Electronic Supplementary Material (ESI) for Organic & Biomolecular Chemistry.

Supporting Information

Asymmetric Synthesis of 9-Alkyl Tetrahydroxanthenones via Tandem Asymmetric Michael/Cyclization Promoted by Chiral Phosphoric Acid

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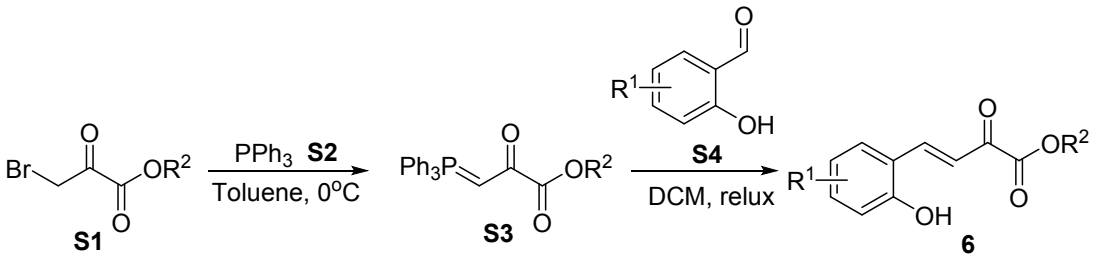
Table of Contents

1.General Information

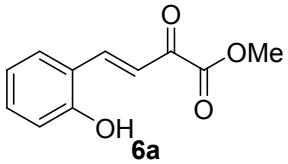
Unless otherwise noted, all reagents were obtained from commercial sources and used directly without further purification. Non-aqueous reaction was conducted under inert atmosphere of argon in flame-dried glassware. Anhydrous solvents were treated as follow: chloroform and carbon tetrachloride were distilled from phosphorus pentoxide under argon atmosphere; tetrahydrofuran and hexane were distilled from sodium under argon atmosphere; dichloromethane and toluene were distilled from calcium hydride under argon atmosphere. Anhydrous 1,2-dichloroethane and acetonitrile (Adamas-beta, SafeDry, with molecular sieves) were commercial available. Thin layer chromatography was conducted on Merck 60 F254 pre-coated silica gel plates. Column chromatography was carried out by normal silica gel (40-60 μm, 200-400 mesh, Silicycle P60). NMR data including ^{1}H NMR or ^{13}C NMR spectra were recorded on Bruker AVANCE III 500MHz. All of the ^{13}C NMR spectra were broad band proton-decoupled. ^{1}H NMR Chemical shifts were reported in ppm relative to residual signals of the solvents ($CDCl_3$: 7.26 ppm; $(CD_3)_2CO$: 2.09 ppm; $(CD_3)_2SO$: 2.54 ppm). ^{13}C NMR chemical shifts were reported in ppm relative to the solvent ($CDCl_3$:77.36 ppm; $(CD_3)_2CO$: 30.6 ppm; $(CD_3)_2SO$: 40.45 ppm). Multiplicities are reported using the following abbreviations: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad resonance. Chiral HPLC analyses were performed on Waters 2487 Series using Daicel Chiralpak (AD-H, OD-H and IE-3) column with hexane/*i*PrOH as the eluent. Optical rotations were measured on Anton Paar MCP 300 polarimeter. High resolution mass spectra were obtained from IonSpec 4.7 Tesla FTMS mass spectrometer (MALDI), Bruker APEXIII 7.0 TESLA FTMS (ESI). Photoirradiation was carried out with 24 W blue LED.

2. General Procedure for Synthesis of (*E*)-2-Hydroxyaryl-2-Oxobut-3-Enoate[1][2].



To a violent stirred solution of triphenyl phosphine **S2** (1.0 eqviu., 30 mmol) in toluene (15 mL) was added dropwise a solution of methyl bromopyruvate **S1** (1.0 eqiuv., 30 mmol) in toluene (20 mL) over 30 min at 0 °C. After the mixture was stirred at 0 °C for 48 h, the supernatant was decanted liquid and the solid is washed with Et_2O. The resulting solid is dissolved in MeOH (30 mL) and aqueous sodium carbonate (1 M) was then added to the solution until pH reached 10. The mixture was diluted to 100 mL by adding ice water and the solid was collected. It was then dissolved in CH_2Cl_2 and dried with Na_2SO_4. The solution was concentrated by rotary evaporator to afford the wittig reagent as a white solid **S3**.

Phosphoris ylide (**S3**, 1.0 equiv., 10 mmol), salicylaldehyde **S4** (1.2 equiv., 12 mmol) and CH_2Cl_2 (1 M) were added to a reaction tube equipped with a magnetic stir bar and the mixture stirred at 40 °C for 4 d. The solvent was concentrated by rotary evaporator and the residue was purified by column chromatography on silica gel (EtOAc/petroleum ether = 1: 5) to provide the desired product **6**.



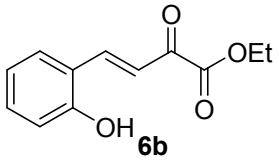
6a

Following the general procedure, compound **6a** was isolated as a yellow solid in 26% yield (two steps, 727 mg).

^{1}H NMR (500 MHz, $(CD_3)_2CO$): δ 9.38 (s, 1H), 8.14 (d, *J* = 16.3 Hz, 1H), 7.74 (d, *J* = 7.8 Hz, 1H), 7.44 (d, *J* = 16.4 Hz, 1H), 7.38 (t, *J* = 8.0 Hz, 1H), 7.05 (d, *J* = 8.3 Hz, 1H), 6.98 (t, *J* = 7.8 Hz, 1H), 3.93 (s, 3H).

^{13}CNMR (126MHz, $(CD_3)_2CO$): δ 185.58, 165.11, 159.20, 145.26, 134.62, 131.29, 122.84, 122.81, 121.88, 118.07, 53.66.

HRMS (ESI): exact mass calcd for $C_{11}H_9O_4$: m/z 205.0501 $[M-H]^-$, found: m/z 205.0506.



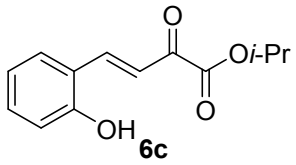
6b

Following the general procedure, compound **6b** was isolated as a yellow solid in 22% yield (two steps, 645 mg).

^{1}H NMR (500 MHz, $(CD_3)_2CO$): δ 9.43 (s, 1H), 8.14 (d, *J* = 16.4 Hz, 1H), 7.74 (dd, *J* = 7.9, 1.7 Hz, 1H), 7.42 (d, *J* = 16.3 Hz, 1H), 7.40 – 7.35 (m, 1H), 7.05 (d, *J* = 8.2 Hz, 1H), 6.98 (t, *J* = 7.6 Hz, 1H), 4.40 (q, *J* = 7.1 Hz, 2H), 1.39 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (126 MHz, $(CD_3)_2CO$): δ 186.04, 164.74, 159.15, 145.20, 134.59, 131.15, 122.78, 121.83, 118.02, 63.30, 15.09.

HRMS (ESI): exact mass calcd for $C_{12}H_{11}O_4$: m/z 219.0657 [M-H]$^-$, found: m/z 219.0663.



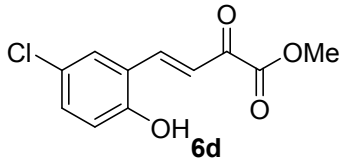
6c

Following the general procedure, compound **6c** was isolated as a yellow solid in 22% yield (two steps, 679 mg).

^{1}H NMR (500 MHz, $(CD_3)_2CO$): δ 9.37 (s, 1H), 8.14 (d, *J* = 16.2 Hz, 1H), 7.74 (d, *J* = 7.8 Hz, 1H), 7.40 – 7.32 (m, 2H), 7.05 (d, *J* = 8.2 Hz, 1H), 6.98 (t, *J* = 7.8 Hz, 1H), 5.29 – 5.18 (m, 1H), 1.40 (d, *J* = 5.7 Hz, 6H).

^{13}C NMR (126 MHz, $(CD_3)_2CO$): δ 186.61, 164.53, 159.10, 145.21, 134.59, 131.01, 122.93, 121.87, 118.04, 71.45, 22.61.

HRMS (ESI): exact mass calcd for $C_{13}H_{13}O_4$: m/z 233.0814 [M-H]$^-$, found: m/z 233.0819.



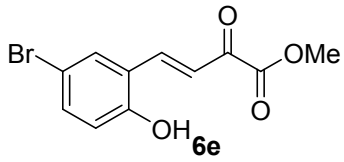
6d

Following the general procedure, compound **6d** was isolated as a yellow solid in 25% yield (two steps, 803 mg).

^{1}H NMR (500 MHz, $(CD_3)_2CO$): δ 9.69 (s, 1H), 8.06 (d, *J* = 16.4 Hz, 1H), 7.79 (d, *J* = 2.6 Hz, 1H), 7.51 (d, *J* = 16.3 Hz, 1H), 7.37 (dd, *J* = 8.7, 2.6 Hz, 1H), 7.07 (d, *J* = 8.7 Hz, 1H), 3.93 (s, 3H).

^{13}C NMR (126 MHz, $(CD_3)_2CO$): δ 185.31, 164.73, 157.79, 143.39, 133.87, 130.32, 126.18, 124.37, 123.96, 119.62, 53.75.

HRMS (ESI): exact mass calcd for $C_{11}H_8ClO_4$: m/z 239.0111 [M-H]$^-$, found: m/z 239.0117.



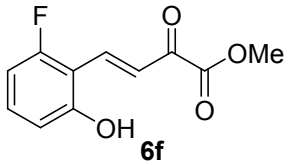
6e

Following the general procedure, compound **6e** was isolated as a yellow solid in 27% yield (two steps, 1.03 g).

^{1}H NMR (500 MHz, $(CD_3)_2CO$): δ 9.69 (s, 1H), 8.04 (d, *J* = 16.4 Hz, 1H), 7.91 (s, 1H), 7.54 – 7.46 (m, 2H), 7.02 (d, *J* = 8.5 Hz, 1H), 3.93 (s, 3H).

^{13}C NMR (126 MHz, $(CD_3)_2CO$): δ 185.35, 164.77, 158.26, 143.34, 136.75, 133.36, 125.01, 124.03, 120.07, 113.29, 53.75.

HRMS (ESI): exact mass calcd for $C_{11}H_8BrO_4$: m/z 282.9606 [M-H]$^-$, found: m/z 282.9611.



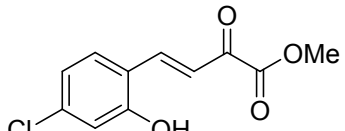
6f

Following the general procedure, compound **6f** was isolated as a yellow solid in 20% yield (two steps, 605 mg).

^{1}H NMR (500 MHz, $(CD_3)_2CO$): δ 9.96 (s, 1H), 8.08 (d, *J* = 16.5 Hz, 1H), 7.70 (d, *J* = 16.5 Hz, 1H), 7.42 – 7.34 (m, 1H), 6.90 (d, *J* = 8.3 Hz, 1H), 6.82 – 6.75 (m, 1H), 3.93 (s, 3H).

^{13}C NMR (126 MHz, $(CD_3)_2CO$): δ 185.44 , 164.71 , 164.60 (d, *J* = 251.9 Hz), 160.57 (d, *J* = 6.3 Hz), 137.74 (d, *J* = 3.8 Hz), 134.67 (d, *J* = 12.0 Hz), 125.92 (d, *J* = 9.0 Hz), 113.81 (d, *J* = 3.1 Hz), 112.08 (d, *J* = 13.0 Hz), 108.42 (d, *J* = 22.8 Hz), 53.75 .

HRMS (ESI): exact mass calcd for $C_{11}H_8FO_4$: m/z 223.0407 $[M-H]^-$, found: m/z 223.0412.



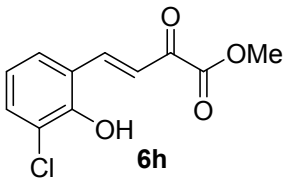
6g

Following the general procedure, compound **6g** was isolated as a yellow solid in 29% yield (two steps, 945 mg).

^{1}H NMR (500 MHz, $(CD_3)_2CO$): δ 9.86 (s, 1H), 8.06 (d, *J* = 16.3 Hz, 1H), 7.77 (d, *J* = 8.4 Hz, 1H), 7.46 (d, *J* = 16.3 Hz, 1H), 7.08 (d, *J* = 2.1 Hz, 1H), 7.02 (dd, *J* = 8.4, 2.1 Hz, 1H), 3.92 (s, 3H).

^{13}C NMR (126 MHz, $(CD_3)_2CO$): δ 185.24, 164.83, 159.68, 143.72, 139.10, 132.58, 123.21, 122.11, 121.96, 117.91, 53.71.

HRMS (ESI): exact mass calcd for $C_{11}H_8ClO_4$: m/z 239.0111 $[M-H]^-$, found: m/z 239.0117.



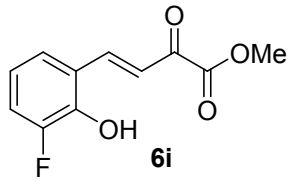
6h

Following the general procedure, compound **6h** was isolated as a yellow solid in 21% yield (two steps, 669 mg).

^{1}H NMR (500 MHz, $(CD_3)_2CO$): δ 9.03 (s, 1H), 8.14 (d, *J* = 16.3 Hz, 1H), 7.76 (dd, *J* = 7.9, 1.5 Hz, 1H), 7.55 (dd, *J* = 7.9, 1.5 Hz, 1H), 7.48 (d, *J* = 16.3 Hz, 1H), 7.04 (t, *J* = 7.9 Hz, 1H), 3.93 (s, 3H).

^{13}C NMR (126 MHz, $(CD_3)_2CO$): δ 185.11, 164.66, 154.02, 143.79, 133.94, 129.71, 125.06, 124.12, 123.17, 122.75, 53.78.

HRMS (ESI): exact mass calcd for $C_{11}H_8ClO_4$: m/z 239.0111 $[M-H]^-$, found: m/z 239.0117.



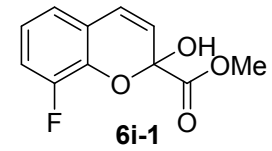
6i

Following the general procedure, compound **6i** was obtained together with the hemiketal **6i-1**, which was hardly eliminated, as a yellow solid in 50% yield (two steps, 1.48 g, **6i**:**6i-1** = 2:1).

^{1}H NMR (500 MHz, $(CD_3)_2CO$): δ 9.57 (s, 1H), 8.12 (d, *J* = 16.4 Hz, 1H), 7.59 (d, *J* = 7.9 Hz, 1H), 7.51 (d, *J* = 16.4 Hz, 1H), 7.34 – 7.28 (m, 1H), 7.03 – 6.96 (m, 1H), 3.93 (s, 3H).

^{13}C NMR (126 MHz, $(CD_3)_2CO$): δ 185.21 , 164.70 , 153.52 (d, *J* = 238.3 Hz), 146.61 (d, *J* = 15.7 Hz), 143.53 (d, *J* = 3.9 Hz), 126.45 (d, *J* = 3.3 Hz), 125.45 (d, *J* = 2.9 Hz), 123.97 , 121.58 (d, *J* = 7.2 Hz), 119.79 (d, *J* = 18.7 Hz), 53.77 .

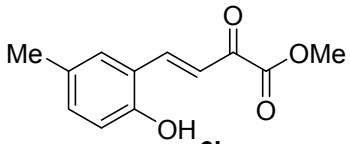
HRMS (ESI): exact mass calcd for $C_{11}H_8FO_4$: m/z 223.0407 [M-H]$^-$, found: m/z 223.0412.



6i-1

^{1}H NMR (500 MHz, $(CD_3)_2CO$): δ 7.18 – 7.10 (m, 2H), 6.99 – 6.96 (overlapped, 1H), 6.93 (dd, *J* = 9.9, 1.8 Hz, 1H), 6.84 (s, 1H), 6.10 (d, *J* = 9.9 Hz, 1H), 3.86 (s, 3H).

^{13}C NMR (126 MHz, $(CD_3)_2CO$): δ170.05, 152.43 (d, *J* = 244.5 Hz), 140.07 (d, *J* = 11.0 Hz), 126.80 (d, *J* = 3.6 Hz), 124.00 (d, *J* = 3.3 Hz), 123.64 (d, *J* = 2.4 Hz), 123.57, 123.10 (d, *J* = 7.1 Hz), 117.86 (d, *J* = 18.2 Hz), 95.74, 54.17.



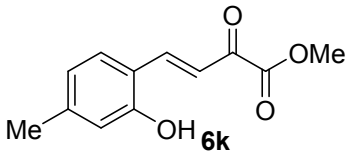
6j

Following the general procedure, compound **6j** was isolated as a yellow solid in 29% yield (two steps, 851 mg).

^{1}H NMR (500 MHz, $(CD_3)_2CO$): δ 9.16 (s, 1H), 8.12 (d, *J* = 16.3 Hz, 1H), 7.55 (s, 1H), 7.41 (d, *J* = 16.3 Hz, 1H), 7.19 (d, *J* = 8.0 Hz, 1H), 6.94 (d, *J* = 8.3 Hz, 1H), 3.93 (s, 3H), 2.31 (s, 3H).

^{13}C NMR (126 MHz, $(CD_3)_2CO$): δ 185.58, 165.17, 157.15, 145.40, 135.43, 131.16, 130.90, 122.48, 117.97, 53.63, 21.05.

HRMS (ESI): exact mass calcd for $C_{12}H_{11}O_4$: m/z 219.0657 [M-H]$^-$, found: m/z 219.0663.



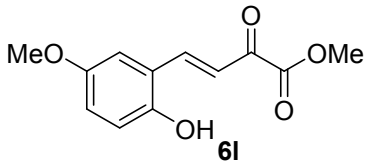
6k

Following the general procedure, compound **6k** was isolated as a yellow solid in 32% yield (two steps, 929 mg).

^{1}H NMR (500 MHz, $(CD_3)_2CO$): δ 9.33 (s, 1H), 8.11 (d, *J* = 16.3 Hz, 1H), 7.62 (d, *J* = 8.0 Hz, 1H), 7.39 (d, *J* = 16.3 Hz, 1H), 6.87 (s, 1H), 6.81 (d, *J* = 8.0 Hz, 1H), 3.92 (s, 3H), 2.33 (s, 3H).

^{13}C NMR (126 MHz, $(CD_3)_2CO$): δ 185.49, 165.19, 159.20, 145.76, 145.39, 131.25, 122.95, 121.63, 120.18, 118.43, 53.60, 22.34.

HRMS (ESI): exact mass calcd for $C_{12}H_{11}O_4$: m/z 219.0657 [M-H]$^-$, found: m/z 219.0663.



6l

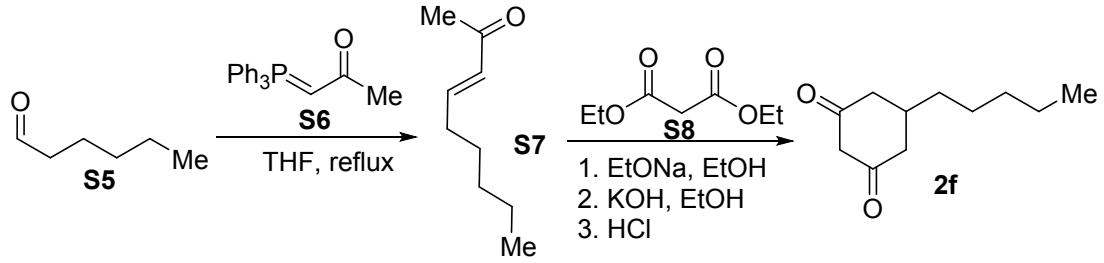
Following the general procedure, compound **6l** was isolated as a yellow solid in 24% yield (two steps, 755 mg).

^{1}H NMR (500 MHz, $(CD_3)_2CO$): δ 9.01 (s, 1H), 8.14 (d, *J* = 16.3 Hz, 1H), 7.43 (d, *J* = 16.3 Hz, 1H), 7.30 (s, 1H), 7.02 – 6.95 (m, 2H), 3.92 (s, 3H), 3.83 (s, 3H).

^{13}C NMR (126 MHz, $(CD_3)_2CO$): δ 185.54, 165.08, 154.91, 153.42, 145.08, 122.82, 122.65, 121.96, 119.00, 113.60, 56.77, 53.66.

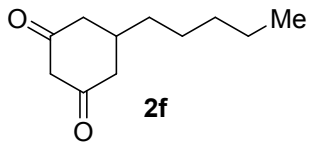
HRMS (ESI): exact mass calcd for $C_{12}H_{11}O_5$: m/z 235.0606 [M-H]$^-$, found: m/z 235.0612.

3. Procedure for the Synthesis of Cyclic 1,3-Dione[3]



To a mixture of aldehyde **S5**(10 mmol, 1.00g) and methylcarbonylmethylenephosphorane (**S6**) (12 mmol, 3.82g) was added THF (50 mL) and the solution was then refluxed for 48 h under argon. After aldehyde was consumed completely, the mixture was cooled to room temperature and concentrated in vacuo. The residue was purified by column chromatography on silica gel to yield the desired product **S7** (996 mg, 71%).

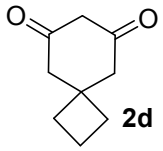
To EtOH (30 mL) was added sodium metal (326 mg, 14.2 mmol) at room temperature under argon. After the sodium was dissolved completely, **S8** (2.27g, 14.2 mmol) was added to the solution of EtONa, followed by addition of **S7** (996 mg, 7.1 mmol) at room temperature. The mixture was heated to reflux for 24 h reflux and then cooled to room temperature. After a solution of KOH (4.5 g, 80 mmol) in H_2O (20 mL) was added, the resulting mixture was heated to reflux for 48 h. Thereafter, the mixture was acidified with 6 N HCl to pH 3 at 0 °C and evaporated under reduced pressure. The aqueous residue was extracted with EtOAc (3 x 80 mL) and the organic extracts were washed with brine and dried over Na_2SO_4. The solvent was removed by rotary evaporator and the residue was purified by column chromatography to yield **2f** (594 mg, 46%) as a white solid.



^{1}H NMR (500 MHz, $CDCl_3$): δ 3.37 (s, 2H), 2.73 (dd, *J* = 15.6, 4.3 Hz, 2H), 2.36 (dd, *J* = 15.4, 10.2 Hz, 2H), 2.09 – 2.01 (m, 1H), 1.40 – 1.26 (m, 8H), 0.88 (t, *J* = 6.8 Hz, 3H).

^{13}C NMR (126 MHz, $CDCl_3$): δ 204.03, 58.33, 46.76, 35.57, 31.92, 31.03, 26.61, 22.83, 14.30.

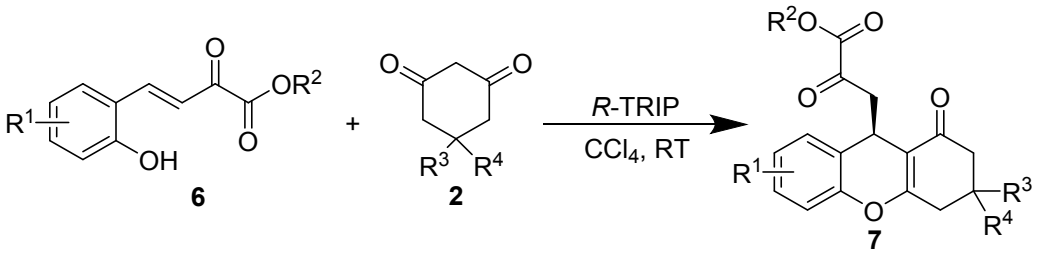
HRMS (ESI): exact mass calcd for $C_{11}H_{18}O_2$: m/z 183.1385 $[M+H]^+$, found: m/z 183.1380.



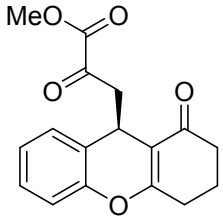
2d were prepared according to the reference[3].

^{1}H NMR (500 MHz, $(CD_3)_2SO$): δ 11.04 (s, 1H), 5.20 (s, 1H), 2.40 (s, 4H), 1.94 – 1.84 (m, 2H), 1.84 – 1.70 (m, 4H).

4. General Procedure for the Synthesis of 9-Substituted Tetrahydroxanthenones



(*E*)-2-hydroxyaryl-2-oxobut-3-enoate **6**(0.1 mmol), 1,3-cyclo-dione **2**(0.12 mmol), *R*-TRIP (0.01 mmol, 7.5 mg) and CCl_4(3.0 mL) were added to a reaction tube equipped with a magnetic stir bar. The mixture was stirred at room temperature under argon overnight and monitored by TLC. The solvent was removed by rotary evaporator and the residue was directly purified by column chromatography on silica gel (EtOAc/petroleum ether = 1: 5) to yield the desired products.



According to the general procedure, compound **7a** was prepared as a yellowish solid in 98% yield (29.4 mg).

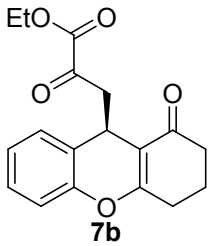
$[\alpha]_D^{25}$ = -69.06 (c 0.488, CH_2Cl_2)

Enantiomeric excess was found to be 92% by chiral HPLC (ChiralPak AD-H column, hexane/i-PrOH = 9: 1, 214 nm, 1.0 mL/min, tmajor = 14.42 min, tminor = 16.55 min).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.33 (d, *J* = 7.6 Hz, 1H), 7.23 – 7.17 (m, 1H), 7.15 – 7.09 (m, 1H), 7.01 (d, *J* = 7.6 Hz, 1H), 4.41 (t, *J* = 6.1 Hz, 1H), 3.86 (s, 3H), 3.28 (dd, *J* = 15.4, 5.1 Hz, 1H), 2.90 (dd, *J* = 15.3, 7.0 Hz, 1H), 2.67 (dt, *J* = 17.7, 5.3 Hz, 1H), 2.61 – 2.53 (m, 1H), 2.46 (dt, *J* = 16.7, 5.3 Hz, 1H), 2.40 – 2.31 (m, 1H), 2.09 – 2.01 (m, 2H).

^{13}C NMR (126 MHz, $CDCl_3$): δ 198.20, 191.28, 168.70, 161.39, 150.30, 129.44, 128.43, 125.54, 124.39, 116.85, 112.64, 53.28, 48.85, 37.07, 28.67, 28.22, 20.71.

HRMS (ESI): exact mass calcd for $C_{17}H_{16}NaO_5$: m/z 323.0895 $[M+Na]^+$, found: m/z 323.0890.



According to the general procedure, compound **7b** was prepared as a yellowish solid in 99% yield (31.1 mg).

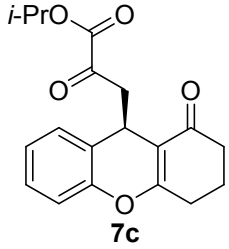
$[\alpha]_D^{25}$ = -67.29 (c 0.345, CH_2Cl_2)

Enantiomeric excess was found to be 91% by chiral HPLC (ChiralPak AD-H column, hexane/i-PrOH = 9: 1, 214 nm, 1.0 mL/min, tmajor = 12.82 min, tminor = 15.96 min).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.32 (d, *J* = 7.6 Hz, 1H), 7.20 (t, *J* = 7.6 Hz, 1H), 7.10 (t, *J* = 7.4 Hz, 1H), 7.01 (d, *J* = 8.1 Hz, 1H), 4.41 (t, *J* = 5.9 Hz, 1H), 4.29 (q, *J* = 7.1 Hz, 2H), 3.27 (dd, *J* = 15.6, 5.3 Hz, 1H), 2.92 (dd, *J* = 15.6, 6.7 Hz, 1H), 2.66 (dt, *J* = 17.7, 5.3 Hz, 1H), 2.61 – 2.52 (m, 1H), 2.46 (dt, *J* = 16.7, 5.3 Hz, 1H), 2.39 – 2.30 (m, 1H), 2.08 – 2.00 (m, 2H), 1.36 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (126 MHz, $CDCl_3$): δ 198.09, 191.77, 168.66, 160.86, 150.32, 129.41, 128.38, 125.47, 124.41, 116.81, 112.64, 62.72, 48.57, 37.09, 28.56, 28.20, 20.69, 14.33.

HRMS (ESI): exact mass calcd for $C_{18}H_{18}NaO_5$: m/z 337.1052 $[M+Na]^+$, found: m/z 337.1046.



7c

According to the general procedure, compound **7c** was prepared as a yellowish solid in 95% yield (31.1 mg).

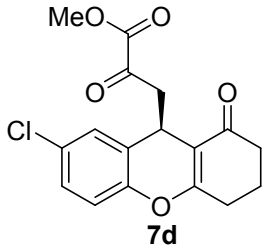
$[\alpha]_D^{25}$ = -72.87 (c 0.320, CH_2Cl_2)

Enantiomeric excess was found to be 83% by chiral HPLC (ChiralPak AD-H column, hexane/i-PrOH = 9: 1, 214 nm, 1.0 mL/min, tmajor = 10.72 min, tminor = 13.90 min).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.32 (d, *J* = 7.0 Hz, 1H), 7.20 (td, *J* = 7.7, 1.6 Hz, 1H), 7.10 (td, *J* = 7.5, 1.2 Hz, 1H), 7.01 (d, *J* = 8.1 Hz, 1H), 5.18 – 4.99 (m, 1H), 4.40 (t, *J* = 5.9 Hz, 1H), 3.25 (dd, *J* = 15.8, 5.4 Hz, 1H), 2.94 (dd, *J* = 15.8, 6.4 Hz, 1H), 2.67 (dt, *J* = 17.7, 5.3 Hz, 1H), 2.62 – 2.52 (m, 1H), 2.46 (dt, *J* = 16.7, 5.3 Hz, 1H), 2.41 – 2.30 (m, 1H), 2.12 – 1.97 (m, 2H), 1.35 (d, *J* = 6.3 Hz, 3H), 1.32 (d, *J* = 6.3 Hz, 3H).

^{13}C NMR (126 MHz, $CDCl_3$): δ 197.99, 192.18, 168.63, 160.41, 150.39, 129.43, 128.36, 125.45, 124.49, 116.81, 112.72, 70.90, 48.38, 37.15, 28.53, 28.23, 21.93, 20.71.

HRMS (ESI): exact mass calcd for $C_{19}H_{20}NaO_5$: m/z 351.1208 $[M+Na]^+$, found: m/z 351.1203.



7d

According to the general procedure, compound **7d** was prepared as a yellow oil in 97% yield (32.5 mg).

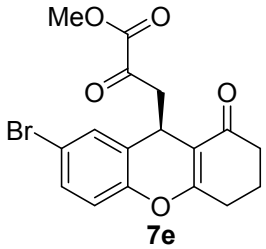
$[\alpha]_D^{25}$ = -31.94 (c 0.740, CH_2Cl_2)

Enantiomeric excess was found to be 94% by chiral HPLC (ChiralPak OD-H column, hexane/i-PrOH = 9: 1, 254 nm, 1.0 mL/min, tmajor = 19.64 min, tminor = 41.93 min).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.30 (s, 1H), 7.15 (d, *J* = 8.1 Hz, 1H), 6.95 (d, *J* = 8.5 Hz, 1H), 4.35 (t, *J* = 6.2 Hz, 1H), 3.86 (s, 3H), 3.34 – 3.25 (m, 1H), 2.90 (dd, *J* = 16.0, 6.1 Hz, 1H), 2.70 – 2.30 (m, 4H), 2.09 – 1.99 (m, 2H).

^{13}C NMR (126 MHz, $CDCl_3$): δ 197.99, 190.94, 168.45, 161.17, 148.86, 130.31, 129.06, 128.53, 126.04, 118.22, 112.14, 53.37, 48.49, 36.99, 28.47, 28.07, 20.61.

HRMS (ESI): exact mass calcd for $C_{17}H_{15}ClNaO_5$: m/z 357.0506 $[M+Na]^+$, found: m/z 357.0500.



7e

According to the general procedure, compound **7e** was prepared as a yellowish solid in 99% yield (37.5 mg).

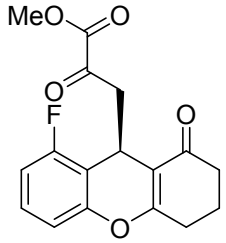
$[\alpha]_D^{25}$ = -12.96 (c 0.313, CH_2Cl_2)

Enantiomeric excess was found to be 91% by chiral HPLC (ChiralPak AD-H column, hexane/i-PrOH = 9: 1, 214 nm, 1.0 mL/min, tmajor = 17.18 min, tminor = 19.78 min).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.45 (s, 1H), 7.30 (d, *J* = 8.6 Hz, 1H), 6.89 (d, *J* = 8.6 Hz, 1H), 4.34 (t, *J* = 5.9 Hz, 1H), 3.86 (s, 3H), 3.29 (dd, *J* = 16.1, 4.9 Hz, 1H), 2.90 (dd, *J* = 16.3, 6.8 Hz, 1H), 2.65 (dt, *J* = 17.9, 5.2 Hz, 1H), 2.60 – 2.51 (m, 1H), 2.45 (dt, *J* = 17.1, 5.2 Hz, 1H), 2.39 – 2.30 (m, 1H), 2.08 – 1.98 (m, 2H).

^{13}C NMR (126 MHz, $CDCl_3$): δ 197.95, 190.94, 168.40, 161.18, 149.41, 132.02, 131.47, 126.52, 118.60, 117.78, 112.26, 53.35, 48.50, 36.99, 28.41, 28.07, 20.61.

HRMS (ESI): exact mass calcd for $C_{17}H_{15}BrNaO_5$: m/z 401.0001 $[M+Na]^+$, found: m/z 400.9995.



7f

According to the general procedure, compound **7f** was prepared as a yellow oil in 29% yield (9.1 mg).

