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Supporting Information

Asymmetric Cross Rauhut-Currier Reaction of Vinyl Ketones with Carbonyl *para*-Quinone Methides via Phosphine Catalysis

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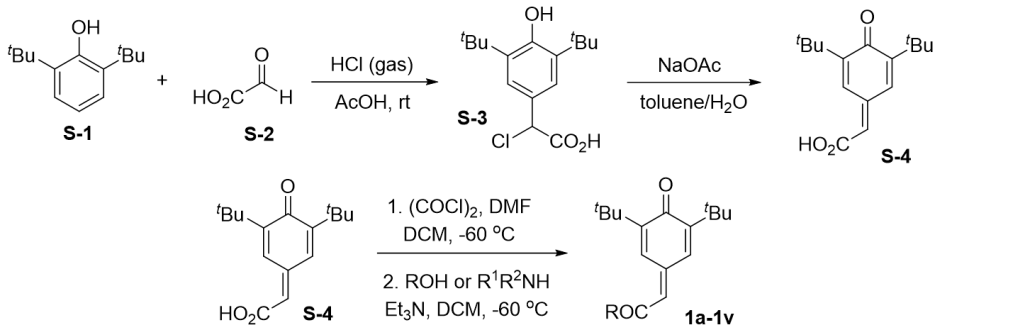
1. General Informations

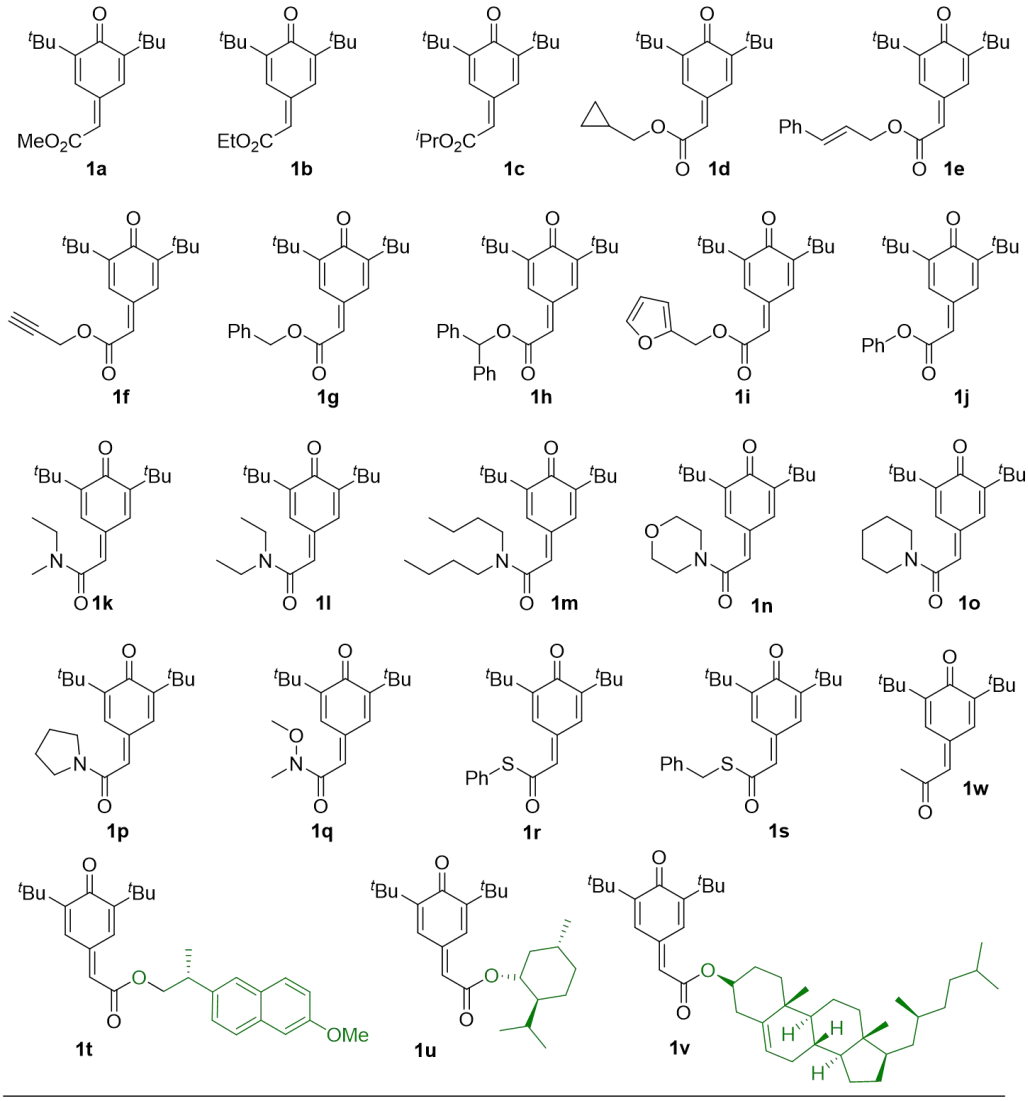
^{1}H and ^{13}C NMR spectra were recorded at 400 and 100 MHz by JEOL (7.26 ppm for ^{1}H NMR, 77.00 ppm for ^{13}C NMR as internal references when $CDCl_3$ used), respectively. High-resolution mass spectra were recorded by ESI method. The used organic solvents were dried by standard methods if it was necessary. Optical rotations were determined at 589 nm (sodium D line) by using a Perkin-Elmer-341 MC digital polarimeter; $[\alpha]_D$-values are given in unit of 10 deg^{-1} cm^2 g^{-1}. Chiral HPLC was performed on a SHIMADZU LC-20AT LC System with chiral columns [Chiralpak OD-H and AD-H columns 4.6 x 250 mm, (Daicel Chemical Ind., Ltd.)]. Commercially obtained reagents were used without further purification. All these reactions were monitored by TLC with silica-gel-coated plates. Flash column chromatography was carried out by using silica gel at increased pressure.

All the racemic products were carried out with triphenylphosphine PPh_3 (20 mol%) as catalyst in toluene at room temperature.

2. Experimental procedure and characterization data

General procedure (*I*) for the synthesis of carbonyl *p*-QM (1a-1w)





p-QMs were prepared according to the modified procedure of literature.[1]

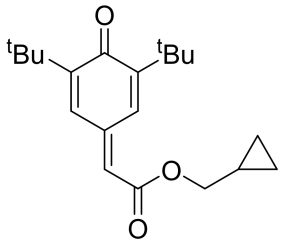
Procedure (*I*): 2,6-di-tert-Butyl-phenol (**S-1**, 30 g, 145 mmol) and glyoxylic acid monohydrate (**S-2**, 28 g, 187 mmol) were dissolved in glacial acetic acid (100 mL). Gaseous HCl (6.3 g, 180 mmol, generated in situ from solid NaCl and H_2SO_4)

of were then bubbled into the reaction mixture with stirring and cooling in an ice bath over a period of 3 hrs, keeping the temperature between 0-10 °C. The mixture was then stirred at room temperature overnight. The precipitated white solid was isolated by filtration and washed with 50 mL H_2O, giving the yellowish and wet cake of the chloride compound (**S-3**, 35 g). This material was used directly for the next step without purification. **S-3** (10 g) dissolved in toluene, a solution of NaOAc (5.5 g, 67 mmol) in water was injected to the above solvent, the mixture stirred at room temperature for 3 hours. The precipitated orange solid was isolated by filtration, washed with H_2O and cold ethanol sequentially, evacuate to remove the residue organic solvent to give the dry orange solid compound (**S-4**, 5.4 g, 61% yield), **S-4** was used directly without any purification.

Compound **S-4** (5 mmol) was dissolved in dry DCM (15 mL) under argon. A few drops of DMF were added, followed by the dropwise addition of oxalyl chloride (5 mmol) slowly. Stirring at room temperature to ensure full conversion to the acetyl chloride. A solution of alcohol (1.5 equiv.), thiol (1.5 equiv.) or amine (1.5 equiv.) and triethylamine (1.0 equiv) in 15 mL of anhydrous DCM was cooled to -70 ℃ to -60 ℃ under nitrogen atmosphere. The solution of the acetyl chloride was added dropwise while maintaining the temperature at -70 ℃ to -60 ℃. After stirring at this temperature for another 20 min, the reaction mixture was allowed to warm to room temperature for a full conversion. The filtrate was concentrated under reduced pressure. The residue was purified by 300 mesh silica gel column chromatography to give the corresponding product **1**.

Compounds **1a-1c**, **1g**, **1l-1p** and **1w** were known compounds. The spectra data were correspondence with the literature data.[1]

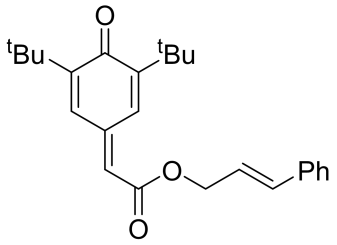
Cyclopropylmethyl 2-(3,5-di-*tert*-butyl-4-oxocyclohexa-2,5-dien-1-ylidene)acetate (1d).



1d

Compound **1d** (609.4 mg, 47% yield) was obtained as a orange solid following the *general procedure I* from **S-4** (4.1 mmol, 1.08 g) and cyclopropylmethanol (6.0 mmol, 0.49 mL); **Mp**: 68-69 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.29 (d, *J* = 2.4 Hz, 1H), 6.79 (d, *J* = 2.0 Hz, 1H), 6.18 (s, 1H), 4.04 (d, *J* = 7.2 Hz, 2H), 1.30 (s, 9H), 1.28 (s, 9H), 1.24-1.14 (m, 1H), 0.63-0.59 (m, 2H), 0.34-0.30 (m, 2H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 186.7, 165.9, 151.3, 151.1, 142.1, 133.6, 127.2, 125.8, 69.7, 35.7, 35.2, 29.5, 29.4, 9.8, 3.4; **HRMS** Calcd. For $C_{20}H_{29}O_3^+$ $[M+H]^+$: 317.2117, found: 317.2118.

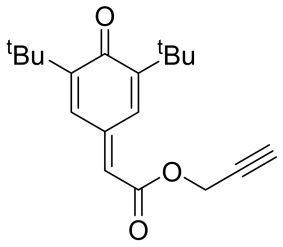
Cinnamyl 2-(3,5-di-*tert*-butyl-4-oxocyclohexa-2,5-dien-1-ylidene)acetate (1e)



1e

Compound **1e** (206 mg, 27% yield) was obtained as a orange liquid following the *general procedure I* from **S-4** (2.0 mmol, 0.52 g) and cinnamyl alcohol (3.0 mmol, 0.39 ml); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.32 (d, *J* = 2.4 Hz, 1H), 7.42-7.27 (m, 5H), 6.79 (d, *J* = 2.4 Hz, 1H), 6.73-6.67 (m, 1H), 6.38-6.31 (m, 1H), 6.19 (s, 1H), 4.88 (dd, *J* = 6.4, 1.6 Hz, 1H), 1.31 (s, 9H), 1.29 (s, 9H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 186.6, 165.4, 151.4, 151.2, 142.6, 136.0, 134.5, 133.5, 128.6, 128.1, 127.0, 126.6, 125.2, 122.6, 65.3, 35.7, 35.2, 29.5, 29.4; **HRMS** Calcd. For $C_{25}H_{29}O_3^-$ $[M-H]^-$: 377.2117, found: 377.2108.

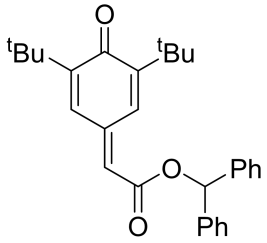
Prop-2-yn-1-yl 2-(3,5-di-*tert*-butyl-4-oxocyclohexa-2,5-dien-1-ylidene)acetate (1f)



1f

Compound **1f** (238.9 mg, 40% yield) was obtained as a orange solid following the *general procedure I* from **S-4** (2.0 mmol, 0.52 g) and propargyl alcohol (3.0 mmol, 0.18 ml); **Mp**: 69-71 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.26 (d, *J* = 2.4 Hz, 1H), 6.77 (d, *J* = 2.4 Hz, 1H), 6.15 (s, 1H), 4.80 (dd, *J* = 2.8, 0.8 Hz, 2H), 2.51 (td, *J* = 2.8, 0.8 Hz, 1H), 1.29 (d, *J* = 0.8 Hz, 9H), 1.27 (d, *J* = 0.8 Hz, 9H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 186.6, 164.8, 151.8, 151.5, 143.4, 133.3, 126.9, 123.9, 75.2, 52.2, 35.7, 35.3, 29.5, 29.4; **HRMS** Calcd. For $C_{19}H_{25}O_3^+$ $[M+H]^+$: 301.1804, found: 301.1805.

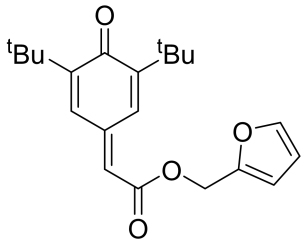
Benzhydryl 2-(3,5-di-*tert*-butyl-4-oxocyclohexa-2,5-dien-1-ylidene)acetate (1h).



1h

Compound **1h** (174.0 mg, 41% yield) was obtained as a orange solid following the *general procedure I* from **S-4** (1.0 mmol, 0.26 g) and diphenylmethanol (1.5 mmol, 280.0 mg); **Mp**: 88-90 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.29 (d, *J* = 2.0 Hz, 1H), 7.38-7.31 (m, 10H), 7.03 (s, 1H), 6.82 (d, *J* = 2.0 Hz, 1H), 6.32 (s, 1H), 1.30 (s, 9H), 1.29 (s, 9H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 186.6, 164.7, 151.6, 151.3, 142.9, 142.2, 139.8, 133.5, 128.6, 128.3, 128.1, 127.4, 127.2, 127.1, 127.0, 125.2, 79.9, 35.7, 35.3, 29.5, 29.4; **HRMS** Calcd. For $C_{29}H_{33}O_3^+$ $[M+H]^+$: 429.2430, found: 429.2432.

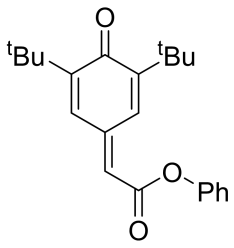
Furan-2-ylmethyl 2-(3,5-di-*tert*-butyl-4-oxocyclohexa-2,5-dien-1-ylidene)acetate (1i).



1i

Compound **1i** (131.1 mg, 38% yield) was obtained as a red liquid following the *general procedure I* from **S-4** (1.0 mmol, 0.26 g) and furan-2-ylmethanol (1.5 mmol, 0.13 ml); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.25 (d, *J* = 2.0 Hz, 1H), 7.44-7.43 (m, 1H), 6.75 (d, *J* = 2.4 Hz, 1H), 6.47-6.45 (m, 1H), 6.39-6.37 (m, 1H), 6.14 (s, 1H), 5.19 (s, 2H), 1.28 (s, 9H), 1.26 (s, 9H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 186.6, 165.3, 151.5, 151.3, 149.0, 143.5, 142.8, 133.5, 127.0, 124.9, 110.9, 110.6, 58.3, 35.7, 35.3, 29.5, 29.4; **HRMS** Calcd. For $C_{21}H_{27}O_4^+$ $[M+H]^+$: 343.1909, found: 343.1909.

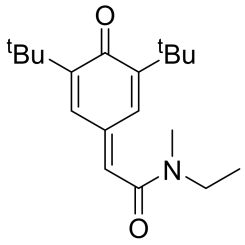
Phenyl 2-(3,5-di-*tert*-butyl-4-oxocyclohexa-2,5-dien-1-ylidene)acetate (1j)



1j

Compound **1j** (57.0 mg, 17% yield) was obtained as a orange solid following the *general procedure I* from **S-4** (1.0 mmol, 0.26 g) and phenol (1.5 mmol, 0.15 g); **Mp**: 88-90 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.36 (d, *J* = 2.4 Hz, 1H), 7.45-7.41 (m, 2H), 7.30-7.28 (m, 1H), 7.17-7.15 (m, 2H), 6.87 (d, *J* = 2.0 Hz, 1H), 6.37 (s, 1H), 1.31 (s, 9H), 1.30 (s, 9H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 186.6, 164.3, 152.0, 151.6, 150.3, 144.2, 133.3, 129.5, 126.9, 126.1, 124.0, 121.5, 35.8, 35.3, 29.50, 29.47; **HRMS** Calcd. For $C_{22}H_{27}O_3^+$ $[M+H]^+$: 339.1960, found: 339.1961.

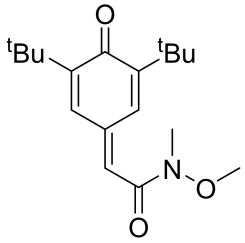
2-(3,5-di-*tert*-butyl-4-oxocyclohexa-2,5-dien-1-ylidene)-N-ethyl-N-methylacetamide (1k)



1k

Compound **1k** (292.0 mg, 48% yield) was obtained as a yellow solid following the *general procedure I* from **S-4** (2.0 mmol, 0.52 g) and *N*-methylethanamine (3.0 mmol, 0.26 ml); **Mp**: 97-100 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.57-7.50 (m, 1H), 6.81 (s, 1H), 6.48 (s, 1H), 3.53 (q, *J* = 7.2 Hz, 1H), 3.40 (q, *J* = 7.2 Hz, 1H), 3.03 (s, 3H), 1.26 (s, 18H), 1.19 (t, *J* = 7.2 H, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 186.5, 186.4, 165.8, 165.7, 150.13, 150.09, 149.7, 137.1, 136.4, 133.34, 133.27, 130.8, 130.3, 127.8, 127.7, 45.2, 42.1, 35.5, 35.37, 35.35, 35.1, 32.3, 29.40, 29.38, 13.7, 12.2; **HRMS** Calcd. For $C_{19}H_{30}NO_2^+$ $[M+H]^+$: 304.2277, found: 304.2276.

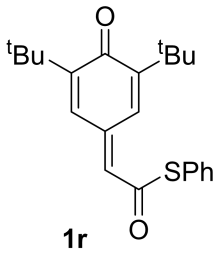
2-(3,5-di-*tert*-butyl-4-oxocyclohexa-2,5-dien-1-ylidene)-N-methoxy-N-methylaceta mide (1q)



1q

Compound **1q** (281.6 mg, 92% yield) was obtained as a yellow solid following the *general procedure I* from **S-4** (1.0 mmol, 0.26 g) and *N*,*O*-dimethylhydroxylamine (1.5 mmol, 0.14 mL); **Mp**: 108-110 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.26 (s, 1H), 6.82 (s, 1H), 6.65 (s, 1H), 3.75 (s, 3H), 3.30 (s, 3H), 1.29 (s, 9H), 1.28 (s, 9H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 186.7, 166.1, 150.8, 150.5, 140.7, 134.1, 127.8, 124.7, 62.1, 35.6, 35.2, 32.3, 29.52, 29.48; **HRMS** Calcd. For $C_{18}H_{28}NO_3^+$ $[M+H]^+$: 306.2069, found: 306.2067.

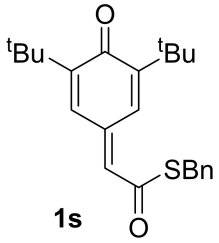
***S*-phenyl 2-(3,5-di-*tert*-butyl-4-oxocyclohexa-2,5-dien-1-ylidene)ethanethioate (1r)**



1r

Compound **1r** (18.2 mg, 5% yield) was obtained as a orange solid following the *general procedure I* from **S-4** (1.0 mmol, 262 mg) and thiophenol (1.5 mmol, 0.15 mL); **Mp**: 97-99 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.12 (d, *J* = 2.0 Hz, 1H), 7.47 (s, 5H), 6.76 (d, *J* = 2.4 Hz, 1H), 6.39 (s, 1H), 1.29 (s, 9H), 1.25 (s, 9H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 187.7, 186.6, 152.7, 152.4, 139.9, 134.4, 133.3, 129.9, 129.5, 129.4, 127.7, 127.4, 35.7, 35.5, 29.54, 29.47; **HRMS** Calcd. For $C_{22}H_{25}O_2S^-$ $[M-H]^-$: 353.1575, found: 353.1588.

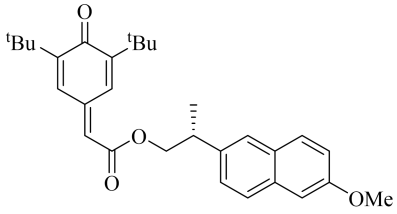
***S*-benzyl 2-(3,5-di-*tert*-butyl-4-oxocyclohexa-2,5-dien-1-ylidene)ethanethioate (1s)**



1s

Compound **1s** (72.9 mg, 10% yield) was obtained as a orange solid following the *general procedure I* from **S-4** (2.0 mmol, 0.52 g) and benzyl mercapten (3.0 mmol, 0.35 ml); **Mp**: 51-53 ℃; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.19 (s, 1H), 7.35-7.30 (m, 5H), 6.72 (s, 1H), 6.29 (s, 1H), 4.27 (s, 2H), 1.31 (s, 9H), 1.28 (s, 9H); **^{13}C NMR** (100 MHz, $CDCl_3$) 188.7, 186.5, 152.4, 152.2, 139.1, 136.9, 133.4, 130.0, 128.9, 128.7, 127.8, 127.5, 35.7, 35.4, 33.9, 29.53, 29.45; **HRMS** Calcd. For $C_{23}H_{29}O_2S^+$ $[M+H]^+$: 369.1888, found: 369.1877.

(*R*)-2-(6-methoxynaphthalen-2-yl)propyl 2-(3,5-di-*tert*-butyl-4-oxocyclohexa-2,5-dien-1-ylidene)acetate (1t)

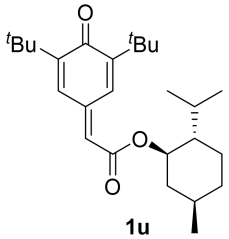


1t

Compound **1t** (265.8 mg, 58% yield) was obtained as a orange solid following the *general procedure I* from **S-4** (1.0 mmol, 0.26 g) and (*R*)-2-(6-methoxynaphthalen-2-yl)propan-1-ol (1.5 mmol, 0.32 g); **Mp**: 149-151 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.24 (dd, *J* = 2.4, 0.8 Hz, 1H), 7.72-7.69 (m, 2H), 7.61 (d, *J* = 1.2 Hz, 1H), 7.36 (dd, *J* = 8.4, 2.0 Hz, 1H), 7.16-7.12 (m, 2H), 6.75 (dd, *J* = 2.4, 0.8 Hz, 1H), 6.10-6.09 (m, 1H), 4.44-4.34 (m, 2H), 3.92 (s, 3H), 3.35-3.26 (m, 1H), 1.42 (d, *J* = 7.2 Hz, 3H), 1.28 (s, 9H), 1.26 (s, 9H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 186.7, 165.7, 157.4, 151.4, 151.1, 142.5, 138.0, 133.6, 133.5, 129.1, 128.9, 127.0, 126.2, 125.5, 125.4, 118.9, 105.5, 69.6, 55.3, 38.8, 35.6, 35.2, 29.5, 29.4, 18.3; **HRMS** Calcd. For $C_{30}H_{37}O_4^+$ $[M+H]^+$: 461.2692, found: 461.2694.

(1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl

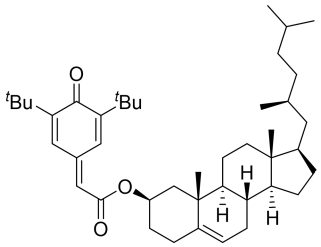
2-(3,5-di-*tert*-butyl-4-oxocyclohexa-2,5-dien-1-ylidene)acetate (1u)



1u

Compound **1u** (257.2 mg, 64% yield) was obtained as a orange liquid following the *general procedure I* from **S-4** (1.0 mmol, 0.26 g) and *L*-menthol (1.5 mmol, 0.24 g); **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.30 (s, 1H), 6.78 (s, 1H), 6.15 (s, 1H), 4.81 (td, *J* = 11.2, 4.4 Hz, 1H), 2.07 (d, *J* = 12.0 Hz, 1H), 1.94-1.87 (m, 1H), 1.70 (d, *J* = 10.8 Hz, 2H), 1.55-1.41 (m, 2H), 1.30 (s, 9H), 1.27 (s, 9H), 1.14-0.98 (m, 2H), 0.91 (t, *J* = 7.6 Hz, 6H), 0.78 (d, *J* = 7.2 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 186.7, 165.4, 151.3, 151.0, 142.0, 133.7, 127.2, 126.4, 74.9, 47.1, 41.0, 35.7, 35.2, 34.2, 31.4, 29.53, 29.46, 26.3, 23.5, 22.0, 20.7, 16.4; **HRMS** Calcd. For $C_{26}H_{41}O_3^+$ $[M+H]^+$: 401.3056, found: 401.3055.

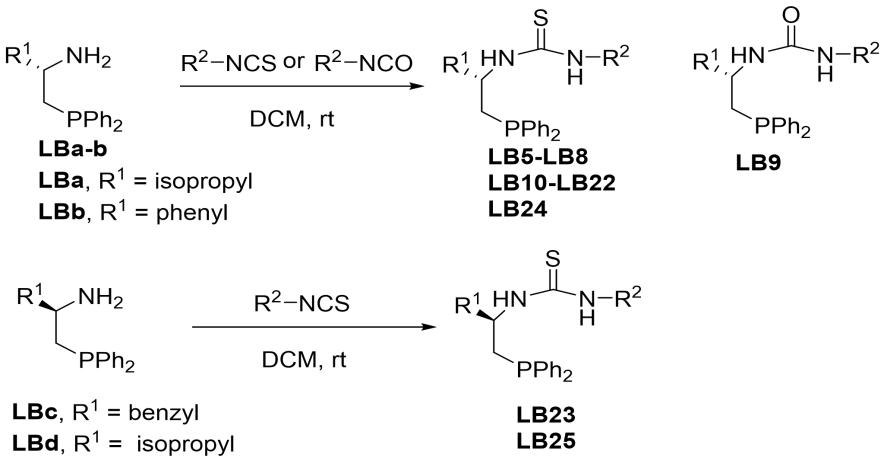
(2*S*,8*S*,9*S*,10*R*,13*R*,14*S*,17*S*)-17-((*S*)-2,5-dimethylhexyl)-10,13-dimethyl-2,3,4,7,8,9, 10,11,12,13,14,15,16,17-tetradecahydro-1*H*-cyclopenta[*a*]phenanthren-2-yl 2-(3,5-di-*tert*-butyl-4-oxocyclohexa-2,5-dien-1-ylidene)acetate (1v)



1v

Compound **1v** (409.9 mg, 65% yield) was obtained as a orange solid following the *general procedure I* from **S-4** (1.0 mmol, 0.26 g) and Cholesterol (1.5 mmol, 0.58 g); **Mp**: 72-74 °C; **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.28 (s, 1H), 6.78 (s, 1H), 6.13 (s, 1H), 5.41 (d, *J* = 4.0 Hz, 1H), 4.79-4.71 (m, 1H), 2.40-2.35 (m, 2H), 2.03-1.96 (m, 2H), 1.95-1.88 (m, 2H), 1.86-1.79 (m, 1H), 1.71-1.64 (m, 1H), 1.57-1.55 (m, 1H), 1.53-1.50 (m, 2H), 1.48-1.43 (m, 2H), 1.41-1.33 (m, 4H), 1.30 (s, 9H), 1.28 (s, 9H), 1.21-1.06 (m, 8H), 1.04 (s, 3H), 1.02-0.94 (m, 3H), 0.92 (d, *J* = 6.8 Hz, 3H), 0.86 (dd, *J* = 6.8, 1.6 Hz, 6H), 0.68 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) 186.7, 165.2, 151.2, 151.0, 141.9, 139.3, 133.7, 127.2, 126.4, 123.0, 74.6, 56.7, 56.1, 50.0, 42.3, 39.7, 39.5, 38.2, 37.0, 36.6, 36.2, 35.8, 35.7, 35.2, 31.9, 31.8, 29.53, 29.46, 28.2, 28.0, 27.9, 24.3, 23.8, 22.8, 22.6, 21.0, 19.3, 18.7, 11.9; **HRMS** Calcd. For $C_{43}H_{67}O_3^+$ $[M+H]^+$: 631.5090, found: 631.5091.

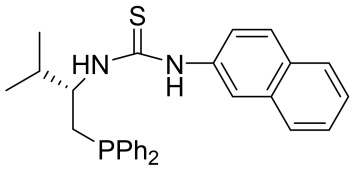
General procedure (*II*) for the synthesis of chiral phosphines.



LBa-d, isothiocyanate and isocyanate were prepared according to the reported literature.[2,3] Catalysts **LB1-LB5**, **LB7**, **LB11**, **LB18-LB20** were known compounds.[4]

Procedure (*II*): To a solution of **LBa-d** (1.0 eq) in DCM under N_2 atmosphere was added isothiocyanate or isocyanate (1.2 eq), and the reaction mixture was stirred at room temperature for 24 hrs. Solvent was then removed under reduced pressure, and the residue was directly subjected to column chromatographic separation on silica gel (hexane/ethyl acetate = 15:1 to 10:1) to afford chiral phosphines as a white solid.

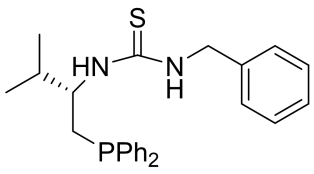
(*S*)-1-(1-(diphenylphosphaneyl)-3-methylbutan-2-yl)-3-(naphthalen-2-yl)thiourea (LB6)



LB6

Compound **LB6** (168.8 mg, 74% yield) was obtained as a white solid following the *general procedure II* from **LBa** (0.5 mmol, 136 mg) and 2-isothiocyanatonaphthalene (0.6 mmol, 111 mg) stirred for 24 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.76-8.67 (m,1H), 8.10 (s, 1H), 7.91-7.84 (m, 2H), 7.56-7.40 (m, 7H), 7.29-7.28 (m, 7H), 5.80 (brs, 1H), 4.62 (brs, 1H), 2.30 (dd, *J* = 14.4, 5.6 Hz, 1H), 2.21 (dd, *J* = 14.4, 8.0 Hz, 1H), 2.06-1.97 (m, 1H), 0.74 (d, *J* = 6.8 Hz, 3H), 0.63 (d, *J* = 6.8 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 180.8, 134.4, 132.7 (d, *J* = 8.2 Hz), 132.5 (d, *J* = 8.2 Hz), 131.5, 129.7, 128.5, 128.34, 128.30, 128.27, 128.23, 128.18, 127.2, 126.8, 125.5, 125.0, 122.7, 58.0 (d, *J* = 14.5 Hz), 31.4 (d, *J* = 8.6 Hz), 31.1 (d, *J* = 13.5 Hz), 18.6, 17.5; **^{31}P NMR** (162 MHz, $CDCl_3$, 85% H_3PO_4) δ -24.3; **Mp**: 61-63 ºC. **HRMS** Calcd. for $C_{28}H_{30}N_2PS^+$ $[M+H]^+$: 457.1867, found: 457.1852; $[\alpha]^{20}_D$ = +77.7 (c 0.22, CH_2Cl_2).

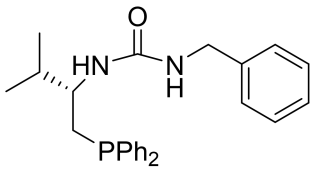
(*S*)-1-benzyl-3-(1-(diphenylphosphaneyl)-3-methylbutan-2-yl)thiourea (LB8)



LB8

Compound **LB8** (196.9 mg, 94% yield) was obtained as a white solid following the *general procedure II* from **LBa** (0.5 mmol, 136 mg) and isothiocyanatomethylbenzene (0.6 mmol, 89.5 mg, 79 ul) stirred for 24 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.48-7.28 (m, 13H), 7.22 (d, *J* = 7.2 Hz, 2H), 7.12-7.02 (m, 1H), 6.07 (brs, 1H), 4.38 (brs, 2H), 2.40-2.27 (m, 2H), 2.06-1.98 (m, 1H), 0.78 (s, 6H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 181.1, 138.1 (d, *J* = 12.3 Hz), 137.9, 136.8, 132.6 (d, *J* = 19.1 Hz), 132.5 (d, *J* = 18.9 Hz), 128.54, 128.48, 128.33, 128.28 (d, *J* = 1.1 Hz), 128.2, 127.5, 127.1, 57.6, 47.4, 31.8, 31.1 (d, *J* = 8.5 Hz), 18.4, 17.6; **^{31}P NMR** (162 MHz, $CDCl_3$, 85% H_3PO_4) δ -23.5; **Mp**: 99-101 ºC. **HRMS** Calcd. for $C_{25}H_{30}N_2PS^+$ $[M+H]^+$: 421.1867, found: 421.1854; $[\alpha]^{20}_D$ = +16.0 (c 0.21, CH_2Cl_2).

(*S*)-1-benzyl-3-(1-(diphenylphosphaneyl)-3-methylbutan-2-yl)urea (LB9)

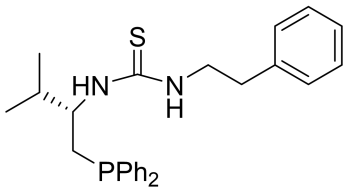


LB9

Compound **LB9** (301.9 mg, 75% yield) was obtained as a white solid following the *general procedure II* from **LBa** (0.1 mmol, 272 mg) and (isothiocyanatomethyl)benzene (1.2 mmol, 159.8 mg, 148 μL) stirred for 24 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.51-7.43 (m, 5H), 7.36-7.31 (m, 6H), 7.24-7.18 (m, 4H), 5.97 (brs, 1H), 5.70 (brs, 1H), 4.18 (d, *J* = 5.6 Hz, 2H), 3.82 (brs, 1H), 2.22 (d, *J* = 7.2 Hz, 2H), 1.93-1.85 (m, 1H), 0.82 (d, *J* = 6.8 Hz, 6H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 158.3 (d, *J* = 3.3 Hz), 139.6, 138.8 (d, *J* = 13.8 Hz), 138.6 (d, *J* = 12.5 Hz), 132.8, 132.6 (d, *J* = 2.6 Hz), 132.5, 128.32, 128.25, 128.21 (d, *J* = 1.8 Hz), 128.2, 126.9, 126.6, 52.8 (d, *J* = 15.0 Hz), 43.8, 32.6 (d, *J* = 13.8 Hz), 32.4 (d, *J* = 8.8 Hz), 19.0, 17.2; **^{31}P NMR** (162 MHz, $CDCl_3$, 85% H_3PO_4) δ -22.0; **Mp**: 104-105 ºC. **HRMS**

Calcd. for $C_{25}H_{30}N_2OP^+$ $[M+H]^+$: 405.2096, found: 405.2085; $[\alpha]^{20}_D$ = +24.1 (c 0.23, CH_2Cl_2).

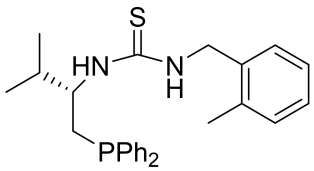
(*S*)-1-(1-(diphenylphosphaneyl)-3-methylbutan-2-yl)-3-phenethylthiourea (LB10)



LB10

Compound **LB10** (434.0 mg, 99% yield) was obtained as a white solid following the *general procedure II* from **LBa** (0.1 mmol, 272 mg) and (2-isothiocyanatoethyl)benzene (1.2 mmol, 195.6 mg) stirred for 24 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.49-7.44 (m, 4H), 7.33-7.28 (m, 8H), 7.22-7.15 (m, 3H), 6.51 (brs, 1H), 4.56 (brs, 1H), 3.51 (brs, 2H), 2.81 (t, *J* = 7.2 Hz, 2H), 2.41-2.34 (m, 2H), 2.09-2.00 (m, 1H), 0.91 (d, *J* = 6.4 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 180.9, 138.0, 137.7 (d, *J* = 11.2 Hz), 137.5, 132.5 (d, *J* = 19.0 Hz), 132.3 (d, *J* = 18.6 Hz), 128.5, 128.3, 128.2, 128.1 (d, *J* = 1.5 Hz), 126.1, 56.8, 45.0, 34.7, 31.6 (d, *J* = 8.0 Hz), 31.0 (d, *J* = 15.5 Hz), 18.4, 17.7; **^{31}P NMR** (162 MHz, $CDCl_3$, 85% H_3PO_4) δ -23.0; **Mp**: 61-63 ºC; **HRMS** Calcd. for $C_{26}H_{32}N_2PS^+$ $[M+H]^+$: 435.2024, found: 435.2011; $[\alpha]^{20}_D$ = +10.8 (c 0.20, CH_2Cl_2).

(*S*)-1-(1-(diphenylphosphaneyl)-3-methylbutan-2-yl)-3-(2-methylbenzyl)thiourea (LB12)

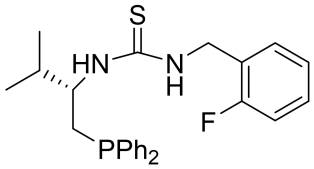


LB12

Compound **LB12** (183.6 mg, 85% yield) was obtained as a white solid following the *general procedure II* from **LBa** (0.05 mmol, 136 mg) and 1-(isothiocyanatomethyl)-2-methylbenzene (0.6 mmol, 89.4 mg) stirred for 24 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.46-7.31 (m, 11H), 7.19-7.12 (m, 4H), 6.68 (brs, 1H),

6.15 (brs, 1H), 4.36 (brs, 2H), 2.42-2.37 (m, 1H), 2.32-2.30 (m, 1H), 2.26 (s, 3H), 2.10-2.01 (m, 1H), 0.82 (d, *J* = 7.2 Hz, 6H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 181.1, 138.1 (d, *J* = 11.5 Hz), 137.8, 136.0, 134.5, 132.7, 132.6, 132.4, 130.4, 128.6, 128.5, 128.28 (d, *J* = 6.8 Hz), 128.26 (d, *J* = 6.9 Hz), 127.8, 127.6, 126.0, 57.5, 45.9, 31.8, 31.2 (d, *J* = 13.6 Hz), 18.9, 18.4, 17.7; **^{31}P NMR** (162 MHz, $CDCl_3$, 85% H_3PO_4) δ -23.5; **Mp**: 54-56 ºC. **HRMS** Calcd. for $C_{26}H_{32}N_2PS^+$ $[M+H]^+$: 435.2024, found: 435.2012; $[\alpha]^{20}_D$ = +15.8 (c 0.26, CH_2Cl_2).

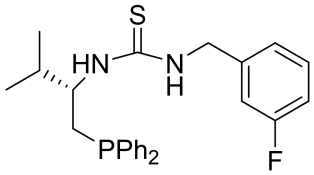
(*S*)-1-(1-(diphenylphosphaneyl)-3-methylbutan-2-yl)-3-(2-fluorobenzyl)thiourea (LB13)



LB13

Compound **LB13** (209.8 mg, 89% yield) was obtained as a white solid following the *general procedure II* from **LBa** (0.54 mmol, 146 mg) and 1-fluoro-2-(isothiocyanatomethyl)benzene (0.65 mmol, 108 mg) stirred for 24 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.45-7.29 (m, 11H), 7.25-7.21 (m, 1H), 7.09-6.98 (m, 2H), 6.60 (brs, 1H), 6.10 (brs, 1H), 4.43 (brs, 2H), 2.42-2.26 (m, 2H), 2.07-2.02 (m, 1H), 0.83 (d, *J* = 6.8 Hz, 6H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 181.3, 160.2 (d, *J* = 244.5 Hz), 138.0 (d, *J* = 11.6 Hz), 137.7, 132.7 (d, *J* = 19.1 Hz), 132.5 (d, *J* = 18.9 Hz), 129.6 (d, *J* = 3.1 Hz), 129.1 (d, *J* = 8.0 Hz), 128.6, 128.5, 128.3 (d, *J* = 6.8 Hz), 128.27 (d, *J* = 6.9 Hz), 124.2 (d, *J* = 3.1 Hz), 115.0 (d, *J* = 21.3 Hz), 57.6, 41.0, 31.9 (d, *J* = 6.5 Hz), 31.2 (d, *J* = 12.9 Hz), 18.4, 17.7; **^{31}P NMR** (162 MHz, $CDCl_3$, 85% H_3PO_4) δ -23.2; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -118.3; **Mp**: 43-45 ºC; **HRMS** Calcd. for $C_{25}H_{29}FN_2PS^+$ $[M+H]^+$: 439.1773, found: 439.1761; $[\alpha]^{20}_D$ = +7.8 (c 0.20, CH_2Cl_2).

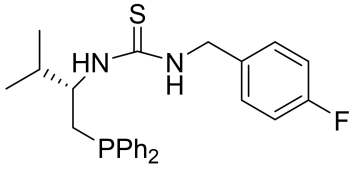
(*S*)-1-(1-(diphenylphosphaneyl)-3-methylbutan-2-yl)-3-(3-fluorobenzyl)thiourea (LB14)



LB14

Compound **LB14** (189.2 mg, 86% yield) was obtained as a white solid following the *general procedure II* from **LBa** (0.5mmol, 136 mg) and 1-fluoro-3-(isothiocyanatomethyl)benzene (0.6 mmol, 100.3 mg, 82 μL) stirred for 24 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.45-7.30 (m, 10H), 7.24-7.20 (m, 1H), 6.99-6.90 (m, 3H), 6.34 (brs, 1H), 4.44 (brs, 2H), 2.39-2.25 (m, 2H), 2.08-1.99 (m, 1H), 0.79 (s, 6H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 181.6, 162.8 (d, *J* = 245.5 Hz), 139.8, 138.1, 132.8, 132.7, 132.5, 130.3 (d, *J* = 9.5 Hz), 130.1 (d, *J* = 8.1 Hz), 128.7 (d, *J* = 11.5 Hz), 128.44 (d, *J* = 6.8 Hz), 128.41 (d, *J* = 6.9 Hz), 122.8, 114.4 (d, *J* = 21.1 Hz), 114.1 (d, *J* = 21.8 Hz), 57.7, 47.1, 30.0, 31.2 (d, *J* = 11.3 Hz), 18.5, 17.7; **^{31}P NMR** (162 MHz, $CDCl_3$, 85% H_3PO_4) δ -23.5; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -112.0; **Mp**: 97-99 ºC. **HRMS** Calcd. for $C_{25}H_{29}FN_2PS^+$ $[M+H]^+$: 439.1773, found: 439.1762; $[\alpha]^{20}_D$ = +13.5 (c 0.21, CH_2Cl_2).

(*S*)-1-(1-(diphenylphosphaneyl)-3-methylbutan-2-yl)-3-(4-fluorobenzyl)thioure (LB15)

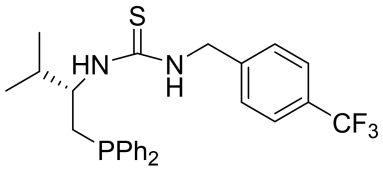


LB15

Compound **LB15** (179.6 mg, 82% yield) was obtained as a white solid following the *general procedure II* from **LBa** (0.5 mmol, 136 mg) and 1-fluoro-4-(isothiocyanatomethyl)benzene (0.6 mmol, 100.3 mg, 82 μL) stirred for 24 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.44-7.30 (m, 10H), 7.18-7.15 (m, 2H), 6.98-6.93 (m, 2H), 6.29 (brs, 1H), 4.37 (brs, 2H), 2.40-2.25 (m, 2H), 2.04-1.98 (m, 1H), 0.79 (d, *J* = 6.8 Hz, 6H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 181.2, 161.9 (d, *J* = 244.8 Hz), 138.0 (d, *J* = 11.3 Hz), 137.7, 132.7, 132.6, 132.4, 128.9 (d, *J* = 7.9 Hz),

128.6, 128.5, 128.32 (d, *J* = 6.8 Hz), 128.28 (d, *J* = 6.9 Hz), 115.3 (d, *J* = 21.4 Hz), 57.6, 46.7, 31.9, 31.1 (d, *J* = 13.3 Hz), 18.3, 17.7; **^{31}P NMR** (162 MHz, $CDCl_3$, 85% H_3PO_4) δ -23.6; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -114.2; **Mp**: 93-95 ºC. **HRMS** Calcd. for $C_{25}H_{29}N_2FPS^+$ $[M+H]^+$: 439.1773, found: 439.1761; $[\alpha]^{20}_D$ = +10.8 (c 0.21, CH_2Cl_2).

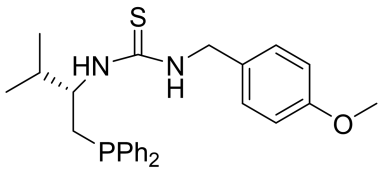
(*S*)-1-(1-(diphenylphosphaneyl)-3-methylbutan-2-yl)-3-(4-(trifluoromethyl)benzyl) thiourea (LB16)



LB16

Compound **LB16** (154.4 mg, 83% yield) was obtained as a white solid following the *general procedure II* from **LBa** (0.38 mmol, 103 mg) and 1-(isothiocyanatomethyl)-4-(trifluoromethyl)benzene (0.76 mmol, 165 mg) stirred for 24 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.53-7.30 (m, 14H), 7.15 (brs, 1H), 6.39 (brs, 1H), 4.51 (brs, 2H), 2.42-2.24 (m, 2H), 2.05-1.97 (m, 1H), 0.81 (s, 6H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 181.6, 141.5, 138.1 (d, *J* = 10.4 Hz), 137.6, 132.7 (d, *J* = 19.1 Hz), 132.4 (d, *J* = 18.8 Hz), 128.7, 128.5, 128.4 (d, *J* = 6.8 Hz), 128.3 (d, *J* = 7.0 Hz), 127.3, 125.3 (d, *J* = 3.8 Hz), 123.8 (q, *J* = 271 Hz), 57.6 (d, *J* = 16.3 Hz), 46.9, 32.1, 31.3, 18.3, 17.7; **^{31}P NMR** (162 MHz, $CDCl_3$, 85% H_3PO_4) δ -23.4; **^{19}F NMR** (376 MHz, $CDCl_3$) δ -62.3; **Mp**: 101-103 ºC. **HRMS** Calcd. for $C_{26}H_{29}N_2F_3PS^+$ $[M+H]^+$: 489.1741, found: 489.1730; $[\alpha]^{20}_D$ = +7.7 (c 0.15, CH_2Cl_2).

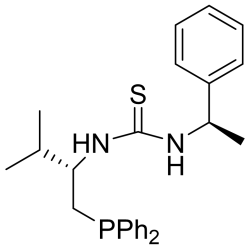
(S)-1-(1-(diphenylphosphaneyl)-3-methylbutan-2-yl)-3-(4-methoxybenzyl)thioure a (LB17)



LB17

Compound **LB17** (403.8 mg, 90% yield) was obtained as a white solid following the *general procedure II* from **LBa** (1 mmol, 272 mg) and 1-(isothiocyanatomethyl)-4-methoxybenzene (1.2 mmol, 215 mg, 198 μL) stirred for 24 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.46-7.28 (m, 10H), 7.12 (d, *J* = 8.4 Hz, 2H), 6.80 (d, *J* = 8.4 Hz, 2H), 4.53 (brs, 2H), 3.69 (s, 3H), 2.37-2.25 (m, 2H), 2.08-1.95 (m, 1H), 0.76 (s, 6H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 180.9, 158.7, 138.0 (d, *J* = 12.1 Hz), 137.8, 132.6, 132.5, 132.3, 128.4, 128.3, 128.2, 128.14, 128.09, 113.8, 57.4, 54.9, 46.8, 31.7, 31.1 (d, *J* = 13.9 Hz), 18.3, 17.6; **^{31}P NMR** (162 MHz, $CDCl_3$, 85% H_3PO_4) δ -23.5; **Mp**: 43-45 ºC. **HRMS** Calcd. for $C_{26}H_{32}N_2OPS^+$ $[M+H]^+$: 451.1973, found: 451.1962; $[\alpha]^{20}_D$ = +18.5 (c 0.22, CH_2Cl_2).

1-((*S*)-1-(diphenylphosphaneyl)-3-methylbutan-2-yl)-3-((R)-1-phenylethyl)thiourea (LB21)

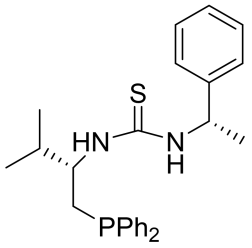


LB21

Compound **LB21** (193 mg, 89% yield) was obtained as a white solid following the *general procedure II* from **LBa** (0.5 mmol, 136 mg) and (*R*)-(1-isothiocyanatoethyl)benzene (0.6 mmol, 98 mg) stirred for 24 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.53 (t, *J* = 7.2 Hz, 2H), 7.45 (t, *J* = 7.2 Hz, 2H), 7.35-7.28 (m, 8H), 7.22 (t, *J* = 7.2 Hz, 1H), 7.17 (d, *J* = 7.2 Hz, 2H), 6.89 (brs, 1H), 5.11 (brs, 1H), 4.56 (brs, 1H), 3.63 (brs, 1H), 2.37 (dd, *J* = 14.4, 5.2 Hz, 1H), 2.26 (dd, *J* = 14.4, 8.0 Hz, 1H), 1.84-1.79 (m, 1H), 1.31 (d, *J* = 6.8 Hz, 3H), 0.52 (s, 3H), 0.41 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 179.2, 142.0, 138.2, 132.7 (d, *J* = 19.3 Hz), 132.4 (d, *J* = 18.9 Hz), 128.9, 128.5, 128.3 (d, *J* = 3.3 Hz), 128.2 (d, *J* = 2.6 Hz), 128.1, 127.6, 125.3, 58.1, 52.8, 31.4 (d, *J* = 9.0 Hz), 30.8 (d, *J* = 13.0 Hz), 23.6, 17.8, 17.1; **^{31}P NMR** (162 MHz, $CDCl_3$, 85% H_3PO_4) δ -23.6; **Mp**:51-53 ºC. **HRMS** Calcd. for

$C_{26}H_{32}N_2PS^+$ $[M+H]^+$: 435.2024, found: 435.2013; $[\alpha]^{20}_D$ = +0.38 (c 0.26, CH_2Cl_2).

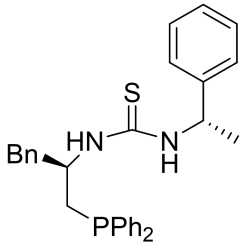
1-((*S*)-1-(diphenylphosphaneyl)-3-methylbutan-2-yl)-3-((S)-1-phenylethyl)thioure a (LB22)



LB22

Compound **LB22** (1.0 g, 88% yield) was obtained as a white solid following the *general procedure II* from **LBa** (2.62 mmol, 713 mg) and (*S*)-(1-isothiocyanatoethyl)benzene (3.14 mmol, 512 mg) stirred for 24 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.41-7.30 (m, 14H), 7.24-7.20 (m, 1H), 6.54 (brs, 1H), 5.82 (brs, 1H), 4.83 (brs, 1H), 4.27 (brs, 1H), 2.18-2.00 (m, 3H), 1.48 (d, *J* = 6.4 Hz, 3H), 0.82 (d, *J* = 6.8 Hz, 3H), 0.75 (d, *J* = 4.0 Hz, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 180.5, 142.2, 137.8 (d, *J* = 11.9 Hz), 132.6, 132.5, 132.3, 128.7, 128.3, 128.2, 128.1 (d, *J* = 6.6 Hz), 128.0 (d, *J* = 6.9 Hz), 127.3, 125.6, 57.1 (d, *J* = 14.9 Hz), 53.5, 31.3 (d, *J* = 14.6Hz), 31.0, 22.9, 18.6, 17.0; **^{31}P NMR** (162 MHz, $CDCl_3$, 85% H_3PO_4) δ -23.9; **Mp**: 49-51 ºC; **HRMS** Calcd. for $C_{26}H_{32}N_2PS^+$ $[M+H]^+$: 435.2024, found: 435.2011; $[\alpha]^{20}_D$ = +34.4 (c 0.24 CH_2Cl_2).

1-((*R*)-1-(diphenylphosphaneyl)-3-phenylpropan-2-yl)-3-((*S*)-1-phenylethyl)thiou rea (LB23)

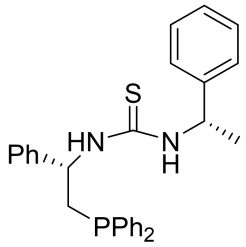


LB23

Compound **LB23** (216.2 mg, 88% yield) was obtained as a white solid following the *general procedure II* from **LBc** (0.6 mmol, 194 mg) and

(*S*)-(1-isothiocyanatoethyl)benzene (0.72 mmol, 119 mg) stirred for 24 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.49-7.31 (m, 14H), 7.22-7.16 (m, 5H), 6.91 (s, 2H), 5.54 (brs, 1H), 4.93 (brs, 1H), 4.05 (brs, 1H), 2.96-2.92 (m, 1H), 2.73 (s, 1H), 2.49-2.45 (m, 1H), 2.28-2.22 (m, 1H), 1.37 (d, *J* = 6.4 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 179.4, 141.9, 137.8 (d, *J* = 11.8 Hz), 137.3, 136.8, 132.7 (d, *J* = 19.3 Hz), 132.4 (d, *J* = 18.9 Hz), 128.9, 128.8, 128.6, 128.5, 128.3 (d, *J* = 13.6 Hz), 128.2, 128.1, 127.5, 126.0, 125.3, 54.0 (d, *J* = 14.9 Hz), 52.9, 40.6 (d, *J* = 9.5 Hz), 32.4 (d, *J* = 15.3 Hz), 23.5; **^{31}P NMR** (162 MHz, $CDCl_3$, 85% H_3PO_4) δ -23.7; **Mp**: 53-55 ºC; **HRMS** Calcd. for $C_{30}H_{32}N_2PS^+$ $[M+H]^+$: 483.2024, found: 483.2012; $[\alpha]^{20}_D$ = -12.7 (c 0.23 CH_2Cl_2).

1-((*S*)-2-(diphenylphosphaneyl)-1-phenylethyl)-3-((*S*)-1-phenylethyl)thiourea (LB24)

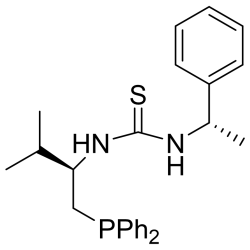


LB24

Compound **LB24** (229 mg, 98% yield) was obtained as a white solid following the *general procedure II* from **LBb** (0.5 mmol, 152.5 mg) and (*S*)-(1-isothiocyanatoethyl)benzene (0.6 mmol, 100 mg) stirred for 24 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.39-7.31 (m, 18H), 7.16-7.14 (m, 2H), 6.64 (brs, 1H), 6.14 (brs, 1H), 5.06 (brs, 1H), 2.74-2.69 (m, 1H), 2.37 (brs, 1H), 1.31 (d, *J* = 6.8 Hz, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 180.2, 142.3, 140.9 (d, *J* = 3.0 Hz), 137.4, 136.9, 132.73 (d, *J* = 15.3 Hz), 132.68 (d, *J* = 15.3 Hz), 128.8, 128.7 (d, *J* = 3.6 Hz), 128.4 (d, *J* = 5.5 Hz), 127.9, 127.6, 126.3, 125.9, 56.5 (d, *J* = 14.2 Hz), 53.9, 36.7 (d, *J* = 12.0 Hz), 22.4; **^{31}P NMR** (162 MHz, $CDCl_3$, 85% H_3PO_4) δ -23.7; **Mp**: 62-64 ºC; **HRMS** Calcd. for $C_{29}H_{30}N_2PS^+$ $[M+H]^+$: 469.1867, found: 469.1856; $[\alpha]^{20}_D$ = +10.5 (c 0.20 CH_2Cl_2).

1-((*R*)-1-(diphenylphosphaneyl)-3-methylbutan-2-yl)-3-((*S*)-1-phenylethyl)thiour

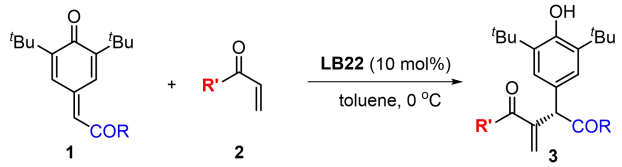
ea (LB25)



LB25

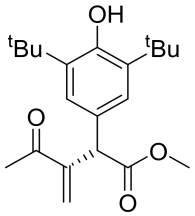
Compound **LB25** (205.5 mg, 95% yield) was obtained as a white solid following the *general procedure II* from **LBd** (0.5 mmol, 136 mg) and (*S*)-(1-isothiocyanatoethyl)benzene (0.6 mmol, 97.8 mg) stirred for 24 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.54-7.28 (m, 12H), 7.23-7.15 (m, 3H), 7.00 (brs, 1H), 5.10 (brs, 1H), 4.56 (brs, 1H), 3.61 (brs, 1H), 2.36 (dd, *J* = 14.4, 4.8 Hz, 1H), 2.26 (dd, *J* = 14.4, 8.4 Hz, 1H), 1.85-1.77 (m, 1H), 1.30 (d, *J* = 6.4 Hz, 3H), 0.50 (s, 3H), 0.41 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 179.3, 142.0, 138.3, 132.6 (d, *J* = 26.7 Hz), 132.4 (d, *J* = 26.2 Hz), 128.9, 128.5, 128.3, 128.2 (d, *J* = 1.9 Hz), 128.1, 127.6, 125.3, 58.1, 52.8, 31.5 (d, *J* = 9.4 Hz), 30.8 (d, *J* = 14.4 Hz), 23.6, 17.9, 17.1; **^{31}P NMR** (162 MHz, $CDCl_3$, 85% H_3PO_4) δ -23.5; **Mp**: 51-56 ºC. **HRMS** Calcd. for $C_{26}H_{32}N_2PS^+$ $[M+H]^+$: 435.2024, found: 435.2012; $[\alpha]^{20}_D$ = -4.7 (c 0.23, CH_2Cl_2).

General procedure (*III*) for the synthesis of R-C compounds 3



Procedure (*III*): To a solution of compound **1** (0.1 mmol, 1.0 eq.) and chiral phosphine **LB22** (0.01 mmol, 0.1 eq.) in toluene (1.0 mL) was added vinyl ketone **2** (0.15 mmol, 1.5 eq.) under nitrogen atmosphere at 0 ºC. TLC monitor until the compound **1** consumed after six hours. The reaction mixture was then concentrated on a rotary evaporator under reduce pressure and the residue was subjected to purification by column chromatography (silica gel, PE/EtOAc: 20/1 to 10/1, R_f = 0.5-0.6) to afford the corresponding product **3**.

Methyl (*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-4-oxopentanoate (3a)

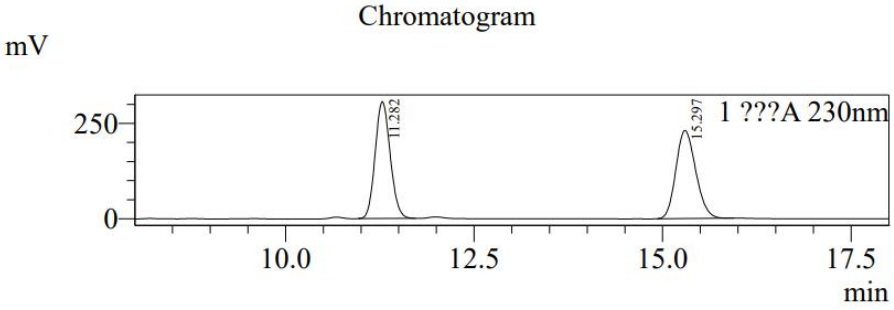


3a

Compound **3a** (34.5 mg, 99% yield) was obtained as a white solid following the *general procedure III* from **1a** (0.1 mmol, 27.6 mg) and **2a** (0.15 mmol, 10.5 mg, 12.5 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.99 (s, 2H), 6.22 (s, 1H), 5.57 (s, 1H), 5.20 (s, 1H), 4.77 (s, 1H), 3.69 (s, 3H), 2.40 (s, 3H), 1.41 (s, 18H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.9, 173.0, 153.2, 148.1, 136.1, 128.4, 126.4, 125.5, 52.3, 51.7, 34.3, 30.2, 25.9; **Mp**: 111-113 ºC; **HRMS** Calcd. for $C_{21}H_{29}O_4^-$ [M-H]$^-$: 345.2066, found: 345.2078.

$[\alpha]^{20}_D$ = -106.4 (c 0.16, CH_2Cl_2) for 95% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 15.167 min, t_{major} = 11.200 min.

Racemic Sample 3a

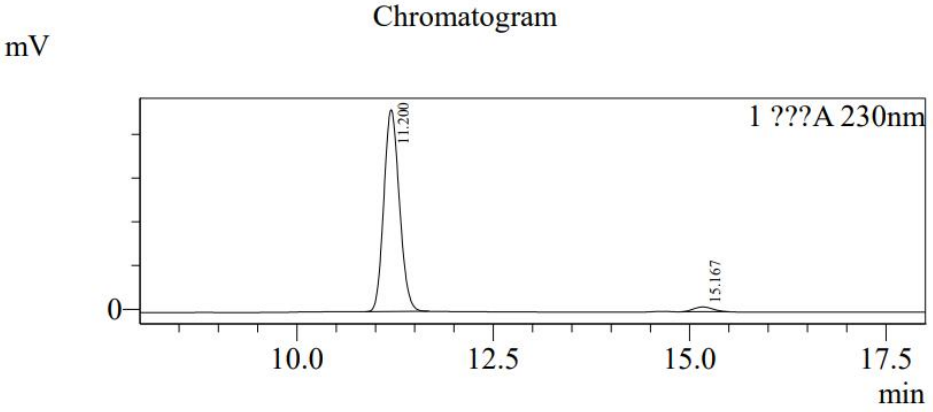


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	11.282	4248400	306421	50.172
2	15.297	4219319	230706	49.828
Total		8467720	537127	100.000

Enantiomeric Sample 3a

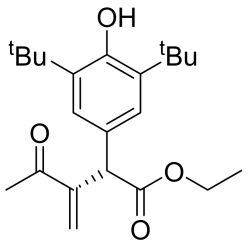


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	11.200	3180643	230830	97.255
2	15.167	89788	5436	2.745
Total		3270431	236265	100.000

Ethyl (S)-2-(3,5-di-tert-butyl-4-hydroxyphenyl)-3-methylene-4-oxopentanoate (3b)



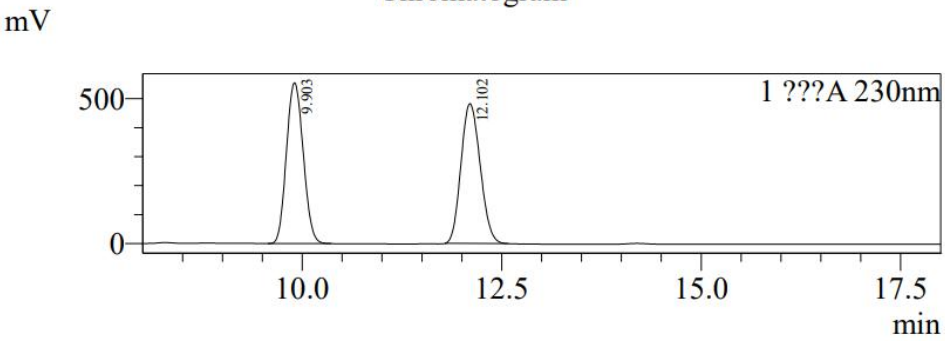
3b

Compound **3b** (39.8 mg, 94% yield) was obtained as a white solid following the *general procedure III* from **1b** (0.1 mmol, 34.1 mg) and **2a** (0.15 mmol, 10.5 mg, 12.5 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.99 (s, 2H), 6.20 (s, 1H), 5.56-5.55 (m, 1H), 5.18 (s, 1H), 4.75 (s, 1H), 4.23-4.08 (m, 2H), 2.39 (s, 3H), 1.41 (s, 18H), 1.23 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.9, 172.4, 153.1, 148.3, 136.1, 128.1, 126.6, 125.5, 61.0, 51.9, 34.3, 30.2, 25.8, 14.1; **Mp**: 108-110 ºC; **HRMS** Calcd. for $C_{22}H_{31}O_4^-$ $[M-H]^-$: 359.2222, found: 359.2218.

$[\alpha]^{20}_D$ = -112.9 (c 0.14, CH_2Cl_2) for 91% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 12.179 min, t_{major} = 9.930 min.

Racemic Sample 3b

Chromatogram



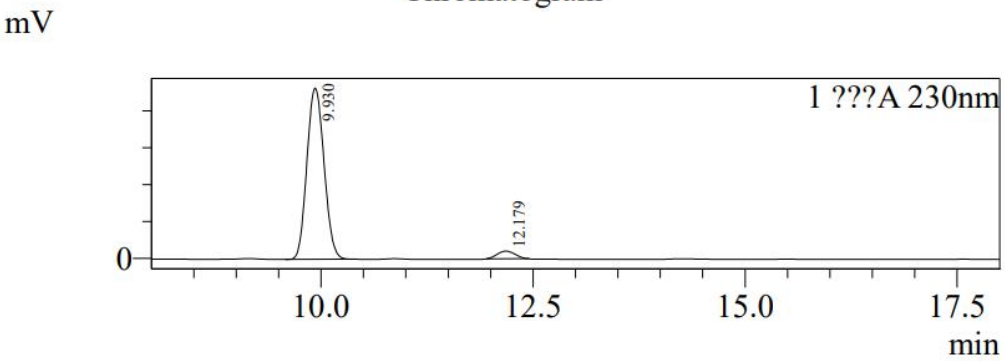
Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	9.903	8131440	555040	50.149
2	12.102	8083260	482457	49.851
Total		16214701	1037497	100.000

Enantiomeric Sample 3b

Chromatogram

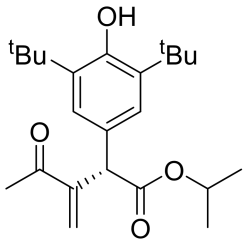


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	9.930	6538877	464195	95.506
2	12.179	307692	20954	4.494
Total		6846570	485148	100.000

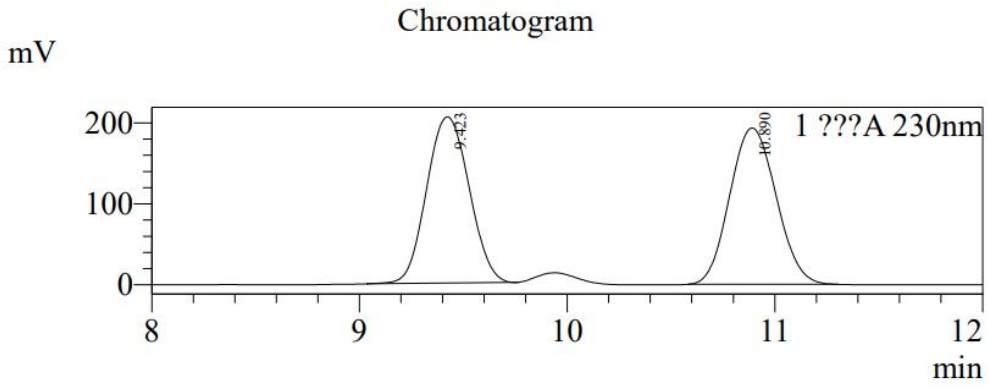
Isopropyl
(*S*)-2-(3,5-di-tert-butyl-4-hydroxyphenyl)-3-methylene-4-oxopentanoate (3c)



3c

Compound **3c** (36.6 mg, 98% yield) was obtained as a white solid following the *general procedure III* from **1c** (0.1 mmol, 30.4 mg) and **2a** (0.15 mmol, 10.5 mg, 12.5 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.97 (s, 2H), 6.18 (s, 1H), 5.52 (s, 1H), 5.16 (s, 1H), 5.07-4.97 (m, 1H), 4.72 (s, 1H), 2.39 (s, 3H), 1.41 (s, 18H), 1.25 (d, *J* = 6.4 Hz, 3H), 1.16 (d, *J* = 6.4 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 199.0, 171.8, 153.0, 148.5, 136.0, 127.8, 126.8, 125.5, 68.2, 52.2, 34.3, 30.3, 25.8, 21.7, 21.4; **Mp**: 111-112 ºC; **HRMS** Calcd. for $C_{23}H_{33}O_4^-$ $[M-H]^-$: 373.2384, found: 373.2390. $[\alpha]^{20}_D$ = -86.4 (c 0.30, CH_2Cl_2) for 92% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 10.901 min, t_{major} = 9.440 min.

Racemic Sample 3c

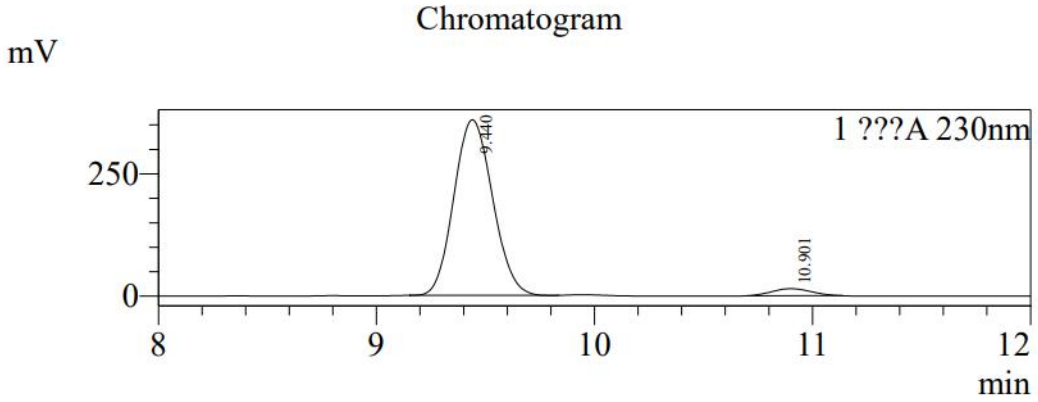


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	9.423	2921028	205326	49.334
2	10.890	2999843	193091	50.666
Total		5920870	398417	100.000

Enantiomeric Sample 3c

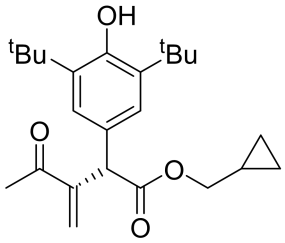


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	9.440	4435534	359236	96.081
2	10.901	180942	14376	3.919
Total		4616476	373612	100.000

Cyclopropylmethyl
(*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-4-oxopentanoate (3d)

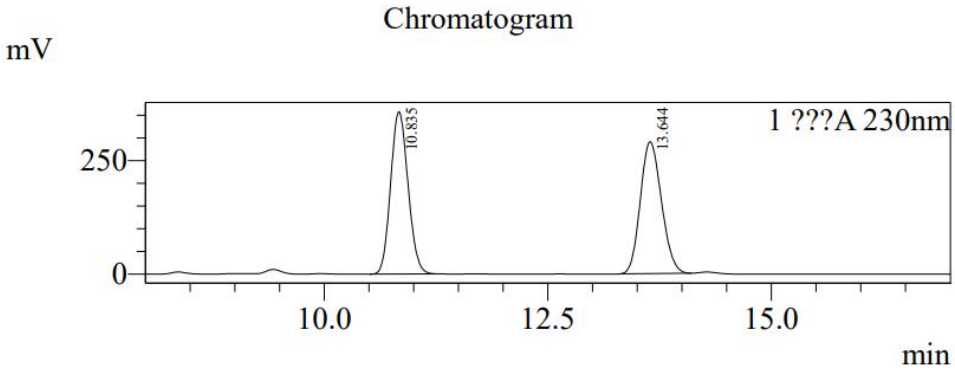


3d

Compound **3d** (35.2 mg, 91% yield) was obtained as a white solid following the *general procedure III* from **1d** (0.1 mmol, 31.6 mg) and **2a** (0.15 mmol, 10.5 mg, 12.5 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.00 (s, 2H), 6.21 (s, 1H), 5.57 (s, 1H), 5.17 (s, 1H), 4.79 (s, 1H), 3.98-3.89 (m, 2H), 2.40 (s, 3H), 1.41 (s, 18H), 1.14-1.07 (m, 1H), 0.54-0.49 (m, 2H), 0.24 (q, *J* = 5.2 Hz, 2H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.9, 172.6, 153.1, 148.3, 136.0, 128.0, 126.7, 125.6, 69.6, 52.0, 34.3, 30.3, 25.9, 9.7, 3.3, 3.1; **Mp**: 106-109 ºC; **HRMS** Calcd. for $C_{24}H_{33}O_4^-$ [M-H]$^-$: 385.2379, found: 385.2373.

$[\alpha]^{20}_D$ = -4.4 (c 0.07, CH_2Cl_2) for 91% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 13.709 min, t_{major} = 10.864 min.

Racemic Sample 3d

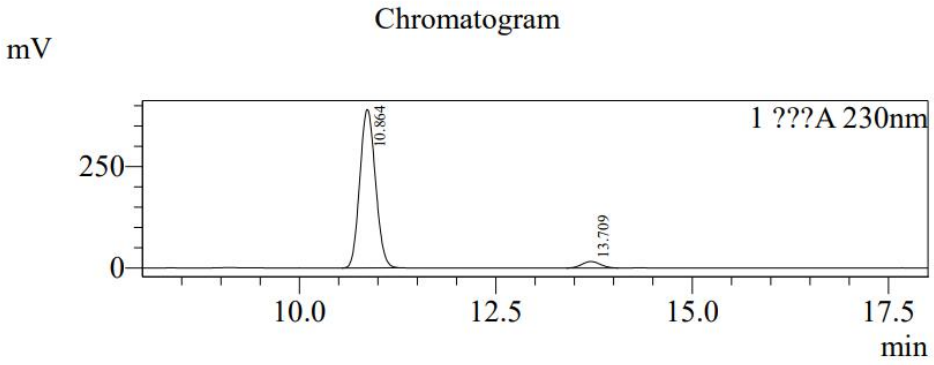


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	10.835	4838777	357510	50.338
2	13.644	4773867	290278	49.662
Total		9612644	647788	100.000

Enantiomeric Sample 3d

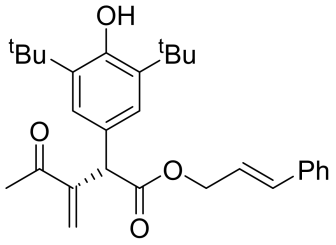


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	10.864	5429406	390440	95.424
2	13.709	260377	16014	4.576
Total		5689784	406454	100.000

Cinnamyl (*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-4-oxopentanoate (3e)



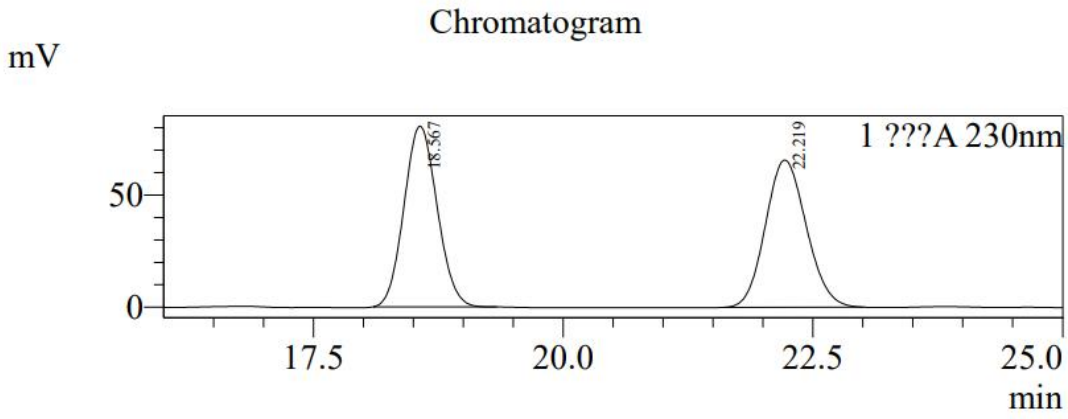
3e

Compound **3e** (37.6 mg, 83% yield) was obtained as a white solid following the

general procedure III from **1e** (0.1mmol, 37.8 mg) and **2a** (0.15 mmol, 10.5 mg, 12.5 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.34-7.27 (m, 4H), 7.25-7.21 (m, 1H), 7.01 (s, 2H), 6.56 (d, *J* = 16.0 Hz, 1H), 6.27-6.20 (m, 2H), 5.59 (s, 1H), 5.18 (s, 1H), 4.82 (s, 1H), 4.77 (d, *J* = 6.4 Hz, 2H), 2.41 (s, 3H), 1.39 (s, 18H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.9, 172.2, 153.2, 148.1, 136.2, 136.1, 133.9, 128.5, 128.3, 127.9, 126.6, 126.4, 125.6, 123.1, 65.4, 51.9, 34.3, 30.2, 25.8; **Mp**: 104-106 ºC; **HRMS** Calcd. for $C_{29}H_{35}O_4^-$ $[M-H]^-$: 447.2541, found: 447.2550.

$[\alpha]^{20}_D$ = -88.9 (c 0.18, CH_2Cl_2) for 94% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 22.167 min, t_{major} = 18.444 min.

