

Supporting Information

Electroreductive 4-Pyridylation of Unsaturated Compounds

Using Gaseous Ammonia as Hydrogen Source

Wei jie Ding,^{a#} Jie Sheng,^{a#} Jin Li,^{*b} and Xu Cheng^{*a}

^a Institute of Chemistry and Biomedical Sciences, Jiangsu Key Laboratory of Advanced Organic Materials, School of Chemistry and Chemical Engineering, National Demonstration Center for Experimental Chemistry Education, Nanjing University, Nanjing, 210023, China.

^b Jiangsu Provincial Engineering Laboratory of Advanced Materials for Salt Chemical Industry, College of Chemical Engineering, Huaiyin Institute of Technology, Huaian, 223003, China.

Table of Contents

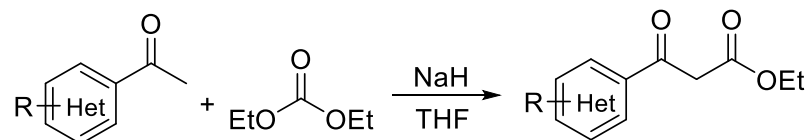
1. General Information.....	S3
2. General procedures.....	S4
3. Preparation of the several special substrates	S6
4. Cyclic voltammetry experiments	S9
5. Controlled experiments	S10
6. NMR titration	S11
7. Hydrazine in the electrochemical reaction	S12
8. Large-scale reaction	S12
9. Additional optimization with varied parameters	S13
10. Spectroscopic data for the products	S14
11. Reference.....	S33
12. Copies of NMR spectra for the products	S34
13. HPLC traces of mixture of diastereoisomers:	S90

1. General Information

Unless otherwise noted, all reactions were carried out under ammonia atmosphere. All materials were obtained from commercial suppliers and used directly without further purification. Other chemical reagents were purchased from commercial sources and used without further purification. Flash chromatography utilized 300-400 mesh silica gel from Qingdao Haiyang Chemical Co., Ltd. Reactions were monitored by thin-layer chromatography (TLC) using 254 nm UV light to visualize the progress of the reactions. ^1H NMR and ^{13}C NMR spectra were recorded on Bruker Avance III 400 (400 MHz and 100 MHz). All ^1H NMR and ^{13}C NMR spectra are reported in parts per million (ppm) downfield of TMS. Spectra were reported as follows: chemical shift (δ ppm), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), coupling constants (Hz) and integration. Melting points were measured with digital melting point detector. High-resolution mass spectra (HRMS) were obtained by ESI or EI source and a TOF detector mass spectrometer.

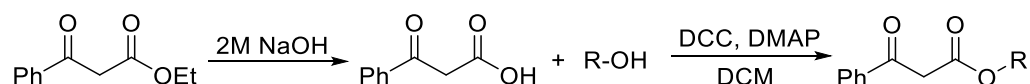
2. General procedures

General procedure A:



The β -ketoesters were prepared from the acetophenones following a literature-known procedure: ^[1] To a suspension of sodium hydride (0.4 g, 10 mmol, 2.0 eq.) in 20 mL of THF was added appropriately substituted acetophenone (5 mmol, 1.0 eq.) and the mixture stirred at the room temperature for 10 min. Then the mixture was added the diethyl carbonate (10 mmol, 2.0 eq.) and stirred at 70 °C for 2 -3 h until the consumption of acetophenone (monitored by TLC). The reaction mixture was cooled and acidified with saturated NH_4Cl aqueous solution. The aqueous layer was extracted with ethyl acetate, the combined organic layers were dried over Na_2SO_4 , filtered and concentrated. The crude product was purified by column chromatography on a silica gel (petroleum ether/ethyl acetate) to afford the desired product.

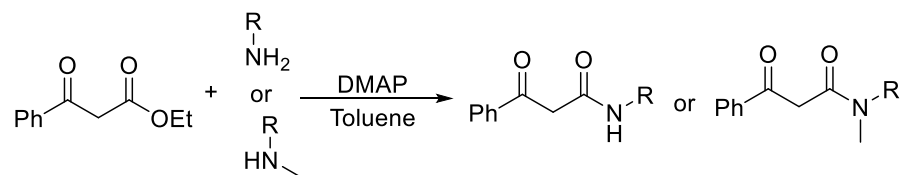
General procedure B:



The substrate was prepared following a literature-known procedure: ^[2] β -ketoester (50 mmol, 1.0 eq.) and aqueous NaOH (2 M, 50 mL) are stirred for 12 h at room temperature open to air. Upon completion, the reaction mixture was then diluted with ethyl acetate. Then the aqueous phase was washed twice with ethyl acetate, and then cooled to 0 °C before being acidified with aqueous HCl (3M) to pH 1-2. β -keto acid was filtered, washed with H_2O , dried under vacuum, and used without further purification.

A flask was charged with the β -keto acid (5 mmol, 1.0 eq.), ROH (6 mmol, 1.2 eq.), DMAP (122 mg, 1 mmol, 0.2 eq.) and anhydrous DCM (20 mL). Then the reaction mixture cooled to 0 °C before DCC (7 mmol, 1.4 eq.) was added and stirred for 2-4 h at 0 °C. The reaction was quenched with H_2O and the resulting mixture was extracted with ethyl acetate for three times. The combined organic layers were washed with brine, dried over Na_2SO_4 , filtered and concentrated. The residue was purified by flash chromatography to afford the desired product.

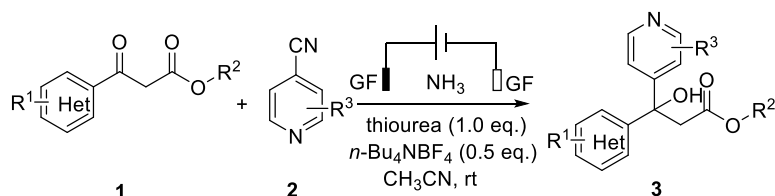
General procedure C:



The substrate was prepared following a literature-known procedure: ^[3] A solution of β -ketoester (2.0 mmol, 1.0 eq.), amine (2.0 mmol, 1 eq.), DMAP (0.2 mmol, 0.1 equiv.), 4Å MS (200 mg) and

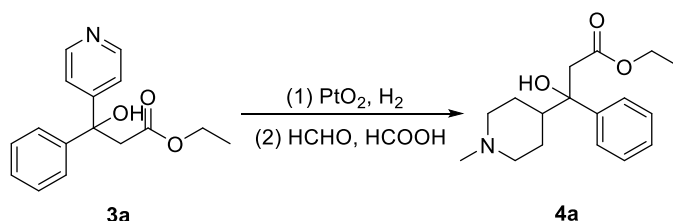
toluene (4 mL) in a 10 mL sealed tube equipped with a Teflon-coated stirring bar was microwave irradiated at 150 °C for 1 h whereupon the reaction mixture was cooled to room temperature. The solution was removed under reduced pressure and purified by flash chromatography to afford the desired product.

General procedure D:



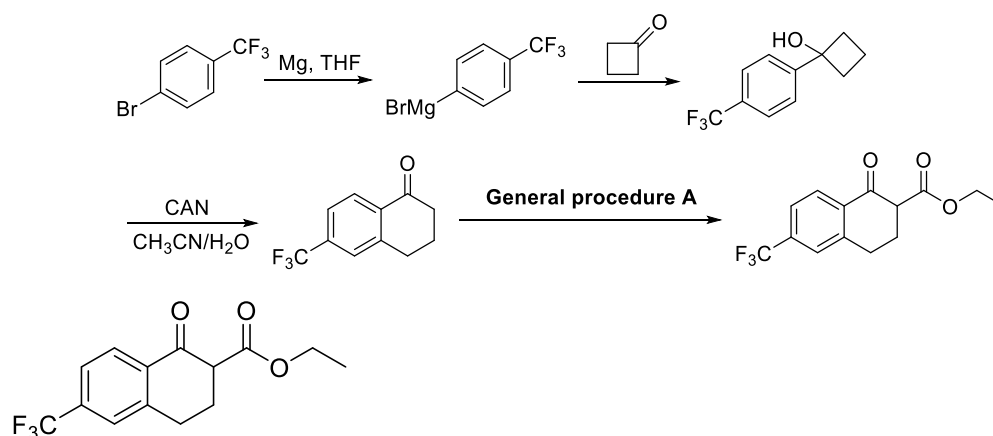
A 10 mL two-necked heart-shaped flask was charged with the substrate **1** (0.2 mmol, 1.0 eq.), **2** (0.6 mmol, 3.0 eq.), thiourea (0.2 mmol, 1.0 eq.), $n\text{-Bu}_4\text{NBF}_4$ (0.1 mmol, 0.5 eq.) and a magnetic stir bar. The flask was equipped with a rubber stopper, graphite felt (2 cm x 1 cm x 0.5 cm) as anode and cathode. Two electrodes were separated with a Teflon film. The graphite felt anode attached to a platinum wire and cathode attached to a silver wire. A Teflon wire tied around two electrodes. The flask was evacuated and backfilled with ammonia gas for three times and an ammonia gas balloon was connected to this flask via a needle. Then 5 mL of anhydrous CH_3CN was added via syringe. The mixture was stirred under room temperature and constant current electrolysis. After the reaction was completed by monitoring with TLC or GC-MS analysis, quenched with 2M Na_2CO_3 aqueous solution (3 mL). The mixture was stirred under air for another 15 minutes. 10 mL of brine was added to the reaction mixture and the aqueous layer was extracted with ethyl acetate. The organic layers were washed with brine, dried over Na_2SO_4 , filtered and concentrated. The residue was purified by chromatography on silica gel to afford the desired product.

Procedure E:



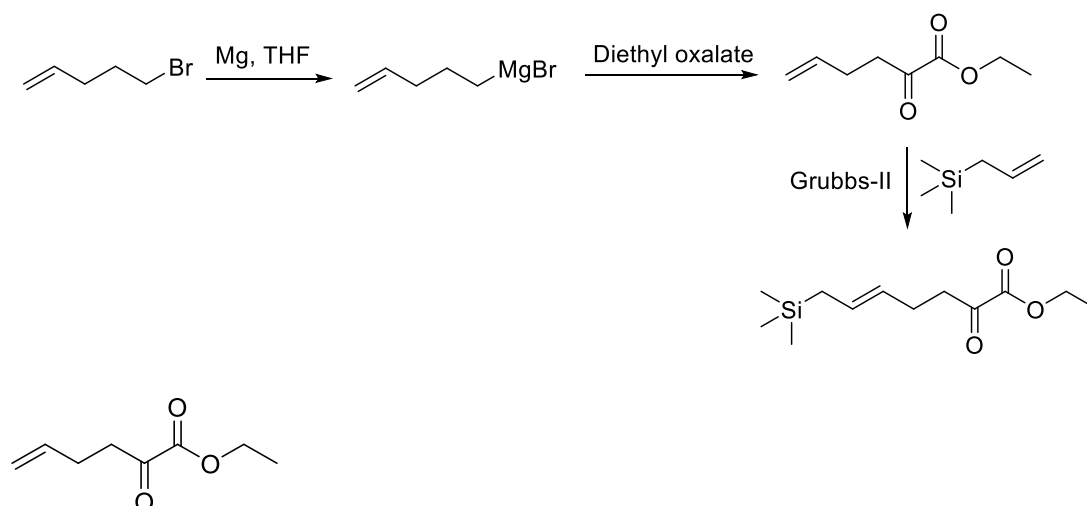
The substrate was prepared following a literature-known procedure:^[4] To a solution of H_2O (0.8 mL) and $\text{C}_2\text{H}_5\text{OH}$ (1 mL) was added **3a** (1 mmol), con. HCl (200 μL) and PtO_2 . The reaction mixture was kept in a flask under hydrogen pressure (150 psi) and hydrogenated for 12 h. After completion of the reaction (monitored by GC-MS), the reaction mixture was filtered through a celite pad, the reaction mixture was extracted with ethyl acetate. The combined organic layers were washed with brine, dried over Na_2SO_4 , filtered and concentrated to afford the crude product. Then the crude product, a yellow oil, was dissolved in 5 mL 88% formic acid and 2 mL formalin (37%) was added. After warming on the 110 °C oil bath for 8h, 2M HCl was added and the solution was concentrated to dryness in vacuo. The residue was dissolved in water, made basic with ammonium hydroxide and extracted with ethyl acetate. Then the residue purified by chromatography on silica gel to afford the desired product.

3. Preparation of the several special substrates



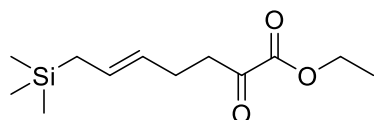
The substrate was prepared following a literature-known procedure:^[5] The Grignard reagents were prepared in dry THF from the commercially available aryl bromide. Then to the solution of cyclobutanone (1.0 eq.) was added the above Grignard reagent (1.2 eq.) at 0 °C, after addition was complete, the solution was allowed to warm to rt over 15h. The reaction was quenched by the addition of a saturated solution of NH_4Cl and diluted with ethyl acetate. The combined organic layers were washed with brine, dried over Na_2SO_4 , filtered and concentrated. The crude product was purified by flash column chromatography to provide compound as an orange-yellow oil. Next, to a solution of above compound, in a water-acetonitrile mixture was stirred in an open reactor at 60 °C for 60s. Subsequently, CAN was added and the mixture was stirred at 60 °C for another 60s. Then, saturated sodium thiosulfate was added to quench the reaction. Followed, the reaction mixture was extracted with ethyl acetate. The combined organic layers were washed with brine, dried over Na_2SO_4 , filtered and concentrated. The residue was purified by column chromatography with petroleum ether and diethyl ether to yield the product. Finally, the title compound was prepared following the *General procedure A*.

Ethyl 1-oxo-6-(trifluoromethyl)-1,2,3,4-tetrahydronaphthalene-2-carboxylate. Light yellow liquid. ^1H NMR (400 MHz, CDCl_3) δ 12.43 (s, 1H), 7.89 (d, $J = 8.1$ Hz, 1H), 7.53 (d, $J = 8.0$ Hz, 1H), 7.42 (s, 1H), 4.30 (qd, $J = 7.1, 1.3$ Hz, 2H), 2.87 (t, $J = 7.8$ Hz, 2H), 2.66 – 2.56 (m, 2H), 1.36 (td, $J = 7.2, 1.4$ Hz, 3H).



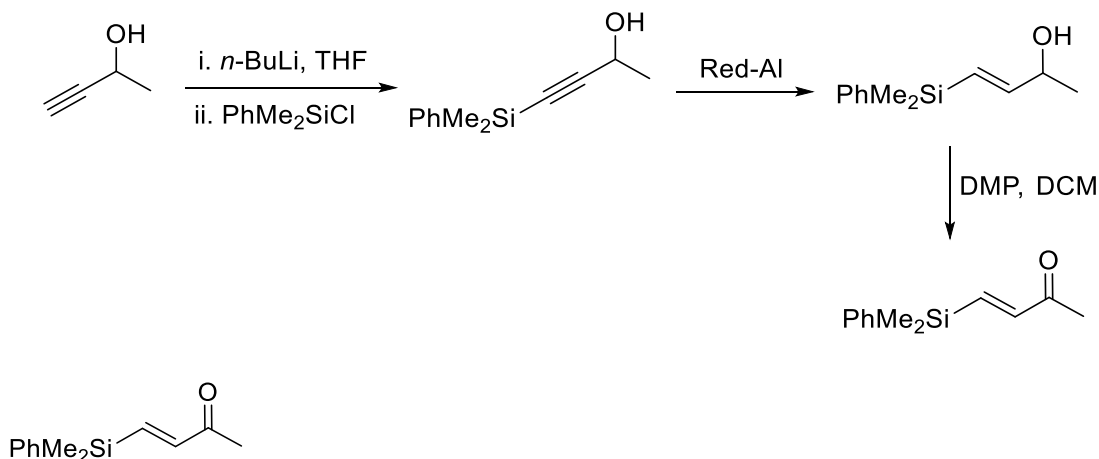
The substrate was prepared following a literature-known procedure:^[6] The Grignard reagents were prepared in dry THF from the commercially available 4-bromobut-1-ene. Then to a solution of diethyl oxalate (1.0 eq.) in THF/Et₂O (1:1) was added the above Grignard reagents (1.2 eq.) at –78 °C, after addition was complete, the solution was allowed to warm to –60 °C and stirred at this temperature for 2h. Until the diethyl oxalate was completely consumed, the reaction was quenched by the addition of a saturated solution of NH₄Cl and diluted with ethyl acetate. The combined organic layers were washed with brine, dried over Na₂SO₄, filtered and concentrated. The crude product was purified by flash column chromatography to provide the title compound as a light yellow liquid.

Ethyl 2-oxohex-5-enoate. Light yellow liquid. ¹H NMR (400 MHz, CDCl₃) δ 5.88 – 5.71 (m, 1H), 5.12 – 4.89 (m, 2H), 4.29 (qd, *J* = 7.2, 2.2 Hz, 2H), 2.92 (t d, *J* = 7.3, 2.1 Hz, 2H), 2.36 (h, *J* = 5.8, 5.3 Hz, 2H), 1.34 (td, *J* = 7.1, 2.2 Hz, 3H).



To a solution of ethyl 2-oxohex-5-enoate (1.0 eq.) in CH₂Cl₂ under Ar was added Grubbs-II (0.02 eq.) and allyltrimethylsilane (3.0 eq.). The solution was allowed to warm to 50 °C and stirred for about 2 h, diluted with ethyl acetate until the ethyl 2-oxohex-5-enoate was almost completely consumed detected by GC-MS. The combined organic layers were washed with brine, dried over Na₂SO₄, filtered and concentrated. The crude product was purified by flash column chromatography to provide the title compound as a brown liquid.

Ethyl 2-oxo-7-(trimethylsilyl)hept-5-enoate. Brown liquid. ¹H NMR (400 MHz, CDCl₃) δ 5.50 – 5.39 (m, 1H), 5.27 – 5.16 (m, 1H), 4.30 (t, *J* = 7.2 Hz, 2H), 2.87 (t, *J* = 7.2 Hz, 2H), 2.36 – 2.27 (m, 2H), 1.39 – 1.33 (m, 5H), -0.03 (s, 9H).



The substrate was prepared following a literature-known procedure:^[7] To a solution of but-3-yn-2-ol (1.0 eq.) in THF was added *n*-BuLi (2.1 eq.) at $-78\text{ }^{\circ}\text{C}$. After addition was complete, the solution was allowed to warm to rt. After 1.5h, the mixture cool to $-78\text{ }^{\circ}\text{C}$ and chlorodimethyl(phenyl)silane (2.0 eq.) was added dropwise through a syringe. The solution was allowed to warm to rt over 24h, and the reaction was quenched by the addition of an aqueous solution of HCl. The combined organic layers were washed with brine, dried over Na₂SO₄, filtered and concentrated. The crude product was purified by flash column chromatography to provide the title compound as a pale yellow liquid. Next, to a solution of 4-(Dimethyl(phenyl)silyl)but-3-yn-2-ol (1.0 eq.) obtained above in Et₂O was slowly added Red-Al (2.0 eq.) as a solution in Et₂O at $0\text{ }^{\circ}\text{C}$. The mixture warm to rt over 2h and then quenched by an aqueous solution of H₂SO₄ at $0\text{ }^{\circ}\text{C}$. The combined organic layers were washed with brine, dried over Na₂SO₄, filtered and concentrated. The crude product was purified by flash column chromatography to provide the title compound as a colorless liquid. Finally, to a solution of (E)-4-(dimethyl(phenyl)silyl)but-3-en-2-ol (1.0 eq.) obtained above in CH₂Cl₂ was added DMP (1.5 eq.) in three equal portions at 30 minute intervals at rt. The mixture stir for 30 min. The mixture was diluted with 15% aqueous solution of NaOH and Et₂O and allowed to stir for 10 min. At this time, the layers were separated and the aqueous layer was washed with Et₂O. The combined organic layers were washed with brine, dried over Na₂SO₄, filtered and concentrated. The crude product was purified by flash column chromatography to provide the title compound as a pale yellow liquid.

(E)-4-(dimethyl(phenyl)silyl)but-3-en-2-one. ¹H NMR (400 MHz, Chloroform-*d*) δ 7.55 – 7.48 (m, 2H), 7.39 (d, *J* = 6.1 Hz, 3H), 7.12 (d, *J* = 19.2 Hz, 1H), 6.49 (d, *J* = 19.2 Hz, 1H), 2.29 (s, 3H), 0.44 (s, 6H).

4. Cyclic voltammetry experiments

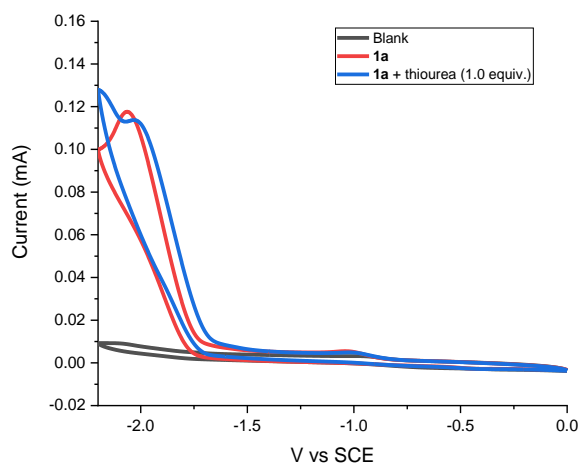


Figure S1. Cyclic voltammetry experiment of **1a** and **1a** with thiourea using glassy carbon working electrode at 50 mV/s.

A solution of **1a** (0.1 mmol) and $n\text{-Bu}_4\text{NBF}_4$ (0.05 mmol) in 5 mL anhydrous CH_3CN was subject to cyclic voltammetry experiment. Electrodes included a glassy carbon working electrode, a Pt counter electrode and a saturated calomel electrode (SCE). Potential sweep rate was 50 mV/s.

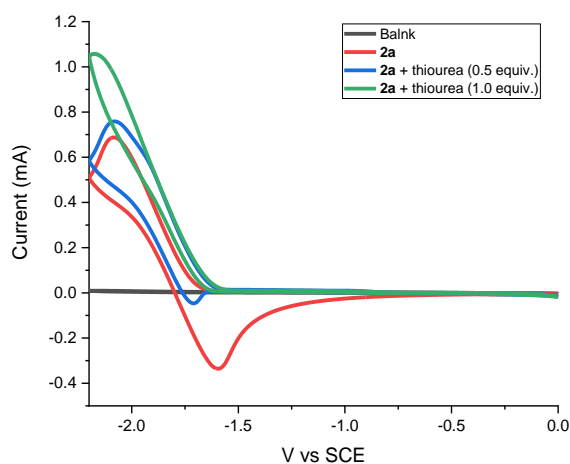


Figure S2. Cyclic voltammetry experiment of **2a** and **2a** with thiourea using glassy carbon working electrode at 50 mV/s.

A solution of **2a** (0.2 mmol) and $n\text{-Bu}_4\text{NBF}_4$ (0.2 mmol) in 5 mL anhydrous CH_3CN was subject to cyclic voltammetry experiment. Electrodes included a glassy carbon working electrode, a Pt counter electrode and a saturated calomel electrode (SCE). Potential sweep rate was 50 mV/s.

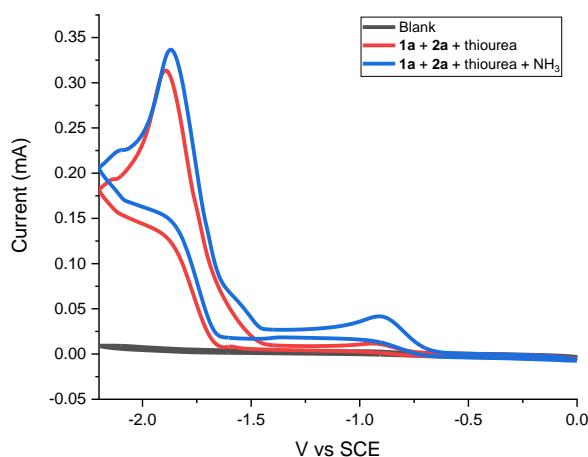
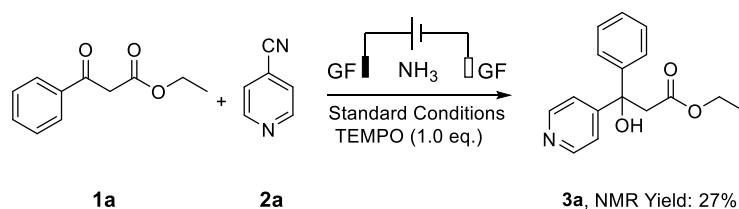


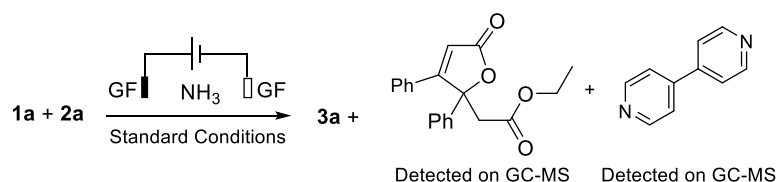
Figure S3. Cyclic voltammetry experiment of **1a**, **2a** and thiourea using glassy carbon working electrode at 50 mV/s.

A solution of **1a** (0.05 mmol), **2a** (0.05 mmol), thiourea (0.05 mmol) and *n*-Bu₄NBF₄ (0.2 mmol) in 5 mL anhydrous CH₃CN was subject to cyclic voltammetry experiment. Electrodes included a glassy carbon working electrode, a Pt counter electrode and a saturated calomel electrode (SCE). Potential sweep rate was 50 mV/s.

5. Controlled experiments



A 10 mL two-necked heart-shaped flask was charged with compound **1a** (0.2 mmol), **2a** (0.6 mmol), thiourea (0.2 mmol), TEMPO (0.2 mmol), *n*-Bu₄NBF₄ (0.1 mmol) in 5 mL anhydrous CH₃CN was carried out according to the *general procedure D*. After the reaction completed as monitored with TLC and GC-MS analysis, product **3a** was detected in 27% ¹H NMR yield.



A 10 mL two-necked heart-shaped flask was charged with compound **1a** (0.2 mmol), **2a** (0.6 mmol), thiourea (0.2 mmol), *n*-Bu₄NBF₄ (0.1 mmol) in 5 mL anhydrous CH₃CN was carried out according to the *general procedure D*. Then a sample of the reaction mixture was diluted with EtOAc and analyzed with GC-MS.

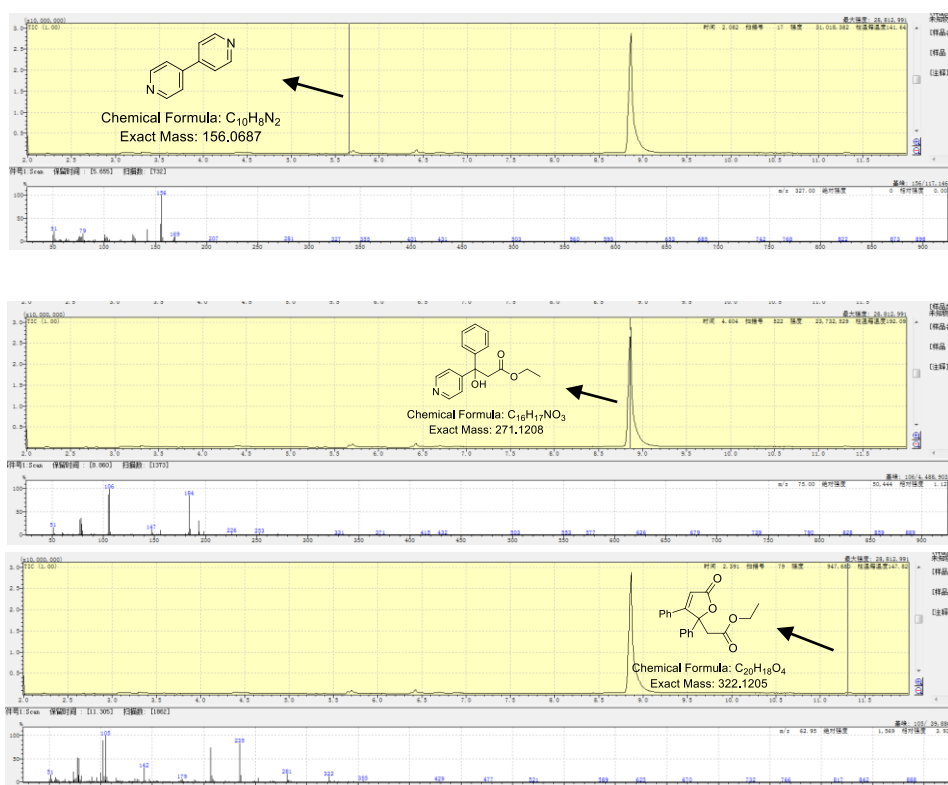


Figure S4. GC-MS analysis of the standard condition.

6. NMR titration

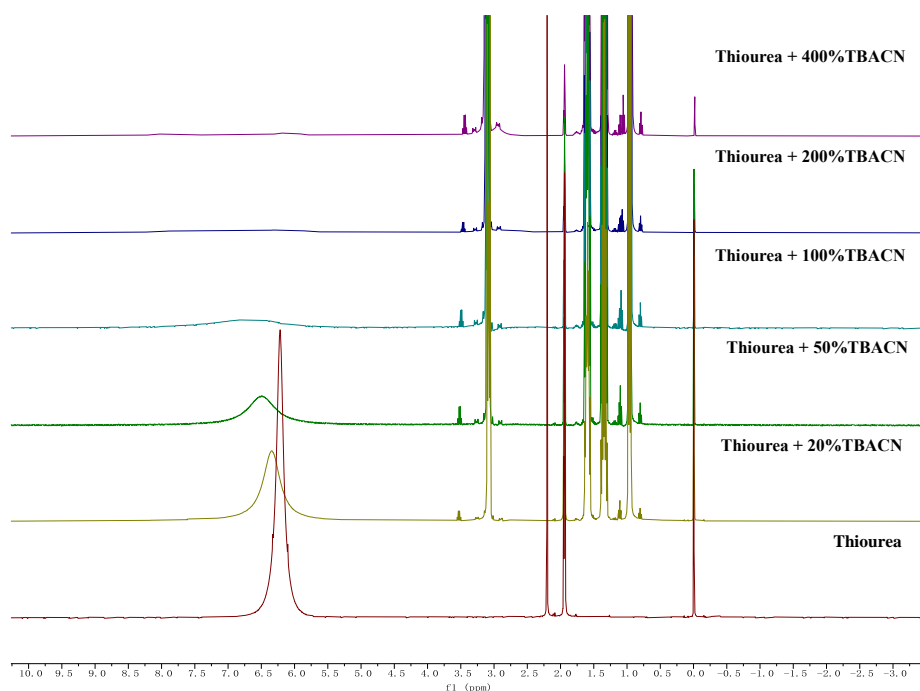
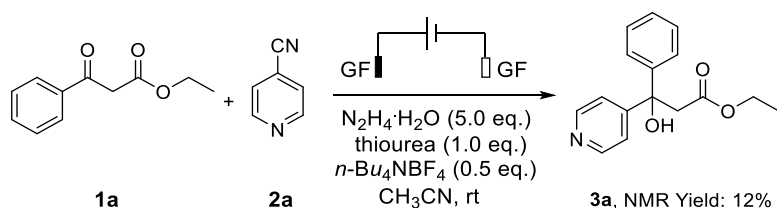


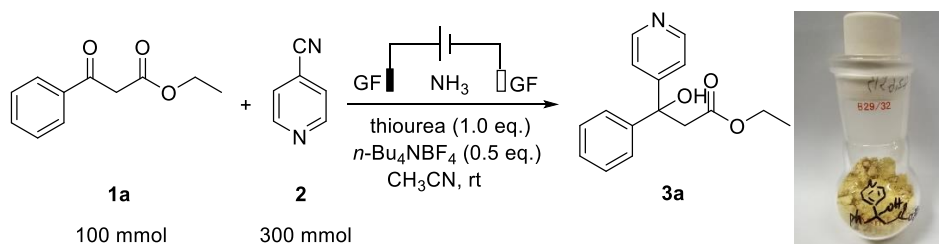
Figure S5. NMR titration of thiourea and tetrabutylammonium cyanide (TBACN).

7. Hydrazine in the electrochemical reaction



A 10 mL two-necked heart-shaped flask was charged with compound **1a** (0.2 mmol), **2a** (0.6 mmol), thiourea (0.2 mmol), hydrazine mono hydrate (1.0 mmol), $n\text{-Bu}_4\text{NBF}_4$ (0.1 mmol) in 5 mL anhydrous CH_3CN was carried out according to the *general procedure D*. After the reaction completed as monitored with TLC and GC-MS analysis, product **3a** was detected in 12% ^1H NMR yield.

8. Large-scale reaction



A 500 mL flask (as shown below) was charged with the substrate **1a** (0.1 mol, 1.0 eq.), **2** (0.3 mol, 3.0 eq.), thiourea (0.1 mol, 1.0 eq.), $n\text{-Bu}_4\text{NBF}_4$ (0.05 mol, 0.5 eq.) and a magnetic stir bar. The flask was equipped with a rubber stopper, graphite felt as anode and cathode separated with pp (200 μm). The graphite felt attached to a platinum wire. The flask was evacuated and backfilled with ammonia gas for three times and an ammonia gas balloon was connected to this flask via a needle. Then 300 mL of anhydrous CH_3CN was added via syringe. The mixture was stirred under room temperature and constant current (400 mA). After the reaction was completed by monitoring with TLC or GC-MS analysis (90 h), the mixture was extracted with ethyl acetate. The organic layers were washed with brine, dried over Na_2SO_4 , filtered and concentrated. The residue was purified by chromatography on silica gel to afford the desire product **3a** as a pale yellow solid (16.3 g, 60%).



Reaction setup

9. Additional optimization with varied parameters

9.1) Optimization using different hydrogen source

The reactions were conducted with *general procedure D*, except ammonia was replaced by other hydrogen sources.

Entry	Hydrogen Sources	NMR Yield
1	H ₂ O (10 eq)	45%
2	HCOONH ₄ (10 eq)	26%
3	<i>i</i> PrOH (10 eq)	15%

1a (0.2 mmol), **2a** (3.0 equiv.), thiourea (1.0 equiv.), *n*Bu₄NBF₄ (0.5 equiv.), CH₃CN (5 mL), graphite felt as anode and cathode, undivided cell, 20 mA/cm², 4 h.

9.2) Optimization using different solvent

The reactions were conducted with *general procedure D*, except CH₃CN was replaced by other solvents.

Entry	Solvents	NMR Yield
1	DMAc	nd
2	DCE	16%
3	EtOH	24%

1a (0.2 mmol), **2a** (3.0 equiv.), thiourea (1.0 equiv.), *n*Bu₄NBF₄ (0.5 equiv.), solvent (5 mL), graphite felt as anode and cathode, NH₃, undivided cell, 20 mA/cm², 4 h.

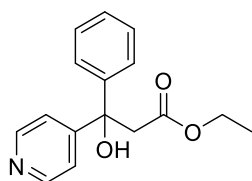
9.3) Optimized the current efficiency of standard reaction

A 10 mL two-necked heart-shaped flask was charged with the substrate **1a** (1.0 mmol, 1.0 eq.), **2** (3.0 mmol, 3.0 eq.), thiourea (1.0 mmol, 1.0 eq.), *n*-Bu₄NBF₄ (0.5 mmol, 0.5 eq.) and a magnetic stir bar. The flask was equipped with a rubber stopper, graphite felt (2 cm x 1 cm x 0.5 cm) as anode and cathode. Two electrodes were separated with a Teflon film. The graphite felt anode attached to a platinum wire and cathode attached to a silver wire. A Teflon wire tied around two electrodes. The

flask was evacuated and backfilled with ammonia gas for three times and an ammonia gas balloon was connected to this flask via a needle. Then 5 mL of anhydrous CH₃CN was added via syringe. The mixture was stirred under room temperature and constant current electrolysis (20 mA). After four hours of reaction, 50% of the target products were produced by ¹H NMR analysis. It can be calculated that the current efficiency of the reaction can be increased to 33.5%.

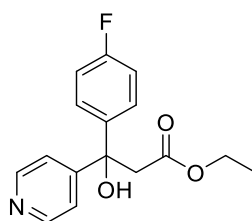
Entry	concentration of 1a	current efficiency (%)
1	0.04 M	9.6
2	0.2 M	33.5

10. Spectroscopic data for the products



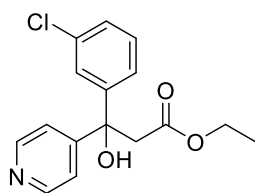
Ethyl 3-hydroxy-3-phenyl-3-(pyridin-4-yl)propanoate (**3a**)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3a** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a light yellow solid (72%, 39.0 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.51 (d, *J* = 4.6 Hz, 2H), 7.43 – 7.40 (m, 2H), 7.35 (d, *J* = 6.1 Hz, 2H), 7.31 (t, *J* = 7.5 Hz, 2H), 7.24 (t, *J* = 7.2 Hz, 1H), 5.24 (s, 1H), 4.09 (q, *J* = 7.1 Hz, 2H), 3.24 (q, *J* = 16.3 Hz, 2H), 1.15 (t, *J* = 7.1 Hz, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 172.21, 154.72, 149.75, 144.38, 128.45, 127.58, 125.40, 120.56, 75.61, 61.20, 44.72, 13.90. HRMS (ESI): *m/z* [*M* + *H*]⁺ calcd for C₁₆H₁₈NO₃: 272.1287; found: 272.1286.



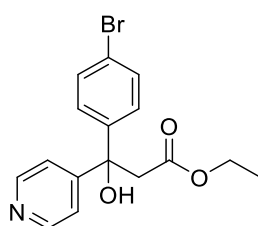
Ethyl 3-(4-fluorophenyl)-3-hydroxy-3-(pyridin-4-yl)propanoate (**3b**)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3b** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow solid (62%, 35.8 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.52 (d, *J* = 5.8 Hz, 2H), 7.34 (dd, *J* = 10.4, 7.4 Hz, 4H), 7.28 (d, *J* = 8.7 Hz, 2H), 5.29 (s, 1H), 4.10 (q, *J* = 7.1 Hz, 2H), 3.25 – 3.15 (m, 2H), 1.16 (t, *J* = 7.1 Hz, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 172.05, 154.26, 149.86, 143.01, 133.58, 128.62, 126.92, 120.42, 77.32, 77.00, 76.68, 75.29, 61.36, 44.56, 13.92. HRMS (ESI): *m/z* [*M* + Na]⁺ calcd for C₁₆H₁₆FNO₃Na: 312.1012; found: 312.1020.



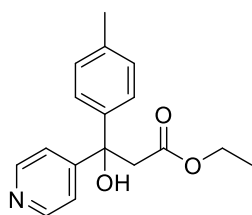
Ethyl 3-(3-chlorophenyl)-3-hydroxy-3-(pyridin-4-yl)propanoate (3c)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3c** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a light yellow oil (60%, 36.6 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.55 (d, *J* = 6.0 Hz, 2H), 7.47 (s, 1H), 7.37 (d, *J* = 6.0 Hz, 2H), 7.31 – 7.23 (m, 3H), 5.33 (s, 1H), 4.15 – 4.10 (m, 2H), 3.28 – 3.19 (m, 2H), 1.19 (t, *J* = 7.1 Hz, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 172.01, 154.12, 149.83, 146.5, 134.59, 129.74, 127.81, 125.85, 123.61, 120.45, 75.30, 61.39, 44.53, 13.91. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₁₆H₁₇ClNO₃: 306.0897; found: 306.0894.



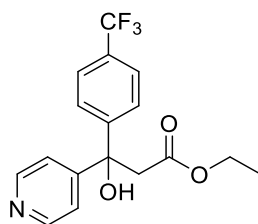
Ethyl 3-(4-bromophenyl)-3-hydroxy-3-(pyridin-4-yl)propanoate (3d)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3d** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a light yellow oil (62%, 43.3 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.52 (d, *J* = 6.0 Hz, 2H), 7.47 – 7.40 (m, 2H), 7.32 (dd, *J* = 4.6, 1.6 Hz, 2H), 7.31 – 7.26 (m, 2H), 5.29 (s, 1H), 4.10 (q, *J* = 7.1 Hz, 2H), 3.27 – 3.13 (m, 2H), 1.17 (t, *J* = 7.1 Hz, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 172.03, 154.21, 149.85, 143.54, 131.58, 127.25, 121.76, 120.42, 75.32, 61.37, 44.48, 13.91. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₁₆H₁₇BrNO₃: 350.0392; found: 350.0389.



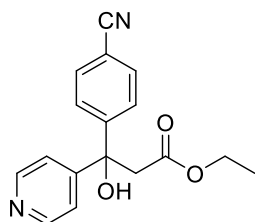
Ethyl 3-hydroxy-3-(pyridin-4-yl)-3-(p-tolyl)propanoate (3e)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3e** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a colorless oil (60%, 33.1 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.51 (d, *J* = 5.2 Hz, 2H), 7.35 (d, *J* = 5.7 Hz, 2H), 7.29 (d, *J* = 8.1 Hz, 2H), 7.12 (d, *J* = 8.0 Hz, 2H), 5.17 (s, 1H), 4.10 (q, *J* = 7.0 Hz, 2H), 3.22 (q, *J* = 16.5 Hz, 2H), 2.30 (s, 3H), 1.17 (t, *J* = 7.0 Hz, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 172.30, 154.91, 149.76, 141.50, 137.32, 129.15, 125.32, 120.51, 75.52, 61.18, 44.74, 20.91, 13.93. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₁₇H₂₀NO₃: 286.1443; found: 286.1450.



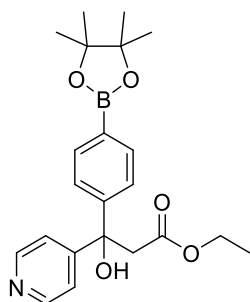
Ethyl 3-hydroxy-3-(pyridin-4-yl)-3-(4-(trifluoromethyl)phenyl)propanoate (3f)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3f** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a light yellow oil (58%, 39.3 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.54 (dd, *J* = 4.7, 1.5 Hz, 2H), 7.61 – 7.52 (m, 4H), 7.35 (dd, *J* = 4.6, 1.6 Hz, 2H), 5.35 (s, 1H), 4.11 (q, *J* = 7.1 Hz, 2H), 3.30 – 3.19 (m, 2H), 1.18 (t, *J* = 7.1 Hz, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 172.03, 153.96, 149.94, 148.35, 129.92 (q, *J* = 33.3 Hz), 125.90, 125.51 (q, *J* = 3.7 Hz), 123.89 (d, *J* = 272.7 Hz), 120.45, 75.44, 61.51, 44.46, 13.91. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₁₇H₁₇NO₃: 286.1443; found: 286.1450. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₁₇H₁₇F₃NO₃: 340.1161; found: 340.1167.



Ethyl 3-(4-cyanophenyl)-3-hydroxy-3-(pyridin-4-yl)propanoate (3g)

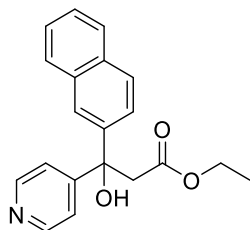
Following the *general procedure D*, when the reaction was finished after 4 h, the product **3g** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a colorless oil (38%, 22.5 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.55 (d, *J* = 6.0 Hz, 2H), 7.63 – 7.61 (m, 2H), 7.57 – 7.55 (m, 1H), 7.34 (d, *J* = 6.0 Hz, 2H), 5.34 (s, 1H), 4.12 (q, *J* = 7.1 Hz, 2H), 3.23 (s, 2H), 1.19 (t, *J* = 7.1 Hz, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 171.91, 153.52, 150.03, 149.54, 132.38, 126.28, 120.37, 118.33, 111.73, 75.41, 61.64, 44.23, 13.94. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₁₇H₁₆N₂O₃: 297.1239; found: 297.1240.



Ethyl-3-hydroxy-3-(pyridin-4-yl)-3-(4-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)propanoate (3h)

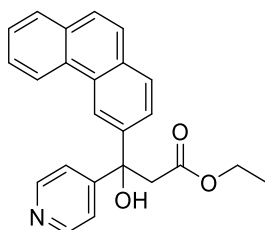
Following the *general procedure D*, when the reaction was finished after 4 h, the product **3h** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a white solid (40%, 30.7 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.51 (d, *J* = 5.1 Hz, 2H), 7.77 (d, *J* = 7.9 Hz, 2H), 7.43 (d, *J* = 7.9 Hz, 2H), 7.35 (d, *J* = 5.3 Hz, 2H), 5.22 (s, 1H), 4.12 – 4.07 (m, 2H), 3.24 (dd, *J* = 37.4, 16.5 Hz, 2H), 1.31 (s, 12H), 1.18 (t, *J* = 7.1 Hz, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 172.29, 154.60, 149.73,

147.27, 135.02, 124.70, 120.53, 83.84, 75.68, 74.97, 61.32, 44.48, 24.82, 24.79, 13.96. HRMS (ESI): m/z $[M + H]^+$ calcd for $C_{22}H_{29}BNO_5$: 398.2139; found: 398.2141.



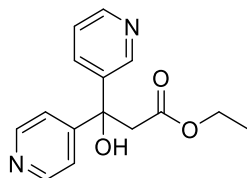
Ethyl 3-hydroxy-3-(naphthalen-2-yl)-3-(pyridin-4-yl)propanoate (3i)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3i** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow solid (75%, 48.2 mg). 1H NMR (400 MHz, $CDCl_3$) δ 8.53 (d, J = 6.0 Hz, 2H), 7.91 (d, J = 1.4 Hz, 1H), 7.84 – 7.77 (m, 3H), 7.50 – 7.47 (m, 3H), 7.41 (dd, J = 4.6, 1.6 Hz, 2H), 5.38 (s, 1H), 4.12 (qd, J = 7.1, 1.7 Hz, 2H), 3.35 (dd, J = 41.8, 16.3 Hz, 2H), 1.17 (t, J = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.31, 154.65, 149.74, 141.69, 132.91, 132.58, 128.47, 128.20, 127.50, 126.36, 126.33, 123.92, 123.87, 120.70, 75.82, 61.29, 44.62, 13.94. HRMS (ESI): m/z $[M + H]^+$ calcd for $C_{20}H_{20}NO_3$: 322.1443; found: 322.1450.



Ethyl 3-hydroxy-3-(phenanthren-3-yl)-3-(pyridin-4-yl)propanoate (3j)

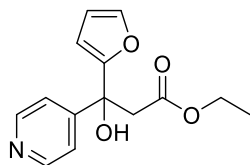
Following the *general procedure D*, when the reaction was finished after 4 h, the product **3j** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow solid (74%, 54.9 mg). 1H NMR (400 MHz, $CDCl_3$) δ 8.87 (s, 1H), 8.71 (d, J = 8.2 Hz, 1H), 8.58 (d, J = 5.0 Hz, 2H), 7.91 (d, J = 7.7 Hz, 1H), 7.86 (d, J = 8.4 Hz, 1H), 7.78 – 7.69 (m, 3H), 7.63 (t, J = 7.8 Hz, 2H), 7.48 (d, J = 5.0 Hz, 2H), 5.50 (s, 1H), 4.15 (q, J = 7.1 Hz, 2H), 3.44 (dd, J = 51.6, 16.3 Hz, 2H), 1.20 (t, J = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.37, 154.71, 149.83, 142.40, 132.18, 131.21, 130.17, 128.94, 128.63, 127.42, 126.76, 126.63, 126.26, 124.32, 122.55, 120.69, 119.13, 76.12, 61.37, 44.90, 13.97. HRMS (ESI): m/z $[M + H]^+$ calcd for $C_{24}H_{22}NO_3$: 372.1600; found: 372.1608.