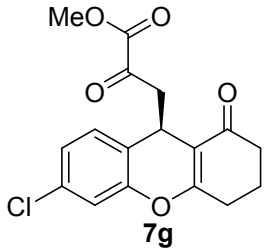
$[\alpha]_D^{25}$ = -13.12 (c 0.125, CH_2Cl_2)

Enantiomeric excess was found to be 62% by chiral HPLC (ChiralPak OD-H column, hexane/i-PrOH = 9: 1, 254 nm, 1.0 mL/min, tmajor = 21.01 min, tminor = 37.57 min).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.21 – 7.14 (m, 1H), 6.87 – 6.80 (m, 2H), 4.51 (t, *J* = 5.4 Hz, 1H), 3.83 (s, 3H), 3.41 (d, *J* = 15.6 Hz, 1H), 3.03 (dd, *J* = 15.6, 6.5 Hz, 1H), 2.70 – 2.62 (m, 1H), 2.60 – 2.52 (m, 1H), 2.50 – 2.42 (m, 1H), 2.40 – 2.31 (m, 1H), 2.07 – 1.99 (m, 2H).

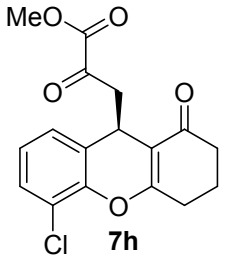
^{13}C NMR (126 MHz, $CDCl_3$): δ 197.93 , 191.51 , 168.69 , 160.98 , δ 160.53 (d, *J* = 247.9 Hz), 151.51 (d, *J* = 6.9 Hz), 128.85 (d, *J* = 10.0 Hz), 112.61 , 112.44 (d, *J* = 3.4 Hz), 111.77, δ 111.73 (d, *J* = 21.1 Hz), 53.27, 45.29 , 37.06 , 28.09 , 24.52 , 20.55 .

HRMS (ESI): exact mass calcd for $C_{17}H_{15}FNaO_5$: m/z 341.0801 $[M+Na]^+$, found: m/z 341.0796.



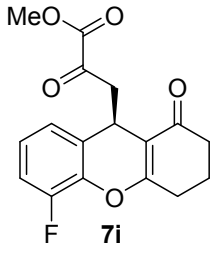
7g

According to the general procedure, compound **7g** was prepared as a yellow oil in 82% yield (27.4 mg).
$[\alpha]_D^{25}$ = -20.27 (c 0.360, CH_2Cl_2)
Enantiomeric excess was found to be 79% by chiral HPLC (ChiralPak AD-H column, hexane/i-PrOH = 9: 1, 214 nm, 1.0 mL/min, tmajor = 15.52 min, tminor = 26.19 min).
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.25 (d, *J* = 8.3 Hz, 1H), 7.08 (dd, *J* = 8.2, 2.1 Hz, 1H), 7.03 (d, *J* = 2.1 Hz, 1H), 4.35 (t, *J* = 5.9 Hz, 1H), 3.85 (s, 3H), 3.25 (dd, *J* = 16.0, 5.3 Hz, 1H), 2.90 (dd, *J* = 16.0, 6.6 Hz, 1H), 2.65 (dt, *J* = 17.8, 5.3 Hz, 1H), 2.61 – 2.50 (m, 1H), 2.45 (dt, *J* = 16.7, 5.4 Hz, 1H), 2.41 – 2.30 (m, 1H), 2.08 – 1.98 (m, 2H).
^{13}C NMR (126 MHz, $CDCl_3$): δ 198.01, 191.16, 168.32, 161.25, 150.69, 133.64, 130.38, 125.68, 122.95, 117.21, 112.66, 53.34, 48.46, 37.01, 28.08, 28.03, 20.62.
HRMS (ESI): exact mass calcd for $C_{17}H_{15}ClNaO_5$: m/z 357.0506 $[M+Na]^+$, found: m/z 357.0500.



7h

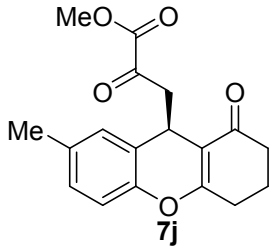
According to the general procedure, compound **7h** was prepared as a yellowish oil in 25% yield (8.3 mg).
$[\alpha]_D^{25}$ = -5.61 (c 0.130, CH_2Cl_2)
Enantiomeric excess was found to be 55% by chiral HPLC (ChiralPak OD-H column, hexane/i-PrOH = 8: 2, 214 nm, 1.0 mL/min, tmajor = 17.50 min, tminor = 30.94 min).
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.28 – 7.22 (m, 2H), 7.04 (t, *J* = 7.9 Hz, 1H), 4.42 (t, *J* = 6.1 Hz, 1H), 3.86 (s, 3H), 3.27 (dd, *J* = 15.8, 5.3 Hz, 1H), 2.91 (dd, *J* = 15.8, 6.7 Hz, 1H), 2.76 (dt, *J* = 17.9, 5.3 Hz, 1H), 2.68 – 2.60 (m, 1H), 2.48 (dt, *J* = 16.8, 5.4 Hz, 1H), 2.42 – 2.32 (m, 1H), 2.11 – 2.03 (m, 2H).
^{13}C NMR (126 MHz, $CDCl_3$): δ 198.04, 191.04, 168.33, 161.30, 146.37, 129.28, 127.81, 126.30, 125.61, 122.23, 112.96, 53.35, 48.70, 37.06, 28.79, 28.00, 20.67.
HRMS (ESI): exact mass calcd for $C_{17}H_{15}ClNaO_5$: m/z 357.0506 $[M+Na]^+$, found: m/z 357.0500.



7i

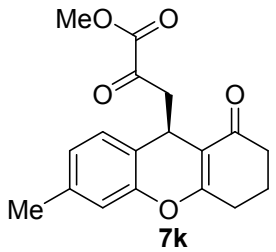
According to the general procedure, compound **7i** was prepared as a yellow oil in 46% yield (15.4 mg).
$[\alpha]_D^{25}$ = -19.86 (c 0.313, CH_2Cl_2)
Enantiomeric excess was found to be 61% by chiral HPLC (ChiralPak OD-H column, hexane/i-PrOH = 9: 1, 254 nm, 1.0 mL/min, tmajor = 22.69 min, tminor = 37.08 min).
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.09 (d, *J* = 7.7 Hz, 1H), 7.07 – 6.97 (m, 2H), 4.42 (t, *J* = 6.0 Hz, 1H), 3.86 (s, 3H), 3.29 (dd, *J* = 15.9, 5.3 Hz, 1H), 2.93 (dd, *J* = 15.9, 6.7 Hz, 1H), 2.73 (dt, *J* = 17.9, 5.3 Hz, 1H), 2.67 – 2.58 (m, 1H), 2.47 (dt, *J* = 16.7, 5.4 Hz, 1H), 2.41 – 2.32 (m, 1H), 2.10 – 2.03 (m, 2H).

^{13}C NMR (126 MHz, $CDCl_3$): ^{13}C NMR (126 MHz, Chloroform-*d*) δ 198.10 , 191.07 , 168.12 , 161.29 , 150.89 (d, *J* = 249.7 Hz), 138.77 (d, *J* = 11.1 Hz), 126.91 , 125.22 (d, *J* = 7.2 Hz), 124.20 (d, *J* = 3.6 Hz), 115.24 (d, *J* = 17.7 Hz), 112.74 , 53.34 , 48.53 , 37.05 , 28.28 (d, *J* = 2.4 Hz), 28.01 , 20.63 .
HRMS (ESI): exact mass calcd for $C_{17}H_{15}FNaO_5$: m/z 341.0801 $[M+Na]^+$, found: m/z 341.0796.



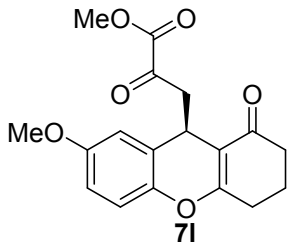
7j

According to the general procedure, compound **7j** was prepared as a yellow oil in 93% yield (29.3 mg).
$[\alpha]_D^{25}$ = -32.58 (c 0.648, CH_2Cl_2)
Enantiomeric excess was found to be 92% by chiral HPLC (ChiralPak AD-H column, hexane/i-PrOH = 9: 1, 214 nm, 1.0 mL/min, tmajor = 13.82 min, tminor = 15.30 min).
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.12 (s, 1H), 6.99 (d, *J* = 8.0 Hz, 1H), 6.89 (d, *J* = 8.2 Hz, 1H), 4.35 (t, *J* = 6.0 Hz, 1H), 3.86 (s, 3H), 3.27 (dd, *J* = 15.4, 4.7 Hz, 1H), 2.85 (dd, *J* = 15.3, 7.2 Hz, 1H), 2.64 (dt, *J* = 17.9, 5.2 Hz, 1H), 2.60 – 2.50 (m, 1H), 2.44 (dt, *J* = 16.8, 5.1 Hz, 1H), 2.39 – 2.31 (m, 1H), 2.30 (s, 3H), 2.07 – 1.99 (m, 2H).
^{13}C NMR (126 MHz, $CDCl_3$): δ 198.31, 191.19, 168.82, 161.41, 148.17, 135.17, 129.57, 129.03, 124.00, 116.52, 112.46, 53.25, 49.03, 37.03, 28.72, 28.22, 21.08, 20.68.
HRMS (ESI): exact mass calcd for $C_{18}H_{18}NaO_5$: m/z 337.1052 $[M+Na]^+$, found: m/z 337.1046.



7k

According to the general procedure, compound **7k** was prepared as a yellow oil in 89% yield (28.0 mg).
$[\alpha]_D^{25}$ = -37.55 (c 0.588, CH_2Cl_2)
Enantiomeric excess was found to be 80% by chiral HPLC (ChiralPak AD-H column, hexane/i-PrOH = 9: 1, 254 nm, 1.0 mL/min, tmajor = 13.23 min, tminor = 25.29 min).
^{1}H NMR (500 MHz, $CDCl_3$): δ 7.20 (d, *J* = 7.7 Hz, 1H), 6.93 (d, *J* = 7.9 Hz, 1H), 6.83 (s, 1H), 4.36 (t, *J* = 6.2 Hz, 1H), 3.85 (s, 3H), 3.30 – 3.22 (m, 1H), 2.86 (dd, *J* = 15.2, 6.9 Hz, 1H), 2.69 – 2.33 (m, 4H), 2.31 (s, 3H), 2.06 – 2.01 (m, 2H).
^{13}C NMR (126 MHz, $CDCl_3$): δ 198.33, 191.33, 168.79, 161.38, 150.05, 138.61, 129.10, 126.39, 121.26, 117.16, 112.68, 53.28, 48.96, 37.05, 28.40, 28.23, 21.34, 20.68.
HRMS (ESI): exact mass calcd for $C_{18}H_{18}NaO_5$: m/z 337.1052 $[M+Na]^+$, found: m/z 337.1046.



7l

According to the general procedure, compound **7l** was prepared as a yellowish solid in 74% yield (24.4 mg).

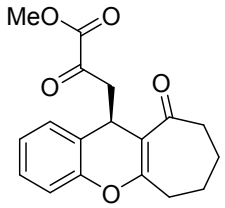
$[\alpha]_D^{25}$ = -25.92 (c 0.260, CH_2Cl_2)

Enantiomeric excess was found to be 91% by chiral HPLC (ChiralPak AD-H column, hexane/i-PrOH = 9: 1, 254 nm, 1.0 mL/min, tmajor = 23.50 min, tminor = 27.93 min).

^{1}H NMR (500 MHz, $CDCl_3$): δ 6.94 (d, *J* = 8.6 Hz, 1H), 6.83 (s, 1H), 6.74 (d, *J* = 8.6 Hz, 1H), 4.39 (t, *J* = 6.3 Hz, 1H), 3.86 (s, 3H), 3.78 (s, 3H), 3.33 – 3.25 (m, 1H), 2.88 (dd, *J* = 15.2, 6.4 Hz, 1H), 2.68 – 2.50 (m, 2H), 2.50 – 2.30 (m, 2H), 2.09 – 1.98 (m, 2H).

^{13}C NMR (126 MHz, $CDCl_3$): δ 198.25, 191.22, 168.88, 161.40, 157.08, 144.30, 125.15, 117.73, 114.59, 113.18, 111.83, 56.03, 53.31, 48.84, 37.06, 29.07, 28.23, 20.70.

HRMS (ESI): exact mass calcd for $C_{18}H_{18}NaO_6$: m/z 353.1001 $[M+Na]^+$, found: m/z 353.0996.



7m

According to the general procedure, compound **7m** was prepared as a colorless oil in 46% yield (14.3 mg).

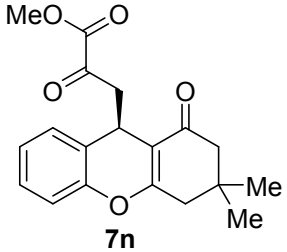
$[\alpha]_D^{25}$ = +18.77 (c 0.500, CH_2Cl_2)

Enantiomeric excess was found to be 92% by chiral HPLC (ChiralPak AD-H column, hexane/i-PrOH = 9: 1, 214 nm, 1.0 mL/min, tmajor = 17.18 min, tminor = 22.42 min).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.34 (d, *J* = 7.5 Hz, 1H), 7.23 – 7.18 (m, 1H), 7.14 – 7.10 (m, 1H), 7.02 (d, *J* = 8.0 Hz, 1H), 4.36 (dd, *J* = 7.7, 5.2 Hz, 1H), 3.87 (s, 3H), 3.21 (dd, *J* = 14.5, 5.3 Hz, 1H), 2.84 – 2.63 (m, 4H), 2.62 – 2.54 (m, 1H), 2.02 – 1.73 (m, 4H).

^{13}C NMR (126 MHz, $CDCl_3$): δ 201.36, 191.08, 170.29, 161.38, 150.67, 129.05, 128.26, 125.42, 124.85, 116.55, 115.26, 53.29, 49.47, 41.67, 32.20, 31.63, 23.80, 21.43.

HRMS (ESI): exact mass calcd for $C_{18}H_{18}NaO_5$: m/z 337.1052 $[M+Na]^+$, found: m/z 337.1046.



7n

According to the general procedure, compound **7n** was prepared as a yellowish solid in 90% yield (29.6 mg).

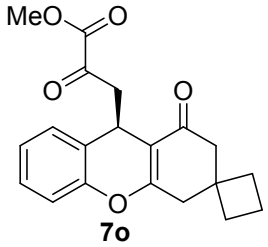
$[\alpha]_D^{25}$ = -29.39 (c 0.705, CH_2Cl_2)

Enantiomeric excess was found to be 87% by chiral HPLC (ChiralPak AD-H column, hexane/i-PrOH = 9: 1, 214 nm, 1.0 mL/min, tmajor = 11.62 min, tminor = 17.87 min).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.33 (d, *J* = 7.6 Hz, 1H), 7.23 – 7.18 (m, 1H), 7.14 – 7.09 (m, 1H), 7.01 (d, *J* = 8.1 Hz, 1H), 4.41 (t, *J* = 6.1 Hz, 1H), 3.85 (s, 3H), 3.29 (dd, *J* = 15.4, 5.0 Hz, 1H), 2.93 (dd, *J* = 15.4, 7.1 Hz, 1H), 2.54 – 2.43 (m, 2H), 2.27 (s, 2H), 1.13 (s, 3H), 1.10 (s, 3H).

^{13}C NMR (126 MHz, $CDCl_3$): δ 198.14, 191.34, 167.07, 161.37, 150.38, 129.43, 128.44, 125.53, 124.32, 116.90, 111.46, 53.27, 50.92, 48.73, 41.92, 32.50, 29.66, 28.73, 27.70.

HRMS (ESI): exact mass calcd for $C_{19}H_{20}NaO_5$: m/z 351.1208 $[M+Na]^+$, found: m/z 351.1203.



7o

According to the general procedure, compound **7o** was prepared as a yellow oil in 84% yield (28.7 mg).

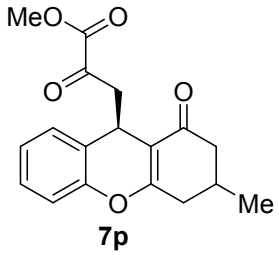
$[\alpha]_D^{25}$ = -24.83 (c 0.350, CH_2Cl_2)

Enantiomeric excess was found to be 74% by chiral HPLC (ChiralPak AD-H column, hexane/i-PrOH = 9: 1, 214 nm, 1.0 mL/min, tmajor = 12.69 min, tminor = 18.88 min).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.32 (d, *J* = 7.1 Hz, 1H), 7.23 – 7.17 (m, 1H), 7.14 – 7.09 (m, 1H), 7.01 (d, *J* = 8.1 Hz, 1H), 4.38 (t, *J* = 6.1 Hz, 1H), 3.85 (s, 3H), 3.27 (dd, *J* = 15.4, 5.0 Hz, 1H), 2.86 (dd, *J* = 15.4, 7.2 Hz, 1H), 2.78 (d, *J* = 17.3 Hz, 1H), 2.67 – 2.55 (m, 2H), 2.44 (d, *J* = 16.1 Hz, 1H), 1.99 – 1.83 (m, 6H).

^{13}C NMR (126 MHz, $CDCl_3$): δ 197.89, 191.16, 166.95, 161.32, 150.31, 129.41, 128.42, 125.54, 124.25, 116.86, 112.50, 53.29, 49.28, 48.85, 40.93, 38.51, 32.26, 32.11, 28.73, 15.46.

HRMS (ESI): exact mass calcd for $C_{20}H_{20}NaO_5$: m/z 363.1208 $[M+Na]^+$, found: m/z 363.1203.



7p

According to the general procedure, compound **7p** was prepared as a yellow oil in 95% yield (29.7 mg).

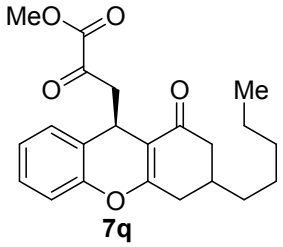
$[\alpha]_D^{25}$ = -16.96 (c 0.583, CH_2Cl_2)

Enantiomeric excess was found to be 87% by chiral HPLC and diasteromeric ratio was found to be 4: 1. (ChiralPak OD-H column, hexane/i-PrOH = 95: 5, 214 nm, 1.0 mL/min, tmajor = 40.62 min, tminor = 60.13 min).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.32 (d, *J* = 7.5 Hz, 1H), 7.23 – 7.17 (m, 1H), 7.14 – 7.08 (m, 1H), 7.00 (d, *J* = 8.1 Hz, 1H), 4.39 (t, *J* = 6.0 Hz, 1H), 3.84 (s, 3H), 3.32 – 3.22 (m, 1H), 2.95 – 2.84 (m, 1H), 2.69 – 2.57 (m, 1H), 2.54 – 2.37 (m, 2H), 2.36 – 2.23 (m, 1H), 2.22 – 2.01 (m, 1H), 1.12 (d, *J* = 6.8 Hz, 3H).

^{13}C NMR (126 MHz, $CDCl_3$): δ 198.19, 191.26, 167.76, 161.38, 150.28, 129.40, 128.43, 125.50, 124.20, 116.83, 112.15, 53.26, 48.58, 45.15, 35.97, 28.74, 28.66, 20.98.

HRMS (ESI): exact mass calcd for $C_{18}H_{18}NaO_5$: m/z 337.1052 $[M+Na]^+$, found: m/z 337.1046.



7q

According to the general procedure, compound **7q** was prepared as a yellowish oil in 90% yield (33.3 mg).

$[\alpha]_D^{25}$ = -11.63 (c 0.178, CH_2Cl_2)

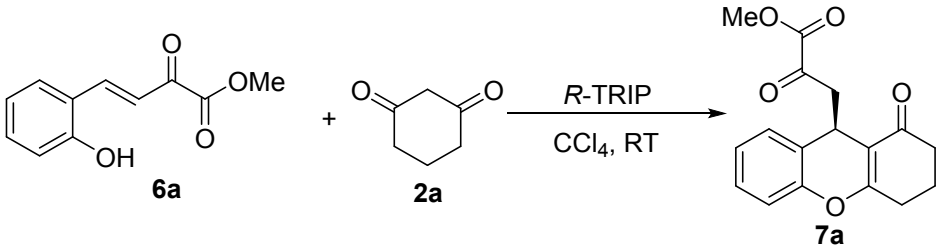
Enantiomeric excess was found to be 89% by chiral HPLC and diasteromeric ratio was found to be 5.3: 1). (ChiralPak IE-3 column, hexane/i-PrOH = 9: 1, 214 nm, 0.7 mL/min, tmajor = 63.87 min, tminor = 51.78 min).

^{1}H NMR (500 MHz, $CDCl_3$): δ 7.32 (d, *J* = 7.2 Hz, 1H), 7.22 – 7.17 (m, 1H), 7.13 – 7.08 (m, 1H), 7.00 (d, *J* = 8.1 Hz, 1H), 4.39 (t, *J* = 6.0 Hz, 1H), 3.84 (s, 3H), 3.25 (dd, *J* = 15.6, 5.0 Hz, 1H), 2.92 (dd, *J* = 15.5, 7.0 Hz, 1H), 2.73 – 2.56 (m, 1H), 2.56 – 2.38 (m, 2H), 2.30 – 1.99 (m, 2H), 1.42 – 1.25 (m, 8H), 0.88 (t, *J* = 6.7 Hz, 3H).

^{13}C NMR (126 MHz, $CDCl_3$): δ 198.35, 191.18, 168.02, 161.38, 150.26, 129.39, 128.42, 125.48, 124.16, 116.81, 112.27, 53.27, 48.58, 43.62, 35.44, 34.35, 33.70, 32.01, 28.72, 26.58, 22.88, 14.34.

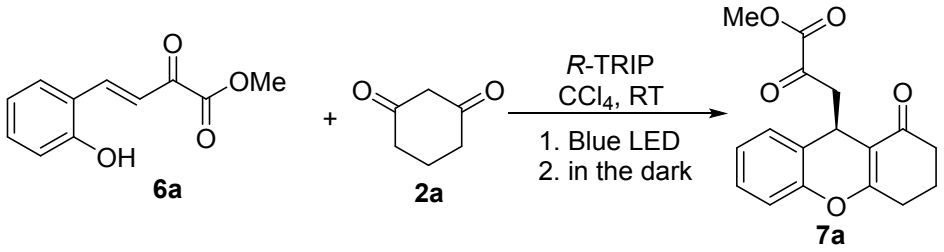
HRMS (ESI): exact mass calcd for $C_{22}H_{26}NaO_5$: m/z 393.1678 $[M+Na]^+$, found: m/z 393.1672.

5. Procedure for 1 mmol Scale Synthesis of 7a



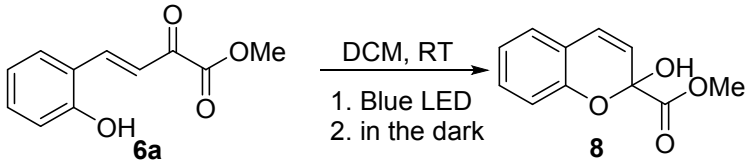
To a 50 ml round-bottom flask equipped with a magnetic stir bar was added **6a** (1.0 mmol, 206.2mg), 1,3-cyclo-dione **2a** (0.12 mmol, 134.6 mg), *R*-TRIP (0.1 mmol, 75.3mg) and CCl_4 (30 mL). The mixture was stirred at room temperature under argon overnight and monitored by TLC. The solvent was removed by rotary evaporator and the residue was directly purified by column chromatography on silica gel (EtOAc/petroleum ether = 1: 5) to yield **7a** in 90% yield (271.2 mg). Enantiomeric excess was found to be 94% by chiral HPLC (ChiralPak AD column, hexane/i-PrOH = 9: 1, 214 nm, 1.0 mL/min, t_{major} = 14.42 min, t_{minor} = 16.55 min).

6. Mechanistic Studies



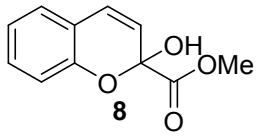
To a 50 ml round-bottom flask equipped with a magnetic stir bar was added **6a** (0.1 mmol, 20.6 mg), 1,3-cyclo-dione **2a** (0.12 mmol, 13.5 mg), *R*-TRIP (0.1 mmol, 7.5mg) and CCl_4 (3 mL). The mixture was irradiated by blue LED and stirred at room temperature under argon overnight and monitored by TLC. The solvent was removed by rotary evaporator and the residue was directly purified by column chromatography on silica gel (EtOAc/petroleum ether = 1: 5) to yield **7a** in 96% yield (28.8 mg). Enantiomeric excess was found to be 90% by chiral HPLC (ChiralPak AD column, hexane/i-PrOH = 9: 1, 214 nm, 1.0 mL/min, t_{major} = 14.42 min, t_{minor} = 16.55 min).

To a 50 ml round-bottom flask equipped with a magnetic stir bar was added **6a** (0.1 mmol, 20.6 mg), 1,3-cyclo-dione **2a** (0.12 mmol, 13.5 mg), *R*-TRIP (0.1 mmol, 7.5mg) and CCl_4 (3 mL). The mixture was stirred in the dark, using aluminium foil to wrap up the reaction flask, at room temperature under argon overnight and monitored by TLC. The solvent was removed by rotary evaporator and the residue was directly purified by column chromatography on silica gel (EtOAc/petroleum ether = 1: 5) to yield **7a** in 99% yield (29.8mg). Enantiomeric excess was found to be 92% by chiral HPLC (ChiralPak AD column, hexane/i-PrOH = 9: 1, 214 nm, 1.0 mL/min, t_{major} = 14.42 min, t_{minor} = 16.55 min).



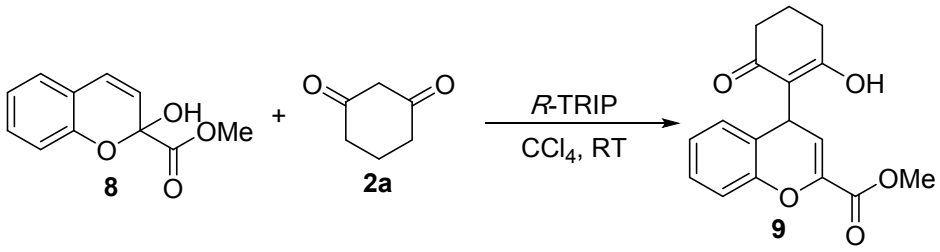
(*E*)-2-hydroxyaryl-2-oxobut-3-enoate **6a** (0.3 mmol, 61.8 mg) and DCM (9.0 mL) were added to a reaction tube equipped with a magnetic stir bar. The mixture was irradiated by blue LED and stirred at room temperature under argon for 8h. After **6a** was consumed completely, the solvent was removed by rotary evaporator. The residue was compound **8** without any purification.

(*E*)-2-hydroxyaryl-2-oxobut-3-enoate **6a** (0.3 mmol, 61.8 mg) and DCM (9.0 mL) were added to a reaction tube equipped with a magnetic stir bar. The mixture was stirred in the dark, using aluminium foil to wrap up the reaction flask, at room temperature under argon for 7 days. The solvent was removed by rotary evaporator and the residue was directly purified by column chromatography on silica gel (EtOAc/petroleum ether = 1: 10) to yield **8** in 82% yield (50.7 mg).

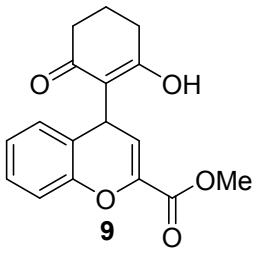


^{1}H NMR (500 MHz, $(CD_3)_2CO$): δ 7.31 – 7.24 (m, 2H), 7.05 – 6.99 (m, 1H), 6.96 (d, *J* = 8.1 Hz, 1H), 6.87 (d, *J* = 9.8 Hz, 1H), 6.49 (s, 1H), 6.01 (d, *J* = 9.8 Hz, 1H), 3.85 (s, 3H).

^{13}C NMR (126 MHz, $(CD_3)_2CO$): δ 170.50, 152.44, 131.20, 128.65, 127.38, 123.22, 122.57, 121.24, 117.83, 95.67, 53.98.



Compound **8** (0.15 mmol, 30.9 mg), 1,3-cyclohexanedione **2a**(0.18 mmol, 20.2 mg), *R*-TRIP (0.015 mmol, 11.3 mg) and CCl_4 (5 mL) were added to a reaction tube equipped with a magnetic stir bar. The mixture was stirred at room temperature under argon overnight and monitored by TLC. The solvent was filtered and the residue was collected and washed with DCM to obtain compound **9** as a white solid in 50% yield (22.7 mg).



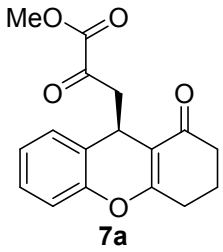
^{1}H NMR (500 MHz, $(CD_3)_2SO$): δ 10.95 (s, 1H), 7.17 – 7.10 (m, 1H), 7.00 – 6.91 (m, 2H), 6.87 (d, *J* = 7.4 Hz, 1H), 5.90 (d, *J* = 4.2 Hz, 1H), 5.03 (d, *J* = 4.2 Hz, 1H), 3.78 (s, 3H), 2.48 – 2.27 (m, 4H), 1.97 – 1.81 (m, 2H).

^{13}C NMR (126 MHz, $(CD_3)_2SO$): δ 162.55, 151.51, 140.61, 128.65, 128.09, 124.55, 124.00, 118.15, 118.11, 116.40, 115.15, 52.94, 28.98, 21.26.

7. Reference

[1]. Yang H., Zhao Y., Sang R., Wei Y., Shi M.. *Adv. Synth. Catal*., **2014**, 356, 3799.
[2]. Allais C., Liéby-Muller F., Rodriguez J., Constantieux T.. *Eur. J. Org. Chem*., **2013**, 19, 4131.
[3]. Jin X., Xu W., Yang J., Lu J., Fu Y., Xie L., Zhu Q., Dong W.. *Tetrahedron Lett*., **2015**, 56 , 6287.

