

## **Supporting Information**

### **C–C Bond Cleavage at the *N*- $\alpha$ Position Enabled by the Low-potential Electrochemical Oxidation of the 2,7-Dimethoxynaphthyl Electroauxiliary**

Kazuhiro Okamoto,<sup>[a]</sup> Yasushi Imada,<sup>[b]</sup> Naoki Shida,<sup>[a]</sup> Yoshikazu Kitano<sup>[b]</sup>, Mahito

Atobe,<sup>[a]</sup> and Kazuhiro Chiba <sup>\*[b]</sup>

[a] Graduate School of Engineering, Yokohama National University, 79-7 Tokiwadai, Hodogaya-ku, Yokohama, Kanagawa 240-8501, Japan

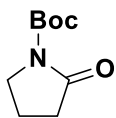
[b] Department of Applied Biological Science, Tokyo University of Agriculture and Technology, 3-5-8 Saiwai-cho, Fuchu, Tokyo 183-8509, Japan

\* E-mail: chiba@cc.tuat.ac.jp

## **Table of Contents**

<b>I</b>	Experimental section	S2
<b>II</b>	Computations (Table S1-S2)	S6
<b>III</b>	GC-MS spectrum (Figure S1-S2)	S10
<b>IV</b>	<sup>1</sup> H and <sup>13</sup> C-NMR spectra of compounds	S12

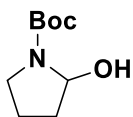
## I. Experimental section



**tert-butyl 2-oxopyrrolidine-1-carboxylate (1):** To a solution of 2-pyrrolidone (5 mL, 66 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (100 mL) was added Et<sub>3</sub>N (27.6 mL, 198 mmol), DMAP (4.03 g, 33 mmol), and Boc<sub>2</sub>O (19.7 mL, 85.8 mmol), and the mixture was stirred at RT for 17 h. Reaction mixture was quenched with saturated aqueous NH<sub>4</sub>Cl (200 mL) and organic layer was partitioned. The aqueous layer was extracted with CH<sub>2</sub>Cl<sub>2</sub> (15 mL x 3), and combined organic layer was washed with saturated aqueous NH<sub>4</sub>Cl (200 mL x 2), saturated aqueous NaHCO<sub>3</sub> (200 mL) and dried over anhydrous Na<sub>2</sub>SO<sub>4</sub>. After filtrate was concentrated in vacuo, resulting crude was purified by silica gel column chromatography (Hex:EtOAc = 3:1 to 3:2), and 11.48 g of title compound was obtained as yellow oil (61.97 mmol, 94%).

**<sup>1</sup>H-NMR (600 MHz, CDCl<sub>3</sub>)**  $\delta$  3.75-3.73 (2H, t, H-3,  $J_{3-4}$  = 7.56 Hz,  $J_{\text{gem}}$  = 14.4 Hz), 2.52-2.49 (2H, t, H-5,  $J_{5-4}$  = 7.56 Hz,  $J_{\text{gem}}$  = 15.8 Hz), 2.02-1.97 (2H, quin, H-4,  $J_{4-5}$  = 8.25 Hz,  $J_{4-3}$  = 8.25 Hz,  $J_{\text{gem}}$  = 15.8 Hz), 1.52 (9H, s, *N*-Boc).

This is a known compound.<sup>18</sup>

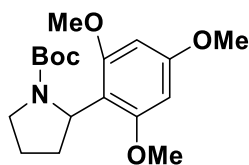


**tert-butyl 2-hydroxypyrrolidine-1-carboxylate (2):** A solution of **1** (7.8 g, 42.1 mmol) in THF (126 mL) was cooled to -78 °C, and treated with DIBAL (1.0 M solution in hexane, 58.9 mL, 58.9 mmol). After stirred at -78 °C for 1 h, reaction mixture was quenched with saturated aqueous NH<sub>4</sub>Cl (200 mL) and saturated aqueous Na<sub>2</sub>SO<sub>4</sub> (100 mL) and stirred at RT for 1 h. Resulting gel was filtered through celite pad and resulting cake was washed with EtOAc (300 mL). Resulting filtrate was partitioned with saturated aqueous NH<sub>4</sub>Cl (300 mL) and aqueous layer was extracted with EtOAc

(200 mL x 3). The combined organic layer was dried over anhydrous Na<sub>2</sub>SO<sub>4</sub> and filtrate was concentrated in vacuo. Resulting crude was purified by silica gel column chromatography (Hex:EtOAc = 4:1 to 3:1), and 6.53 g of title compound was obtained as colorless oil (34.9 mmol, 83%).