Racemic Sample 3e

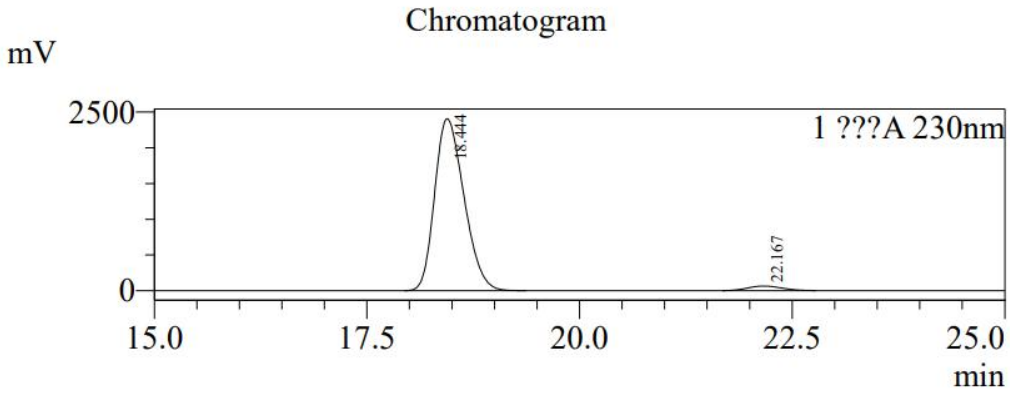


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	18.567	1865395	80606	49.947
2	22.219	1869350	65604	50.053
Total		3734745	146210	100.000

Enantiomeric Sample 3e

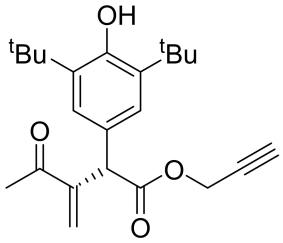


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	18.444	57838448	2406319	97.019
2	22.167	1777277	63743	2.981
Total		59615725	2470062	100.000

Prop-2-yn-1-yl
2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-4-oxopentanoate (3f)

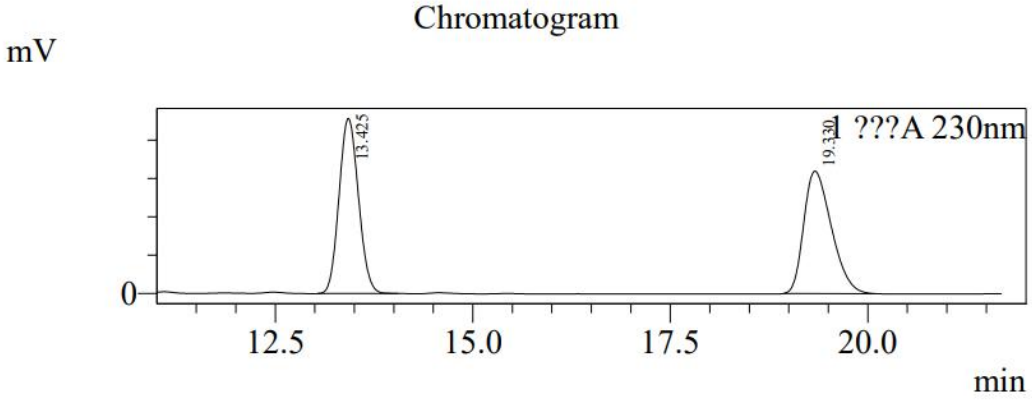


3f

Compound **3f** (36.3 mg, 98% yield) was obtained as a white solid following the *general procedure III* from **1f** (0.1mmol, 30.0 mg) and **2a** (0.15 mmol, 10.5 mg, 12.5 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.99 (s, 2H), 6.23 (s, 1H), 5.58 (s, 1H), 5.20 (s, 1H), 4.80 (s, 1H), 4.73-4.64 (m, 2H), 2.43-2.42 (m, 1H), 2.40 (s, 3H), 1.41 (s, 18H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.8, 171.6, 153.3, 147.8, 136.2, 128.5, 125.9, 125.6, 77.6, 74.8, 52.4, 51.6, 34.3, 30.2, 25.8; **Mp**: 103-105 ºC; **HRMS** Calcd. for $C_{23}H_{29}O_4^-$ [M-H]$^-$: 369.2066, found: 369.2066.

$[\alpha]^{20}_D$ = -100.8 (c 0.13, CH_2Cl_2) for 91% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 19.404 min, t_{major} = 13.592 min.

Racemic Sample 3f

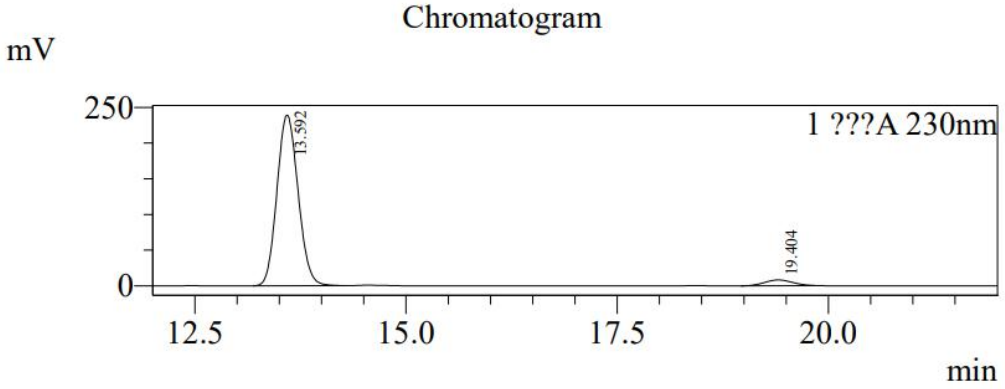


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	13.425	3904637	228424	50.147
2	19.330	3881680	159480	49.853
Total		7786317	387904	100.000

Enantiomeric Sample 3f

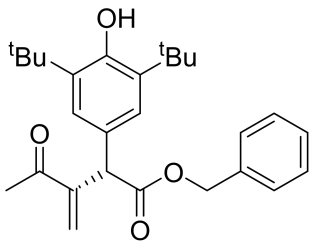


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	13.592	4163916	239148	95.556
2	19.404	193645	8198	4.444
Total		4357561	247346	100.000

Benzyl 2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-4-oxopentanoate (3g)

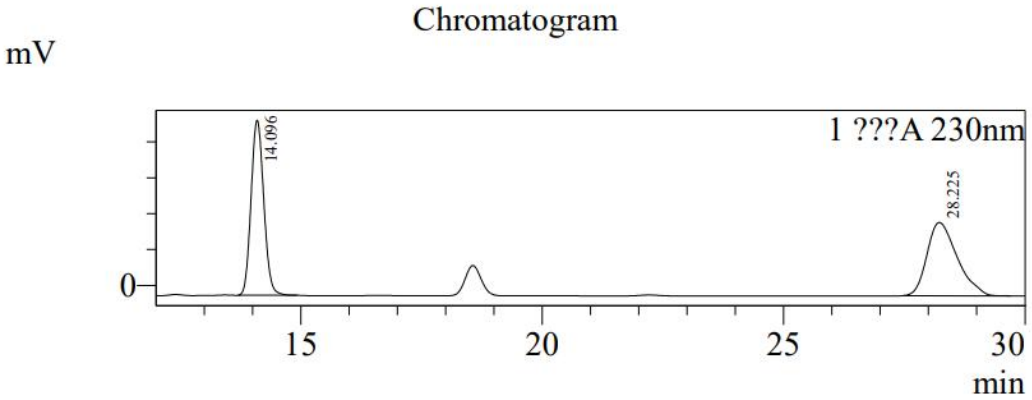


3g

Compound **3g** (24.6 mg, 97% yield) was obtained as a white solid following the *general procedure III* from **1g** (0.06 mmol, 21.5 mg) and **2a** (0.15 mmol, 10.5 mg, 12.5 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.31-7.27 (m, 4H), 7.26-7.25 (m, 1H), 6.96 (s, 2H), 6.21 (s, 1H), 5.59 (s, 1H), 5.17 (s, 1H), 5.14 (s, 2H), 4.83 (s, 1H), 2.39 (s, 3H), 1.38 (s, 18H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.9, 172.3, 153.2, 148.0, 136.1, 136.0, 128.4, 128.3, 127.97, 127.95, 126.4, 125.6, 66.5, 51.9, 34.3, 30.2, 25.8; **Mp**: 108-110 ºC; **HRMS** Calcd. for $C_{27}H_{33}O_4^-$ [M-H]$^-$: 421.2379, found: 421.2373.

$[\alpha]^{20}_D$ = -122.8 (c 0.22, CH_2Cl_2) for 94% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 28.510 min, t_{major} = 14.157 min.

Racemic Sample 3g

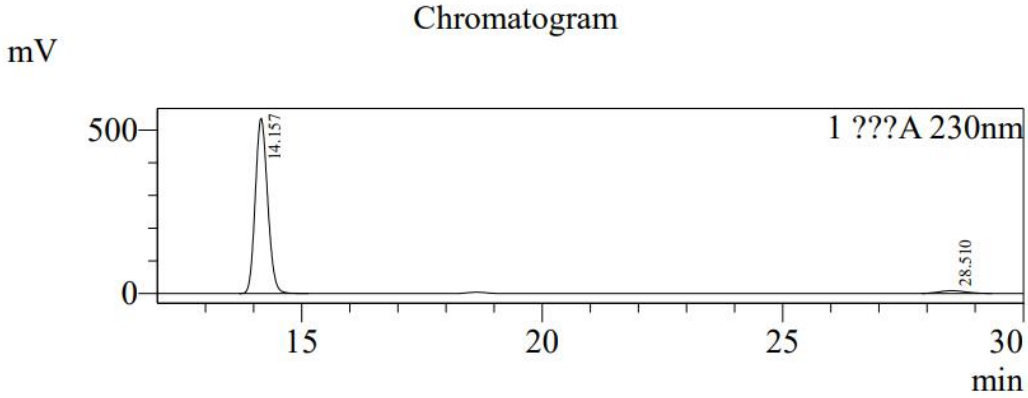


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	14.096	4454080	243864	50.127
2	28.225	4431558	102105	49.873
Total		8885638	345969	100.000

Enantiomeric Sample 3g

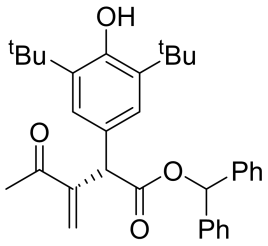


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	14.157	9553896	536041	96.764
2	28.510	319500	8429	3.236
Total		9873396	544470	100.000

Benzhydryl
(*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-4-oxopentanoate (3h)

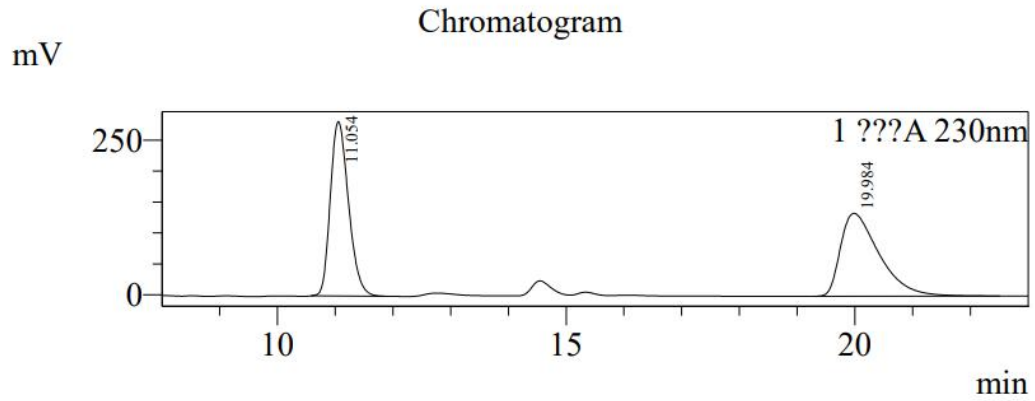


3h

Compound **3h** (41.8 mg, 84% yield) was obtained as a white solid following the *general procedure III* from **1h** (0.1 mmol, 42.8 mg) and **2a** (0.15 mmol, 10.5 mg, 12.5 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.33-7.28 (m, 5H), 7.21-7.20 (m, 3H), 7.11-7.09 (m, 2H), 6.93 (s, 2H), 6.86 (s, 1H), 6.21 (s, 1H), 5.63 (s, 1H), 5.16 (s, 1H), 4.96 (s, 1H), 2.36 (s, 3H), 1.36 (s, 18H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.8, 171.3, 153.1, 147.7, 140.0, 139.8, 136.0, 128.4, 128.2, 128.0, 127.8, 127.6, 127.2, 127.0, 126.3, 125.6, 77.2, 51.9, 34.3, 30.2, 25.8; **Mp**: 99-101 ºC; **HRMS** Calcd. for $C_{33}H_{37}O_4^-$ $[M-H]^-$: 497.2692, found: 497.2709.

$[\alpha]^{20}_D$ = -73.6 (c 0.38, CH_2Cl_2) for 78% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 20.419 min, t_{major} = 11.165 min.

Racemic Sample 3h

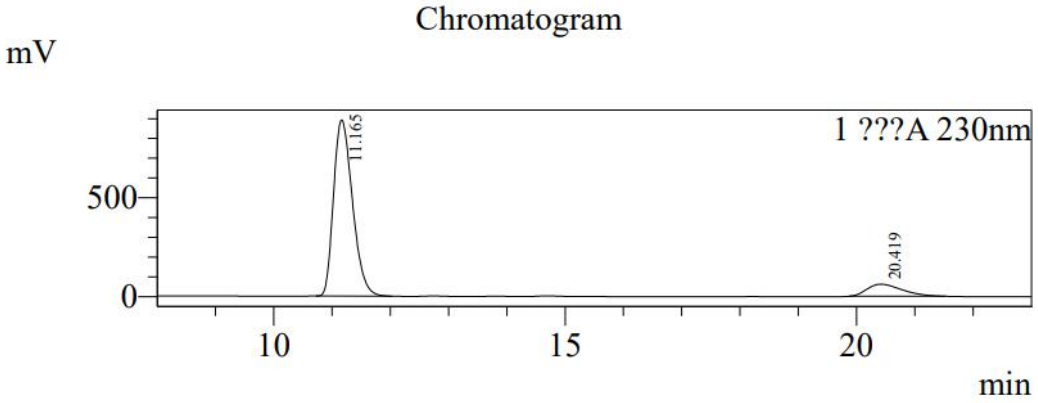


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	11.054	6187971	282085	49.758
2	19.984	6248188	134032	50.242
Total		12436158	416117	100.000

Enantiomeric Sample 3h

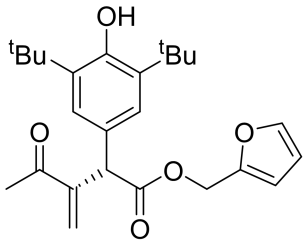


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	11.165	20124349	890450	88.839
2	20.419	2528370	60645	11.161
Total		22652720	951095	100.000

Furan-2-ylmethyl
(*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-4-oxopentanoate (3i)

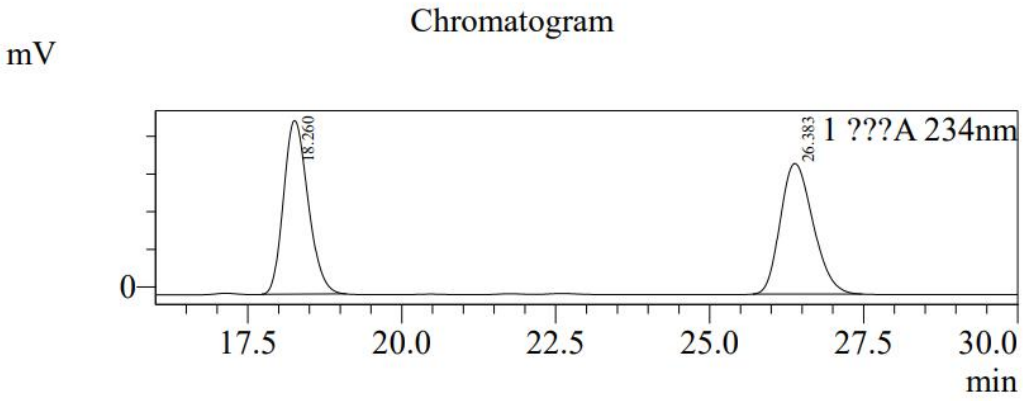


3i

Compound **3i** (20.2 mg, 98% yield) was obtained as a white solid following the *general procedure III* from **1i** (0.05 mmol, 17.1 mg) and **2a** (0.075 mmol, 5.26 mg, 7 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.36 (t, *J* = 0.8 Hz, 1H), 6.94 (s, 2H), 6.36 (d, *J* = 2.8 Hz, 1H), 6.33-6.31(m, 1H), 6.20 (s, 1H), 5.55 (s, 1H), 5.16 (s, 1H), 5.09 (s, 2H), 4.79 (s, 1H), 2.38 (s, 3H), 1.38 (s, 18H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.8, 172.0, 153.2, 149.5, 148.0, 143.0, 136.0, 128.3, 126.2, 125.6, 110.6, 110.5, 58.5, 51.7, 34.3, 30.2, 25.8; **Mp**: 66-67 ºC; **HRMS** Calcd. for $C_{25}H_{31}O_5^-$ [M-H]$^-$: 411.2171, found: 411.2184.

$[\alpha]^{20}_D$ = -85.6 (c 0.13, CH_2Cl_2) for 92% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 26.416 min, t_{major} = 18.209 min.

Racemic Sample 3i

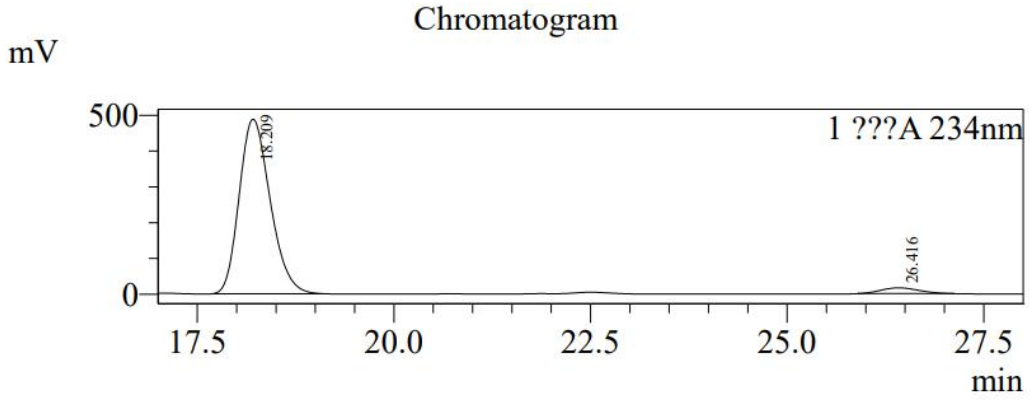


Peak Table

???A 234nm

Peak#	Ret. Time	Area	Height	Area%
1	18.260	6408256	230644	49.964
2	26.383	6417413	173327	50.036
Total		12825669	403971	100.000

Enantiomeric Sample 3i

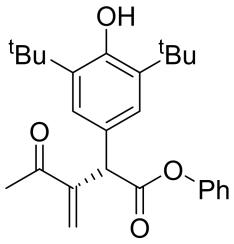


Peak Table

???A 234nm

Peak#	Ret. Time	Area	Height	Area%
1	18.209	13391237	488112	96.106
2	26.416	542536	16117	3.894
Total		13933773	504229	100.000

Phenyl (*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-4-oxopentanoate (3j)

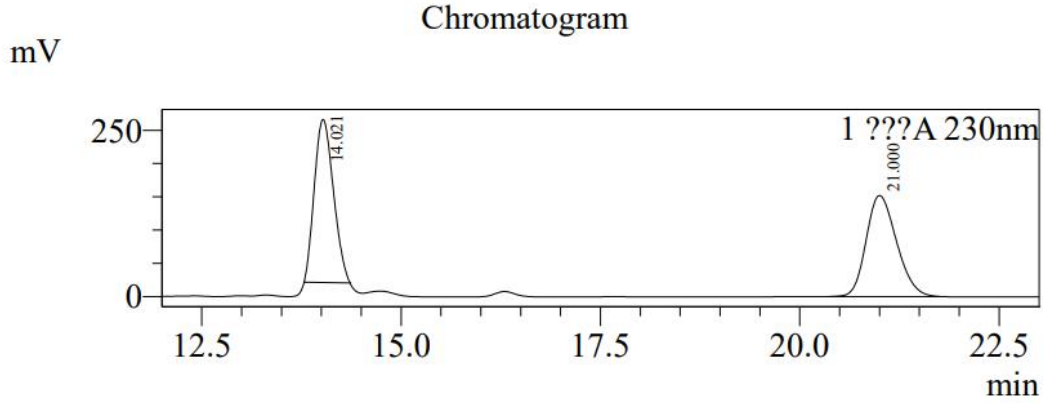


3j

Compound **3j** (18.7 mg, 92% yield) was obtained as a white solid following the *general procedure III* from **1j** (0.05 mmol, 15.4 mg) and **2a** (0.075 mmol, 5.26 mg, 7 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.35 (t, *J* = 7.6 Hz, 2H), 7.20 (t, *J* = 7.6 Hz, 1H), 7.10 (s, 2H), 7.06 (d, *J* = 8.4 Hz, 2H), 6.27 (s, 1H), 5.63 (s, 1H), 5.24 (s, 1H), 4.95 (s, 1H), 2.44 (s, 3H), 1.44 (s, 18H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 199.0, 171.1, 153.4, 151.0, 148.0, 136.3, 129.3, 128.7, 126.0, 125.71, 125.65, 121.5, 52.2, 34.4, 30.3, 25.8; **Mp**: 100-102 ºC; **HRMS** Calcd. for $C_{26}H_{31}O_4^-$ [M-H]$^-$: 407.2228, found: 407.2235.

$[\alpha]^{20}_D$ = -104.7 (c 0.12, CH_2Cl_2) for 91% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 22.126 min, t_{major} = 14.505 min.

<u>Racemic Sample 3j</u>

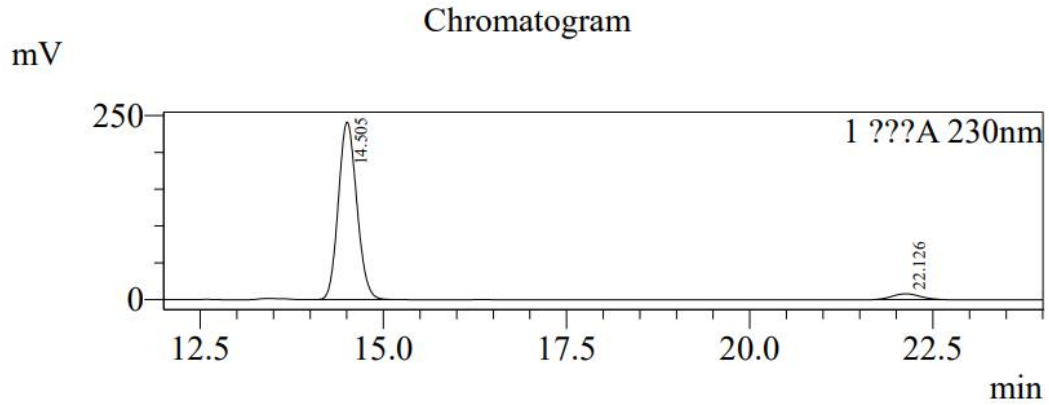


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	14.021	4076636	244908	50.237
2	21.000	4038091	151943	49.763
Total		8114727	396851	100.000

Enantiomeric Sample 3j

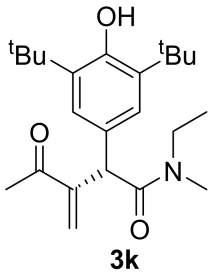


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	14.505	4232976	241099	95.413
2	22.126	203524	7871	4.587
Total		4436500	248969	100.000

(*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-*N*-ethyl-*N*-methyl-3-methylene-4-oxopentanamide (3k)

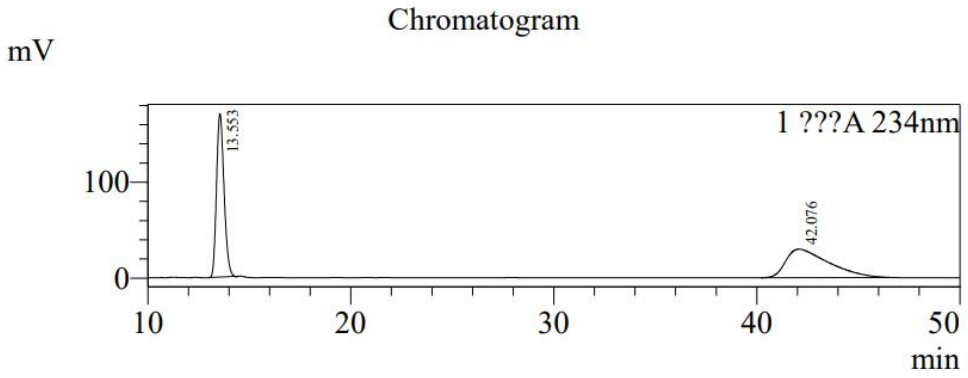


3k

Compound **3k** (21.9 mg, 59% yield) was obtained as a white solid following the *general procedure III* from **1k** (0.05 mmol, 16 mg) and **2a** (0.075 mmol, 5.26 mg, 7 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.96 (d, *J* = 4.8 Hz, 2H), 6.13 (d, *J* = 5.6 Hz, 1H), 5.35 (d, *J* = 32.0 Hz, 1H), 5.16 (s, 1H), 5.02 (d, *J* = 16.8 Hz, 1H), 3.67-3.33 (m, 1H), 3.26-3.11 (m, 1H), 2.88 (d, *J* = 5.2 Hz, 3H), 2.40 (s, 3H), 1.41 (s, 18H), 1.07-0.99 (m, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 200.03, 199.98, 171.3, 171.1, 152.9, 152.8, 150.0, 149.8, 136.2, 127.41, 127.36, 127.3, 126.9, 125.7, 125.6, 53.4, 50.0, 49.6, 44.8, 43.0, 35.2, 34.4, 33.0, 30.3, 26.1, 12.7, 12.0; **Mp**: 151-153 ºC; **HRMS** Calcd. for $C_{23}H_{34}NO_3^-$ [M-H]$^-$: 372.2539, found: 372.2540.

$[\alpha]^{20}_D$ = -105.2 (c 0.13, CH_2Cl_2) for 85% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 234 nm, t_{minor} = 43.920 min, t_{major} = 13.580 min.

Racemic Sample 3k

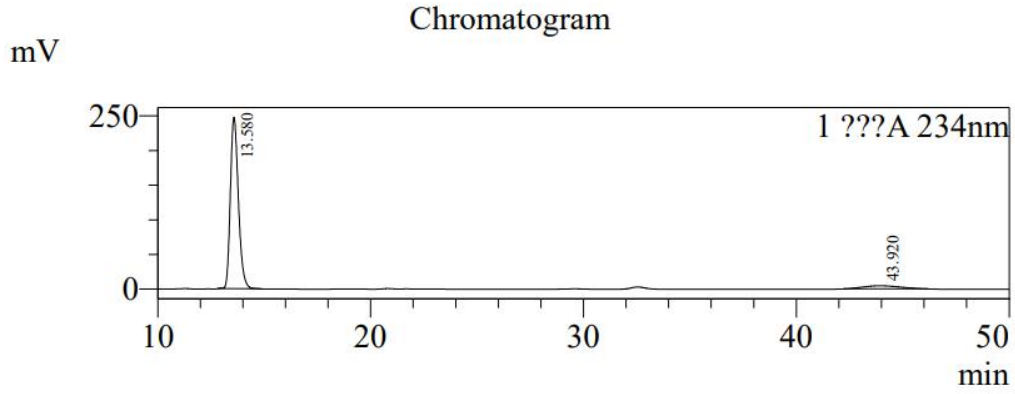


Peak Table

???A 234nm

Peak#	Ret. Time	Area	Height	Area%
1	13.553	4371257	170388	49.985
2	42.076	4373801	29723	50.015
Total		8745058	200111	100.000

Enantiomeric Sample 3k

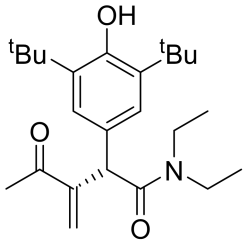


Peak Table

???A 234nm

Peak#	Ret. Time	Area	Height	Area%
1	13.580	6488205	247465	92.260
2	43.920	544355	4511	7.740
Total		7032559	251976	100.000

(*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-*N*,*N*-diethyl-3-methylene-4-oxopentanamide (3l)

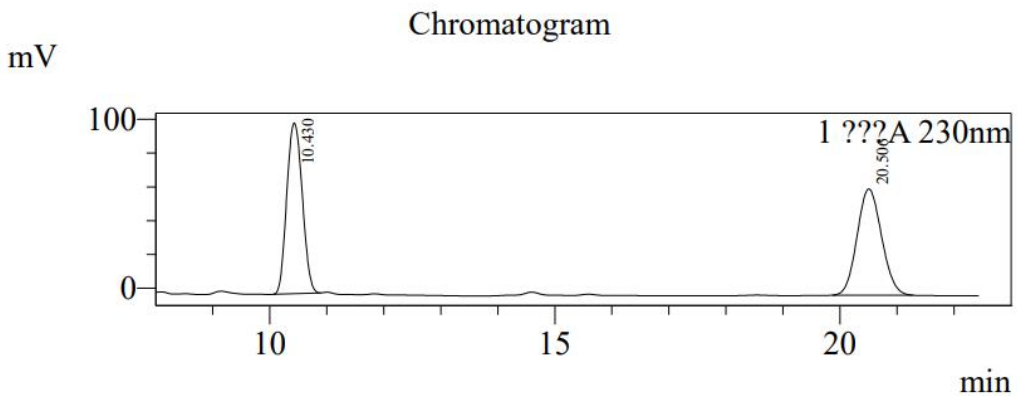


3l

Compound **3l** (27.5mg, 71% yield) was obtained as a yellow solid following the *general procedure III* from **1l** (0.1 mmol, 31.7 mg) and **2a** (0.15 mmol, 10.5 mg, 12.5 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.95 (s, 2H), 6.13 (d, *J* = 0.4 Hz, 1H), 5.31 (d, *J* = 1.6 Hz, 1H), 5.15 (s, 1H), 5.00 (s, 1H), 3.70-3.61 (m, 1H), 3.35-3.26 (m, 1H), 3.15-2.96 (m, 2H), 2.40 (s, 3H), 1.40 (s, 18H), 1.07 (td, *J* = 7.2, 3.6 Hz, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 200.2, 170.8, 152.9, 150.1, 136.3, 127.6, 127.5, 125.7, 49.9, 42.6, 40.6, 34.5, 30.5, 26.2, 13.7, 12.8; **Mp**: 131-133 ºC; **HRMS** Calcd. for $C_{24}H_{36}NO_3^-$ [M-H]$^-$: 386.2695, found: 386.2701.

$[\alpha]^{20}_D$ = -115 .0 (c 0.10, CH_2Cl_2) for 81% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 19.882 min, t_{major} = 10.512 min.

Racemic Sample 3l

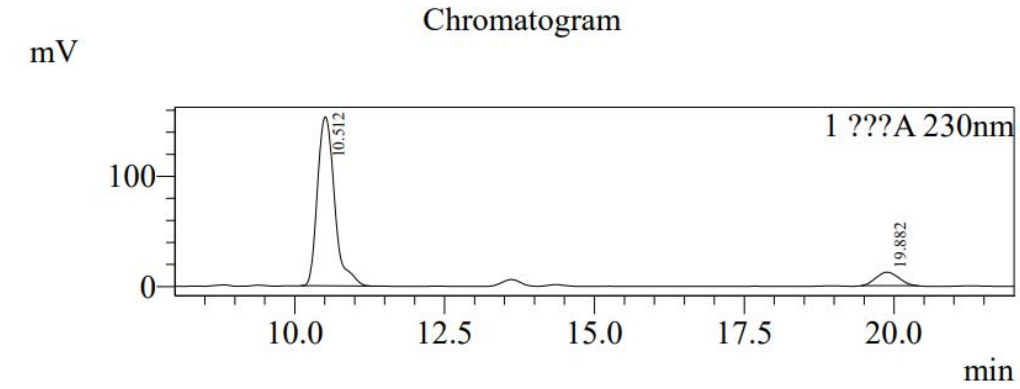


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	10.430	1904710	101003	50.375
2	20.506	1876365	62894	49.625
Total		3781075	163897	100.000

Enantiomeric Sample 3l

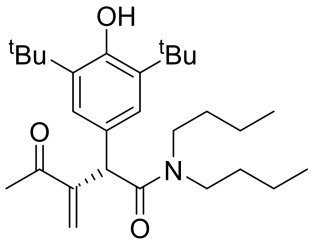


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	10.512	3068306	153352	90.478
2	19.882	322923	12222	9.522
Total		3391230	165574	100.000

(*S*)-*N*,*N*-dibutyl-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-4-oxopentana mide (3m)

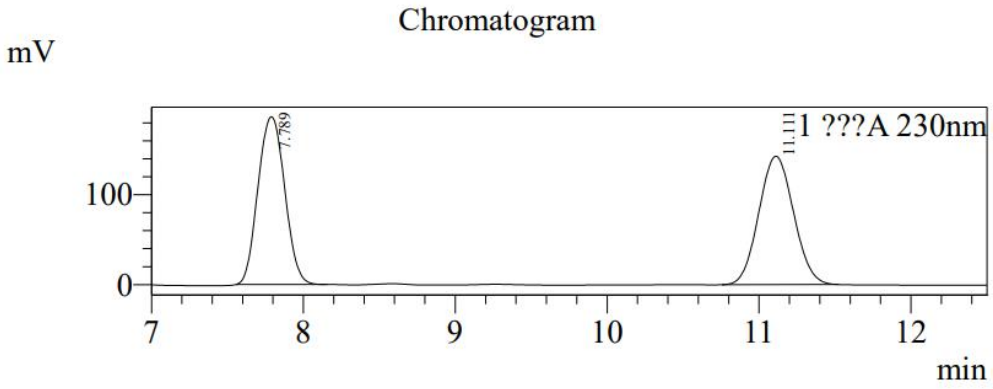


3m

Compound **3m** (43.8 mg, 99% yield) was obtained as a white solid following the *general procedure III* from **1m** (0.1 mmol, 37.3 mg) and **2a** (0.15 mmol, 10.5 mg, 12.5 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.94 (s, 2H), 6.11 (s, 1H), 5.28 (s, 1H), 5.15 (s, 1H), 4.98 (s, 1H), 3.64-3.57 (m, 1H), 3.25-3.17 (m, 1H), 3.02-2.90 (m, 2H), 2.40 (s, 3H), 1.64-1.58 (m, 1H), 1.56-1.49 (m, 2H), 1.40 (s, 18H), 1.29-1.14 (m, 5H), 0.89-0.83 (m, 6H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 200.1, 171.1, 152.8, 150.1, 136.2, 127.6, 127.1, 125.7, 50.3, 48.0, 45.8, 34.3, 30.3, 29.7, 26.1, 20.1, 13.9, 13.8; **Mp**: 114-116 ºC; **HRMS** Calcd. for $C_{28}H_{44}NO_3^-$ $[M-H]^-$: 442.3321, found: 442.3333.

$[\alpha]^{20}_D$ = -60.5 (c 0.16, CH_2Cl_2) for 55% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 11.064 min, t_{major} = 7.608 min.

Racemic Sample 3m

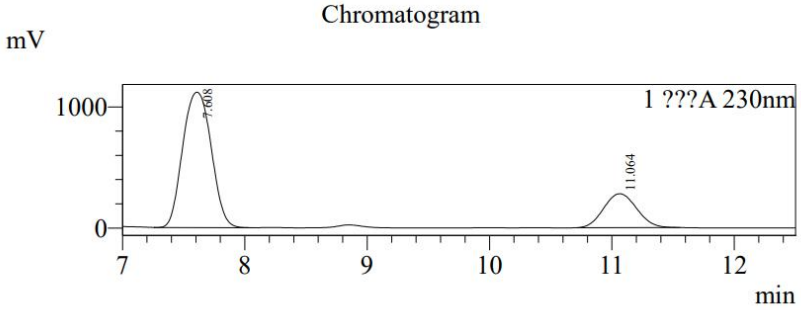


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	7.789	2282418	186649	50.050
2	11.111	2277868	142787	49.950
Total		4560287	329436	100.000

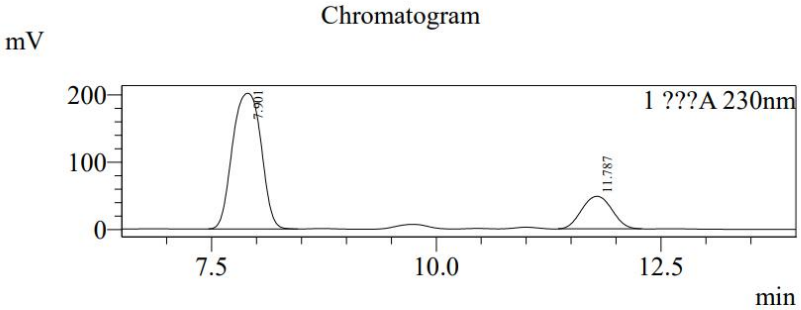
Enantiomeric Sample 3m



Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	7.608	18139881	1118302	77.543
2	11.064	5253294	280344	22.457
Total		23393175	1398646	100.000

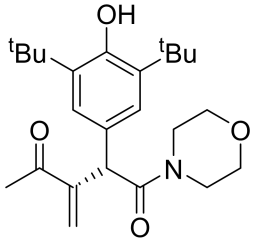


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	7.901	4481932	201502	79.798
2	11.787	1134682	48334	20.202
Total		5616614	249837	100.000

(*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-1-morpholinopentane-1,4-dione (3n)

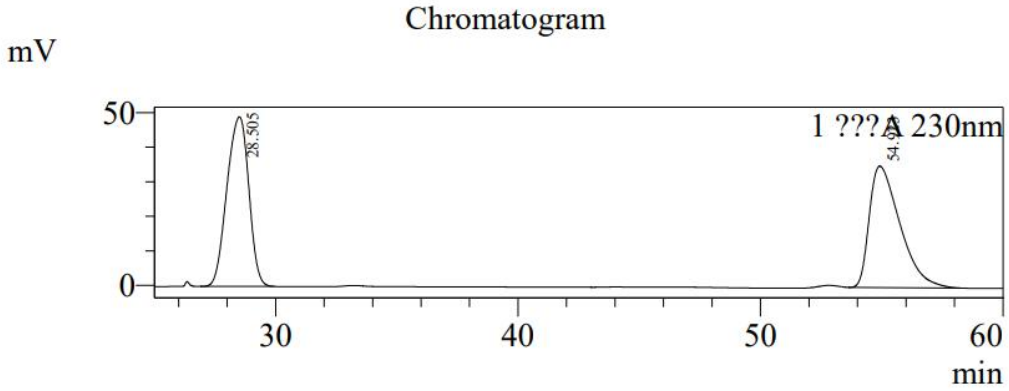


3n

Compound **3n** (21.9 mg, 99% yield) was obtained as a white solid following the *general procedure III* from **1n** (0.05 mmol, 16.6 mg) and **2a** (0.075 mmol, 5.3 mg, 7 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.93 (s, 2H), 6.17 (s, 1H), 5.35 (s, 1H), 5.20 (s, 1H), 5.01 (s, 1H), 3.83-3.66 (m, 2H), 3.56-3.33 (m, 5H), 3.03 (t, *J* = 8.4 Hz, 1H), 2.42 (s, 3H), 1.41 (s, 18H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 199.9, 170.3, 153.0, 149.4, 136.5, 127.6, 126.8, 125.6, 66.8, 66.2, 49.6, 46.6, 42.5, 34.4, 30.3, 26.0;

Mp: 141-143 ºC; **HRMS** Calcd. for $C_{24}H_{34}NO_4^-$ [M-H]$^-$: 400.2488, found: 400.2498. $[\alpha]^{20}_D$ = -84.4 (c 0.16, CH_2Cl_2) for 81% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, tminor = 54.764 min, tmajor = 28.587 min.

Racemic Sample 3n

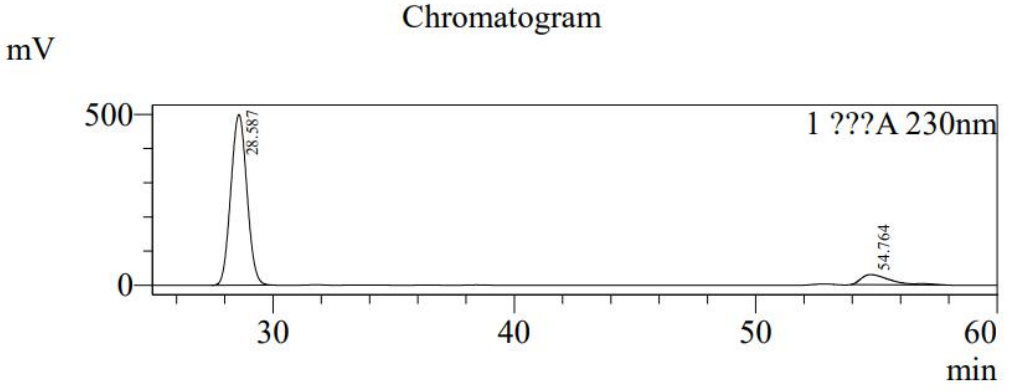


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	28.505	3077414	49045	49.906
2	54.923	3089056	35146	50.094
Total		6166470	84190	100.000

Enantiomeric Sample 3n

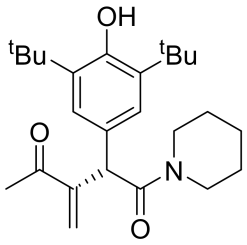


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	28.587	23153758	498985	90.332
2	54.764	2477982	29268	9.668
Total		25631740	528254	100.000

(*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-1-(piperidin-1-yl)pentane-1,4-dione (3o)

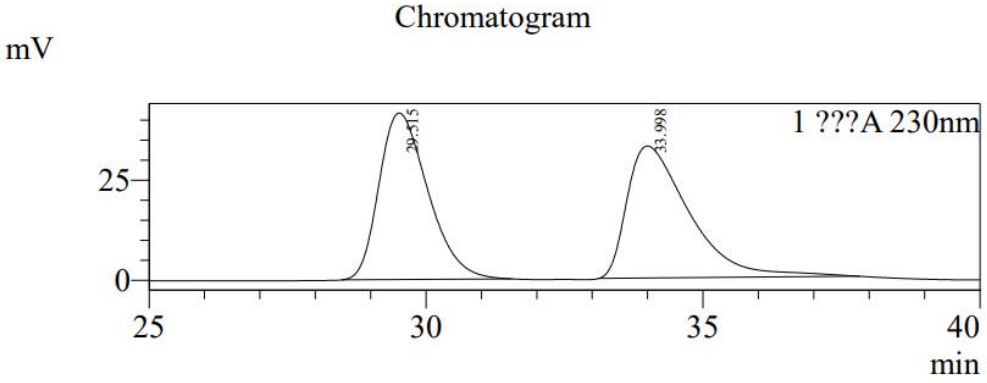


3o

Compound **3o** (20.1 mg, 99% yield) was obtained as a white solid following the *general procedure III* from **1o** (0.05 mmol, 16.45 mg) and **2a** (0.075 mmol, 5.26 mg, 7 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.94 (s, 2H), 6.12 (s, 1H), 5.33 (s, 1H), 5.16 (s, 1H), 5.06 (s, 1H), 3.84 (d, *J* = 13.2 Hz, 1H), 3.40 (d, *J* = 13.2 Hz, 1H), 3.27-3.19 (m, 2H), 2.42 (s, 3H), 1.56-1.49 (m, 4H), 1.40 (s, 18H), 1.38-1.35 (m, 2H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 200.1, 169.8, 152.8, 149.9, 136.2, 127.4, 126.9, 125.7, 50.0, 47.2, 43.3, 34.4, 30.3, 26.1, 25.6, 25.3, 24.5; **Mp**: 147-149 ºC; **HRMS** Calcd. for $C_{25}H_{36}NO_3^-$ [M-H]$^-$: 398.2695, found: 398.2705.

$[\alpha]^{20}_D$ = -31.3 (c 0.48, CH_2Cl_2) for 75% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 99/1, 0.5 mL/min, 230nm, t_{minor} = 31.083 min, t_{major} = 35.919 min.

Racemic Sample 3o

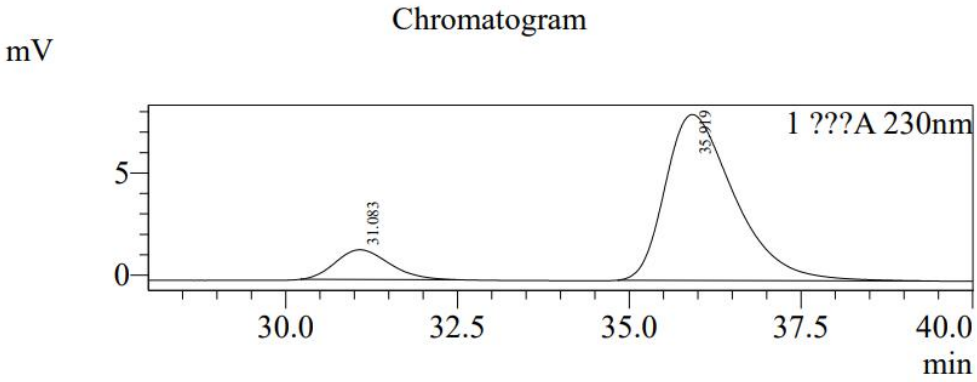


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	29.515	2549499	41576	49.689
2	33.998	2581397	32972	50.311
Total		5130896	74548	100.000

Enantiomeric Sample 3o

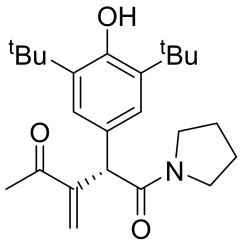


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	31.083	79590	1453	12.284
2	35.919	568346	8114	87.716
Total		647936	9567	100.000

(*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-1-(pyrrolidin-1-yl)pentane -1,4-dione (3p)

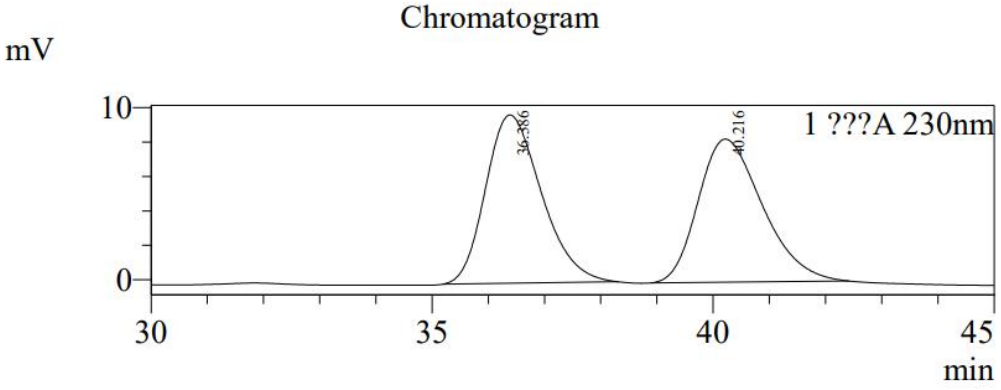


3p

Compound **3p** (10.2 mg, 53% yield) was obtained as a white solid following the *general procedure III* from **1p** (0.05 mmol, 16.5 mg) and **2a** (0.075 mmol, 5.3 mg, 7 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.03 (s, 2H), 6.17 (s, 1H), 5.48 (s, 1H), 5.16 (s, 1H), 4.90 (s, 1H), 3.69-3.62 (m, 1H), 3.57-3.50 (m, 1H), 3.39-3.33 (m, 1H), 3.26-3.20 (m, 1H), 2.40 (s, 3H), 1.97-1.92 (m, 1H), 1.86-1.74 (m, 3H), 1.42 (s, 18H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 199.9, 170.1, 152.9, 149.4, 136.0, 127.8, 127.0, 125.8, 50.9, 46.5, 46.0, 34.3, 30.3, 26.1, 24.3; **Mp**: 155-157 ºC; **HRMS** Calcd. for $C_{24}H_{34}NO_3^-$ [M-H]$^-$: 384.2544, found: 384.2550.

$[\alpha]^{20}_D$ = -73.3 (c 0.09, CH_2Cl_2) for 73% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 99/1, 0.5 mL/min, 230nm, t_{minor} = 37.907 min, t_{major} = 41.120 min.

Racemic Sample 3p

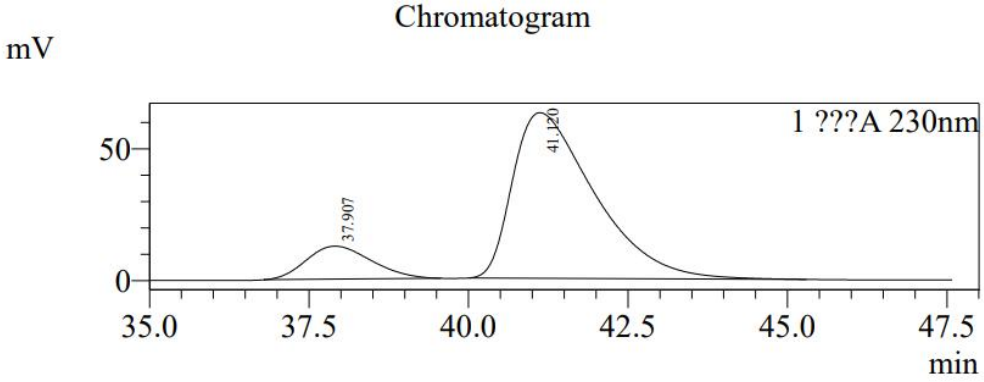


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	36.386	674123	9765	50.549
2	40.216	659480	8305	49.451
Total		1333603	18070	100.000

Enantiomeric Sample 3p

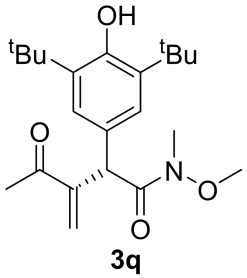


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	37.907	890358	12553	13.700
2	41.120	5608502	62908	86.300
Total		6498860	75461	100.000

(*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-*N*-methoxy-*N*-methyl-3-methylene-4-oxopentanamide (3q)



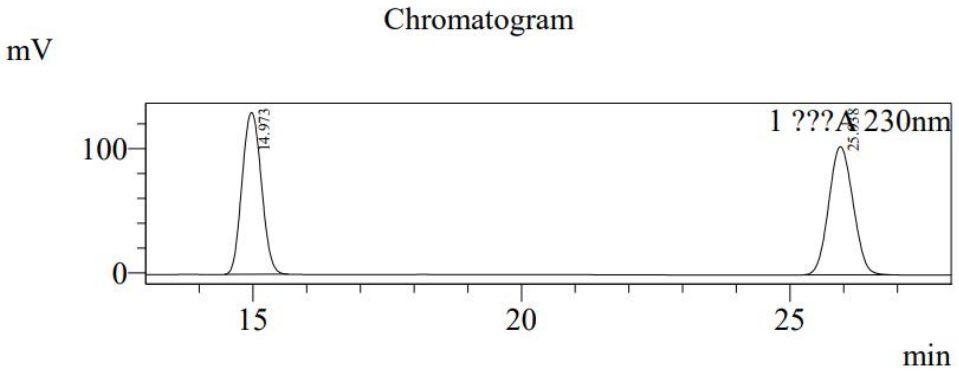
3q

Compound **3q** (21.3 mg, 99% yield) was obtained as a white solid following the *general procedure III* from **1q** (0.05 mmol, 15.3 mg) and **2a** (0.075 mmol, 5.3 mg, 7

μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.01 (s, 2H), 6.21 (s, 1H), 5.52 (s, 1H), 5.25 (s, 1H), 5.15 (s, 1H), 3.56 (s, 3H), 3.17 (s, 3H), 2.40 (s, 3H), 1.41 (s, 18H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 199.5, 173.1, 152.9, 148.9, 136.0, 128.3, 126.9, 125.8, 60.9, 48.4, 34.3, 30.3, 26.0; **Mp**: 121-123 ºC; **HRMS** Calcd. for $C_{22}H_{32}NO_4^-$ [M-H]$^-$: 374.2337, found: 374.2342.

$[\alpha]^{20}_D$ = -108.8 (c 0.16, CH_2Cl_2) for 91% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 25.825 min, t_{major} = 14.922 min.

Racemic Sample 3q

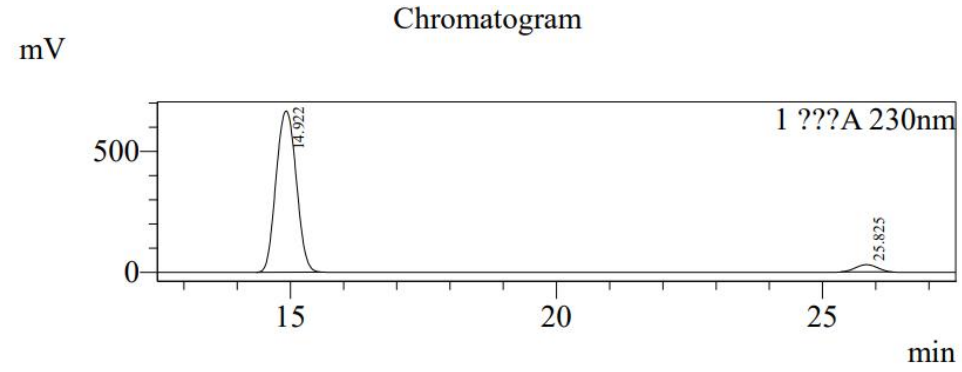


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	14.973	3256441	130244	50.150
2	25.938	3236959	103058	49.850
Total		6493400	233302	100.000

Enantiomeric Sample 3q

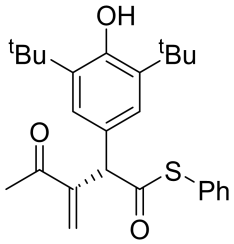


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	14.922	17579680	666610	95.367
2	25.825	854037	30085	4.633
Total		18433717	696695	100.000

***S*-phenyl**
(*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-4-oxopentanethioate (3r)

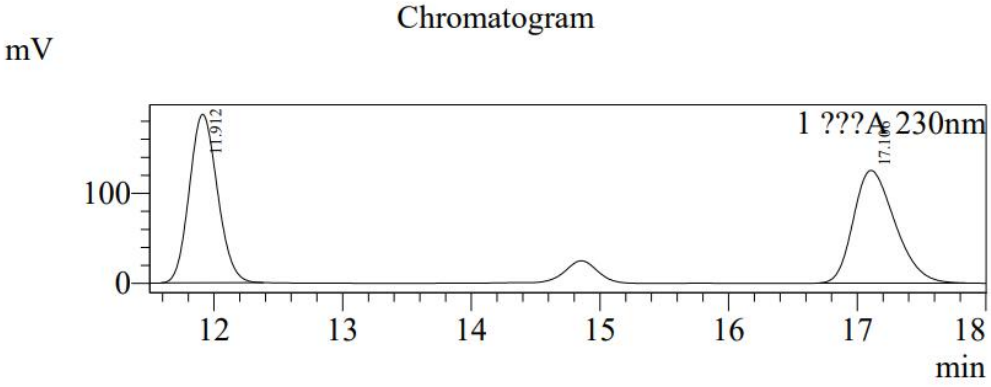


3r

Compound **3r** (8.4 mg, 47% yield) was obtained as a yellow viscous liquid following the *general procedure III* from **1r** (0.042 mmol, 14.75 mg) and **2a** (0.063 mmol, 4.4 mg, 5.3 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.38 (s, 5H), 7.01 (s, 2H), 6.26 (s, 1H), 5.75 (d, *J* = 1.2 Hz, 1H), 5.22 (s, 1H), 5.19 (s, 1H), 2.39 (s, 3H), 1.42 (s, 18H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.4, 197.0, 153.4, 147.5, 136.1, 134.6, 129.3, 129.1, 128.8, 128.2, 126.0, 125.9, 58.6, 34.4, 30.3, 25.9; **HRMS** Calcd. for $C_{26}H_{31}O_3S^-$ $[M-H]^-$: 423.1999, found: 423.2009.

$[\alpha]^{20}_D$ = -68.1 (c 0.12, CH_2Cl_2) for 82% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230 nm, t_{minor} = 16.993 min, t_{major} = 11.776 min.

Racemic Sample 3r

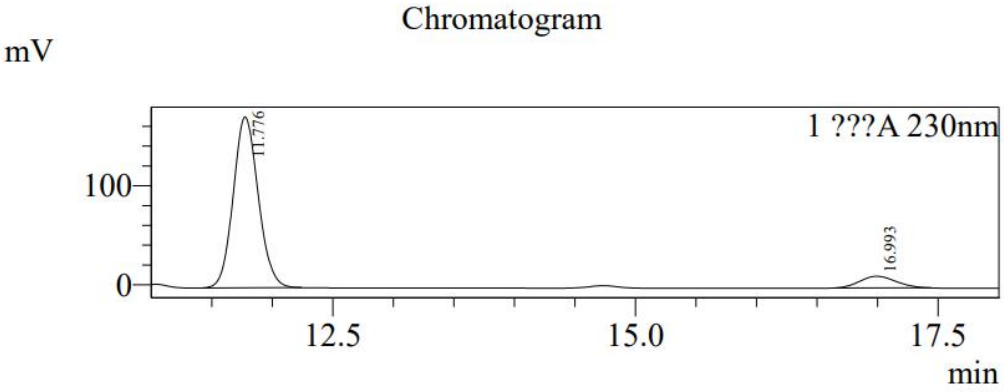


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	11.912	2841123	187004	50.257
2	17.106	2812060	125068	49.743
Total		5653184	312072	100.000

Enantiomeric Sample 3r

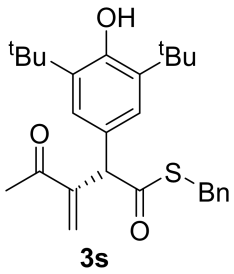


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	11.776	2479919	172628	91.067
2	16.993	243273	11767	8.933
Total		2723192	184395	100.000

_S_-benzyl
(_S_)-2-(3,5-di-_tert_-butyl-4-hydroxyphenyl)-3-methylene-4-oxopentanethioate (3s)



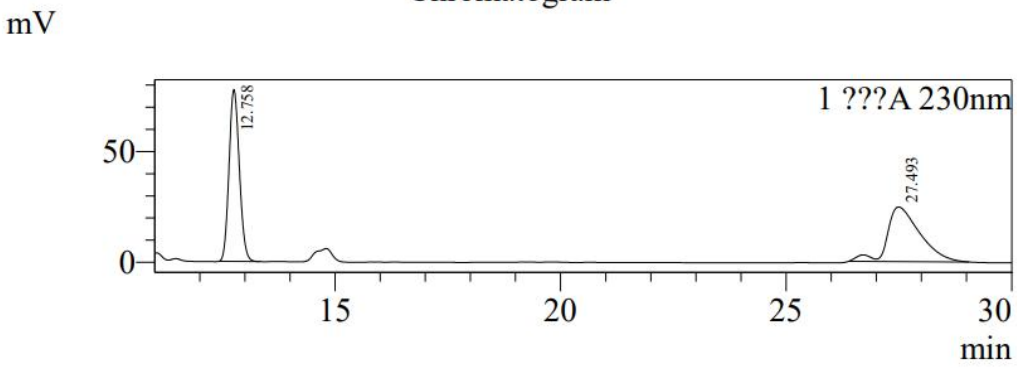
3s

Compound **3s** (10.5 mg, 32% yield) was obtained as a yellow viscous liquid following the *general procedure III* from **1u** (0.076 mmol, 27.8 mg) and **2a** (0.09 mmol, 6.3 mg, 7.5 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.25-7.20 (m, 5H), 6.96 (s, 2H), 6.27 (s, 1H), 5.71 (d, *J* = 1.2 Hz, 1H), 5.18 (s, 1H), 5.10 (s, 1H), 4.17 (d, *J* = 14.0 Hz, 1H), 4.05 (d, *J* = 14.0 Hz, 1H), 2.40 (s, 3H), 1.38 (s, 18H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.4, 198.0, 153.3, 147.5, 137.6, 136.0, 129.0, 128.8, 128.5, 127.1, 126.3, 125.7, 58.9, 34.3, 33.5, 30.2, 25.9; **HRMS** Calcd. for $C_{27}H_{33}O_3S^-$ [M-H]$^-$: 437.2156, found: 437.2162.

$[\alpha]^{20}_D$ = -13.1 (c 0.54, CH_2Cl_2) for 84% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 27.489 min, t_{major} = 12.685 min.

Racemic Sample 3s

Chromatogram



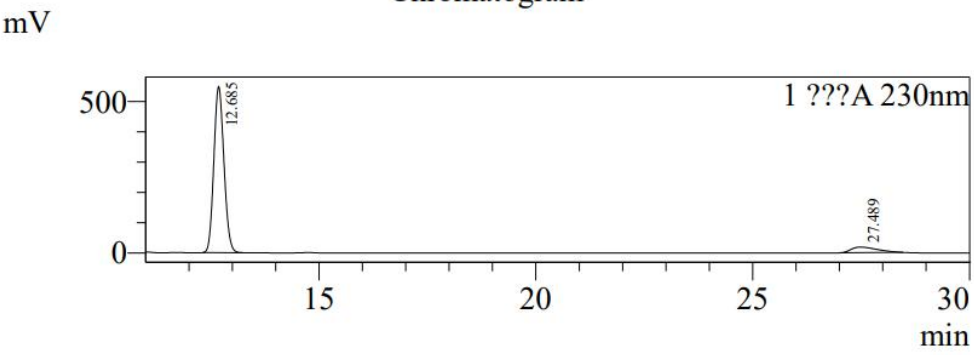
Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	12.758	1240664	77635	50.043
2	27.493	1238531	24625	49.957
Total		2479195	102259	100.000

Enantiomeric Sample 3s

Chromatogram

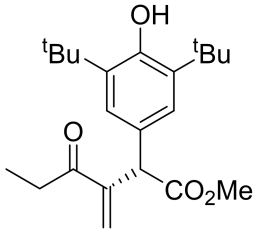


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	12.685	8899540	548362	92.012
2	27.489	772576	18531	7.988
Total		9672116	566893	100.000

Methyl (*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-4-oxohexanoate (3t)



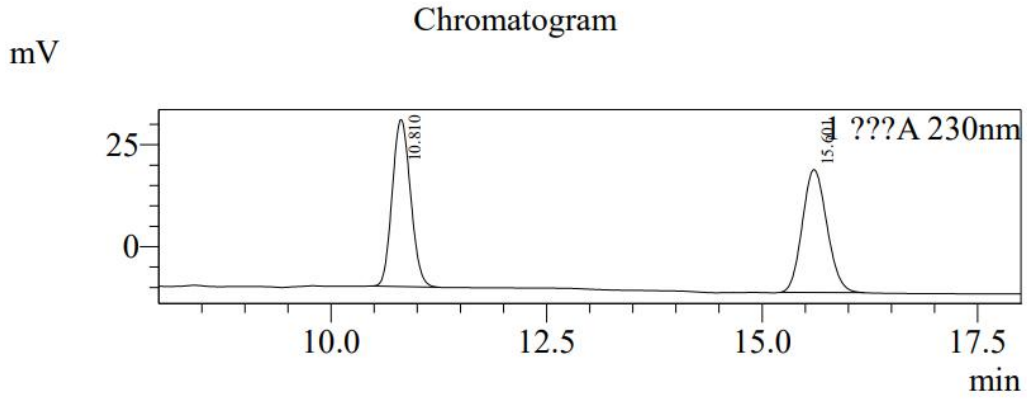
3t

Compound **3t** (28.9 mg, 94% yield) was obtained as a white solid following the

general procedure III from **1a** (0.1 mmol, 27.6 mg) and **2b** (0.15 mmol, 12.6 mg, 14.8 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.99 (s, 2H), 6.21 (s, 1H), 5.51 (d, *J* = 1.2 Hz, 1H), 4.78 (s, 1H), 3.69 (s, 3H), 2.78 (q, *J* = 7.2 Hz, 2H), 1.41 (s, 18H), 1.12 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 201.6, 173.1, 153.2, 147.6, 136.1, 126.9, 126.5, 125.6, 52.2, 52.0, 34.3, 30.8, 30.2, 8.2; **Mp**: 92-94 ºC; **HRMS** Calcd. for $C_{22}H_{33}O_4^+$ $[M+H]^+$: 361.2373, found: 361.2379.

$[\alpha]^{20}_D$ = -125.2 (c 0.14, CH_2Cl_2) for 90% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, tminor = 10.759 min, tmajor = 15.462 min.

Racemic Sample 3t

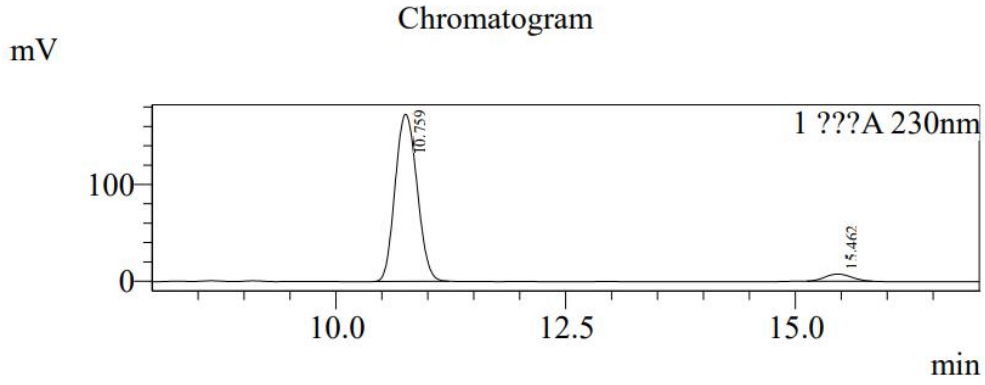


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	10.810	606309	40986	50.317
2	15.601	598659	30130	49.683
Total		1204968	71116	100.000

Enantiomeric Sample 3t

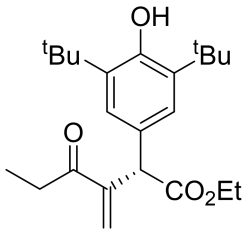


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	10.759	2869975	172716	95.187
2	15.462	145129	7302	4.813
Total		3015104	180018	100.000

Ethyl (*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-4-oxohexanoate (3u)

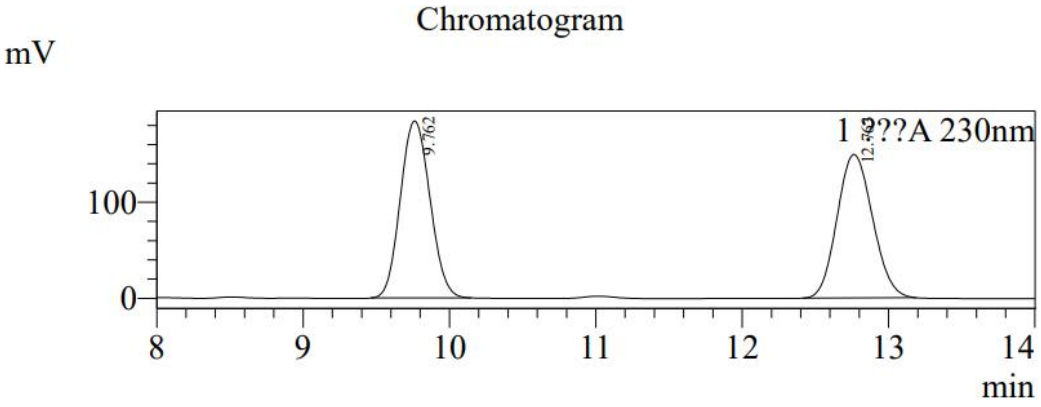


3u

Compound **3u** (30.7 mg, 82% yield) was obtained as a white solid following the *general procedure III* from **1b** (0.1 mmol, 30.6 mg) and **2b** (0.15 mmol, 12.6 mg, 15 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.98 (s, 2H), 6.20 (s, 1H), 5.49 (d, *J* = 1.6 Hz, 1H), 5.18 (s, 1H), 4.76 (s, 1H), 4.22-4.08 (m, 2H), 2.78 (q, *J* = 7.2 Hz, 2H), 1.41 (s, 18H), 1.23 (t, *J* = 7.2 Hz, 3H), 1.12 (t, *J* = 7.2 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 201.6, 172.5, 153.1, 147.8, 136.0, 126.9, 126.6, 125.5, 61.0, 52.2, 34.3, 30.8, 30.2, 14.1, 8.3; **Mp**: 65-67 ºC; **HRMS** Calcd. for $C_{22}H_{33}O_4^-$ $[M-H]^-$: 373.2384, found: 373.2390.

$[\alpha]^{20}_D$ = -92.4 (c 0.15, CH_2Cl_2) for 91% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 12.749 min, t_{major} = 9.759 min.

Racemic Sample 3u

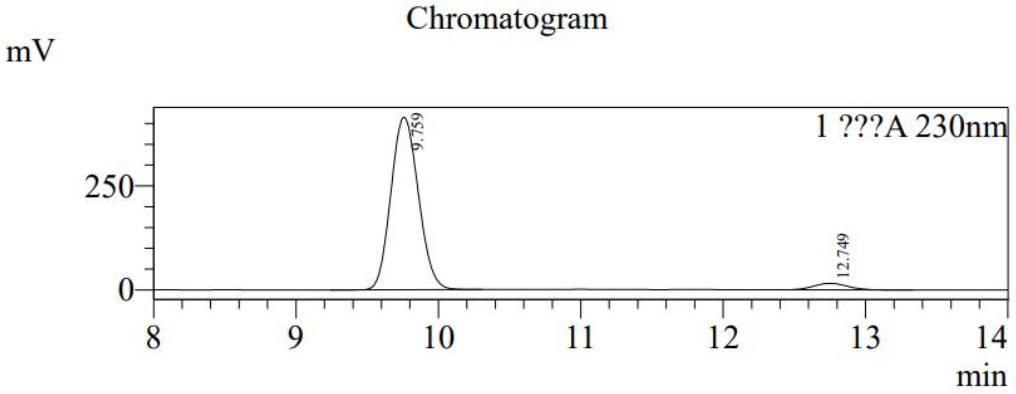


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	9.762	2598217	184158	50.805
2	12.763	2515854	149360	49.195
Total		5114070	333518	100.000

Enantiomeric Sample 3u

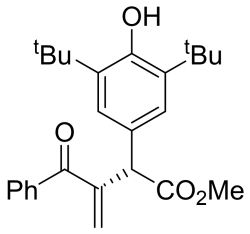


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	9.759	5564462	414562	95.581
2	12.749	257267	15607	4.419
Total		5821730	430169	100.000

Methyl (*S*)-3-benzoyl-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)but-3-enoate (3v)



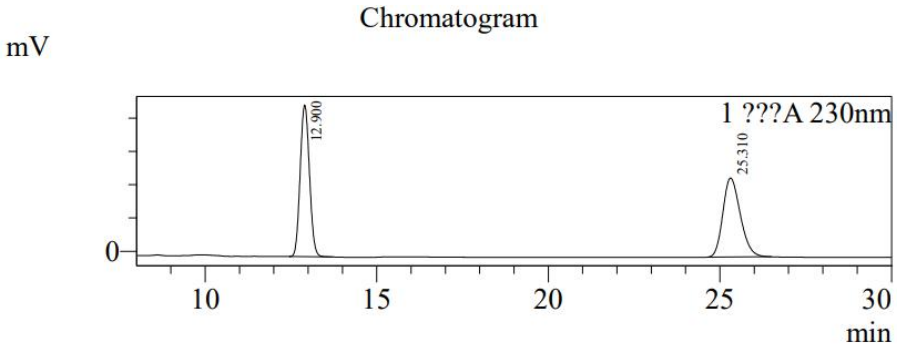
3v

Compound **3v** (36.2 mg, 89% yield) was obtained as a white solid following the

general procedure III from **1a** (0.1 mmol, 27.6 mg) and **2c** (0.15 mmol, 19.8 mg, 19 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.82 (d, *J* = 7.6 Hz, 2H), 7.54 (t, *J* = 7.6 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 2H), 7.09 (s, 2H), 5.80 (s, 1H), 5.58 (s, 1H), 5.22 (s, 1H), 5.06 (s, 1H), 3.69 (s, 3H), 1.44 (s, 18H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 197.6, 173.0, 153.3, 147.3, 137.5, 136.2, 132.3, 129.7, 128.5, 128.1, 126.3, 125.7, 53.0, 52.3, 34.3, 30.3; **Mp**: 136-138 ºC; **HRMS** Calcd. for $C_{26}H_{33}O_4^+$ $[M+H]^+$: 409.2373, found: 409.2378.

$[\alpha]^{20}_D$ = -12.8 (c 0.13, CH_2Cl_2) for 20% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 25.423 min, t_{major} = 12.923 min.

Racemic Sample 3v

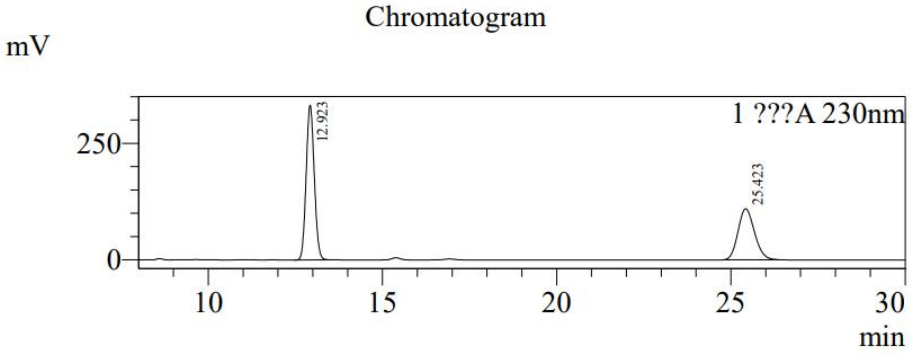


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	12.900	4278375	227685	50.517
2	25.310	4190744	118559	49.483
Total		8469119	346244	100.000

Enantiomeric Sample 3v

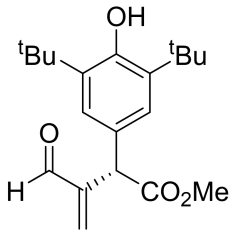


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	12.923	5368095	331709	59.852
2	25.423	3600819	109540	40.148
Total		8968914	441248	100.000

Methyl (*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-formylbut-3-enoate (3w)



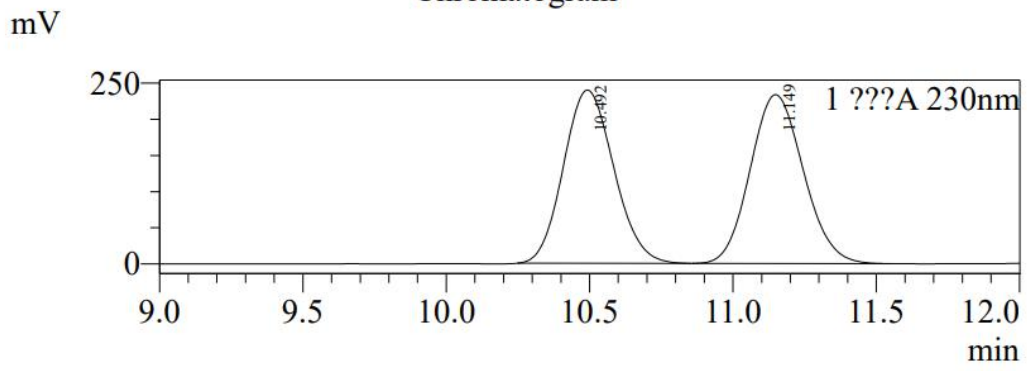
3w

Compound **3w** (16 mg, 96% yield) was obtained as a white solid following the *general procedure III* from **1a** (0.05 mmol, 13.8 mg) and acrolein **2d** (0.075 mmol, 4.2 mg, 5 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 9.60 (s, 1H), 7.03 (s, 2H), 6.20 (d, *J* = 9.6 Hz, 2H), 5.20 (s, 1H), 4.70 (s, 1H), 3.71 (s, 3H), 1.42 (s, 18H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 193.2, 172.2, 153.3, 148.7, 136.6, 136.2, 125.8, 125.3, 52.4, 49.6, 34.4, 30.2; **Mp**: 131-134 ºC; **HRMS** Calcd. for $C_{20}H_{29}O_4^+$ $[M+H]^+$: 333.2066, found: 333.2065.

$[\alpha]^{20}_D$ = -74.1 (c 0.32, CH_2Cl_2) for 86% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 11.231 min, t_{major} = 10.565 min.

Racemic Sample 3w

Chromatogram



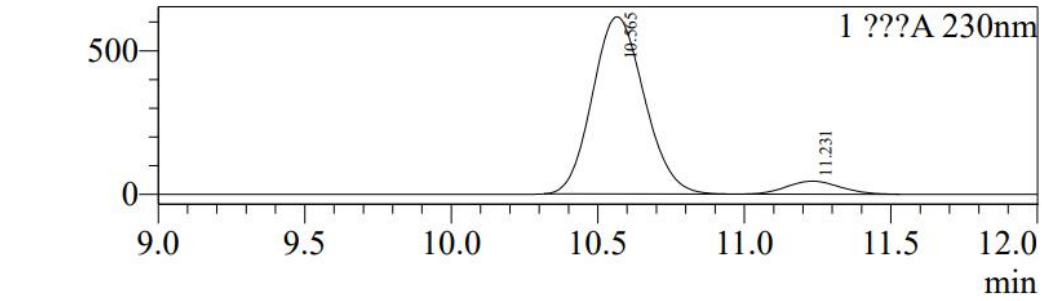
Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	10.492	2930001	239888	49.275
2	11.149	3016259	233636	50.725
Total		5946260	473524	100.000

Enantiomeric Sample 3w

Chromatogram

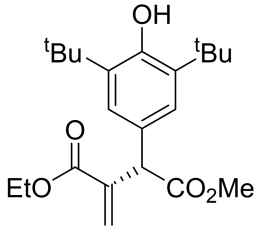


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	10.565	7601215	617370	92.971
2	11.231	574657	45186	7.029
Total		8175872	662556	100.000

4-ethyl-1-methyl (*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylenesuccinate (3x).