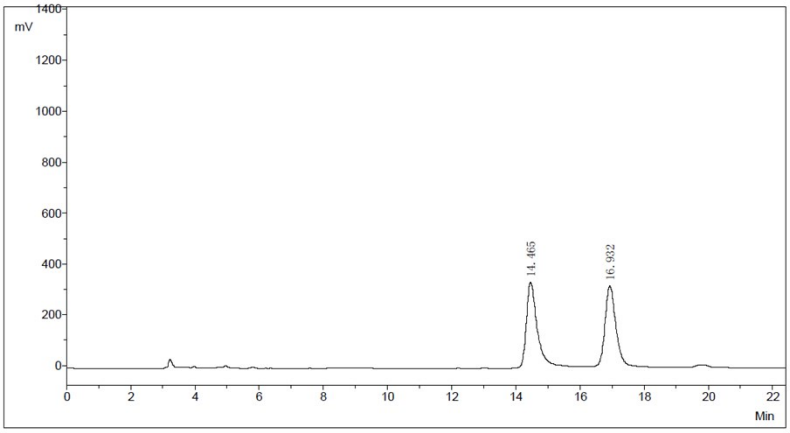
8. HPLC Data



7a

HPLC Report

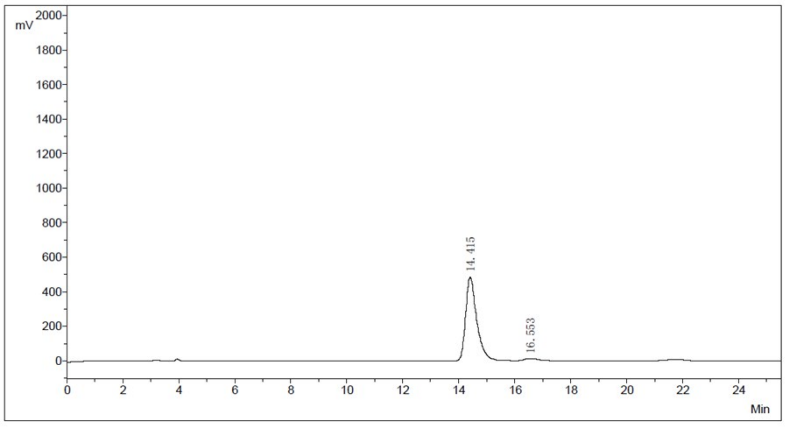
Sample Name:GYQ-V-51-1 AD 9010 214 1.0 Recording Time:2018.06.04 16:57



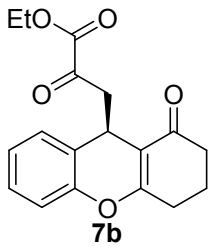
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		14.465	335618.8	7973560.9	51.3479
2	2		16.932	317319.8	7554940.6	48.6521
Total				652938.6	15528501.6	100.0000

HPLC Report

Sample Name:GYQ-VIII-24-2 AD 9010 214 1.0 Recording Time:2020.01.23 19:11



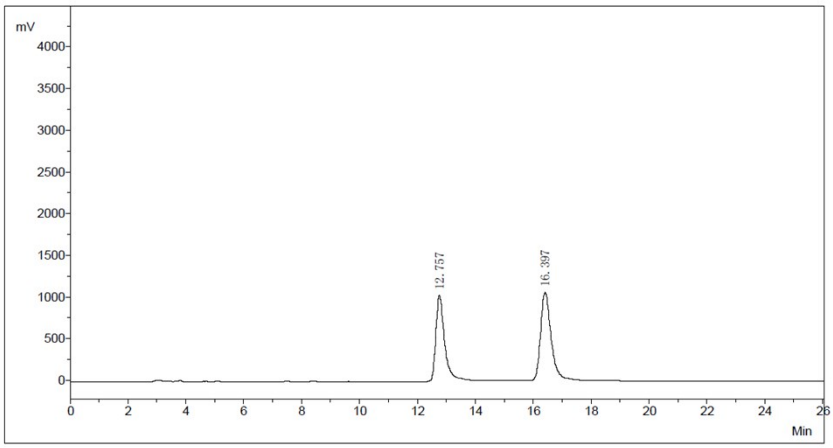
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		14.415	484184.9	13332441.6	97.3396
2	2		16.553	11349.3	364384.6	2.6604
Total				495534.2	13696826.1	100.0000



7b

HPLC Report

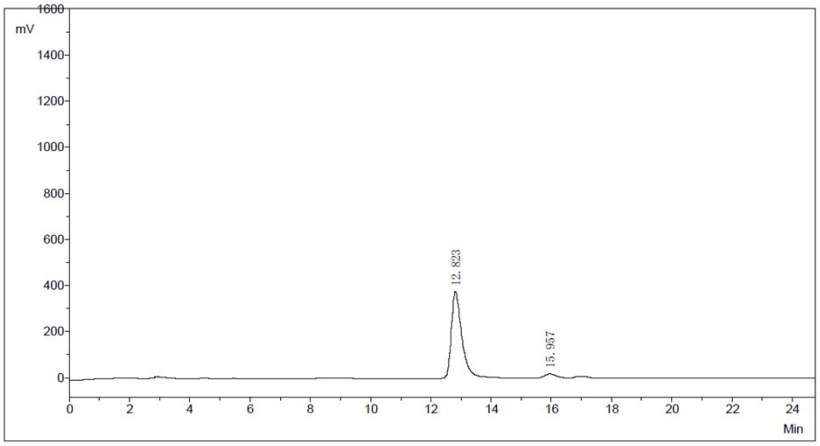
Sample Name:HY-III-24-2 AD 9010 214 1.0 Recording Time:2019.01.26 20:13



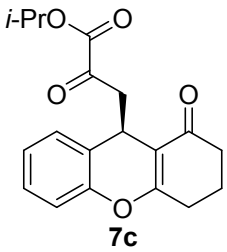
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		12.757	1037838.7	22390907.9	46.6097
2	2		16.397	1049850.5	25648209.6	53.3903
Total				2087689.1	48039117.4	100.0000

HPLC Report

Sample Name:GYQ-VI-9 AD 9010 214 1.0 Recording Time:2018.08.24 20:30



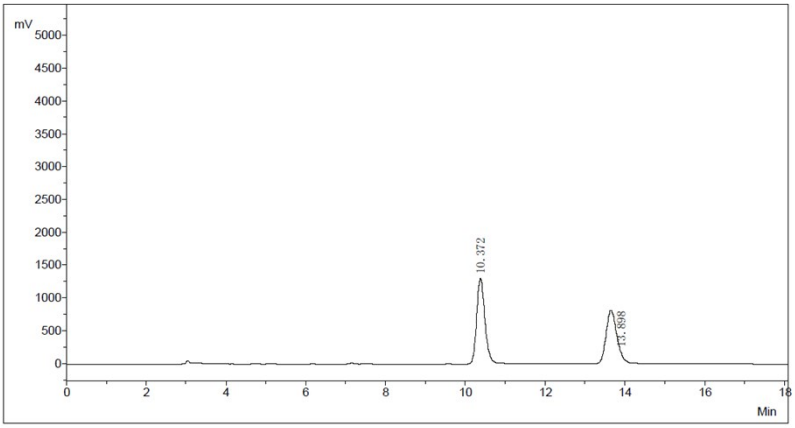
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		12.823	375718.0	9111540.7	95.4775
2	2		15.957	18366.0	431584.2	4.5225
Total				394084.0	9543124.9	100.0000



7c

HPLC Report

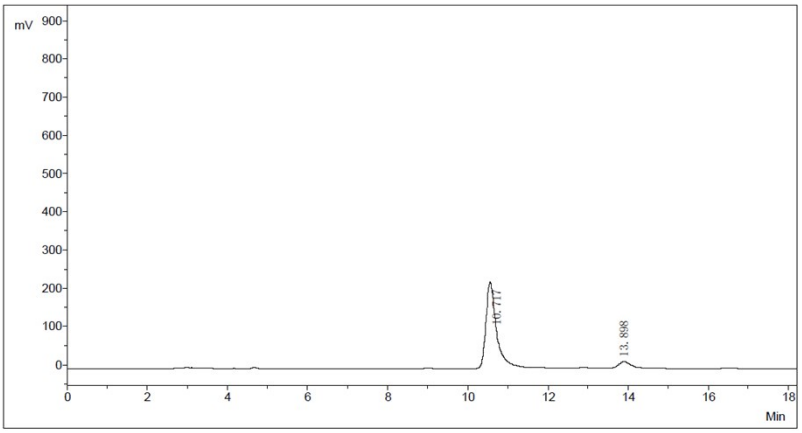
Sample Name:HY-III-28 AD-H 9010 214 1.0 Recording Time:2019.02.27 22:04



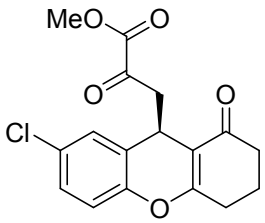
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		10.372	1271390.2	17400135.1	51.9294
2	2		13.898	178845.3	16107127.3	48.0706
Total				1450235.5	33507262.4	100.0000

HPLC Report

Sample Name:GYQ-VI-26 AD 9010 214 1.0 Recording Time:2018.10.16 19:45

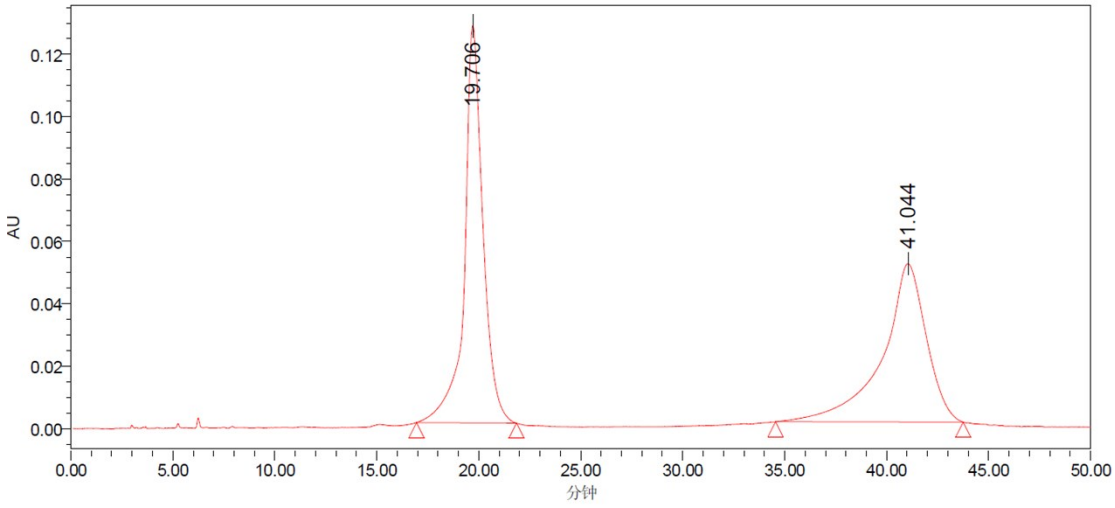


No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		10.717	99449.4	4219535.3	91.6164
2	2		13.898	17427.5	386120.8	8.3836
Total				116876.9	4605656.1	100.0000



7d

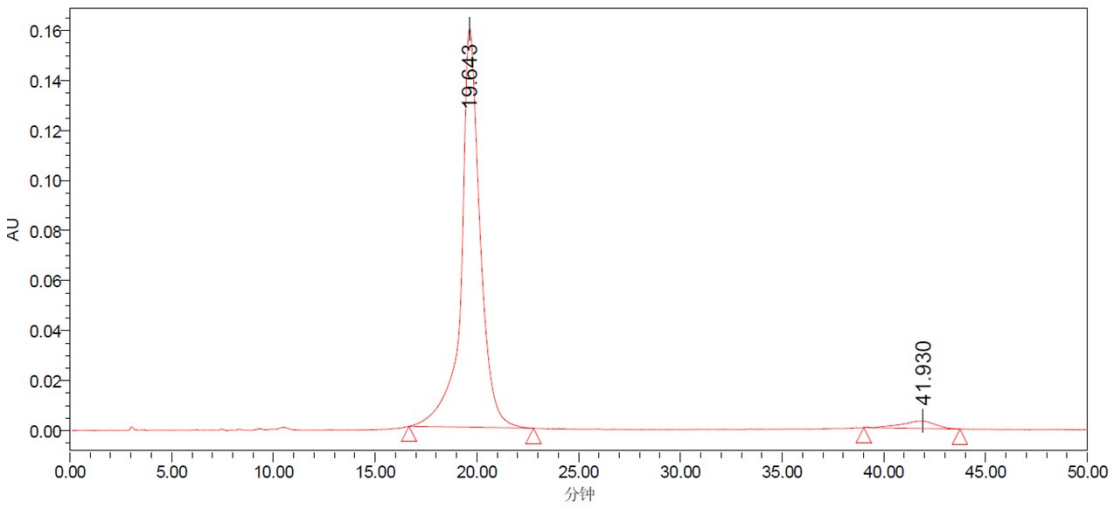
自动标尺色谱图



峰结果

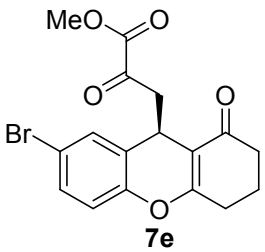
	名称	开始时间 (分钟)	结束时间 (分钟)	保留时间 (分钟)	面积 (微伏*秒)	高度 (微伏)	% 面积
1		16.950	21.850	19.706	8009823	127333	51.33
2		34.550	43.750	41.044	7594231	50777	48.67

自动标尺色谱图



峰结果

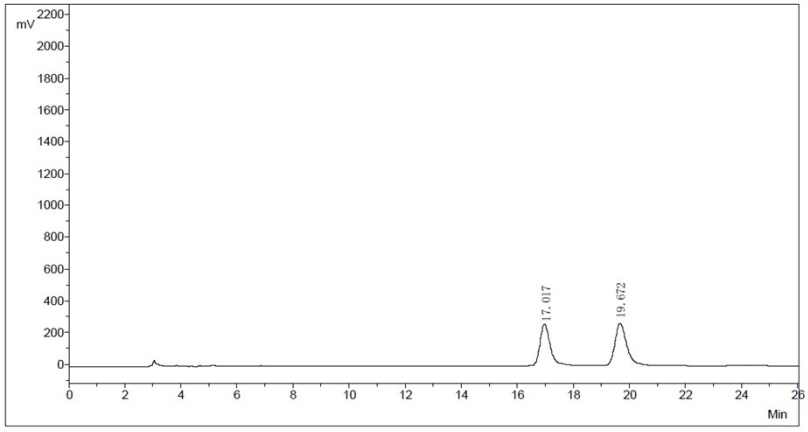
	名称	开始时间 (分钟)	结束时间 (分钟)	保留时间 (分钟)	面积 (微伏*秒)	高度 (微伏)	% 面积
1		16.667	22.783	19.643	10306795	159471	96.81
2		39.017	43.733	41.930	339856	2968	3.19



7e

HPLC Report

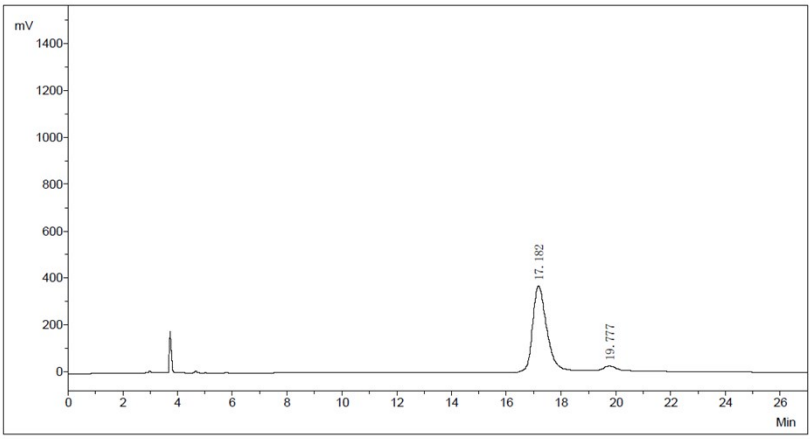
Sample Name:HY-III-26 AD-H 9010 214 1.0 Recording Time:2019.02.27 21:12



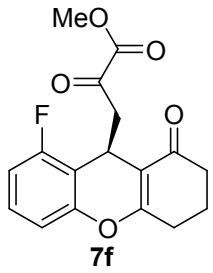
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		17.017	247153.2	6666152.5	50.2382
2	2		19.672	251550.1	6602938.3	49.7618
Total				498703.3	13269090.8	100.0000

HPLC Report

Sample Name:GYQ-VI-24-1 AD 9010 214 1.0 Recording Time:2018.10.16 15:59

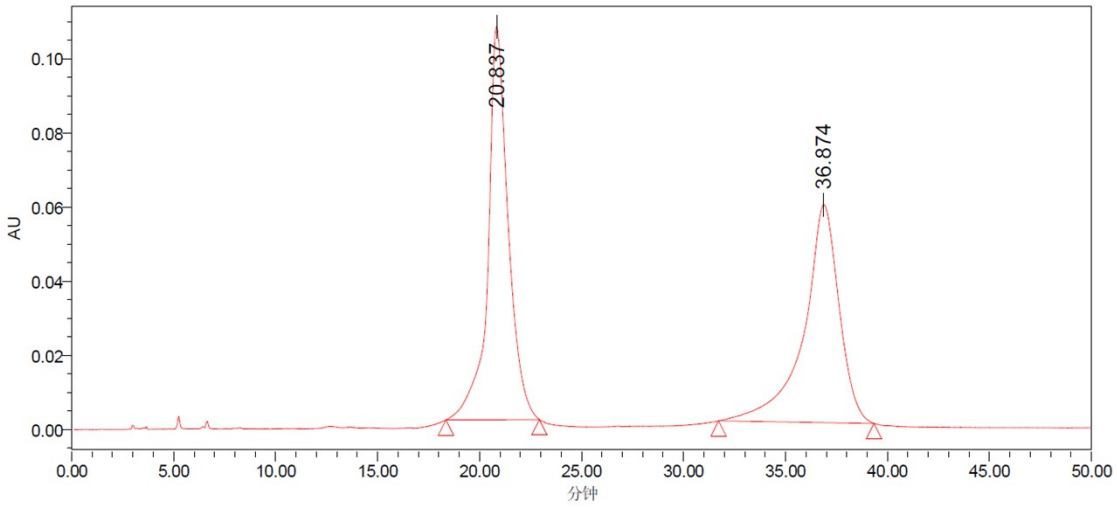


No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		17.182	366515.2	13094549.0	95.4103
2	2		19.777	20245.8	629905.3	4.5897
Total				386761.0	13724454.4	100.0000



7f

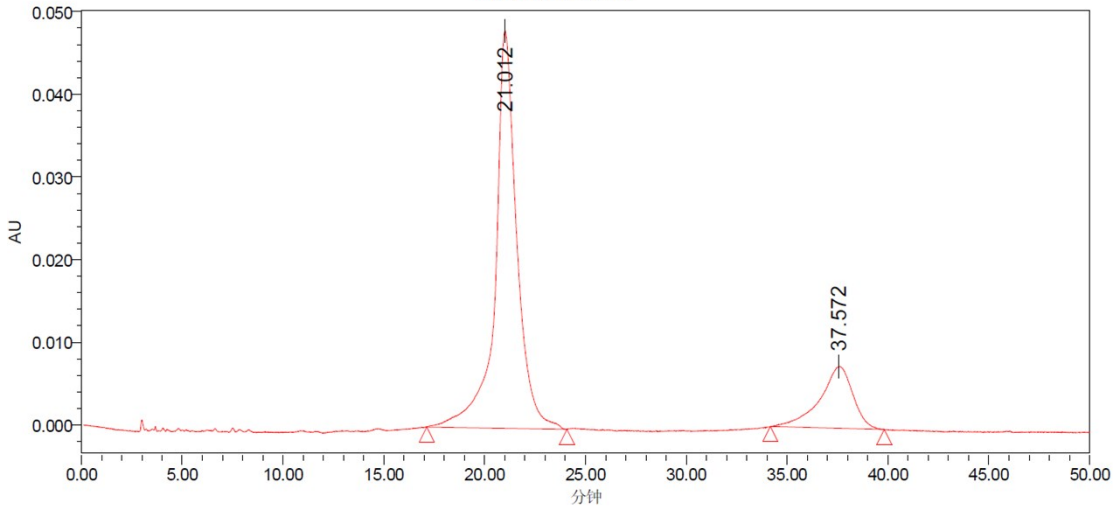
自动标尺色谱图



峰结果

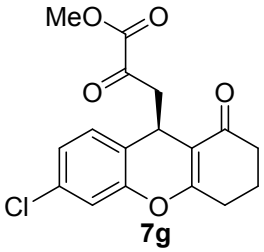
	名称	开始时间 (分钟)	结束时间 (分钟)	保留时间 (分钟)	面积 (微伏*秒)	高度 (微伏)	% 面积
1		18.350	22.933	20.837	7332969	105967	50.82
2		31.717	39.333	36.874	7097212	58776	49.18

自动标尺色谱图



峰结果

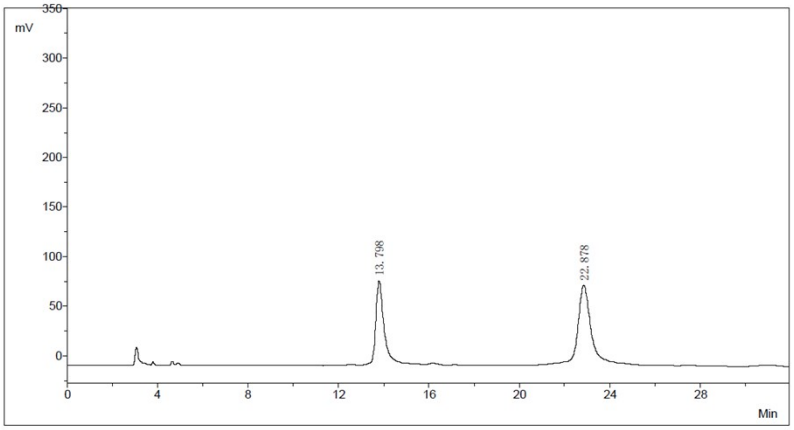
	名称	开始时间 (分钟)	结束时间 (分钟)	保留时间 (分钟)	面积 (微伏*秒)	高度 (微伏)	% 面积
1		17.133	24.083	21.012	3581886	48061	80.82
2		34.167	39.817	37.572	850159	7490	19.18



7g

HPLC Report

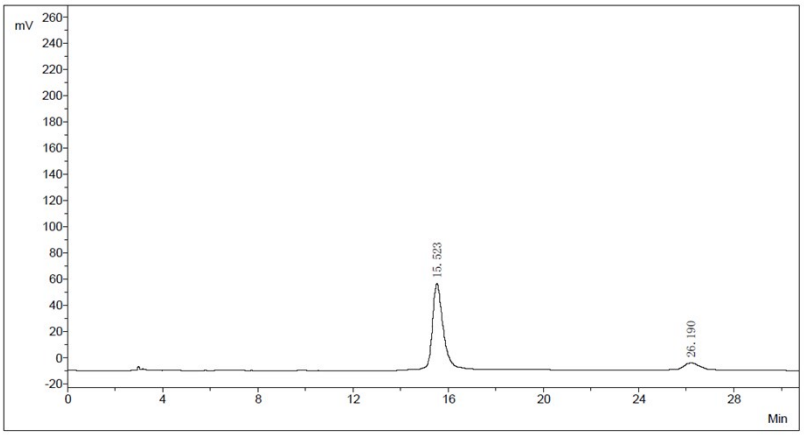
Sample Name:HY-III-38 AD-H 9010 214 1.0.che Recording Time:2019.04.08 10:32



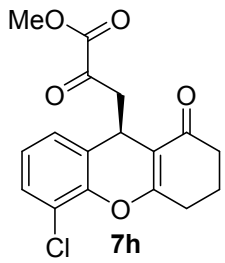
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		13.798	84368.7	2165347.4	48.5480
2	2		22.878	71973.4	2294869.8	51.4520
Total				156342.1	4460217.2	100.0000

HPLC Report

Sample Name:GYQ-VI-28 AD 9010 214 1.0 Recording Time:2018.10.16 20:08



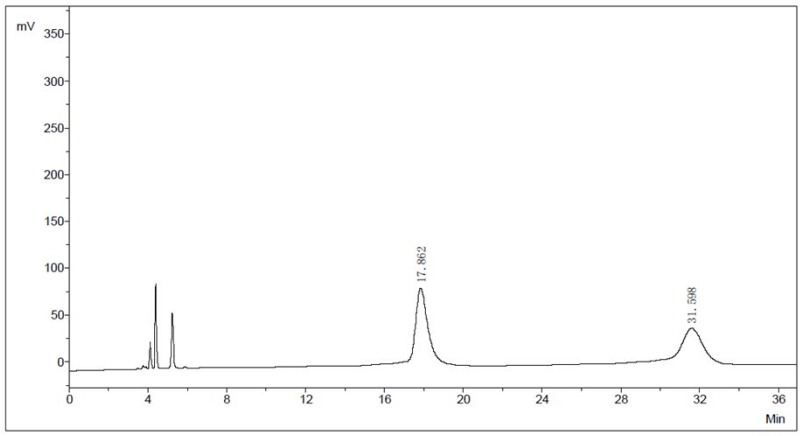
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		15.523	65774.7	2094409.3	89.3042
2	2		26.190	5525.9	250842.8	10.6958
Total				71300.5	2345252.1	100.0000



7h

HPLC Report

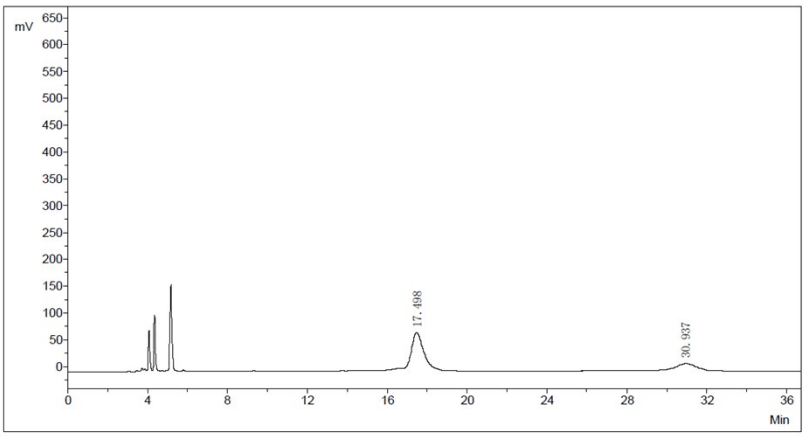
Sample Name:HY-III-71 OD 8020 214 1.0 Recording Time:2019.12.25 16:10



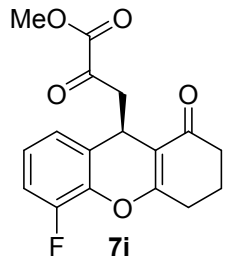
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	2		17.862	81859.1	3769047.1	50.3629
2	3		31.598	38816.8	3714727.0	49.6371
Total				120675.9	7483774.1	100.0000

HPLC Report

Sample Name:GYQ-VII-98 OD 8020 214 1.0 Recording Time:2019.12.25 16:49

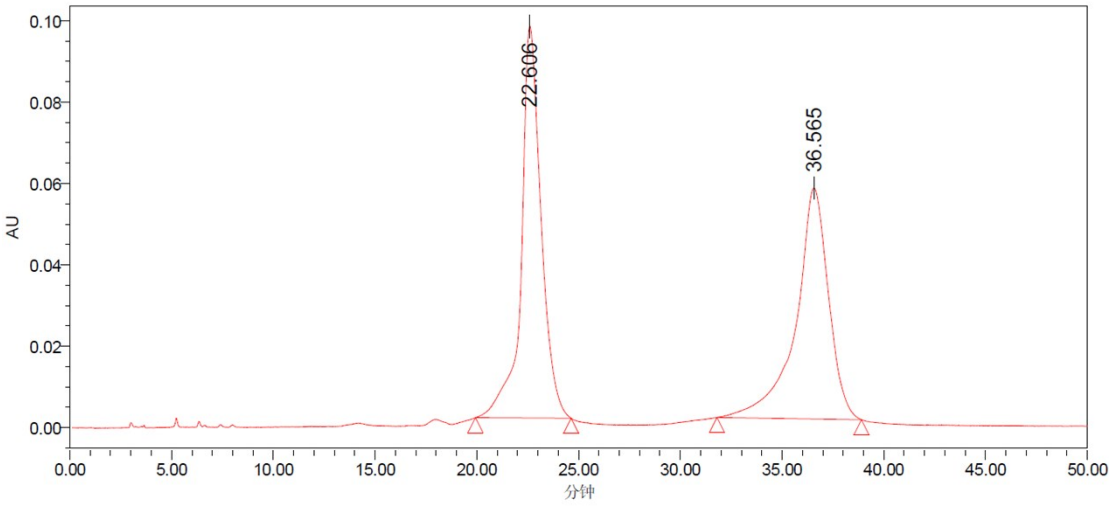


No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		17.498	69886.1	3042347.7	77.6060
2	2		30.937	12797.0	877899.1	22.3940
Total				82683.0	3920246.8	100.0000



7i

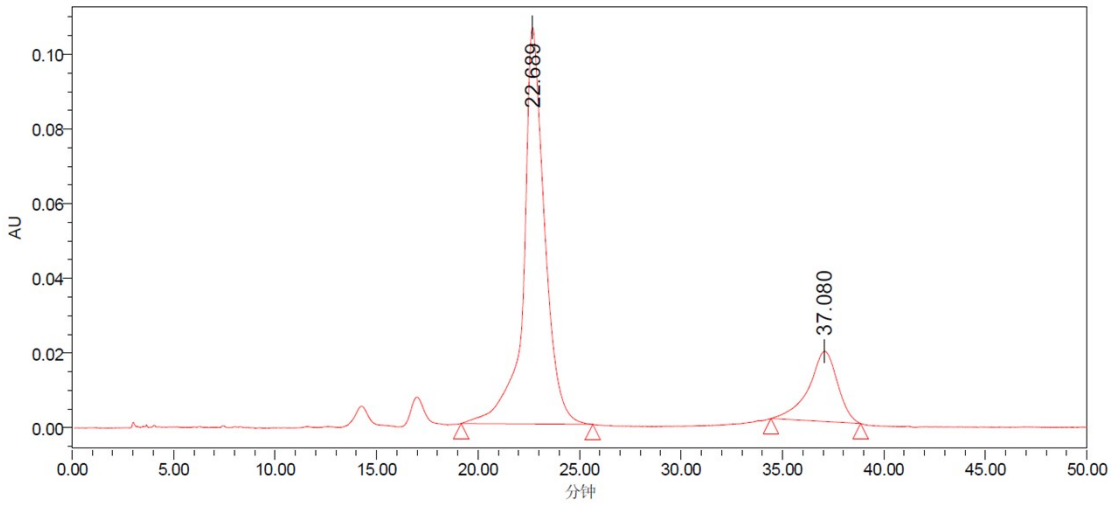
自动标尺色谱图



峰结果

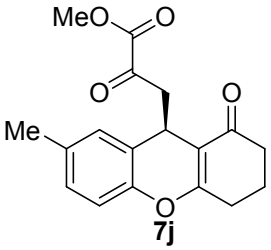
	名称	开始时间 (分钟)	结束时间 (分钟)	保留时间 (分钟)	面积 (微伏*秒)	高度 (微伏)	% 面积
1		19.933	24.633	22.606	6547110	96282	50.72
2		31.800	38.900	36.565	6360738	56786	49.28

自动标尺色谱图



峰结果

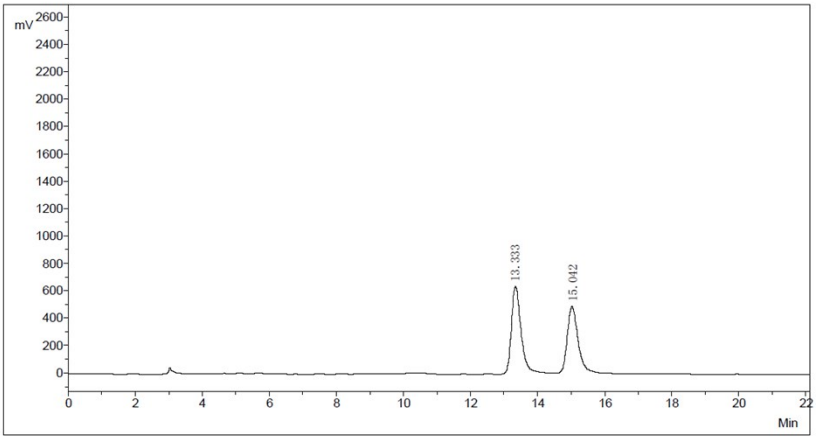
	名称	开始时间 (分钟)	结束时间 (分钟)	保留时间 (分钟)	面积 (微伏*秒)	高度 (微伏)	% 面积
1		19.167	25.650	22.689	7686590	106244	80.55
2		34.433	38.850	37.080	1855899	18835	19.45



7j

HPLC Report

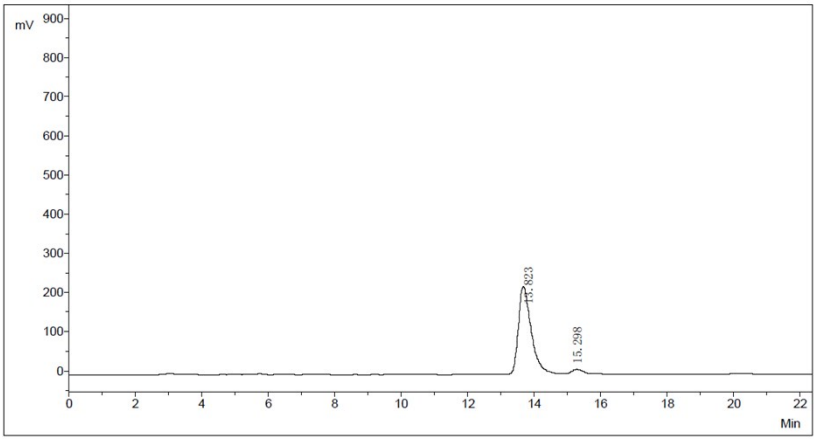
Sample Name:HY-III-29 AD-H 9010 214 1.0 Recording Time:2019.02.27 22:23



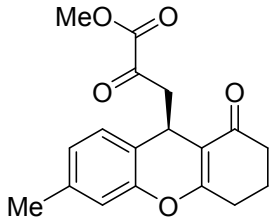
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		13.333	629895.3	11976750.7	52.2340
2	2		15.042	486473.5	10952299.5	47.7660
Total				1116368.8	22929050.2	100.0000

HPLC Report

Sample Name:GYQ-VI-25-1 AD 9010 214 1.0 Recording Time:2018.10.16 18:46

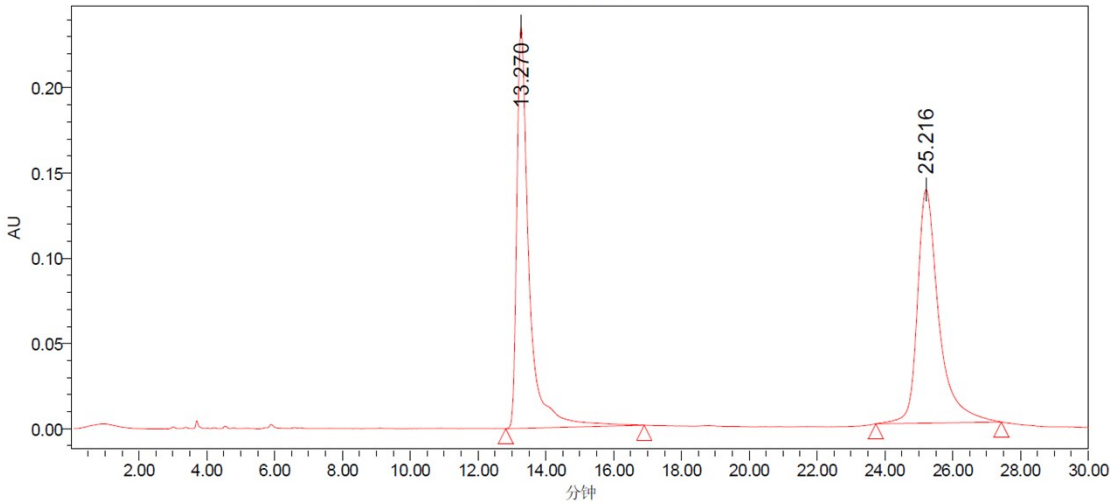


No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		13.823	166518.0	5968143.8	95.7662
2	2		15.298	11789.3	263849.9	4.2338
Total				178307.3	6231993.6	100.0000



