

# Supplementary Information

## Enantioselective copper-catalyzed azidation/click cascade reaction for access to chiral 1,2,3-triazoles

Ling-Feng Jiang<sup>1</sup>, Shao-Hua Wu<sup>1</sup>, Yu-Xuan Jiang<sup>1</sup>, Hong-Xiang Ma<sup>1</sup>, Jia-Jun He<sup>1</sup>, Yang-Bo Bi<sup>1</sup>, De-Yi Kong<sup>1</sup>, Yi-Fei Cheng<sup>1</sup>, Xuan Cheng<sup>1</sup> and Qing-Hai Deng<sup>1\*</sup>

E-mail: qinghaideng@shnu.edu.cn

<sup>1</sup> The Education Ministry Key Laboratory of Resource Chemistry, Joint International Research Laboratory of Resource Chemistry of Ministry of Education, Shanghai Key Laboratory of Rare Earth Functional Materials, and Shanghai Frontiers Science Center of Biomimetic Catalysis, Shanghai Normal University, Shanghai 200234, China.

### Table of Contents

|   |     |
|---|-----|
| Supplementary Information .....   | 1   |
| 1. Supplementary Methods .....  | 3   |
| 1.1 General Information .....   | 3   |
| 1.2 Optimization of Reaction Conditions .....   | 3   |
| 1.3. General Procedure for the Synthesis of Substrates <b>2a-2x</b> , <b>4a-4z</b> .....                  | 6   |
| 1.4. General Procedure for the Synthesis of <b>1a-1g</b> .....  | 40  |
| 1.5. General Procedure for the Synthesis of Racemic Products <b>3</b> and <b>5</b> .....                  | 44  |
| 1.6. General Procedure for the Synthesis of Chiral Products <b>3</b> and <b>5</b> .....                   | 45  |
| 1.7. Procedure for synthesis of <b>3a</b> in gram-scale .....   | 77  |
| 2. Supplementary Discussion .....   | 79  |
| 2.1. Radical inhibition experiments .....   | 79  |
| 2.2. Nonlinear effect study .....   | 79  |
| 2.3. Investigation of intermediate azide .....  | 80  |
| 2.4. Control experiments with other substrates .....  | 82  |
| 2.5. DFT calculations .....   | 86  |
| 3. Supplementary Notes .....  | 88  |
| 3.1 Determination of the Absolute Configuration of <b>5b</b> by X-ray Analysis .....                      | 88  |
| 3.2 Determination of the Absolute Configuration of <b>5d</b> by X-ray Analysis .....                      | 90  |
| 3.3 Determination of the Absolute Configuration of <b>5x</b> by X-ray Analysis .....                      | 92  |
| 4. Supplementary Figures .....  | 94  |
| 4.1 NMR Spectra of New Compounds ( <sup>1</sup> H NMR, <sup>13</sup> C NMR and <sup>19</sup> F NMR) ..... | 94  |
| 4.2 Chromatographic Data for Chiral Products .....  | 318 |
| 5. Supplementary References .....   | 373 |

**CAUTION:** It might be potentially explosive about azidating reagents, intermediates, or products. Although we did not encounter any problems under the conditions and scale described here, appropriate precautions should be taken when handling these compounds. A blast shield was necessary while the azidation reactions and subsequent workups were performed.

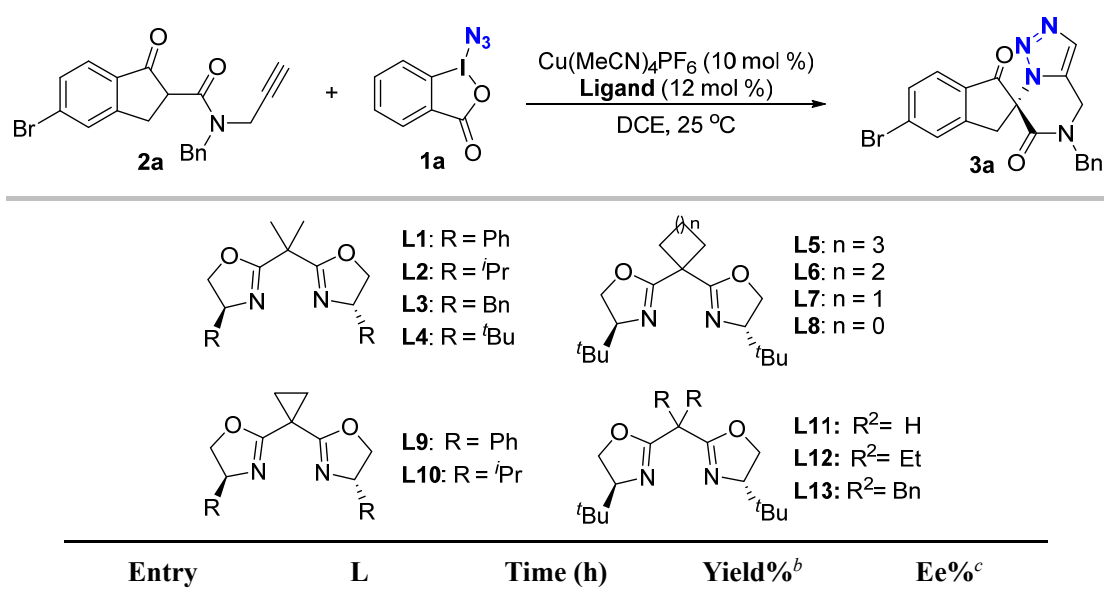
## 1. Supplementary Methods

### 1.1 General Information

All manipulations were maintained under an atmosphere of nitrogen unless otherwise stated. Commercially available reagents were used without further purification. Solvents were pre-dried over activated 4 Å molecular sieves and were refluxed over sodium-benzophenone (toluene, tetrahydrofuran), phosphorus pentoxide (chloroform) or calcium hydride (dichloromethane, dichloroethane, acetonitrile). Column chromatography was performed on silica gel (200-300 mesh). <sup>1</sup>H NMR spectra were recorded on a 400 or 600 MHz NMR spectrometer and <sup>13</sup>C NMR spectra were recorded on a 101 MHz NMR spectrometer. Infrared spectra were prepared as KBr pellets and were recorded on a Varian Excalibur 3100 series FT-IR spectrometer. Mass spectra were recorded by the mass spectrometry service of Shanghai Institute of Organic Chemistry. HPLC analyses on a Waters 1596 or Shimadzu SPD-15C. Optical rotations were measured with Rudolph Research Analytical in a 1 dm cuvette.I.

### 1.2. Optimization of Reaction Conditions

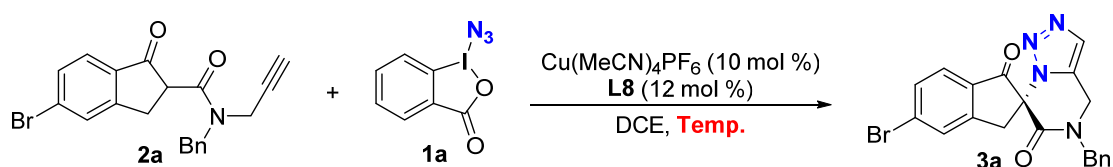
**Supplementary Table 1.** Optimization of the Reaction Conditions (**Ligand**) for the Synthesis of Product **3a**<sup>a</sup>



|          |            |           |           |           |
|----------|------------|-----------|-----------|-----------|
| 1        | <b>L1</b>  | 24        | 35        | 14        |
| 2        | <b>L2</b>  | 24        | 28        | 12        |
| 3        | <b>L3</b>  | 24        | 50        | 23        |
| 4        | <b>L4</b>  | 24        | 37        | 75        |
| 5        | <b>L5</b>  | 24        | 44        | 44        |
| 6        | <b>L6</b>  | 24        | 40        | 82        |
| 7        | <b>L7</b>  | 24        | 45        | 80        |
| <b>8</b> | <b>L8</b>  | <b>24</b> | <b>62</b> | <b>92</b> |
| 9        | <b>L9</b>  | 24        | 47        | 33        |
| 10       | <b>L10</b> | 24        | 52        | 31        |
| 11       | <b>L11</b> | 24        | 47        | 14        |
| 12       | <b>L12</b> | 24        | 68        | 81        |
| 13       | <b>L13</b> | 24        | 42        | 32        |

<sup>a</sup>Reaction conditions: **2a** (0.10 mmol), **1a** (1.5 equiv), Cu(MeCN)<sub>4</sub>PF<sub>6</sub> (10 mol %), **Ligand** (12 mol %), DCE (2.0 mL), 25 °C, nitrogen. <sup>b</sup>The yields of isolated products. <sup>c</sup>Determined by HPLC analysis.

**Supplementary Table 2.** Optimization of the Reaction Conditions (**Temperature**) for the Synthesis of Product **3a**<sup>a</sup>

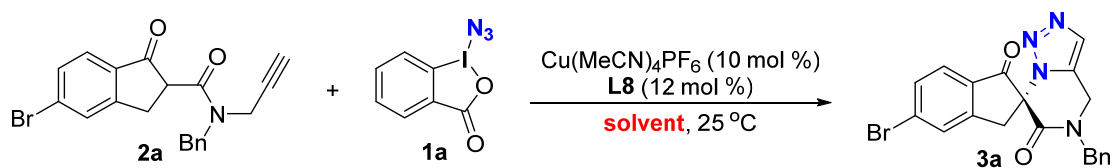


| Entry    | Time (h)  | Temp. (°C)   | Yield% <sup>b</sup> | Ee% <sup>c</sup> |
|----------|-----------|--------------|---------------------|------------------|
| 1        | 24        | 40 °C        | 57                  | 89               |
| 2        | 24        | 30 °C        | 62                  | 91               |
| <b>3</b> | <b>24</b> | <b>25 °C</b> | <b>62</b>           | <b>92</b>        |

<sup>a</sup>Reaction conditions: **2a** (0.10 mmol), **1a** (1.5 equiv), Cu(MeCN)<sub>4</sub>PF<sub>6</sub> (10 mol %), **L8** (12 mol %), DCE (2.0 mL), **Temperature**, nitrogen. <sup>b</sup>The yields of isolated products. <sup>c</sup>Determined by HPLC analysis.



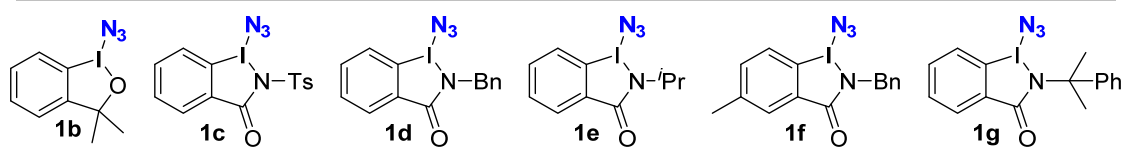
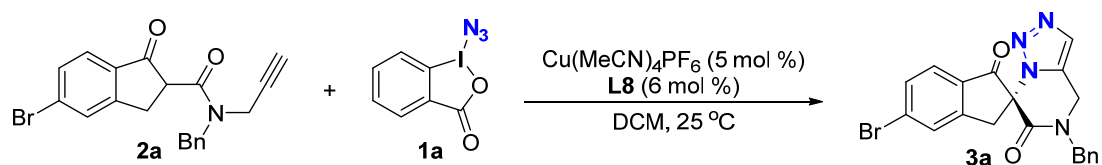
**Supplementary Table 3.** Optimization of the Reaction Conditions (**Solvent**) for the Synthesis of Product **3a**<sup>a</sup>



| Entry | Solvent    | Time (h)  | Yield% <sup>b</sup> | Ee% <sup>c</sup> |
|-------|------------|-----------|---------------------|------------------|
| 1     | DCE        | 24        | 62                  | 92               |
| 2     | <b>DCM</b> | <b>24</b> | <b>70</b>           | <b>94</b>        |
| 3     | MeCN       | 24        | 43                  | 88               |
| 4     | THF        | 24        | trace               | /                |

<sup>a</sup>Reaction conditions: **2a** (0.10 mmol), **1a** (1.5 equiv), Cu(MeCN)<sub>4</sub>PF<sub>6</sub> (10 mol %), **L8** (12 mol %), **Solvent** (2.0 mL), 25 °C, nitrogen. <sup>b</sup>The yields of isolated products. <sup>c</sup>Determined by HPLC analysis.

**Supplementary Table 4.** Optimization of the “**N<sub>3</sub>**” at the standard Conditions for the Synthesis of Product **3a**<sup>a</sup>



| Entry          | <b>N<sub>3</sub></b> | Oxidant | Time (h) | Yield% <sup>b</sup> | Ee% <sup>c</sup> |
|----------------|----------------------|---------|----------|---------------------|------------------|
| 1 <sup>d</sup> | <b>1a</b>            | /       | 24       | 70                  | 94               |
| 2              | <b>1a</b>            | /       | 24       | 60                  | 94               |
| 3 <sup>d</sup> | <b>1b</b>            | /       | 24       | 30                  | 27               |
| 4              | <b>1c</b>            | /       | 24       | 80                  | 90               |
| 5              | <b>1d</b>            | /       | 24       | <b>99</b>           | <b>94</b>        |

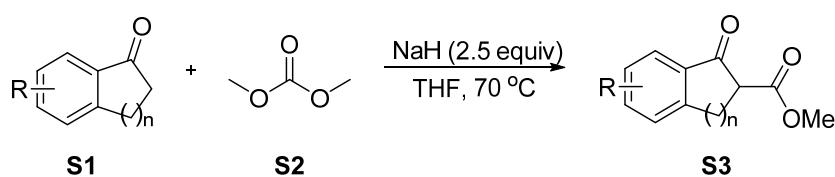
|    |                         |                       |    |       |    |
|----|-------------------------|-----------------------|----|-------|----|
| 6  | <b>1e</b>               | /                     | 24 | 78    | 94 |
| 7  | <b>1f</b>               | /                     | 24 | 95    | 93 |
| 8  | <b>1g</b>               | /                     | 24 | 93    | 93 |
| 9  | <b>TMSN<sub>3</sub></b> | O <sub>2</sub>        | 24 | trace | /  |
| 10 | <b>TMSN<sub>3</sub></b> | TPHP                  | 24 | 20    | 10 |
| 11 | <b>TMSN<sub>3</sub></b> | TBPB                  | 24 | 30    | 18 |
| 12 | <b>TMSN<sub>3</sub></b> | PhI(OAc) <sub>2</sub> | 24 | 50    | 23 |

<sup>a</sup>Reaction conditions: **2a** (0.10 mmol), "**N<sub>3</sub>**" (1.5 equiv), Cu(MeCN)<sub>4</sub>PF<sub>6</sub> (5 mol %), **L8** (6 mol %), DCM (2.0 mL), 30 °C, nitrogen. <sup>b</sup>The yields of isolated products. <sup>c</sup>Determined by HPLC analysis.

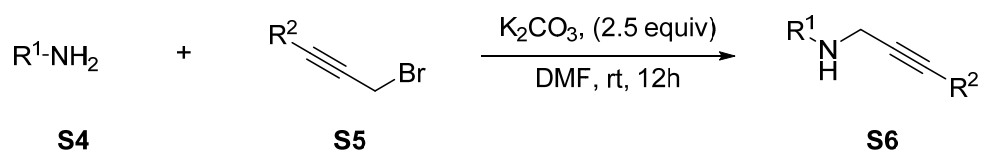
<sup>d</sup>10 mol % of Cu(MeCN)<sub>4</sub>PF<sub>6</sub> and 12 mol % of **L8** were used instead.

### 1.3. General Procedure for the Synthesis of Substrates **2a-2x**, **4a-4z**

#### 1.3.1 General Procedure for the Synthesis of Substrates **2a-2x**, **4w-4z**<sup>1-2</sup>

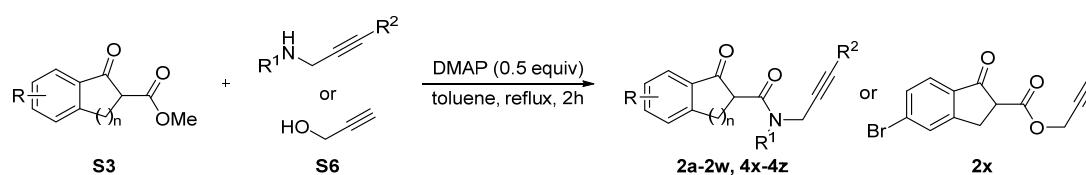


NaH (12.5 mmol, 2.5 equiv, 60% dispersion in mineral oil) was dispersed in dry tetrahydrofuran solution. Dimethyl carbonate (**S2**) (25 mmol, 5 equiv) was added at 0 °C, then **S1** (5 mmol, 1.0 equiv) was dropped slowly. The mixture was stirred at 70 °C overnight. After cooling to room temperature, the mixture was quenched with HCl (aq.) and was then extracted with EtOAc (three times). The combined organic layer was washed with brine, dried over MgSO<sub>4</sub>, and concentrated in vacuo. The residue was purified by column chromatography on silica gel (ethyl acetate/ petroleum ether = 1 : 8) to give the product **S3** as yellow solid.



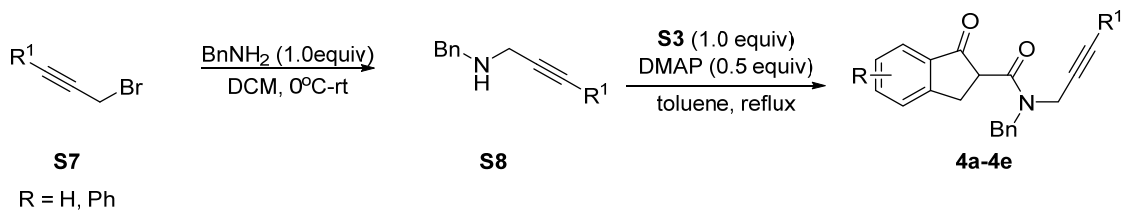
$\text{R}^1 = \text{Bn, Me, } ^t\text{Bu}$      $\text{R}^2 = \text{H, Me, Et, Cy}$   
 1-methylnaphthalene,  
 diphenylmethane

The mixture of **S4** (15 mmol, 3.0 equiv),  $\text{K}_2\text{CO}_3$  (17.5 mmol, 2.5 equiv) and DMF (5 mL) was stirred at the room temperature for 15 min, and then **S5** (5 mmol, 1.0 equiv) in DMF (5 mL) was slowly added dropwise. The mixture was stirred at room temperature for 12 h. Once the reaction was completed, water (20 mL) was added and the mixture was extracted three times with ethyl acetate (20 mL). The combined organic layer was washed with water (20 mL) and saturated brine (20 mL), dried over anhydrous  $\text{Na}_2\text{SO}_4$ , and concentrated in vacuo. The crude mixture was purified via column chromatography with hexane/ethyl acetate (5:1) to afford **S6** as yellow oil.



DMAP (0.5 mmol, 0.5 equiv) and **S3** (1 mmol, 1.0 equiv) were dissolved in dry toluene (3 mL), then **S6** (1.5 mmol) was added. The mixture was stirring at 110 °C for 2 h. After disappearance of **S3** (monitored by TLC), the mixture was cooled to room temperature and was quenched with HCl (aq.). The residue was extracted three times with ethyl acetate, and was then washed with  $\text{NaHCO}_3$  (aq.). Finally, the crude product was purified by silica gel flash chromatography to get the desired products **2a-2x** and **4x-4z**.

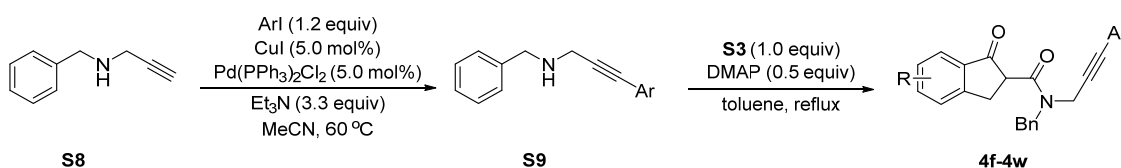
### 1.3.2 General Procedure for the Synthesis of Substrates **4a-4v**<sup>3-4</sup>



1) BnNH<sub>2</sub> (5 mmol, 1.0 equiv) was added dropwise to **S7** (30 mmol, 6 equiv) in DCM at 0 °C. Upon complete addition, the reaction was allowed to warm to room temperature and stirred over 17 h. Then, aqueous 1 M NaOH (22.5 mL) and Et<sub>2</sub>O (22.5 mL) were added and the layers were separated. After extraction of the aqueous layer with Et<sub>2</sub>O (2 x 25 mL), the combined organic layers were washed with brine (25 mL), dried over MgSO<sub>4</sub> and the solvent was removed under vacuo. The crude was purified by flash column chromatography to afford **S8** as a yellow oil.

2) DMAP (0.5 mmol, 0.5 equiv) and **S3** (1 mmol, 1.0 equiv) were dissolved in dry toluene (3 mL), then **S8** (1.5 mmol) was added, and the mixture was stirring at 110 °C for 2 h. After the disappearance of substrate **S8** (monitored by TLC), the mixture was cooled to room temperature and then quenched with HCl (aq.). The residue was extracted three times with ethyl acetate, and was then washed with NaHCO<sub>3</sub> (aq.). Finally, the crude product was purified by silica gel flash chromatography to afford the desired products **4a-4e**.

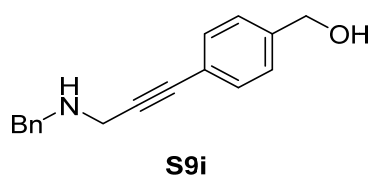
### 1.3.3 General Procedure for the Synthesis of Substrates **4f-4w**<sup>5</sup>



1) To a flame-dried 100 mL round bottom flask equipped with a Teflon-coated magnetic stirring bar, Pd(PPh<sub>3</sub>)<sub>2</sub>Cl<sub>2</sub> (5 mol %), CuI (5mol %), Et<sub>3</sub>N (3.3 equiv) and degassed (by bubbling dry N<sub>2</sub> for 10 minutes) MeCN (30 mL) were added. Then, the iodoarene (1.1 equiv) was added and the mixture was heated to 60 °C and stirred for 5 minutes. Benzyl propargyl amine **S8** (1.0 equiv) was added and the reaction mixture

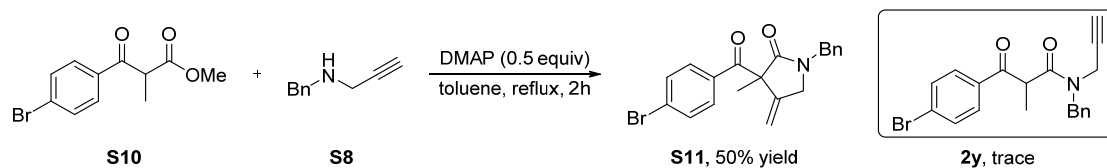
was stirred for 7 hours at 60 °C. Then, the reaction mixture was cooled down to ambient temperature and concentrated in vacuo. The resulting crude mixture was dissolved in EtOAc (20 mL), then washed with water (20 mL) and brine (20 mL). The organic layer was dried over Na<sub>2</sub>SO<sub>4</sub>, filtered, and concentrated in vacuo. The crude product **S9** was purified by silica gel flash chromatography.

2) DMAP (0.5 mmol, 0.5 equiv) and **S3** (1 mmol, 1.0 equiv) were dissolved in dry toluene (3 mL), then **S9** (1.5 mmol) was added, and the mixture was stirring at 110 °C for 2 h. After the disappearance of substrate **S9** (monitored by TLC), the mixture was cooled to room temperature and then quenched with HCl (aq.). The residue was extracted three times with ethyl acetate, and was then washed with NaHCO<sub>3</sub> (aq.). Finally, the crude product was purified by silica gel flash chromatography to afford the desired products **4f-4w**.



**(4-(3-(benzylamino)prop-1-yn-1-yl)phenyl)methanol (S9i)**; TLC:  $R_f = 0.20$  (petroleum ether /ethyl acetate = 2/1, v/v, UV); brown oil; yield: 27%; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.72-7.05 (m, 9H), 4.64 (s, 2H), 3.93 (brs, 2H), 3.62 (brs, 2H), 2.36 (s, 2H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 141.3, 139.3, 131.9, 128.9, 128.6, 127.4, 126.8, 122.2, 87.3, 83.9, 64.7, 52.5, 38.1; HRMS (ESI, m/z): calcd. For C<sub>17</sub>H<sub>18</sub>NO<sup>+</sup> [M+H]<sup>+</sup>: 252.1383, found: 252.1385.

#### 1.3.4 Failed substrate

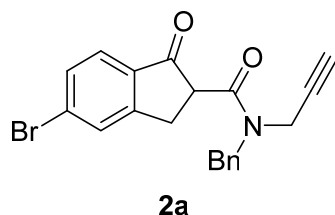


DMAP (0.5 mmol, 0.5 equiv) and **S10** (1 mmol, 1.0 equiv) were dissolved in dry

toluene (3 mL), then **S8** (1.5 mmol) was added. The mixture was stirring at 110 °C for 12 h. After disappearance of **S10** (monitored by TLC), the mixture was cooled to room temperature and was quenched with HCl (aq.). The residue was extracted three times with ethyl acetate, and was then washed with NaHCO<sub>3</sub> (aq.). Finally, the crude product was purified by silica gel flash chromatography to get the product **S11**.

**1-benzyl-3-(4-bromobenzoyl)-3-methyl-4-methylenepyrrolidin-2-one (S11)**; TLC:  $R_f = 0.40$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); yellow oil; yield: 50%; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.42 – 7.31 (m, 7H), 7.26-7.24 (m, 2H), 5.07 (s, 1H), 4.96 (s, 1H), 4.82 (d,  $J = 14.4$  Hz, 1H), 4.25 (d,  $J = 14.4$  Hz, 1H), 4.13 – 4.05 (m, 2H), 1.61 (s, 3H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 195.2, 173.6, 143.1, 135.3, 134.8, 131.7, 130.0, 129.0, 128.9, 128.3, 127.4, 111.2, 60.9, 50.0, 46.7, 23.1; HRMS (ESI, m/z): calcd. For C<sub>20</sub>H<sub>19</sub>BrNO<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 384.0594, found: 384.0601.

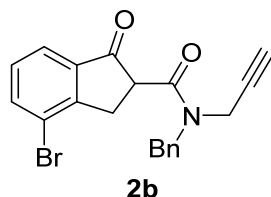
**Compound 2a (Fig. 2)**



**N-benzyl-5-bromo-1-oxo-N-(prop-2-yn-1-yl)-2,3-dihydro-1H-indene-2-carboxamide (2a)**; TLC:  $R_f = 0.40$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 92-93°C); yield: 42%; Enol isomerization were observed by NMR; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.69 (d,  $J = 20.6$  Hz, 1H), 7.58 (dd,  $J = 8.0, 6.0$  Hz, 1H), 7.50 (td,  $J = 8.4, 1.6$  Hz, 1H), 7.39 (dd,  $J = 8.0, 6.8$  Hz, 1H), 7.36-7.30 (m, 2H), 7.29-7.22 (m, 2H), 5.25 (dd,  $J = 16.1, 12.2$  Hz, 1H), 4.90-4.83 (m, 1H), 4.35 (dd,  $J = 17.5, 2.4$  Hz, 0.4H), 4.31-4.24 (m, 1.2H), 4.17 (dd,  $J = 17.4, 2.5$  Hz, 0.4H), 4.04 (dd,  $J = 7.9, 3.6$  Hz, 0.4H), 3.97-3.83 (m, 1.2H), 3.76 (dd,  $J = 17.3, 3.7$  Hz, 0.4H), 3.34-2.12 (m, 1H), 2.33-2.22 (m, 1H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 200.5 (200.1), 167.7 (168.3), 156.4 (156.2), 136.3 (136.2), 134.1 (134.2), 131.41 (131.40), 131.1 (131.0), 129.9 (130.0), 128.8 (129.1), 128.0, 126.9 (127.7), 125.73 (125.72), 78.7 (78.5), 73.0 (72.5), 51.1 (49.3), 51.0 (50.8), 37.0 (35.5), 30.5 (30.7); HRMS (ESI, m/z): calcd. For

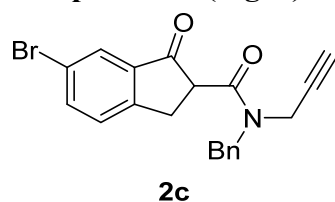
$C_{20}H_{17}BrNO_2^+ [M+H]^+$ : 382.0437, found: 382.0438.

**Compound 2b (Fig. 2)**



***N*-benzyl-4-bromo-1-oxo-*N*-(prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (2b)**; TLC:  $R_f = 0.60$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); yellow oil; yield: 69%; Enol isomerization were observed by NMR;  $^1H$  NMR (400 MHz,  $CDCl_3$ ):  $\delta$  7.83-7.74 (m, 1H), 7.74-7.66 (m, 1H), 7.46-7.39 (m, 1H), 7.35 (d,  $J = 8.2$  Hz, 2H), 7.32-7.24 (m, 3H), 5.25 (dd,  $J = 16.2, 8.4$  Hz, 1H), 4.92-4.82 (m, 1H), 4.41-4.29 (m, 1.6H), 4.22 (dd,  $J = 17.3, 2.5$  Hz, 0.4H), 4.08 (dd,  $J = 8.0, 3.7$  Hz, 0.4H), 3.95 (dd,  $J = 18.9, 2.5$  Hz, 0.6H), 3.84 (dd,  $J = 17.7, 3.6$  Hz, 0.6H), 3.71 (dd,  $J = 17.6, 3.6$  Hz, 0.4H), 3.35-3.12 (m, 1H), 2.35-2.25 (m, 1H);  $^{13}C\{^1H\}$ NMR (101 MHz,  $CDCl_3$ ):  $\delta$  201.1 (200.6), 167.7 (168.3), 154.5 (154.2), 138.3 (138.2), 137.3 (137.2), 136.4 (136.2), 129.5 (129.1), 128.8, 128.0, 126.9 (127.6), 123.4, 122.1 (122.0), 78.7 (78.5), 73.1 (72.5), 51.1 (49.3), 50.90 (50.87), 37.1 (35.5), 31.2 (32.2); HRMS (ESI,  $m/z$ ): calcd. For  $C_{20}H_{17}BrNO_2^+ [M+H]^+$ : 382.0437, found: 382.0439.

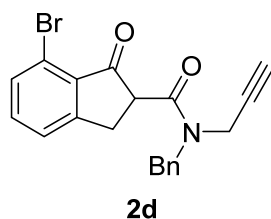
**Compound 2c (Fig. 2)**



***N*-benzyl-6-bromo-1-oxo-*N*-(prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (2c)**; TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); yellow oil; yield: 25%; Enol isomerization were observed by NMR;  $^1H$  NMR (400 MHz,  $CDCl_3$ ):  $\delta$  7.84 (dd,  $J = 7.0, 1.9$  Hz, 1H), 7.69 (ddd,  $J = 11.8, 8.1, 1.9$  Hz, 1H), 7.44-7.30 (m, 4H), 7.29-7.22 (m, 2H), 5.24 (dd,  $J = 16.1, 7.3$  Hz, 1H), 4.91-4.79 (m, 1H), 4.39-4.24 (m, 1.6H), 4.17 (dd,  $J = 17.4, 2.5$  Hz, 0.4H), 4.07 (dd,  $J = 7.9, 3.6$  Hz, 0.4H), 3.91 (dd,  $J = 19.0, 2.5$  Hz, 0.6H), 3.82 (dd,  $J = 17.4, 3.5$  Hz, 0.6H), 3.70 (dd,  $J = 17.6, 3.6$  Hz, 0.4H).

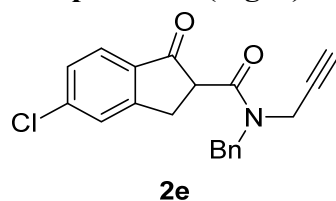
= 17.2, 3.6 Hz, 0.4H), 3.31-3.09 (m, 1H), 2.33-2.23 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.4 (199.9), 167.7 (168.3), 153.5 (153.2), 138.3 (138.2), 137.1 (137.0), 136.3 (136.2), 128.8 (129.1), 128.2 (128.1), 127.97 (127.98), 127.7 (127.4), 126.9 (127.4), 121.8, 78.7 (78.5), 73.0 (72.5), 51.4 (49.3), 51.3 (50.8), 37.0 (35.5), 30.5 (30.7); HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{20}\text{H}_{17}\text{BrNO}_2^+$   $[\text{M}+\text{H}]^+$ : 382.0437, found: 382.0438.

**Compound 2d (Fig. 2)**



***N*-benzyl-7-bromo-1-oxo-*N*-(prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (2d)**; TLC:  $R_f$  = 0.50 (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 83-84°C.); yield: 83%;  $^1\text{H}$  NMR (400 MHz, Chloroform-*d*):  $\delta$  7.56-7.35 (m, 4H), 7.36-7.22 (m, 4H), 5.29 (dd,  $J$  = 30.9, 16.2 Hz, 1H), 4.94-4.81 (m, 1H), 4.39 (dd,  $J$  = 17.4, 2.5 Hz, 0.5H), 4.33 (dd,  $J$  = 8.0, 3.9 Hz, 0.5H), 4.28 (d,  $J$  = 15.2 Hz, 0.5H), 4.14 (dd,  $J$  = 17.3, 2.5 Hz, 0.5H), 4.07 (dd,  $J$  = 8.0, 3.8 Hz, 0.5H), 3.89 (td,  $J$  = 19.1, 3.2 Hz, 1H), 3.75 (dd,  $J$  = 17.2, 3.9 Hz, 0.5H), 3.31-3.08 (m, 1H), 2.31-2.22 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  199.1 (198.6), 167.8 (168.3), 157.6 (157.5), 136.25 (136.29), 135.9 (135.8), 132.8 (132.7), 132.48 (132.53), 128.8 (129.1), 127.93 (127.90), 126.8 (127.6), 125.7 (125.6), 120.32 (120.28), 78.7 (78.5), 73.0 (72.5), 51.8 (51.6), 49.3 (50.8), 37.0 (35.6), 29.8 (30.0); HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{20}\text{H}_{17}\text{BrNO}_2^+$   $[\text{M}+\text{H}]^+$ : 382.0437, found: 382.0440.

**Compound 2e (Fig. 2)**

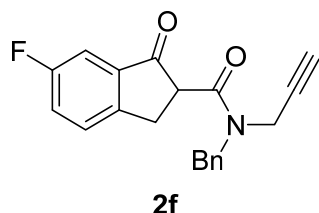


***N*-benzyl-5-chloro-1-oxo-*N*-(prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamid (2e)**; TLC:  $R_f$  = 0.30 (petroleum ether /ethyl acetate = 5/1, v/v, UV); white



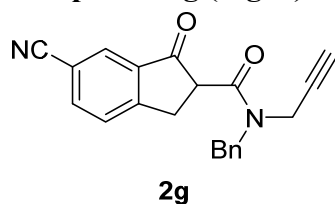
solid (mp: 774-75°C.); yield: 44%; Enol isomerization were observed by NMR; **<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)** δ 7.65 (dd, *J* = 8., 5.6 Hz, 1H), 7.50 (dd, *J* = 20.4, 1.6 Hz, 1H), 7.43-7.36 (m, 1H), 7.36-7.31 (m, 3H), 7.30-7.24 (m, 2H), 5.25 (dd, *J* = 14.8, 12.0 Hz, 1H), 4.92-4.81 (m, 1H), 4.40-4.23 (m, 1.5H), 4.17 (dd, *J* = 17.2, 2.4 Hz, 0.5H), 4.06 (dd, *J* = 8.0, 3.6 Hz, 0.5H), 3.90 (td, *J* = 18.8, 2.8 Hz, 1H), 3.75 (dd, *J* = 17.2, 3.6 Hz, 0.5H), 3.34-3.12 (m, 1H), 2.33-2.23 (m, 1H); **<sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>)**: δ 200.3 (199.8), 167.8 (168.3), 156.3 (156.1), 142.2 (142.1), 136.4 (136.3), 133.7 (133.8), 129.1 (128.6), 128.0 (128.8), 127.7, 126.9, 126.9 (126.8), 125.7 (125.6), 78.7 (78.5), 73.0 (72.5), 51.2 (49.3), 51.0 (50.8), 37.0 (35.5), 30.5 (30.7); **HRMS (ESI, m/z)**: calcd. For C<sub>20</sub>H<sub>17</sub>ClNO<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 338.0942, found: 338.0940.

**Compound 2f (Fig. 2)**



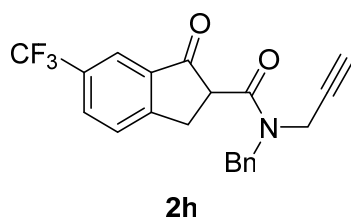
***N*-benzyl-6-fluoro-1-oxo-*N*-(prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (2f)**; TLC: *R<sub>f</sub>* = 0.30 (petroleum ether /ethyl acetate = 5/1, v/v, UV); yellow oil; yield: 76%; Enol isomerization were observed by NMR; **<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**: δ 7.53-7.41 (m, 1H), 7.41-7.30 (m, 5H), 7.30-7.23 (m, 2H), 5.25 (dd, *J* = 16.1, 7.5 Hz, 1H), 4.92-4.80 (m, 1H), 4.39-4.24 (m, 1.6H), 4.19 (dd, *J* = 17.4, 2.5 Hz, 0.4H), 4.09 (dd, *J* = 7.8, 3.6 Hz, 0.4H), 3.92 (dd, *J* = 18.9, 2.5 Hz, 0.6H), 3.85 (dd, *J* = 17.5, 3.5 Hz, 0.6H), 3.73 (dd, *J* = 17.0, 4.1 Hz, 0.4H), 3.34-3.12 (m, 1H), 2.33-2.23 (m, 1H); **<sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>)**: δ 200.9 (d, *J* = 3.2 Hz) [200.4 (d, *J* = 3.1 Hz)], 167.8 (168.4), 162.5 (d, *J* = 248.3 Hz), 150.4 (d, *J* = 2.2 Hz) [150.1 (d, *J* = 2.2 Hz)], 136.9 (d, *J* = 7.5 Hz) [137.1 (d, *J* = 7.4 Hz)], 136.4 (136.3), 128.9 (129.1), 128.1 (127.9), 128.02 (128.00), 126.9 (127.7), 123.4 (d, *J* = 23.9 Hz) [123.2 (d, *J* = 23.7 Hz)], 110.3 (d, *J* = 22.1 Hz), 78.8 (78.6), 73.0 (72.5), 52.0 (49.3), 51.8 (50.9), 37.1 (35.5), 30.3 (30.5); **<sup>19</sup>FNMR (376 MHz, Chloroform-*d*)**: δ -114.2; **HRMS (ESI, m/z)**: calcd. For C<sub>20</sub>H<sub>17</sub>FNO<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 322.1238, found: 322.1240.

**Compound 2g (Fig. 2)**



***N*-benzyl-6-cyano-1-oxo-*N*-(prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (2g)**; TLC:  $R_f = 0.30$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); yellow oi; yield: 65%; Enol isomerization were observed by NMR;  **$^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )**:  $\delta$  8.01 (d,  $J = 7.5$  Hz, 1H), 7.85 (ddd,  $J = 11.6, 8.0, 1.6$  Hz, 1H), 7.65 (dd,  $J = 20.4, 8.0$  Hz, 1H), 7.45-7.19 (m, 5H), 5.24 (t,  $J = 15.6$  Hz, 1H), 4.85 (dd,  $J = 21.9, 17.6$  Hz, 1H), 4.38-4.25 (m, 1.6H), 4.17 (dd,  $J = 17.3, 2.5$  Hz, 0.5H), 4.11 (dd,  $J = 8.0, 3.6$  Hz, 0.4H), 3.95 (td,  $J = 18.6, 3.0$  Hz, 1H), 3.86 (dd,  $J = 17.9, 3.6$  Hz, 0.5H), 3.45-3.22 (m, 1H), 2.34-2.24 (m, 1H);  **$^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ )**:  $\delta$  199.9 (199.4), 167.2 (167.8), 158.9 (158.7), 138.0 (137.9), 136.2 (136.0), 136.0 (135.9), 128.9 (129.1), 128.8 (128.8), 128.0 (126.9), 127.9 (128.1), 127.77 (127.83), 117.9, 112.13 (112.11), 78.5 (78.3), 73.2 (72.6), 51.2 (49.4), 51.0 (50.9), 37.1 (35.6), 31.3 (31.5); **HRMS (ESI, m/z)**: calcd. For  $\text{C}_{21}\text{H}_{17}\text{N}_2\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 329.1285, found: 329.1286.

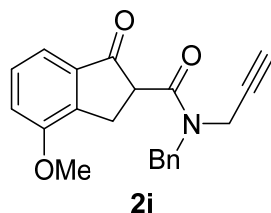
**Compound 2h (Fig. 2)**



***N*-benzyl-1-oxo-*N*-(prop-2-yn-1-yl)-6-(trifluoromethyl)-2,3-dihydro-1*H*-indene-2-carboxamide (2h)**; TLC:  $R_f = 0.30$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); yellow oil; yield: 89%; Enol isomerization were observed by NMR;  **$^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ )**:  $\delta$  7.99 (dd,  $J = 7.4, 1.7$  Hz, 1H), 7.85 (ddd,  $J = 11.8, 8.1, 1.8$  Hz, 1H), 7.65 (dd,  $J = 20.6, 8.0$  Hz, 1H), 7.44-7.23 (m, 5H), 5.35-5.16 (m, 1H), 4.94-4.81 (m, 1H), 4.44-4.23 (m, 1.6H), 4.23-4.06 (m, 1H), 3.95 (ddd,  $J = 18.9, 9.7, 3.0$  Hz, 1H), 3.84 (dd,  $J = 17.6, 3.6$  Hz, 0.4H), 3.44-3.21 (m, 1H), 2.34-2.23 (m, 1H);  **$^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ )**:  $\delta$  200.6 (200.1), 167.5 (168.1), 158.1 (157.8), 136.3 (136.2), 135.6

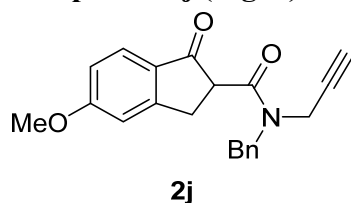
(135.7), 131.9 (q,  $J = 3.5$  Hz) [131.8 (q,  $J = 3.4$  Hz)], 130.6 (q,  $J = 33.1$  Hz), 128.8 (129.1), 128.0 (126.9), 127.7 (128.0), 127.4 (127.3), 123.8 (q,  $J = 272.3$  Hz), 121.8 (q,  $J = 3.6$  Hz) 78.6 (78.4), 73.1 (72.5), 51.4 (49.3), 51.2 (50.9), 37.1 (35.5), 30.9 (31.1);  $^{19}\text{F}$ NMR (376 MHz, Chloroform-*d*):  $\delta$  -62.5 (d,  $J = 3.8$  Hz); HRMS (ESI, *m/z*): calcd. For  $\text{C}_{21}\text{H}_{17}\text{F}_3\text{NO}_2^+$  [ $\text{M}+\text{H}$ ] $^+$ : 372.1206, found: 372.1208.

### Compound 2i (Fig. 2)



*N*-benzyl-4-methoxy-1-oxo-*N*-(prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (**2i**); TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 92-93°C.); yield: 82%; Enol isomerization were observed by NMR;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.43-7.21 (m, 7H), 7.03 (ddd,  $J = 11.6, 6.1, 2.7$  Hz, 1H), 5.23 (d,  $J = 16.0$  Hz, 1H), 4.94-4.79 (m, 1H), 4.38-4.26 (m, 1H), 4.28-4.13 (m, 1H), 4.00 (dd,  $J = 7.8, 3.5$  Hz, 0.4H), 3.97-3.84 (m, 3.6H), 3.74 (dd,  $J = 17.6, 3.5$  Hz, 0.6H), 3.62 (dd,  $J = 17.5, 3.5$  Hz, 0.4H), 3.28-3.08 (m, 1H), 2.34-2.22 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  201.9 (201.5), 168.2 (168.8), 157.0 (156.9), 143.8 (143.5), 136.8 (136.6), 136.5 (136.3), 129.2 (129.0), 128.7, 127.9 (126.9), 127.5 (127.8), 115.7, 115.9 (115.5), 78.8 (78.6), 72.9 (72.3), 55.6 (55.5), 50.9 (49.0), 50.7 (50.7), 37.0 (35.2), 27.6 (27.9); HRMS (ESI, *m/z*): calcd. For  $\text{C}_{21}\text{H}_{20}\text{NO}_3^+$  [ $\text{M}+\text{H}$ ] $^+$ : 334.1438, found: 334.1439.

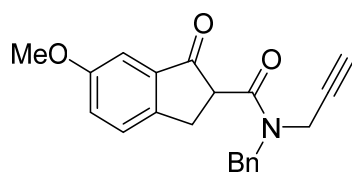
### Compound 2j (Fig. 2)



*N*-benzyl-5-methoxy-1-oxo-*N*-(prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (**2j**); TLC:  $R_f = 0.20$  (petroleum ether /ethyl acetate = 5/1, v/v, UV);

white solid (mp: 108-109°C.); yield: 83%; Enol isomerization were observed by NMR; **<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**: δ 7.65 (dd, *J* = 8.4, 5.6 Hz, 1H), 7.43-7.22 (m, 5H), 6.97-6.84 (m, 2H), 5.29 (dd, *J* = 24.0, 17.2 Hz, 1H), 4.91 (dd, *J* = 28.8, 18.0 Hz, 1H), 4.35 (dd, *J* = 17.6, 2.0 Hz, 0.4H), 4.32-4.23 (m, 1H), 4.18 (dd, *J* = 17.2, 2.4 Hz, 0.4H), 4.04 (dd, *J* = 8.0, 3.6 Hz, 0.4H), 3.93 (d, *J* = 2.4 Hz, 0.3H), 3.88 (d, *J* = 8.0 Hz, 3.5H), 3.82 (d, *J* = 3.6 Hz, 0.3H), 3.73 (dd, *J* = 17.2, 3.6 Hz, 0.4H), 3.30-3.08 (m, 1H), 2.31-2.21 (m, 1H); **<sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>)**: δ 199.7 (199.3), 168.5 (169.0), 166.1 (166.0), 158.1 (157.8), 136.54 (136.51), 128.8 (129.0), 128.6 (128.5), 128.0 (127.0), 127.6 (127.9), 126.30 (126.29), 116.1 (116.0), 109.6 (109.5), 79.0 (78.7), 72.8 (72.4), 55.9 (55.8), 51.3 (49.2), 51.1 (50.9), 37.0 (35.4), 30.8 (31.0); **HRMS (ESI, m/z)**: calcd. For C<sub>21</sub>H<sub>20</sub>NO<sub>3</sub><sup>+</sup> [M+H]<sup>+</sup>: 334.1438, found: 334.1440.

**Compound 2k (Fig. 2)**

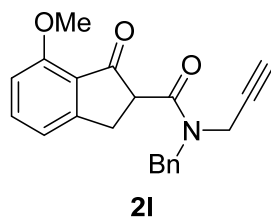


**2k**

***N*-benzyl-6-methoxy-1-oxo-*N*-(prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-**

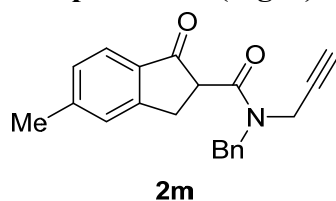
**carboxamide (2k)**; TLC: *R<sub>f</sub>* = 0.40 (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 115-116°C.); yield: 55%; Enol isomerization were observed by NMR; **<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**: δ 7.43-7.38 (m, 1H), 7.38-7.30 (m, 3H), 7.30-7.24 (m, 2H), 7.24-7.13 (m, 2H), 5.24 (d, *J* = 14.8 Hz, 1H), 4.93-4.82 (m, 1H), 4.38-4.26 (m, 1.6H), 4.20 (dd, *J* = 17.3, 2.5 Hz, 0.4H), 4.06 (dd, *J* = 7.7, 3.5 Hz, 0.4H), 3.92 (dd, *J* = 18.9, 2.5 Hz, 0.6H), 3.84-3.73 (m, 3.6H), 3.65 (dd, *J* = 16.6, 3.6 Hz, 0.4H), 3.29-3.08 (m, 1H), 2.32-2.22 (m, 1H); **<sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>)**: δ 201.7 (201.3), 168.2 (168.9), 159.7, 147.9 (147.6), 136.5 (136.4), 128.8 (129.0), 128.0, 127.6 (127.9), 127.3 (127.2), 127.0, 125.0 (124.9), 105.6, 78.9 (78.7), 72.9 (72.4), 55.7, 51.8 (51.7), 49.1 (50.8), 37.0 (35.3), 30.1 (30.3); **HRMS (ESI, m/z)**: calcd. For C<sub>21</sub>H<sub>20</sub>NO<sub>3</sub><sup>+</sup> [M+H]<sup>+</sup>: 334.1438, found: 334.1439.

**Compound 2l (Fig. 2)**



***N*-benzyl-7-methoxy-1-oxo-*N*-(prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (2l)**; TLC:  $R_f = 0.30$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 139-140°C.); yield: 93%; Enol isomerization were observed by NMR;  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )**:  $\delta$  7.53 (dt,  $J = 12.1, 7.9$  Hz, 1H), 7.41-7.21 (m, 5H), 7.03 (dd,  $J = 19.0, 7.6$  Hz, 1H), 6.77 (t,  $J = 8.9$  Hz, 1H), 5.33 (dd,  $J = 16.2, 8.9$  Hz, 1H), 5.01-4.78 (m, 1H), 4.35 (dd,  $J = 17.3, 2.5$  Hz, 0.4H), 4.27 (dd,  $J = 7.9, 4.0$  Hz, 0.6H), 4.22 (d,  $J = 15.2$  Hz, 0.6H), 4.14 (dd,  $J = 17.3, 2.5$  Hz, 0.4H), 4.03 (dd,  $J = 7.9, 3.8$  Hz, 0.4H), 3.93 (d,  $J = 7.5$  Hz, 3H), 3.86 (ddd,  $J = 17.2, 9.0, 3.2$  Hz, 1.2H), 3.74 (dd,  $J = 17.1, 3.8$  Hz, 0.4H), 3.29-3.08 (m, 1H), 2.29-2.19 (m, 1H);  **$^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz,  $\text{CDCl}_3$ )**:  $\delta$  199.2 (198.8), 168.3 (168.7), 158.64 (158.67), 157.2 (157.1), 137.3 (137.2), 136.4 (136.5), 128.7 (128.9), 127.8 (127.0), 127.4 (127.8), 123.3 (123.4), 118.3 (118.2), 109.1, 78.9 (78.7), 72.7 (72.3), 55.81 (55.78), 51.4 (49.1), 51.2 (50.7), 36.8 (35.3), 30.2 (30.5); **HRMS (ESI, m/z)**: calcd. For  $\text{C}_{21}\text{H}_{20}\text{NO}_3^+$   $[\text{M}+\text{H}]^+$ : 334.1438, found: 334.1437.

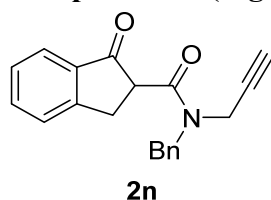
**Compound 2m (Fig. 2)**



***N*-benzyl-5-methyl-1-oxo-*N*-(prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (2m)**; TLC:  $R_f = 0.30$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 88-89°C.); yield: 89%; Enol isomerization were observed by NMR;  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )**:  $\delta$  7.62 (dd,  $J = 7.9, 5.3$  Hz, 1H), 7.43-7.29 (m, 4H), 7.27 (d,  $J = 10.7$  Hz, 2H), 7.17 (t,  $J = 8.1$  Hz, 1H), 5.28 (t,  $J = 17.0$  Hz, 1H), 4.96-4.84 (m, 1H), 4.40-4.24 (m, 1.6H), 4.19 (dd,  $J = 17.3, 2.5$  Hz, 0.4H), 4.04 (dd,  $J = 7.8, 3.7$  Hz, 0.4H), 3.92 (dd,  $J = 19.0, 2.5$  Hz, 0.6H), 3.84 (dd,  $J = 17.1, 3.6$  Hz, 0.6H), 3.72 (dd,  $J$

= 17.0, 3.7 Hz, 0.4H), 3.31-3.10 (m, 1H), 2.31-2.21 (d,  $J = 8.5$  Hz, 3H), 2.26 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  201.1 (200.6), 168.3 (168.8), 155.3 (155.1), 146.8 (146.7), 136.5 (136.4), 133.0 (132.9), 128.93 (128.91), 128.7, 127.9 (127.8), 127.5, 126.9 (126.8), 124.3, 78.9 (78.6), 72.7 (72.2), 51.2 (49.1), 51.0 (50.7), 36.9 (35.3), 30.5 (30.7), 22.2 (22.1); HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{21}\text{H}_{20}\text{NO}_2^+$   $[\text{M}+\text{H}]^+$ : 318.1489, found: 318.1491.

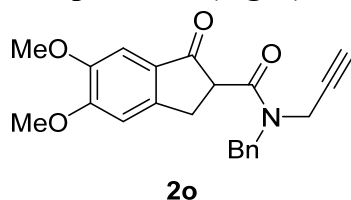
**Compound 2n (Fig. 2)**



***N*-benzyl-1-oxo-*N*-(prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (2n);**

TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 65-66°C.); yield: 79%; Enol isomerization were observed by NMR;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.78-7.70 (m, 1H), 7.66-7.57 (m, 1H), 7.51 (dd,  $J = 20.2, 7.7$  Hz, 1H), 7.44-7.31 (m, 4H), 7.31-7.23 (m, 2H), 5.27 (dd,  $J = 16.2, 11.3$  Hz, 1H), 4.94-4.85 (m, 1H), 4.41-4.24 (m, 1.6H), 4.19 (dd,  $J = 17.3, 2.5$  Hz, 0.4H), 4.05 (dd,  $J = 7.9, 3.7$  Hz, 0.4H), 3.91 (ddd,  $J = 17.1, 11.6, 3.1$  Hz, 1.2H), 3.78 (dd,  $J = 17.1, 3.7$  Hz, 0.4H), 3.38-3.16 (m, 1H), 2.32-2.22 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  201.8 (201.4), 168.2 (168.8), 154.9 (154.6), 136.5 (136.4), 135.6 (135.5), 135.2 (135.3), 128.8 (129.1), 128.0 (127.7), 127.6 (127.9), 127.0, 126.7 (126.6), 124.6, 78.9 (78.7), 72.9 (72.4), 51.1 (51.0), 49.2 (50.9), 37.0 (35.4), 30.8 (31.0); HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{20}\text{H}_{18}\text{NO}_2^+$   $[\text{M}+\text{H}]^+$ : 304.1332, found: 304.1329.

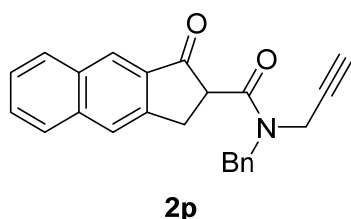
**Compound 2o (Fig. 2)**



***N*-benzyl-5,6-dimethoxy-1-oxo-*N*-(prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (2o);** TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 5/1, v/v, UV);

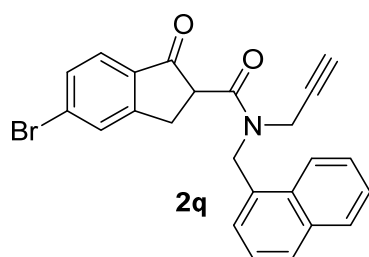
white solid (mp: 159-160°C.); yield: 55%; Enol isomerization were observed by NMR;  
**<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>):** δ 7.42-7.29 (m, 3H), 7.29-7.21 (m, 2H), 7.12 (d, *J* = 5.7 Hz, 1H), 6.91 (d, *J* = 20.1 Hz, 1H), 5.27 (dd, *J* = 18.6, 15.4 Hz, 1H), 5.02-4.81 (m, 1H), 4.36-4.23 (m, 1.6H), 4.19 (dd, *J* = 17.4, 2.5 Hz, 0.4H), 4.04 (dd, *J* = 7.5, 3.2 Hz, 0.4H), 3.96 (d, *J* = 8.6 Hz, 3.6H), 3.88 (d, *J* = 5.7 Hz, 3H), 3.76 (dd, *J* = 17.1, 3.1 Hz, 0.6H), 3.64 (dd, *J* = 16.9, 3.2 Hz, 0.4H), 3.26-3.04 (m, 1H), 2.31-2.21 (m, 1H); **<sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>):** δ 200.1 (199.7), 168.5 (169.0), 156.2 (156.1), 150.6 (150.3), 149.73 (149.70), 136.52 (136.45), 128.8 (129.0), 127.9 (127.0), 127.9 (128.0), 127.5 (127.8), 107.4 (107.4), 104.8, 79.0 (78.7), 72.8 (72.3), 56.42 (56.39), 56.2, 51.3 (49.1), 51.1 (50.8), 37.0 (35.3), 30.5 (30.7); **HRMS (ESI, m/z):** calcd. For C<sub>22</sub>H<sub>22</sub>NO<sub>4</sub><sup>+</sup> [M+H]<sup>+</sup>: 364.1543, found: 364.1540.

**Compound 2p (Fig. 2)**



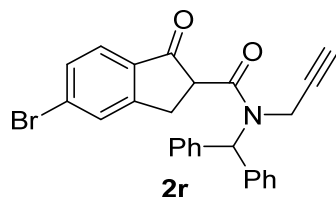
***N*-benzyl-1-oxo-*N*-(prop-2-yn-1-yl)-2,3-dihydro-1*H*-cyclopenta[*b*]naphthalene-2-carboxamide (2p);** TLC: *R<sub>f</sub>* = 0.60 (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 151-152°C.); yield: 28%; Enol isomerization were observed by NMR;  
**<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>):** δ 8.31 (d, *J* = 6.4 Hz, 1H), δ 8.02-7.81 (m, 3H), 7.63-7.56 (m, 1H), 7.54-7.44 (m, 1H), 7.45-7.26 (m, 5H), 5.30 (dd, *J* = 16.4, 13.6 Hz, 1H), 4.92 (d, *J* = 16.8 Hz, 1H), 4.44-4.34 (m, 1H), 4.32 (d, *J* = 15.2 Hz, 0.5H), 4.21 (dd, *J* = 17.6, 2.4 Hz, 0.5H), 4.15 (dd, *J* = 8.5, 4.5 Hz, 0.5H), 4.07 (ddd, *J* = 16.8, 4.4, 1.2 Hz, 0.5H), 3.96 (dd, *J* = 19.2, 2.4 Hz, 1H), 3.56-3.34 (m, 1H), 2.34-2.23 (m, 1H); **<sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>):** δ 202.1 (201.7), 168.3 (168.9), 146.9 (146.7), 137.7 (137.6), 136.5 (136.4), 133.1 (133.2), 132.5, 130.5 (129.2), 129.1, 128.8, 128.0, 127.98 (127.96), 127.0 (127.6), 126.4 (126.3), 125.70 (125.66), 124.82 (124.75), 78.9 (78.7), 72.9 (72.4), 51.9 (51.8), 49.2 (50.9), 37.1 (35.4), 30.3 (30.6); **HRMS (ESI, m/z):** calcd. For C<sub>24</sub>H<sub>20</sub>NO<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 354.1489, found: 354.1492.

**Compound 2q (Fig. 2)**



**5-bromo-N-(naphthalen-1-ylmethyl)-1-oxo-N-(prop-2-yn-1-yl)-2,3-dihydro-1H-indene-2-carboxamide (2q)**; TLC:  $R_f = 0.40$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 105-106°C.); yield: 86%; Enol isomerization were observed by NMR;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  8.01 (dd,  $J = 27.4, 9.2$  Hz, 1H), 7.93-7.73 (m, 22H), 7.65-7.32 (m, 7H), 5.90 (d,  $J = 18.3$  Hz, 0.4H), 5.66 (d,  $J = 15.3$  Hz, 0.6H), 5.28 (d,  $J = 18.3$  Hz, 0.4H), 4.86-4.77 (m, 1.2H), 4.62 (dd,  $J = 17.4, 2.6$  Hz, 0.4H), 4.31 (dd,  $J = 7.9, 3.6$  Hz, 0.6H), 4.19 (dd,  $J = 17.4, 2.5$  Hz, 0.4H), 3.95-3.87 (m, 1.6H), 3.78 (dd,  $J = 17.4, 3.7$  Hz, 0.4H), 3.36-3.05 (m, 1H), 2.31-2.23 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.3 (200.1), 167.7 (169.0), 156.4 (156.2), 134.2 (134.1), 134.0 (133.9), 131.6 (131.8), 131.4 (131.5), 131.4 (131.1), 131. (130.7), 130.0 (129.9), 128.8 (129.1), 128.7 (128.4), 126.6 (126.8), 126.44 (126.36), 126.1 (123.5), 125.8 (125.7), 125.5 (125.6), 122.9 (122.5), 78.7 (78.6), 73.1 (72.7), 51.3 (51.1), 47.1 (48.6), 36.7 (36.4), 30.5 (30.7); HRMS (ESI, m/z): calcd. For  $\text{C}_{24}\text{H}_{19}\text{BrNO}_2^+$   $[\text{M}+\text{H}]^+$ : 432.0594, found: 432.0595.

**Compound 2r (Fig. 2)**

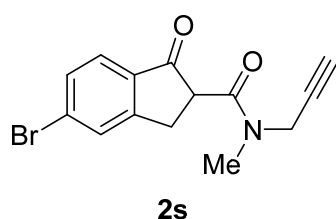


**N-benzhydryl-5-bromo-1-oxo-N-(prop-2-yn-1-yl)-2,3-dihydro-1H-indene-2-carboxamide (2r)**; TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 133-134°C.); yield: 27%; Enol isomerization were observed by NMR;  $^1\text{H NMR}$  (400 MHz, Chloroform-*d*):  $\delta$  7.67 (d,  $J = 29.3$  Hz, 1H), 7.61 (d,  $J = 8.2$  Hz, 1H), 7.55-7.33 (m, 9H), 7.27 (t,  $J = 8.4$  Hz, 2H), 7.08 (d,  $J = 4.3$  Hz, 1H), 5.02 (dd,  $J =$



19.1, 2.5 Hz, 0.7H), 4.52 (dd,  $J = 7.8, 3.7$  Hz, 0.7H), 4.21 (dd,  $J = 17.2, 2.5$  Hz, 0.3H), 4.05-3.71 (m, 2.3H), 3.36-2.93 (m, 1H), 2.05-1.99 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  201.1 (200.5), 168.5 (168.7), 156.6 (156.5), 138.8 (139.3), 138.6 (138.7), 134.2, 131.4 (131.1), 130.3 (130.8), 130.0 (129.9), 128.8(128.9), 128.6 (128.8), 128.5, 128.1 (127.9), 128.0, 127.5 (127.7), 125.74 (125.71), 79.8, 72.0 (71.0), 62.2 (65.0), 52.1 (51.8), 35.1 (34.5), 30.5 (30.8); HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{26}\text{H}_{21}\text{BrNO}_2^+$   $[\text{M}+\text{H}]^+$ : 458.0750, found: 458.0748.

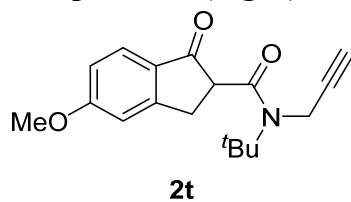
### Compound 2s (Fig. 2)



### 5-bromo-*N*-methyl-1-oxo-*N*-(prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-

**carboxamide (2s)**; TLC:  $R_f = 0.30$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 109-110°C.); yield: 82%; Enol isomerization were observed by NMR;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.69 (d,  $J = 4.6$  Hz, 1H), 7.58-7.46 (m, 2H), 4.96 (dd,  $J = 18.8, 2.5$  Hz, 0.4H), 4.50 (dd,  $J = 17.3, 2.5$  Hz, 0.6H), 4.14 (ddd,  $J = 24.9, 7.9, 3.6$  Hz, 1H), 4.08-3.96 (m, 1H), 3.86-3.71 (m, 1H), 3.38 (s, 1.8H), 3.24 (dt,  $J = 17.4, 8.9$  Hz, 1H), 3.07 (s, 1.2H), 2.35-2.24 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.2 (200.5), 167.6 (167.2), 156.2 (156.4), 134.2 (134.1), 131.38 (131.39), 131.0 (131.1), 129.95 (129.96), 125.65 (125.68), 78.5 (78.4), 72.3 (73.2), 50.8 (51.0), 37.3 (40.1), 35.5 (34.5), 30.3 (30.40); HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{14}\text{H}_{13}\text{BrNO}_2^+$   $[\text{M}+\text{H}]^+$ : 306.0124, found: 306.0120.

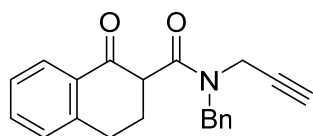
### Compound 2t (Fig. 2)



### *N*-(*tert*-butyl)-5-methoxy-1-oxo-*N*-(prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-

**carboxamide (2t)**; TLC:  $R_f = 0.30$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 123-124°C.); yield: 22%;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.63 (d,  $J = 8.4$  Hz, 1H), 6.94-6.84 (m, 2H), 5.01 (dd,  $J = 20.0, 2.4$  Hz, 1H), 4.25 (dd,  $J = 7.6, 3.2$  Hz, 1H), 4.13 (dd,  $J = 20.0, 2.4$  Hz, 1H), 3.88 (s, 3H), 3.72 (dd,  $J = 16.8, 3.2$  Hz, 1H), 3.20 (dd,  $J = 17.2, 7.6$  Hz, 1H), 2.30 (t,  $J = 2.4$  Hz, 1H), 1.50 (s, 9H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.6, 168.9, 165.9, 158.3, 128.7, 126.2, 115.9, 109.4, 81.5, 72.2, 58.7, 55.8, 53.3, 34.9, 31.5, 28.8; HRMS (ESI, m/z): calcd. For  $\text{C}_{18}\text{H}_{22}\text{NO}_3^+$   $[\text{M}+\text{H}]^+$ : 300.1594, found: 300.1594.

**Compound 2u (Fig. 2)**

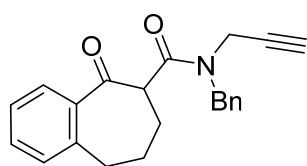


**2u**

***N*-benzyl-1-oxo-*N*-(prop-2-yn-1-yl)-1,2,3,4-tetrahydronaphthalene-2-**

**carboxamide (2u)**; TLC:  $R_f = 0.30$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 75-76°C.); yield: 40%;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  8.04 (t,  $J = 6.7$  Hz, 1H), 7.53 – 7.22 (m, 8H), 5.32 (d,  $J = 15.1$  Hz, 0.6H), 4.79 (q,  $J = 20.6$  Hz, 0.8H), 4.37 – 4.21 (m, 2H), 4.00 (dd,  $J = 12.2, 4.6$  Hz, 0.6H), 3.85 – 3.78 (m, 1H), 3.14 – 3.06 (m, 1.6H), 2.91 (ddd,  $J = 16.5, 11.7, 4.4$  Hz, 0.4H), 2.63 (dq,  $J = 23.7, 12.1, 5.0$  Hz, 1H), 2.38 – 2.24 (m, 2H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  194.6 (194.3), 170.2 (170.6), 144.3 (144.1), 136.5 (136.3), 134.1 (134.0), 132.0, 129.1 (128.9), 128.8 (129.0), 128.1 (127.8), 127.5 (127.9), 126.94 (126.92), 126.8, 78.9 (78.8), 72.9 (72.2), 52.2 (52.0), 48.8 (50.7), 36.7 (34.8), 28.5 (28.3), 26.6(26.7); HRMS (ESI, m/z): calcd. For  $\text{C}_{21}\text{H}_{20}\text{NO}_2^+$   $[\text{M}+\text{H}]^+$ : 318.1489, found: 318.1498.

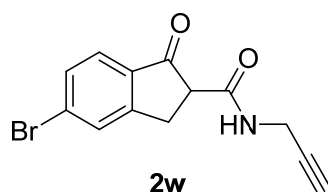
**Compound 2v (Fig. 2)**



**2v**

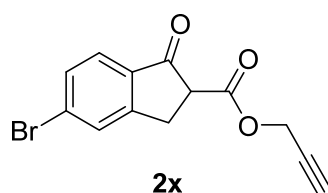
***N*-benzyl-5-oxo-*N*-(prop-2-yn-1-yl)-6,7,8,9-tetrahydro-5*H*-benzo[7]annulene-6-carboxamide (2v)**; TLC:  $R_f = 0.30$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 96-97°C.); yield: 30%;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.72 (dd,  $J = 7.8, 1.5$  Hz, 0.5H), 7.62 (dd,  $J = 7.7, 1.5$  Hz, 0.5H), 7.50 – 7.14 (m, 8H), 5.15 (d,  $J = 15.1$  Hz, 0.5H), 4.62 (s, 1H), 4.40 (d,  $J = 15.1$  Hz, 0.5H), 4.34 (dd,  $J = 17.3, 2.5$  Hz, 0.5H), 4.21 (dd,  $J = 17.4, 2.5$  Hz, 0.5H), 4.13 – 4.09 (m, 1H), 3.92 (dd,  $J = 11.3, 3.9$  Hz, 0.5H), 3.75 (dd,  $J = 18.7, 2.5$  Hz, 0.5H), 3.00 (dd,  $J = 8.1, 4.6$  Hz, 1H), 2.93 – 2.89 (m, 1H), 2.30 – 1.72 (m, 5H).;  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  202.4 (202.2), 170.7 (170.5), 141.0 (141.0), 138.3 (138.2), 136.6 (136.2), 132.7 (132.5), 129.9 (129.8), 129.1 (128.9), 129.0 (128.8), 128.2 (127.0), 128.0 (127.6), 127.02 (126.98), 78.7 (78.5), 73.0 (72.3), 54.1 (54.0), 50.7 (48.7), 36.7 (34.9), 32.8 (32.7), 26.0 (25.8), 24.6 (24.5); HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{18}\text{H}_{22}\text{NO}_3^+$   $[\text{M}+\text{H}]^+$ : 332.1645, found: 332.1655.

**Compound 2w (Fig. 2)**



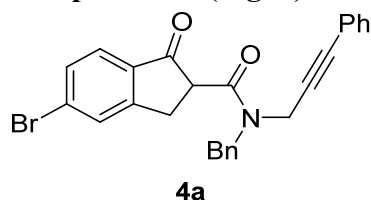
**5-bromo-1-oxo-*N*-(prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (2w)**; TLC:  $R_f = 0.30$  (petroleum ether /ethyl acetate = 3/1, v/v, UV); white solid (mp: 180-181°C.); yield: 50%;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.70 (s, 1H), 7.62 – 7.52 (m, 2H), 7.33 (s, 1H), 4.19 – 4.01 (m, 2H), 3.78 (dd,  $J = 17.9, 4.2$  Hz, 1H), 3.57 (dd,  $J = 8.5, 4.1$  Hz, 1H), 3.34 (dd,  $J = 17.9, 8.3$  Hz, 1H), 2.25 (s, 1H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  201.8, 165.9, 155.8, 134.2, 131.6, 131.6, 130.2, 125.7, 79.3, 71.8, 52.8, 29.6, 28.4; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{13}\text{H}_{11}\text{BrNO}_2^+$   $[\text{M}+\text{H}]^+$ : 291.9968, found: 291.9976.

**Compound 2x (Fig. 2)**



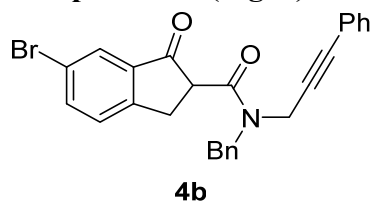
**prop-2-yn-1-yl 5-bromo-1-oxo-2,3-dihydro-1H-indene-2-carboxylate (2x)**; TLC:  $R_f = 0.30$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 119-120°C.); yield: 45%;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.69 (d,  $J = 1.5$  Hz, 1H), 7.63-7.61 (m, 1H), 7.55 – 7.51 (m, 1H), 4.86 – 4.73 (m, 2H), 3.77 (dd,  $J = 8.3, 4.2$  Hz, 1H), 3.59 – 3.54 (m, 1H), 3.38 (dd,  $J = 17.5, 8.3$  Hz, 1H), 2.54-2.50 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  197.6, 168.1, 155.0 (145.2), 134.1 (135.7), 131.8 (131.2), 130.0 (130.4), 126.0 (128.3), 122.2 (124.4), 77.8, 75.6 (75.3), 53.3, 53.0 (51.8), 30.0 (32.5); HRMS (ESI, m/z): calcd. For  $\text{C}_{13}\text{H}_{10}\text{BrO}_3^+ [\text{M}+\text{H}]^+$ : 292.9808, found: 292.9810.

**Compound 4a (Fig. 3)**



**N-benzyl-5-bromo-1-oxo-N-(3-phenylprop-2-yn-1-yl)-2,3-dihydro-1H-indene-2-carboxamide (4a)**; TLC:  $R_f = 0.60$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 79-80°C.); yield: 78%; Enol isomerization were observed by NMR;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.70 (dd,  $J = 19.5, 1.5$  Hz, 1H), 7.62-7.49 (m, 2H), 7.42-7.26 (m, 10H), 5.35-5.22 (m, 1H), 5.11-4.93 (m, 1H),  $\delta$  4.54-4.34=8 (m, 2H), 4.17-4.04 (m, 1H), 3.93-3.74 (m, 1H), 3.37-3.13 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.6 (200.2), 167.9 (168.4), 156.4 (156.2), 136.61 (136.58), 134.2 (134.3), 131.8 (131.4), 131.1 (131.0), 130.0 (129.9), 128.8 (129.1), 128.5 (128.8), 128.3 (128.5), 128.1, 127.6 (127.9), 126.9, 125.7, 122.3 (122.8), 84.8 (84.5), 83.9 (84.0), 51.3 (49.6), 51.1 (50.9), 38.1 (36.4), 30.6 (30.8); HRMS (ESI, m/z): calcd. For  $\text{C}_{26}\text{H}_{21}\text{BrNO}_2^+ [\text{M}+\text{H}]^+$ : 458.0751, found: 458.0750.

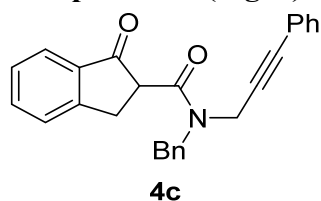
**Compound 4b (Fig. 3)**



**N-benzyl-6-bromo-1-oxo-N-(3-phenylprop-2-yn-1-yl)-2,3-dihydro-1H-indene-2-**

**carboxamide (4b)**; TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); yellow oil; yield: 31%; Enol isomerization were observed by NMR;  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )**:  $\delta$  7.86 (dd,  $J = 9.6, 1.9$  Hz, 1H), 7.73-7.67 (m, 1H), 7.42-7.26 (m, 11H), 5.34-5.22 (m, 1H), 5.01-4.93 (m, 1H), 4.54-4.40 (m, 2H), 4.18-4.09 (m, 1H), 3.87-3.69 (m, 1H), 3.33-3.09 (m, 1H);  **$^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz,  $\text{CDCl}_3$ )**:  $\delta$  200.4 (200.0), 167.8 (168.4), 153.5 (153.2), 138.2 (138.1), 137.1 (137.2), 136.6, 131.8, 128.8 (129.1), 128.8 (128.4), 128.5 (128.3), 128.2 (128.1), 128.0 (127.4), 127.6 (127.9), 126.9 (127.4), 122.3 (122.7), 121.8, 84.8 (84.5), 83.9 (83.9), 51.5 (49.6), 51.4 (50.9), 38.1 (36.4), 30.5 (30.8); **HRMS (ESI, m/z)**: calcd. For  $\text{C}_{26}\text{H}_{21}\text{BrNO}_2^+$   $[\text{M}+\text{H}]^+$ : 458.0751, found: 458.0753.

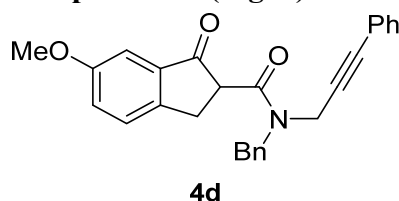
**Compound 4c (Fig. 3)**



***N*-benzyl-1-oxo-*N*-(3-phenylprop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-**

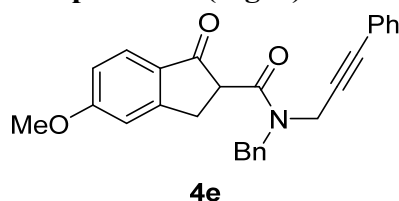
**carboxamide (4c)**; TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 76-77°C.); yield: 39%; Enol isomerization were observed by NMR;  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )**:  $\delta$  7.76 (t,  $J = 8.3$  Hz, 1H), 7.61 (dt,  $J = 11.8, 7.4$  Hz, 1H), 7.51 (dd,  $J = 19.5, 7.7$  Hz, 1H), 7.43-7.26 (m, 11H), 5.37-5.25 (m, 1H), 5.15-4.95 (m, 1H), 4.56-4.38-4.34 (m, 2H), 4.20-4.05 (m, 1H), 3.95-3.76 (m, 1H), 3.40-3.16 (m, 1H);  **$^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz,  $\text{CDCl}_3$ )**:  $\delta$  201.9 (201.5), 168.4 (168.9), 154.9 (154.6), 136.68 (136.71), 135.5, 135.4 (135.3), 131.83 (131.82), 128.8 (129.0), 128.7 (128.4), 128.5 (128.3), 128.0 (127.7), 127.6 (127.8), 126.9, 126.7 (126.6), 124.6, 122.4 (122.8), 84.6 (84.4), 84.0 (84.1), 51.2 (49.5), 51.1 (50.9), 38.1 (36.3), 30.8 (31.1); **HRMS (ESI, m/z)**: calcd. For  $\text{C}_{26}\text{H}_{22}\text{NO}_2^+$   $[\text{M}+\text{H}]^+$ : 380.1646, found: 380.1648.

**Compound 4d (Fig. 3)**



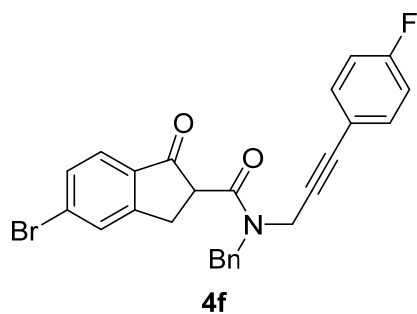
***N*-benzyl-6-methoxy-1-oxo-*N*-(3-phenylprop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (4d)**; TLC:  $R_f = 0.40$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); yellow oi; yield: 81%; Enol isomerization were observed by NMR;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.42-7.22 (m, 11H), 7.18 (td,  $J = 9.4, 2.9$  Hz, 2H), 5.34-5.23 (m, 1H), 5.12-4.94 (m, 1H), 4.56-4.39-4.37 (m, 2H), 4.16 (d,  $J = 19.0$  Hz, 0.6H), 4.08 (dd,  $J = 7.7, 3.5$  Hz, 0.4H), 3.82 (d,  $J = 7.4$  Hz, 3.4H), 3.72-3.59 (m, 0.6H), 3.32-3.08 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  201.8 (201.4), 168.4 (169.0), 159.66 (159.65), 147.9 (147.6), 136.72 (136.70), 136.5 (136.6), 131.83 (131.82), 128.8 (129.0), 128.7 (128.4), 128.5 (128.3), 128.0 (127.0), 127.5 (127.8), 127.3 (127.2), 125.0 (124.9), 122.4 (122.8), 105.6, 84.6 (84.4), 84.0 (84.1), 55.7, 51.9 (49.5), 51.8 (50.91, 38.1 (36.3), 30.2 (30.5); HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{27}\text{H}_{24}\text{NO}_3^+$   $[\text{M}+\text{H}]^+$ : 410.1751, found: 410.1752.

**Compound 4e (Fig. 3)**



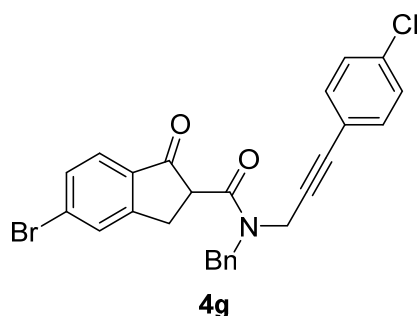
***N*-benzyl-5-methoxy-1-oxo-*N*-(3-phenylprop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (4e)**; TLC:  $R_f = 0.30$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); yellow oil; yield: 95%; Enol isomerization were observed by NMR;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.67 (t,  $J = 8.8$  Hz, 1H), 7.42-7.39 (m, 3H), 7.36-7.31 (m, 5H), 7.30-7.26 (m, 2H), 6.95-6.88 (m, 2H), 5.41-5.25 (m, 1H), 5.21-4.94 (m, 1H), 4.55-4.37 (m, 2H), 4.17-4.04 (m, 1H), 3.87 (d,  $J = 11.6$  Hz, 3.6H), 3.74 (dd,  $J = 16.8, 3.6$  Hz, 0.4H), 3.32-3.09 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  199.8 (199.4), 168.6 (169.1), 166.0 (165.9), 158.0 (157.8), 136.8 (136.7), 131.8, 128.7 (128.9), 128.7 (128.6), 128.5 (128.3), 128.4 (128.3), 128.0 (126.9), 127.5 (127.7), 126.20 (126.18), 122.4 (122.8), 116.0 (115.9), 109.52 (109.49), 84.5 (84.3), 84.2, 55.78 (55.76), 51.3 (49.4), 51.2 (50.9), 38.0 (36.3), 30.8 (31.1); HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{27}\text{H}_{24}\text{NO}_3^+$   $[\text{M}+\text{H}]^+$ : 410.1751, found: 410.1755.

**Compound 4f (Fig. 3)**



***N*-benzyl-5-bromo-*N*-(3-(4-fluorophenyl)prop-2-yn-1-yl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxamide (4f)**; TLC:  $R_f$  = 0.50 (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 94-95°C.); yield: 53%; Enol isomerization were observed by NMR;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.69 (d,  $J$  = 19.3 Hz, 1H), 7.59 (t,  $J$  = 8.8 Hz, 1H), 7.51 (t,  $J$  = 9.0 Hz, 1H), 7.43 – 7.24 (m, 7H), 7.03 – 6.95 (m, 2H), 5.36-5.18 (m, 1H), 5.09-4.90 (m, 1H), 4.51 (d,  $J$  = 5.4 Hz, 1H), 4.43 (d,  $J$  = 15.1 Hz, 0.4H), 4.36 (dd,  $J$  = 7.9, 3.6 Hz, 0.6H), 4.15 (d,  $J$  = 19.0 Hz, 0.6H), 4.05 (dd,  $J$  = 7.9, 3.6 Hz, 0.4H), 3.92-3.74 (m, 1H), 3.36-3.12 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.6 (200.2), 167.9 (168.4), 163.9 (d,  $J$  = 18.2 Hz) [161.5 (d,  $J$  = 17.5 Hz)], 156.4 (156.2), 136.6, 134.15 (134.23), 133.8 (d,  $J$  = 2.5 Hz) [133.7 (d,  $J$  = 2.4 Hz)], 131.43 (131.41), 131.1 (131.0), 130.0 (129.9), 128.8 (129.1), 128.1 (126.8), 127.7 (127.9), 125.7 (125.7), 118.4 (d,  $J$  = 3.7 Hz) [118.8 (d,  $J$  = 3.6 Hz)], 115.7 (t,  $J$  = 21.9 Hz), 83.7 (83.6), 83.6 (83.3), 51.2 (49.6), 51.1 (51.0), 38.0 (36.4), 30.6 (30.8);  $^{19}\text{F NMR}$  (376 MHz, Chloroform-*d*):  $\delta$  -110.1 (-110.8); HRMS (ESI, *m/z*): calcd. For  $\text{C}_{26}\text{H}_{20}\text{BrFNO}_2^+$  [M+H] $^+$ : 476.0656, found: 476.0658.

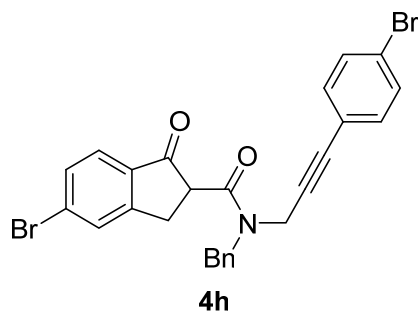
**Compound 4g (Fig. 3)**



***N*-benzyl-5-bromo-*N*-(3-(4-chlorophenyl)prop-2-yn-1-yl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxamide (4g)**; TLC:  $R_f$  = 0.50 (petroleum ether /ethyl acetate = 5/1, v/v,

UV); white solid (mp: 111-112°C.); yield: 46%; Enol isomerization were observed by NMR; **<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**: δ 7.71 (d, *J* = 19.1 Hz, 1H), 7.65-7.49 (m, 2H), 7.43-7.23 (m, 9H), 5.37-5.19 (m, 1H), 5.11-4.90 (m, 1H), 4.53 (d, *J* = 3.7 Hz, 1H), 4.43 (d, *J* = 15.1 Hz, 0.5H), 4.37 (dd, *J* = 7.9, 3.6 Hz, 0.5H), 4.17 (d, *J* = 19.1 Hz, 0.5H), 4.07 (dd, *J* = 7.9, 3.7 Hz, 0.5H), 3.94-3.76 (m, 1H), 3.37-3.14 (m, 1H); **<sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>)**: δ 200.6 (200.2), 167.9 (168.4), 156.4 (156.2), 136.5, 134.9 (134.5), 134.1 (134.2), 133.1, 131.47 (131.45), 131.2 (131.0), 130.0 (129.9), 128.9 (129.1), 128.9 (128.7), 128.1 (126.8), 127.7 (128.0), 125.77 (125.75), 120.8 (121.2), 84.9 (85.1), 83.7, (83.3), 51.2 (49.7), 51.1 (51.1), 38.1 (36.5), 30.6 (30.8); **HRMS (ESI, m/z)**: calcd. For C<sub>26</sub>H<sub>20</sub>BrClNO<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 492.0361, found: 492.0363.

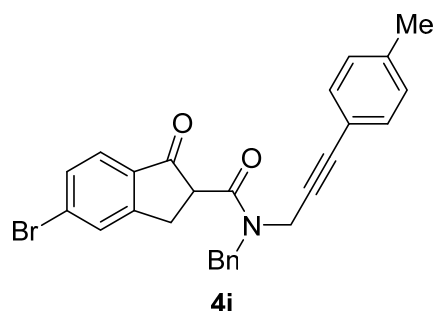
**Compound 4h (Fig. 3)**



***N*-benzyl-5-bromo-*N*-(3-(4-bromophenyl)prop-2-yn-1-yl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxamide (4h)**; TLC: *R<sub>f</sub>* = 0.50 (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 113-114°C.); yield: 29%; Enol isomerization were observed by NMR; **<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**: δ 7.69 (d, *J* = 19.1 Hz, 1H), 7.59 (t, *J* = 8.5 Hz, 1H), 7.51 (t, *J* = 8.8 Hz, 1H), 7.48-7.21 (m, 8H), 7.18 (d, *J* = 8.5 Hz, 1H), 5.36-5.18 (m, 1H), 5.09-4.89 (dd, *J* = 63.8, 18.2 Hz, 1H), 4.51 (d, *J* = 2.7 Hz, 1H), 4.42 (d, *J* = 15.2 Hz, 0.5H), 4.35 (dd, *J* = 7.8, 3.7 Hz, 0.5H), 4.15 (d, *J* = 19.1 Hz, 0.5H), 4.05 (dd, *J* = 7.8, 3.6 Hz, 0.5H), 3.92-3.74 (m, 1H), 3.36-3.13 (m, 1H); **<sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>)**: δ 200.6 (200.2), 167.8 (168.4), 156.4 (156.2), 136.5, 134.2 (134.1), 133.30 (133.27), 131.8 (131.6), 131.5 (131.4), 131.2 (131.0), 130.0 (129.9), 128.9 (129.1), 128.1 (126.8), 127.7 (128.0), 125.8 (125.7), 123.1 (122.7), 121.2 (121.7), 85.1 (85.3), 83.7 (83.4), 51.2 (49.7), 51.1 (51.1), 38.1 (36.5), 30.6 (30.8); **HRMS (ESI, m/z)**: calcd. For C<sub>26</sub>H<sub>20</sub>Br<sub>2</sub>NO<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 537.9835, found: 537.9838.

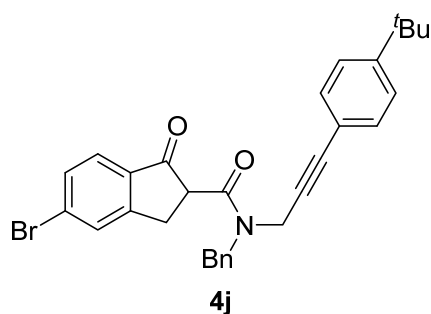


### Compound 4i (Fig. 3)



*N*-benzyl-5-bromo-1-oxo-*N*-(3-(*p*-tolyl)prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (**4i**); TLC:  $R_f = 0.60$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 120-121°C.); yield: 71%; Enol isomerization were observed by NMR;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.69 (d,  $J = 19.5$  Hz, 1H), 7.59 (t,  $J = 8.6$  Hz, 1H), 7.51 (t,  $J = 9.0$  Hz, 1H), 7.45-7.21 (m, 7H), 7.11 (dd,  $J = 17.1, 7.9$  Hz, 2H), 5.34-5.22 (m, 1H), 5.10-5.94 (m, 1H), 4.53 (d,  $J = 2.3$  Hz, 1H), 4.45-4.36 (m, 1H), 4.22-4.00 (m, 1H), 3.92-3.73 (m, 1H), 3.36-3.11 (m, 1H), 2.35 (d,  $J = 8.6$  Hz, 3H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.6 (200.2), 167.9 (168.4), 156.4 (156.2), 139.0 (138.5), 136.6 (136.6), 134.2 (134.3), 131.70 (131.71), 131.4, 131.0 (130.9), 130.0 (129.9), 129.2 (129.1), 128.8 (129.0), 128.0 (126.9), 127.6 (127.8), 125.71 (125.69), 119.2 (119.6), 84.9 (84.6), 83.15 (83.17), 51.2 (49.5), 51.1 (50.8), 38.1 (36.4), 30.6 (30.8), 21.59 (21.56); HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{27}\text{H}_{23}\text{BrNO}_2^+$   $[\text{M}+\text{H}]^+$ : 472.0907, found: 472.0908.

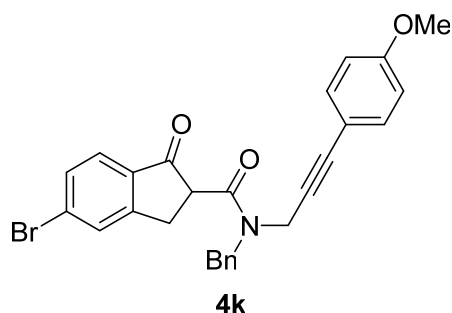
### Compound 4j (Fig. 3)



*N*-benzyl-5-bromo-*N*-(3-(4-(*tert*-butyl)phenyl)prop-2-yn-1-yl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxamide (**4j**); TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 91-92°C.); yield: 40%; Enol isomerization were observed

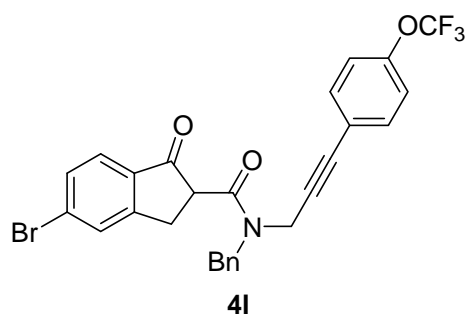
by NMR;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.73-7.65 (m, 1H), 7.60 (t,  $J = 8.5$  Hz, 2H), 7.56-7.48 (m, 1H), 7.45-7.25 (m, 9H), 5.34-5.22 (m, 1H), 5.10-4.94 (m, 1H), 4.54 (d,  $J = 3.4$  Hz, 1H), 4.46-4.36 (m, 1H), 4.21-4.00 (m, 1H), 3.92-3.74 (m, 1H), 3.36-3.12 (m, 1H), 1.31 (d,  $J = 5.1$  Hz, 9H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.7 (200.2), 168.0 (168.4), 156.5 (156.2), 152.2 (151.7), 136.6 (136.7), 134.2 (134.3), 131.6, 131.4, 131.1 (130.9), 130.0 (129.9), 128.8 (129.1), 128.1 (126.9), 127.6 (127.9), 125.8, 125.5 (125.3), 119.3 (119.7), 84.9 (84.7), 83.2, 51.3 (49.6), 51.2 (50.8), 38.2 (36.5), 34.93 (34.87), 31.3, 30.6 (30.8); **HRMS (ESI, m/z)**: calcd. For  $\text{C}_{30}\text{H}_{29}\text{BrNO}_2^+$   $[\text{M}+\text{H}]^+$ : 514.1377, found: 514.1379.

**Compound 4k (Fig. 3)**



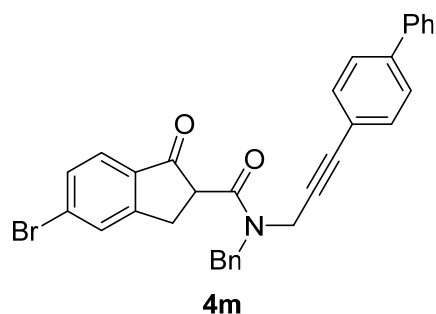
***N*-benzyl-5-bromo-*N*-(3-(4-methoxyphenyl)prop-2-yn-1-yl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxamide (4k)**; TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 86-87°C.); yield: 33%; Enol isomerization were observed by NMR;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.70 (d,  $J = 19.8$  Hz, 1H), 7.66-7.58 (m, 1H), 7.53 (t,  $J = 8.8$  Hz, 1H), 7.46-7.26 (m, 7H), 6.85 (dd,  $J = 15.8, 8.8$  Hz, 2H), 5.36-5.23 (m, 1H), 5.10-4.95 (m, 1H), 4.54 (s, 1H), 4.48-4.37 (m, 1H), 4.21-4.04 (m, 1H), 3.99-3.67 (m, 4H), 3.38-3.13 (m 1H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.6 (200.2), 168.0 (168.4), 160.0 (159.7), 156.4 (156.2), 136.65 (136.68), 134.2 (134.3), 133.3, 131.4, 131.0 (130.9), 130.0 (129.9), 128.8 (129.0), 128.0 (126.9), 127.6 (127.8), 125.72 (125.70), 114.3 (114.8), 114.1 (113.9), 84.7 (84.4), 82.5, 55.41 (55.37), 51.2 (49.6), 51.1 (50.9), 38.2 (36.5), 30.6 (30.8); **HRMS (ESI, m/z)**: calcd. For  $\text{C}_{27}\text{H}_{23}\text{BrNO}_3^+$   $[\text{M}+\text{H}]^+$ : 488.0856, found: 488.0858.

**Compound 4l (Fig. 3)**



***N*-benzyl-5-bromo-1-oxo-*N*-(3-(4-(trifluoromethoxy)phenyl)prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (4l)**; TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 96-97°C.); yield: 32%; Enol isomerization were observed by NMR;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.69 (d,  $J = 19.0$  Hz, 1H), 7.64-7.48 (m, 2H), 7.45-7.24 (m, 7H), 7.15 (dd,  $J = 18.2, 8.2$  Hz, 2H), 5.37-5.17 (m, 1H), 5.13-4.87 (m, 1H), 4.52 (d,  $J = 6.5$  Hz, 1H), 4.44 (d,  $J = 15.1$  Hz, 0.5H), 4.36 (dd,  $J = 7.9, 3.6$  Hz, 0.5H), 4.17 (d,  $J = 19.1$  Hz, 0.5H), 4.06 (dd,  $J = 7.9, 3.7$  Hz, 0.5H), 3.93-3.75 (m, 1H), 3.36-3.13 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.6 (200.2), 167.8 (168.4), 156.4 (156.2), 149.3 (149.1), 136.5, 134.1 (134.2), 133.42 (133.39), 131.48 (131.46), 131.2 (131.1), 130.0 (129.9), 128.9 (129.1), 128.1 (126.8), 127.7 (128.0), 125.78 (125.75), 121.1 (121.5), 121.0 (120.9), 120.5 (q,  $J = 258.9$  Hz), 84.9 (85.0), 83.4 (83.0), 51.2 (49.7), 51.12 (51.08), 38.0 (36.5), 30.6 (30.8);  $^{19}\text{F NMR}$  (376 MHz, Chloroform-*d*):  $\delta$  -57.8; HRMS (ESI, *m/z*): calcd. For  $\text{C}_{27}\text{H}_{20}\text{BrF}_3\text{NO}_3^+$   $[\text{M}+\text{H}]^+$ : 542.0574, found: 5542.0576.

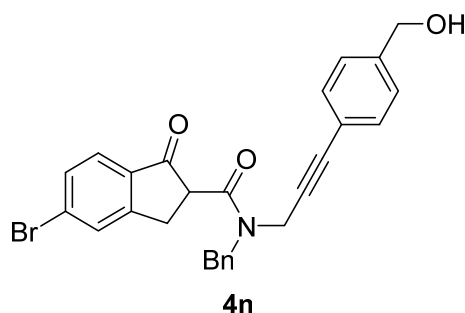
**Compound 4m (Fig. 3)**



***N*-(3-([1,1'-biphenyl]-4-yl)prop-2-yn-1-yl)-*N*-benzyl-5-bromo-1-oxo-2,3-dihydro-1*H*-indene-2-carboxamide (4m)**; TLC:  $R_f = 0.30$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 148-149°C.); yield: 63%; Enol isomerization were observed

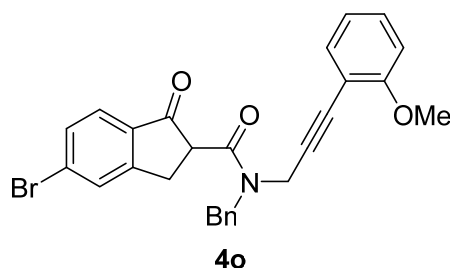
by NMR;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.70 (d,  $J = 20.4$  Hz, 1H), 7.65-7.50 (m, 6H), 7.50-7.26 (m, 10H), 5.37-5.24 (m, 1H), 5.14-4.96 (m, 1H), 4.57 (s, 1H), 4.50-4.37 (m, 1H), 4.24-4.03 (m, 1H), 3.94-3.76 (m, 1H), 3.38-3.13 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.6 (200.2), 167.9 (168.4), 156.4 (156.2), 141.5 (141.1), 140.2 (140.4), 136.57 (136.59), 134.16 (134.24), 132.3, 131.39 (131.38), 131.1 (130.9), 130.0 (129.9), 129.0 (129.1), 128.8 (128.9), 128.0 (127.9), 127.6 (127.7), 127.14 (127.09), 127.1, 127.0 (126.9), 125.7 (125.7), 121.1 (121.6), 84.6 (84.5), 84.3, 51.2 (49.6), 51.1 (50.9), 38.1 (36.5), 30.6 (30.8); **HRMS (ESI, m/z)**: calcd. For  $\text{C}_{32}\text{H}_{25}\text{BrNO}_2^+$   $[\text{M}+\text{H}]^+$ : 534.1064, found: 534.1065.

**Compound 4n (Fig. 3)**



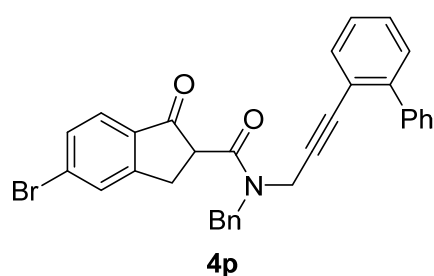
***N*-benzyl-5-bromo-*N*-(3-(4-(hydroxymethyl)phenyl)prop-2-yn-1-yl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxamide (4n)**; TLC:  $R_f = 0.30$  (petroleum ether /ethyl acetate = 2/1, v/v, UV); white solid (mp: 125-126°C.); yield: 35%; Enol isomerization were observed by NMR;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.68 (d,  $J = 18.7$  Hz, 1H), 7.59 (t,  $J = 9.1$  Hz, 1H), 7.51 (t,  $J = 9.2$  Hz, 1H), 7.43-7.22 (m, 9H), 5.34-5.20 (m, 1H), 5.09-4.92 (m, 1H), 4.75-4.49 (m, 3H), 4.44-4.34 (m, 1H), 4.15 (d,  $J = 19.0$  Hz, 0.5H), 4.05 (dd,  $J = 7.9, 3.7$  Hz, 0.5H), 3.90-3.72 (m, 1H), 3.36-3.11 (m, 1H), 2.06 (s, 1H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.7 (200.3), 168.0 (168.5), 156.4 (156.2), 141.8 (141.4), 136.51 (136.49), 134.2 (134.1), 131.96 (131.95), 131.42 (131.41), 131.1 (131.0), 130.0 (129.9), 128.8 (129.1), 128.0, 127.6 (127.9), 126.9 (126.7), 125.73 (125.71), 121.3 (121.8), 84.6 (84.3), 83.8 (83.9), 64.8 (64.9), 51.2 (51.1), 49. (51.0), 38.1 (36.5), 30.5 (30.8); **HRMS (ESI, m/z)**: calcd. For  $\text{C}_{27}\text{H}_{23}\text{BrNO}_3^+$   $[\text{M}+\text{H}]^+$ : 488.0856, found: 488.0859.

**Compound 4o (Fig. 3)**



***N*-benzyl-5-bromo-*N*-(3-(2-methoxyphenyl)prop-2-yn-1-yl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxamide (4o)**; TLC:  $R_f$  = 0.50 (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 46-47°C.); yield: 89%; Enol isomerization were observed by NMR;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.68 (d,  $J$  = 20.9 Hz, 1H), 7.63-7.54 (m, 1H), 7.55-7.45 (m, 1H), 7.45-7.20 (m, 7H), 6.95-6.82 (m, 2H), 5.33-5.26 (m, 1H), 5.13-5.01 (m, 1H), 4.59 (d,  $J$  = 5.8 Hz, 1H), 4.50-4.37 (m, 1H), 4.23-4.02 (m, 1H), 3.95-3.69 (m, 4H), 3.36-3.10 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.7 (200.2), 168.1 (168.4), 160.3, 156.4 (156.2), 136.6 (136.7), 134.2 (134.3), 133.7 (133.8), 131.4, 131.0 (130.9), 130.2, 129.9 (129.9), 128.8 (129.0), 128.0 (127.1), 127.5 (127.8), 125.7 (125.7), 120.6 (120.4), 111.5 (111.9), 110.72 (110.67), 87.92 (87.88), 81.3 (81.2), 55.80 (55.78), 51.3 (49.5), 51.1 (50.6), 38.4 (36.5), 30.6 (30.8); HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{27}\text{H}_{23}\text{BrNO}_3^+$   $[\text{M}+\text{H}]^+$ : 488.0856, found: 488.0853.

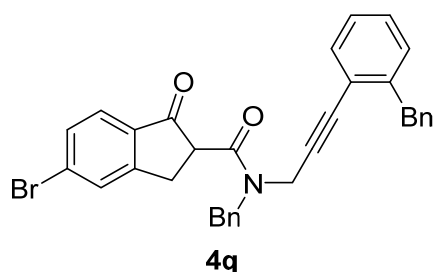
**Compound 4p (Fig. 3)**



***N*-(3-([1,1'-biphenyl]-2-yl)prop-2-yn-1-yl)-*N*-benzyl-5-bromo-1-oxo-2,3-dihydro-1*H*-indene-2-carboxamide (4p)**; TLC:  $R_f$  = 0.60 (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 42-43°C.); yield: 60%; Enol isomerization were observed by NMR;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.68 (dd,  $J$  = 5.0, 1.5 Hz, 1H), 7.61-7.46 (m, 5H), 7.46-7.16 (m, 11H), 5.14 (d,  $J$  = 15.2 Hz, 0.7H), 5.05 (d,  $J$  = 17.1 Hz, 0.3H), 4.97 (dd,  $J$  = 19.1, 1.2 Hz, 0.7H), 4.69 (d,  $J$  = 17.1 Hz, 0.3H), 4.46 (d,  $J$  = 17.5 Hz, 0.3H),

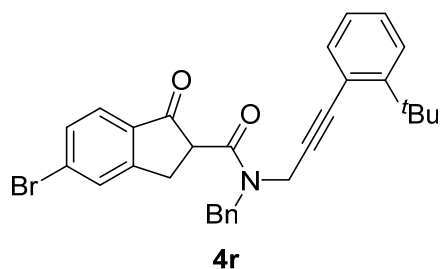
4.33 (d,  $J = 17.5$  Hz, 0.3H), 4.16 (d,  $J = 15.2$  Hz, 0.7H), 4.09-3.93 (m, 1.7H), 3.76-3.69 (m, 1H), 3.17-2.93 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.7 (200.1), 167.8 (168.3), 156.5 (156.2), 144.5 (144.2), 140.6(140.7), 136.6 (136.5), 134.2 (134.3), 133.1 (133.4), 131.3 (131.4), 131.0 (130.9), 129.93 (129.91), 129.7 (129.6), 129.3 (129.4), 129.1 (129.0), 128.7 (128.8), 128.1 (128.2), 128.0 (127.8), 127.7 (127.), 127.5 (127.3), 127.1 (126.9), 125.68 (125.72), 120.7 (121.1), 86.83 (86.76), 84.4 (84.1), 51.2 (51.0), 49.5 (50.5), 38.0 (36.1), 30.4 (30.8); HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{32}\text{H}_{25}\text{BrNO}_2^+$   $[\text{M}+\text{H}]^+$ : 534.1064, found: 534.1065.

**Compound 4q (Fig. 3)**



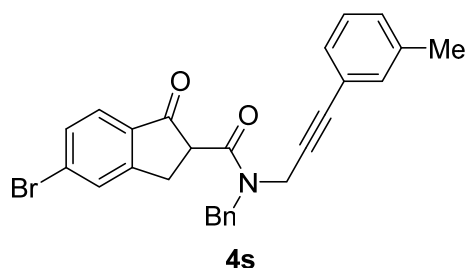
*N*-benzyl-*N*-(3-(2-benzylphenyl)prop-2-yn-1-yl)-5-bromo-1-oxo-2,3-dihydro-1*H*-indene-2-carboxamide (**4q**); TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 10/1, v/v, UV); white solid (mp: 79-80°C.); yield: 54%; Enol isomerization were observed by NMR;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.67 (d,  $J = 6.7$  Hz, 1H), 7.63-7.47 (m, 2H), 7.44-7.08 (m, 14H), 5.20-5.05 (m, 1.5H), 4.85 (d,  $J = 17.2$  Hz, 0.5H), 4.53 (q,  $J = 17.4$  Hz, 1H), 4.30 (d,  $J = 15.1$  Hz, 0.6H), 4.21 (dd,  $J = 7.8, 3.6$  Hz, 0.6H), 4.17-4.07 (m, 2.4H), 4.03 (dd,  $J = 7.9, 3.6$  Hz, 0.4H), 3.83-3.70 (m, 1H), 3.13 (dt,  $J = 17.1, 8.2$  Hz, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  168.4 (167.8), 156.2 (156.5), 143.2 (143.0), 140.4 (140.6), 136.6 (136.5), 134.2 (134.3), 132.7 (132.6), 131.4, 131.1 (130.9), 129.9 (130.0), 129.5, 129.1, 128.8, 128.7, 128.54 (128.50), 128.0, 127.9 (127.6), 126.9, 126.5 (126.2), 126.2 (126.1), 125.73 (125.72), 122.6 (122.2), 87.9, 83.6 (83.3), 51.2 (51.1), 49.6 (50.8), 40.4 (40.2), 38.1 (36.4), 30.5 (30.8); HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{33}\text{H}_{27}\text{BrNO}_2^+$   $[\text{M}+\text{H}]^+$ : 548.1220, found: 548.1222.

**Compound 4r (Fig. 3)**



***N*-benzyl-5-bromo-*N*-(3-(2-(*tert*-butyl)phenyl)prop-2-yn-1-yl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxamide (4r)**; TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); yellow oil; yield: 30%; Enol isomerization were observed by NMR;  $^1\text{H NMR}$  (400 MHz, Chloroform-*d*)  $\delta$  7.72 – 7.68 (m, 1H), 7.63- 7.58(m, 1H), 7.56-7.49 (m, 1H), 7.43 – 7.22 (m, 8H), 7.17 – 7.09 (m, 1H), 5.35 (dd,  $J = 16.2, 4.1$  Hz, 1H), 5.20 – 5.14 (m, 0.6H), 4.98 – 4.94 (m, 0.4H), 4.66 (d,  $J = 17.4$  Hz, 0.4H), 4.51 (d,  $J = 20.0$  Hz, 0.4H), 4.45 – 4.41 (m, 0.7H), 4.33 (d,  $J = 15.2$  Hz, 0.6H), 4.18 (d,  $J = 19.1$  Hz, 0.6H), 4.07 (dd,  $J = 7.9, 3.6$  Hz, 0.3H), 3.90 (dd,  $J = 17.3, 3.6$  Hz, 0.6H), 3.78 (dd,  $J = 17.3, 3.6$  Hz, 0.4H), 3.30 (dd,  $J = 17.3, 7.8$  Hz, 0.6H), 3.17 (dd,  $J = 17.1, 7.8$  Hz, 0.4H), 1.48 (d,  $J = 7.9$  Hz, 9H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.6 (200.1), 167.9 (168.3), 156.5 (156.2), 151.66 (151.73), 136.6 (136.5), 135.55 (135.64), 134.1 (134.3), 131.5 (131.4), 131.2 (130.9), 130.0 (129.9), 129.1 (128.87), 128.89 (128.5), 128.0, 127.7 (127.9), 126.8, 125.76 (125.79), 125.6 (125.7), 120.5 (121.0), 89.5 (89.6), 86.2 (85.6), 51.2 (49.6), 51.1 (50.9), 38.3 (36.6), 35.9, 30.5 (30.8), 30.1; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{30}\text{H}_{29}\text{BrNO}_2^+ [\text{M}+\text{H}]^+$ : 514.1376, found: 514.1380.

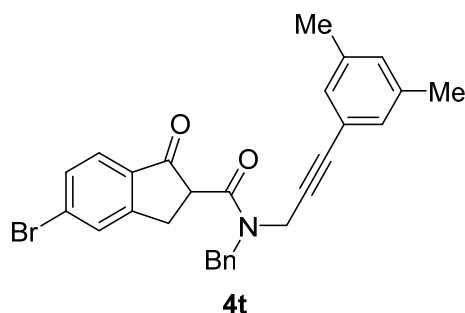
**Compound 4s (Fig. 3)**



***N*-benzyl-5-bromo-1-oxo-*N*-(3-(*m*-tolyl)prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (4s)**; TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); yellow oil; yield: 23%; Enol isomerization were observed by NMR;  $^1\text{H NMR}$  (400

**MHz, Chloroform-*d***)  $\delta$  7.69 (d,  $J = 21.0$  Hz, 1H), 7.65-7.47 (m, 2H), 7.47-7.26 (m, 5H), 7.28-7.08 (m, 4H), 5.35-5.22 (m, 1H), 5.14-4.90 (m, 1H), 4.65-4.27 (m, 2H), 4.14 (d,  $J = 19.0$  Hz, 0.6H), 4.05 (dd,  $J = 7.9, 3.7$  Hz, 0.4H), 3.93-3.74 (m, 1H), 3.37-3.12 (m, 1H), 2.32 (d,  $J = 12.0$  Hz, 3H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.6 (200.2), 167.9 (168.4), 156.5 (156.2), 138.2 (138.0), 136.6 (136.7), 134.2 (134.3), 132.4 (132.5), 131.4, 131.1 (131.0), 130.0 (129.9), 129.7 (129.4), 128.9 (129.1), 128.8 (128.4), 128.1 (128.2), 127.9 (127.6), 126.9, 125.76 (125.75), 122.6 (122.1), 85.0 (84.7), 83.5 (83.6), 51.3 (51.2), 50.9 (49.6), 38.1 (36.5), 30.6 (30.8), 21.33 (21.30); **HRMS (ESI, *m/z*)**: calcd. For  $\text{C}_{27}\text{H}_{23}\text{BrNO}_2^+$   $[\text{M}+\text{H}]^+$ : 472.0907, found: 472.0909.

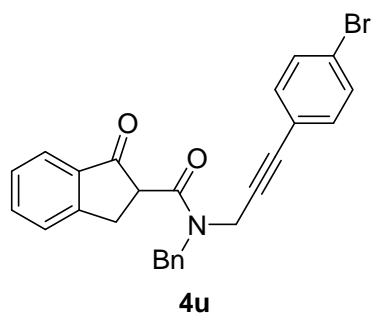
**Compound 4t (Fig. 3)**



***N*-benzyl-5-bromo-*N*-(3-(3,5-dimethylphenyl)prop-2-yn-1-yl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxamide (4t)**; TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 10/1, v/v, UV); white solid (mp: 101-102°C.); yield: 48%; Enol isomerization were observed by NMR;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.69 (d,  $J = 19.6$  Hz, 1H), 7.60 (t,  $J = 8.2$  Hz, 1H), 7.55-7.47 (m, 1H), 7.45-7.24 (m, 5H), 7.13-6.89 (m, 3H), 5.34-5.23 (m, 1H), 5.09-4.93 (m, 1H), 4.60-4.29 (m, 2H), 4.21-4.00 (m, 1H), 3.95-3.63 (m, 1H), 3.36-3.12 (m, 1H), 2.28 (d,  $J = 12.0$  Hz, 6H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.6 (200.2), 167.9 (168.4), 156.5 (156.2), 138.1 (137.9), 136.6 (136.7), 134.2 (134.3), 131.4, 131.1 (130.9), 130.7 (130.3), 130.0 (129.9), 129.5 (128.8), 128.0 (129.1), 127.8 (127.6), 126.9, 125.73 (125.71), 121.9 (122.3), 85.1 (84.9), 83.2 (83.1), 51.2 (51.1), 49.5 (50.8), 38.1 (36.4), 30.6 (30.8), 21.20 (21.17); **HRMS (ESI, *m/z*)**: calcd. For  $\text{C}_{28}\text{H}_{25}\text{BrNO}_2^+$   $[\text{M}+\text{H}]^+$ : 486.1064, found: 486.1066.

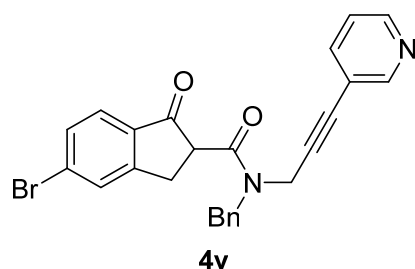
**Compound 4u (Fig. 3)**





***N*-benzyl-*N*-(3-(4-bromophenyl)prop-2-yn-1-yl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxamide (4u)**; TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 102-103°C.); yield: 58%; Enol isomerization were observed by NMR;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.75 (t,  $J = 8.3$  Hz, 1H), 7.65-7.58 (m, 1H), 7.55-7.12 (m, 11H), 5.36 (d,  $J = 17.3$  Hz, 0.5H), 5.22 (d,  $J = 15.2$  Hz, 0.5H), 5.11 (dd,  $J = 19.0, 1.3$  Hz, 0.5H), 4.92 (d,  $J = 17.2$  Hz, 0.5H), 4.52 (s, 1H), 4.43 (d,  $J = 15.2$  Hz, 0.5H), 4.36 (dd,  $J = 7.8, 3.7$  Hz, 0.5H), 4.16 (d,  $J = 19.0$  Hz, 0.5H), 4.05 (d,  $J = 3.8$  Hz, 0.5H), 3.95-3.77 (m, 1H), 3.39-3.17 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  201.8 (201.5), 168.3 (168.9), 154.9 (154.7), 136.6 (136.7), 135.6 (135.5), 135.3 (135.4), 133.28 (133.31), 131.8 (131.6), 128.8 (129.1), 128.1 (127.8), 127.7 (127.9), 126.9 (127.6), 126.7 (126.6), 124.63 (124.62), 123.1 (122.7), 121.8, (121.3), 85.3 (85.4), 83.6 (83.3), 51.2 (51.1), 49.6 (51.1), 38.1 (36.4), 30.8 (31.1); HRMS (ESI, m/z): calcd. For  $\text{C}_{26}\text{H}_{21}\text{BrNO}_2^+$   $[\text{M}+\text{H}]^+$ : 458.0751, found: 458.0752.

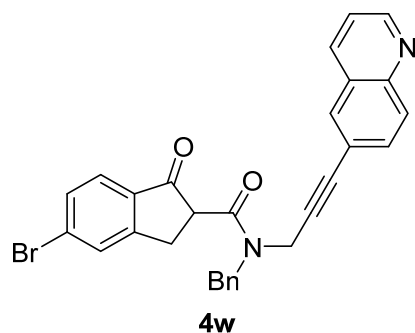
**Compound 4v (Fig. 3)**



***N*-benzyl-5-bromo-1-oxo-*N*-(3-(pyridin-3-yl)prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (4v)**; TLC:  $R_f = 0.30$  (petroleum ether /ethyl acetate = 2/1, v/v, UV); yellow solid (mp: 98-99°C.); yield: 25%; Enol isomerization were observed by NMR;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  8.55 (t,  $J = 21.0$  Hz, 2H), 7.75-7.46 (m, 4H), 7.45-7.17 (m, 6H), 5.35 (d,  $J = 17.3$  Hz, 0.5H), 5.24-5.06 (m, 1H), 4.90 (d,  $J = 17.3$  Hz,

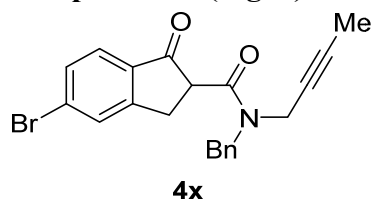
0.5H), 4.53 (s, 1H), 4.46 (d,  $J = 15.1$  Hz, 0.5H), 4.35 (dd,  $J = 7.8, 3.6$  Hz, 0.5H), 4.19 (d,  $J = 19.0$  Hz, 0.5H), 4.07 (dd,  $J = 7.9, 3.6$  Hz, 0.5H), 3.93-3.75 (m, 1H), 3.37-3.14 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.5 (200.1), 167.8 (168.4), 156.4 (156.2), 152.44 (152.41), 149.1 (148.7), 138.88 (138.85), 136.44 (136.37), 134.2 (134.1), 131.48 (131.45), 131.2 (131.1), 130.0 (129.9), 128.9 (129.1), 128.1, 128.0 (127.7), 125.8 (125.7), 126.8, 123.2 (123.1), 87.7 (87.5), 81.5 (81.0), 51.2, 51.1 (49.7), 38.0 (36.5), 30.7 (30.5); HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{25}\text{H}_{20}\text{BrN}_2\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 459.0703, found: 459.0701.

### Compound 4w (Fig. 3)



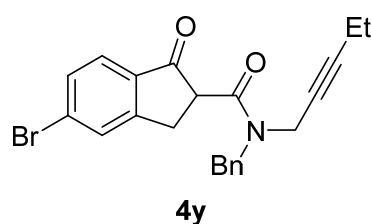
*N*-benzyl-5-bromo-1-oxo-*N*-(3-(quinolin-6-yl)prop-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (**4w**); TLC:  $R_f = 0.30$  (petroleum ether /ethyl acetate = 2/1, v/v, UV); white solid (mp: 116-117°C.); yield: 23%; Enol isomerization were observed by NMR;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  8.90 (ddd,  $J = 10.6, 4.4, 1.7$  Hz, 1H), 8.15-7.96 (m, 2H), 7.84 (d,  $J = 29.4$  Hz, 1H), 7.75-7.47 (m, 4H), 7.45-7.23 (m, 6H), 5.38 (d,  $J = 17.3$  Hz, 0.5H), 5.19 (dd,  $J = 36.9, 17.1$  Hz, 1H), 4.96 (d,  $J = 17.3$  Hz, 0.5H), 4.58 (d,  $J = 3.5$  Hz, 1H), 4.47 (d,  $J = 15.1$  Hz, 0.5H), 4.40 (dd,  $J = 7.8, 3.6$  Hz, 0.5H), 4.22 (d,  $J = 19.1$  Hz, 0.5H), 4.07 (dd,  $J = 7.9, 3.6$  Hz, 0.5H), 3.95-3.76 (m, 1H), 3.38-3.14 (m, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.6 (200.2), 167.8 (168.4), 156.4 (156.2), 151.3 (151.1), 147.9 (147.7), 136.6, 135.9, 134.2 (134.1), 132.3 (132.1), 131.6 (131.5), 131.5 (131.4), 131.2 (131.0), 130.0 (129.9), 129.8 (129.6), 128.9 (129.1), 128.1, 128.0 (127.7), 126.9, 125.8 (125.7), 122.0 (121.8), 120.6 (121.0), 85.4 (85.2), 84.4 (84.0), 51.3 (51.1), 51.1 (49.7), 38.1 (36.5), 30.6 (30.8).; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{29}\text{H}_{22}\text{BrN}_2\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 509.0860, found: 509.0862.

**Compound 4x (Fig. 3)**



***N*-benzyl-5-bromo-*N*-(but-2-yn-1-yl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxamide (4x)**; TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); yellow oil; yield: 91%; Enol isomerization were observed by NMR;  **$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )**:  $\delta$  7.68 (d,  $J = 21.9$  Hz, 1H), 7.57 (t,  $J = 7.2$  Hz, 1H), 7.50 (t,  $J = 9.3$  Hz, 1H), 7.42-7.19 (m, 5H), 5.23 (dd,  $J = 16.2, 13.0$  Hz, 1H), 4.95-4.65 (m, 1H), 4.39-4.22 (m, 1.5H), 4.13 (dd,  $J = 17.1, 2.5$  Hz, 0.5H), 4.01 (dd,  $J = 7.9, 3.6$  Hz, 0.5H), 3.86 (dd,  $J = 16.4, 2.7$  Hz, 1H), 3.74 (dd,  $J = 17.3, 3.6$  Hz, 0.5H), 3.34-3.09 (m, 1H), 1.80 (dt,  $J = 17.8, 2.4$  Hz, 3H);  **$^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz,  $\text{CDCl}_3$ )**:  $\delta$  200.7 (200.3), 167.8 (168.2), 156.4 (156.3), 136.71 (136.68), 134.2 (134.3), 131.4, 131.0 (130.9), 129.94 (129.87), 128.7 (129.0), 127.9 (127.5), 126.8 (127.8), 125.7, 80.8 (80.3), 73.9 (73.7), 51.14 (51.06), 49.2 (50.6), 37.5 (36.0), 30.6 (30.8), 3.70 (3.67); **HRMS (ESI, m/z)**: calcd. For  $\text{C}_{21}\text{H}_{19}\text{BrNO}_2^+ [\text{M}+\text{H}]^+$ : 396.0594, found: 396.0596.

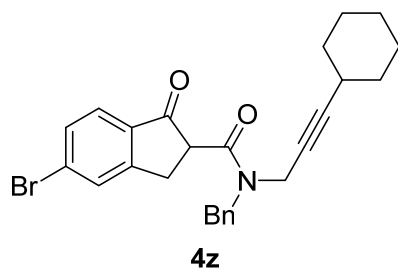
**Compound 4y (Fig. 3)**



***N*-benzyl-5-bromo-1-oxo-*N*-(pent-2-yn-1-yl)-2,3-dihydro-1*H*-indene-2-carboxamide (4y)**; TLC:  $R_f = 0.30$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 75-76°C.); yield: 50%; Enol isomerization were observed by NMR;  **$^1\text{H}$  NMR (400 MHz, Chloroform-*d*)**  $\delta$  7.68 (d,  $J = 23.3$  Hz, 1H), 7.58 (t,  $J = 7.7$  Hz, 1H), 7.50 (t,  $J = 8.4$  Hz, 1H), 7.42-7.21 (m, 5H), 5.22 (dd,  $J = 28.2, 16.2$  Hz, 1H), 4.87 (d,  $J = 17.3$  Hz, 0.4H), 4.78 (dq,  $J = 18.7, 2.0$  Hz, 0.6H), 4.36-4.17 (m, 2H), 4.00 (dd,  $J = 7.9, 3.6$  Hz, 0.5H), 3.93-3.80 (m, 1H), 3.73 (dd,  $J = 17.3, 3.6$  Hz, 0.5H), 3.34-3.08 (m, 1H), 2.27-2.09 (m, 2H), 1.10 (dt,  $J = 19.9, 7.5$  Hz, 3H);  **$^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz,**

$\text{CDCl}_3$ ):  $\delta$  200.6 (200.3), 167.9 (168.3), 156.4 (156.3), 136.76 (136.84), 134.28 (134.34), 131.37 (131.35), 131.0 (130.9), 130.0 (129.9), 128.7 (129.0), 128.0 (126.8), 127.5 (127.5), 125.71 (125.69), 86.7 (86.4), 74.1 (73.8), 51.2 (49.3), 51.2 (50.6), 37.7 (36.1), 30.6 (30.8), 13.9 (13.8), 12.47 (12.51); **HRMS (ESI, m/z)**: calcd. For  $\text{C}_{22}\text{H}_{21}\text{BrNO}_2^+$   $[\text{M}+\text{H}]^+$ : 410.0751, found: 410.0753.

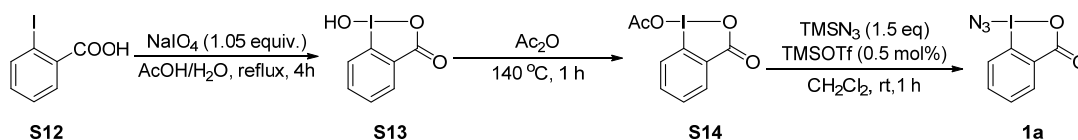
### Compound 4z (Fig. 3)



*N*-benzyl-5-bromo-*N*-(3-cyclohexylprop-2-yn-1-yl)-1-oxo-2,3-dihydro-1*H*-indene-2-carboxamide (**4z**); TLC:  $R_f = 0.60$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 78-79°C.); yield: 65%; Enol isomerization were observed by NMR;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.70 (dd,  $J = 25.0, 1.5$  Hz, 1H), 7.60 (t,  $J = 8.4$  Hz, 1H), 7.56-7.49 (m, 1H), 7.44-7.18 (m, 5H), 5.31-5.16 (m, 1H), 4.92-4.79 (m, 1H), 4.41-4.26 (m, 2H), 4.01 (dd,  $J = 7.9, 3.7$  Hz, 0.5H), 3.94-3.85 (ddd,  $J = 16.5, 14.2, 2.9$  Hz, 1H), 3.78-3.69 (m, 0.5H), 3.35-3.10 (m, 1H), 2.48-2.28 (m, 1H), 1.87-1.62 (m, 4H), 1.59-1.22 (m, 6H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.7 (200.4), 168.0 (168.3), 156.4 (156.3), 136.8 (137.0), 134.30 (134.34), 131.38 (131.36), 131.0 (130.9), 130.0 (129.9), 128.8 (129.0), 128.0 (127.5), 126.8 (127.7), 125.73 (125.70), 89.6 (89.4), 74.7 (74.3), 51.22 (51.24), 49.4 (50.5), 37.8 (36.2), 32.7 (32.6), 30.6 (30.8), 29.1 (29.1), 25.9 (26.0), 24.9; **HRMS (ESI, m/z)**: calcd. For  $\text{C}_{26}\text{H}_{27}\text{BrNO}_2^+$   $[\text{M}+\text{H}]^+$ : 464.1220, found: 464.1223.

## 1.4. General Procedure for the Synthesis of 1a-1g

### 1.4.1 General Procedure for the Synthesis of 1a<sup>6</sup>

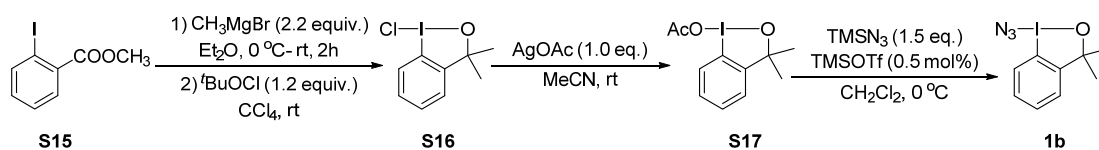


1) **Caution: reaction carried out behind a safety shield!** NaIO<sub>4</sub> (7.24 g, 33.8 mmol, 1.00 equiv) and 2-iodo benzoic acid (**S12**) (8.00 g, 32.2 mmol, 1.00 equiv) were suspended in 30% (v:v) aq AcOH (48 mL) under air. The mixture was vigorously stirred and refluxed for 4 h. the reaction mixture was then diluted with cold water (180 mL) and allowed to cool to room temperature, protecting it from light. The mixture is then filtered and further washed with ice water and cold acetone, air dried in the dark overnight to give the pure compound **S13** (8.14 g, 30.4 mmol, 94%) as a colorless solid.

2) Compound **S13** (3.00 g, 11.3 mmol, 1.00 equiv) was heated in Ac<sub>2</sub>O (10 mL) to reflux until the solution turned clear (without suspension). The mixture was then left to cool down and white crystals started to form. The crystallization was continued at -18 °C. The crystal were then collected and dried overnight under high vacuum to give compound **S14** (3.06 g, 10.0 mmol, 86%).

3) **Caution: reaction carried out behind a safety shield!** **S14** (1.00 g, 3.28 mmol, 1.00 equiv) was stirred in dry DCM (3 mL) then TMSN<sub>3</sub> (0.66 mL, 4.9 mmol, 1.5 equiv) was cautiously added. A catalytic amount of TMSOTf (3 μL, 0.02 mmol, 0.005 equiv) was added last to the mixture which was then stirred for 30 minutes. The reaction mixture was then died in vacuo to give a yellow precipitate, which was washed a few times with hexanes to give compound **1a** (0.70 g, 2.4 mmol, 74%) as a pure pale yellow crystal.

#### 1.4.2 General Procedure for the Synthesis of **1b**<sup>6</sup>



1) Methyl 2-iodobenzoate (**S15**) (12 mL, 76 mmol) was dissolved under N<sub>2</sub>

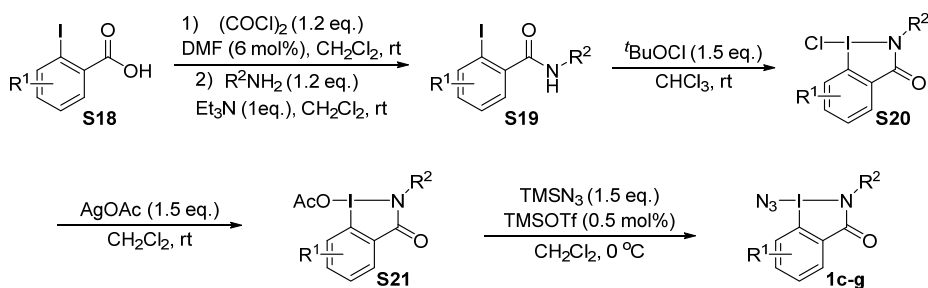
atmosphere in dry diethyl ether (400 mL) and then the solution was cooled down at 0 °C with an ice bath. Methylmagnesium bromide (56.0 mL, 168 mmol, 2.20 equiv) was added dropwise and the reaction was stirred for 30 min at 0 °C. The reaction mixture was then allowed to warm to room temperature and it was further stirred for 2 h. The reaction was quenched with NH<sub>4</sub>Cl in an iced bath. The organic layer was separated and extracted with Et<sub>2</sub>O (3 x 100 mL), water (2 x 200 mL), brine (1 x 100 mL) and the combined organic layers were dried over MgSO<sub>4</sub>. The solvent was removed in vacuum.

2) With no further purification the crude mixture was dissolved in CCl<sub>4</sub> (7 mL) and tert-butyl hypochlorite (10 mL, 92 mmol, 1.2 equiv) and the reaction mixture was stirred at room temperature. After one hour a yellow precipitate was collected by filtration and washed with hexane (60 mL) to afford compound **S16** (7.7 g, 26 mmol, 34% yield) as a yellow solid.

3) 1-Chloro-1,3-dihydro-3,3-dimethyl-1,2-benziodoxole (**S16**) (2.60 g, 8.77 mmol) was dissolved in dry acetonitrile (25 mL) under N<sub>2</sub> atmosphere. The reaction flask was covered with aluminum foils and protected from light. Silver acetate (1.46 g, 8.77 mmol, 1.00 equiv) was then added in one portion. The reaction mixture was stirred in the dark at room temperature for 16 h. Filtration over a Celite plug and evaporation of the solvent yielded compound **S17** (2.6 g, 8.8 mmol, 93%) as a light brownish solid.

4) *Caution: This reaction should be carried out behind a safety shield!* 1-Acetoxy-1,3-dihydro-3,3-dimethyl-1,2-benziodoxole (**S17**) (2.30 g, 7.18 mmol) was dissolved in dry CH<sub>2</sub>Cl<sub>2</sub> (36 mL) under N<sub>2</sub> atmosphere. The reaction was placed in an iced bath and trimethylsilylazide (0.954 mL, 7.18 mmol, 1.00 equiv) was added via syringe, followed by TMSOTf (0.0065 mL, 0.036 mmol, 0.0050 equiv). The reaction was stirred for 15 min then the ice bath was removed and the stirring was continued for 1 h. The solvent was evaporated and the solid obtained was washed with n-hexane (2 x 30 mL) to afford **1b** as a yellow crystalline solid (2.10 g, 7.18 mmol, 96%).

#### 1.4.3 General Procedure for the Synthesis of **1c-1g**<sup>7</sup>



1) Under  $\text{N}_2$ , the *o*-iodobenzoic acid **S18** (20 mmol, 1.0 equiv.) and DMF (6 mol %) were dissolved in anhydrous  $\text{CH}_2\text{Cl}_2$  (100 mL, 0.2 M), and  $(\text{COCl})_2$  (3.05g, 24 mmol, 1.2 equiv.) was dropwise added at  $0\text{ }^\circ\text{C}$ . The reaction mixture was then stirred at room temperature for 3 h. Upon completion, the solvent was removed under reduced pressure to afford *o*-iodobenzoyl chloride. To a 200 mL Shrek bottle equipped with a magnetic stir bar were sequentially added *o*-iodobenzoyl chloride, primary amine (24 mmol, 1.2 equiv.) and anhydrous  $\text{CH}_2\text{Cl}_2$  (50 mL, 0.4 M). Thereafter, the mixture was cooled to  $0\text{ }^\circ\text{C}$  followed by addition of triethylamine (2.02 g, 20 mmol, 1.0 equiv.). The mixture was then heated with stirring at room temperature for 4 h. And then the mixture was washed with brine twice. The organic phase was dried over  $\text{MgSO}_4$ , filtered and the solvent was removed under reduced pressure. The crude mixture was purified by column chromatography (eluent: petroleum ether/EtOAc = 4/1) to give *o*-iodobenzamide **S19**.

2) To a solution of *o*-iodobenzamide **S19** (15 mmol, 1.0 equiv.) in  $\text{CHCl}_3$  (40 mL, 0.375 M) was added  $t\text{BuOCl}$  (2.44 g, 22.5 mmol, 1.5 equiv.), the reaction mixture was stirred at room temperature for 30 min. Thereafter, the precipitate was filtered and crystallized from petroleum ether to give compound **S20**.

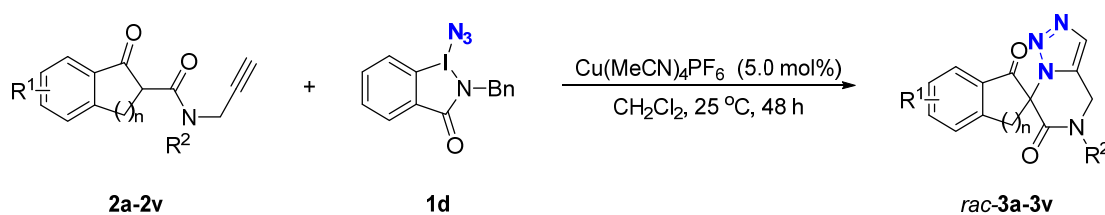
3) To a solution of **S20** (10 mmol, 1.0 equiv.) in DCM (80 mL, 0.125 M) was added  $\text{AgOAc}$  (2.0 g, 12 mmol, 1.2 equiv.) in dark, the reaction mixture was stirred at room temperature in dark overnight. Thereafter, the precipitate was filtered and crystallized from petroleum ether to give compound **S21**.

4) **Caution: This reaction should be carried out behind a safety shield!** Compound **S21** (4-9 mmol, 1.0 equiv.) was placed into an oven-dried Schlenk flask

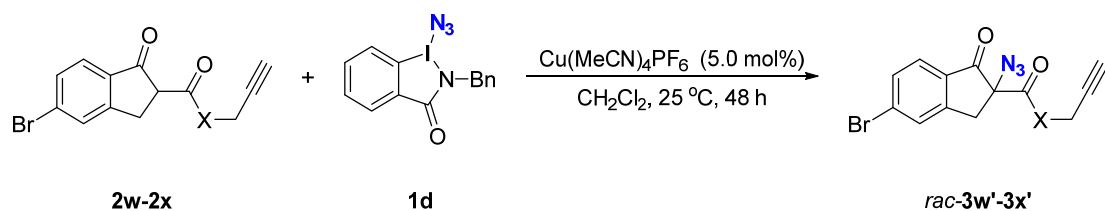
equipped with a stirring bar under an N<sub>2</sub> atmosphere, and then freshly distilled DCM (0.2 M), TMSN<sub>3</sub> (1.5 equiv.), and TMSOTf (0.5 mol%) were added in that order. The reaction was stirred at 0 °C for 20 min. The precipitate was filtered off, washed with pentane and dried under vacuum to afford the corresponding product **1c-1g**

## 1.5. General Procedure for the Synthesis of Racemic Products **3** and **5**

### 1.5.1 General Procedure for the synthesis of racemic **3a-3v** and **3w'-3x'**



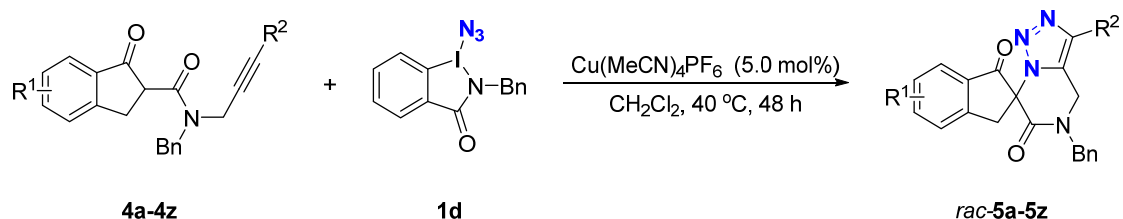
To a mixture of Cu(MeCN)<sub>4</sub>PF<sub>6</sub> (0.005 mmol, 5 mol %), substrates **2a-2v** (0.10 mmol), **1d** (0.15 mmol) and dry dichloromethane (2 mL) under nitrogen atmosphere. The reaction system was stirred at 25 °C for 48 h, the substrates **2a-2v** was disappeared (monitored by TLC) completely. Finally, the crude product was purified by silica gel flash chromatography to afford the desired product *rac-3a - rac-3v*.



To a mixture of Cu(MeCN)<sub>4</sub>PF<sub>6</sub> (0.005 mmol, 5 mol %), substrates **2w-2x** (0.10 mmol), **1d** (0.15 mmol) and dry dichloromethane (2 mL) under nitrogen atmosphere. The reaction system was stirred at 25 °C for 48 h, the substrates **2w-2x** was disappeared (monitored by TLC) completely. Finally, the crude product was purified by silica gel flash chromatography to afford the azidation product *rac-3w' - rac-3x'*.

### 1.5.2 General Procedure for the synthesis of racemic **5a-5z**

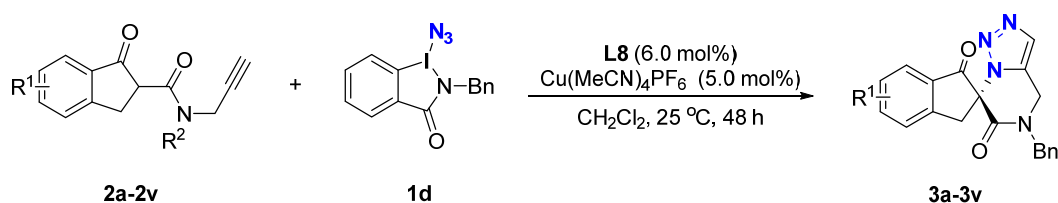




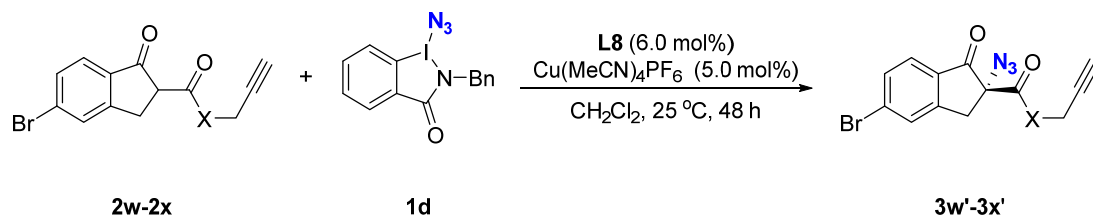
To a mixture of  $\text{Cu(MeCN)}_4\text{PF}_6$  (0.005 mmol, 5 mol %), substrates **4a-4z** (0.10 mmol), **1d** (0.15 mmol) and dry dichloromethane (2 mL) under nitrogen atmosphere. The reaction system was stirred at 40 °C for 48 h, the substrates **4a-4z** was disappeared (monitored by TLC) completely. Finally, the crude product was purified by silica gel flash chromatography to afford the desired products *rac-5a - rac-5z*.

## 1.6. General Procedure for the Synthesis of Chiral Products 3 and 5

### 1.6.1 General Procedure for the synthesis of chiral **3a-3v** and **3w'-3x'**



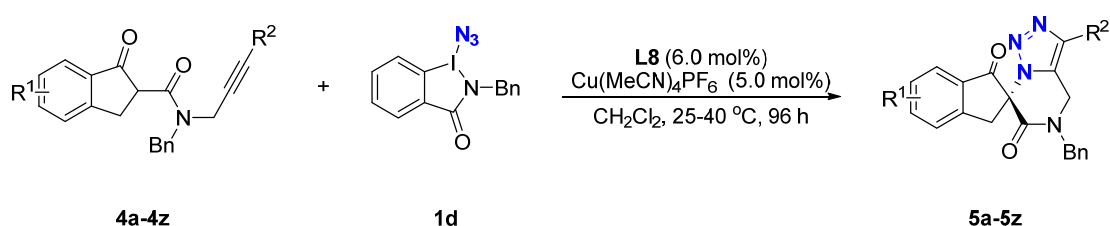
After stirring a mixture of  $\text{Cu(MeCN)}_4\text{PF}_6$  (0.005 mmol, 5 mol %) and **L8** (0.006 mmol, 6 mol %) in dry dichloromethane (1 mL) at 25 °C under nitrogen atmosphere for 1.5 h, substrates **2a-2v** (0.10 mmol) and **1d** (0.15 mmol) in dry dichloromethane (1 mL) was added and the reaction mixture was stirred at 25 °C under nitrogen atmosphere. After 48 h, the substrates **2a-2v** was disappeared (monitored by TLC) completely. Finally, the crude product was purified by silica gel flash chromatography to afford the desired products **3a-3v**.



After stirring a mixture of  $\text{Cu(MeCN)}_4\text{PF}_6$  (0.005 mmol, 5 mol %) and **L8** (0.006

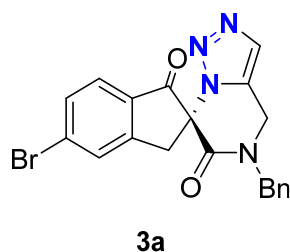
mmol, 6 mol %) in dry dichloromethane (1 mL) at 25 °C under nitrogen atmosphere for 1.5 h, substrates **2w-2x** (0.10 mmol) and **1d** (0.15 mmol) in dry dichloromethane (1 mL) was added and the reaction mixture was stirred at 25 °C under nitrogen atmosphere. After 48 h, the substrates **2w-2x** was disappeared (monitored by TLC) completely. Finally, the crude product was purified by silica gel flash chromatography to afford the azidation products **3w'-3x'**.

### 1.6.2 General Procedure for the synthesis of chiral **5a-5z**



After stirring a mixture of  $\text{Cu}(\text{MeCN})_4\text{PF}_6$  (0.005 mmol, 5 mol %) and **L8** (0.006 mmol, 6 mol %) in dry dichloromethane (1 mL) at 25 °C under nitrogen atmosphere for 1.5 h, substrates **4a-4z** (0.10 mmol) and **1d** (0.15 mmol) in dry dichloromethane (1 mL) was added and the reaction mixture was stirred at 25 °C under nitrogen atmosphere. After 48 h, when the substrates **4a-4z** was disappeared (monitored by TLC), the reaction mixture was stirred at 40 °C for more 48 h. Finally, the crude product was purified by silica gel flash chromatography to afford the desired product **5a-5z**.

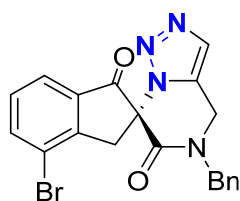
### Compound **3a** (Fig. 2)



**(R)**-5'-benzyl-5-bromo-4',5'-dihydro-6*H*-spiro[indene-2,7'-[1,2,3]triazolo[1,5-*a*]pyrazine]-1,6'(3*H*)-dione (**3a**); TLC:  $R_f$  = 0.20 (petroleum ether /ethyl acetate = 3/1, v/v, UV); white solid (mp: 70-71 °C); yield: 99% (41.9 mg, 0.099 mmol);  $[\alpha]_D^{25}$  = 103

(*c* = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.84 (s, 1H), 7.68-7.51 (m, 3H), 7.43-7.29 (m, 3H), 7.26 (d, *J* = 8.0 Hz, 1H), 4.89 (dd, *J* = 16.2, 1.0 Hz, 1H), 4.82 (d, *J* = 14.8 Hz, 1H), 4.72 (d, *J* = 14.8 Hz, 1H), 4.58 (d, *J* = 16.2 Hz, 1H), 4.35 (d, *J* = 17.2 Hz, 1H), 4.27 (d, *J* = 17.2 Hz, 1H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 195.4, 162.8, 155.4, 134.7, 132.9, 132.4, 130.6, 130.0, 129.2, 128.6, 128.5, 128.2, 127.1, 72.0, 51.3, 41.8, 36.5; HRMS (ESI, *m/z*): calcd. For C<sub>20</sub>H<sub>16</sub>BrN<sub>4</sub>O<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 423.0451, found: 423.0452; HPLC: Chiralpak AD-H Column, hexane/<sup>i</sup>PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 14.7 min (major), 20.8 min (minor), ee: 94%.

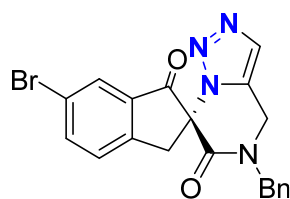
### Compound 3b (Fig. 2)



**3b**

(*R*)-5'-benzyl-4-bromo-4',5'-dihydro-6'*H*-spiro[indene-2,7'-[1,2,3]triazolo[1,5-*α*]pyrazine]-1,6'(3*H*)-dione (**3b**); TLC: *R<sub>f</sub>* = 0.20 (petroleum ether /ethyl acetate = 3/1, v/v, UV); white solid (mp: 82-83 °C); yield: 90% (38.1 mg, 0.090 mmol); [*α*]<sub>D</sub><sup>25</sup> = 67 (*c* = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.92 (dd, *J* = 7.8, 1.0 Hz, 1H), 7.75 (dd, *J* = 7.6, 1.0 Hz, 1H), 7.62 (s, 1H), 7.42-7.31 (m, 4H), 7.27 (dd, *J* = 7.9, 1.7 Hz, 2H), 4.90 (dd, *J* = 16.2, 1.0 Hz, 1H), 4.84 (d, *J* = 14.8 Hz, 1H), 4.75 (d, *J* = 14.7 Hz, 1H), 4.60 (d, *J* = 16.6 Hz, 1H), 4.26 (s, 2H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 196.0, 162.8, 153.8, 139.7, 134.7, 133.8, 130.3, 130.0, 129.3, 128.6, 128.5, 128.3, 124.9, 121.9, 71.7, 51.3, 41.9, 38.4; HRMS (ESI, *m/z*): calcd. For C<sub>20</sub>H<sub>16</sub>BrN<sub>4</sub>O<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 423.0451, found: 423.0450; HPLC: Chiralpak OD-H Column, hexane/<sup>i</sup>PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 58.2 min (major), 55.0 min (minor), ee: 90%.

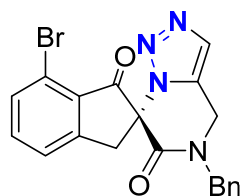
### Compound 3c (Fig. 2)



**3c**

**(R)-5'-benzyl-6-bromo-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5- $\alpha$ ]pyrazine]-1,6'(3H)-dione (3c);** TLC:  $R_f$  = 0.30 (petroleum ether /ethyl acetate = 2/1, v/v, UV); white solid (mp: 83-84 °C); yield: 95% (40.2 mg, 0.095 mmol);  $[\alpha]_D^{25}$  = 70 ( $c$  = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>):  $\delta$  7.91 (d,  $J$  = 1.9 Hz, 1H), 7.85 (dd,  $J$  = 8.2, 1.9 Hz, 1H), 7.62 (s, 1H), 7.55 (d,  $J$  = 8.2 Hz, 1H), 7.41-7.32 (m, 3H), 7.29-7.20 (m, 2H), 4.90 (dd,  $J$  = 16.2, 1.0 Hz, 1H), 4.83 (d,  $J$  = 14.8 Hz, 1H), 4.73 (d,  $J$  = 14.8 Hz, 1H), 4.58 (d,  $J$  = 16.2 Hz, 1H), 4.33 (dd,  $J$  = 17.1, 1.0 Hz, 1H), 4.24 (d,  $J$  = 17.1 Hz, 1H).; <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>):  $\delta$  195.3, 162.7, 152.7, 139.8, 134.7, 133.6, 130.0, 129.3, 128.8, 128.6, 128.5, 128.2, 128.1, 122.7, 72.3, 51.3, 41.9, 36.6; HRMS (ESI,  $m/z$ ): calcd. For C<sub>20</sub>H<sub>16</sub>BrN<sub>4</sub>O<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 423.0451, found: 423.0449; HPLC: Chiralpak AD-H Column, hexane/<sup>i</sup>PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 12.7 min (major), 21.7 min (minor), ee: 95%.

### Compound 3d (Fig. 2)

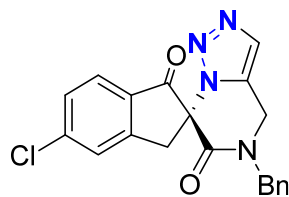


**3d**

**(R)-5'-benzyl-7-bromo-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5- $\alpha$ ]pyrazine]-1,6'(3H)-dione (3d);** TLC:  $R_f$  = 0.30 (petroleum ether /ethyl acetate = 2/1, v/v, UV); white solid (mp: 78-79 °C); yield: 90% (38.1 mg, 0.090 mmol);  $[\alpha]_D^{25}$  = 103 ( $c$  = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>):  $\delta$  7.67-7.52 (m, 4H), 7.41-7.30 (m, 3H), 7.26 (dd,  $J$  = 5.5, 2.7 Hz, 2H), 4.95 (dd,  $J$  = 16.1, 1.1 Hz, 1H), 4.85 (d,  $J$  = 14.7 Hz, 1H), 4.70 (d,  $J$  = 14.8 Hz, 1H), 4.58 (d,  $J$  = 16.2 Hz, 1H), 4.40 (d,  $J$  = 17.1 Hz, 1H),

4.28 (d,  $J = 17.1$  Hz, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  194.2, 162.7, 156.9, 137.3, 134.7, 133.6, 130.1, 129.6, 129.2, 128.9, 128.5, 128.2, 125.5, 122.0, 72.7, 51.4, 41.8, 35.5; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{20}\text{H}_{16}\text{BrN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 423.0451, found: 423.0453; HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 14.3 min (major), 21.1 min (minor), ee: 91%.

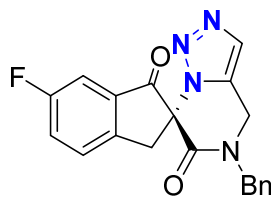
### Compound 3e (Fig. 2)



3e

**(R)-5'-benzyl-5-chloro-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (3e)**; TLC:  $R_f = 0.30$  (petroleum ether /ethyl acetate = 2/1, v/v, UV); white solid (mp: 71-72 °C); yield: 98% (37.1 mg, 0.098 mmol);  $[\alpha]_D^{25} = 75$  ( $c = 0.1$ ,  $\text{CHCl}_3$ );  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.72 (d,  $J = 8.2$  Hz, 1H), 7.64 (d,  $J = 18.6$  Hz, 2H), 7.45 (dd,  $J = 8.3, 1.8$  Hz, 1H), 7.40-7.30 (m, 3H), 7.26 (dd,  $J = 5.8, 2.2$  Hz, 2H), 4.91 (dd,  $J = 16.2, 1.0$  Hz, 1H), 4.83 (d,  $J = 14.8$  Hz, 1H), 4.74 (d,  $J = 14.8$  Hz, 1H), 4.58 (d,  $J = 16.2$  Hz, 1H), 4.37 (d,  $J = 17.2$  Hz, 1H), 4.28 (d,  $J = 17.2$  Hz, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.1, 162.8, 155.4, 143.9, 134.7, 130.2, 130.0, 129.6, 129.2, 128.6, 128.5, 128.2, 127.1, 126.9, 72.1, 51.3, 41.9, 36.6; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{20}\text{H}_{16}\text{ClN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 379.0956, found: 379.0957; HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 14.1 min (major), 21.2 min (minor), ee: 92%.

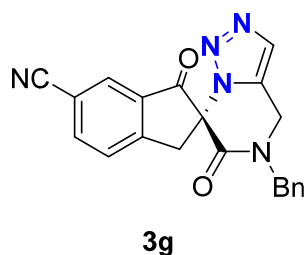
### Compound 3f (Fig. 2)



3f

**(R)-5'-benzyl-6-fluoro-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (3f)**; TLC:  $R_f$  = 0.30 (petroleum ether /ethyl acetate = 1/1, v/v, UV); white solid (mp: 68-69 °C); yield: 91% (33.0 mg, 0.091 mmol);  $[\alpha]_D^{25}$  = 88 (c = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.69-7.60 (m, 2H), 7.48 (td,  $J$  = 8.5, 2.6 Hz, 1H), 7.42 (dd,  $J$  = 7.2, 2.5 Hz, 1H), 7.40-7.32 (m, 3H), 7.26 (dd,  $J$  = 5.9, 2.2 Hz, 2H), 4.91 (dd,  $J$  = 16.2, 1.0 Hz, 1H), 4.83 (d,  $J$  = 14.8 Hz, 1H), 4.74 (d,  $J$  = 14.8 Hz, 1H), 4.59 (d,  $J$  = 16.1 Hz, 1H), 4.35 (d,  $J$  = 16.7 Hz, 1H), 4.26 (d,  $J$  = 16.8 Hz, 1H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 195.8 (d,  $J$  = 3.2 Hz), 162.84 (d,  $J$  = 250.0 Hz), 162.80, 149.8 (d,  $J$  = 2.2 Hz), 134.7, 133.5 (d,  $J$  = 8.0 Hz), 130.0, 129.3, 128.6, 128.5, 128.2, 128.1 (d,  $J$  = 8.0 Hz), 124.9 (d,  $J$  = 23.8 Hz), 111.7 (d,  $J$  = 22.5 Hz), 72.7, 51.3, 41.9, 36.5; <sup>19</sup>F NMR (376 MHz, Chloroform-*d*): δ -112.5; HRMS (ESI,  $m/z$ ): calcd. For C<sub>20</sub>H<sub>16</sub>FN<sub>4</sub>O<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 363.1252, found: 363.1250; HPLC: Chiralpak AD-H Column, hexane/*i*PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 12.0 min (major), 18.8 min (minor), ee: 90%.

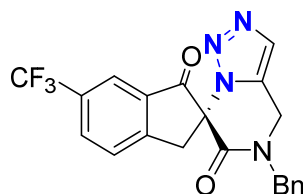
**Compound 3g (Fig. 2)**



**(R)-5'-benzyl-1,6'-dioxo-1,3,5',6'-tetrahydro-4'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-6-carbonitrile (3g)**; TLC:  $R_f$  = 0.20 (petroleum ether /ethyl acetate = 2/1, v/v, UV); white solid (mp: 92-93 °C); yield: 81% (30.0 mg, 0.081 mmol);  $[\alpha]_D^{25}$  = 127 (c = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 8.08 (d,  $J$  = 1.6 Hz, 1H), 7.99 (dd,  $J$  = 8.0, 1.6 Hz, 1H), 7.81 (dd,  $J$  = 8.1, 1.0 Hz, 1H), 7.63 (s, 1H), 7.46-7.32 (m, 3H), 7.32-7.22 (m, 2H), 4.91 (dd,  $J$  = 16.3, 0.9 Hz, 1H), 4.84 (d,  $J$  = 14.8 Hz, 1H), 4.73 (d,  $J$  = 14.8 Hz, 1H), 4.61 (d,  $J$  = 16.3 Hz, 1H), 4.45 (d,  $J$  = 17.7 Hz, 1H), 4.36 (d,  $J$  = 17.7 Hz, 1H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 194.9, 162.3, 157.8, 139.2, 134.5, 132.7, 130.1, 129.3, 128.6, 128.4, 128.2, 127.8, 126.5, 117.4, 113.1, 71.8,

51.4, 41.9, 37.3; **HRMS (ESI, m/z)**: calcd. For  $C_{21}H_{16}BrN_5O_2^+$   $[M+H]^+$ : 370.1299, found: 370.1297; **HPLC**: Chiralpak AD-H Column, hexane/ $i$ PrOH = 60/40, 1.0 mL/min, 254 nm, 30 °C; RT = 13.8 min (major), 27.2 min (minor), ee: 95%.

### Compound 3h (Fig. 2)

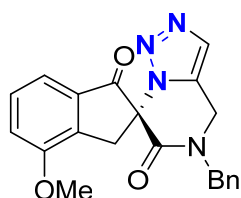


**3h**

### (*R*)-5'-benzyl-6-(trifluoromethyl)-4',5'-dihydro-6'*H*-spiro[indene-2,7'-

[1,2,3]triazolo[1,5-*a*]pyrazine]-1,6'(3*H*)-dione (**3h**); **TLC**:  $R_f$  = 0.30 (petroleum ether /ethyl acetate = 2/1, v/v, UV); white solid (mp: 60-61 °C); yield: 90% (37.2 mg, 0.090 mmol);  $[\alpha]_D^{25}$  = 80 ( $c$  = 0.1,  $CHCl_3$ );  **$^1H$  NMR (400 MHz,  $CDCl_3$ )**:  $\delta$  8.06 (s, 1H), 8.00 (dd,  $J$  = 8.1, 1.8 Hz, 1H), 7.81 (d,  $J$  = 8.1 Hz, 1H), 7.63 (s, 1H), 7.47-7.32 (m, 3H), 7.32-7.23 (m, 2H), 4.92 (dd,  $J$  = 16.3, 1.0 Hz, 1H), 4.85 (d,  $J$  = 14.8 Hz, 1H), 4.73 (d,  $J$  = 14.8 Hz, 1H), 4.61 (d,  $J$  = 16.3 Hz, 1H), 4.45 (d,  $J$  = 17.4 Hz, 1H), 4.37 (d,  $J$  = 17.4 Hz, 1H);  **$^{13}C\{^1H\}$  NMR (101 MHz,  $CDCl_3$ )**:  $\delta$  195.6, 162.6, 157.2, 134.7, 133.4 (q,  $J$  = 3.4 Hz), 132.3, 131.6 (d,  $J$  = 33.5 Hz), 130.1, 129.3, 128.7, 128.6, 128.3, 127.4, 123.5 (q,  $J$  = 272.9 Hz), 123.3 (q,  $J$  = 4.0 Hz), 72.1, 51.4, 41.9, 37.1;  **$^{19}F$  NMR (376 MHz, Chloroform-*d*)**:  $\delta$  -62.7; **HRMS (ESI, m/z)**: calcd. For  $C_{21}H_{16}F_3N_4O_2^+$   $[M+H]^+$ : 413.1220, found: 413.1218; **HPLC**: Chiralpak AD-H Column, hexane/ $i$ PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 8.6 min (major), 12.9 min (minor), ee: 93%.

### Compound 3i (Fig. 2)

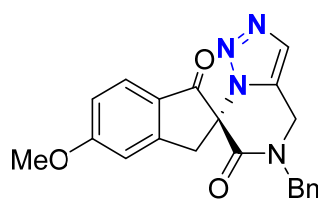


**3i**

### (*R*)-5'-benzyl-4-methoxy-4',5'-dihydro-6'*H*-spiro[indene-2,7'-[1,2,3]triazolo[1,5-

***a*[pyrazine]-1,6'(3*H*)-dione (3i)**; TLC:  $R_f = 0.20$  (petroleum ether /ethyl acetate = 2/1, v/v, UV); white solid (mp: 74-75 °C); yield: 95% (35.6 mg, 0.095 mmol);  $[\alpha]_D^{25} = 95$  ( $c = 0.1$ , CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.68 (t,  $J = 7.9$  Hz, 1H), 7.59 (s, 1H), 7.41-7.29 (m, 3H), 7.31-7.23 (m, 2H), 7.22-7.15 (m, 1H), 6.85 (d,  $J = 8.3$  Hz, 1H), 4.95 (dd,  $J = 15.9, 1.0$  Hz, 1H), 4.81 (d,  $J = 14.9$  Hz, 1H), 4.74 (d,  $J = 14.9$  Hz, 1H), 4.54 (d,  $J = 15.9$  Hz, 1H), 4.38 (d,  $J = 17.2$  Hz, 1H), 4.27 (d,  $J = 17.1$  Hz, 1H), 3.93 (s, 3H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 196.8, 163.2, 156.8, 143.3, 134.9, 133.1, 130.2, 129.9, 129.2, 128.6, 128.4, 128.3, 117.3, 117.1, 72.0, 55.8, 51.2, 41.9, 34.2; HRMS (ESI,  $m/z$ ): calcd. For C<sub>21</sub>H<sub>19</sub>N<sub>4</sub>O<sub>3</sub><sup>+</sup> [M+H]<sup>+</sup>: 375.1452, found: 375.1450; HPLC: Chiralpak OD-H Column, hexane/*i*PrOH = 50/50, 1.0 mL/min, 254 nm, 30 °C; RT = 27.7 min (major), 25.7 min (minor), ee: 95%.

**Compound 3j (Fig. 2)**

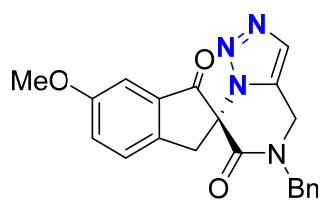


**3j**

**(*R*)-5'-benzyl-5-methoxy-4',5'-dihydro-6'*H*-spiro[indene-2,7'-[1,2,3]triazolo[1,5-*a*]pyrazine]-1,6'(3*H*)-dione (3j)**; TLC:  $R_f = 0.20$  (petroleum ether /ethyl acetate = 2/1, v/v, UV); white solid (mp: 81-82 °C); yield: 91% (34.1 mg, 0.091 mmol);  $[\alpha]_D^{25} = 85$  ( $c = 0.1$ , CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.70 (d,  $J = 8.6$  Hz, 1H), 7.60 (s, 1H), 7.42-7.21 (m, 5H), 7.07 (d,  $J = 2.2$  Hz, 1H), 6.98 (dd,  $J = 8.6, 2.2$  Hz, 1H), 4.93 (d,  $J = 15.9$  Hz, 1H), 4.83 (d,  $J = 14.8$  Hz, 1H), 4.75 (d,  $J = 14.8$  Hz, 1H), 4.56 (d,  $J = 16.0$  Hz, 1H), 4.36 (d,  $J = 17.0$  Hz, 1H), 4.26 (d,  $J = 17.1$  Hz, 1H), 3.95 (s, 3H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 194.3, 167.2, 163.5, 157.4, 134.9, 130.0, 129.2, 128.8, 128.4, 128.2, 127.9, 124.6, 117.3, 109.5, 72.6, 56.1, 51.3, 41.9, 36.5; HRMS (ESI,  $m/z$ ): calcd. For C<sub>21</sub>H<sub>19</sub>N<sub>4</sub>O<sub>3</sub><sup>+</sup> [M+H]<sup>+</sup>: 375.1452, found: 375.1452; HPLC: Chiralpak AD-H Column, hexane/*i*PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 14.7 min (major), 21.0 min (minor), ee: 85%.



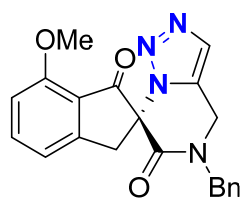
### Compound 3k (Fig. 2)



3k

**(R)-5'-benzyl-6-methoxy-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (3k)**; TLC:  $R_f$  = 0.20 (petroleum ether /ethyl acetate = 2/1, v/v, UV); white solid (mp: 73-74 °C); yield: 95% (35.6 mg, 0.095 mmol);  $[\alpha]_D^{25}$  = 69 (c = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.61 (s, 1H), 7.54 (d,  $J$  = 8.5 Hz, 1H), 7.42-7.24 (m, 6H), 7.18 (d,  $J$  = 2.5 Hz, 1H), 4.91 (dd,  $J$  = 16.1, 1.0 Hz, 1H), 4.85 (d,  $J$  = 14.8 Hz, 1H), 4.73 (d,  $J$  = 14.8 Hz, 1H), 4.58 (d,  $J$  = 16.2 Hz, 1H), 4.30 (d,  $J$  = 16.7 Hz, 1H), 4.21 (d,  $J$  = 16.7 Hz, 1H), 3.84 (s, 3H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 196.5, 163.2, 160.3, 147.4, 134.9, 132.9, 129.9, 129.2, 128.6, 128.5, 128.3, 127.3, 126.7, 106.8, 72.8, 55.9, 51.3, 41.9, 36.4; HRMS (ESI, m/z): calcd. For C<sub>21</sub>H<sub>19</sub>N<sub>4</sub>O<sub>3</sub><sup>+</sup> [M+H]<sup>+</sup>: 375.1452, found: 375.1450; HPLC: Chiralpak AD-H Column, hexane/<sup>i</sup>PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 15.5 min (major), 20.8 min (minor), ee: 89%.

### Compound 3l (Fig. 2)

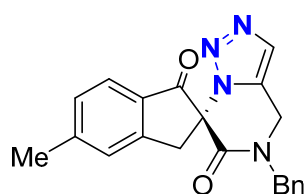


3l

**(R)-5'-benzyl-7-methoxy-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (3l)**; TLC:  $R_f$  = 0.20 (petroleum ether /ethyl acetate = 2/1, v/v, UV); white solid (mp: 85-86 °C); yield: 75% (28.1mg, 0.075 mmol);  $[\alpha]_D^{25}$  = 75 (c = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.60 (s, 1H), 7.43 (t,  $J$  = 7.8 Hz, 1H), 7.40-7.32 (m, 4H), 7.30-7.24 (m, 2H), 7.17 (dd,  $J$  = 7.9, 1.0 Hz, 1H), 4.91 (dd,  $J$  = 16.1, 1.0 Hz, 1H), 4.83 (d,  $J$  = 14.8 Hz, 1H), 4.75 (d,  $J$  = 14.8 Hz, 1H), 4.58 (dd,  $J$  = 16.1, 0.7 Hz, 1H), 4.23 (s, 2H), 3.96 (s, 3H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 193.8,

163.4, 159.8, 156.1, 139.1, 134.9, 130.0, 129.2, 129.0, 128.3, 128.2, 120.0, 118.3, 110.0, 72.7, 56.0, 51.3, 41.9, 35.7; **HRMS (ESI, m/z)**: calcd. For  $C_{21}H_{19}N_4O_3^+$   $[M+H]^+$ : 375.1452, found: 375.1451; **HPLC**: Chiralpak OD-H Column, hexane/*i*PrOH = 50/50, 1.0 mL/min, 254 nm, 30 °C; RT = 44.4 min (major), 26.6 min (minor), ee: 93%.

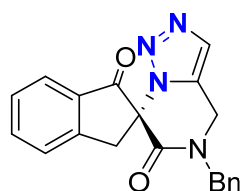
### Compound 3m (Fig. 2)



**3m**

**(R)-5'-benzyl-5-methyl-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (3m)**; **TLC**:  $R_f = 0.30$  (petroleum ether /ethyl acetate = 2/1, v/v, UV); white solid (mp: 66-67 °C); yield: 84% (30.2 mg, 0.084 mmol);  $[\alpha]_D^{25} = 70$  ( $c = 0.1$ ,  $CHCl_3$ );  **$^1H$  NMR (400 MHz,  $CDCl_3$ )**:  $\delta$  7.67 (d,  $J = 7.9$  Hz, 1H), 7.59 (s, 1H), 7.45 (s, 1H), 7.40-7.31 (m, 3H), 7.27 (dd,  $J = 6.5, 1.9$  Hz, 3H), 4.92 (dd,  $J = 16.1, 1.0$  Hz, 1H), 4.82 (d,  $J = 14.8$  Hz, 1H), 4.74 (d,  $J = 14.8$  Hz, 1H), 4.56 (d,  $J = 16.1$  Hz, 1H), 4.35 (d,  $J = 17.0$  Hz, 1H), 4.25 (d,  $J = 17.0$  Hz, 1H), 2.50 (s, 3H);  **$^{13}C\{^1H\}$  NMR (101 MHz,  $CDCl_3$ )**:  $\delta$  195.8, 163.3, 154.6, 148.9, 134.9, 130.0, 129.9, 129.4, 129.2, 128.7, 128.4, 128.2, 127.0, 126.0, 72.5, 51.2, 41.9, 36.6, 22.5; **HRMS (ESI, m/z)**: calcd. For  $C_{21}H_{19}N_4O_2^+$   $[M+H]^+$ : 359.1503, found: 359.1503; **HPLC**: Chiralpak AD-H Column, hexane/*i*PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 12.3 min (major), 16.7 min (minor), ee: 90%.

### Compound 3n (Fig. 2)

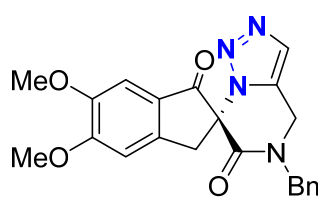


**3n**

**(R)-5'-benzyl-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-**

**1,6'(3*H*)-dione (3n)**; TLC:  $R_f = 0.20$  (petroleum ether /ethyl acetate = 2/1, v/v, UV); white solid (mp: 67-68 °C); yield: 93% (32.1 mg, 0.093 mmol);  $[\alpha]_D^{25} = 74$  (c = 0.1, CHCl<sub>3</sub>); **<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**: δ 7.80-7.75 (m, 2H), 7.66 (dt,  $J = 7.8, 1.0$  Hz, 1H), 7.61 (s, 1H), 7.48 (t,  $J = 8.0$ , 1H), 7.41-7.32 (m, 3H), 7.31-7.24 (m, 2H), 4.93 (dd,  $J = 16.2, 1.0$  Hz, 1H), 4.83 (d,  $J = 14.8$  Hz, 1H), 4.75 (d,  $J = 14.8$  Hz, 1H), 4.58 (d,  $J = 16.1$  Hz, 1H), 4.41 (d,  $J = 17.0$  Hz, 1H), 4.32 (d,  $J = 17.0$  Hz, 1H); **<sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>)**: δ 196.6, 163.2, 154.2, 137.1, 134.9, 131.8, 130.0, 129.2, 128.7, 128.7, 128.5, 128.2, 126.6, 126.2, 72.2, 51.3, 41.9, 36.8; **HRMS (ESI, m/z)**: calcd. For C<sub>20</sub>H<sub>17</sub>N<sub>4</sub>O<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 345.1346, found: 345.1346; **HPLC**: Chiralpak AD-H Column, hexane/<sup>i</sup>PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 13.0 min (major), 15.1 min (minor), ee: 93%.

**Compound 3o (Fig. 2)**

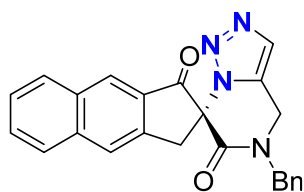


**3o**

**(*R*)-5'-benzyl-5,6-dimethoxy-4',5'-dihydro-6'*H*-spiro[indene-2,7'-**

**[1,2,3]triazolo[1,5-*a*]pyrazine]-1,6'(3*H*)-dione (3o)**; TLC:  $R_f = 0.20$  (petroleum ether /ethyl acetate = 2/1, v/v, UV); white solid (mp: 170-171 °C); yield: 80% (32.4 mg, 0.080 mmol);  $[\alpha]_D^{25} = 46$  (c = 0.1, CHCl<sub>3</sub>); **<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**: δ 7.60 (s, 1H), 7.41-7.30 (m, 3H), 7.31-7.24 (m, 2H), 7.14 (s, 1H), 7.06 (s, 1H), 4.93 (d,  $J = 16.0$  Hz, 1H), 4.86 (d,  $J = 14.8$  Hz, 1H), 4.72 (d,  $J = 14.8$  Hz, 1H), 4.56 (d,  $J = 16.1$  Hz, 1H), 4.30 (d,  $J = 16.7$  Hz, 1H), 4.21 (d,  $J = 16.8$  Hz, 1H), 4.03 (s, 3H), 3.90 (s, 3H); **<sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>)**: δ 194.7, 163.5, 157.6, 150.5, 150.4, 135.0, 129.9, 129.2, 128.7, 128.4, 128.2, 124.3, 107.5, 105.8, 72.7, 56.7, 56.3, 51.3, 41.9, 36.5; **HRMS (ESI, m/z)**: calcd. For C<sub>22</sub>H<sub>21</sub>N<sub>4</sub>O<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 405.1557, found: 405.1555; **HPLC**: Chiralpak AD-H Column, hexane/<sup>i</sup>PrOH = 60/40, 1.0 mL/min, 254 nm, 30 °C; RT = 14.1 min (major), 24.1 min (minor), ee: 81%.