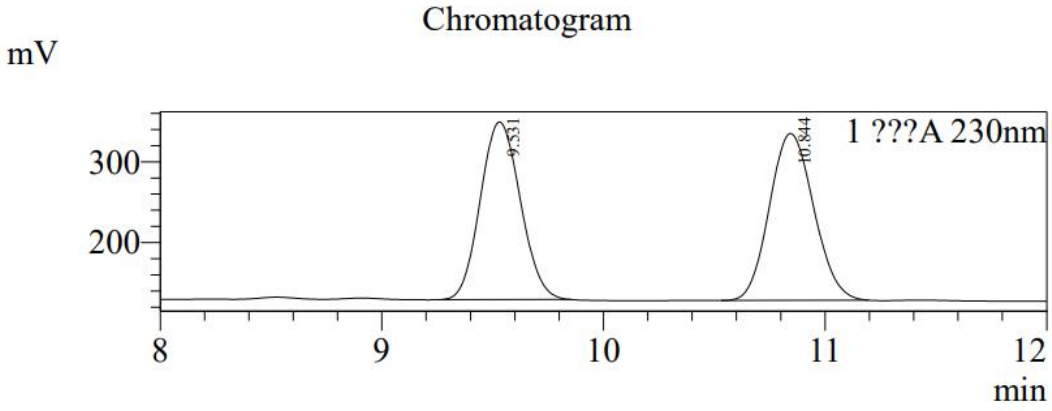


3x

Compound **3x** (21.4 mg, 55% yield) was obtained as a white solid following the *general procedure III* from **1a** (0.1 mmol, 27.6 mg) and ethyl acrylate **2e** (0.15 mmol, 15 mg, 16 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ (s, 2H), 6.38 (s, 1H), 5.35 (s, 1H), 5.20 (s, 1H), 4.72 (s, 1H), 4.28-4.19 (m, 2H), 3.71 (d, *J* = 1.2 Hz, 3H), 1.42 (d, *J* = 1.2 Hz, 18H), 1.30 (td, *J* = 7.2, 1.2 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 172.8, 166.5, 153.3, 139.8, 136.1, 127.8, 126.1, 125.6, 61.0, 53.0, 52.3, 34.3, 30.2, 14.1; **Mp**: 104-106 ºC; **HRMS** Calcd. for $C_{22}H_{33}O_5^+$ $[M+H]^+$: 377.2323, found: 377.2328.

$[\alpha]^{20}_D$ = -3.0 (c 0.10, CH_2Cl_2) for 86% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 10.840 min, t_{major} = 9.518 min.

Racemic Sample 3x



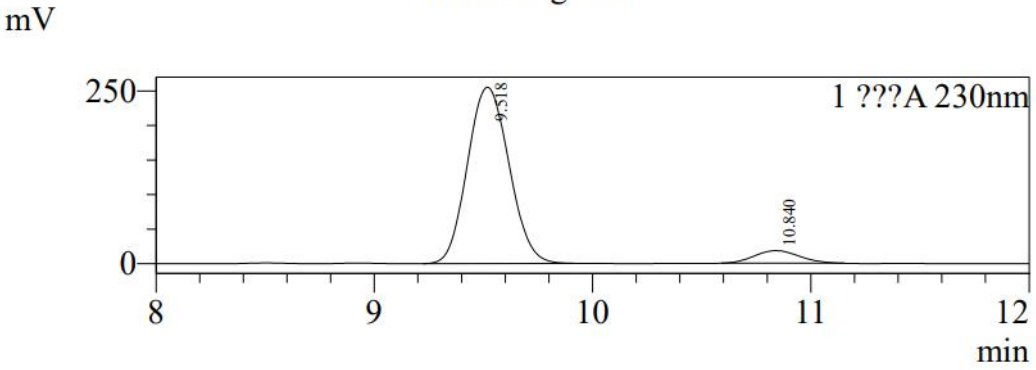
Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	9.531	2766647	220079	49.075
2	10.844	2870933	206730	50.925
Total		5637580	426809	100.000

Enantiomeric Sample 3x

Chromatogram

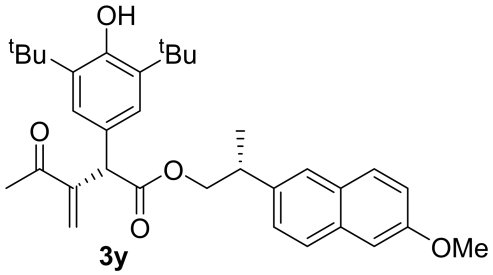


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	9.518	3388542	255515	92.855
2	10.840	260748	18165	7.145
Total		3649290	273680	100.000

(*R*)-2-(6-methoxynaphthalen-2-yl)propyl
(*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-4-oxopentanoate (3y)

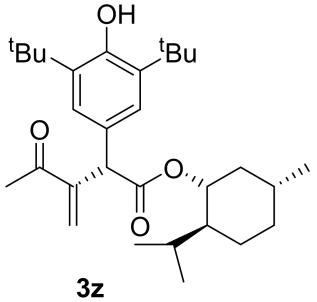


3y

Compound **3y** (44.7 mg, 84% yield, >20:1 dr) was obtained as a white solid following the *general procedure III* from **1t** (0.1 mmol, 46 mg) and **2a** (0.15 mmol, 10.5 mg, 12.5 µL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.67 (d, *J* = 2.0 Hz, 1H), 7.65 (s, 1H), 7.56 (s, 1H), 7.29 (dd, *J* = 8.8, 2.0 Hz, 1H), 7.14-7.09 (m, 2H), 7.00 (s, 2H), 6.17 (d, *J* = 1.2 Hz, 1H), 5.58 (d, *J* = 1.6 Hz, 1H), 5.19 (s, 1H), 4.77 (s, 1H), 4.32-4.18 (m, 2H), 3.91 (s, 3H), 3.21 (h, *J* = 6.8 Hz, 1H), 2.31 (s, 3H), 1.41 (s, 18H), 1.31-1.29 (m, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.9, 172.4, 157.3, 153.1, 147.9, 138.2, 136.0, 133.4, 129.1, 128.9, 128.1, 126.8, 126.5, 126.4, 125.6, 125.5, 118.7, 105.4, 69.9, 55.3, 52.0, 38.7, 34.3, 30.2, 25.8, 17.9; **Mp**: 126-128 ºC. **HRMS** Calcd. for $C_{34}H_{41}O_5^-$ [M-H]$^-$: 529.2960, found: 529.2969; $[\alpha]^{20}_D$ = -95.1 (c 0.20, CH_2Cl_2).

(1*R*,2*S*,5*R*)-2-isopropyl-5-methylcyclohexyl

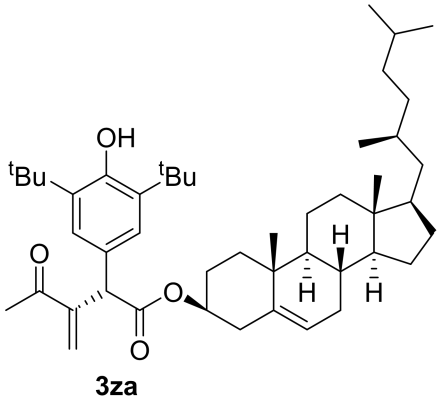
(*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-4-oxopentanoate (3z)



3z

Compound **3z** (16 mg, 68% yield, >20:1 dr) was obtained as a white solid following the *general procedure III* from **1r** (0.05 mmol, 20 mg) and **2a** (0.075 mmol, 5.26 mg, 12.5 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.98 (s, 2H), 6.21 (s, 1H), 5.62 (s, 1H), 5.15 (s, 1H), 4.67 (s, 1H), 4.61-4.55 (m, 1H), 2.39 (s, 3H), 2.06 (d, *J* = 12.0 Hz, 1H), 1.65-1.59 (m, 3H), 1.40 (s, 18H), 1.32-1.25 (m, 3H), 1.08-0.96 (m, 2H), 0.89 (d, *J* = 6.4 Hz, 3H), 0.66 (d, *J* = 6.8 Hz, 3H), 0.49 (d, *J* = 6.8 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 199.1, 172.1, 153.1, 148.0, 136.0, 128.0, 126.6, 125.7, 74.6, 52.5, 46.9, 40.8, 34.3, 31.4, 30.3, 25.9, 23.5, 22.0, 20.4, 16.2; **Mp**: 100-102 ºC; **HRMS** Calcd. for $C_{30}H_{45}O_4^-$ [M-H]$^-$: 469.3323, found: 469.3330; $[\alpha]^{20}_D$ = -126.4 (c 0.13, CH_2Cl_2).

(3*R*,8*S*,9*S*,10*R*,13*R*,14*S*,17*R*)-17-((*S*)-2,5-dimethylhexyl)-10,13-dimethyl-2,3,4,7,8,9,10,11,12,13,14,15,16,17-tetradecahydro-1*H*-cyclopenta[a]phenanthren-3-yl (*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-4-oxopentanoate (3za)

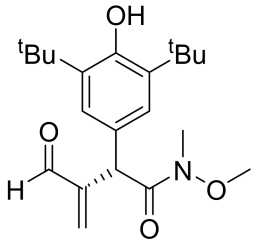


3za

Compound **3za** (60.5 mg, 85% yield, >20:1 dr) was obtained as a white solid following the *general procedure III* from **1s** (0.1 mmol, 63.07 mg) and **2a** (0.15 mmol, 10.5 mg, 12.5 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.98 (s, 2H), 6.18 (s, 1H), 5.52 (s, 1H), 5.36 (d, *J* = 4.4 Hz, 1H), 5.16 (s, 1H), 4.73 (s, 1H),

4.72-4.61 (m, 1H), 2.39 (s, 3H), 2.36-2.31 (m, 2H), 2.01-1.93 (m, 2H), 1.87-1.77 (m, 3H), 1.53-1.45 (m, 8H), 1.41 (s, 18H), 1.33-1.32 (m, 3H), 1.17-1.05 (m, 7H), 1.03-0.99 (m, 5H), 0.91 (d, J = 6.4 Hz, 4H), 0.86 (d, J = 6.4 Hz, 6H), 0.66 (s, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 198.9, 171.7, 153.0, 148.5, 139.6, 136.0, 127.8, 126.8, 125.5, 122.6, 74.5, 56.6, 56.1, 52.2, 50.0, 42.3, 39.7, 39.5, 37.9, 36.9, 36.5, 36.1, 35.8, 34.3, 31.9, 30.3, 28.2, 28.0, 27.4, 25.9, 24.2, 23.8, 22.8, 22.5, 21.0, 19.3, 18.7, 11.8; **Mp**: 191-193 ºC; **HRMS** Calcd. for $C_{47}H_{71}O_4^-$ [M-H]$^-$: 699.5358, found: 699.5367; $[\alpha]^{20}_D$ = -68.3 (c 0.17, CH_2Cl_2).

(*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-formyl-*N*-methoxy-*N*-methylbut-3-enamide (3zb)

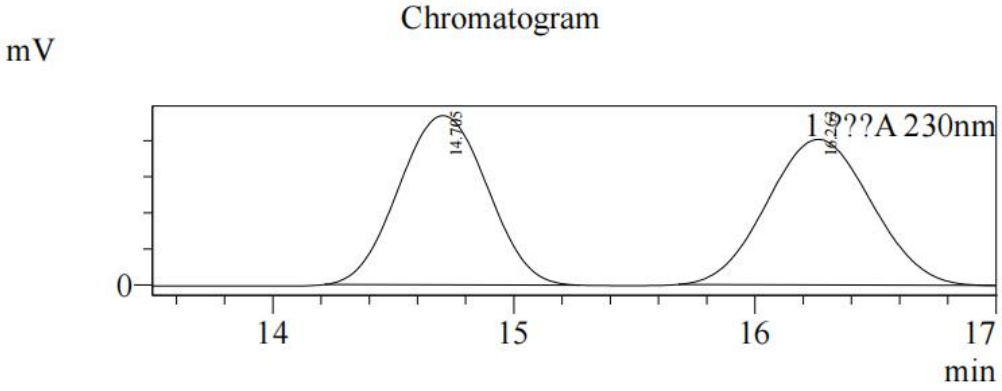


3zb

Compound **3zb** (15.4 mg, 85% yield) was obtained as a white solid following the *general procedure III* from **1q** (0.05 mmol, 15.3 mg) and acrolein **2d** (0.075 mmol, 4.2 mg, 5 μL) stirred for 8 hours. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 9.60 (s, 1H), 7.06 (s, 2H), 6.21 (s, 1H), 6.15 (s, 1H), 5.16 (s, 1H), 3.58 (s, 3H), 3.19 (s, 3H), 1.41 (s, 18H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 193.6, 153.1, 149.4, 137.1, 136.1, 126.4, 125.6, 61.1, 46.0, 34.4, 30.3; **Mp**: 114-115 ºC; **HRMS** Calcd. for $C_{21}H_{30}NO_4^-$ [M-H]$^-$: 360.2175, found: 360.2176.

$[\alpha]^{20}_D$ = -83.2 (c 0.51, CH_2Cl_2) for 88% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230 nm, t_{minor} = 16.304 min, t_{major} = 14.738 min.

Racemic Sample 3zb

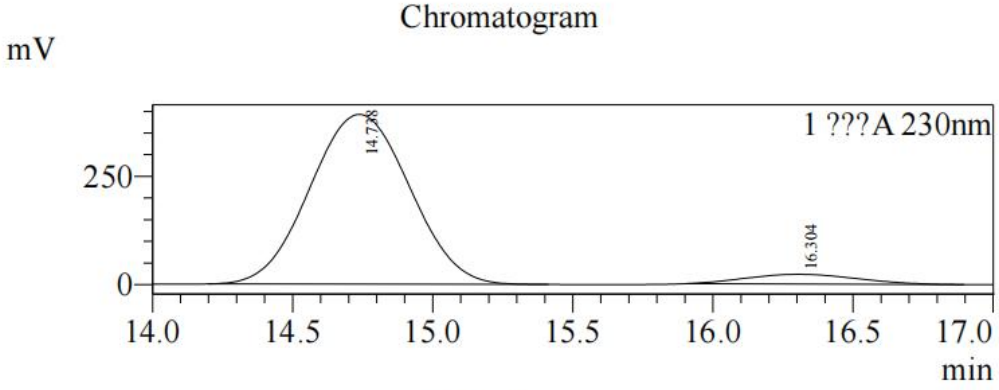


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	14.705	2395275	93720	49.650
2	16.263	2429055	80638	50.350
Total		4824330	174359	100.000

Enantiomeric Sample 3zb

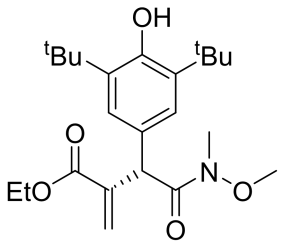


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	14.738	9702234	391916	94.080
2	16.304	610558	22329	5.920
Total		10312792	414246	100.000

Ethyl (*S*)-3-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-4-(methoxy(methyl)amino)-2-methylene-4-oxobutanoate (3zc)

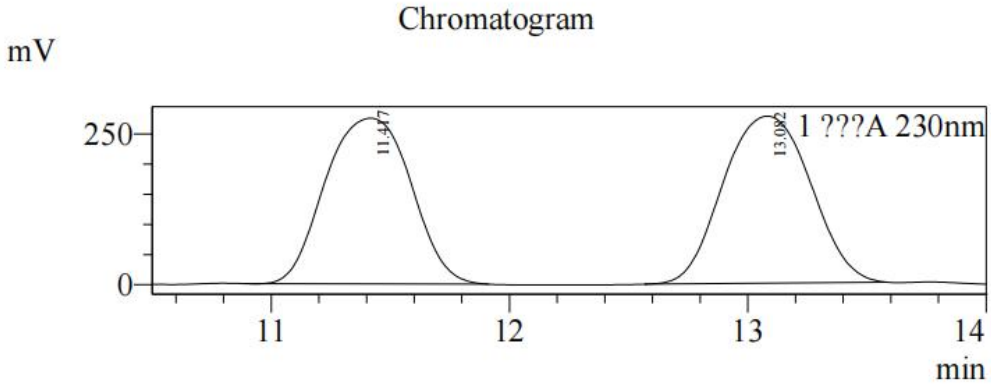


3zc

Compound **3zc** (10.0 mg, 24% yield) was obtained as a yellow viscous liquid following the *general procedure III* from **1q** (0.1 mmol, 30.6 mg) and ethyl acrylate **2e** (0.15 mmol, 15 mg, 16 μL) stirred for 8 hours. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.04 (s, 2H), 6.38 (s, 1H), 5.32 (s, 1H), 5.30 (s, 1H), 5.15 (s, 1H), 4.27-4.17 (m, 2H), 3.54 (s, 3H), 3.19 (s, 3H), 1.41 (s, 18H), 1.29 (t, J = 7.0 Hz, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 166.9, 153.0, 140.6, 136.0, 127.8, 126.7, 125.9, 61.0, 60.9, 49.5. 34.3, 30.4, 14.2; **HRMS** Calcd. for $C_{23}H_{34}NO_5^-$ [M-H]$^-$: 404.2437, found: 404.2433.

$[\alpha]^{20}_D$ = -37.6 (c 0.19, CH_2Cl_2) for 77% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230 nm, t_{minor} = 11.380 min, t_{major} = 13.036 min.

Racemic Sample 3zc

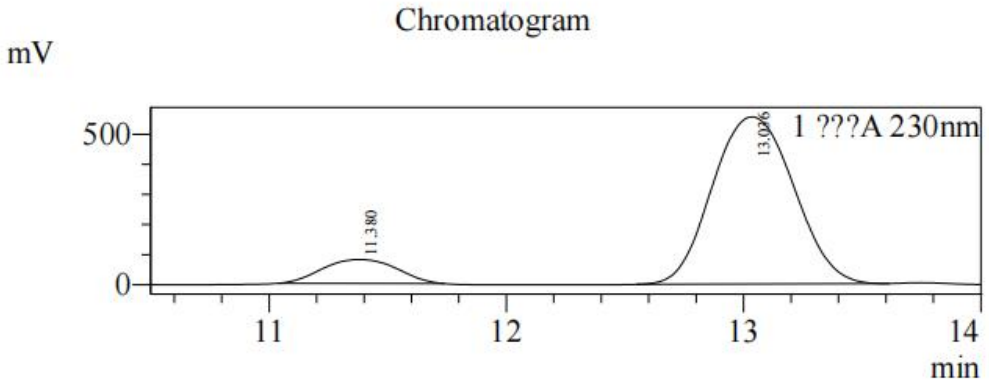


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	11.417	6874910	274700	49.253
2	13.082	7083433	276882	50.747
Total		13958343	551582	100.000

Enantiomeric Sample 3zc

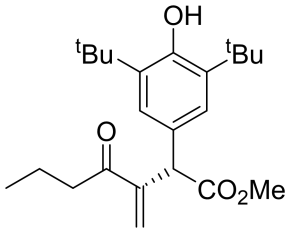


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	11.380	1722414	79109	11.511
2	13.036	13241104	555059	88.489
Total		14963518	634168	100.000

Methyl (*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-4-oxoheptanoate (3zd)



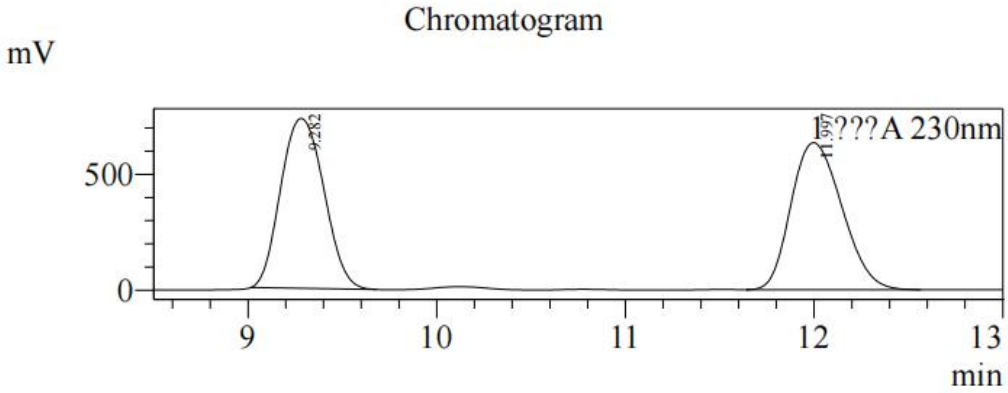
3zd

Compound **3zd** (28.9 mg, 77% yield) was obtained as a colorless viscous liquid following the *general procedure III* from **1a** (0.1 mmol, 27.6 mg) and hex-1-en-3-one **2f** (0.15 mmol, 14.7 mg, 19 μL) stirred for 8 hours. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 6.99 (s, 2H), 6.20 (s, 1H), 5.52 (d, *J* = 2.0 Hz, 1H), 5.18 (s, 1H), 4.78 (s, 1H), 3.68 (s, 3H), 2.77-2.66 (m, 2H), 1.70-1.63 (m, 2H), 1.41 (s, 18H), 0.93 (t, *J* = 7.0 Hz, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 201.2, 173.0, 153.2, 148.0, 136.1, 126.9, 126.5, 125.6, 52.2, 52.0, 39.6, 34.3, 30.3, 17.8, 13.7; **HRMS** Calcd. for $C_{23}H_{33}O_4^-$ [M-H]$^-$: 373.2379, found: 373.2380.

$[\alpha]^{20}_D$ = -91.0 (c 0.58, CH_2Cl_2) for 93% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230 nm,

t_{minor} = 12.015 min, t_{major} = 9.273 min.

Racemic Sample 3zd

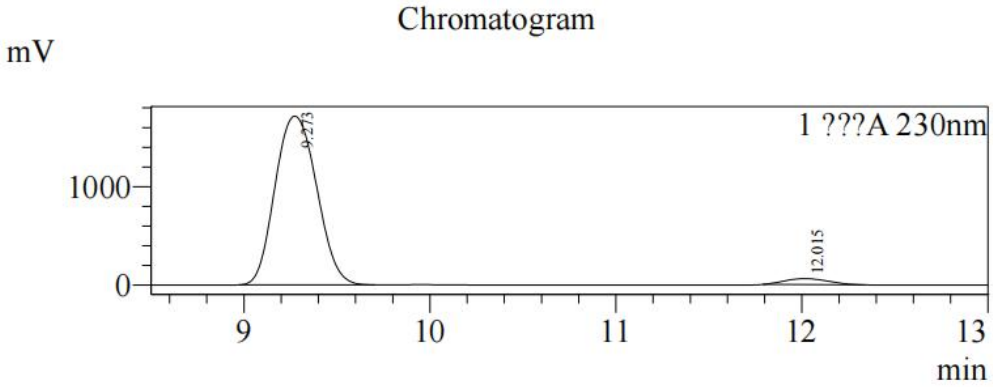


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	9.282	11678746	732848	49.563
2	11.997	11884774	633609	50.437
Total		23563519	1366457	100.000

Enantiomeric Sample 3zd

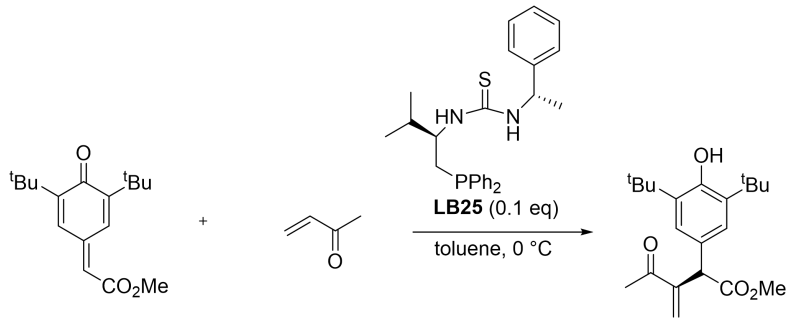


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	9.273	26668420	1713806	96.454
2	12.015	980415	60057	3.546
Total		27648835	1773863	100.000

Methyl (*R*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylene-4-oxopentanoate (3a')



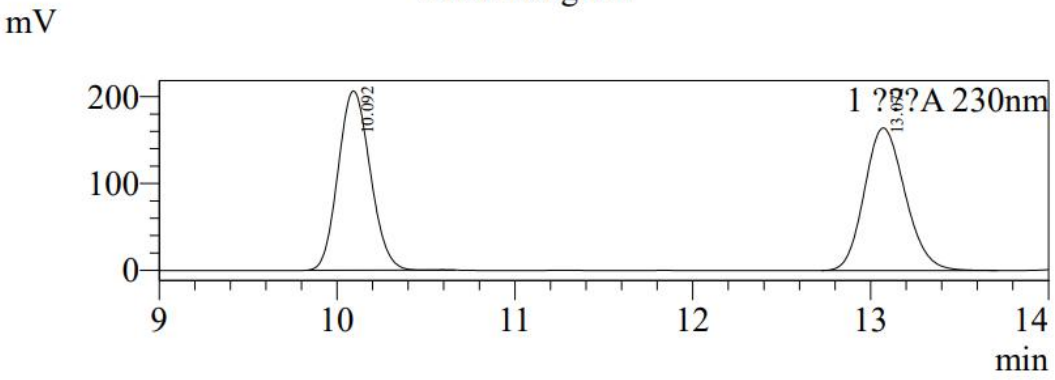
A stirred solution of **1a** (0.05 mmol), **LB25** (0.075 mmol) in 1 mL of toluene was cooled to 0 °C. Subsequently, methyl vinyl ketone **2a** (0.075 mmol) was added through a syringe. The mixture was stirred at this temperature for 6 hours. After completion of the reaction, the reaction mixture was directly purified by silica gel chromatography using petroleum ether/EtOAc as the eluent to afford the desired products.

Compound **3a'** (17.2 mg, 99% yield) was obtained as a white solid following the *general procedure III*a from **1a** (0.05 mmol, 13.8 mg) and **2b** (0.075 mmol, 5.3 mg, 7 μL) stirred for 6 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 6.99 (s, 2H), 6.22 (d, *J* = 1.2 Hz, 1H), 5.57 (d, *J* = 1.6 Hz, 1H), 5.20 (s, 1H), 4.77 (s, 1H), 3.69 (s, 3H), 2.40 (s, 3H), 1.41 (s, 18H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 199.0, 173.0, 153.2, 148.1, 136.1, 128.4, 126.4, 125.5, 52.3, 51.7, 34.3, 30.2, 25.9; **Mp**: 79-81 ºC; **HRMS** Calcd. for $C_{21}H_{29}O_4^-$ [M-H]$^-$: 345.2066, found: 345.2078.

$[\alpha]^{20}_D$ = +98.5 (c 0.33, CH_2Cl_2) for -95% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 10.233 min, t_{major} = 12.937 min.

Racemic Sample 3a'

Chromatogram



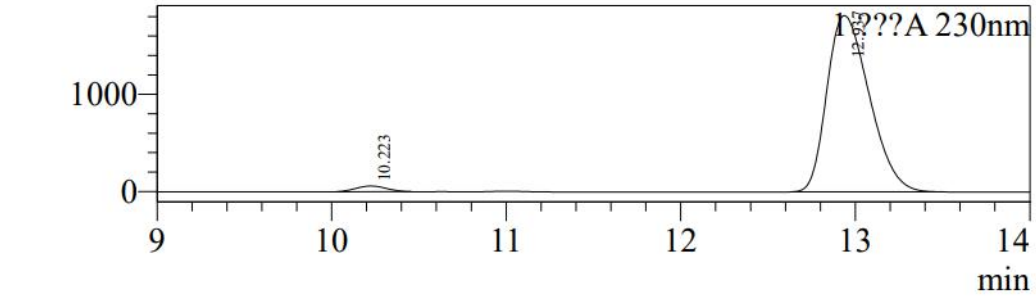
Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	10.092	2589020	206559	49.763
2	13.071	2613693	164067	50.237
Total		5202713	370626	100.000

Enantiomeric Sample 3a'

Chromatogram



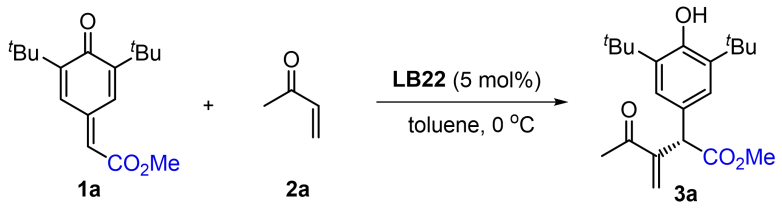
Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	10.223	708129	58332	2.263
2	12.937	30584592	1814626	97.737
Total		31292721	1872958	100.000

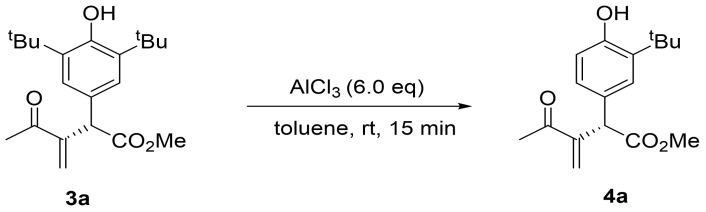
3. Synthetic applications

a) Scale-up experiment for the synthesis of 3a



The scale up experiment was followed the general procedure *III*. To a solution of compound **1a** (2.0 mmol, 1.0 eq.) and chiral phosphine **LB22** (0.1 mmol, 0.05 eq.) in toluene (10 mL) was added vinyl ketone **2** (3.0 mmol, 1.5 eq.) under nitrogen atmosphere at 0 °C. TLC monitor until the compound **1a** consumed after 6 hours. The reaction mixture was then concentrated on a rotary evaporator under reduce pressure and the residue was subjected to purification by column chromatography (silica gel, PE/EtOAc: 20/1 to 10/1, R_f = 0.5-0.6) to afford the corresponding product **3a** (0.57 g, 83% yield, 92% ee) as a white solid.

b) de-tert-butylation



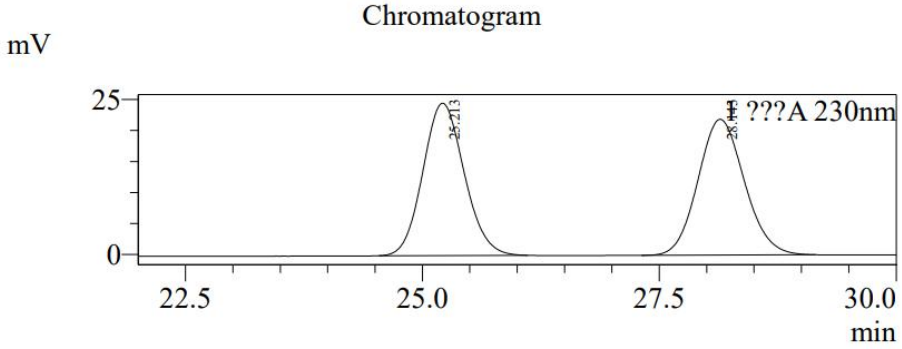
Procedure (*IV*): To a solution of **3a** (1.0 equiv.) in dry toluene was added $AlCl_3$ (6.0 equiv.) under nitrogen. The reaction mixture was stirred at ambient temperature for 15 min. The mixture was then quenched with water and extracted twice with EtOAc, the organic layers were combined and dried over Na_2SO_4. The residue obtained was purified by column chromatography (petroleum ether/EtOAc) to afford the product **4a** in 88% yield with 92% ee.

Methyl (*S*)-2-(3-(*tert*-butyl)-4-hydroxyphenyl)-3-methylene-4-oxopentanoate (4a). Compound **4** (25.6 mg, 88% yield) was obtained as colorless viscous liquid following the *procedure IV* from **3a** (0.1 mmol, 34.6 mg) and $AlCl_3$ (0.6 mmol, 80 mg) stirred for 15 min. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.07 (d, *J* = 2.0 Hz, 1H), 6.91 (dd, *J* = 8.0,

2.0 Hz, 1H), 6.64 (d, *J* = 8.0 Hz, 1H), 6.24 (d, *J* = 0.8 Hz, 1H), 5.59 (d, *J* = 1.6 Hz, 1H), 4.78 (s, 1H), 3.69 (s, 3H), 2.40 (s, 3H), 1.38 (s, 9H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 199.2, 173.1, 153.9, 147.9, 136.6, 128.6, 128.0, 127.4, 127.1, 116.8, 52.4, 51.4, 34.6, 29.4, 25.8; **HRMS** Calcd. for $C_{17}H_{21}O_4^-$ [M-H]$^-$: 289.1445, found: 289.1450.

$[\alpha]^{20}_D$ = -104.9 (c 0.25, CH_2Cl_2) for 92% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230nm, t_{minor} = 25.104 min, t_{major} = 27.982 min.

Racemic Sample 4a

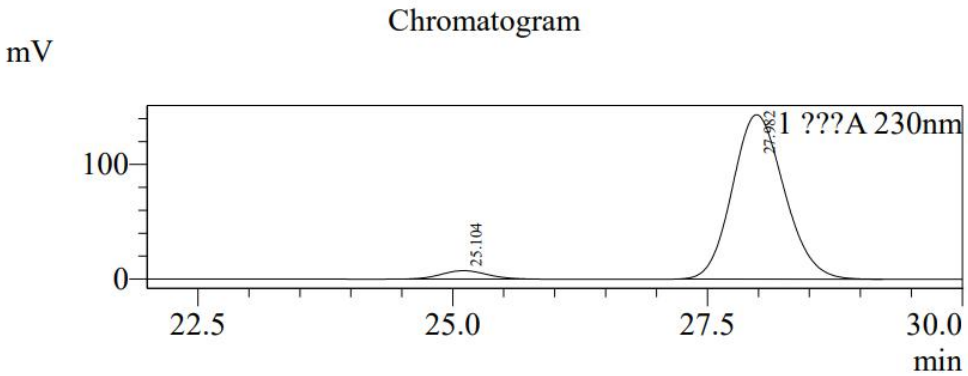


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	25.213	744923	24566	49.944
2	28.143	746596	21898	50.056
Total		1491519	46464	100.000

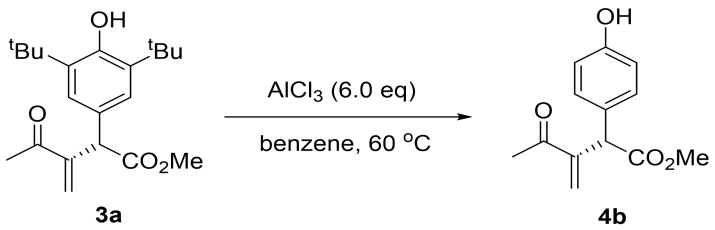
Enantiomeric Sample 4a



Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	25.104	224331	7307	4.227
2	27.982	5083146	143465	95.773
Total		5307477	150772	100.000



3a **4b**

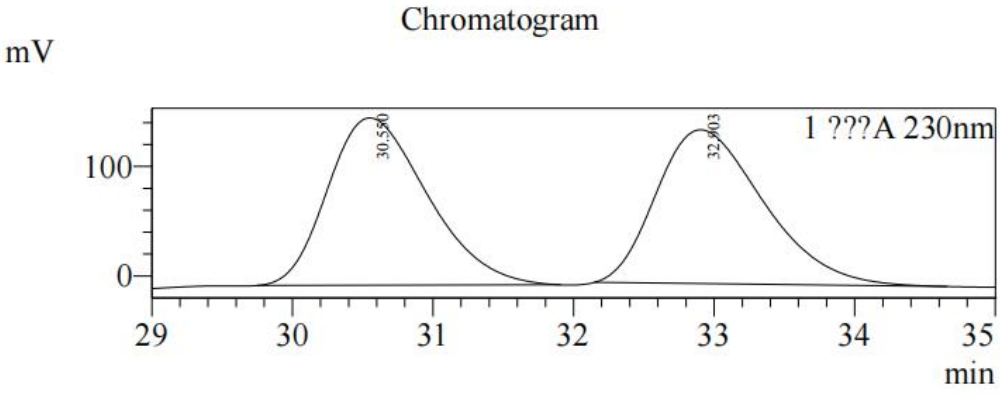
To a solution of **3a** (0.1 mmol, 34.6 mg) in benzene was added $AlCl_3$ (6.0 equiv.) under nitrogen. The reaction mixture was stirred at 60 °C for 3 h. The mixture was then quenched with water and extracted twice with EtOAc, the organic layers were combined and dried over Na_2SO_4. The residue obtained was purified by column chromatography (petroleum ether/EtOAc) to afford the product **4b** in 41% yield with 92% ee.

Methyl (*S*)-2-(4-hydroxyphenyl)-3-methylene-4-oxopentanoate (4b)

Compound **4b** (9.7 mg, 41% yield) was obtained as white solid following the *procedure IV* from **3a** (0.1 mmol, 34.6 mg) and $AlCl_3$ (0.6 mmol, 80 mg) stirred for 3 h. **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.09 (d, *J* = 8.5 Hz, 2H), 6.80 (d, *J* = 8.5 Hz, 2H), 6.23 (s, 1H), 5.62 (d, *J* = 1.5 Hz, 1H), 4.79 (s, 1H), 3.68 (s, 3H), 2.39 (s, 3H); **^{13}C NMR** (125 MHz, $CDCl_3$) δ 199.0, 172.9, 155.3, 147.7, 130.3, 128.2, 128.0, 115.8, 52.4, 51.1, 25.8; **Mp**: 123-125 °C; **HRMS** Calcd. for $C_{13}H_{13}O_4^-$[M-H]$^-$: 233.0814, found: 233.0820.

$[\alpha]^{20}_D$ = -94.9 (c 0.32, CH_2Cl_2) for 92% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230 nm, t_{minor} = 30.734 min, t_{major} = 32.878 min.

Racemic Sample 4b

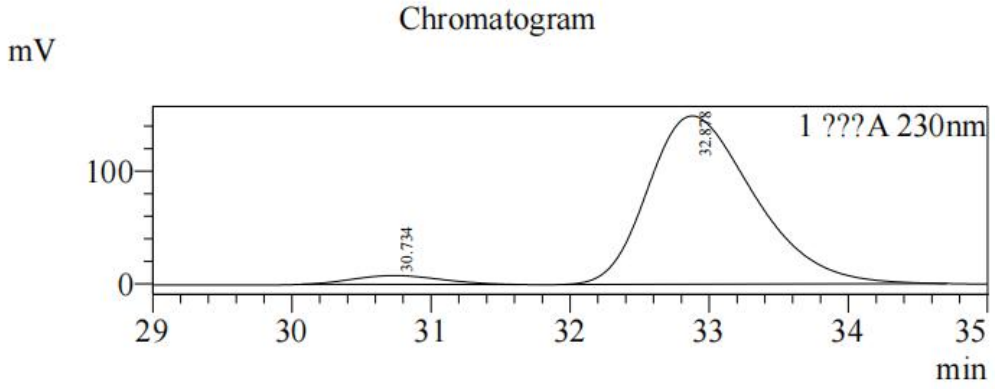


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	30.550	7515348	152775	50.209
2	32.903	7452852	140378	49.791
Total		14968201	293153	100.000

Enantiomeric Sample 4b

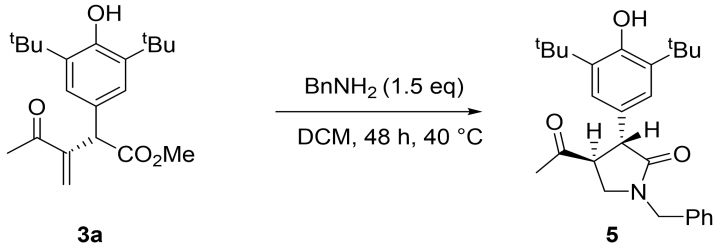


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	30.734	344859	7834	4.174
2	32.878	7917386	149297	95.826
Total		8262244	157131	100.000

c) Synthesis of compound 5



3a **5**

Procedure (*V*): Add $BnNH_2$ to a solution of **3a** in anhydrous DCM with a reflux

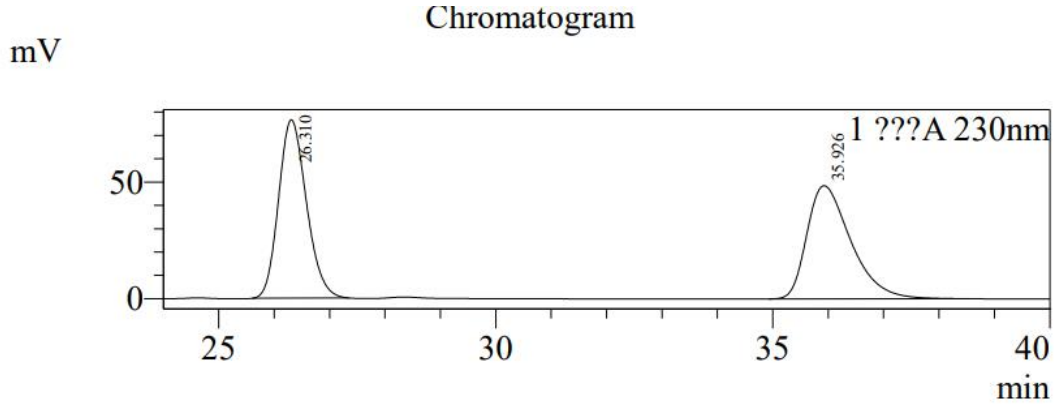
reactor, then the mixture was heated to 40 ℃ for 24 hours. After conversion, the mixture was purified by column chromatography (petroleum ether/EtOAc = 5/1) to afford the product **5** in 44% yield with 92% ee.

(3*S*,4*R*)-4-acetyl-1-benzyl-3-(3,5-di-*tert*-butyl-4-hydroxyphenyl)pyrrolidin-2-one (5)

Compound **5** (93.1 mg, 44% yield) was obtained as a white solid following the *procedure V* from **3a** (0.5 mmol, 173 mg) and $BnNH_2$ (0.75mmol, 80.4 mg, 80 μL) stirred at 40 ºC for 24 hours. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.37-7.29 (m, 5H), 7.00 (s, 2H), 5.22 (s, 1H), 4.81 (d, *J* = 14.4 Hz, 1H), 4.30 (d, *J* = 14.4 Hz, 1H), 3.83 (d, *J* = 7.6 Hz, 1H), 3.49 (dd, *J* = 7.6, 1.2 Hz, 2H), 3.33 (q, *J* = 7.6 Hz, 1H), 2.11 (s, 3H), 1.43 (s, 18H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 205.8, 173.1, 153.1, 136.2, 136.1, 129.6, 128.7, 128.1, 127.7, 124.5, 53.4, 50.8, 46.8, 45.7, 34.3, 30.1, 29.3; **Mp**: 146-148 ºC; **HRMS** Calcd. for $C_{27}H_{34}NO_3^-$ [M-H]$^-$: 420.2544, found: 420.2553.

$[\alpha]^{20}_D$ = -112.7 (c 0.16, CH_2Cl_2) for 91% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 90/10, 0.5 mL/min, 230nm, t_{minor} = 26.588 min, t_{major} = 36.085 min.

Racemic Sample 5

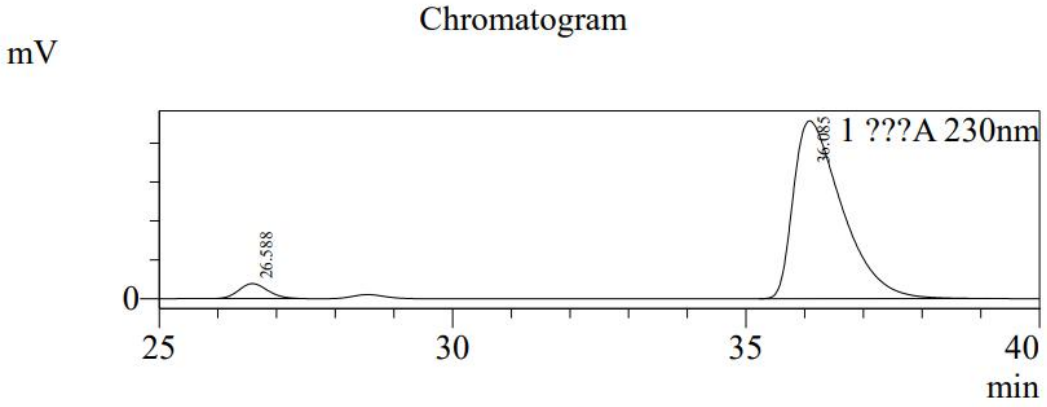


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	26.310	2674822	76516	50.001
2	35.926	2674686	48554	49.999
Total		5349509	125070	100.000

Enantiomeric Sample 5

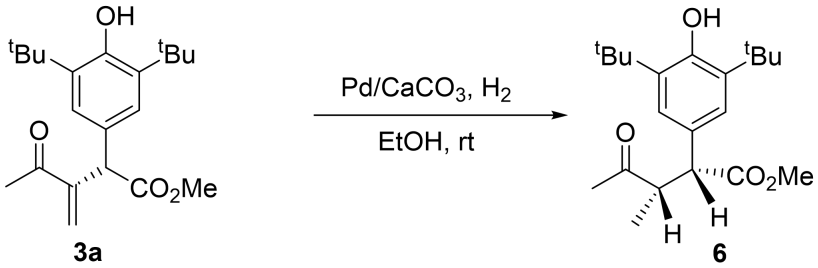


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	26.588	646553	19107	4.675
2	36.085	13183006	228520	95.325
Total		13829559	247627	100.000

d) Preparation of compound 6



Procedure (*VI*): Compound **3a** was dissolved in ethanol, and then 5% $Pd/CaCO_3$ was added. The mixture was stirred overnight under a hydrogen balloon at room temperature. Then the mixture was filtered through a Celite pad and the solvent removed in vacuum, the residue obtained was purified by column chromatography (petroleum ether/EtOAc) to afford the product **6** in 80% yield with 91% ee.

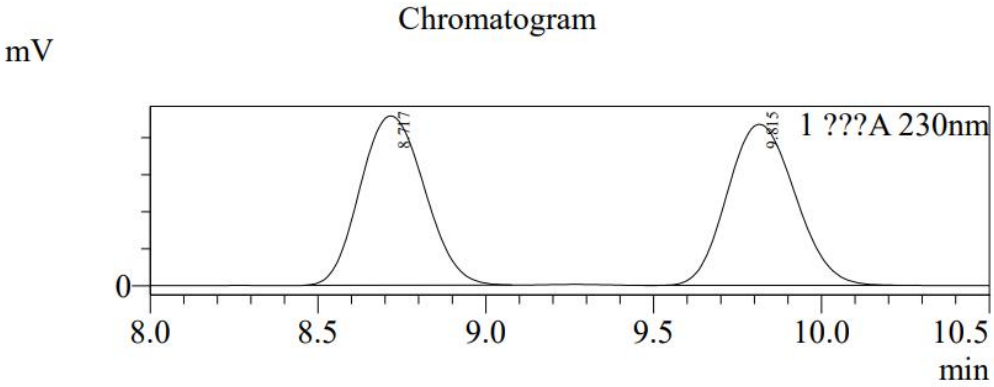
Methyl (2*S*,3*R*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methyl-4-oxopentanoate (6).

Compound **6** (27.7 mg, 80% yield) was obtained as colorless viscous liquid following the *procedure VI* from **3a** (0.1 mmol, 34.6 mg) and 5% $Pd/CaCO_3$ (0.05 mmol, 5.5 mg) stirred overnight. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.07 (s, 2H), 5.16 (s, 1H), 3.69 (d, *J* = 10.8 Hz, 1H), 3.67 (s, 3H), 3.33 (dq, *J* = 10.8, 6.8 Hz, 1H), 1.81 (s, 3H), 1.40 (s, 18H), 1.16 (d, *J* = 6.8 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 210.8, 173.3, 153.1,

135.9, 127.2, 124.7, 54.1, 51.9, 50.0, 34.3, 30.19, 30.16, 15.6; **HRMS** Calcd. for $C_{21}H_{31}O_4^-$ [M-H]$^-$: 347.2228, found: 347.2233.

$[\alpha]^{20}_D$ = -69.2 (c 0.42, CH_2Cl_2) for 91% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230nm, t_{minor} = 9.833 min, t_{major} = 8.736 min.

Racemic Sample 6

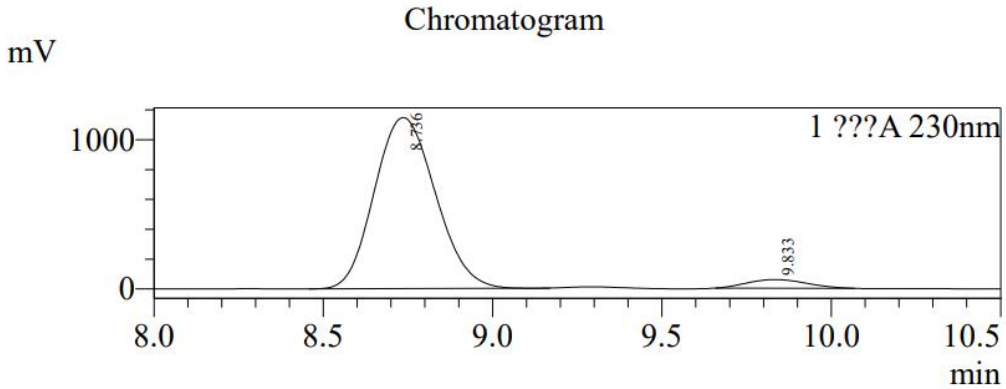


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	8.717	6111826	457673	49.929
2	9.815	6129184	435426	50.071
Total		12241009	893099	100.000

Enantiomeric Sample 6

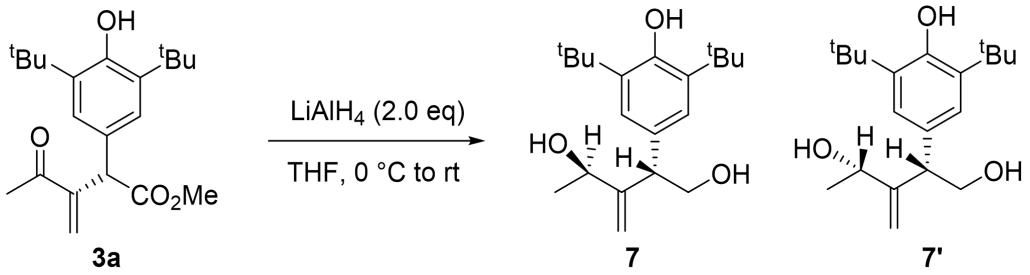


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	8.736	14358530	1146532	95.332
2	9.833	703133	57673	4.668
Total		15061663	1204205	100.000

d) Preparation of 7 and 7'



3a **7** **7'**

Procedure (*VII*): A solution of $LiAlH_4$ in anhydrous THF was cooled to 0 ℃ under nitrogen atomasphere, the solution of **3a** in anhydrous THF was added dropwised while mataining temperature at 0℃, then the mixture was warmed to room temperature for full conversion. The mixture was then quenched with water and extracted twice with EtOAc, the organic layers were combined and dried over anhydrous Na_2SO_4. The residue obtained was purified by column chromatography (petroleum ether/EtOAc) to afford the product **7** in 27% yield with 90% ee and the product **7'** in in 53% yield with 99% ee.

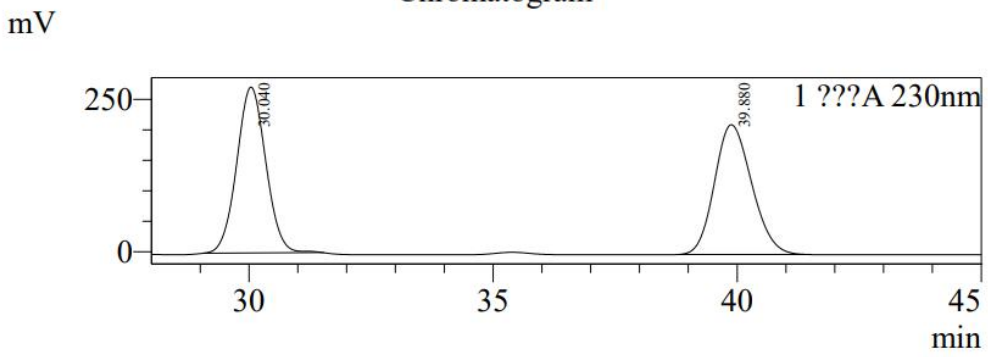
(2*S*,4*R*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylenepentane-1,4-diol (7)

Compound **7** (17.0 mg, 27% yield) was obtained as colorless viscous liquid following the *procedure VII* from **3a** (0.2 mmol, 69.2 mg) and $LiAlH_4$ (0.4 mmol, 15.2 mg) stirred until full conversion. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.02 (s, 2H), 5.38 (s, 1H), 5.13 (s, 1H), 5.08 (s, 1H), 4.20 (q, *J* = 6.4 Hz, 1H), 3.97 (dd, *J* = 10.8, 8.0 Hz, 1H), 3.85 (dd, *J* = 10.8, 6.4 Hz, 1H), 3.52 (t, *J* = 7.2 Hz, 1H), 1.91 (brs, 2H), 1.42 (s, 18H), 1.26 (d, *J* = 6.4 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 153.8, 152.7, 136.0, 130.4, 124.5, 109.6, 70.2, 66.1, 49.8, 34.4, 30.3, 22.5; **HRMS** Calcd. for $C_{20}H_{31}O_3^-$ [M-H]$^-$: 319.2273, found: 319.2284.

$[\alpha]^{20}_D$ = +34.6 (c 0.24, CH_2Cl_2) for 90% ee; Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230 nm, t_{minor} = 40.092 min, t_{major} = 30.504 min.

<u>Racemic Sample 7</u>

Chromatogram



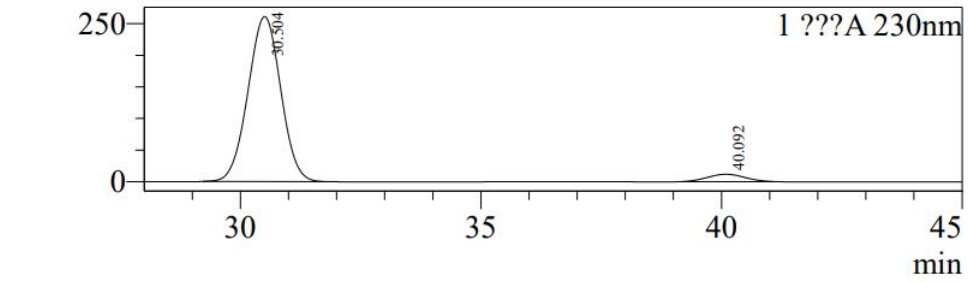
Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	30.040	11288094	272142	49.988
2	39.880	11293366	212889	50.012
Total		22581460	485031	100.000

Enantiomeric Sample 7

Chromatogram



Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	30.504	12383138	261003	95.177
2	40.092	627528	11655	4.823
Total		13010666	272658	100.000

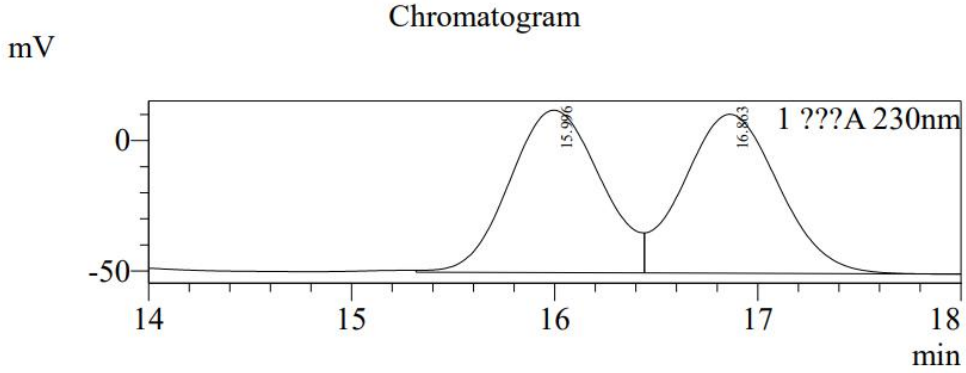
(2*S*,4*S*)-2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)-3-methylenepentane-1,4-diol (7')

Compound **7'** (33.9 mg, 53% yield) was obtained as white solid following the *procedure VII* from **3a** (0.2 mmol, 69.2 mg) and $LiAlH_4$ (0.4 mmol, 15.2 mg) stirred until full conversion. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.04 (s, 2H), 5.36 (s, 1H), 5.09 (s, 1H), 4.18 (q, *J* = 6.4 Hz, 1H), 3.90 (dd, *J* = 10.8, 8.0 Hz, 1H), 3.82 (dd, *J* = 10.8, 6.8 Hz, 1H), 3.61 (t, *J* = 7.2 Hz, 1H), 2.19 (brs, 2H), 1.42 (s, 18H), 1.23 (d, *J* = 6.4 Hz, 3H); **^{13}C NMR** (100 MHz, $CDCl_3$) δ 152.9, 152.7, 135.9, 130.3, 124.7, 109.8, 70.6, 66.1, 50.2, 34.4, 30.2, 22.2; **Mp**: 102-104 ºC; **HRMS** Calcd. for $C_{20}H_{31}O_3^-$[M-H]$^-$:

319.2273, found: 319.2284.

$[\alpha]^{20}_{D}$ = +65.9 (c 0.14, CH_2Cl_2) for 99% ee; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230 nm, t_{major} = 15.921 min.

Racemic Sample 7'

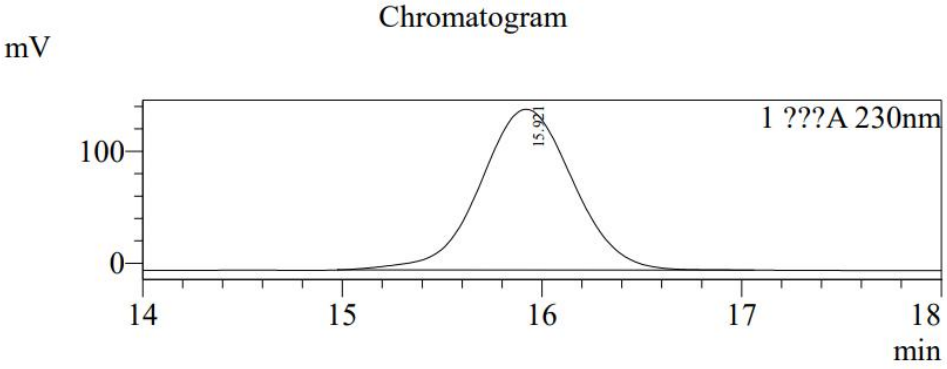


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	15.996	1956656	62294	49.557
2	16.863	1991620	60979	50.443
Total		3948276	123274	100.000

Enantiomeric Sample 7'



Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	15.921	4658443	143539	100.000
Total		4658443	143539	100.000

4. References

[1] (a) R. Zhuge, L. Wu, M. Quan, N. Butt, G. Yang, W. Zhang, *Adv. Synth. Catal.*, **2017**, *359*, 1028-1036; (b) P. Nesvadba, *Synth. Commun.*, **2000**, *30*, 2825-2832.

[2] (a) M. Ito, A. Osaku, C. Kobayashi, A. Shiibashi, T. Ikariya, *Organometallics* **2009**, *28*, 390-393.

[3] G. Bian, W. Shan, W. Su, *J. Chem. Res.*, **2005**, 585-586.

[4] (a) H. Xiao, Z. Chai, C.-W. Zheng, Y.-Q. Yang, W. Liu, J.-K. Zhang, G. Zhao, *Angew. Chem., Int. Ed.,* **2010**, *49*, 4467; (b) X. Han, Y. Wang, F. Zhong, Y. Lu, *J. Am. Chem. Soc.,* **2011**, *133*, 1726; (c) X. Han, Y. Wang, F. Zhong, Y. Lu, *Org. Biomol. Chem.*, **2011**, *9*, 6734-6740; (d) F. Zhong, Y. Wang, X. Han, K.-W. Huang, Yixin Lu, *Org. Lett.*, **2011**, *13*, 1310-1313; (b) J. Gong, T. Li, K. Pan, X. Wu, *Chem. Commun.*, **2011**, *47*, 1491-1493; (c) H. Zhang, C. Jiang, J. Tan, H. Hu, Y. Chen, X. Ren, H. Zhang, T. Wang, *ACS Catal.*, **2020**, *10*, 5698-5706; (e) H. Deng, Y. Wei, M. Shi, *Adv. Synth. Catal.*, **2012**, *354*, 783-789; (f) Y. Jiang, Y. Yang, Q. He, W. Du, Y. Chen, *J. Org. Chem.*, **2020**, *85*, 10760–10771.

5. X-ray data of compound 3e and 5

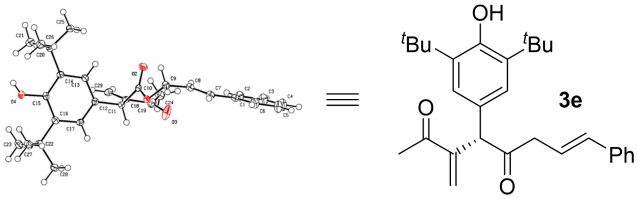
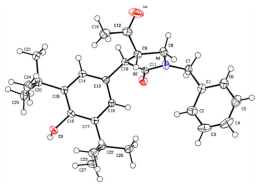
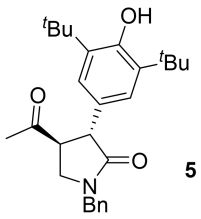


Table 1. Crystal data and structure refinement for Orth-full_a-finalcif.

Identification code	Orth-full_a	
Empirical formula	C29 H36 O4	
Formula weight	448.58	
Temperature	100(2) K	
Wavelength	1.54178 ?	
Crystal system	Orthorhombic	
Space group	$P2_12_12$	
Unit cell dimensions	a = 18.9096(6) ?	a= 90?
	b = 22.5975(8) ?	b= 90?
	c = 5.9615(2) ?	g = 90?
Volume	2547.41(15) ?^{3}	
Z	4	
Density (calculated)	1.170 Mg/m^3	
Absorption coefficient	0.604 mm^{-1}	
F(000)	968	
Crystal size	0.25 x 0.08 x 0.06 mm^3	
Theta range for data collection	3.912 to 72.210?	
Index ranges	-23<=h<=22, -27<=k<=27, -7<=l<=7	
Reflections collected	30354	
Independent reflections	5037 [R(int) = 0.0454]	
Completeness to theta = 67.679?	99.9 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.964 and 0.944	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	5037 / 3 / 308	
Goodness-of-fit on F^2	1.073	
Final R indices [I>2sigma(I)]	R1 = 0.0300, wR2 = 0.0780	
R indices (all data)	R1 = 0.0324, wR2 = 0.0794	
Absolute structure parameter	-0.01(6)	
Extinction coefficient	n/a	
Largest diff. peak and hole	0.187 and -0.241 e.?$^{-3}$	



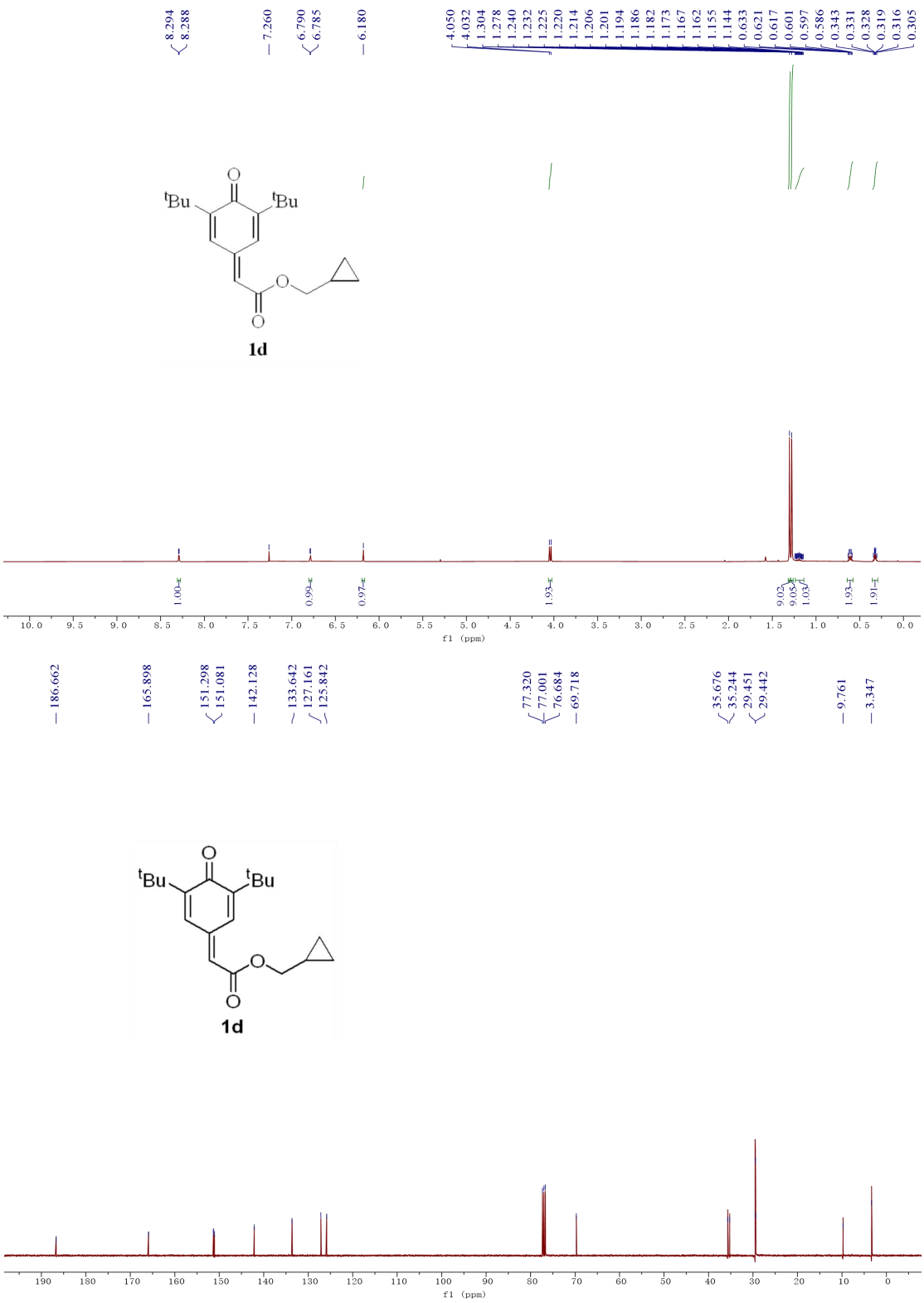


5

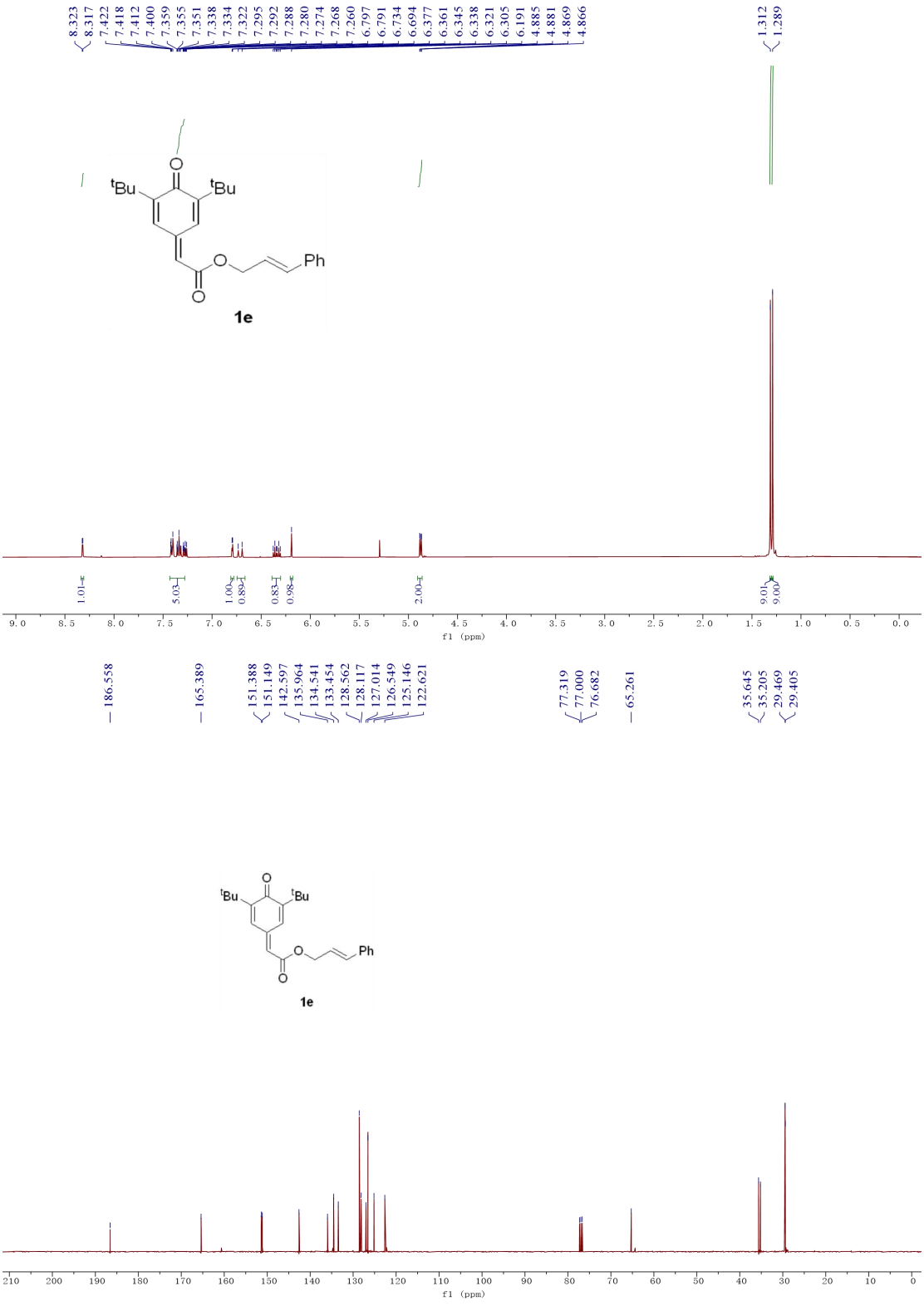
Table 1. Crystal data and structure refinement for ORTH-FULL2_a-finalcif.

