Supporting Information

Synthesis of Five-Membered Cyclic Nitrones Based on the Lewis Acid-Catalysed [3+2]-Annulation Reaction of Donor-Acceptor Cyclopropanes with 1,4,2-Dioxazoles

Zhe-Hao Wang, Huan-Huan Zhang*, Peng-Fei Xu and Yong-Chun Luo*

State Key Laboratory of Applied Organic Chemistry, College of Chemistry and Chemical Engineering, Lanzhou University, Lanzhou 730000, P. R. China

E-mail：zhanghh@lzu.edu.cn; luoych@lzu.edu.cn

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1. General information

Chemicals and solvents were either purchased from commercial suppliers or purified by standard techniques. Analytical thin-layer chromatography (TLC) was performed on silica gel plates with F-254 indicator and compounds were visualized by irradiation with UV light. Flash chromatography was carried out utilizing silica gel 200-300 mesh. The ^{1}H NMR spectra was recorded on 400 MHz spectrometers, and the ^{13}C NMR was recorded on 100 MHz spectrometer. The spectra were recorded in $CDCl_3$ at room temperature. ^{1}H and ^{13}CNMR chemical shifts are reported in ppm relative to either the residual solvent peak (^{13}C) (δ = 77.00 ppm) or TMS (^{1}H) (δ = 0 ppm as an internal standard. Data for ^{1}H NMR are reported as follows: chemical shift (δ ppm), multiplicity (s = singlet, d = doublet, t = triplet, m = multiplet, br = broad), integration, coupling constant (Hz) and assignment. HRMS were performed on FT–ICRMS mass instrument (ESI). Enantiomeric excess values were determined by HPLC with a CHIRALPAK OD-3 column with *i*-PrOH and *n*-hexane.

2. Experimental procedures

Cyclopropanes used in this work were prepared according to the methods reported in literature.[1] Dioxazoles were synthesized according to the literature.[2,3] spectral data of **6h** matched that reported in the literature.[4]

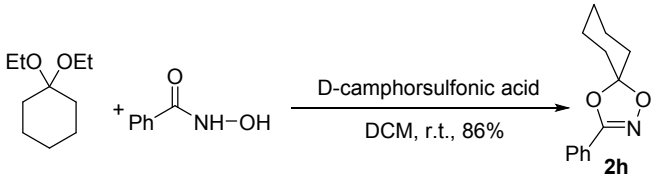
1. M. Skvorcova, L. Grigorjeva and A. Jirgensons, *Org. Lett*., 2015, **17**, 2902–2904.

2. M. Chen, N. Sun, H. Chen and Y. Liu, *Chem. Commun.,* 2016,**52**, 6324-6327.

3. M. Couturier, L. Tucker, C. Proulx, G. Boucher, P. Dubé, B. M. Andresen and A. Ghosh, *J. Org. Chem.*, 2002, **67**, 4833–4838.

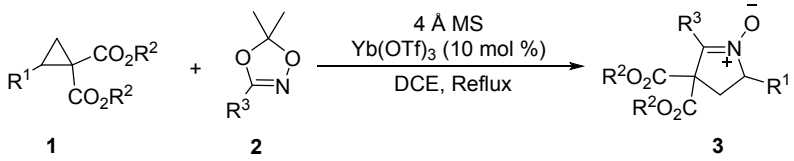
4. T. Shiba, D. kuroda, T. Kurahashi and S. Matsubara, *Synlett*, 2014, **25**, 2005–2008.

2.1 Procedure for the synthesis of dioxazole 2h



1,1-Diethoxycyclohexane[5] (7.0 mmol, 1.20 g) and D-camphorsulfonic acid (2.3 mmol, 0.53 g) were added to the solution of N-hydroxybenzamide (2.7 mmol, 0.32 g) in DCM (50 mL). The reaction mixture was stirred at room temperature. When N-hydroxybenzamide was fully exhausted (monitored by TLC), the reaction was quenched with saturated $NaHCO_3$ solution. Then the reaction mixture was extracted with dichloromethane, and the combined organic layers was dried over anhydrous Na_2SO_4. After removing the solvent, the residue was purified by column chromatography on silica gel (petroleum ether/ethyl acetate, V:V = 15:1) to afford the dioxazole **2h** as a colorless oil in 86% isolated yield。

2.2 General procedure for the synthesis of cyclic nitrone 3



The 4 Å MS (200 mg), $Yb(OTf)_3$ (12.4 mg, 0.02 mmol, 0.10 equiv), D-A cyclopropane **1** (0.24 mmol, 1.20 equiv), dioxazole **2** (0.20 mmol, 1.00 equiv) and 1,2-dichloroethane (1 mL) were sequentially added into a dry flask under argon atmosphere. Then, the reaction mixture was stirred and heated to reflux. Upon completion of the reaction (monitored by TLC), the solvent was removed under reduced pressure. Purification of the residue by column chromatography on silica gel (petroleum ether/ethyl acetate) offered the corresponding nitrone **3**.

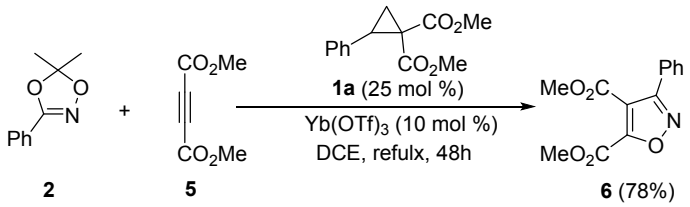
5. D. B. G. Williams and M. C. Lawton, *Green Chem.,* 2008, **10**, 914-917.

2.3 Procedure for the [3+2]-annulation reaction of cyclic nitrone 3a with dimethyl acetylenedicarboxylate

3a **5** **7**

Nitrone **3a** (0.6 mmol, 211.8 mg) was mixed with dimethyl acetylenedicarboxylate **5** (1.8 mmol, 255.8 mg) in 1,2-dichloroethane (1 mL). The reaction mixture was stirred at 60 °C until nitrone **3a** was fully exhausted (monitored by TLC). After removal the solvent, the residue was purified by silica gel chromatography (petroleum ether/ethyl acetate, V:V = 3:1) to give the product **7** (24.8 mg) in 8% yield.

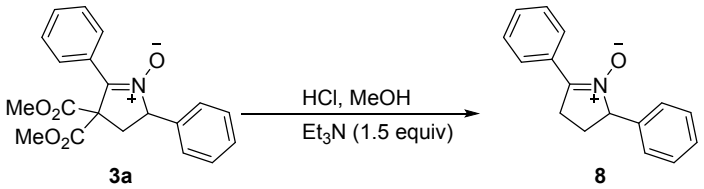
2.4 Procedure for the Lewis acid/D-A cyclopropane co-catalysed annulation reactions of dimethyl acetylenedicarboxylate with 1,2,4-dioxazole.



2 **5** **6** (78%)

The 4 Å MS (200 mg), $Yb(OTf)_3$ (25 mg, 0.04 mmol, 0.10 equiv), D-A cyclopropane **1** (24 mg, 0.1 mmol, 0.25 equiv), dioxazole **2** (71 mg, 0.4 mmol, 1.00 equiv) and 1,2-dichloroethane (2 mL) were sequentially added into a dry flask under argon atmosphere. Then, the reaction mixture was stirred and heated to reflux. Upon completion of the reaction (48 h), the solvent was removed under reduced pressure. Purification of the residue by column chromatography on silica gel (petroleum ether/ethyl acetate) offered the oxazole **6** (81 mg, 0.31 mmol) in 78% yield. cyclopropane **1a** (21 mg, 0.09 mmol) was recycled in 90% yield.

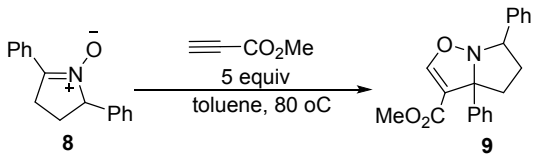
2.5. Decarboxylation procedure for the nitrone 3a



3a 8

Nitrone **3a** (0.3 mmol, 106 mg) was dissolved in the mixture of methanol and concentrated hydrochloric acid (4 mL, V:V=1:1). The reaction mixture was stirred at room temperature vigorously. When nitrone **3a** was exhausted completely (monitored by TLC), the solvent was removed by rotary evaporator. Then, the residue was dissolved by ethanol (1 mL) and basified by triethylamine (0.1 mL). The resulting mixture was stirred for additional 4 hours. Then, the solvent was removed and the residue was purified by silica gel column chromatography (petroleum ether/ethyl acetate, V:V = 3:1). Product **8** was obtained in 84 % yield.

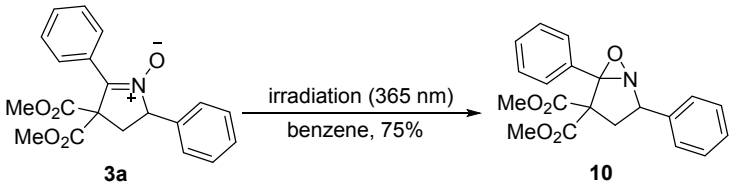
2.6 Procedure for the 1,3-dipolar cycloaddition of nitrone 8 with methyl propiolate



8 9

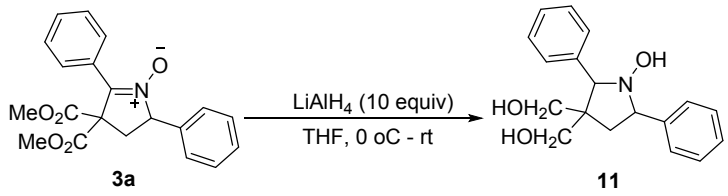
Nitrone **8** (0.2 mmol, 47.4 mg) was mixed with methyl propiolate (1 mmol, 84.1 mg) in toluene (1 mL) and was heated for 2.5 h at 80 °C. After removal of solvent, the residue was purified by silica gel chromatography (petroleum ether/ethyl acetate, V:V = 12:1) to give the product **9** (38.5 mg) in 65% yield.

2.7 Procedure for the synthesis of oxaziridine 10



A solution of nitrone **3a** (0.2 mmol, 70.6mg) in anhydrous and degassed benzene (2 mL) was placed in a quartz tube equipped with an ultraviolet lamp (365 nm). The solution was irradiated at room temperature with continuous stirring. Upon completion of the reaction (monitored by TLC), the solvent was removed to give the crude mixture of oxaziridine which was purified by column chromatography on silica gel (petroleum ether/ethyl acetate, V:V = 5:1) to afford the oxaziridine **10** in 75% yield.

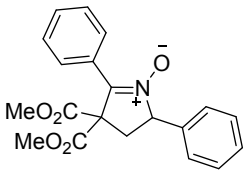
2.8 Procedure for the reduction of nitrone 3a



To a solution of nitrone (0.3 mmol, 106 mg) in anhydrous THF (3 mL) at 0 °C was added $LiAlH_4$ (3.0 mmol, 114 mg) under argon atmosphere. After stirring at 0 °C for 15 mins, the reaction was allowed to warmed up to room temperature and continued to stir until **3a** completely conversed (monitored by TLC), the reaction was cooled to 0 ℃ and quenched with H_2O (3 mL). The reaction mixture was extracted with dichloromethane, then the combined organic phase were dried over $MgSO_4$. After filtration and evaporation, the residue was purified by flash column chromatography on silica gel to afford the hydroxylamine **11** (68.2 mg) in 76% yield. (petroleum ether/ethyl acetate, V:V = 1:1).

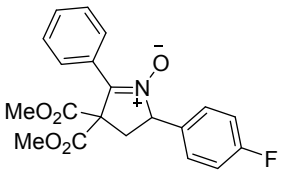
3. Characterization data of Products

4,4-bis(methoxycarbonyl)-2,5-diphenyl-3,4-dihydro-2*H*-pyrrole 1-oxide (3a)



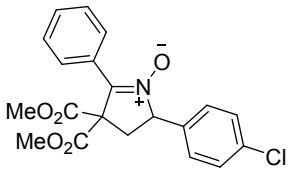
Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 2:1) gave as white solid (63.5 mg, 0.18 mmol, 90 % yield); mp: 154–156 °C; R_f = 0.26 (EtOAc/ petroleum ether, v/v = 1/2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.30–8.27 (m, 2H), 7.44–7.36 (m, 8H), 5.38 (t, *J* = 8.0 Hz, 1H), 3.81 (s, 3H), 3.71 (s, 3H), 3.37 (dd, *J* = 13.2 Hz, 8.0 Hz, 1H), 2.83 (dd, *J* = 13.6 Hz, 8.0 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.4, 168.9, 138.8, 136.6, 130.2, 128.9, 128.2, 128.0, 127.9, 76.4, 63.3, 53.5, 53.4, 38.2; HRMS calcd for $C_{20}H_{20}NO_5$ $[M+H]^+$: 354.1336, found for: 354.1338. The enantiomeric excess of product (*R*)-**3a** was determined to be 91.2 % *ee* by HPLC with an OD-H column. (*n*-hexane:*i*-PrOH = 50:50), 1 mL/min; major enantiomer t_R = 6.78 min, minor enantiomer t_R = 33.70 min;

2-(4-fluorophenyl)-4,4-bis(methoxycarbonyl)-5-phenyl-3,4-dihydro-2*H*-pyrrole 1-oxide (3b)



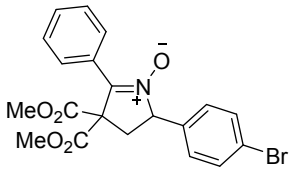
Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 2:1) gave as white solid (65.3 mg, 0.18 mmol, 88 % yield); mp: 138–140 °C; R_f = 0.36 (EtOAc/ petroleum ether, v/v = 1/2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.28–8.25 (m, 2H), 7.42–7.40 (m, 3H), 7.37–7.33 (m, 2H), 7.15–7.08 (m, 2H), 5.37 (t, *J* = 8.4 Hz, 1H), 3.81 (s, 3H), 3.73 (s, 3H), 3.37 (dd, *J* = 13.6 Hz, 8.0 Hz, 1H), 2.80 (dd, *J* = 13.2 Hz, 8.4 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.4, 168.8, 163.0 (d, *J* = 247.0 Hz), 138.7, 132.4, 130.3, 129.7 (d, *J* = 9.0 Hz), 128.2, 128.1, 127.9, 115.9 (d, *J* = 22.0 Hz), 75.7, 63.2, 53.6, 53.5, 38.1; HRMS calcd for $C_{20}H_{19}FNO_5$ $[M+H]^+$: 372.1242, found for: 372.1241.

2-(4-chlorophenyl)-4,4-bis(methoxycarbonyl)-5-phenyl-3,4-dihydro-2*H*-pyrrole 1-oxide (3c)



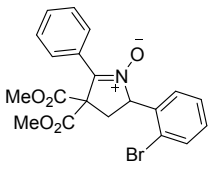
Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 3:1) gave as white solid (69.7 mg, 0.18 mmol, 90 % yield); mp: 113–115 °C; R_f = 0.46 (EtOAc/ petroleum ether, v/v = 1/2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.29–8.24 (m, 2H), 7.43–7.38 (m, 5H), 7.30 (dt, *J* = 8.4 Hz, 2.4 Hz, 2H), 5.37 (t, *J* = 8.4 Hz, 1H), 3.81 (s, 3H), 3.72 (s, 3H), 3.36 (dd, *J* = 13.6 Hz, 8.0 Hz, 1H), 2.78 (dd, *J* = 13.6 Hz, 8.4 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.3, 168.8, 138.9, 135.1, 135.0, 130.4, 129.2, 128.1, 127.9, 75.7, 63.3, 53.6, 53.5, 38.0; HRMS calcd for $C_{20}H_{19}ClNO_5$ $[M+H]^+$: 388.0946, found for: 388.0947.

2-(4-bromophenyl)-4,4-bis(methoxycarbonyl)-5-phenyl-3,4-dihydro-2*H*-pyrrole 1-oxide (3d)



Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 2:1) gave as white solid (82.8 mg, 0.19 mmol, 96 % yield); mp: 112–114 °C; R_f = 0.38 (EtOAc/ petroleum ether, v/v = 1/2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.28–8.25 (m, 2H), 7.57–7.53 (m, 2H), 7.43–7.39 (m, 3H), 7.26–7.23 (m, 2H), 5.35 (t, *J* = 8.4 Hz, 1H), 3.80 (s, 3H), 3.72 (s, 3H), 3.36 (dd, *J* = 13.6 Hz, 8.0 Hz, 1H), 2.76 (dd, *J* = 13.6 Hz, 8.4 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.3, 168.7, 139.0, 135.6, 132.1, 130.4, 129.5, 128.1, 127.9, 123.1, 75.8, 63.3, 53.6, 53.5, 37.9; HRMS calcd for $C_{20}H_{19}BrNO_5$ $[M+H]^+$: 432.0441, found for: 432.0445.

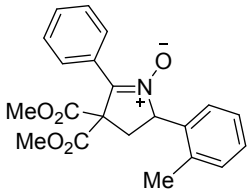
2-(2-bromophenyl)-4,4-bis(methoxycarbonyl)-5-phenyl-3,4-dihydro-2*H*-pyrrole 1-oxide (3e)



Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 2:1) gave as white solid (38.4 mg, 0.09 mmol, 45 % yield); mp: 121–123 °C; R_f = 0.35 (EtOAc/ petroleum ether, v/v = 1/2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.33–8.31 (m, 2H), 7.60 (dd, *J* = 8.0 Hz, 1.2 Hz, 1H), 7.45–7.42 (m, 3H), 7.36–7.32 (m, 1H), 7.27–7.19 (m, 2H), 5.82 (dd, *J* = 8.8 Hz, 6.0 Hz, 1H), 3.78 (s, 3H), 3.64 (s, 3H), 3.42 (dd, *J* = 13.6 Hz, 8.8 Hz, 1H), 2.79 (dd, *J* = 13.2 Hz, 6.0 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.0, 168.9, 140.3, 136.3, 133.1, 130.4, 129.9, 128.1, 127.9, 127.8, 123.3, 76.3, 63.5, 53.7, 53.3, 37.1; HRMS calcd for $C_{20}H_{19}BrNO_5$ $[M+H]^+$: 432.0441, found

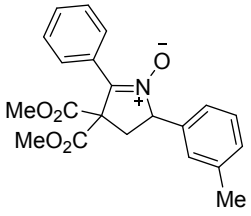
for: 432.0450.

4,4-bis(methoxycarbonyl)-5-phenyl-2-(o-tolyl)-3,4-dihydro-2*H*-pyrrole 1-oxide (3f)



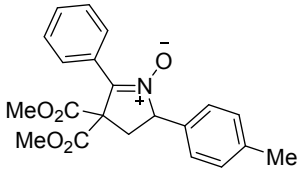
Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 2:1) gave as white solid (63.1 mg, 0.17 mmol, 86 % yield); mp: 118–120 °C; R_f = 0.35 (EtOAc/ petroleum ether, v/v = 1/2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.33–8.29 (m, 2H), 7.44–7.40 (m, 3H), 7.25–7.18 (m, 4H), 5.64 (t, *J* = 8.0 Hz, 1H), 3.80 (s, 3H), 3.68 (s, 3H), 3.35 (dd, *J* = 13.2 Hz, 8.4 Hz, 1H), 2.75 (dd, *J* = 13.2 Hz, 7.6 Hz, 1H), 2.40 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.3, 169.1, 139.2, 136.2, 135.1, 130.9, 130.2, 128.5, 128.4, 128.1, 127.9, 126.6, 126.2, 73.8, 63.5, 53.6, 53.3, 37.4, 19.2; HRMS calcd for $C_{21}H_{22}NO_5$ $[M+H]^+$: 368.1492, found for: 368.1494.

4,4-bis(methoxycarbonyl)-5-phenyl-2-(m-tolyl)-3,4-dihydro-2*H*-pyrrole 1-oxide (3g)



Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 1:1) gave as white solid (61.7 mg, 0.17 mmol, 84 % yield); mp: 110–112 °C; R_f = 0.20 (EtOAc/ petroleum ether, v/v = 1/2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.32–8.29 (m, 2H), 7.42–7.39 (m, 3H), 7.33–7.29 (m, 1H), 7.20–7.16 (m, 3H), 5.35 (t, *J* = 8.4 Hz, 1H), 3.81 (s, 3H), 3.74 (s, 3H), 3.35 (dd, *J* = 13.2 Hz, 8.0 Hz, 1H), 2.81 (dd, *J* = 13.2 Hz, 8.4 Hz, 1H), 2.38 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.5, 168.9, 138.6, 136.6, 130.1, 130.0, 129.7, 128.8, 128.4, 128.0, 127.9, 124.8, 76.4, 63.3, 53.5, 53.4, 38.2, 21.4; HRMS calcd for $C_{21}H_{22}NO_5$ $[M+H]^+$: 368.1492, found for: 368.1493.

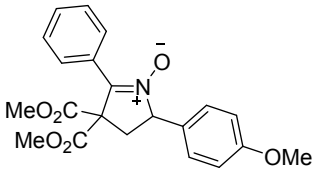
4,4-bis(methoxycarbonyl)-5-phenyl-2-(p-tolyl)-3,4-dihydro-2*H*-pyrrole 1-oxide (3h)



Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 2:1) gave as white solid (63.8 mg, 0.17 mmol, 87 % yield); mp: 123–125 °C; R_f = 0.26 (EtOAc/ petroleum ether, v/v = 1/2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.30–8.27 (m, 2H), 7.41–7.38 (m, 3H), 7.26–7.20 (m, 4H), 5.34 (t, *J* = 8.4 Hz, 1H), 3.80 (s, 3H),

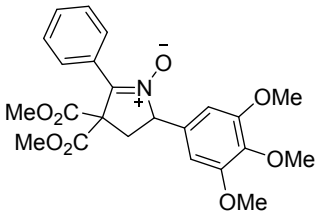
3.71 (s, 3H), 3.34 (dd, *J* = 13.2 Hz, 8.0 Hz, 1H), 2.82 (dd, *J* = 13.2 Hz, 8.8 Hz, 1H), 2.36 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.4, 168.9, 138.9, 138.4, 133.6, 130.1, 129.6, 128.3, 128.0, 127.8, 127.7, 76.1, 63.2, 53.5, 53.3, 38.1, 21.1; HRMS calcd for $C_{21}H_{22}NO_5$ $[M+H]^+$: 368.1492, found for: 368.1491.

4,4-bis(methoxycarbonyl)-2-(4-methoxyphenyl)-5-phenyl-3,4-dihydro-2*H*-pyrrole 1-oxide (3i)



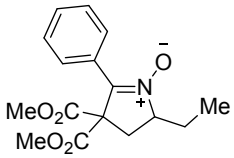
Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 1:1) gave as white solid (55.9 mg, 0.15 mmol, 73 % yield); mp: 125–127 °C; R_f = 0.21 (EtOAc/ petroleum ether, v/v = 1/2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.29–8.26 (m, 2H), 7.41–7.38 (m, 3H), 7.31–7.29 (m, 2H), 6.96–6.93 (m, 2H), 5.32 (t, *J* = 8.4 Hz, 1H), 3.82 (s, 3H), 3.81 (s, 3H), 3.74 (s, 3H), 3.34 (dd, *J* = 13.6 Hz, 8.0 Hz, 1H), 2.81 (dd, *J* = 13.6 Hz, 8.4 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.5, 168.9, 160.0, 138.2, 130.1, 129.2, 128.4, 128.3, 128.0, 127.8, 114.3, 75.8, 63.0, 55.2, 53.4, 38.0, 30.8, 14.1; HRMS calcd for $C_{21}H_{22}NO_6$ $[M+H]^+$: 384.1442, found for: 384.1443.

4,4-bis(methoxycarbonyl)-5-phenyl-2-(3,4,5-trimethoxyphenyl)-3,4-dihydro-2*H*-pyrrole 1-oxide (3j)



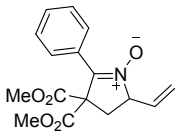
Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 1:2) gave as white solid (65.6 mg, 0.15 mmol, 74 % yield); mp: 136–138 °C; R_f = 0.15 (EtOAc/ petroleum ether, v/v = 1/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.29–8.26 (m, 2H), 7.42–7.40 (m, 3H), 6.59 (s, 2H), 5.30 (t, *J* = 8.0 Hz, 1H), 3.86 (s, 6H), 3.84 (s, 3H), 3.79 (s, 3H), 3.76 (s, 3H), 3.36 (dd, *J* = 13.6 Hz, 8.4 Hz, 1H), 2.82 (dd, *J* = 13.6 Hz, 8.0 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.6, 168.9, 153.6, 138.6, 138.2, 132.3, 130.3, 128.1, 128.0, 127.9, 104.7, 63.2, 60.7, 56.1, 53.6, 53.5, 53.4, 37.8; HRMS calcd for $C_{23}H_{26}NO_8$ $[M+H]^+$: 444.1653, found for: 444.1654.

2-ethyl-4,4-bis(methoxycarbonyl)-5-phenyl-3,4-dihydro-2*H*-pyrrole 1-oxide (3k)



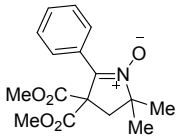
Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 2:1) gave as white solid (18.3 mg, 0.06 mmol, 30 % yield); mp: 93–95 °C; R_f = 0.45 (EtOAc/ petroleum ether, v/v = 1/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.19–8.15 (m, 2H), 7.42–7.36 (m, 3H), 4.20 (ddd, *J* = 16.8 Hz, 8.4 Hz, 3.6 Hz, 1H), 3.77 (s, 3H), 3.72 (s, 3H), 3.03 (dd, *J* = 12.0 Hz, 4.0 Hz, 1H), 2.47 (dd, *J* = 12.8 Hz, 8.0 Hz, 1H), 2.35–2.25 (m, 1H), 1.83–1.72 (m, 1H), 1.02 (t, *J* = 7.6 Hz, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.8, 169.3, 138.1, 130.1, 128.5, 128.1, 128.0, 73.1, 63.2, 53.6, 53.5, 34.5, 25.2, 9.1; HRMS calcd for $C_{16}H_{20}NO_5$ $[M+H]^+$: 306.1336, found for: 306.1335.

