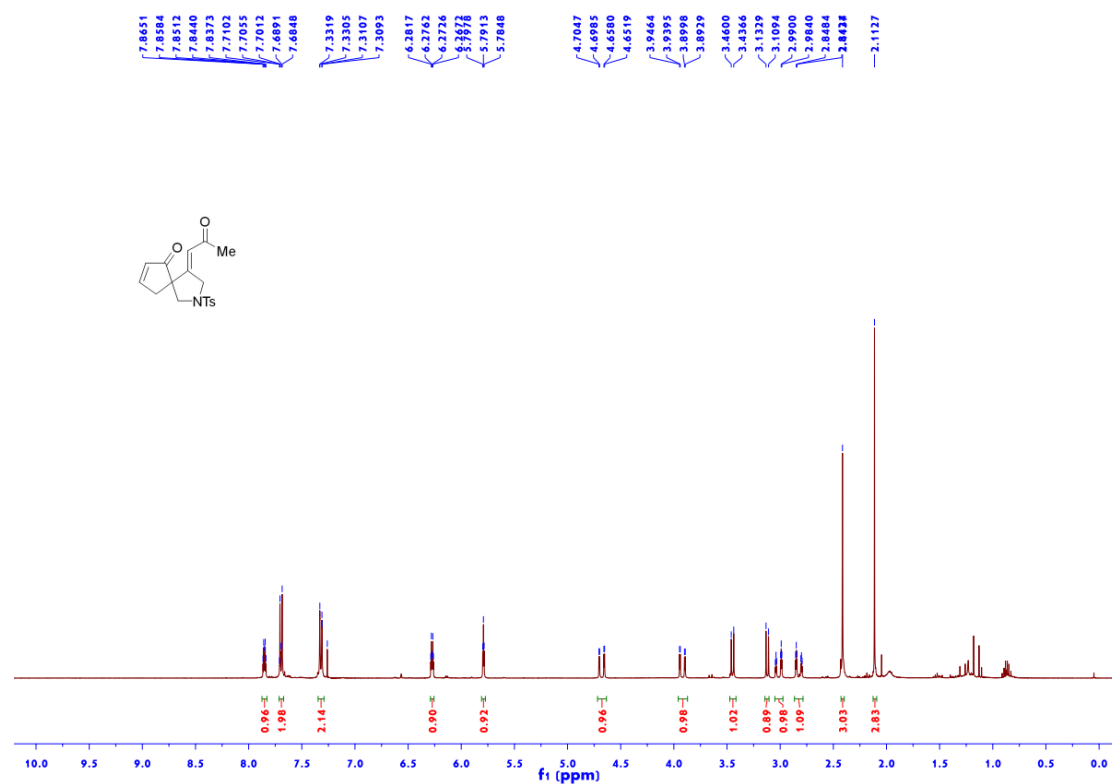


Figure S284 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 7a

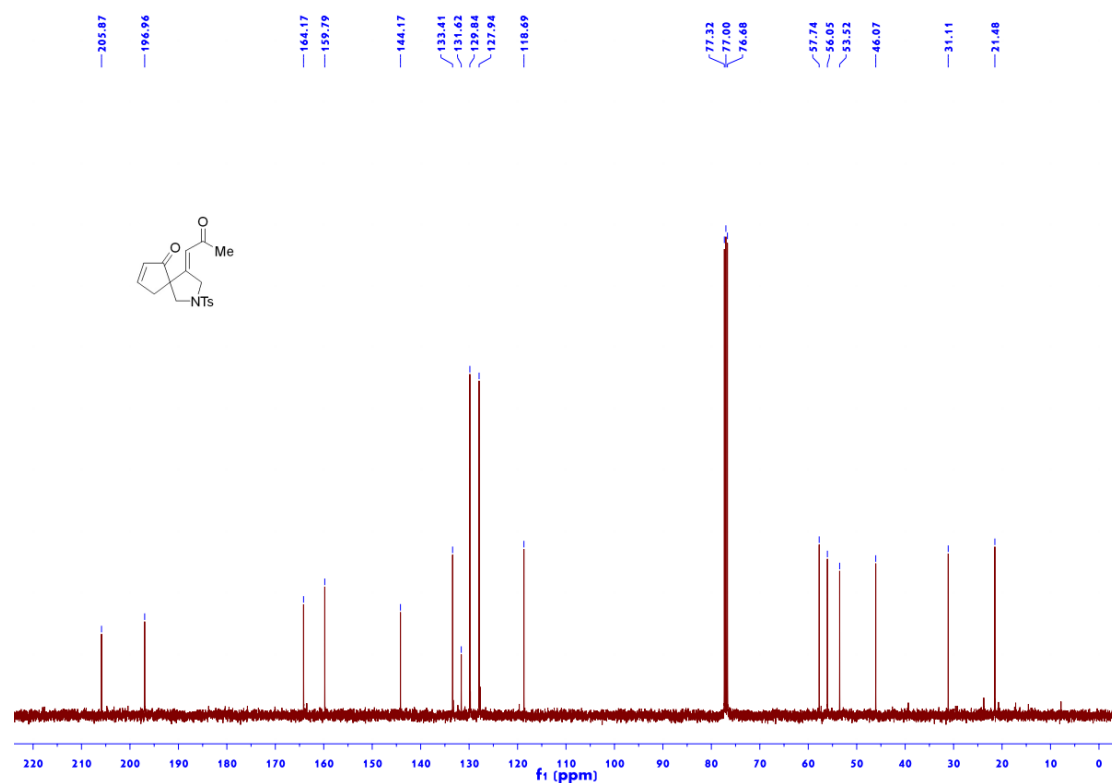


Figure S285 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 7b

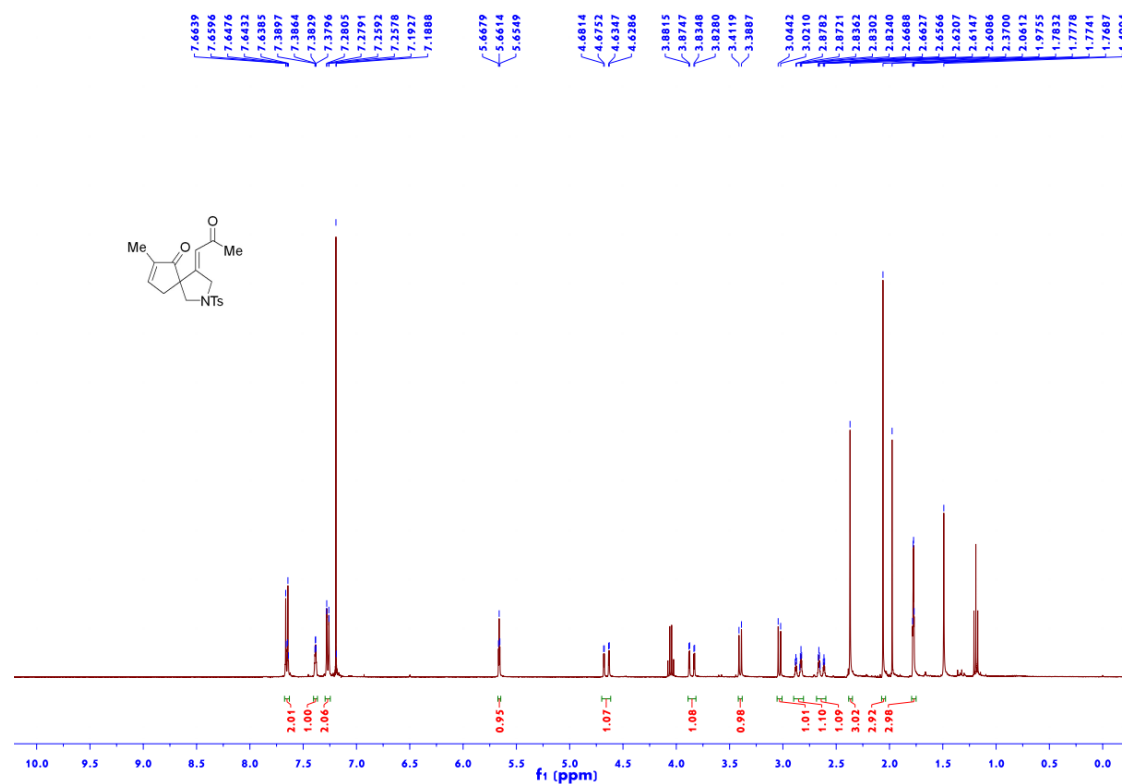


Figure S286 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 7b

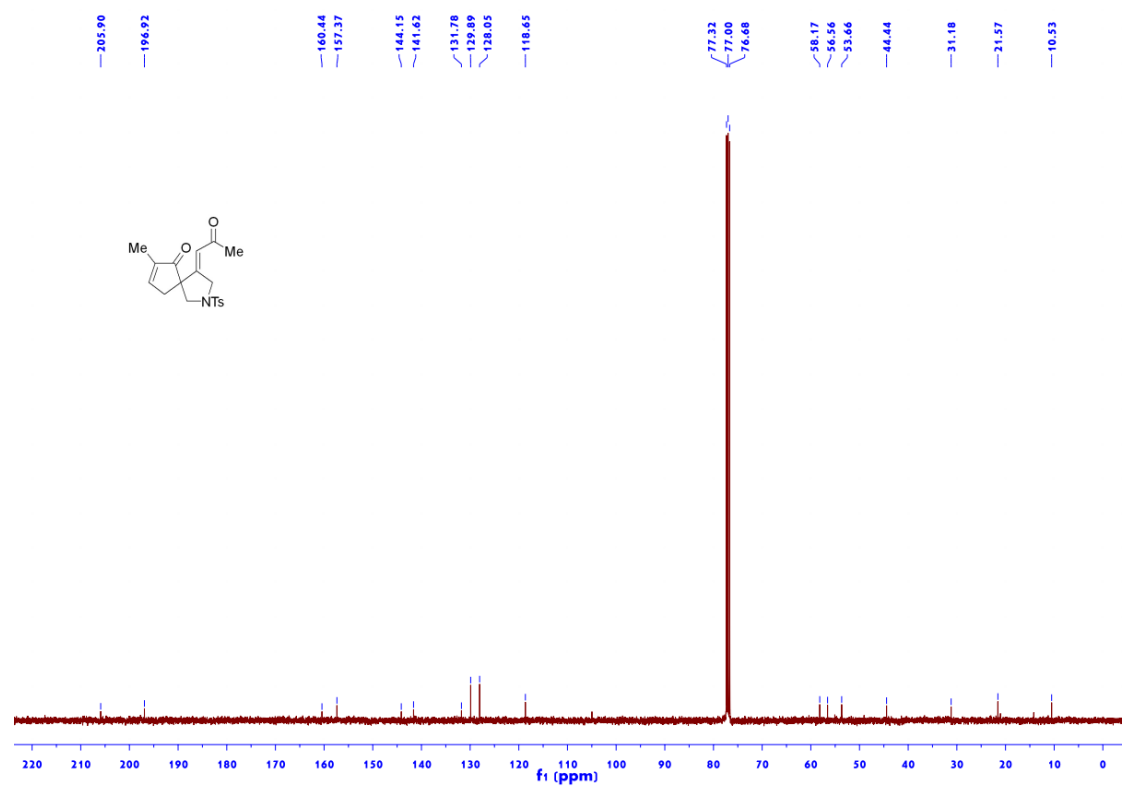


Figure S287 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 7c

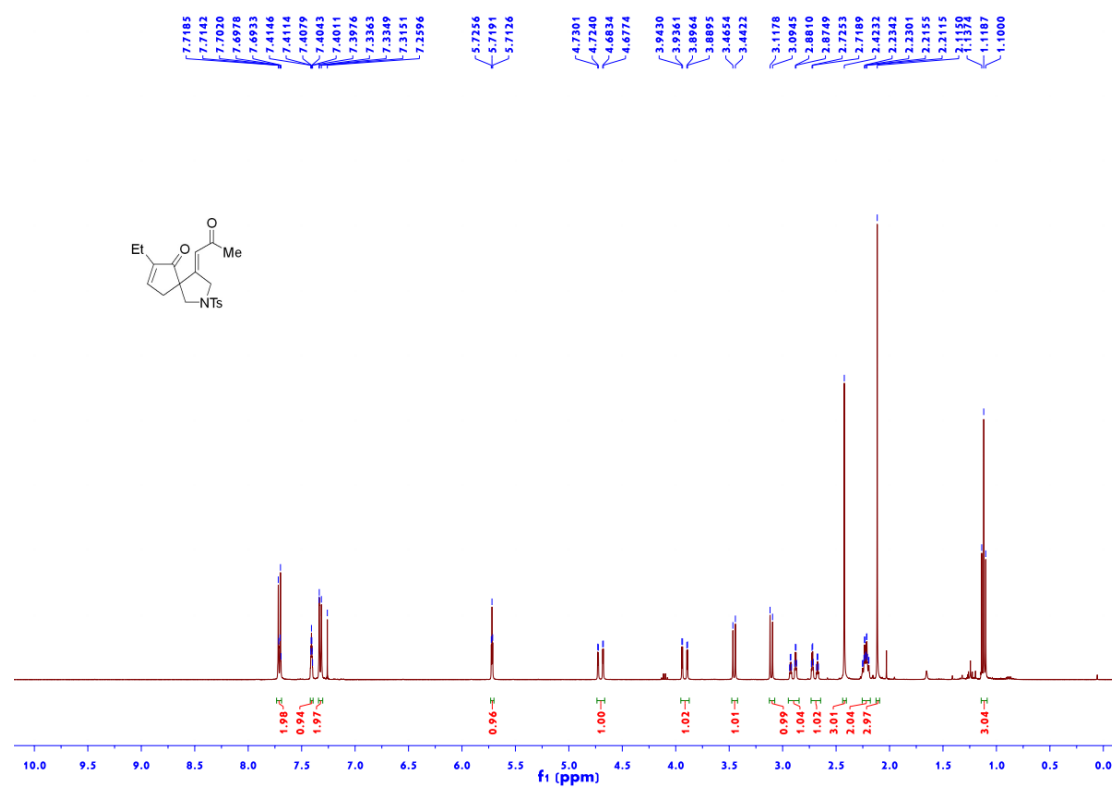


Figure S288 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 7c

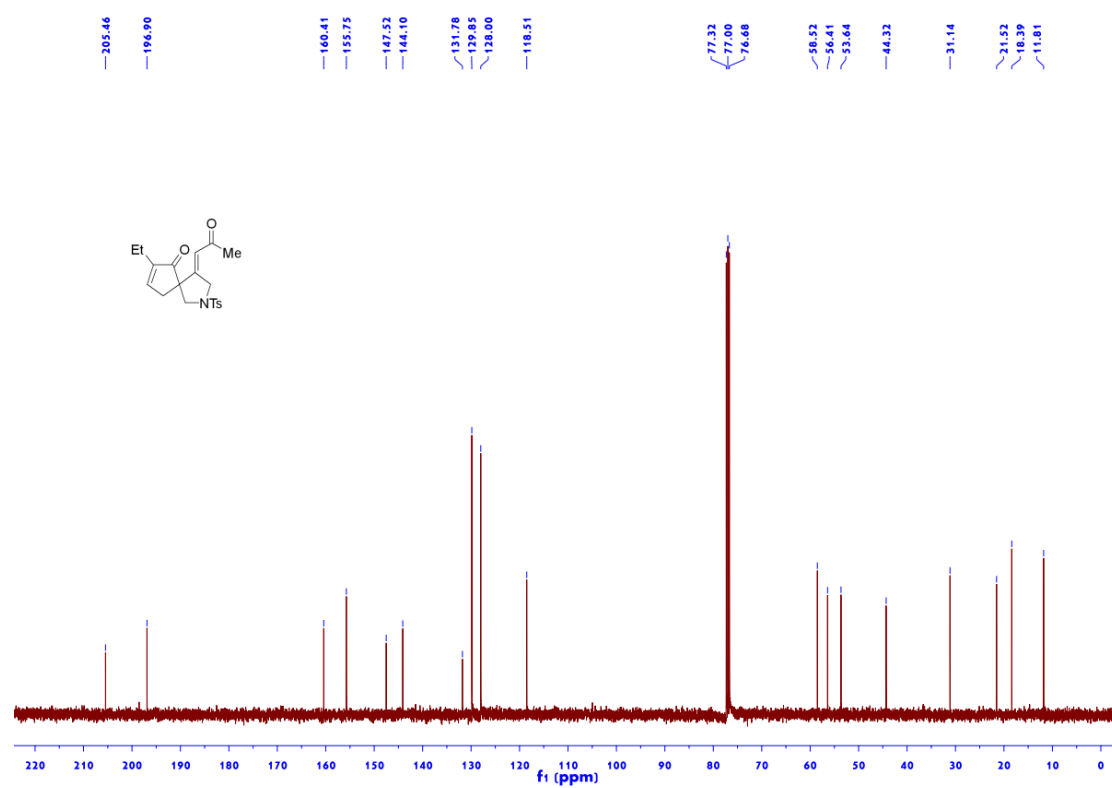


Figure S289 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 7d

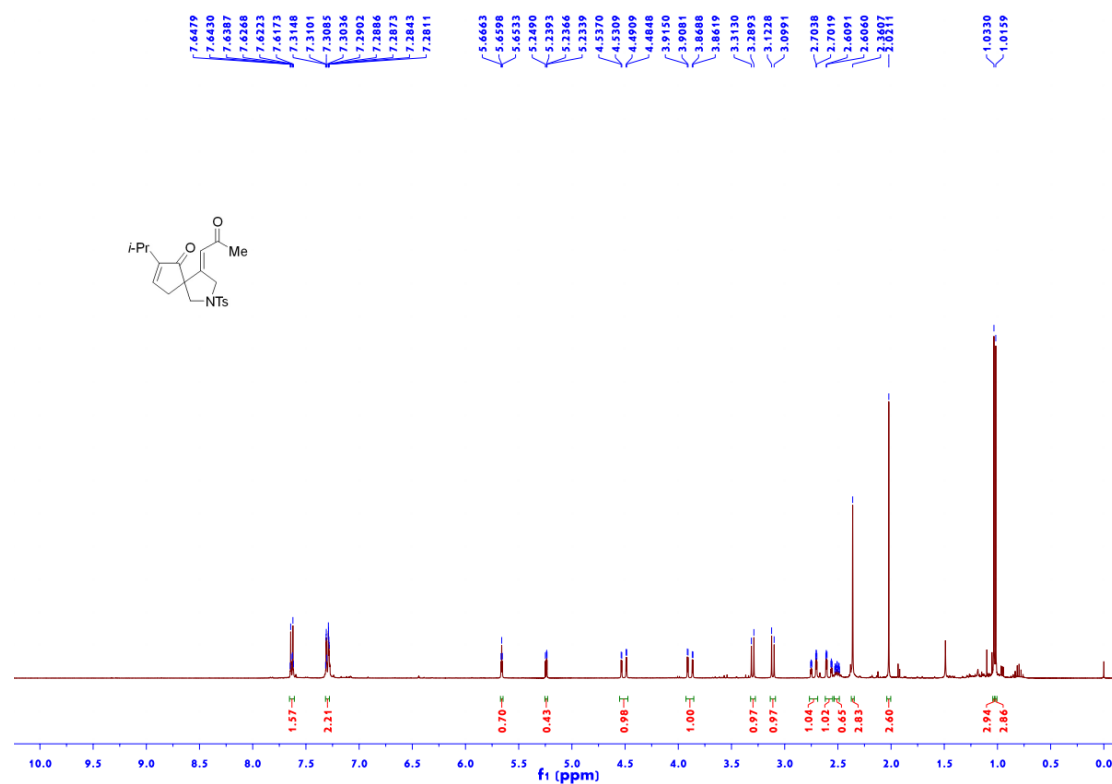


Figure S290 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 7d

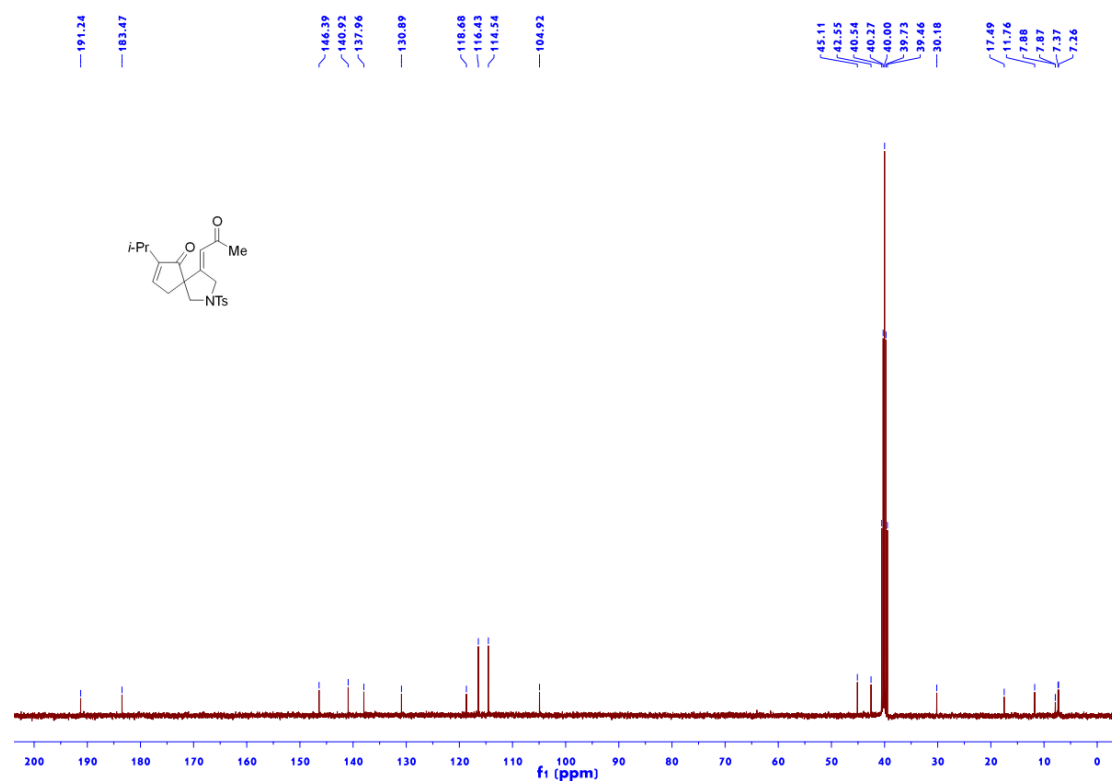


Figure S291 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 7e

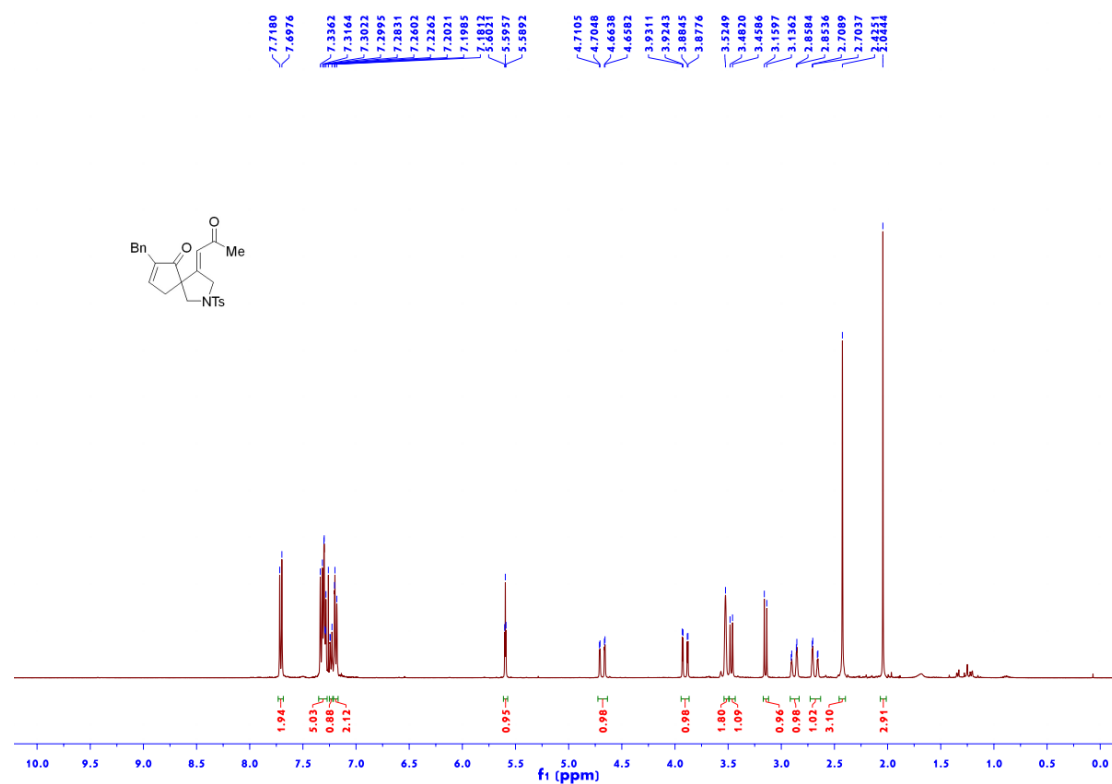


Figure S292 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 7e

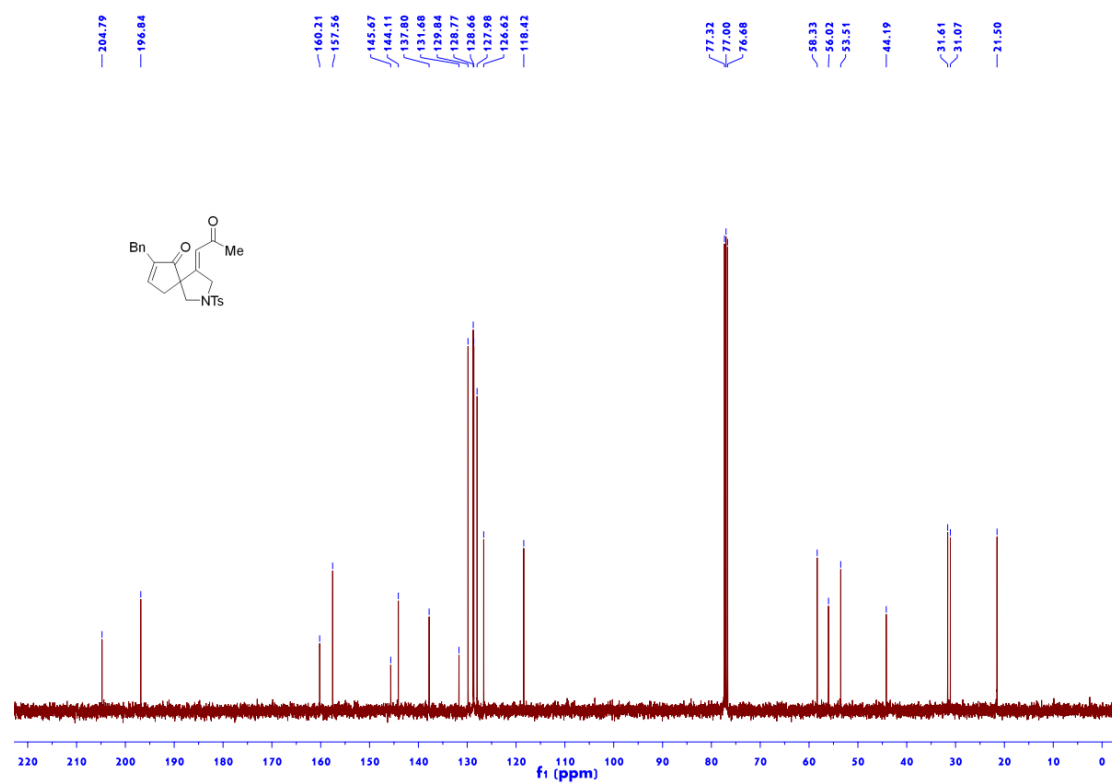


Figure S293 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 7f

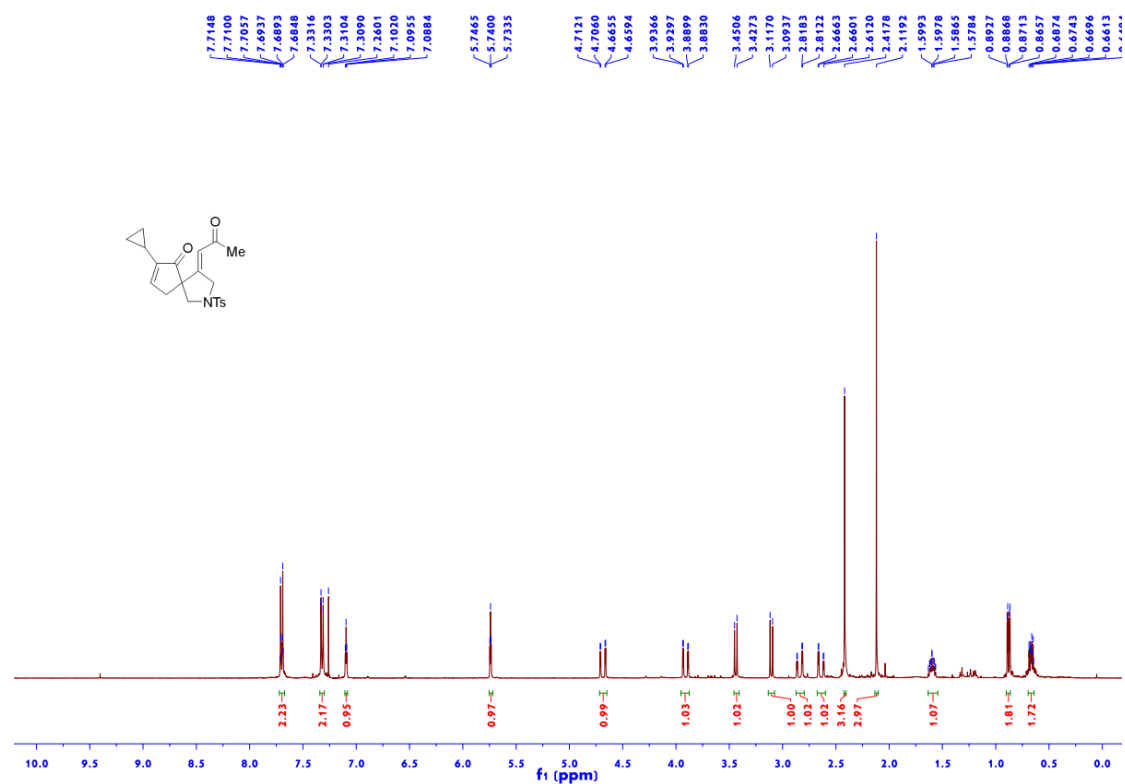


Figure S294 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 7f

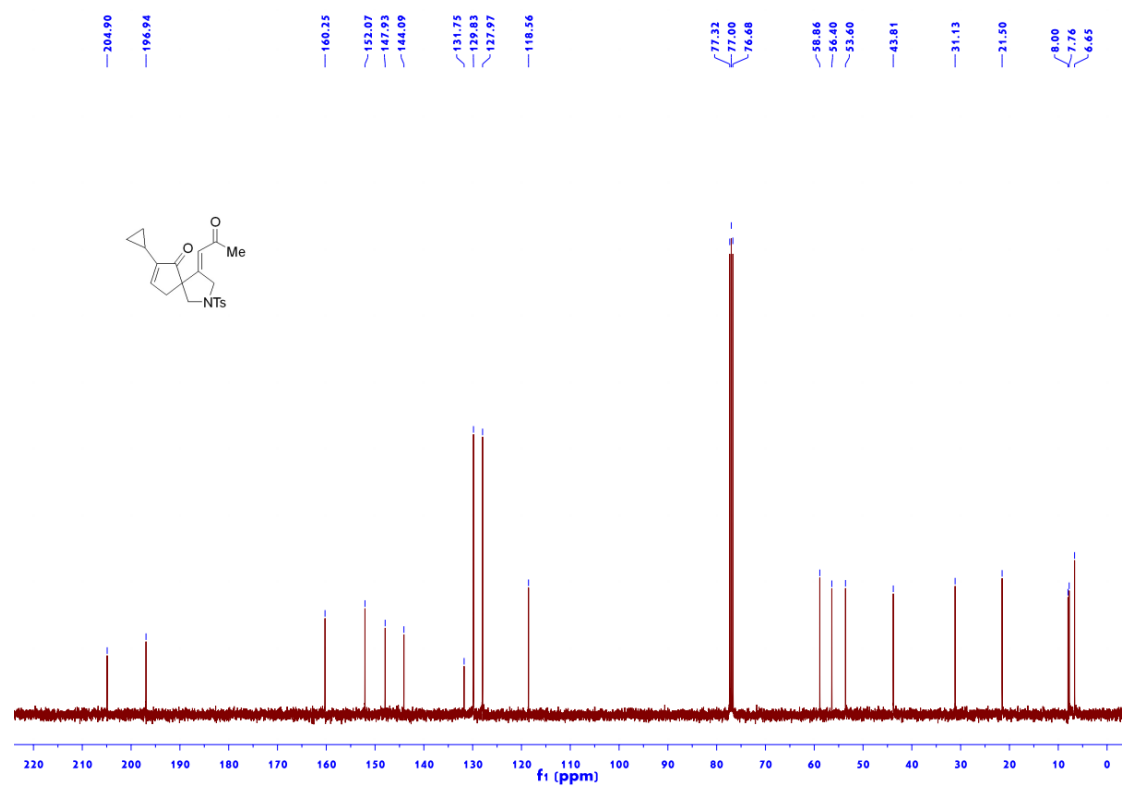


Figure S295 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 7g

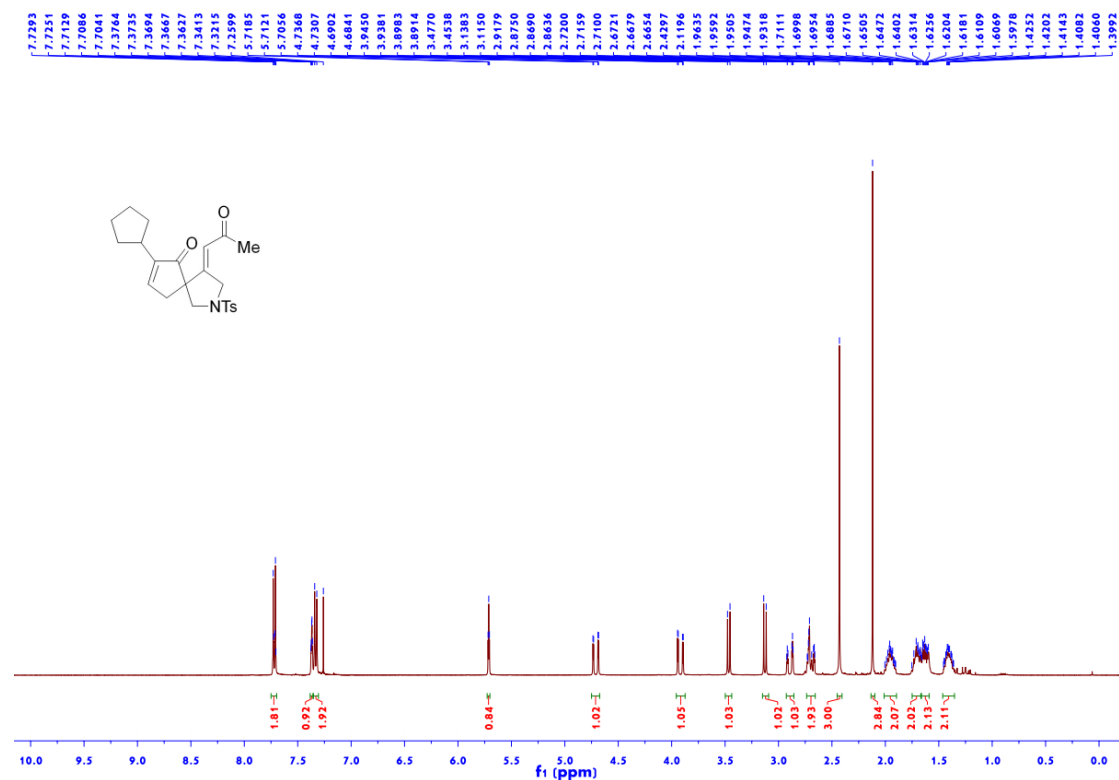