Identification code	ORTH-FULL2_a	
Empirical formula	C27 H35 N O3	
Formula weight	421.56	
Temperature	100(2) K	
Wavelength	1.54178 ?	
Crystal system	Orthorhombic	
Space group	$P2_12_12_1$	
Unit cell dimensions	a = 10.0735(3) ?	a= 90?
	b = 10.4515(3) ?	b= 90?
	c = 22.6325(7) ?	g = 90?
Volume	2382.82(12) $?^3$	
Z	4	
Density (calculated)	1.175 Mg/m^3	
Absorption coefficient	0.593 mm^{-1}	
F(000)	912	
Crystal size	0.2 x 0.15 x 0.12 mm^3	
Theta range for data collection	3.906 to 72.378?	
Index ranges	-11<=h<=12, -12<=k<=12, -27<=l<=27	
Reflections collected	54308	
Independent reflections	4703 [R(int) = 0.0575]	
Completeness to theta = 67.679?	99.7 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	0.931 and 0.899	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	4703 / 1 / 290	
Goodness-of-fit on F^2	1.038	
Final R indices [I>2sigma(I)]	R1 = 0.0284, wR2 = 0.0694	
R indices (all data)	R1 = 0.0306, wR2 = 0.0709	
Absolute structure parameter	0.07(6)	
Extinction coefficient	n/a	
Largest diff. peak and hole	0.162 and -0.166 $e.?^{-3}$	

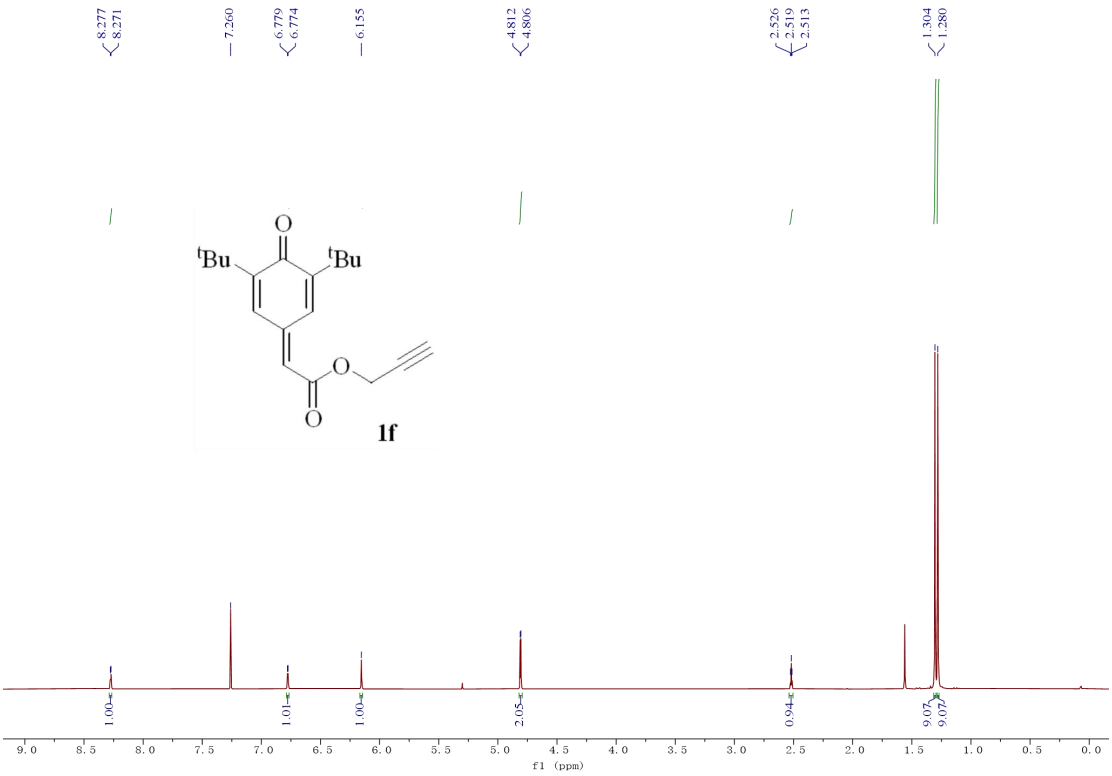
6. NMR Spectra

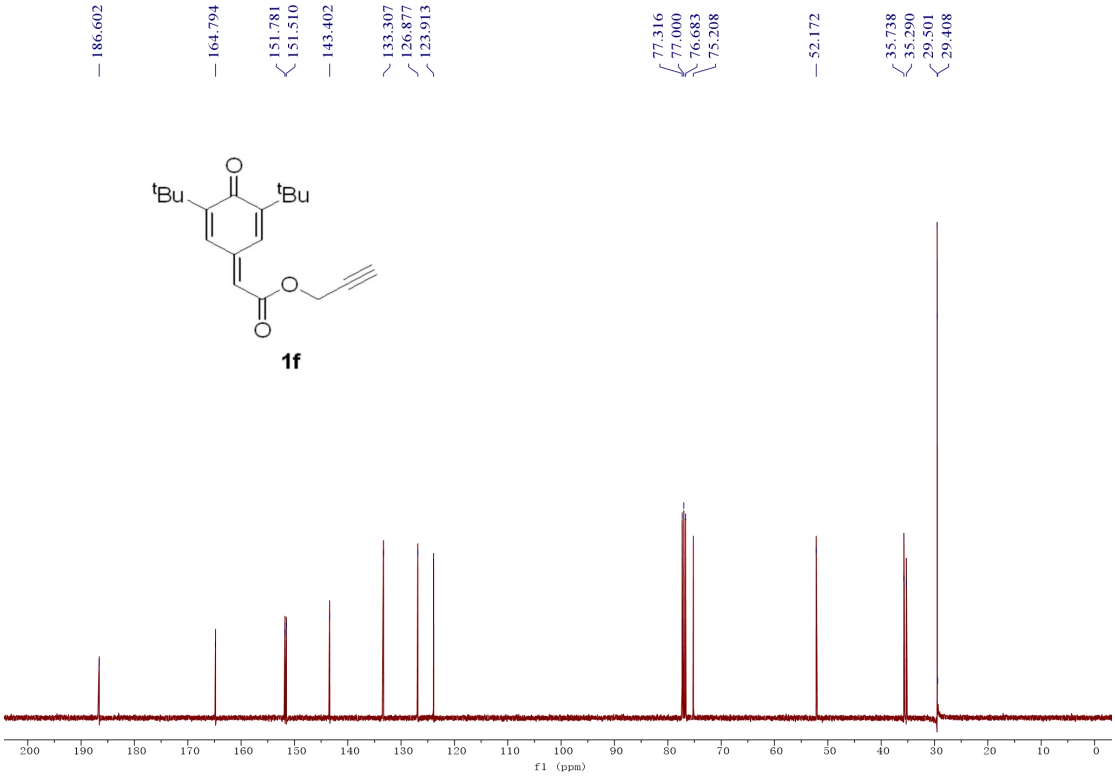


^{1}H and ^{13}C NMR spectra of compound **1d**

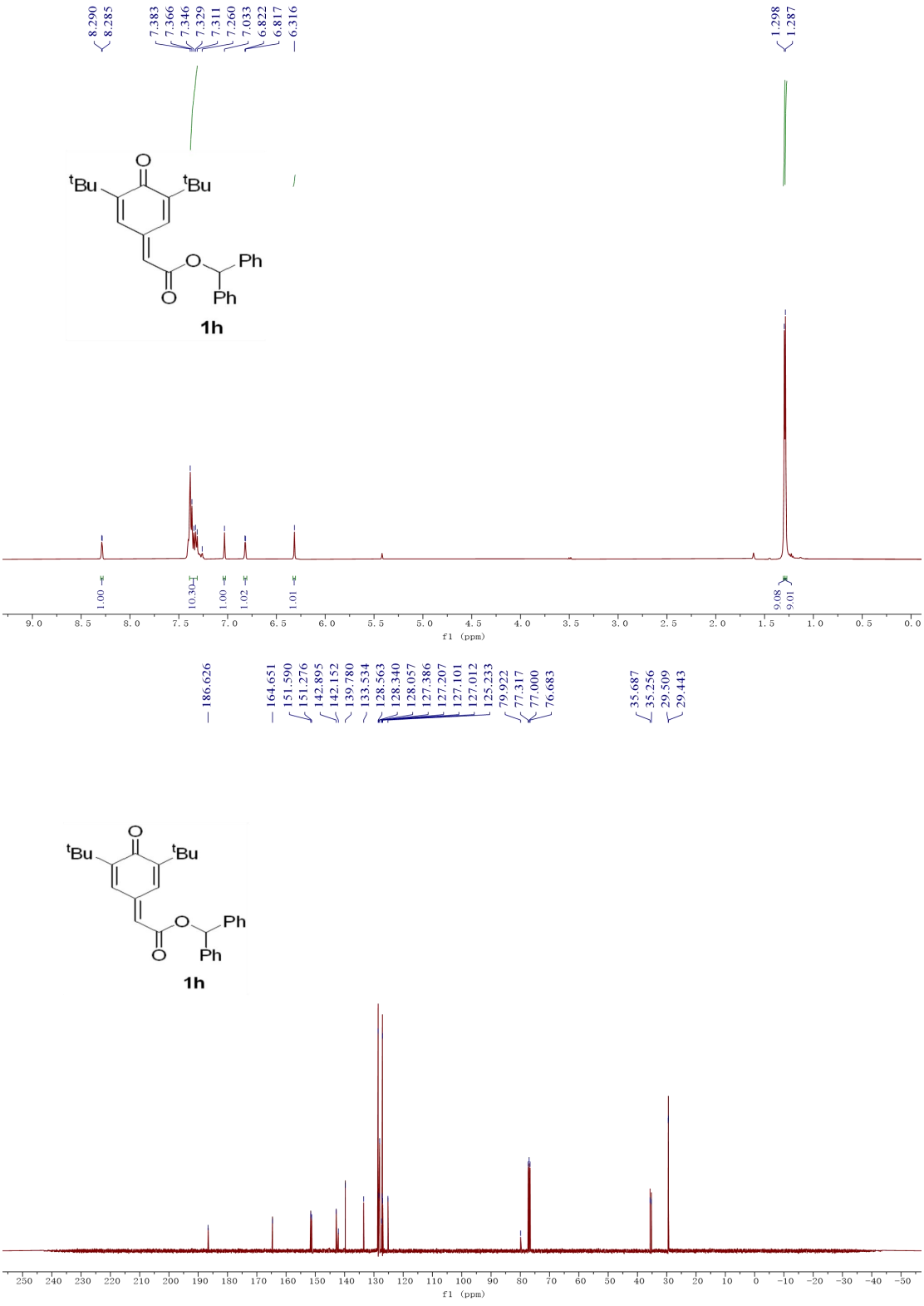


^{1}H and ^{13}C NMR spectra of compound **1e**

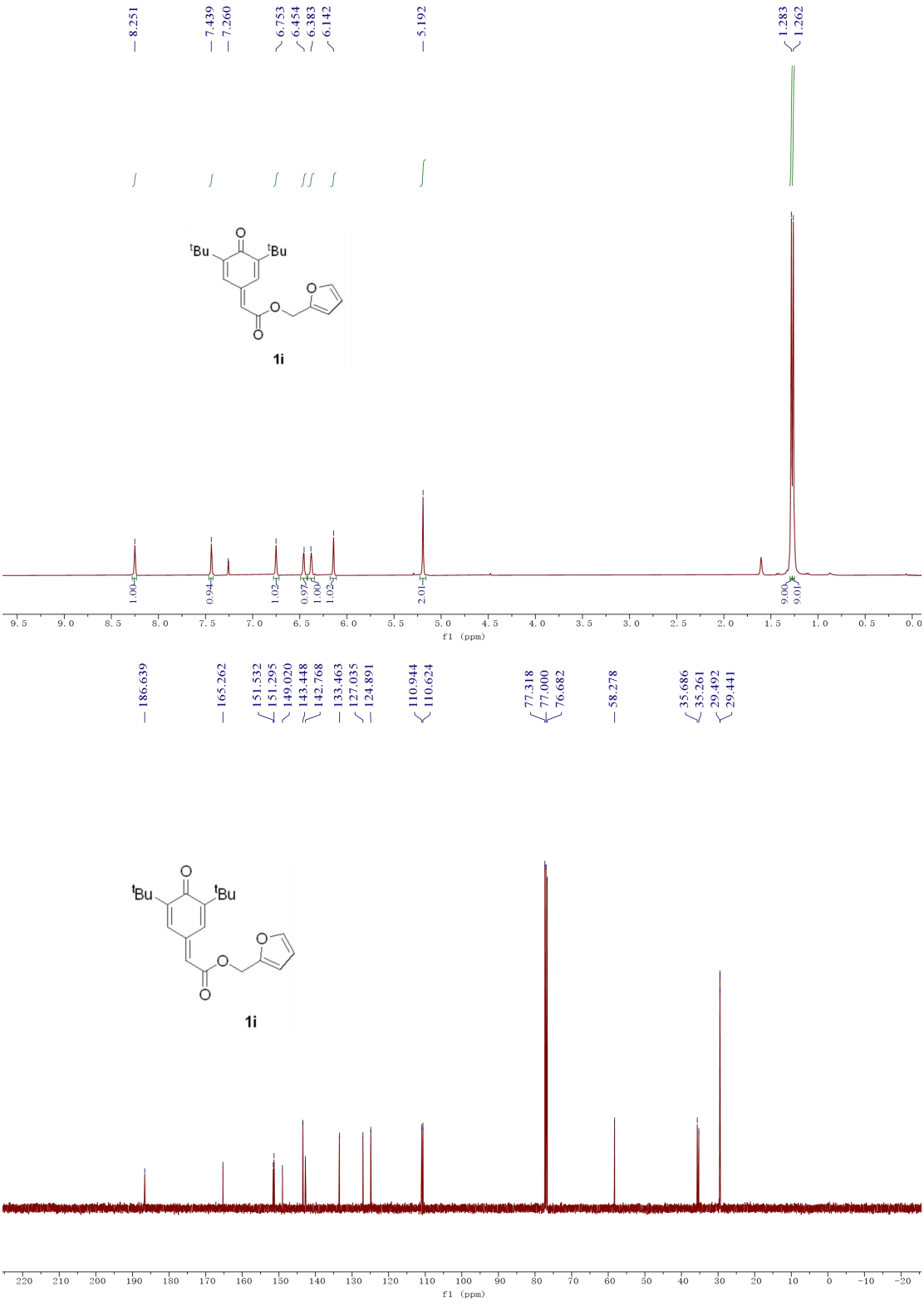




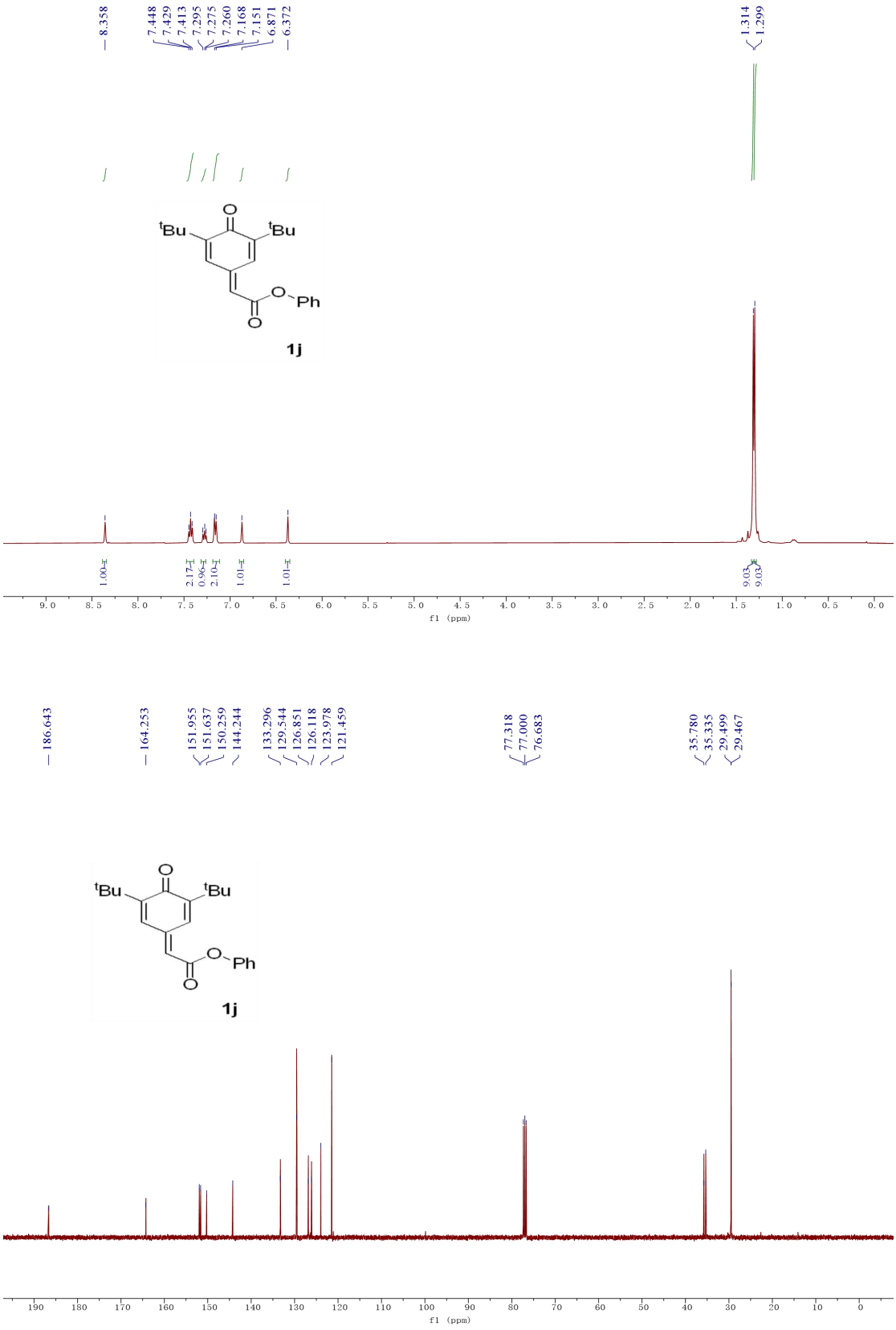
^{1}H and ^{13}C NMR spectra of compound **1f**



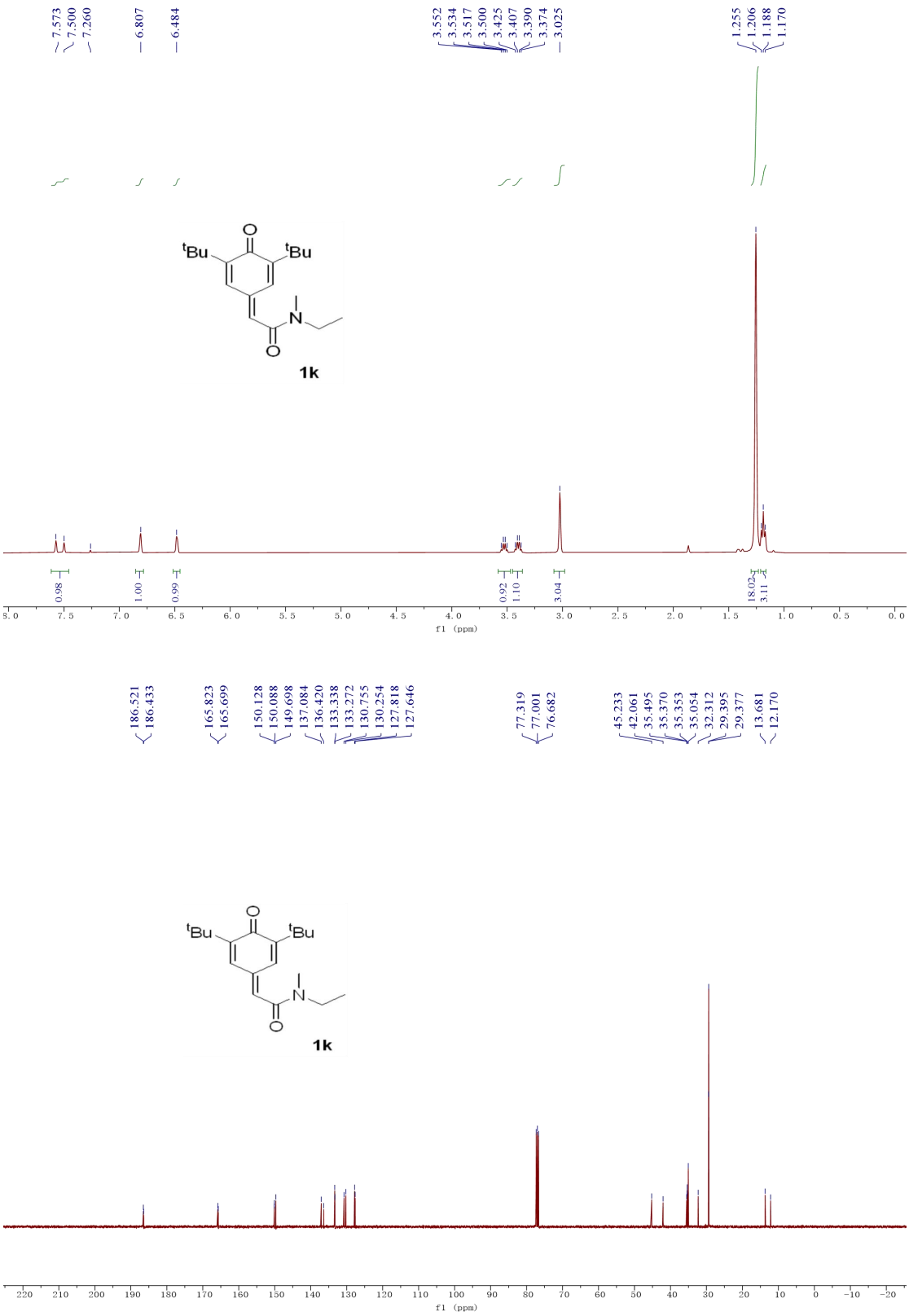
^{1}H and^{13}C NMR spectra of compound **1h**



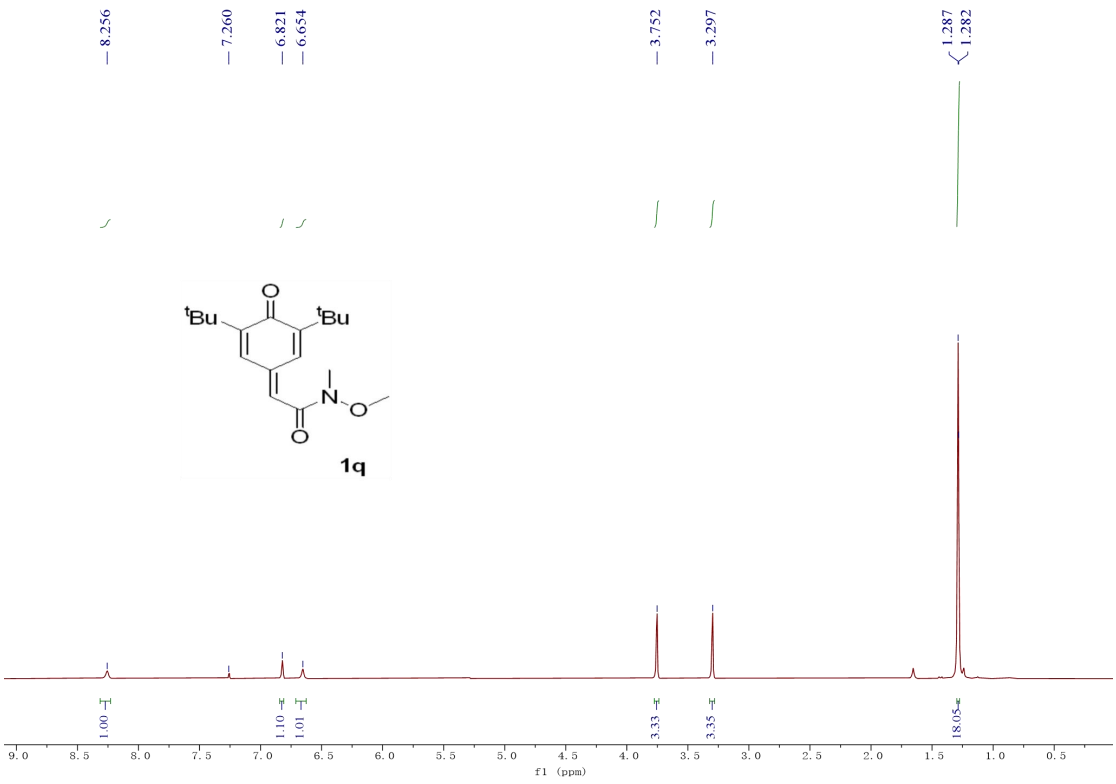
^{1}H and^{13}C NMR spectra of compound **1i**

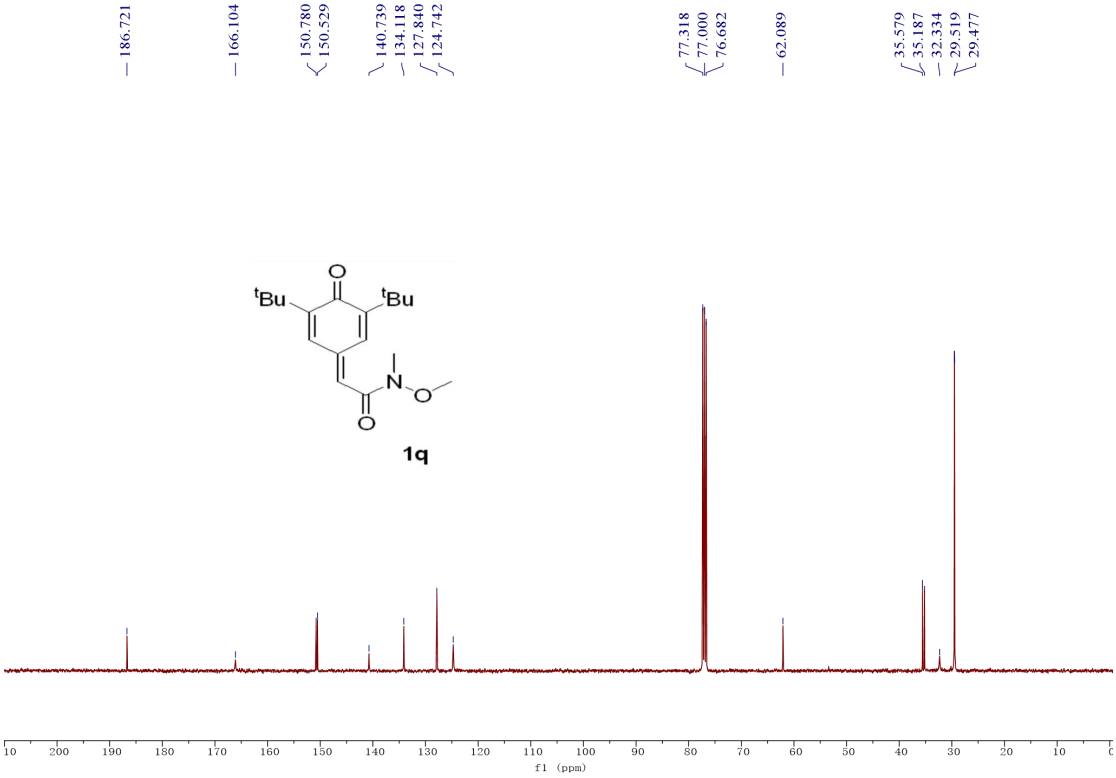


^{1}H and^{13}C NMR spectra of compound **1j**

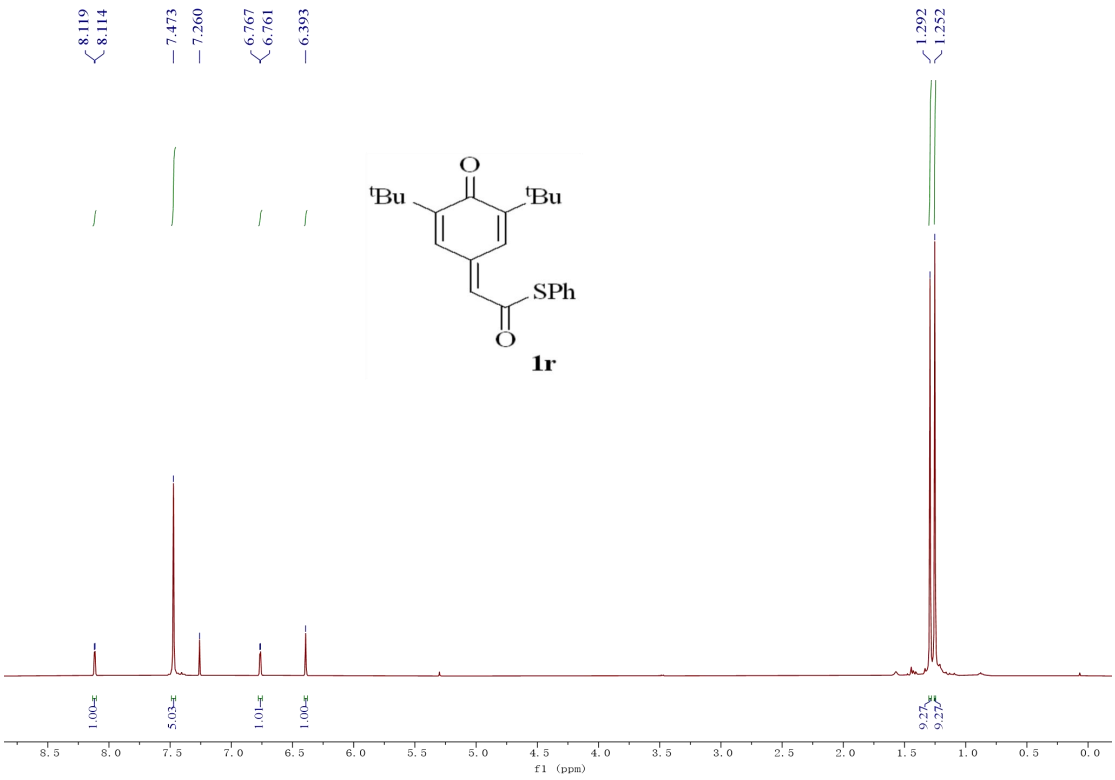


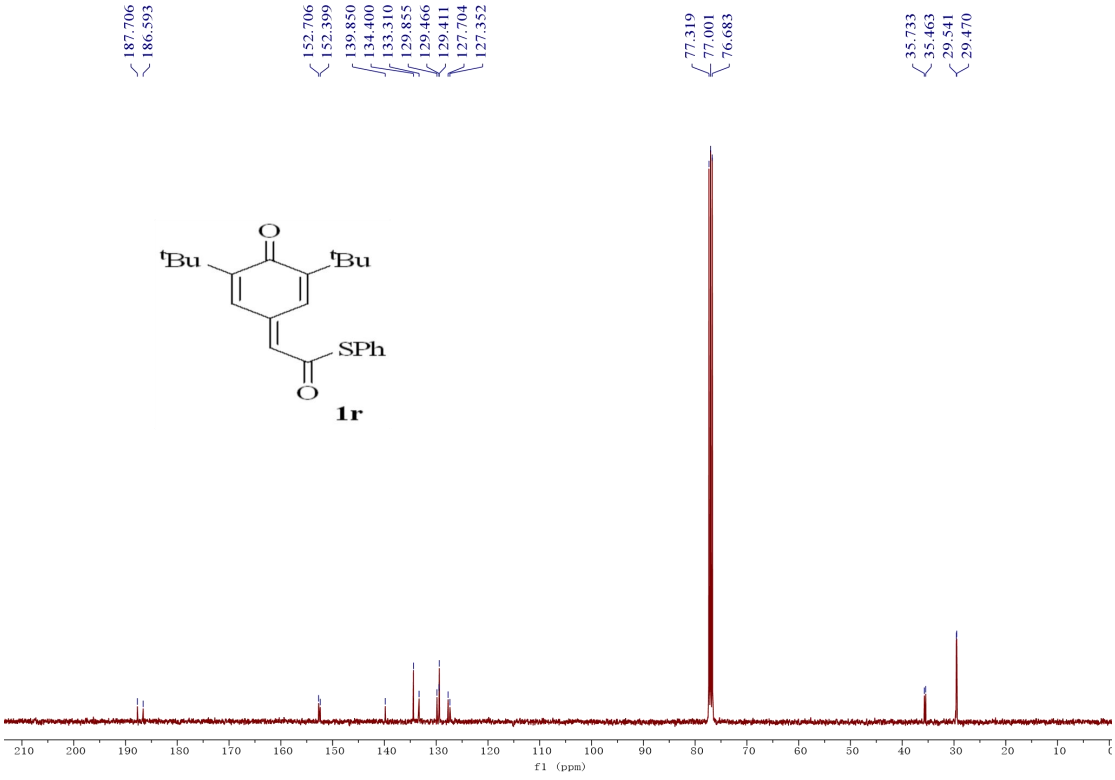
^{1}H and ^{13}C NMR spectra of compound **1k**



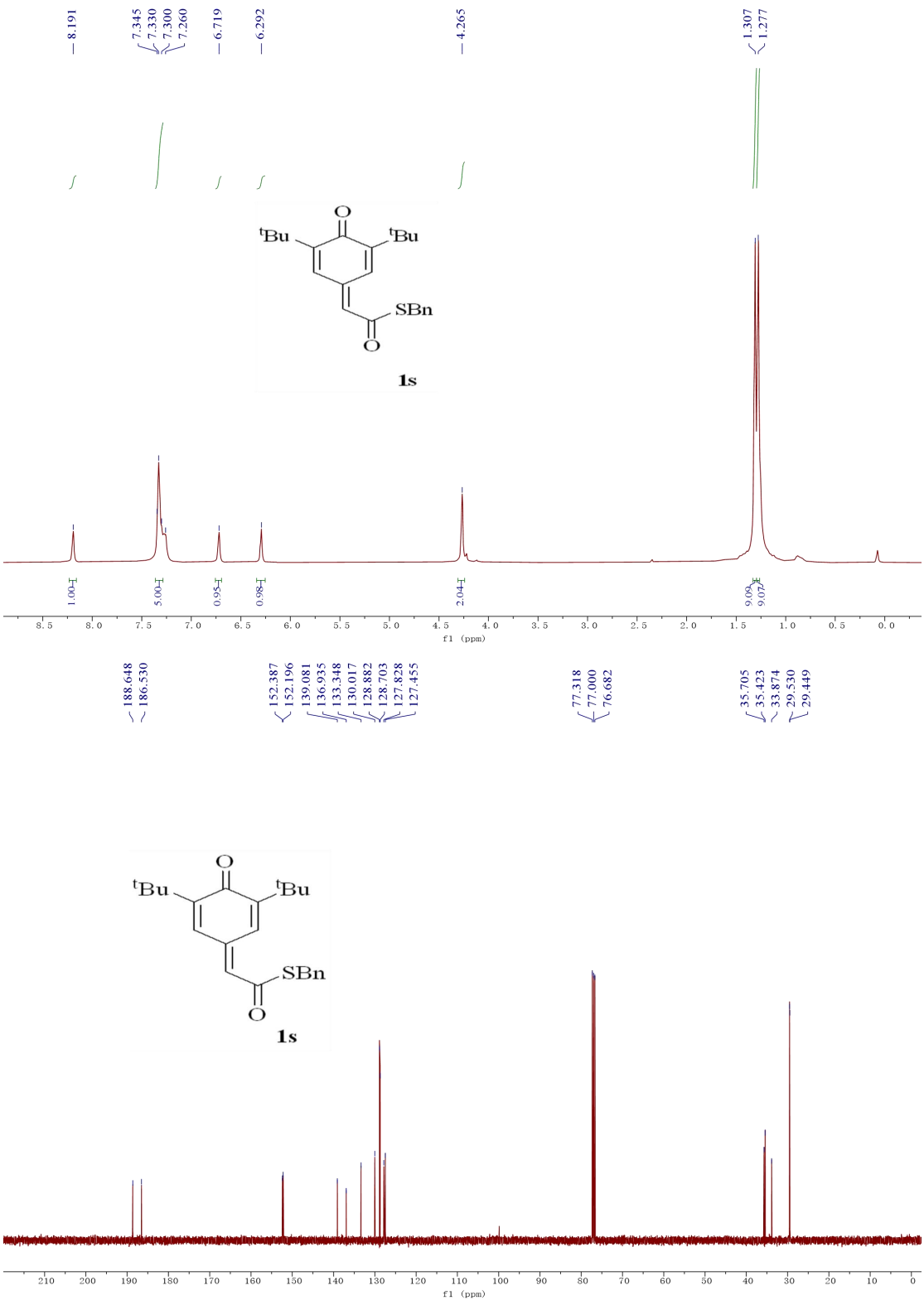


^{1}H and^{13}C NMR spectra of compound **1q**



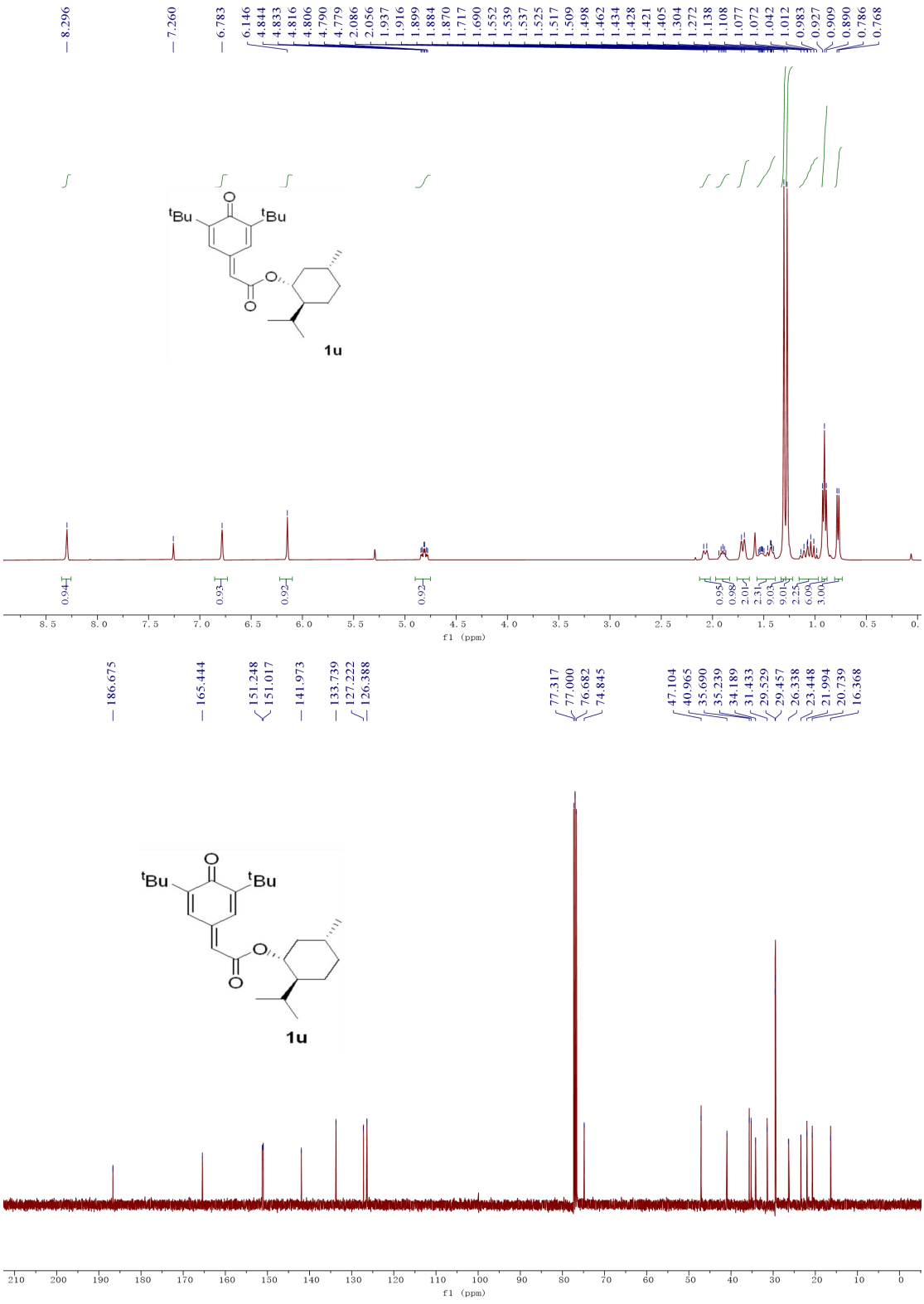


^{1}H and ^{13}C NMR spectra of compound **1r**

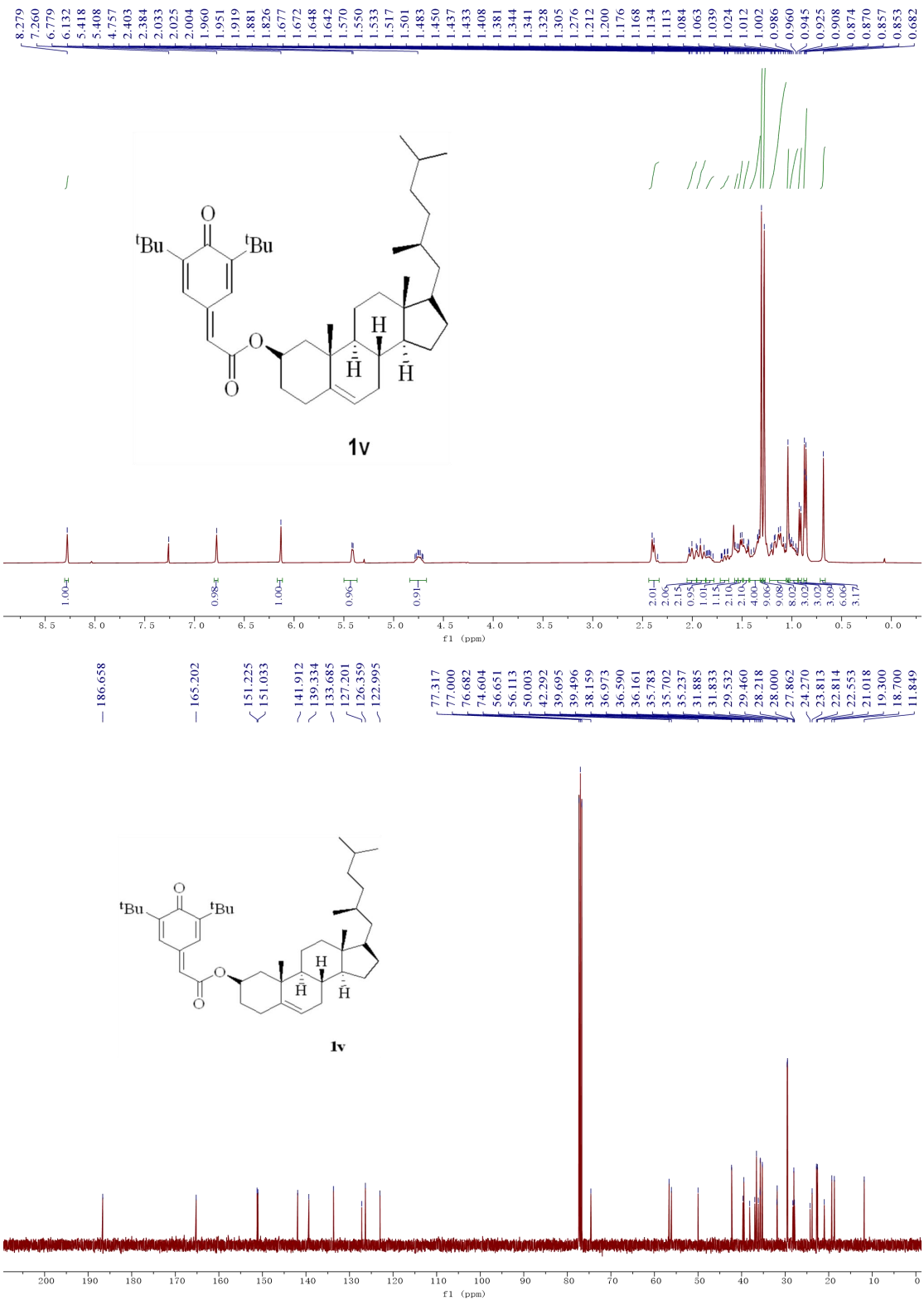


^{1}H and ^{13}C NMR spectra of compound **1s**

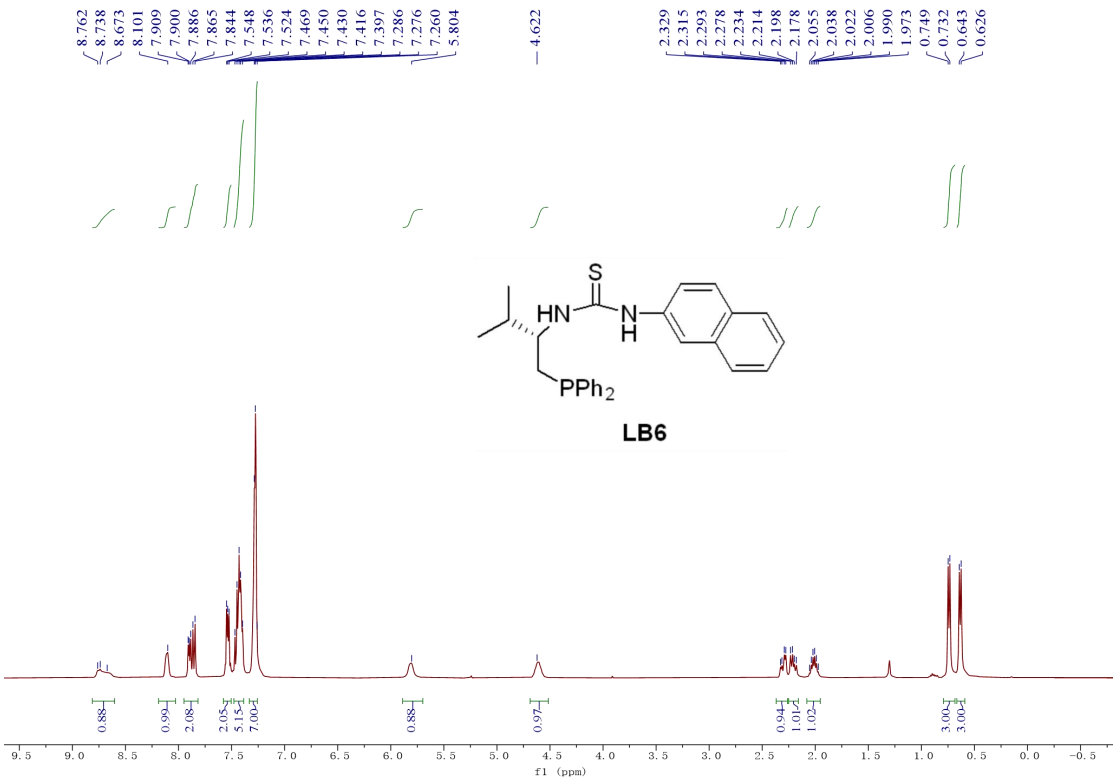
^{1}H and ^{13}C NMR spectra of compound **1t**



^{1}H and ^{13}C NMR spectra of compound **1u**



^{1}H and ^{13}C NMR spectra of compound **1v**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7.260
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2.293
2.278
2.234
2.214
2.198
2.178
2.055
2.038
2.022
2.006
1.990
1.973
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0.732
0.643
0.626
S
HN
N
H
PPh2
LB6
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0.99
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2.05
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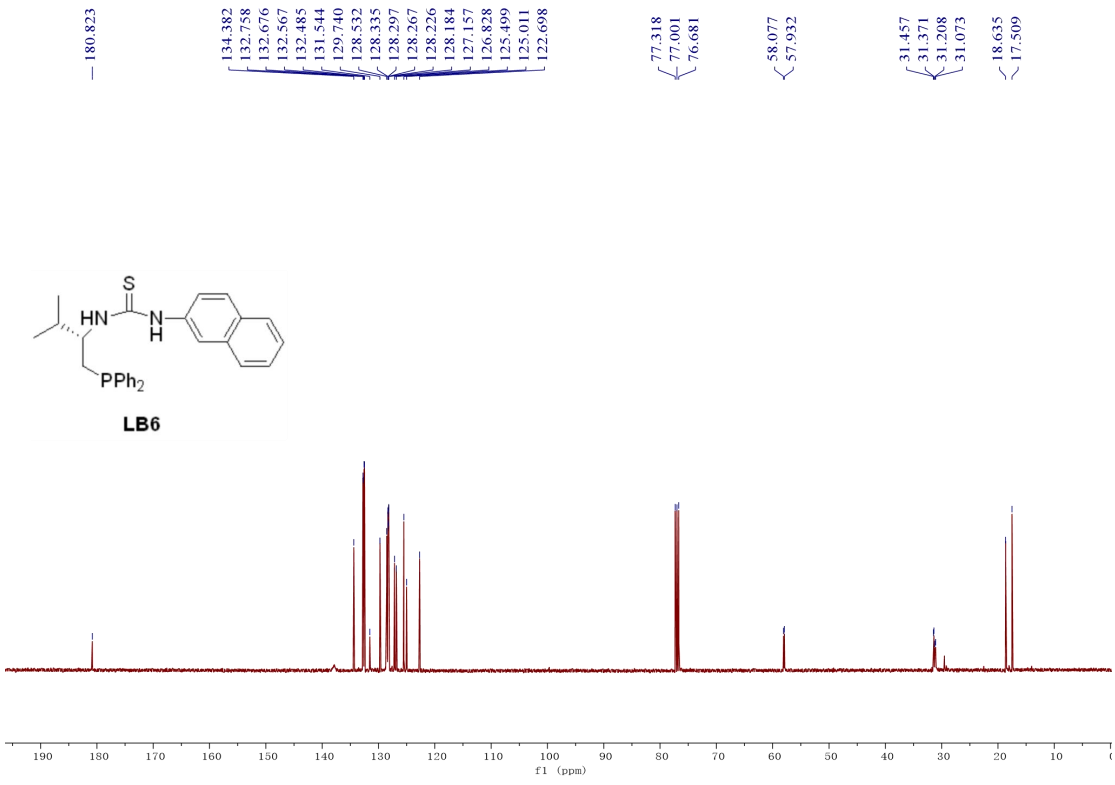
7.00
0.88
0.97
0.94
1.01
1.02
3.00
3.00
f1 (ppm)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128.335
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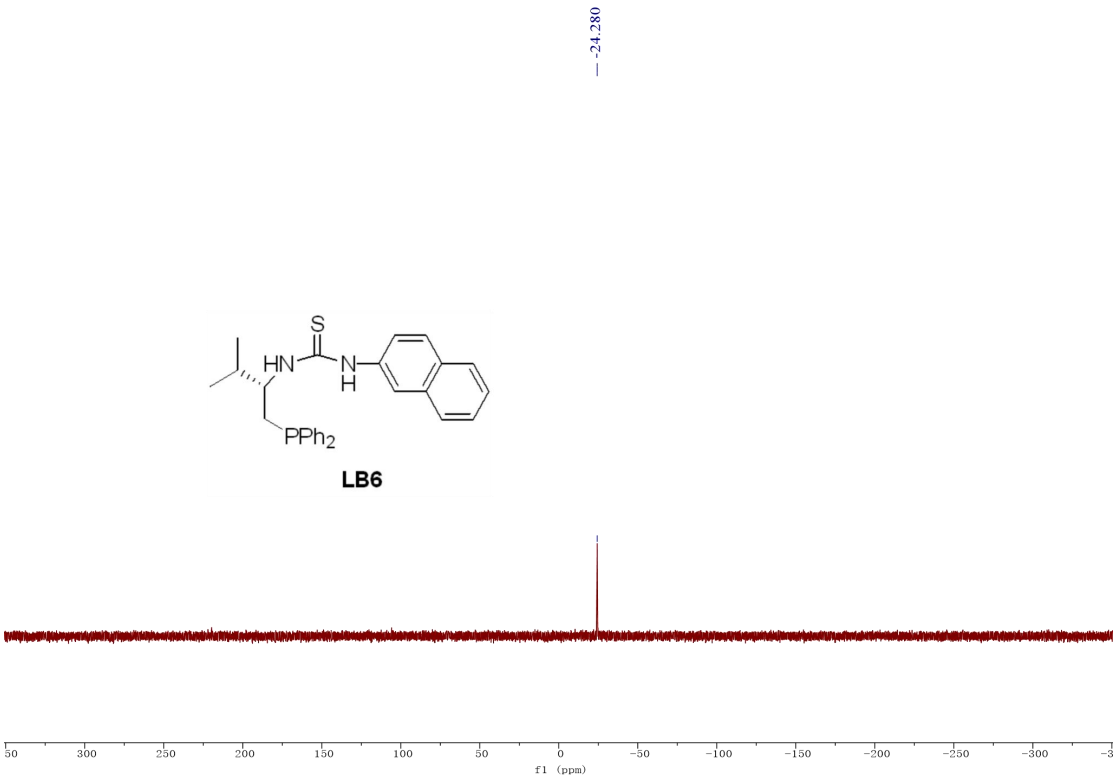
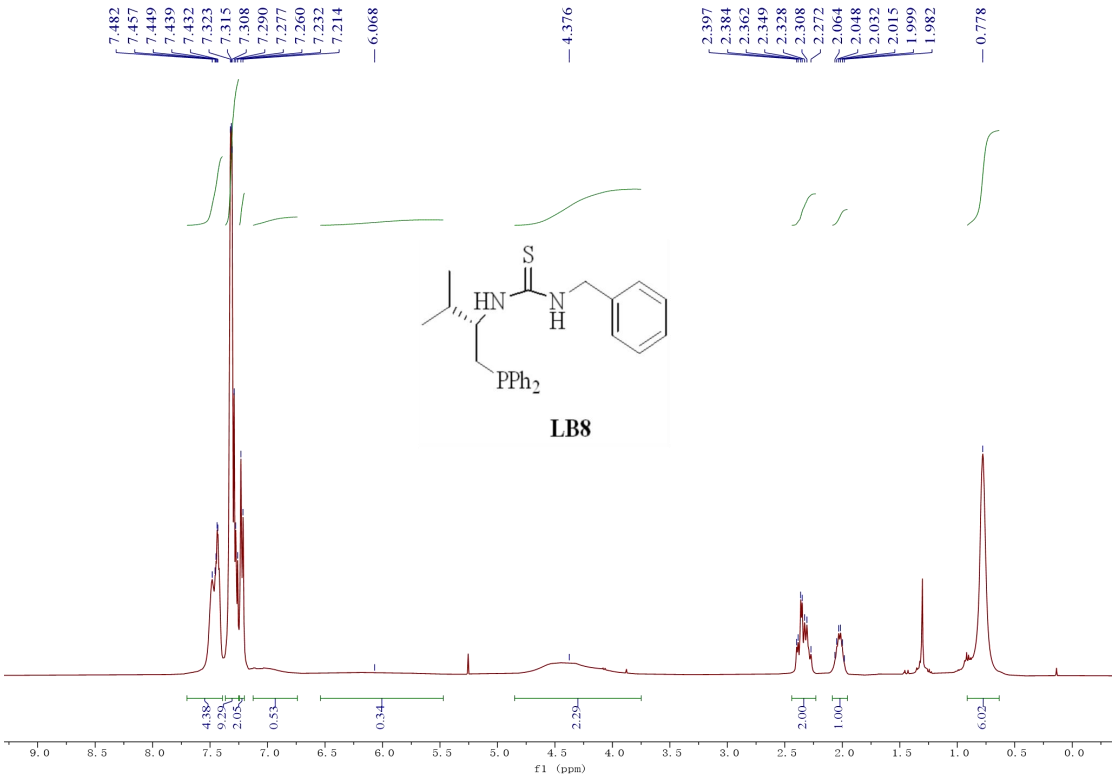
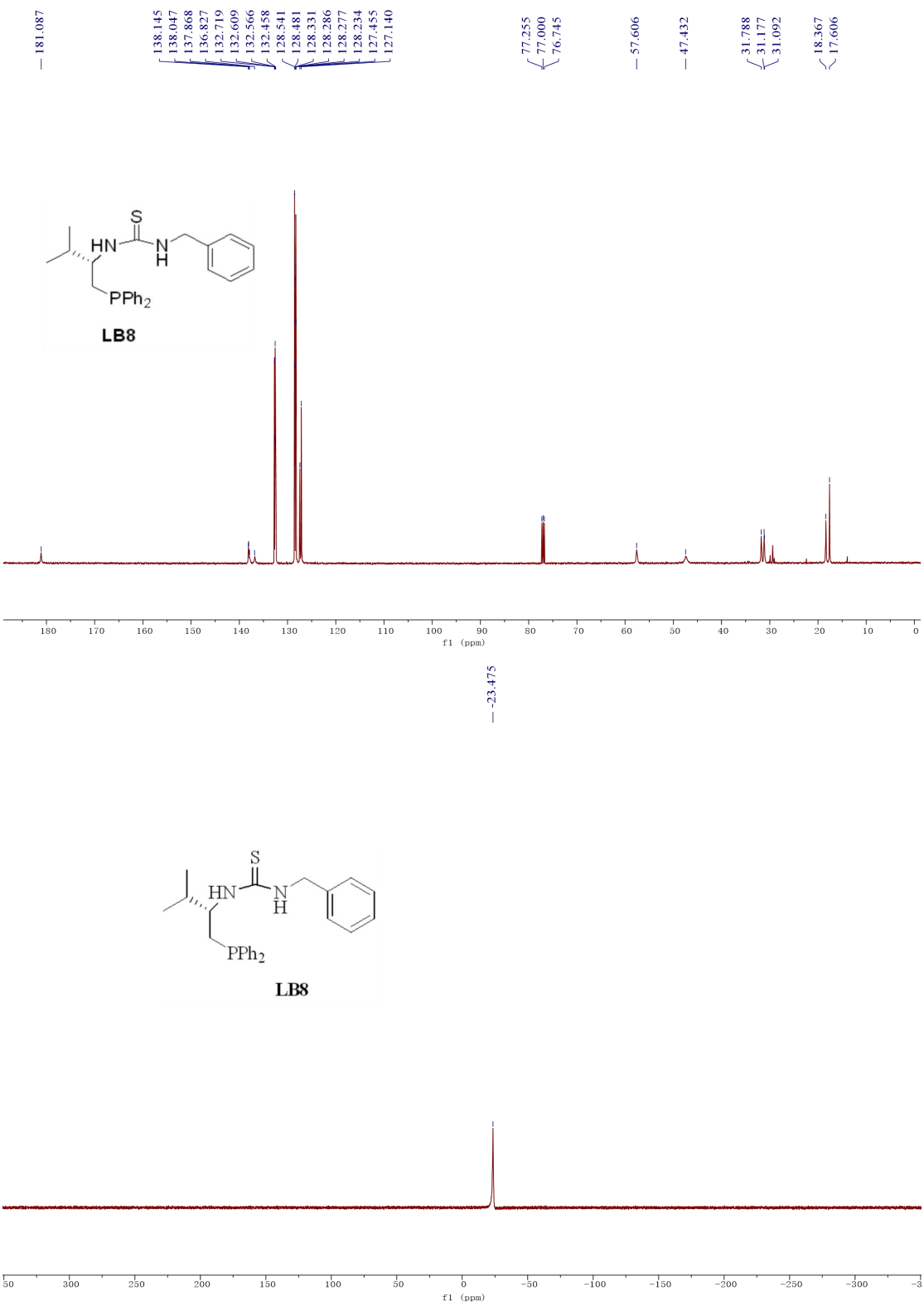
S
HN
N
H
PPh2
LB6
f1 (ppm)

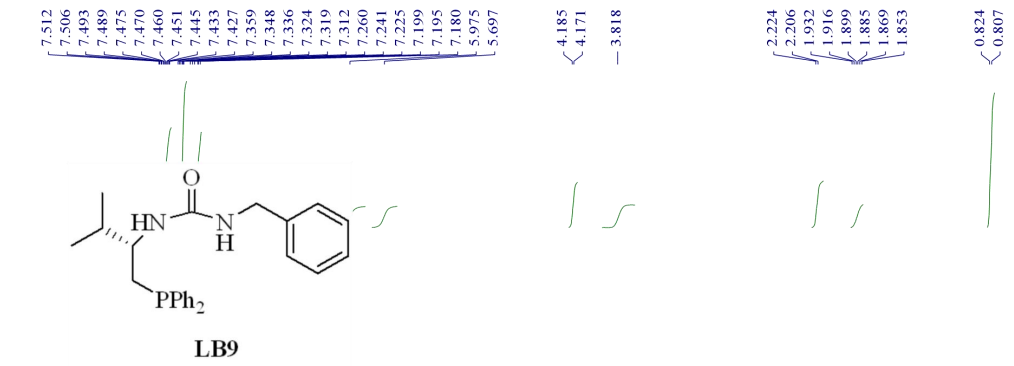


^{1}H, ^{13}C and ^{31}P NMR spectra of compound **LB6**





^{1}H, ^{13}C and ^{31}P NMR spectra of compound **LB8**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7.433
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7.348
7.336
7.324
7.319
7.312
7.260
7.241
7.225
7.199
7.195
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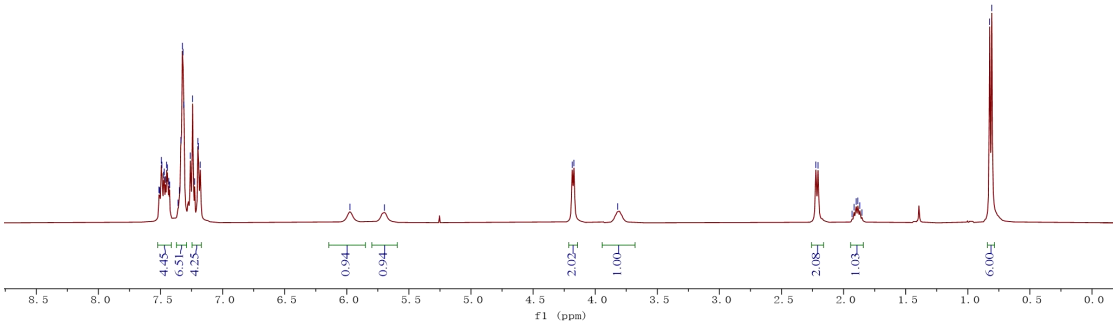
N
H
PPh2

LB9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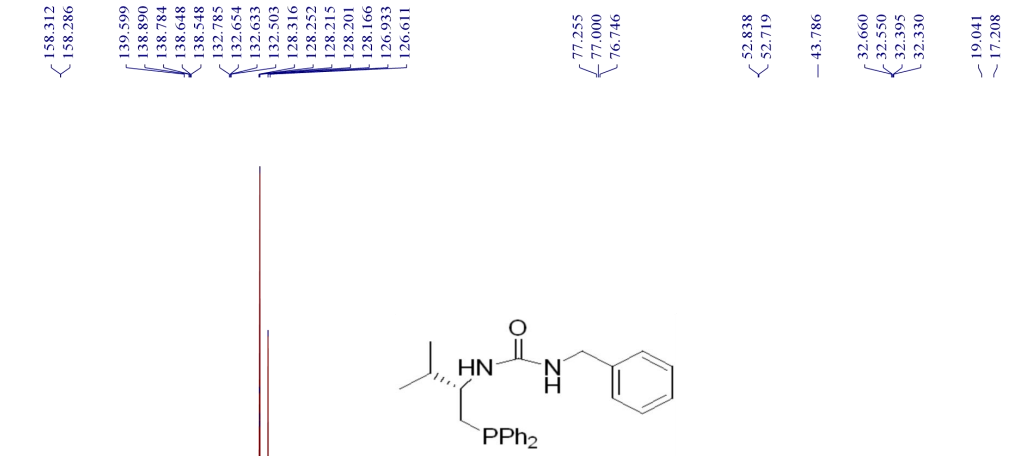
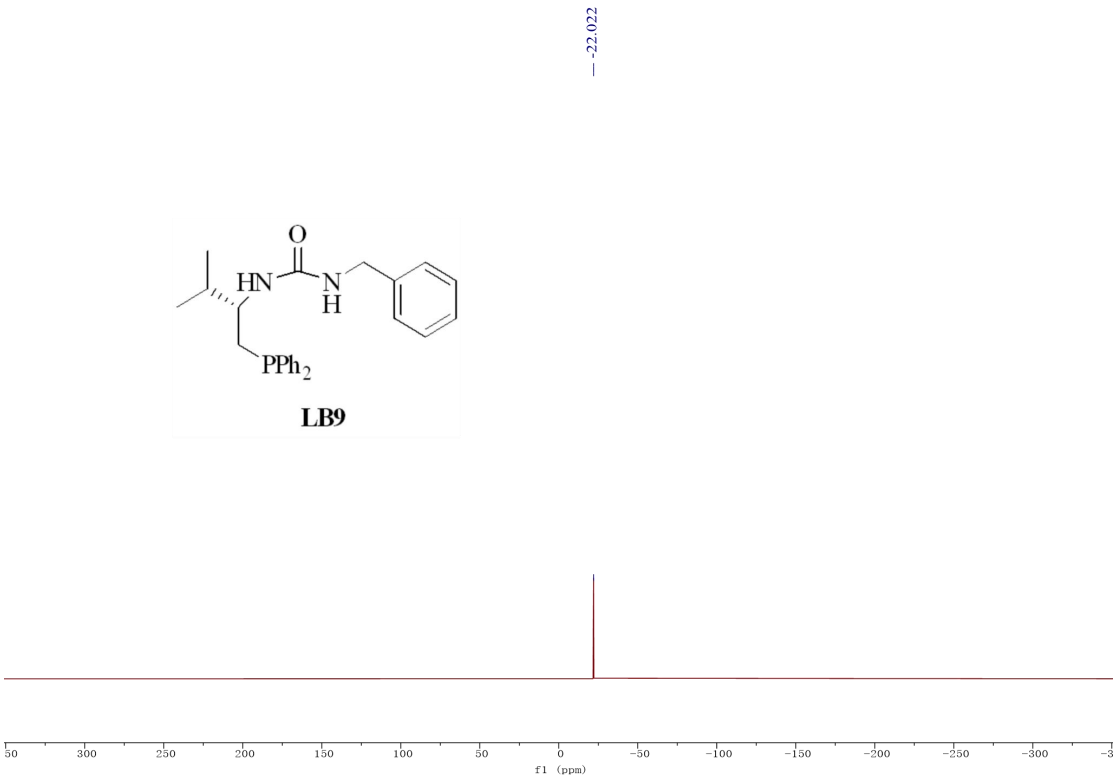
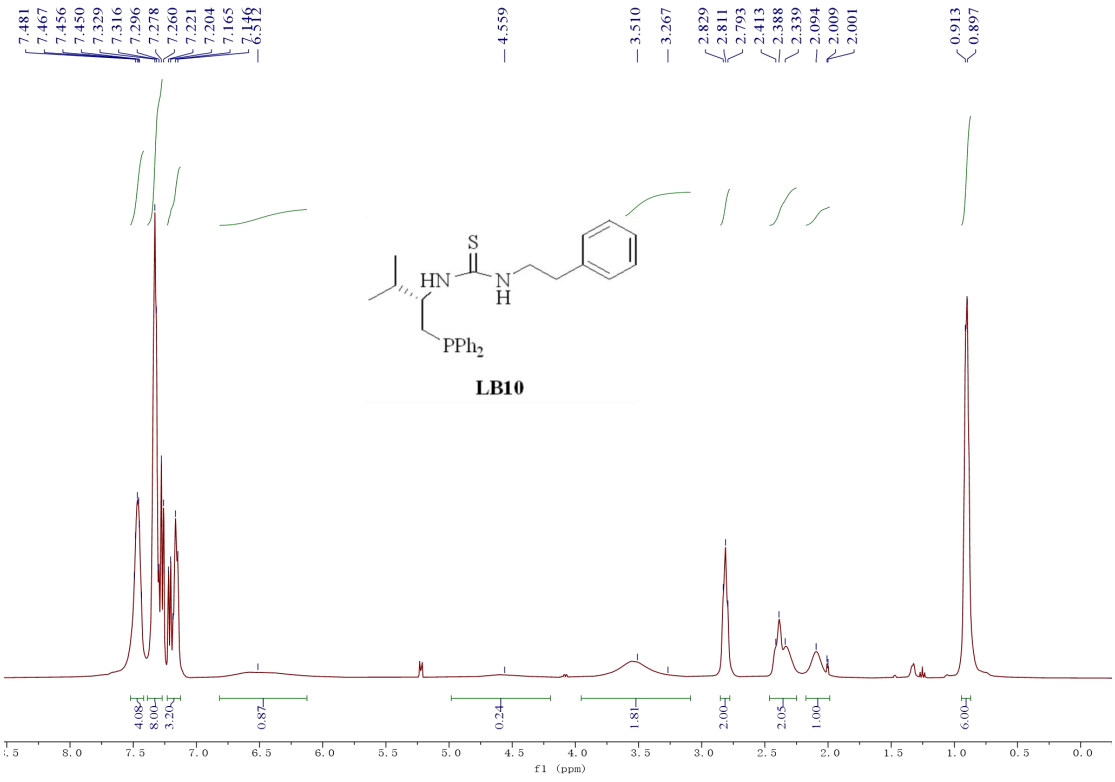
6.00
f1 (ppm)

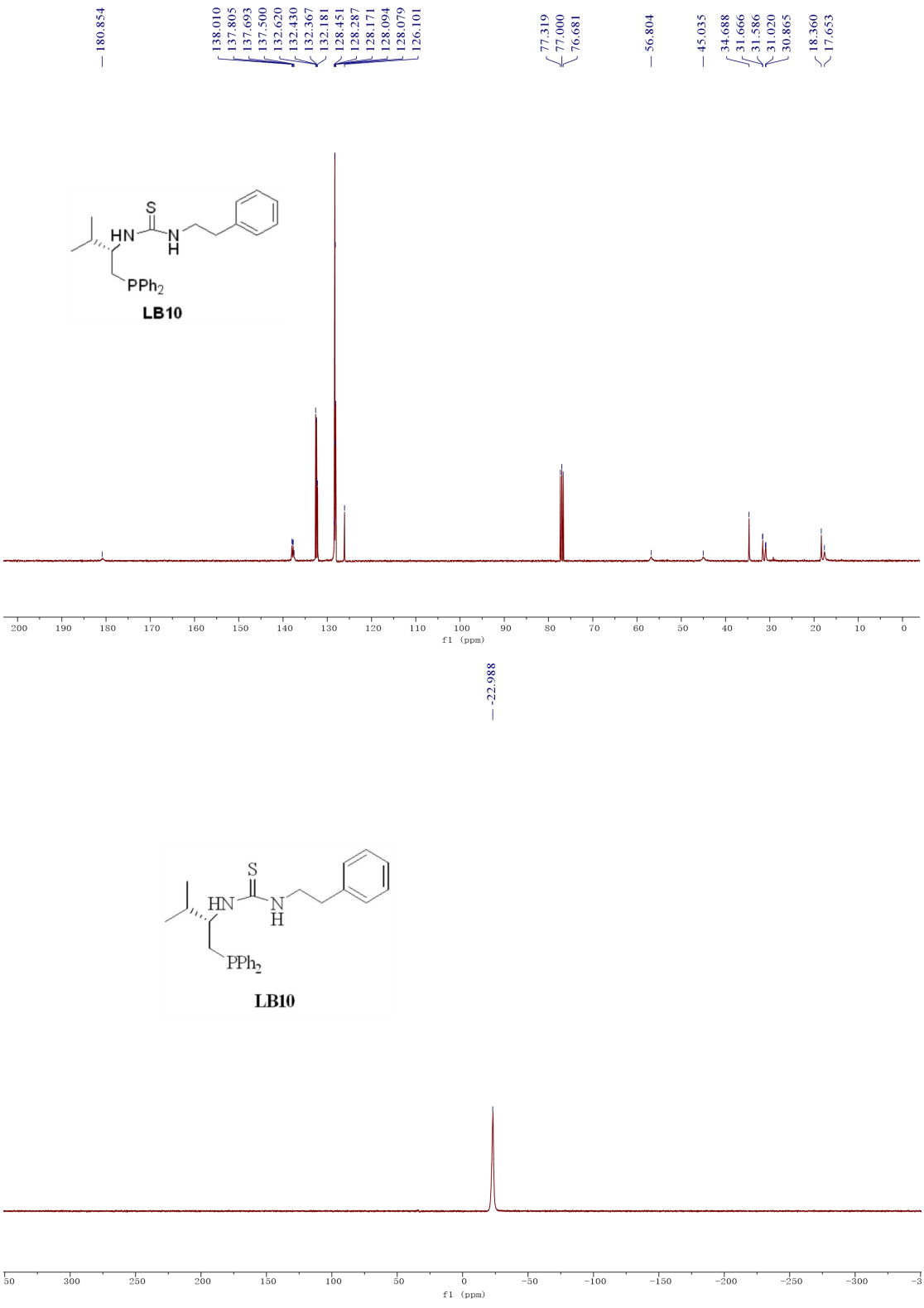

158.312
158.286
139.599
138.890
138.784
138.648
138.548
132.785
132.654
132.633
132.503
128.316
128.252
128.215
128.201
128.166
126.933
126.611
77.255
77.000
76.746
52.838
52.719
43.786
32.660
32.550
32.395
32.330
19.041
17.208
O
HN
N
H
PPh2
f1 (ppm)

LB9

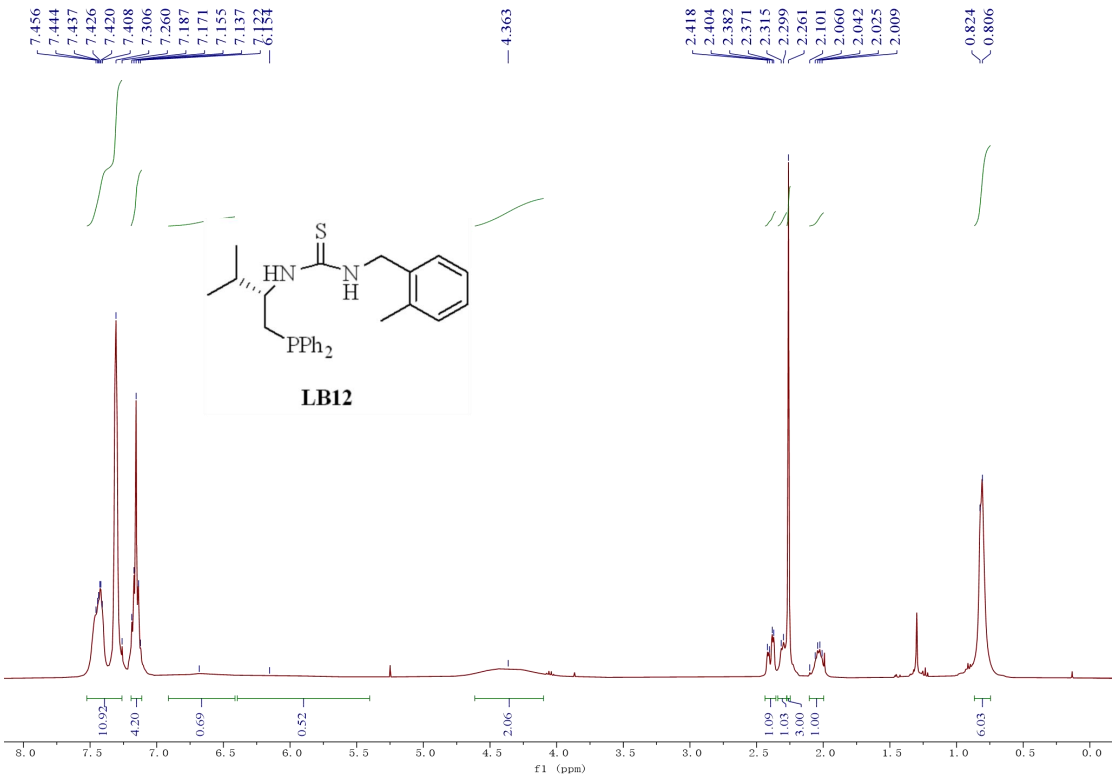


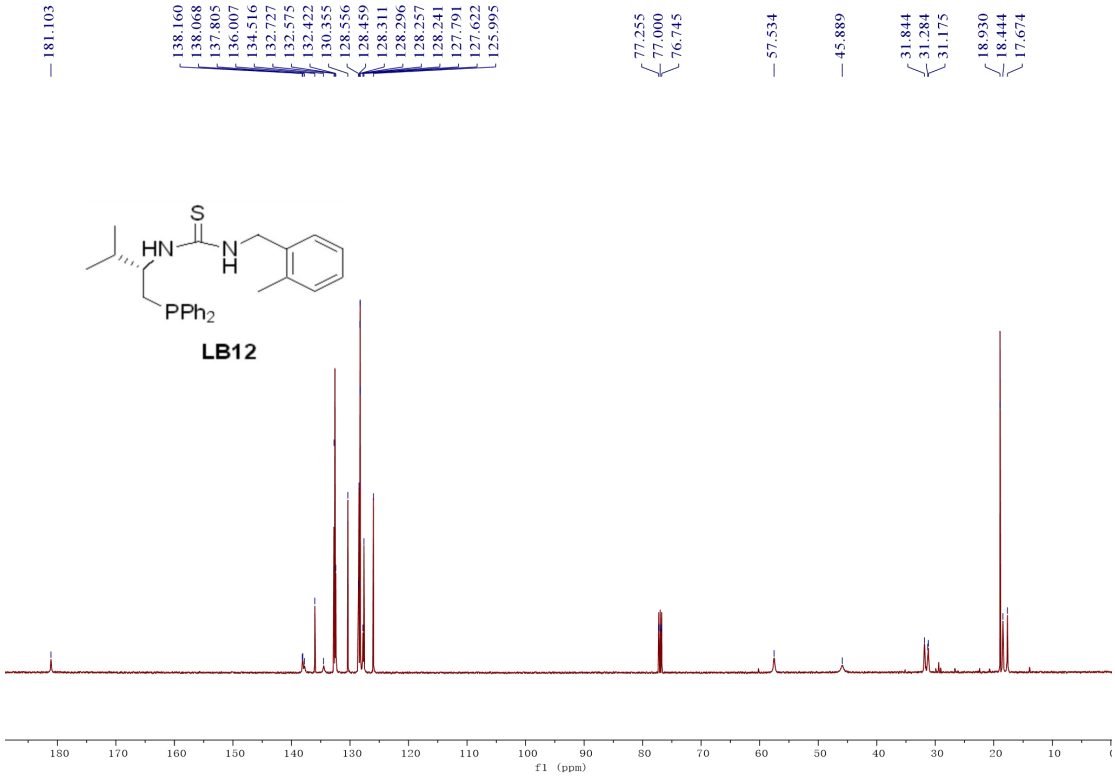
^{1}H, ^{13}C and ^{31}P NMR spectra of compound **LB9**

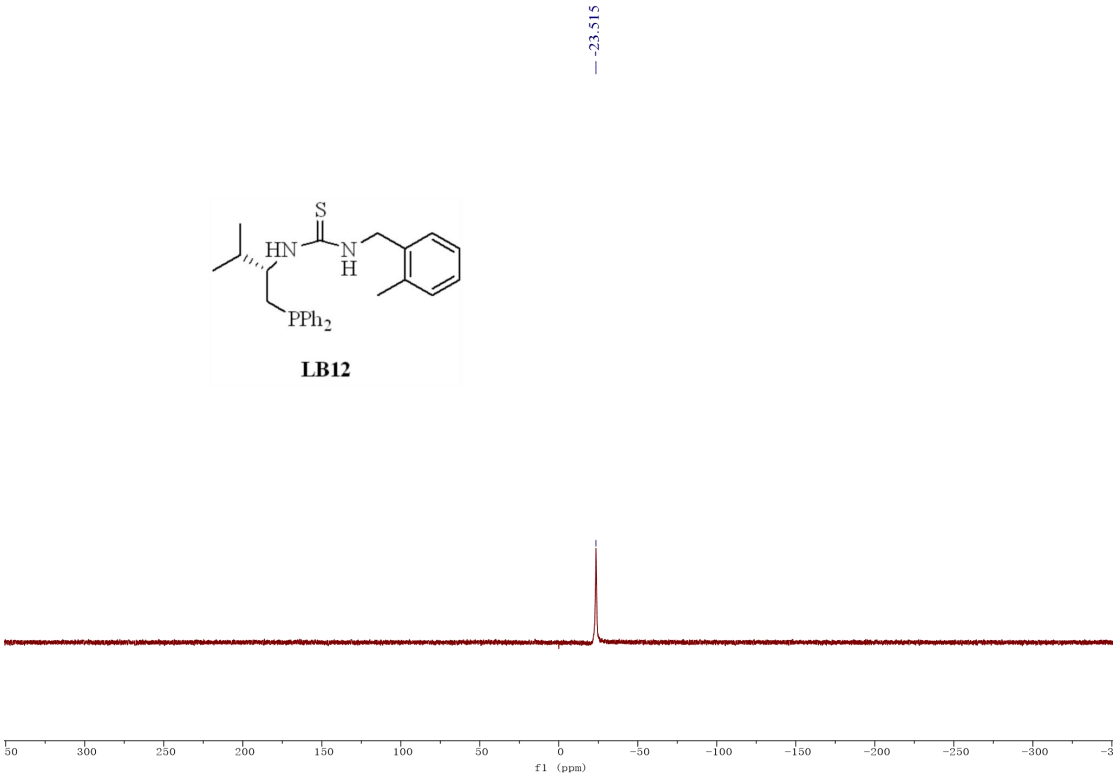




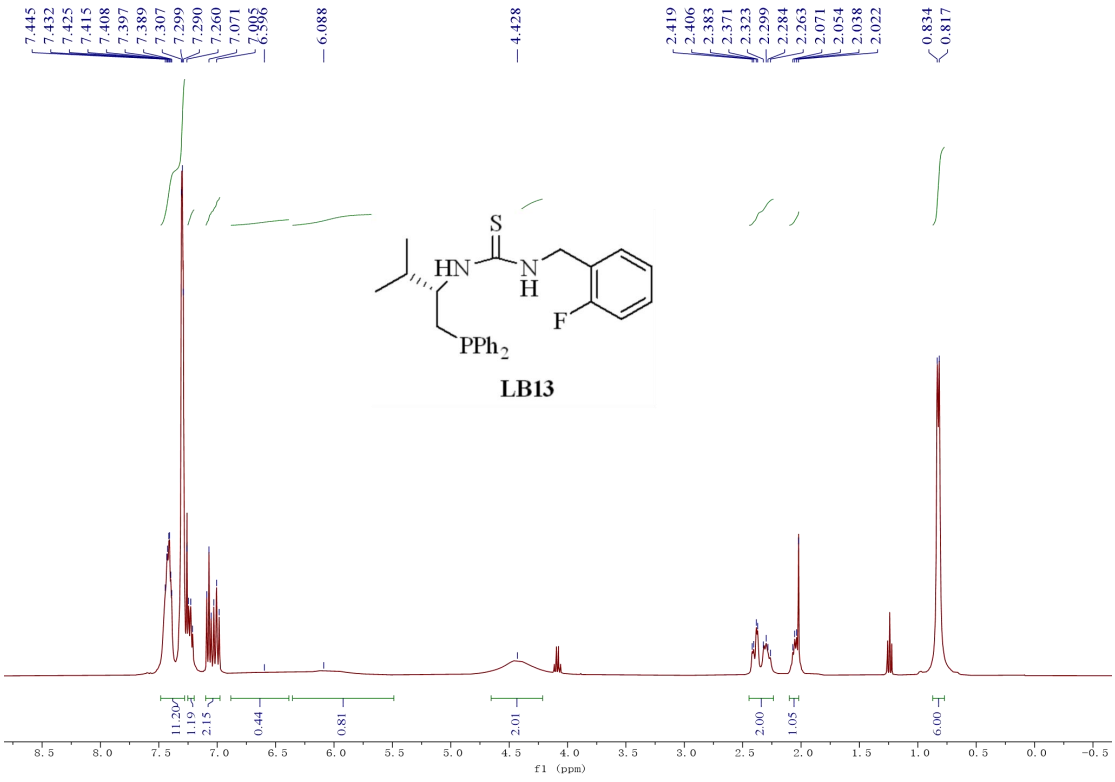
^{1}H, ^{13}C and ^{31}P NMR spectra of compound **LB10**

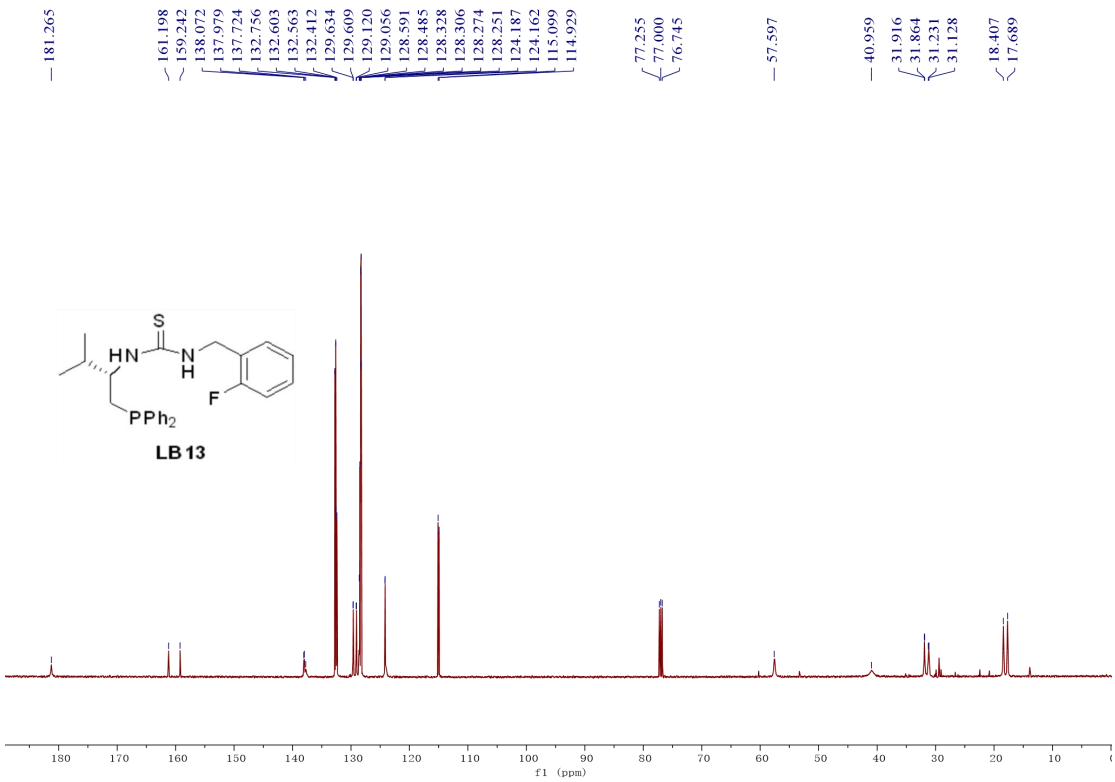

7.456
7.444
7.437
7.426
7.420
7.408
7.306
7.260
7.187
7.171
7.155
7.137
6.154
4.363
2.418
2.404
2.382
2.371
2.315
2.299
2.261
2.101
2.060
2.042
2.025
2.009
0.824
0.806
S
HN
N
H
PPh2
LB12
10.92
4.20
0.69
0.52
2.06
1.09
1.03
3.00
1.00
6.03
f1 (ppm)