### Compound 3p (Fig. 2)

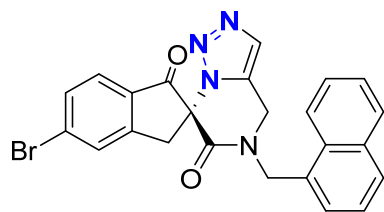


**3p**

### (*R*)-5'-benzyl-4',5'-dihydro-6'*H*-spiro[cyclopenta[*b*]naphthalene-2,7'-

[1,2,3]triazolo[1,5-*a*]pyrazine]-1,6'(3*H*)-dione (**3p**); TLC:  $R_f$  = 0.20 (petroleum ether /ethyl acetate = 2/1, v/v, UV); white solid (mp: 85-86 °C); yield: 93% (36.7mg, 0.093 mmol);  $[\alpha]_D^{25}$  = 66 ( $c$  = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 8.41 (s, 1H), 8.06 (s, 1H), 7.99 (d,  $J$  = 8.3 Hz, 1H), 7.93 (d,  $J$  = 8.8 Hz, 1H), 7.70-7.61 (m, 2H), 7.54 (td,  $J$  = 7.5, 6.8, 1.3 Hz, 1H), 7.42-7.31 (m, 3H), 7.31-7.27 (m, 2H), 4.95 (dd,  $J$  = 16.1, 1.0 Hz, 1H), 4.84 (d,  $J$  = 14.8 Hz, 1H), 4.76 (d,  $J$  = 14.8 Hz, 1H), 4.61-4.58 (m, 2H), 4.49 (dd,  $J$  = 16.9, 1.3 Hz, 1H).; <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 196.8, 163.4, 145.4, 138.4, 134.9, 132.9, 130.7, 130.1, 130.0, 129.5, 129.3, 128.8, 128.5, 128.3, 128.2, 128.1, 126.8, 124.9, 72.9, 51.3, 41.9, 36.5; HRMS (ESI,  $m/z$ ): calcd. For C<sub>24</sub>H<sub>19</sub>N<sub>4</sub>O<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 395.1503, found: 395.1501; HPLC: Chiralpak AD-H Column, hexane/*i*PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 20.6 min (major), 29.2 min (minor), ee: 91%.

### Compound 3q (Fig. 2)



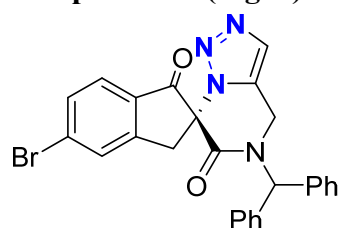
**3q**

### (*R*)-5-bromo-5'-(naphthalen-1-ylmethyl)-4',5'-dihydro-6'*H*-spiro[indene-2,7'-

[1,2,3]triazolo[1,5-*a*]pyrazine]-1,6'(3*H*)-dione (**3q**); TLC:  $R_f$  = 0.20 (petroleum ether /ethyl acetate = 3/1, v/v, UV); white solid (mp: 93-94 °C); yield: 89% (42.1 mg, 0.089 mmol);  $[\alpha]_D^{25}$  = 101 ( $c$  = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 8.01-7.93 (m, 1H), 7.94-7.85 (m, 3H), 7.70-7.60 (m, 2H), 7.58-7.40 (m, 5H), 5.34 (d,  $J$  = 14.9 Hz,

1H), 5.20 (d,  $J = 14.9$  Hz, 1H), 4.77 (d,  $J = 16.3$  Hz, 1H), 4.52 (d,  $J = 16.3$  Hz, 1H), 4.37 (d,  $J = 17.1$  Hz, 1H), 4.31 (d,  $J = 17.1$  Hz, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.2, 162.6, 155.4, 134.1, 133.0, 132.5, 131.6, 130.8, 130.1, 130.0, 130.0, 129.7, 129.1, 128.6, 127.8, 127.2, 127.1, 126.6, 125.4, 123.3, 72.1, 49.3, 41.5, 36.7; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{24}\text{H}_{18}\text{BrN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 473.0608, found: 473.0606; HPLC: Chiralpak AS-H Column, hexane/ $i$ PrOH = 60/40, 1.0 mL/min, 254 nm, 30 °C; RT = 23.7 min (major), 19.7 min (minor), ee: 94%.

### Compound 3r (Fig. 2)

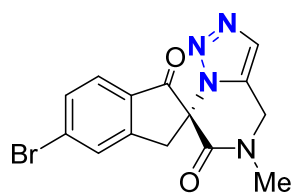


3r

### (*R*)-5'-benzhydryl-5-bromo-4',5'-dihydro-6'*H*-spiro[indene-2,7'-

[1,2,3]triazolo[1,5-*a*]pyrazine]-1,6'(3*H*)-dione (3r); TLC:  $R_f = 0.20$  (petroleum ether/ethyl acetate = 3/1, v/v, UV); white solid (mp: 156-157 °C); yield: 98% (48.9mg, 0.098 mmol);  $[\alpha]_{\text{D}}^{25} = 33$  ( $c = 0.1$ ,  $\text{CHCl}_3$ );  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.85 (s, 1H), 7.64-7.59 (m, 3H), 7.45-7.32 (m, 6H), 7.26 (d,  $J = 7.0$  Hz, 2H), 7.20-7.11 (m, 3H), 4.70 (dd,  $J = 16.3, 1.0$  Hz, 1H), 4.55-4.39 (m, 2H), 4.31 (d,  $J = 17.2$  Hz, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.5, 163.1, 155.5, 136.9, 133.0, 132.4, 130.6, 130.4, 130.0, 129.1, 128.9, 128.6, 128.4, 127.2, 72.5, 61.9, 39.4, 36.2; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{26}\text{H}_{20}\text{BrN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 499.0764, found: 499.0763; HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 14.0 min (major), 26.7 min (minor), ee: 88%.

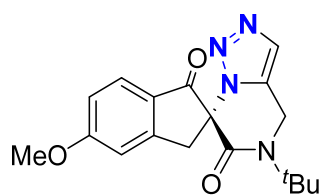
### Compound 3s (Fig. 2)



3s

**(R)-5-bromo-5'-methyl-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (3s)**; TLC:  $R_f$  = 0.20 (petroleum ether /ethyl acetate = 3/1, v/v, UV); white solid (mp: 229-230 °C); yield: 80% (27.8 mg, 0.080 mmol);  $[\alpha]_D^{25}$  = 110 (c = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.83 (t,  $J$  = 1.1 Hz, 1H), 7.69 (s, 1H), 7.60 (d,  $J$  = 0.8 Hz, 1H), 5.06 (dd,  $J$  = 16.1, 1.0 Hz, 1H), 4.69 (dd,  $J$  = 16.1, 0.7 Hz, 1H), 4.32 (dd,  $J$  = 17.1, 1.1 Hz, 1H), 4.20 (dd,  $J$  = 17.0, 1.0 Hz, 1H), 3.18 (s, 3H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 195.4, 162.6, 155.5, 132.9, 132.4, 130.7, 130.0, 129.9, 128.5, 127.1, 72.0, 44.4, 36.4, 35.7; HRMS (ESI, m/z): calcd. For C<sub>14</sub>H<sub>12</sub>BrN<sub>4</sub>O<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 347.0138, found: 347.0140; HPLC: Chiralpak AD-H Column, hexane/<sup>i</sup>PrOH = 90/10, 1.0 mL/min, 254 nm, 30 °C; RT = 42.7 min (major), 46.9 min (minor), ee: 95%.

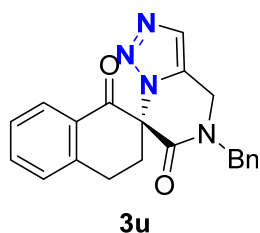
**Compound 3t (Fig. 2)**



**3t**

**(R)-5'-(tert-butyl)-5-methoxy-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (3t)**; TLC:  $R_f$  = 0.20 (petroleum ether /ethyl acetate = 3/1, v/v, UV); white solid (mp: 70-71 °C); yield: 80% (27.3 mg, 0.080 mmol);  $[\alpha]_D^{25}$  = 90 (c = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.67 (s, 1H), 7.66 (d,  $J$  = 8.6 Hz, 1H), 7.04 (d,  $J$  = 2.2 Hz, 1H), 6.95 (dd,  $J$  = 8.6, 2.2 Hz, 1H), 4.97 (dd,  $J$  = 15.7, 1.1 Hz, 1H), 4.84 (d,  $J$  = 15.7 Hz, 1H), 4.30 (d,  $J$  = 17.0 Hz, 1H), 4.16 (d,  $J$  = 17.0 Hz, 1H), 3.92 (s, 3H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 194.9, 167.1, 163.8, 157.6, 130.1, 129.7, 127.7, 124.8, 117.1, 109.4, 73.3, 59.9, 56.0, 39.1, 36.3, 27.9; HRMS (ESI, m/z): calcd. For C<sub>18</sub>H<sub>21</sub>N<sub>4</sub>O<sub>3</sub><sup>+</sup> [M+H]<sup>+</sup>: 341.1608, found: 341.1606; HPLC: Chiralpak AD-H Column, hexane/<sup>i</sup>PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 7.5 min (major), 9.9 min (minor), ee: 78%.

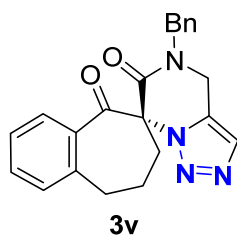
**Compound 3u (Fig. 2)**



**(R)-5'-benzyl-3,4,4',5'-tetrahydro-1H,6'H-spiro[naphthalene-2,7'-**

**[1,2,3]triazolo[1,5-a]pyrazine]-1,6'-dione (3u);** TLC:  $R_f = 0.40$  (petroleum ether /ethyl acetate = 3/1, v/v, UV); colorless oil; yield: 39% (14.0 mg, 0.039 mmol);  $[\alpha]_D^{25} = 25$  ( $c = 0.1$ ,  $\text{CHCl}_3$ );  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  8.00 (dd,  $J = 7.8, 1.4$  Hz, 1H), 7.61 – 7.57 (m, 2H), 7.38-7.30 (m, 5H), 7.27 – 7.24 (m, 2H), 4.80-4.76 (m, 3H), 4.54 (d,  $J = 16.2$  Hz, 1H), 3.79 (ddd,  $J = 16.9, 8.9, 5.5$  Hz, 1H), 3.53 (dt,  $J = 16.9, 5.8$  Hz, 1H), 3.34 (ddd,  $J = 14.3, 8.9, 5.5$  Hz, 1H), 3.15 (dt,  $J = 14.2, 5.9$  Hz, 1H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  189.7, 164.6, 145.0, 135.2, 135.0, 130.0, 129.2, 129.2, 129.1, 129.0, 128.4, 128.2, 128.1, 127.2, 69.3, 51.0, 41.8, 31.6, 26.3; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{21}\text{H}_{19}\text{N}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 359.1053, found: 359.1045; HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 10.6 min (major), 16.1 min (minor), ee: 44%.

**Compound 3v (Fig. 2)**

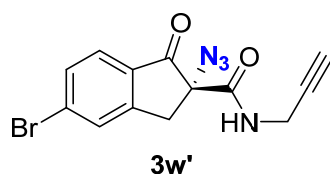


**(R)-5'-benzyl-4',5',8,9-tetrahydro-6'H-spiro[benzo[7]annulene-6,7'-**

**[1,2,3]triazolo[1,5-a]pyrazine]-5,6'(7H)-dione (3v);** TLC:  $R_f = 0.40$  (petroleum ether /ethyl acetate = 3/1, v/v, UV); colorless oil; yield: 43% (16.0 mg, 0.043 mmol);  $[\alpha]_D^{25} = 2$  ( $c = 0.1$ ,  $\text{CHCl}_3$ );  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.58 (s, 1H), 7.48 (td,  $J = 7.3, 2.0$  Hz, 1H), 7.35-7.29 (m, 5H), 7.28 – 7.20 (m, 3H), 4.77 (d,  $J = 14.7$  Hz, 1H), 4.65 (d,  $J = 15.2$  Hz, 2H), 4.50 (d,  $J = 16.1$  Hz, 1H), 3.51 (ddd,  $J = 15.6, 9.6, 6.5$  Hz, 1H), 3.14 – 2.97 (m, 2H), 2.57 (dt,  $J = 15.2, 4.8$  Hz, 1H), 2.37 – 2.12 (m, 2H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  201.2, 164.5, 139.0, 137.8, 135.0, 132.7, 129.2, 129.2, 128.9, 128.8,

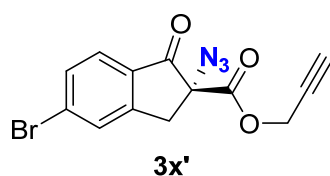
128.7, 128.4, 128.2, 127.0, 74.0, 51.1, 41.6, 32.2, 31.9, 22.3; **HRMS (ESI, m/z)**: calcd. For  $C_{22}H_{21}N_4O_2^+$   $[M+H]^+$ : 373.1659, found: 373.1665; **HPLC**: Chiralpak AD-H Column, hexane/*i*-PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 12.9 min (major), 9.4 min (minor), ee: 10%.

### Compound 3w' (Fig. 2)



**(R)-2-azido-5-bromo-1-oxo-N-(prop-2-yn-1-yl)-2,3-dihydro-1H-indene-2-carboxamide (3w')**; **TLC**:  $R_f$  = 0.70 (petroleum ether /ethyl acetate = 3/1, v/v, UV); white solid (mp: 80-81°C); yield: 55% (18.3 mg, 0.055 mmol);  $[\alpha]_D^{25}$  = 10 (c = 0.1, CHCl<sub>3</sub>); **<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**: δ 7.70 (d,  $J$  = 1.6 Hz, 1H), 7.66 (d,  $J$  = 8.2 Hz, 1H), 7.59 (dd,  $J$  = 8.3, 1.6 Hz, 1H), 6.95 (s, 1H), 4.14 (ddd,  $J$  = 17.6, 5.8, 2.6 Hz, 1H), 4.05 – 3.93 (m, 2H), 3.22 (d,  $J$  = 17.6 Hz, 1H), 2.28 (t,  $J$  = 2.6 Hz, 1H); **<sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>)**: δ 196.7, 165.8, 153.8, 132.7, 132.4, 132.2, 130.0, 126.7, 78.5, 72.7, 72.55, 37.4, 30.0; **HRMS (ESI, m/z)**: calcd. For  $C_{13}H_{10}BrN_4O_2^+$   $[M+H]^+$ : 332.9982, found: 332.9990; **HPLC**: Chiralpak AD-H Column, hexane/*i*-PrOH = 90/10, 1.0 mL/min, 254 nm, 30 °C; RT = 15.7 min (major), 18.2 min (minor), ee: 74%.

### Compound 3x' (Fig. 2)

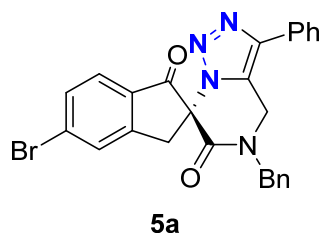


**prop-2-yn-1-yl (R)-2-azido-5-bromo-1-oxo-2,3-dihydro-1H-indene-2-carboxylate (3x')**; **TLC**:  $R_f$  = 0.70 (petroleum ether /ethyl acetate = 3/1, v/v, UV); white solid (mp: 99-100°C); yield: 76% (25.4 mg, 0.076 mmol);  $[\alpha]_D^{25}$  = 96 (c = 0.1, CHCl<sub>3</sub>); **<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**: δ 7.73 – 7.66 (m, 2H), 7.61 (dd,  $J$  = 8.2, 1.6 Hz, 1H), 4.86 (dd,  $J$  = 15.5, 2.5 Hz, 1H), 4.71 (dd,  $J$  = 15.5, 2.5 Hz, 1H), 3.68 (d,  $J$  = 17.6 Hz, 1H), 3.03 (d,



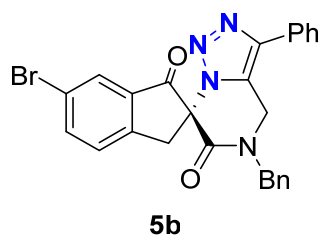
$J = 17.6$  Hz, 1H), 2.51 (t,  $J = 2.5$  Hz, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.8, 167.5, 153.5, 132.4, 132.4, 131.8, 130.0, 126.9, 76.4, 76.3, 70.1, 54.2, 38.1; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{13}\text{H}_9\text{BrN}_3\text{O}_3^+$   $[\text{M}+\text{H}]^+$ : 333.9822, found: 333.9812; HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 95/5, 1.0 mL/min, 254 nm, 30 °C; RT = 17.0 min (major), 15.7 min (minor), ee: 52%.

### Compound 5a (Fig. 3)



(*R*)-5'-benzyl-5-bromo-3'-phenyl-4',5'-dihydro-6'*H*-spiro[indene-2,7'-[1,2,3]triazolo[1,5-*a*]pyrazine]-1,6'(3*H*)-dione (**5a**); TLC:  $R_f = 0.50$  (petroleum ether/ethyl acetate = 4/1, v/v, UV); white solid (mp: 86-87 °C); yield: 75% (37.4 mg, 0.075 mmol);  $[\alpha]_{\text{D}}^{25} = 165$  ( $c = 0.1$ ,  $\text{CHCl}_3$ );  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.86 (s, 1H), 7.69-7.59 (m, 4H), 7.44 (t,  $J = 7.5$  Hz, 2H), 7.36 (tt,  $J = 7.0, 5.9$  Hz, 4H), 7.32-7.25 (m, 2H), 5.12 (d,  $J = 16.2$  Hz, 1H), 4.96 (d,  $J = 14.9$  Hz, 1H), 4.69 (t,  $J = 15.9$  Hz, 2H), 4.43 (d,  $J = 17.2$  Hz, 1H), 4.30 (d,  $J = 17.2$  Hz, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.4, 162.8, 155.5, 142.9, 134.8, 133.0, 132.4, 130.7, 130.1, 130.0, 129.3, 129.2, 128.5, 128.5, 128.0, 127.2, 126.5, 124.8, 72.2, 51.5, 43.2, 36.4; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{26}\text{H}_{20}\text{BrN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 499.0764, found: 499.0763; HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 25.8 min (major), 18.3 min (minor), ee: 93%.

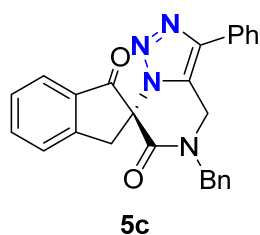
### Compound 5b (Fig. 3)



(*R*)-5'-benzyl-6-bromo-3'-phenyl-4',5'-dihydro-6'*H*-spiro[indene-2,7'-[1,2,3]triazolo[1,5-*a*]pyrazine]-1,6'(3*H*)-dione (**5b**); TLC:  $R_f = 0.50$  (petroleum ether

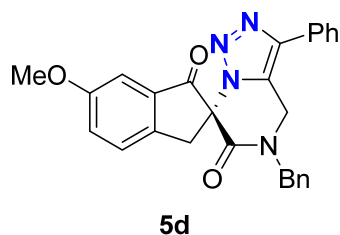
/ethyl acetate = 4/1, v/v, UV); white solid (mp: 190-191 °C); yield: 64% (31.9 mg, 0.064 mmol);  $[\alpha]_D^{25} = 78$  (c = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.93 (d, *J* = 1.9 Hz, 1H), 7.86 (dd, *J* = 8.2, 2.0 Hz, 1H), 7.64-7.62 (m, 2H), 7.56 (d, *J* = 8.2 Hz, 1H), 7.47-7.44 (m, 2H), 7.41-7.32 (m, 4H), 7.29-7.27 (m, 2H), 5.12 (d, *J* = 16.2 Hz, 1H), 4.97 (d, *J* = 14.9 Hz, 1H), 4.71 (d, *J* = 16.2 Hz, 1H), 4.67 (d, *J* = 14.9 Hz, 1H), 4.39 (d, *J* = 17.3 Hz, 1H), 4.27 (d, *J* = 17.2 Hz, 1H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 195.3, 162.8, 152.8, 142.9, 139.8, 134.7, 133.6, 130.1, 129.3, 129.2, 128.8, 128.5, 128.5, 128.1, 128.0, 126.5, 124.8, 122.7, 72.4, 51.5, 43.2, 36.5; HRMS (ESI, *m/z*): calcd. For C<sub>26</sub>H<sub>20</sub>BrN<sub>4</sub>O<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 499.0764, found: 499.0762; HPLC: Chiralpak AD-H Column, hexane/<sup>i</sup>PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 28.1 min (major), 19.2 min (minor), ee: 93%.

### Compound 5c (Fig. 3)



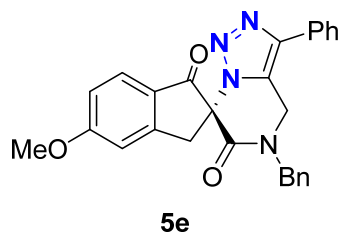
(*R*)-5'-benzyl-3'-phenyl-4',5'-dihydro-6'*H*-spiro[indene-2,7'-[1,2,3]triazolo[1,5- $\alpha$ ]pyrazine]-1,6'(3*H*)-dione (**5c**); TLC: *R<sub>f</sub>* = 0.50 (petroleum ether /ethyl acetate = 4/1, v/v, UV); white solid (mp: 89-90 °C); yield: 70% (29.5 mg, 0.070 mmol);  $[\alpha]_D^{25} = 190$  (c = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.82 (d, *J* = 7.7 Hz, 1H), 7.77 (td, *J* = 7.5, 1.2 Hz, 1H), 7.68 (d, *J* = 7.8 Hz, 1H), 7.65-7.63 (m, 2H), 7.53-7.42 (m, 3H), 7.39-7.25 (m, 4H), 7.30 (d, *J* = 6.5 Hz, 2H), 5.15 (d, *J* = 16.1 Hz, 1H), 4.97 (d, *J* = 14.9 Hz, 1H), 4.70 (dd, *J* = 15.5, 7.4 Hz, 2H), 4.48 (d, *J* = 17.0 Hz, 1H), 4.35 (d, *J* = 17.0 Hz, 1H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 196.5, 163.2, 154.3, 142.8, 137.1, 134.9, 131.8, 130.3, 129.3, 129.2, 128.7, 128.4, 128.4, 128.0, 126.7, 126.5, 126.2, 124.9, 72.4, 51.5, 43.3, 36.7; HRMS (ESI, *m/z*): calcd. For C<sub>26</sub>H<sub>21</sub>N<sub>4</sub>O<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 421.1659, found: 421.1660; HPLC: Chiralpak AD-H Column, hexane/<sup>i</sup>PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 18.6 min (major), 13.3 min (minor), ee: 94%.

### Compound 5d (Fig. 3)



**(R)-5'-benzyl-6-methoxy-3'-phenyl-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (5d)**; TLC:  $R_f$  = 0.40 (petroleum ether/ethyl acetate = 4/1, v/v, UV); white solid (mp: 219-220 °C); yield: 67% (30.2 mg, 0.067 mmol);  $[\alpha]_D^{25}$  = 120 (c = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.65-7.63 (m, 2H), 7.55 (d,  $J$  = 8.4 Hz, 1H), 7.46-7.43 (m, 2H), 7.41-7.32 (m, 5H), 7.30-7.29 (m, 2H), 7.20 (d,  $J$  = 2.6 Hz, 1H), 5.13 (d,  $J$  = 16.1 Hz, 1H), 4.98 (d,  $J$  = 14.9 Hz, 1H), 4.71 (d,  $J$  = 16.1 Hz, 1H), 4.67 (d,  $J$  = 14.9 Hz, 1H), 4.37 (d,  $J$  = 16.6 Hz, 1H), 4.24 (d,  $J$  = 16.7 Hz, 1H), 3.85 (s, 3H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 196.5, 163.2, 160.3, 147.5, 142.7, 134.9, 133.0, 130.3, 129.3, 129.1, 128.40, 128.38, 128.0, 127.3, 126.7, 126.5, 124.8, 106.8, 73.0, 55.9, 51.4, 43.3, 36.3; HRMS (ESI, m/z): calcd. For C<sub>27</sub>H<sub>23</sub>N<sub>4</sub>O<sub>3</sub><sup>+</sup> [M+H]<sup>+</sup>: 451.1765, found: 451.1763; HPLC: Chiralpak AD-H Column, hexane/PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 27.7 min (major), 18.6 min (minor), ee: 88%.

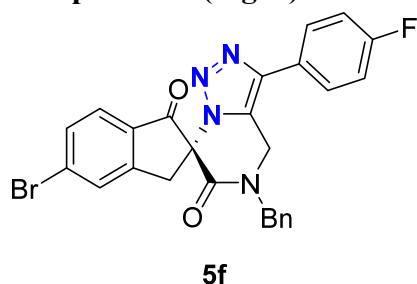
### Compound 5e (Fig. 3)



**(R)-5'-benzyl-5-methoxy-3'-phenyl-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (5e)**; TLC:  $R_f$  = 0.20 (petroleum ether/ethyl acetate = 3/1, v/v, UV); white solid (mp: 120-121 °C); yield: 62% (28.0 mg, 0.062 mmol);  $[\alpha]_D^{25}$  = 105 (c = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.72 (d,  $J$  = 8.6 Hz, 1H), 7.64-7.62 (m, 2H), 7.44-7.42 (m, 2H), 7.39-7.27 (m, 6H), 7.09 (d,  $J$  = 2.2 Hz, 1H), 6.99 (dd,  $J$  = 8.6, 2.2 Hz, 1H), 5.16 (d,  $J$  = 16.0 Hz, 1H), 4.97 (d,  $J$  = 15.0 Hz, 10H), 4.70 (d,  $J$  = 5.1 Hz, 1H), 4.66 (d,  $J$  = 4.0 Hz, 1H), 4.43 (d,  $J$  = 17.0 Hz, 1H), 4.29 (d,  $J$

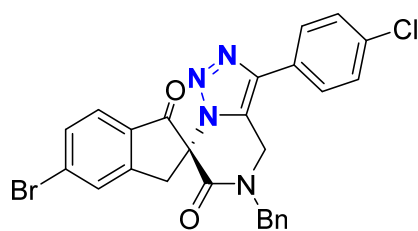
= 17.1 Hz, 1H), 3.95 (s, 3H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  194.3, 167.3, 163.3, 157.5, 142.8, 135.0, 130.3, 129.2, 129.1, 128.4, 128.3, 128.0, 127.9, 126.5, 125.0, 124.7, 117.3, 109.6, 72.8, 56.1, 51.5, 43.3, 36.4; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{27}\text{H}_{23}\text{N}_4\text{O}_3^+$   $[\text{M}+\text{H}]^+$ : 451.1765, found: 451.1768; HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 20.1 min (major), 18.8 min (minor), ee: 83%.

**Compound 5f (Fig. 3)**



**(*R*)-5'-benzyl-5-bromo-3'-(4-fluorophenyl)-4',5'-dihydro-6'*H*-spiro[indene-2,7'-[1,2,3]triazolo[1,5-*a*]pyrazine]-1,6'(3*H*)-dione (5f)**; TLC:  $R_f$  = 0.50 (petroleum ether /ethyl acetate = 4/1, v/v, UV); white solid (mp: 198-199 °C); yield: 63% (32.6 mg, 0.063 mmol);  $[\alpha]_{\text{D}}^{25}$  = 75 ( $c$  = 0.1,  $\text{CHCl}_3$ );  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.86 (d,  $J$  = 1.5 Hz, 1H), 7.70-7.52 (m, 4H), 7.44-7.31 (m, 3H), 7.29-7.27 (m, 2H), 7.16-7.12 (m, 2H), 5.10 (d,  $J$  = 16.1 Hz, 1H), 4.96 (d,  $J$  = 14.9 Hz, 1H), 4.67 (dd,  $J$  = 15.5, 3.6 Hz, 2H), 4.43 (d,  $J$  = 17.2 Hz, 1H), 4.31 (d,  $J$  = 17.2 Hz, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.4, 162.81, 162.80 (d,  $J$  = 249.7 Hz), 155.5, 142.1, 134.7, 133.1, 132.5, 130.6, 130.1, 129.3, 128.5, 128.3 (d,  $J$  = 8.3 Hz), 128.0, 127.2, 126.4 (d,  $J$  = 3.3 Hz), 124.6, 116.3 (d,  $J$  = 21.8 Hz), 72.2, 51.5, 43.1, 36.3;  $^{19}\text{F}$ NMR (376 MHz, Chloroform-*d*):  $\delta$  -112.6; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{26}\text{H}_{19}\text{BrFN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 517.0670, found: 517.0671; HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 19.7 min (major), 17.3 min (minor), ee: 94%.

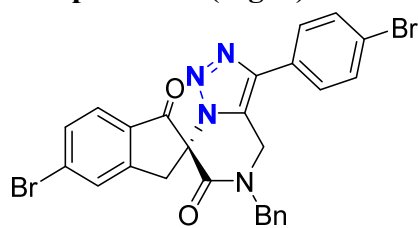
**Compound 5g (Fig. 3)**



**5g**

**(R)-5'-benzyl-5-bromo-3'-(4-chlorophenyl)-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (5g)**; TLC:  $R_f$  = 0.50 (petroleum ether /ethyl acetate = 4/1, v/v, UV); white solid (mp: 178-179 °C); yield: 74% (39.4 mg, 0.074 mmol);  $[\alpha]_D^{25}$  = 65 (c = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.86 (d,  $J$  = 1.5 Hz, 1H), 7.69-7.59 (m, 2H), 7.57-7.54 (m, 2H), 7.44-7.31 (m, 5H), 7.29-7.27 (m, 2H), 5.10 (d,  $J$  = 16.2 Hz, 1H), 4.96 (d,  $J$  = 14.9 Hz, 1H), 4.67 (d,  $J$  = 16.2 Hz, 2H), 4.41 (d,  $J$  = 17.2 Hz, 1H), 4.30 (d,  $J$  = 17.2 Hz, 1H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 195.3, 162.7, 155.5, 141.9, 134.7, 134.4, 133.1, 132.5, 130.6, 130.0, 129.4, 129.3, 128.6, 128.5, 128.0, 127.7, 127.2, 124.9, 72.2, 51.5, 43.1, 36.3; HRMS (ESI, m/z): calcd. For C<sub>26</sub>H<sub>19</sub>BrClN<sub>4</sub>O<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 533.0374, found: 533.0377; HPLC: Chiralpak AD-H Column, hexane/<sup>i</sup>PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 23.8 min (major), 19.0 min (minor), ee: 94%.

**Compound 5h (Fig. 3)**

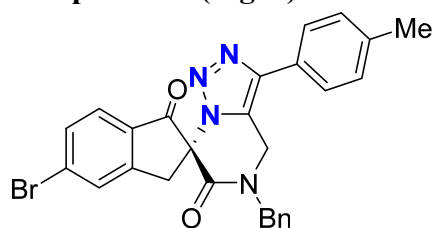


**5h**

**(R)-5'-benzyl-5-bromo-3'-(4-bromophenyl)-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (5h)**; TLC:  $R_f$  = 0.50 (petroleum ether /ethyl acetate = 4/1, v/v, UV); white solid (mp: 70-71 °C); yield: 71% (41.0mg, 0.071 mmol);  $[\alpha]_D^{25}$  = 105 (c = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.86 (d,  $J$  = 1.5 Hz, 1H), 7.69-7.59 (m, 2H), 7.57-7.55 (m, 2H), 7.50-7.47 (m, 2H), 7.43-7.31 (m, 4H), 7.29-7.27 (m, 2H), 5.09 (d,  $J$  = 16.2 Hz, 1H), 4.95 (d,  $J$  = 14.9 Hz, 1H), 4.67 (dd,  $J$  =

15.5, 4.0 Hz, 2H), 4.41 (d,  $J = 17.2$  Hz, 1H), 4.30 (d,  $J = 17.2$  Hz, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.3, 162.7, 155.5, 141.9, 134.7, 133.1, 132.5, 132.3, 130.6, 130.1, 129.3, 128.5, 128.3, 128.0, 127.9, 127.2, 125.0, 122., 72.2, 51.5, 43.1, 36.3; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{26}\text{H}_{19}\text{Br}_2\text{N}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 576.9869, found: 576.9870; HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 26.0 min (major), 20.2 min (minor), ee: 94%.

**Compound 5i (Fig. 3)**

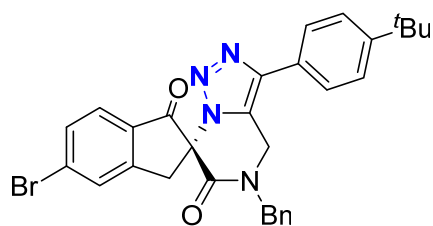


**5i**

**(R)-5'-benzyl-5-bromo-3'-(p-tolyl)-4',5'-dihydro-6'H-spiro[indene-2,7'-**

**[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (5i);** TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 4/1, v/v, UV); white solid (mp: 86-87 °C); yield: 54% (26.2 mg, 0.054 mmol);  $[\alpha]_{\text{D}}^{25} = 150$  ( $c = 0.1$ ,  $\text{CHCl}_3$ );  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.86 (d,  $J = 1.4$  Hz, 1H), 7.72-7.59 (m, 2H), 7.52-7.50 (m, 2H), 7.40-7.36 (m, 3H), 7.32-7.22 (m, 4H), 5.11 (d,  $J = 16.2$  Hz, 1H), 4.94 (d,  $J = 14.9$  Hz, 1H), 4.69 (d,  $J = 16.3$  Hz, 2H), 4.44 (d,  $J = 17.1$  Hz, 1H), 4.30 (d,  $J = 17.2$  Hz, 1H), 2.38 (s, 3H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.5, 162.9, 155.6, 143.0, 138.5, 134.8, 133.0, 132.4, 130.7, 130.1, 129.9, 129.3, 128.5, 128.0, 127.3, 127.2, 126.4, 124.4, 72.2, 51.5, 43.2, 36.4, 21.4; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{27}\text{H}_{22}\text{BrN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 513.0921, found: 513.0920; HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 26.3 min (major), 19.6 min (minor), ee: 94%.

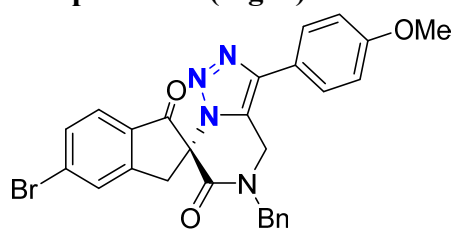
**Compound 5j (Fig. 3)**



**5j**

**(R)-5'-benzyl-5-bromo-3'-(4-(tert-butyl)phenyl)-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (5j)**; TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 4/1, v/v, UV); white solid (mp: 199-200 °C); yield: 60% (33.3 mg, 0.060 mmol);  $[\alpha]_D^{25} = 124$  (c = 0.1,  $\text{CHCl}_3$ );  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.86 (s, 1H), 7.71-7.59 (m, 2H), 7.58-7.56 (m, 2H), 7.48-7.46 (m, 2H), 7.41-7.26 (m, 5H), 5.12 (d,  $J = 16.1$  Hz, 1H), 4.95 (d,  $J = 15.0$  Hz, 1H), 4.69 (dd,  $J = 17.0, 15.5$  Hz, 2H), 4.44 (d,  $J = 17.2$  Hz, 1H), 4.31 (d,  $J = 17.2$  Hz, 1H), 1.34 (s, 9H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.4, 162.9, 155.6, 151.6, 142.9, 134.8, 132.9, 132.4, 130.7, 130.0, 129.3, 128.4, 128.0, 127.3, 127.1, 126.2, 126.1, 124.5, 72.2, 51.5, 43.3, 36.4, 34.8, 31.4; HRMS (ESI, m/z): calcd. For  $\text{C}_{30}\text{H}_{28}\text{BrN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 555.1390, found: 555.1394; HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 16.5 min (major), 15.5 min (minor), ee: 93%.

**Compound 5k (Fig. 3)**

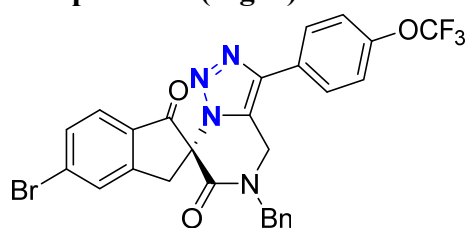


**5k**

**(R)-5'-benzyl-5-bromo-3'-(4-methoxyphenyl)-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione**; TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 4/1, v/v, UV); white solid (mp: 70-71 °C); yield: 50% (26.5 mg, 0.050 mmol);  $[\alpha]_D^{25} = 99$  (c = 0.1,  $\text{CHCl}_3$ );  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.86 (s, 1H), 7.68-7.60 (m, 2H), 7.55 (d,  $J = 8.7$  Hz, 2H), 7.44-7.28 (m, 5H), 6.97 (d,  $J = 8.8$  Hz, 2H), 5.09 (d,  $J = 16.1$  Hz, 1H), 4.95 (d,  $J = 14.9$  Hz, 1H), 4.67 (dd,  $J = 15.5, 4.0$  Hz, 2H), 4.43 (d,

$J = 17.2$  Hz, H), 4.30 (d,  $J = 17.2$  Hz, 1H), 3.84 (s, 3H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.5, 162.9, 159.8, 155.6, 142.8, 134.8, 133.0, 132.4, 130.7, 130.1, 129.3, 128.5, 128.0, 127.9, 127.2, 123.9, 122.7, 114.6, 72.2, 55.5, 51.5, 43.2, 36.4; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{27}\text{H}_{22}\text{BrN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 529.0870, found: 529.0868; HPLC: Chiralpak AS-H Column, hexane/ $i$ PrOH = 60/40, 1.0 mL/min, 254 nm, 30 °C; RT = 25.4 min (major), 20.1 min (minor), ee: 94%.

**Compound 5l (Fig. 3)**

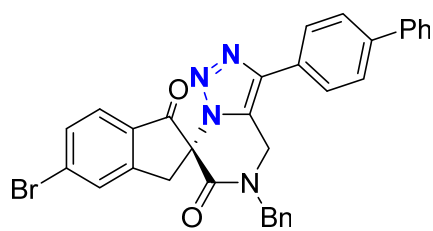


5l

**(R)-5'-benzyl-5-bromo-3'-(4-(trifluoromethoxy)phenyl)-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione**; TLC:  $R_f = 0.40$  (petroleum ether /ethyl acetate = 4/1, v/v, UV); white solid (mp: 190-191 °C); yield: 75% (43.7 mg, 0.075 mmol);  $[\alpha]_{\text{D}}^{25} = 136$  ( $c = 0.1$ ,  $\text{CHCl}_3$ );  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.87 (s, 1H), 7.68-7.62 (m, 4H), 7.43-7.27 (m, 7H), 5.11 (d,  $J = 16.2$  Hz, 1H), 4.98 (d,  $J = 14.9$  Hz, 1H), 4.68 (dd,  $J = 15.5, 4.2$  Hz, 2H), 4.44 (d,  $J = 17.2$  Hz, 1H), 4.32 (d,  $J = 17.2$  Hz, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.3, 162., 155.5, 149.2, 141.7, 134.7, 133.1, 132.5, 130.6, 130.1, 129.4, 128.9, 128.6, 128.0, 127.9, 127.2, 125.1, 121.7, 120.6 (q,  $J = 257.9$  Hz), 72.3, 51.5, 43.1, 36.3;  $^{19}\text{F}$ NMR (376 MHz, Chloroform- $d$ ):  $\delta$  -57.8; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{27}\text{H}_{19}\text{BrF}_3\text{N}_4\text{O}_3^+$   $[\text{M}+\text{H}]^+$ : 583.0587, found: 583.0588; HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 16.4 min (major), 13.2 min (minor), ee: 94%.

**Compound 5m (Fig. 3)**

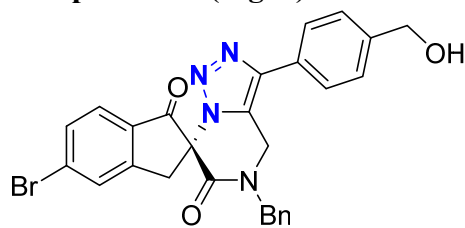




**5m**

**(R)-3'-([1,1'-biphenyl]-4-yl)-5'-benzyl-5-bromo-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (5m)**; TLC:  $R_f$  = 0.50 (petroleum ether /ethyl acetate = 4/1, v/v, UV); white solid (mp: 247-248 °C); yield: 50% (28.8 mg, 0.050 mmol);  $[\alpha]_D^{25}$  = 58 ( $c$  = 0.1,  $\text{CHCl}_3$ );  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.87 (d,  $J$  = 1.5 Hz, 1H), 7.74-7.59 (m, 8H), 7.48-7.44 (m, 2H), 7.42-7.28 (m, 6H), 5.16 (d,  $J$  = 16.2 Hz, 1H), 4.98 (d,  $J$  = 15.0 Hz, 1H), 4.72 (dd,  $J$  = 20.7, 15.5 Hz, 2H), 4.45 (d,  $J$  = 17.2 Hz, 1H), 4.32 (d,  $J$  = 17.2 Hz, 1H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.4, 162.9, 155.6, 142.6, 141.3, 140.4, 134.8, 133.0, 132.5, 130.7, 130.1, 129.3, 129.1, 129.0, 128.5, 128.0, 127.8, 127.8, 127.2, 127.2, 126.9, 124.8, 72.2, 51.5, 43.3, 36.4; **HRMS (ESI, m/z)**: calcd. For  $\text{C}_{32}\text{H}_{24}\text{BrN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 575.1077, found: 575.1078; **HPLC**: Chiralpak OD-H Column, hexane/ $i$ PrOH = 50/50, 1.0 mL/min, 254 nm, 30 °C; RT = 25.8 min (major), 42.7 min (minor), ee: 94%.

**Compound 5n (Fig. 3)**

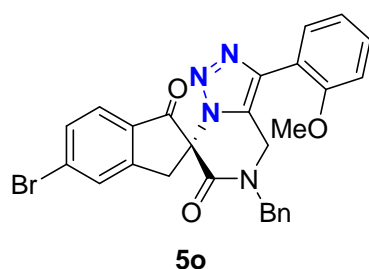


**5n**

**(R)-5'-benzyl-5-bromo-3'-(4-(hydroxymethyl)phenyl)-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (5n)**; TLC:  $R_f$  = 0.20 (petroleum ether /ethyl acetate = 1/1, v/v, UV); white solid (mp: 87-88 °C); yield: 51% (27.0 mg, 0.051 mmol);  $[\alpha]_D^{25}$  = 93 ( $c$  = 0.1,  $\text{CHCl}_3$ );  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.86 (d,  $J$  = 1.4 Hz, 1H), 7.71-7.54 (m, 4H), 7.45-7.38 (m, 5H), 7.32-7.22 (m, 2H), 5.95 (brs, 1H), 5.11 (d,  $J$  = 16.3 Hz, 1H), 4.94 (d,  $J$  = 14.9 Hz, 1H), 4.71 (s, 2H), 4.69

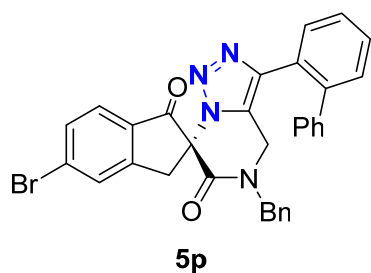
(d,  $J = 16.4$  Hz, 2H), 4.42 (d,  $J = 17.2$  Hz, 1H), 4.30 (d,  $J = 17.2$  Hz, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.4, 162.9, 155.6, 142.7, 141.3, 134.8, 133.0, 132.5, 130.7, 130.1, 129.5, 129.3, 128.5, 128.1, 127.7, 127.2, 126.7, 124.8, 72.2, 65.0, 51.5, 43.2, 36.4; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{27}\text{H}_{22}\text{BrN}_4\text{O}_3^+$   $[\text{M}+\text{H}]^+$ : 529.0870, found: 529.0873; HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 60/40, 1.0 mL/min, 254 nm, 30 °C; RT = 12.2 min (major), 23.9 min (minor), ee: 92%.

### Compound 5o (Fig. 3)



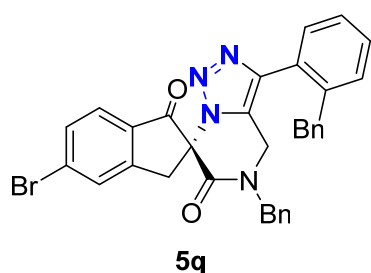
(*R*)-5'-benzyl-5-bromo-3'-(2-methoxyphenyl)-4',5'-dihydro-6'*H*-spiro[indene-2,7'-[1,2,3]triazolo[1,5-*a*]pyrazine]-1,6'(3*H*)-dione (**5o**); TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 117-118 °C); yield: 40% (21.2mg, 0.040 mmol);  $[\alpha]_D^{25} = 78$  ( $c = 0.1$ ,  $\text{CHCl}_3$ );  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.86 (d,  $J = 1.5$  Hz, 1H), 7.80 (dd,  $J = 7.6, 1.8$  Hz, 1H), 7.69-7.57 (m, 2H), 7.43-7.27 (m, 6H), 7.09-7.05 (m, 1H), 6.92 (dd,  $J = 8.4, 1.0$  Hz, 1H), 4.88 (d,  $J = 16.7$  Hz, 1H), 4.78 (s, 2H), 4.62 (d,  $J = 16.7$  Hz, 1H), 4.44 (d,  $J = 17.2$  Hz, 1H), 4.31 (d,  $J = 17.2$  Hz, 1H), 3.62 (s, 3H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.7, 162.9, 155.8, 155.6, 140.2, 135.1, 132.8, 132.3, 130.9, 130.8, 130.3, 130.0, 129.2, 128.4, 128.3, 127.1, 126.7, 121.4, 119.2, 111.1, 72.2, 55.2, 51.3, 43.6, 36.6; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{27}\text{H}_{22}\text{BrN}_4\text{O}_3^+$   $[\text{M}+\text{H}]^+$ : 529.0870, found: 529.0869; HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 60/40, 1.0 mL/min, 254 nm, 30 °C; RT = 30.3 min (major), 25.7 min (minor), ee: 92%.

### Compound 5p (Fig. 3)



**(R)-3'-([1,1'-biphenyl]-2-yl)-5'-benzyl-5-bromo-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (5p)**; TLC:  $R_f$  = 0.50 (petroleum ether /ethyl acetate = 5/1, v/v, UV); white solid (mp: 78-79 °C); yield: 60% (34.5 mg, 0.060 mmol);  $[\alpha]_D^{25}$  = 51 (c = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.84 (d,  $J$  = 1.5 Hz, 1H), 7.76 (dd,  $J$  = 6.9, 2.1 Hz, 1H), 7.67-7.57 (m, 2H), 7.52-7.38 (m, 3H), 7.35-7.31 (m, 3H), 7.25-7.12 (m, 5H), 7.02-7.00 (m, 2H), 4.85 (d,  $J$  = 14.7 Hz, 1H), 4.42 (d,  $J$  = 17.1 Hz, 1H), 4.23 (d,  $J$  = 17.2 Hz, 1H), 3.98 (d,  $J$  = 14.7 Hz, 1H), 3.46 (d,  $J$  = 16.6 Hz, 1H), 3.12 (d,  $J$  = 16.5 Hz, 1H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 195.2, 162.6, 155.5, 143.2, 140.6, 140.3, 134.6, 132.8, 132.4, 131.4, 130.7, 130.3, 130.0, 129.4, 129.2, 129.1, 129.0, 128.5, 128.2, 128.1, 128.0, 127.4, 127.1, 126.2, 72.2, 51.1, 42.0, 36.0; HRMS (ESI, m/z): calcd. For C<sub>32</sub>H<sub>24</sub>BrN<sub>4</sub>O<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 575.1077, found: 575.1080; HPLC: Chiralpak AD-H Column, hexane/<sup>i</sup>PrOH = 80/20, 1.0 mL/min, 254 nm, 30 °C; RT = 19.8 min (major), 18.1 min (minor), ee: 93%.

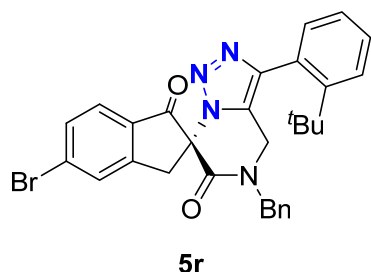
### Compound 5q (Fig. 3)



**(R)-5'-benzyl-3'-(2-benzylphenyl)-5-bromo-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (5q)**; TLC:  $R_f$  = 0.50 (petroleum ether /ethyl acetate = 4/1, v/v, UV); white solid (mp: 88-89 °C); yield: 60% (35.3 mg, 0.060 mmol);  $[\alpha]_D^{25}$  = 63 (c = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.87 (d,  $J$  = 1.4 Hz, 1H), 7.74-7.58 (m, 2H), 7.40-7.24 (m, 6H), 7.17-7.14 (m, 3H), 7.12-7.08 (m, 2H),

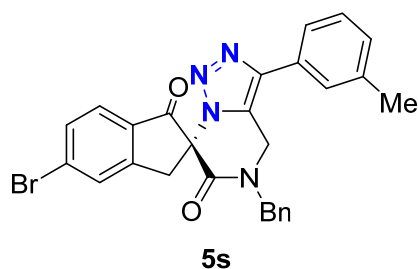
7.06-7.01 (m, 1H), 6.89-6.84 (m, 2H), 4.82 (d,  $J = 14.8$  Hz, 1H), 4.39 (d,  $J = 16.5$  Hz, 2H), 4.34 (d,  $J = 14.8$  Hz, 1H), 4.28 (d,  $J = 17.2$  Hz, 1H), 4.07 (d,  $J = 15.2$  Hz, 1H), 3.98 (d,  $J = 15.2$  Hz, 1H), 3.83 (d,  $J = 16.3$  Hz, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.4, 162.8, 155.4, 142.7, 141.6, 141.0, 134.8, 132.9, 132.4, 131.0, 130.9, 130.5, 130.0, 129.5, 129.2, 129.1, 128.8, 128.3, 128.2, 128.1, 127.1, 126.7, 126.4, 126.0, 71.9, 51.3, 42.0, 39.7, 36.8; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{33}\text{H}_{26}\text{BrN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 589.1234, found: 589.1235; HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 50/50, 1.0 mL/min, 254 nm, 30 °C; RT = 51.8 min (major), 13.3 min (minor), ee: 94%.

### Compound 5r (Fig. 3)



(*R*)-5'-benzyl-5-bromo-3'-(2-(*tert*-butyl)phenyl)-4',5'-dihydro-6'*H*-spiro[indene-2,7'-[1,2,3]triazolo[1,5-*a*]pyrazine]-1,6'(3*H*)-dione (**5r**); TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 4/1, v/v, UV); yellow oil; yield: 36% (20.0 mg, 0.036 mmol);  $[\alpha]_D^{25} = 102$  ( $c = 0.1$ ,  $\text{CHCl}_3$ );  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.88 (s, 1H), 7.68 – 7.62 (m, 2H), 7.56 (dd,  $J = 8.1, 1.2$  Hz, 1H), 7.40 – 7.29 (m, 4H), 7.21-7.17 (m, 3H), 6.98 (dd,  $J = 7.5, 1.6$  Hz, 1H), 4.78 – 4.73 (m, 3H), 4.52 (d,  $J = 17.1$  Hz, 1H), 4.34 (dd,  $J = 16.8, 14.3$  Hz, 2H), 1.19 (s, 9H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.7, 163.0, 155.6, 150.9, 145.9, 134.7, 133.01, 132.96, 132.4, 130.6, 130.1, 129.5, 129.2, 128.4, 128.2, 127.9, 127.3, 127.2, 126.5, 125.9, 72.5, 51.3, 42.2, 36.5, 35.9, 31.8; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{30}\text{H}_{28}\text{BrN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 555.1390, found: 555.1401; HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 50/50, 1.0 mL/min, 254 nm, 30 °C; RT = 59.8 min (major), 8.5 min (minor), ee: 93%.

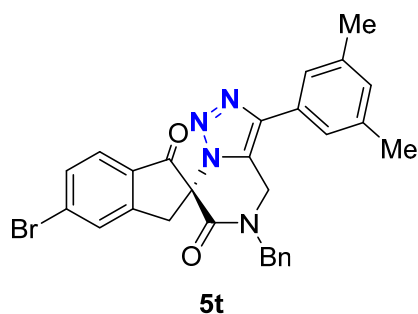
### Compound 5s (Fig. 3)



**(R)-5'-benzyl-5-bromo-3'-(m-tolyl)-4',5'-dihydro-6'H-spiro[indene-2,7'-**

**[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (5s);** TLC:  $R_f = 0.50$  (petroleum ether /ethyl acetate = 4/1, v/v, UV); white solid (mp: 85-86 °C); yield: 65% (33.3 mg, 0.065 mmol);  $[\alpha]_D^{25} = 92$  ( $c = 0.1$ ,  $\text{CHCl}_3$ );  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.86 (s, 1H), 7.67-7.61 (m, 2H), 7.53 (s, 1H), 7.40-7.26 (m, 7H), 7.18 (t,  $J = 4.6$  Hz, 1H), 5.12 (d,  $J = 16.1$  Hz, 1H), 4.94 (d,  $J = 14.9$  Hz, 1H), 4.70 (dd,  $J = 15.6, 3.5$  Hz, 2H), 4.44 (d,  $J = 17.2$  Hz, 1H), 4.30 (d,  $J = 17.2$  Hz, 1H), 2.40 (s, 3H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.4, 162.9, 155.5, 143.0, 139.0, 134.8, 133.0, 132.4, 130.7, 130.0, 129.31, 129.27, 129.0, 128.4, 128.0, 127.3, 127.2, 125.9, 124.8, 123.5, 72.2, 51.5, 43.2, 36.3, 21.6; **HRMS (ESI, m/z):** calcd. For  $\text{C}_{27}\text{H}_{22}\text{BrN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 513.0921, found: 513.0920; **HPLC:** Chiralpak AD-H Column, hexane/ $i$ PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 22.4 min (major), 17.1 min (minor), ee: 90%.

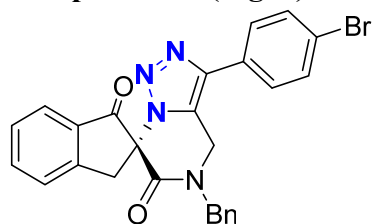
**Compound 5t (Fig. 3)**



**(R)-5'-benzyl-5-bromo-3'-(3,5-dimethylphenyl)-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (5t);** TLC:  $R_f = 0.30$  (petroleum ether /ethyl acetate = 4/1, v/v, UV); white solid (mp: 86-87 °C); yield: 50% (26.4 mg, 0.050 mmol);  $[\alpha]_D^{25} = 121$  ( $c = 0.1$ ,  $\text{CHCl}_3$ );  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.86 (s, 1H), 7.73-7.53 (m, 2H), 7.43-7.24 (m, 5H), 7.23 (s, 2H), 7.01 (s, 1H), 5.13 (d,  $J = 16.1$  Hz, 1H), 4.92 (d,  $J = 14.9$  Hz, 1H), 4.71 (dd,  $J = 15.5, 6.8$  Hz, 2H), 4.45 (d,  $J = 17.2$

Hz, 1H), 4.30 (d,  $J = 17.2$  Hz, 1H), 2.35 (s, 6H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.4, 162.9, 155.6, 143.1, 138.8, 134.82, 132.9, 132.4, 130.7, 130.2, 130.0, 130.0, 129.3, 128.4, 128.0, 127.1, 124.7, 124.4, 72.2, 51.5, 43.2, 36.3, 21.5; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{28}\text{H}_{24}\text{BrN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 527.1077, found: 527.1080; HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 50/50, 1.0 mL/min, 254 nm, 30 °C; RT = 14.5 min (major), 12.8 min (minor), ee: 94%.

### Compound 5u (Fig. 3)

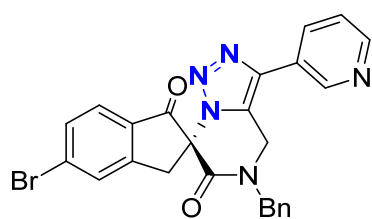


5u

### (*R*)-5'-benzyl-3'-(4-bromophenyl)-4',5'-dihydro-6'*H*-spiro[indene-2,7'-

[1,2,3]triazolo[1,5-*a*]pyrazine]-1,6'(3*H*)-dione (5u); TLC:  $R_f = 0.40$  (petroleum ether/ethyl acetate = 4/1, v/v, UV); white solid (mp: 94-95 °C); yield: 70% (34.9 mg, 0.070 mmol);  $[\alpha]_D^{25} = 151$  ( $c = 0.1$ ,  $\text{CHCl}_3$ );  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.83-7.75 (m, 2H), 7.68 (d,  $J = 7.8$  Hz, 1H), 7.57 (d,  $J = 8.5$  Hz, 2H), 7.53-7.46 (m, 3H), 7.41-7.29 (m, 5H), 5.12 (d,  $J = 16.1$  Hz, 1H), 4.96 (d,  $J = 14.9$  Hz, 1H), 4.68 (dd,  $J = 15.5, 9.3$  Hz, 2H), 4.46 (d,  $J = 17.1$  Hz, 1H), 4.34 (d,  $J = 17.1$  Hz, 1H);  $^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  196.4, 163.1, 154.2, 141.9, 137.2, 134.8, 132.3, 131.7, 129.3, 129.2, 128.7, 128.5, 128.0, 128.0, 126.7, 126.2, 125.1, 122.5, 72.4, 51.5, 43.1, 36.6; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{26}\text{H}_{20}\text{BrN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 499.0764, found: 499.0760; HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 31.9 min (major), 18.7 min (minor), ee: 92%.

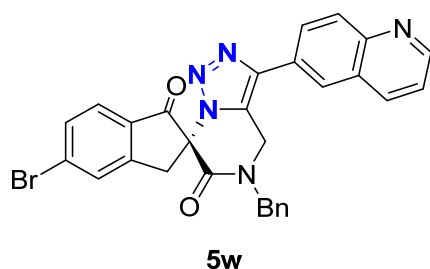
### Compound 5v (Fig. 3)



5v

**(R)-5'-benzyl-5-bromo-3'-(pyridin-3-yl)-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (5v)**; TLC:  $R_f$  = 0.20 (petroleum ether /ethyl acetate = 1/1, v/v, UV); white solid (mp: 109-110 °C); yield: 60% (30.0 mg, 0.060 mmol);  $[\alpha]_D^{25}$  = 102 (c = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 8.75 (s, 1H), 8.60 (s, 1H), 8.14 (d,  $J$  = 7.9 Hz, 1H), 7.87 (s, 1H), 7.72-7.61 (m, 2H), 7.46-7.27 (m, 6H), 5.13 (d,  $J$  = 16.3 Hz, 1H), 4.96 (d,  $J$  = 14.8 Hz, 1H), 4.72 (dd,  $J$  = 22.9, 15.5 Hz, 2H), 4.41 (d,  $J$  = 17.2 Hz, 1H), 4.31 (d,  $J$  = 17.2 Hz, 1H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 195.2, 162.6, 155.4, 149.4, 146.9, 139.8, 134.5, 134.1, 133.1, 132.5, 130.6, 130.0, 129.3, 128.6, 128.2, 127.2, 126.6, 125.6, 124.2, 72.2, 51.5, 43.0, 36.4; HRMS (ESI, m/z): calcd. For C<sub>25</sub>H<sub>19</sub>BrN<sub>5</sub>O<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 500.0717, found: 500.0720; HPLC: Chiralpak AD-H Column, hexane/<sup>i</sup>PrOH = 60/40, 1.0 mL/min, 254 nm, 30 °C; RT = 17.2min (major), 20.5 min (minor), ee: 90%.

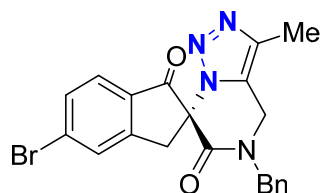
**Compound 5w (Fig. 3)**



**(R)-5'-benzyl-5-bromo-3'-(quinolin-6-yl)-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (5w)**; TLC:  $R_f$  = 0.20 (petroleum ether /ethyl acetate = 1/1, v/v, UV); white solid (mp: 119-120 °C); yield: 60% (33.0 mg, 0.060 mmol);  $[\alpha]_D^{25}$  = 106 (c = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 8.93 (d,  $J$  = 5.2 Hz, 1H), 8.20-8.16 (m, 2H), 8.09 (s, 1H), 7.96 (dd,  $J$  = 8.7, 2.0 Hz, 1H), 7.87 (s, 1H), 7.74-7.61 (m, 2H), 7.53-7.28 (m, 6H), 5.24 (d,  $J$  = 16.1 Hz, 1H), 4.99 (d,  $J$  = 15.0 Hz, 1H), 4.81 (d,  $J$  = 16.2 Hz, 1H), 4.71 (d,  $J$  = 15.0 Hz, 1H), 4.46 (d,  $J$  = 17.2 Hz, 1H), 4.33 (d,  $J$  = 17.2 Hz, 1H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 195.3, 162.7, 155.5, 151.1, 147.9, 142.2, 136.5, 134.7, 133.1, 132.5, 130.6, 130.5, 130.1, 129.3, 128.5, 128.5, 128.4, 128.0, 127.7, 127.2, 125.4, 125.4, 122.0, 72.3, 51.5, 43.3, 36.4; HRMS (ESI, m/z): calcd. For C<sub>29</sub>H<sub>21</sub>BrN<sub>5</sub>O<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 550.0873, found: 550.0870; HPLC:

Chiralpak AD-H Column, hexane/*i*PrOH = 60/40, 1.0 mL/min, 254 nm, 30 °C; RT = 14.3 min (major), 25.0 min (minor), ee: 94%.

### Compound 5x (Fig. 3)

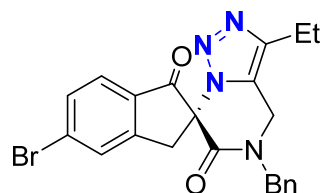


5x

### (*R*)-5'-benzyl-5-bromo-3'-methyl-4',5'-dihydro-6'*H*-spiro[indene-2,7'-

[1,2,3]triazolo[1,5-*a*]pyrazine]-1,6'(3*H*)-dione (5x); TLC:  $R_f$  = 0.30 (petroleum ether /ethyl acetate = 1/1, v/v, UV); white solid (mp: 206-207 °C); yield: 71% (31.0 mg, 0.071 mmol);  $[\alpha]_D^{25}$  = 105 (c = 0.1, CHCl<sub>3</sub>); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>): δ 7.83 (s, 1H), 7.67-7.56 (m, 2H), 7.42-7.31 (m, 3H), 7.28-7.26 (m, 2H), 4.89 (d, *J* = 14.8 Hz, 1H), 4.80 (d, *J* = 16.0 Hz, 1H), 4.68 (d, *J* = 14.8 Hz, 1H), 4.44 (d, *J* = 16.0 Hz, 1H), 4.33 (d, *J* = 17.2 Hz, 1H), 4.24 (d, *J* = 17.2 Hz, 1H), 2.28 (s, 3H); <sup>13</sup>C{<sup>1</sup>H}NMR (101 MHz, CDCl<sub>3</sub>): δ 195.6, 163.0, 155.5, 138.9, 134.8, 132.9, 132.4, 130.7, 130.0, 129.2, 128.4, 128.1, 127.1, 125.1, 71.9, 51.4, 41.9, 36.5, 10.2; HRMS (ESI, *m/z*): calcd. For C<sub>21</sub>H<sub>18</sub>BrN<sub>4</sub>O<sub>2</sub><sup>+</sup> [M+H]<sup>+</sup>: 437.0608, found: 437.0610; HPLC: Chiralpak AD-H Column, hexane/*i*PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 10.7 min (major), 14.9 min (minor), ee: 95%.

### Compound 5y (Fig. 3)



5y

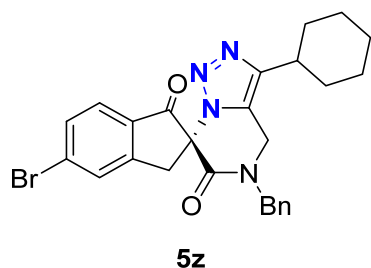
### (*R*)-5'-benzyl-5-bromo-3'-ethyl-4',5'-dihydro-6'*H*-spiro[indene-2,7'-

[1,2,3]triazolo[1,5-*a*]pyrazine]-1,6'(3*H*)-dione (5y); TLC:  $R_f$  = 0.30 (petroleum ether /ethyl acetate = 1/1, v/v, UV); white solid (mp: 204-205 °C); yield: 60% (27.1 mg, 0.060



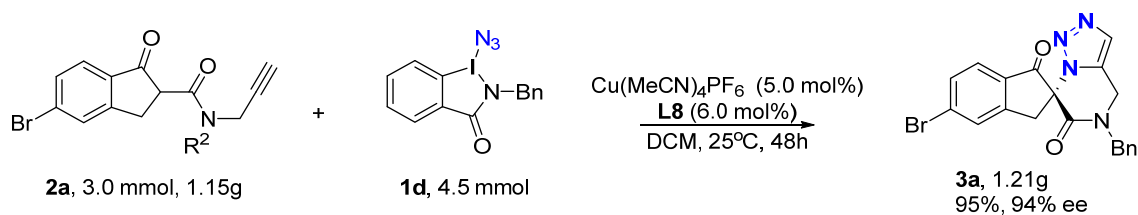
mmol);  $[\alpha]_D^{25} = 133$  ( $c = 0.1$ ,  $\text{CHCl}_3$ );  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.84 (d,  $J = 1.5$  Hz, 1H), 7.68-7.56 (m, 2H), 7.42-7.31 (m, 3H), 7.29-7.24 (m, 2H), 4.85 (dd,  $J = 22.0$ , 15.4 Hz, 2H), 4.70 (d,  $J = 14.8$  Hz, 1H), 4.46 (d,  $J = 15.9$  Hz, 1H), 4.35 (d,  $J = 17.1$  Hz, 1H), 4.25 (d,  $J = 17.2$  Hz, 1H), 2.67 (q,  $J = 7.6$  Hz, 2H), 1.25 (t,  $J = 7.6$  Hz, 3H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.6, 163.1, 155.6, 144.4, 134.9, 132.8, 132.3, 130.8, 130.0, 129.2, 128.4, 128.1, 127.1, 124.6, 72.0, 51.4, 41.9, 36.5, 18.6, 13.3; **HRMS (ESI, m/z)**: calcd. For  $\text{C}_{22}\text{H}_{20}\text{BrN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 451.0764, found: 451.0760; **HPLC**: Chiralpak AD-H Column, hexane/ $i$ PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 10.5 min (major), 14.2 min (minor), ee: 92%.

### Compound 5z (Fig. 3)



**(R)-5'-benzyl-5-bromo-3'-cyclohexyl-4',5'-dihydro-6'H-spiro[indene-2,7'-[1,2,3]triazolo[1,5-a]pyrazine]-1,6'(3H)-dione (5z)**; **TLC**:  $R_f = 0.50$  (petroleum ether/ethyl acetate = 3/1, v/v, UV); white solid (mp: 70-71 °C); yield: 50% (25.3 mg, 0.050 mmol);  $[\alpha]_D^{25} = 39$  ( $c = 0.1$ ,  $\text{CHCl}_3$ );  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.83 (s, 1H), 7.67-7.56 (m, 2H), 7.40-7.33 (m, 3H), 7.32-7.28 (m, 2H), 4.89 (dd,  $J = 18.8$ , 15.4 Hz, 2H), 4.67 (d,  $J = 14.9$  Hz, 1H), 4.51 (d,  $J = 15.9$  Hz, 1H), 4.36 (d,  $J = 17.2$  Hz, 1H), 4.24 (d,  $J = 17.2$  Hz, 1H), 2.67 (tt,  $J = 12.0$ , 3.6 Hz, 1H), 1.85 (dd,  $J = 29.0$ , 11.7 Hz, 4H), 1.71 (d,  $J = 11.5$  Hz, 1H), 1.57-1.47 (m, 2H), 1.39-1.22 (m, 3H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.7, 163.1, 155.6, 147.8, 134.9, 132.8, 132.3, 130.8, 130.0, 129.2, 128.4, 128.0, 127.1, 123.9, 72.0, 51.4, 42.4, 36.5, 35.6, 32.3, 32.3, 26.4, 26.4, 25.9; **HRMS (ESI, m/z)**: calcd. For  $\text{C}_{26}\text{H}_{26}\text{BrN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 505.1234, found: 505.1230; **HPLC**: Chiralpak AD-H Column, hexane/ $i$ PrOH = 70/30, 1.0 mL/min, 254 nm, 30 °C; RT = 15.9 min (major), 9.9 min (minor), ee: 93%.

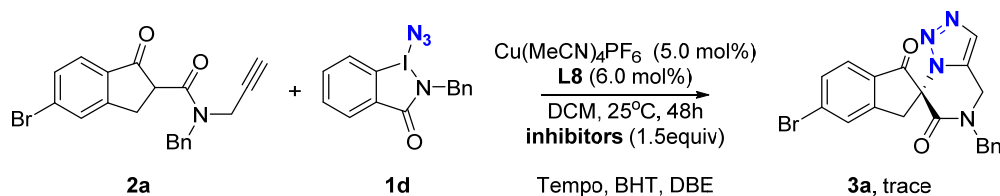
### 1.7. Procedure for synthesis of 3a in gram-scale



After stirring a mixture of  $\text{Cu}(\text{MeCN})_4\text{PF}_6$  (5 mol %) and **L8** (6 mol %) in dry dichloromethane (10 mL) at 25 °C under nitrogen atmosphere at for 2 h, substrates **2a** (3.0 mmol) and **1d** (4.5 mmol) in dry dichloromethane (30 mL) was added and the reaction mixture was stirred at 25 °C under nitrogen atmosphere. After 48 h, when the substrates **2a** was disappeared (monitored by TLC), the reaction mixture was stirred at 40 °C for another 48 h. Finally, the crude product was purified by silica gel flash chromatography to afford the desired product **3a** (1.21g, 95% yield, 94% ee).

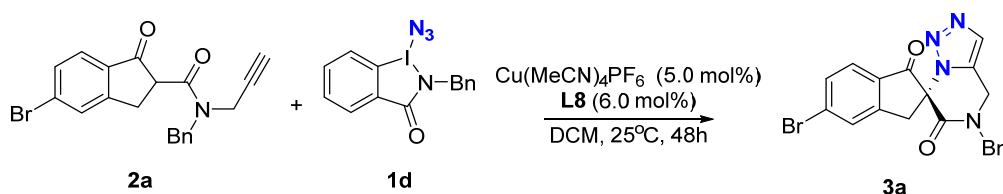
## 2. Supplementary Discussion

### 2.1. Radical inhibition experiments



The radical inhibition experiments were carried out according to the general procedure: After stirring a mixture of Cu(CH<sub>3</sub>CN)<sub>4</sub>PF<sub>6</sub> (5 mol %) and **L8** (6 mol %) in dry dichloromethane (1 mL) at 25 °C under nitrogen atmosphere for 1.5 h, substrates **2a** (0.1 mmol), **1d** (0.15 mmol) and inhibitors (1.5 equiv) in dry dichloromethane (1 mL) was added and the reaction mixture was stirred at 25 °C under nitrogen atmosphere. After 48 h, the reaction was monitored by TLC and <sup>1</sup>H NMR, all of these control reactions did not work.

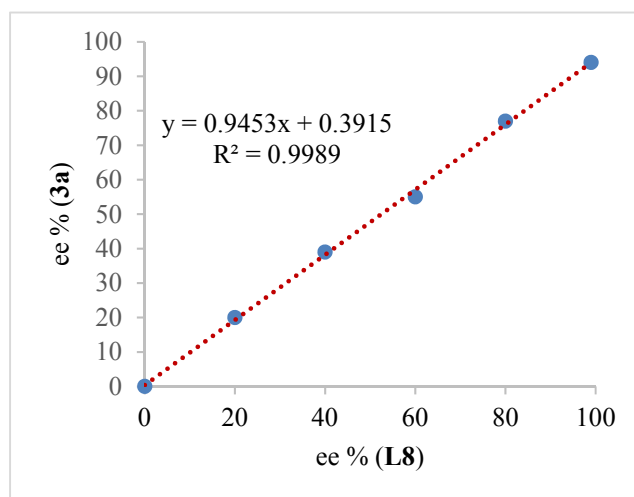
### 2.2. Nonlinear effect study



The nonlinear effect study experiments were carried out according to the general procedure: After stirring a mixture of Cu(CH<sub>3</sub>CN)<sub>4</sub>PF<sub>6</sub> (0.005 mmol, 5 mol %) and **L8** (0.006 mmol, 6 mol %) in dry dichloromethane (1 mL) at 25 °C under nitrogen atmosphere for 1.5 h, substrates **2a** (0.10 mmol) and **1d** (0.15 mmol) in dry dichloromethane (1 mL) was added and the reaction mixture was stirred at 25 °C under nitrogen atmosphere. After 48 h, the substrates **2a** was disappeared (monitored by TLC) completely. The crude product was purified by silica gel flash chromatography to afford the desired product **3a**. And the ee values were determined by HPLC analysis.

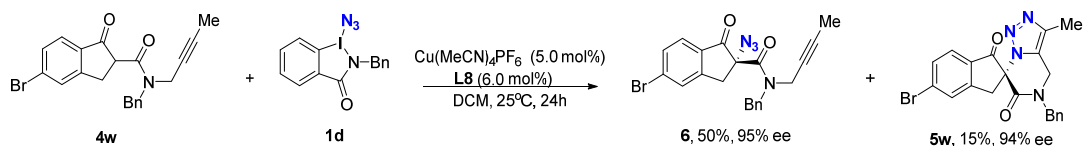
**Supplementary Table 5.** Nonlinear effect study comparing the ee of **L8** with the ee of the product **3a**

| entry | ee of <b>L8</b> (%) | ee of <b>3a</b> (%) |
|-------|---------------------|---------------------|
| 1     | 0                   | 0                   |
| 2     | 20                  | 20                  |
| 3     | 40                  | 39                  |
| 4     | 60                  | 55                  |
| 5     | 80                  | 77                  |
| 6     | 99                  | 94                  |



**Supplementary Fig. 1.** Nonlinear effect study comparing the ee of **L8** with the ee of the product **3a**

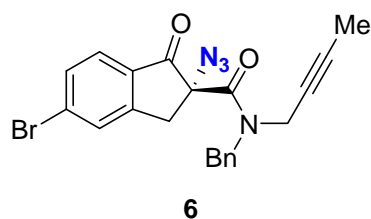
### 2.3. Investigation of intermediate azide



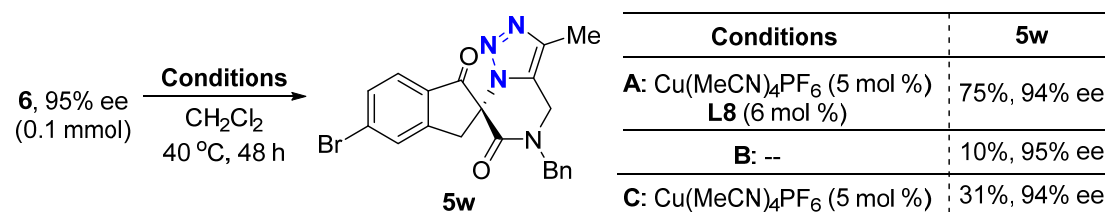
The investigation of intermediate azide experiment was carried out according to the general procedure: After stirring a mixture of  $\text{Cu}(\text{CH}_3\text{CN})_4\text{PF}_6$  (0.005 mmol, 5 mol %) and **L8** (0.006 mmol, 6 mol %) in dry dichloromethane (1 mL) at 25 °C under

nitrogen atmosphere for 1.5 h, substrates **4w** (0.10 mmol) and **1d** (0.15 mmol) in dry dichloromethane (1 mL) was added and the reaction mixture was stirred at room temperature under nitrogen atmosphere. The reaction was terminated after stirring for 24 h. The crude product was purified by silica gel flash chromatography to afford the desired product **6** with 50% yield and 95% ee.

#### Compound **6** (Fig. 4)



**(R)-2-azido-N-benzyl-5-bromo-N-(but-2-yn-1-yl)-1-oxo-2,3-dihydro-1H-indene-2-carboxamide (6)**; TLC:  $R_f = 0.70$  (petroleum ether /ethyl acetate = 3/1, v/v, UV); white solid; yield;  $[\alpha]_D^{25} = 229$  ( $c = 0.1$ ,  $\text{CHCl}_3$ );  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.71 (d,  $J = 8.1$  Hz, 1H), 7.66-7.58 (m, 2H), 7.45-7.15 (m, 5H), 4.74 (s, 2H), 4.40-3.84 (m, 2H), 3.75 (d,  $J = 17.5$  Hz, 1H), 3.14 (d,  $J = 17.4$  Hz, 1H), 1.86 (s, 3H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  195.7, 167.4, 151.8, 135.4, 132.7, 132.4, 131.9, 129.9, 128.9, 128.5, 128.0, 126.8, 84.2, 73.0, 69.4, 48.8, 38.3, 37.0, 3.7; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{21}\text{H}_{18}\text{BrN}_4\text{O}_2^+$   $[M+H]^+$ : 437.0608, found: 437.0600; HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 90/10, 1.0 mL/min, 254 nm, 30 °C; RT = 18.9 min (major), 20.4 min (minor), ee: 95%.



**Condition A:** After stirring a mixture of  $\text{Cu}(\text{CH}_3\text{CN})_4\text{PF}_6$  (0.005 mmol, 5 mol %) and L8 (0.006 mmol, 6 mol %) in dry dichloromethane (1 mL) at 25 °C under nitrogen atmosphere for 1.5 h, intermediated **6** (0.1 mmol) was added and the reaction was stirred at 40 °C under nitrogen atmosphere for 48 h. when the intermediated **6** was disappeared

and the product **5w** was detected (monitored by TLC), the crude product was purified by silica gel flash chromatography to afford the desired product **5w** with 75% yield and 94% ee.

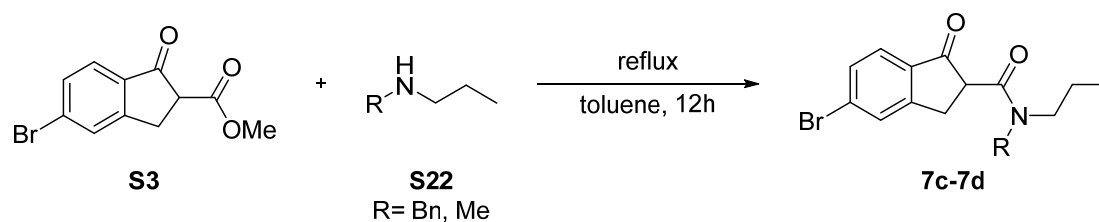
**Condition B:** The intermediated **6** (0.05 mmol) was dissolved in dry dichloromethane (1 mL) and stirred at 40 °C under nitrogen atmosphere for 48 h, the reaction was terminated and the crude product was purified by silica gel flash chromatography to afford the desired product **5w** with 10% yield and 95% ee.

**Condition C:** After stirring a mixture of  $\text{Cu}(\text{CH}_3\text{CN})_4\text{PF}_6$  (0.005 mmol, 5 mol %) and **6** (0.1 mmol) in dry dichloromethane (1 mL) at 40 °C under nitrogen atmosphere for 48 h, the reaction was terminated and the crude product was purified by silica gel flash chromatography to afford the desired product **5w** with 31% yield and 94% ee.

## 2.4. Control experiments with other substrates

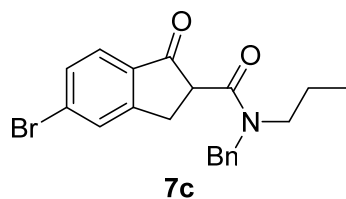
### 2.4.1 General Procedure for the synthesis of racemic **7a-7d**

**7a** and **7b** were synthesized according to the literature procedures.<sup>8-9</sup> **7c** and **7d** were synthesized according to the general procedure.



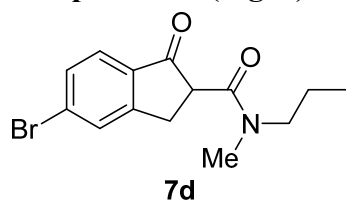
**S3** (1 mmol, 1.0 equiv) were dissolved in dry toluene (20 mL), then propylamine **S22** (1.5 mmol) was added, and the mixture was stirring at 110 oC for 12 h. After the disappearance of substrate (monitored by TLC), the mixture was cooled to room temperature and was quenched with HCl (aq.). The residue was extracted three times with ethyl acetate, and was then washed with  $\text{NaHCO}_3$  (aq.). Finally, the crude product was purified by silica gel flash chromatography to get the desired products **7c-7d**.

### Compound **7c** (Fig. 4)



***N*-benzyl-5-bromo-1-oxo-*N*-propyl-2,3-dihydro-1*H*-indene-2-carboxamide**; TLC:  $R_f = 0.40$  (petroleum ether /ethyl acetate = 10/1, v/v, UV); yellow oil; Enol isomerization were observed by NMR;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.67 (dd,  $J = 17.7, 1.5$  Hz, 1H), 7.58 (dd,  $J = 15.8, 8.2$  Hz, 1H), 7.50 (ddd,  $J = 9.9, 8.4, 1.5$  Hz, 1H), 7.39-7.22 (m, 5H), 5.33 (d,  $J = 17.7$  Hz, 0.5H), 5.01 (d,  $J = 15.2$  Hz, 0.5H), 4.56 (d,  $J = 17.8$  Hz, 0.5H), 4.34 (d,  $J = 15.2$  Hz, 0.5H), 4.13 (dd,  $J = 7.9, 3.8$  Hz, 0.5H), 3.96 (dd,  $J = 7.9, 3.6$  Hz, 0.5H), 3.85-3.73 (m, 2H), 3.32-3.19 (m, 1H), 3.34-2.99 (m, 1H), 1.77-1.58 (m, 2H), 0.91 (dt,  $J = 10.3, 7.4$  Hz, 3H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.9 (200.8), 168.41 (168.39), 156.44 (156.40), 137.3 (137.2), 134.4 (134.3), 131.33 (131.27), 130.84 (130.82), 129.91 (129.87), 129.1 (128.7), 127.7 (127.3) 127.6 (126.2), 125.7 (125.6), 51.4 (51.1), 50.5 (49.4), 49.1 (48.9), 30.9 (30.6), 22.2 (20.9), 11.42 (11.35); HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{20}\text{H}_{21}\text{BrNO}_2^+$   $[\text{M}+\text{H}]^+$ : 386.0750, found: 386.0741.

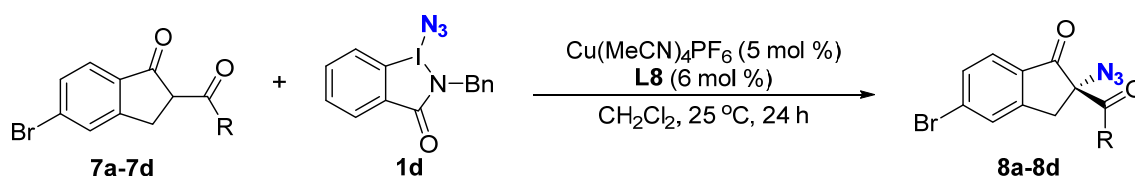
**Compound 7d (Fig. 4)**



**5-bromo-*N*-methyl-1-oxo-*N*-propyl-2,3-dihydro-1*H*-indene-2-carboxamide**; TLC:  $R_f = 0.40$  (petroleum ether /ethyl acetate = 10/1, v/v, UV); yellow oil; Enol isomerization were observed by NMR;  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.66 (d,  $J = 1.6$  Hz, 1H), 7.53 (dd,  $J = 8.2, 4.2$  Hz, 1H), 7.47 (d,  $J = 8.1$  Hz, 1H),  $\delta$  4.09 (dd,  $J = 7.9, 3.6$  Hz, 0.6H), 4.04 (dd,  $J = 7.9, 3.6$  Hz, 0.4H), 3.84 – 3.78 (m, 0.4H), 3.77 – 3.67 (m, 1H), 3.47 (dt,  $J = 13.1, 7.5$  Hz, 0.6H), 3.34-3.16 (m, 4H), 2.97 (s, 1H), 1.78-1.54 (m, 2H), 0.91 (dt,  $J = 27.1, 7.5$  Hz, 3H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  200.7 (200.5), 167.6 (167.4), 156.23 (156.21), 134.22 (134.18), 131.02 (130.97), 130.48 (130.46),

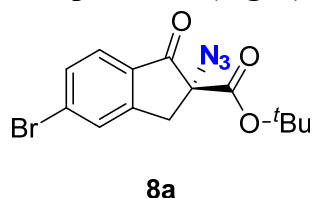
129.68 (129.67), 125.33 (125.29), 52.0 (50.8), 50.2 (50.0), 36.0 (34.1), 30.7 (30.2), 21.8 (20.3), 11.12 (11.08); **HRMS (ESI, m/z)**: calcd. For  $C_{14}H_{17}BrNO_2^+$   $[M+H]^+$ : 310.0473, found: 310.0473.

#### 2.4.2 General Procedure for the synthesis of racemic **8a-8d**



After stirring a mixture of  $Cu(MeCN)_4PF_6$  (0.005 mmol, 5 mol %) and **L8** (0.006 mmol, 6 mol %) in dry dichloromethane (1 mL) at 25 °C under nitrogen atmosphere for 1.5 h, substrates **7a-7d** (0.10 mmol) and **1d** (0.15 mmol) in dry dichloromethane (1 mL) was added and the reaction mixture was stirred at 25 °C under nitrogen atmosphere. After 24 h, the substrates **7a-7d** was disappeared (monitored by TLC) completely. Finally, the crude product was purified by silica gel flash chromatography to afford the desired products **8a-8d**.

#### Compound **8a** (Fig. 4)

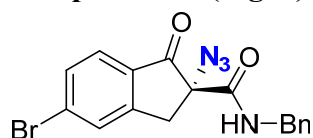


The NMR of **8a** according to the literature<sup>8</sup>.

**tert-butyl (R)-2-azido-5-bromo-1-oxo-2,3-dihydro-1H-indene-2-carboxylate (8a)**;  
**TLC**:  $R_f = 0.80$  (petroleum ether /ethyl acetate = 10/1, v/v, UV); colorless oil; yield: 91% (32.0 mg, 0.091 mmol);  $[\alpha]_D^{25} = 115$  ( $c = 1.0$ ,  $CHCl_3$ ); {ref. 8:  $[\alpha]_D^{25} +143.2$  ( $c = 0.94$ ,  $CHCl_3$ , 90% ee, *R* absolute configuration)};  **$^1H$  NMR (400 MHz,  $CDCl_3$ )**:  $\delta$  7.67 (d,  $J = 8.2$  Hz, 1H), 7.64 (d,  $J = 1.5$  Hz, 1H), 7.58 (dd,  $J = 8.2, 1.6$  Hz, 1H), 3.61 (d,  $J = 17.4$  Hz, 1H), 2.96 (d,  $J = 17.4$  Hz, 1H), 1.46 (s, 9H); **HPLC**: Chiralpak AD-H Column, hexane/*i*PrOH = 99/1, 1.0 mL/min, 254 nm, 30 °C; RT = 12.6 min (major), 10.6 min (minor), ee: 55%.



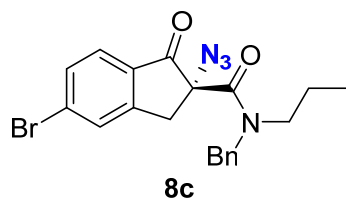
**Compound 8b (Fig. 4)**



**8b**

**(R)-2-azido-N-benzyl-5-bromo-1-oxo-2,3-dihydro-1H-indene-2-carboxamide (8b);** TLC:  $R_f = 0.40$  (petroleum ether /ethyl acetate = 5/1, v/v, UV); colorless oil; yield: 71% (27.3 mg, 0.071 mmol);  $[\alpha]_D^{25} = 29$  (c = 0.5,  $\text{CHCl}_3$ );  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.71 (s, 1H), 7.67 (d,  $J = 8.2$  Hz, 1H), 7.59 (d,  $J = 8.3$  Hz, 1H), 7.40 – 7.23 (m, 5H), 7.06 (s, 1H), 4.57 – 4.40 (m, 2H), 4.02 (d,  $J = 17.5$  Hz, 1H), 3.23 (d,  $J = 17.5$  Hz, 1H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  197.0, 166.0, 153.9, 137.3, 132.6, 132.4, 132.3, 130.0, 129.0, 127.9, 127.8, 126.7, 73.0, 44.2, 37.5; **HRMS (ESI, m/z)**: calcd. For  $\text{C}_{17}\text{H}_{14}\text{BrN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 385.0295, found: 385.0289; **HPLC**: Chiralpak AD-H Column, hexane/*i*PrOH = 80/20, 1.0 mL/min, 254 nm, 30 °C; RT = 10.0 min (major), 14.6 min (minor), ee: 46%.

**Compound 8c (Fig. 4)**

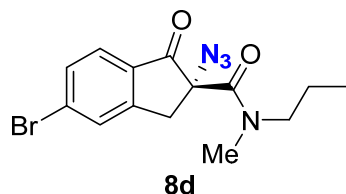


**8c**

**(R)-2-azido-N-benzyl-5-bromo-1-oxo-N-propyl-2,3-dihydro-1H-indene-2-carboxamide (8c);** TLC:  $R_f = 0.60$  (petroleum ether /ethyl acetate = 10/1, v/v, UV); colorless oil; yield: 90% (38.4 mg, 0.090 mmol);  $[\alpha]_D^{25} = 199$  (c = 1.0,  $\text{CHCl}_3$ ); two rotamers were observed by NMR;<sup>10-14</sup>  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.73-7.68 (m, 1H), 7.63-7.57 (m, 2H), 7.37-7.17 (m, 5H), 4.80-4.59 (m, 2H), 3.57 (dd,  $J = 36.5, 17.4$  Hz, 1H), 3.29-3.07 (m, 3H), 1.65-1.53 (m, 2H), 0.80 (dt,  $J = 27.2, 7.5$  Hz, 3H);  $^{13}\text{C}\{^1\text{H}\}\text{NMR}$  (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  196.6, 167.5, 151.8, 136.7 (136.0), 132.7 (132.4), 131.8, 129.9, 129.0 (128.9), 128.0, 127.7, 126.8, 126.7, 72.2 (71.8), 50.9 (48.6), 48.3, 38.6 (38.5), 21.2 (20.1), 11.3 (11.2); **HRMS (ESI, m/z)**: calcd. For  $\text{C}_{20}\text{H}_{20}\text{BrN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 427.0764, found: 427.0760; **HPLC**: Chiralpak AD-H Column, hexane/*i*PrOH

= 90/10, 1.0 mL/min, 254 nm, 30 °C; RT = 21.8 min (major), 17.5 min (minor), ee: 90%.

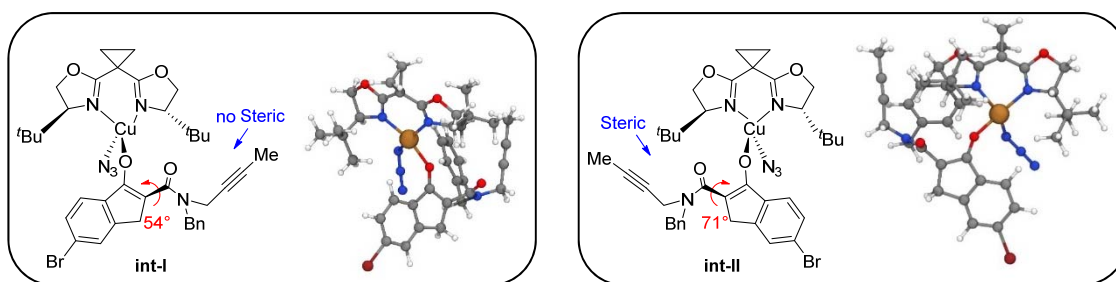
#### Compound 8d (Fig. 4)



**(R)-2-azido-5-bromo-N-methyl-1-oxo-N-propyl-2,3-dihydro-1H-indene-2-carboxamide (8d)**; TLC:  $R_f = 0.60$  (petroleum ether /ethyl acetate = 10/1, v/v, UV); colorless oil; yield: 85% (29.8 mg, 0.085 mmol);  $[\alpha]_D^{25} = 232$  ( $c = 1.0$ ,  $\text{CHCl}_3$ );  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ):  $\delta$  7.69 (d,  $J = 8.2$  Hz, 1H), 7.62 (d,  $J = 1.6$  Hz, 1H), 7.58 (dd,  $J = 8.1, 1.6$  Hz, 1H), 3.55 (d,  $J = 17.4$  Hz, 1H), 3.40-3.26 (m, 2H), 3.13 (d,  $J = 17.4$  Hz, 1H), 2.97 (d,  $J = 17.0$  Hz, 3H), 1.59 (q,  $J = 7.5$  Hz, 2H), 0.90-0.88 (m, 3H).;  $^{13}\text{C}\{^1\text{H}\}$  NMR (101 MHz,  $\text{CDCl}_3$ ):  $\delta$  196.7, 166.7, 151.8, 132.7, 132.4, 131.7, 129.9, 126.6, 72.0, 51.2, 38.3, 35.4, 20.1, 11.2; HRMS (ESI,  $m/z$ ): calcd. For  $\text{C}_{20}\text{H}_{20}\text{BrN}_4\text{O}_2^+$   $[\text{M}+\text{H}]^+$ : 351.0451, found: 351.0442. HPLC: Chiralpak AD-H Column, hexane/ $i$ PrOH = 80/20, 1.0 mL/min, 254 nm, 30 °C; RT = 8.8 min (major), 7.8 min (minor), ee: 83%.

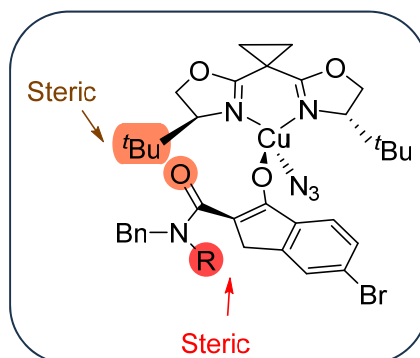
#### 2.5. DFT calculations

For both conformations, the systems were set with a charge and spin multiplicity of 1 and 3, respectively. Optimizations were then performed at the M06-2X/def2-SVP level, incorporating Grimme's D3 empirical dispersion correction<sup>15</sup>. The Polarizable Continuum Model (PCM) was employed across all calculations, utilizing dichloromethane as the solvent to mimic the dielectric environment of the solution. Subsequently, frequency calculations were conducted to obtain the free energies. All computational analyses were executed using the Gaussian 16 software.



**Supplementary Fig. 2.** Chemical structure of **int-I** and **int-II**

**Discussions:** The favored conformation exhibits an energy that is 8.337718 kcal/mol lower than that of the other side. This discrepancy is primarily attributed to the steric hindrance caused by the carbonyl group and the tert-butyl group. Such hindrance leads to an increase in the angle between the exocyclic amide carbonyl and the five-membered ring from 54 degrees on the left to 71 degrees on the right. The enlargement of this angle results in a deterioration of conjugation, which not only elevates the energy level but also makes the enol double bond more reactive due to the loss of conjugation.



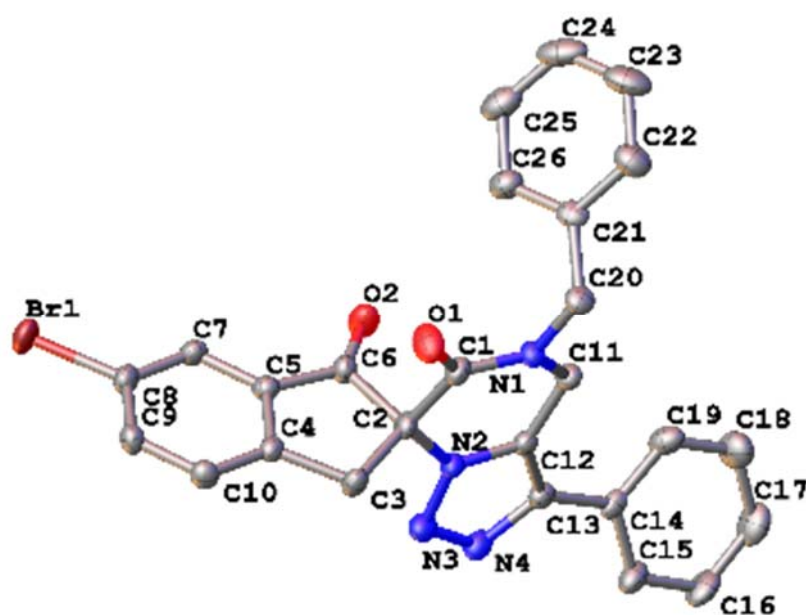
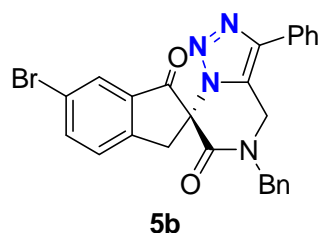
**Supplementary Fig. 3.** The influence of *N*-propargyl group

**Discussions:** Additionally, the enlargement of the angle causes the groups attached to the amide, such as the alkynyl group in this case, to rotate towards the backside of the  $\alpha$ -carbon, thereby obstructing the approach of azides, as depicted in the figure below

### 3. Supplementary Notes

#### 3.1 Determination of the Absolute Configuration of **5b** by X-ray Analysis .

##### Compound **5b** (Fig. 3)



**Supplementary Fig. 4.** X-ray analysis to determine the absolute configuration of compound **5b** (CCDC2327853)

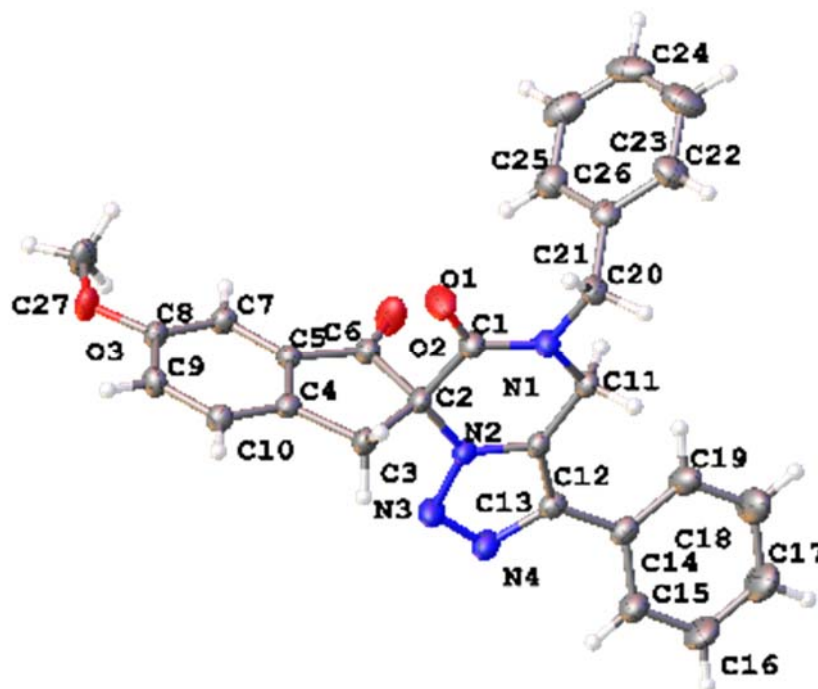
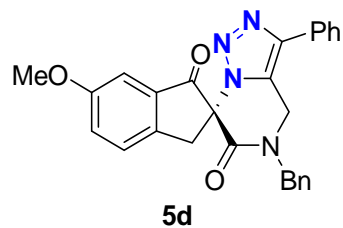
**Supplementary Table 6.** Crystal data and structure refinement for **5b** (CCDC2327853)

|                      |  |          |
|----------------------|--|----------|
| Identification code  | 231127cx_a   |          |
| Empirical formula    | C <sub>26</sub> H <sub>19</sub> Br N <sub>4</sub> O <sub>2</sub> |          |
| Formula weight       | 499.36   |          |
| Temperature          | 173.00 K   |          |
| Wavelength           | 1.34139 Å  |          |
| Crystal system       | Orthorhombic   |          |
| Space group          | P2 <sub>1</sub> 2 <sub>1</sub> 2 <sub>1</sub>                    |          |
| Unit cell dimensions | a = 10.7747(2) Å   | a = 90°. |

|                                   |   |          |
|-----------------------------------|---|----------|
|                                   | b = 10.8254(2) Å                                | b = 90°. |
|                                   | c = 18.5960(3) Å                                | g = 90°. |
| Volume                            | 2169.05(7) Å <sup>3</sup>                       |          |
| Z                                 | 4   |          |
| Density (calculated)              | 1.529 Mg/m <sup>3</sup>                         |          |
| Absorption coefficient            | 1.874 mm <sup>-1</sup>                          |          |
| F(000)                            | 1016  |          |
| Crystal size                      | 0.17 x 0.17 x 0.05 mm <sup>3</sup>              |          |
| Theta range for data collection   | 4.111 to 54.949°.                               |          |
| Index ranges                      | -13<=h<=13, -<br>13<=k<=13, -<br>22<=l<=20      |          |
| Reflections collected             | 19722   |          |
| Independent reflections           | 4113 [R(int) = 0.0469]                          |          |
| Completeness to theta = 53.594°   | 99.8 %  |          |
| Absorption correction             | Semi-empirical from<br>equivalents              |          |
| Max. and min. transmission        | 0.7508 and 0.5919                               |          |
| Refinement method                 | Full-matrix least-<br>squares on F <sup>2</sup> |          |
| Data / restraints / parameters    | 4113 / 0 / 298                                  |          |
| Goodness-of-fit on F <sup>2</sup> | 1.061   |          |
| Final R indices [I>2sigma(I)]     | R1 = 0.0292, wR2 =<br>0.0624                    |          |
| R indices (all data)              | R1 = 0.0352, wR2 =<br>0.0654                    |          |
| Absolute structure parameter      | 0.021(10)                                       |          |
| Extinction coefficient            | n/a   |          |
| Largest diff. peak and hole       | 0.263 and -0.512 e.Å <sup>-3</sup>              |          |

### 3.2 Determination of the Absolute Configuration of 5d by X-ray Analysis

#### Compound 5d (Fig. 3)



**Supplementary Fig. 5.** X-ray analysis to determine the absolute configuration of compound **5d** (CCDC2327852)

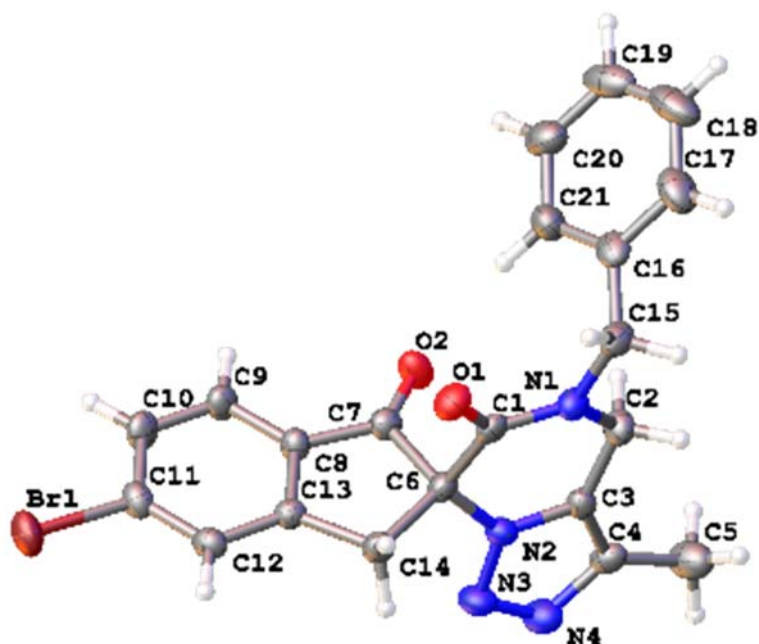
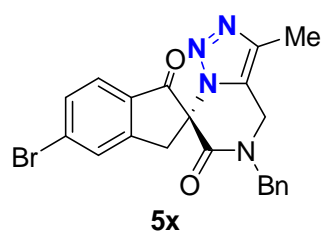
**Supplementary Table 7.** Crystal data and structure refinement for **5d** (CCDC2327852)

|                      |   |          |
|----------------------|---|----------|
| Identification code  | 231127cx_c  |          |
| Empirical formula    | C <sub>27</sub> H <sub>21</sub> N <sub>4</sub> O <sub>3</sub> |          |
| Formula weight       | 449.48  |          |
| Temperature          | 173.00 K  |          |
| Wavelength           | 1.34139 Å   |          |
| Crystal system       | Orthorhombic  |          |
| Space group          | P2 <sub>1</sub> 2 <sub>1</sub> 2 <sub>1</sub>                 |          |
| Unit cell dimensions | a = 10.8149(2) Å  | a = 90°. |
|                      | b = 11.3892(2) Å  | b = 90°. |

|  |  |                  |
|--|--|------------------|
|  | $c = 18.1350(4) \text{ \AA}$   | $g = 90^\circ$ . |
| Volume                                 | $2233.74(8) \text{ \AA}^3$   |                  |
| Z                                      | 4  |                  |
| Density (calculated)                   | $1.337 \text{ Mg/m}^3$   |                  |
| Absorption coefficient                 | $0.461 \text{ mm}^{-1}$  |                  |
| F(000)                                 | 940  |                  |
| Crystal size                           | $0.17 \times 0.17 \times 0.05 \text{ mm}^3$                                |                  |
| Theta range for data collection        | $4.141$ to $54.907^\circ$ .  |                  |
| Index ranges                           | $-13 \leq h \leq 12$ , -<br>$13 \leq k \leq 13$ , -<br>$21 \leq l \leq 22$ |                  |
| Reflections collected                  | 28567  |                  |
| Independent reflections                | 4236 [R(int) = 0.0553]   |                  |
| Completeness to theta = $53.594^\circ$ | 99.8 %   |                  |
| Absorption correction                  | Semi-empirical from equivalents  |                  |
| Max. and min. transmission             | 0.7508 and 0.6201  |                  |
| Refinement method                      | Full-matrix least-squares on $F^2$   |                  |
| Data / restraints / parameters         | 4236 / 0 / 308   |                  |
| Goodness-of-fit on $F^2$               | 1.055  |                  |
| Final R indices [ $I > 2\sigma(I)$ ]   | R1 = 0.0354, wR2 = 0.0949  |                  |
| R indices (all data)                   | R1 = 0.0396, wR2 = 0.0970  |                  |
| Absolute structure parameter           | 0.10(9)  |                  |
| Extinction coefficient                 | n/a  |                  |
| Largest diff. peak and hole            | 0.439 and $-0.351 \text{ e.\AA}^{-3}$                                      |                  |

### 3.3 Determination of the Absolute Configuration of 5x by X-ray Analysis

#### Compound 5x (Fig. 4)



**Supplementary Fig. 6.** X-ray analysis to determine the absolute configuration of compound 5x (CCDC2327851)

**Supplementary Table 8.** Crystal data and structure refinement for 5x (CCDC2327851)

|                      |  |          |
|----------------------|--|----------|
| Identification code  | 231116cx_6_2a  |          |
| Empirical formula    | C <sub>21</sub> H <sub>16</sub> Br N <sub>4</sub> O <sub>2</sub> |          |
| Formula weight       | 436.29   |          |
| Temperature          | 173.00 K   |          |
| Wavelength           | 1.34139 Å  |          |
| Crystal system       | Orthorhombic   |          |
| Space group          | P2 <sub>1</sub> 2 <sub>1</sub> 2 <sub>1</sub>                    |          |
| Unit cell dimensions | a = 8.8875(2) Å  | a = 90°. |
|                      | b = 10.0683(2) Å   | b = 90°. |
|                      | c = 21.2805(4) Å   | g = 90°. |



|                                   |   |  |
|-----------------------------------|---|--|
| Volume                            | 1904.22(7) Å <sup>3</sup>                       |  |
| Z                                 | 4   |  |
| Density (calculated)              | 1.522 Mg/m <sup>3</sup>                         |  |
| Absorption coefficient            | 2.075 mm <sup>-1</sup>                          |  |
| F(000)                            | 884   |  |
| Crystal size                      | 0.17 x 0.17 x 0.05 mm <sup>3</sup>              |  |
| Theta range for data collection   | 3.614 to 54.919°.                               |  |
| Index ranges                      | -10<=h<=10, -<br>10<=k<=12, -<br>20<=l<=25      |  |
| Reflections collected             | 11847   |  |
| Independent reflections           | 3597 [R(int) = 0.0478]                          |  |
| Completeness to theta = 53.594°   | 99.8 %  |  |
| Absorption correction             | Semi-empirical from<br>equivalents              |  |
| Max. and min. transmission        | 0.7508 and 0.4592                               |  |
| Refinement method                 | Full-matrix least-<br>squares on F <sup>2</sup> |  |
| Data / restraints / parameters    | 3597 / 0 / 254                                  |  |
| Goodness-of-fit on F <sup>2</sup> | 1.060   |  |
| Final R indices [I>2sigma(I)]     | R1 = 0.0383, wR2 =<br>0.0850                    |  |
| R indices (all data)              | R1 = 0.0498, wR2 =<br>0.0907                    |  |
| Absolute structure parameter      | 0.048(14)                                       |  |
| Extinction coefficient            | n/a   |  |
| Largest diff. peak and hole       | 0.559 and -0.506 e.Å <sup>-3</sup>              |  |

7.417  
7.397  
7.373  
7.359  
7.353  
7.342  
7.323  
7.291  
7.272  
7.260

4.641

3.929

3.622

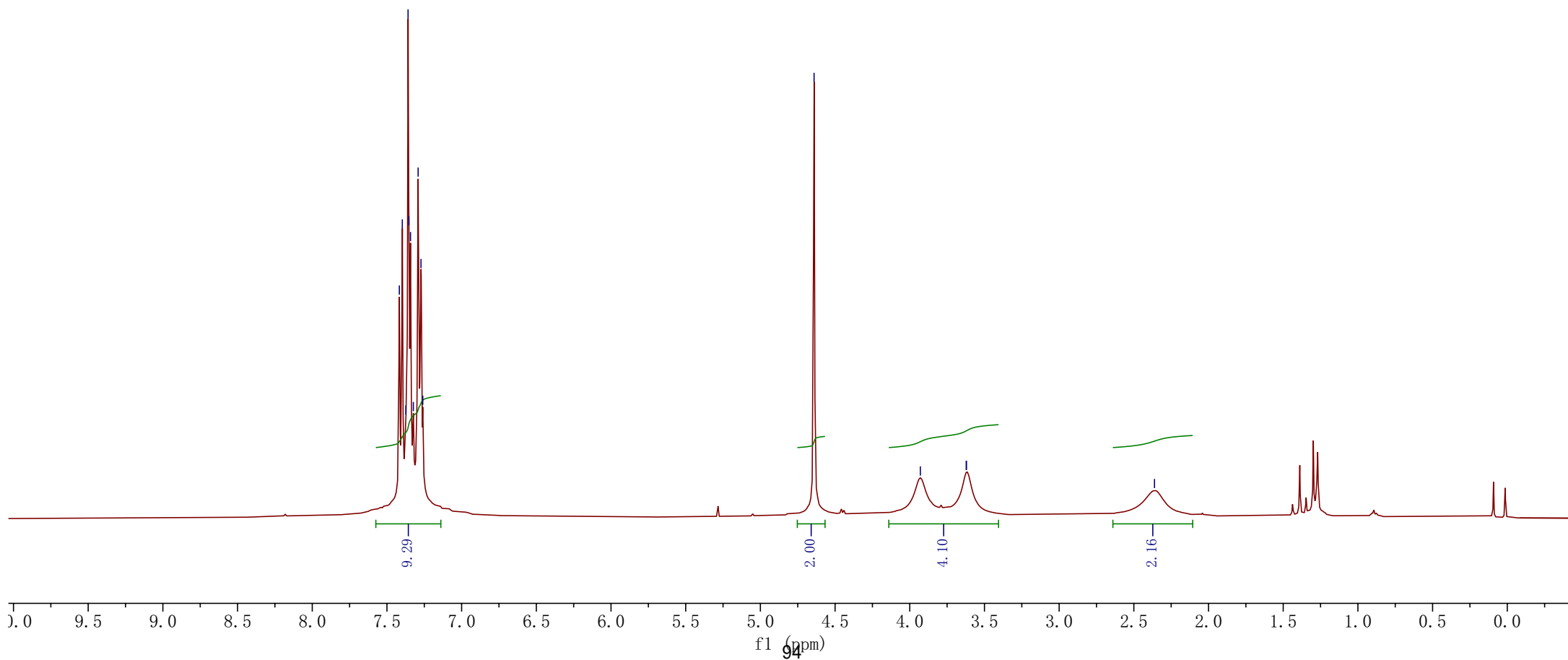
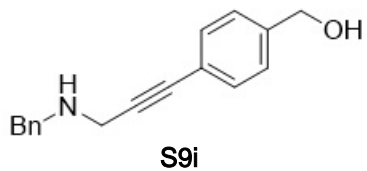
3.621

2.362

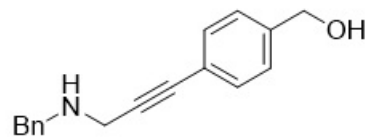
## 4. Supplementary Figures

### 4.1 NMR Spectra of New Compounds (<sup>1</sup>H NMR, <sup>13</sup>C NMR and <sup>19</sup>F NMR)

S9i, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



S9i, <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)



S9i

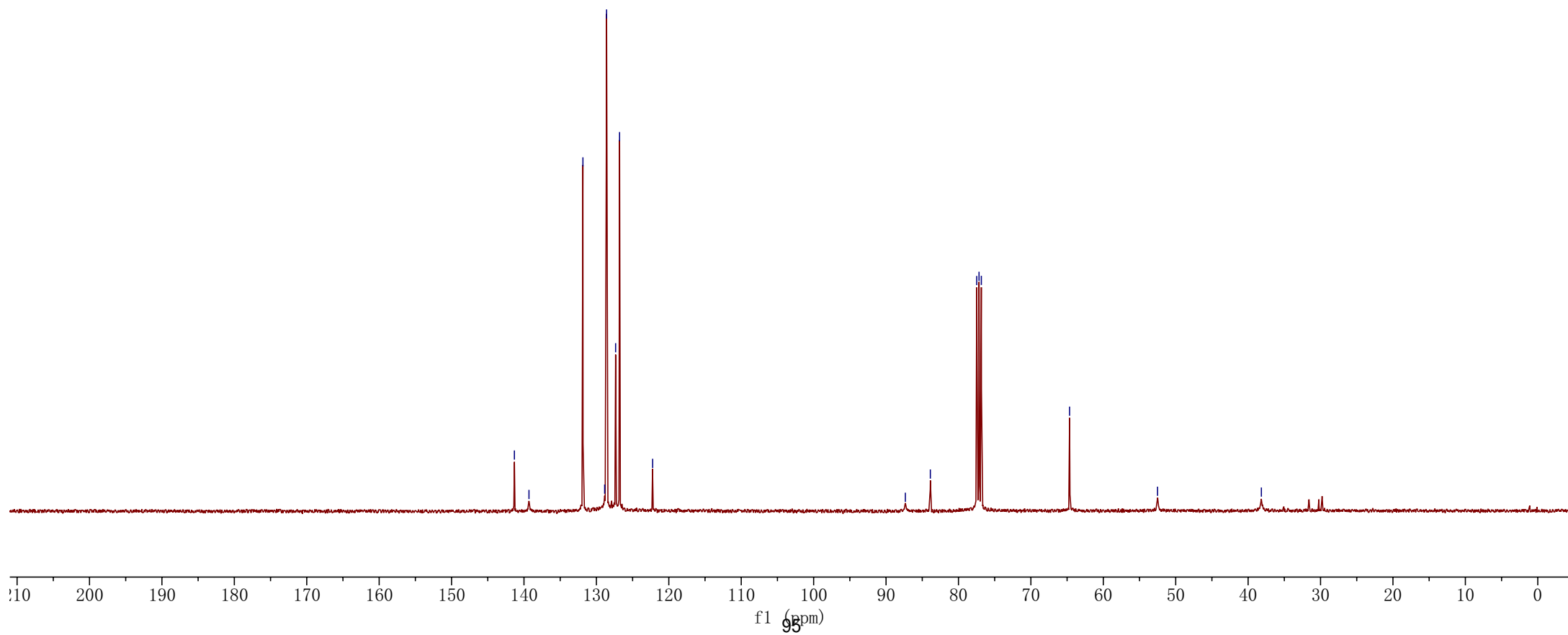
141.323  
139.312  
131.862  
128.859  
128.594  
127.345  
126.800  
122.232

87.333  
83.884  
77.478  
77.160  
76.842

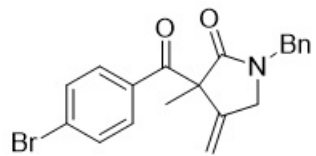
64.655

52.506

38.170



S11, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



S11

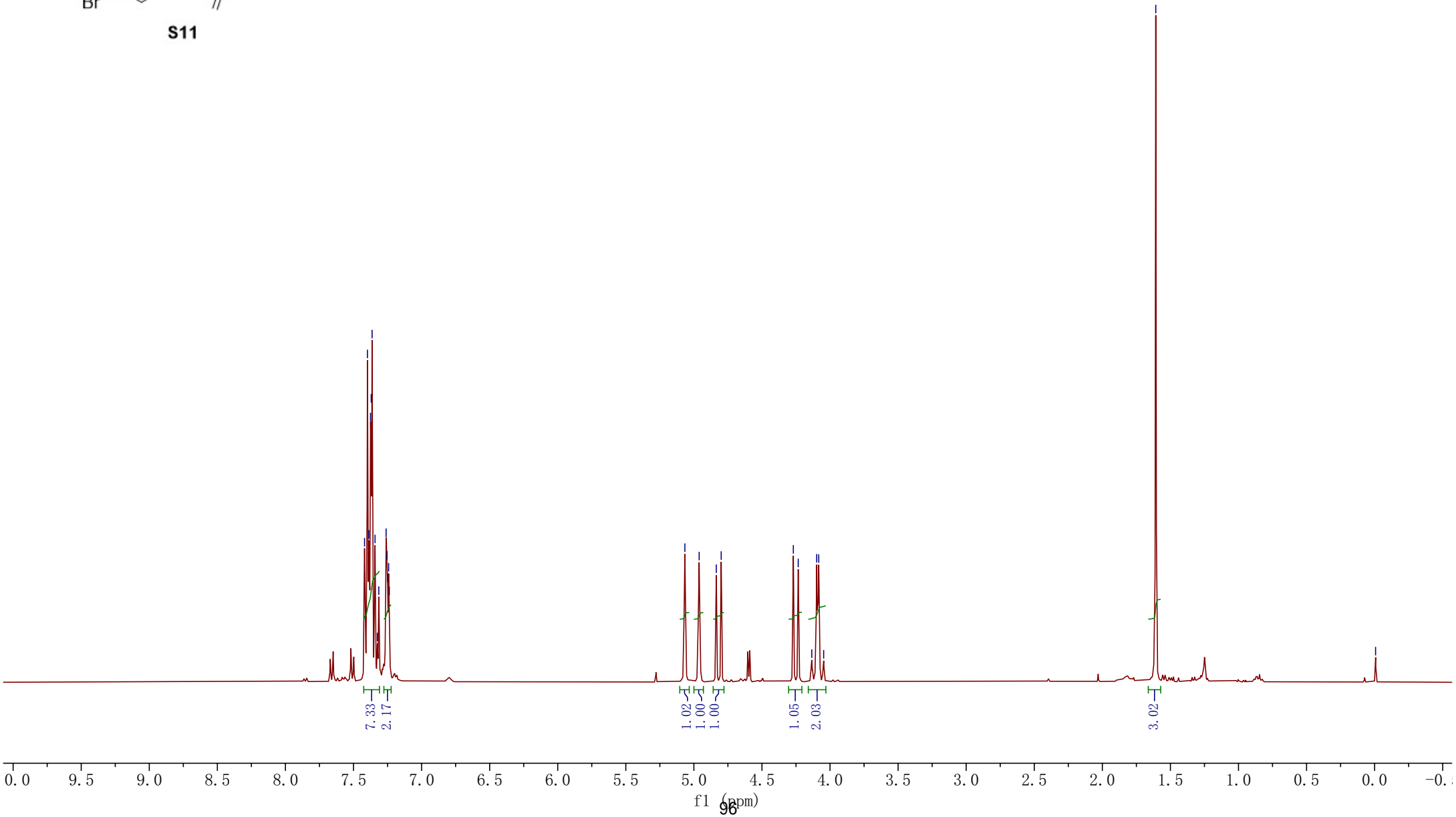
7.419  
7.398  
7.388  
7.375  
7.370  
7.363  
7.342  
7.325  
7.314  
7.261  
7.254  
7.249  
7.242  
7.237

5.066  
4.961  
4.835  
4.799

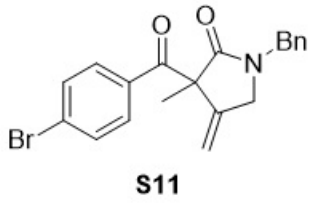
4.270  
4.234  
4.134  
4.098  
4.083  
4.047

1.607

-0.007



S11, <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)



195.171  
173.551  
143.062  
135.253  
134.788  
131.669  
130.035  
129.042  
128.931  
128.298  
127.399  
111.244

77.478  
77.160  
76.842

60.847

49.978  
46.739

23.139

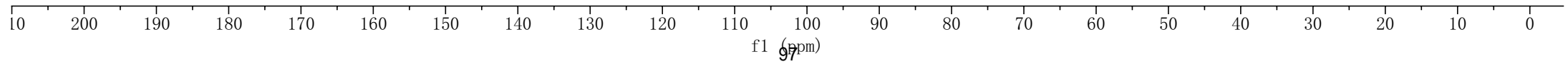
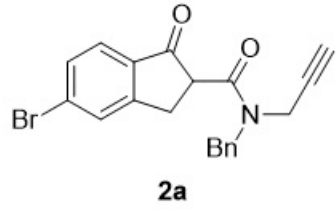
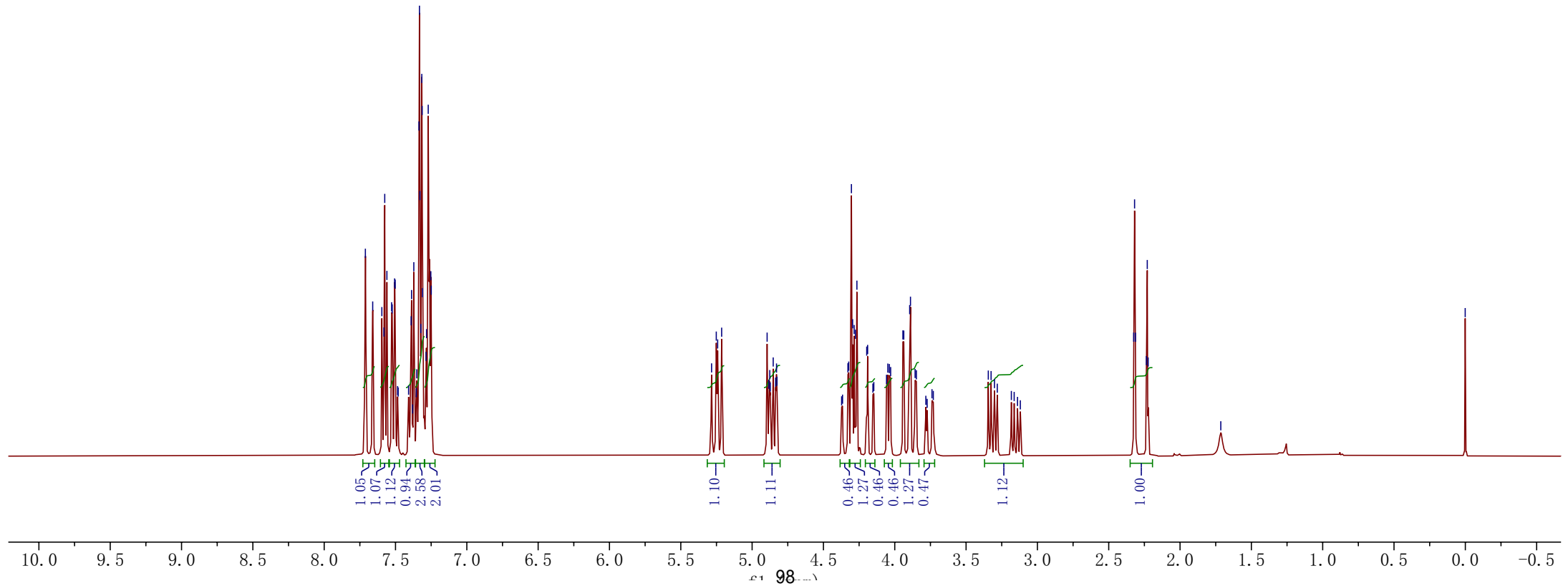


Fig. 2: 2a, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



7.711  
7.660  
7.596  
7.581  
7.575  
7.560  
7.527  
7.523  
7.506  
7.502  
7.485  
7.481  
7.408  
7.390  
7.387  
7.380  
7.372  
7.354  
7.351  
7.336  
7.332  
7.329  
7.322  
7.316  
7.313  
7.310  
7.286  
7.282  
7.271  
7.252  
7.249

5.284  
5.251  
5.242  
5.214  
4.895  
4.883  
4.876  
4.873  
4.852  
4.835  
4.829  
4.825  
4.822  
4.820  
4.817  
4.814  
4.811  
4.808  
4.805  
4.802  
4.800  
4.797  
4.794  
4.791  
4.788  
4.785  
4.782  
4.779  
4.776  
4.773  
4.770  
4.767  
4.764  
4.761  
4.758  
4.755  
4.752  
4.749  
4.746  
4.743  
4.740  
4.737  
4.734  
4.731  
4.728  
4.725  
4.722  
4.719  
4.716  
4.713  
4.710  
4.707  
4.704  
4.701  
4.698  
4.695  
4.692  
4.689  
4.686  
4.683  
4.680  
4.677  
4.674  
4.671  
4.668  
4.665  
4.662  
4.659  
4.656  
4.653  
4.650  
4.647  
4.644  
4.641  
4.638  
4.635  
4.632  
4.629  
4.626  
4.623  
4.620  
4.617  
4.614  
4.611  
4.608  
4.605  
4.602  
4.599  
4.596  
4.593  
4.590  
4.587  
4.584  
4.581  
4.578  
4.575  
4.572  
4.569  
4.566  
4.563  
4.560  
4.557  
4.554  
4.551  
4.548  
4.545  
4.542  
4.539  
4.536  
4.533  
4.530  
4.527  
4.524  
4.521  
4.518  
4.515  
4.512  
4.509  
4.506  
4.503  
4.500  
4.497  
4.494  
4.491  
4.488  
4.485  
4.482  
4.479  
4.476  
4.473  
4.470  
4.467  
4.464  
4.461  
4.458  
4.455  
4.452  
4.449  
4.446  
4.443  
4.440  
4.437  
4.434  
4.431  
4.428  
4.425  
4.422  
4.419  
4.416  
4.413  
4.410  
4.407  
4.404  
4.401  
4.398  
4.395  
4.392  
4.389  
4.386  
4.383  
4.380  
4.377  
4.374  
4.371  
4.368  
4.365  
4.362  
4.359  
4.356  
4.353  
4.350  
4.347  
4.344  
4.341  
4.338  
4.335  
4.332  
4.329  
4.326  
4.323  
4.320  
4.317  
4.314  
4.311  
4.308  
4.305  
4.302  
4.299  
4.296  
4.293  
4.290  
4.287  
4.284  
4.281  
4.278  
4.275  
4.272  
4.269  
4.266  
4.263  
4.260  
4.257  
4.254  
4.251  
4.248  
4.245  
4.242  
4.239  
4.236  
4.233  
4.230  
4.227  
4.224  
4.221  
4.218  
4.215  
4.212  
4.209  
4.206  
4.203  
4.200  
4.197  
4.194  
4.191  
4.188  
4.185  
4.182  
4.179  
4.176  
4.173  
4.170  
4.167  
4.164  
4.161  
4.158  
4.155  
4.152  
4.149  
4.146  
4.143  
4.140  
4.137  
4.134  
4.131  
4.128  
4.125  
4.122  
4.119  
4.116  
4.113  
4.110  
4.107  
4.104  
4.101  
4.098  
4.095  
4.092  
4.089  
4.086  
4.083  
4.080  
4.077  
4.074  
4.071  
4.068  
4.065  
4.062  
4.059  
4.056  
4.053  
4.050  
4.047  
4.044  
4.041  
4.038  
4.035  
4.032  
4.029  
4.026  
4.023  
4.020  
4.017  
4.014  
4.011  
4.008  
4.005  
4.002  
4.000



200.532  
200.093

168.297  
167.729

156.420  
156.165

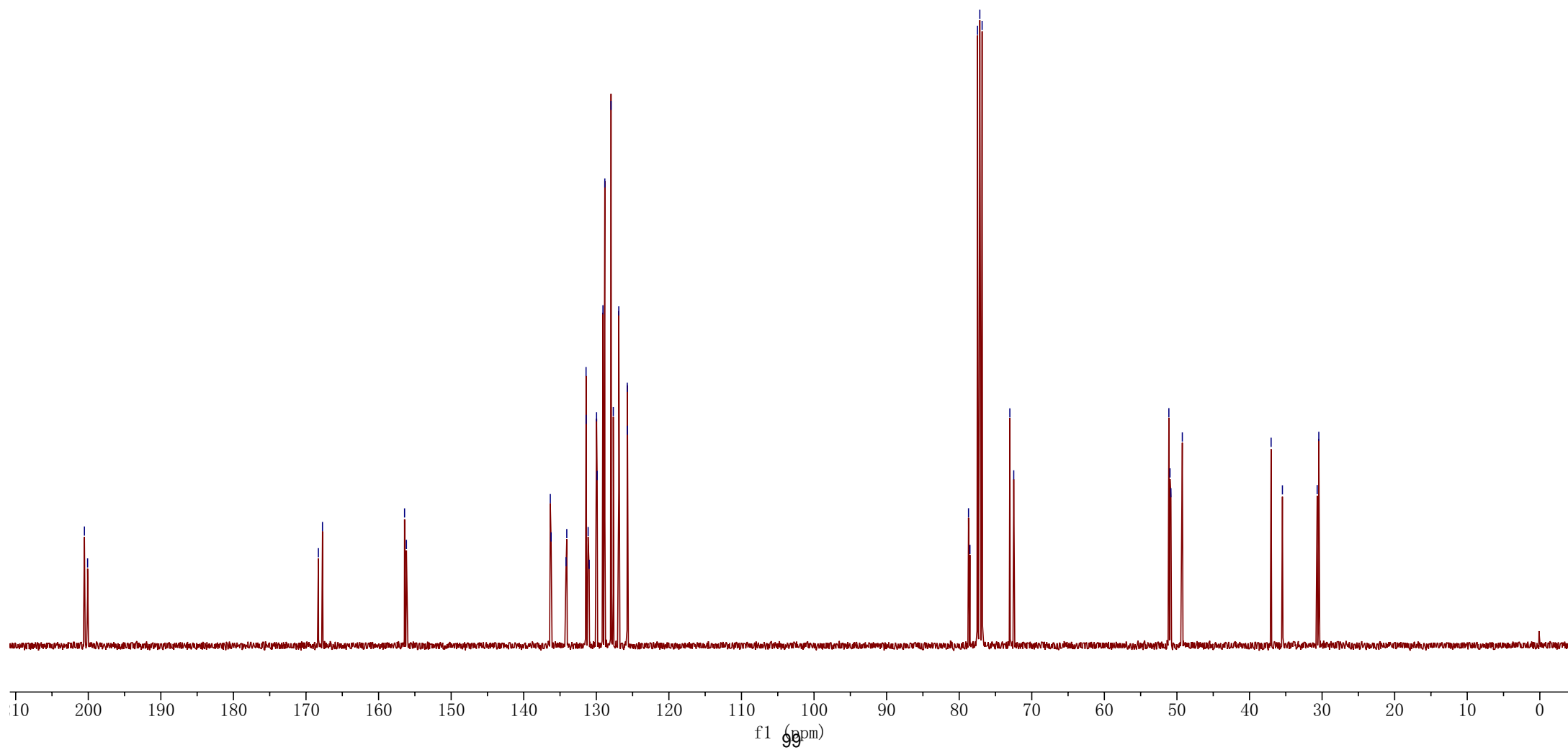
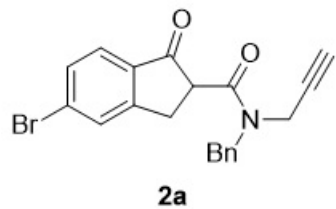
136.340  
136.229  
134.177  
134.069  
131.414  
131.401  
131.129  
130.982  
129.966  
129.884  
129.084  
128.826  
127.972  
127.659  
126.904  
125.734  
125.718

78.717  
78.522  
77.478  
77.160  
76.842  
73.022  
72.485

51.111  
50.955  
50.829  
49.257

37.024  
35.467  
30.676  
30.451

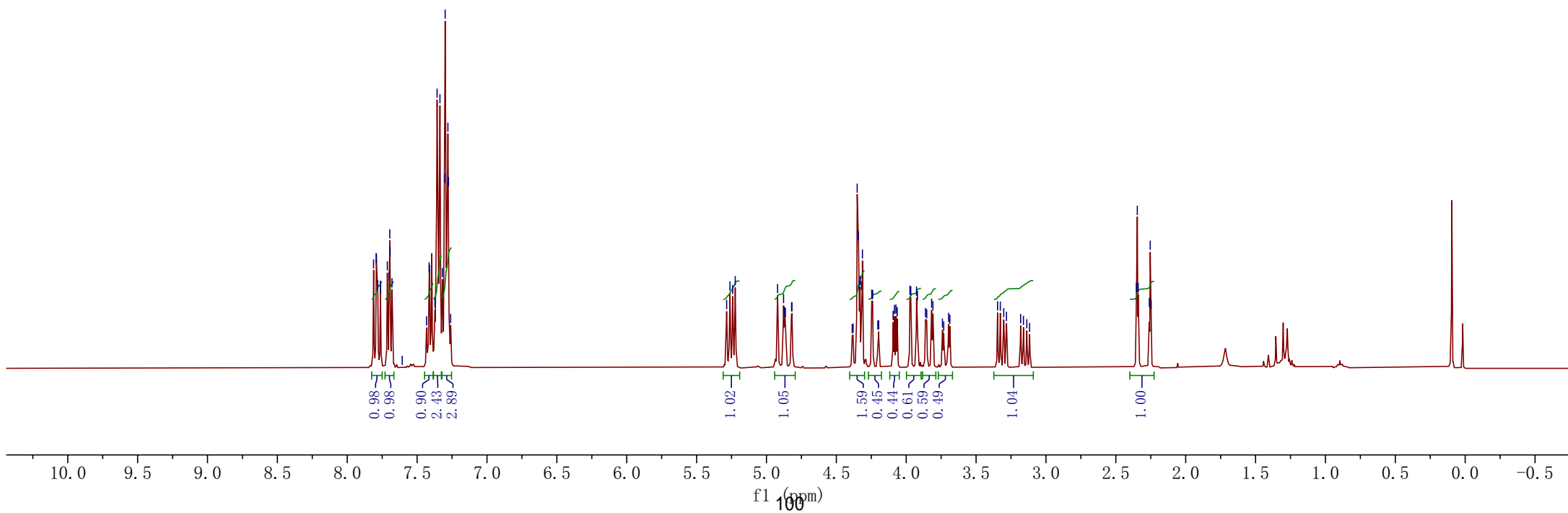
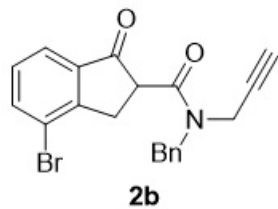
Fig. 2: **2a**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



7.812  
7.793  
7.791  
7.782  
7.763  
7.761  
7.713  
7.699  
7.696  
7.693  
7.680  
7.606  
7.433  
7.414  
7.411  
7.372  
7.357  
7.337  
7.319  
7.304  
7.299  
7.280  
7.275  
7.260

5.285  
5.262  
5.242  
5.224  
4.921  
4.878  
4.871  
4.864  
4.820  
4.818  
4.386  
4.380  
4.351  
4.342  
4.337  
4.330  
4.330  
4.321  
4.313  
4.247  
4.240  
4.203  
4.197  
4.094  
4.084  
4.074  
4.065  
3.973  
3.967  
3.926  
3.920  
3.862  
3.853  
3.818  
3.809  
3.741  
3.732  
3.697  
3.688  
3.346  
3.327  
3.302  
3.282  
3.181  
3.161  
3.137  
3.117  
3.353  
2.346  
2.340  
2.260  
2.254  
2.248

Fig. 2: **2b**,  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )





201.061  
200.623

168.314  
167.735

154.492  
154.234

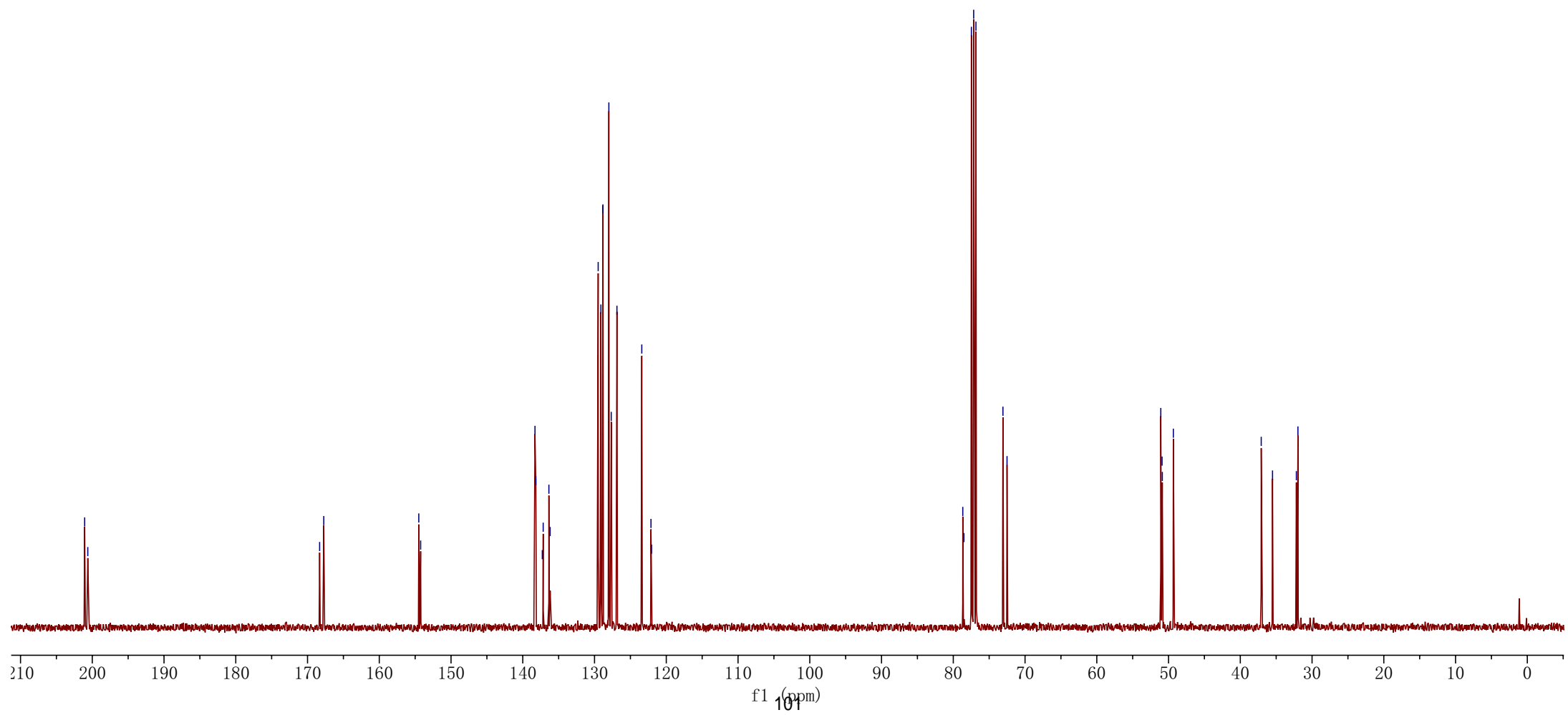
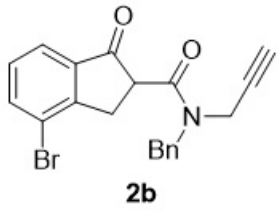
138.298  
138.177  
137.280  
137.154  
136.360  
136.189  
129.491  
129.113  
128.830  
128.003  
127.672  
126.877  
123.415  
122.133  
122.049

78.676  
78.516  
77.478  
77.160  
76.842  
73.081  
72.510

51.080  
50.904  
50.869  
49.331

37.083  
35.508  
32.187  
31.968

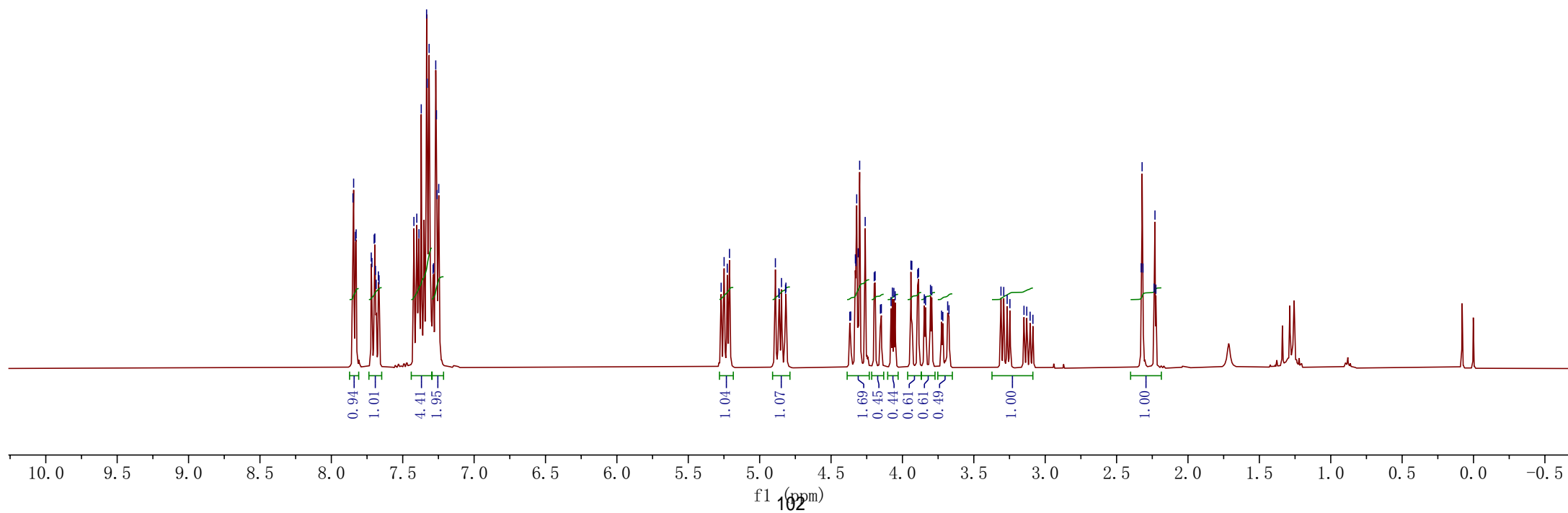
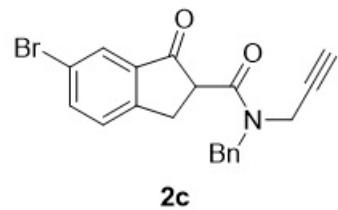
Fig. 2: **2b**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



7.849  
7.844  
7.831  
7.826  
7.721  
7.716  
7.700  
7.695  
7.691  
7.686  
7.671  
7.666  
7.422  
7.401  
7.386  
7.370  
7.333  
7.328  
7.315  
7.287  
7.284  
7.269  
7.264  
7.260  
7.248

5.270  
5.249  
5.227  
5.211  
4.890  
4.866  
4.863  
4.847  
4.819  
4.816  
4.369  
4.362  
4.330  
4.325  
4.320  
4.310  
4.300  
4.261  
4.197  
4.191  
4.154  
4.148  
4.080  
4.070  
4.060  
4.051  
3.940  
3.934  
3.893  
3.887  
3.847  
3.838  
3.803  
3.795  
3.726  
3.717  
3.683  
3.674  
3.310  
3.290  
3.267  
3.247  
3.149  
3.129  
3.106  
3.086  
2.328  
2.321  
2.315  
2.237  
2.231  
2.225

Fig. 2: 2c, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



200.359  
199.910

168.261  
167.670

153.459  
153.178

138.267  
138.147  
137.127  
137.017  
136.322  
136.204  
129.082  
128.825  
128.181  
128.101  
127.982  
127.965  
127.668  
127.429  
127.406  
126.889  
121.813

78.696  
78.504  
77.479  
77.160  
76.842  
73.040  
72.500

51.422  
51.286  
50.834  
49.259

37.028  
35.472  
30.685  
30.447

Fig. 2: **2c**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )

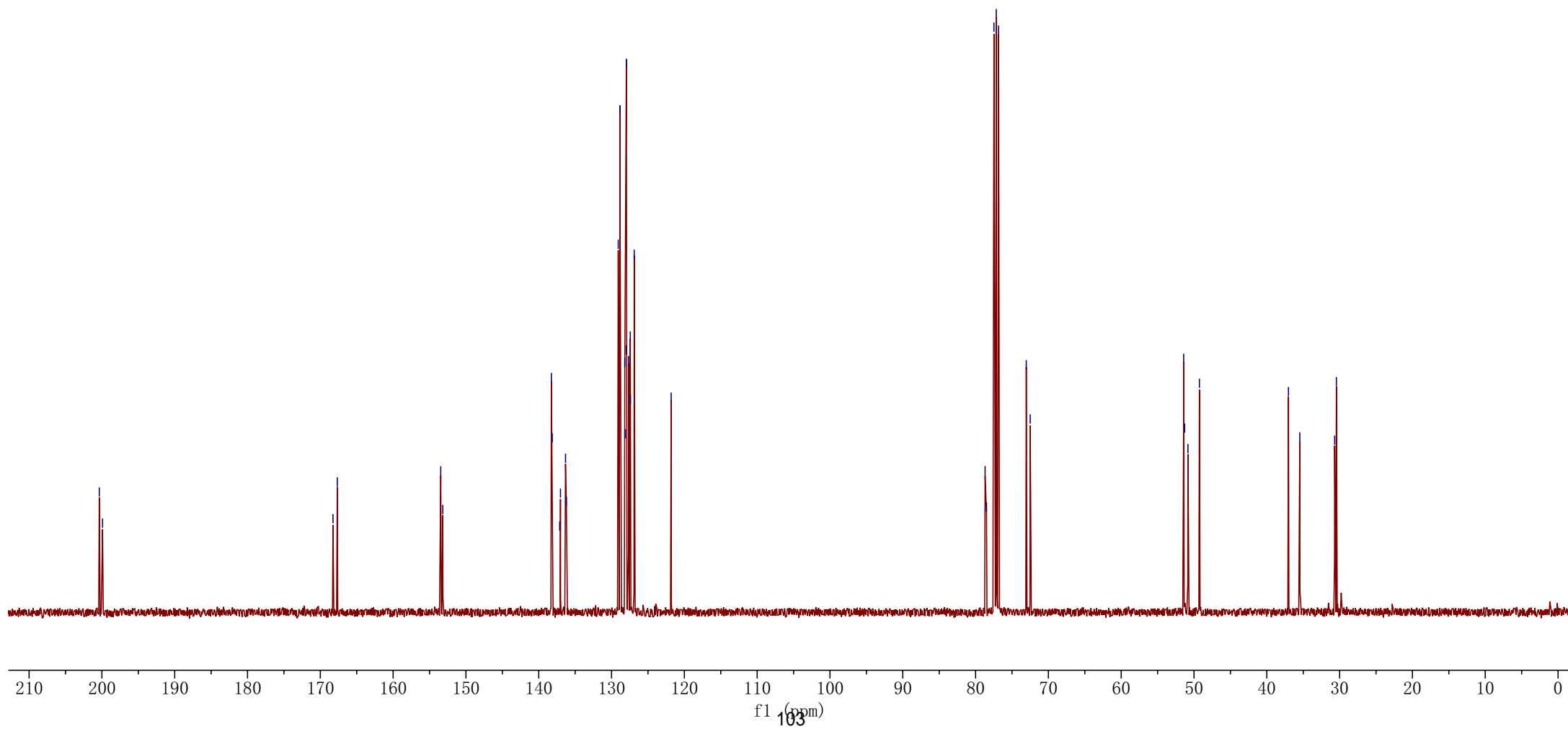
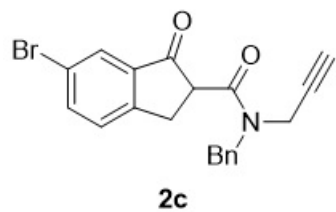
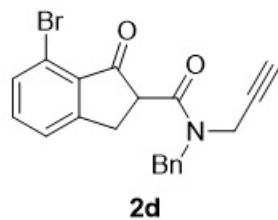


Fig. 2: 2d, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



7.536  
7.534  
7.518  
7.514  
7.496  
7.491  
7.479  
7.476  
7.460  
7.457  
7.439  
7.426  
7.421  
7.411  
7.406  
7.401  
7.396  
7.388  
7.380  
7.370  
7.363  
7.354  
7.351  
7.347  
7.336  
7.333  
7.330  
7.323  
7.315  
7.305  
7.286  
7.280  
7.268  
7.261  
7.244  
5.349  
5.306  
5.269  
5.231  
4.917  
4.913  
4.910  
4.907  
4.879  
4.869  
4.866  
4.863  
4.860  
4.836  
4.413  
4.407  
4.370  
4.363  
4.342  
4.333  
4.322  
4.313  
4.294  
4.256  
4.168  
4.162  
4.125  
4.118  
4.084  
4.074  
4.063  
4.054  
3.939  
3.932  
3.891  
3.885  
3.880  
3.847  
3.837  
3.777  
3.767  
3.734  
3.724  
3.309  
3.289  
3.265  
3.246  
3.146  
3.126  
3.103  
2.314  
2.308  
2.302  
2.231  
2.225  
2.219  
1.713  
0.078

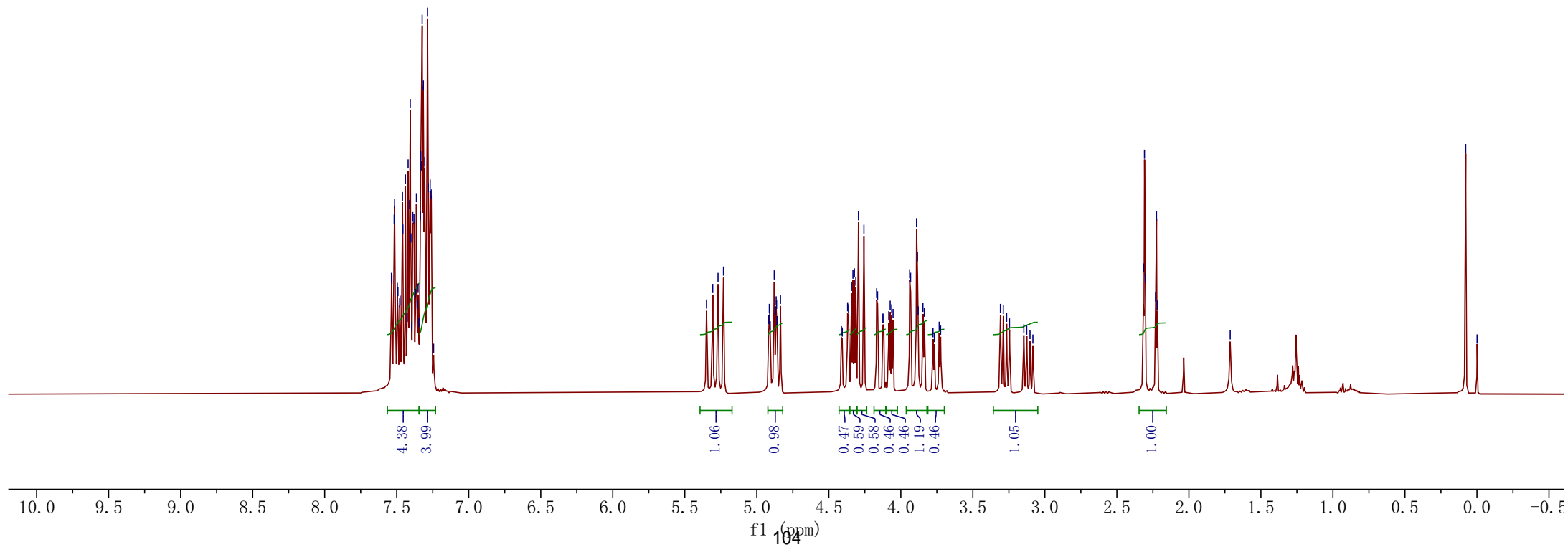
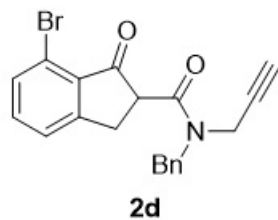


Fig. 2: **2d**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )

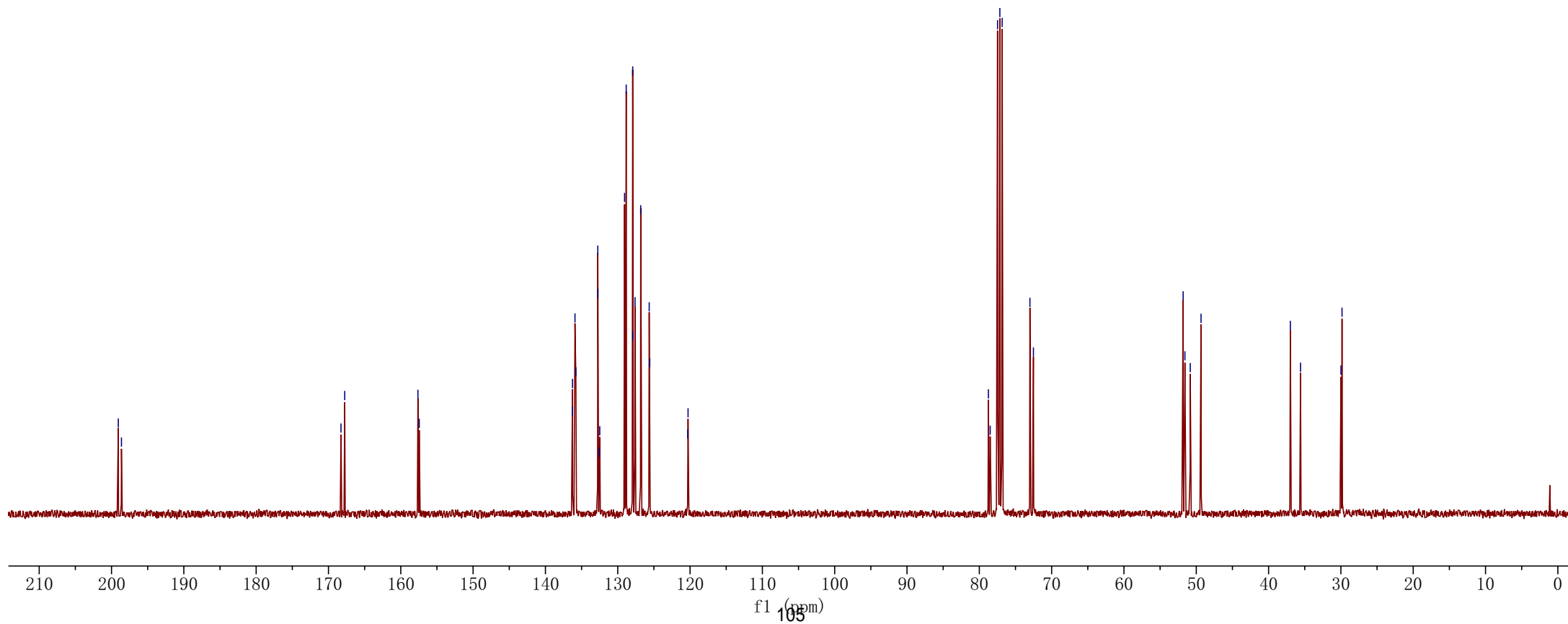


199.062  
198.627  
168.266  
167.754  
157.629  
157.448  
136.289  
136.249  
135.911  
135.791  
132.756  
132.744  
132.584  
132.485  
129.055  
128.827  
127.932  
127.899  
127.606  
126.824  
125.649  
125.573  
120.317  
120.276

78.743  
78.496  
77.479  
77.161  
76.843  
73.001  
72.517

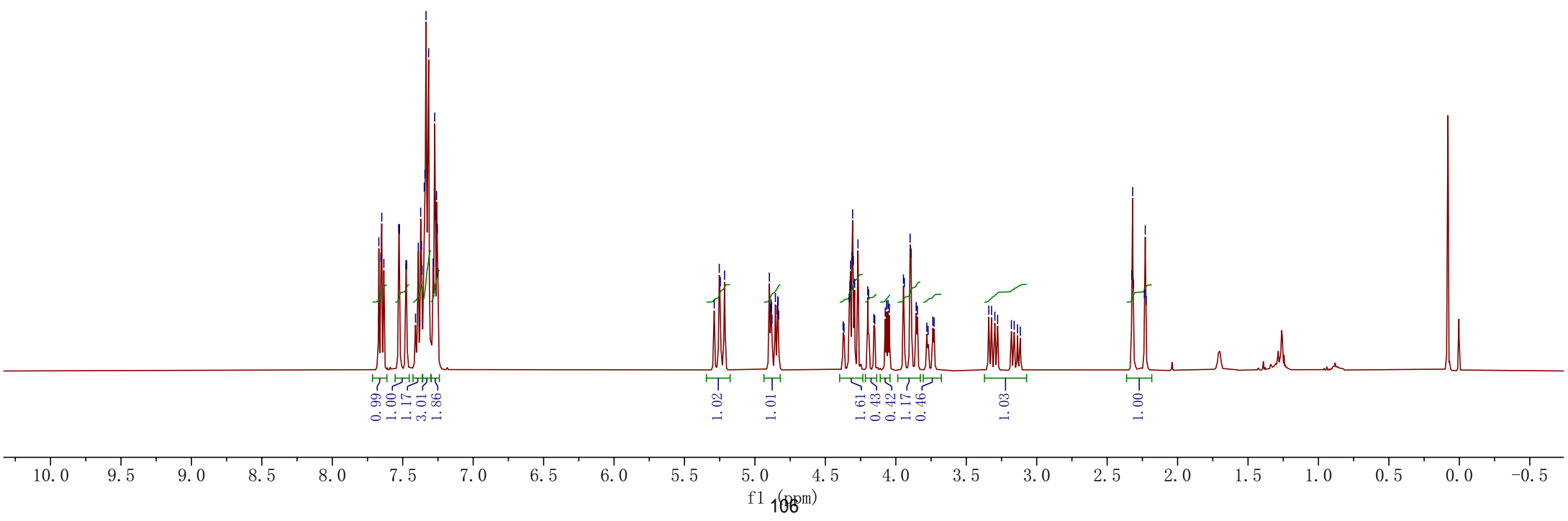
51.816  
51.570  
50.830  
49.342

36.991  
35.580  
29.994  
29.843



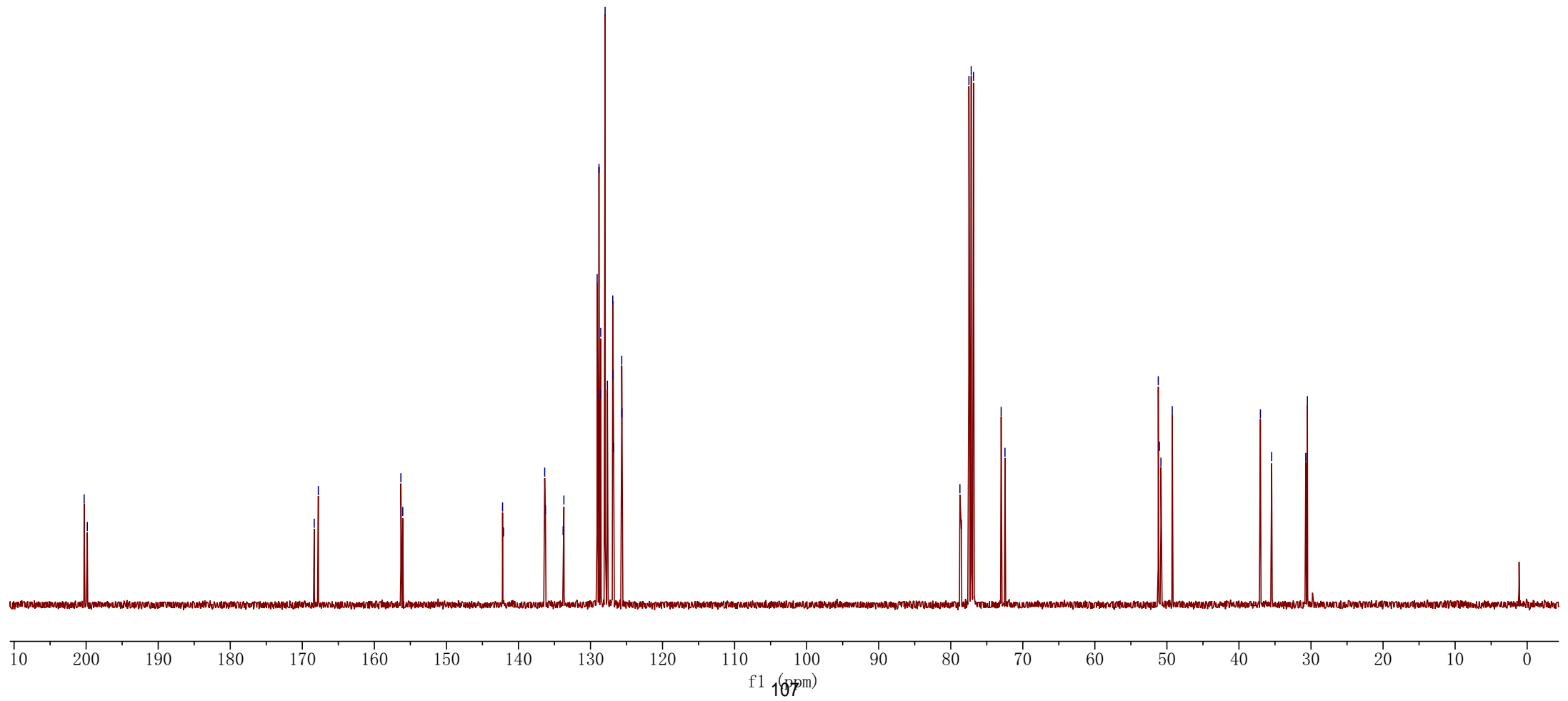
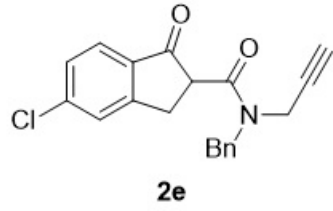
7.669  
7.655  
7.649  
7.634  
7.528  
7.524  
7.477  
7.473  
7.409  
7.390  
7.380  
7.373  
7.367  
7.363  
7.347  
7.342  
7.335  
7.316  
7.284  
7.273  
7.267  
7.260  
7.254  
7.251  
5.289  
5.253  
5.246  
5.216  
4.898  
4.889  
4.885  
4.883  
4.879  
4.855  
4.842  
4.838  
4.835  
4.832  
4.374  
4.368  
4.331  
4.325  
4.321  
4.312  
4.307  
4.302  
4.292  
4.269  
4.199  
4.193  
4.156  
4.149  
4.075  
4.066  
4.055  
4.046  
3.946  
3.940  
3.899  
3.892  
3.856  
3.847  
3.780  
3.771  
3.737  
3.728  
3.340  
3.321  
3.297  
3.277  
3.180  
3.160  
3.136  
3.117  
2.325  
2.319  
2.313  
2.236  
2.229  
2.223

Fig. 2: 2e, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



200.278  
199.841  
168.343  
167.775  
156.314  
156.057  
142.204  
142.065  
136.356  
136.251  
133.799  
133.691  
129.080  
128.823  
128.578  
128.565  
127.971  
127.653  
126.910  
126.863  
126.785  
125.663  
125.644  
78.730  
78.531  
77.479  
77.160  
76.843  
73.006  
72.473  
51.198  
51.043  
50.829  
49.260  
37.025  
35.462  
30.729  
30.503

Fig. 2: **2e**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



7.516  
7.505  
7.495  
7.484  
7.465  
7.454  
7.444  
7.432  
7.413  
7.393  
7.377  
7.367  
7.360  
7.338  
7.320  
7.310  
7.289  
7.277  
7.260

5.277  
5.256  
5.234  
5.218  
4.900  
4.871  
4.857  
4.824  
4.374  
4.368  
4.358  
4.349  
4.339  
4.330  
4.325  
4.311  
4.273  
4.256  
4.249  
4.211  
4.205  
4.168  
4.162  
4.109  
4.100  
4.089  
4.080  
3.950  
3.944  
3.903  
3.897  
3.873  
3.865  
3.830  
3.820  
3.752  
3.741  
3.709  
3.699  
3.342  
3.322  
3.299  
3.280  
3.181  
3.161  
3.138  
3.119  
2.325  
2.319  
2.313  
2.237  
2.231  
2.225  
1.665  
0.000

Fig. 2: 2f, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)

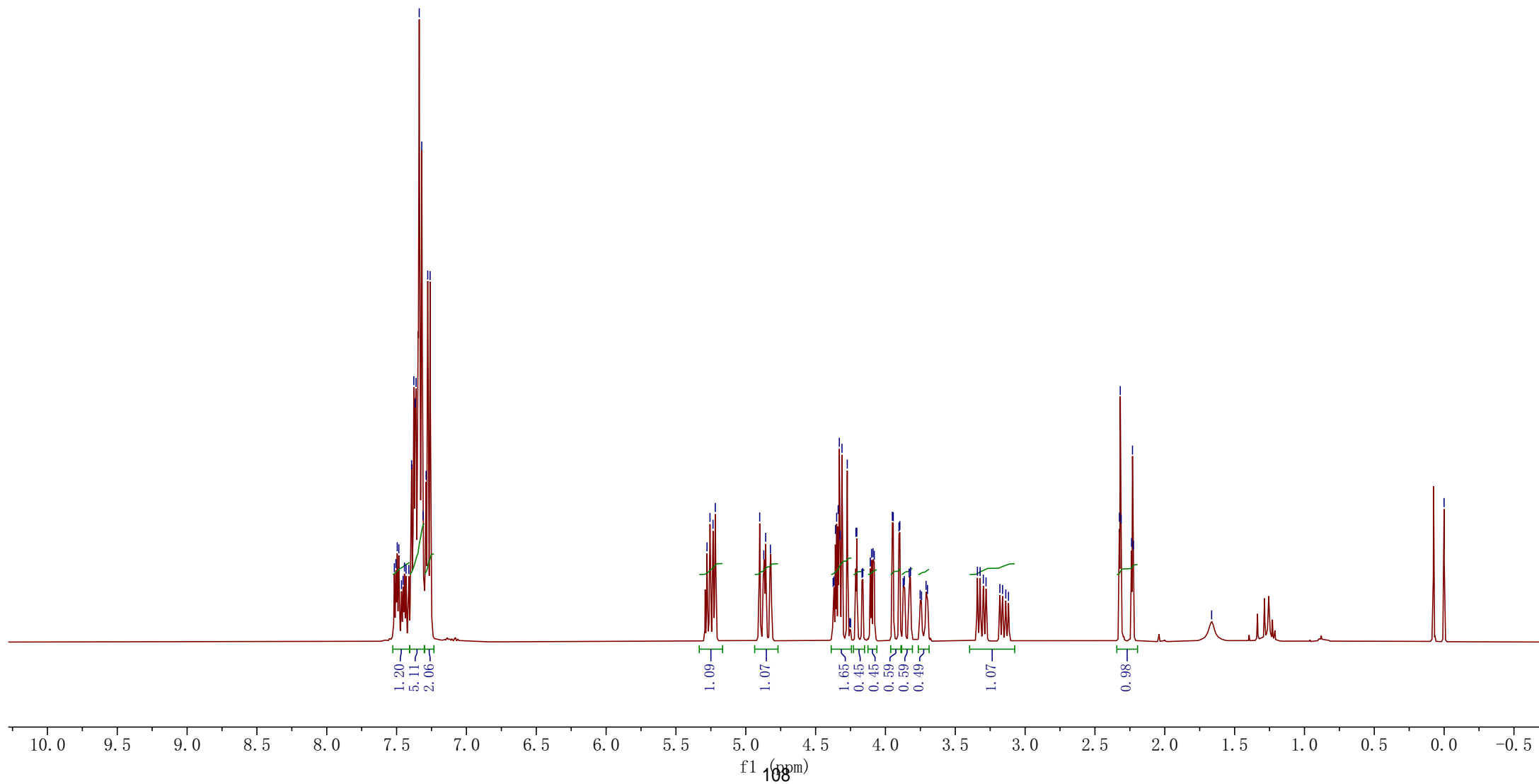
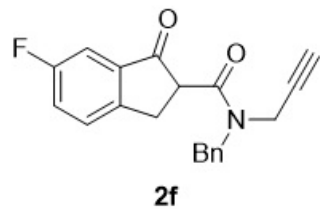
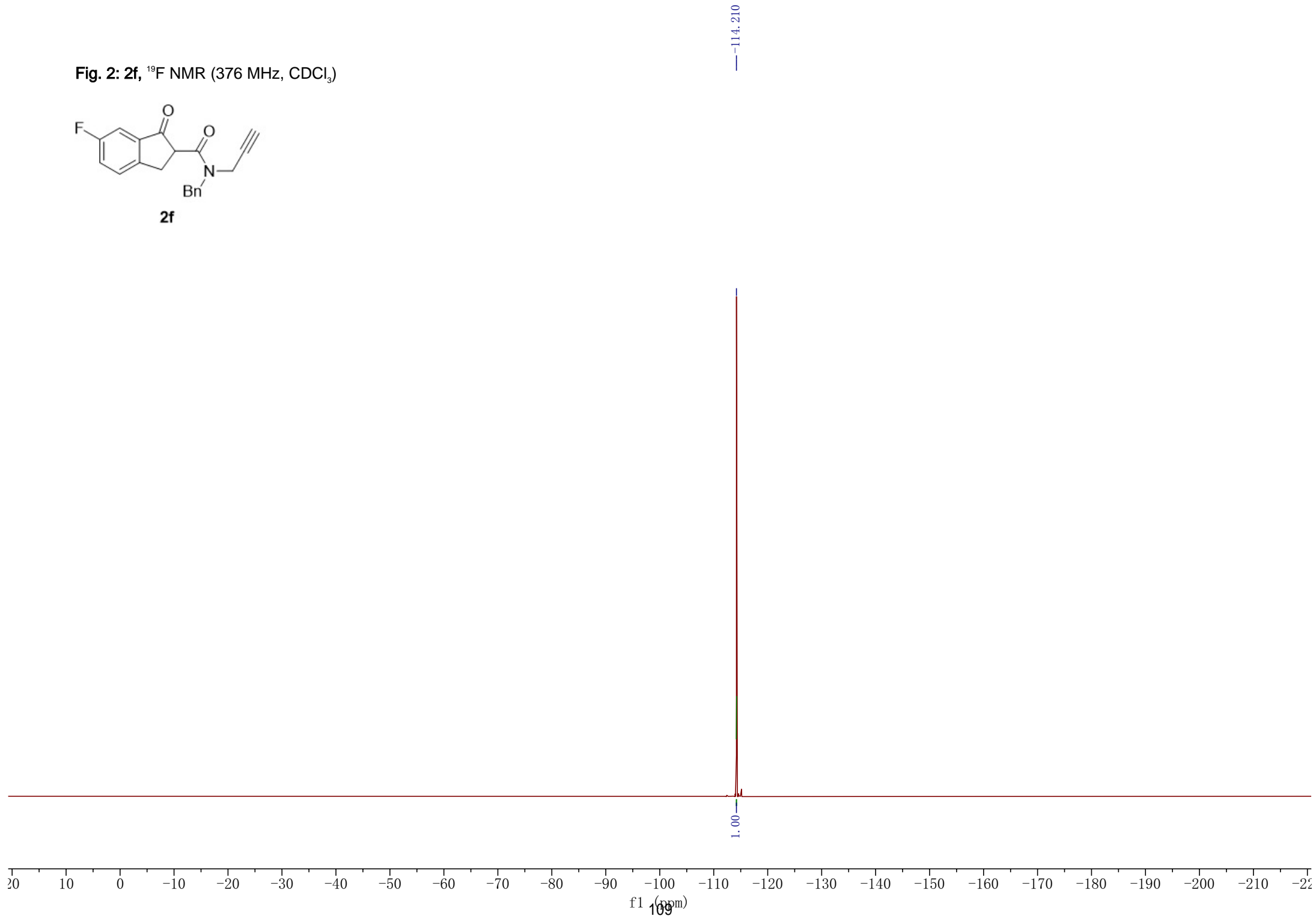
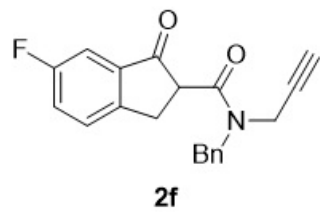




Fig. 2: **2f**,  $^{19}\text{F}$  NMR (376 MHz,  $\text{CDCl}_3$ )