Figure S296 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 7g

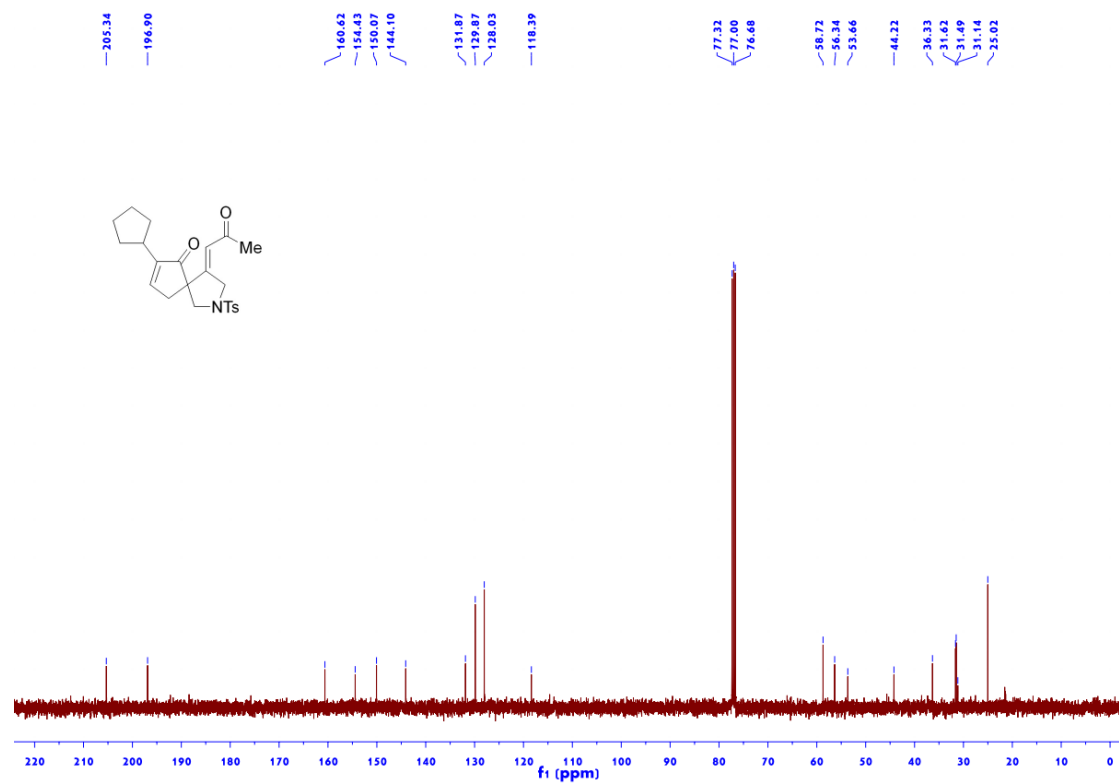




Figure S297 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 7h

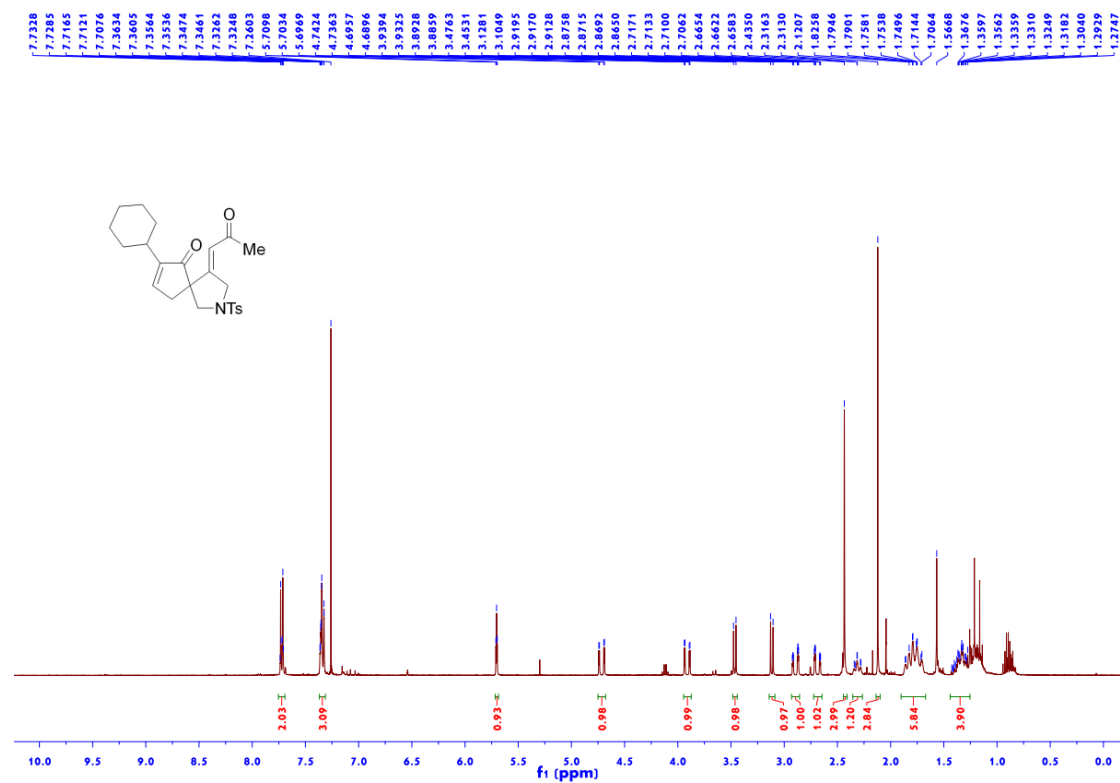


Figure S298 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 7h

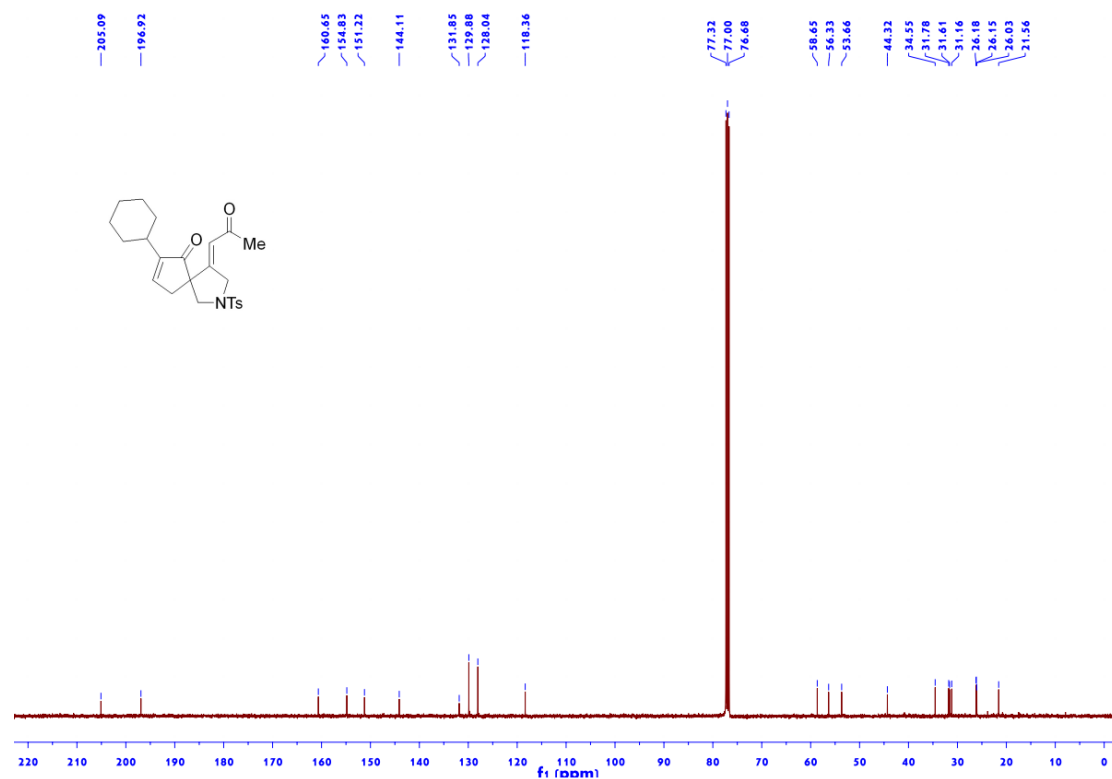


Figure S299 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 7i

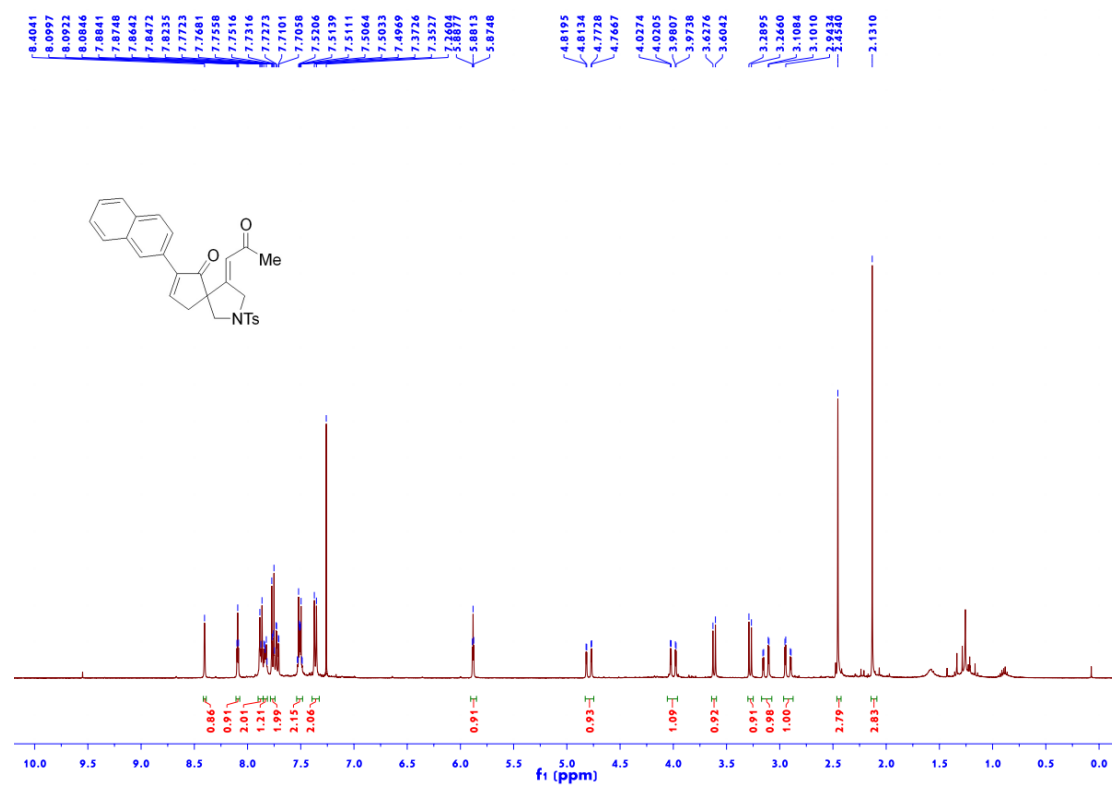


Figure S300 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 7i

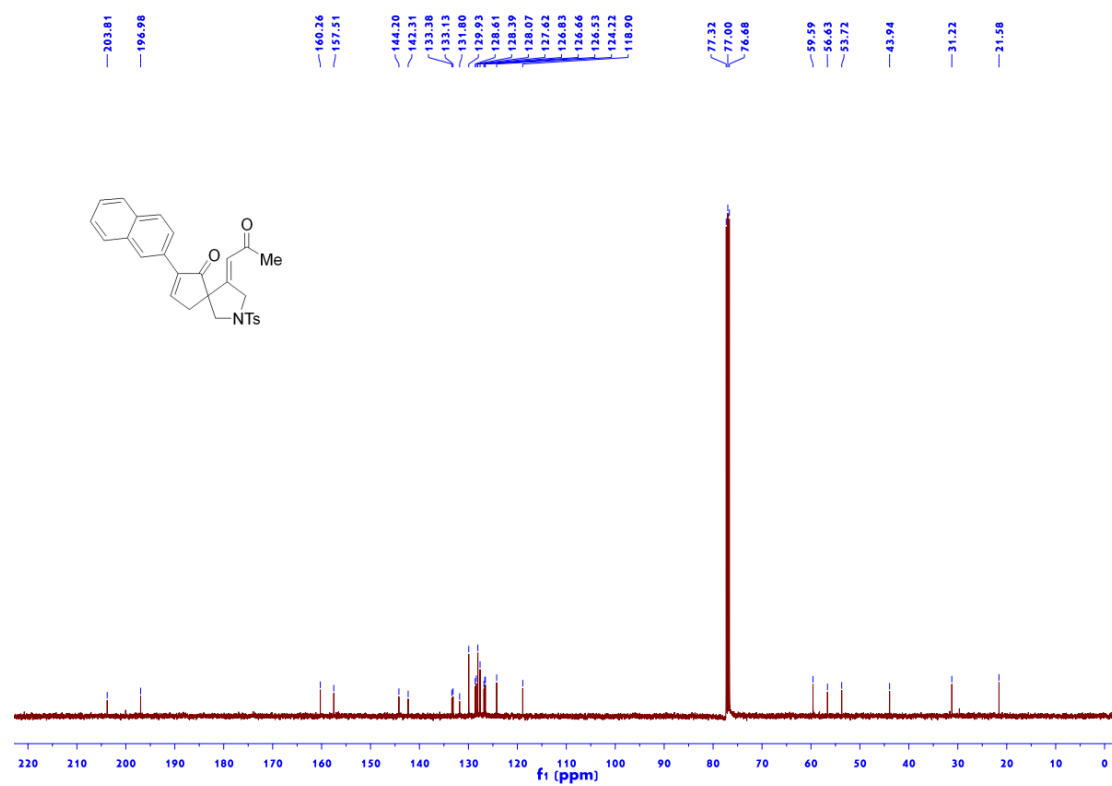


Figure S301 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 7j

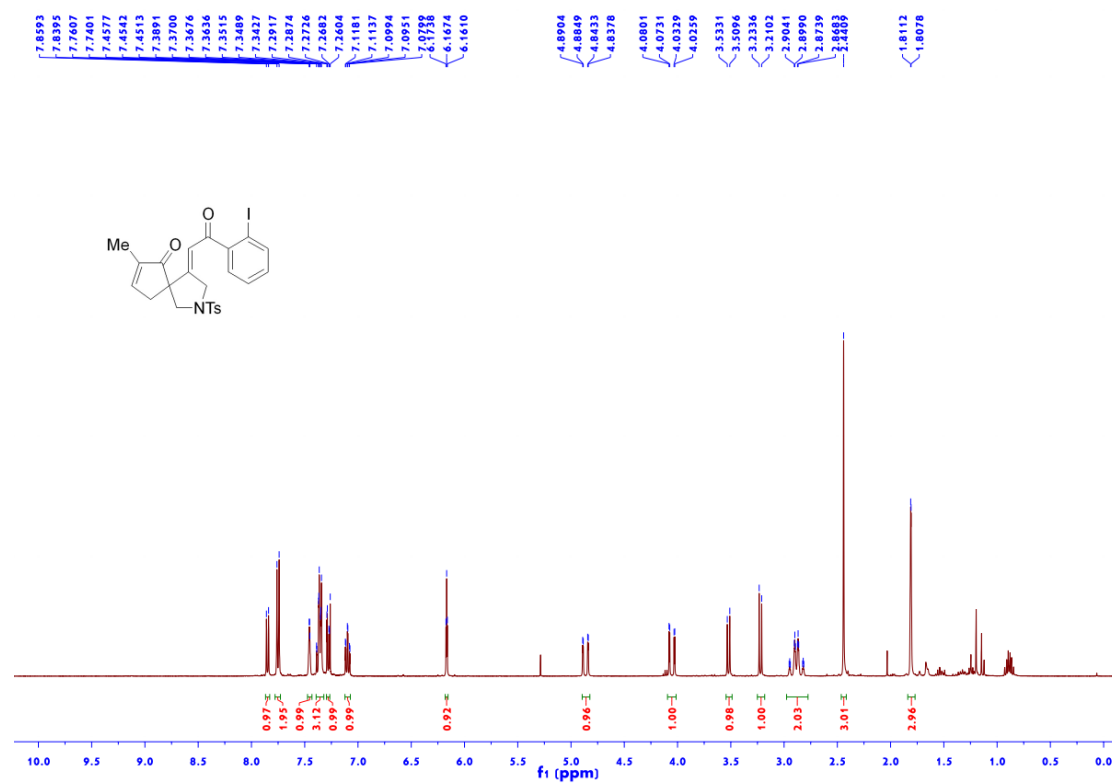


Figure S302 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 7j

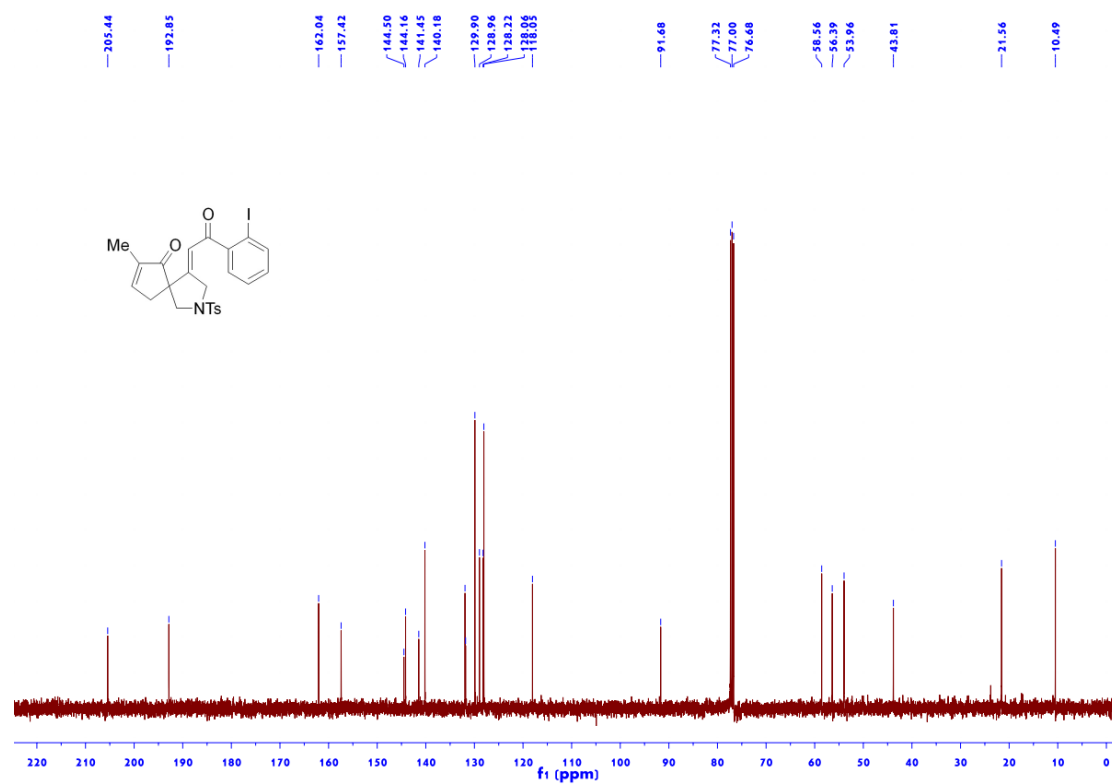


Figure S303 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 7k

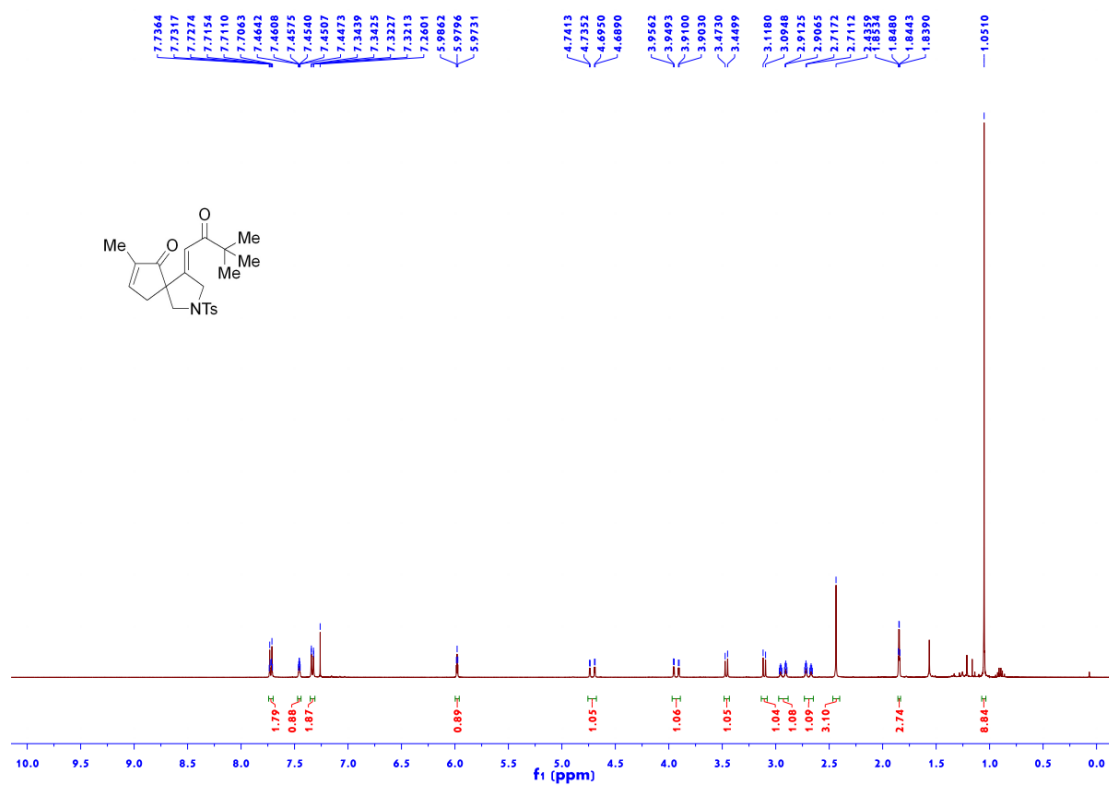


Figure S304 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 7k

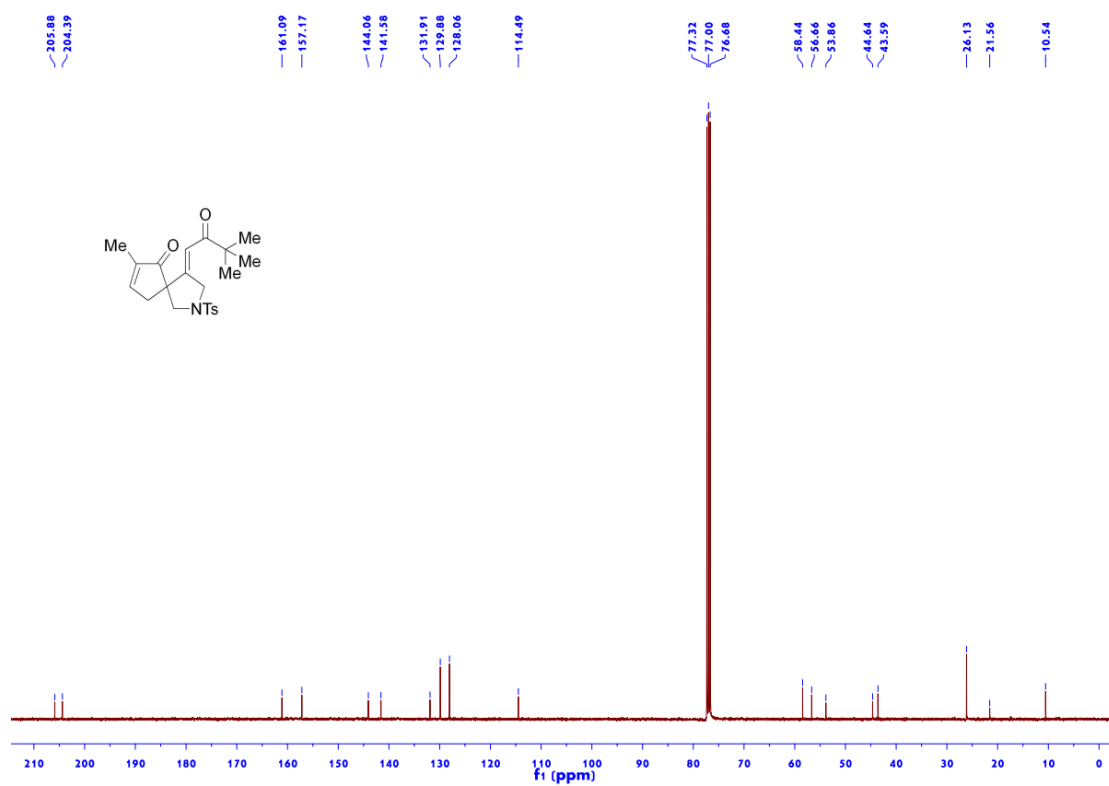


Figure S305 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 71

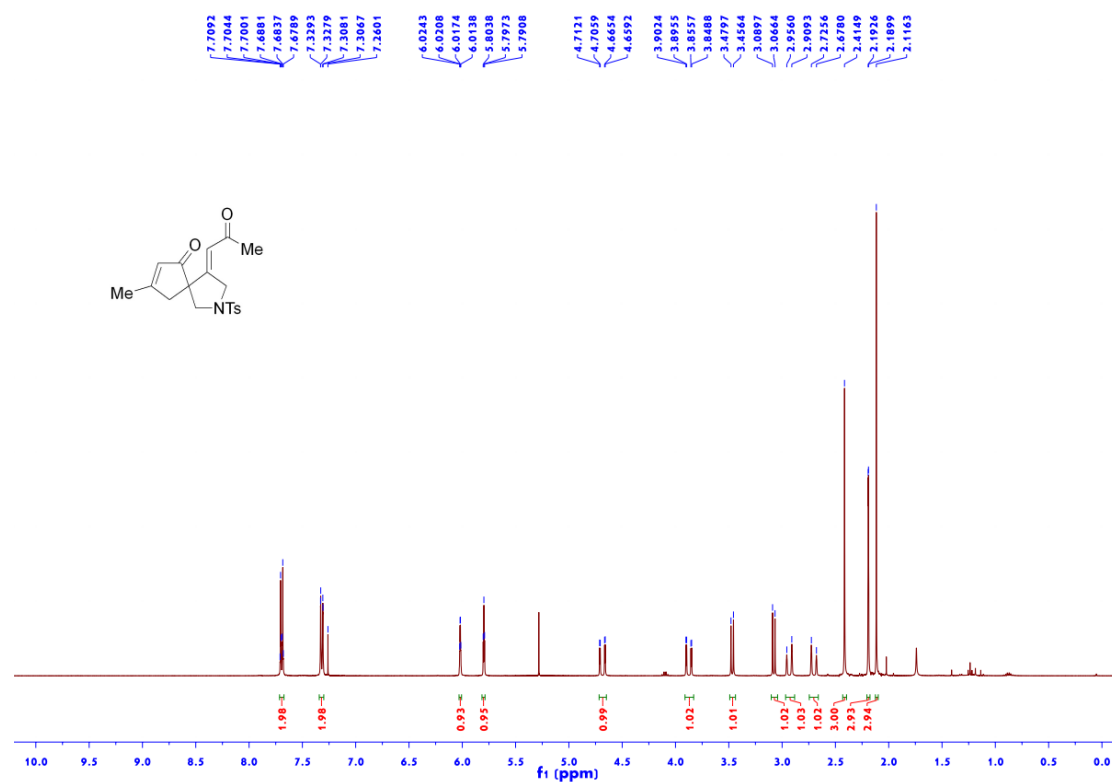


Figure S306 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 71

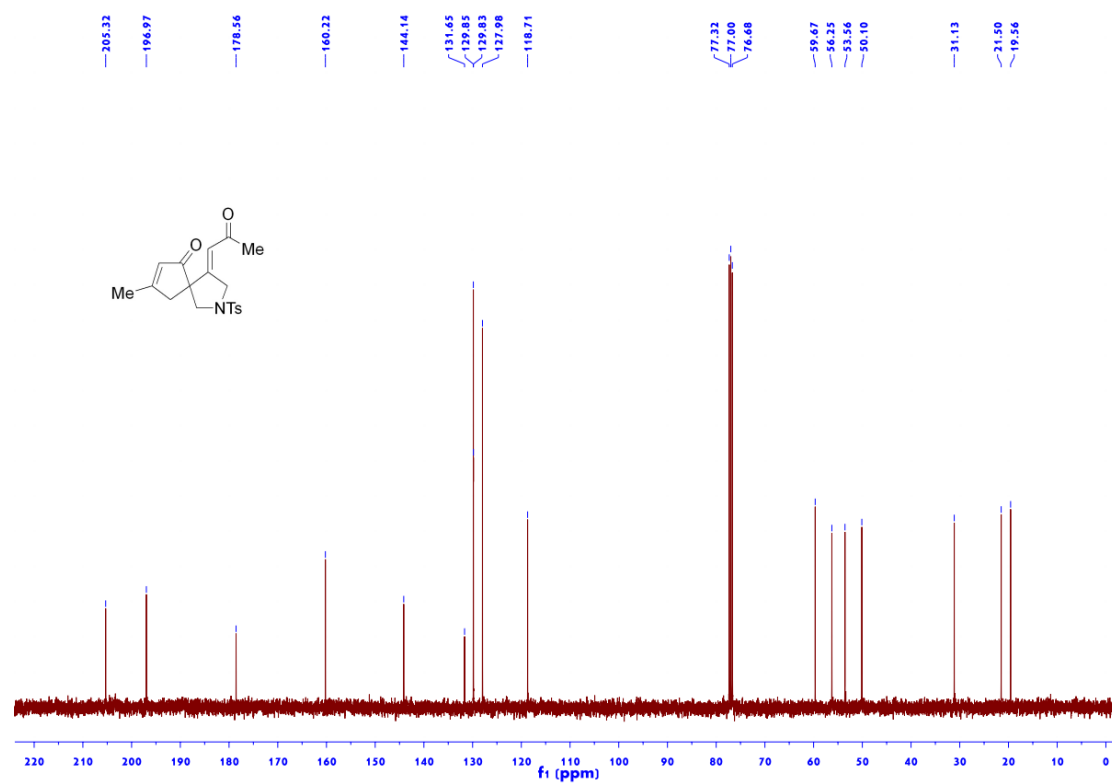


Figure S307 <sup>1</sup>H NMR (600 MHz, CDCl<sub>3</sub>) of 7m

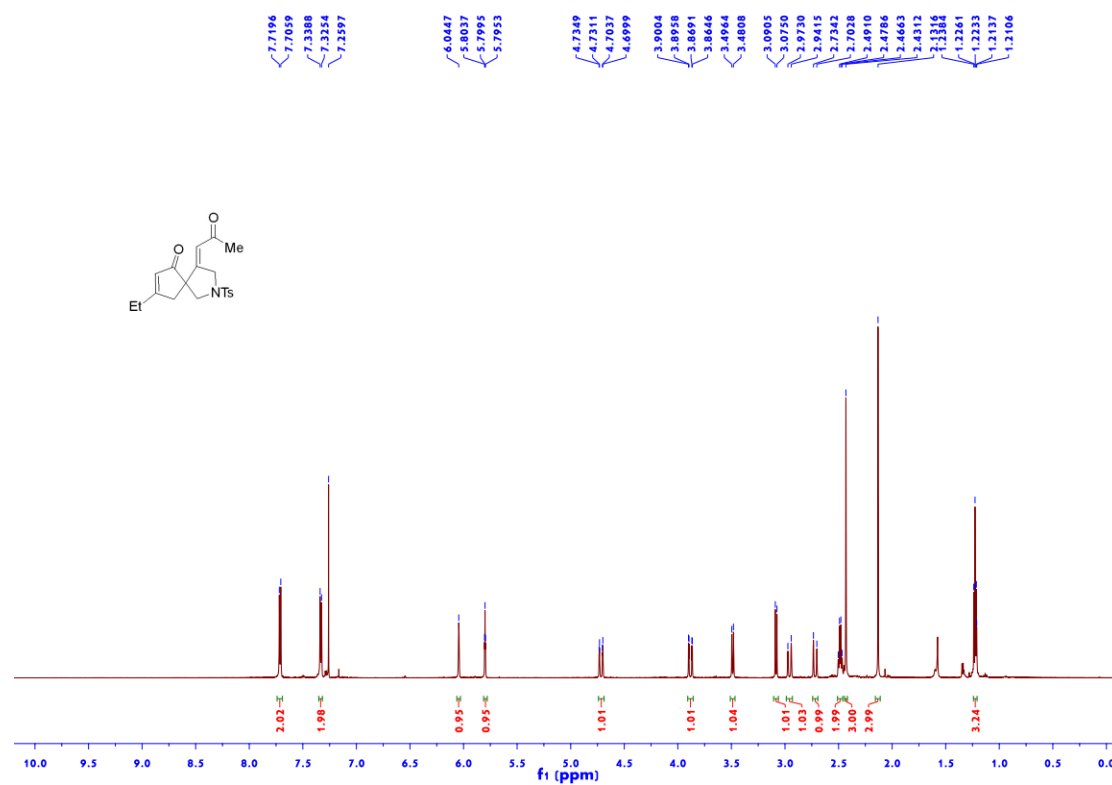


Figure S308 <sup>13</sup>C NMR (150 MHz, CDCl<sub>3</sub>) of 7m

