Electronic Supplementary Material (ESI) for Chemical Communications.

Catalyst-Controlled Regiodivergent C–H Bond Alkenylation of 2-Pyridylthiophenes

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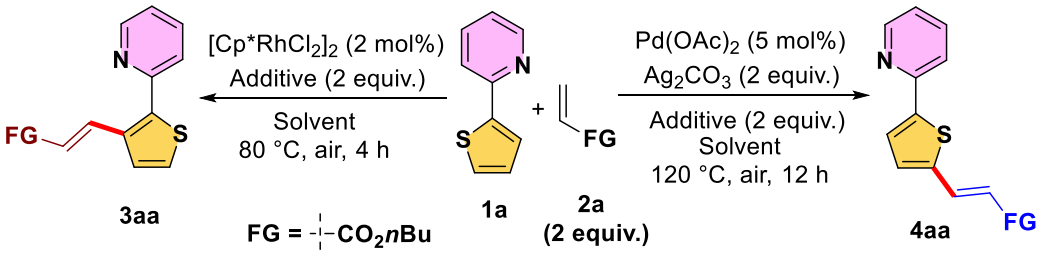
1. General information

All the reagents were purchased from Bide Pharmatech Ltd. and Energy Chemical. All solvents were purchased from Greagent (Shanghai Titansci incorporated company) and used without further purification. Unless otherwise stated, all reactions were carried out in oven-dried glassware under air atmosphere. All heating reactions were heated by metal sand bath (WATTCAS, LAB-500).

^{1}H-NMR spectra were obtained on Bruker-600. NMR spectra for all the samples were recorded in deuterochloroform ($CDCl_3$) or deuterated dimethyl sulfoxide (DMSO-d_6). Chemical shifts (δ) were reported in parts per million relative to residual chloroform (7.28 ppm for ^{1}H; 77.23 ppm for ^{13}C), deuterated dimethyl sulfoxide (2.50 ppm for ^{1}H; 39.52 ppm for ^{13}C), constants were reported in Hertz. ^{1}H NMR assignment abbreviations were the following: singlet (s), doublet (d), triplet (t), quartet (q), doublet of doublets (dd), doublet of triplets (dt), triplet of doublets (td), triplet of triplets (tt) and multiplet (m). ^{13}C NMR spectra were recorded at 151 MHz on the same spectrometer and reported in ppm. All spectra were processed using the MestReNova program.

High-resolution mass spectra (HRMS) were recorded on a mass spectrometer (Thermo fisher Q Exactive HRMS) using electrospray ionization-time of flight (ESI-TOF) reflection experiments.

2. Optimization of reaction conditions[a]

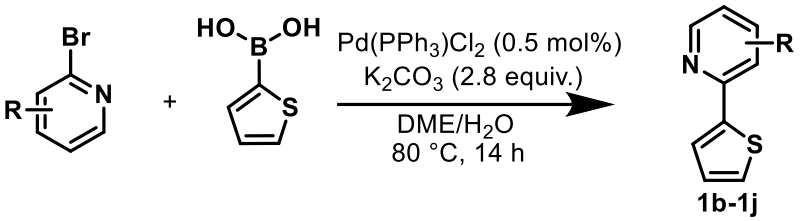


entry	additive	solvent	**3aa** (%)[b]	**4aa** (%)[c]
1	$Cu(OAc)_2$	toluene	65	–
2	$Cu(OAc)_2$	CH_3CN	89	–
3	$Cu(OAc)_2$	1,4-dioxane	51	–
4	$Cu(OAc)_2$	THF	64	–
5	$Cu(OAc)_2$	DCE	(91, 90[d])	–
6	–	DCE	n. d	–
7	AgOAc	DCE	83	–
8	Ag_2CO_3	DCE	80	–
9	Pyridine	toluene	–	69
10	Pyridine	1,4-dioxane	–	71
11	Pyridine	DCE	–	trace
12	Pyridine	CH_3CN	–	trace
13	Pyridine	$PhCF_3$	–	(75, 61[e])
14	–	$PhCF_3$	–	trace
15	2,2'-bipyridine	$PhCF_3$	–	51
16	Et_3N	$PhCF_3$	–	trace
17	KOAc	$PhCF_3$	–	11
18	K_2CO_3	$PhCF_3$	–	12
19	K_3PO_4	$PhCF_3$	–	10
20	PivOK	$PhCF_3$	–	25

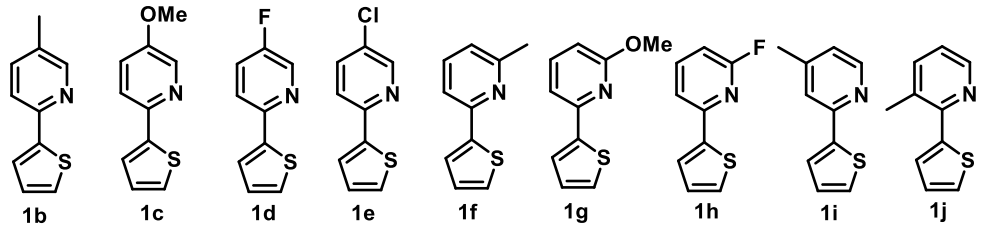
[a]Reaction conditions: **1a** (0.30 mmol), **2a** (0.60 mmol), additive (2 equiv.) and solvent (2.0 mL). [b]Isolated yields of **3aa** (entries 1–8). [c]Isolated yields of **4aa** (entries 9–20). [d]Isolated yield of **3aa** in the presence of $AgSbF_6$. [e]Isolated yield of **4aa** using $Cu(OAc)_2$ instead of Ag_2CO_3.

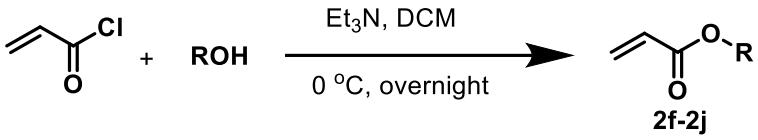
3. Experimental Procedure

3.1 Procedure for the synthesis of starting materials

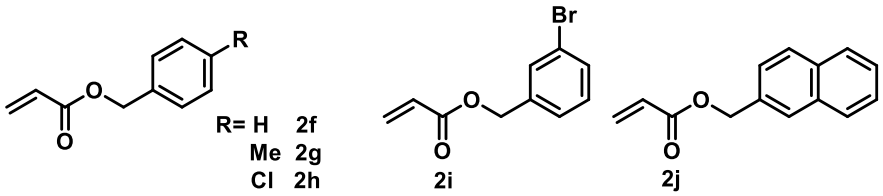


Synthesis of of substrates 1b-1j[1]: To a solution of boronic acid derivatives (1.2 mmol, 1.2 equiv.), K_2CO_3 (2.8 mmol, 2.8 equiv.) and $[Pd(PPh_3)_2Cl_2]$ (3.5 mg, 0.5 mol%) in DME (30 mL) and H_2O (14 mL) was added substituted 2-bromopyridine derivatives (1.0 mmol, 1.0 equiv.). The reaction mixture was stirred at 80 °C for 14 h. Then the reaction mixture was quenched with water (10 mL) and extracted with EtOAc (3 x 20 mL). The combined organic phases were washed with brine (25 mL), dried over Na_2SO_4 and concentrated in vacuo. The residue was purified by flash chromatography (petroleum ether/ethyl acetate = 30:1) to get the desired products.





Synthesis of of acrylates 2f-2j[2]: The mixture of alcohols or phenols (3 mmol) and Et_3N (4.5 mmol) in dry CH_2Cl_2 (10 mL) was cooled to 0 °C in an ice-water bath and acryloyl chloride (3.6 mmol) was added dropwise. The mixture was warmed to room temperature and stirred for overnight. The solvent was removed under reduced pressure and the residue was chromatographed on silica gel to get the desired products.

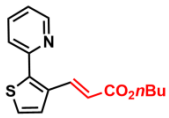


3.2 Rh(III)-Catalyzed C3-Alkenylation: Procedure and Compound Characterizations

General Procedure A: To a 15 mL oven dried Schlenk tube, $Cu(OAc)_2$ (0.6 mmol, 2 equiv.), 2-pyridylthiophene derivatives (0.3 mmol, 1 equiv.), $[Cp^*RhCl_2]_2$ (3.8 mg, 0.006 mmol, 2 mol%), alkenes (0.6 mmol, 2 equiv.), and DCE (2 mL) were successively added. The reaction mixture was stirred at 80 °C (metal sand bath temperature) for 4 hours under air. After cooling the reaction at room temperature and concentration, the crude mixture was purified by silica column chromatography to afford the desired alkenylated products.

3.3 Pd(II)-Catalyzed C5-Alkenylation: Procedure and Compound Characterizations

General Procedure B: To a 15 mL oven dried Schlenk tube, Ag_2CO_3 (0.6 mmol, 2 equiv.), 2-pyridylthiophene derivatives (0.3 mmol, 1 equiv.), $Pd(OAc)_2$ (3.4 mg, 0.015 mmol, 5 mol%), pyridine (0.6 mmol, 2 equiv.), alkenes (0.6 mmol, 2 equiv.) and $PhCF_3$ (2 mL) were successively added. The reaction mixture was stirred at 120 °C (metal sand bath temperature) for 12 hours under air. After cooling the reaction at room temperature and concentration, the crude mixture was purified by silica column chromatography to afford the desired alkenylated products.

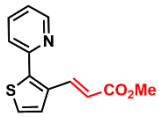


Butyl (*E*)-3-(2-(pyridin-2-yl)thiophen-3-yl)acrylate (3aa). Following the general procedure **A** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and butyl acrylate (76.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3aa** (78.5 mg, 91%) as a brown liquid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.67 (d, *J* = 6.3 Hz, 1H), 8.13 (d, *J* = 15.9 Hz, 1H), 7.73 (td, *J* = 7.7, 1.8 Hz, 1H), 7.49 (d, *J* = 7.9 Hz, 1H), 7.35 – 7.31 (m, 2H), 7.23 (dd, *J* = 8.0, 4.4 Hz, 1H), 6.35 (d, *J* = 15.9 Hz, 1H), 4.18 (t, *J* = 6.7 Hz, 2H), 1.66 (dt, *J* = 14.5, 6.7 Hz, 2H), 1.41 (h, *J* = 7.4 Hz, 2H), 0.94 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 167.4, 152.1, 150.1, 144.6, 137.8, 136.9, 134.2, 126.8, 126.7, 123.5, 122.6, 119.8, 64.4, 30.8, 19.3, 13.8.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{16}H_{18}NO_2S$ 288.1052; Found 288.1049.

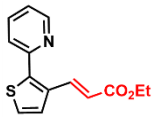


Methyl (*E*)-3-(2-(pyridin-2-yl)thiophen-3-yl)acrylate (3ab). Following the general procedure **A** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and methyl acrylate (51.5 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3ab** (61.0 mg, 83%) as a brown liquid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.68 (d, *J* = 4.5 Hz, 1H), 8.12 (d, *J* = 15.9 Hz, 1H), 7.75 (td, *J* = 7.8, 1.7 Hz, 1H), 7.49 (d, *J* = 7.9 Hz, 1H), 7.34 (q, *J* = 5.4 Hz, 2H), 7.24 (dd, *J* = 7.1, 5.2 Hz, 1H), 6.36 (d, *J* = 15.9 Hz, 1H), 3.78 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 168.0, 152.3, 150.3, 145.0, 138.2, 137.2, 134.3, 127.1, 127.0, 123.8, 122.8, 119.6, 52.0.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{13}H_{12}NO_2S$ 246.0583; Found 246.0580.

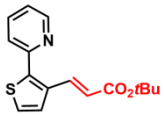


Ethyl (*E*)-3-(2-(pyridin-2-yl)thiophen-3-yl)acrylate (3ac). Following the general procedure **A** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and ethyl acrylate (60.0 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3ac** (67.6 mg, 87%) as a light yellow liquid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.68 (d, *J* = 4.7 Hz, 1H), 8.12 (d, *J* = 15.9 Hz, 1H), 7.74 (td, *J* = 7.8, 1.8 Hz, 1H), 7.50 (d, *J* = 7.9 Hz, 1H), 7.33 (q, *J* = 5.4 Hz, 2H), 7.23 (dd, *J* = 8.0, 5.3 Hz, 1H), 6.36 (d, *J* = 15.9 Hz, 1H), 4.24 (q, *J* = 7.1 Hz, 2H), 1.31 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 167.4, 152.1, 150.1, 144.7, 137.8, 136.9, 134.2, 126.9, 126.8, 123.6, 122.6, 119.8, 60.6, 14.4.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{14}H_{14}NO_2S$ 260.0739; Found 260.0736.

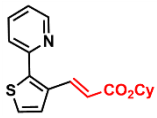


***tert*-Butyl (*E*)-3-(2-(pyridin-2-yl)thiophen-3-yl)acrylate (3ad).** Following the general procedure **A** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and *tert*-butyl acrylate (76.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3ad** (75.8 mg, 88%) as a yellow liquid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.67 (d, *J* = 5.5 Hz, 1H), 8.05 (d, *J* = 15.8 Hz, 1H), 7.74 (td, *J* = 7.8, 1.8 Hz, 1H), 7.51 (d, *J* = 7.9 Hz, 1H), 7.36 – 7.31 (m, 2H), 7.23 (dd, *J* = 8.0, 5.3 Hz, 1H), 6.30 (d, *J* = 15.8 Hz, 1H), 1.51 (s, 9H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 166.7, 152.3, 150.1, 144.4, 136.9, 136.8, 134.3, 126.9, 126.7, 123.5, 122.5, 121.6, 80.5, 28.3.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{16}H_{18}NO_2S$ 288.1052; Found 288.1048.

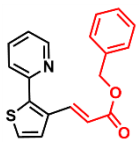


Cyclohexyl (*E*)-3-(2-(pyridin-2-yl)thiophen-3-yl)acrylate (3ae). Following the general procedure **A** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and cyclohexyl acrylate (92.4 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3ae** (84.6 mg, 90%) as a yellow liquid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.67 (d, *J* = 4.7 Hz, 1H), 8.13 (d, *J* = 15.9 Hz, 1H), 7.73 (td, *J* = 7.7, 1.8 Hz, 1H), 7.50 (d, *J* = 7.9 Hz, 1H), 7.35 – 7.30 (m, 2H), 7.23 (dd, *J* = 7.2, 5.2 Hz, 1H), 6.35 (d, *J* = 15.9 Hz, 1H), 4.87 (tt, *J* = 8.8, 3.8 Hz, 1H), 1.92 – 1.84 (m, 2H), 1.77 – 1.70 (m, 2H), 1.54 – 1.29 (m, 6H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 166.8, 152.2, 150.1, 144.5, 137.5, 136.9, 134.3, 126.9, 126.7, 123.5, 122.5, 120.3, 72.7, 31.8, 25.5, 23.8.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{18}H_{20}NO_2S$ 314.1209; Found 314.1204.



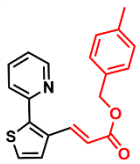
Benzyl (*E*)-3-(2-(pyridin-2-yl)thiophen-3-yl)acrylate (3af). Following the general procedure **A** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and benzyl acrylate (97.2 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3af** (65.5 mg, 68%) as a yellow liquid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.69 (d, *J* = 4.7 Hz, 1H), 8.22 (d, *J* = 15.9 Hz, 1H), 7.74 (td, *J* = 7.7, 1.8 Hz, 1H), 7.51 (d, *J* = 7.9 Hz, 1H), 7.43 – 7.32 (m, 7H), 7.26 – 7.23 (m, 1H), 6.42 (d, *J* = 15.9

Hz, 1H), 5.25 (s, 2H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 167.2, 152.1, 150.1, 144.9, 138.5, 136.9, 136.2, 134.1, 128.7, 128.3, 128.2, 126.9, 126.8, 123.6, 122.6, 119.3, 66.4.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{19}H_{16}NO_2S$ 322.0896; Found 322.0892.

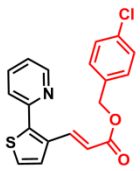


4-Methylbenzyl (*E*)-3-(2-(pyridin-2-yl)thiophen-3-yl)acrylate (3ag). Following the general procedure **A** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and 4-methylbenzyl acrylate (105.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3ag** (67.2 mg, 67%) as a light yellow liquid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.71 (d, *J* = 4.2 Hz, 1H), 8.22 (d, *J* = 15.9 Hz, 1H), 7.77 (td, *J* = 7.8, 1.7 Hz, 1H), 7.53 (d, *J* = 7.9 Hz, 1H), 7.39 – 7.34 (m, 2H), 7.33 (d, *J* = 7.9 Hz, 2H), 7.27 (dd, *J* = 6.9, 4.9 Hz, 1H), 7.21 (d, *J* = 7.8 Hz, 2H), 6.43 (d, *J* = 15.9 Hz, 1H), 5.23 (s, 2H), 2.38 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 167.2, 152.1, 150.1, 144.9, 138.3, 138.1, 136.9, 134.2, 133.2, 129.3, 128.4, 126.9, 126.8, 123.6, 122.6, 119.5, 66.3, 21.3.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{20}H_{18}NO_2S$ 336.1052; Found 336.1048.

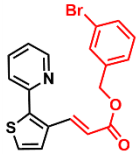


4-Chlorobenzyl (*E*)-3-(2-(pyridin-2-yl)thiophen-3-yl)acrylate (3ah). Following the general procedure **A** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and 4-chlorobenzyl acrylate (117.6 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3ah** (67.0 mg, 63%) as a yellow liquid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.68 (d, *J* = 4.8 Hz, 1H), 8.22 (d, *J* = 15.9 Hz, 1H), 7.74 (td, *J* = 7.7, 1.8 Hz, 1H), 7.50 (d, *J* = 7.9 Hz, 1H), 7.36 – 7.31 (m, 6H), 7.25 (dd, *J* = 8.5, 4.9 Hz, 1H), 6.40 (d, *J* = 15.9 Hz, 1H), 5.20 (s, 2H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 167.1, 152.1, 150.1, 145.0, 138.7, 137.0, 134.8, 134.15, 134.10, 129.6, 128.8, 126.83, 126.80, 123.6, 122.7, 119.0, 65.5.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{19}H_{15}ClNO_2S$ 356.0506; Found 356.0502.

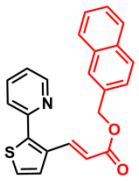


3-Bromobenzyl (*E*)-3-(2-(pyridin-2-yl)thiophen-3-yl)acrylate (3ai). Following the general procedure **A** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and 3-bromobenzyl acrylate (144.0 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3ai** (74.2 mg, 62%) as a yellow liquid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.70 (d, *J* = 5.6 Hz, 1H), 8.23 (d, *J* = 15.9 Hz, 1H), 7.76 (td, *J* = 7.8, 1.8 Hz, 1H), 7.56 (s, 1H), 7.51 (d, *J* = 7.9 Hz, 1H), 7.45 (d, *J* = 8.0 Hz, 1H), 7.35 (s, 2H), 7.31 (d, *J* = 7.7 Hz, 1H), 7.27 – 7.25 (m, 1H), 7.24 (d, *J* = 7.6 Hz, 1H), 6.41 (d, *J* = 15.9 Hz, 1H), 5.20 (s, 2H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 167.0, 152.1, 150.2, 145.1, 138.8, 138.5, 137.0, 134.1, 131.3, 131.0, 130.2, 126.83, 126.81, 126.6, 123.6, 122.72, 122.70, 118.9, 65.3.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{19}H_{15}BrNO_2S$ 400.0001; Found 399.9997.

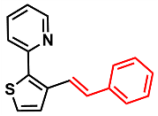


Naphthalen-2-ylmethyl (*E*)-3-(2-(pyridin-2-yl)thiophen-3-yl)acrylate (3aj). Following the general procedure **A** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and naphthalen-2-ylmethyl acrylate (127.2 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3aj** (72.3 mg, 65%) as a light yellow liquid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.69 (d, *J* = 5.5 Hz, 1H), 8.25 (d, *J* = 15.9 Hz, 1H), 7.90 – 7.83 (m, 4H), 7.73 (td, *J* = 7.8, 1.7 Hz, 1H), 7.51 (dd, *J* = 10.5, 5.2Hz, 4H), 7.35 (s, 2H), 7.24 (dd, *J* = 8.0, 5.3 Hz, 1H), 6.46 (d, *J* = 15.9 Hz, 1H), 5.42 (s, 2H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 167.2, 152.1, 150.1, 145.0, 138.5, 136.9, 134.2, 133.7, 133.3, 133.2, 128.5, 128.1, 127.8, 127.3, 126.9, 126.8, 126.4, 126.3, 125.9, 123.6, 122.6, 119.3, 66.5.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{23}H_{18}NO_2S$ 372.1052; Found 372.1047.

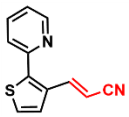


(*E*)-2-(3-Styrylthiophen-2-yl)pyridine (3ak). Following the general procedure **A** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and styrene (62.4 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3ak** (48.1 mg, 61%) as a yellow liquid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.71 (d, *J* = 4.2 Hz, 1H), 7.72 (td, *J* = 7.7, 1.8 Hz, 1H), 7.61 (d, *J* = 16.3 Hz, 1H), 7.57 (d, *J* = 7.9 Hz, 1H), 7.51 (d, *J* = 7.5 Hz, 2H), 7.43 (d, *J* = 5.3 Hz, 1H), 7.39 – 7.35 (m, 3H), 7.28 (t, *J* = 7.3 Hz, 1H), 7.21 (dd, *J* = 7.9, 5.3 Hz, 1H), 7.09 (d, *J* = 16.3 Hz, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 153.1, 149.9, 139.5, 137.5, 137.0, 136.6, 130.9, 128.7, 127.7, 127.0, 126.6, 126.4, 123.1, 122.7, 121.8.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{17}H_{14}NS$ 264.0841; Found 264.0837.

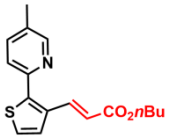


(*E*)-3-(2-(Pyridin-2-yl)thiophen-3-yl)acrylonitrile (3al). Following the general procedure **A** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and acrylonitrile (31.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3al** (27.3 mg, 43%) as a brown liquid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.71 (d, *J* = 4.8 Hz, 1H), 8.13 (d, *J* = 16.6 Hz, 1H), 7.78 (td, *J* = 7.7, 1.7 Hz, 1H), 7.51 (d, *J* = 7.9 Hz, 1H), 7.37 (d, *J* = 5.3 Hz, 1H), 7.31 – 7.28 (m, 2H), 5.80 (d, *J* = 16.6 Hz, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 151.8, 150.1, 144.6, 144.4, 137.1, 133.6, 126.9, 125.8, 123.5, 122.9, 118.7, 97.0.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{12}H_9N_2S$ 213.0480; Found 213.0477.

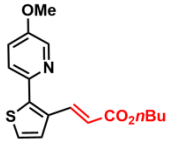


Butyl (*E*)-3-(2-(5-methylpyridin-2-yl)thiophen-3-yl)acrylate (3ba). Following the general procedure **A** using 5-methyl-2-(thiophen-2-yl)pyridine (52.5 mg, 0.3 mmol) and butyl acrylate (76.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3ba** (79.5 mg, 88%) as a light yellow liquid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.50 (s, 1H), 8.10 (d, *J* = 15.9 Hz, 1H), 7.54 (d, *J* = 8.0 Hz, 1H), 7.39 (d, *J* = 8.0 Hz, 1H), 7.33 – 7.29 (m, 2H), 6.34 (d, *J* = 15.9 Hz, 1H), 4.18 (t, *J* = 6.7 Hz, 2H), 2.36 (s, 3H), 1.66 (dt, *J* = 14.5, 6.7 Hz, 2H), 1.45 – 1.38 (m, 2H), 0.94 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 167.5, 150.6, 149.5, 145.0, 137.9, 137.3, 133.8, 132.4, 126.7, 126.3, 123.1, 119.4, 64.4, 30.8, 19.3, 18.3, 13.8.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{17}H_{20}NO_2S$ 302.1209; Found 302.1206.

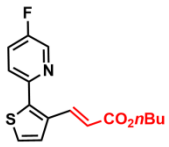


Butyl (*E*)-3-(2-(5-methoxypyridin-2-yl)thiophen-3-yl)acrylate (3ca). Following the general procedure **A** using 5-methoxy-2-(thiophen-2-yl)pyridine (57.3 mg, 0.3 mmol) and butyl acrylate (76.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3ca** (85.6 mg, 90%) as a light yellow liquid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.38 (d, *J* = 2.9 Hz, 1H), 8.07 (d, *J* = 15.9 Hz, 1H), 7.43 (d, *J* = 8.6 Hz, 1H), 7.30 (d, *J* = 5.4 Hz, 1H), 7.27 (d, *J* = 5.4 Hz, 1H), 7.24 (dd, *J* = 8.7, 3.0 Hz, 1H), 6.32 (d, *J* = 15.9 Hz, 1H), 4.18 (t, *J* = 6.7 Hz, 2H), 3.88 (s, 3H), 1.66 (dt, *J* = 14.5, 6.7 Hz, 2H), 1.42 (h, *J* = 7.4 Hz, 2H), 0.94 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 167.5, 155.1, 144.8, 144.7, 137.92, 137.89, 133.2, 126.6, 125.8, 124.0, 121.0, 119.2, 64.4, 55.8, 30.8, 19.3, 13.8.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{17}H_{20}NO_3S$ 318.1158; Found 318.1155.



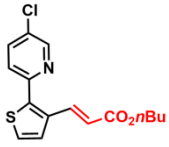
Butyl (*E*)-3-(2-(5-fluoropyridin-2-yl)thiophen-3-yl)acrylate (3da). Following the general procedure **A** using 5-fluoro-2-(thiophen-2-yl)pyridine (53.7 mg, 0.3 mmol) and butyl acrylate (76.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3da** (83.2 mg, 91%) as a light yellow liquid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.53 (d, *J* = 2.8 Hz, 1H), 8.06 (d, *J* = 15.9 Hz, 1H), 7.51 – 7.44 (m, 2H), 7.34 – 7.29 (m, 2H), 6.35 (d, *J* = 15.9 Hz, 1H), 4.18 (t, *J* = 6.7 Hz, 2H), 1.66 (dt, *J* = 14.5, 6.7 Hz, 2H), 1.42 (h, *J* = 7.4 Hz, 2H), 0.94 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 167.4, 143.2, 138.5, 138.4, 137.4, 134.2, 126.8, 126.6, 124.43, 124.40, 123.8, 123.7, 120.0, 64.5, 30.8, 19.3, 13.8.

^{19}F NMR (565 MHz, $CDCl_3$) δ -127.53(s).

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{16}H_{17}FNO_2S$ 306.0885; Found 306.0893.

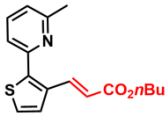


Butyl (*E*)-3-(2-(5-chloropyridin-2-yl)thiophen-3-yl)acrylate (3ea). Following the general procedure **A** using 5-chloro-2-(thiophen-2-yl)pyridine (58.5 mg, 0.3 mmol) and butyl acrylate (76.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3ea** (86.7 mg, 90%) as a light yellow liquid

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.61 (s, 1H), 8.09 (d, *J* = 15.9 Hz, 1H), 7.70 (dd, *J* = 8.4, 2.5 Hz, 1H), 7.44 (d, *J* = 8.4 Hz, 1H), 7.37 – 7.30 (m, 2H), 6.35 (d, *J* = 15.9 Hz, 1H), 4.19 (t, *J* = 6.7 Hz, 2H), 1.67 (dt, *J* = 14.5, 6.7 Hz, 2H), 1.42 (h, *J* = 7.4 Hz, 2H), 0.95 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 167.3, 150.3, 148.9, 143.0, 137.4, 136.6, 134.7, 131.1, 127.1, 127.0, 123.9, 120.2, 64.5, 30.8, 19.3, 13.8.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{16}H_{17}ClNO_2S$ 322.0590; Found 322.0598.

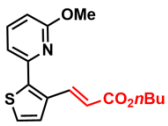


Butyl (*E*)-3-(2-(6-methylpyridin-2-yl)thiophen-3-yl)acrylate (3fa). Following the general procedure **A** using 2-methyl-6-(thiophen-2-yl)pyridine (52.5 mg, 0.3 mmol) and butyl acrylate (76.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3fa** (82.2 mg, 91%) as a light yellow liquid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.21 (d, *J* = 15.9 Hz, 1H), 7.61 (t, *J* = 7.8 Hz, 1H), 7.35 – 7.27 (m, 3H), 7.09 (d, *J* = 7.7 Hz, 1H), 6.33 (d, *J* = 15.9 Hz, 1H), 4.18 (t, *J* = 6.6 Hz, 2H), 2.60 (s, 3H), 1.66 (dt, *J* = 14.5, 6.7 Hz, 2H), 1.42 (h, *J* = 7.4 Hz, 2H), 0.94 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 167.5, 159.0, 151.5, 144.8, 138.1, 137.0, 134.2, 126.7, 126.4, 122.2, 120.7, 119.4, 64.4, 30.9, 24.6, 19.3, 13.8.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{17}H_{20}NO_2S$ 302.1209; Found 302.1207.

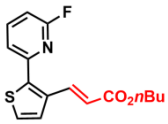


Butyl (*E*)-3-(2-(6-methoxypyridin-2-yl)thiophen-3-yl)acrylate (3ga). Following the general procedure **A** using 2-methoxy-6-(thiophen-2-yl)pyridine (57.3 mg, 0.2 mmol) and butyl acrylate (76.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3ga** (72.3 mg, 76%) as a light yellow liquid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.59 (d, *J* = 16.1 Hz, 1H), 7.61 – 7.57 (m, 1H), 7.33 (d, *J* = 5.3 Hz, 1H), 7.29 (d, *J* = 5.3 Hz, 1H), 7.13 (d, *J* = 7.3 Hz, 1H), 6.70 (d, *J* = 8.3 Hz, 1H), 6.33 (d, *J* = 16.0 Hz, 1H), 4.19 (t, *J* = 6.7 Hz, 2H), 4.04 (s, 3H), 1.67 (dt, *J* = 14.6, 6.8 Hz, 2H), 1.42 (h, *J* = 7.4 Hz, 2H), 0.95 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 167.6, 163.7, 149.8, 143.9, 139.3, 138.9, 134.6, 127.1, 126.0, 119.2, 115.8, 110.1, 64.4, 53.8, 30.9, 19.3, 13.9.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{17}H_{20}NO_3S$ 318.1158; Found 318.1155.



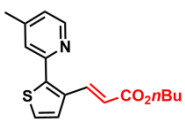
Butyl (*E*)-3-(2-(6-fluoropyridin-2-yl)thiophen-3-yl)acrylate (3ha). Following the general procedure **A** using 2-fluoro-6-(thiophen-2-yl)pyridine (53.7 mg, 0.3 mmol) and butyl acrylate (76.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3ha** (85.0 mg, 93%) as a light yellow liquid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.17 (d, *J* = 15.9 Hz, 1H), 7.83 (q, *J* = 8.0 Hz, 1H), 7.38 – 7.34 (m, 2H), 7.31 (d, *J* = 5.4 Hz, 1H), 6.87 (dd, *J* = 8.2, 2.8 Hz, 1H), 6.35 (d, *J* = 15.9 Hz, 1H), 4.19 (t, *J* = 6.6 Hz, 2H), 1.67 (dt, *J* = 14.5, 6.7 Hz, 2H), 1.43 (h, *J* = 7.4 Hz, 2H), 0.94 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 167.3, 150.8, 150.7, 142.3, 141.95, 141.89, 137.4, 135.0, 127.3, 127.1, 120.50, 120.47, 120.37, 108.5, 108.3, 64.5, 30.8, 19.3, 13.8.

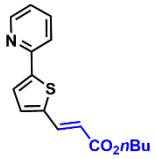
^{19}F NMR (565 MHz, $CDCl_3$) δ -65.46(s).

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{16}H_{17}FNO_2S$ 306.0885; Found 306.0893.



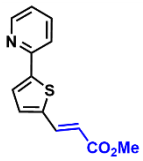
Butyl (*E*)-3-(2-(4-methylpyridin-2-yl)thiophen-3-yl)acrylate (3ia). Following the general procedure **A** using 4-methyl-2-(thiophen-2-yl)pyridine (52.5 mg, 0.3 mmol) and butyl acrylate (76.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **3ia** (70.3 mg, 78%) as a yellow liquid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.52 (d, J = 5.0 Hz, 1H), 8.13 (d, J = 15.9 Hz, 1H), 7.32 (d, J = 6.2 Hz, 3H), 7.06 (d, J = 5.5 Hz, 1H), 6.34 (d, J = 15.9 Hz, 1H), 4.18 (t, J = 6.6 Hz, 2H), 2.39 (s, 3H), 1.66 (dt, J = 14.5, 6.7 Hz, 2H), 1.42 (dq, J = 14.7, 7.4 Hz, 2H), 0.94 (t, J = 7.4 Hz, 3H).
^{13}C NMR (151 MHz, $CDCl_3$) δ 167.4, 152.0, 149.8, 148.1, 144.8, 137.9, 134.1, 126.7, 126.5, 124.5, 123.6, 119.6, 64.4, 30.8, 21.2, 19.3, 13.8.
HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{17}H_{20}NO_2S$ 302.1209; Found 302.1205.



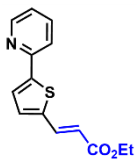
Butyl (*E*)-3-(5-(pyridin-2-yl)thiophen-2-yl)acrylate (4aa). Following the general procedure **B** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and butyl acrylate (76.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **4aa** (64.6 mg, 75%) as a yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.55 (d, *J* = 4.6 Hz, 1H), 7.72 (d, *J* = 15.7 Hz, 1H), 7.66 (td, *J* = 7.7, 1.7 Hz, 1H), 7.62 (d, *J* = 7.9 Hz, 1H), 7.47 (d, *J* = 3.9 Hz, 1H), 7.20 (d, *J* = 3.9 Hz, 1H), 7.15 (dt, *J* = 8.3, 4.9 Hz, 1H), 6.27 (d, *J* = 15.7 Hz, 1H), 4.18 (t, *J* = 6.7 Hz, 2H), 1.66 (dt, *J* = 14.6, 6.8 Hz, 2H), 1.41 (h, *J* = 7.4 Hz, 2H), 0.94 (t, *J* = 7.4 Hz, 3H).
^{13}C NMR (151 MHz, $CDCl_3$) δ 166.9, 151.8, 149.8, 147.4, 141.1, 137.1, 136.8, 131.9, 125.2, 122.7, 119.1, 117.6, 64.5, 30.8, 19.3, 13.8.
HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{16}H_{18}NO_2S$ 288.1052; Found 288.1048.



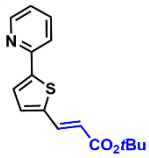
Methyl (*E*)-3-(5-(pyridin-2-yl)thiophen-2-yl)acrylate (4ab). Following the general procedure **B** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and methyl acrylate (51.6 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **4ab** (45.6 mg, 62%) as a yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.56 (d, *J* = 4.8 Hz, 1H), 7.75 (d, *J* = 15.7 Hz, 1H), 7.68 (td, *J* = 7.7, 1.7 Hz, 1H), 7.64 (d, *J* = 8.0 Hz, 1H), 7.48 (d, *J* = 3.9 Hz, 1H), 7.22 (d, *J* = 3.9 Hz, 1H), 7.17 (dt, *J* = 6.2, 4.9 Hz, 1H), 6.28 (d, *J* = 15.7 Hz, 1H), 3.78 (s, 3H).
^{13}C NMR (151 MHz, $CDCl_3$) δ 167.3, 151.8, 149.8, 147.6, 141.0, 137.4, 136.8, 132.1, 125.2, 122.7, 119.1, 117.1, 51.8.
HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{13}H_{12}NO_2S$ 246.0583; Found 246.0579.



Ethyl (*E*)-3-(5-(pyridin-2-yl)thiophen-2-yl)acrylate (4ac). Following the general procedure **B** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and ethyl acrylate (60.0 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **4ac** (52.8 mg, 68%) as a yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.56 (d, *J* = 4.7 Hz, 1H), 7.74 (d, *J* = 15.7 Hz, 1H), 7.68 (td, *J* = 7.7, 1.8 Hz, 1H), 7.63 (d, *J* = 8.0 Hz, 1H), 7.48 (d, *J* = 3.9 Hz, 1H), 7.22 (d, *J* = 3.8 Hz, 1H), 7.18 – 7.15 (m, 1H), 6.27 (d, *J* = 15.7 Hz, 1H), 4.24 (q, *J* = 7.1 Hz, 2H), 1.32 (t, *J* = 7.1 Hz, 3H).
^{13}C NMR (151 MHz, $CDCl_3$) δ 166.9, 151.8, 149.8, 147.4, 141.1, 137.1, 136.8, 132.0, 125.2, 122.7, 119.1, 117.6, 60.6, 14.4.
HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{14}H_{14}NO_2S$ 260.0739; Found 260.0736.

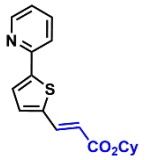


***tert*-Butyl (*E*)-3-(5-(pyridin-2-yl)thiophen-2-yl)acrylate (4ad).** Following the general procedure **B** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and *tert*-butyl acrylate (76.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **4ad** (50.0 mg, 58%) as a yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.54 (d, *J* = 4.8 Hz, 1H), 7.68 – 7.58 (m, 3H), 7.46 (d, *J* = 3.9 Hz, 1H), 7.18 (d, *J* = 3.9 Hz, 1H), 7.16 – 7.11 (m, 1H), 6.21 (d, *J* = 15.7 Hz, 1H), 1.51 (s, 9H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 166.1, 151.8, 149.8, 147.0, 141.3, 136.8, 136.1, 131.5, 125.2, 122.6, 119.6, 119.1, 80.6, 28.3.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{16}H_{18}NO_2S$ 288.1052; Found 288.1048.

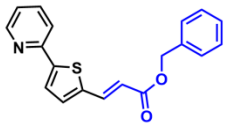


Cyclohexyl (*E*)-3-(5-(pyridin-2-yl)thiophen-2-yl)acrylate (4ae). Following the general procedure **B** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and cyclohexyl acrylate (92.4 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **4ae** (59.2 mg, 63%) as a yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.56 (d, *J* = 5.3 Hz, 1H), 7.72 (d, *J* = 15.7 Hz, 1H), 7.68 (td, *J* = 7.8, 1.7 Hz, 1H), 7.63 (d, *J* = 8.0 Hz, 1H), 7.48 (d, *J* = 3.9 Hz, 1H), 7.22 (d, *J* = 3.9 Hz, 1H), 7.18 – 7.15 (m, 1H), 6.27 (d, *J* = 15.7 Hz, 1H), 4.87 (tt, *J* = 9.1, 3.9 Hz, 1H), 1.93 – 1.88 (m, 2H), 1.81 – 1.71 (m, 2H), 1.60 – 1.29 (m, 6H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 166.3, 151.9, 149.8, 147.3, 141.2, 136.82, 136.80, 131.8, 125.2, 122.7, 119.1, 118.3, 72.9, 31.8, 25.5, 23.9.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{18}H_{20}NO_2S$ 314.1209; Found 314.1204.

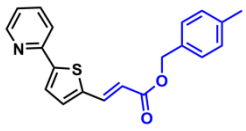


Benzyl (*E*)-3-(5-(pyridin-2-yl)thiophen-2-yl)acrylate (4af). Following the general procedure **B** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and benzyl acrylate (97.2 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **4af** (58.8 mg, 61%) as a yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.57 (d, *J* = 4.8 Hz, 1H), 7.79 (d, *J* = 15.7 Hz, 1H), 7.69 (td, *J* = 7.7, 1.7 Hz, 1H), 7.64 (d, *J* = 8.0 Hz, 1H), 7.49 (d, *J* = 3.9 Hz, 1H), 7.44 – 7.36 (m, 4H), 7.34 (t, *J* = 7.1 Hz, 1H), 7.23 (d, *J* = 3.9 Hz, 1H), 7.19 – 7.16 (m, 1H), 6.34 (d, *J* = 15.7 Hz, 1H), 5.25 (s, 2H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 166.7, 151.8, 149.9, 147.7, 141.0, 137.7, 136.8, 136.2, 132.2, 128.7, 128.39, 128.36, 125.2, 122.7, 119.2, 117.1, 66.5.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{19}H_{16}NO_2S$ 322.0896; Found 322.0891.



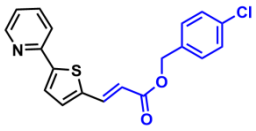
4-Methylbenzyl (*E*)-3-(5-(pyridin-2-yl)thiophen-2-yl)acrylate (4ag). Following the general procedure **B** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and 4-methylbenzyl acrylate (105.7 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **4ag** (60.3 mg, 60%) as a yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.57 (d, *J* = 5.4 Hz, 1H), 7.78 (d, *J* = 15.7 Hz, 1H), 7.69 (td, *J* = 7.7, 1.7 Hz, 1H), 7.64 (d, *J* = 8.0 Hz, 1H), 7.49 (d, *J* = 3.9 Hz, 1H), 7.31 (d, *J* = 8.0 Hz, 2H), 7.22 (d, *J* = 3.9 Hz, 1H), 7.21 – 7.19 (m, 2H), 7.17 (d, *J* = 7.3 Hz, 1H), 6.32 (d, *J* = 15.7 Hz, 1H), 5.21 (s, 2H),

2.36 (s, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 166.7, 151.8, 149.9, 147.6, 141.0, 138.2, 137.6, 136.8, 133.1, 132.1, 129.4, 128.6, 125.2, 122.7, 119.2, 117.3, 66.5, 21.3.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{20}H_{18}NO_2S$ 336.1052; Found 336.1049.

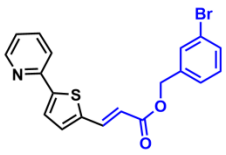


4-Chlorobenzyl (*E*)-3-(5-(pyridin-2-yl)thiophen-2-yl)acrylate (4ah). Following the general procedure **B** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and 4-chlorobenzyl acrylate (117.6 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **4ah** (61.8 mg, 58%) as a yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.57 (d, *J* = 4.8 Hz, 1H), 7.78 (d, *J* = 15.7 Hz, 1H), 7.69 (td, *J* = 7.7, 1.7 Hz, 1H), 7.64 (d, *J* = 8.0 Hz, 1H), 7.49 (d, *J* = 3.9 Hz, 1H), 7.34 (s, 4H), 7.24 (d, *J* = 3.9 Hz, 1H), 7.20 – 7.16 (m, 1H), 6.31 (d, *J* = 15.7 Hz, 1H), 5.20 (s, 2H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 166.6, 151.7, 149.9, 147.9, 140.9, 137.9, 136.8, 134.7, 134.2, 132.4, 129.8, 128.9, 125.2, 122.8, 119.2, 116.8, 65.6.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{19}H_{15}ClNO_2S$ 356.0506; Found 356.0502.

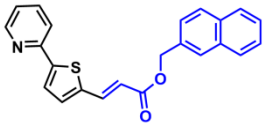


3-Bromobenzyl (*E*)-3-(5-(pyridin-2-yl)thiophen-2-yl)acrylate (4ai). Following the general procedure **B** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and 3-bromobenzyl acrylate (144.0 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **4ai** (67.0 mg, 56%) as a yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.57 (d, *J* = 4.4 Hz, 1H), 7.79 (d, *J* = 15.7 Hz, 1H), 7.69 (t, *J* = 7.7 Hz, 1H), 7.64 (d, *J* = 7.9 Hz, 1H), 7.56 (s, 1H), 7.49 (d, *J* = 3.9 Hz, 1H), 7.46 (d, *J* = 8.0 Hz, 1H), 7.32 (d, *J* = 7.6 Hz, 1H), 7.26 – 7.22 (m, 2H), 7.20 – 7.15 (m, 1H), 6.32 (d, *J* = 15.7 Hz, 1H), 5.19 (s, 2H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 166.5, 151.7, 149.9, 147.9, 140.8, 138.4, 138.0, 136.8, 132.4, 131.4, 131.2, 130.3, 126.8, 125.2, 122.8, 122.7, 119.2, 116.7, 65.4.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{19}H_{15}BrNO_2S$ 400.0001; Found 399.9997.

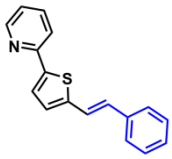


Naphthalen-2-ylmethyl (*E*)-3-(5-(pyridin-2-yl)thiophen-2-yl)acrylate (4aj). Following the general procedure **B** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and naphthalen-2-ylmethyl acrylate (127.2 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **4aj** (44.5 mg, 40%) as a yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.58 (d, *J* = 4.8 Hz, 1H), 7.86 (dd, *J* = 12.8, 7.4, 4H), 7.82 (d, *J* = 15.7 Hz, 1H), 7.69 (td, *J* = 7.7, 1.7 Hz, 1H), 7.64 (d, *J* = 8.0 Hz, 1H), 7.54 – 7.48 (m, 4H), 7.24 (d, *J* = 3.9 Hz, 1H), 7.20 – 7.15 (m, 1H), 6.37 (d, *J* = 15.7 Hz, 1H), 5.41 (s, 2H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 166.8, 151.8, 149.9, 141.0, 137.8, 136.8, 133.6, 133.34, 133.26, 132.3, 128.5, 128.1, 127.8, 127.5, 126.42, 126.38, 126.1, 125.3, 122.8, 119.2, 117.1, 66.6.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{23}H_{18}NO_2S$ 372.1052; Found 372.1048.