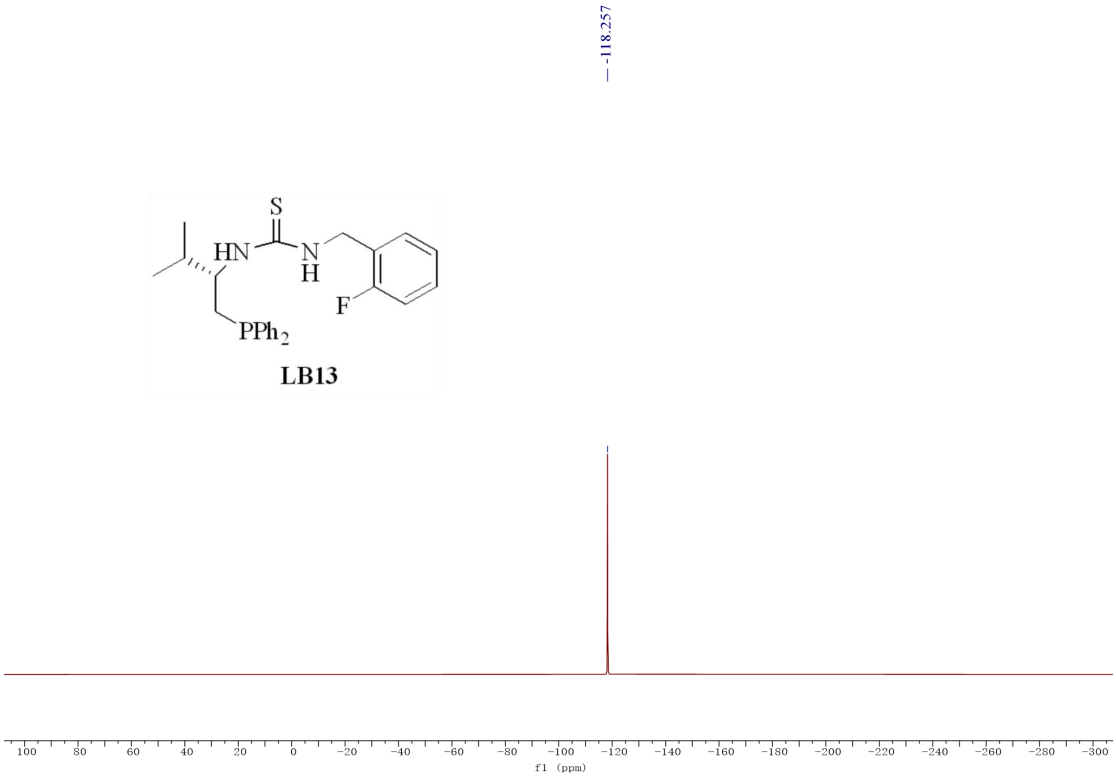

181.103
138.160
138.068
137.805
136.007
134.516
132.727
132.575
132.422
130.355
128.556
128.459
128.311
128.296
128.257
128.241
127.791
127.622
125.995
77.255
77.000
76.745
57.534
45.889
31.844
31.284
31.175
18.930
18.444
17.674
S
HN
N
H
PPh2
LB12
f1 (ppm)

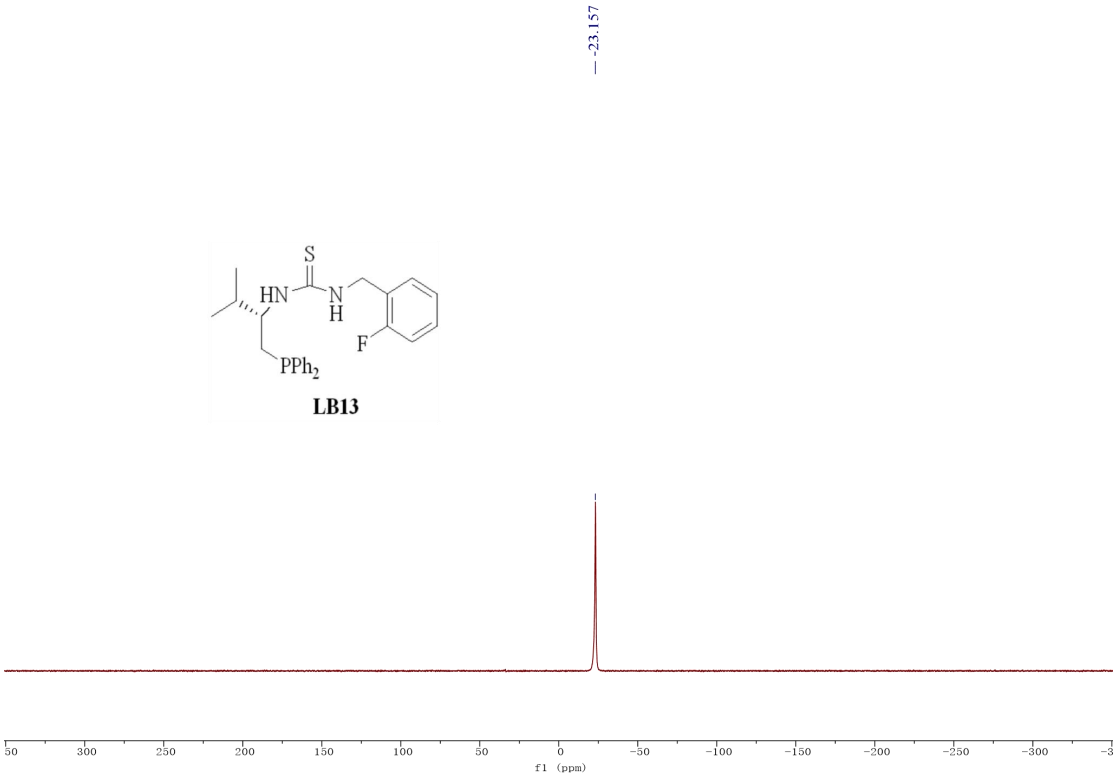


^{1}H, ^{13}C and ^{31}P NMR spectra of compound **LB12**

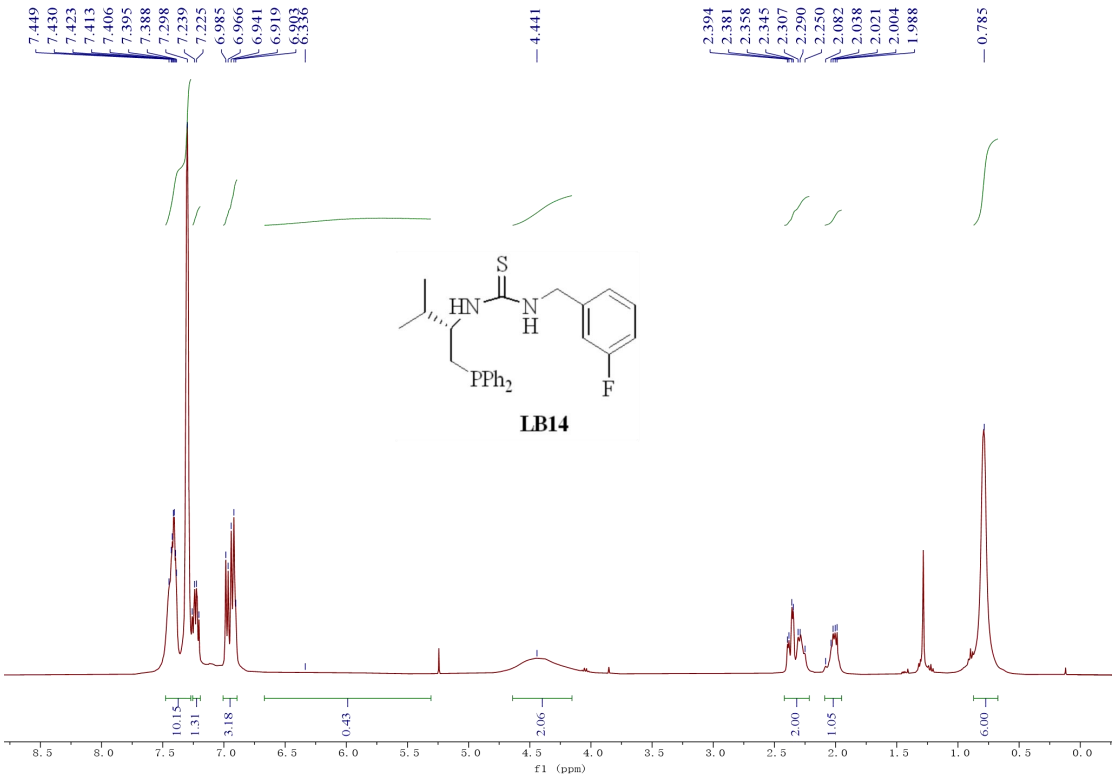


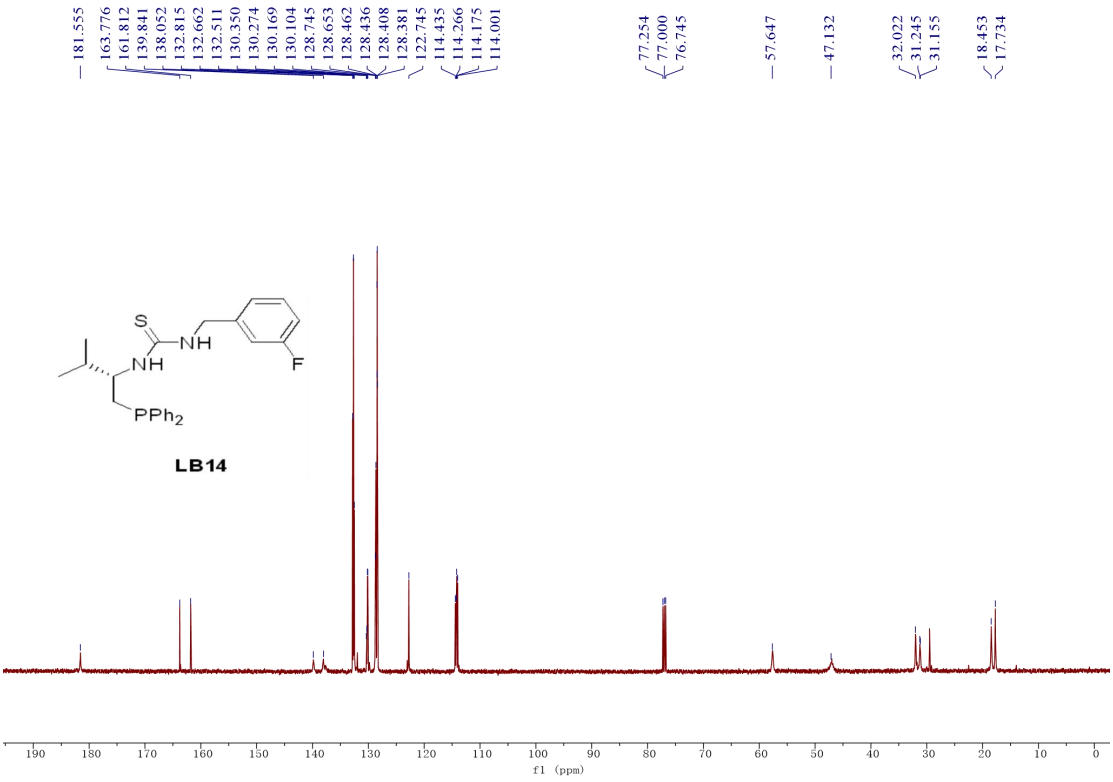

181.265
161.198
159.242
138.072
137.979
137.724
132.756
132.603
132.563
132.412
129.634
129.609
129.120
129.056
128.591
128.485
128.328
128.306
128.274
128.251
124.187
124.162
115.099
114.929
77.255
77.000
76.745
57.597
40.959
31.916
31.864
31.231
31.128
18.407
17.689
LB13
f1 (ppm)

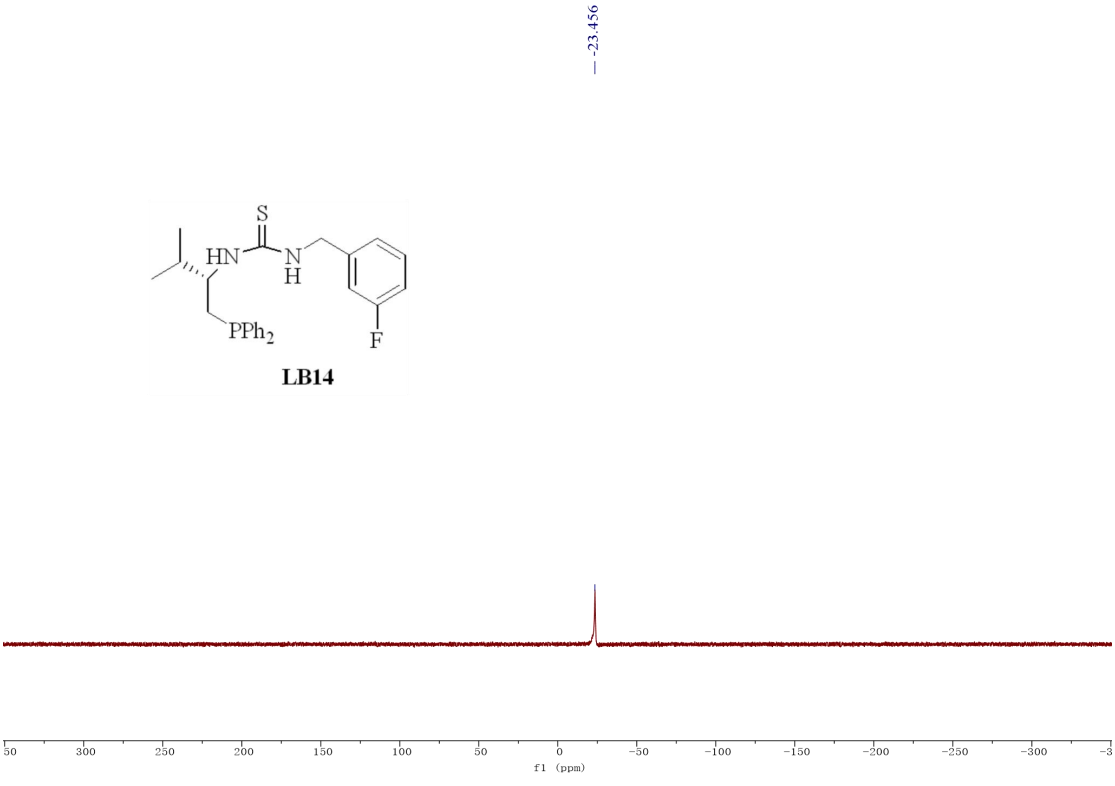

-118.257
LB13
f1 (ppm)

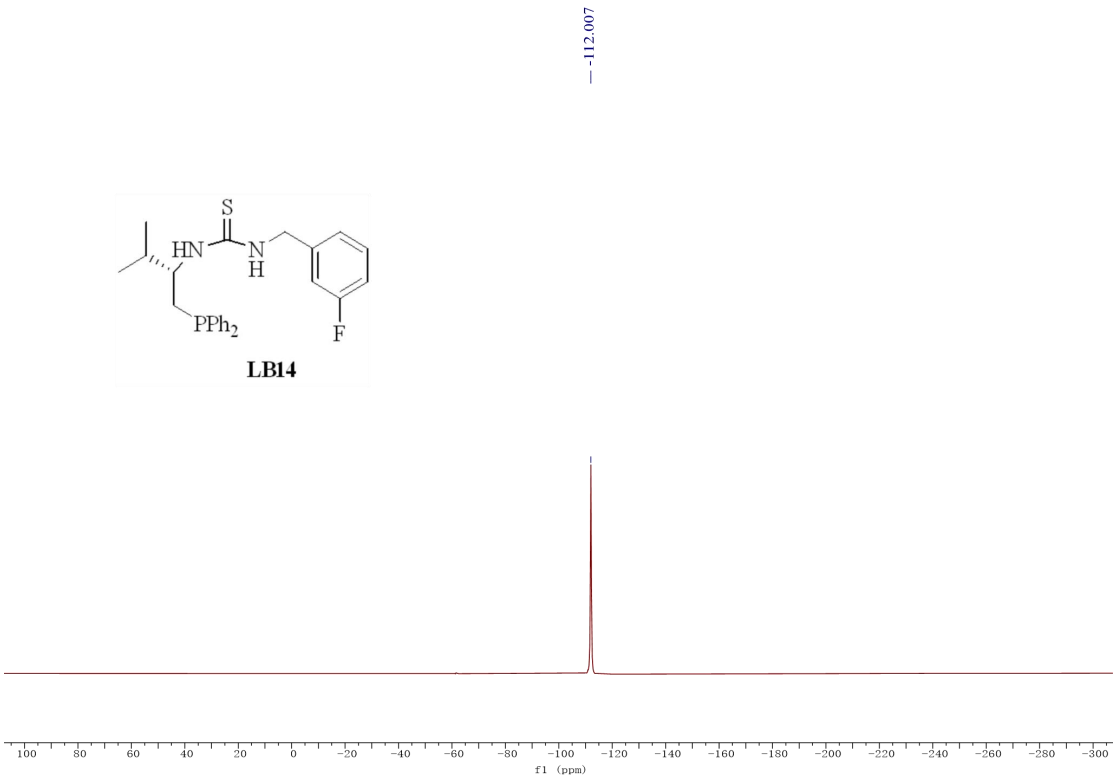


^{1}H, ^{13}C, ^{19}F and ^{31}P NMR spectra of compound **LB13**

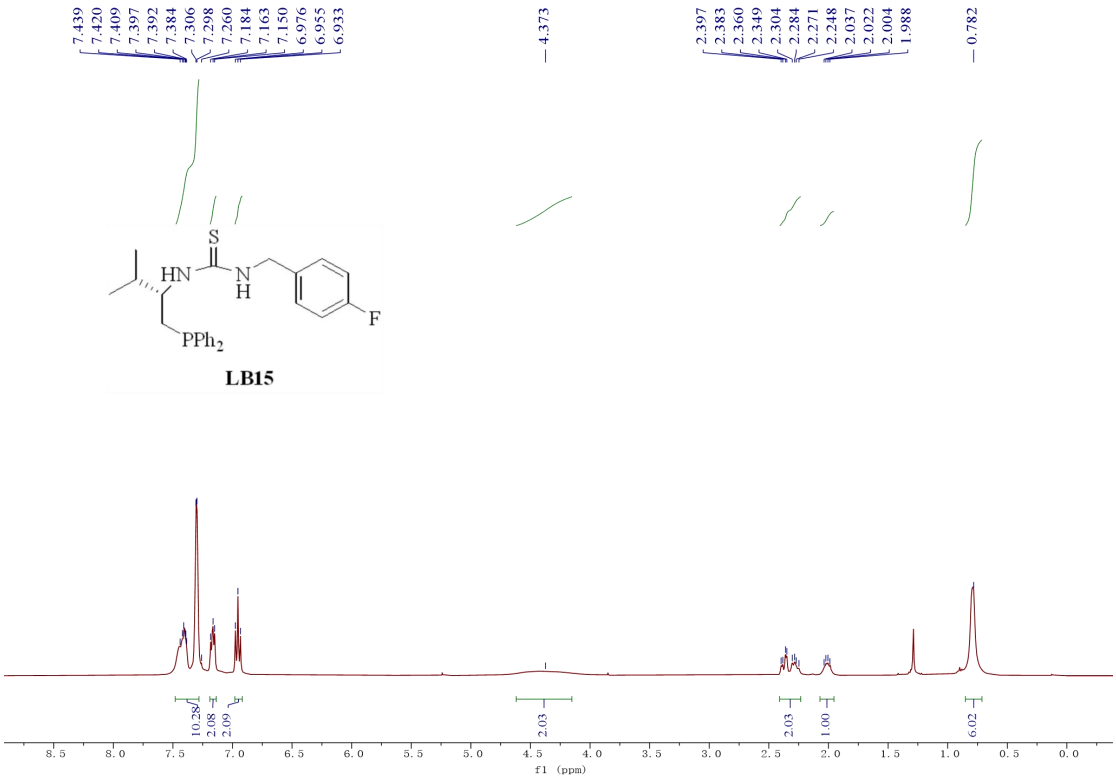


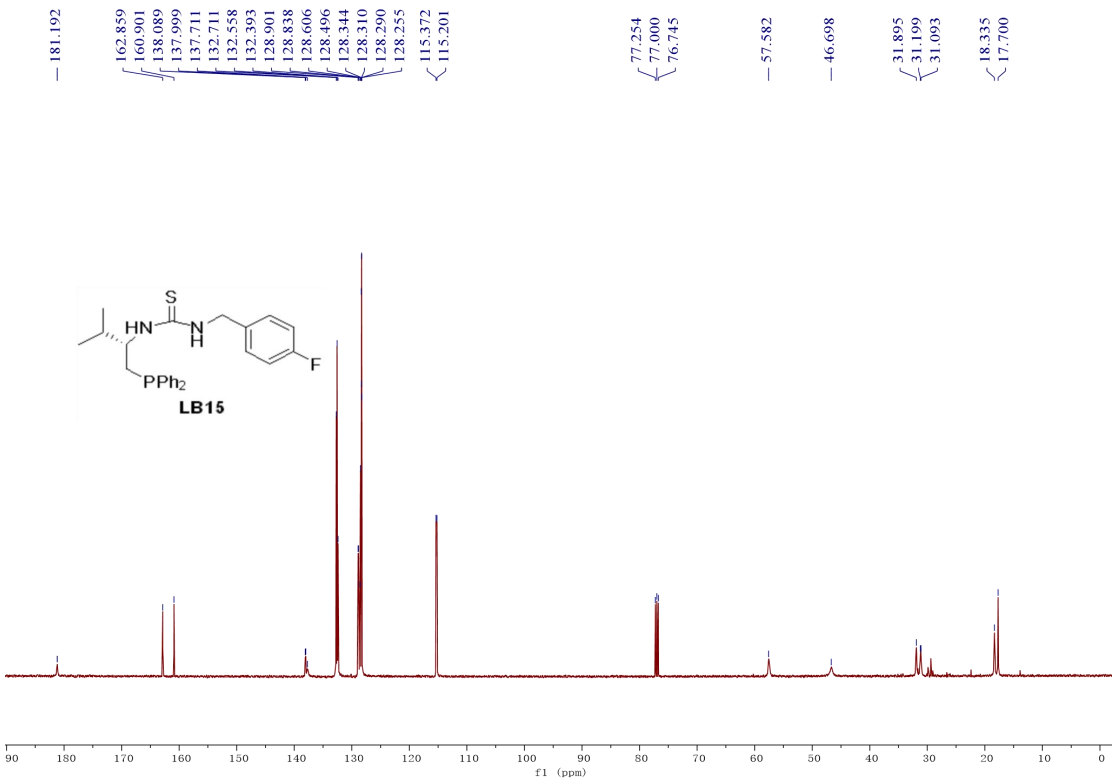

181.555
163.776
161.812
139.841
138.052
132.815
132.662
132.511
130.350
130.274
130.169
130.104
128.745
128.653
128.462
128.436
128.408
128.381
122.745
114.435
114.266
114.175
114.001
77.254
77.000
76.745
57.647
47.132
32.022
31.245
31.155
18.453
17.734
S
NH
NH
F
PPh2
LB14
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

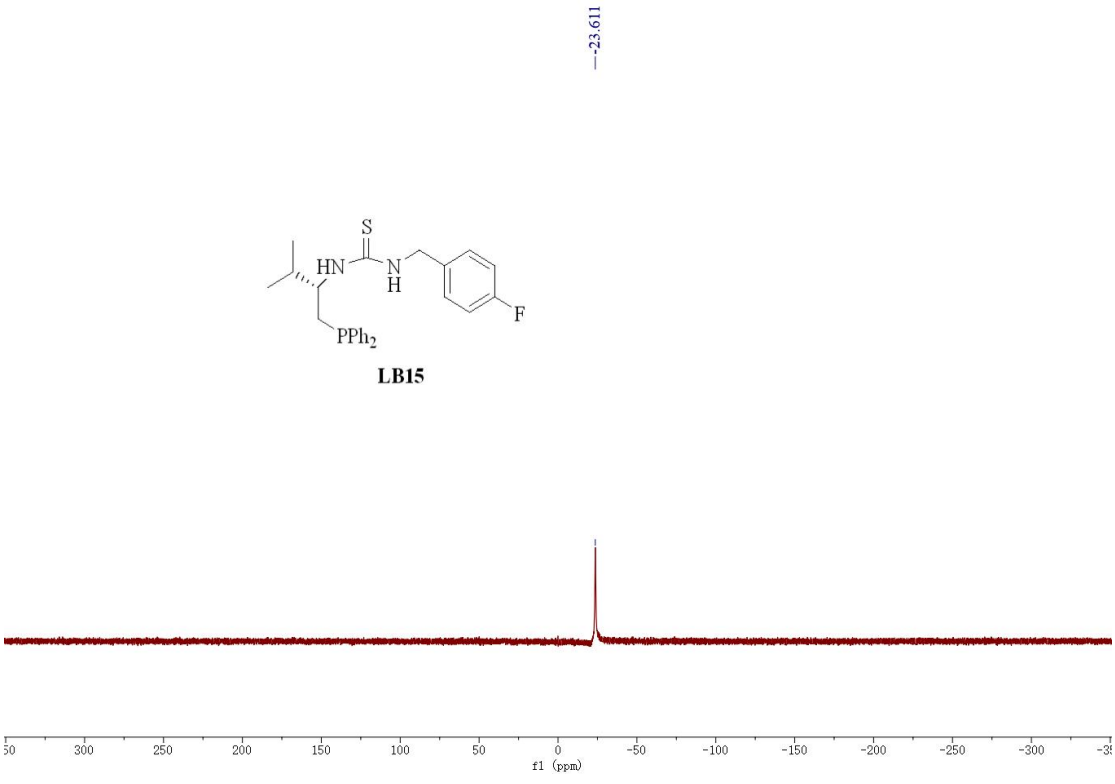

-23.456
S
HN
N
H
PPh2
F
LB14
50
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-3
f1 (ppm)

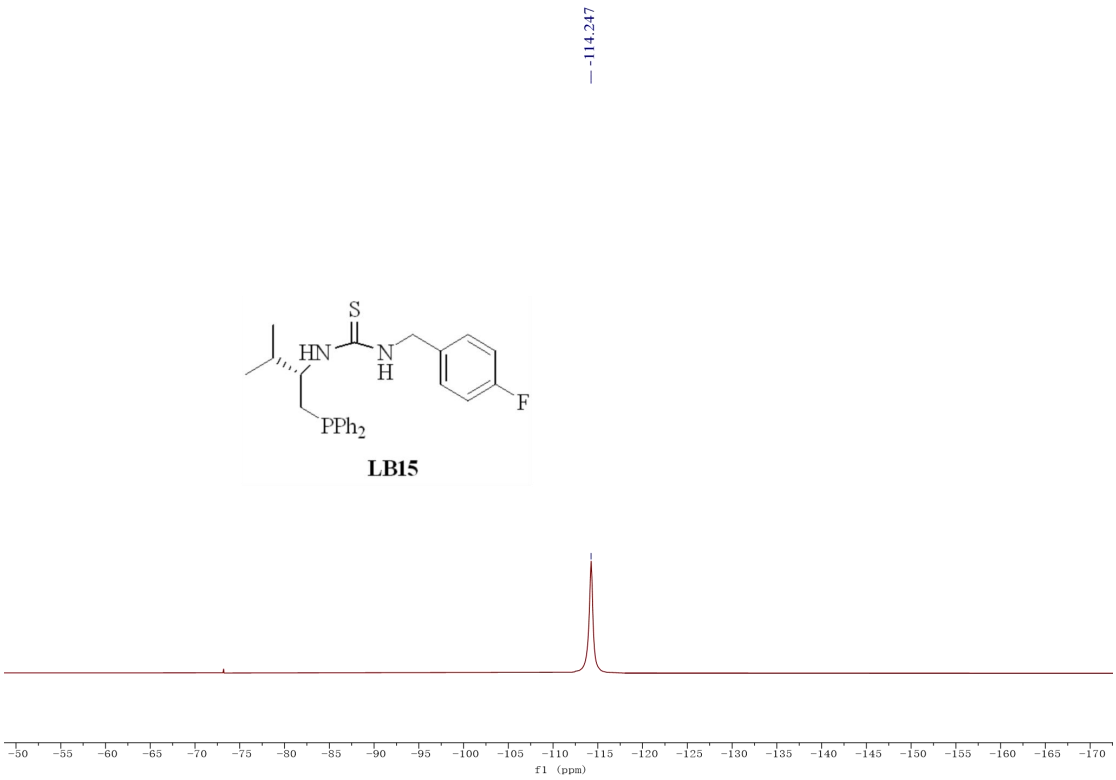


^{1}H, ^{13}C, ^{31}P and ^{19}F NMR spectra of compound **LB14**

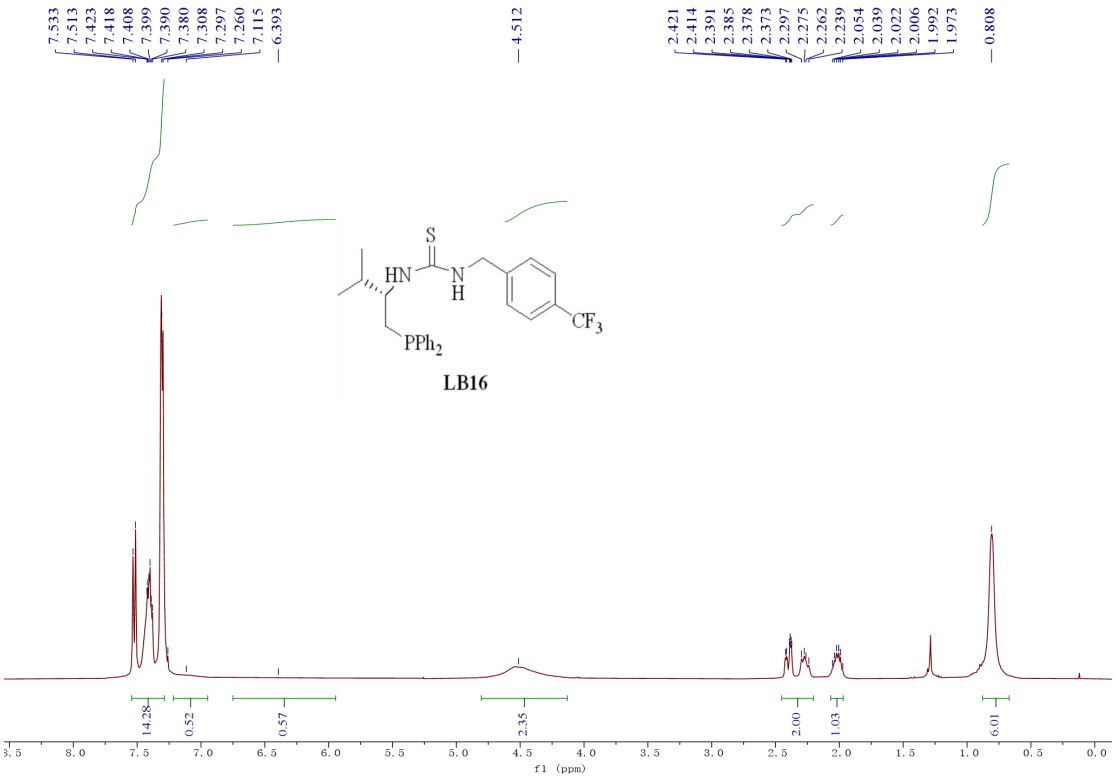


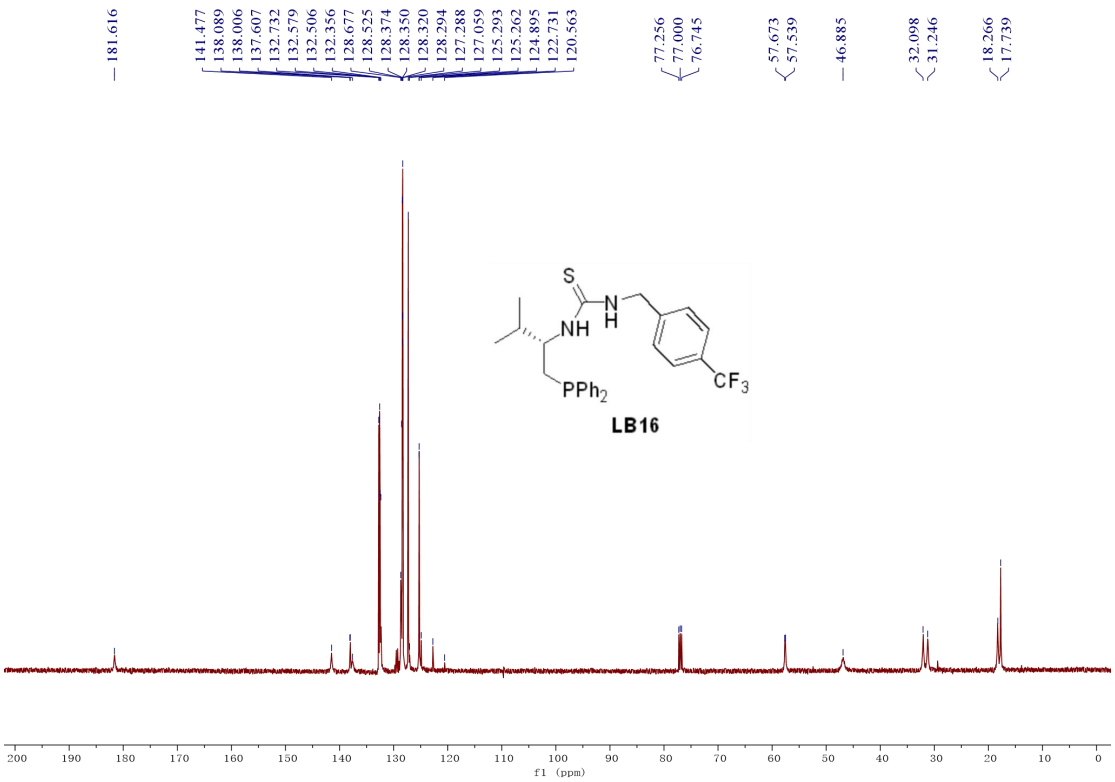

181.192
162.859
160.901
138.089
137.999
137.711
132.711
132.558
132.393
128.901
128.838
128.606
128.496
128.344
128.310
128.290
128.255
115.372
115.201
77.254
77.000
76.745
57.582
46.698
31.895
31.199
31.093
18.335
17.700
HN
S
N
H
F
PPh2
LB15
f1 (ppm)

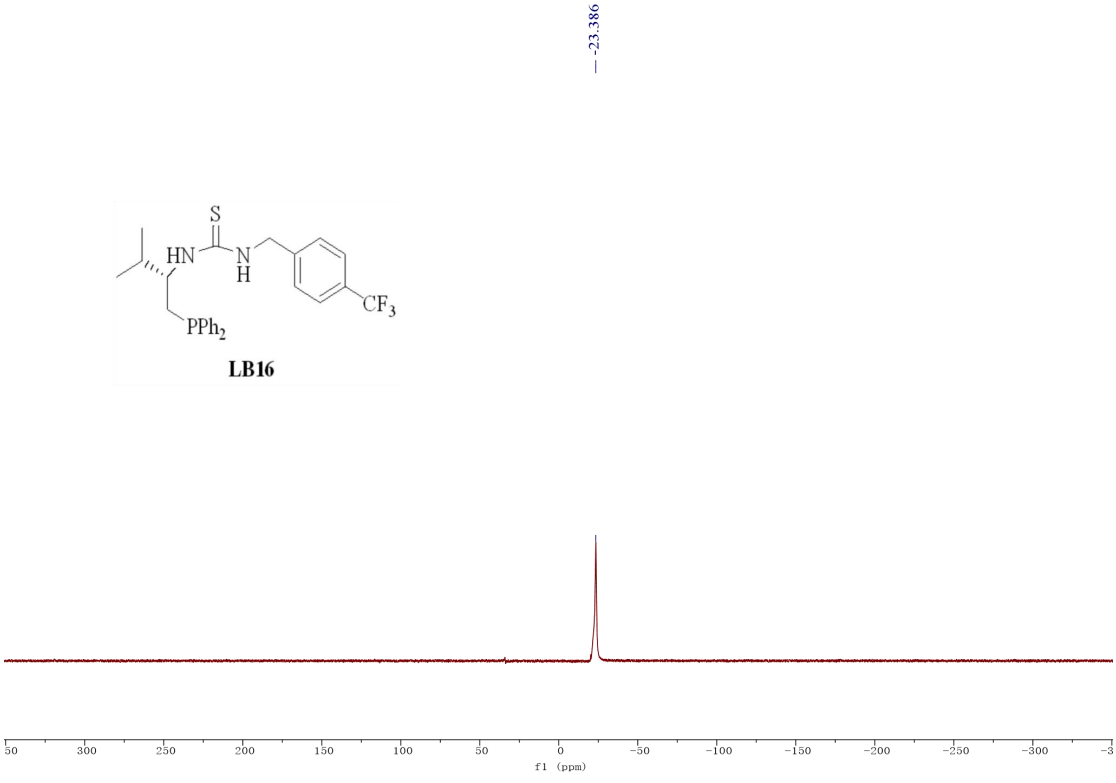

-23.611
HN
S
N
H
F
PPh2
LB15
f1 (ppm)

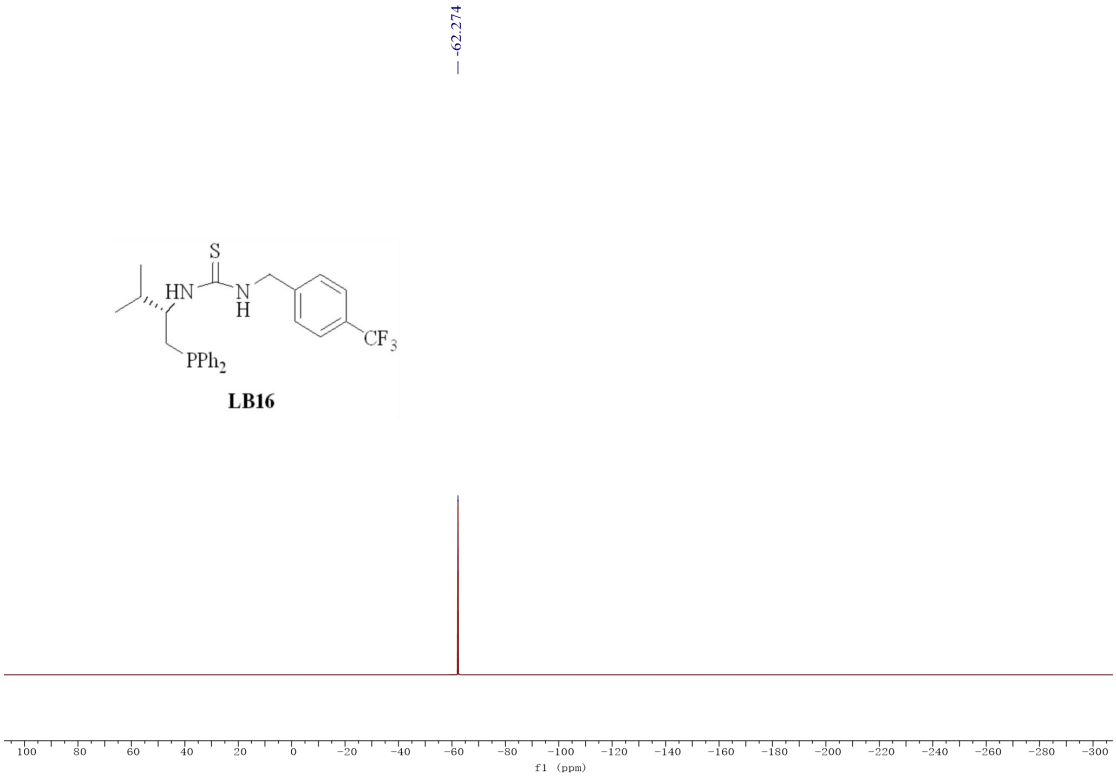


^{1}H, ^{13}C, ^{31}P and ^{19}F NMR spectra of compound **LB15**

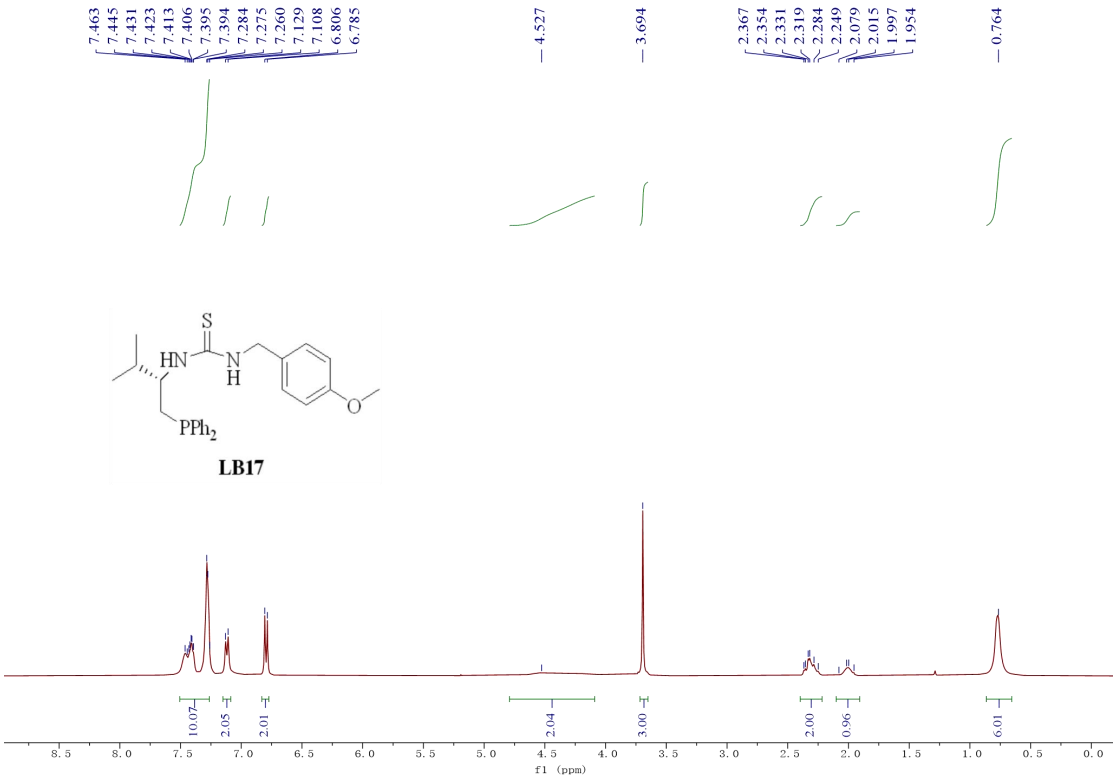


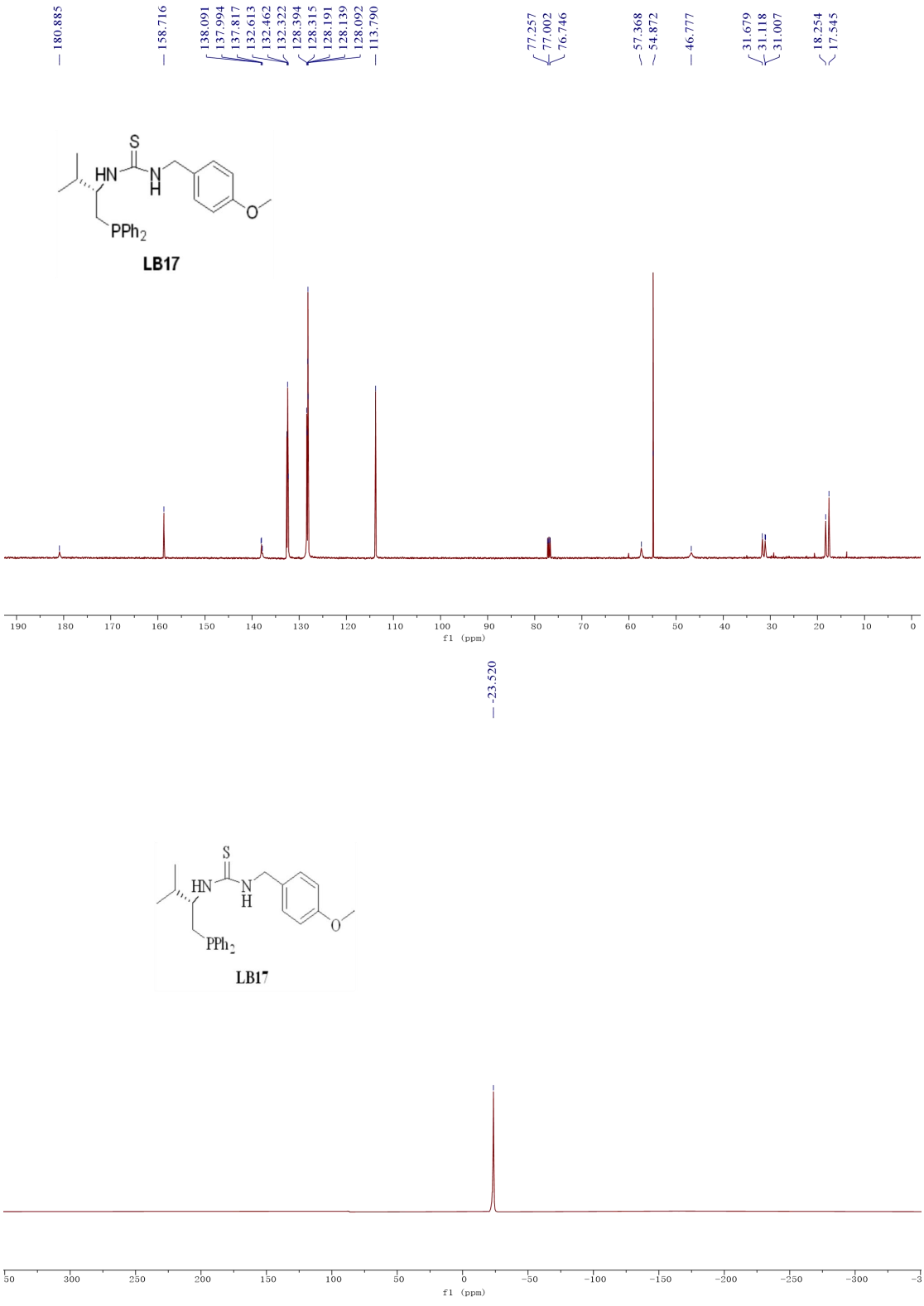

181.616
141.477
138.089
138.006
137.607
132.732
132.579
132.506
132.356
128.677
128.525
128.374
128.350
128.320
128.294
127.288
127.059
125.293
125.262
124.895
122.731
120.563
77.256
77.000
76.745
57.673
57.539
46.885
32.098
31.246
18.266
17.739
S
N
H
NH
PPh2
CF3
LB16
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


-23.386
S
HN
N
H
PPh2
CF3
LB16
50
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-3
f1 (ppm)

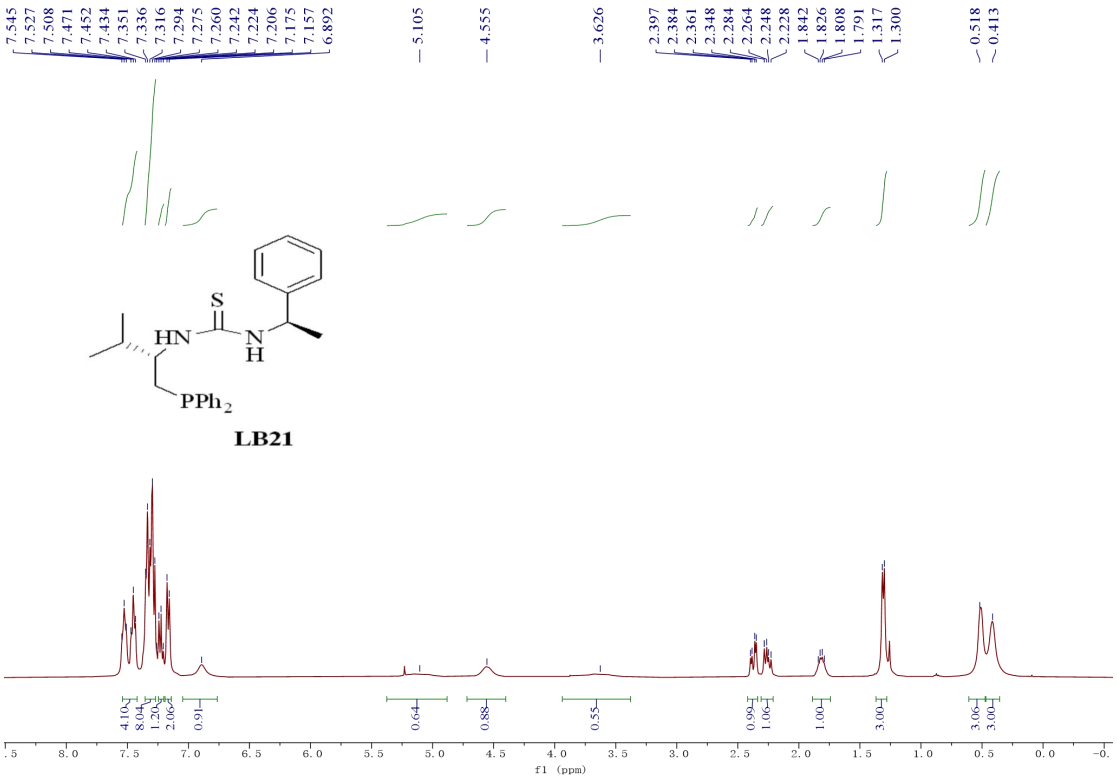


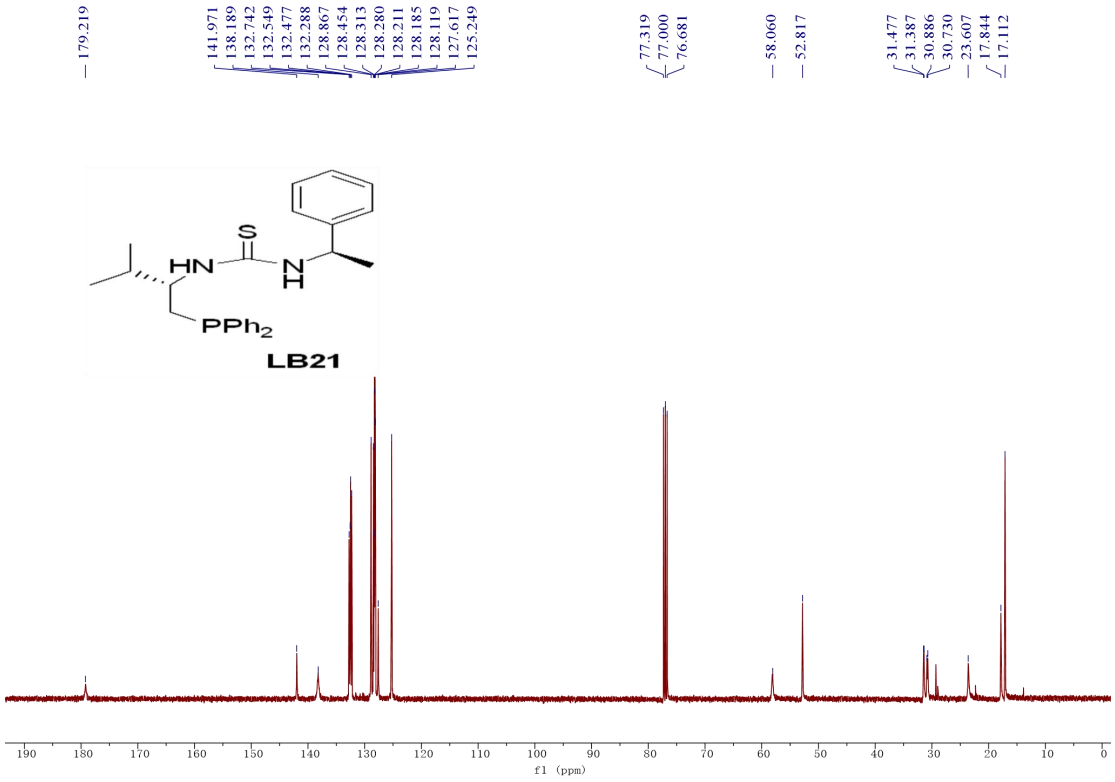
^{1}H, ^{13}C, ^{31}P and ^{19}F NMR spectra of compound **LB16**

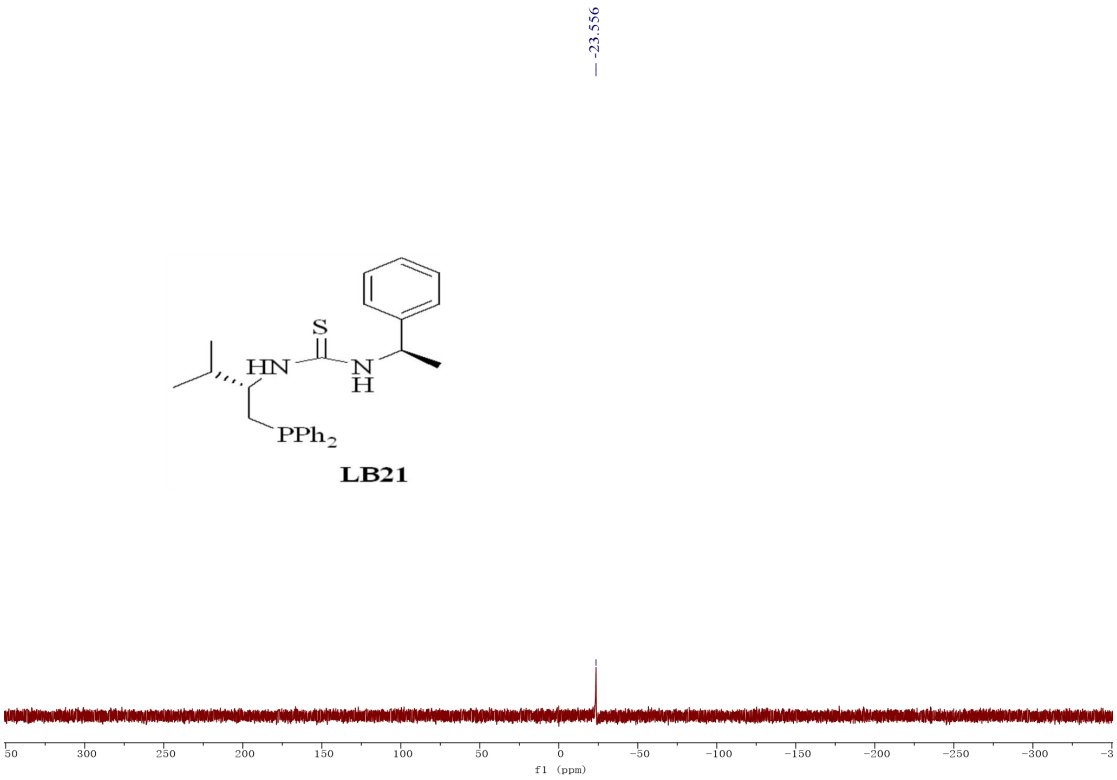




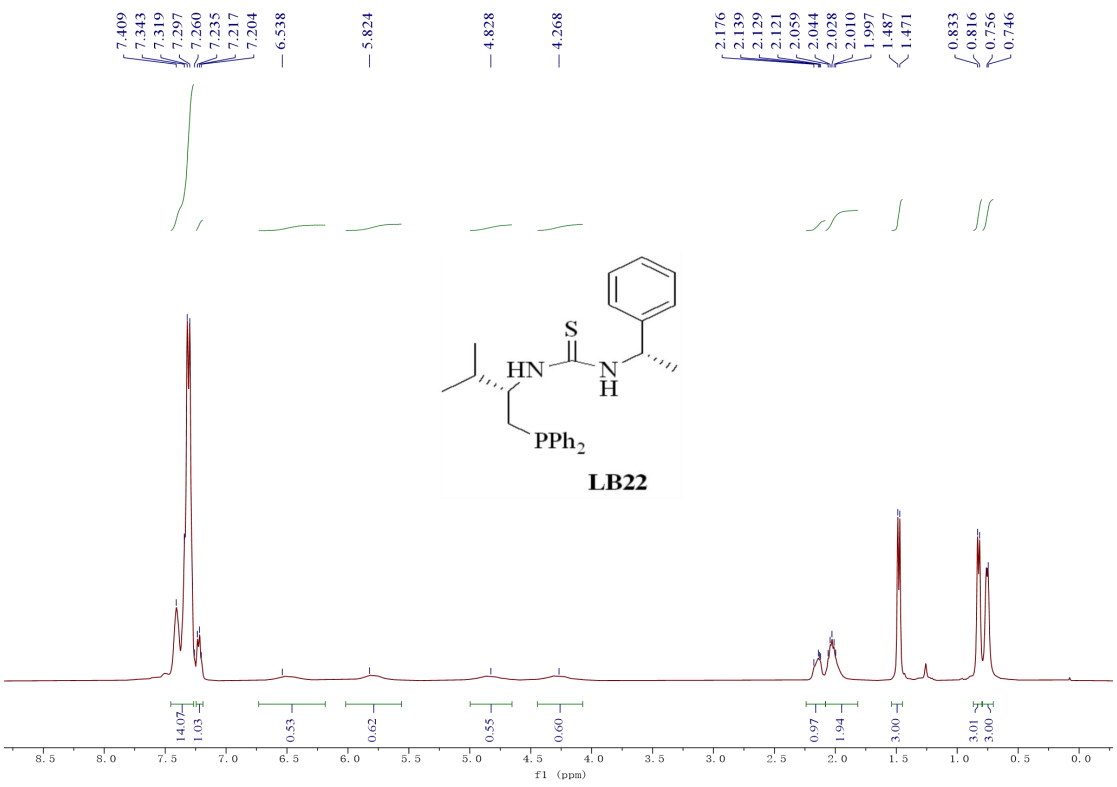
^{1}H, ^{13}C and ^{31}P NMR spectra of compound **LB17**

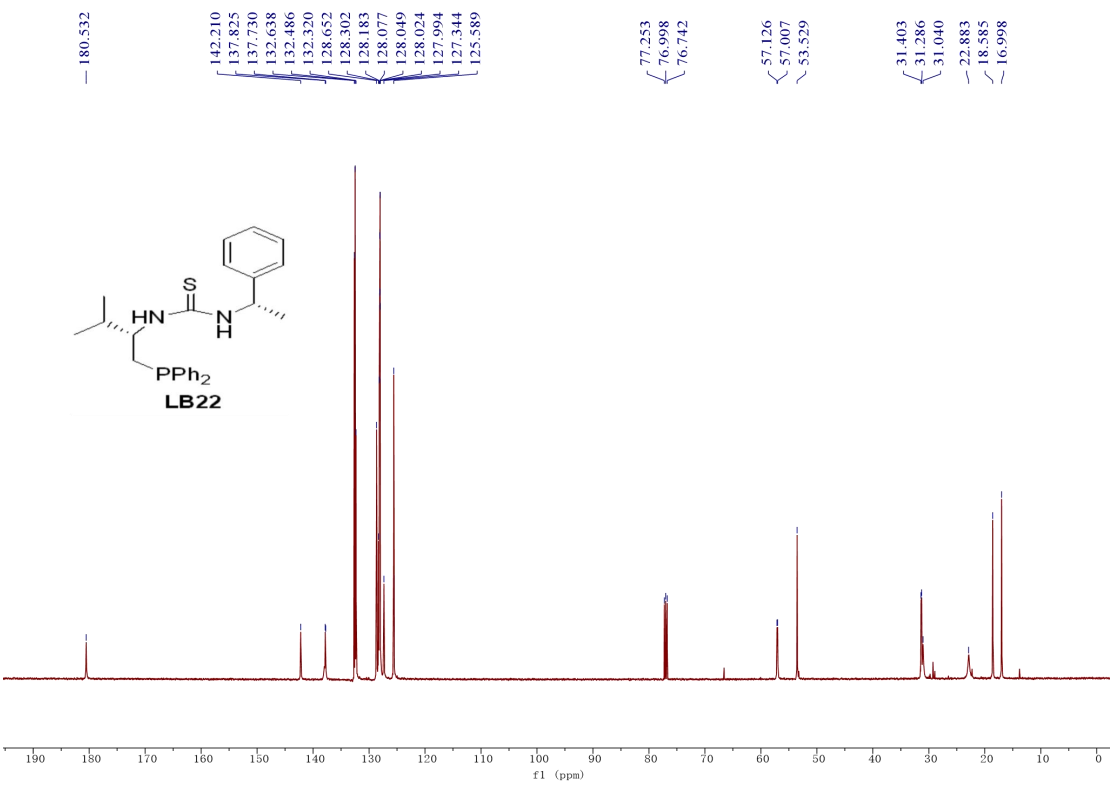

7.545
7.527
7.508
7.471
7.452
7.434
7.351
7.336
7.316
7.294
7.275
7.260
7.242
7.224
7.206
7.175
7.157
6.892
5.105
4.555
3.626
2.397
2.384
2.361
2.348
2.284
2.264
2.248
2.228
1.842
1.826
1.808
1.791
1.317
1.300
0.518
0.413
S
HN
N
H
PPh2
LB21
4.10
8.04
1.20
2.06
0.91
0.64
0.88
0.55
0.99
1.06
1.00
3.00
3.06
3.00
f1 (ppm)

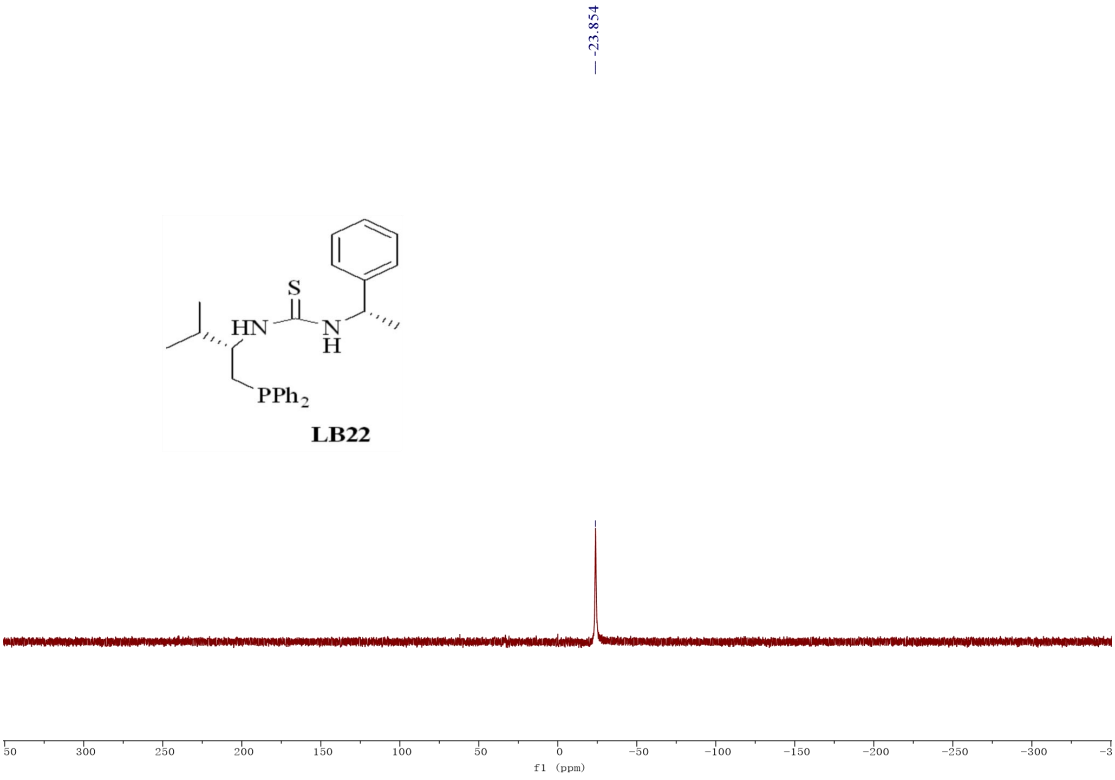

179.219
141.971
138.189
132.742
132.549
132.477
132.288
128.867
128.454
128.313
128.280
128.211
128.185
128.119
127.617
125.249
77.319
77.000
76.681
58.060
52.817
31.477
31.387
30.886
30.730
23.607
17.844
17.112
S
HN
N
H
PPh2
LB21
f1 (ppm)



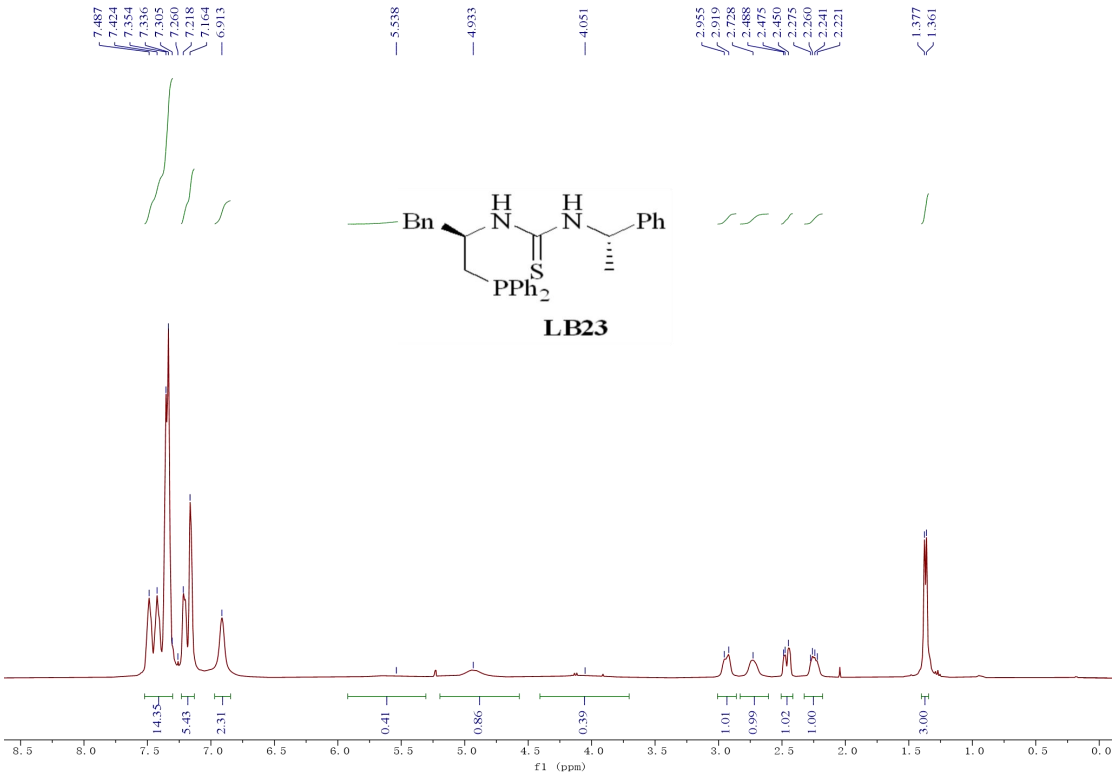
^{1}H, ^{13}C and ^{31}P NMR spectra of compound **LB21**

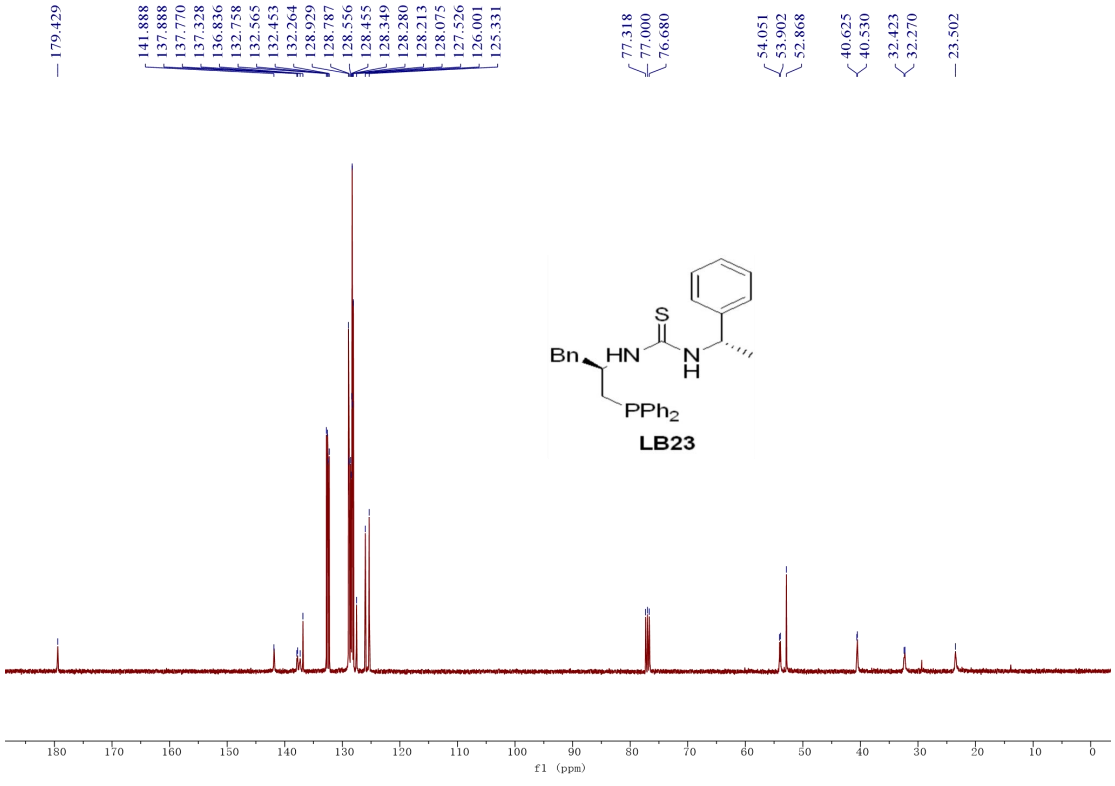


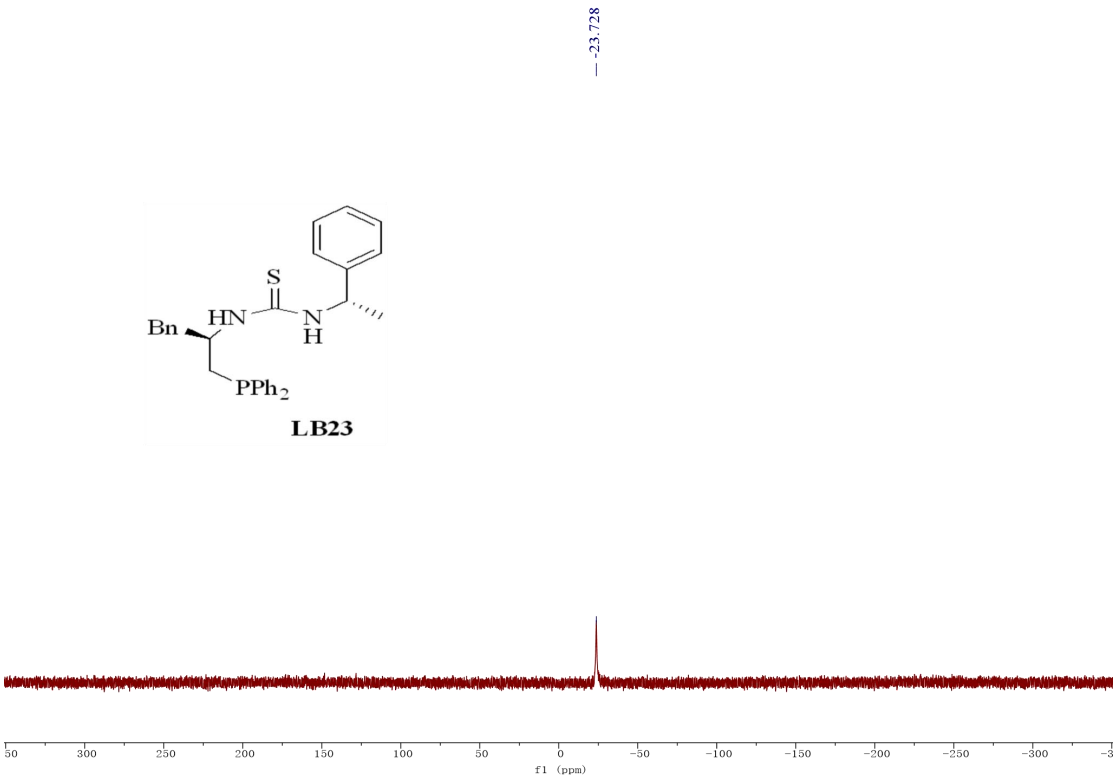




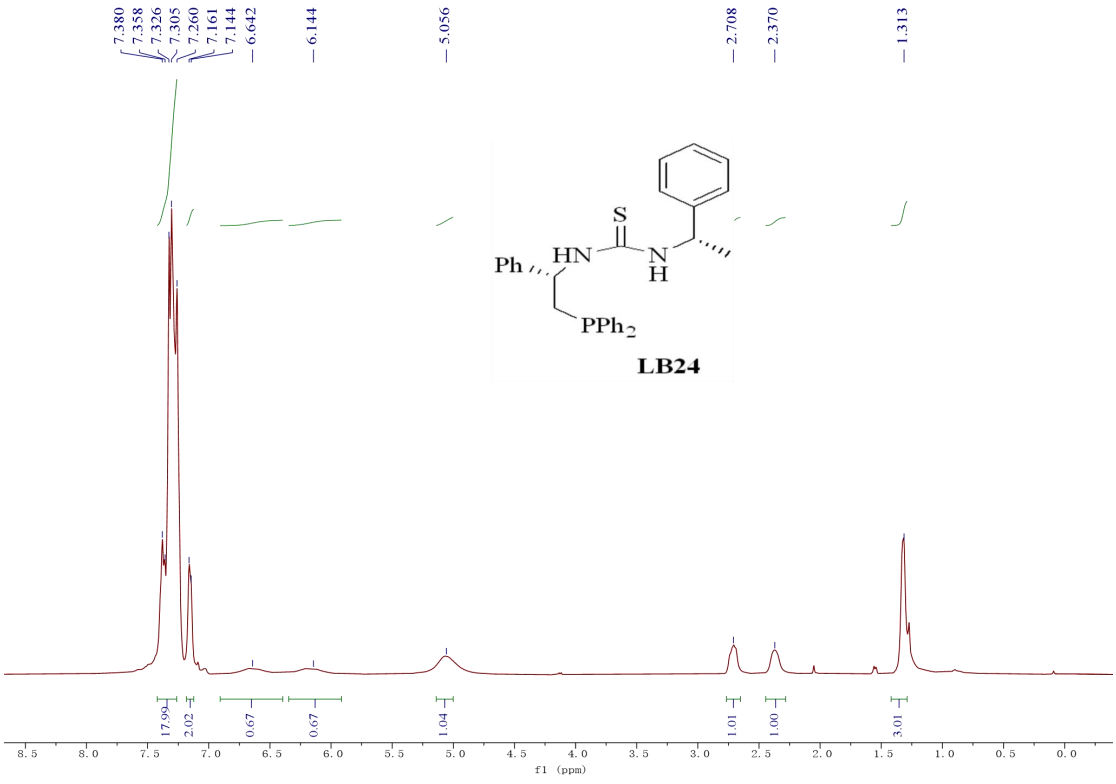
^{1}H, ^{13}C and ^{31}P NMR spectra of compound **LB22**