200.875  
200.844  
200.434  
200.402

168.426  
167.829  
163.766  
161.299

150.383  
150.362  
150.098  
150.077

137.092  
137.019  
136.961  
136.886  
136.398  
136.287

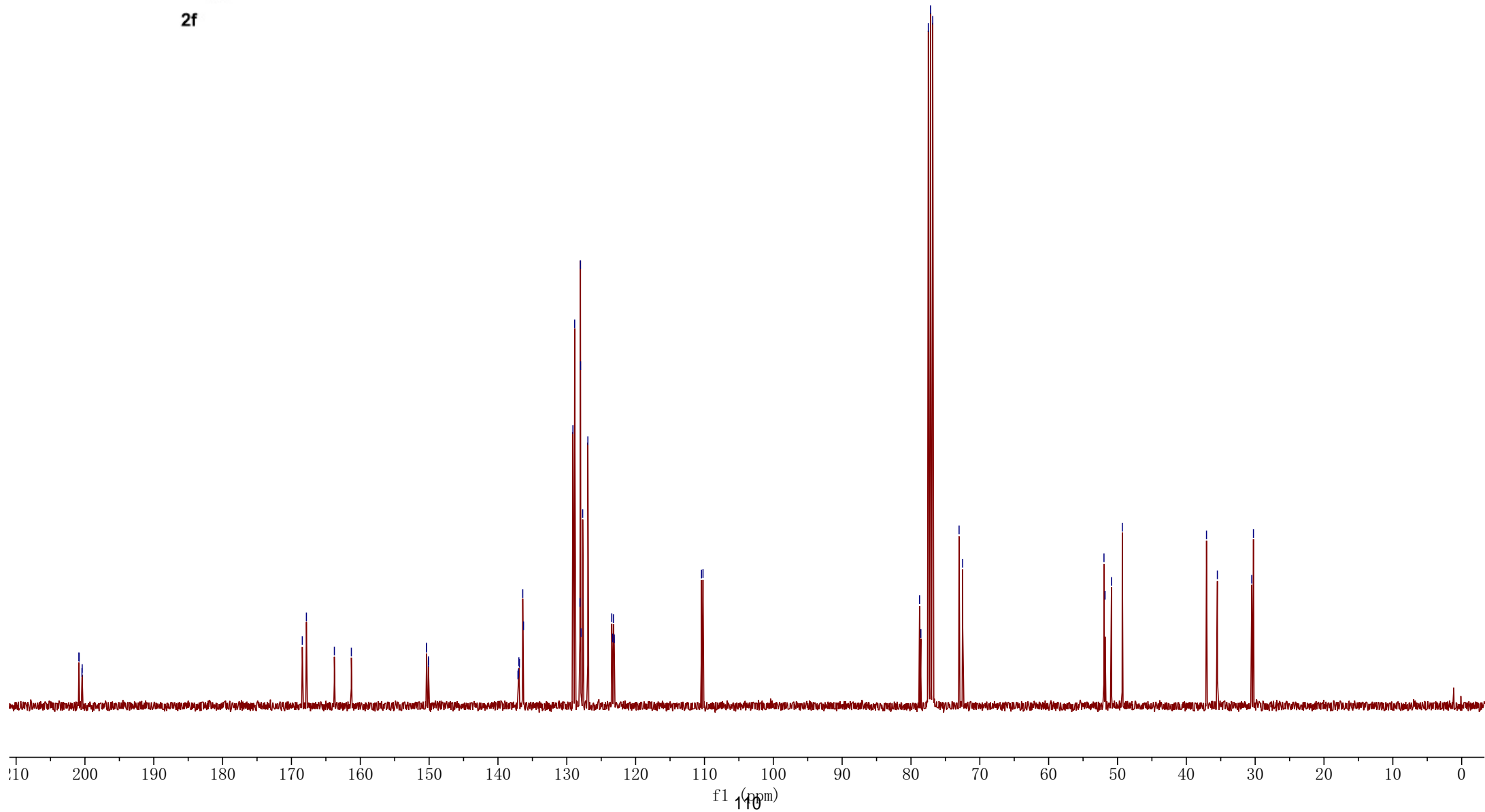
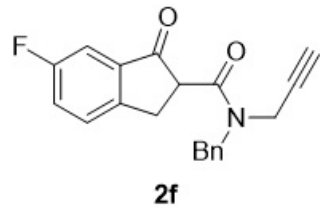
129.111  
128.855  
128.086  
128.020  
128.004  
127.923  
127.692  
126.937  
123.470  
123.341  
123.233  
123.106  
110.431  
110.211

78.752  
78.562  
77.478  
77.160  
76.843  
73.010  
72.487

51.962  
51.804  
50.876  
49.301

37.068  
35.489  
30.493  
30.249

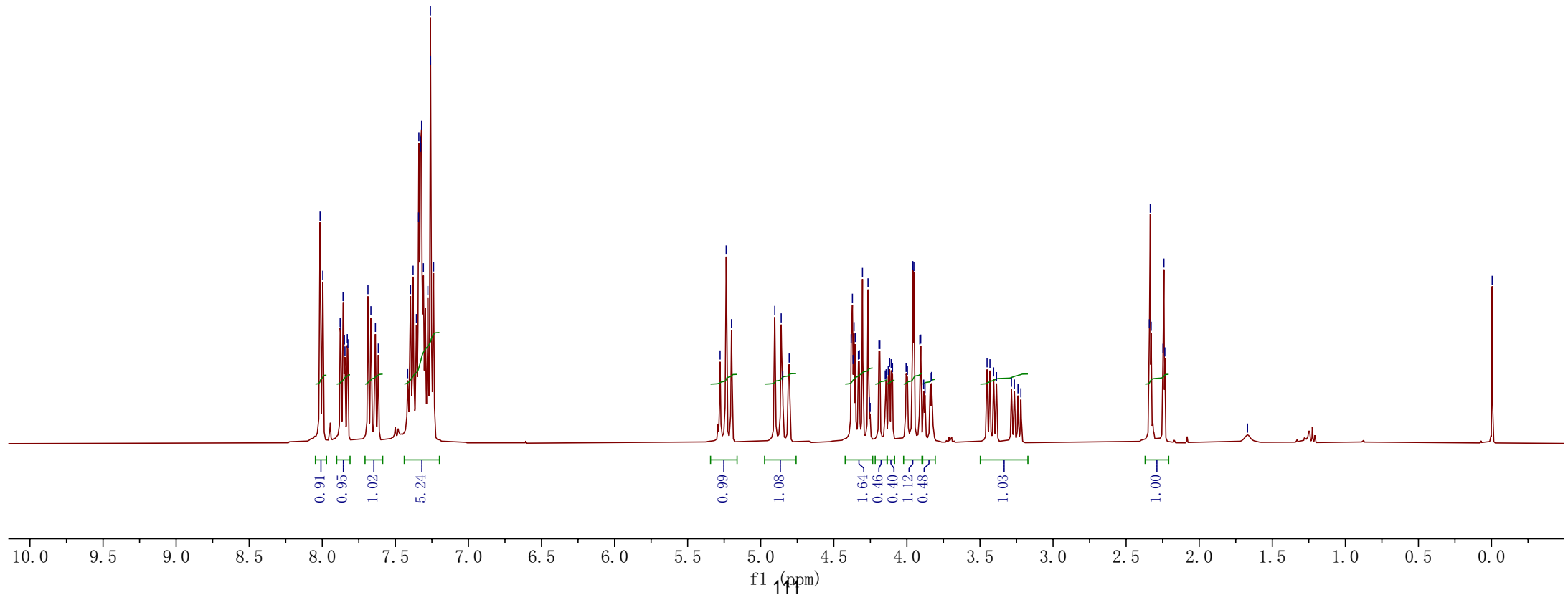
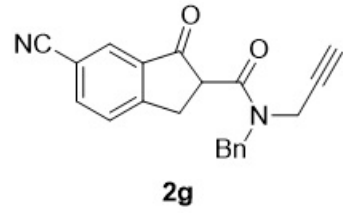
Fig. 2: 2f,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



8.015  
7.996  
7.878  
7.874  
7.858  
7.854  
7.849  
7.829  
7.825  
7.687  
7.667  
7.636  
7.617  
7.416  
7.396  
7.379  
7.356  
7.341  
7.339  
7.328  
7.327  
7.320  
7.308  
7.278  
7.260  
7.259  
7.239

5.278  
5.236  
5.200  
4.904  
4.860  
4.849  
4.805  
4.381  
4.373  
4.368  
4.362  
4.353  
4.332  
4.326  
4.304  
4.266  
4.257  
4.251  
4.191  
4.185  
4.148  
4.142  
4.127  
4.118  
4.107  
4.098  
4.005  
3.996  
3.959  
3.952  
3.911  
3.905  
3.885  
3.876  
3.840  
3.831  
3.452  
3.432  
3.407  
3.387  
3.285  
3.265  
3.240  
3.220  
2.341  
2.335  
2.329  
2.248  
2.241  
2.235  
1.669  
-0.005

Fig. 2: **2g**, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



199.871  
199.401

167.771  
167.204

158.912  
158.649

137.957  
137.853  
136.146  
136.023  
135.986  
135.887  
129.144  
128.870  
128.844  
128.803  
128.078  
127.956  
127.901  
127.825  
127.768  
126.851  
117.928

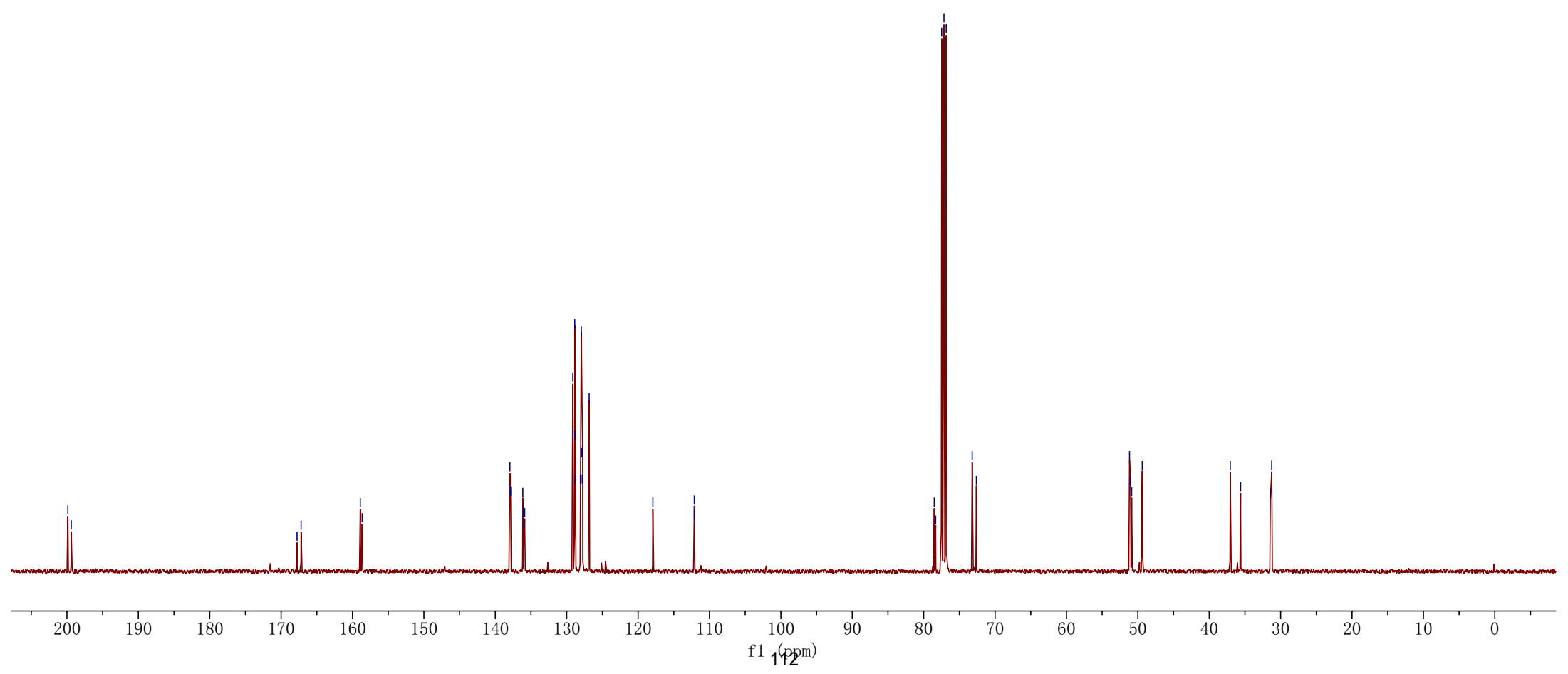
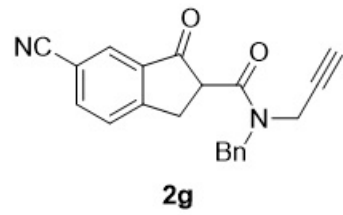
112.128  
112.113

78.517  
78.323  
77.478  
77.160  
76.842  
73.208  
72.618

51.166  
51.021  
50.871  
49.382

37.060  
35.608  
31.446  
31.246

Fig. 2: 2g, <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)



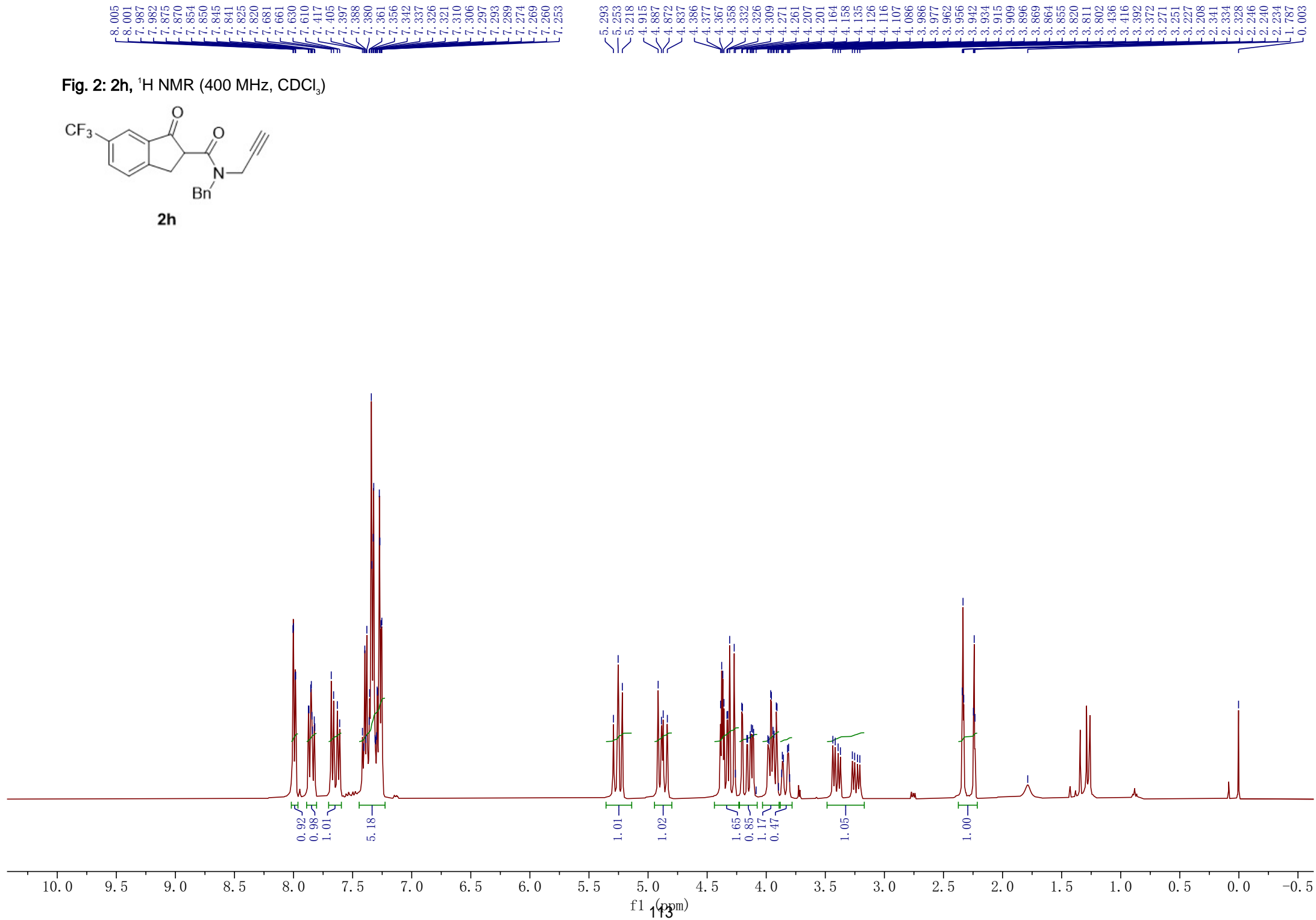
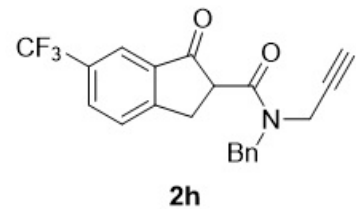
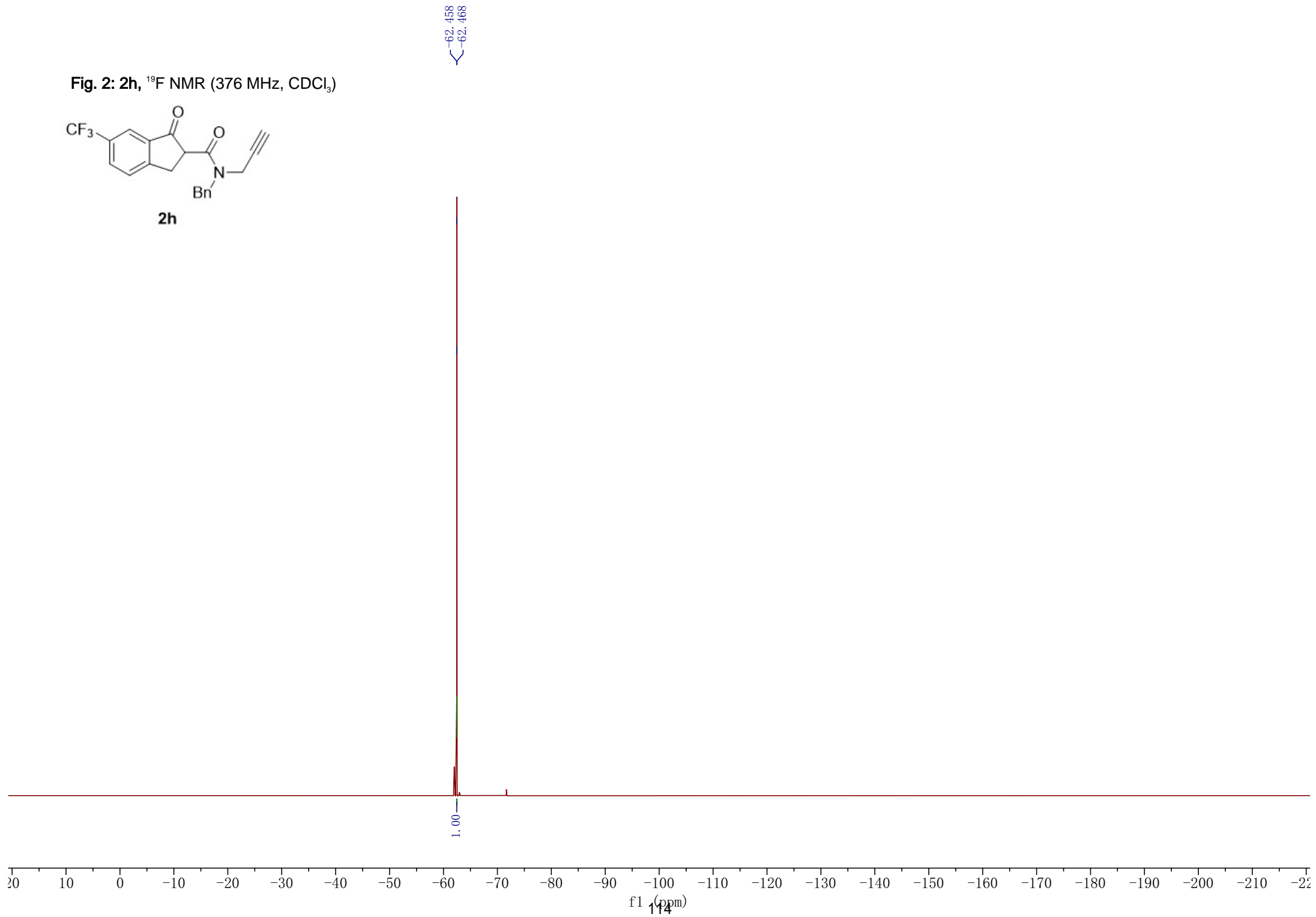
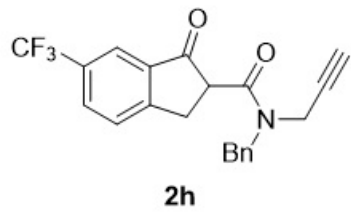


Fig. 2: 2h,  $^{19}\text{F}$  NMR (376 MHz,  $\text{CDCl}_3$ )



200.601  
200.134

168.092  
167.517

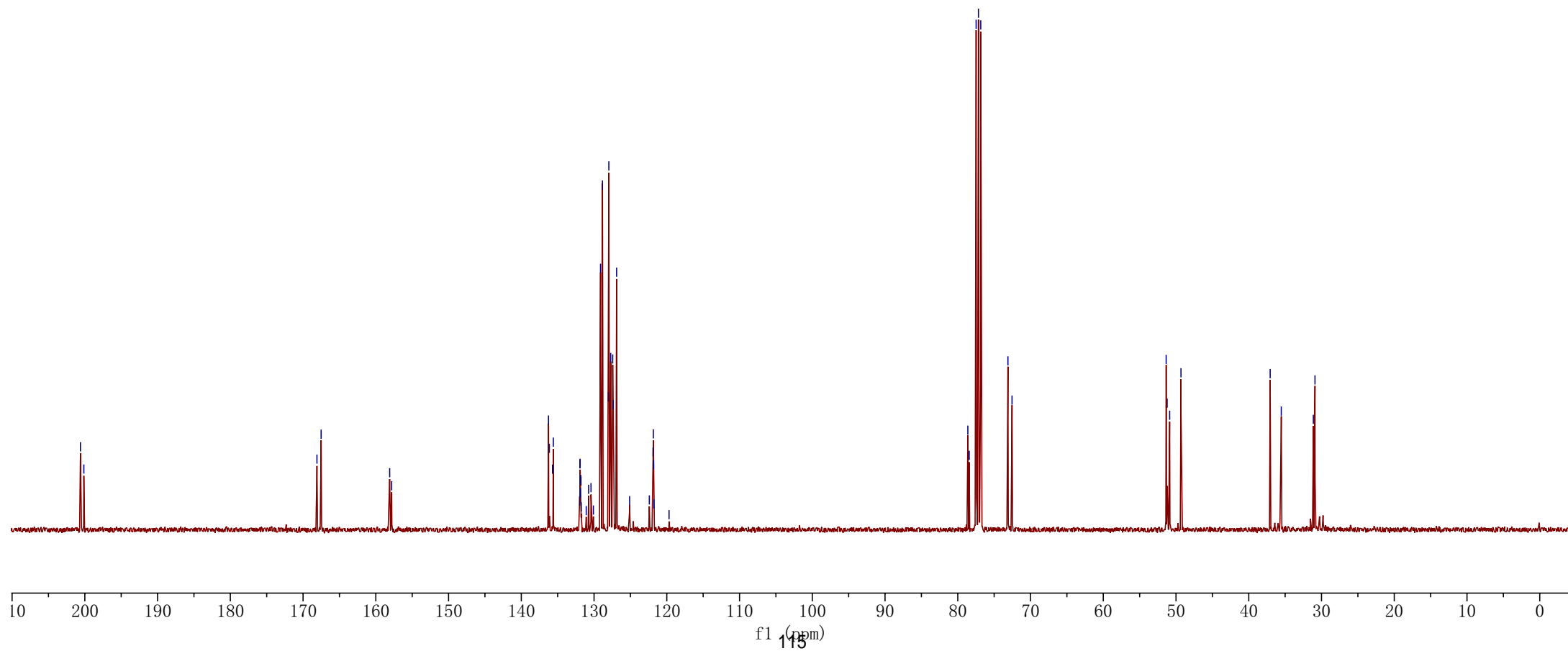
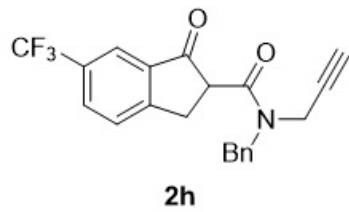
158.095  
157.824  
136.266  
136.146  
135.708  
135.600  
131.981  
131.947  
131.913  
131.877  
131.831  
131.797  
131.762  
131.075  
130.746  
130.418  
130.089  
129.111  
128.845  
128.028  
127.966  
127.711  
127.436  
127.356  
126.898  
125.108  
122.401  
121.888  
121.850  
121.814  
121.777  
119.693

78.616  
78.431  
77.477  
77.160  
76.842  
73.104  
72.542

51.354  
51.223  
50.875  
49.318

37.056  
35.531  
31.124  
30.896

Fig. 2: 2h,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )







201.912  
201.504

168.843  
168.219

156.971  
156.890

143.754  
143.468

136.763  
136.628  
136.450

136.271  
129.221  
128.970

128.717  
127.905  
127.838  
127.498  
126.884

115.913  
115.661  
115.544

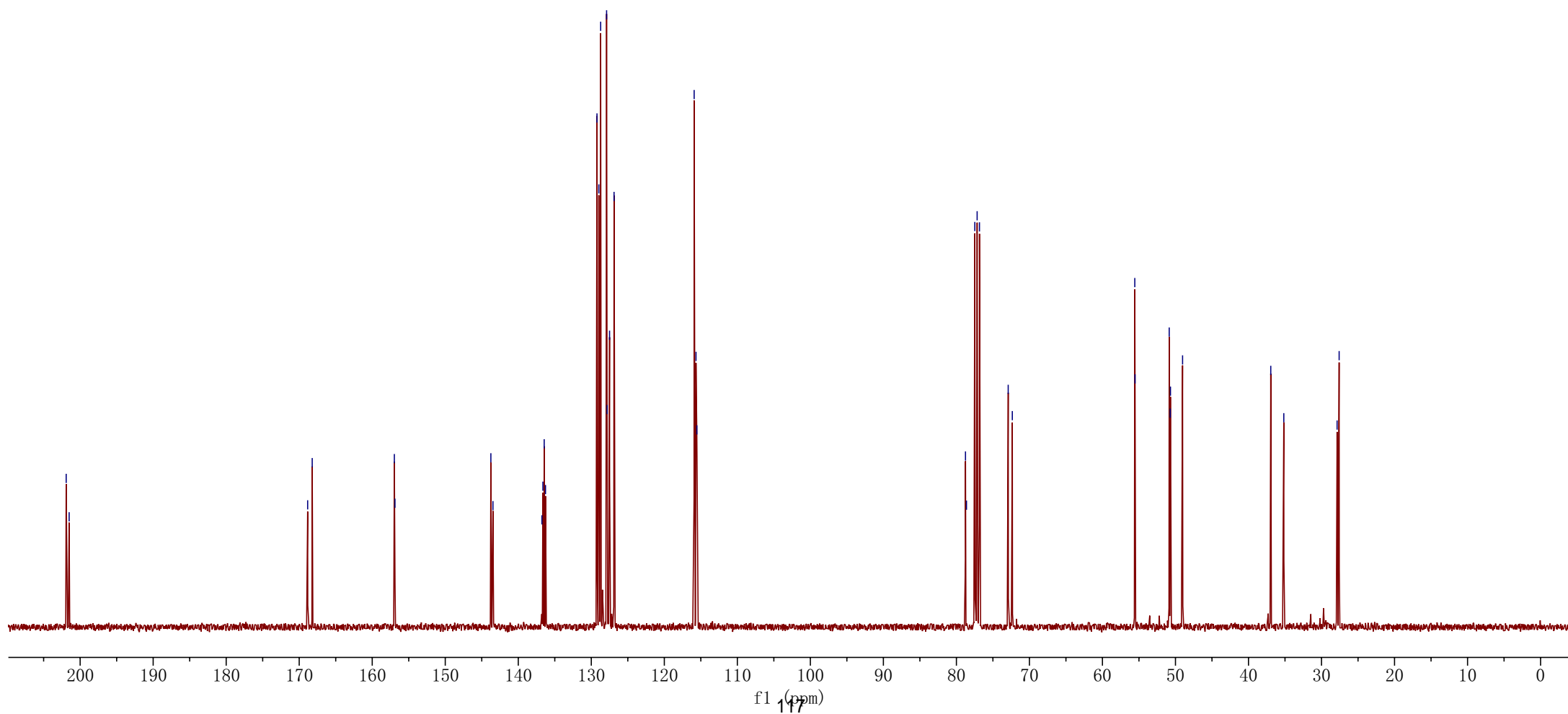
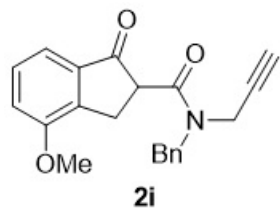
78.756  
78.619  
77.478  
77.160  
76.843  
72.906  
72.343

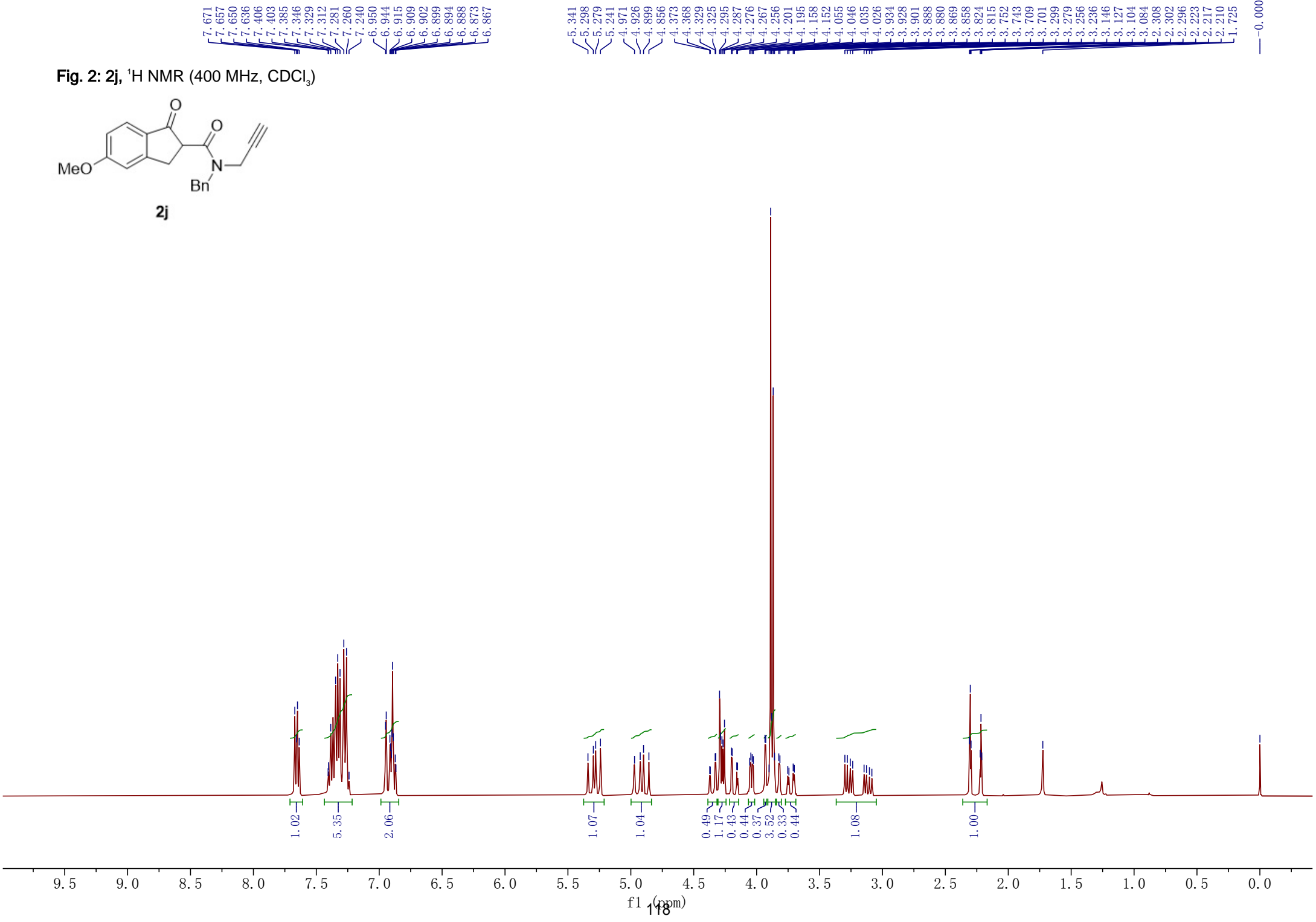
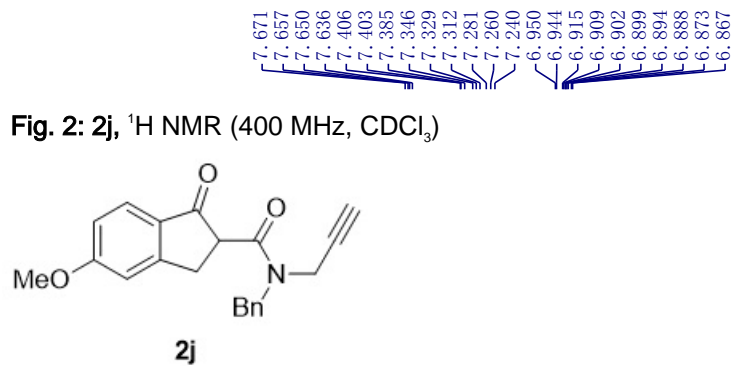
55.570  
55.535  
50.857  
50.717  
50.684  
49.026

36.949  
35.164

27.867  
27.585

Fig. 2: **2i**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )





199.737  
199.345

169.034  
168.474  
166.072  
165.963

158.081  
157.796

136.536  
136.506  
129.034  
128.818  
128.569  
128.447  
127.967  
127.876  
127.574  
126.995  
126.305  
126.288  
116.060  
115.997

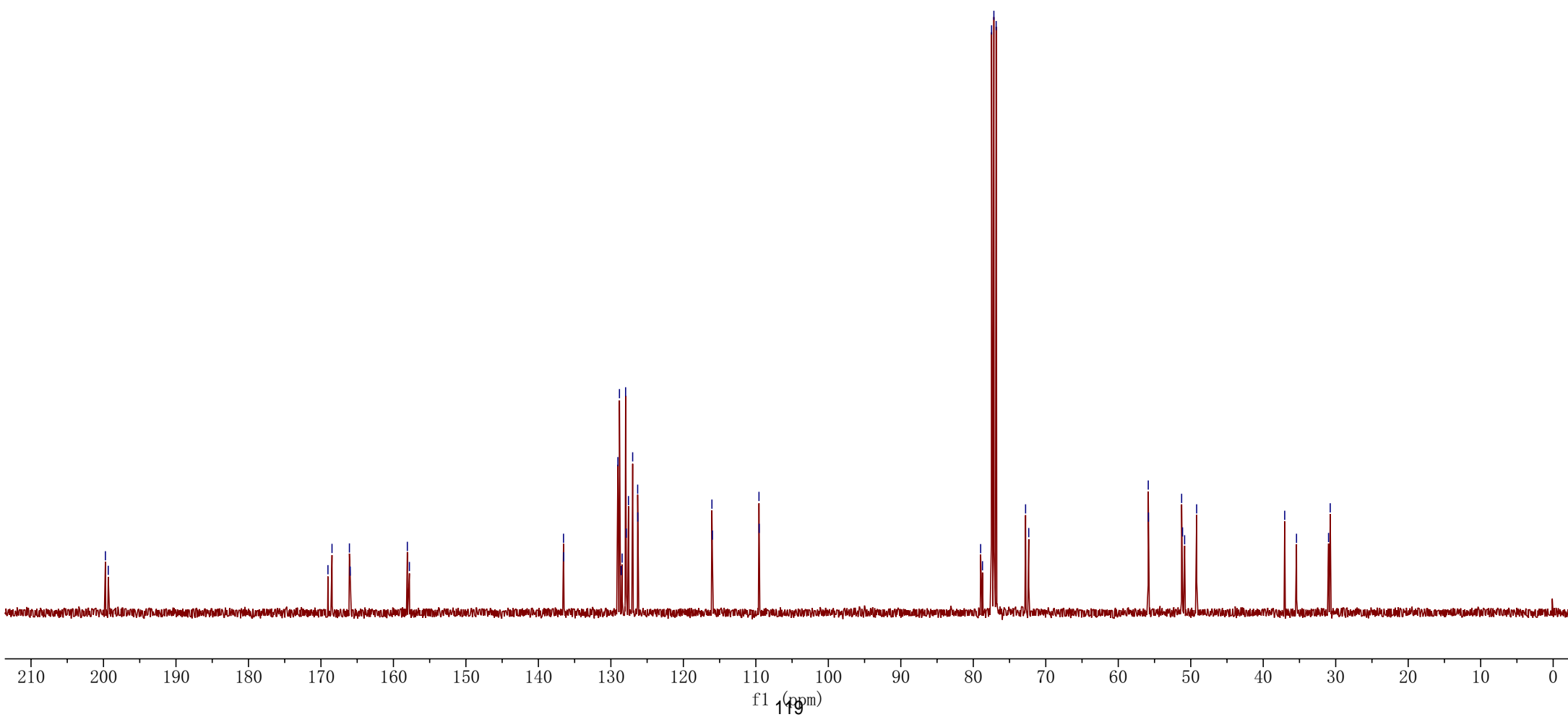
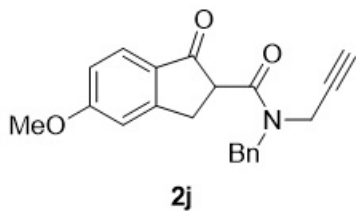
109.568  
109.539

78.986  
78.731  
77.478  
77.160  
76.843  
72.786  
72.350

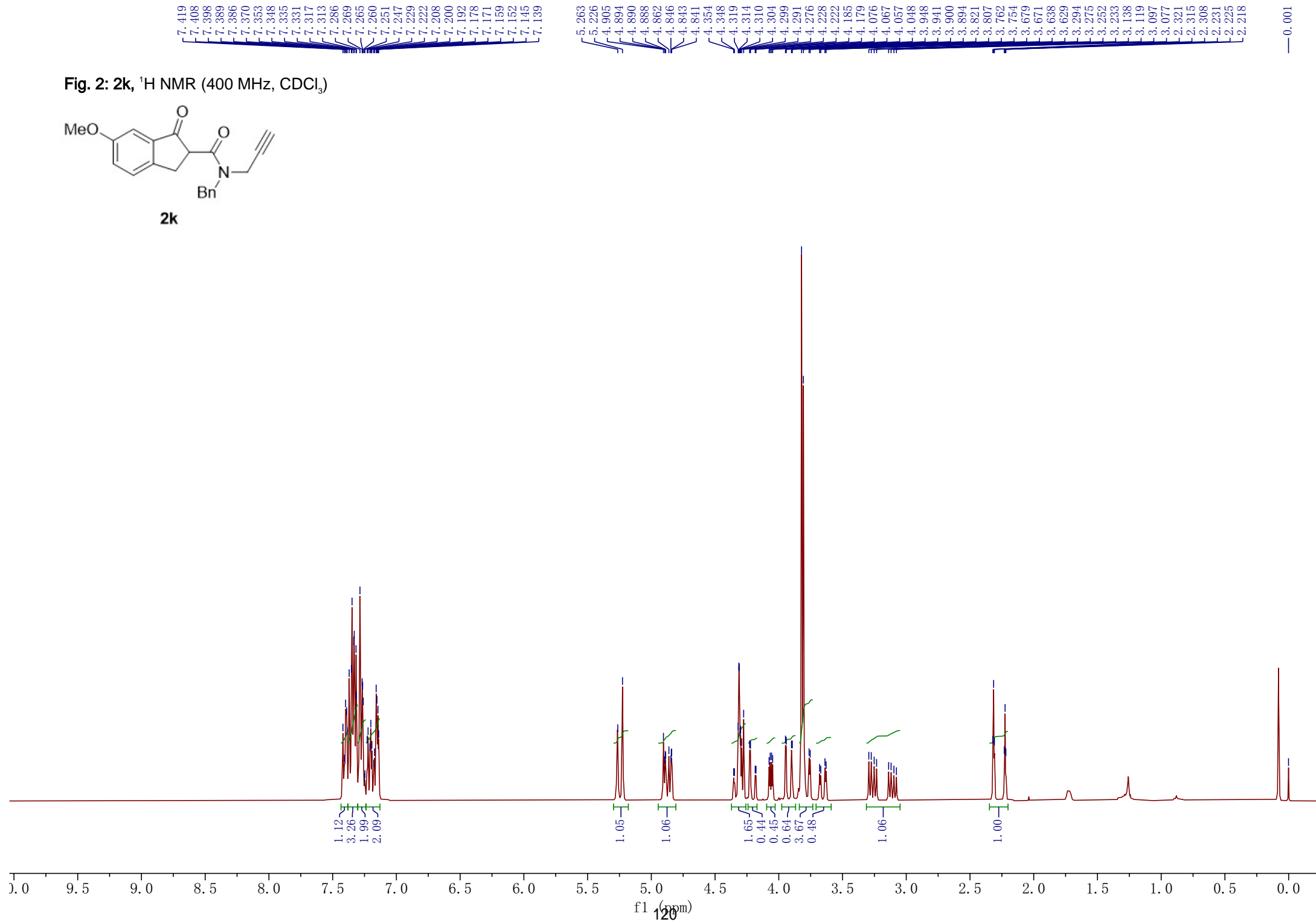
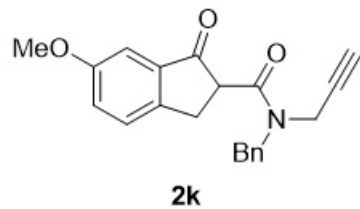
55.862  
55.837  
51.257  
51.132  
50.846  
49.185

37.038  
35.409  
30.989  
30.755

Fig. 2: **2j**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



**Fig. 2: 2k**, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



201.693  
201.272

168.860  
168.242

159.658

147.857  
147.547

136.503  
136.367  
136.353

129.034  
128.788  
127.980  
127.911  
127.581  
127.311  
127.225

126.968  
125.015  
124.876

105.615

78.847  
78.671  
77.478  
77.160  
76.842  
72.886  
72.371

55.709  
51.809  
51.659  
50.821  
49.135

37.023  
35.304

30.345  
30.053

Fig. 2: 2k,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )

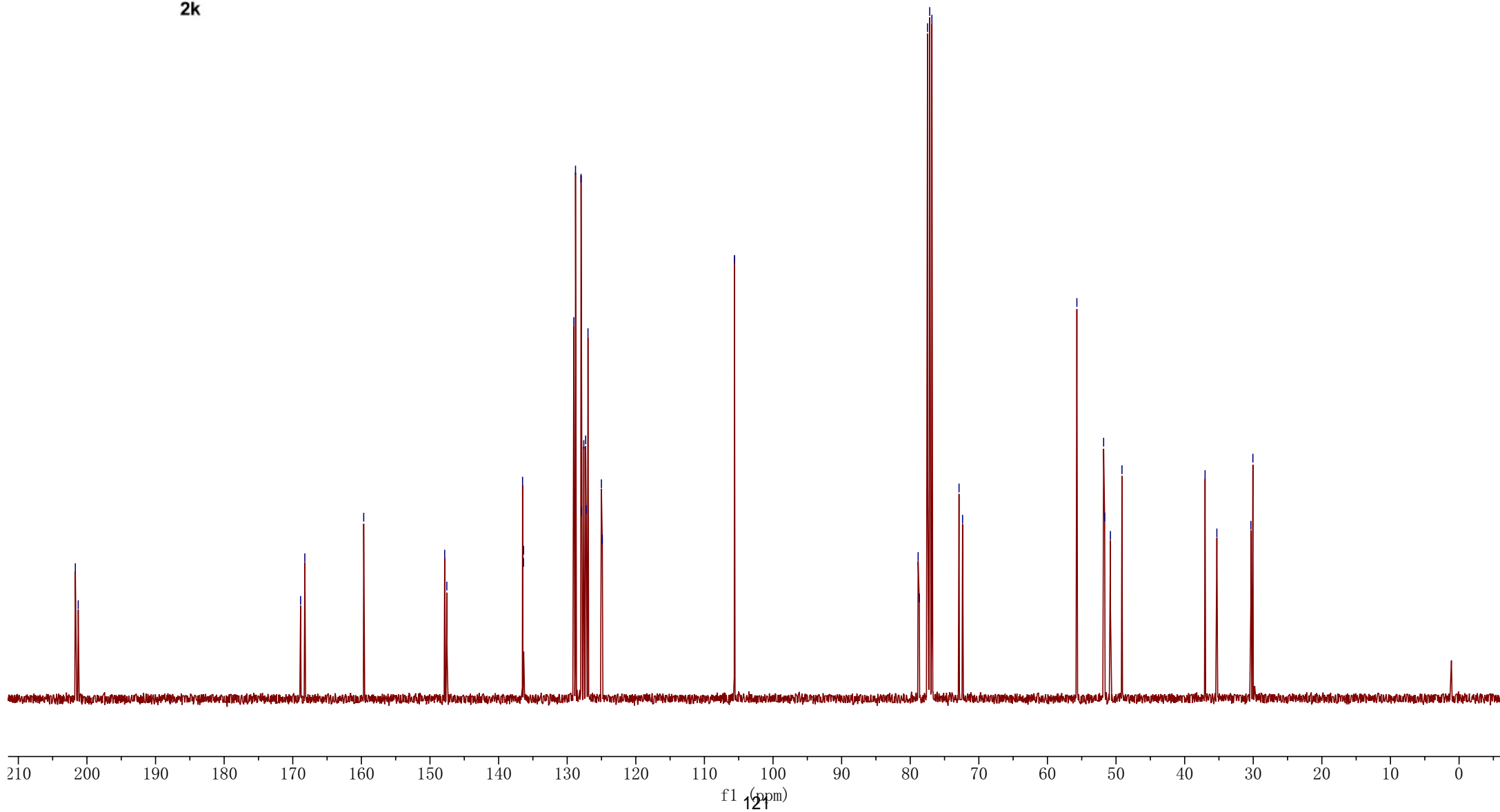
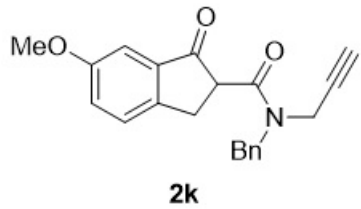


Fig. 2: 2I, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)

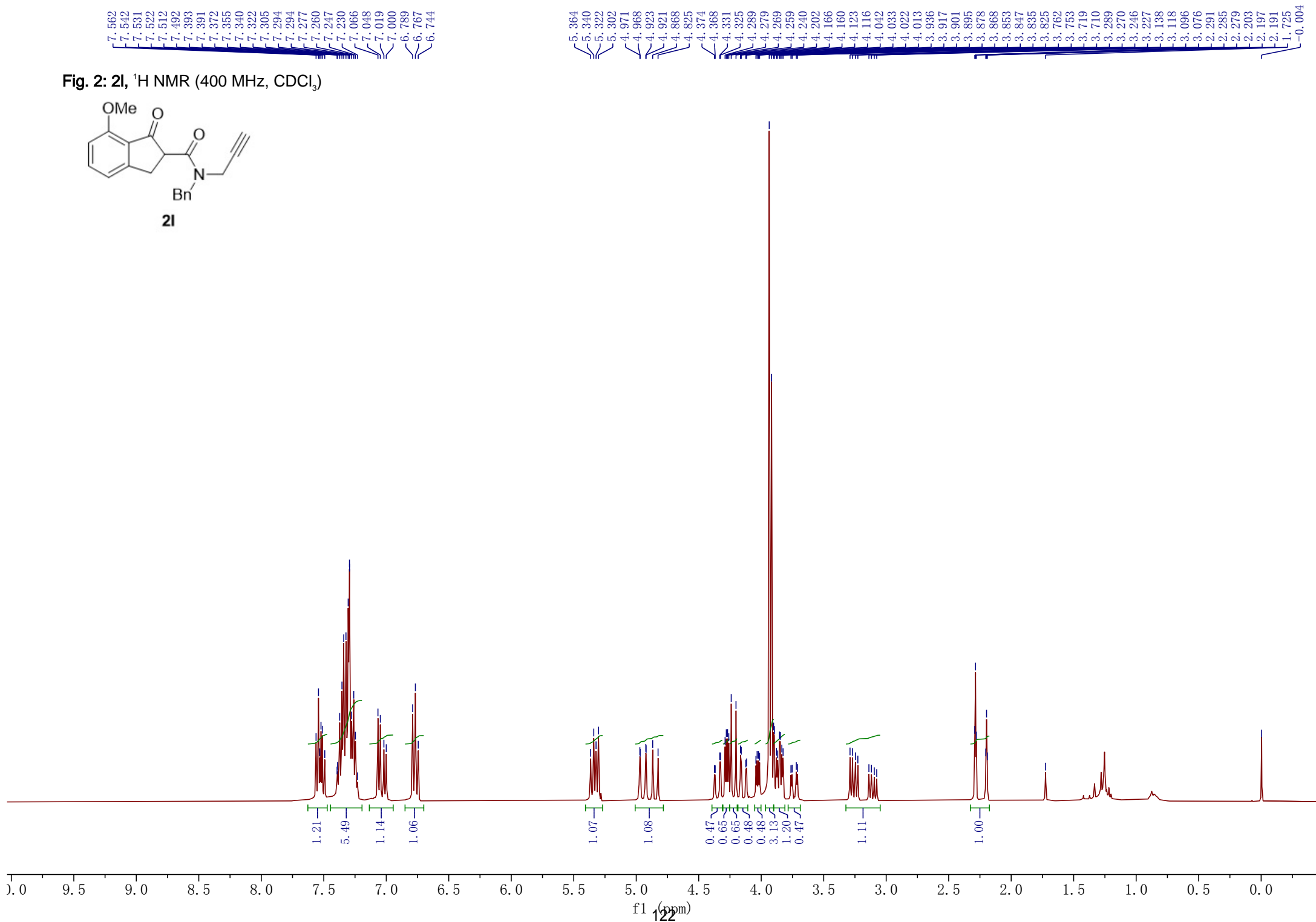
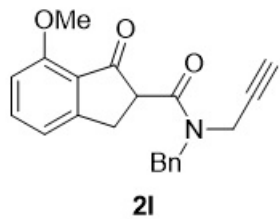
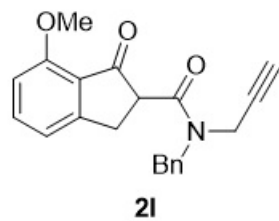


Fig. 2: **2l**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



199.199  
198.769

168.738  
168.267

158.670  
158.639  
157.237  
157.101

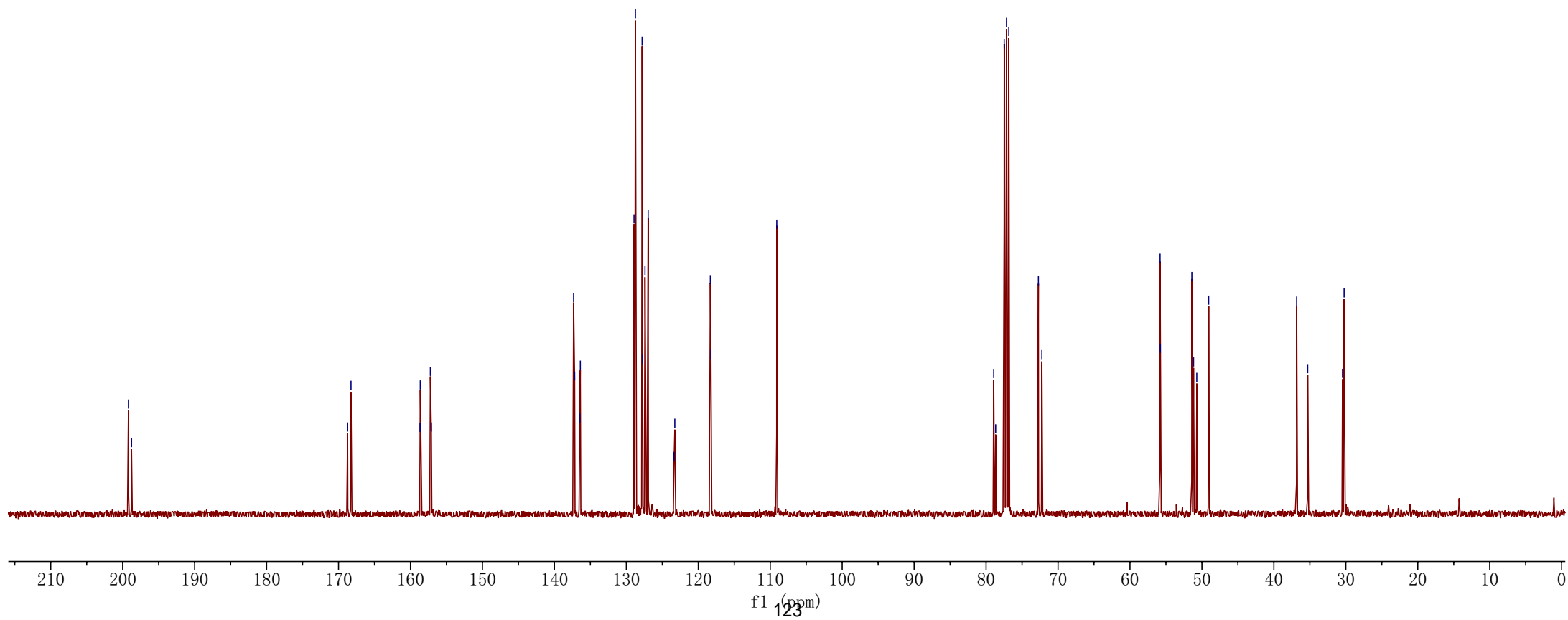
137.325  
137.187  
136.478  
136.393  
128.933  
128.739  
127.806  
127.749  
127.407  
126.969  
123.373  
123.264  
118.326  
118.242

109.093

78.937  
78.669  
77.479  
77.160  
76.842  
72.727  
72.245

55.813  
55.777  
51.401  
51.164  
50.716  
49.062

36.832  
35.301  
30.460  
30.239



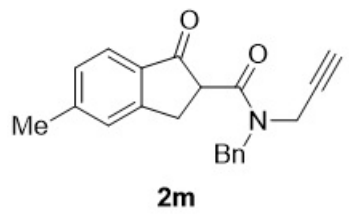
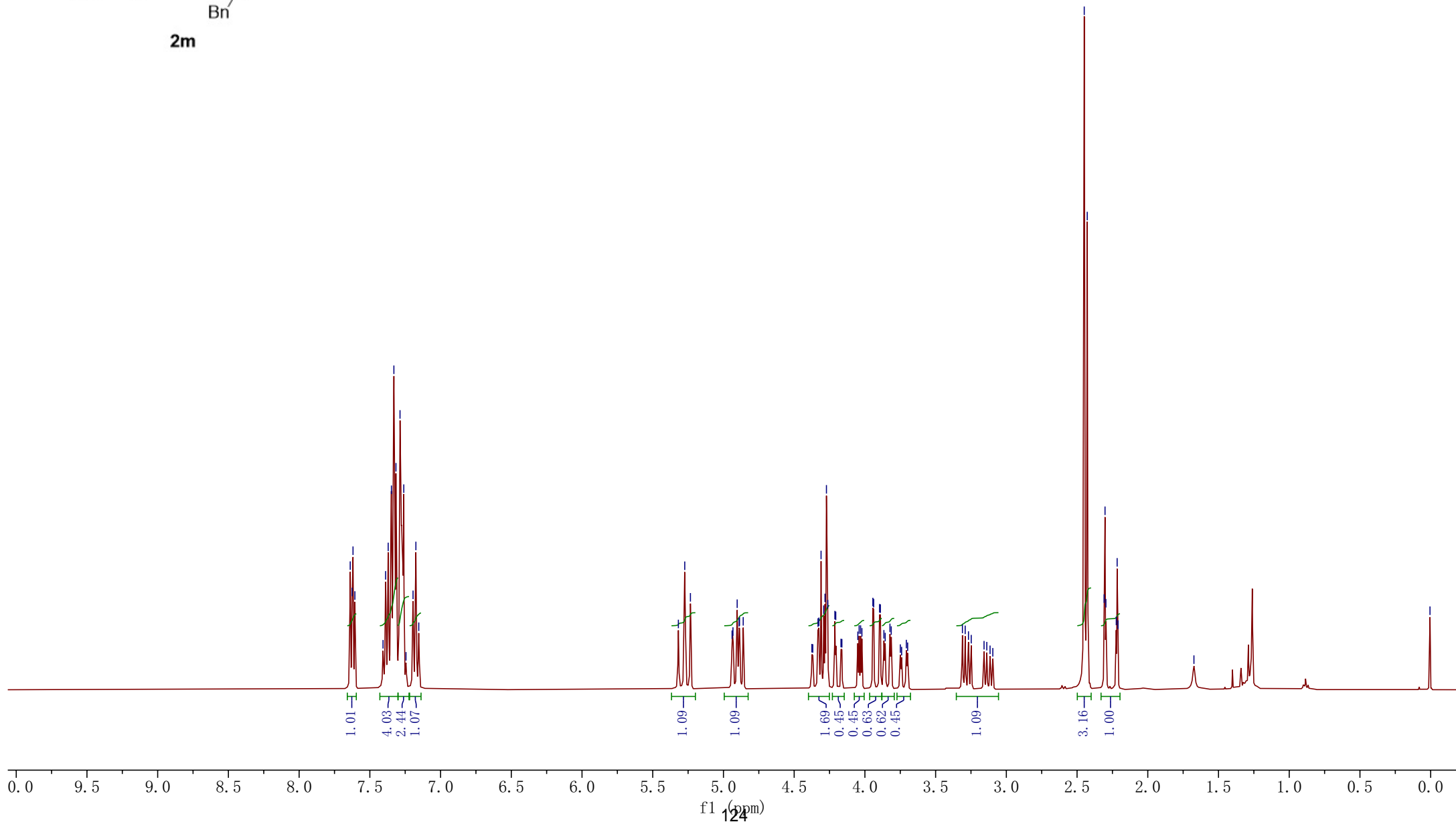


Fig. 2: 2m, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)

7.639  
7.626  
7.619  
7.606  
7.407  
7.389  
7.370  
7.347  
7.330  
7.315  
7.287  
7.260  
7.245  
7.195  
7.174  
7.154

5.319  
5.274  
5.234  
4.939  
4.933  
4.903  
4.889  
4.886  
4.860  
4.375  
4.368  
4.332  
4.325  
4.310  
4.291  
4.282  
4.272  
4.263  
4.212  
4.206  
4.169  
4.163  
4.050  
4.041  
4.030  
4.021  
3.944  
3.938  
3.896  
3.890  
3.866  
3.857  
3.823  
3.814  
3.750  
3.740  
3.707  
3.698  
3.310  
3.291  
3.268  
3.248  
3.158  
3.138  
3.115  
3.096  
2.449  
2.428  
2.309  
2.296  
2.223  
2.217  
2.210  
1.674  
0.005





201.059  
200.644

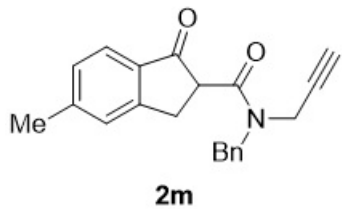
168.836  
168.257

155.321  
155.058

146.839  
146.691

136.458  
136.397  
133.032  
132.915  
128.933  
128.912  
128.702  
127.896  
127.784  
127.471  
126.890  
126.806  
124.325

Fig. 2: 2m,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )

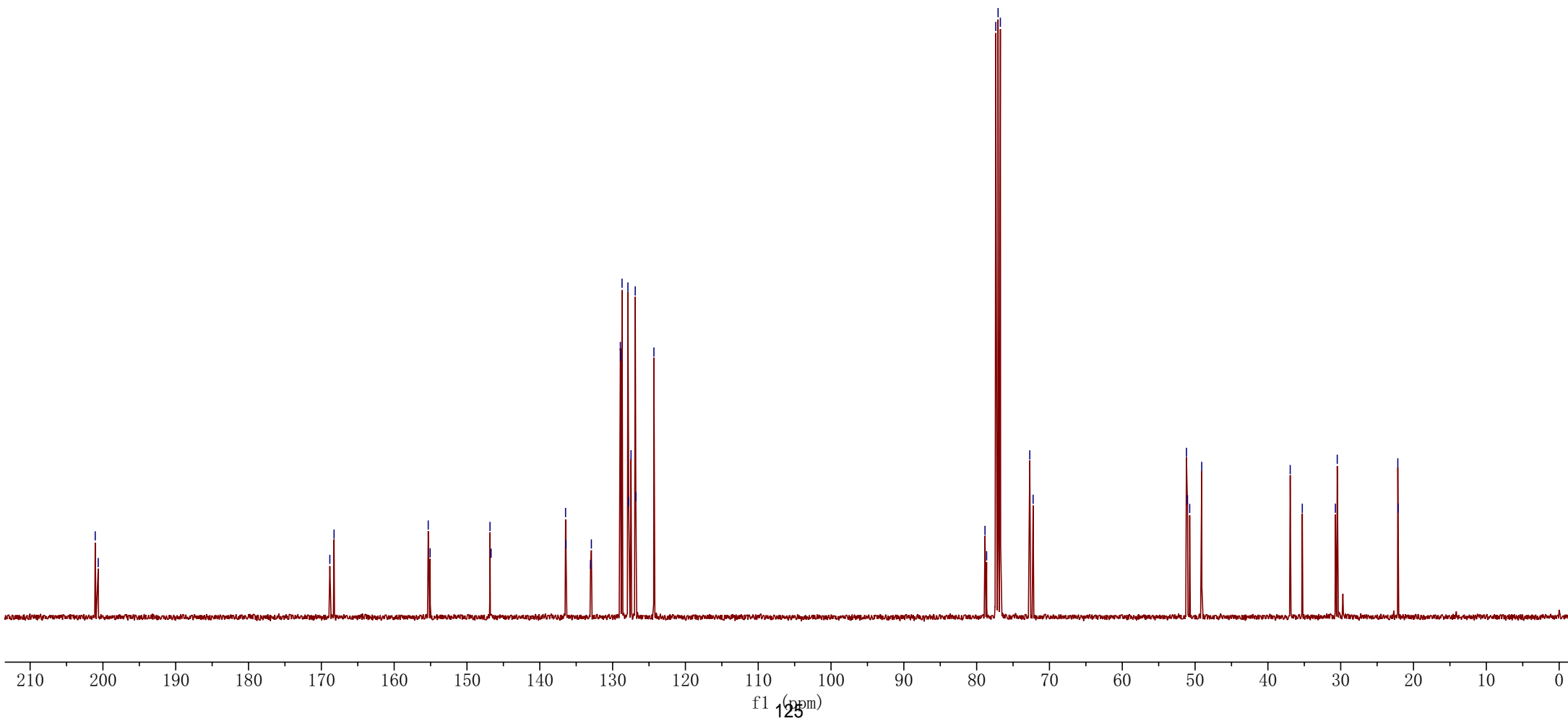


78.853  
78.631  
77.375  
77.058  
76.740  
72.706  
72.244

51.188  
51.044  
50.741  
49.088

36.936  
35.276  
30.732  
30.476

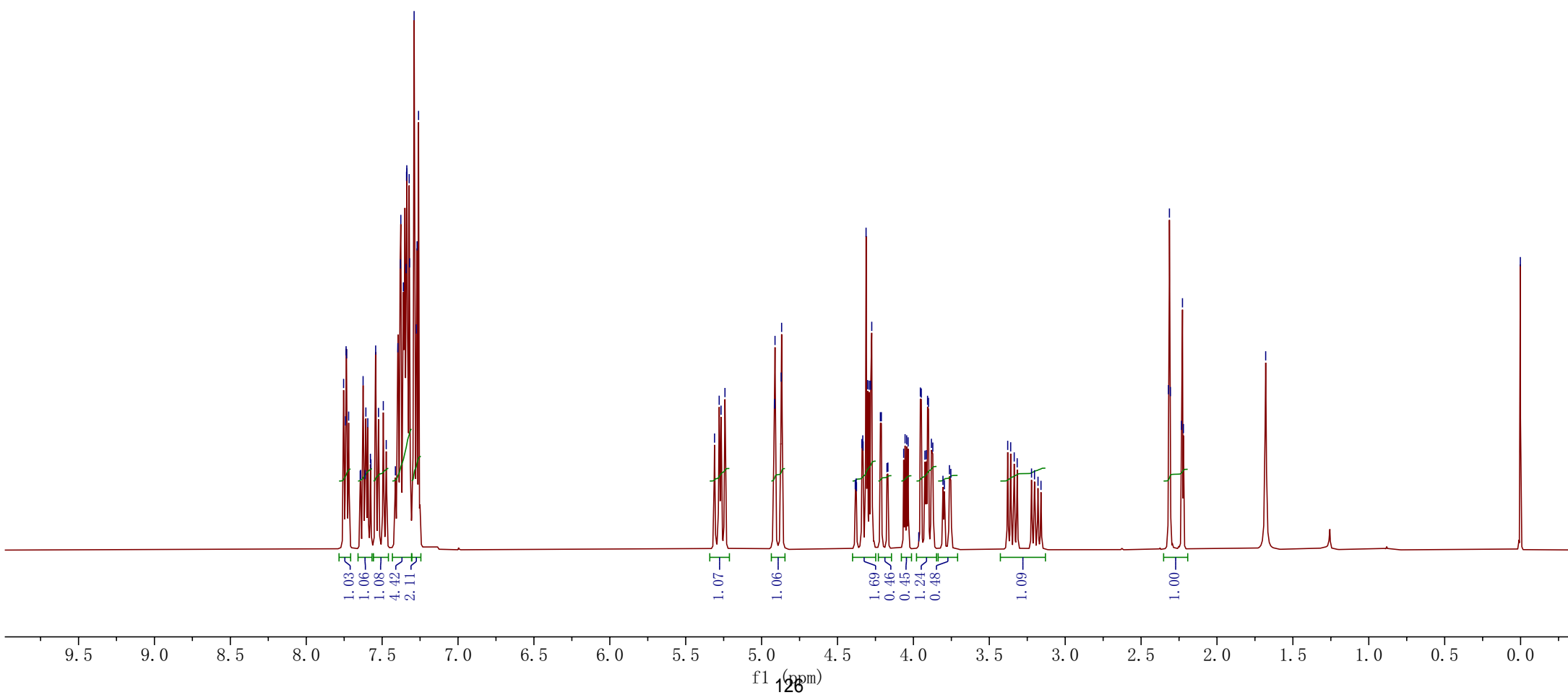
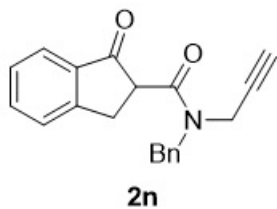
22.156  
22.122



7.754  
7.741  
7.737  
7.734  
7.721  
7.644  
7.641  
7.625  
7.611  
7.607  
7.594  
7.577  
7.574  
7.543  
7.524  
7.492  
7.473  
7.413  
7.396  
7.379  
7.377  
7.360  
7.342  
7.339  
7.337  
7.336  
7.322  
7.319  
7.289  
7.274  
7.270  
7.260

5.310  
5.279  
5.267  
5.241  
4.914  
4.914  
4.912  
4.871  
4.868  
4.883  
4.881  
4.877  
4.875  
4.840  
4.834  
4.832  
4.812  
4.801  
4.291  
4.282  
4.274  
4.217  
4.211  
4.174  
4.168  
4.064  
4.055  
4.044  
4.035  
3.965  
3.954  
3.948  
3.924  
3.915  
3.907  
3.901  
3.881  
3.872  
3.805  
3.796  
3.763  
3.753  
3.379  
3.359  
3.336  
3.316  
3.222  
3.202  
3.179  
3.159  
2.320  
2.313  
2.307  
2.234  
2.227  
2.221  
1.679  
0.002

Fig. 2: 2n, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



201.821  
201.393

168.796  
168.202

154.909  
154.639

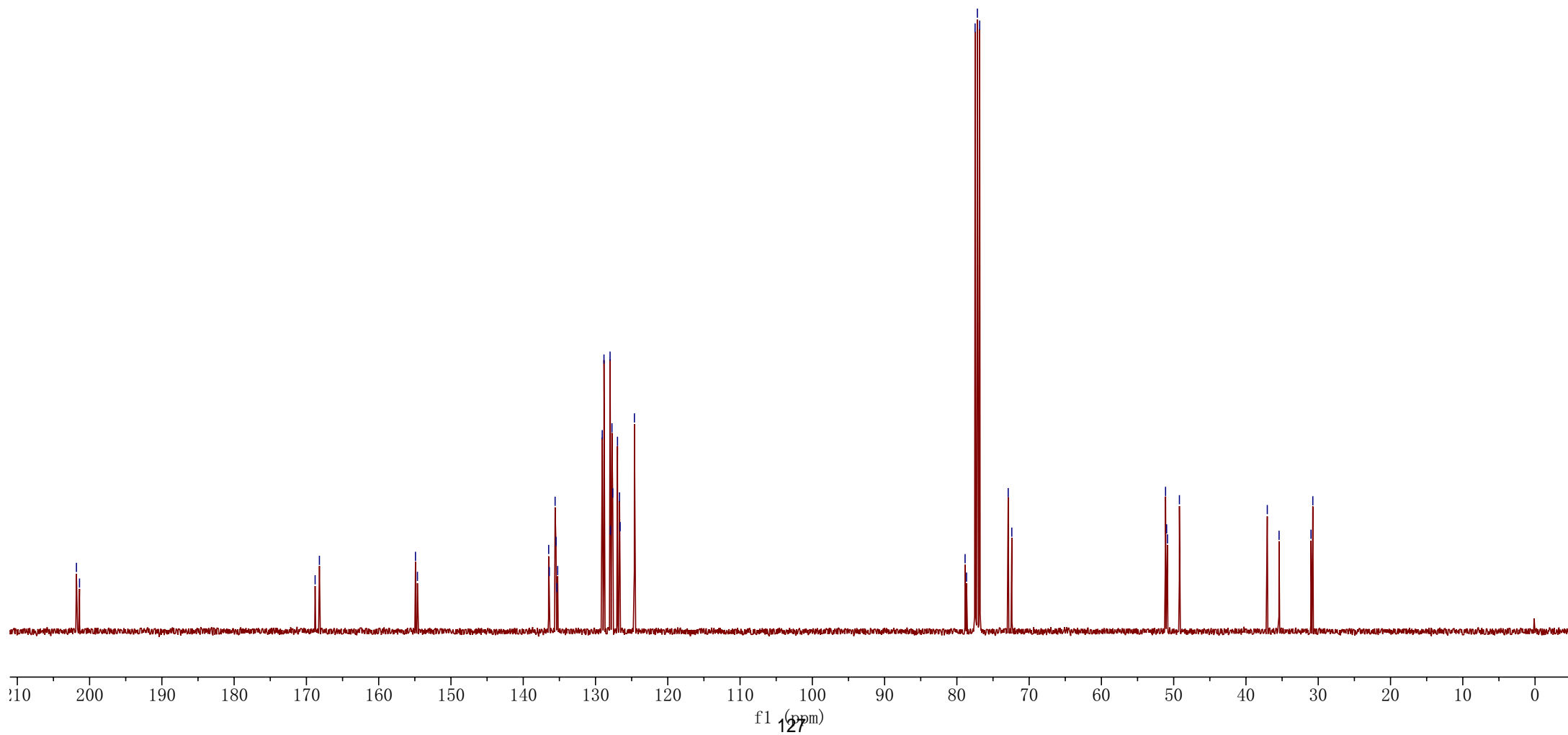
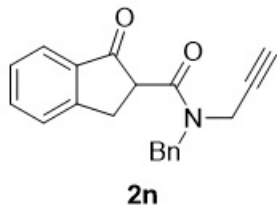
136.481  
136.392  
135.589  
135.461  
135.345  
135.233  
129.068  
128.827  
127.984  
127.933  
127.722  
127.616  
126.958  
126.673  
126.591  
124.617

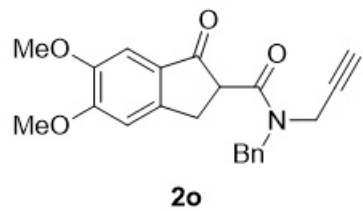
78.864  
78.662  
77.478  
77.160  
76.842  
72.899  
72.400

51.126  
50.977  
50.861  
49.208

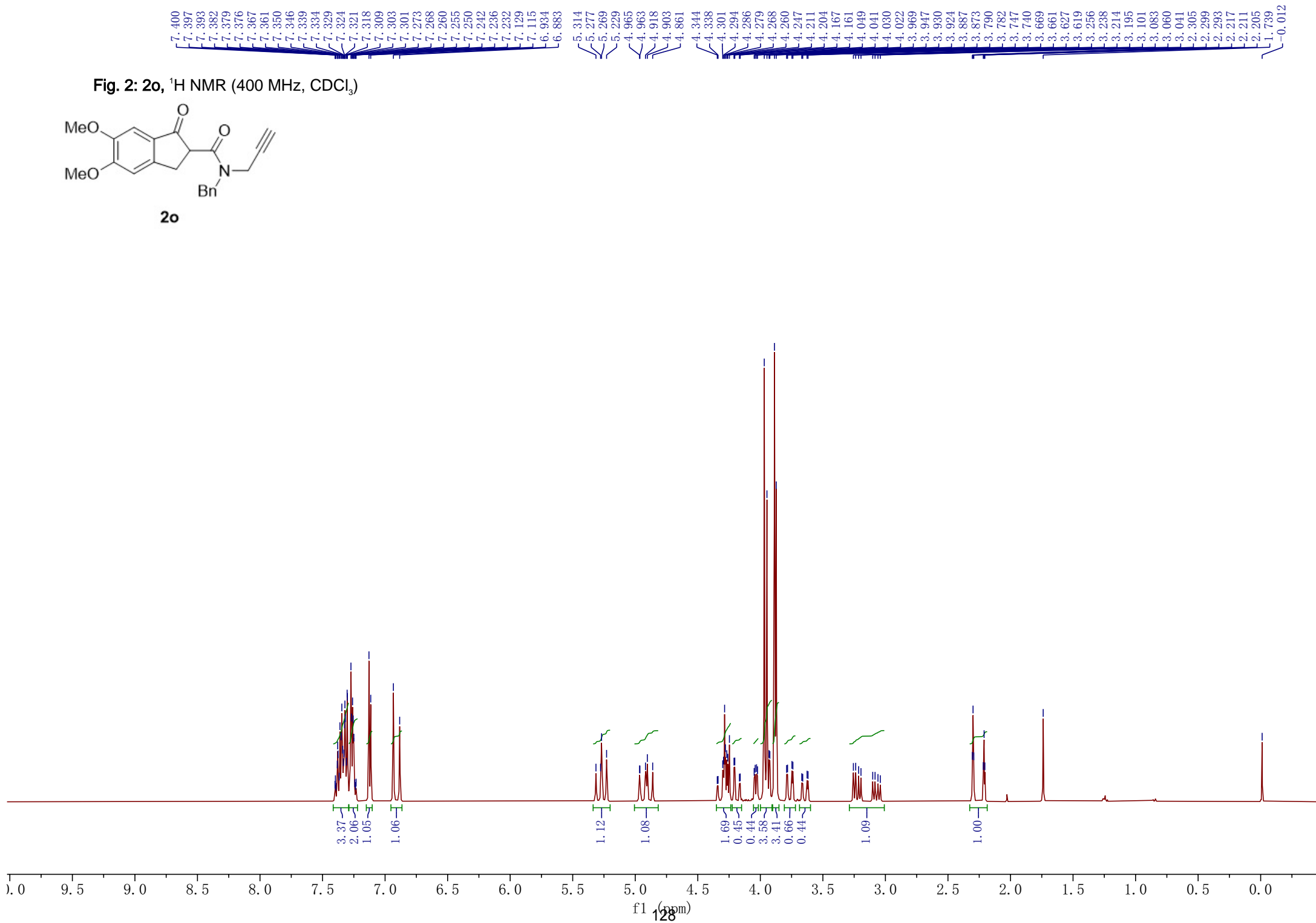
37.049  
35.418  
31.005  
30.748

Fig. 2: 2n,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )





**Fig. 2: 2o,  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )**



200.096  
199.706

169.045  
168.475

156.219  
156.097  
150.628  
150.289  
149.726  
149.702

136.523  
136.454  
128.982  
128.759  
128.020  
127.937  
127.863  
127.841  
127.526  
126.999

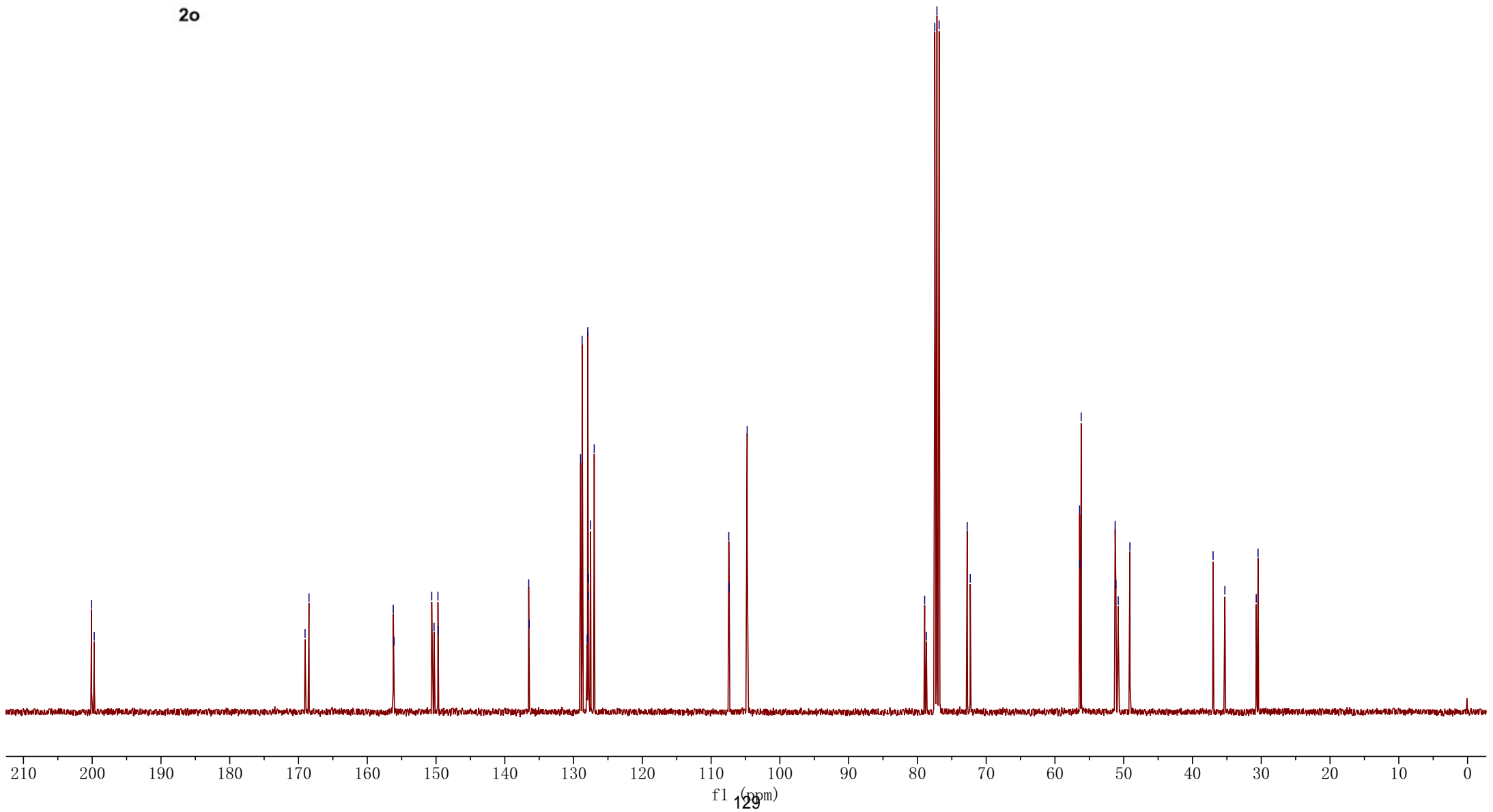
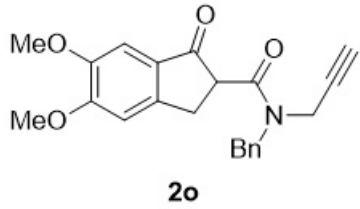
107.428  
107.361  
104.760

78.946  
78.703  
77.478  
77.160  
76.842  
72.765  
72.316

56.418  
56.387  
56.187  
51.249  
51.133  
50.798  
49.102

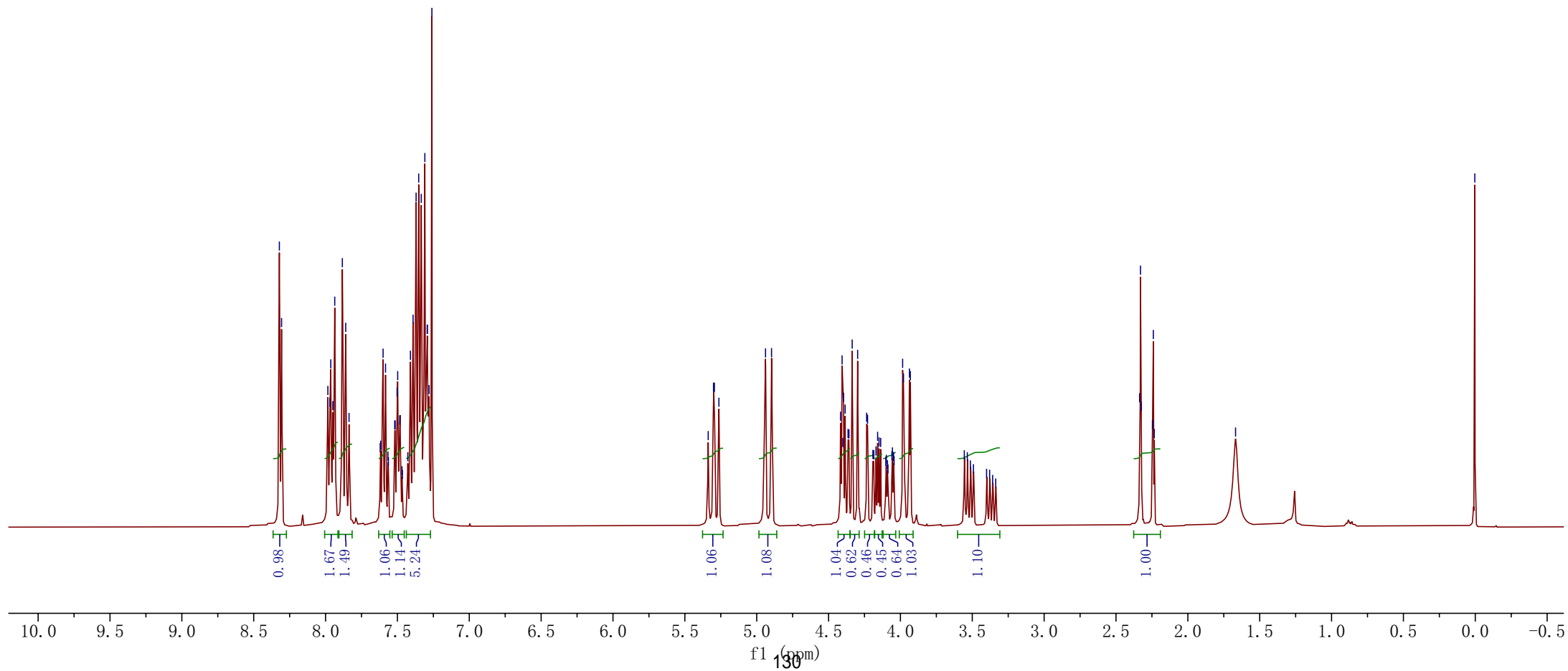
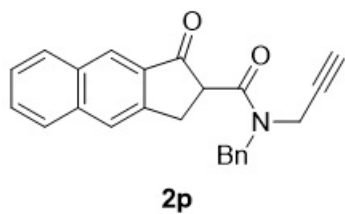
37.006  
35.291  
30.733  
30.469

Fig. 2: **2o**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



8.322  
8.306  
7.984  
7.970  
7.964  
7.949  
7.936  
7.883  
7.860  
7.837  
7.620  
7.617  
7.600  
7.583  
7.566  
7.563  
7.519  
7.516  
7.502  
7.498  
7.483  
7.468  
7.465  
7.428  
7.409  
7.391  
7.370  
7.352  
7.334  
7.309  
7.292  
7.292  
7.280  
7.260  
5.337  
5.301  
5.294  
5.263  
4.939  
4.897  
4.417  
4.406  
4.401  
4.396  
4.384  
4.364  
4.358  
4.336  
4.298  
4.235  
4.229  
4.192  
4.185  
4.170  
4.159  
4.149  
4.137  
4.101  
4.098  
4.090  
4.087  
4.059  
4.055  
4.048  
4.044  
3.985  
3.979  
3.937  
3.931  
3.556  
3.535  
3.513  
3.492  
3.400  
3.379  
3.358  
3.337  
2.336  
2.330  
2.323  
2.246  
2.240  
2.234  
1.668  
0.003

Fig. 2: 2p, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



202.089  
201.662

168.904  
168.294

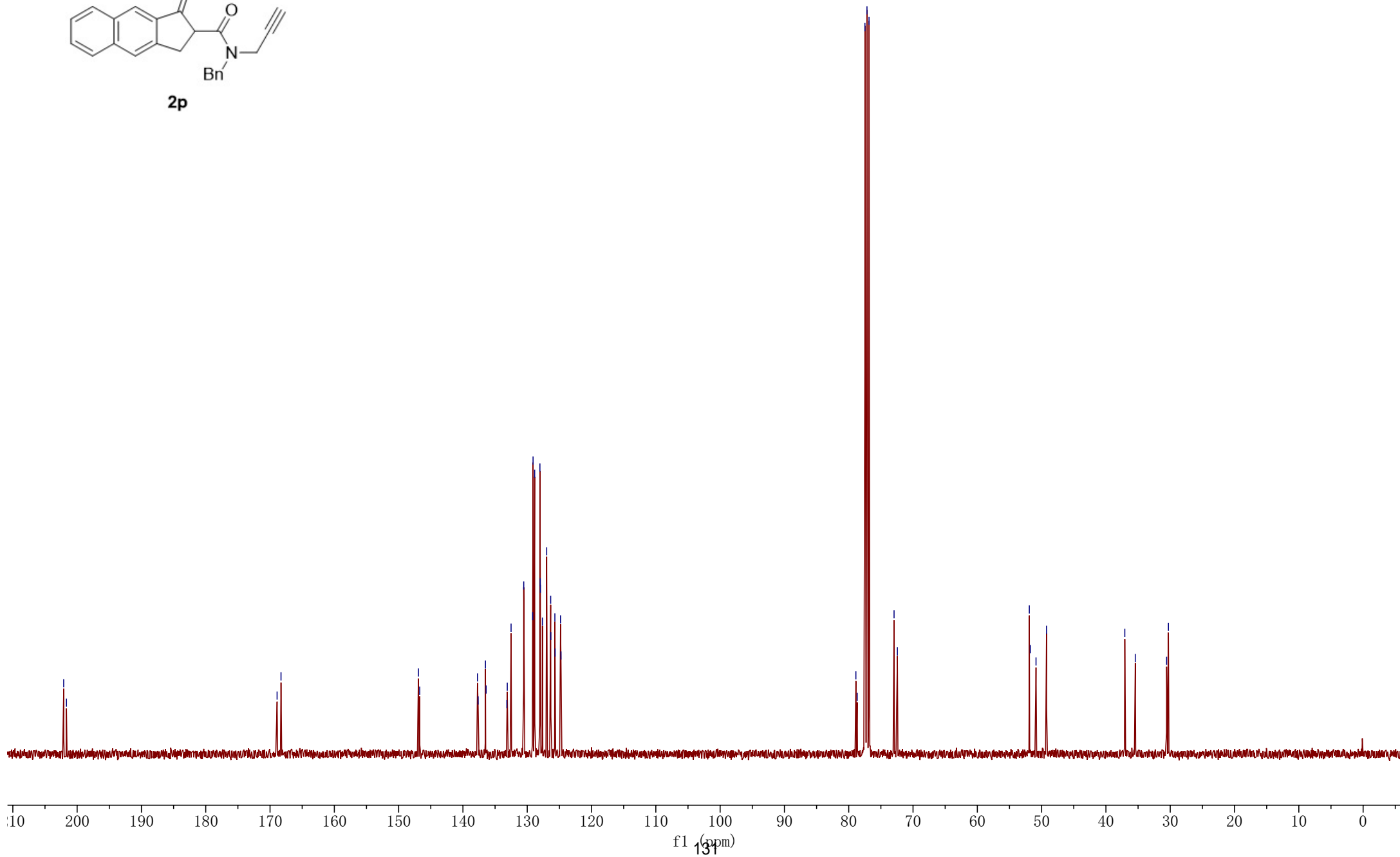
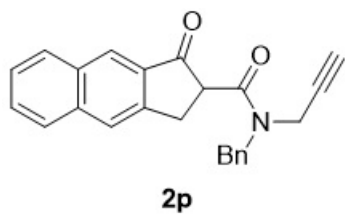
146.928  
146.722  
137.734  
137.641  
136.500  
136.395  
133.169  
133.104  
132.513  
130.541  
129.147  
129.094  
128.844  
128.027  
127.984  
127.959  
127.639  
126.977  
126.353  
126.335  
125.701  
125.664  
124.822  
124.752

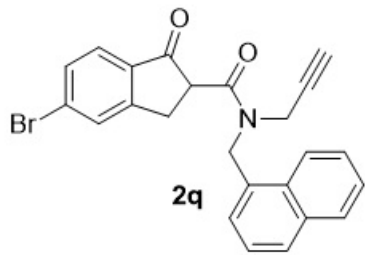
78.888  
78.683  
77.480  
77.162  
76.844  
72.950  
72.434

51.916  
51.761  
50.872  
49.238

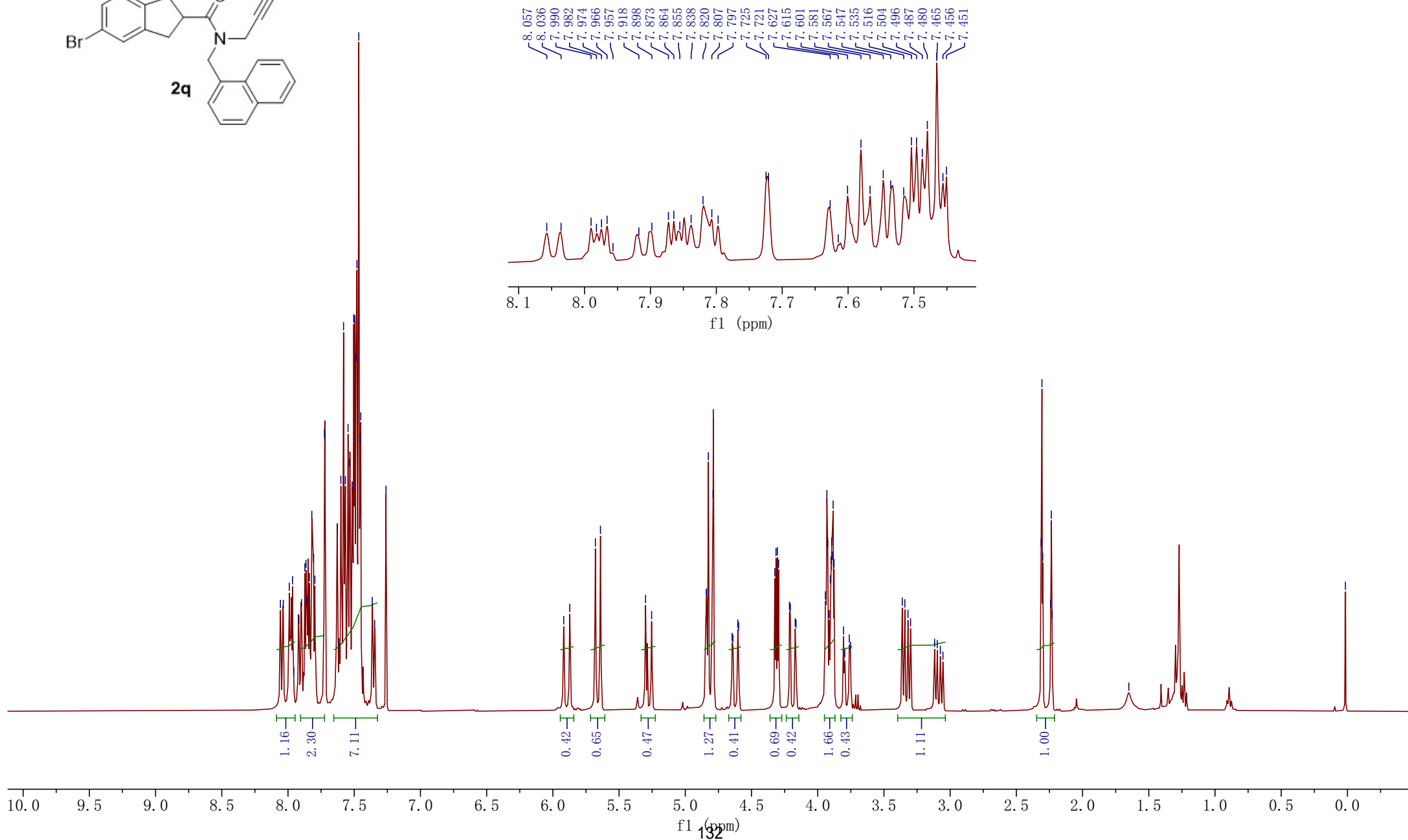
37.064  
35.436  
30.559  
30.282

Fig. 2: 2p,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )





**Fig. 2: 2q, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**





200.305  
200.142

168.981  
167.666

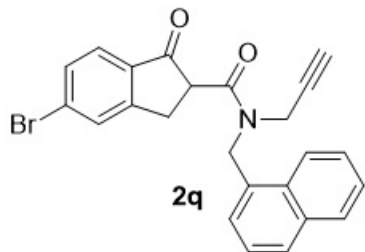
156.352  
156.161  
134.136  
133.950  
133.870  
131.749  
131.566  
131.501  
131.436  
131.378  
131.110  
130.966  
130.707  
129.983  
129.850  
129.075  
128.767  
128.677  
128.406  
126.812  
126.587  
126.441  
126.355  
126.092  
125.751  
125.707  
125.560  
125.498  
123.530  
122.868  
122.459

78.735  
78.629  
77.478  
77.160  
76.843  
73.049  
72.657

51.328  
51.096  
48.614  
47.098

36.702  
36.377  
30.683  
30.535

Fig. 2: 2q, <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)



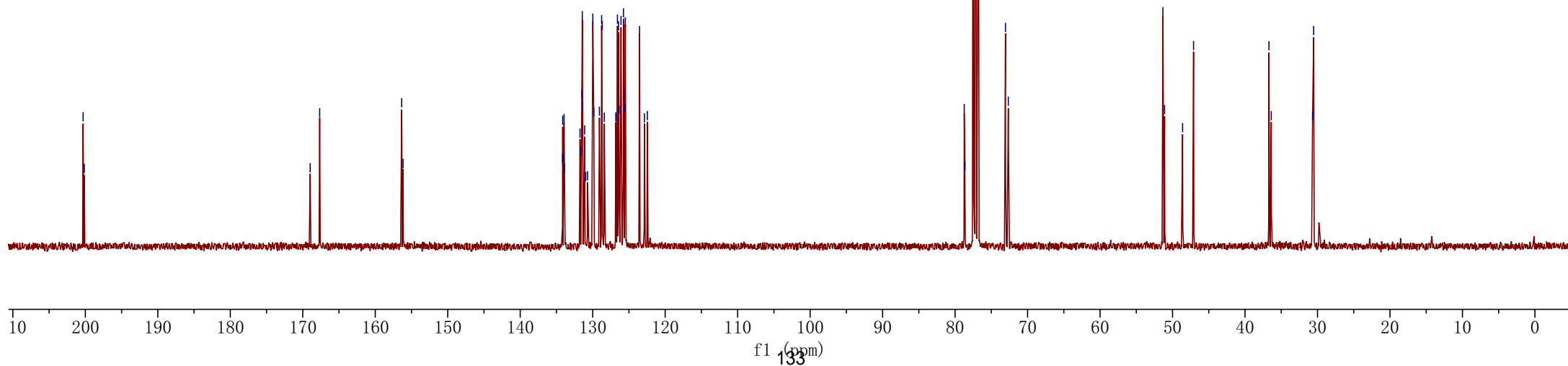
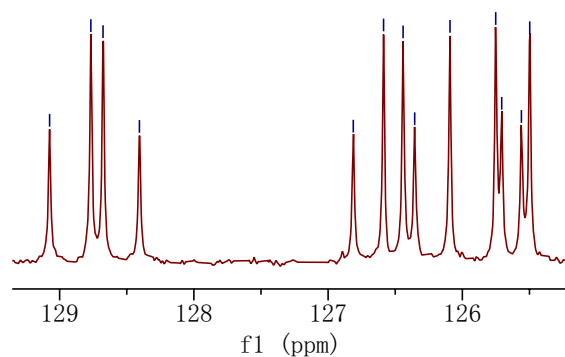
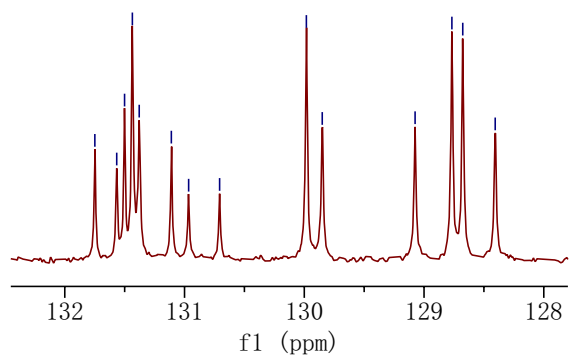
131.749  
131.566  
131.501  
131.436  
131.378  
131.110  
130.966  
130.707

129.983  
129.850

129.075  
128.767  
128.677  
128.406

129.075  
128.767  
128.677  
128.406

126.812  
126.587  
126.441  
126.355  
126.092  
125.751  
125.707  
125.560  
125.498



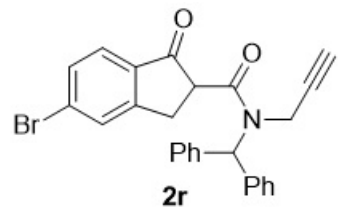
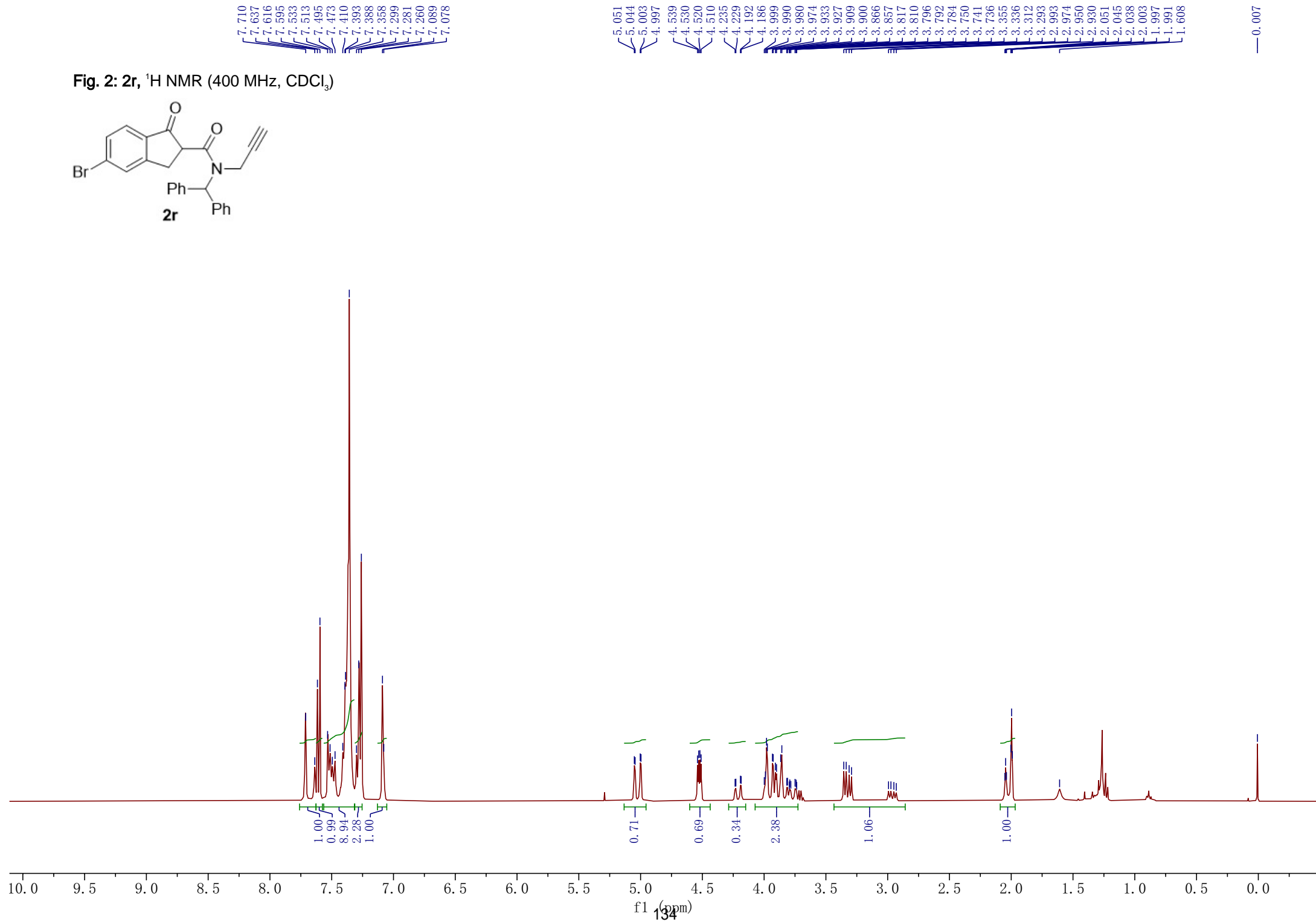


Fig. 2: **2r**, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



201.132  
200.487

168.670  
168.453

156.614  
156.463

139.253  
138.805  
138.679  
138.558  
134.168  
131.427  
131.131  
130.747  
130.258  
130.000  
129.891  
128.839  
128.746  
128.631  
128.525  
128.096  
128.013  
127.941  
127.721  
127.458  
125.742  
125.713

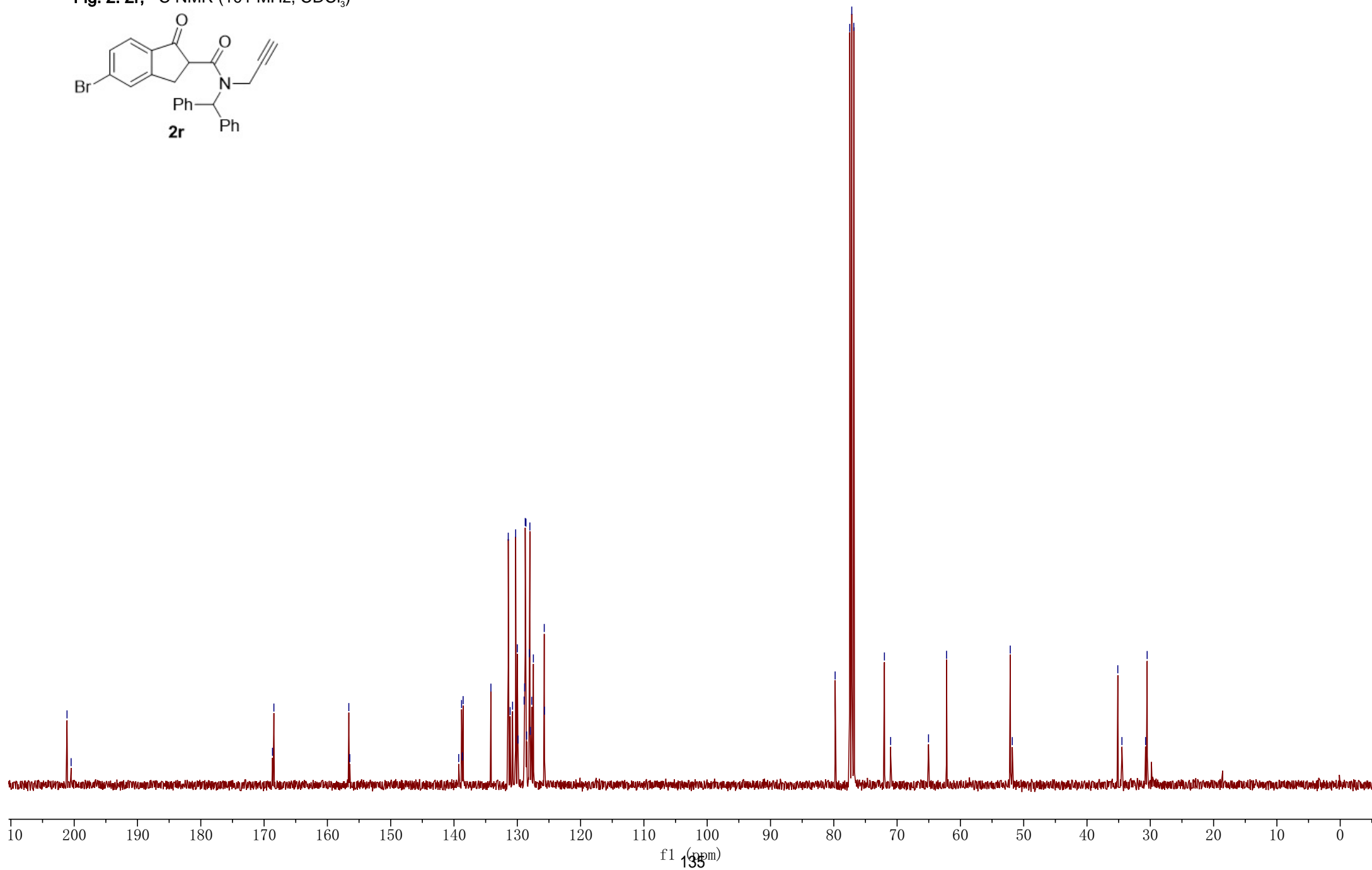
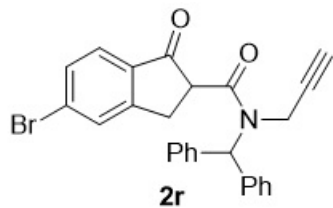
79.789  
77.478  
77.161  
76.843  
72.004  
71.018

65.035  
62.188

52.122  
51.800

35.134  
34.480  
30.745  
30.496

Fig. 2: 2r,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



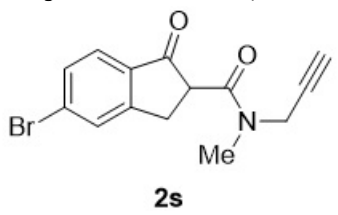
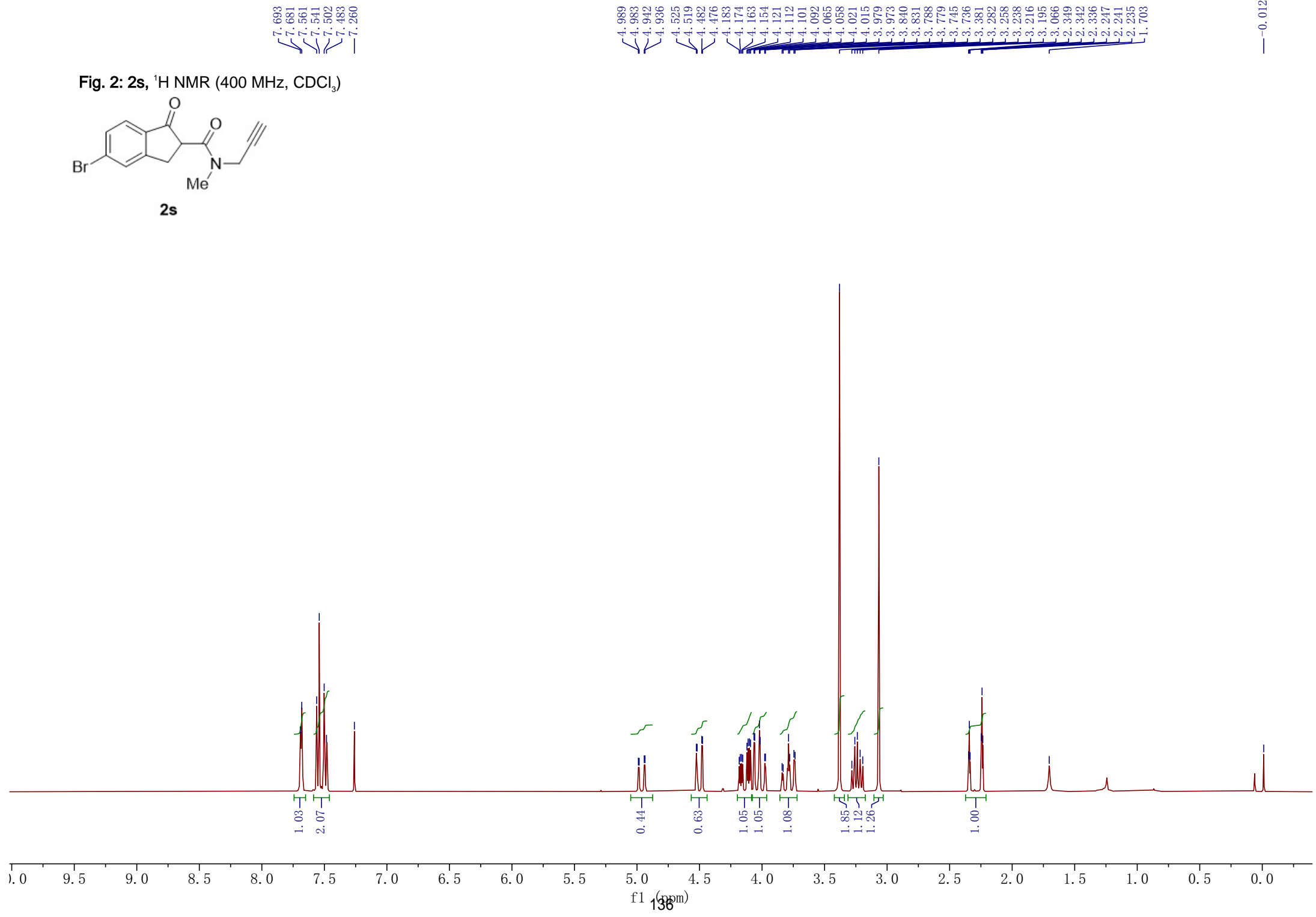


Fig. 2: **2s**, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



200.462  
200.149

167.572  
167.170

156.414  
156.187

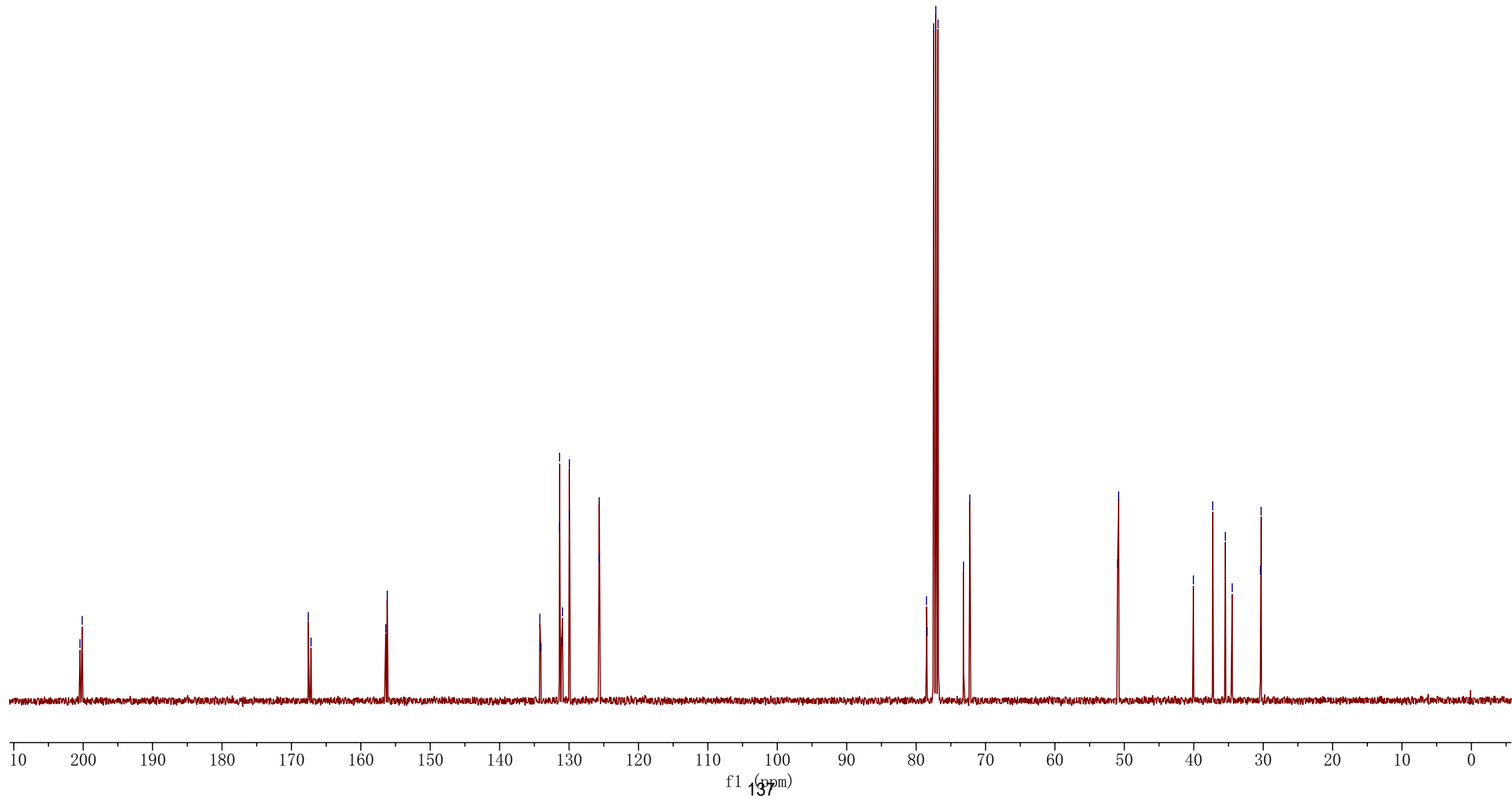
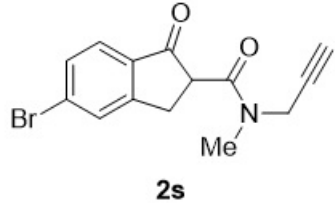
134.210  
134.065  
131.388  
131.375  
131.096  
130.949  
129.960  
129.946  
125.683  
125.655

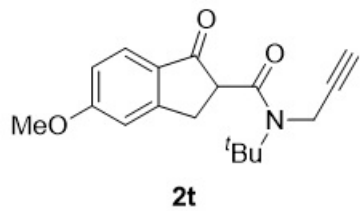
78.510  
78.417  
77.477  
77.160  
76.842  
73.162  
72.256

50.977  
50.822

40.046  
37.273  
35.451  
34.462  
30.397  
30.303

Fig. 2: **2s**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )





**Fig. 2: 2t,  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )**

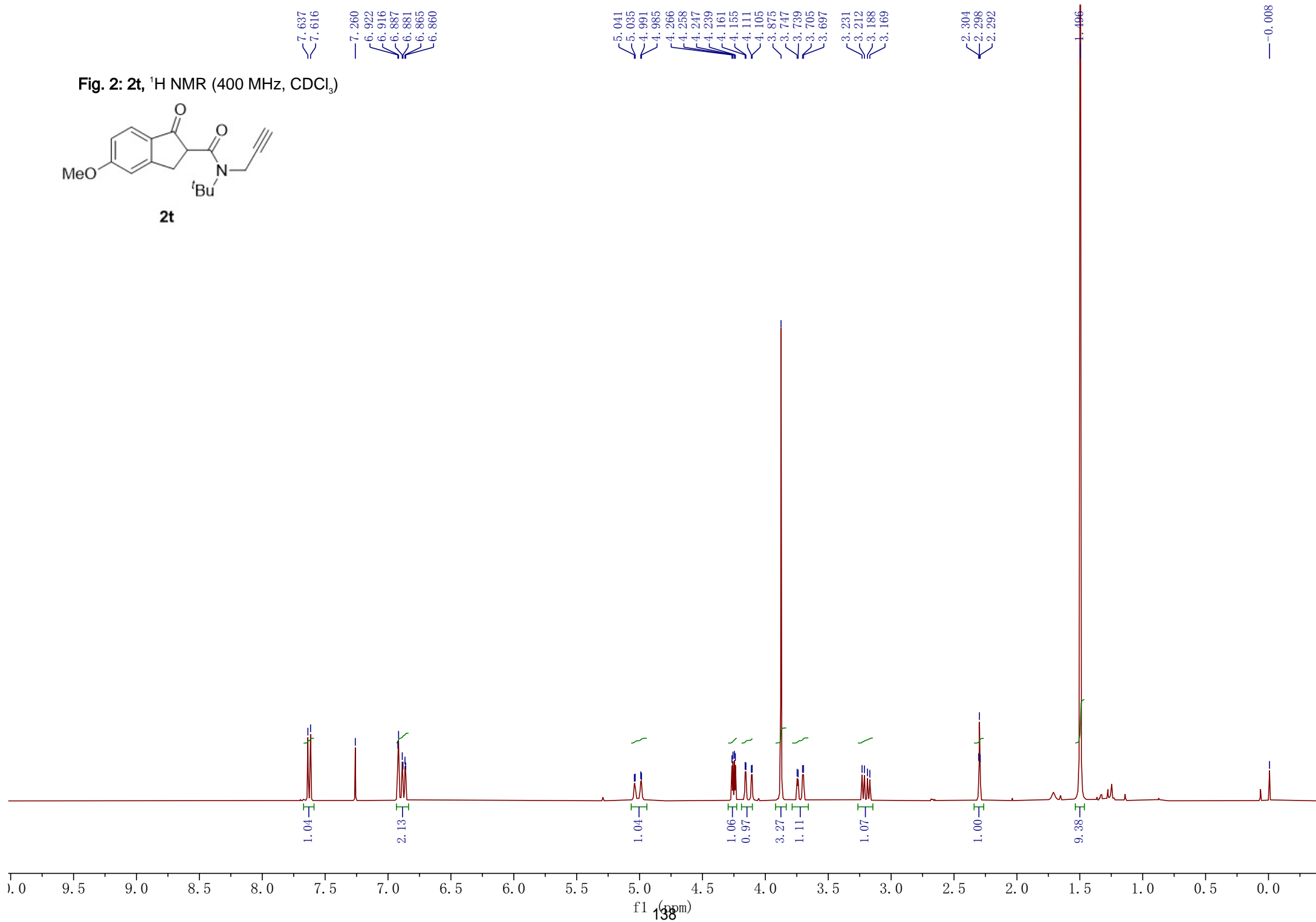
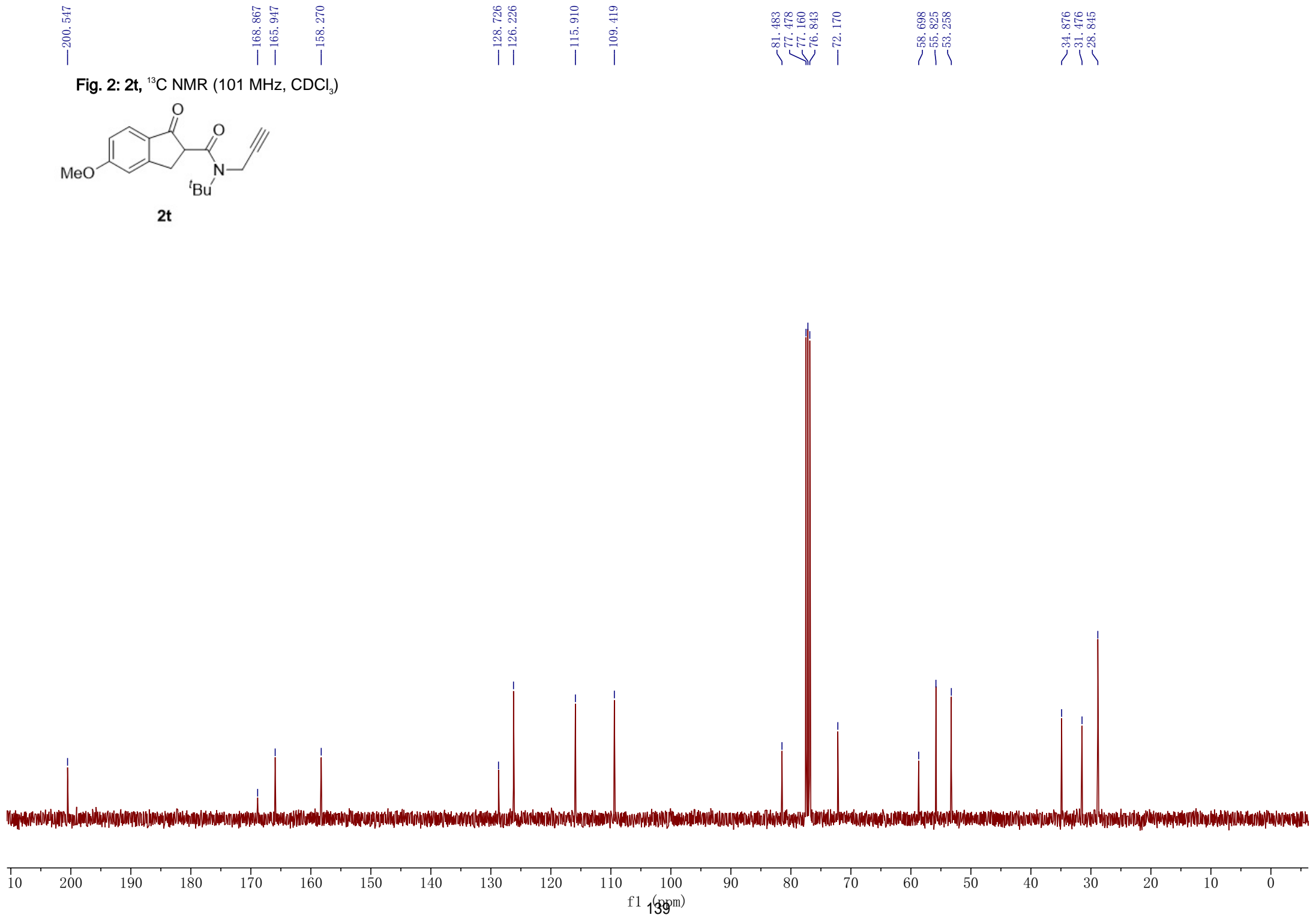
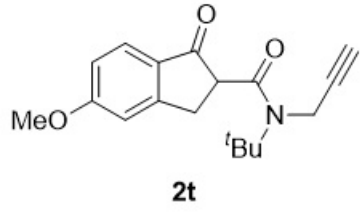


Fig. 2: **2t**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )

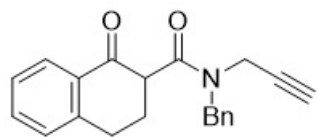


8.057  
8.039  
8.023  
7.528  
7.509  
7.491  
7.474  
7.455  
7.388  
7.369  
7.321  
7.300  
7.294  
7.281  
7.236  
7.217

5.337  
5.299

4.854  
4.811  
4.759  
4.717  
4.374  
4.319  
4.280  
4.250  
4.225  
4.017  
4.005  
3.986  
3.975  
3.845  
3.822  
3.810  
3.794  
3.781  
3.135  
3.125  
3.113  
3.098  
3.088  
3.066  
3.055  
2.952  
2.941  
2.922  
2.911  
2.898  
2.880  
2.870  
2.715  
2.701  
2.684  
2.670  
2.654  
2.640  
2.624  
2.612  
2.594  
2.583  
2.564  
2.553  
2.301  
2.241  
1.769  
0.002

Fig. 2: 2u, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



2u

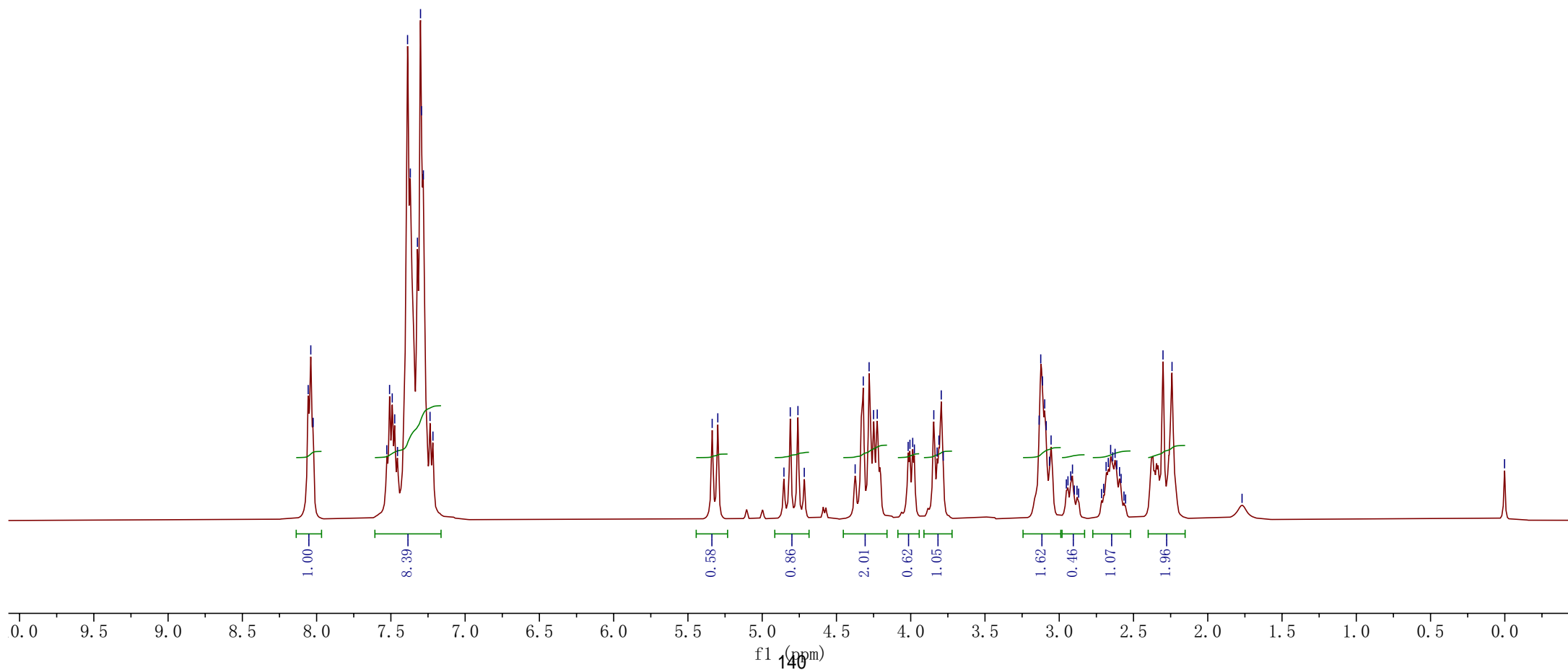
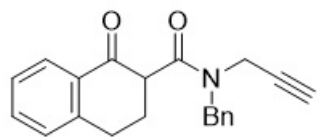
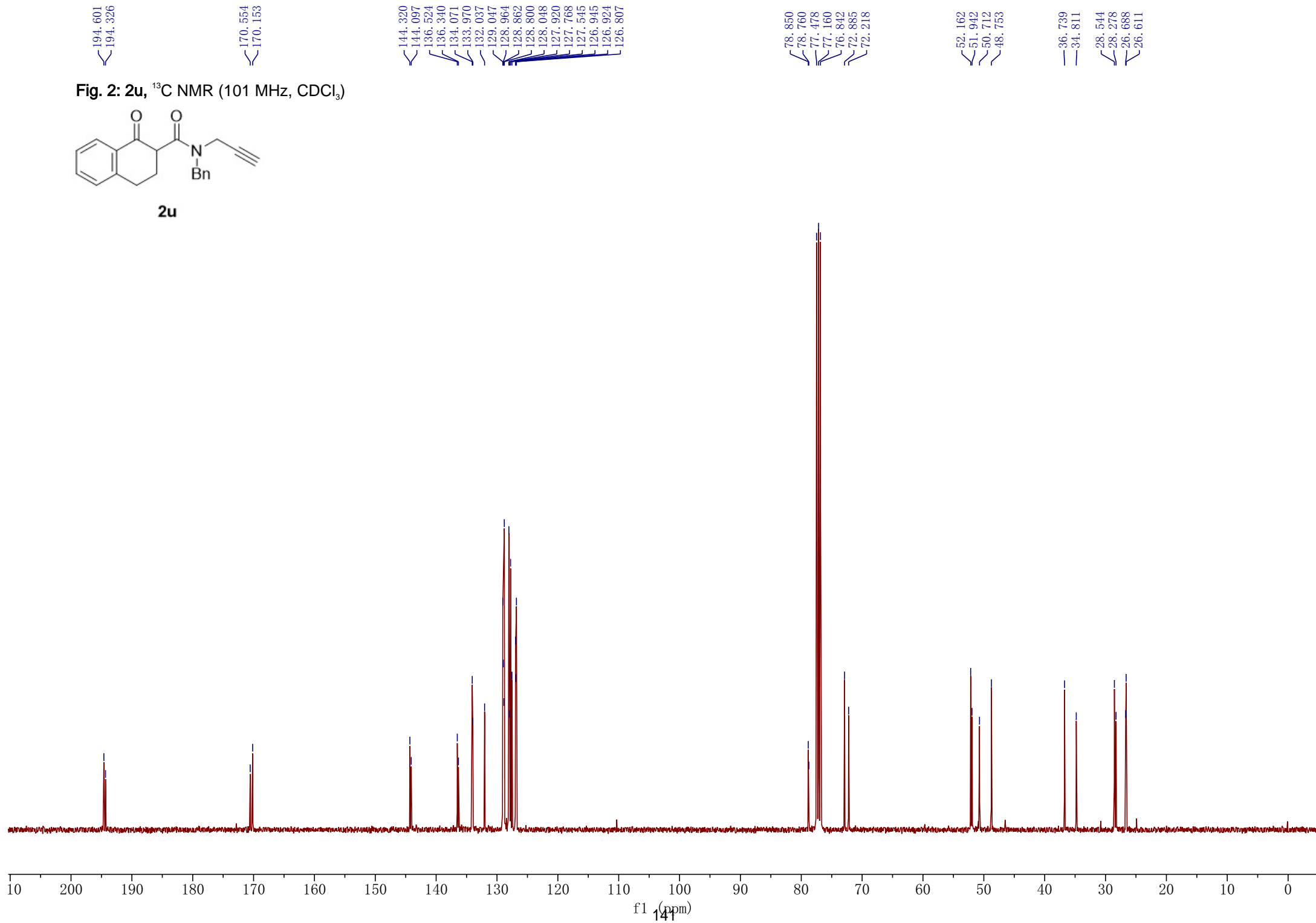




Fig. 2: **2u**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )

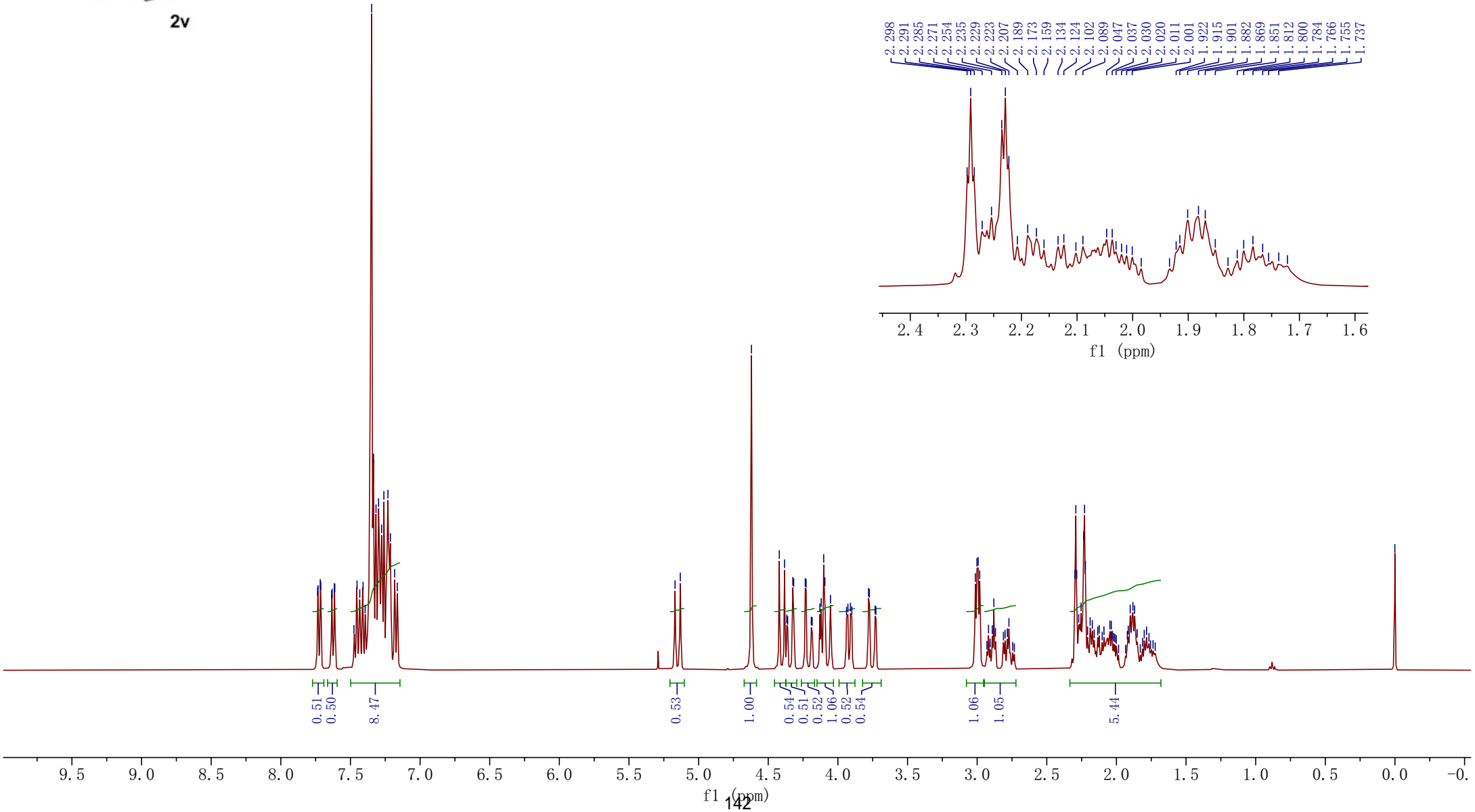
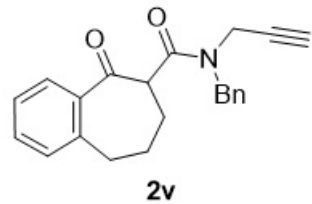


**2u**



7.736  
7.732  
7.717  
7.713  
7.635  
7.631  
7.616  
7.612  
7.475  
7.453  
7.433  
7.409  
7.394  
7.348  
7.334  
7.316  
7.298  
7.276  
7.260  
7.231  
7.213  
7.183  
7.164  
5.169  
5.131  
4.621  
4.421  
4.383  
4.367  
4.361  
4.324  
4.317  
4.234  
4.228  
4.191  
4.185  
4.129  
4.120  
4.102  
4.093  
4.053  
3.938  
3.928  
3.910  
3.900  
3.780  
3.774  
3.733  
3.727  
3.013  
3.001  
2.993  
2.981  
2.930  
2.918  
2.907  
2.880  
2.880  
2.869  
2.811  
2.800  
2.783  
2.772  
2.744  
2.733  
2.733  
2.298  
2.291  
2.285  
2.271  
2.254  
2.235  
2.229  
2.223  
2.207  
2.189  
2.173  
2.159  
2.134  
2.124  
2.102  
2.089  
2.073  
2.047  
2.037  
2.030  
2.020  
2.011  
2.001  
1.922  
1.915  
1.901  
1.882  
1.869  
1.851  
1.812  
1.800  
1.784  
1.766  
1.755  
1.737  
1.722  
1.722  
1.001

Fig. 2: 2v, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



202.410  
202.201

170.702  
170.460

141.029  
140.955  
138.343  
138.169  
136.600  
136.240  
132.698  
132.513  
129.863  
129.794  
129.109  
129.042  
128.869  
128.791  
128.172  
127.998  
127.576  
127.016  
126.981  
126.952

78.739  
78.489  
77.479  
77.161  
76.844  
73.008  
72.278

54.049  
54.023  
50.743  
48.673

36.741  
34.876  
32.775  
32.670  
26.038  
25.792  
24.559  
24.505

Fig. 2: 2v,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )

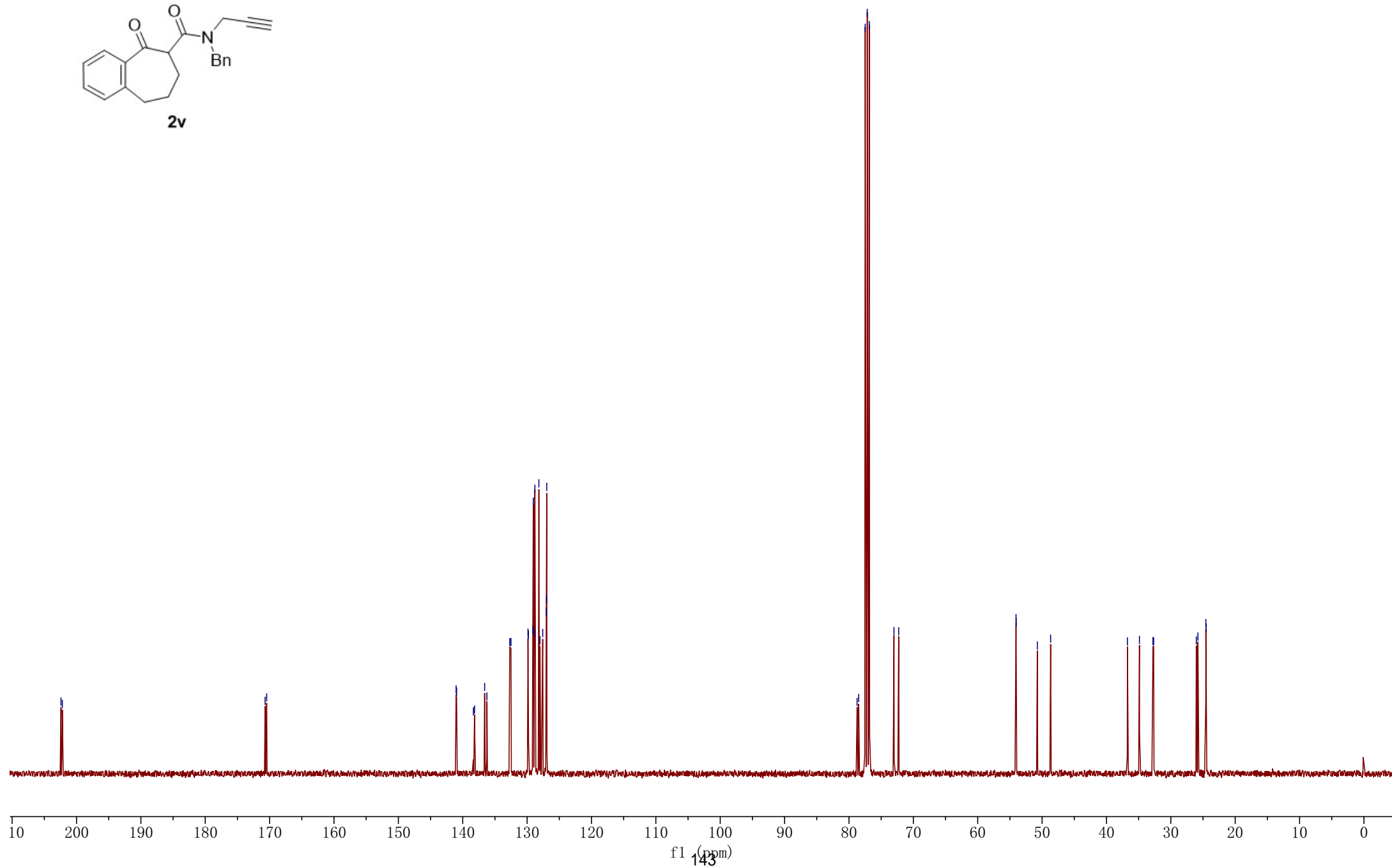
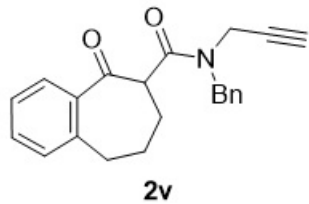


Fig. 2: **2w**, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)

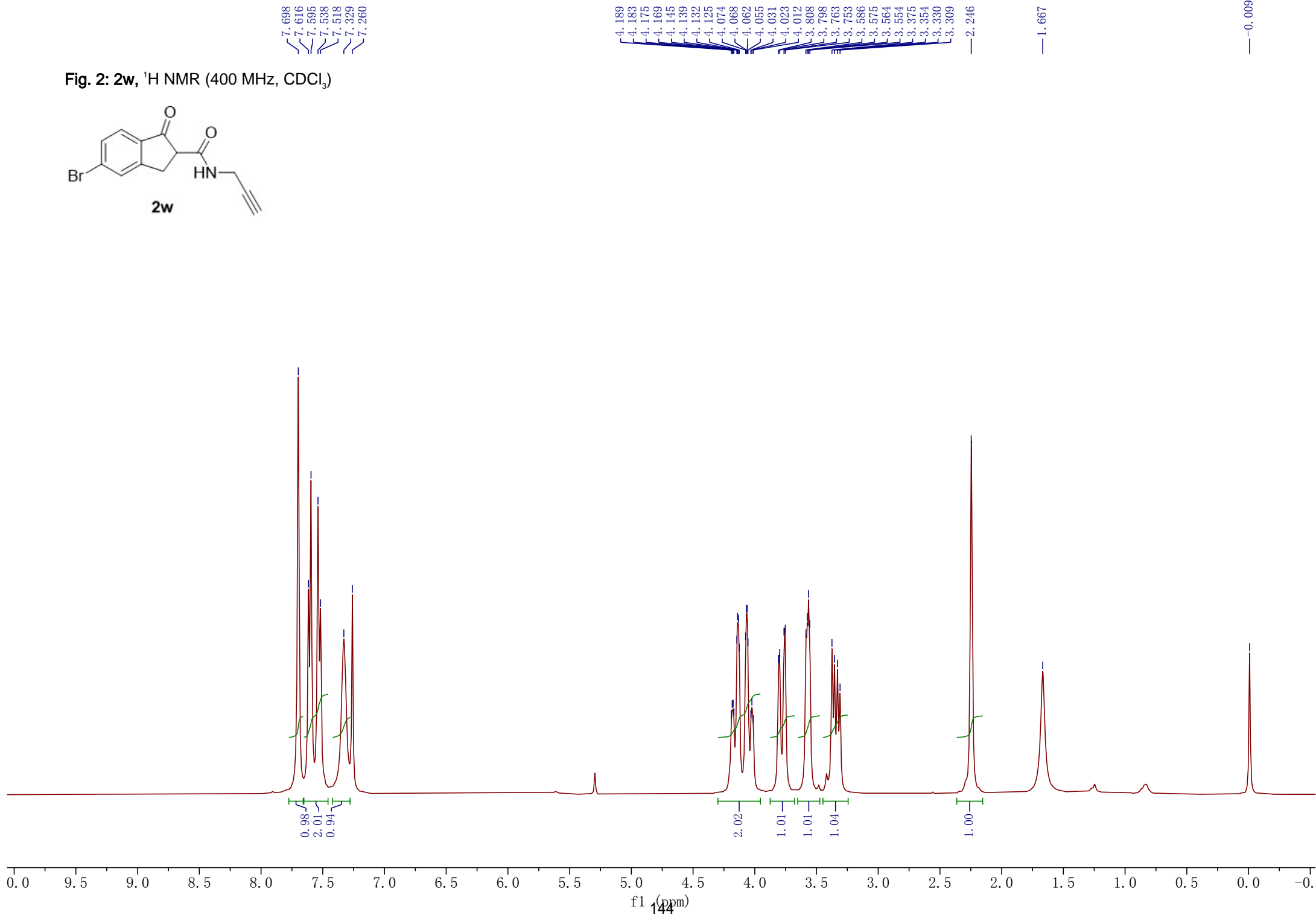
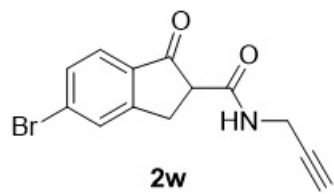
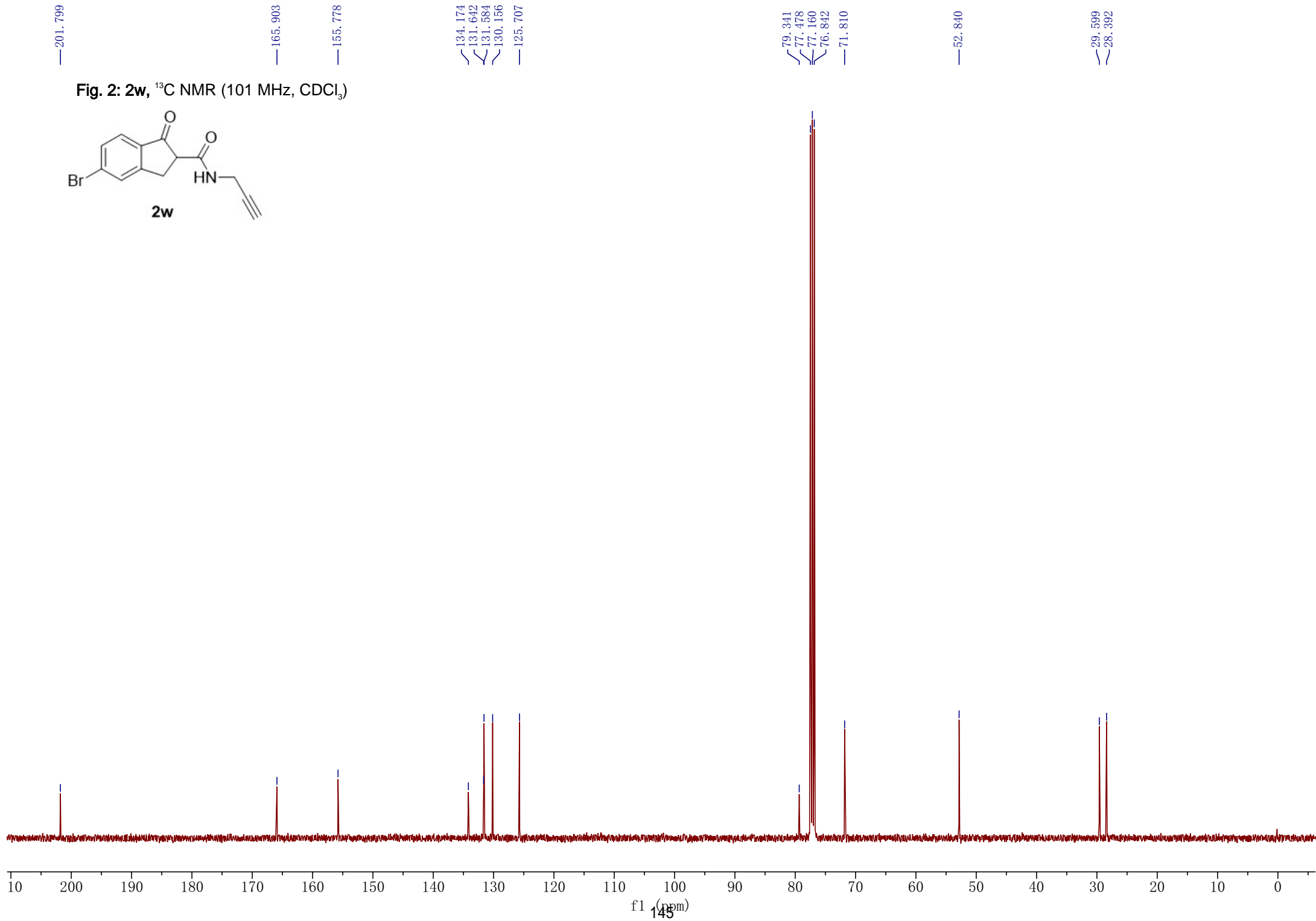
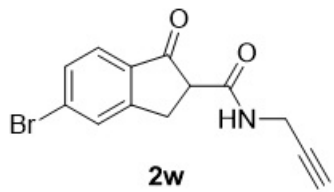
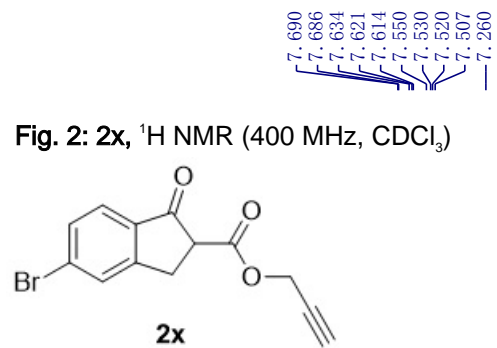


Fig. 2: **2w**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )





7.690  
7.686  
7.634  
7.621  
7.614  
7.550  
7.530  
7.520  
7.507  
7.260

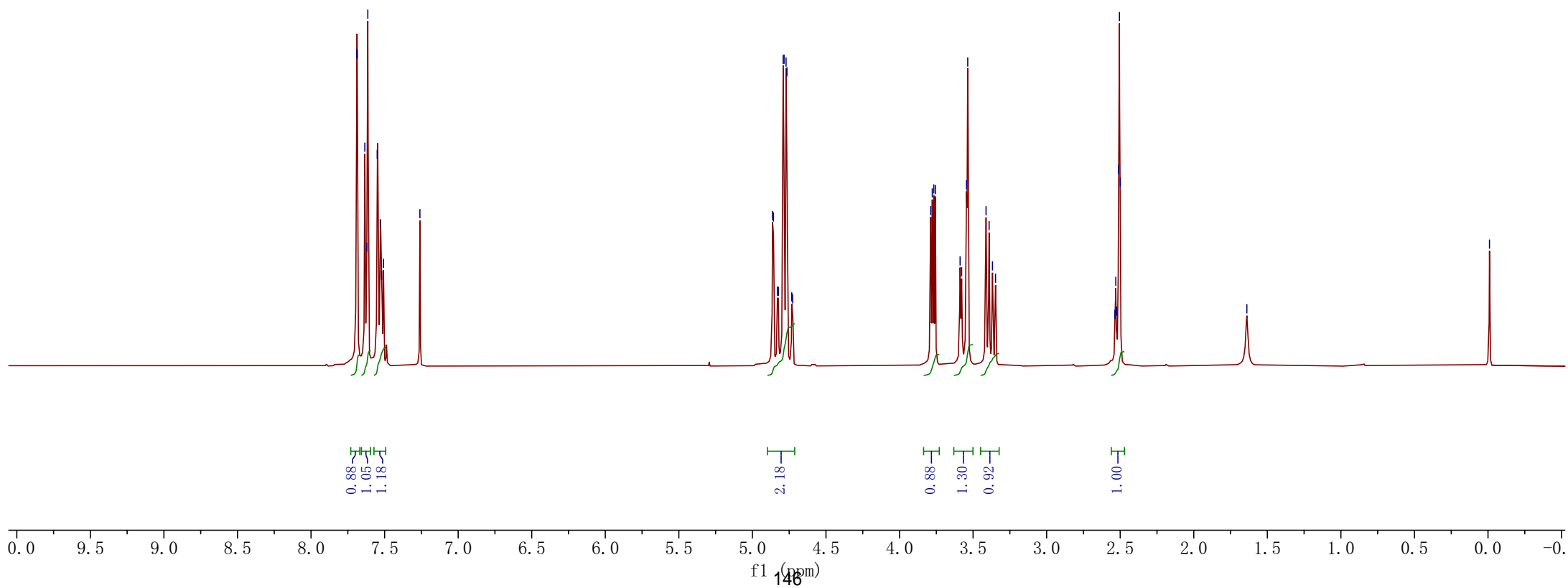
4.863  
4.857  
4.830  
4.823  
4.791  
4.785  
4.771  
4.765  
4.732  
4.726

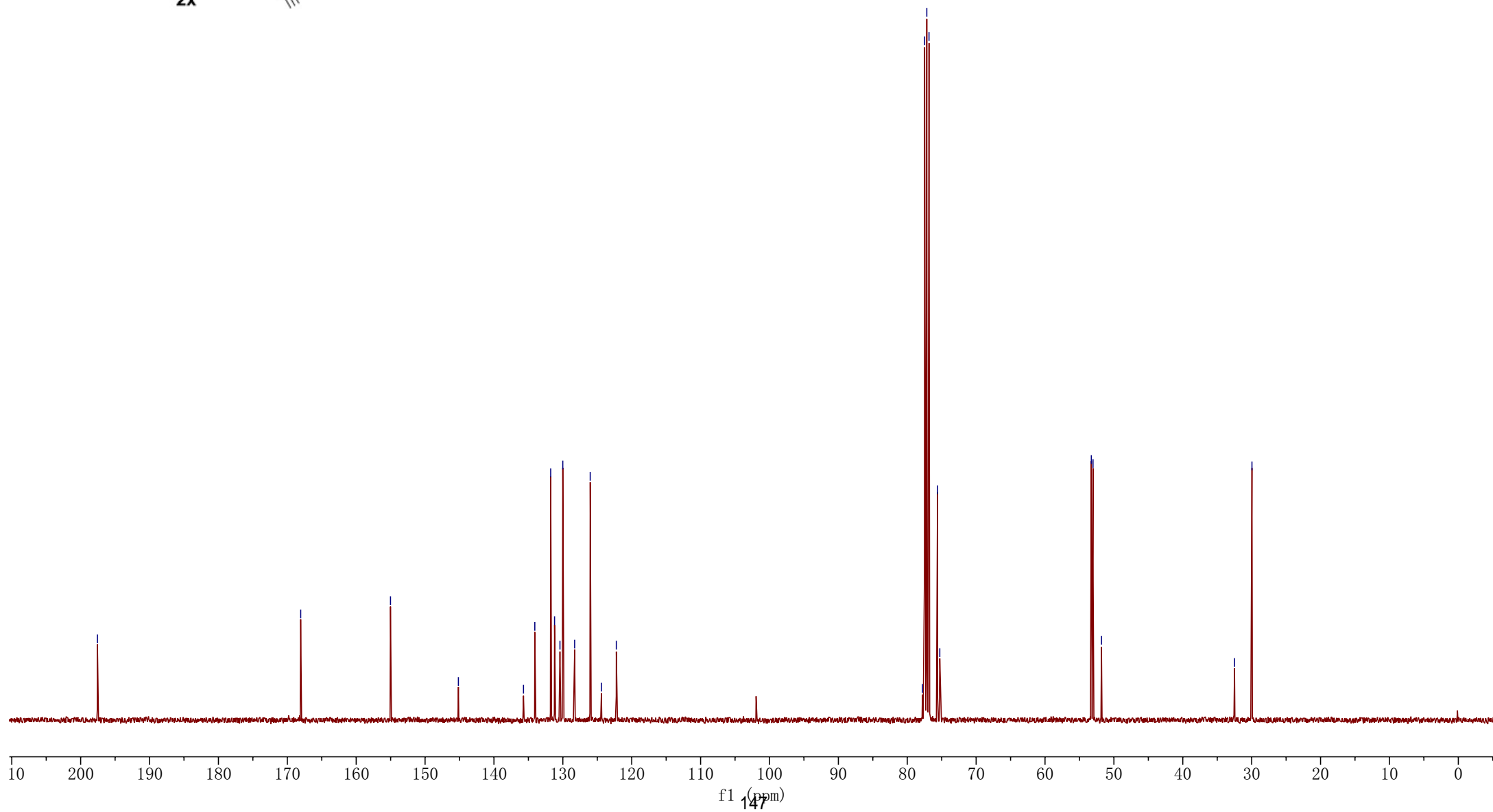
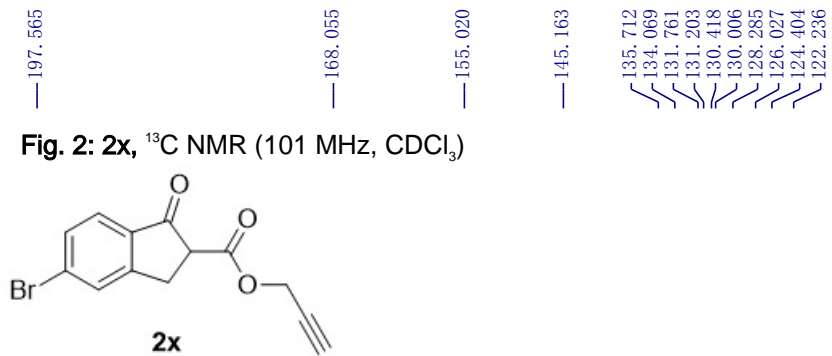
3.788  
3.777  
3.767  
3.757  
3.588  
3.578  
3.545  
3.536  
3.412  
3.391  
3.368  
3.347

2.536  
2.530  
2.524  
2.512  
2.505  
2.499

—1.639

—-0.010

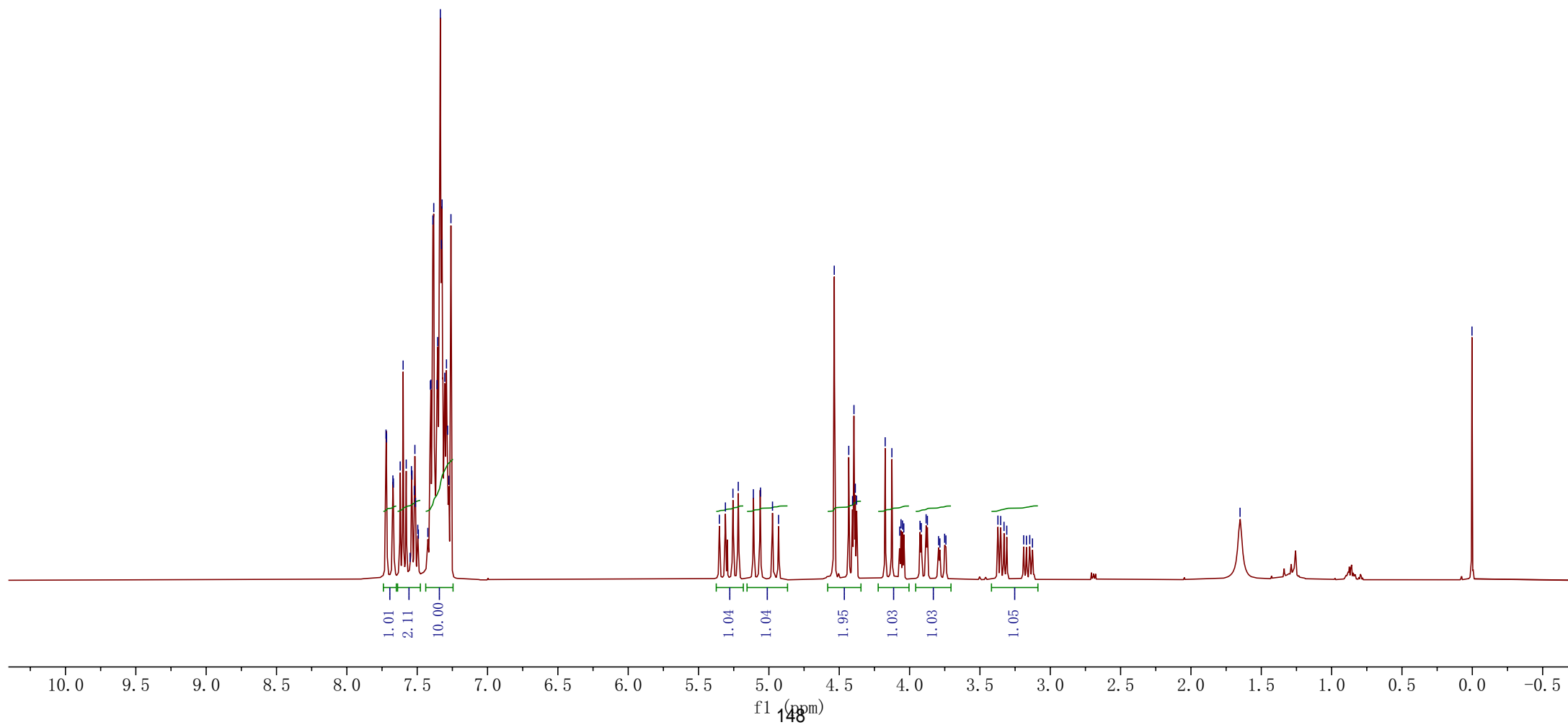
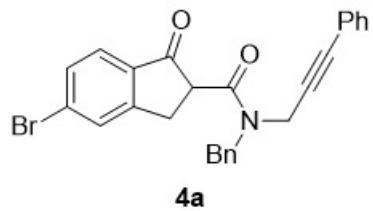




7.722  
7.718  
7.673  
7.669  
7.621  
7.600  
7.578  
7.550  
7.541  
7.537  
7.520  
7.516  
7.512  
7.496  
7.492  
7.424  
7.406  
7.402  
7.388  
7.382  
7.359  
7.355  
7.335  
7.328  
7.323  
7.304  
7.292  
7.284  
7.275  
7.260

5.352  
5.309  
5.256  
5.218  
5.110  
5.060  
4.974  
4.931  
4.535  
4.432  
4.405  
4.395  
4.386  
4.377  
4.173  
4.126  
4.070  
4.061  
4.050  
4.041  
3.926  
3.917  
3.882  
3.873  
3.794  
3.785  
3.751  
3.742  
3.372  
3.352  
3.329  
3.309  
3.189  
3.146  
3.126  
1.651  
0.002

Fig. 3: 4a, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)





200.623  
200.208

168.384  
167.904

156.442  
156.215

136.607  
136.583  
134.272  
134.189  
131.837  
131.415  
131.094  
130.959  
129.989  
129.906  
129.071  
128.829  
128.801  
128.507  
128.451  
128.328  
128.053  
127.894  
127.634  
126.900  
125.744  
122.755  
122.301

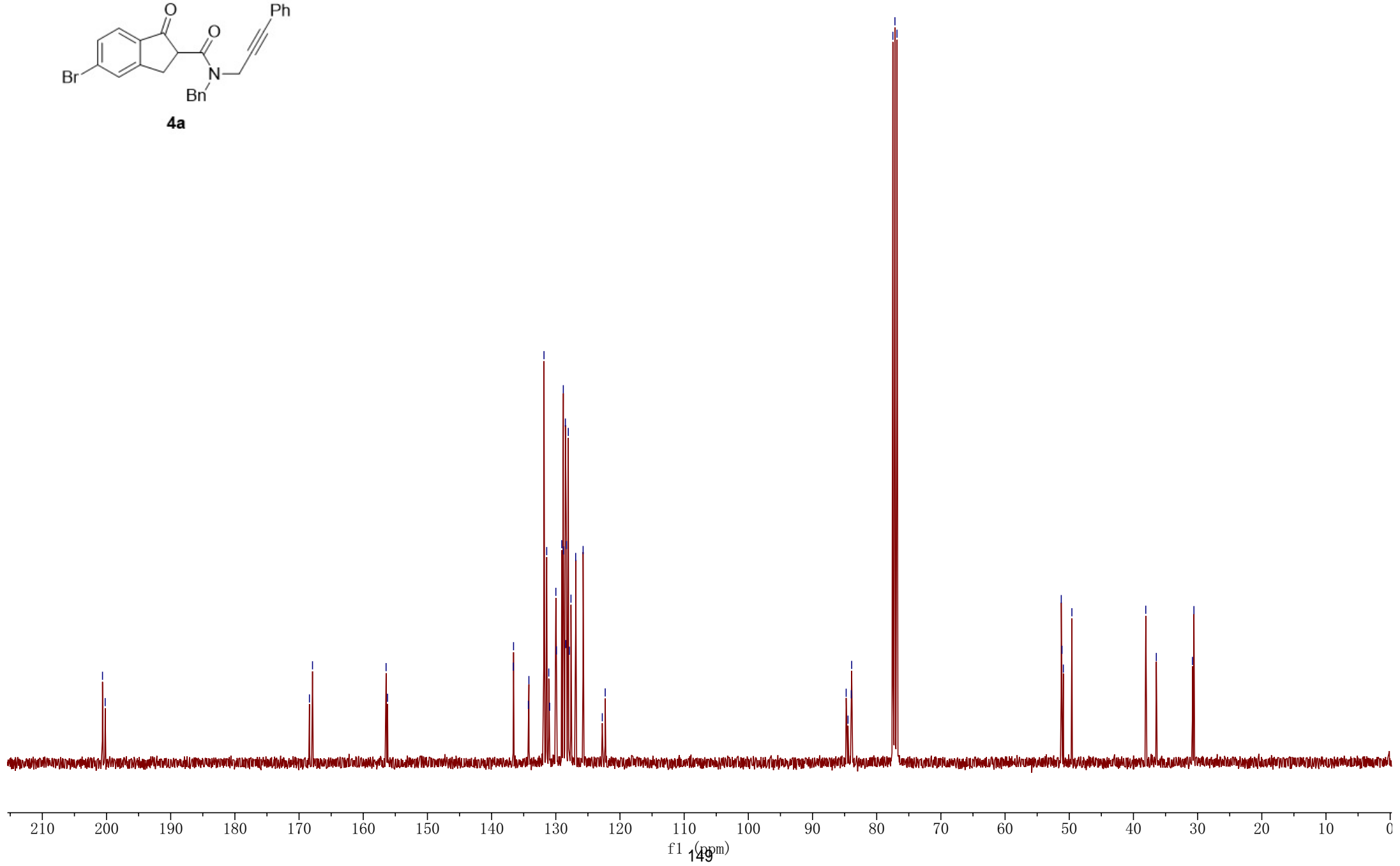
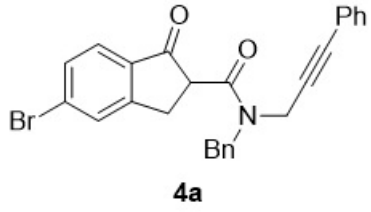
84.758  
84.476  
83.959  
83.900  
77.478  
77.160  
76.842

51.246  
51.132  
50.921  
49.590

38.078  
36.437

30.804  
30.573

Fig. 3: 4a, <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)

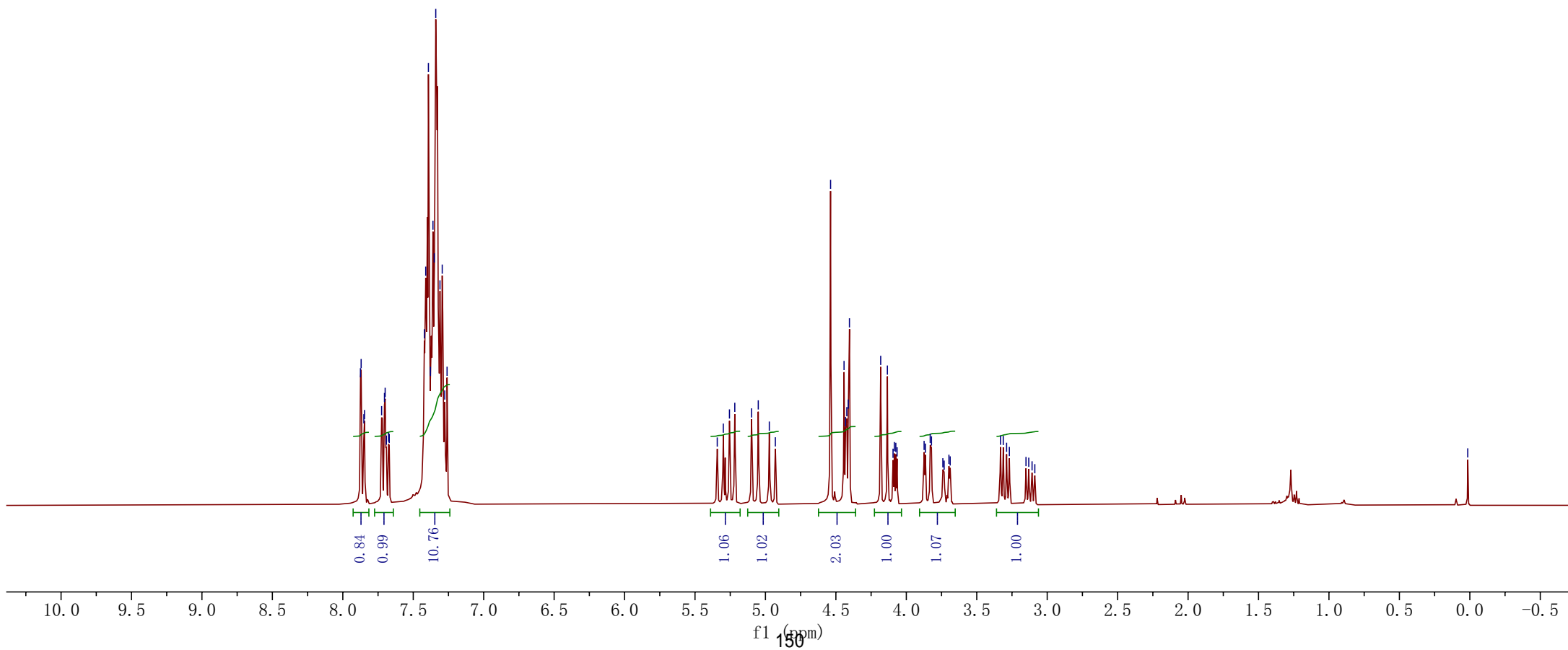
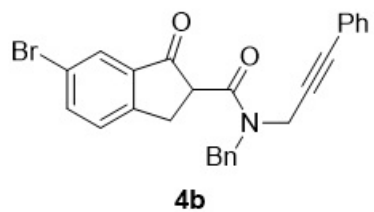


7.875  
7.870  
7.851  
7.846  
7.725  
7.704  
7.699  
7.691  
7.675  
7.670  
7.421  
7.411  
7.392  
7.378  
7.360  
7.351  
7.340  
7.310  
7.294  
7.276  
7.260

5.342  
5.299  
5.255  
5.218  
5.099  
5.051  
4.973  
4.930  
4.538  
4.442  
4.431  
4.422  
4.412  
4.404  
4.182  
4.134  
4.094  
4.085  
4.075  
4.066  
3.874  
3.865  
3.830  
3.822  
3.741  
3.732  
3.698  
3.689  
3.331  
3.312  
3.288  
3.269  
3.151  
3.131  
3.107  
3.088

— 0.015

Fig. 3: **4b**, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



200.434  
200.019

168.350  
167.843

153.460  
153.209

138.220  
138.108  
137.200  
137.114  
136.553  
131.823  
129.055  
128.811  
128.785  
128.485  
128.438  
128.312  
128.189  
128.104  
128.027  
127.884  
127.629  
127.427  
127.403  
126.871  
122.721  
122.275  
121.808

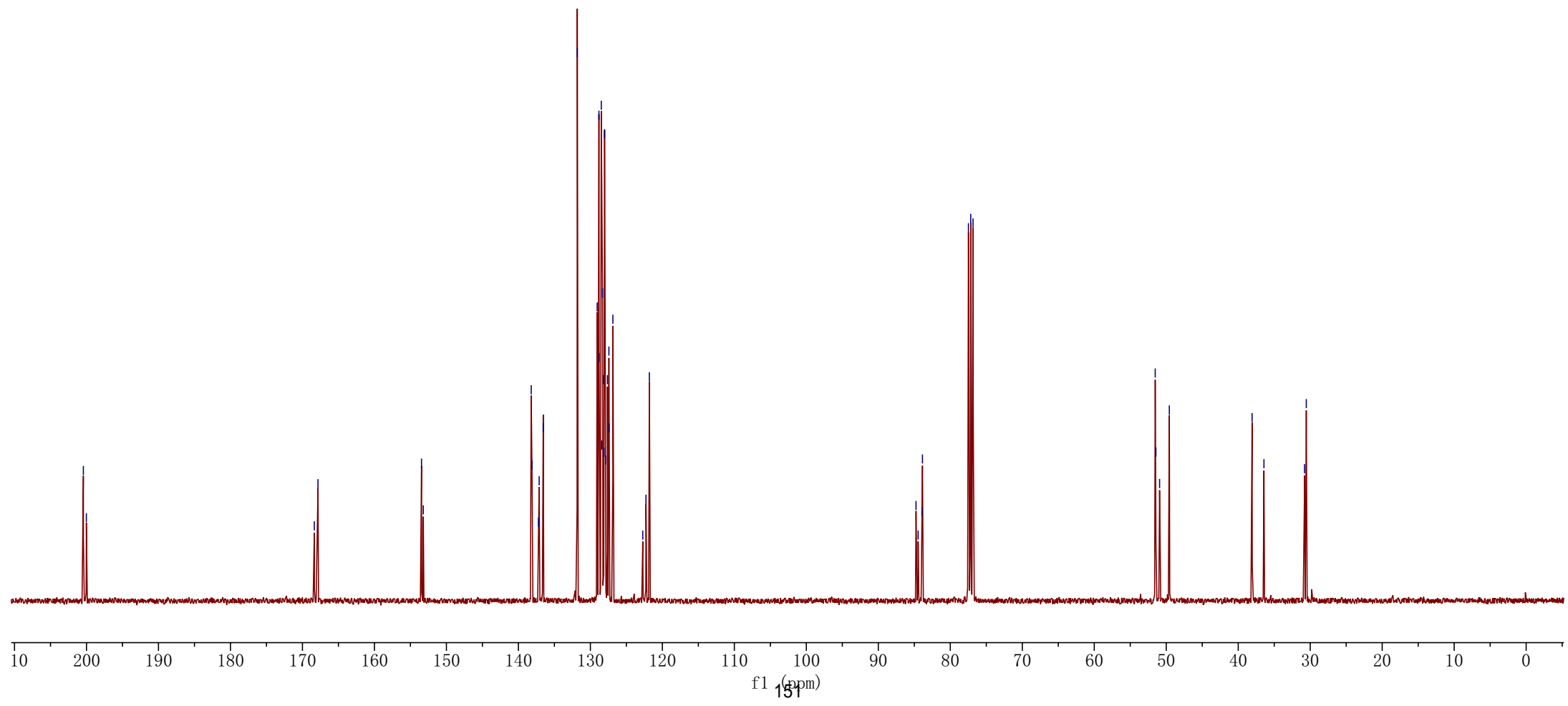
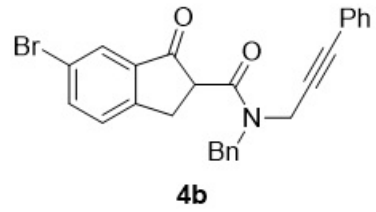
84.760  
84.463  
83.936  
83.868  
77.479  
77.161  
76.842