Ethyl 3-hydroxy-3-(pyridin-3-yl)-3-(pyridin-4-yl)propanoate (3k)

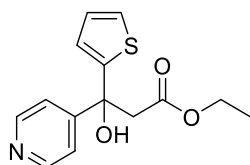
Following the *general procedure D*, when the reaction was finished after 4 h, the product **3k** was isolated by chromatography on silica gel (PE/EA = 1/2, eluent) as a light yellow oil (36%, 19.6 mg). 1H NMR (400 MHz, $CDCl_3$) δ 8.69 (s, 1H), 8.58 (s, 2H), 8.53 (s, 1H), 7.79 (d, J = 7.8 Hz, 1H), 7.38 (s, 2H), 7.28 (s, 1H), 5.38 (s, 1H), 4.14 (q, J = 6.4, 5.9 Hz, 2H), 3.28 (s, 2H), 1.21 (t, J = 6.5 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 171.98, 153.72, 150.08, 148.96, 146.90, 139.99, 133.49, 123.39,

120.38, 74.51, 61.57, 44.31, 13.93. HRMS (ESI): m/z $[M + H]^+$ calcd for $C_{15}H_{17}N_2O_3$: 273.1239; found: 273.1241.



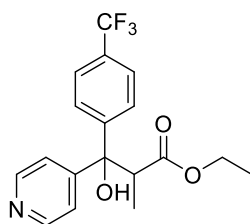
Ethyl 3-(furan-2-yl)-3-hydroxy-3-(pyridin-4-yl)propanoate (3l)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3l** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow solid (56%, 29.2 mg). 1H NMR (400 MHz, $CDCl_3$) δ 8.54 (d, J = 6.1 Hz, 2H), 7.39 (d, J = 6.1 Hz, 2H), 7.37 – 7.33 (m, 1H), 6.30 (dd, J = 3.3, 1.8 Hz, 1H), 6.22 (d, J = 3.3 Hz, 1H), 5.27 (s, 1H), 4.10 (dtt, J = 10.8, 7.1, 3.7 Hz, 2H), 3.17 (m, 2H), 3.02 (d, J = 16.2 Hz, 1H), 1.16 (t, J = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 171.71, 155.79, 152.42, 149.66, 142.51, 120.34, 110.43, 106.96, 72.68, 61.25, 43.76, 13.89. HRMS (ESI): m/z $[M + H]^+$ calcd for $C_{14}H_{16}NO_4$: 262.1079; found: 262.1087.



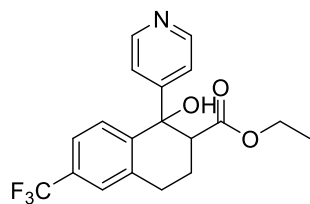
Ethyl 3-hydroxy-3-(pyridin-4-yl)-3-(thiophen-2-yl)propanoate (3m)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3m** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow solid (64%, 35.5 mg). 1H NMR (400 MHz, $CDCl_3$) δ 8.55 (d, J = 6.1 Hz, 2H), 7.42 (d, J = 6.2 Hz, 2H), 7.24 (d, J = 5.0 Hz, 1H), 6.93 – 6.89 (m, 2H), 5.52 (s, 1H), 4.11 (q, J = 7.1 Hz, 2H), 3.24 (dd, J = 47.3, 16.3 Hz, 2H), 1.17 (t, J = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 171.79, 153.94, 149.82, 149.48, 126.65, 125.75, 123.75, 120.15, 74.56, 61.39, 45.86, 13.91. HRMS (ESI): m/z $[M + H]^+$ calcd for $C_{14}H_{16}NO_3S$: 278.0851; found: 278.0847.



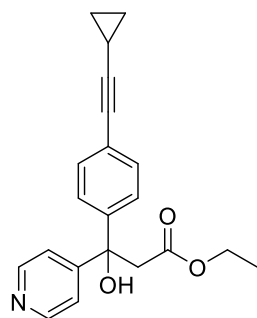
Ethyl 3-hydroxy-2-methyl-3-(pyridin-4-yl)-3-(4-(trifluoromethyl)phenyl)propanoate (3n)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3n** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow oil (61%, 43.1 mg). 1H NMR (400 MHz, $CDCl_3$) δ 8.52 (s, 2H), 7.67 (d, J = 7.9 Hz, 2H), 7.57 (s, 2H), 7.39 – 7.34 (m, 2H), 4.97 (s, 0H), 4.92 (s, 1H), 4.09 – 4.05 (m, 2H), 3.64 – 3.58 (m, 1H), 1.16 – 1.12 (m, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 176.58, 152.09, 149.88, 125.72, 125.54, 125.50, 125.47, 125.43, 120.24, 77.36, 61.35, 46.08, 13.84, 12.64. ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.66. HRMS (ESI): m/z $[M + H]^+$ calcd for $C_{18}H_{19}F_3NO_3$: 354.1317; found: 354.1315.



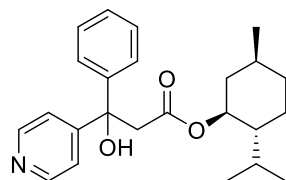
Ethyl 1-hydroxy-1-(pyridin-4-yl)-6-(trifluoromethyl)1,2,3,4-tetrahydronaphthalene-2-carboxylate (3o)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3o** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a light yellow oil (48%, 35.0 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.58 (d, *J* = 5.1 Hz, 2H), 7.46 (s, 1H), 7.37 (d, *J* = 8.3 Hz, 1H), 7.28 (d, *J* = 5.5 Hz, 2H), 7.05 (d, *J* = 8.2 Hz, 1H), 5.26 (s, 1H), 4.08 (tq, *J* = 7.1, 3.2 Hz, 2H), 3.15 (dd, *J* = 10.9, 2.9 Hz, 1H), 3.12 – 3.05 (m, 2H), 2.45 (ddt, *J* = 15.6, 10.8, 7.8 Hz, 1H), 2.12 (dt, *J* = 13.2, 3.5 Hz, 1H), 1.13 (t, *J* = 7.1 Hz, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 174.76, 155.13, 149.45, 142.74, 136.43, 130.04, 125.72 (q, *J* = 4.0 Hz), 123.85 (d, *J* = 271.0 Hz), 123.47 (q, *J* = 4.0 Hz), 121.74, 74.56, 61.39, 50.95, 28.37, 22.42, 13.88. ¹⁹F NMR (376 MHz, CDCl₃) δ -62.79. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₁₉H₁₉F₃NO₃: 366.1317; found: 366.1318.



Ethyl 3-(4-(cyclopropylethynyl)phenyl)-3-hydroxy-3-(pyridin-4-yl)propanoate (3p)

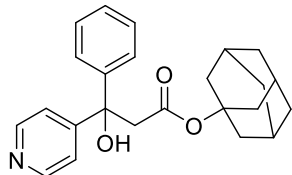
Following the *general procedure D*, when the reaction was finished after 4 h, the product **3p** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a white solid (78%, 52.3 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.49 (d, *J* = 5.1 Hz, 2H), 7.32 – 7.30 (m, 6H), 5.26 (s, 1H), 4.06 (q, *J* = 7.1 Hz, 2H), 3.18 (q, *J* = 16.3 Hz, 2H), 1.43 – 1.36 (m, 1H), 1.14 (t, *J* = 7.1 Hz, 3H), 0.85 – 0.79 (m, 2H), 0.77 – 0.73 (m, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 172.04, 154.39, 149.73, 143.53, 131.62, 125.29, 123.32, 120.46, 93.99, 75.45, 75.12, 61.22, 44.54, 13.88, 8.53, 0.06. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₂₁H₂₂NO₃: 336.1600; found: 336.1607.



(1S,2R,5S)-2-isopropyl-5-methylcyclohexyl 3-hydroxy-3-phenyl-3-(pyridin-4-yl)propanoate (3q)

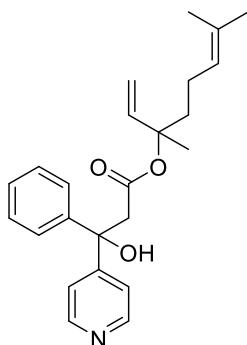
Following the *general procedure D*, when the reaction was finished after 4 h, the product **3q** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow solid (56%, 42.7 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.52 (t, *J* = 4.1 Hz, 2H), 7.42 (d, *J* = 7.7 Hz, 2H), 7.37 (d, *J* = 5.7 Hz, 2H), 7.33 – 7.29 (m, 2H), 7.26 – 7.22 (m, 1H), 5.33 (s, 1H), 4.64 (td, *J* = 10.9, 4.3 Hz, 1H), 3.30 –

3.16 (m, 2H), 1.78 – 1.75 (m, 1H), 1.65 – 1.55 (m, 3H), 1.41 – 1.35 (m, 2H), 0.99 – 0.95 (m, 1H), 0.88 – 0.83 (m, 8H), 0.57 (dd, $J = 6.9, 3.6$ Hz, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 171.96, 154.73, 149.77, 144.35, 128.46, 127.61, 125.48, 120.60, 75.69, 75.49, 46.79, 45.04, 40.51, 34.00, 31.28, 26.10, 23.14, 21.85, 20.68, 15.94. HRMS (ESI): m/z $[\text{M} + \text{H}]^+$ calcd for $\text{C}_{24}\text{H}_{32}\text{NO}_3$: 382.2382; found: 382.2373.



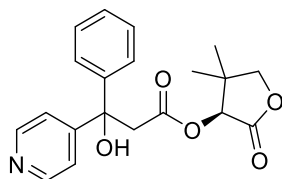
Adamantan-1-yl 3-hydroxy-3-phenyl-3-(pyridin-4-yl)propanoate (3r)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3r** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a light brown solid (61%, 46.0 mg). ^1H NMR (400 MHz, CDCl_3) δ 8.56 (s, 2H), 7.43–7.38 (m, 4H), 7.31 (t, $J = 7.5$ Hz, 2H), 7.24 (d, $J = 7.0$ Hz, 1H), 5.27 (s, 1H), 3.20 – 3.10 (dd, $J = 16.0, 22.0$ Hz, 2H), 2.10 (s, 3H), 1.95 (s, 6H), 1.60 (s, 6H). ^{13}C NMR (101 MHz, CDCl_3) δ 171.31, 154.86, 149.68, 144.51, 128.38, 127.49, 125.51, 82.79, 75.78, 45.93, 41.08, 35.92, 30.72. HRMS (ESI): m/z $[\text{M} + \text{H}]^+$ calcd for $\text{C}_{24}\text{H}_{28}\text{NO}_3$: 378.2069; found: 378.2076.



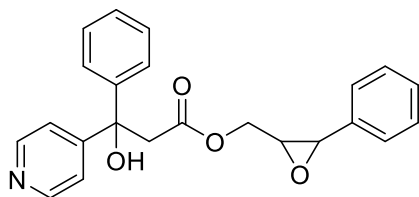
3,7-dimethylocta-1,6-dien-3-yl 3-hydroxy-3-phenyl-3-(pyridin-4-yl)propanoate (3s)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3s** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a Colorless oil (76%, 57.6 mg). ^1H NMR (400 MHz, CDCl_3) δ 8.54 (s, 2H), 7.45 (d, $J = 7.1$ Hz, 2H), 7.38 (s, 2H), 7.33 (t, $J = 6.9$ Hz, 2H), 7.26 (d, $J = 6.7$ Hz, 1H), 5.79 (dd, $J = 17.1, 11.2$ Hz, 1H), 5.31 (s, 1H), 5.13 – 4.97 (m, 3H), 3.22 (q, $J = 16.0$ Hz, 2H), 1.97 – 1.84 (m, 2H), 1.72 (d, $J = 23.0$ Hz, 5H), 1.58 (s, 3H), 1.41 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 171.16, 154.65, 149.72, 144.35, 140.68, 131.99, 128.37, 127.51, 125.46, 123.28, 120.59, 113.60, 85.01, 75.67, 45.46, 39.81, 25.56, 23.08, 23.06, 22.12, 17.53. HRMS (ESI): m/z $[\text{M} + \text{H}]^+$ calcd for $\text{C}_{24}\text{H}_{30}\text{NO}_3$: 380.2226; found: 380.2228.



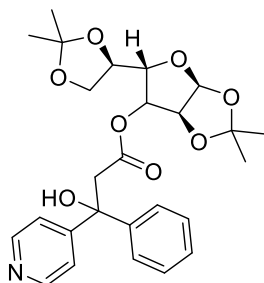
(S)-4,4-dimethyl-2-oxotetrahydrofuran-3-yl 3-hydroxy-3-phenyl-3-(pyridin-4-yl)propanoate (3t)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3t** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a white solid (49%, 34.8 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.56 (d, *J* = 4.4 Hz, 2H), 7.47 (d, *J* = 7.6 Hz, 2H), 7.41 (d, *J* = 5.0 Hz, 2H), 7.39 - 7.34 (m, 2H), 7.28 (t, *J* = 6.6 Hz, 1H), 5.32 (s, 1H), 4.88 (s, 1H), 4.01 (q, *J* = 9.1 Hz, 2H), 3.54 - 3.40 (m, 2H), 1.03 (d, *J* = 3.3 Hz, 3H), 0.97 (d, *J* = 11.9 Hz, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 171.74, 170.94, 154.52, 149.81, 144.03, 128.69, 127.90, 125.46, 120.57, 77.32, 77.00, 76.68, 76.09, 75.69, 44.92, 40.16, 22.65, 19.70. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₂₀H₂₂NO₅: 356.1498; found: 356.1500.



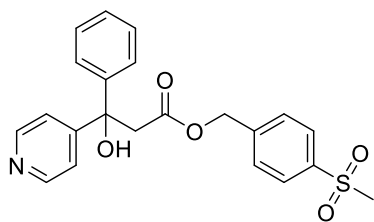
(3-phenyloxiran-2-yl)methyl 3-hydroxy-3-phenyl-3-(pyridin-4-yl)propanoate (3u)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3u** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a light yellow oil (42%, 158 mg, 1 mmol). ¹H NMR (400 MHz, CDCl₃) δ 8.54 (d, *J* = 5.0 Hz, 2H), 7.45 (d, *J* = 7.8 Hz, 2H), 7.40 - 7.32 (m, 8H), 7.23 (d, *J* = 6.9 Hz, 2H), 5.09 (d, *J* = 3.6 Hz, 1H), 4.49 (t, *J* = 11.4 Hz, 1H), 4.15 - 4.07 (m, 1H), 3.71 (s, 1H), 3.37 (qd, *J* = 16.4, 4.4 Hz, 2H), 3.14 (s, 1H). ¹³C NMR (101 MHz, CDCl₃) δ 171.60, 154.69, 149.45, 144.11, 135.70, 128.44, 127.60, 125.50, 125.30, 125.27, 120.52, 120.50, 75.49, 64.44, 58.59, 56.22, 44.63. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₂₃H₂₂NO₄: 376.1549; found: 376.1544.



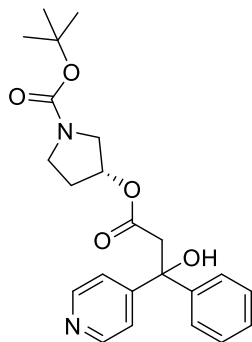
(3aS,5S,6aS)-5-((R)-2,2-dimethyl-1,3-dioxolan-4-yl)-2,2-dimethyltetrahydrofuro[2,3-d][1,3]dioxol-6-yl 3-hydroxy-3-phenyl-3-(pyridin-4-yl)propanoate (3v)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3v** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a brown oil (63%, 61.1 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.51 (s, 2H), 7.46 - 7.40 (t, *J* = 9.0 Hz, 2H), 7.39 - 7.29 (m, 4H), 7.26 (t, *J* = 8.0 Hz, 1H), 5.68 - 5.67 (m, 1H), 5.14 (dd, *J* = 10.5, 2.5 Hz, 1H), 4.96 (s, 1H), 4.14 - 4.02 (m, 3H), 4.02 - 3.92 (m, 2H), 3.40 - 3.19 (m, 2H), 1.45 (s, 3H), 1.36 (d, *J* = 4.0 Hz, 3H), 1.32 (s, 3H), 1.21 (d, *J* = 7.0 Hz, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 170.88, 154.66, 149.68, 144.08, 128.57, 127.83, 125.58, 120.62, 112.32, 109.53, 104.92, 82.93, 79.42, 75.78, 72.29, 67.36, 45.21, 26.88, 26.53, 26.00, 25.18. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₂₆H₃₂NO₈: 486.2128; found: 486.2130.



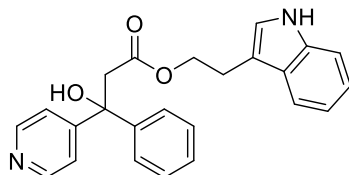
4-(methylsulfonyl)benzyl 3-hydroxy-3-phenyl-3-(pyridin-4-yl)propanoate (3w)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3w** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow oil (57%, 46.9 mg). ^1H NMR (400 MHz, CDCl_3) δ 8.55 – 8.48 (m, 2H), 7.90 (d, J = 7.8 Hz, 2H), 7.43 (d, J = 7.1 Hz, 2H), 7.35 (d, J = 11.1 Hz, 7H), 5.16 (d, J = 15.2 Hz, 2H), 4.99 (s, 1H), 3.47 – 3.27 (m, 2H), 3.08 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 171.79, 154.40, 149.75, 143.97, 141.02, 128.59, 127.83, 127.71, 125.37, 120.50, 75.67, 65.59, 44.79, 44.40. HRMS (ESI): m/z $[\text{M} + \text{H}]^+$ calcd for $\text{C}_{22}\text{H}_{22}\text{NO}_5\text{S}$: 412.1219; found: 412.1218.



tert-butyl (3R)-3-((3-hydroxy-3-phenyl-3-(pyridin-4-yl)propanoyl)oxy)pyrrolidine-1-carboxylate (3x)

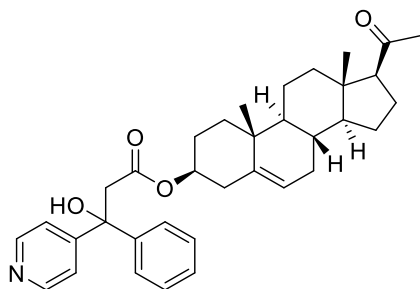
Following the *general procedure D*, when the reaction was finished after 4 h, the product **3x** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a white solid. (60%, 49.4 mg). ^1H NMR (400 MHz, CDCl_3) δ 8.51 (d, J = 5.7 Hz, 2H), 7.40 (t, J = 6.1 Hz, 2H), 7.36 – 7.30 (m, 4H), 7.24 (t, J = 7.2 Hz, 1H), 5.22 (s, 1H), 5.06 (s, 1H), 3.51 – 3.38 (m, 2H), 3.33 – 3.27 (m, 2H), 3.23 – 3.16 (m, 2H), 1.95 (s, 1H), 1.78 (s, 1H), 1.46 (s, 9H). ^{13}C NMR (101 MHz, CDCl_3) δ 171.81, 154.41, 154.16, 149.78, 144.04, 128.54, 127.73, 125.34, 120.43, 79.62, 75.68, 74.89, 51.52, 44.92, 43.69, 30.52, 28.41. HRMS (ESI): m/z $[\text{M} + \text{H}]^+$ calcd for $\text{C}_{23}\text{H}_{29}\text{N}_2\text{O}_5$: 413.2076; found: 413.2070.



2-(1H-indol-3-yl)ethyl 3-hydroxy-3-phenyl-3-(pyridin-4-yl)propanoate (3y)

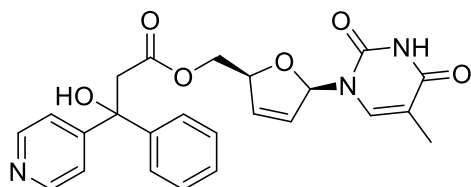
Following the *general procedure D*, when the reaction was finished after 4 h, the product **3y** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a white solid (72%, 55.6 mg). ^1H NMR (400 MHz, CDCl_3) δ 8.57 (s, 1H), 8.49 (d, J = 5.4 Hz, 2H), 7.63 (d, J = 7.8 Hz, 1H), 7.39 (d, J = 7.4 Hz, 3H), 7.35 – 7.23 (m, 6H), 7.18 (t, J = 7.4 Hz, 1H), 6.93 (d, J = 2.0 Hz, 1H), 5.23 (s, 1H), 4.43 – 4.28 (m, 2H), 3.33 – 3.19 (m, 2H), 3.12 – 2.97 (m, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 172.18, 154.80, 149.56, 144.23, 136.21, 128.46, 127.58, 127.23, 125.33, 122.08, 122.06, 120.60,

119.36, 118.57, 111.29, 111.27, 75.57, 65.29, 44.74, 24.48. HRMS (ESI): m/z $[M + H]^+$ calcd for $C_{24}H_{23}N_2O_3$: 387.1709; found: 387.1712.



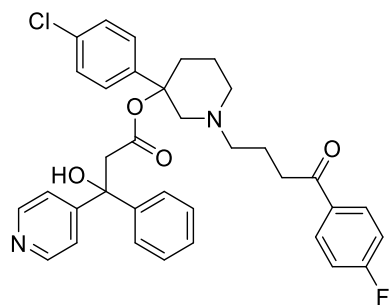
(3S, 8S, 9S, 10R, 13S, 14S, 17S)-17-acetyl-10,13-dimethyl-2,3,4,7,8,9,10,11,12,13,14,15,16,17-tetradecahydro-1H-cyclopenta[a]phenanthren-3-yl-3-hydroxy-3-phenyl-3-(pyridin-4-yl)propanoate (3z)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3z** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a white solid (47%, 50.9 mg). 1H NMR (400 MHz, $CDCl_3$) δ 8.56 (d, J = 3.7 Hz, 2H), 7.44 (d, J = 7.6 Hz, 2H), 7.41 (d, J = 5.6 Hz, 2H), 7.35 (t, J = 7.5 Hz, 2H), 7.28 (t, J = 6.5 Hz, 1H), 5.34 (d, J = 3.6 Hz, 1H), 5.25 (s, 1H), 4.62 – 4.56 (m, 1H), 3.25 (qd, J = 16.3, 2.4 Hz, 2H), 2.54 (t, J = 8.7 Hz, 1H), 2.22 (dd, J = 21.9, 11.2 Hz, 3H), 2.14 (s, 3H), 2.04 (d, J = 11.4 Hz, 1H), 1.88 – 1.81 (m, 1H), 1.75 – 1.65 (m, 3H), 1.60 (s, 2H), 1.47 (t, J = 8.2 Hz, 3H), 1.22 (dd, J = 30.6, 7.9 Hz, 2H), 1.11 (dd, J = 13.8, 3.9 Hz, 1H), 1.02 (s, 3H), 0.64 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 209.52, 171.78, 154.98, 149.55, 144.26, 139.01, 128.49, 127.67, 125.43, 122.80, 120.69, 75.73, 75.01, 63.59, 56.72, 49.74, 44.98, 43.91, 38.68, 37.66, 36.76, 36.48, 31.70, 31.52, 27.42, 24.42, 22.76, 20.95, 19.21, 13.18. HRMS (ESI): m/z $[M + H]^+$ calcd for $C_{35}H_{44}NO_4$: 542.3270; found: 542.3264.



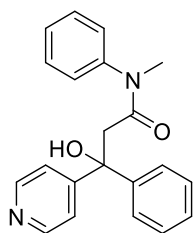
(2R,5R)-5-(5-methyl-2,4-dioxo-3,4-dihydropyrimidin-1(2H)-yl)-2,5-dihydrofuran-2-yl 3-hydroxy-3-phenyl-3-(pyridin-4-yl)propanoate (3aa)

Following the *general procedure D*, when the reaction was finished after 8 h, the product **3aa** was isolated by chromatography on silica gel (DCM/MeOH = 10/1, eluent) as a yellow oil (45%, 39.2 mg). 1H NMR (400 MHz, $CDCl_3$) δ 9.27 (d, J = 16.6 Hz, 1H), 8.68 – 8.49 (m, 2H), 7.48 – 7.38 (m, 4H), 7.38 – 7.31 (m, 2H), 7.29 – 7.23 (m, 1H), 7.06 (t, J = 1.8 Hz, 1H), 6.99 (dt, J = 3.4, 1.6 Hz, 1H), 6.16 (td, J = 4.1, 2.0 Hz, 1H), 5.92 (dq, J = 6.0, 2.0 Hz, 1H), 5.12 – 4.89 (m, 2H), 4.33 (ddd, J = 13.1, 7.9, 5.5 Hz, 1H), 4.24 (ddd, J = 11.8, 7.4, 3.4 Hz, 1H), 3.41 – 3.23 (m, 2H), 1.84 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 171.70, 163.57, 150.74, 148.75, 135.08, 132.66, 128.76, 128.03, 127.69, 125.33, 120.93, 111.21, 90.10, 83.65, 75.69, 65.48, 44.70, 12.58. HRMS (ESI): m/z $[M + H]^+$ calcd for $C_{24}H_{24}N_3O_6$: 450.1665; found: 450.1654.



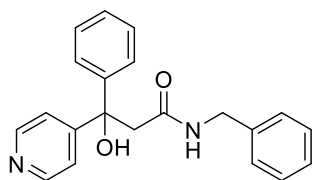
3-(4-chlorophenyl)-1-(4-(4-fluorophenyl)-4-oxobutyl)piperidin-3-yl-3-hydroxy-3-phenyl-3-(pyridin-4-yl)propanoate. (3ab)

Following the *general procedure D*, when the reaction was finished after 6 h, the product **3ab** was isolated by chromatography on silica gel (DCM/MeOH = 10/1, eluent) as a light yellow solid (38%, 45.6 mg). ^1H NMR (400 MHz, CDCl_3) δ 8.55 (d, J = 4.3 Hz, 2H), 8.13 – 7.94 (m, 2H), 7.43 (d, J = 7.3 Hz, 2H), 7.36 (d, J = 5.6 Hz, 4H), 7.30 (d, J = 9.3 Hz, 2H), 7.20 (d, J = 7.8 Hz, 2H), 7.14 (t, J = 8.1 Hz, 2H), 7.02 (d, J = 8.0 Hz, 2H), 5.07 (s, 1H), 3.43 – 3.17 (m, 2H), 2.99 (t, J = 6.5 Hz, 2H), 2.72 (d, J = 10.5 Hz, 2H), 2.43 (t, J = 6.4 Hz, 2H), 2.31 (d, J = 13.4 Hz, 2H), 2.12 (q, J = 10.5 Hz, 2H), 2.01 – 1.94 (m, 2H), 1.93 – 1.83 (m, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 198.19, 170.86, 154.48, 149.92, 144.18, 133.37, 130.66, 130.56, 128.62, 128.59, 127.76, 125.78, 125.56, 120.63, 115.74, 115.52, 82.19, 75.62, 57.51, 48.93, 48.85, 45.39, 36.08, 35.29, 35.20, 21.79. HRMS (ESI): m/z $[\text{M} + \text{H}]^+$ calcd for $\text{C}_{35}\text{H}_{35}\text{ClFN}_2\text{O}_4$: 601.2269; found: 601.2273.



3-hydroxy-N-methyl-N, 3-diphenyl-3-(pyridin-4-yl)propanamide. (3ac)

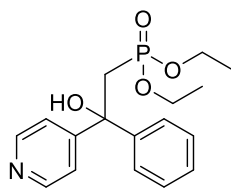
Following the *general procedure D*, when the reaction was finished after 4 h, the product **3ac** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow oil (54%, 35.9 mg). ^1H NMR (400 MHz, CDCl_3) δ 8.50 (d, J = 5.0 Hz, 2H), 7.48 (t, J = 7.2 Hz, 2H), 7.42 (t, J = 7.2 Hz, 1H), 7.29 – 7.26 (m, 4H), 7.23 – 7.21 (m, 3H), 7.10 (d, J = 7.9 Hz, 2H), 6.92 (s, 1H), 3.16 (s, 3H), 2.96 (s, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 171.69, 155.33, 149.55, 144.80, 142.60, 130.15, 128.54, 128.28, 127.33, 126.87, 125.47, 120.77, 76.26, 42.66, 37.11.



N-benzyl-3-hydroxy-3-phenyl-3-(pyridin-4-yl)propanamide (3ad)

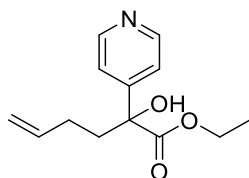
Following the *general procedure D*, when the reaction was finished after 4 h, the product **3ad** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow oil (43%, 28.6 mg). ^1H NMR (400 MHz, CDCl_3) δ 8.39 (d, J = 6.1 Hz, 2H), 7.39 (d, J = 6.8 Hz, 2H), 7.34 – 7.27 (m, 5H), 7.22 – 7.21 (m, 3H), 6.91 – 6.89 (m, 2H), 6.80 (t, J = 5.6 Hz, 1H), 4.29 (dd, J = 5.7, 2.4 Hz, 2H), 3.11 (q, J = 15.1 Hz, 2H). ^{13}C NMR (101 MHz, CDCl_3) δ 171.25, 155.29, 149.43, 144.48, 137.29,

128.63, 128.50, 127.57, 127.51, 127.33, 125.52, 120.90, 76.08, 45.35, 43.17. HRMS (ESI): m/z $[M + H]^+$ calcd for $C_{21}H_{21}N_2O_2$: 333.1603; found: 333.1606.



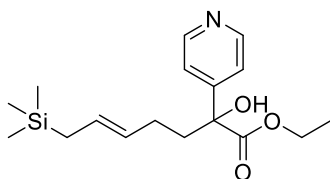
Diethyl (2-hydroxy-2-phenyl-2-(pyridin-4-yl)ethyl)phosphonate (3ae)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3ae** was isolated by chromatography on silica gel (DCM/MeOH = 15/1, eluent) as a yellow oil (65%, 43.6 mg). 1H NMR (400 MHz, $CDCl_3$) δ 8.52 (d, J = 5.4 Hz, 2H), 7.48 (d, J = 7.7 Hz, 2H), 7.41 (d, J = 5.4 Hz, 2H), 7.32 (t, J = 7.5 Hz, 2H), 7.24 (d, J = 7.1 Hz, 1H), 5.88 (s, 1H), 3.90 – 3.82 (m, 2H), 3.76 – 3.62 (m, 2H), 2.89 – 2.75 (m, 2H), 1.13 (t, J = 7.1 Hz, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 155.19, 149.65, 144.88, 128.34, 127.49, 125.47, 120.64, 74.72, 62.12, 61.87, 38.17, 36.80, 16.09. ^{31}P NMR (162 MHz, $CDCl_3$) δ 28.00. HRMS (ESI): m/z $[M + H]^+$ calcd for $C_{17}H_{23}NO_4P$: 336.1365; found: 336.1367.



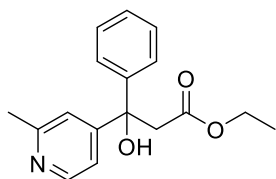
Ethyl 2-hydroxy-2-(pyridin-4-yl)hex-5-enoate (3af)

Following the *general procedure D*, when the reaction was finished after 2.5 h, the product **3af** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow oil (50%, 23. mg). 1H NMR (400 MHz, $CDCl_3$) δ 8.57 (d, J = 5.8 Hz, 2H), 7.54 (d, J = 5.9 Hz, 2H), 5.81 – 5.72 (m, 1H), 5.02 – 4.93 (m, 2H), 4.32 – 4.16 (m, 3H), 2.25 – 2.03 (m, 5H), 1.28 (t, J = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 173.95, 150.74, 149.67, 137.28, 120.71, 115.26, 63.07, 38.87, 27.90, 14.02. HRMS (ESI): m/z $[M + H]^+$ calcd for $C_{13}H_{18}NO_3$: 236.1287; found: 236.1286.



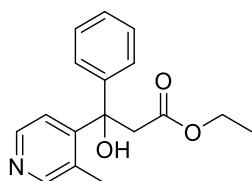
Ethyl 2-hydroxy-2-(pyridin-4-yl)-7-(trimethylsilyl)hept-5-enoate (3ag)

Following the *general procedure D*, when the reaction was finished after 2.5 h, the product **3ag** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a brown yellow oil (48%, 30.8 mg). 1H NMR (400 MHz, $CDCl_3$) δ 8.56 (dd, J = 4.4, 2.0 Hz, 2H), 7.53 (dd, J = 4.5, 2.2 Hz, 2H), 5.47 – 5.30 (m, 1H), 5.19 (dd, J = 13.2, 6.8 Hz, 1H), 4.24 (ddtt, J = 12.9, 10.6, 6.8, 2.9 Hz, 3H), 2.27 – 2.09 (m, 1H), 2.09 – 1.87 (m, 3H), 1.38 (dd, J = 17.0, 7.9 Hz, 2H), 1.27 (td, J = 7.1, 2.3 Hz, 3H), -0.06 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 150.91, 149.57, 127.34, 126.96, 120.68, 77.47, 62.83, 40.12, 27.01, 22.59, 13.99, -2.07. HRMS (ESI): m/z $[M + H]^+$ calcd for $C_{17}H_{28}NO_3Si$: 322.1838; found: 322.1833.



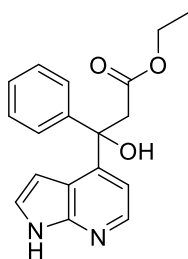
Ethyl 3-hydroxy-3-(2-methylpyridin-4-yl)-3-phenylpropanoate (3ah)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3ah** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a white solid (56%, 31.9 mg). ^1H NMR (400 MHz, CDCl_3) δ 8.43 (d, J = 4.5 Hz, 1H), 7.44 (d, J = 7.4 Hz, 2H), 7.33 (d, J = 7.4 Hz, 2H), 7.28 (s, 2H), 7.15 (d, J = 3.1 Hz, 1H), 5.20 (s, 1H), 4.17 – 4.04 (m, 2H), 3.25 (q, J = 16.4 Hz, 2H), 2.54 (s, 3H), 1.19 (t, J = 6.7 Hz, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 172.38, 158.59, 154.93, 149.11, 144.48, 128.44, 127.54, 125.39, 120.01, 117.65, 75.64, 75.64, 61.19, 44.73, 24.55, 13.94. HRMS (ESI): m/z $[\text{M} + \text{H}]^+$ calcd for $\text{C}_{17}\text{H}_{20}\text{NO}_3$: 286.1443; found: 286.1435.



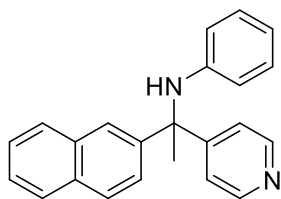
Ethyl 3-hydroxy-3-(3-methylpyridin-4-yl)-3-phenylpropanoate (3ai)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3ai** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a light yellow oil (50%, 28.5 mg). ^1H NMR (400 MHz, CDCl_3) δ 8.46 (d, J = 4.2 Hz, 1H), 8.32 (s, 1H), 7.34 – 7.30 (m, 6H), 5.36 (s, 1H), 4.24 – 4.11 (m, 2H), 3.33 (d, J = 16.3 Hz, 1H), 3.07 (d, J = 16.3 Hz, 1H), 2.09 (s, 3H), 1.23 (t, J = 7.0 Hz, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 172.82, 153.19, 151.16, 147.10, 143.73, 132.92, 128.23, 127.40, 125.59, 119.95, 76.91, 61.35, 45.40, 18.21, 13.98. HRMS (ESI): m/z $[\text{M} + \text{H}]^+$ calcd for $\text{C}_{17}\text{H}_{20}\text{NO}_3$: 286.1443; found: 286.1440.



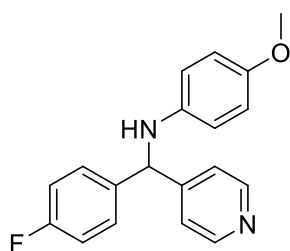
Ethyl 3-hydroxy-3-phenyl-3-(1H-pyrrolo[2,3-b]pyridin-4-yl)propanoate (3aj)

Following the *general procedure D*, when the reaction was finished after 5 h, the product **3aj** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow oil (65%, 40.3 mg). ^1H NMR (400 MHz, CDCl_3) δ 11.34 (s, 1H), 8.27 (d, J = 4.3 Hz, 1H), 7.52 (d, J = 7.6 Hz, 2H), 7.33 (t, J = 7.5 Hz, 2H), 7.29 – 7.24 (m, 2H), 7.17 (d, J = 5.0 Hz, 1H), 6.62 (d, J = 3.2 Hz, 1H), 5.41 (s, 1H), 4.12 (q, J = 7.1 Hz, 2H), 3.53 (d, J = 16.2 Hz, 1H), 3.39 (d, J = 16.2 Hz, 1H), 1.16 (t, J = 7.1 Hz, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 172.71, 149.39, 147.17, 144.58, 141.88, 128.18, 127.36, 125.70, 124.84, 117.86, 112.33, 101.66, 76.94, 61.06, 44.75, 13.91. HRMS (ESI): m/z $[\text{M} + \text{H}]^+$ calcd for $\text{C}_{18}\text{H}_{19}\text{N}_2\text{O}_3$: 311.1396; found: 311.1400.



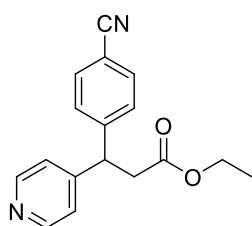
N-(1-(naphthalen-2-yl)-1-(pyridin-4-yl)ethyl)aniline (3ak)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3ak** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow oil (68%, 44.1 mg). ¹H NMR (400 MHz, Chloroform-*d*) δ 8.58 (d, *J* = 5.0 Hz, 2H), 7.90 – 7.78 (m, 4H), 7.59 (d, *J* = 8.7 Hz, 1H), 7.54 – 7.41 (m, 4H), 7.05 (t, *J* = 7.6 Hz, 2H), 6.71 (t, *J* = 7.2 Hz, 1H), 6.47 (d, *J* = 8.0 Hz, 2H), 4.44 (s, 1H), 2.20 (s, 3H). ¹³C NMR (101 MHz, Chloroform-*d*) δ 155.36, 150.10, 145.25, 142.88, 133.04, 132.37, 128.79, 128.60, 128.26, 127.44, 126.36, 125.16, 124.86, 122.03, 118.32, 116.30, 62.13, 26.24.



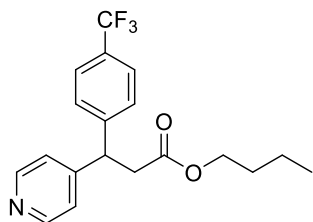
N-((4-fluorophenyl)(pyridin-4-yl)methyl)-4-methoxyaniline (3al)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3al** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow oil (40%, 24.6 mg). ¹H NMR (400 MHz, Chloroform-*d*) δ 8.59 (d, *J* = 5.0 Hz, 2H), 7.36 – 7.29 (m, 4H), 7.06 (d, *J* = 8.3 Hz, 2H), 6.75 (d, *J* = 8.7 Hz, 2H), 6.49 (d, *J* = 8.5 Hz, 2H), 5.39 (s, 1H), 3.95 (s, 1H), 3.74 (s, 3H). ¹³C NMR (101 MHz, Chloroform-*d*) δ 162.32 (d, *J*_{C-F} = 248.2 Hz), 152.68, 151.70, 150.28, 140.73, 137.55, 129.23 (d, *J*_{C-F} = 8.1 Hz), 122.24, 116.03, 115.81, 114.83, 114.81, 62.38, 55.69. ¹⁹F NMR (376 MHz, Chloroform-*d*) δ -113.93.



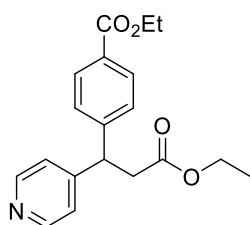
Ethyl 3-(4-cyanophenyl)-3-(pyridin-4-yl)propanoate (3am)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3am** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow oil (73%, 40.9 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.51 (d, *J* = 4.4 Hz, 2H), 7.58 (d, *J* = 8.0 Hz, 2H), 7.32 (d, *J* = 7.9 Hz, 2H), 7.11 (d, *J* = 4.7 Hz, 2H), 4.56 (t, *J* = 7.8 Hz, 1H), 4.03 (q, *J* = 7.0 Hz, 2H), 3.09 – 2.95 (m, 2H), 1.11 (t, *J* = 7.1 Hz, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 170.46, 150.62, 150.17, 146.97, 132.54, 128.52, 122.72, 118.36, 111.12, 60.89, 46.22, 39.31, 13.95. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₁₇H₁₇N₂O₂: 281.1290; found: 281.1287.



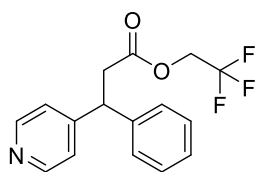
Butyl 3-(pyridin-4-yl)-3-(4-(trifluoromethyl)phenyl)propanoate (**3an**)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3an** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow oil (73%, 51.2 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.51 (d, *J* = 5.8 Hz, 2H), 7.55 (d, *J* = 8.2 Hz, 2H), 7.32 (d, *J* = 8.1 Hz, 2H), 7.13 (d, *J* = 6.4 Hz, 2H), 4.57 (t, *J* = 7.9 Hz, 1H), 3.98 (t, *J* = 6.6 Hz, 2H), 3.19 – 2.94 (m, 2H), 1.49 – 1.42 (m, 2H), 1.25 – 1.15 (m, 2H), 0.83 (t, *J* = 7.4 Hz, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 170.82, 151.17, 150.11, 145.63, 129.41 (q, *J* = 3.7 Hz), 128.08, 125.72 (q, *J* = 3.7 Hz), 123.89 (d, *J* = 270 Hz), 122.78, 64.71, 46.13, 39.59, 30.38, 18.86, 13.46. ¹⁹F NMR (376 MHz, CDCl₃) δ -62.58. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₁₉H₂₁F₃NO₂: 352.1524; found: 352.1518.



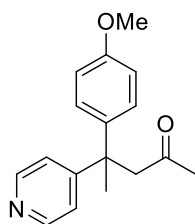
Ethyl 4-(3-ethoxy-3-oxo-1-(pyridin-4-yl)propyl)benzoate (**3ao**)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3ao** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow oil (84%, 54.9 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.51 (d, *J* = 3.6 Hz, 2H), 7.98 (d, *J* = 7.7 Hz, 2H), 7.29 (d, *J* = 7.5 Hz, 2H), 7.15 (d, *J* = 4.0 Hz, 2H), 4.58 (t, *J* = 7.5 Hz, 1H), 4.35 (dd, *J* = 13.5, 6.6 Hz, 2H), 4.05 (dd, *J* = 13.5, 6.6 Hz, 2H), 3.06 (d, *J* = 6.4 Hz, 2H), 1.36 (t, *J* = 6.8 Hz, 3H), 1.13 (t, *J* = 6.9 Hz, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 170.75, 166.05, 151.36, 150.02, 146.59, 129.99, 129.37, 127.66, 122.80, 60.82, 60.75, 46.22, 39.54, 14.21, 13.96. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₁₉H₂₂NO₄: 328.1549; found: 328.1544.



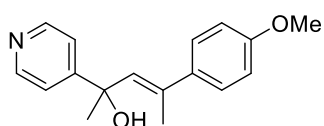
2,2,2-trifluoroethyl 3-phenyl-3-(pyridin-4-yl)propanoate (**3ap**)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3ap** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow oil (85%, 52.5 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.54 (d, *J* = 5.0 Hz, 2H), 7.34 (t, *J* = 7.3 Hz, 2H), 7.28 (d, *J* = 7.1 Hz, 1H), 7.23 (d, *J* = 7.6 Hz, 2H), 7.18 (d, *J* = 5.0 Hz, 2H), 4.55 (t, *J* = 7.9 Hz, 1H), 4.40 (q, *J* = 8.3 Hz, 2H), 3.27 – 3.14 (m, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 169.56, 151.49, 150.11, 141.01, 128.92, 127.53, 127.36, 122.74, 60.40 (q, *J* = 37 Hz), 46.14, 39.21. ¹⁹F NMR (376 MHz, CDCl₃) δ -73.80. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₁₆H₁₅F₃NO₂: 310.1055; found: 310.1062.



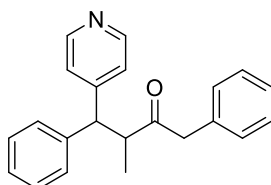
4-(4-methoxyphenyl)-4-(pyridin-4-yl)pentan-2-one (3aq)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3aq** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a white solid (56%, 30.2 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.60 – 8.45 (m, 2H), 7.17 – 7.02 (m, 4H), 6.91 – 6.79 (m, 2H), 3.81 (s, 3H), 3.34 – 3.12 (m, 2H), 1.85 (s, 3H), 1.80 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 206.63, 158.20, 158.11, 149.56, 128.05, 122.20, 113.73, 55.21, 53.64, 44.66, 31.97, 27.22. HRMS (ESI): m/z [M + Na]⁺ calcd for C₁₇H₁₉NONa: 292.1313; found: 292.1305.



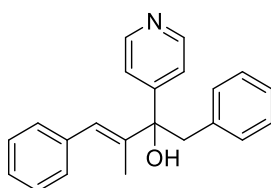
(E)-4-(4-methoxyphenyl)-2-(pyridin-4-yl)pent-3-en-2-ol (3aq')

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3aq'** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow oil (14%, 7.5 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.59 – 8.52 (m, 2H), 7.49 – 7.42 (m, 2H), 7.33 (d, *J* = 8.8 Hz, 2H), 6.86 (d, *J* = 8.8 Hz, 2H), 6.18 (d, *J* = 1.3 Hz, 1H), 3.82 (s, 3H), 2.24 (s, 1H), 1.85 (s, 3H), 1.68 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 149.47, 140.81, 135.59, 131.96, 126.91, 120.39, 113.68, 73.33, 55.32, 34.40, 17.52.



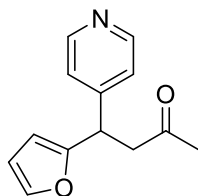
3-methyl-1,4-diphenyl-4-(pyridin-4-yl)butan-2-one (3ar)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3ar** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow solid (58%, 36.6 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.52 (d, *J* = 6.0 Hz, 2H), 7.32 – 7.26 (m, 3H), 7.26 – 7.20 (m, 5H), 7.19 – 7.16 (m, 2H), 6.94 (dd, *J* = 7.1, 2.0 Hz, 2H), 4.13 (d, *J* = 11.5 Hz, 1H), 3.69 – 3.57 (m, 1H), 3.52 (s, 2H), 1.05 (d, *J* = 6.8 Hz, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 210.02, 151.19, 150.00, 141.29, 133.25, 129.52, 128.81, 128.60, 127.77, 127.03, 126.99, 123.51, 54.14, 50.22, 48.62, 16.71. HRMS (ESI): m/z [M + H]⁺ calcd for C₂₂H₂₂NO: 316.1701; found: 316.1697.



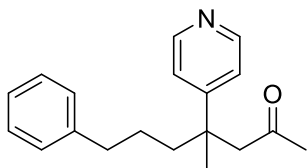
(E)-3-methyl-1,4-diphenyl-2-(pyridin-4-yl)but-3-en-2-ol. Light yellow solid (3ar')

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3ar'** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow oil (14%, 8.8 mg). ^1H NMR (400 MHz, CDCl_3) δ 8.60 – 8.52 (m, 2H), 7.40 – 7.33 (m, 4H), 7.30 – 7.23 (m, 6H), 7.02 – 6.99 (m, 2H), 6.81 (s, 1H), 3.55 (d, J = 13.2 Hz, 1H), 3.42 (d, J = 13.2 Hz, 1H), 2.61 (s, 1H), 1.77 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 149.40, 140.66, 135.12, 130.64, 128.99, 128.24, 128.14, 127.07, 126.70, 126.08, 121.31, 78.61, 44.97, 15.14.



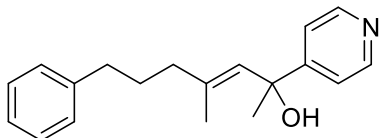
4-(furan-2-yl)-4-(pyridin-4-yl)butan-2-one (3as)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3as** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow oil (55%, 23.7 mg). ^1H NMR (400 MHz, CDCl_3) δ 8.58 – 8.45 (m, 2H), 7.35 (d, J = 1.9 Hz, 1H), 7.20 (s, 1H), 7.18 – 7.12 (m, 2H), 6.17 (d, J = 1.7 Hz, 1H), 4.44 (t, J = 7.2 Hz, 1H), 3.15 – 2.96 (m, 2H), 2.12 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 205.55, 152.23, 150.03, 143.53, 139.15, 126.51, 122.95, 109.91, 48.96, 36.46, 30.53. HRMS (ESI): m/z $[\text{M} + \text{H}]^+$ calcd for $\text{C}_{13}\text{H}_{14}\text{NO}_2$: 216.1025; found: 216.1030.