**<sup>1</sup>H-NMR (400 MHz, CD<sub>3</sub>OD)** δ 5.54-5.37 (1H, m, H-2), 3.47-3.38 (1H, m), 3.27-3.20 (1H, m), 2.14-1.80 (4H, m), 1.51-1.43 (9H, m, *N*-Boc).

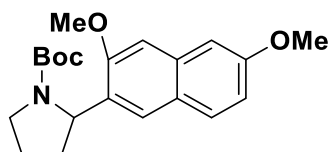
This is a known compound.<sup>18</sup>



*tert-butyl 2-(2,4,6-trimethoxyphenyl)pyrrolidine-1-carboxylate*

**(3a):** To a solution of **2** (160.4 mg, 0.86 mmol) and 1,3,5-trimethoxybenzene (289 mg, 1.72 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (8.6 mL) was added BF<sub>3</sub>·OEt<sub>2</sub> (138 μL, 0.95 mmol) at 0 °C. After stirred at 0 °C for 2 h, reaction mixture was quenched with saturated aqueous NaHCO<sub>3</sub> (30 mL) and organic layer was partitioned. The aqueous layer was extracted with CH<sub>2</sub>Cl<sub>2</sub> (10 mL x 3) and combined organic layer was dried over anhydrous Na<sub>2</sub>SO<sub>4</sub>. After filtrate was concentrated in vacuo, resulting crude was purified by silica gel column chromatography (Hex:EtOAc = 2:1), and 173.2 mg of title compound was obtained as white solid (0.51 mmol, 59%).

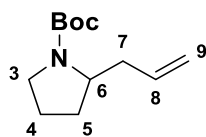
**<sup>1</sup>H-NMR (600 MHz, CDCl<sub>3</sub>)** δ 6.11 (2H, s, Ar), 5.28-5.17 (1H, t, H-2, *J*<sub>2-3</sub> = 8.25 Hz, *J*<sub>gem</sub> = 16.5 Hz), 3.81-3.76 (9H, m, OCH<sub>3</sub> x 3), 3.66-3.42 (2H, m, H-5), 2.16-1.98 (2H, m, H-3), 1.97-1.73 (2H, m, H-4), 1.39-1.09 (9H, m, *N*-Boc); **<sup>13</sup>C-NMR (151 MHz, CDCl<sub>3</sub>)** δ 159.8, 158.8, 158.6, 154.4, 113.0, 91.5, 90.7, 78.2, 56.1, 55.8, 55.5, 55.3, 52.5, 52.0, 47.4, 46.9, 33.0, 32.6, 28.8, 28.3, 25.3, 25.2; **HRMS (ESI):** Calcd. for [C<sub>18</sub>H<sub>28</sub>NO<sub>5</sub>]<sup>+</sup> 338.1962, found 338.1955; **Melting point:** 89-91 °C.



*tert-butyl*

**2-(3,6-dimethoxynaphthalen-2-yl)pyrrolidine-1-carboxylate (3b):** To a solution of **2** (496 mg, 2.52 mmol) and 2,7-dimethoxynaphthalene (949 mg, 5.04 mmol) in CH<sub>2</sub>Cl<sub>2</sub> (25 mL) was added BF<sub>3</sub>·OEt<sub>2</sub> (317  $\mu$ L, 2.52 mmol) at 0 °C. After stirred at 0 °C for 1 h, H<sub>2</sub>O (252  $\mu$ L), NaHCO<sub>3</sub> (635 mg, 7.56 mmol), Boc<sub>2</sub>O (825 mg, 3.78 mmol) was added to the mixture and vigorously stirred at RT for 1 h. Reaction mixture was quenched with saturated aqueous NaHCO<sub>3</sub> (50 mL) and the aqueous layer was extracted with CHCl<sub>3</sub> (20 mL x 3) and combined organic layer was dried over anhydrous Na<sub>2</sub>SO<sub>4</sub>. After filtrate was concentrated in vacuo, resulting crude was purified by silica gel column chromatography (Hex:EtOAc = 6:1 to 3:1), and 723 mg of title compound was obtained as brown crystal (2.02 mmol, 80%).