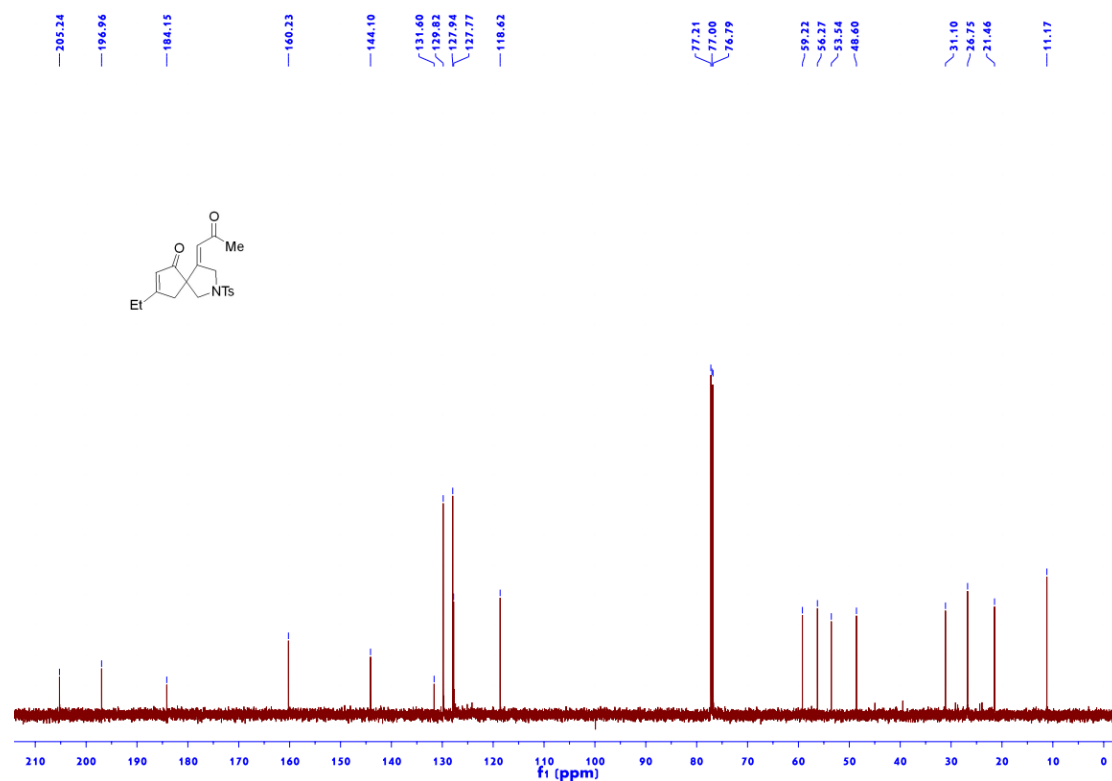


Figure S309 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 7n

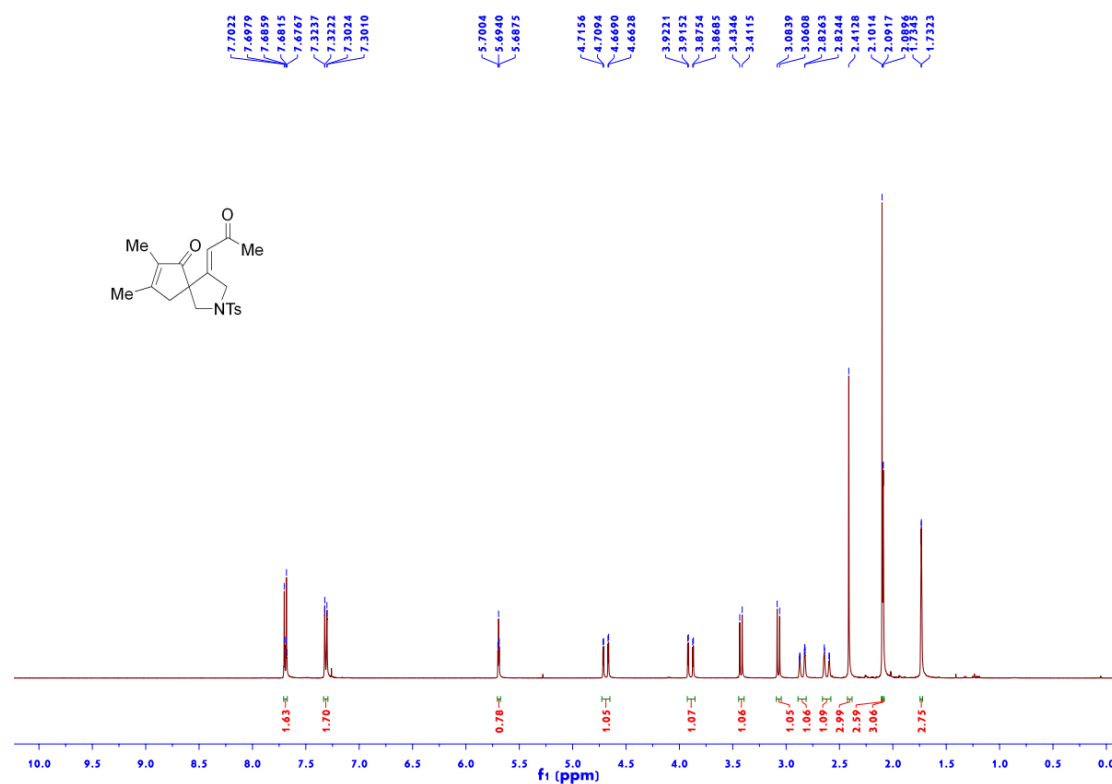


Figure S310 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 7n

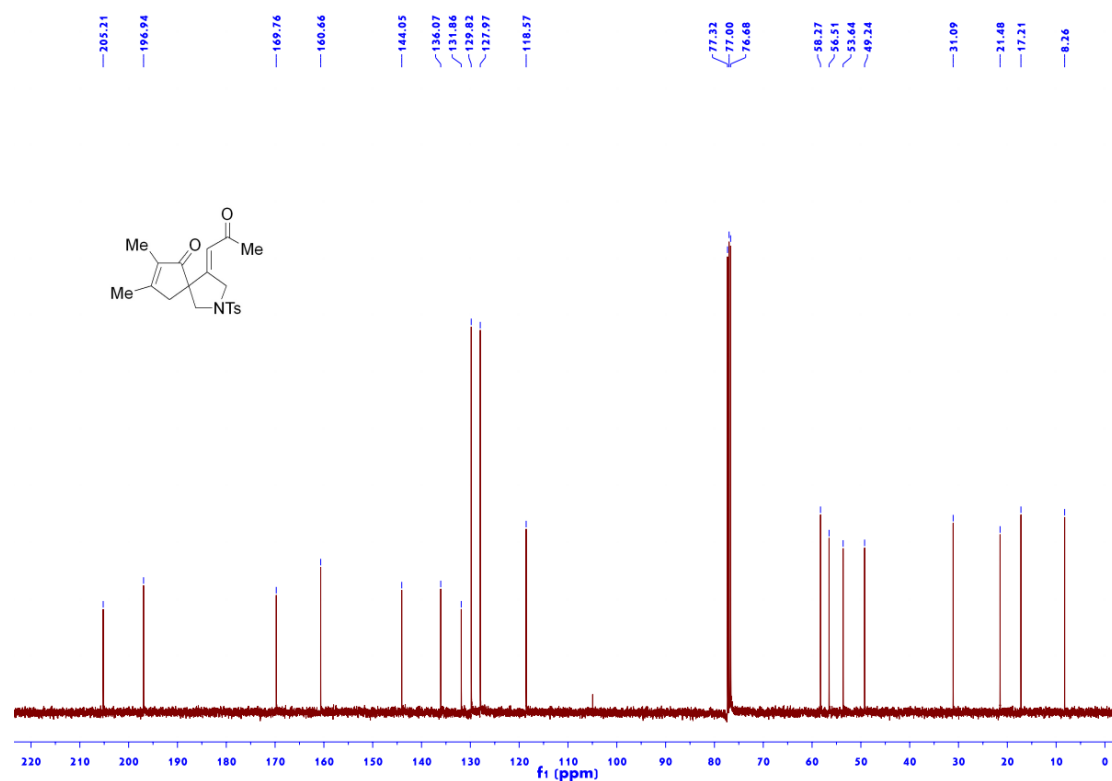


Figure S311 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 7o

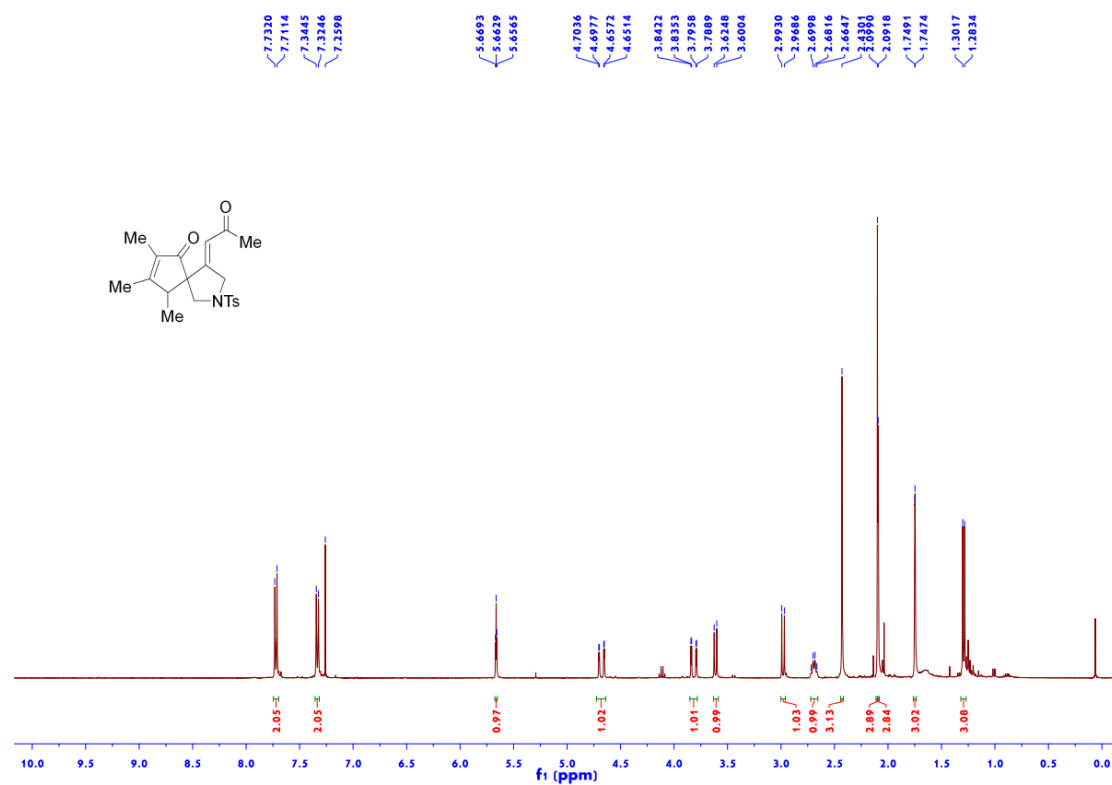


Figure S312 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 7o

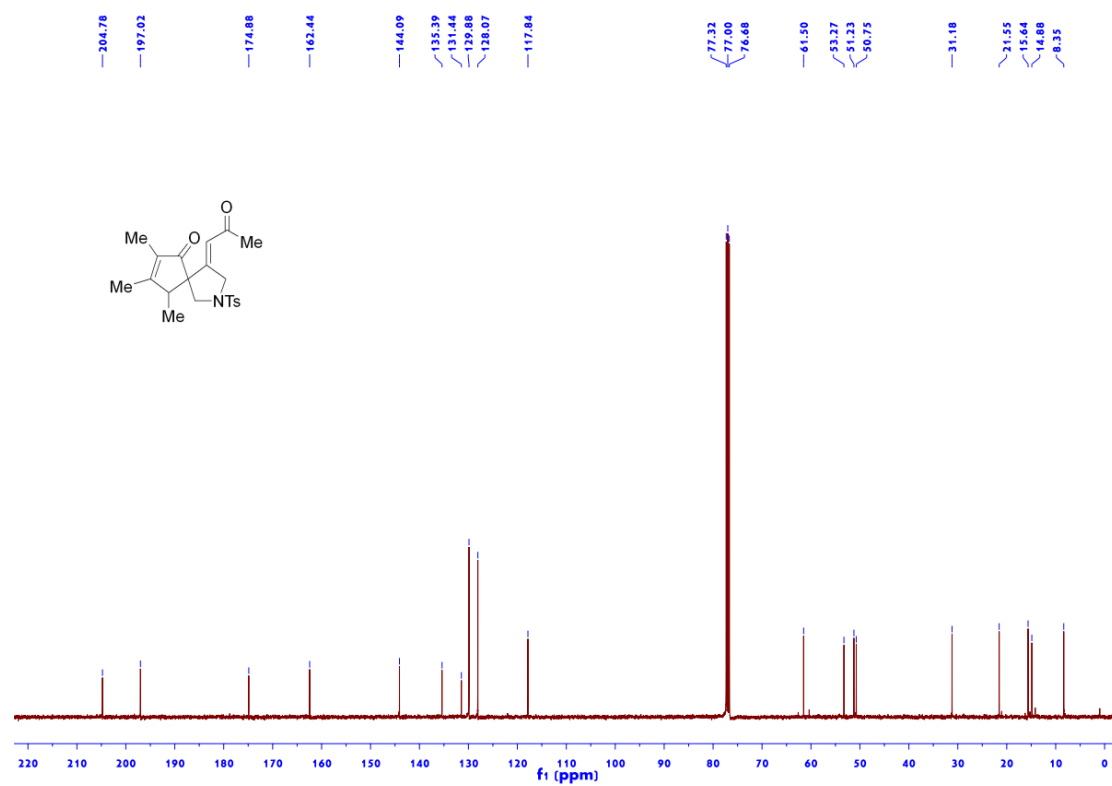




Figure S313 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 7p

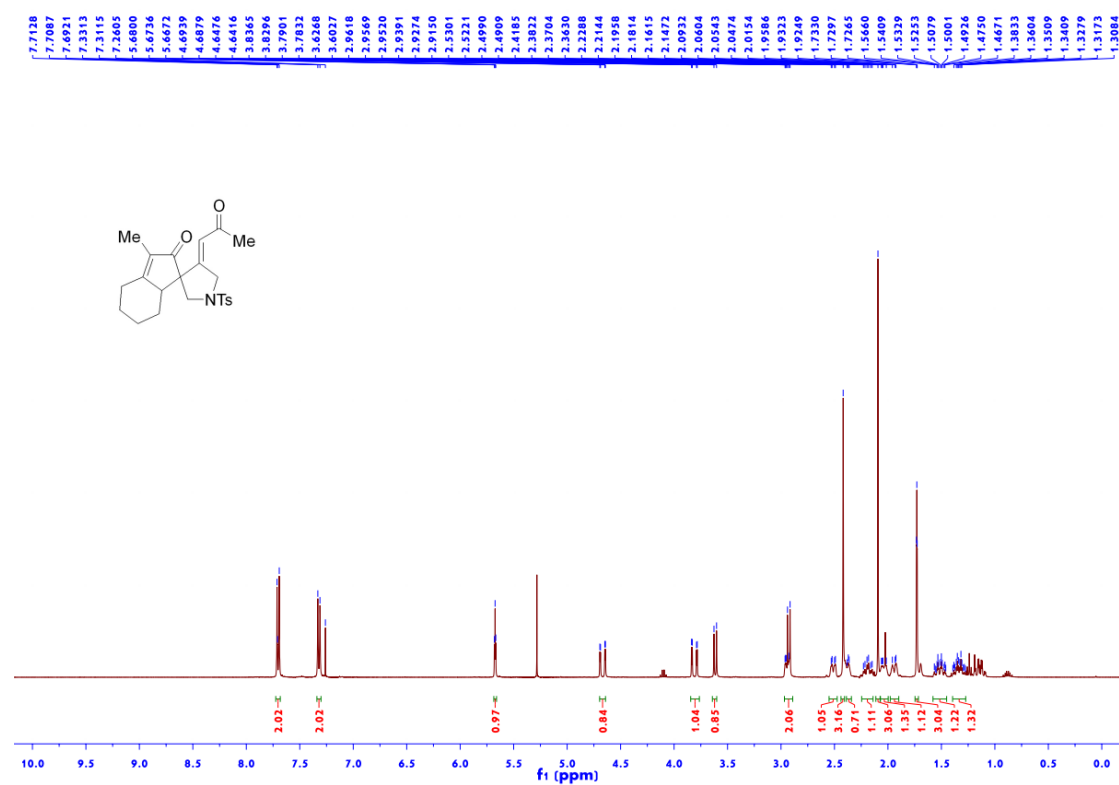


Figure S314 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 7p

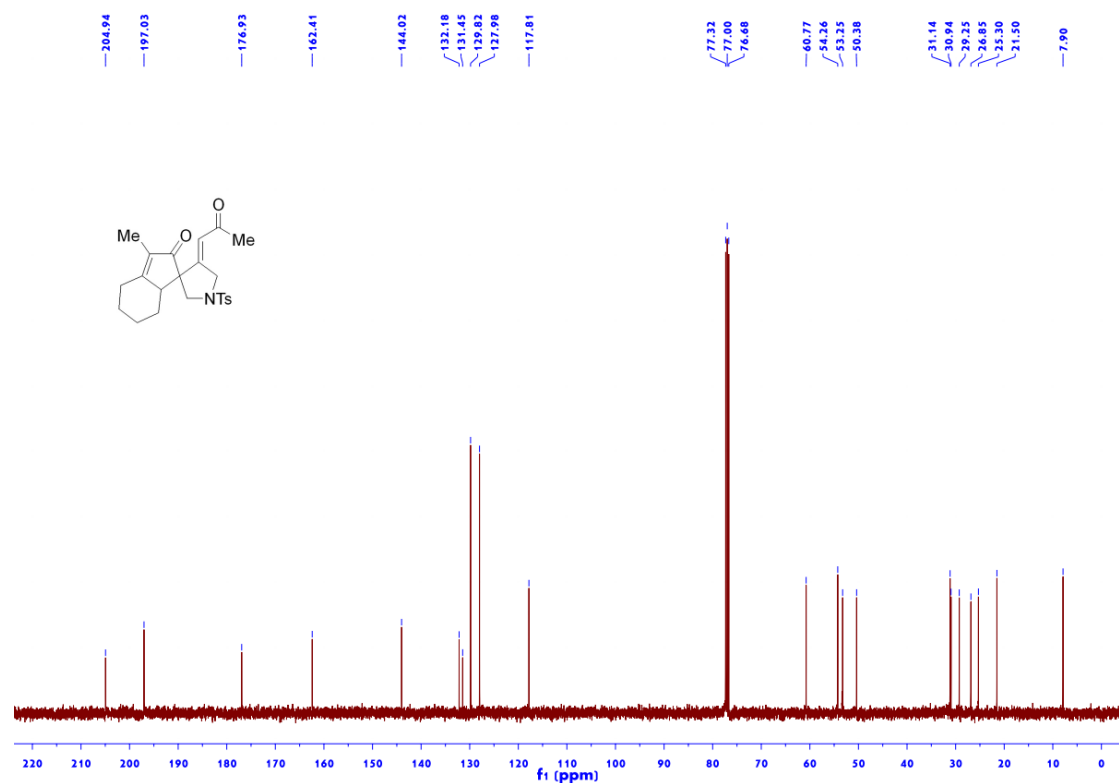


Figure S315  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) of 7q

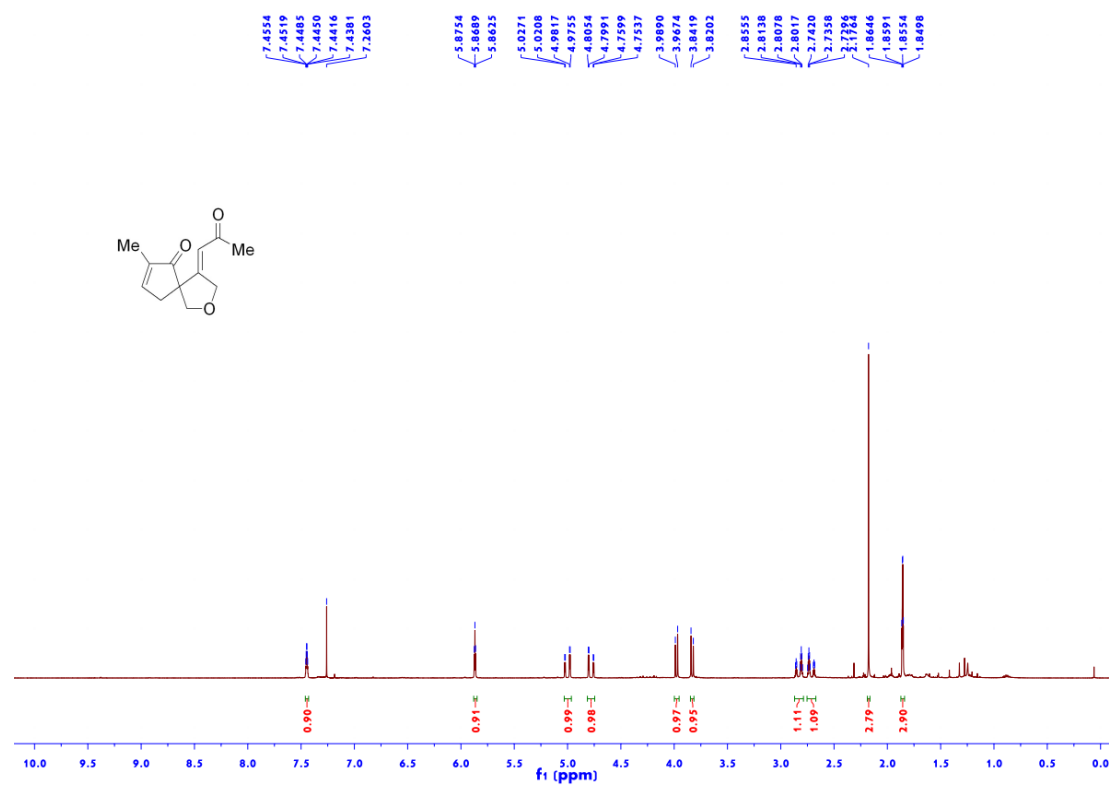


Figure S316  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ) of 7q

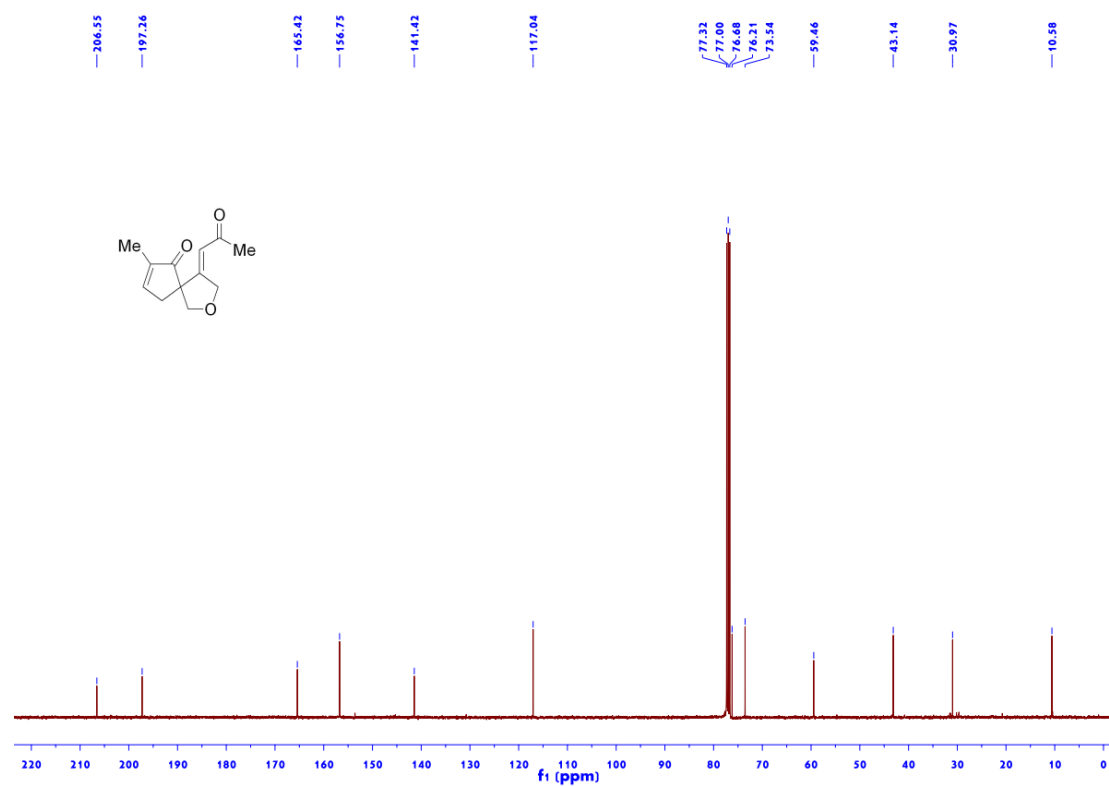


Figure S317 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 7r

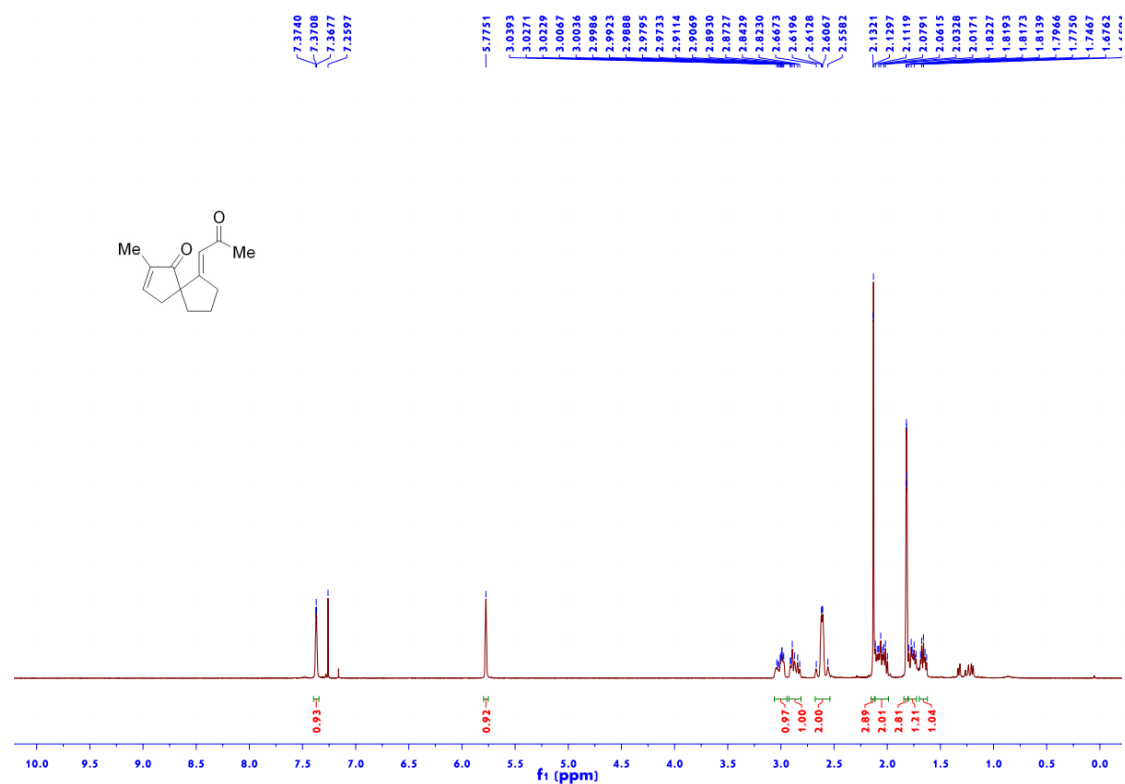


Figure S318 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 7r

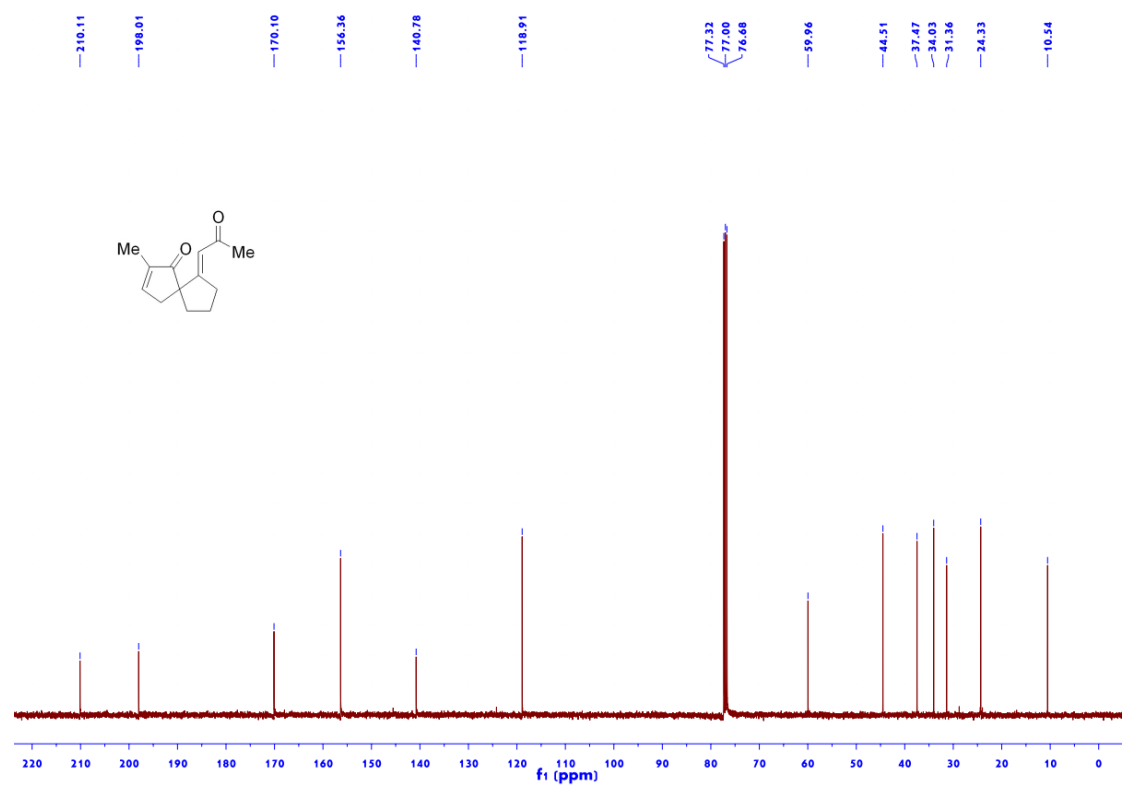


Figure S319 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 7s

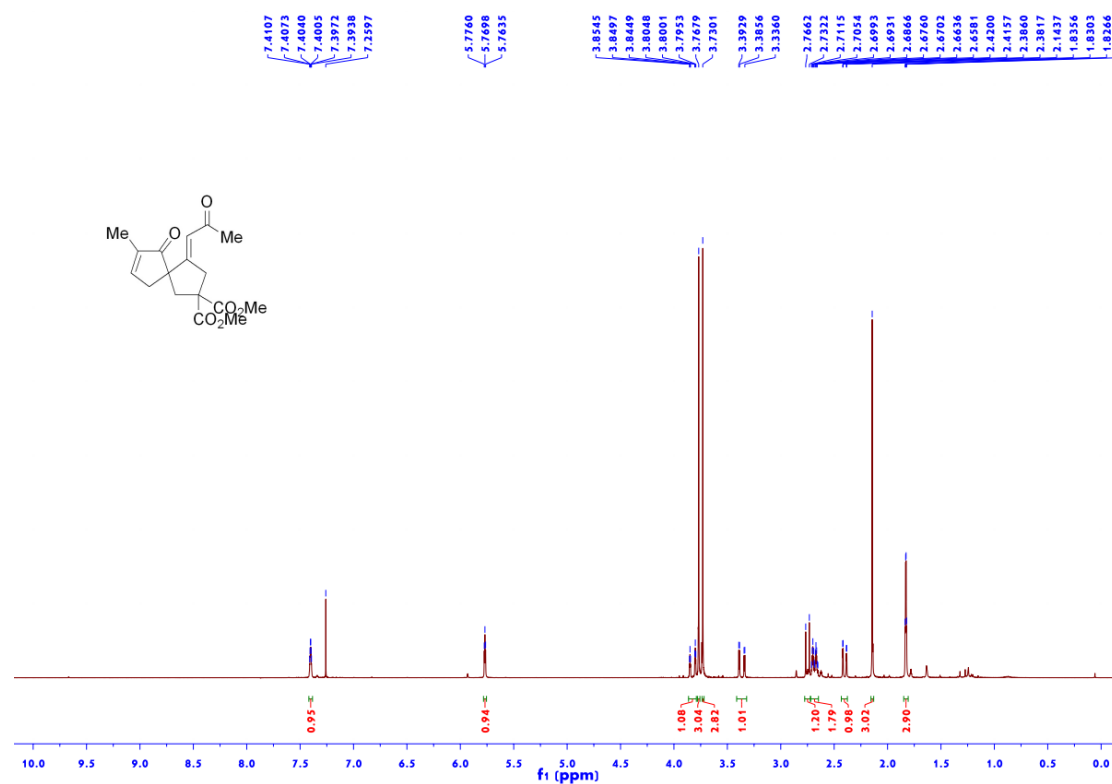


Figure S320 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 7s