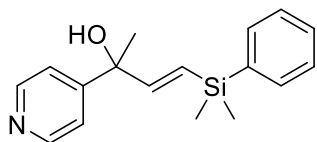
4-methyl-7-phenyl-4-(pyridin-4-yl)heptan-2-one (3at)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3at** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a light yellow oil (53%, 29.8 mg). ^1H NMR (400 MHz, CDCl_3) δ 8.53 (d, J = 5.6 Hz, 2H), 7.28 (d, J = 5.1 Hz, 2H), 7.20 (d, J = 7.2 Hz, 1H), 7.17 (d, J = 6.0 Hz, 2H), 7.09 (d, J = 7.3 Hz, 2H), 2.91 (d, J = 16.1 Hz, 1H), 2.68 (d, J = 16.1 Hz, 1H), 2.59 – 2.50 (dd, J = 15.3, 8.2 Hz, 2H), 1.94 (s, 3H), 1.75 (ddd, J = 21.4, 12.3, 4.4 Hz, 2H), 1.55 – 1.47 (m, 1H), 1.45 (s, 3H), 1.30 – 1.22 (m, 1H). ^{13}C NMR (101 MHz, CDCl_3) δ 206.37, 149.50, 128.30, 125.86, 121.45, 54.59, 41.90, 40.12, 36.02, 31.75, 25.68, 23.20. HRMS (ESI): m/z $[\text{M} + \text{H}]^+$ calcd for $\text{C}_{19}\text{H}_{24}\text{NO}$: 282.1858; found: 282.1852.



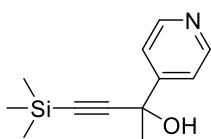
(E)-4-methyl-7-phenyl-2-(pyridin-4-yl)hept-3-en-2-ol (3at')

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3at'** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a light yellow oil (13%, 7.3 mg). ^1H NMR (400 MHz, CDCl_3) δ 8.55 (s, 2H), 7.42 (d, J = 5.3 Hz, 2H), 7.31 (t, J = 7.4 Hz, 2H), 7.20 (t, J = 6.2 Hz, 3H), 5.73 (s, 1H), 2.65 – 2.59 (m, 2H), 2.12 – 2.04 (m, 3H), 1.79 – 1.73 (m, 2H), 1.59 (s, 3H), 1.46 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 158.25, 149.26, 142.30, 142.18, 131.07, 128.38, 128.33, 125.81, 73.03, 39.90, 35.54, 34.09, 29.60, 17.64.



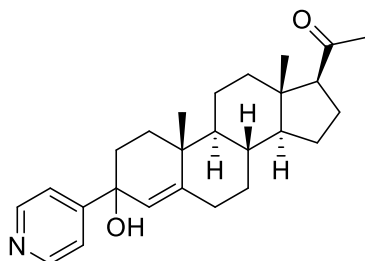
(E)-4-(dimethyl(phenyl)silyl)-2-(pyridin-4-yl)but-3-en-2-ol (3au)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3au** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow solid (82%, 46.4 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.46 (d, *J* = 6.0 Hz, 2H), 7.48 – 7.46 (m, 2H), 7.36 – 7.31 (m, 5H), 6.33 (d, *J* = 18.4 Hz, 1H), 6.10 (d, *J* = 18.4 Hz, 1H), 3.71 (s, 1H), 1.62 (s, 3H), 0.34 (s, 6H). ¹³C NMR (101 MHz, CDCl₃) δ 155.83, 151.99, 149.31, 138.03, 133.71, 129.08, 127.79, 125.66, 120.42, 77.32, 74.76, 29.04, -2.70, -2.72. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₁₇H₂₂NOSi: 284.1471; found: 284.1478.



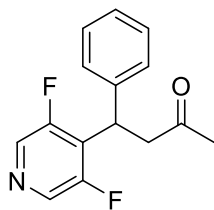
2-(pyridin-4-yl)-4-(trimethylsilyl)but-3-yn-2-ol (3av)

Following the *general procedure D*, when the reaction was finished after 2.5 h, the product **3av** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a white solid (46%, 20.1 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.54 (dd, *J* = 4.8, 1.6 Hz, 2H), 7.54 (dd, *J* = 4.6, 1.6 Hz, 2H), 3.73 (s, 1H), 1.72 (s, 3H), 0.19 (s, 9H). ¹³C NMR (101 MHz, CDCl₃) δ 154.76, 149.52, 120.05, 107.51, 90.02, 69.06, 33.12, -0.21. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₁₂H₁₈NOSi: 220.1158; found: 220.1153.



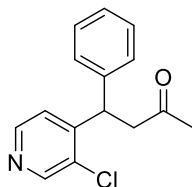
1-((8S,9S,10R,13S,14S,17S)-3-hydroxy-10,13-dimethyl-3-(pyridin-4-yl)-2,3,6,7,8,9,10,11,12,13,14,15,16,17-tetradecahydro-1H-cyclopenta[a]phenanthren-17-yl)ethan-1-one (3aw)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3aw** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow solid (38%, 30.0 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.66 (s, 2H), 7.56 (s, 2H), 5.33 (s, 1H), 2.56 (t, *J* = 9.0 Hz, 1H), 2.43 – 2.31 (m, 1H), 2.20 (ddd, *J* = 11.2, 4.3, 2.1 Hz, 2H), 2.13 (s, 3H), 2.06 – 1.96 (m, 2H), 1.94 – 1.86 (m, 2H), 1.80 – 1.67 (m, 2H), 1.57 (dddd, *J* = 29.7, 12.0, 6.3, 3.8 Hz, 3H), 1.47 – 1.37 (m, 2H), 1.32 – 1.18 (m, 3H), 1.13 (s, 3H), 1.08 (dd, *J* = 13.0, 4.1 Hz, 1H), 0.93 – 0.85 (m, 1H), 0.67 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 209.37, 176.1, 157.5, 149.73, 147.98, 122.88, 73.23, 63.63, 56.22, 54.17, 44.10, 38.75, 37.56, 35.97, 35.91, 33.51, 33.47, 32.36, 31.47, 24.40, 22.85, 21.19, 18.95, 13.38. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₂₆H₃₆NO₂: 394.2746; found: 394.2741.



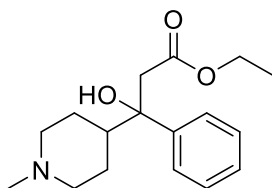
4-(3,5-difluoropyridin-4-yl)-4-phenylbutan-2-one (3ax)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3ax** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow liquid (69%, 36.0 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.27 (s, 2H), 7.35 – 7.30 (m, 4H), 7.25 (ddd, *J* = 7.2, 3.7, 2.2 Hz, 1H), 4.98 (dd, *J* = 8.9, 6.4 Hz, 1H), 3.52 (dd, *J* = 18.2, 8.9 Hz, 1H), 3.33 (ddt, *J* = 18.1, 6.4, 1.5 Hz, 1H), 2.18 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 205.45, 157.5 (d, *J* = 260.6 Hz), 150.77, 140.20, 134.8 – 134.4 (m), 128.91, 127.56, 127.34, 46.65, 35.61, 30.00. ¹⁹F NMR (376 MHz, CDCl₃) δ -128.22. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₁₅H₁₄F₂NO: 262.1043; found: 262.1038.



4-(3-chloropyridin-4-yl)-4-phenylbutan-2-one (3ay)

Following the *general procedure D*, when the reaction was finished after 4 h, the product **3ay** was isolated by chromatography on silica gel (PE/EA = 1/1, eluent) as a yellow oil (62%, 32.1 mg). ¹H NMR (400 MHz, CDCl₃) δ 8.59 – 8.50 (m, 1H), 8.42 (t, *J* = 4.2 Hz, 1H), 7.38 – 7.10 (m, 6H), 5.04 (dq, *J* = 8.2, 3.9, 3.4 Hz, 1H), 3.20 (dq, *J* = 7.3, 3.7 Hz, 2H), 2.16 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 205.21, 149.89, 149.83, 147.92, 147.89, 140.29, 132.02, 128.85, 128.82, 128.02, 127.99, 127.23, 127.21, 122.82, 48.10, 48.08, 41.86, 41.84, 30.26, 30.24. HRMS (ESI): *m/z* [M + H]⁺ calcd for C₁₅H₁₅ClNO: 260.0842; found: 260.0834.



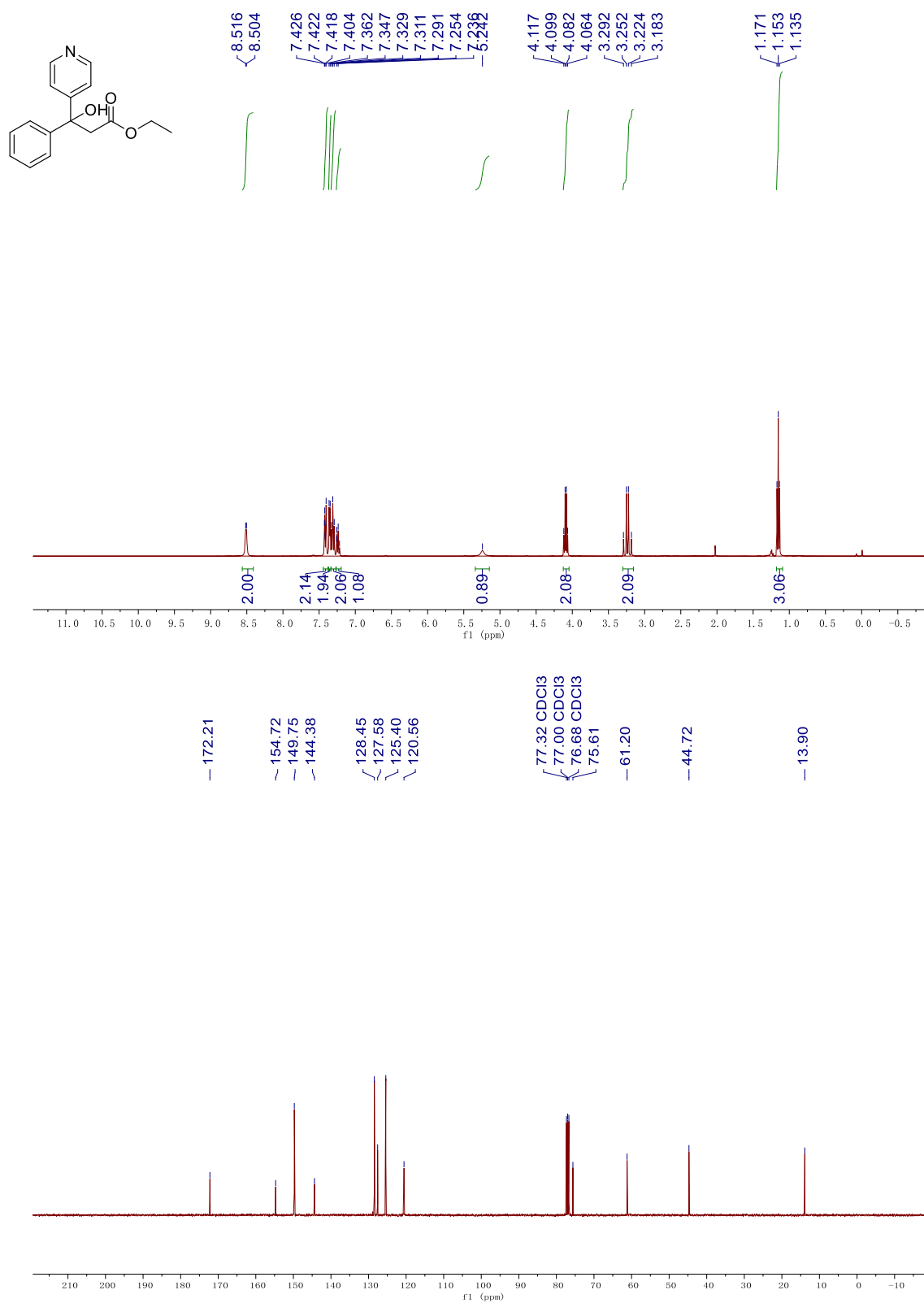
ethyl 3-hydroxy-3-(1-methylpiperidin-4-yl)-3-phenylpropanoate (4)

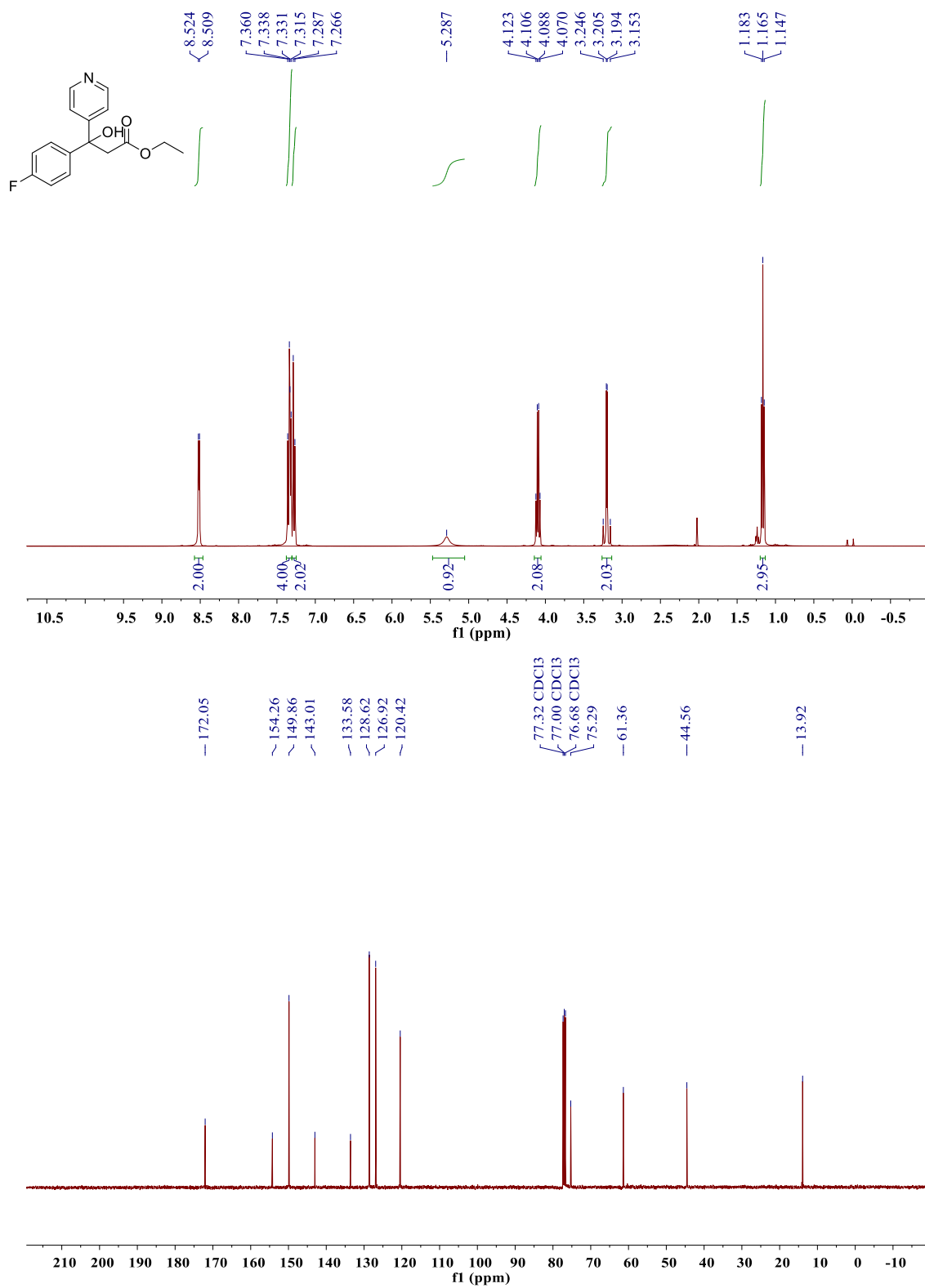
Following the *procedure E*, the product **4** was obtained as a yellow oil (60%, 175 mg). ¹H NMR (400 MHz, CDCl₃) δ 7.36 (d, *J* = 7.5 Hz, 2H), 7.28 (t, *J* = 7.6 Hz, 2H), 7.19 (t, *J* = 7.2 Hz, 1H), 4.36 (s, 1H), 3.96 (q, *J* = 7.1 Hz, 2H), 3.04 (d, *J* = 15.7 Hz, 1H), 2.89 – 2.77 (m, 3H), 2.19 (s, 3H), 1.84 – 1.75 (m, 2H), 1.65 – 1.58 (m, 1H), 1.55 – 1.47 (m, 2H), 1.41 (ddt, *J* = 12.0, 8.8, 4.2 Hz, 2H), 1.03 (t, *J* = 7.1 Hz, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 173.08, 144.39, 127.73, 126.69, 125.67, 76.48, 60.55, 55.95, 55.91, 46.55, 46.04, 41.81, 26.34, 26.15, 13.78.

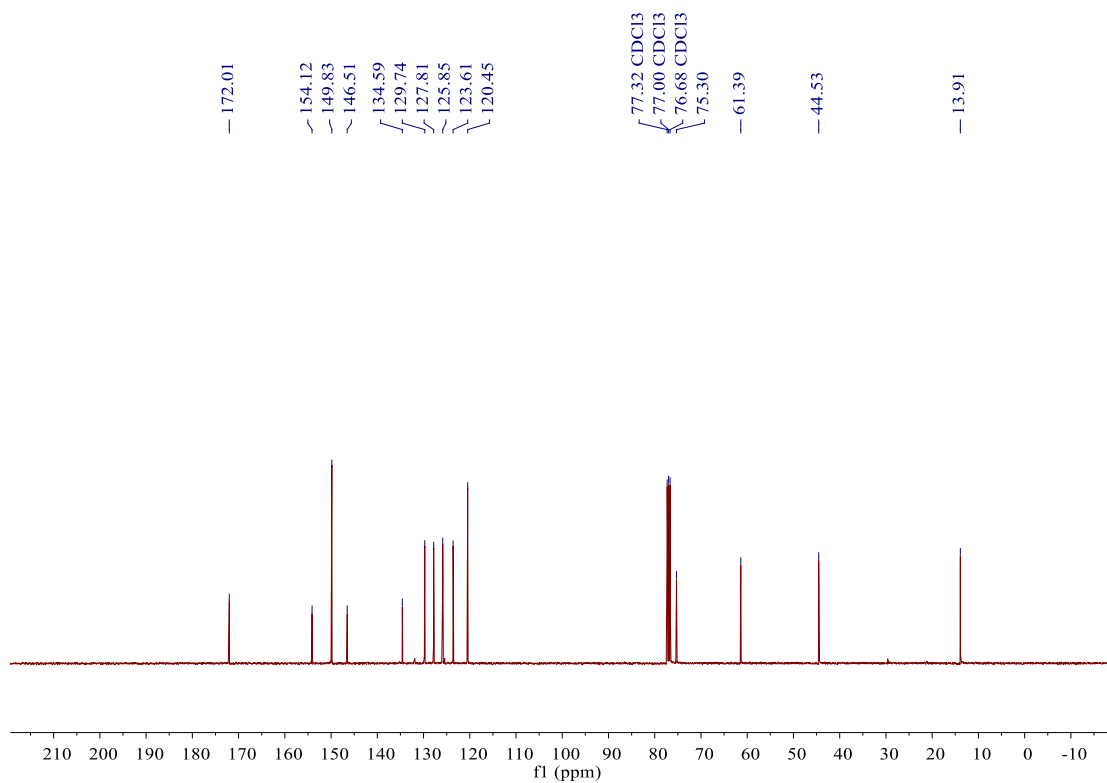
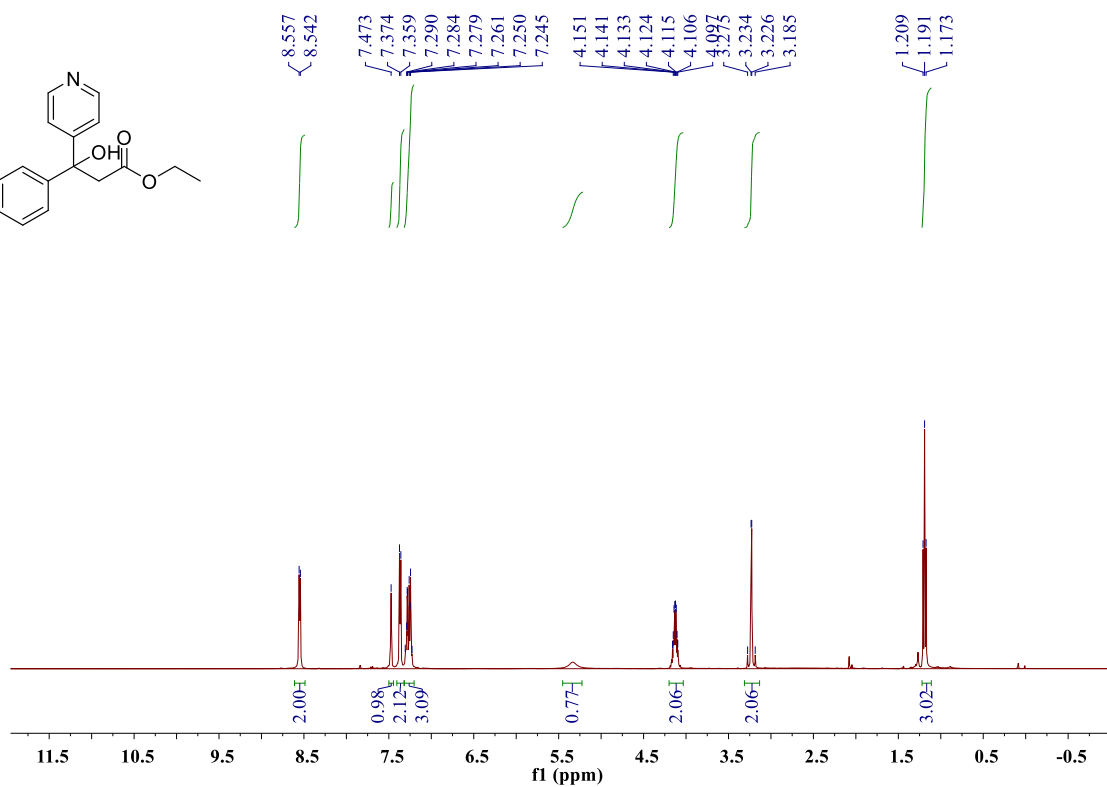
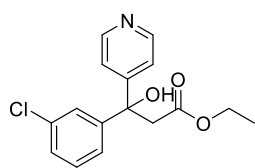
11. Reference

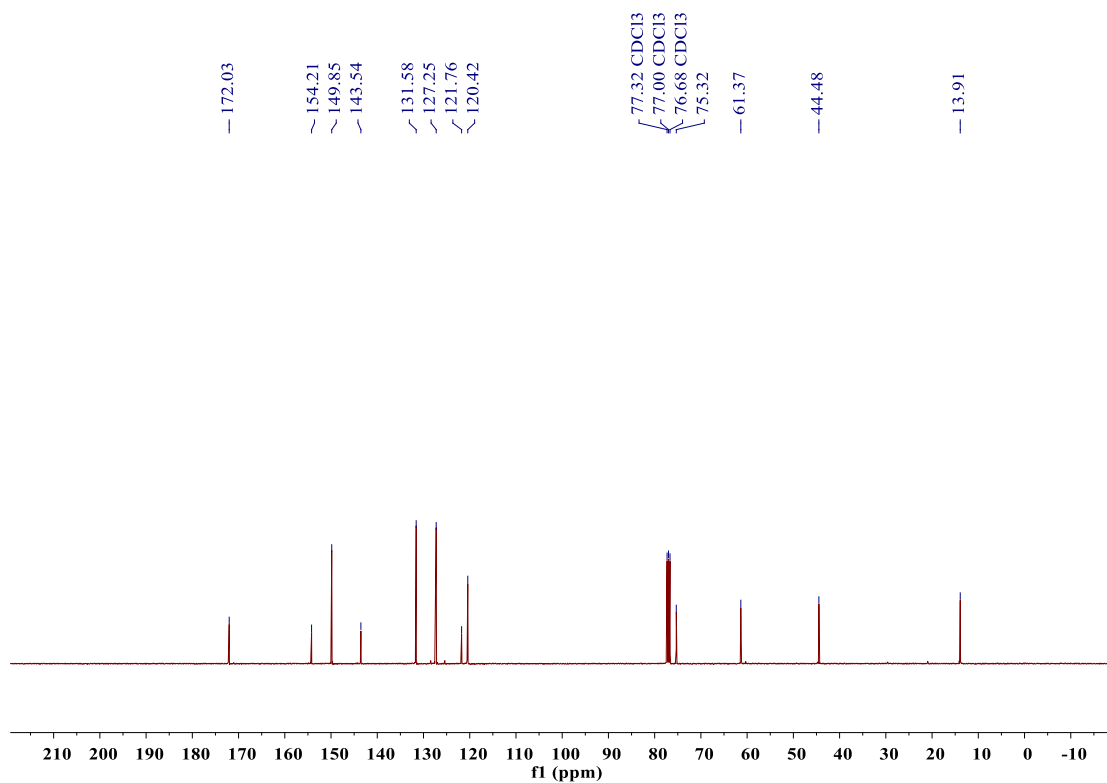
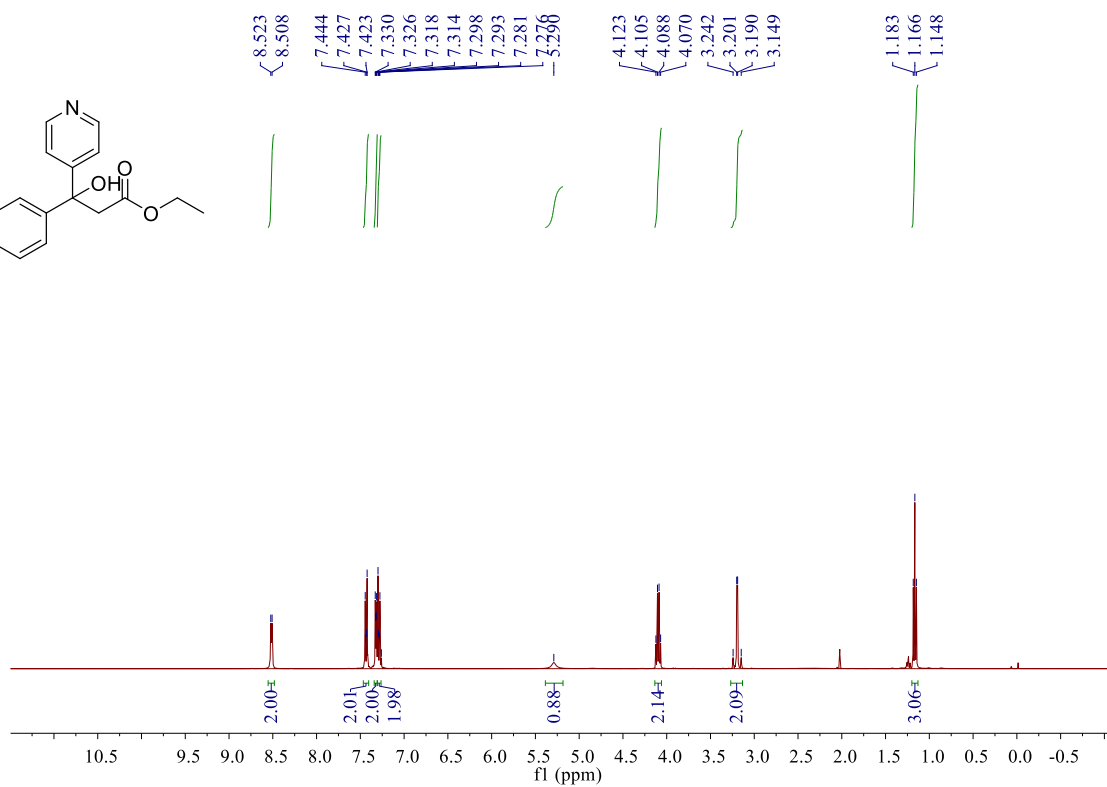
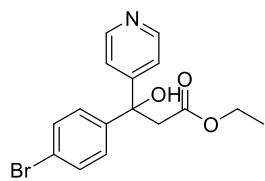
- [1] J. L. Tu, J. L. Liu, W. Tang, M. Su, F. Liu, *Org. Lett.*, **2020**, 22, 1222-1226.
- [2] V. G. Lisnyak, T. Lynch-Colameta, S. A. Snyder, *Angew. Chem. Int. Ed.*, **2018**, 57, 15162-15166.
- [3] C. Allais, O. Baslé, J. M. Grassot, M. Fontaine, S. Anguille, J. Rodriguez, T. Constantieux, *Adv. Synth. Catal.*, **2012**, 354, 2084–2088.
- [4] F. J. Villani, M. S. King, F. J. Villani, *J. Med. Chem.*, **1963**, 6, 142-144.
- [5] J. X. Shen, N. N. Li, Y. J. Yu, C. H. Ma, *Org. Lett.*, **2019**, 21, 7179-7183.
- [6] L. A. Nickerson, V. Huynh, E. I. Balmond, S. P. Cramer, J. T. Shaw, *J. Org. Chem.*, **2016**, 81, 11404–11408.
- [7] F. Chen, Y. Zhang, L. Yu, S. Zhu, *Angew. Chem. Int. Ed.*, **2017**, 56, 2022–2025.

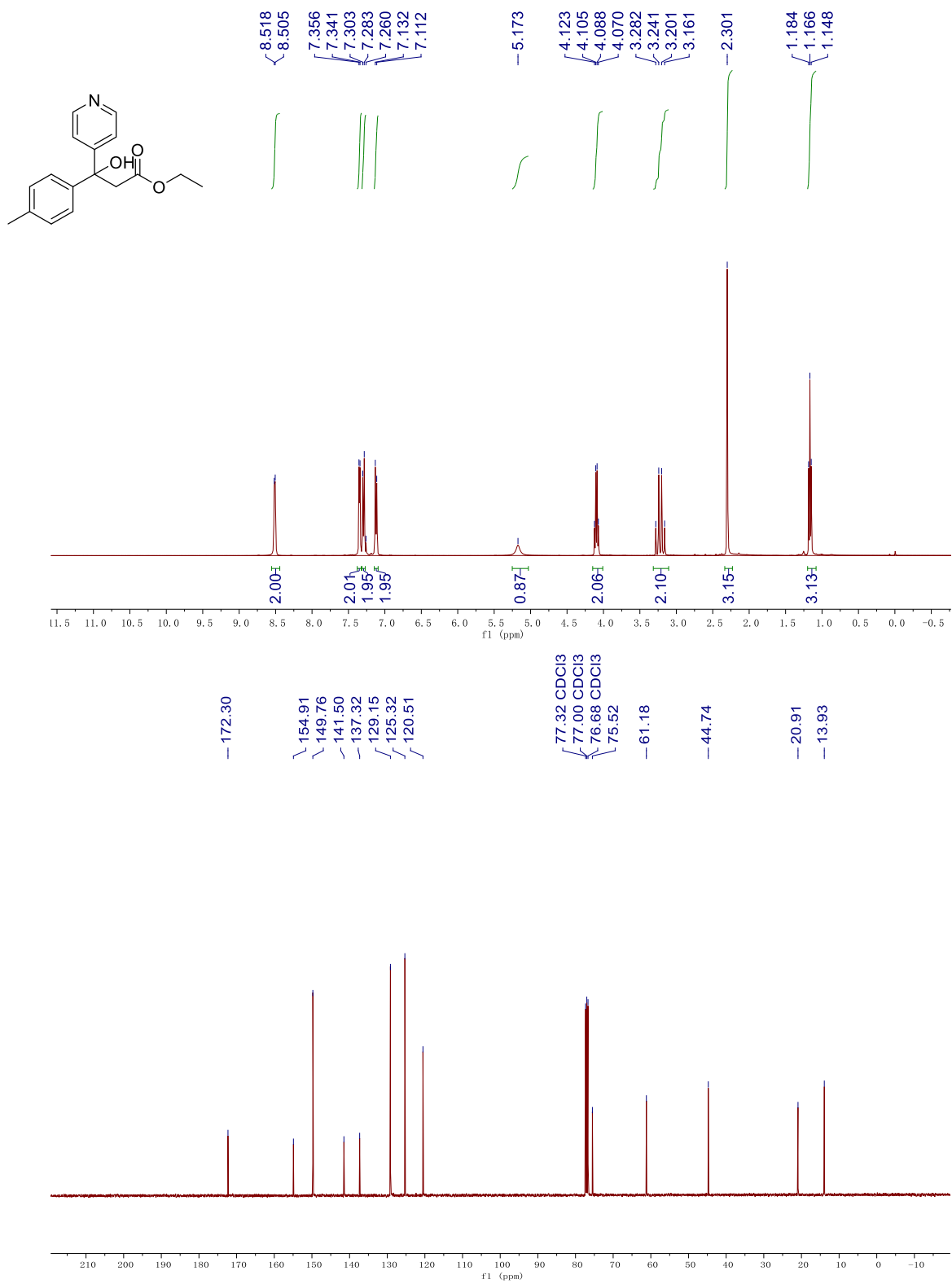
12. Copies of NMR spectra for the products