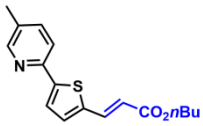


(*E*)-2-(5-Styrylthiophen-2-yl)pyridine (4ak). Following the general procedure **B** using 2-(thiophen-2-yl)pyridine (48.3 mg, 0.3 mmol) and styrene (62.4 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **4ak** (36.3 mg, 46%) as a yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.59 (d, *J* = 4.8 Hz, 1H), 7.71 – 7.63 (m, 2H), 7.51 – 7.47 (m, 3H), 7.37 (t, *J* = 7.7 Hz, 2H), 7.27 (t, *J* = 7.3 Hz, 1H), 7.22 (d, *J* = 16.1 Hz, 1H), 7.17 – 7.12 (m, 1H), 7.07 (d, *J* = 3.8 Hz, 1H), 7.04 (d, *J* = 16.1 Hz, 1H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 152.7, 149.9, 145.1, 143.5, 137.1, 136.9, 129.6, 129.1, 128.1, 127.6, 126.8, 125.4, 122.2, 122.1, 119.0.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{17}H_{14}NS$ 264.0841; Found 264.0836.

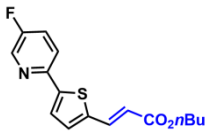


Butyl (*E*)-3-(5-(5-methylpyridin-2-yl)thiophen-2-yl)acrylate (4ba). Following the general procedure **B** using 5-methyl-2-(thiophen-2-yl)pyridine (52.5 mg, 0.3 mmol) and butyl acrylate (76.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **4ba** (60.5 mg, 67%) as a yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.37 (s, 1H), 7.72 (d, *J* = 15.7 Hz, 1H), 7.53 (s, 1H), 7.49 – 7.44 (m, 1H), 7.41 (d, *J* = 3.8 Hz, 1H), 7.19 (d, *J* = 3.8 Hz, 1H), 6.25 (d, *J* = 15.7 Hz, 1H), 4.18 (t, *J* = 6.7 Hz, 2H), 2.32 (s, 3H), 1.66 (dt, *J* = 14.6, 6.8 Hz, 2H), 1.41 (h, *J* = 7.4 Hz, 2H), 0.94 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 167.0, 150.1, 149.2, 147.7, 140.4, 137.3, 137.2, 132.5, 132.0, 124.6, 118.7, 117.3, 64.5, 30.9, 19.3, 18.4, 13.8.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{17}H_{20}NO_2S$ 302.1209; Found 302.1205.



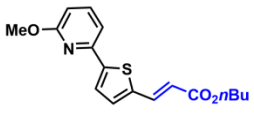
Butyl (*E*)-3-(5-(5-fluoropyridin-2-yl)thiophen-2-yl)acrylate (4da). Following the general procedure **B** using 5-fluoro-2-(thiophen-2-yl)pyridine (53.7 mg, 0.3 mmol) and butyl acrylate (76.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **4da** (68.4 mg, 75%) as a yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.40 (d, *J* = 2.8 Hz, 1H), 7.70 (d, *J* = 15.7 Hz, 1H), 7.62 (dd, *J* = 8.8, 4.1 Hz, 1H), 7.42 – 7.36 (m, 2H), 7.19 (d, *J* = 3.9 Hz, 1H), 6.26 (d, *J* = 15.7 Hz, 1H), 4.18 (t, *J* = 6.7 Hz, 2H), 1.66 (dt, *J* = 14.5, 6.8 Hz, 2H), 1.41 (h, *J* = 7.4 Hz, 2H), 0.94 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 166.9, 159.6, 157.9, 148.29, 148.26, 146.1, 141.2, 138.1, 137.9, 136.9, 131.9, 125.12, 125.11, 123.8, 123.7, 120.1, 120.0, 117.7, 64.6, 30.9, 19.3, 13.8.

^{19}F NMR (565 MHz, $CDCl_3$) δ -127.46(s).

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{16}H_{17}FNO_2S$ 306.0958; Found 306.0952.



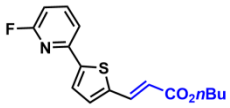
Butyl (*E*)-3-(5-(6-methoxypyridin-2-yl)thiophen-2-yl)acrylate (4ga). Following the general procedure **B** using 2-methoxy-6-(thiophen-2-yl)pyridine (57.3 mg, 0.3 mmol) and butyl acrylate (76.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel

(petroleum ether/ethyl acetate = 30:1) to afford **4ga** (50.4 mg, 53%) as a yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.73 (d, *J* = 15.6 Hz, 1H), 7.56 – 7.52 (m, 1H), 7.45 (d, *J* = 3.9 Hz, 1H), 7.20 (d, *J* = 7.5 Hz, 1H), 7.19 (d, *J* = 3.9 Hz, 1H), 6.63 (d, *J* = 8.2 Hz, 1H), 6.28 (d, *J* = 15.7 Hz, 1H), 4.19 (t, *J* = 6.7 Hz, 2H), 3.98 (s, 3H), 1.67 (dt, *J* = 14.5, 6.7 Hz, 2H), 1.43 (h, *J* = 7.4 Hz, 2H), 0.96 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 167.0, 163.6, 149.2, 147.8, 140.7, 139.1, 137.2, 132.0, 124.9, 117.2, 111.7, 110.1, 64.5, 53.4, 30.9, 19.3, 13.8.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{17}H_{20}NO_3S$ 318.1158; Found 318.1154.



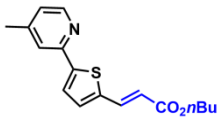
Butyl (*E*)-3-(5-(6-fluoropyridin-2-yl)thiophen-2-yl)acrylate (4ha). Following the general procedure **B** using 2-fluoro-6-(thiophen-2-yl)pyridine (53.7 mg, 0.3 mmol) and butyl acrylate (76.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **4ha** (66.8 mg, 73%) as a yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 7.76 (q, *J* = 7.9 Hz, 1H), 7.70 (d, *J* = 15.7 Hz, 1H), 7.52 (d, *J* = 3.9 Hz, 1H), 7.47 (dd, *J* = 7.5, 2.1 Hz, 1H), 7.20 (d, *J* = 3.9 Hz, 1H), 6.79 (dd, *J* = 8.1, 2.6 Hz, 1H), 6.26 (d, *J* = 15.7 Hz, 1H), 4.18 (t, *J* = 6.7 Hz, 2H), 1.66 (dt, *J* = 14.6, 6.8 Hz, 2H), 1.41 (h, *J* = 7.4 Hz, 2H), 0.94 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 166.8, 163.9, 162.3, 150.5, 145.2, 141.82, 141.77, 141.69, 136.7, 131.8, 126.4, 118.1, 116.31, 116.28, 108.3, 108.1, 64.6, 30.8, 19.3, 13.8.

^{19}F NMR (565 MHz, $CDCl_3$) δ -66.35(s).

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{16}H_{17}FNO_2S$ 306.0958; Found 306.0953.

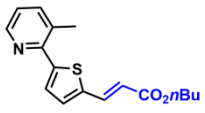


Butyl (*E*)-3-(5-(4-methylpyridin-2-yl)thiophen-2-yl)acrylate (4ia). Following the general procedure **B** using 4-methyl-2-(thiophen-2-yl)pyridine (52.5 mg, 0.3 mmol) and butyl acrylate (76.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **4ia** (58.7 mg, 65%) as a yellow solid.

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.41 (d, *J* = 5.0 Hz, 1H), 7.72 (d, *J* = 15.7 Hz, 1H), 7.46 (d, *J* = 3.9 Hz, 1H), 7.45 (s, 1H), 7.21 (d, *J* = 3.9 Hz, 1H), 6.99 (d, *J* = 5.0 Hz, 1H), 6.26 (d, *J* = 15.7 Hz, 1H), 4.18 (t, *J* = 6.7 Hz, 2H), 2.36 (s, 3H), 1.67 (dt, *J* = 14.5, 6.8 Hz, 2H), 1.42 (h, *J* = 7.4 Hz, 2H), 0.95 (t, *J* = 7.4 Hz, 3H)

^{13}C NMR (151 MHz, $CDCl_3$) δ 167.0, 151.6, 149.5, 148.0, 147.6, 140.9, 137.1, 131.9, 125.0, 123.8, 120.0, 117.5, 64.6, 30.9, 21.2, 19.3, 13.8.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{17}H_{20}NO_2S$ 302.1209; Found 302.1213.



Butyl (*E*)-3-(5-(3-methylpyridin-2-yl)thiophen-2-yl)acrylate (4ja). Following the general procedure **B** using 3-methyl-2-(thiophen-2-yl)pyridine (52.5 mg, 0.3 mmol) and butyl acrylate (76.8 mg, 0.6 mmol), the residue was purified by flash chromatography on silica gel (petroleum ether/ethyl acetate = 30:1) to afford **4ja** (31.6 mg, 35%) as a yellow solid.

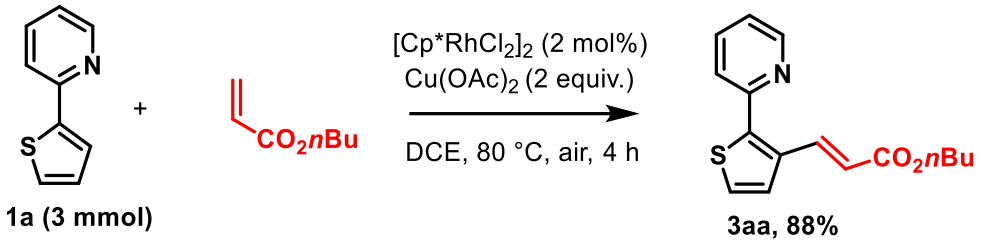
^{1}H NMR (600 MHz, $CDCl_3$) δ 8.45 (d, *J* = 5.7 Hz, 1H), 7.74 (d, *J* = 15.7 Hz, 1H), 7.52 (d, *J* = 7.6 Hz, 1H), 7.39 (d, *J* = 3.9 Hz, 1H), 7.23 (d, *J* = 3.9 Hz, 1H), 7.11 (dd, *J* = 7.6, 4.7 Hz, 1H), 6.30 (d, *J* = 15.7 Hz, 1H), 4.19 (t, *J* = 6.7 Hz, 2H), 2.55 (s, 3H), 1.67 (dt, *J* = 14.5, 6.8 Hz, 2H), 1.42 (h, *J* =

7.4 Hz, 2H), 0.95 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 167.0, 150.6, 148.2, 147.1, 140.7, 139.6, 137.1, 131.7, 130.2, 127.7, 122.4, 117.7, 64.5, 30.9, 21.6, 19.3, 13.8.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{17}H_{20}NO_2S$ 302.1209; Found 302.1204.

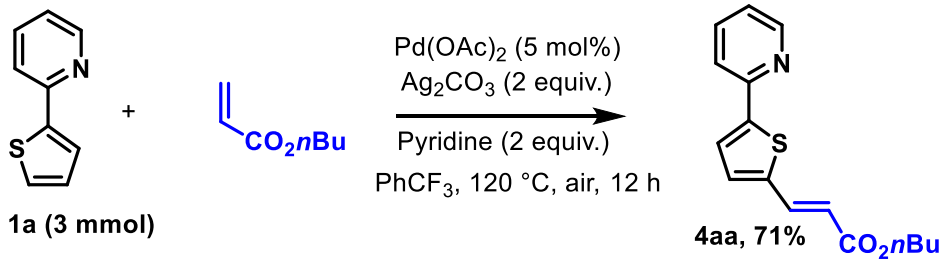
3.4 Rh(III)-Catalyzed C3-Alkenylation: Reaction on 3 mmol Scale



1a (3 mmol) **3aa, 88%**

To a 100 mL oven dried Schlenk tube, $Cu(OAc)_2$ (1.20 g, 6 mmol, 2 equiv.), 2-(thiophen-2-yl)pyridine (483.0 mg, 3 mmol, 1 equiv.), $[Cp^*RhCl_2]_2$ (37.1 mg, 0.06 mmol, 2 mol%), butyl acrylate (769.0 mg, 6 mmol, 2 equiv.), and DCE (20 mL) were successively added. The reaction mixture was stirred at 80 °C (metal sand bath temperature) for 4 hours under air. After cooling the reaction at room temperature and concentration, the crude mixture was purified by silica column chromatography to afford the desired alkenylated product **3aa** (757.9 mg, 88%).

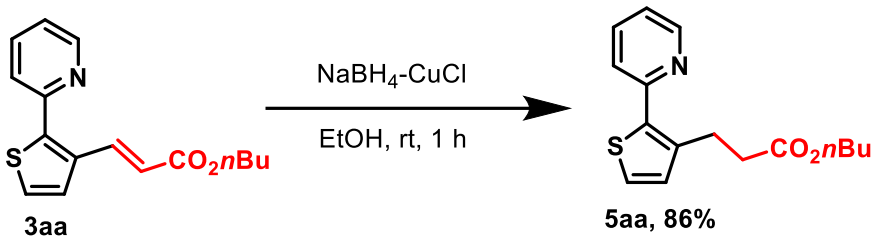
3.5 Pd(II)-Catalyzed C5-Alkenylation: Reaction on 3 mmol Scale



1a (3 mmol) **4aa, 71%**

To a 100 mL oven dried Schlenk tube, Ag_2CO_3 (1.64 g, 6 mmol, 2 equiv.), 2-(thiophen-2-yl)pyridine (483.0 mg, 3 mmol, 1 equiv.), $Pd(OAc)_2$ (33.6 mg, 0.15 mmol, 5 mol%), pyridine (474.6 mg, 6 mmol, 2 equiv.), butyl acrylate (769.0 mg, 6 mmol, 2 equiv.) and $PhCF_3$ (20 mL) were successively added. The reaction mixture was stirred at 120 °C (metal sand bath temperature) for 12 hours under air. After cooling the reaction at room temperature and concentration, the crude mixture was purified by silica column chromatography to afford the desired alkenylated product **4aa** (611.5 mg, 71%).

3.6 Preparation and Characterization of Products 5aa, 6aa, 7aa, 8aa, 9aea, 9aee

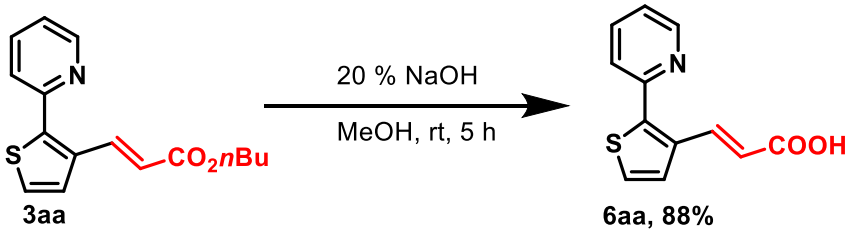


To a 15 mL oven dried Schlenk tube, CuCl (11.9 mg, 0.12 mmol, 60 mol%), **3aa** (57.5 mg, 0.2 mmol), $NaBH_4$ (18.9 mg, 0.50 mmol, 2.5 equiv.), and EtOH (1.5 mL) were successively added. The resulting solution was allowed to stir at room temperature. After 1 h, the mixture was concentrated in vacuo. The residue was extracted with EtOAc (3 × 15 mL), and the combined organic layers were washed with brine (10 mL), dried over $MgSO_4$, filtered and evaporated in vacuo. The obtained crude product was purified by column chromatography (petroleum ether/ethyl acetate = 30:1) to afford the yellow liquid **5aa** (49.7 mg, 86%).

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.61 (d, *J* = 4.8 Hz, 1H), 7.69 (td, *J* = 7.8, 1.8 Hz, 1H), 7.53 (d, *J* = 8.0 Hz, 1H), 7.28 (d, *J* = 5.1 Hz, 1H), 7.15 (dd, *J* = 7.5, 5.7 Hz, 1H), 6.98 (d, *J* = 5.1 Hz, 1H), 4.06 (t, *J* = 6.7 Hz, 2H), 3.29 – 3.22 (m, 2H), 2.71 – 2.64 (m, 2H), 1.57 (dt, *J* = 14.6, 6.8 Hz, 2H), 1.34 (h, *J* = 7.4 Hz, 2H), 0.91 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 173.2, 153.3, 149.7, 138.7, 138.3, 136.6, 130.5, 125.8, 121.9, 121.6, 64.5, 35.1, 30.7, 25.0, 19.2, 13.8.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{16}H_{20}NO_2S$ 290.1209; Found 290.1214.

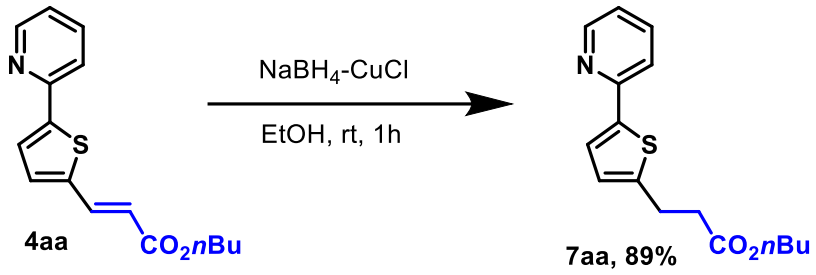


The alkenylated product **3aa** (57.5 mg, 0.2 mmol) was dissolved with 20% aqueous NaOH in MeOH (1 mL). The resulting solution was allowed to stir at room temperature. After 5 h, the mixture was concentrated in vacuo. Dilute hydrochloric acid solution was used to adjust the residue PH to 2-3. The residue was filtered out into liquid and washed three times with DCM to afford the white solid **6aa** (40.6 mg, 88%).

^{1}H NMR (600 MHz, DMSO-d_6) δ 8.69 (s, 1H), 8.05 (d, *J* = 15.9 Hz, 1H), 7.93 (t, *J* = 7.4 Hz, 1H), 7.69 (d, *J* = 5.1 Hz, 1H), 7.63 (d, *J* = 5.2 Hz, 1H), 7.59 (d, *J* = 7.8 Hz, 1H), 7.40 (s, 1H), 6.50 (d, *J* = 15.9 Hz, 1H).

^{13}C NMR (151 MHz, DMSO-d_6) δ 168.0, 151.5, 150.0, 143.6, 137.6, 136.8, 134.1, 127.6, 127.5, 123.3, 123.0, 120.9.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{12}H_{10}NO_2S$ 232.0426; Found 232.0429.

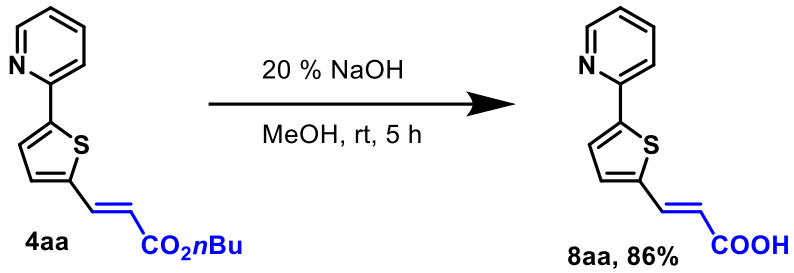


To a 15 mL oven dried Schlenk tube, CuCl (11.9 mg, 0.12 mmol, 60 mol%), **4aa** (57.5 mg, 0.2 mmol), $NaBH_4$ (18.9 mg, 0.50 mmol, 2.5 equiv.), and EtOH (1.5 mL) were successively added. The resulting solution was allowed to stir at room temperature. After 1 h, the mixture was concentrated in vacuo. The residue was extracted with EtOAc (3 × 15 mL), and the combined organic layers were washed with brine (10 mL), dried over $MgSO_4$, filtered and evaporated in vacuo. The obtained crude product was purified by column chromatography (petroleum ether/ethyl acetate = 30:1) to afford the yellow liquid **7aa** (51.4 mg, 89%).

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.51 (d, *J* = 4.7 Hz, 1H), 7.65 – 7.60 (m, 1H), 7.57 (d, *J* = 8.0 Hz, 1H), 7.37 (d, *J* = 3.7 Hz, 1H), 7.09 (dd, *J* = 6.8, 5.4 Hz, 1H), 6.81 (d, *J* = 3.6 Hz, 1H), 4.09 (t, *J* = 6.7 Hz, 2H), 3.16 (t, *J* = 7.6 Hz, 2H), 2.70 (t, *J* = 7.6 Hz, 2H), 1.59 (dt, *J* = 14.6, 6.8 Hz, 2H), 1.34 (dt, *J* = 14.7, 7.4 Hz, 2H), 0.90 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 172.5, 152.7, 149.6, 145.8, 142.9, 136.6, 125.9, 124.5, 121.7, 118.5, 64.6, 36.0, 30.7, 25.8, 19.2, 13.8.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{16}H_{20}NO_2S$ 290.1209; Found 290.1213.

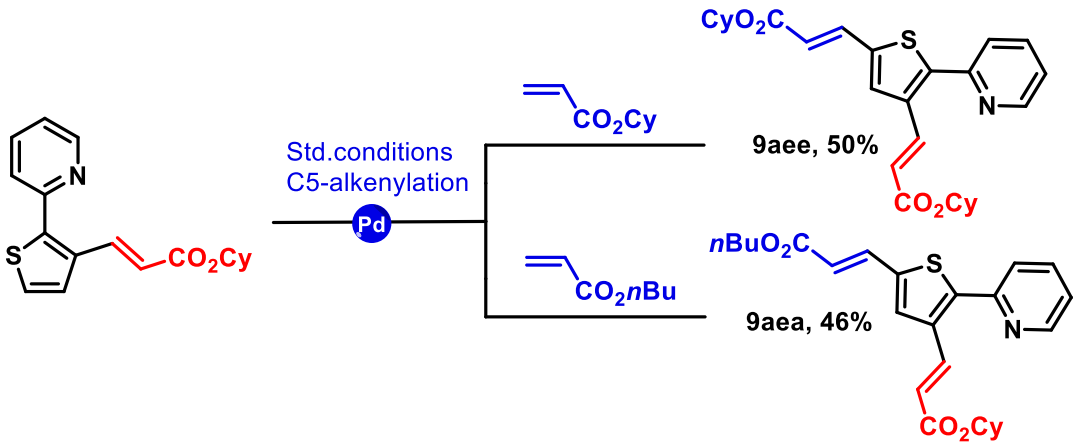


The alkenylated product **4aa** (57.5 mg, 0.2 mmol) was dissolved with 20% aqueous NaOH in MeOH (1 mL). The resulting solution was allowed to stir at room temperature. After 5 h, the mixture was concentrated in vacuo. Dilute hydrochloric acid solution was used to adjust the residue PH to 2-3. The residue was filtered out into liquid and washed three times with DCM to afford the white solid **8aa** (40.6 mg, 86%).

^{1}H NMR (600 MHz, DMSO-d_6) δ 8.56 (d, J = 4.7 Hz, 1H), 8.00 (d, J = 7.9 Hz, 1H), 7.92 (t, J = 7.7 Hz, 1H), 7.87 (s, 1H), 7.72 (d, J = 15.7 Hz, 1H), 7.55 (d, J = 3.9 Hz, 1H), 7.40 – 7.34 (m, 1H), 6.28 (d, J = 15.7 Hz, 1H).

^{13}C NMR (151 MHz, DMSO-d_6) δ 167.2, 151.0, 149.6, 147.1, 140.4, 137.3, 136.7, 132.9, 126.2, 123.1, 119.2, 118.1.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{12}H_{10}NO_2S$ 232.0426; Found 232.0430.



To a 15 mL oven dried Schlenk tube, Ag_2CO_3 (163.8 mg, 0.6 mmol, 2 equiv.), cyclohexyl (*E*)-3-(2-(pyridin-2-yl)thiophen-3-yl)acrylate (93.9 mg, 0.3 mmol, 1 equiv.), $Pd(OAc)_2$ (3.4 mg, 0.015 mmol, 5 mol%), pyridine (0.6 mmol, 2 equiv.), cyclohexyl acrylate (92.4 mg, 0.6 mmol, 2 equiv.) and $PhCF_3$ (2 mL) were successively added. The reaction mixture was stirred at 120 °C (metal sand bath temperature) for 12 hours under air. After cooling the reaction at room temperature and concentration, the crude mixture was purified by silica column chromatography to afford the red liquid **9aee** (69.8 mg, 50%).

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.69 (d, *J* = 5.3 Hz, 1H), 8.09 (d, *J* = 15.9 Hz, 1H), 7.77 (td, *J* = 7.8, 1.7 Hz, 1H), 7.71 (d, *J* = 15.7 Hz, 1H), 7.54 (d, *J* = 7.9 Hz, 1H), 7.45 (s, 1H), 7.28 (dd, *J* = 7.6, 4.0 Hz, 1H), 6.36 (d, *J* = 15.9 Hz, 1H), 6.29 (d, *J* = 15.7 Hz, 1H), 4.89 (tt, *J* = 9.2, 3.7 Hz, 2H), 1.91 (dd, *J* = 18.4, 9.3, 4H), 1.78 – 1.73 (m, 4H), 1.55 – 1.30 (m, 12H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 166.5, 165.9, 151.5, 150.2, 145.9, 139.8, 137.0, 136.8, 136.0, 134.9, 130.1, 123.5, 123.1, 121.2, 119.5, 73.1, 72.8, 31.8, 31.7, 25.50, 25.48, 23.9, 23.7.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{27}H_{32}NO_4S$ 466.2046; Found 466.2050.

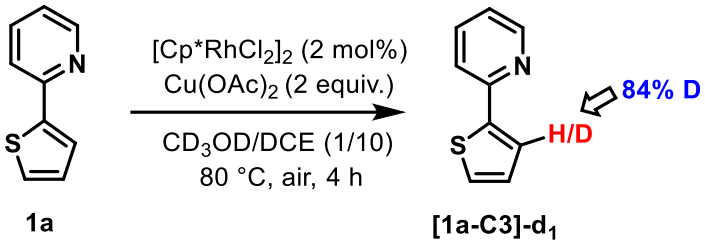
To a 15 mL oven dried Schlenk tube, Ag_2CO_3 (163.8 mg, 0.6 mmol, 2 equiv.), cyclohexyl (*E*)-3-(2-(pyridin-2-yl)thiophen-3-yl)acrylate (93.9 mg, 0.3 mmol, 1 equiv.), $Pd(OAc)_2$ (3.4 mg, 0.015 mmol, 5 mol%), pyridine (0.6 mmol, 2 equiv.), butyl acrylate (76.8 mg, 0.6 mmol, 2 equiv.) and $PhCF_3$ (2 mL) were successively added. The reaction mixture was stirred at 120 °C (metal sand bath temperature) for 12 hours under air. After cooling the reaction at room temperature and concentration, the crude mixture was purified by silica column chromatography to afford the yellow solid **9aea** (60.6 mg, 46%).

^{1}H NMR (600 MHz, $CDCl_3$) δ 8.70 (d, *J* = 4.7 Hz, 1H), 8.09 (d, *J* = 15.9 Hz, 1H), 7.78 (td, *J* = 7.8, 1.8 Hz, 1H), 7.72 (d, *J* = 15.7 Hz, 1H), 7.54 (d, *J* = 7.9 Hz, 1H), 7.46 (s, 1H), 7.28 (dd, *J* = 6.6, 5.0 Hz, 1H), 6.36 (d, *J* = 15.9 Hz, 1H), 6.30 (d, *J* = 15.7 Hz, 1H), 4.90 (tt, *J* = 8.7, 3.8 Hz, 1H), 4.21 (t, *J* = 6.7 Hz, 2H), 1.92 – 1.88 (m, 2H), 1.78 – 1.74 (m, 2H), 1.72 – 1.67 (m, 2H), 1.52 – 1.30 (m, 8H), 0.97 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (151 MHz, $CDCl_3$) δ 166.6, 166.5, 150.2, 139.7, 137.0, 136.8, 136.3, 134.9, 130.2, 123.5, 123.1, 121.2, 118.9, 72.9, 64.7, 31.7, 30.8, 25.5, 23.8, 19.3, 13.8.

HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{25}H_{30}NO_4S$ 440.1890; Found 440.1895.

3.7 Procedure for the synthesis of [1a-C3/C5]-d_1 of 2-(thiophen-2-yl)pyridine.



2-(thiophen-2-yl)pyridine **1a** (48.3 mg, 0.3 mmol), $[Cp^*RhCl_2]_2$ (3.8 mg, 0.06 mmol), $Cu(OAc)_2$ (119.8 mg, 0.6 mmol), CD_3OD (0.2 mL) and DCE (2 mL) were charged into a Schlenk tube. The mixture was then stirred at 80 °C under air for 4 h. Then, the reaction mixture was cooled to room temperature and filtered through a plug of celite. The organic phase was concentrated under reduced pressure, and the residue was purified by silica gel chromatography (petroleum ether/ethyl acetate = 10:1) to afford **[1a-C3]-d_1**. Upon analyzing the ^{1}H NMR spectra as shown in **Figure S1**, the estimated deuterium incorporation at the C3-position of the thiophen ring was 84%.

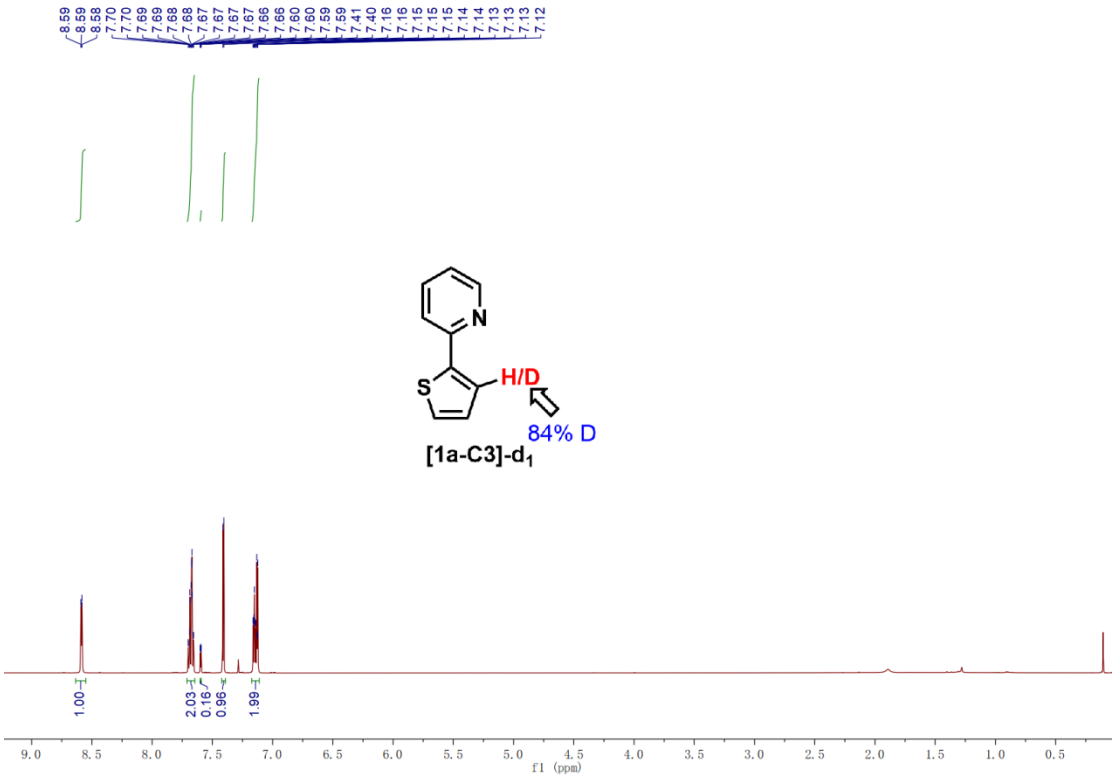
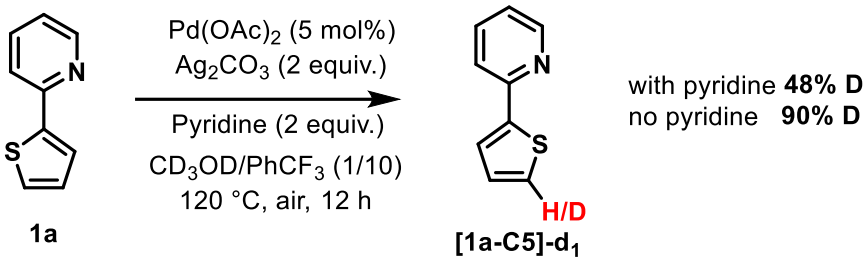


Figure S1. The ^{1}H NMR spectra of [**1a-C3]-d_1**



2-(thiophen-2-yl)pyridine **1a** (48.3 mg, 0.3 mmol), Ag_2CO_3 (163.8 mg, 0.6 mmol, 2 equiv.), $Pd(OAc)_2$ (3.4 mg, 0.015 mmol, 5 mol%), pyridine (47.5 mg, 0.6 mmol, 2 equiv.) , CD_3OD (0.2 mL) and $PhCF_3$ (2 mL) were successively added. The reaction mixture was stirred at 120 °C (metal sand bath temperature) for 12 hours under air. The organic phase was concentrated under reduced pressure, and the residue was purified by silica gel chromatography (petroleum ether/ethyl acetate = 10:1) to afford **[1a-C5]-d_1**, Upon analyzing the ^{1}H NMR spectra as shown in **Figure S2**, the estimated deuterium incorporation at the C5-position of the thiophen ring was 48%. In the absence of pyridine, the estimated deuterium incorporation at the C5-position of the thiophen ring was 90% , Upon analyzing the ^{1}H NMR spectra as shown in **Figure S3**.

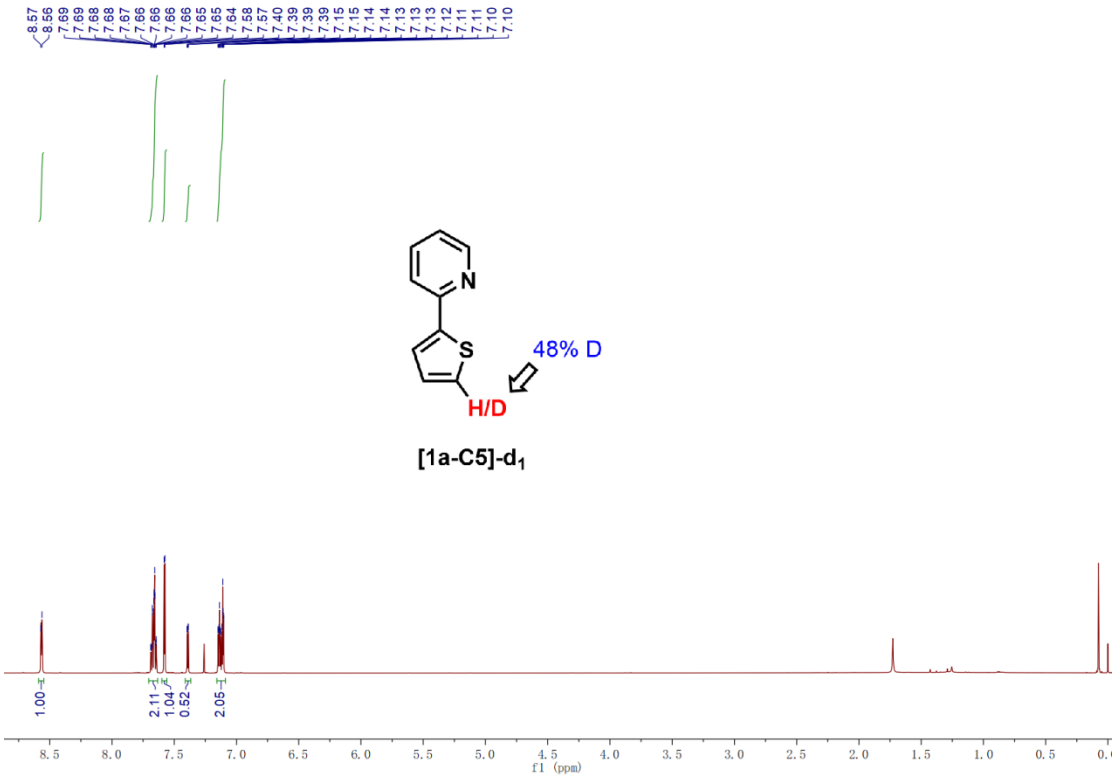


Figure S2. The ^{1}H NMR spectra of **[1a-C5]-d_1**

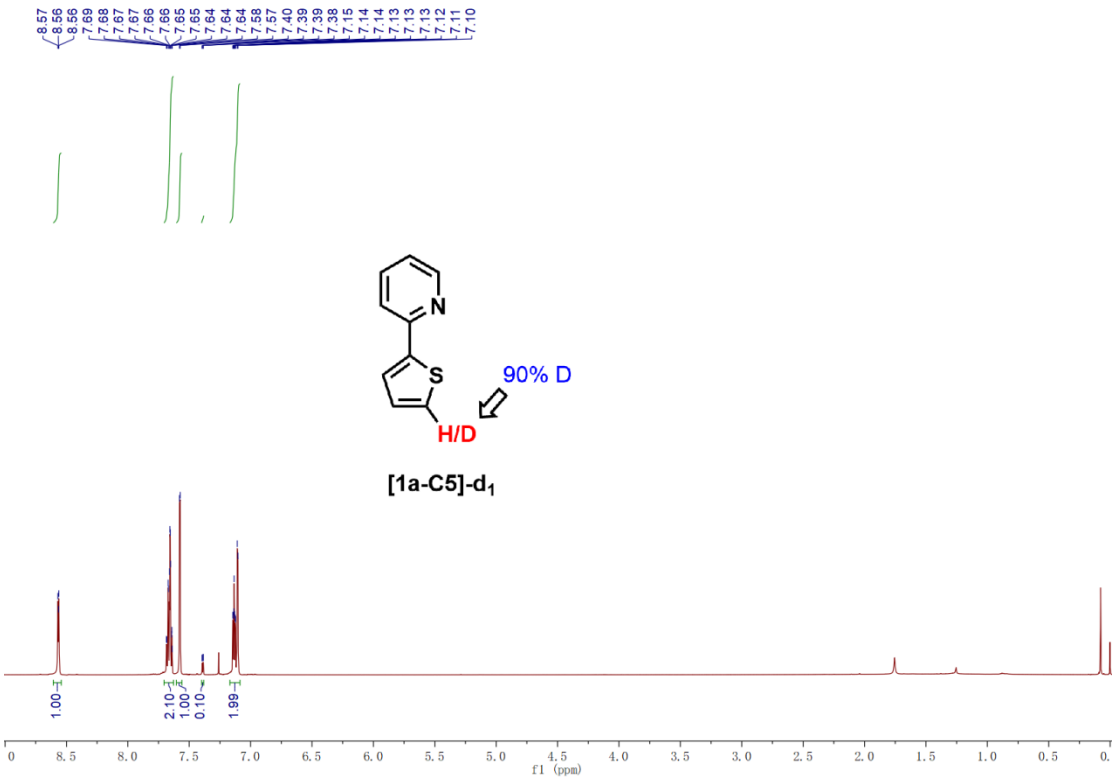
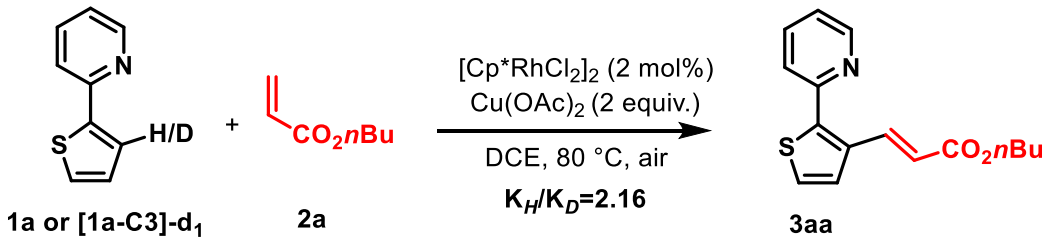


Figure S3. The ^{1}H NMR spectra of **[1a-C5]-d$_1$**

3.8 KIE Determination



1a or [1a-C3]-d$_1$ **2a** **3aa**

To a 15 mL oven dried Schlenk tube, $Cu(OAc)_2$ (0.6 mmol, 2 equiv.), **1a** or **[1a-C3]-d$_1$** (0.3 mmol, 1 equiv.), $[Cp^*RhCl_2]_2$ (3.8 mg, 0.006 mmol, 2 mol%), butyl acrylate (0.6 mmol, 2 equiv.), and DCE (2 mL) were successively added. The reaction mixture was stirred at 80 °C (metal sand bath temperature) for 4 hours under air. After cooling the reaction at room temperature and concentration, the yield was determined by ^{1}H NMR analysis of crude product using dibromomethane as the internal standard. For **1a**, y=29.04+0.712x, R^2=0.9964; For **[1a-C3]-d$_1$**, y=20.545+0.329x, R^2=0.9747; KIE value (2.16) was determined by comparing the relative initial rates.

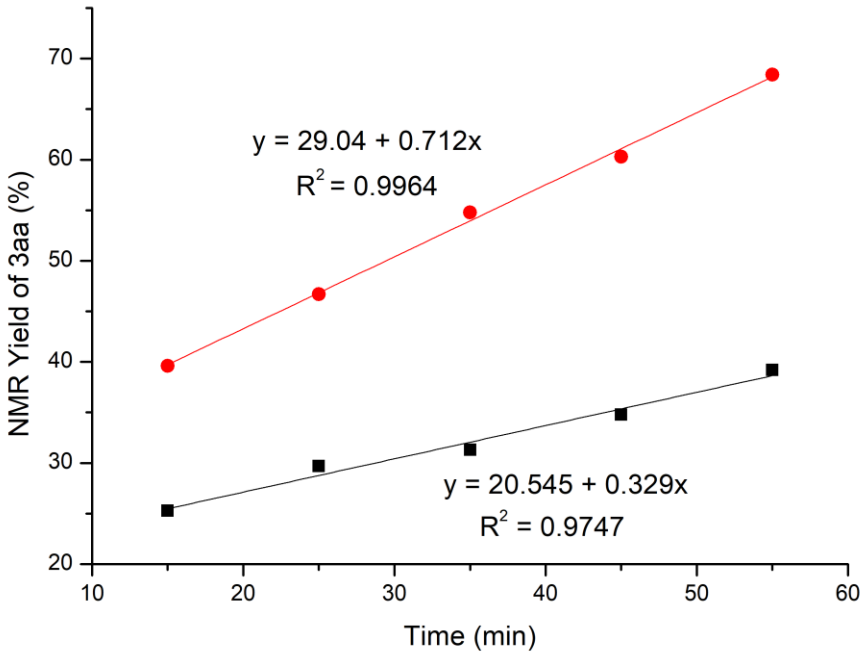
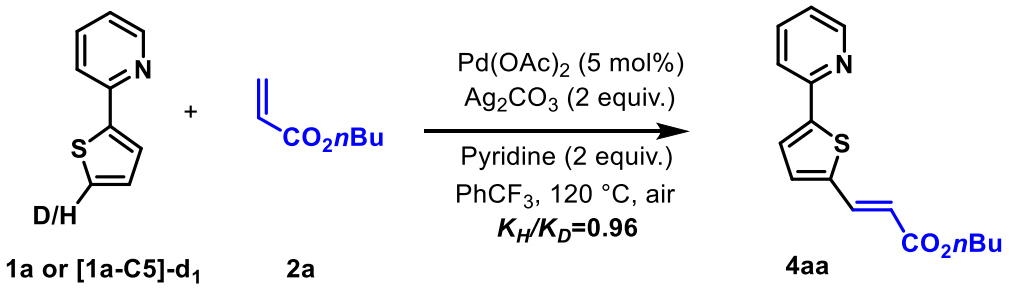


Chart S1. Kinetic profile of the reaction yield of **3aa** from **1a** (red line) and yield of **3aa** from **[1a-C3]-d_1** (black line)



1a or [1a-C5]-d_1 **2a** **4aa**

To a 15 mL oven dried Schlenk tube, Ag_2CO_3 (0.6 mmol, 2 equiv.), **1a** or **[1a-C5]-d_1** (0.3 mmol, 1 equiv.), $Pd(OAc)_2$ (3.4 mg, 0.015 mmol, 5 mol%), pyridine (0.6 mmol, 2 equiv.), butyl acrylate (0.6 mmol, 2 equiv.) and $PhCF_3$ (2 mL) were successively added. The reaction mixture was stirred at 120 °C (metal sand bath temperature) for 12 hours under air. After cooling the reaction at room temperature and concentration, the yield was determined by ^1H NMR analysis of crude product using dibromomethane as the internal standard. For **1a**, y=10.5+8.83x, R^2=0.9979; For **[1a-C5]-d_1**, y=1.05+9.16x, R^2=0.9989; KIE value (0.96) was determined by comparing the relative initial rates.