4,4-bis(methoxycarbonyl)-5-phenyl-2-vinyl-3,4-dihydro-2*H*-pyrrole 1-oxide (3l)



Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 3:2) gave as white solid (33.3 mg, 0.11 mmol, 55 % yield); mp: 82–84 °C; R_f = 0.38 (EtOAc/ petroleum ether, v/v = 1/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.22–8.20 (m, 2H), 7.41–7.37 (m, 3H), 6.05 (ddd, *J* = 17.2 Hz, 10.0 Hz, 7.2 Hz, 1H), 5.49–5.45 (m, 2H), 4.83–4.77 (dd, *J* = 15.2 Hz, 7.6 Hz, 1H), 3.77 (s, 3H), 3.73 (s, 3H), 3.13 (dd, *J* = 12.0 Hz, 8.0 Hz, 1H), 2.64 (dd, *J* = 12.0 Hz, 8.0 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.2, 168.8, 137.8, 133.2, 130.0, 128.2, 127.9, 127.7, 121.3, 74.8, 63.3, 53.4, 53.3, 35.4; HRMS calcd for $C_{16}H_{18}NO_5$ $[M+H]^+$: 304.1179, found for: 304.1181.

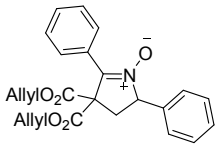
4,4-bis(methoxycarbonyl)-2,2-dimethyl-5-phenyl-3,4-dihydro-2*H*-pyrrole 1-oxide (3m)



Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 2:1) gave as colorless oil (16.7 mg, 0.05 mmol, 30 % yield); R_f = 0.38 (EtOAc/ petroleum ether, v/v = 1/2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.18–8.16 (m, 2H), 7.39–7.36 (m, 3H), 3.74 (s, 6H), 2.83 (s, 2H), 1.51 (s, 6H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.9, 135.9, 129.8, 128.8, 128.0, 127.9, 73.8, 62.3, 53.4, 53.3, 42.7, 26.3, 25.0; HRMS calcd for $C_{16}H_{20}NO_5$ $[M+H]^+$: 306.1336, found for: 306.1333.

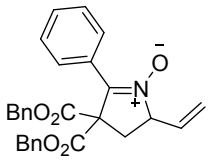
4,4-bis((allyloxy)carbonyl)-2,5-diphenyl-3,4-dihydro-2*H*-pyrrole 1-oxide (3n)

Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 2:1) gave



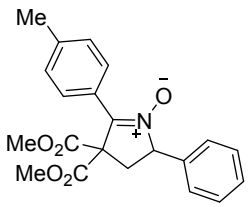
as colorless oil (62.2 mg, 0.15 mmol, 77 % yield); R_f = 0.38 (EtOAc/ petroleum ether, v/v = 1/2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.31–8.29 (m, 2H), 7.44–7.34 (m, 8H), 5.85–5.66 (m, 2H), 5.40 (t, *J* = 8.0 Hz, 1H), 5.28–5.17 (m, 4H), 4.70 (dd, *J* = 2.4 Hz, 1.2 Hz, 1H), 4.68 (dd, *J* = 2.4 Hz, 1.2 Hz, 1H), 4.61–4.59 (m, 2H), 3.39 (dd, *J* = 13.2 Hz, 8.0 Hz, 1H), 2.85 (dd, *J* = 13.6 Hz, 8.4 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.5, 168.1, 138.8, 136.7, 128.9, 128.8, 128.1, 128.0, 127.7, 119.7, 119.6, 76.4, 67.3, 67.0, 63.6, 38.1; HRMS calcd for $C_{24}H_{24}NO_5$ $[M+H]^+$: 406.1656, found for: 406.1649.

4,4-bis((benzyloxy)carbonyl)-5-phenyl-2-vinyl-3,4-dihydro-2*H*-pyrrole 1-oxide (3o)



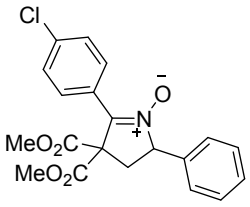
Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 2:1) gave as colorless oil (54.6 mg, 0.12 mmol, 60 % yield); R_f = 0.26 (EtOAc/ petroleum ether, v/v = 2/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.11–8.08 (m, 2H), 7.33–7.21 (m, 9H), 7.14–7.09 (m, 4H), 5.97 (ddd, *J* = 17.6 Hz, 10.4 Hz, 7.6 Hz, 1H), 5.42–5.37 (m, 2H), 5.16 (s, 1H), 5.15 (s, 1H), 5.13 (s, 2H), 4.73 (dd, *J* = 12.8 Hz, 4.0 Hz, 1H), 3.10 (dd, *J* = 12.8 Hz, 8.0 Hz, 1H), 2.63 (dd, *J* = 12.0 Hz, 8.0 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.6, 168.2, 137.8, 134.3, 134.2, 133.3, 129.9, 128.6, 128.5, 128.4, 128.3, 128.1, 127.9, 121.3, 74.9, 68.5, 68.3, 63.8, 35.3; HRMS calcd for $C_{28}H_{26}NO_5$ $[M+H]^+$: 456.1805, found for: 456.1804.

4,4-bis(methoxycarbonyl)-2-phenyl-5-(p-tolyl)-3,4-dihydro-2*H*-pyrrole 1-oxide (3p)



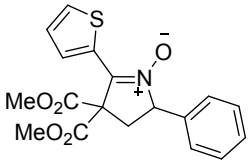
Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 2:1) gave as white solid (60.9 mg, 0.17 mmol, 83 % yield); mp: 142–144 °C; R_f = 0.33 (EtOAc/ petroleum ether, v/v = 1/2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.22–8.21 (m, 2H), 7.43–7.33 (m, 5H), 7.22–7.20 (m, 2H), 5.37 (t, *J* = 8.0 Hz, 1H), 3.79 (s, 3H), 3.71 (s, 3H), 3.35 (dd, *J* = 13.2 Hz, 8.0 Hz, 1H), 2.79 (dd, *J* = 13.2 Hz, 8.0 Hz, 1H), 2.37 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.5, 168.9, 140.6, 138.8, 136.8, 128.9, 128.8, 128.7, 127.8, 127.6, 125.5, 76.2, 63.2, 53.5, 53.3, 38.2, 21.4; HRMS calcd for $C_{21}H_{22}NO_5$ $[M+H]^+$: 368.1492, found for: 368.1492.

5-(4-chlorophenyl)-4,4-bis(methoxycarbonyl)-2-phenyl-3,4-dihydro-2*H*-pyrrole 1-oxide (3q)



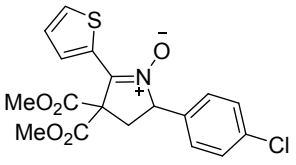
Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 2:1) gave as white solid (69.7 mg, 0.18 mmol, 90 % yield); mp: 140–142 °C; R_f = 0.34 (EtOAc/ petroleum ether, v/v = 1/2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.30–8.27 (m, 2H), 7.45–7.32 (m, 7H), 5.37 (t, *J* = 8.0 Hz, 1H), 3.81 (s, 3H), 3.73 (s, 3H), 3.37 (dd, *J* = 13.2 Hz, 8.0 Hz, 1H), 2.81 (dd, *J* = 13.6 Hz, 8.4 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.3, 168.7, 137.8, 136.4, 135.8, 129.4, 129.1, 128.8, 128.5, 128.1, 127.9, 127.5, 126.8, 76.5, 63.2, 53.6, 53.5, 38.2; HRMS calcd for $C_{20}H_{19}ClNO_5$ $[M+H]^+$: 388.0946, found for: 388.0945.

4,4-bis(methoxycarbonyl)-2-phenyl-5-(thiophen-2-yl)-3,4-dihydro-2*H*-pyrrole 1-oxide (3r)



Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 3:1) gave as white solid (67.5 mg, 0.19 mmol, 94 % yield); mp: 151–153 °C; R_f = 0.40 (EtOAc/ petroleum ether, v/v = 1/2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 4.0 Hz, 1H), 7.50 (d, *J* = 5.6 Hz, 1H), 7.43–7.36 (m, 3H), 7.33–7.30 (m, 2H), 7.16 (t, *J* = 8.4 Hz, 1H), 5.39 (t, *J* = 8.0 Hz, 1H), 3.81 (s, 3H), 3.80 (s, 3H), 3.50 (dd, *J* = 13.2 Hz, 8.0 Hz, 1H), 2.81 (dd, *J* = 13.6 Hz, 8.4 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.1, 168.2, 136.3, 136.0, 129.4, 129.1, 129.0, 128.7, 127.7, 126.4, 74.4, 62.6, 53.6, 53.5, 38.2; HRMS calcd for $C_{18}H_{18}NO_5S$ $[M+H]^+$: 360.0900, found for: 360.0901.

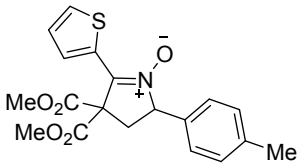
2-(4-chlorophenyl)-4,4-bis(methoxycarbonyl)-5-(thiophen-2-yl)-3,4-dihydro-2*H*-pyrrole 1-oxide (3s)



Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 3:1) gave as white solid (72.3 mg, 0.18 mmol, 92 % yield); mp: 122–124 °C; R_f = 0.43 (EtOAc/ petroleum ether, v/v = 1/2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 4.0 Hz, 1H), 7.52 (d, *J* = 4.8 Hz, 1H), 7.

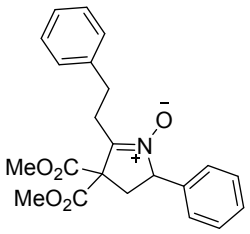
39–7.37 (m, 2H), 7.28–7.25 (m, 2H), 7.17 (t, *J* = 4.8 Hz, 1H), 5.37 (t, *J* = 8.0 Hz, 1H), 3.82 (s, 3H), 3.80 (s, 3H), 3.50 (dd, *J* = 13.6 Hz, 8.4 Hz, 1H), 2.77 (dd, *J* = 13.2 Hz, 8.0 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.0, 168.0, 135.1, 134.8, 129.3, 129.2, 129.1, 128.9, 126.5, 73.6, 62.5, 53.7, 53.6, 38.0; HRMS calcd for $C_{18}H_{17}ClNO_5S$ $[M+H]^+$: 394.0510, found for: 394.0513.

4,4-bis(methoxycarbonyl)-5-(thiophen-2-yl)-2-(p-tolyl)-3,4-dihydro-2*H*-pyrrole 1-oxide (3t)



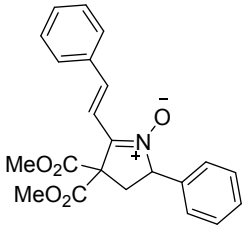
Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 3:1) gave as white solid (64.2 mg, 0.17 mmol, 86 % yield); mp: 120–122 °C*; R_f* = 0.47 (EtOAc/ petroleum ether, v/v = 1/2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54 (ddd, *J* = 4.0 Hz, 1.2 Hz, 0.4 Hz, 1H), 7.49 (dd, *J* = 5.2 Hz, 0.8 Hz, 1H), 7.21 (s, 4H), 7.15 (dd, *J* = 5.2 Hz, 4.0 Hz, 1H), 5.35 (t, *J* = 8.0 Hz, 1H), 3.82 (s, 3H), 3.79 (s, 3H), 3.48 (dd, *J* = 13.2 Hz, 8.0 Hz, 1H), 2.80 (dd, *J* = 13.6 Hz, 8.4 Hz, 1H), 2.35 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.2, 168.2, 139.0, 135.7, 133.2, 129.7, 129.5, 129.0, 128.6, 127.7, 126.3, 74.1, 62.5, 53.5, 38.1, 21.2; HRMS calcd for $C_{19}H_{20}NO_5S$ $[M+H]^+$: 374.1057, found for: 374.1058.

4,4-bis(methoxycarbonyl)-5-phenethyl-2-phenyl-3,4-dihydro-2*H*-pyrrole 1-oxide (3u)



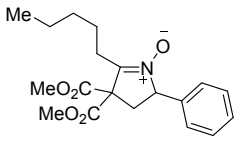
Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 1:1) gave as colorless oil (65.5 mg, 0.17 mmol, 86 % yield); R_f = 0.36 (EtOAc/ petroleum ether, v/v = 1/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43–7.34 (m, 3H), 7.32–7.24 (m, 6H), 7.22–7.18 (m, 1H), 5.19 (t, *J* = 8.0 Hz, 1H), 3.79 (s, 3H), 3.78 (s, 3H), 3.27 (dd, *J* = 14.0 Hz, 8.4 Hz, 1H), 3.07–3.00 (m, 2H), 2.98–2.83 (m, 2H), 2.67 (dd, *J* = 14.0 Hz, 8.0 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.7, 168.2, 142.3, 141.3, 136.8, 129.0, 128.9, 128.5, 128.4, 127.6, 126.1, 74.9, 63.2, 53.5, 35.7, 29.6; HRMS calcd for $C_{22}H_{24}NO_5$ $[M+H]^+$: 382.1649, found for: 382.1647.

(E)-4,4-bis(methoxycarbonyl)-2-phenyl-5-styryl-3,4-dihydro-2*H*-pyrrole 1-oxide (3v)



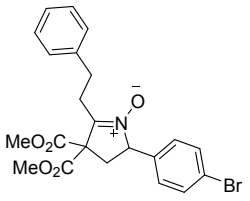
Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 2:1) gave as colorless oil (26.3 mg, 0.07 mmol, 35 % yield); R_f = 0.34 (EtOAc/ petroleum ether, v/v = 2/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.32 (d, *J* = 16.4 Hz, 1H), 7.54–7.52 (m, 2H), 7.44–7.31 (m, 8H), 7.03 (d, *J* = 16.4 Hz, 1H), 5.29 (t, *J* = 8.4 Hz, 1H), 3.85 (s, 3H), 3.84 (s, 3H), 3.38 (dd, *J* = 13.6 Hz, 8.0 Hz, 1H), 2.68 (dd, *J* = 13.6 Hz, 8.4 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.1, 168.4, 138.4, 137.3, 137.2, 136.7, 129.0, 127.6, 127.5, 115.0, 114.8, 75.3, 62.1, 53.6, 53.5, 36.5; HRMS calcd for $C_{22}H_{22}NO_5$ $[M+H]^+$: 380.1492, found for: 380.1493.

4,4-bis(methoxycarbonyl)-5-pentyl-2-phenyl-3,4-dihydro-2*H*-pyrrole 1-oxide (3w)



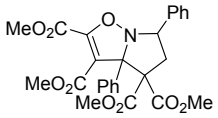
Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 1:1) gave as colorless oil (53.4 mg, 0.15 mmol, 77 % yield); R_f = 0.18 (EtOAc/ petroleum ether, v/v = 1/2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.41–7.31 (m, 3H), 7.27–7.25 (m, 2H), 5.15 (t, *J* = 8.0 Hz, 1H), 3.83 (s, 3H), 3.81 (s, 3H), 3.24 (dd, *J* = 14.0 Hz, 8.8 Hz, 1H), 2.69–2.55 (m, 3H), 1.65–1.58 (m, 2H), 1.38–1.30 (m, 4H), 0.92–0.87 (m, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.9, 168.4, 143.6, 137.0, 128.9, 128.8, 127.4, 74.7, 63.1, 53.5, 35.8, 32.1, 31.3, 29.6, 27.1, 23.8, 22.5, 14.0; HRMS calcd for $C_{19}H_{26}NO_5$ $[M+H]^+$: 348.1805, found for: 348.1804.

2-(4-bromophenyl)-4,4-bis(methoxycarbonyl)-5-phenethyl-3,4-dihydro-2*H*-pyrrole 1-oxide (3x)



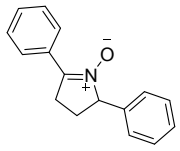
Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 2:1) gave as colorless oil (86.9 mg, 0.19 mmol, 90 % yield); R_f = 0.32 (EtOAc/ petroleum ether, v/v = 1/2); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55–7.52 (m, 2H), 7.32–7.16 (m, 7H), 5.16 (t, *J* = 8.4 Hz, 1H), 3.79 (s, 3H), 3.78 (s, 3H), 3.25 (dd, *J* = 14.0 Hz, 8.8 Hz, 1H), 3.05–2.84 (m, 4H), 2.63 (dd, *J* = 14.0 Hz, 8.0 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.5, 168.0, 142.7, 141.0, 135.6, 132.1, 129.3, 128.4, 126.1, 123.1, 74.2, 63.1, 53.6, 35.3, 29.4; HRMS calcd for $C_{22}H_{23}BrNO_5$ $[M+H]^+$: 460.0754, found for: 460.0760.

Tetramethyl 3a,6-diphenyl-5,6-dihydropyrrolo[1,2-b]isoxazole-2,3,4,4(3a*H*)-tetracarboxylate (7)



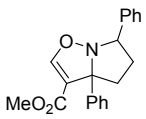
Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 3:1) gave as colorless oil (24.8 mg, 0.05 mmol, 8 % yield); R_f = 0.48 (EtOAc/ petroleum ether, v/v = 2/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.59–7.54 (m, 4H), 7.42–7.38 (m, 2H), 7.36–7.29 (m, 4H), 4.84 (dd, *J* = 12.8 Hz, 5.6 Hz, 1H), 3.85 (s, 3H), 3.83 (s, 3H), 3.76 (s, 3H), 3.12 (s, 3H), 3.05 (dd, *J* = 14.0 Hz, 12.8 Hz, 1H), 2.43 (dd, *J* = 14.0 Hz, 5.6 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.7, 168.9, 164.0, 159.5, 153.7, 142.6, 138.1, 128.7, 128.2, 128.0, 127.8, 127.2, 109.4, 83.9, 76.7, 69.4, 65.4, 53.2, 52.2, 52.0, 41.1; HRMS calcd for $C_{26}H_{26}NO_9$ $[M+H]^+$: 496.1602, found for: 496.1615. HRMS calcd for $C_{26}H_{26}NO_9$ $[M+H]^+$: 496.1602, found for: 496.1615.

2,5-diphenyl-3,4-dihydro-2*H*-pyrrole 1-oxide (8)



Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 3:1) gave as white solid (59.7 mg, 0.25 mmol, 84 % yield); mp: 98–100 °C*;* R_f = 0.24 (EtOAc/ petroleum ether, v/v = 3/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.44–8.41 (m, 2H), 7.47–7.40 (m, 3H), 7.39–7.30 (m, 5H), 5.29–5.26 (m, 1H), 3.32–3.15 (m, 2H), 2.72–2.62 (m, 1H), 2.27–2.19 (m, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.0, 138.6, 130.2, 129.2, 128.8, 128.3, 128.2, 127.3, 127.0, 79.1, 29.2, 26.1; HRMS calcd for $C_{16}H_{16}NO$ $[M+H]^+$: 238.1226, found for: 238.1224.

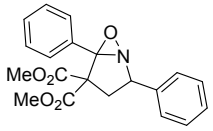
Methyl 3a,6-diphenyl-3a,4,5,6-tetrahydropyrrolo[1,2-b]isoxazole-3-carboxylate (9)



Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 12:1) gave as colorless oil (41.7 mg, 0.12 mmol, 65 % yield); R_f = 0.40 (EtOAc/ petroleum ether, v/v = 8/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.74–7.72 (m, 2H), 7.47 (d, *J* = 7.2 Hz, 2H), 7.37–7.23 (m, 7H), 4.37 (dd, *J* = 11.2 Hz, 6.0 Hz, 1H), 3.17 (s, 3H), 2.82 (ddd, *J* = 19.2 Hz, 11.6 Hz, 8.0 Hz, 1H), 2.67 (ddd, *J* = 13.2 Hz, 7.2 Hz, 2.0 Hz, 1H), 2.19 (ddd, *J* = 15.6 Hz, 8.0 Hz, 2.4 Hz, 1H), 1.91–1.81 (m, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.2, 152.2, 145.3, 140.4, 128.5, 128.2, 127.5, 127.0, 126.9, 126.1, 113.6,

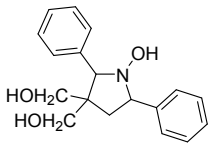
77.5, 73.4, 51.2, 36.5, 31.6; HRMS calcd for $C_{20}H_{20}NO_3$ $[M+H]^+$: 322.1438, found for: 322.1449.

Dimethyl 2,5-diphenyl-6-oxa-1-azabicyclo[3.1.0]hexane-4,4-dicarboxylate (10)



Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 5:1) gave as colorless oil (53.0 mg, 0.15 mmol, 75 % yield); R_f = 0.35 (EtOAc/ petroleum ether, v/v = 5/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54–7.51 (m, 2H), 7.45–7.37 (m, 2H), 7.34–7.18 (m, 6H), 4.87 (dd, *J* = 12.0 Hz, 4.0 Hz, 1H), 3.77 (s, 3H), 3.20 (s, 3H), 3.06 (dd, *J* = 20.0 Hz, 12.0 Hz, 1H), 2.85 (dd, *J* = 16.0 Hz, 4.0 Hz, 1H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.1, 168.5, 139.2, 133.1, 129.3, 128.3, 128.1, 127.8, 127.3, 126.6, 92.0, 67.4, 64.9, 53.1, 52.5, 39.9; HRMS calcd for $C_{20}H_{20}NO_5$ $[M+H]^+$: 354.1331, found for: 354.1336.

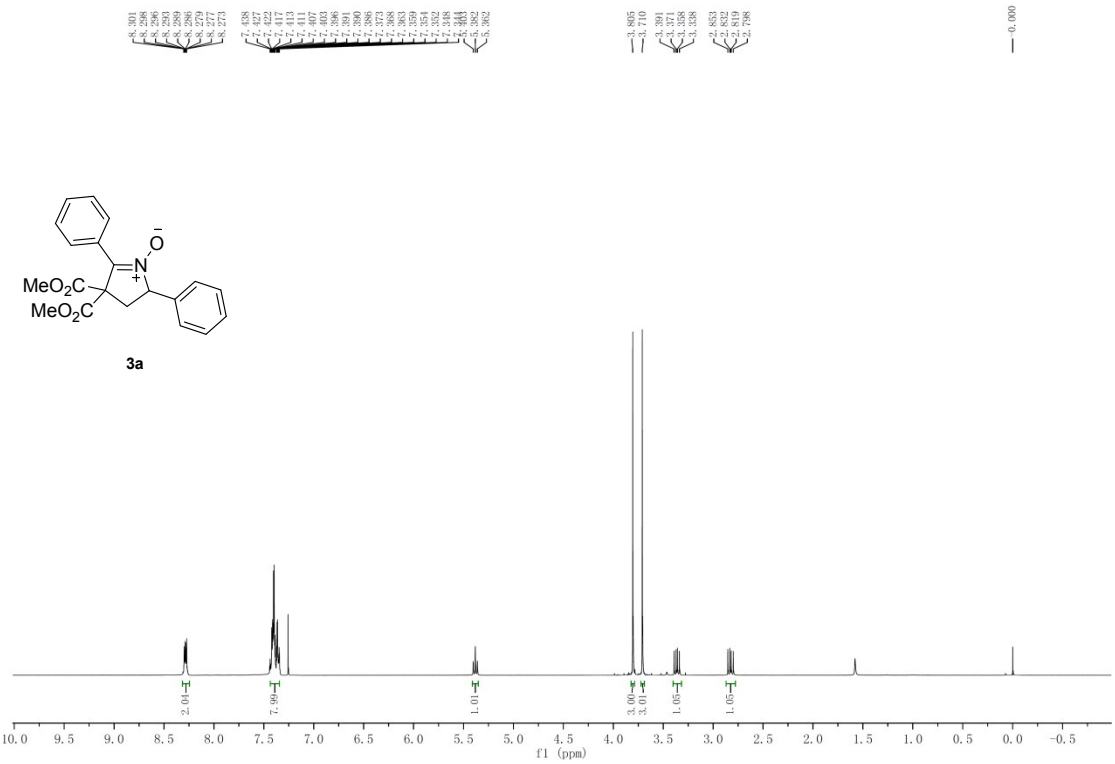
trans - (1-hydroxy-2,5-diphenylpyrrolidine-3,3-diyl)dimethanol (11)



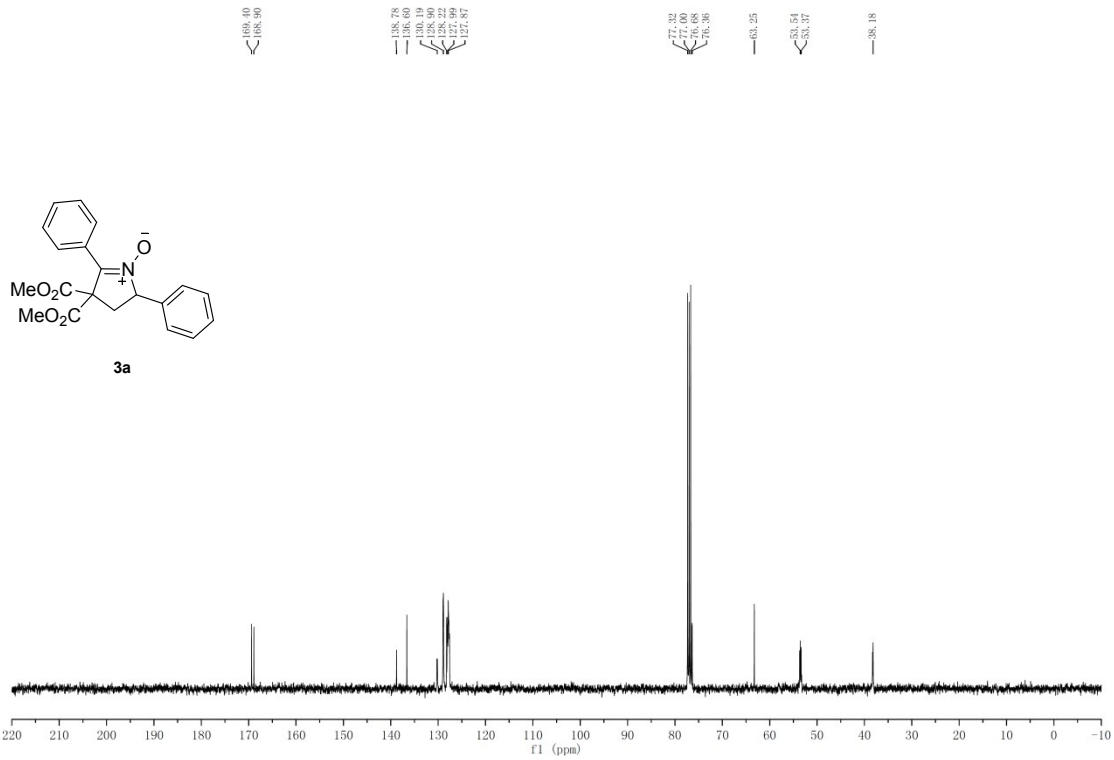
Purification by flash chromatography on silica gel petroleum ether/EtOAc (V/V = 1:1) gave as white solid (68.2 mg, 0.23 mmol, 76 % yield); mp: 196–198 °C*;* R_f = 0.28 (EtOAc/ petroleum ether, v/v = 1/1); ^{1}H NMR (400 MHz, CD_3OH) δ 7.56–7.54 (m, 4H), 7.37–7.32 (m, 4H), 7.27–7.23 (m, 2H), 4.17 (s, 1H), 4.00 (dd, *J* = 10.8 Hz, 8.0 Hz, 1H), 3.73 (d, *J* = 11.2 Hz, 1H), 3.65 (d, *J* = 10.8 Hz, 1H), 3.28 (d, *J* = 10.8 Hz, 1H), 2.85 (d, *J* = 11.2 Hz, 1H), 2.24 (dd, *J* = 14.4 Hz, 8.8 Hz, 1H), 1.82 (dd, *J* = 13.2 Hz, 10.8 Hz, 1H) ppm; ^{13}C NMR (100 MHz, CD_3OH) δ 144.2, 140.1, 129.5, 129.4, 129.1, 128.7, 128.1, 128.0, 76.1, 71.8, 67.4, 66.3, 47.5, 39.0; HRMS calcd for $C_{18}H_{22}NO_3$ $[M+H]^+$: 300.1594, found for: 300.1592.