51.531  
51.435  
50.924  
49.571

38.074  
36.427

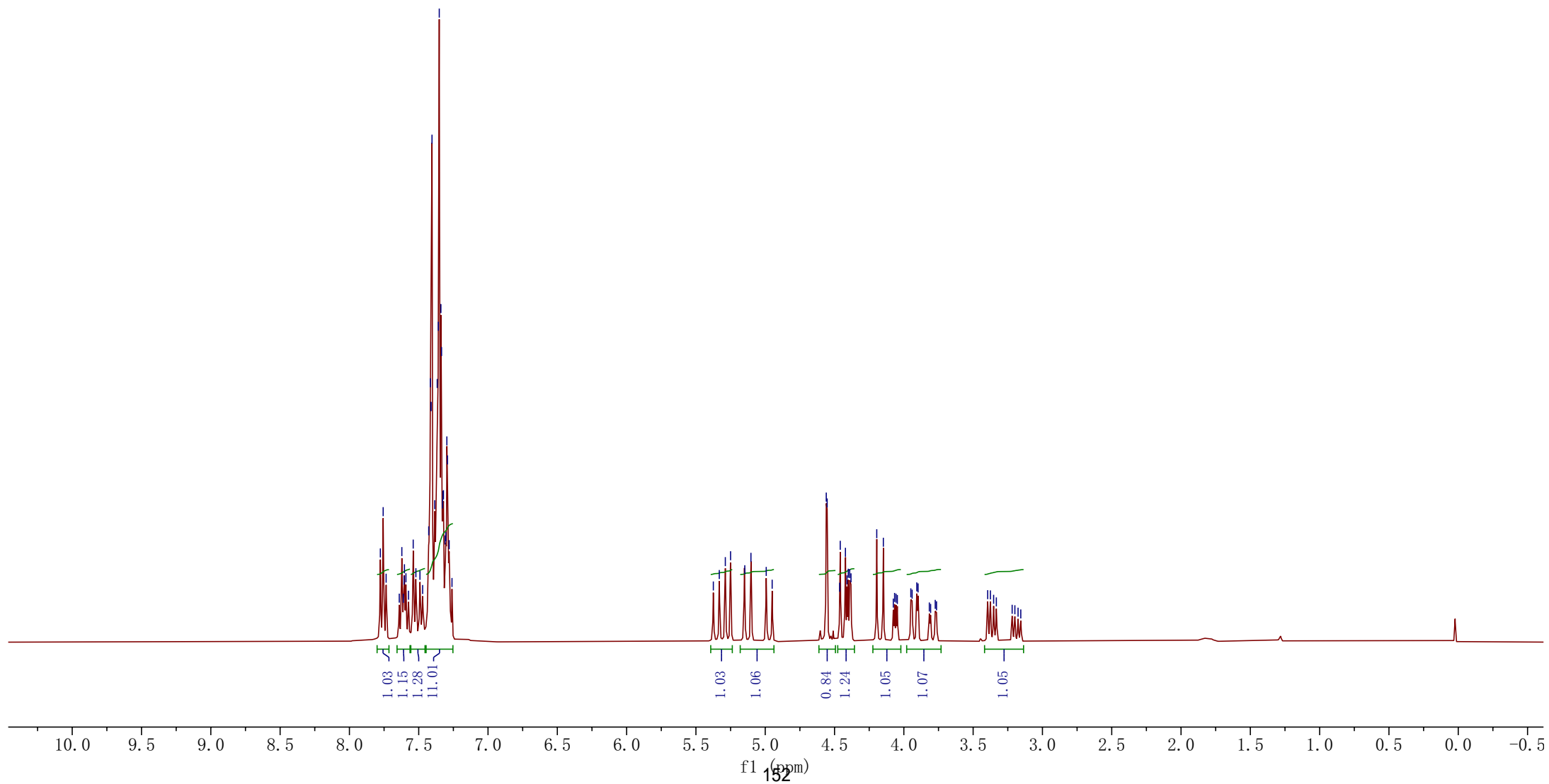
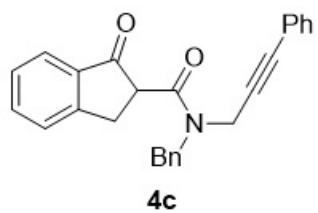
30.790  
30.544

Fig. 3: **4b**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



7.777  
7.757  
7.735  
7.640  
7.622  
7.611  
7.606  
7.603  
7.592  
7.574  
7.540  
7.520  
7.491  
7.472  
7.428  
7.416  
7.412  
7.412  
7.404  
7.385  
7.367  
7.358  
7.352  
7.340  
7.335  
7.328  
7.325  
7.322  
7.310  
7.304  
7.297  
7.293  
7.280  
7.260  
5.374  
5.331  
5.288  
5.250  
5.147  
5.103  
4.993  
4.950  
4.560  
4.553  
4.463  
4.459  
4.421  
4.410  
4.401  
4.391  
4.381  
4.195  
4.148  
4.076  
4.067  
4.056  
4.047  
3.950  
3.940  
3.907  
3.897  
3.816  
3.807  
3.773  
3.764  
3.395  
3.375  
3.352  
3.333  
3.219  
3.199  
3.176  
3.156

Fig. 3: 4c, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



201.869  
201.471

168.862  
168.352

154.881  
154.639  
136.714  
136.682  
135.512  
135.393  
135.303  
131.832  
131.817  
129.010  
128.786  
128.728  
128.468  
128.388  
128.294  
128.015  
127.809  
127.680  
127.548  
126.923  
126.654  
126.569  
124.574  
122.789  
122.358

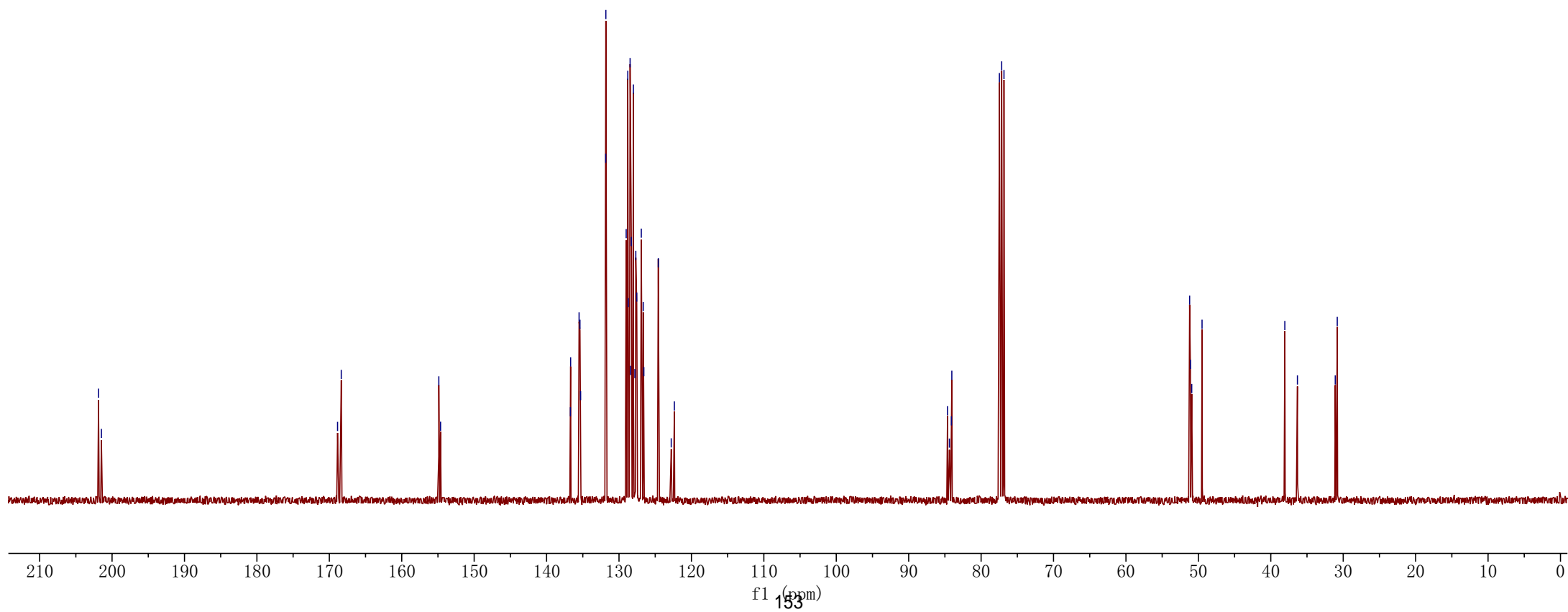
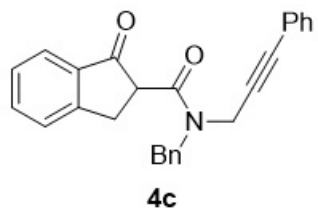
84.639  
84.377  
84.098  
84.043  
77.477  
77.159  
76.842

51.207  
51.096  
50.916  
49.492

38.061  
36.323

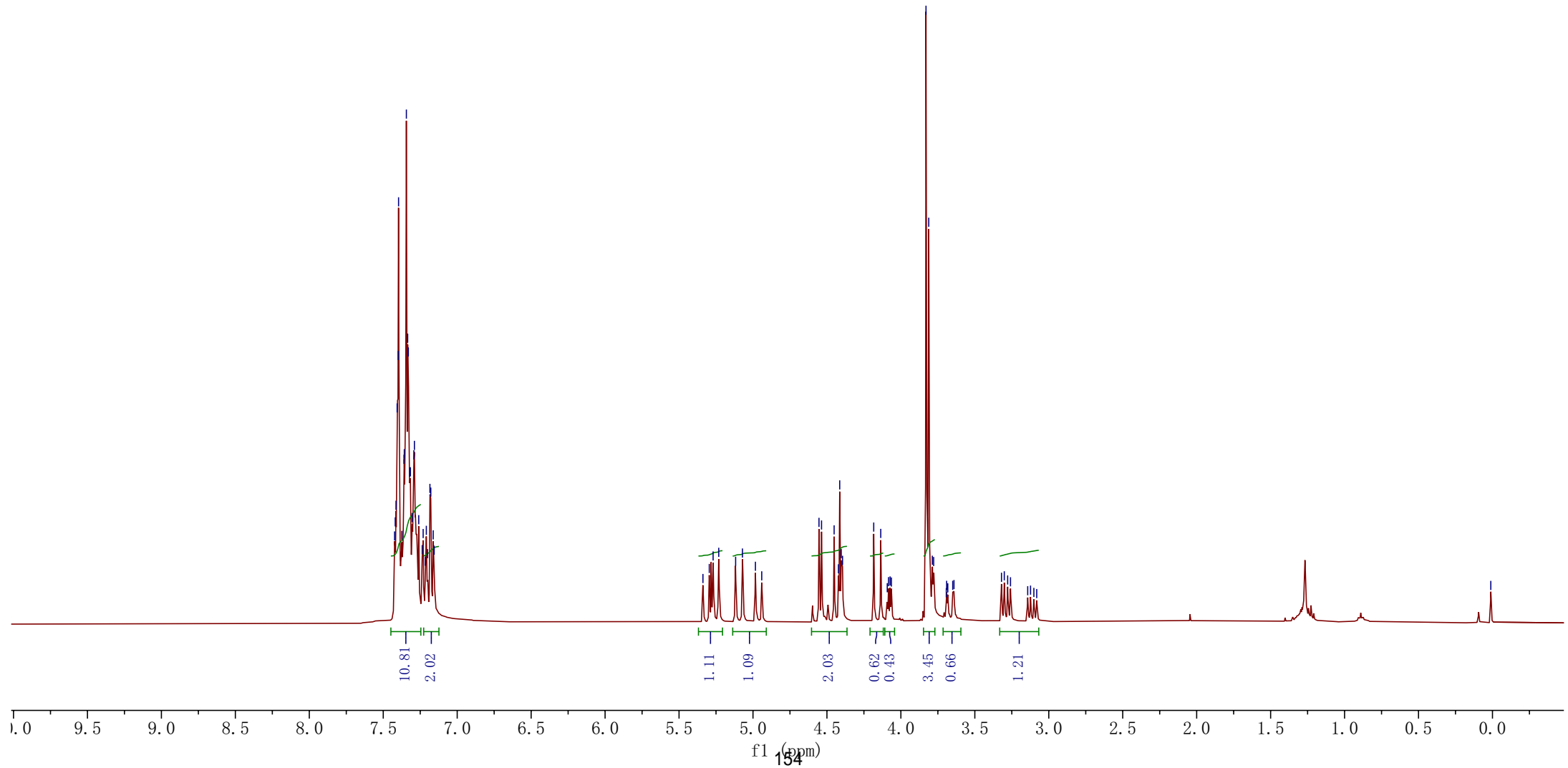
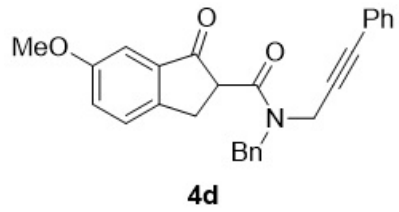
31.098  
30.823

Fig. 3: **4c**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



7.423  
7.419  
7.414  
7.406  
7.399  
7.396  
7.374  
7.360  
7.358  
7.344  
7.335  
7.330  
7.321  
7.317  
7.304  
7.293  
7.289  
7.260  
7.237  
7.230  
7.216  
7.209  
7.201  
7.184  
7.178  
7.162  
7.156  
5.338  
5.296  
5.270  
5.232  
5.117  
5.071  
4.984  
4.941  
4.554  
4.536  
4.451  
4.422  
4.414  
4.403  
4.394  
4.184  
4.136  
4.092  
4.084  
4.073  
4.064  
4.830  
3.812  
3.787  
3.778  
3.693  
3.691  
3.683  
3.649  
3.641  
3.320  
3.301  
3.278  
3.259  
3.142  
3.123  
3.101  
3.081

Fig. 3: 4d, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



201.793  
201.400

168.965  
168.441

159.661  
159.646

147.858  
147.580

136.718  
136.702

136.569  
136.451

131.835  
131.818

129.008  
128.777

128.728  
128.469

128.389  
128.298

128.037  
127.816

127.544  
127.321

127.231  
126.947

124.978  
124.859

122.802  
122.364

105.613

84.641  
84.360

84.121  
84.041

77.479  
77.161

76.844

55.710  
51.915

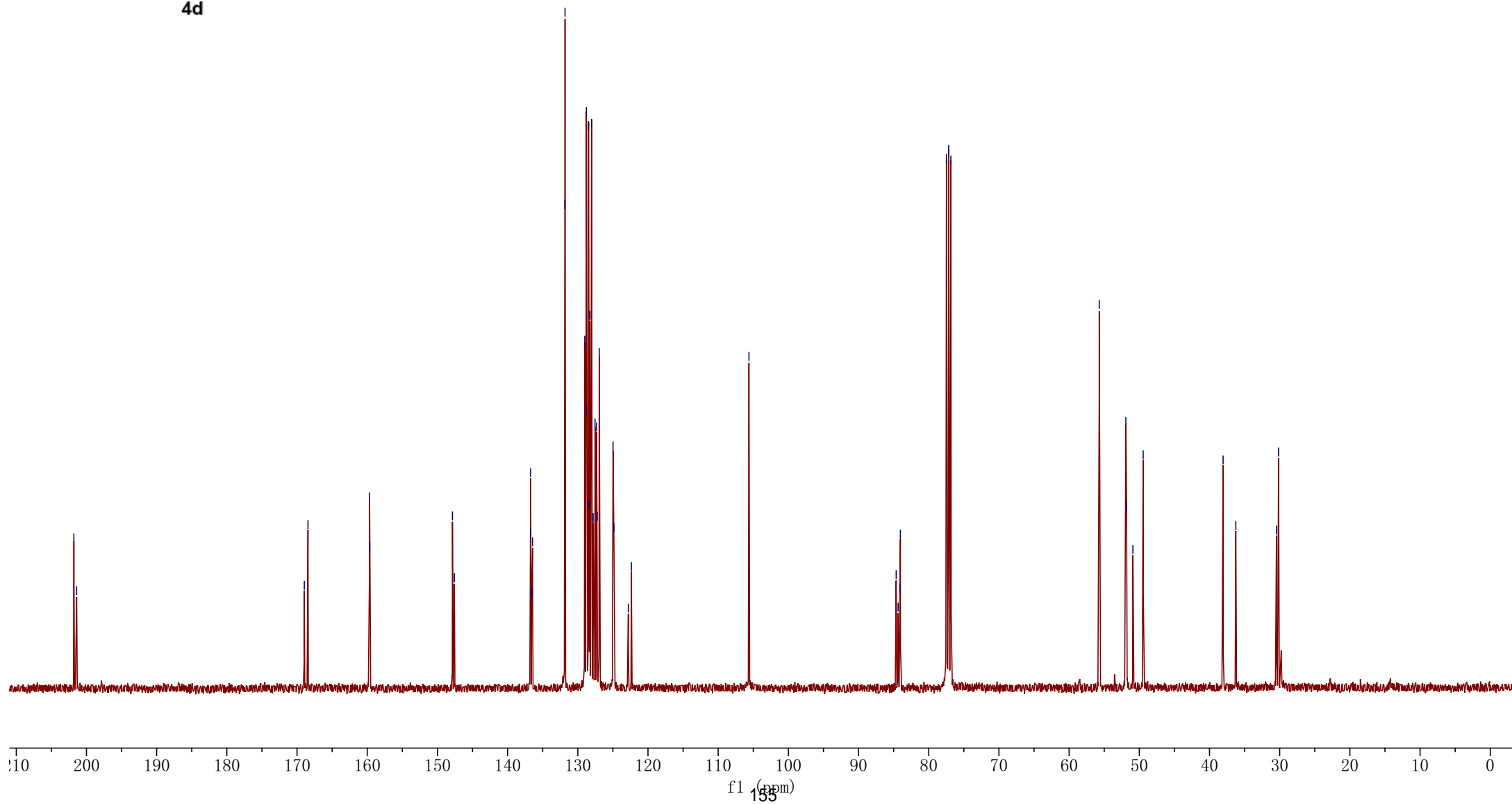
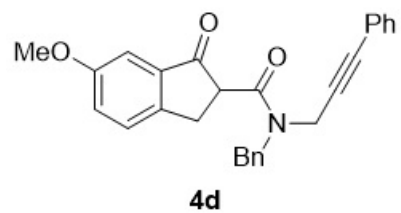
51.806  
50.913

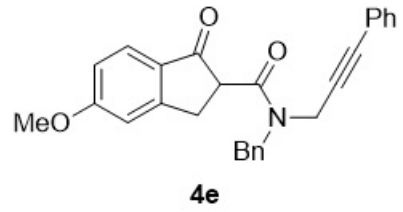
49.451

38.063  
36.249

30.461  
30.160

Fig. 3: 4d, <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)



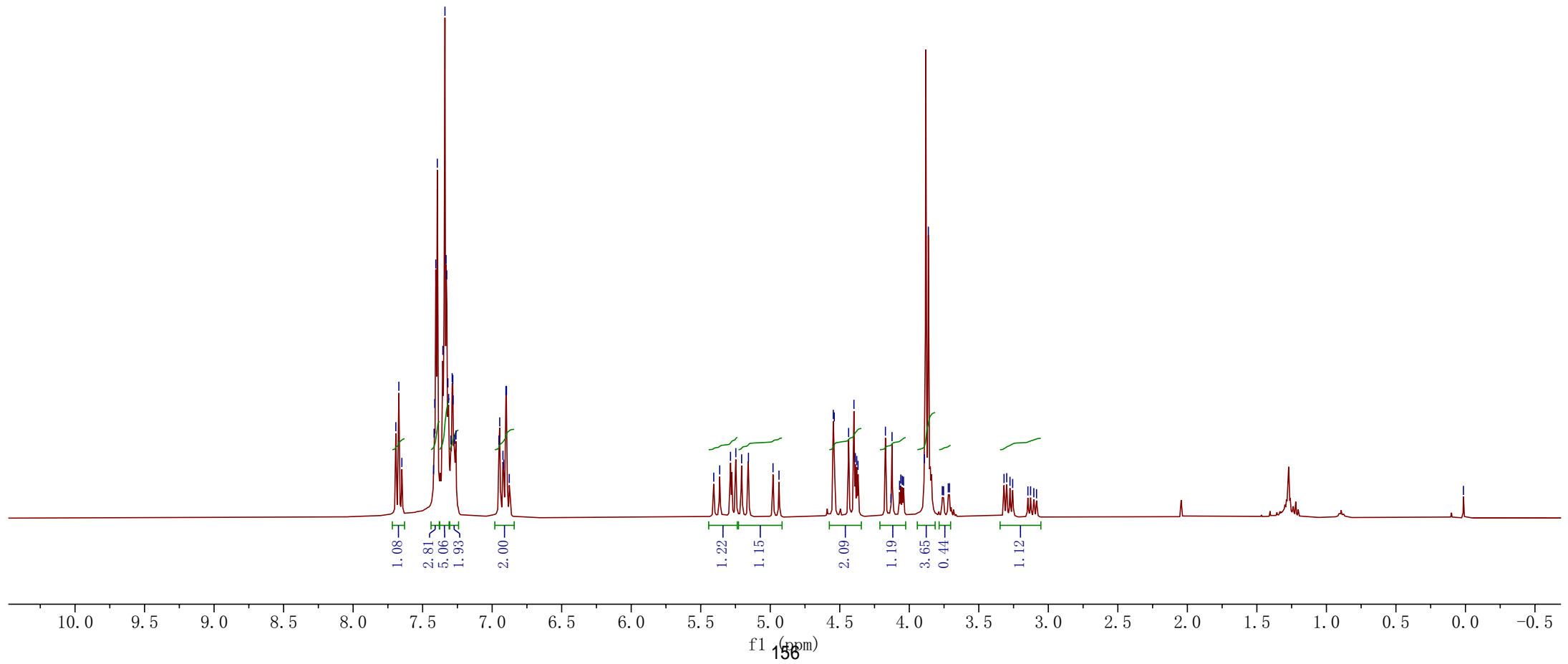


**Fig. 3: 4e, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**

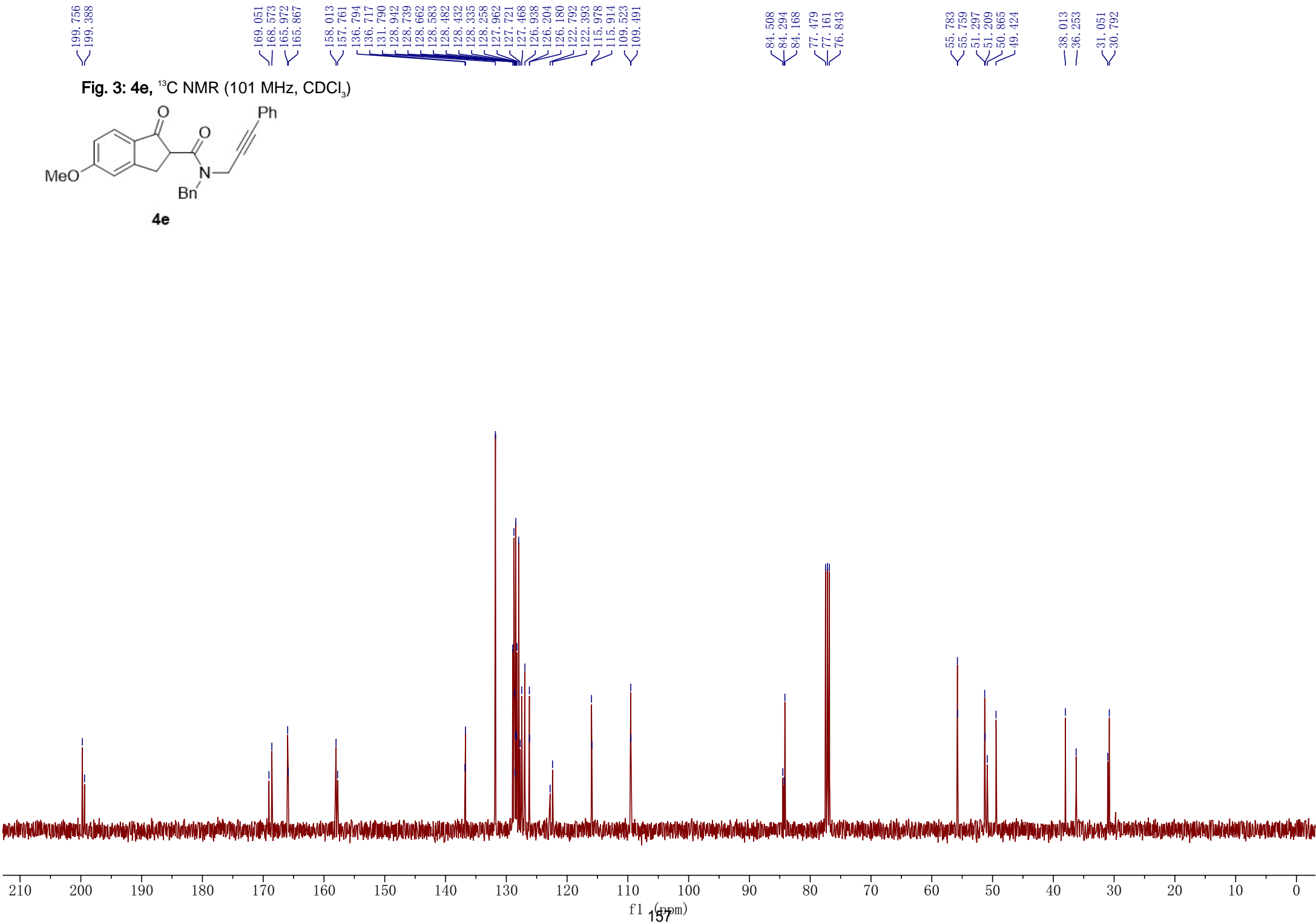
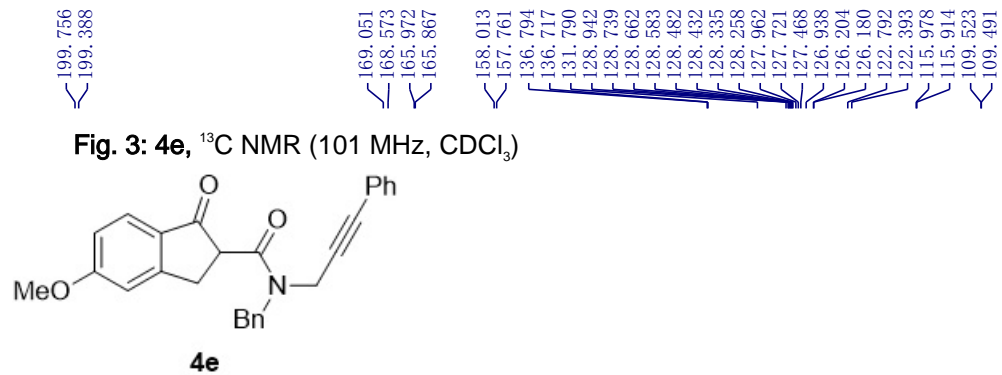
7.693  
7.671  
7.649  
7.421  
7.418  
7.413  
7.405  
7.394  
7.355  
7.340  
7.331  
7.327  
7.318  
7.313  
7.296  
7.288  
7.283  
7.281  
7.270  
7.260  
6.951  
6.946  
6.922  
6.917  
6.901  
6.897  
6.877

5.406  
5.363  
5.286  
5.248  
5.206  
5.157  
4.980  
4.937  
4.547  
4.540  
4.436  
4.398  
4.388  
4.378  
4.369  
4.172  
4.132  
4.124  
4.070  
4.061  
4.050  
4.041  
3.892  
3.863  
3.762  
3.753  
3.720  
3.711  
3.319  
3.299  
3.276  
3.256  
3.147  
3.127  
3.104  
3.085

— 0.014







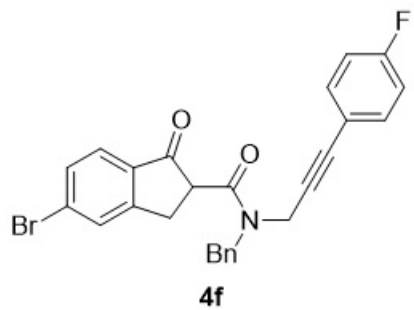


Fig. 3: **4f**,  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )

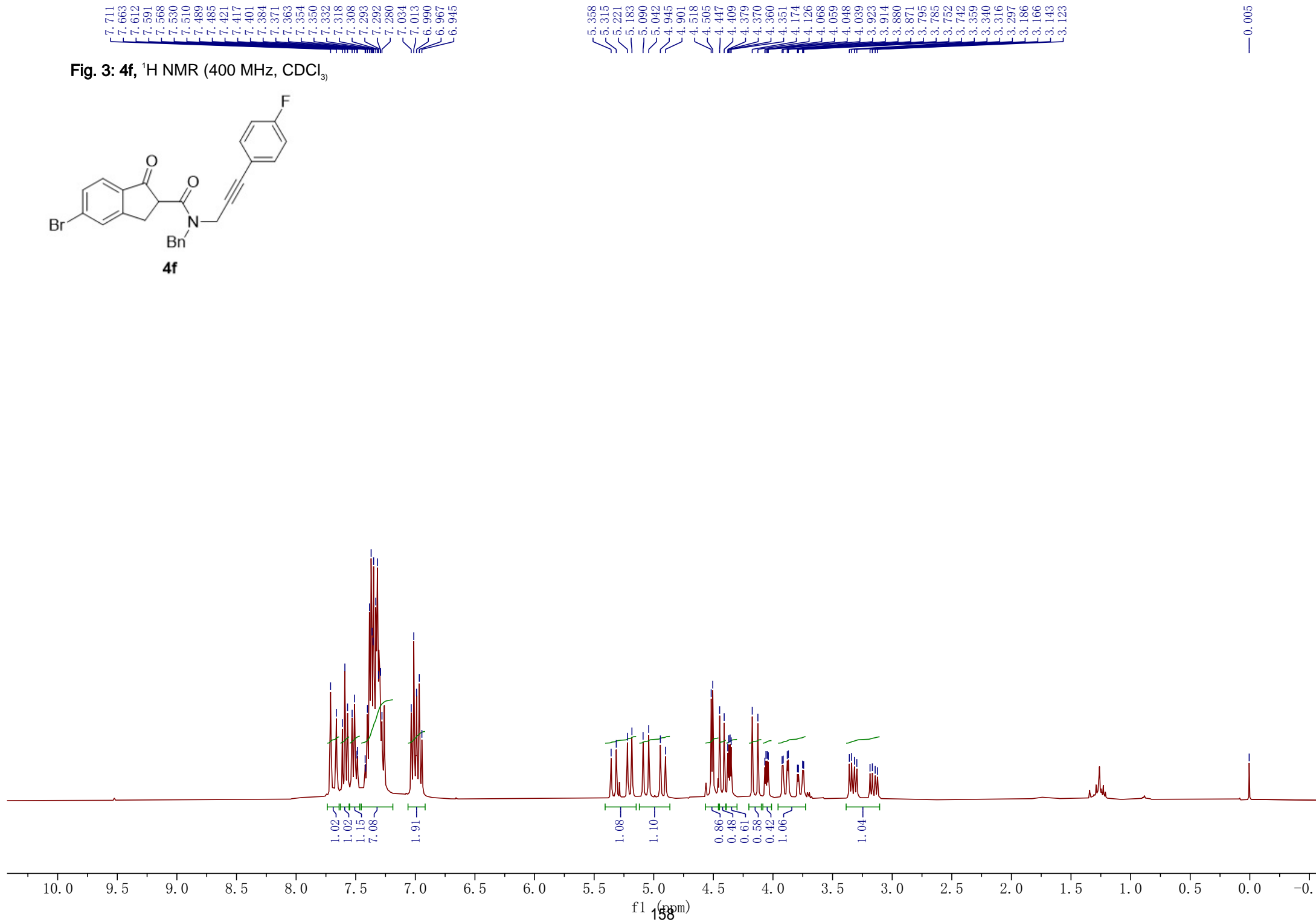
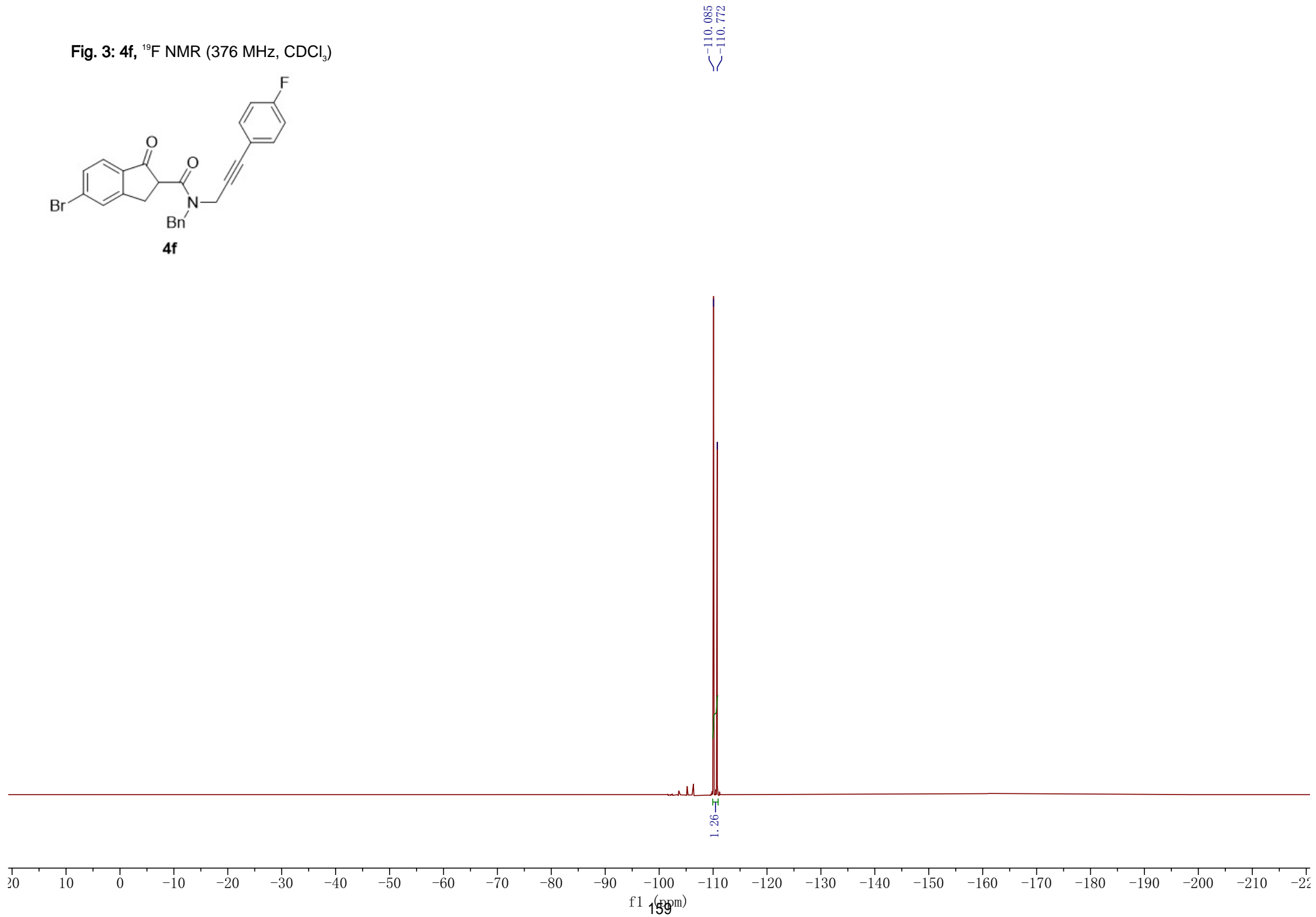
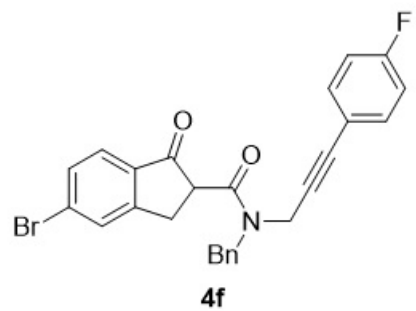


Fig. 3: 4f,  $^{19}\text{F}$  NMR (376 MHz,  $\text{CDCl}_3$ )



200.558  
200.185  
168.391  
167.846  
164.027  
163.846  
161.540  
161.367  
156.398  
156.198  
136.560  
134.233  
134.154  
133.818  
133.794  
133.735  
133.711  
131.432  
131.410  
131.120  
130.987  
129.980  
129.902  
129.073  
128.823  
128.045  
127.911  
127.647  
126.844  
125.744  
125.719  
118.836  
118.801  
118.394  
118.357  
115.918  
115.699  
115.483

83.713  
83.645  
83.630  
83.342  
77.478  
77.160  
76.842

51.217  
51.106  
50.993  
49.603

38.033  
36.425  
30.769  
30.556

Fig. 3: 4f,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )

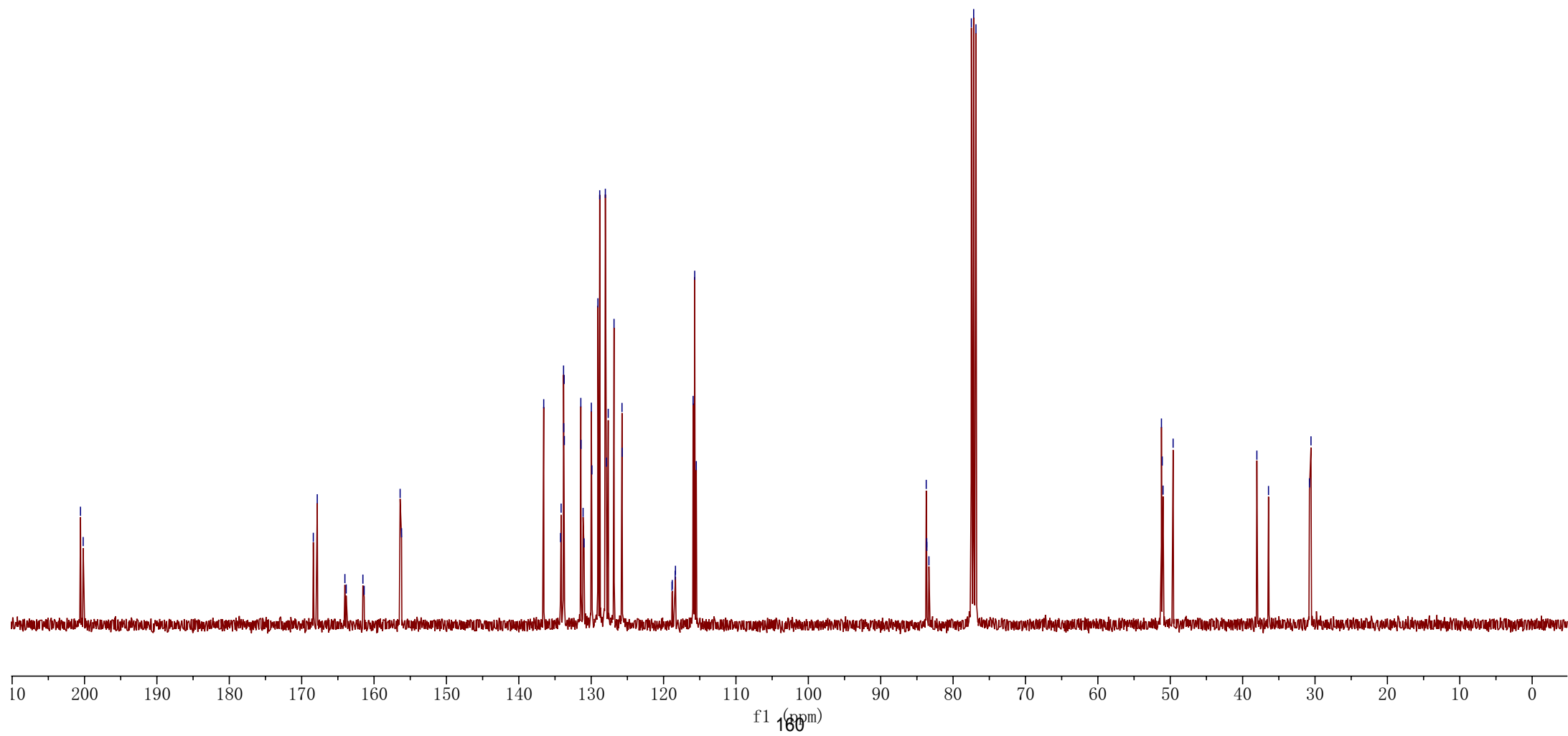
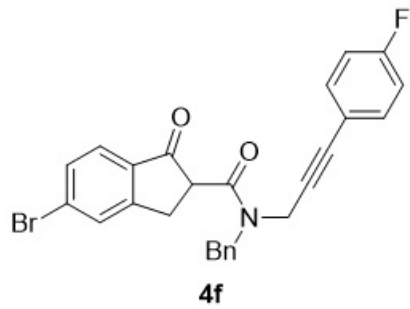
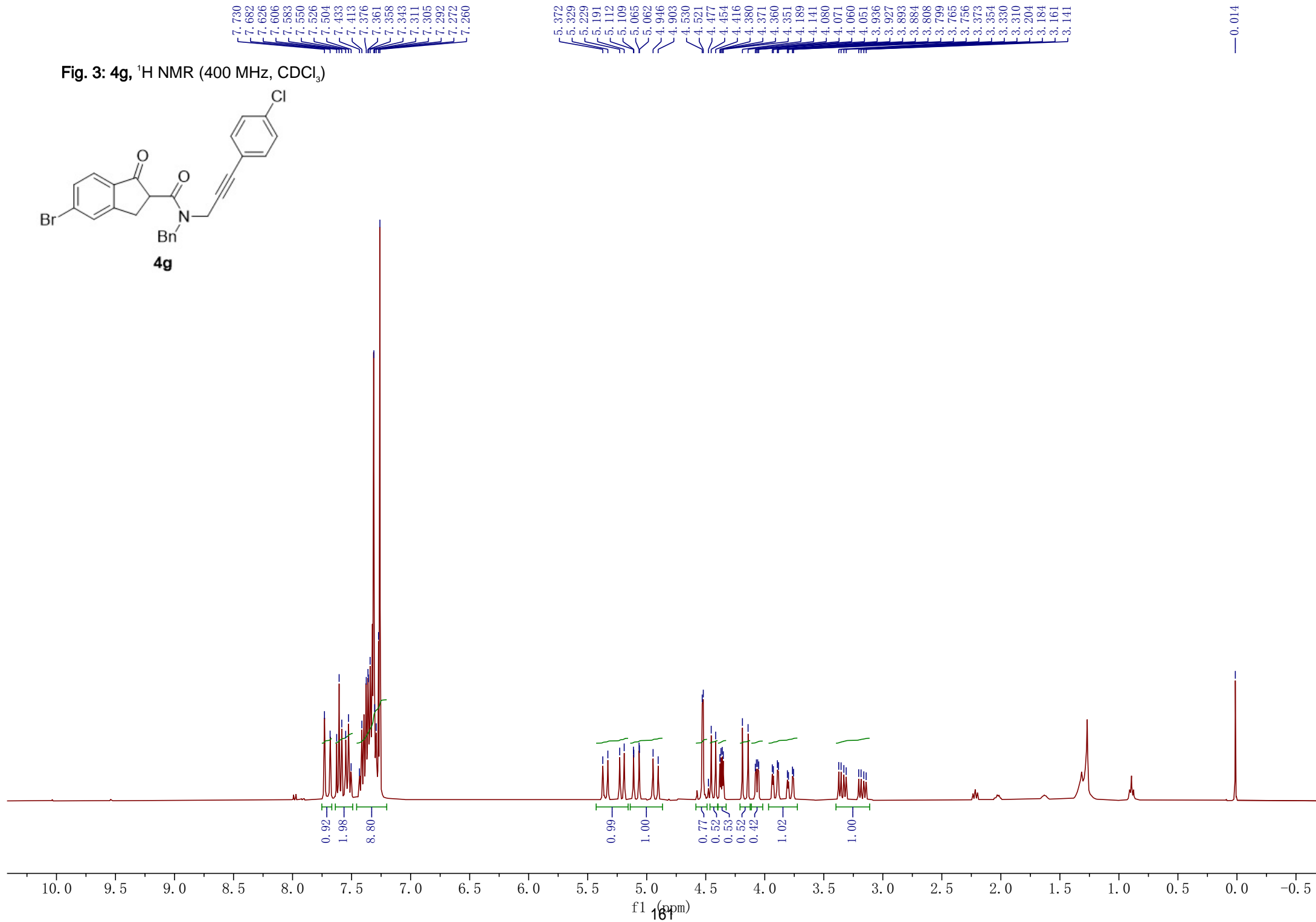
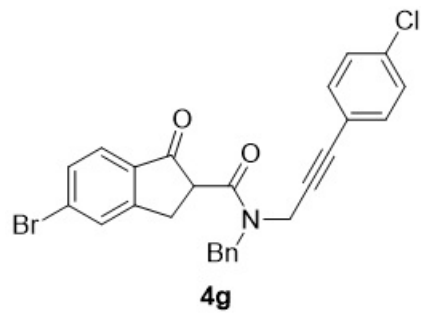
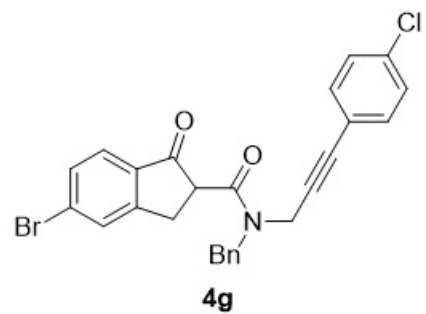
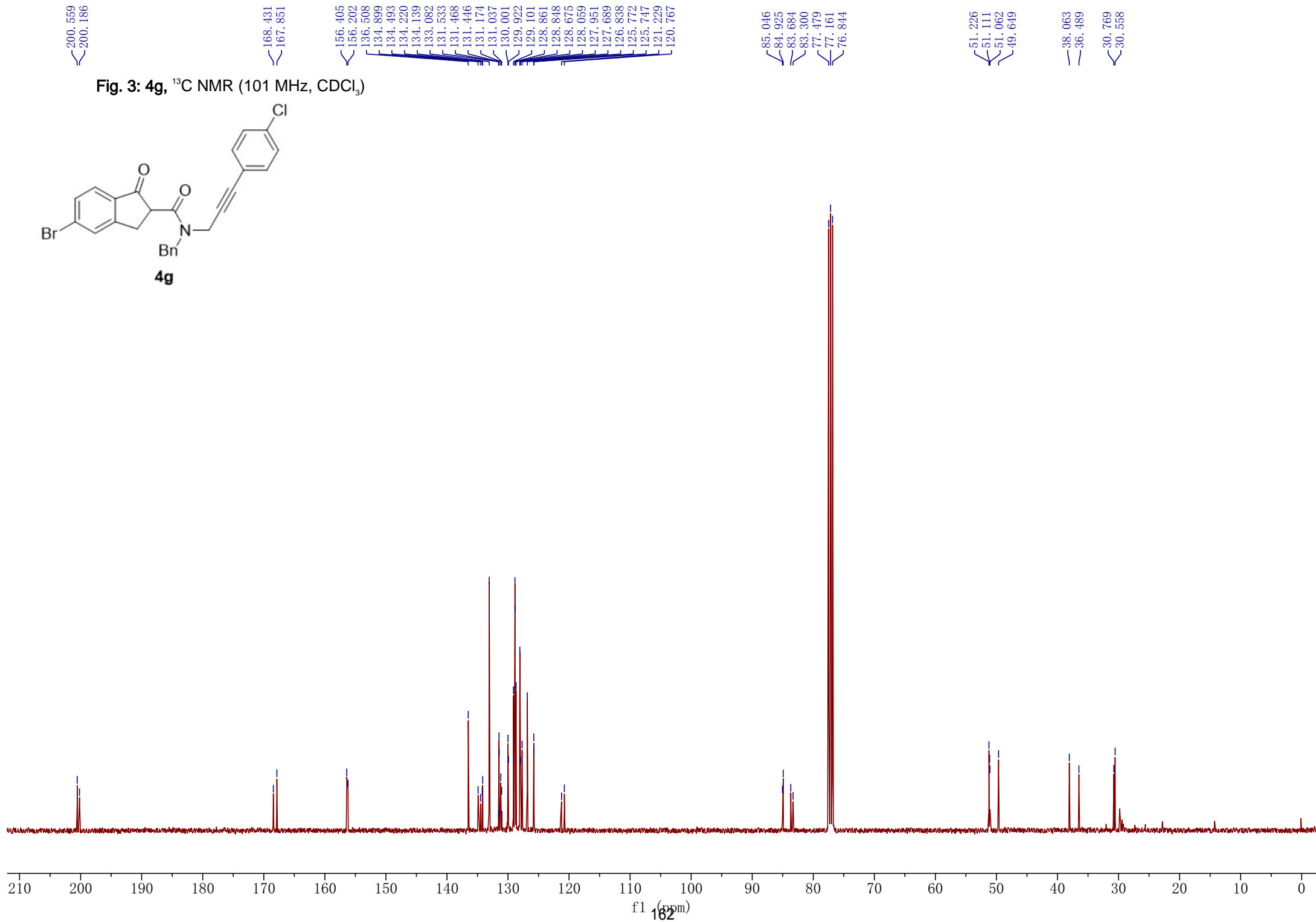


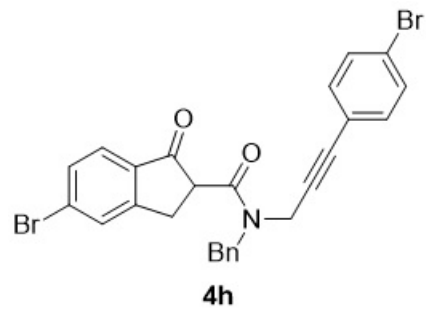
Fig. 3: 4g, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



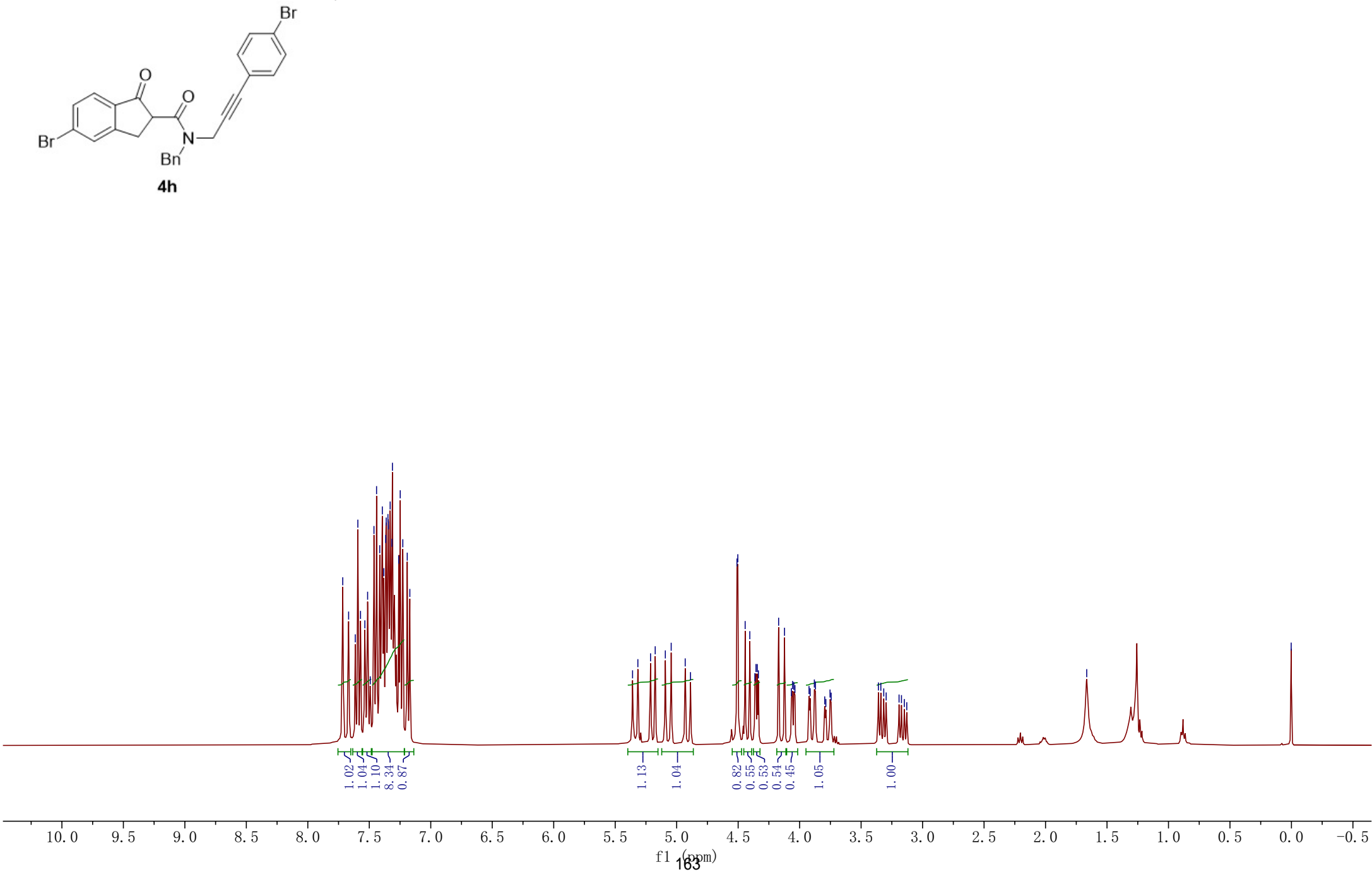


**Fig. 3: 4g,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**





**Fig. 3: 4h, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**



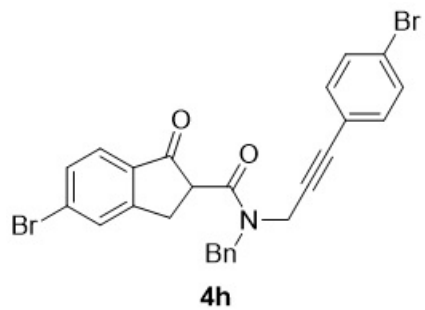
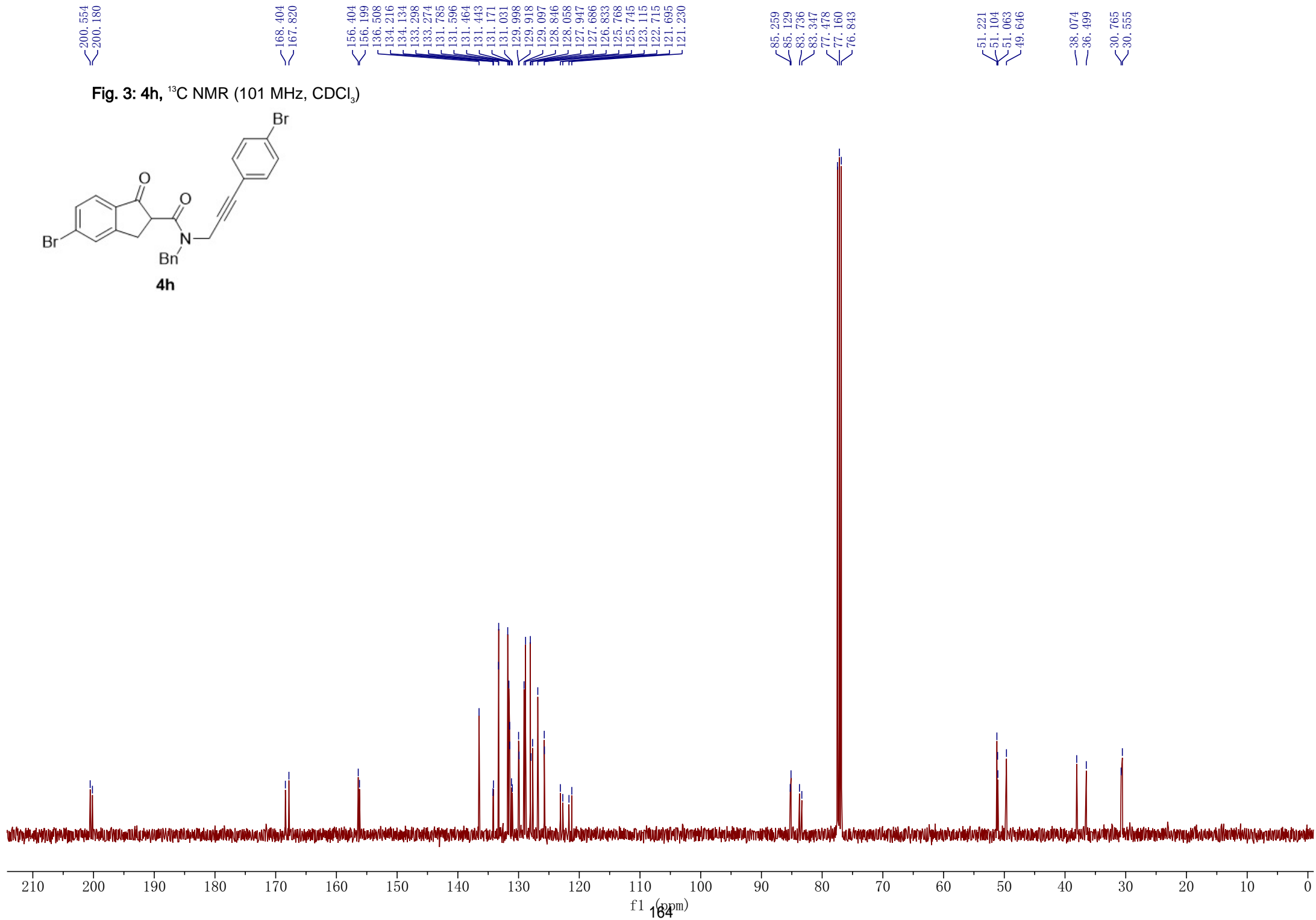
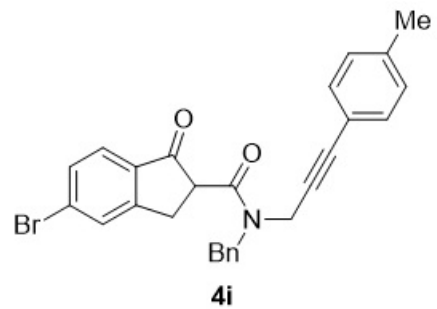


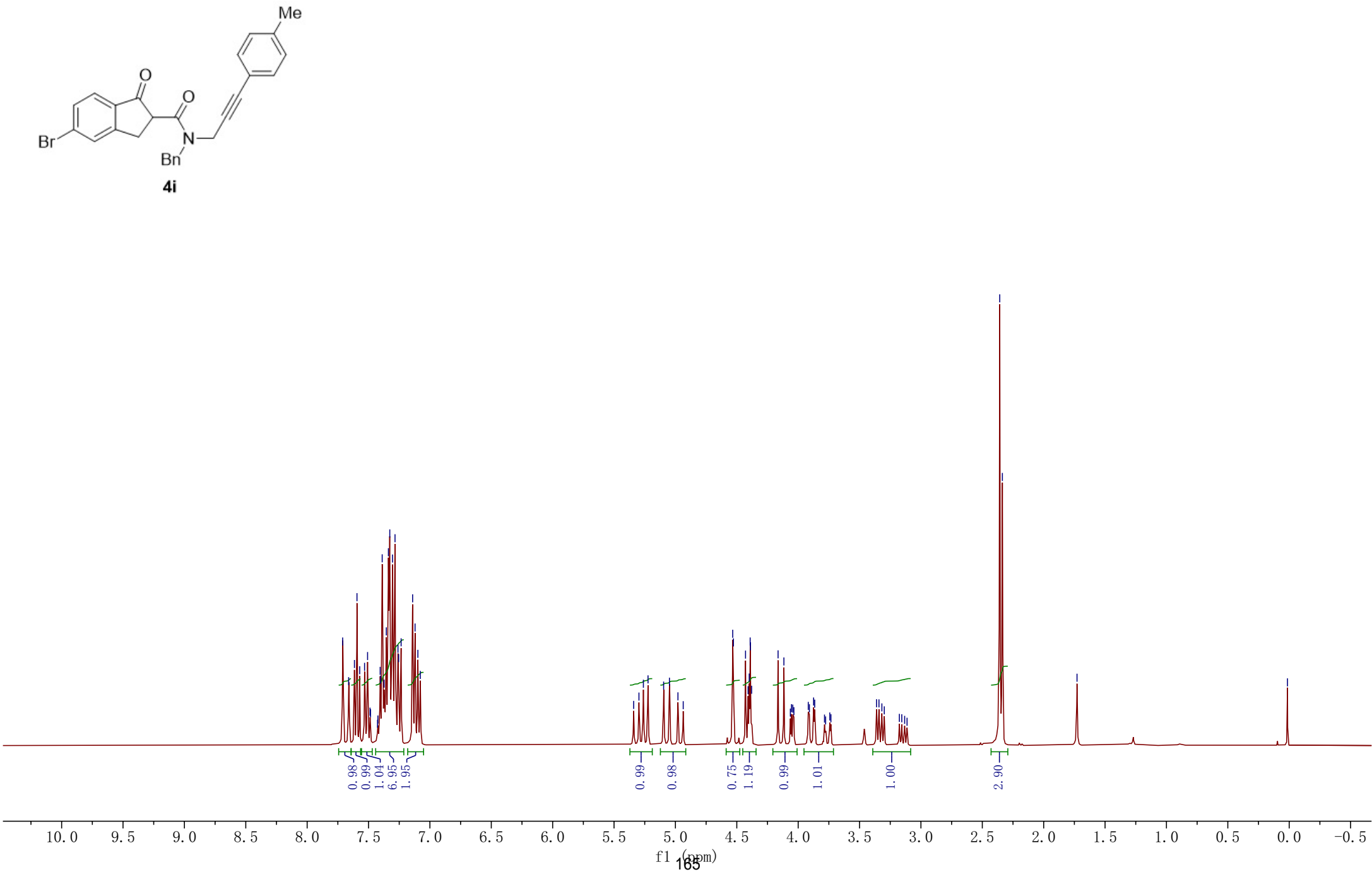
Fig. 3: **4h**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )







**Fig. 3: 4i, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**



200.637  
200.222

168.362  
167.919

156.424  
156.196  
138.965  
138.531  
136.618  
136.591  
134.255  
134.174  
131.713  
131.697  
131.367  
131.035  
130.909  
129.952  
129.869  
129.237  
129.064  
129.026  
128.787  
128.008  
127.837  
127.580  
126.883  
125.706  
125.692  
119.636  
119.177

84.859  
84.598  
83.174  
83.155  
77.479  
77.161  
76.843

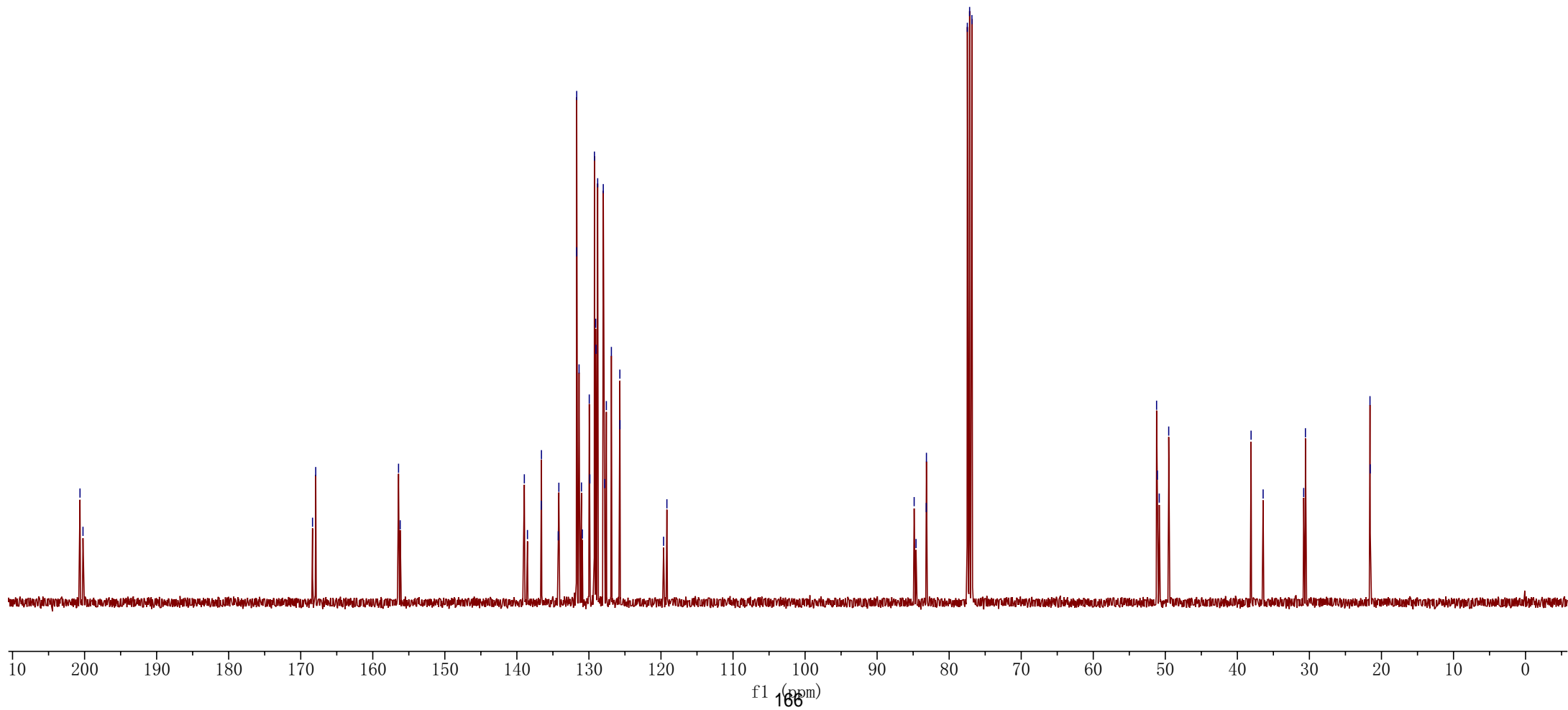
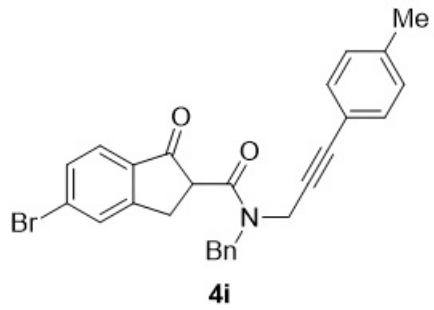
51.211  
51.103  
50.840  
49.529

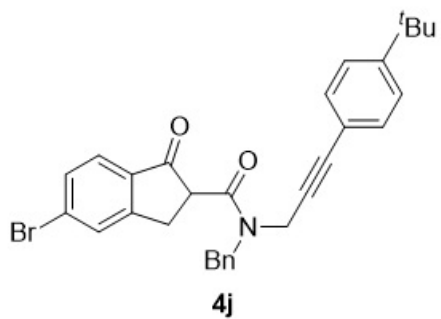
38.095  
36.424

30.792  
30.552

21.592  
21.562

Fig. 3: **4i**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )





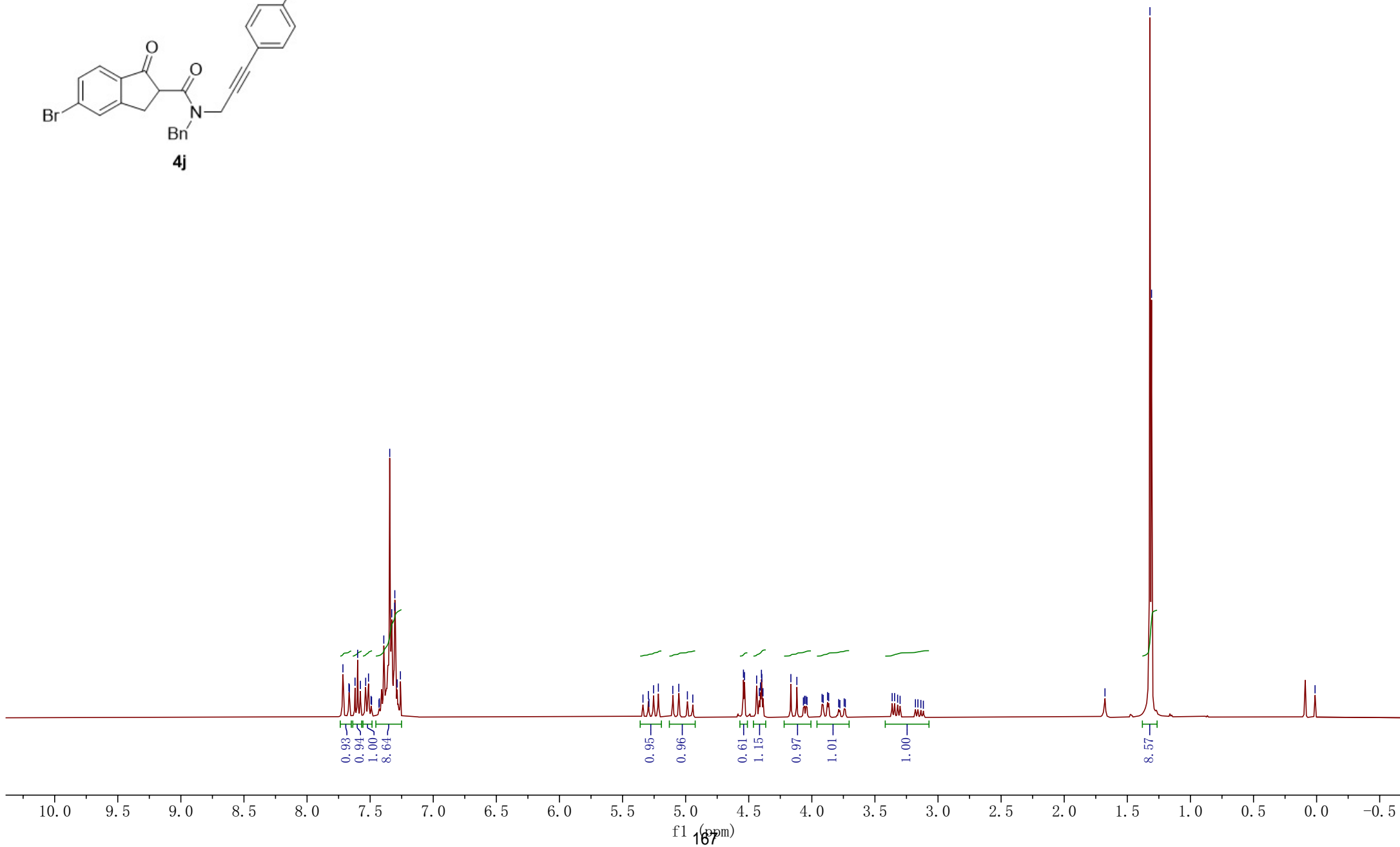
7.716  
7.668  
7.665  
7.620  
7.599  
7.577  
7.535  
7.513  
7.493  
7.489  
7.430  
7.427  
7.392  
7.345  
7.329  
7.305  
7.304  
7.286  
7.260

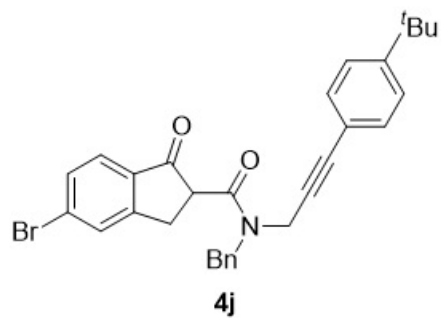
5.338  
5.295  
5.291  
5.254  
5.216  
5.102  
5.054  
4.986  
4.943  
4.542  
4.533  
4.437  
4.416  
4.407  
4.399  
4.396  
4.387  
4.166  
4.119  
4.067  
4.058  
4.047  
4.038  
3.919  
3.910  
3.876  
3.866  
3.787  
3.778  
3.744  
3.735  
3.363  
3.344  
3.320  
3.301  
3.179  
3.159  
3.136  
3.116

— 1.677

1.321  
1.308

— 0.012





200.671  
200.238

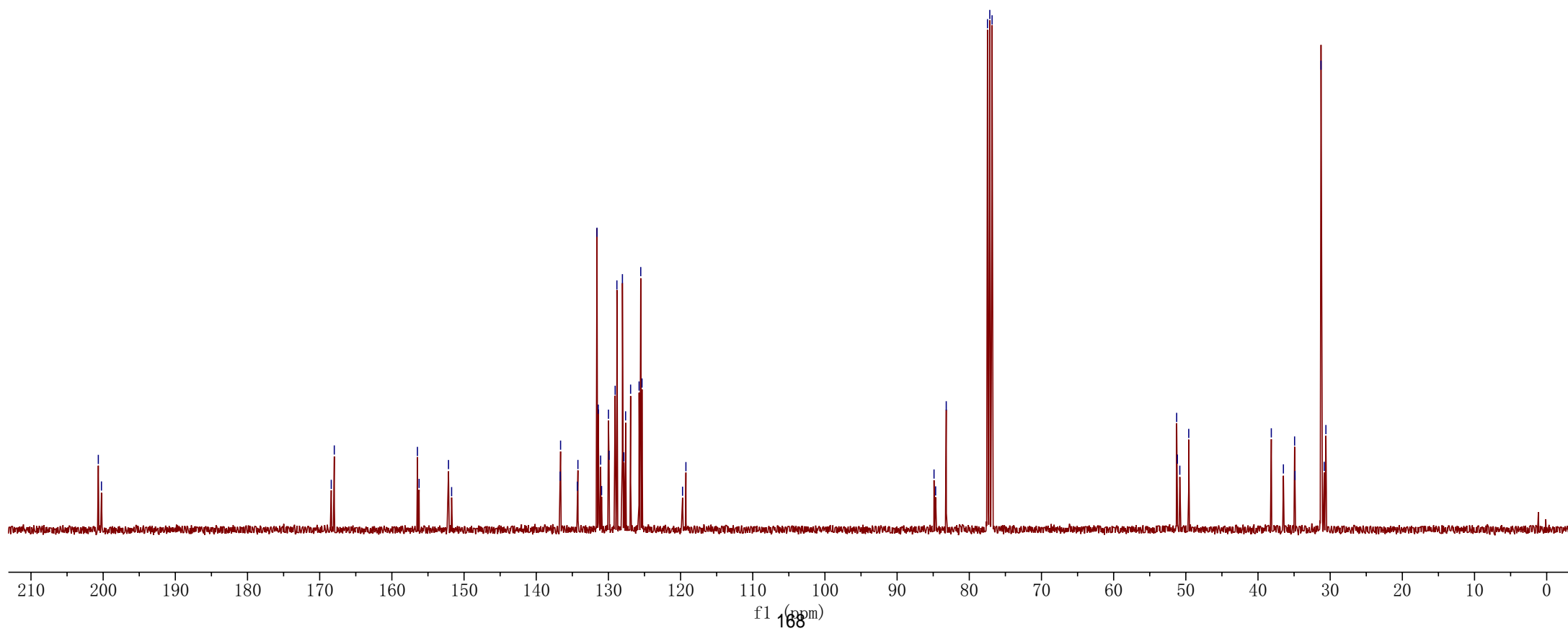
168.400  
167.977

156.459  
156.227  
152.154  
151.722  
136.680  
136.626  
134.305  
134.223  
131.583  
131.407  
131.073  
130.943  
129.992  
129.907  
129.065  
128.824  
128.058  
127.868  
127.618  
126.924  
125.747  
125.520  
125.343  
119.727  
119.262

84.885  
84.661  
83.193  
77.478  
77.161  
76.843

51.268  
51.166  
50.832  
49.597

38.156  
36.480  
34.929  
34.871  
31.269  
30.829  
30.590

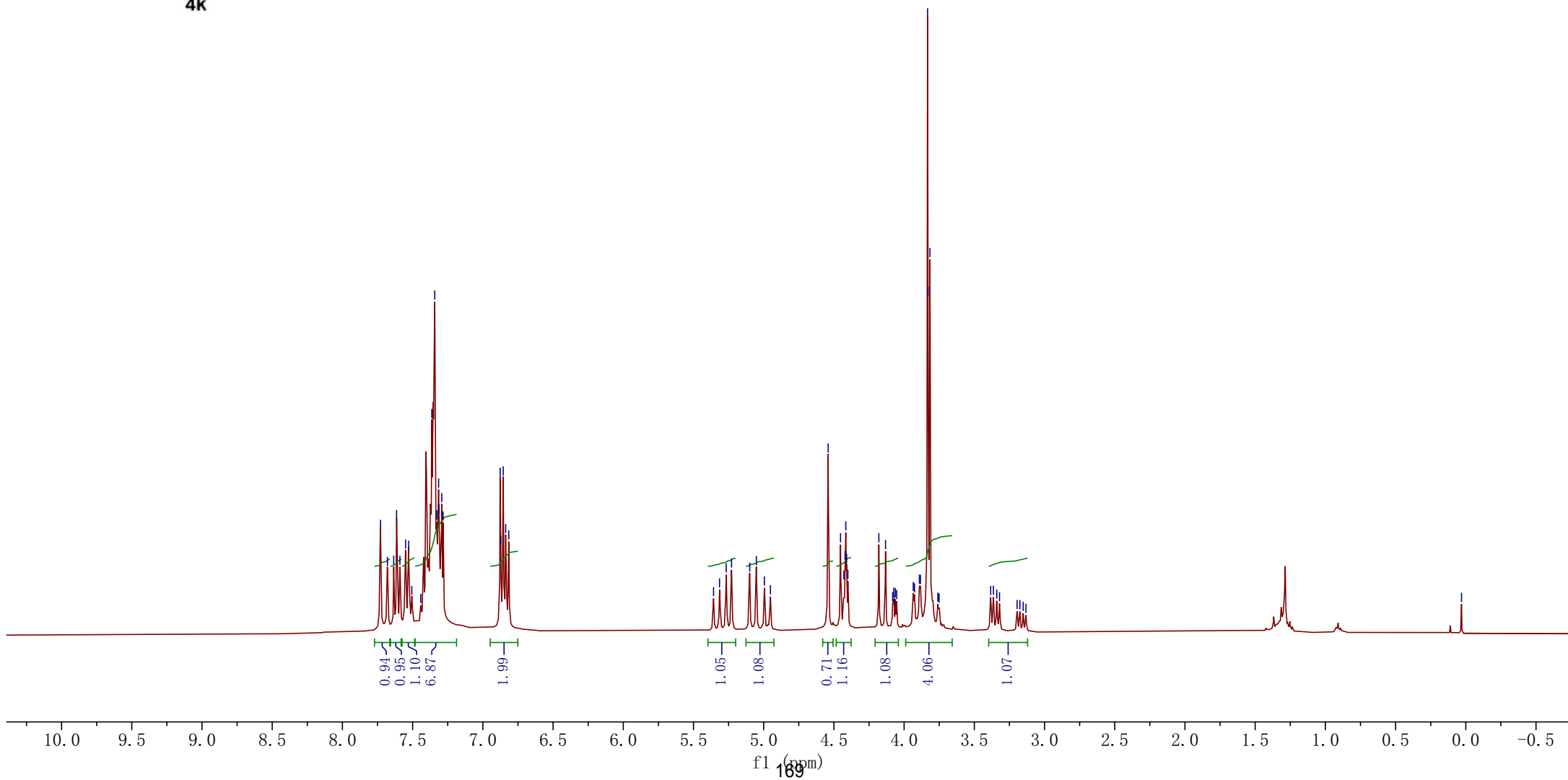
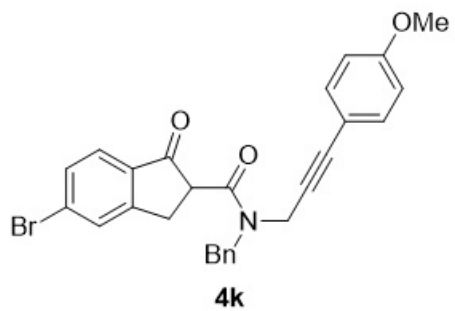


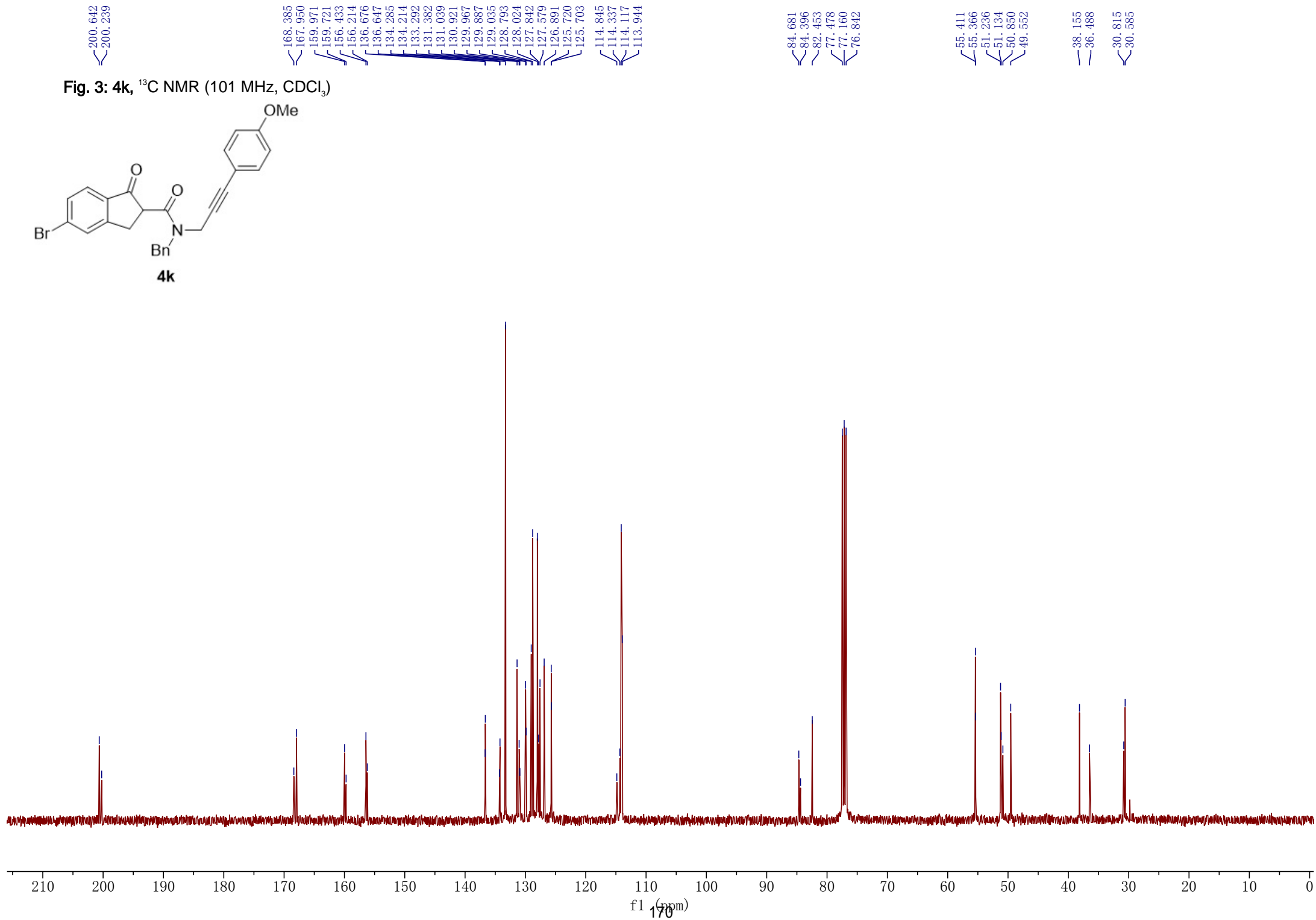
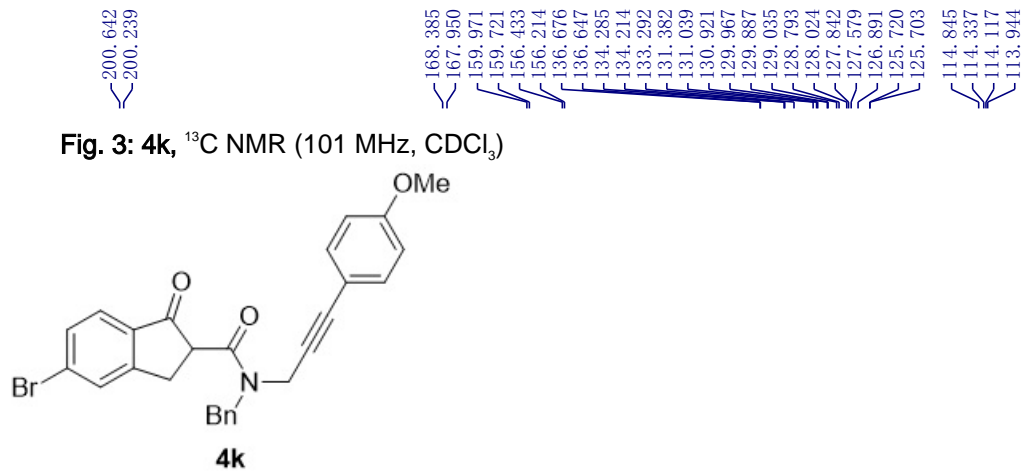
7.729  
7.679  
7.635  
7.615  
7.591  
7.550  
7.528  
7.506  
7.442  
7.364  
7.342  
7.329  
7.315  
7.313  
7.293  
7.283  
6.877  
6.873  
6.855  
6.837  
6.816

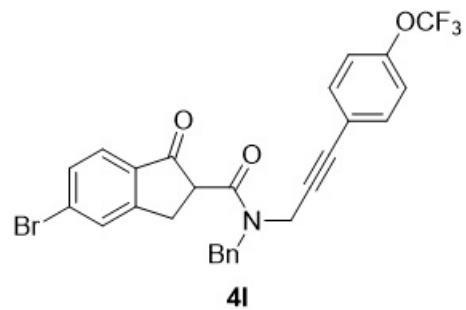
5.357  
5.314  
5.267  
5.229  
5.099  
5.052  
4.995  
4.952  
4.541  
4.453  
4.429  
4.420  
4.415  
4.409  
4.400  
4.180  
4.132  
4.082  
4.073  
4.070  
4.062  
4.053  
3.935  
3.926  
3.891  
3.883  
3.833  
3.830  
3.816  
3.760  
3.751  
3.383  
3.364  
3.340  
3.321  
3.195  
3.175  
3.152  
3.132

— 0.030

Fig. 3: 4k, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)







7.721  
7.673  
7.617  
7.596  
7.573  
7.536  
7.520  
7.495  
7.426  
7.420  
7.410  
7.404  
7.398  
7.389  
7.369  
7.357  
7.351  
7.335  
7.318  
7.301  
7.285  
7.260  
7.180  
7.159  
7.134  
7.114

5.369  
5.325  
5.211  
5.173  
5.111  
5.063  
4.936  
4.893  
4.829  
4.513  
4.459  
4.421  
4.370  
4.361  
4.350  
4.341  
4.191  
4.143  
4.074  
4.065  
4.054  
4.045  
3.930  
3.921  
3.886  
3.877  
3.802  
3.793  
3.759  
3.750  
3.662  
3.343  
3.319  
3.299  
3.196  
3.176  
3.153  
3.133  
1.663

— 0.002

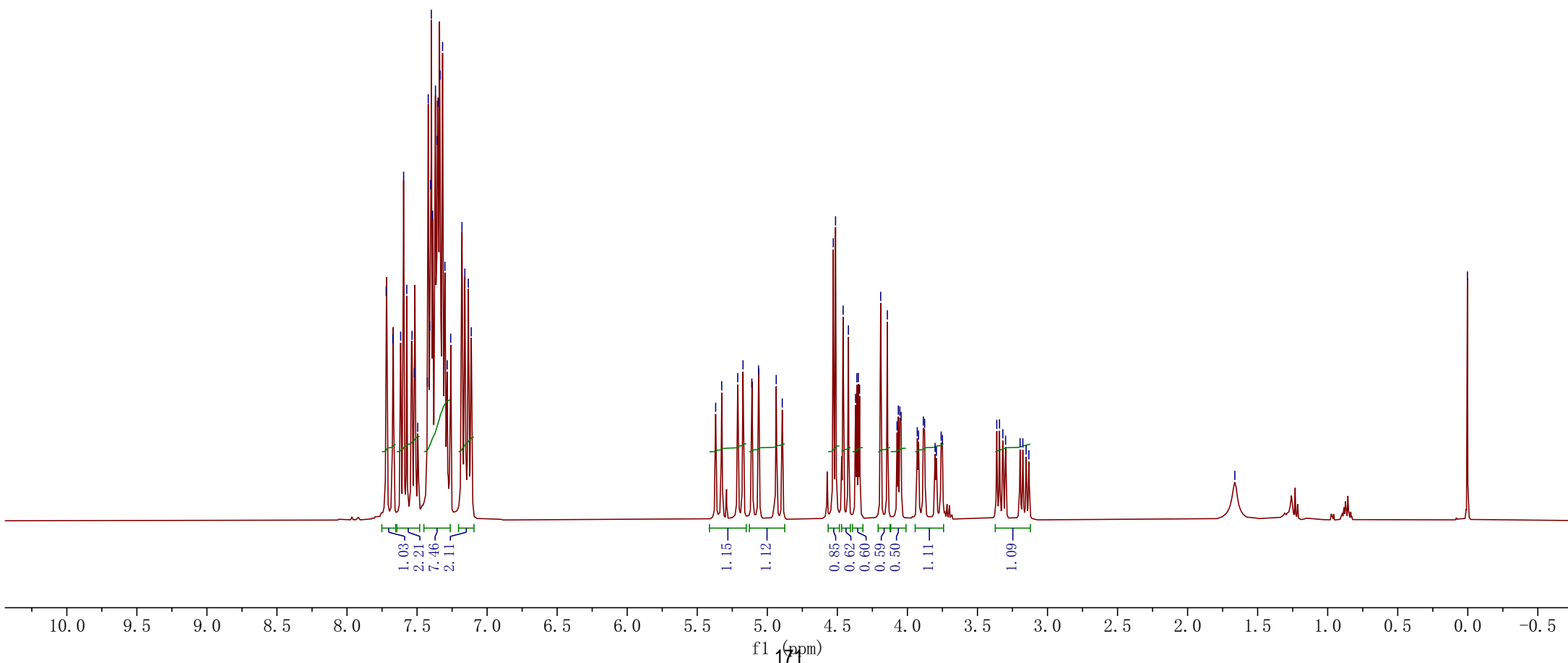
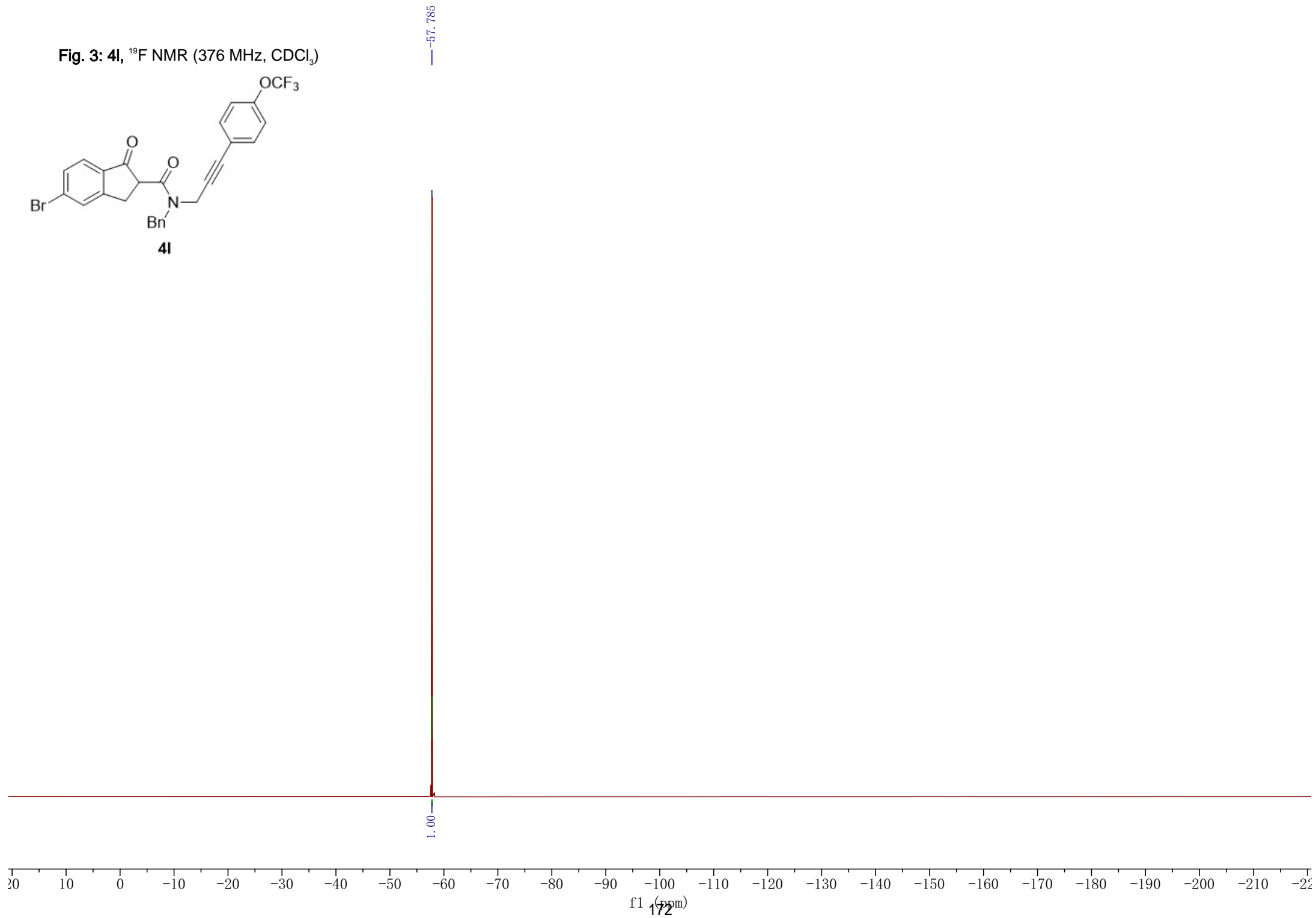
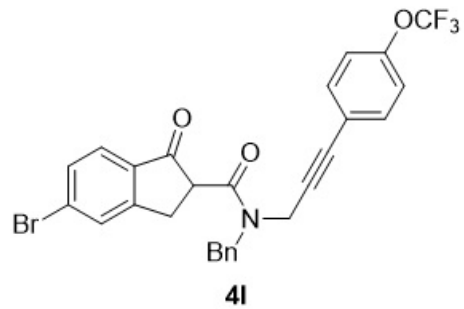
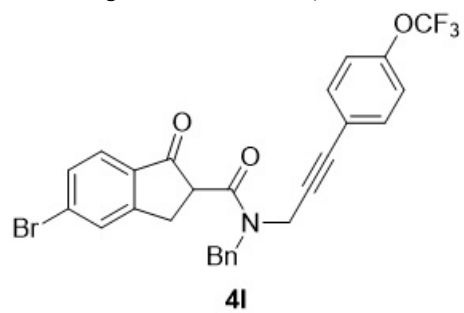


Fig. 3: 4l,  $^{19}\text{F}$  NMR (376 MHz,  $\text{CDCl}_3$ )







200.552  
200.181

168.422  
167.829

156.410  
156.209

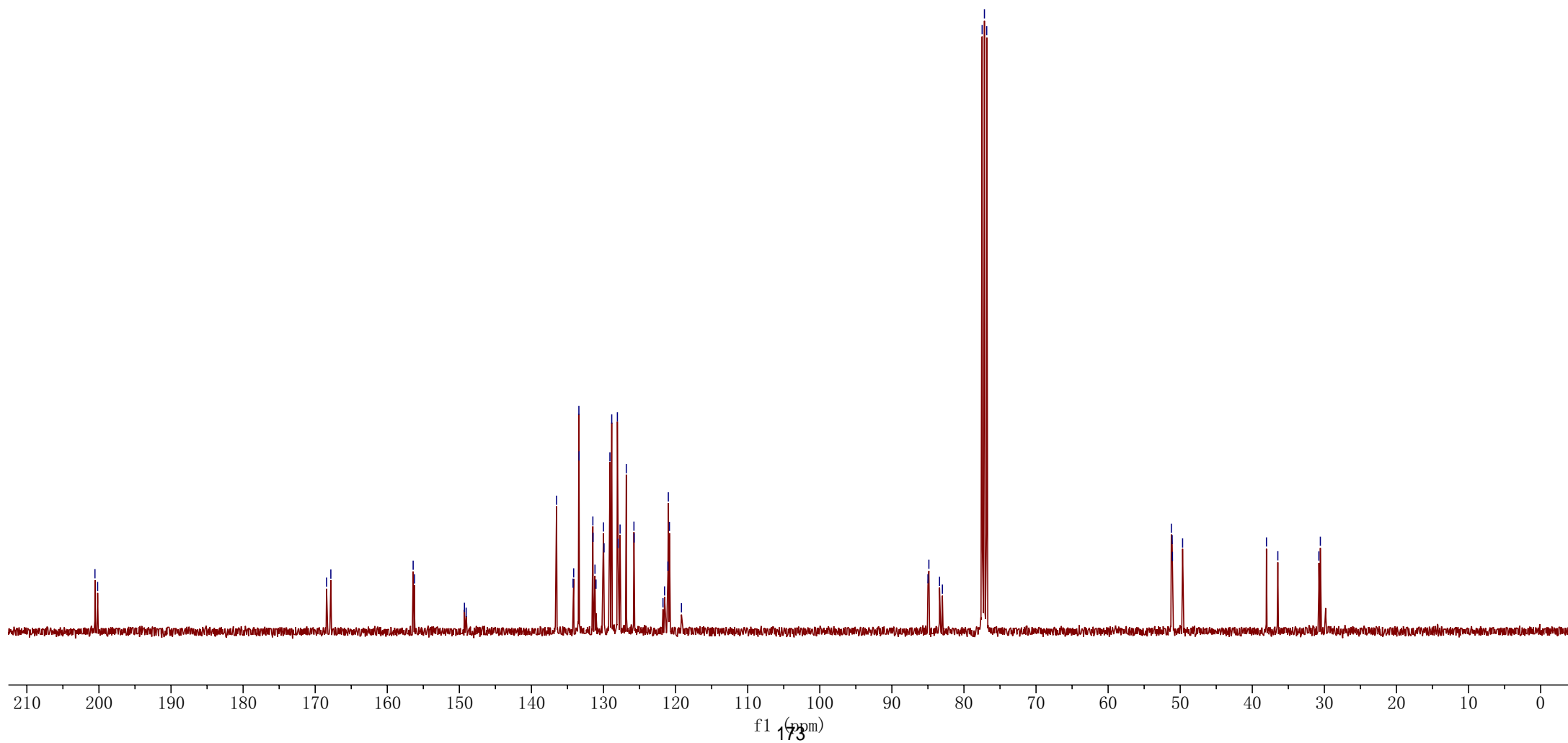
149.293  
149.054

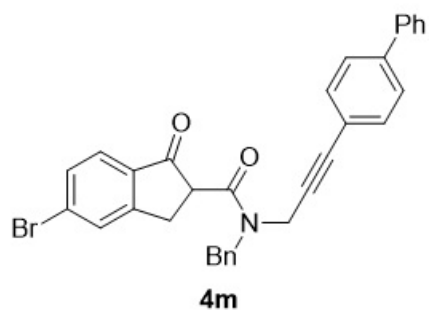
136.519  
134.226  
134.142  
133.420  
133.395  
131.480  
131.455  
131.187  
131.045  
130.009  
129.931  
129.115  
128.861  
128.078  
127.967  
127.706  
126.843  
125.782  
125.753  
121.752  
121.536  
121.066  
121.013  
120.858  
119.189

84.994  
84.866  
83.388  
82.991  
77.478  
77.160  
76.842

51.233  
51.115  
51.076  
49.667

38.035  
36.456  
30.765  
30.560

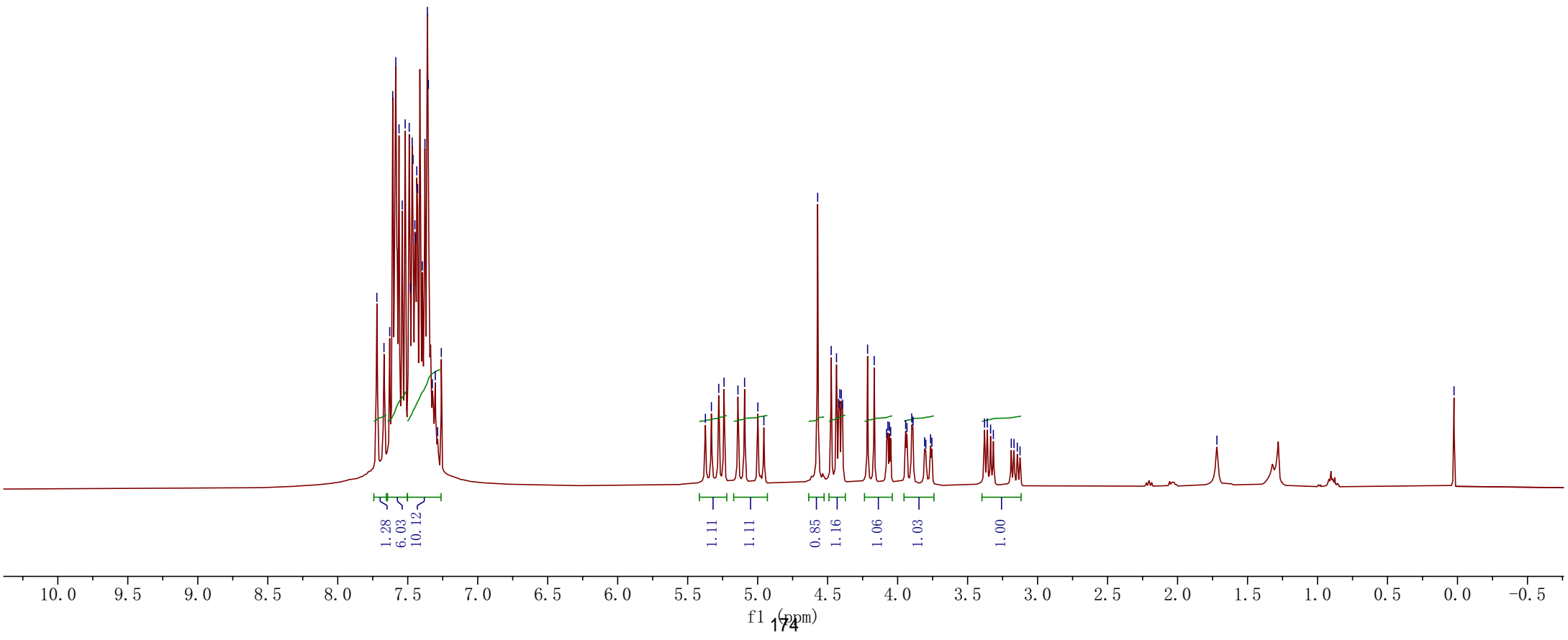




7.721  
7.670  
7.629  
7.607  
7.585  
7.562  
7.539  
7.518  
7.489  
7.480  
7.468  
7.462  
7.449  
7.443  
7.435  
7.430  
7.396  
7.377  
7.360  
7.352  
7.325  
7.303  
7.286  
7.260

5.373  
5.331  
5.278  
5.240  
5.141  
5.093  
4.999  
4.956  
4.571  
4.475  
4.437  
4.422  
4.413  
4.402  
4.393  
4.215  
4.167  
4.079  
4.069  
4.059  
4.050  
3.943  
3.933  
3.899  
3.890  
3.808  
3.799  
3.765  
3.755  
3.379  
3.359  
3.336  
3.316  
3.188  
3.168  
3.145  
3.125  
1.719

—0.025



200.612  
200.202

168.392  
167.904

156.420  
156.193  
141.522

141.138  
140.353  
140.203

136.590  
136.571  
134.242

134.161  
132.253  
131.394

131.376  
131.077  
130.942

129.968  
129.883  
129.064

128.995  
128.941  
128.821

128.039  
127.884  
127.737

127.630  
127.298  
127.141

127.099  
127.087  
126.978

126.893  
125.723  
125.704

121.619  
121.127  
84.632

84.540  
84.325  
77.478

77.160  
76.842

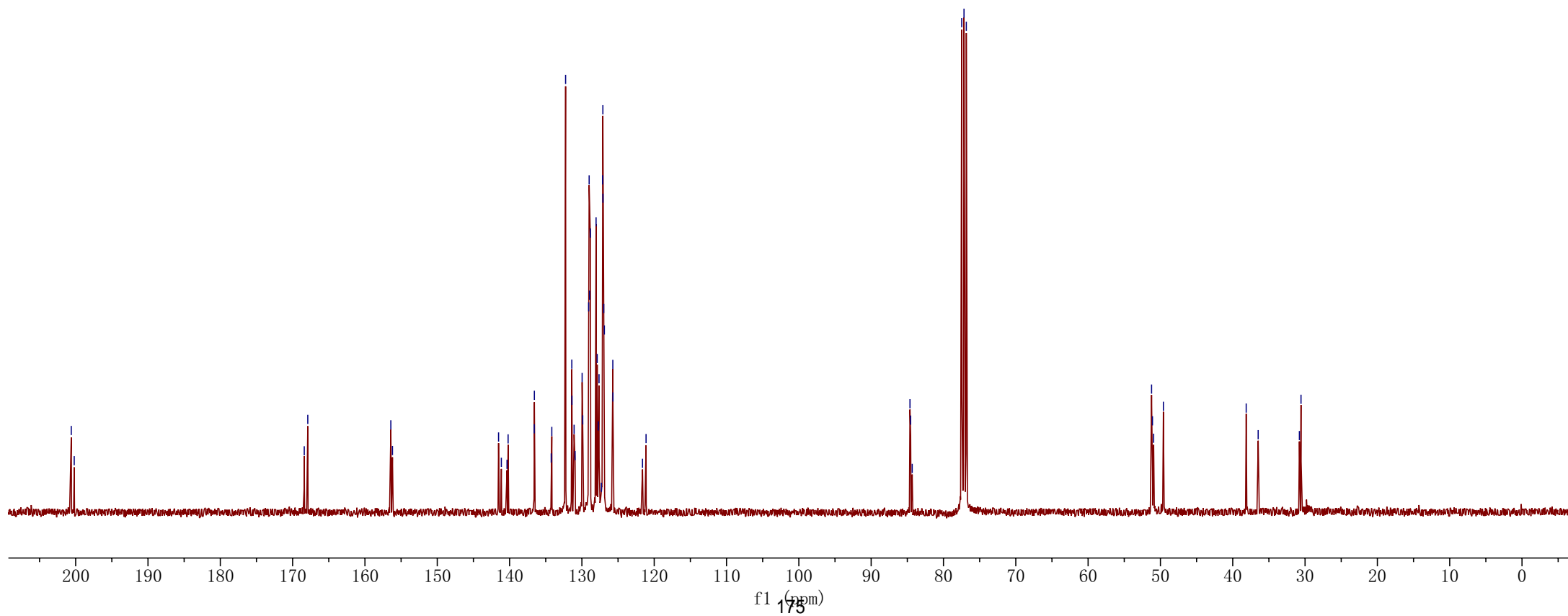
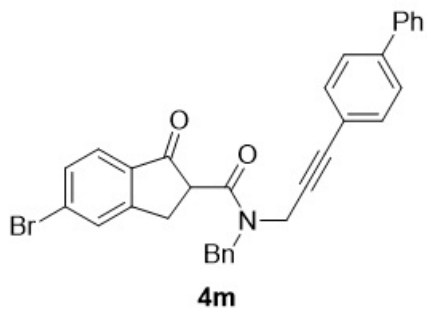
51.224  
51.101  
50.937

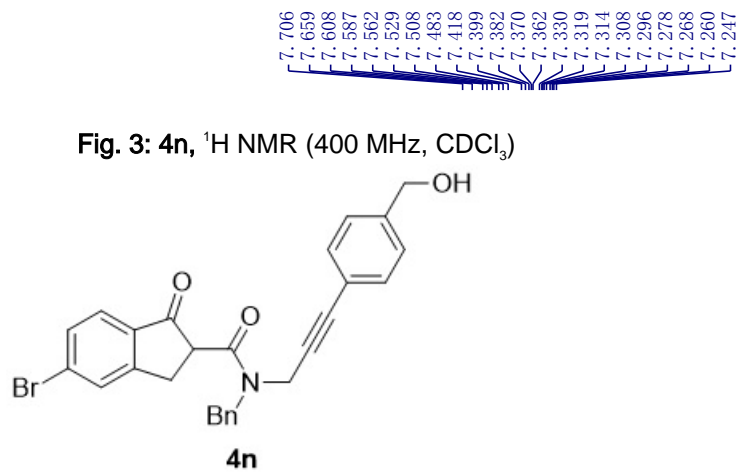
49.589

38.139  
36.483

30.784  
30.560

Fig. 3: **4m**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )

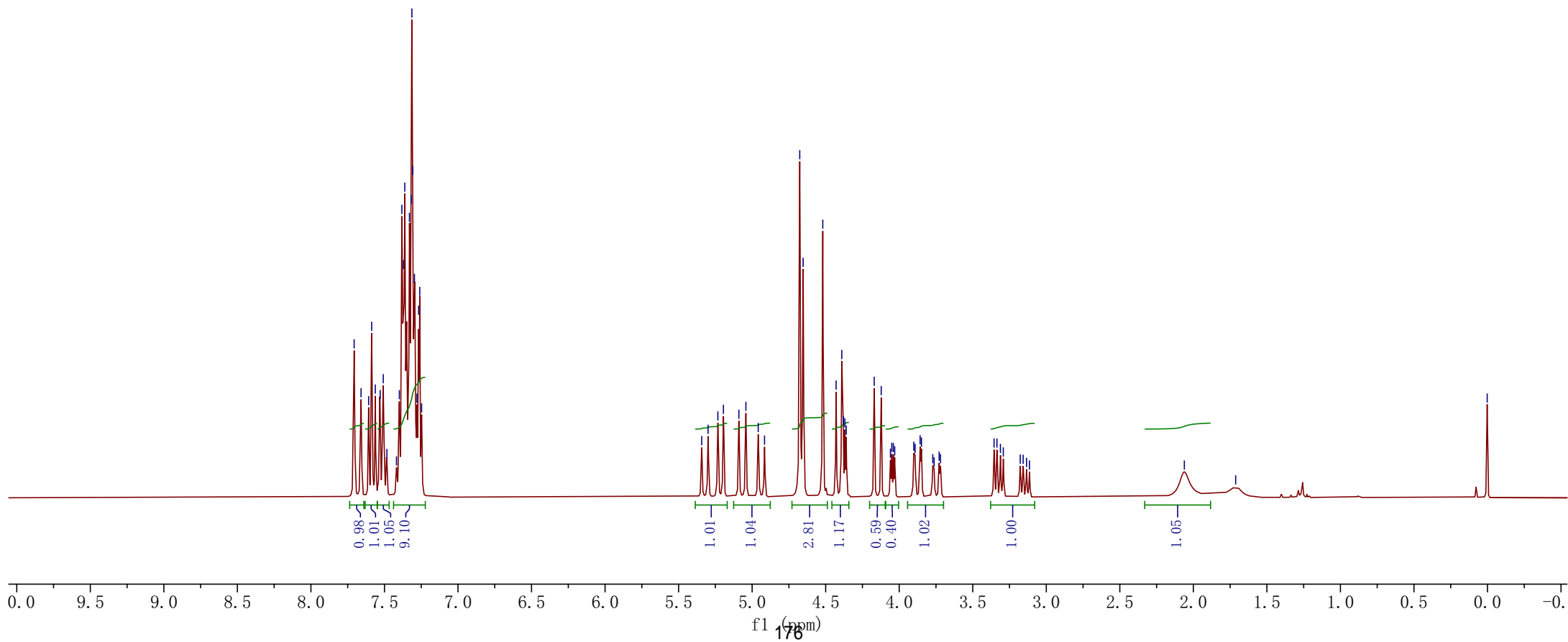


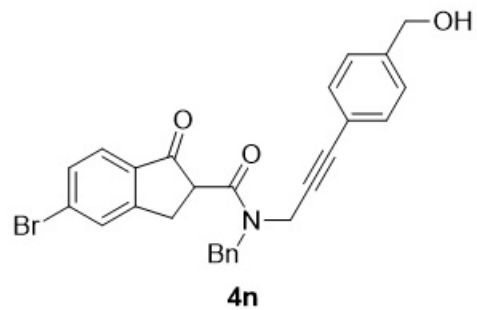


7.706  
7.659  
7.608  
7.587  
7.562  
7.529  
7.508  
7.483  
7.418  
7.399  
7.382  
7.370  
7.362  
7.330  
7.319  
7.314  
7.308  
7.296  
7.278  
7.268  
7.260  
7.247

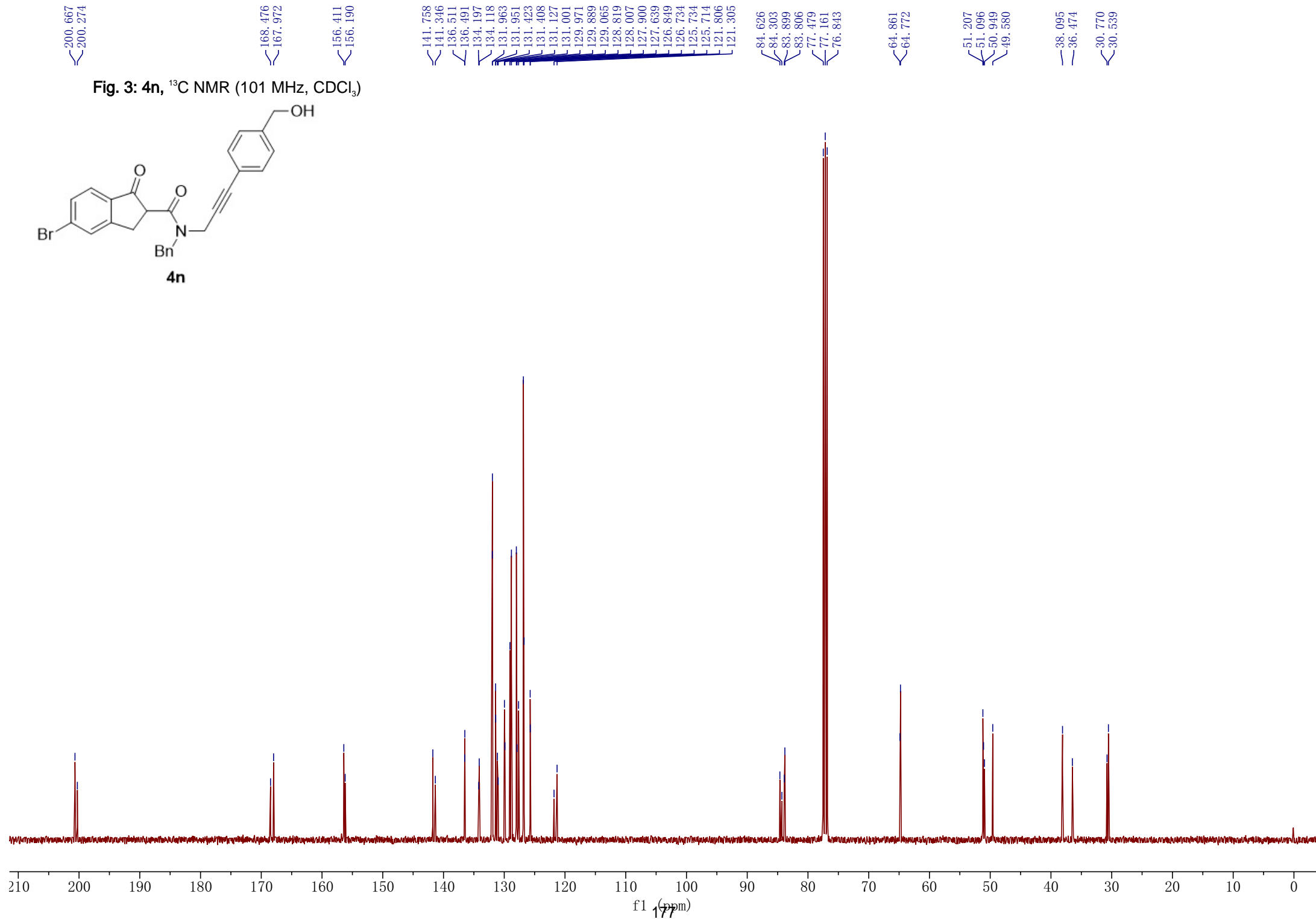
5.343  
5.300  
5.233  
5.195  
5.090  
5.042  
4.959  
4.916  
4.676  
4.653  
4.520  
4.429  
4.390  
4.380  
4.369  
4.360  
4.170  
4.122  
4.060  
4.050  
4.040  
4.031  
3.901  
3.892  
3.858  
3.849  
3.772  
3.763  
3.728  
3.719  
3.355  
3.336  
3.312  
3.292  
3.177  
3.157  
3.134  
3.114  
2.061  
1.712

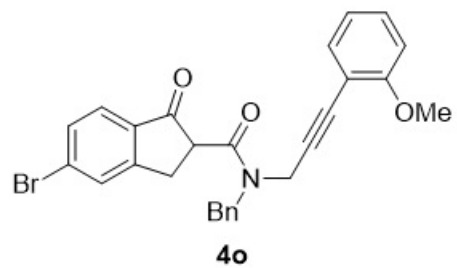
0.002



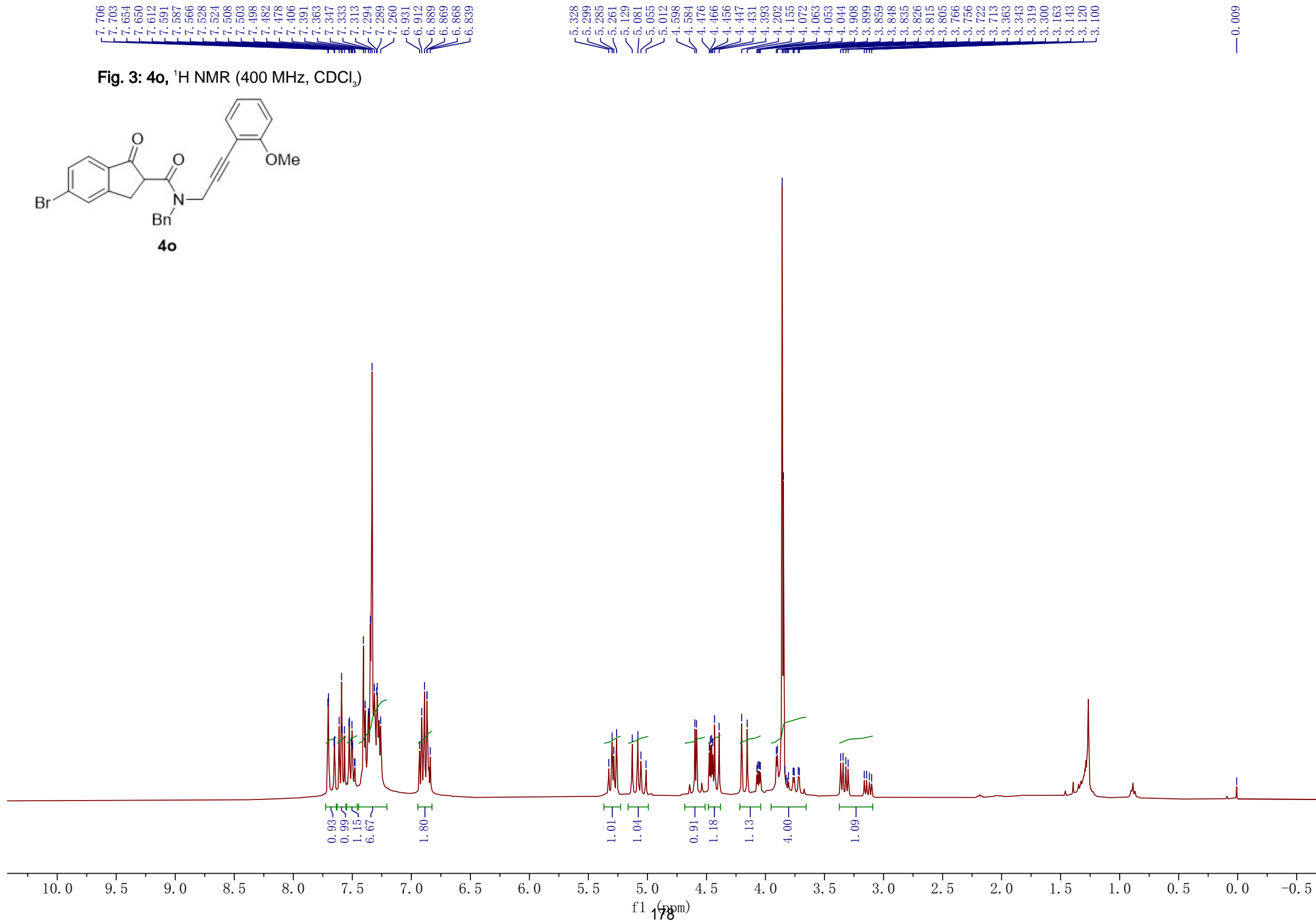


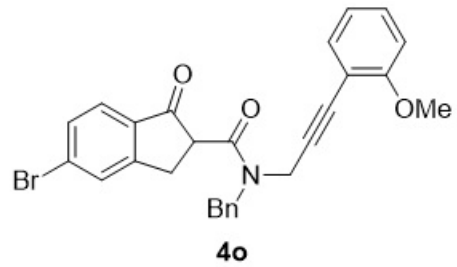
**Fig. 3: 4n,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**





**Fig. 3: 4o, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**





200.700  
200.231

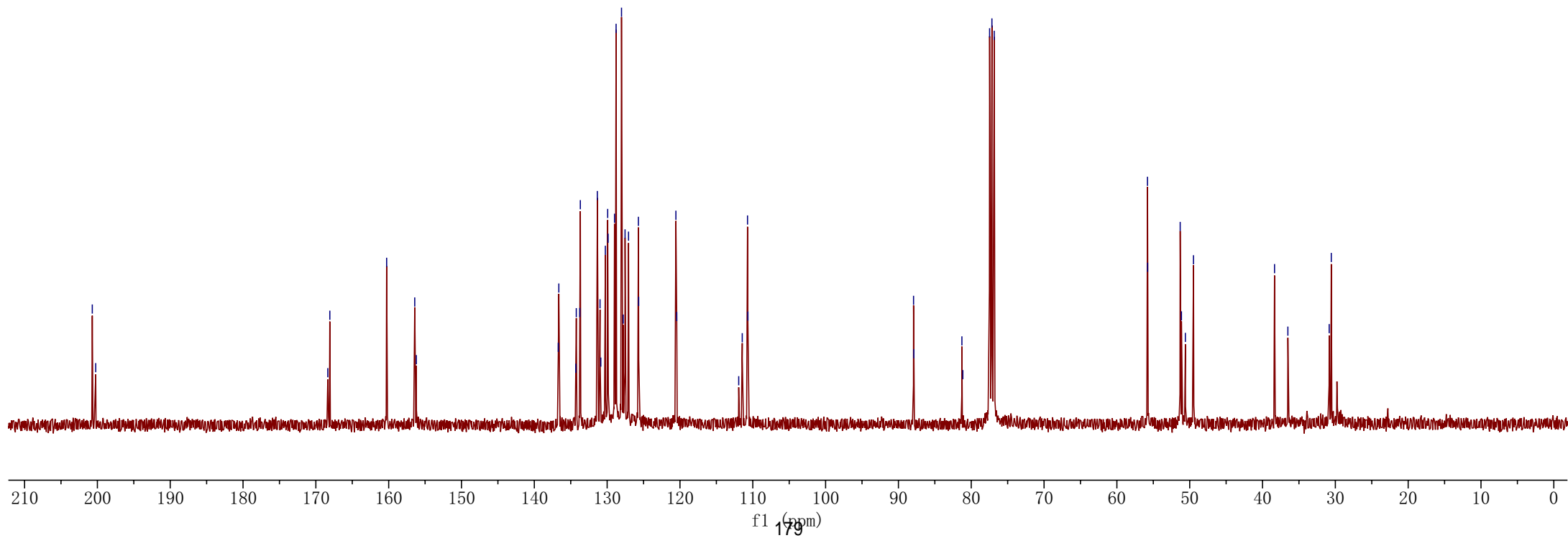
168.360  
168.082  
160.279  
156.421  
156.203  
136.709  
136.635  
134.306  
134.238  
133.754  
133.681  
131.347  
130.977  
130.868  
130.245  
129.926  
129.870  
128.987  
128.771  
128.026  
127.792  
127.541  
127.062  
125.708  
125.672  
120.559  
120.440

111.932  
111.446  
110.723  
110.671

87.922  
87.880  
81.283  
81.153  
77.479  
77.161  
76.843

55.799  
55.779  
51.307  
51.138  
50.596  
49.482

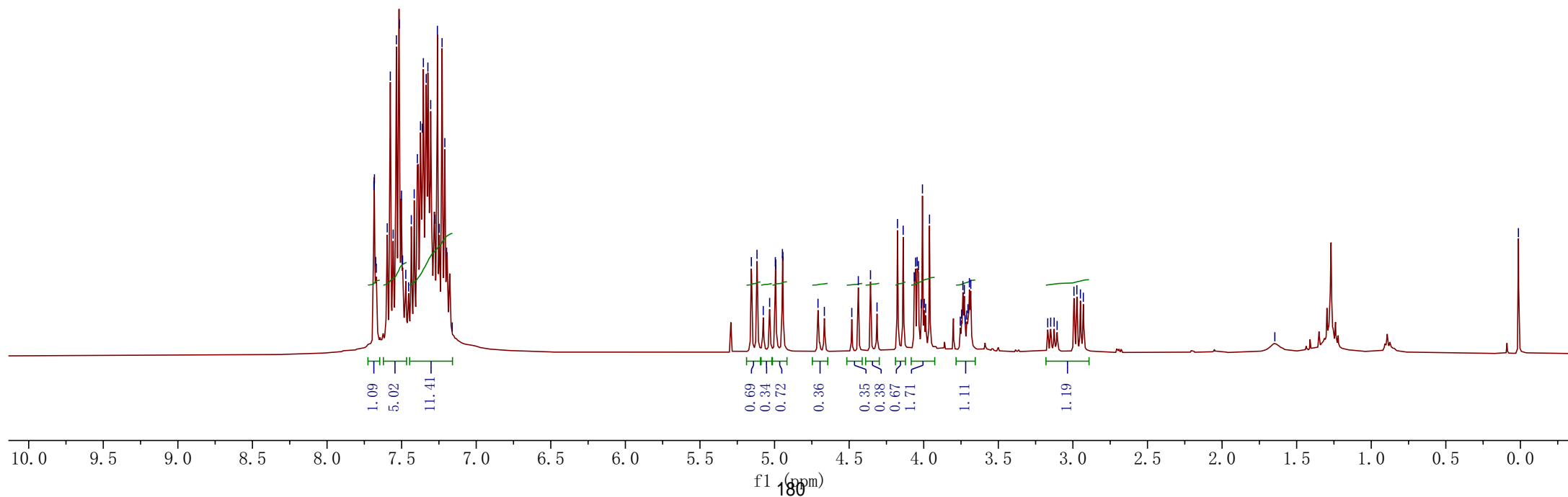
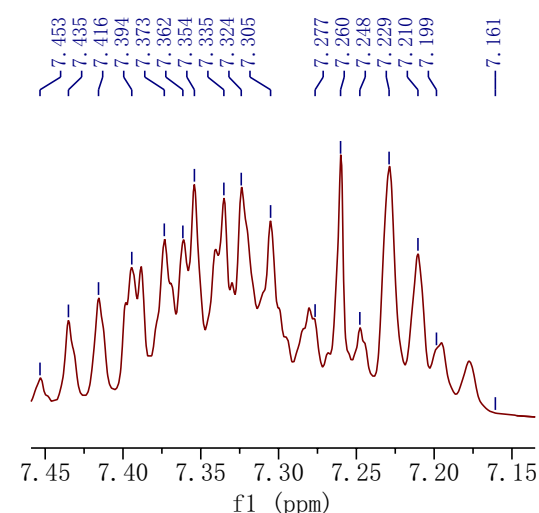
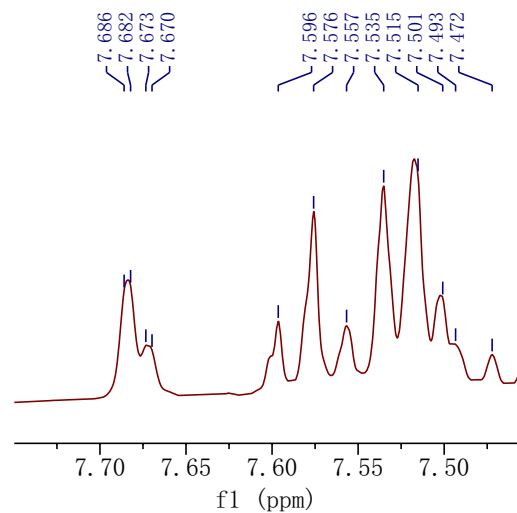
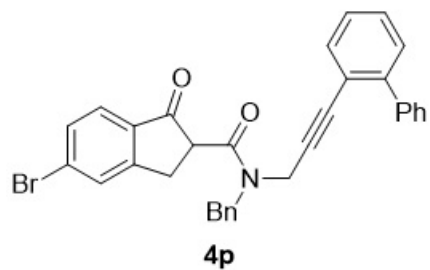
38.352  
36.519  
30.844  
30.558



7.686  
7.682  
7.673  
7.670  
7.596  
7.576  
7.557  
7.535  
7.515  
7.501  
7.493  
7.472  
7.453  
7.435  
7.416  
7.394  
7.373  
7.362  
7.354  
7.335  
7.324  
7.305  
7.277  
7.260  
7.248  
7.229  
7.210  
7.199  
7.161

5.156  
5.118  
5.076  
5.033  
4.992  
4.947  
4.944  
4.709  
4.666  
4.482  
4.438  
4.357  
4.313  
4.176  
4.138  
4.064  
4.055  
4.044  
4.035  
4.016  
4.009  
4.006  
3.996  
3.987  
3.961  
3.755  
3.746  
3.737  
3.728  
3.722  
3.712  
3.704  
3.694  
3.685  
3.169  
3.149  
3.126  
3.106  
2.993  
2.973  
2.950  
2.930  
1.646

Fig. 3: 4p, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)





200.702  
200.117

168.260  
167.803

156.538  
156.164

144.455  
144.171

140.728  
140.573

136.554  
136.448

134.321  
134.170

133.383  
133.095

131.403  
131.332

130.994  
130.917

129.927  
129.905

129.667  
129.558

129.378  
129.251

129.070  
129.003

128.787  
128.660

128.182  
128.112

127.995  
127.807

127.659  
127.582

127.497  
127.497

127.258  
127.089

126.896  
125.724

125.685  
121.141

120.668  
86.830

86.758  
84.368

84.048  
77.477

77.159  
76.842

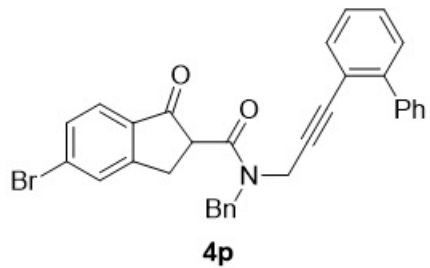
51.183  
51.012

50.488  
49.524

37.948  
36.113

30.826  
30.405

Fig. 3: 4p,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



131.403  
131.332  
130.994  
130.917

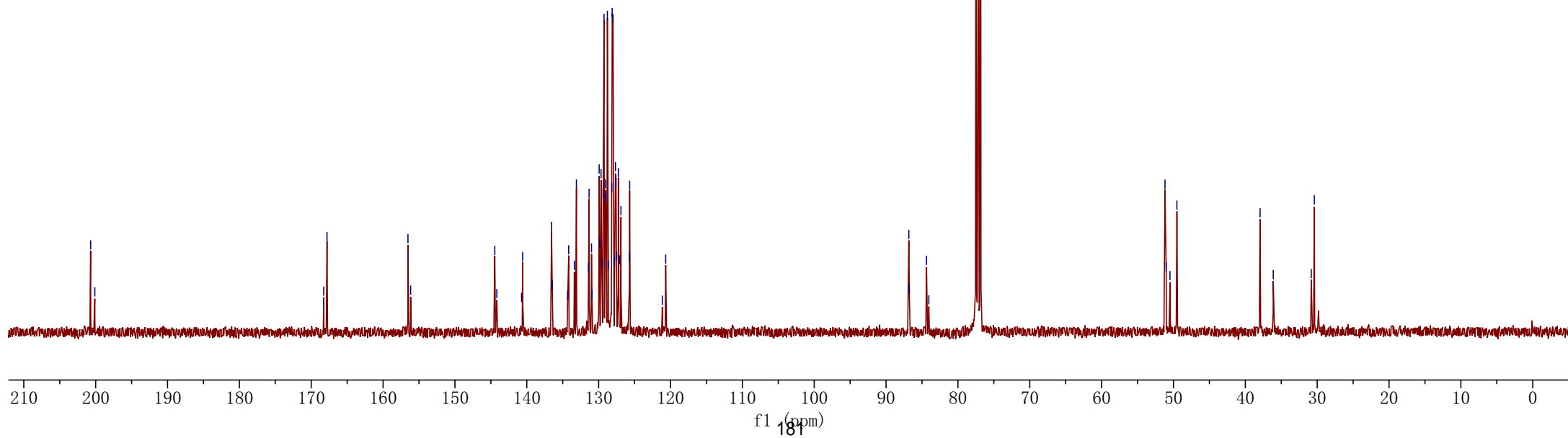
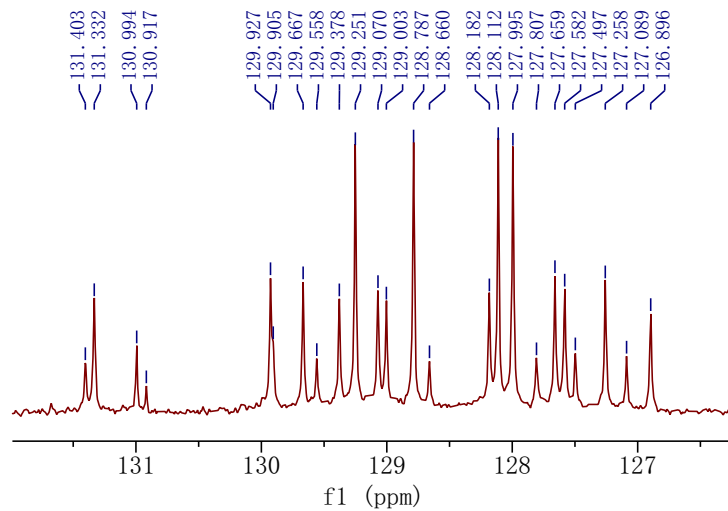
129.927  
129.905  
129.667  
129.558

129.378  
129.251  
129.070  
129.003

128.787  
128.660  
128.182  
128.112

127.995  
127.807  
127.659  
127.582

127.497  
127.258  
127.089  
126.896

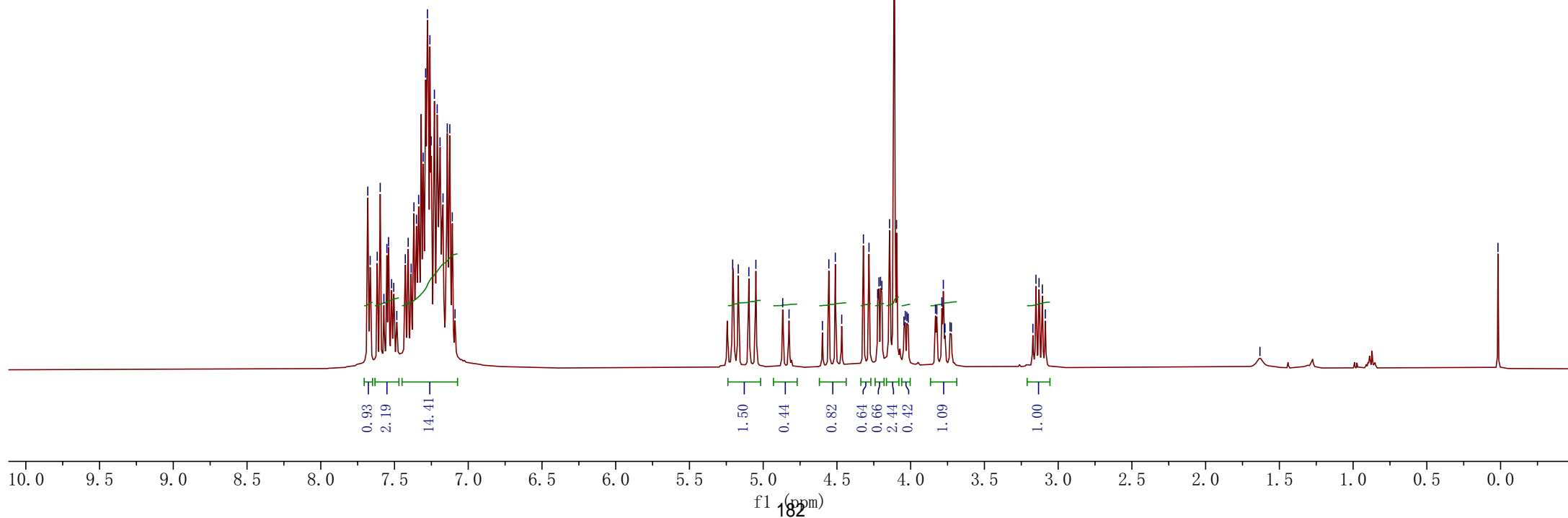
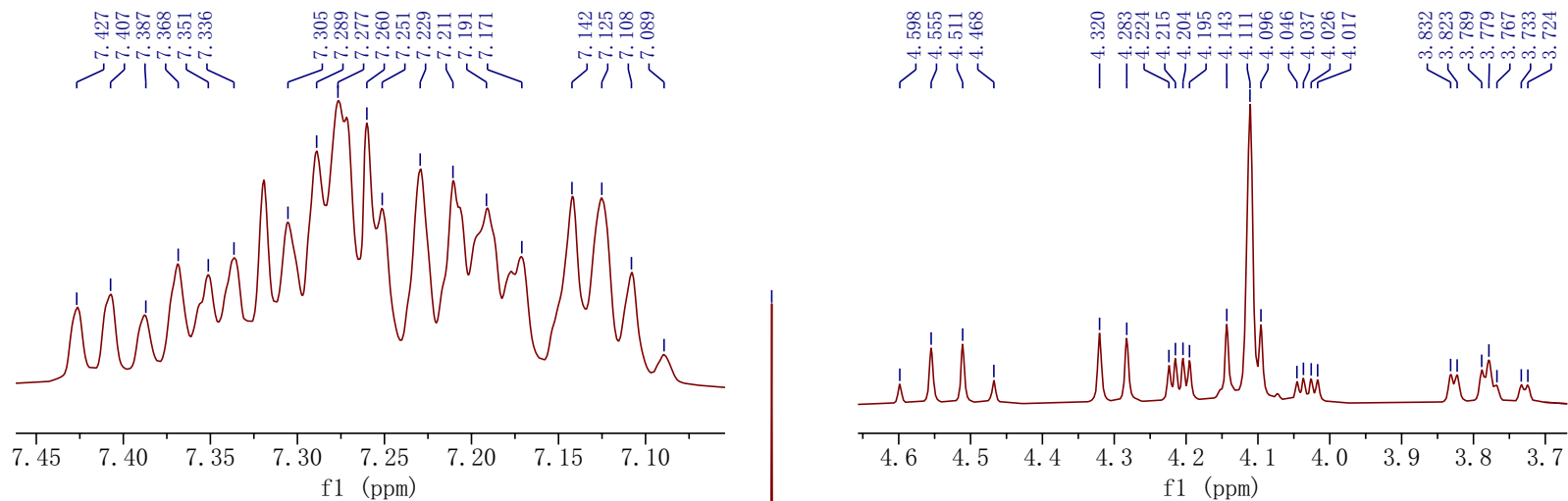
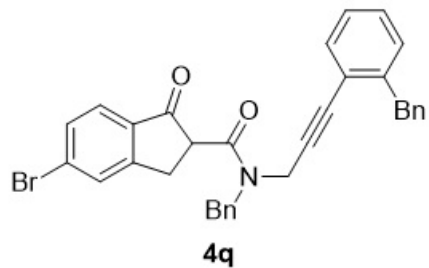


7.681  
7.665  
7.617  
7.597  
7.572  
7.552  
7.540  
7.520  
7.505  
7.484  
7.427  
7.407  
7.387  
7.368  
7.351  
7.336  
7.305  
7.289  
7.277  
7.260  
7.251  
7.229  
7.211  
7.191  
7.171  
7.142  
7.125  
7.108  
7.089

5.207  
5.169  
5.097  
5.050  
4.868  
4.825  
4.598  
4.555  
4.511  
4.468  
4.320  
4.283  
4.224  
4.215  
4.204  
4.195  
4.143  
4.111  
4.096  
4.046  
4.037  
4.026  
4.017  
3.832  
3.823  
3.789  
3.779  
3.767  
3.733  
3.724  
3.711  
3.150  
3.130  
3.107  
3.087  
1.632

0.018

Fig. 3: 4q, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



200.643  
200.116

168.366  
167.844

156.494  
156.177  
143.212  
142.957  
140.627  
140.424  
136.546  
136.496  
134.275  
134.177  
132.668  
132.643  
131.390  
131.064  
130.927

129.965  
129.898  
129.501  
129.067  
128.830  
128.743  
128.545  
128.496  
128.025  
127.887  
127.637  
126.863  
126.450  
126.211  
126.179  
126.128  
125.733  
125.717  
122.547  
122.210  
87.913  
83.588  
83.288

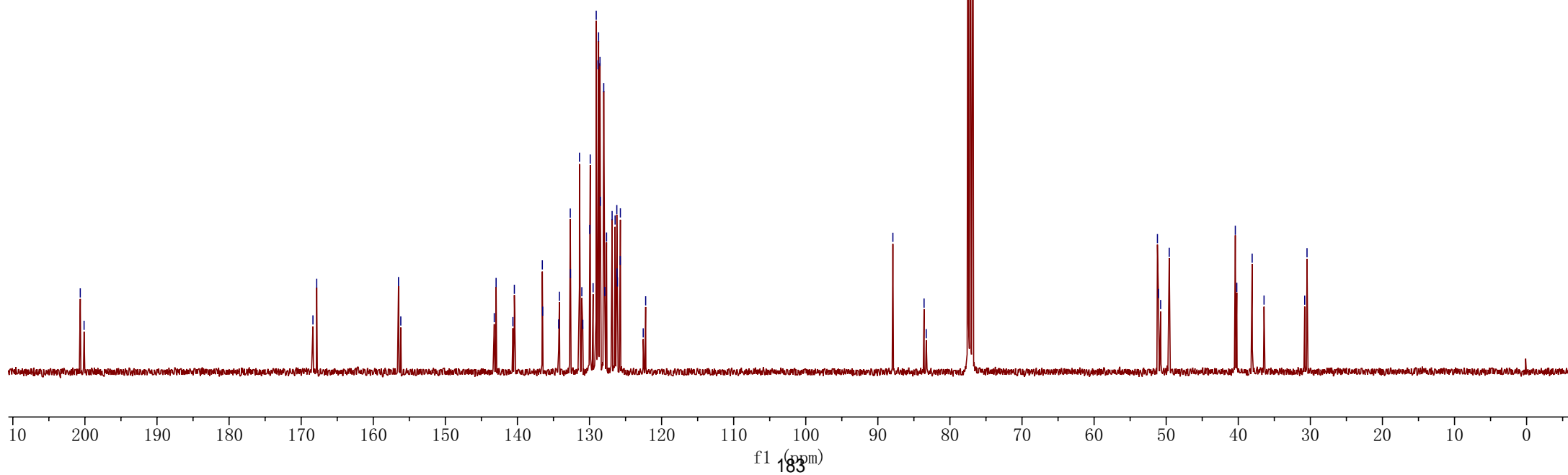
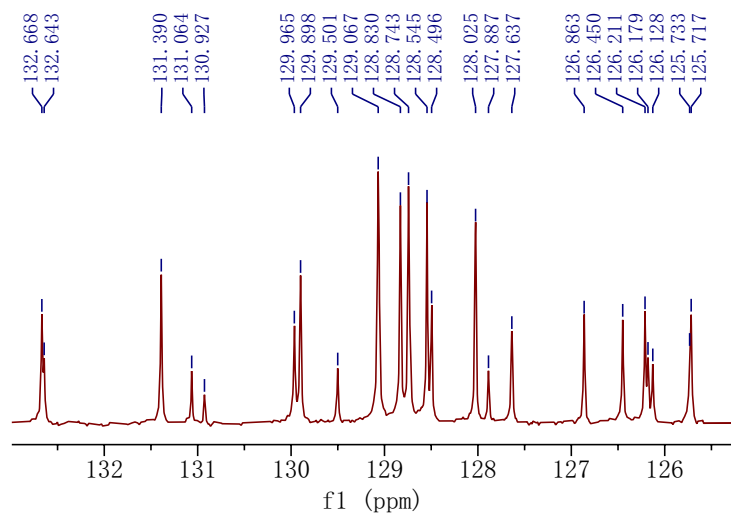
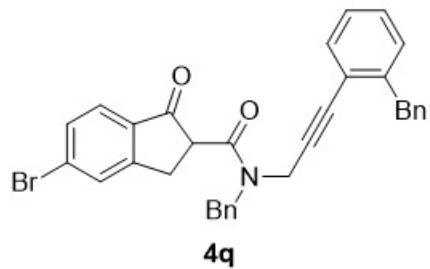
77.478  
77.160  
76.842

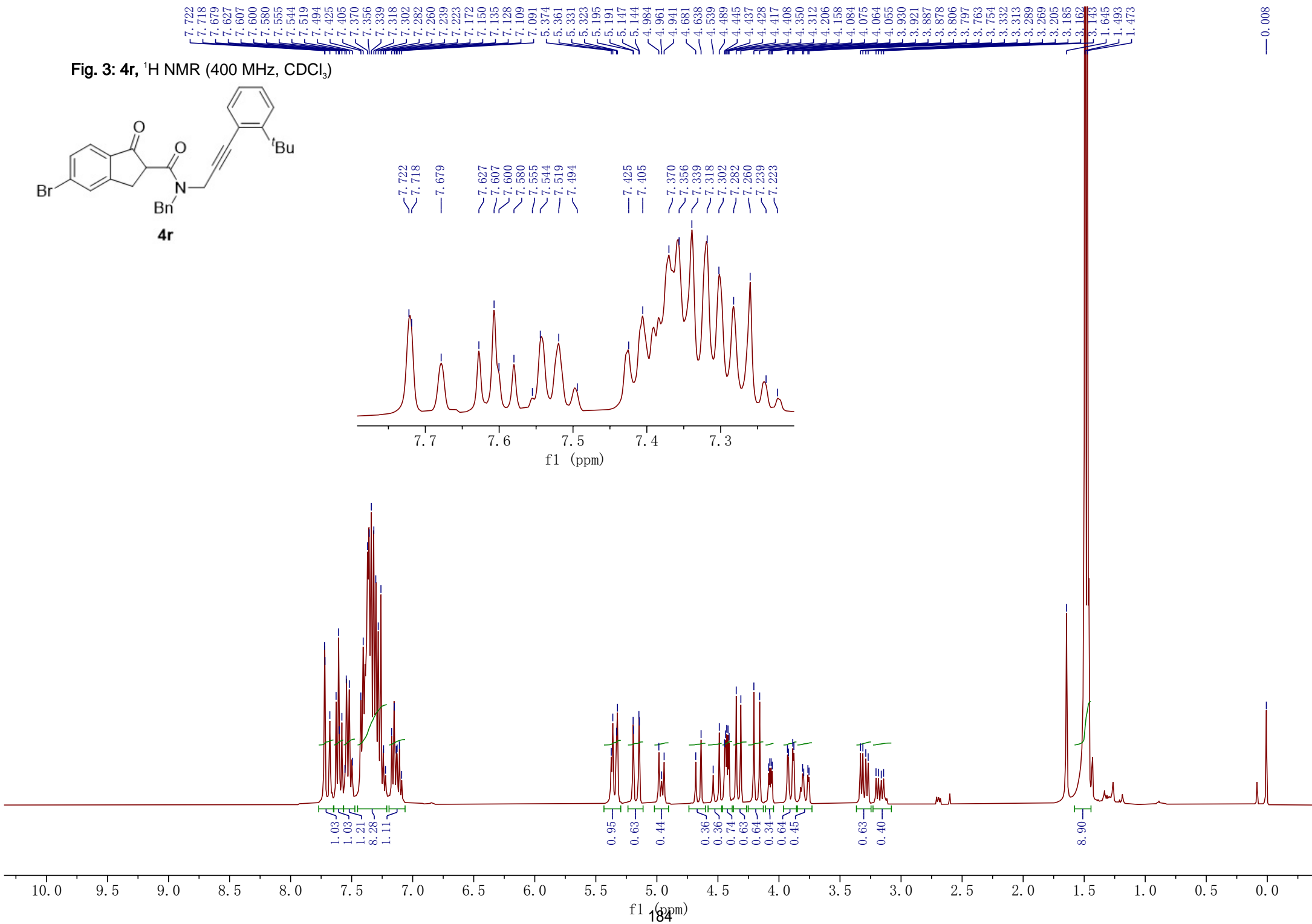
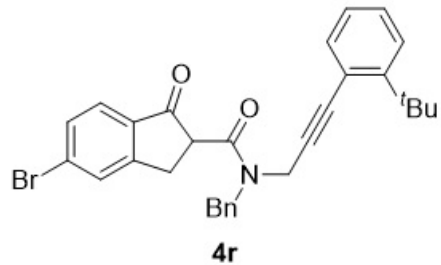
51.214  
51.063  
50.767  
49.575

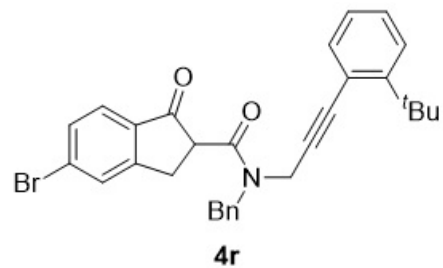
40.410  
40.206  
38.072  
36.424

30.783  
30.462

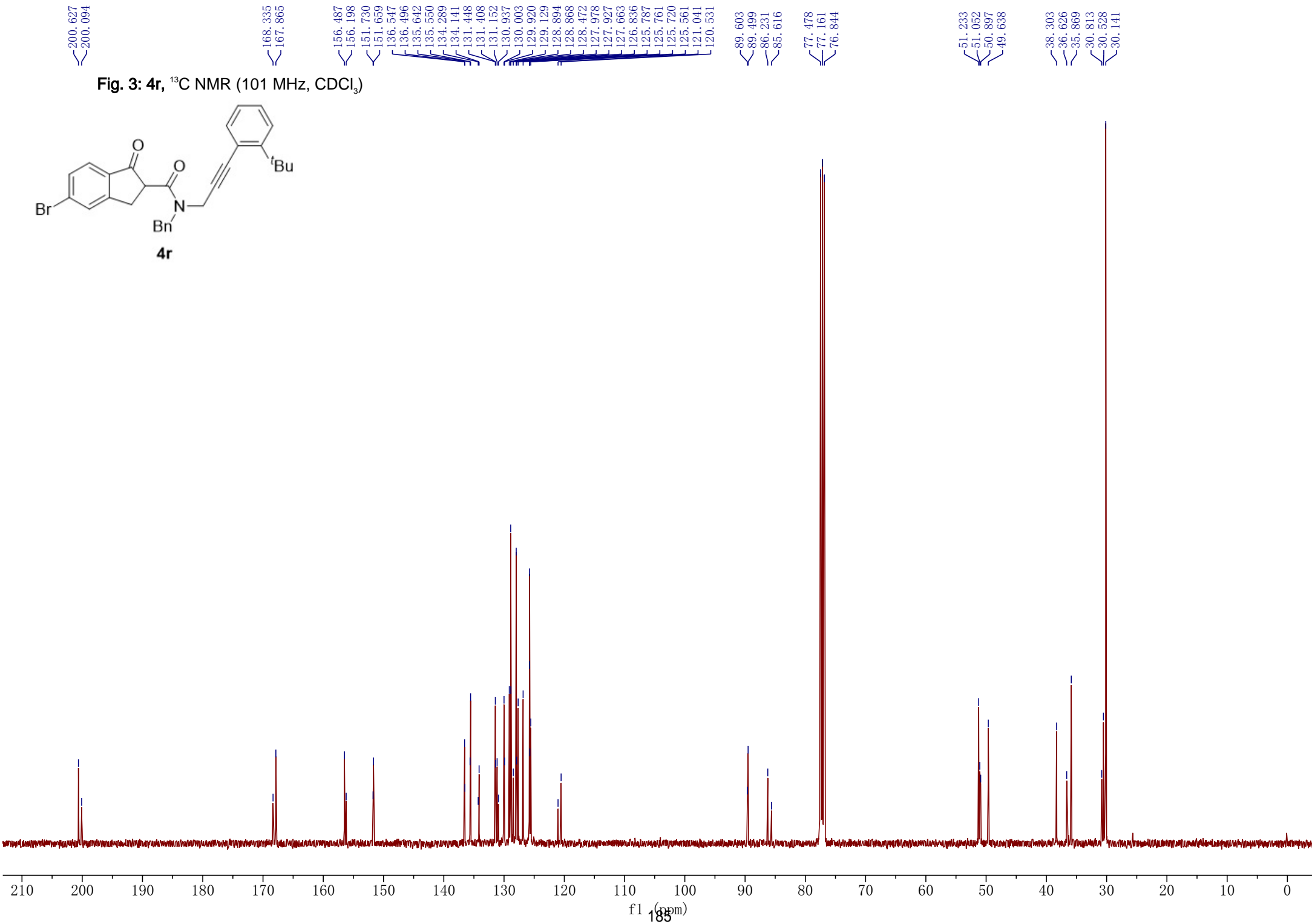
Fig. 3: **4q**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )





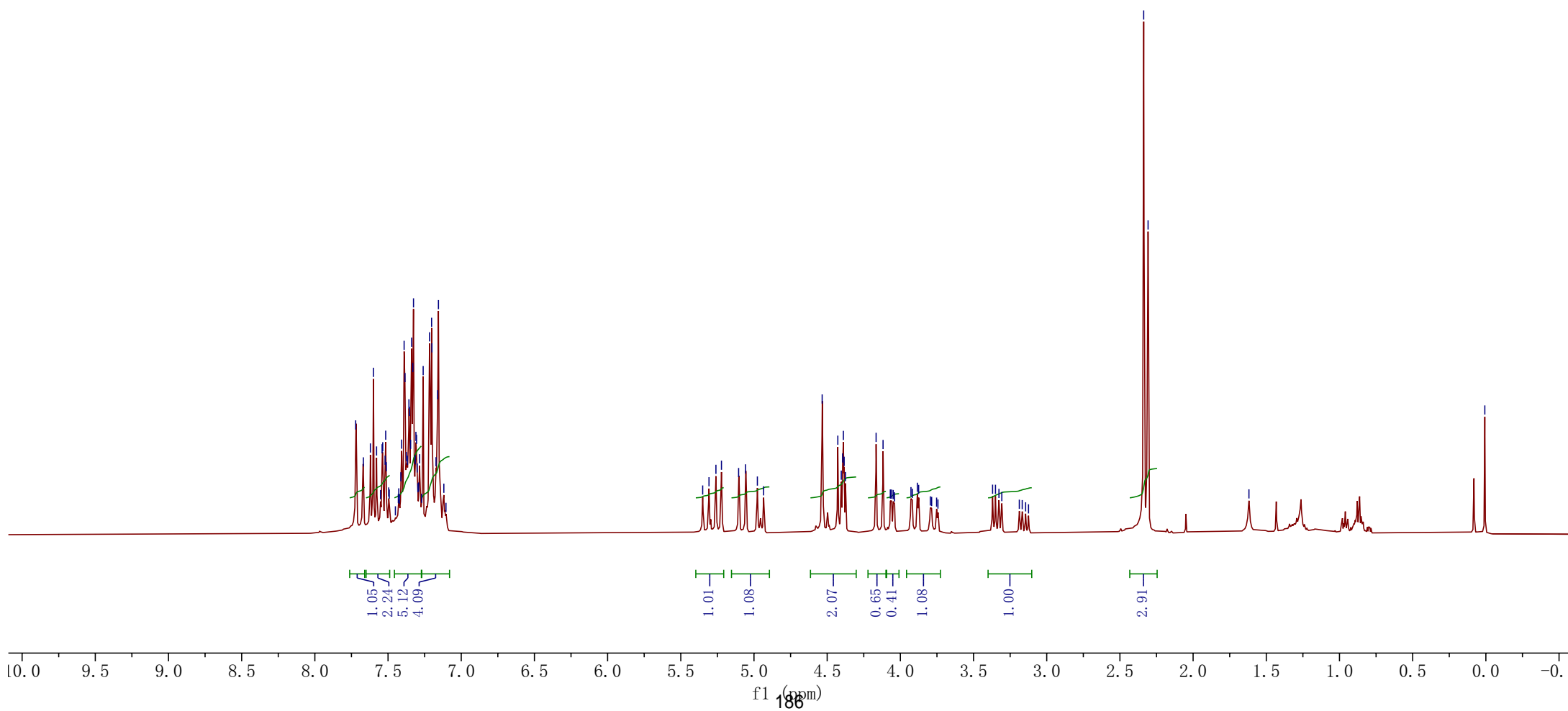
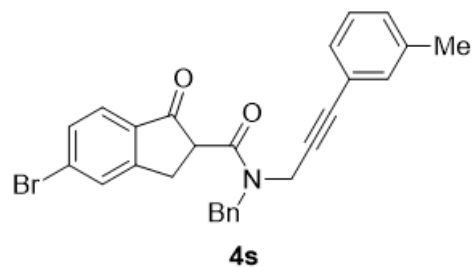


**Fig. 3: 4r,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**

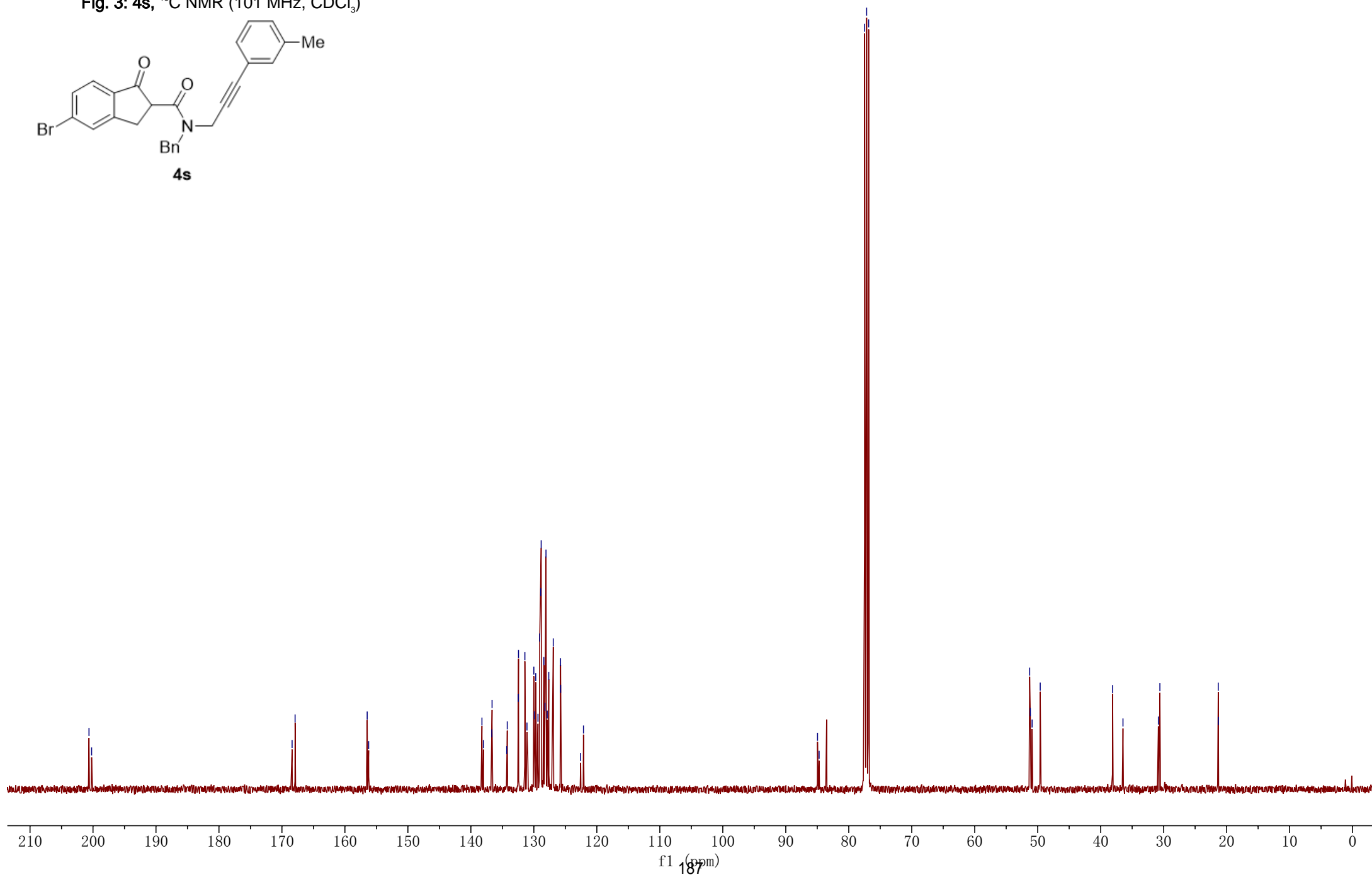
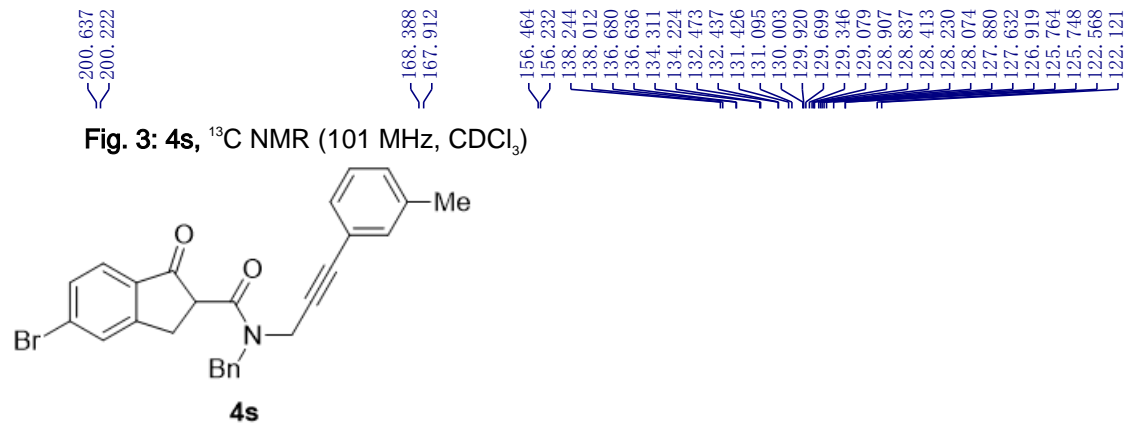


7.721  
7.669  
7.621  
7.600  
7.578  
7.551  
7.541  
7.536  
7.520  
7.516  
7.512  
7.496  
7.492  
7.430  
7.427  
7.412  
7.407  
7.390  
7.384  
7.375  
7.367  
7.357  
7.354  
7.346  
7.339  
7.331  
7.326  
7.314  
7.310  
7.305  
7.301  
7.296  
7.290  
7.284  
7.281  
7.271  
7.260  
7.216  
7.202  
7.200  
7.172  
7.161  
7.156  
7.119  
5.350  
5.307  
5.260  
5.222  
5.105  
5.058  
4.977  
4.934  
4.534  
4.427  
4.404  
4.395  
4.389  
4.384  
4.375  
4.166  
4.118  
4.069  
4.059  
4.049  
4.039  
3.927  
3.918  
3.884  
3.875  
3.795  
3.786  
3.752  
3.743  
3.370  
3.350  
3.326  
3.307  
3.187  
3.167  
3.144  
3.124  
2.338  
2.308  
1.619

Fig. 3: 4s, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



— 0.007



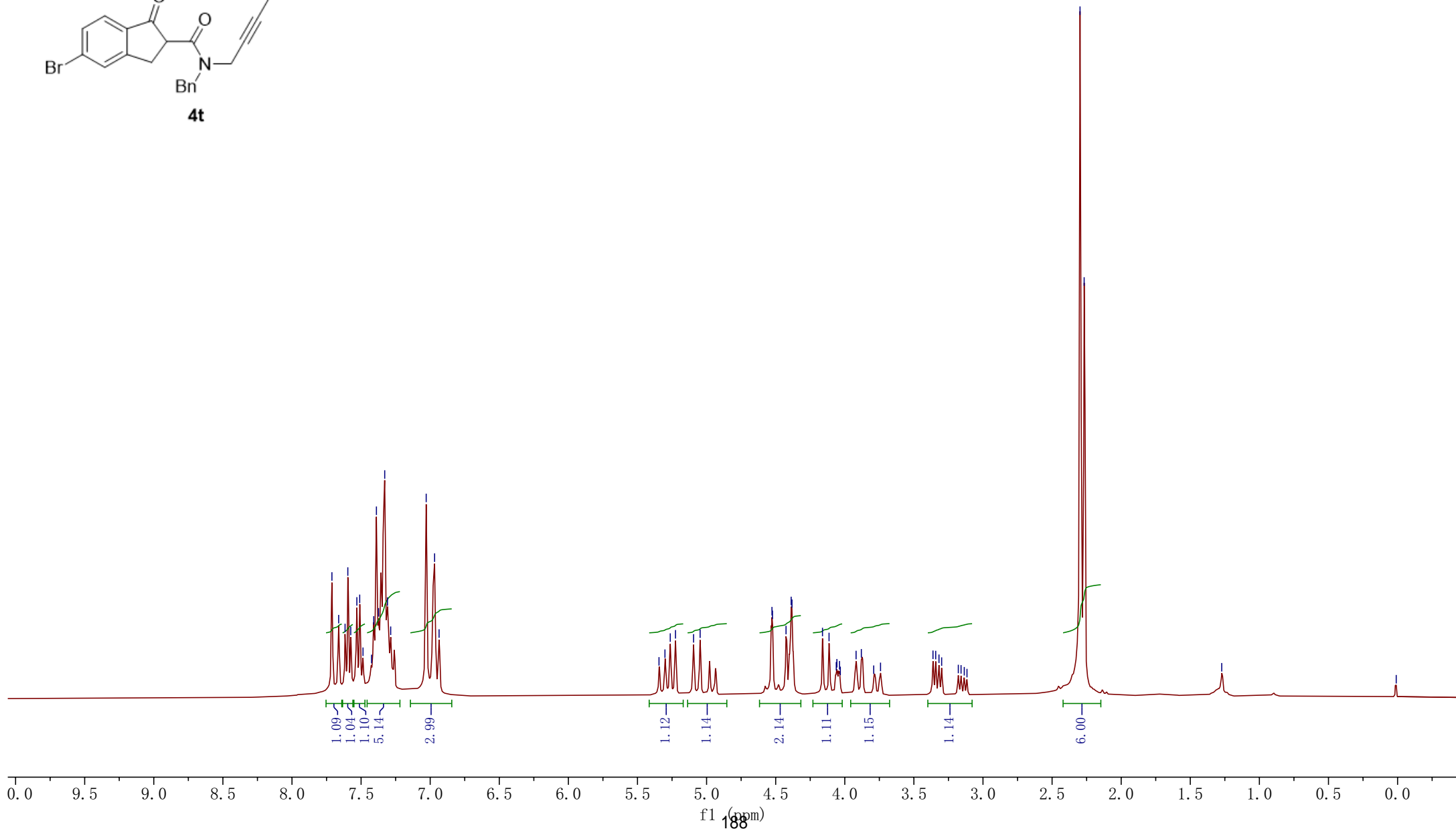
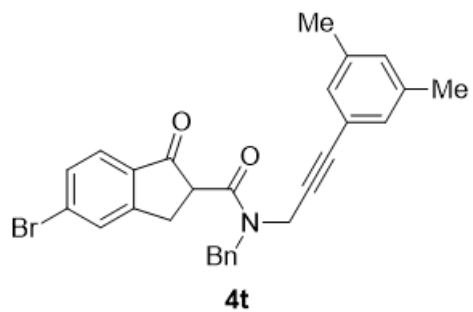
7.711  
7.662  
7.616  
7.596  
7.575  
7.531  
7.510  
7.486  
7.424  
7.408  
7.389  
7.374  
7.329  
7.309  
7.286  
7.029  
6.968  
6.936

5.344  
5.301  
5.263  
5.225  
5.094  
5.047  
4.527  
4.523  
4.425  
4.388  
4.382  
4.161  
4.114  
4.062  
4.057  
4.038  
4.032  
3.918  
3.880  
3.791  
3.741  
3.362  
3.342  
3.318  
3.299  
3.178  
3.159  
3.135  
3.116  
2.298  
2.268

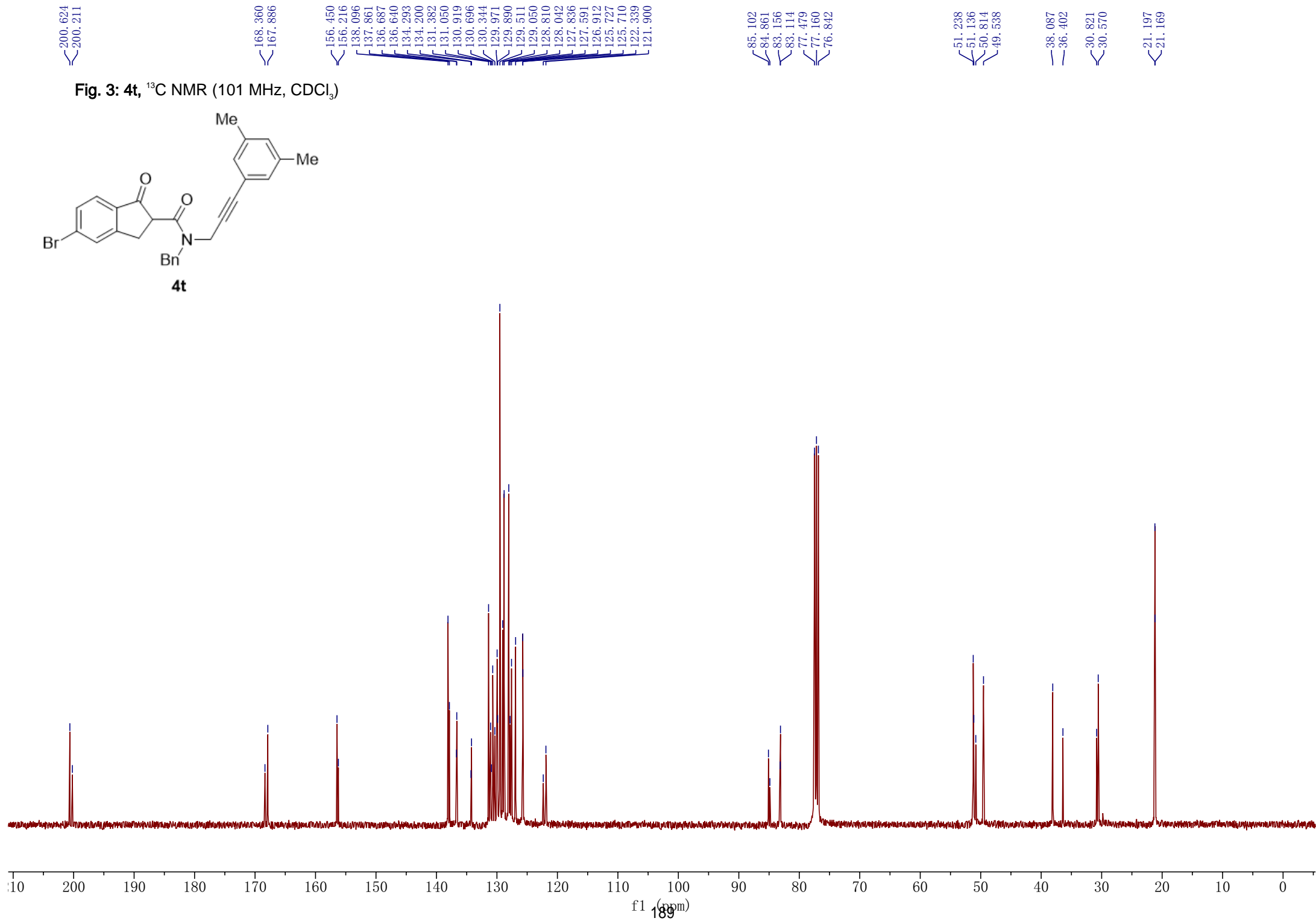
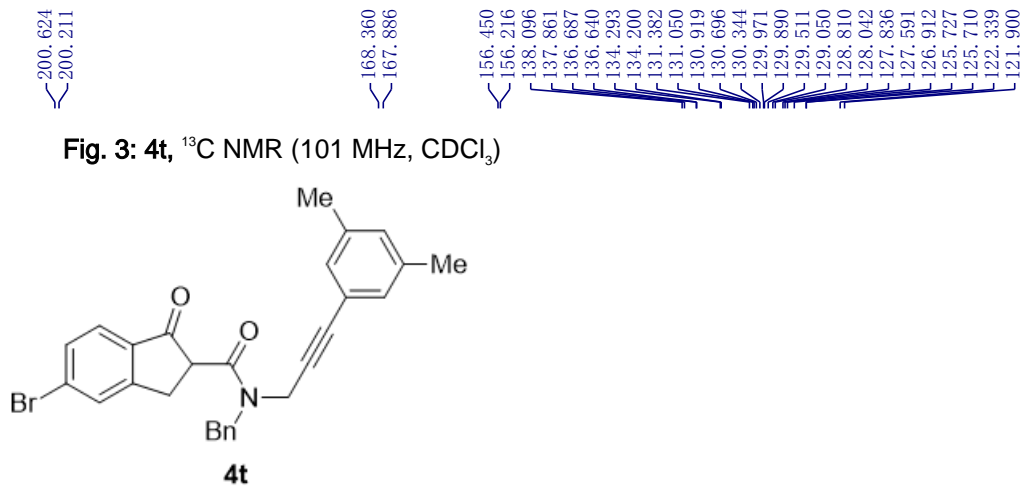
1.272