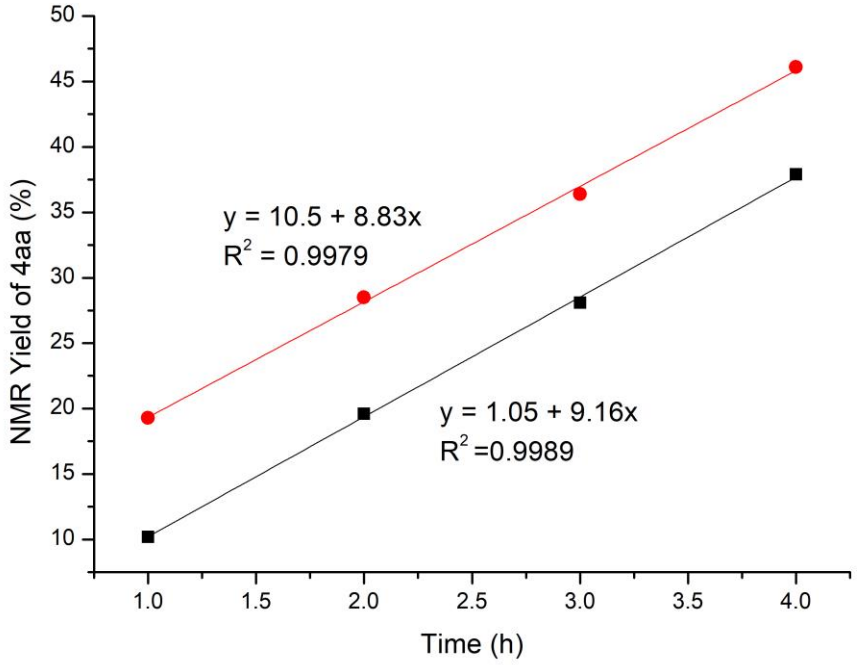


Chart S2. Kinetic profile of the reaction yield of **4aa** from **1a** (red line) and yield of **4aa** from **[1a-C5]-d_1** (black line)

3.9 Proposed Mechanism

On the basis of the aforementioned studies and previous research, we proposed two catalytic cycles for C3-alkenylation *via* chelation assisted rhodation and C5-alkenylation *via* electrophilic palladation (**Figure S4**). During the first step in the C3-alkenylation[3], the coordination of **1a** with Cp*Rh(III) center followed by C–H bond cleavage furnishes a five-membered rhodacycle intermediate **I**. Then, regioselective incorporation of **2a** into the Rh–C bond delivers a seven-membered rhodacycle **II**, which undergoes *β*-hydride elimination to afford the stereoselective alkenylation product **3aa** and regenerates the active Cp*Rh(III) species by the $Cu(OAc)_2$-oxidation to complete the catalytic cycle. In the C5-alkenylation[4], the intermediate **III** is formed first through electrophilic substitution using **1a** and $Pd(OAc)_2$ in the presence of pyridine ligand. Thereafter, migratory insertion of **2a** affords the intermediate **IV** and subsequent *β*-hydride elimination leads to the generation of the expected product **4aa,** along with the hydride palladium species that can be straightway reduced to Pd^0. Finally, the active Pd^0 species is oxidized by Ag_2CO_3 to regenerate Pd^{II}.

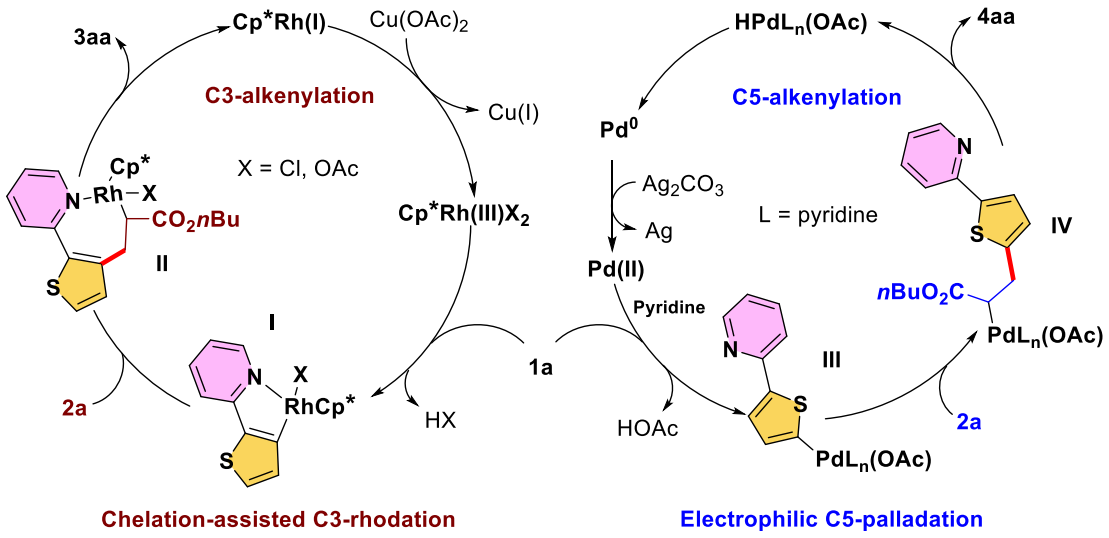


Figure S4. Proposed Catalytic Pathways

4. Crystallographic Description

White block-like single crystals of **4ja** were grown by layering a dichlormethane solution with hexane at ambient temperature. X-Ray diffraction data of one these crystals were collected on a R-AXIS SPIDER diffractometer. The measurements were performed with Mo-Kα radiation (λ = 0.71073 Å). Data were collected at 298(2) K, using the *ω*- and *φ*- scans to a maximum θ value of 28.327°. The data were refined by full-matrix least-squares techniques on F^2 with SHELXL-2018/3. And the structures were solved by direct methods SHELXL-2018/3. All the non-hydrogen atoms were refined anisotropically. The hydrogen atoms were included at geometrically idealized positions. And an ORTEP representation of the structure is shown below.

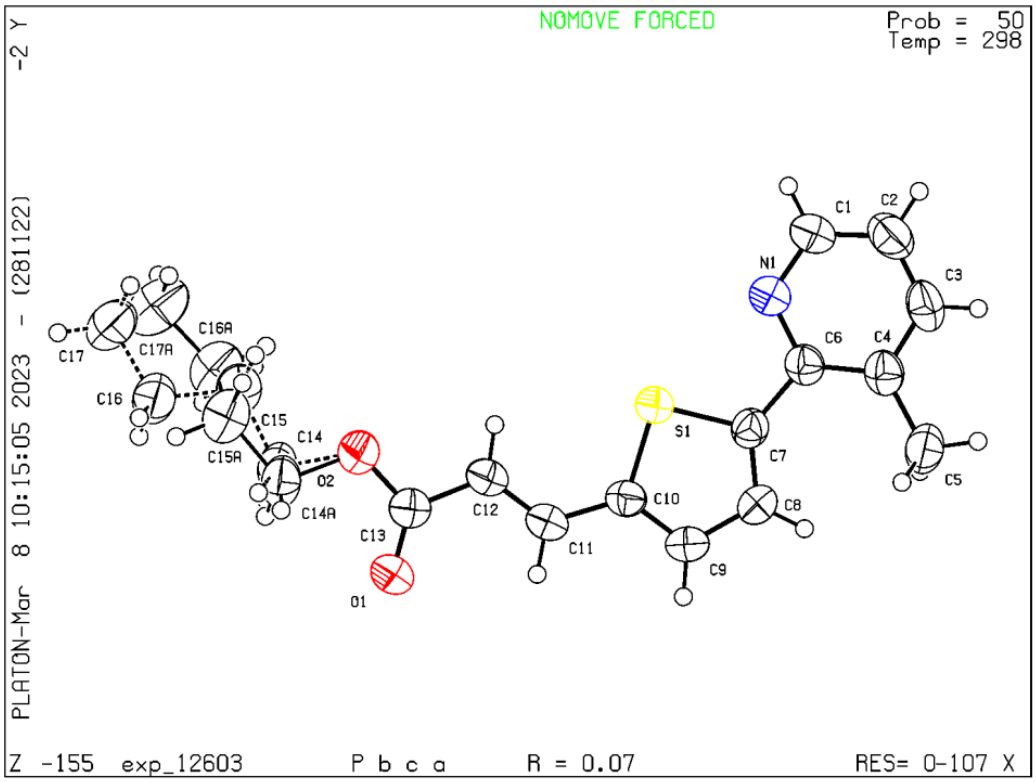


Figure S5. ORTEP diagram of **4ja** with the thermal ellipsoids set at 50% probability.

Table 1. Crystal data and structure refinement for **4ja.**

Identification code	exp_12603
Empirical formula	$C_{17}H_{19}NO_2S$
Formula weight	301.39
Temperature/K	298(2)
Crystal system	orthorhombic
Space group	Pbca
a/Å	14.4622(13)
b/Å	7.9861(9)
c/Å	27.635(2)
α/°	90

β/°	90
γ/°	90
Volume/Å^3	3191.7(5)
Z	8
ρ_{calc}g/cm^3	1.254
μ/mm^{-1}	0.207
F(000)	1280.0
Crystal size/mm^3	0.030 × 0.020 × 0.010
Radiation	MoKα (λ = 0.71073)
2Θ range for data collection/°	4.076 to 58.95
Index ranges	-19 ≤ h ≤ 19, -10 ≤ k ≤ 10, -37 ≤ l ≤ 36
Reflections collected	25609
Independent reflections	4019 [R_{int} = 0.0781, R_{sigma} = 0.0543]
Data/restraints/parameters	4019/37/230
Goodness-of-fit on F^2	1.087
Final R indexes [I>=2σ (I)]	R_1 = 0.0730, wR_2 = 0.1413
Final R indexes [all data]	R_1 = 0.1215, wR_2 = 0.1606
Largest diff. peak/hole / e Å^{-3}	0.19/-0.20

Table 2. Fractional Atomic Coordinates (×10^4) and Equivalent Isotropic Displacement Parameters (Å^2×10^3) for **4ja**. U_{eq} is defined as 1/3 of of the trace of the orthogonalised U_{IJ} tensor.

Atom	***x***	***y***	***z***	**U(eq)**
S1	4330.8(5)	7236.7(10)	6707.4(2)	55.3(2)
O2	7298.3(14)	6658(3)	5636.3(7)	74.4(6)
O1	6303.7(15)	5779(4)	5082.6(7)	93.2(8)
N1	3639.8(16)	8142(3)	7603.6(8)	60.5(6)
C7	3175.3(17)	7090(3)	6852.7(9)	48.0(6)
C6	2907.5(18)	7760(3)	7325.8(9)	48.9(6)
C4	1998.1(19)	8052(3)	7477.3(9)	53.4(7)
C10	4159.3(18)	6344(4)	6148.9(9)	50.8(6)
C11	4895(2)	6120(4)	5803.9(9)	55.0(7)
C13	6452(2)	6278(4)	5483.4(10)	61.8(8)
C9	3261(2)	5927(4)	6088.7(10)	61.8(8)
C8	2703.0(19)	6348(4)	6484.7(10)	62.8(8)
C12	5774(2)	6522(4)	5865.1(10)	59.0(8)
C3	1895(2)	8745(4)	7931.4(10)	66.6(8)
C5	1165.4(19)	7659(5)	7175.9(11)	72.2(9)
C1	3496(2)	8792(4)	8036.7(10)	72.0(9)
C2	2631(2)	9112(4)	8215.4(11)	74.1(9)

C14	8109(6)	6260(30)	5351(4)	69(4)
C15	8932(5)	6450(12)	5691(3)	67(2)
C17	10651(6)	6276(16)	5727(3)	85(3)
C16	9804(4)	6246(10)	5412(2)	76(2)
C15A	8919(5)	7018(11)	5442(3)	79(2)
C16A	9282(6)	5857(12)	5799(3)	86(3)
C17A	10252(7)	6261(16)	5968(4)	108(4)
C14A	7983(6)	6630(30)	5243(4)	76(4)

Table 3. Anisotropic Displacement Parameters ($Å^2 \times 10^3$) for **4ja**. The Anisotropic displacement factor exponent takes the form: $-2\pi^2[h^2a^{*2}U_{11}+2hka^*b^*U_{12}+\ldots]$.

Atom	**U_{11}**	**U_{22}**	**U_{33}**	**U_{23}**	**U_{13}**	**U_{12}**
S1	46.9(4)	72.0(5)	47.0(4)	-10.8(3)	1.5(3)	-6.4(3)
O2	54.3(13)	97.0(18)	71.9(13)	-23.8(12)	3.7(10)	-7.2(11)
O1	65.1(14)	162(3)	52.5(12)	-32.0(14)	6.0(11)	-11.9(15)
N1	55.8(15)	76.0(18)	49.6(13)	-8.1(11)	0.5(11)	-1.4(12)
C7	42.5(14)	53.6(16)	47.8(14)	6.0(12)	-0.6(11)	3.6(12)
C6	51.6(15)	50.1(16)	45.1(14)	8.0(12)	2.4(11)	1.7(12)
C4	54.7(16)	53.1(17)	52.3(15)	12.8(12)	7.3(13)	2.1(13)
C10	52.9(16)	57.6(17)	41.8(14)	-2.6(12)	-4.2(12)	1.7(13)
C11	60.3(18)	64.4(19)	40.3(14)	-6.2(12)	-0.9(12)	-0.4(14)
C13	55.6(18)	77(2)	52.7(17)	-8.2(14)	0.0(14)	-6.0(15)
C9	55.8(17)	81(2)	48.8(15)	-13.5(14)	-10.1(13)	-0.9(15)
C8	42.8(16)	88(2)	57.4(16)	-7.4(15)	-6.1(13)	0.4(14)
C12	59.7(18)	71(2)	45.8(15)	-13.4(13)	1.2(13)	-5.1(15)
C3	63(2)	77(2)	59.6(18)	8.8(15)	21.8(15)	4.8(16)
C5	46.7(16)	97(3)	72.5(19)	8.3(17)	6.1(15)	4.8(16)
C1	70(2)	97(3)	48.9(17)	-13.8(16)	0.2(15)	-5.9(18)
C2	83(2)	85(2)	54.2(17)	-8.1(16)	15.0(17)	-5.4(19)
C14	47(5)	85(9)	74(6)	7(6)	5(4)	6(5)
C15	66(5)	68(6)	67(6)	19(4)	1(4)	13(4)
C17	64(5)	99(7)	92(6)	10(6)	-13(4)	-7(5)
C16	57(4)	95(5)	77(5)	8(4)	4(3)	0(4)
C15A	66(5)	75(6)	94(6)	8(4)	1(4)	-1(4)
C16A	84(6)	76(6)	98(6)	19(4)	-3(5)	-8(4)
C17A	91(7)	101(7)	130(9)	23(7)	-30(6)	-12(6)
C14A	52(5)	89(9)	87(7)	-6(6)	11(4)	5(5)

Table 4. Bond Lengths for **4ja.**

Atom	Atom	Length/Å	Atom	Atom	Length/Å
S1	C10	1.718(3)	C10	C9	1.352(4)
S1	C7	1.723(3)	C10	C11	1.440(4)
O2	C13	1.330(3)	C11	C12	1.321(4)
O2	C14	1.448(11)	C13	C12	1.454(4)
O2	C14A	1.471(11)	C9	C8	1.400(4)
O1	C13	1.196(3)	C3	C2	1.356(4)
N1	C1	1.321(3)	C1	C2	1.368(4)
N1	C6	1.343(3)	C14	C15	1.522(11)
C7	C8	1.361(4)	C15	C16	1.487(9)
C7	C6	1.465(4)	C17	C16	1.502(9)
C6	C4	1.400(3)	C15A	C16A	1.453(10)
C4	C3	1.380(4)	C15A	C14A	1.493(11)
C4	C5	1.497(4)	C16A	C17A	1.513(10)

Table 5. Bond Angles for **4ja.**

Atom	Atom	Atom	Angle/˚	Atom	Atom	Atom	Angle/˚
C10	S1	C7	92.35(13)	C12	C11	C10	126.6(2)
C13	O2	C14	121.5(6)	O1	C13	O2	122.3(3)
C13	O2	C14A	112.4(5)	O1	C13	C12	126.6(3)
C1	N1	C6	118.9(3)	O2	C13	C12	111.1(2)
C8	C7	C6	133.9(2)	C10	C9	C8	113.5(2)
C8	C7	S1	110.0(2)	C7	C8	C9	113.5(3)
C6	C7	S1	116.09(19)	C11	C12	C13	121.6(3)
N1	C6	C4	122.2(2)	C2	C3	C4	121.9(3)
N1	C6	C7	112.6(2)	N1	C1	C2	123.0(3)
C4	C6	C7	125.2(2)	C3	C2	C1	118.0(3)
C3	C4	C6	116.1(3)	O2	C14	C15	106.0(8)
C3	C4	C5	120.2(3)	C16	C15	C14	109.5(7)
C6	C4	C5	123.7(2)	C15	C16	C17	113.0(6)
C9	C10	C11	126.8(2)	C16A	C15A	C14A	116.5(9)
C9	C10	S1	110.6(2)	C15A	C16A	C17A	114.0(8)
C11	C10	S1	122.7(2)	O2	C14A	C15A	109.6(9)

Table 6. Hydrogen Atom Coordinates (Å×10^4) and Isotropic Displacement Parameters (Å^2×10^3) for **4ja.**

Atom	*x*	*y*	*z*	U(eq)
H11	4736.02	5644.08	5508.2	66
H9	3034.89	5410.76	5811.22	74
H8	2070.57	6139.68	6495.26	75
H12	5962.44	6972.19	6159.33	71
H3	1302.53	8966.52	8045.87	80
H5A	1226.05	8183.08	6864.85	108
H5B	621.08	8074.3	7334.52	108
H5C	1115.14	6468.99	7135.17	108
H1	4005.45	9043.99	8228.85	86
H2	2551.74	9566.84	8522.38	89
H14A	8164.28	7014.77	5078.7	82
H14B	8072.16	5118.9	5230.03	82
H15A	8917.27	7547.08	5840.75	80
H15B	8900.09	5611.99	5944.16	80
H17A	11193.91	6286.65	5526.99	127
H17B	10658.63	5299.36	5929.4	127
H17C	10642.33	7262.1	5925.77	127
H16A	9848.83	7138.38	5175.29	92
H16B	9784.09	5191.69	5238.53	92
H15C	9351.73	7065.06	5173.69	94
H15D	8899.16	8123.99	5586.09	94
H16C	9277.78	4737.71	5663.03	103
H16D	8873.06	5854.55	6077.85	103
H17D	10675.19	6126.97	5703.03	161
H17E	10421.68	5517.12	6225.67	161
H17F	10274.15	7396.65	6081.36	161
H14C	7818.77	7457.5	4999.56	91
H14D	7988.37	5539.18	5090.39	91

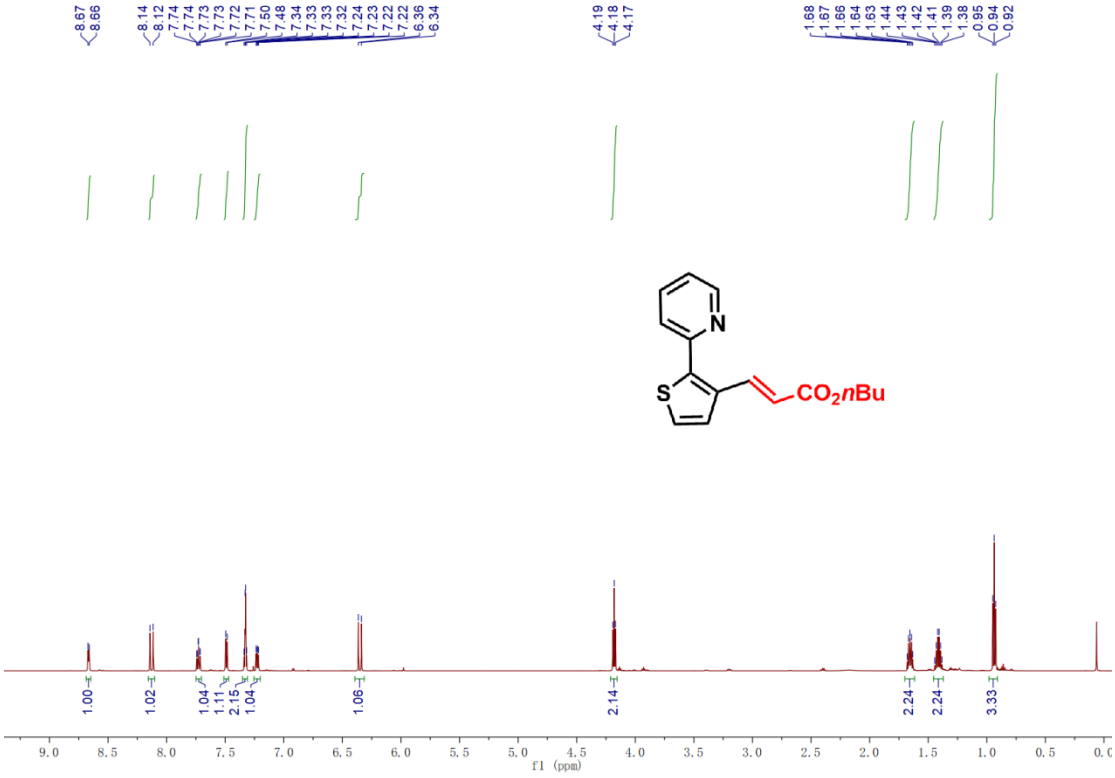
Table 7. Atomic Occupancy for **4ja.**

Atom	*Occupancy*	Atom	*Occupancy*	Atom	*Occupancy*
C14	0.491(7)	H14A	0.491(7)	H14B	0.491(7)
C15	0.491(7)	H15A	0.491(7)	H15B	0.491(7)
C17	0.491(7)	H17A	0.491(7)	H17B	0.491(7)
H17C	0.491(7)	C16	0.491(7)	H16A	0.491(7)
H16B	0.491(7)	C15A	0.509(7)	H15C	0.509(7)
H15D	0.509(7)	C16A	0.509(7)	H16C	0.509(7)
H16D	0.509(7)	C17A	0.509(7)	H17D	0.509(7)

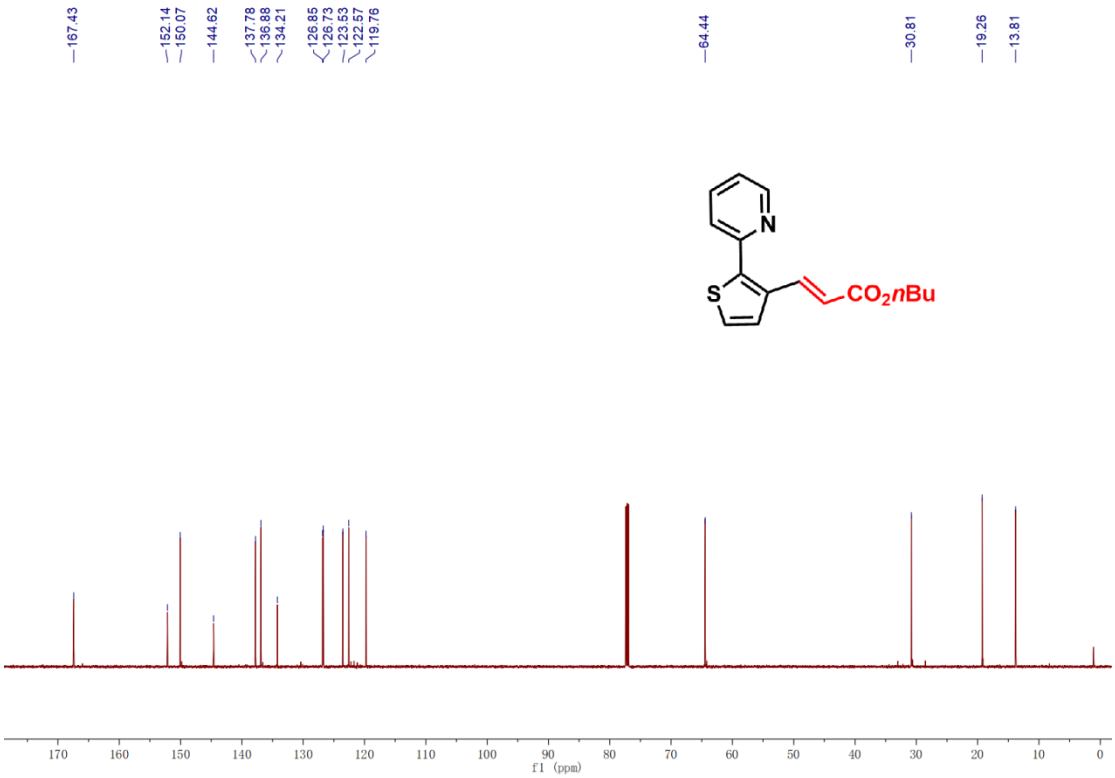
H17E	0.509(7)	H17F	0.509(7)	C14A	0.509(7)
H14C	0.509(7)	H14D	0.509(7)		

5. NMR Charts

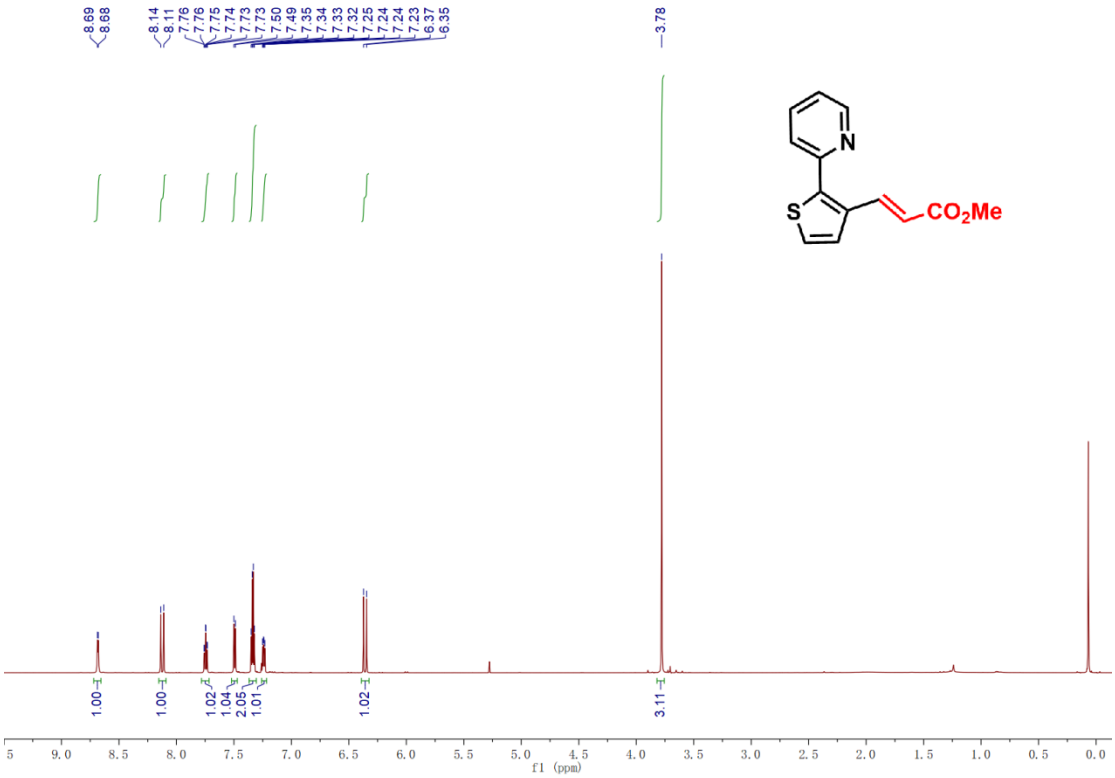
3aa | ^{1}H NMR ($CDCl_3$, 600 MHz)



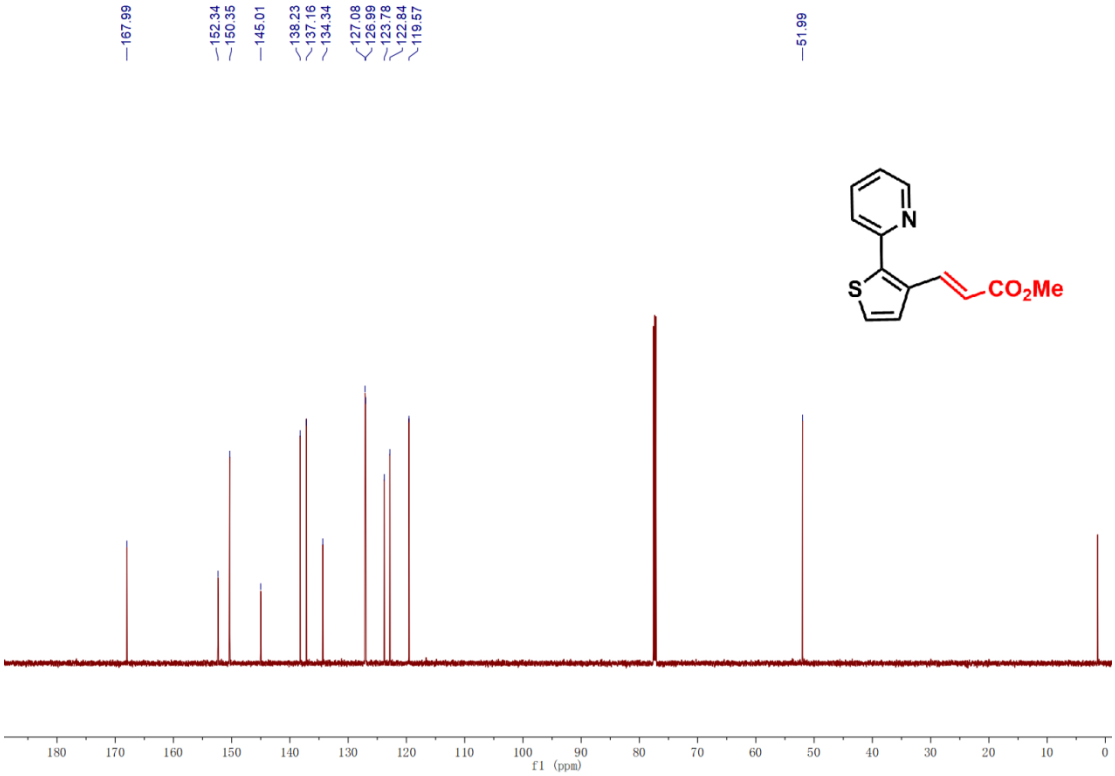
3aa | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



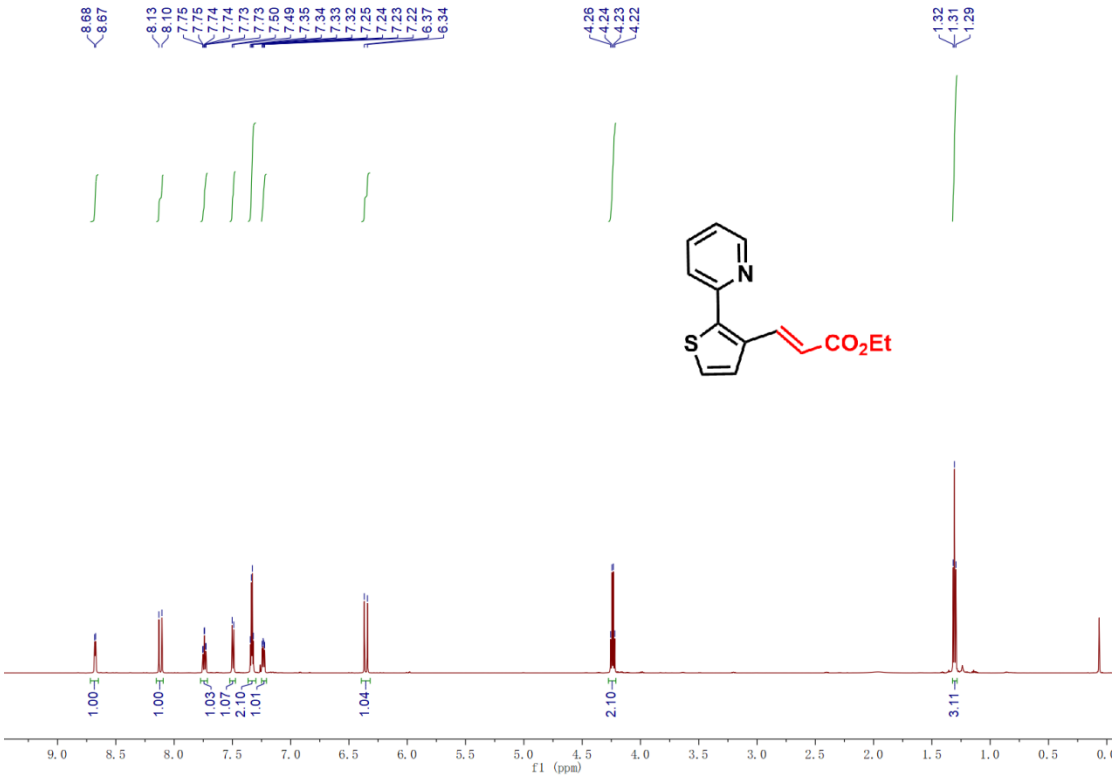
3ab | ^{1}H NMR ($CDCl_3$, 600 MHz)



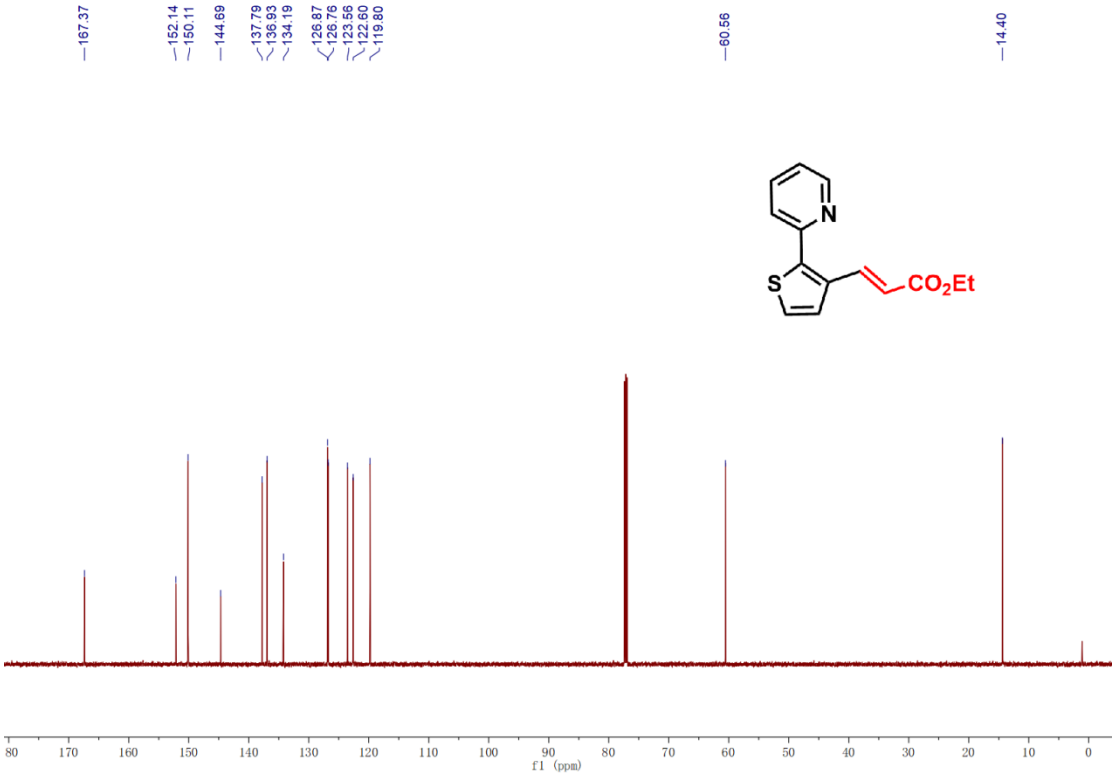
3ab | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



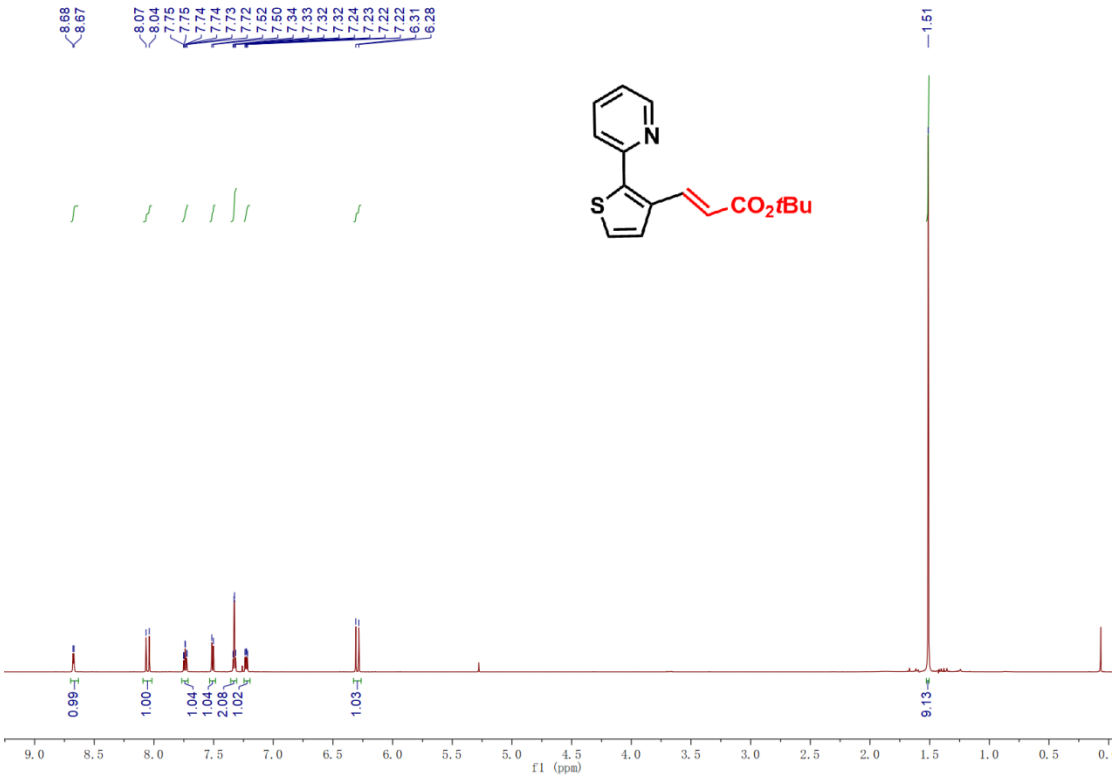
3ac | ^{1}H NMR ($CDCl_3$, 600 MHz)



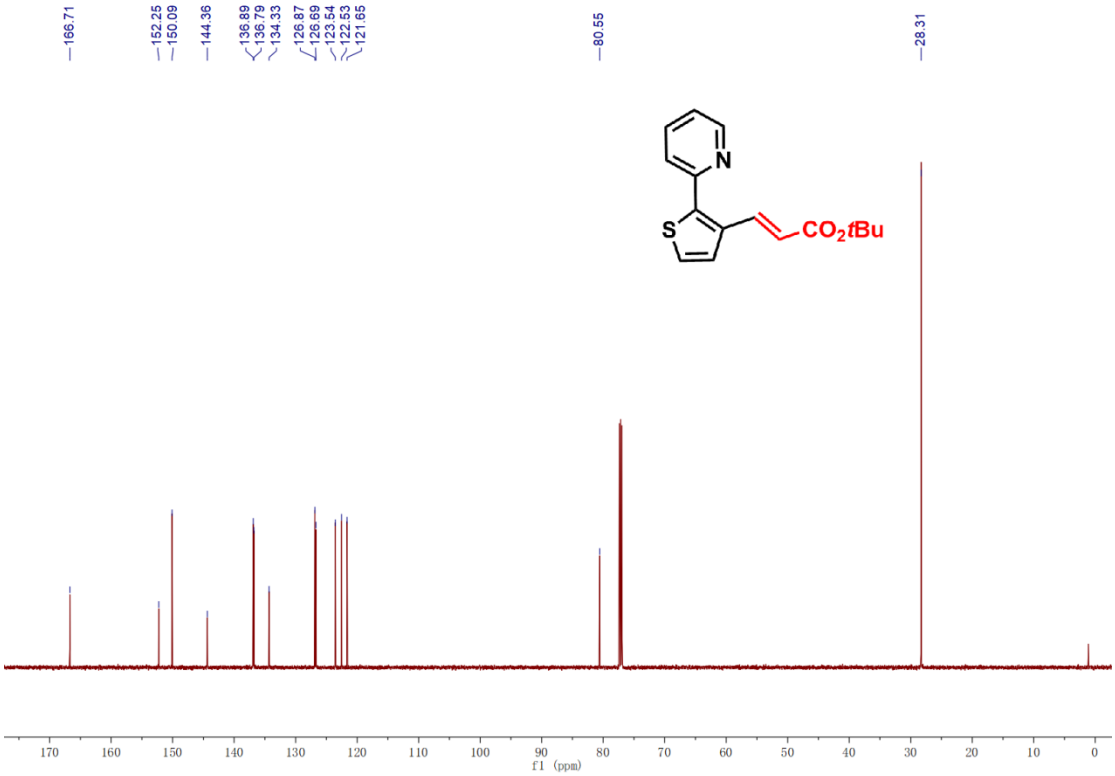
3ac | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



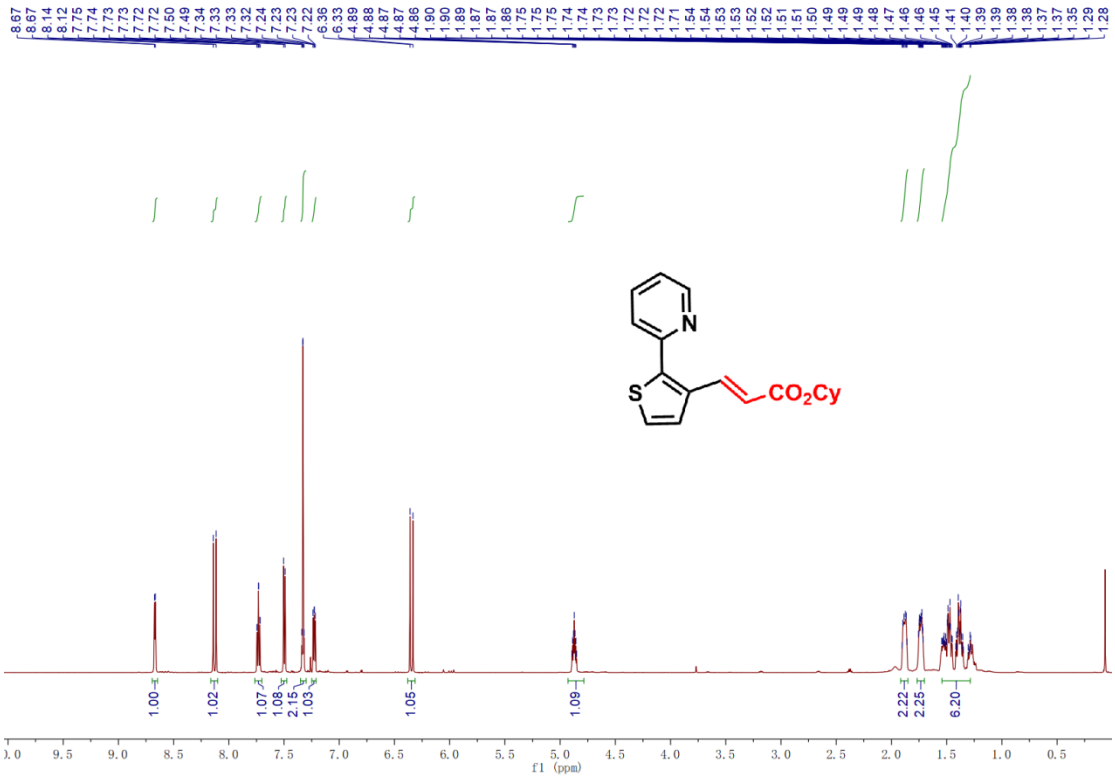
3ad | ^{1}H NMR ($CDCl_3$, 600 MHz)