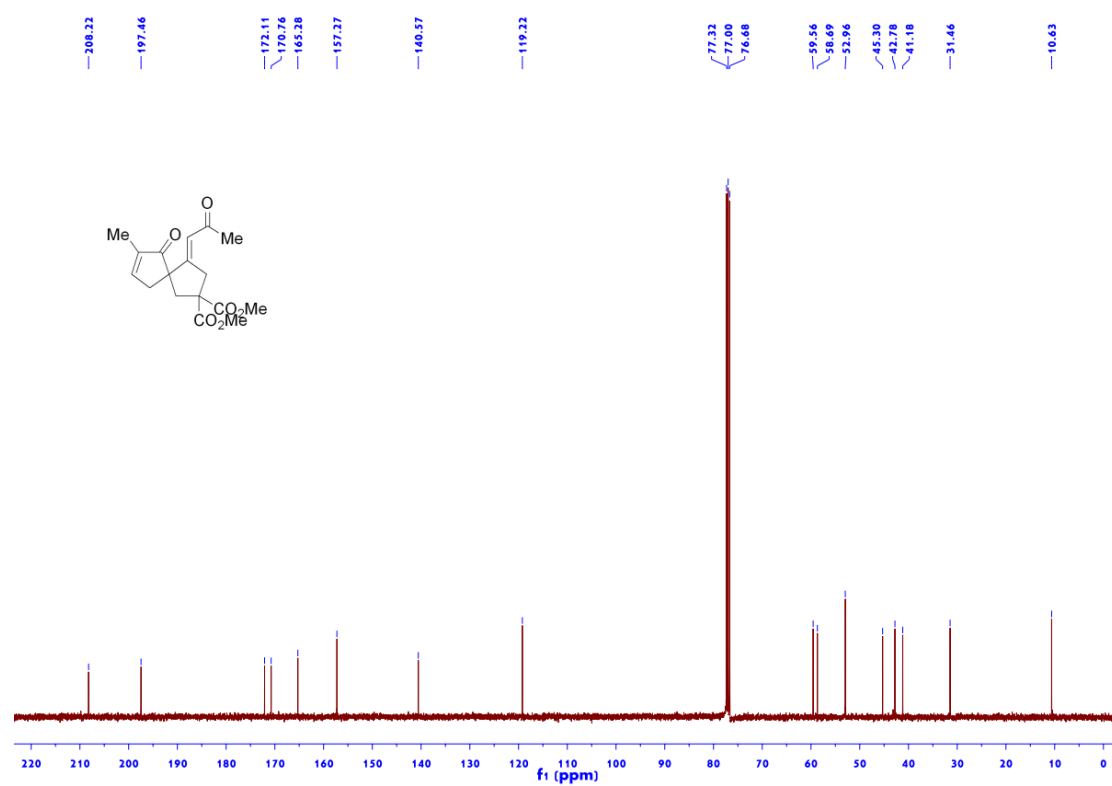


Figure S321 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 9a

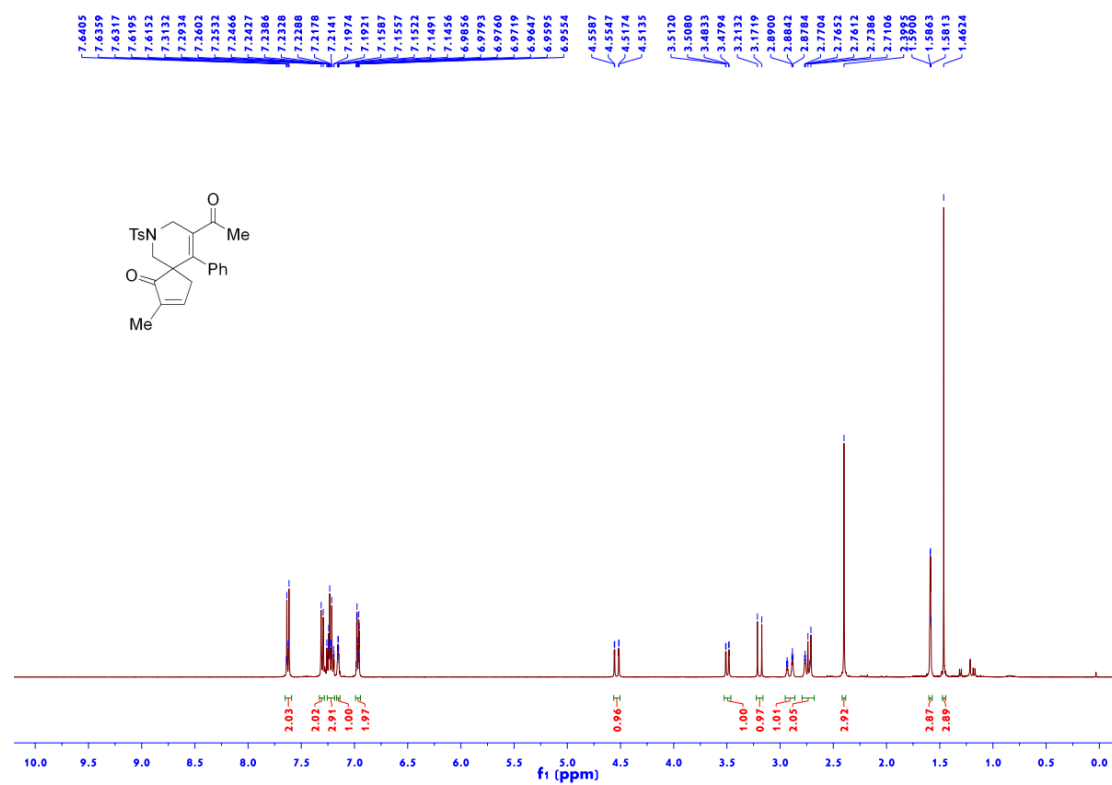


Figure S322 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 9a

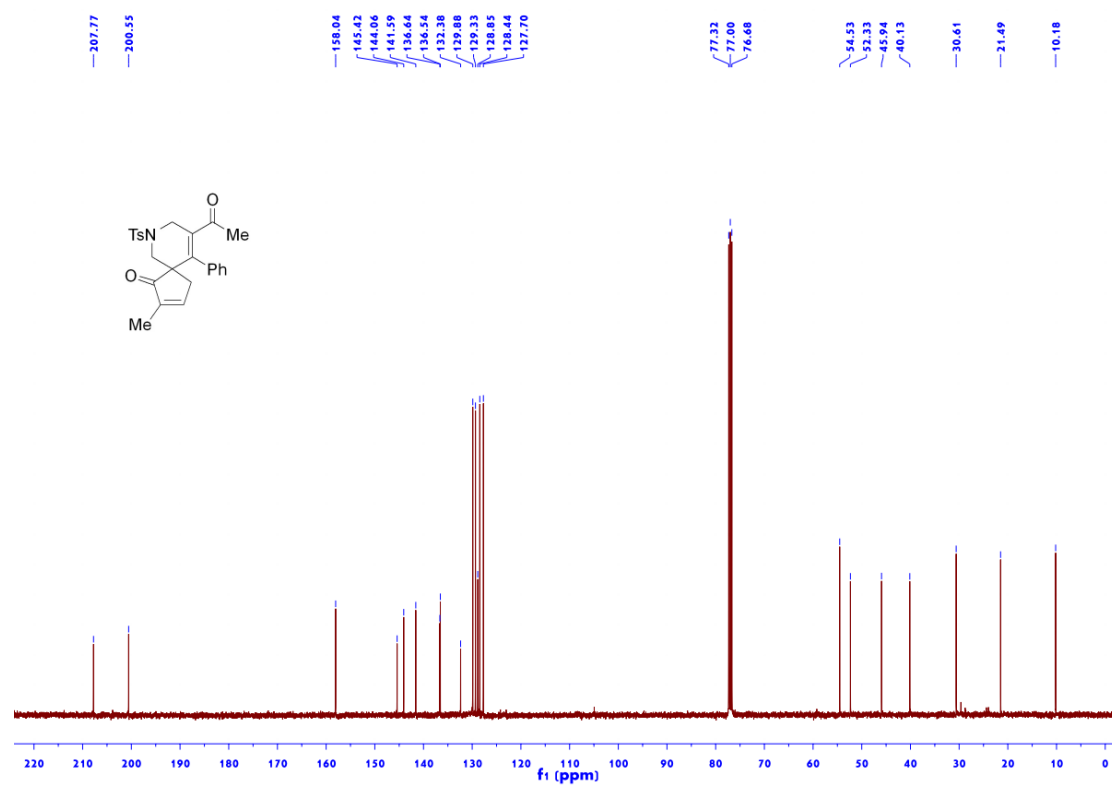


Figure S323 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 9b

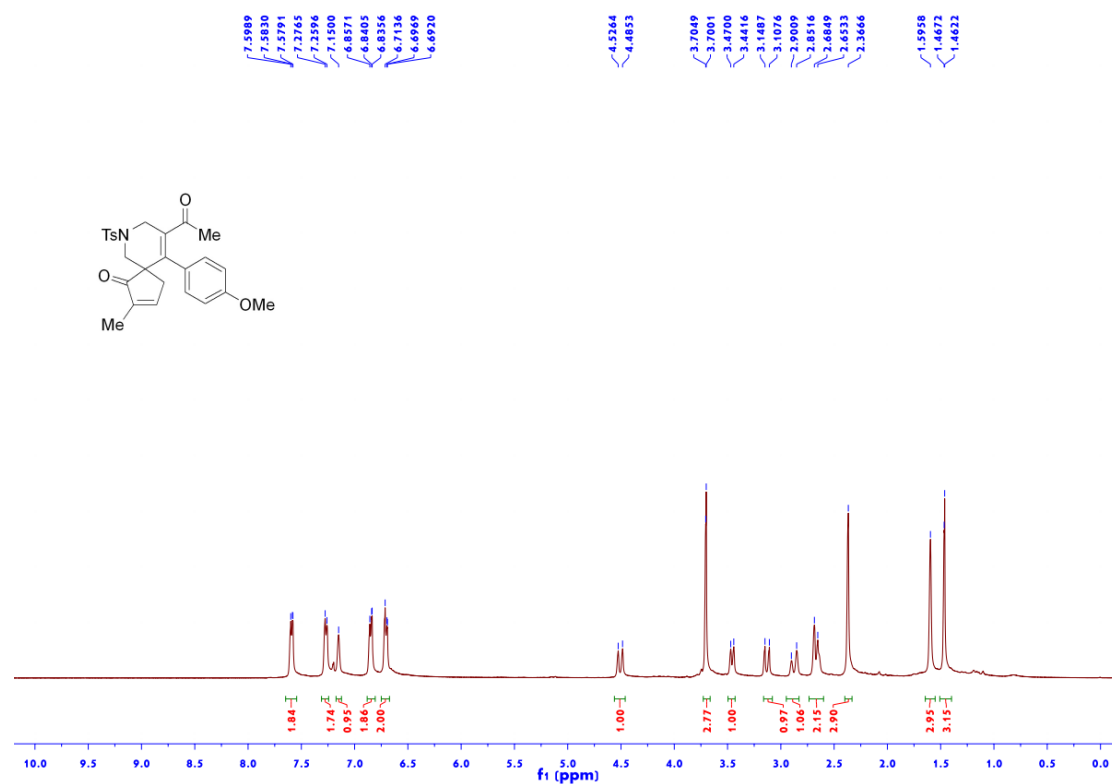


Figure S324 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 9b

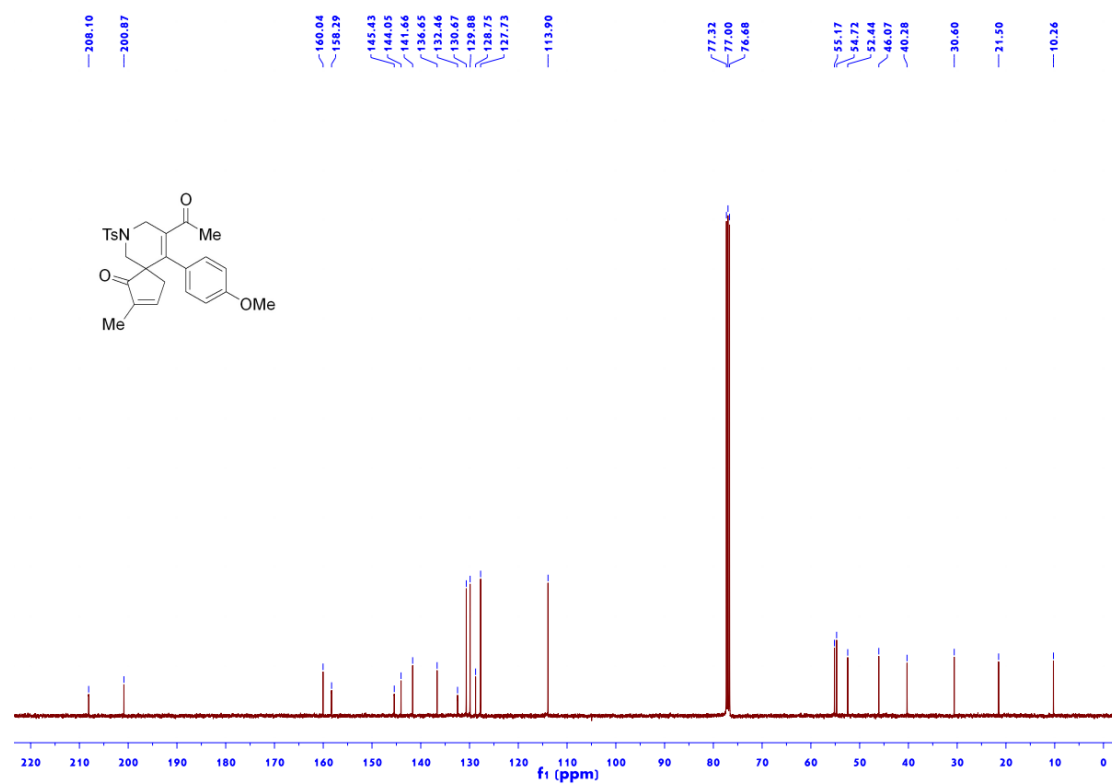


Figure S325  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) of 9c

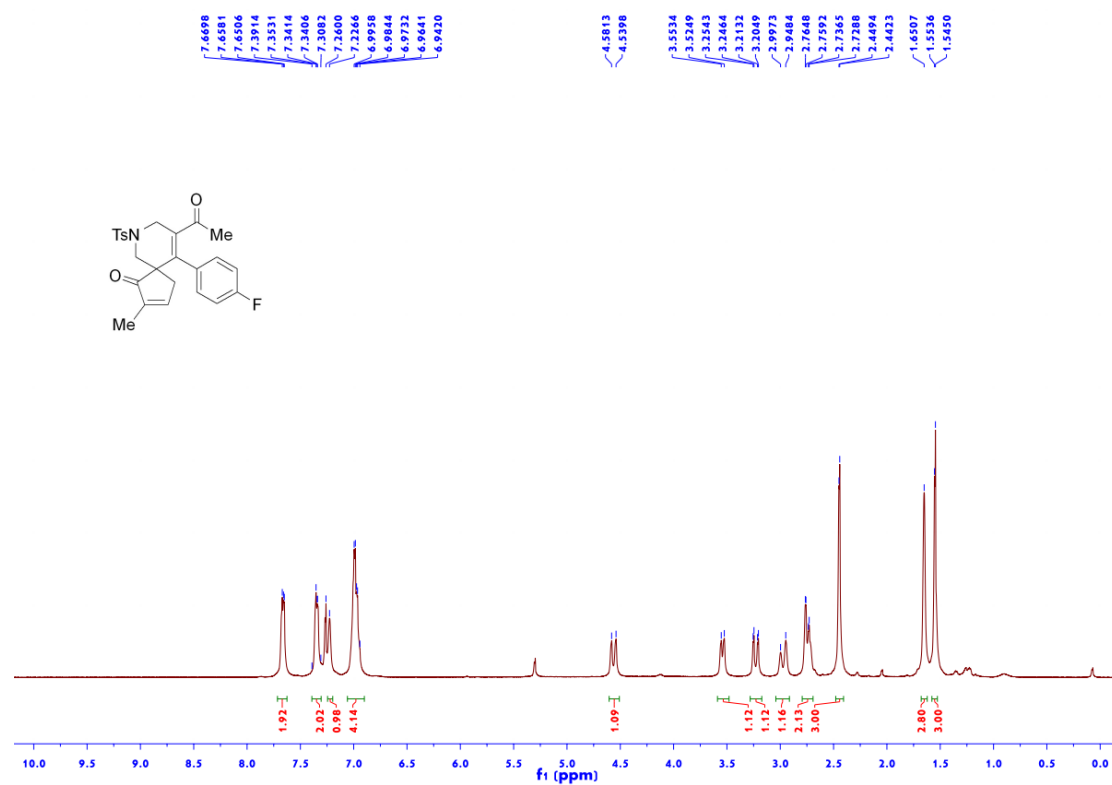


Figure S326  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ) of 9c

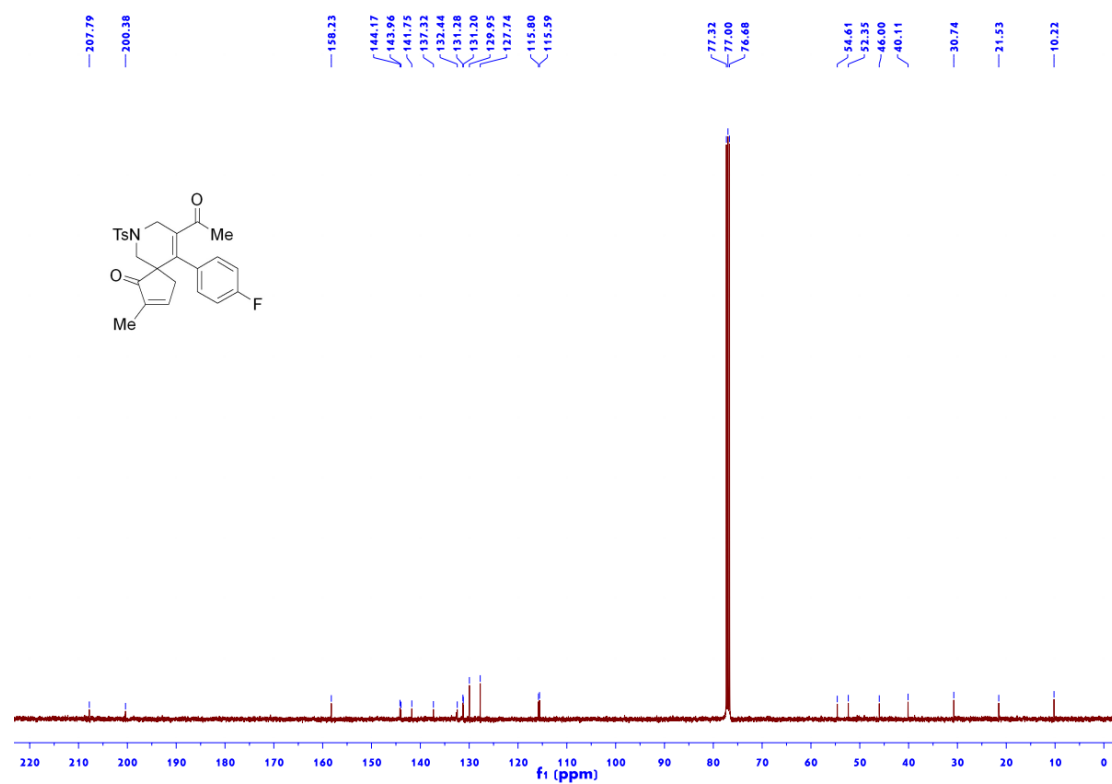


Figure S327 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 9d

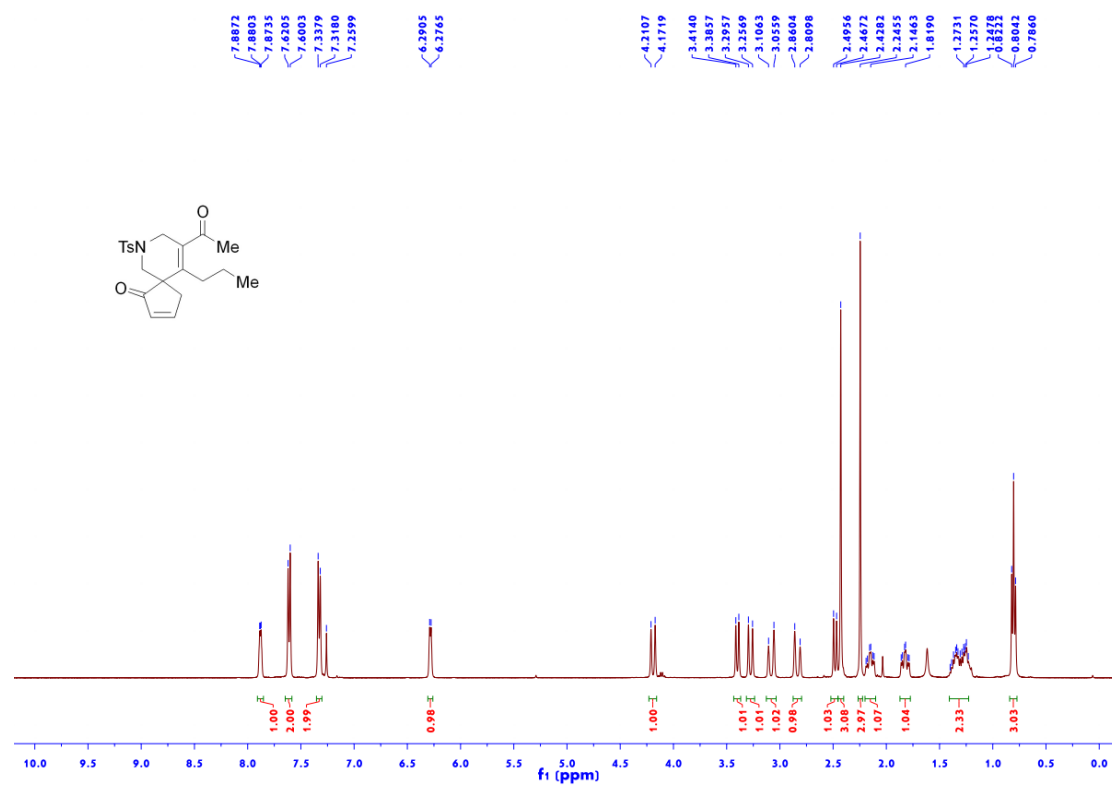


Figure S328 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 9d

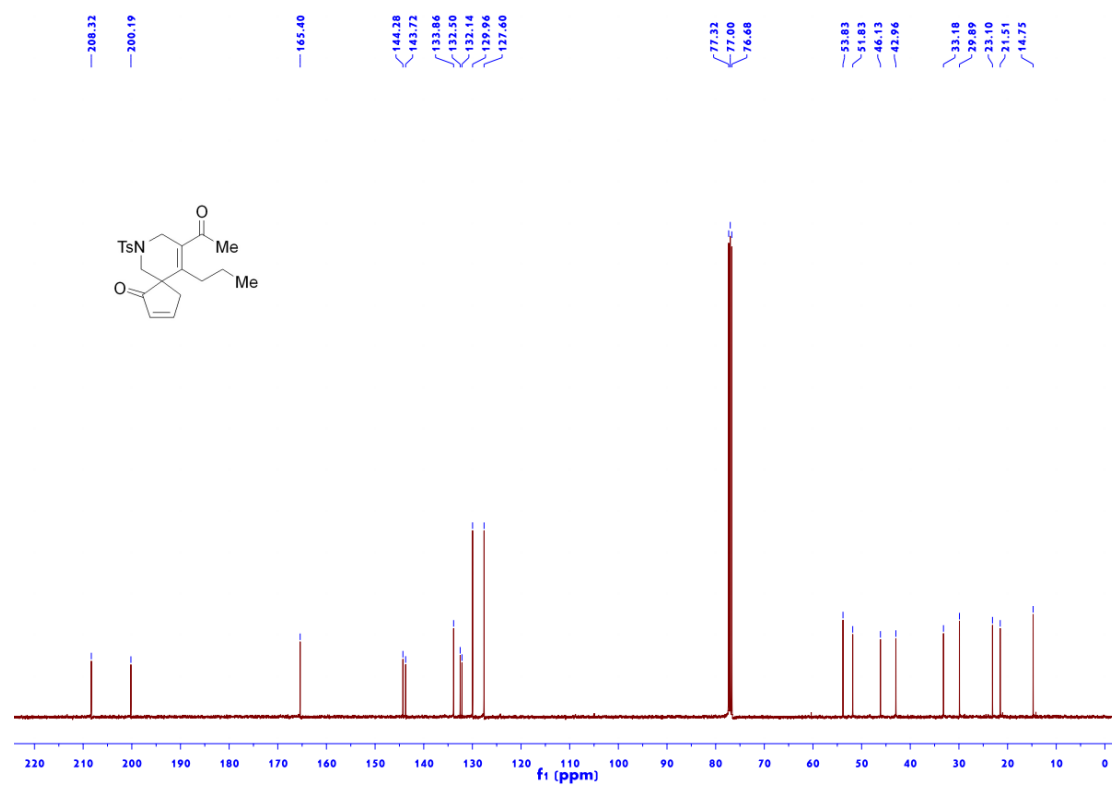




Figure S329 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of 9e

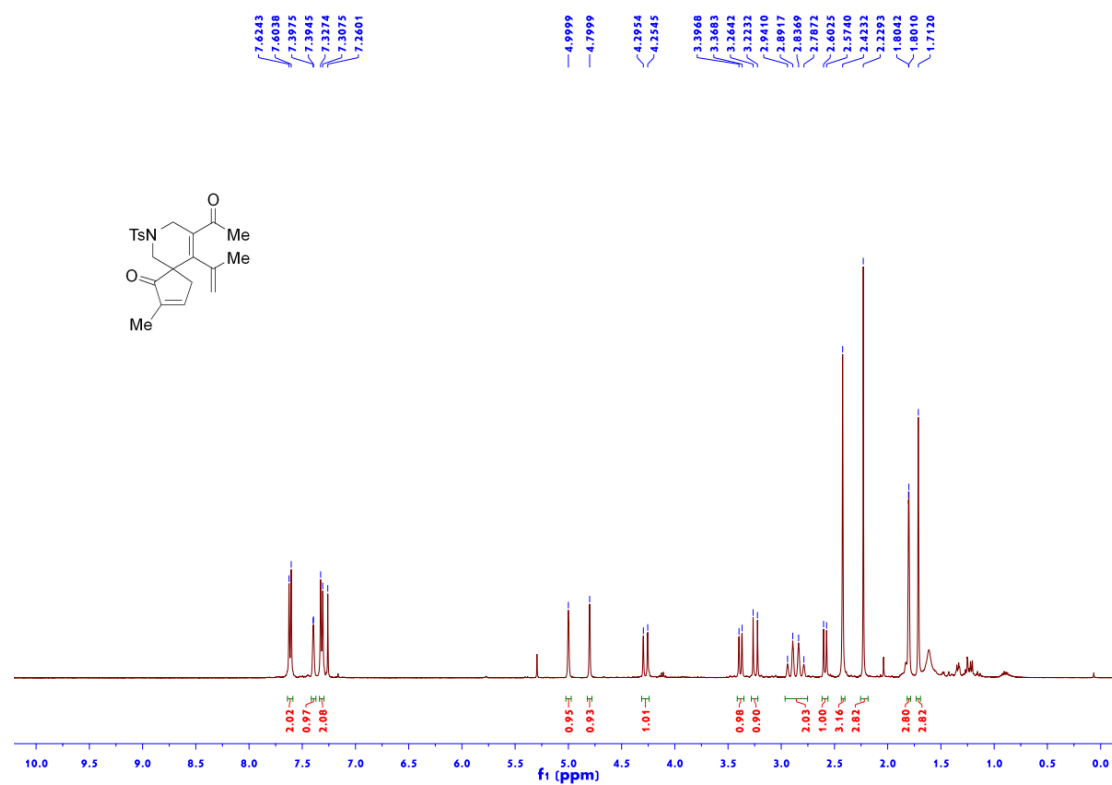


Figure S330 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of 9e

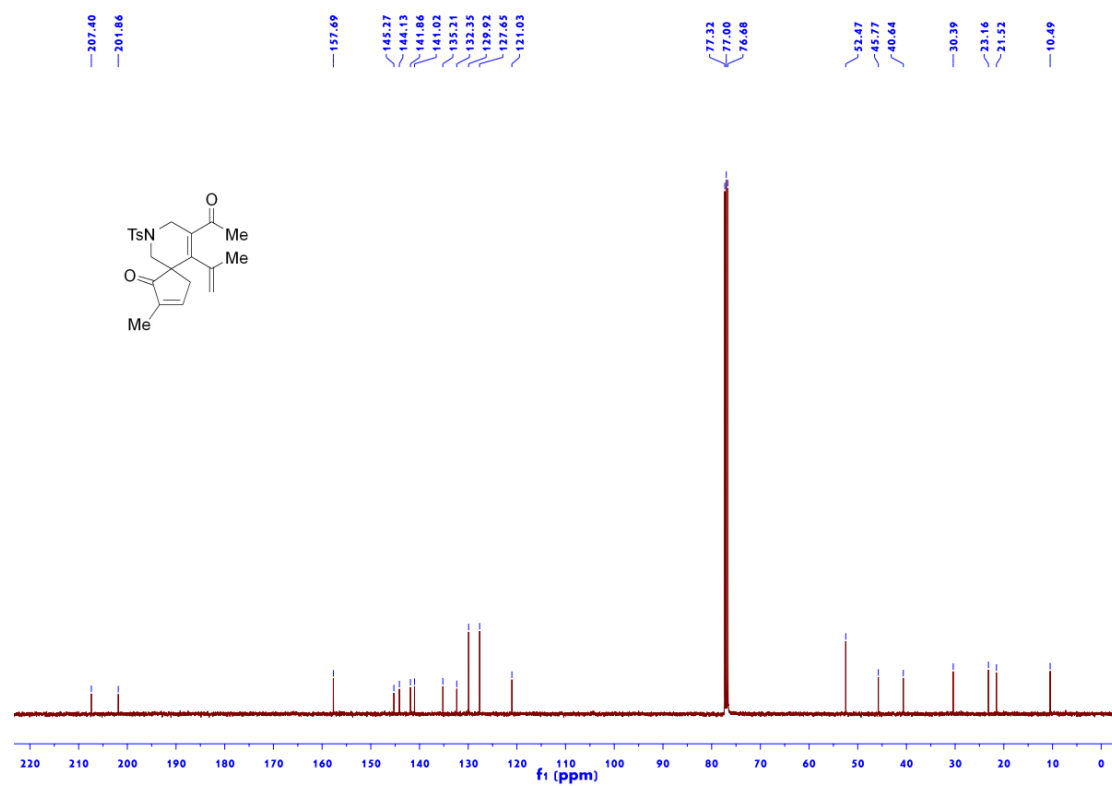


Figure S331  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 10a

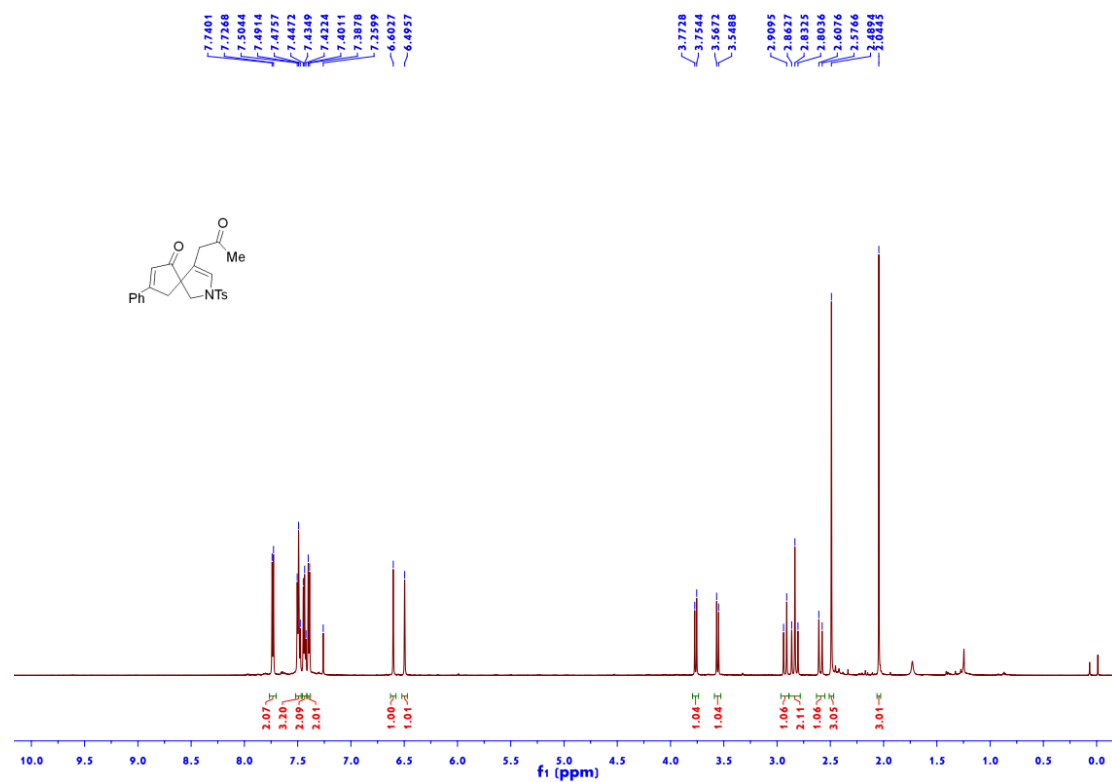


Figure S332  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 10a

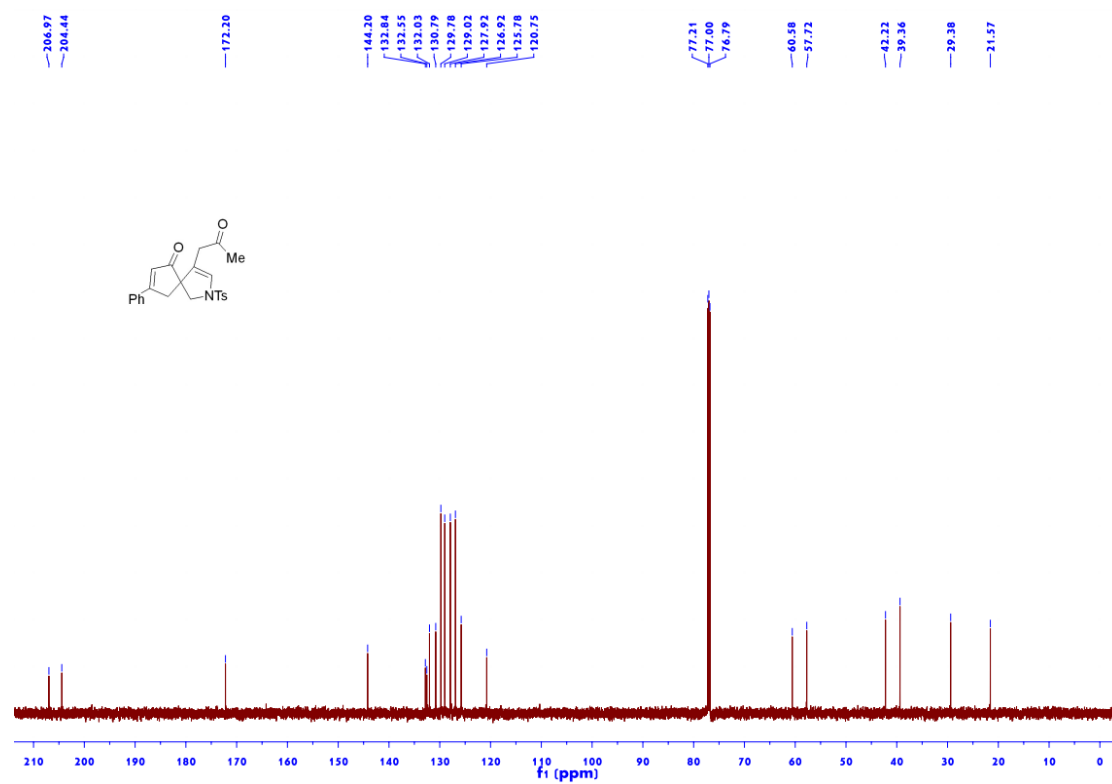