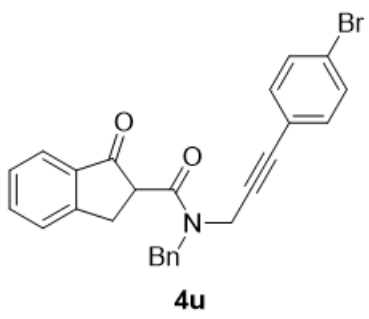
0.010

Fig. 3: **4t**, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)

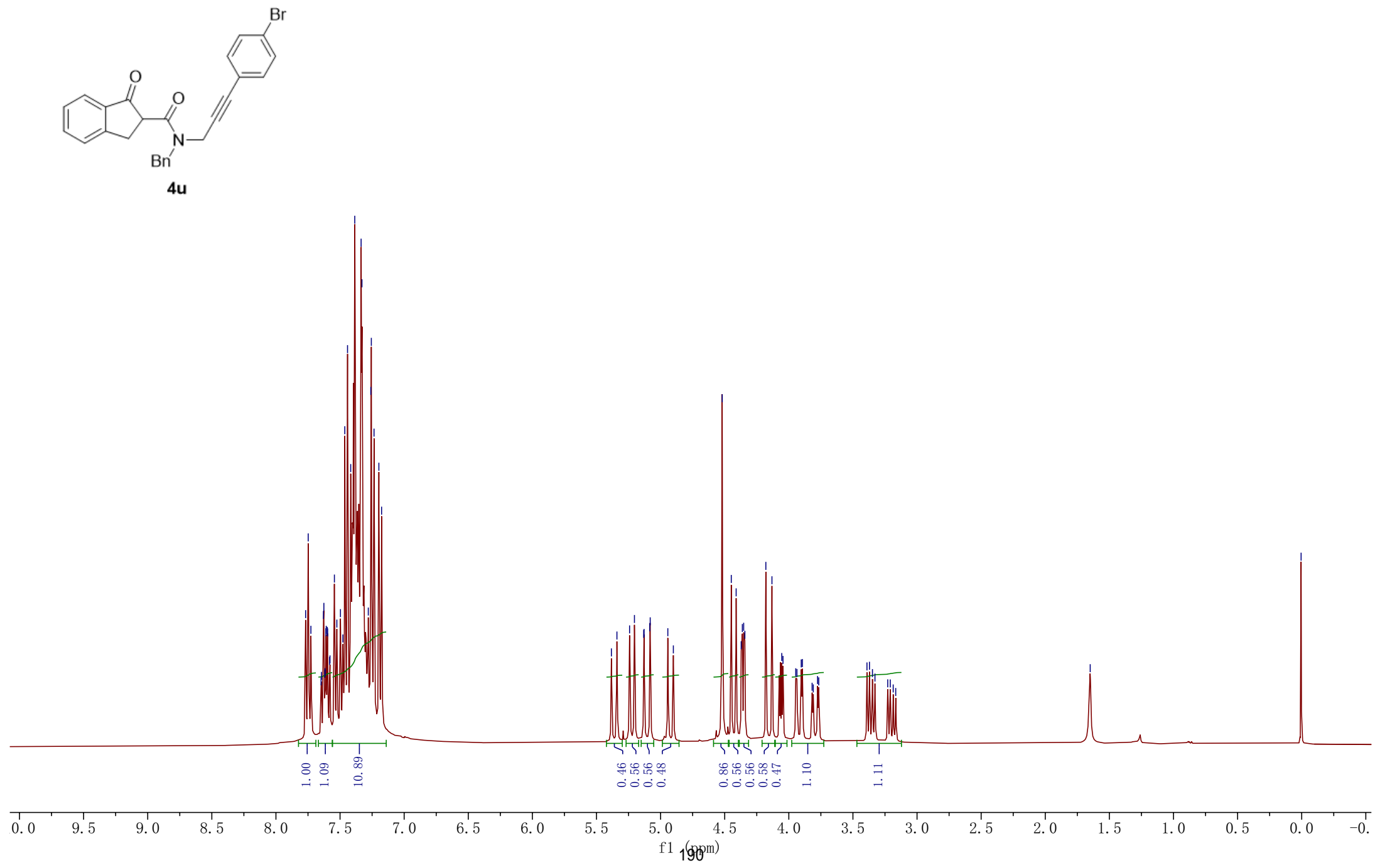








**Fig. 3: 4u, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**



201.818  
201.452

168.872  
168.272

154.876  
154.657  
136.637  
135.593  
135.470  
135.368  
135.284  
133.306  
133.284  
131.767  
131.581  
129.059  
128.826  
128.049  
127.880  
127.748  
127.733  
127.621  
126.878  
126.684  
126.604  
124.633  
124.615  
123.048  
122.662  
121.766  
121.319

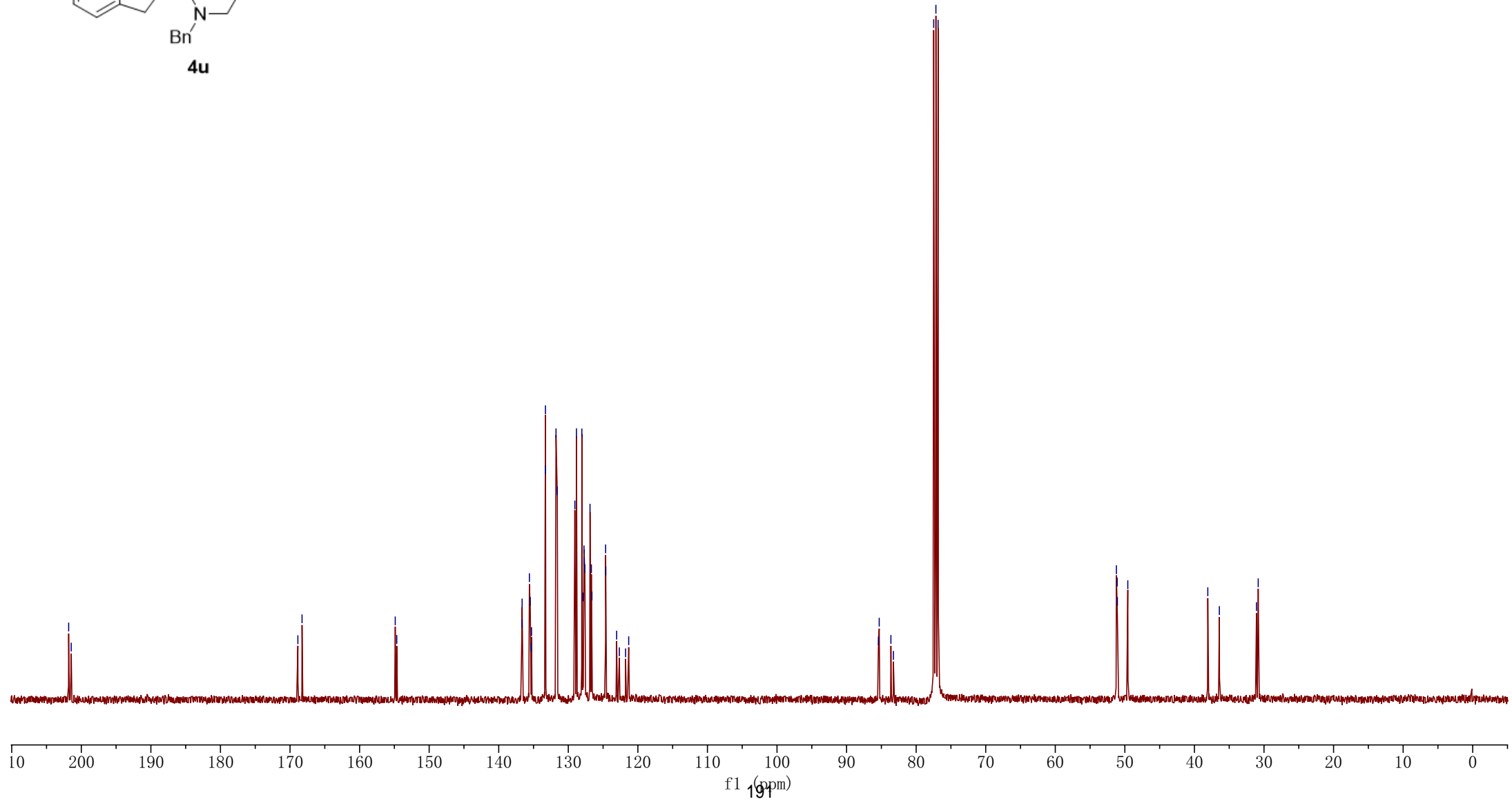
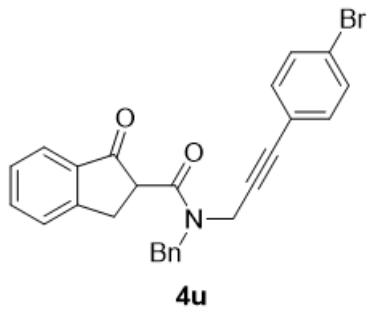
85.426  
85.308  
83.627  
83.265  
77.478  
77.160  
76.843

51.216  
51.103  
51.074  
49.576

38.078  
36.416

31.080  
30.832

Fig. 3: 4u,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



191

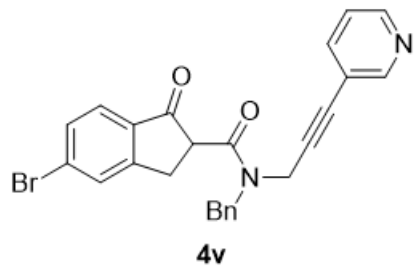
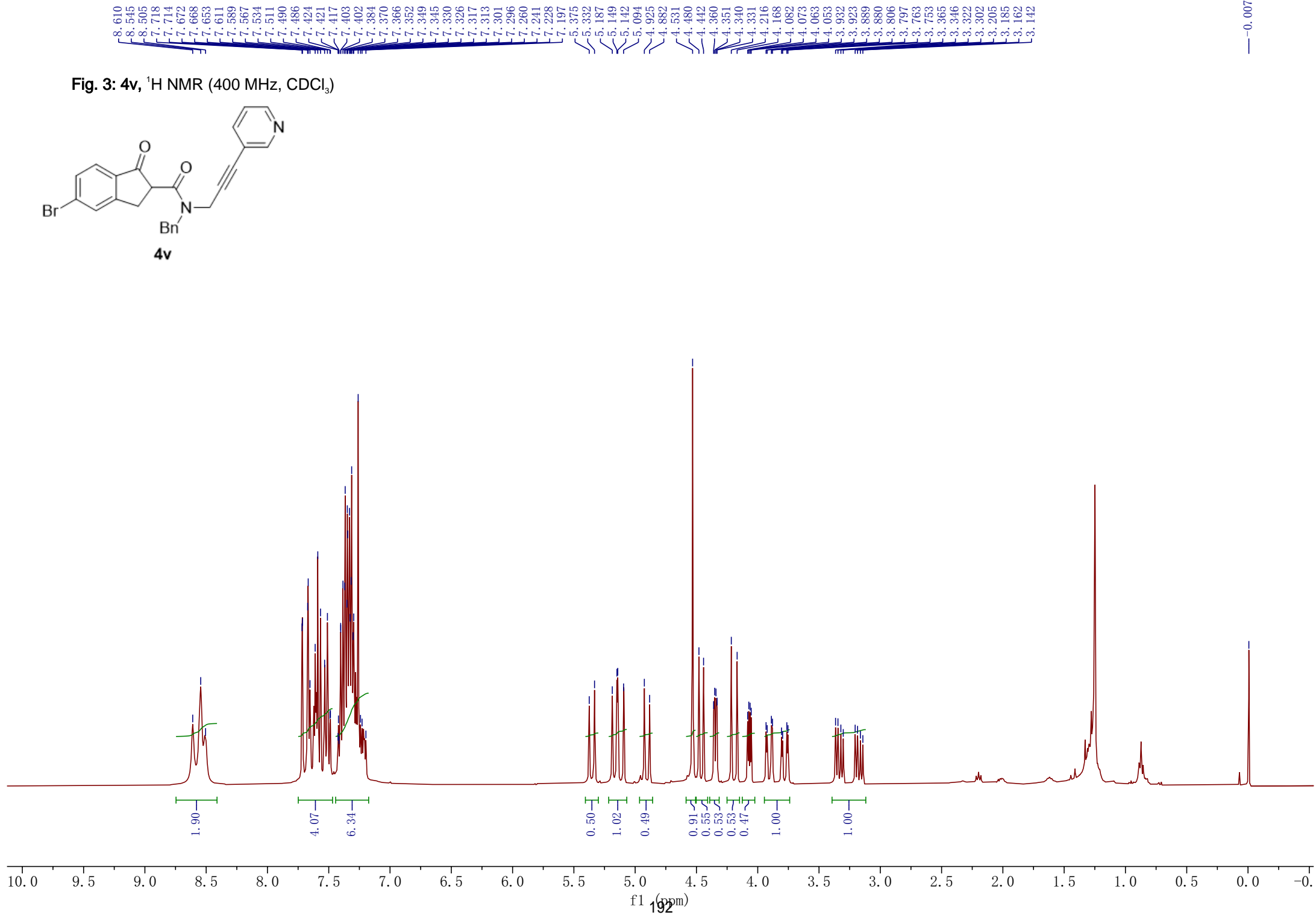
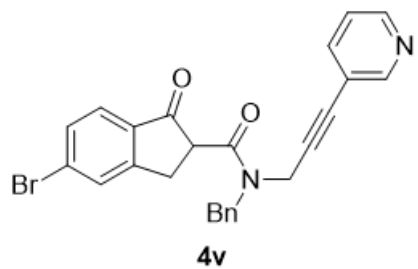
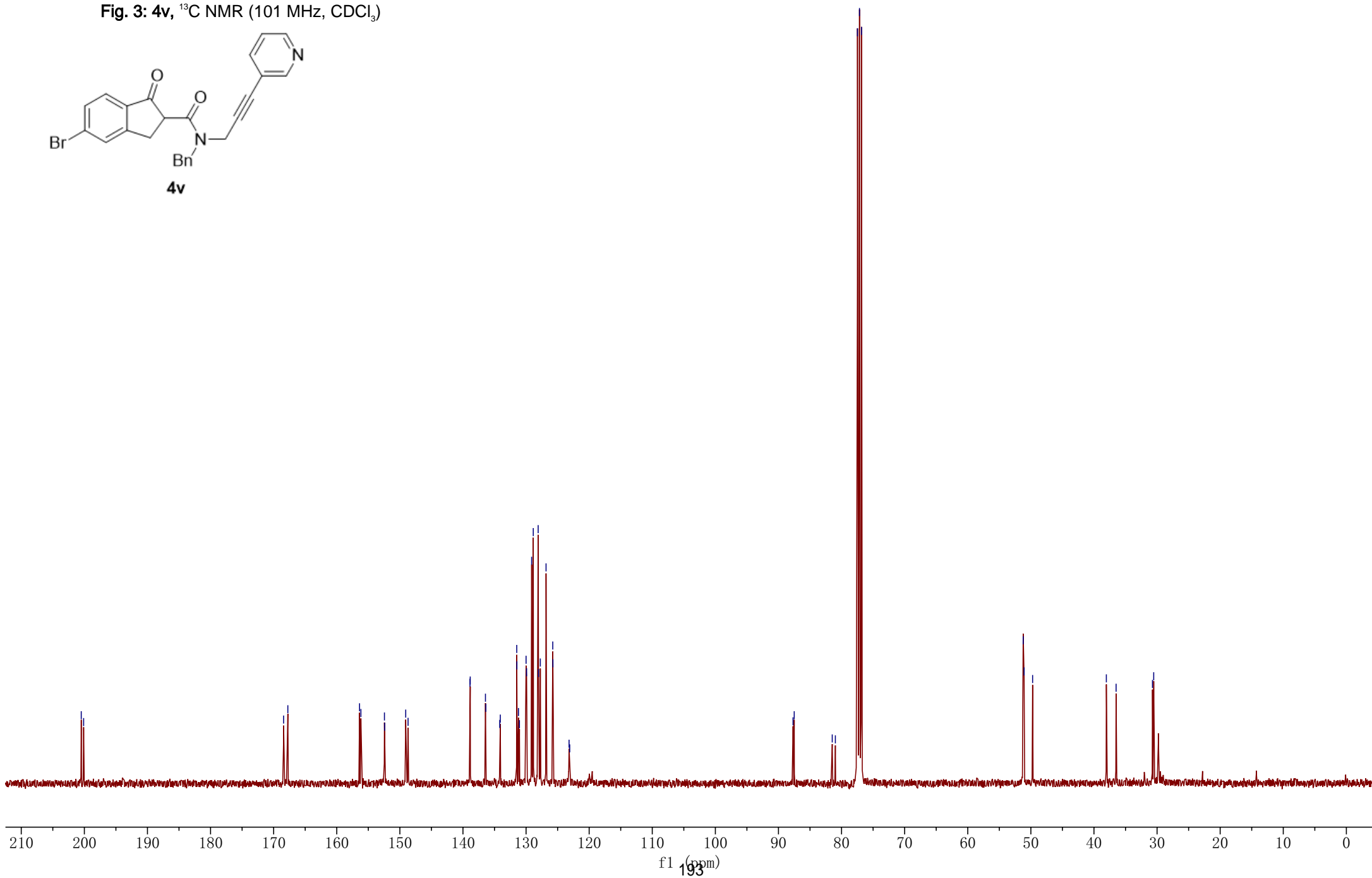


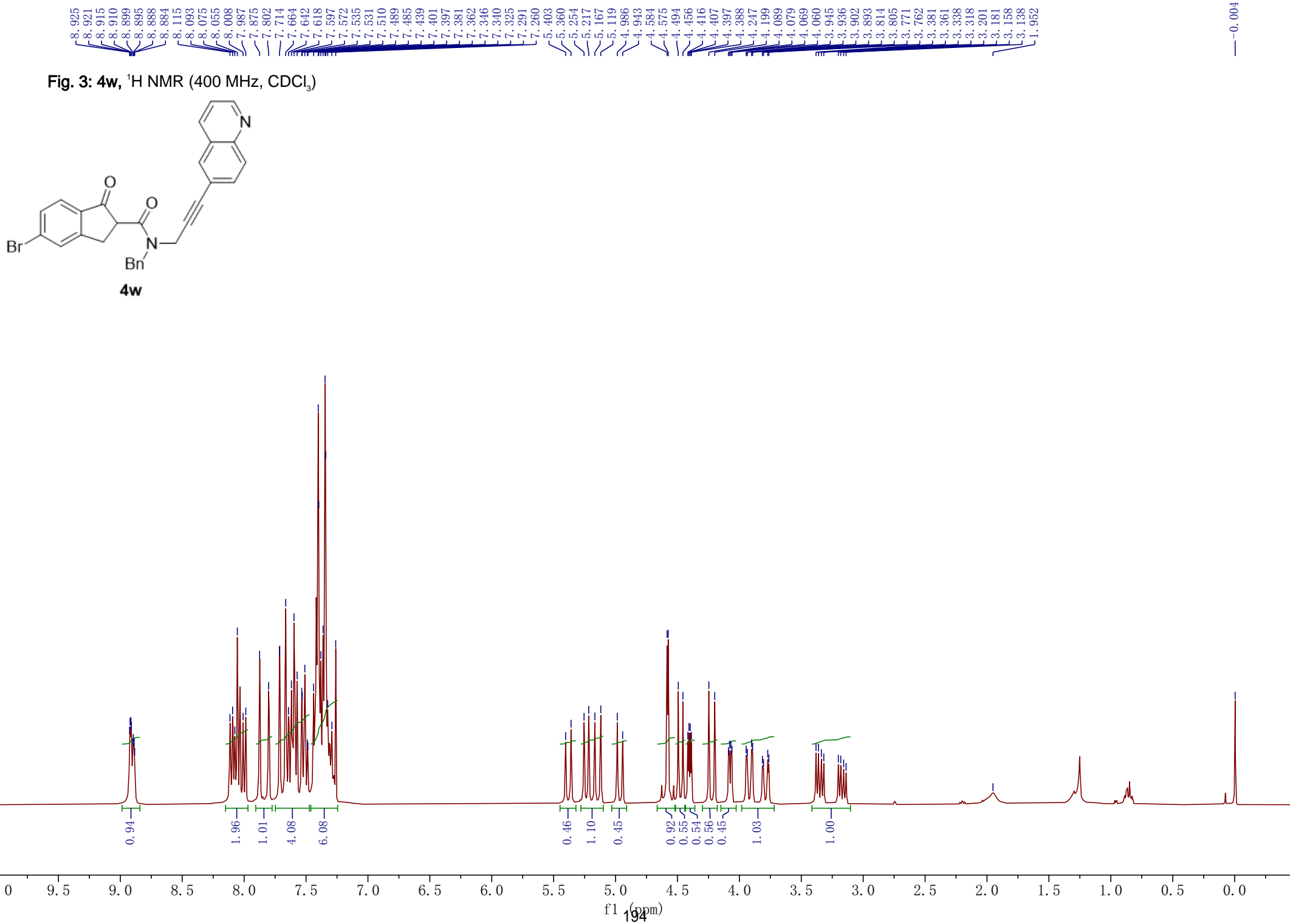
Fig. 3: **4v**,  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )

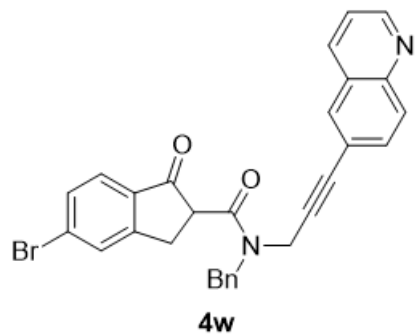




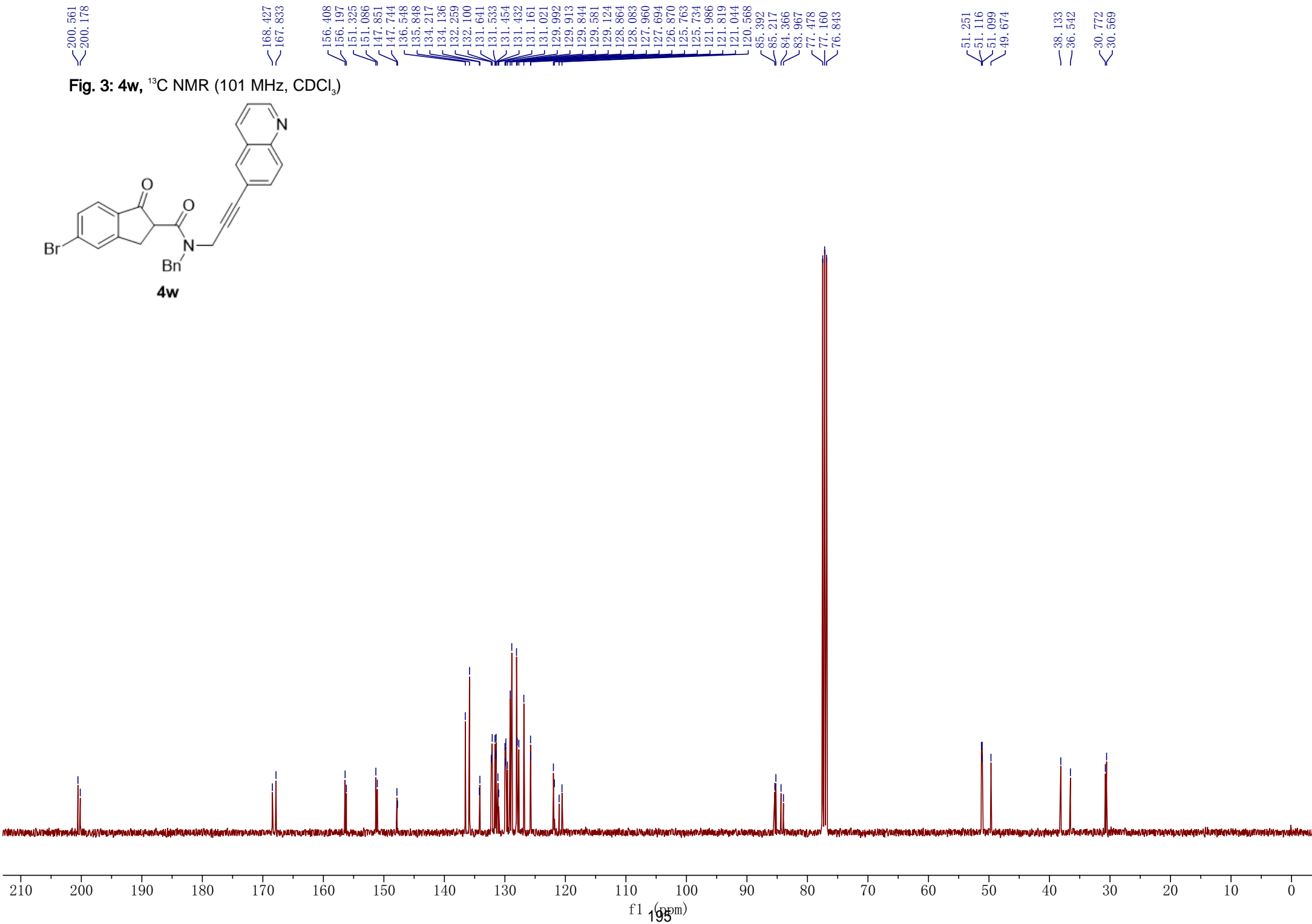
**Fig. 3: 4v,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**

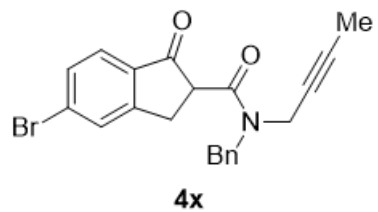




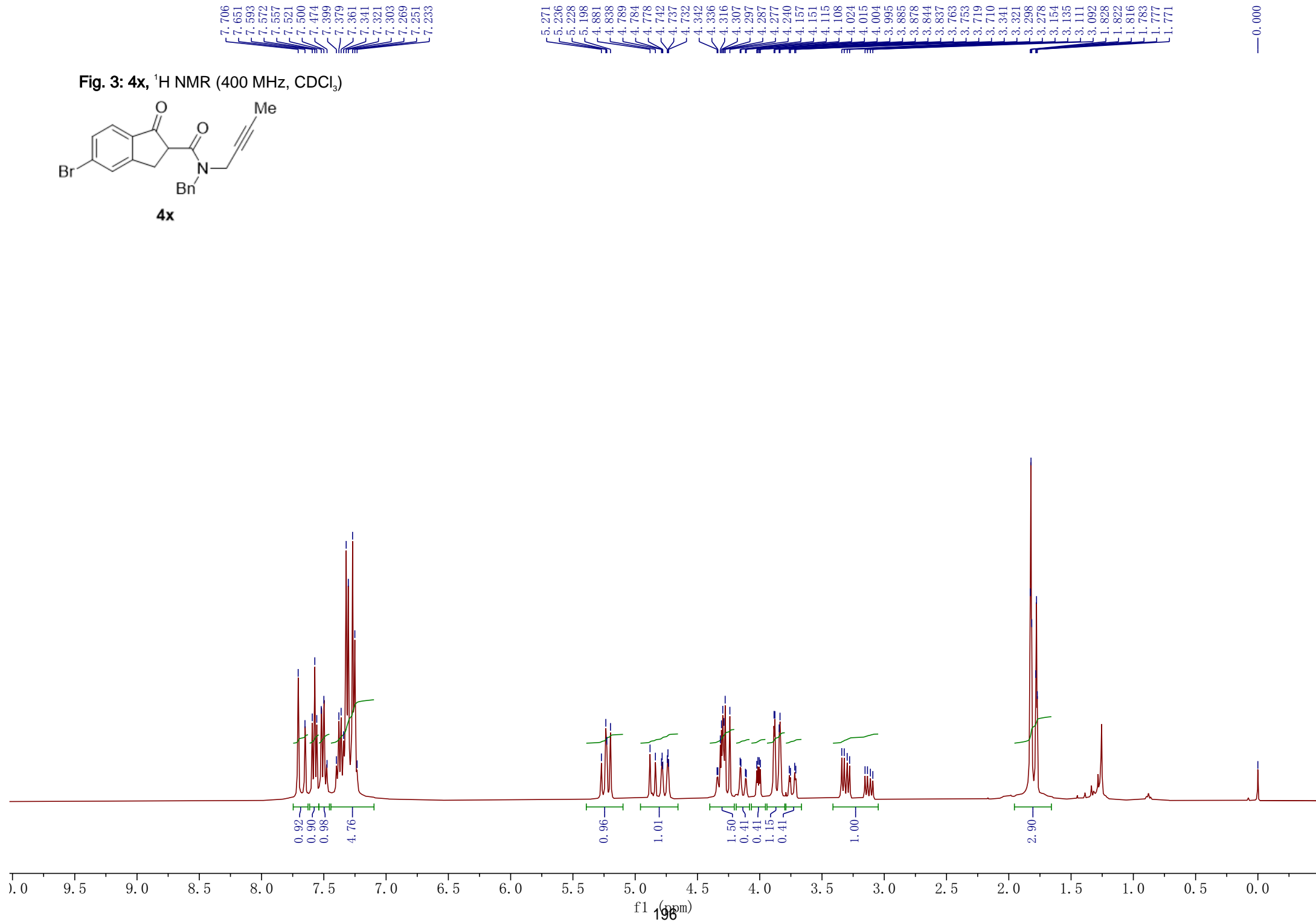


**Fig. 3: 4w,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**

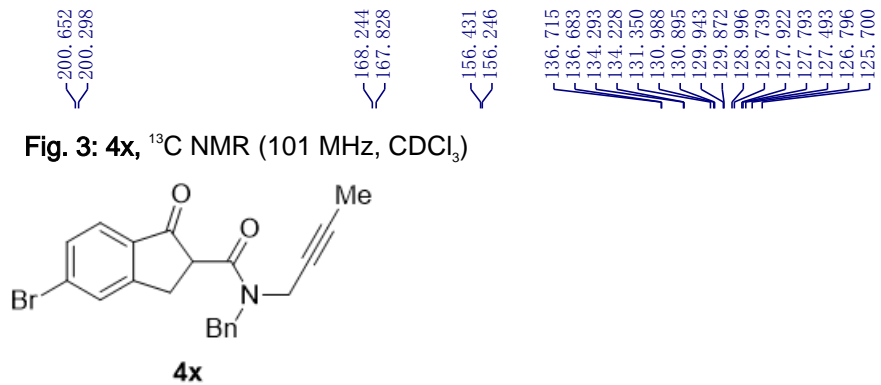




**Fig. 3: 4x, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**







200.652  
200.298

168.244  
167.828

156.431  
156.246

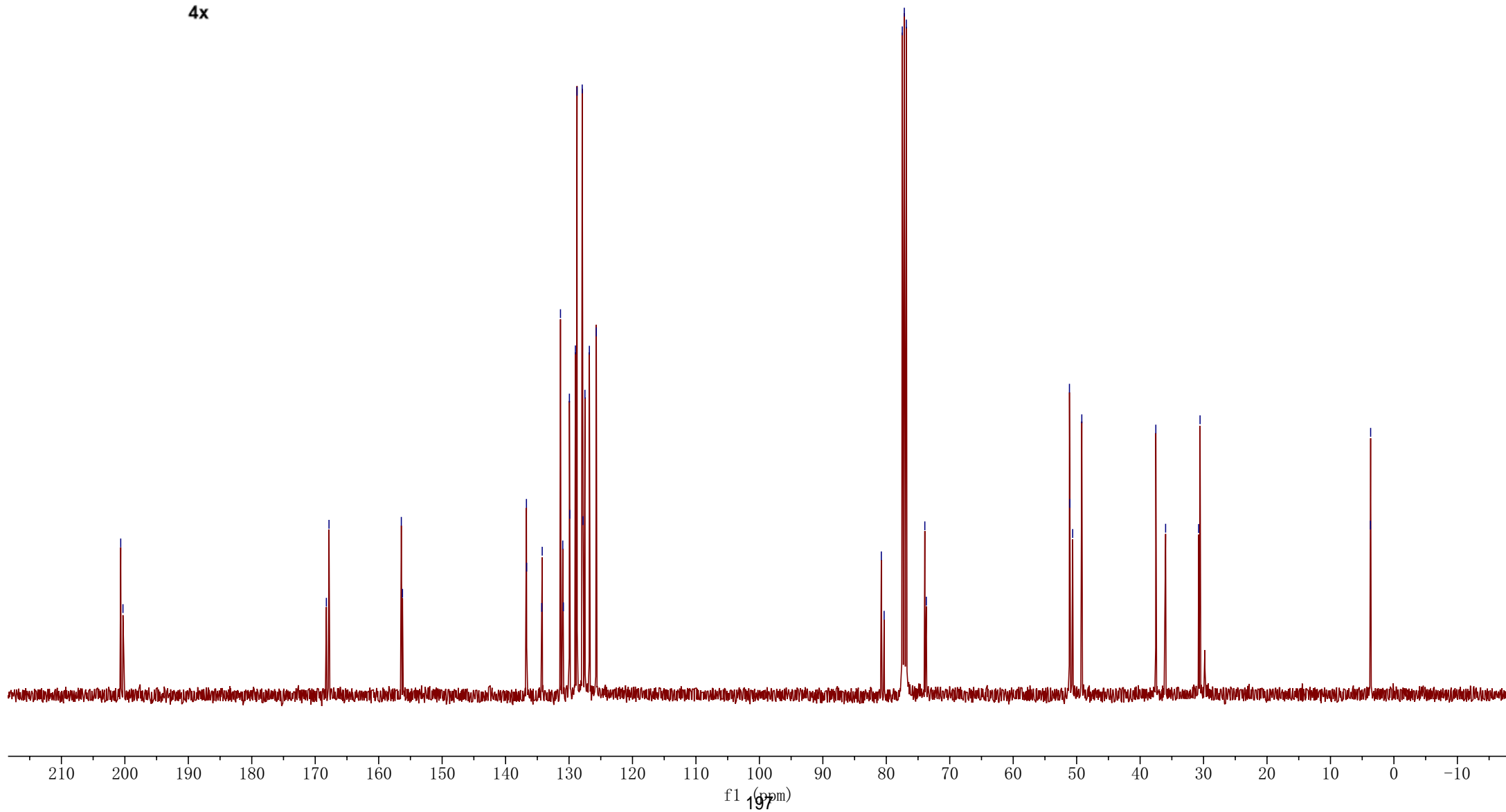
136.715  
136.683  
134.293  
134.228  
131.350  
130.988  
130.895  
129.943  
129.872  
128.996  
128.739  
127.922  
127.793  
127.493  
126.796  
125.700

80.784  
80.342  
77.478  
77.161  
76.843  
73.928  
73.693

51.137  
51.064  
50.626  
49.190

37.523  
35.982  
30.777  
30.552

3.698  
3.669



7.707  
7.648  
7.597  
7.577  
7.558  
7.521  
7.499  
7.479  
7.399  
7.396  
7.378  
7.359  
7.327  
7.306  
7.278  
7.260  
7.252  
7.234

5.279  
5.236  
5.206  
5.168  
4.887  
4.844  
4.809  
4.804  
4.799  
4.795  
4.762  
4.757  
4.753  
4.748  
4.337  
4.331  
4.322  
4.316  
4.311  
4.302  
4.279  
4.250  
4.244  
4.238  
4.206  
4.201  
4.195  
4.016  
4.007  
3.996  
3.987  
3.911  
3.906  
3.900  
3.886  
3.876  
3.864  
3.859  
3.853  
3.843  
3.833  
3.755  
3.746  
3.712  
3.706  
3.703  
3.319  
3.295  
3.275  
3.144  
3.125  
3.101  
3.082  
2.218  
2.199  
2.180  
2.158  
2.139  
2.120  
1.142  
1.124  
1.105  
1.093  
1.074  
1.055  
0.002

Fig. 3: 4y, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)

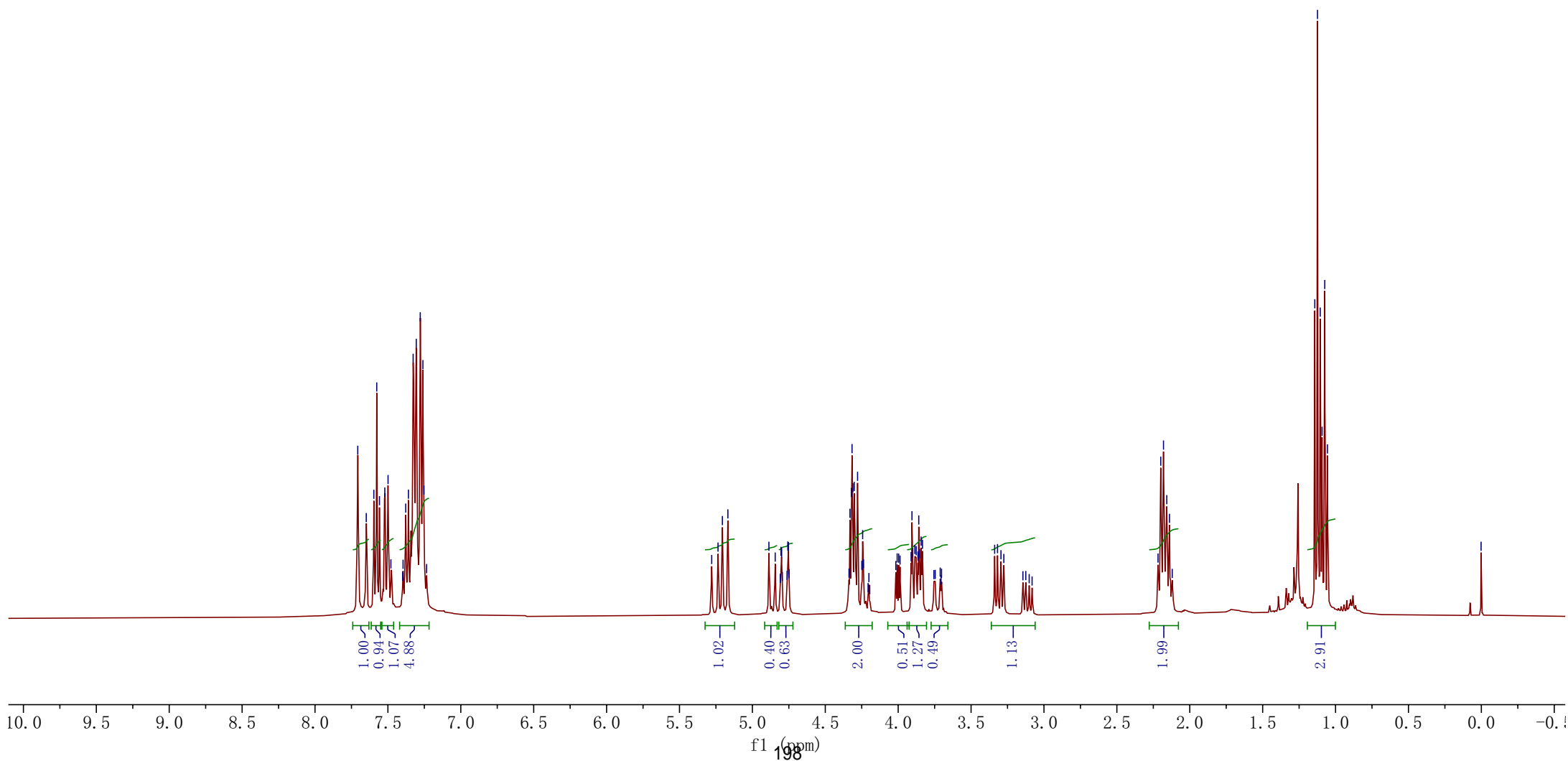
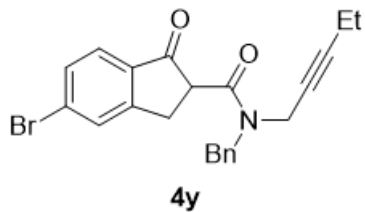
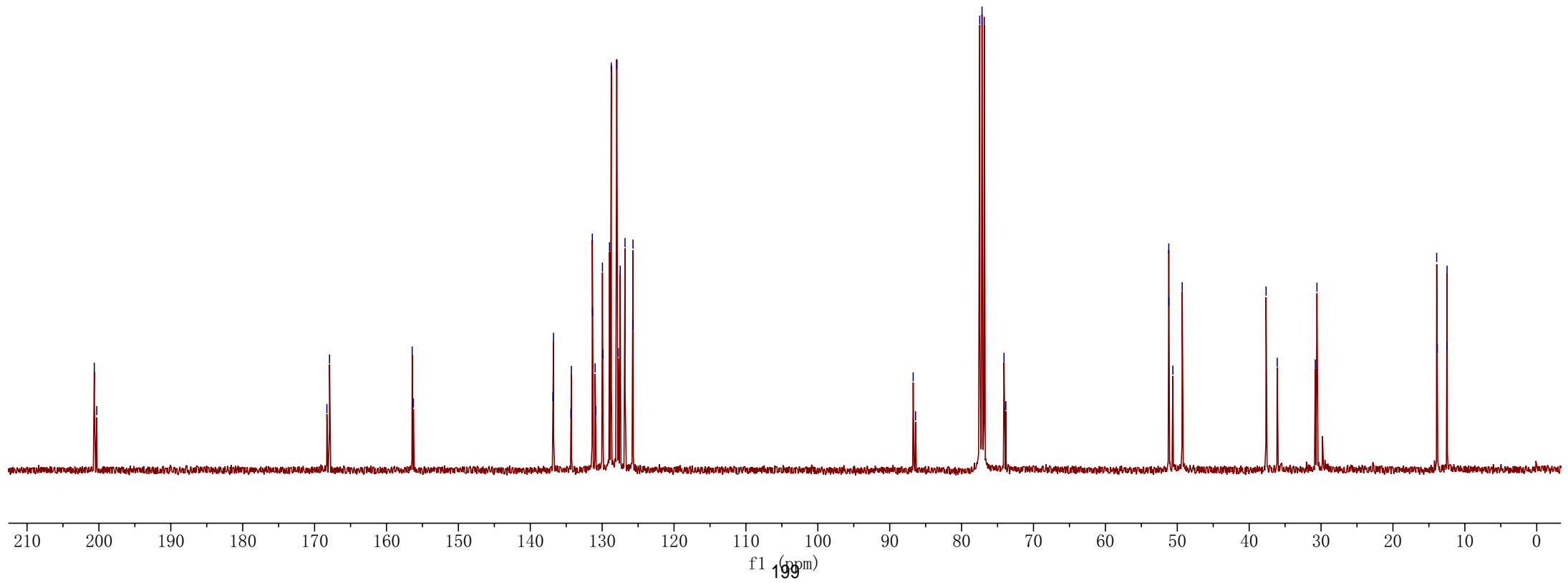
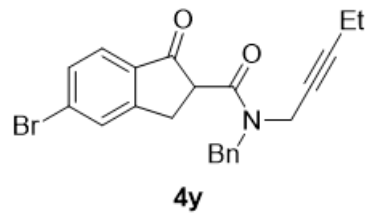


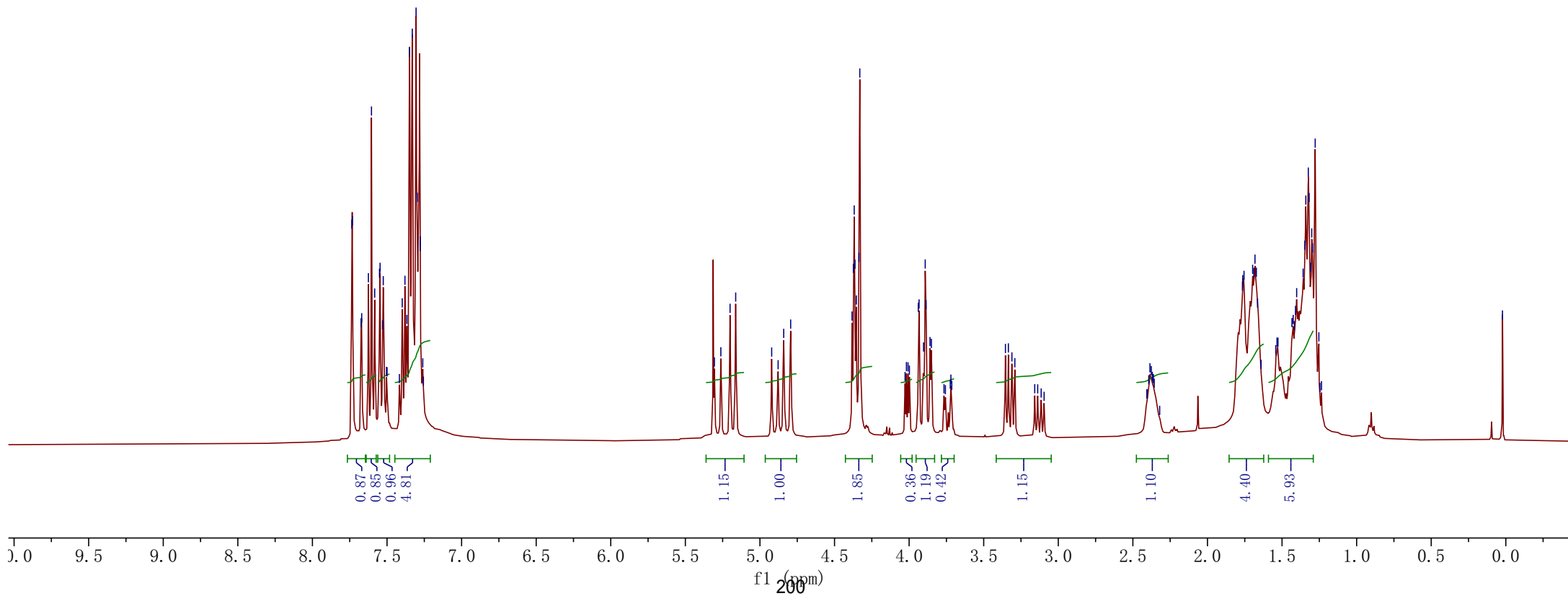
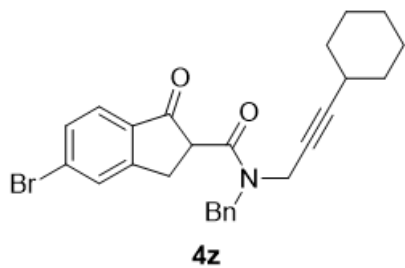


Fig. 3: **4y**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



7.736  
7.732  
7.673  
7.670  
7.625  
7.604  
7.583  
7.550  
7.546  
7.530  
7.525  
7.504  
7.500  
7.417  
7.398  
7.380  
7.367  
7.350  
7.331  
7.305  
7.297  
7.277  
7.260  
7.256  
5.305  
5.262  
5.200  
5.163  
4.921  
4.878  
4.841  
4.794  
4.383  
4.374  
4.368  
4.363  
4.354  
4.336  
4.331  
4.027  
4.018  
4.007  
3.998  
3.939  
3.933  
3.903  
3.892  
3.886  
3.860  
3.851  
3.766  
3.757  
3.724  
3.720  
3.714  
3.354  
3.335  
3.311  
3.291  
3.158  
3.138  
3.115  
3.095  
2.406  
2.405  
2.394  
2.385  
2.376  
2.370  
2.363  
2.357  
2.320  
1.765  
1.764  
1.755  
1.697  
1.689  
1.682  
1.672  
1.664  
1.641  
1.542  
1.534  
1.527  
1.434  
1.425  
1.418  
1.410  
1.402  
1.359  
1.347  
1.341  
1.324  
1.319  
1.307  
1.301  
1.296  
1.278  
1.253  
1.246  
1.236  
0.022

Fig. 3: 4z, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



200.715  
200.363

168.312  
168.040

156.435  
156.264

136.947  
136.762  
134.344  
134.298  
131.382  
131.358  
130.986  
130.887  
129.981  
129.891  
128.963  
128.747  
127.980  
127.724  
127.500  
126.805  
125.728  
125.696

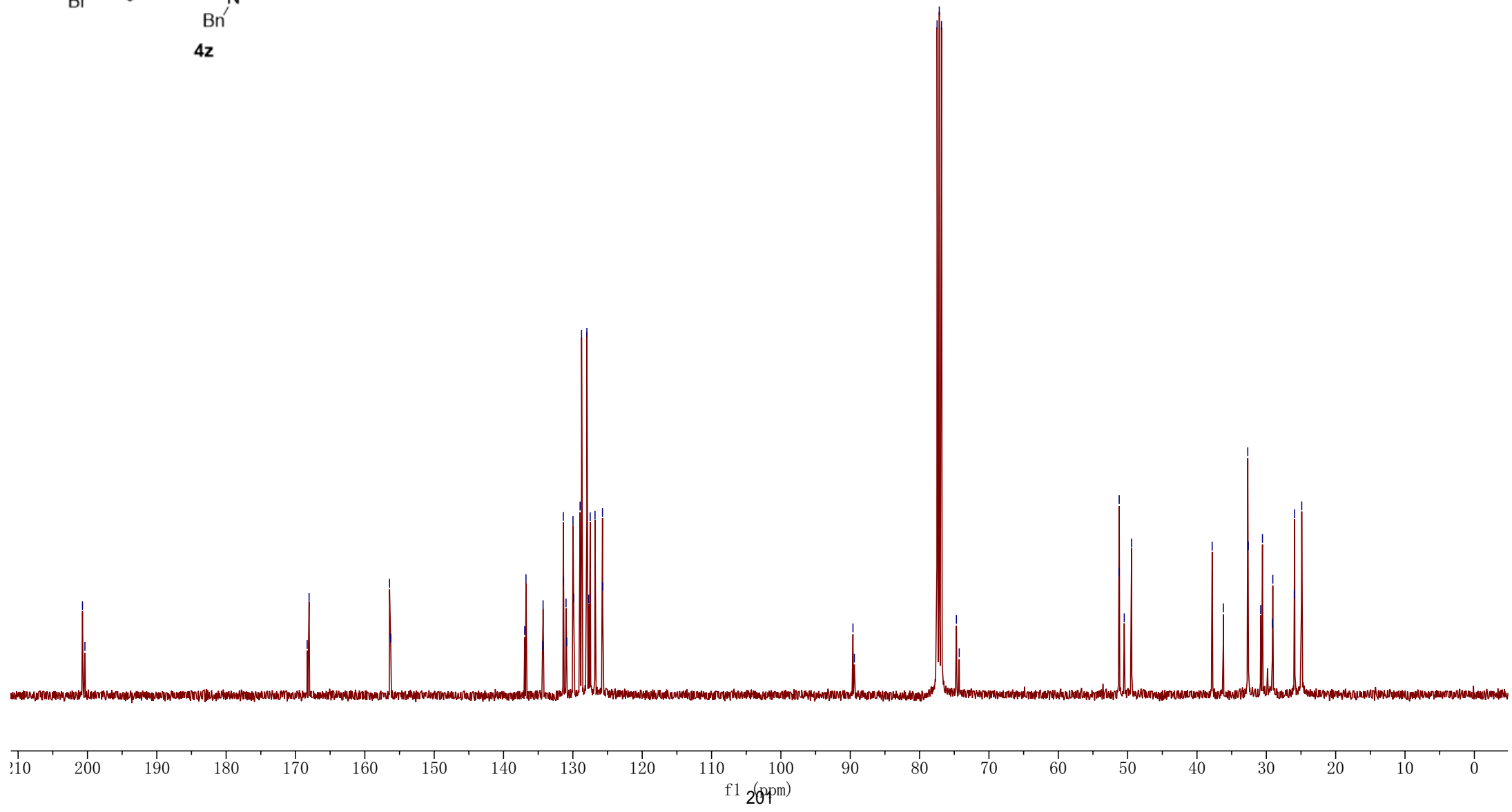
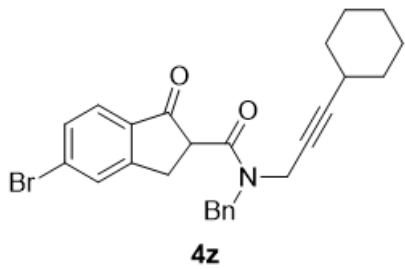
89.610  
89.412

77.479  
77.161  
76.843  
74.689  
74.285

51.236  
51.215  
50.490  
49.430

37.811  
36.201  
32.675  
32.608  
30.812  
30.557  
29.120  
29.066  
25.960  
25.913  
24.895

Fig. 3: 4z, <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)



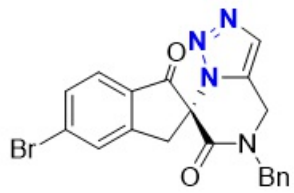
7.839  
7.643  
7.623  
7.614  
7.610  
7.598  
7.590  
7.378  
7.362  
7.343  
7.336  
7.265  
7.260  
7.245

4.914  
4.911  
4.873  
4.871  
4.839  
4.802  
4.741  
4.704  
4.596  
4.555  
4.376  
4.333  
4.290  
4.247

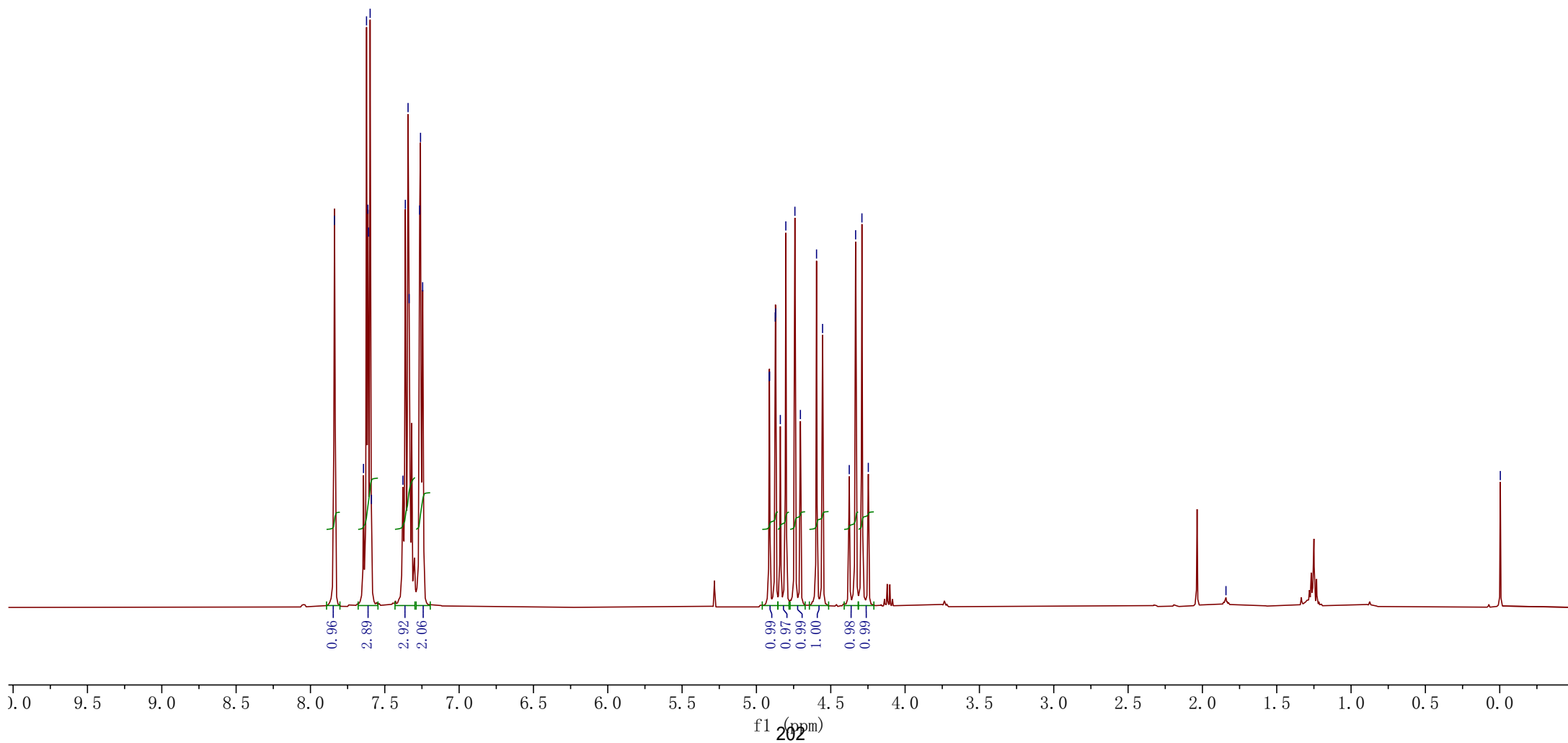
1.841

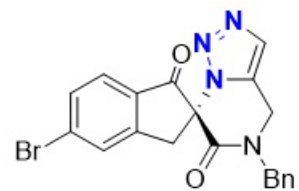
-0.004

Fig. 2: 3a, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



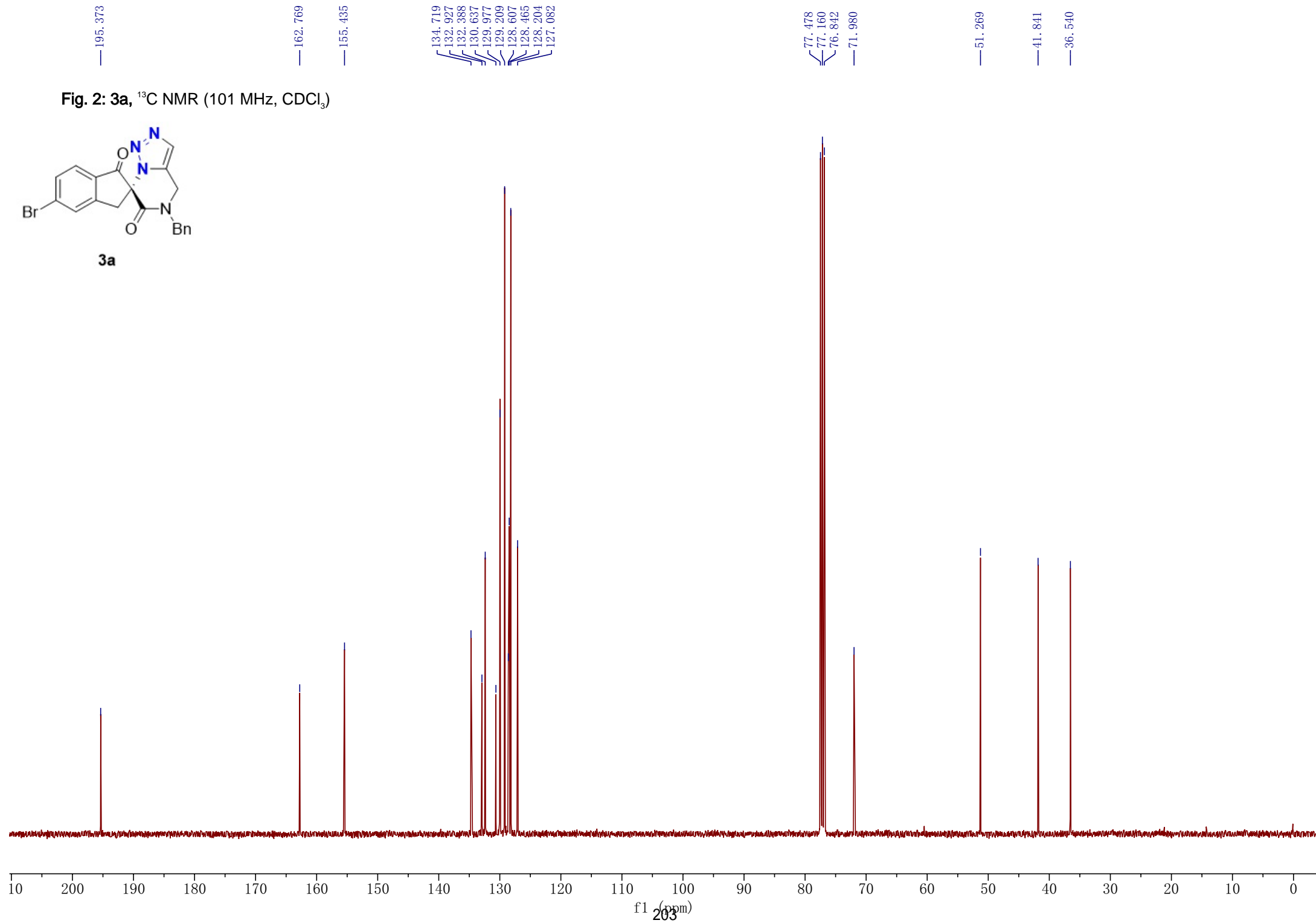
3a





3a

Fig. 2: 3a, <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)





**3b**

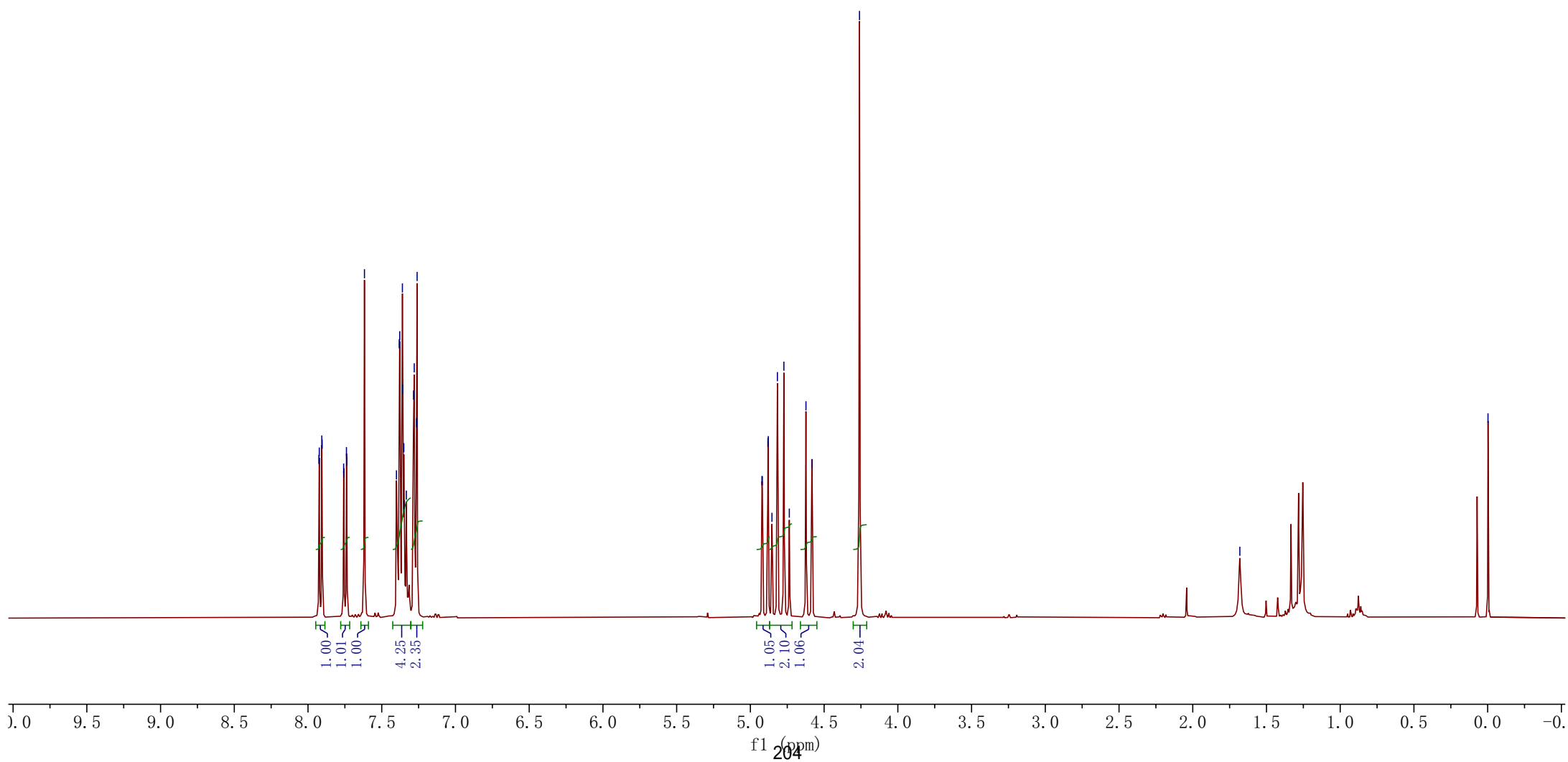
**Fig. 2: 3b, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**

7.926  
7.924  
7.907  
7.904  
7.758  
7.756  
7.739  
7.737  
7.617  
7.400  
7.381  
7.378  
7.360  
7.358  
7.350  
7.346  
7.333  
7.284  
7.280  
7.264  
7.260

4.922  
4.919  
4.881  
4.879  
4.854  
4.817  
4.773  
4.736  
4.623  
4.581  
4.260

1.681

-0.002





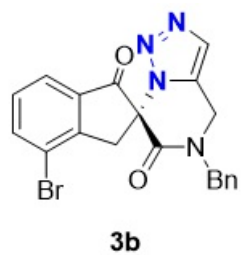


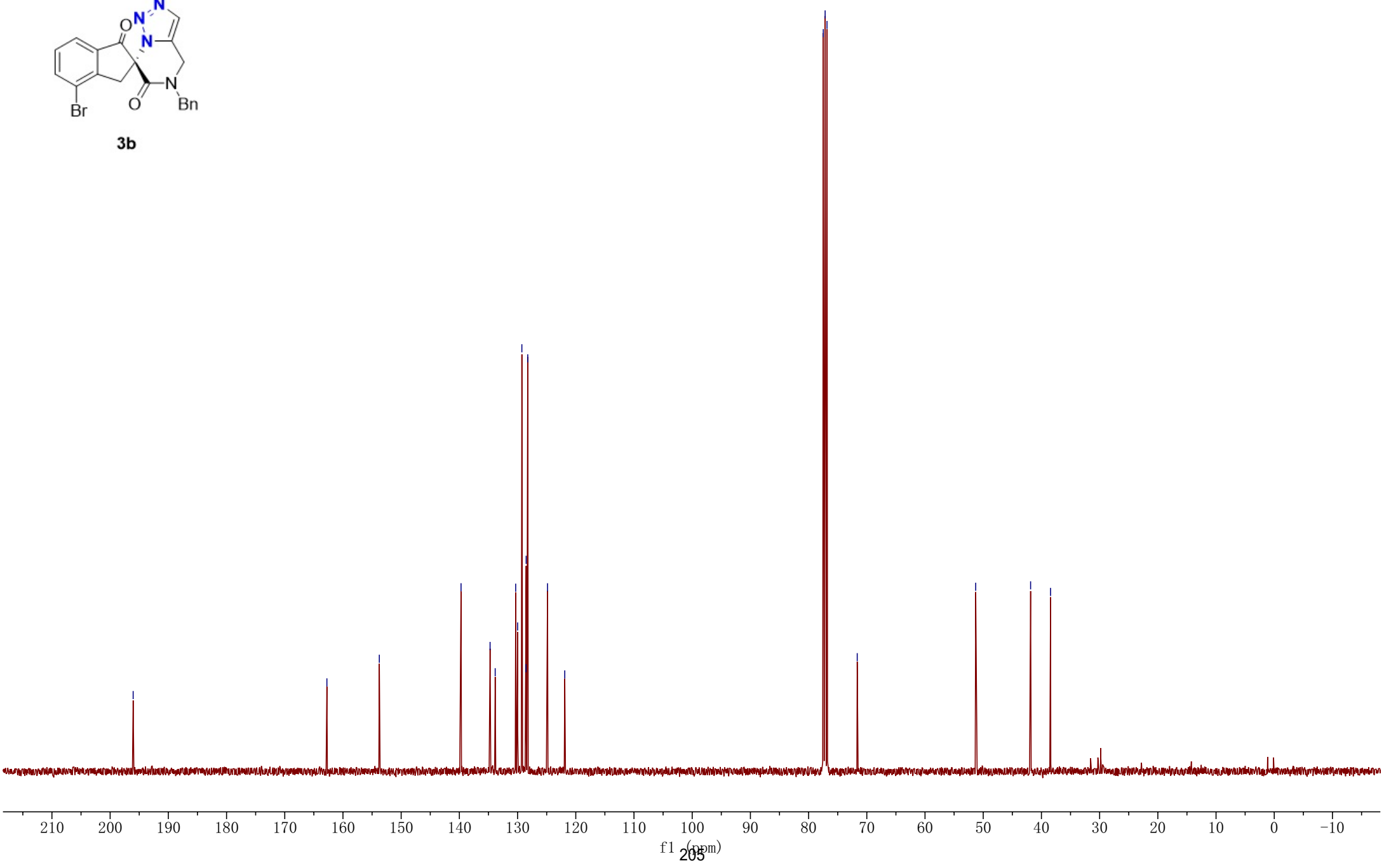
Fig. 2: **3b**, <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)

196.044  
162.759  
153.752

139.713  
134.724  
133.845  
130.324  
129.992  
129.263  
128.556  
128.526  
128.252  
124.854  
121.894

77.477  
77.160  
76.842  
71.645

51.291  
41.859  
38.432



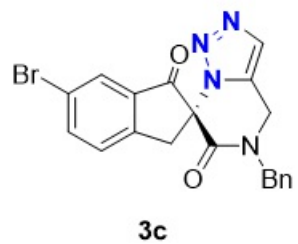


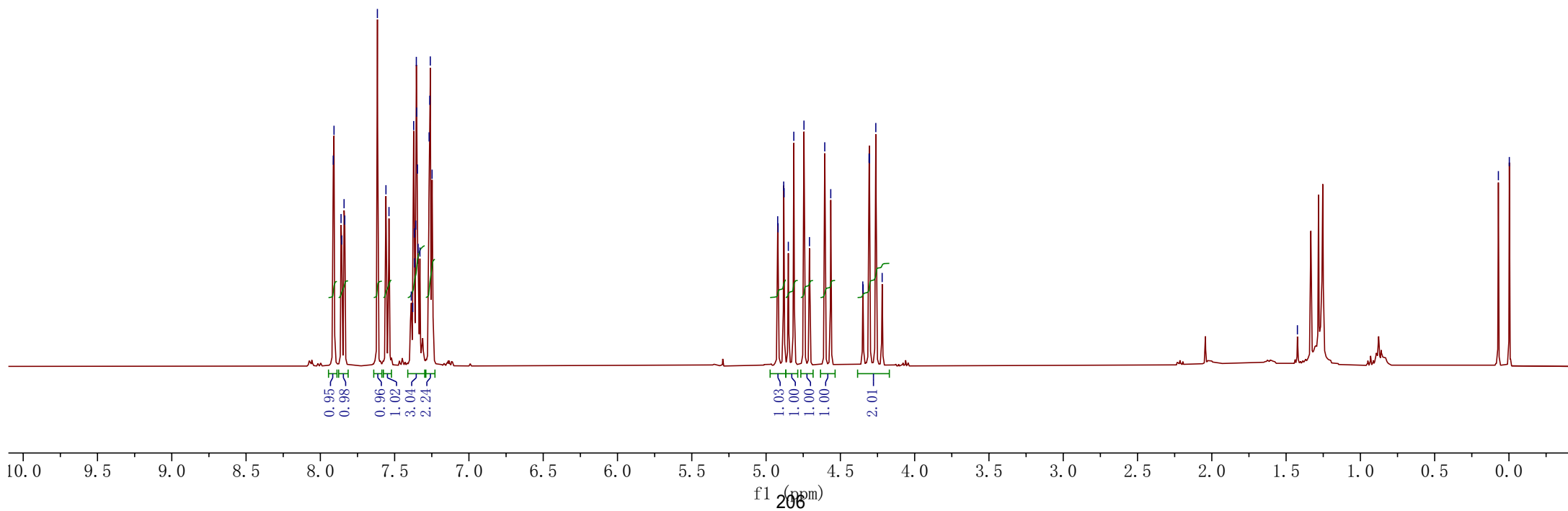
Fig. 2: **3c**, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)

7.913  
7.908  
7.861  
7.856  
7.840  
7.835  
7.616  
7.559  
7.538  
7.388  
7.378  
7.372  
7.367  
7.366  
7.358  
7.354  
7.352  
7.346  
7.342  
7.330  
7.268  
7.263  
7.260  
7.248

4.922  
4.919  
4.881  
4.879  
4.850  
4.813  
4.745  
4.708  
4.605  
4.565  
4.349  
4.347  
4.306  
4.304  
4.261  
4.219

— 1.424

— 0.071  
— 0.002



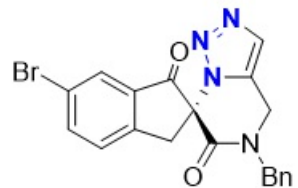
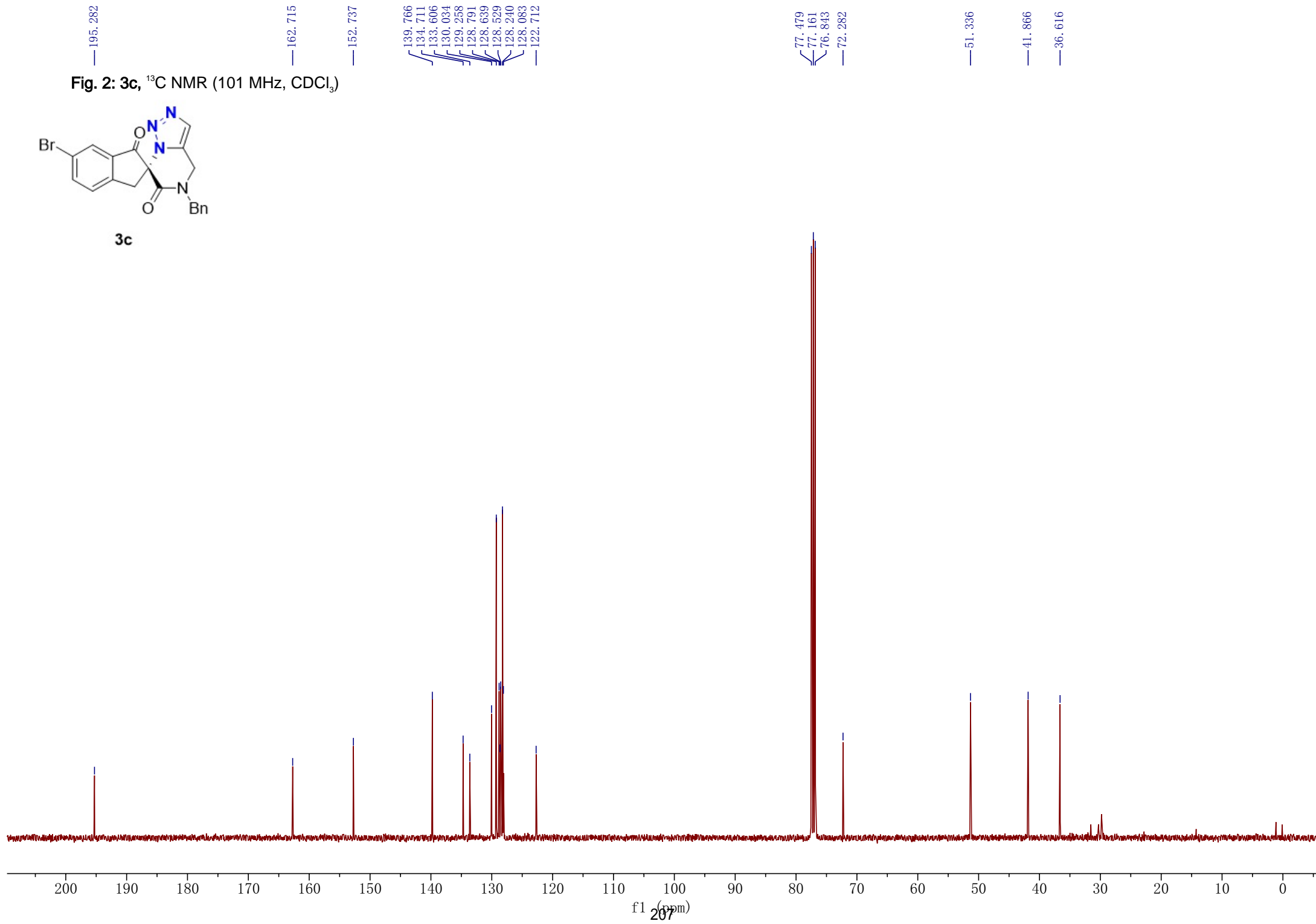


Fig. 2: 3c,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )





**3d**

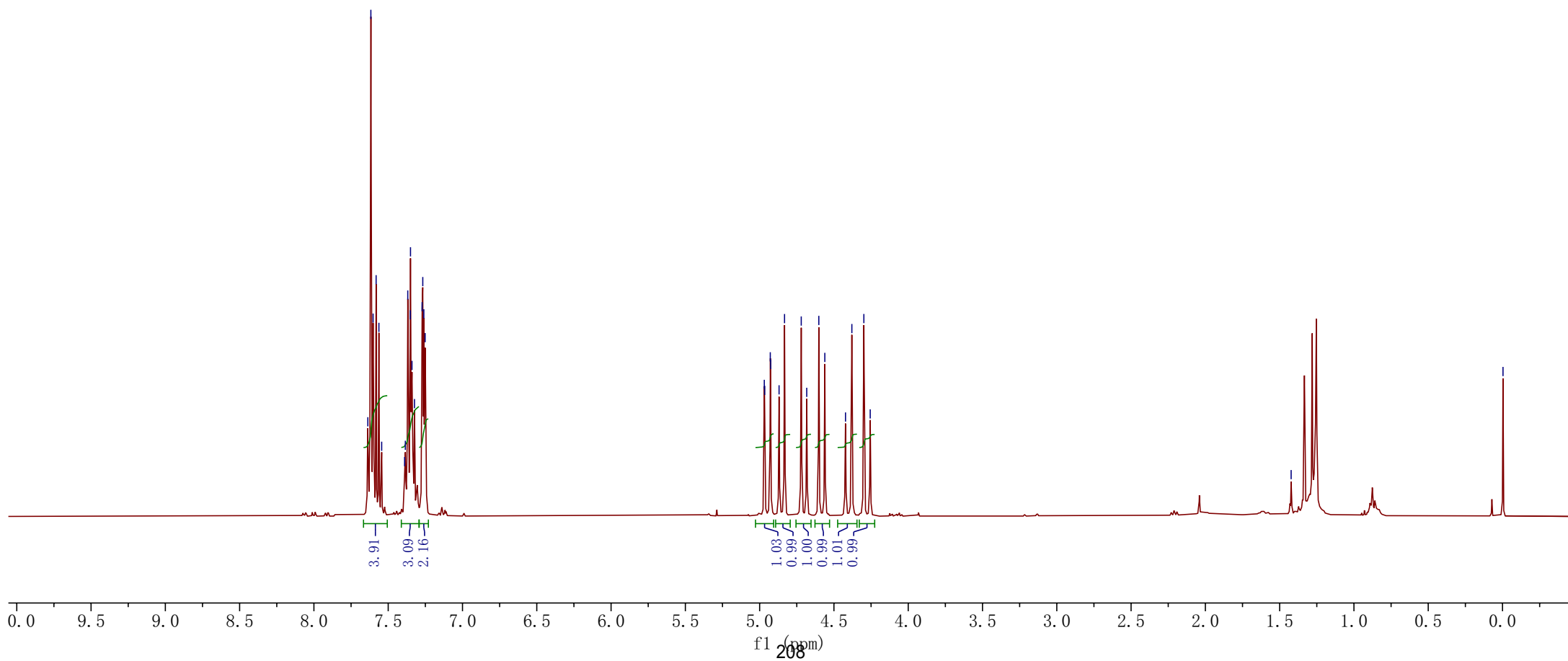
**Fig. 2: 3d, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**

7.637  
7.617  
7.602  
7.581  
7.563  
7.544  
7.390  
7.385  
7.368  
7.351  
7.350  
7.340  
7.323  
7.272  
7.267  
7.260  
7.251

4.969  
4.966  
4.928  
4.926  
4.869  
4.832  
4.720  
4.683  
4.602  
4.561  
4.422  
4.379  
4.299  
4.256

— 1.423

— 0.003



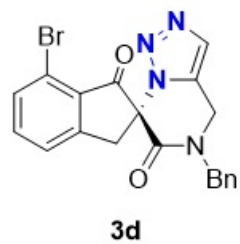
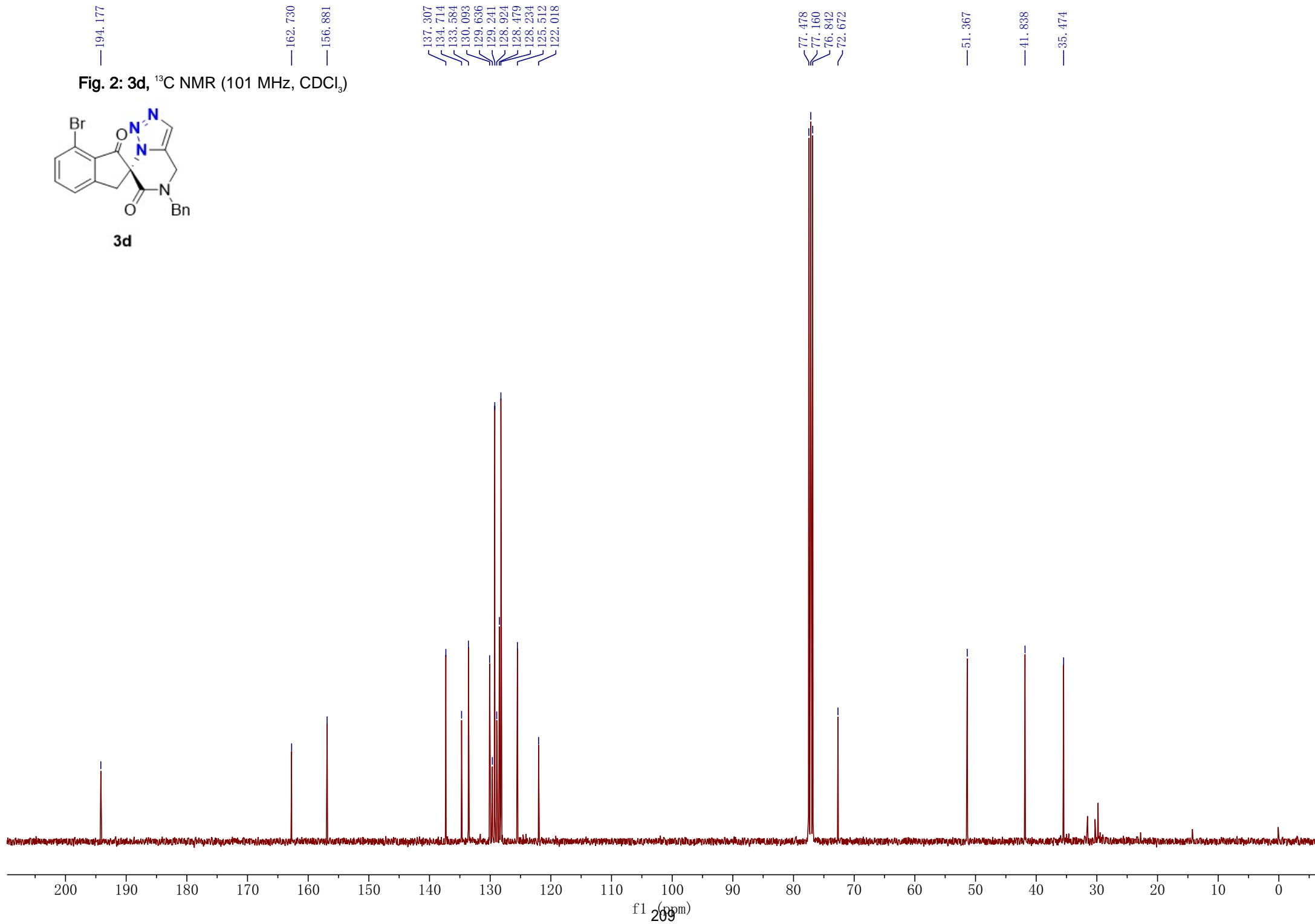
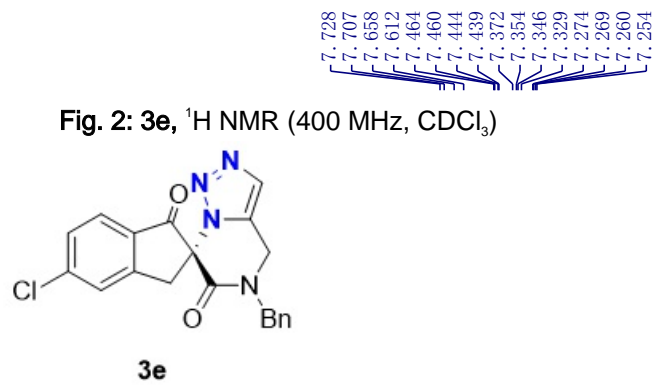


Fig. 2: **3d**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



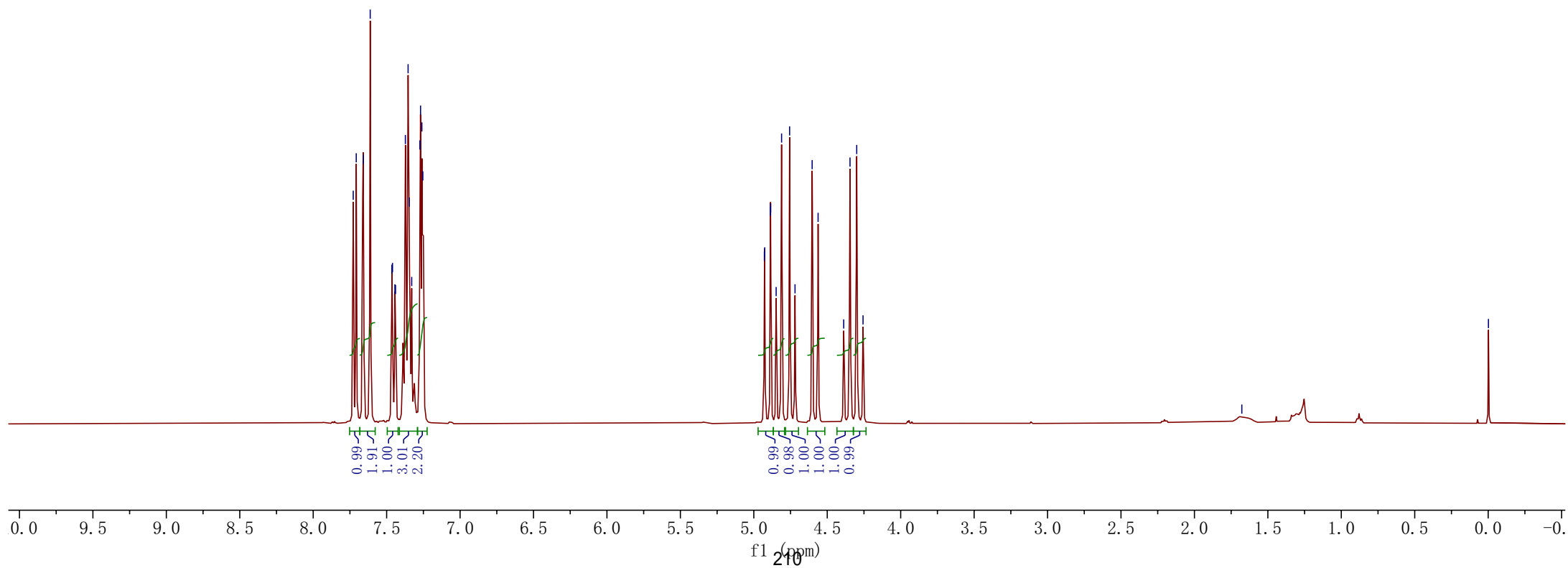


7.728  
7.707  
7.658  
7.612  
7.464  
7.460  
7.444  
7.439  
7.372  
7.354  
7.346  
7.329  
7.274  
7.269  
7.260  
7.254

4.928  
4.926  
4.888  
4.885  
4.848  
4.811  
4.756  
4.719  
4.603  
4.562  
4.388  
4.345  
4.299  
4.256

— 1.677

— -0.002



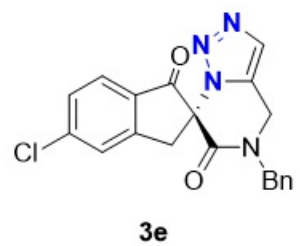
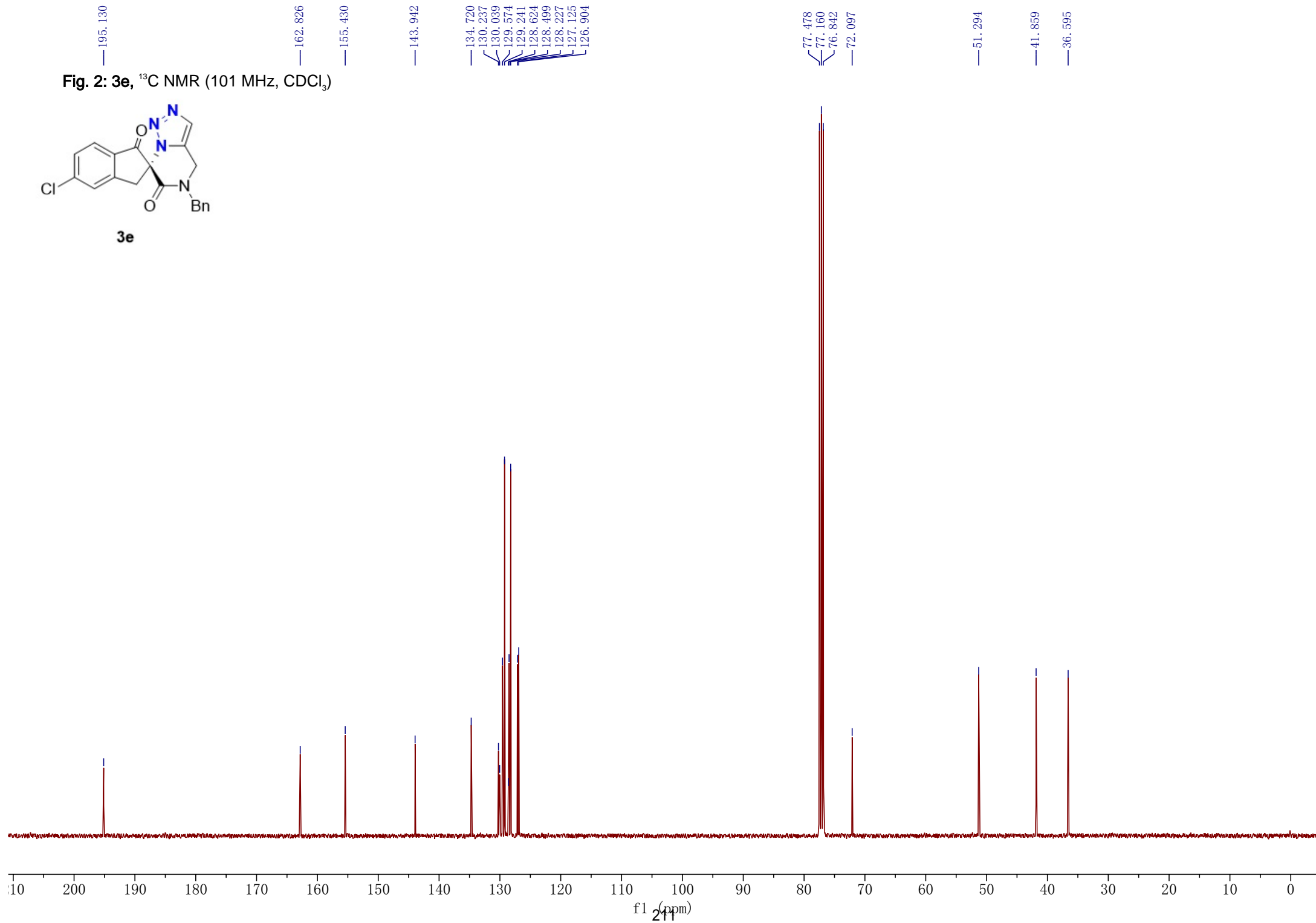


Fig. 2: **3e**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



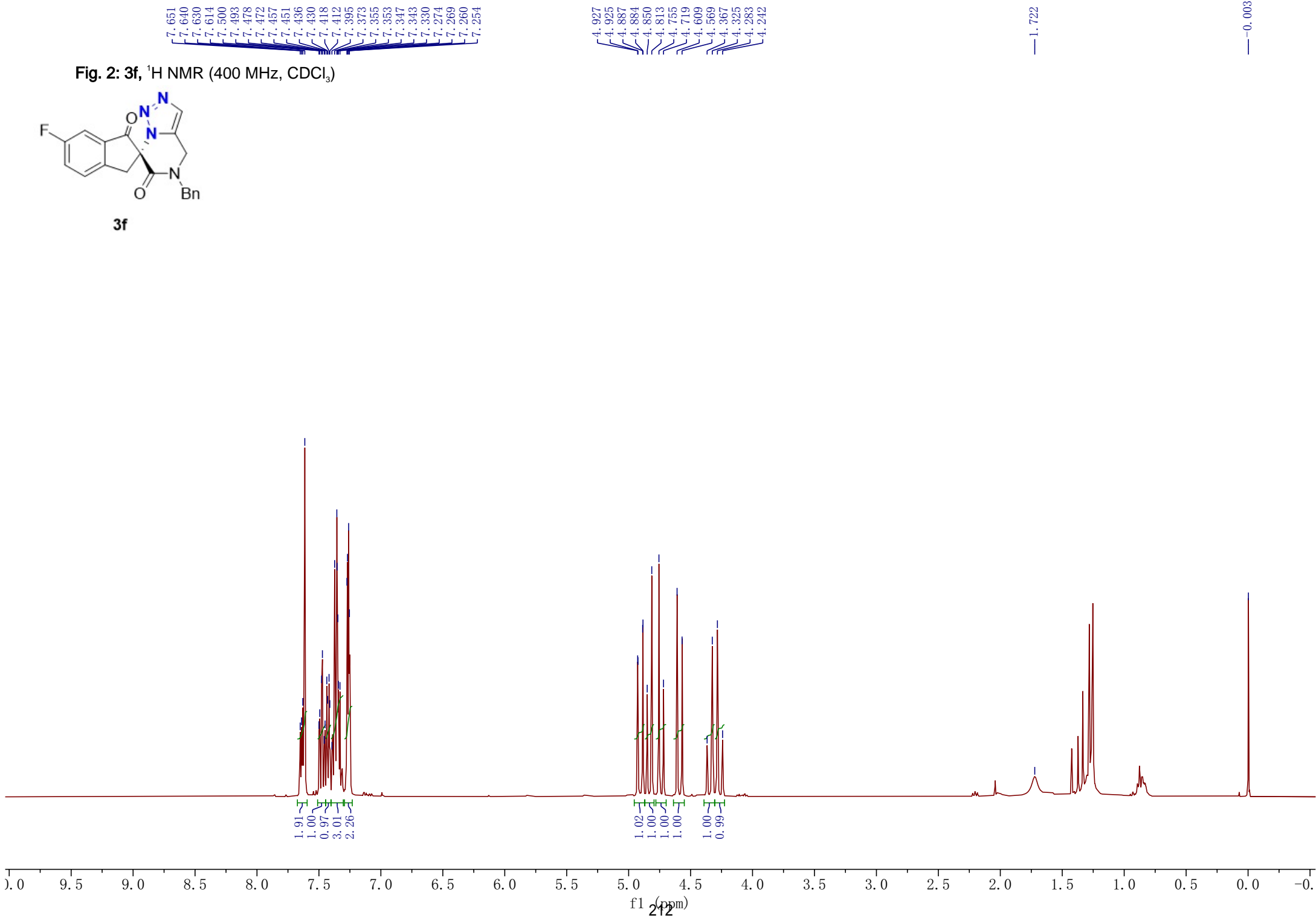
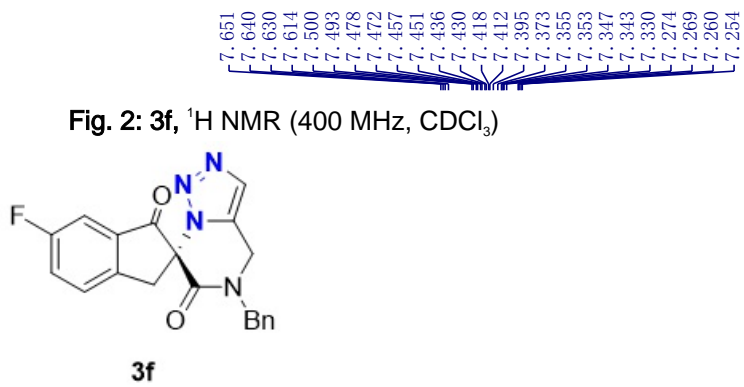




Fig. 2: **3f**,  $^{19}\text{F}$  NMR (376 MHz,  $\text{CDCl}_3$ )

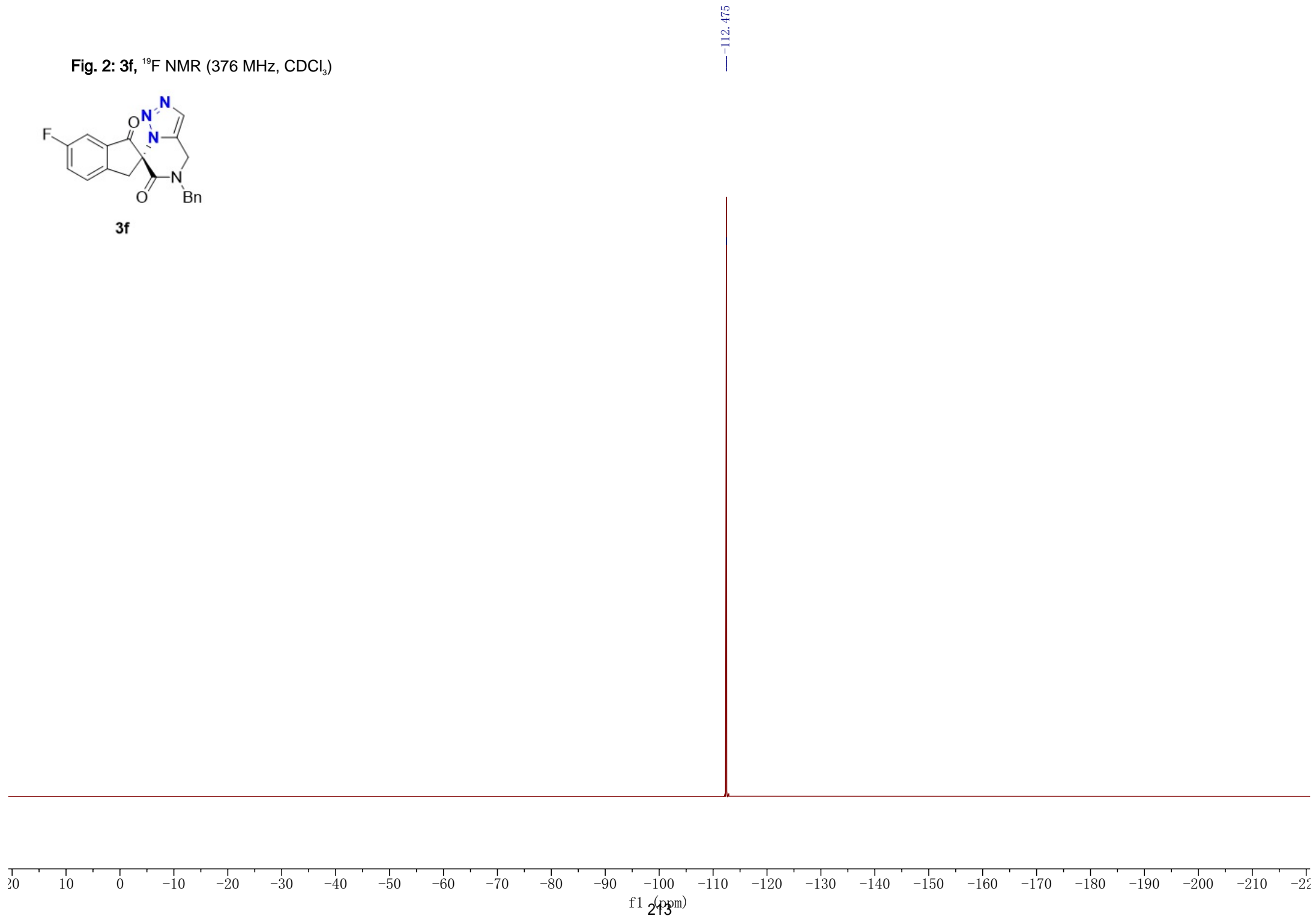
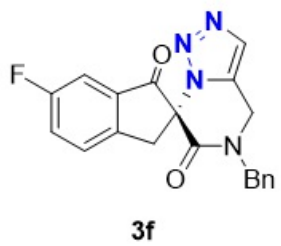
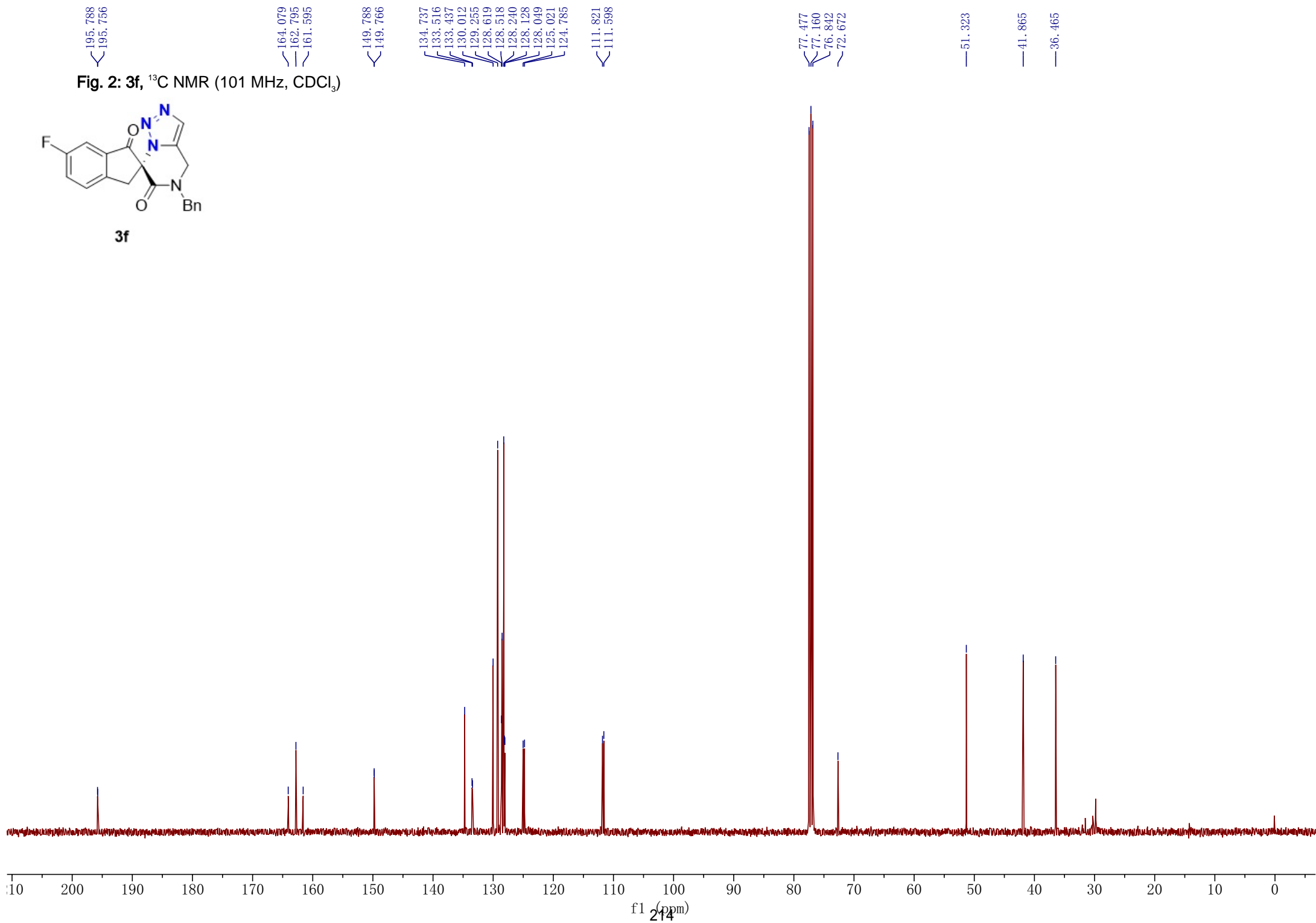
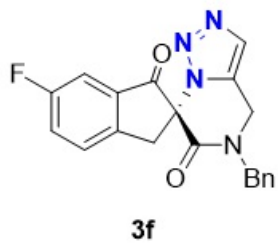


Fig. 2: **3f**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



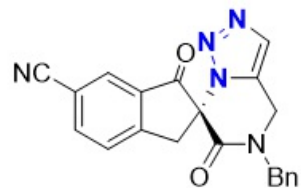
8.081  
8.077  
8.007  
8.003  
7.987  
7.983  
7.817  
7.815  
7.797  
7.795  
7.632  
7.395  
7.379  
7.375  
7.372  
7.366  
7.361  
7.356  
7.339  
7.268  
7.263  
7.260  
7.248  
7.244

4.927  
4.924  
4.886  
4.884  
4.857  
4.820  
4.746  
4.709  
4.629  
4.589  
4.471  
4.427  
4.386  
4.342

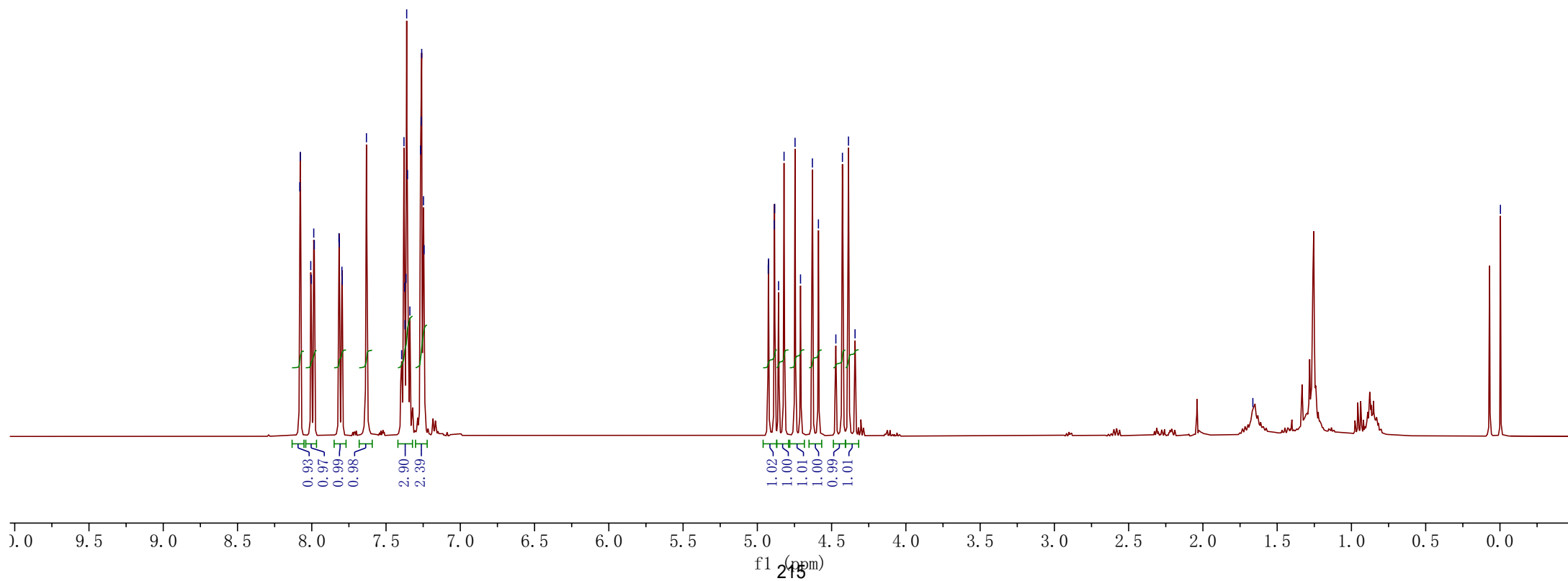
—1.664

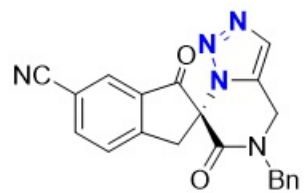
—0.003

Fig. 2: **3g**,  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )



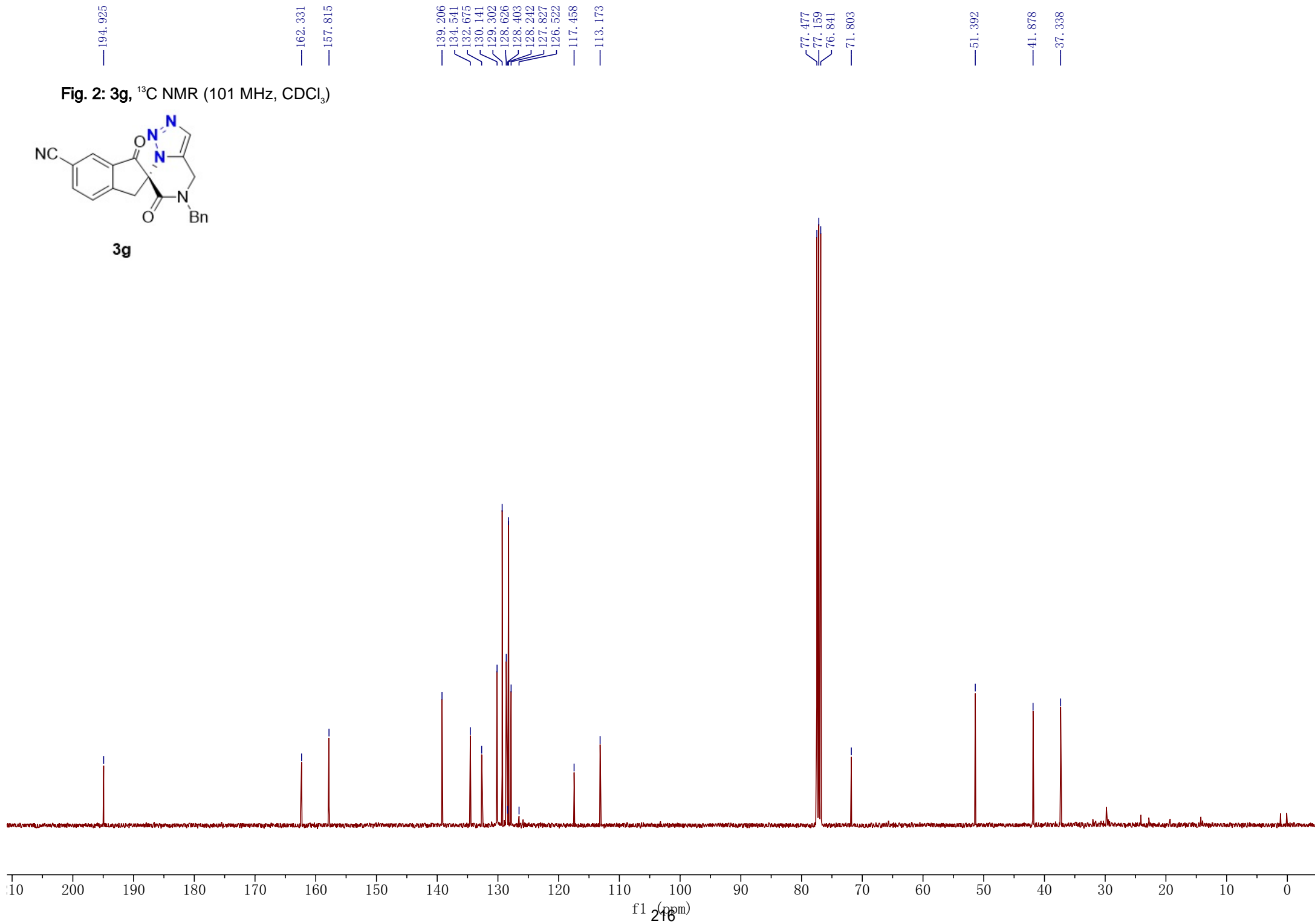
**3g**

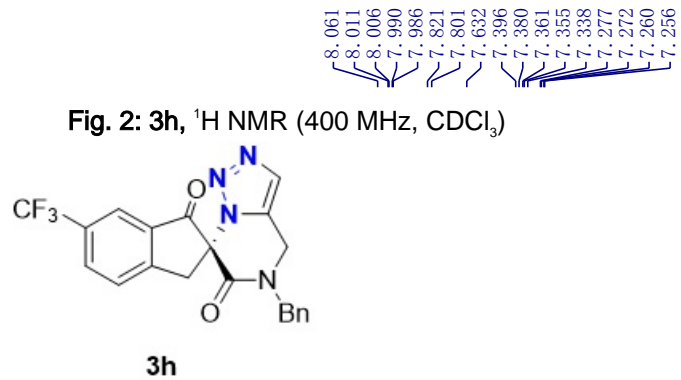




**3g**

**Fig. 2: 3g,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**





8.061  
8.011  
8.006  
7.990  
7.986  
7.821  
7.801  
7.632  
7.396  
7.380  
7.361  
7.355  
7.338  
7.277  
7.272  
7.260  
7.256

4.941  
4.939  
4.901  
4.898  
4.870  
4.833  
4.749  
4.712  
4.627  
4.586  
4.475  
4.432  
4.388  
4.344

—1.684

—0.002

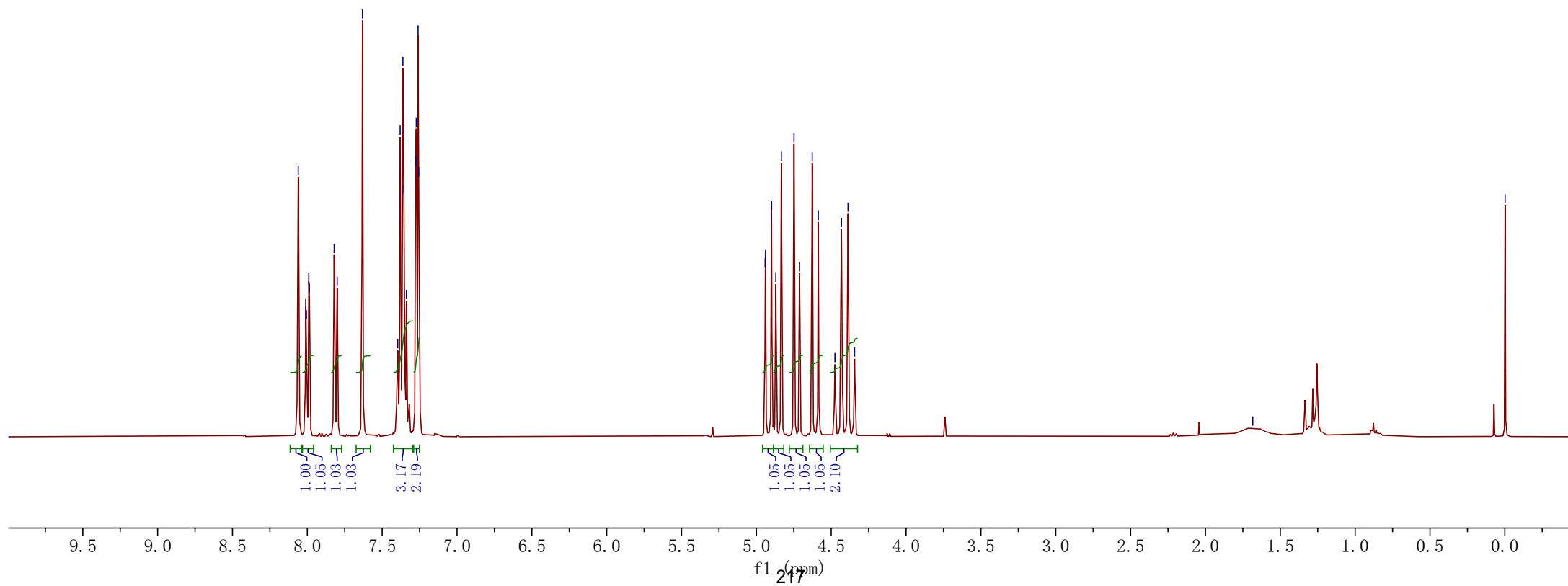
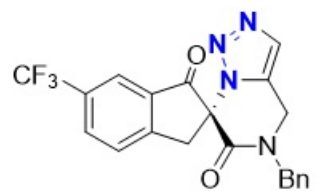
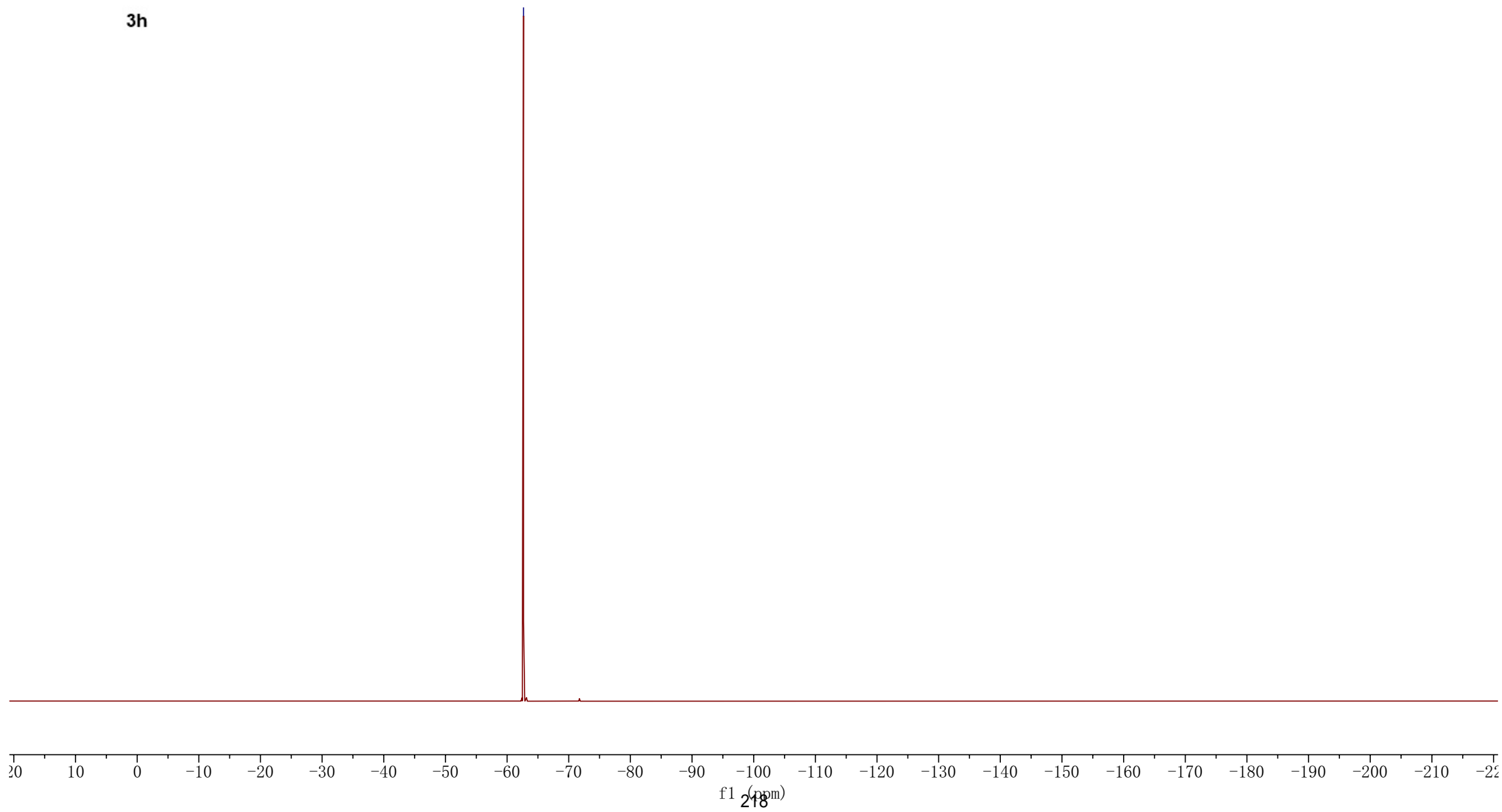
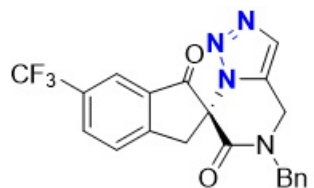


Fig. 2: **3h**,  $^{19}\text{F}$  NMR (376 MHz,  $\text{CDCl}_3$ )



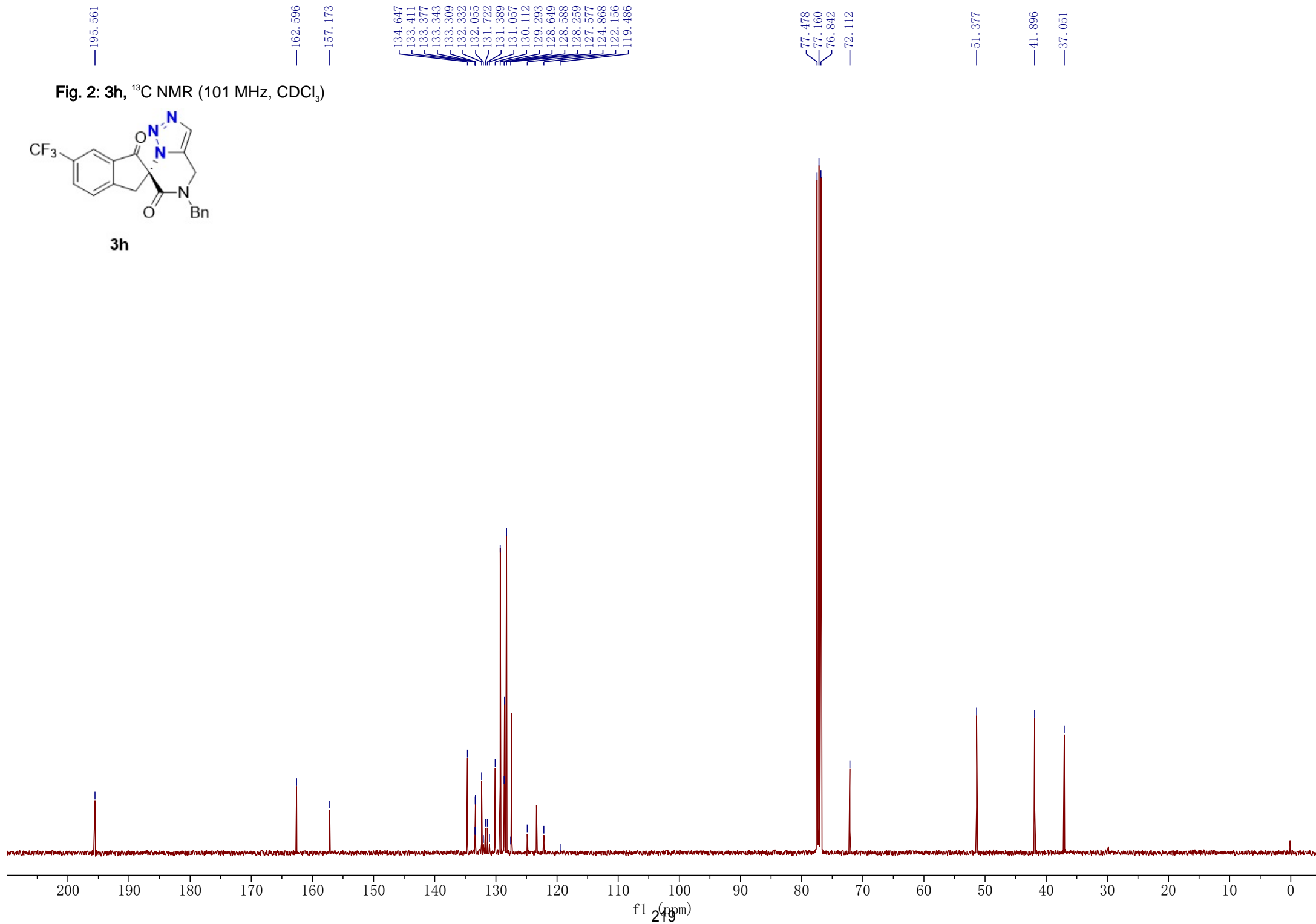
**3h**

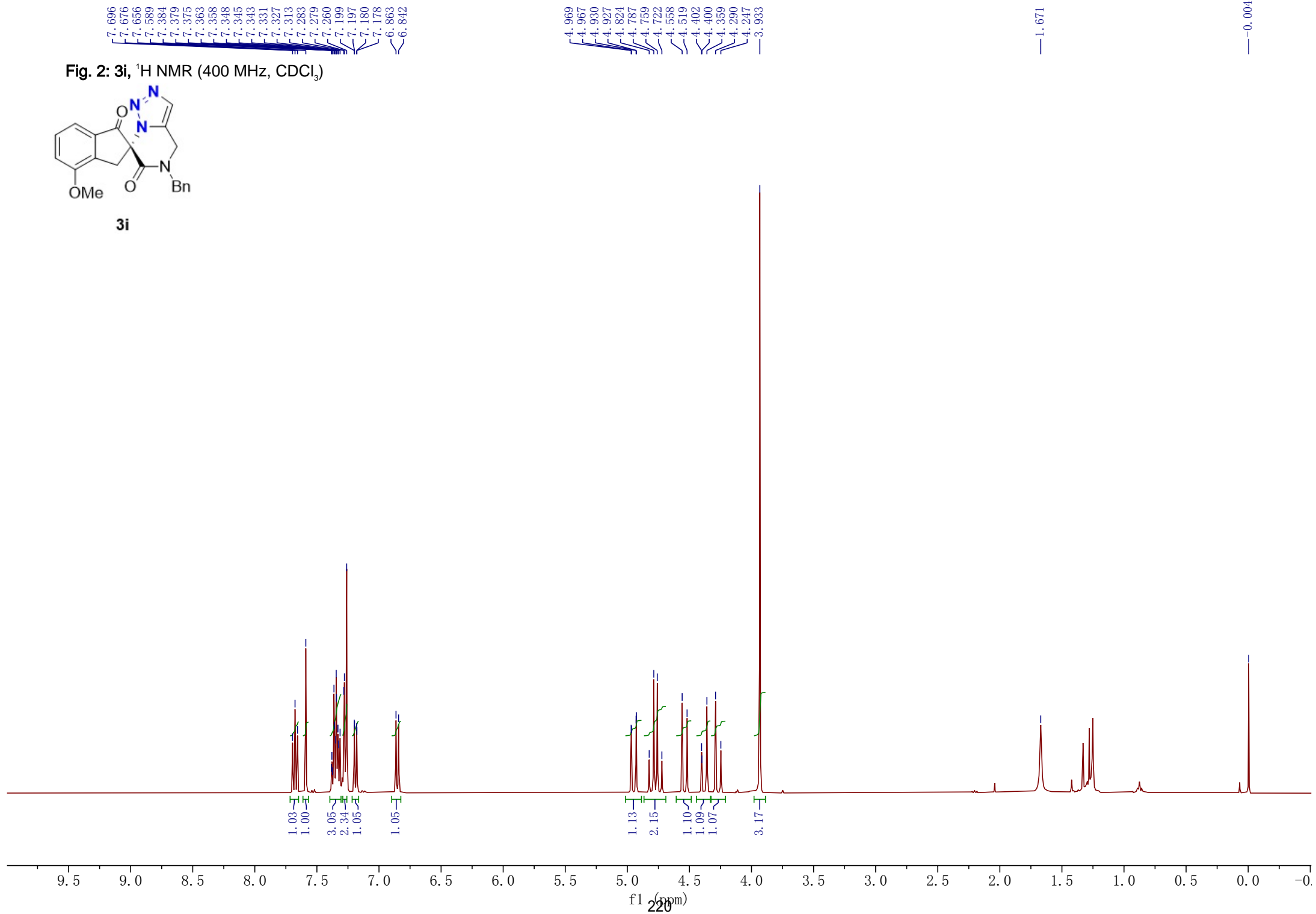
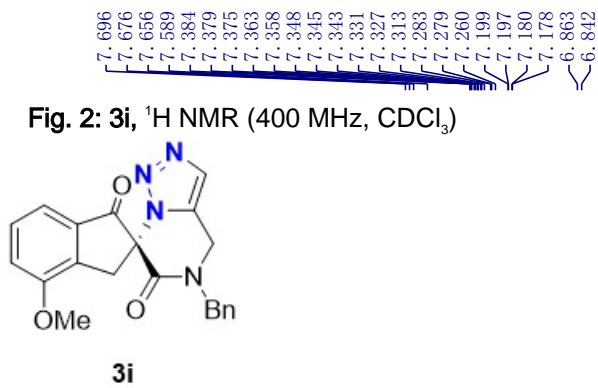




3h

Fig. 2: 3h,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )

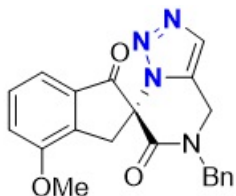




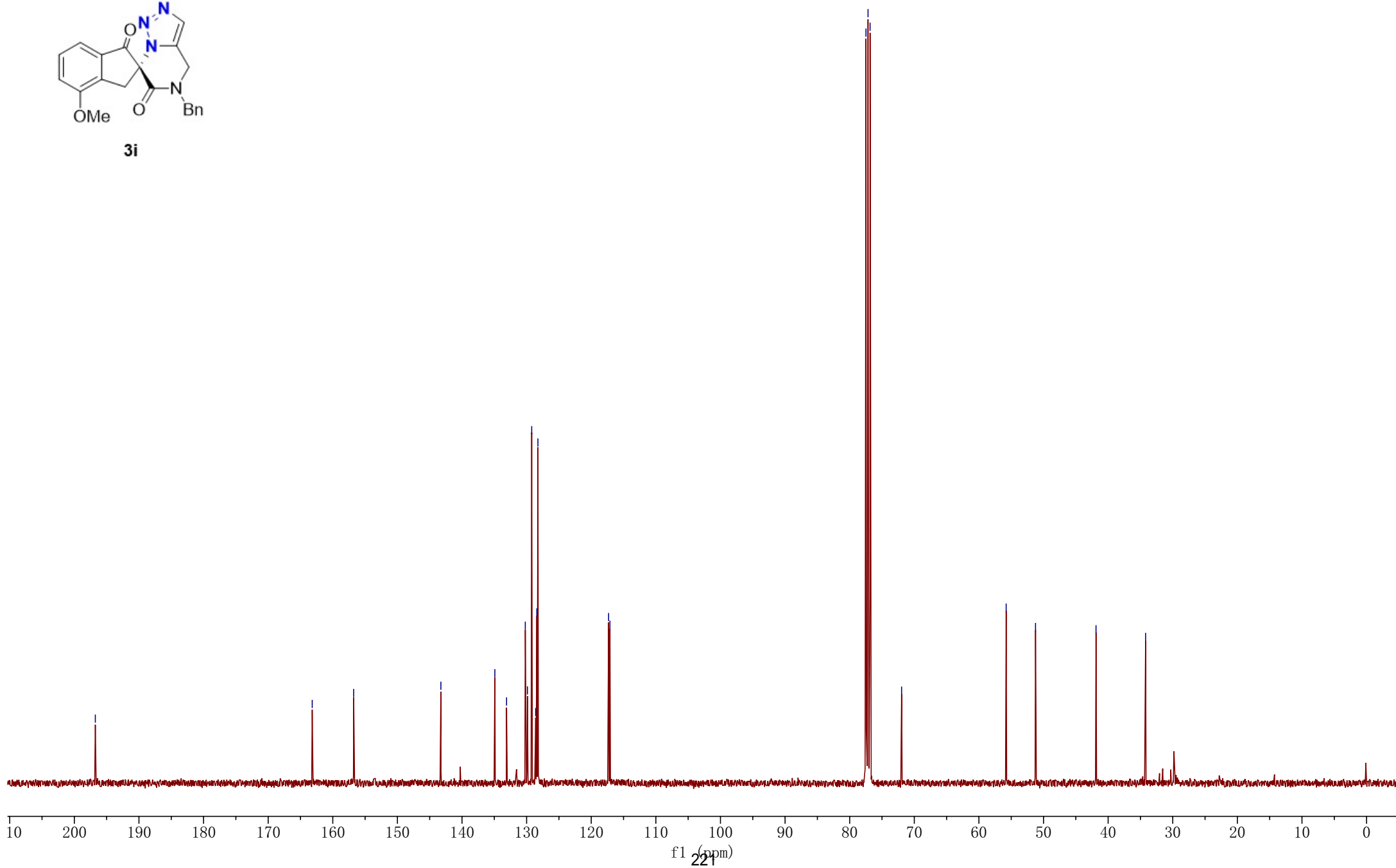


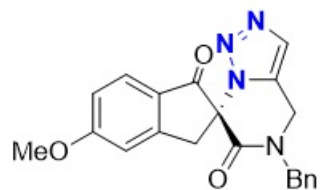
— 196.752  
— 163.181  
— 156.765  
— 143.270  
— 134.917  
— 133.105  
— 130.206  
— 129.872  
— 129.212  
— 128.599  
— 128.422  
— 128.251  
— 117.311  
— 117.105  
— 77.478  
— 77.160  
— 76.842  
— 71.965  
— 55.781  
— 51.238  
— 41.875  
— 34.201

Fig. 2: **3i**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



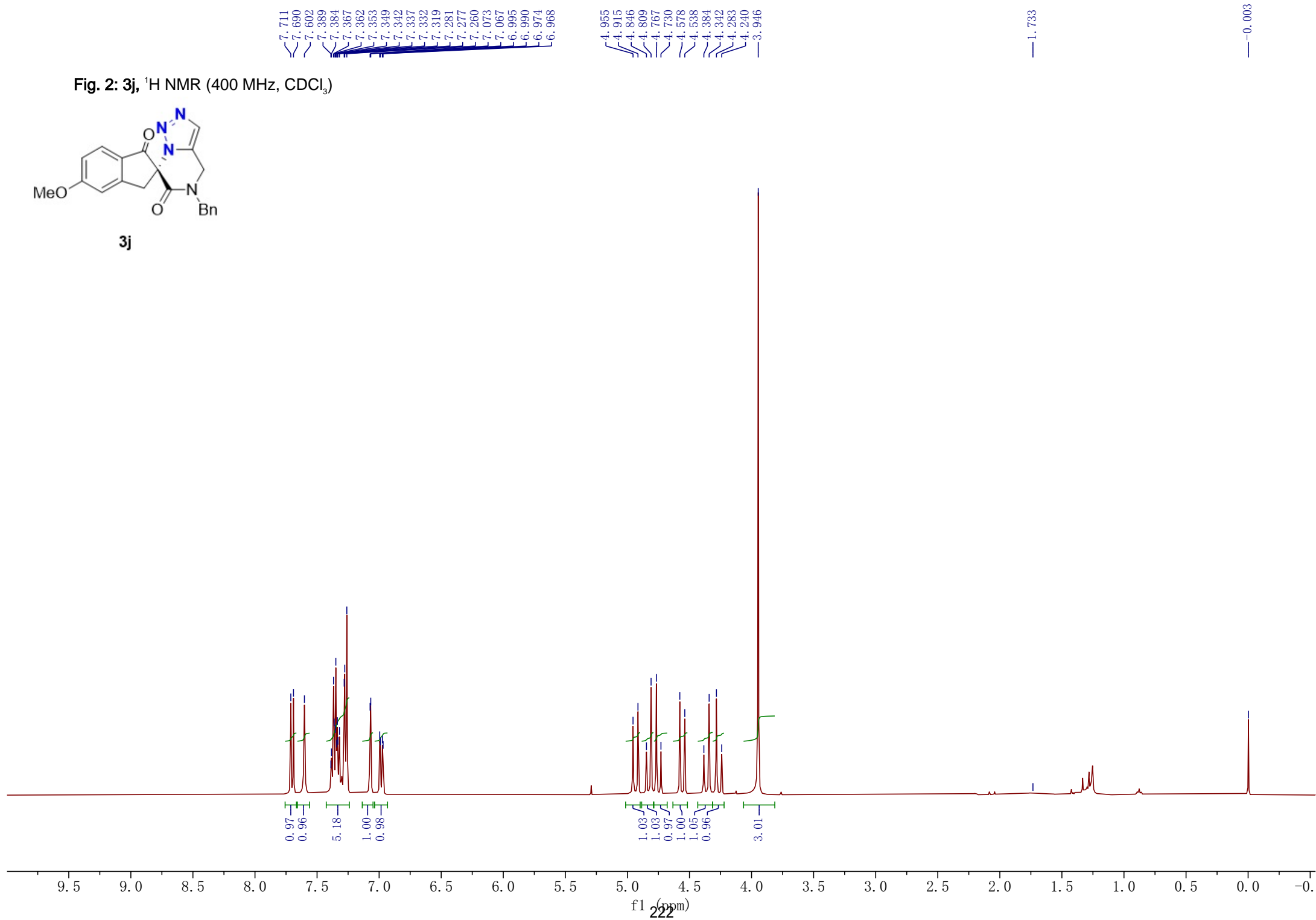
**3i**

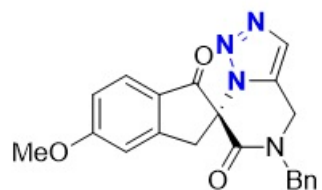




**3j**

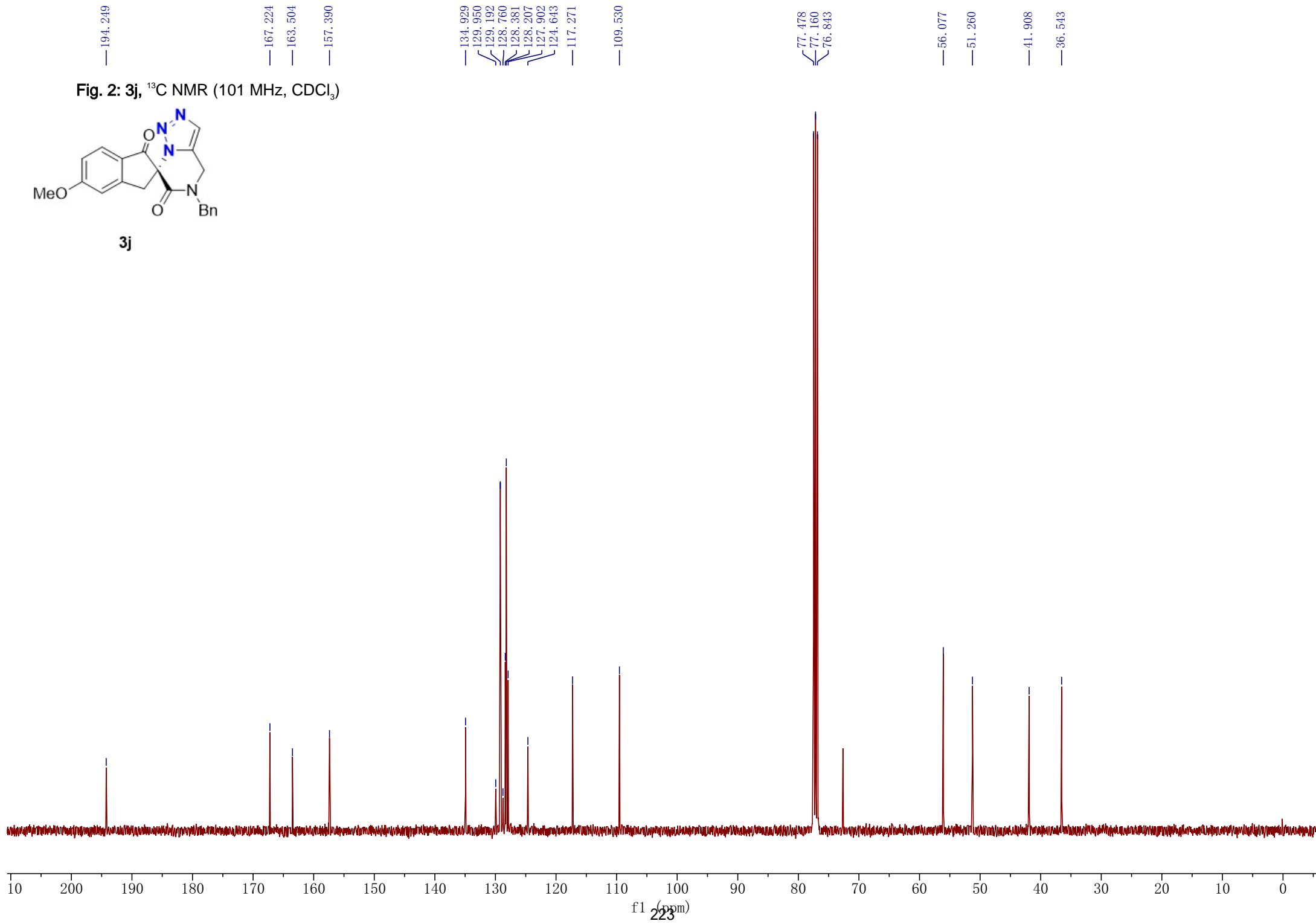
**Fig. 2: 3j, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**

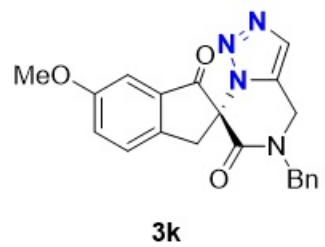




**3j**

**Fig. 2: 3j,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**





**Fig. 2: 3k, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**

7.608  
7.551  
7.529  
7.387  
7.371  
7.356  
7.353  
7.349  
7.342  
7.327  
7.283  
7.278  
7.260  
7.182  
7.175

4.935  
4.932  
4.895  
4.892  
4.867  
4.830  
4.748  
4.711  
4.600  
4.559  
4.320  
4.278  
4.234  
4.193

— 1.664

— -0.002

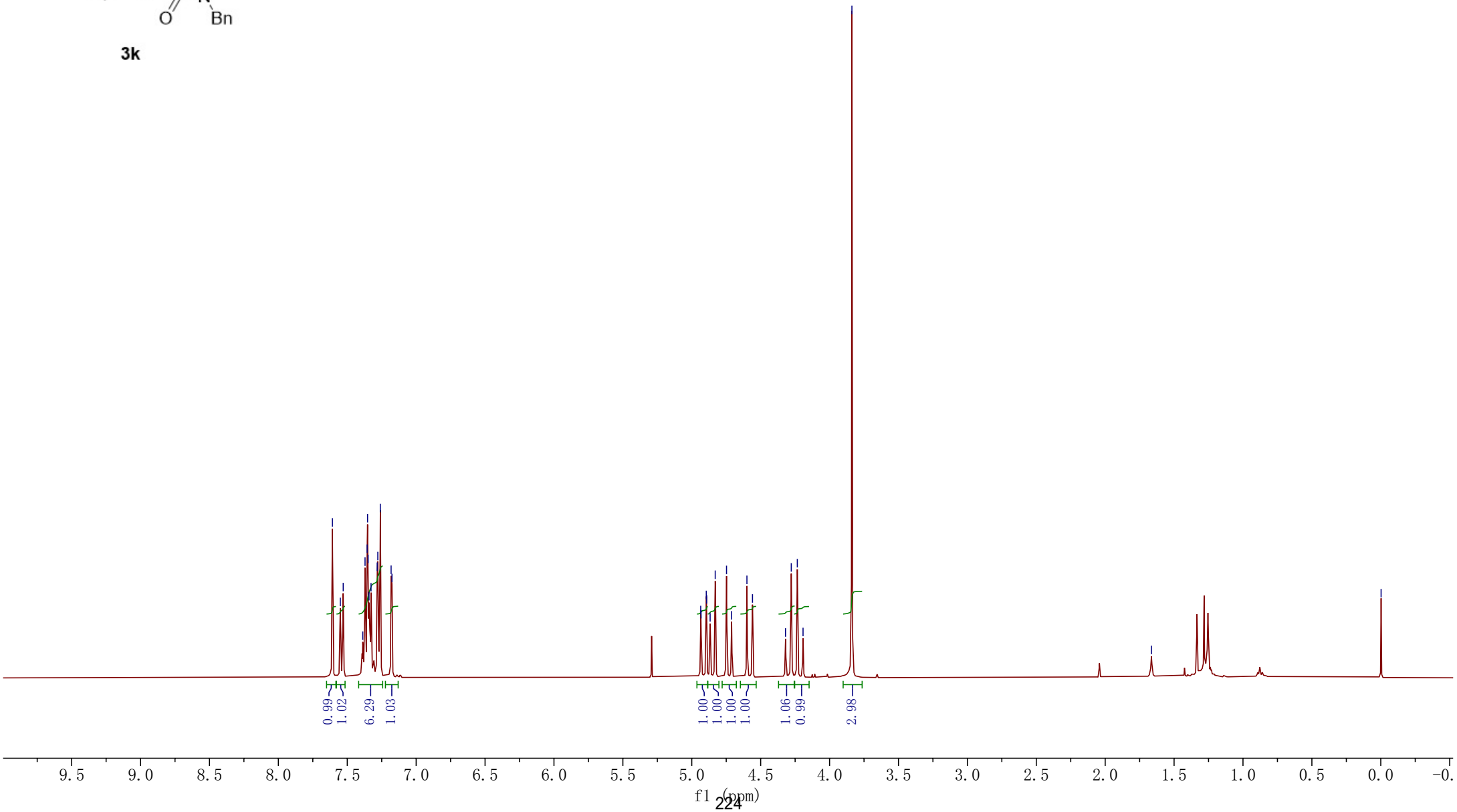
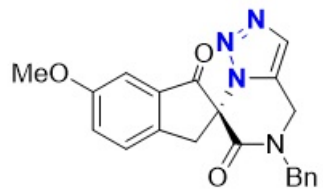


Fig. 2: **3k**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



**3k**

196.465  
163.198  
160.258  
147.421  
134.894  
132.933  
129.918  
129.227  
128.626  
128.450  
128.249  
127.299  
126.734

106.779

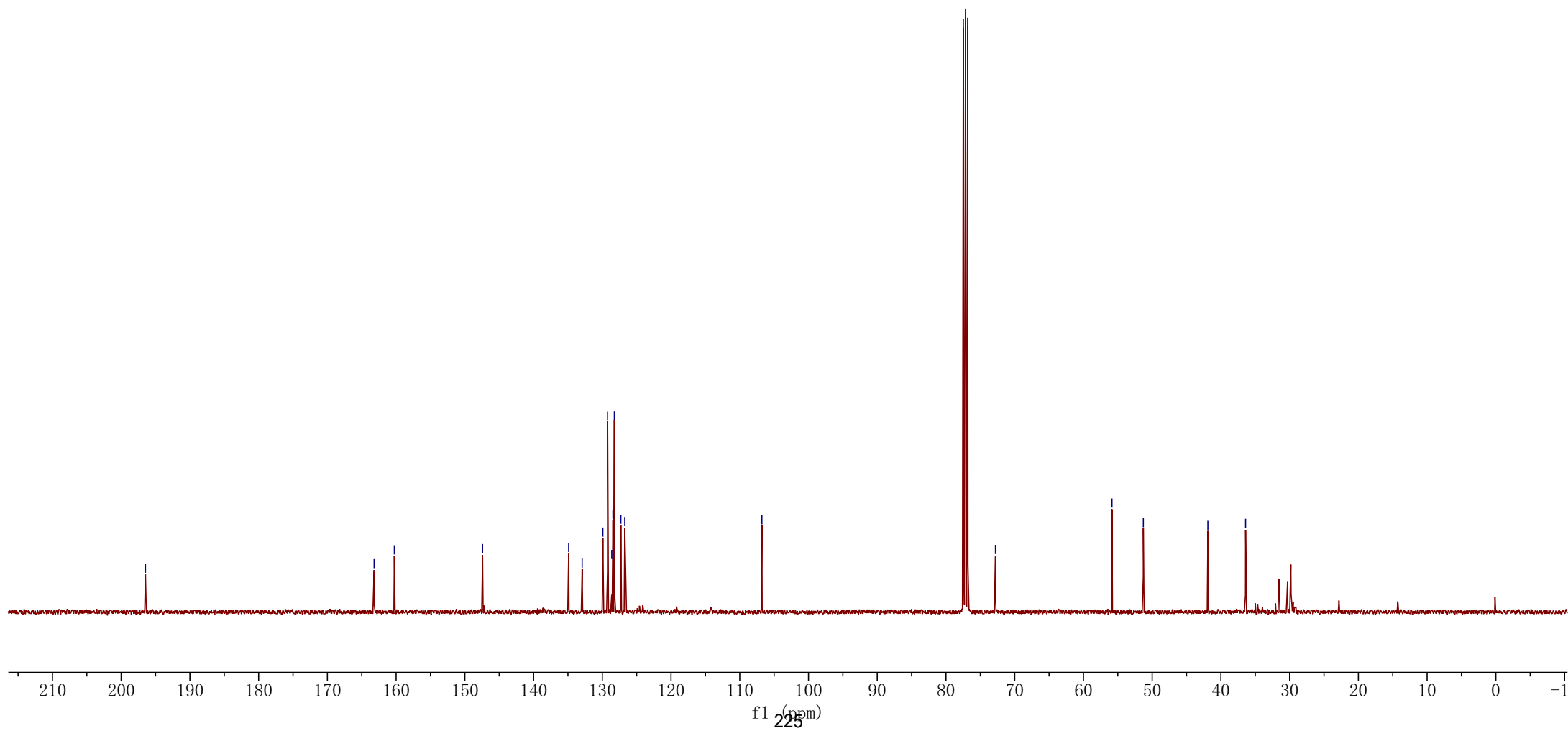
77.477  
77.160  
76.842  
72.798

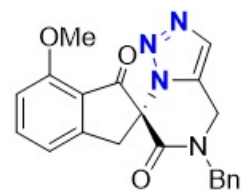
55.847

51.283

41.895

36.409





**3I**

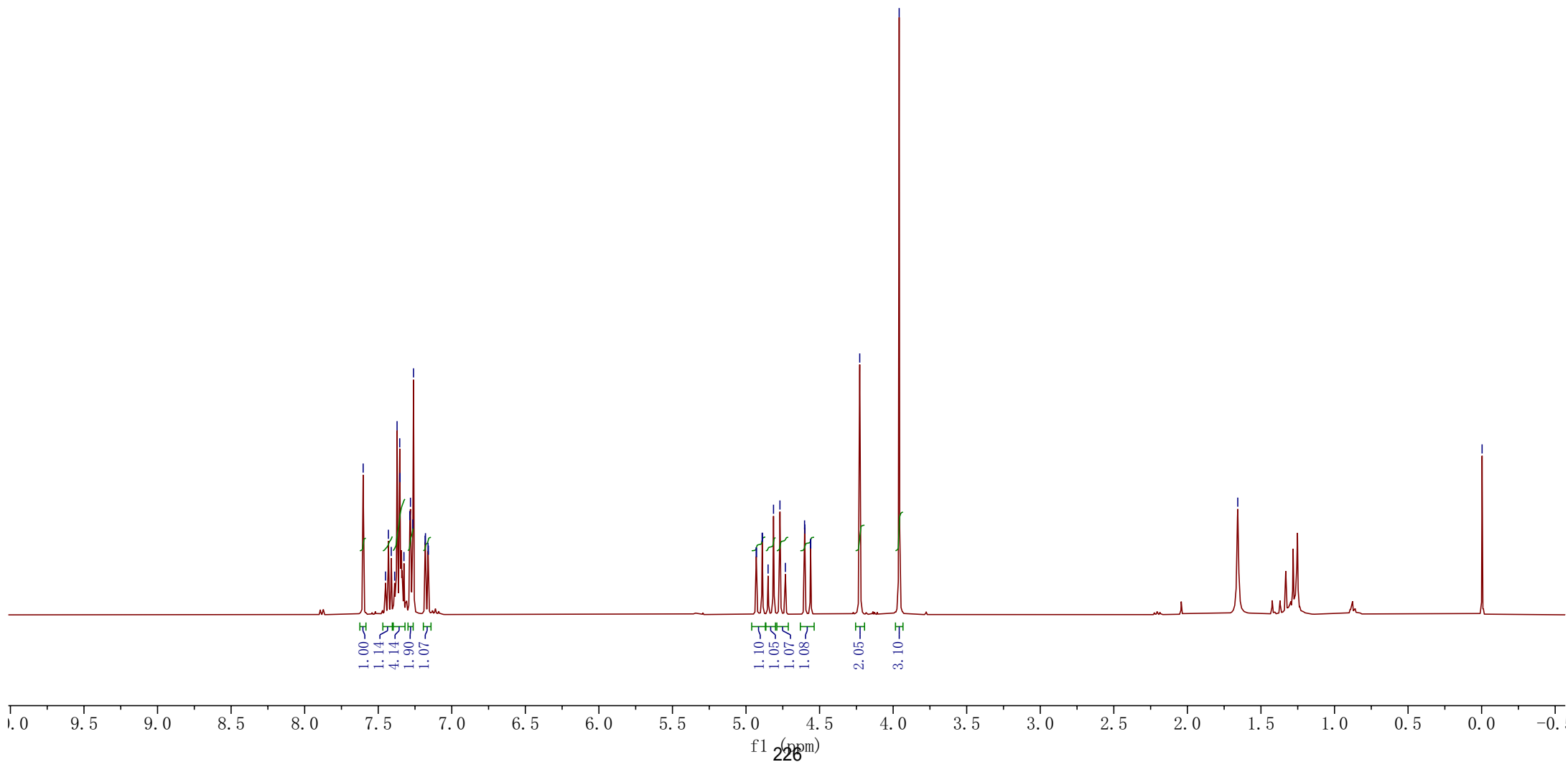
**Fig. 2: 3I, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**

7.602  
7.450  
7.431  
7.411  
7.388  
7.372  
7.354  
7.352  
7.325  
7.286  
7.281  
7.265  
7.260  
7.181  
7.179  
7.162  
7.159

4.931  
4.928  
4.891  
4.888  
4.850  
4.813  
4.769  
4.733  
4.602  
4.600  
4.562  
4.560  
4.227  
3.959

1.658

-0.003



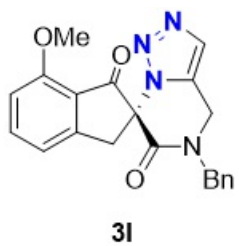
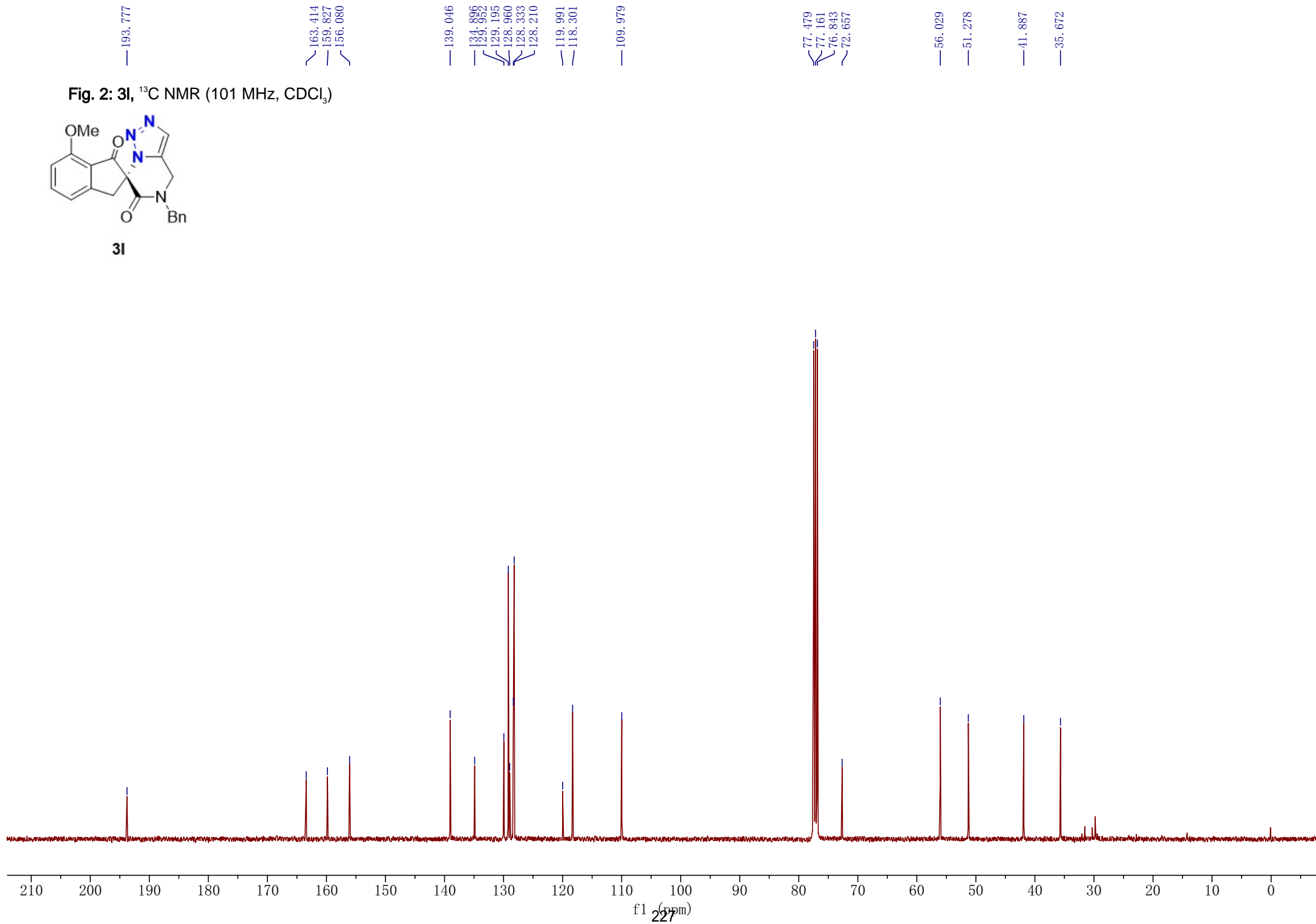
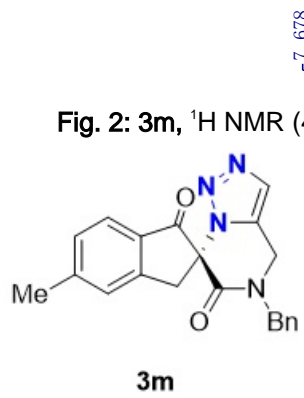


Fig. 2: **3I**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )





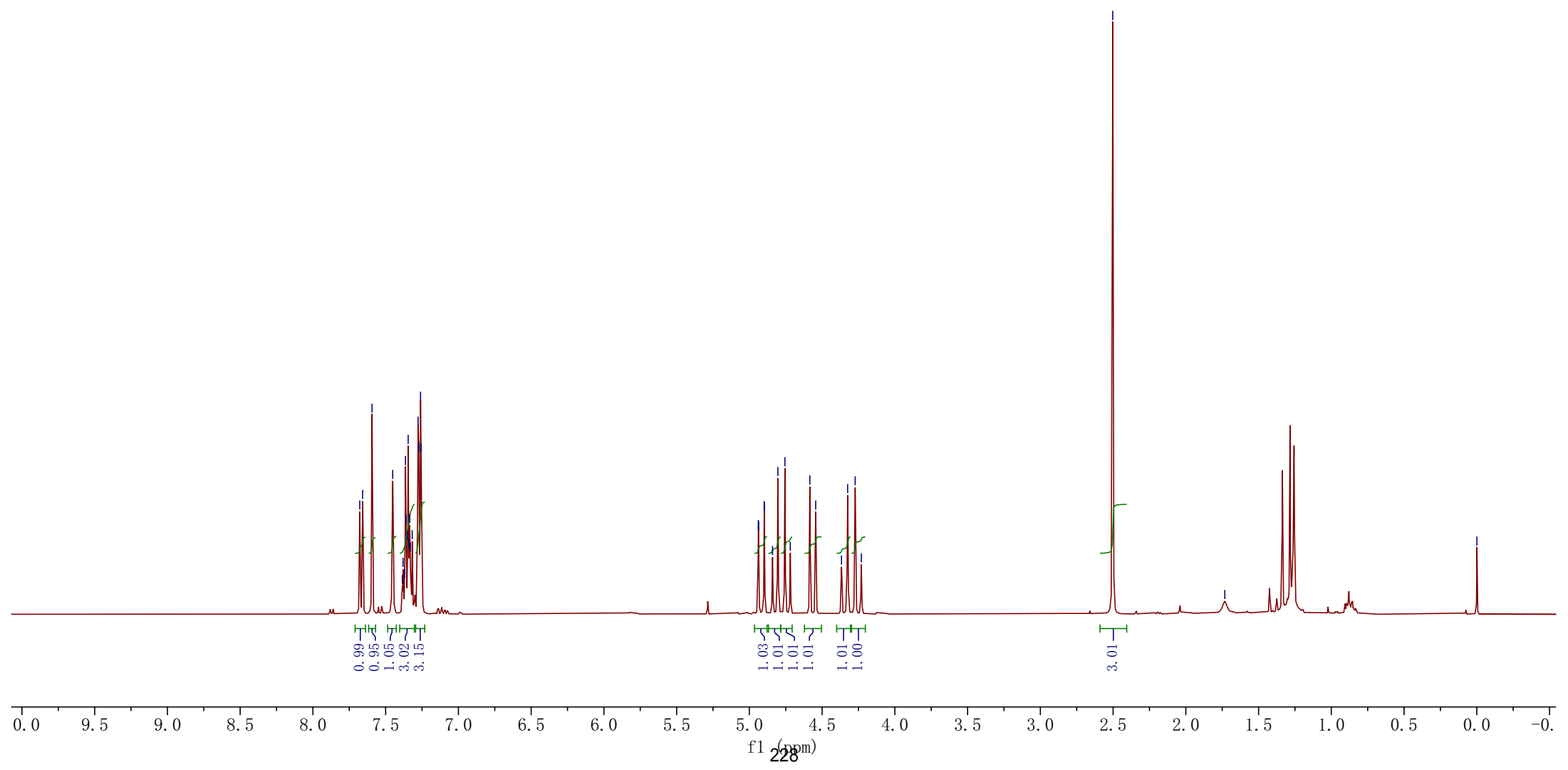
7.678  
7.658  
7.593  
7.452  
7.385  
7.380  
7.369  
7.364  
7.359  
7.349  
7.345  
7.339  
7.334  
7.330  
7.317  
7.277  
7.272  
7.260  
7.256

4.939  
4.936  
4.898  
4.896  
4.841  
4.804  
4.756  
4.719  
4.584  
4.544  
4.367  
4.324  
4.273  
4.230

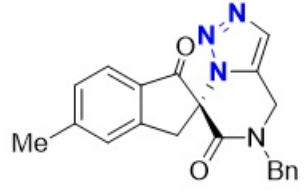
2.502

1.732

-0.000

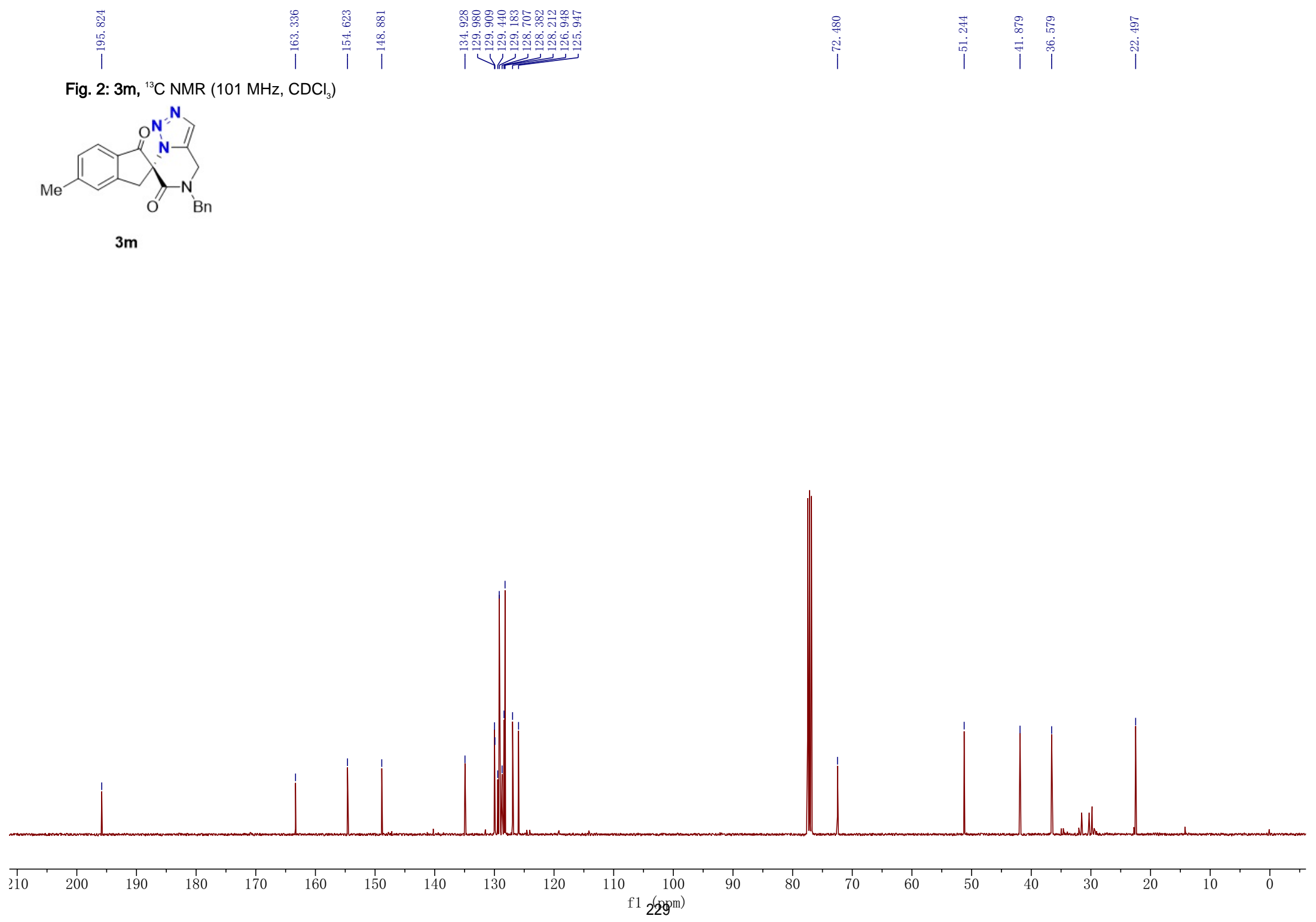






**3m**

**Fig. 2: 3m, <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)**



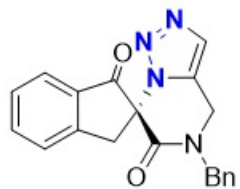
7.799  
7.780  
7.773  
7.755  
7.737  
7.734  
7.615  
7.490  
7.470  
7.450  
7.391  
7.375  
7.357  
7.356  
7.346  
7.342  
7.329  
7.284  
7.279  
7.264  
7.260

4.951  
4.948  
4.911  
4.908  
4.852  
4.815  
4.768  
4.731  
4.604  
4.564  
4.427  
4.384  
4.337  
4.294

— 1.645

— -0.002

Fig. 2: **3n**,  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )



**3n**

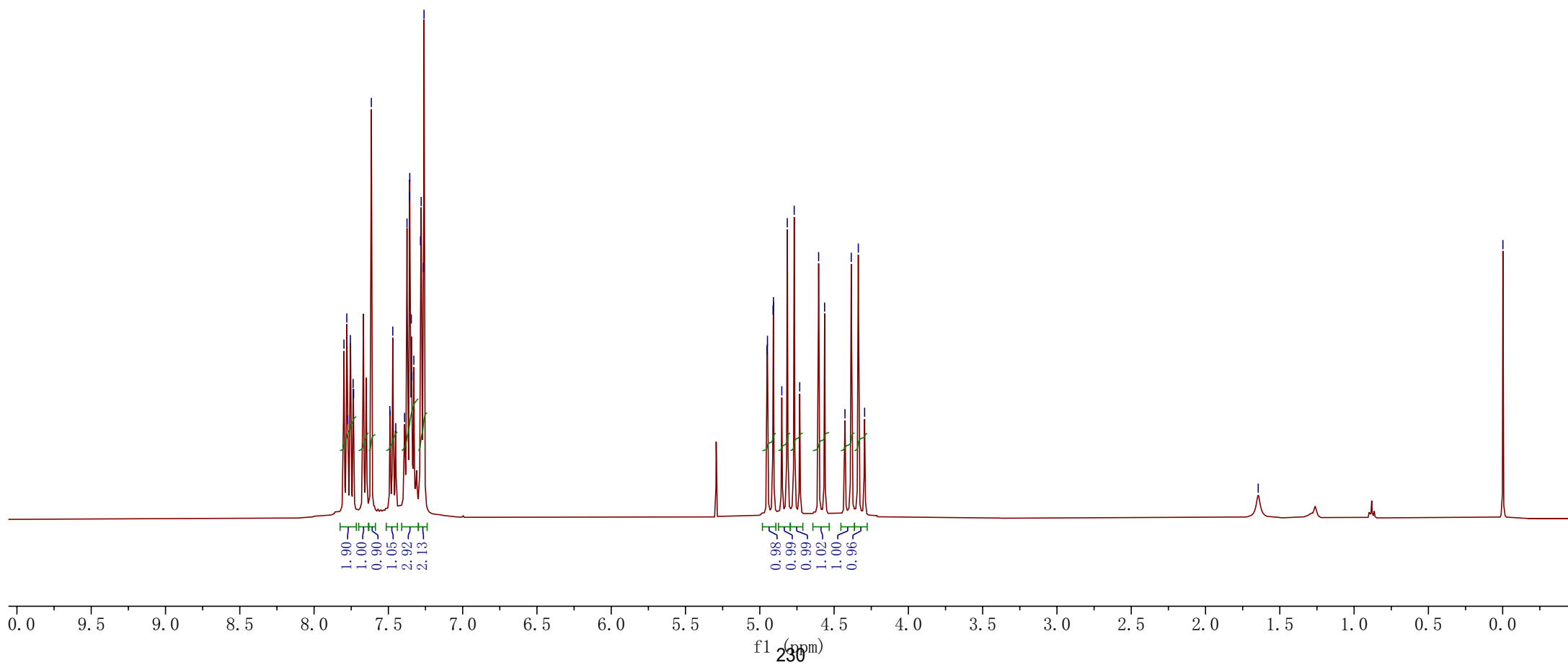
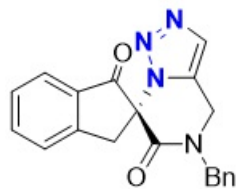