4. ^{1}H-NMR and ^{13}C-NMR spectra of the compounds

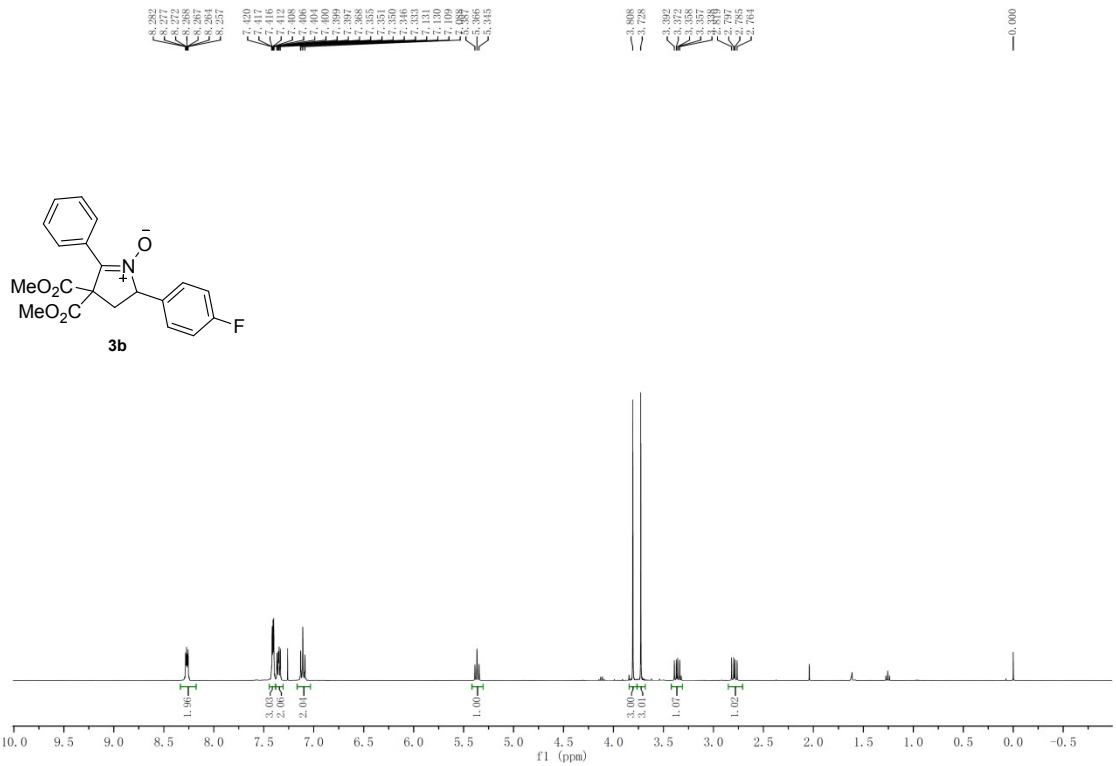
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3a**



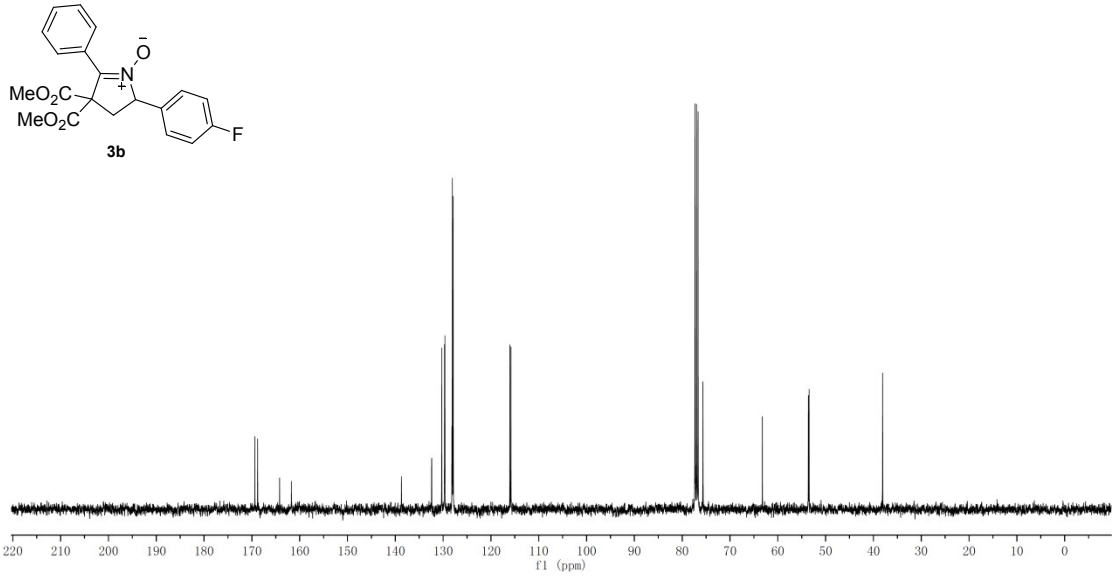
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3a**



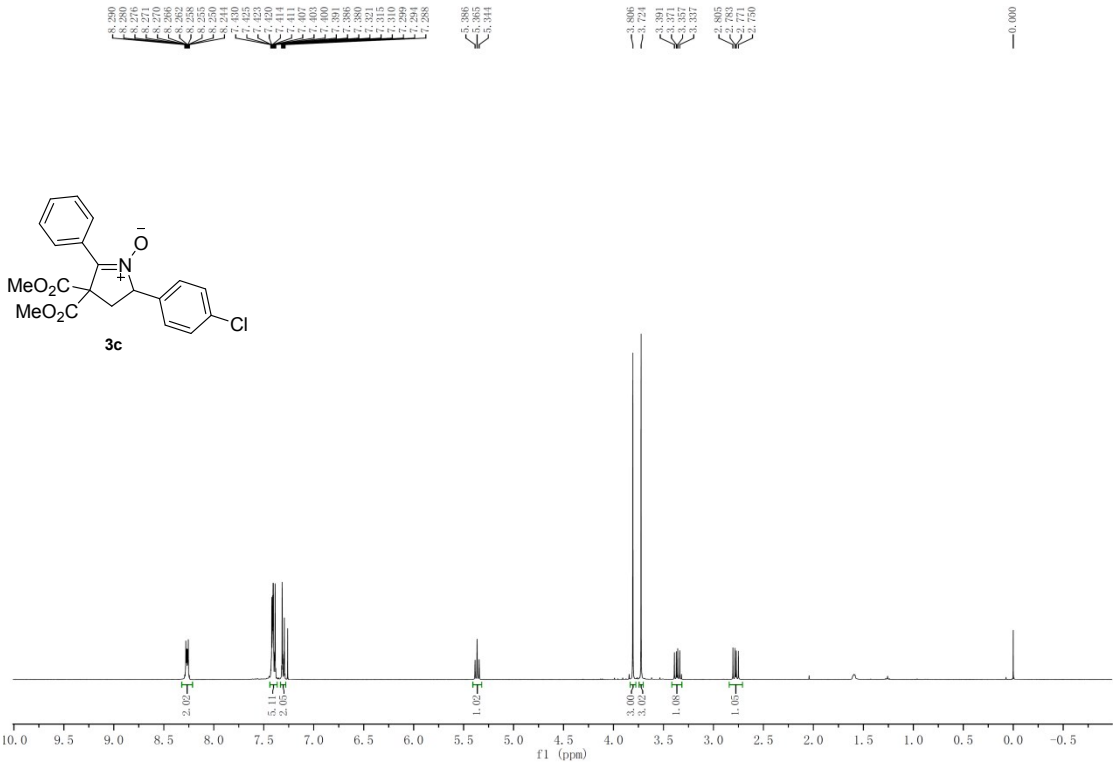
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3b**



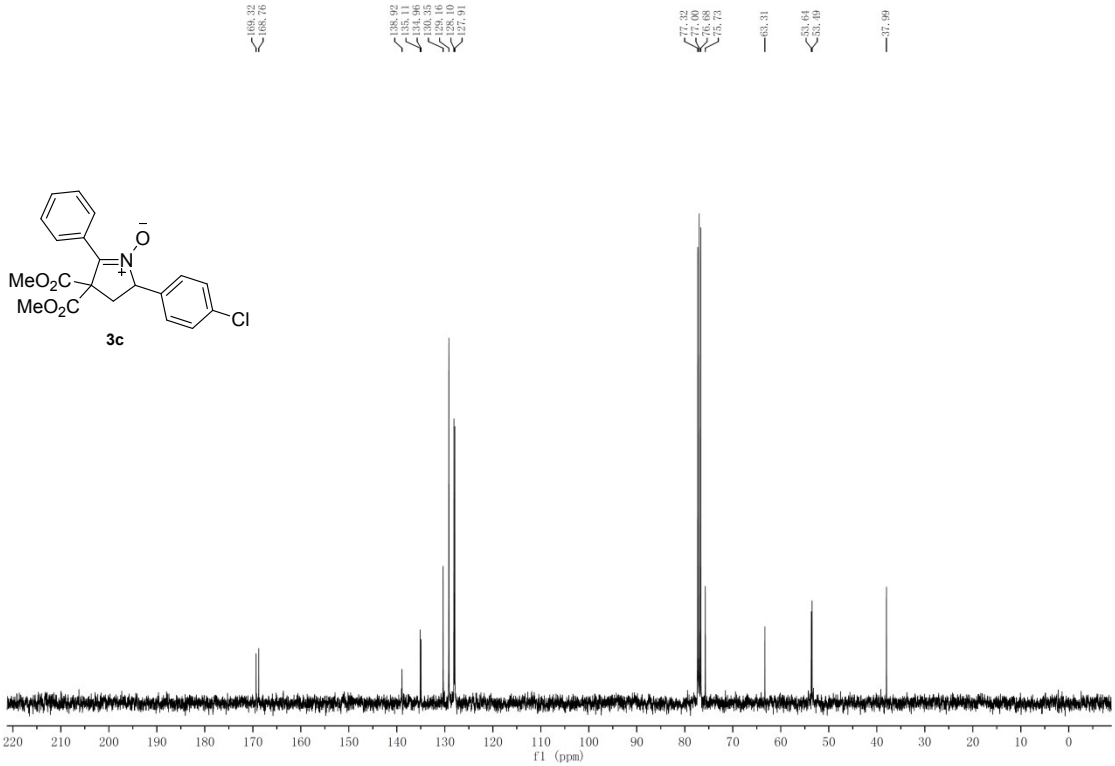
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3b**



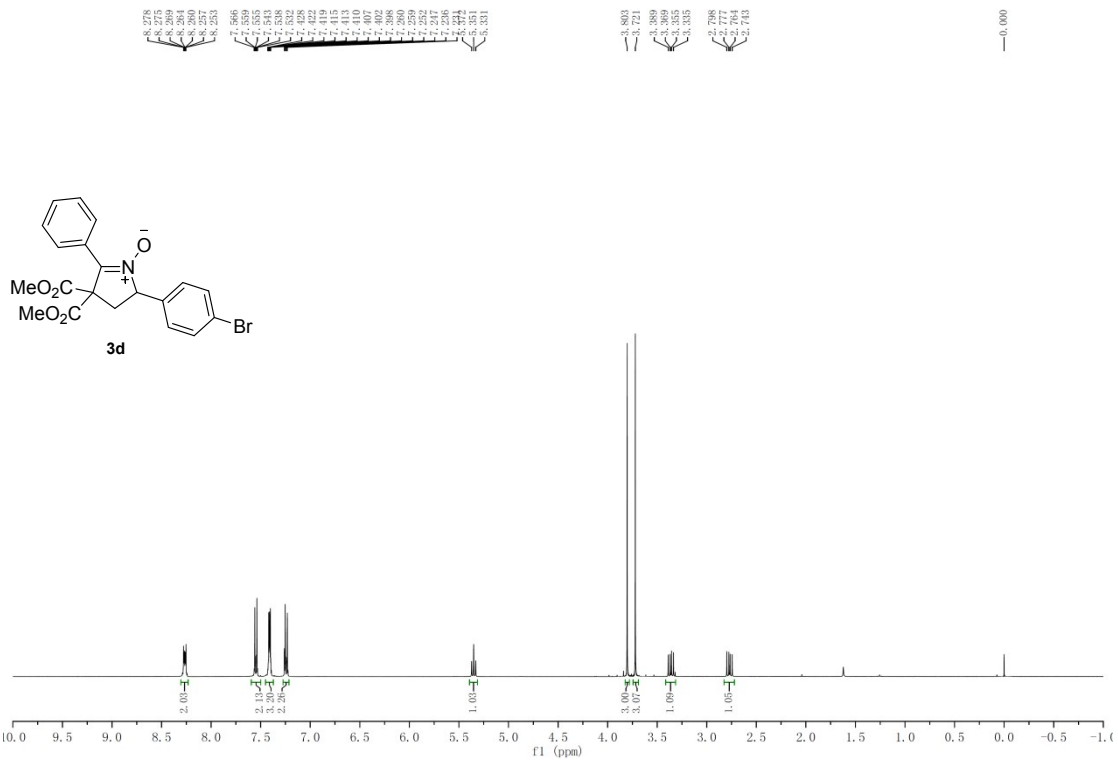
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3c**



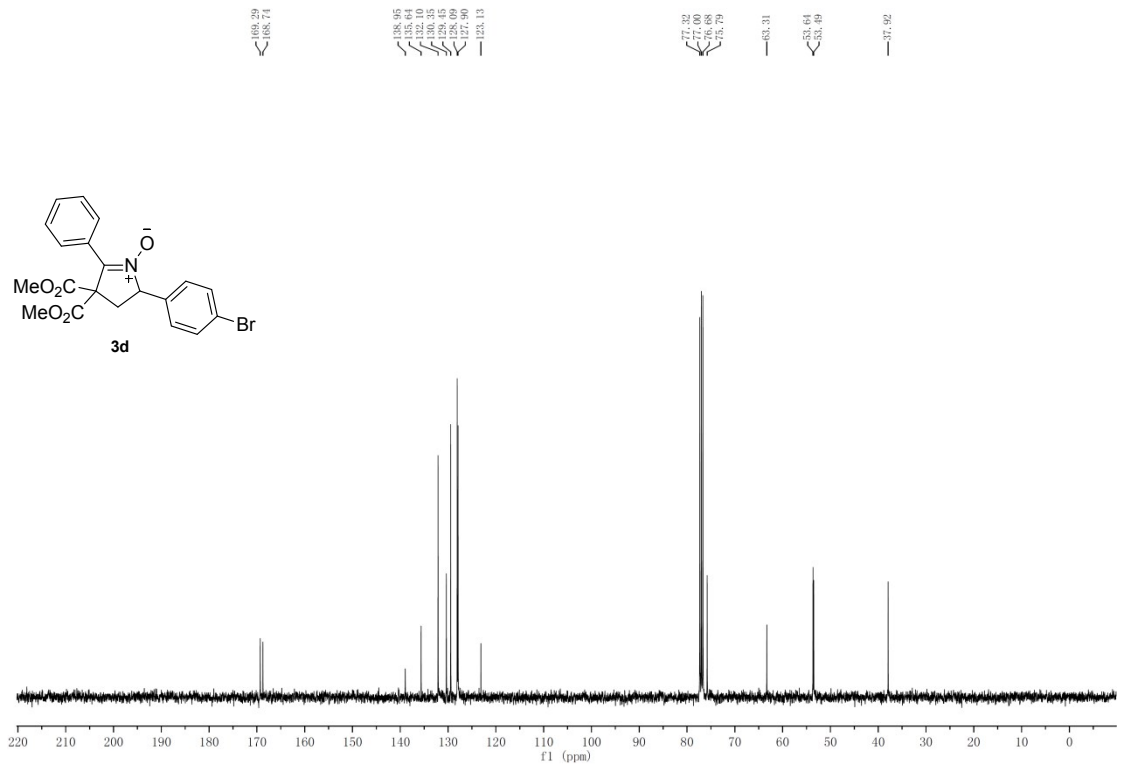
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3c**



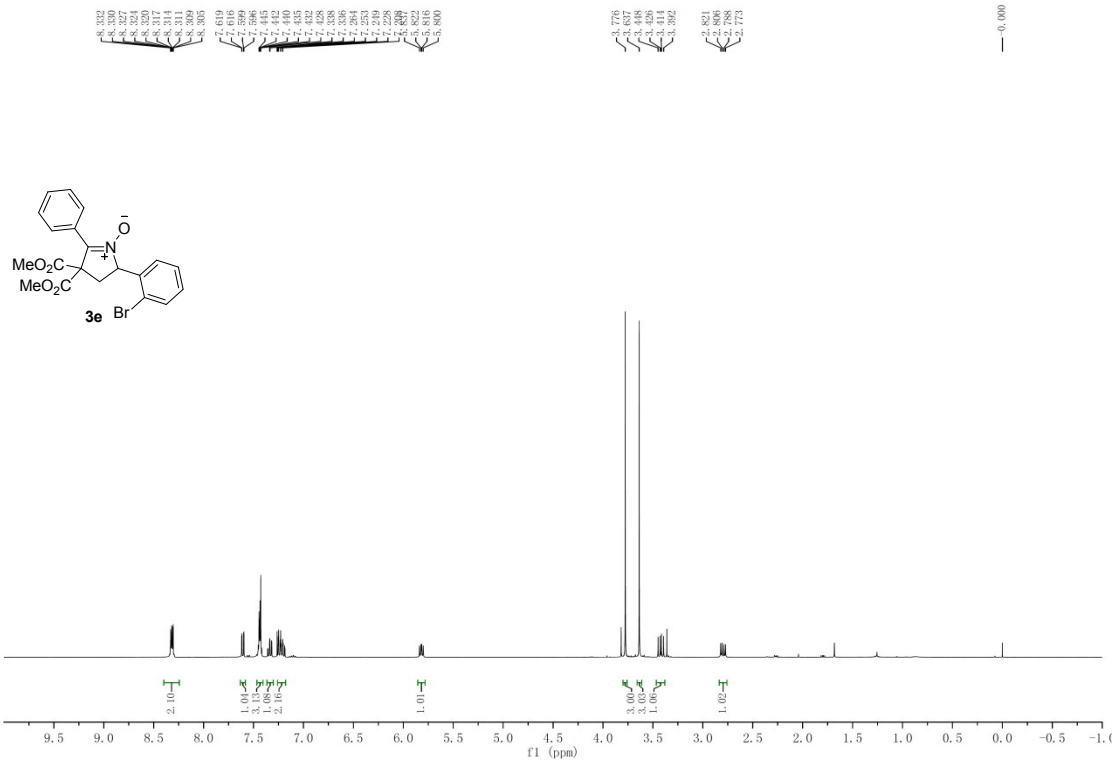
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3d**



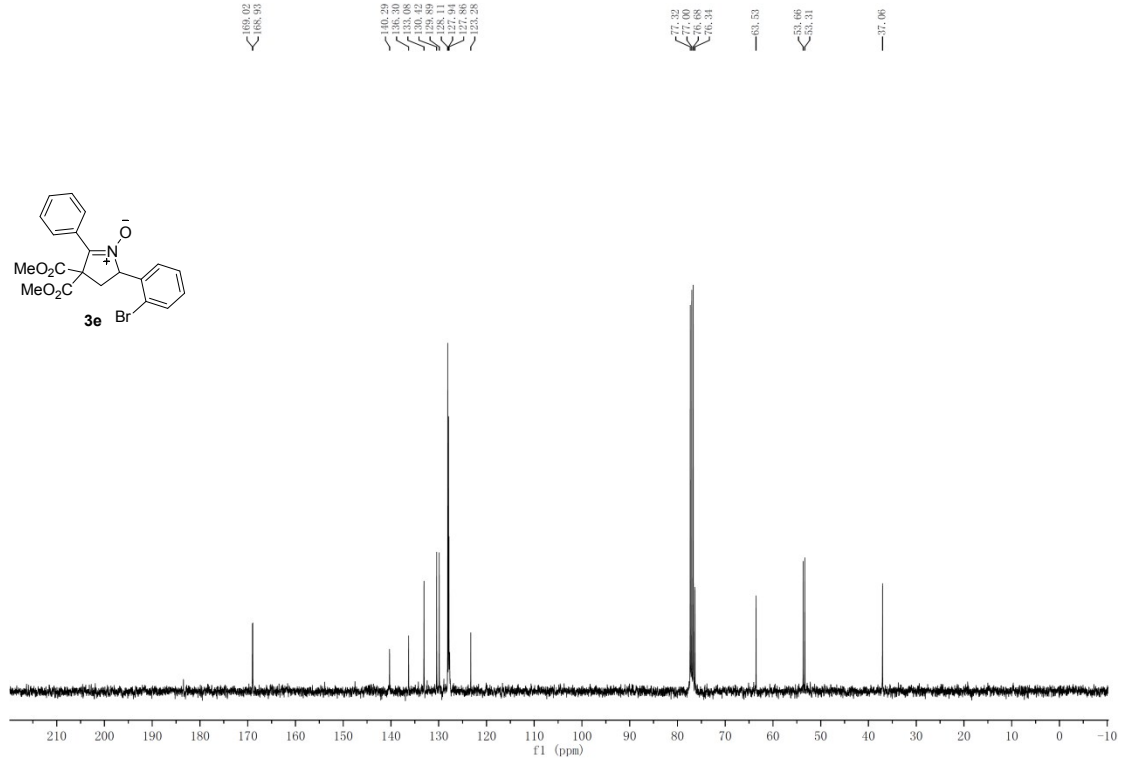
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3d**



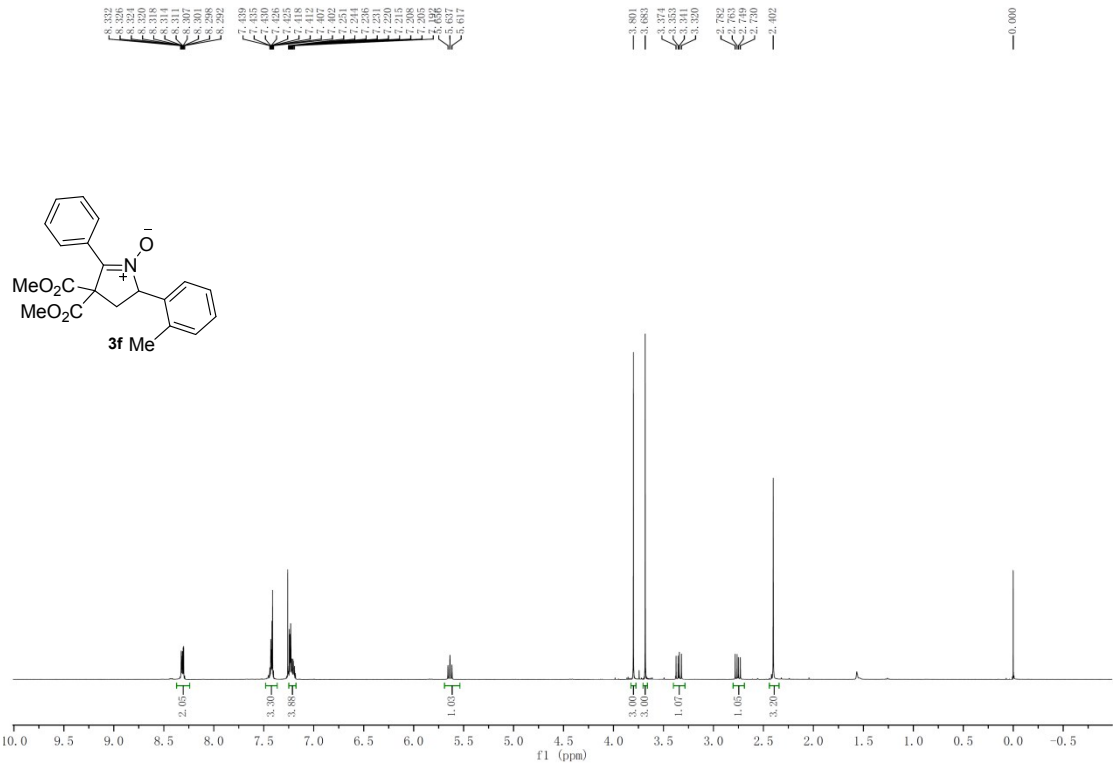
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3e**



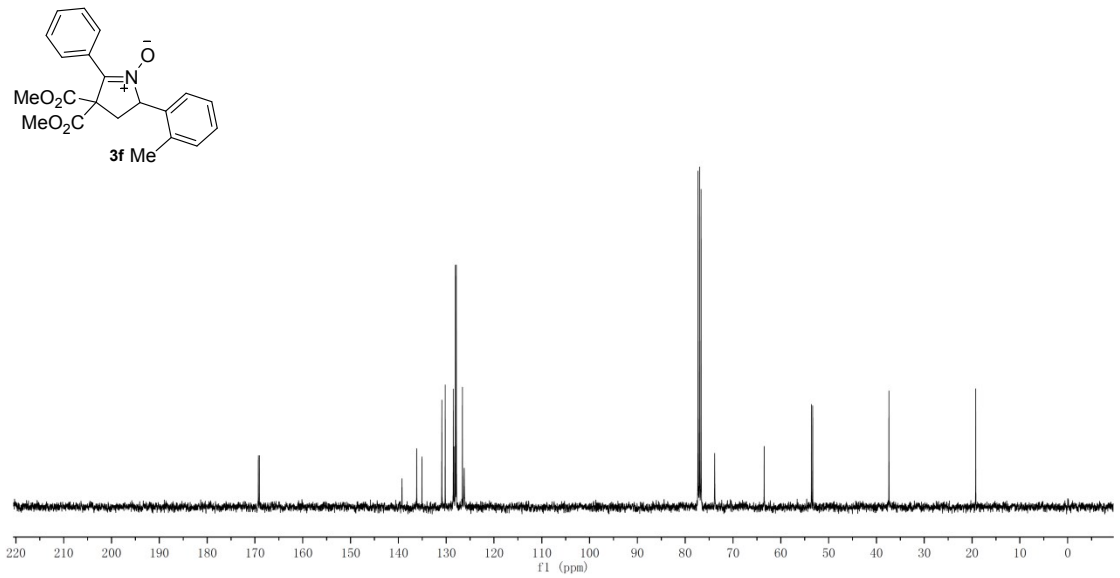
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3e**