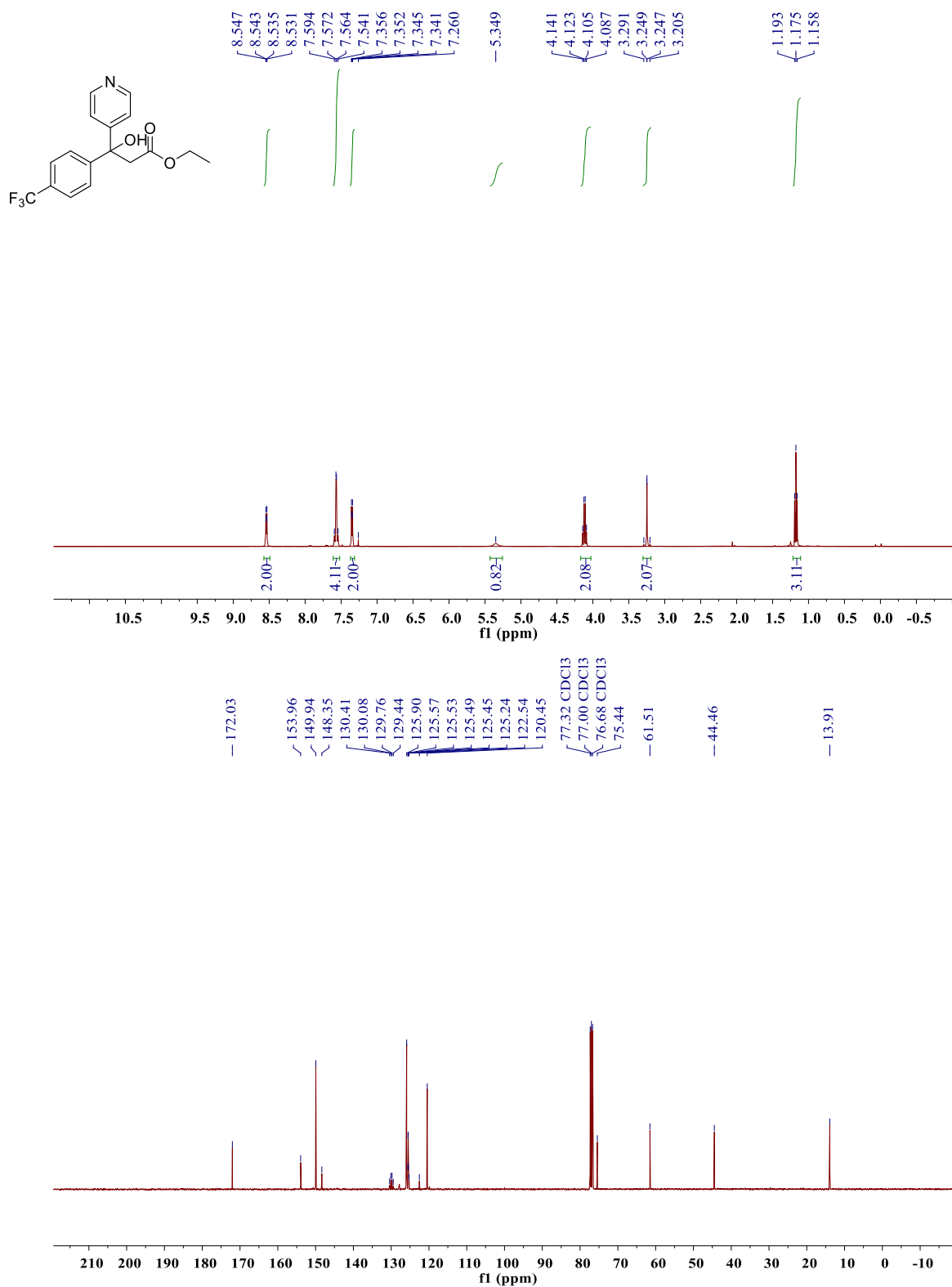


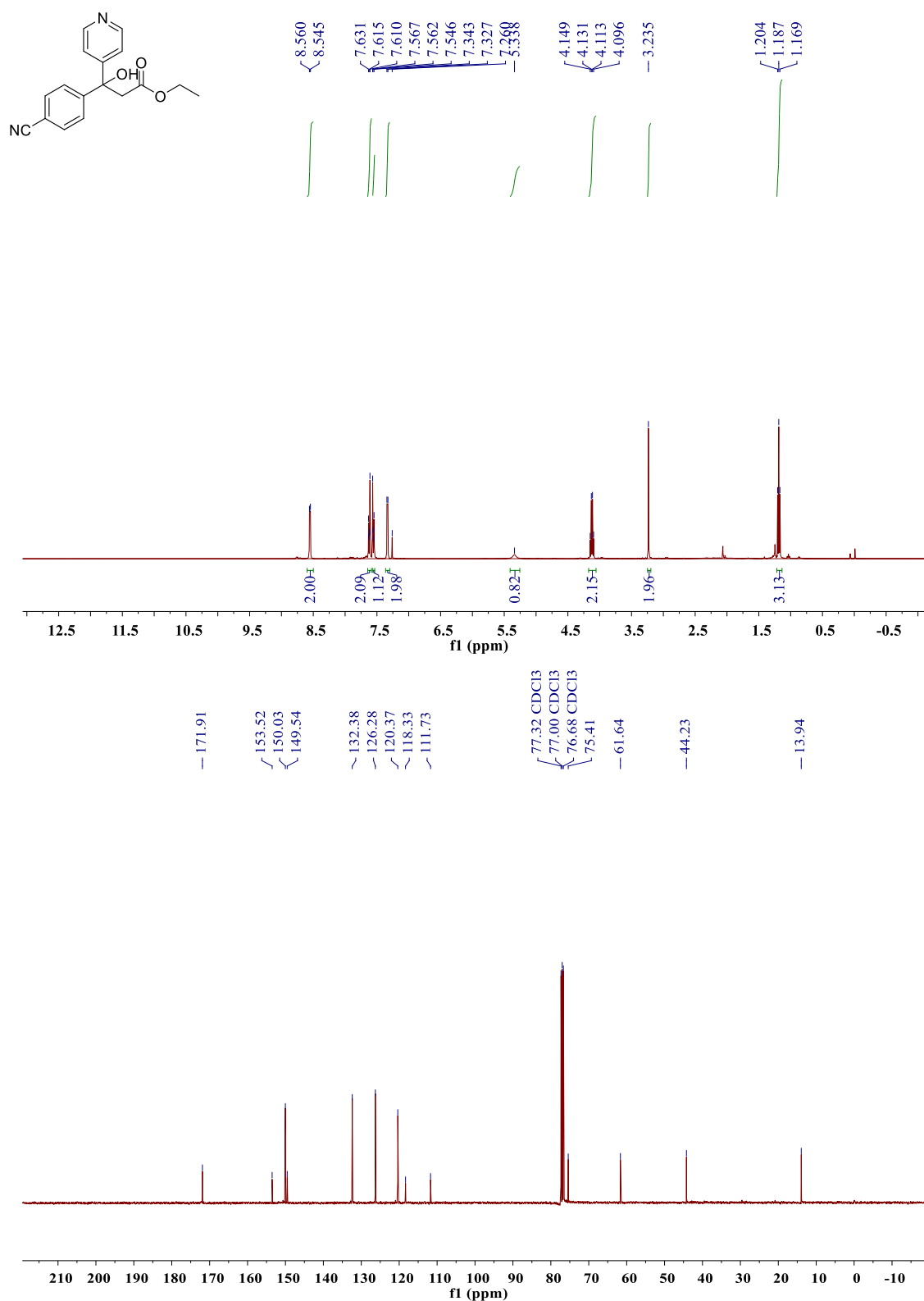


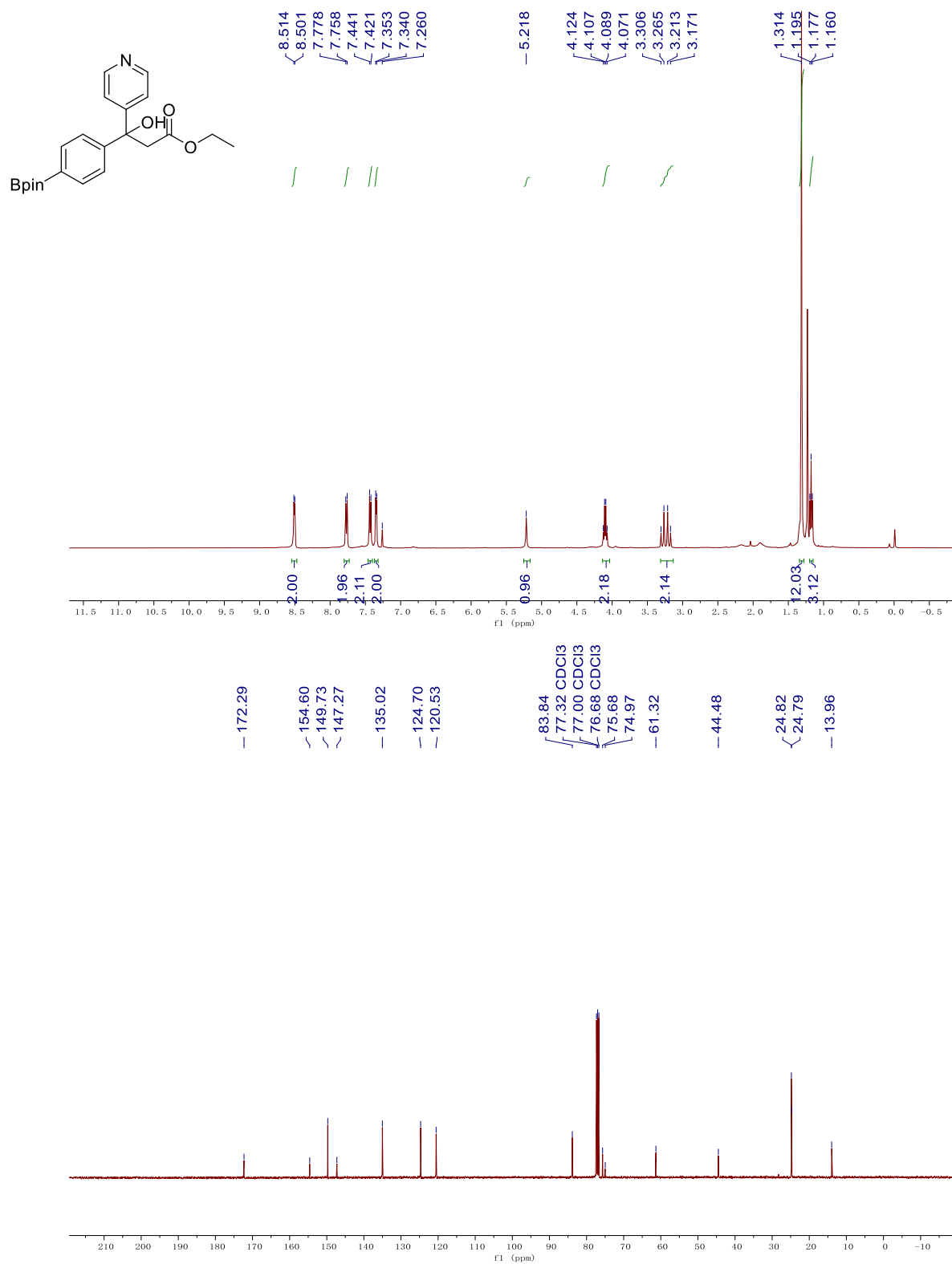


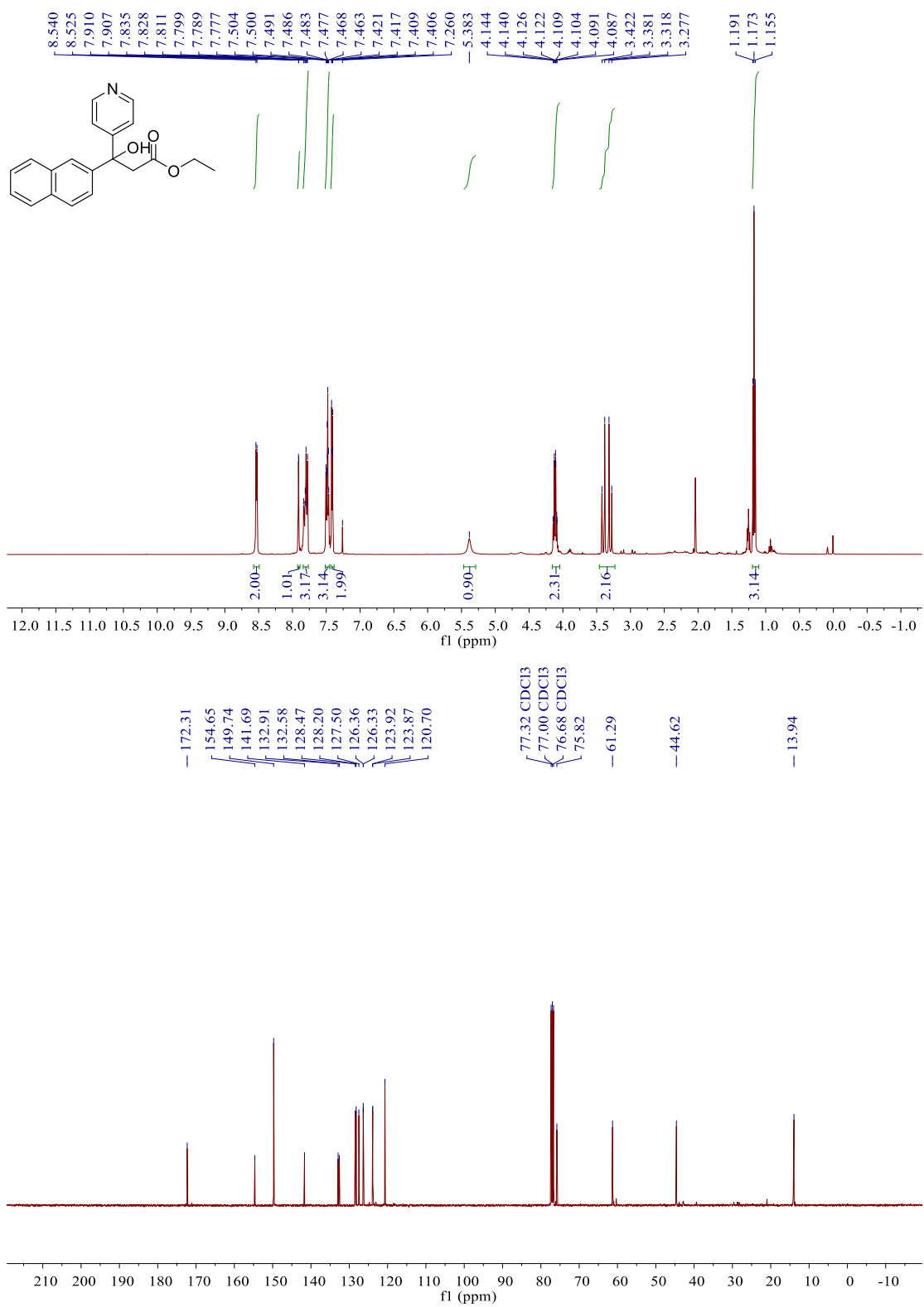


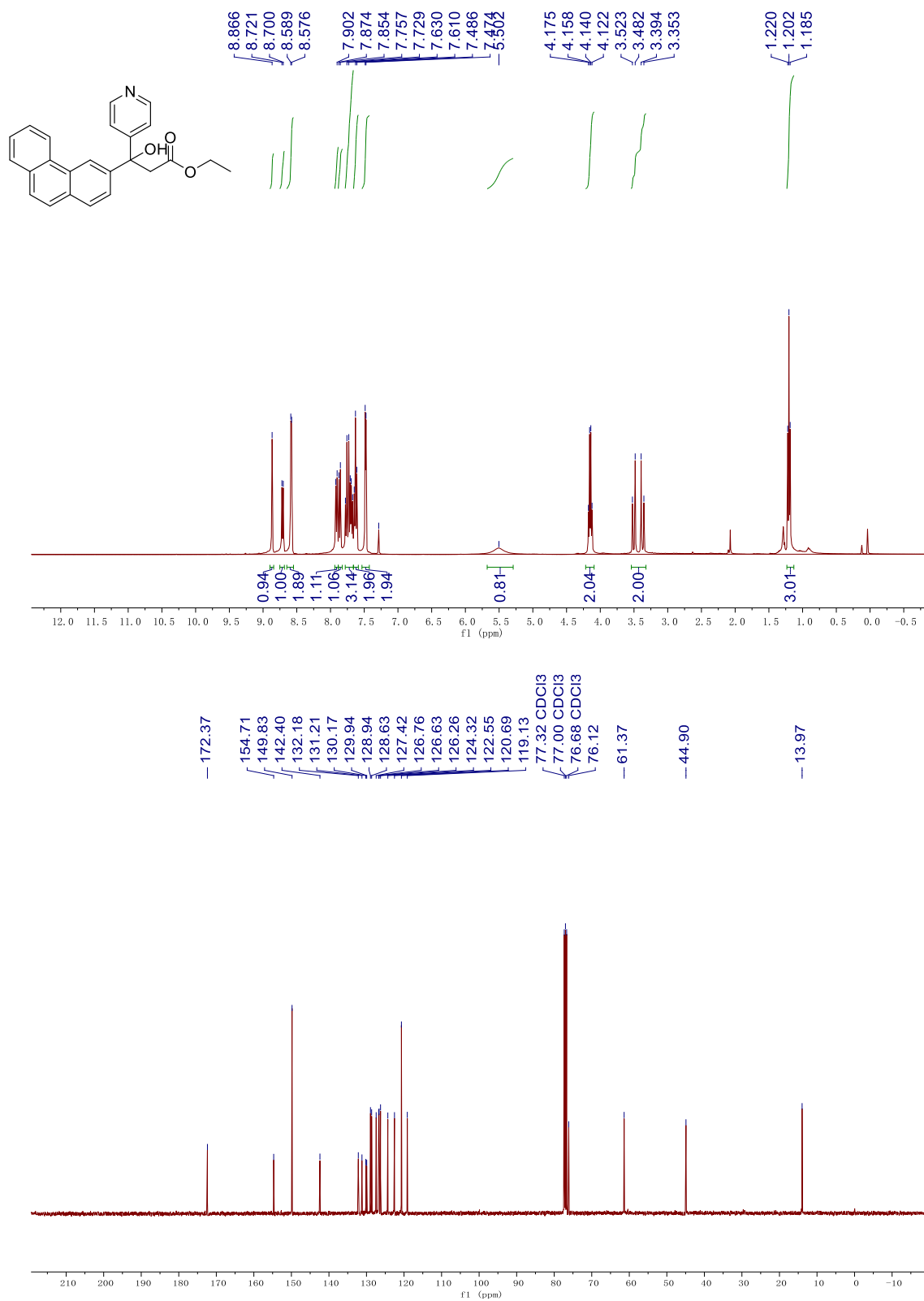


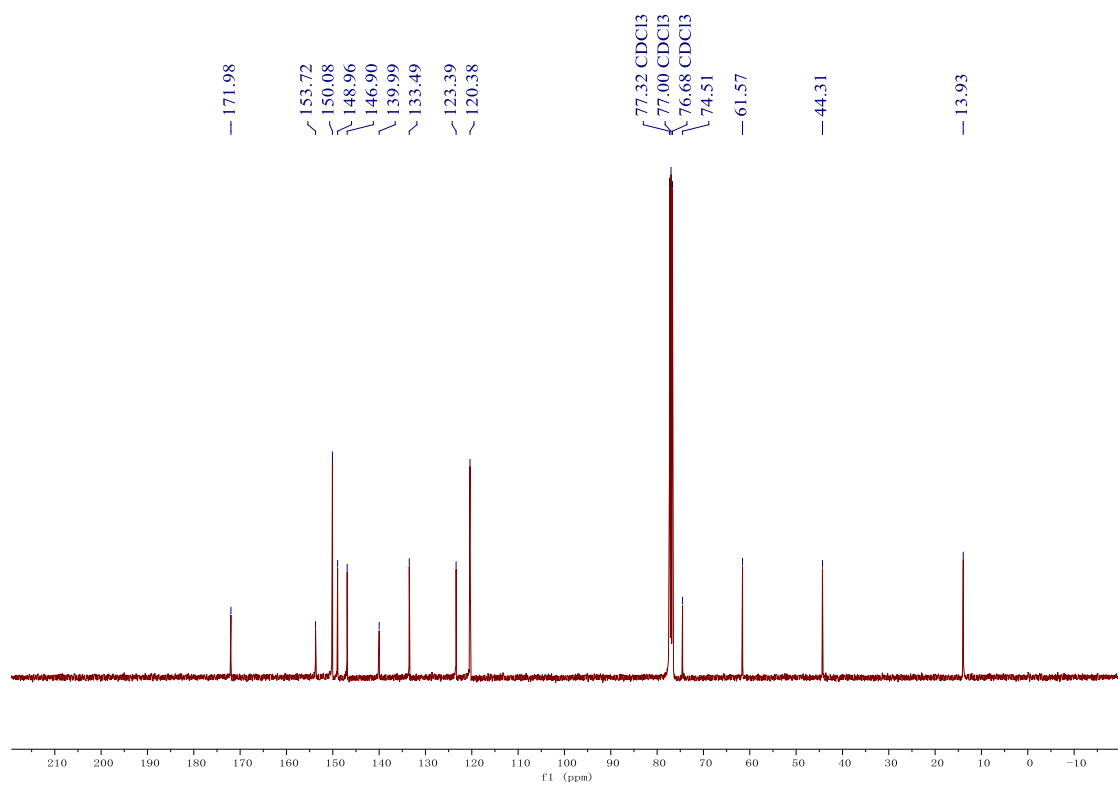
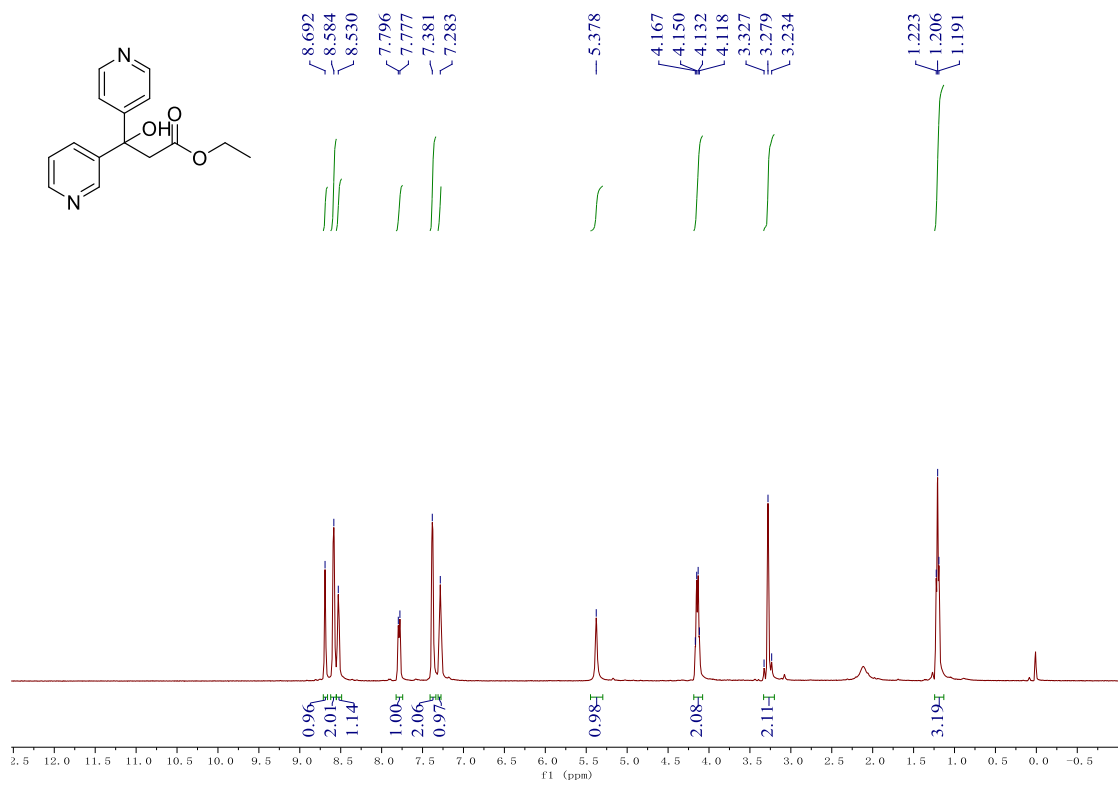


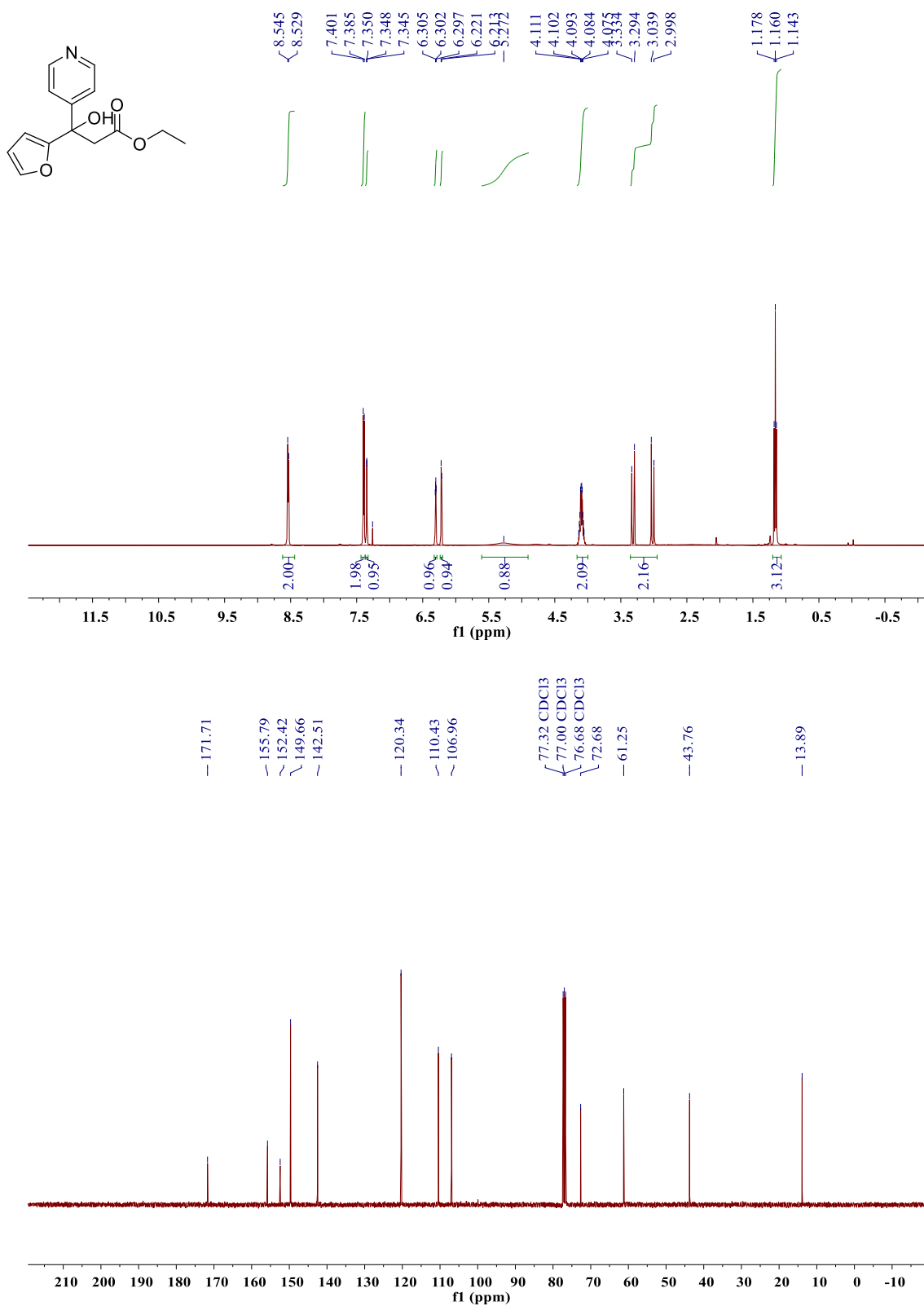


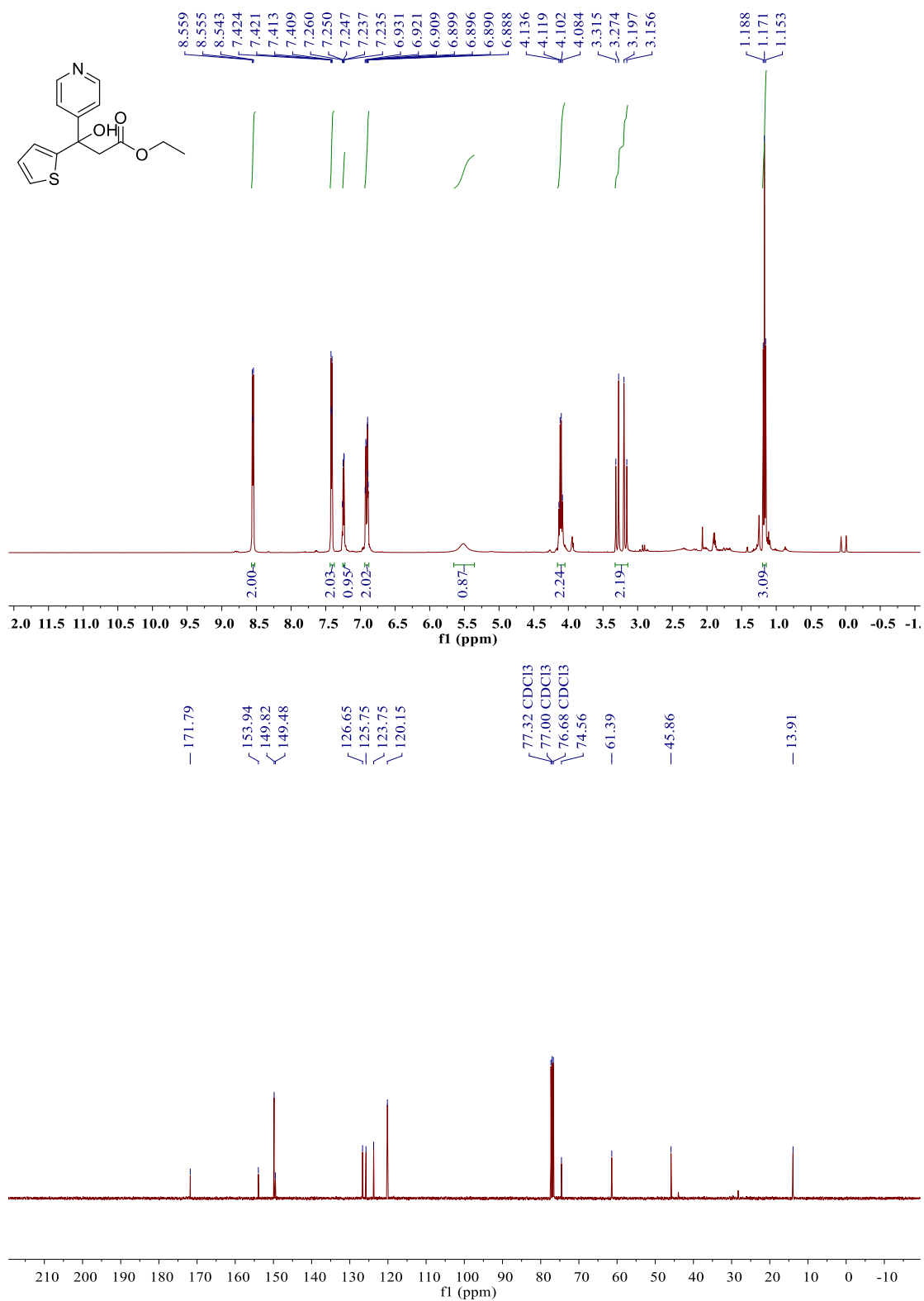


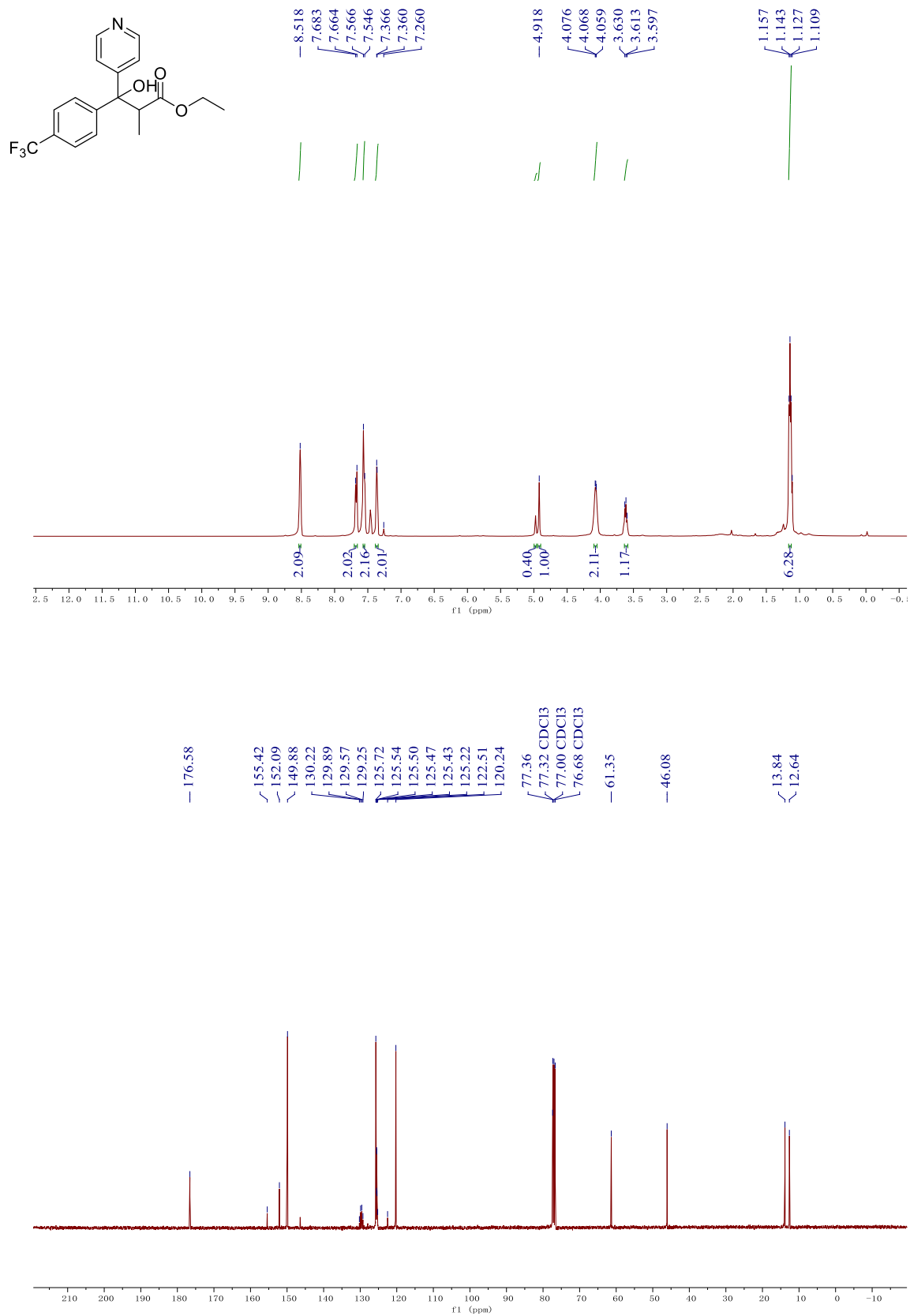


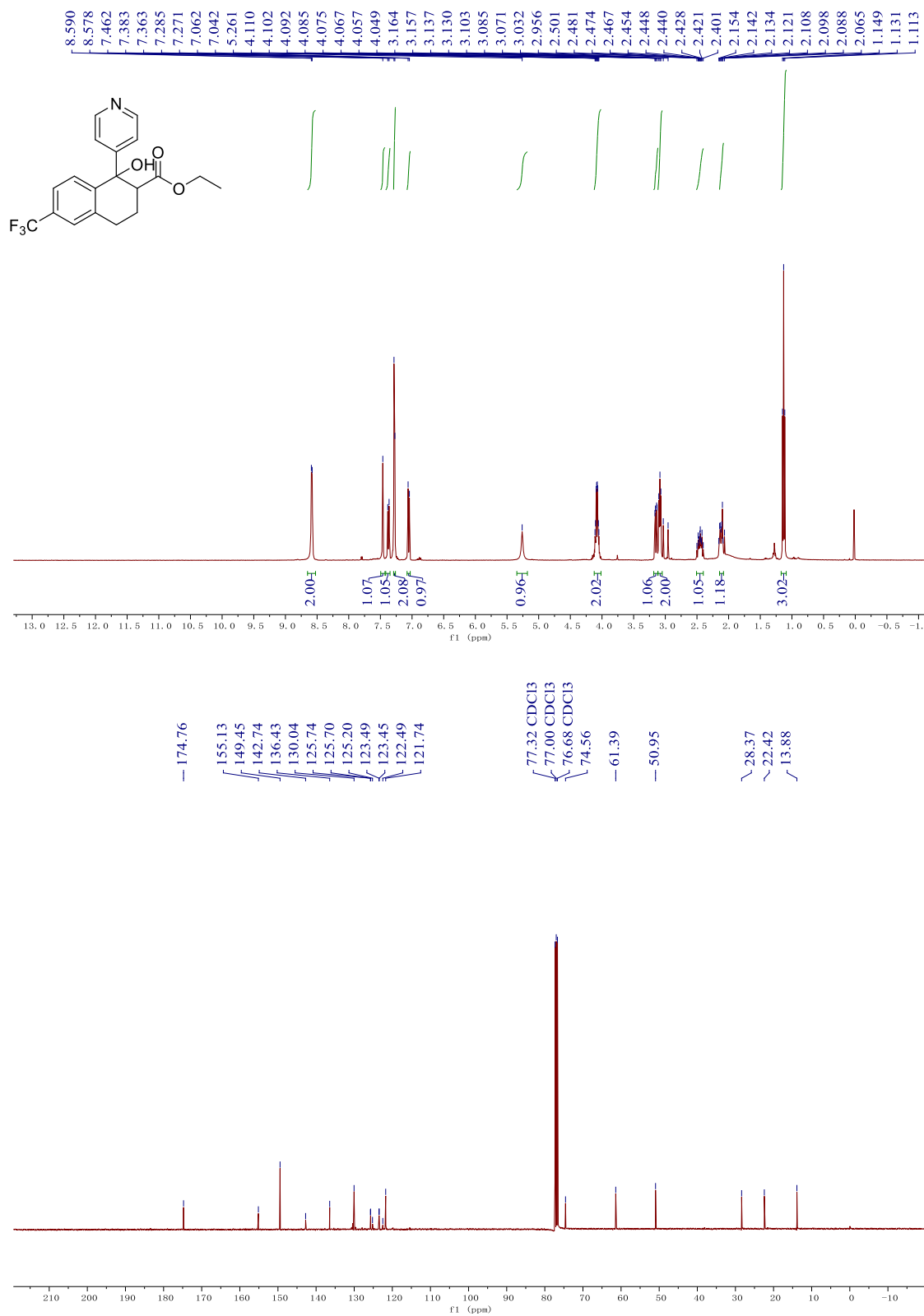


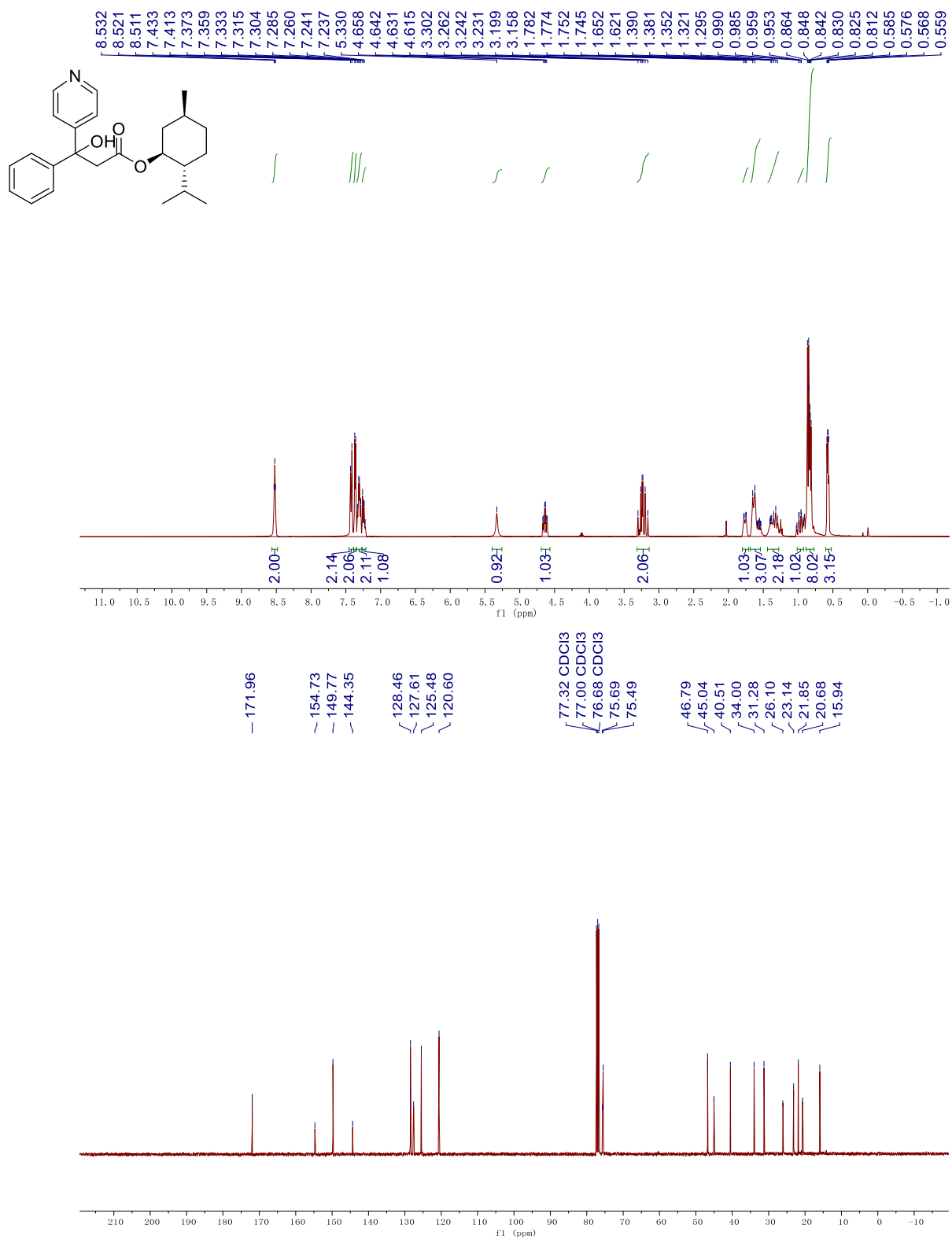


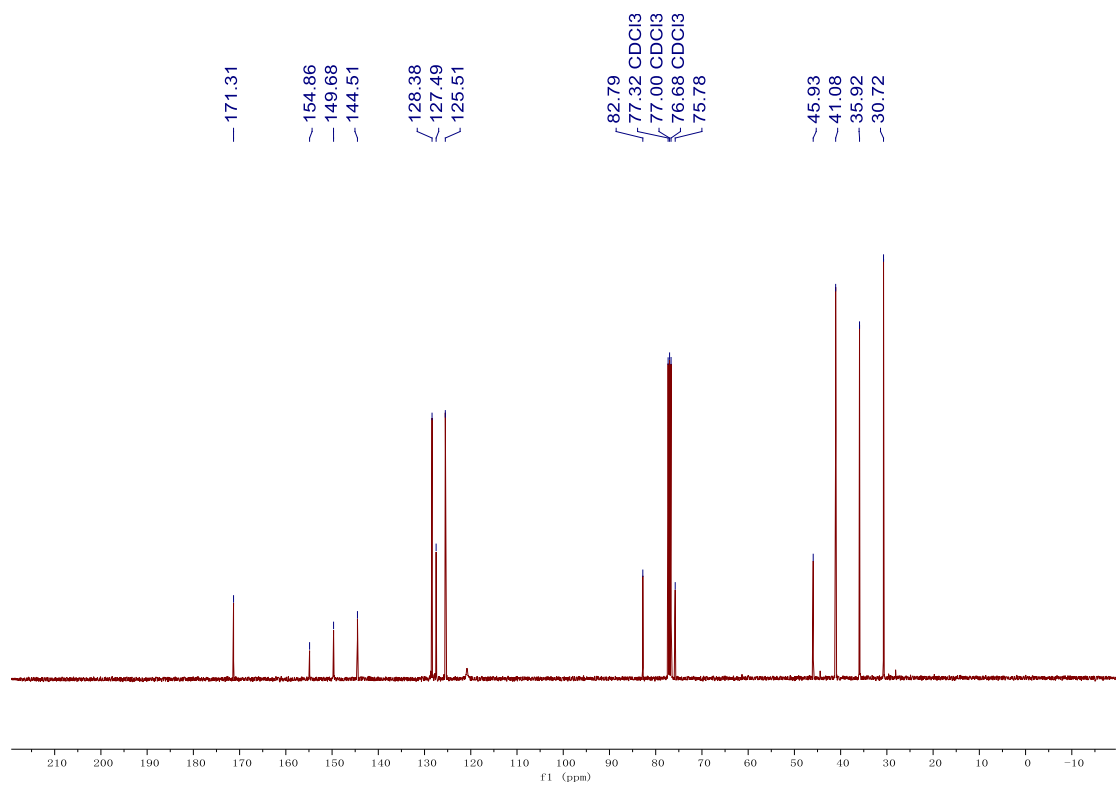
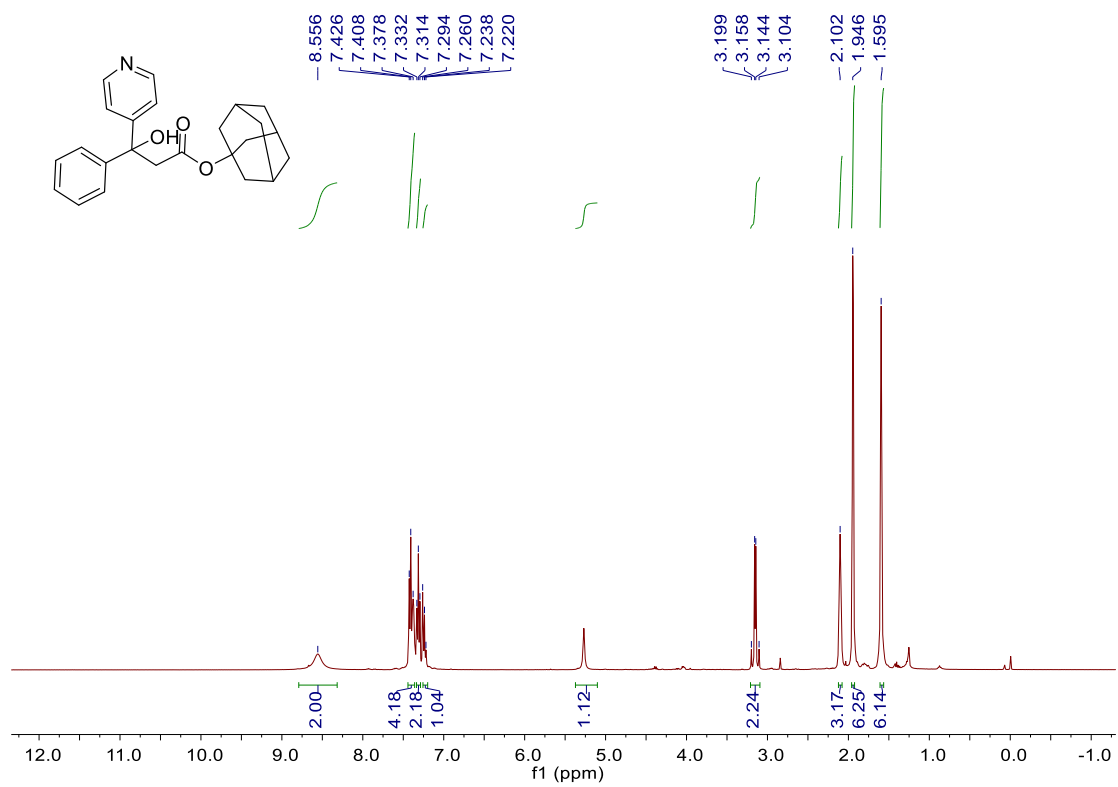


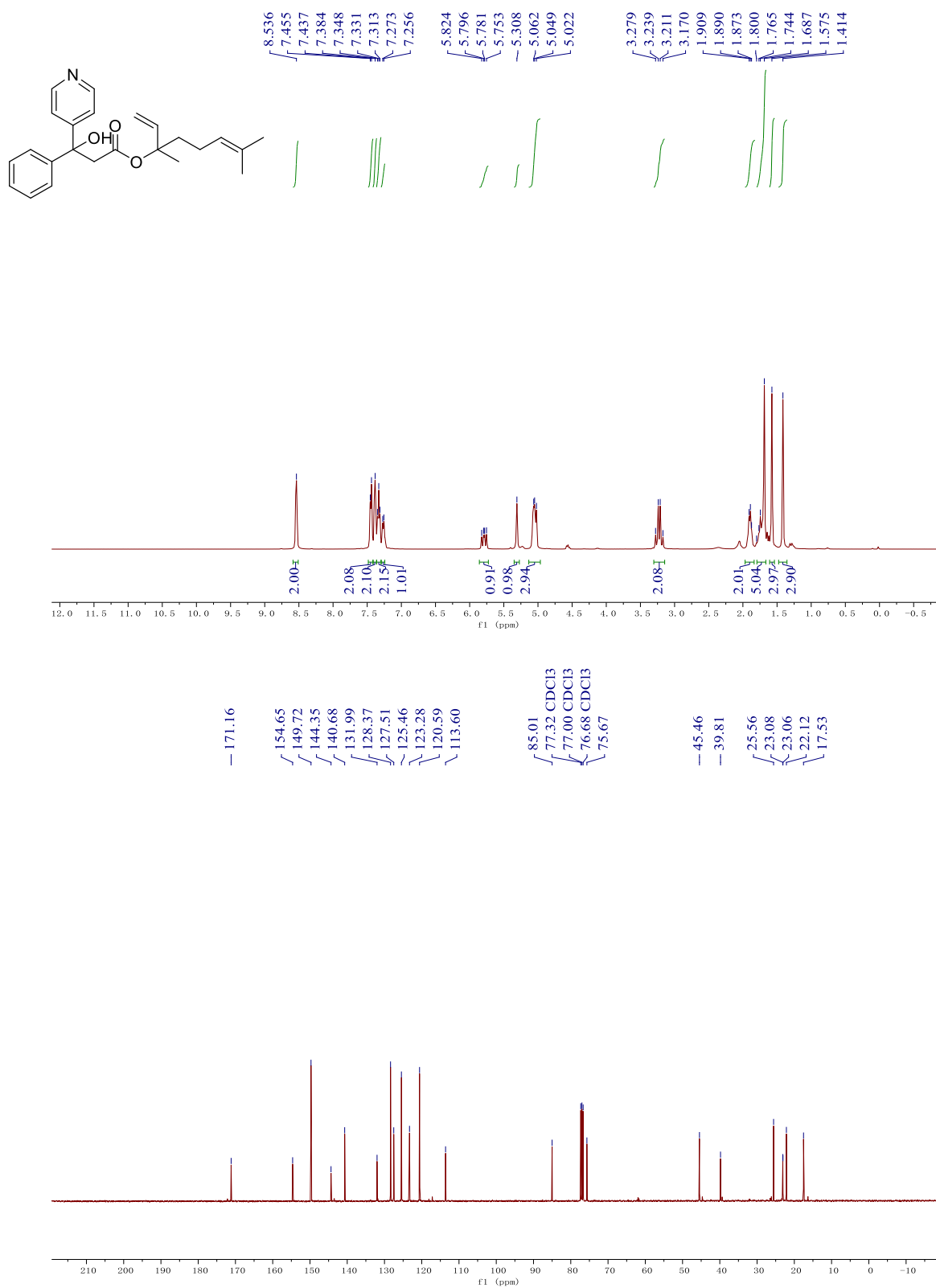


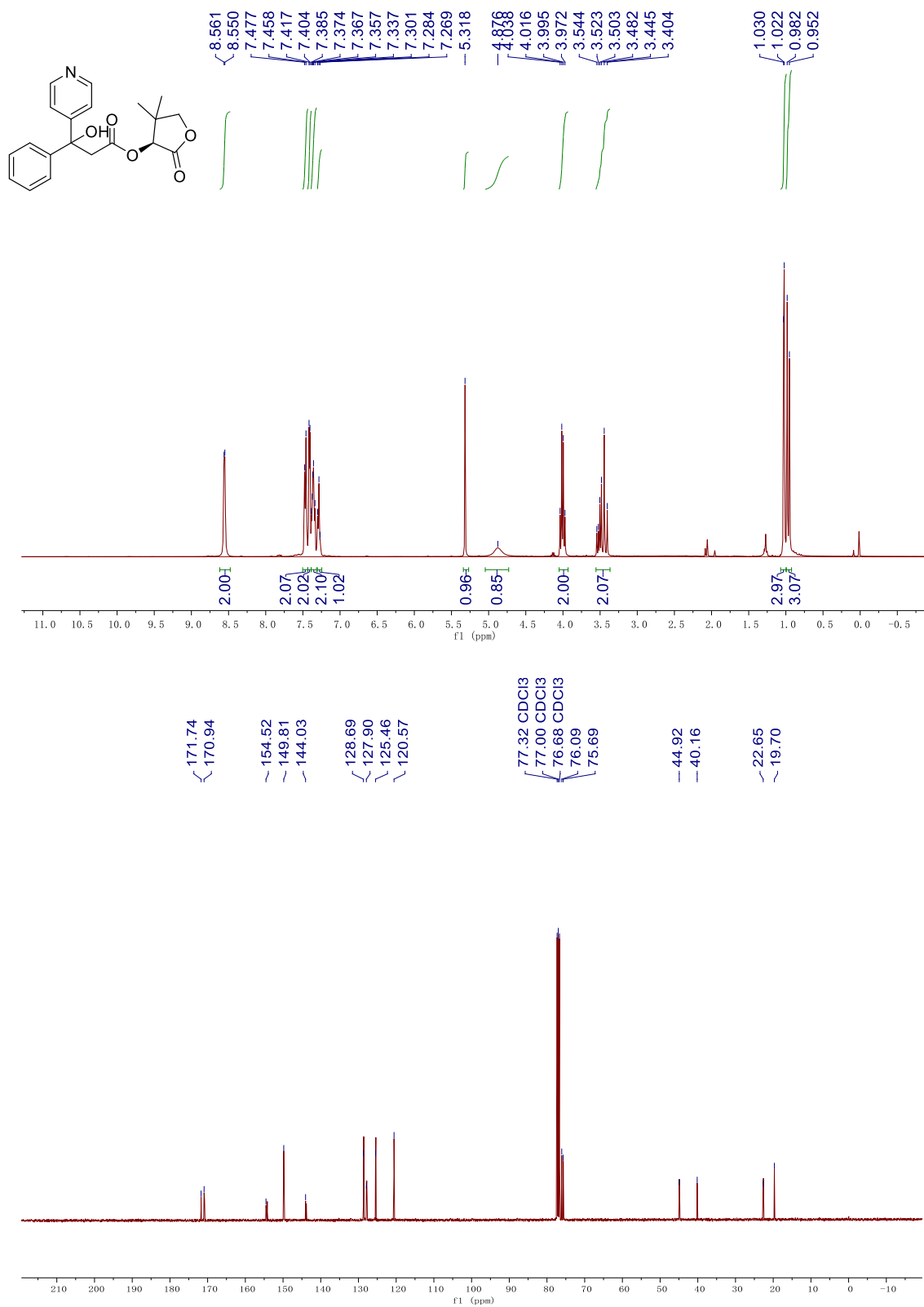


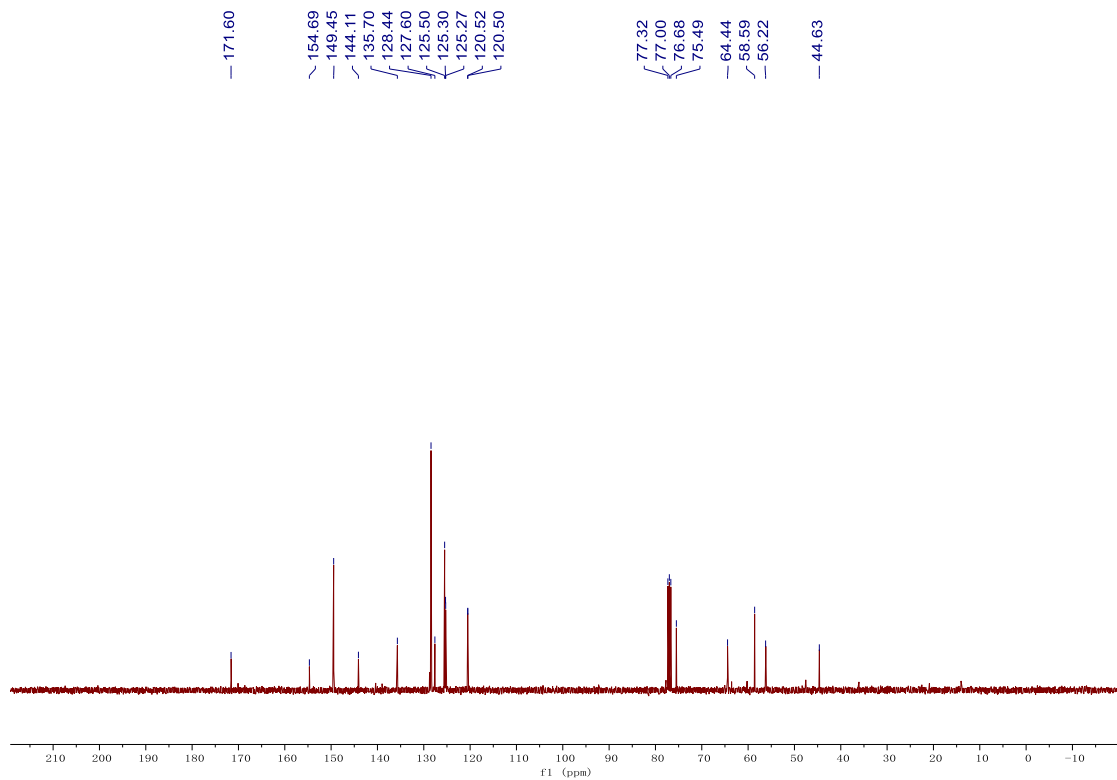
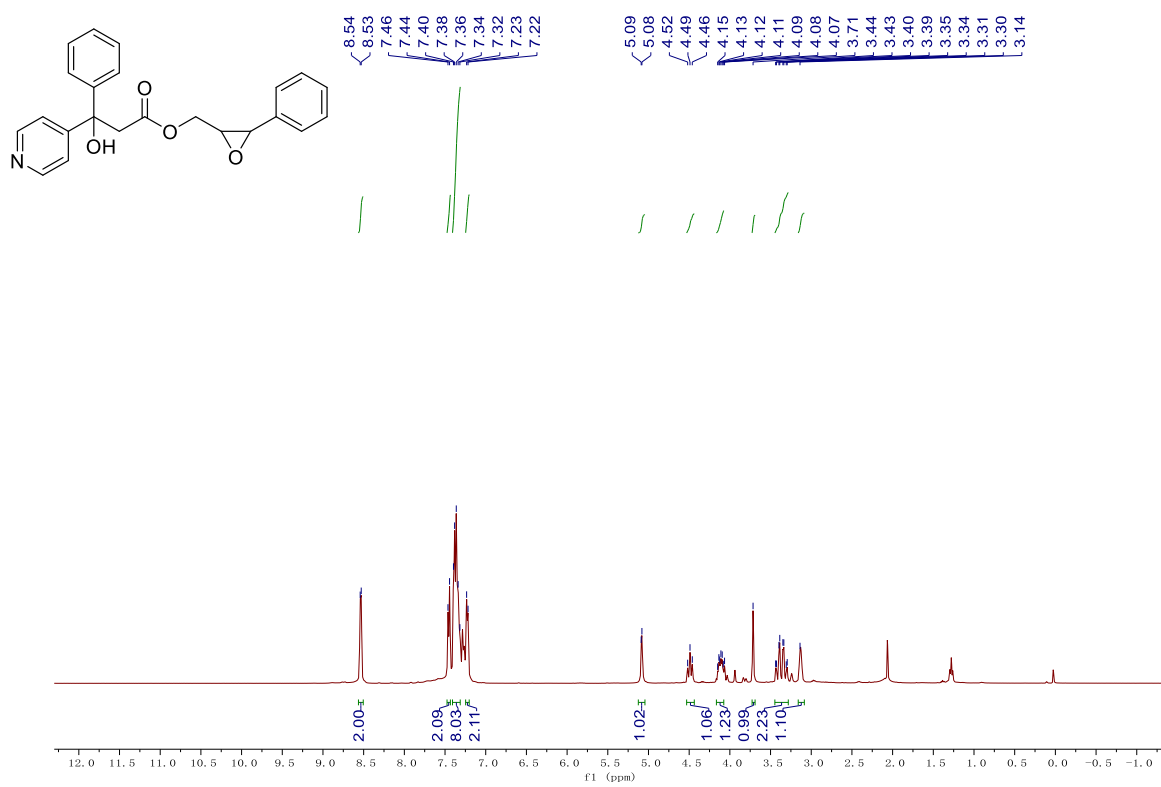