Figure S333  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 11a

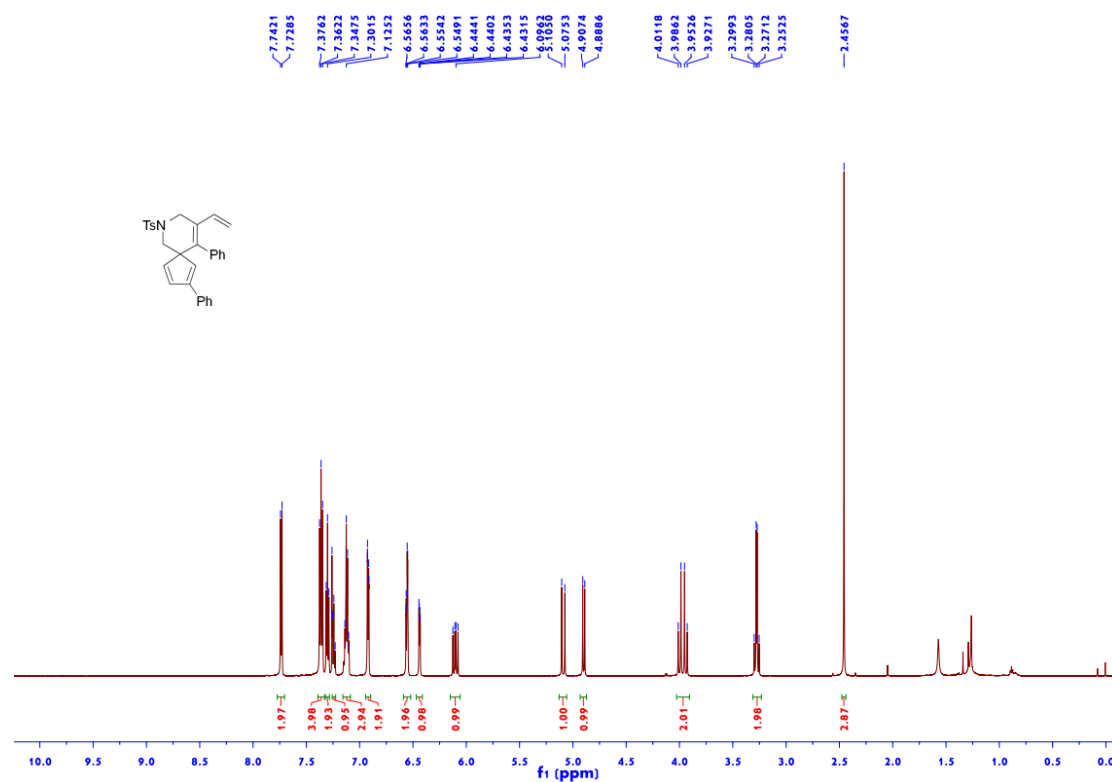


Figure S334  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 11a

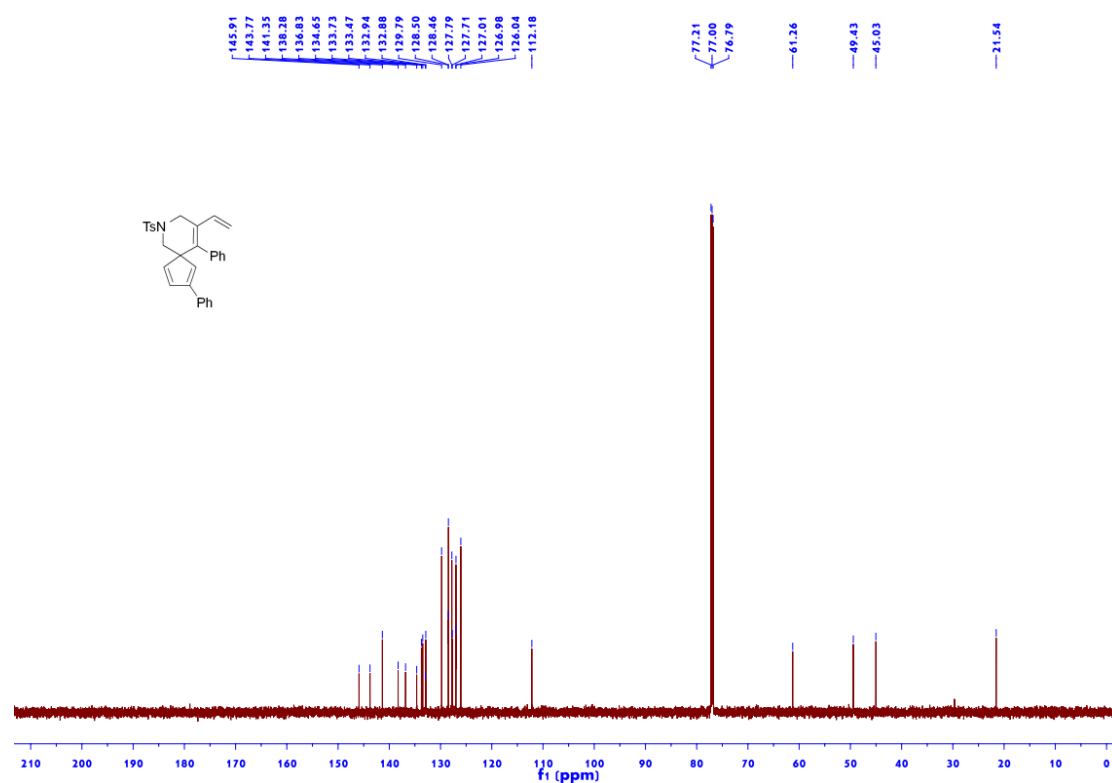


Figure S335  $^1\text{H}$  NMR (600 MHz,  $\text{CDCl}_3$ ) of 12a

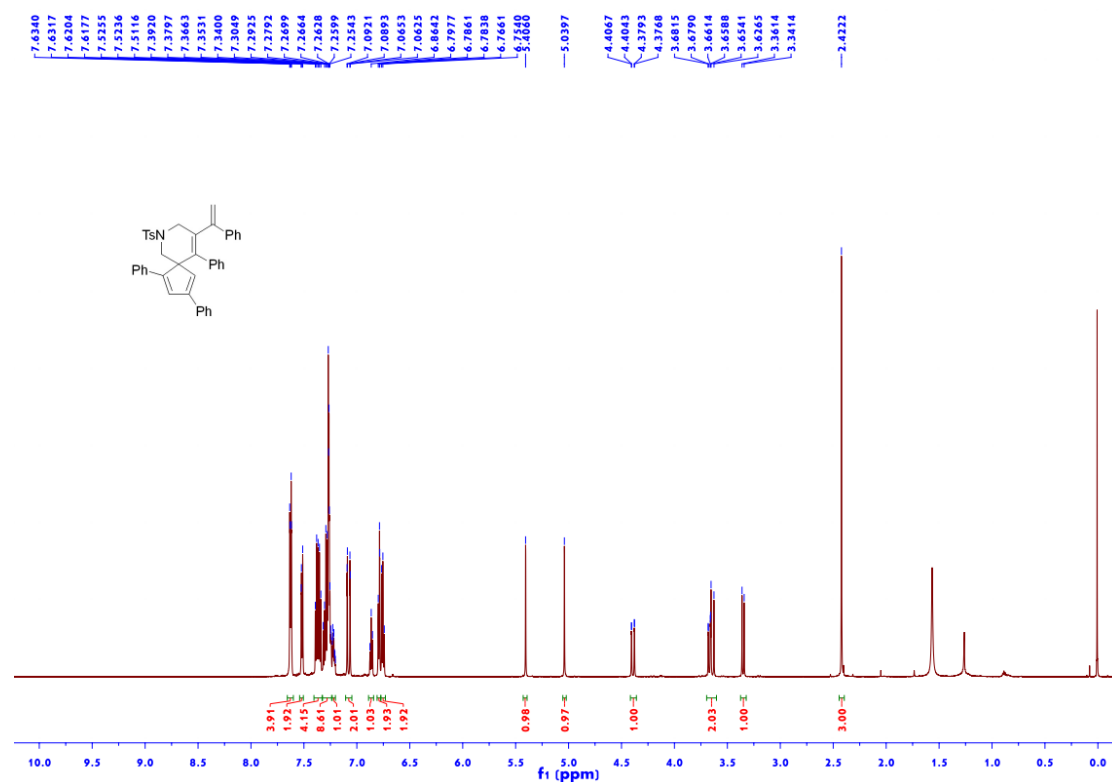
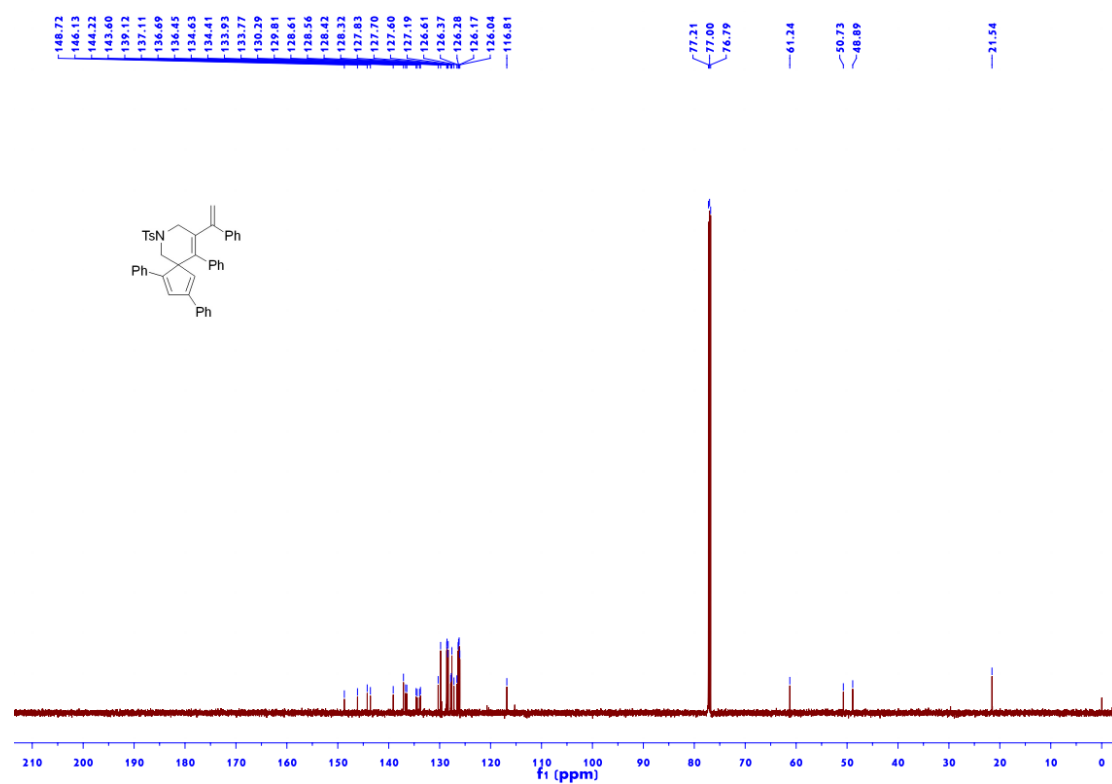


Figure S336  $^{13}\text{C}$  NMR (150 MHz,  $\text{CDCl}_3$ ) of 12a



## 7. X-ray crystal structures of 2a, 3f' and 5a

Crystal preparation: Compound **3a**, **3f'** and **5a** (30 mg) were dissolved in hexane/EA = 9:1 (10 mL) in 25 mL round bottom flask and the resultant solution were allowed to slowly evaporate at room temperature to get pure crystals suitable for X-ray diffraction analysis. The intensity data were collected at 100 K or 150 K on a Rigaku Oxford Diffraction Supernova Dual Source, Cu at Zero equipped with an AtlasS2 CCD using Cu K $\alpha$  radiation. More information on crystal structures can also be obtained from the Cambridge Crystallographic Data Centre (CCDC) with deposition numbers CCDC 2287034 (**3a**), CCDC 2287035 (**3f'**), CCDC 2287036 (**5a**) respectively.

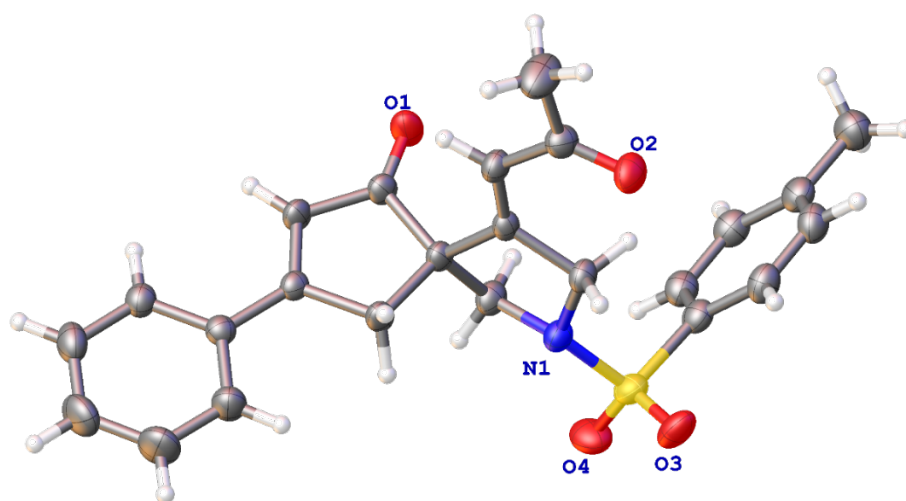


Figure S337. ORTEP Drawing of **3a** with Thermal Ellipsoids at 30% Probability Levels (CCDC 2287034).

**Table S1 Crystal data and structure refinement for 3a**

Identification code	<b>3a</b>