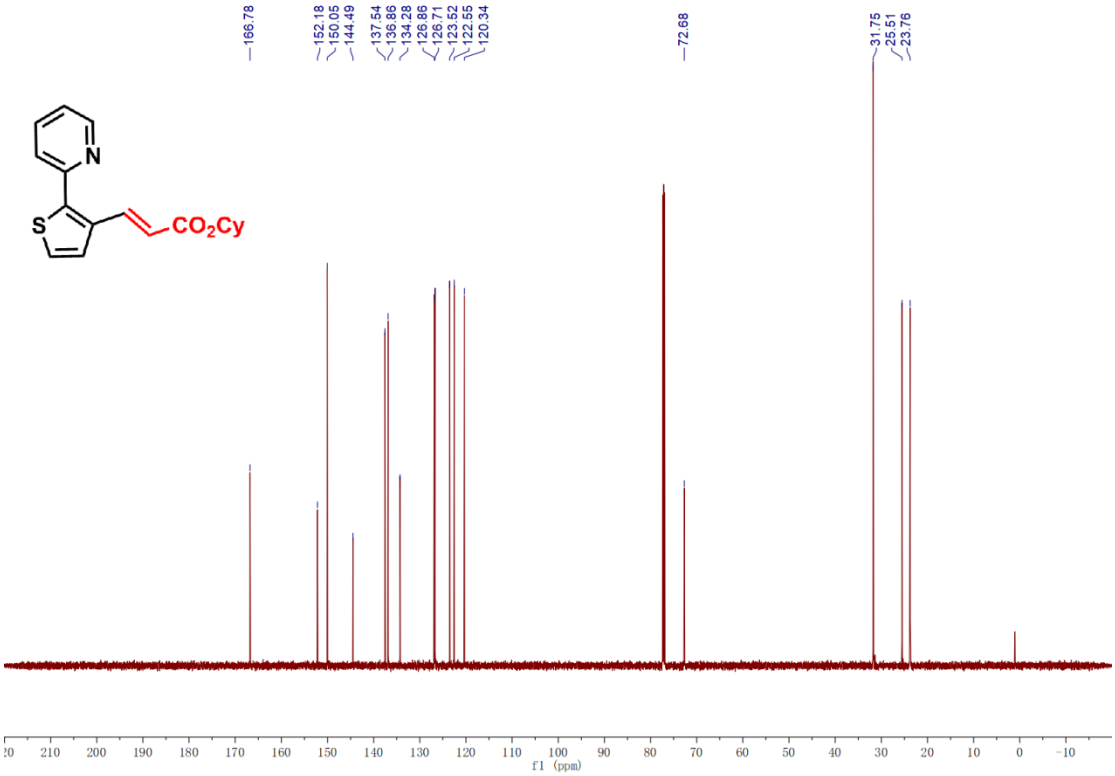
3ad | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



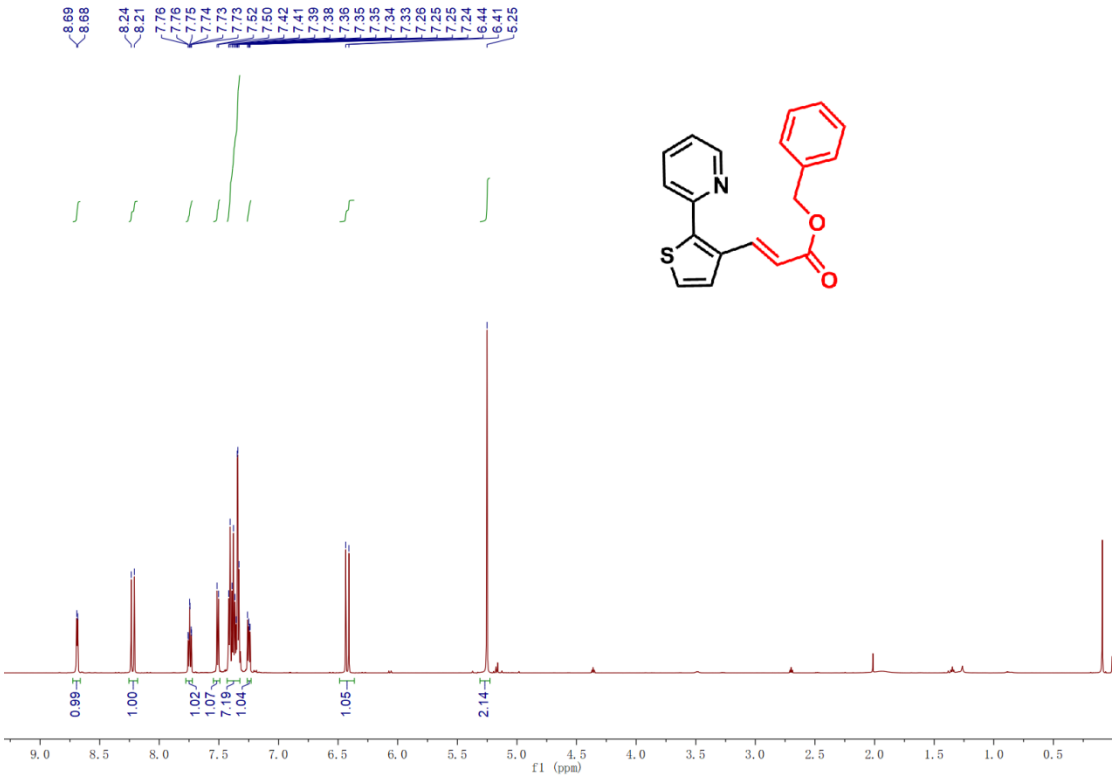
3ae | ^{1}H NMR ($CDCl_3$, 600 MHz)



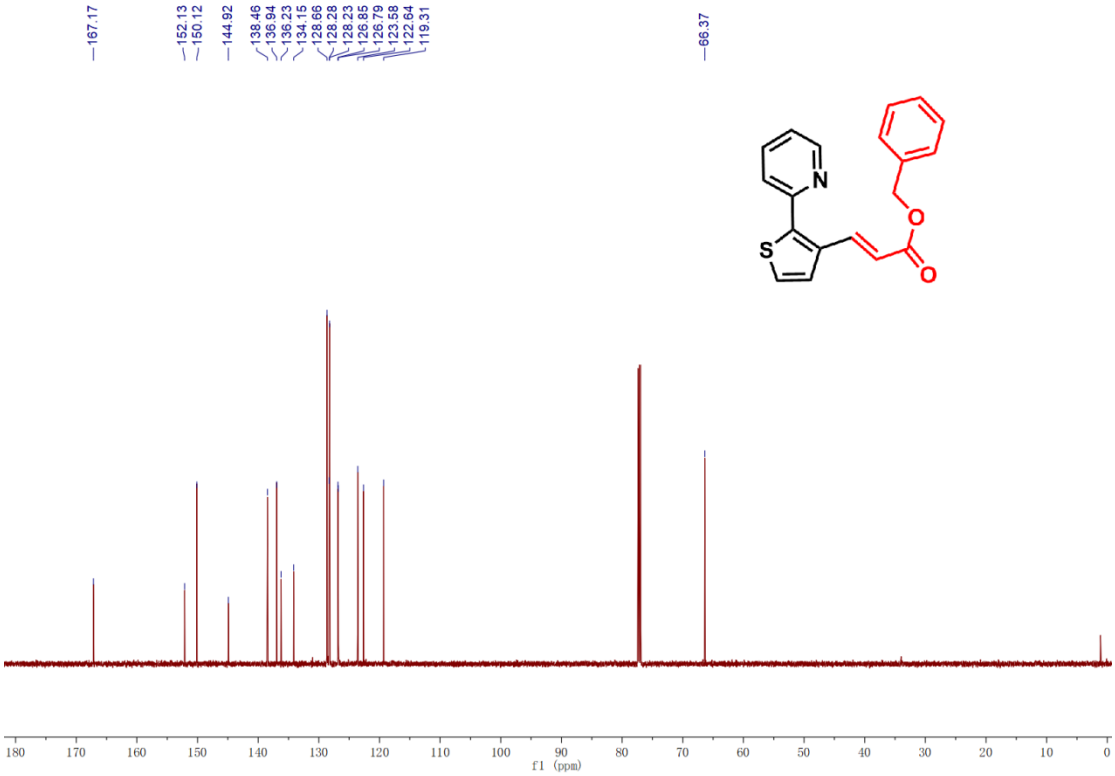
3ae | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



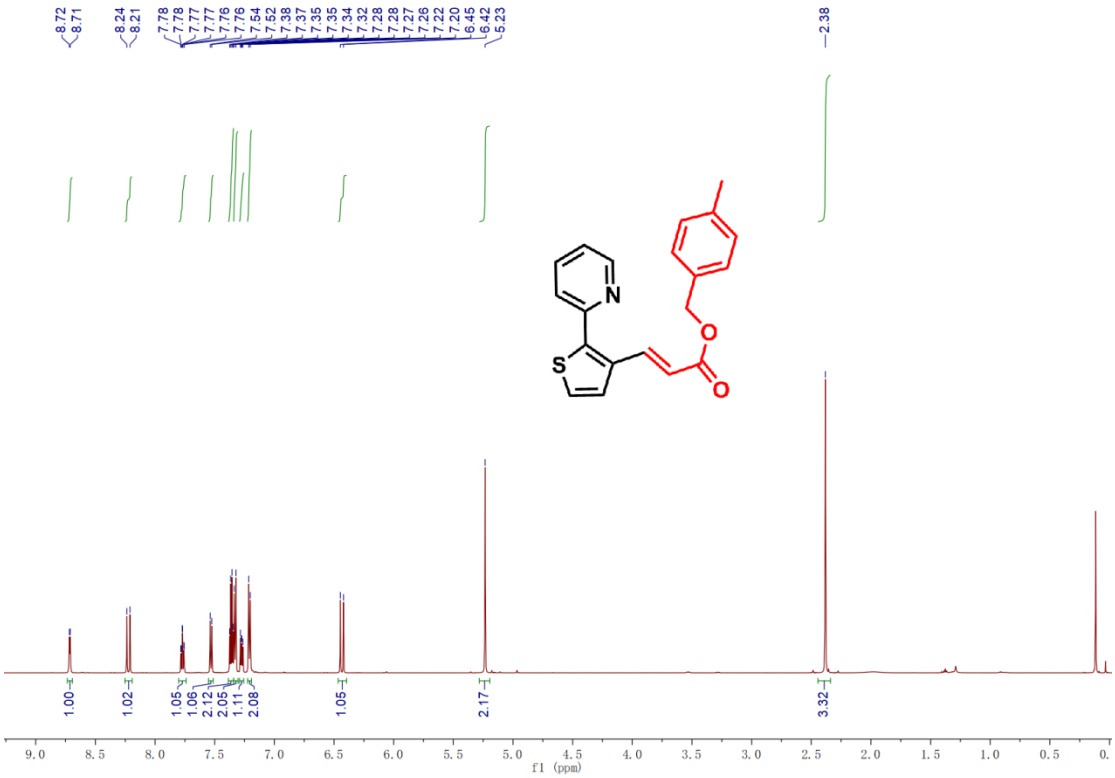
3af | ^{1}H NMR ($CDCl_3$, 600 MHz)



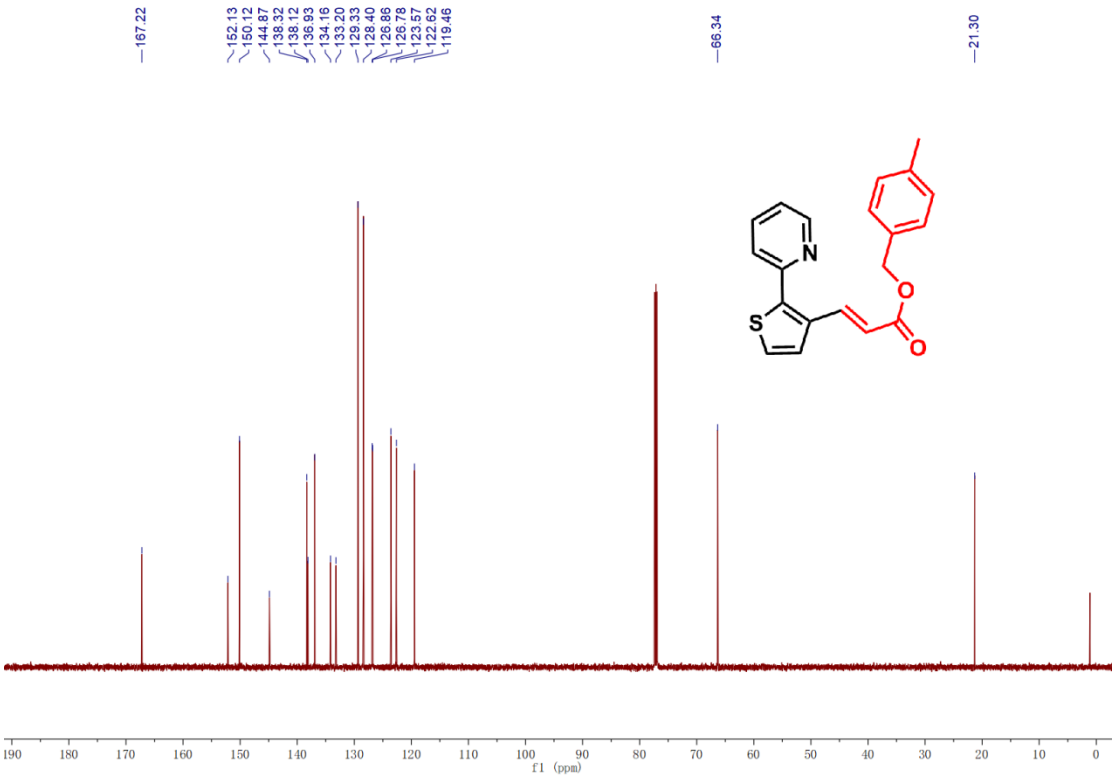
3af | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



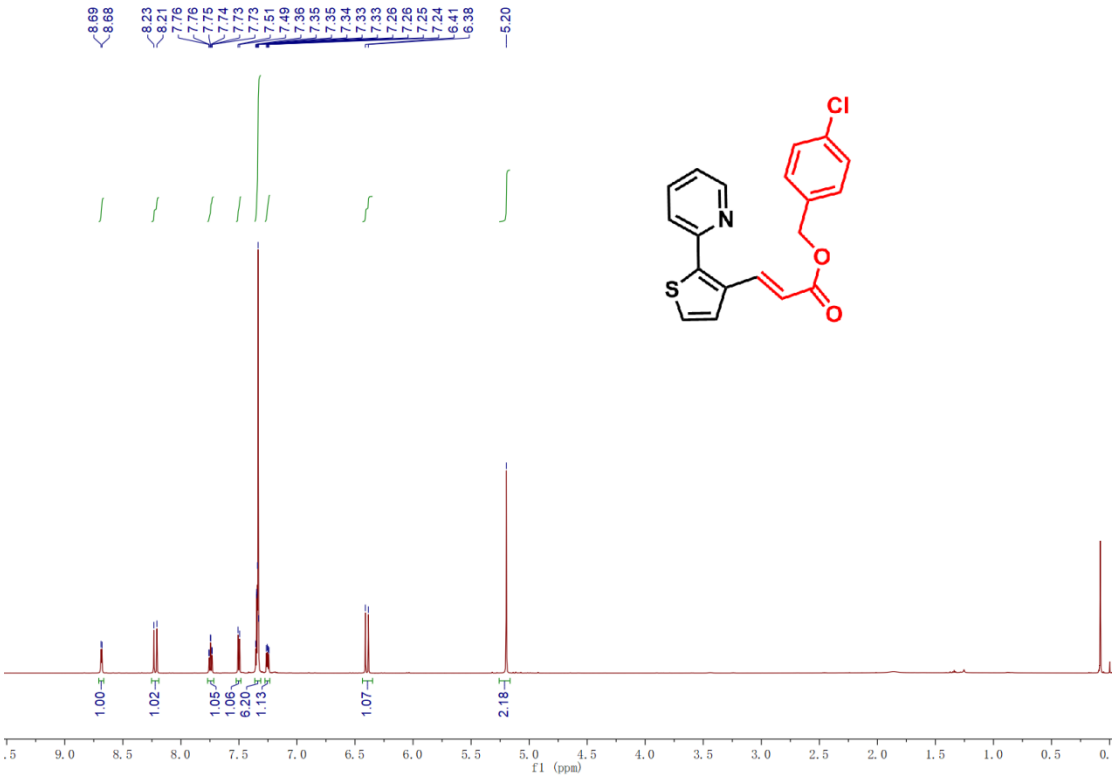
3ag | ^{1}H NMR ($CDCl_3$, 600 MHz)



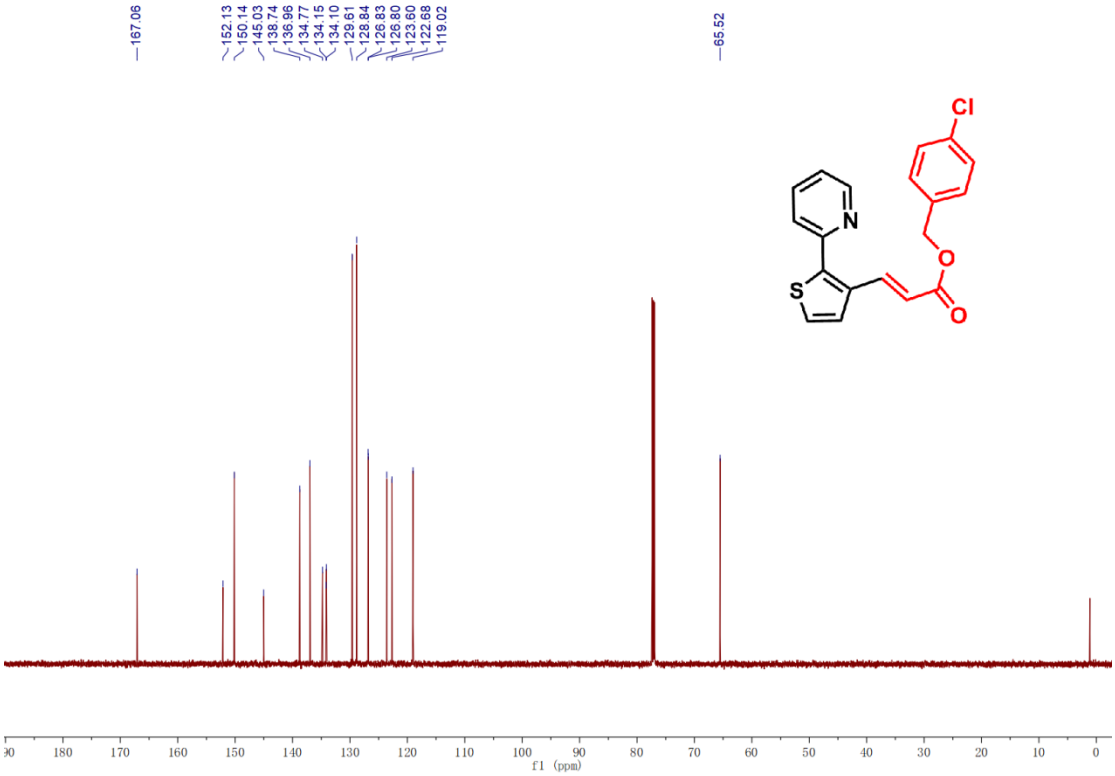
3ag | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



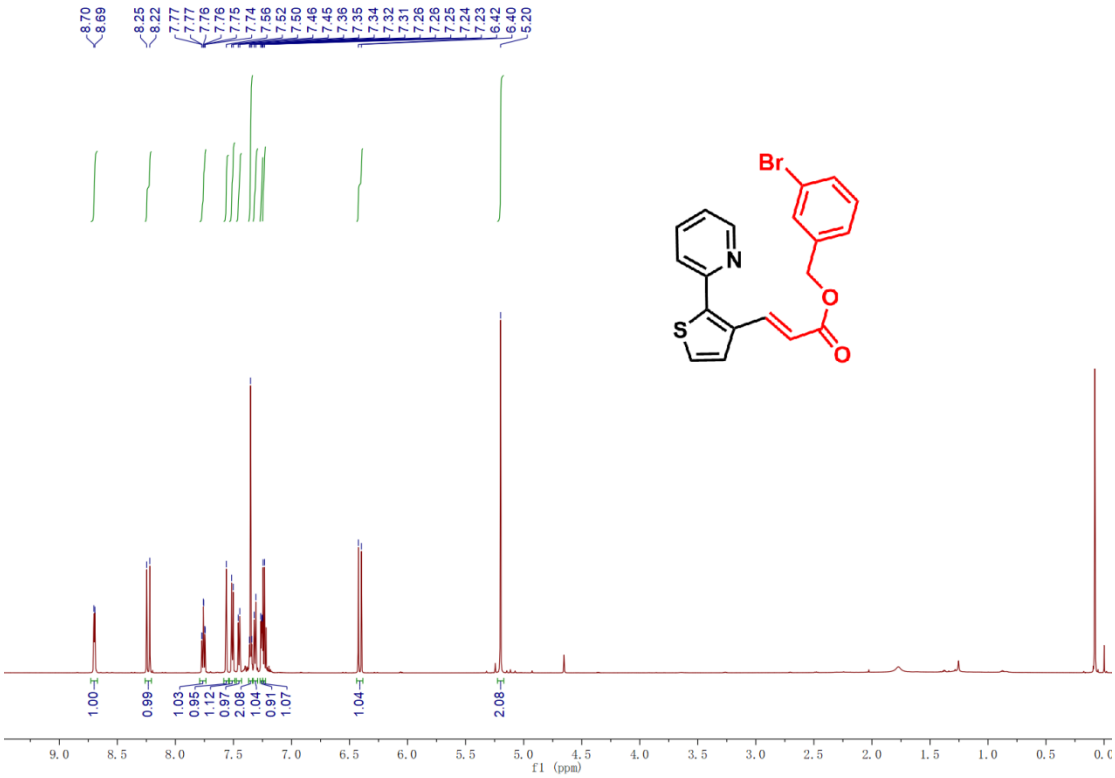
3ah | ^{1}H NMR ($CDCl_3$, 600 MHz)



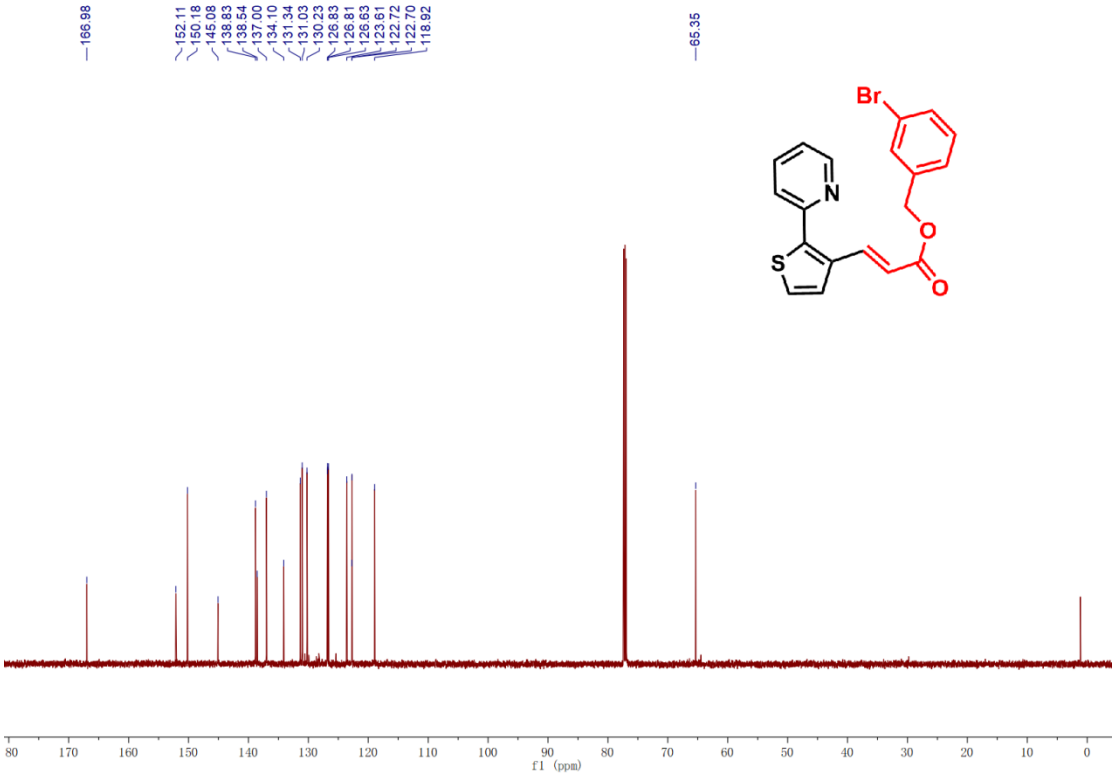
3ah | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



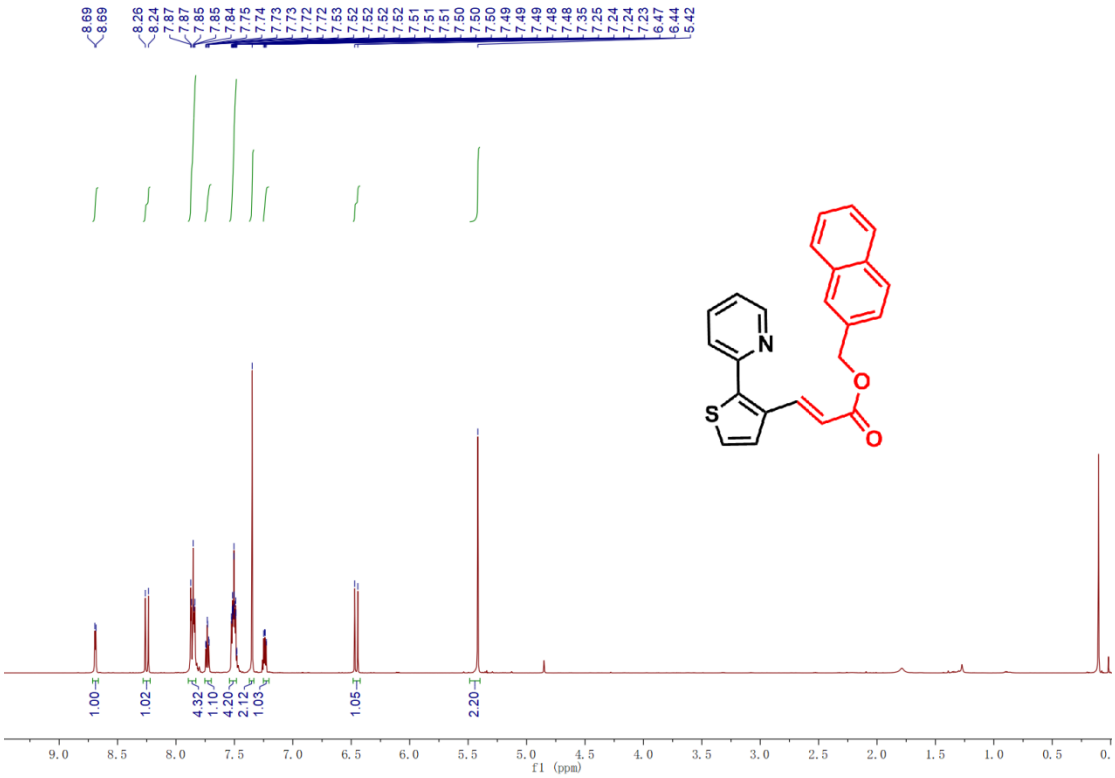
3ai | ^{1}H NMR ($CDCl_3$, 600 MHz)



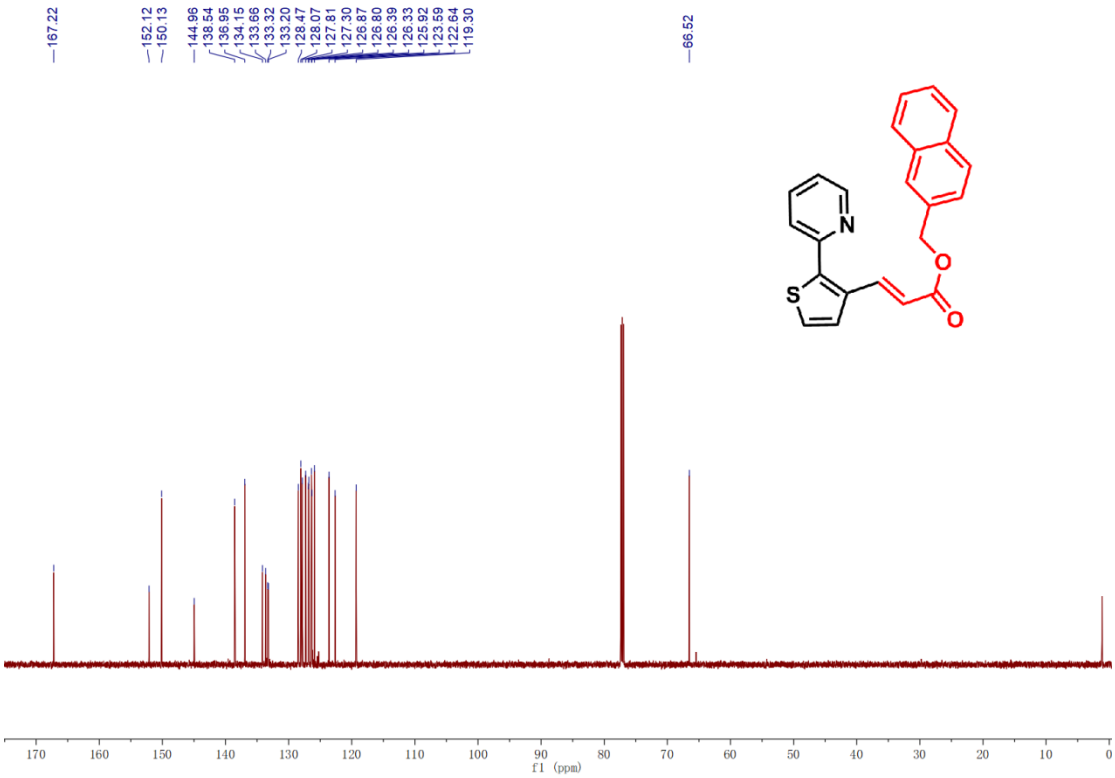
3ai | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



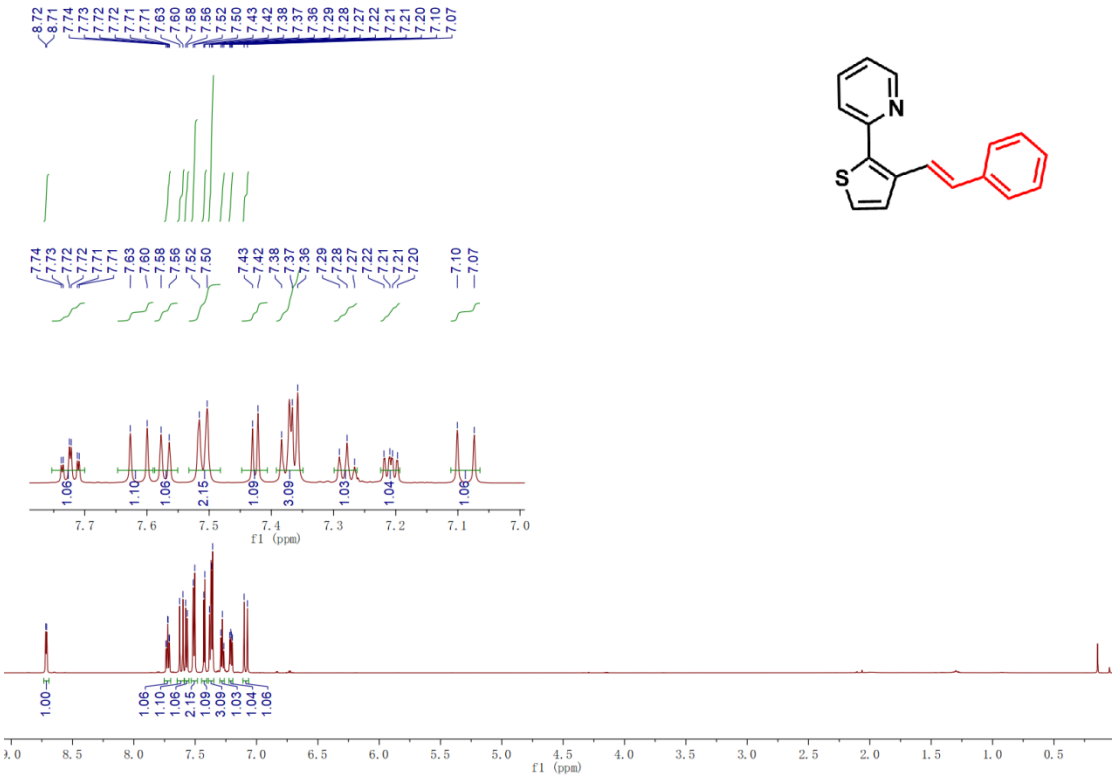
3aj | ^{1}H NMR ($CDCl_3$, 600 MHz)



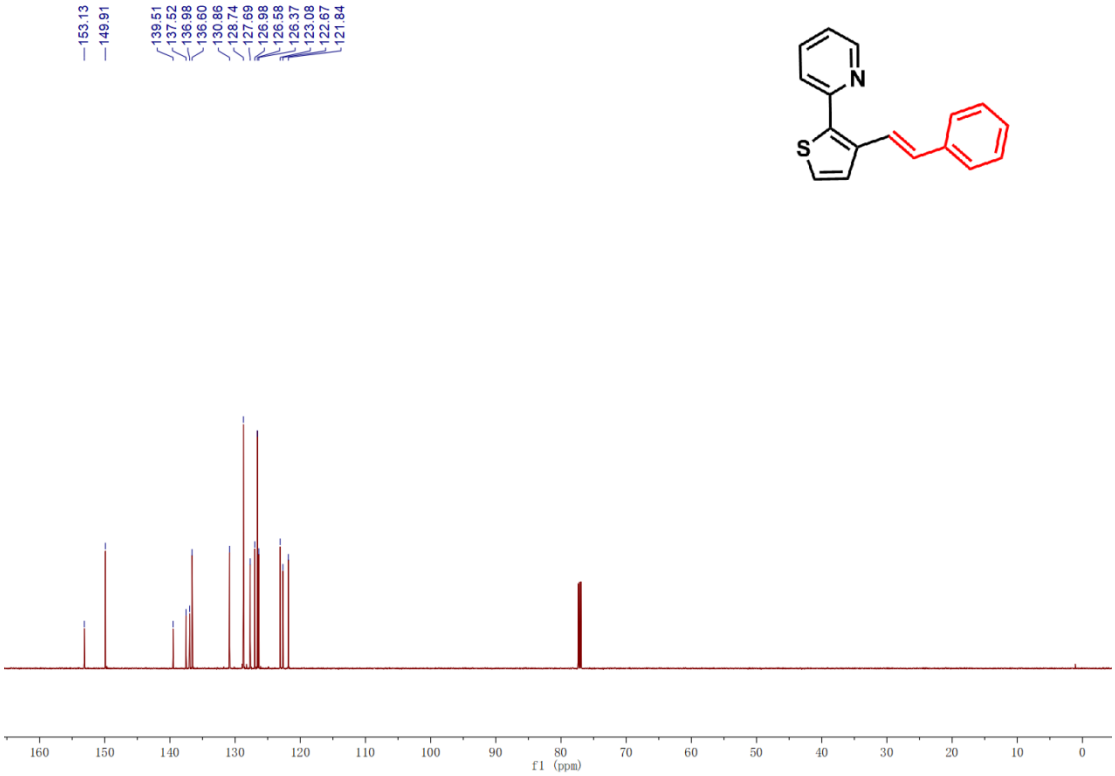
3aj | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



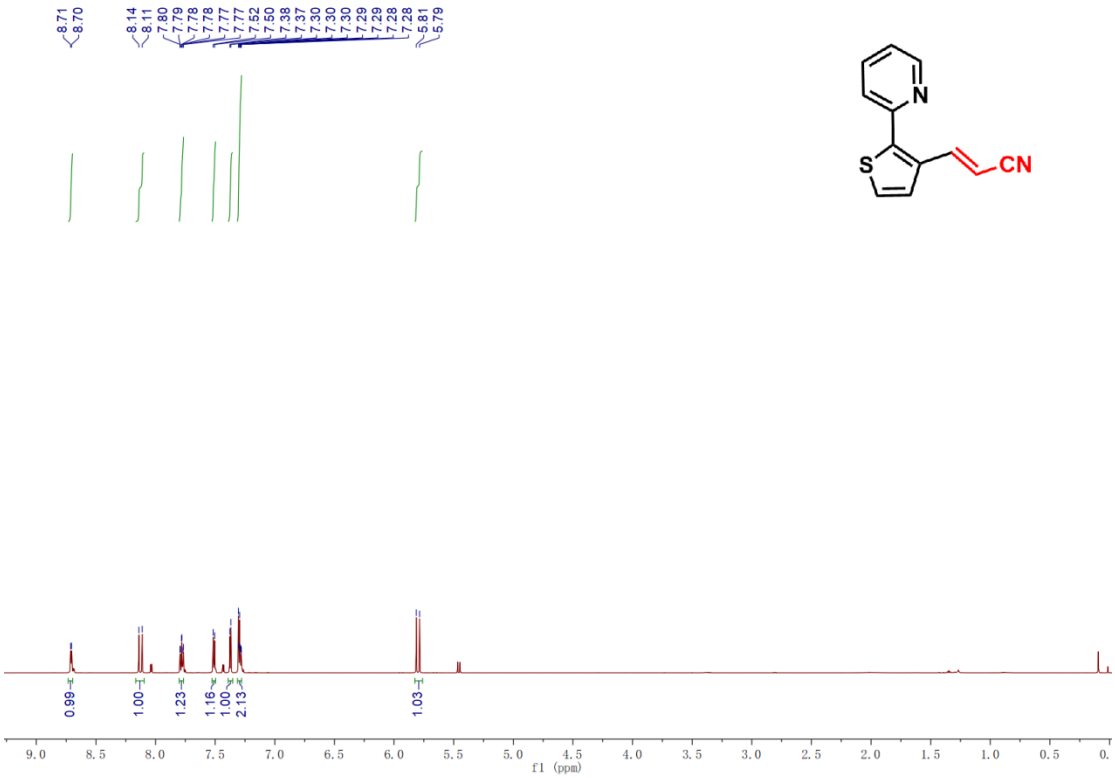
3ak | ^{1}H NMR ($CDCl_3$, 600 MHz)



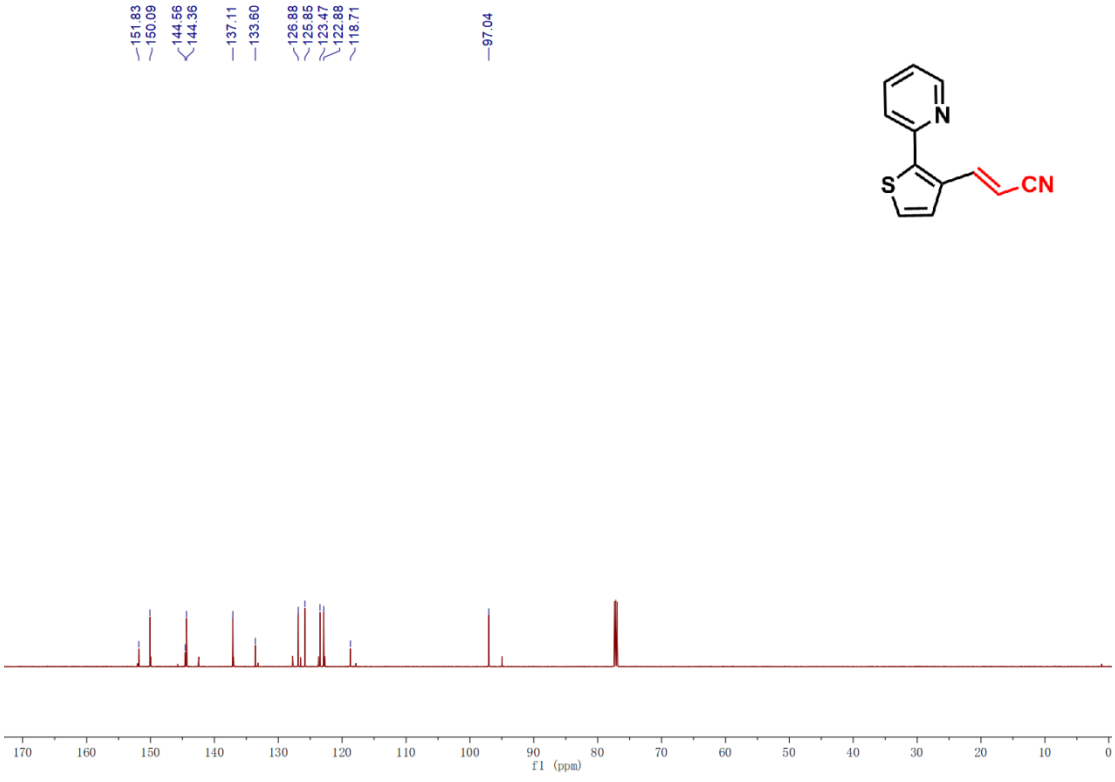
3ak | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



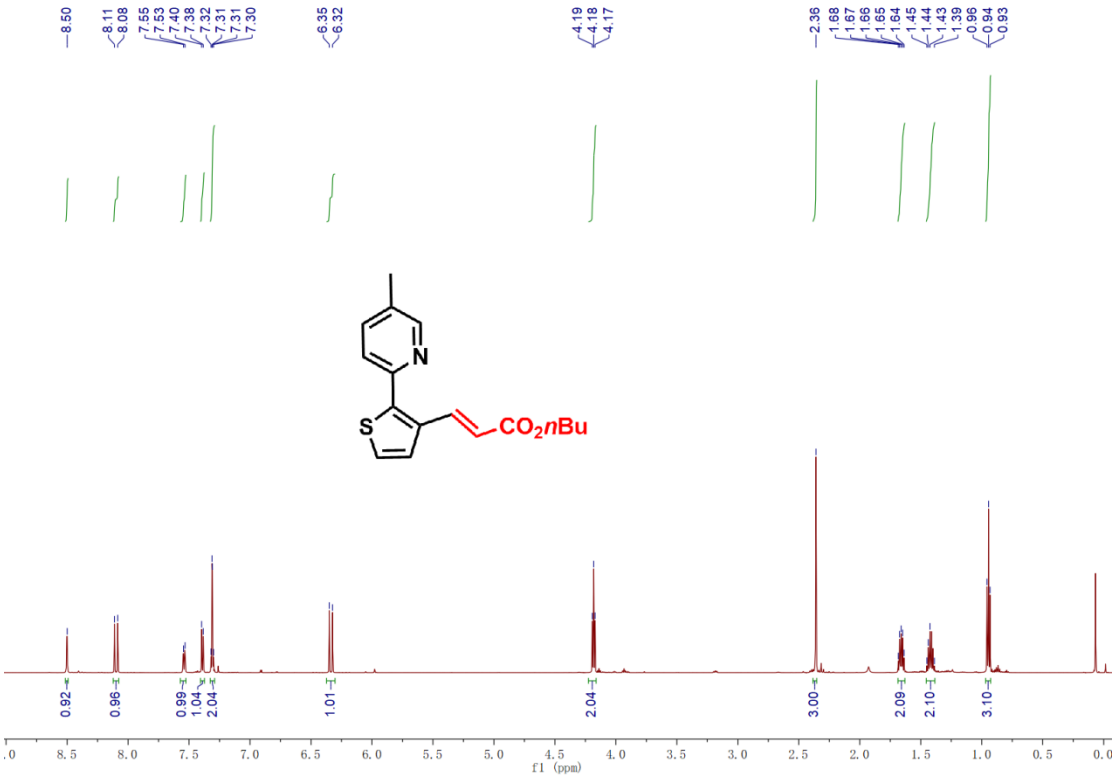
3al | ^{1}H NMR ($CDCl_3$, 600 MHz)