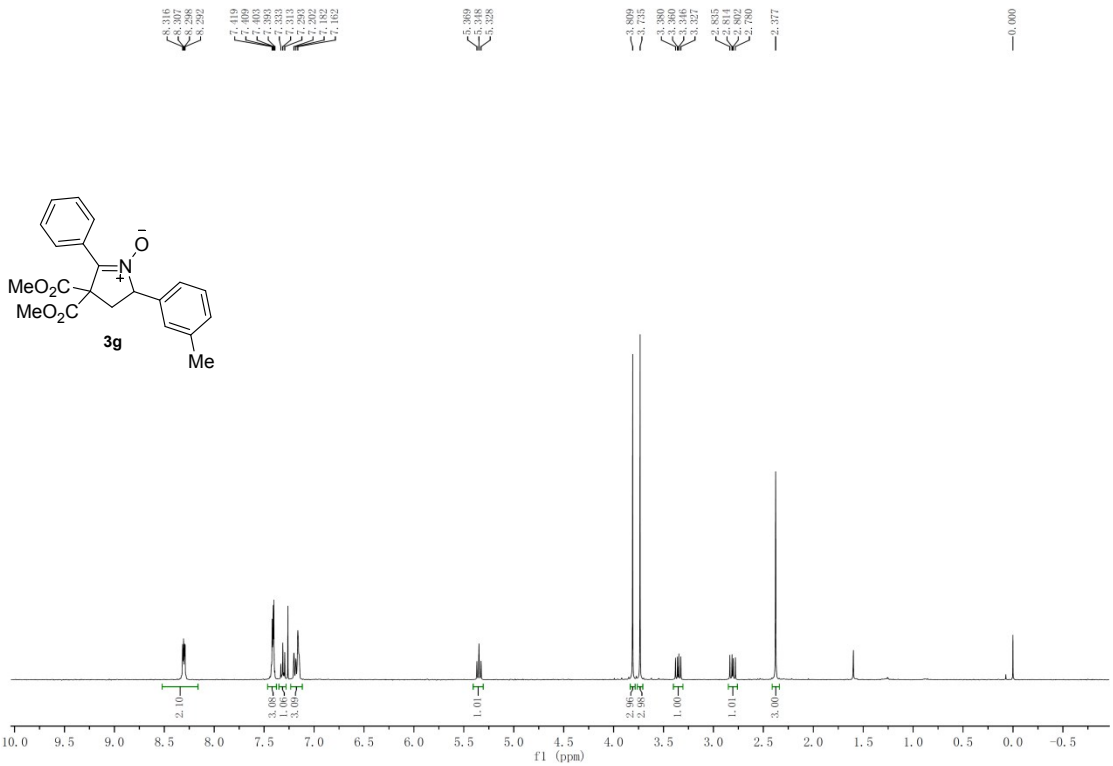
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3f**



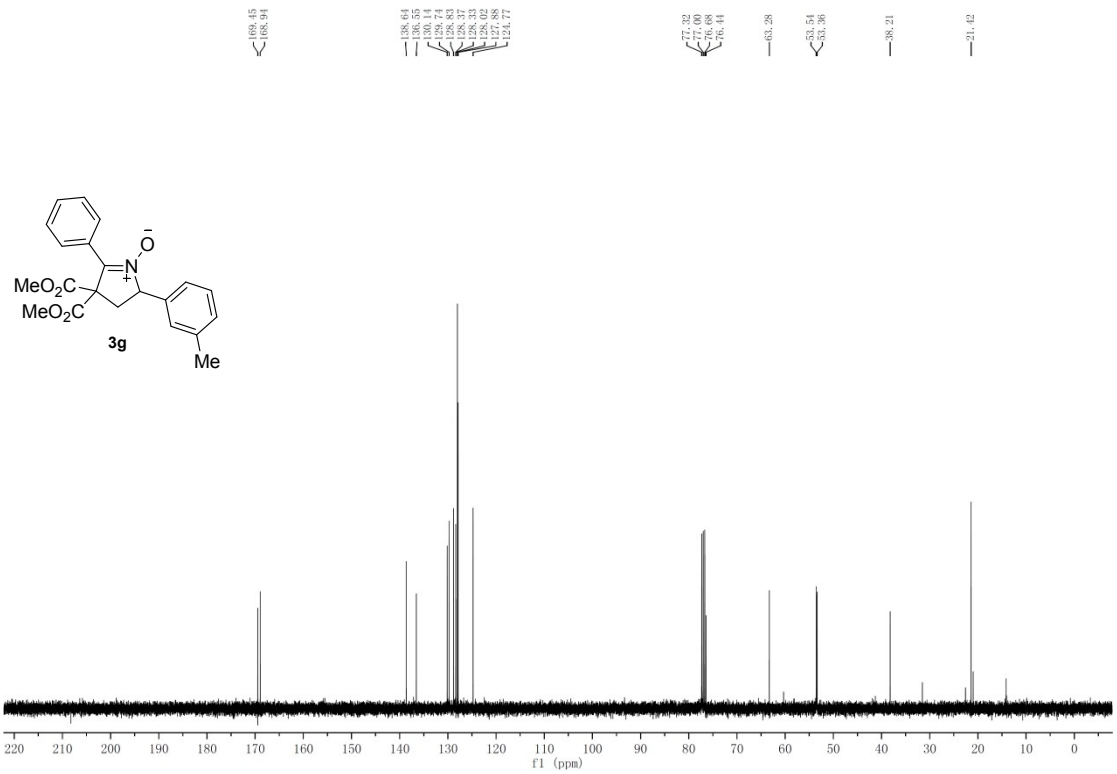
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3f**



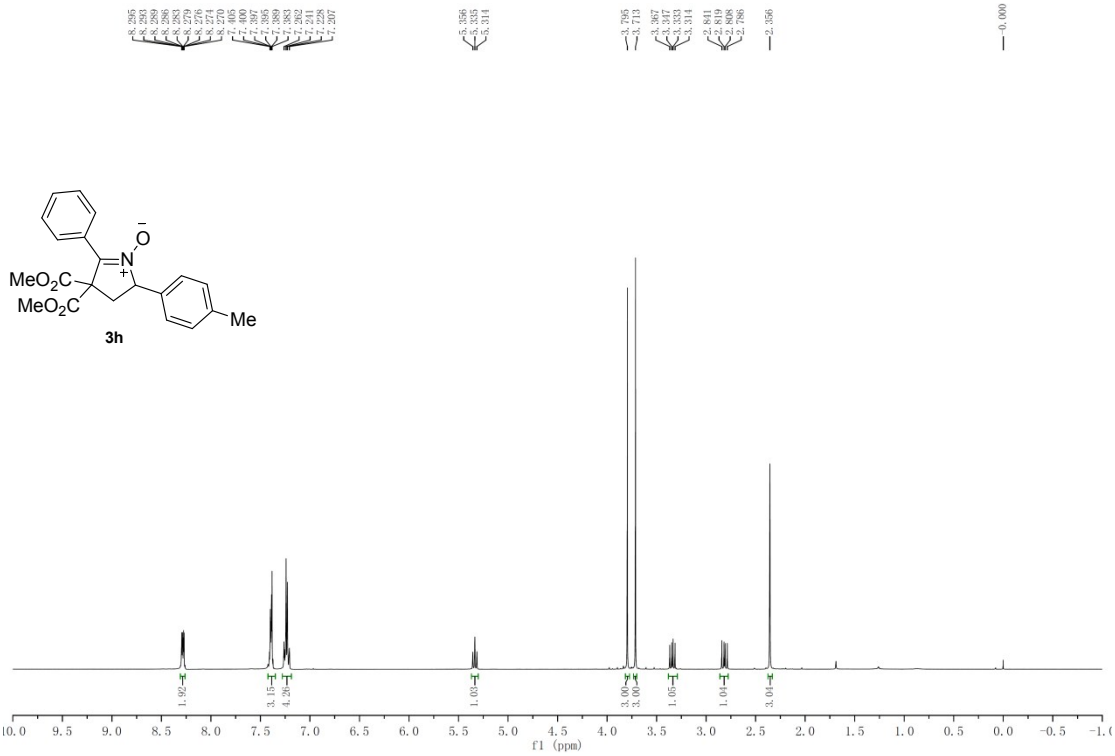
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3g**



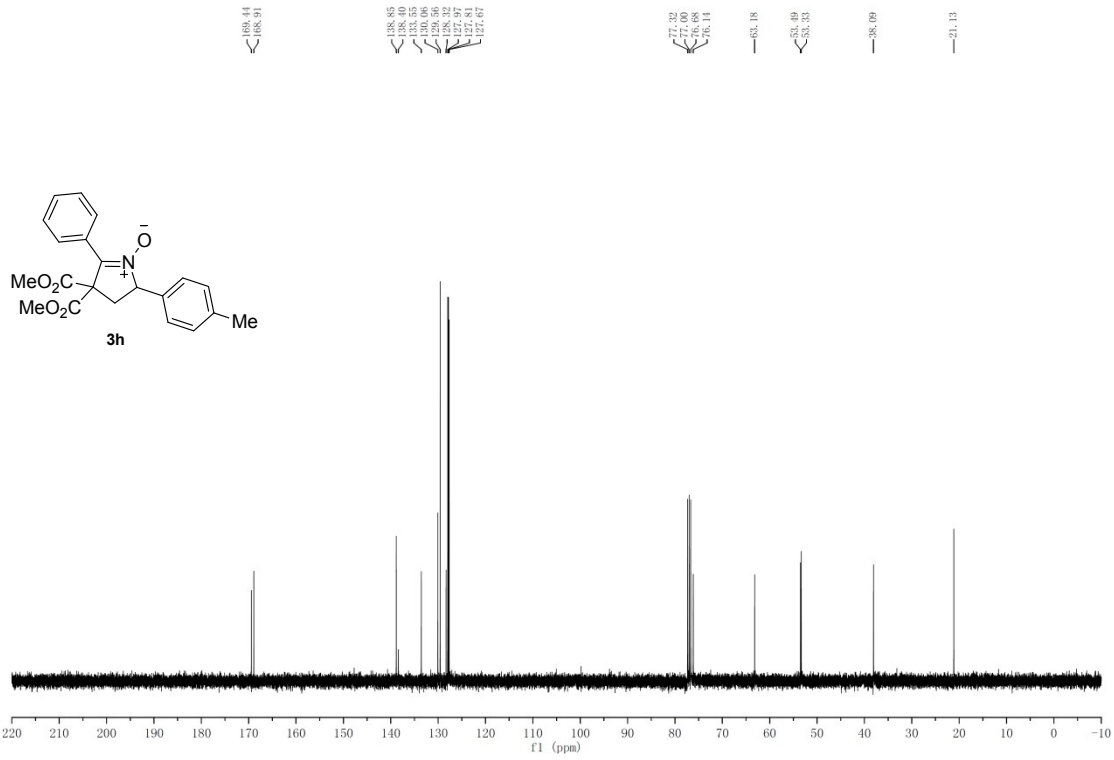
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3g**



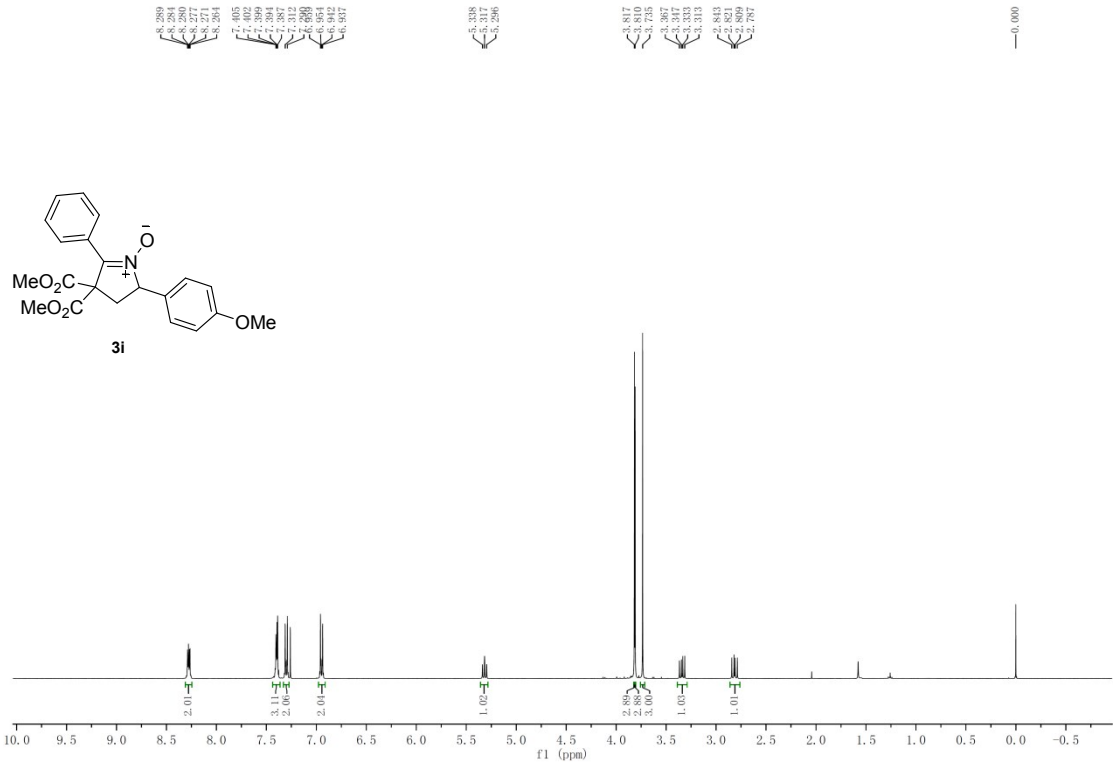
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3h**



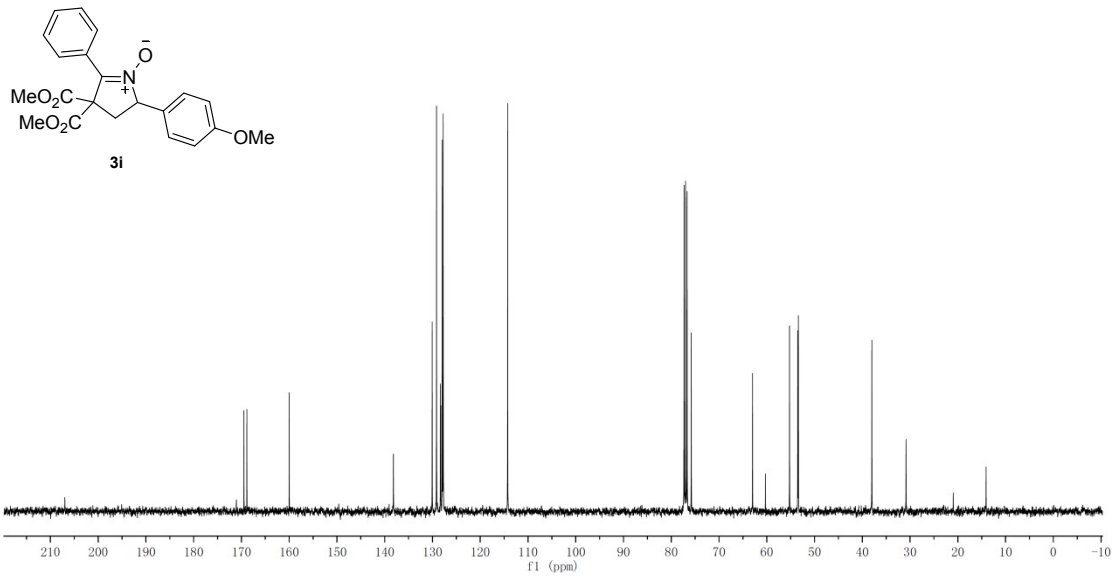
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3h**



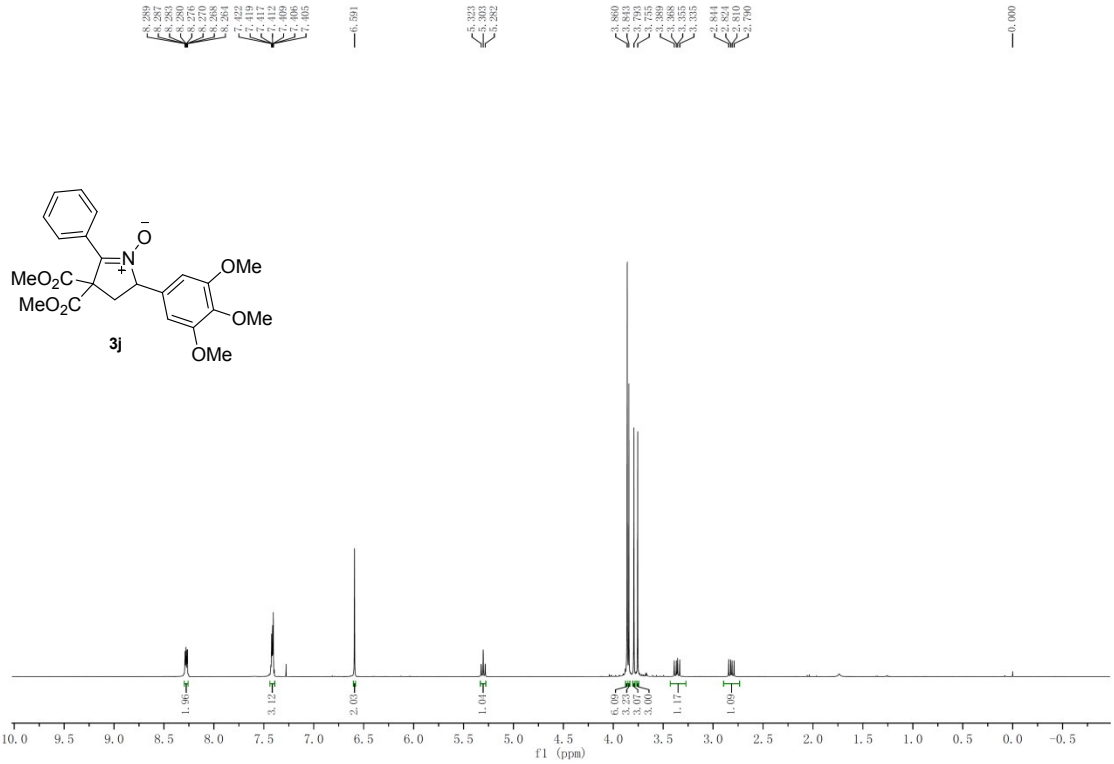
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3i**



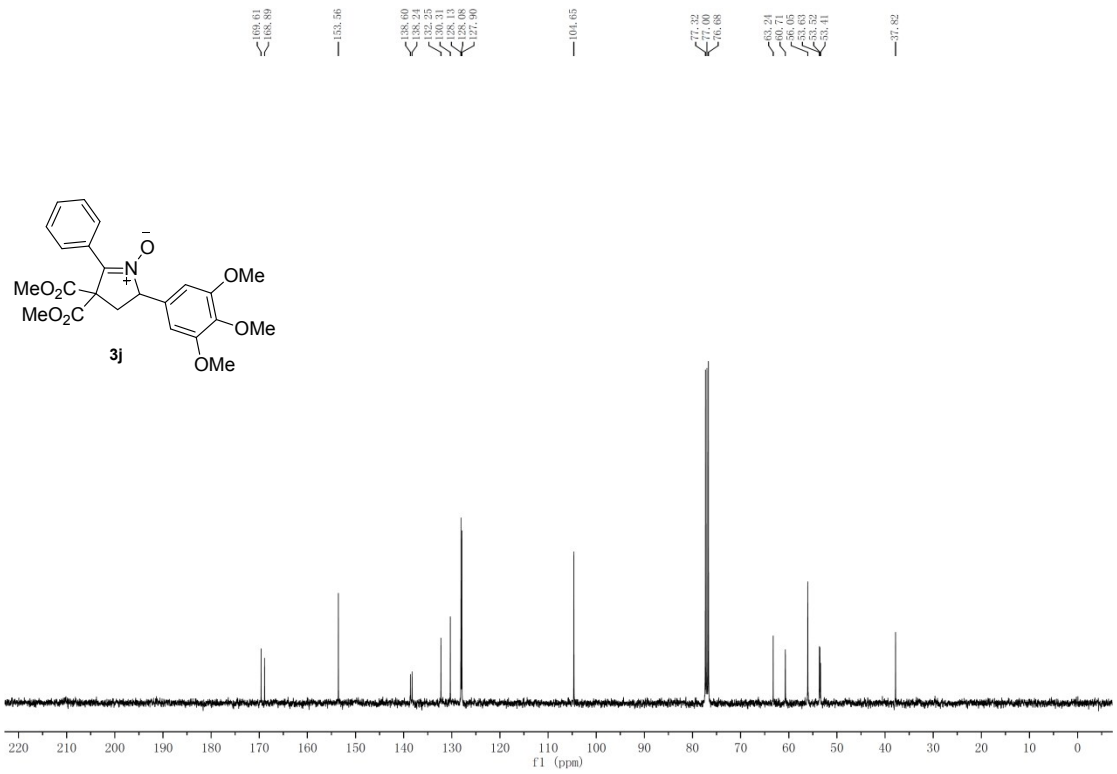
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3i**



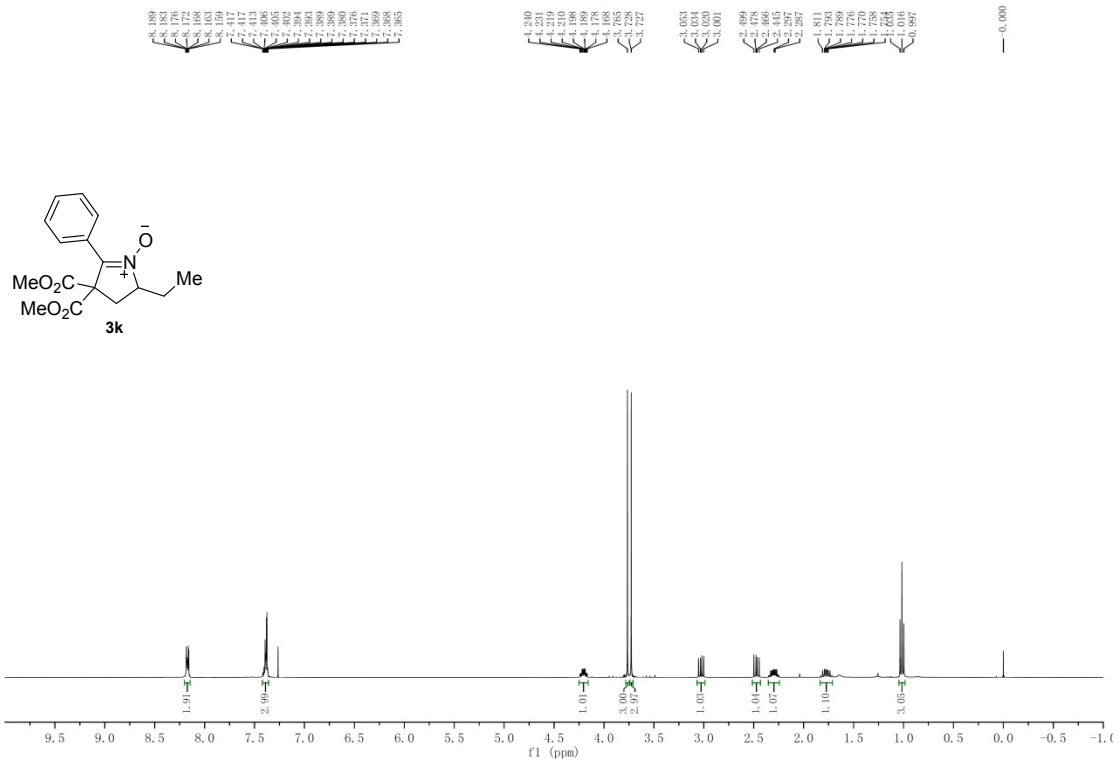
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3j**



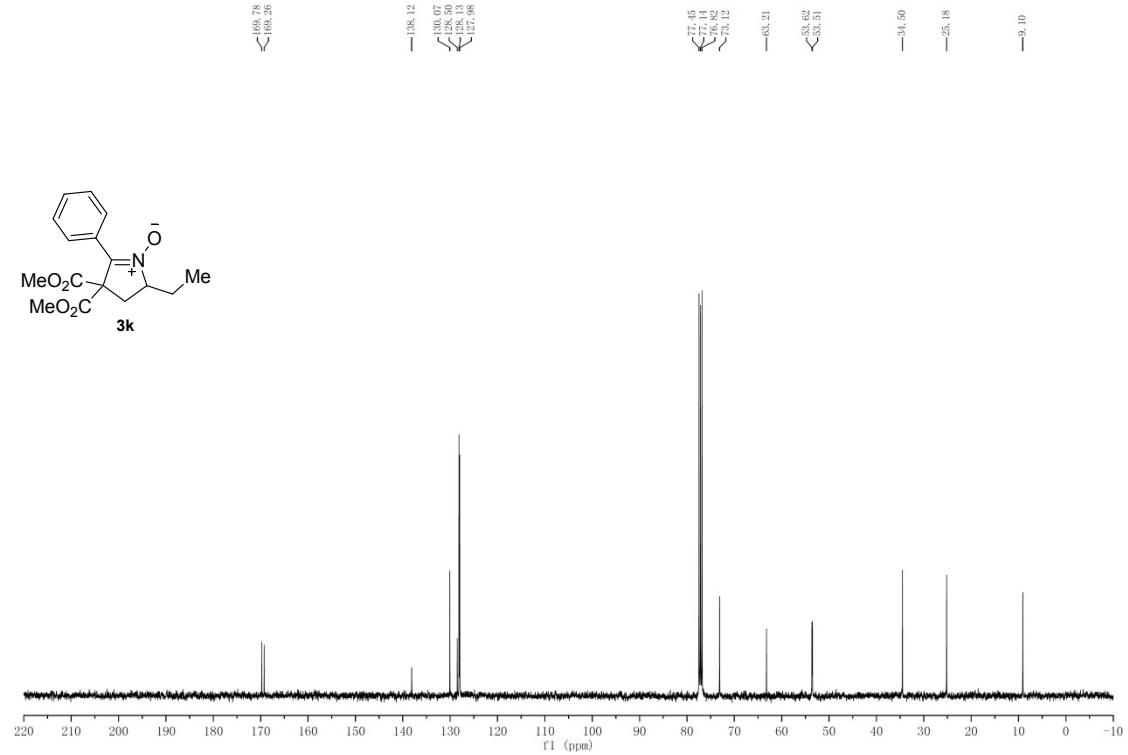
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3j**