Fig. 2: **3n**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



**3n**

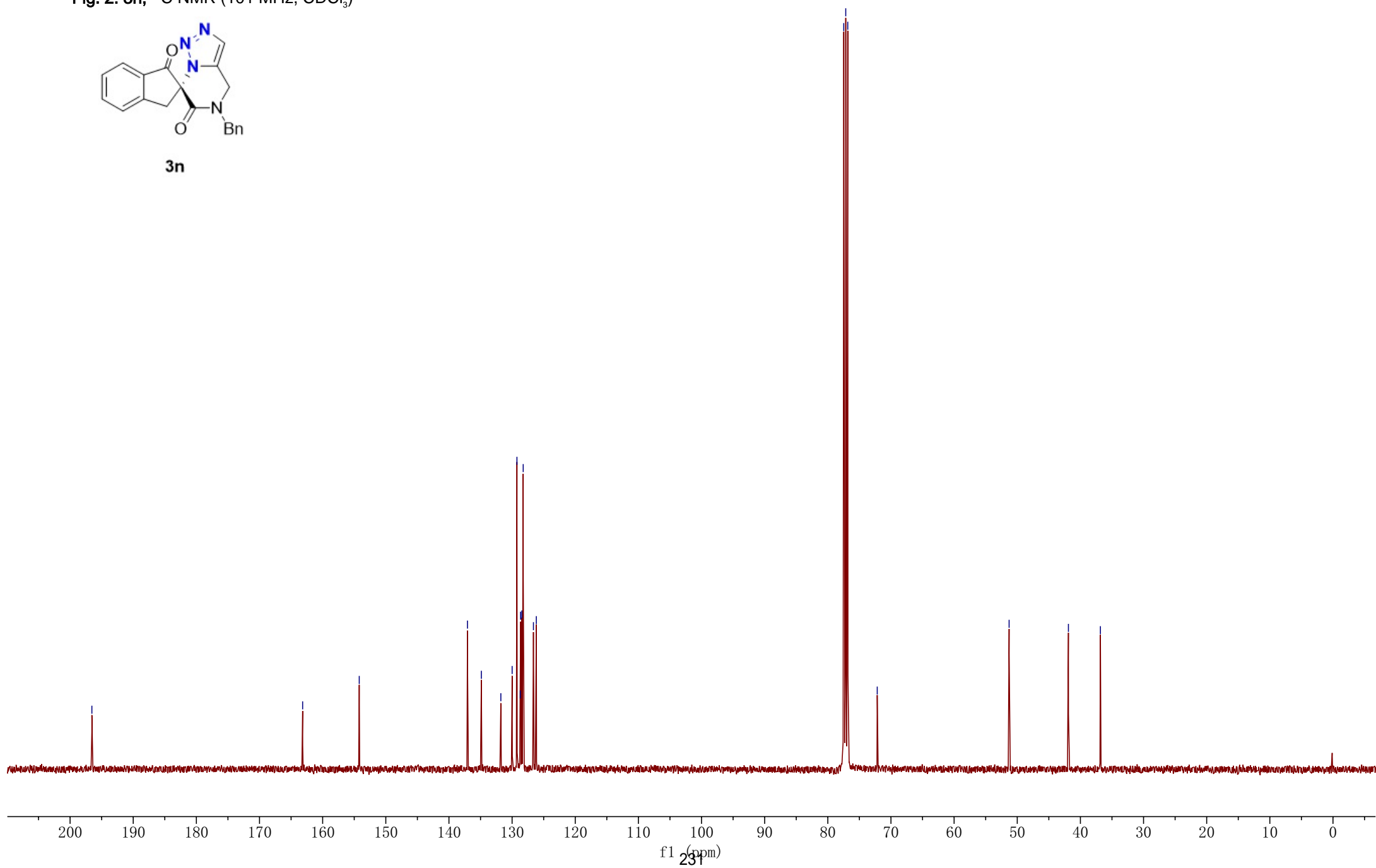


Fig. 2: **3o**, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)

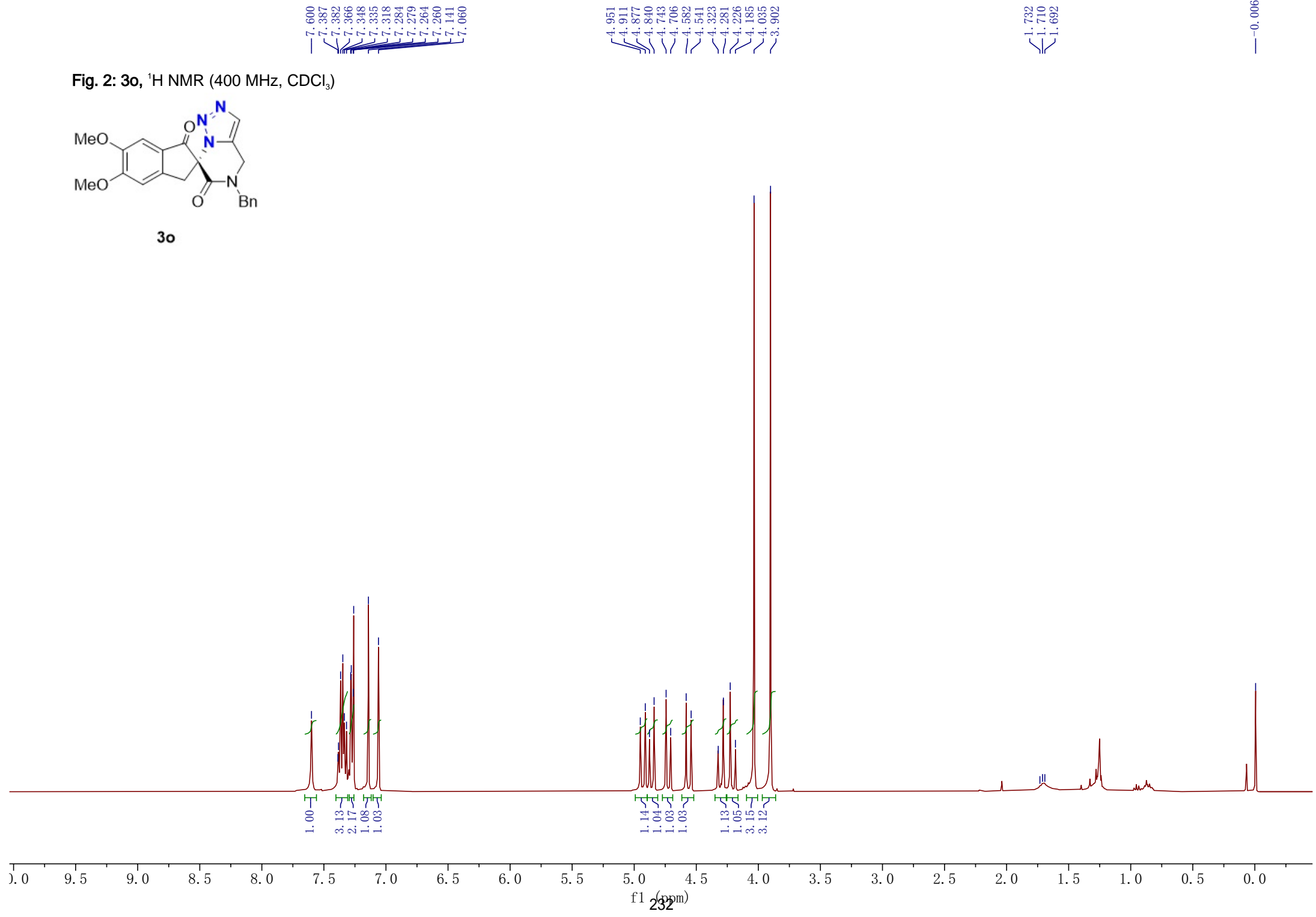
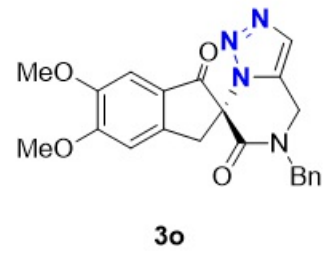
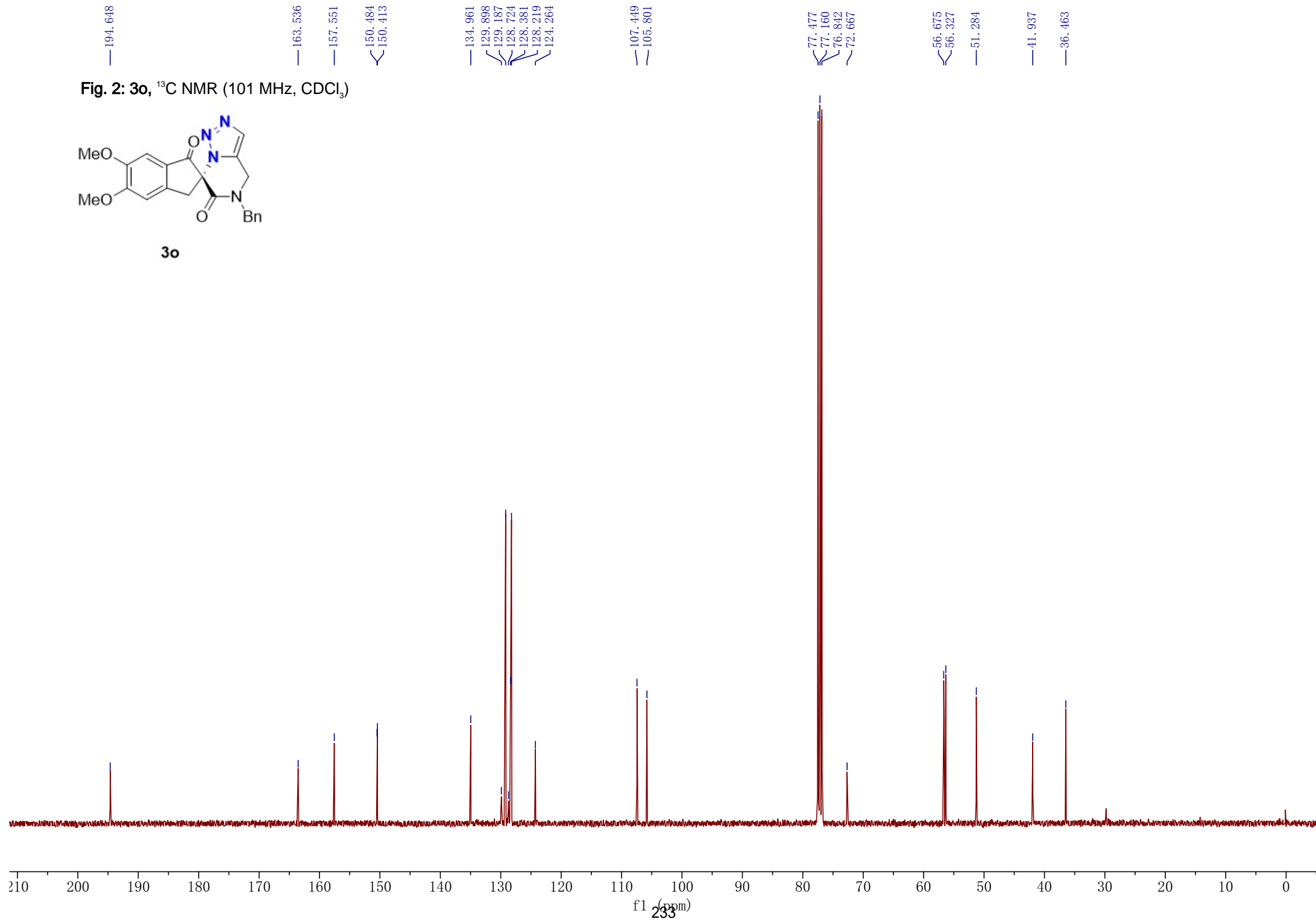
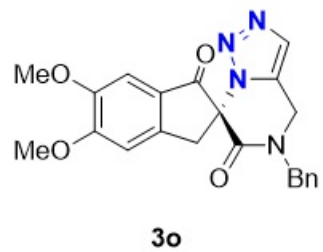
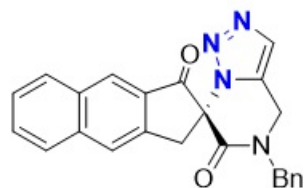


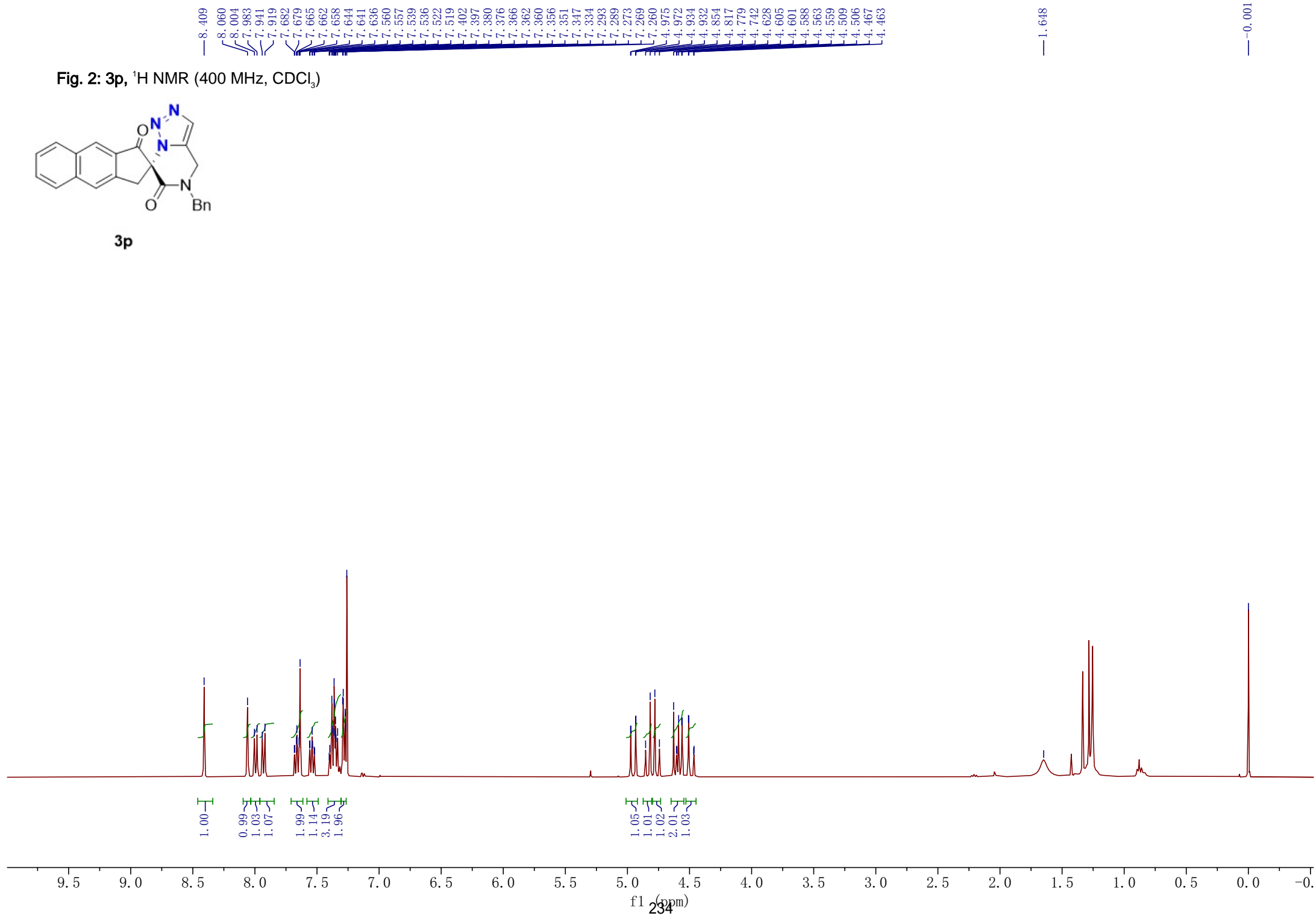
Fig. 2: **3o**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )

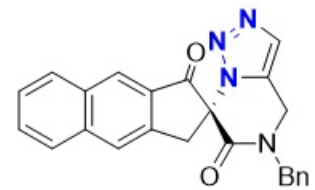




**3p**

**Fig. 2: 3p, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**





**3p**

**Fig. 2: 3p,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**

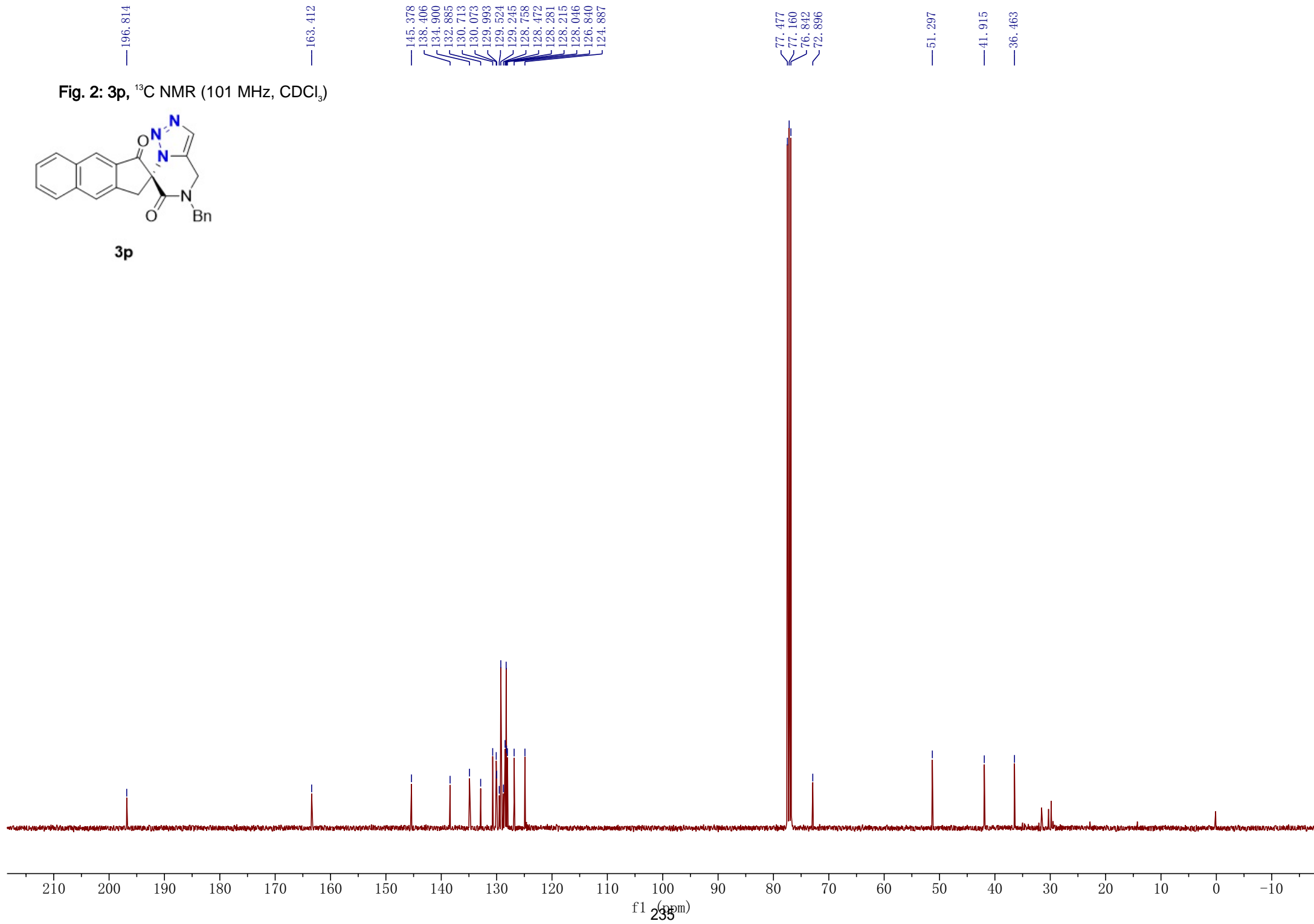
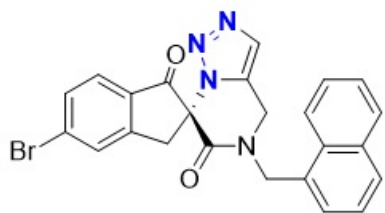


Fig. 2: 3q, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



3q

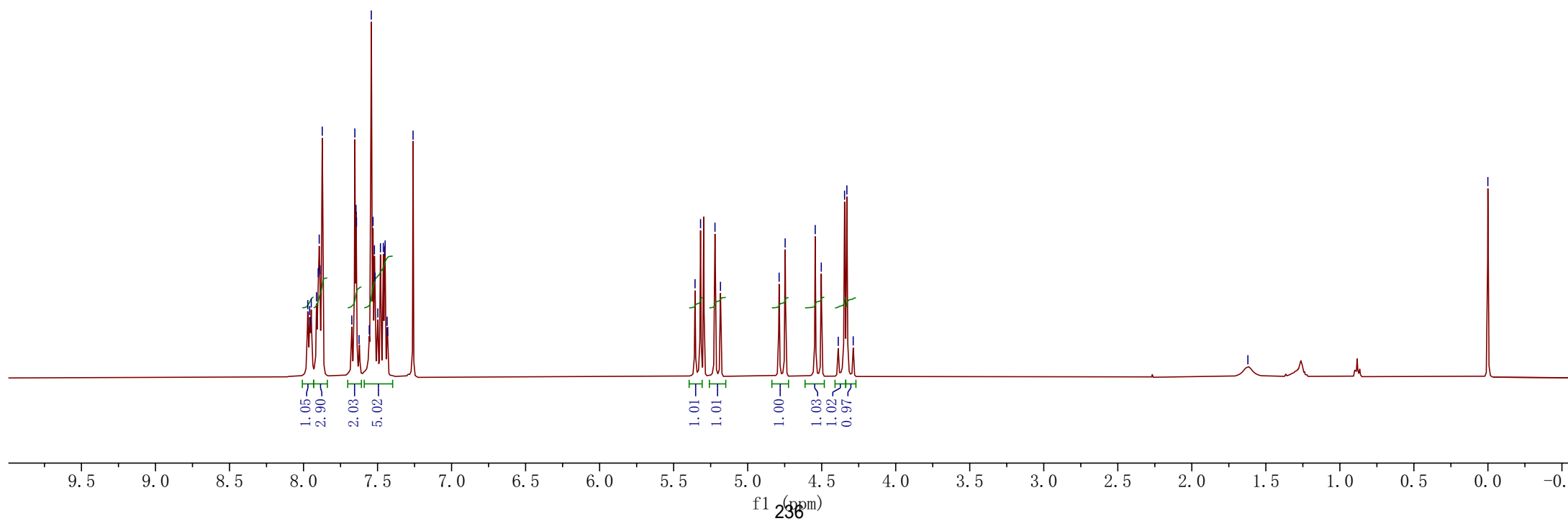
7.971  
7.958  
7.954  
7.948  
7.913  
7.901  
7.894  
7.889  
7.874  
7.674  
7.653  
7.646  
7.642  
7.625  
7.556  
7.542  
7.531  
7.521  
7.517  
7.498  
7.480  
7.461  
7.453  
7.449  
7.435  
7.431  
7.260

5.356  
5.318  
5.221  
5.184

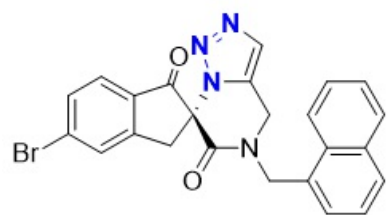
4.788  
4.747  
4.544  
4.503  
4.388  
4.345  
4.330  
4.287

1.621

0.000







**3q**

**Fig. 2: 3q,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**

195.229

162.581

155.424

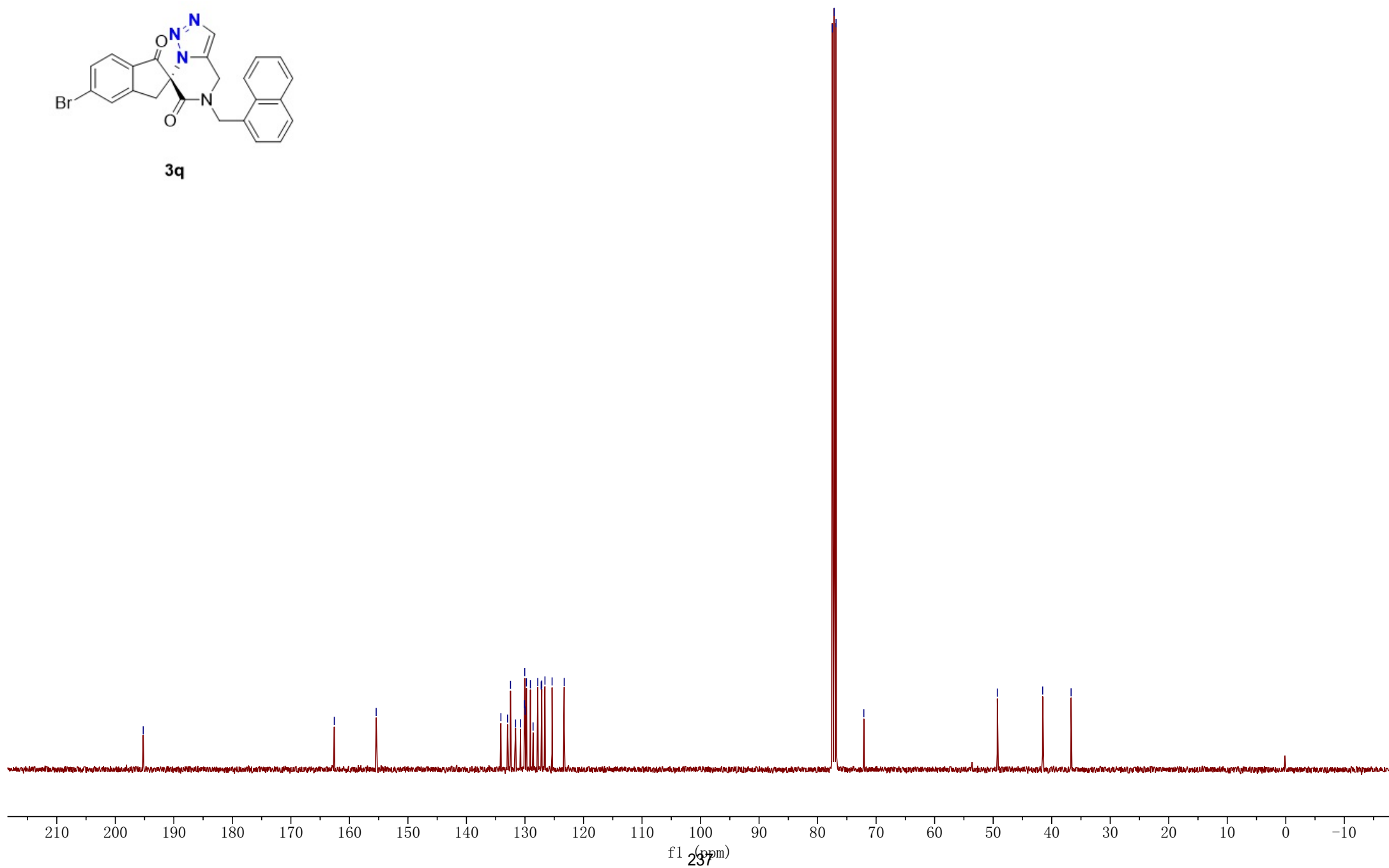
134.112  
132.978  
132.469  
131.604  
130.766  
130.075  
130.043  
129.986  
129.743  
129.075  
128.615  
127.815  
127.233  
127.130  
126.584  
125.367  
123.294

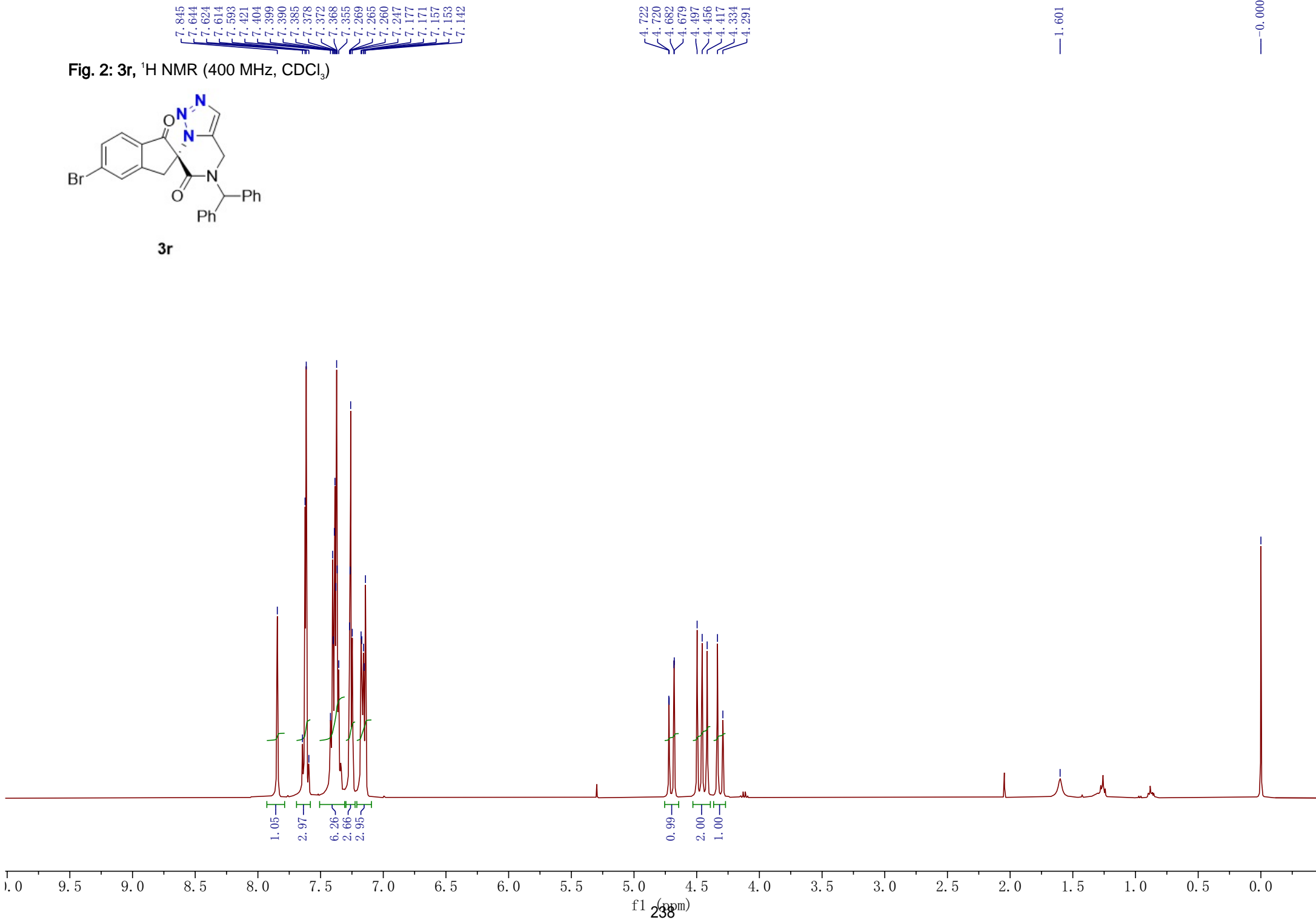
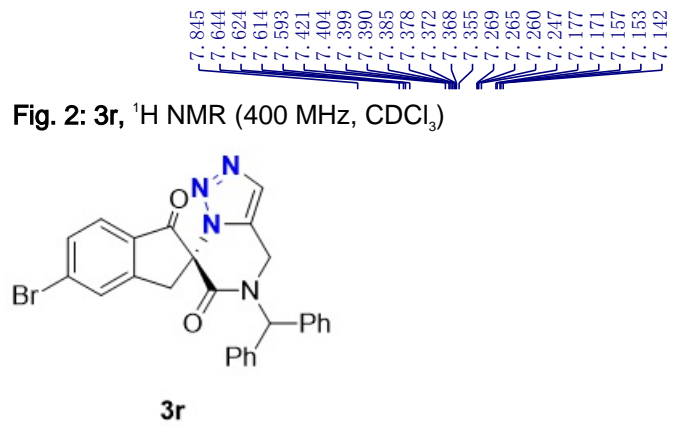
77.480  
77.162  
76.844  
72.097

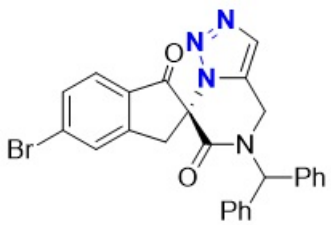
49.290

41.538

36.685

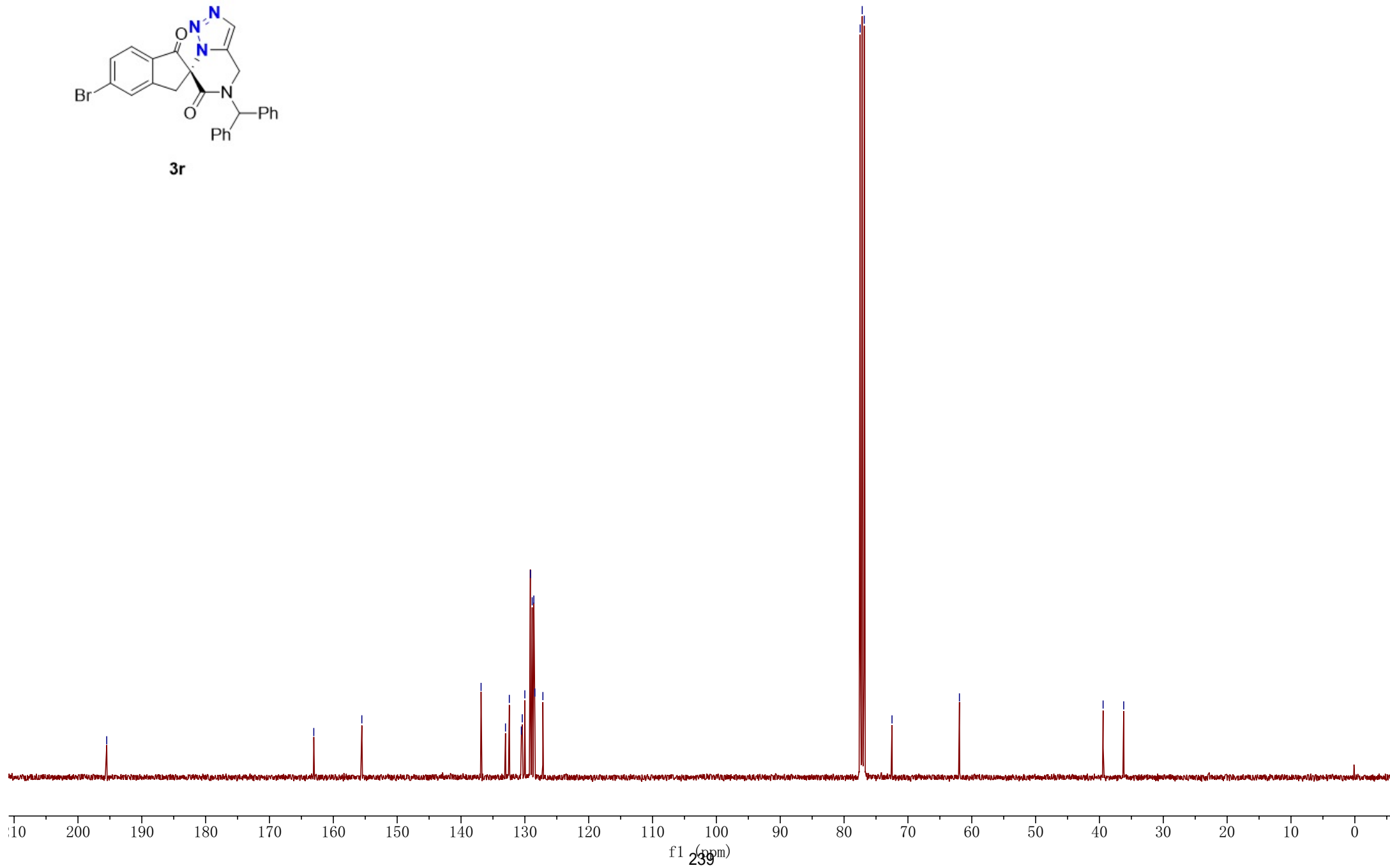


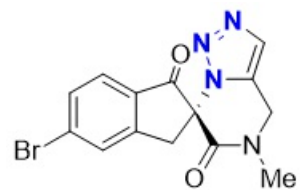




**3r**

**Fig. 2: 3r**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )





**3s**

**Fig. 2: 3s, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**

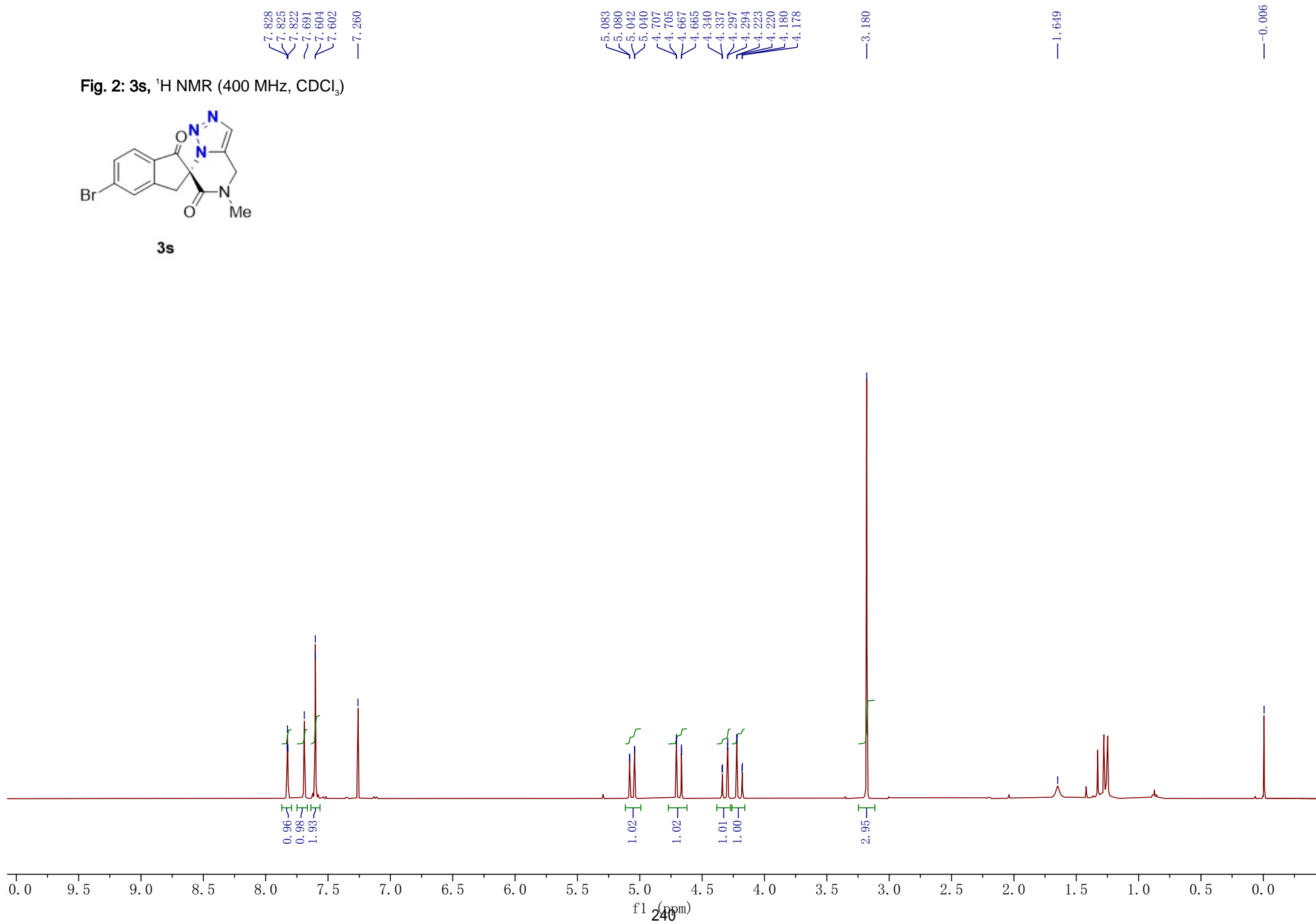
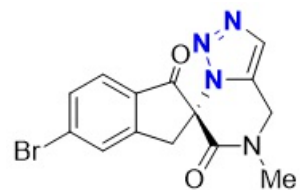


Fig. 2: **3s**, <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)



**3s**

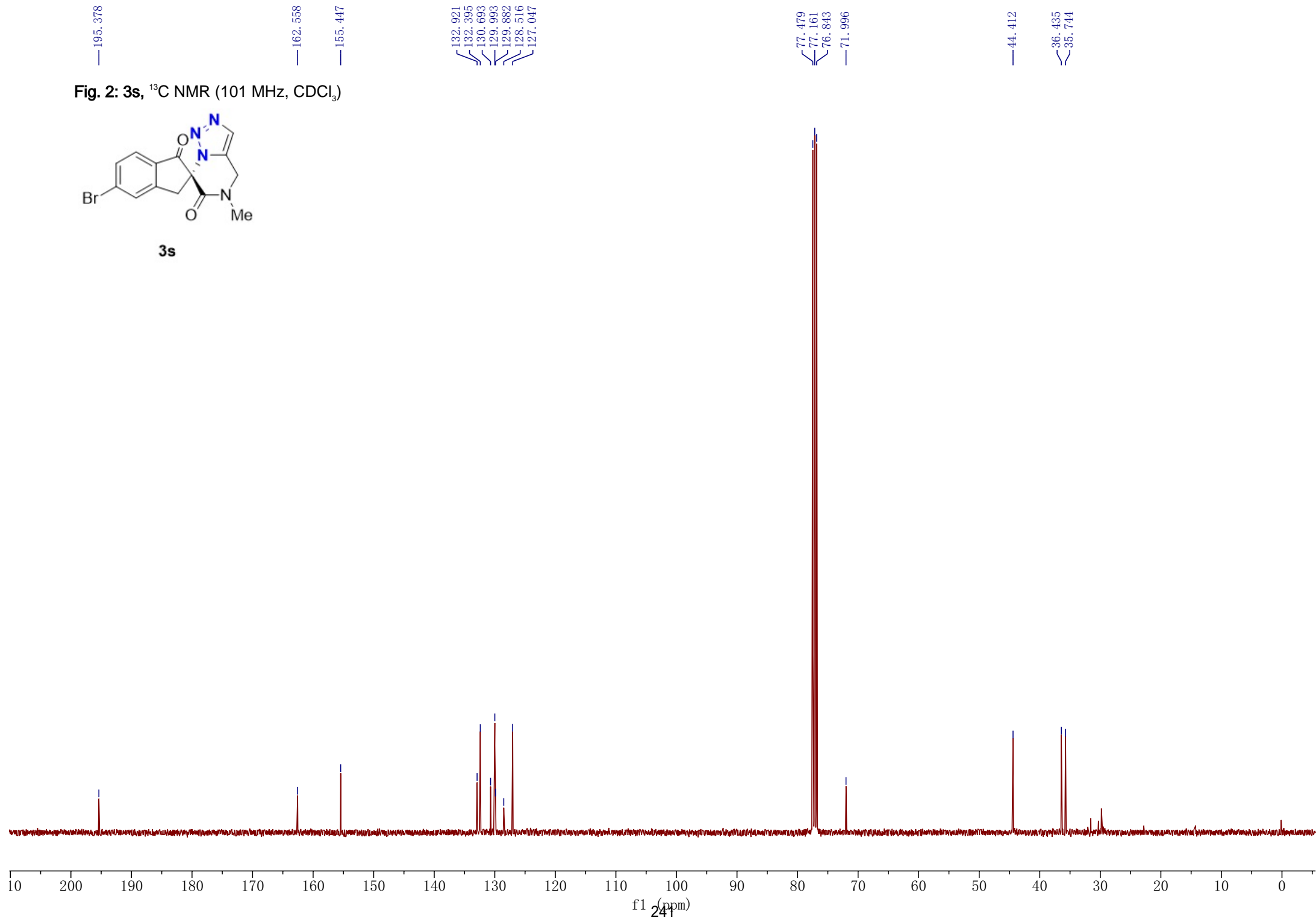
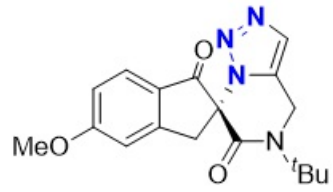


Fig. 2: 3t, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



3t

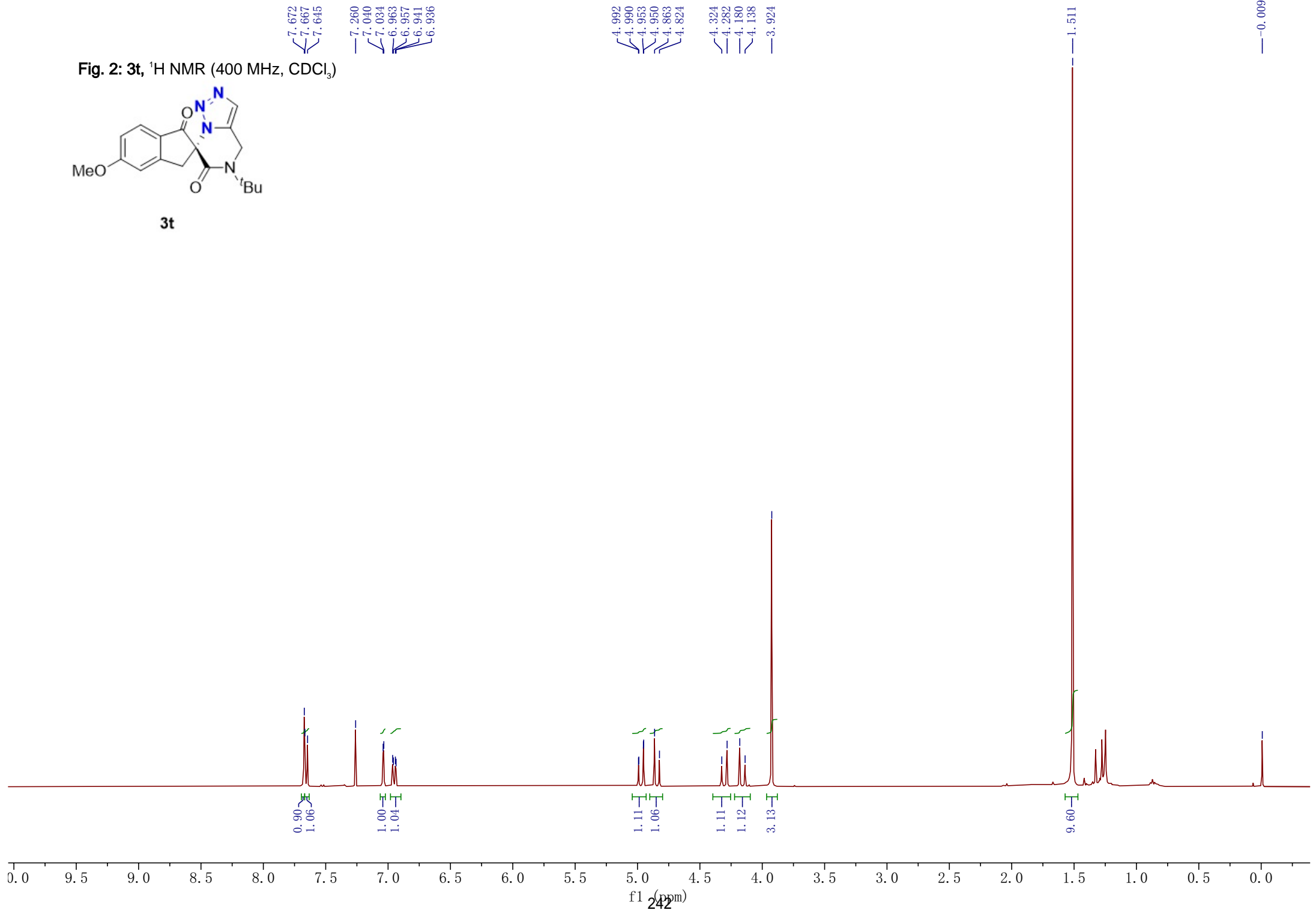
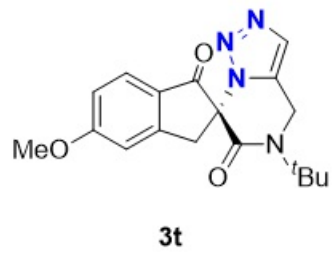


Fig. 2: **3t**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



194.888  
167.120  
163.808  
157.558  
130.118  
129.728  
127.732  
124.781  
117.119  
109.424

77.478  
77.160  
76.843  
73.280

59.885  
56.028

39.119  
36.345

27.931

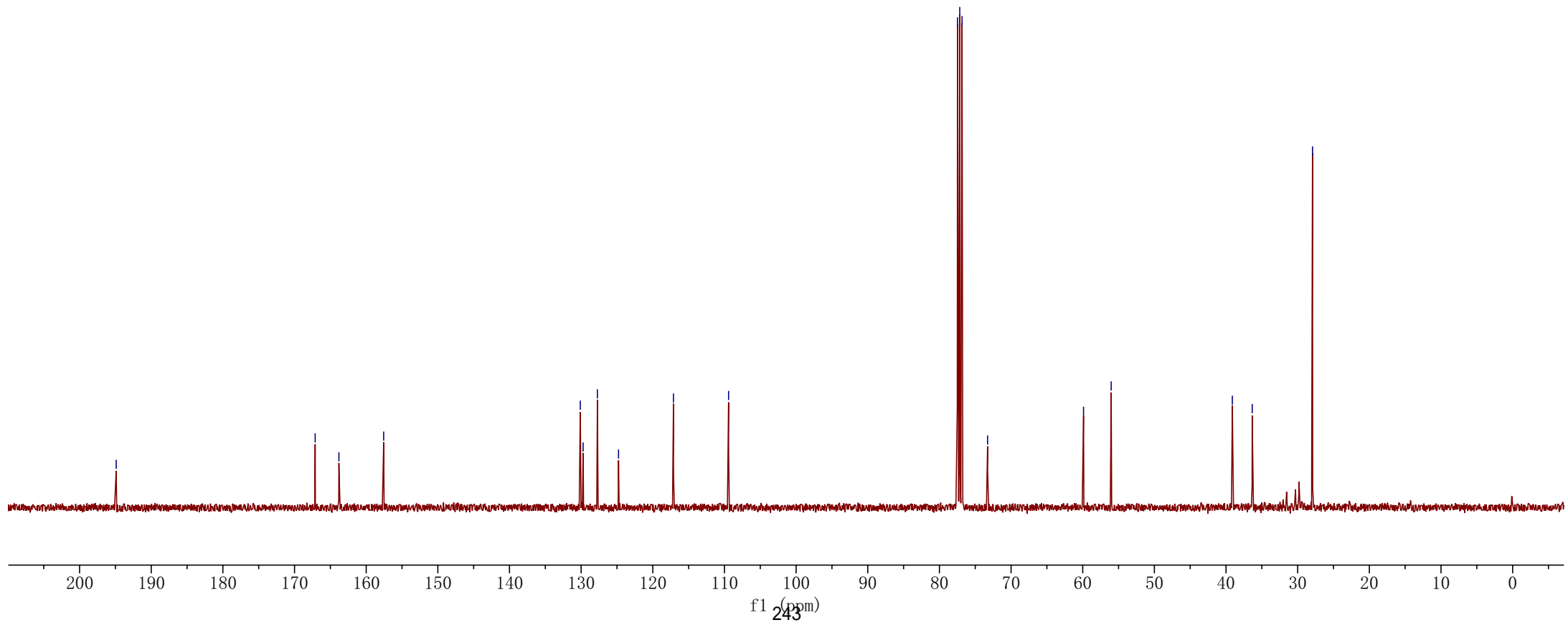


Fig. 2: **3u**, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)

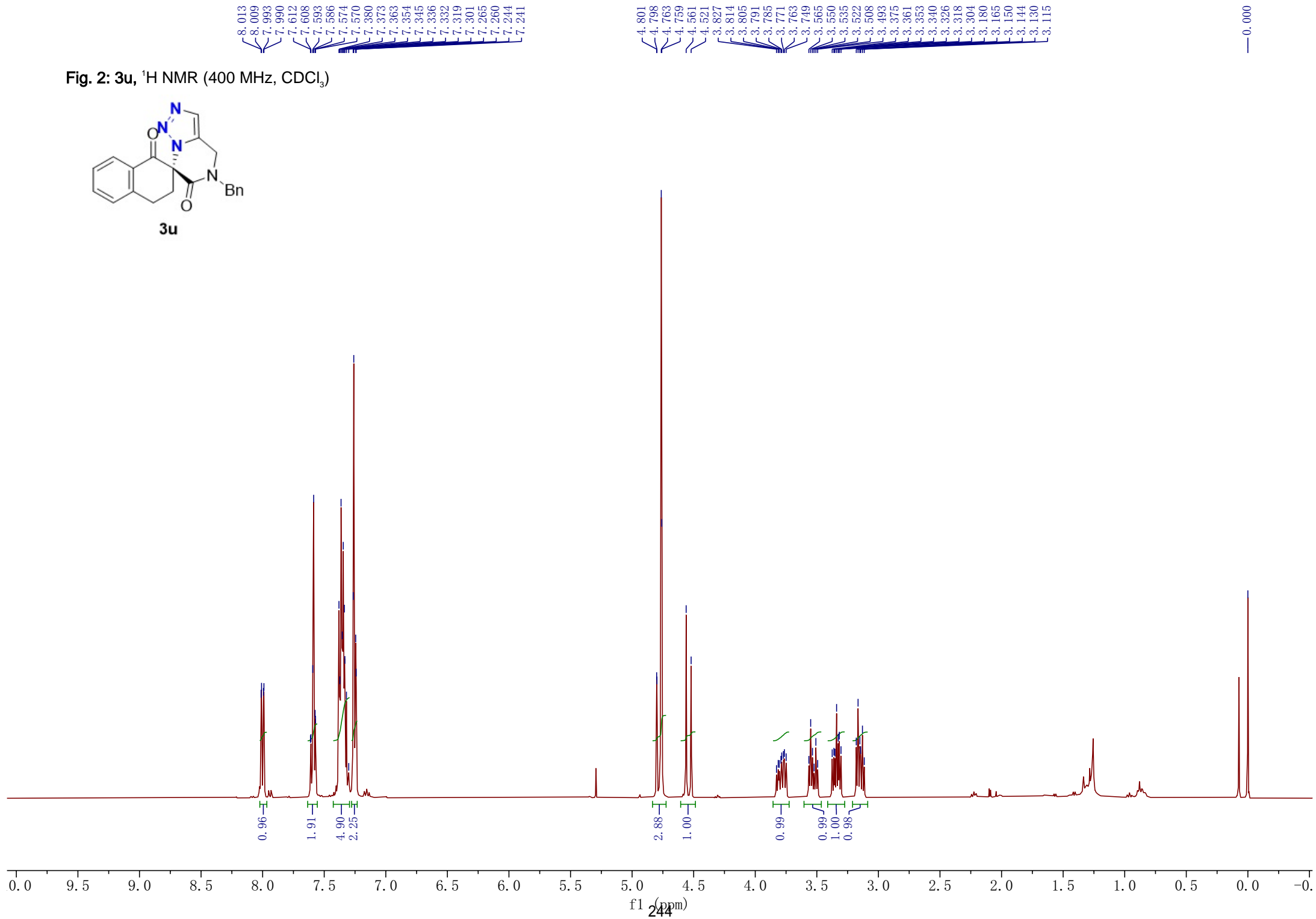
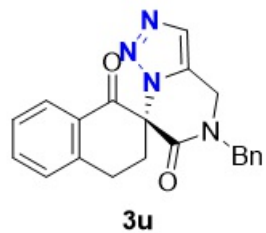




Fig. 2: **3u**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )

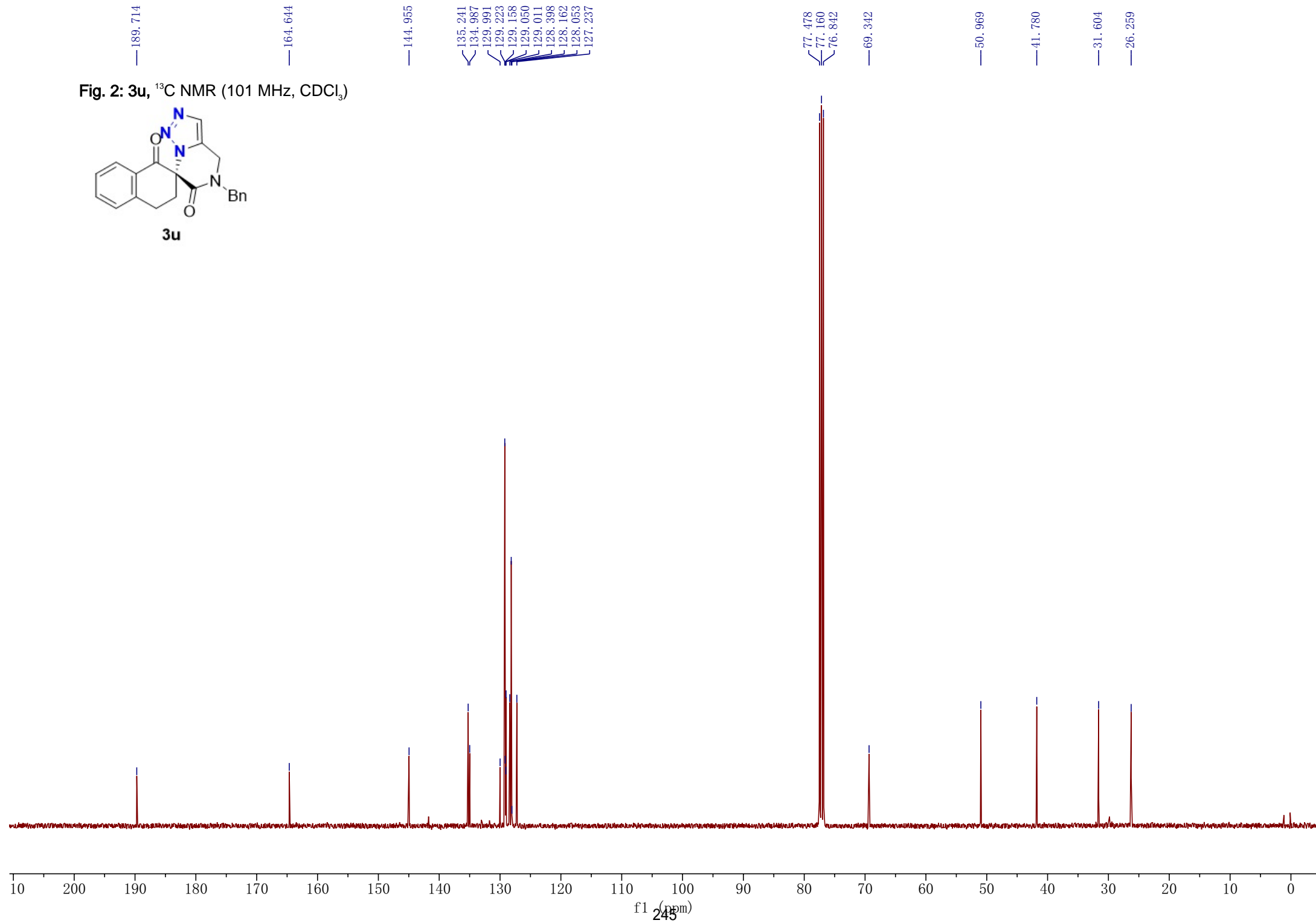
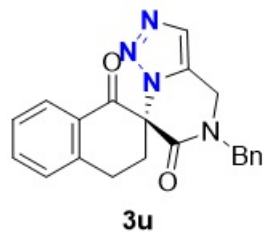
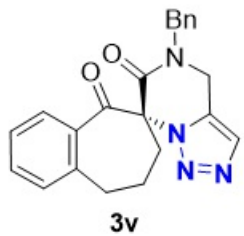
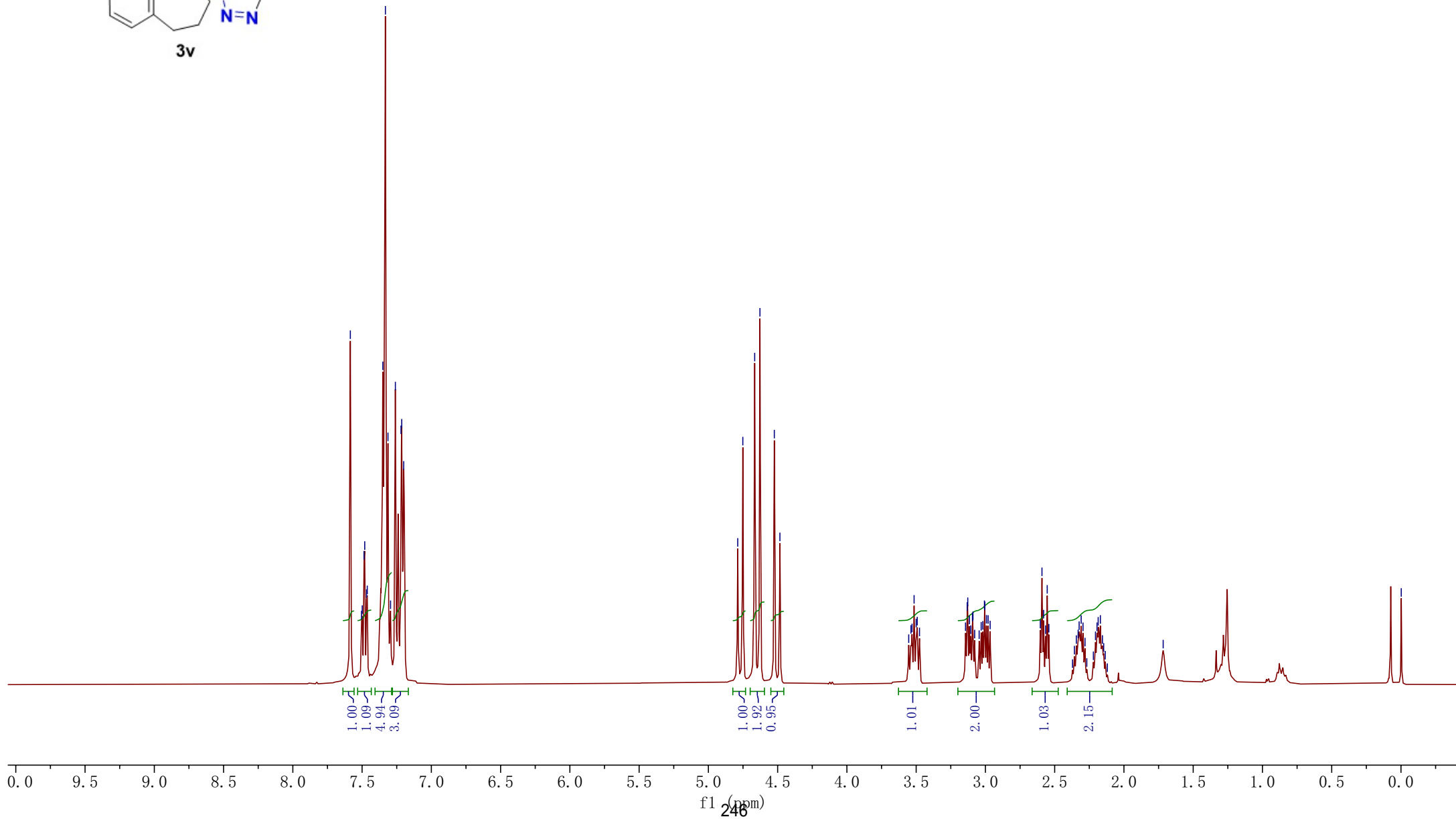


Fig. 2: 3v, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



7.585  
7.504  
7.499  
7.486  
7.481  
7.468  
7.463  
7.350  
7.332  
7.313  
7.294  
7.260  
7.219  
7.214  
7.200

4.788  
4.751  
4.666  
4.628  
4.524  
4.484  
3.554  
3.537  
3.530  
3.515  
3.500  
3.492  
3.476  
3.143  
3.131  
3.127  
3.115  
3.106  
3.094  
3.078  
3.045  
3.031  
3.019  
3.007  
3.004  
2.993  
2.981  
2.966  
2.604  
2.592  
2.580  
2.566  
2.554  
2.542  
2.371  
2.357  
2.344  
2.331  
2.323  
2.309  
2.296  
2.281  
2.268  
2.221  
2.205  
2.194  
2.186  
2.170  
2.155  
2.146  
2.135  
2.120  
1.717  
-0.002



—201.175

—164.505

138.976  
137.793  
135.009  
132.722  
129.238  
129.183  
128.911  
128.804  
128.732  
128.415  
128.173  
126.973

77.478  
77.160  
76.842  
73.948

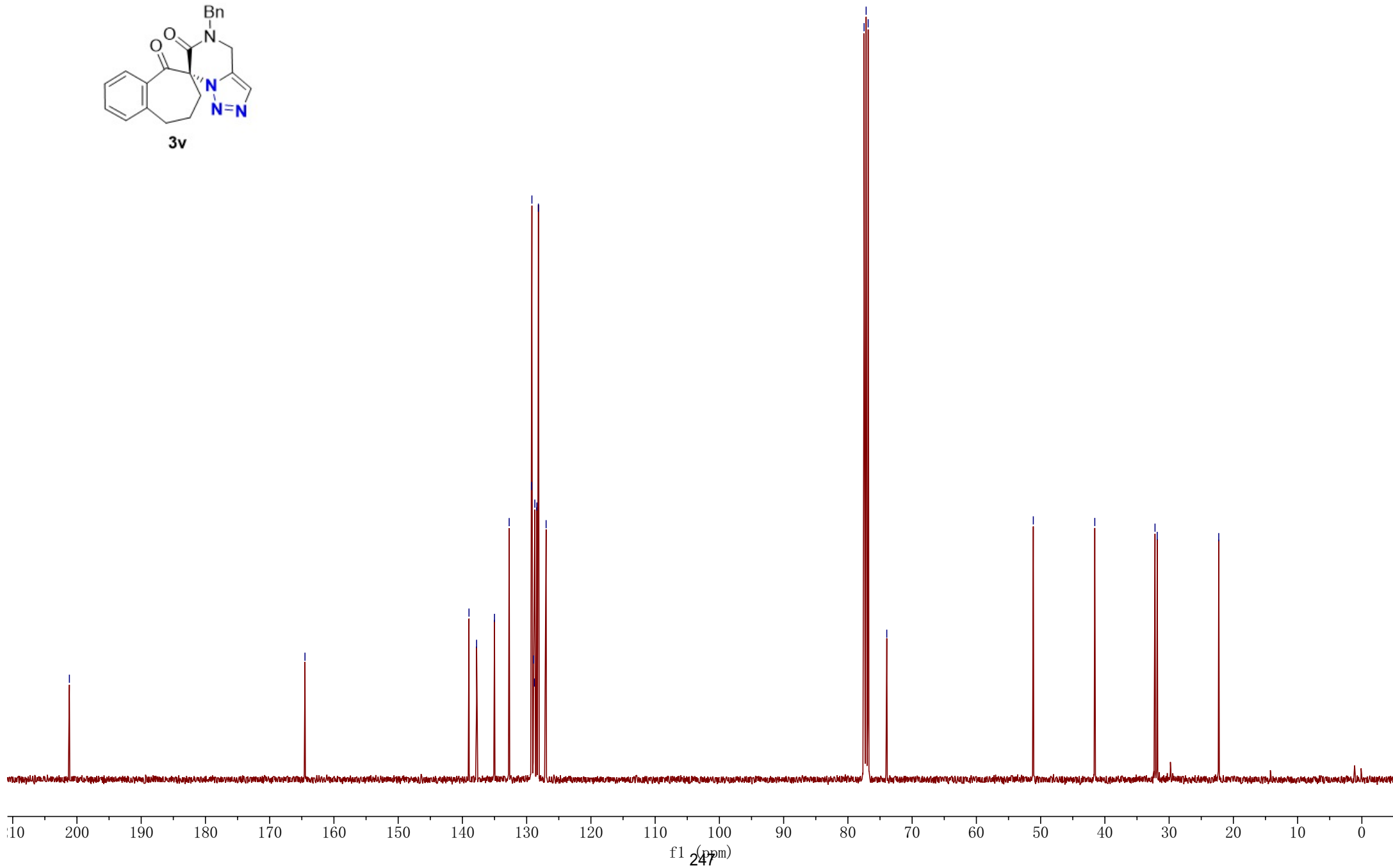
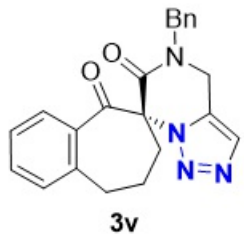
—51.139

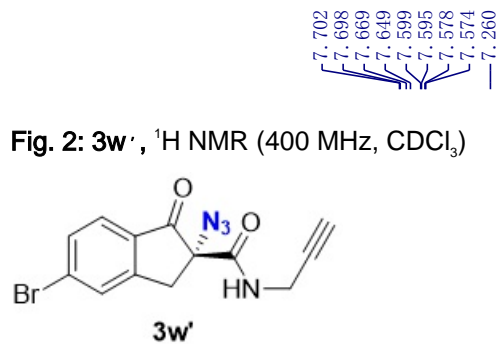
—41.570

32.196  
31.850

—22.274

Fig. 2: **3v**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )





7.702  
7.698  
7.669  
7.649  
7.599  
7.595  
7.578  
7.574  
7.260

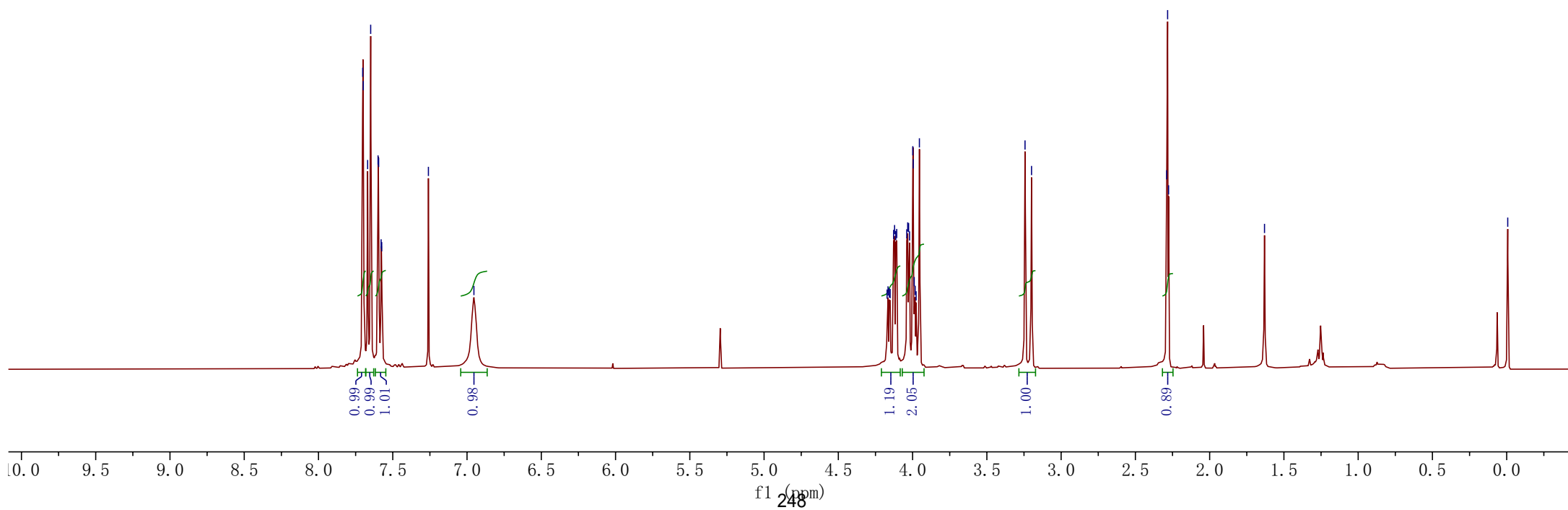
6.954

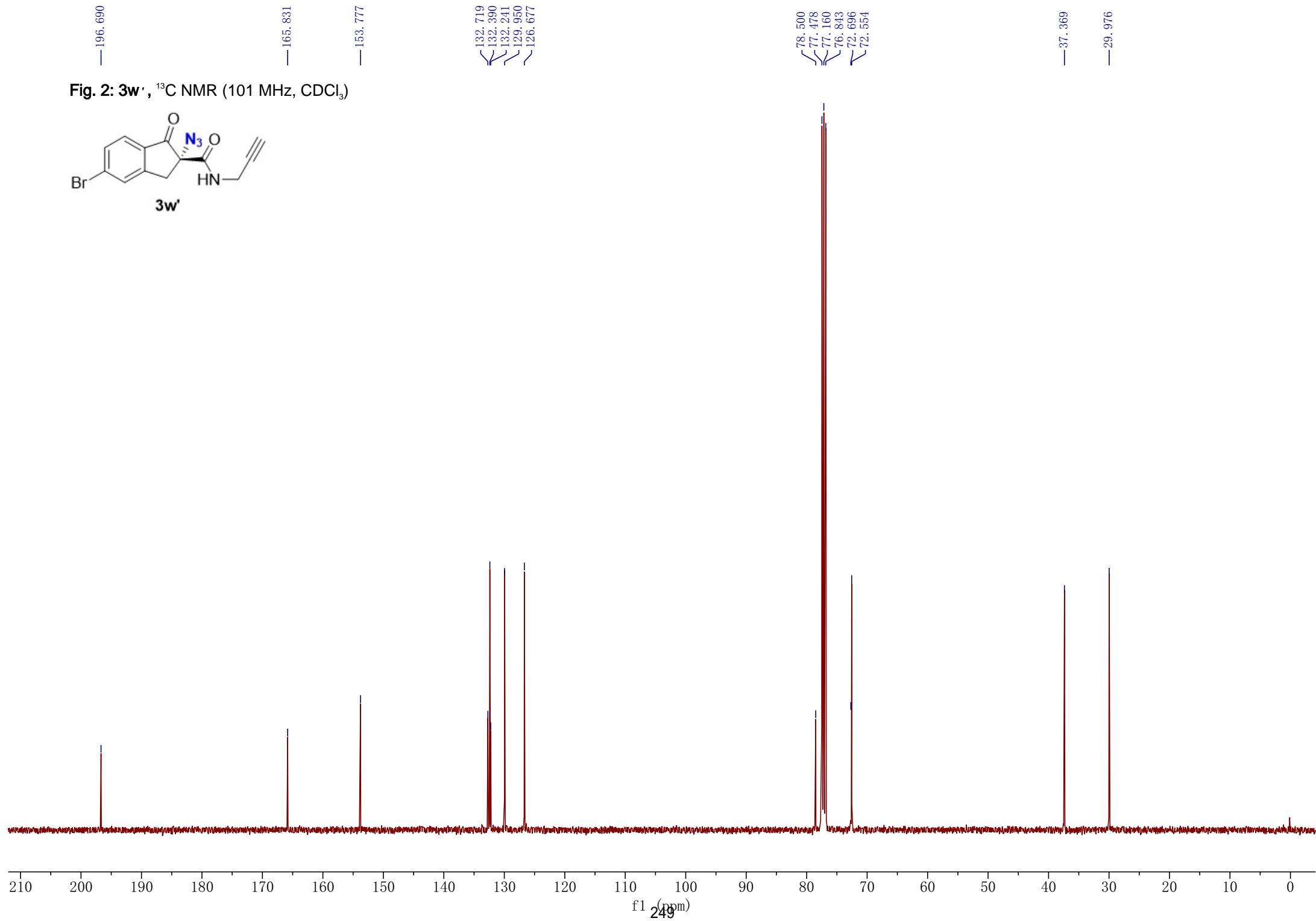
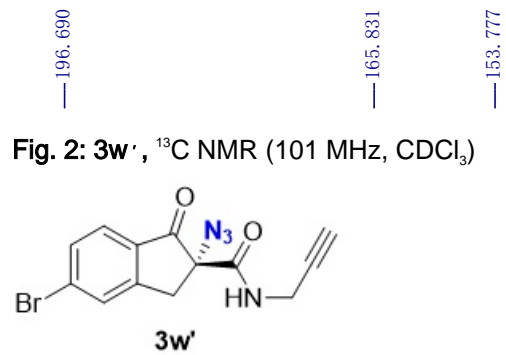
4.172  
4.165  
4.157  
4.151  
4.128  
4.121  
4.113  
4.107  
4.039  
4.033  
4.027  
4.020  
3.999  
3.996  
3.989  
3.983  
3.976  
3.954  
3.243  
3.199

2.289  
2.283  
2.277

1.631

-0.007





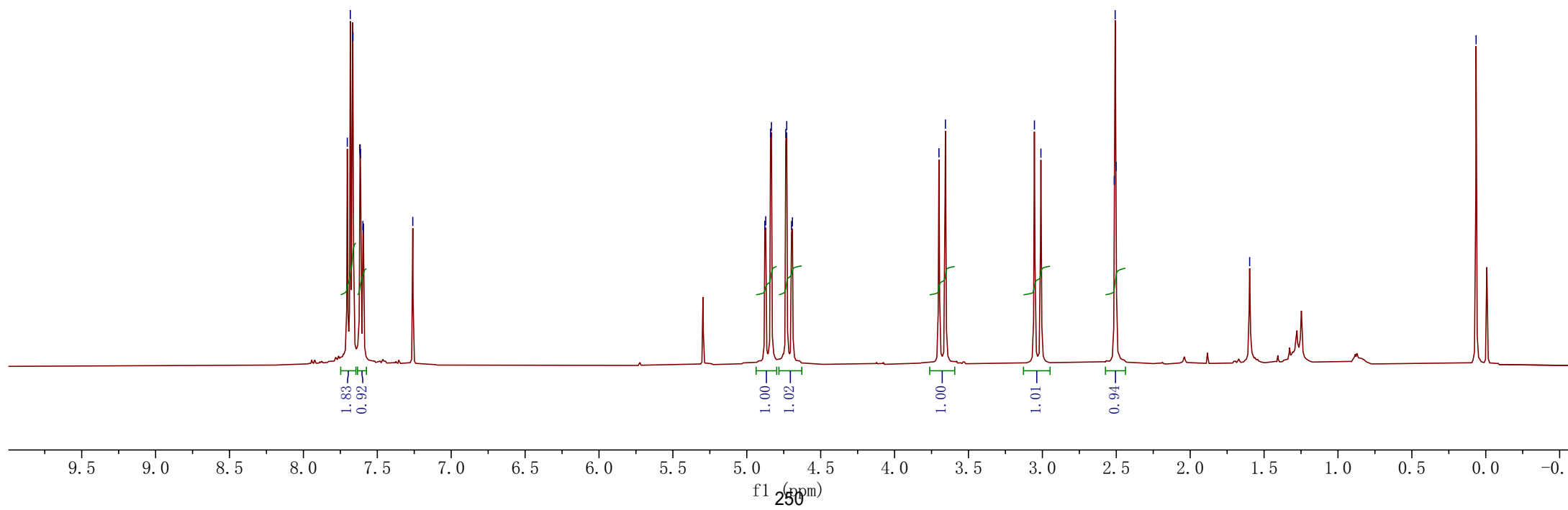
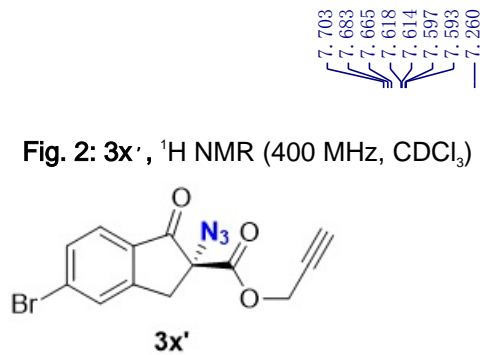
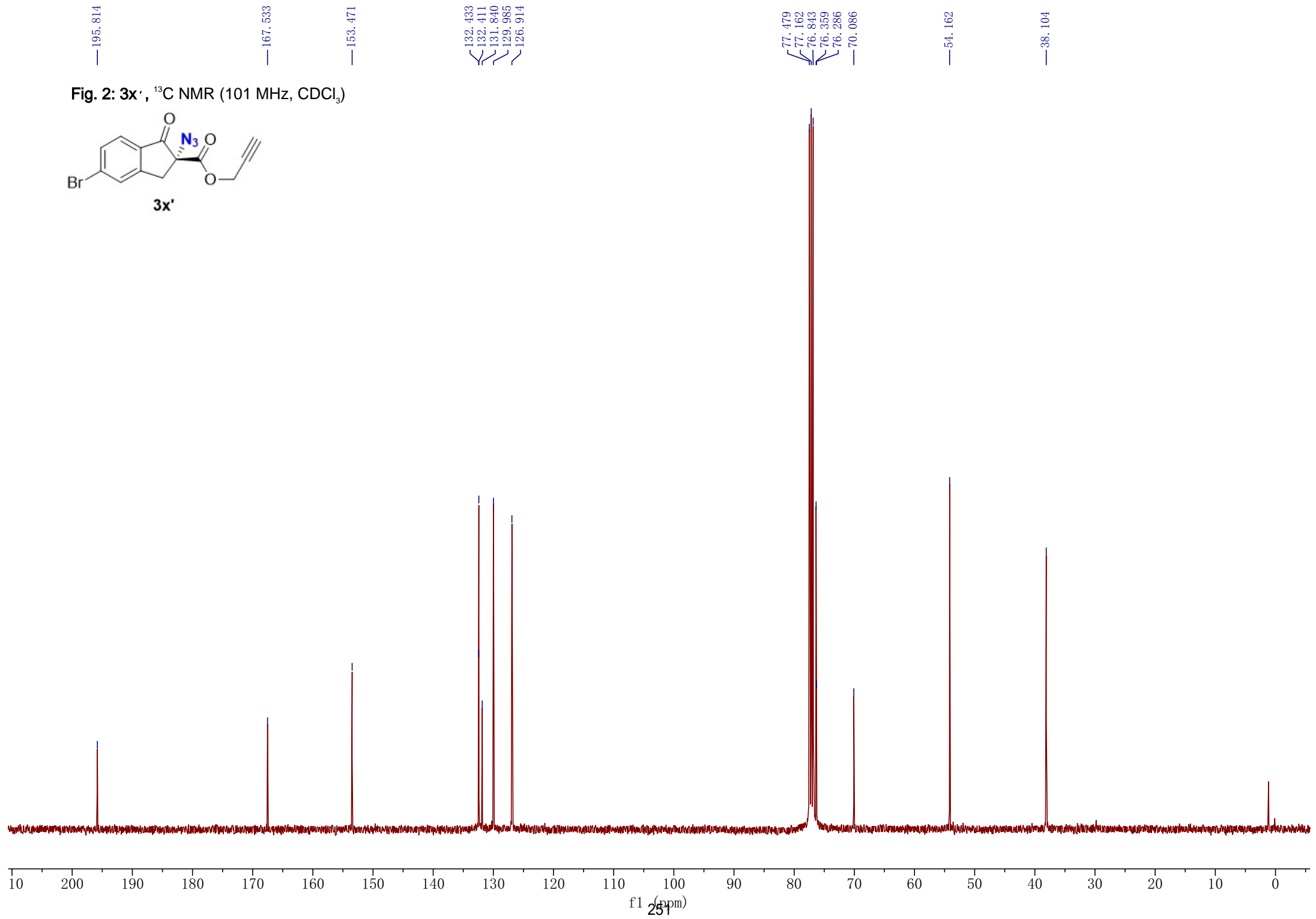
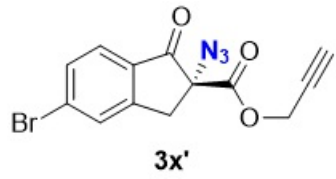
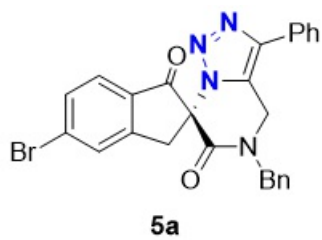


Fig. 2: **3x'**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



**Fig. 3: 5a, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**



7.861  
7.672  
7.651  
7.633  
7.616  
7.613  
7.463  
7.445  
7.425  
7.395  
7.380  
7.375  
7.366  
7.361  
7.356  
7.345  
7.342  
7.328  
7.297  
7.292  
7.276  
7.260

5.143  
5.103  
4.979  
4.942  
4.730  
4.689  
4.651  
4.450  
4.407  
4.324  
4.281

— 1.638

— 0.006

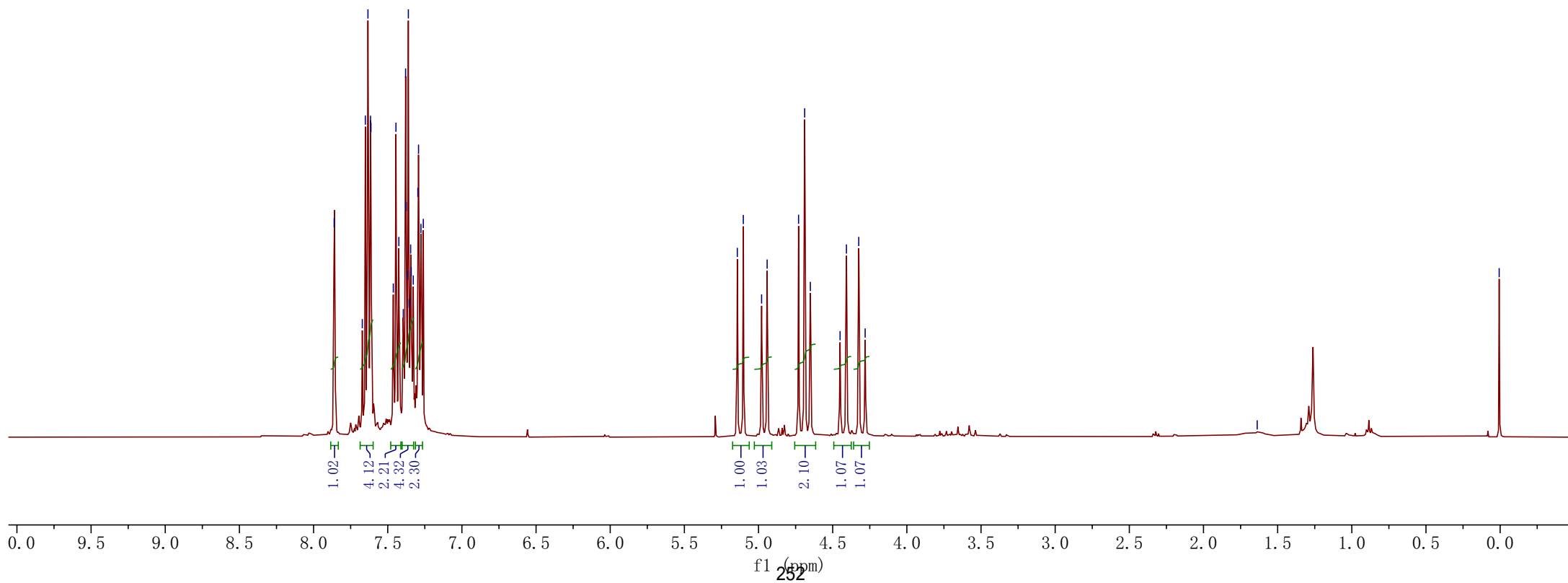
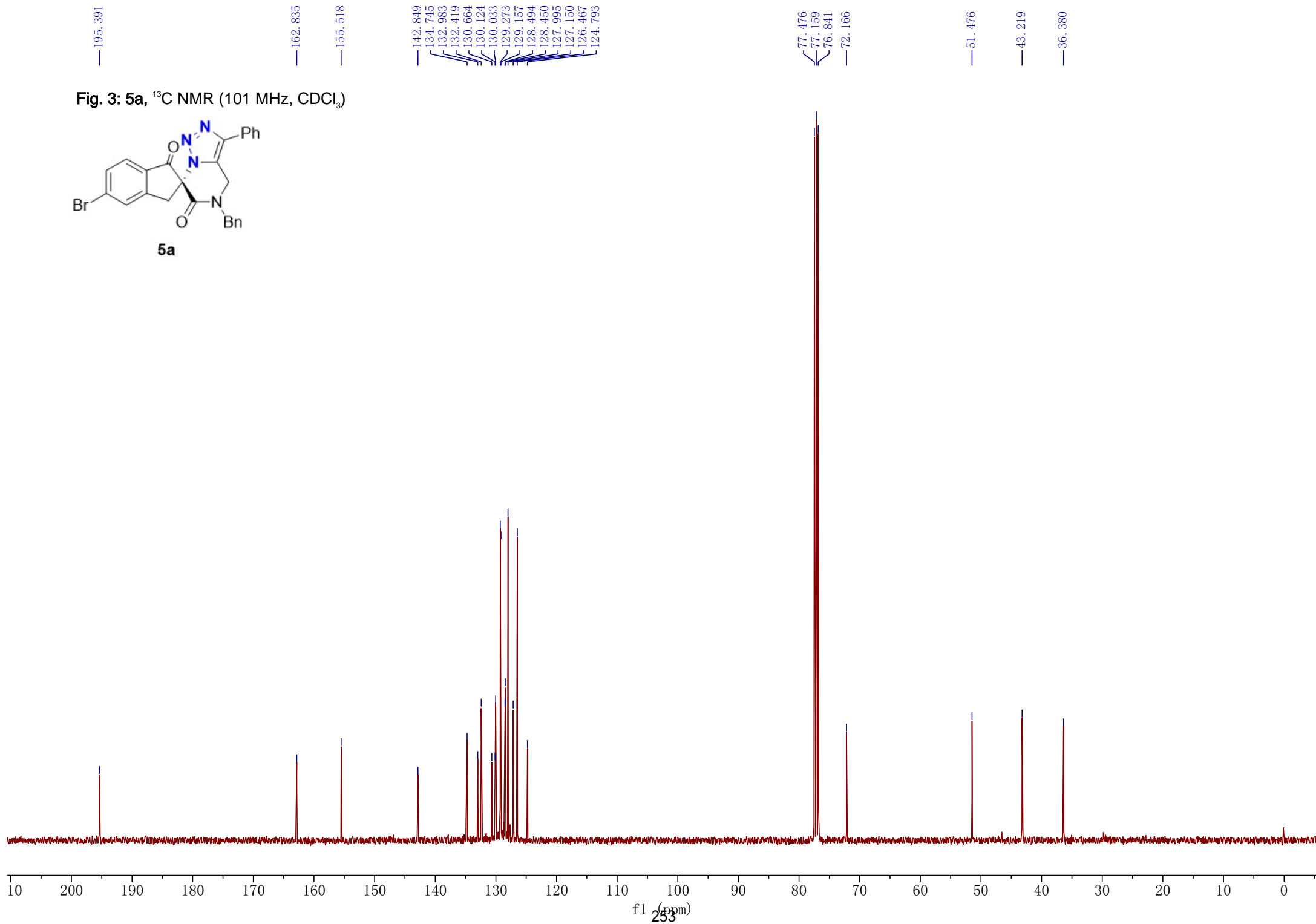
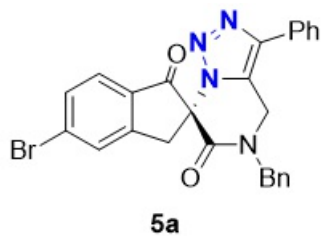


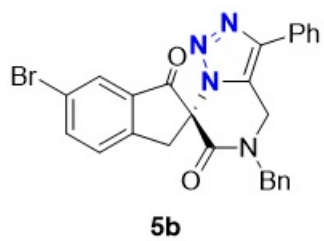


Fig. 3: **5a**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



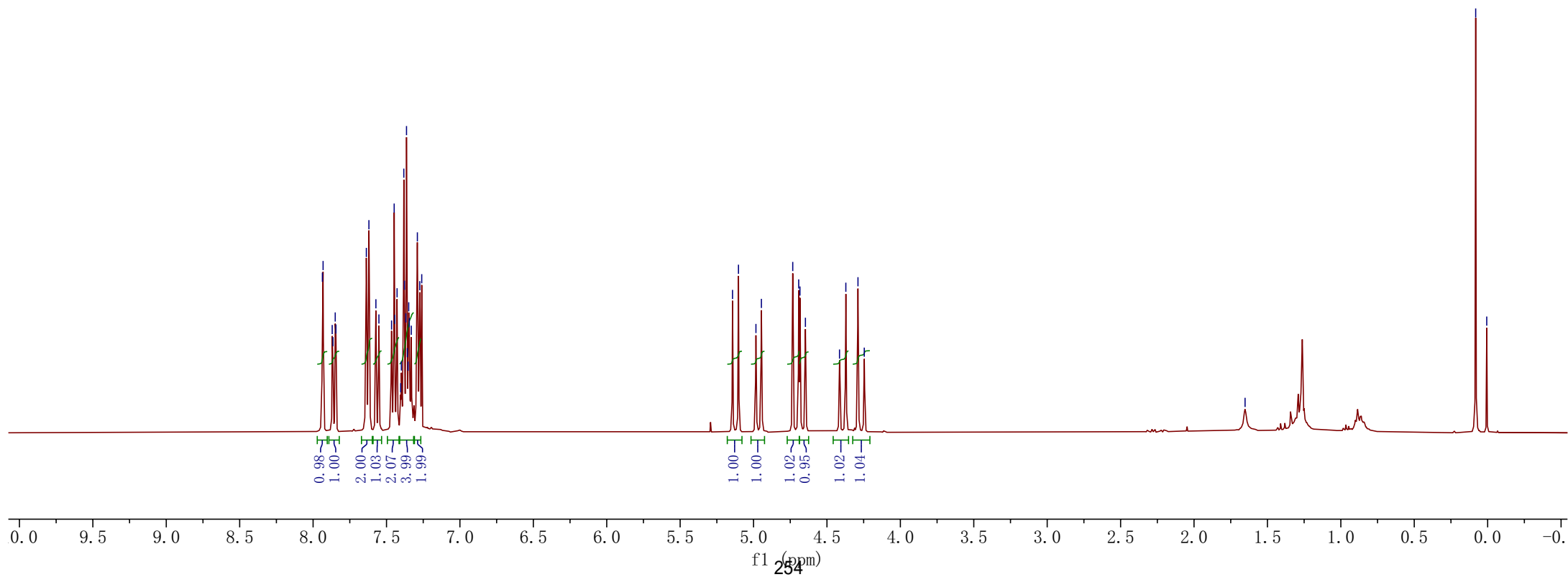
7.937  
7.932  
7.870  
7.865  
7.849  
7.844  
7.637  
7.620  
7.572  
7.552  
7.465  
7.448  
7.444  
7.428  
7.403  
7.399  
7.382  
7.378  
7.368  
7.364  
7.358  
7.353  
7.349  
7.345  
7.331  
7.290  
7.273  
7.260  
5.143  
5.103  
4.984  
4.947  
4.733  
4.693  
4.684  
4.647  
4.415  
4.371  
4.289  
4.246

Fig. 3: 5b, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



— 1.652

— 0.082  
— 0.006



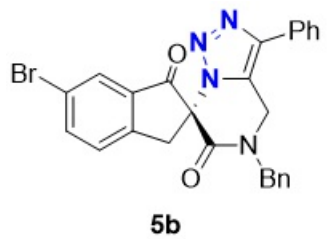
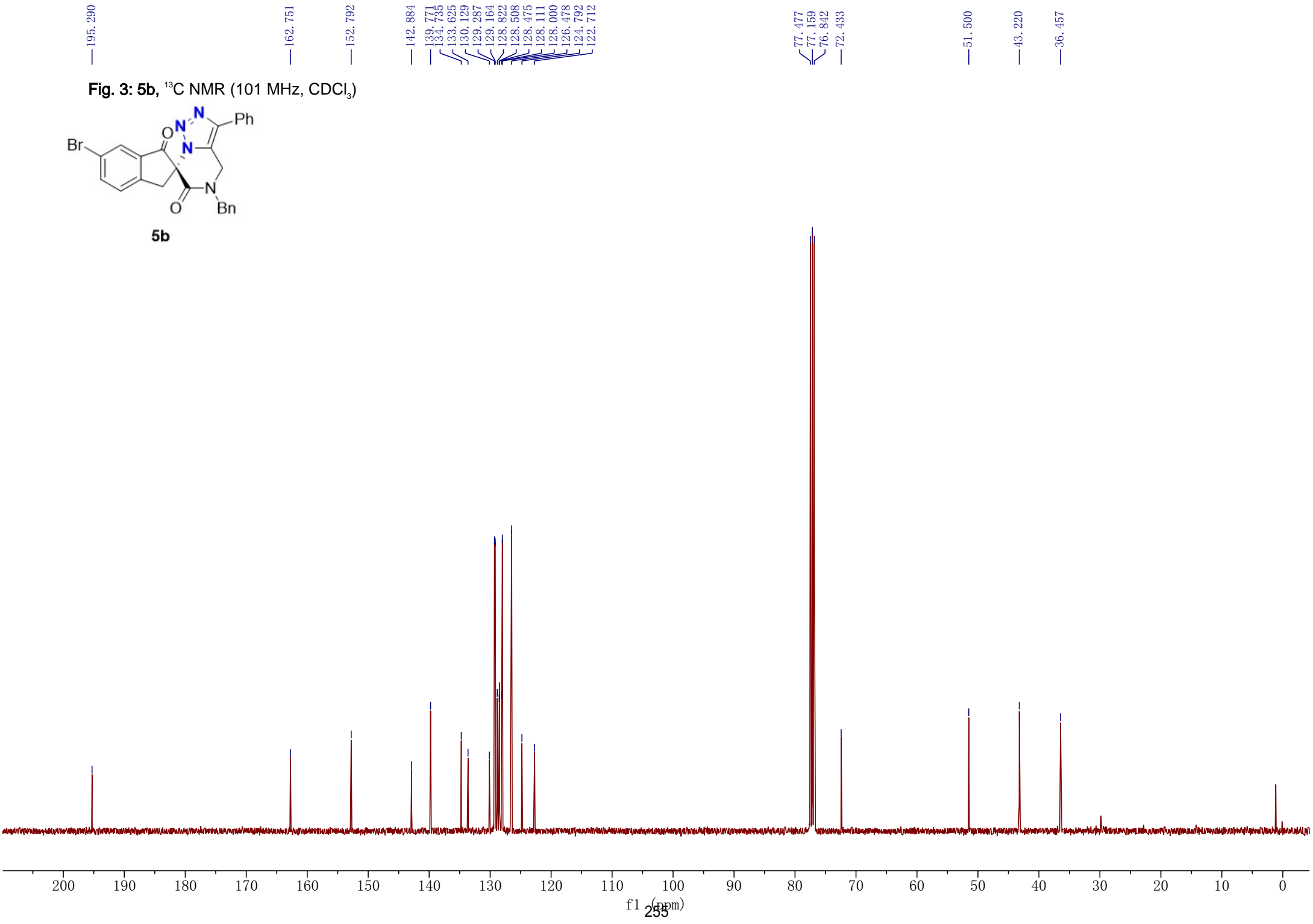


Fig. 3: **5b**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



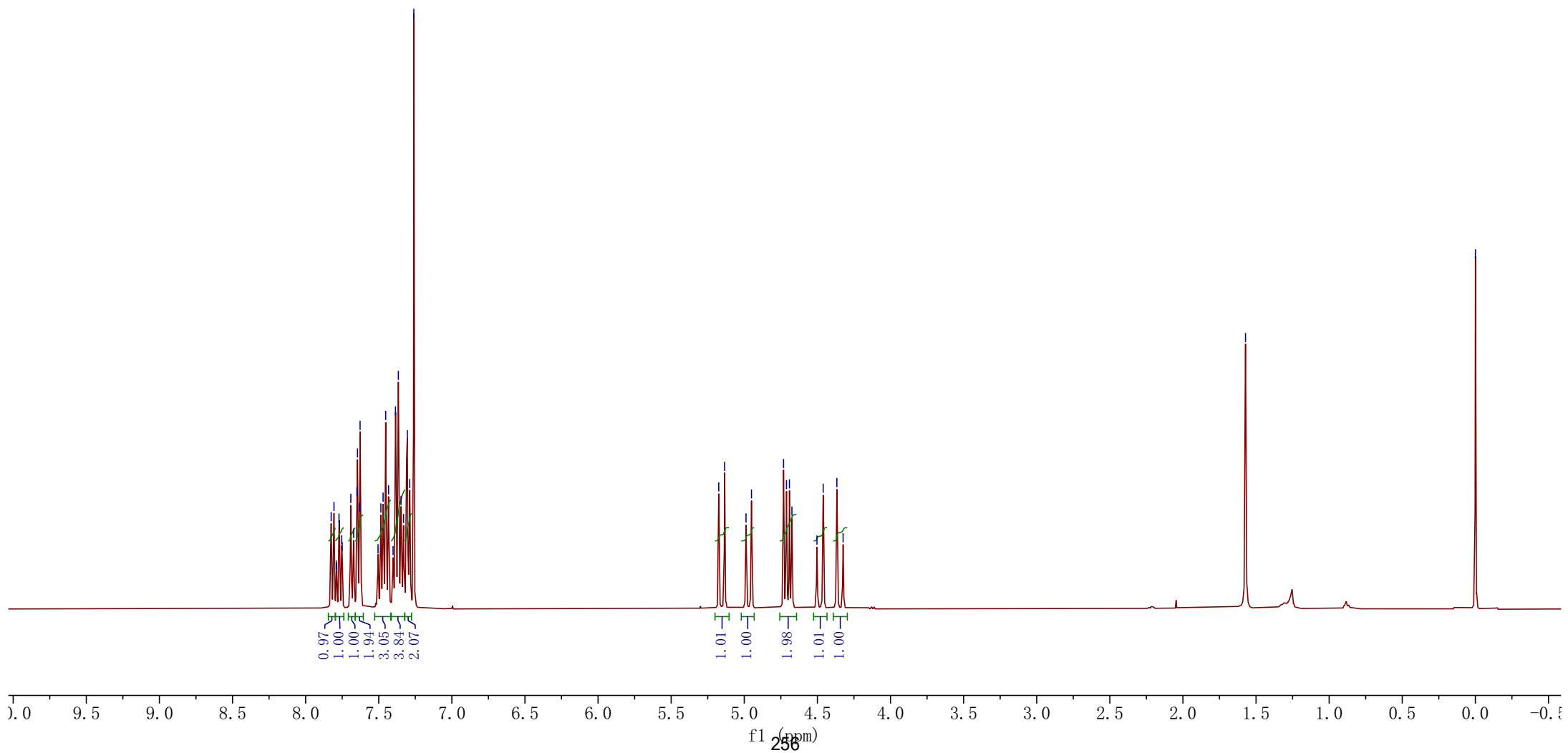
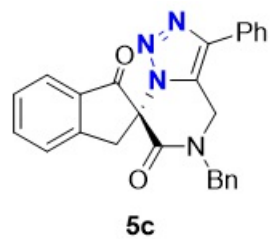
7.825  
7.806  
7.790  
7.788  
7.772  
7.769  
7.753  
7.750  
7.691  
7.671  
7.649  
7.645  
7.631  
7.627  
7.505  
7.485  
7.470  
7.452  
7.433  
7.402  
7.386  
7.366  
7.348  
7.330  
7.304  
7.288  
7.260

5.175  
5.134  
4.988  
4.951  
4.731  
4.711  
4.691  
4.674  
4.503  
4.460  
4.367  
4.324

-1.572

-0.000

Fig. 3: **5c**, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



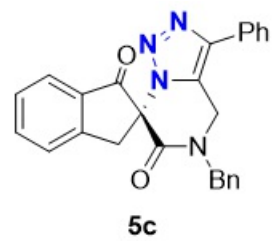
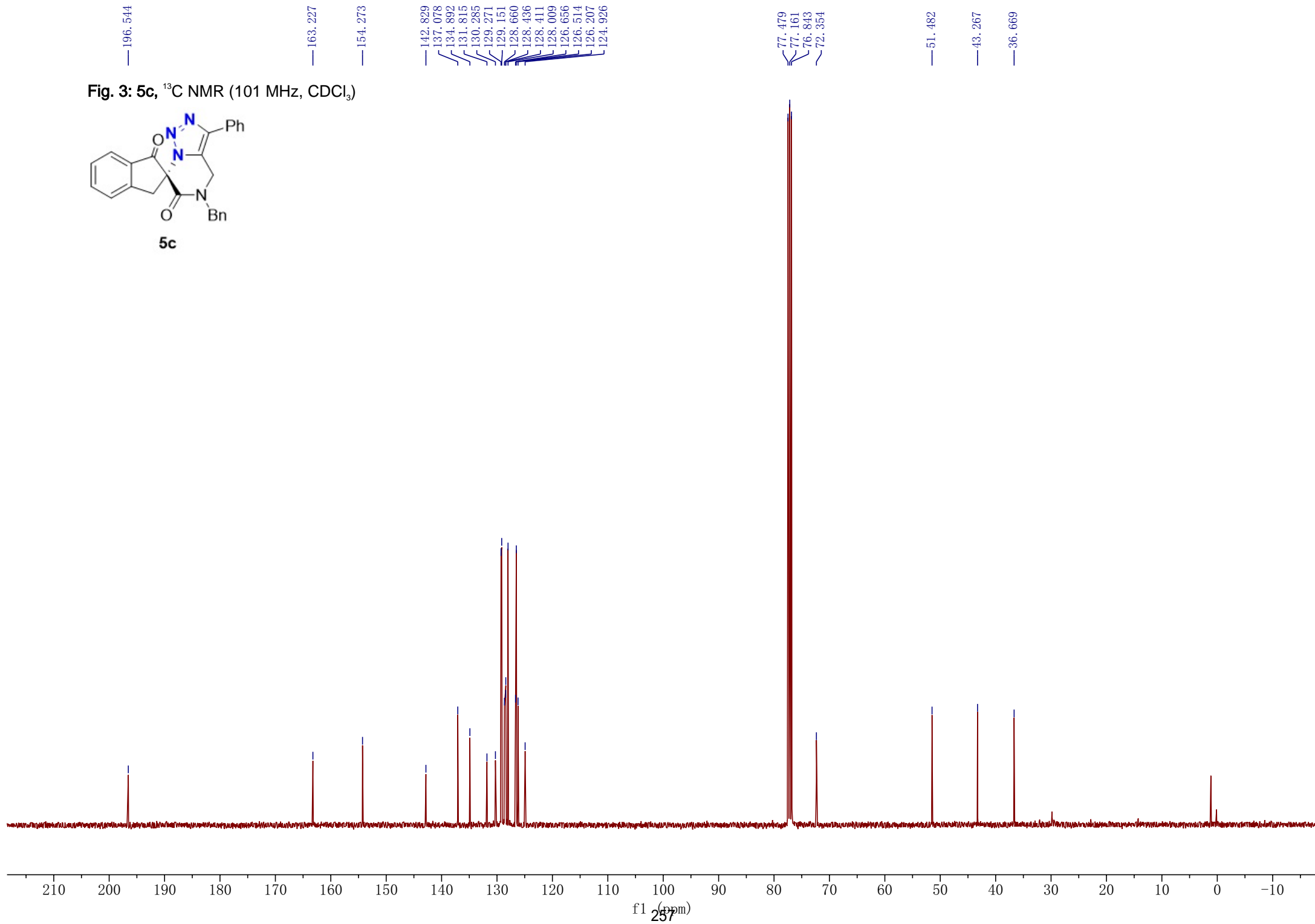
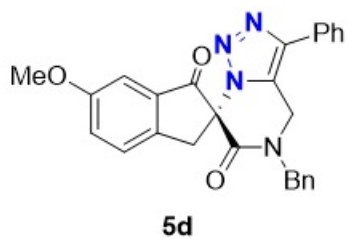
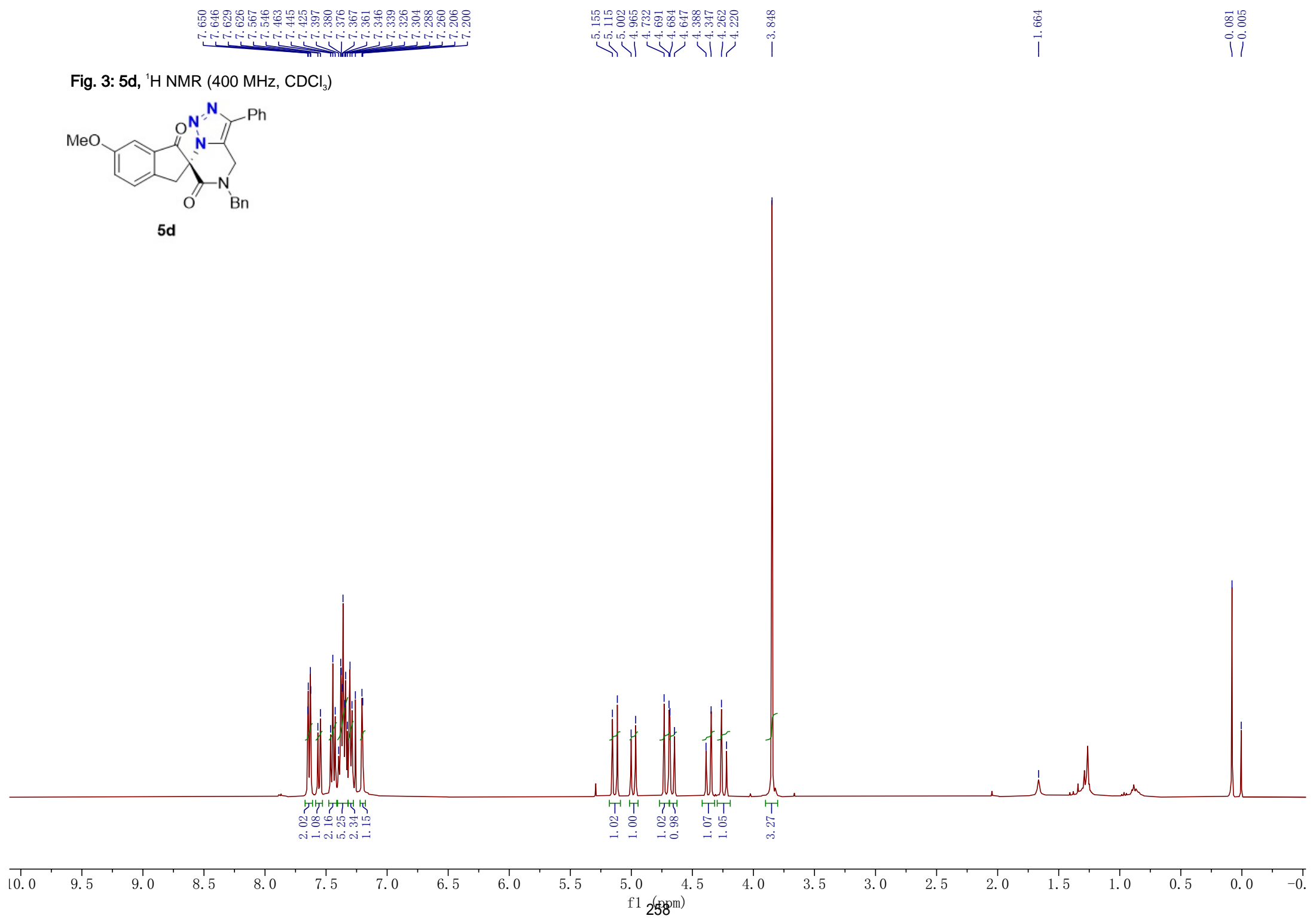


Fig. 3: **5c**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )





**Fig. 3: 5d, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**



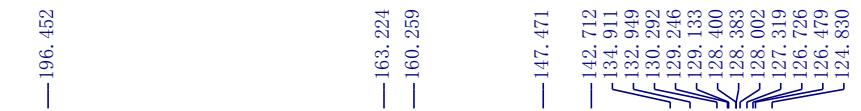
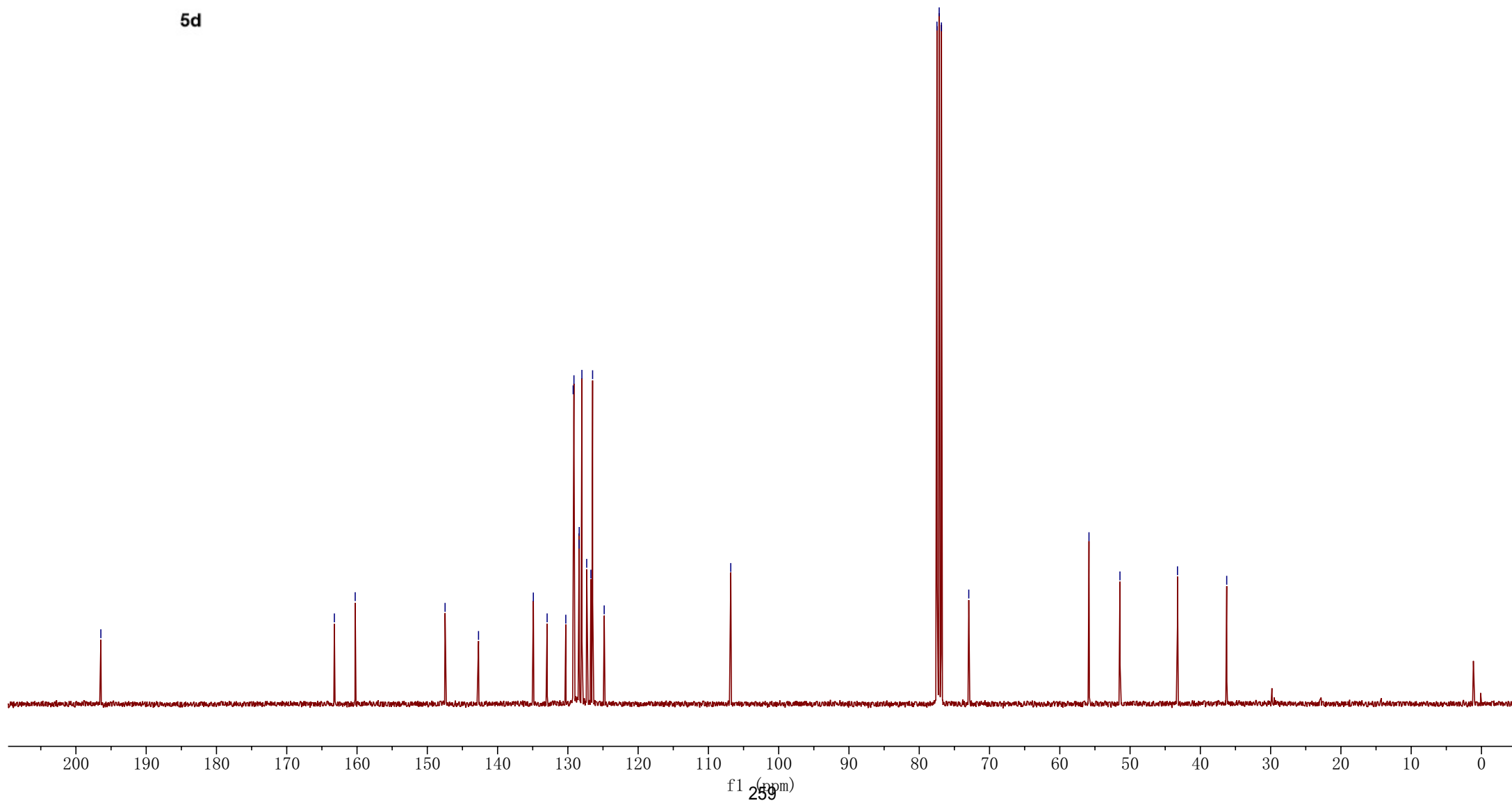
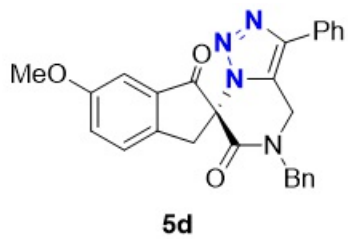
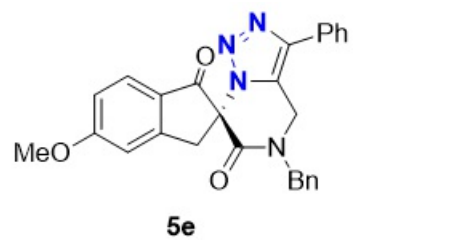


Fig. 3: 5d, <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)



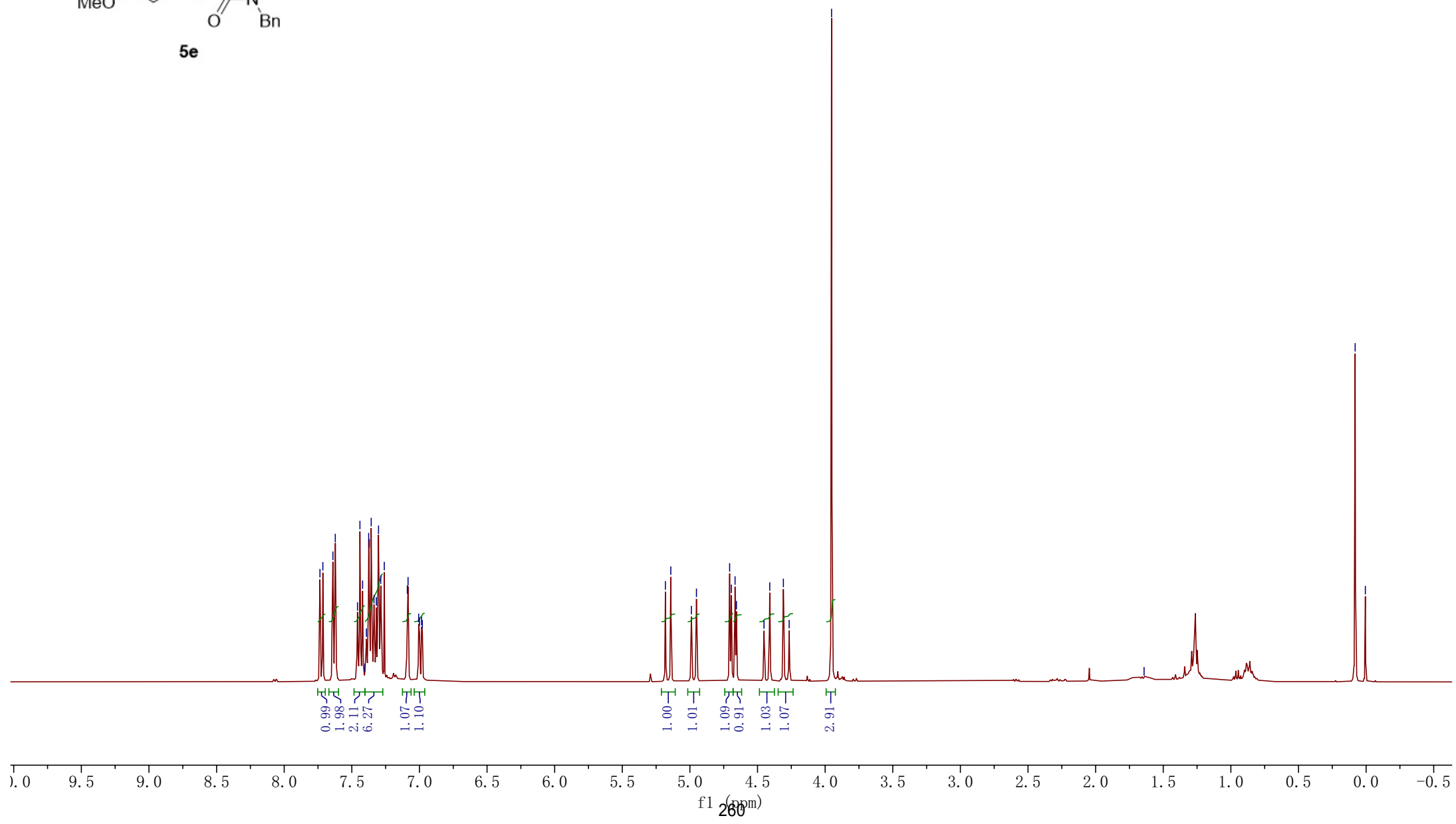


7.736  
7.714  
7.640  
7.622  
7.458  
7.440  
7.420  
7.404  
7.392  
7.375  
7.371  
7.357  
7.336  
7.318  
7.303  
7.286  
7.260  
7.090  
7.084  
7.006  
7.000  
6.984  
6.979

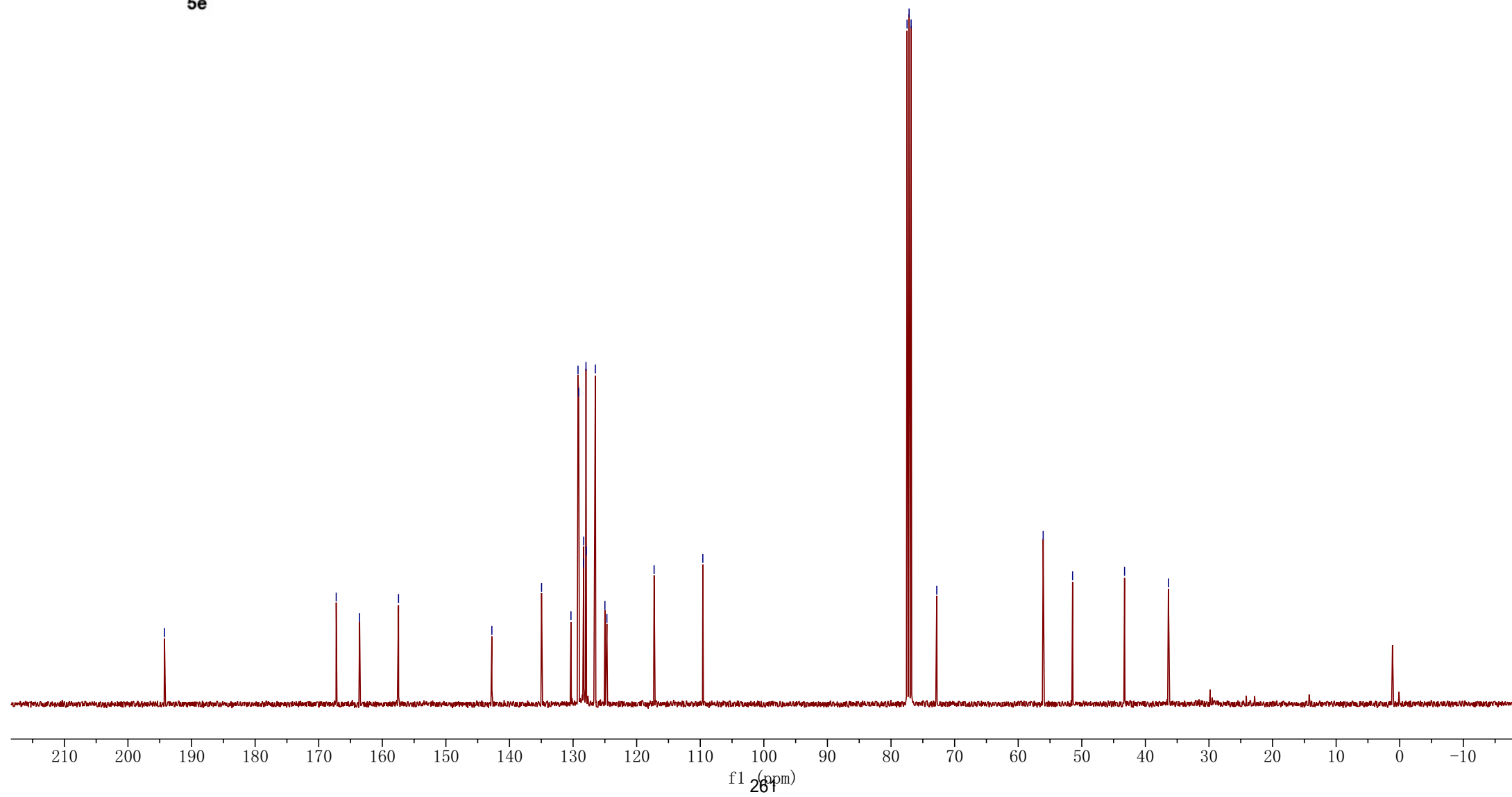
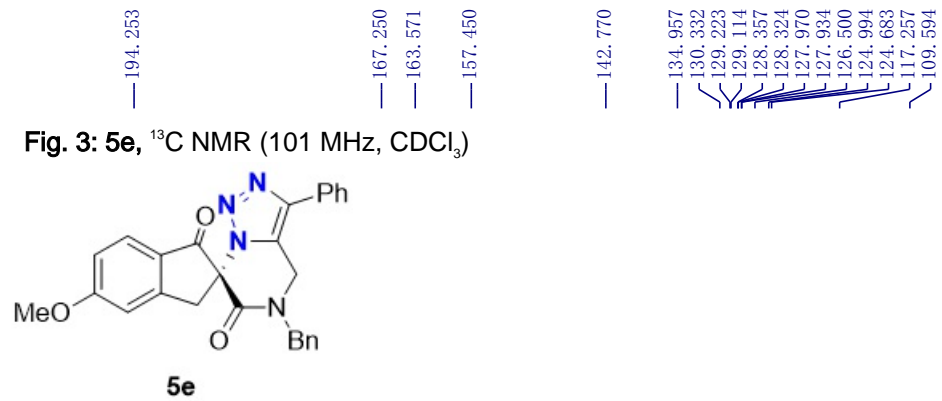
5.181  
5.141  
4.989  
4.952  
4.706  
4.694  
4.666  
4.656  
4.452  
4.410  
4.309  
4.266  
3.953

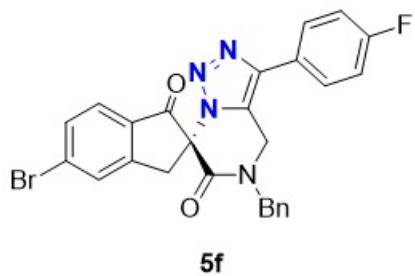
1.642

0.081  
0.006









7.867  
7.863  
7.675  
7.654  
7.638  
7.614  
7.601  
7.592  
7.579  
7.406  
7.401  
7.384  
7.380  
7.366  
7.352  
7.348  
7.334  
7.319  
7.316  
7.292  
7.274  
7.260  
7.159  
7.138  
7.116

5.118  
5.077  
4.983  
4.946  
4.694  
4.687  
4.657  
4.647  
4.449  
4.407  
4.327  
4.284

1.618

0.001

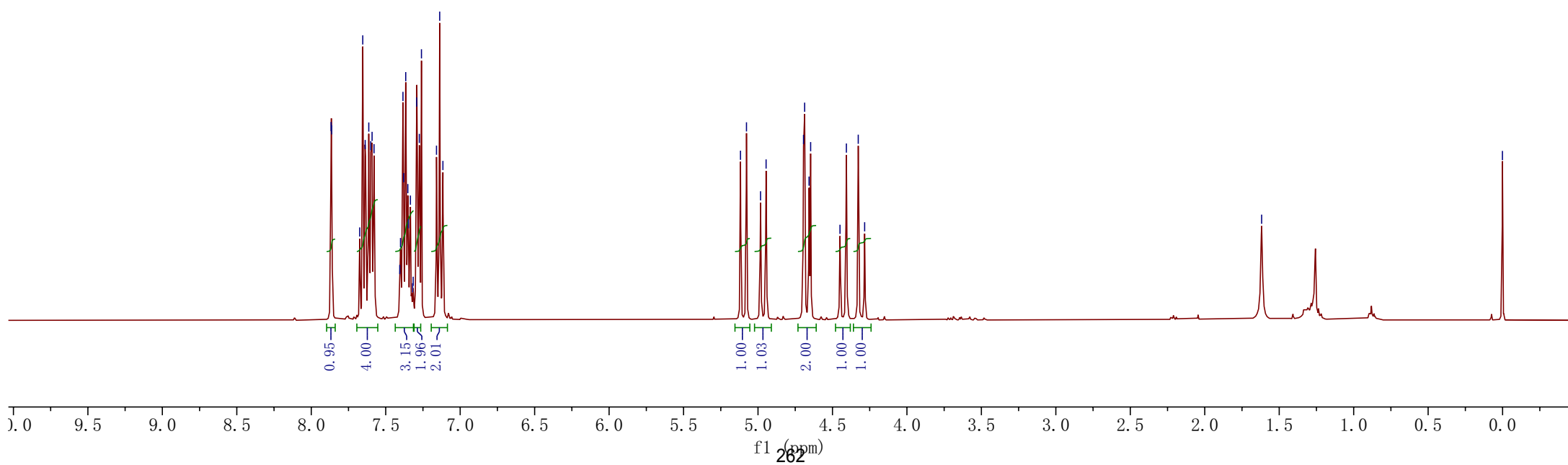
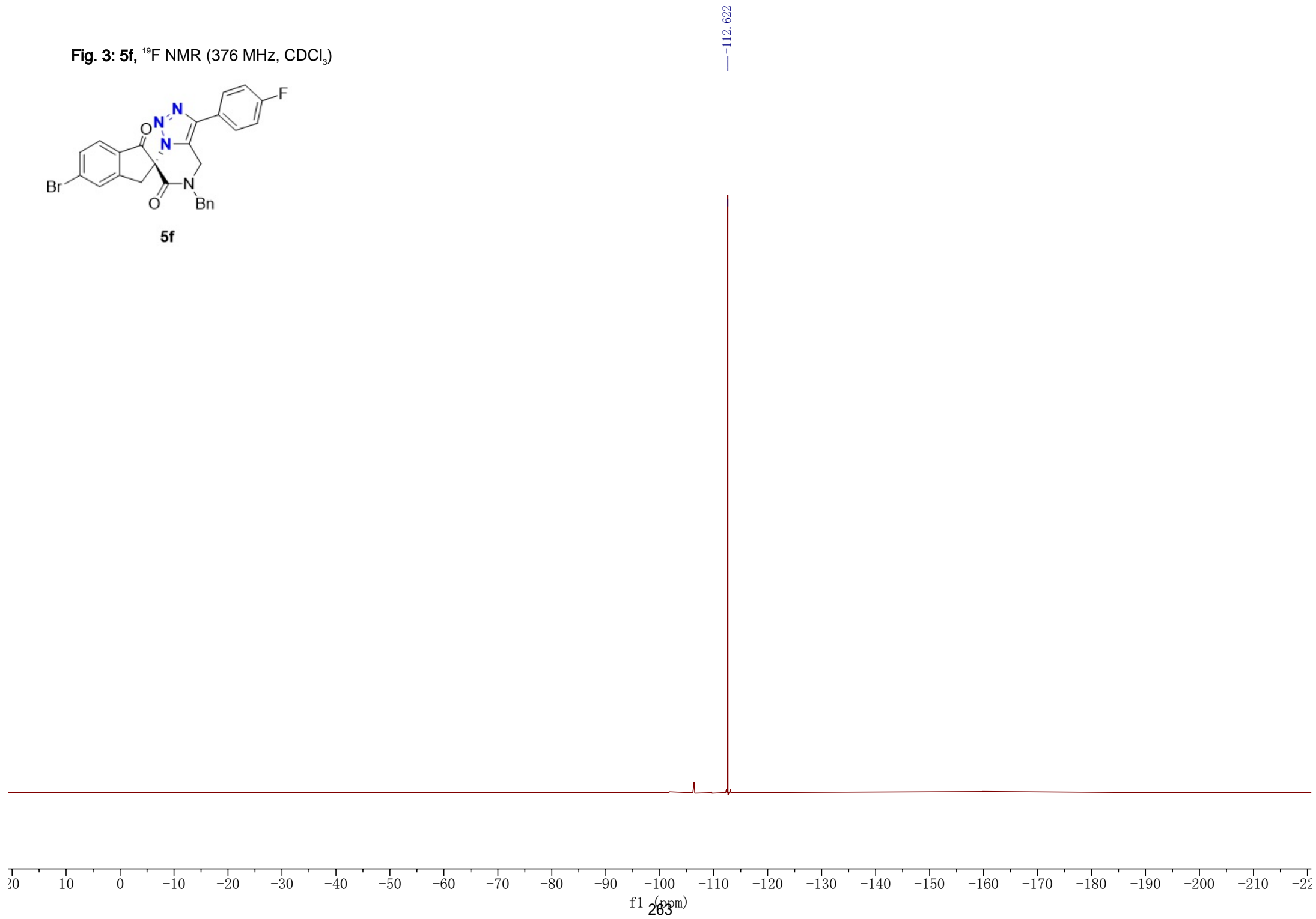
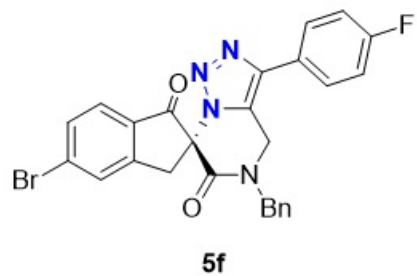
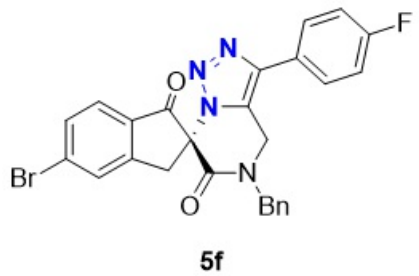


Fig. 3: 5f,  $^{19}\text{F}$  NMR (376 MHz,  $\text{CDCl}_3$ )





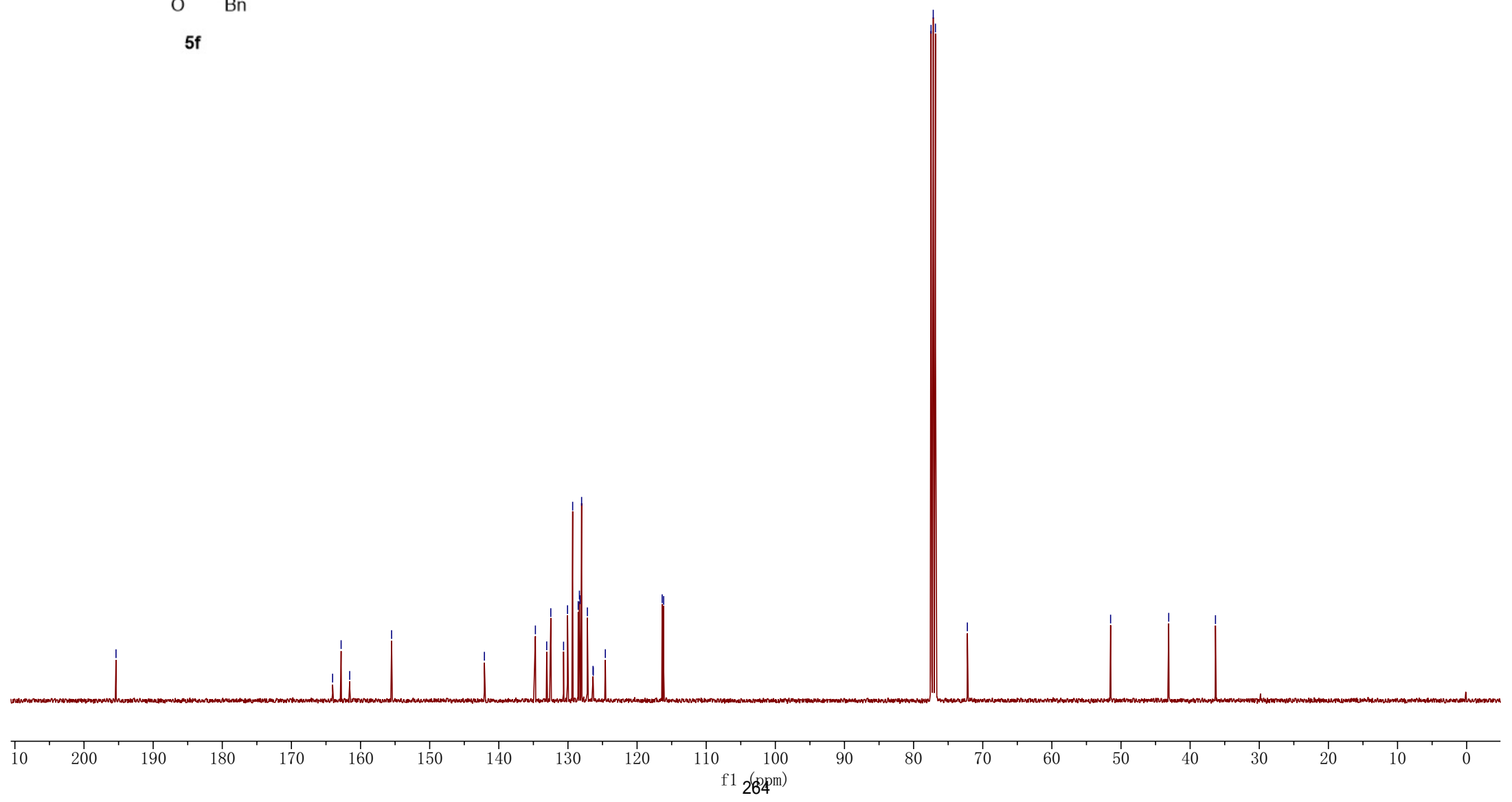
195.371  
 164.041  
 162.811  
 161.570  
 155.510  
 142.087  
 134.710  
 133.070  
 132.481  
 130.634  
 130.061  
 129.317  
 128.516  
 128.340  
 128.258  
 128.024  
 127.188  
 126.370  
 126.337  
 124.593  
 116.370  
 116.154

77.478  
 77.160  
 76.842  
 72.226

51.507

43.098

36.336



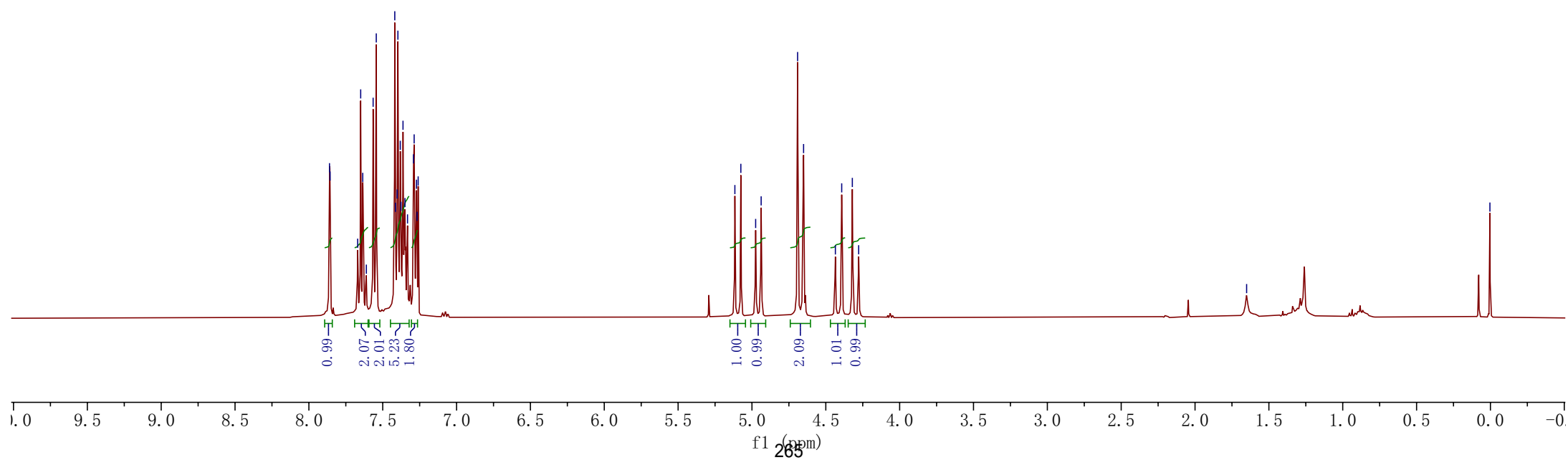
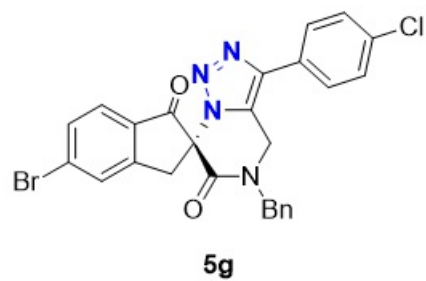
7.861  
7.857  
7.670  
7.649  
7.635  
7.611  
7.565  
7.544  
7.418  
7.413  
7.402  
7.397  
7.381  
7.376  
7.363  
7.349  
7.332  
7.292  
7.287  
7.271  
7.268  
7.260

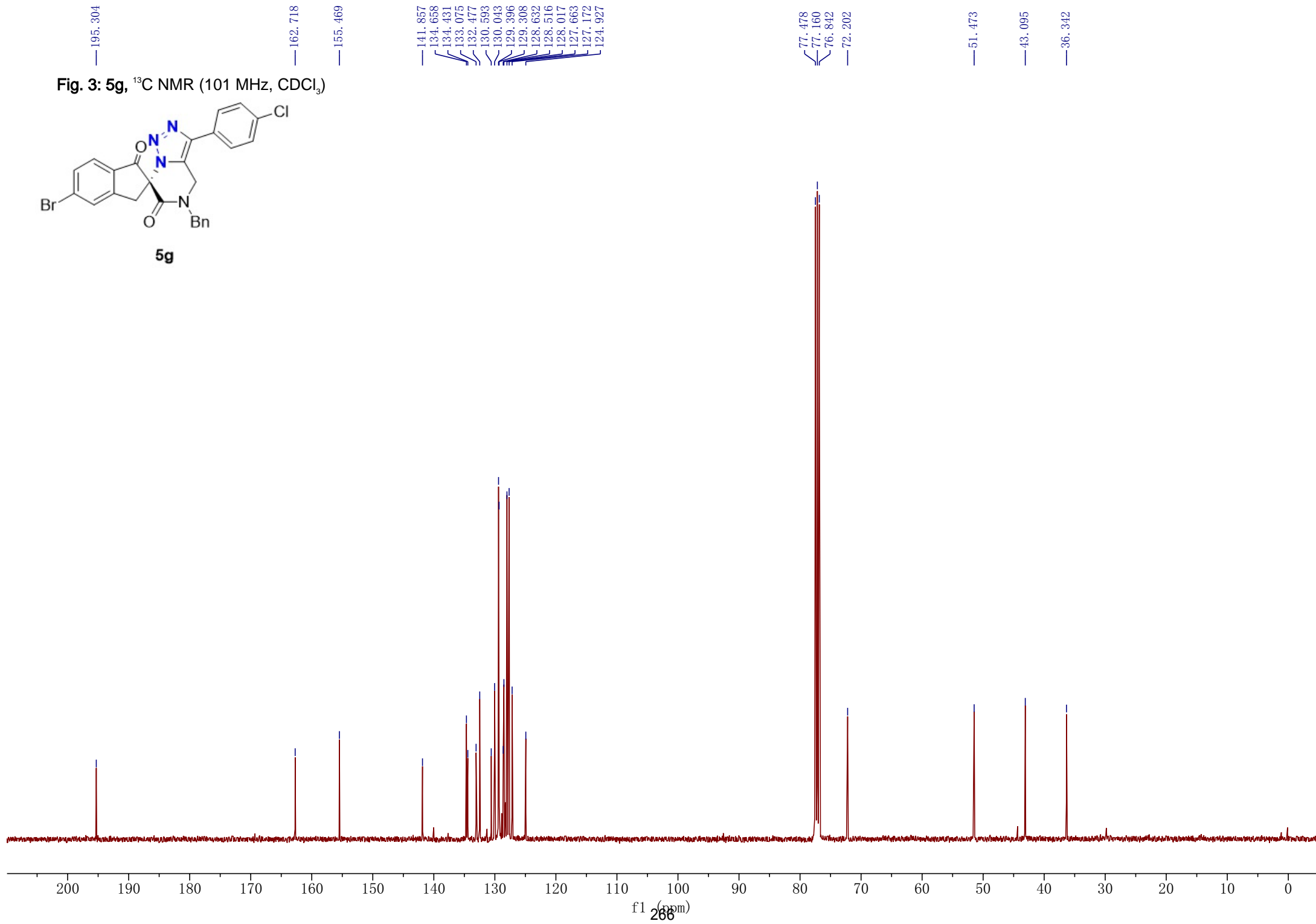
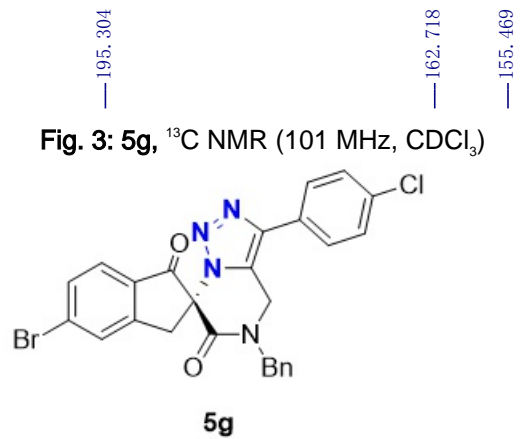
5.116  
5.075  
4.975  
4.938  
4.691  
4.650  
4.435  
4.392  
4.320  
4.277

1.651

0.003

Fig. 3: 5g, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)





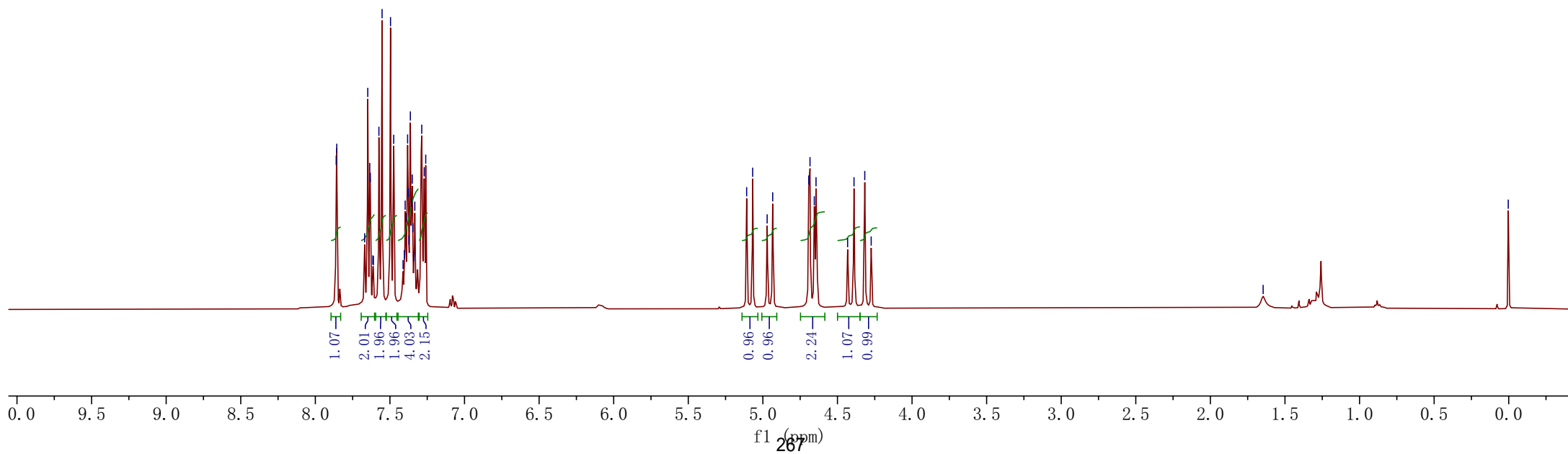
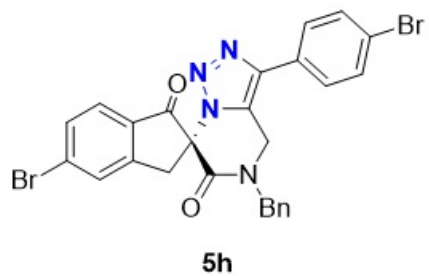
7.860  
7.856  
7.669  
7.649  
7.635  
7.631  
7.615  
7.611  
7.574  
7.553  
7.496  
7.475  
7.412  
7.403  
7.398  
7.393  
7.381  
7.376  
7.372  
7.363  
7.355  
7.350  
7.346  
7.340  
7.333  
7.287  
7.270  
7.260

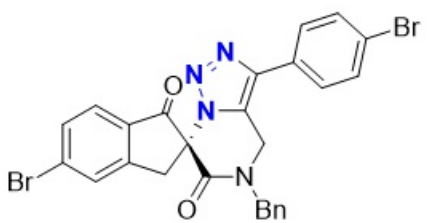
5.109  
5.068  
4.971  
4.934  
4.692  
4.684  
4.655  
4.644  
4.432  
4.389  
4.317  
4.274

— 1.646

— 0.003

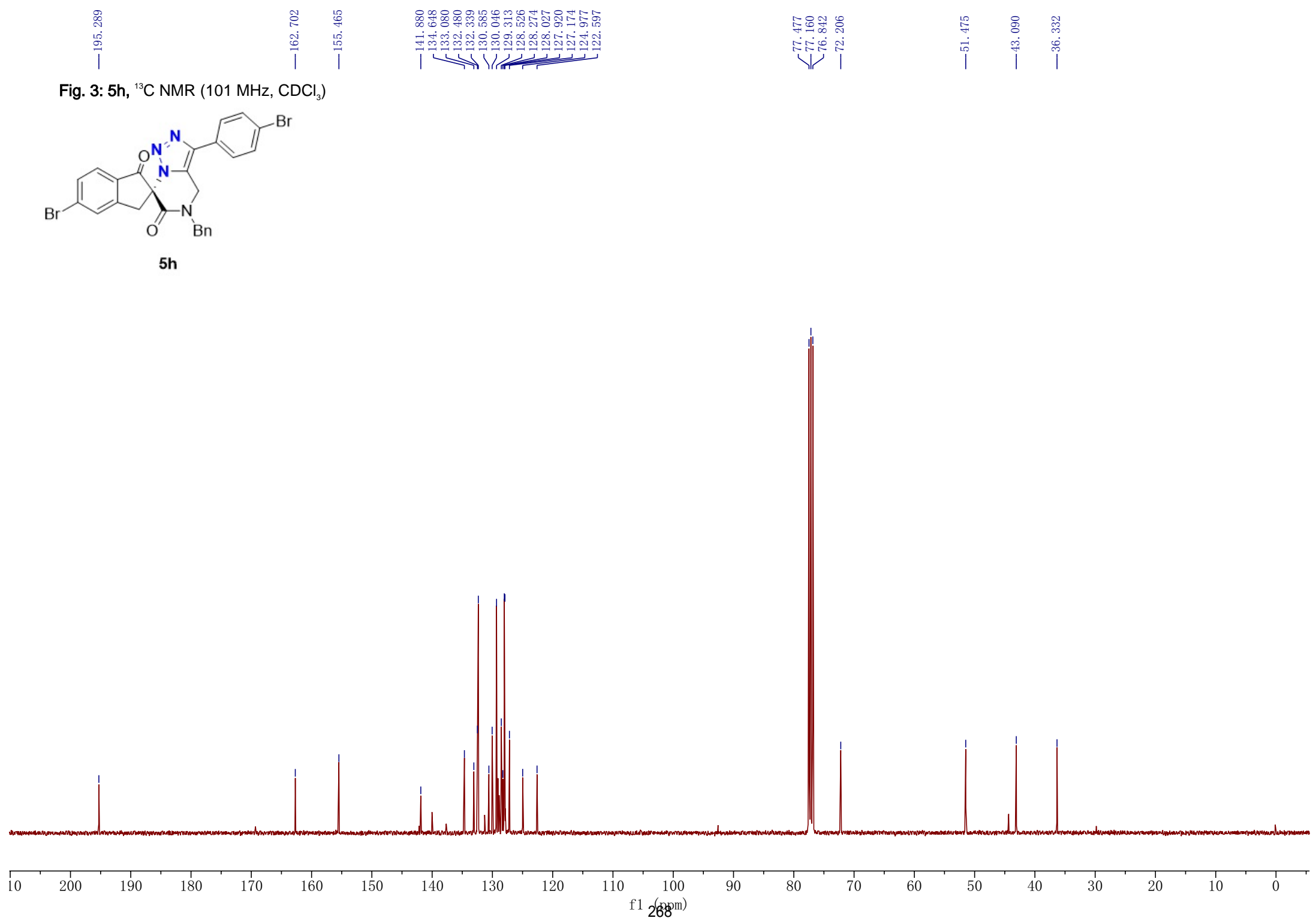
Fig. 3: 5h, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



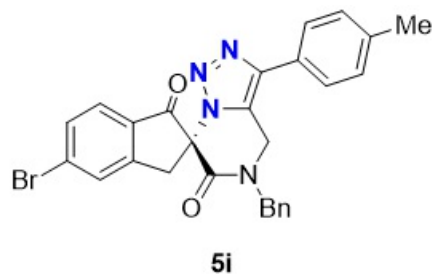


**5h**

**Fig. 3: 5h,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**







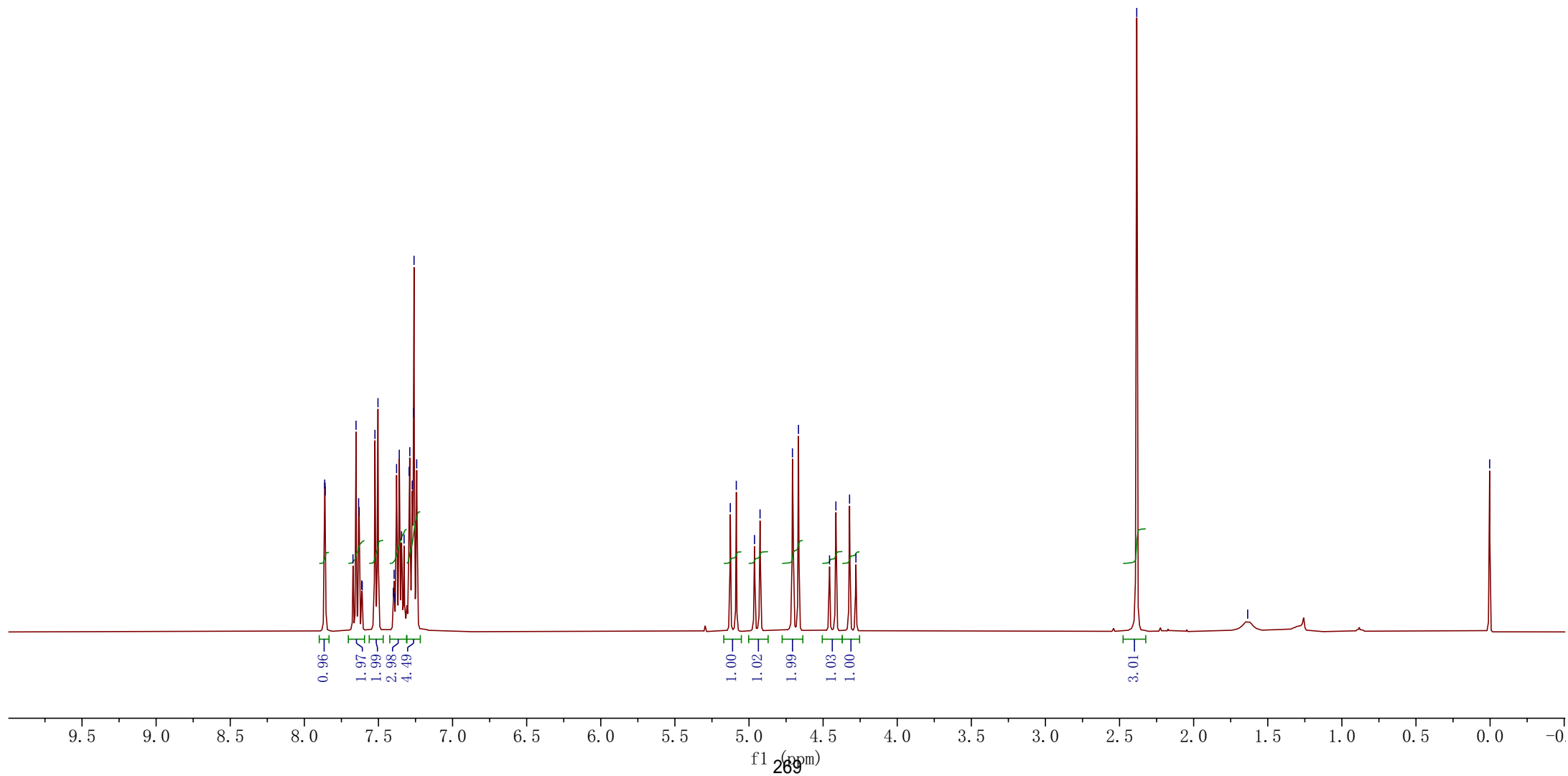
7.863  
7.859  
7.672  
7.651  
7.634  
7.630  
7.613  
7.610  
7.524  
7.503  
7.399  
7.394  
7.390  
7.378  
7.360  
7.344  
7.327  
7.293  
7.289  
7.272  
7.263  
7.260  
7.242

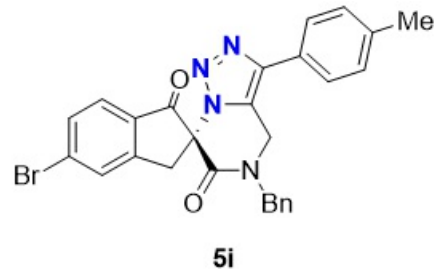
5.126  
5.086  
4.963  
4.926  
4.707  
4.666  
4.457  
4.414  
4.322  
4.279

— 2.384

— 1.636

— 0.003





**Fig. 3: 5i,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**

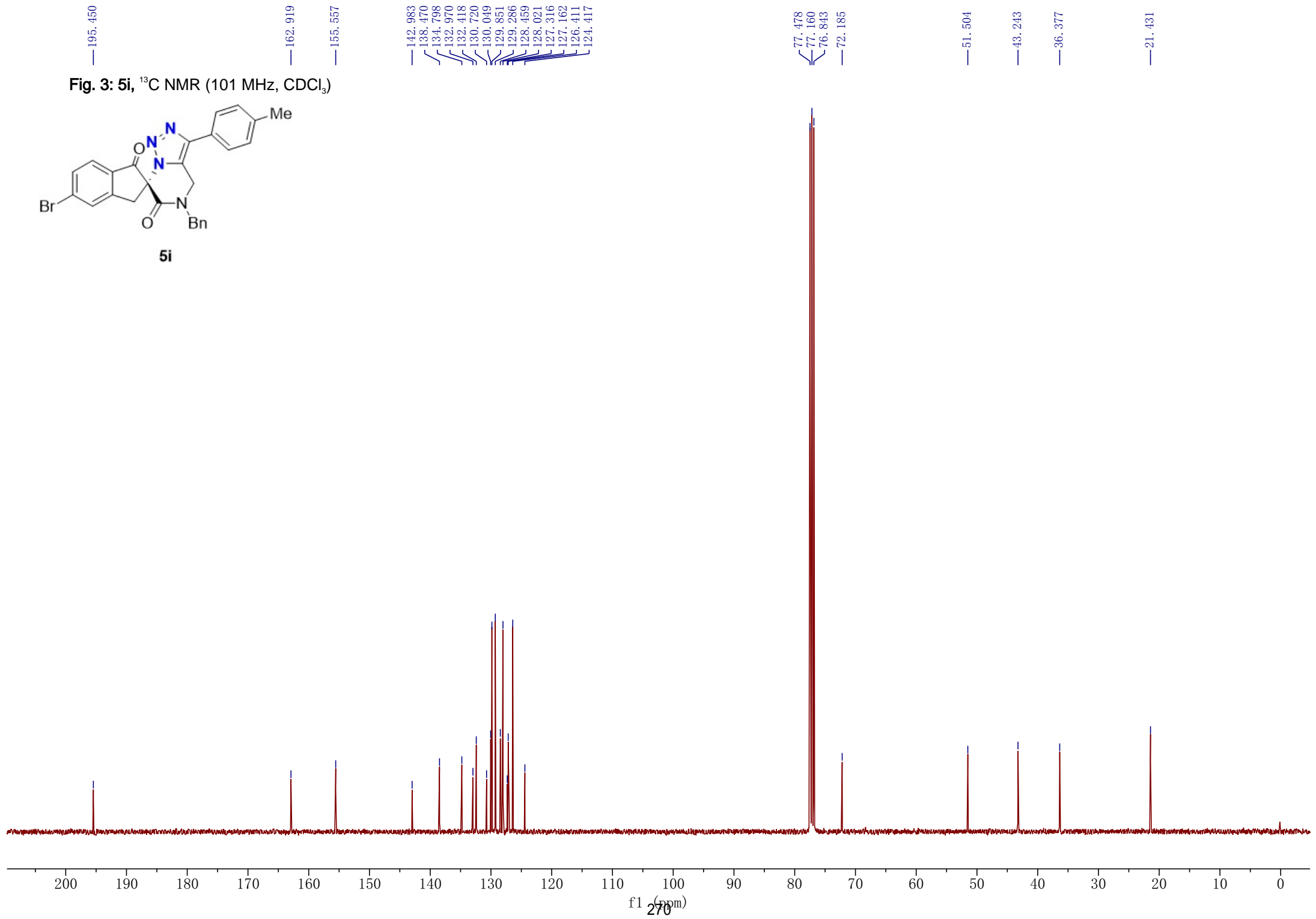
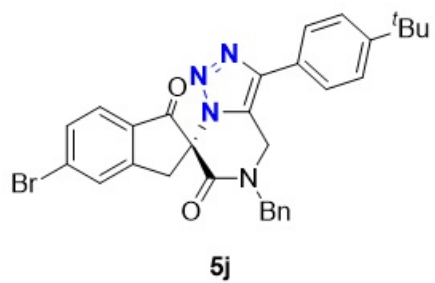


Fig. 3: 5j, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



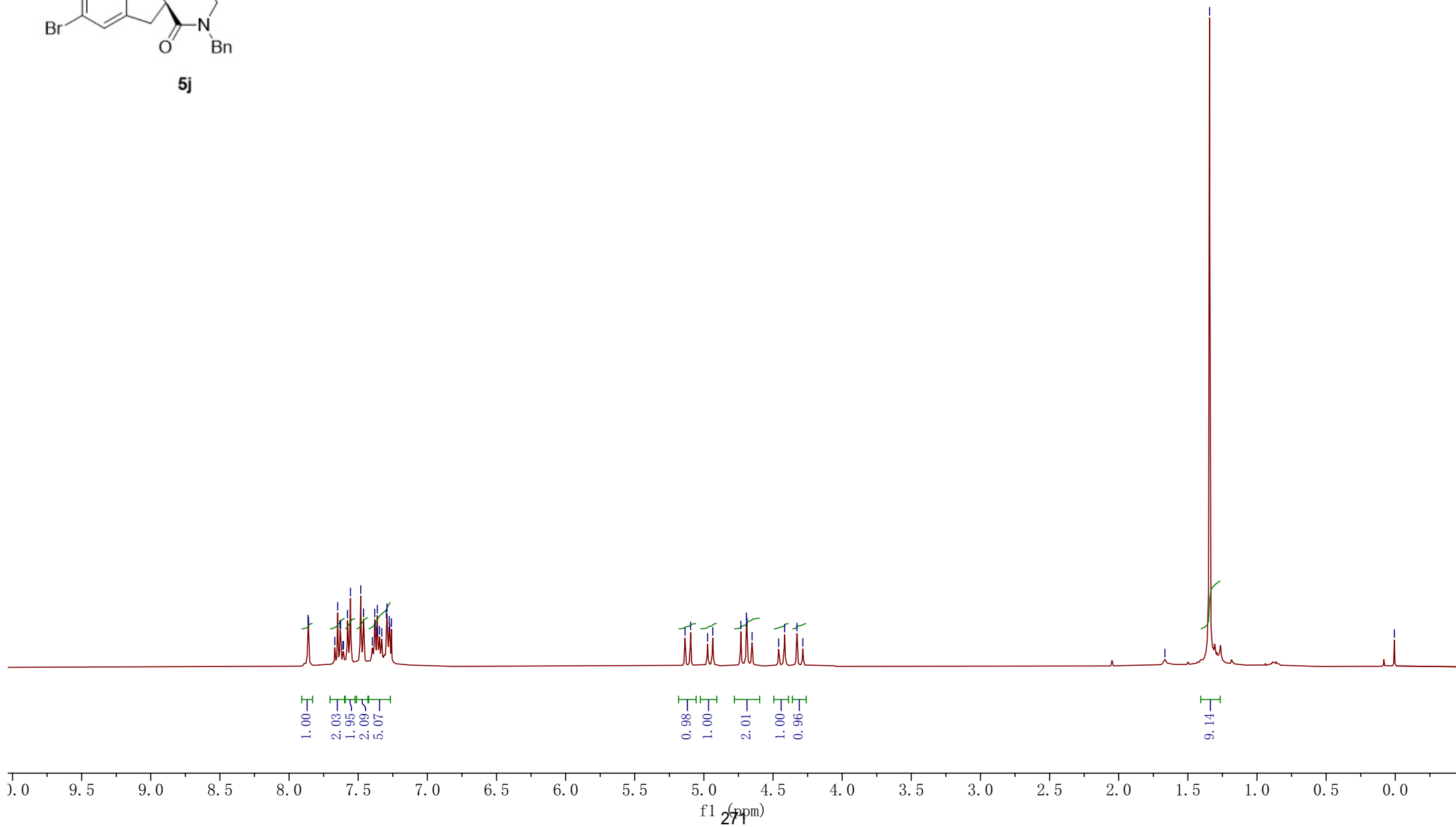
7.863  
7.859  
7.669  
7.648  
7.631  
7.627  
7.611  
7.607  
7.577  
7.556  
7.482  
7.461  
7.397  
7.381  
7.376  
7.366  
7.362  
7.347  
7.329  
7.296  
7.291  
7.275  
7.272  
7.260

5.136  
5.096  
4.973  
4.936  
4.733  
4.692  
4.689  
4.652  
4.459  
4.416  
4.327  
4.284

1.666

1.343

0.007



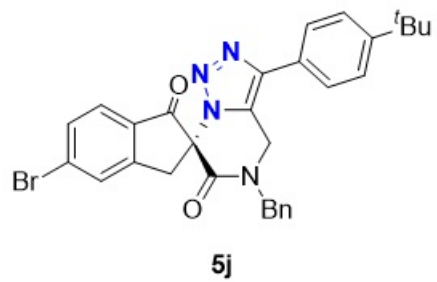
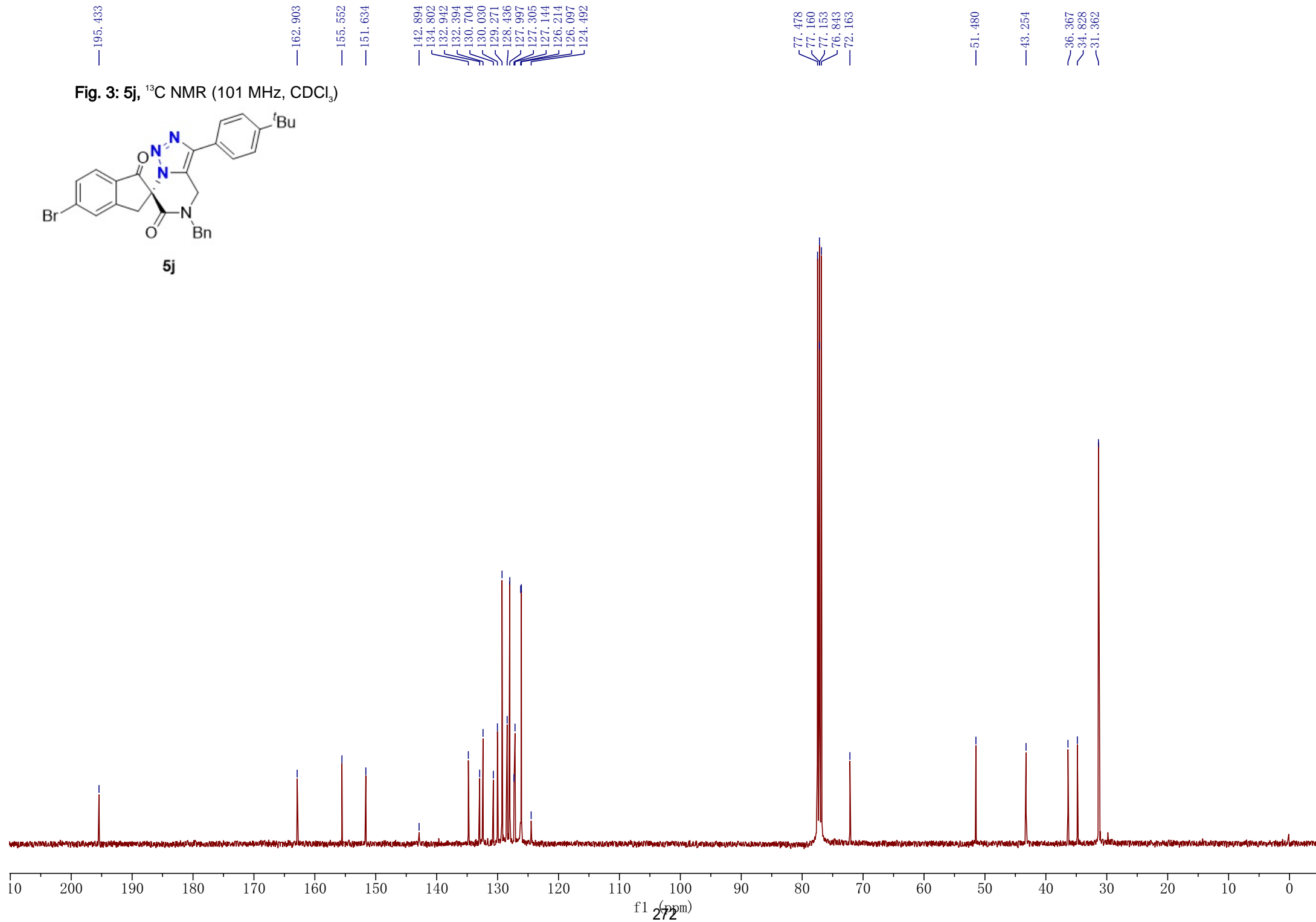


Fig. 3: **5j**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



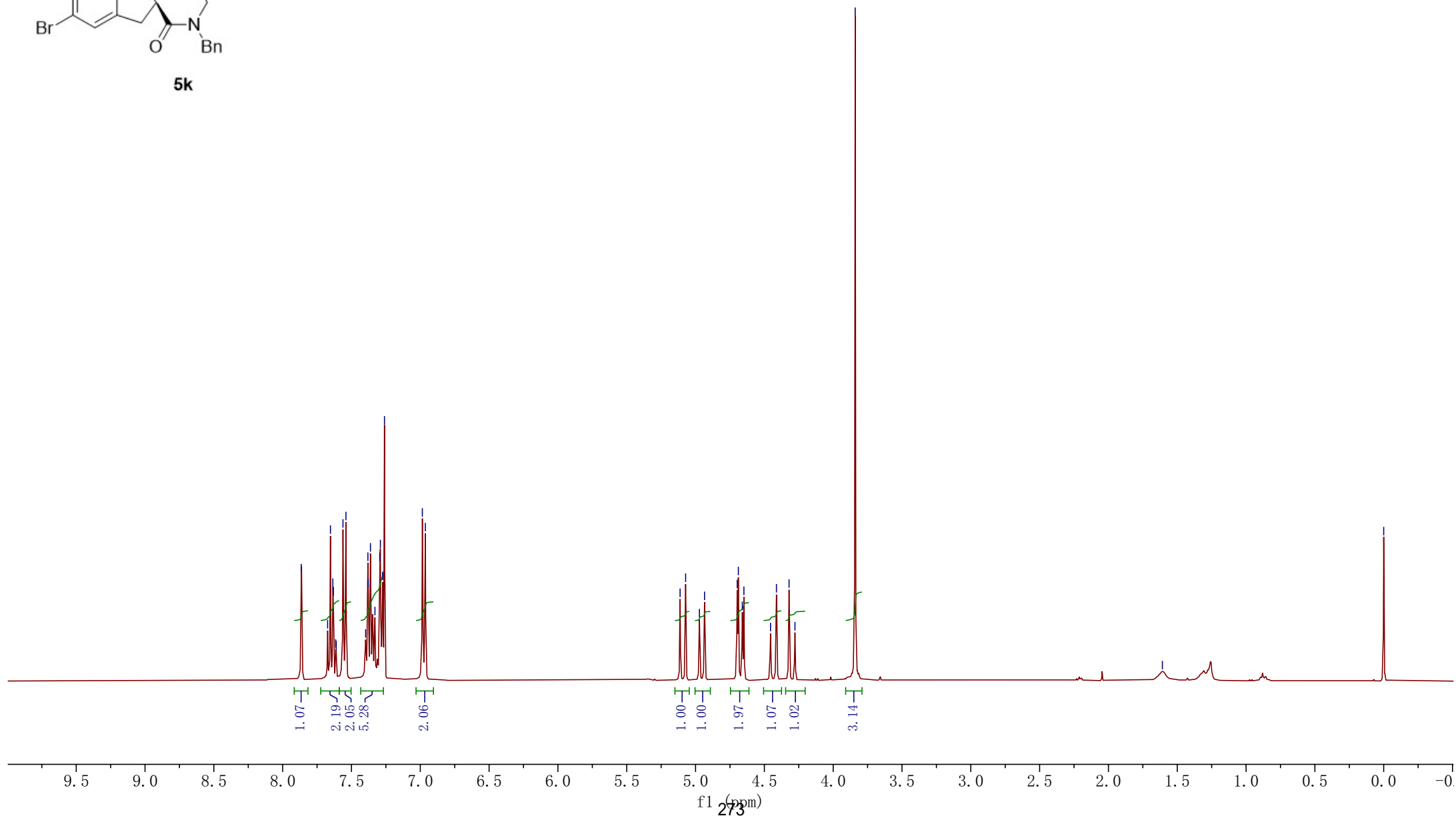
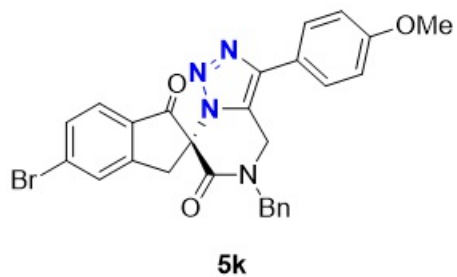
7.865  
7.673  
7.653  
7.635  
7.632  
7.615  
7.611  
7.562  
7.540  
7.397  
7.381  
7.379  
7.362  
7.329  
7.294  
7.290  
7.274  
7.260  
6.985  
6.963

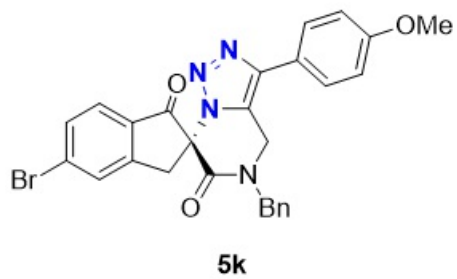
5.112  
5.072  
4.972  
4.935  
4.697  
4.689  
4.660  
4.649  
4.455  
4.412  
4.321  
4.278  
3.840

1.608

-0.000

Fig. 3: 5k, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)