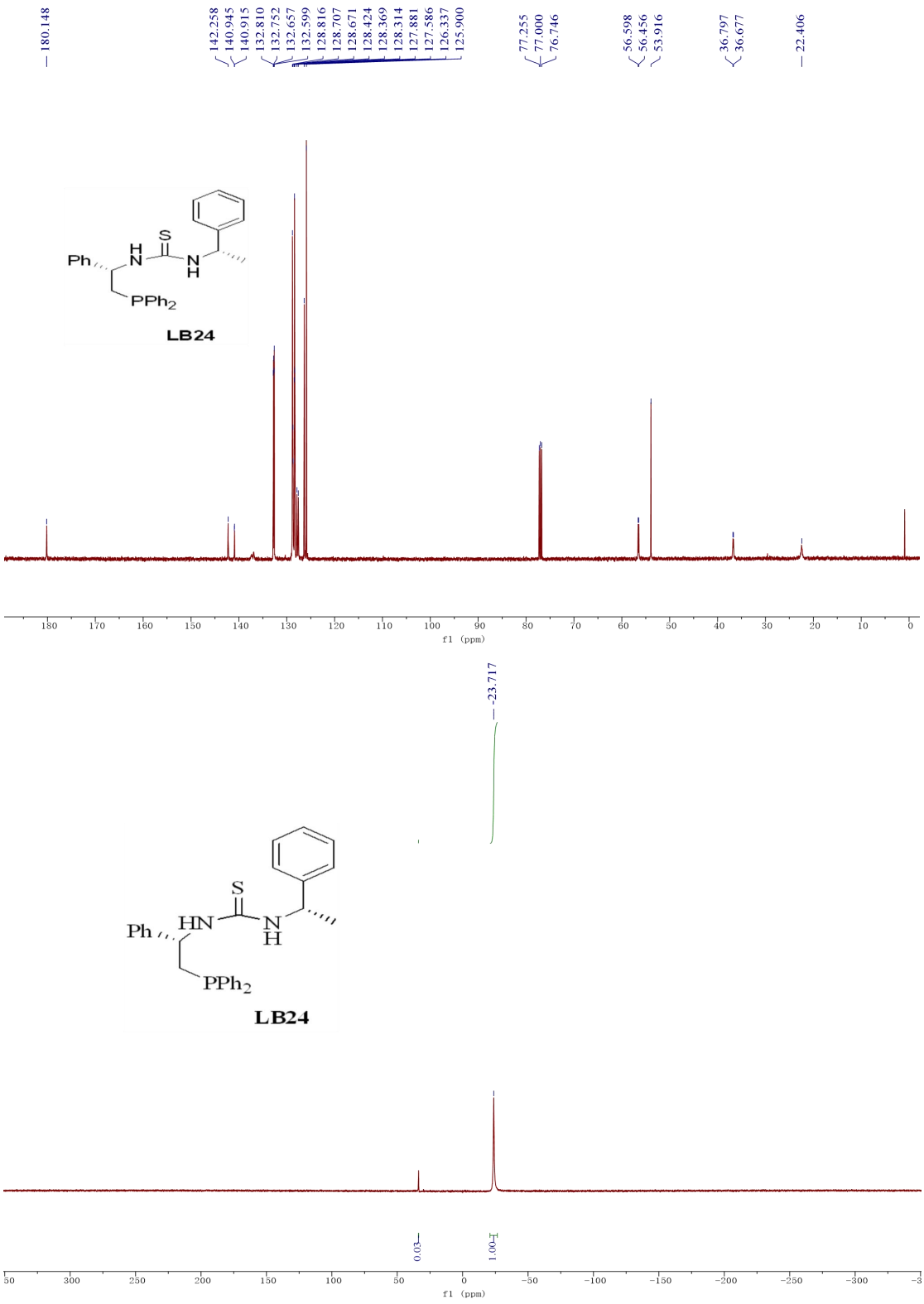

7.487
7.424
7.354
7.336
7.305
7.260
7.218
7.164
6.913
5.538
4.933
4.051
2.955
2.919
2.728
2.488
2.475
2.450
2.275
2.260
2.241
2.221
1.377
1.361
Bn
H
N
H
N
Ph
S
PPh2
LB23
14.35
5.43
2.31
0.41
0.86
0.39
1.01
0.99
1.02
1.00
3.00
f1 (ppm)


179.429
141.888
137.888
137.770
137.328
136.836
132.758
132.565
132.453
132.264
128.929
128.787
128.556
128.455
128.349
128.280
128.213
128.075
127.526
126.001
125.331
77.318
77.000
76.680
54.051
53.902
52.868
40.625
40.530
32.423
32.270
23.502
S
Bn
HN
N
H
PPh2
LB23
f1 (ppm)

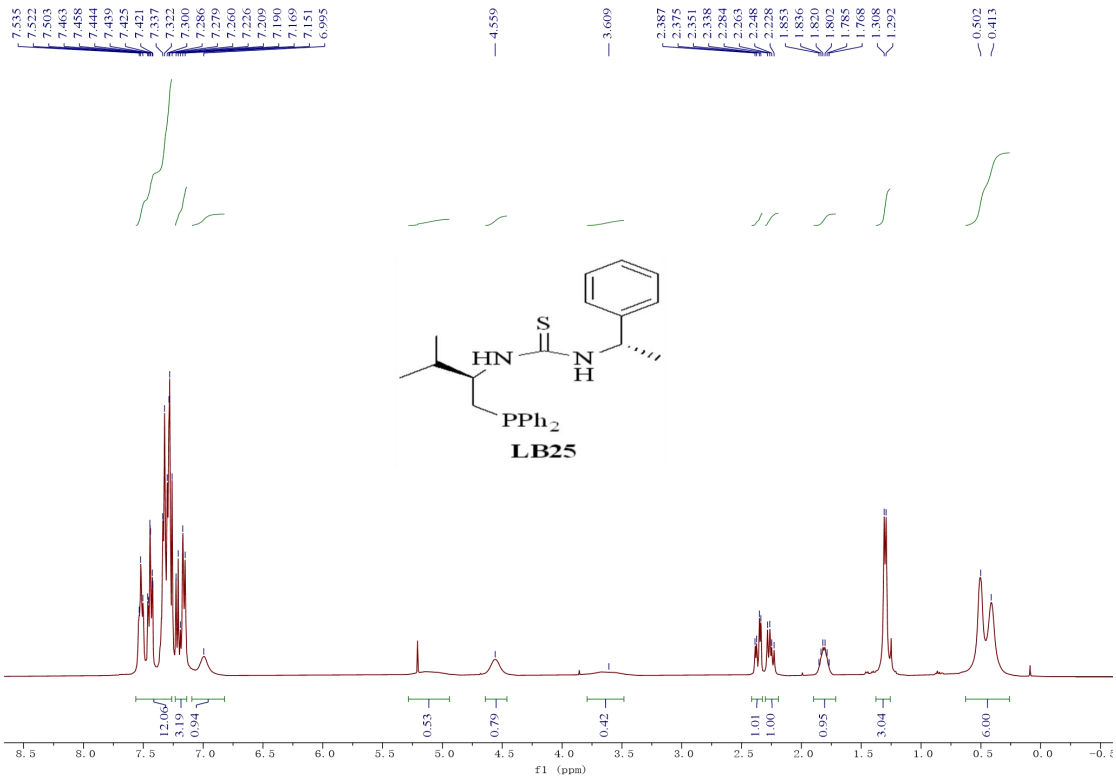


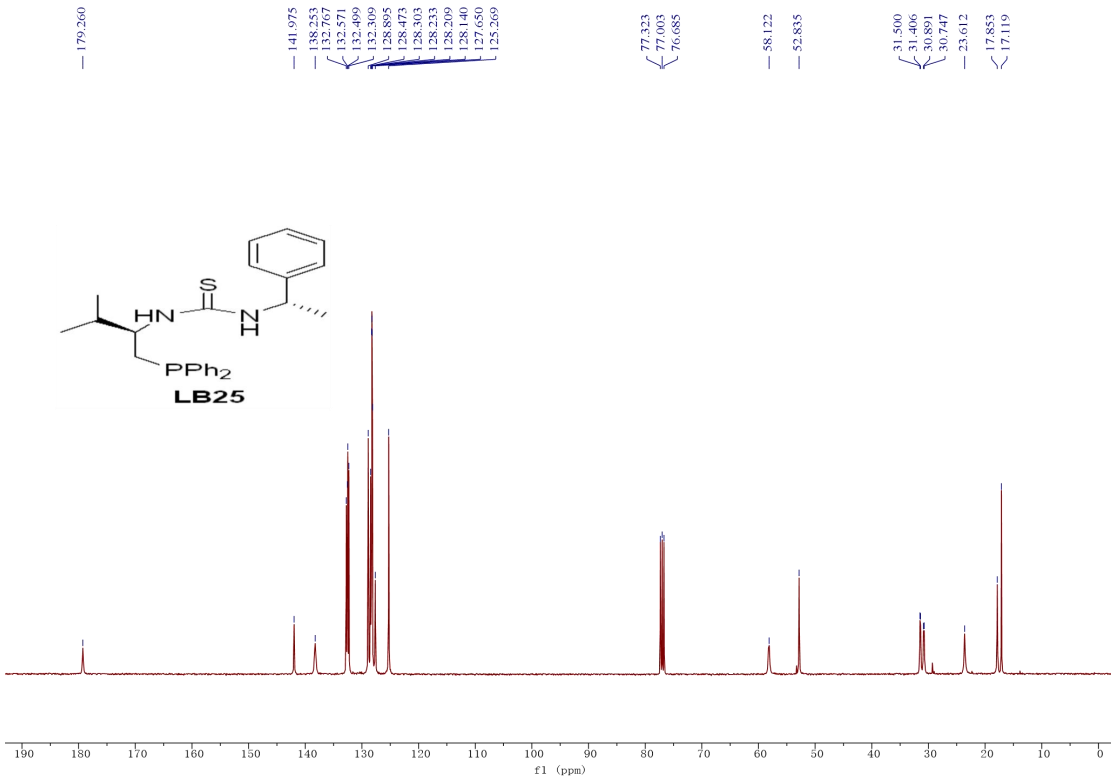
^{1}H, ^{13}C and ^{31}P NMR spectra of compound **LB23**





^{1}H, ^{13}C and ^{31}P NMR spectra of compound **LB24**


7.535
7.522
7.503
7.463
7.458
7.444
7.439
7.425
7.421
7.337
7.322
7.300
7.286
7.279
7.260
7.226
7.209
7.190
7.169
7.151
6.995
4.559
3.609
2.387
2.375
2.351
2.338
2.284
2.263
2.248
2.228
1.853
1.836
1.820
1.802
1.785
1.768
1.308
1.292
0.502
0.413
HN
S
N
H
PPh2
LB25
12.06
3.19
0.94
0.53
0.79
0.42
1.01
1.00
0.95
3.04
6.00
f1 (ppm)


179.260
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138.253
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128.140
127.650
125.269
77.323
77.003
76.685
58.122
52.835
31.500
31.406
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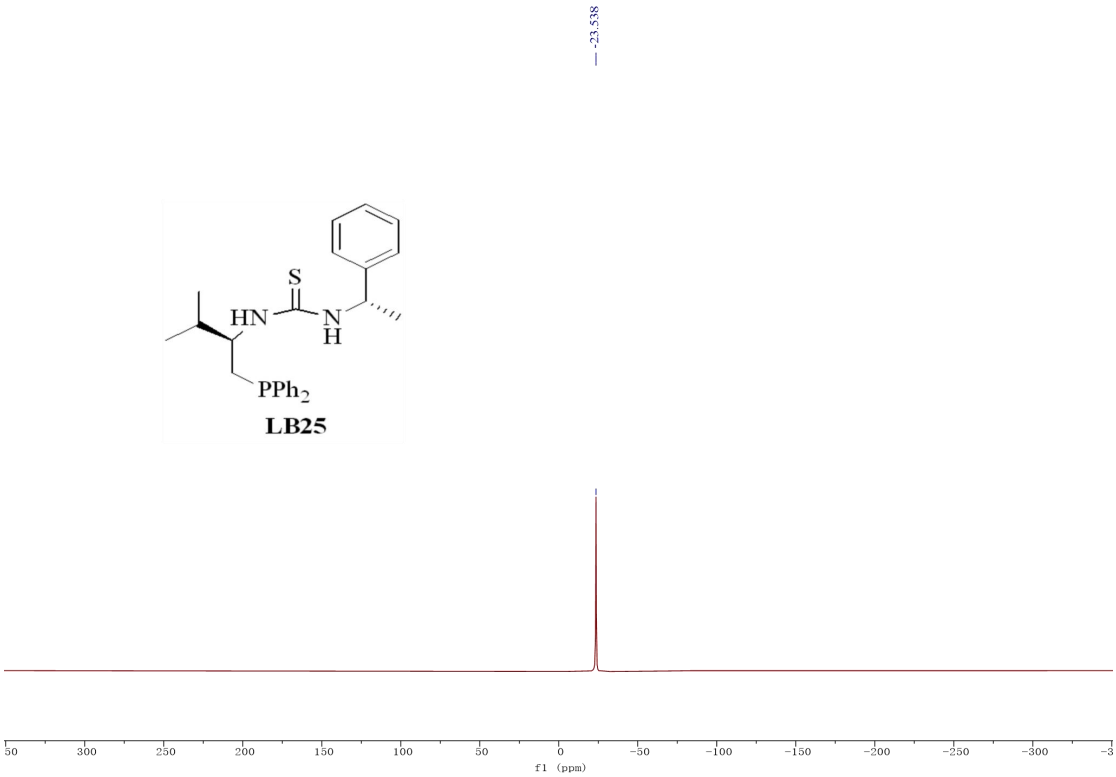
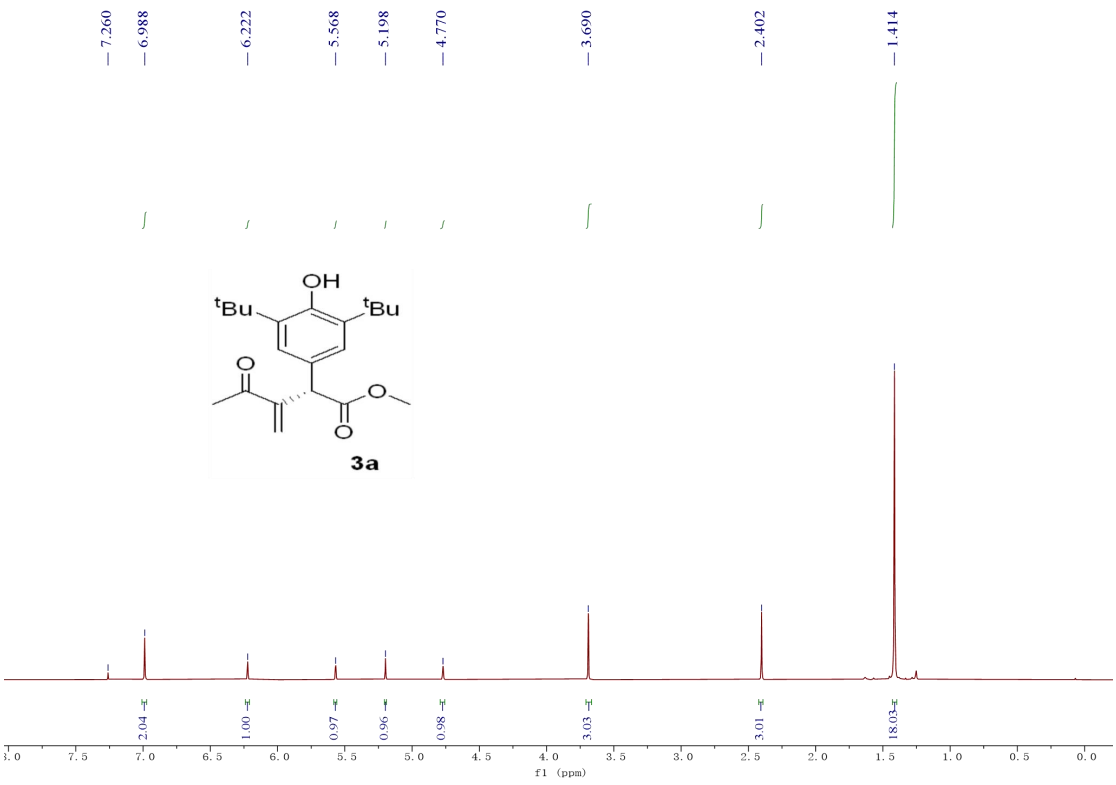
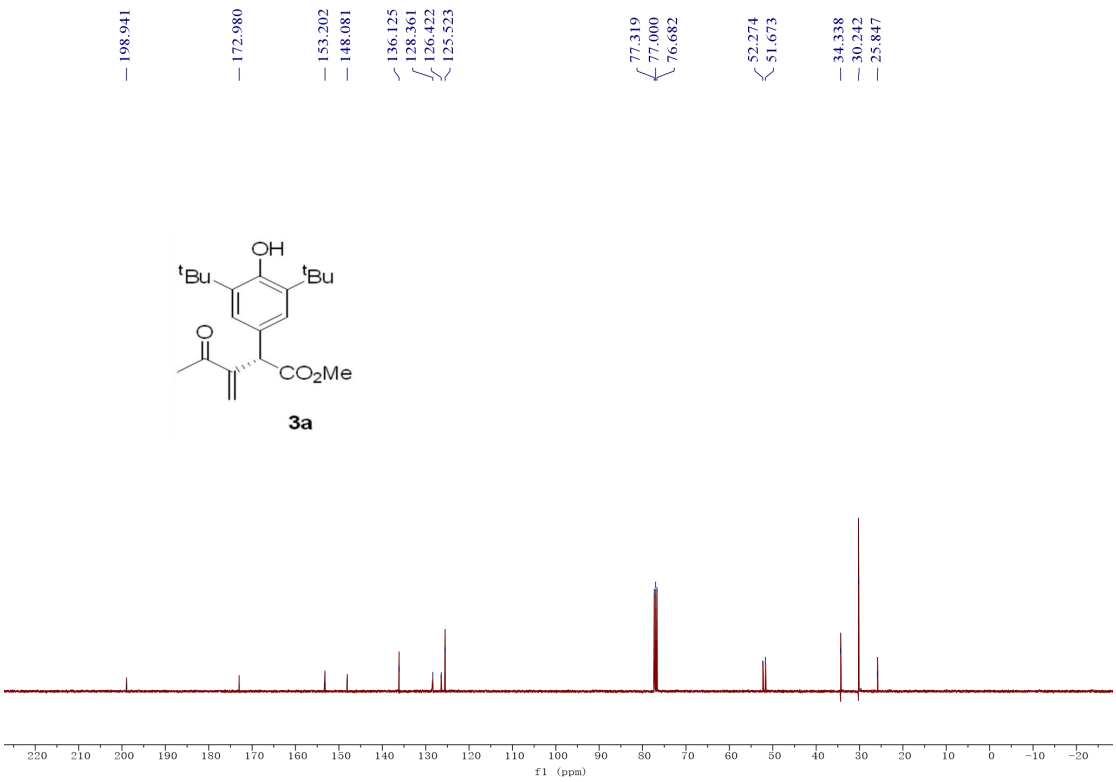
30.747
23.612
17.853
17.119
HN
S
N
H
PPh2
LB25
f1 (ppm)

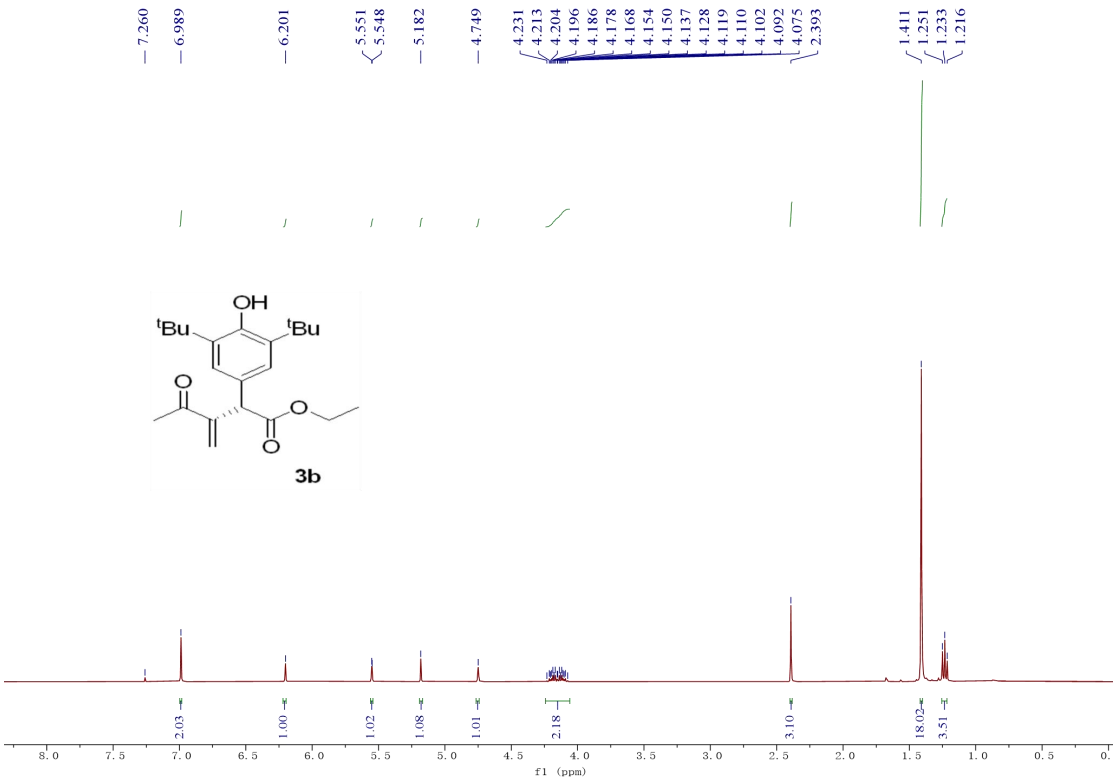


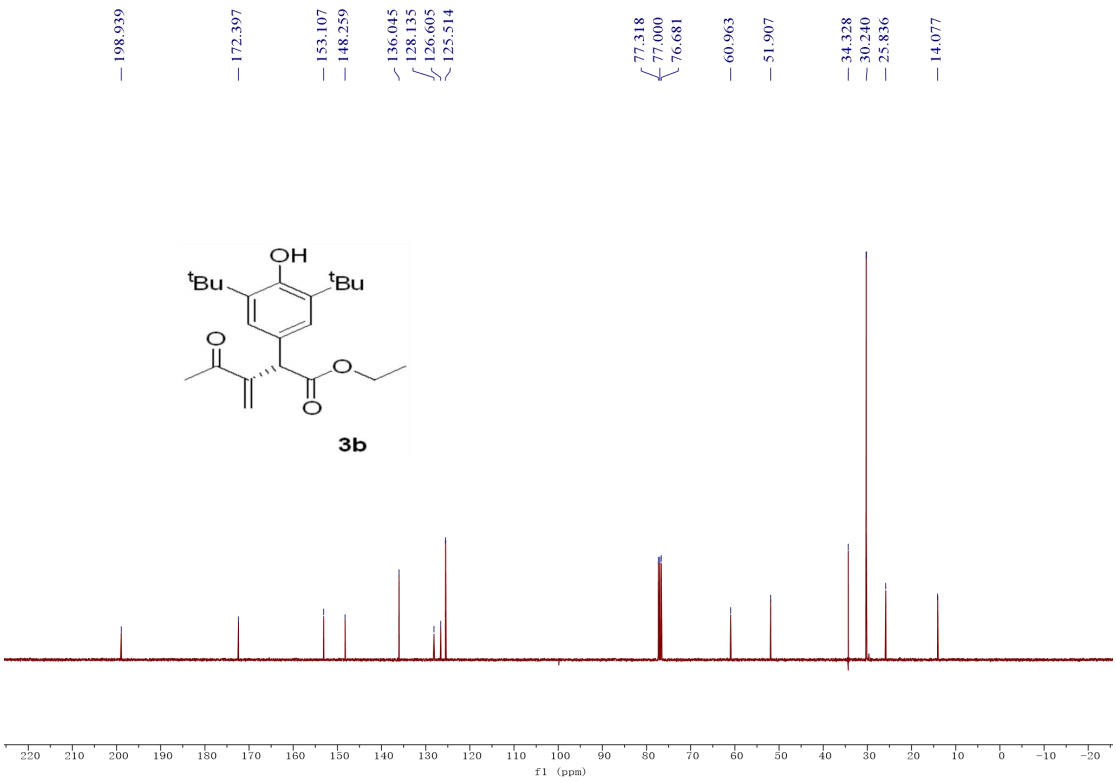
^{1}H, ^{13}C and ^{31}P NMR spectra of compound **LB25**



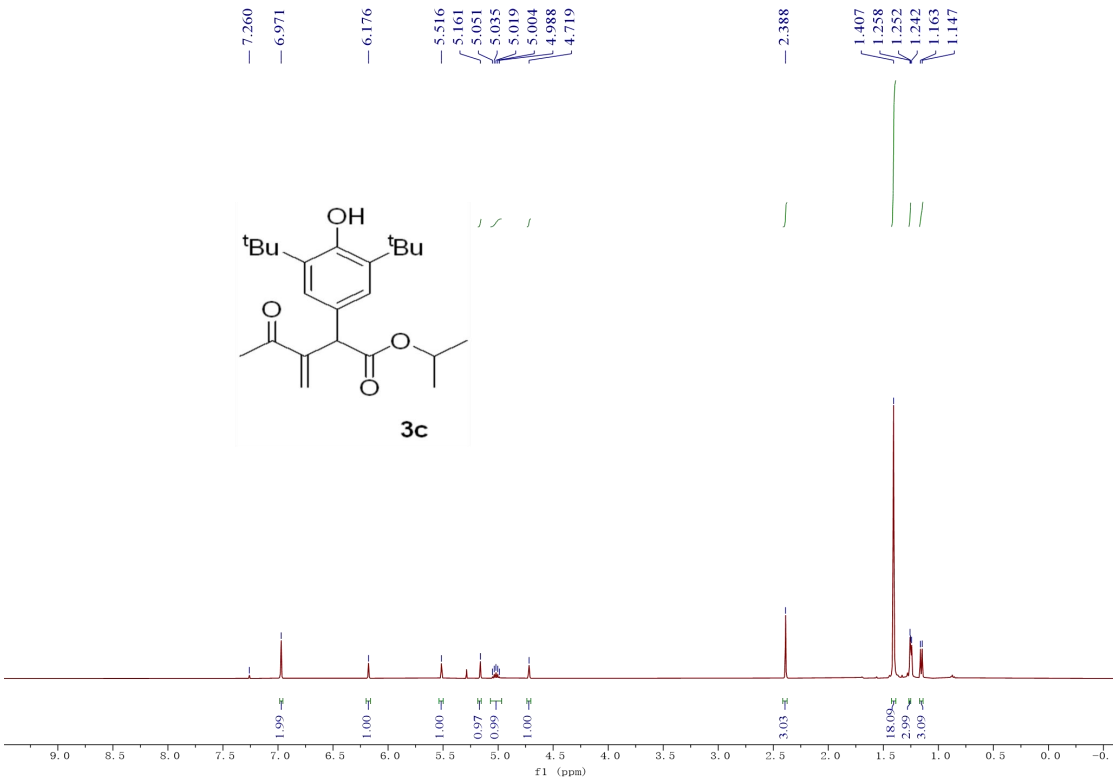


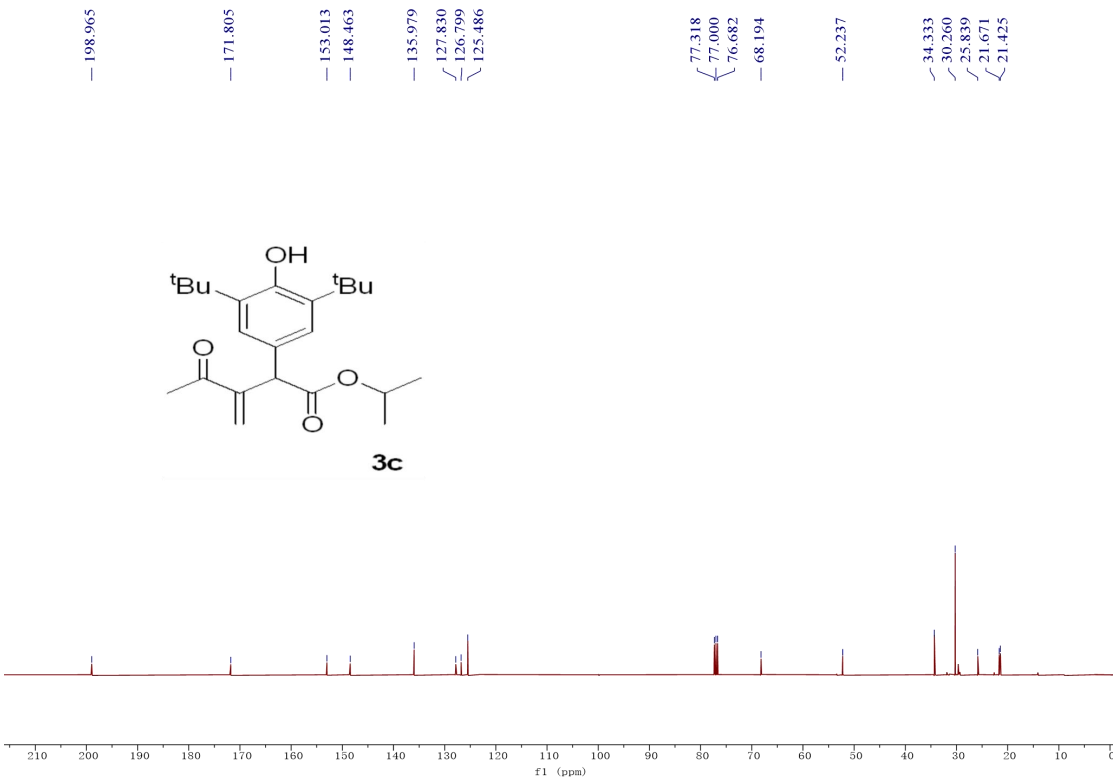
^{1}H and^{13}C NMR spectra of compound **3a**



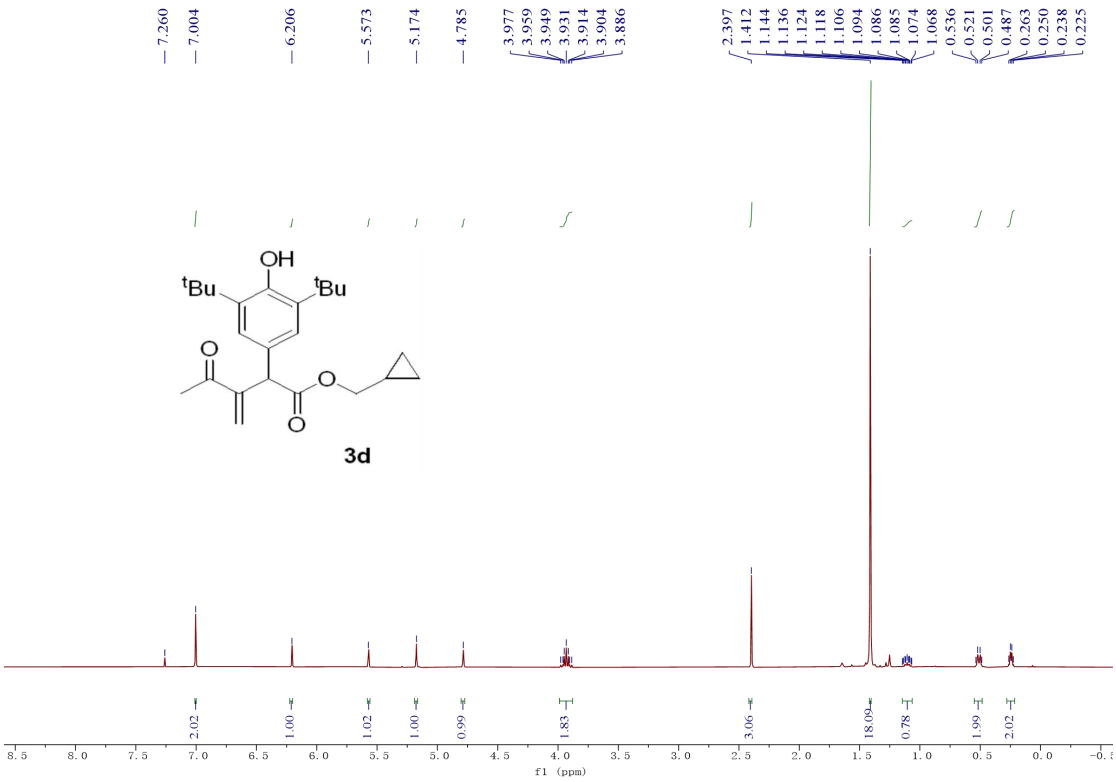


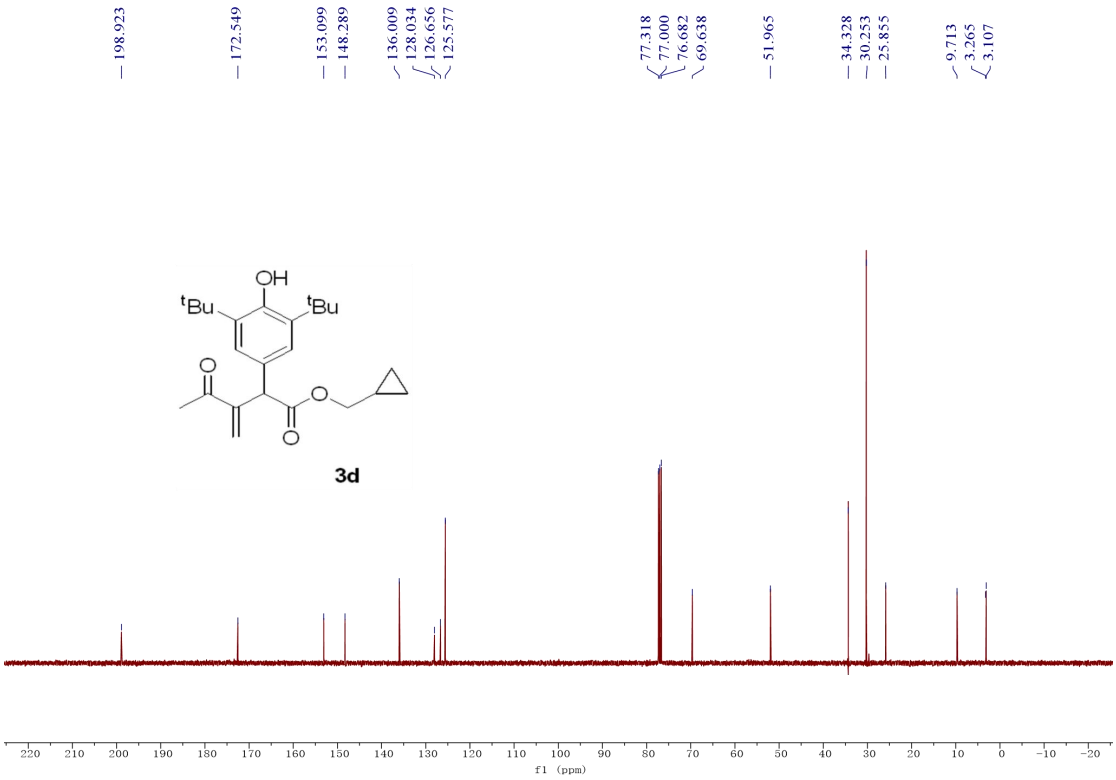
^{1}H and ^{13}C NMR spectra of compound **3b**



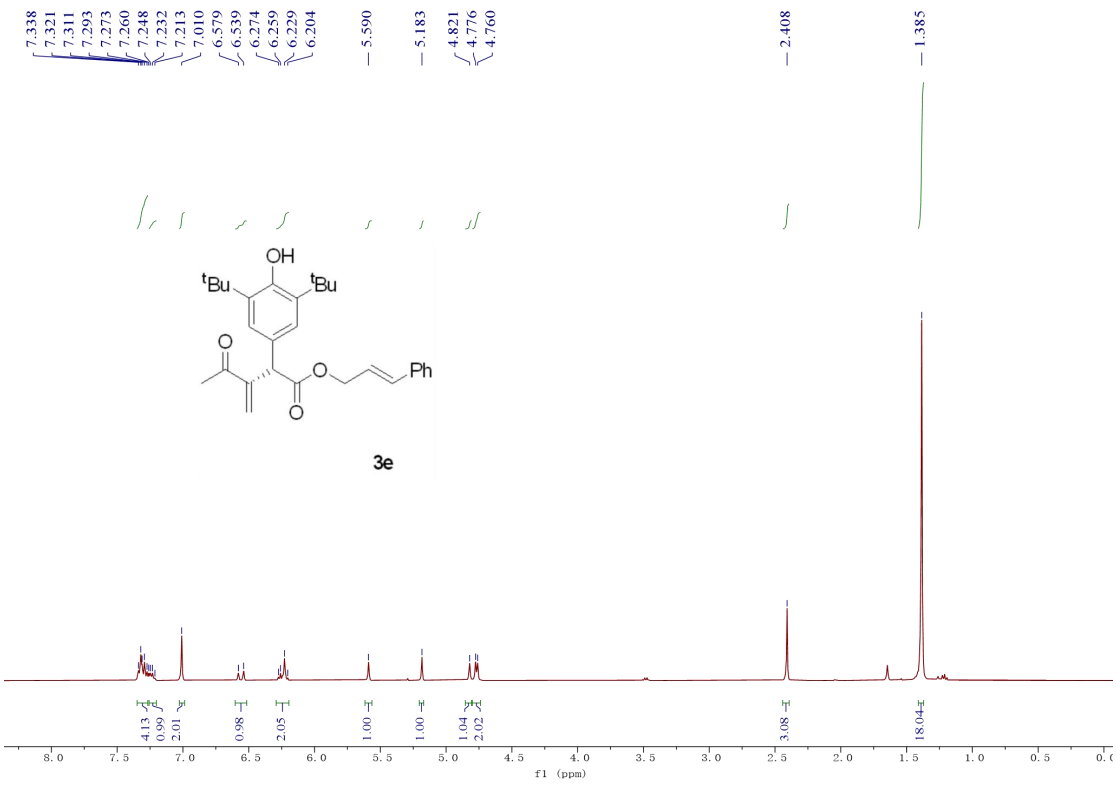


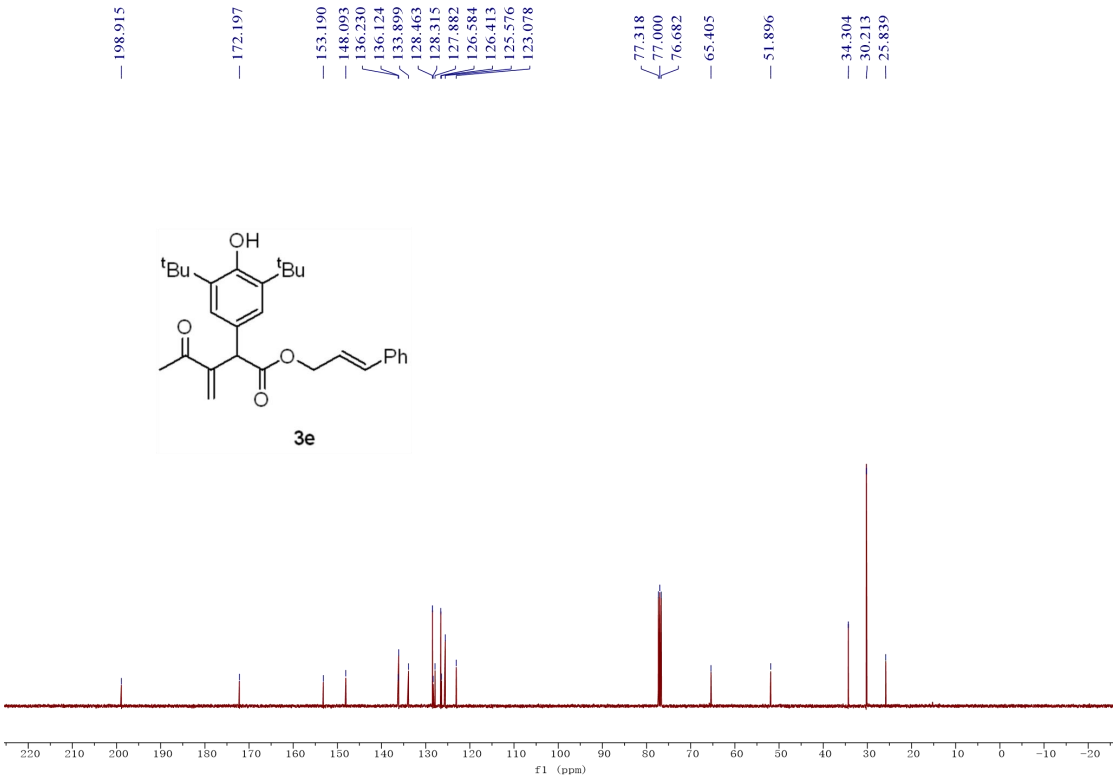
^{1}H and ^{13}C NMR spectra of compound **3c**



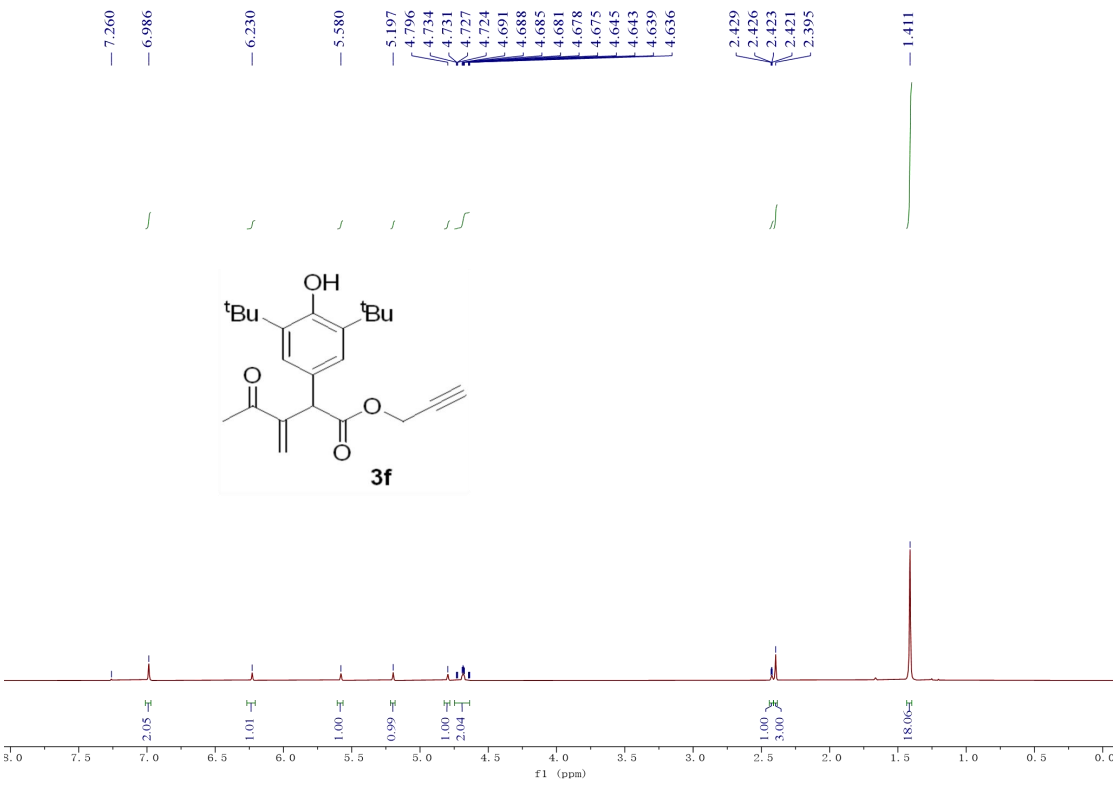


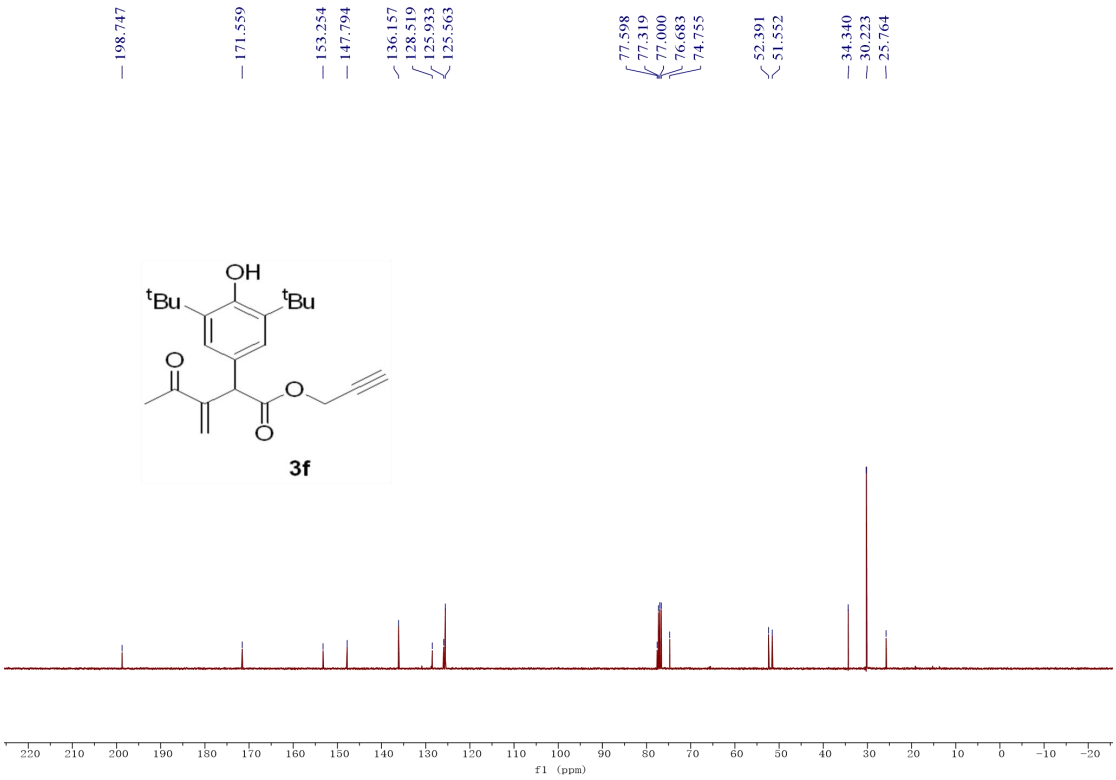
^{1}H and^{13}C NMR spectra of compound **3d**



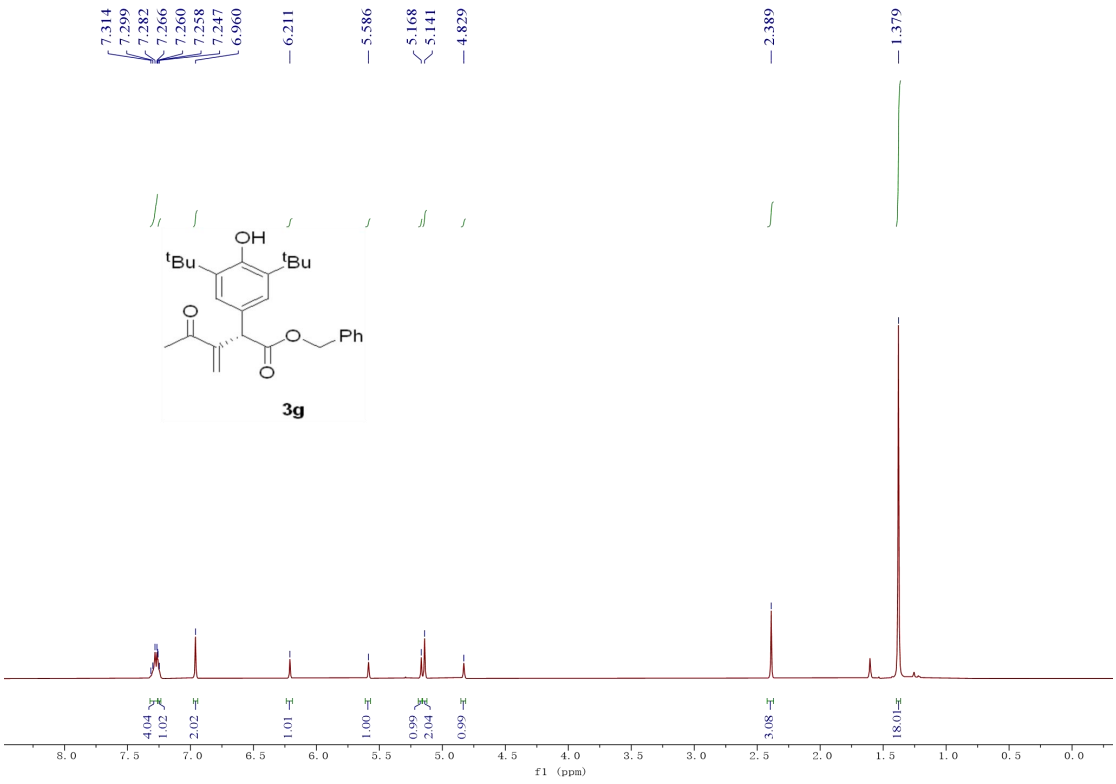


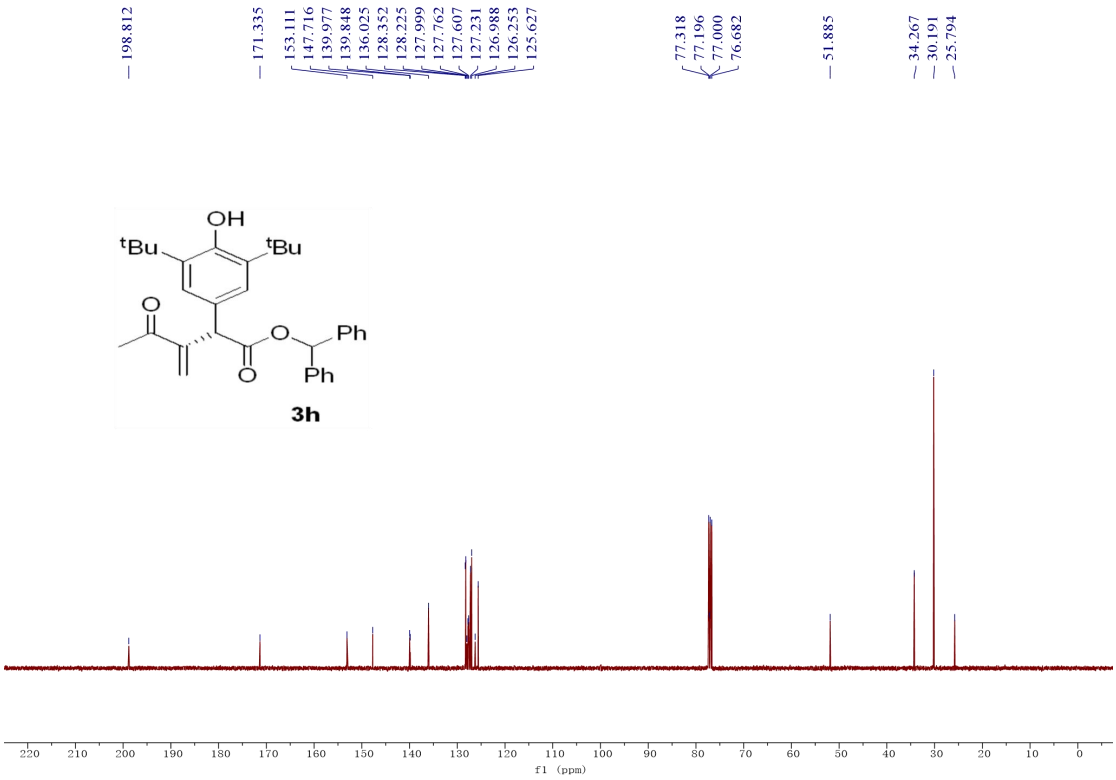
^{1}H and ^{13}C NMR spectra of compound **3e**



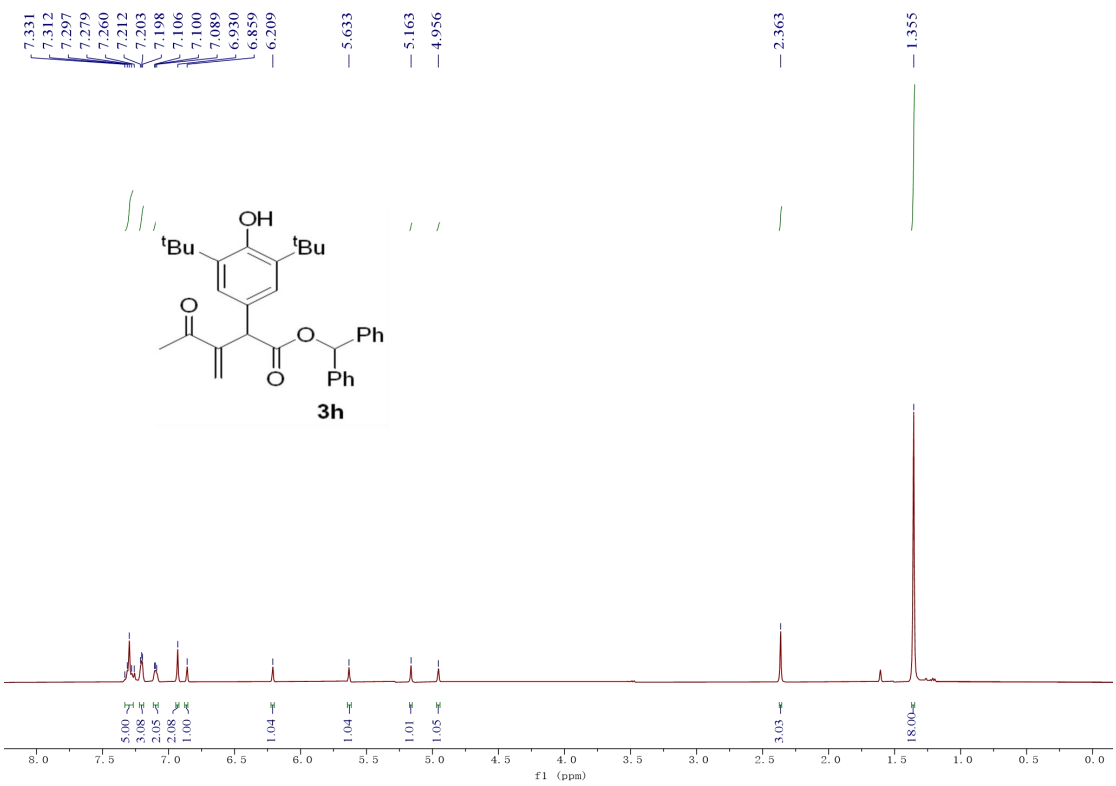


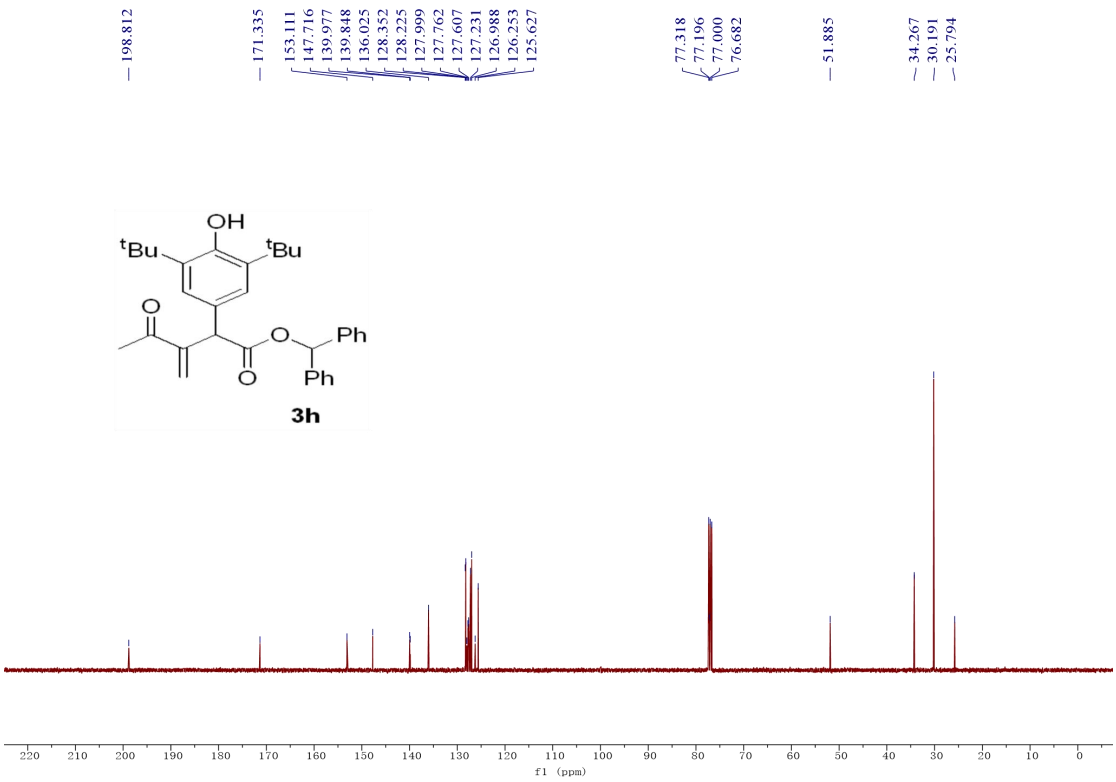
^{1}H and^{13}C NMR spectra of compound **3f**



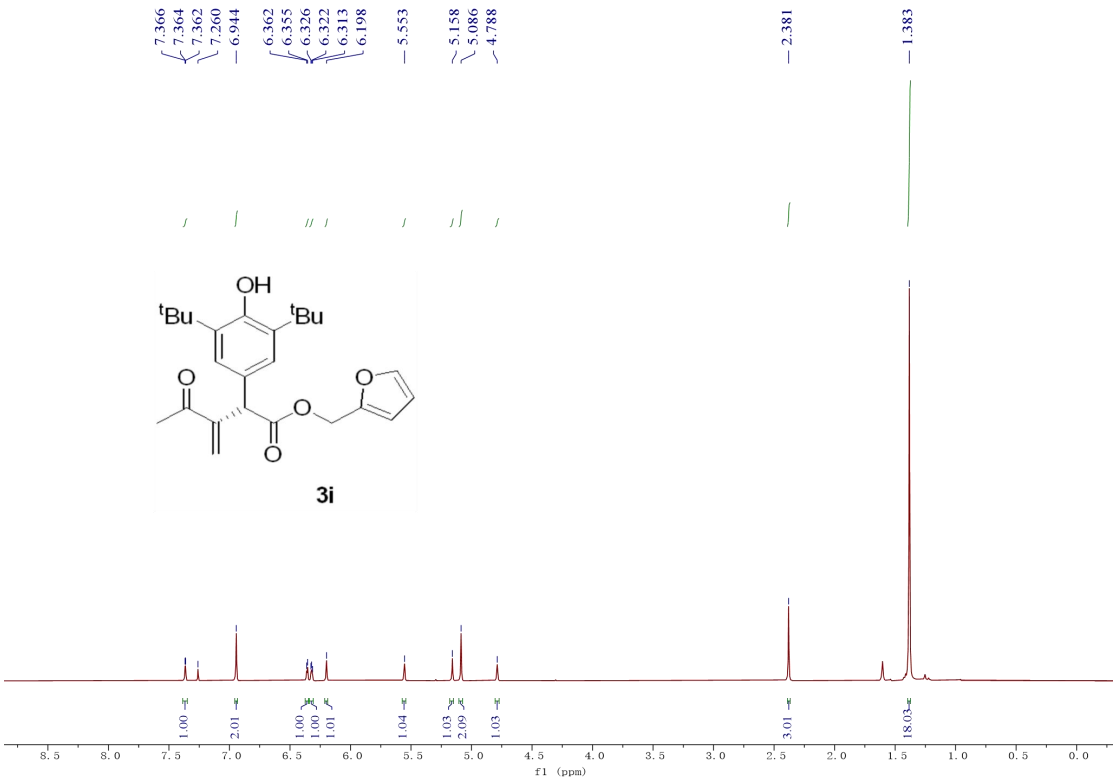


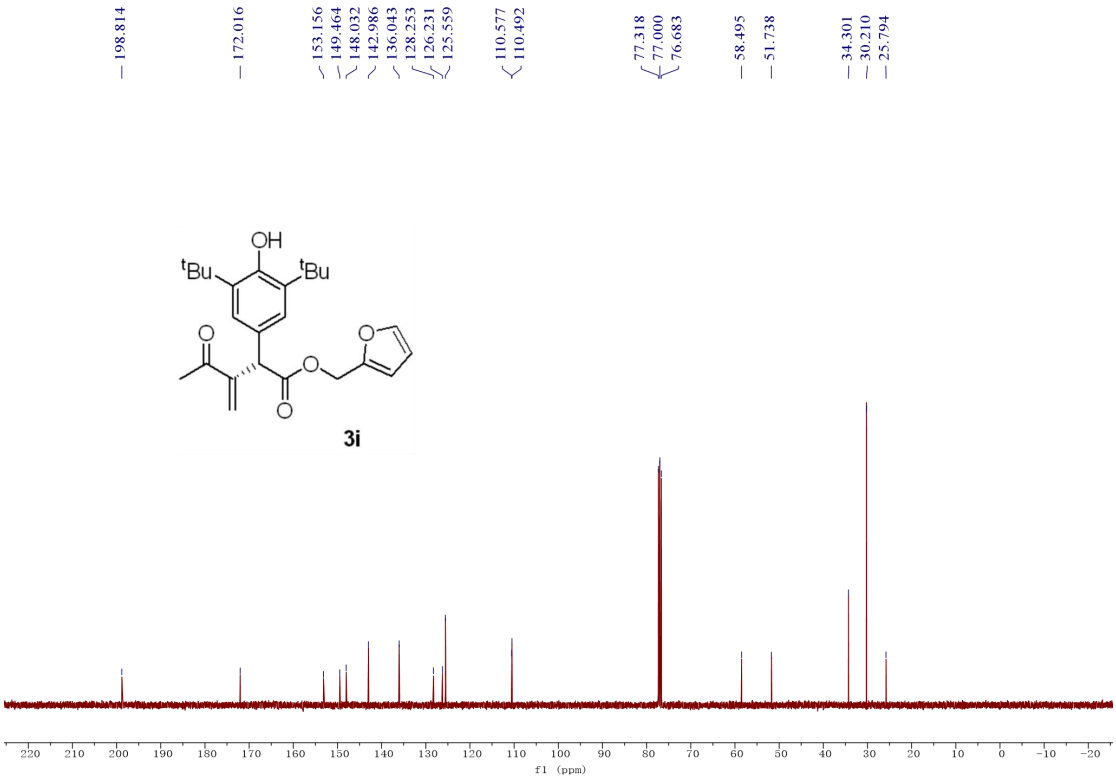
^{1}H and ^{13}C NMR spectra of compound **3g**



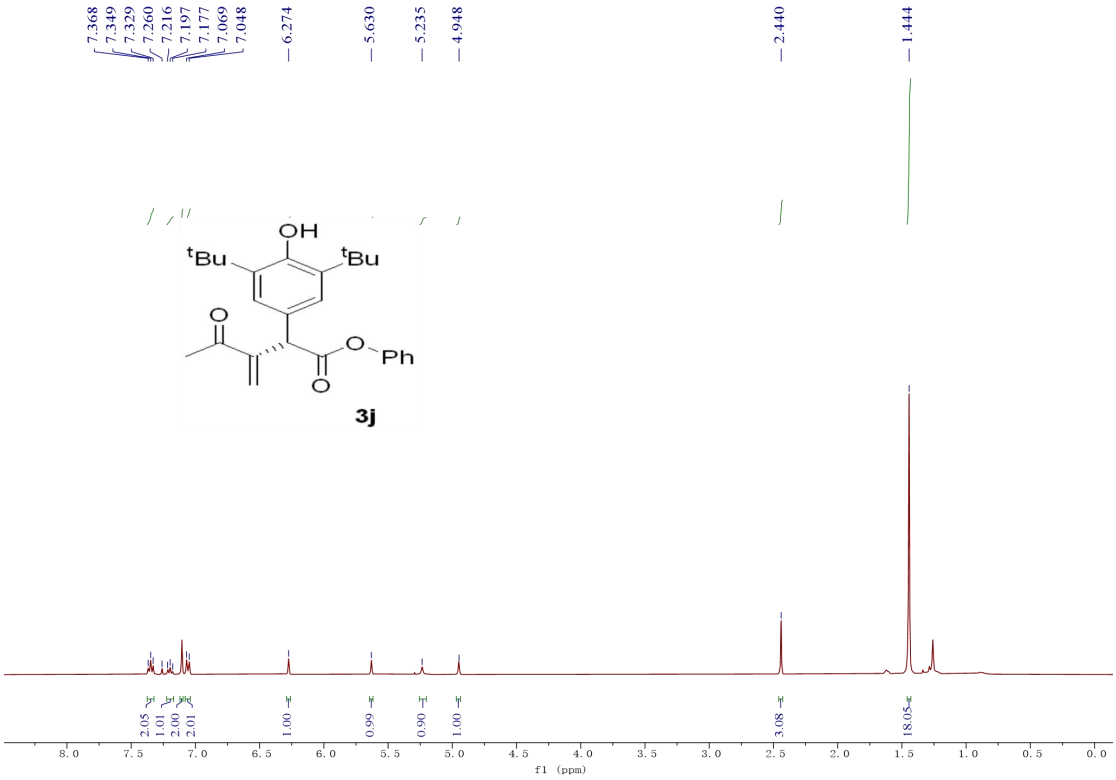


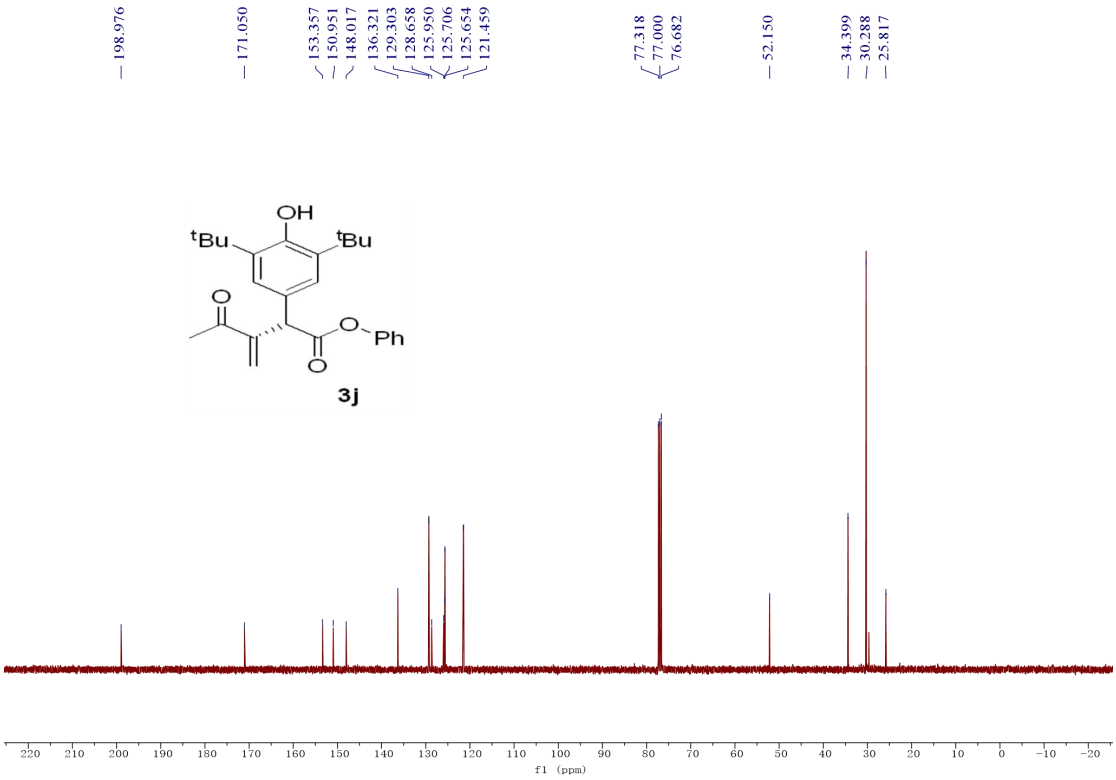
^{1}H and^{13}C NMR spectra of compound **3h**



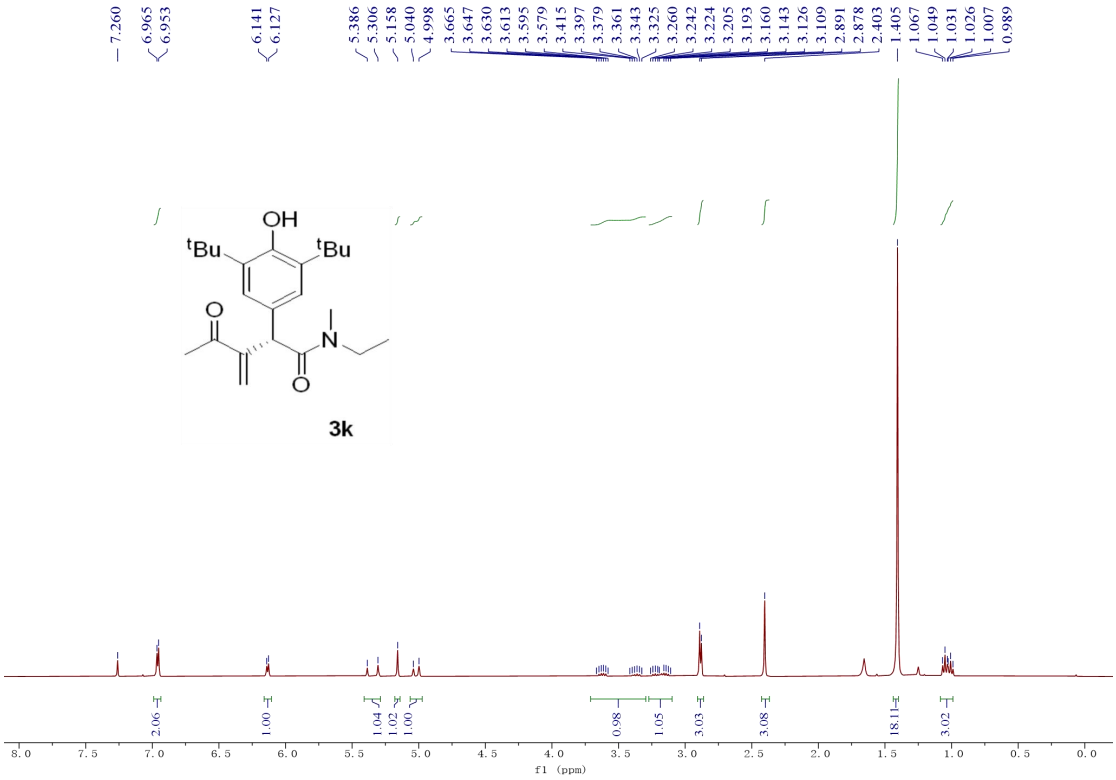


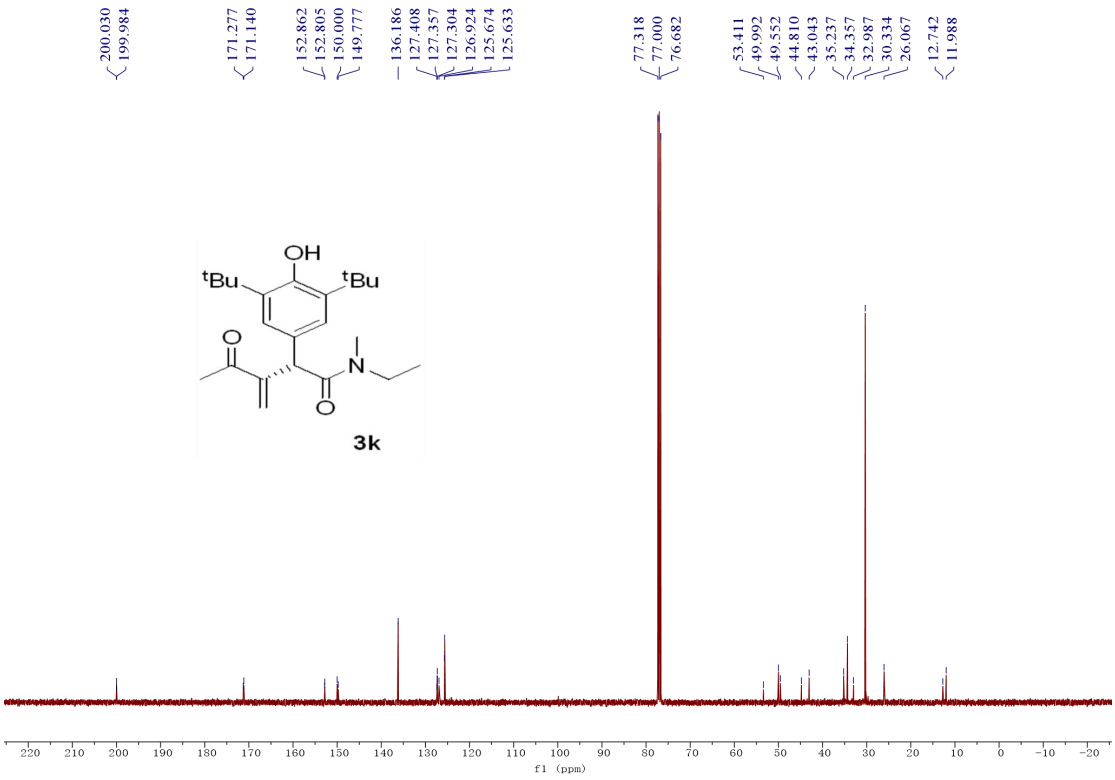
^{1}H and^{13}C NMR spectra of compound **3i**



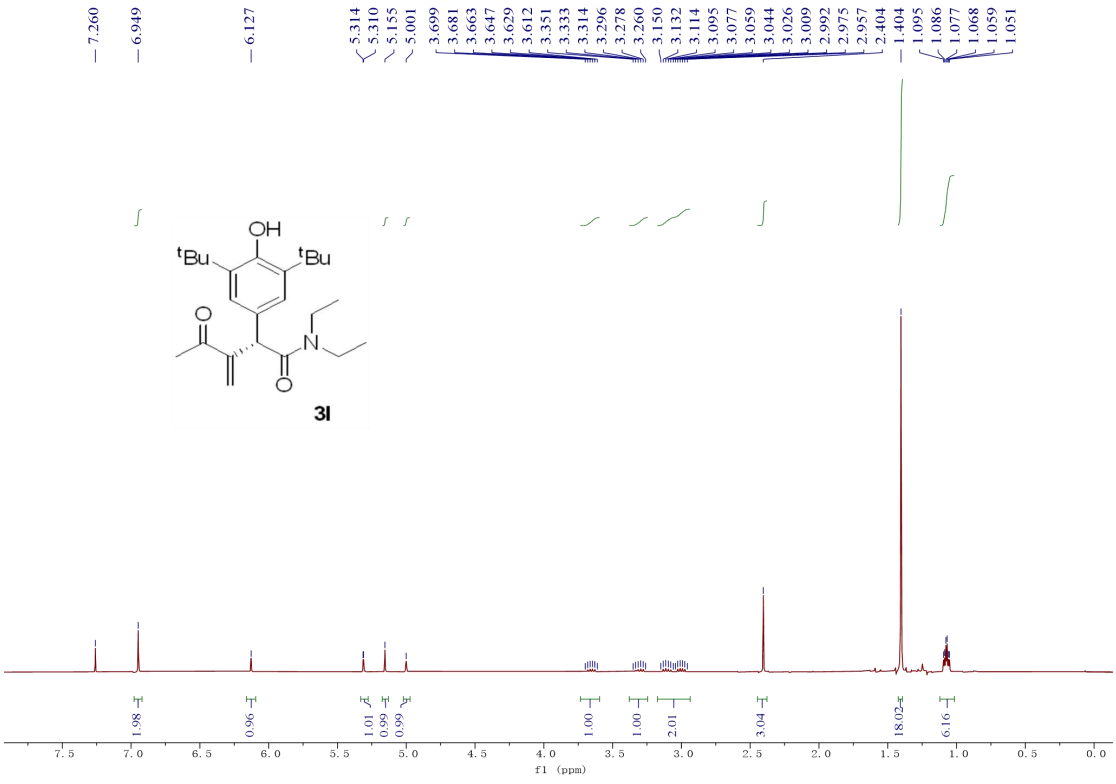


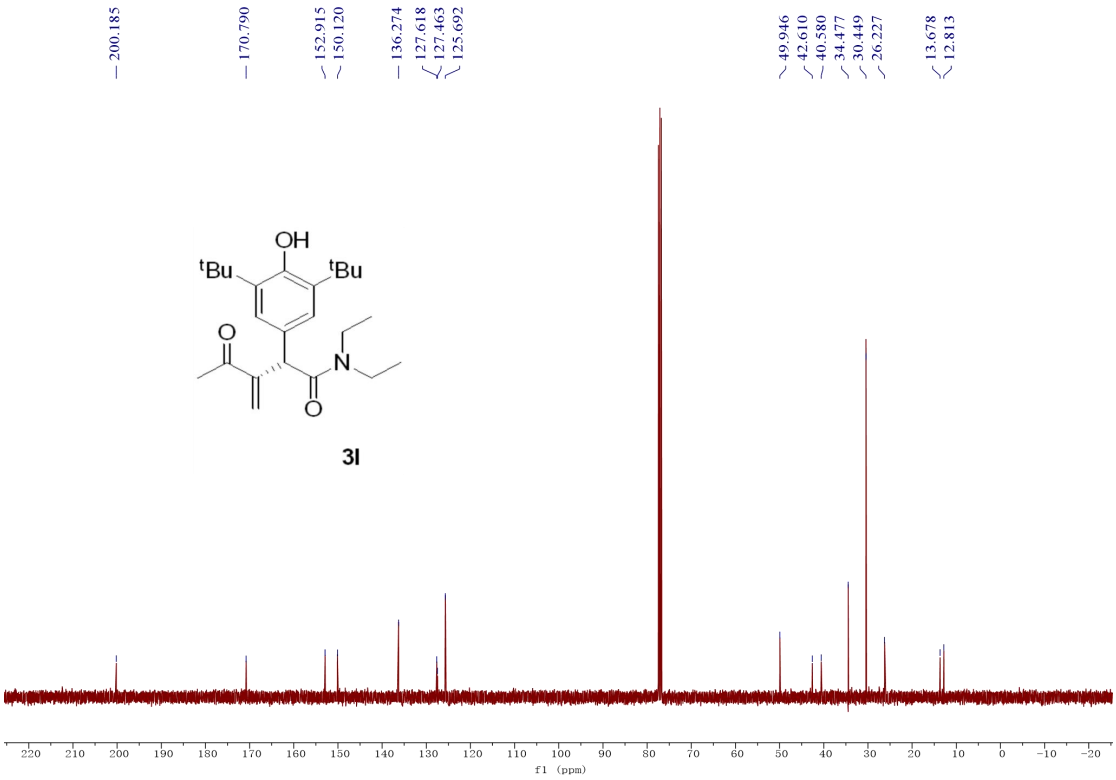
^{1}H and^{13}C NMR spectra of compound **3j**