Empirical formula	C <sub>24</sub> H <sub>23</sub> NO <sub>4</sub> S
Formula weight	421.49
Temperature/K	199.99(10)
Crystal system	triclinic
Space group	P-1
a/Å	9.0233(2)
b/Å	10.7494(2)
c/Å	10.9235(2)
$\alpha$ /°	93.559(2)
$\beta$ /°	94.415(2)

$\gamma/^\circ$	95.578(2)
Volume/ $\text{\AA}^3$	1048.79(4)
Z	2
$\rho_{\text{calc}}/\text{cm}^3$	1.335
$\mu/\text{mm}^{-1}$	1.627
F(000)	444.0
Crystal size/ $\text{mm}^3$	$0.16 \times 0.12 \times 0.09$
Radiation	Cu K $\alpha$ ( $\lambda = 1.54184$ )
$2\Theta$ range for data collection/ $^\circ$	8.138 to 143.354
Index ranges	$-10 \leq h \leq 11, -13 \leq k \leq 13, -11 \leq l \leq 13$
Reflections collected	10782
Independent reflections	3963 [ $R_{\text{int}} = 0.0165, R_{\text{sigma}} = 0.0138$ ]
Data/restraints/parameters	3963/0/281
Goodness-of-fit on $F^2$	1.058
Final R indexes [ $I \geq 2\sigma(I)$ ]	$R_1 = 0.0428, wR_2 = 0.1135$
Final R indexes [all data]	$R_1 = 0.0437, wR_2 = 0.1142$
Largest diff. peak/hole / $e \text{\AA}^{-3}$	0.32/-0.48

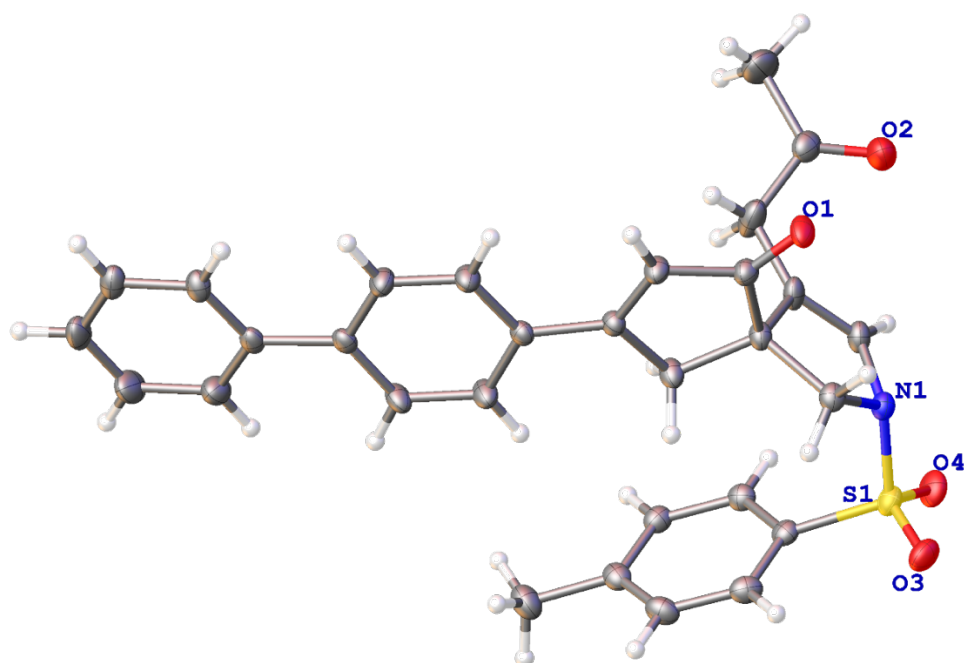


Figure S338. ORTEP Drawing of **3f'** with Thermal Ellipsoids at 30% Probability Levels (CCDC 2287035).

**Table S2 Crystal data and structure refinement for 3f'**

Identification code	<b>3f'</b>
Empirical formula	C <sub>30</sub> H <sub>27</sub> NO <sub>4</sub> S
Formula weight	497.58
Temperature/K	169.99(10)
Crystal system	monoclinic