7k

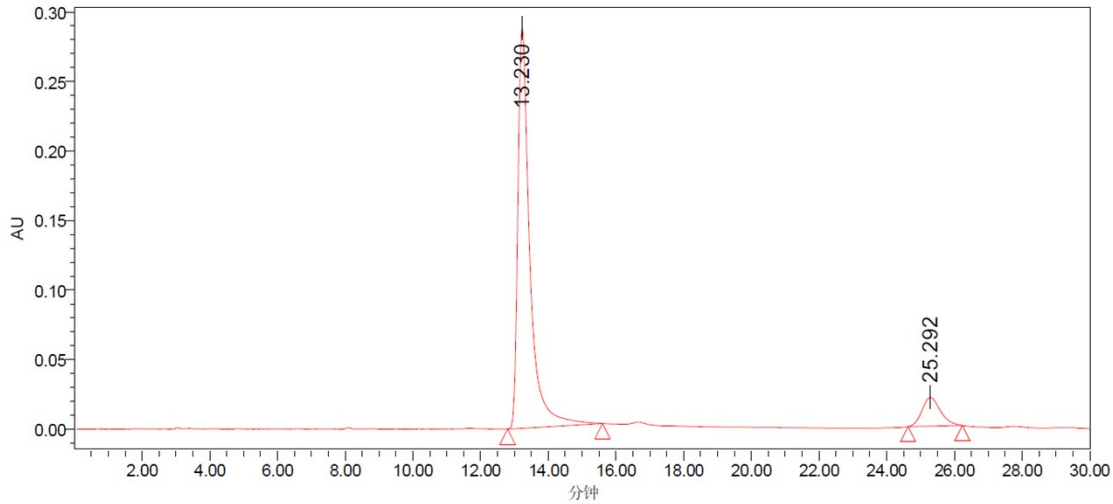
自动标尺色谱图



峰结果

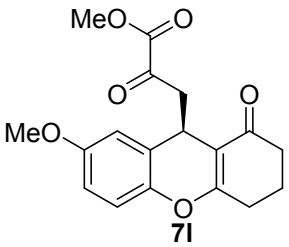
	名称	开始时间 (分钟)	结束时间 (分钟)	保留时间 (分钟)	面积 (微伏*秒)	高度 (微伏)	% 面积
1		12.817	16.900	13.270	5908474	235900	49.49
2		23.733	27.433	25.216	6029532	137116	50.51

自动标尺色谱图



峰结果

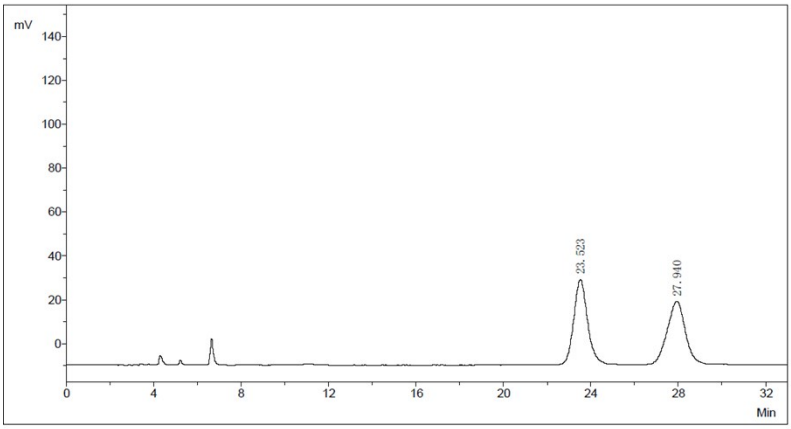
	名称	开始时间 (分钟)	结束时间 (分钟)	保留时间 (分钟)	面积 (微伏*秒)	高度 (微伏)	% 面积
1		12.800	15.600	13.230	7078472	288075	90.08
2		24.633	26.233	25.292	779525	20652	9.92



7l

HPLC Report

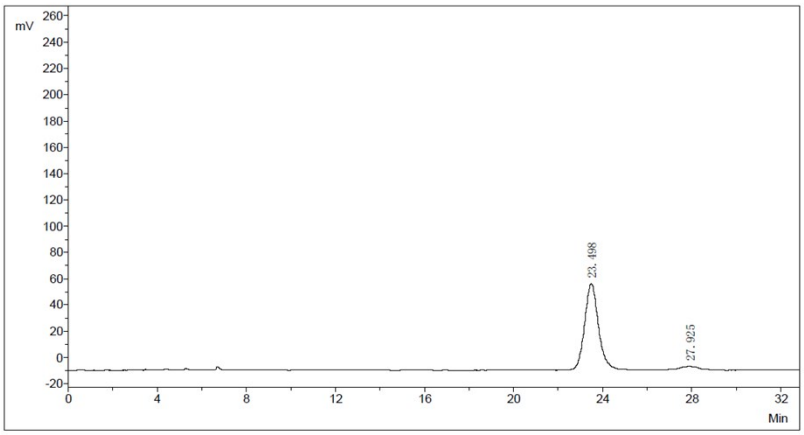
Sample Name:HY-III-37 AD 9010 254 1.0 Recording Time:2019.12.23 16:47



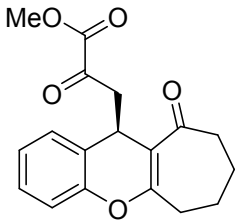
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	2		23.523	38810.2	1690963.7	50.4874
2	3		27.940	28752.6	1658311.8	49.5126
Total				67562.8	3349275.5	100.0000

HPLC Report

Sample Name:GYQ-VII-12-1 AD 9010 254 1.0 Recording Time:2019.12.23 15:24



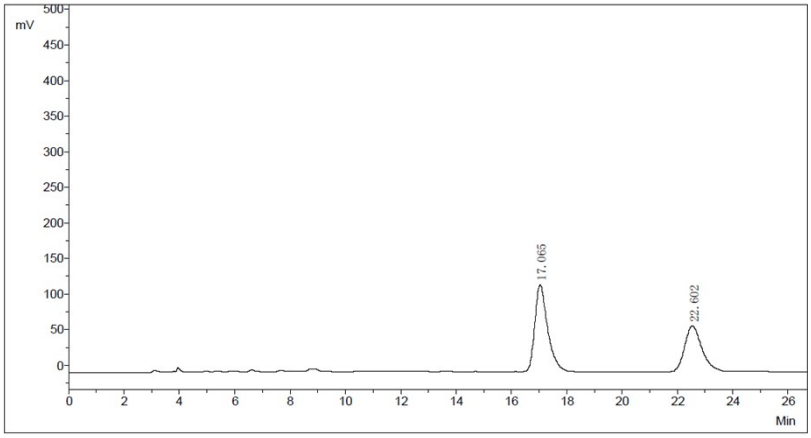
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		23.498	65821.4	2846550.8	95.3474
2	2		27.925	2611.6	138900.8	4.6526
Total				68433.0	2985451.6	100.0000



7m

HPLC Report

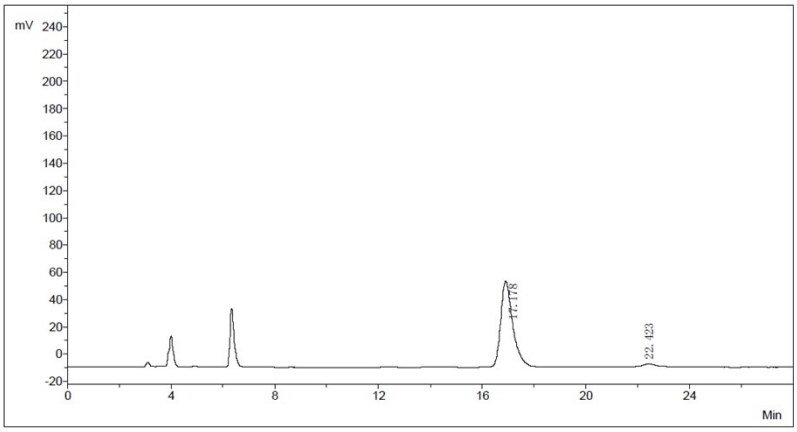
Sample Name:GYQ-VIII-19-2-1 AD 91 214 1.0 Recording Time:2020.01.23 17:17



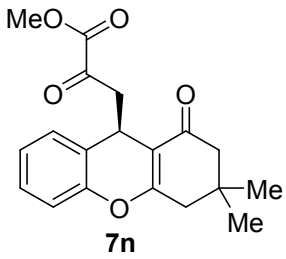
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		17.065	112783.4	3288382.8	54.0694
2	2		22.602	62802.9	2793394.7	45.9306
Total				175586.3	6081777.6	100.0000

HPLC Report

Sample Name:GYQ-VIII-23-1 AD 91 214 1.0 Recording Time:2020.01.23 17:45



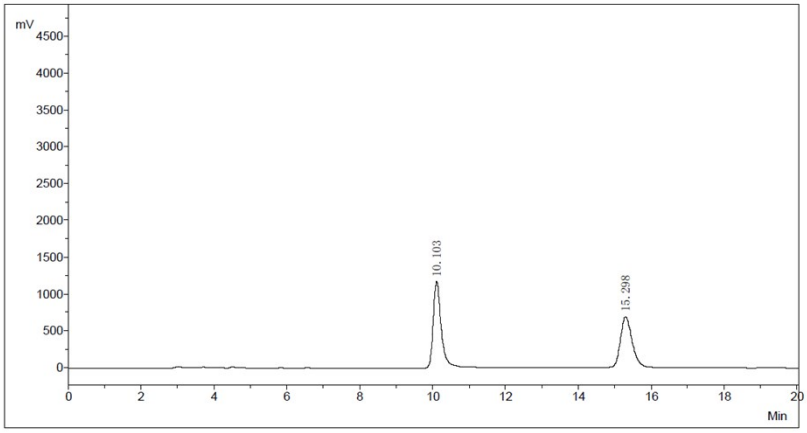
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		17.178	31207.1	2048772.2	95.8233
2	2		22.423	2087.8	89300.5	4.1767
Total				33295.0	2138072.7	100.0000



7n

HPLC Report

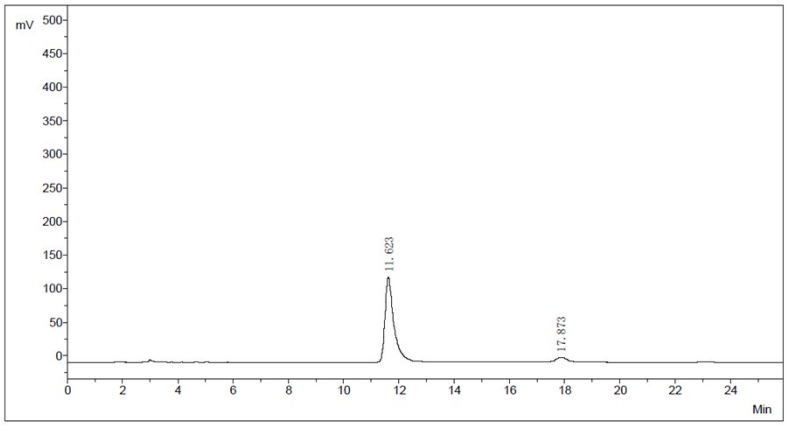
Sample Name:HY-III-42 AD-H 9010 214 1.0 Recording Time:2019.03.10 22:02



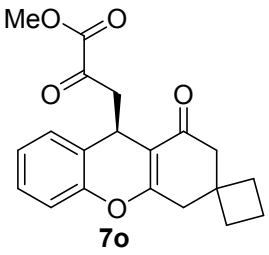
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		10.103	1127273.4	15461050.2	49.2440
2	2		15.298	692353.1	15935778.8	50.7560
Total				1819626.5	31396829.0	100.0000

HPLC Report

Sample Name:GYQ-VI-30 AD 9010 214 1.0 Recording Time:2018.10.16 20:41



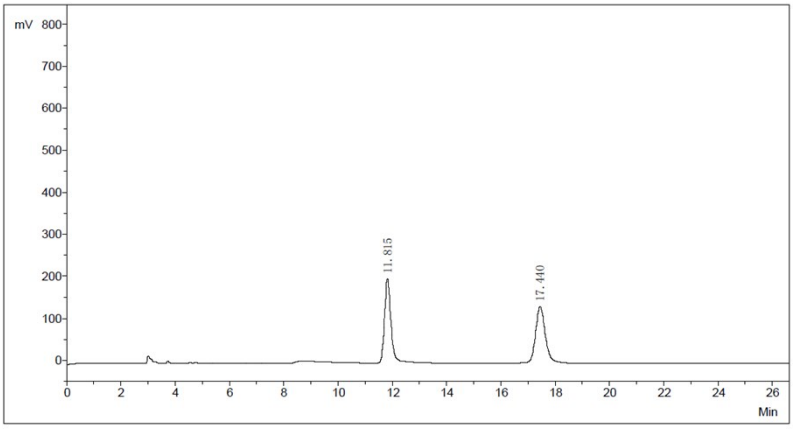
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		11.623	126297.5	2837684.8	93.3943
2	2		17.873	7155.7	200705.7	6.6057
Total				133453.2	3038390.5	100.0000



7o

HPLC Report

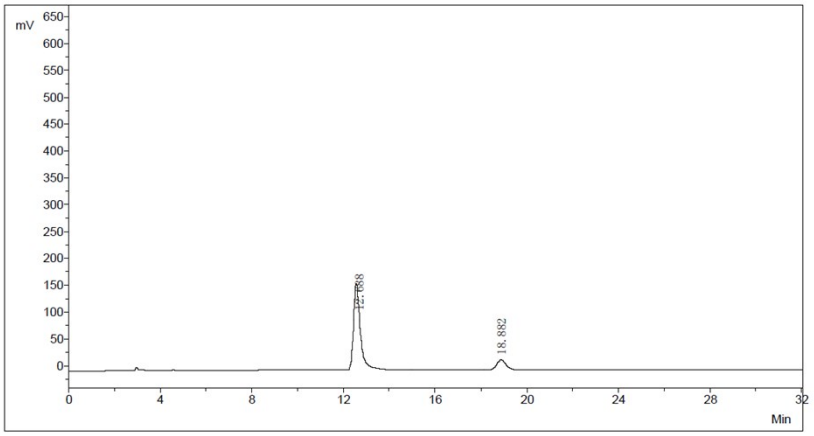
Sample Name:HY-III-45 AD 9010 214 1.0.che Recording Time:2019.05.23 09:53



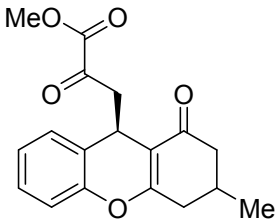
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		11.815	200138.0	3341719.4	49.8612
2	2		17.440	134753.5	3360327.9	50.1388
Total				334891.5	6702047.4	100.0000

HPLC Report

Sample Name:GYQ-VI-34 AD 9010 214 1.0 Recording Time:2018.10.20 10:17



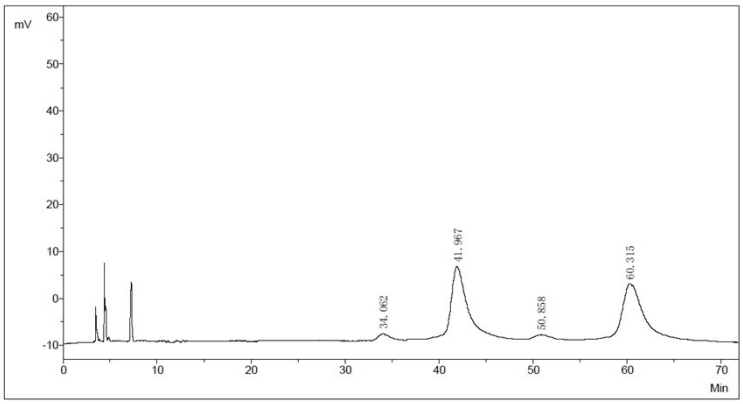
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		12.688	101343.2	3386256.1	86.7071
2	2		18.882	18354.2	519138.6	13.2929
Total				119697.3	3905394.7	100.0000



7p

HPLC Report

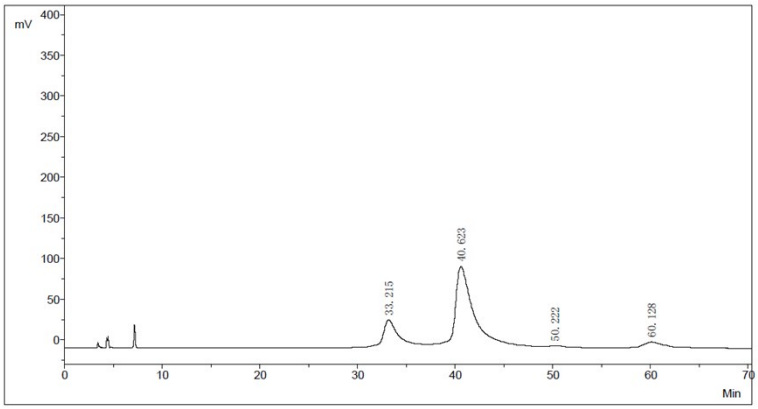
Sample Name:HY-III-41 OD 9505 214 1.0 Recording Time:2019.12.23 21:05



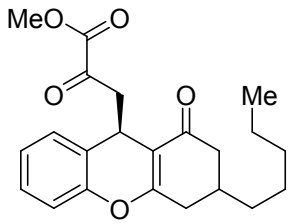
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		34.062	1428.7	123476.0	3.2812
2	2		41.967	15069.9	1790657.3	47.5836
3	3		50.858	985.9	110296.9	2.9309
4	4		60.315	11552.9	1738751.2	46.2043
Total				29037.4	3763181.4	100.0000

HPLC Report

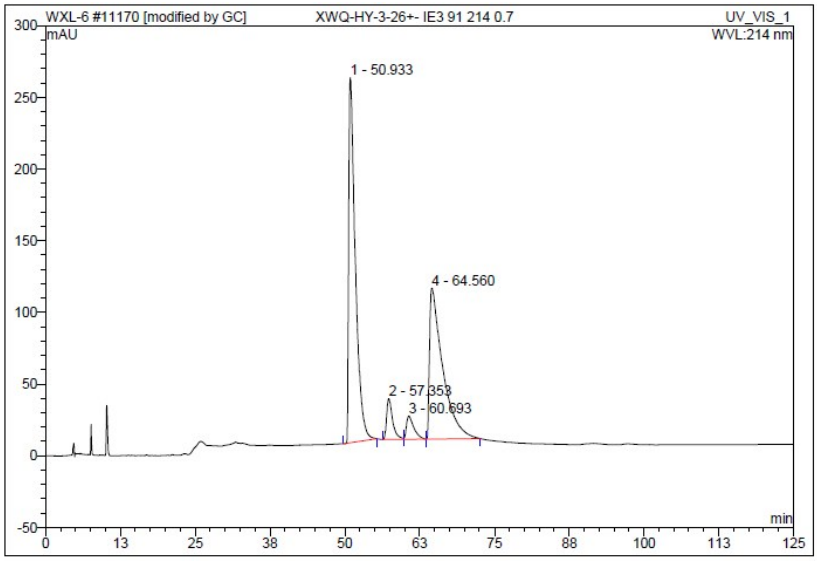
Sample Name:GYQ-VI-33-1 OD-H 9505 214 1.0 Recording Time:2019.12.23 22:23



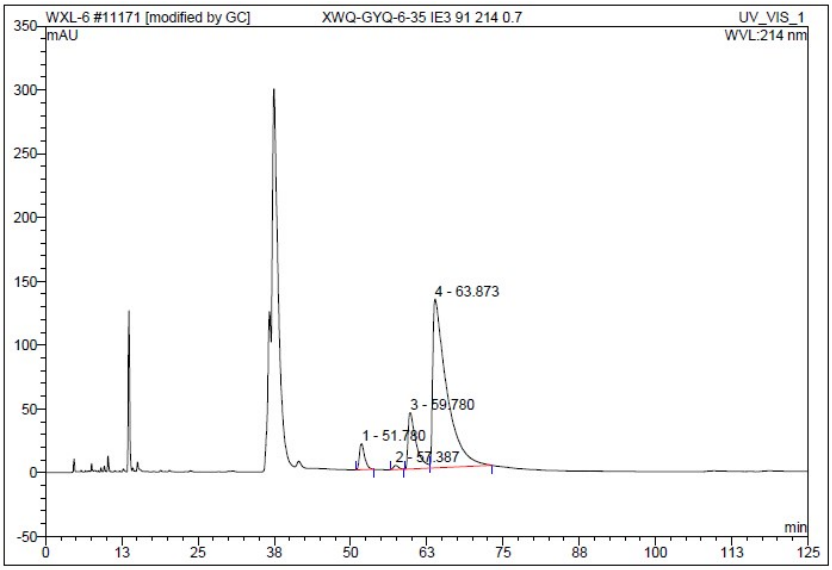
No.	PeakNo	ID.Name	R.Time	PeakHeight	PeakArea	Conc
1	1		33.215	31893.5	3077383.1	19.0682
2	2		40.623	96343.7	12075650.5	74.8237
3	3		50.222	1439.6	143488.5	0.8891
4	4		60.128	6508.4	842274.1	5.2189
Total				136185.1	16138796.1	100.0000



7q

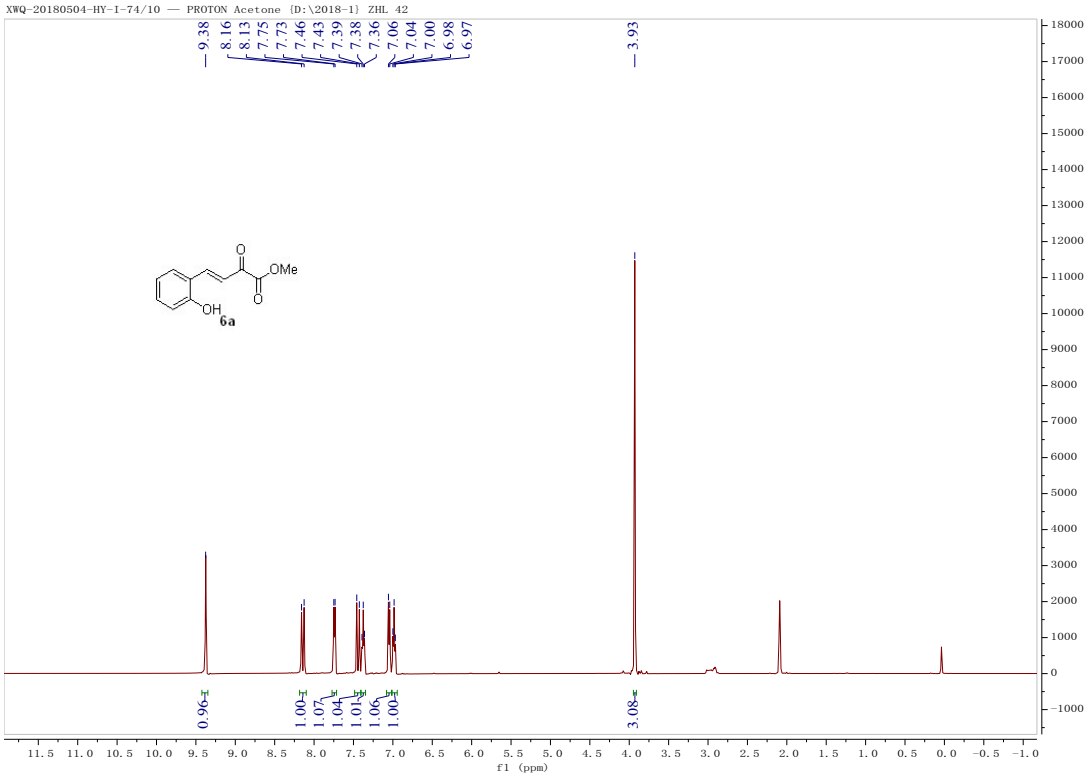


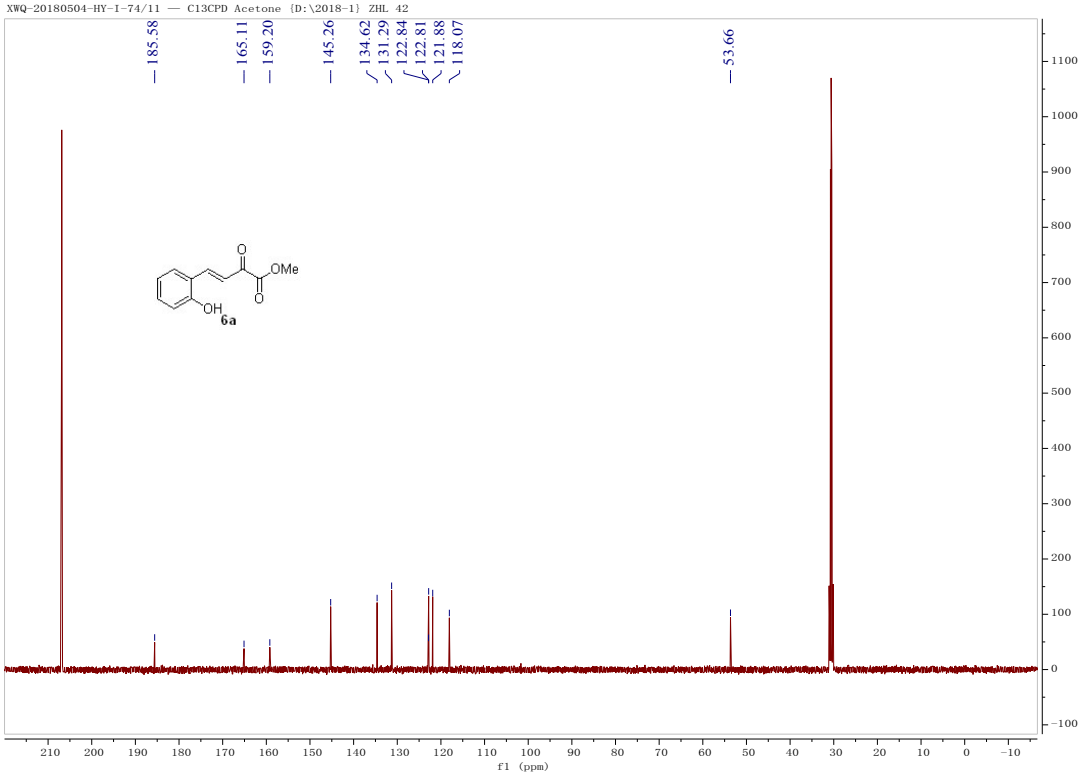
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	50.93	n.a.	254.665	327.523	50.15	n.a.	BMB*
2	57.35	n.a.	28.598	33.222	5.09	n.a.	BM
3	60.69	n.a.	16.422	23.435	3.59	n.a.	MB
4	64.56	n.a.	105.441	268.852	41.17	n.a.	BMB
Total:			405.126	653.031	100.00	0.000	

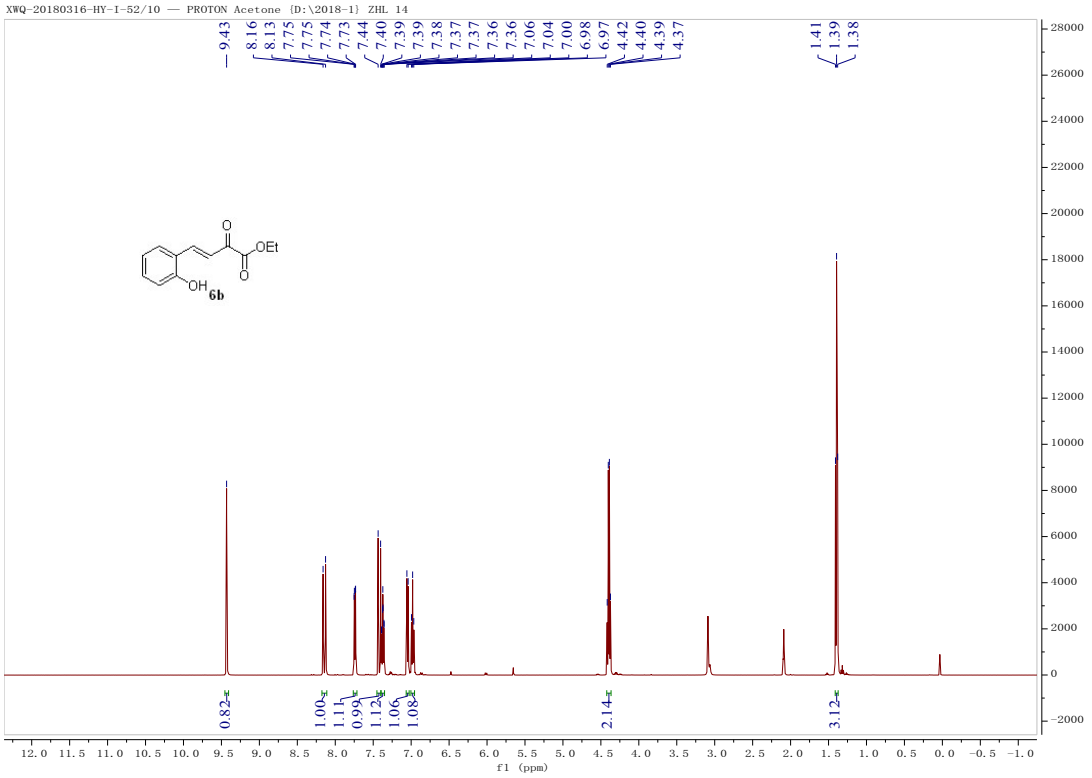


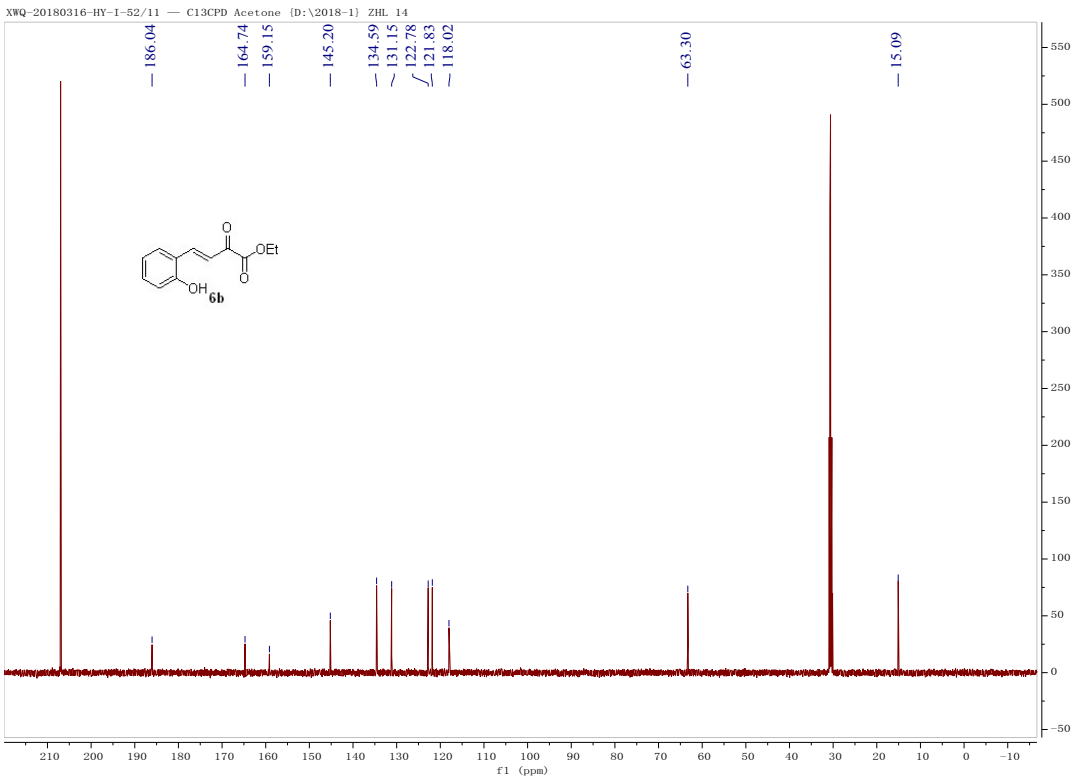
No.	Ret.Time min	Peak Name	Height mAU	Area mAU*min	Rel.Area %	Amount	Type
1	51.78	n.a.	20.244	20.161	4.56	n.a.	BMB
2	57.39	n.a.	3.144	3.123	0.71	n.a.	BMB
3	59.78	n.a.	44.323	67.135	15.18	n.a.	BM
4	63.87	n.a.	132.454	351.864	79.56	n.a.	MB
Total:			200.165	442.283	100.00	0.000	