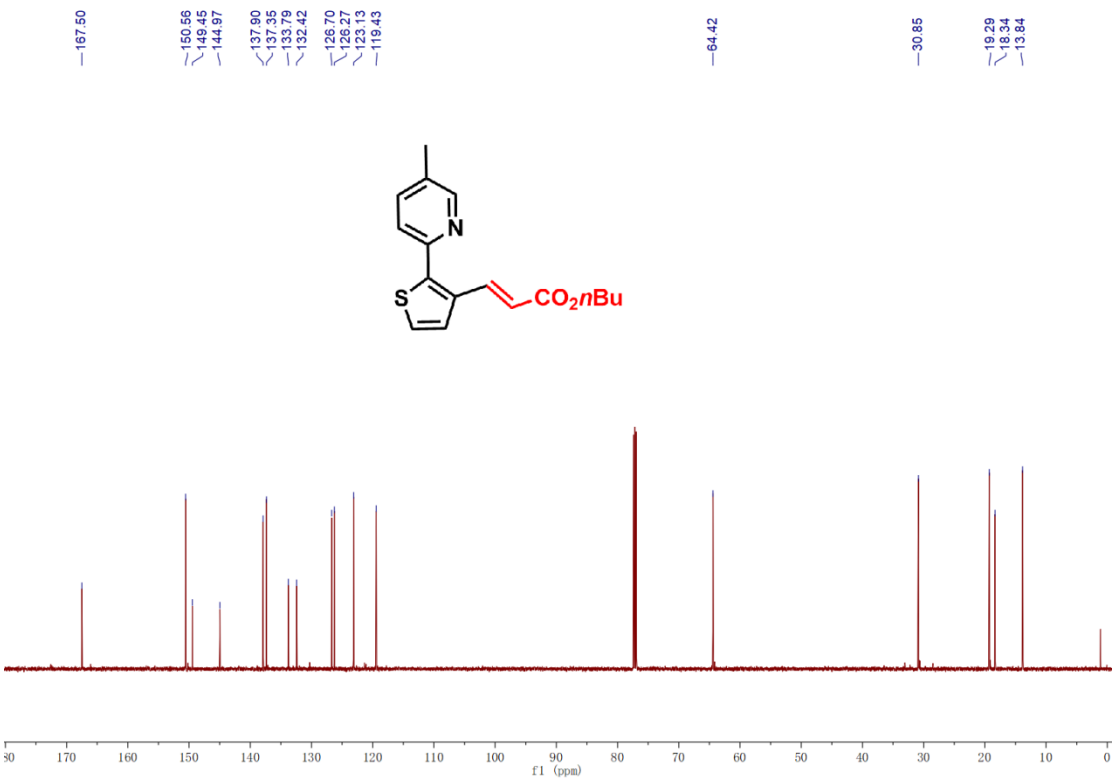
3al | ^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz)



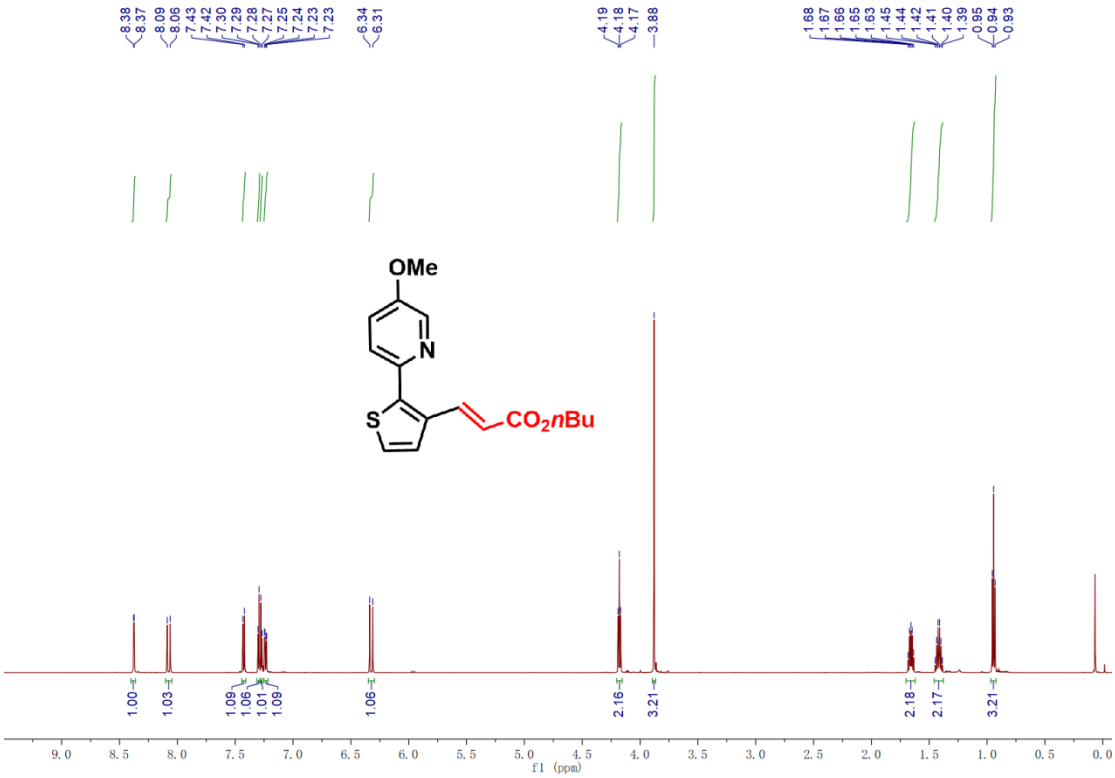
3ba | ^{1}H NMR ($CDCl_3$, 600 MHz)



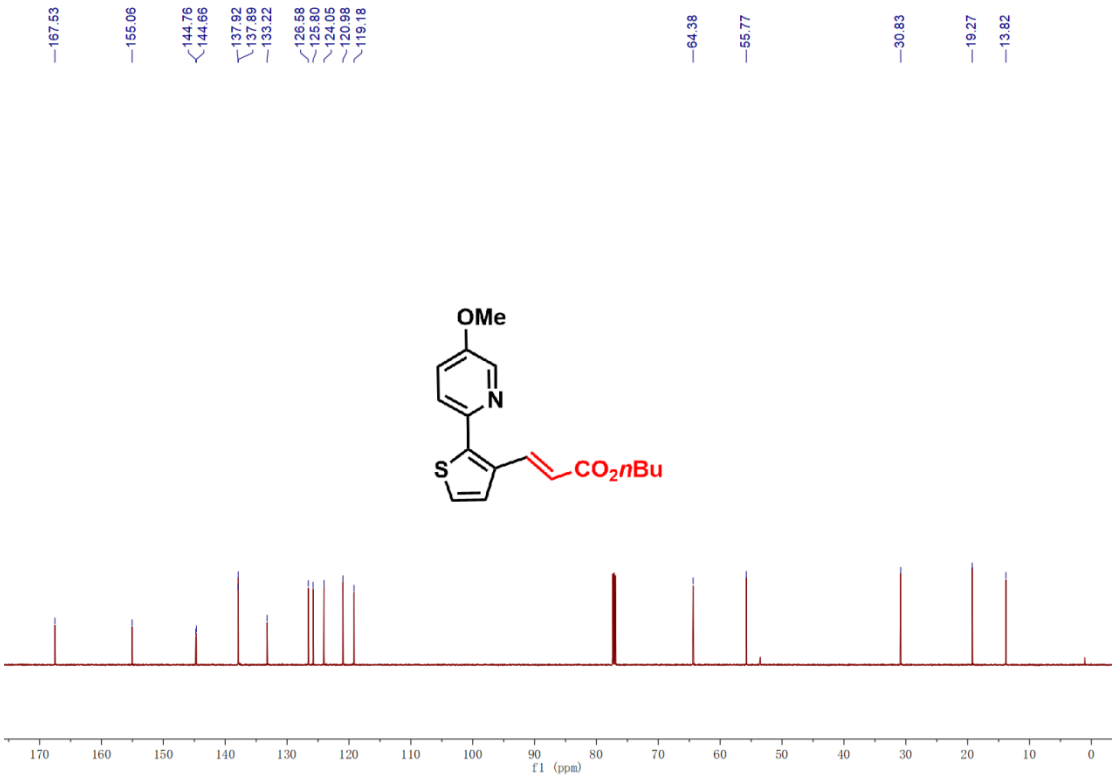
3ba | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



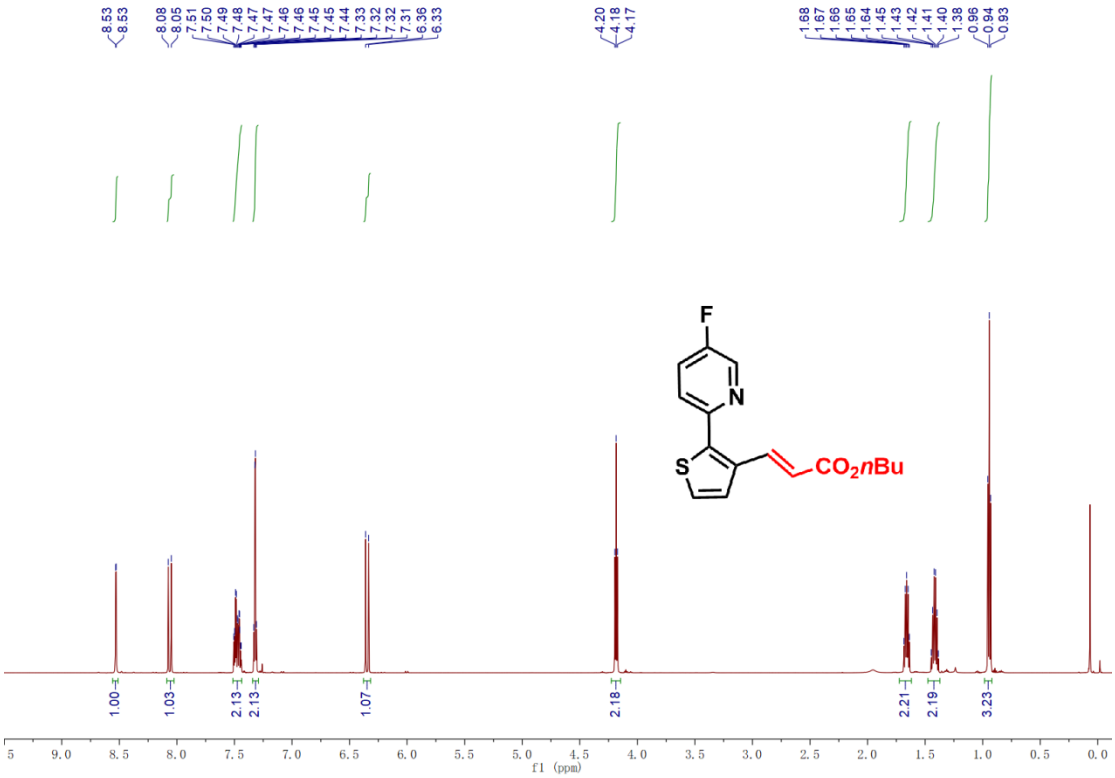
3ca | ^{1}H NMR ($CDCl_3$, 600 MHz)



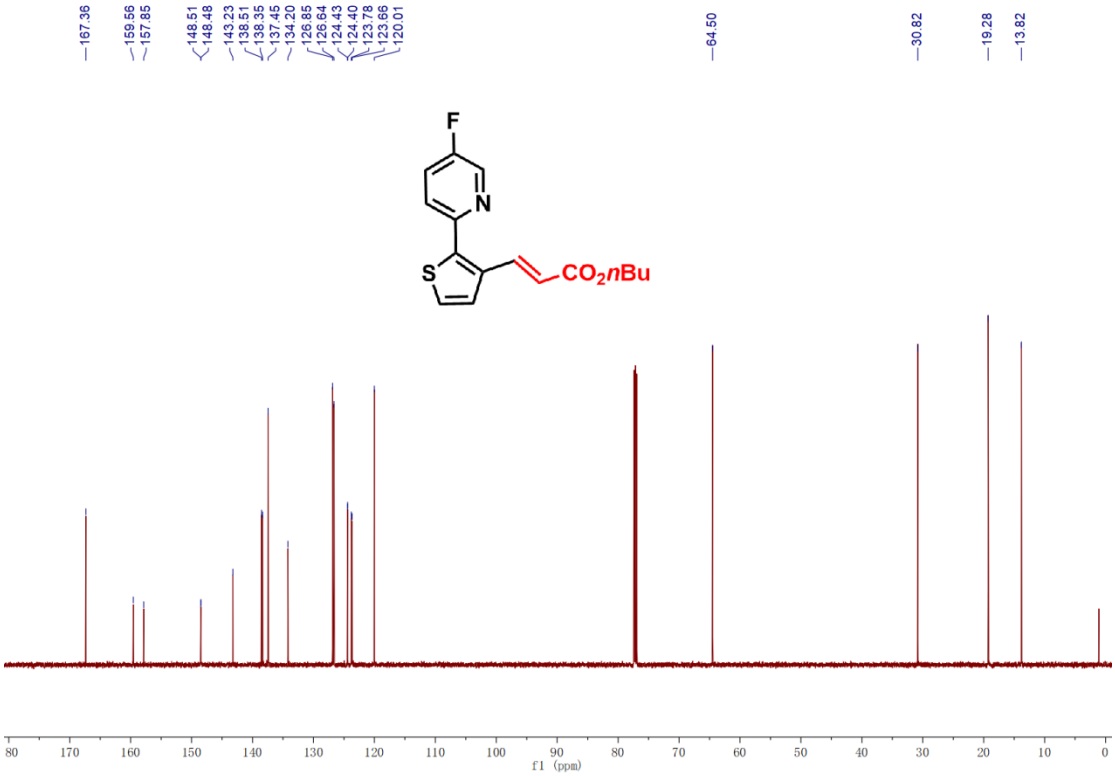
3ca | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



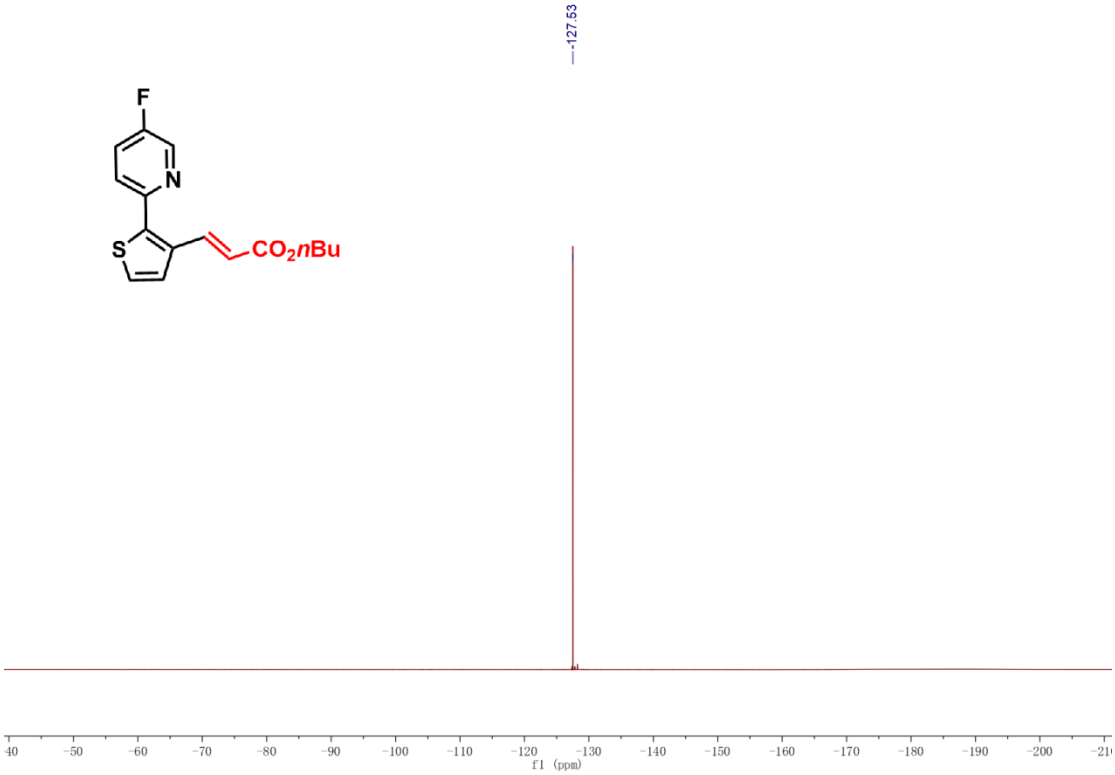
3da | ^{1}H NMR ($CDCl_3$, 600 MHz)



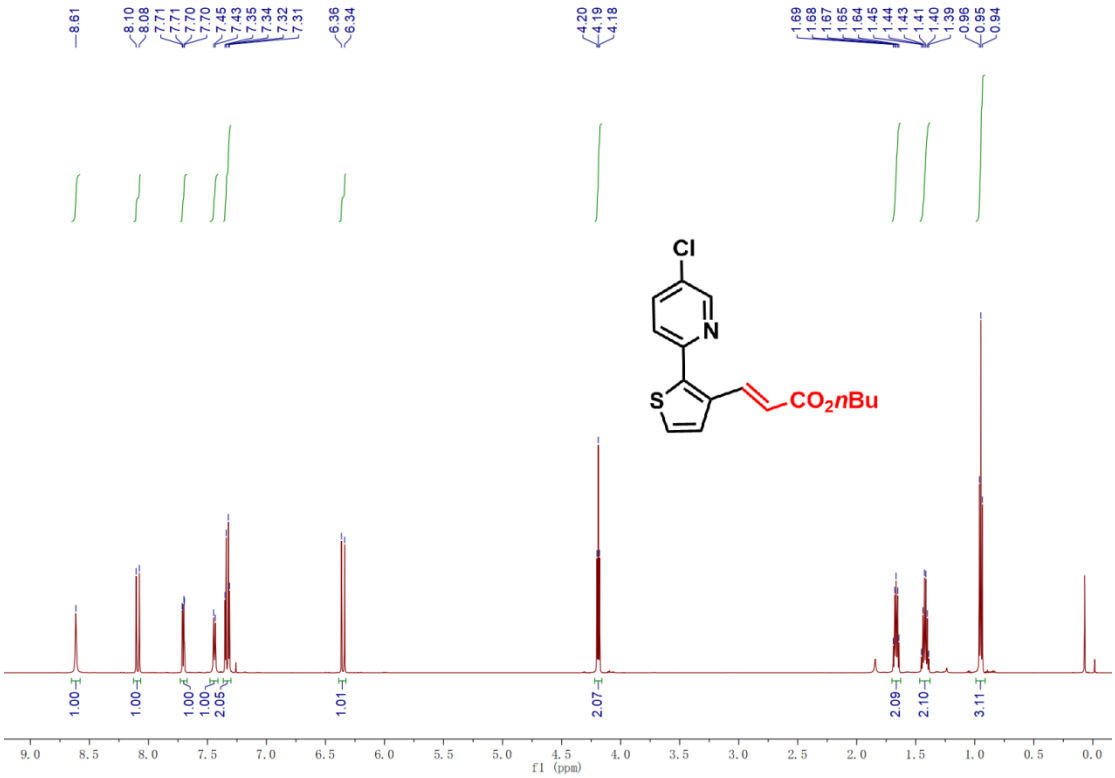
3da | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



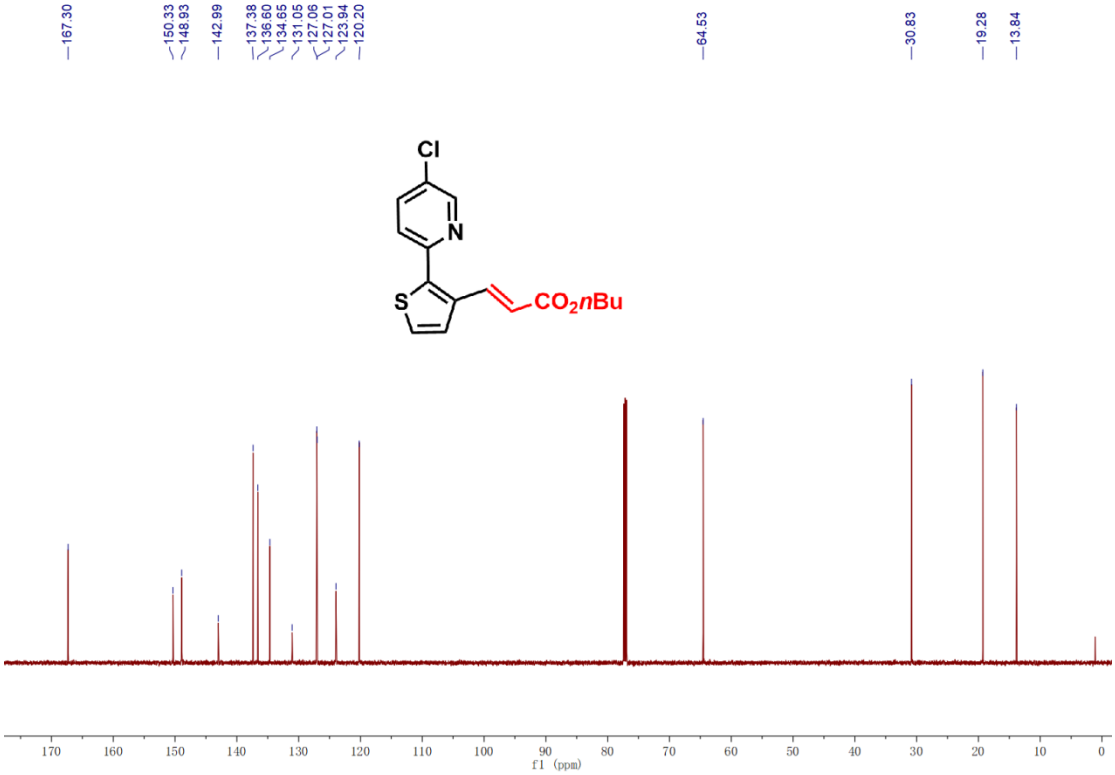
3da | $^{19}F\{^{1}H\}$ NMR ($CDCl_3$, 565 MHz)



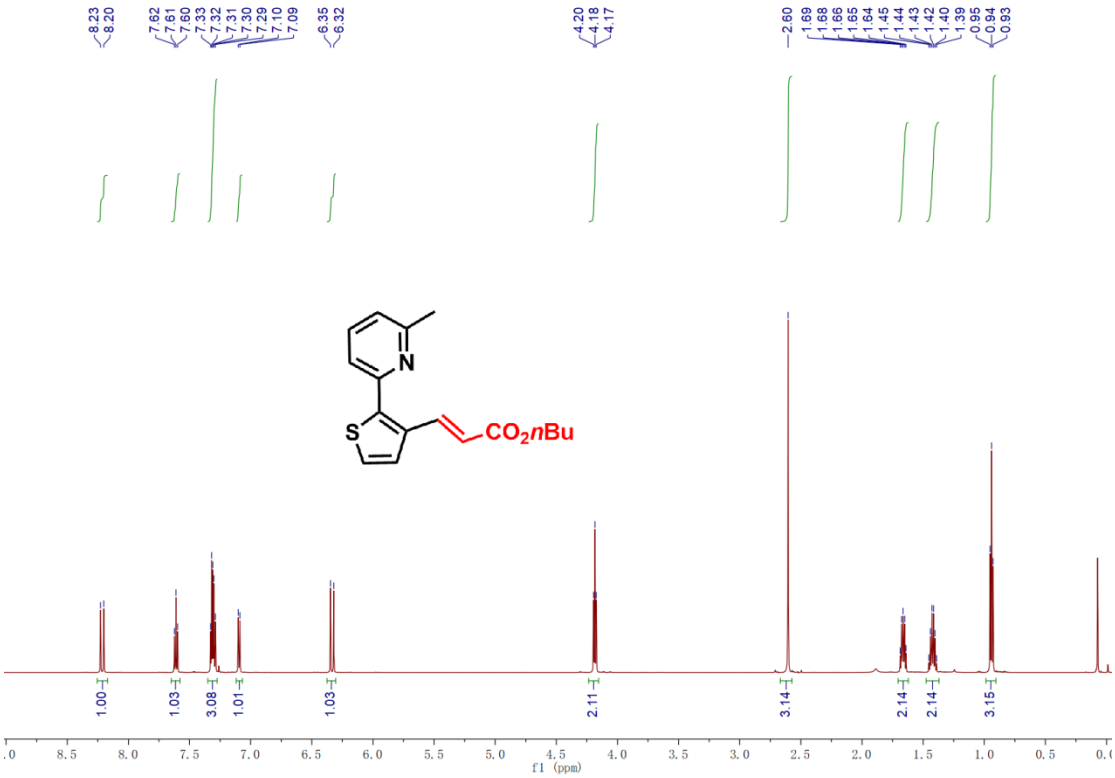
3ea | ^{1}H NMR ($CDCl_3$, 600 MHz)



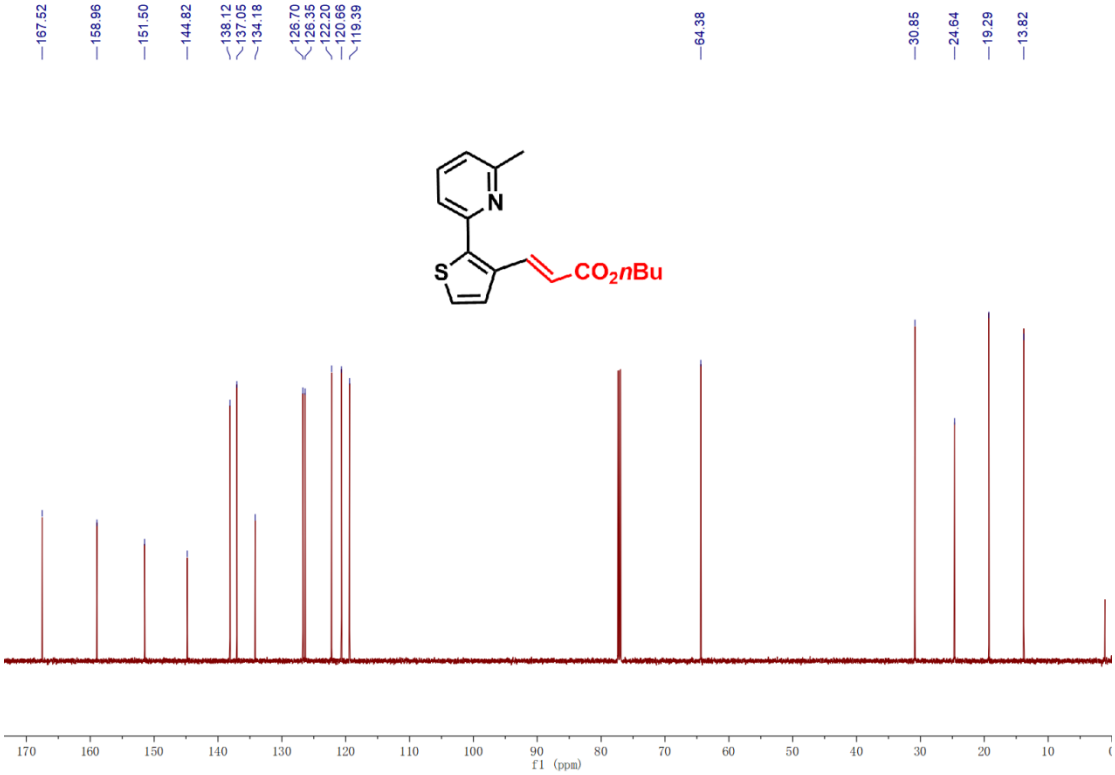
3ea | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



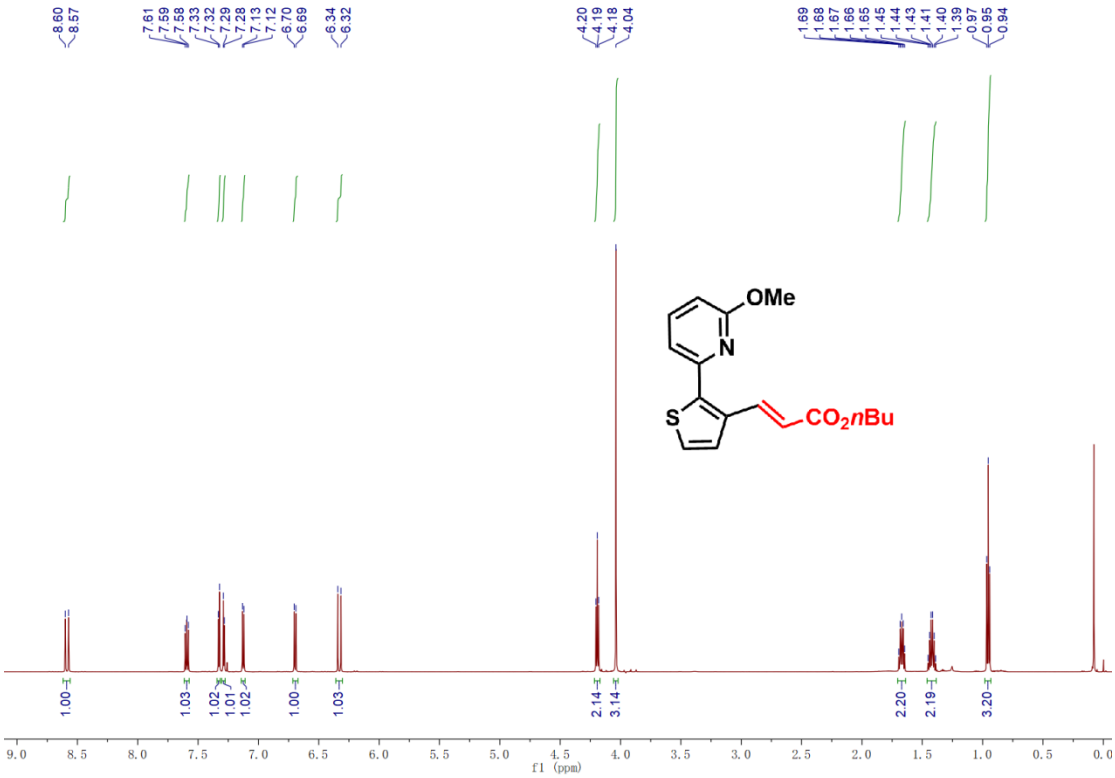
3fa | ^{1}H NMR ($CDCl_3$, 600 MHz)



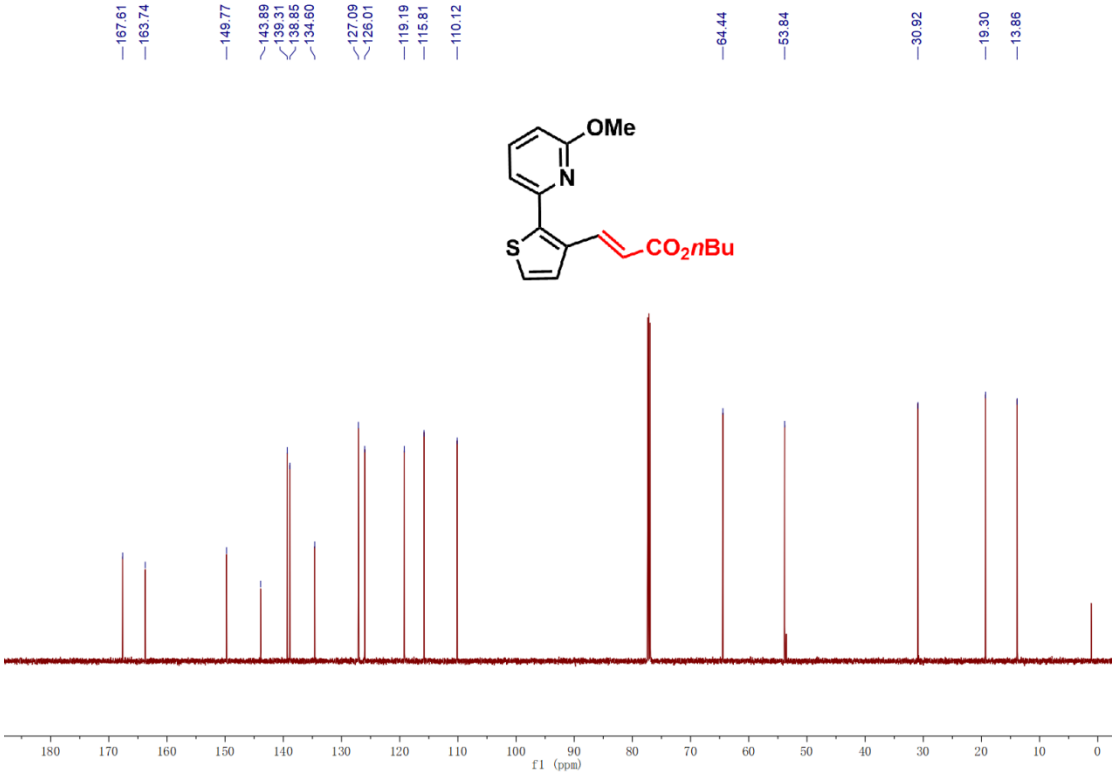
3fa | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



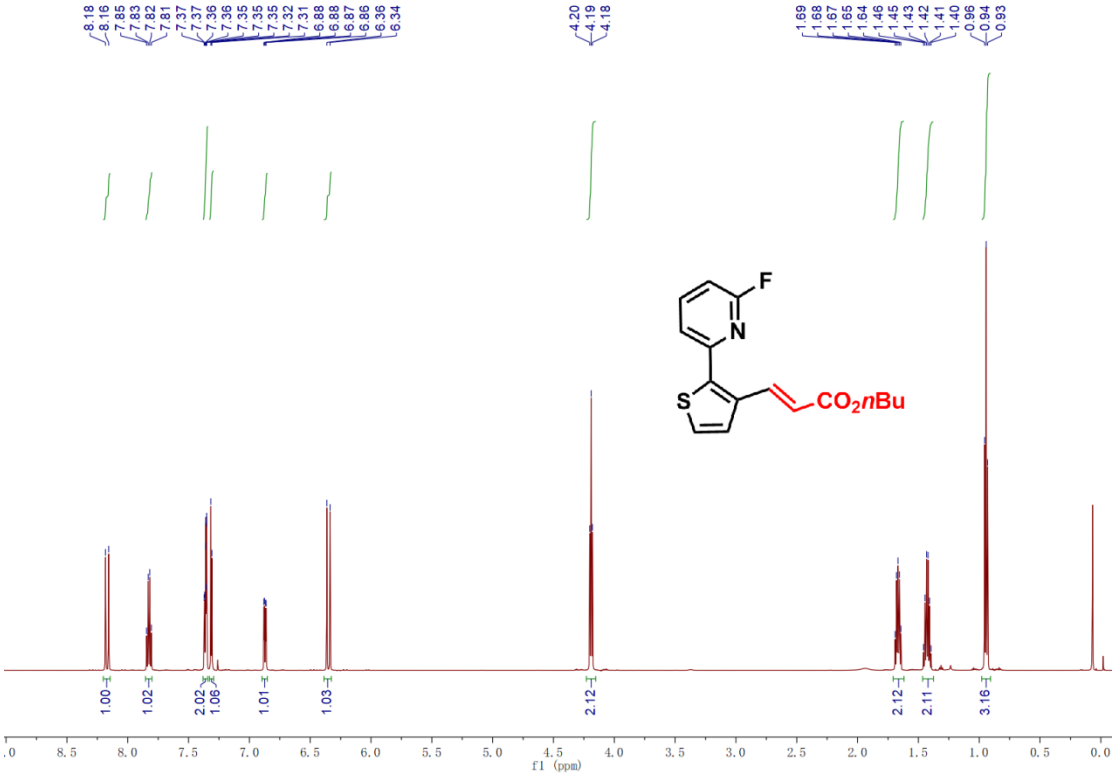
3ga | ^{1}H NMR ($CDCl_3$, 600 MHz)



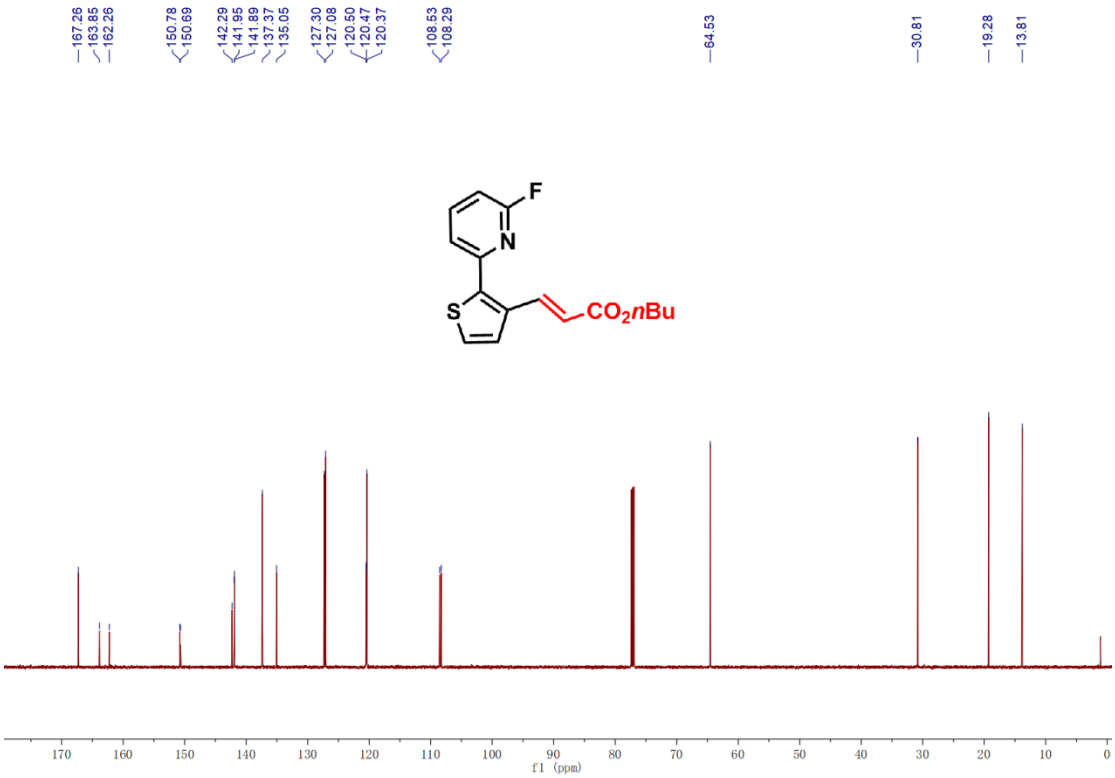
3ga | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



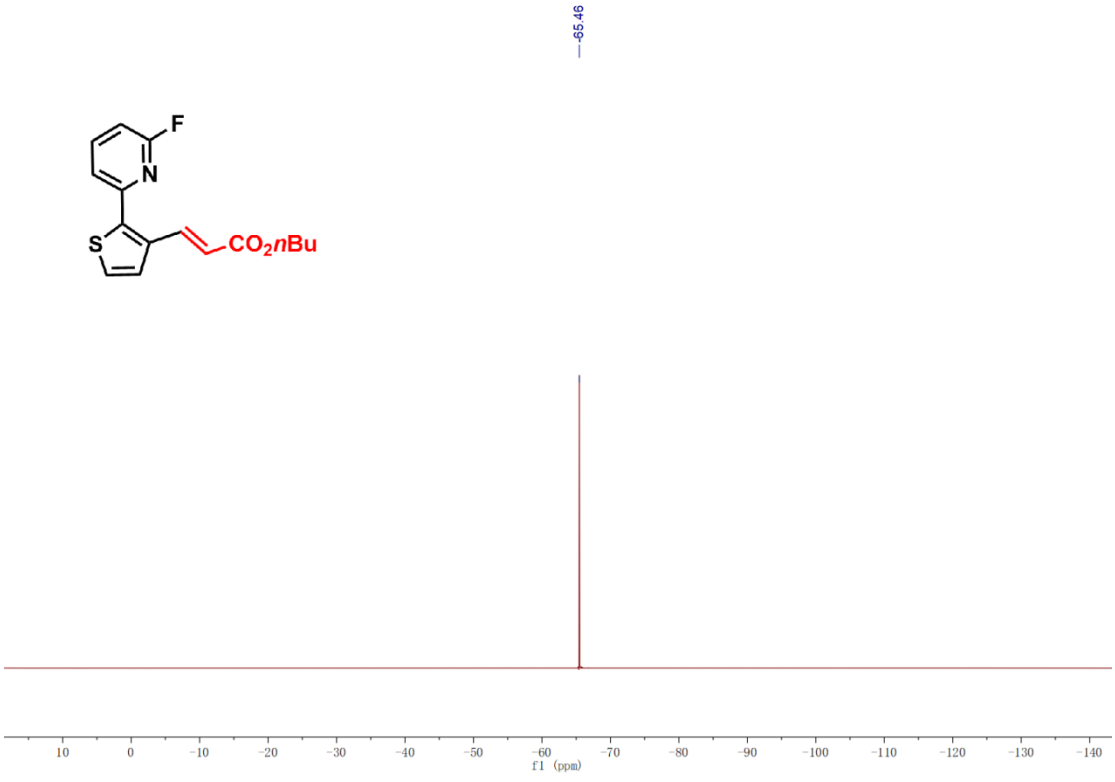
3ha | ^{1}H NMR ($CDCl_3$, 600 MHz)



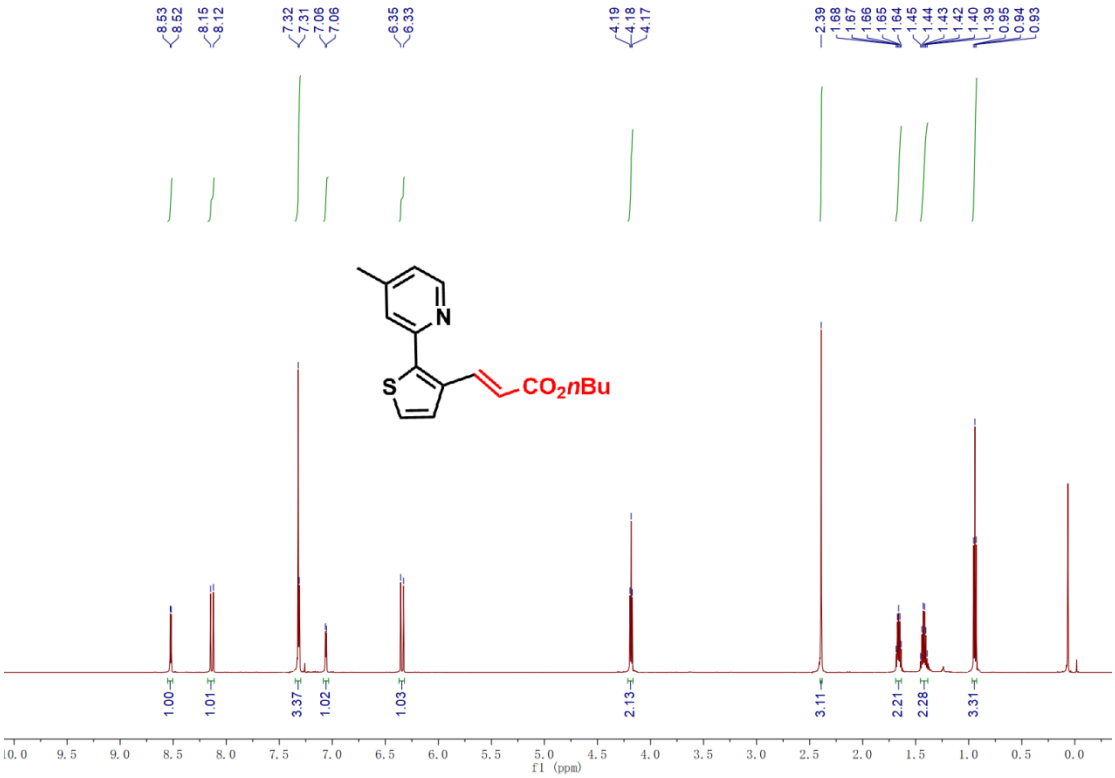
3ha | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