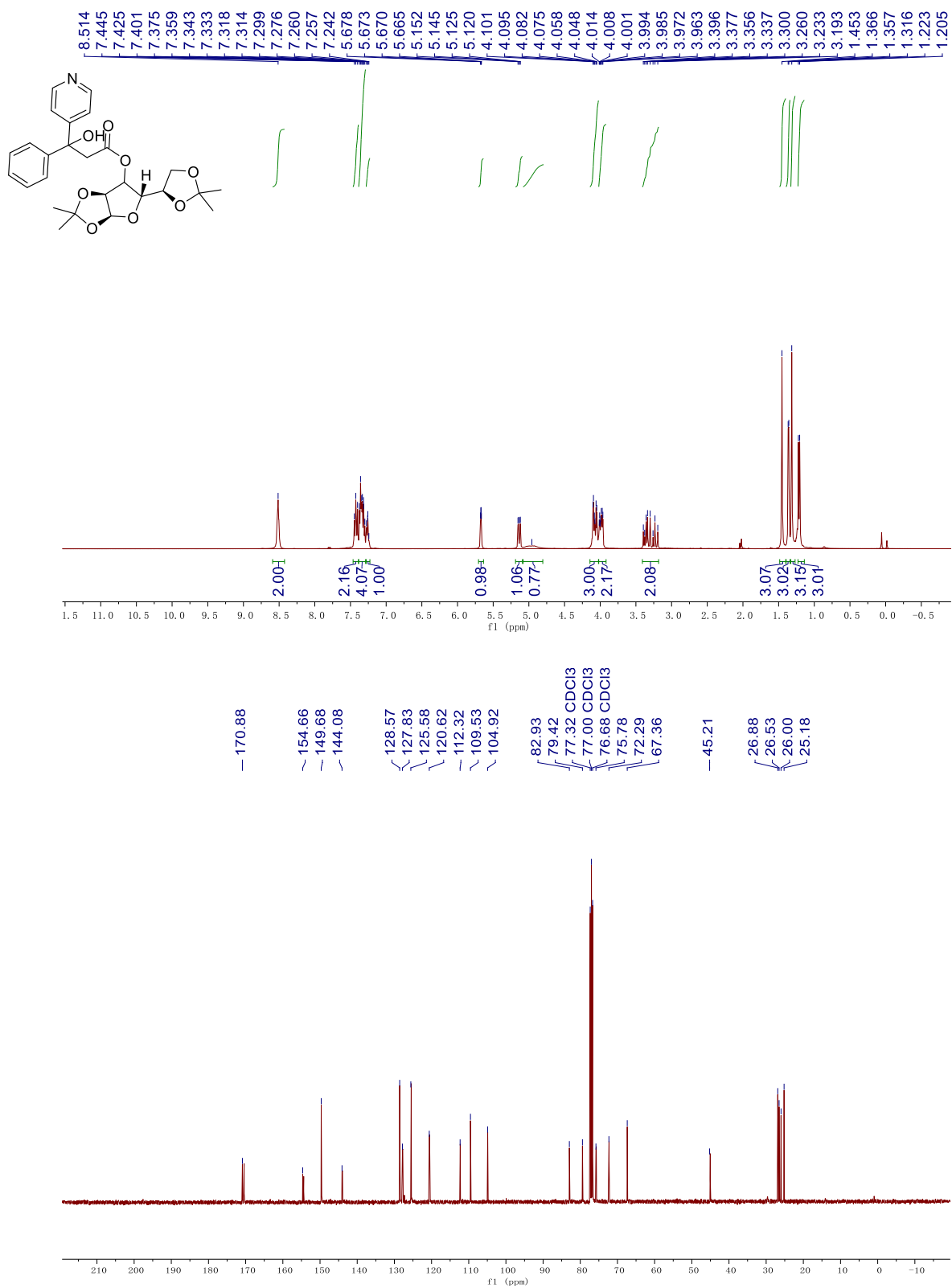


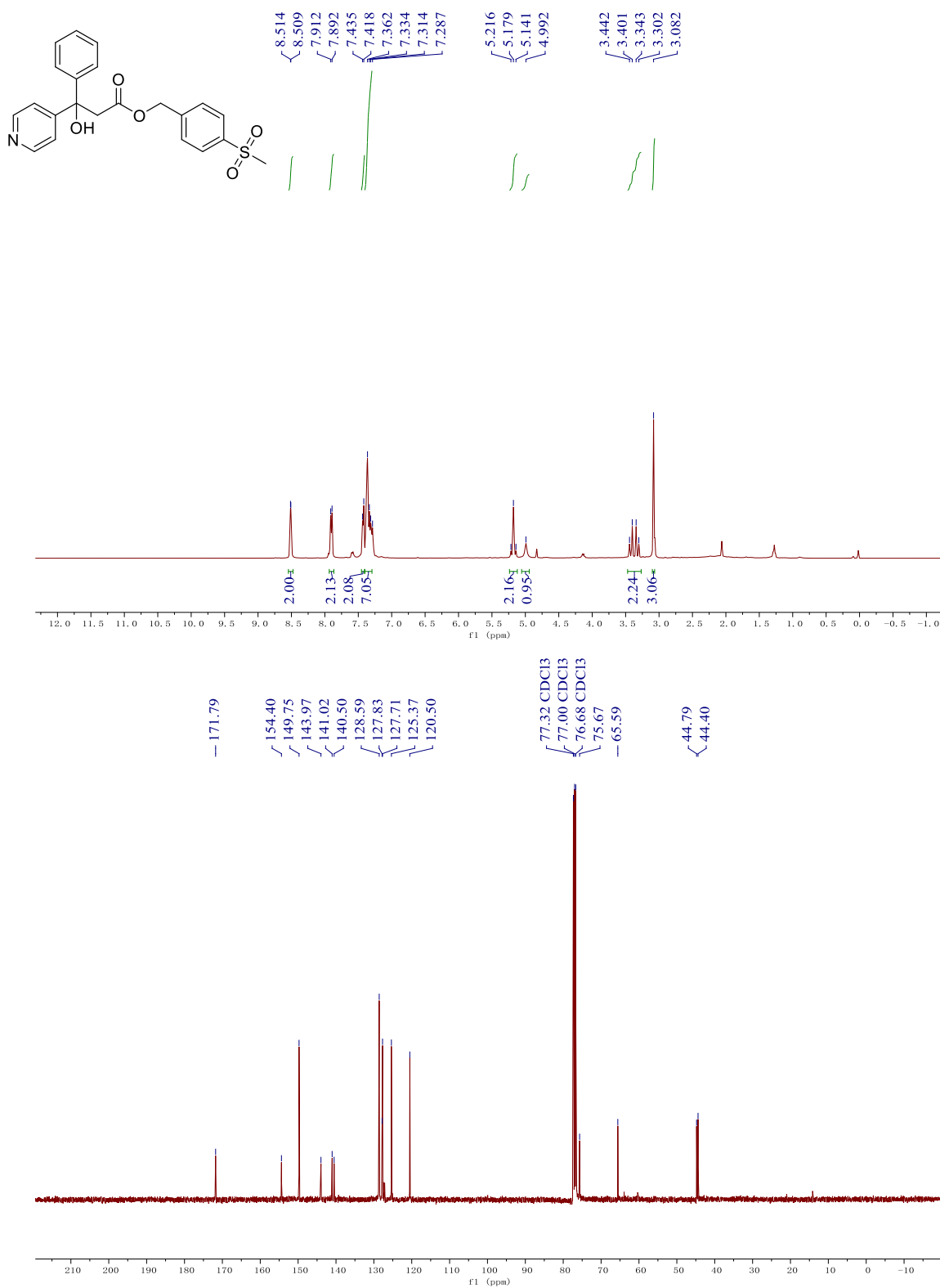


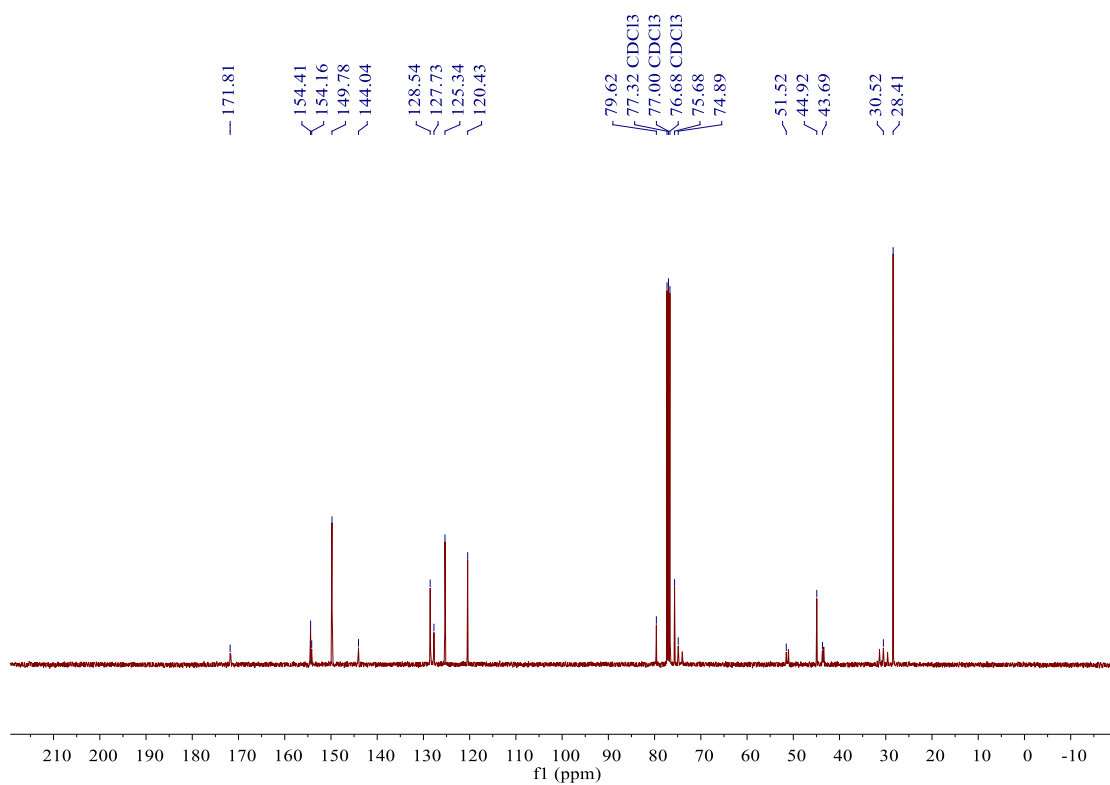
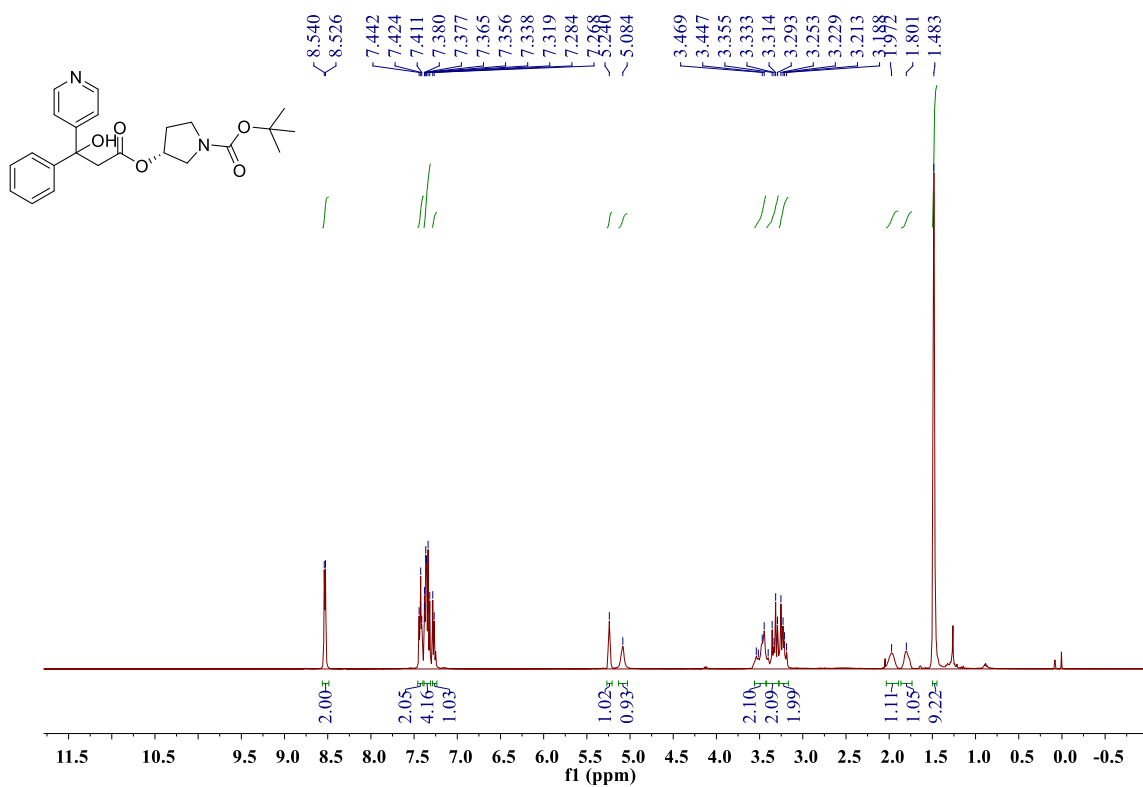


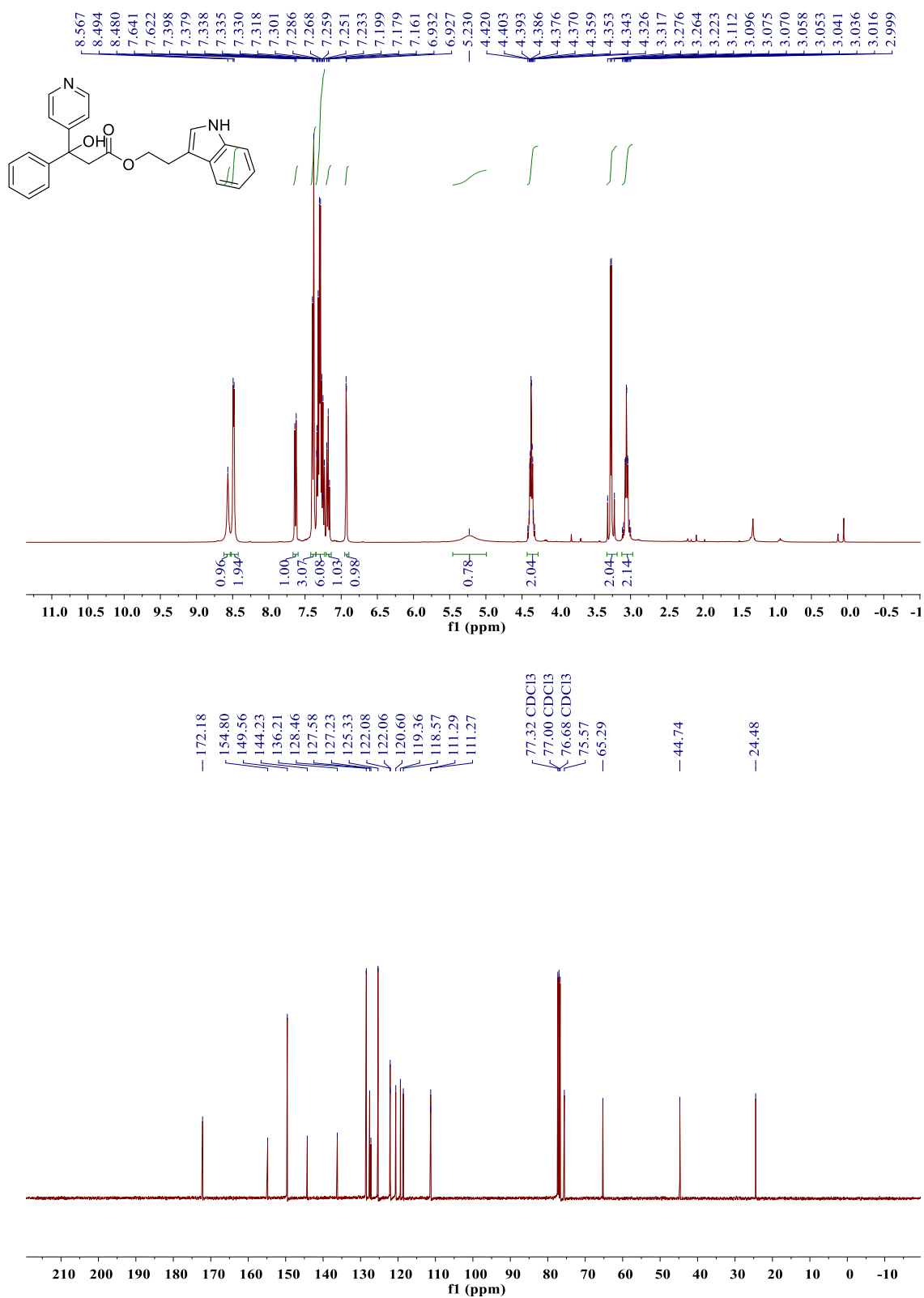


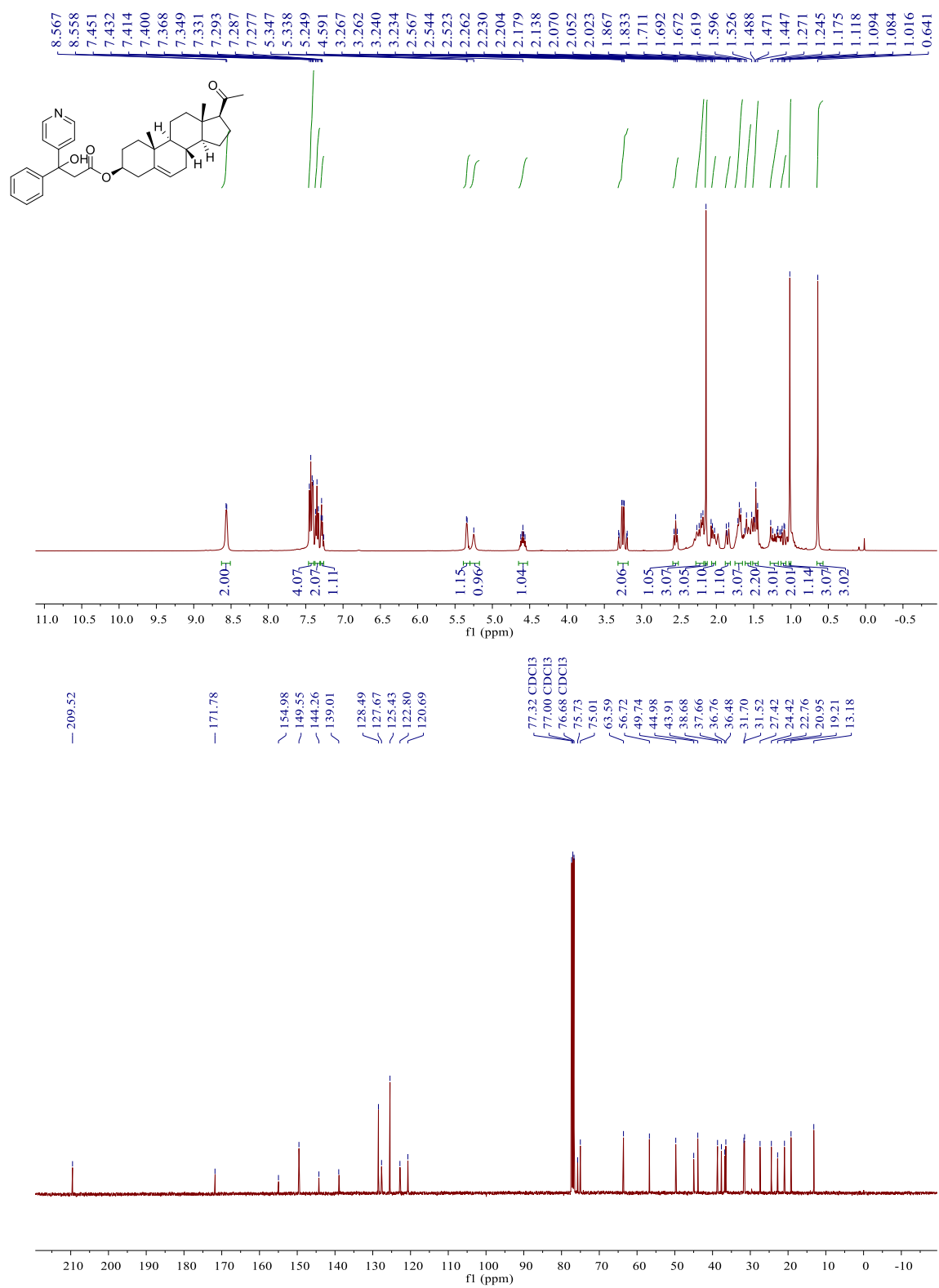


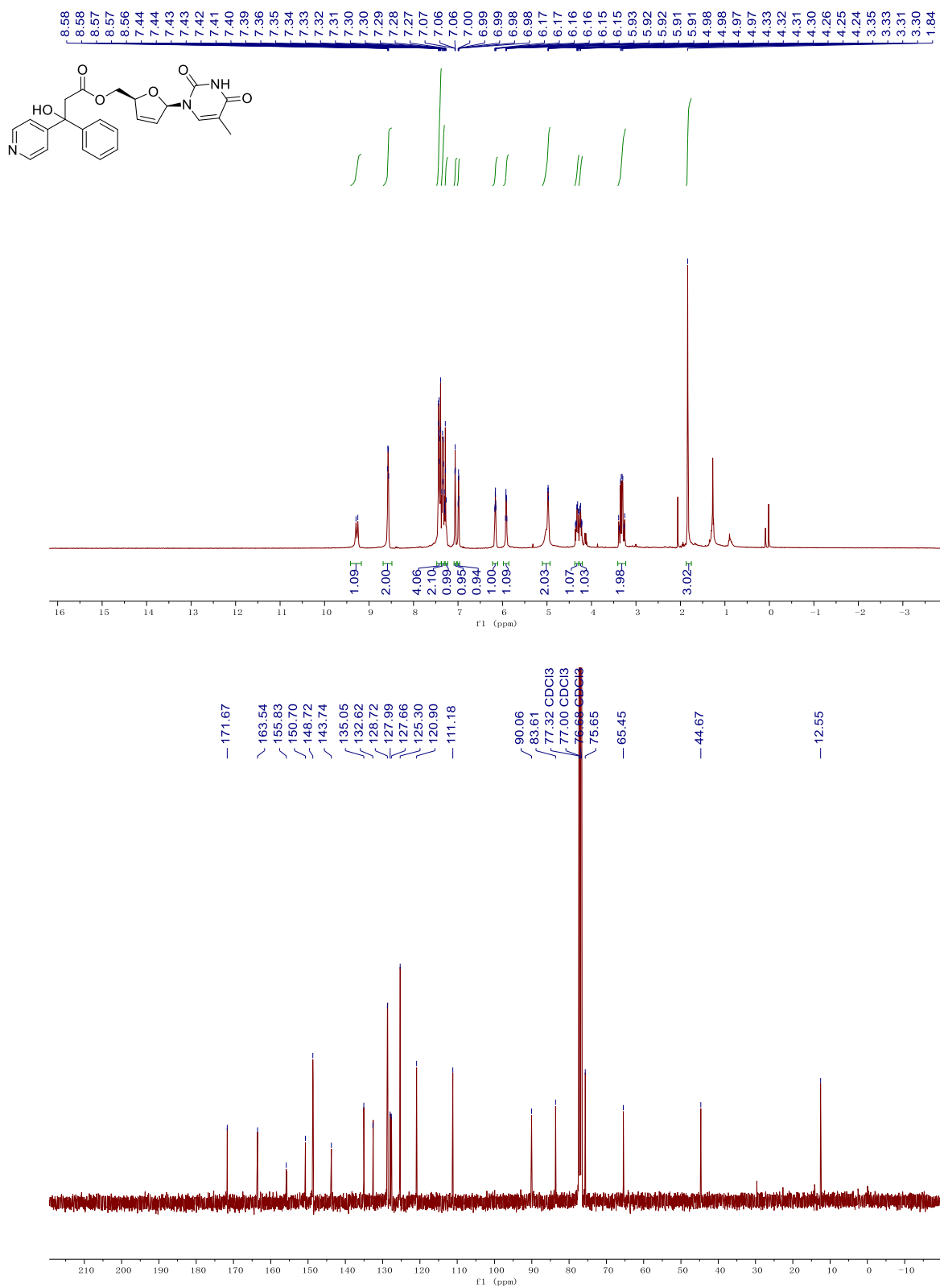


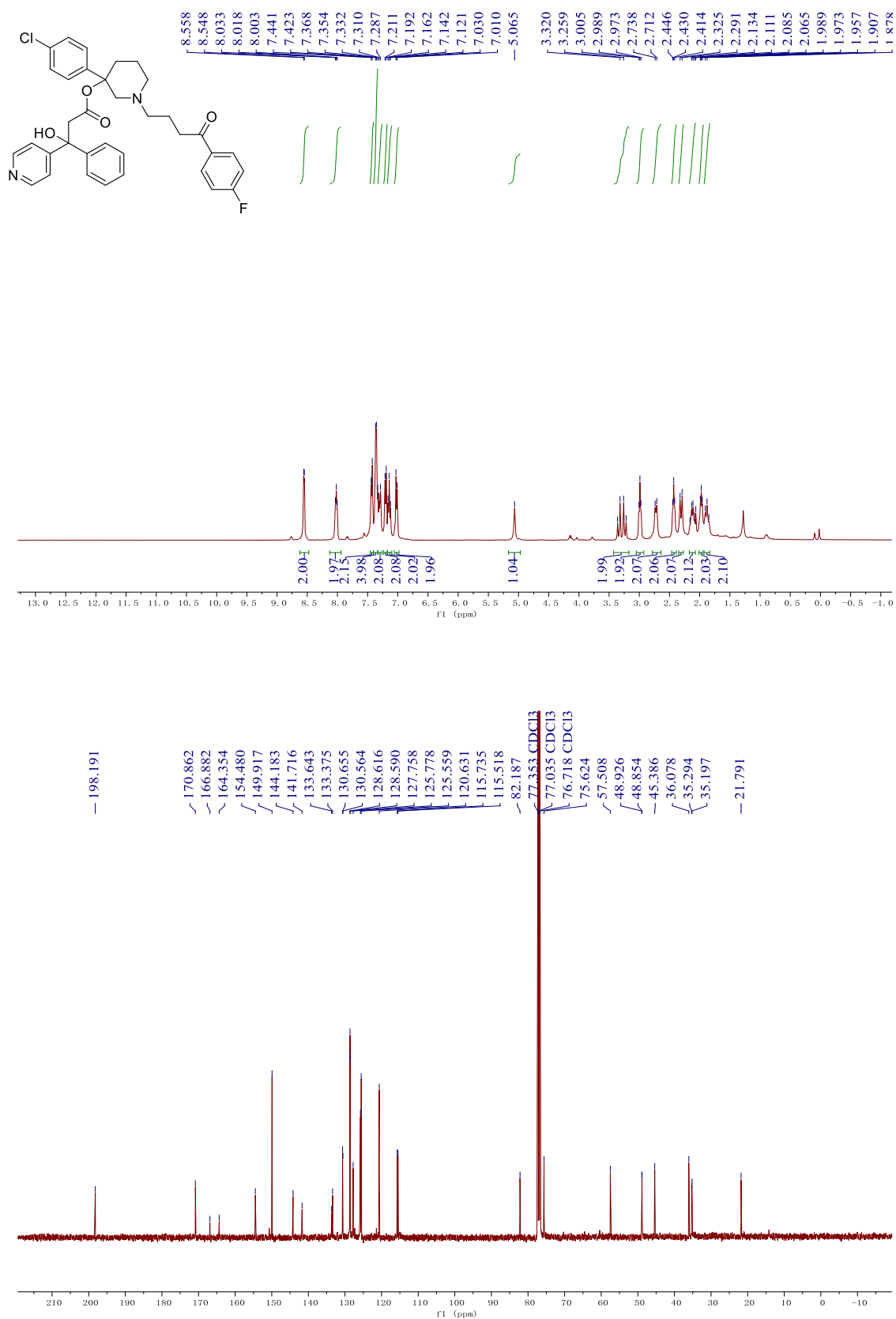


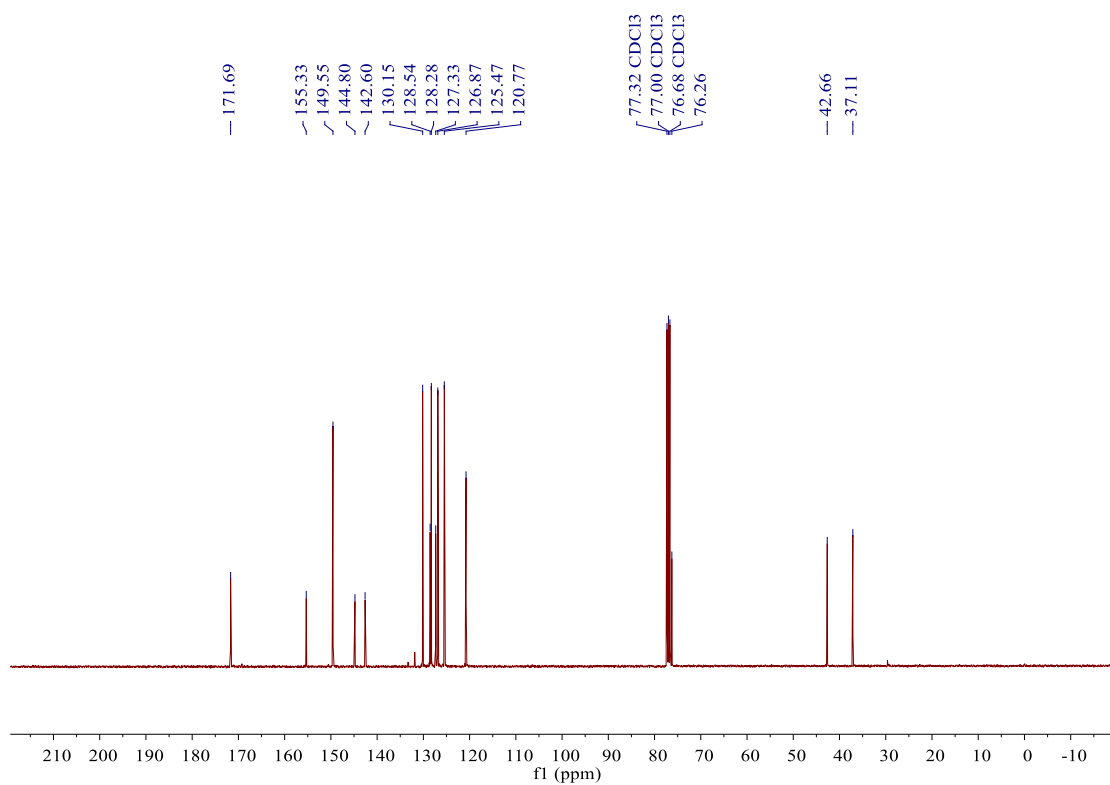
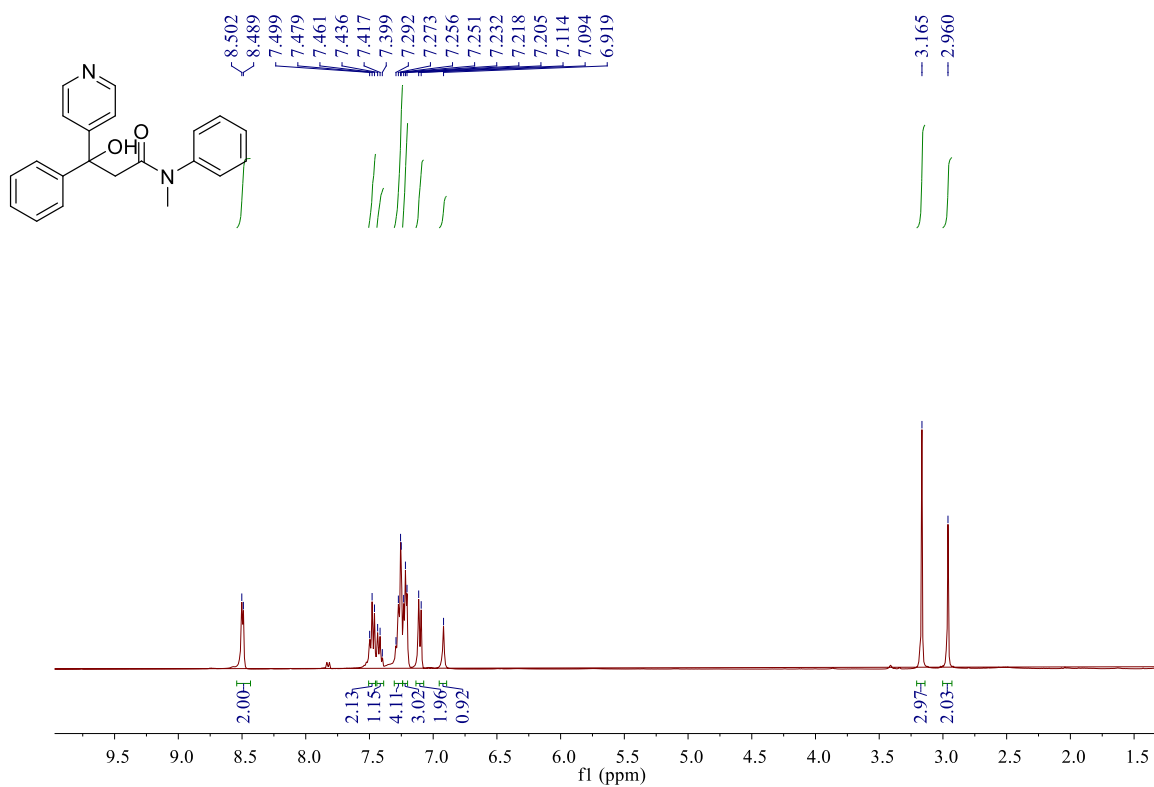


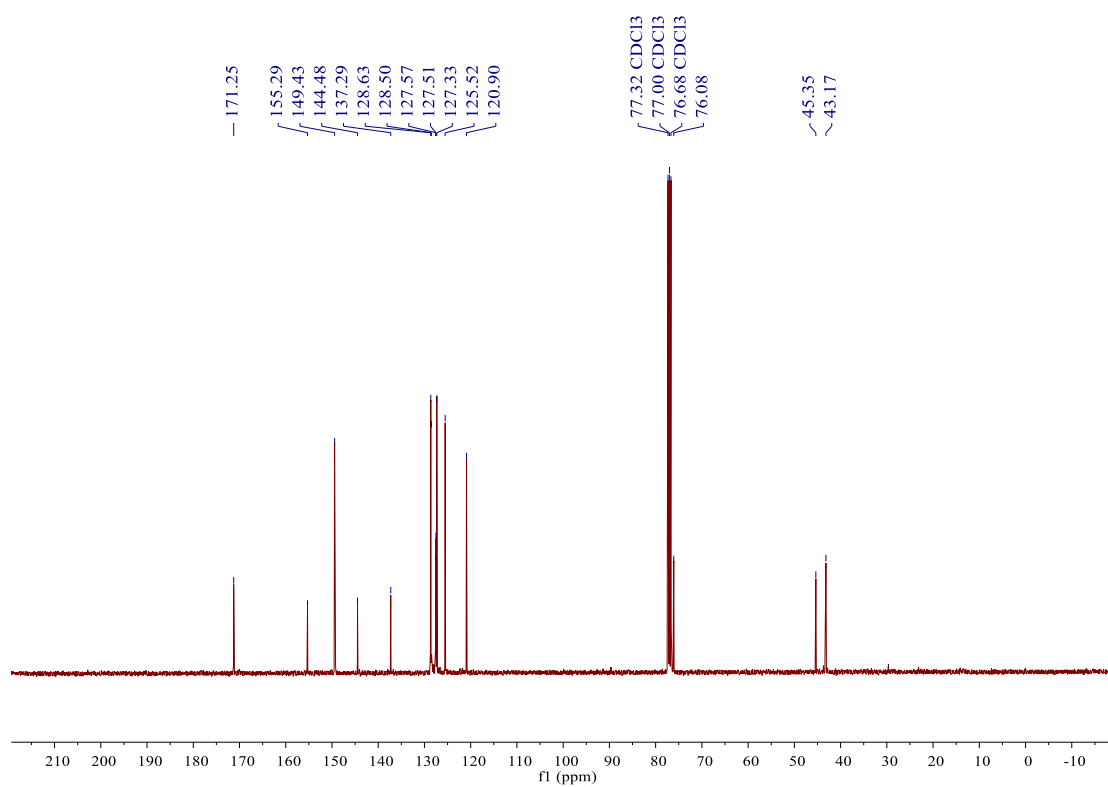
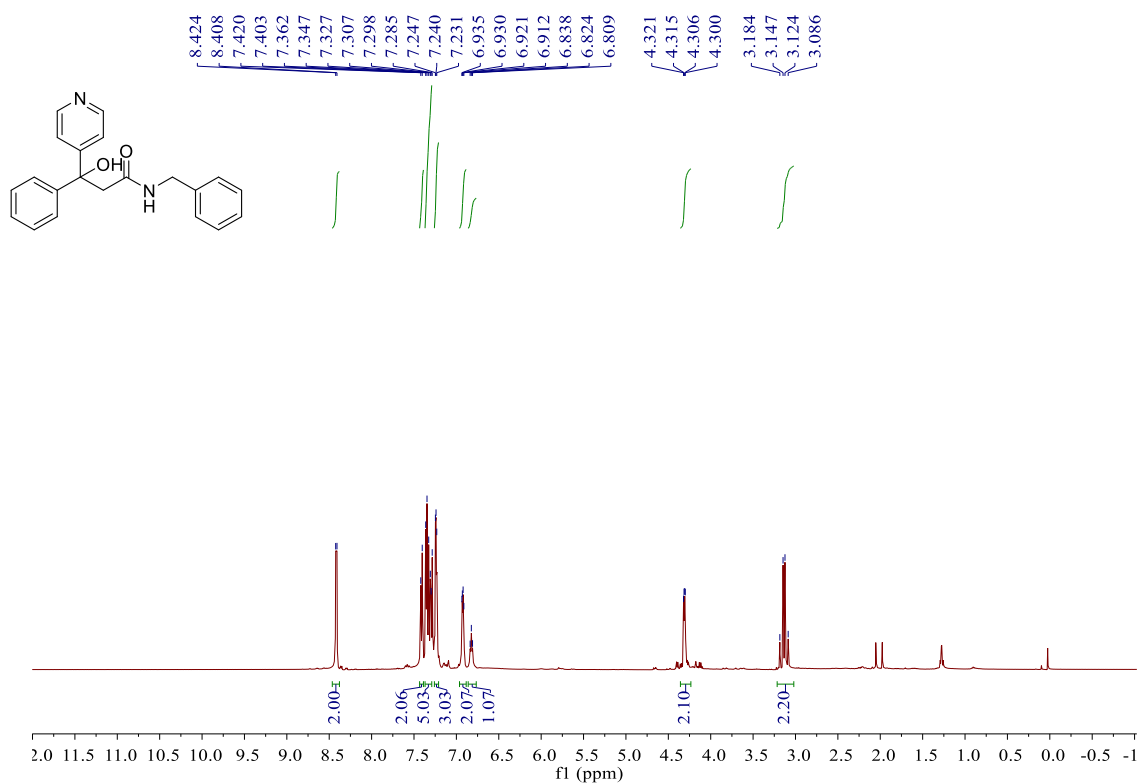