**<sup>1</sup>H-NMR (600 MHz, CDCl<sub>3</sub>)**  $\delta$  7.68-7.65 (2H, m, Ar), 7.32 (1H, s, Ar), 7.11-7.09 (1H, d, Ar,  $J$  = 8.94 Hz), 6.99-6.98 (1H, d, Ar,  $J$  = 8.94 Hz), 5.68-5.59 (1H, m, br, H-2), 3.92-3.90 (6H, m, OCH<sub>3</sub> x 2), 3.84-3.64 (2H, m, H-5), 2.33-2.22 (2H, m, H-3), 2.10-1.97 (2H, m, H-4), 1.36-0.79 (9H, m, br, *N*-Boc); **<sup>13</sup>C-NMR (101 MHz, CDCl<sub>3</sub>)**  $\delta$  157.9, 155.1, 154.5, 133.1, 130.3, 128.3, 125.0, 123.3, 115.9, 111.7, 111.4, 101.9, 101.7, 78.6, 56.8, 55.5, 55.3, 54.9, 47.8, 47.3, 32.8, 28.7, 27.9, 25.4, 25.1; **HRMS (ESI):** Calcd. for [C<sub>21</sub>H<sub>28</sub>NO<sub>4</sub>]<sup>+</sup> 358.2013, found 358.2005; **Melting point:** 105-109 °C.

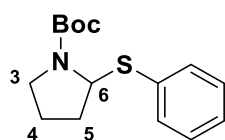


***tert-butyl 2-allylpyrrolidine-1-carboxylate (4):*** General procedure was used for **3a** and **3b** by using allyltrimethylsilane as nucleophile, and purification by silica gel column chromatography (Hex:EtOAc = 10:1) gave title compound as colorless

oil. Isolated yield is 16.9 mg (0.08 mmol, 80% from **3a**) and 12.9 mg (0.061 mmol, 61% from **3b**). Analytical yield was determined by  $^1\text{H}$  NMR by using benzaldehyde (5.1  $\mu\text{L}$ , 0.05 mmol) as an internal standard and integral of H-8 of **4** was compared with reference peak ( $\text{CHO}$  of benzaldehyde).

**$^1\text{H}$ -NMR (500 MHz,  $\text{CDCl}_3$ )**  $\delta$  5.75 (m, 1H, H-8), 5.09-5.00 (m, 2H, H-9), 3.81 (m, 1H, H-6), 3.36 (m, 2H, H-5), 2.49 (m, 1H, H-7a), 2.17-2.07 (m, 1H, H-7b), 1.97-1.65 (m, 4H, H-3, H-4), 1.47 (s, 9H, *N*-Boc).

This is a known compound.<sup>19</sup>



*tert-butyl 2-(phenylthio)pyrrolidine-1-carboxylate* (**5**): General

procedure was used for **3b** by using thiophenol as nucleophile, and silica gel column chromatography (Hex:EtOAc = 20:1 to 10:1) gave 16.4 mg of title compound as colorless oil (0.059 mmol, 59%). Analytical yield was determined by  $^1\text{H}$  NMR by using benzaldehyde (5.1  $\mu\text{L}$ , 0.05 mmol) as an internal standard and integral of H-6 of **5** was compared with reference peak ( $\text{CHO}$  of benzaldehyde).

**$^1\text{H}$ -NMR (500 MHz,  $\text{CDCl}_3$ )**  $\delta$  7.51 (m, 2H, Ar), 7.34-7.27 (m, 3H, Ar), 5.40-5.26 (m, 1H, H-6), 3.56-3.22 (m, 2H, H-3), 2.26-1.85 (m, 4H, H-5, H-4), 1.39 (m, 9H, *N*-Boc).