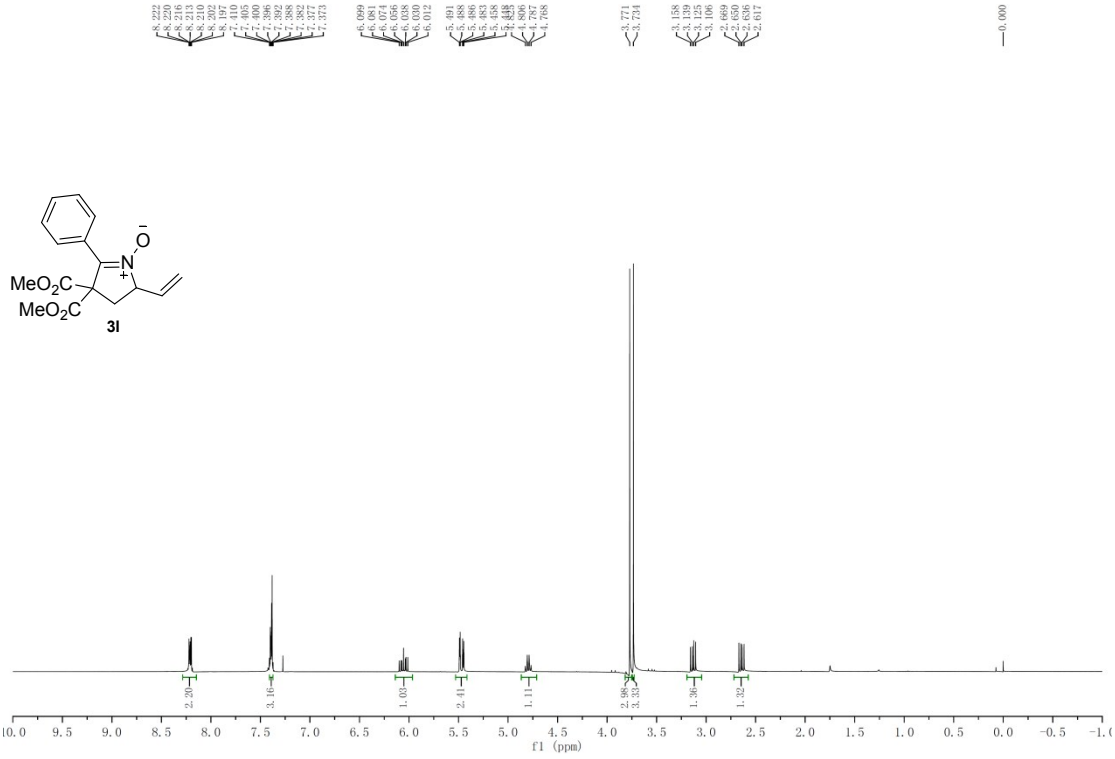
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3k**



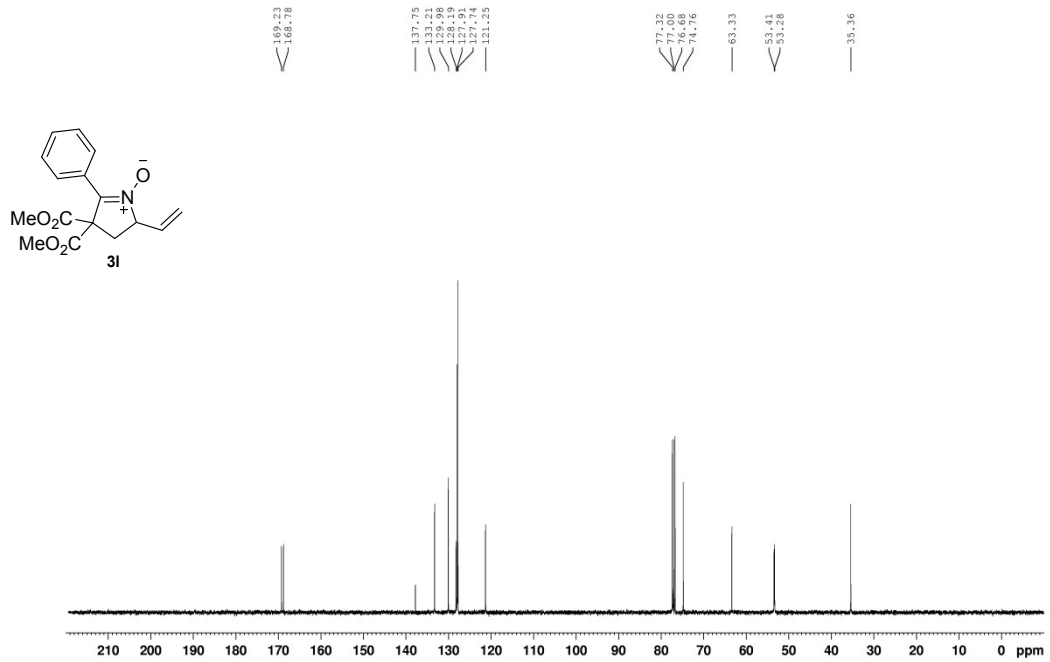
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3k**



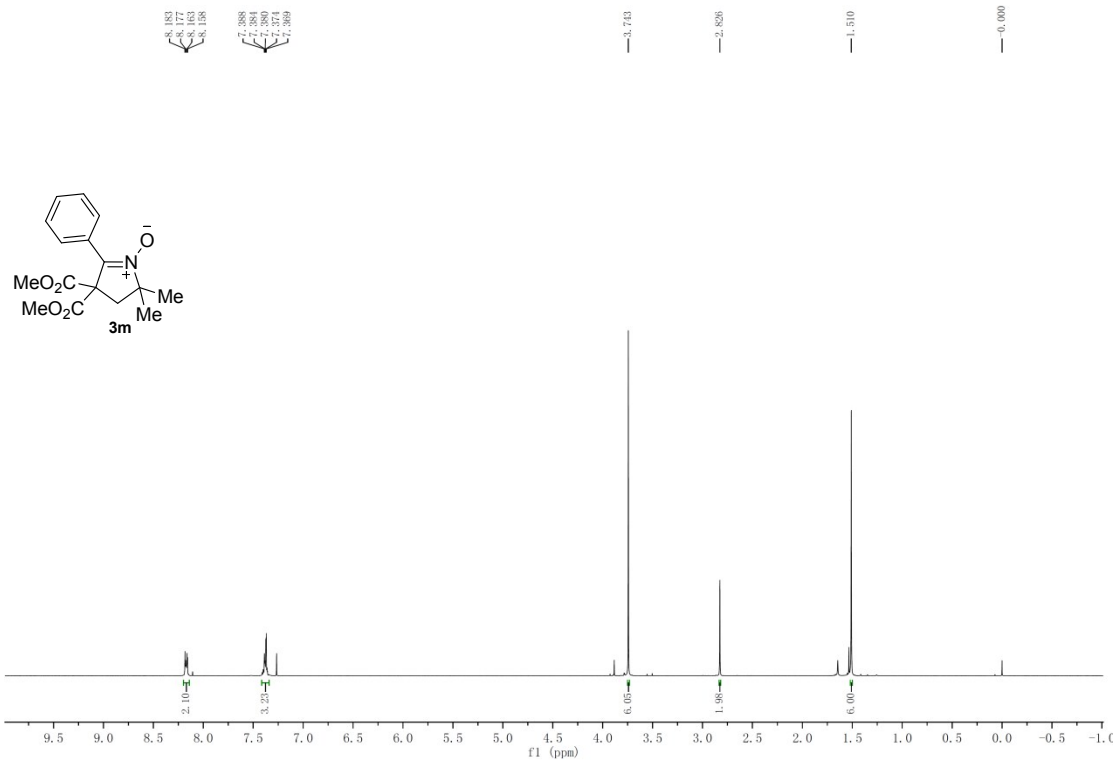
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3l**



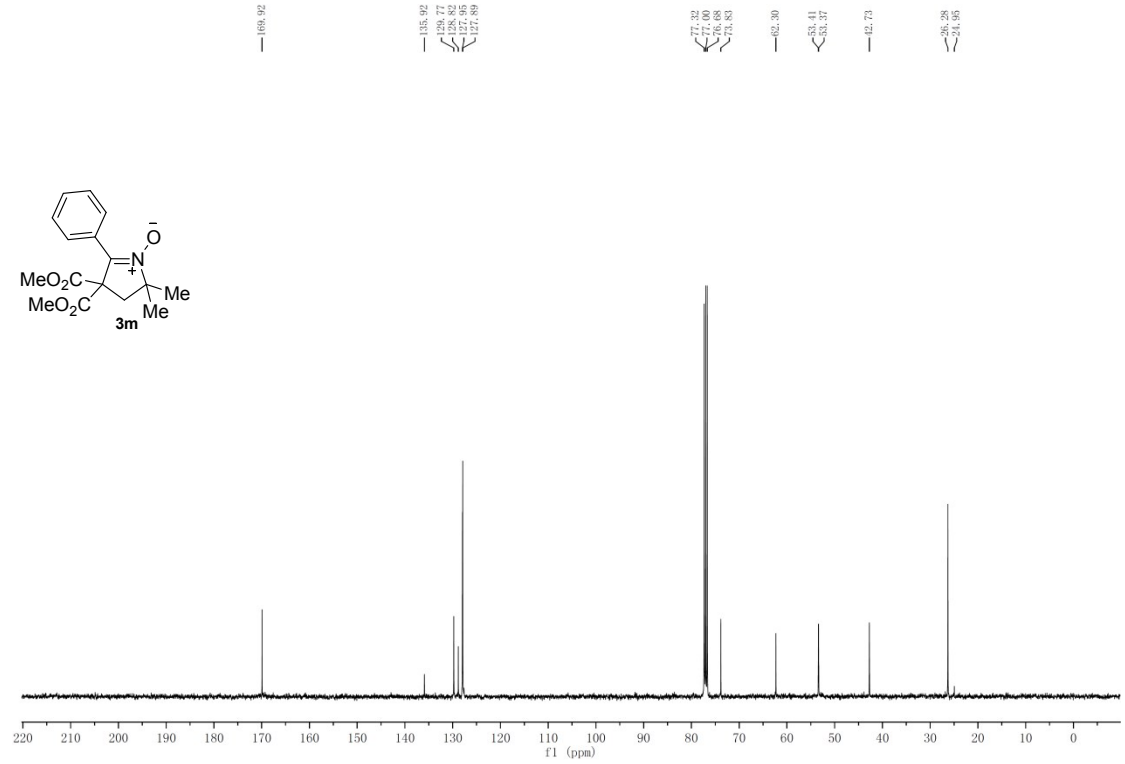
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3l**



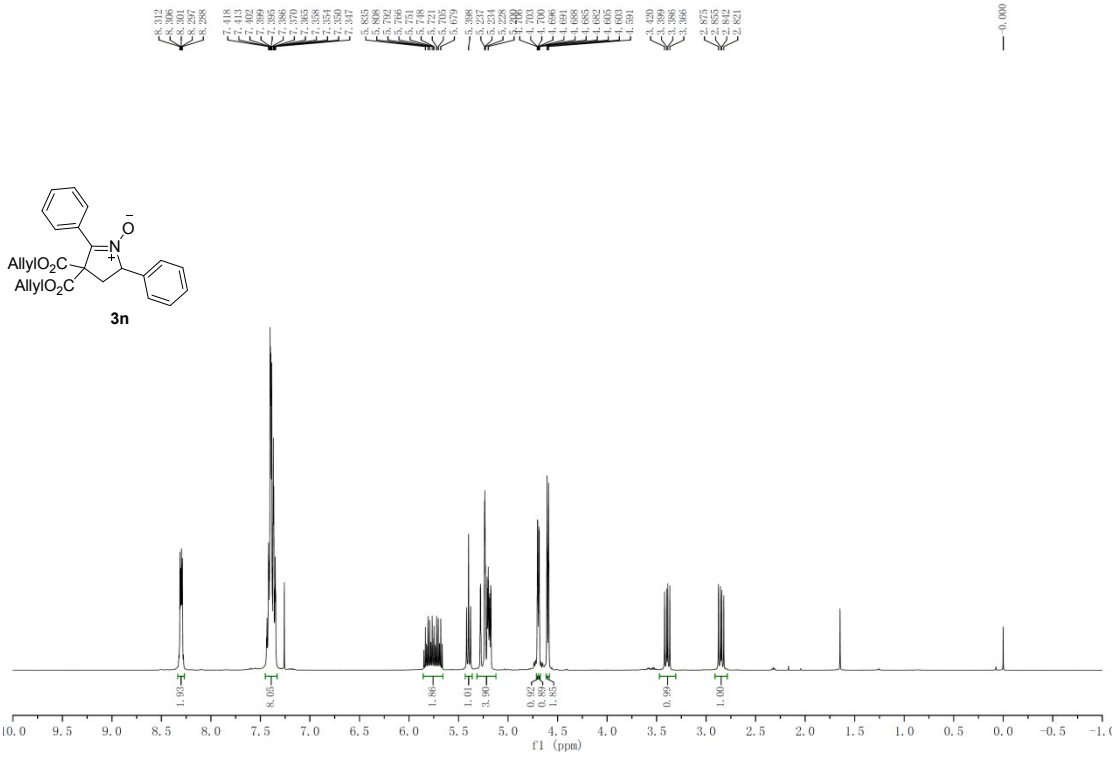
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3m**



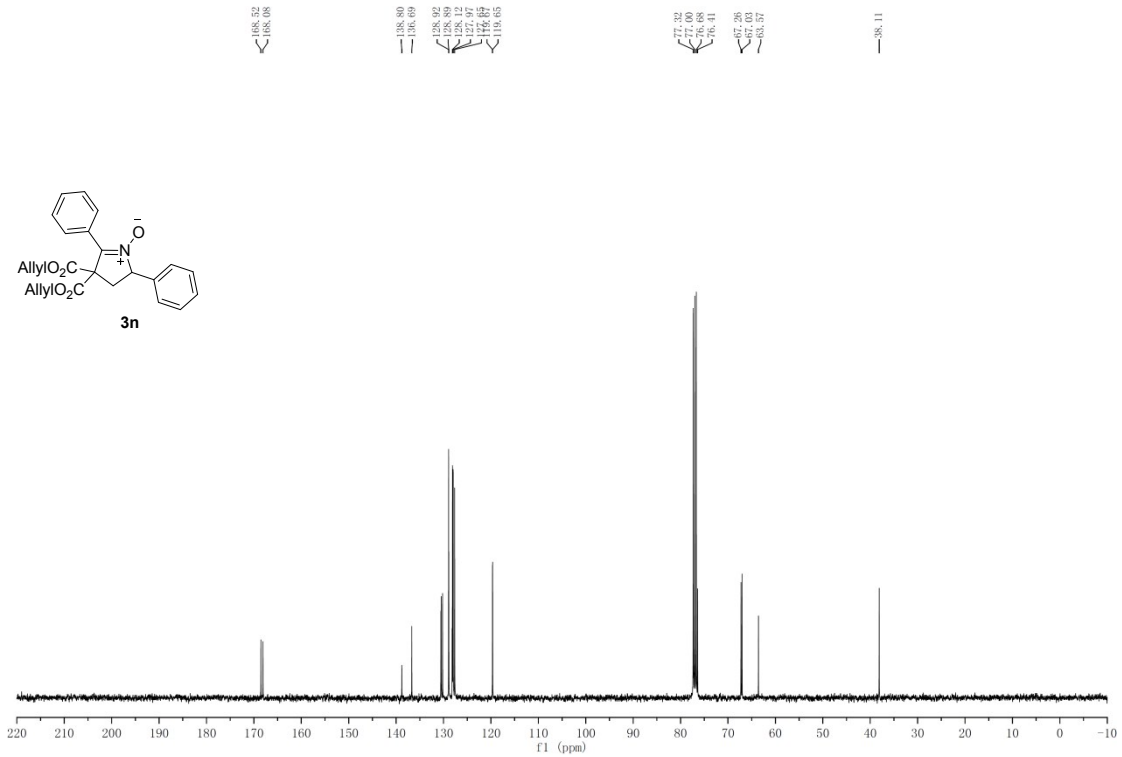
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3m**



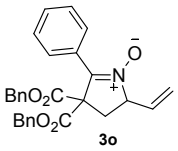
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3n**

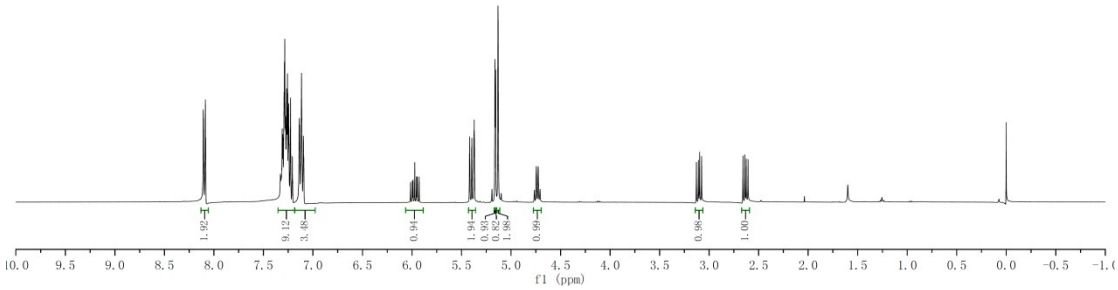


^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3n**

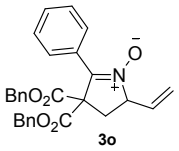


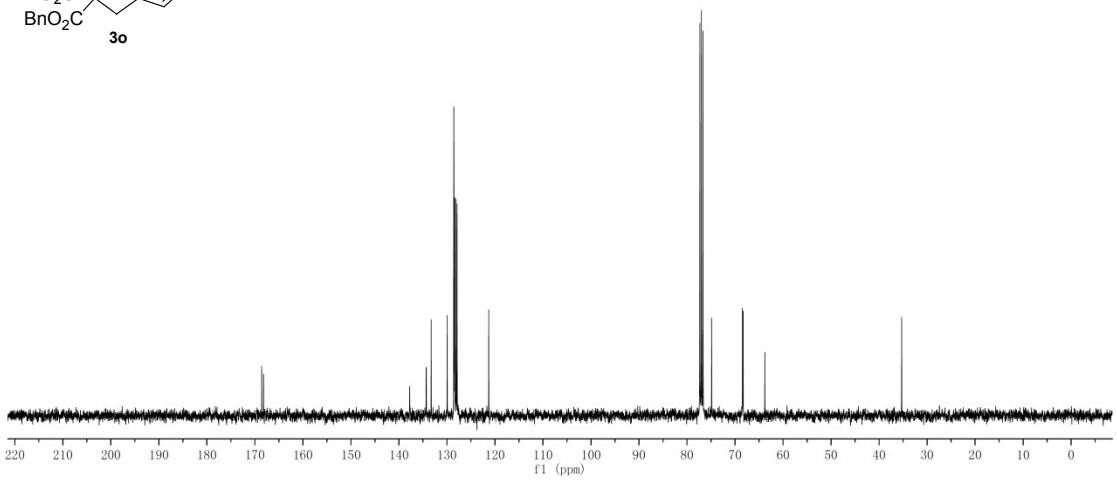
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3o**



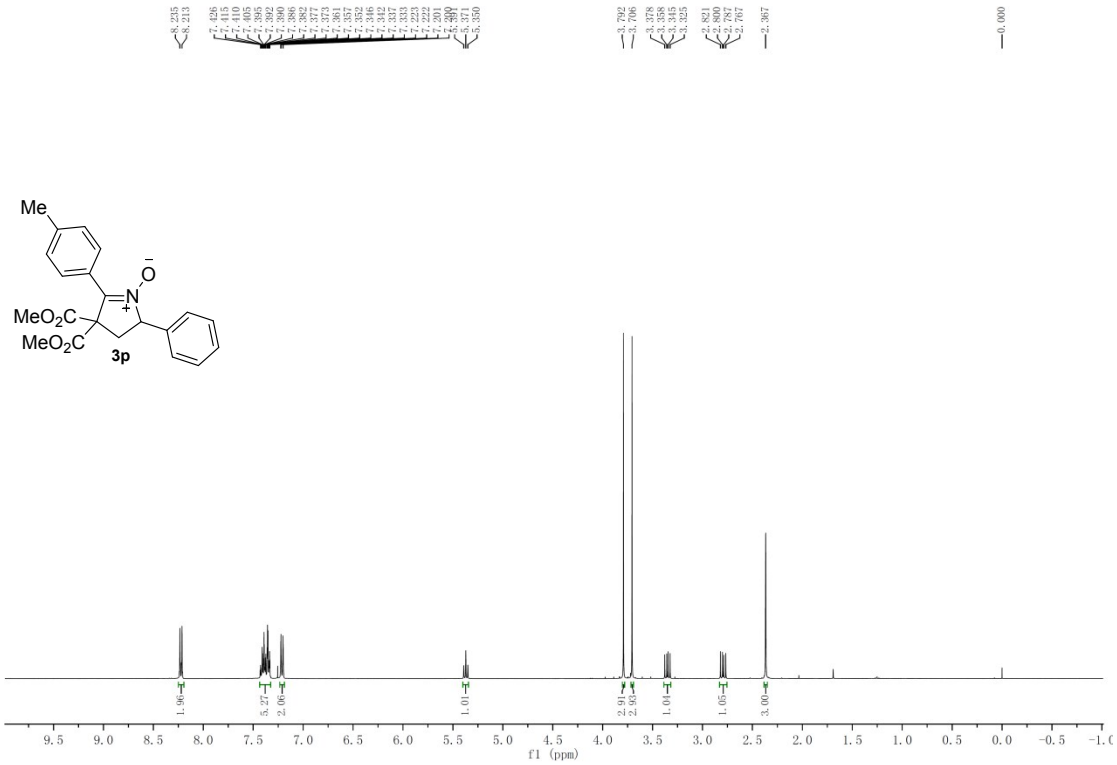


^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3o**

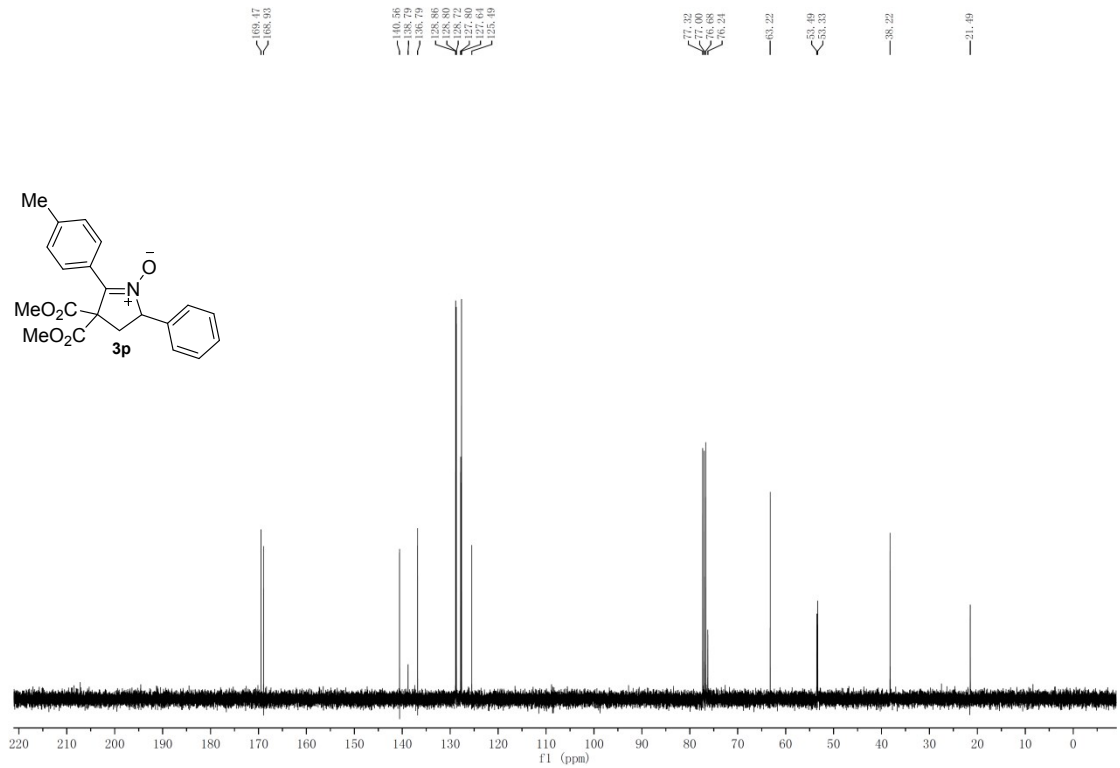




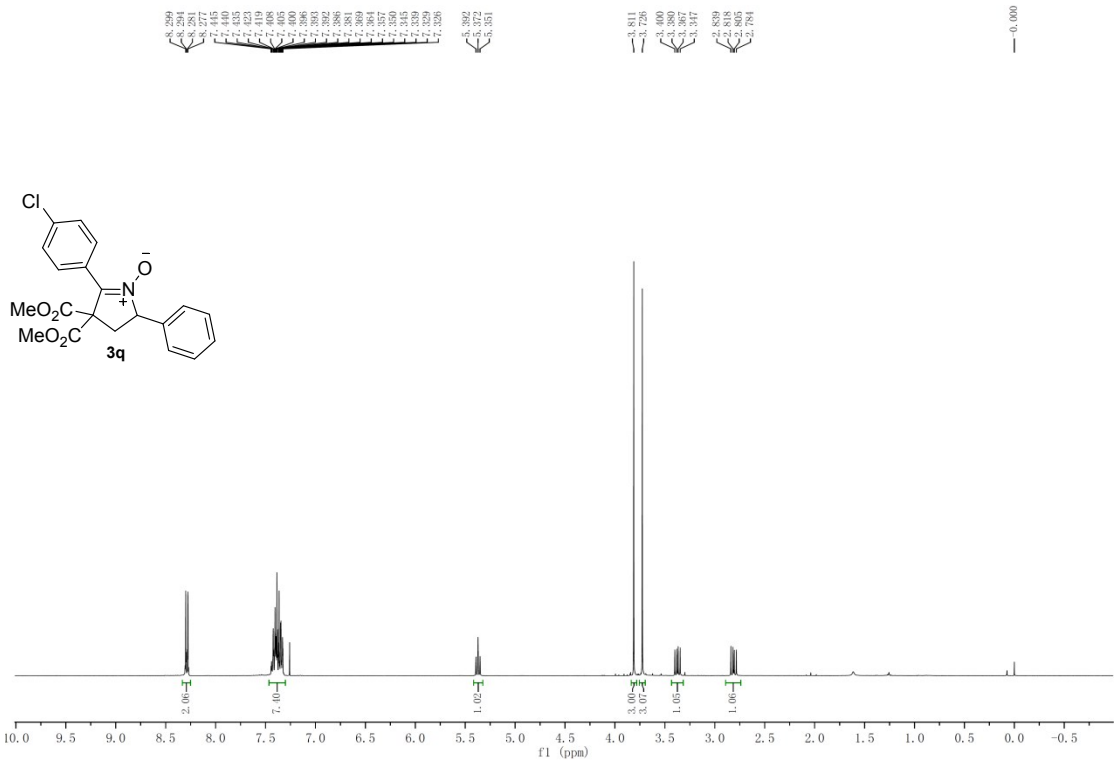
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3p**