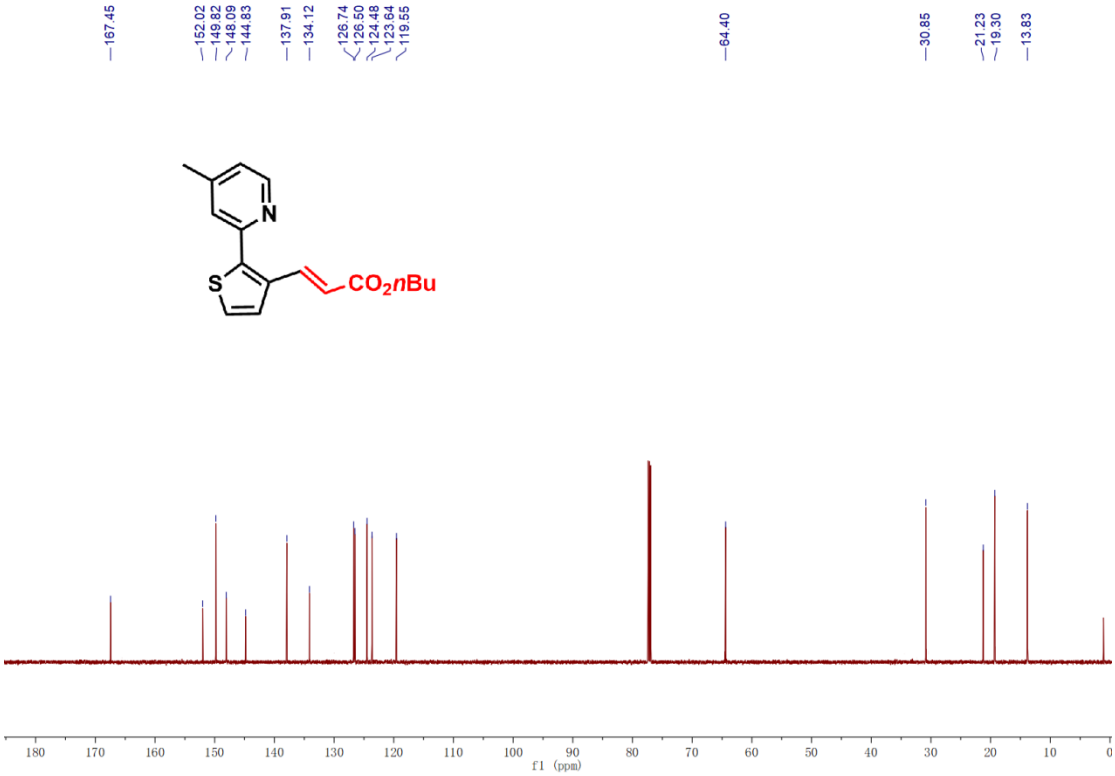
3ha | $^{19}F\{^{1}H\}$ NMR ($CDCl_3$, 565 MHz)



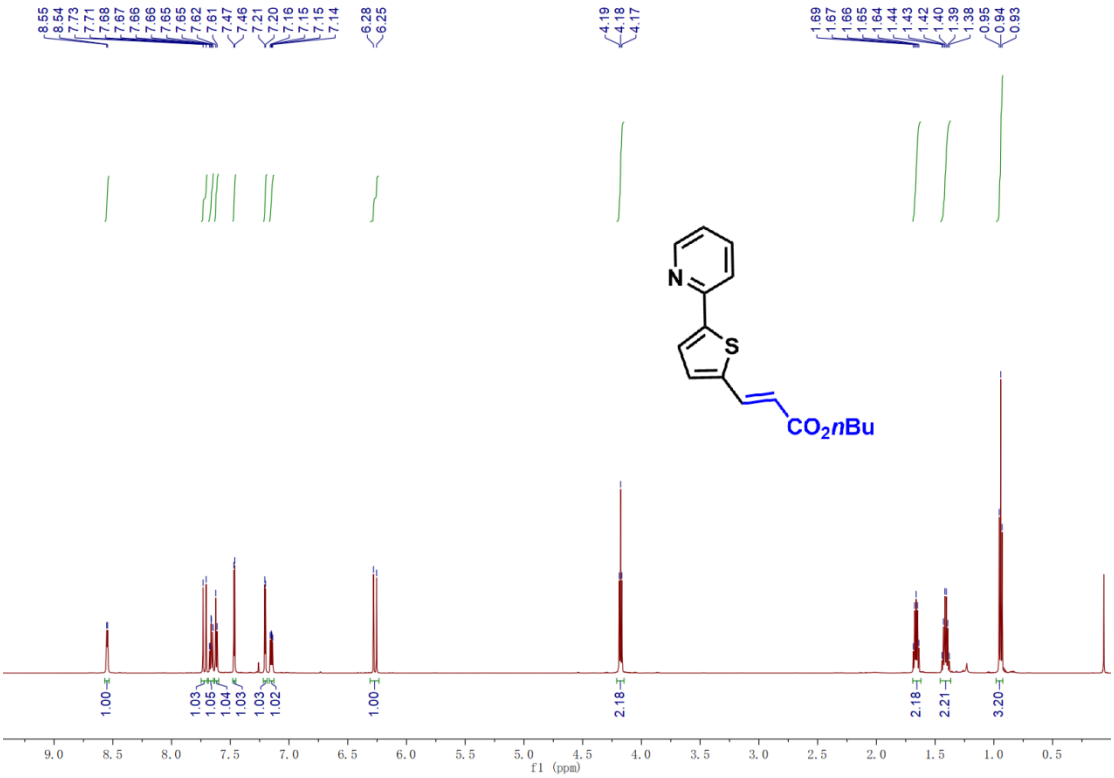
3ia | ^{1}H NMR ($CDCl_3$, 600 MHz)



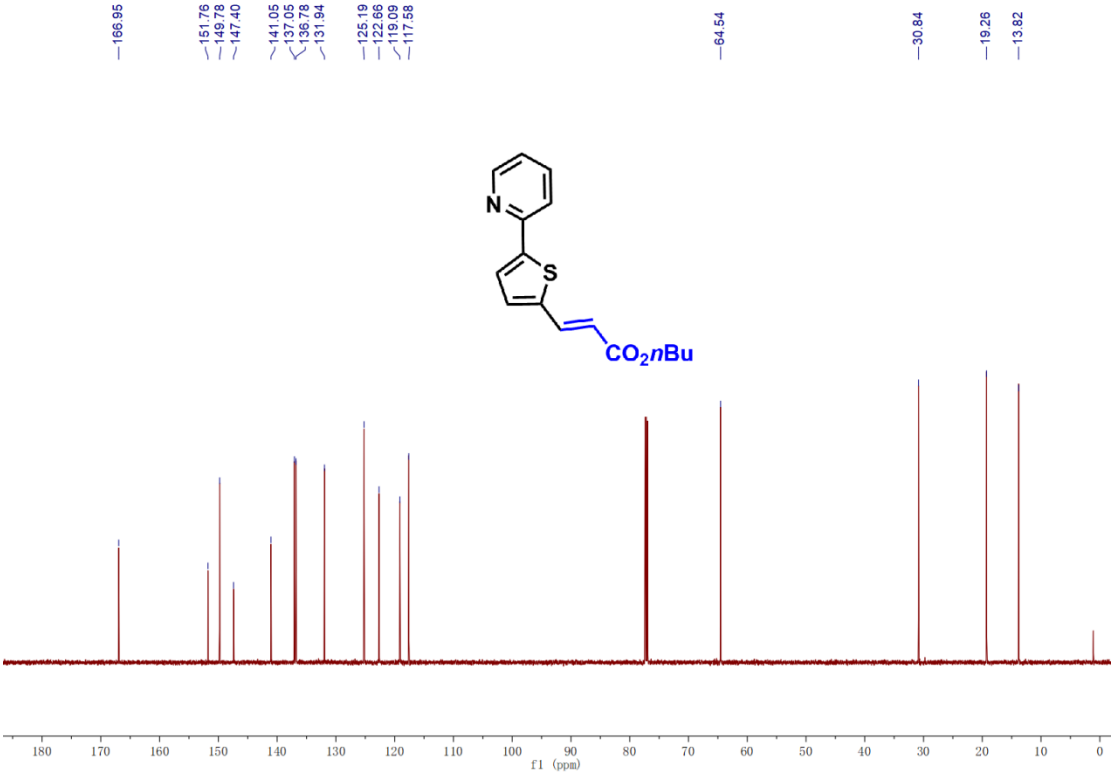
3ia | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



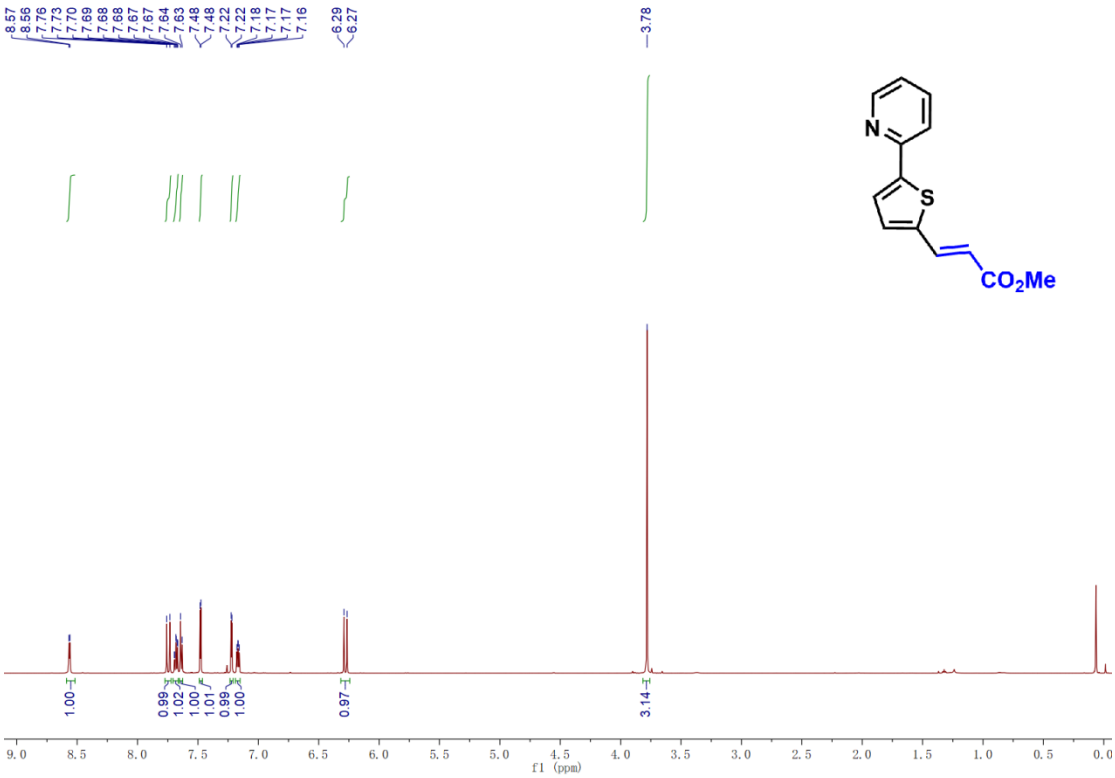
4aa | ^{1}H NMR ($CDCl_3$, 600 MHz)



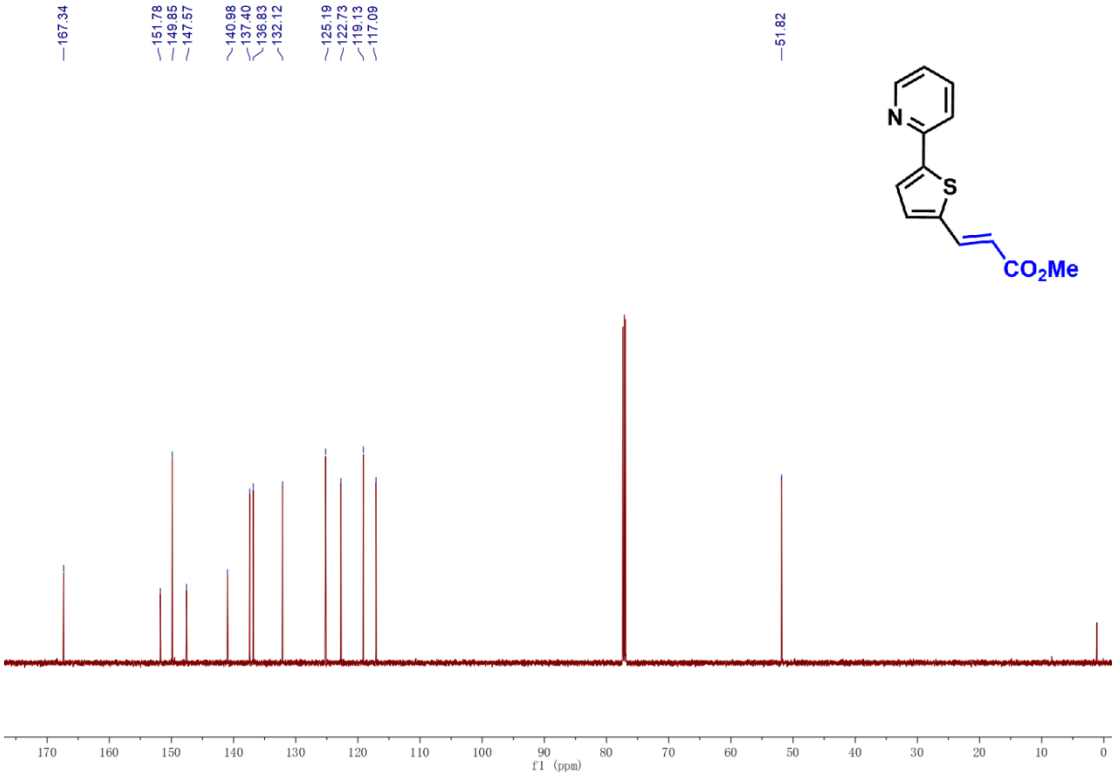
4aa | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



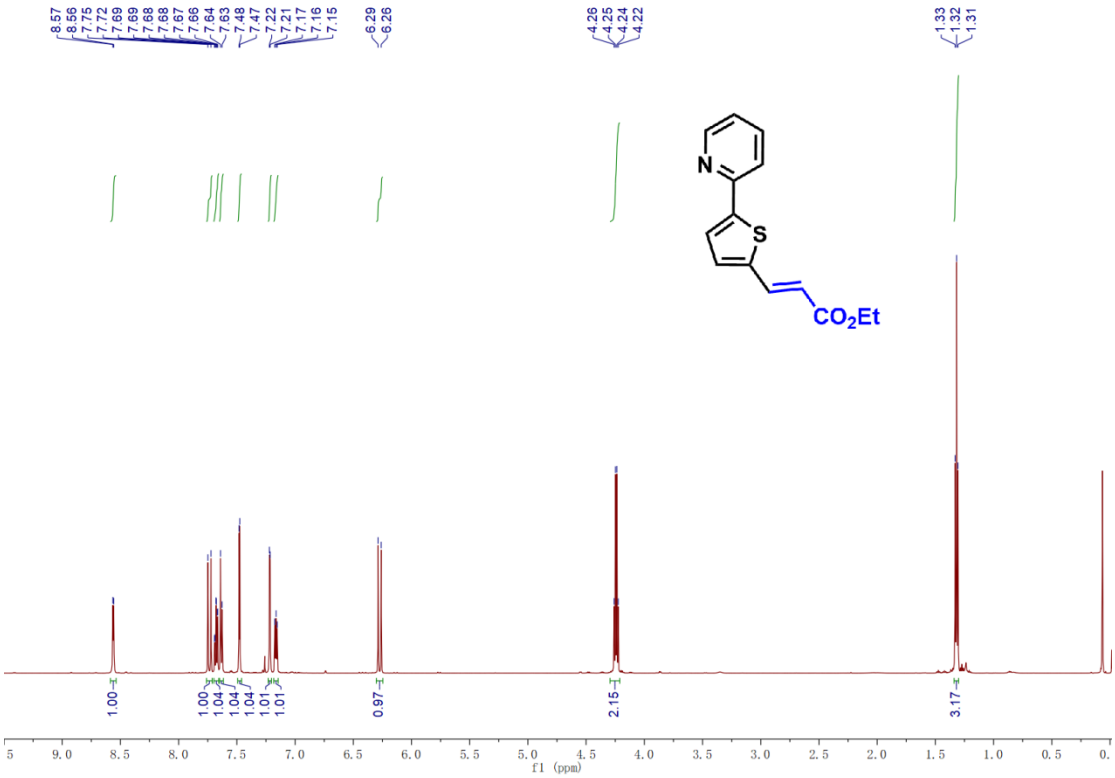
4ab | ^{1}H NMR ($CDCl_3$, 600 MHz)



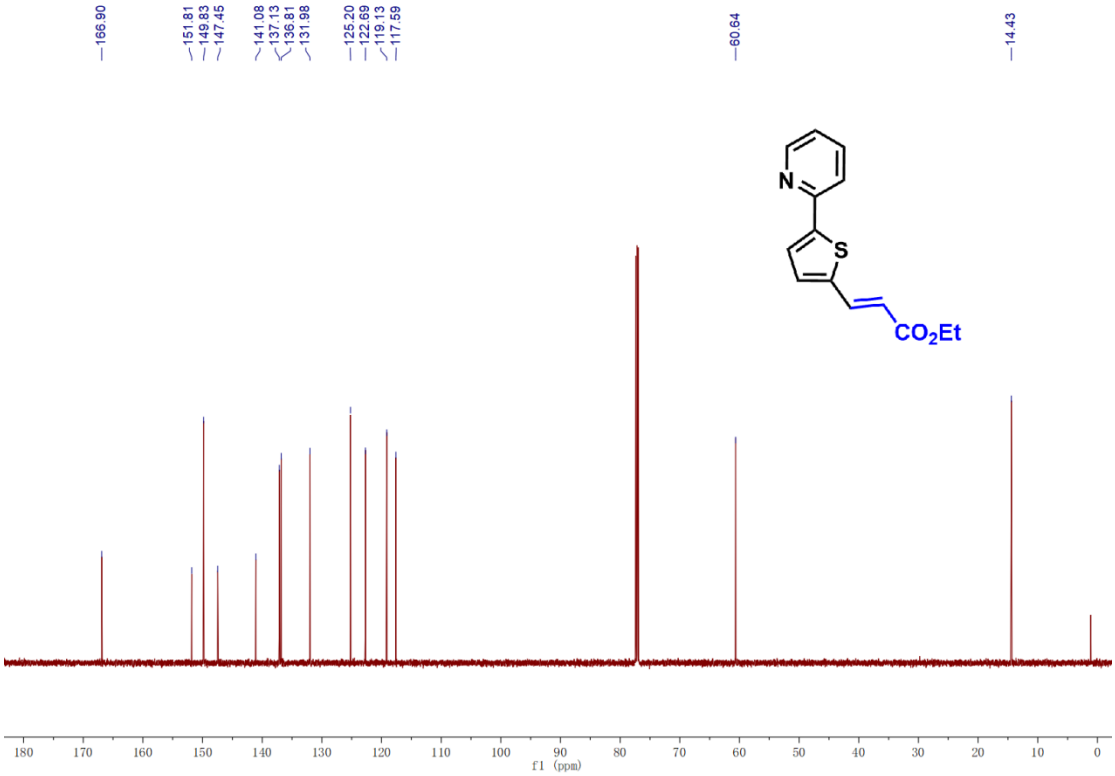
4ab | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



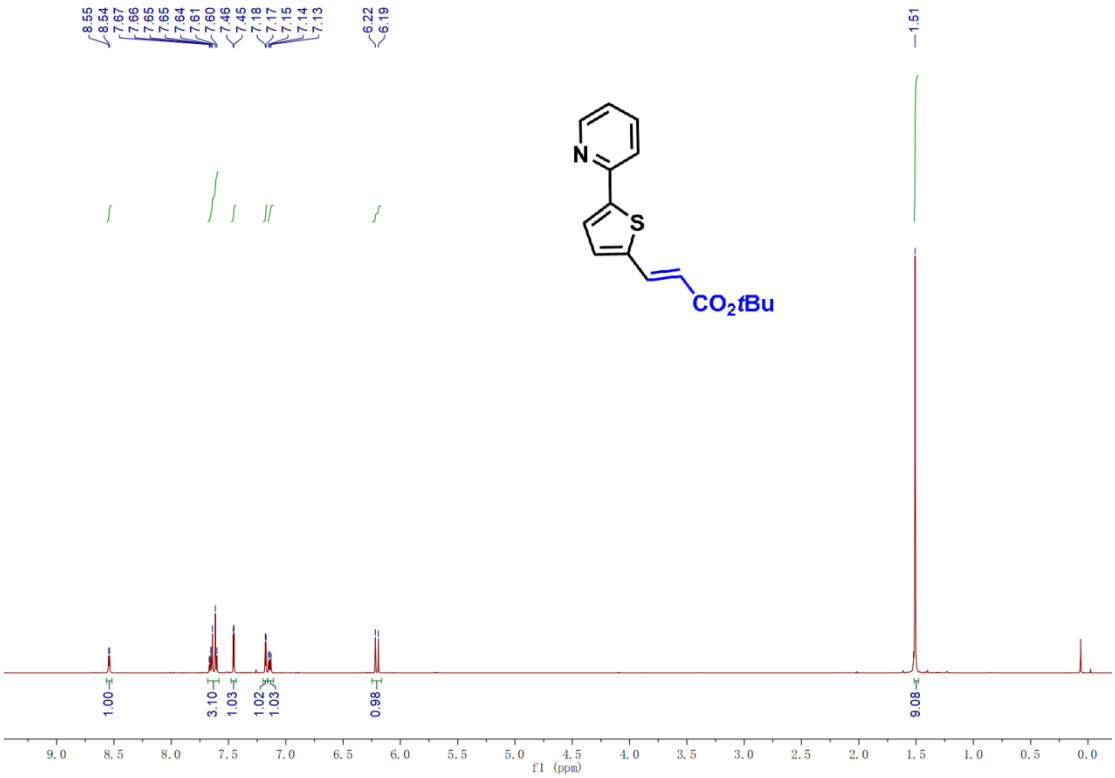
4ac | ^{1}H NMR ($CDCl_3$, 600 MHz)



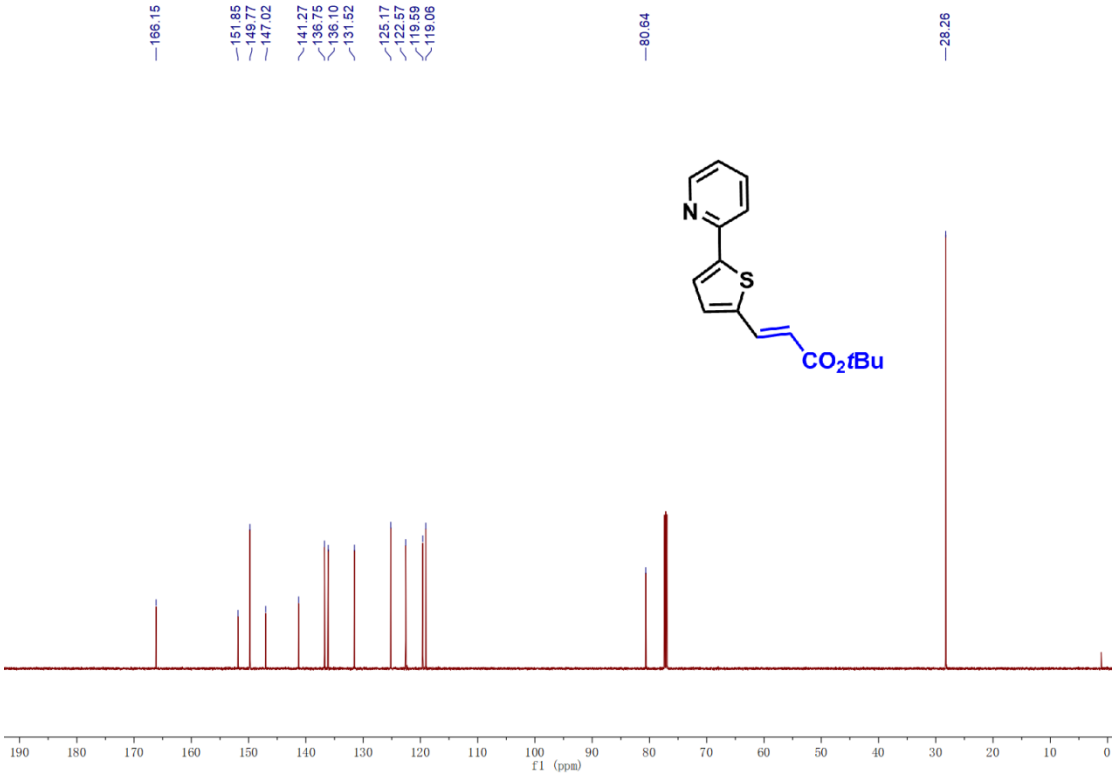
4ac | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



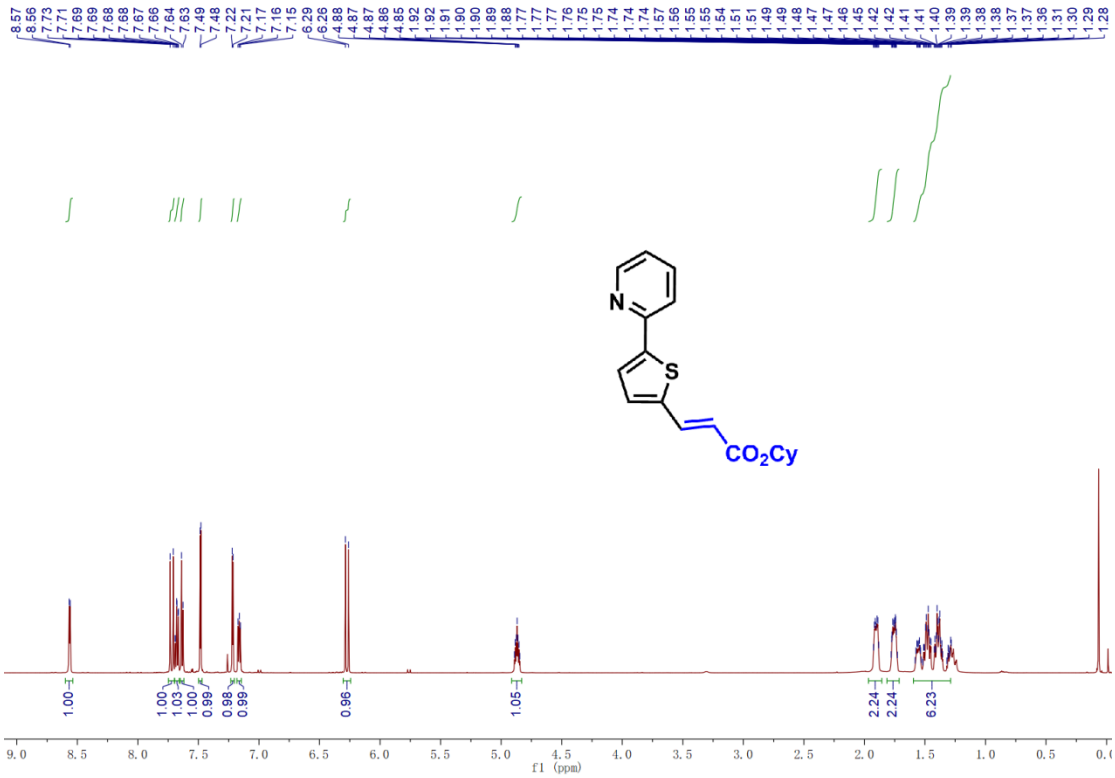
4ad | ^{1}H NMR ($CDCl_3$, 600 MHz)



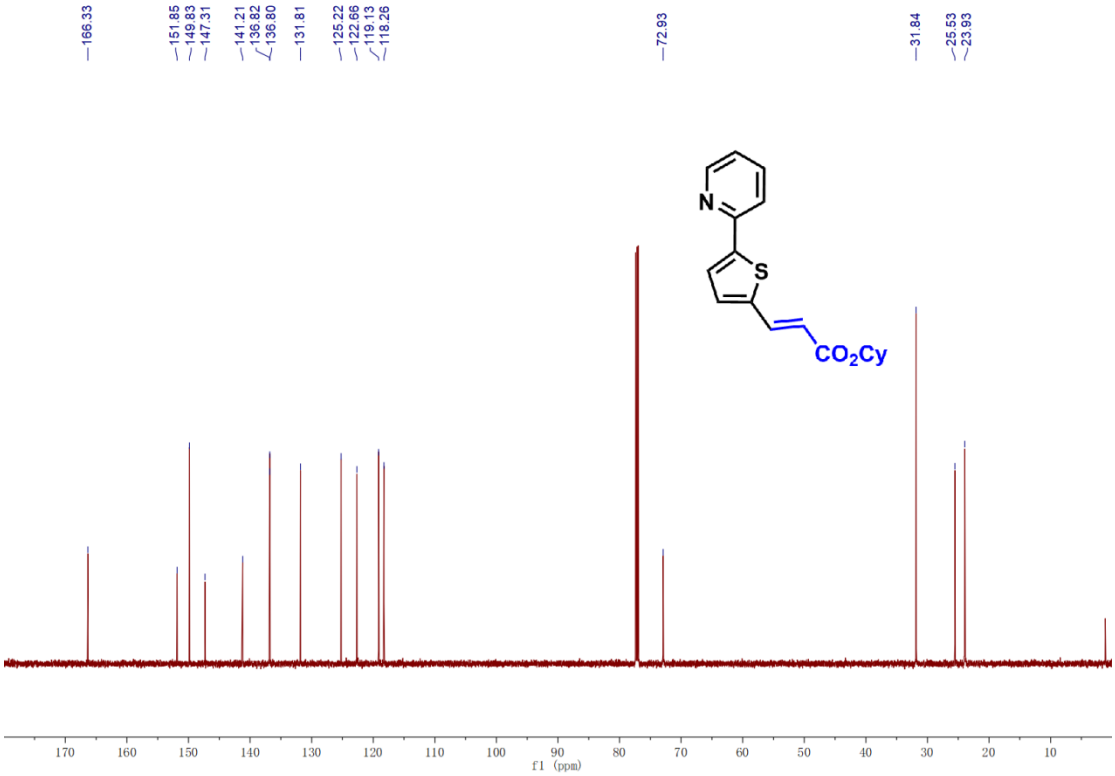
4ad | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



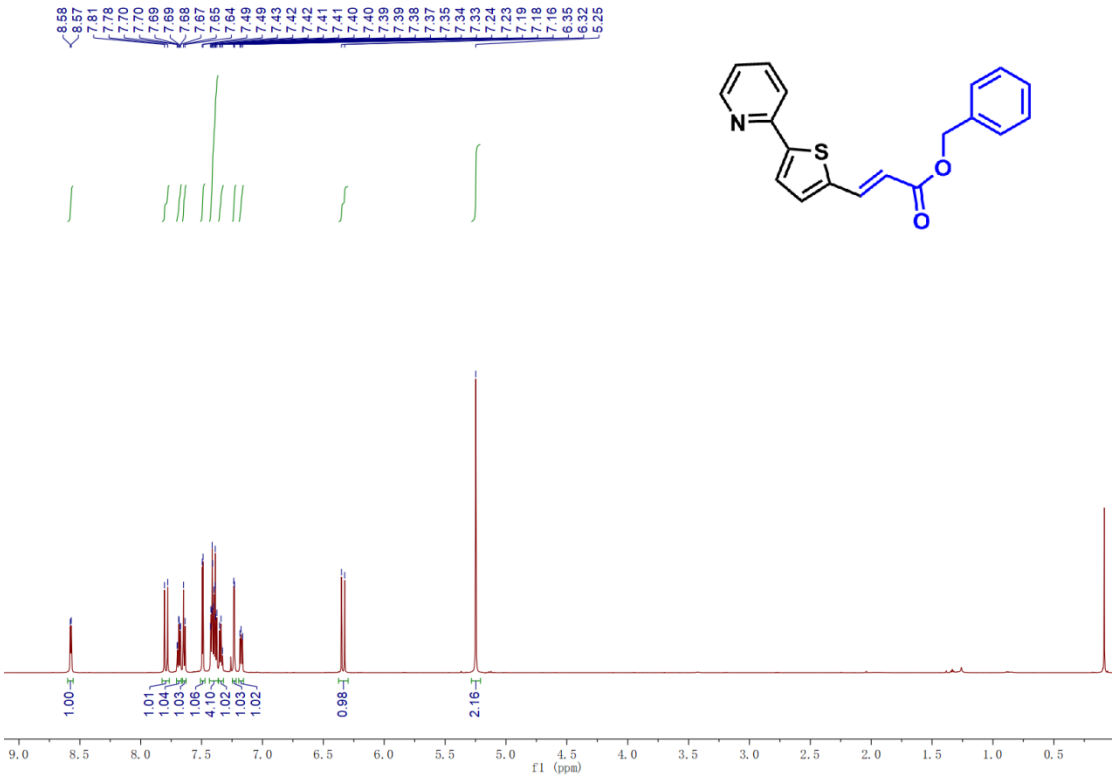
4ae | ^{1}H NMR ($CDCl_3$, 600 MHz)



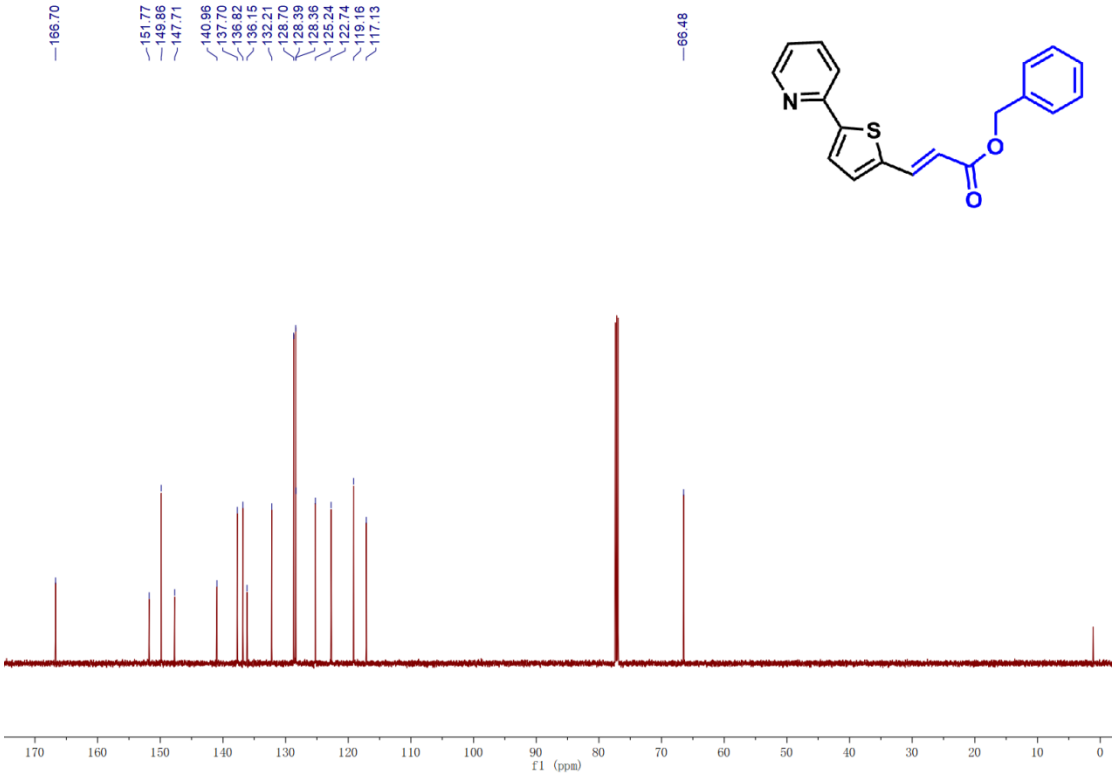
4ae | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



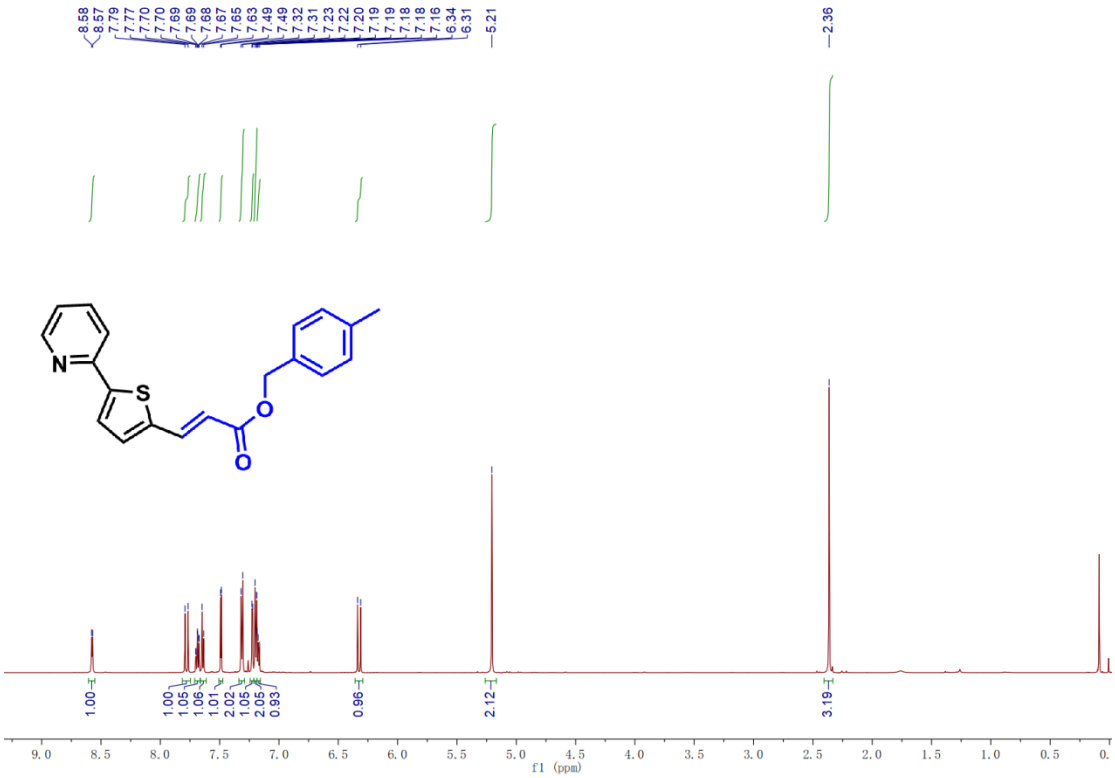
4af | ^{1}H NMR ($CDCl_3$, 600 MHz)



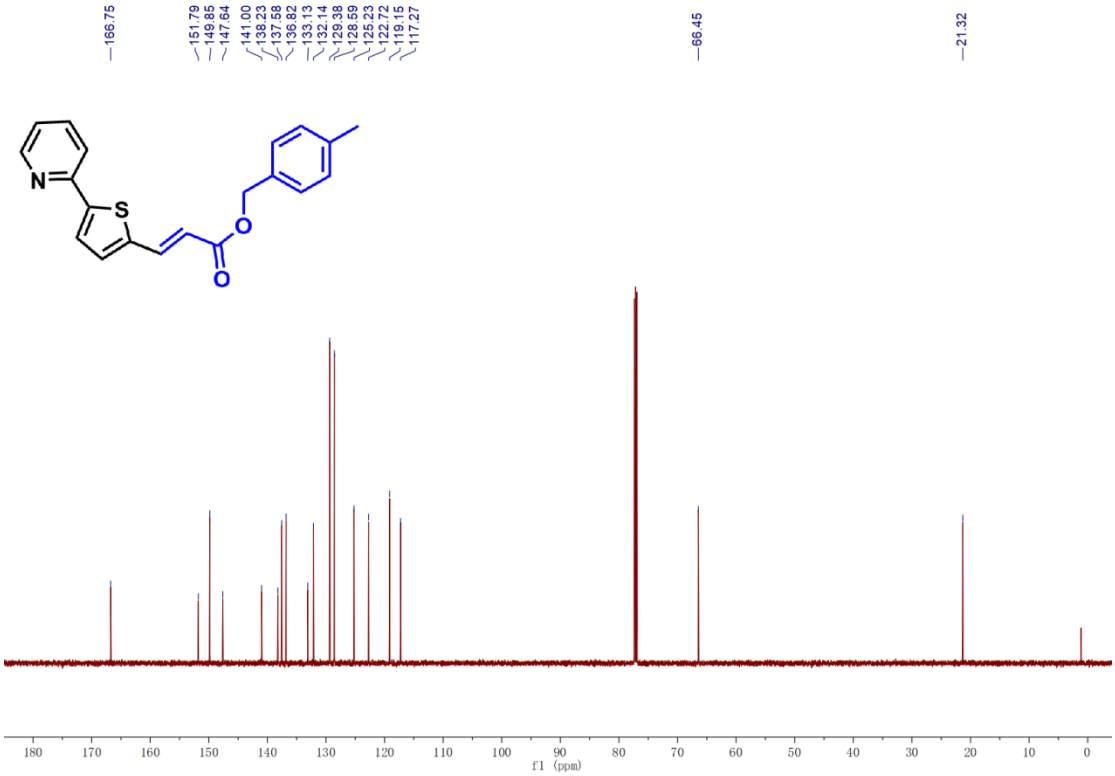
4af | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



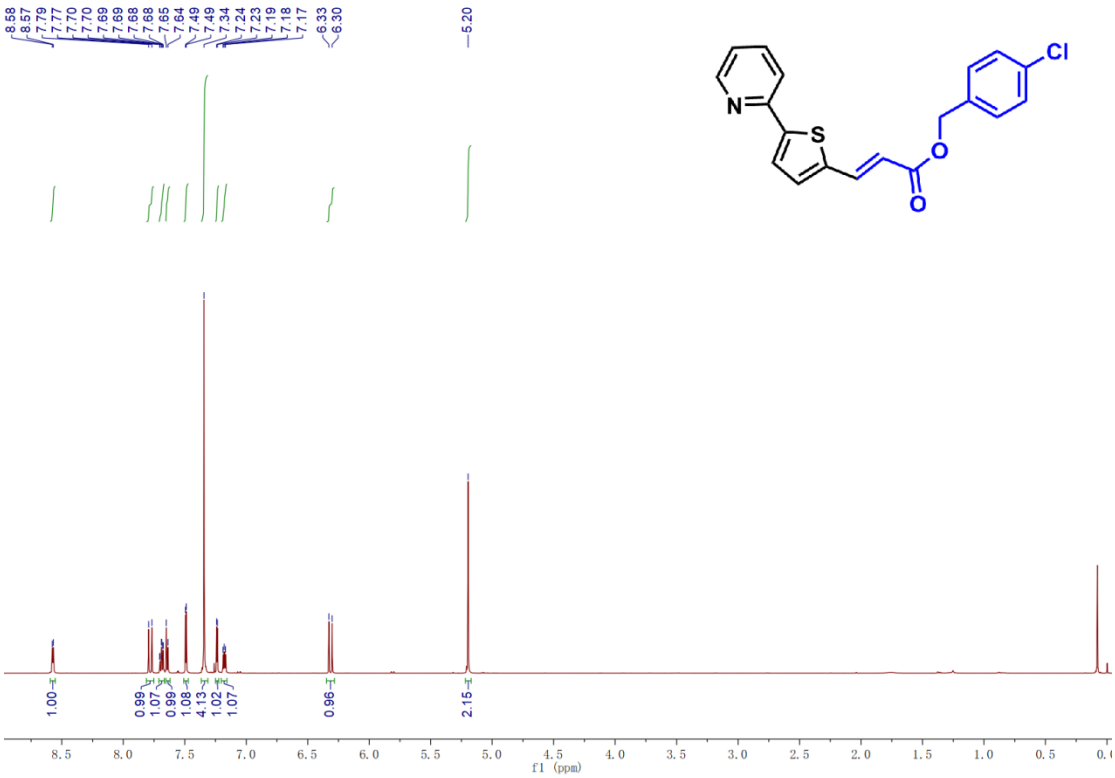
4ag | ^{1}H NMR ($CDCl_3$, 600 MHz)



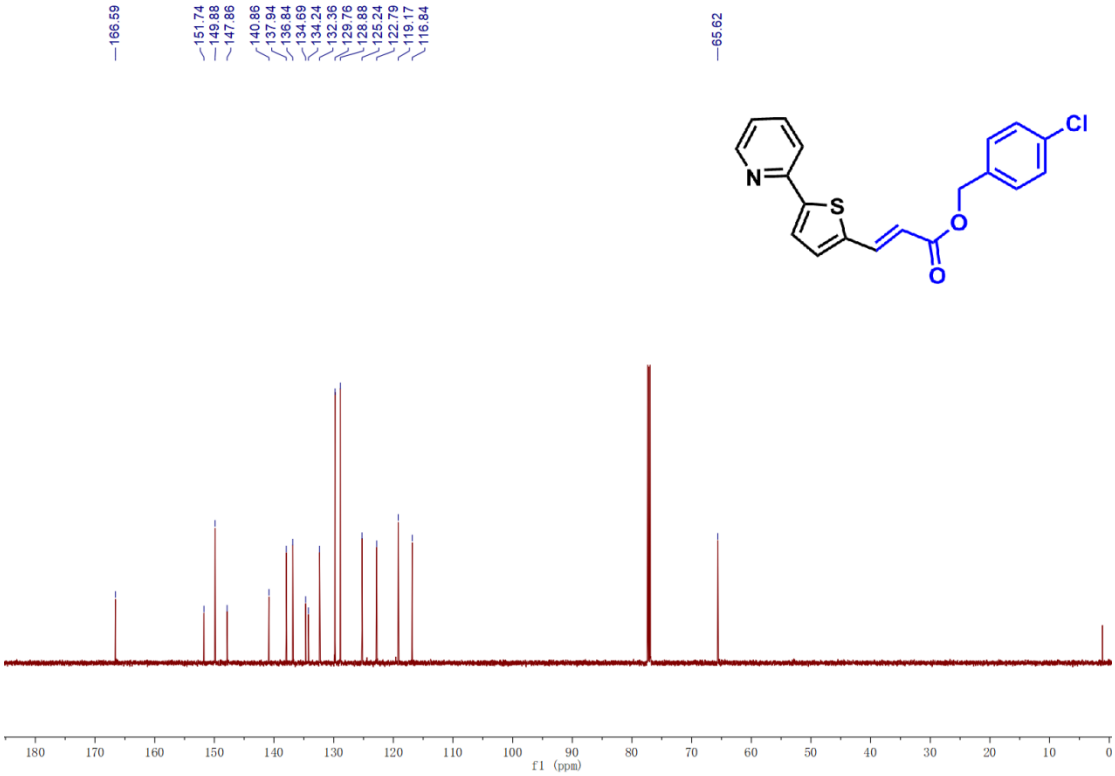
4ag | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