This is a known compound.<sup>20</sup>

## II. Computations (Table S1-S2)

**Table S1.** Optimized structure of **3a<sup>+</sup>**

Symbol	X	Y	Z
C	6.508587	0.998033	-3.29175
C	7.804671	3.505867	-3.19262
C	8.539357	2.379933	-3.50592
C	7.918763	1.082418	-3.582
H	8.239119	4.49509	-3.14348
C	8.741583	-0.11151	-3.98071
H	9.790398	0.198044	-3.97378
C	8.394277	-0.71758	-5.37618
H	8.996232	-0.25638	-6.16241
H	7.339376	-0.54877	-5.60815
C	8.669118	-2.21944	-5.1869
H	8.130808	-2.8344	-5.91264
H	9.739163	-2.42896	-5.2908
C	8.220676	-2.48647	-3.74601
H	7.13882	-2.66079	-3.67942
H	8.724485	-3.32207	-3.25658
N	8.573308	-1.23951	-3.06381
C	8.823412	-1.22338	-1.6988
O	8.695582	-2.22243	-1.0148
O	9.217228	-0.00368	-1.29782
C	9.639315	0.238003	0.113253
C	10.84493	-0.64241	0.44768
H	11.22335	-0.37427	1.439741
H	10.57785	-1.70022	0.454282
H	11.65158	-0.48117	-0.27557
C	10.03078	1.715988	0.085835
H	10.37936	2.026016	1.075626
H	10.83819	1.888821	-0.63324
H	9.174627	2.342064	-0.1876
C	8.45353	-0.00199	1.049849
H	8.732444	0.288807	2.068207

H	7.5955	0.609265	0.74808
H	8.15871	-1.05237	1.058126
C	5.768549	2.128131	-2.97152
H	4.709445	2.056889	-2.77432
C	6.421709	3.377191	-2.9172
O	9.851111	2.390166	-3.78732
O	5.813085	4.518764	-2.61536
O	5.976722	-0.22721	-3.3959
C	10.55809	3.638308	-3.79767
H	10.53291	4.101755	-2.80582
H	11.58413	3.387455	-4.06372
H	10.13329	4.317375	-4.54438
C	4.408046	4.550668	-2.3063
H	4.195576	3.940072	-1.42362
H	4.186769	5.596082	-2.09711
H	3.819733	4.209397	-3.16348
C	4.569262	-0.41557	-3.18708
H	4.394181	-1.47923	-3.34265
H	4.292999	-0.14248	-2.1634
H	3.987928	0.16801	-3.90864