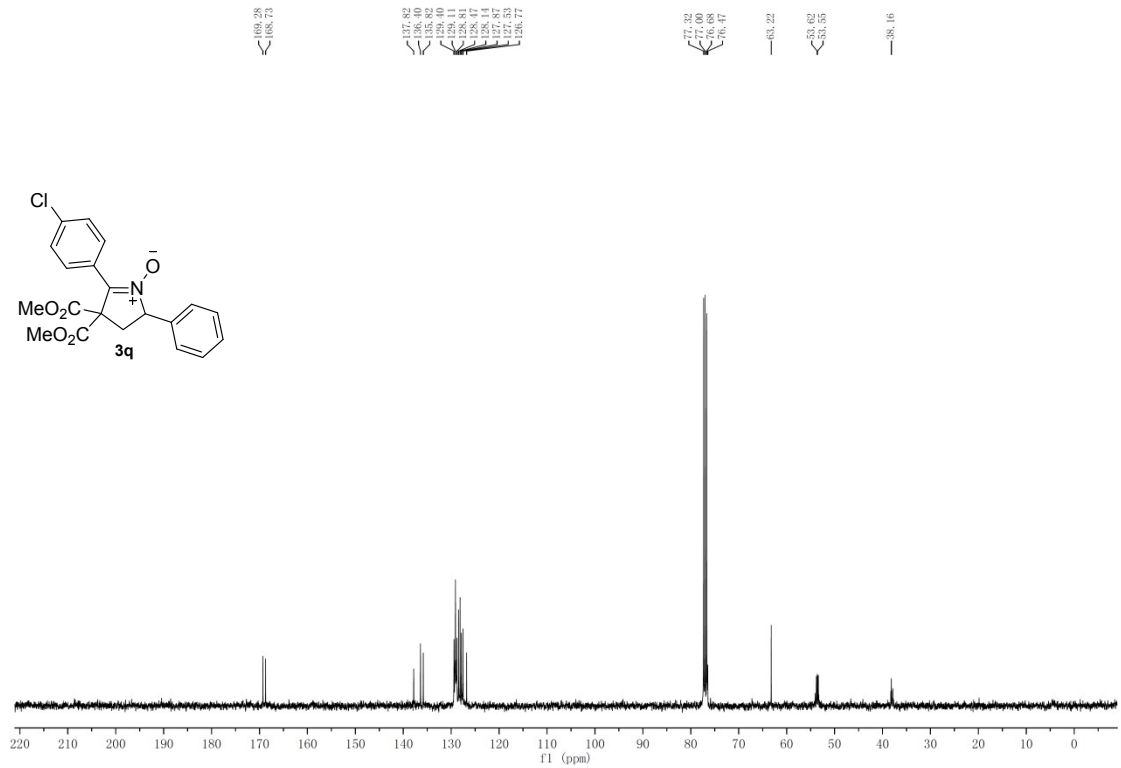
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3p**



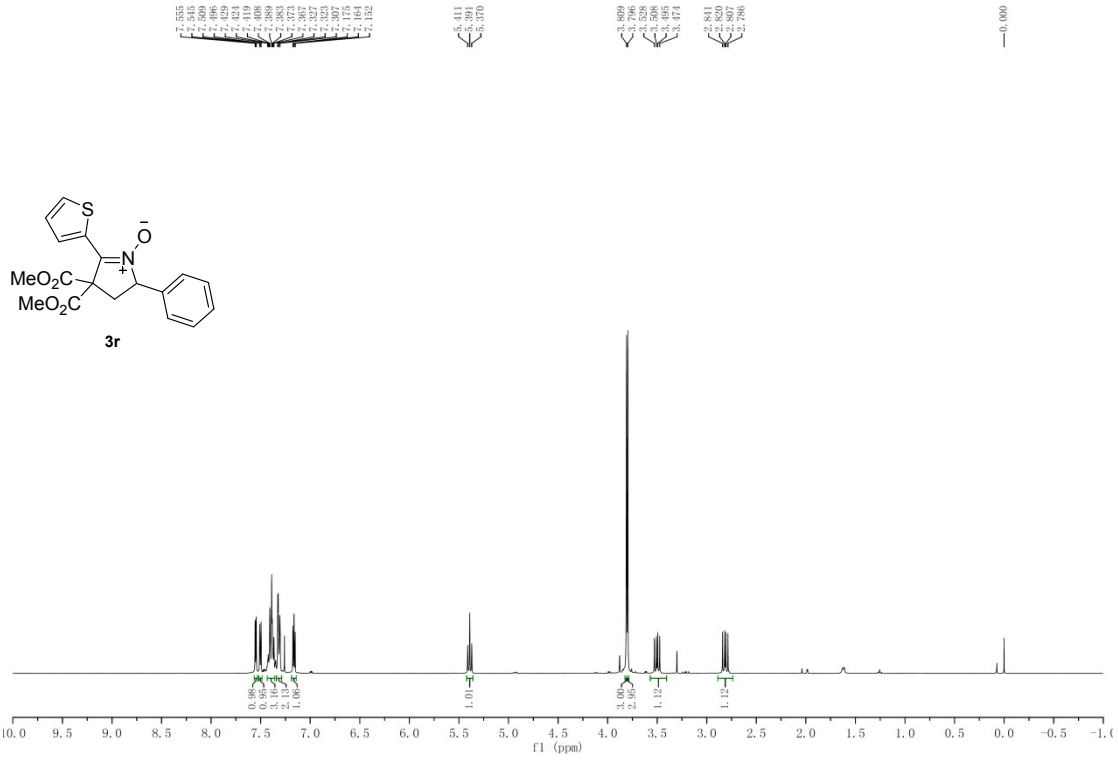
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3q**



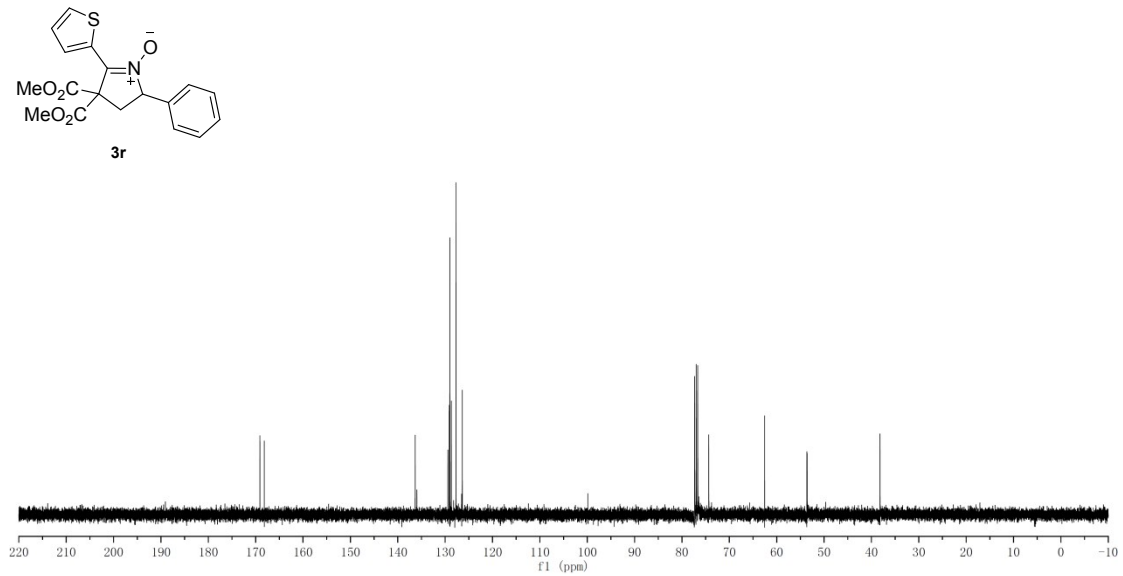
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3q**



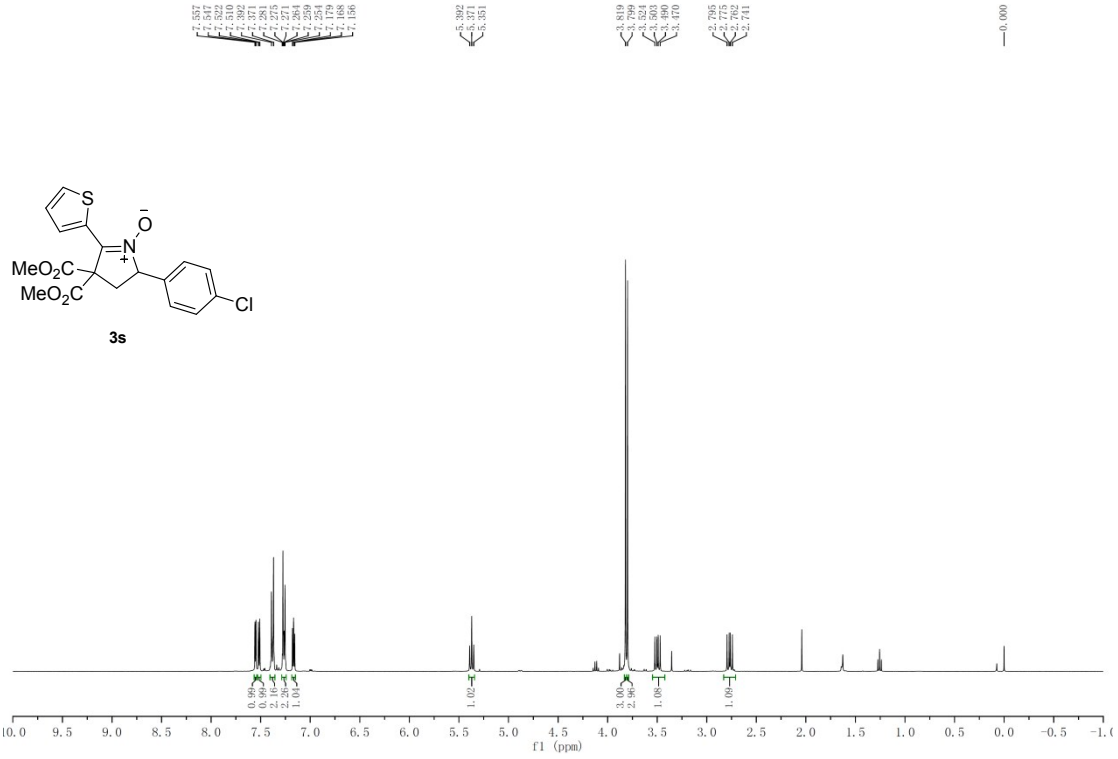
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3r**



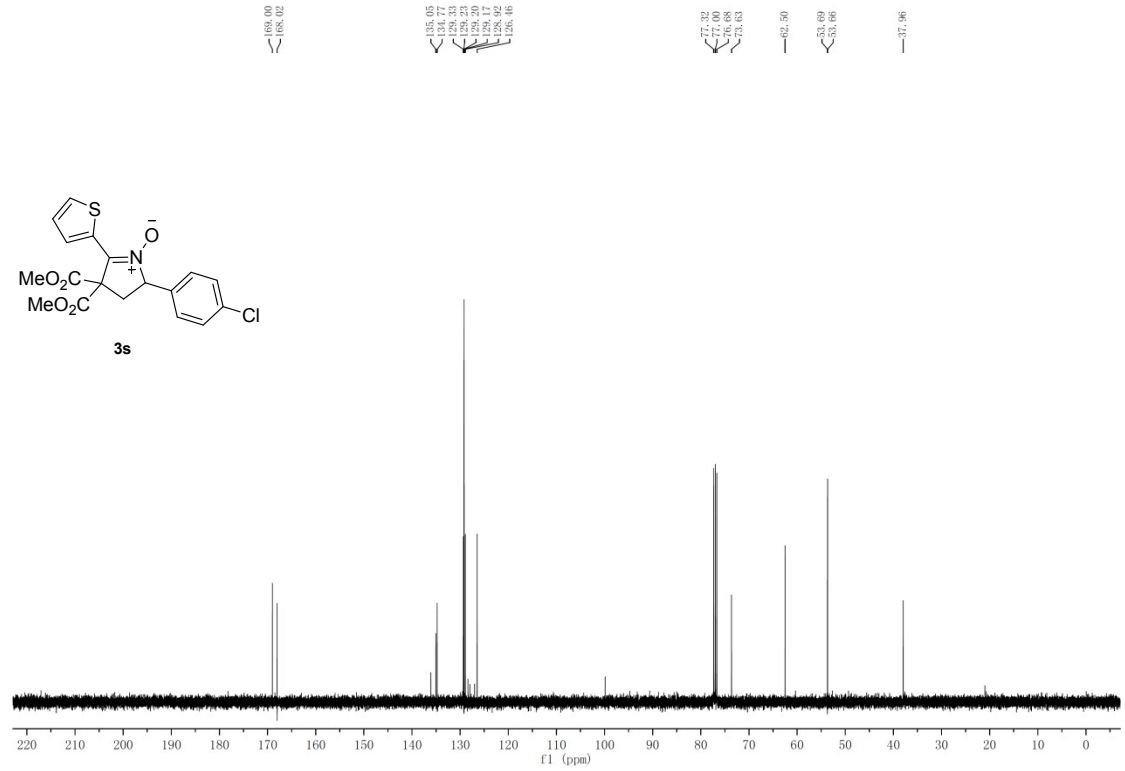
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3r**



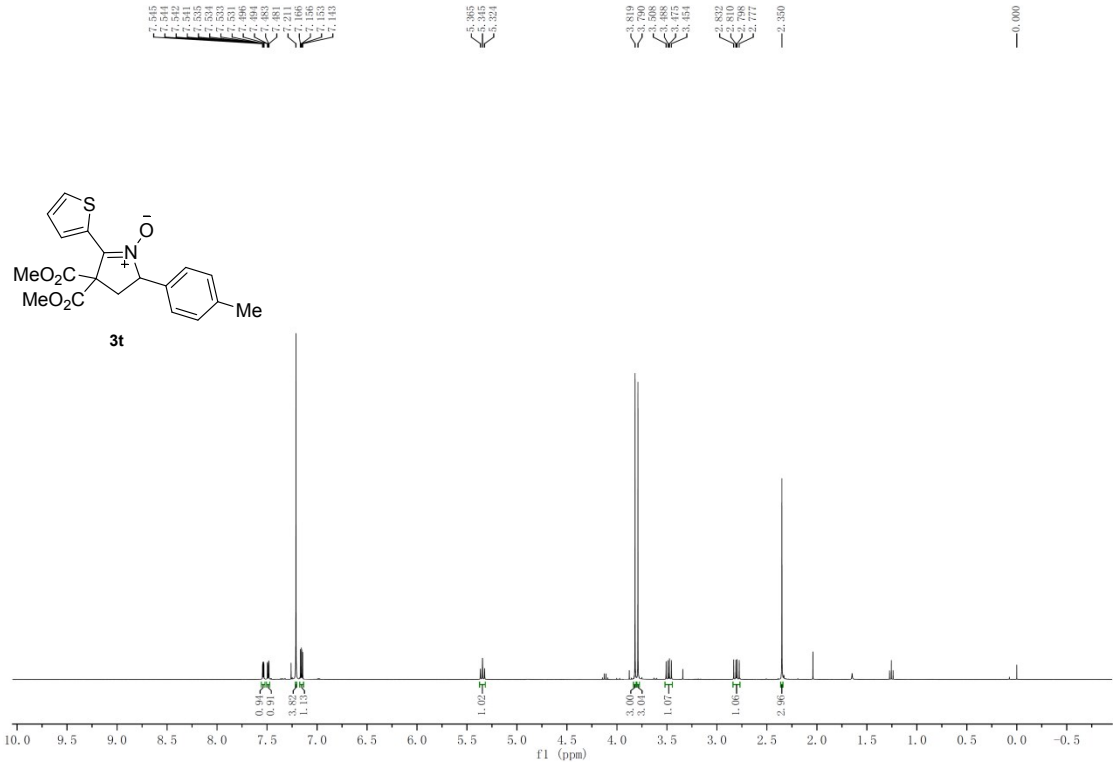
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3s**



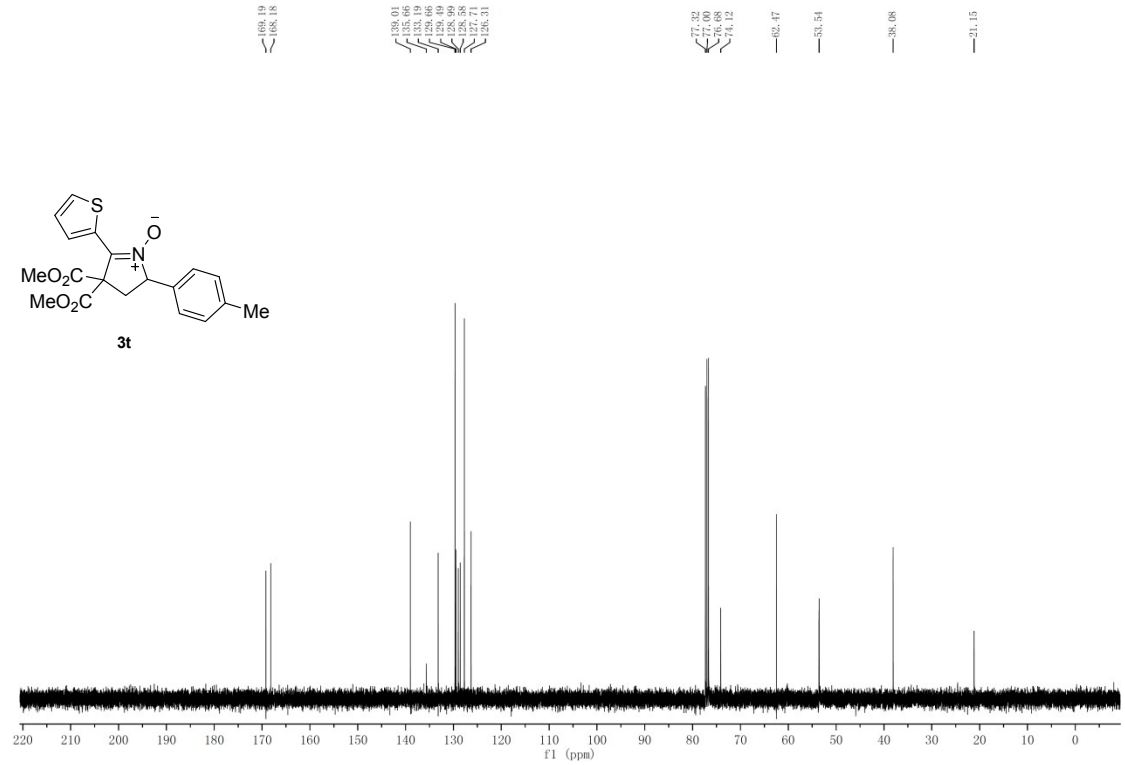
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3s**



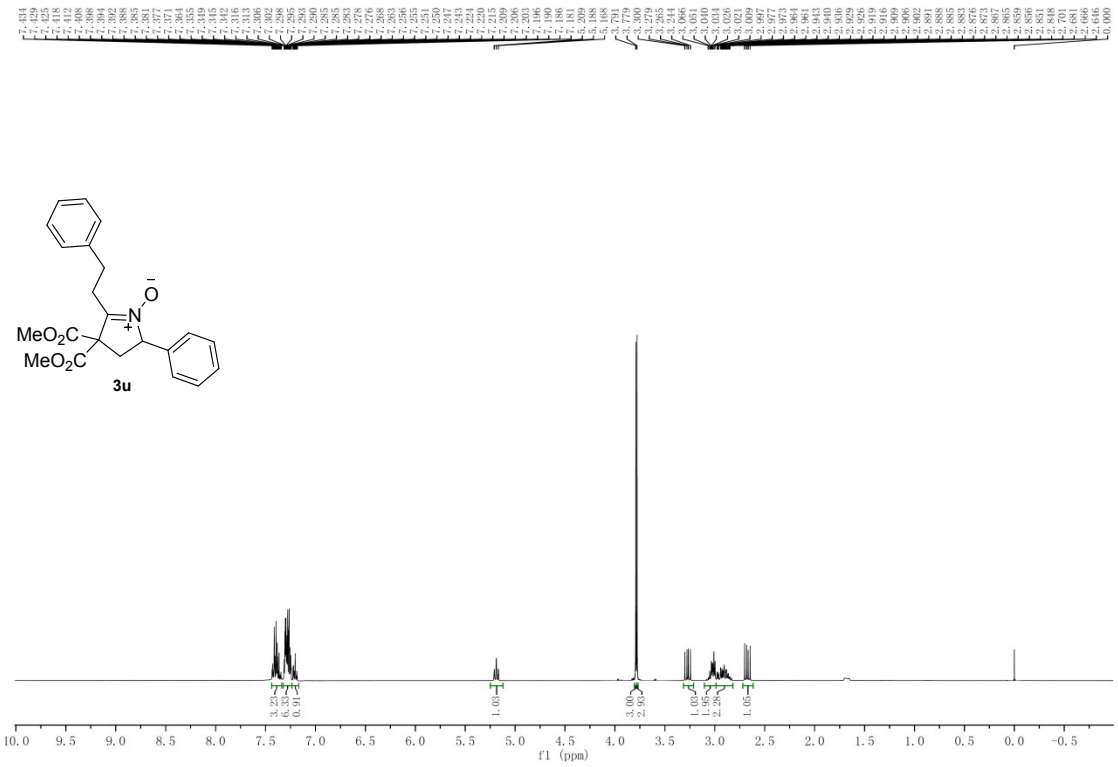
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3t**



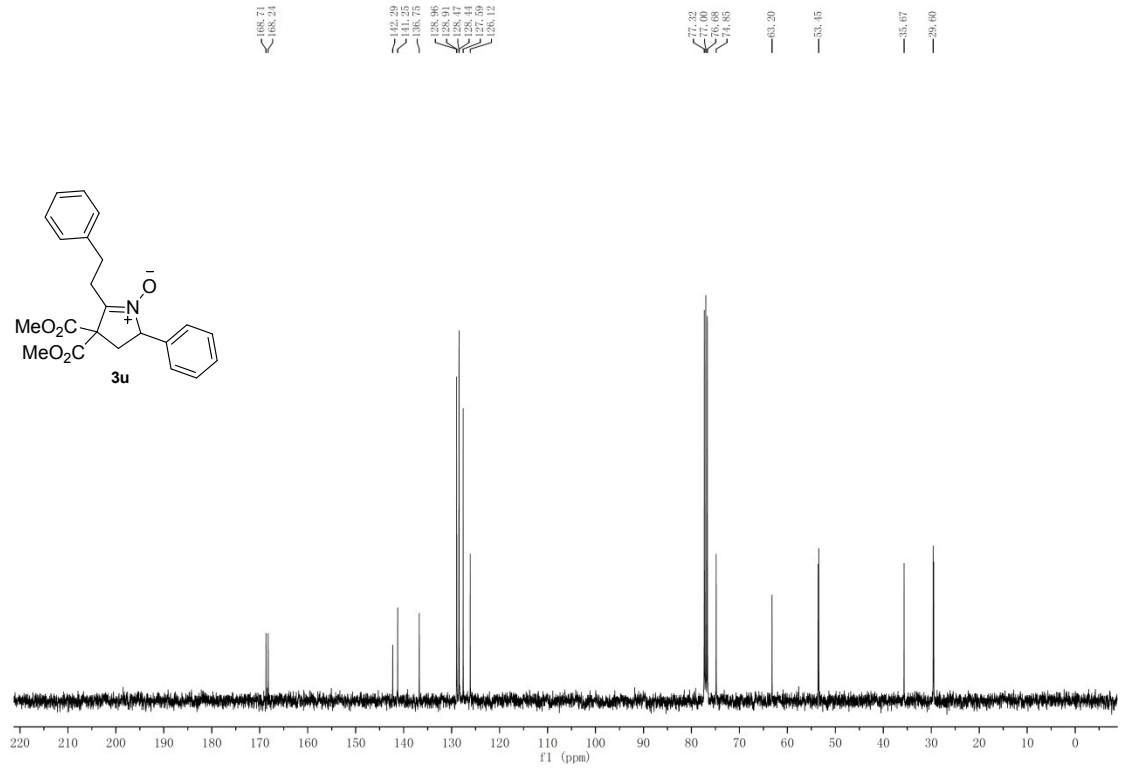
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3t**