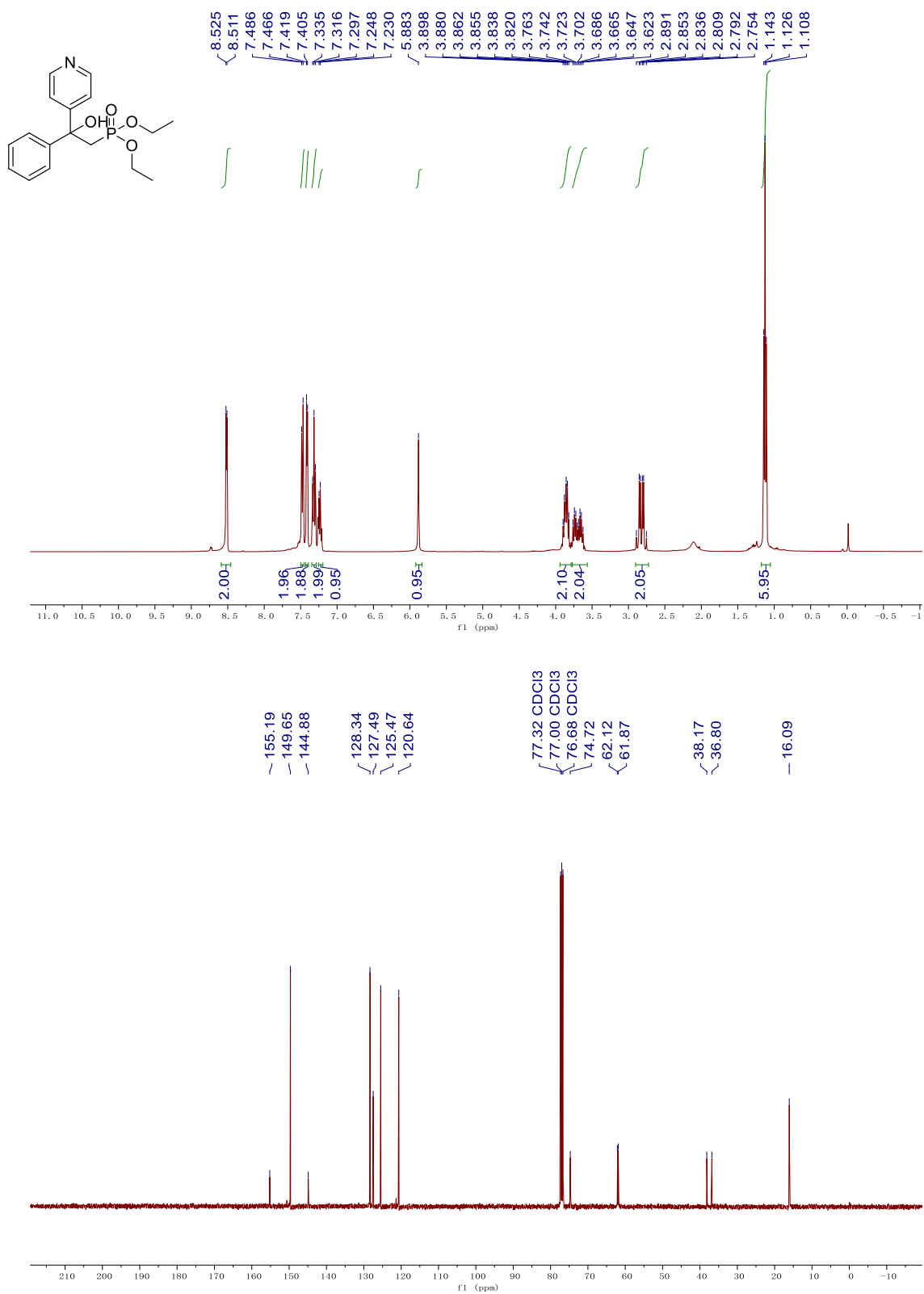


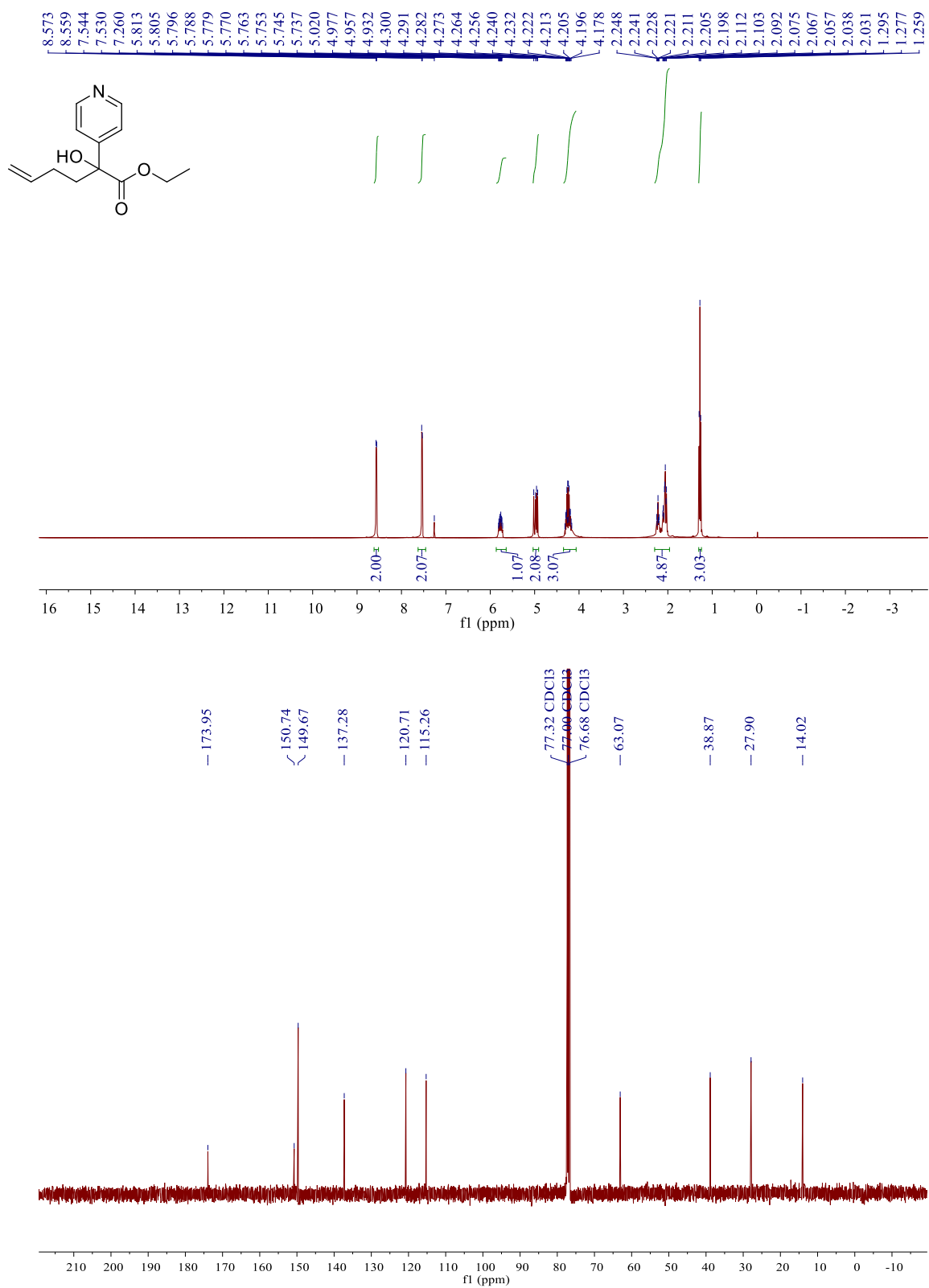


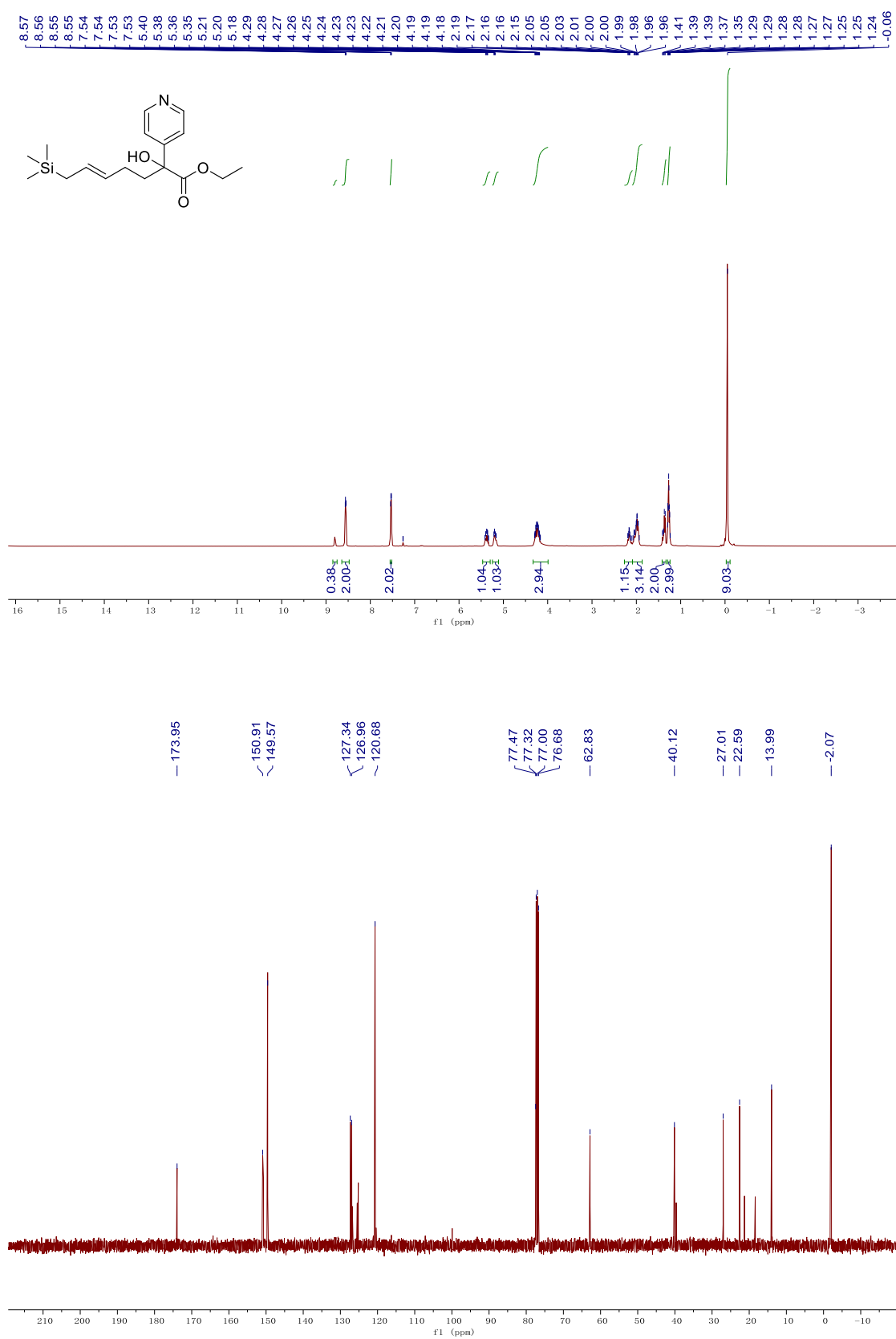


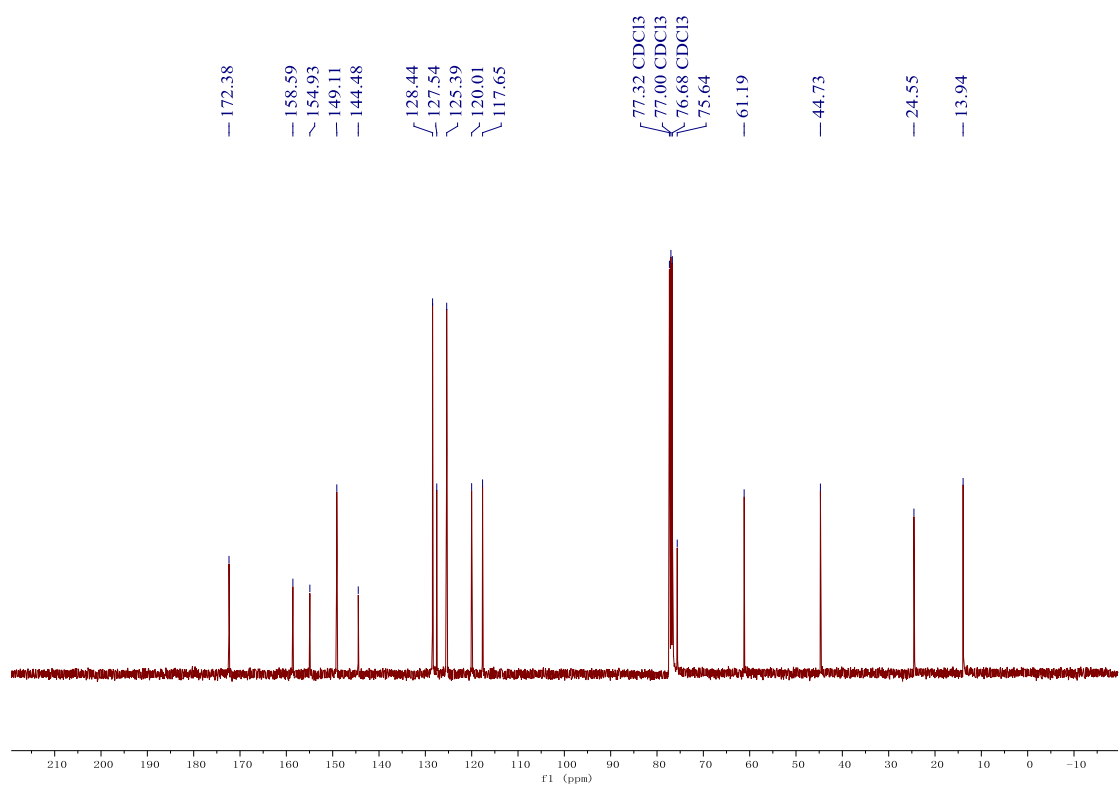
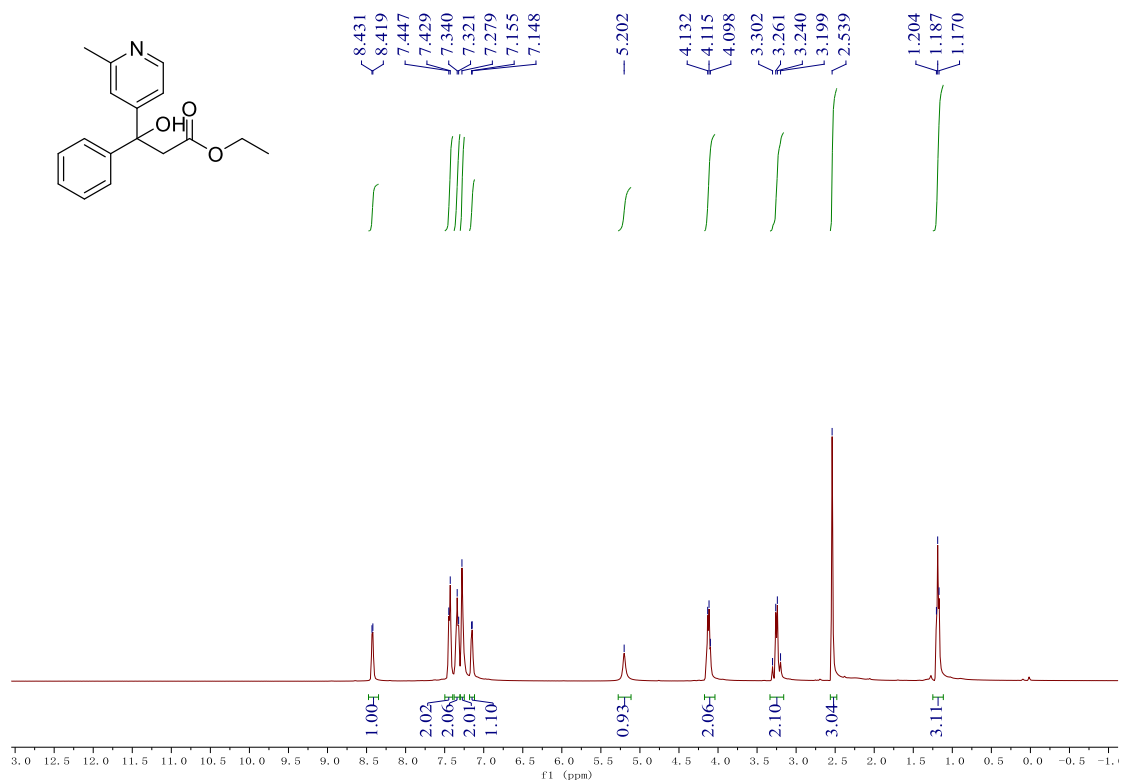


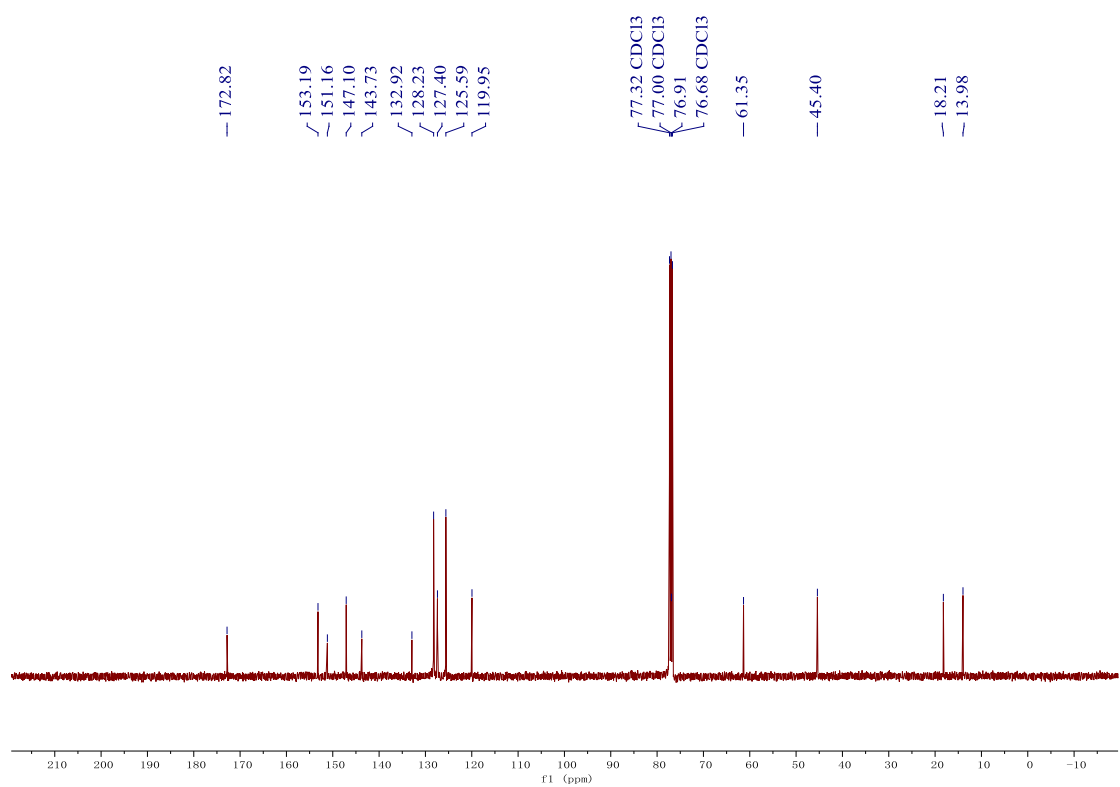
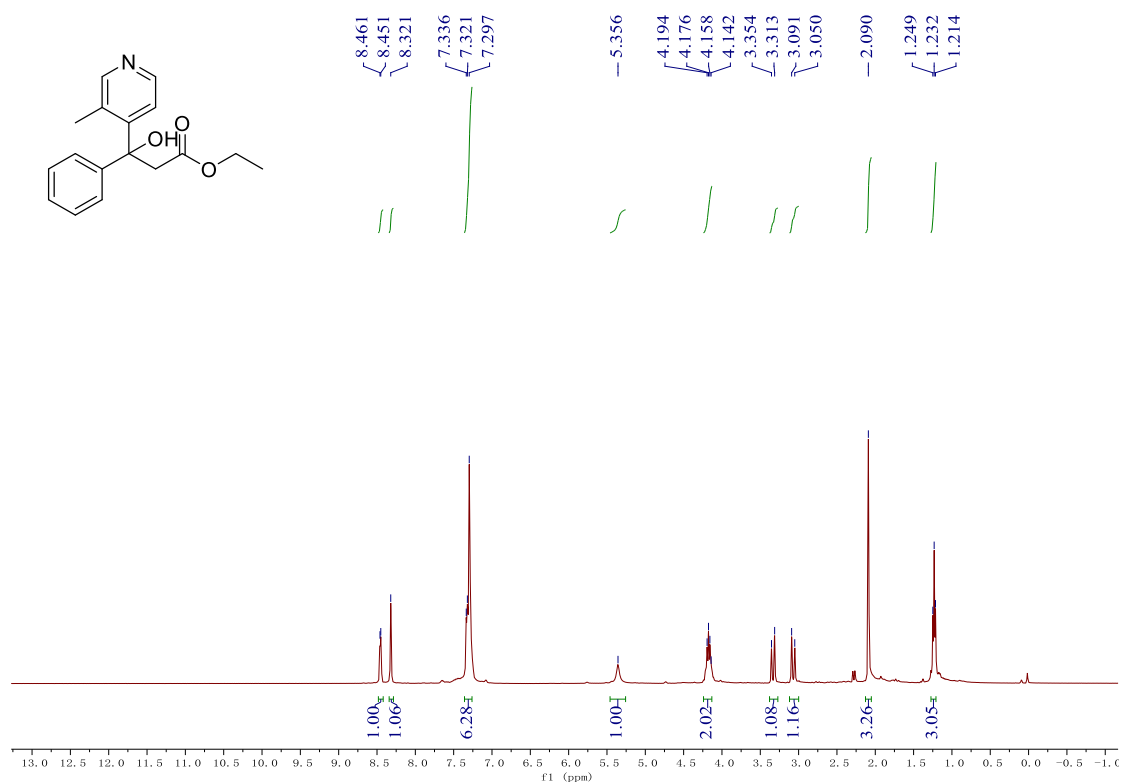


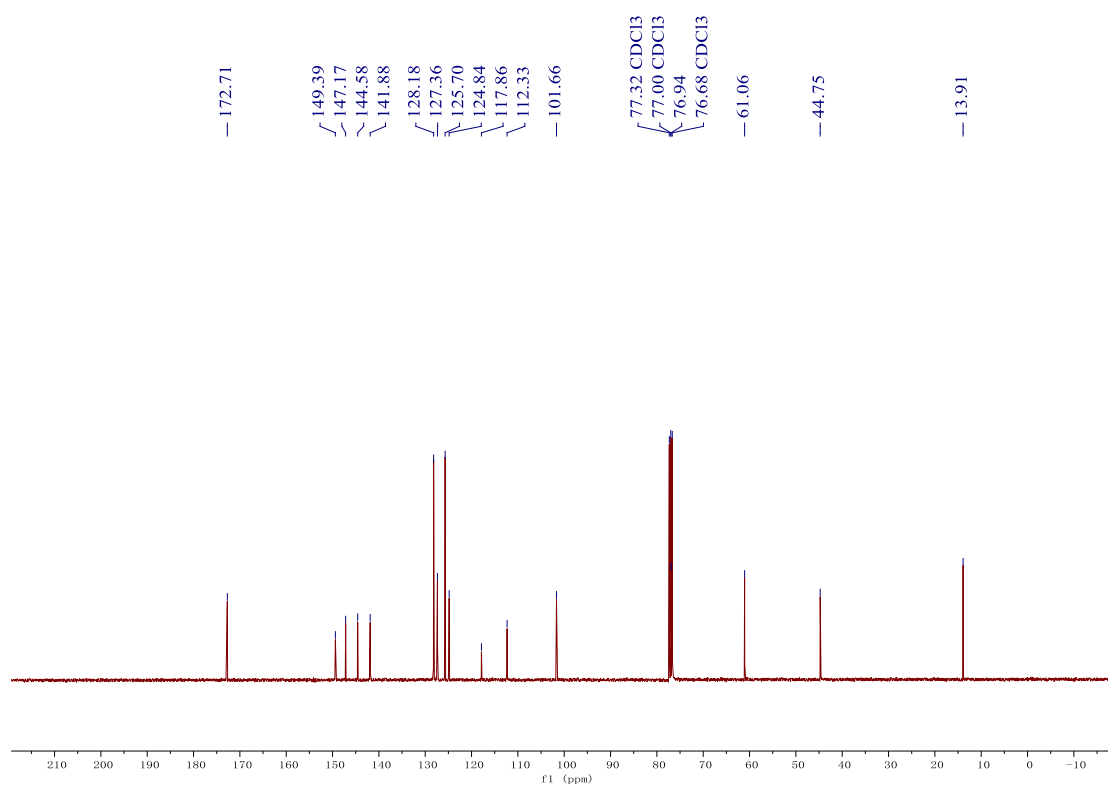
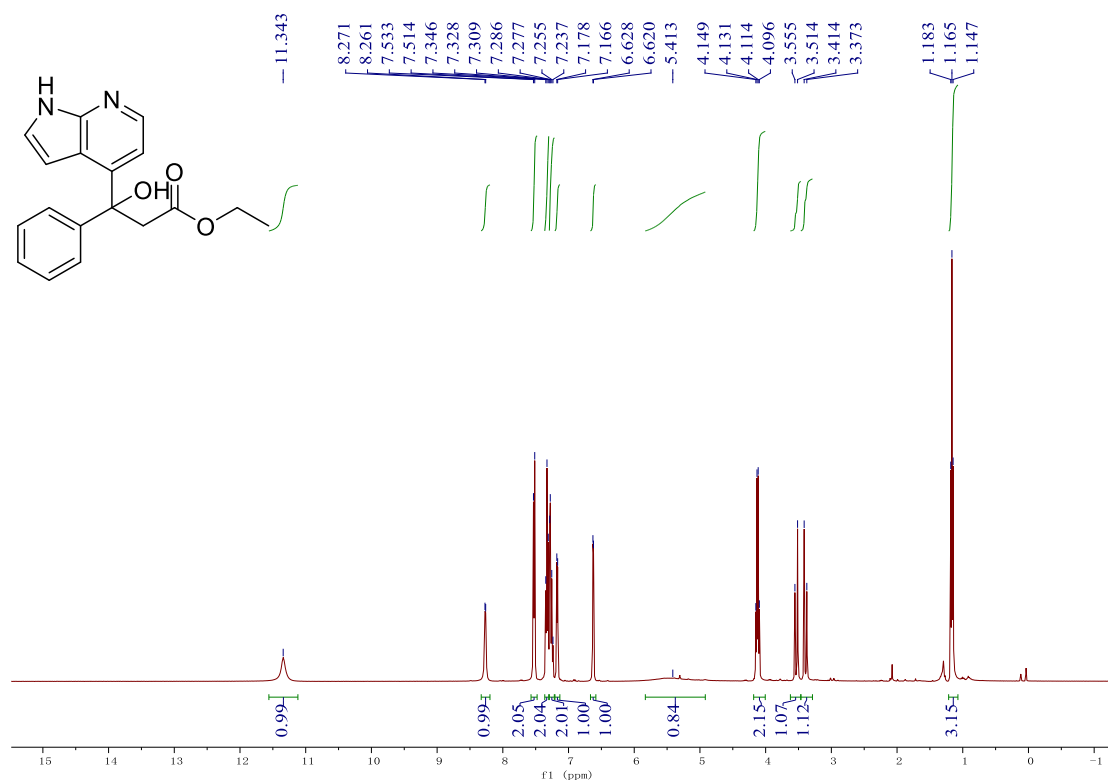


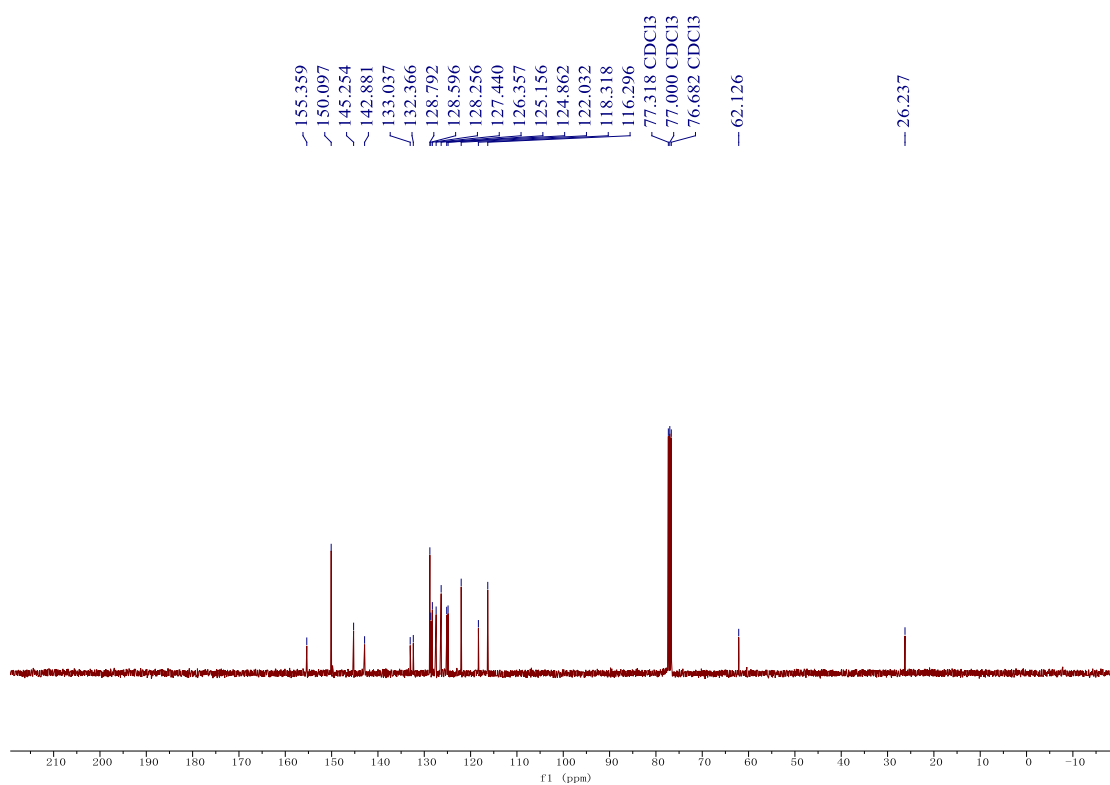
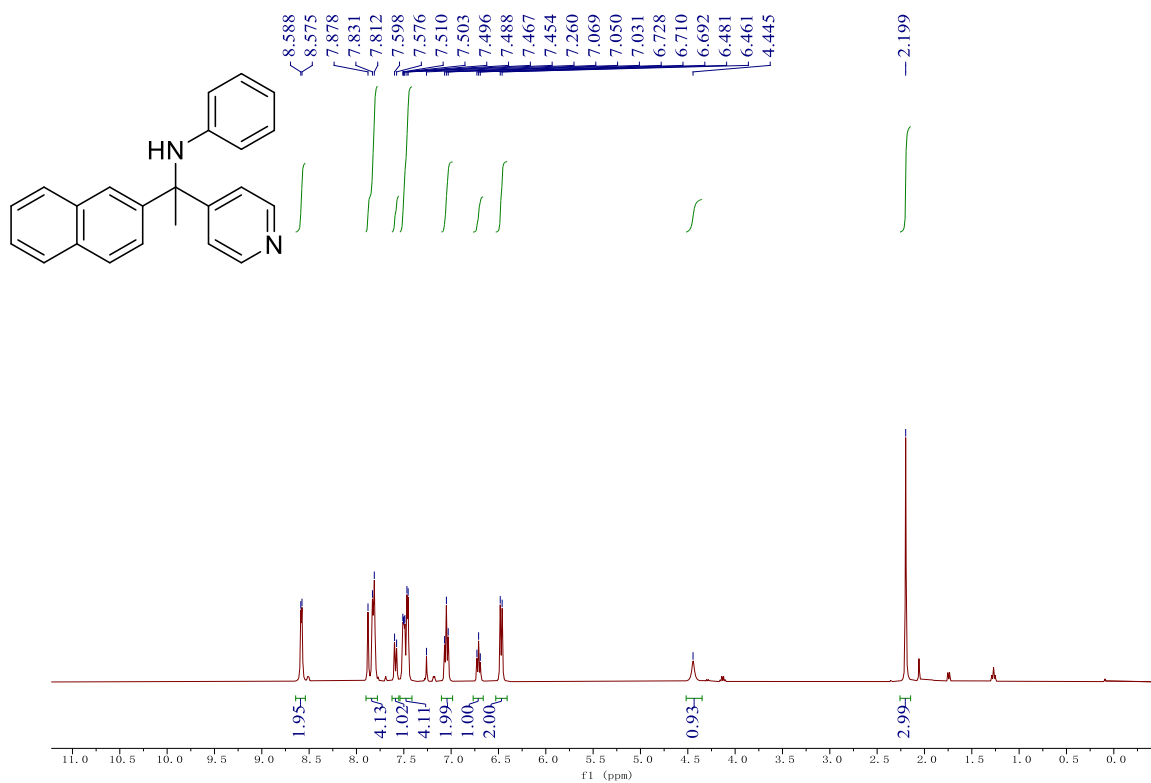


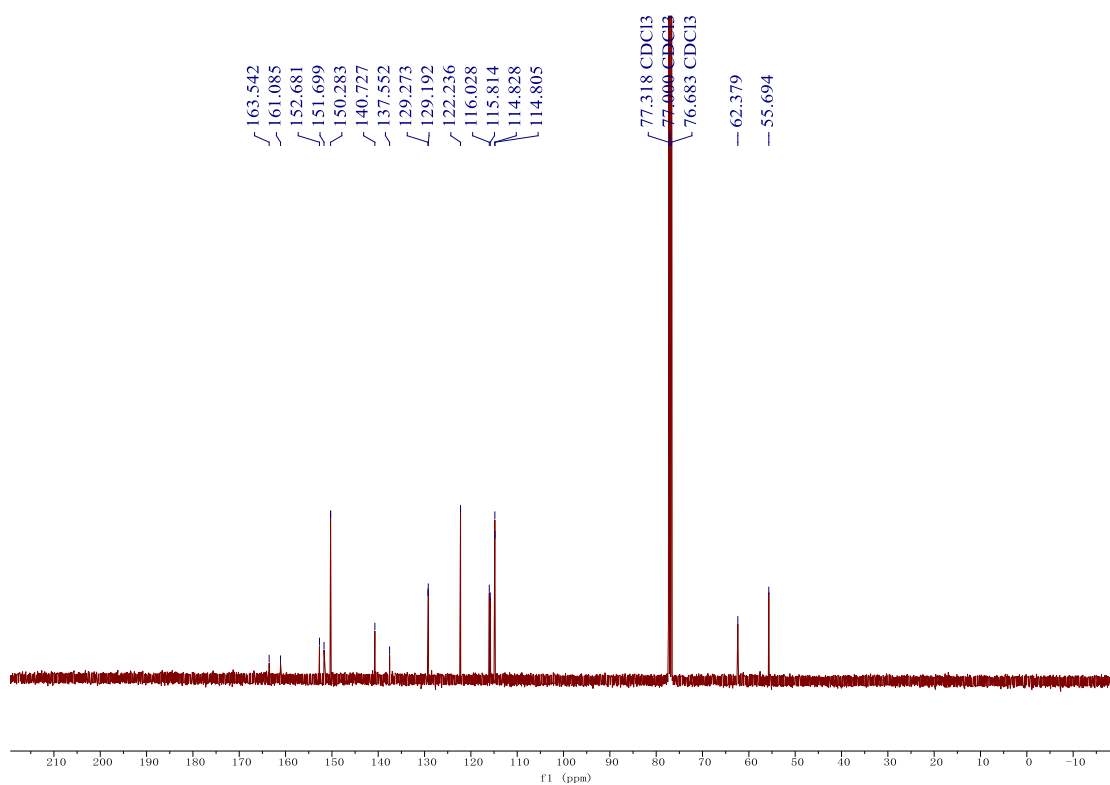
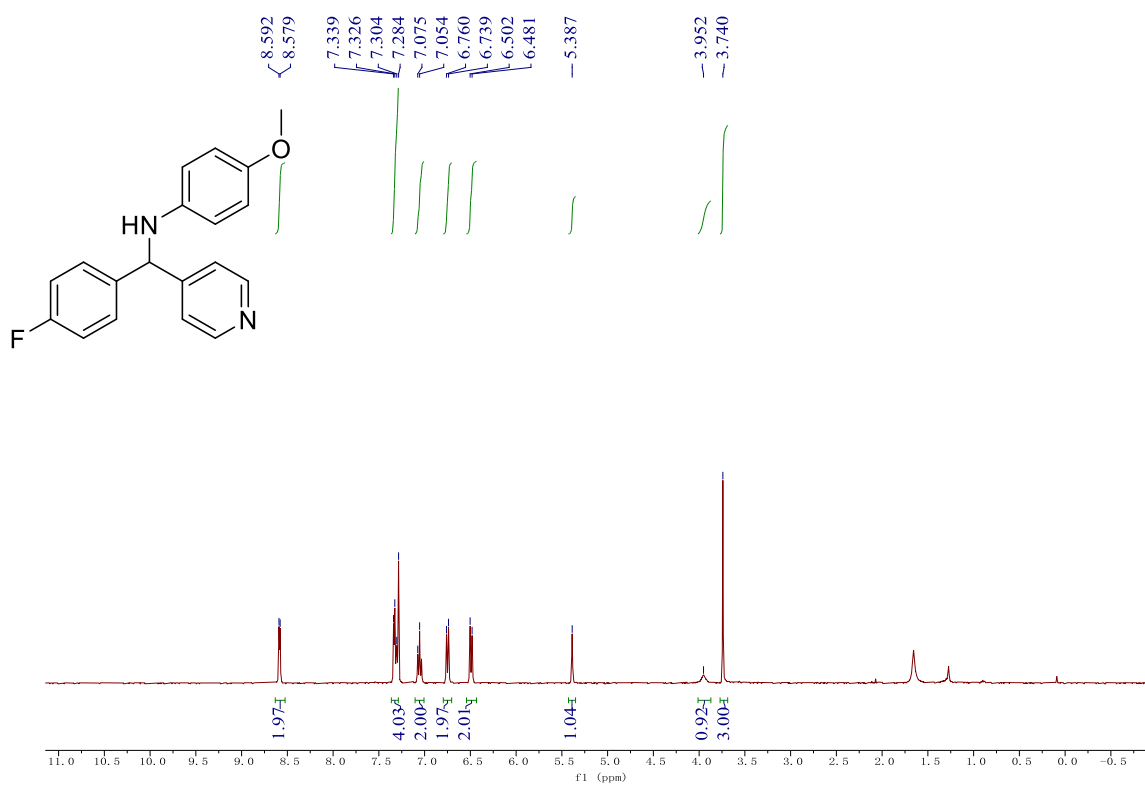


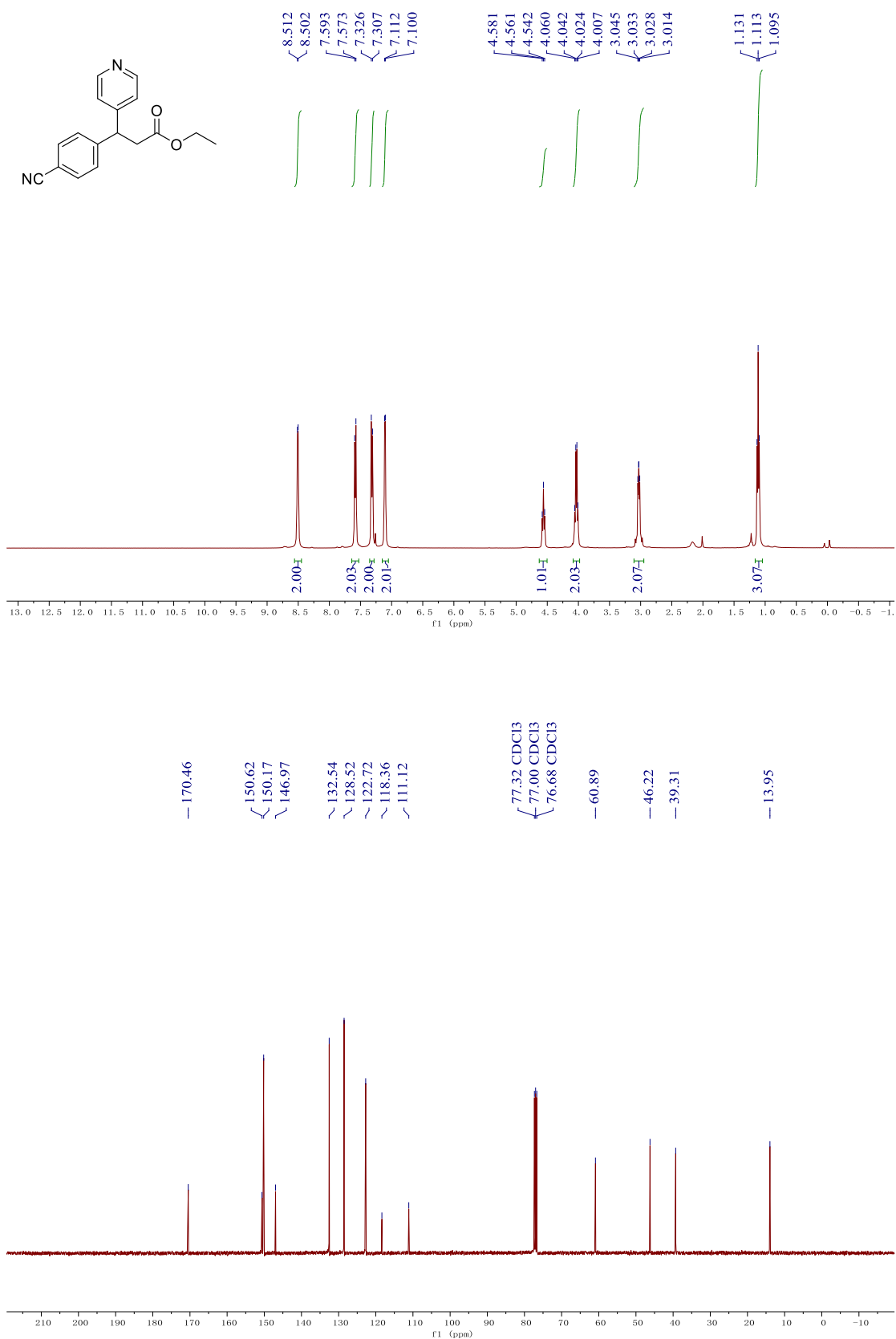


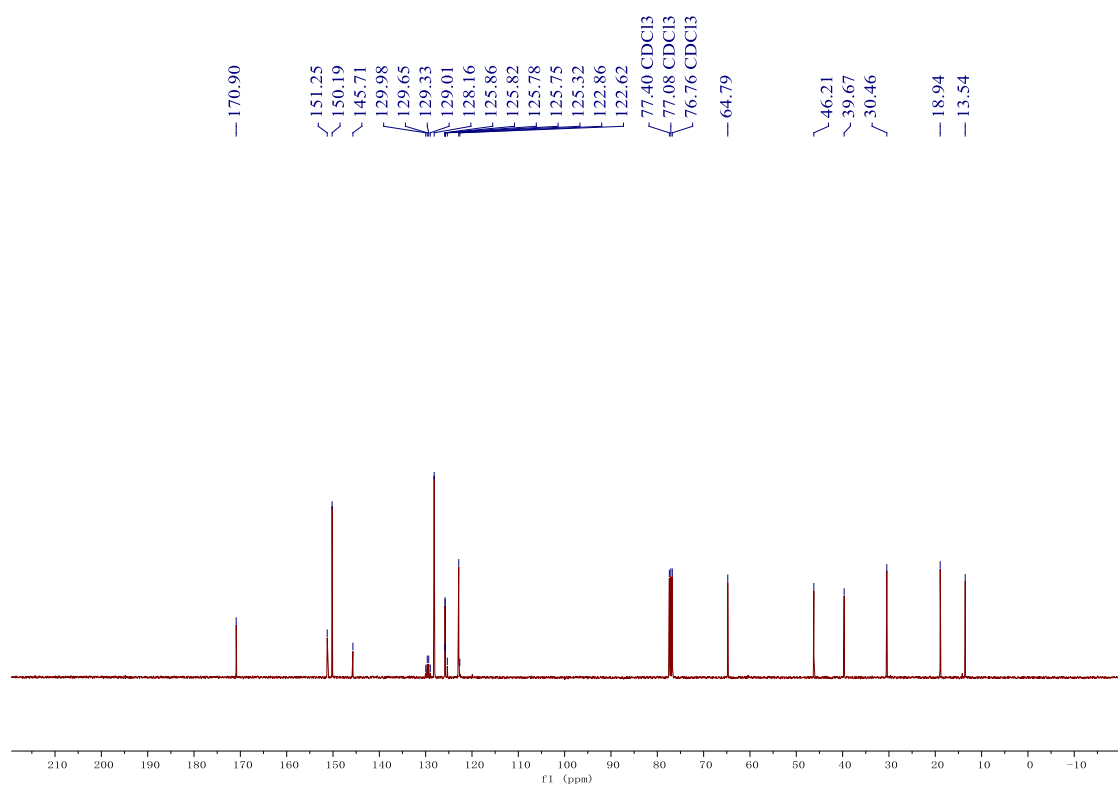
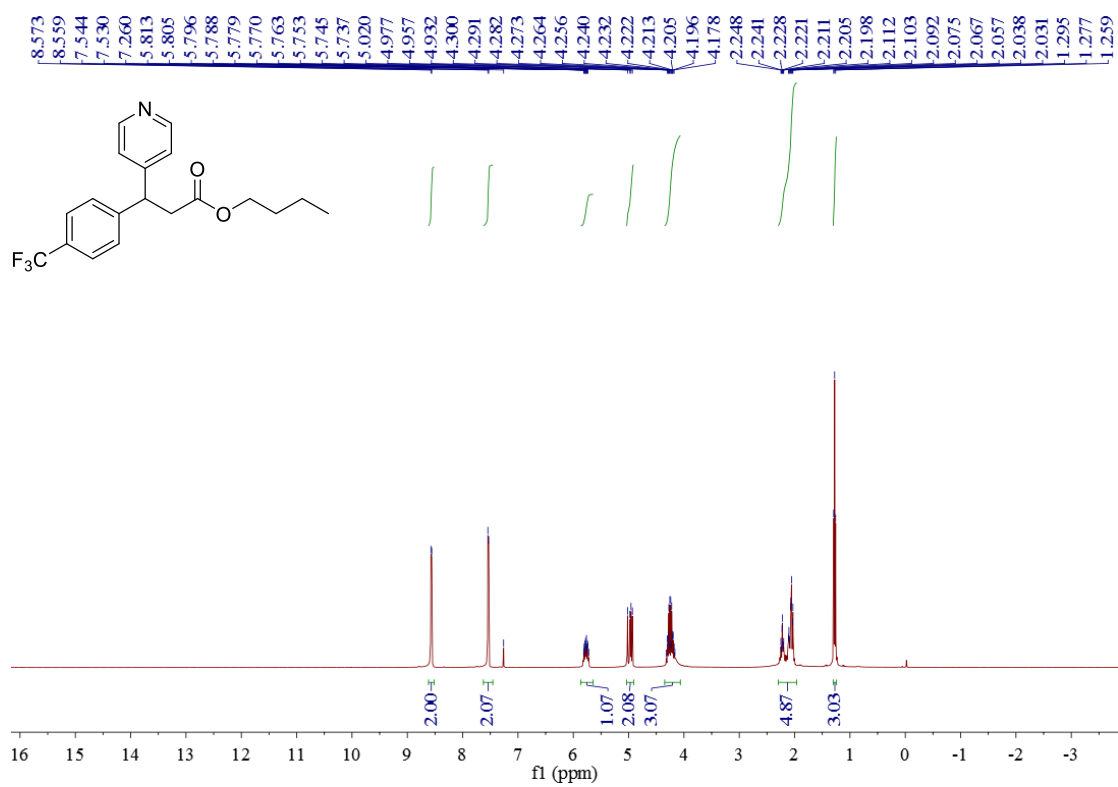