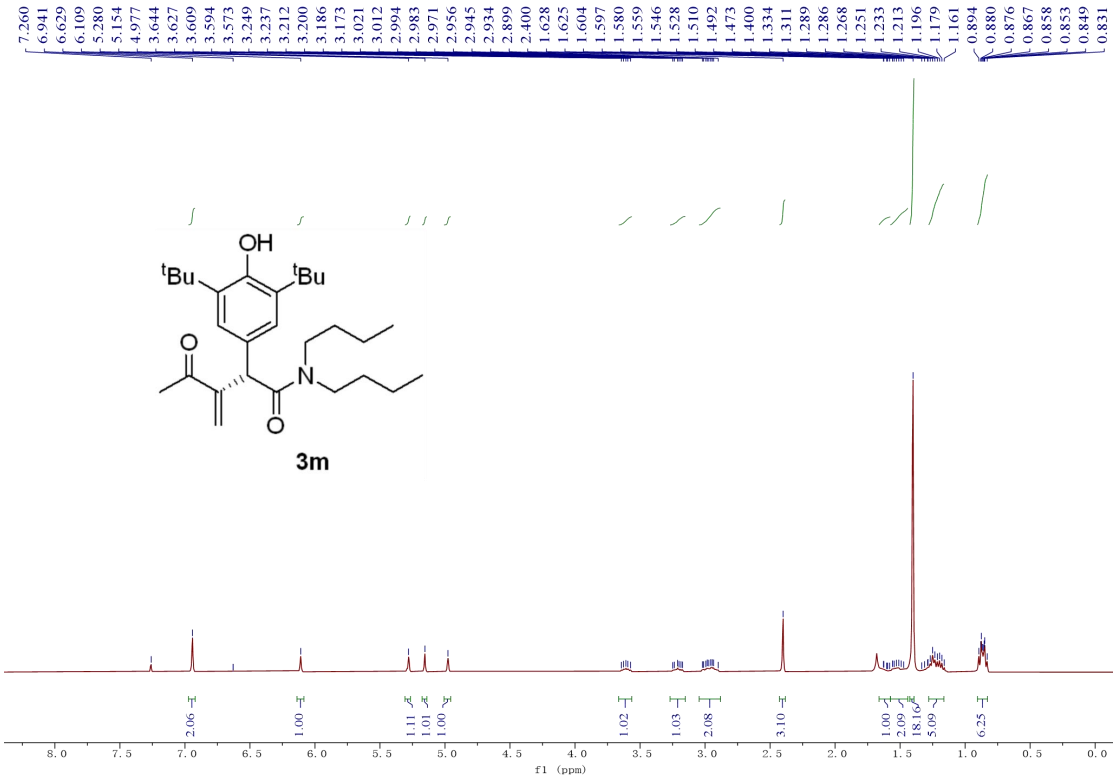


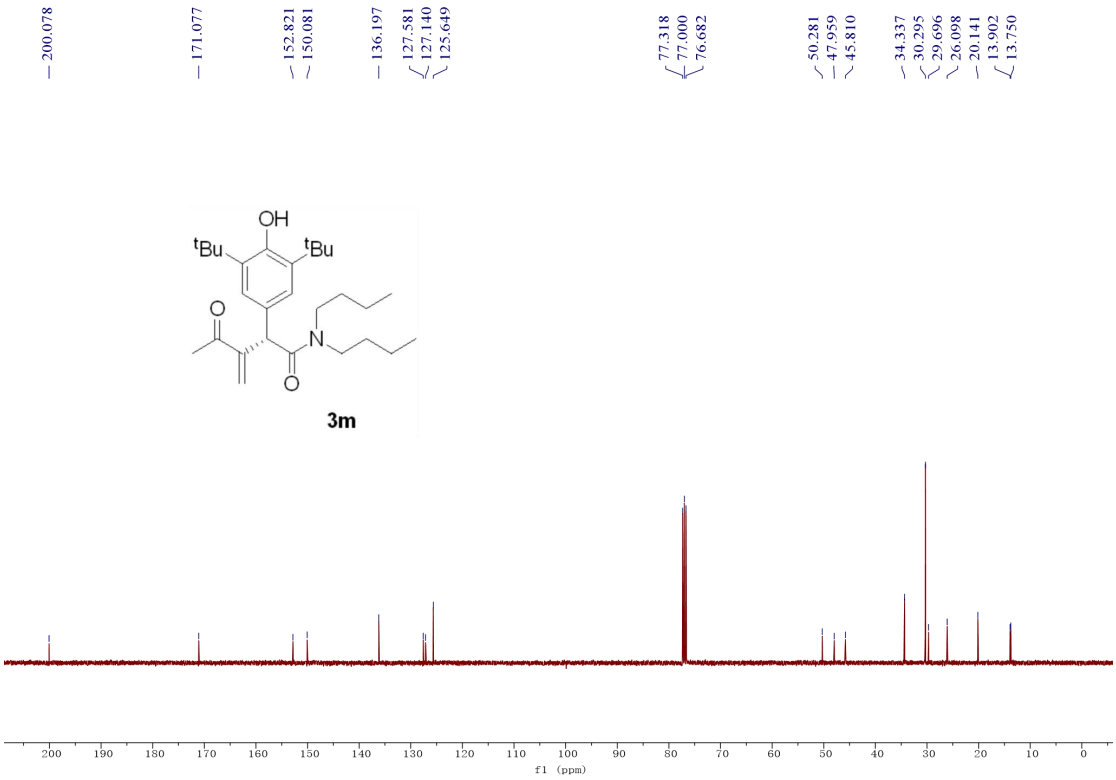
^{1}H and ^{13}C NMR spectra of compound **3k**



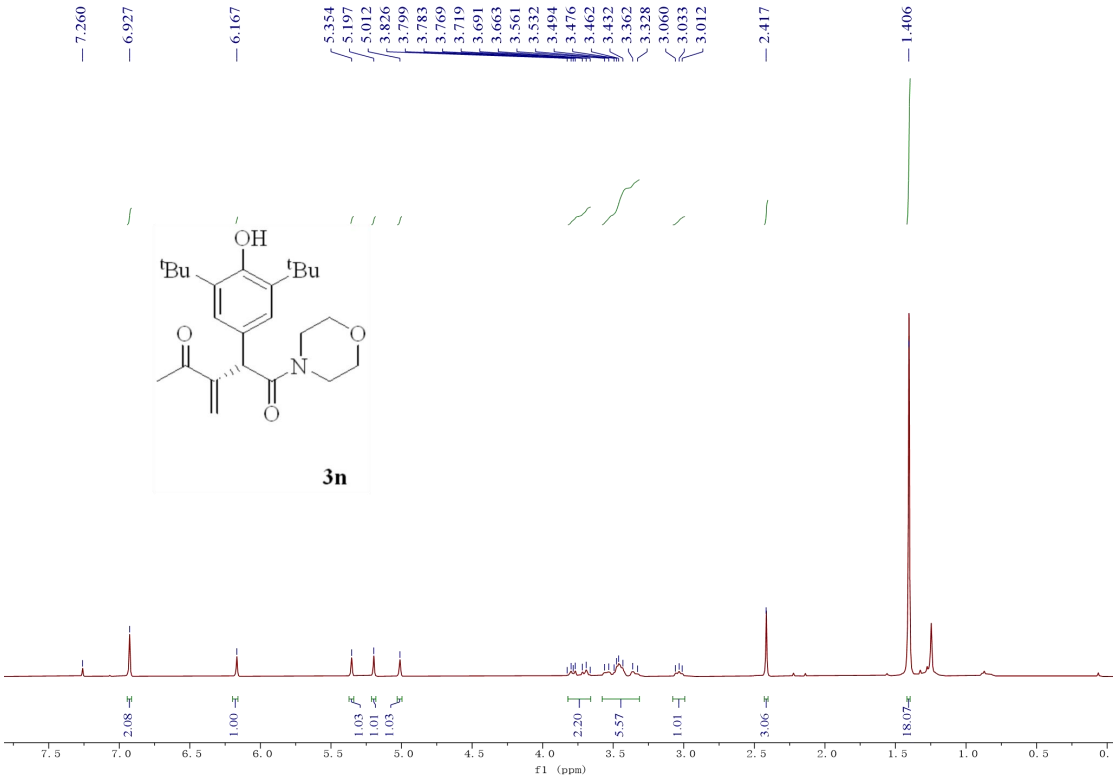


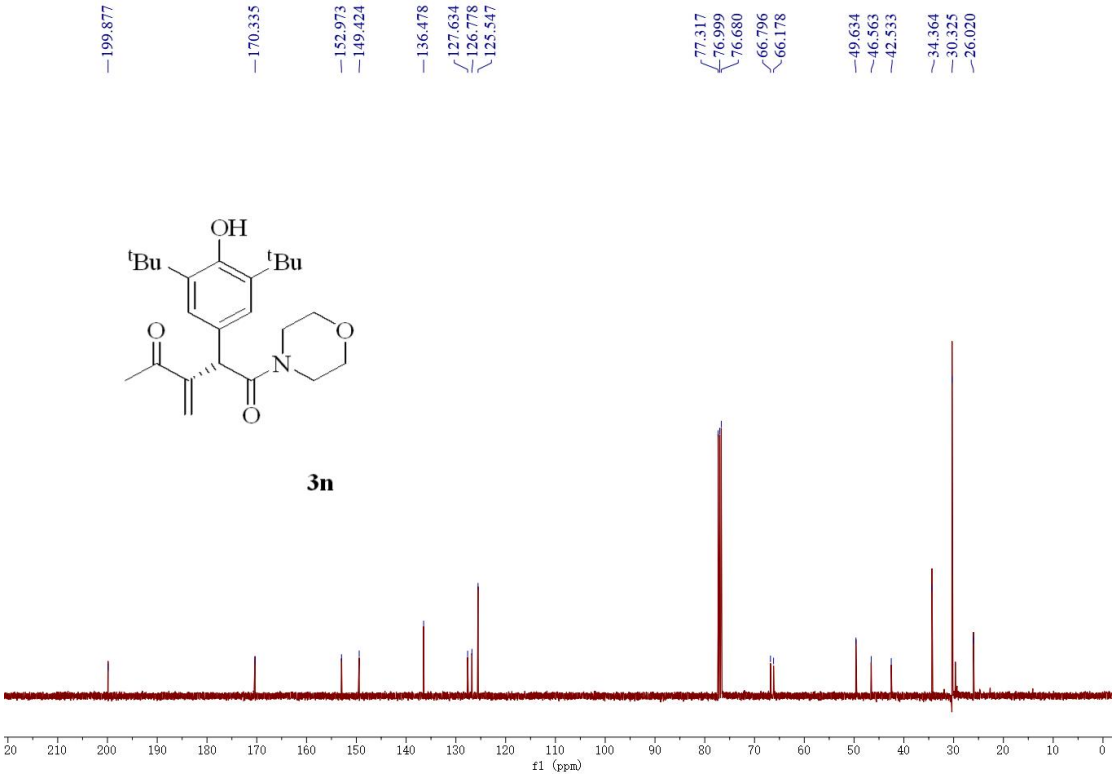
^{1}H and^{13}C NMR spectra of compound **3l**



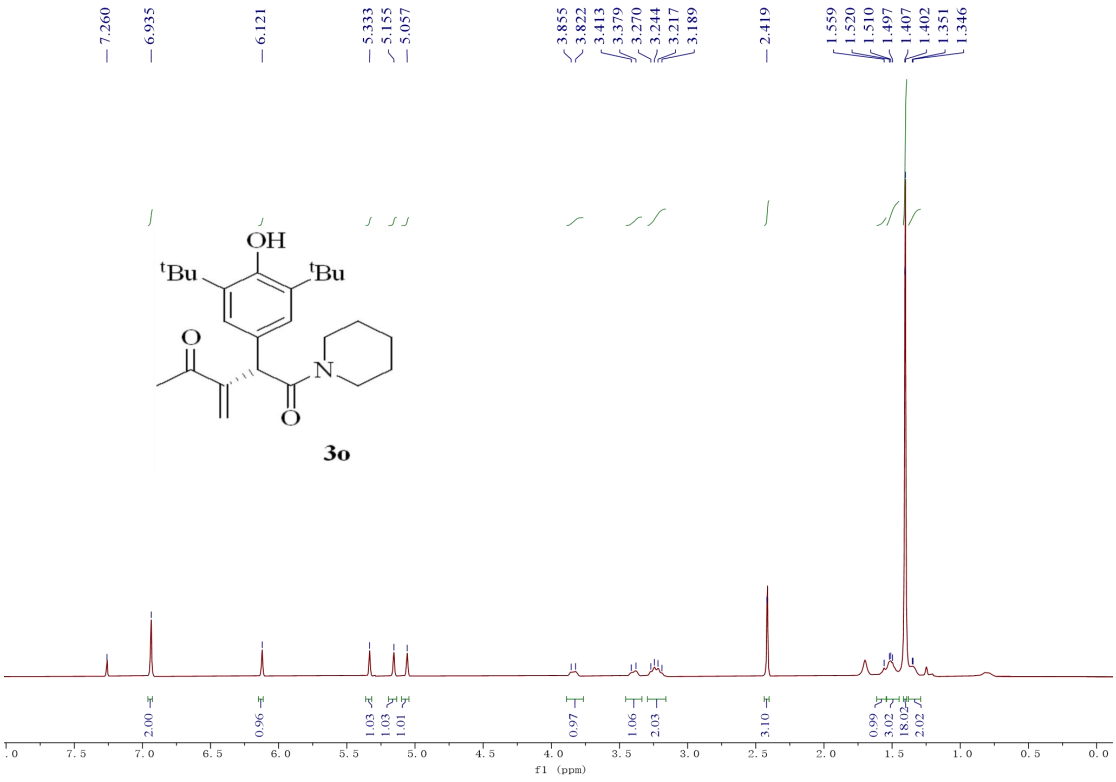


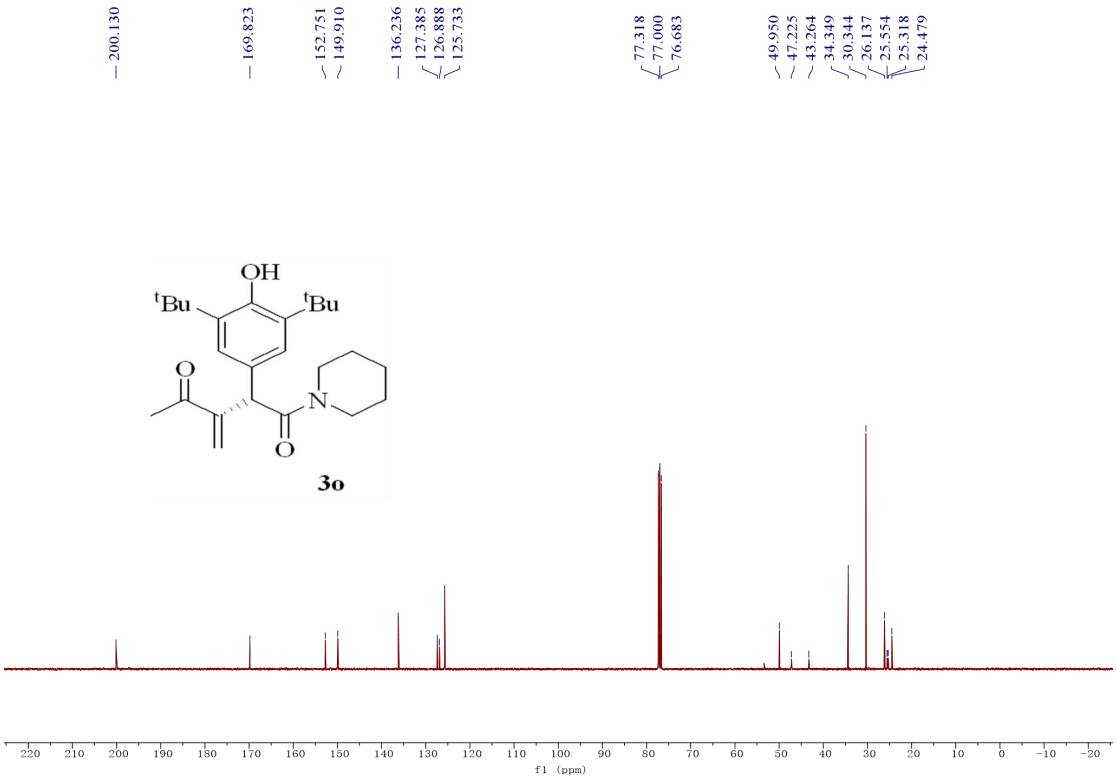
^{1}H and ^{13}C NMR spectra of compound **3m**



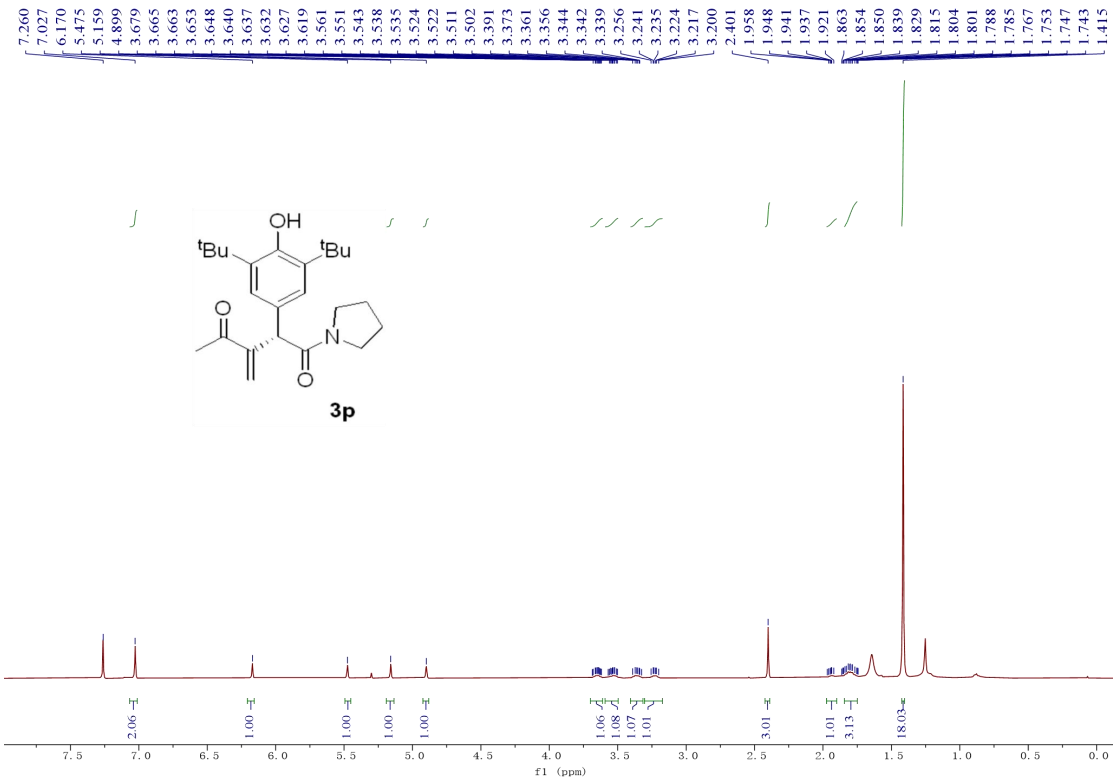


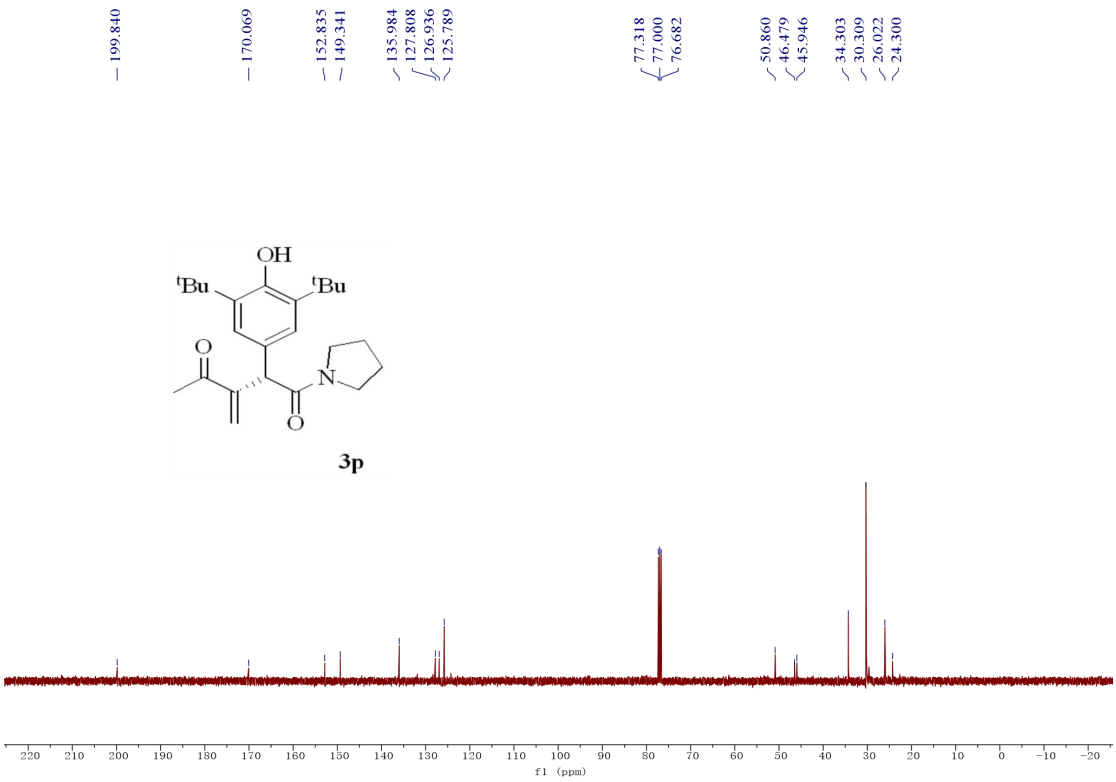
^{1}H and ^{13}C NMR spectra of compound **3n**



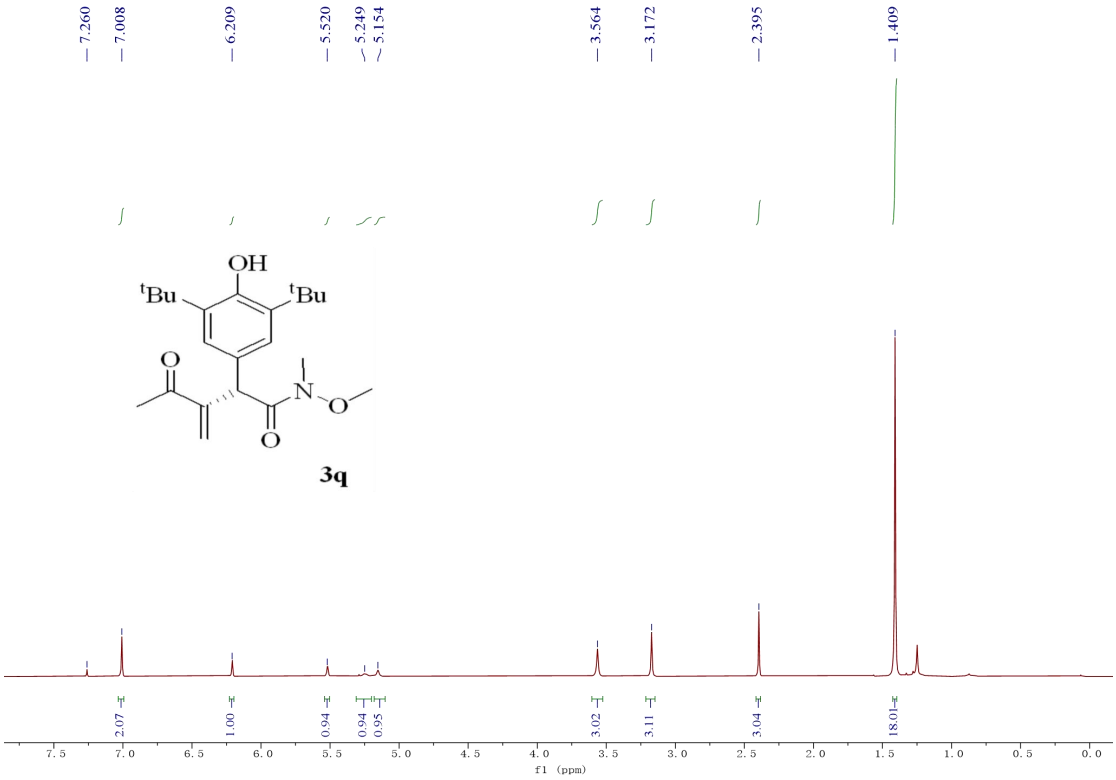


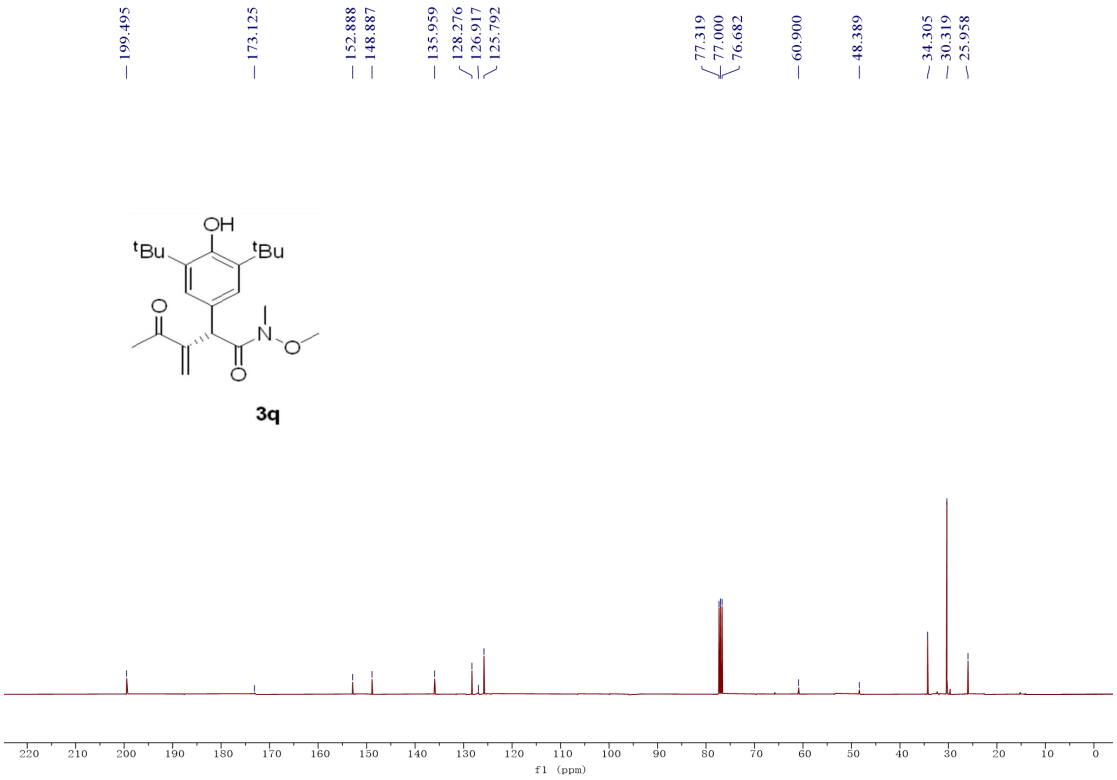
^{1}H and ^{13}C NMR spectra of compound **3o**



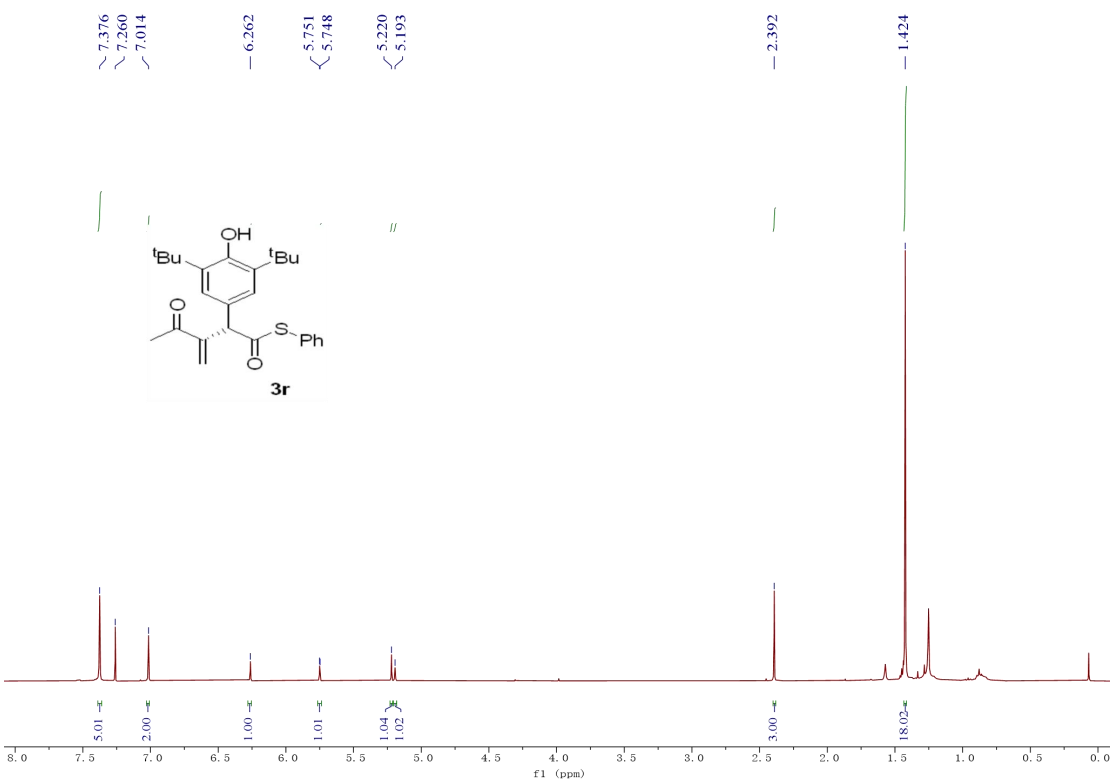


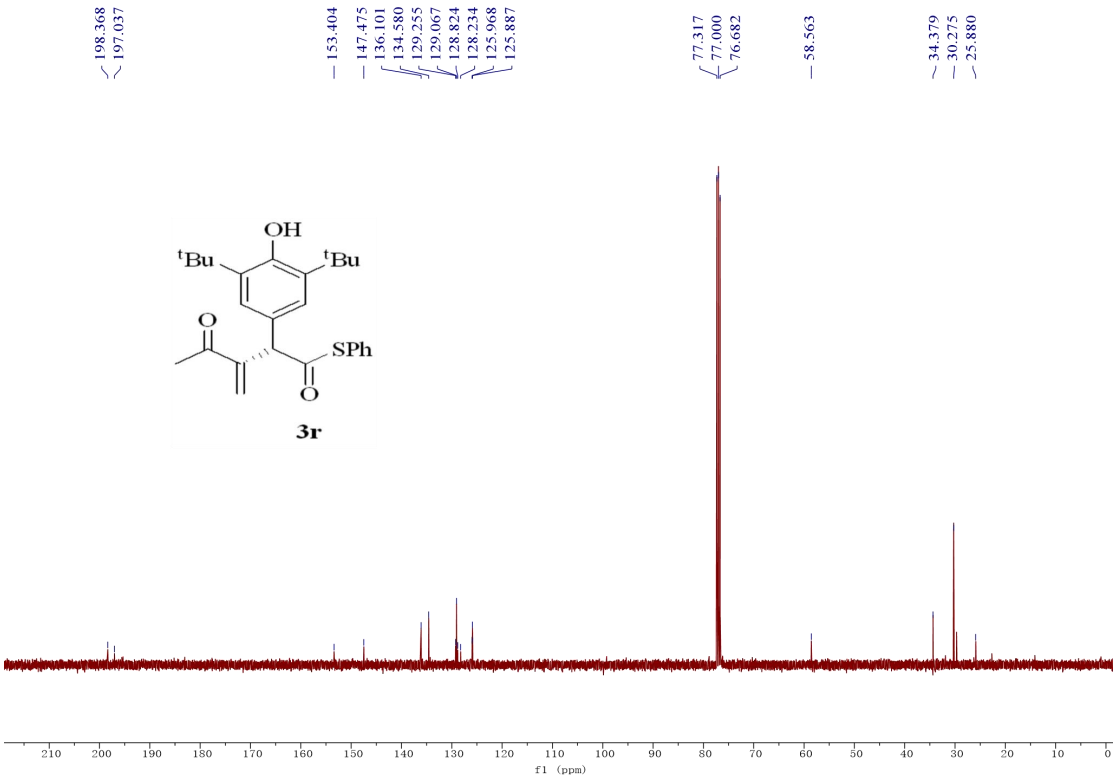
^{1}H and ^{13}C NMR spectra of compound **3p**



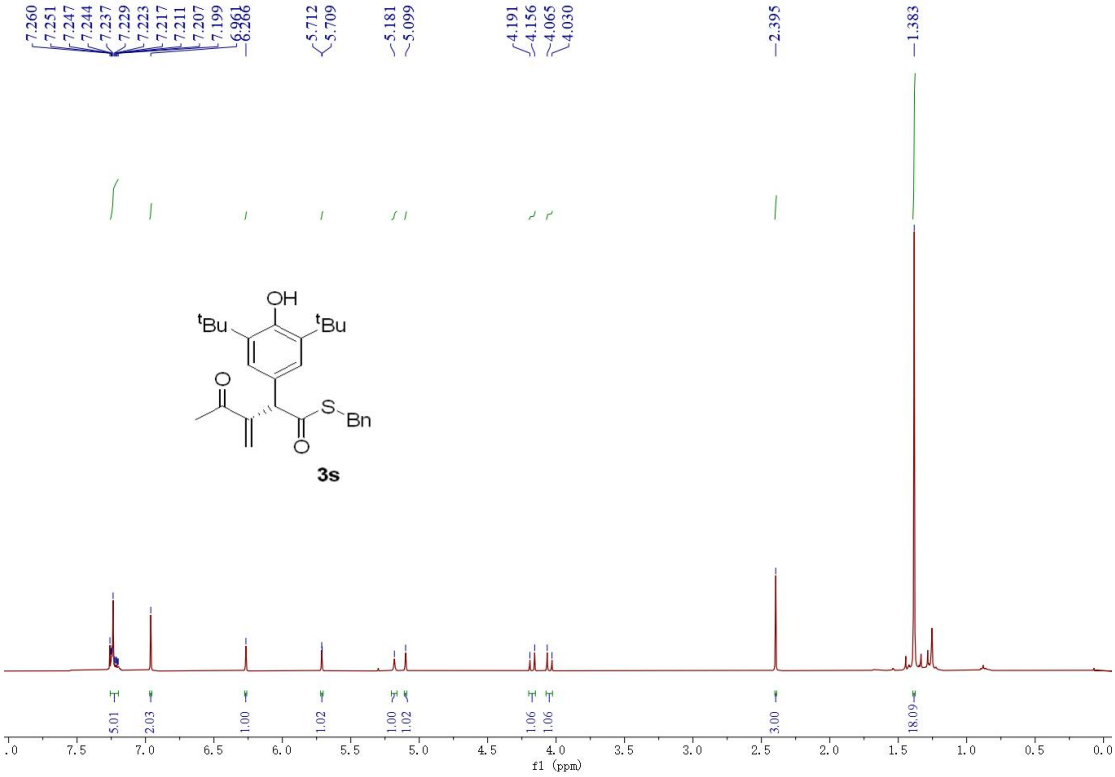


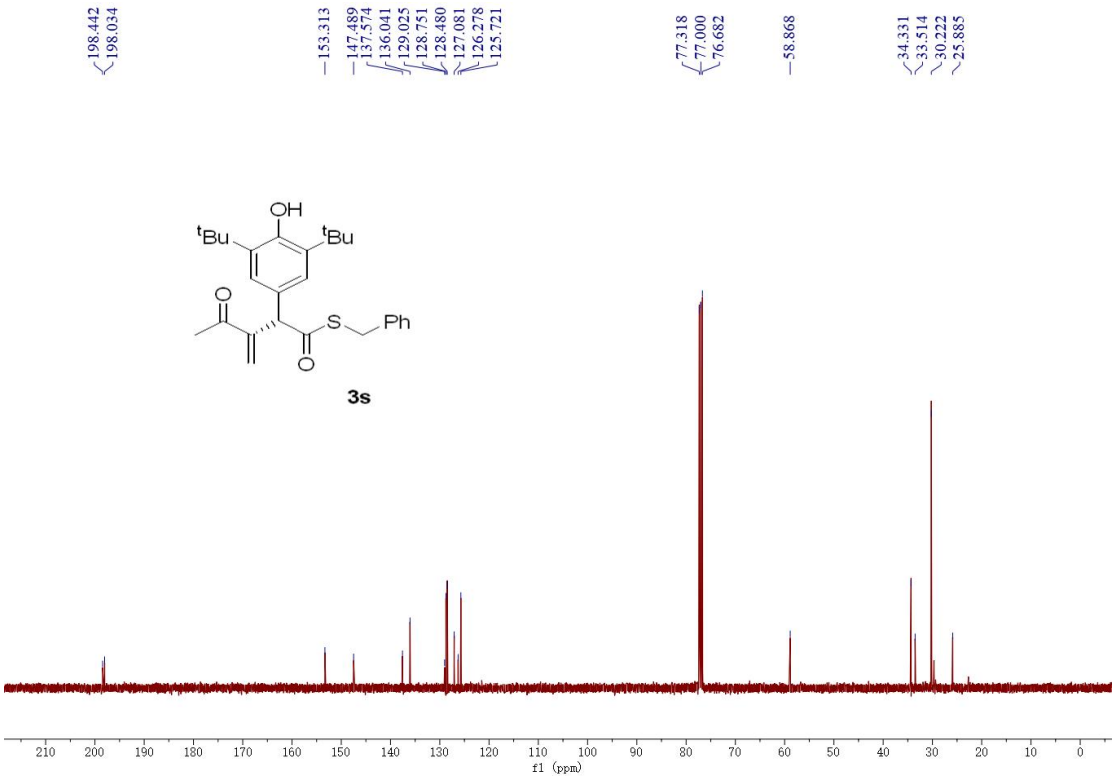
^{1}H and^{13}C NMR spectra of compound **3q**



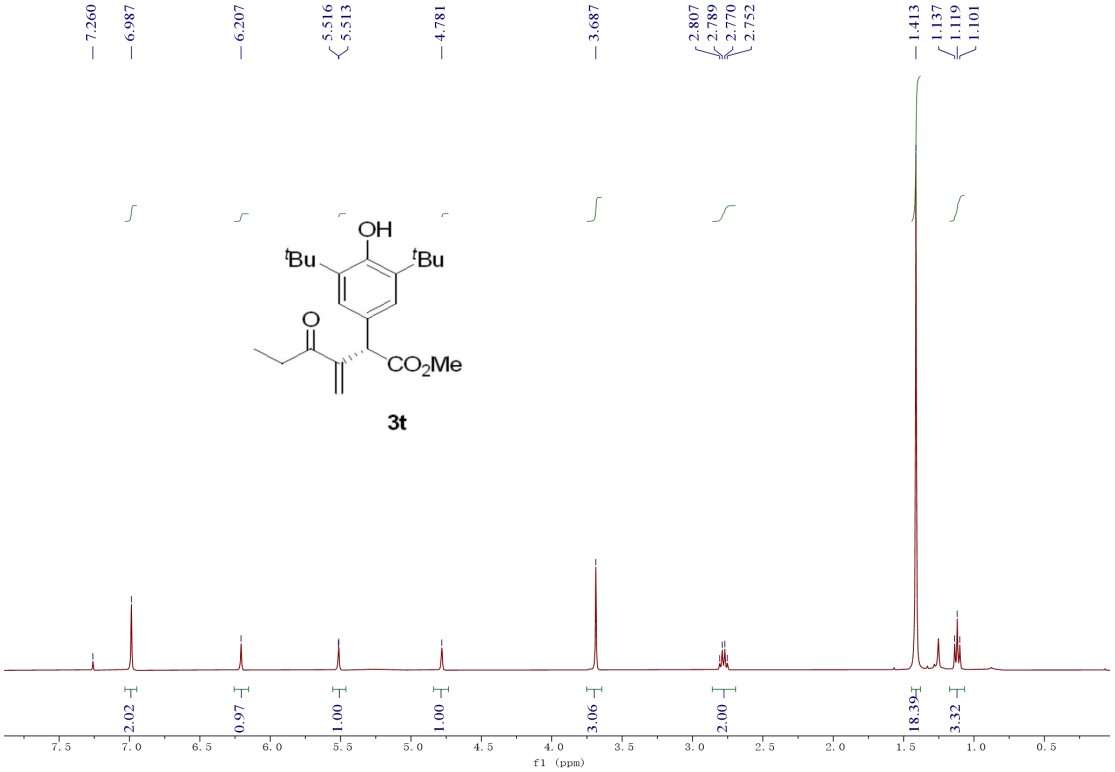


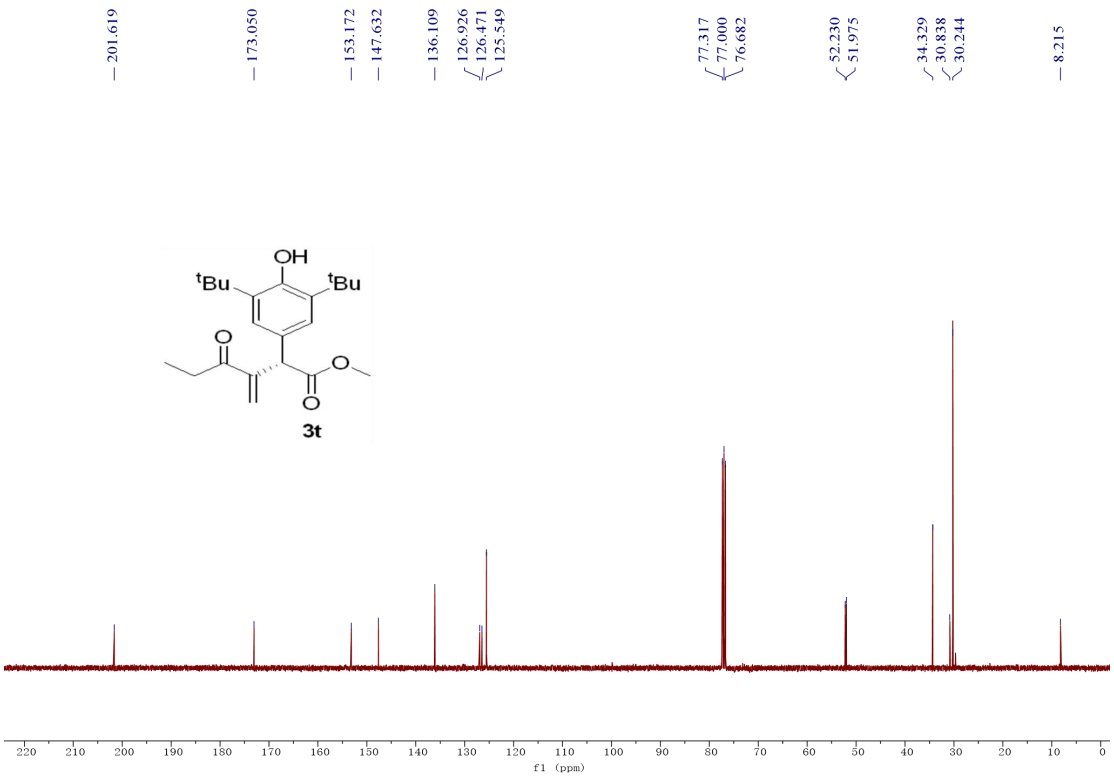
^{1}H and ^{13}C NMR spectra of compound **3r**



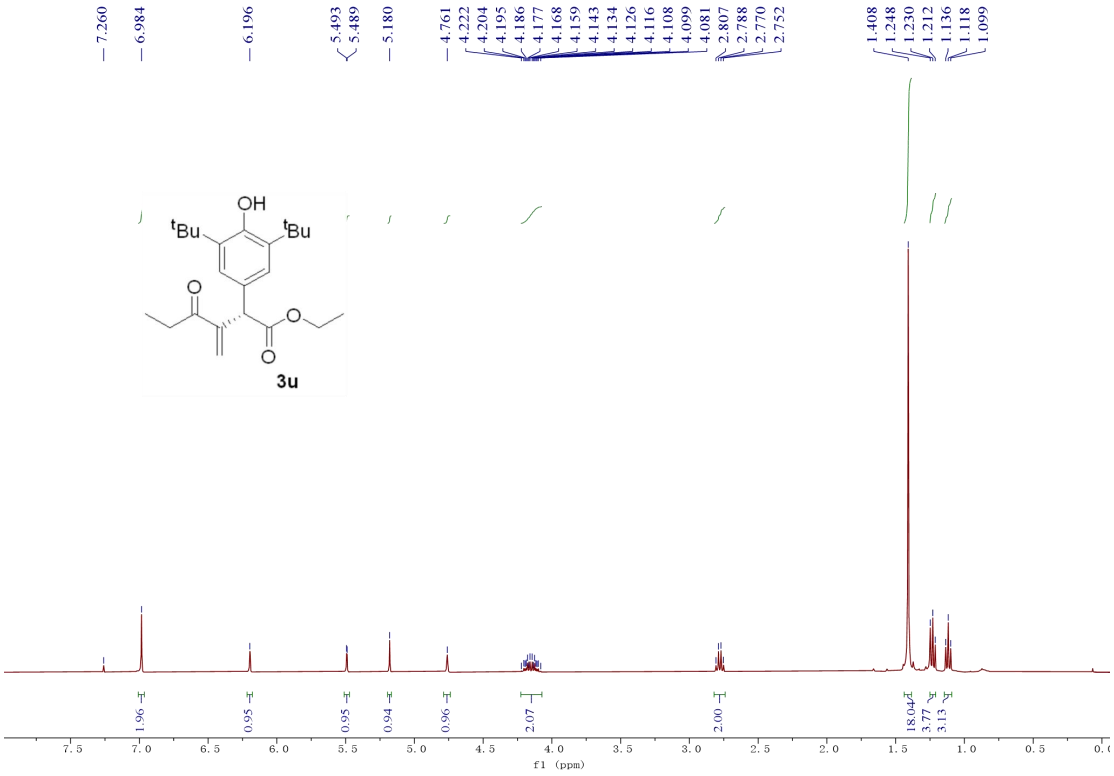


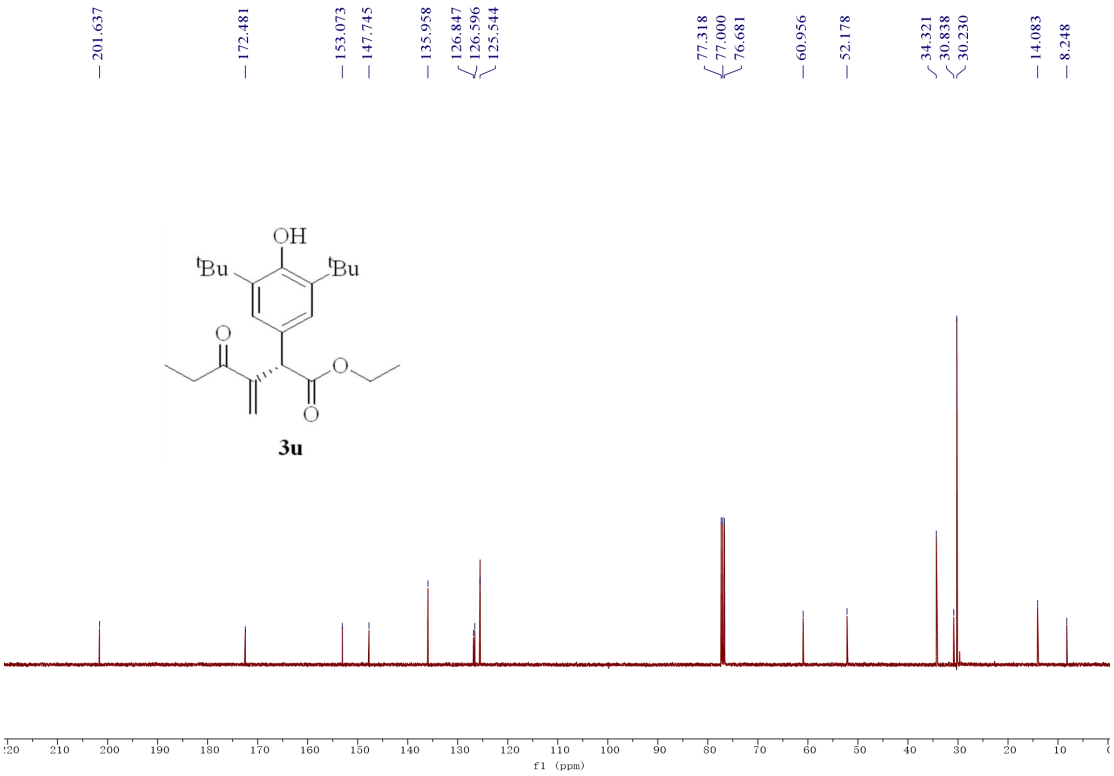
^{1}H and ^{13}C NMR spectra of compound **3s**



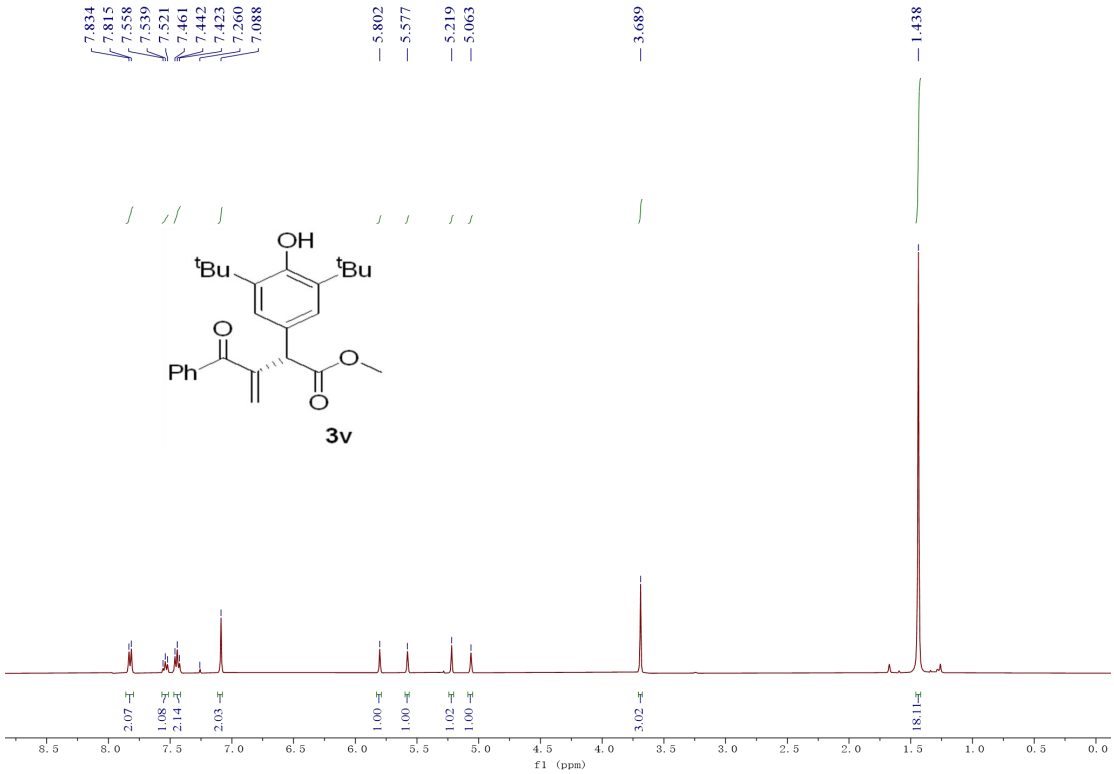


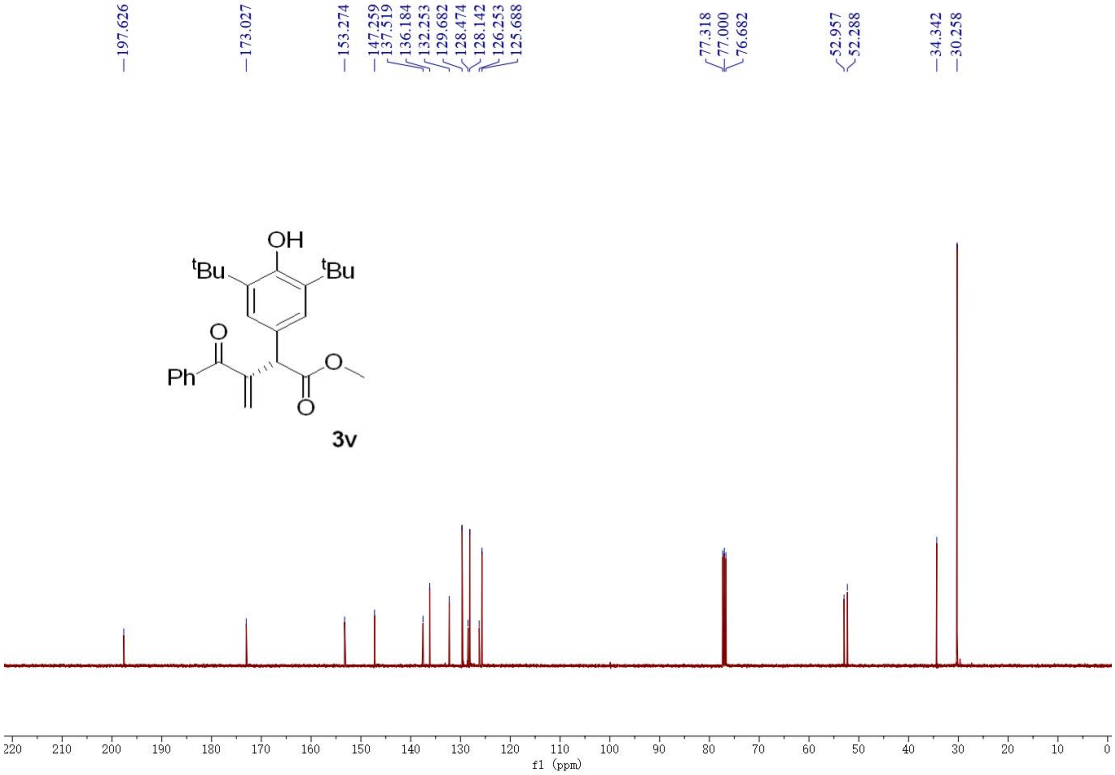
^{1}H and ^{13}C NMR spectra of compound **3t**



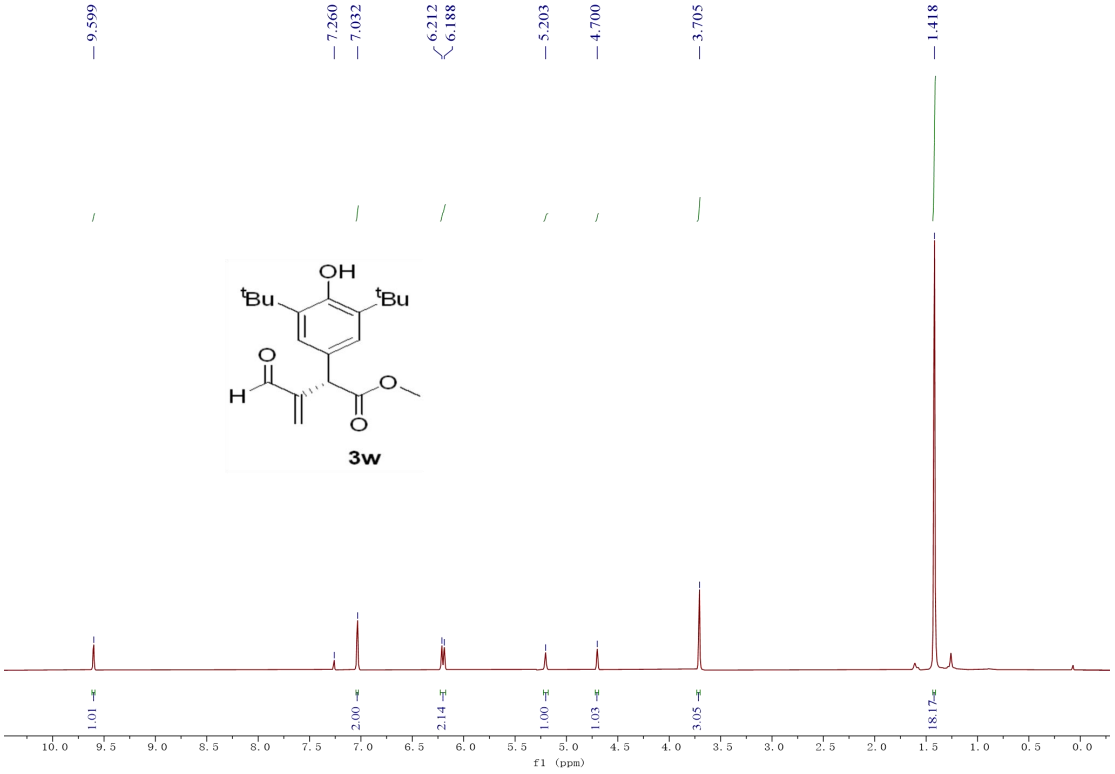


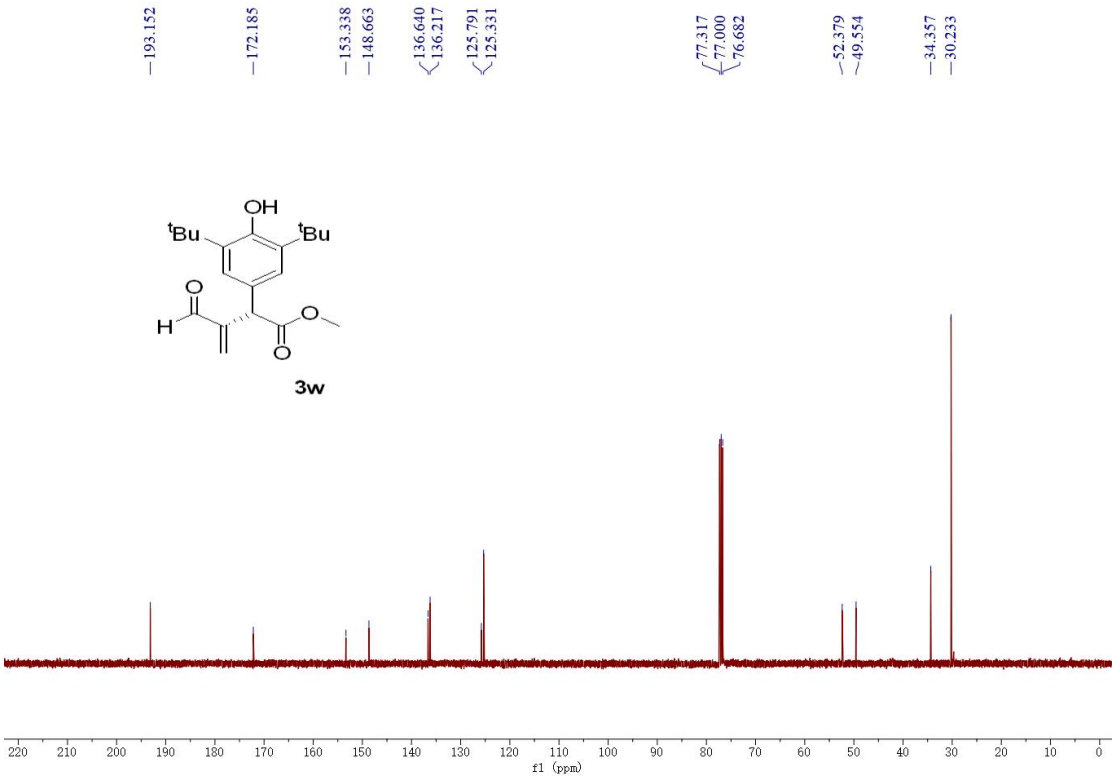
^{1}H and ^{13}C NMR spectra of compound **3u**



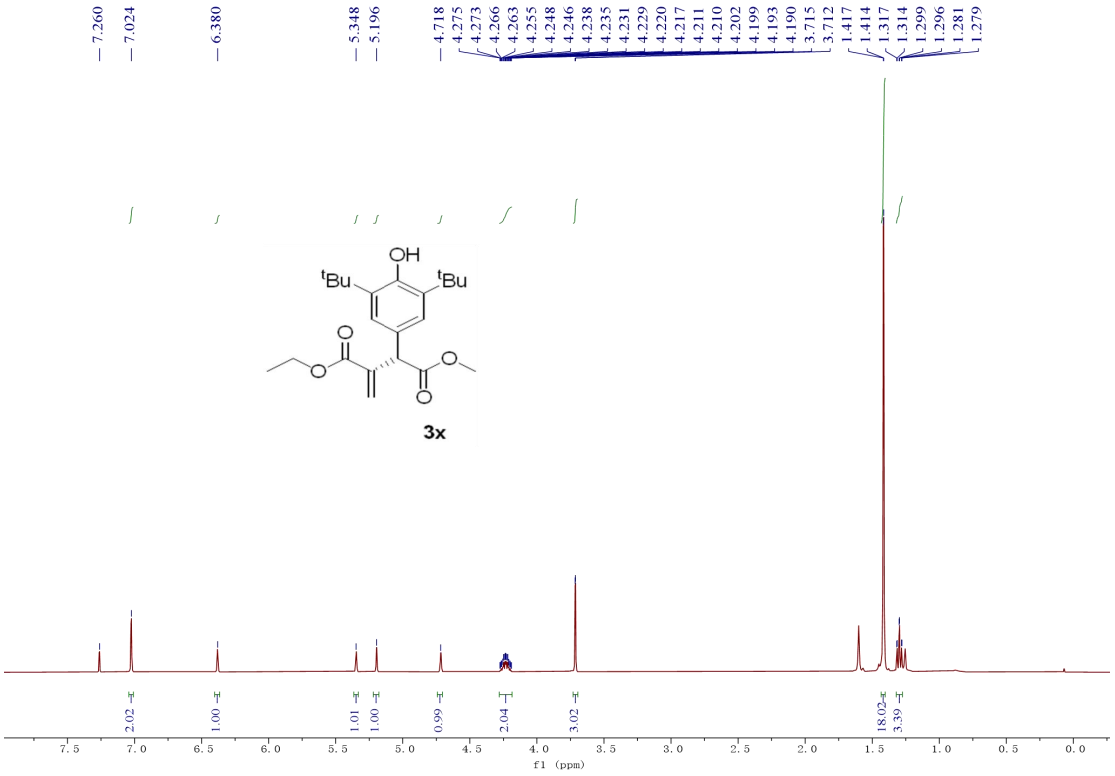


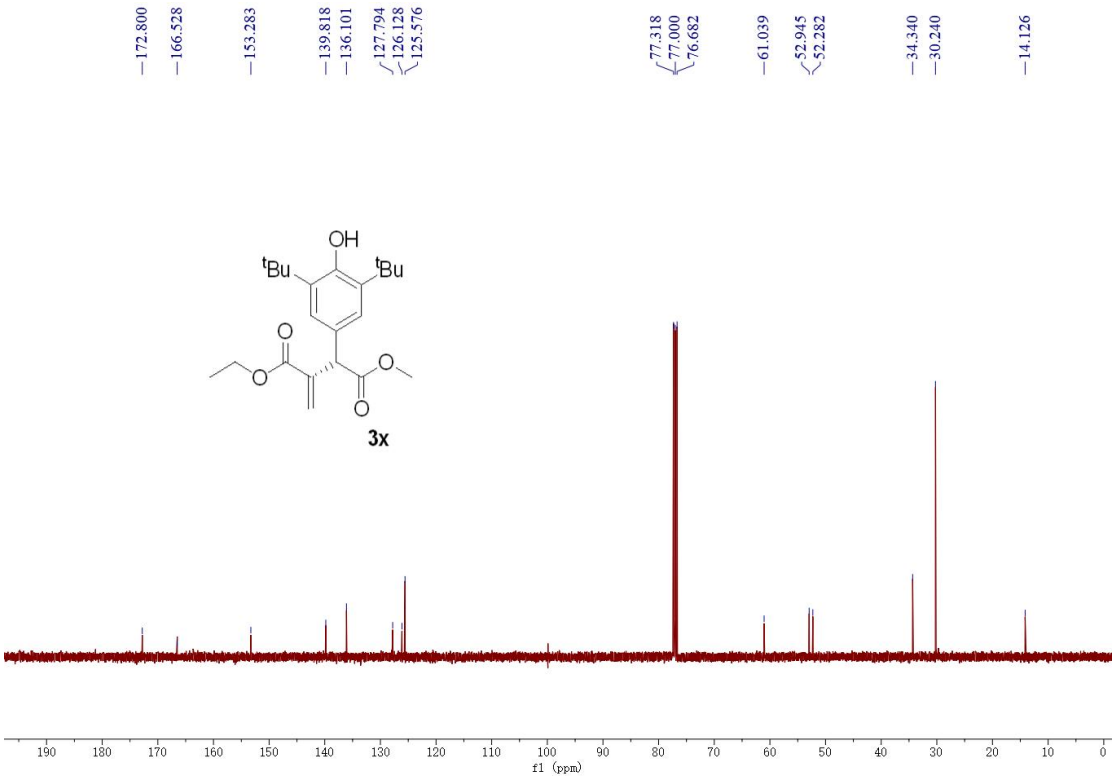
^{1}H and ^{13}C NMR spectra of compound **3v**



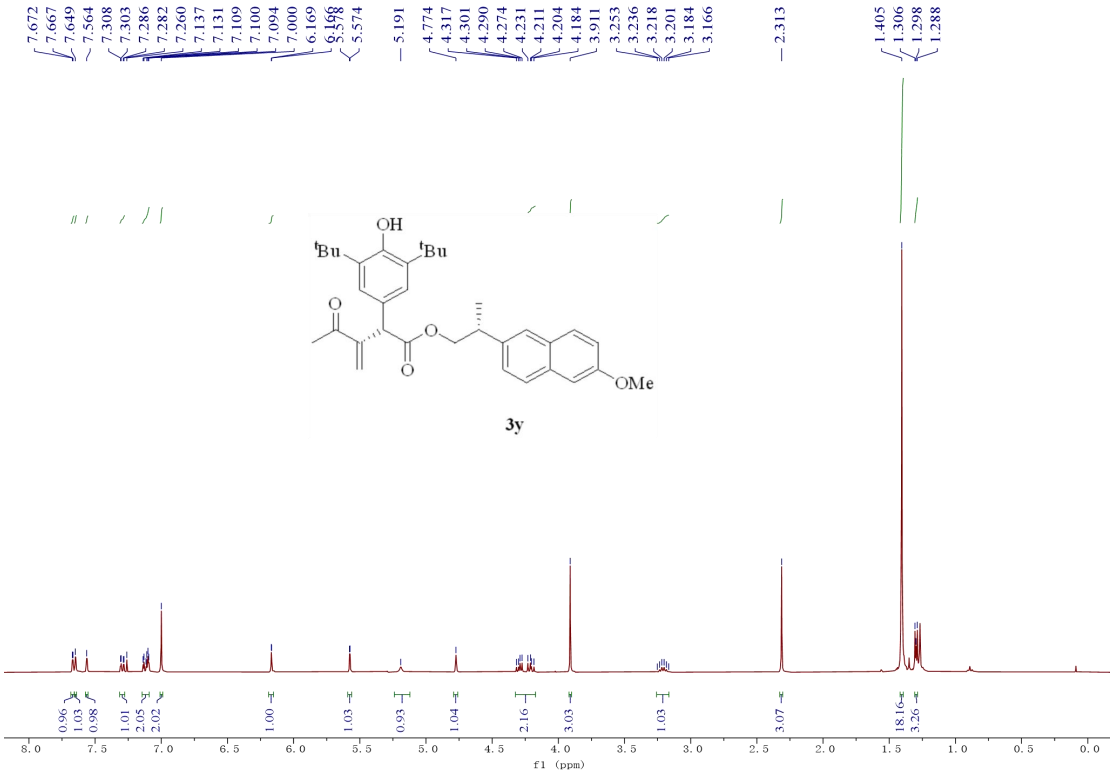


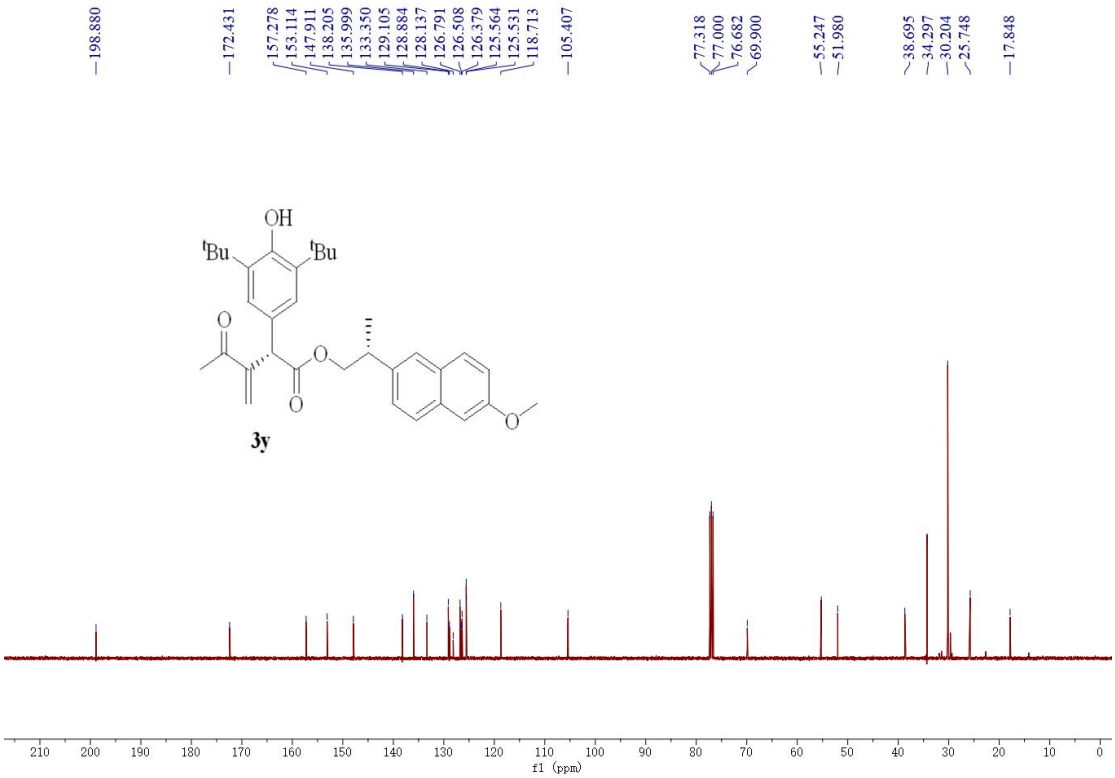
^{1}H and ^{13}C NMR spectra of compound **3w**



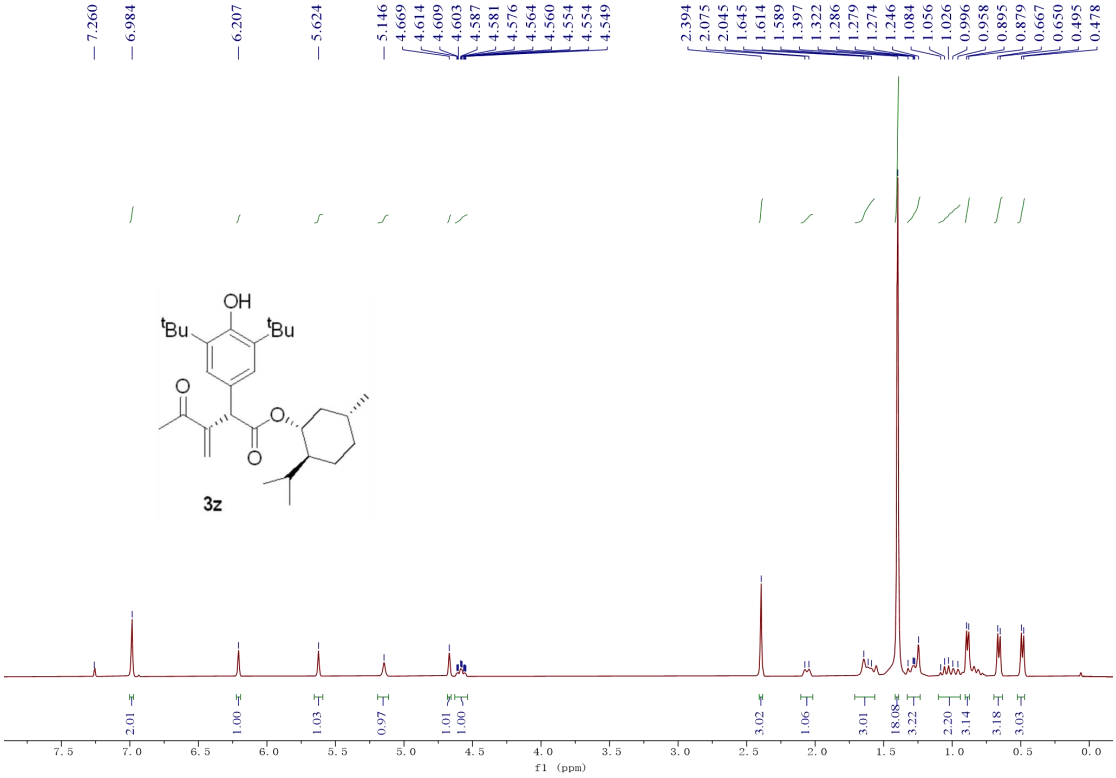


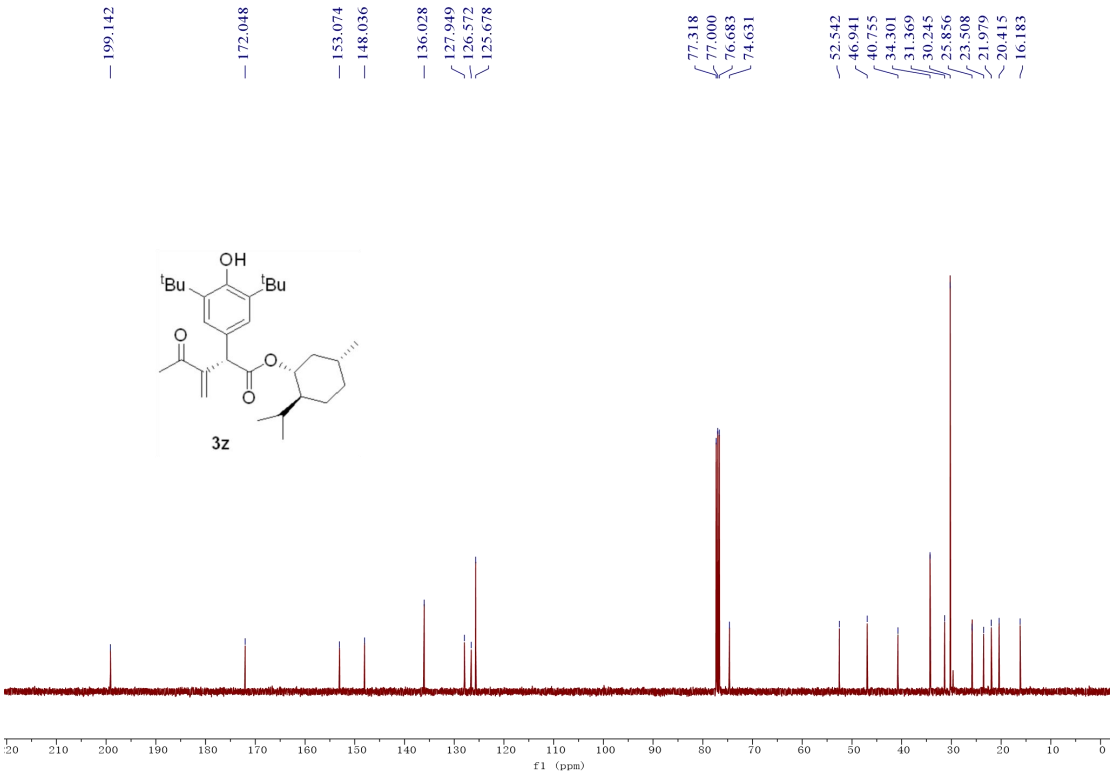
^{1}H and ^{13}C NMR spectra of compound **3x**