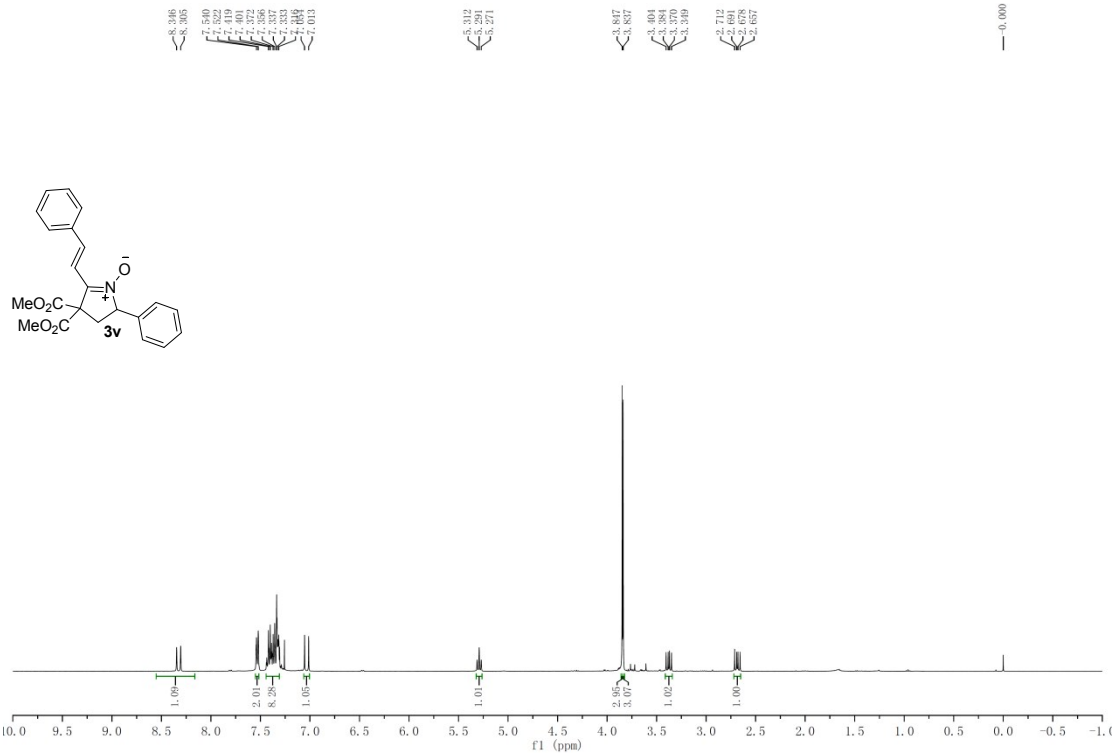
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3u**



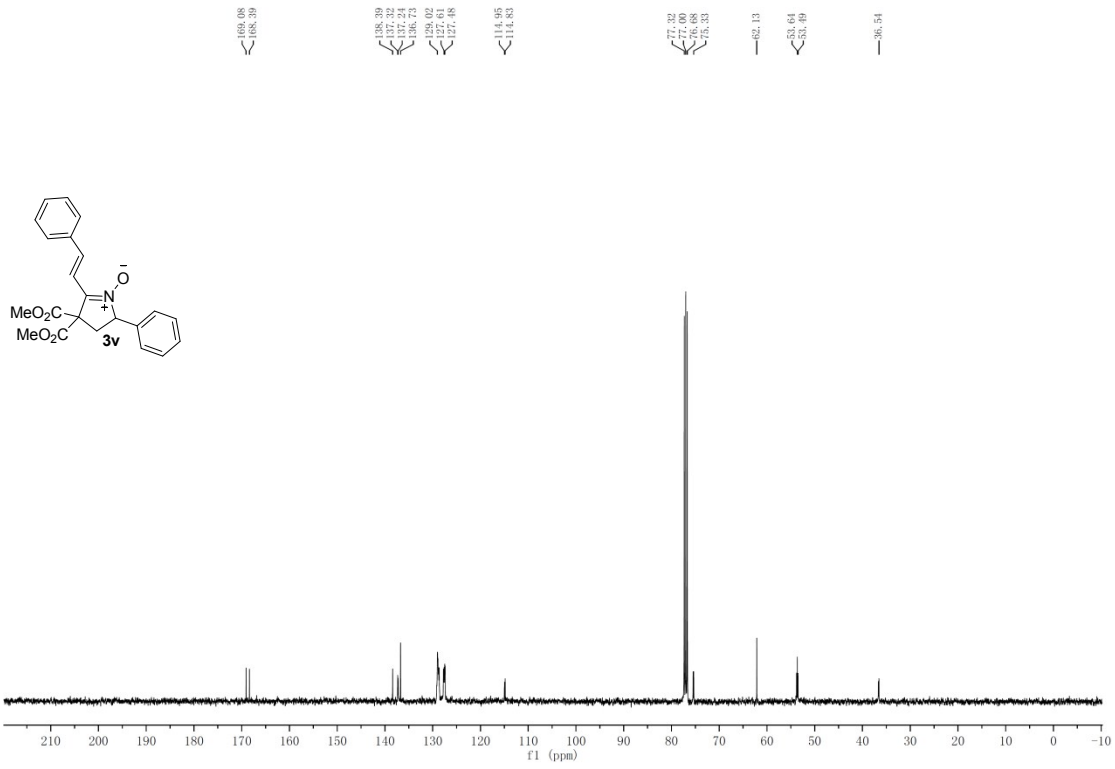
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3u**



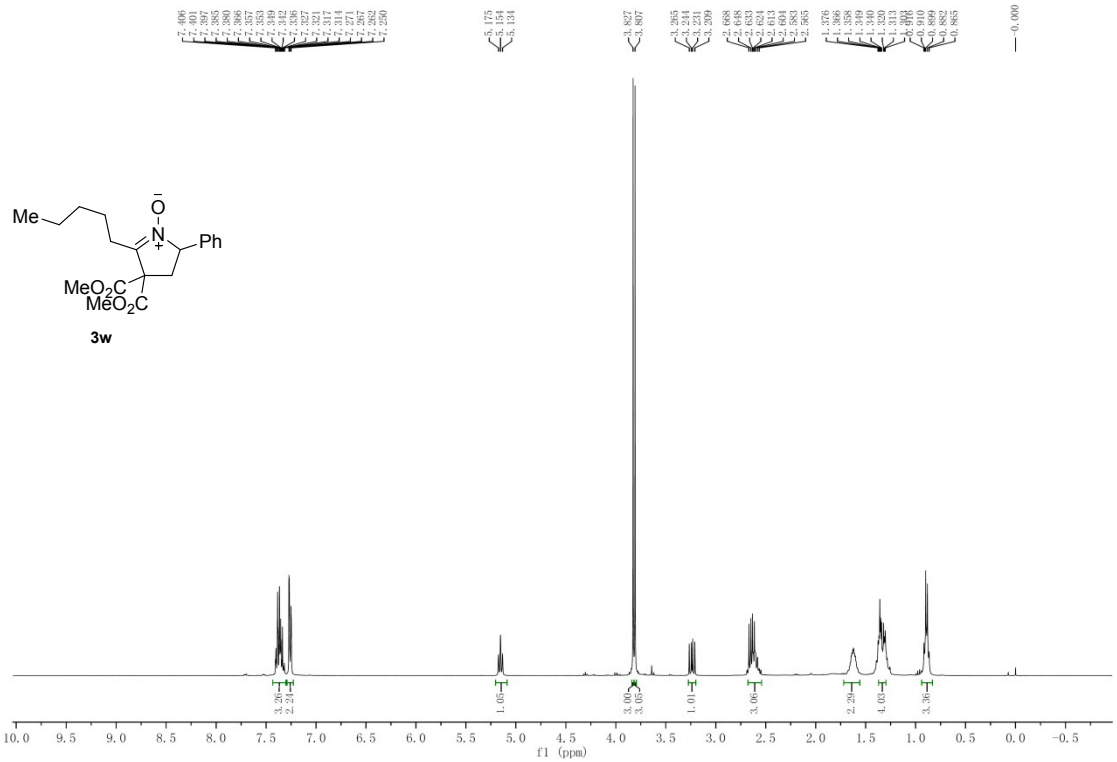
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3v**



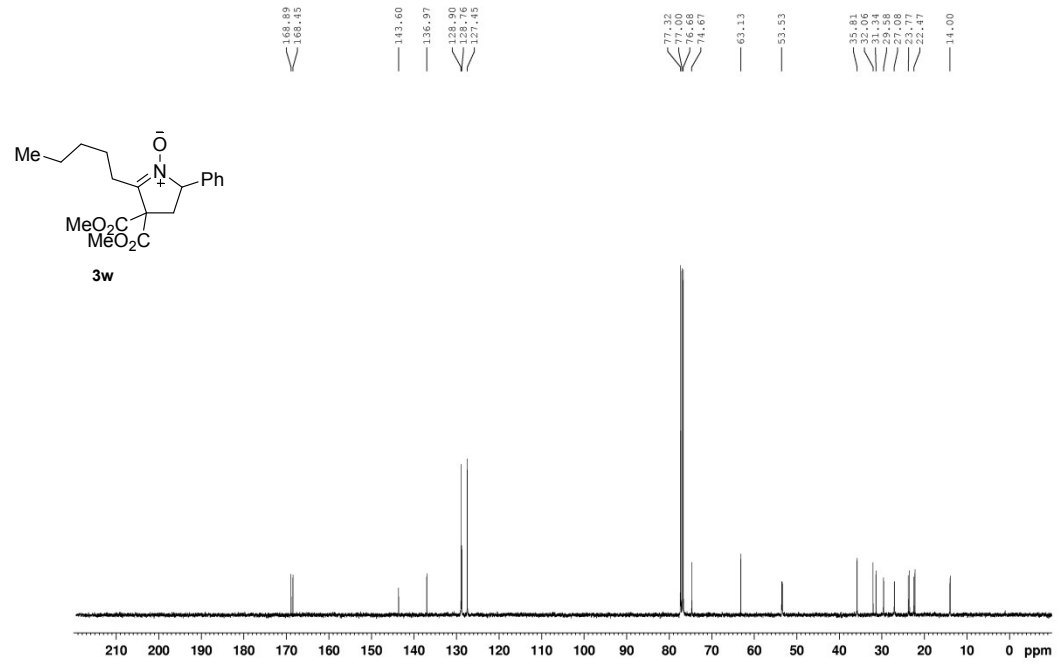
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3v**



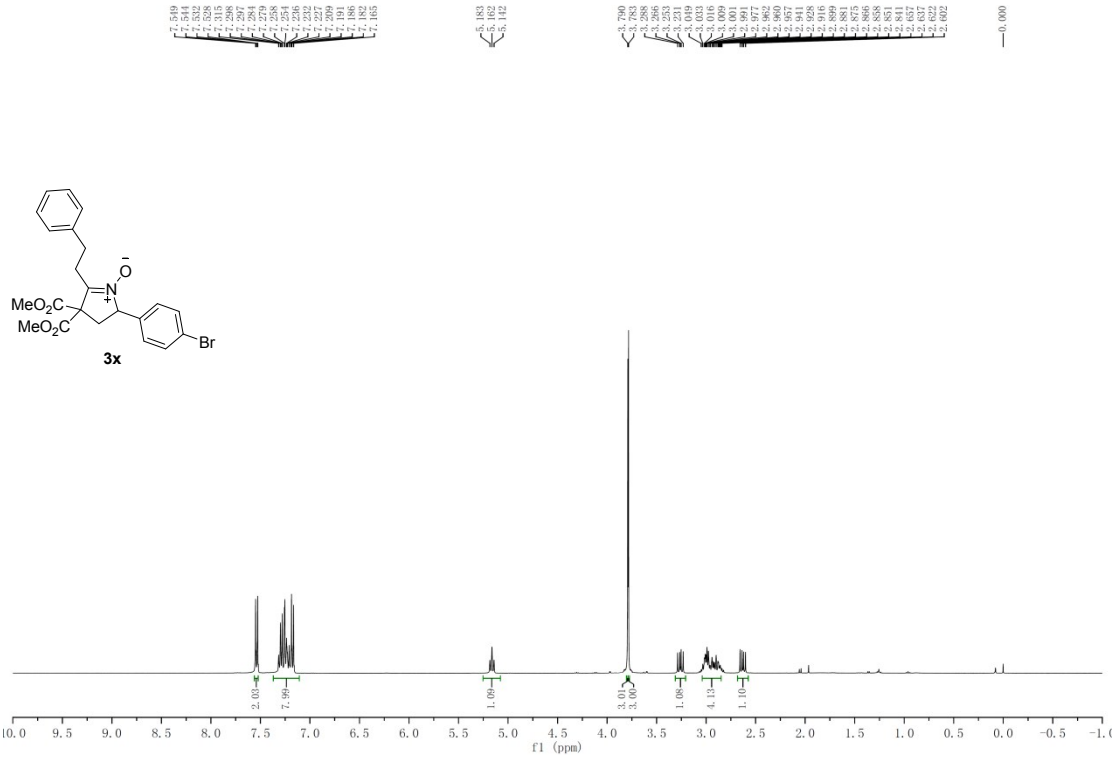
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3w**



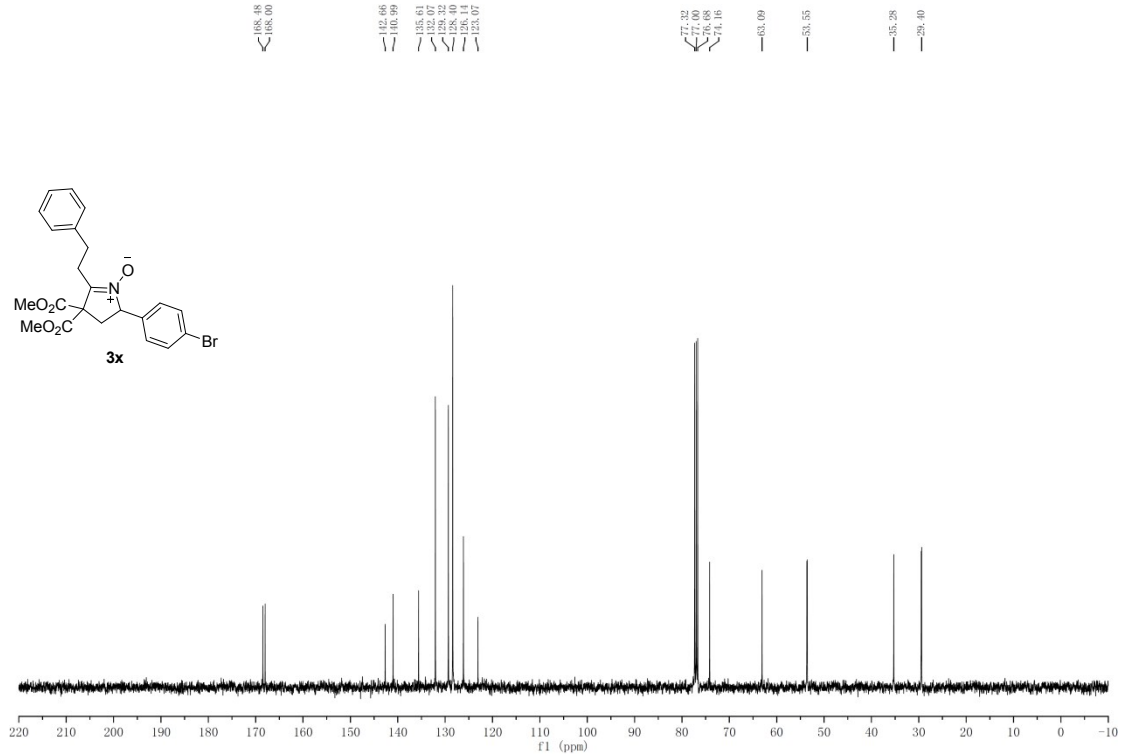
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3w**



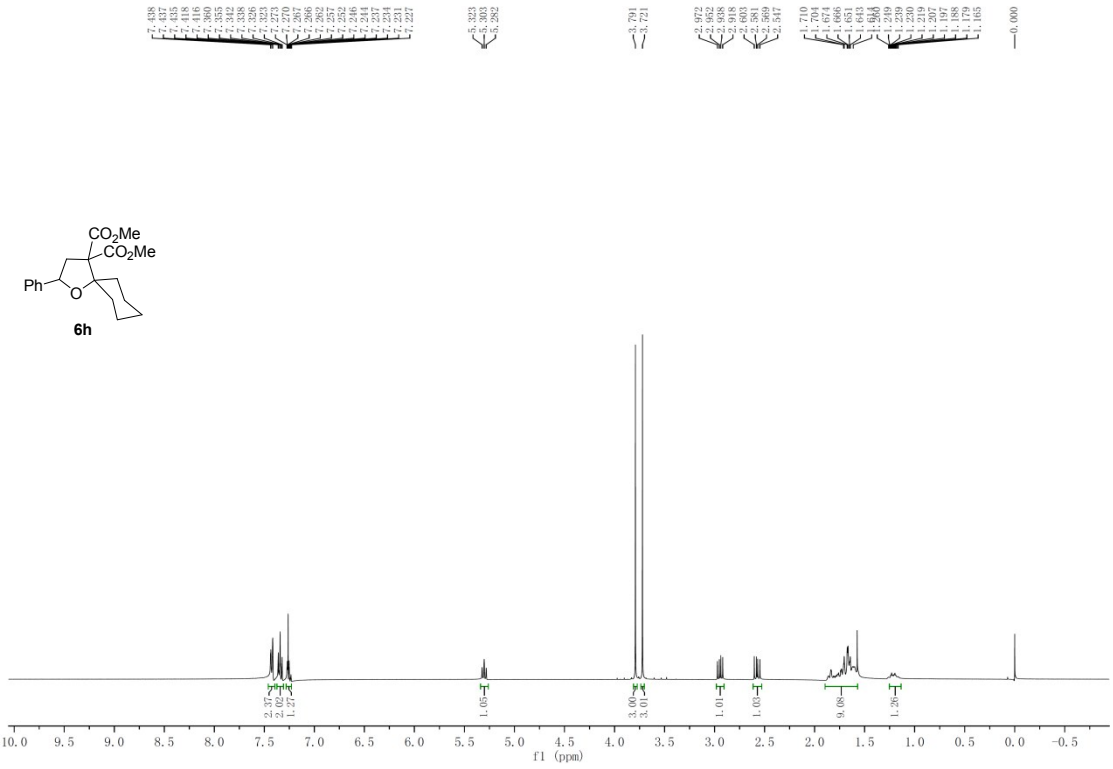
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **3x**



^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **3x**

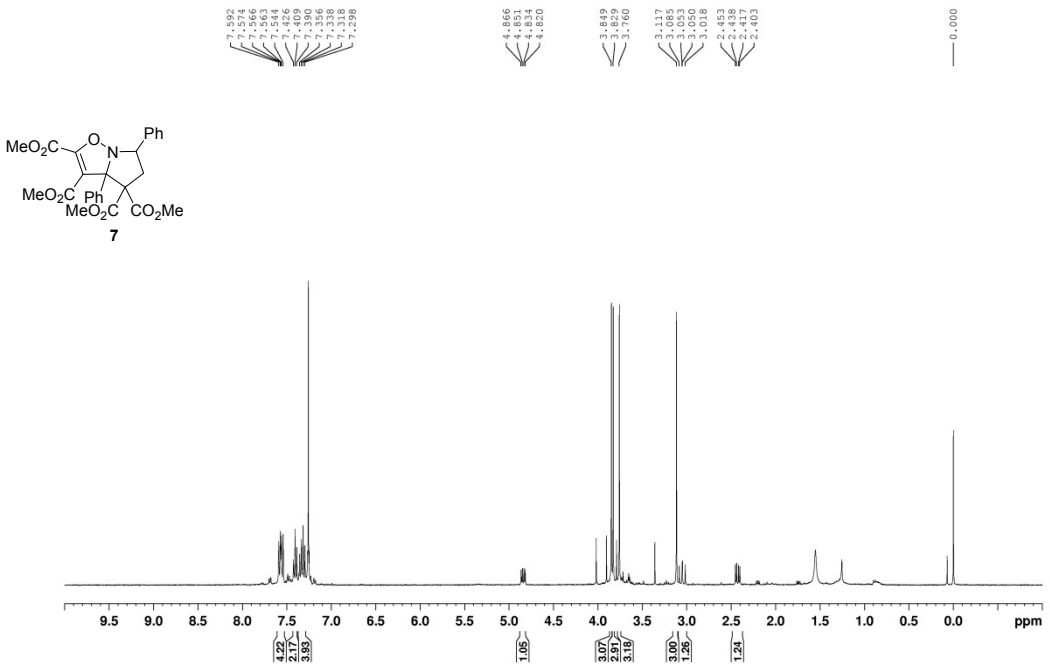


^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **4h**

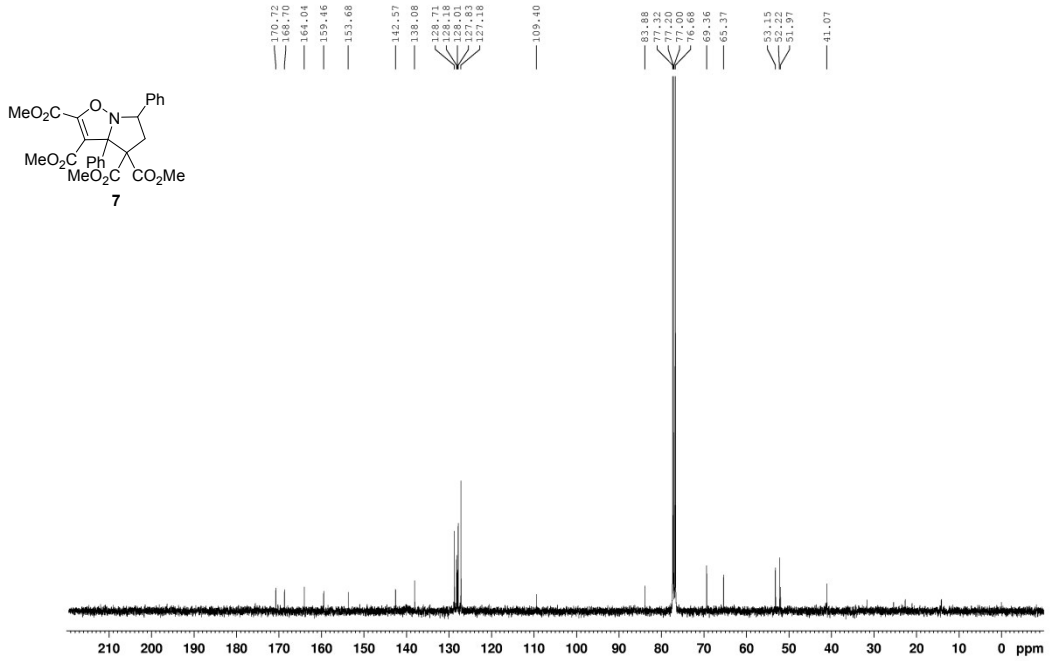


All ^{1}H-NMR spectral data of **4h** matched that reported in the literature. [4]

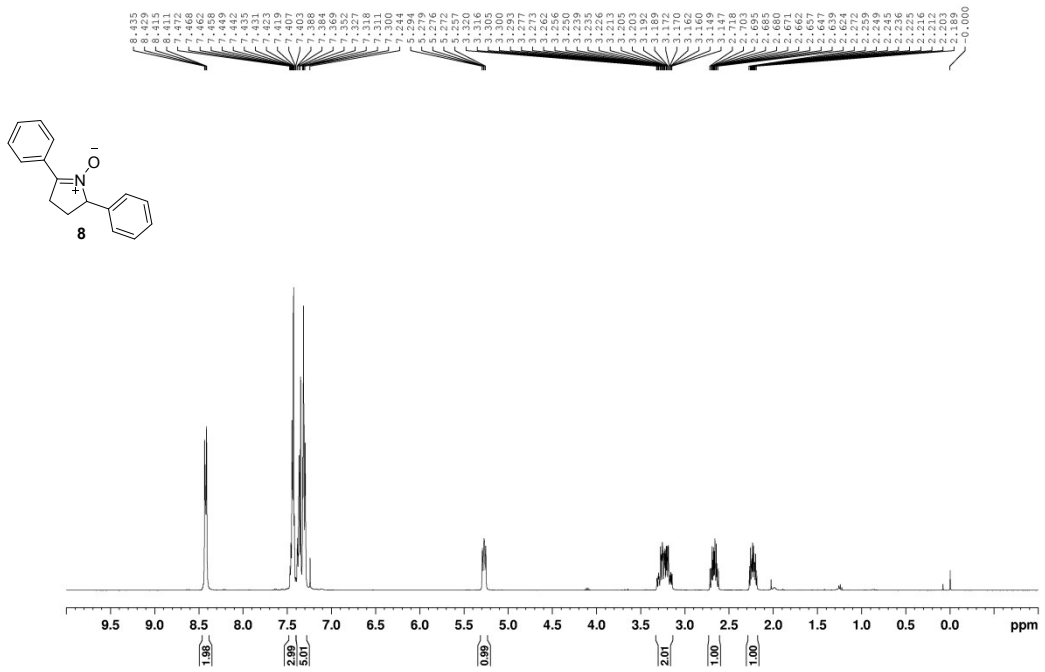
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **7**



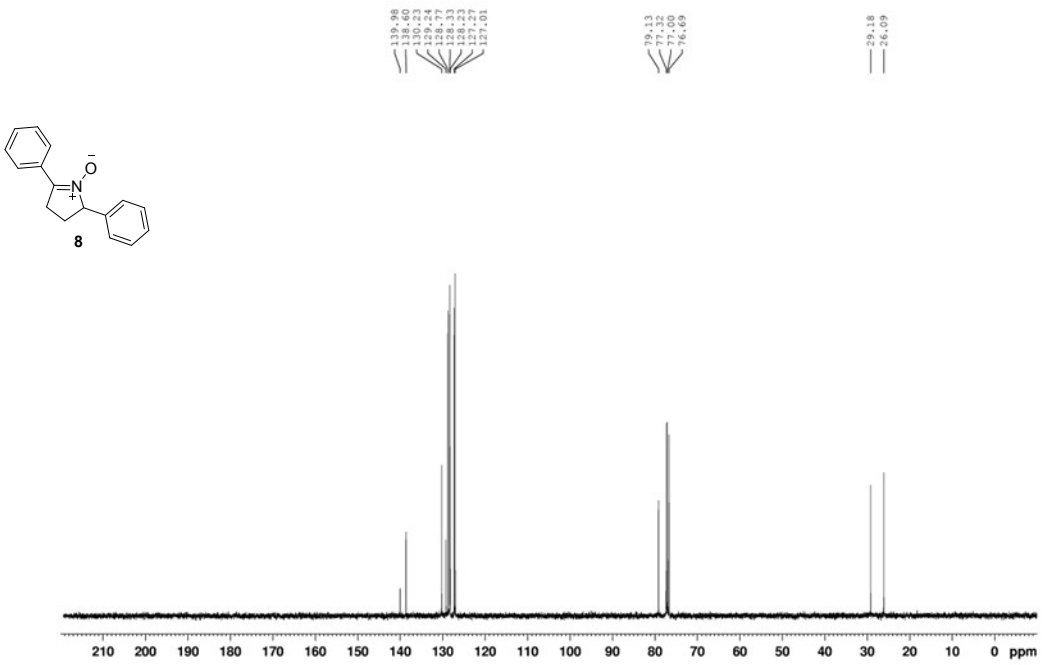
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **7**