— 195.473 — 162.938 — 159.815 — 155.565 — 142.819 — 134.802 — 132.975 — 132.422 — 130.719 — 130.054 — 129.293 — 128.465 — 128.020 — 127.845 — 127.171 — 123.934 — 122.745 — 114.602

77.478 — 77.160 — 76.842 — 72.177

— 55.487 — 51.505

— 43.214

— 36.363

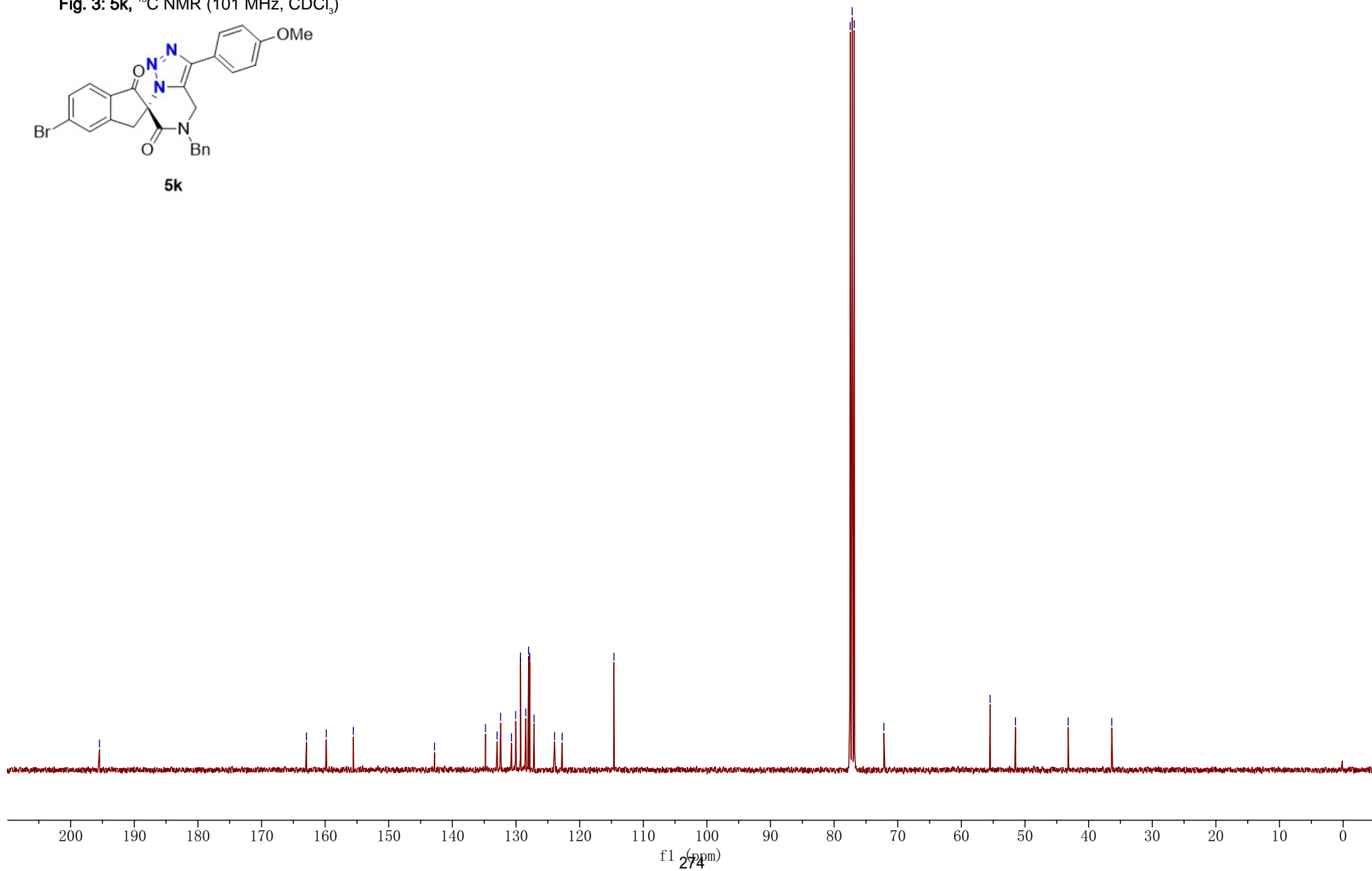
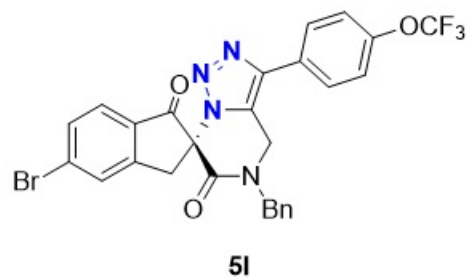


Fig. 3: 5I, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



7.871  
7.679  
7.674  
7.667  
7.659  
7.644  
7.625  
7.621  
7.391  
7.386  
7.372  
7.358  
7.354  
7.341  
7.309  
7.299  
7.294  
7.288  
7.278  
7.275  
7.260

5.133  
5.093  
4.996  
4.959  
4.705  
4.693  
4.665  
4.656  
4.457  
4.414  
4.337  
4.294

— 1.591

— 0.000

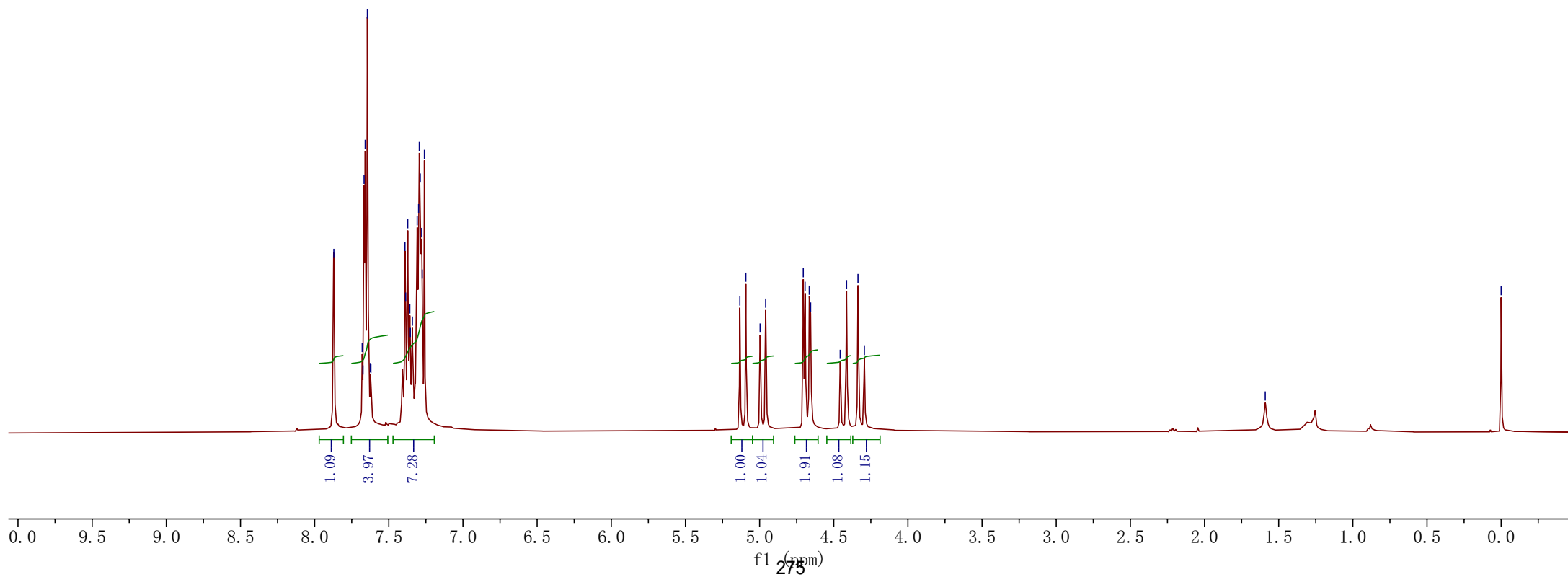
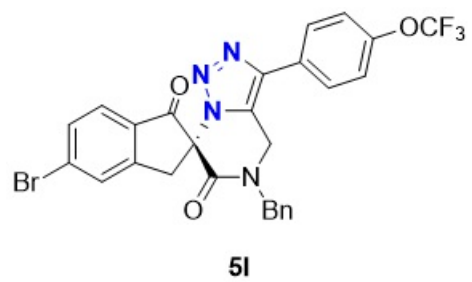
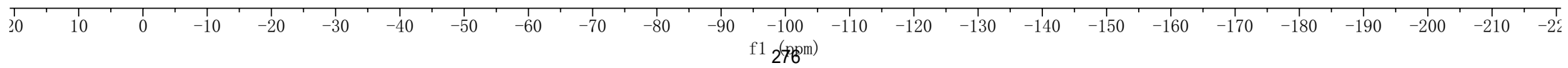


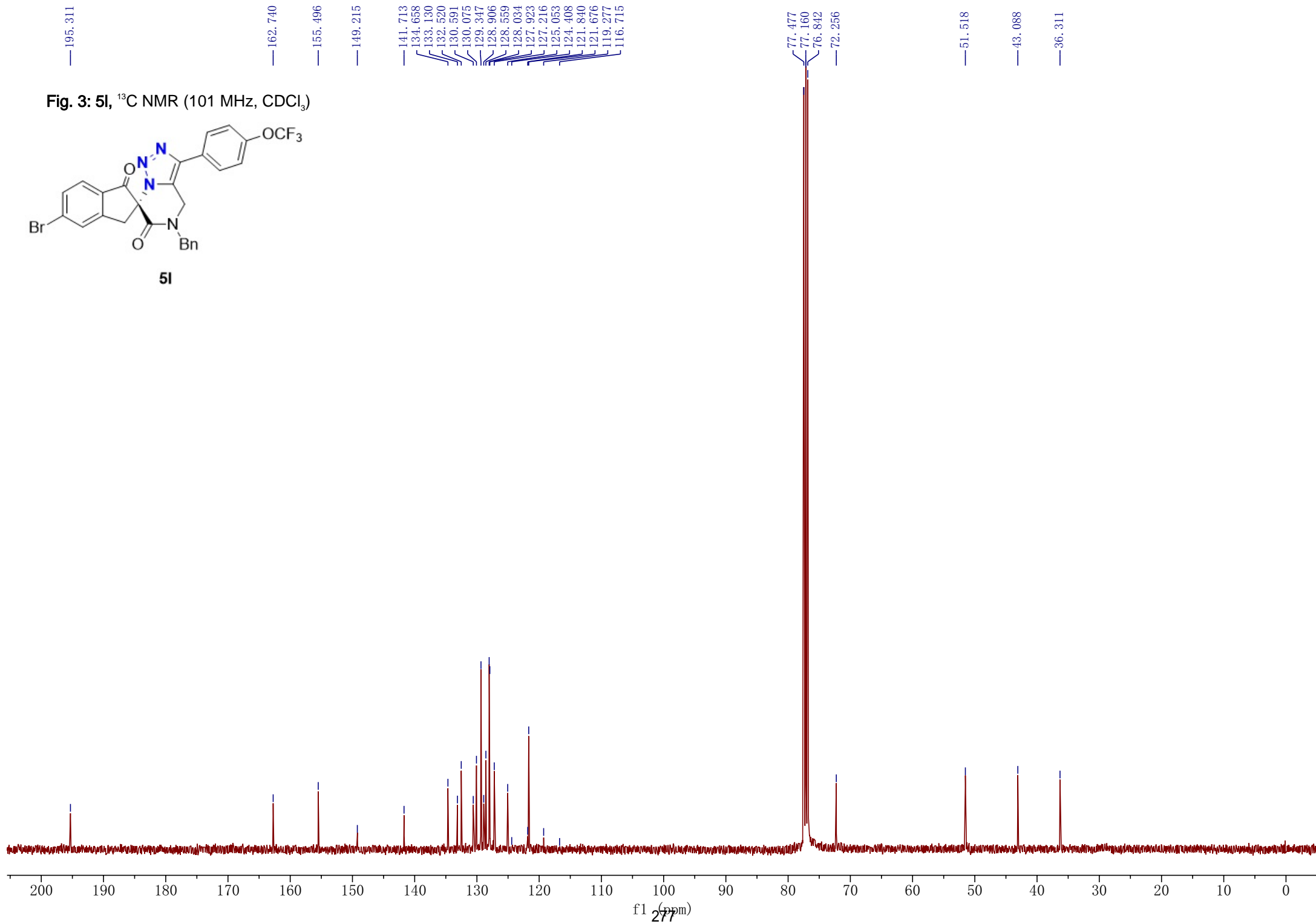
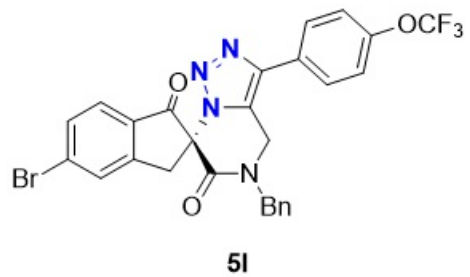
Fig. 2: 5I,  $^{19}\text{F}$  NMR (376 MHz,  $\text{CDCl}_3$ )

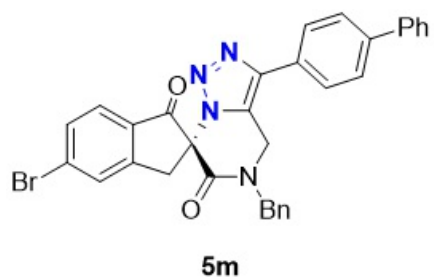


—57.787









7.874  
7.870  
7.721  
7.706  
7.699  
7.691  
7.684  
7.671  
7.669  
7.663  
7.644  
7.640  
7.633  
7.629  
7.624  
7.619  
7.616  
7.612  
7.609  
7.481  
7.463  
7.444  
7.409  
7.396  
7.392  
7.388  
7.379  
7.374  
7.368  
7.360  
7.356  
7.352  
7.338  
7.315  
7.310  
7.298  
7.293

5.181  
5.141  
4.995  
4.957  
4.771  
4.731  
4.718  
4.680  
4.472  
4.429  
4.339  
4.296

— 1.619

— 0.006

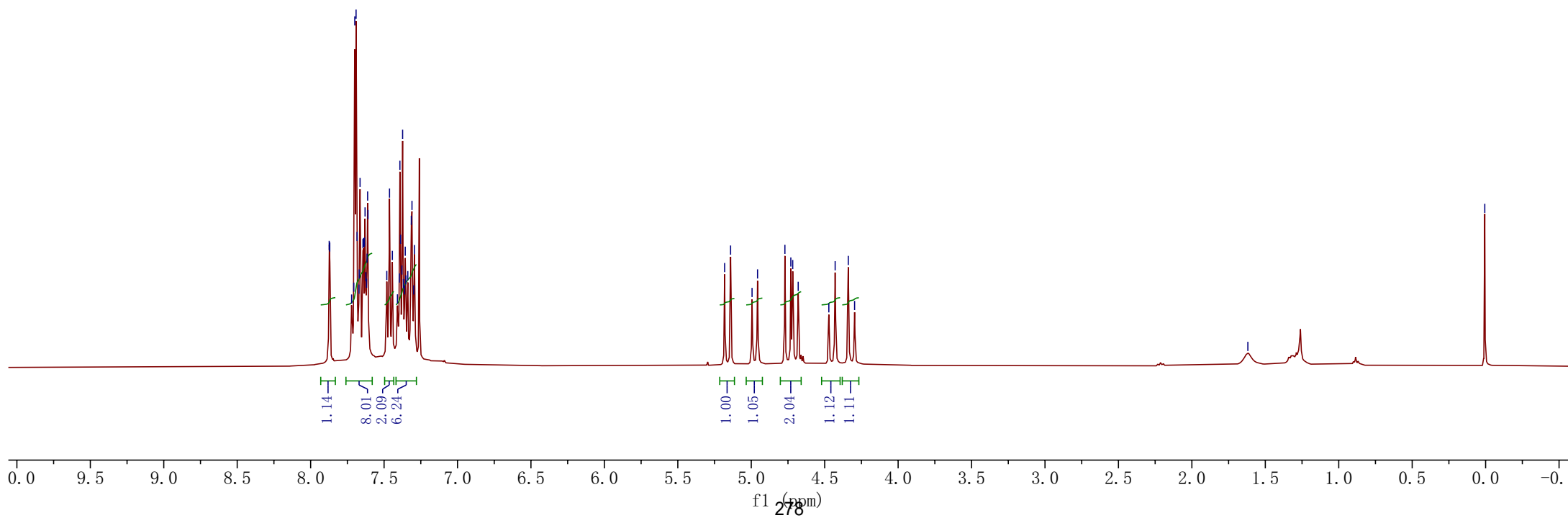
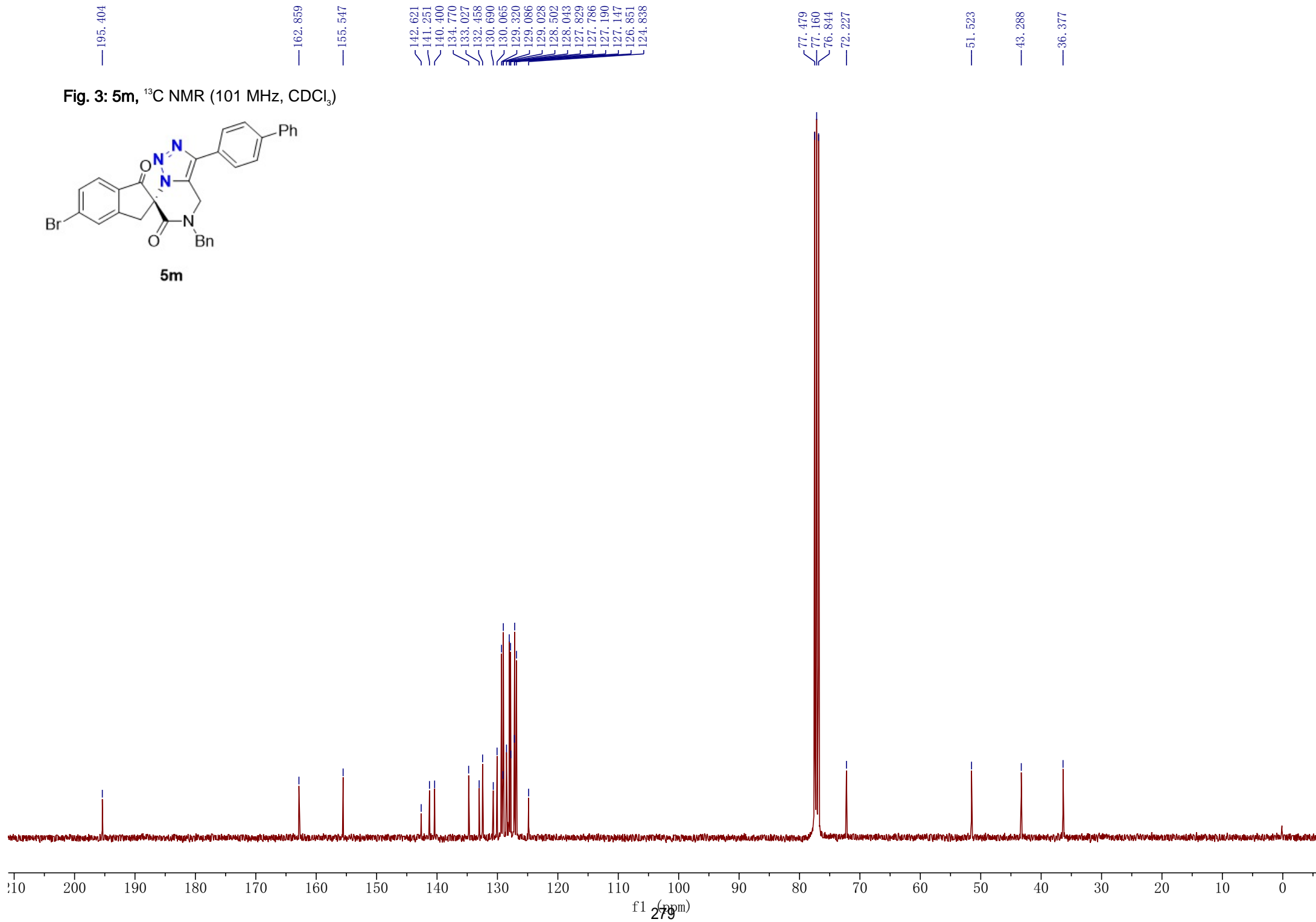
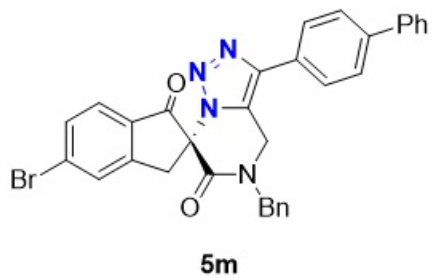


Fig. 3: 5m, <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)

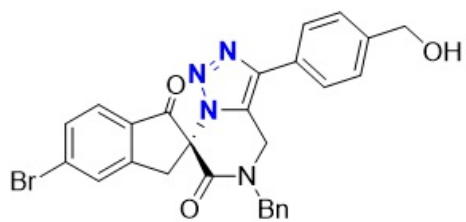


7.862  
7.859  
7.670  
7.650  
7.635  
7.631  
7.614  
7.610  
7.595  
7.575  
7.445  
7.427  
7.407  
7.375  
7.356  
7.290  
7.285  
7.269  
7.260

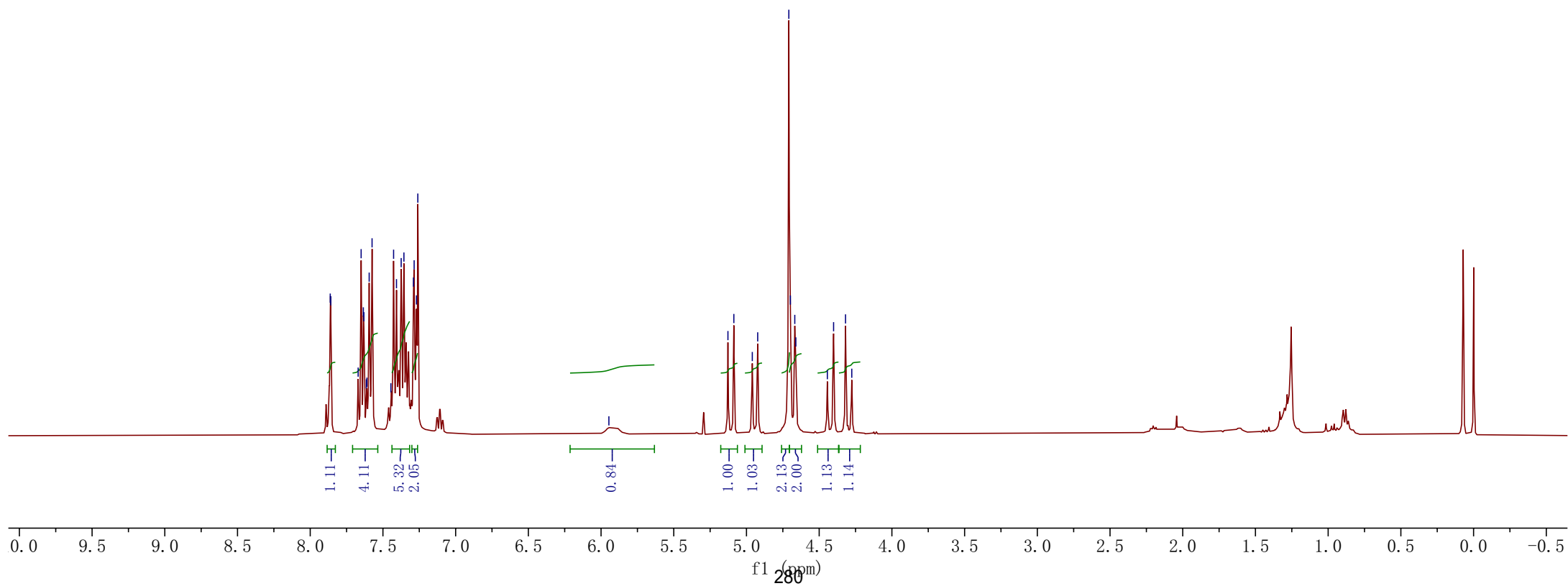
5.946

5.127  
5.087  
4.960  
4.923  
4.709  
4.698  
4.668  
4.661  
4.444  
4.401  
4.319  
4.276

Fig. 3: 5n, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



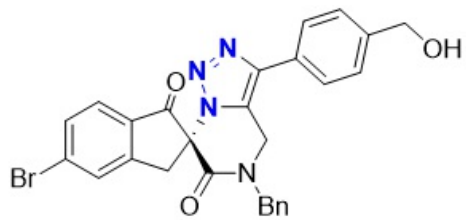
5n



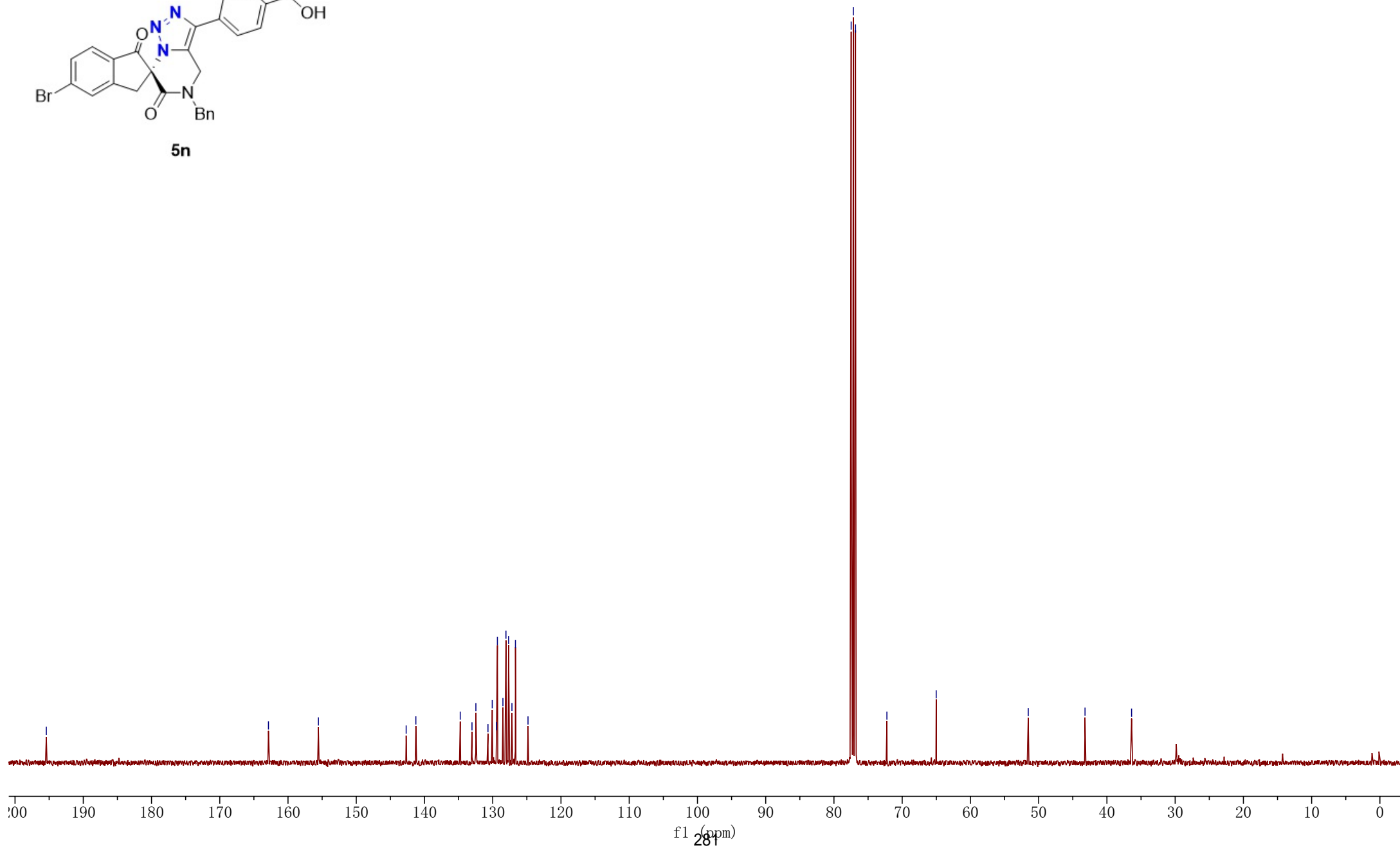
195.416  
162.863  
155.546  
142.685  
141.266  
134.762  
133.041  
132.469  
130.697  
130.071  
129.450  
129.315  
128.507  
128.064  
127.677  
127.186  
126.671  
124.831

77.478  
77.160  
76.843  
72.239  
65.017  
51.529  
43.209  
36.384

Fig. 3: 5n,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



5n



7.864  
7.860  
7.809  
7.805  
7.790  
7.786  
7.670  
7.650  
7.631  
7.627  
7.610  
7.606  
7.393  
7.377  
7.358  
7.327  
7.296  
7.296  
7.296  
7.291  
7.275  
7.272  
7.260  
7.088  
7.085  
7.069  
7.066  
7.050  
7.047  
6.932  
6.930  
6.911  
6.909

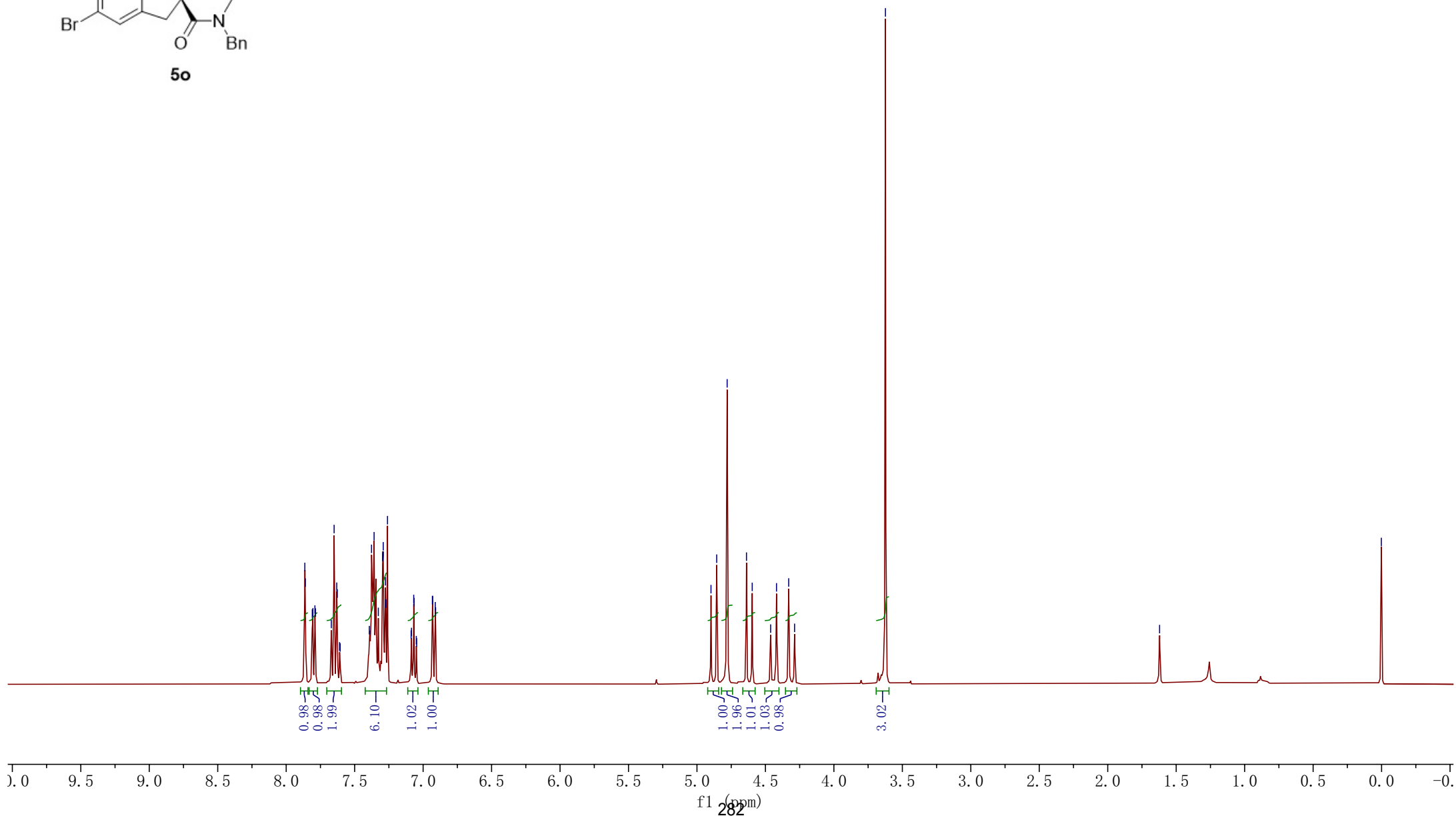
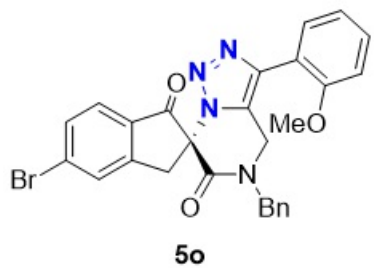
4.898  
4.856  
4.780  
4.638  
4.596  
4.462  
4.419  
4.330  
4.287

3.624

1.621

0.002

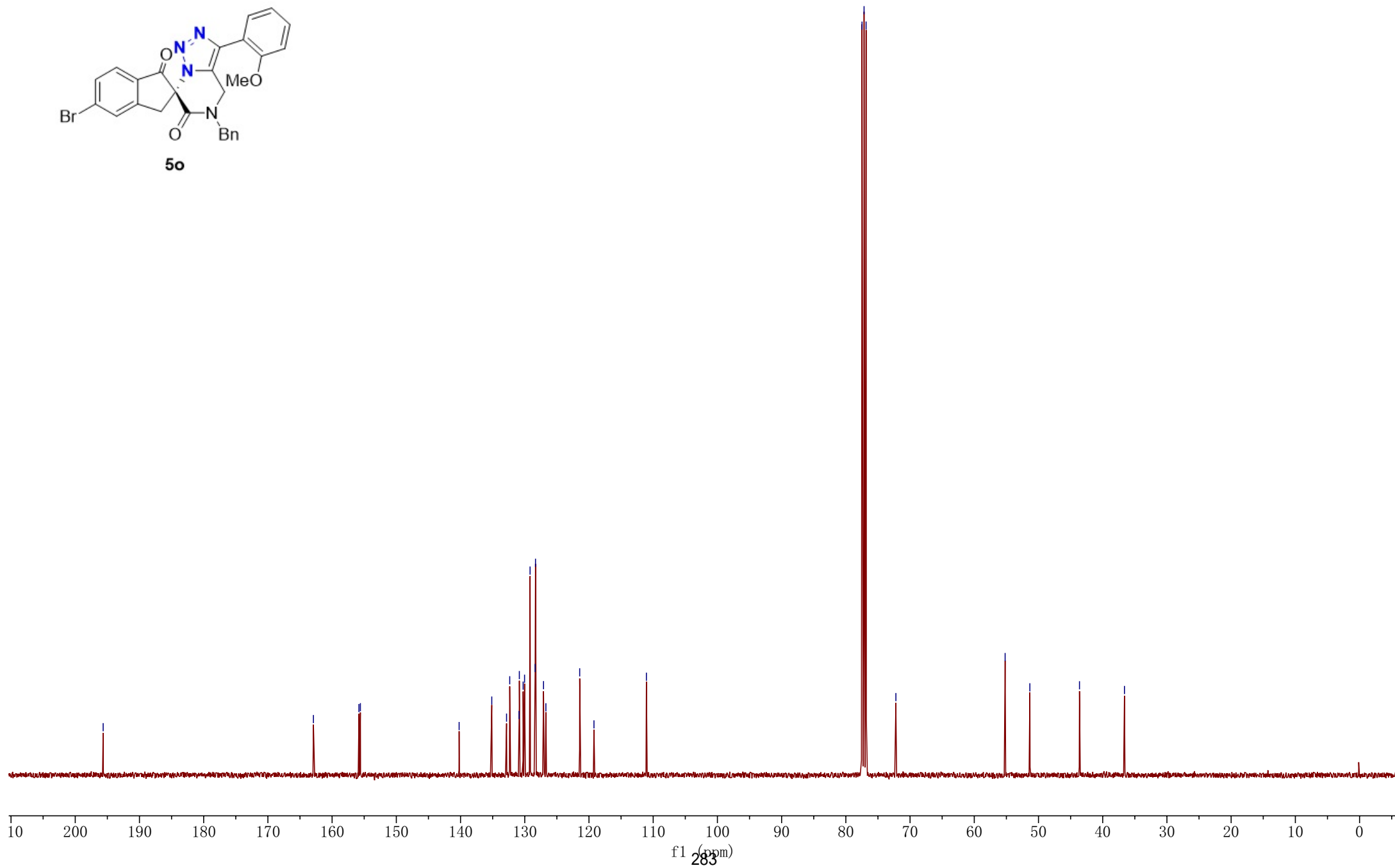
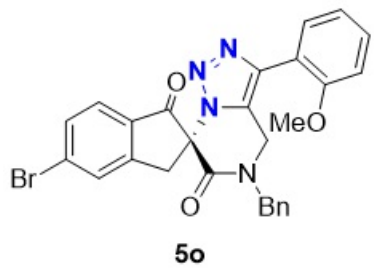
Fig. 3: 5o, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)

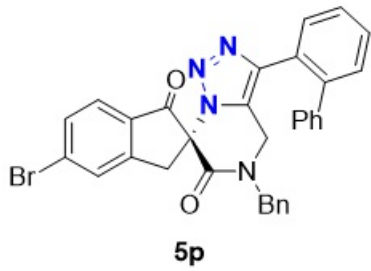


— 195.651  
— 162.910  
— 155.818  
— 155.594  
— 140.219  
— 135.135  
— 132.834  
— 132.339  
— 130.888  
— 130.843  
— 130.252  
— 130.030  
— 129.172  
— 128.381  
— 128.325  
— 127.077  
— 126.709  
— 121.445  
— 119.221  
— 111.057

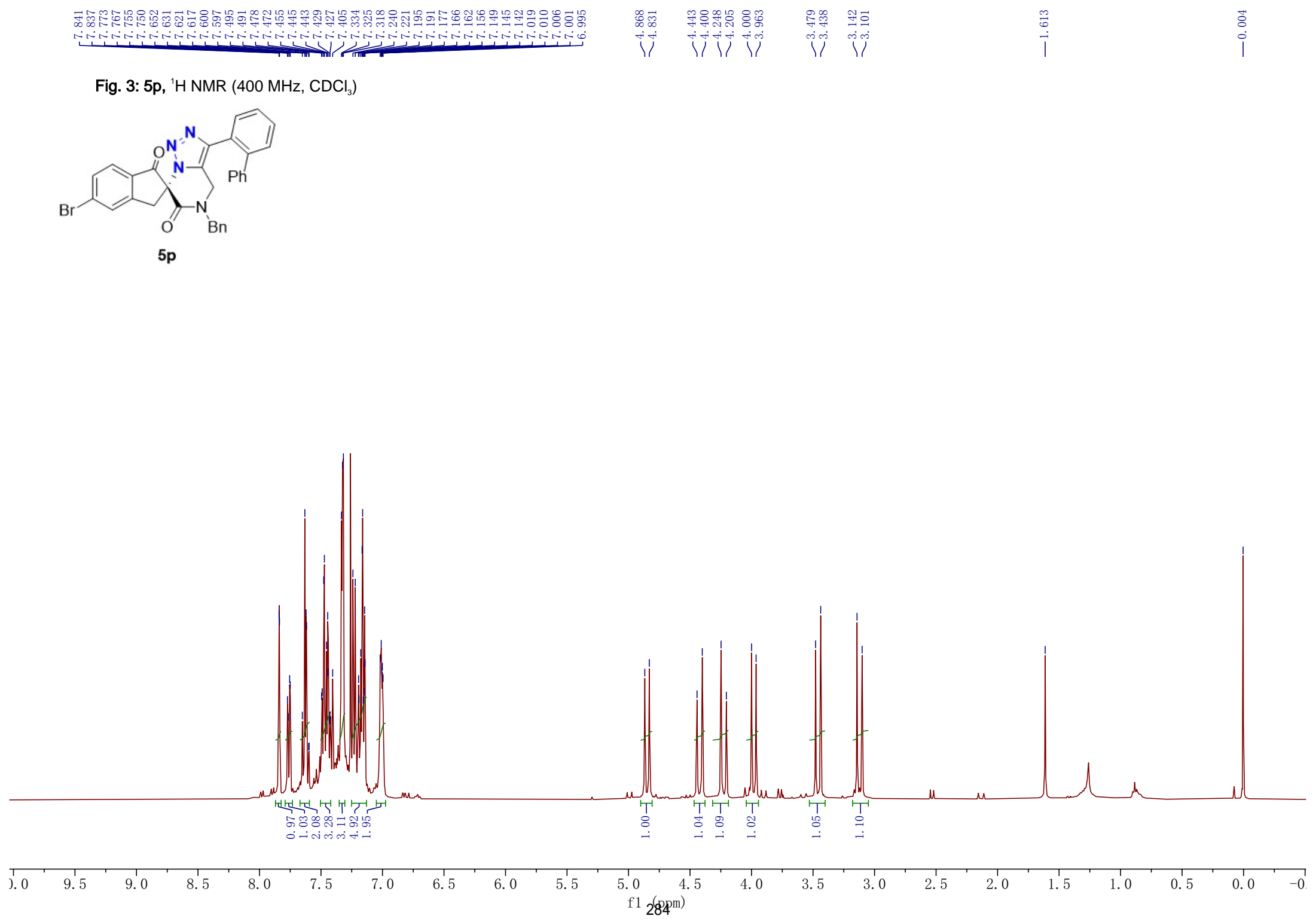
— 77.480  
— 77.162  
— 76.845  
— 72.206  
— 55.195  
— 51.342  
— 43.614  
— 36.612

Fig. 3: **5o**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )

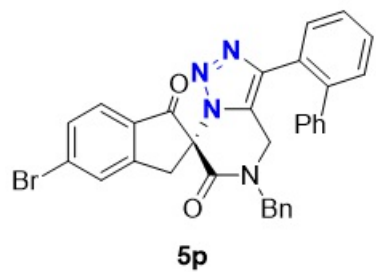




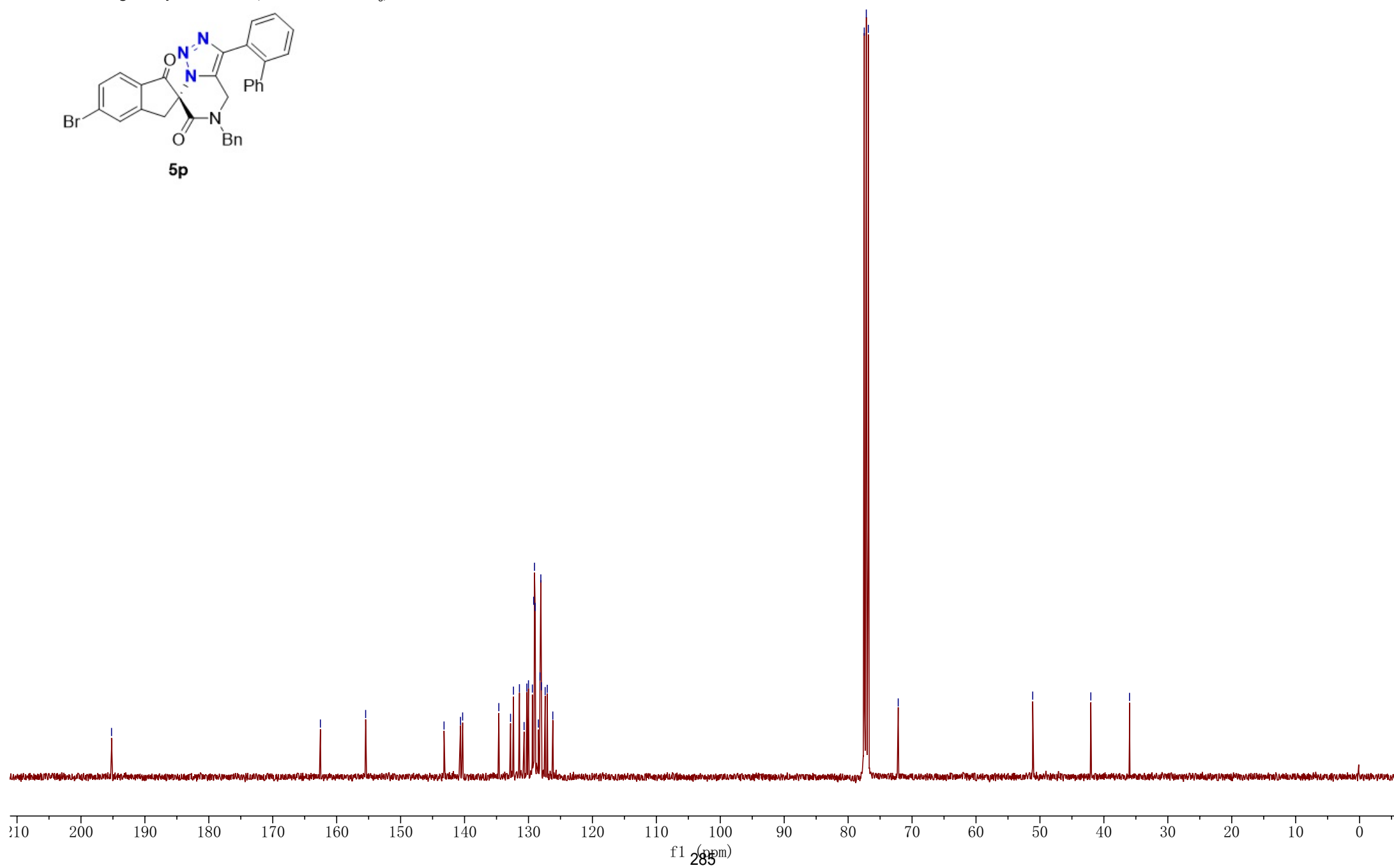
**Fig. 3: 5p, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**







**Fig. 3: 5p,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**

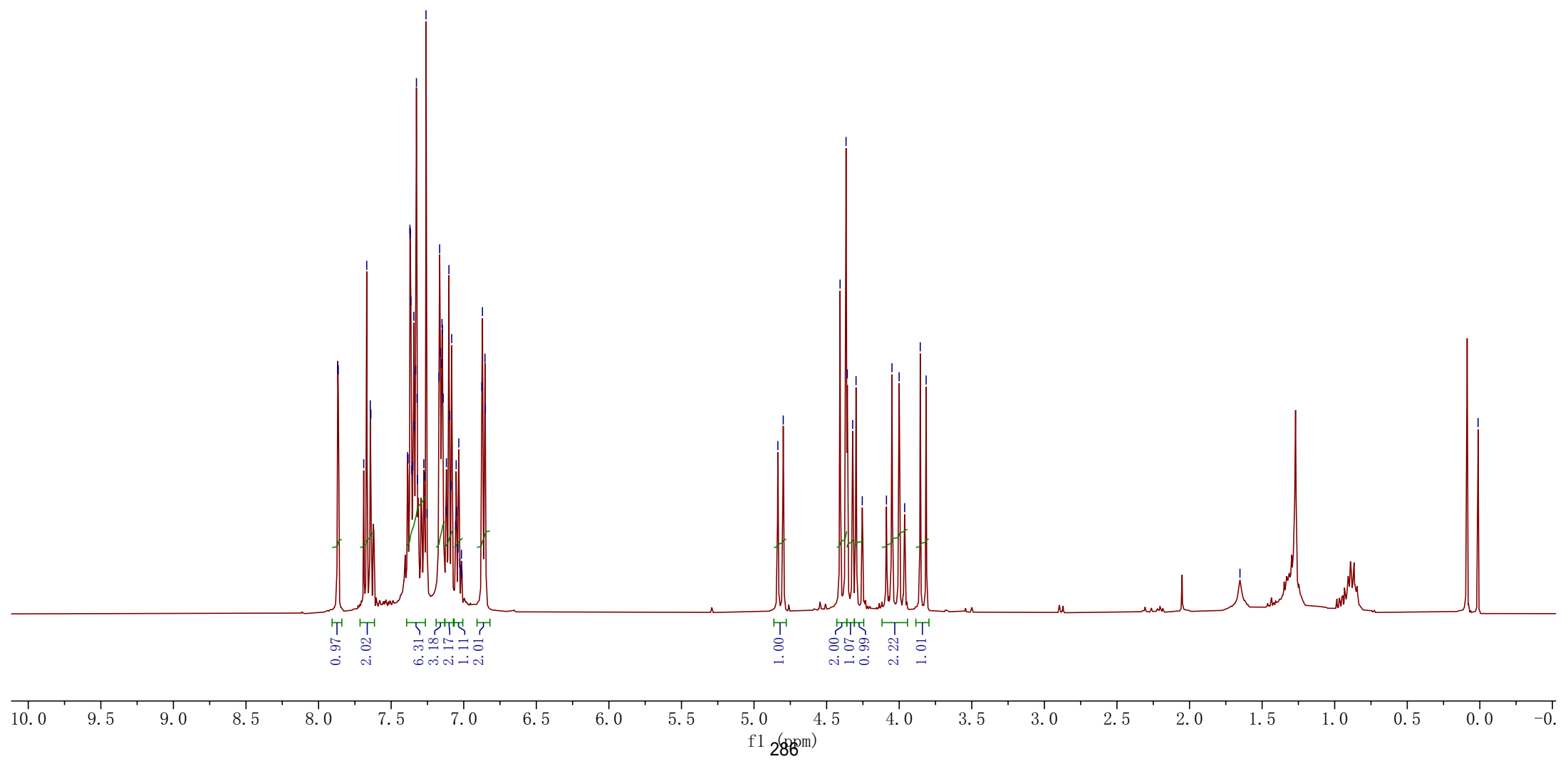
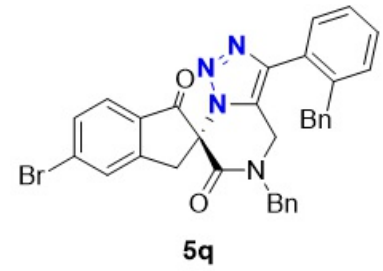


7.868  
7.864  
7.689  
7.668  
7.644  
7.640  
7.387  
7.384  
7.371  
7.368  
7.364  
7.358  
7.351  
7.344  
7.340  
7.331  
7.326  
7.321  
7.319  
7.275  
7.269  
7.260  
7.253  
7.171  
7.166  
7.160  
7.152  
7.150  
7.146  
7.141  
7.123  
7.119  
7.102  
7.098  
7.087  
7.083  
7.056  
7.052  
7.048  
7.040  
7.034  
7.027  
7.019  
7.016  
7.012  
6.875  
6.871  
6.854  
6.851  
4.836  
4.799  
4.407  
4.366  
4.358  
4.321  
4.297  
4.254  
4.088  
4.050  
4.000  
3.963  
3.855  
3.814

— 1.652

— 0.012

Fig. 3: 5q, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)



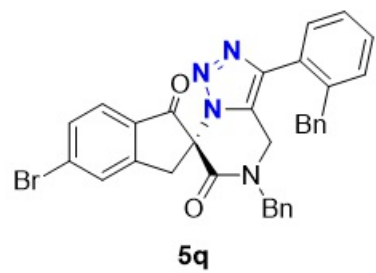
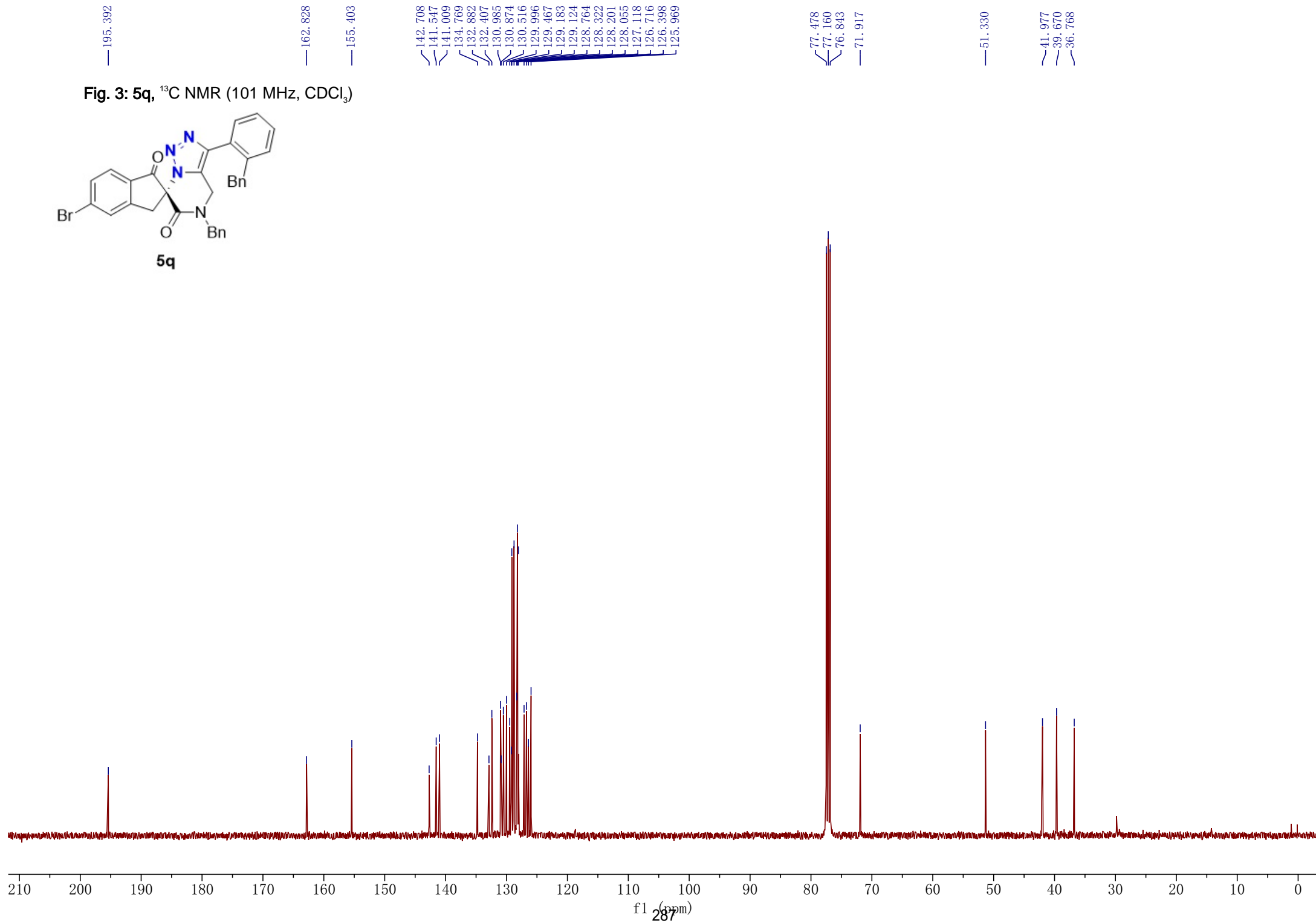
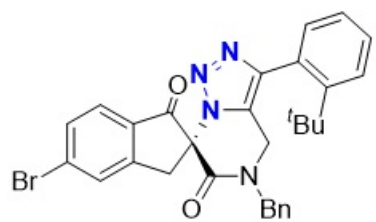


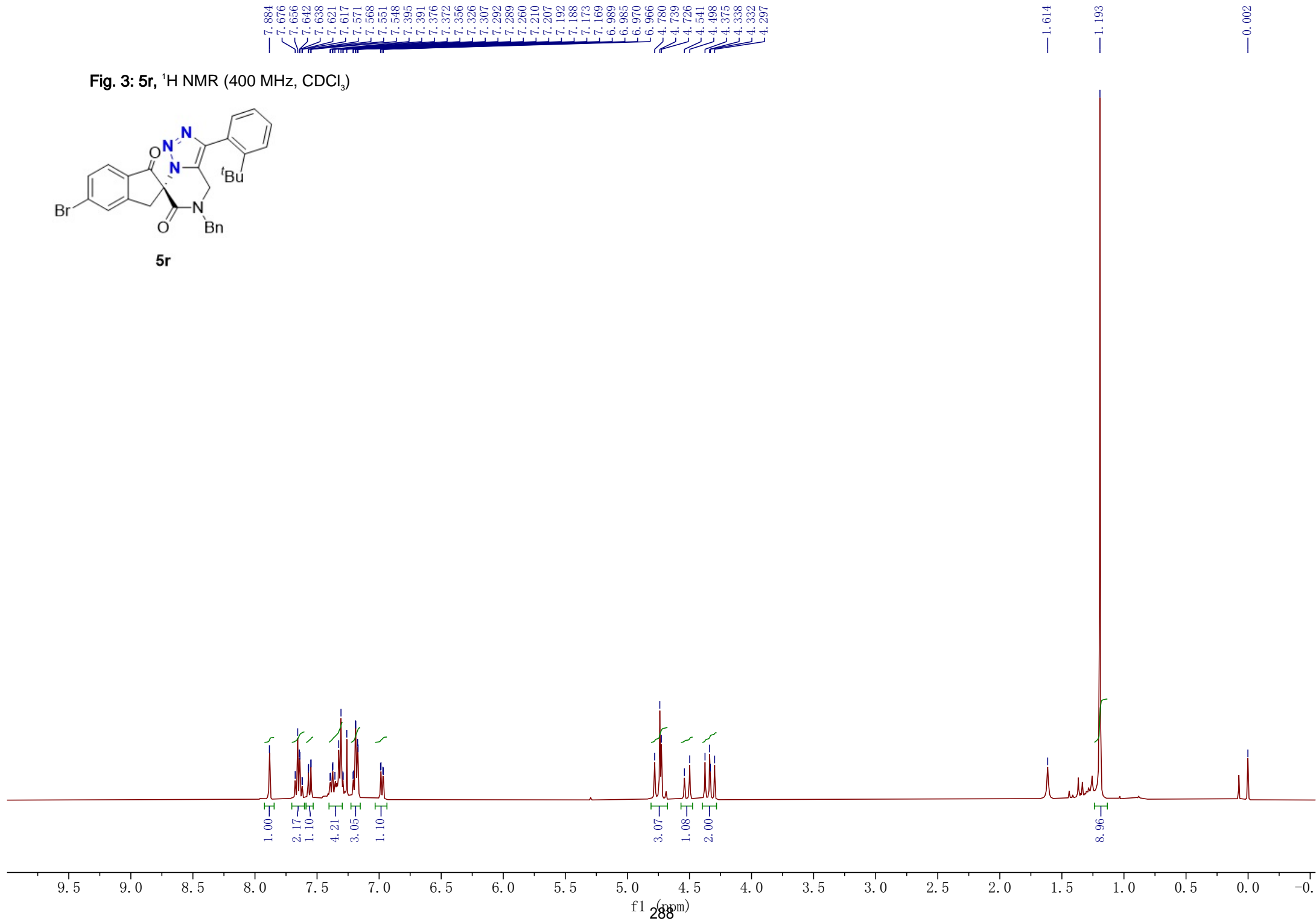
Fig. 3: 5q,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )

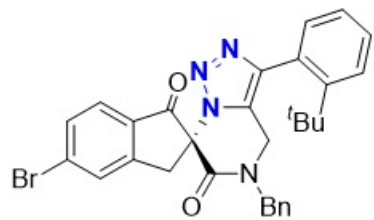




5r

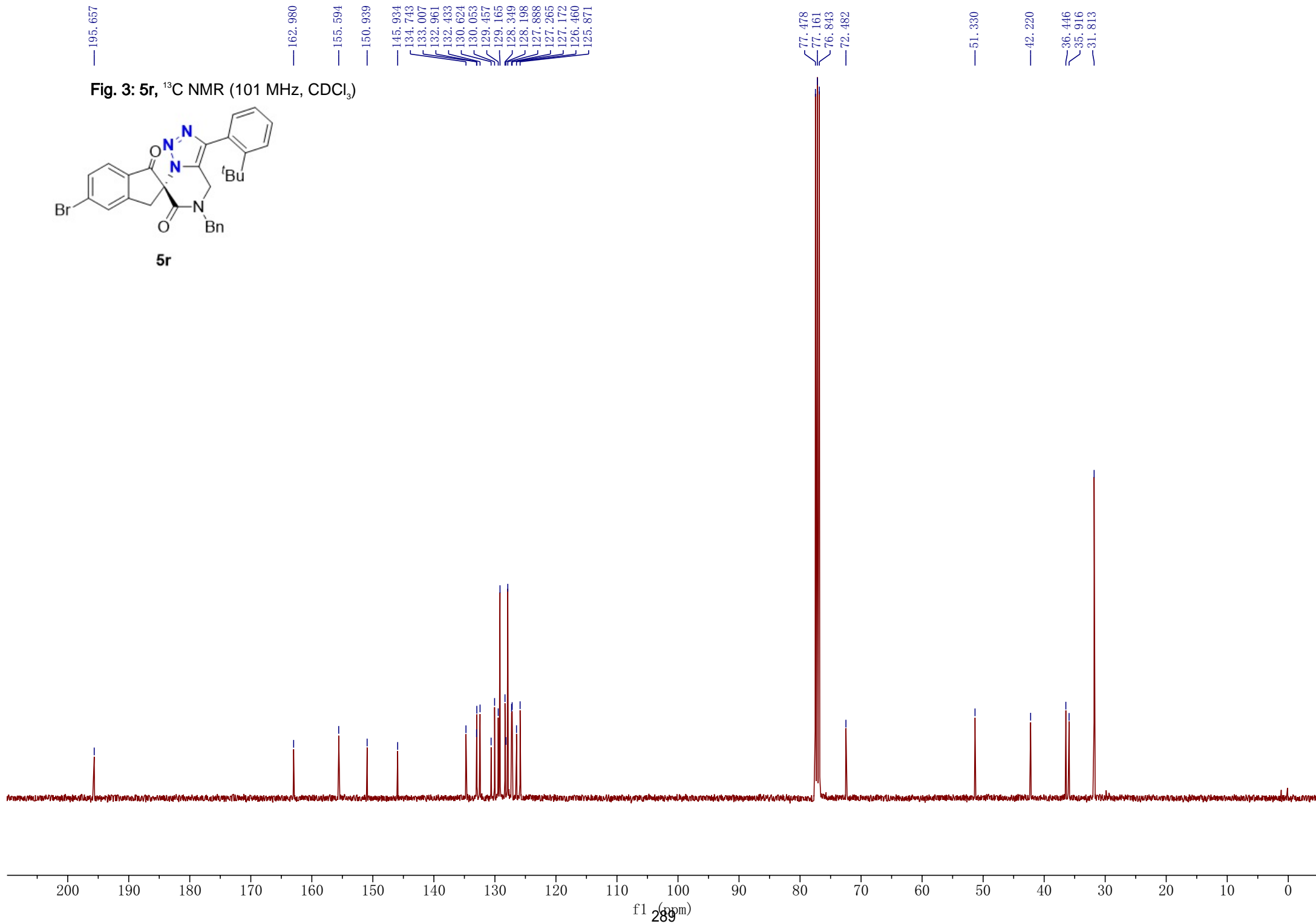
Fig. 3: 5r, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)

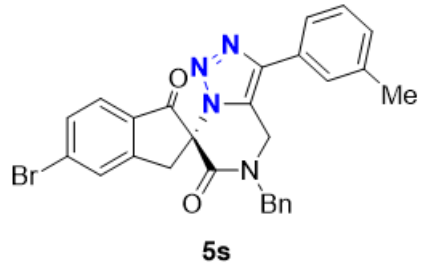




**5r**

**Fig. 3: 5r,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**





7.861  
7.672  
7.652  
7.632  
7.611  
7.528  
7.397  
7.380  
7.361  
7.347  
7.331  
7.320  
7.291  
7.274  
7.260  
7.190  
7.178  
7.167

5.142  
5.102  
4.959  
4.922  
4.723  
4.712  
4.682  
4.675  
4.463  
4.420  
4.325  
4.282

— 2.397

— 1.633

— 0.005

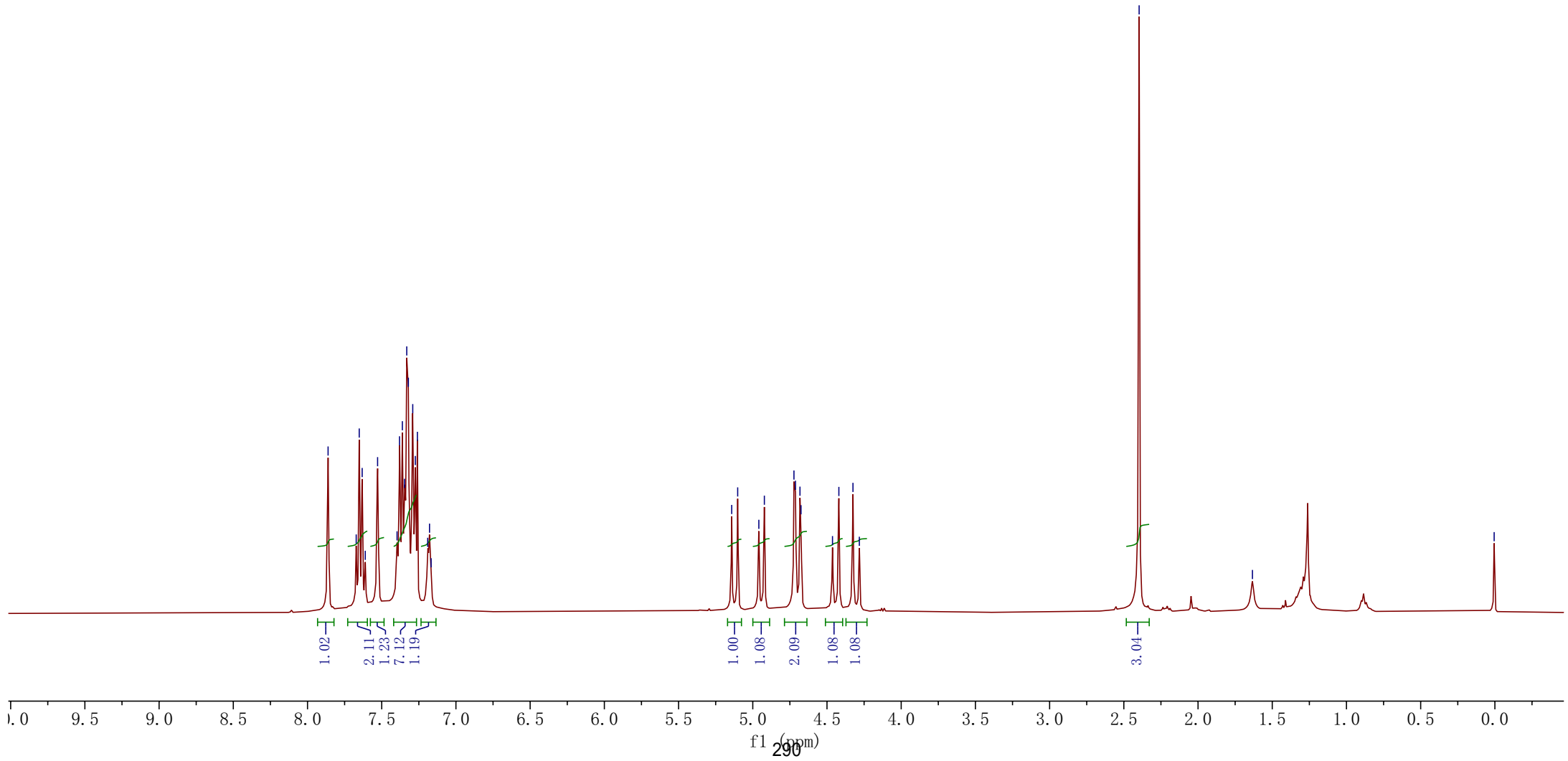
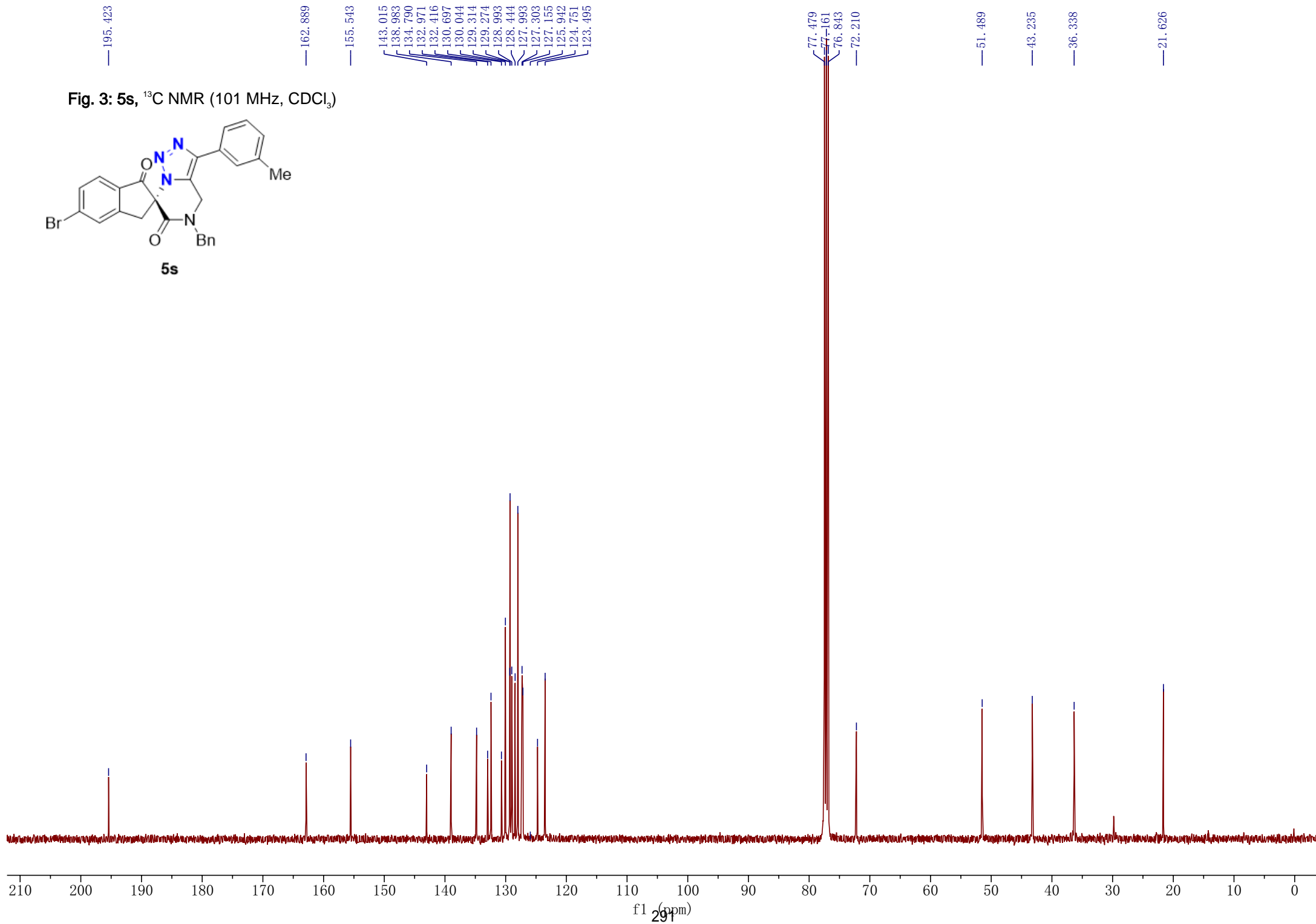
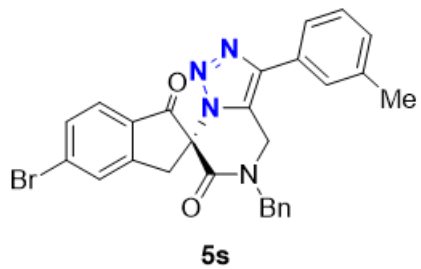
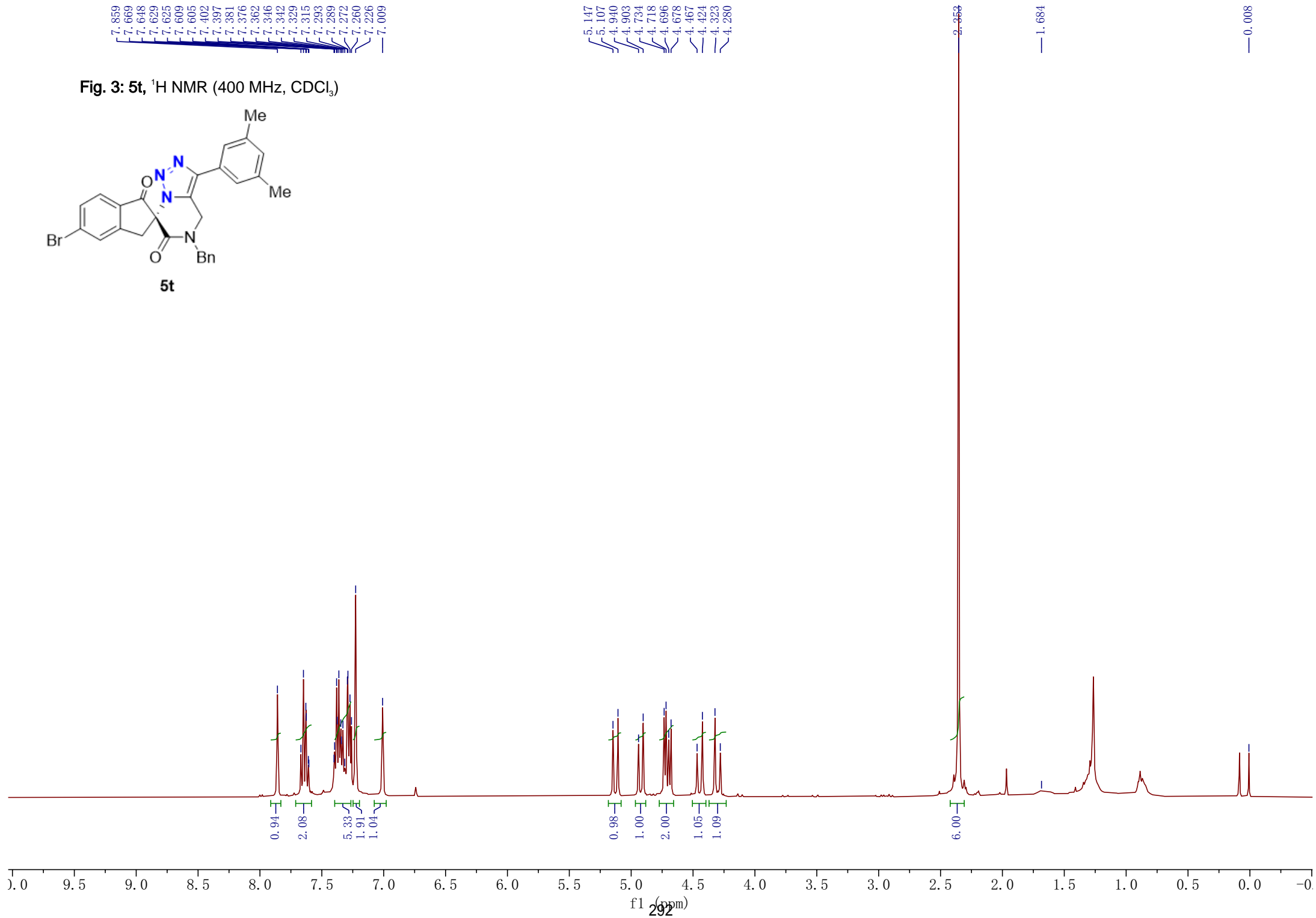
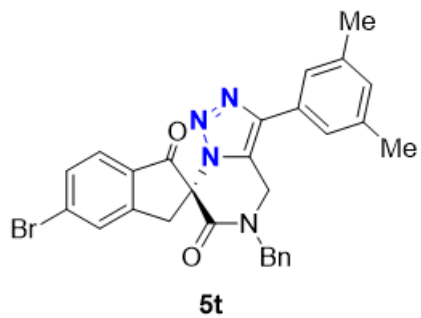
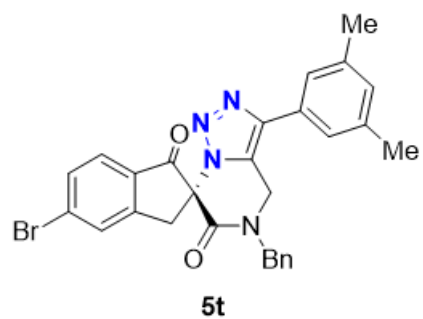


Fig. 3: **5s**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )









**Fig. 3: 5t,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**

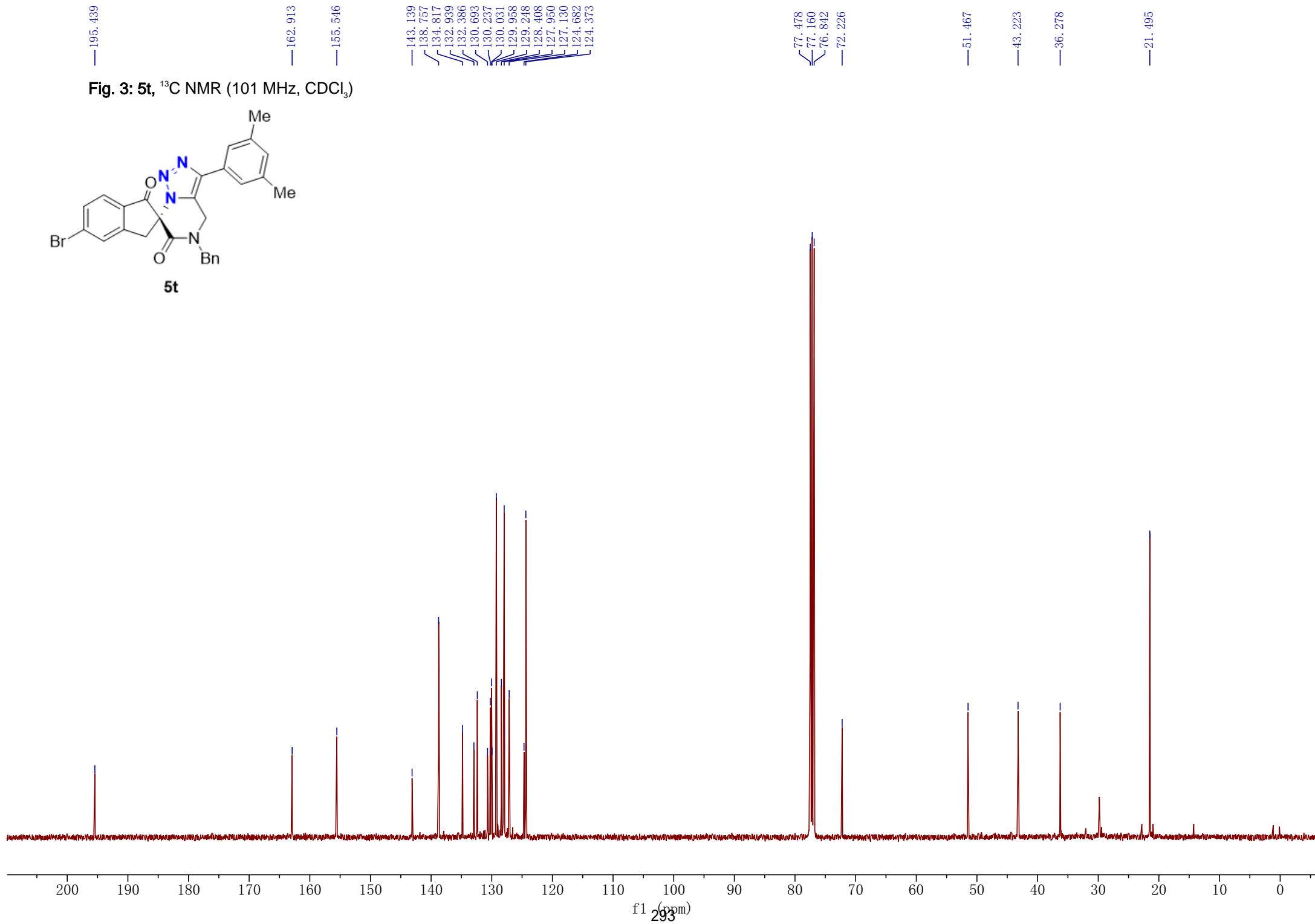
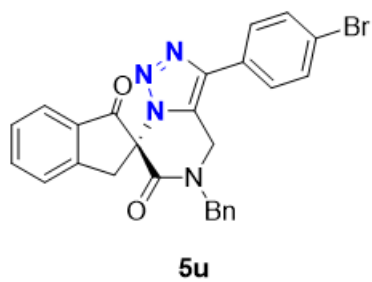


Fig. 3: 5u, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)

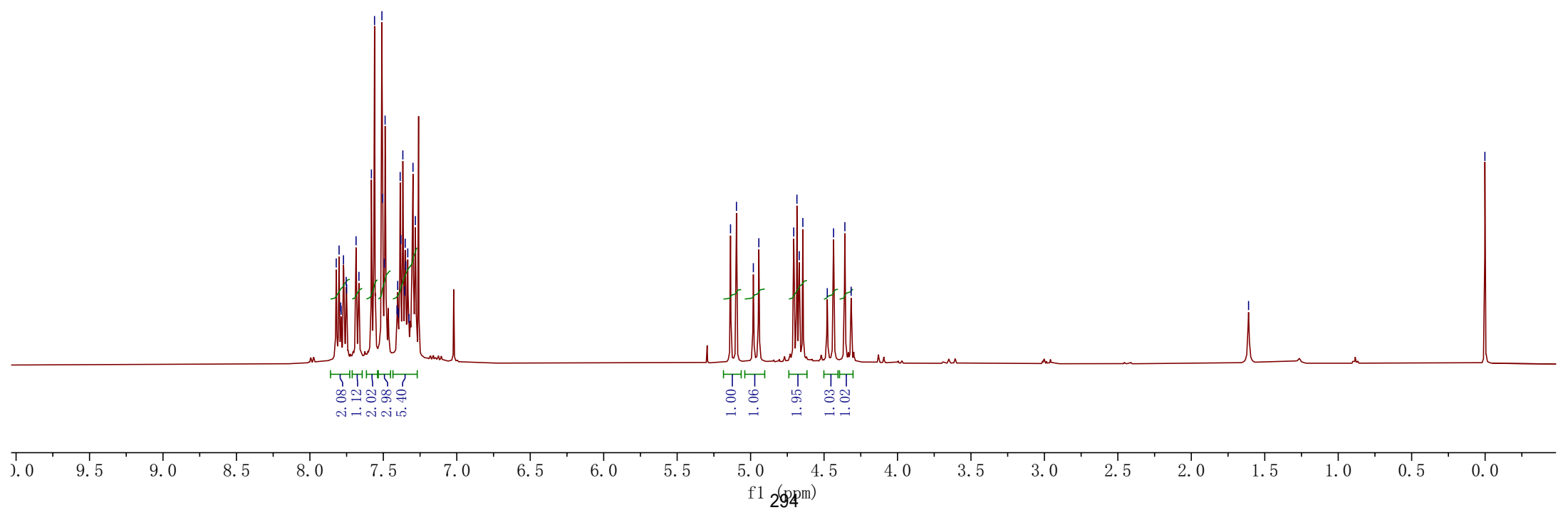


7.821  
7.801  
7.790  
7.787  
7.771  
7.753  
7.750  
7.686  
7.666  
7.581  
7.560  
7.510  
7.504  
7.493  
7.488  
7.407  
7.398  
7.385  
7.381  
7.367  
7.355  
7.351  
7.347  
7.334  
7.325  
7.298  
7.282

5.137  
5.096  
4.981  
4.944  
4.706  
4.685  
4.669  
4.644  
4.478  
4.435  
4.358  
4.316

1.610

0.001



— 196.442  
— 163.075  
— 154.227

— 141.847  
— 137.154  
— 134.780  
— 132.331  
— 131.722  
— 129.305  
— 129.214  
— 128.713  
— 128.479  
— 128.030  
— 127.959  
— 126.663  
— 125.235  
— 125.099  
— 122.531

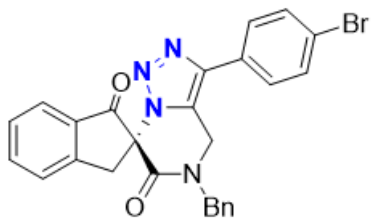
— 77.477  
— 77.160  
— 76.842  
— 72.380

— 51.460

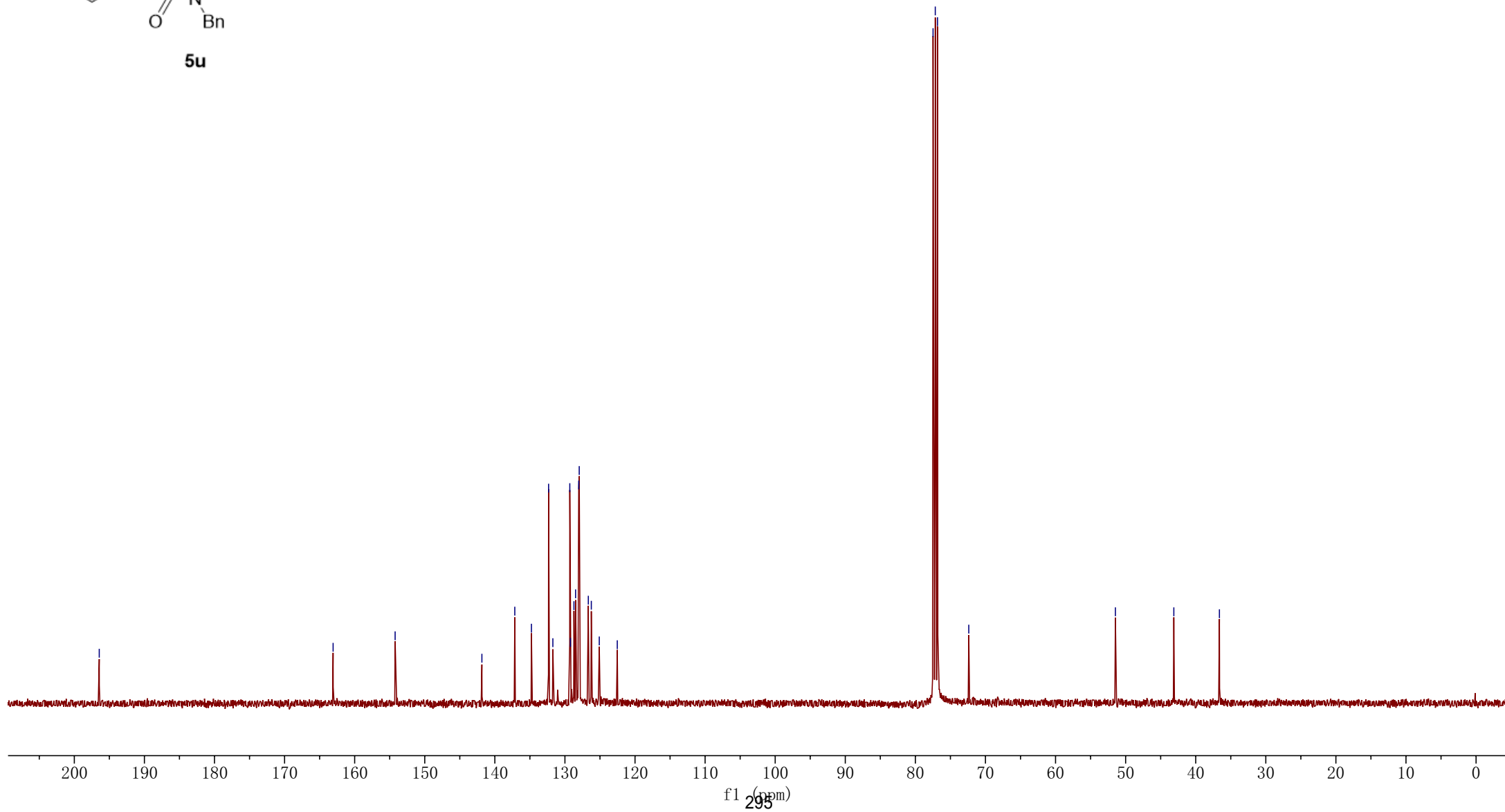
— 43.123

— 36.619

Fig. 3: 5u,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



5u



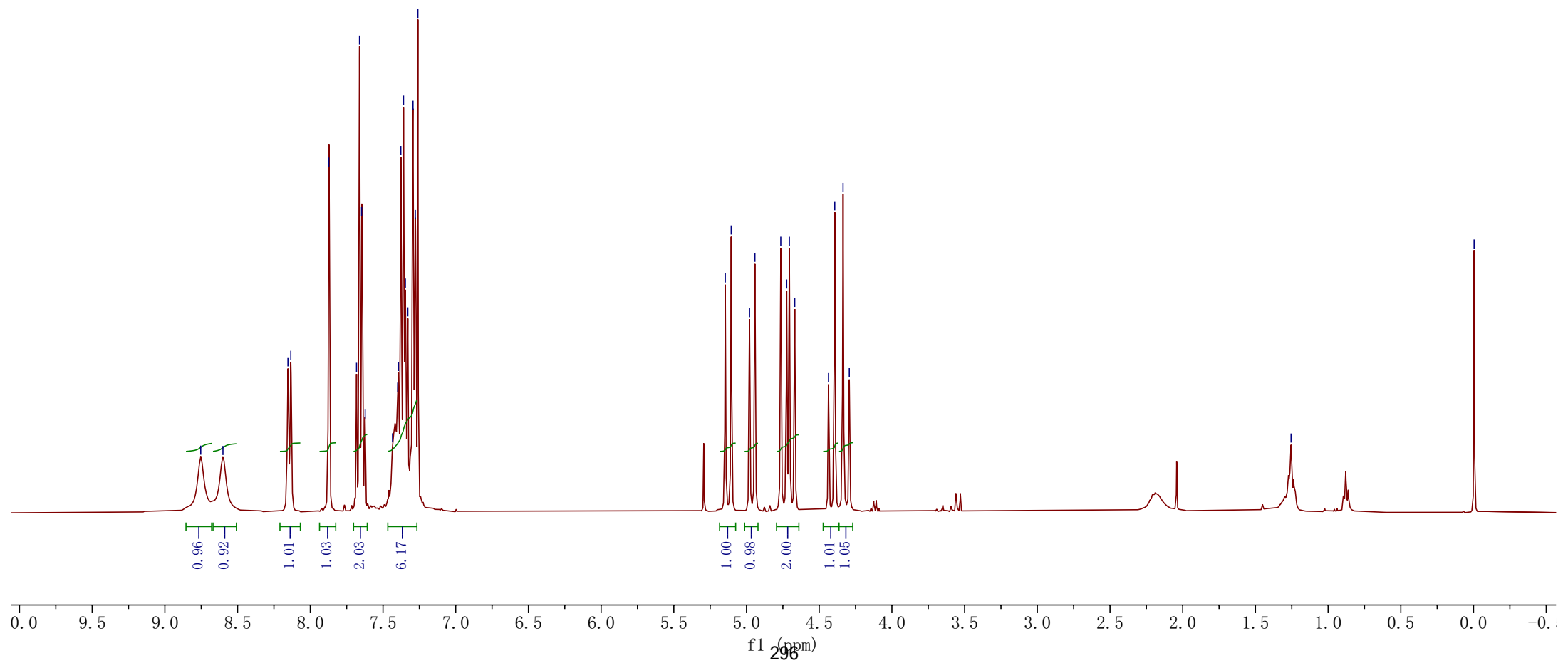
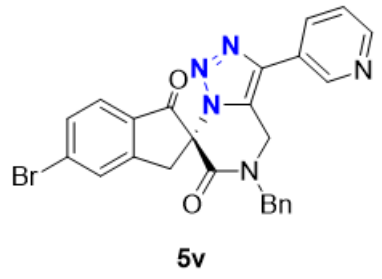
8.753  
8.601  
8.154  
8.134  
7.873  
7.682  
7.661  
7.647  
7.623  
7.435  
7.399  
7.394  
7.377  
7.359  
7.346  
7.329  
7.293  
7.278  
7.260

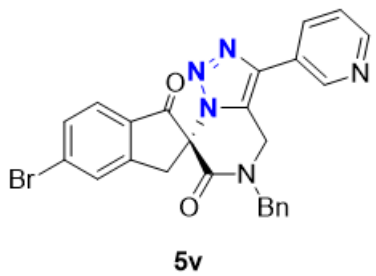
5.146  
5.105  
4.979  
4.942  
4.764  
4.724  
4.705  
4.668  
4.436  
4.393  
4.336  
4.293

1.255

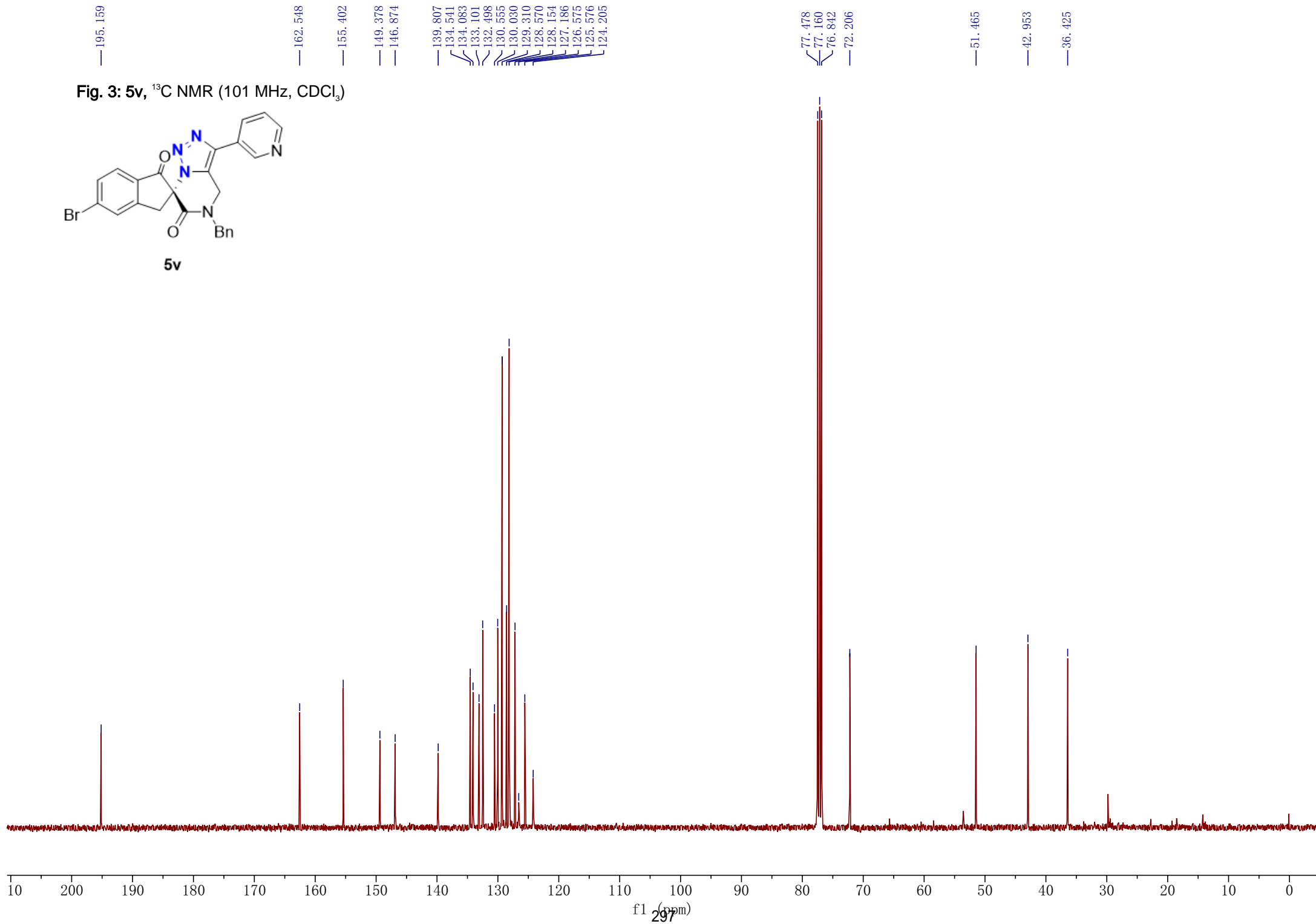
-0.004

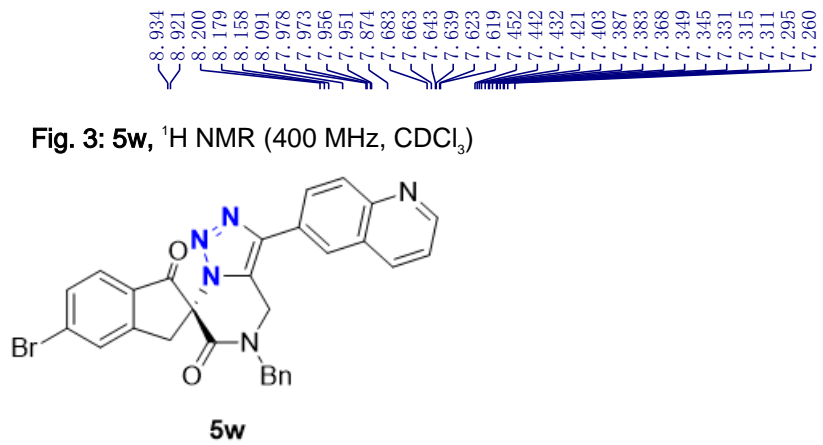
Fig. 3: 5v, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)





**Fig. 3: 5v,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**



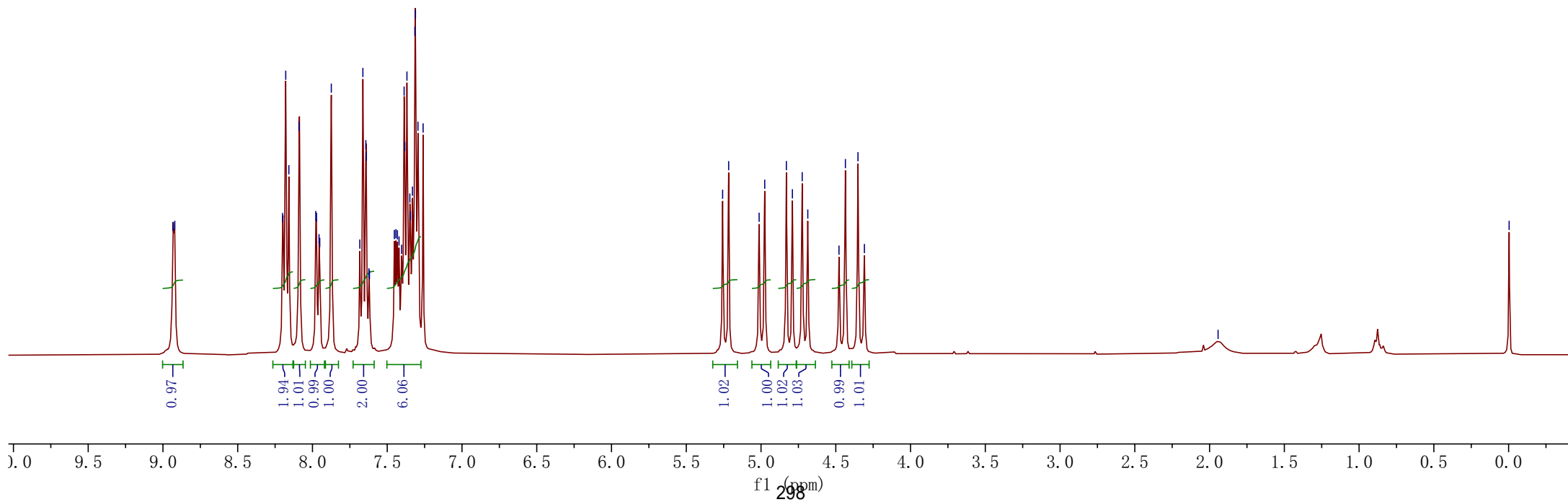


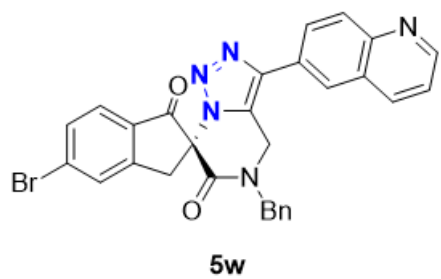
8.934  
8.921  
8.200  
8.179  
8.158  
8.091  
7.978  
7.973  
7.956  
7.951  
7.874  
7.683  
7.663  
7.643  
7.639  
7.623  
7.619  
7.452  
7.442  
7.432  
7.421  
7.403  
7.387  
7.383  
7.368  
7.349  
7.345  
7.331  
7.315  
7.311  
7.295  
7.260

5.257  
5.216  
5.013  
4.975  
4.831  
4.790  
4.725  
4.687  
4.479  
4.436  
4.352  
4.309

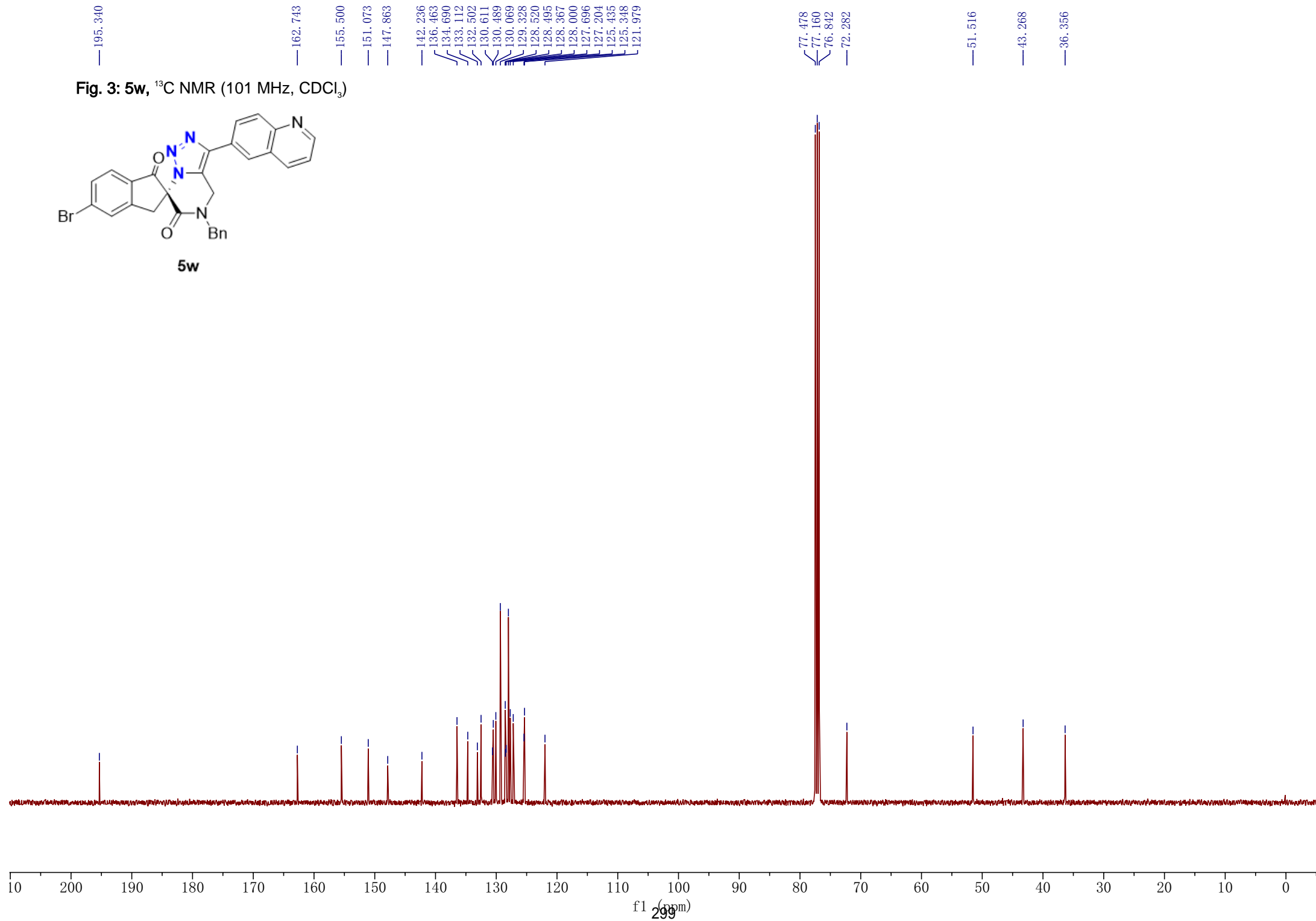
—1.943

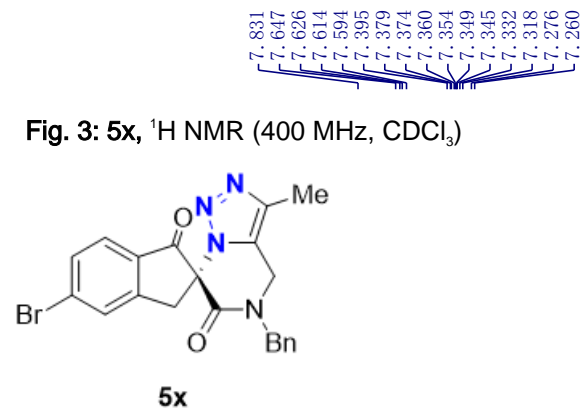
—-0.004





**Fig. 3: 5w,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**





7.831  
7.647  
7.626  
7.614  
7.594  
7.395  
7.379  
7.374  
7.360  
7.354  
7.349  
7.345  
7.332  
7.318  
7.276  
7.260

4.909  
4.872  
4.821  
4.781  
4.700  
4.663  
4.457  
4.417  
4.354  
4.311  
4.261  
4.218

—2.280

—1.622

—0.003

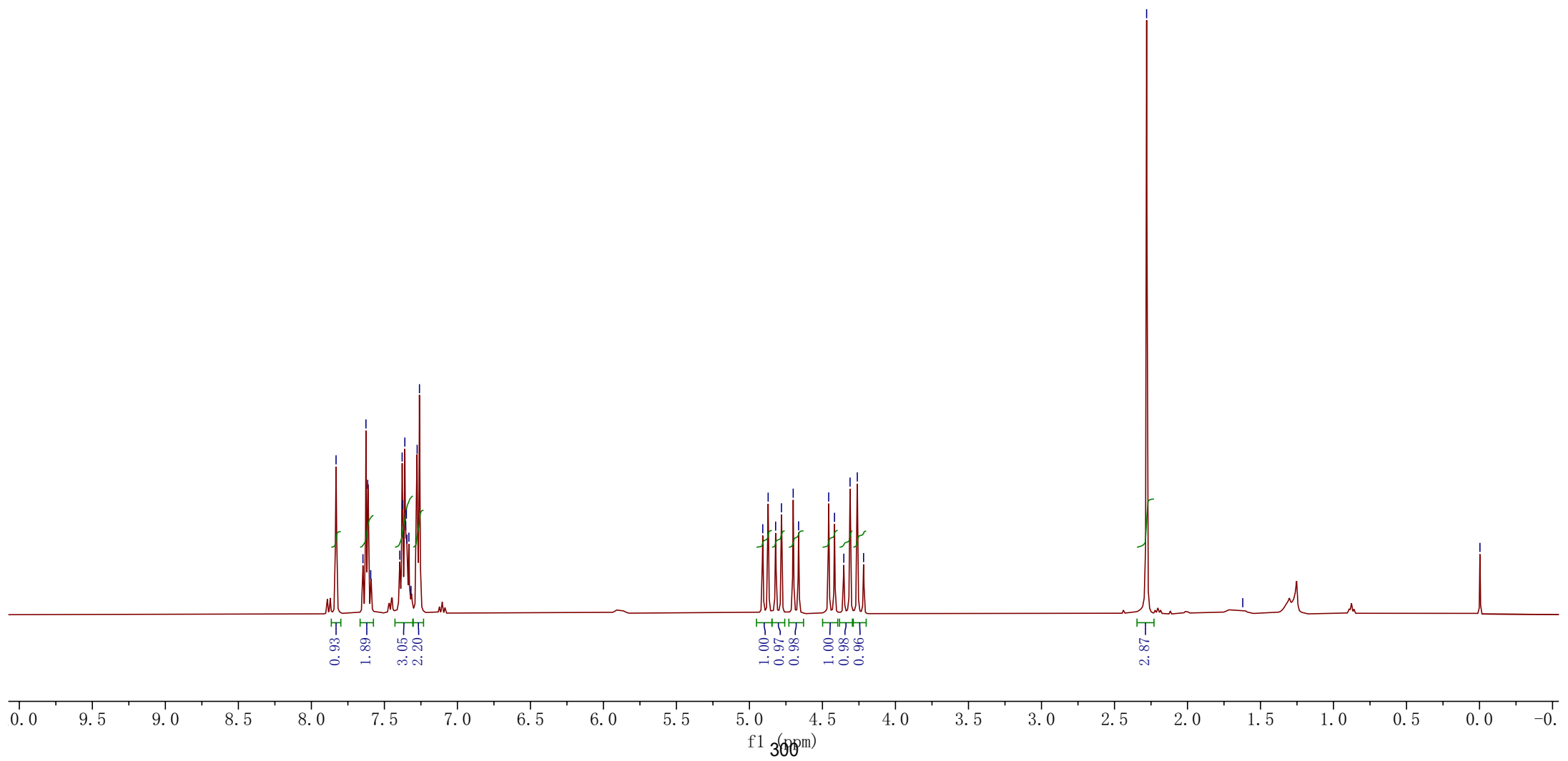
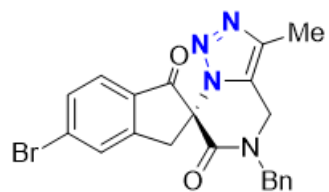
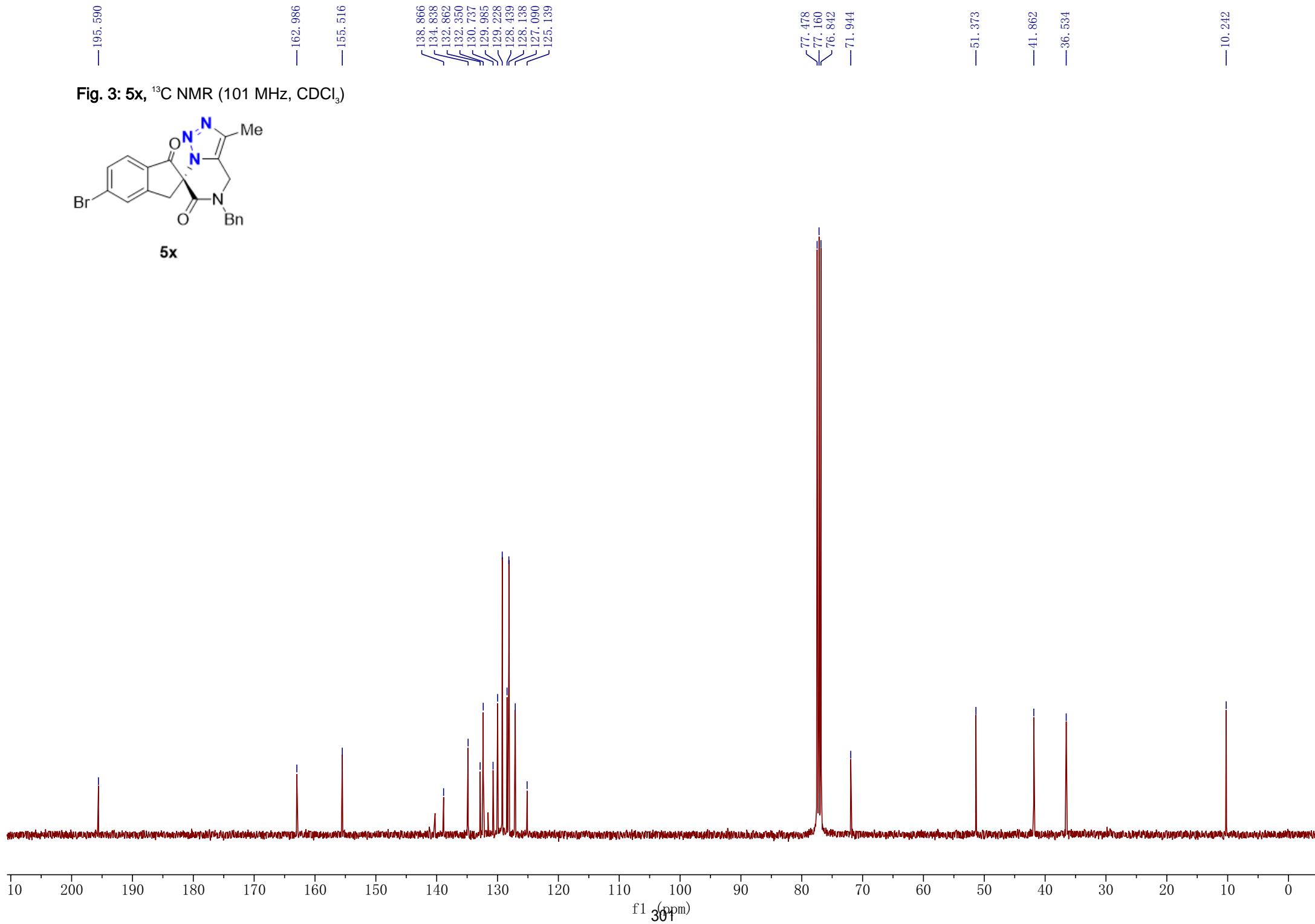




Fig. 3: **5x**, <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)



**5x**



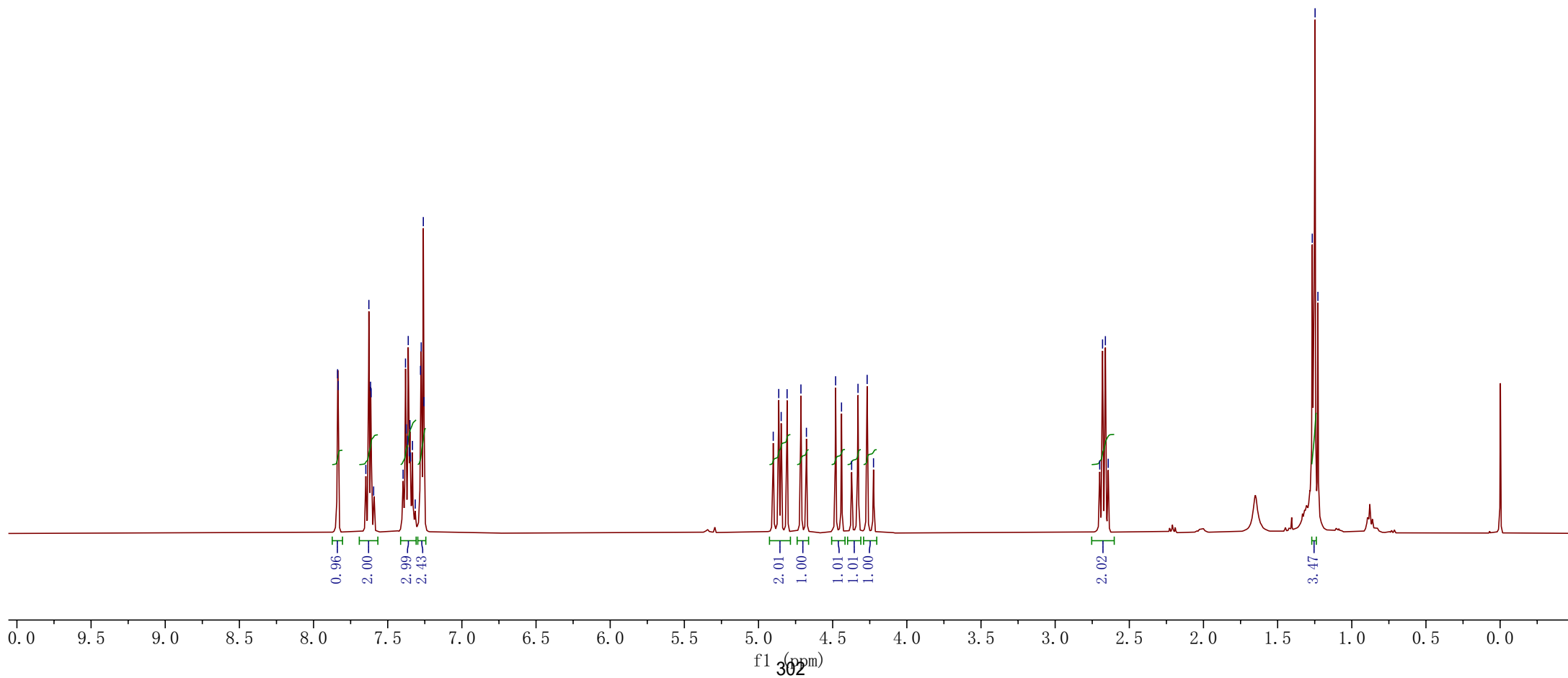
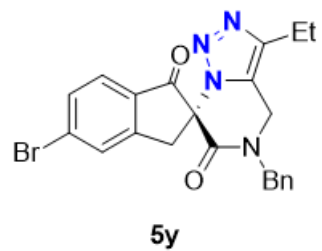
7.838  
7.834  
7.647  
7.627  
7.616  
7.612  
7.595  
7.396  
7.380  
7.375  
7.366  
7.362  
7.355  
7.350  
7.346  
7.333  
7.314  
7.279  
7.274  
7.260  
7.255

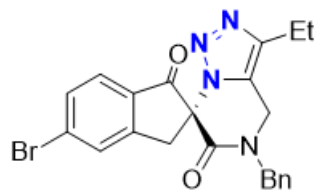
4.901  
4.864  
4.847  
4.807  
4.714  
4.677  
4.480  
4.440  
4.372  
4.329  
4.268  
4.225

2.699  
2.680  
2.661  
2.642

1.267  
1.248  
1.229

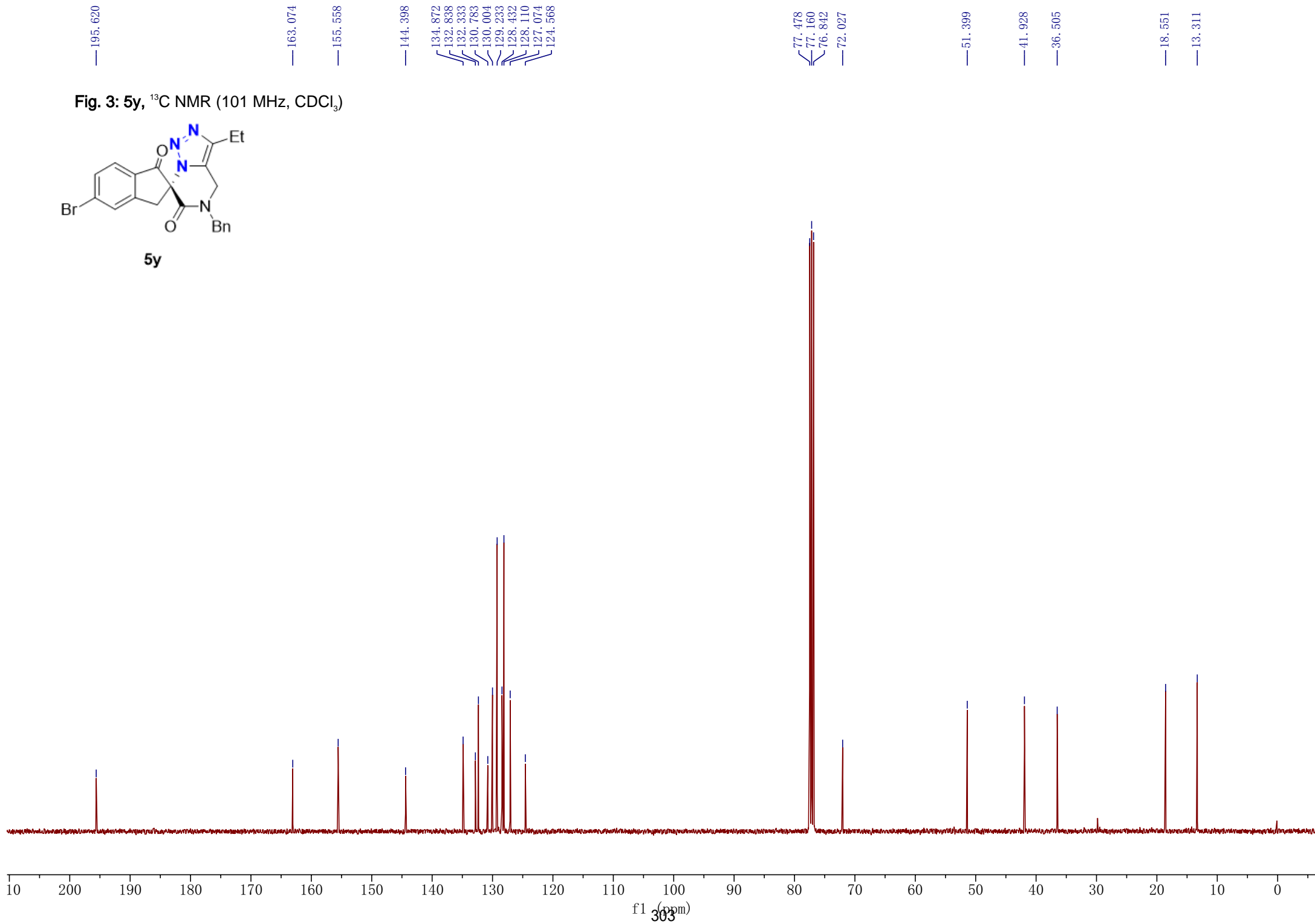
Fig. 3: 5y,  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )

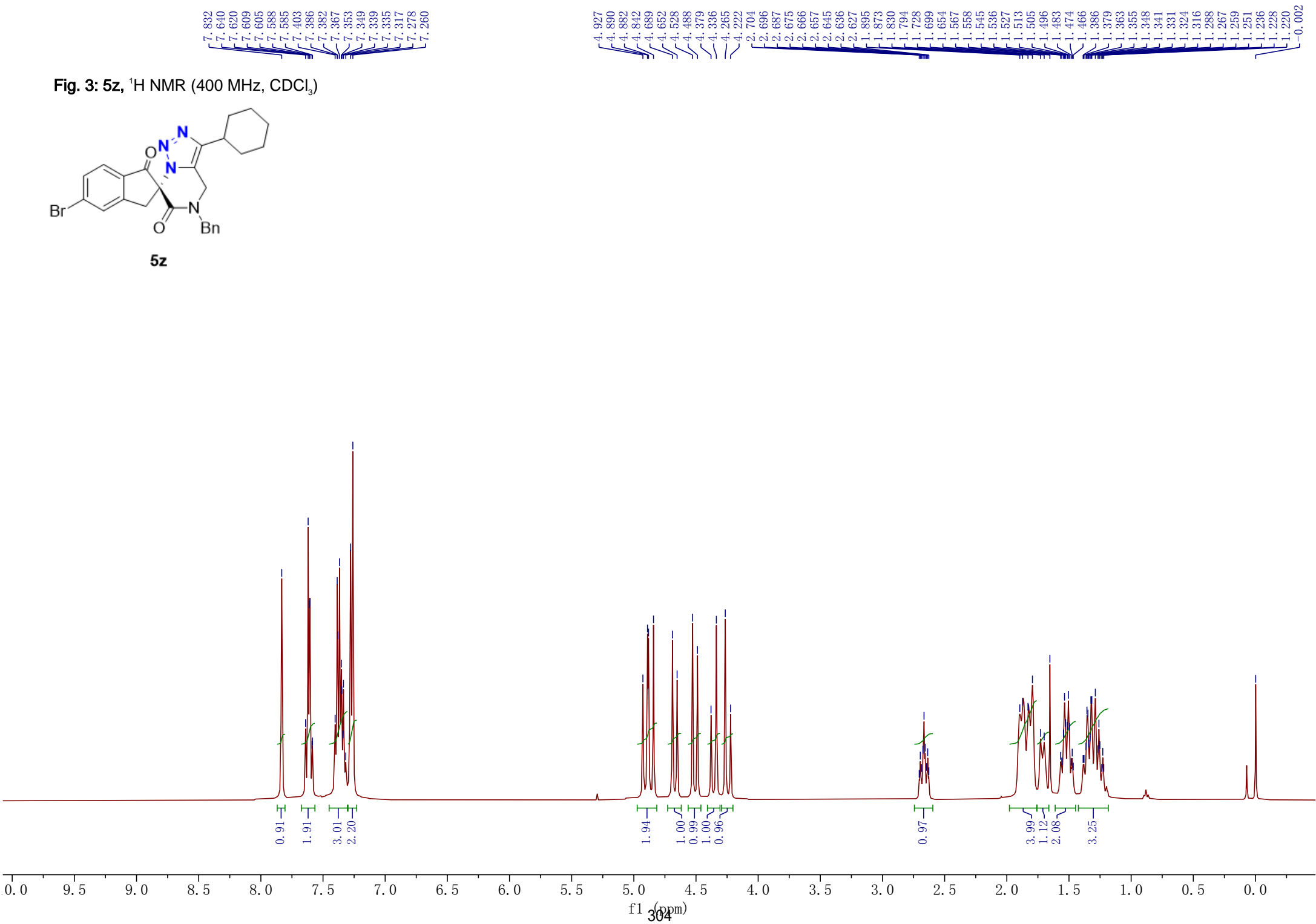
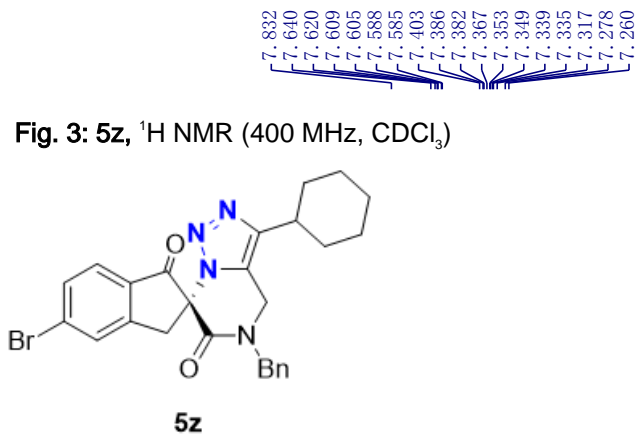


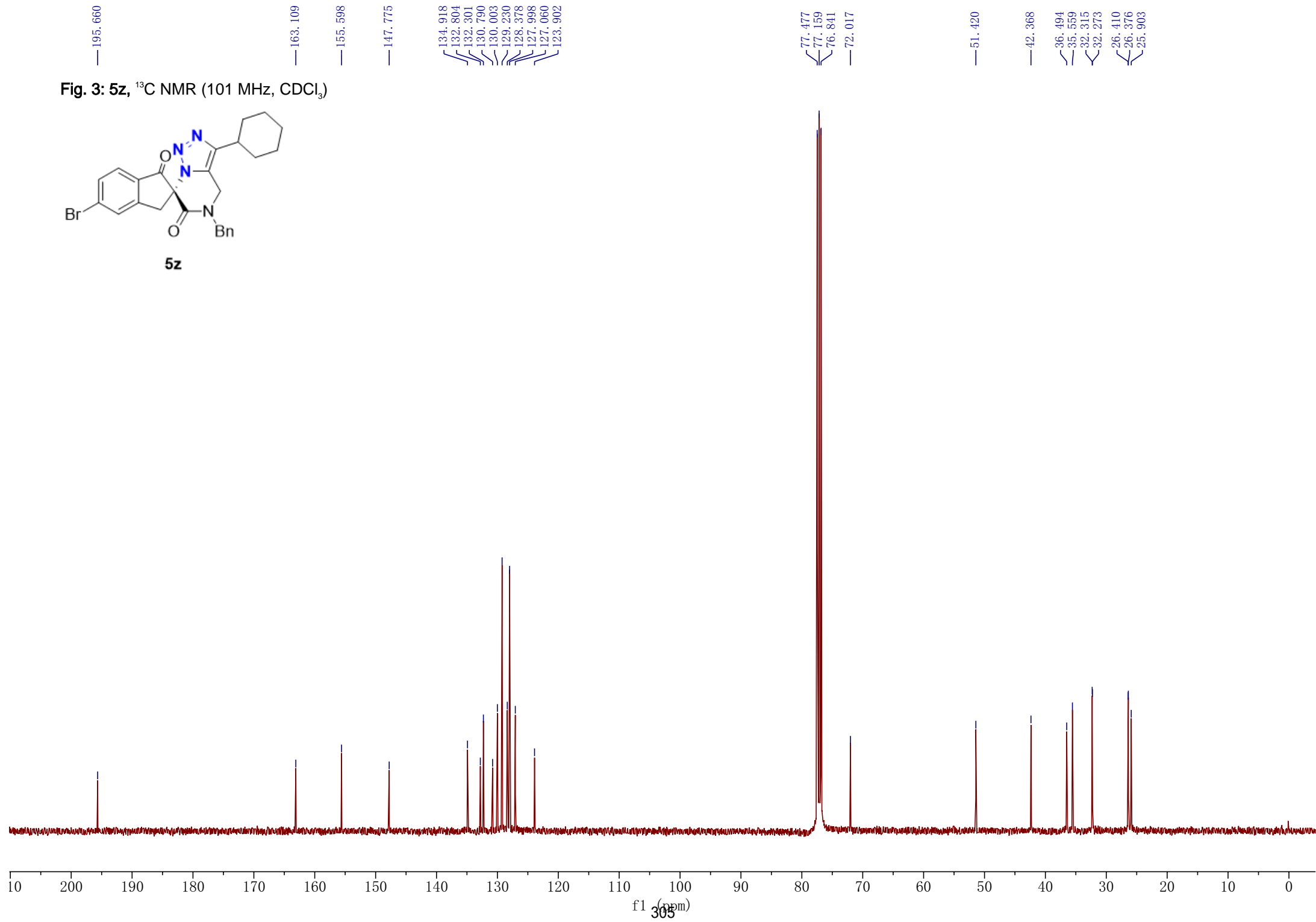
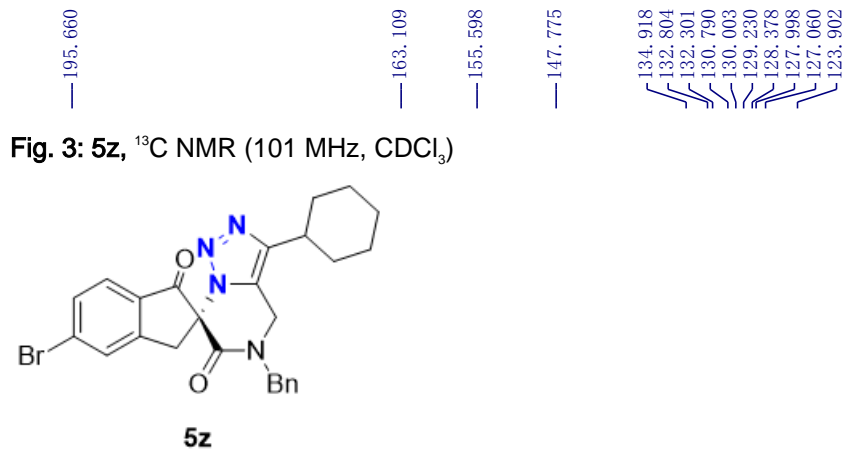


**5y**

**Fig. 3: 5y,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**







7.721  
7.701  
7.660  
7.631  
7.600  
7.580  
7.341  
7.332  
7.319  
7.270  
7.260  
7.251

4.736  
4.282  
4.267  
4.253  
4.228  
3.968  
3.922  
3.768  
3.724

3.164  
3.120

1.857  
1.603

0.000

Fig. 4: 6, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)

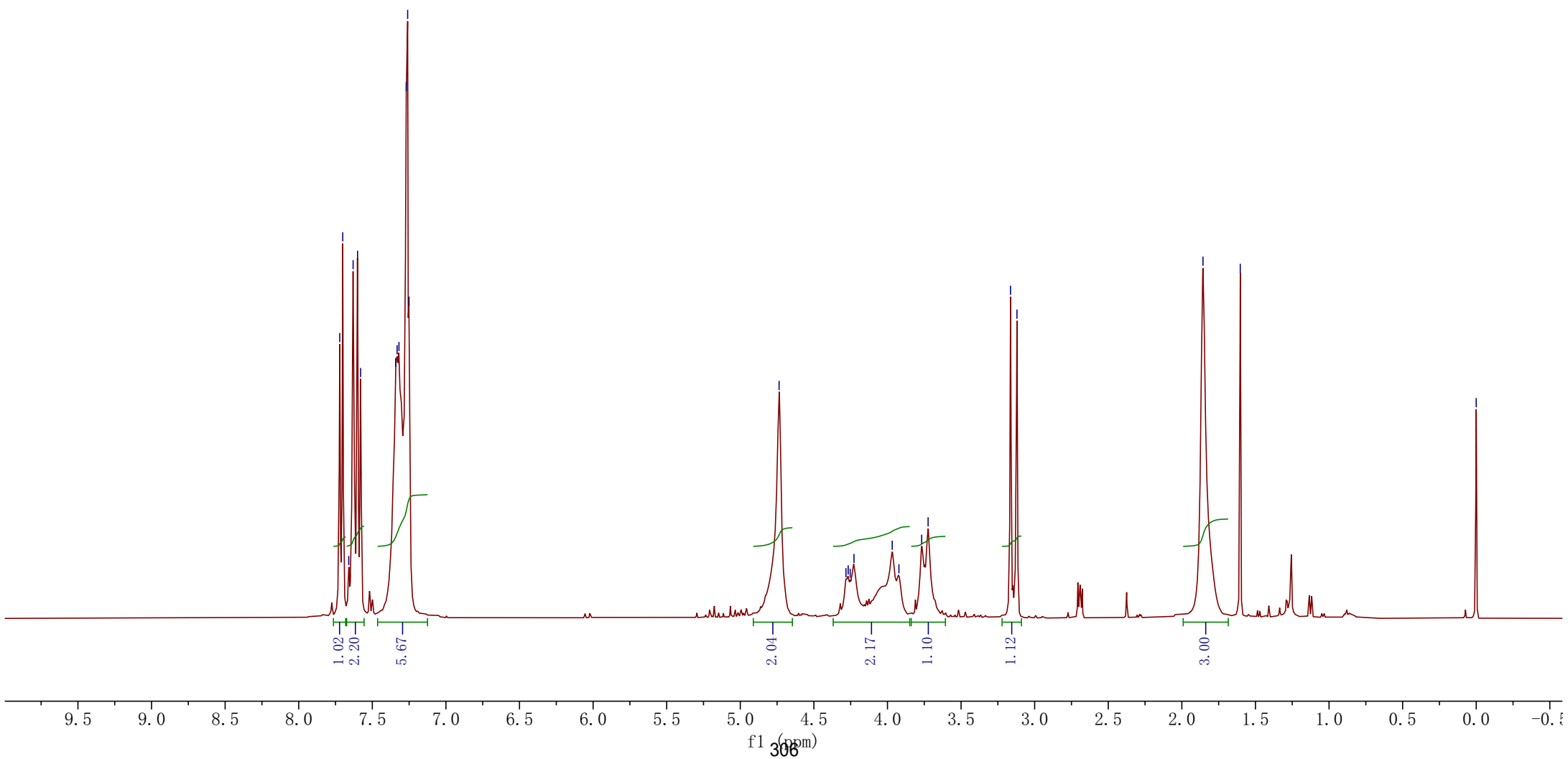
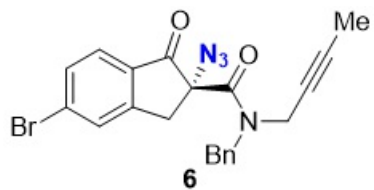


Fig. 4: 6, <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)

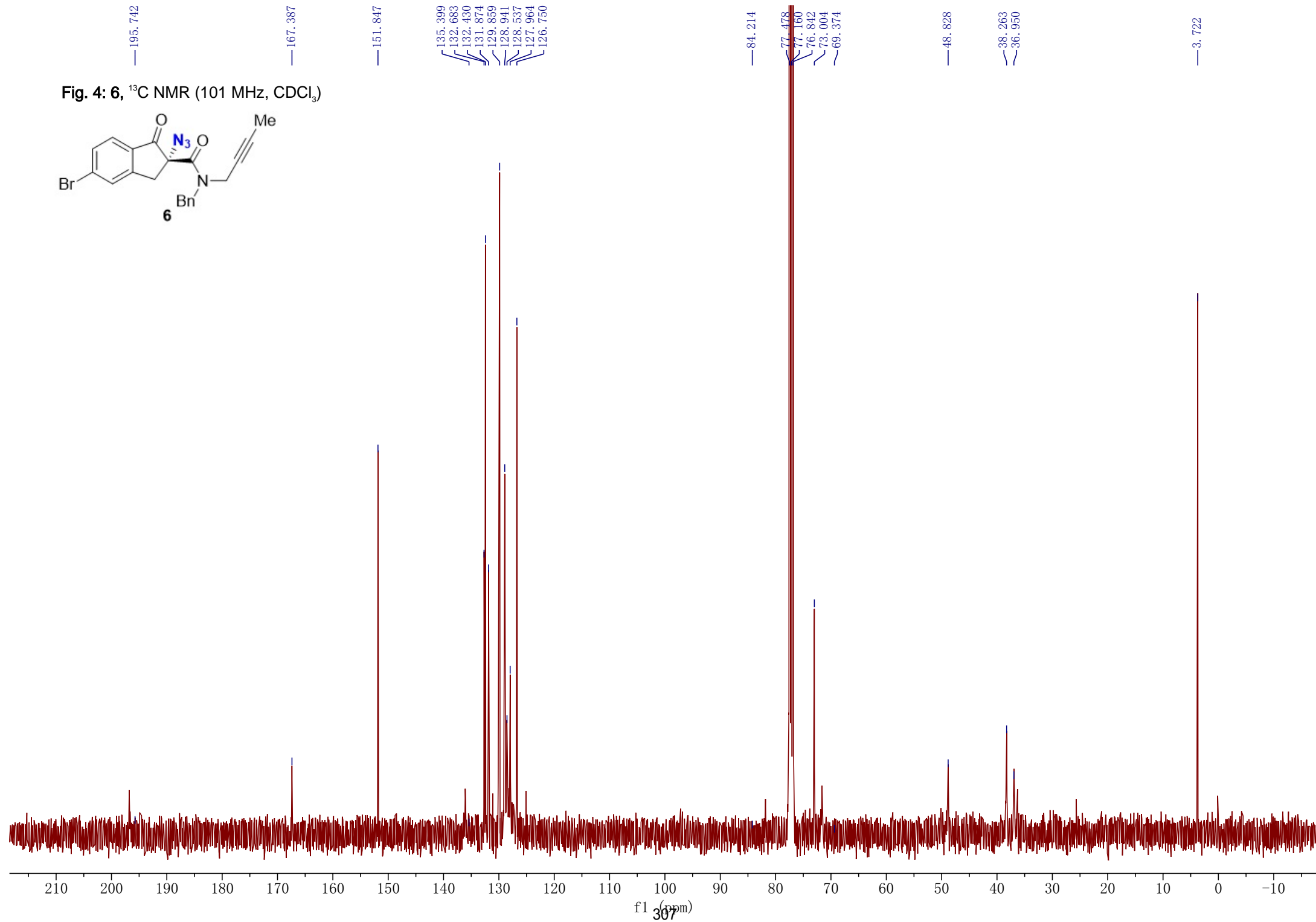
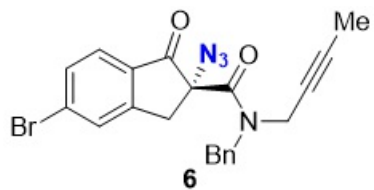
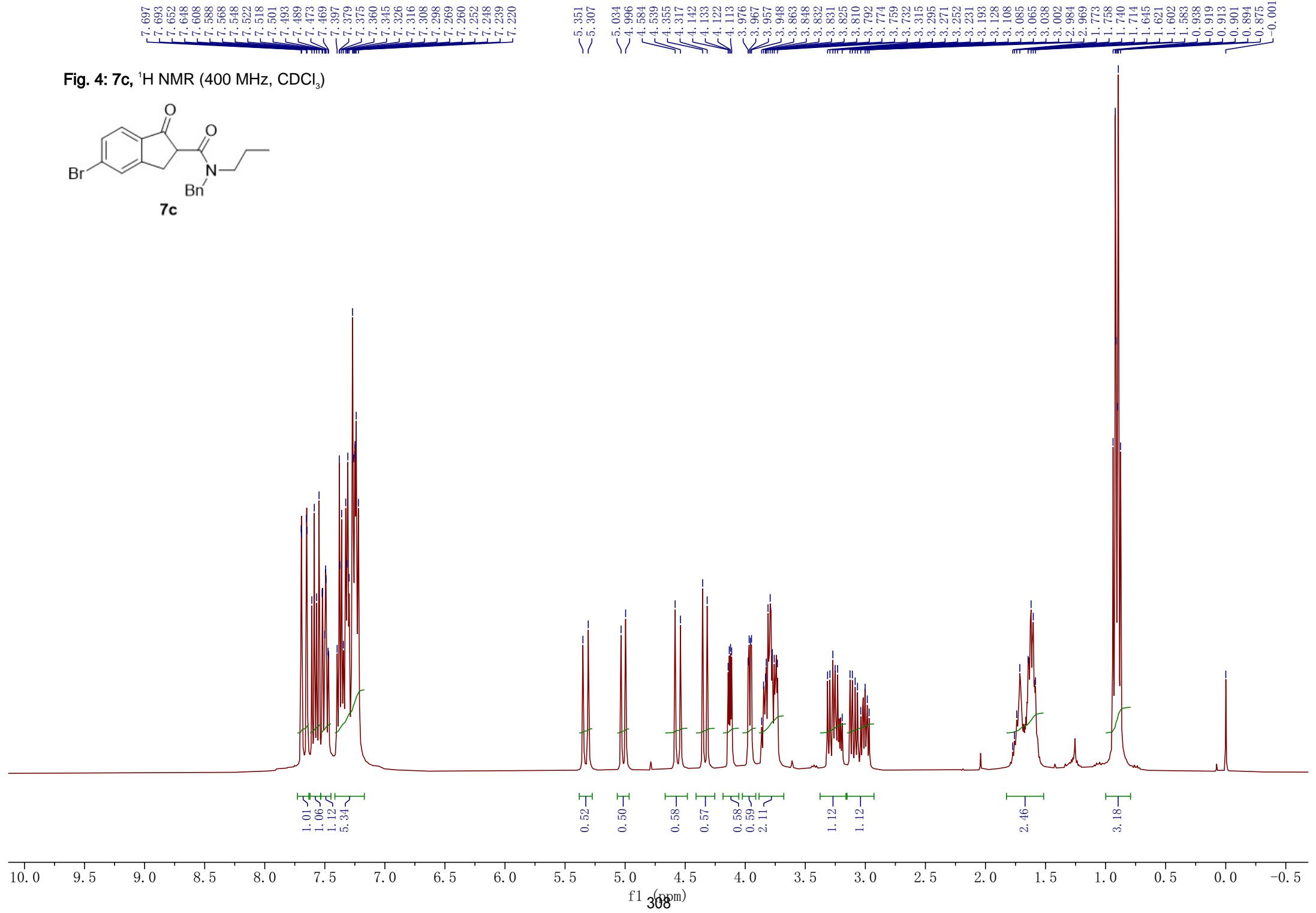
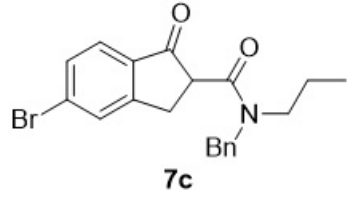


Fig. 4: 7c, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)





200.850  
200.782

168.405  
168.387

156.444  
156.404

137.337  
137.193  
134.416  
134.270  
131.334  
131.271  
130.838  
130.823  
129.905  
129.869  
129.071  
128.712  
127.680  
127.620  
127.309  
126.223  
125.681  
125.620

77.479  
77.161  
76.843

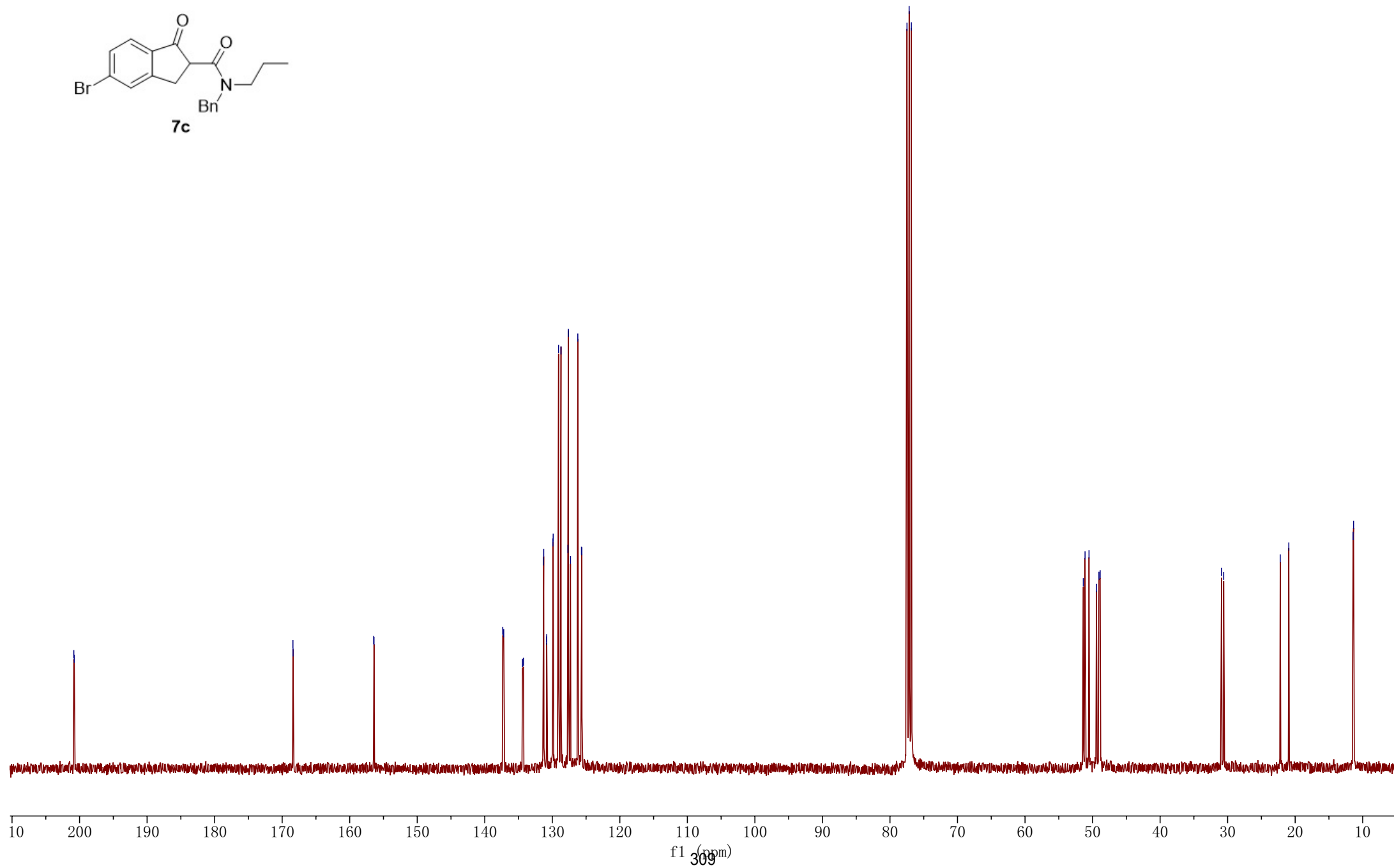
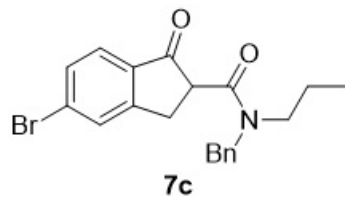
51.368  
51.113  
50.526  
49.423  
49.056  
48.876

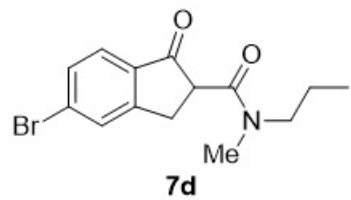
30.904  
30.584

22.212  
20.940

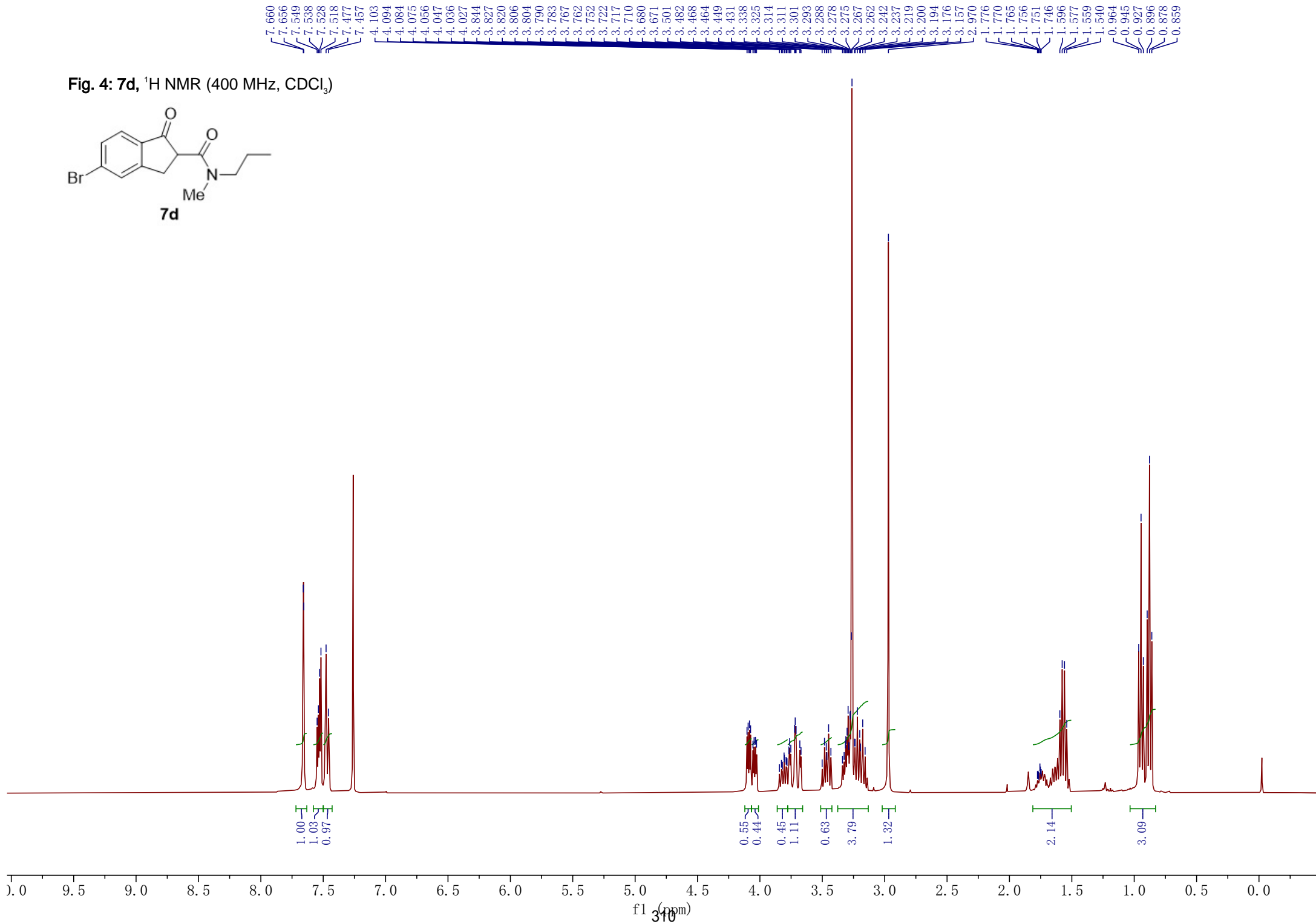
11.421  
11.353

Fig. 4: **7c**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )





**Fig. 4: 7d, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)**



200.680  
200.529  
167.629  
167.422  
156.229  
156.210  
134.225  
134.183  
131.019  
130.970  
130.476  
130.460  
129.682  
129.666  
125.330  
125.287

77.478  
77.159  
76.841

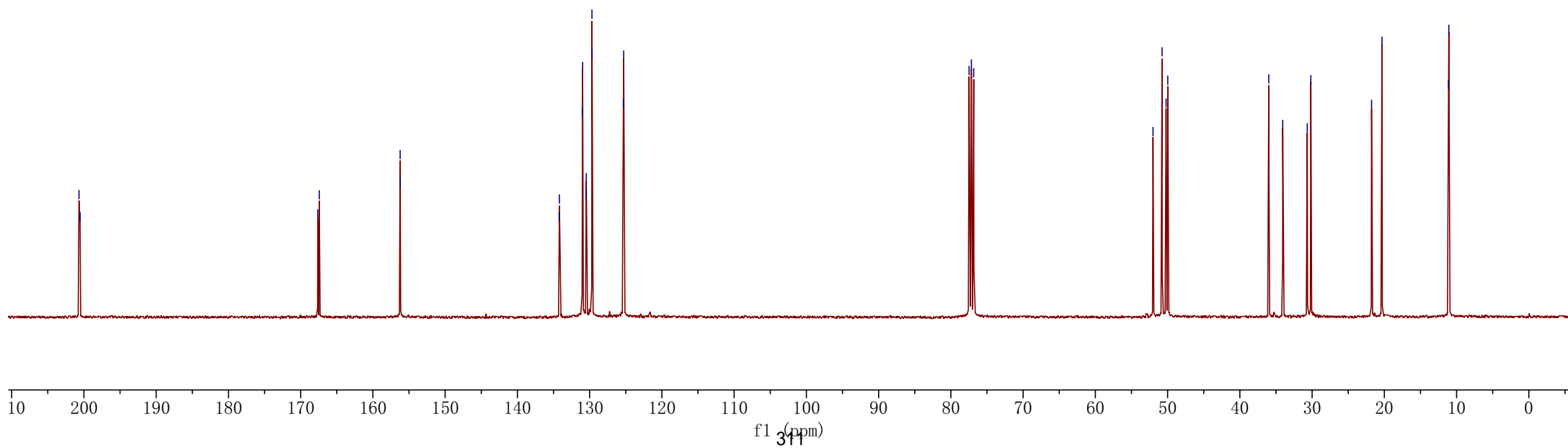
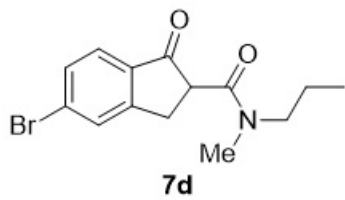
52.021  
50.771  
50.211  
49.979

35.995  
34.066  
30.673  
30.173

21.772  
20.327

11.117  
11.077

Fig. 4: 7d,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



7.712  
7.708  
7.680  
7.660  
7.603  
7.582  
7.382  
7.378  
7.361  
7.343  
7.318  
7.301  
7.298  
7.294  
7.282  
7.278  
7.260  
7.060

4.529  
4.514  
4.492  
4.477  
4.463  
4.440  
4.426  
4.043  
3.999

3.255  
3.211

1.626

0.001

Fig. 4: 8b, <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)

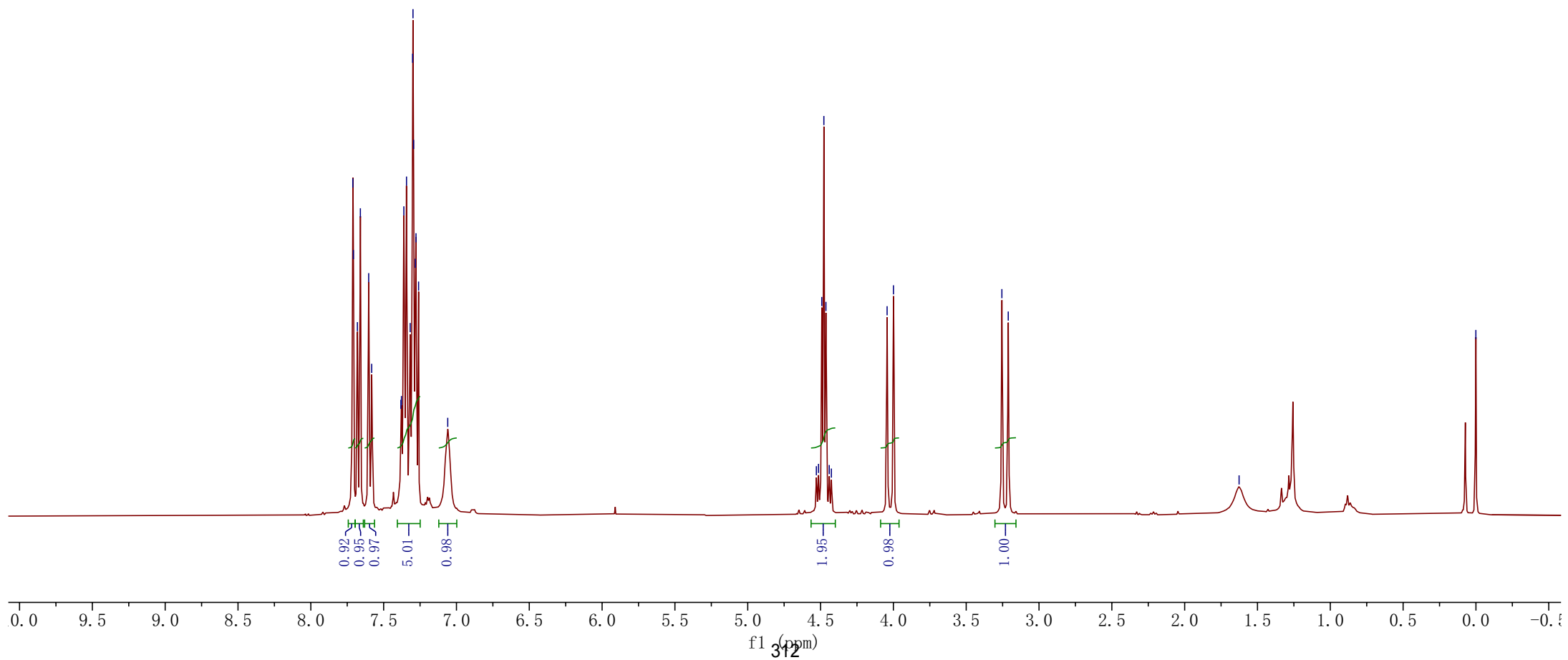
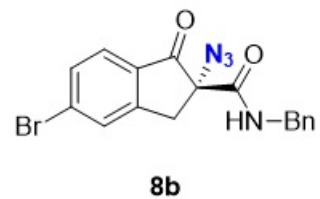
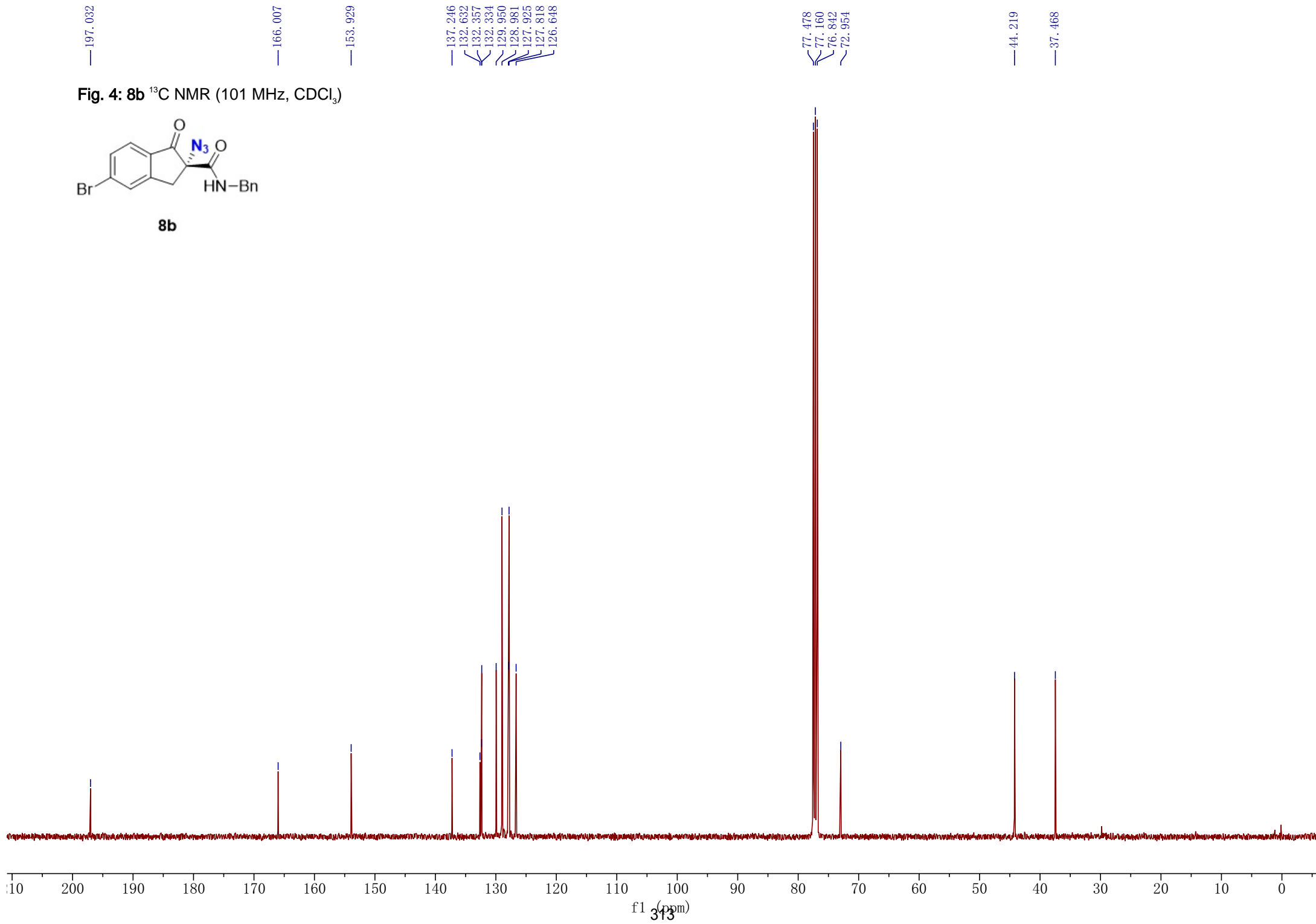
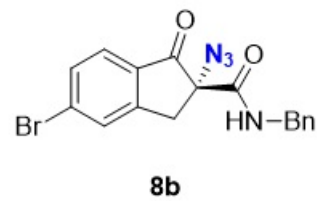
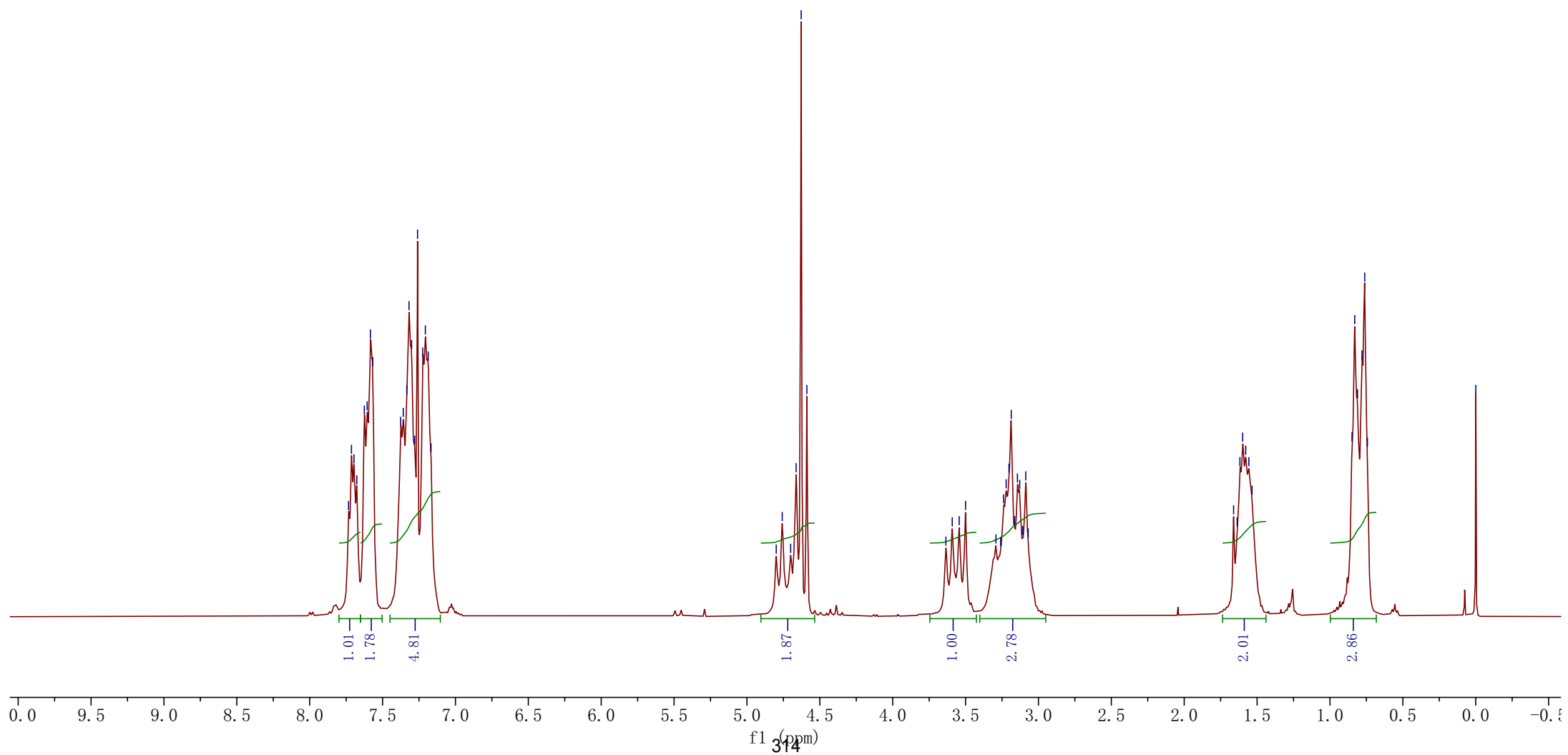
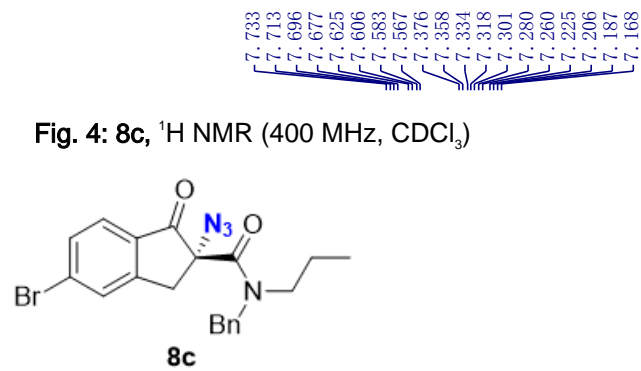
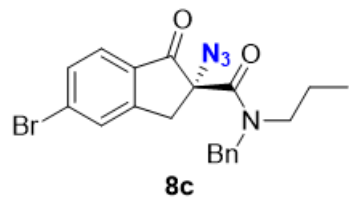


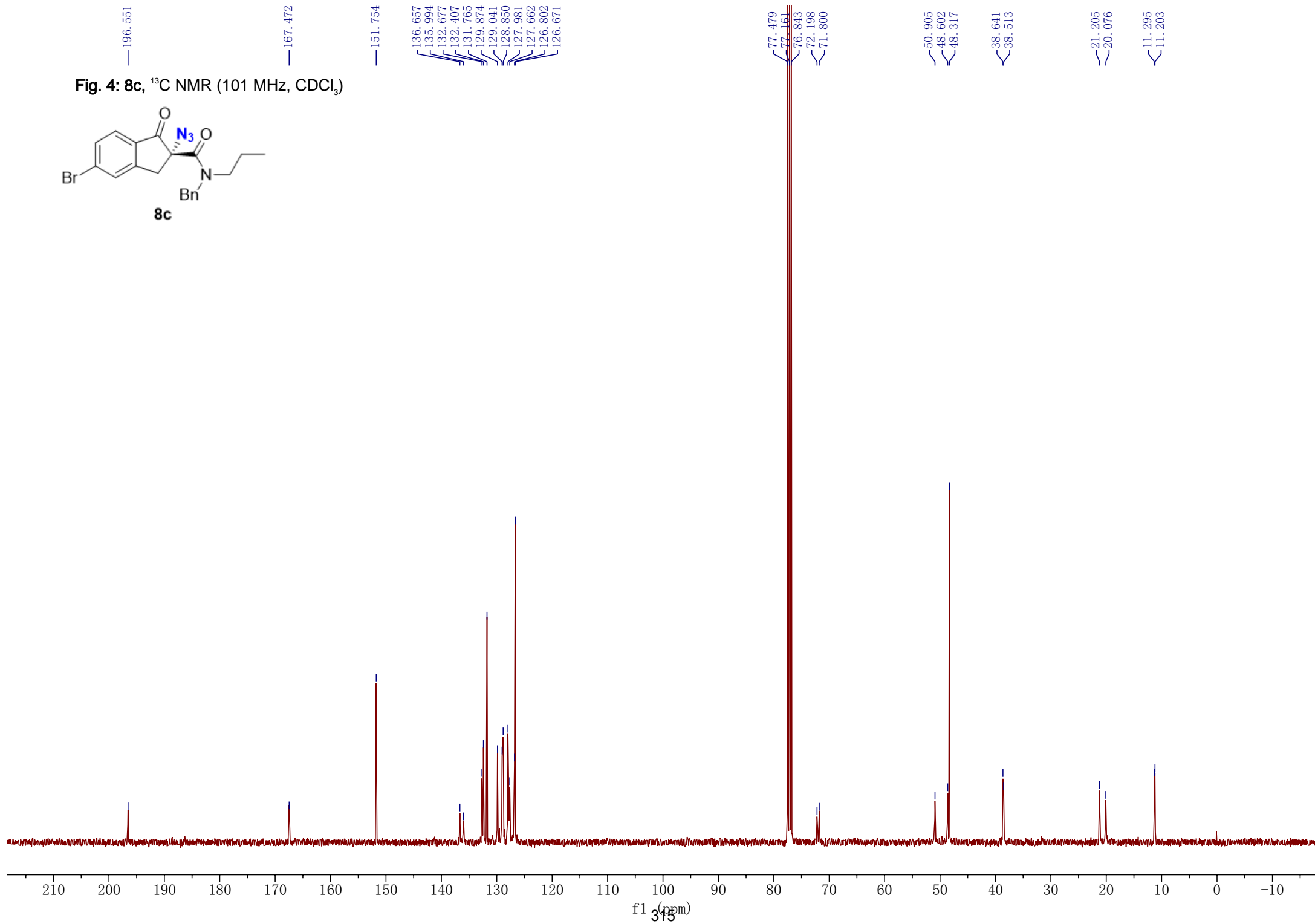
Fig. 4: **8b**  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )