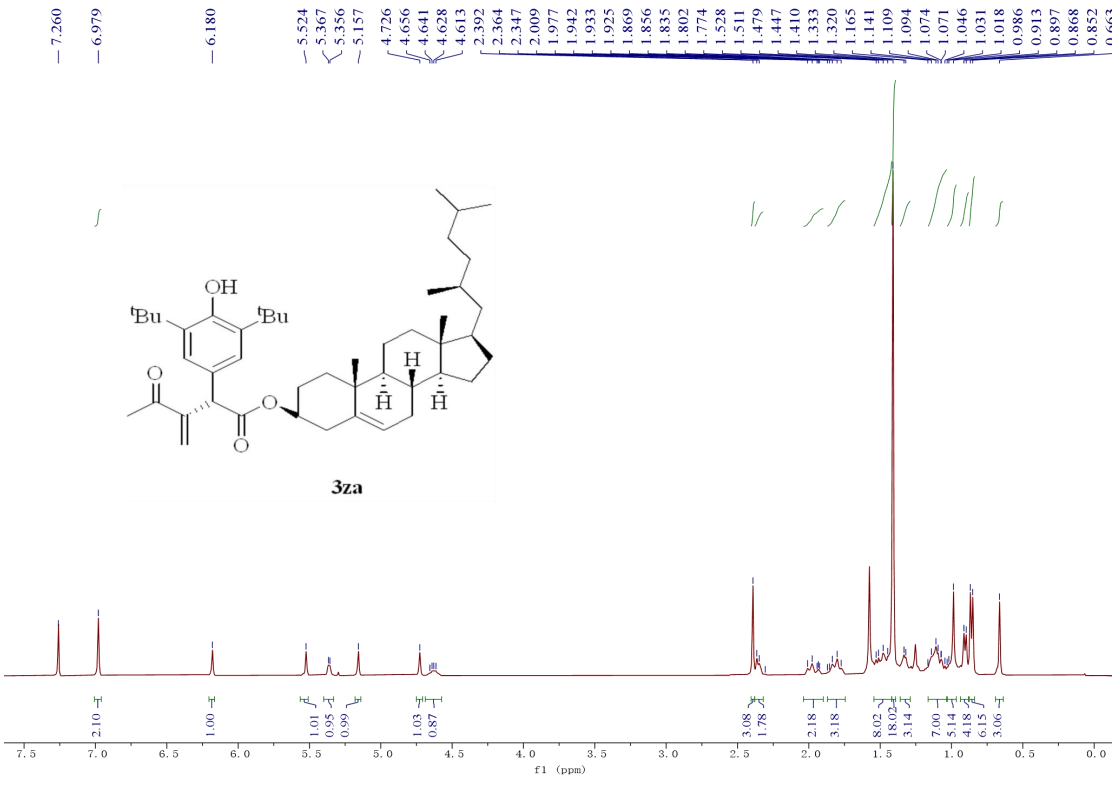


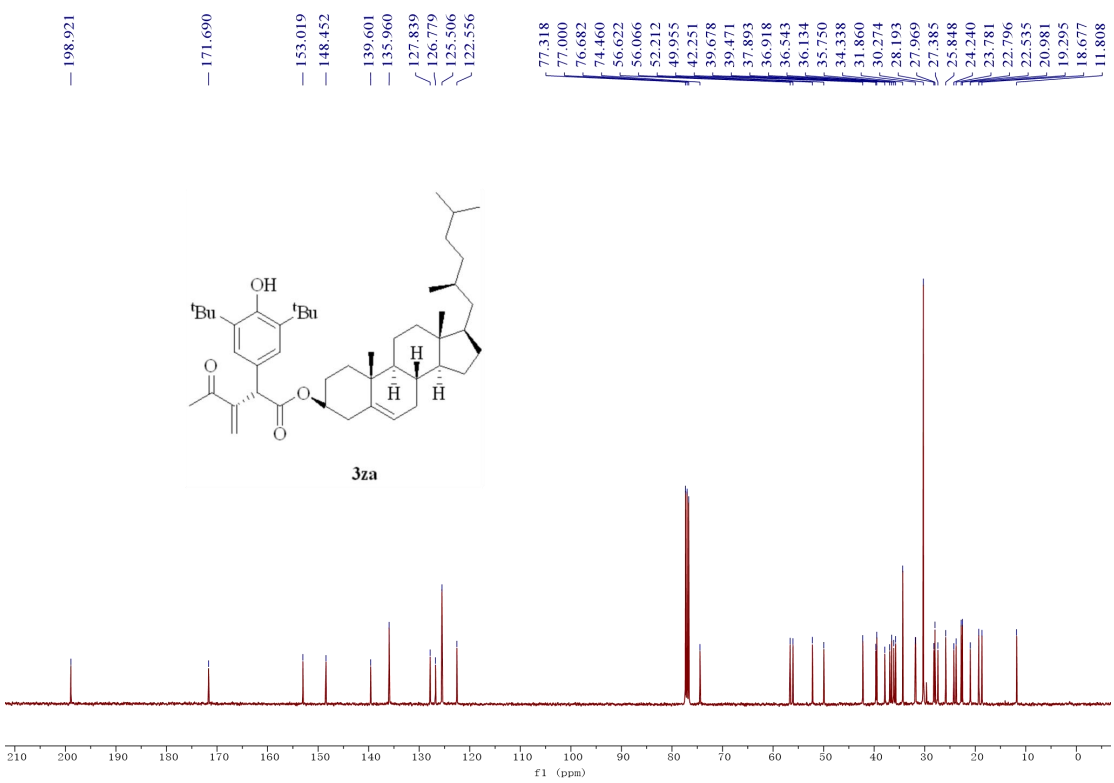
^{1}H and ^{13}C NMR spectra of compound **3y**



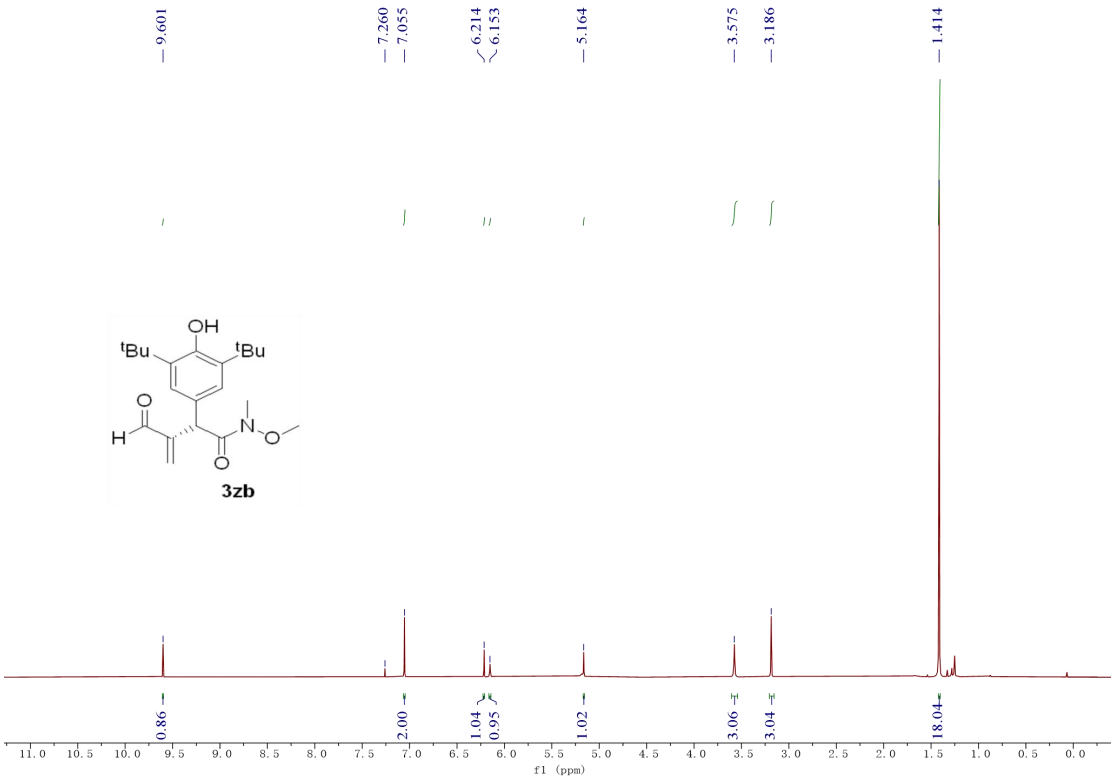


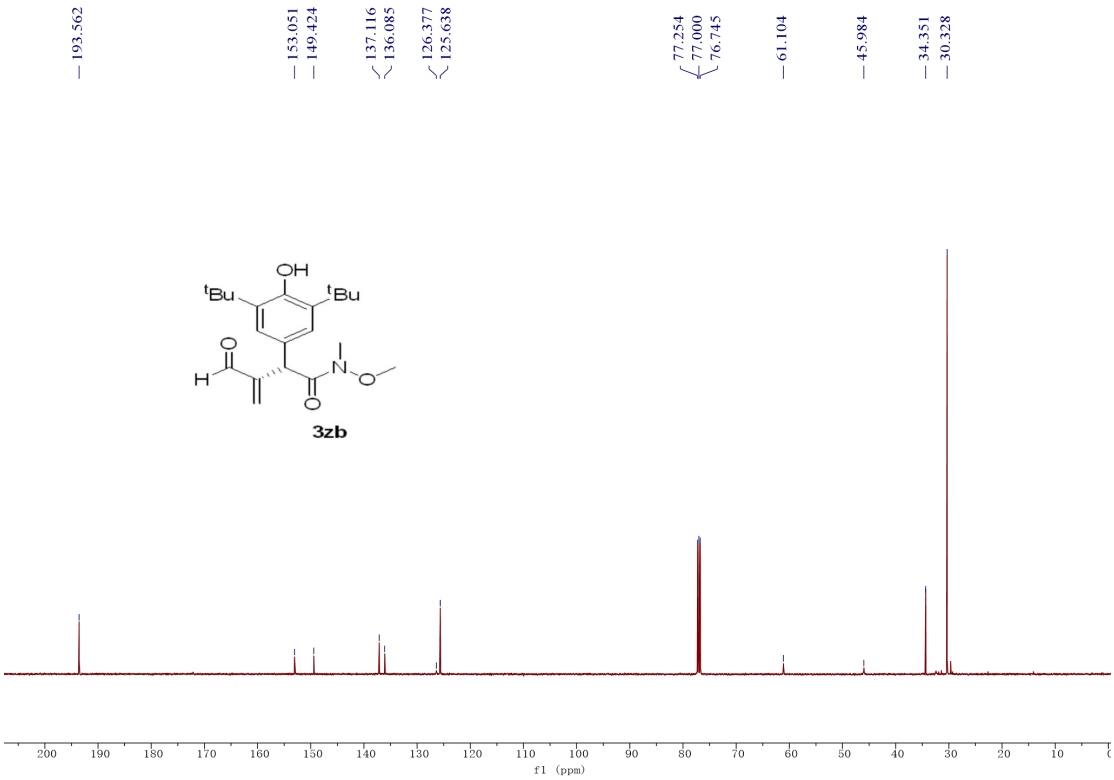
^{1}H and ^{13}C NMR spectra of compound **3z**



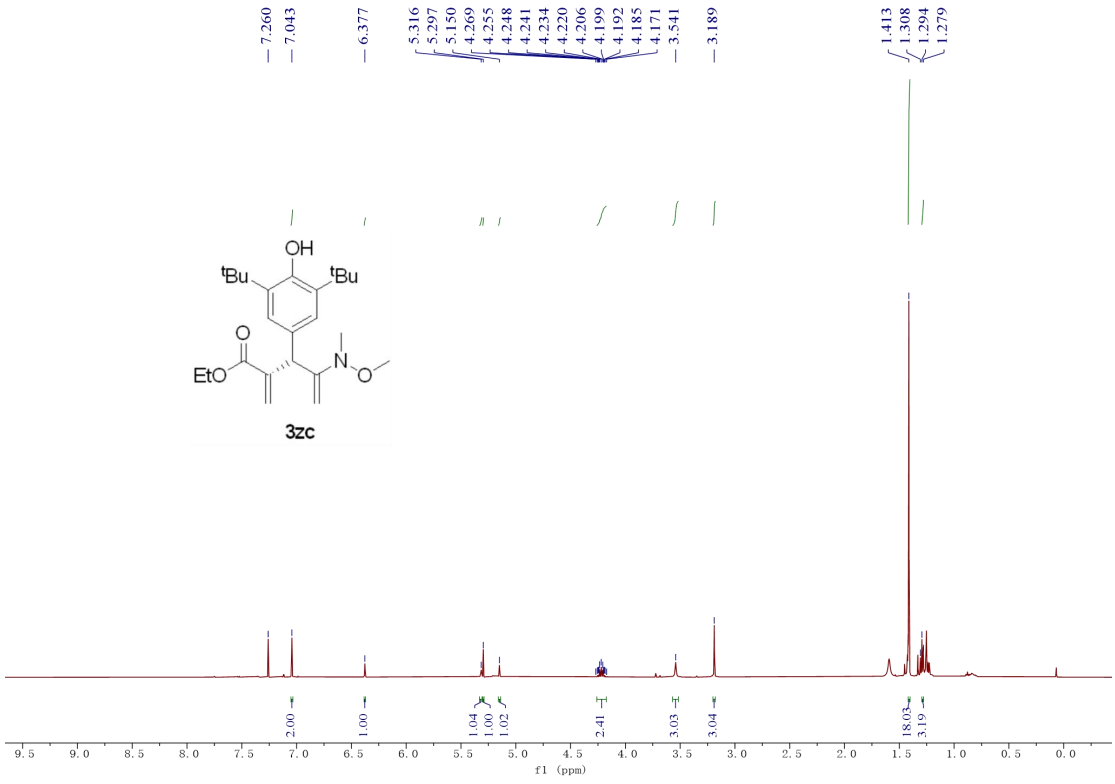


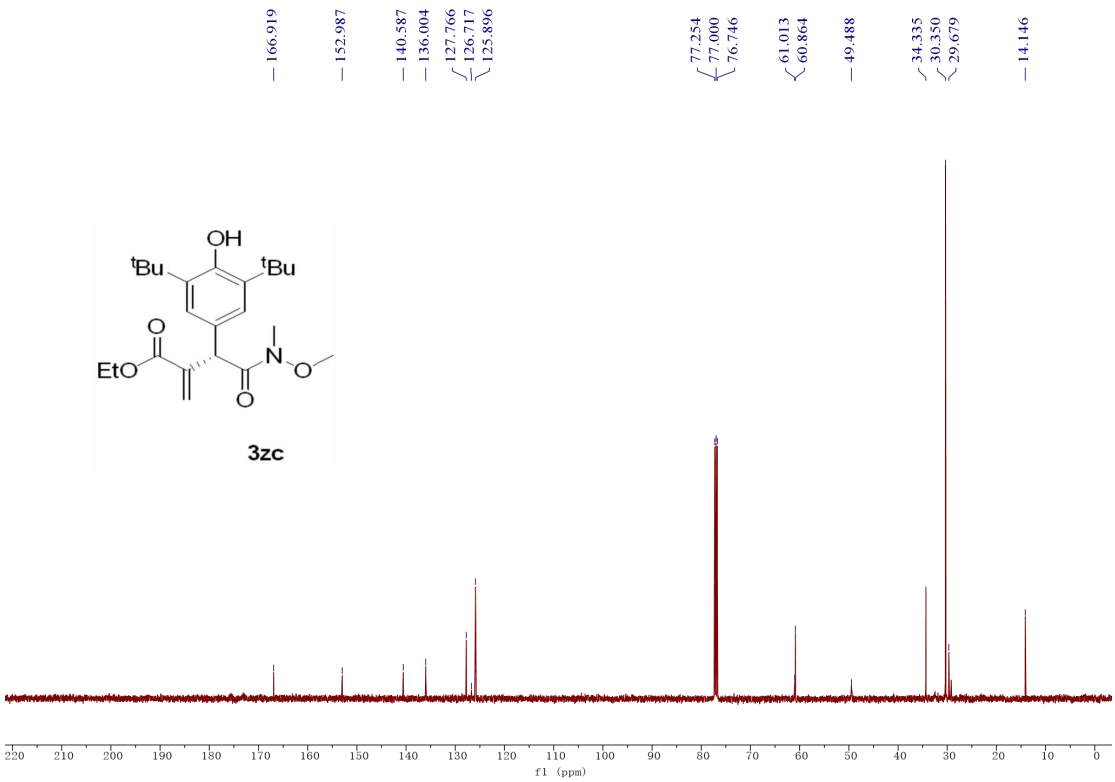
^{1}H and ^{13}C NMR spectra of compound **3za**



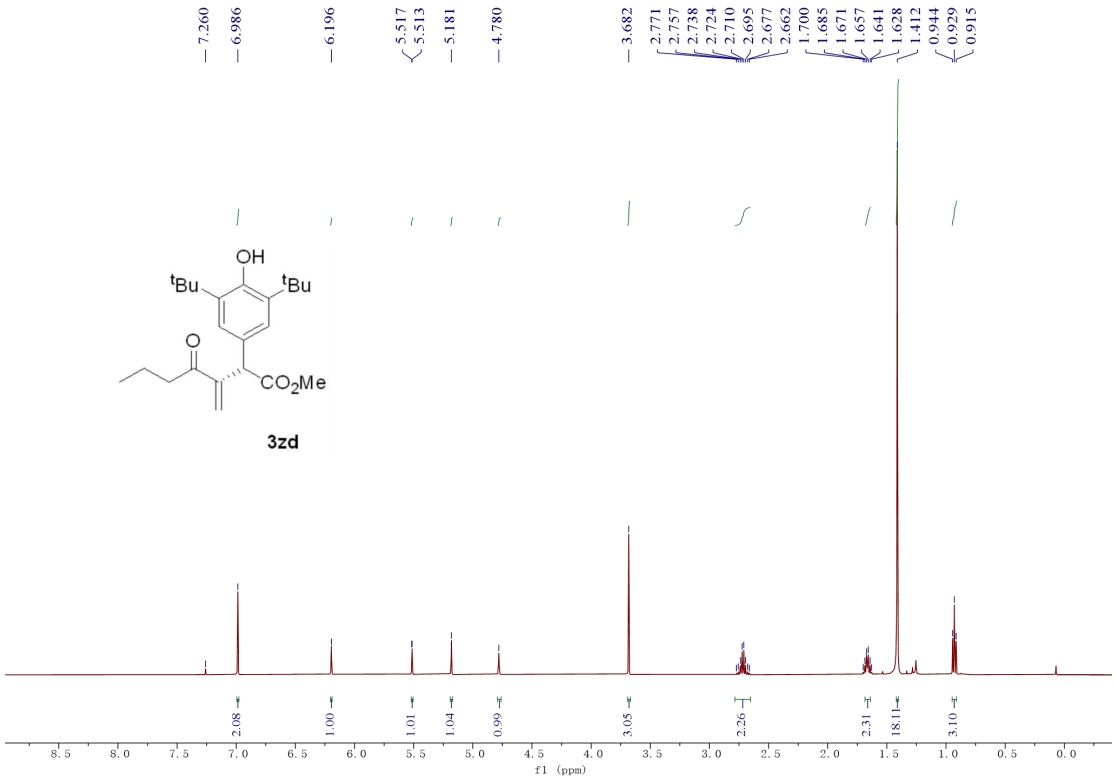


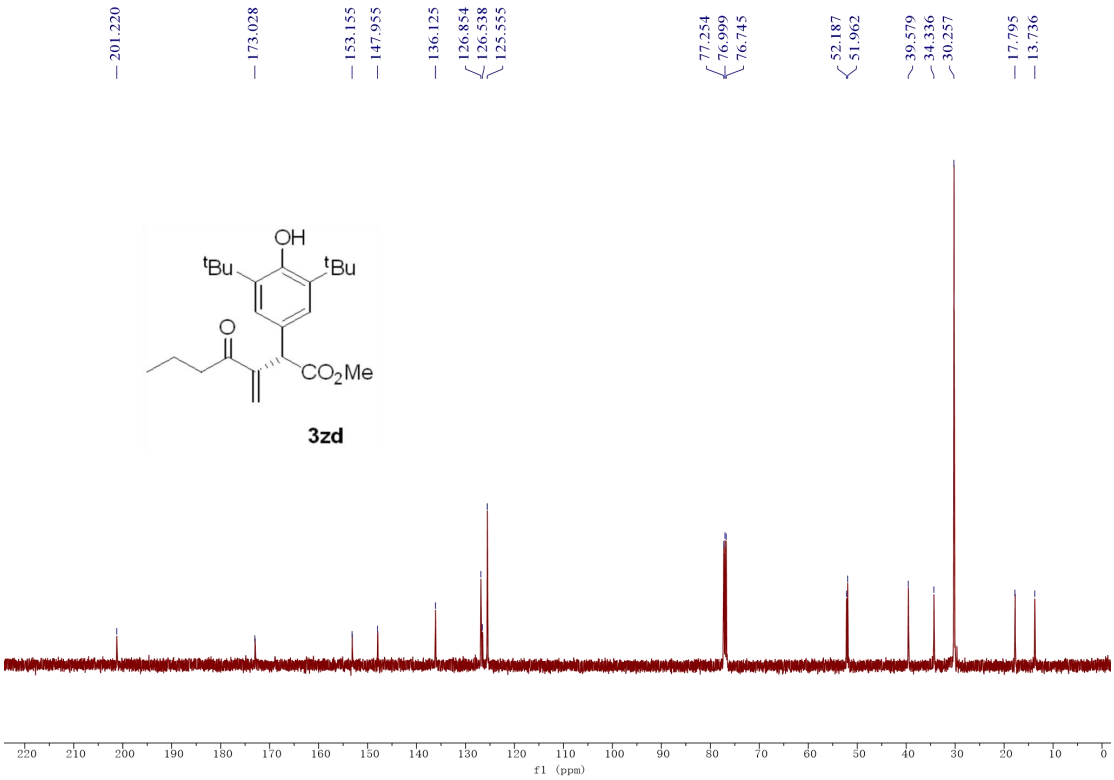
^{1}H and ^{13}C NMR spectra of compound **3zb**



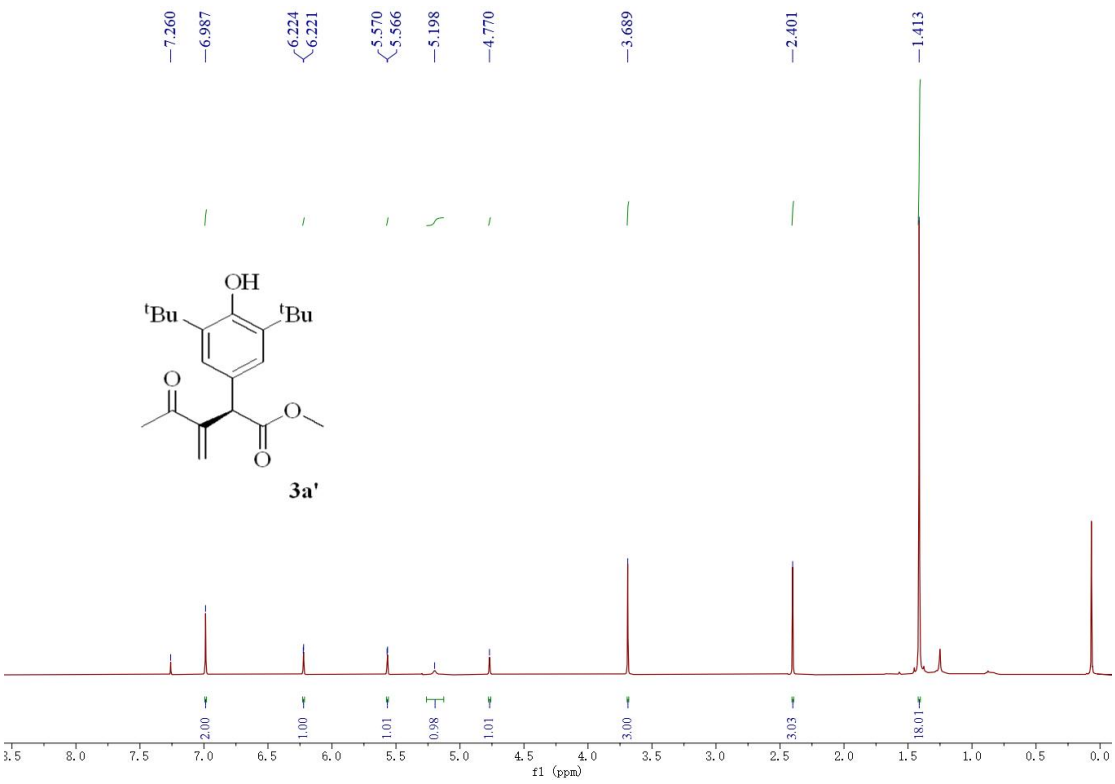


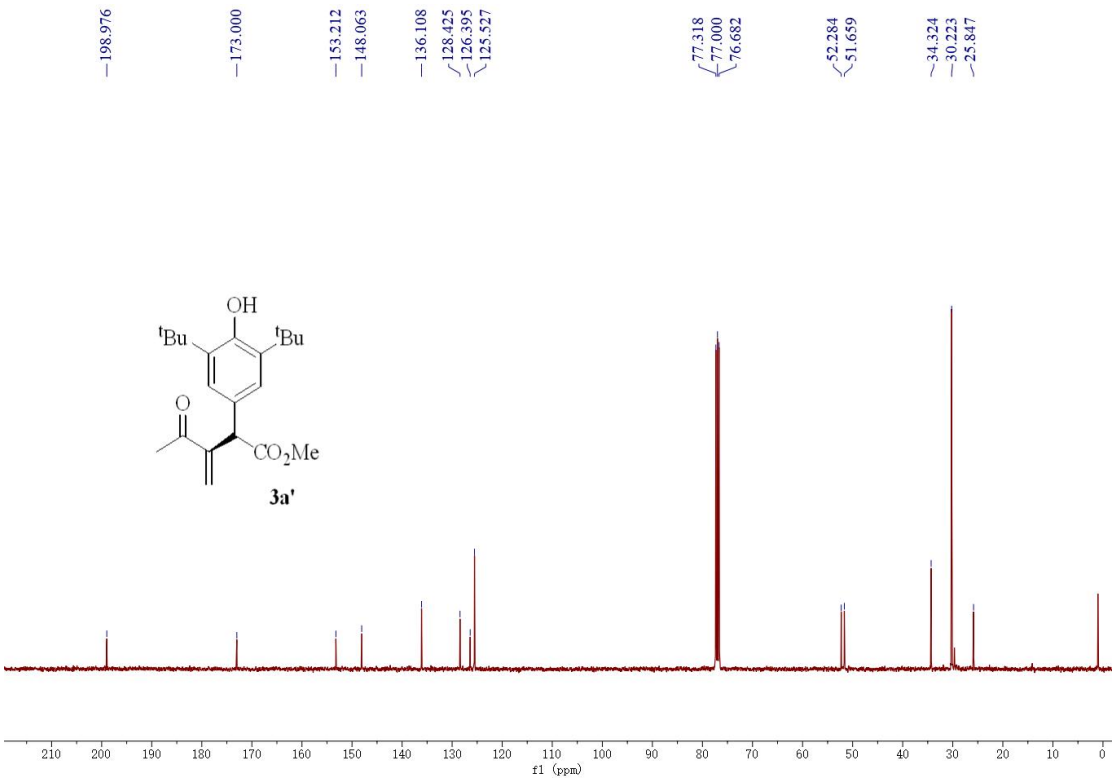
^{1}H and ^{13}C NMR spectra of compound **3zc**



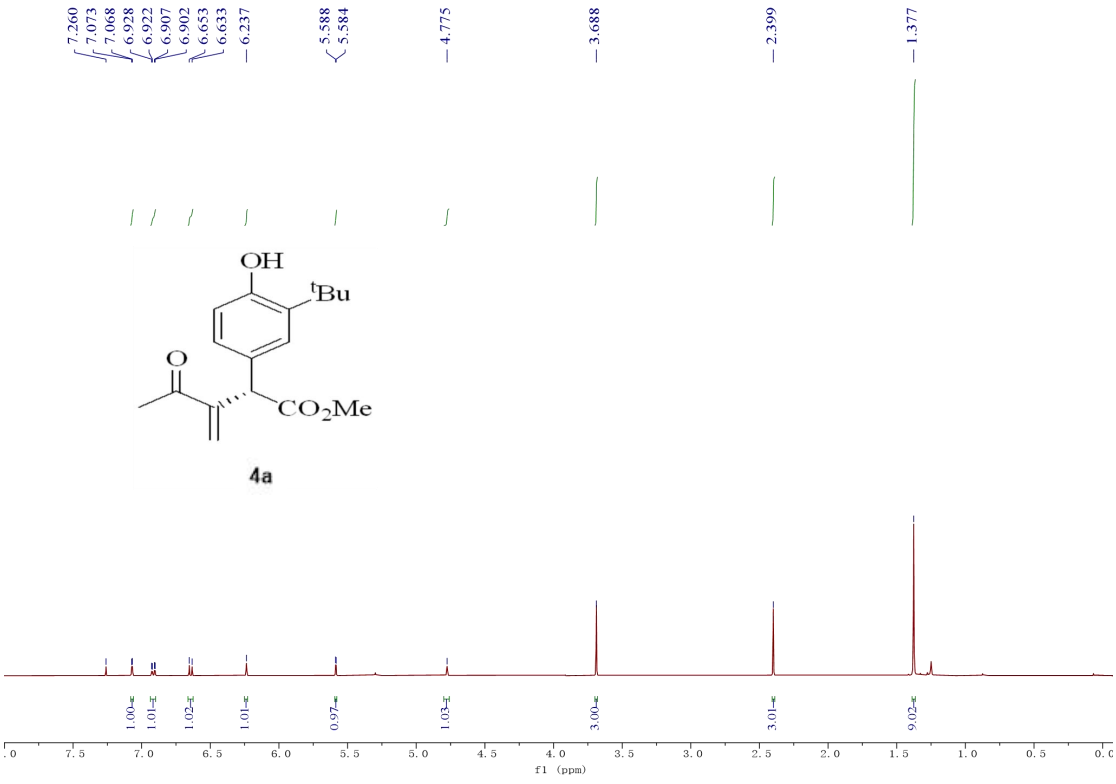


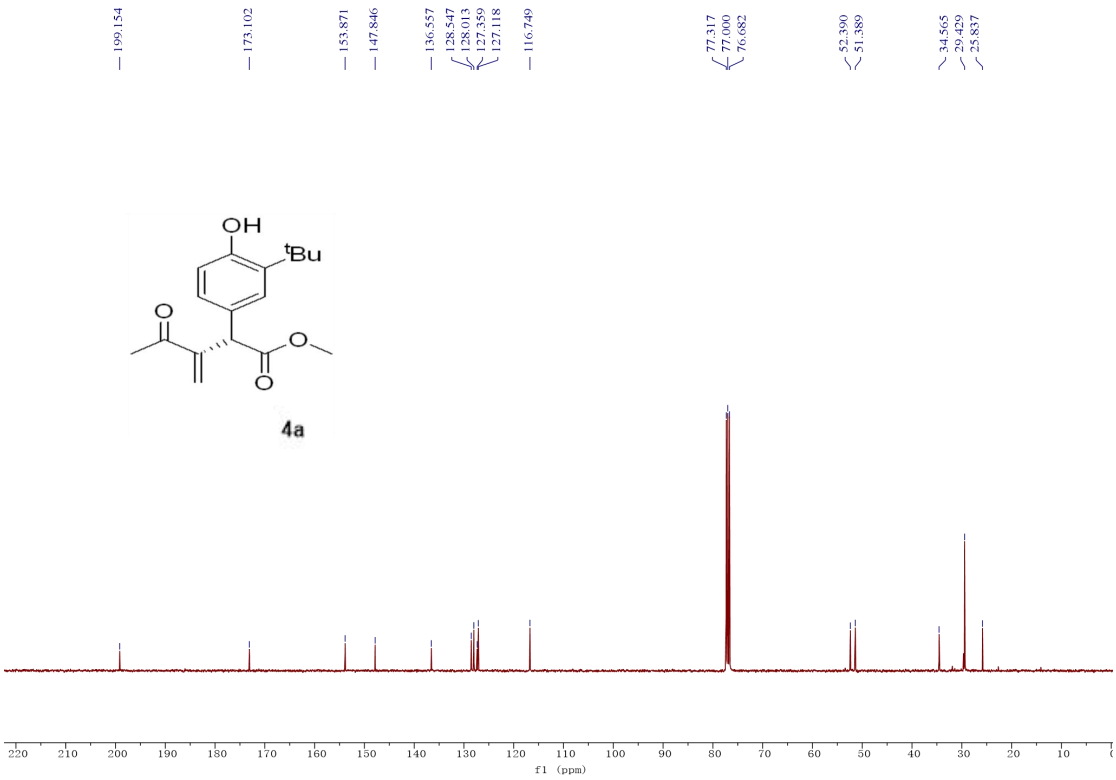
^{1}H and ^{13}C NMR spectra of compound **3zd**



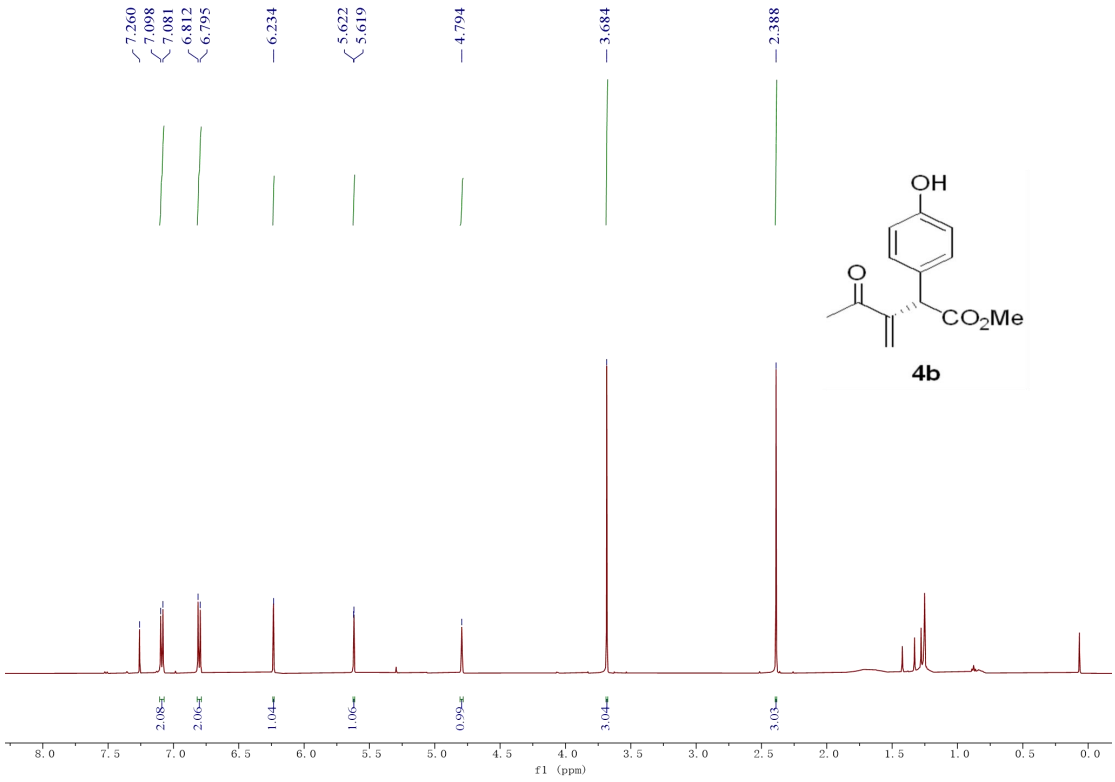


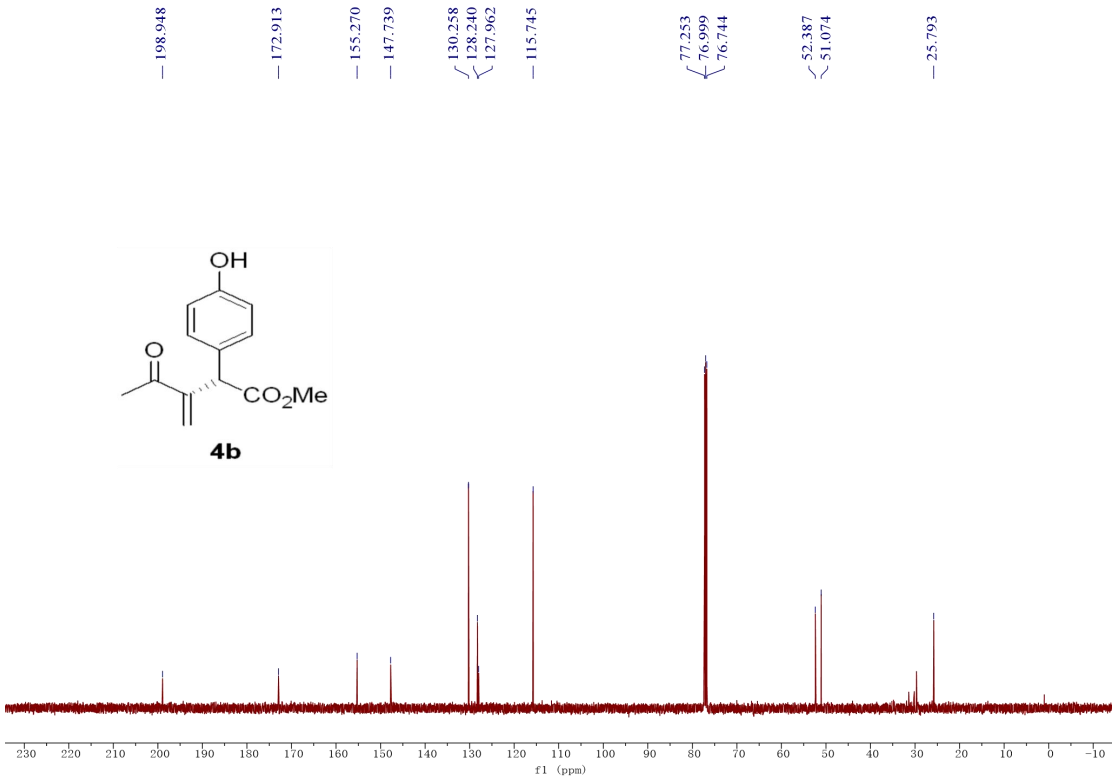
^{1}H and^{13}C NMR spectra of compound **3a'**



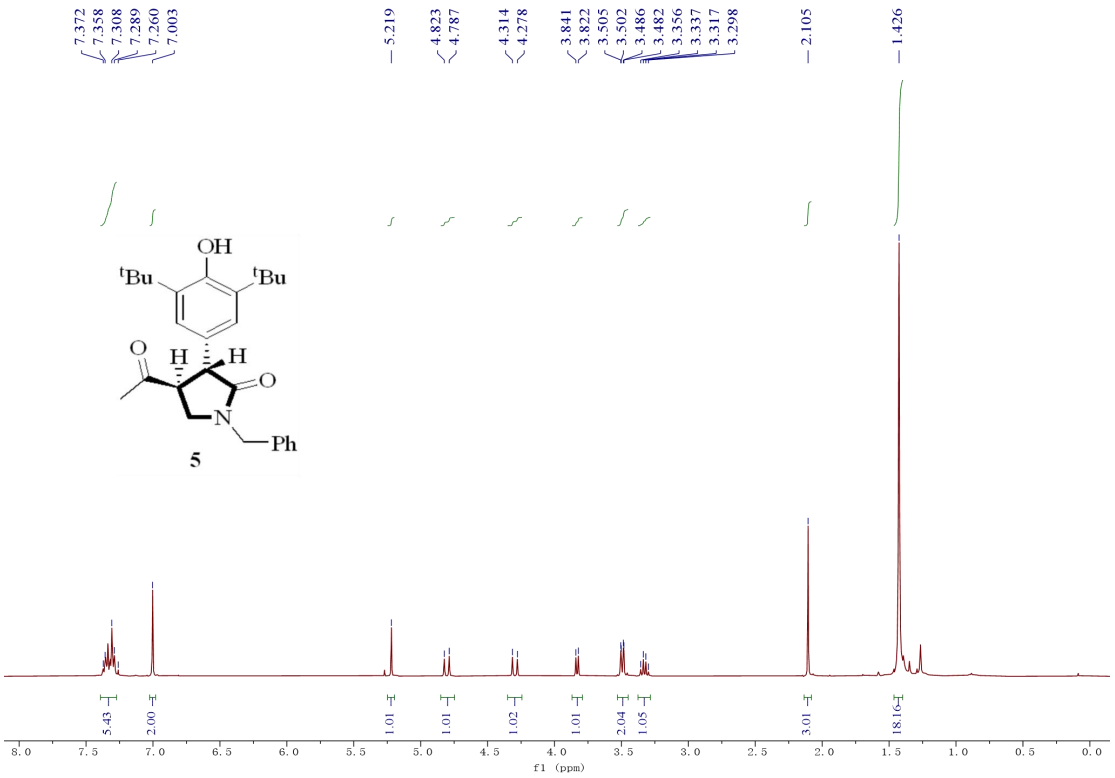


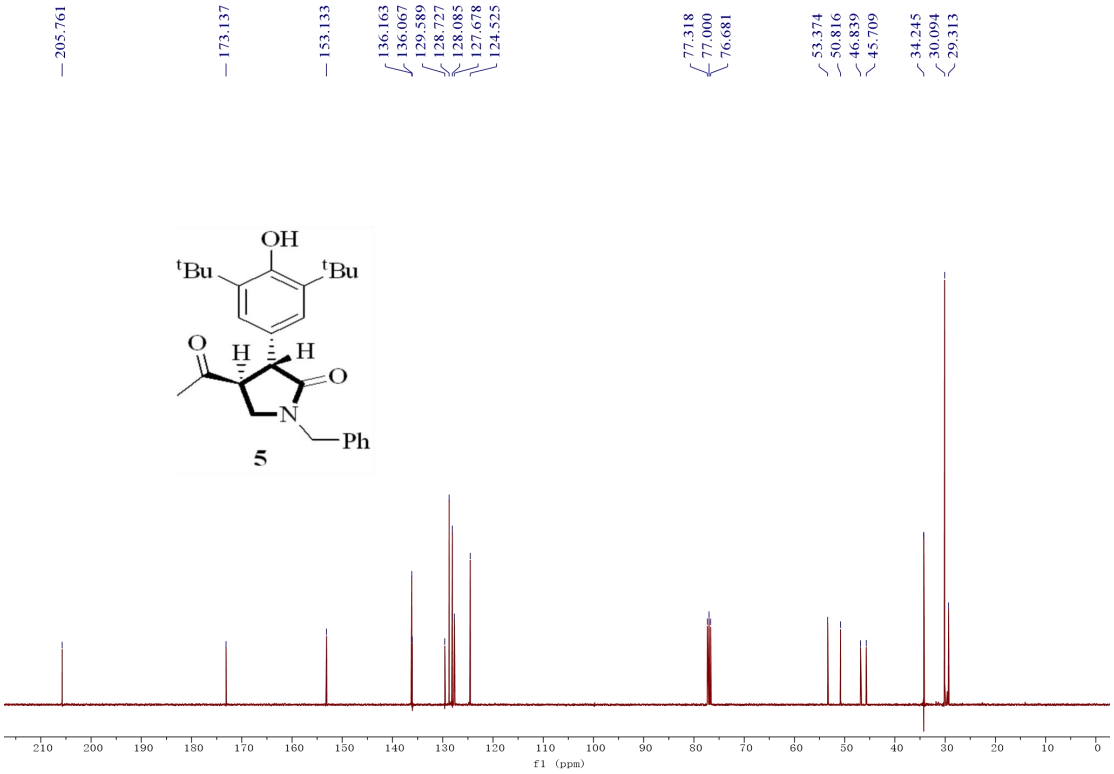
^{1}H and ^{13}C NMR spectra of compound **4a**



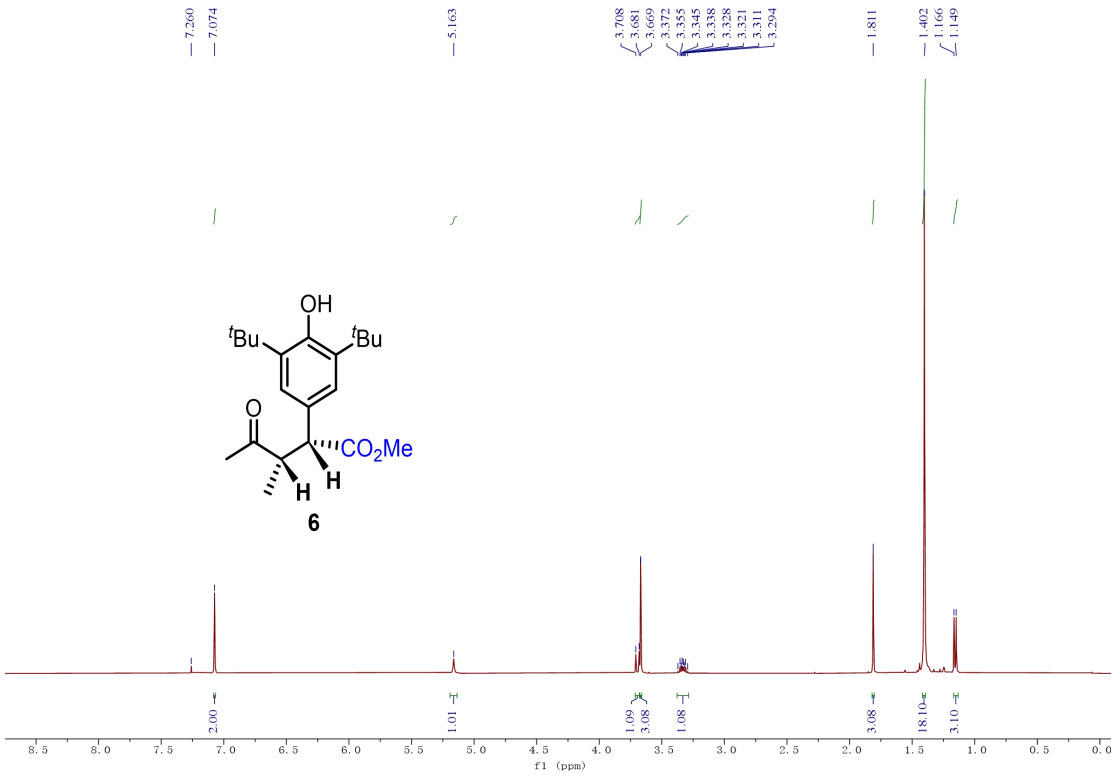


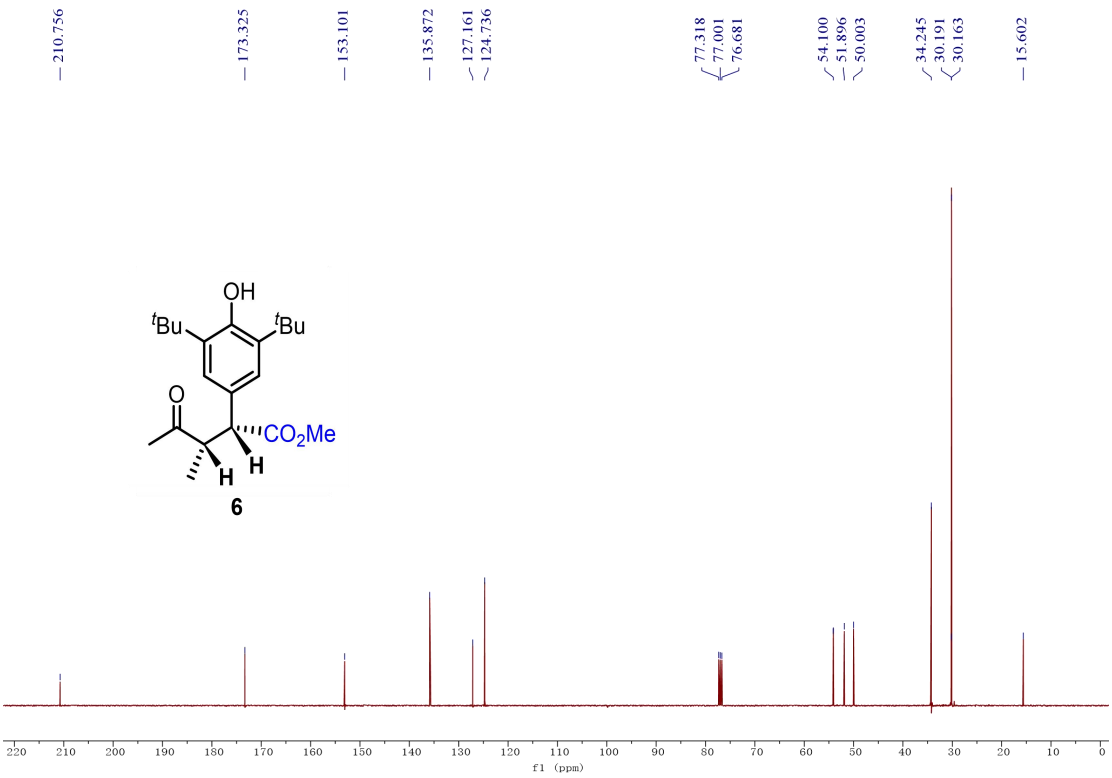
^{1}H and ^{13}C NMR spectra of compound **4b**



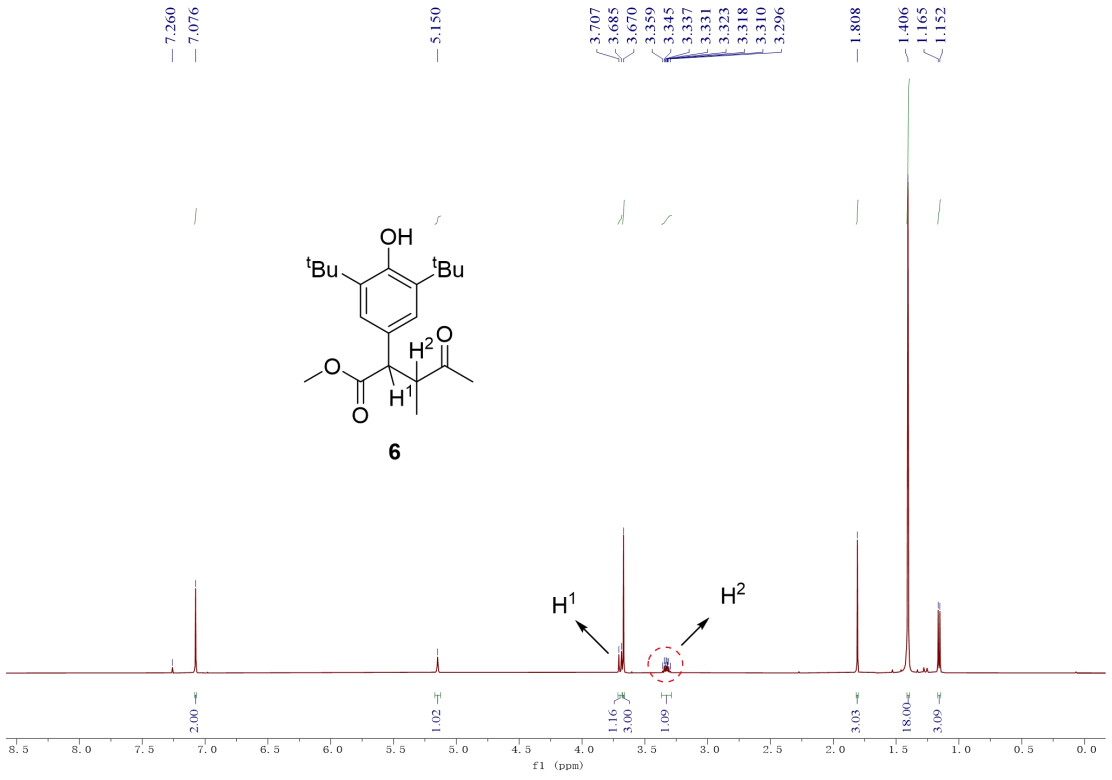


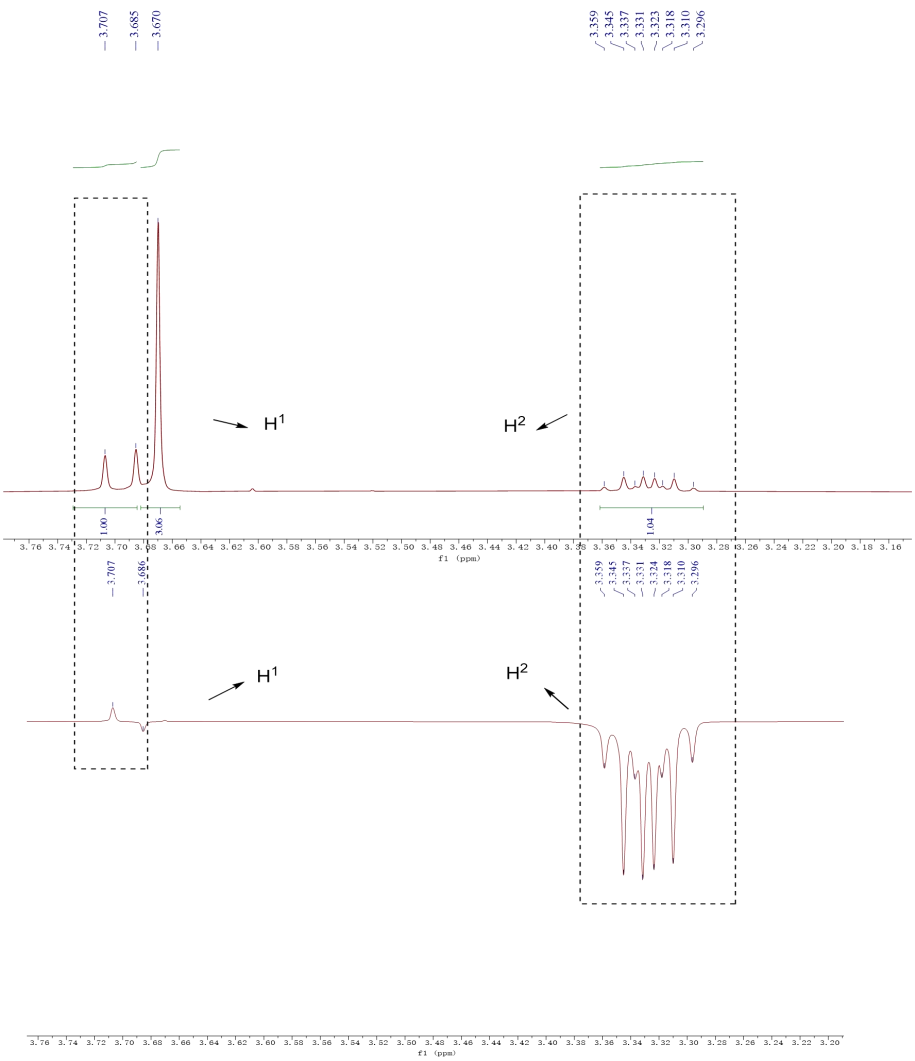
^{1}H and ^{13}C NMR spectra of compound **5**



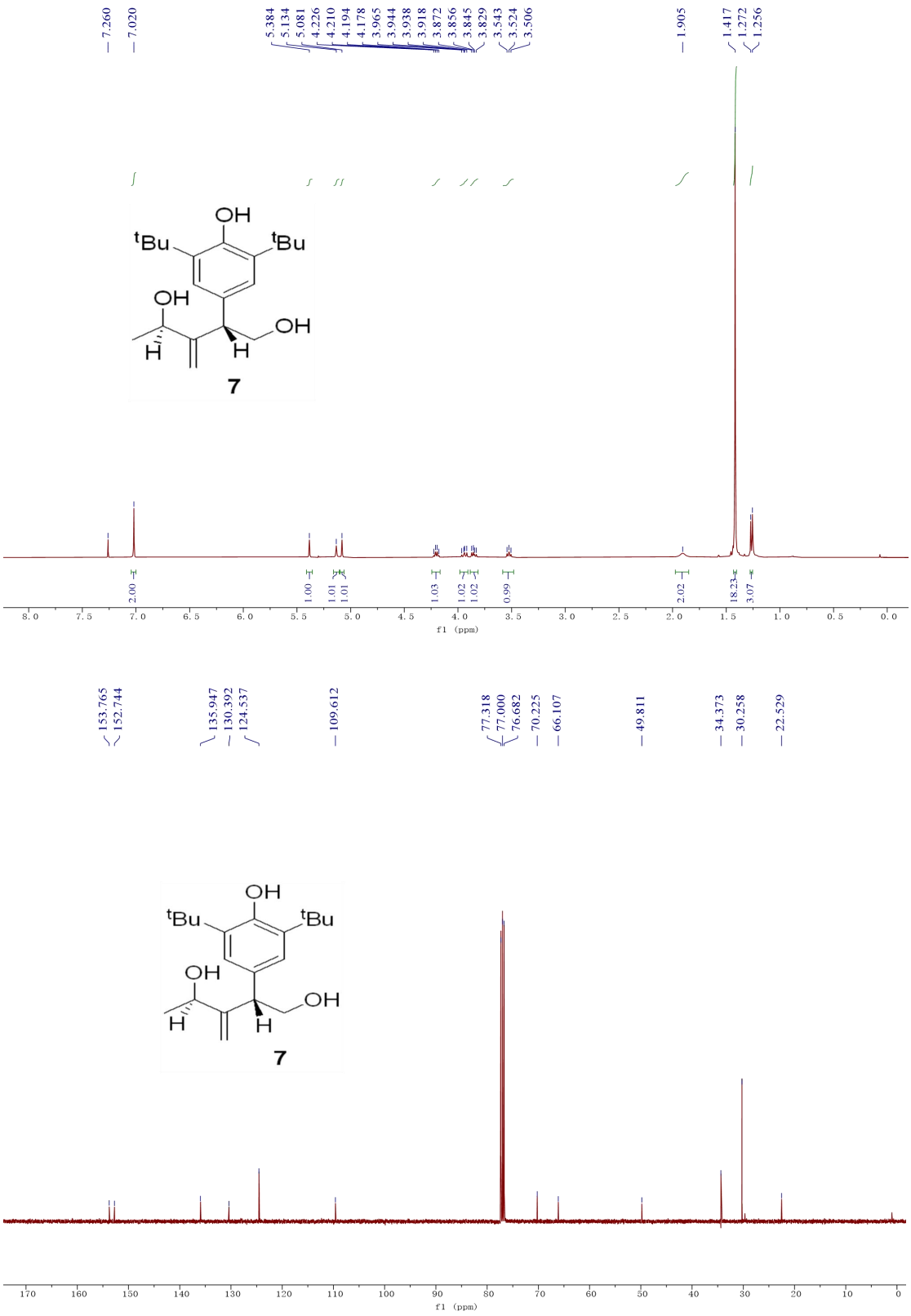


^{1}H and ^{13}C NMR spectra of compound **6**

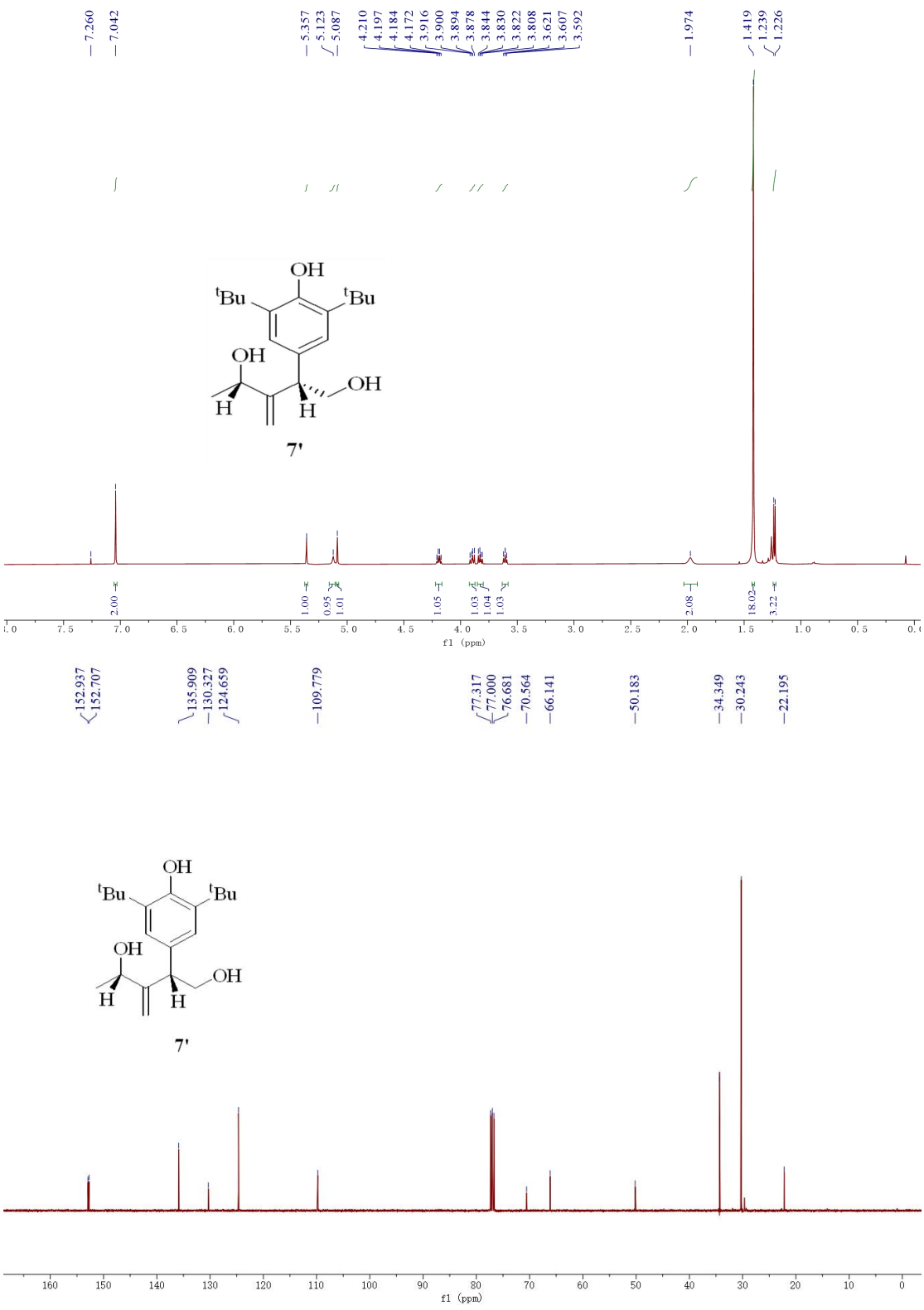




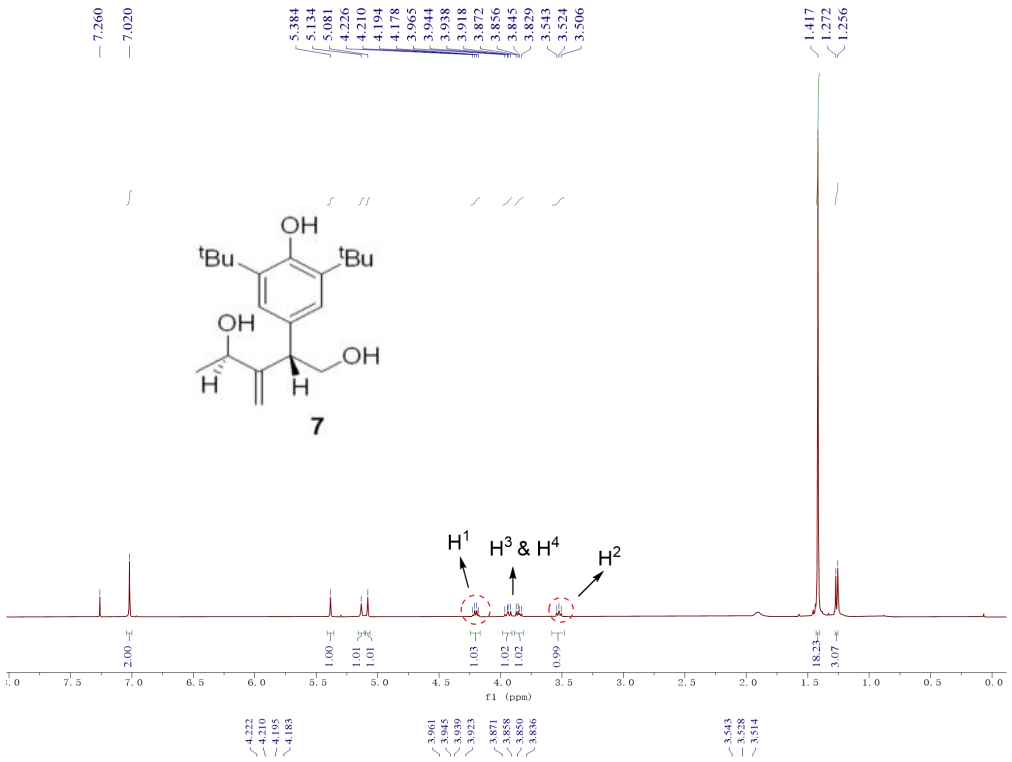
1D NOE of compound **6**

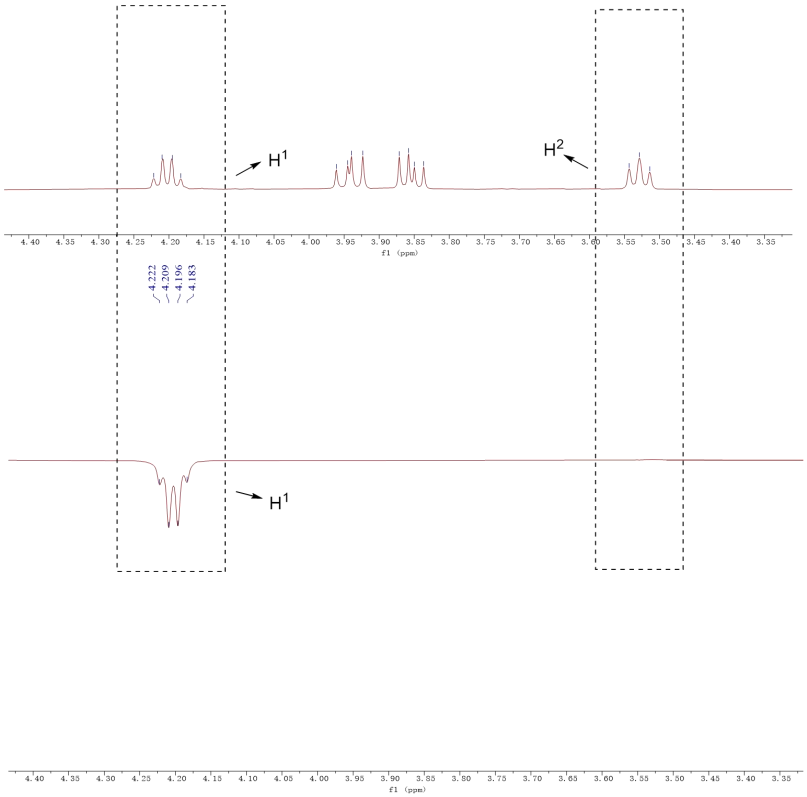


^{1}H and ^{13}C NMR spectra of compound **7**

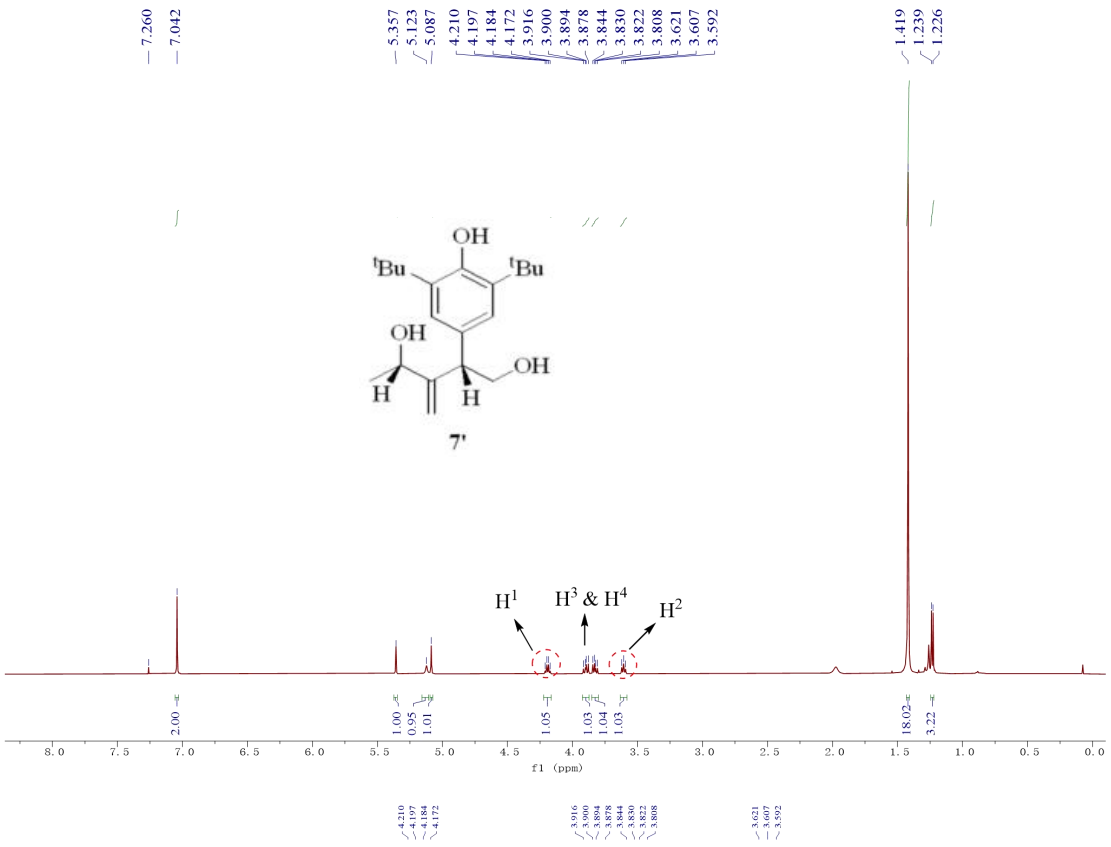


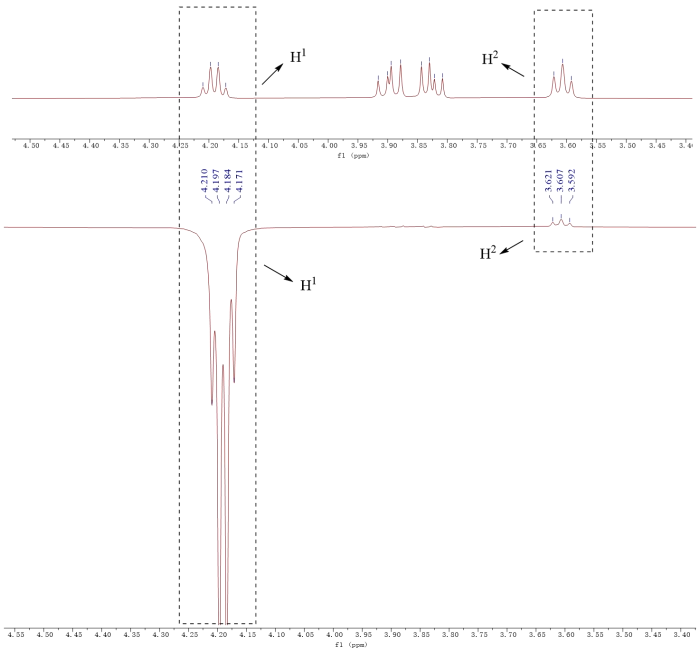
^{1}H and ^{13}C NMR spectra of compound **7'**





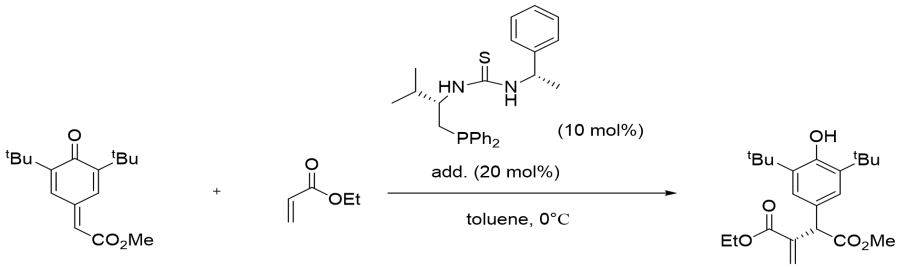
1D NOE of compound **7**





1D NOE of compound **7'**

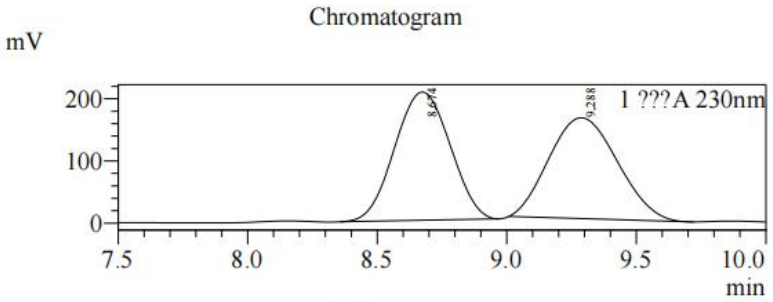
7. Additives effects



add.	yield (%)	ee (%)
PhCOOH	–	–
HFIP	11	73

Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 95/5, 0.5 mL/min, 230 nm, t_{minor} = 9.285 min, t_{major} = 8.661 min.

Racemic Sample of HFIP as addictive

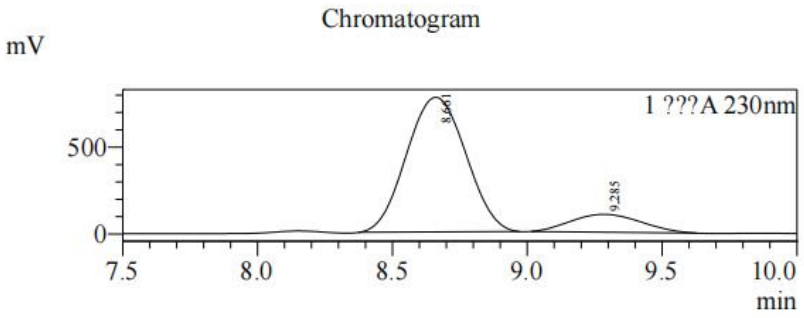


Peak Table

???A 230nm

Peak#	Ret. Time	Area	Height	Area%
1	8.674	3067605	206278	50.708
2	9.288	2981992	162194	49.292
Total		6049597	368472	100.000

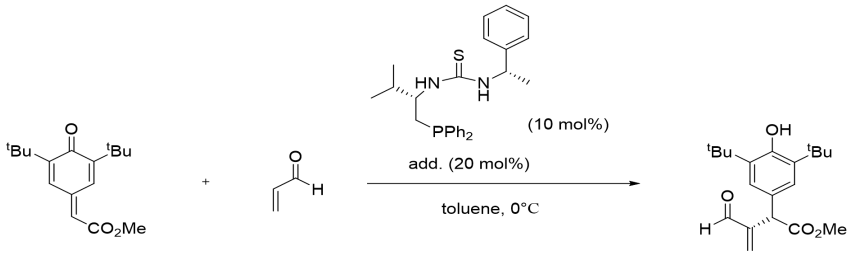
Enantiomeric Sample of HFIP as addictive



Peak Table

???A 230nm

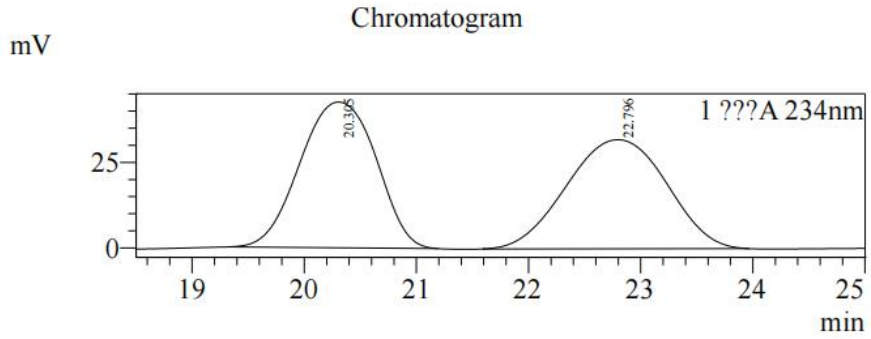
Peak#	Ret. Time	Area	Height	Area%
1	8.661	11835495	775076	86.415
2	9.285	1860567	102581	13.585
Total		13696063	877656	100.000



add.	yield (%)	ee (%)
PhCOOH	-	-
HFIP	45	86

Enantiomeric excess was determined by HPLC with a Chiralcel AD-H column, Hexane/^{i}PrOH = 99/1, 0.5 mL/min, 230 nm, t_{minor} = 24.694 min, t_{major} = 20.823 min.

Racemic Sample of HFIP as addictive

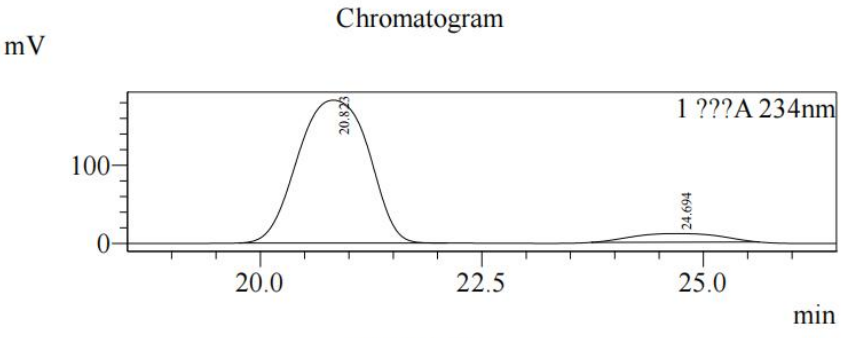


Peak Table

???A 234nm

Peak#	Ret. Time	Area	Height	Area%
1	20.305	2008925	42579	50.376
2	22.796	1978897	31855	49.624
Total		3987821	74434	100.000

Enantiomeric Sample of HFIP as addictive



Peak Table

???A 234nm

Peak#	Ret. Time	Area	Height	Area%
1	20.823	10192368	182771	92.985
2	24.694	768973	11070	7.015
Total		10961341	193841	100.000