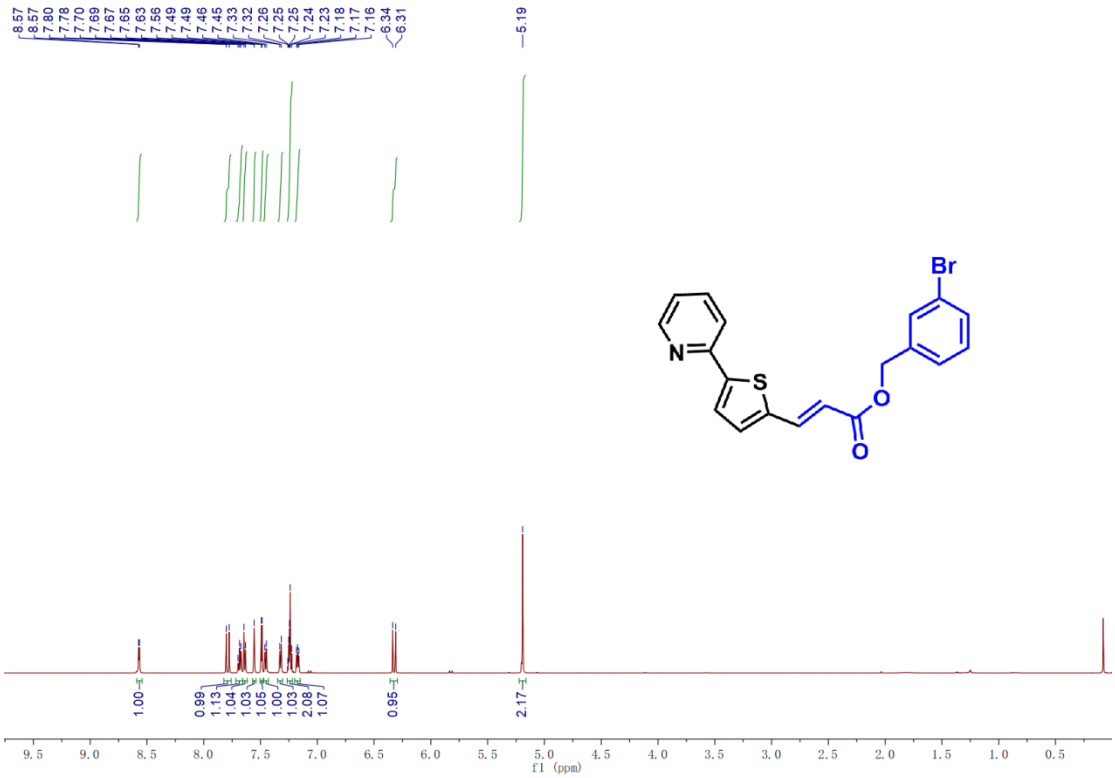
4ah | ^{1}H NMR ($CDCl_3$, 600 MHz)



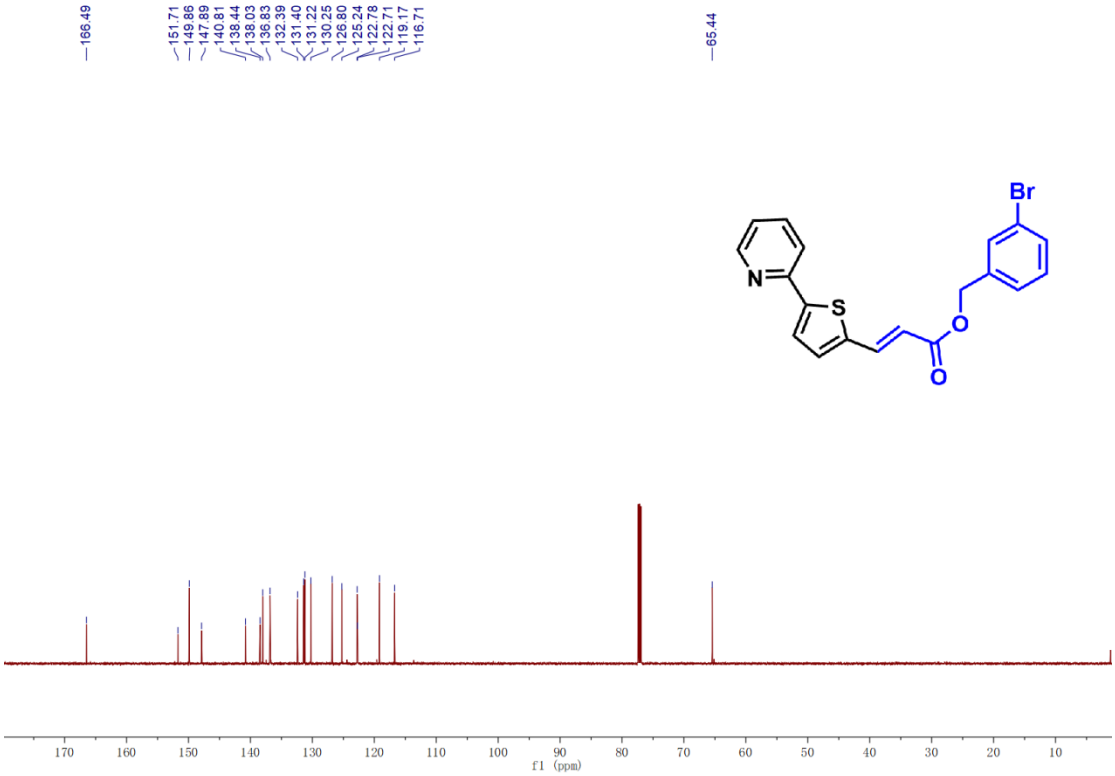
4ah | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



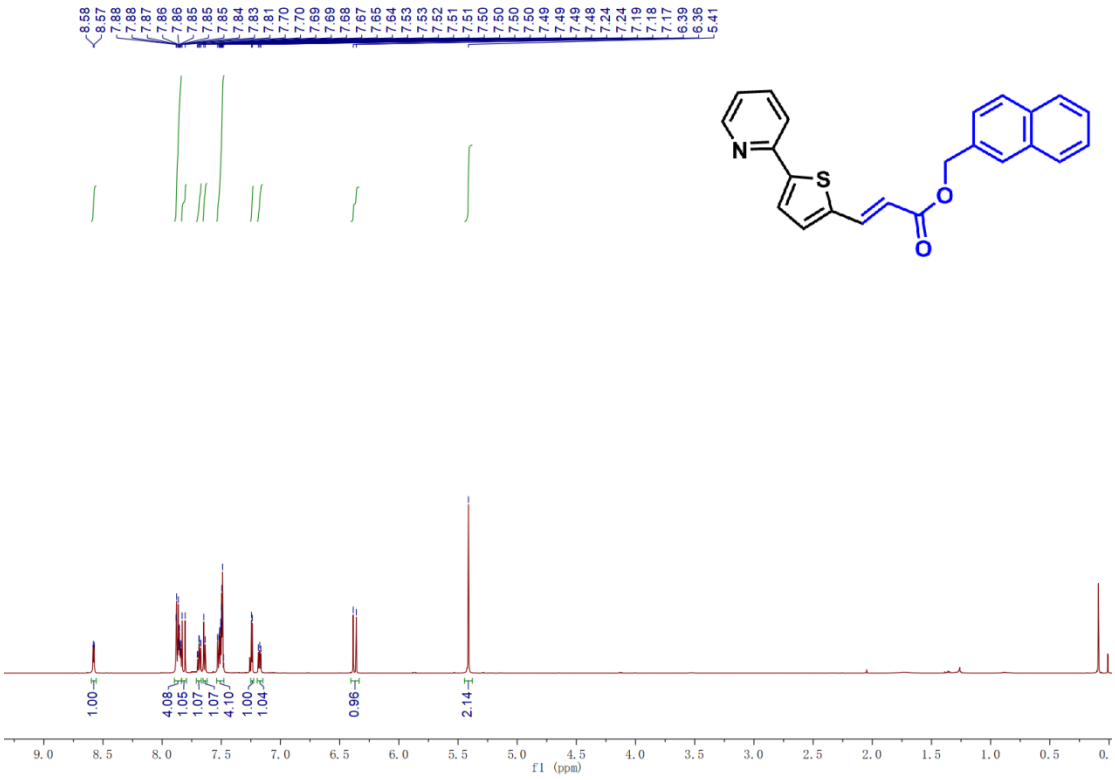
4ai | ^{1}H NMR ($CDCl_3$, 600 MHz)



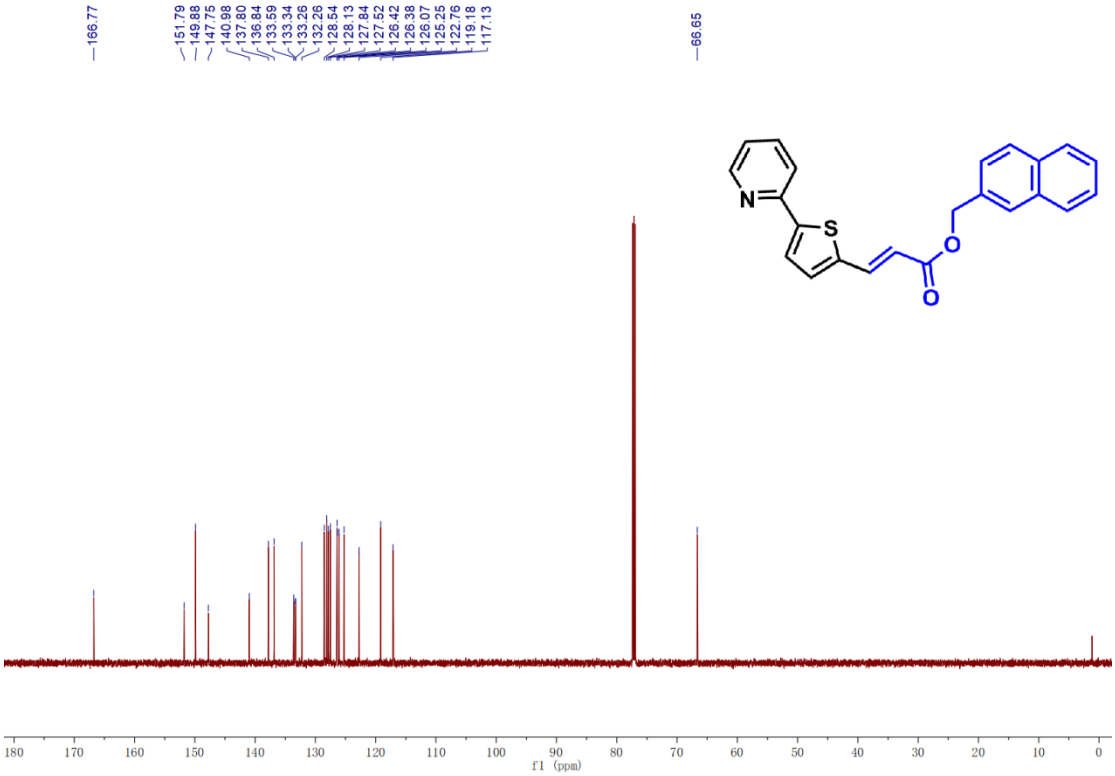
4ai | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



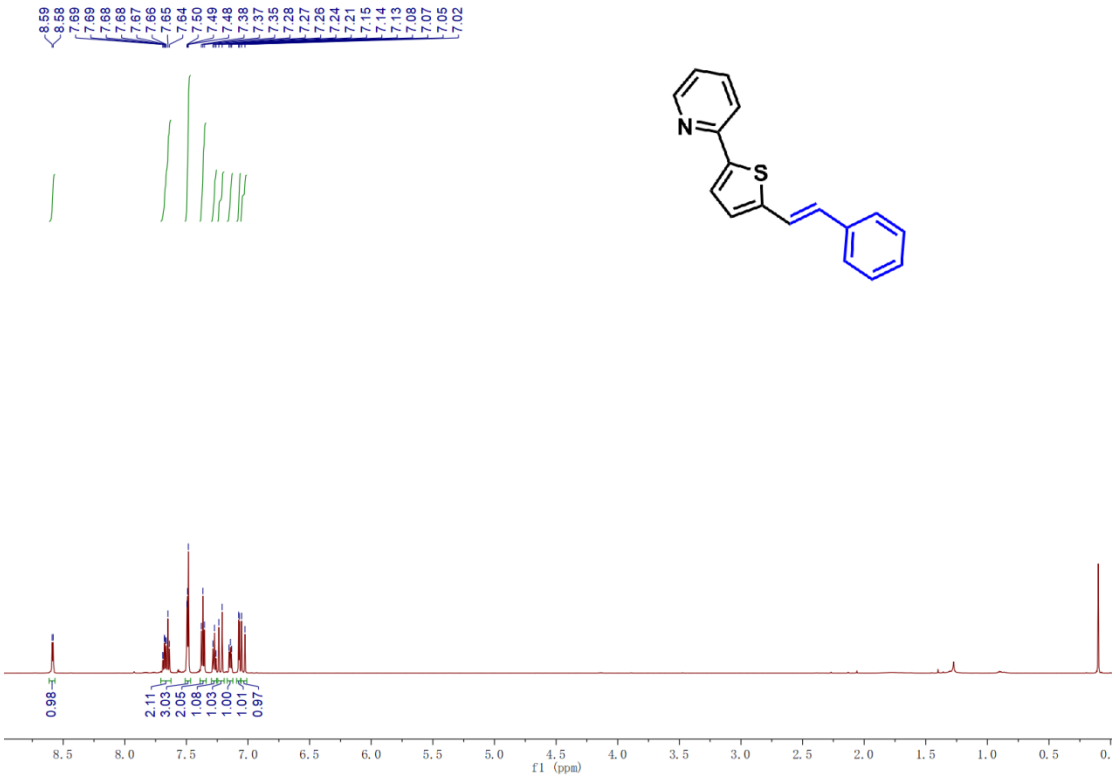
4aj | ^{1}H NMR ($CDCl_3$, 600 MHz)



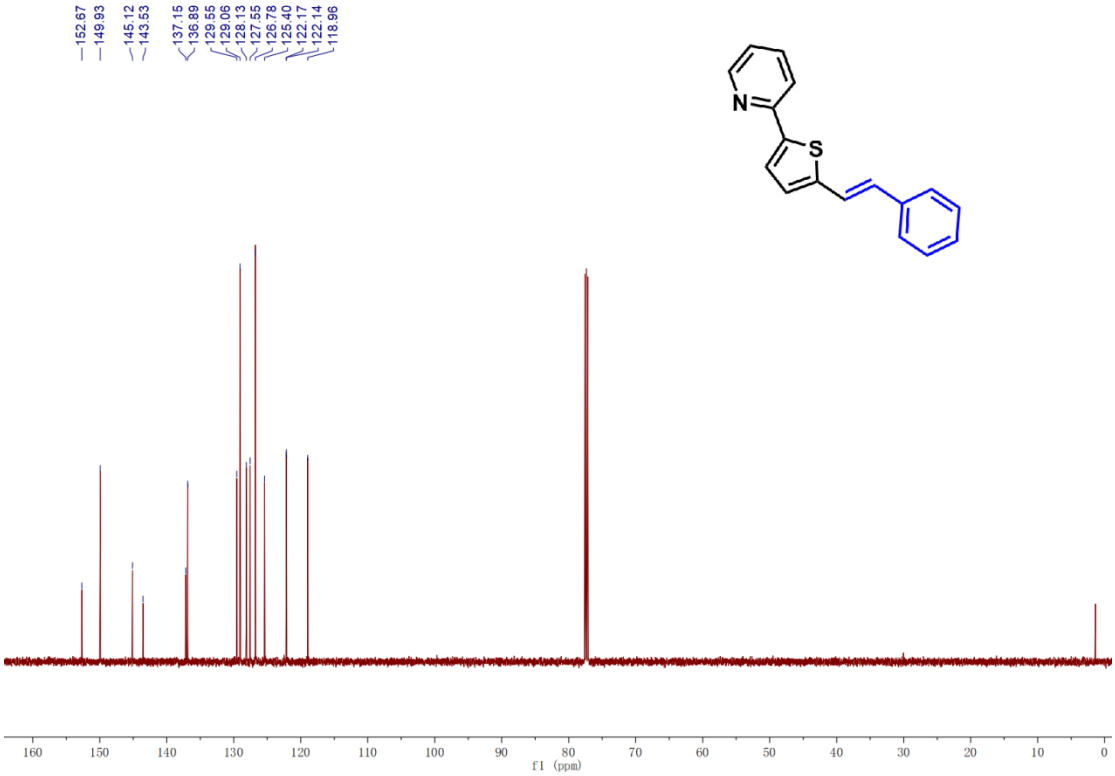
4aj | ^{13}C{^{1}H} NMR ($CDCl_3$, 151 MHz)



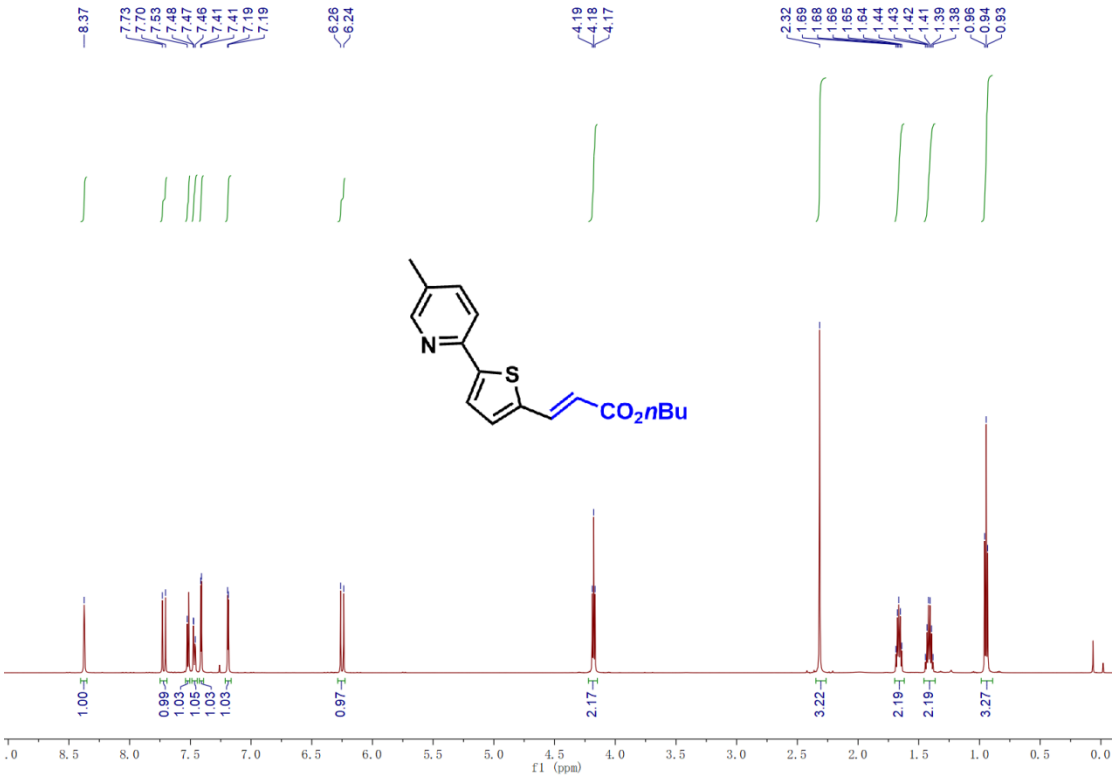
4ak | ^{1}H NMR ($CDCl_3$, 600 MHz)



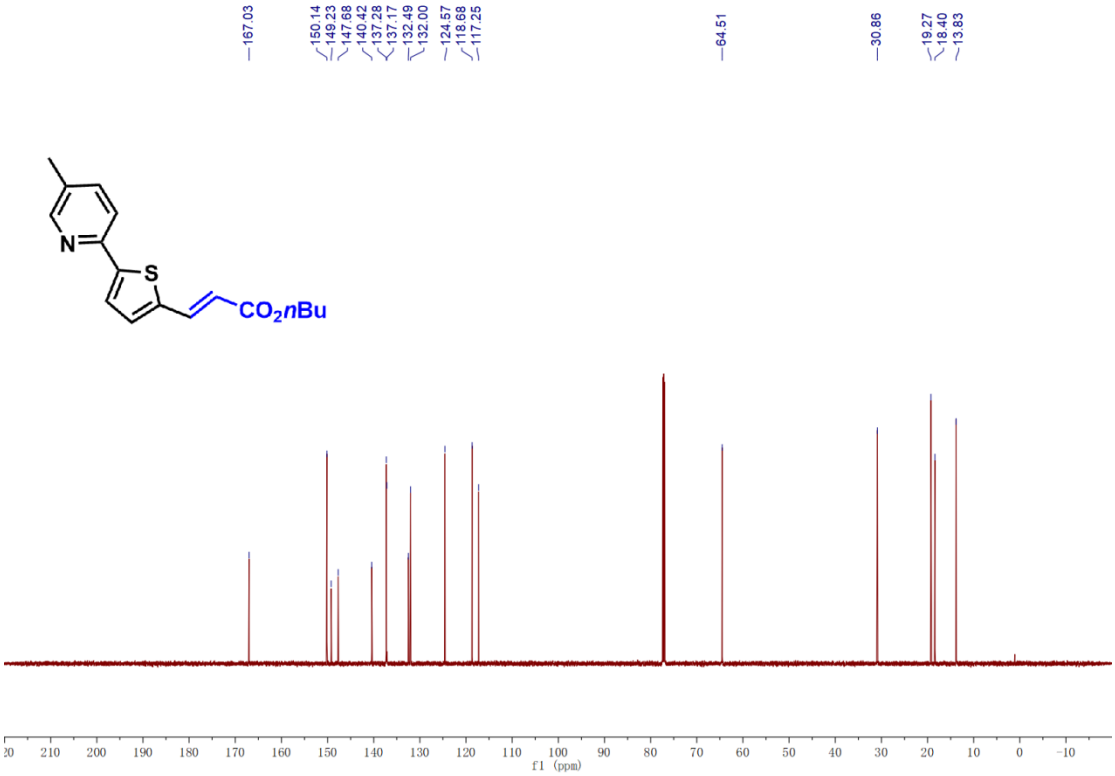
4ak | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



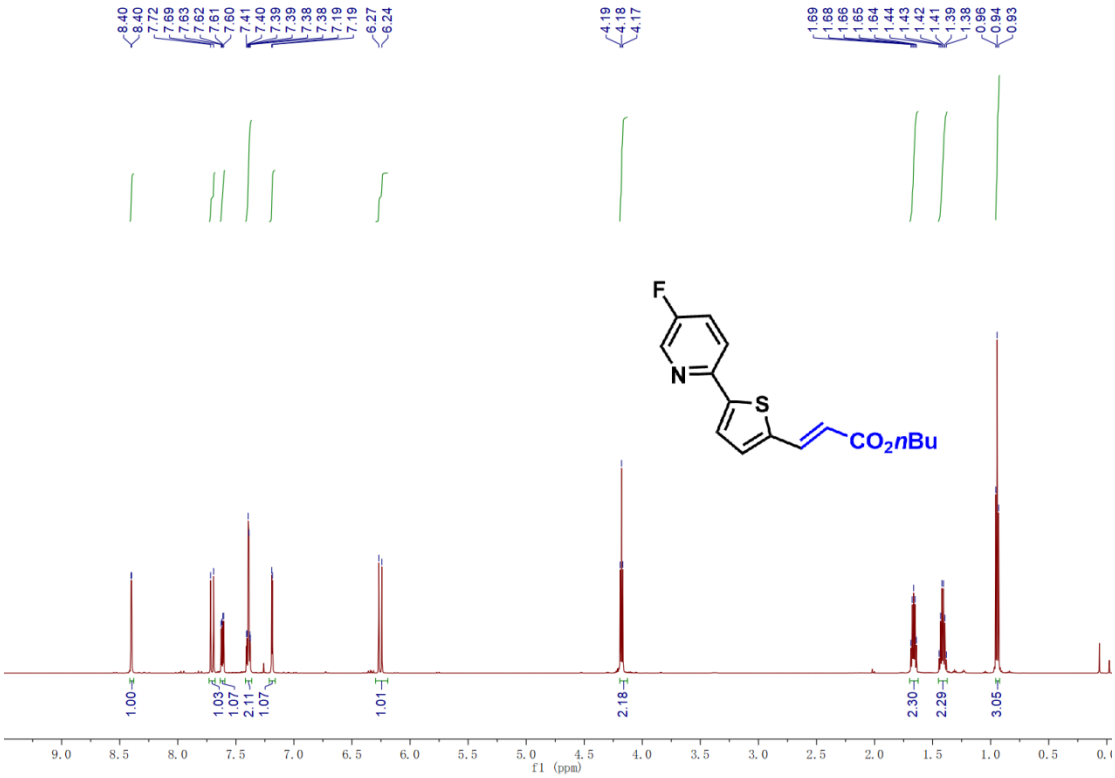
4ba | ^{1}H NMR ($CDCl_3$, 600 MHz)



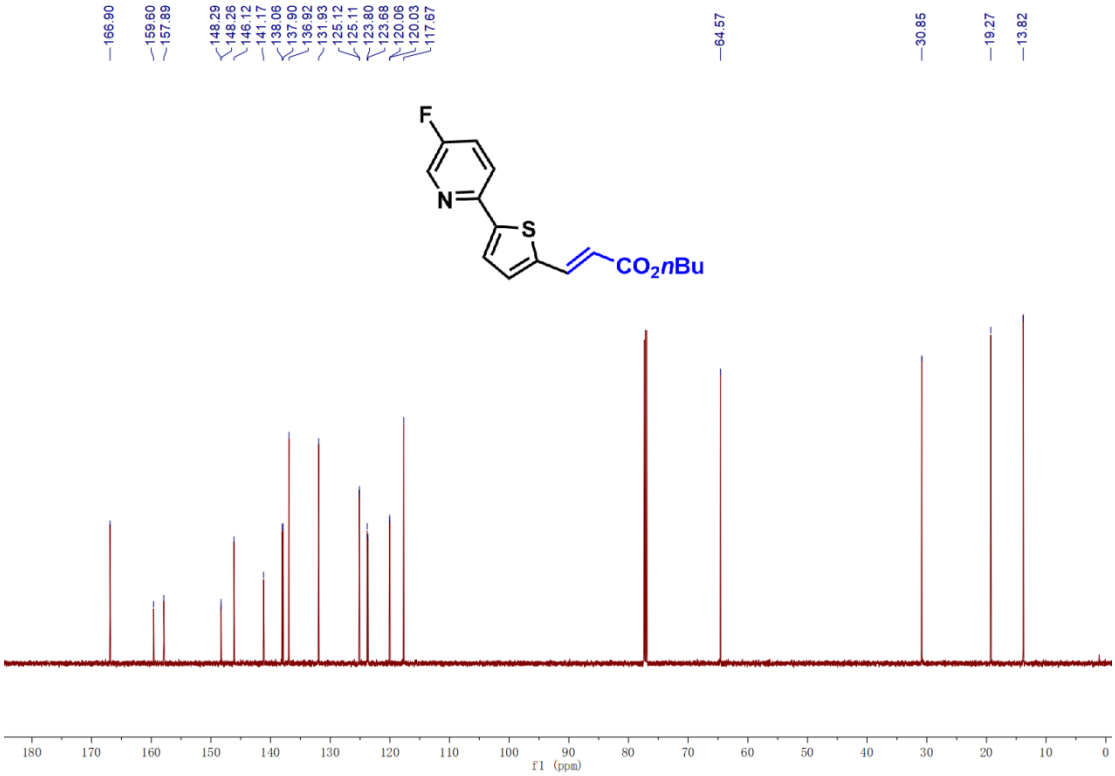
4ba | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



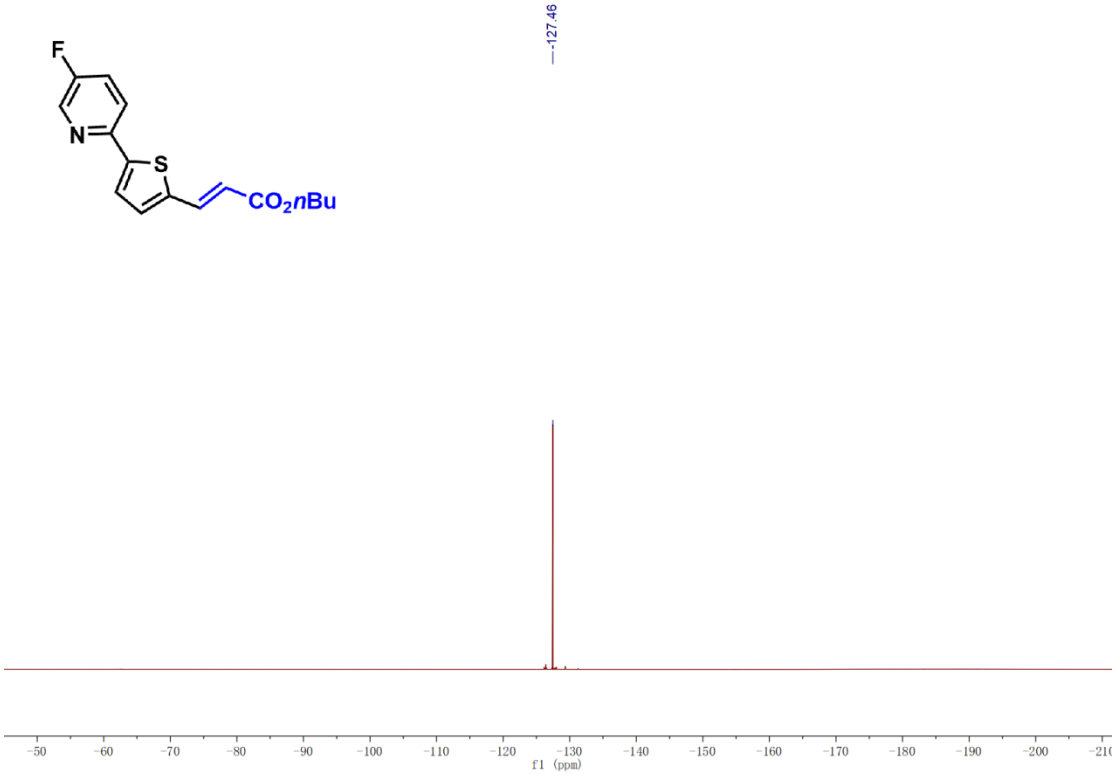
4da | ^{1}H NMR ($CDCl_3$, 600 MHz)



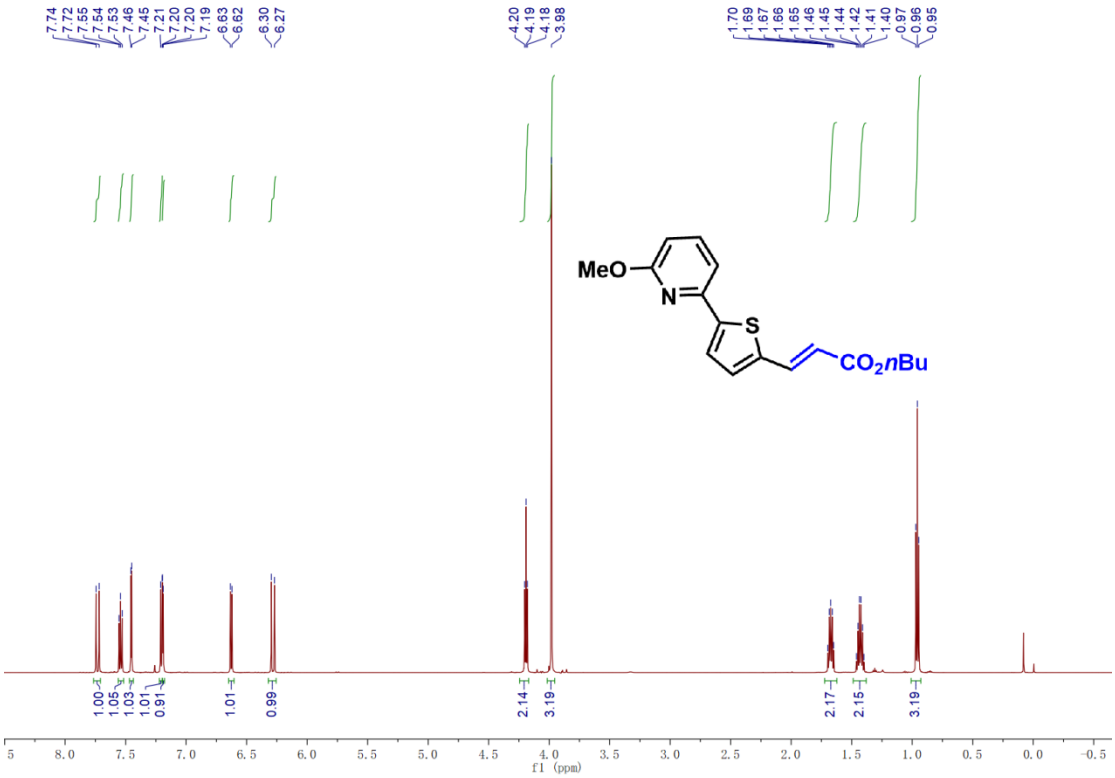
4da | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



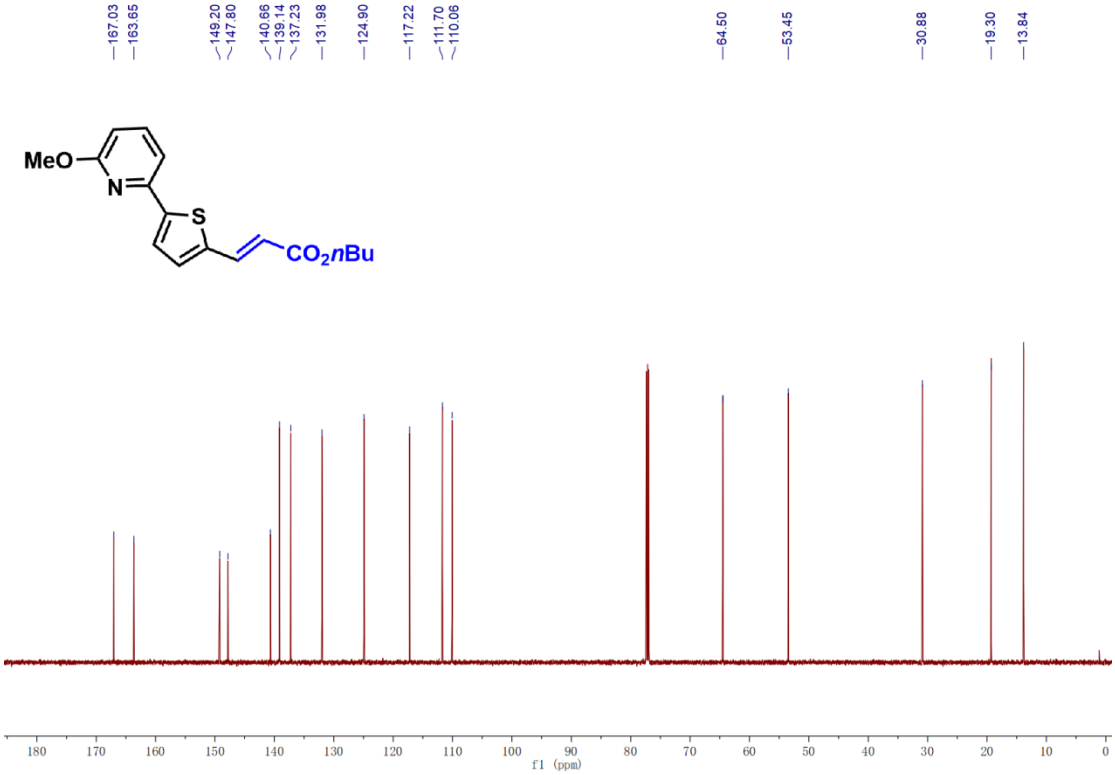
4da | $^{19}F\{^{1}H\}$ NMR ($CDCl_3$, 565 MHz)



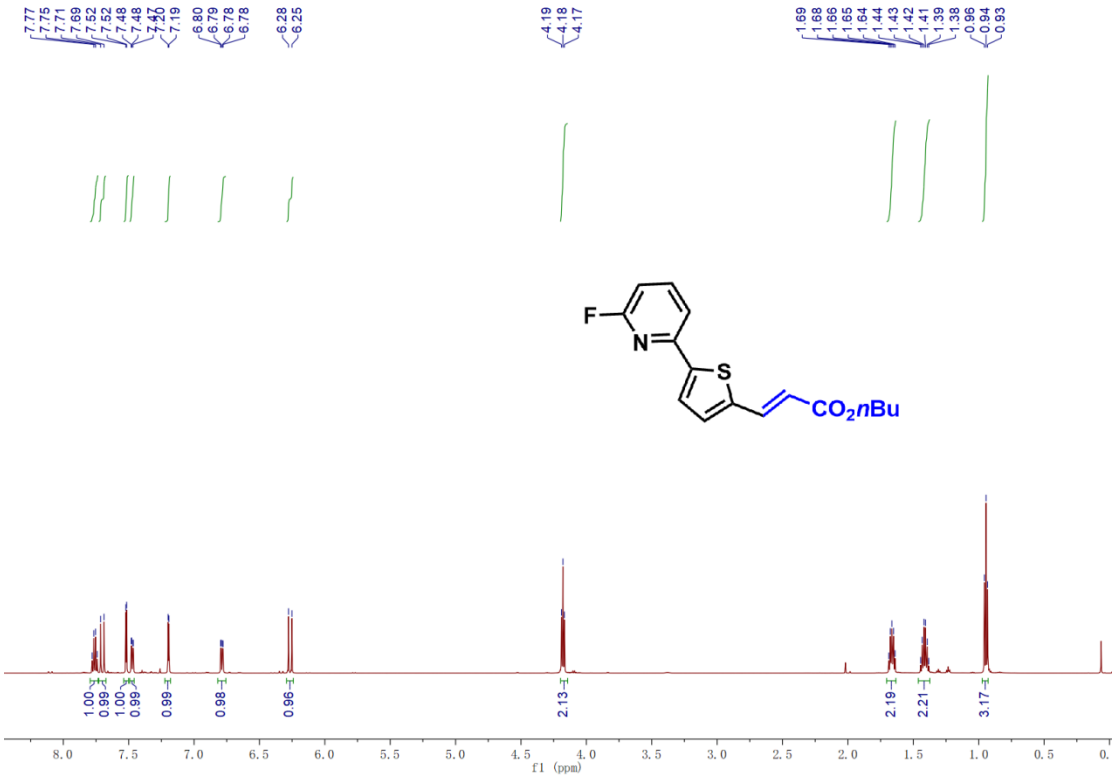
4ga | ^{1}H NMR ($CDCl_3$, 600 MHz)



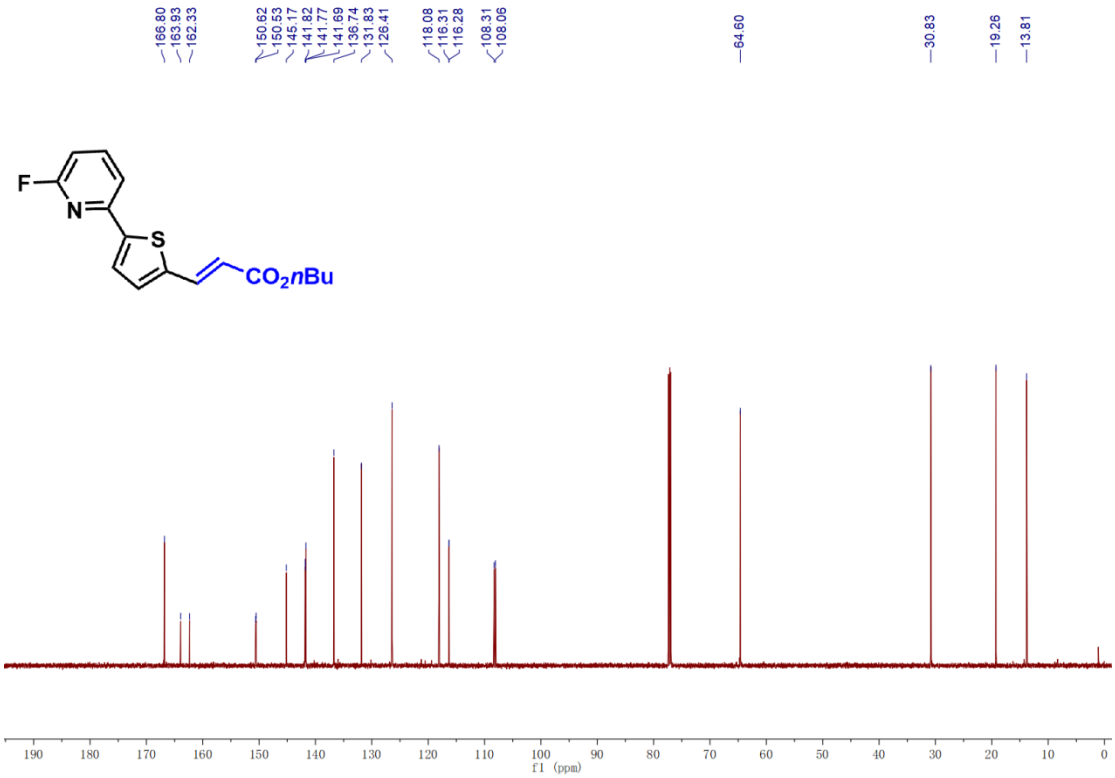
4ga | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



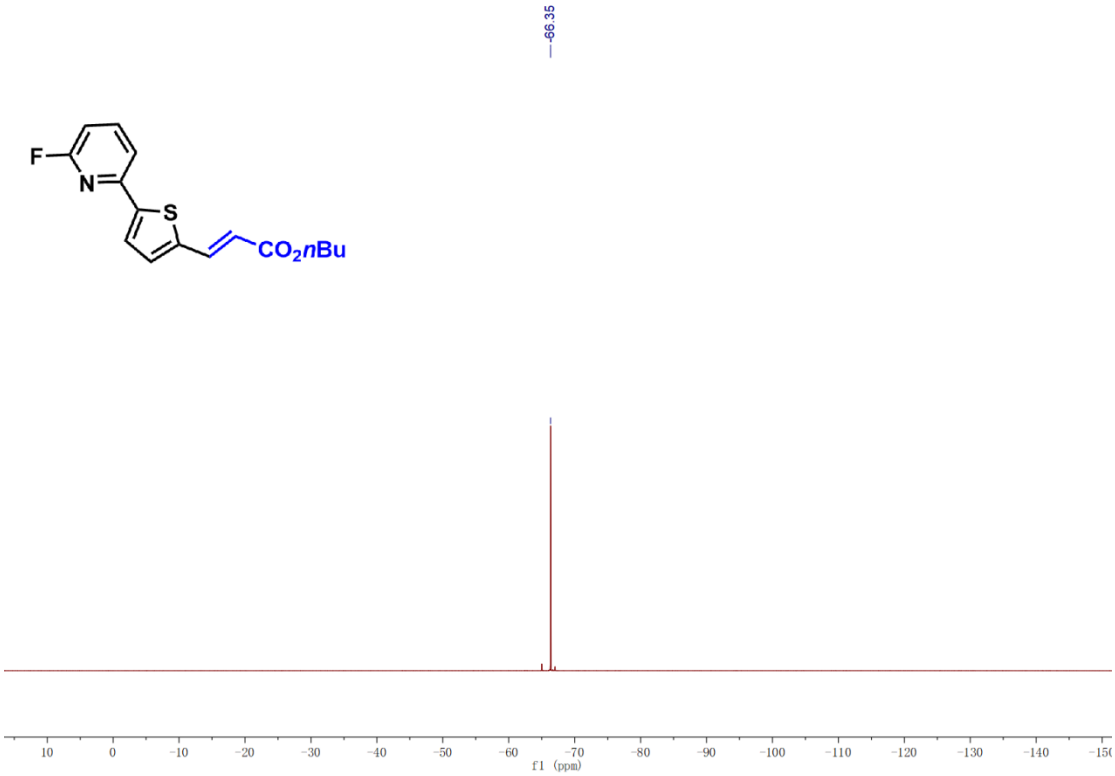
4ha | ^{1}H NMR ($CDCl_3$, 600 MHz)