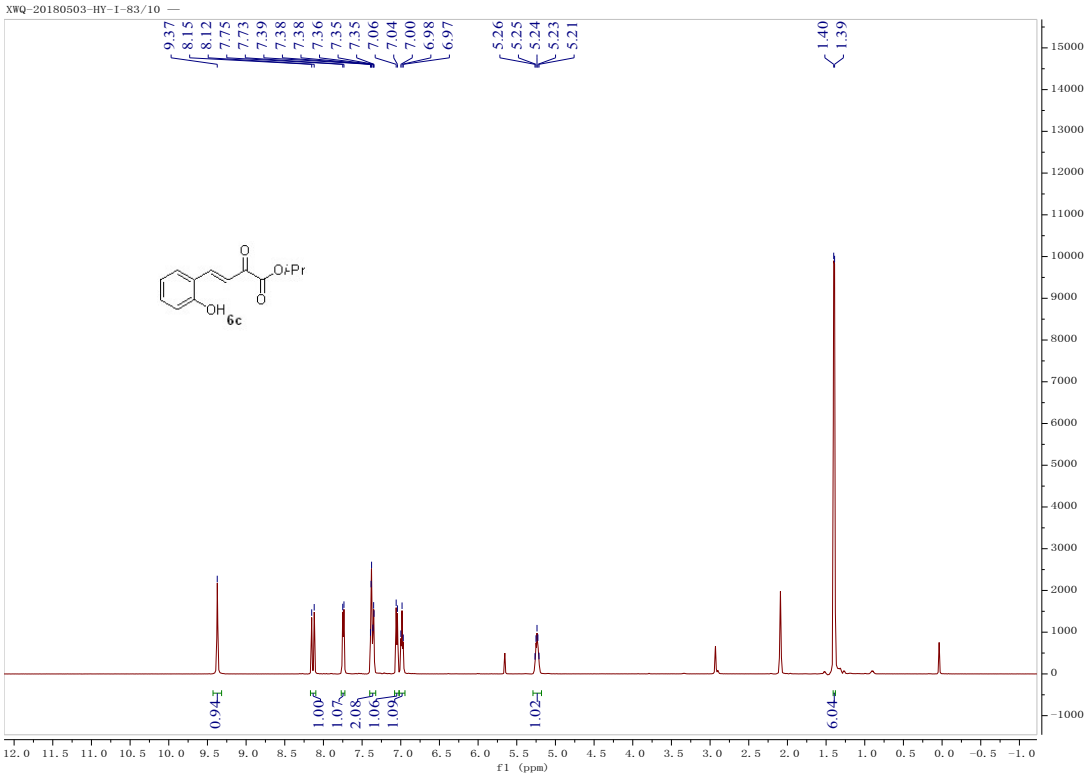
9. NMR Spectra

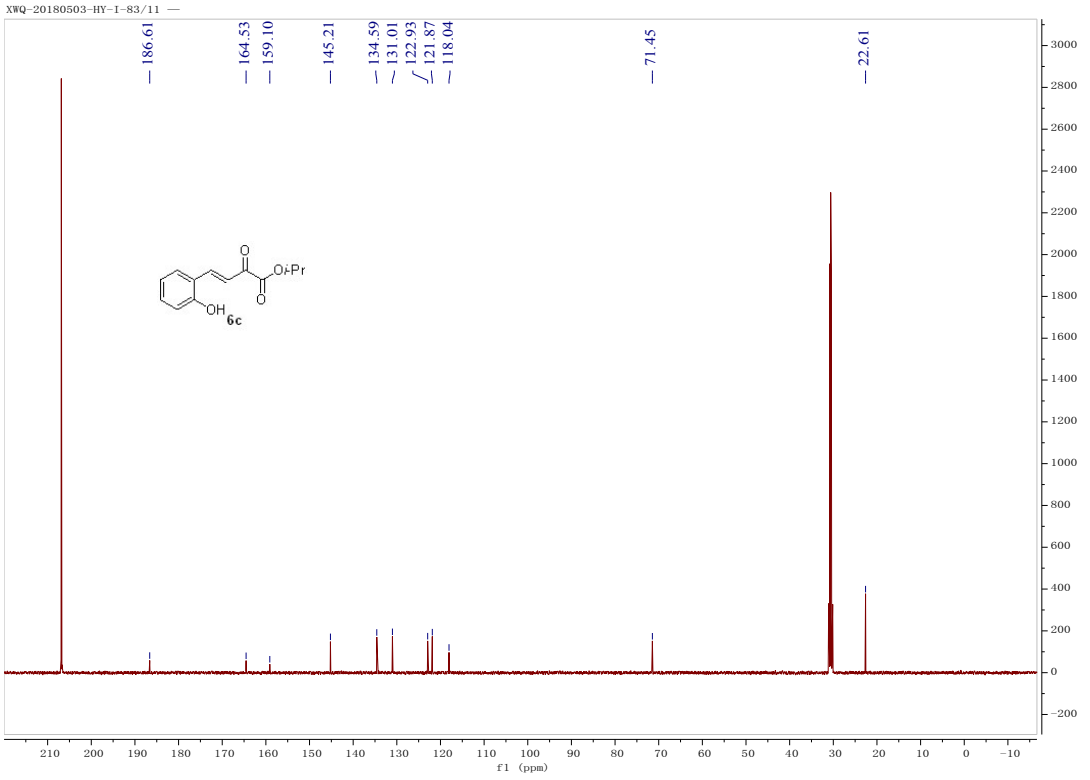


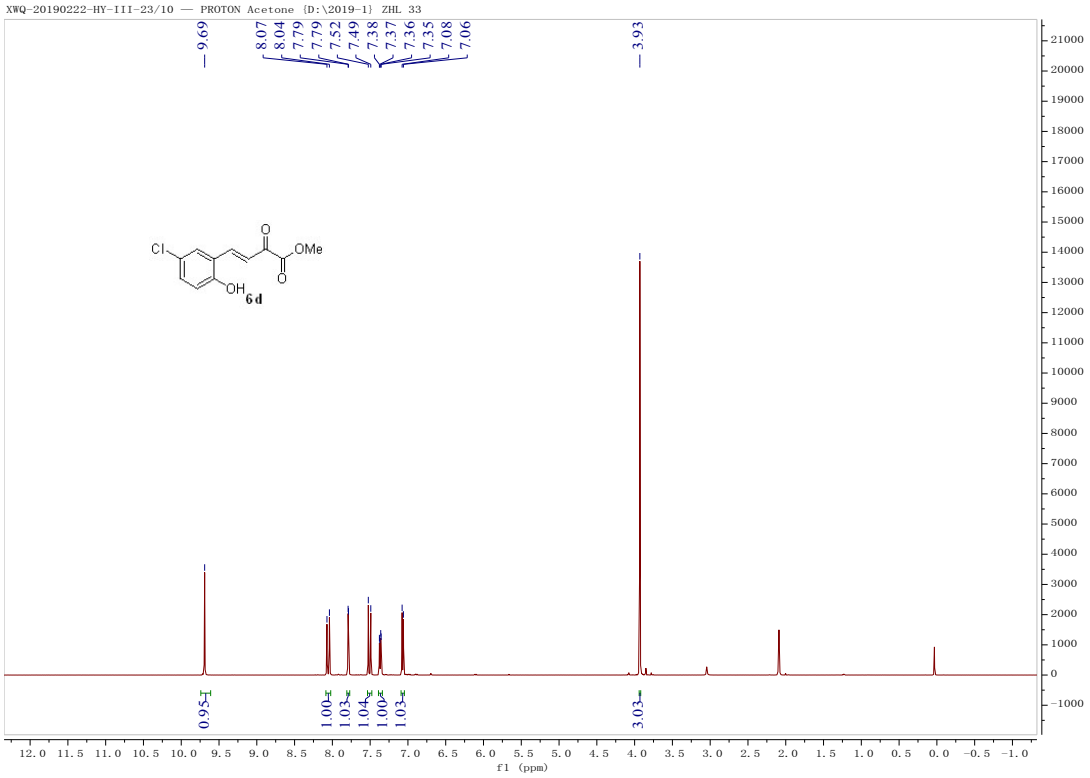


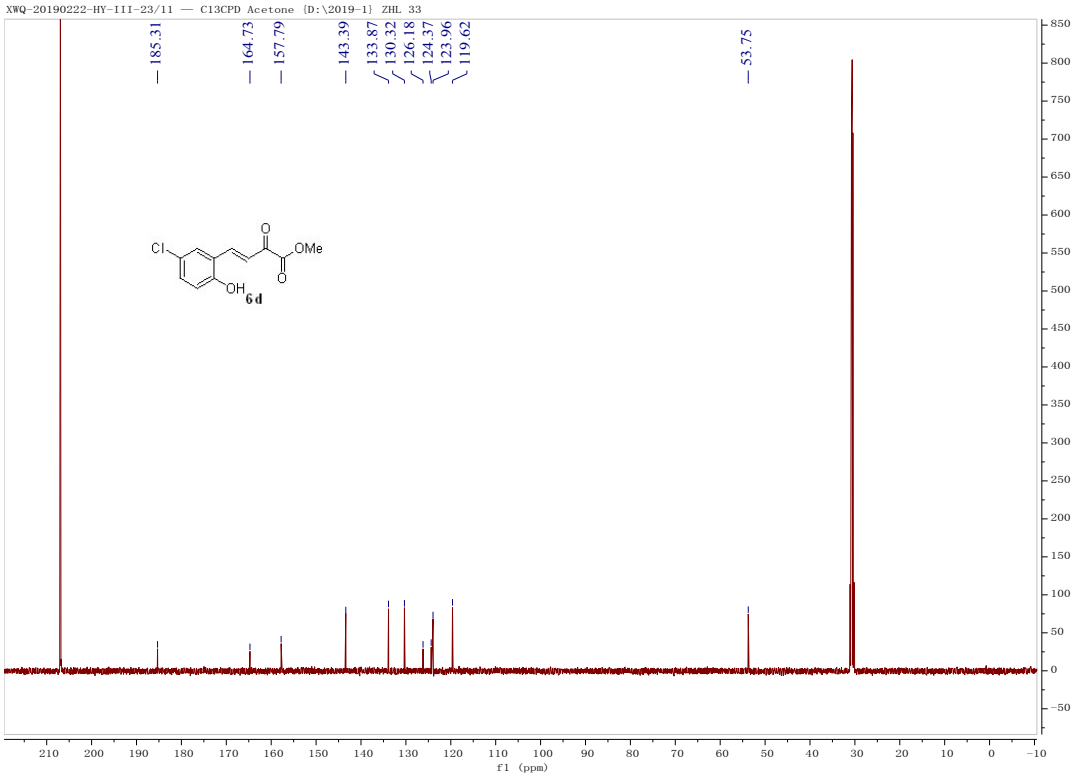

XWQ-20180316-HY-I-52/10 — PROTON Acetone {D:\2018-1} ZHL 14
9.43
8.16
8.13
7.75
7.75
7.74
7.73
7.44
7.40
7.39
7.39
7.38
7.37
7.37
7.36
7.36
7.06
7.04
7.00
6.98
6.97
4.42
4.40
4.39
4.37
1.41
1.39
1.38
OEt
OH
6b
0.82
1.00
1.11
0.99
1.12
1.06
1.08
2.14
3.12
f1 (ppm)

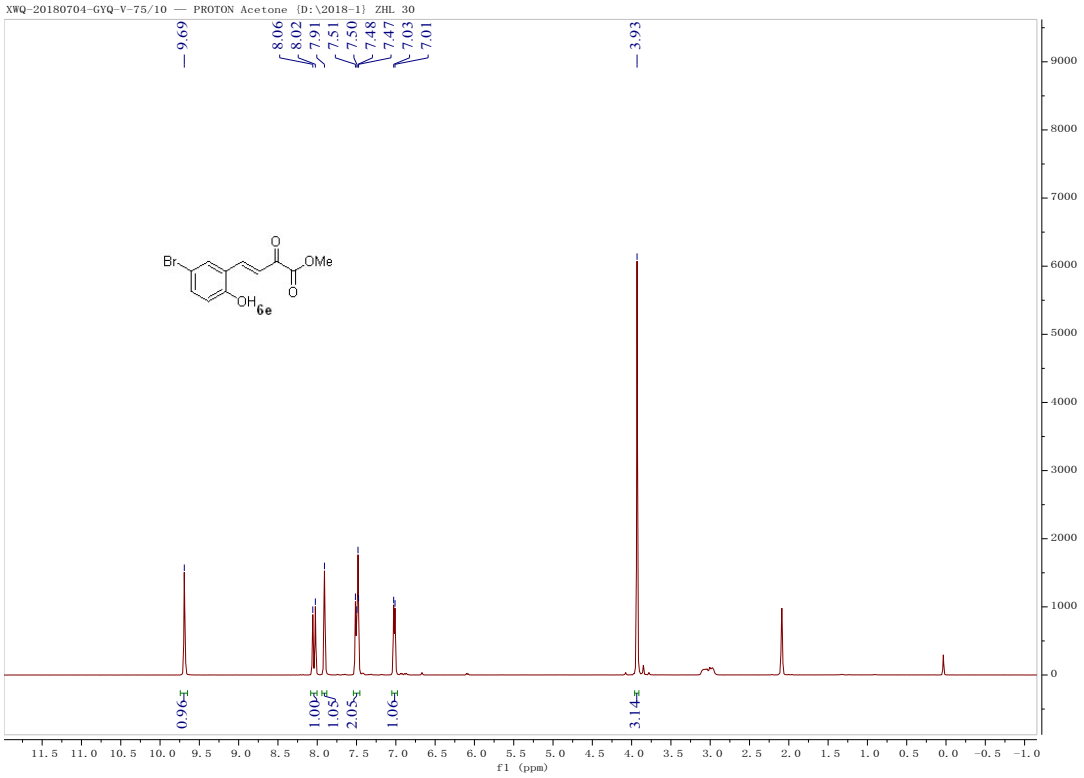

XWQ-20180316-HY-I-52/11 — C13CPD Acetone {D:\2018-1} ZHL 14
186.04
164.74
159.15
145.20
134.59
131.15
122.78
121.83
118.02
63.30
15.09
OEt
OH
6b
f1 (ppm)

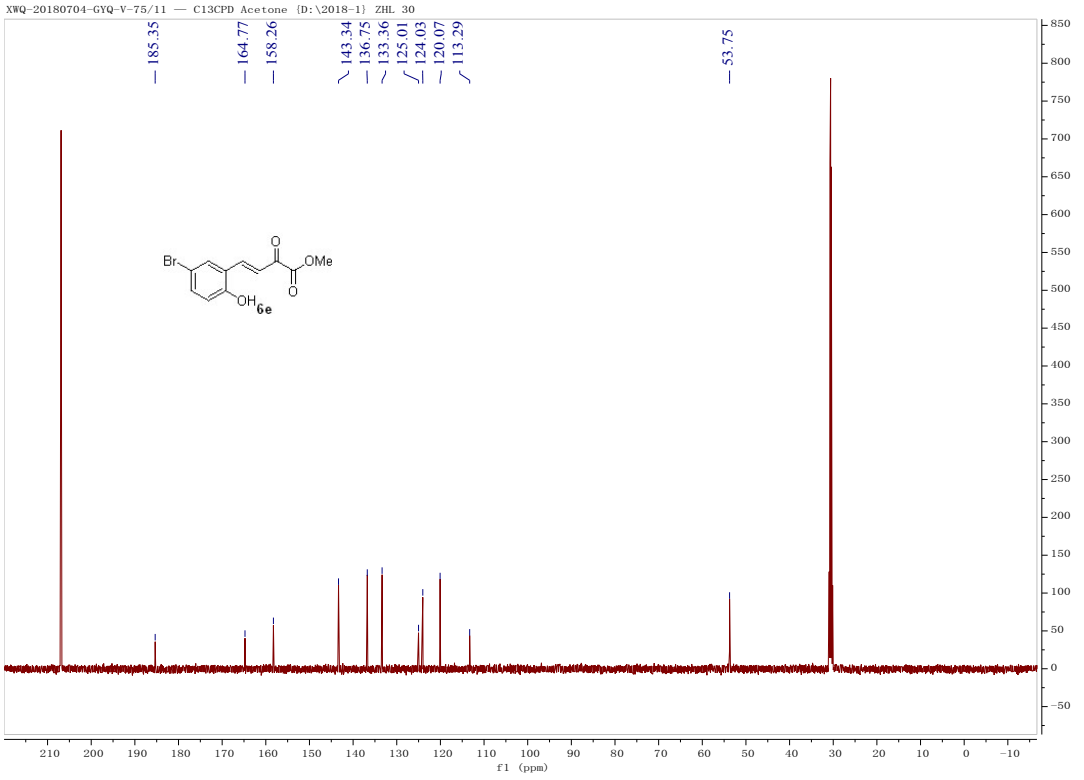

XWQ-20180503-HY-I-83/10
9.37
8.15
8.12
7.75
7.73
7.39
7.38
7.38
7.36
7.35
7.35
7.06
7.04
7.00
6.98
6.97
5.26
5.25
5.24
5.23
5.21
1.40
1.39
O
O
O-i-Pr
OH
6c
0.94
1.00
1.07
2.08
1.06
1.09
1.02
6.04
f1 (ppm)

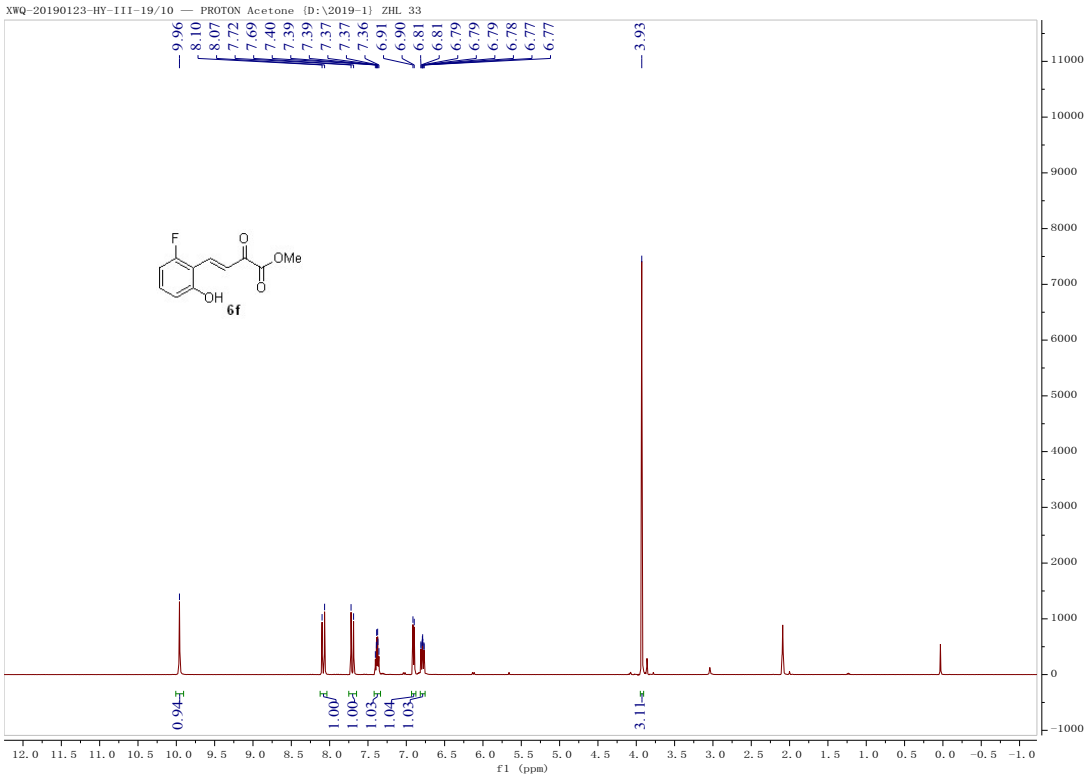

XWQ-20180503-HY-I-83/11
186.61
164.53
159.10
145.21
134.59
131.01
122.93
121.87
118.04
71.45
22.61
O
O
O-i-Pr
OH
6c
f1 (ppm)

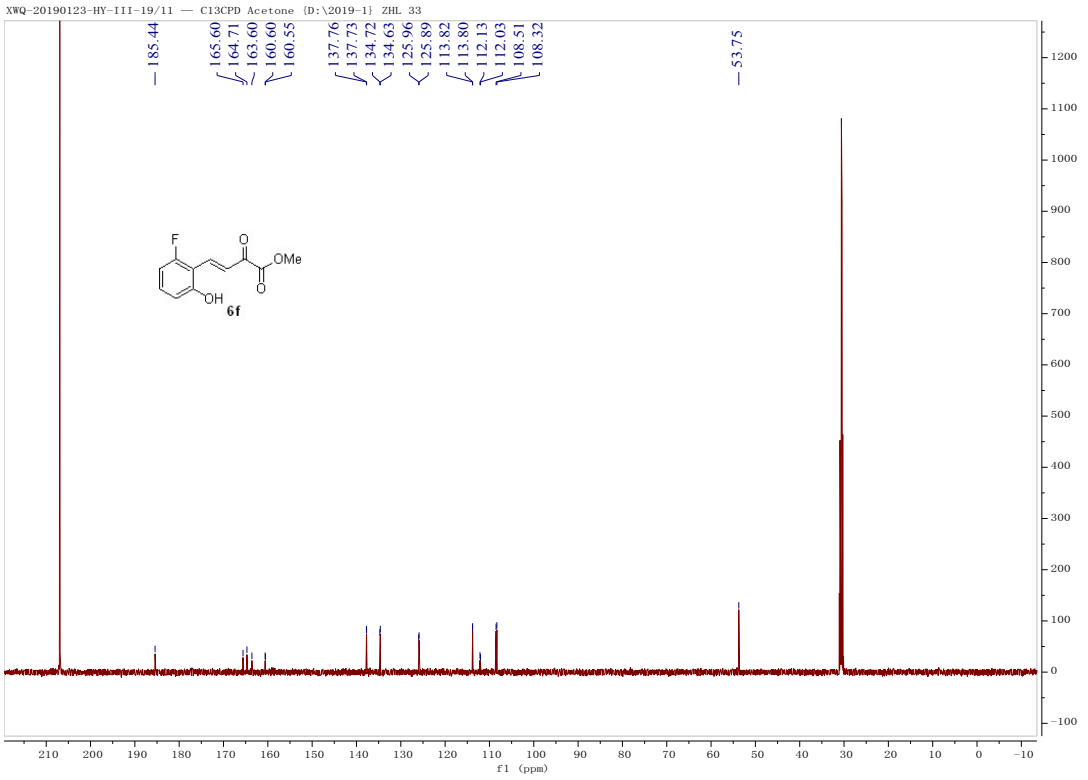

XWQ-20190222-HY-III-23/10 — PROTON Acetone {D:\2019-1} ZHL 33
9.69
8.07
8.04
7.79
7.79
7.52
7.49
7.38
7.37
7.36
7.35
7.08
7.06
3.93
Cl
OH
O
OMe
O
6d
0.95
1.00
1.03
1.04
1.00
1.03
3.03
f1 (ppm)

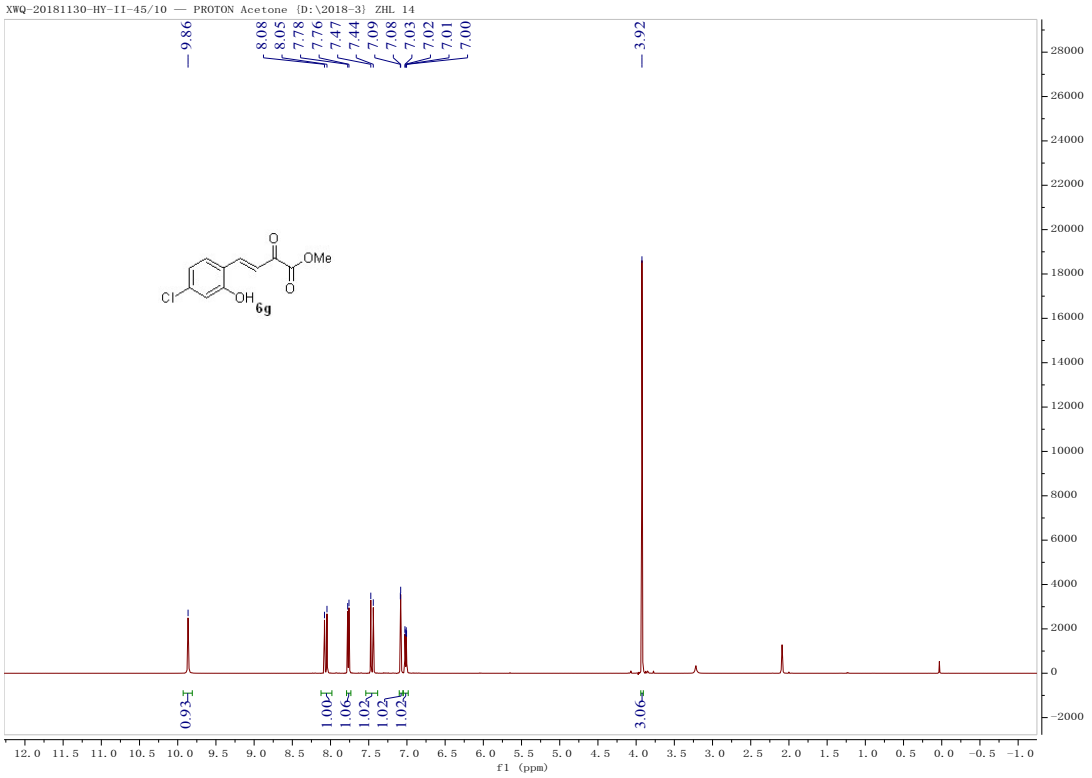

XWQ-20190222-HY-III-23/11 — C13CPD Acetone {D:\2019-1} ZHL 33
185.31
164.73
157.79
143.39
133.87
130.32
126.18
124.37
123.96
119.62
53.75
Cl
OH
O
OMe
O
6d
f1 (ppm)

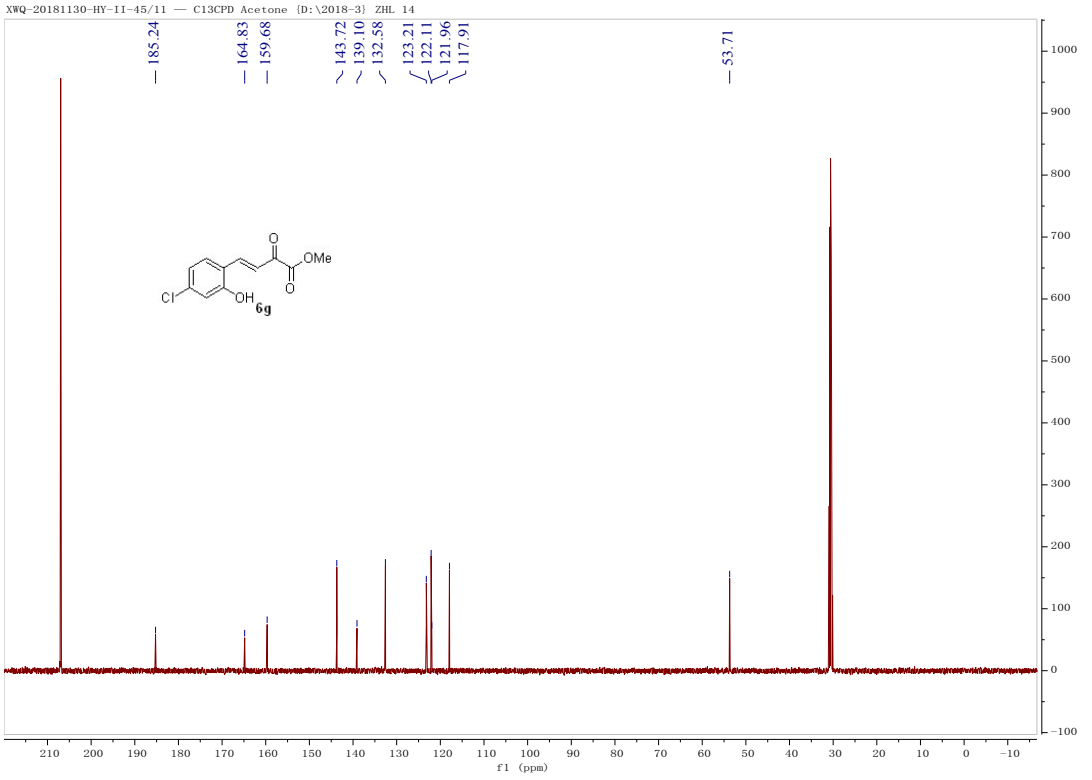

XWQ-20180704-GYQ-V-75/10 — PROTON Acetone {D:\2018-1} ZHL 30
9.69
8.06
8.02
7.91
7.51
7.50
7.48
7.47
7.03
7.01
3.93
Br
OMe
O
O
OH
6e
0.96
1.00
1.05
2.05
1.06
3.14
f1 (ppm)

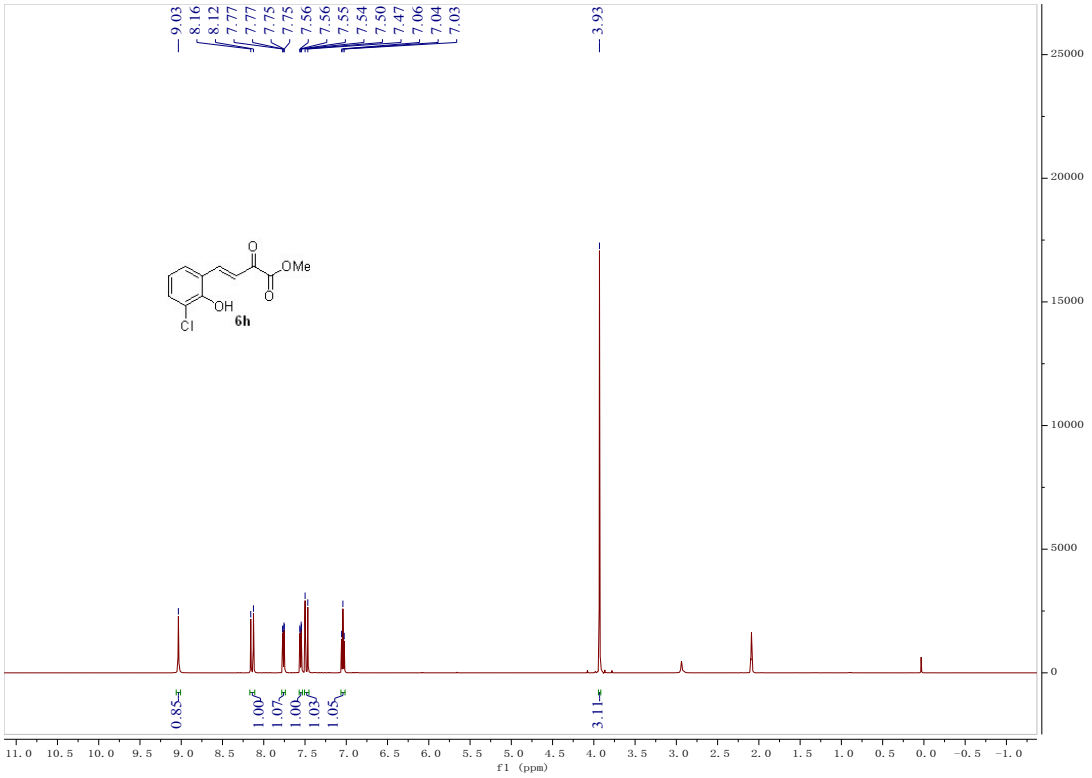

XWQ-20180704-GYQ-V-75/11 — C13CPD Acetone {D:\2018-1} ZHL 30
185.35
164.77
158.26
143.34
136.75
133.36
125.01
124.03
120.07
113.29
53.75
Br
OMe
O
O
OH
6e
f1 (ppm)

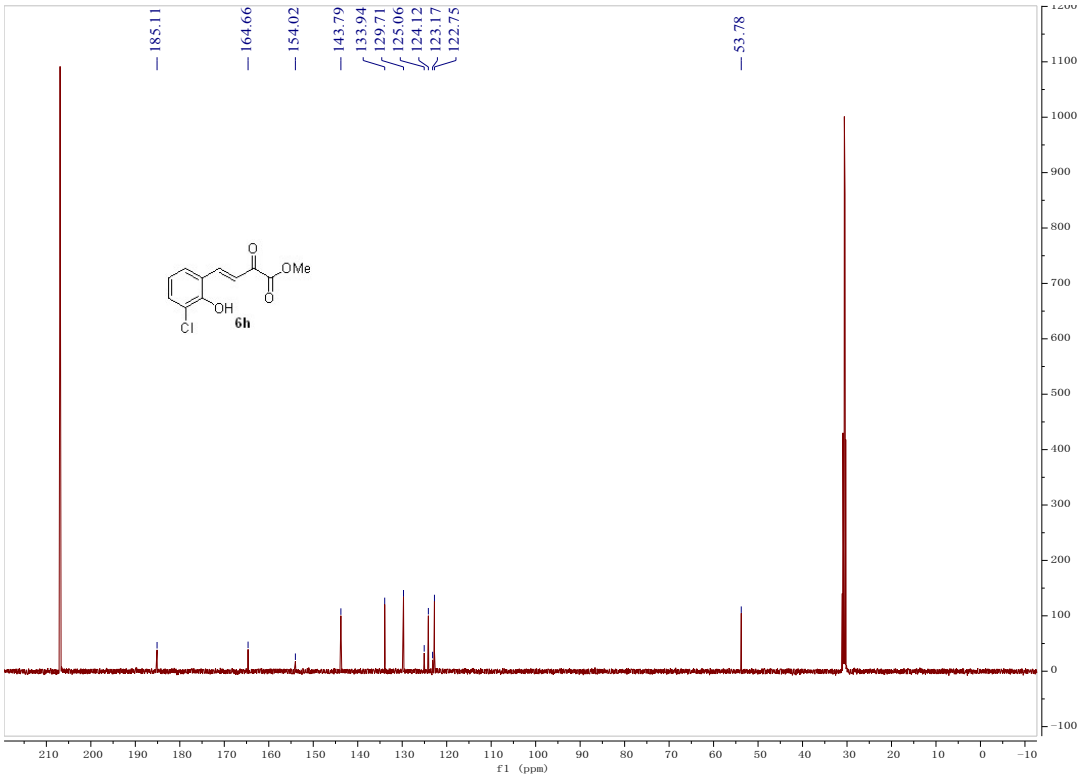

XWQ-20190123-HY-III-19/10 — PROTON Acetone {D:\2019-1} ZHL 33
9.96
8.10
8.07
7.72
7.69
7.40
7.39
7.39
7.37
7.37
7.36
6.91
6.90
6.81
6.81
6.79
6.79
6.79
6.78
6.77
6.77
3.93
F
O
OMe
O
OH
6f
0.94
1.00
1.00
1.03
1.04
1.03
3.11
f1 (ppm)