---

**Table S2.** Optimized structure of **3b<sup>+</sup>**

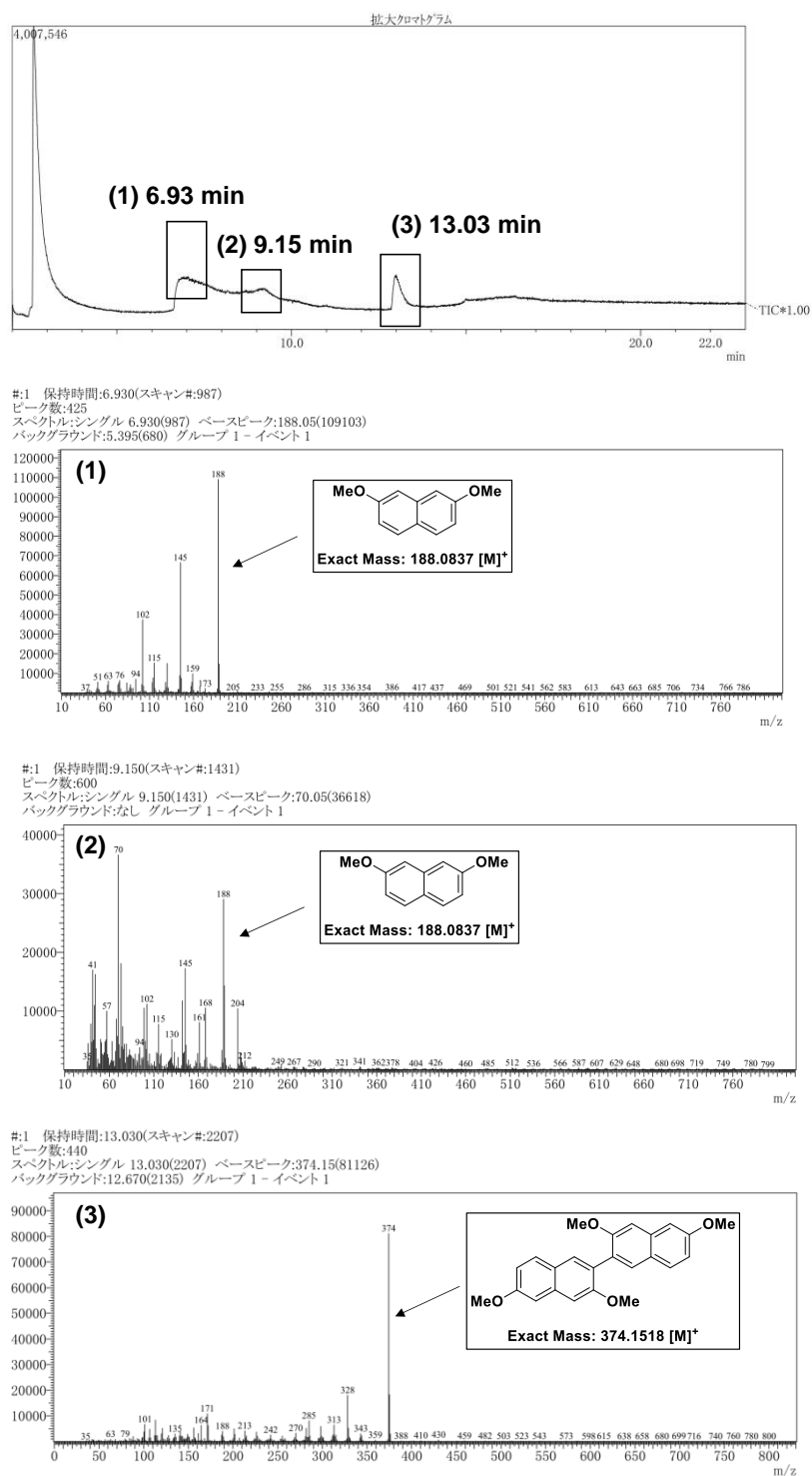
Symbol	X	Y	Z
C	4.591971	2.069814	-2.22385
C	5.94017	2.192092	-2.66985
C	6.491136	3.501292	-2.86601
C	5.688704	4.614985	-2.61682
H	6.358064	0.078074	-2.76089
H	4.182647	1.074007	-2.07646
C	6.752638	1.07778	-2.91807
C	7.840075	3.630006	-3.31785
H	6.060292	5.625185	-2.75839
C	8.61594	2.503525	-3.56614
C	8.076341	1.200056	-3.35747
H	8.240466	4.625157	-3.473
C	8.930969	-0.01599	-3.62317
H	9.965286	0.244417	-3.37171
C	8.864148	-0.49848	-5.10343
H	9.606305	0.013498	-5.71992
H	7.87303	-0.28694	-5.52127
C	9.080934	-2.01532	-4.98942
H	8.712396	-2.55827	-5.86386
H	10.14723	-2.23934	-4.8735
C	8.326467	-2.38225	-3.70618
H	7.258358	-2.54789	-3.90264
H	8.710006	-3.26251	-3.18832
N	8.513812	-1.19275	-2.85718
C	8.737688	-1.34251	-1.49715
O	8.563909	-2.39779	-0.91579
O	9.143425	-0.1749	-0.95832
C	9.476249	-0.07657	0.487184
C	10.64167	-1.01255	0.816035
H	10.9592	-0.84692	1.851087
H	10.35491	-2.0591	0.703731
H	11.49667	-0.80418	0.163654
C	9.895343	1.388091	0.625746