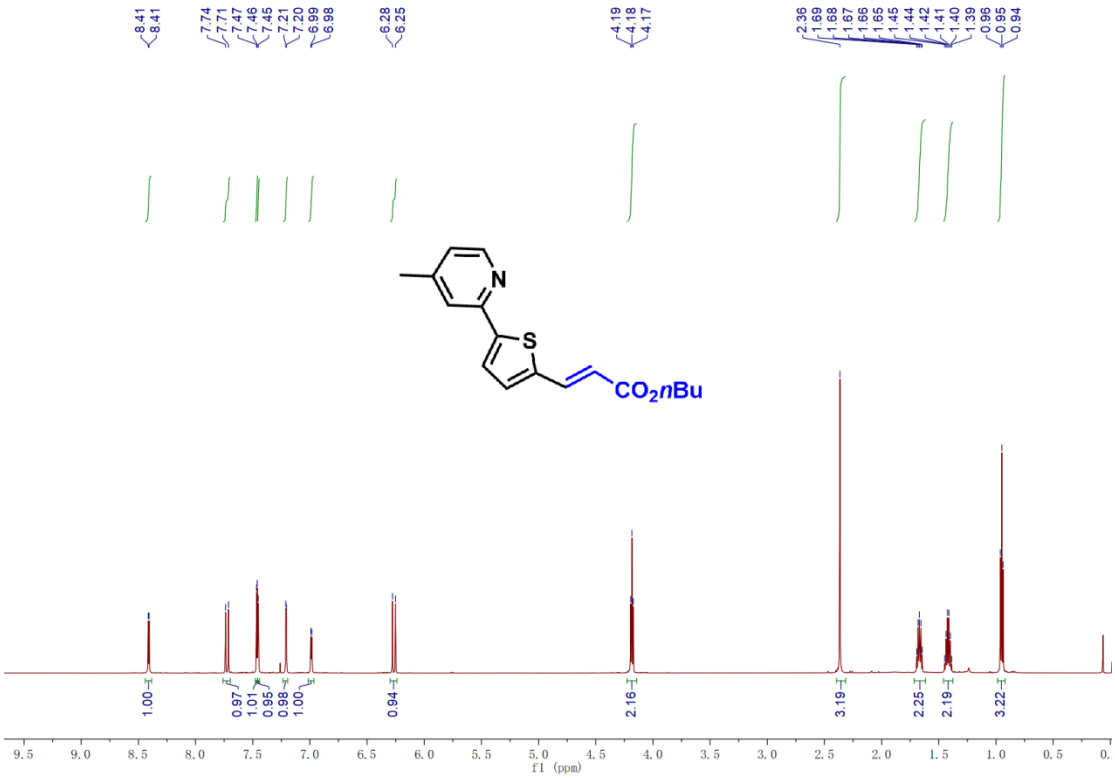
4ha | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



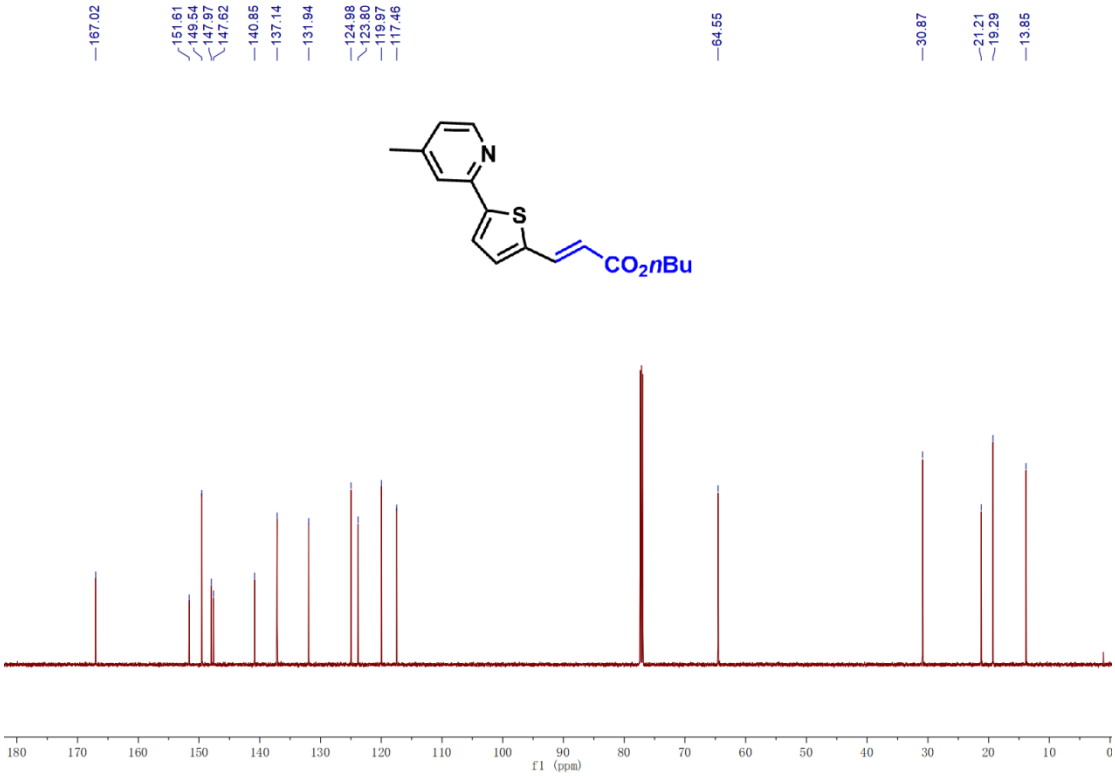
3ha | $^{19}F\{^{1}H\}$ NMR ($CDCl_3$, 565 MHz)



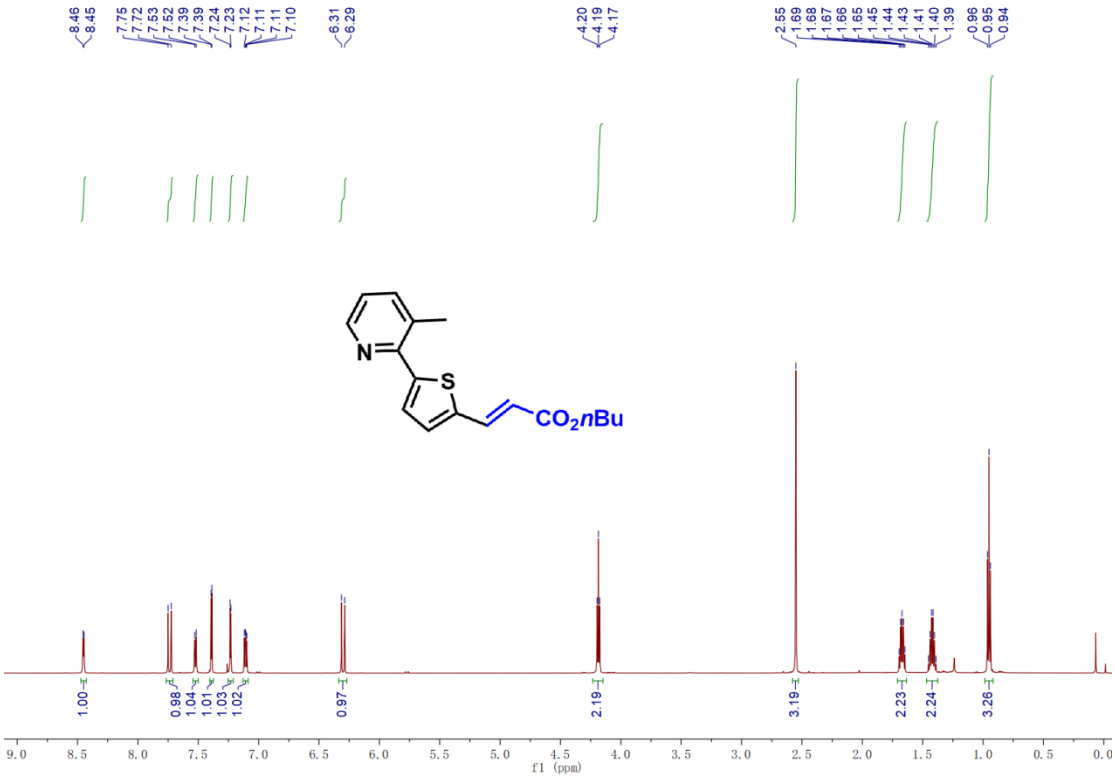
4ia | ^{1}H NMR ($CDCl_3$, 600 MHz)



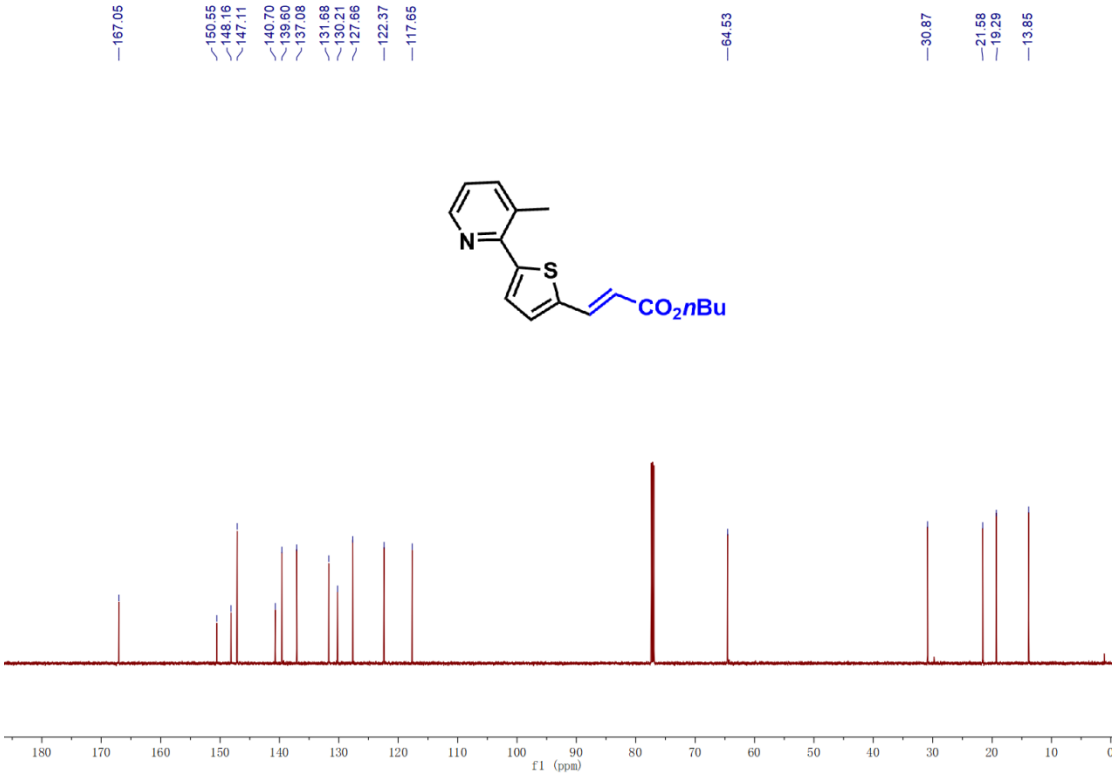
4ia | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



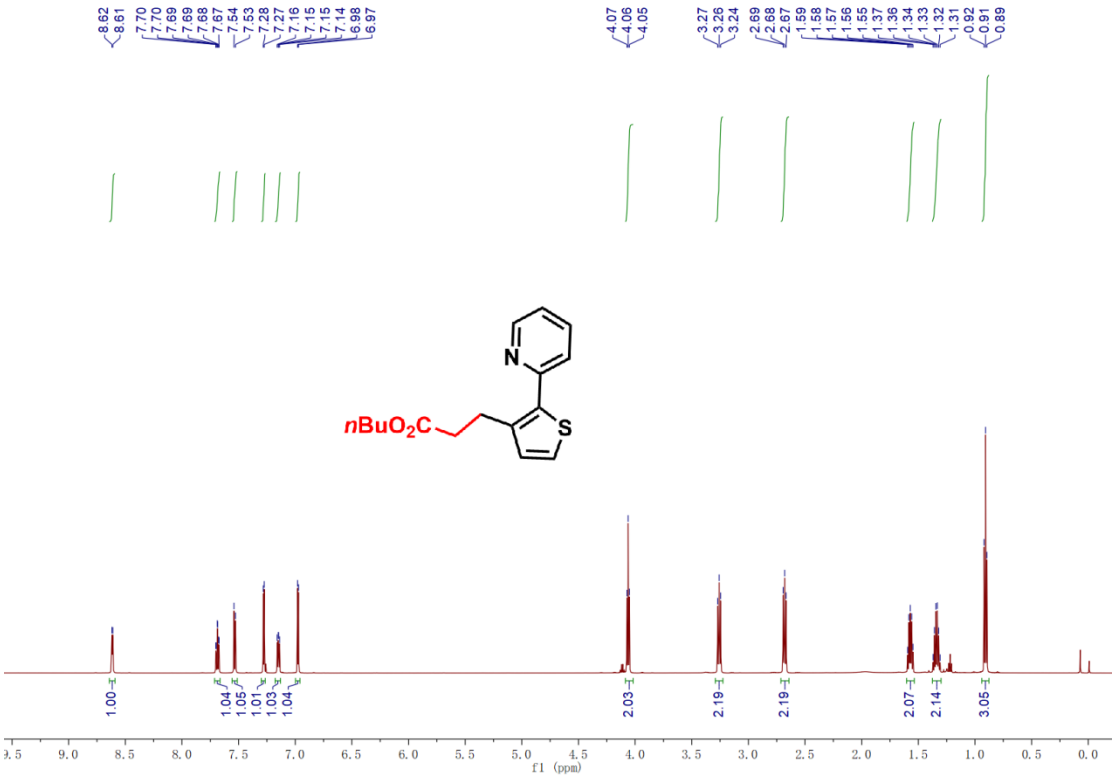
4ja | ^{1}H NMR ($CDCl_3$, 600 MHz)



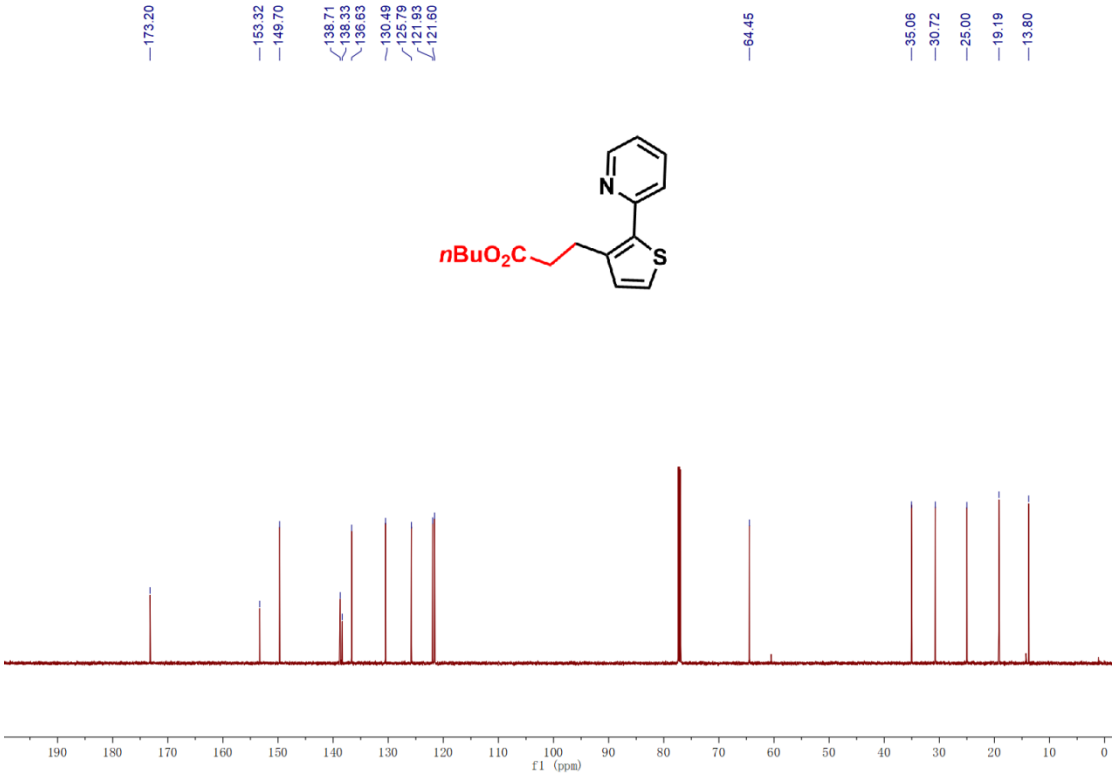
4ja | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



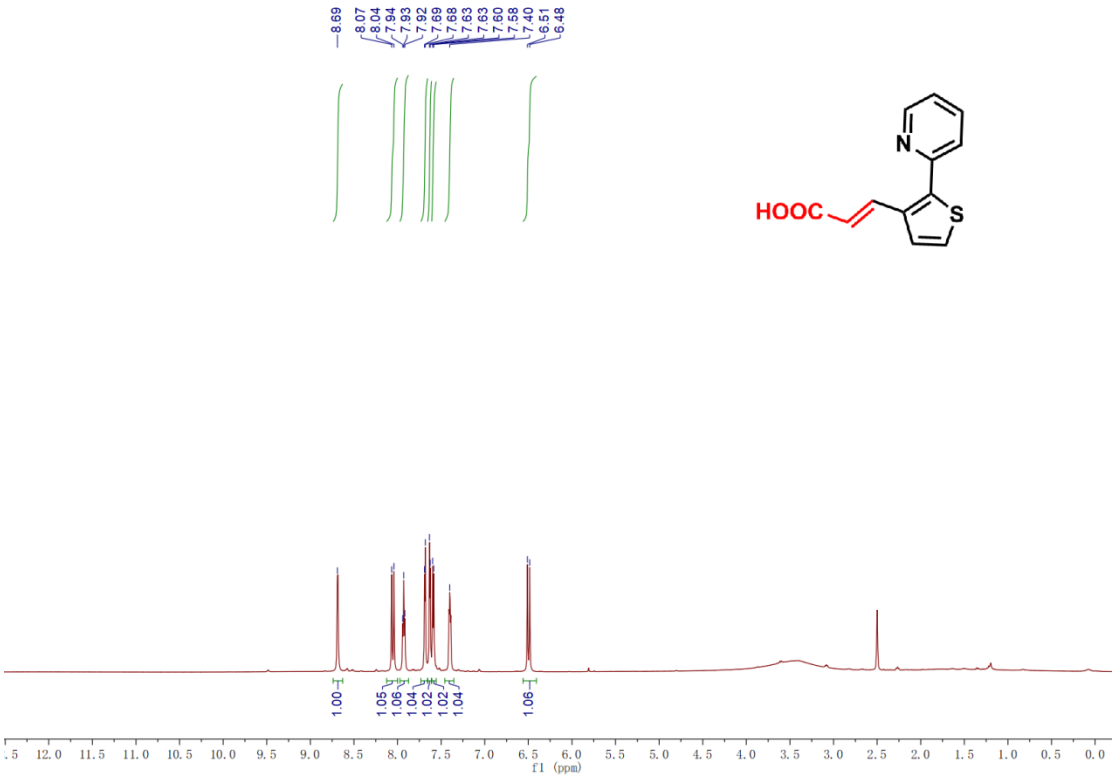
5aa | ^{1}H NMR ($CDCl_3$, 600 MHz)



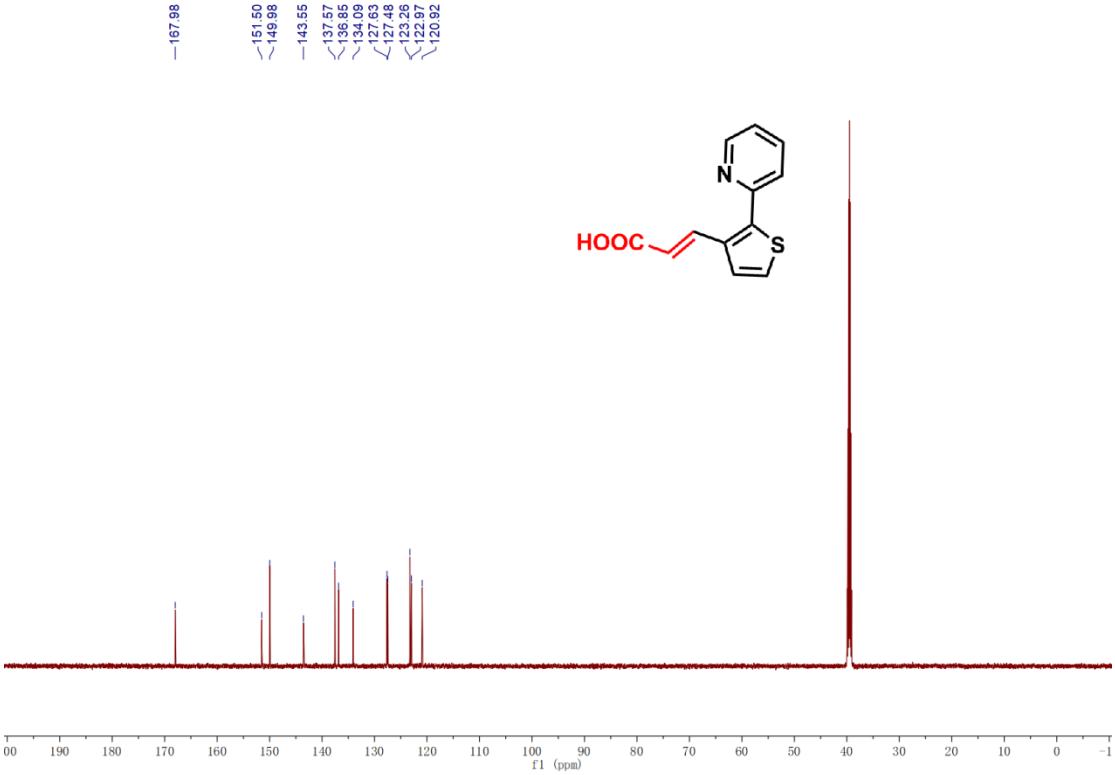
5aa | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



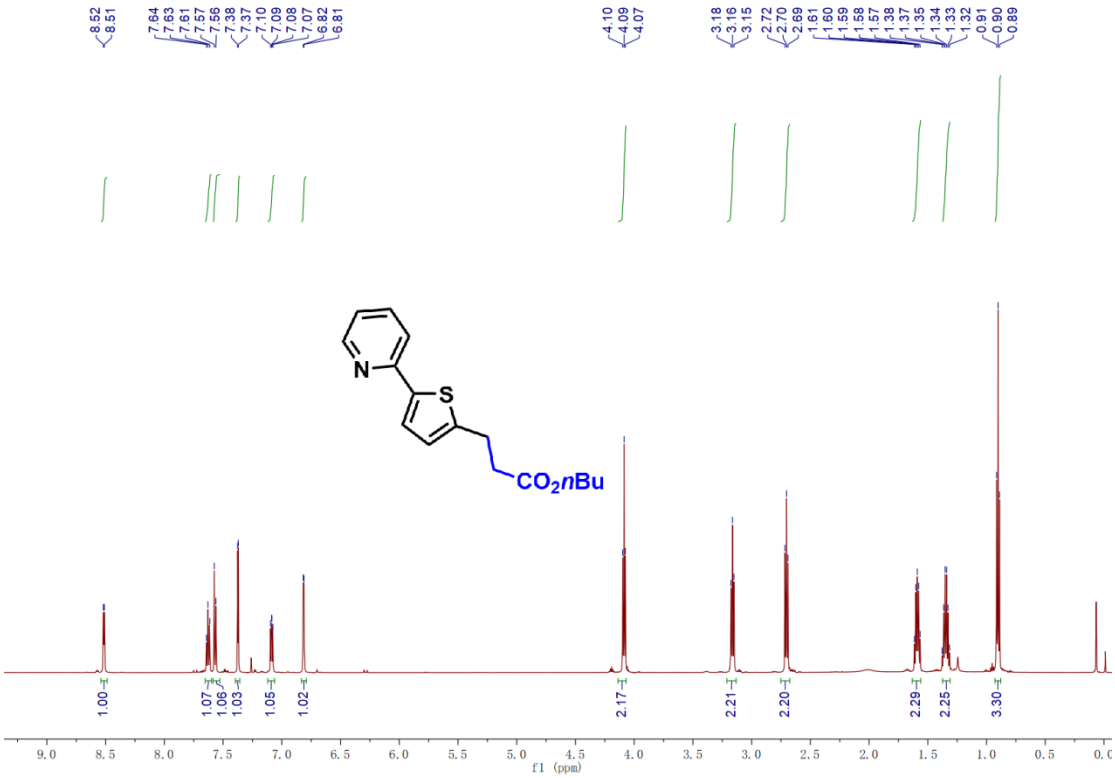
6aa | ^{1}H NMR (DMSO-d_6, 600 MHz)



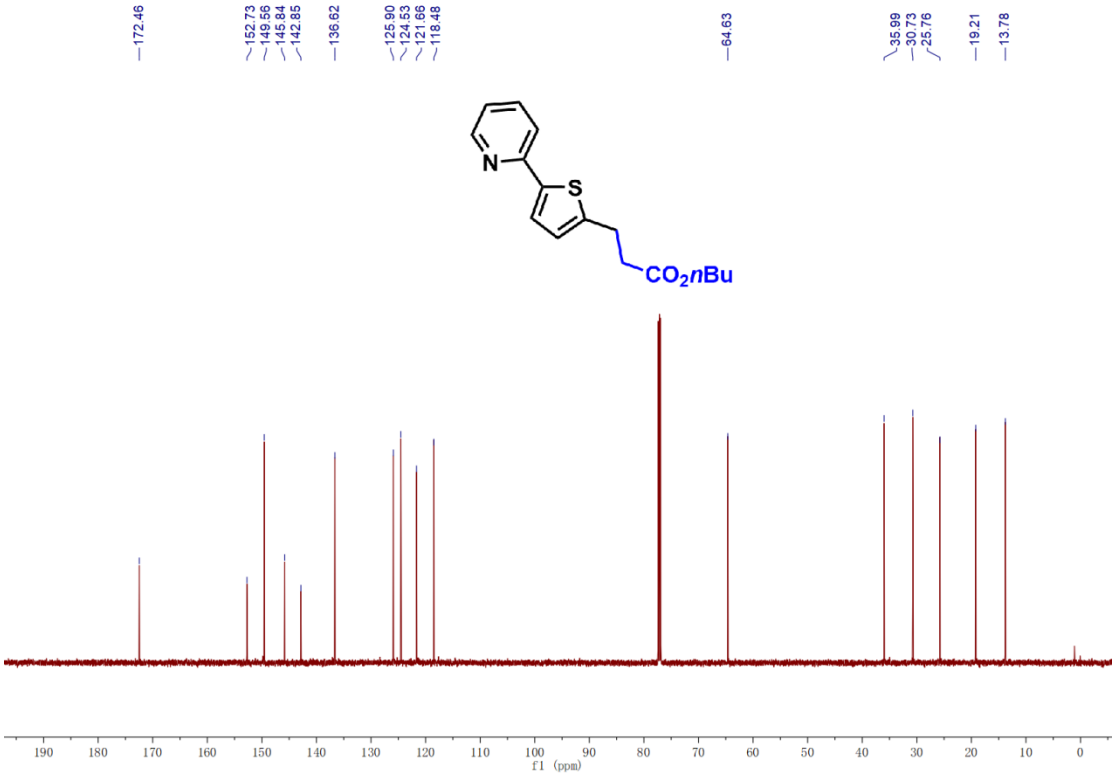
6aa | ^{13}C{^{1}H} NMR (DMSO-d_6, 151 MHz)



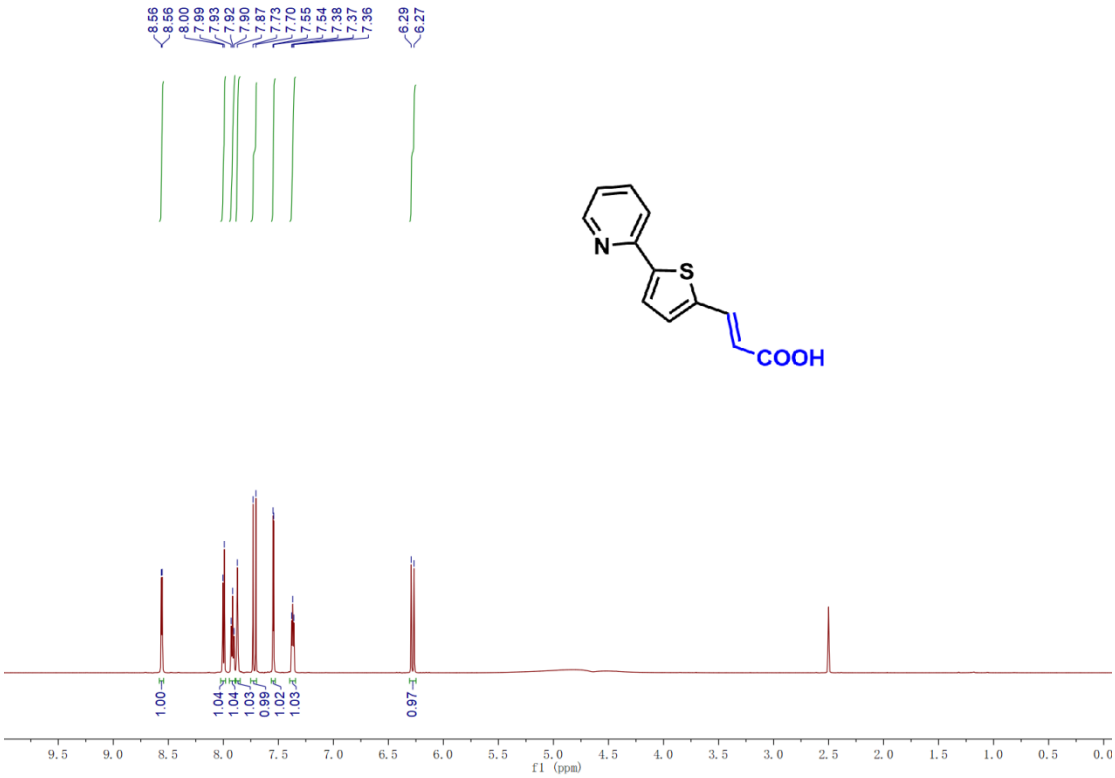
7aa | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



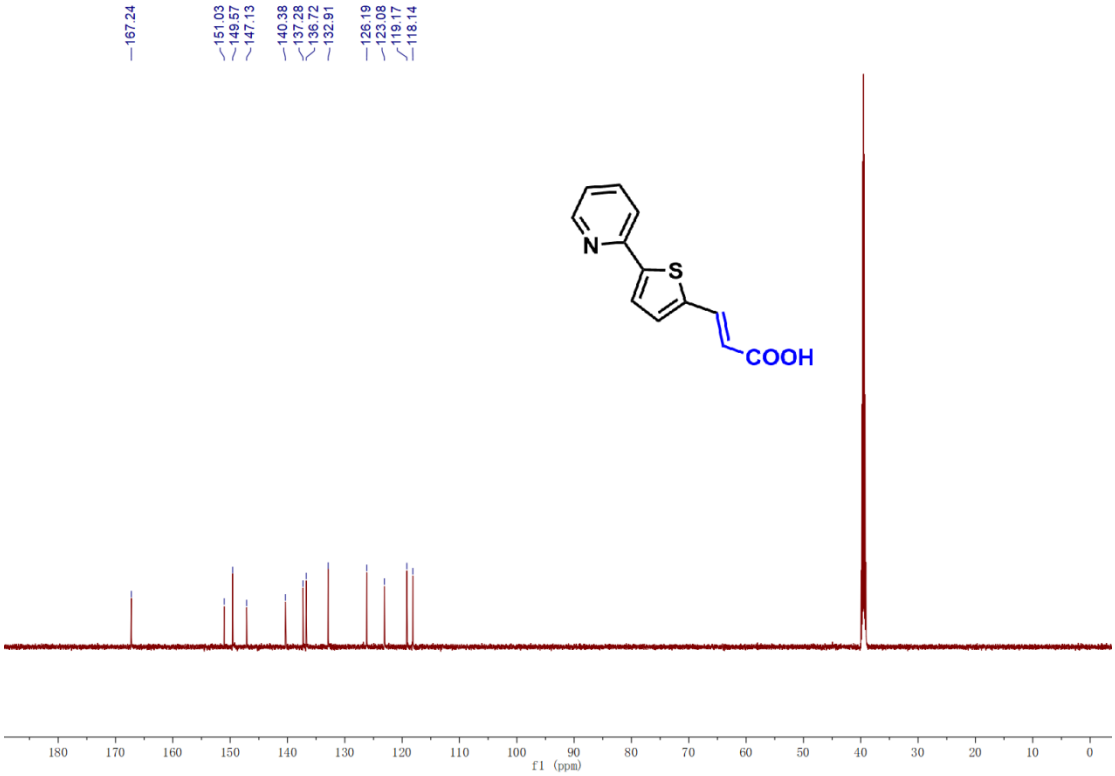
7aa | ^{1}H NMR ($CDCl_3$, 600 MHz)



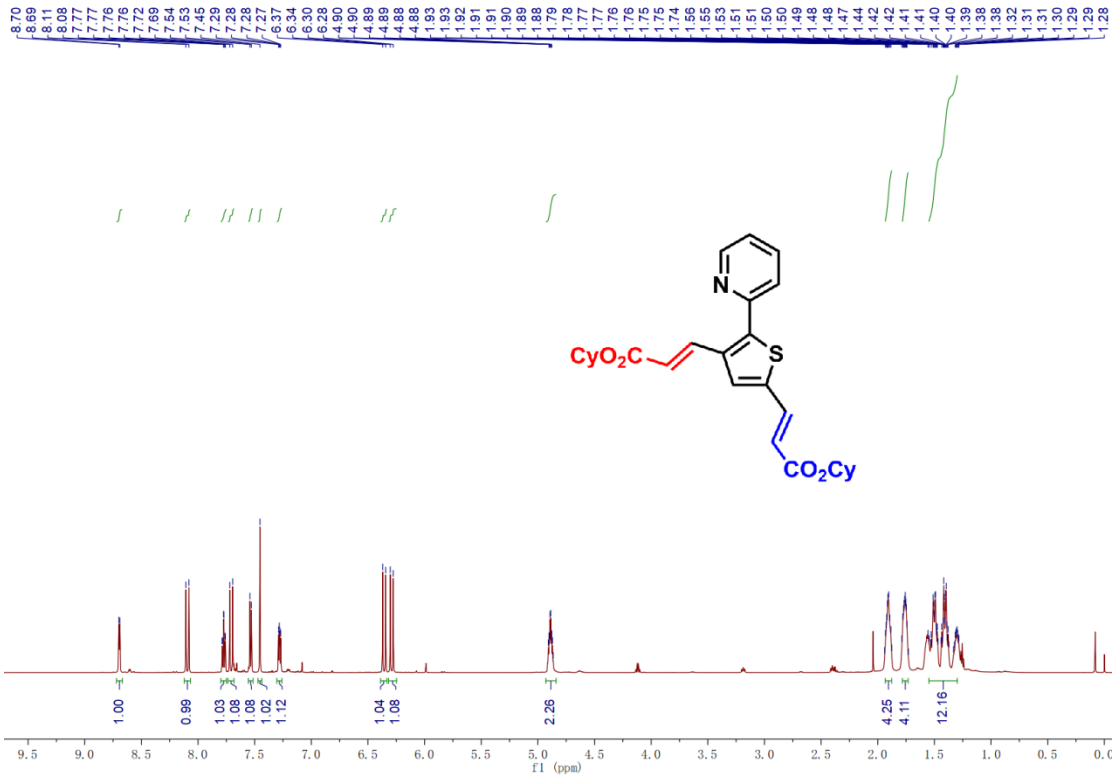
8aa | $^{13}C\{^{1}H\}$ NMR (DMSO-d_6, 151 MHz)



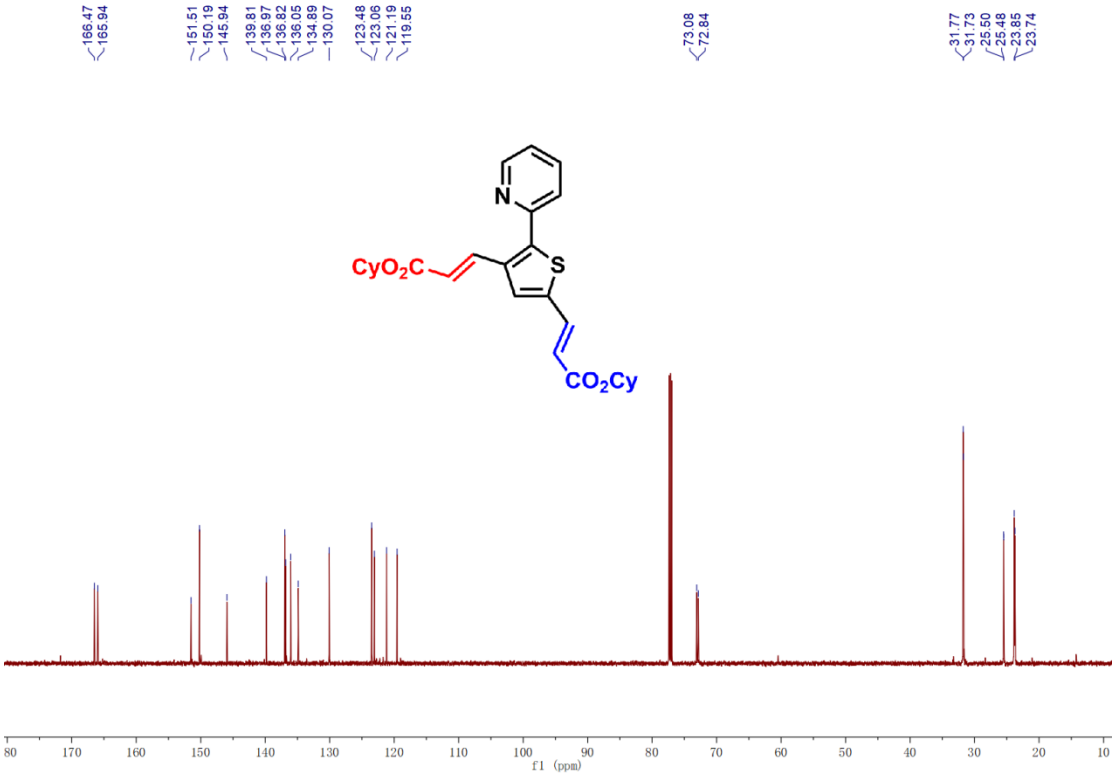
8aa | ^{1}H NMR (DMSO-d_6, 600 MHz)



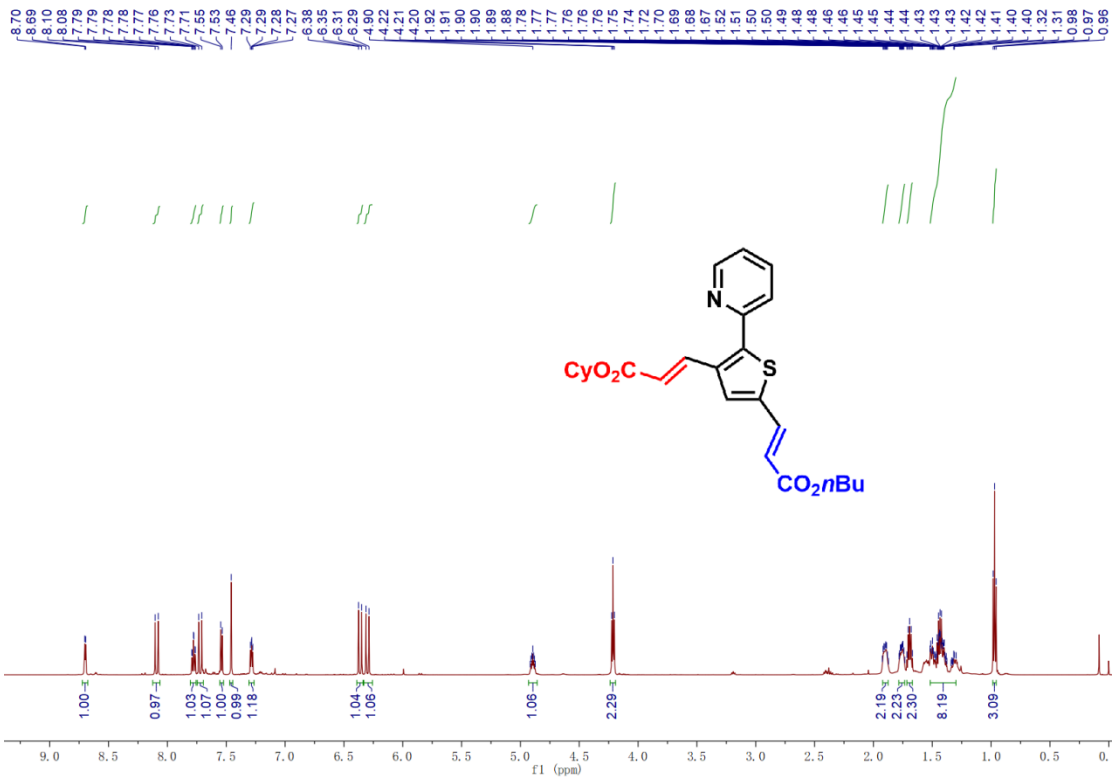
9aee | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



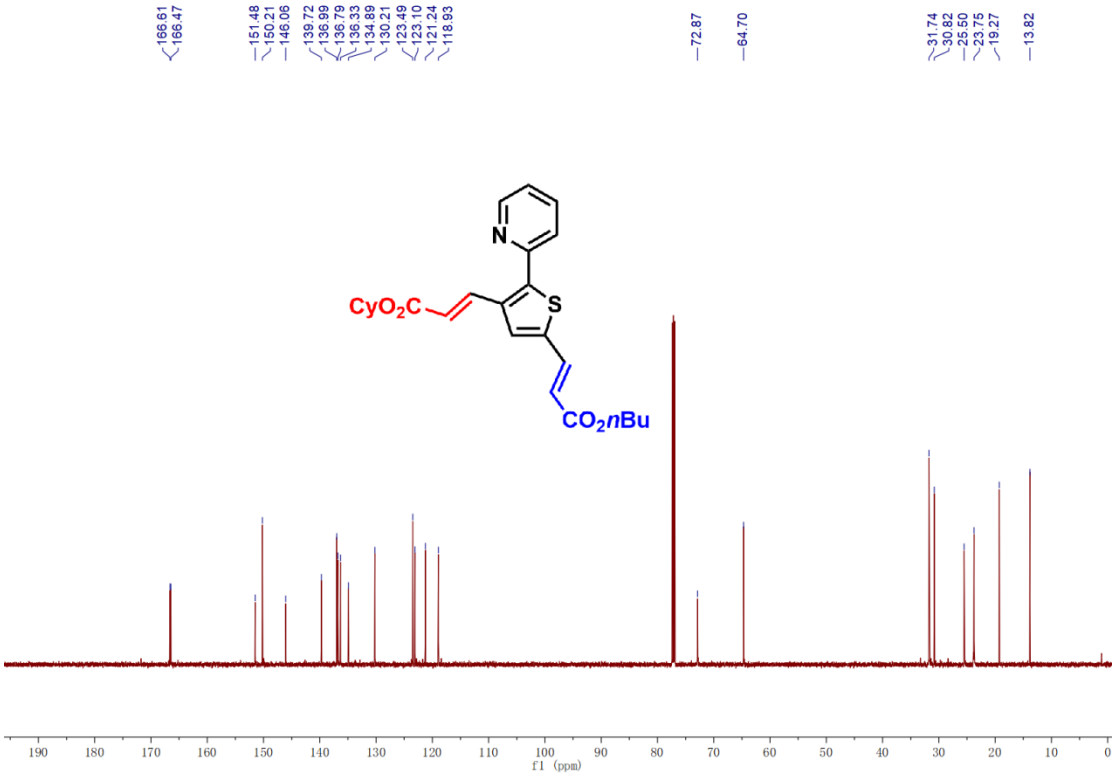
9aee | ^{1}H NMR ($CDCl_3$, 600 MHz)



9aea | ^{1}H NMR ($CDCl_3$, 600 MHz)



9aea | $^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 151 MHz)



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