**Fig. 4: 8c,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )**



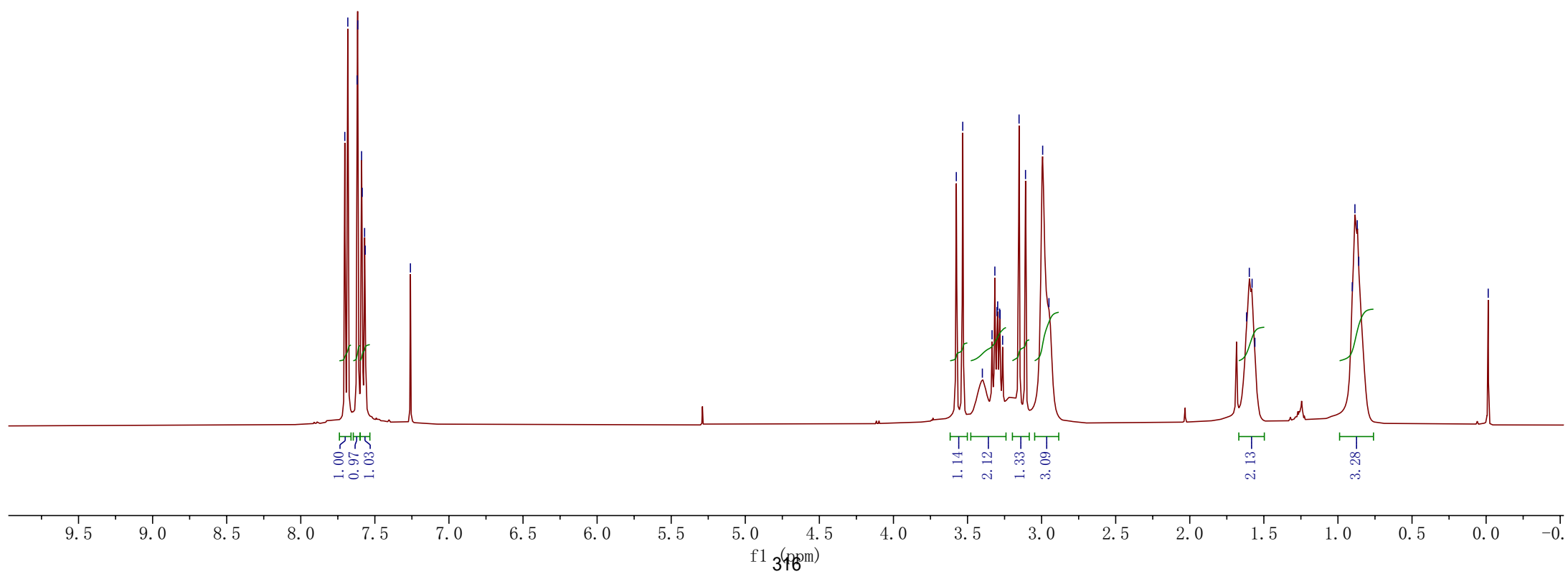
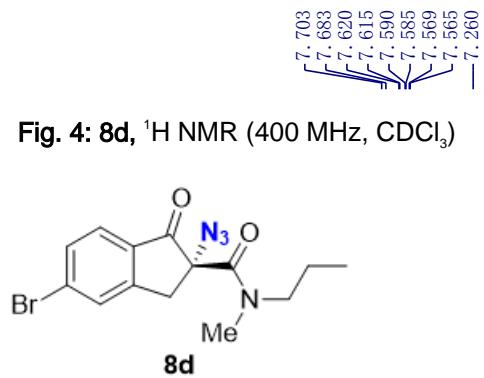
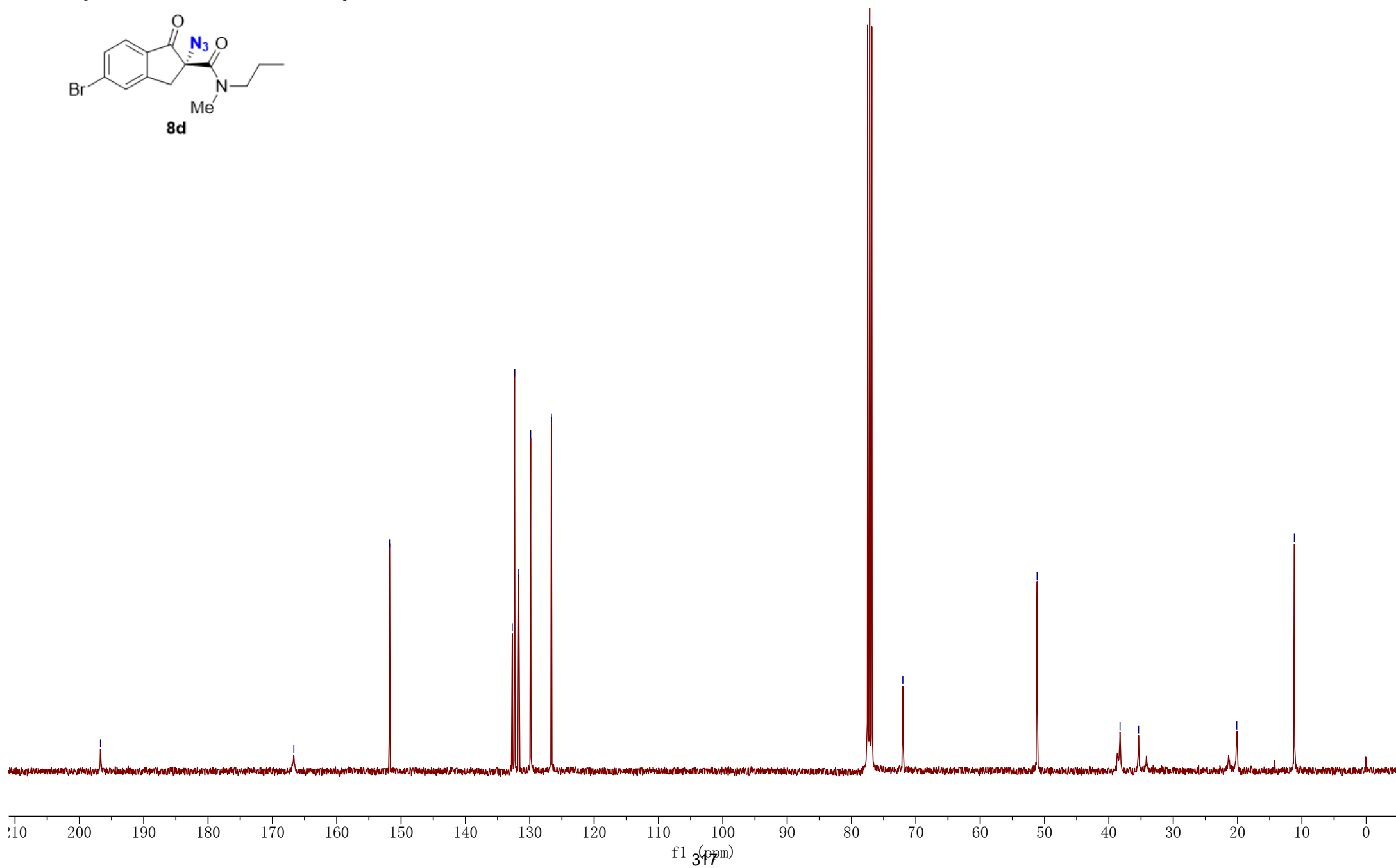
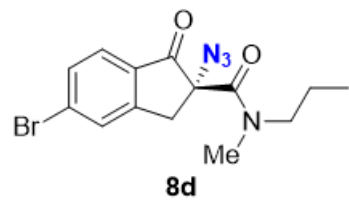
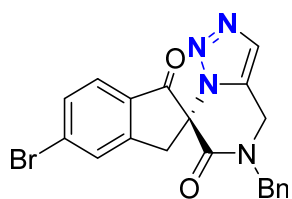




Fig. 4: **8d**,  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )



## 4.2 Chromatographic Data for Chiral Products

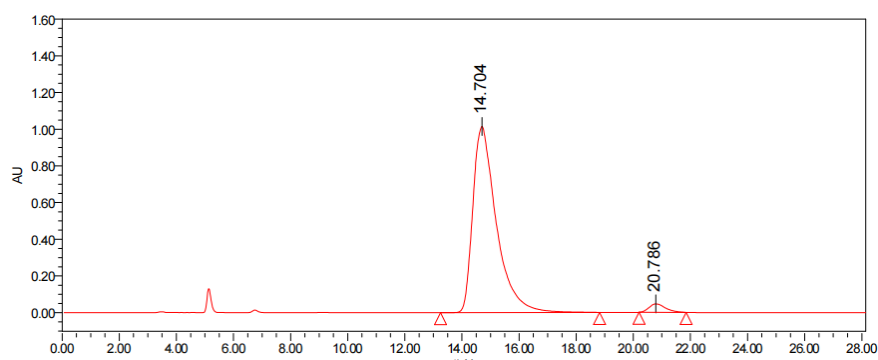


**3a**

### HPLC Conditions

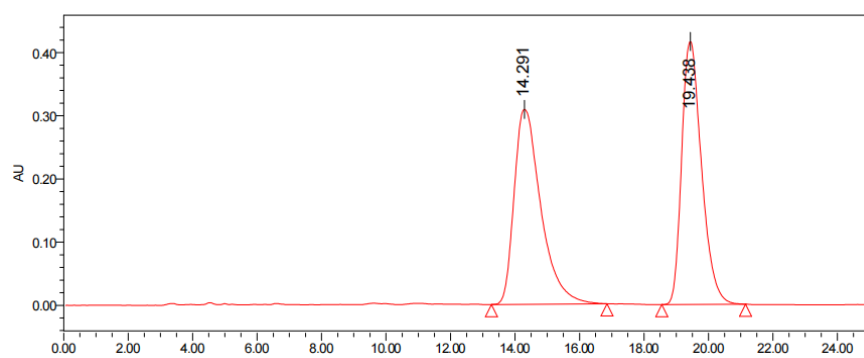
Column: Chiralpak AD-H,  
Daicel Chemical Industries Ltd.  
Eluent: Hexanes / Isopropanol (70:30)  
Flow rate: 1.0 mL/min  
Detection: UV 254 nm

### Chiral



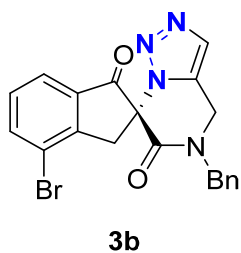
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 14.704       | 58013661 | 96.92 |
| 2 | 20.786       | 1841574  | 3.08  |

### Racemic



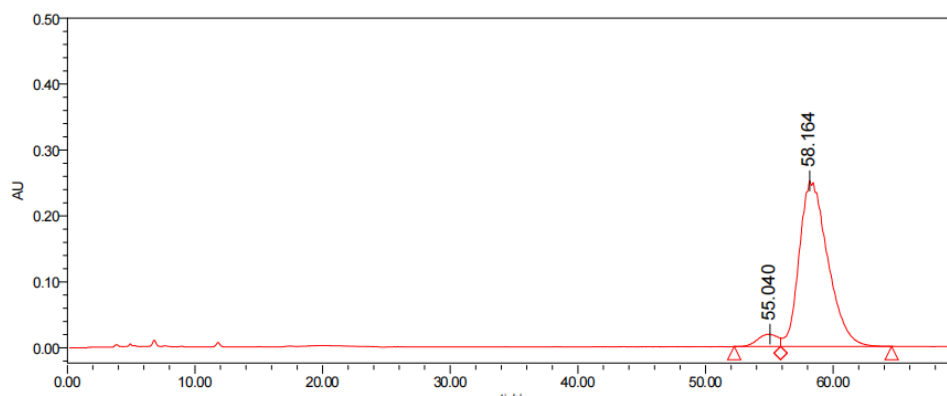
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 14.291       | 17748788 | 49.98 |
| 2 | 19.438       | 17762094 | 50.02 |

**Supplementary Fig. 7.** HPLC spectrum of compound **3a**



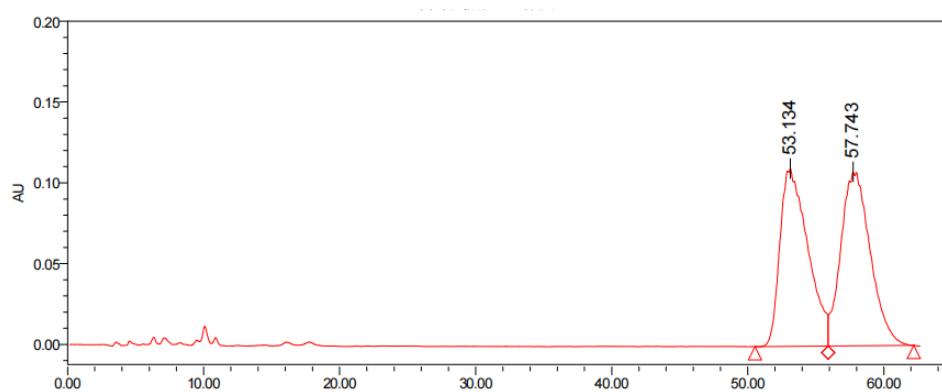
**HPLC Conditions**  
 Column: Chiralpak OD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



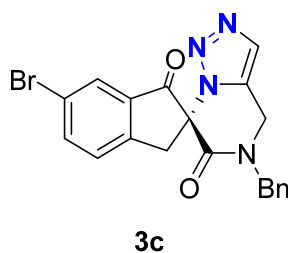
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 55.040       | 2017644  | 4.91  |
| 2 | 58.164       | 39033574 | 95.09 |

### Racemic



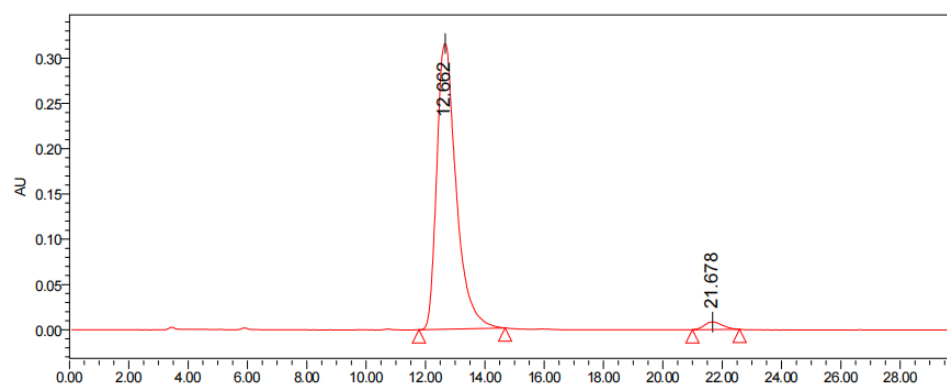
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 53.134       | 15672912 | 49.05 |
| 2 | 57.743       | 16278298 | 50.95 |

**Supplementary Fig. 8.** HPLC spectrum of compound **3b**



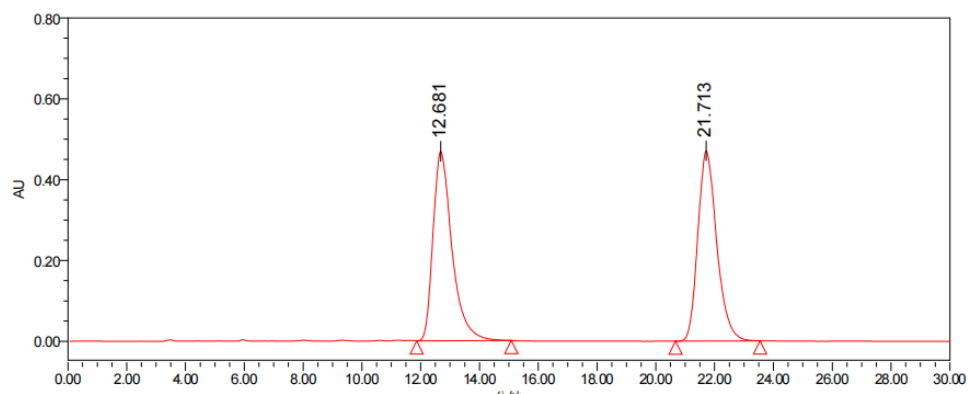
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



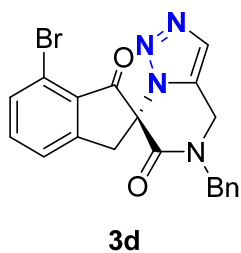
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 12.662       | 14330987 | 97.60 |
| 2 | 21.678       | 352937   | 2.40  |

### Racemic



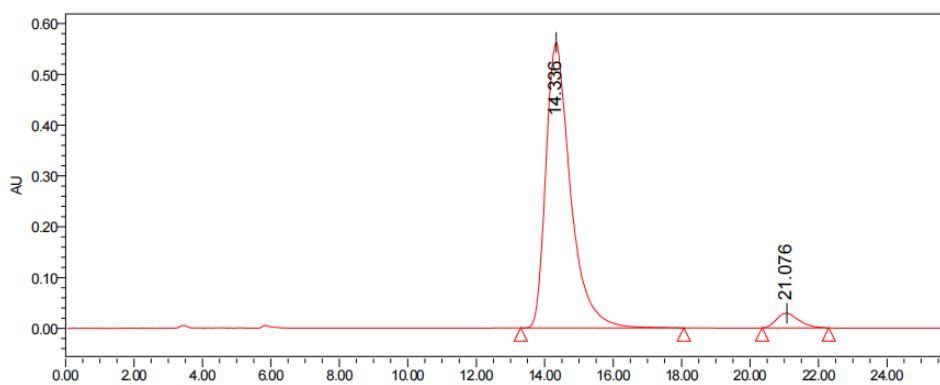
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 12.681       | 20988044 | 49.94 |
| 2 | 21.713       | 21036811 | 50.06 |

**Supplementary Fig. 9.** HPLC spectrum of compound **3c**



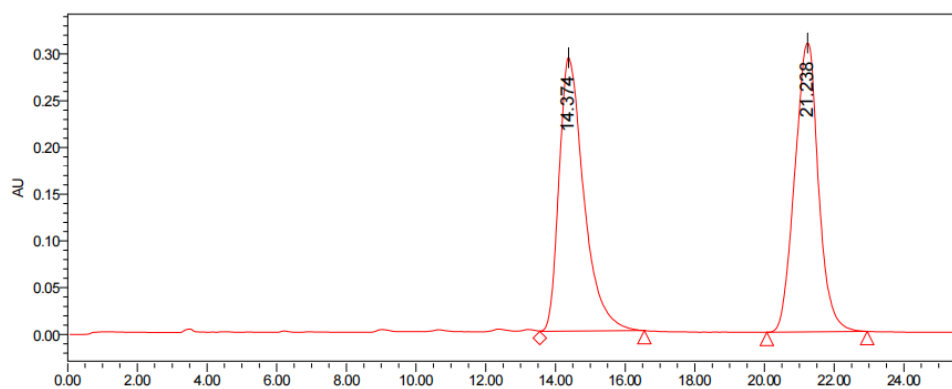
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

**Chiral**



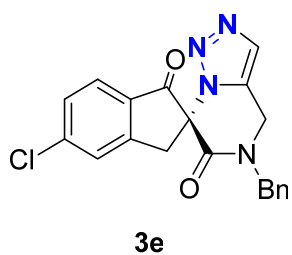
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 14.336       | 28004057 | 95.53 |
| 2 | 21.076       | 1311520  | 4.47  |

**Racemic**



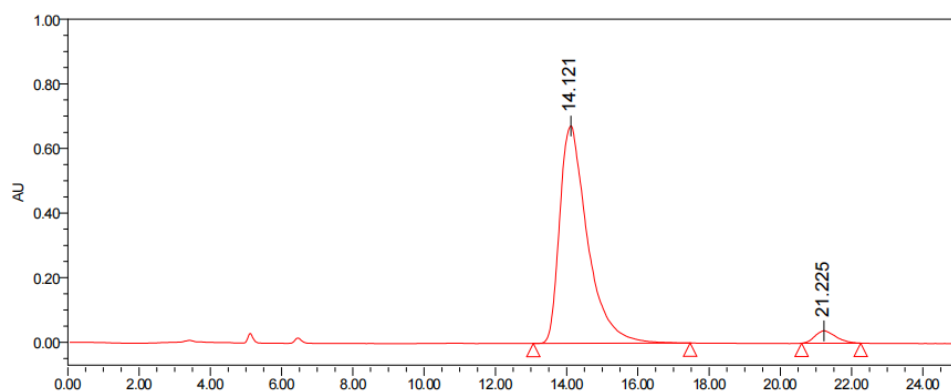
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 14.374       | 14434518 | 49.74 |
| 2 | 21.238       | 14585151 | 50.26 |

**Supplementary Fig. 10. HPLC spectrum of compound 3d**



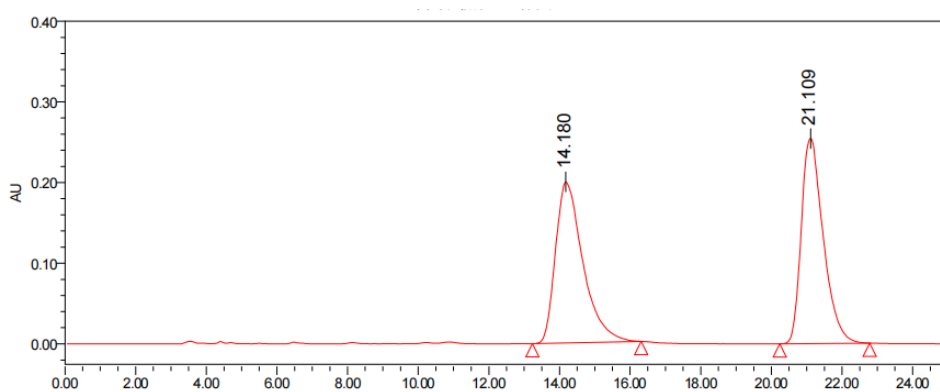
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



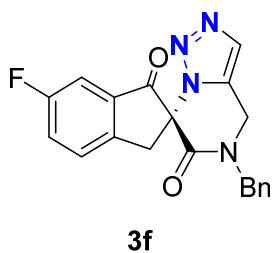
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 14.121       | 36451599 | 95.95 |
| 2 | 21.225       | 1537445  | 4.05  |

### Racemic



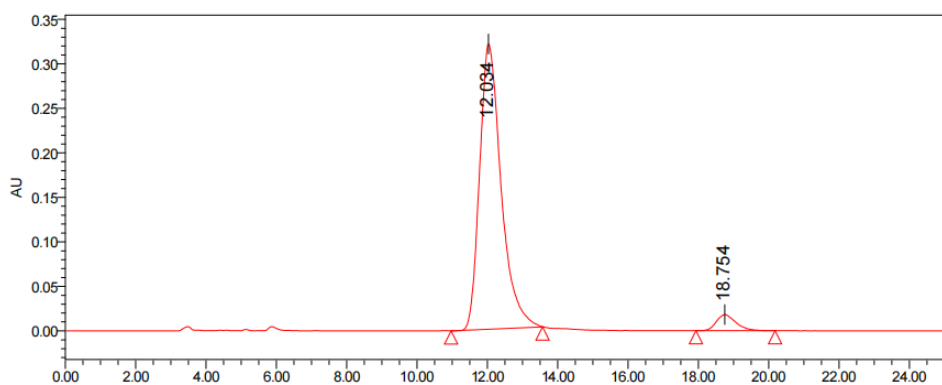
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 14.180       | 10783183 | 49.53 |
| 2 | 21.109       | 10989306 | 50.47 |

Supplementary Fig. 11. HPLC spectrum of compound **3e**



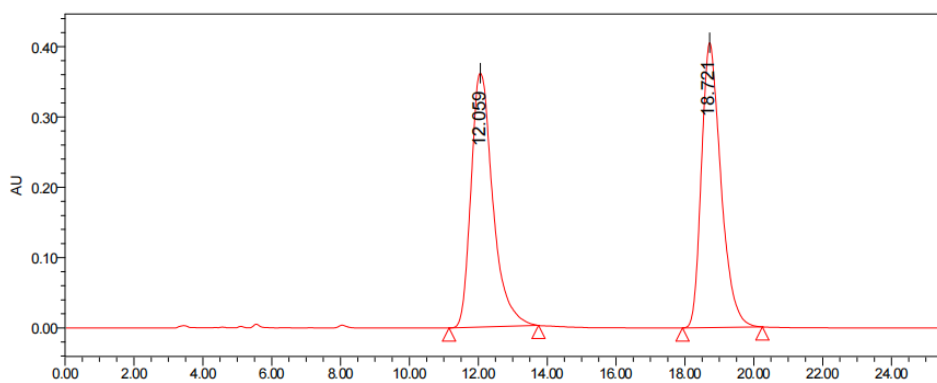
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

**Chiral**



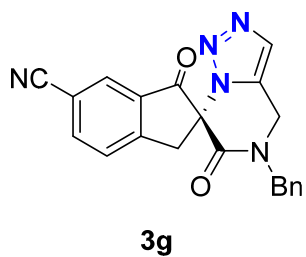
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 12.034       | 13598755 | 95.15 |
| 2 | 18.754       | 693850   | 4.85  |

**Racemic**



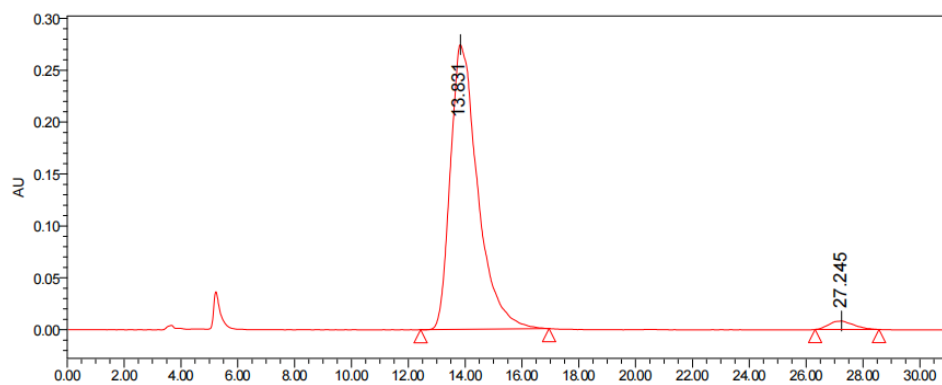
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 12.059       | 15896327 | 50.01 |
| 2 | 18.721       | 15887447 | 49.99 |

**Supplementary Fig. 12.** HPLC spectrum of compound **3f**



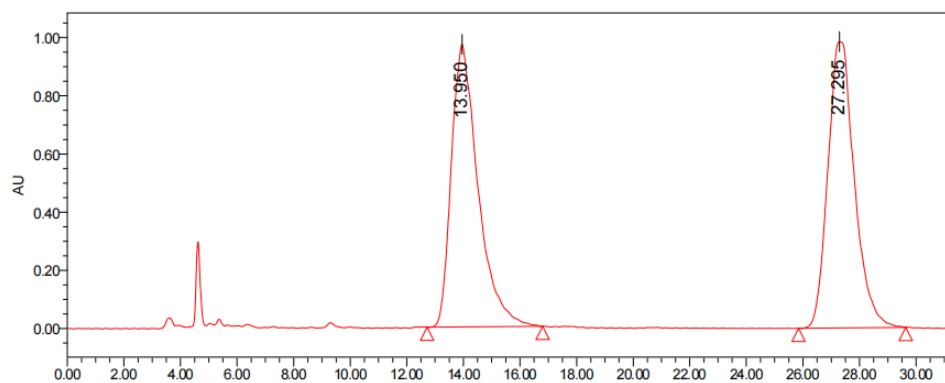
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (60:40)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

**Chiral**



|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 13.831       | 18340667 | 97.44 |
| 2 | 27.245       | 482071   | 2.56  |

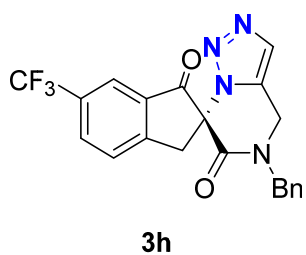
**Racemic**



|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 13.950       | 63643253 | 49.82 |
| 2 | 27.295       | 64112148 | 50.18 |

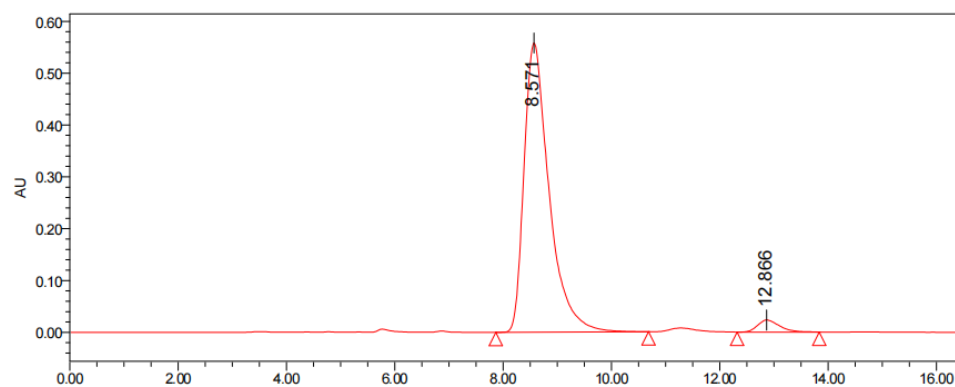
**Supplementary Fig. 13.** HPLC spectrum of compound **3g**





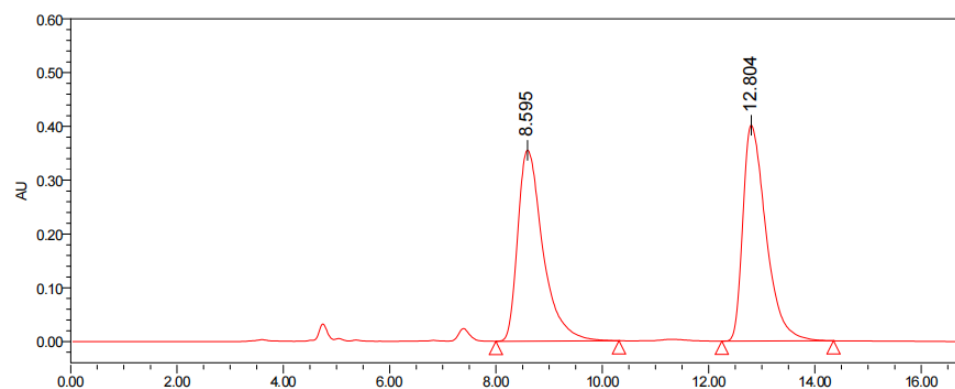
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



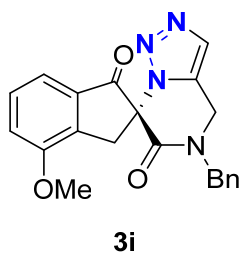
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 8.571        | 17909719 | 96.53 |
| 2 | 12.866       | 642951   | 3.47  |

### Racemic



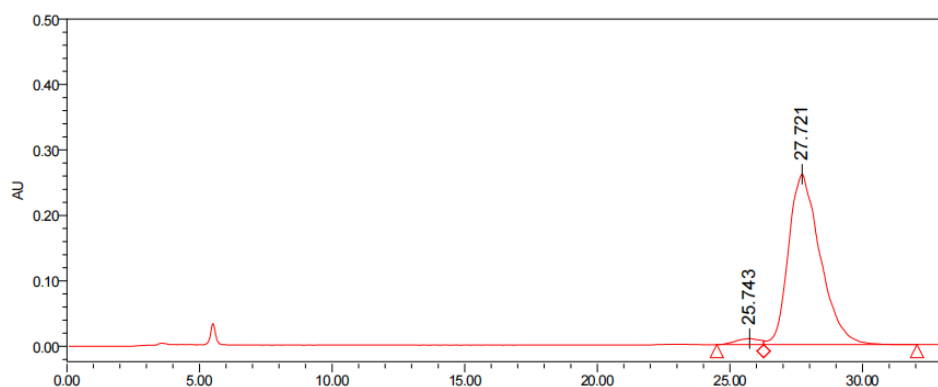
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 8.595        | 11657444 | 49.05 |
| 2 | 12.804       | 12107972 | 50.95 |

Supplementary Fig. 14. HPLC spectrum of compound **3h**



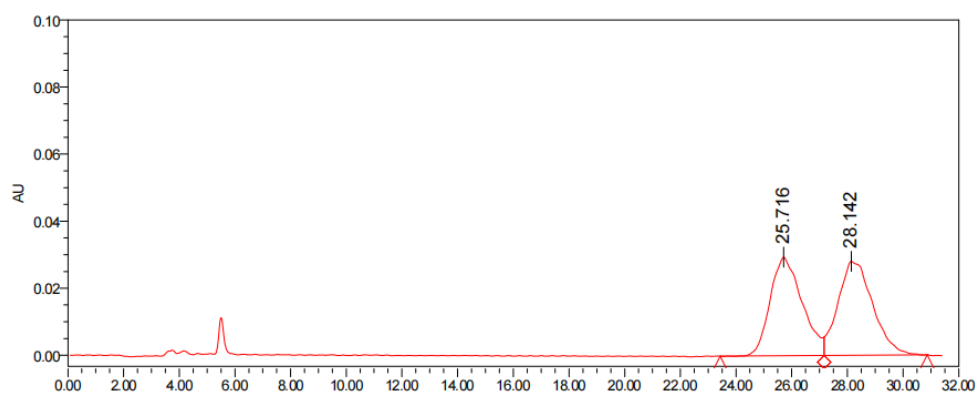
**HPLC Conditions**  
 Column: Chiralpak OD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (50:50)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

**Chiral**



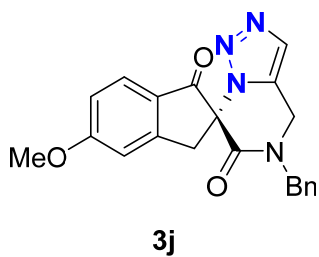
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 25.743       | 571454   | 2.57  |
| 2 | 27.721       | 21626812 | 97.43 |

**Racemic**



|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 25.716       | 2352153 | 49.24 |
| 2 | 28.142       | 2424279 | 50.76 |

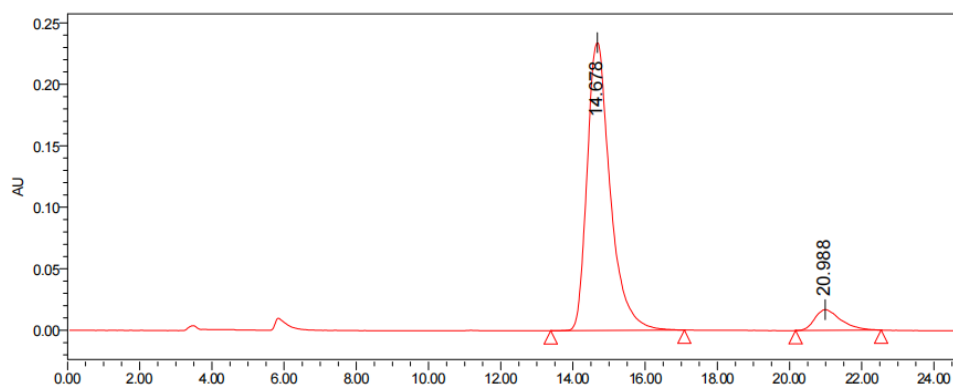
**Supplementary Fig. 15.** HPLC spectrum of compound **3i**



### HPLC Conditions

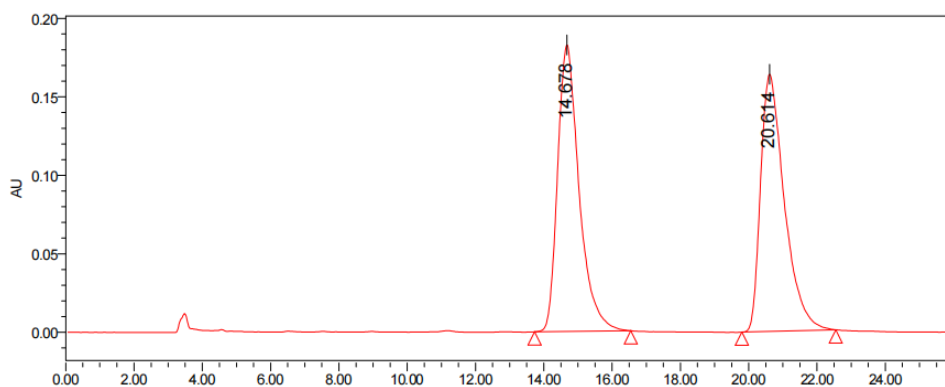
Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



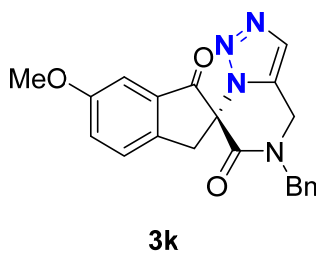
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 14.678       | 10382250 | 92.46 |
| 2 | 20.988       | 846268   | 7.54  |

### Racemic



|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 14.678       | 7979254 | 50.22 |
| 2 | 20.614       | 7908708 | 49.78 |

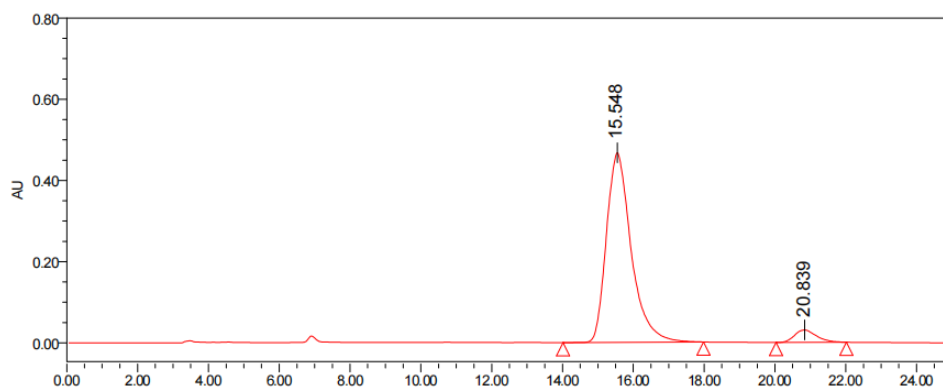
Supplementary Fig. 16. HPLC spectrum of compound 3j



### HPLC Conditions

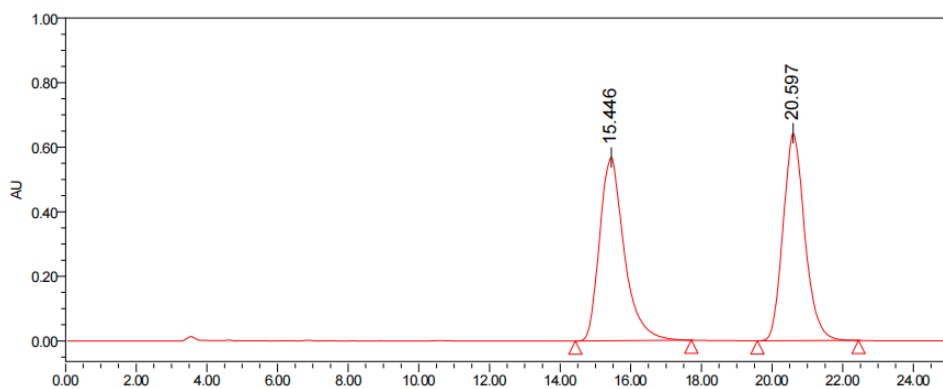
Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



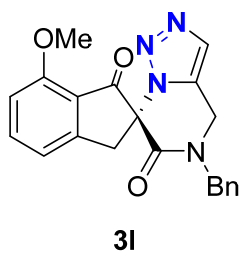
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 15.548       | 22672384 | 94.50 |
| 2 | 20.839       | 1319857  | 5.50  |

### Racemic



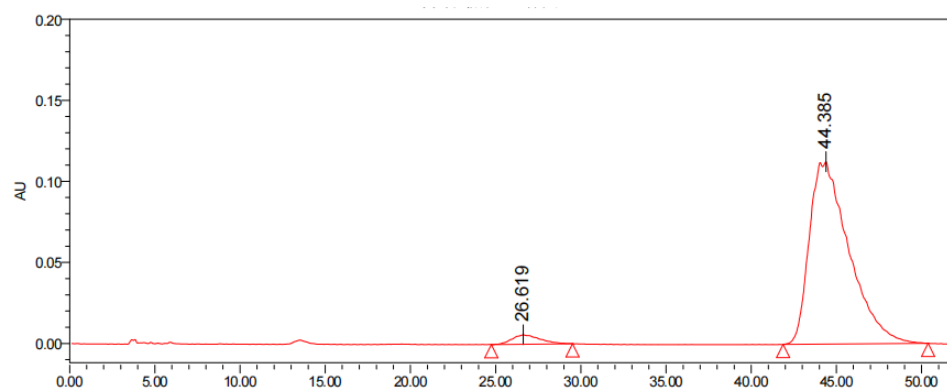
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 15.446       | 27487167 | 50.03 |
| 2 | 20.597       | 27459019 | 49.97 |

Supplementary Fig. 17. HPLC spectrum of compound **3k**



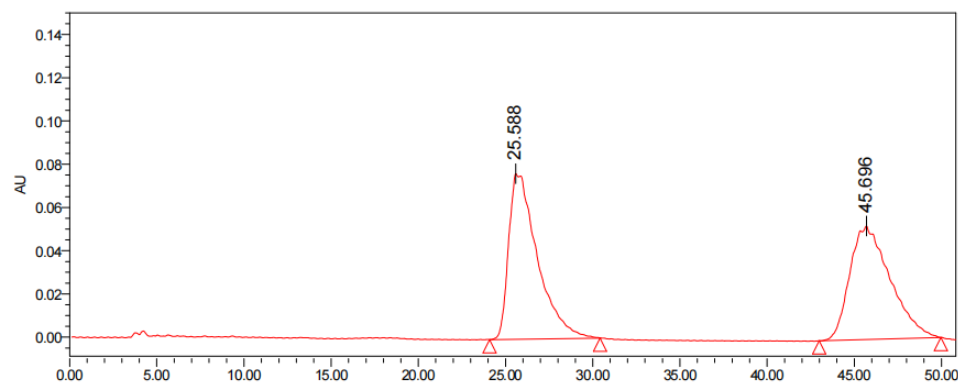
**HPLC Conditions**  
 Column: Chiralpak OD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (50:50)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

**Chiral**



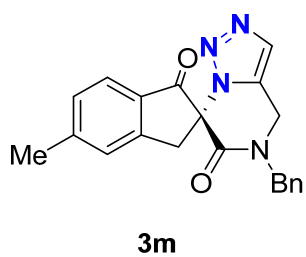
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 26.619       | 660408   | 3.50  |
| 2 | 44.385       | 18202343 | 96.50 |

**Racemic**



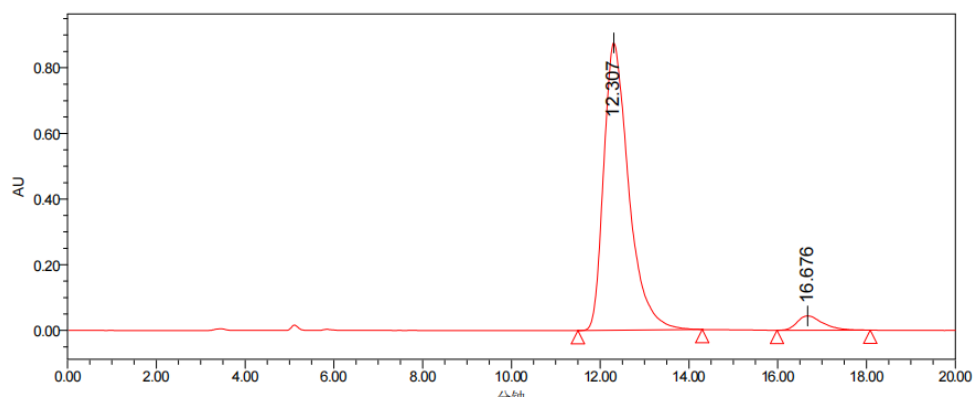
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 25.588       | 8781656 | 51.04 |
| 2 | 45.696       | 8423206 | 48.96 |

**Supplementary Fig. 18.** HPLC spectrum of compound **31**



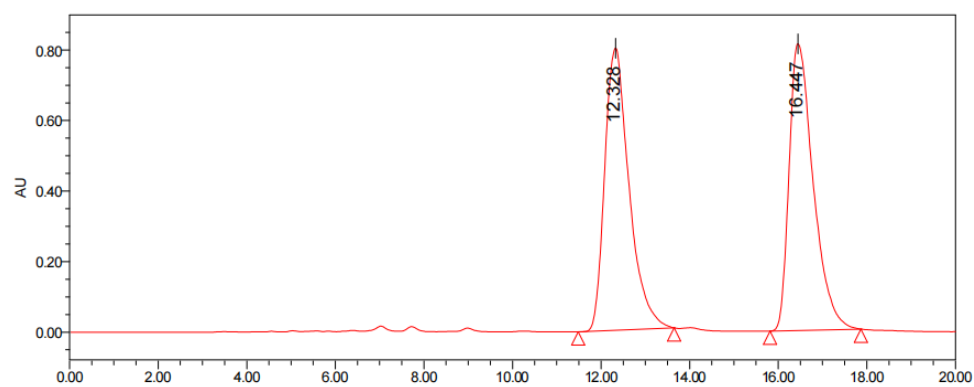
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



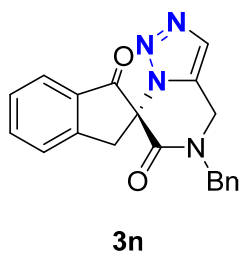
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 12.307       | 34273138 | 95.17 |
| 2 | 16.676       | 1737764  | 4.83  |

### Racemic



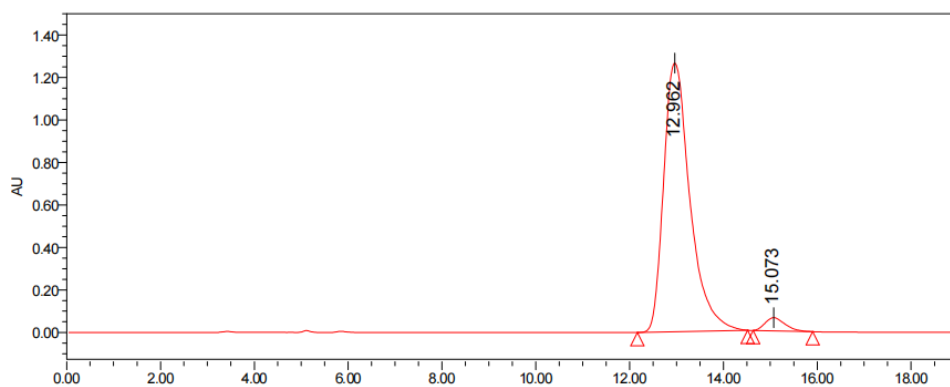
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 12.328       | 30601548 | 49.86 |
| 2 | 16.447       | 30769965 | 50.14 |

Supplementary Fig. 19. HPLC spectrum of compound **3m**



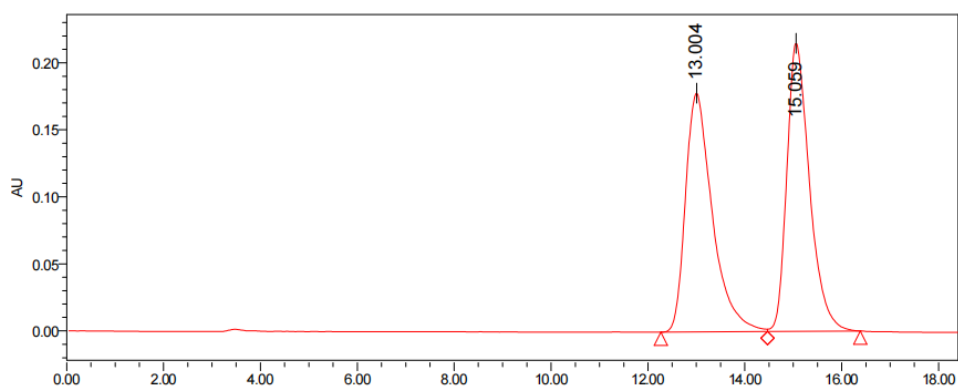
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



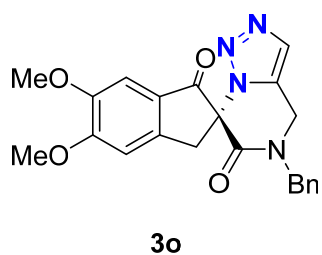
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 12.962       | 49190755 | 96.45 |
| 2 | 15.073       | 1812834  | 3.55  |

### Racemic



|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 13.004       | 6880692 | 49.55 |
| 2 | 15.059       | 7006098 | 50.45 |

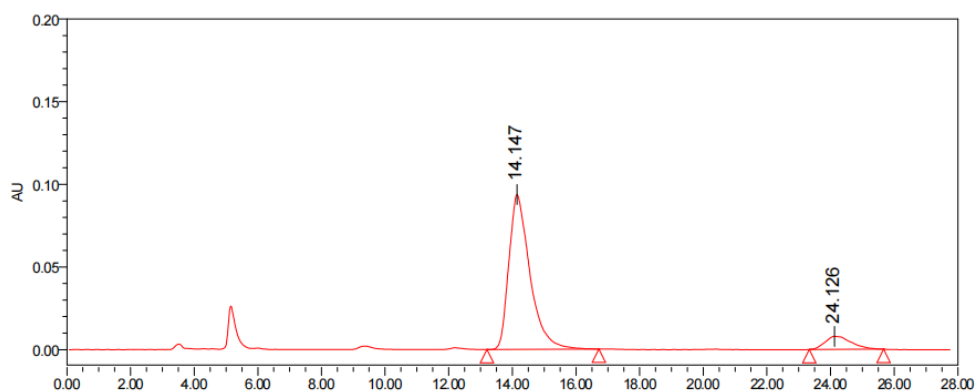
Supplementary Fig. 20. HPLC spectrum of compound **3n**



### HPLC Conditions

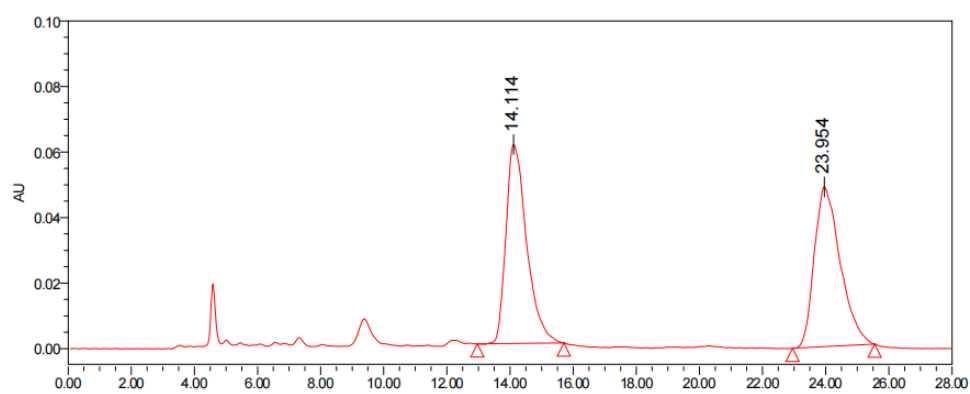
Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (60:40)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 14.147       | 4297604 | 90.58 |
| 2 | 24.126       | 447017  | 9.42  |

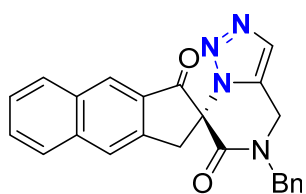
### Racemic



|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 14.114       | 2772424 | 49.92 |
| 2 | 23.954       | 2780886 | 50.08 |

Supplementary Fig. 21. HPLC spectrum of compound **3o**



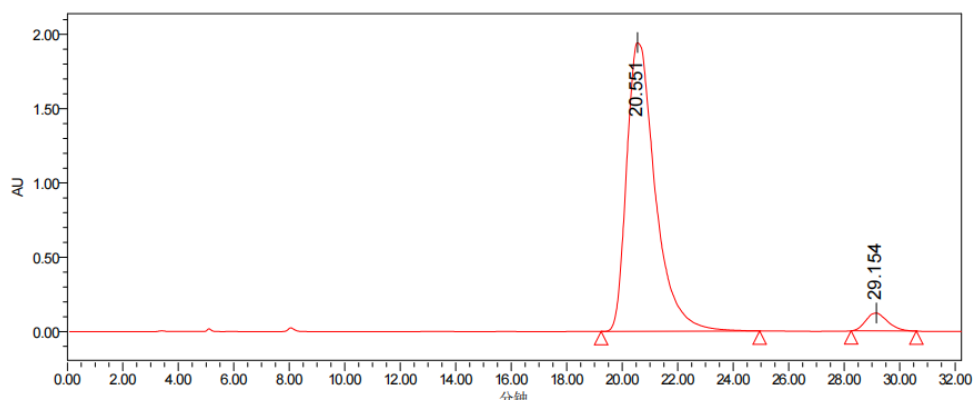


**3p**

### HPLC Conditions

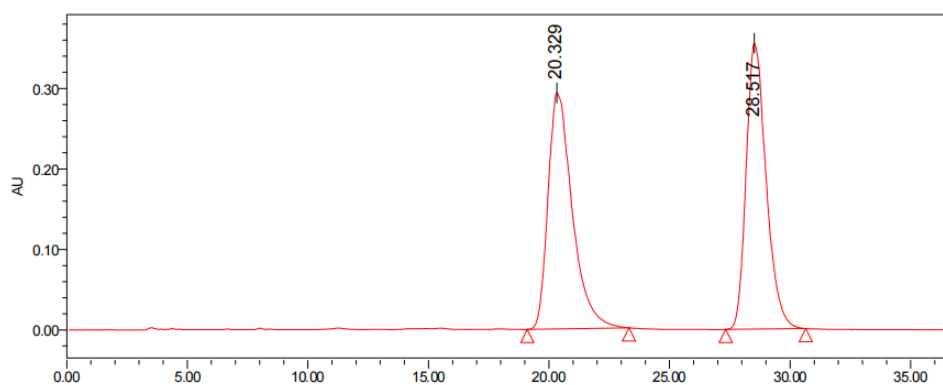
Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



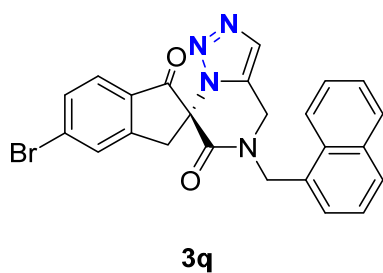
|   | 保留时间<br>(分钟) | 面积        | % 面积  |
|---|--------------|-----------|-------|
| 1 | 20.551       | 139303550 | 95.47 |
| 2 | 29.154       | 6615139   | 4.53  |

### Racemic



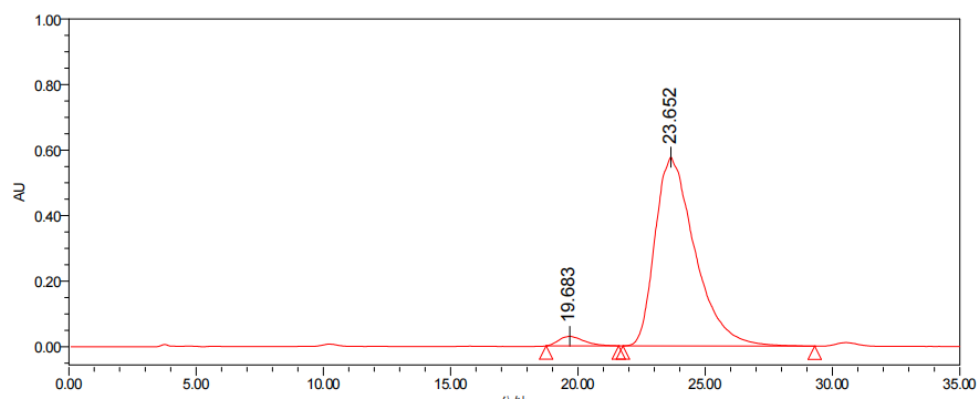
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 20.329       | 20512651 | 50.03 |
| 2 | 28.517       | 20485582 | 49.97 |

**Supplementary Fig. 22.** HPLC spectrum of compound **3p**



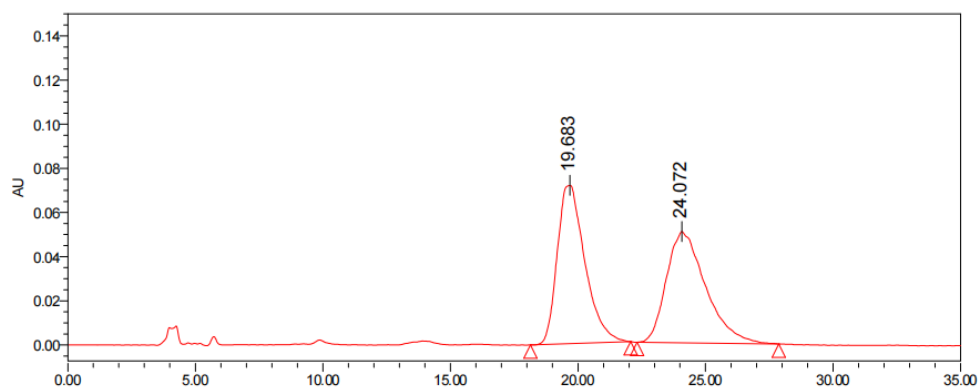
**HPLC Conditions**  
 Column: Chiralpak AS-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (60:40)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



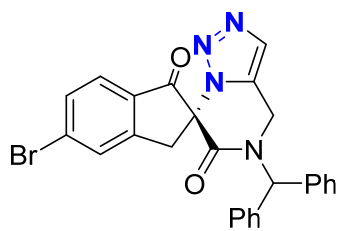
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 19.683       | 1991514  | 3.08  |
| 2 | 23.652       | 62720750 | 96.92 |

### Racemic



|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 19.683       | 5401188 | 50.13 |
| 2 | 24.072       | 5372816 | 49.87 |

Supplementary Fig. 23. HPLC spectrum of compound **3q**

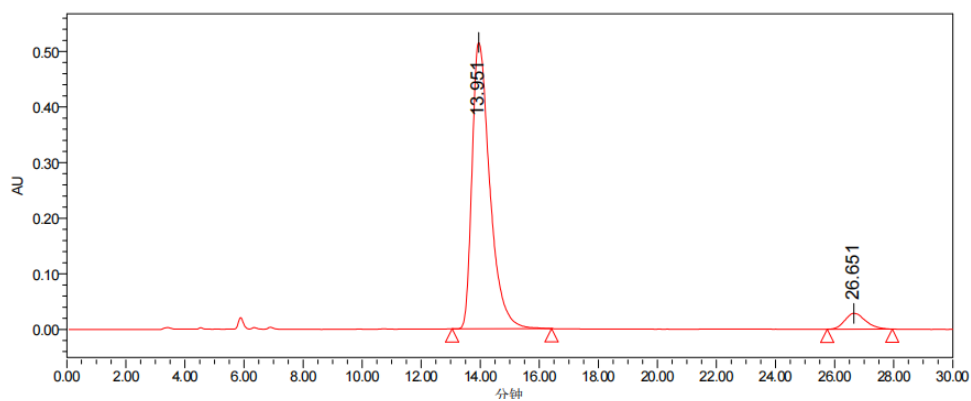


**3r**

**HPLC Conditions**

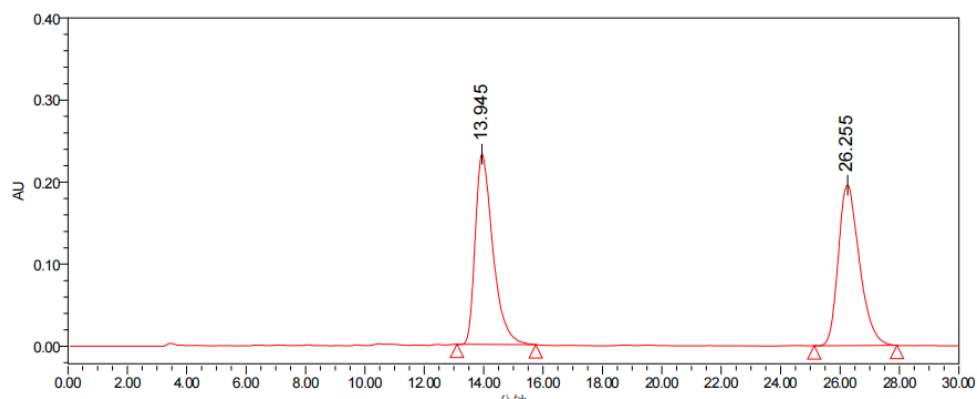
Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

**Chiral**



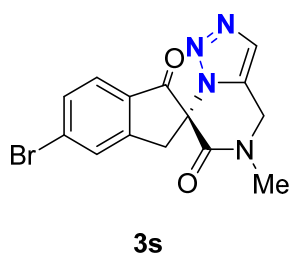
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 13.951       | 21525241 | 93.94 |
| 2 | 26.651       | 1387615  | 6.06  |

**Racemic**



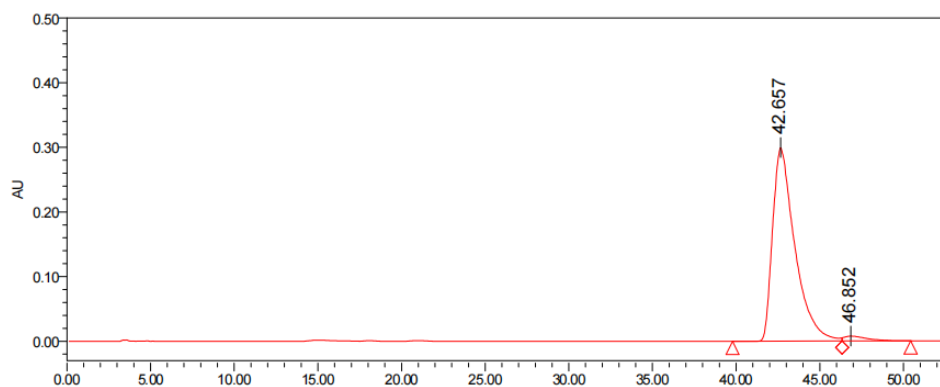
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 13.945       | 9582787 | 49.73 |
| 2 | 26.255       | 9686649 | 50.27 |

**Supplementary Fig. 24.** HPLC spectrum of compound **3r**



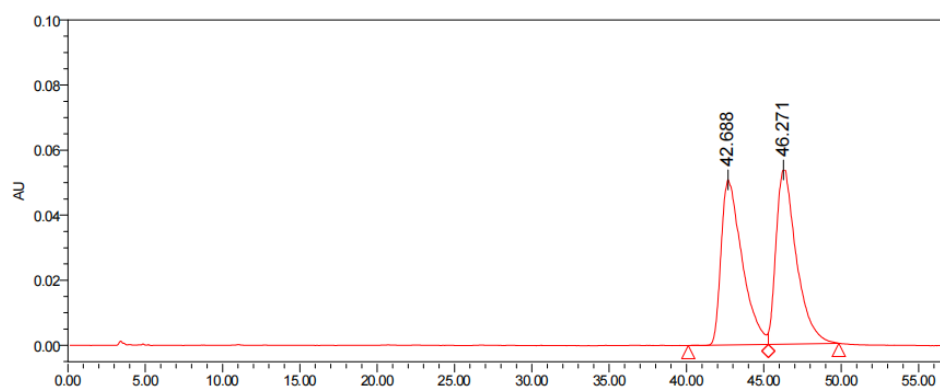
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (90:10)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

**Chiral**



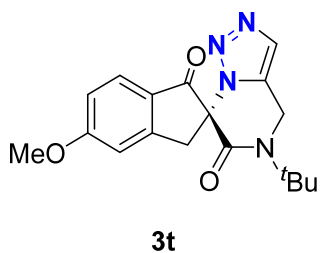
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 42.657       | 27661299 | 97.49 |
| 2 | 46.852       | 712599   | 2.51  |

**Racemic**



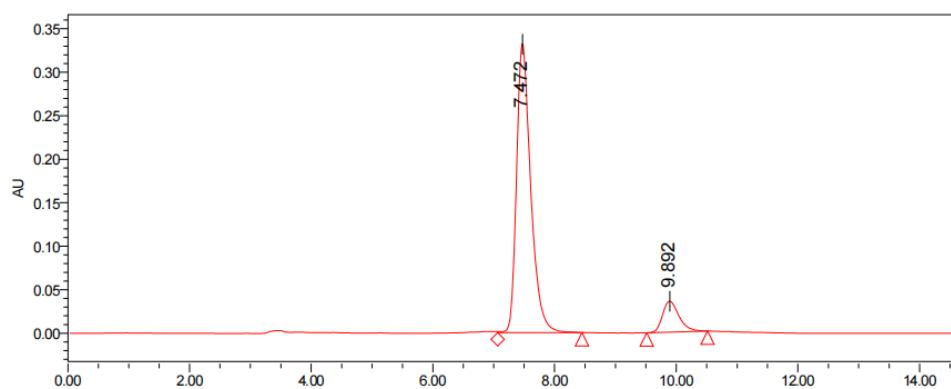
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 42.688       | 4791308 | 49.37 |
| 2 | 46.271       | 4914212 | 50.63 |

**Supplementary Fig. 25.** HPLC spectrum of compound **3s**



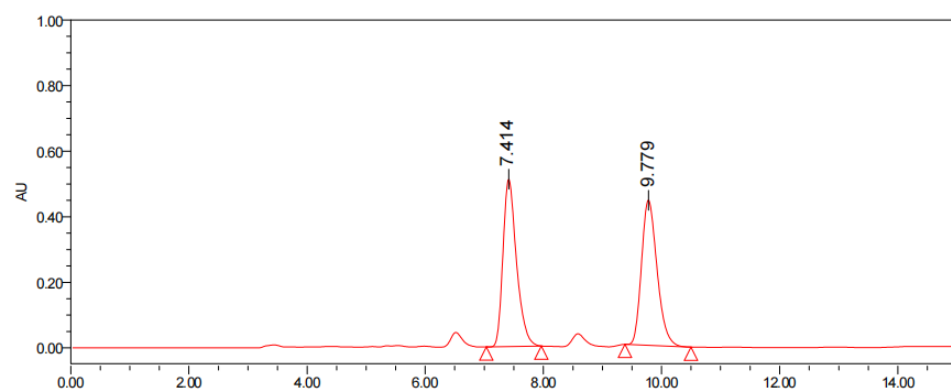
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



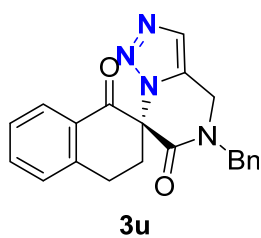
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 7.472        | 5372963 | 89.00 |
| 2 | 9.892        | 664060  | 11.00 |

### Racemic



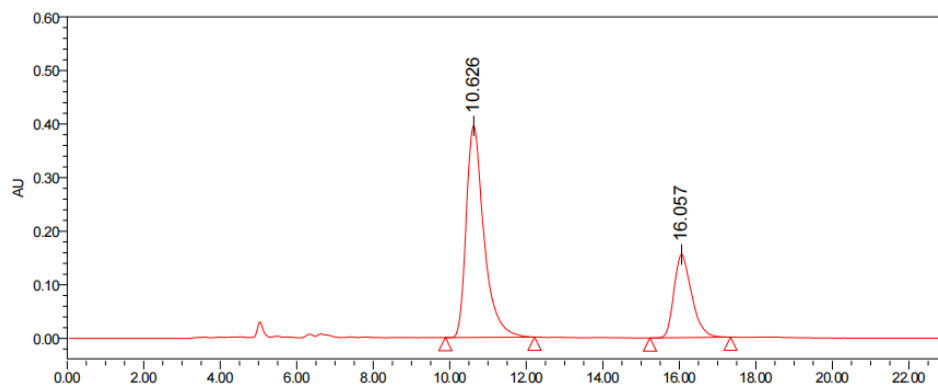
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 7.414        | 8125313 | 50.24 |
| 2 | 9.779        | 8049164 | 49.76 |

Supplementary Fig. 26. HPLC spectrum of compound **3t**



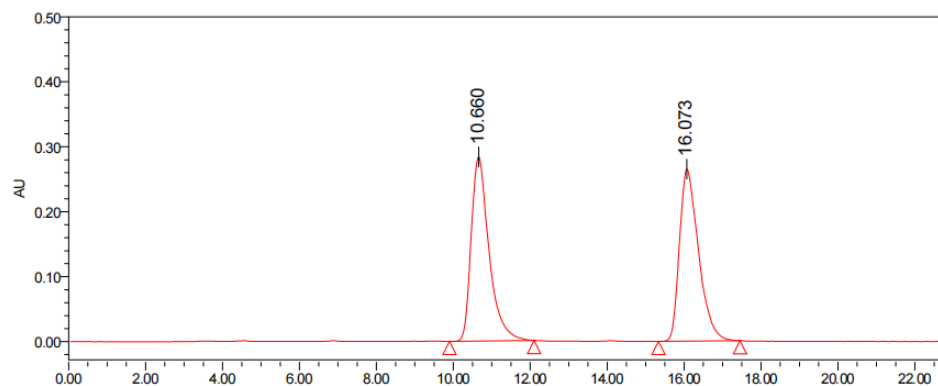
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

**Chiral**



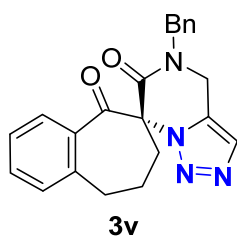
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 10.626       | 12754082 | 71.86 |
| 2 | 16.057       | 4993694  | 28.14 |

**Racemic**



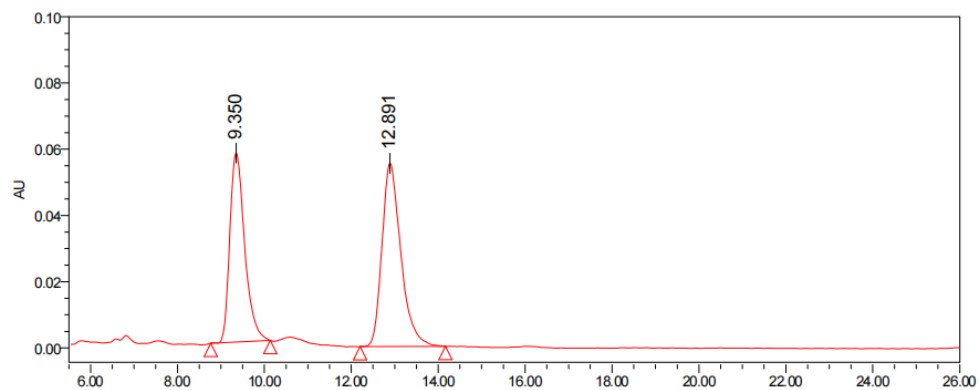
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 10.660       | 9135024 | 50.01 |
| 2 | 16.073       | 9131714 | 49.99 |

**Supplementary Fig. 27.** HPLC spectrum of compound **3u**



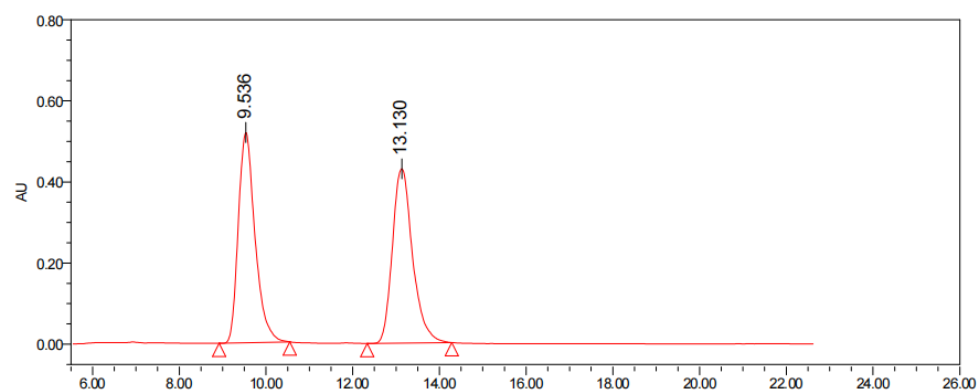
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



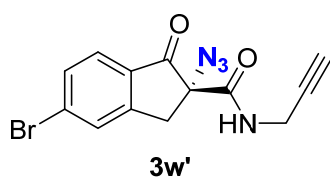
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 9.350        | 1358525 | 44.85 |
| 2 | 12.891       | 1670399 | 55.15 |

### Racemic



|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 9.536        | 13889859 | 50.01 |
| 2 | 13.130       | 13884651 | 49.99 |

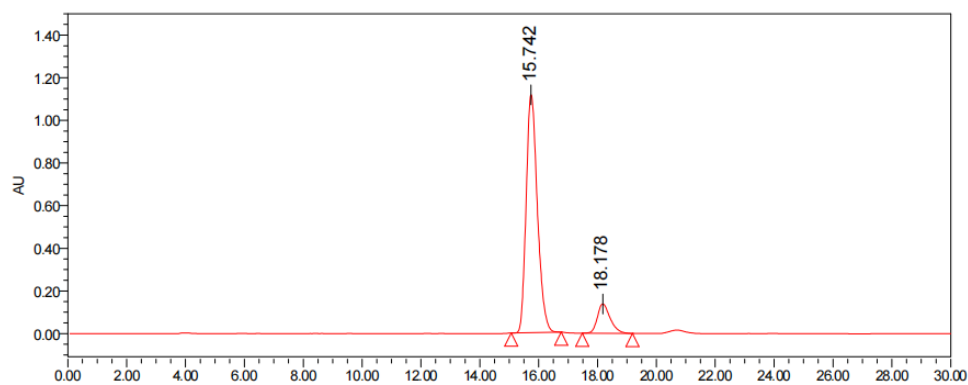
Supplementary Fig. 28. HPLC spectrum of compound **3v**



### HPLC Conditions

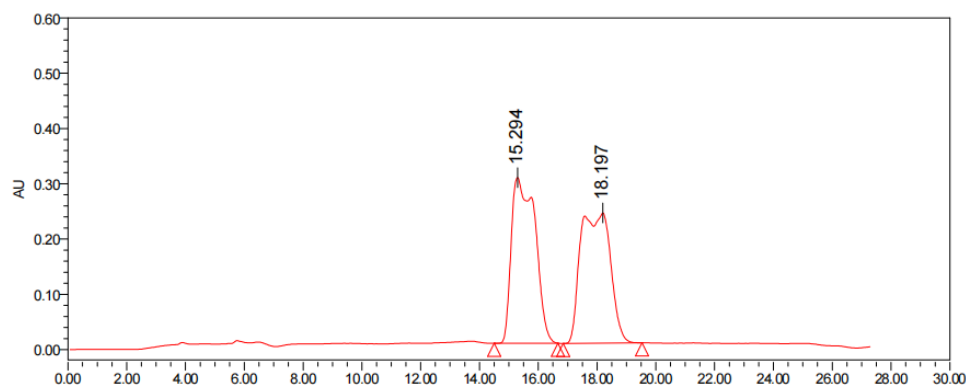
Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (90:10)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 15.742       | 29528095 | 87.72 |
| 2 | 18.178       | 4132625  | 12.28 |

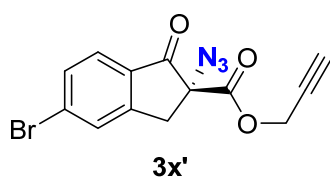
### Racemic



|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 15.294       | 16825642 | 49.99 |
| 2 | 18.197       | 16833906 | 50.01 |

Supplementary Fig. 29. HPLC spectrum of compound 3w'

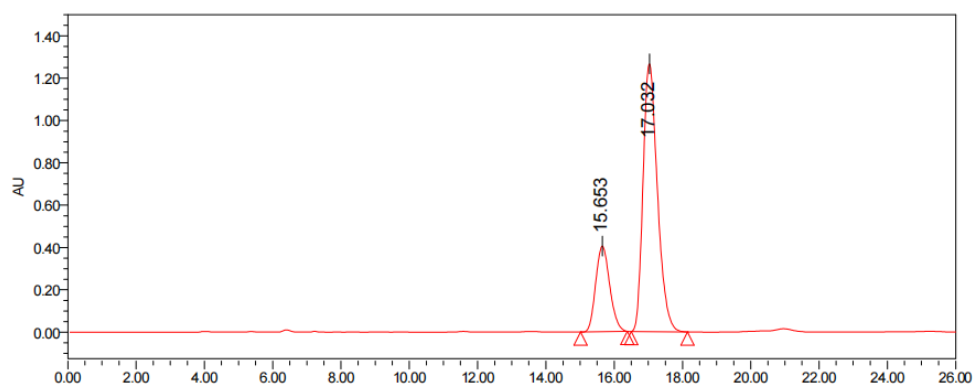




### HPLC Conditions

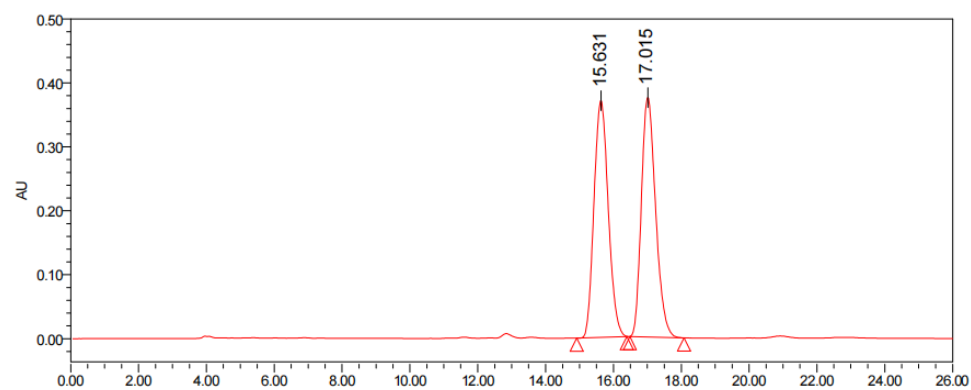
Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (95:5)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



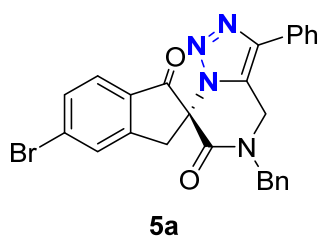
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 15.653       | 11543362 | 23.84 |
| 2 | 17.032       | 36876325 | 76.16 |

### Racemic



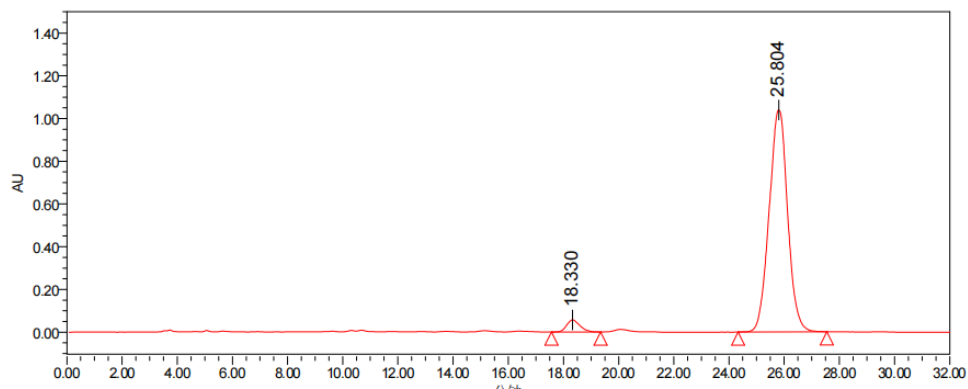
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 15.631       | 10821893 | 49.74 |
| 2 | 17.015       | 10933486 | 50.26 |

Supplementary Fig. 30. HPLC spectrum of compound **3x'**



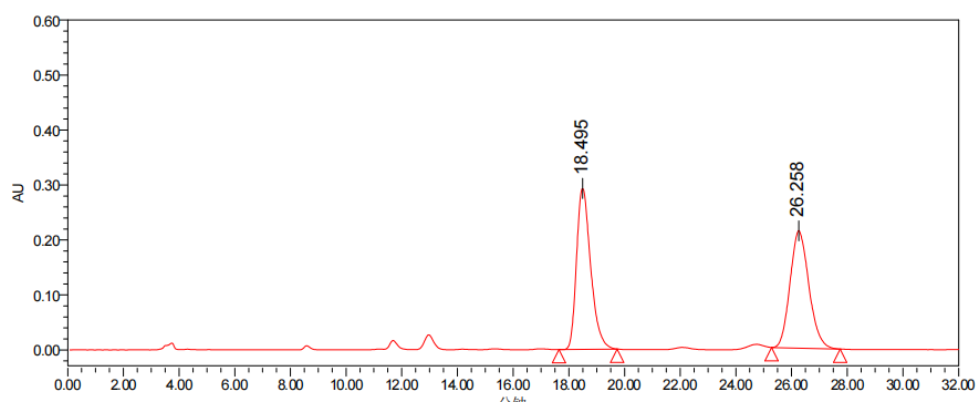
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



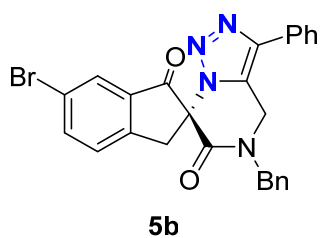
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 18.330       | 1887368  | 3.75  |
| 2 | 25.804       | 48376166 | 96.25 |

### Racemic



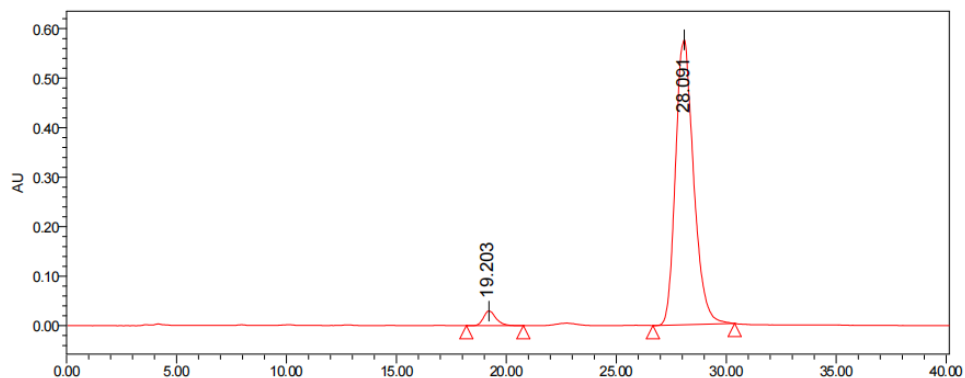
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 18.495       | 10352242 | 50.67 |
| 2 | 26.258       | 10078694 | 49.33 |

Supplementary Fig. 31. HPLC spectrum of compound **5a**



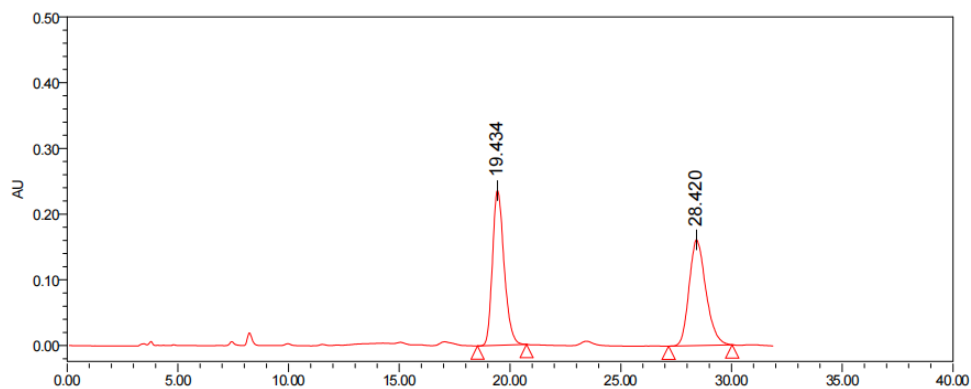
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



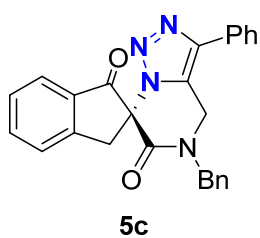
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 19.203       | 1173036  | 3.43  |
| 2 | 28.091       | 33005376 | 96.57 |

### Racemic



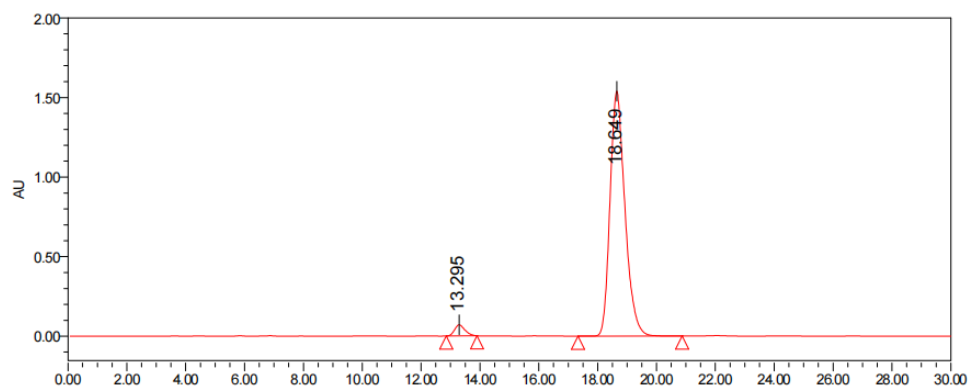
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 19.434       | 8596329 | 50.42 |
| 2 | 28.420       | 8454773 | 49.58 |

Supplementary Fig. 32. HPLC spectrum of compound **5b**



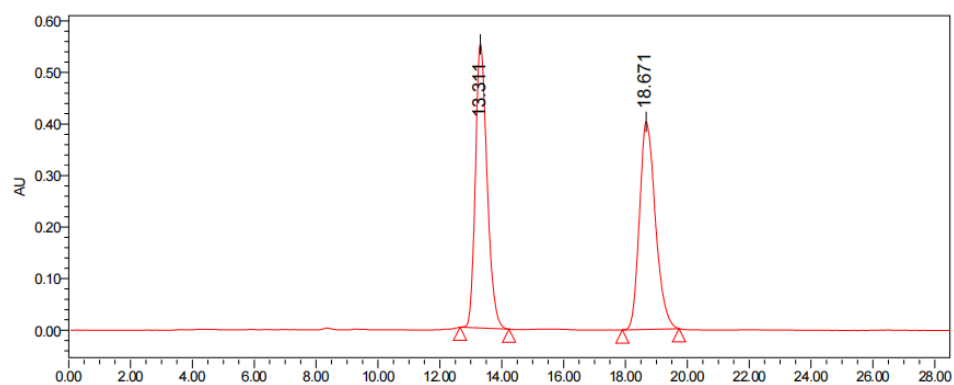
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



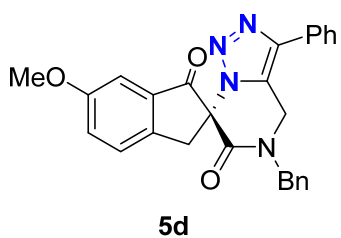
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 13.295       | 1709896  | 3.06  |
| 2 | 18.649       | 54137899 | 96.94 |

### Racemic



|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 13.311       | 14476887 | 50.10 |
| 2 | 18.671       | 14417206 | 49.90 |

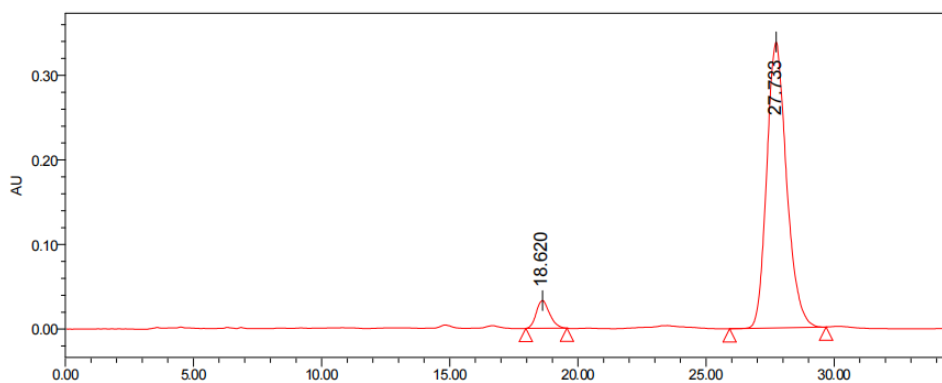
Supplementary Fig. 33. HPLC spectrum of compound **5c**



### HPLC Conditions

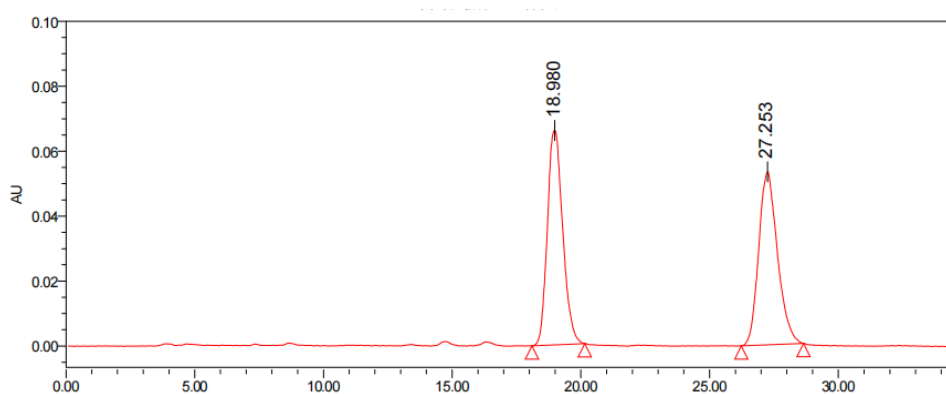
Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



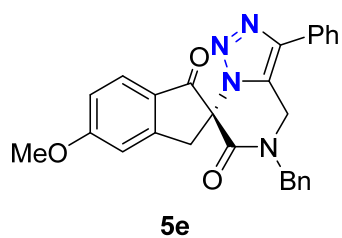
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 18.620       | 1183440  | 6.12  |
| 2 | 27.733       | 18154461 | 93.88 |

### Racemic



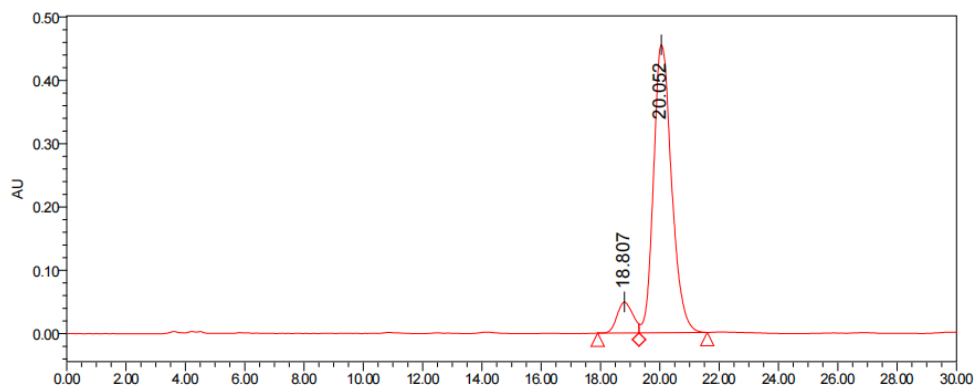
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 18.980       | 2731501 | 50.36 |
| 2 | 27.253       | 2692880 | 49.64 |

Supplementary Fig. 34. HPLC spectrum of compound **5d**



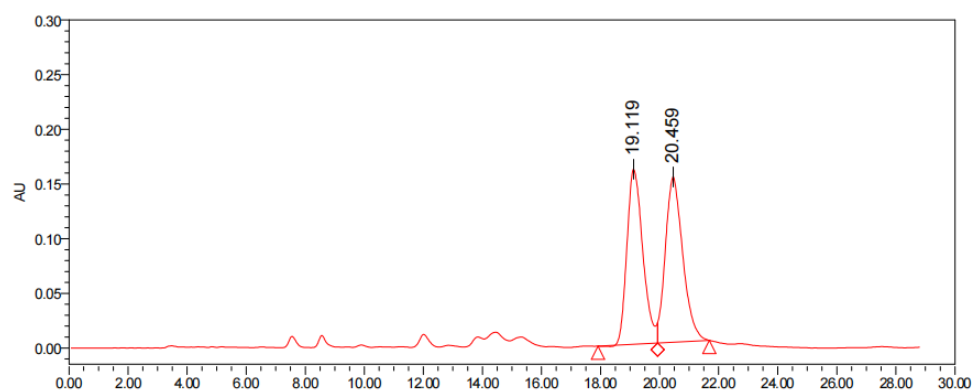
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



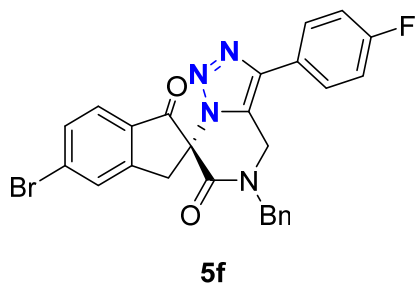
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 18.807       | 1778670  | 8.47  |
| 2 | 20.052       | 19217387 | 91.53 |

### Racemic



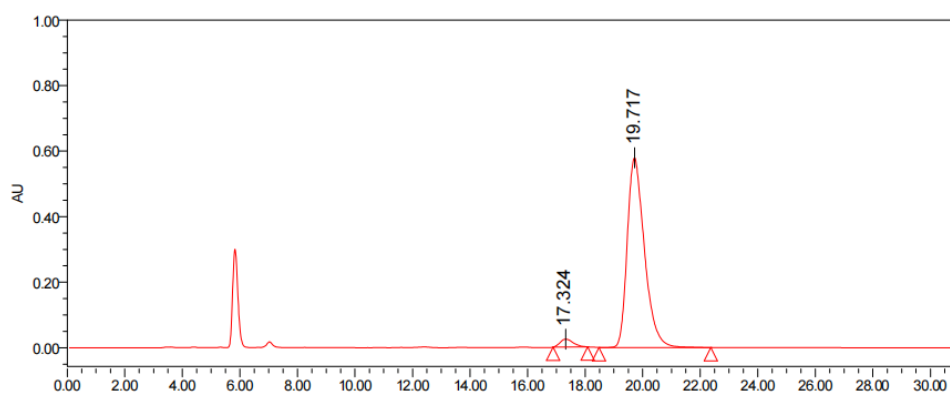
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 19.119       | 6019527 | 49.31 |
| 2 | 20.459       | 6188237 | 50.69 |

Supplementary Fig. 35. HPLC spectrum of compound **5e**



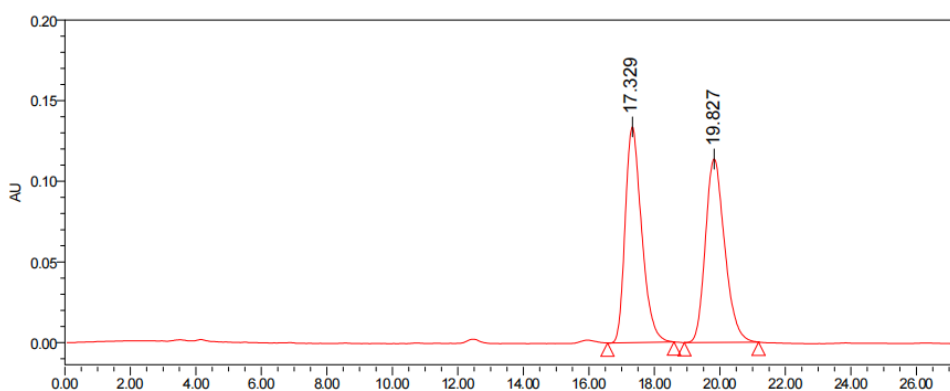
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



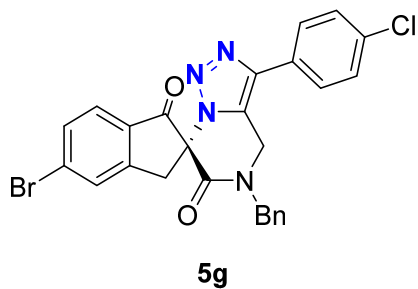
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 17.324       | 762233   | 3.08  |
| 2 | 19.717       | 23999958 | 96.92 |

### Racemic



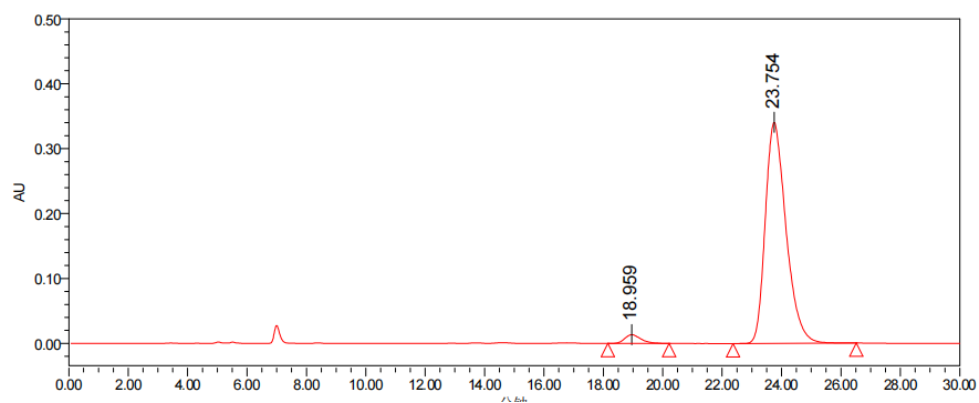
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 17.329       | 4676318 | 50.10 |
| 2 | 19.827       | 4658152 | 49.90 |

**Supplementary Fig. 36.** HPLC spectrum of compound **5f**



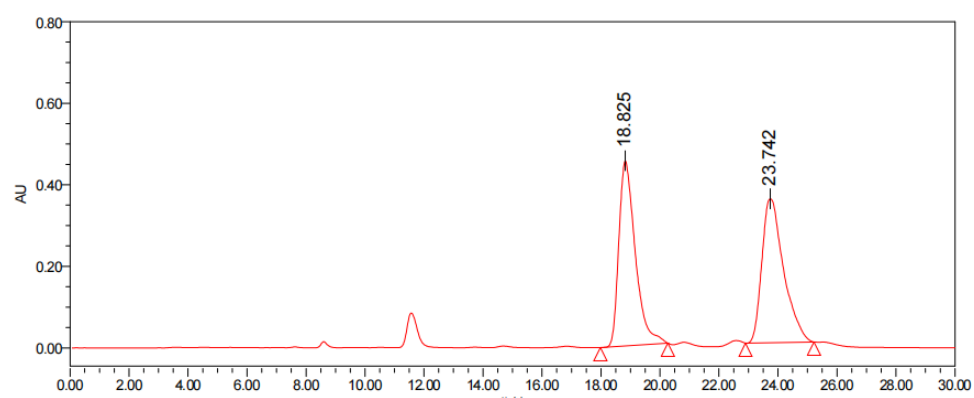
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 18.959       | 509934   | 3.00  |
| 2 | 23.754       | 16513130 | 97.00 |

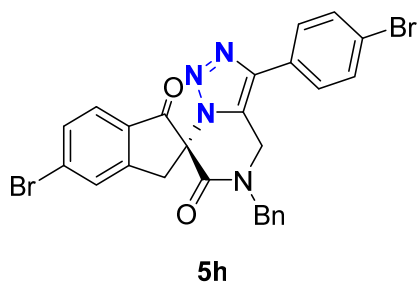
### Racemic



|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 18.825       | 17588911 | 49.36 |
| 2 | 23.742       | 18045576 | 50.64 |

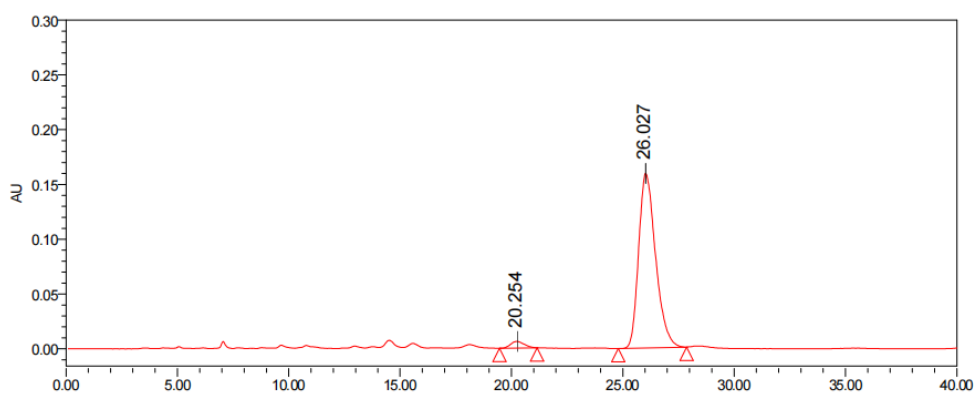
Supplementary Fig. 37. HPLC spectrum of compound **5g**





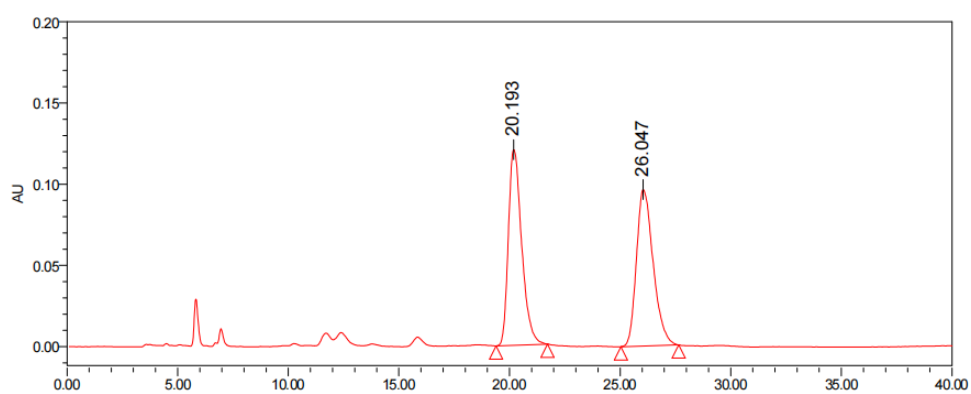
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



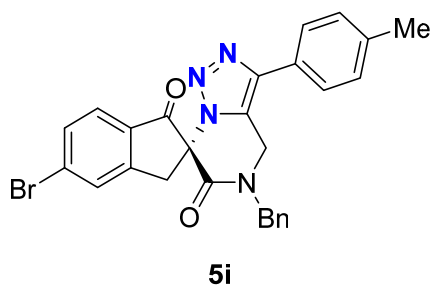
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 20.254       | 254885  | 2.94  |
| 2 | 26.027       | 8424208 | 97.06 |

### Racemic



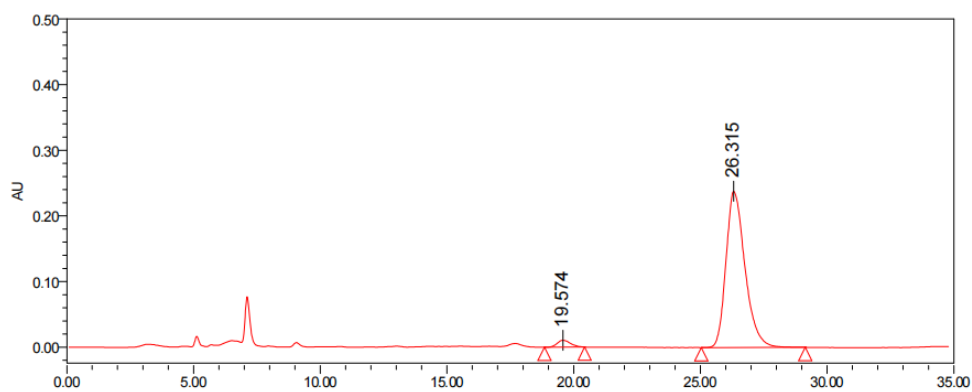
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 20.193       | 5035325 | 49.88 |
| 2 | 26.047       | 5059293 | 50.12 |

**Supplementary Fig. 38. HPLC spectrum of compound 5h**



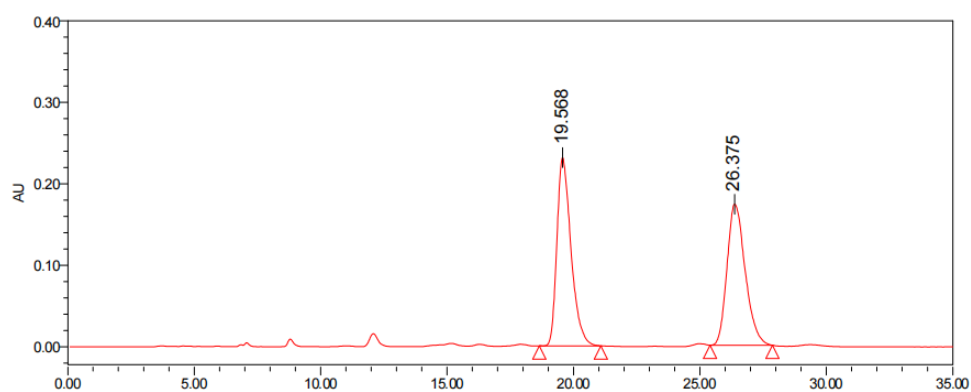
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



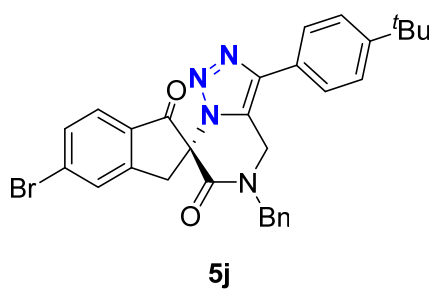
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 19.574       | 384476   | 3.01  |
| 2 | 26.315       | 12397453 | 96.99 |

### Racemic



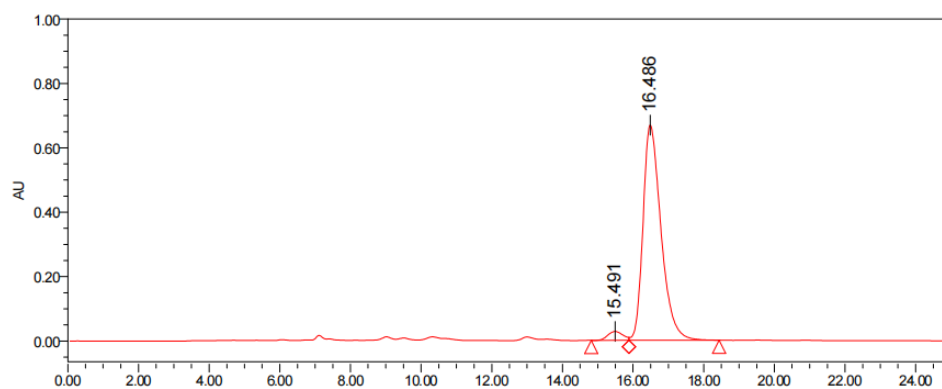
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 19.568       | 8929734 | 50.75 |
| 2 | 26.375       | 8666262 | 49.25 |

**Supplementary Fig. 39.** HPLC spectrum of compound **5i**



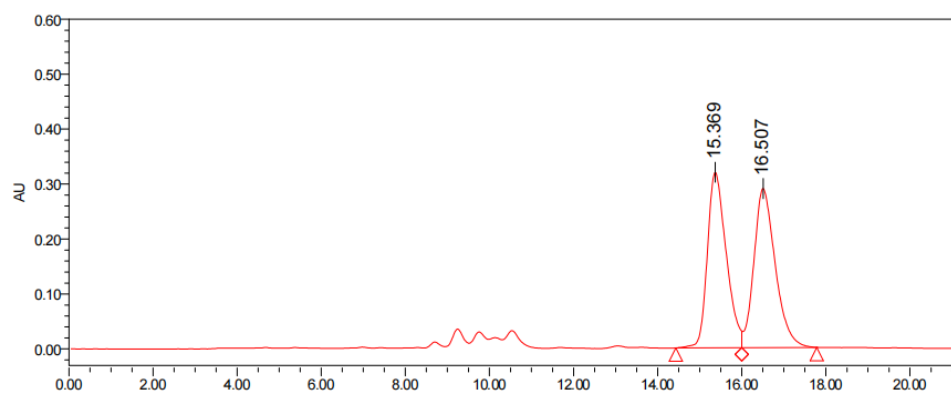
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



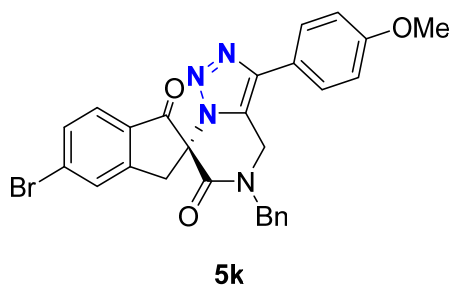
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 15.491       | 810253   | 3.32  |
| 2 | 16.486       | 23616505 | 96.68 |

### Racemic



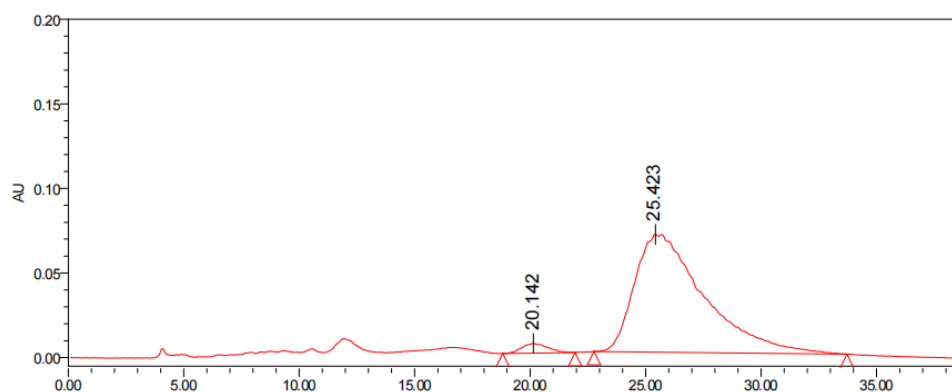
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 15.369       | 9915633  | 49.19 |
| 2 | 16.507       | 10242160 | 50.81 |

**Supplementary Fig. 40.** HPLC spectrum of compound **5j**



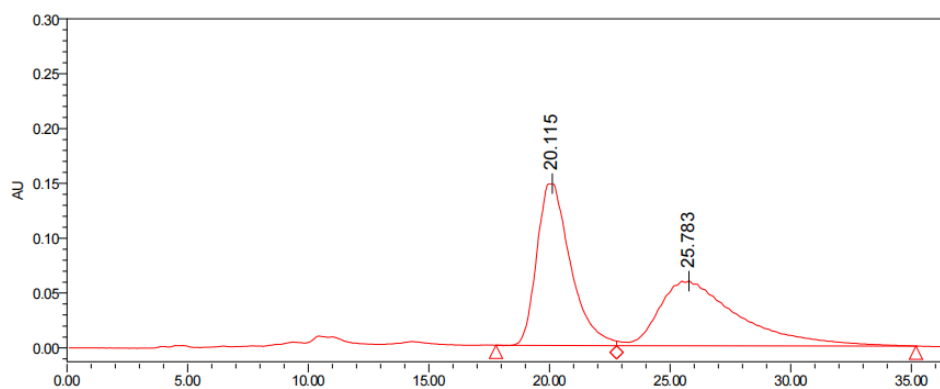
**HPLC Conditions**  
 Column: Chiralpak AS-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (60:40)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



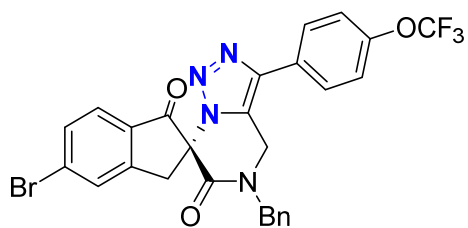
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 20.142       | 438438   | 2.92  |
| 2 | 25.423       | 14562375 | 97.08 |

### Racemic



|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 20.115       | 14305458 | 51.41 |
| 2 | 25.783       | 13519114 | 48.59 |

Supplementary Fig. 41. HPLC spectrum of compound 5k



**51**

**HPLC Conditions**

Column: Chiralpak AD-H,

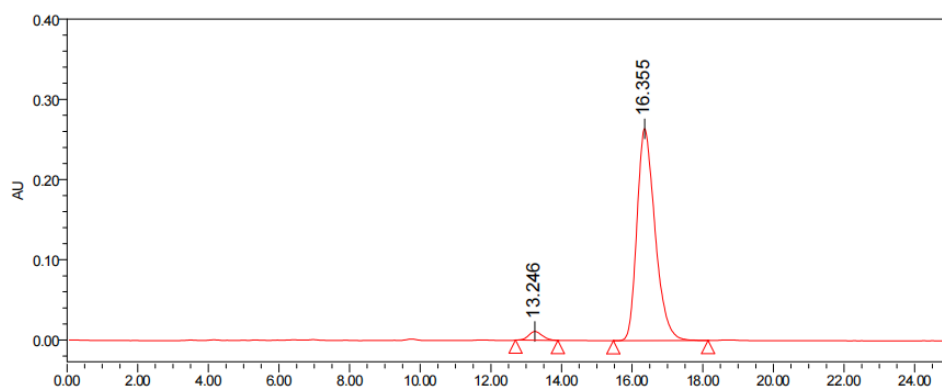
Daicel Chemical Industries Ltd.

Eluent: Hexanes / Isopropanol (70:30)

Flow rate: 1.0 mL/min

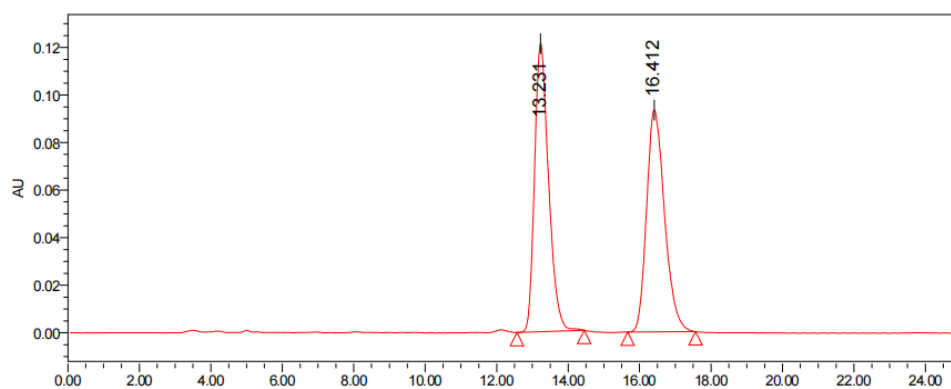
Detection: UV 254 nm

**Chiral**



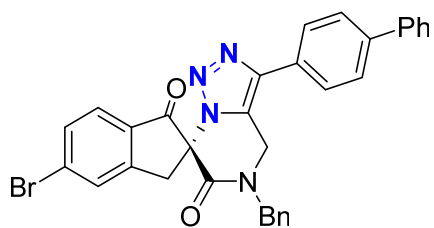
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 13.246       | 295328  | 3.05  |
| 2 | 16.355       | 9382239 | 96.95 |

**Racemic**



|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 13.231       | 3302690 | 50.27 |
| 2 | 16.412       | 3266642 | 49.73 |

**Supplementary Fig. 42. HPLC spectrum of compound 51**



**5m**

### HPLC Conditions

Column: Chiralpak OD-H,

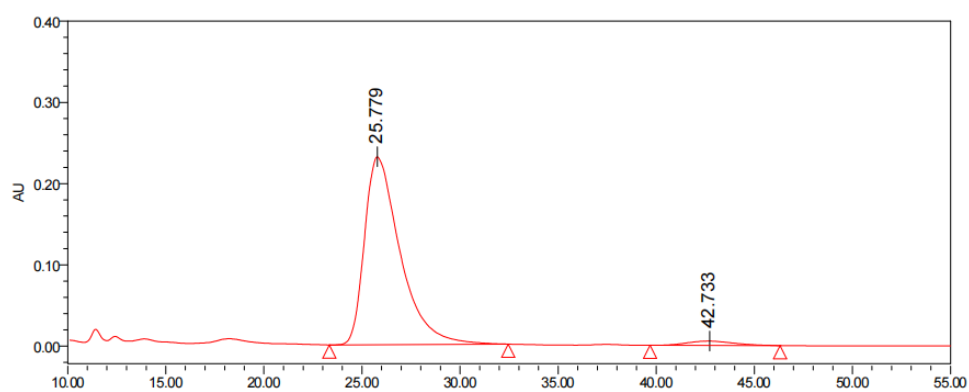
Daicel Chemical Industries Ltd.

Eluent: Hexanes / Isopropanol (50:50)

Flow rate: 1.0 mL/min

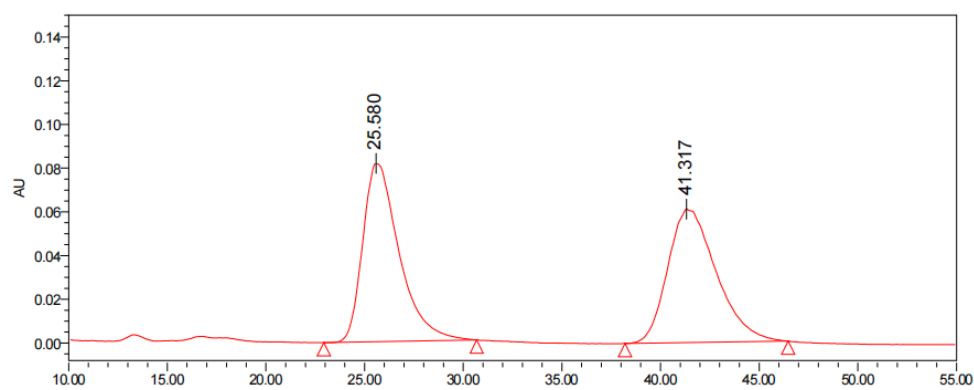
Detection: UV 254 nm

### Chiral



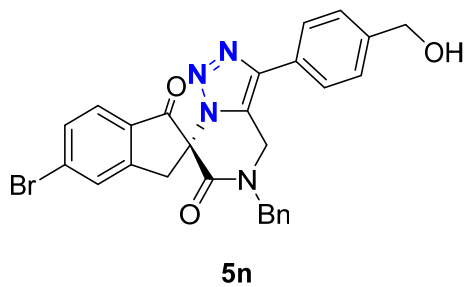
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 25.779       | 29134422 | 97.07 |
| 2 | 42.733       | 880338   | 2.93  |

### Racemic



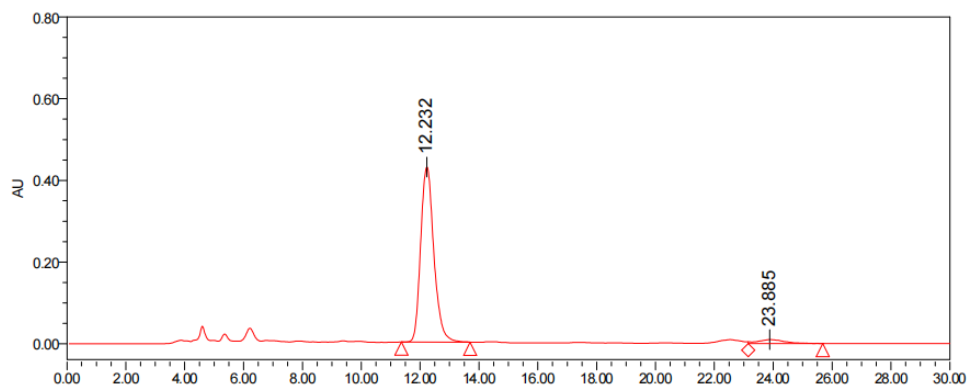
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 25.580       | 10455040 | 50.02 |
| 2 | 41.317       | 10444764 | 49.98 |

**Supplementary Fig. 43. HPLC spectrum of compound 5m**



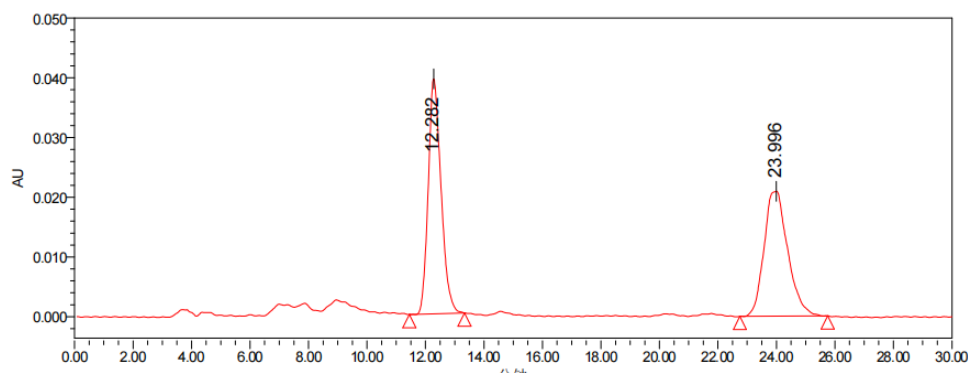
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (60:40)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



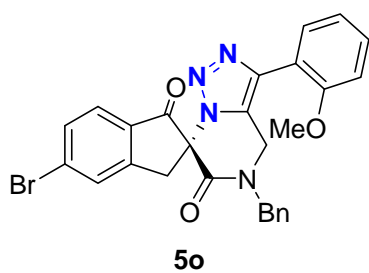
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 12.232       | 13337758 | 95.90 |
| 2 | 23.885       | 569973   | 4.10  |

### Racemic



|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 12.282       | 1195466 | 50.42 |
| 2 | 23.996       | 1175585 | 49.58 |

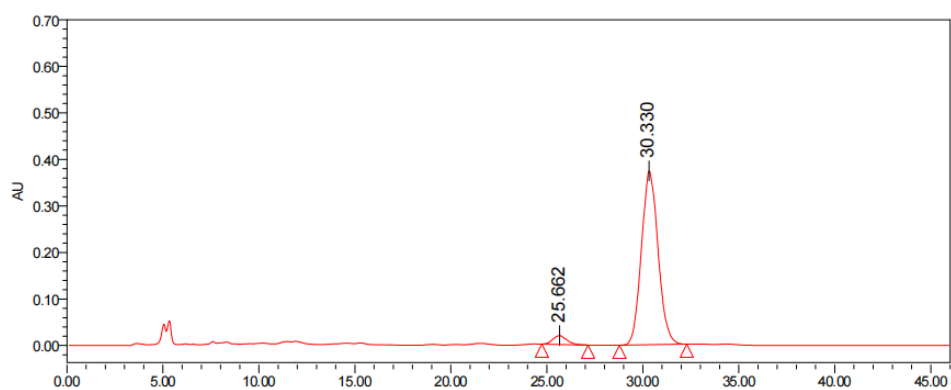
**Supplementary Fig. 44.** HPLC spectrum of compound **5n**



### HPLC Conditions

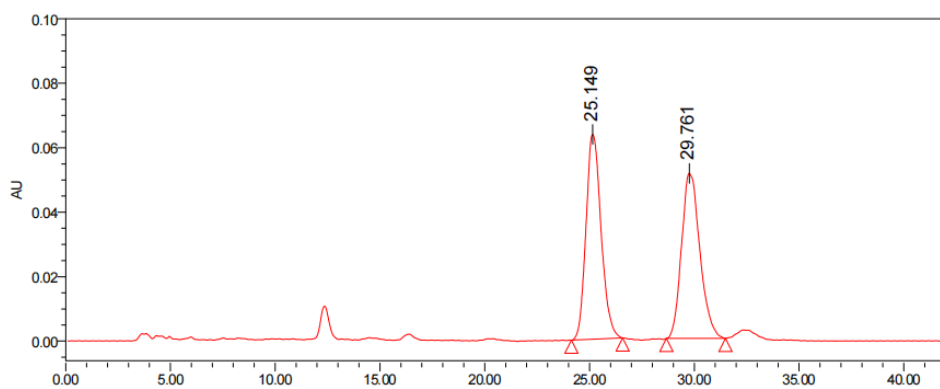
Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (60:40)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 25.662       | 956908   | 4.08  |
| 2 | 30.330       | 22503222 | 95.92 |

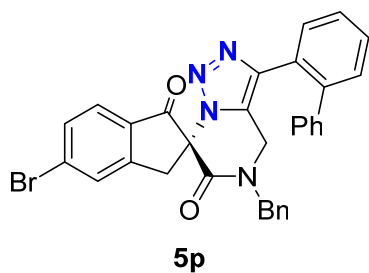
### Racemic



|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 25.149       | 3177126 | 50.45 |
| 2 | 29.761       | 3120923 | 49.55 |

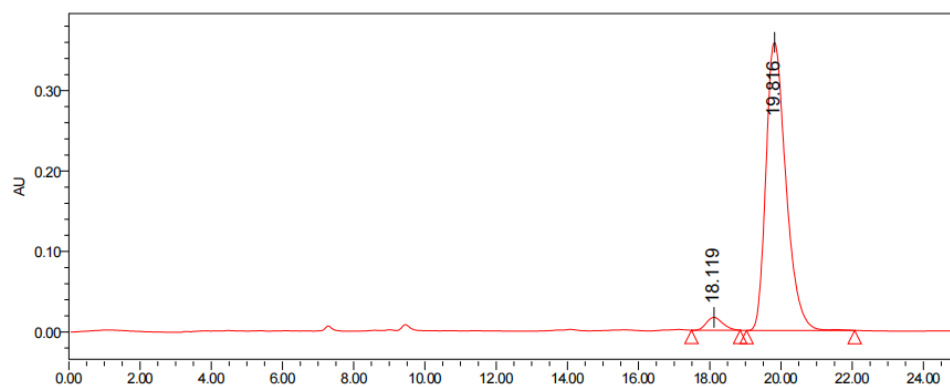
Supplementary Fig. 45. HPLC spectrum of compound **5o**





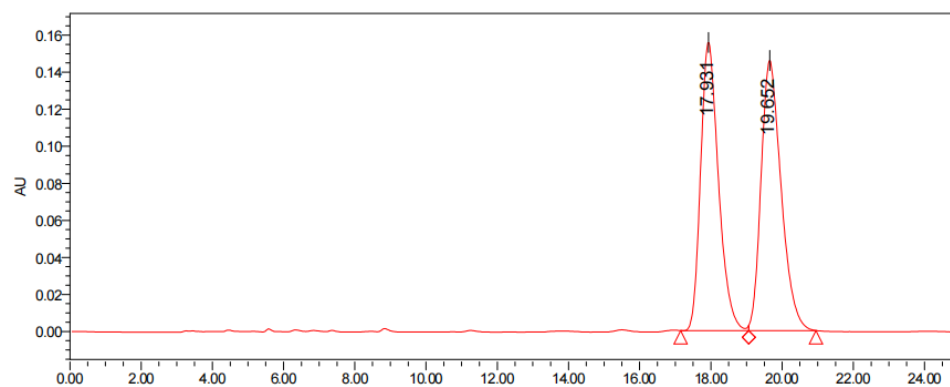
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (80:20)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



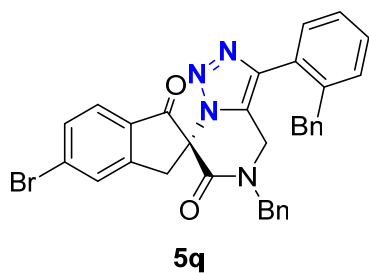
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 18.119       | 510229   | 3.53  |
| 2 | 19.816       | 13958002 | 96.47 |

### Racemic



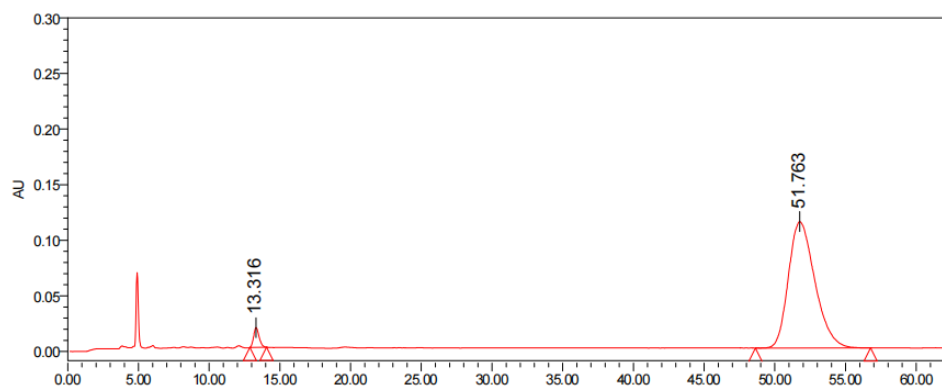
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 17.931       | 5412398 | 48.73 |
| 2 | 19.652       | 5695130 | 51.27 |

Supplementary Fig. 46. HPLC spectrum of compound **5p**



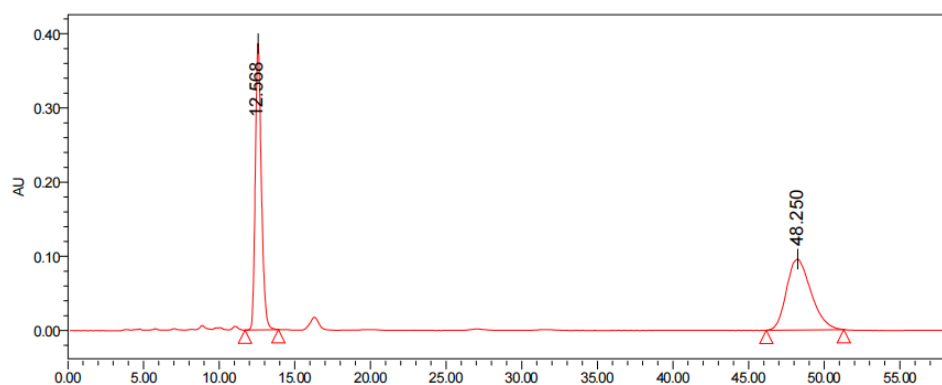
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (50:50)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



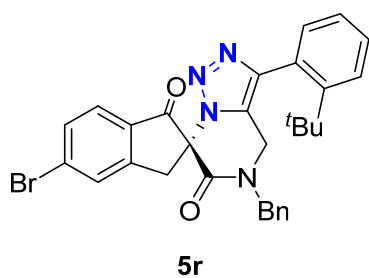
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 13.316       | 479915   | 3.15  |
| 2 | 51.763       | 14764945 | 96.85 |

### Racemic



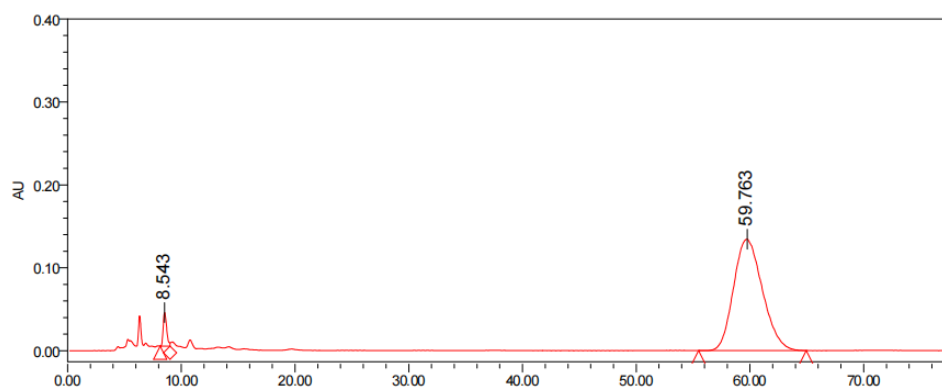
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 12.568       | 10836129 | 50.24 |
| 2 | 48.250       | 10733123 | 49.76 |

Supplementary Fig. 47. HPLC spectrum of compound **5q**



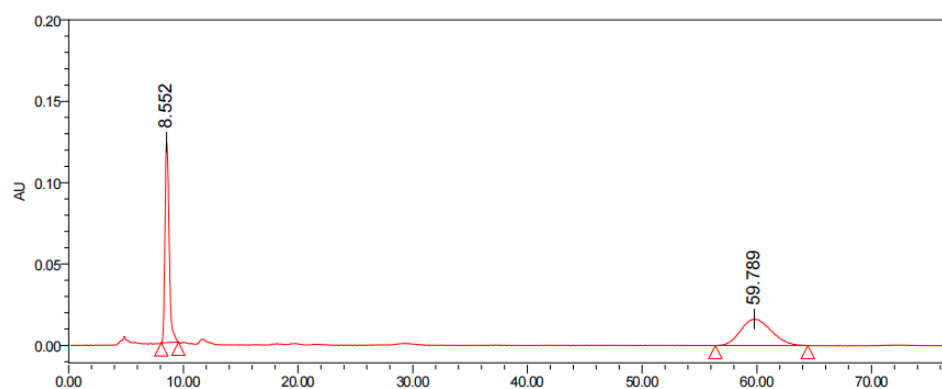
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (50:50)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



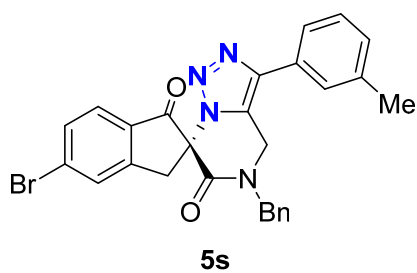
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 8.543        | 851809   | 3.47  |
| 2 | 59.763       | 23677266 | 96.53 |

### Racemic



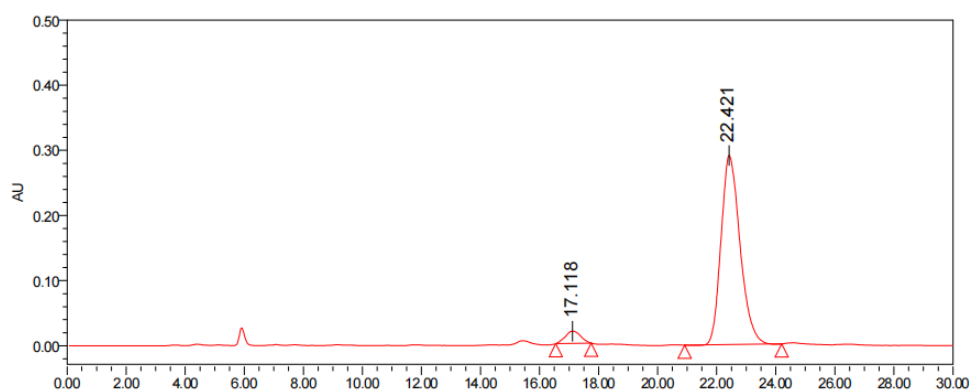
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 8.552        | 3113354 | 50.83 |
| 2 | 59.789       | 3011753 | 49.17 |

**Supplementary Fig. 48.** HPLC spectrum of compound **5r**



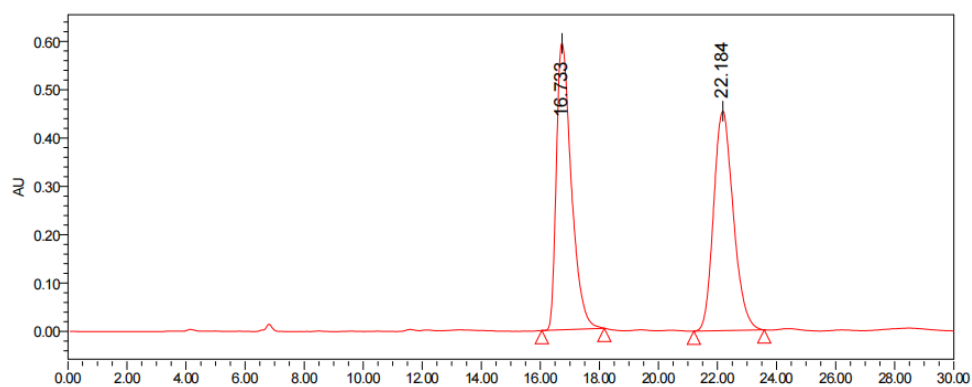
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



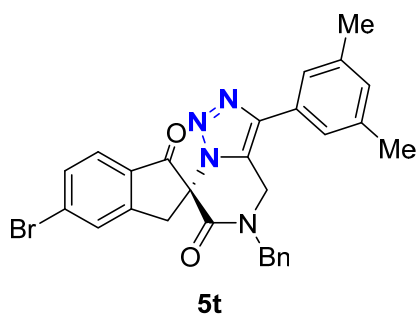
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 17.118       | 688303   | 5.02  |
| 2 | 22.421       | 13015169 | 94.98 |

### Racemic



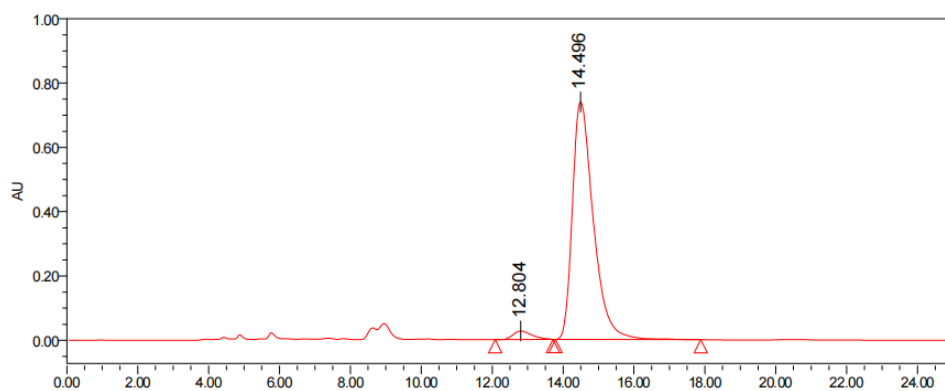
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 16.733       | 20839126 | 49.77 |
| 2 | 22.184       | 21031166 | 50.23 |

Supplementary Fig. 49. HPLC spectrum of compound 5s



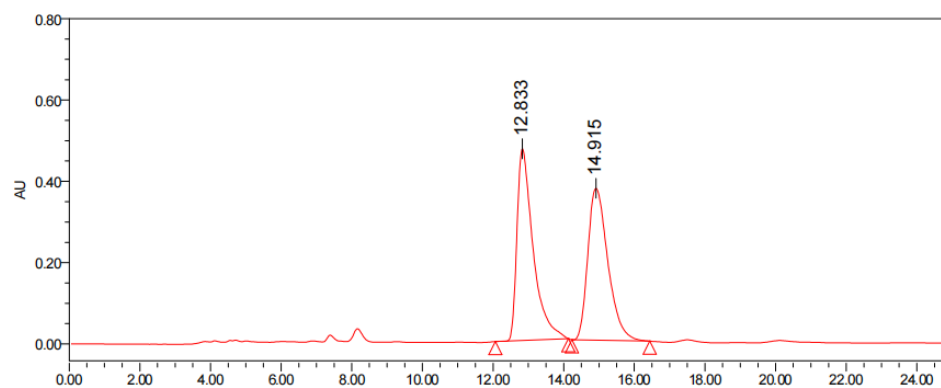
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (50:50)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



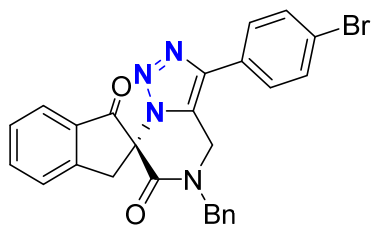
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 12.804       | 969436   | 3.09  |
| 2 | 14.496       | 30381592 | 96.91 |

### Racemic



|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 12.833       | 15004483 | 50.44 |
| 2 | 14.915       | 14743255 | 49.56 |

**Supplementary Fig. 50.** HPLC spectrum of compound **5t**

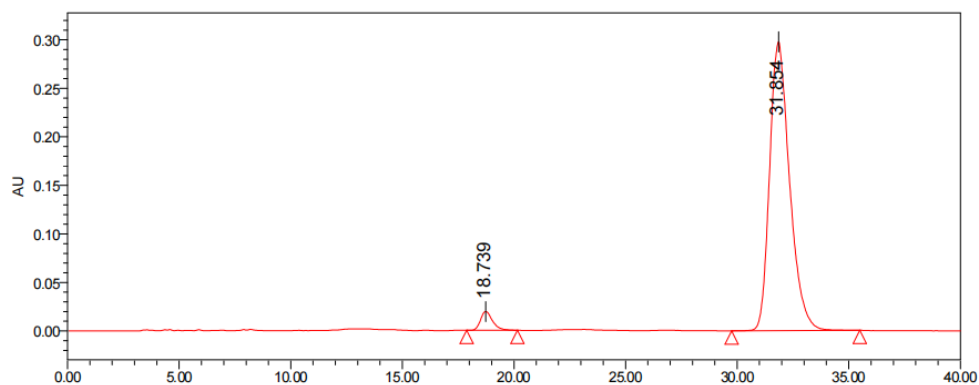


**5u**

**HPLC Conditions**

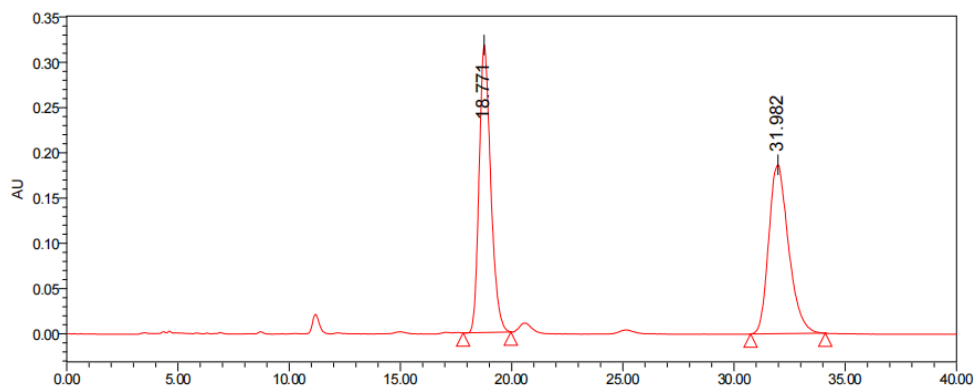
Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

**Chiral**



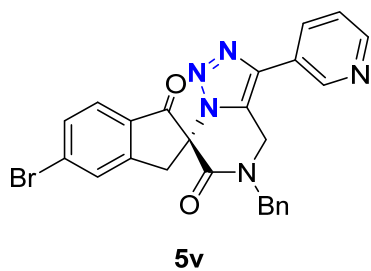
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 18.739       | 731279   | 3.80  |
| 2 | 31.854       | 18523248 | 96.20 |

**Racemic**



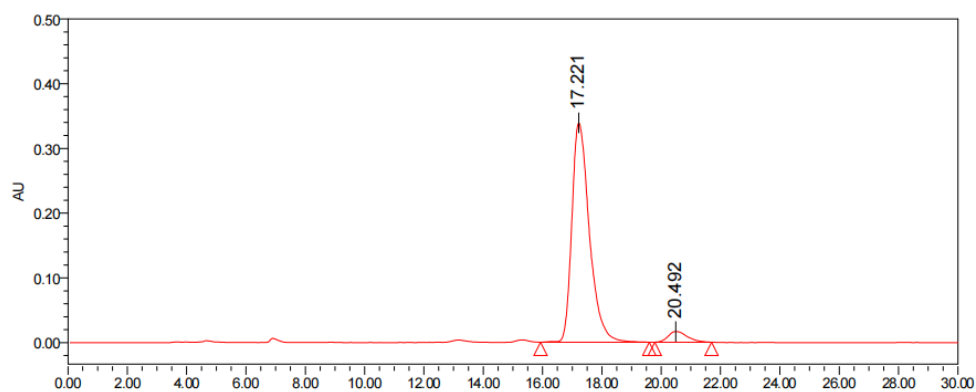
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 18.771       | 11466928 | 49.80 |
| 2 | 31.982       | 11558101 | 50.20 |

**Supplementary Fig. 51. HPLC spectrum of compound 5u**



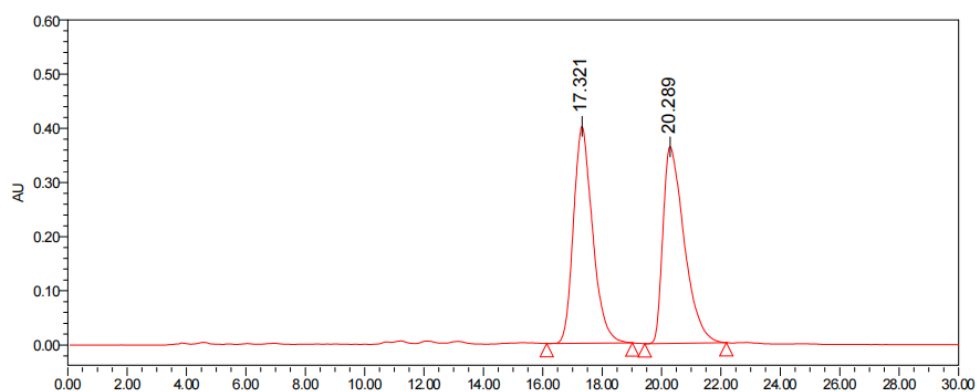
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (60:40)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



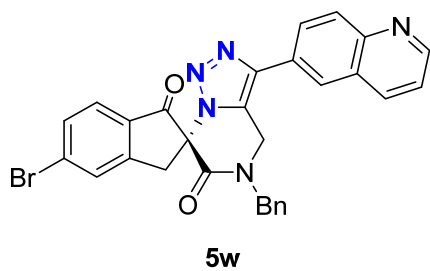
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 17.221       | 13939379 | 94.99 |
| 2 | 20.492       | 735099   | 5.01  |

### Racemic



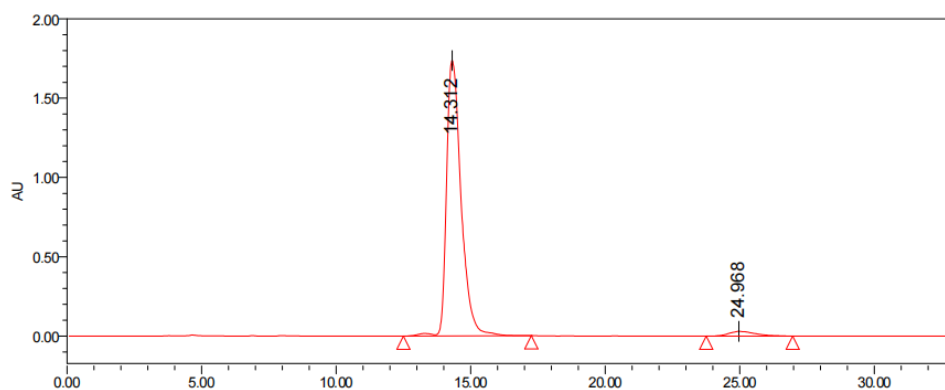
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 17.321       | 17885746 | 49.76 |
| 2 | 20.289       | 18060970 | 50.24 |

Supplementary Fig. 52. HPLC spectrum of compound **5v**



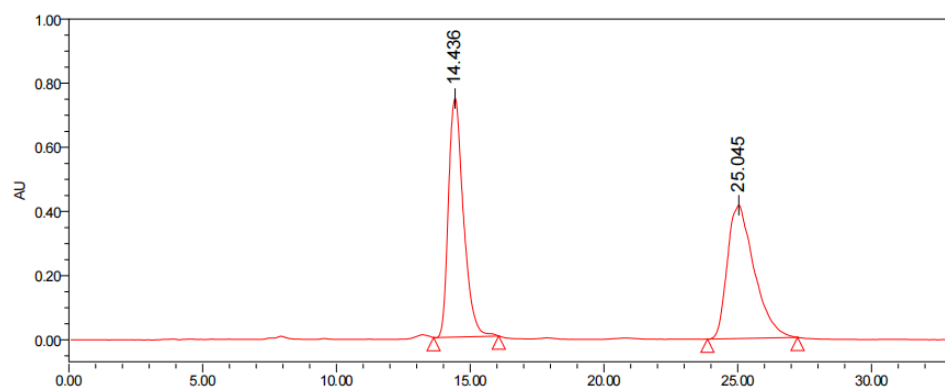
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (60:40)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 14.312       | 65219657 | 97.05 |
| 2 | 24.968       | 1979095  | 2.95  |

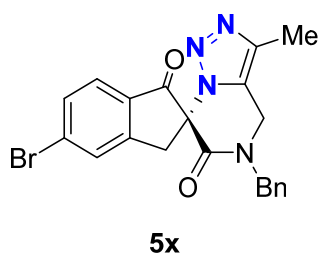
### Racemic



|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 14.436       | 28957141 | 49.95 |
| 2 | 25.045       | 29017213 | 50.05 |

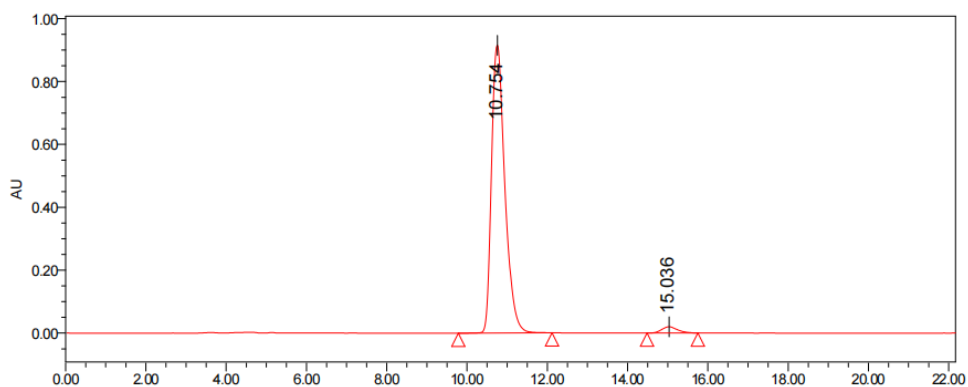
Supplementary Fig. 53. HPLC spectrum of compound 5w





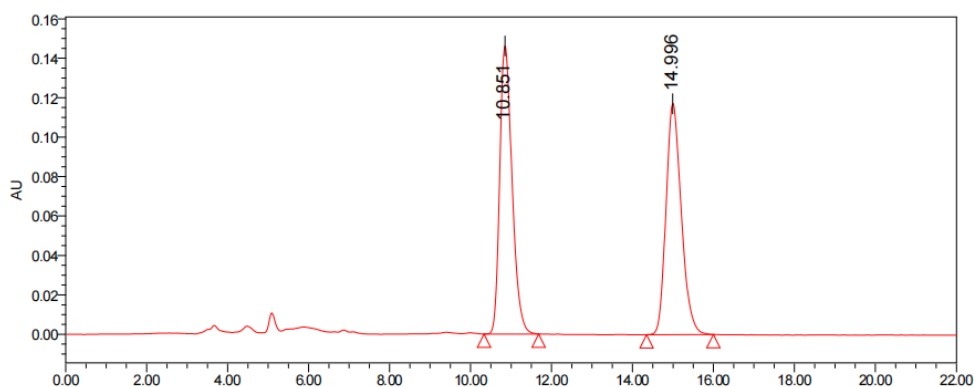
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



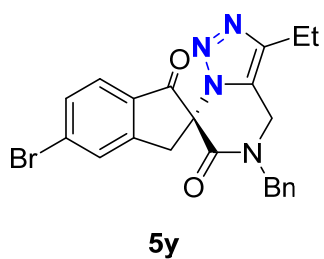
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 10.754       | 20945640 | 97.47 |
| 2 | 15.036       | 542895   | 2.53  |

### Racemic



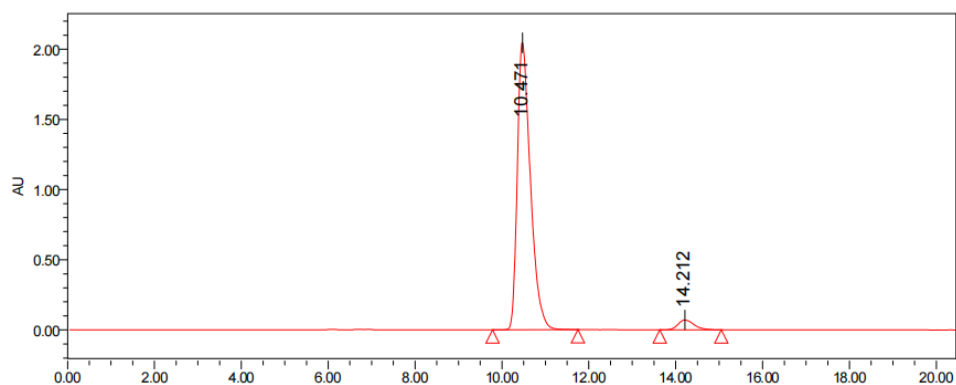
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 10.851       | 3066245 | 50.05 |
| 2 | 14.996       | 3059750 | 49.95 |

Supplementary Fig. 54. HPLC spectrum of compound 5x



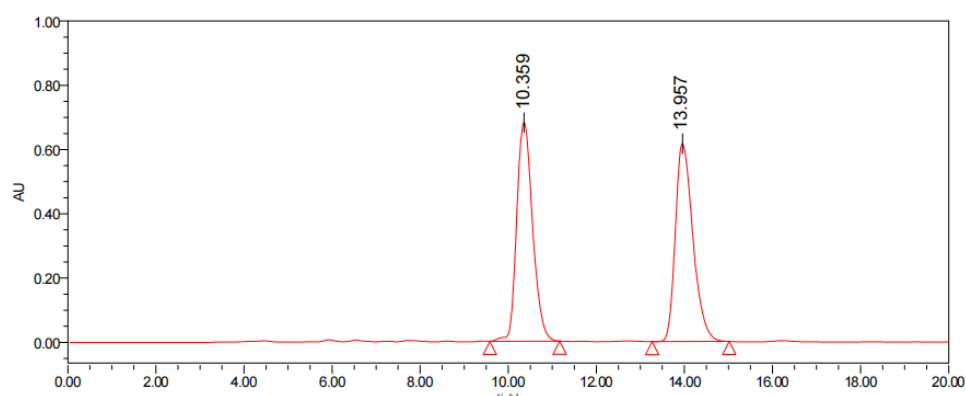
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



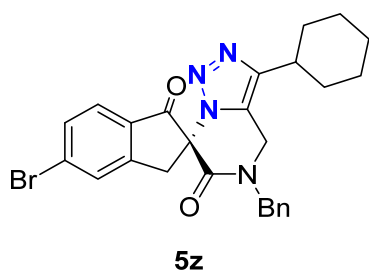
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 10.471       | 42894610 | 95.99 |
| 2 | 14.212       | 1792042  | 4.01  |

### Racemic



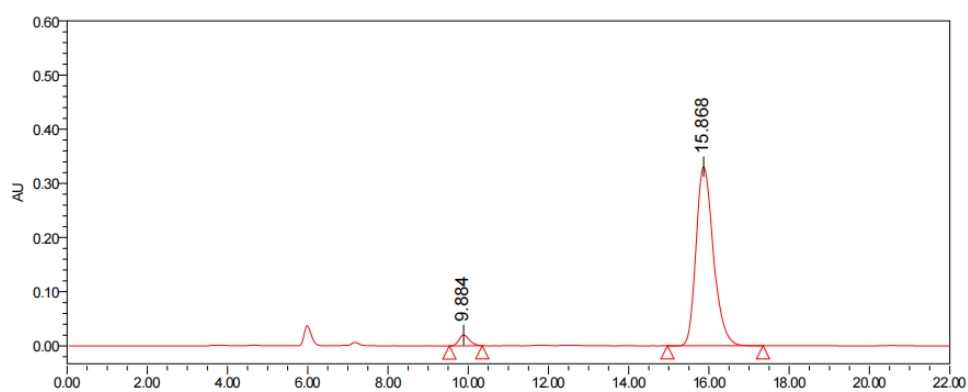
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 10.359       | 17131643 | 50.05 |
| 2 | 13.957       | 17100463 | 49.95 |

Supplementary Fig. 55. HPLC spectrum of compound **5y**



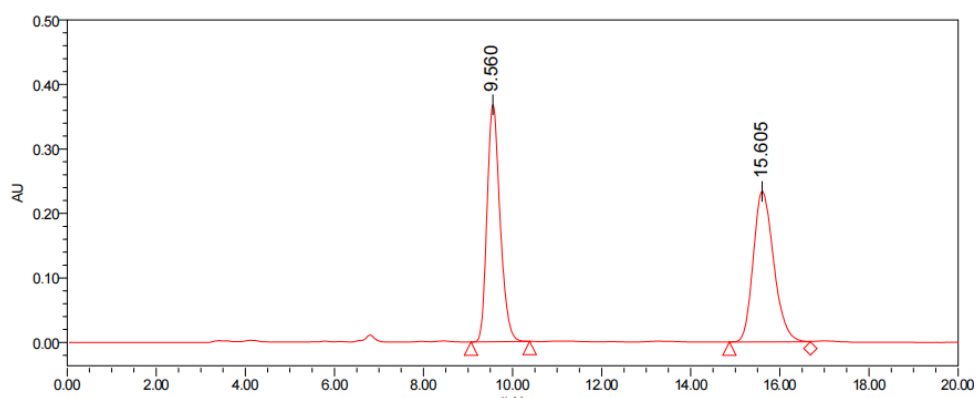
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (70:30)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



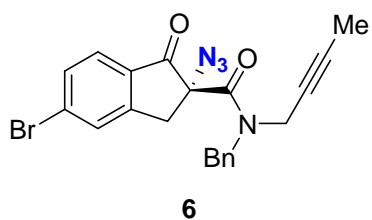
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 9.884        | 362022  | 3.52  |
| 2 | 15.868       | 9935228 | 96.48 |

### Racemic



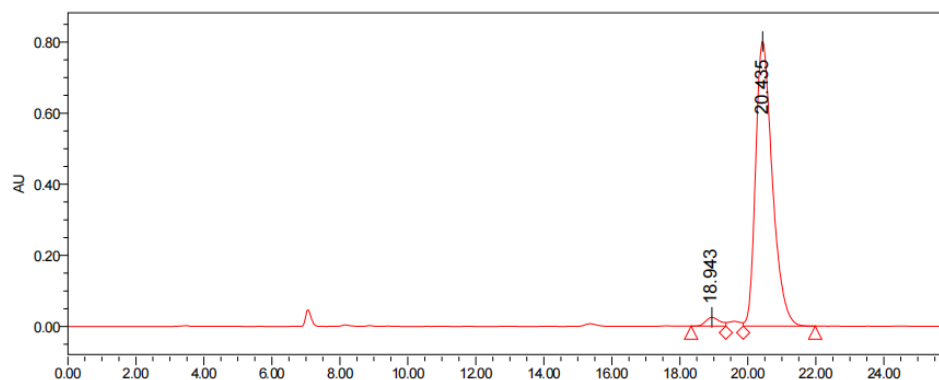
|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 9.560        | 7440329 | 49.89 |
| 2 | 15.605       | 7472805 | 50.11 |

Supplementary Fig. 56. HPLC spectrum of compound **5z**



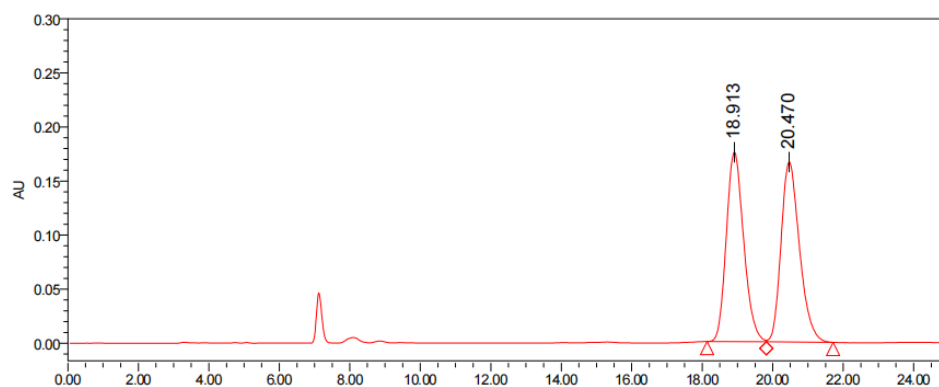
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (90:10)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



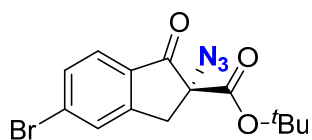
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 18.943       | 699078   | 2.49  |
| 2 | 20.435       | 27353426 | 97.51 |

### Racemic



|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 18.913       | 6004168 | 49.79 |
| 2 | 20.470       | 6055205 | 50.21 |

Supplementary Fig. 57. HPLC spectrum of compound 6

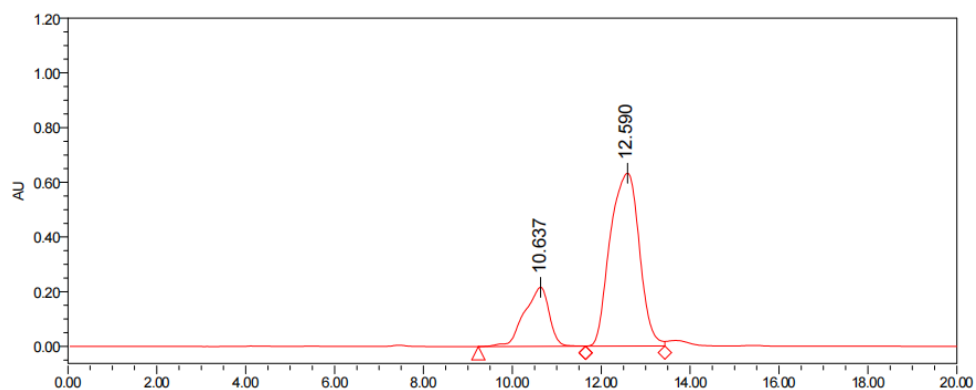


**8a**

### HPLC Conditions

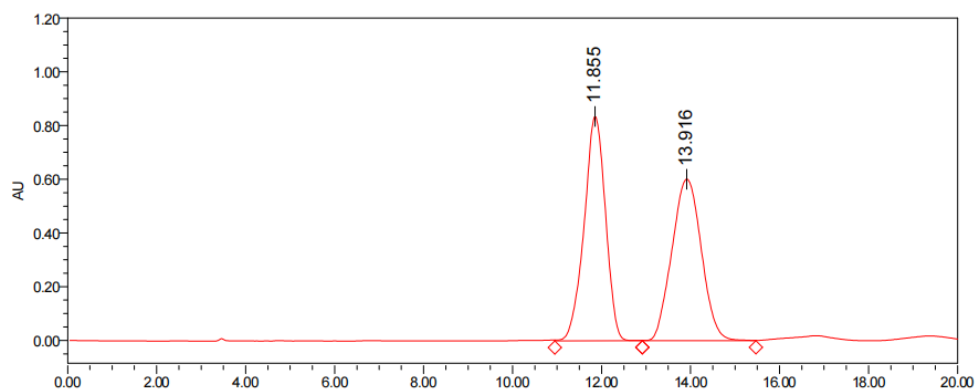
Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (99:1)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



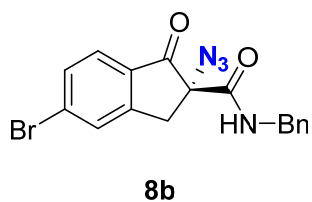
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 10.637       | 8371847  | 22.49 |
| 2 | 12.590       | 28846765 | 77.51 |

### Racemic



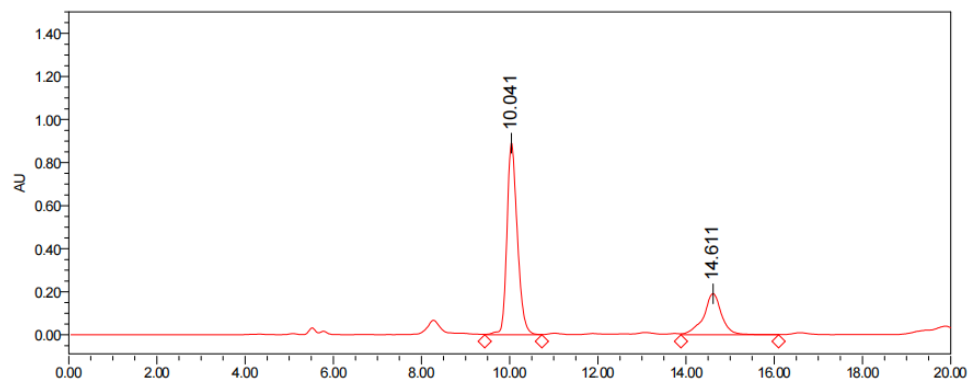
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 11.855       | 27901671 | 50.08 |
| 2 | 13.916       | 27814411 | 49.92 |

**Supplementary Fig. 58.** HPLC spectrum of compound **8a**



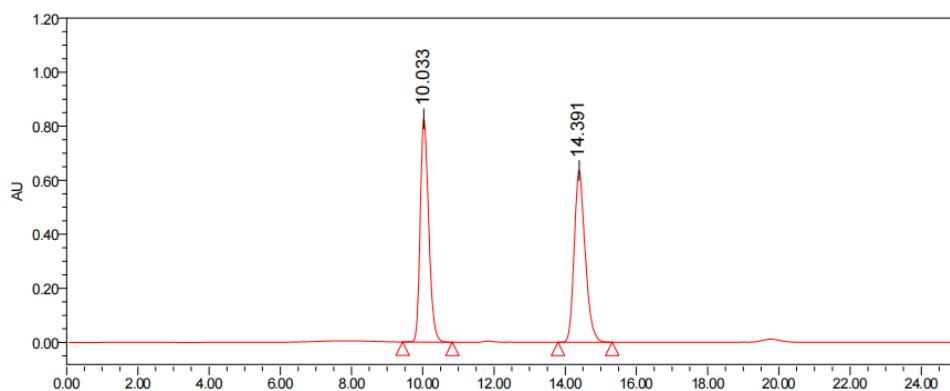
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (80:20)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

**Chiral**



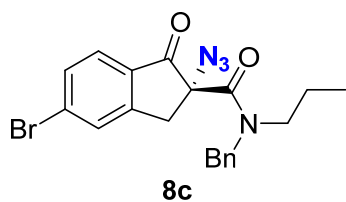
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 10.041       | 14615121 | 73.05 |
| 2 | 14.611       | 5392312  | 26.95 |

**Racemic**



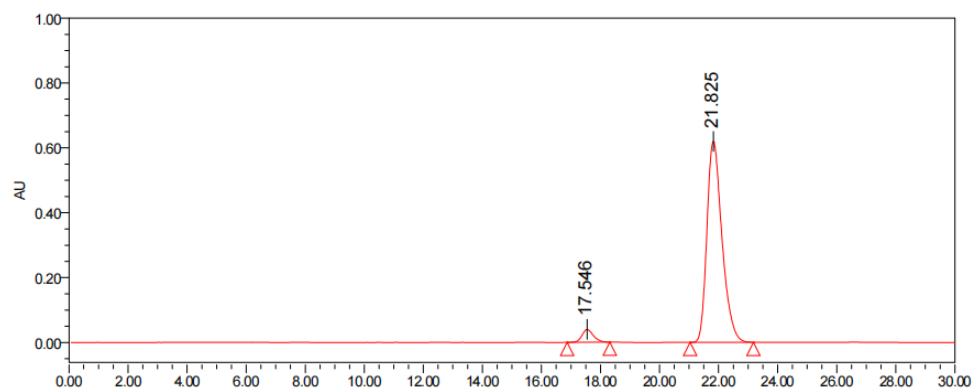
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 10.033       | 13629324 | 49.91 |
| 2 | 14.391       | 13676714 | 50.09 |

**Supplementary Fig. 59.** HPLC spectrum of compound **8b**



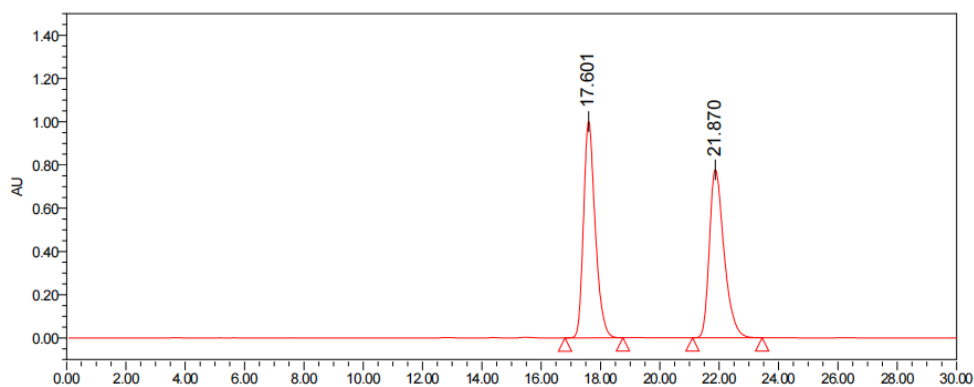
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (90:10)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

**Chiral**



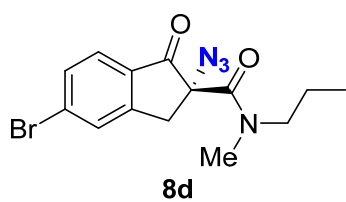
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 17.546       | 1057531  | 4.59  |
| 2 | 21.825       | 21977714 | 95.41 |

**Racemic**



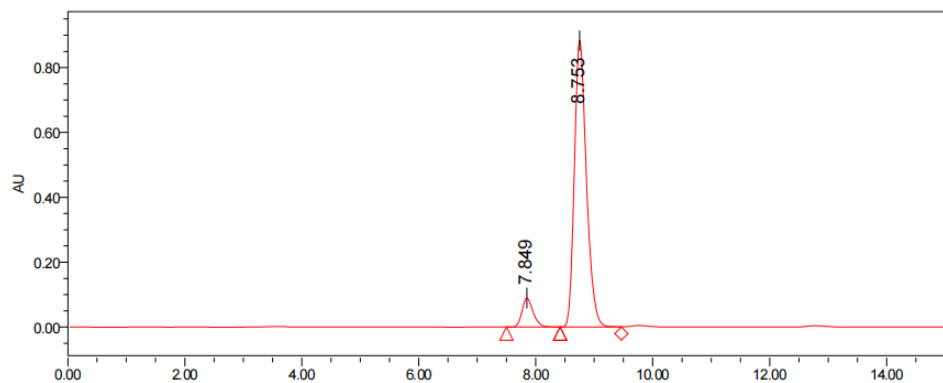
|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 17.601       | 27430558 | 50.62 |
| 2 | 21.870       | 26754989 | 49.38 |

Supplementary Fig. 60. HPLC spectrum of compound **8c**



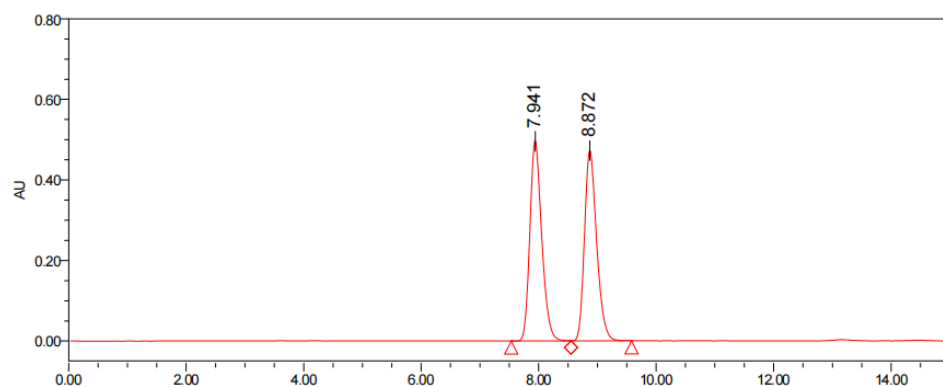
**HPLC Conditions**  
 Column: Chiralpak AD-H,  
 Daicel Chemical Industries Ltd.  
 Eluent: Hexanes / Isopropanol (80:20)  
 Flow rate: 1.0 mL/min  
 Detection: UV 254 nm

### Chiral



|   | 保留时间<br>(分钟) | 面积       | % 面积  |
|---|--------------|----------|-------|
| 1 | 7.849        | 1174435  | 8.51  |
| 2 | 8.753        | 12622371 | 91.49 |

### Racemic



|   | 保留时间<br>(分钟) | 面积      | % 面积  |
|---|--------------|---------|-------|
| 1 | 7.941        | 6969836 | 50.56 |
| 2 | 8.872        | 6814648 | 49.44 |

Supplementary Fig. 61. HPLC spectrum of compound **8d**



## 5. Supplementary References

- [1] Ding, T., Jiang, L., Yang, J., Xu, Y., Wang, G. & Yi, W. Highly carbon-selective monofluoromethylation of  $\beta$ -ketoesters with fluoromethyl iodide. *Org. Lett.* **21**, 6025-6028 (2019).
- [2] Poeira, D. L. et al. Hypervalent iodine (III) reagents with transferable primary amines: Structure and reactivity on the electrophilic  $\alpha$ -amination of stabilized enolates. *Org. Lett.* **24**, 776-781 (2022).
- [3] Yao, C. et al. HDAC1/MAO-B dual inhibitors against alzheimer's disease: Design, synthesis and biological evaluation of N-propargylamine-hydroxamic acid/O-aminobenzamide hybrids. *Bioorg. Chem.* **122**, 105724 (2022).
- [4] Rzayev, J., Zhang, Z., Durand, N. & Soulé, J. F. Upgrading carbazoyl-derived phosphine ligands using Rh (I)-catalyzed P (III)-directed C–H bond alkylation for catalytic CO<sub>2</sub>-fixation reactions. *Org. Lett.* **24**, 6755-6760 (2022).
- [5] Das, A., Buzzetti, L., Puriš, M. & Waser, J. Palladium-catalyzed trans-hydroalkoxylation: Counterintuitive use of an aryl iodide additive to promote C–H bond formation. *ACS Catal.* **12**, 7565-7570 (2022).
- [6] Vita, M. V. & Waser, J. Azidation of  $\beta$ -keto esters and silyl enol ethers with a benziodoxole reagent. *Org. Lett.* **15**, 3246-3249 (2013).
- [7] Chen, Y.-X. et al. Azidobenziodazolones as azido sources for the enantioselective copper-catalyzed azidation of N-unprotected 3-trifluoromethylated oxindoles. *Org. Lett.* **25**, 2739-2744 (2023).
- [8] Deng, Q.-H. et al. Enantioselective iron-catalyzed azidation of  $\beta$ -keto esters and oxindoles. *J. Am. Chem. Soc.* **135**, 5356-5359 (2013).
- [9] Zheng, L.-S., Wei, Y.-L., Jiang, K.-Z., Deng, Y., Zheng, Z.-J. & Xu, L.-W. Enantioselective fluorination of  $\beta$ -ketoamides catalyzed by Ar-BINMOL-derived salen-copper complex. *Adv. Synth. Catal.* **356**, 3769-3776 (2014).
- [10] Lin, C.-Z. et al. Enantioselective synthesis of 3a-azido-pyrroloindolines by copper-catalyzed asymmetric dearomative azidation of tryptamines. *Chem. Commun.* **59**, 7831-7834 (2023).
- [11] Guo, J. et al. Iodine-catalyzed azidation/cyclization cascade approach to 3a-azidofuroindolines and -pyrroloindolines under mild conditions. *Eur. J. Org. Chem.* **2017**, 4773-4777 (2017).
- [12] Zhang, P., Sun, W., Li, G., Hong, L. & Wang, R. Copper-catalyzed cascade azidation-cyclization of tryptophols and tryptamines. *Chem. Commun* **51**, 12293-12296 (2015).
- [13] Scattolin, T., Bouayad-Gervais, S. & Schoenebeck, F. Straightforward access to N-trifluoromethyl amides, carbamates, thiocarbamates and ureas. *Nature* **573**, 102-107 (2019).
- [14] Tu, H.-F., Zhang, X., Zheng, C., Zhu, M. & You, S.-L. Enantioselective dearomative prenylation of indole derivatives. *Nature Catal.* **1**, 601-608 (2018).

- [15] Grimme, S., Ehrlich, S. & Goerigk, L. Effect of the damping function in dispersion corrected density functional theory. *J. Comput. Chem.* **32**, 1456-1465 (2011).