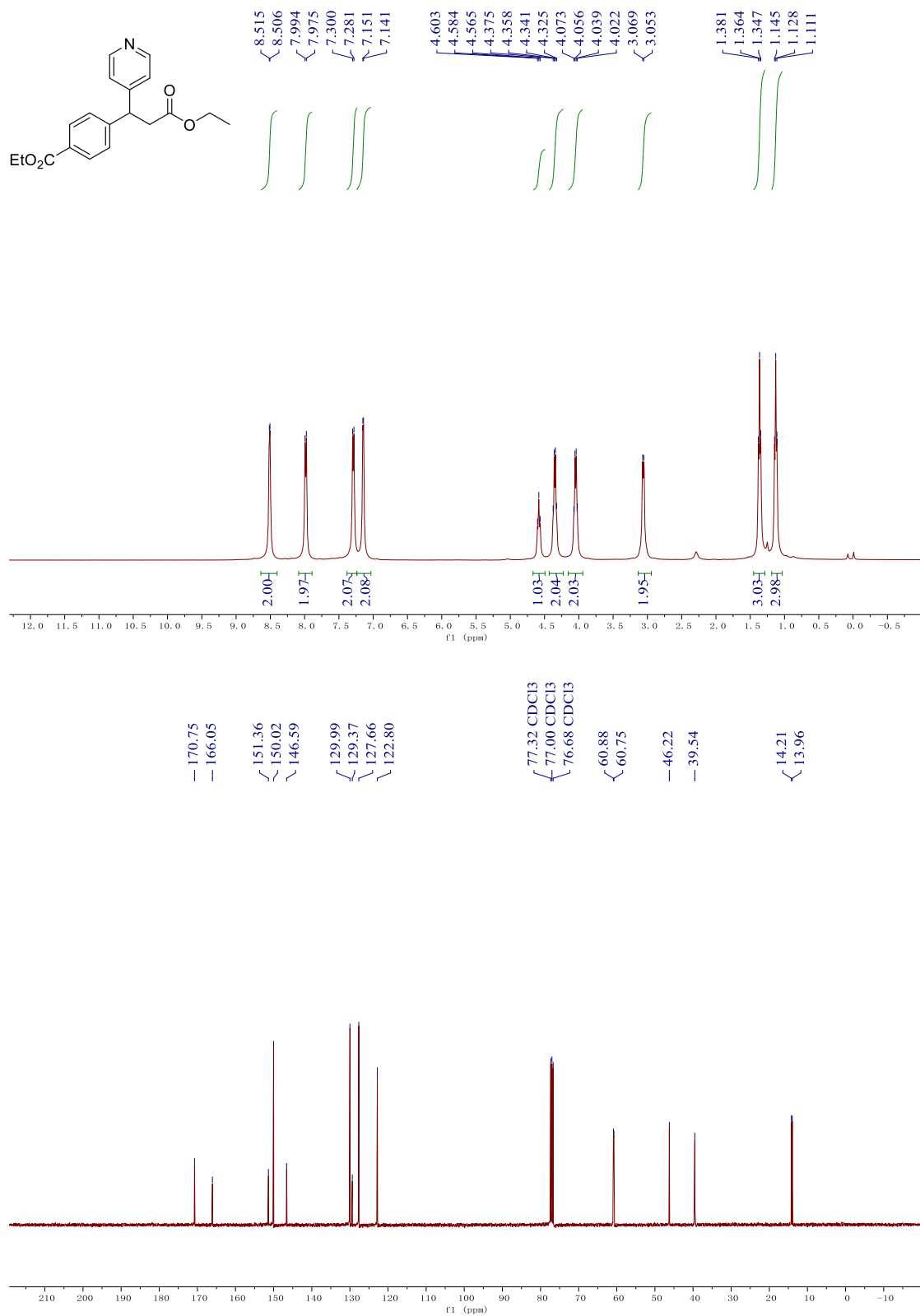


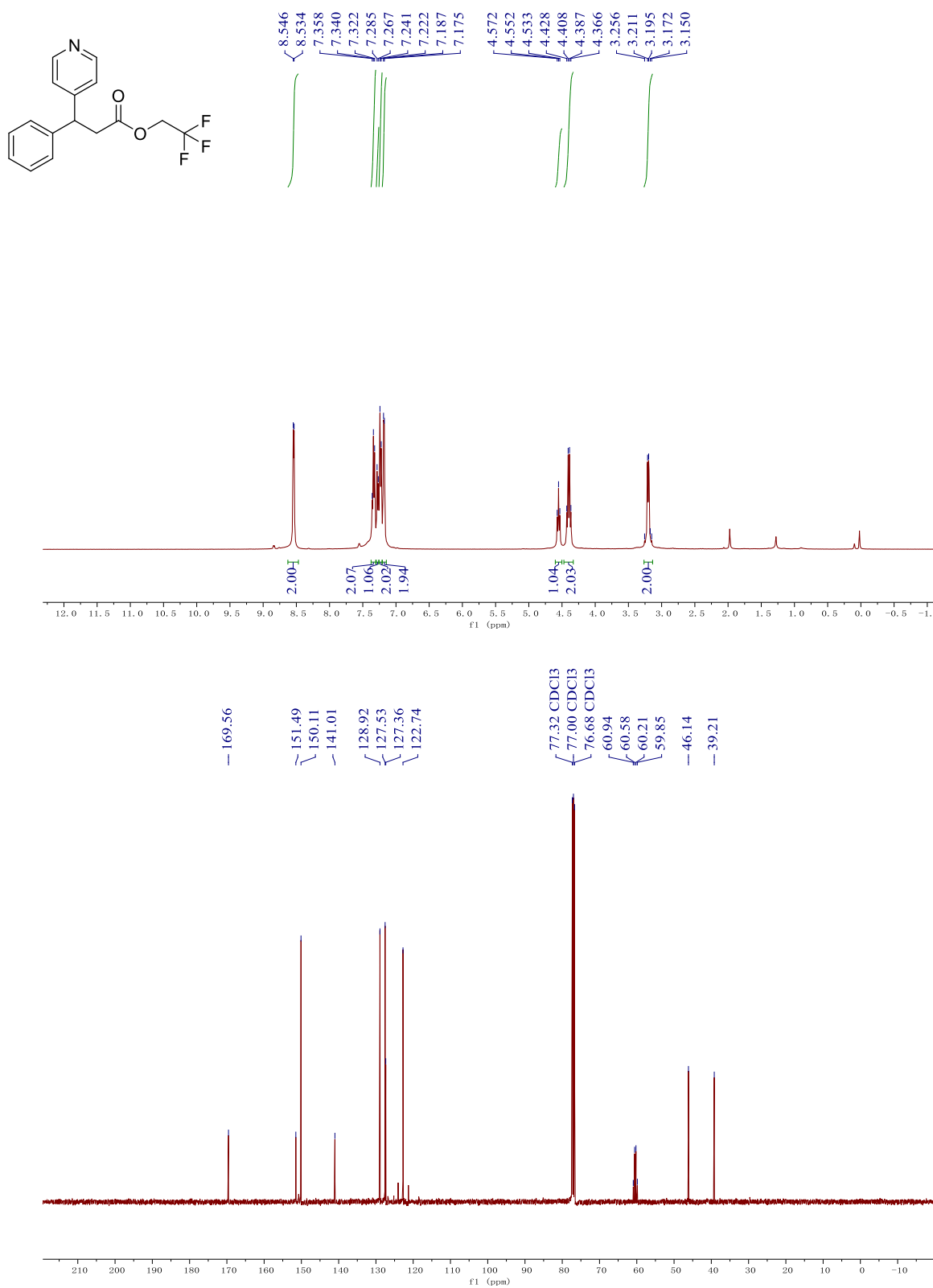


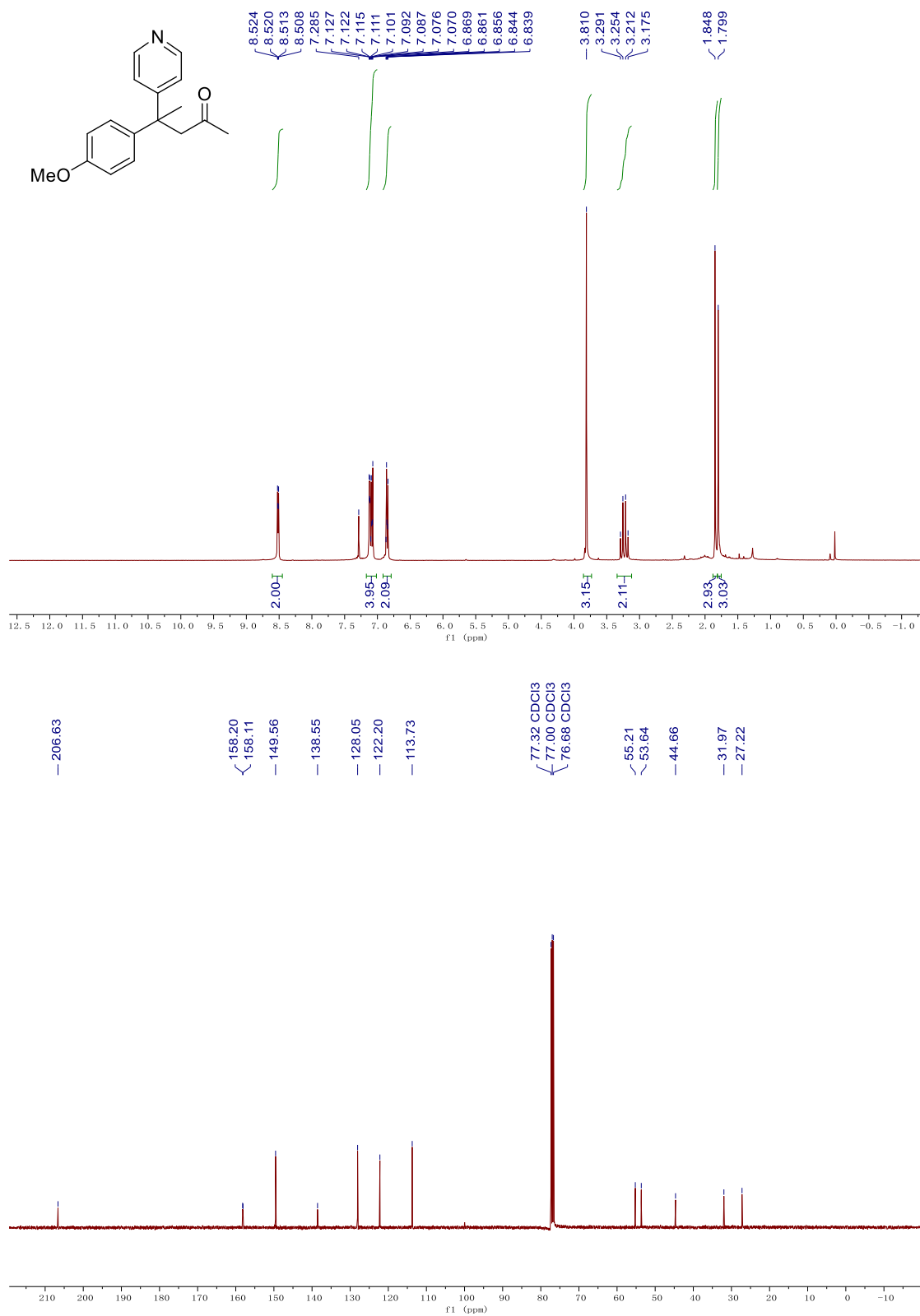


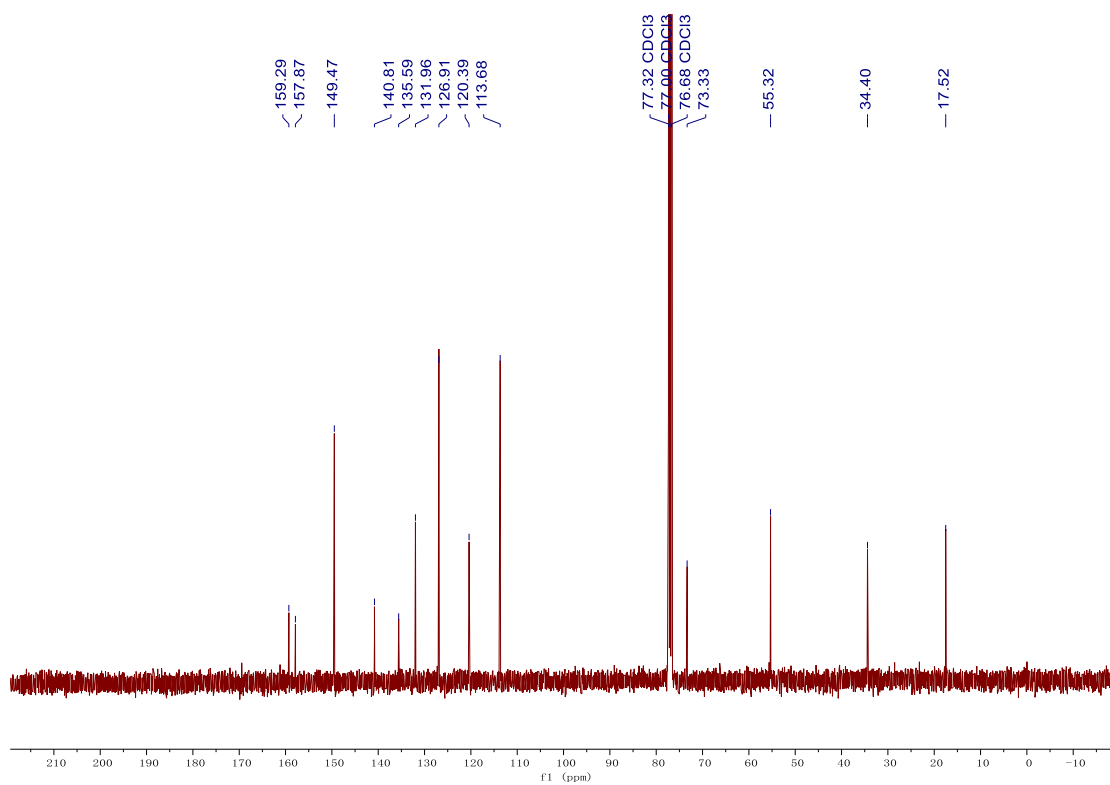
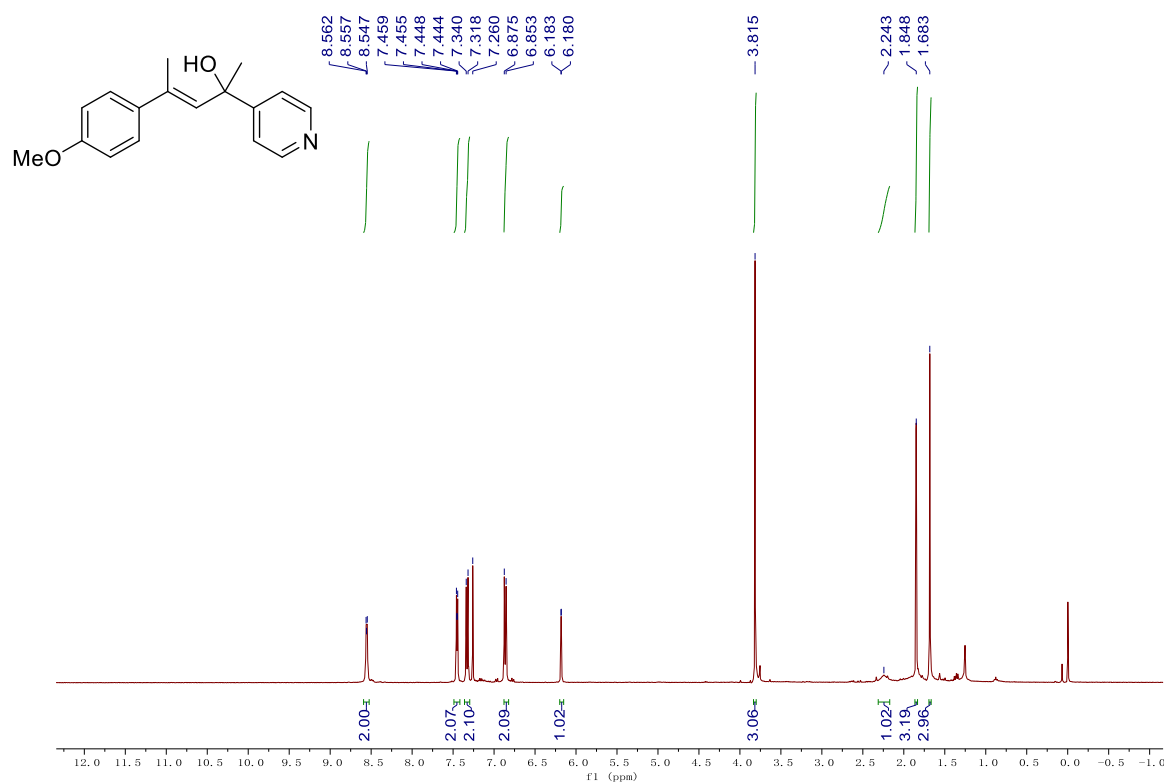


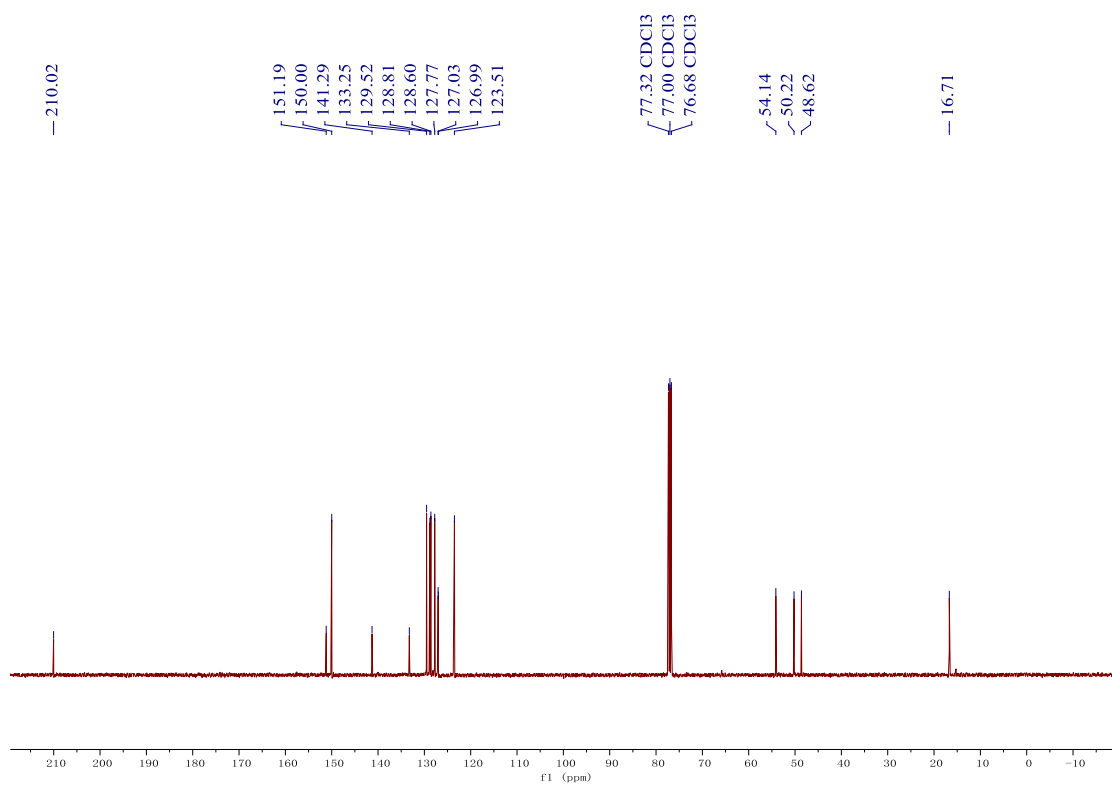
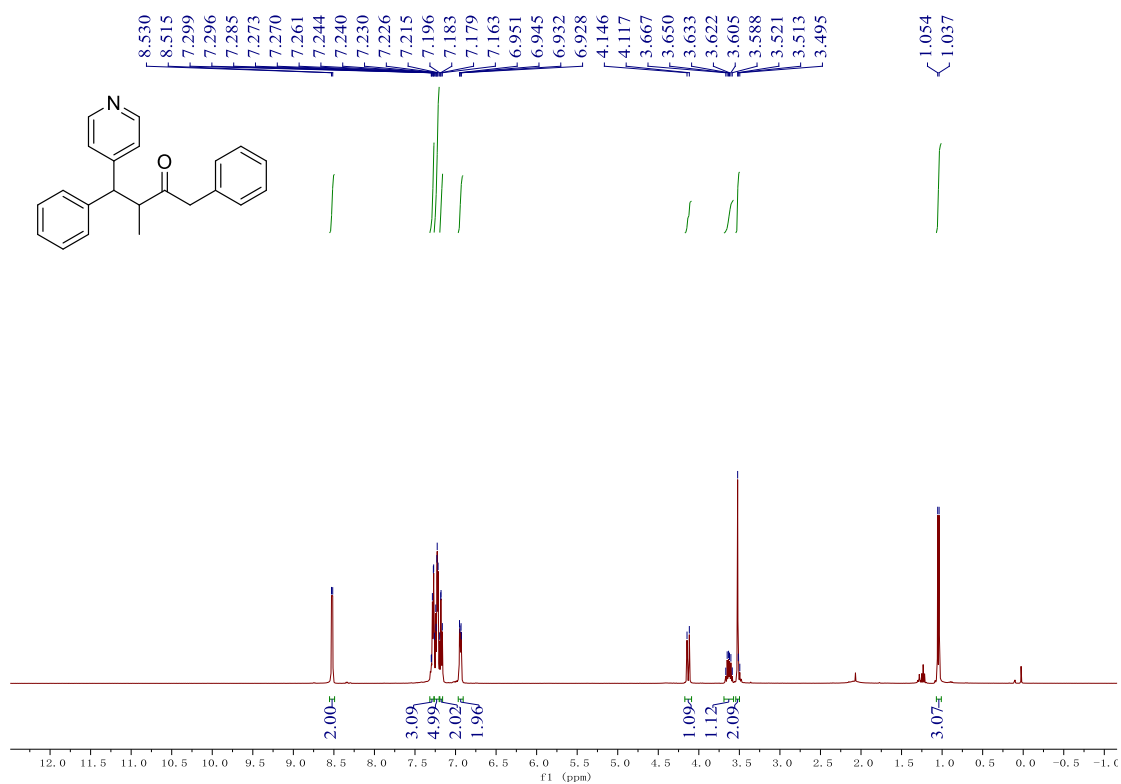


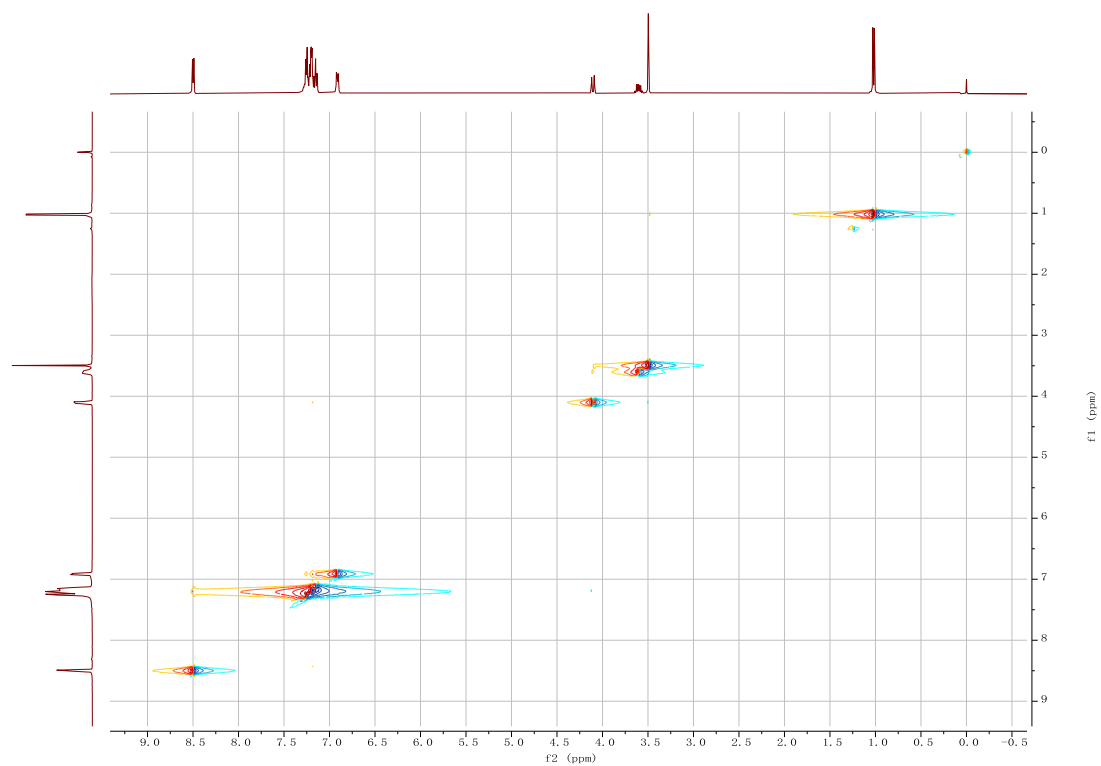


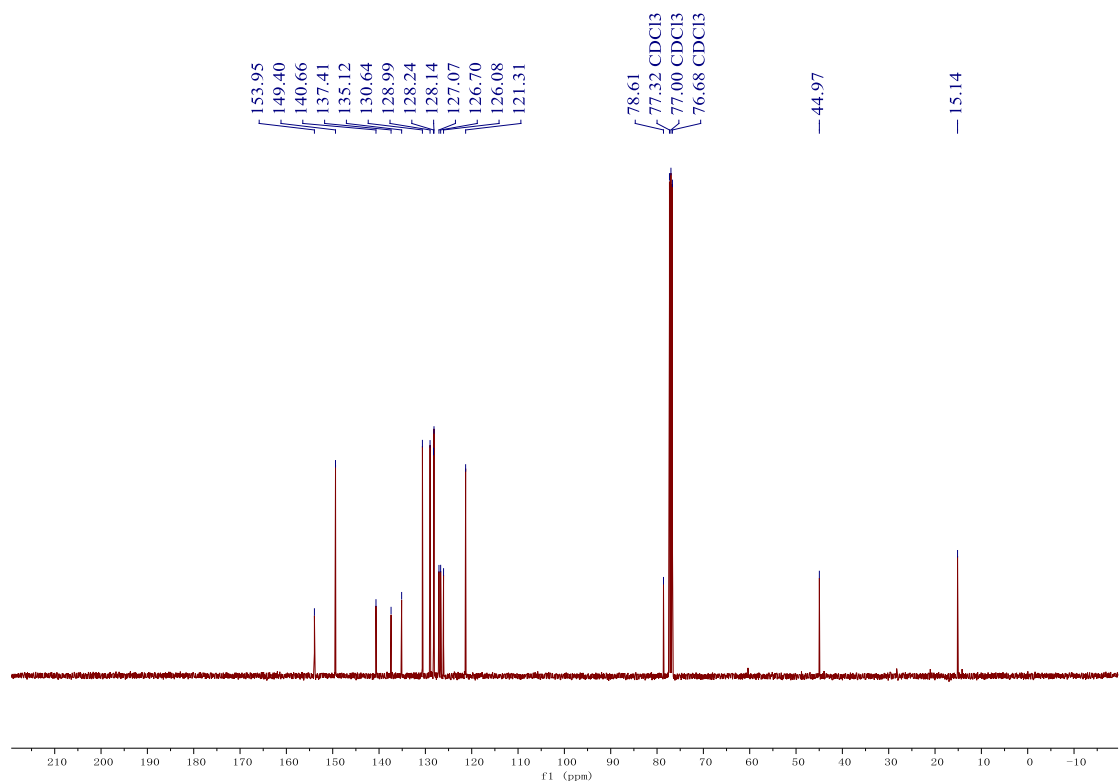
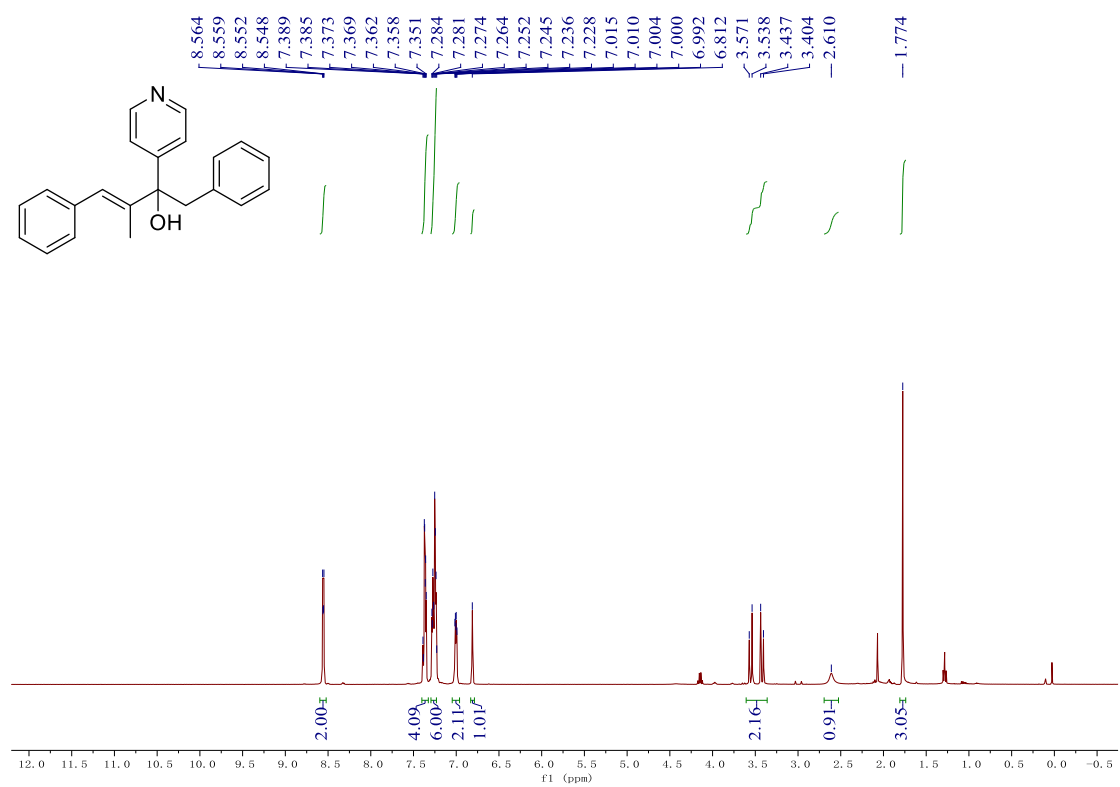


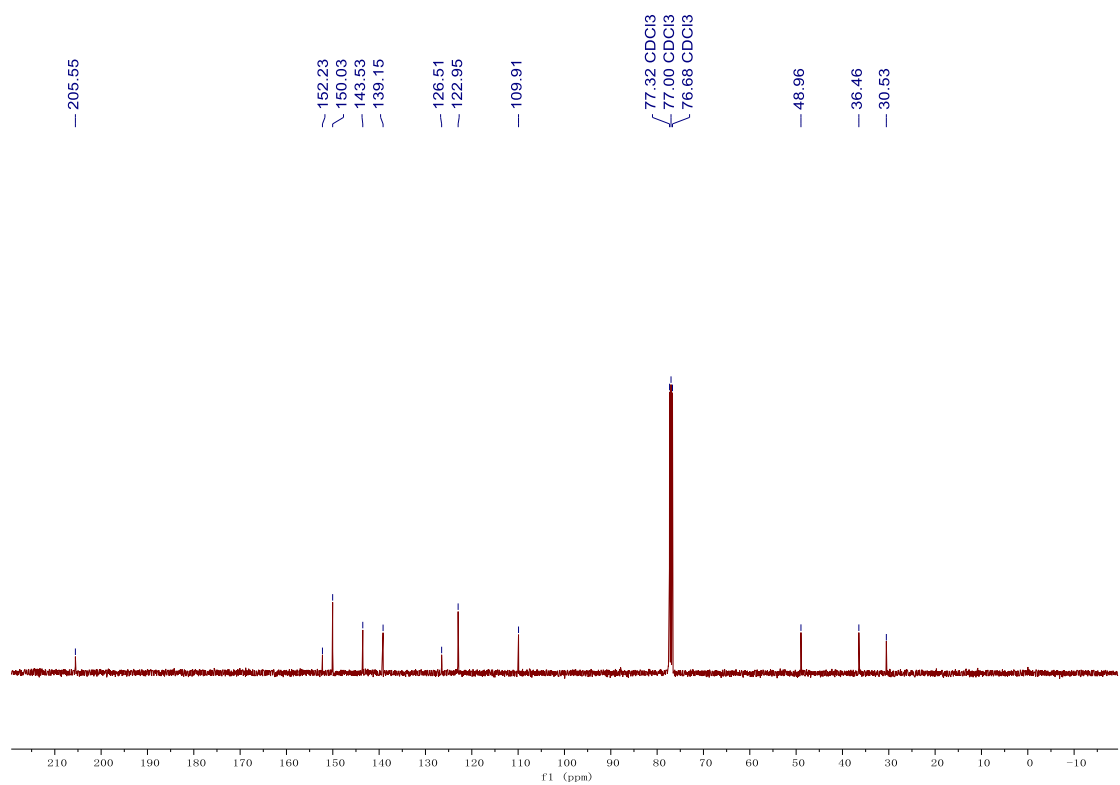
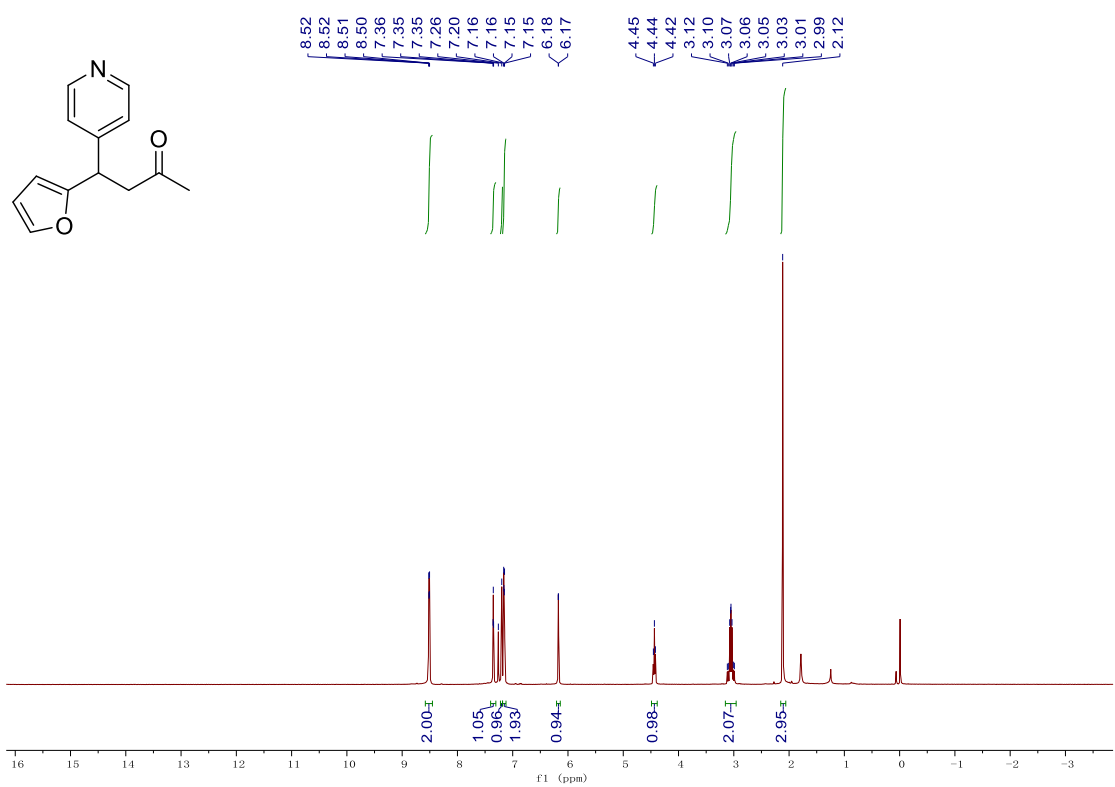


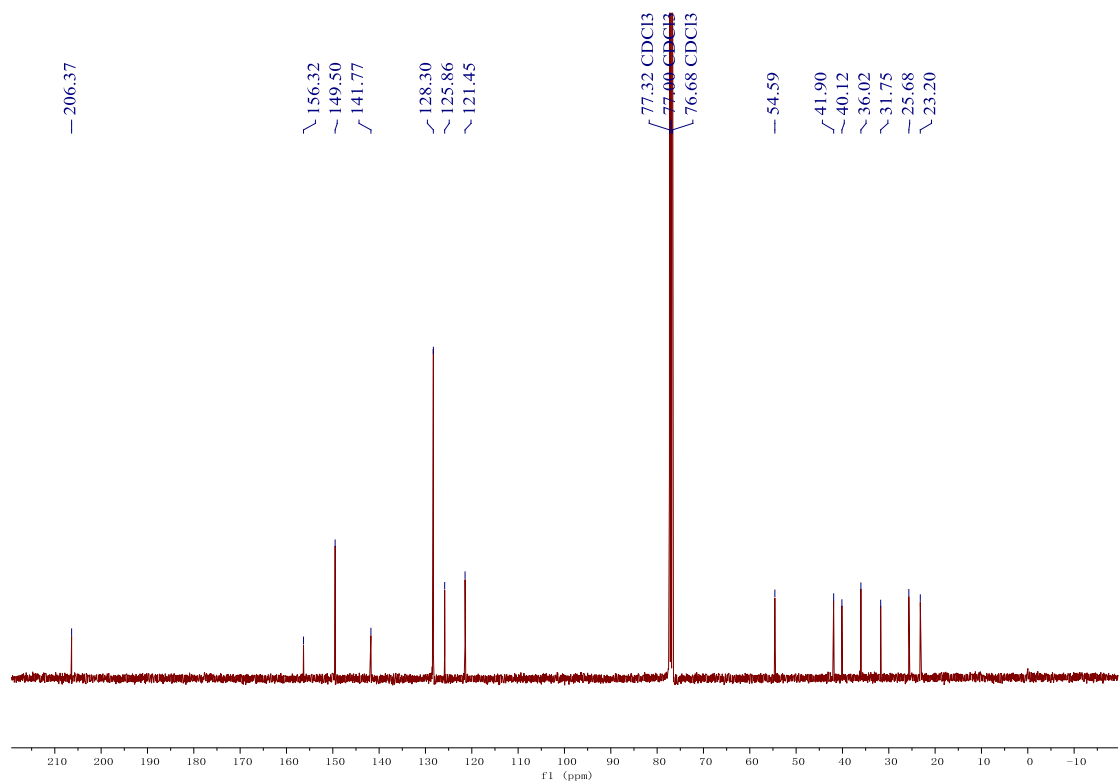
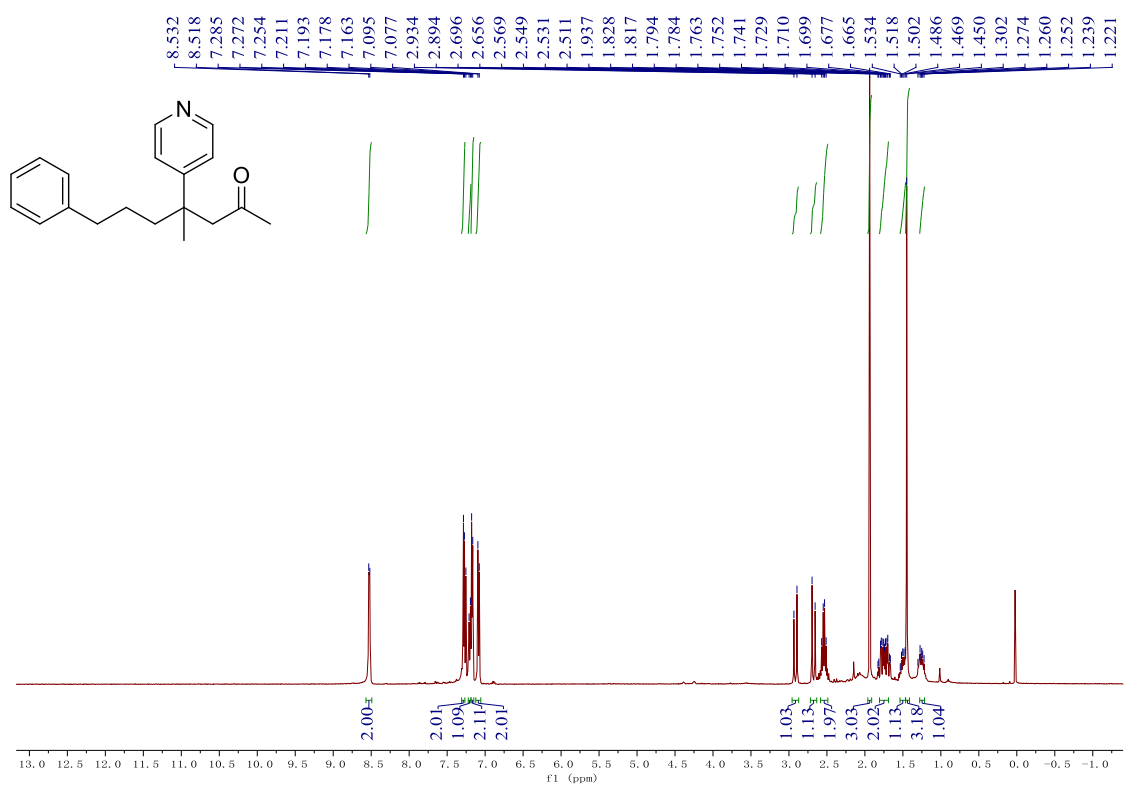


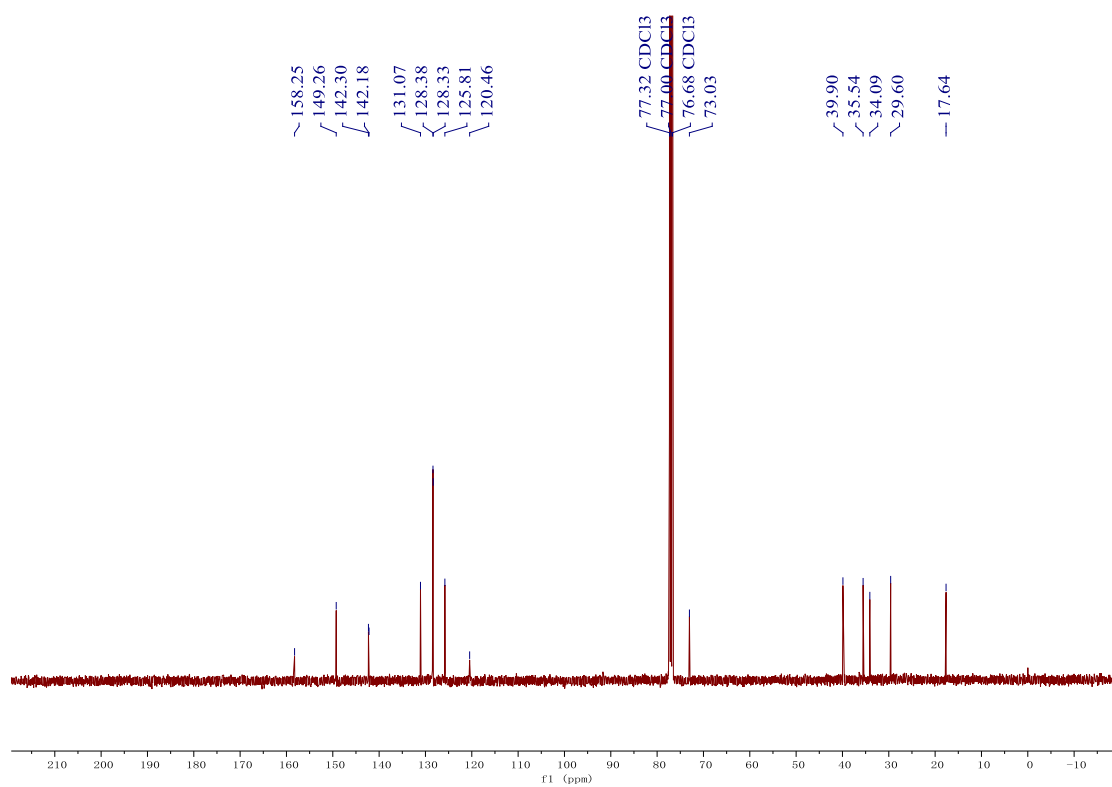
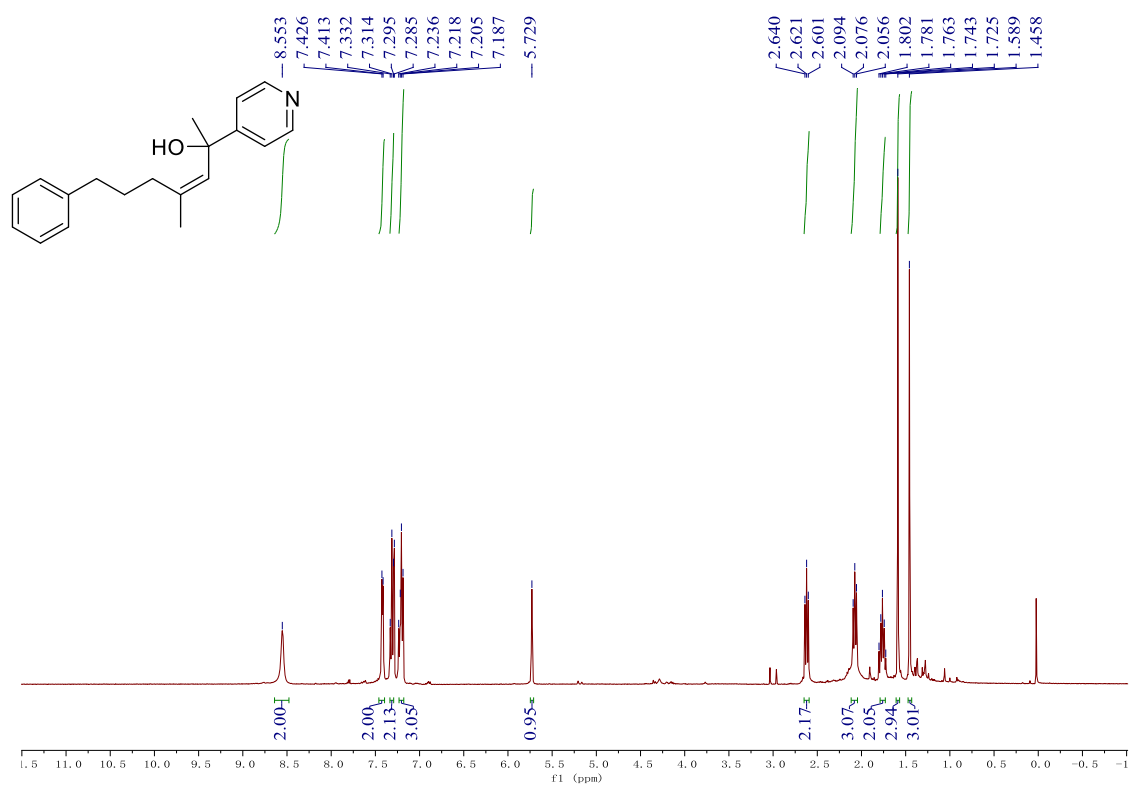


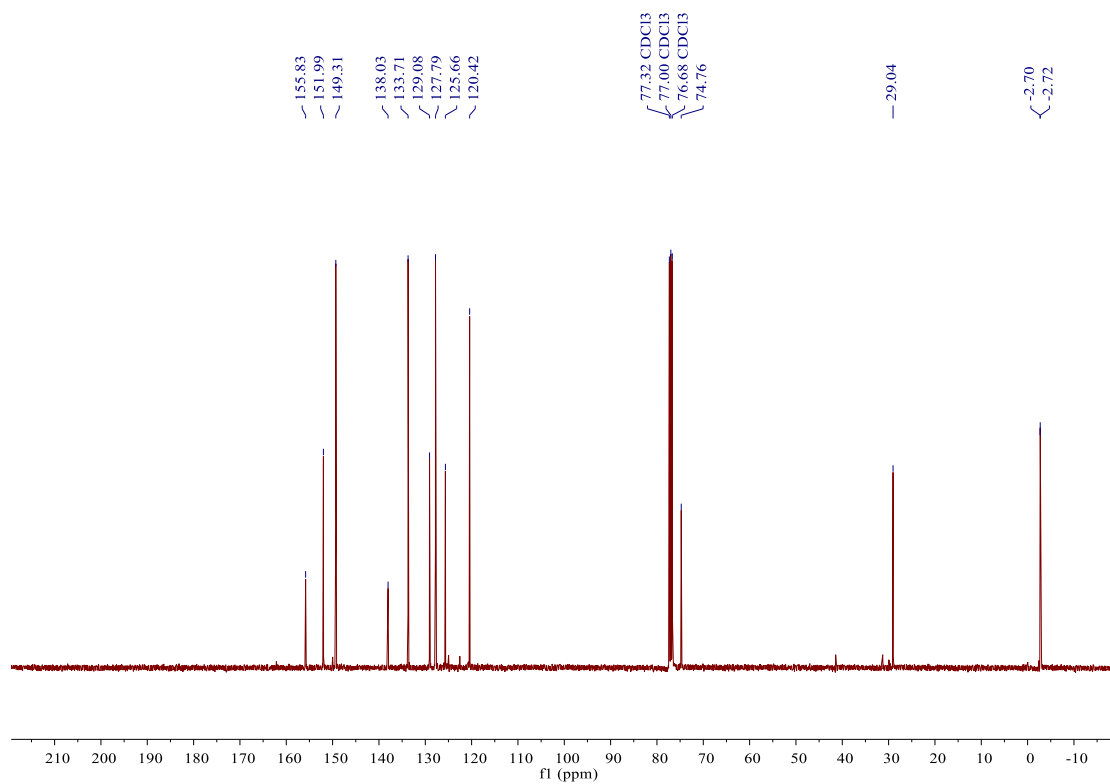
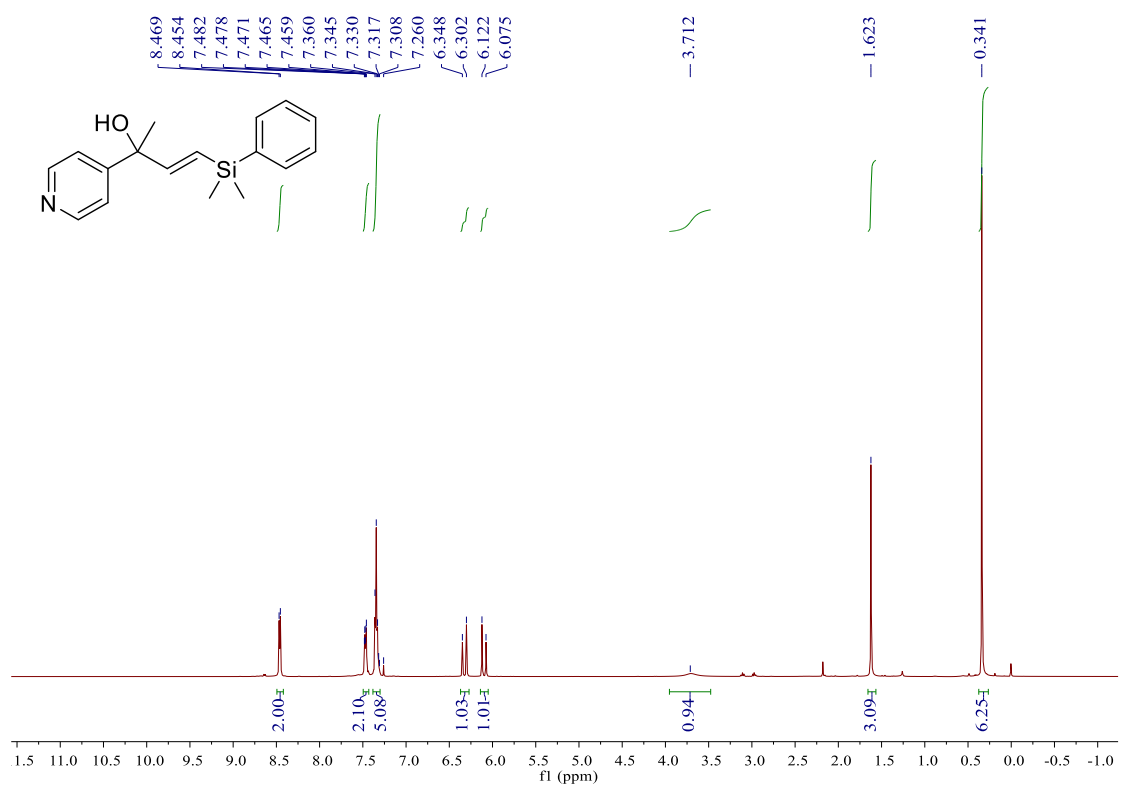


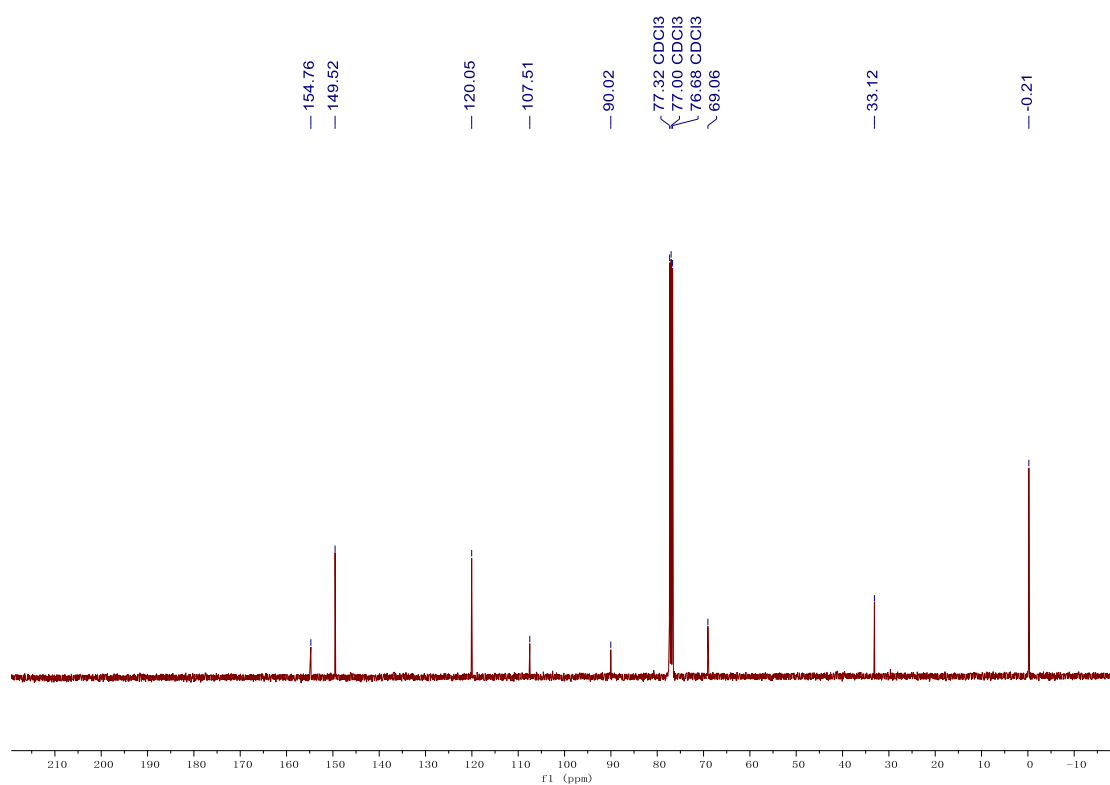
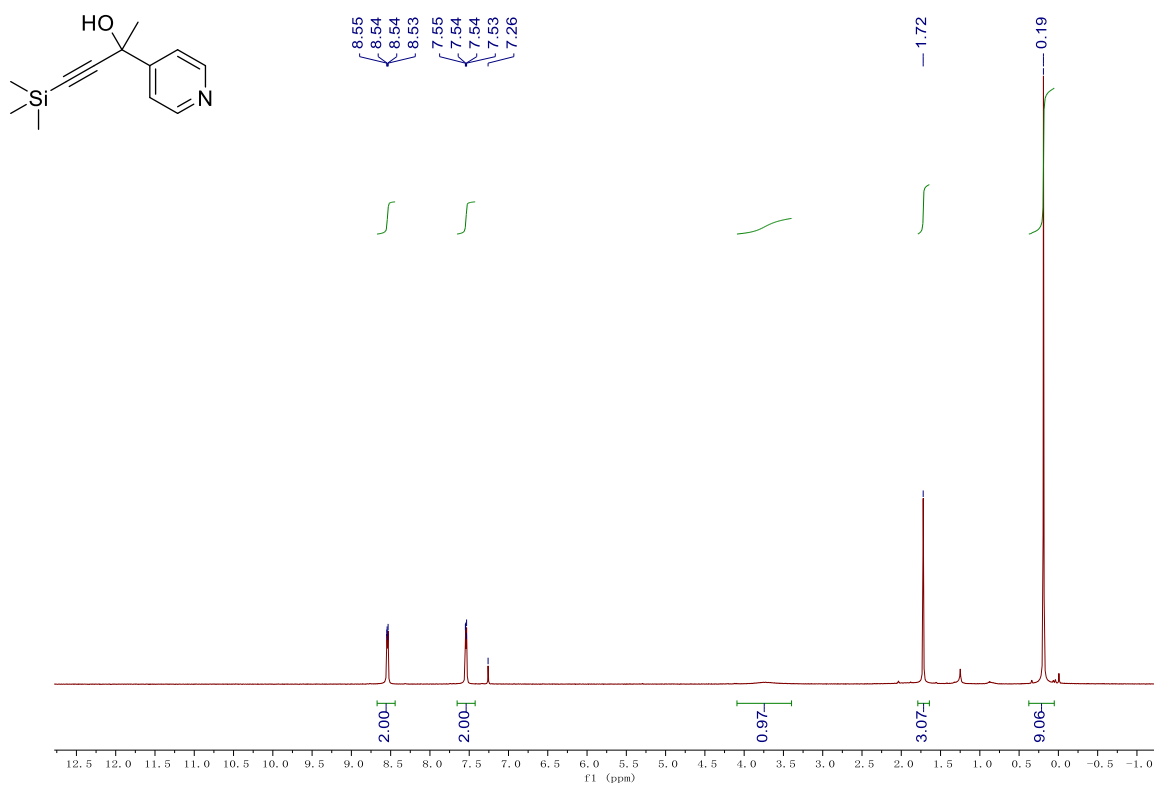