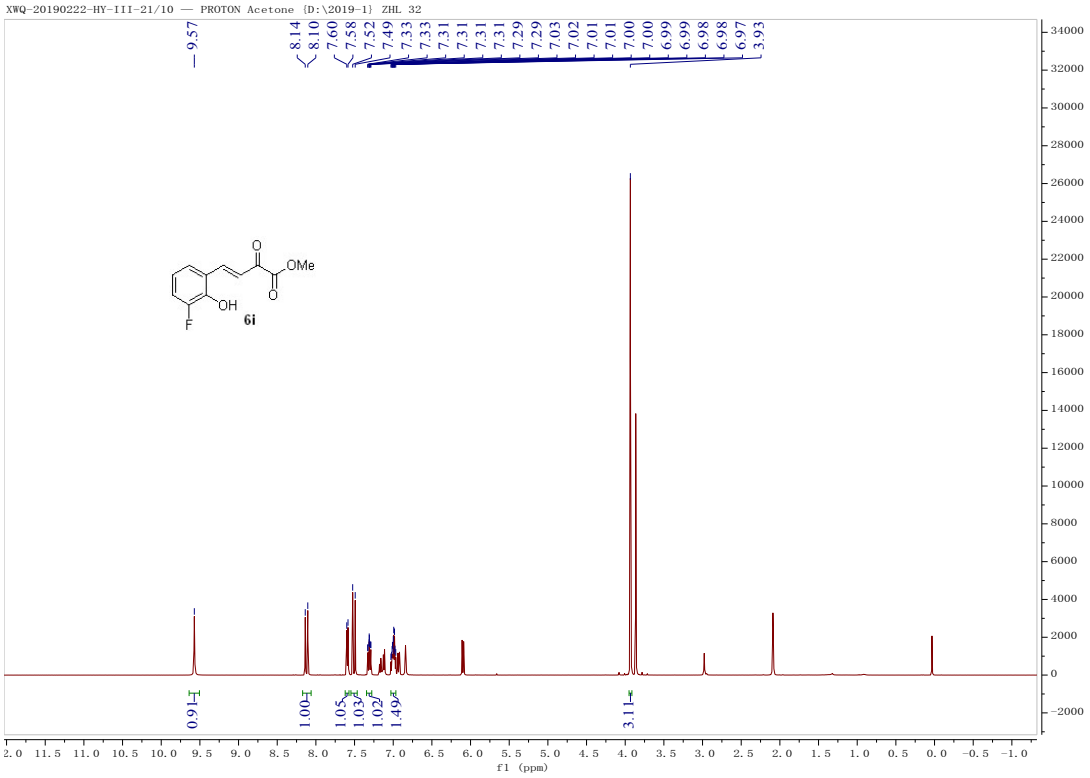

XWQ-20190123-HY-III-19/11 — C13CPD Acetone {D:\2019-1} ZHL 33
185.44
165.60
164.71
163.60
160.60
160.55
137.76
137.73
134.72
134.63
125.96
125.89
113.82
113.80
112.13
112.03
108.51
108.32
53.75
F
O
OMe
O
OH
6f
f1 (ppm)

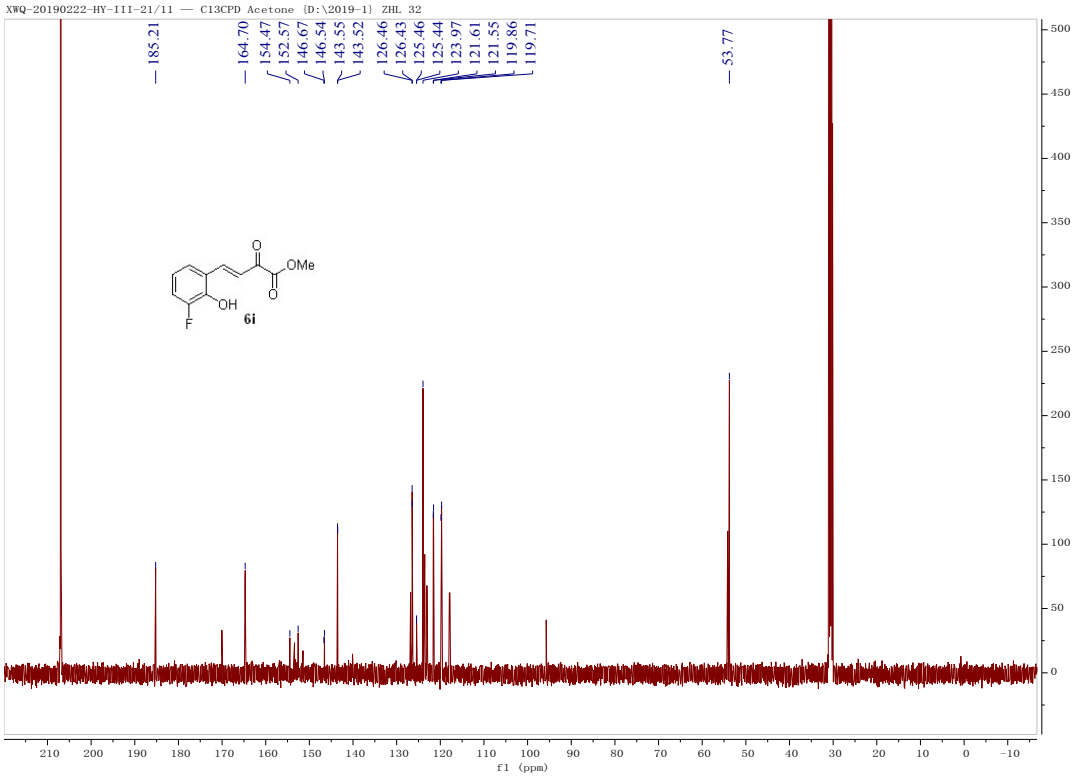

XWQ-20181130-HY-II-45/10 — PROTON Acetone {D:\2018-3} ZHL 14
9.86
8.08
8.05
7.78
7.76
7.47
7.44
7.09
7.08
7.03
7.02
7.01
7.00
3.92
OMe
O
O
Cl
OH
6g
0.93
1.00
1.06
1.02
1.02
3.06
f1 (ppm)

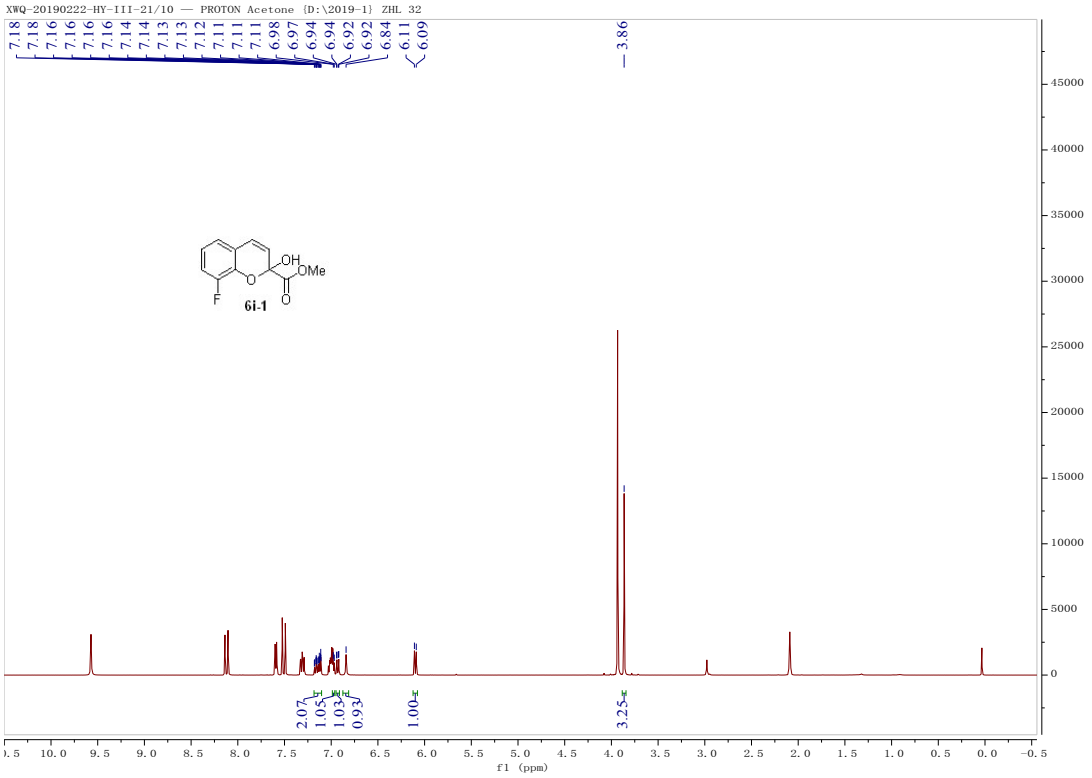

XWQ-20181130-HY-II-45/11 — C13CPD Acetone {D:\2018-3} ZHL 14
185.24
164.83
159.68
143.72
139.10
132.58
123.21
122.11
121.96
117.91
53.71
OMe
O
O
Cl
OH
6g
f1 (ppm)

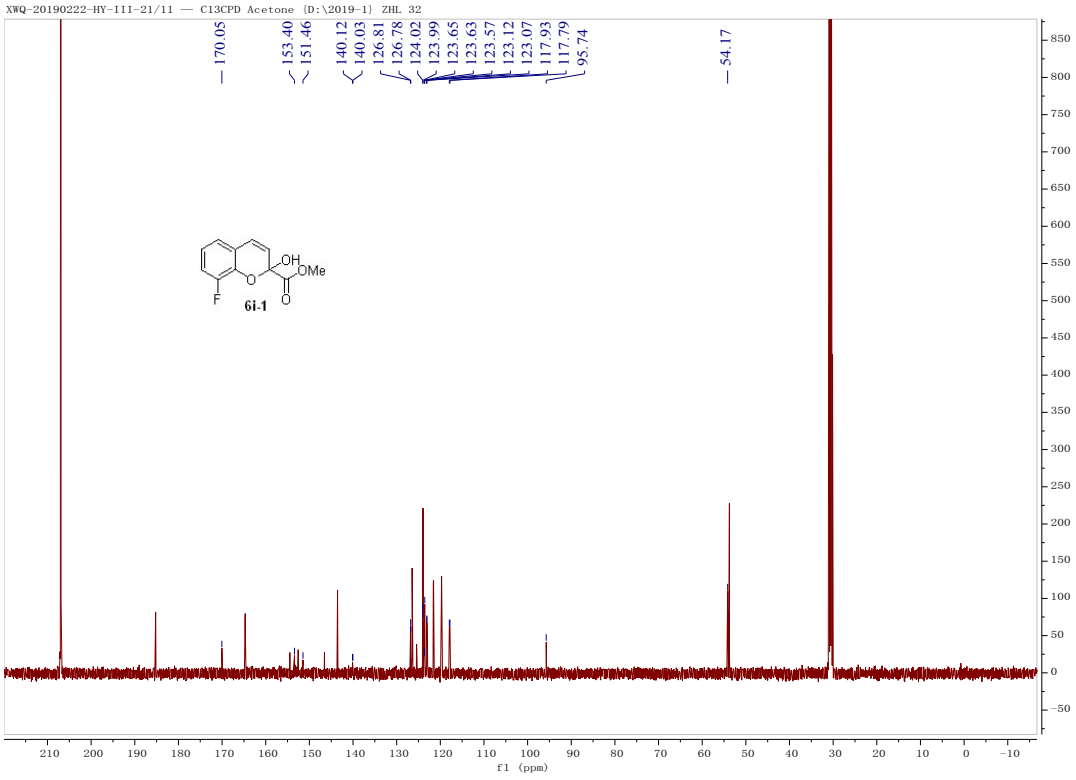

9.03
8.16
8.12
7.77
7.77
7.75
7.75
7.56
7.56
7.55
7.54
7.50
7.47
7.06
7.04
7.03
3.93
OMe
OH
Cl
6h
0.85
1.00
1.07
1.00
1.03
1.05
3.11
f1 (ppm)

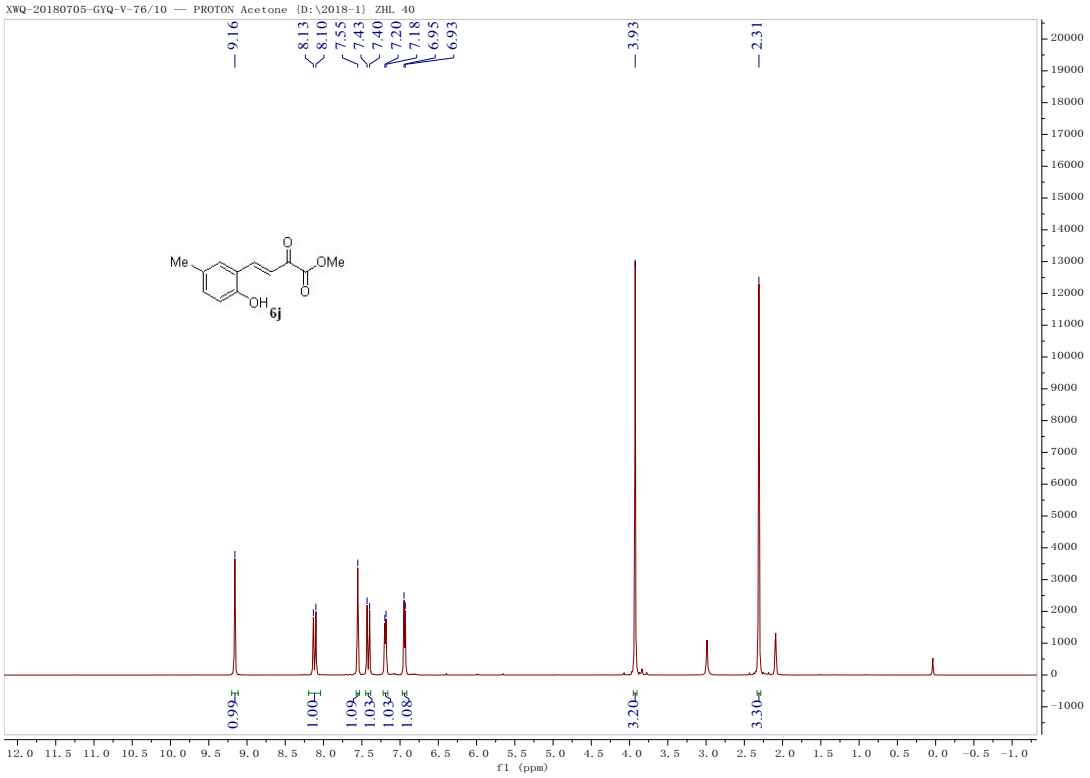

185.11
164.66
154.02
143.79
133.94
129.71
125.06
124.12
123.17
122.75
53.78
OMe
OH
Cl
6h
f1 (ppm)

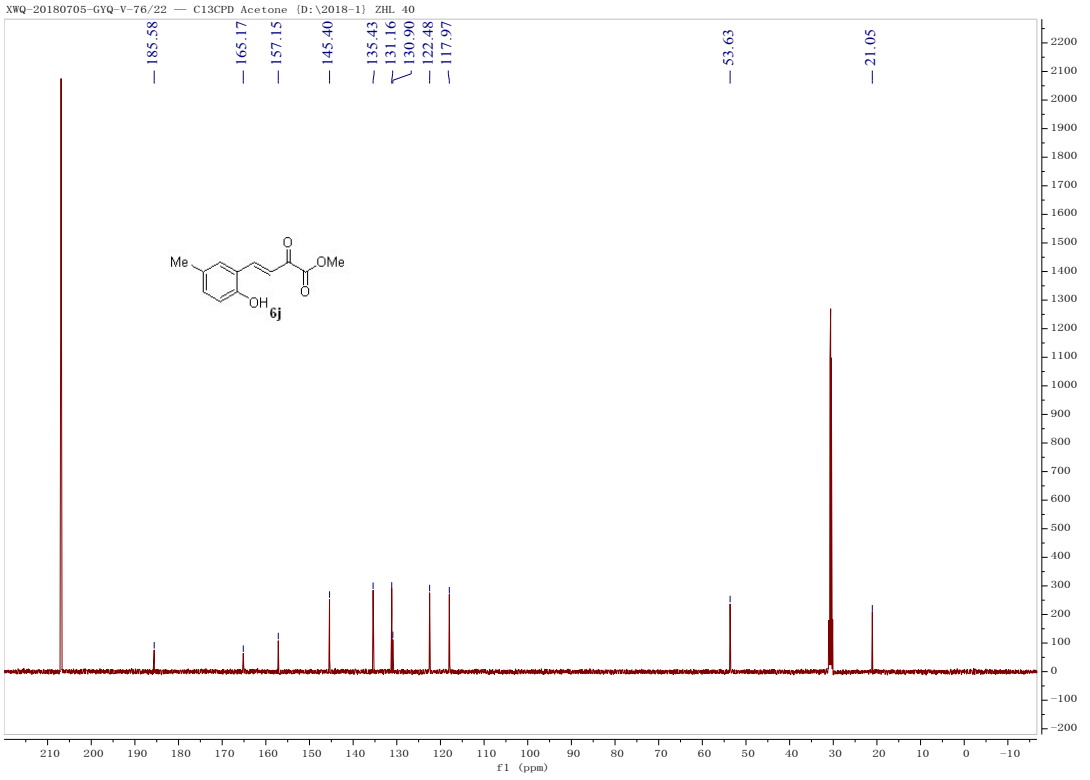

XWQ-20190222-HY-III-21/10 — PROTON Acetone {D:\2019-1} ZHL 32
9.57
8.14
8.10
7.60
7.58
7.52
7.49
7.33
7.33
7.31
7.31
7.31
7.29
7.29
7.03
7.02
7.01
7.01
7.00
7.00
6.99
6.99
6.98
6.98
6.97
3.93
OMe
OH
F
6i
0.91
1.00
1.05
1.03
1.02
1.49
3.11
f1 (ppm)

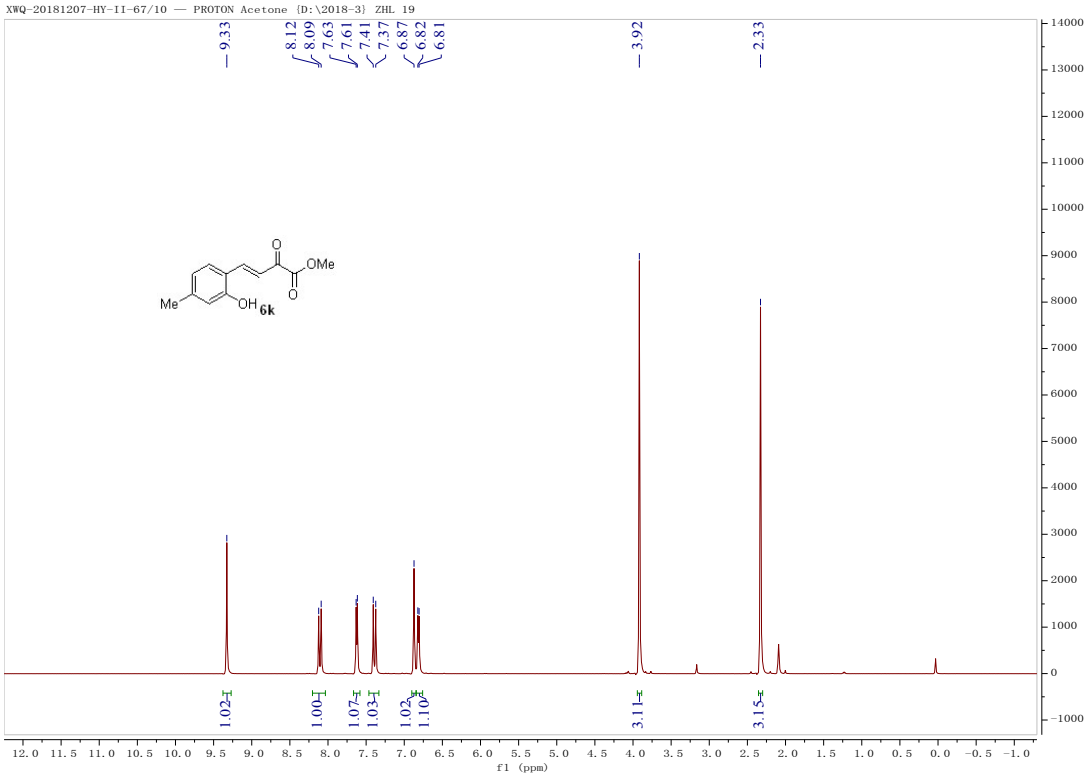

XWQ-20190222-HY-III-21/11 — C13CPD Acetone {D:\2019-1} ZHL 32
185.21
164.70
154.47
152.57
146.67
146.54
143.55
143.52
126.46
126.43
125.46
125.44
123.97
121.61
121.55
119.86
119.71
53.77
OMe
OH
F
6i
f1 (ppm)

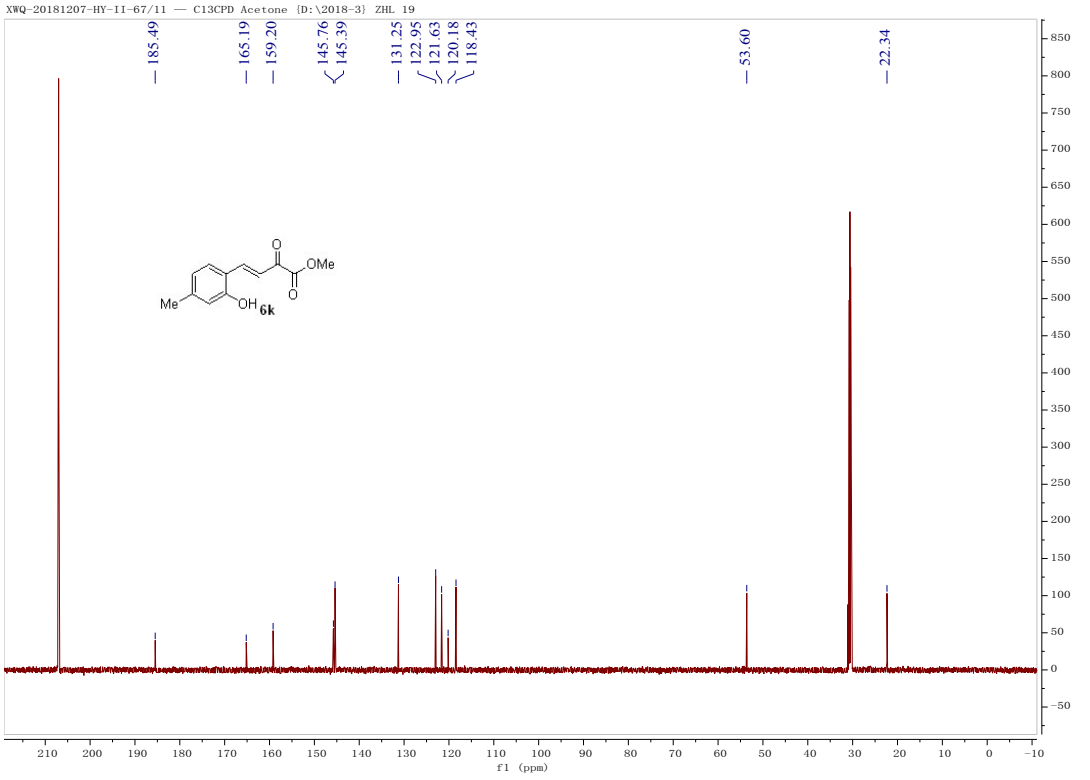

XWQ-20190222-HY-III-21/10 — PROTON Acetone {D:\2019-1} ZHL 32
7.18
7.18
7.16
7.16
7.16
7.16
7.14
7.14
7.13
7.13
7.12
7.11
7.11
7.11
6.98
6.97
6.94
6.94
6.92
6.92
6.84
6.11
6.09
3.86
OH
OMe
O
F
6i-1
2.07
1.05
1.03
0.93
1.00
3.25
f1 (ppm)

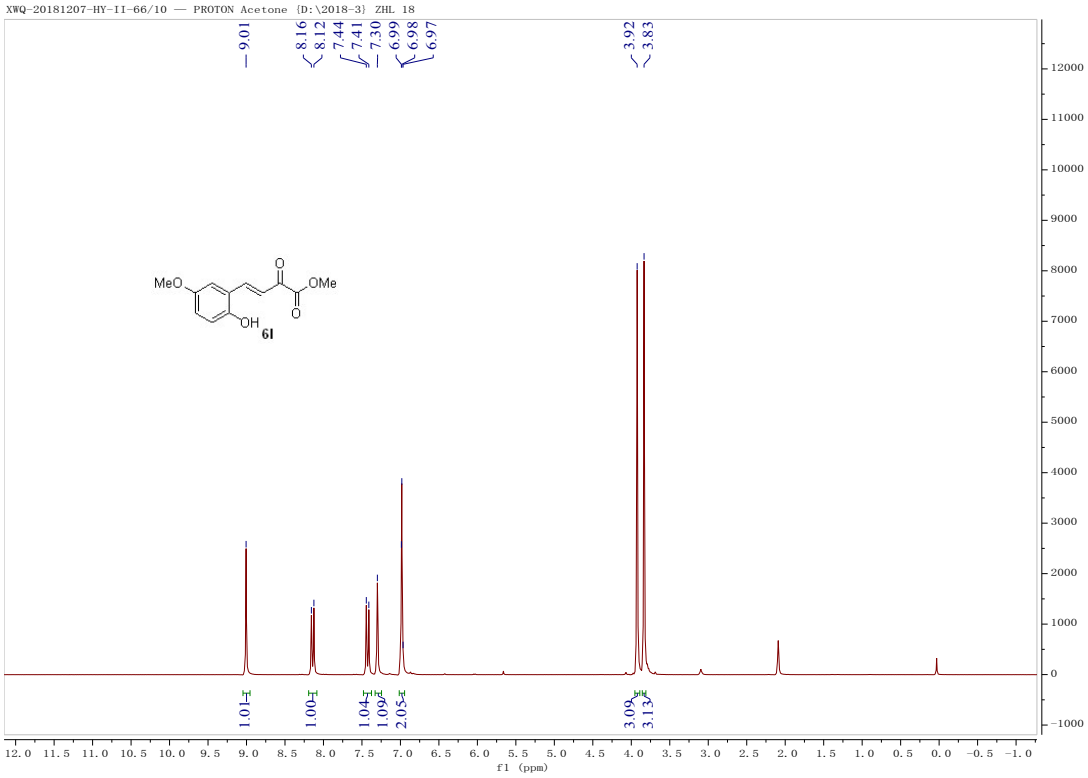

XWQ-20190222-HY-III-21/11 — C13CPD Acetone {D:\2019-1} ZHL 32
170.05
153.40
151.46
140.12
140.03
126.81
126.78
124.02
123.99
123.65
123.63
123.57
123.12
123.07
117.93
117.79
95.74
54.17
OH
OMe
O
F
6i-1
f1 (ppm)

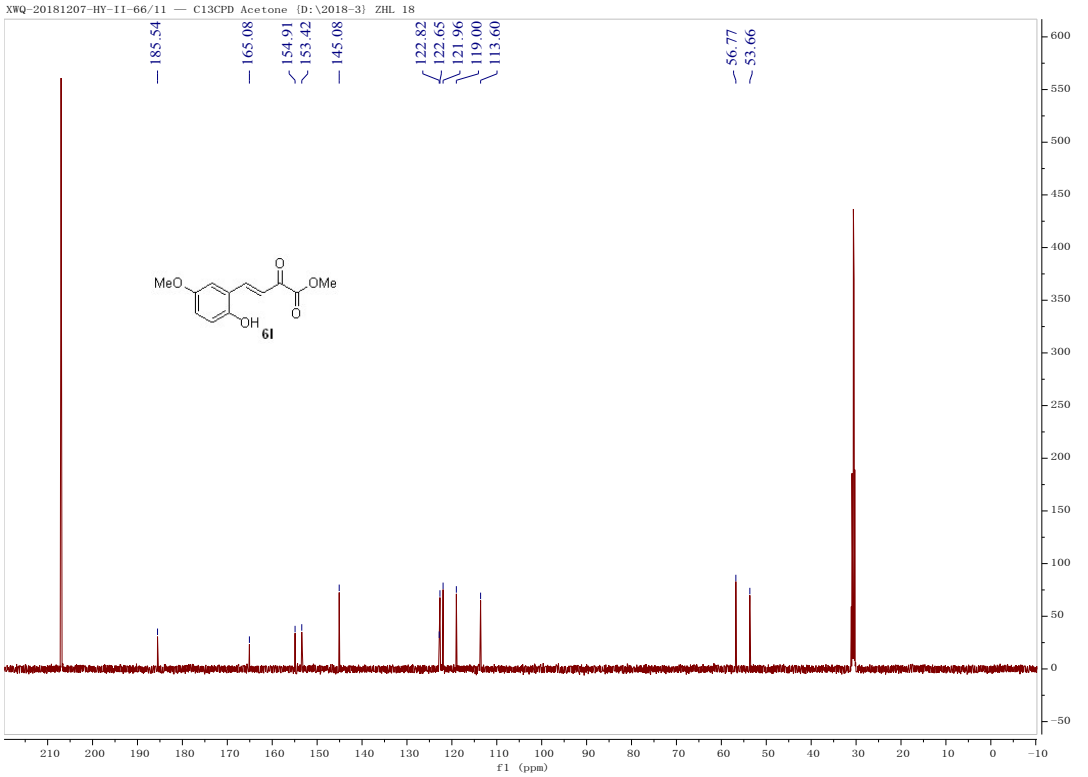

XWQ-20180705-GYQ-V-76/10 — PROTON Acetone {D:\2018-1} ZHL 40
9.16
8.13
8.10
7.55
7.43
7.40
7.20
7.18
6.95
6.93
3.93
2.31
Me
OMe
OH
O
O
6j
0.99
1.00
1.09
1.03
1.03
1.08
3.20
3.30
f1 (ppm)

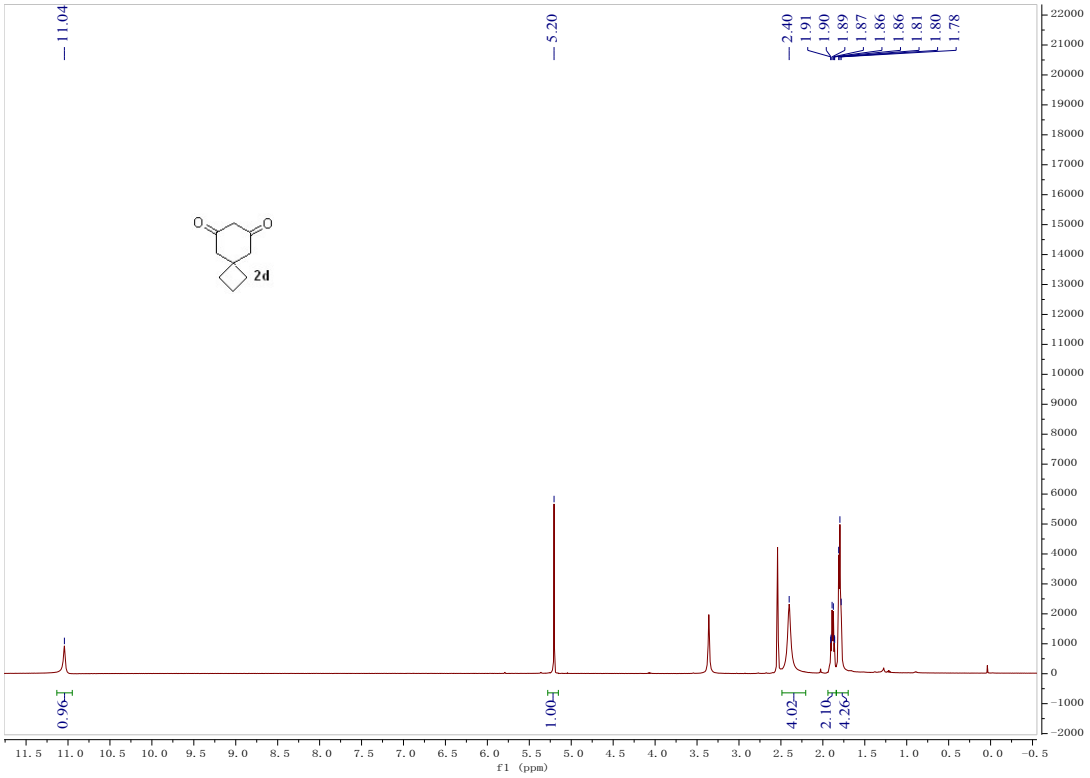

XWQ-20180705-GYQ-V-76/22 — C13CPD Acetone {D:\2018-1} ZHL 40
185.58
165.17
157.15
145.40
135.43
131.16
130.90
122.48
117.97
53.63
21.05
Me
OMe
OH
O
O
6j
f1 (ppm)


XWQ-20181207-HY-II-67/10 — PROTON Acetone {D:\2018-3} ZHL 19
9.33
8.12
8.09
7.63
7.61
7.41
7.37
6.87
6.82
6.81
3.92
2.33
OMe
Me
OH
6k
1.02
1.00
1.07
1.03
1.02
1.10
3.11
3.15
f1 (ppm)