Space group	P2 <sub>1</sub> /c
a/Å	9.9272(8)
b/Å	18.3382(11)
c/Å	13.8851(9)
α/°	90
β/°	103.404(7)
γ/°	90
Volume/Å <sup>3</sup>	2458.9(3)
Z	4
ρ <sub>calc</sub> /cm <sup>3</sup>	1.344
μ/mm <sup>-1</sup>	0.170
F(000)	1048.0
Crystal size/mm <sup>3</sup>	0.14 × 0.12 × 0.1
Radiation	Mo Kα (λ = 0.71073)
2θ range for data collection/°	4.218 to 49.996
Index ranges	-11 ≤ h ≤ 11, -20 ≤ k ≤ 21, -16 ≤ l ≤ 16
Reflections collected	11677
Independent reflections	4337 [R <sub>int</sub> = 0.0293, R <sub>sigma</sub> = 0.0395]
Data/restraints/parameters	4337/0/335
Goodness-of-fit on F <sup>2</sup>	1.075
Final R indexes [I ≥ 2σ (I)]	R <sub>1</sub> = 0.0507, wR <sub>2</sub> = 0.1094
Final R indexes [all data]	R <sub>1</sub> = 0.0666, wR <sub>2</sub> = 0.1184
Largest diff. peak/hole / e Å <sup>-3</sup>	0.46/-0.37

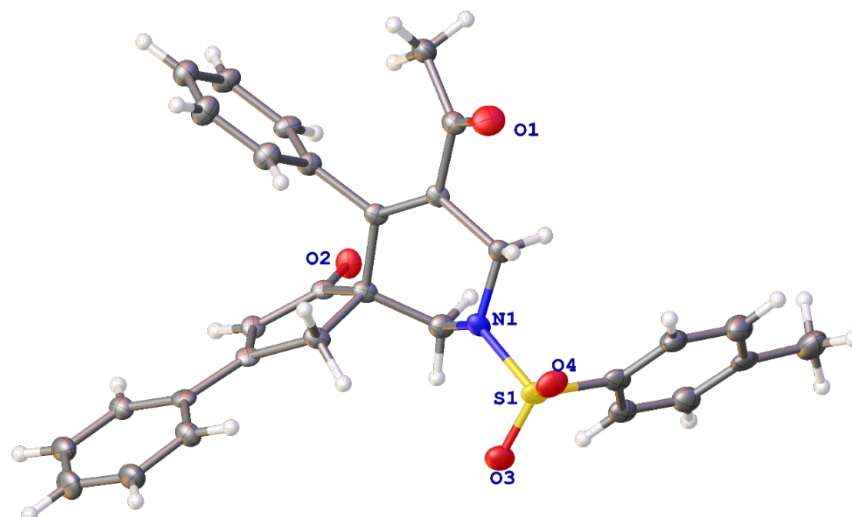


Figure S339. ORTEP Drawing of **5a** with Thermal Ellipsoids at 30% Probability Levels (CCDC 2287036).

**Table S3 Crystal data and structure refinement for 5a**

Identification code	<b>5a</b>
Empirical formula	C <sub>30</sub> H <sub>27</sub> NO <sub>4</sub> S
Formula weight	497.58
Temperature/K	170.00(10)
Crystal system	monoclinic
Space group	P2 <sub>1</sub>
a/Å	18.2577(16)
b/Å	6.2047(4)
c/Å	21.9318(17)
α/°	90
β/°	91.792(8)
γ/°	90
Volume/Å <sup>3</sup>	2483.3(3)
Z	4
ρ <sub>calc</sub> /cm <sup>3</sup>	1.331
μ/mm <sup>-1</sup>	1.462
F(000)	1048.0