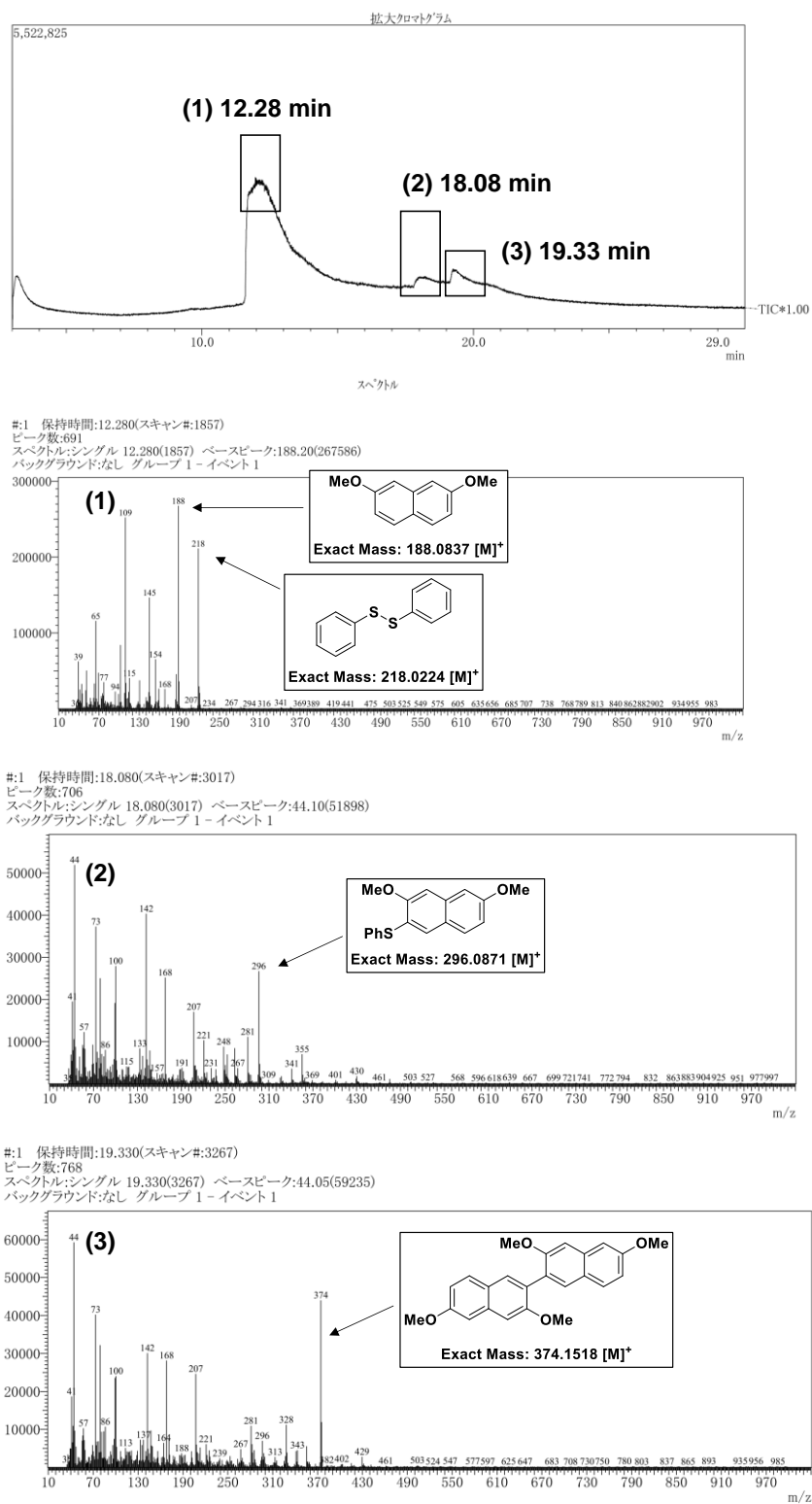
H	10.17049	1.600503	1.663449
H	10.75919	1.607171	-0.01034
H	9.074691	2.056607	0.343981
C	8.229565	-0.3733	1.324269
H	8.449203	-0.19004	2.381489
H	7.405215	0.287183	1.031789
H	7.913179	-1.41109	1.209652
O	9.885527	2.532137	-4.01654
C	10.5327	3.793341	-4.21977
H	11.54151	3.552283	-4.55328
H	10.01907	4.375849	-4.99274
H	10.57972	4.363426	-3.28523
C	4.345343	4.460253	-2.16922
C	3.799637	3.171334	-1.97332
H	2.77937	3.043677	-1.63431
O	3.697984	5.602433	-1.96986
C	2.329468	5.596787	-1.51953
H	2.252919	5.112686	-0.54134
H	2.051209	6.646352	-1.44083
H	1.690741	5.091743	-2.25027

---

### III. GC-MS spectrum (Figure S1-S2)



**Figure S1.** GC-MS spectrum for crude of electrochemical allylation of **3b**. Column oven temperature is 100 to 280 °C (12 min).



**Figure S2.** GC-MS spectrum for crude of electrochemical thiophenylation of **3b**.

Column oven temperature is 100 to 250 °C (12 min).

#### IV. $^1\text{H}$ and $^{13}\text{C}$ -NMR spectra of compounds