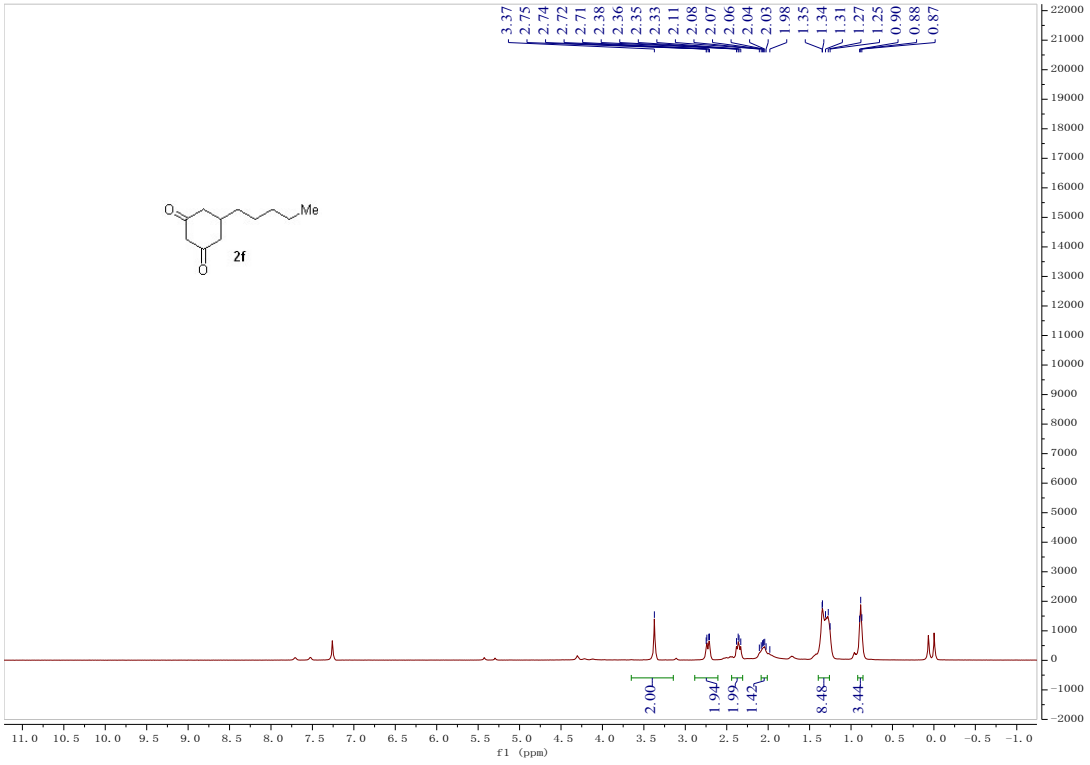

XWQ-20181207-HY-II-67/11 — C13CPD Acetone {D:\2018-3} ZHL 19
185.49
165.19
159.20
145.76
145.39
131.25
122.95
121.63
120.18
118.43
53.60
22.34
OMe
Me
OH
6k
f1 (ppm)

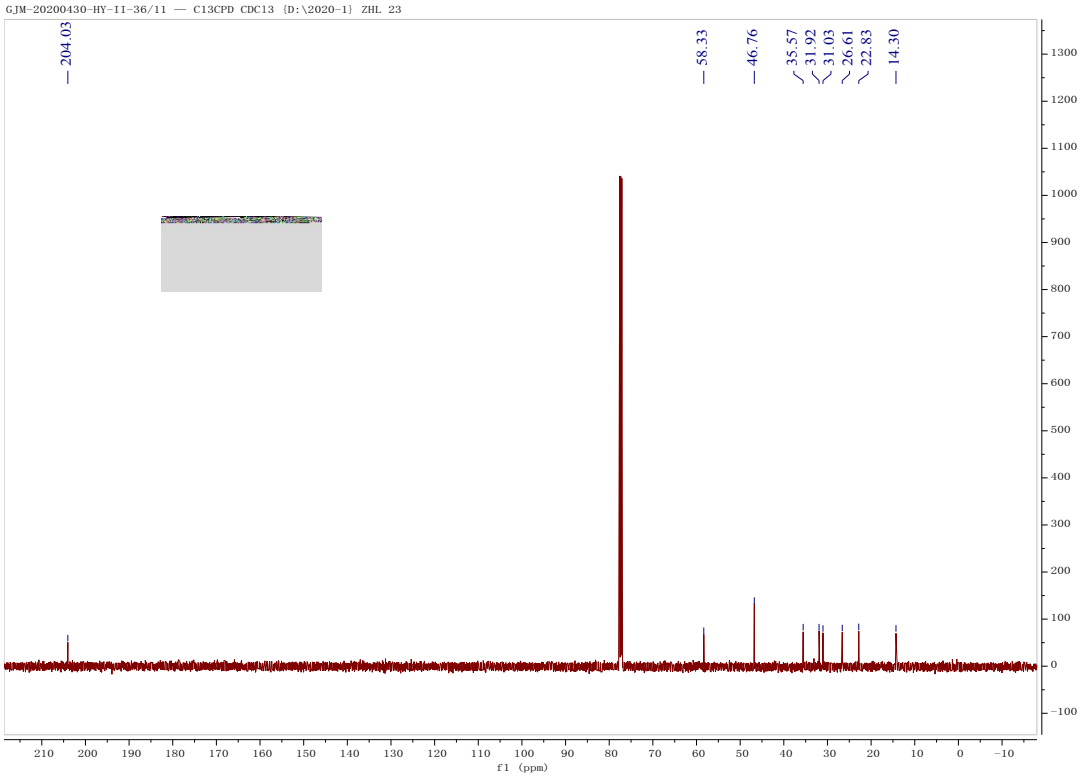

XWQ-20181207-HY-II-66/10 — PROTON Acetone {D:\2018-3} ZHL 18
9.01
8.16
8.12
7.44
7.41
7.30
6.99
6.98
6.97
3.92
3.83
MeO
OMe
OH
6l
1.01
1.00
1.04
1.09
2.05
3.09
3.13
f1 (ppm)

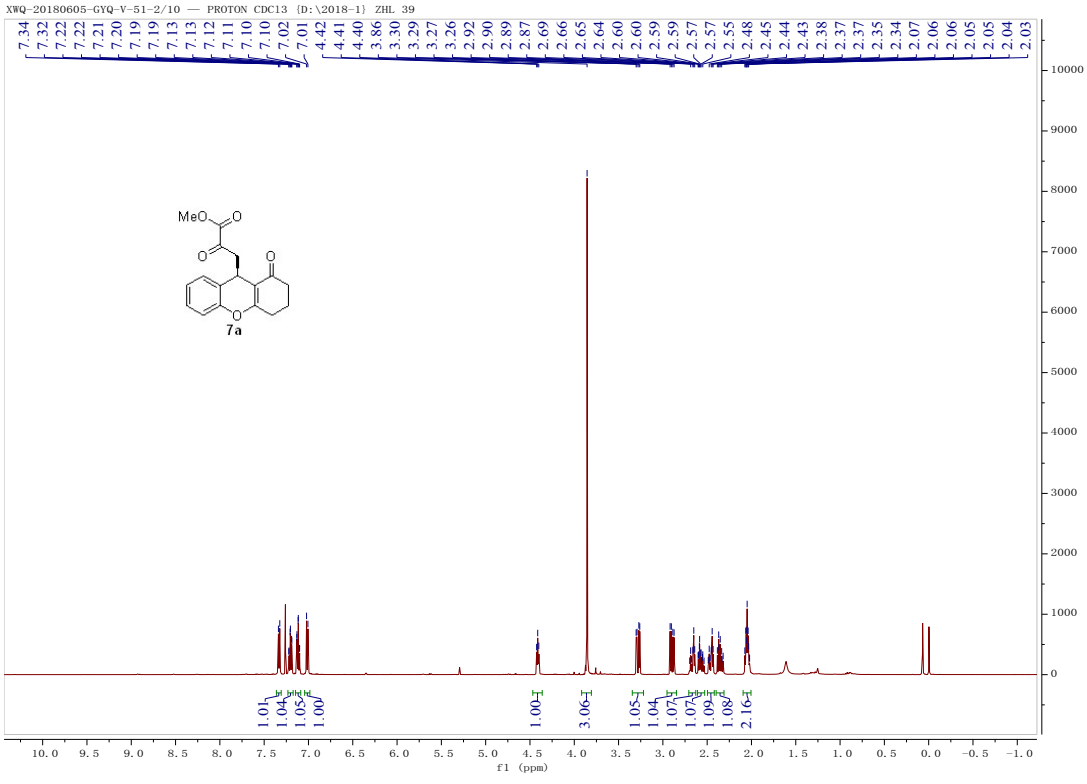

XWQ-20181207-HY-II-66/11 — C13CPD Acetone {D:\2018-3} ZHL 18
185.54
165.08
154.91
153.42
145.08
122.82
122.65
121.96
119.00
113.60
56.77
53.66
MeO
OMe
OH
6l
f1 (ppm)

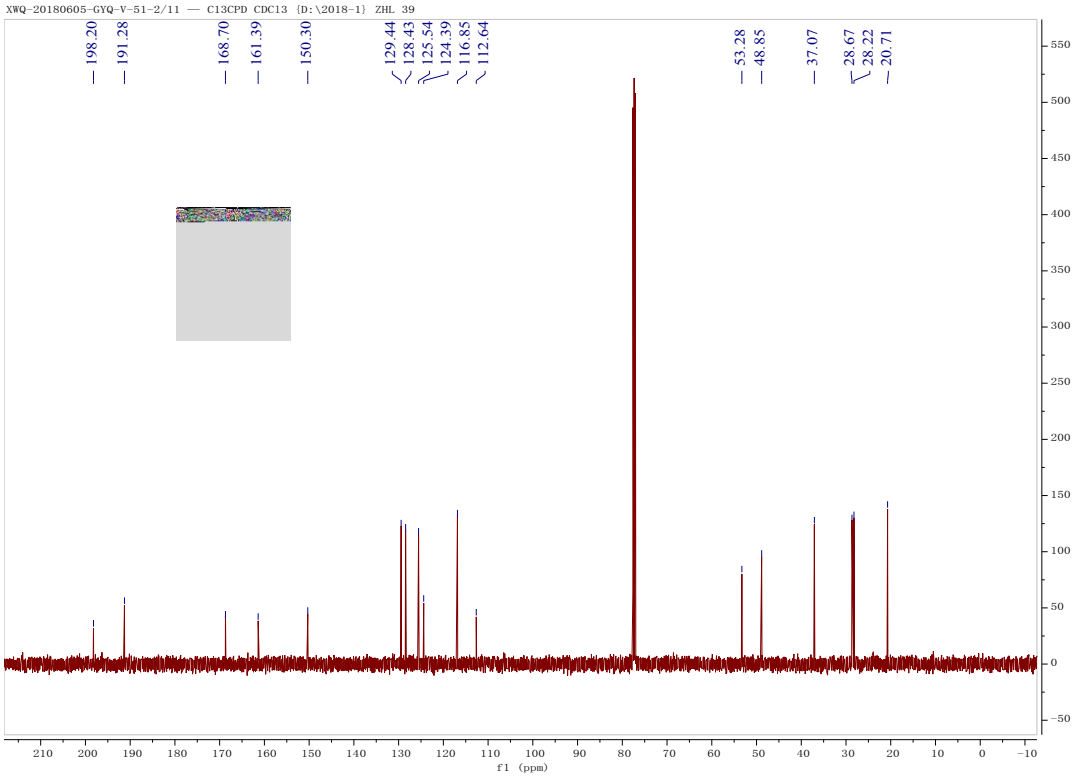


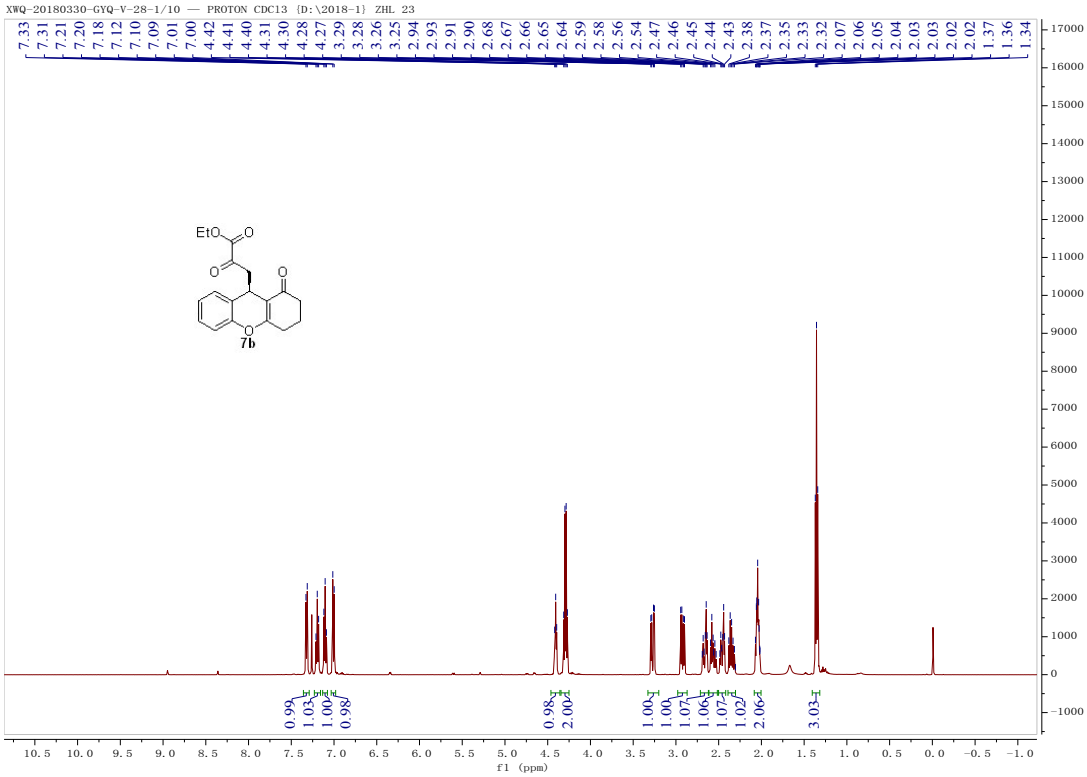
GJM-20200430-HY-II-36/10 — PROTON CDC13 {D:\2020-1} ZHL 23

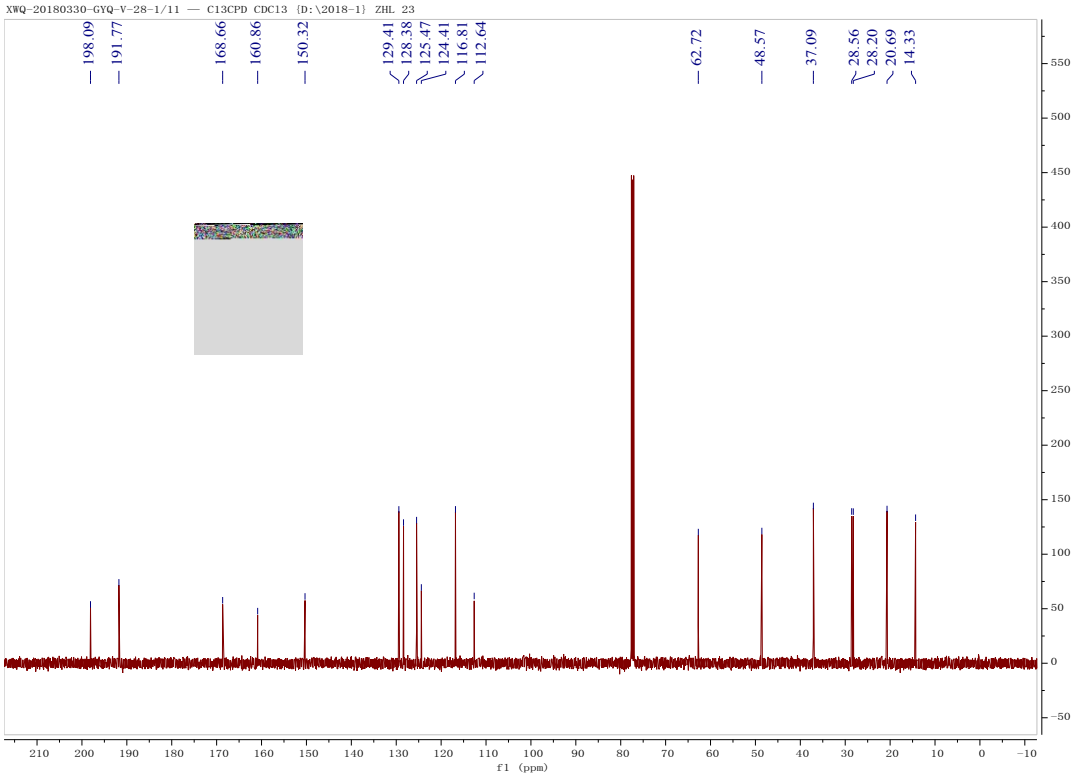


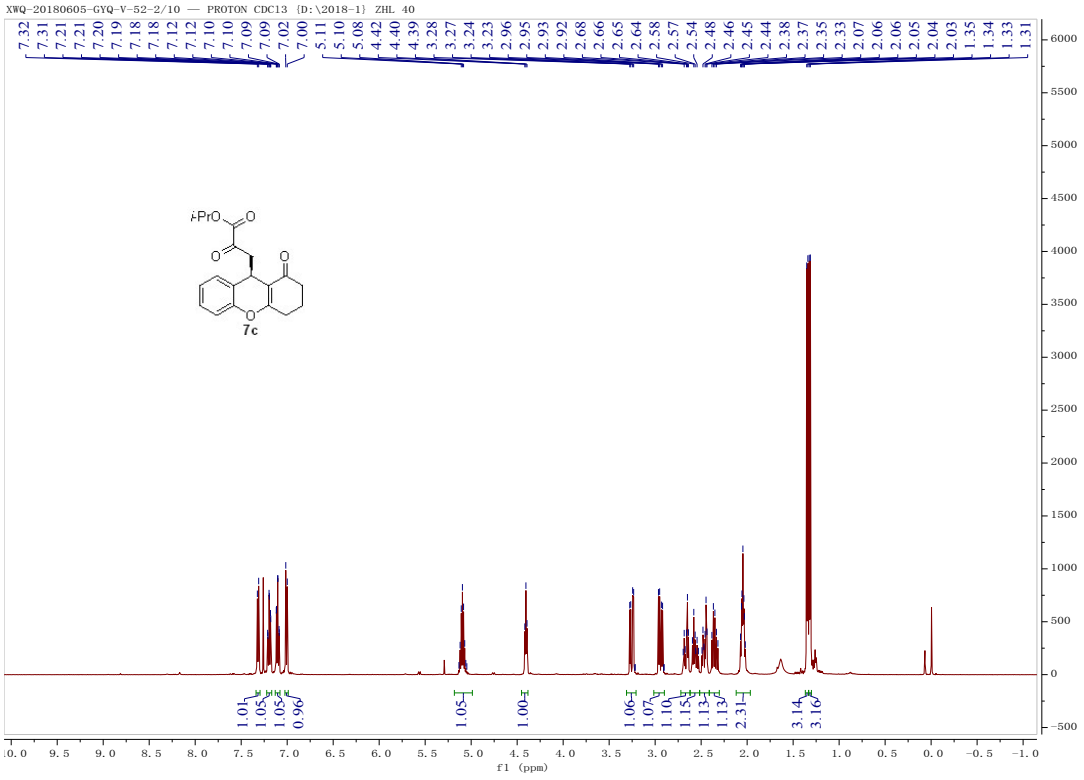

GJM-20200430-HY-II-36/11 — C13CPD CDC13 {D:\2020-1} ZHL 23
204.03
58.33
46.76
35.57
31.92
31.03
26.61
22.83
14.30
f1 (ppm)

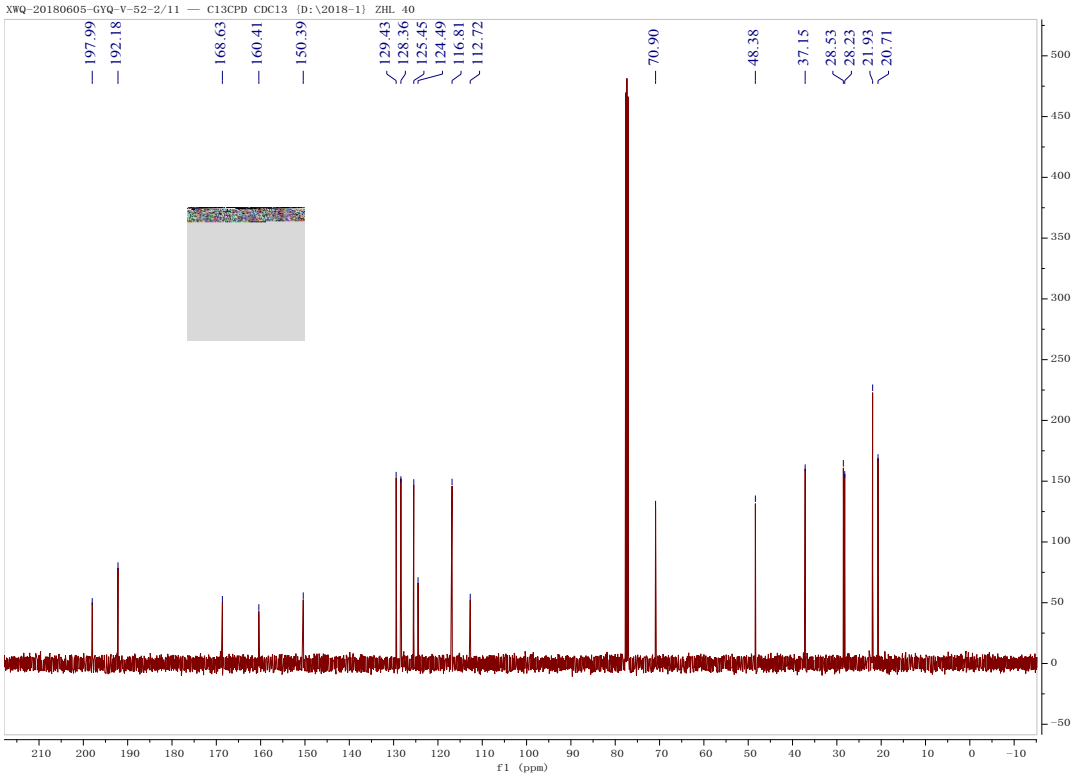

XWQ-20180605-GYQ-V-51-2/10 — PROTON CDC13 {D:\2018-1} ZHL 39
MeO
O
O
O
O
7a
1.01
1.04
1.05
1.00
1.00
3.06
1.05
1.04
1.07
1.09
1.08
2.16
f1 (ppm)

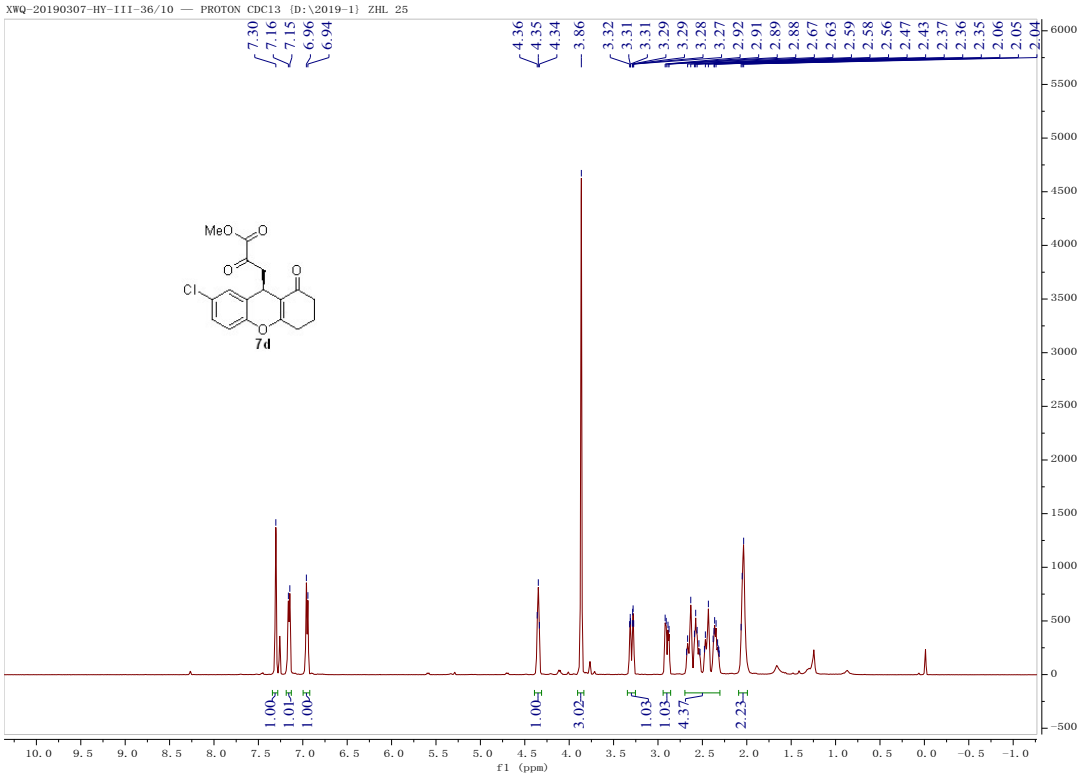

XWQ-20180605-GYQ-V-51-2/11 — C13CPD CDC13 {D:\2018-1} ZHL 39
198.20
191.28
168.70
161.39
150.30
129.44
128.43
125.54
124.39
116.85
112.64
53.28
48.85
37.07
28.67
28.22
20.71
f1 (ppm)


XWQ-20180330-GYQ-V-28-1/10 — PROTON CDC13 {D:\2018-1} ZHL 23
EtO
O
O
O
O
7b
0.99
1.03
1.00
0.98
0.98
2.00
1.00
1.00
1.07
1.06
1.07
1.02
2.06
3.03
f1 (ppm)


XWQ-20180330-GYQ-V-28-1/11 — C13CPD CDC13 {D:\2018-1} ZHL 23
198.09
191.77
168.66
160.86
150.32
129.41
128.38
125.47
124.41
116.81
112.64
62.72
48.57
37.09
28.56
28.20
20.69
14.33
f1 (ppm)

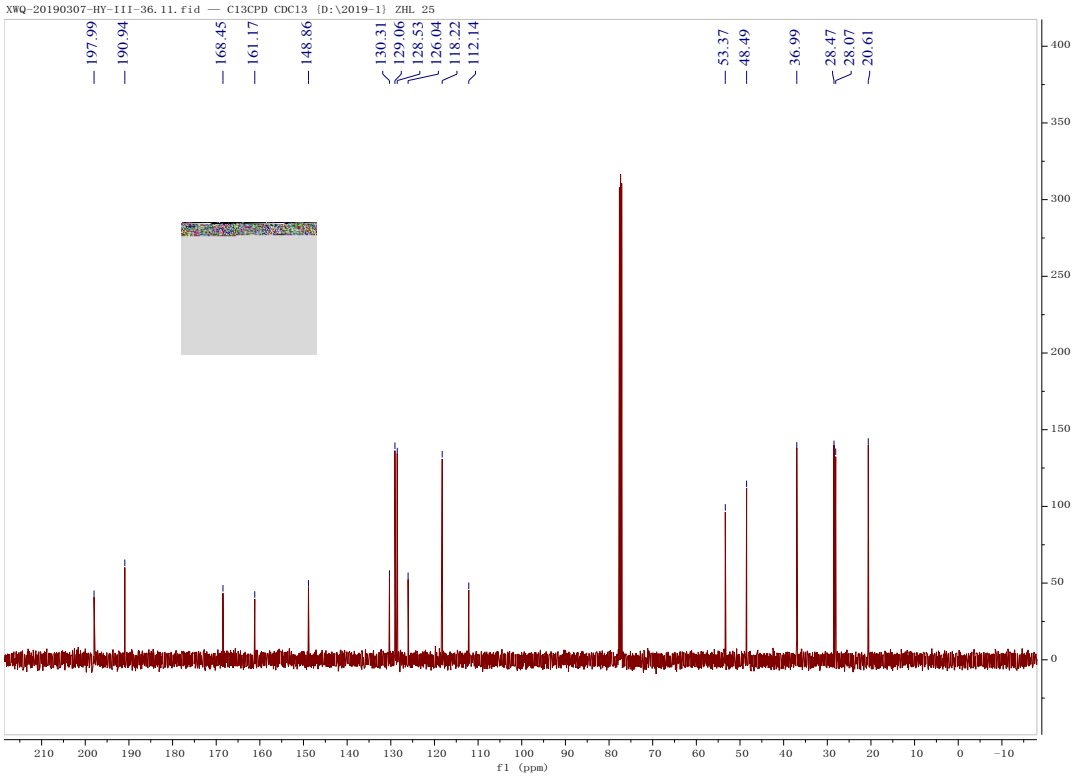

XWQ-20180605-GYQ-V-52-2/10 — PROTON CDC13 {D:\2018-1} ZHL 40
iPrO
O
O
O
O
7c
1.01
1.05
1.05
0.96
1.05
1.00
1.06
1.07
1.10
1.15
1.13
2.31
3.14
3.16
f1 (ppm)

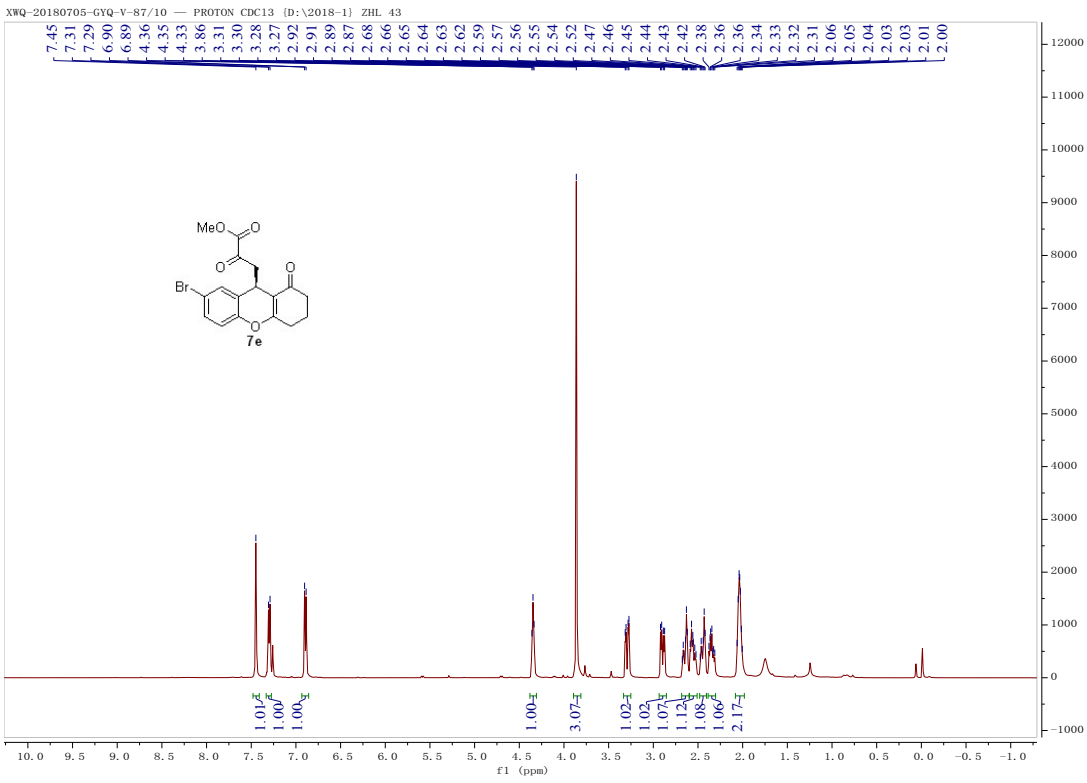

XWQ-20180605-GYQ-V-52-2/11 — C13CPD CDC13 {D:\2018-1} ZHL 40
197.99
192.18
168.63
160.41
150.39
129.43
128.36
125.45
124.49
116.81
112.72
70.90
48.38
37.15
28.53
28.23
21.93
20.71
f1 (ppm)

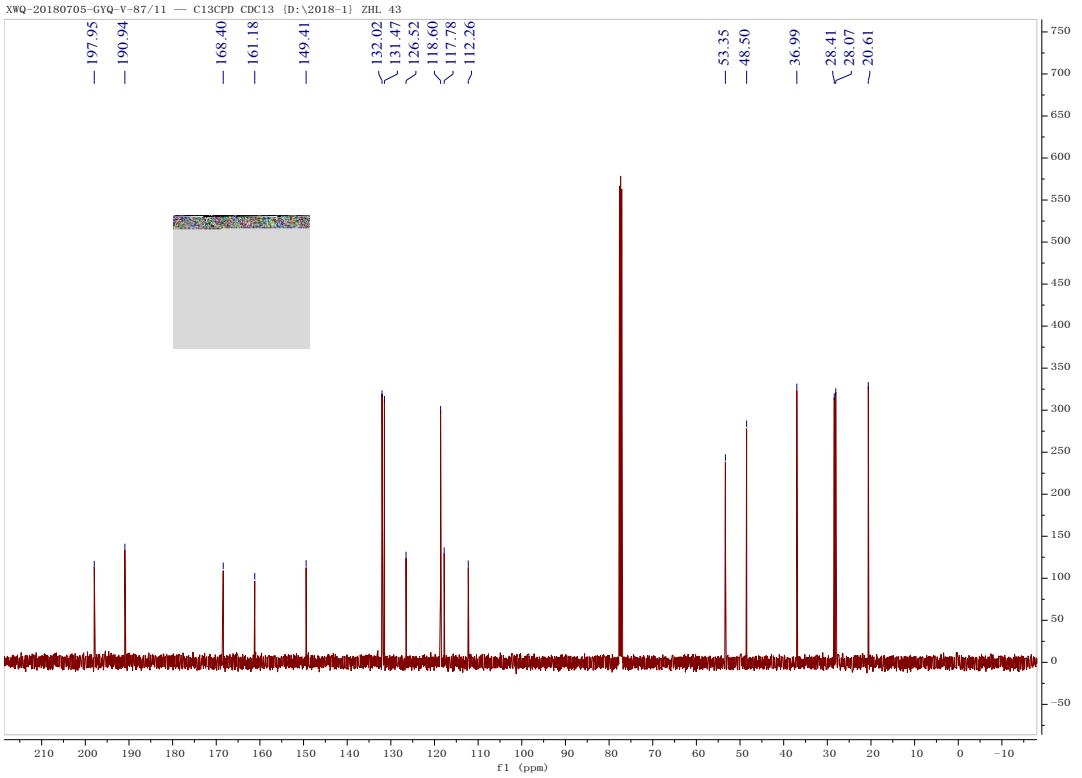

XWQ-20190307-HY-III-36/10 — PROTON CDC13 {D:\2019-1} ZHL 25
7.30
7.16
7.15
6.96
6.94
4.36
4.35
4.34
3.86
3.32
3.31
3.31
3.29
3.29
3.28
3.27
2.92
2.91
2.89
2.88
2.67
2.63
2.59
2.58
2.56
2.47
2.43
2.37
2.36
2.35
2.06
2.05
2.04
1.00
1.01
1.00
1.00
3.02
1.03
1.03
4.37
2.23
f1 (ppm)