Crystal size/mm <sup>3</sup>	0.15 × 0.13 × 0.11
Radiation	Cu Kα (λ = 1.54184)
2θ range for data collection/°	4.03 to 133.184
Index ranges	-21 ≤ h ≤ 21, -7 ≤ k ≤ 7, 0 ≤ l ≤ 26
Reflections collected	6575
Independent reflections	6575 [R <sub>int</sub> = 0.0867, R <sub>sigma</sub> = 0.1040]
Data/restraints/parameters	6575/599/654



Goodness-of-fit on $F^2$	1.118
Final R indexes [ $I \geq 2\sigma(I)$ ]	$R_1 = 0.1353$ , $wR_2 = 0.3633$
Final R indexes [all data]	$R_1 = 0.1488$ , $wR_2 = 0.3736$
Largest diff. peak/hole / $e \text{ \AA}^{-3}$	1.23/-0.72
Flack parameter	0.06(3)

## 8. References

- S1. D. Wang, F. Wang, G. Song and X. Li, Diverse Reactivity in a Rhodium(III)-Catalyzed Oxidative Coupling of *N*-Allyl Arenesulfonamides with Alkyne, *Angew. Chem. Int. Ed.*, 2012, **124**, 12514-12518.
- S2. (a) R. E. Geiger, M. Lalonde, H. Stoller and K. Schleich, Cobalt-Catalyzed Cycloaddition of Alkynes and Nitriles to Pyridines: A New Route to Pyridoxine (Vitamin B6), *Helvetica Chimica Acta*, 1984, **67**, 1274-1282; (b) Y. Shi and V. Gevorgyan, Intramolecular Transannulation of Alkynyl Triazoles via Alkyne–Carbene Metathesis Step: Access to Fused Pyrroles, *Org. Lett.*, **2013**, *15*, 5394-5396; (c) D. Llerena, O. Buisine, C. Aubert and M. Malacria, Synthesis of variously substituted allenediynes and their cobalt(I)-mediated [2+2+2] cycloaddition reactions. *Tetrahedron*, 1998, **54**, 9373-9392.