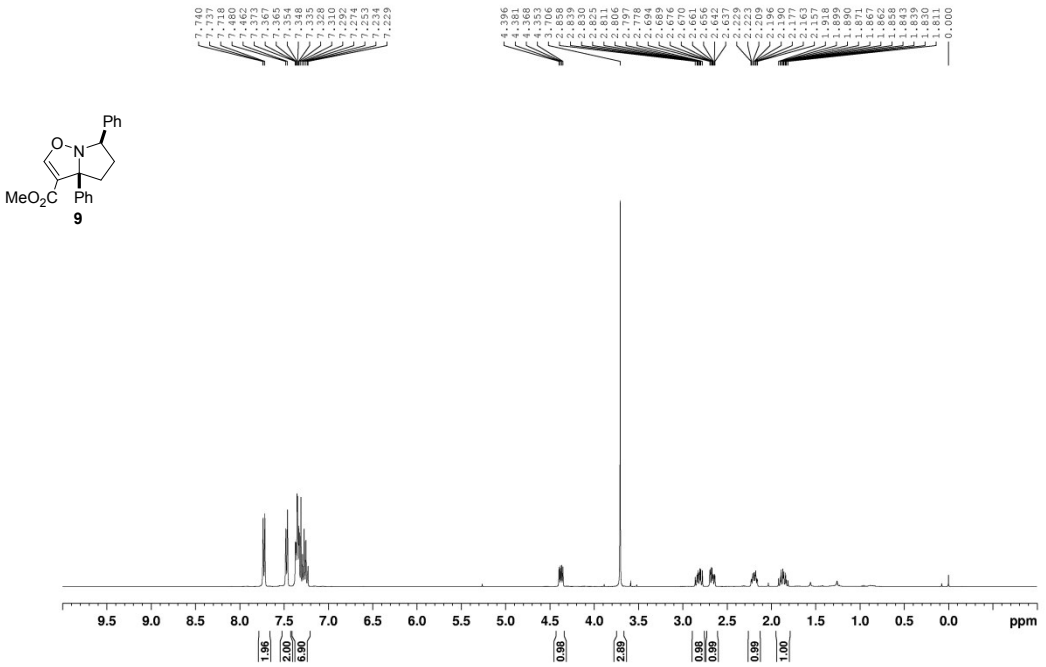
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **8**



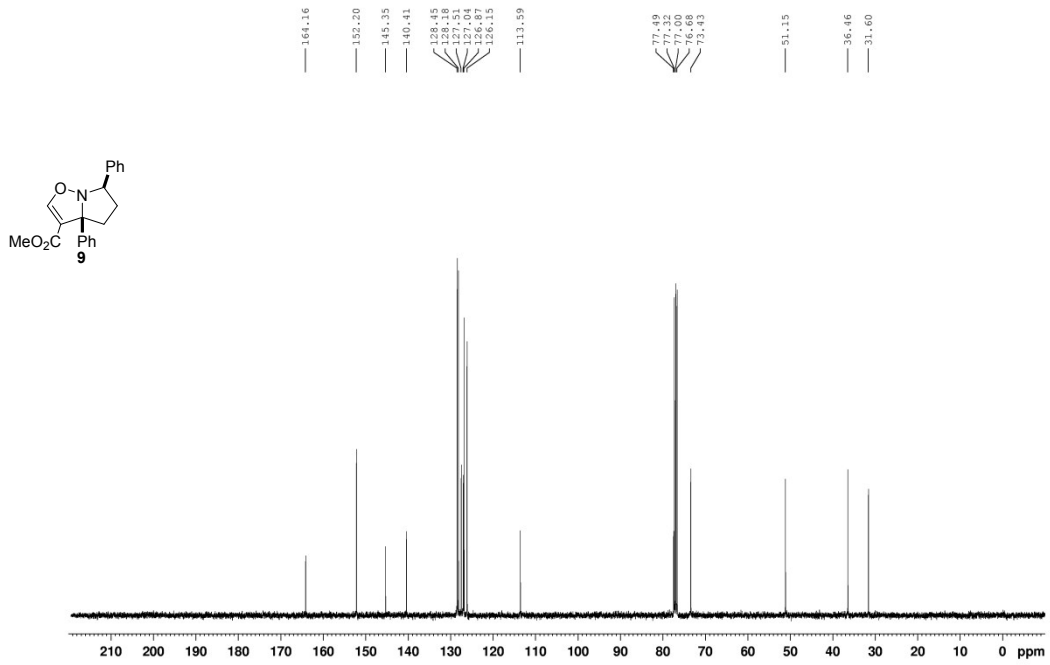
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **8**



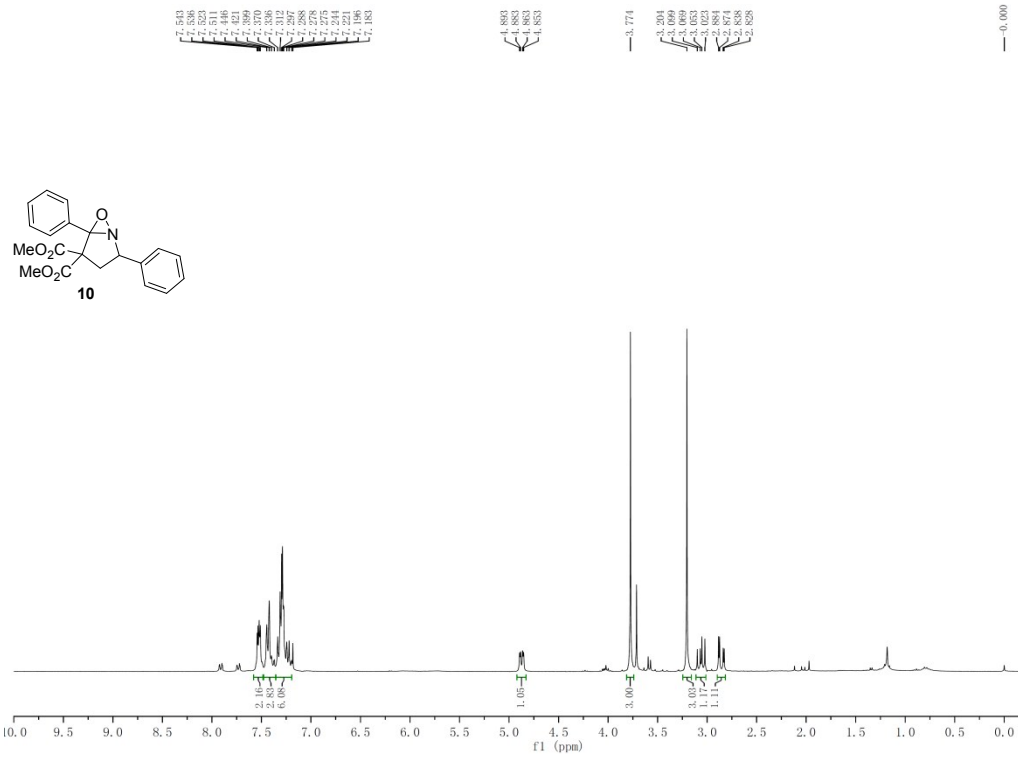
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **9**



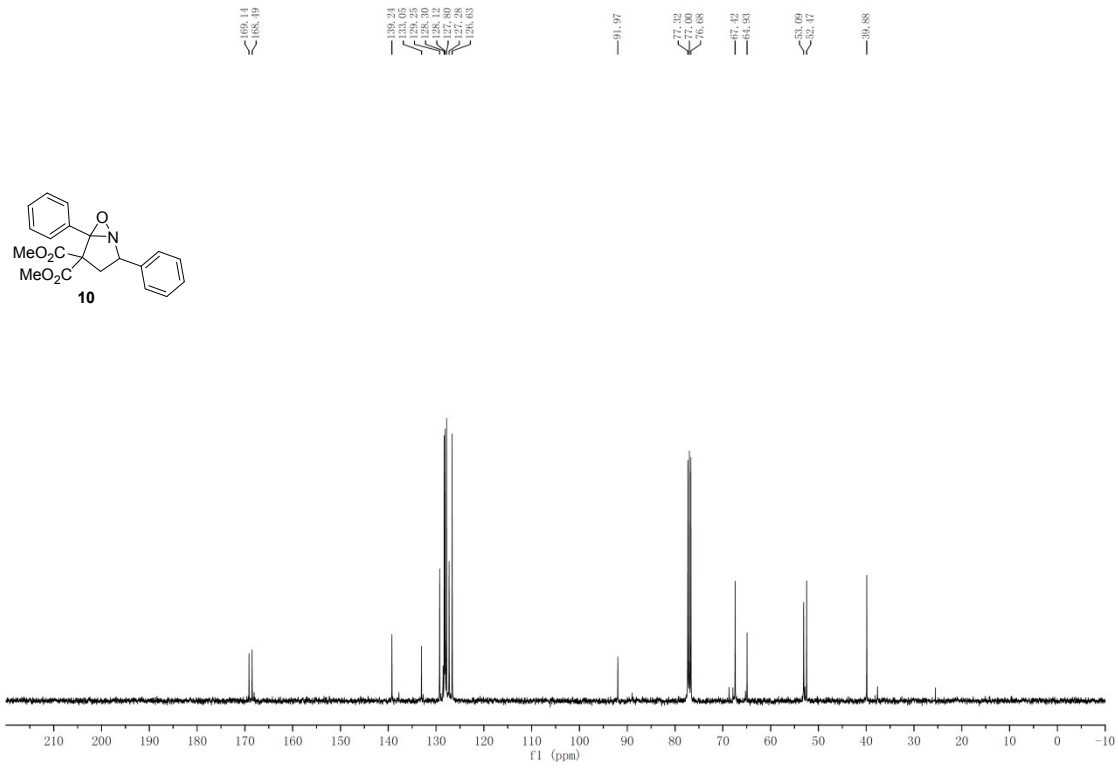
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **9**



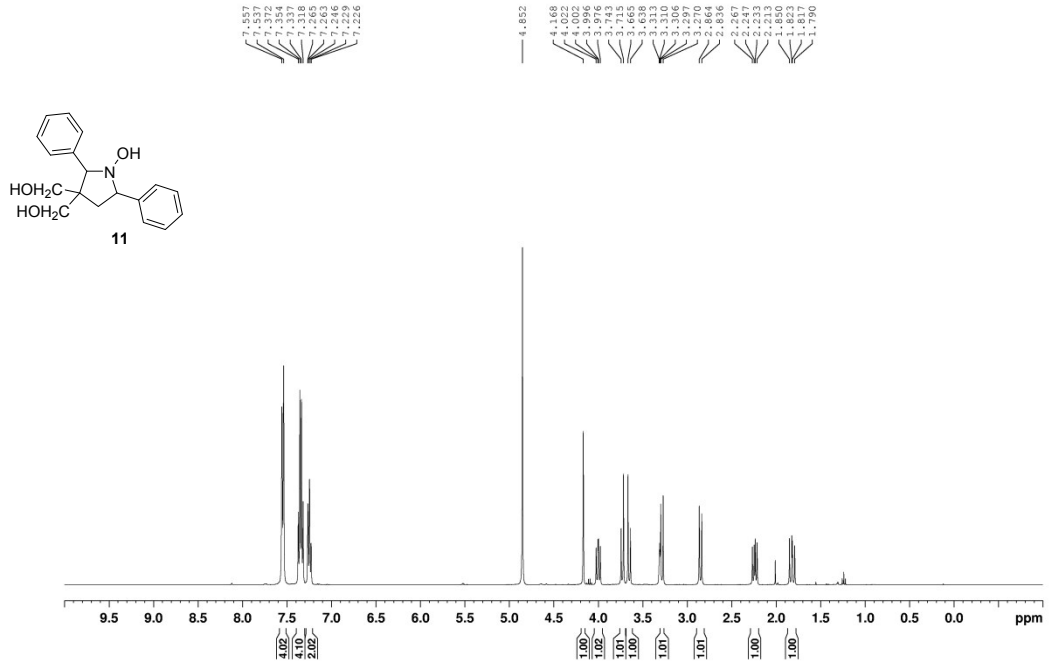
^{1}H-NMR (400 MHz, $CDCl_3$) spectra of compound **10**



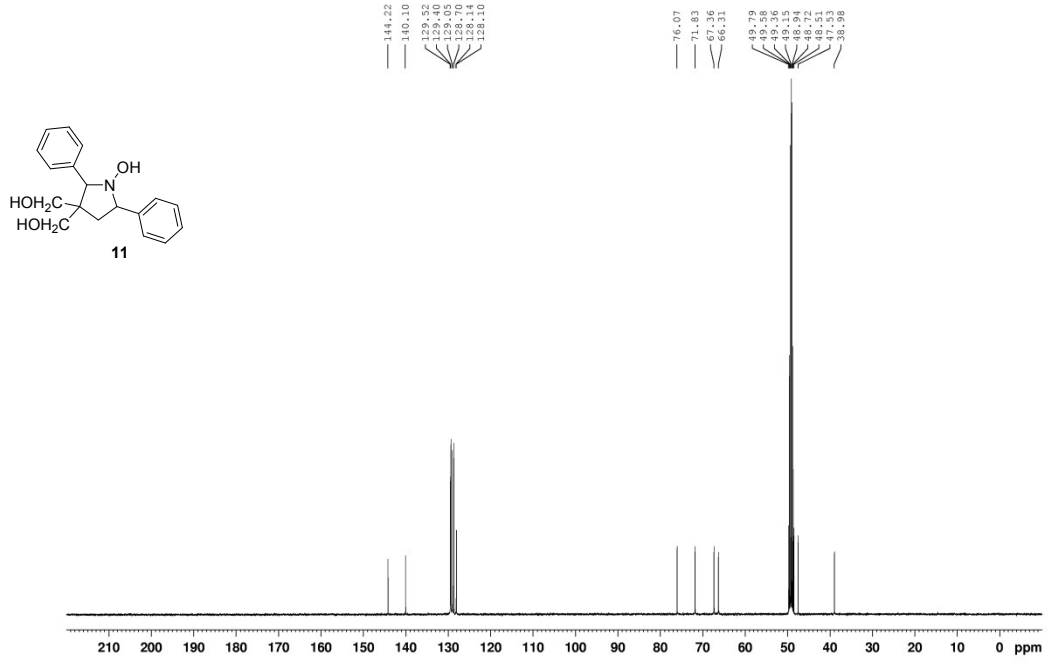
^{13}C-NMR (100 MHz, $CDCl_3$) spectra of compound **10**



^{1}H-NMR (400 MHz, CD_3OH) spectra of compound **11**

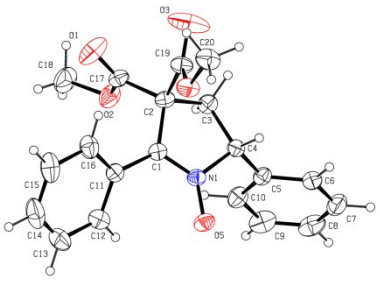


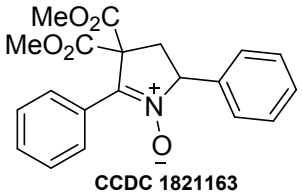
^{13}C-NMR (100 MHz, CD_3OH) spectra of compound **11**



5. X-ray crystallographic data

X-ray Crystallographic Data of Compound *rac*-3a





CCDC 1821163

Bond precision:	C-C = 0.0058 A	Wavelength=0.71073	
Cell:	a=9.683(2)	b=9.746(3)	c=11.167(3)
	alpha=68.90(2)	beta=72.87(2)	gamma=64.67(3)
Temperature:	289 K		
	Calculated	Reported	
Volume	876.2(5)	876.3(5)	
Space group	P -1	P -1	
Hall group	-P 1	-P 1	
Moiety formula	$C_{20}H_{19}NO_5$	$C_{20}H_{19}NO_5$	
Sum formula	$C_{20}H_{19}NO_5$	$C_{20}H_{19}NO_5$	
Mr	353.36	353.36	
Dx,g cm^{-3}	1.339	1.339	
Z	2	2	
Mu (mm^{-1})	0.097	0.097	
F000	372.0	372.0	
F000’	372.20		
h, k, lmax	11, 12, 13	11, 12, 13	
Nref	3443	3432	
Tmin,Tmax	0.980, 0.986	0.778, 1.000	
Tmin’	0.979		

Correction method= # Reported T Limits: Tmin= 0.778 Tmax= 1.000

AbsCorr = MULTI-SCAN

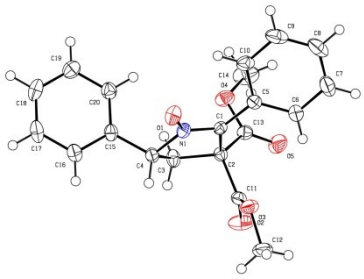
Data completeness= 0.997 Theta(max)= 26.016

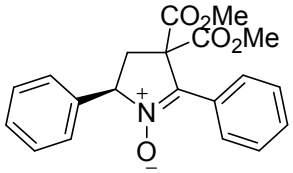
R(reflections)= 0.0696(1875) wR2(reflections)= 0.2149(3432)

S = 1.041 Npar= 237

Displacement ellipsoids are drawn at 30% probability level

X-ray Crystallographic Data of Compound (*R*)-3a





CCDC 1857538

Bond precision:	C-C = 0.0026 A	Wavelength=1.54184	
Cell:	a=8.2648(2)	b=10.1169(2)	c=10.9096(3)
	alpha=90	beta=106.079(3)	gamma=90
Temperature:	173 K		
	Calculated	Reported	
Volume	876.51(4)	876.51(4)	
Space group	P 21	P 1 21 1	
Hall group	P 2yb	P 2yb	
Moiety formula	$C_{20}H_{19}NO_5$	$C_{20}H_{19}NO_5$	
Sum formula	$C_{20}H_{19}NO_5$	$C_{20}H_{19}NO_5$	
Mr	353.36	353.36	
Dx,g cm^{-3}	1.339	1.339	
Z	2	2	
Mu (mm^{-1})	0.799	0.799	
F000	372.0	372.0	
F000’	373.23		
h, k, lmax	9, 12, 12	9, 12, 12	
Nref	3098 [1644]	2269	
Tmin,Tmax	0.886, 0.894	0.767, 1.000	
Tmin’	0.859		

Correction method= # Reported T Limits: Tmin= 0.767 Tmax= 1.000

AbsCorr = MULTI-SCAN

Data completeness= 1.38/0.73 Theta(max)= 66.540

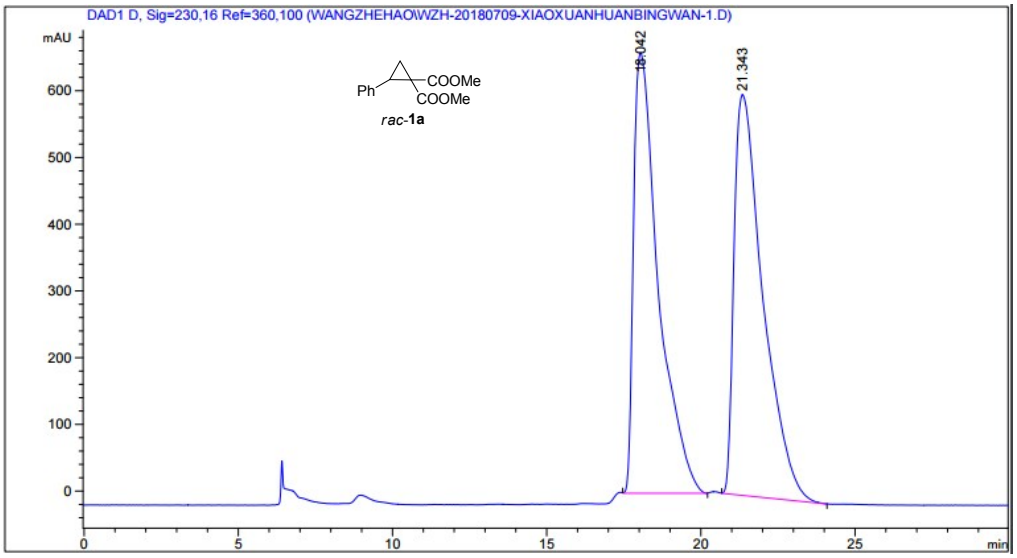
R(reflections)= 0.0283(2242) wR2(reflections)= 0.0747(2269)

S = 1.067 Npar= 237

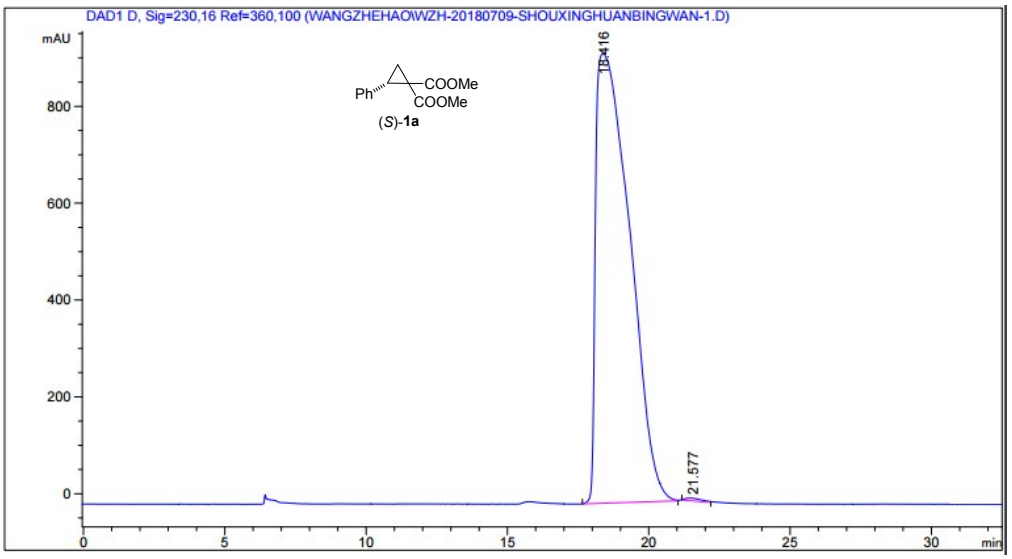
Displacement ellipsoids are drawn at 30% probability level

6. Chiral HPLC chromatograms

Chiral HPLC chromatogram of (*S*)-**1a**

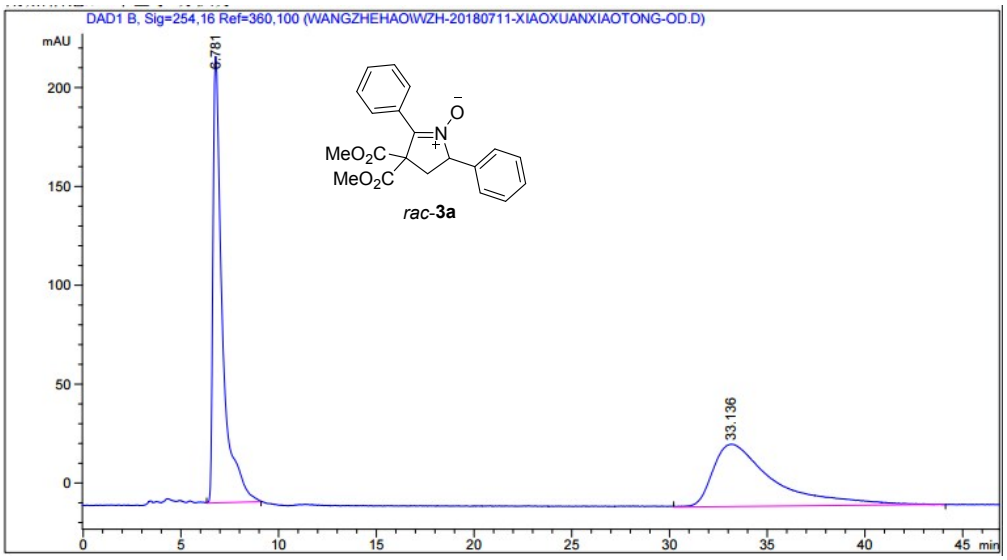


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Area (%)	Peak Height (mAU)
1	DAD 230, 16 nm	18.042	3.68736e4	48.58	660.24542
2	DAD 230, 16 nm	21.343	3.90217e4	51.42	601.15894

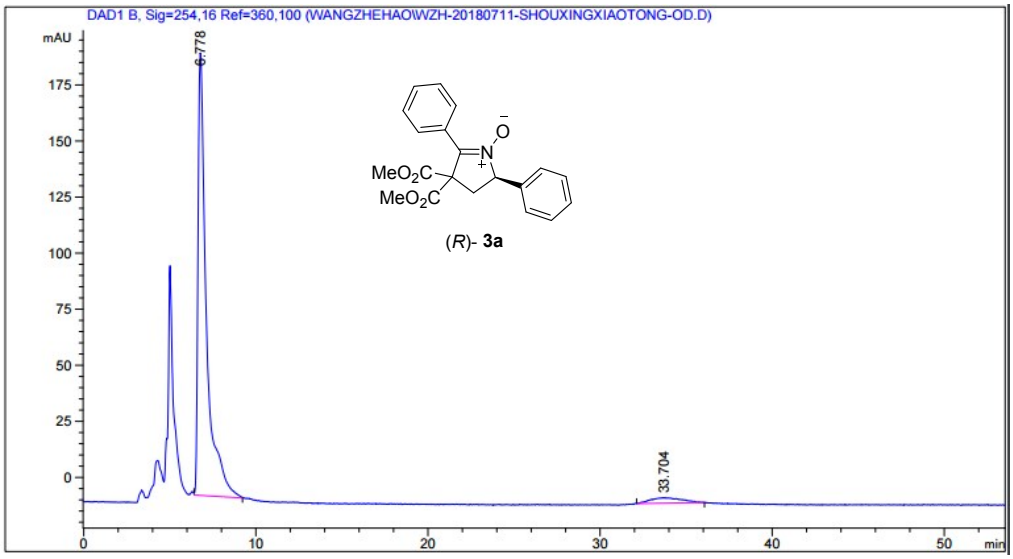


Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Area (%)	Peak Height (mAU)
1	DAD 230, 16 nm	18.416	7.73700e4	99.7096	928.00629
2	DAD 230, 16 nm	21.577	225.32170	0.2904	5.49626

Chiral HPLC chromatogram of the (*R*)-**3a**



Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Area (%)	Peak Height (mAU)
1	DAD 254, 16 nm	6.781	7565.38525	52.84	225.82510
2	DAD 254, 16 nm	33.136	6751.08154	47.16	31.54109



Peak	Processed Channel	Retention Time (min)	Peak Area (mAU*s)	Peak Area (%)	Peak Height (mAU)
1	DAD 254, 16 nm	6.778	6679.58350	95.59	197.24977
2	DAD 254, 16 nm	33.704	308.15250	4.41	2.50177