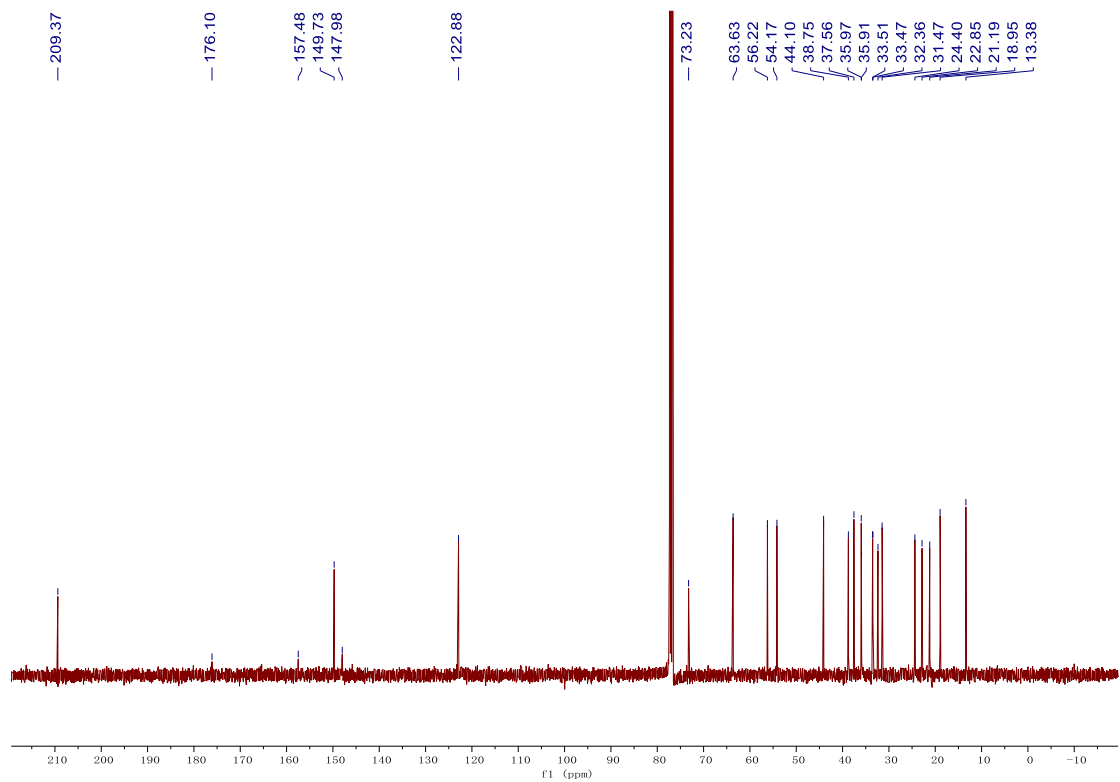
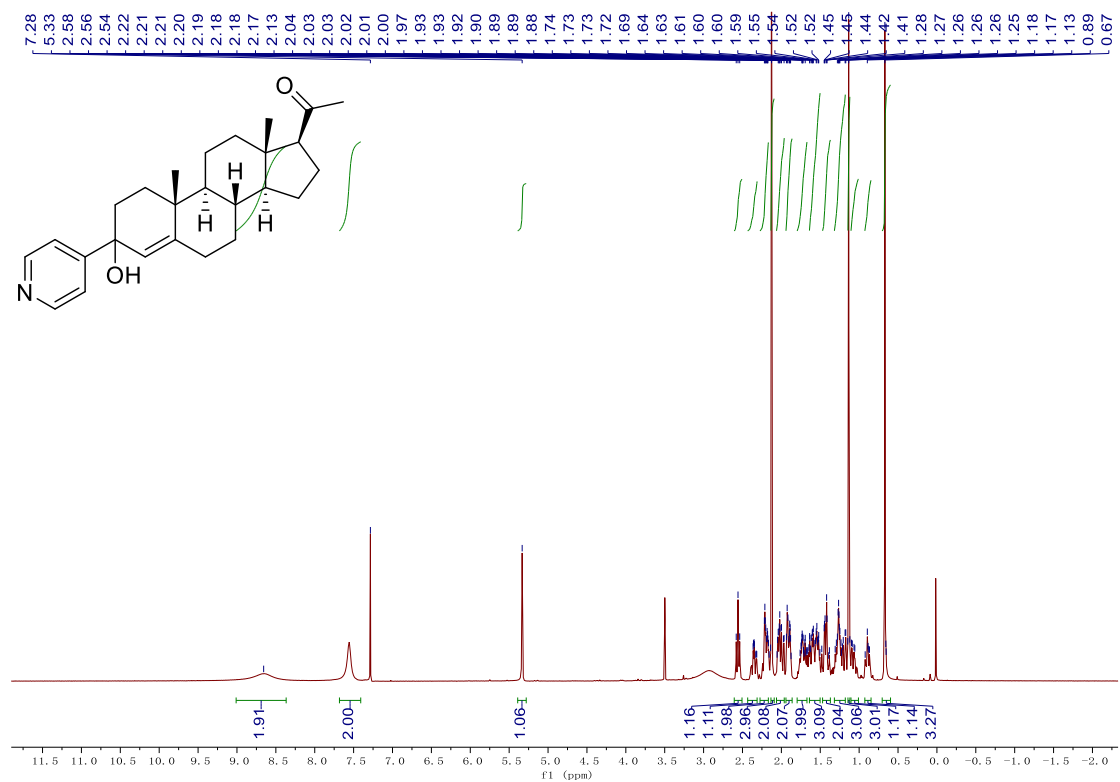


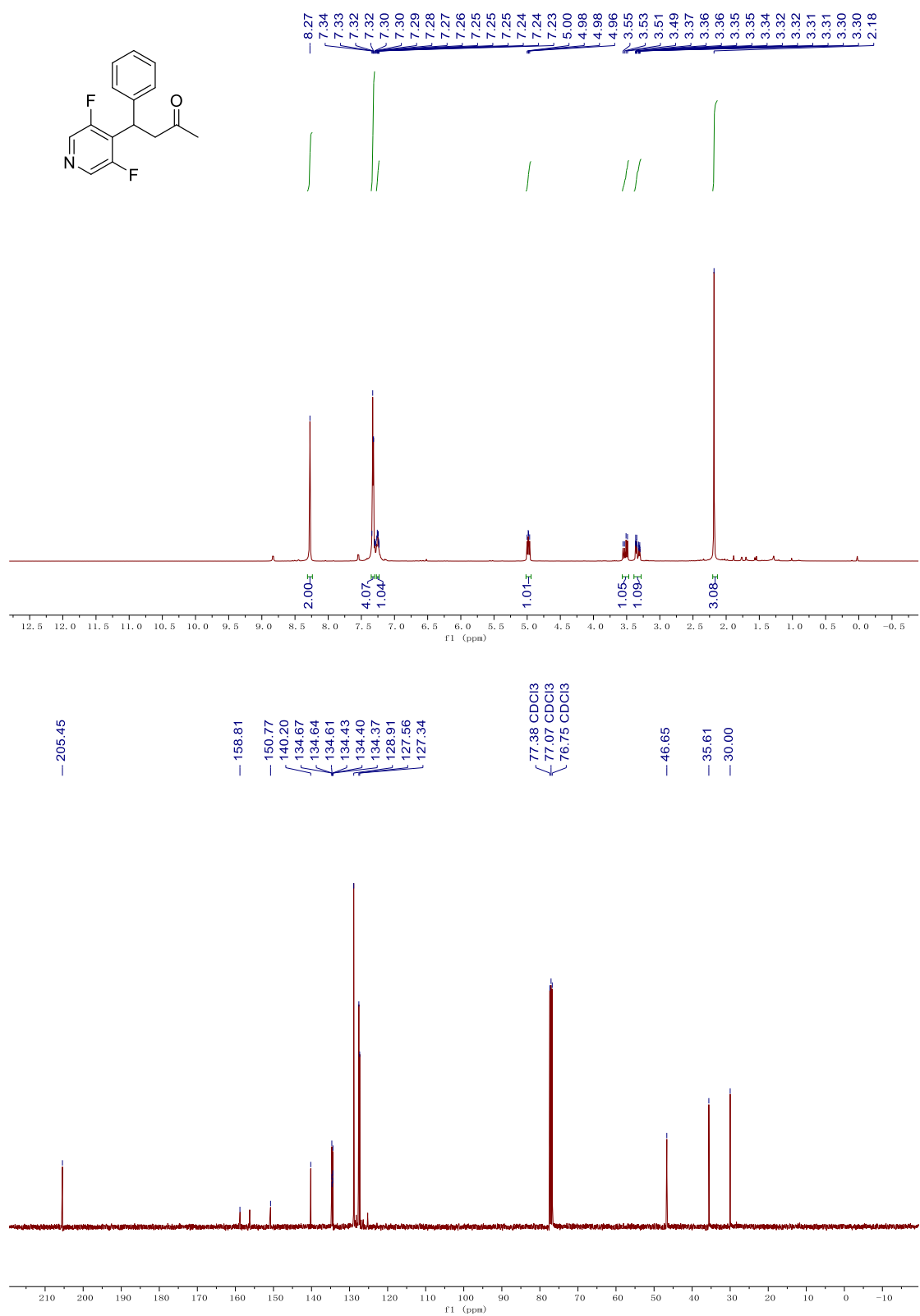


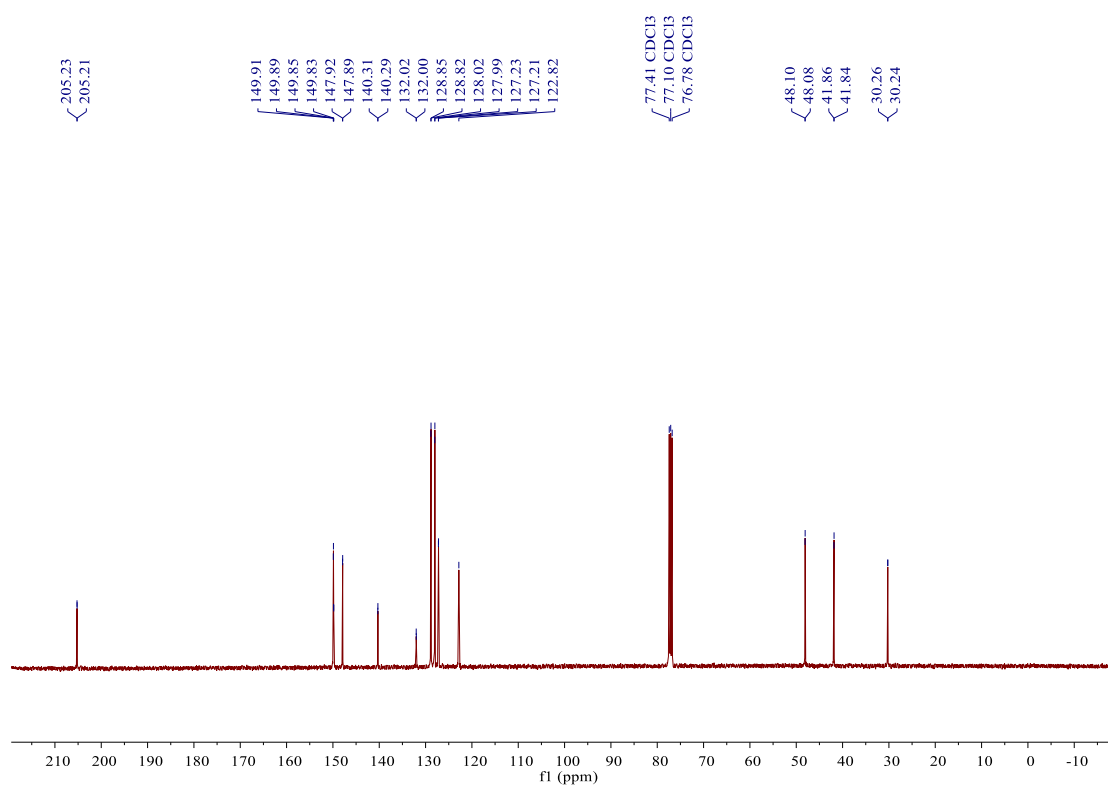
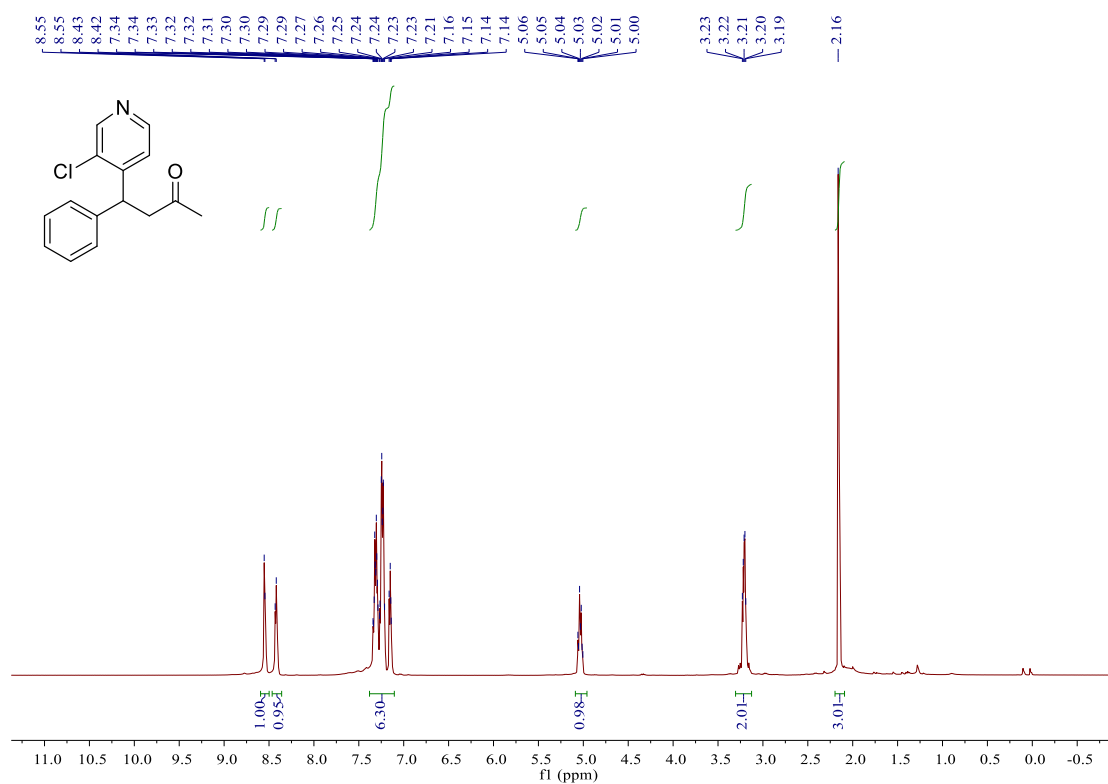


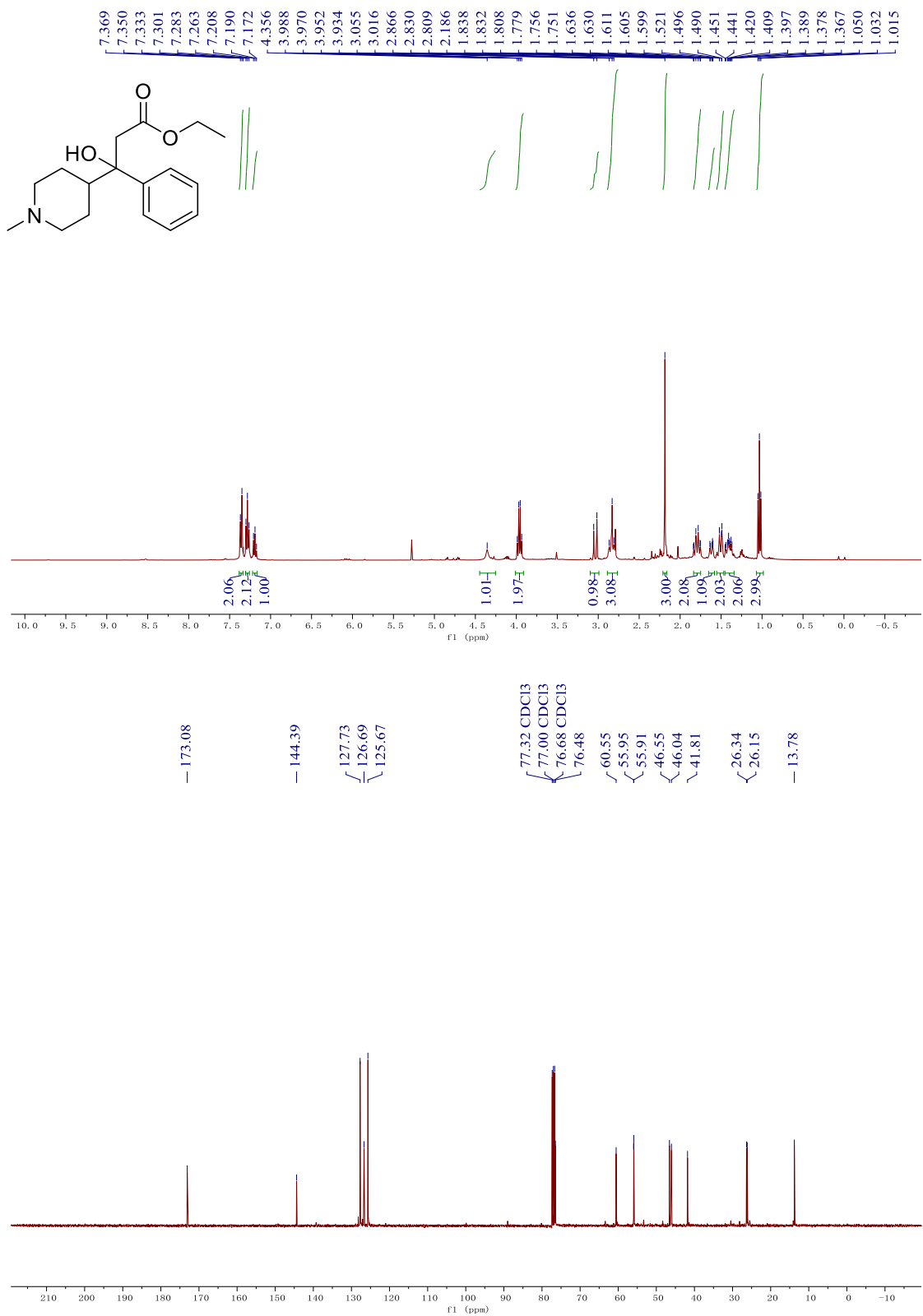




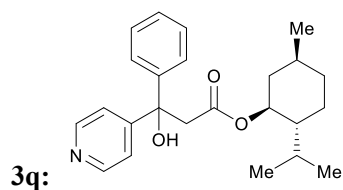




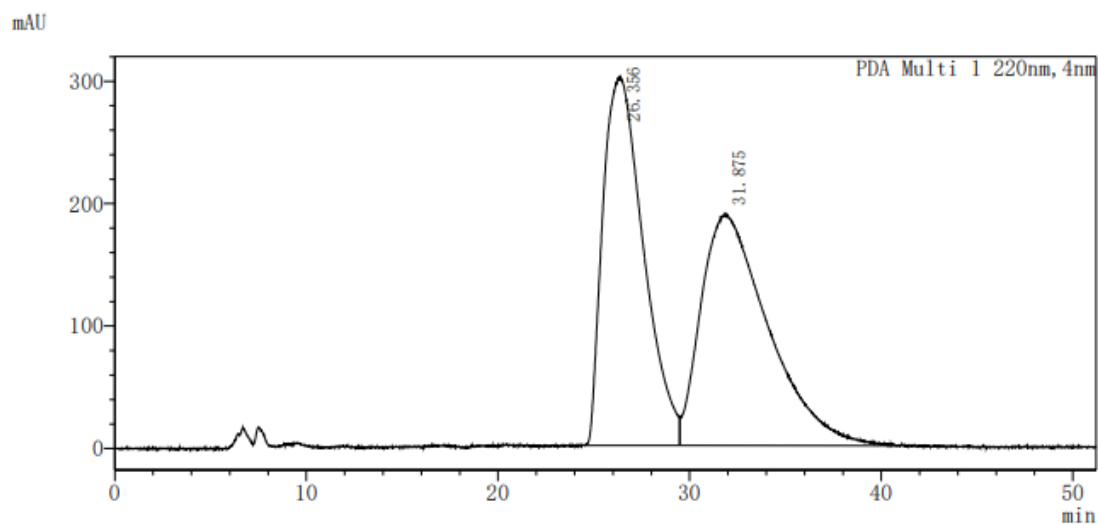




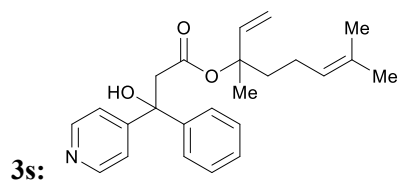
13. HPLC traces of mixture of diastereoisomers:



Diastereoisomers ratio: 49:51, determined by HPLC (Daicel Chiralpak ASH, hexane/isopropanol = 98/2, flow rate 0.5 mL/min, T = 25 °C, 220 nm): t_R = 26.35 min, t_R = 31.88 min.

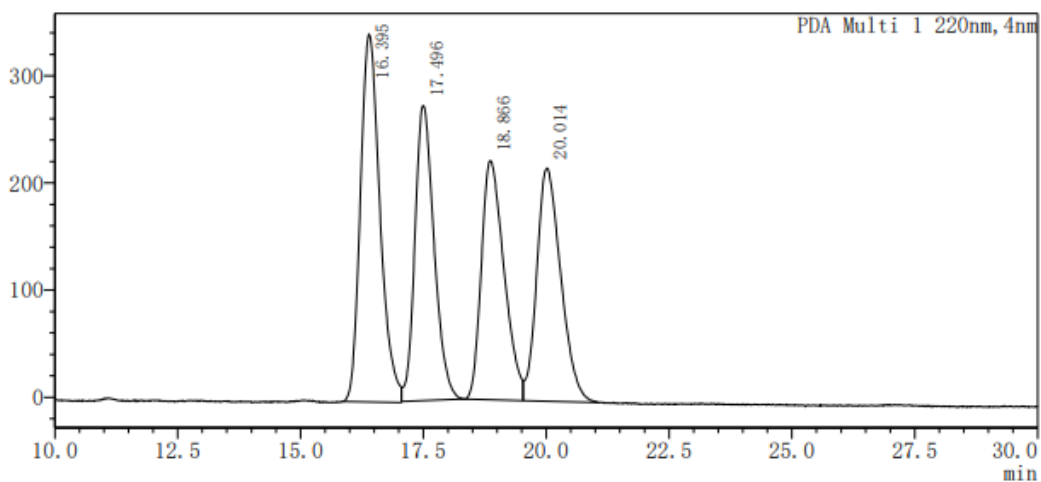


Peak	Ret Time[min]	Area[mAU*s]	Height [mAU]	Area %
1	26.356	44300633	300158	48.946
2	31.875	46208707	188678	51.054
Total		90509340	488837	100.000

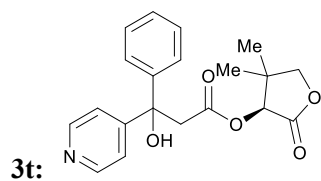


Diastereoisomers ratio: 30:24:23:23, determined by HPLC (Daicel Chiralpak ADH, hexane/isopropanol = 90/10, flow rate 0.5 mL/min, T = 25 °C, 220 nm): t_R = 16.39 min, t_R = 17.50 min, t_R = 18.87 min, t_R = 20.01 min.

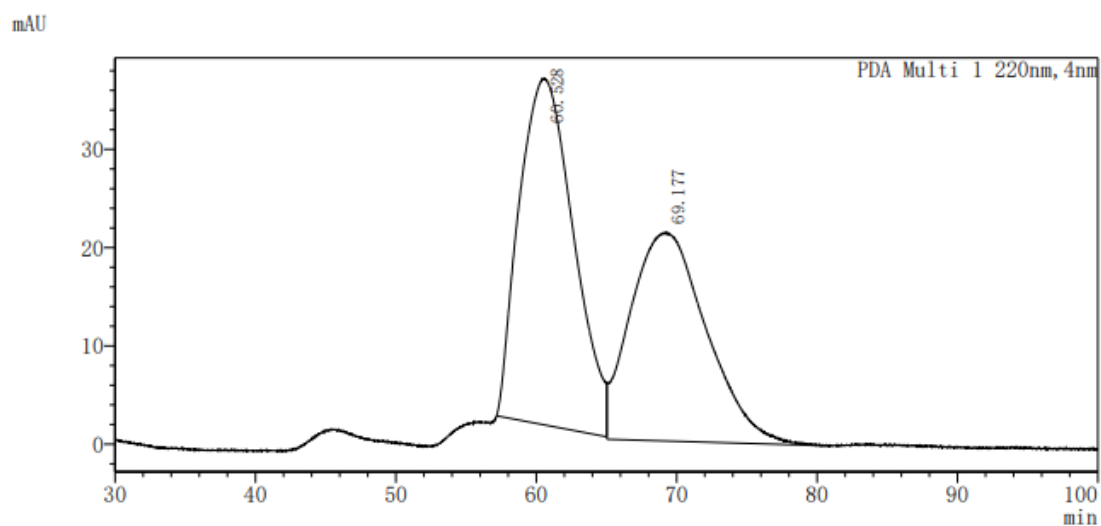
mAU



Peak	Ret Time[min]	Area[mAU*s]	Height [mAU]	Area %
1	16.395	9497180	343060	30.072
2	17.496	7472526	275105	23.661
3	18.866	7180017	223150	22.735
4	20.014	7431548	217478	23.532
Total		31581271	1058792	100.000

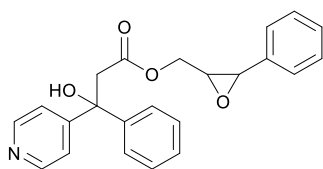


Diastereoisomers ratio: 54:46, determined by HPLC (Daicel Chiralpak ASH, hexane/isopropanol = 90/10, flow rate 0.5 mL/min, T = 25 °C, 220 nm): t_R = 60.53 min, t_R = 69.18 min.



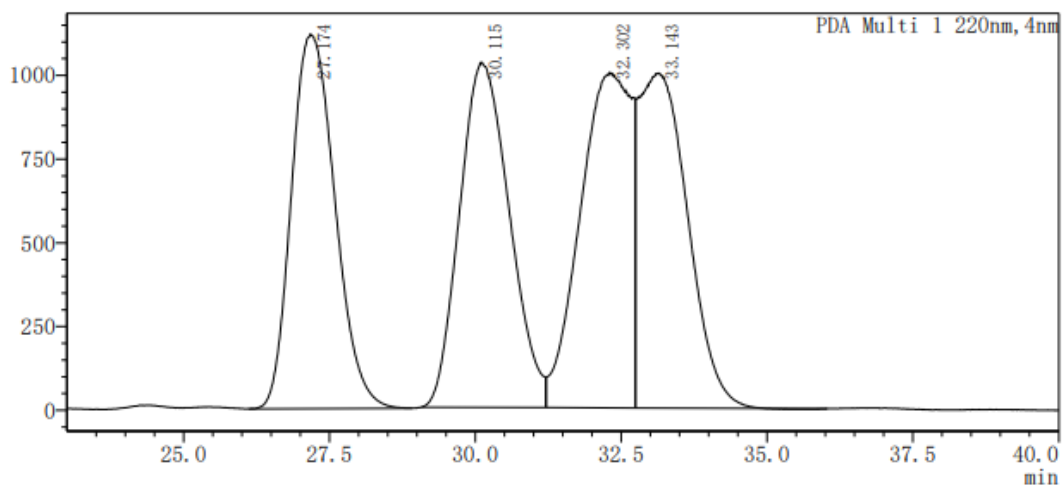
Peak	Ret Time[min]	Area[mAU*s]	Height [mAU]	Area %
1	60.528	9488549	35194	54.233
2	69.177	8007260	21147	45.767
Total		17495809	56341	100.000

3u:

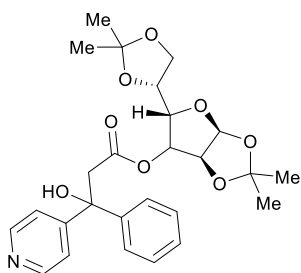


Diastereoisomers ratio: 24:26:26:24, determined by HPLC (Daicel Chiralpak ADH, hexane/isopropanol = 70/30, flow rate 0.5 mL/min, T = 25 °C, 220 nm): t_R = 27.17 min, t_R = 30.12 min, t_R = 32.30 min, t_R = 33.14 min.

mAU



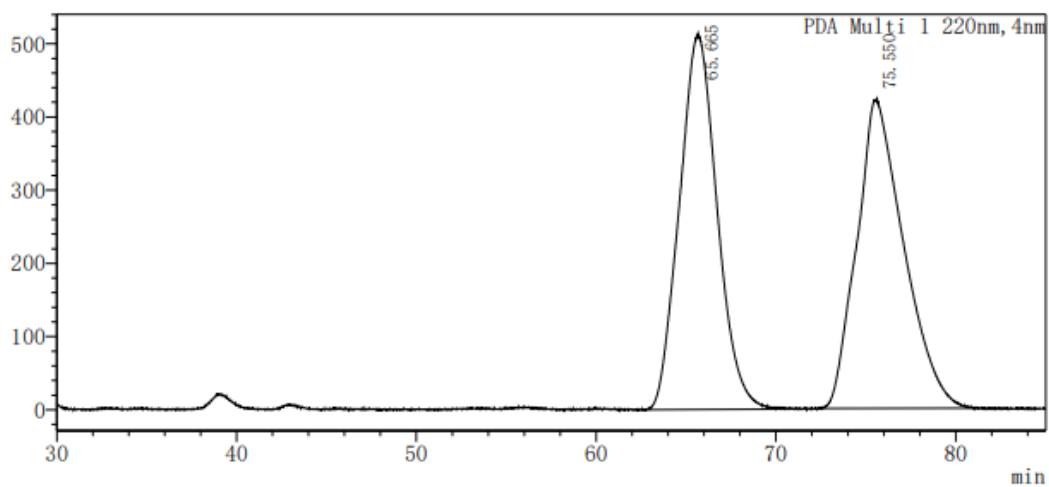
Peak	Ret Time[min]	Area[mAU*s]	Height [mAU]	Area %
1	27.174	58163075	1117478	24.391
2	30.115	61252311	1029764	25.687
3	32.302	61108079	1001399	25.626
4	33.143	57935943	1000331	24.296
Total		238459408	4148972	100.000



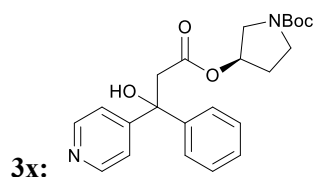
3v:

Diastereoisomers ratio: 49:51, determined by HPLC (Daicel Chiralpak ADH, hexane/isopropanol = 90/10, flow rate 0.5 mL/min, T = 25 °C, 220 nm): t_R = 65.67 min, t_R = 75.55 min.

mAU

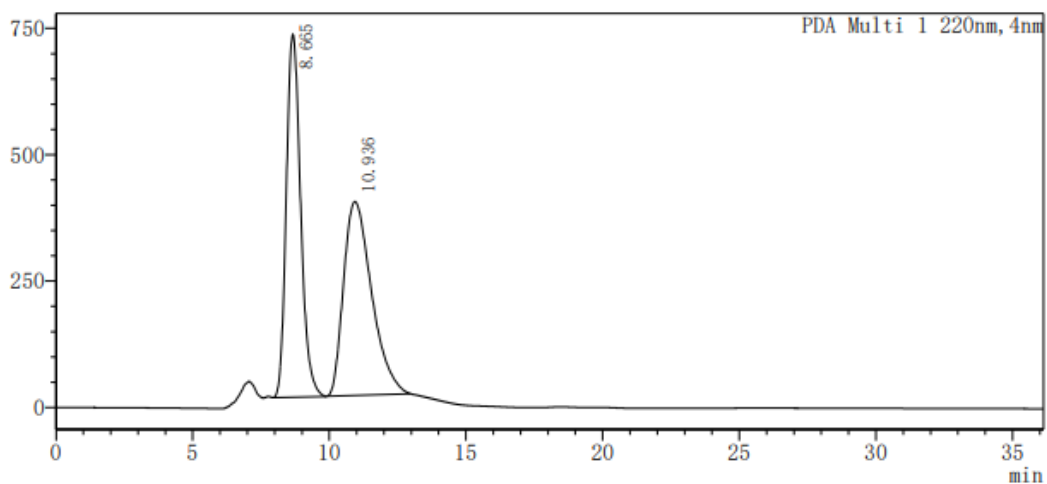


Peak	Ret Time[min]	Area[mAU*s]	Height [mAU]	Area %
1	65.665	74820936	511301	49.379
2	75.550	76703736	422524	50.621
Total		151524673	933825	100.000

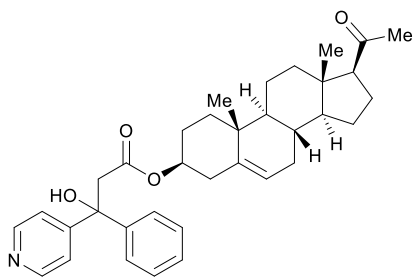


Diastereoisomers ratio: 49:51, determined by HPLC (Daicel Chiralpak ASH, hexane/isopropanol = 50/50, flow rate 0.5 mL/min, T = 25 °C, 220 nm): t_R = 8.67 min, t_R = 10.94 min.

mAU

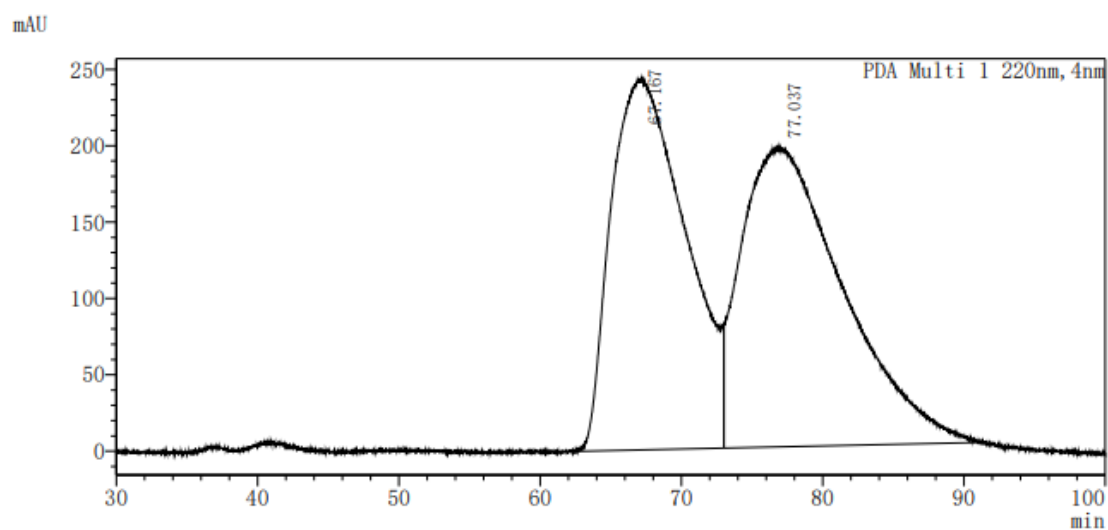


Peak	Ret Time[min]	Area[mAU*s]	Height [mAU]	Area %
1	8.665	26159562	717665	48.846
2	10.936	27395806	383387	51.154
Total		53555368	1101052	100.000

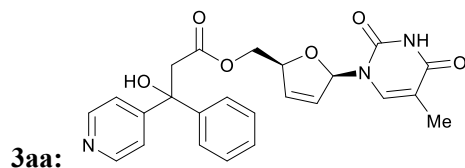


3z:

Diastereoisomers ratio: 48:52, determined by HPLC (Daicel Chiralpak OZH, hexane/isopropanol = 70/30, flow rate 0.5 mL/min, T = 25 °C, 220 nm): t_R = 67.17 min, t_R = 77.04 min.

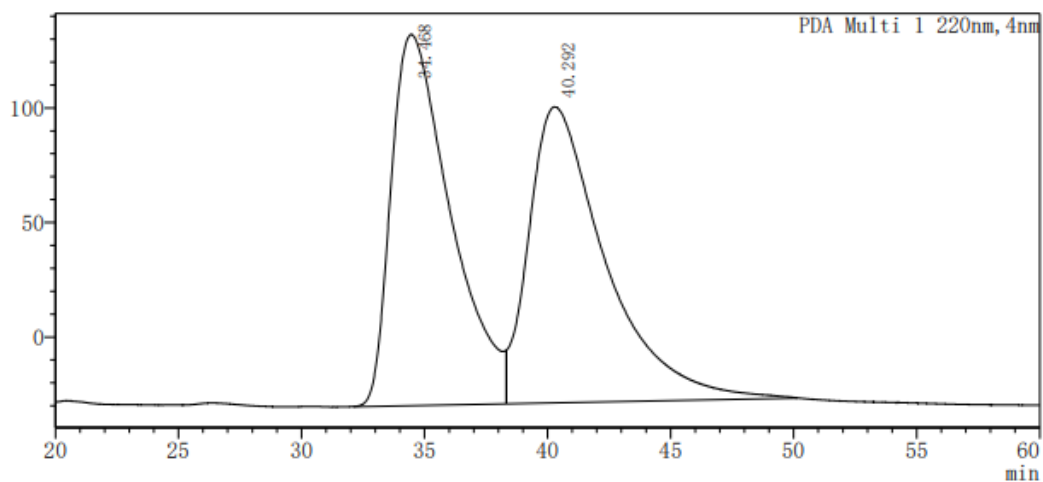


Peak	Ret Time[min]	Area[mAU*s]	Height [mAU]	Area %
1	67.167	89721553	242395	47.695
2	77.037	98393916	195983	52.305
Total		188115469	438378	100.000

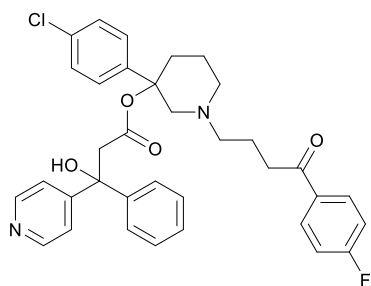


Diastereoisomers ratio: 49:51, determined by HPLC (Daicel Chiralpak ODH, hexane/isopropanol = 50/50, flow rate 0.5 mL/min, T = 25 °C, 220 nm): t_R = 34.47 min, t_R = 40.29 min.

mAU



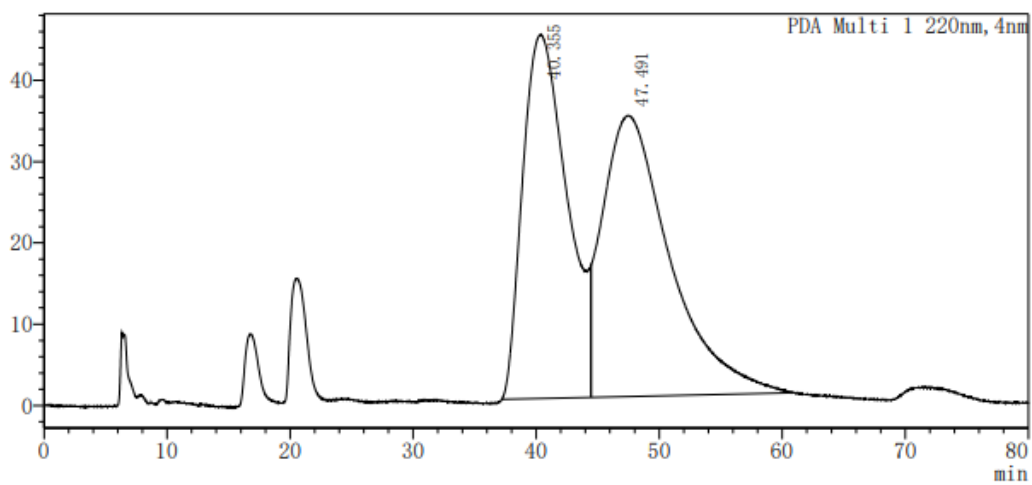
Peak	Ret Time[min]	Area[mAU*s]	Height [mAU]	Area %
1	34.468	27287258	162030	49.316
2	40.292	28044107	129127	50.684
Total		55331364	291158	100.000



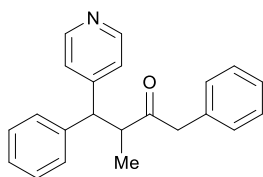
3ab:

Diastereoisomers ratio: 46:54, determined by HPLC (Daicel Chiralpak ASH, hexane/isopropanol = 85/15, flow rate 0.5 mL/min, T = 25 °C, 220 nm): t_R = 40.36 min, t_R = 47.49 min.

mAU



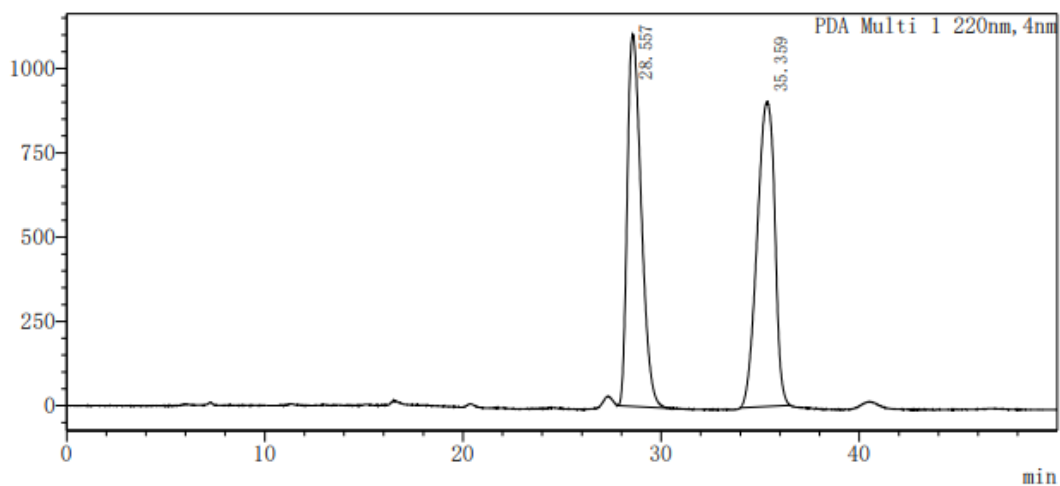
Peak	Ret Time[min]	Area[mAU*s]	Height [mAU]	Area %
1	40.355	11289526	44753	46.147
2	47.491	13175000	34572	53.853
Total		24464526	79325	100.000



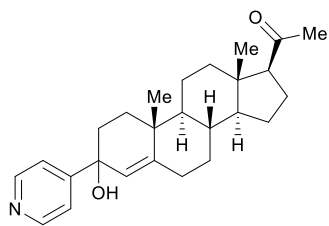
3ar:

Diastereoisomers ratio: 49:51, determined by HPLC (Daicel Chiralpak ADH, hexane/isopropanol = 90/10, flow rate 0.5 mL/min, T = 25 °C, 220 nm): t_R = 28.56 min, t_R = 35.36 min.

mAU



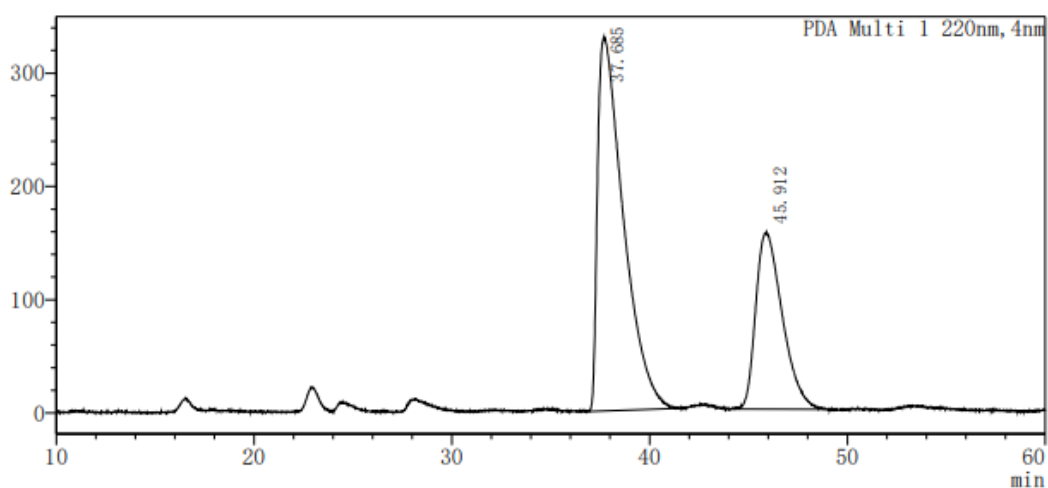
Peak	Ret Time[min]	Area[mAU*s]	Height [mAU]	Area %
1	28.557	53851770	1101927	49.031
2	35.359	55979698	903873	50.969
Total		109831468	2005800	100.000



3aw:

Diastereoisomers ratio: 67:33, determined by HPLC (Daicel Chiralpak ADH, hexane/isopropanol = 90/10, flow rate 0.5 mL/min, T = 25 °C, 220 nm): t_R = 37.69 min, t_R = 45.91 min.

mAU



Peak	Ret Time[min]	Area[mAU*s]	Height [mAU]	Area %
1	37.685	29983811	329642	67.187
2	45.912	14643620	156203	32.813
Total		44627431	485845	100.000