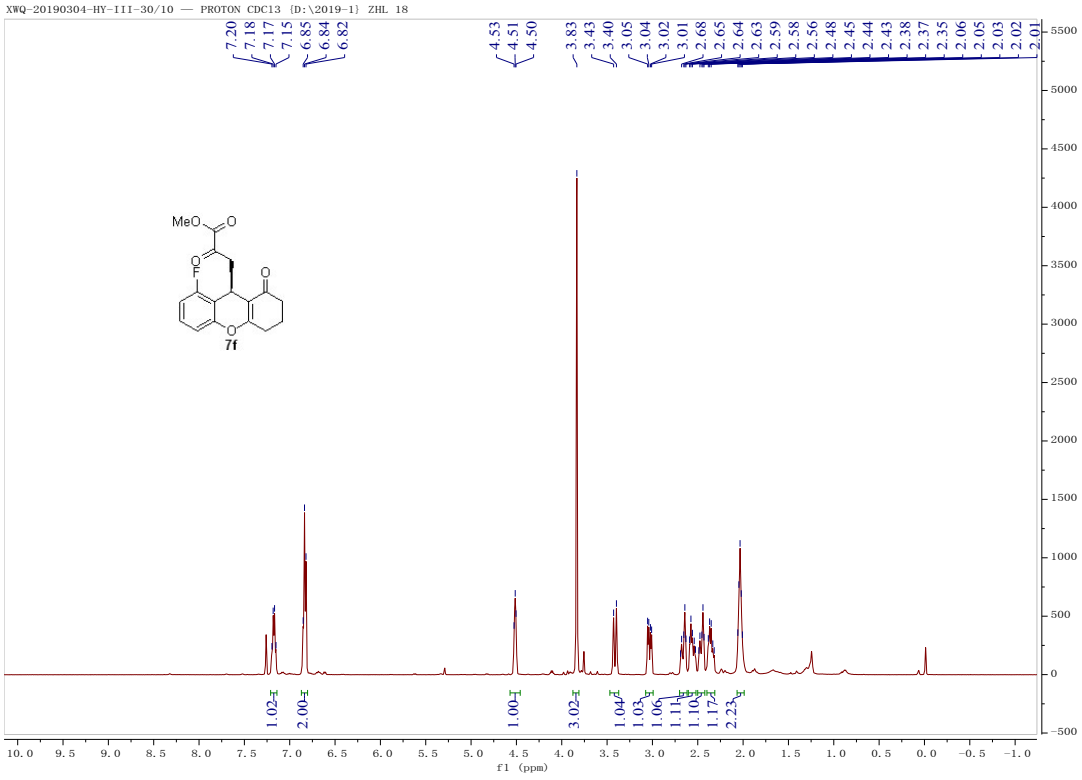
MeO
O
O
O
Cl
O

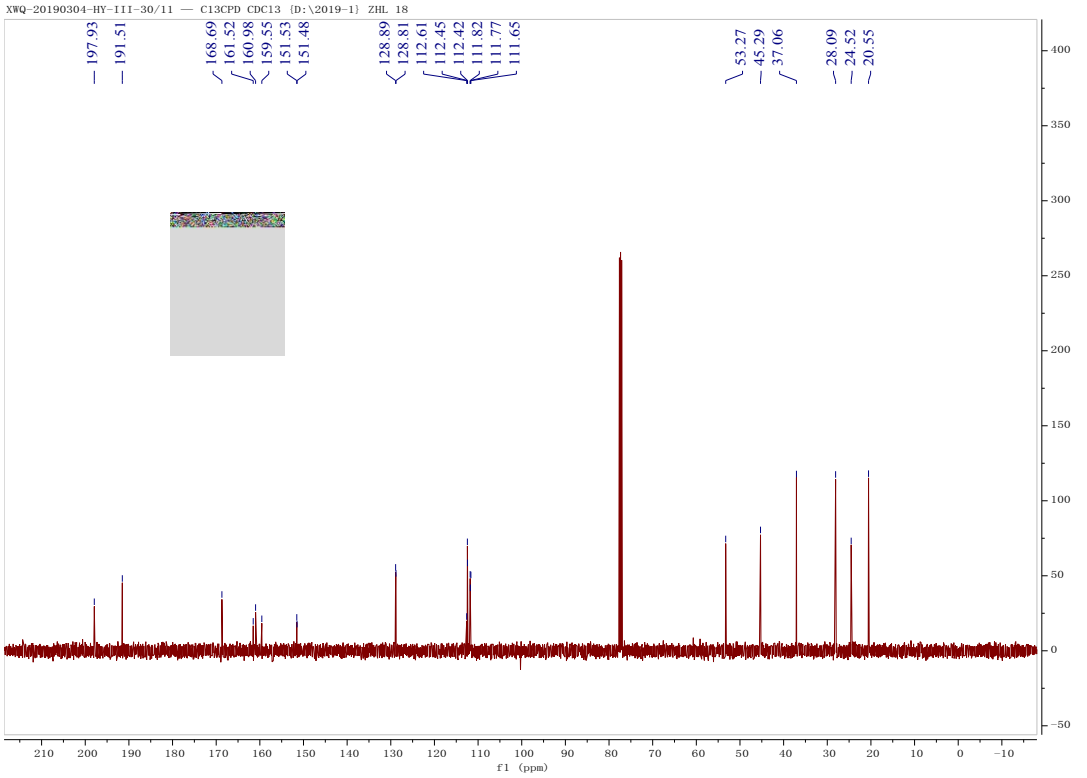
7d

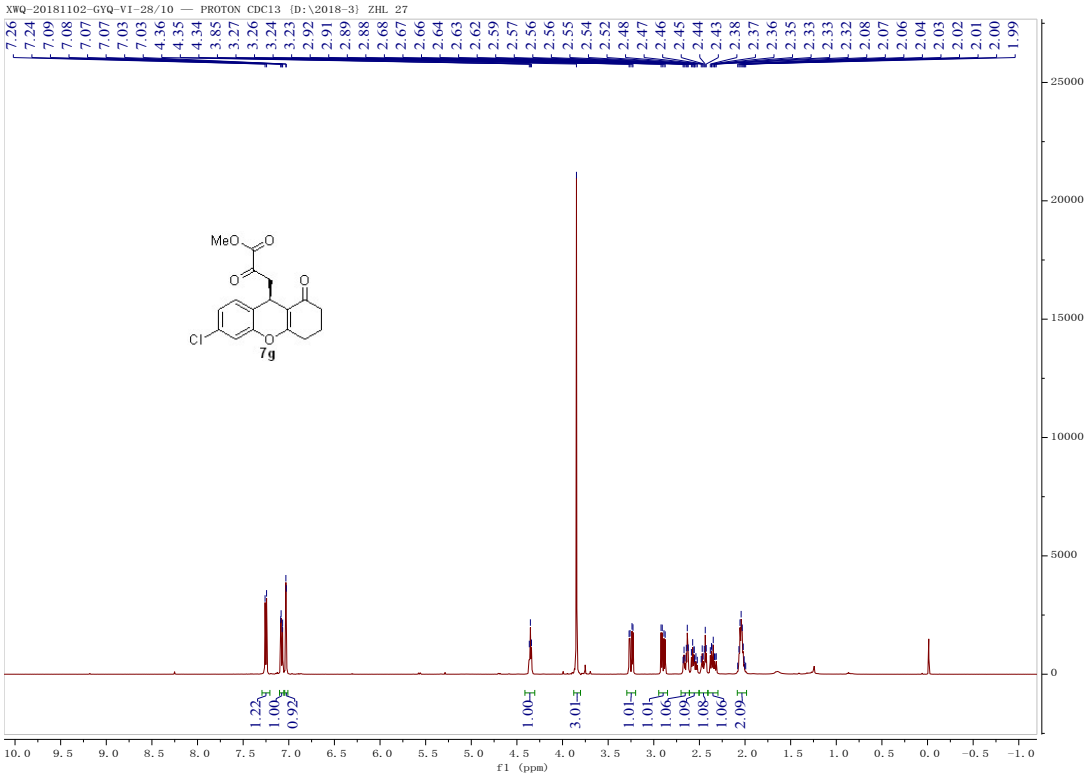

XWQ-20190307-HY-III-36.11.fid — C13CPD CDCl3 {D:\2019-1} ZHL 25
197.99
190.94
168.45
161.17
148.86
130.31
129.06
128.53
126.04
118.22
112.14
53.37
48.49
36.99
28.47
28.07
20.61
f1 (ppm)

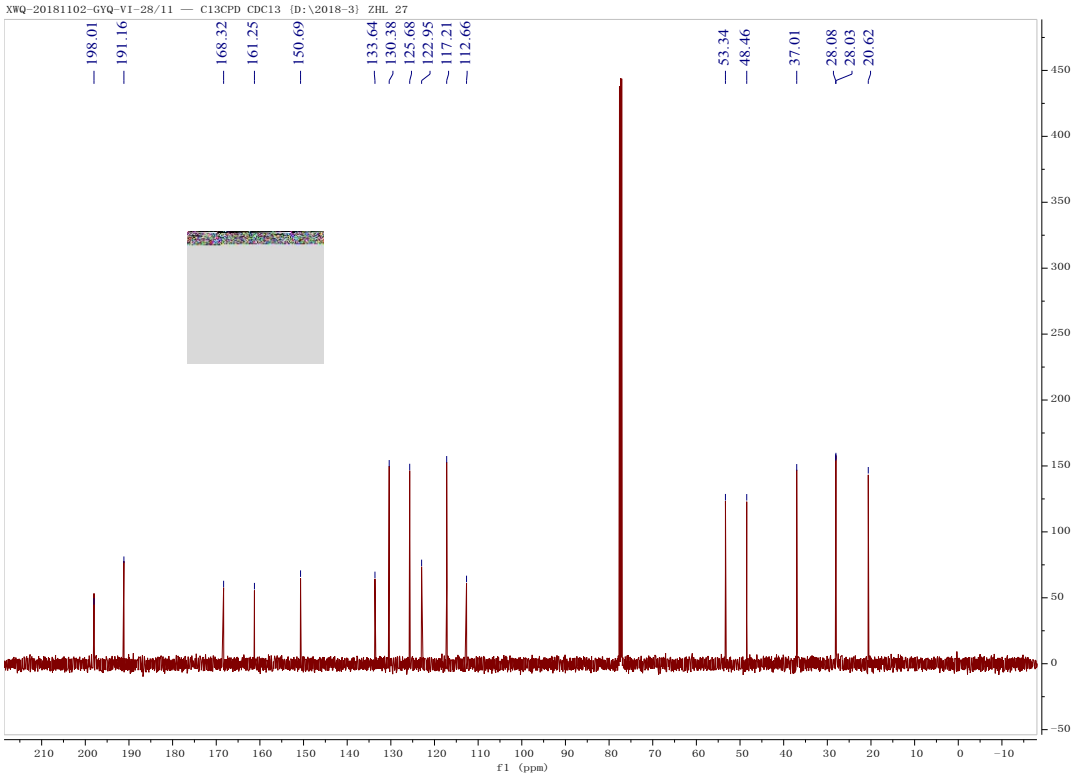

XWQ-20180705-GYQ-V-87/10 — PROTON CDCl3 {D:\2018-1} ZHL 43
MeO
O
O
O
Br
O
7e
1.01
1.00
1.00
1.00
3.07
1.02
1.02
1.07
1.12
1.08
1.06
2.17
f1 (ppm)

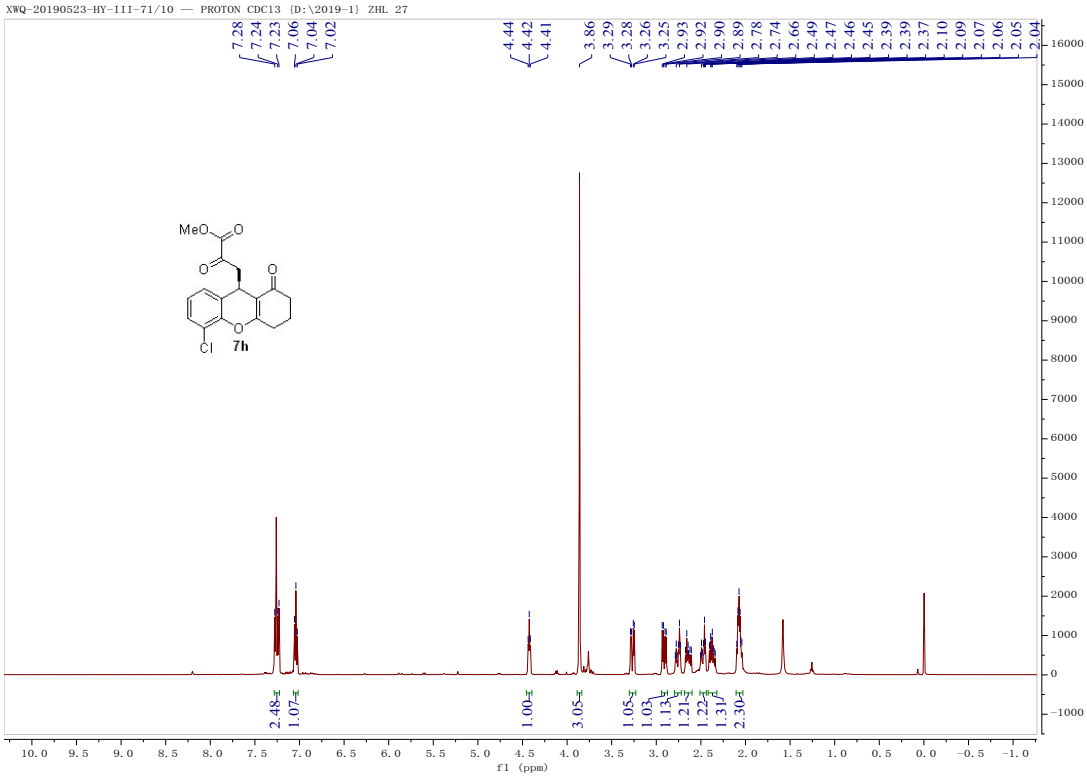

XWQ-20180705-GYQ-V-87/11 — C13CPD CDC13 {D:\2018-1} ZHL 43
197.95
190.94
168.40
161.18
149.41
132.02
131.47
126.52
118.60
117.78
112.26
53.35
48.50
36.99
28.41
28.07
20.61
f1 (ppm)

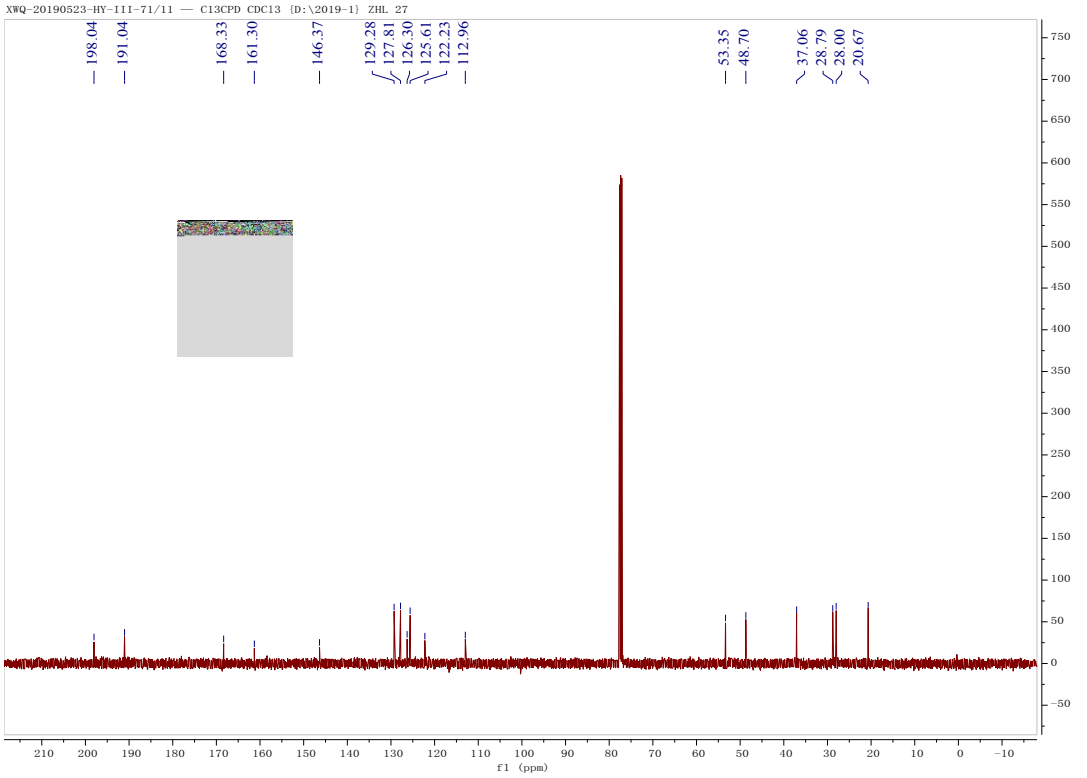

XWQ-20190304-HY-III-30/10 — PROTON CDC13 {D:\2019-1} ZHL 18
7.20
7.18
7.17
7.15
6.85
6.84
6.82
4.53
4.51
4.50
3.83
3.43
3.40
3.05
3.04
3.02
3.01
2.68
2.65
2.64
2.63
2.59
2.58
2.56
2.48
2.45
2.44
2.43
2.38
2.37
2.35
2.06
2.05
2.03
2.02
2.01
MeO
O
O
F
O
O
7f
1.02
2.00
1.00
3.02
1.04
1.03
1.06
1.11
1.10
1.17
2.23
f1 (ppm)

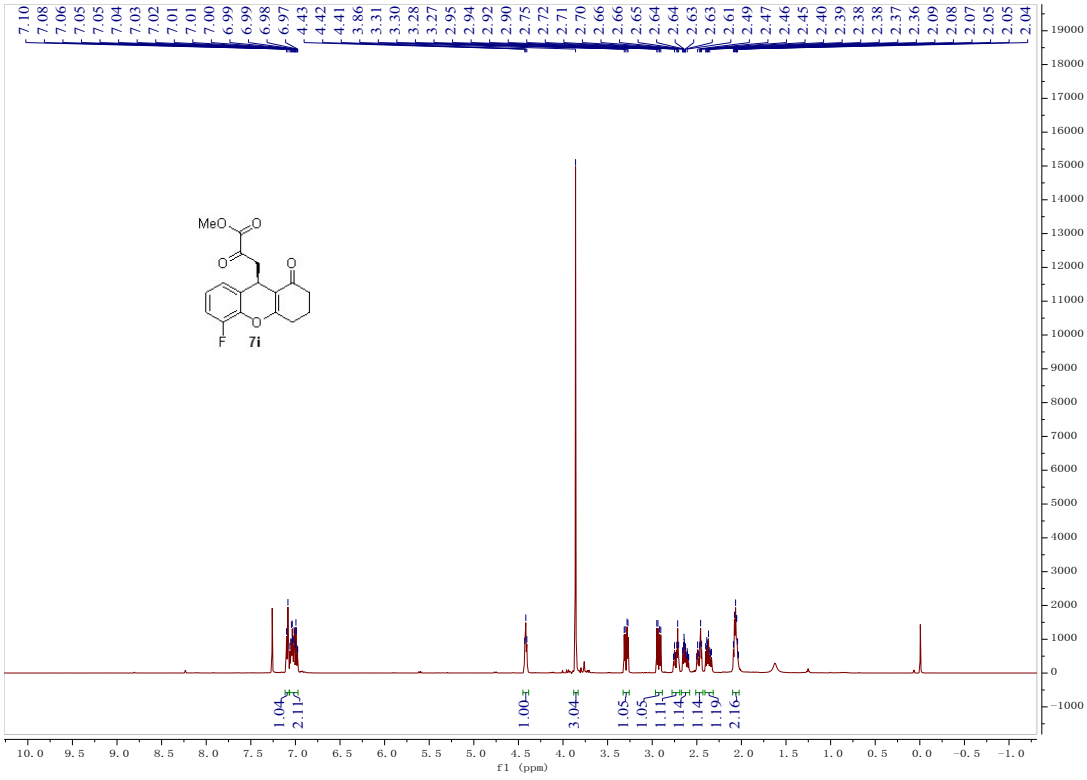

XWQ-20190304-HY-III-30/11 — C13CPD CDC13 {D:\2019-1} ZHL 18
197.93
191.51
168.69
161.52
160.98
159.55
151.53
151.48
128.89
128.81
112.61
112.45
112.42
111.82
111.77
111.65
53.27
45.29
37.06
28.09
24.52
20.55
f1 (ppm)

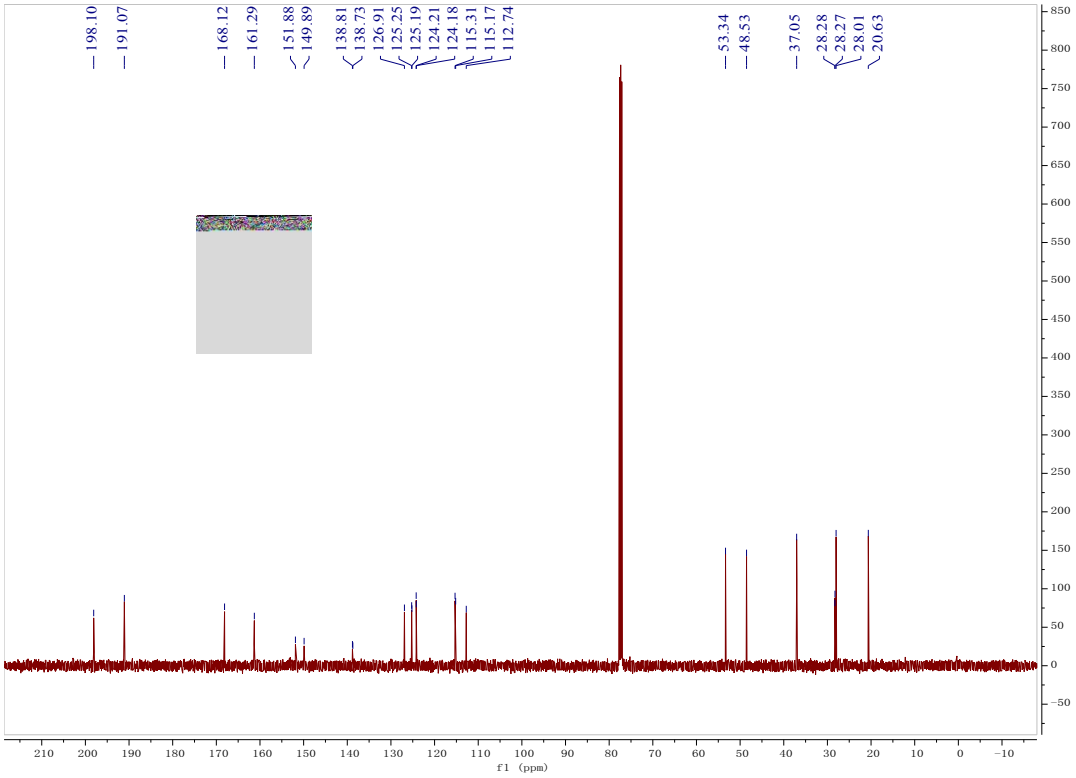

XWQ-20181102-GYQ-VI-28/10 — PROTON CDC13 {D:\2018-3} ZHL 27
MeO
O
O
O
Cl
O
7g
1.22
1.00
0.92
1.00
3.01
1.01
1.01
1.06
1.08
1.08
1.06
2.09
f1 (ppm)

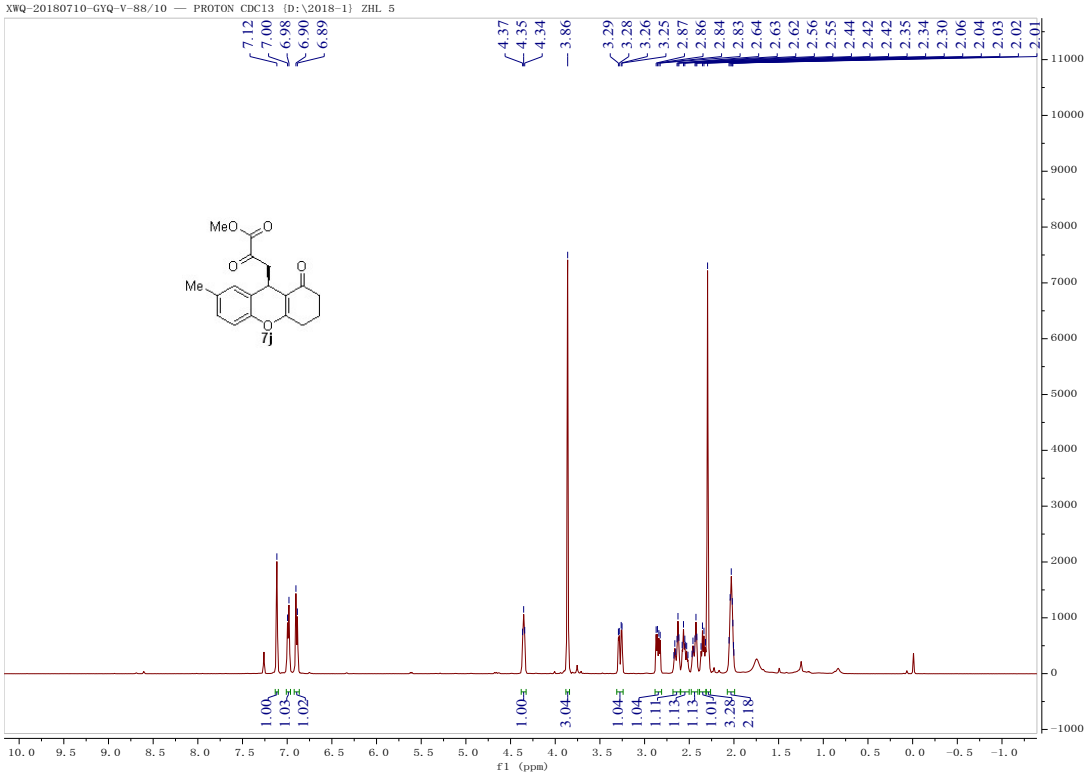

XWQ-20181102-GYQ-VI-28/11 — C13CPD CDC13 {D:\2018-3} ZHL 27
198.01
191.16
168.32
161.25
150.69
133.64
130.38
125.68
122.95
117.21
112.66
53.34
48.46
37.01
28.08
28.03
20.62
f1 (ppm)

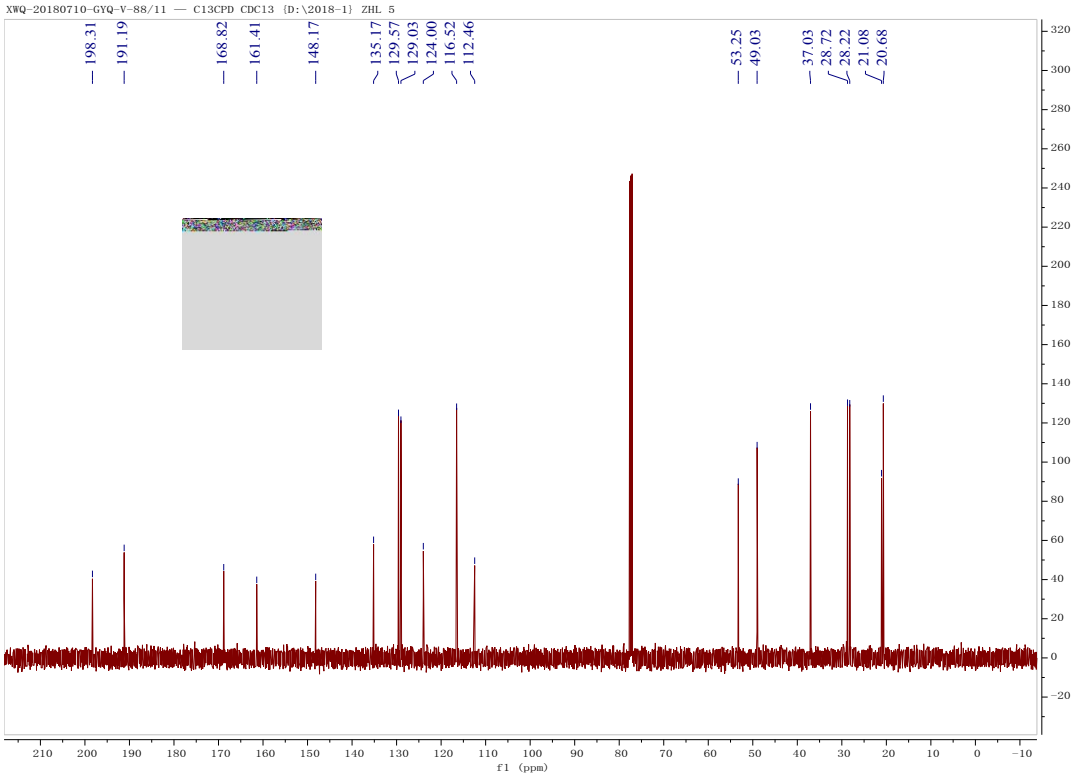

XWQ-20190523-HY-III-71/10 — PROTON CDC13 {D:\2019-1} ZHL 27
7.28
7.24
7.23
7.06
7.04
7.02
4.44
4.42
4.41
3.86
3.29
3.28
3.26
3.25
2.93
2.92
2.90
2.89
2.78
2.74
2.66
2.49
2.47
2.46
2.45
2.39
2.39
2.37
2.10
2.09
2.07
2.06
2.05
2.04
MeO
O
O
O
O
Cl
7h
2.48
1.07
1.00
3.05
1.05
1.03
1.13
1.21
1.22
1.31
2.30
f1 (ppm)

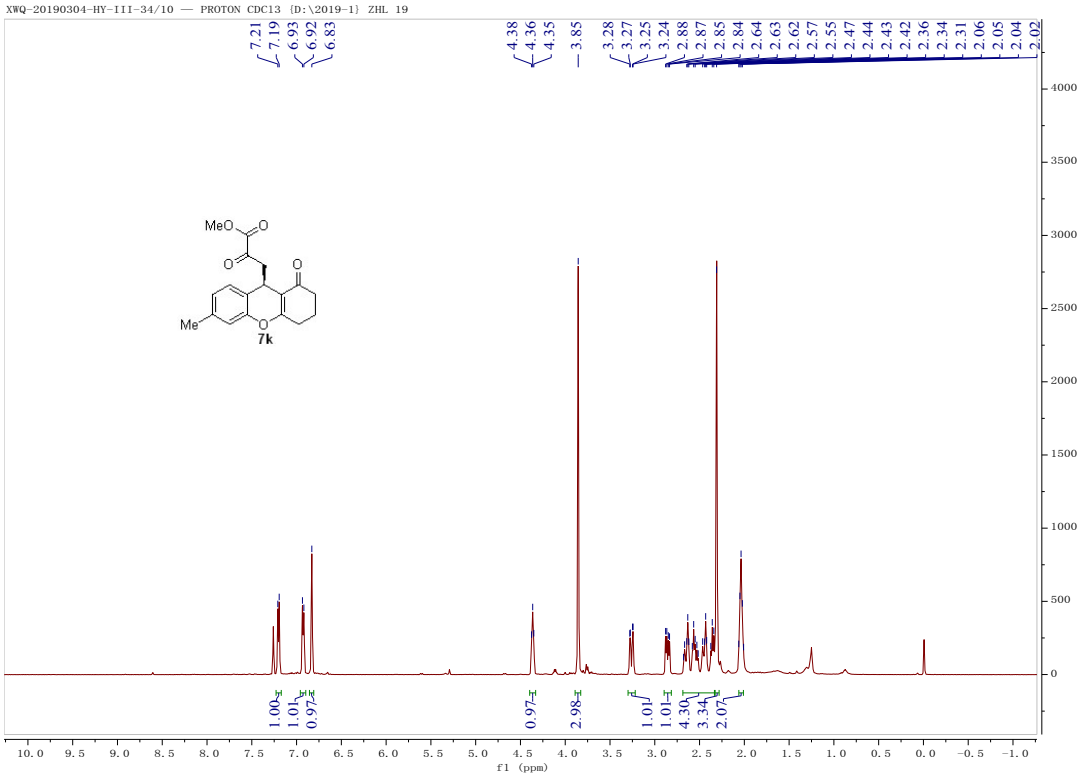

XWQ-20190523-HY-III-71/11 — C13CPD CDC13 {D:\2019-1} ZHL 27
198.04
191.04
168.33
161.30
146.37
129.28
127.81
126.30
125.61
122.23
112.96
53.35
48.70
37.06
28.79
28.00
20.67
f1 (ppm)

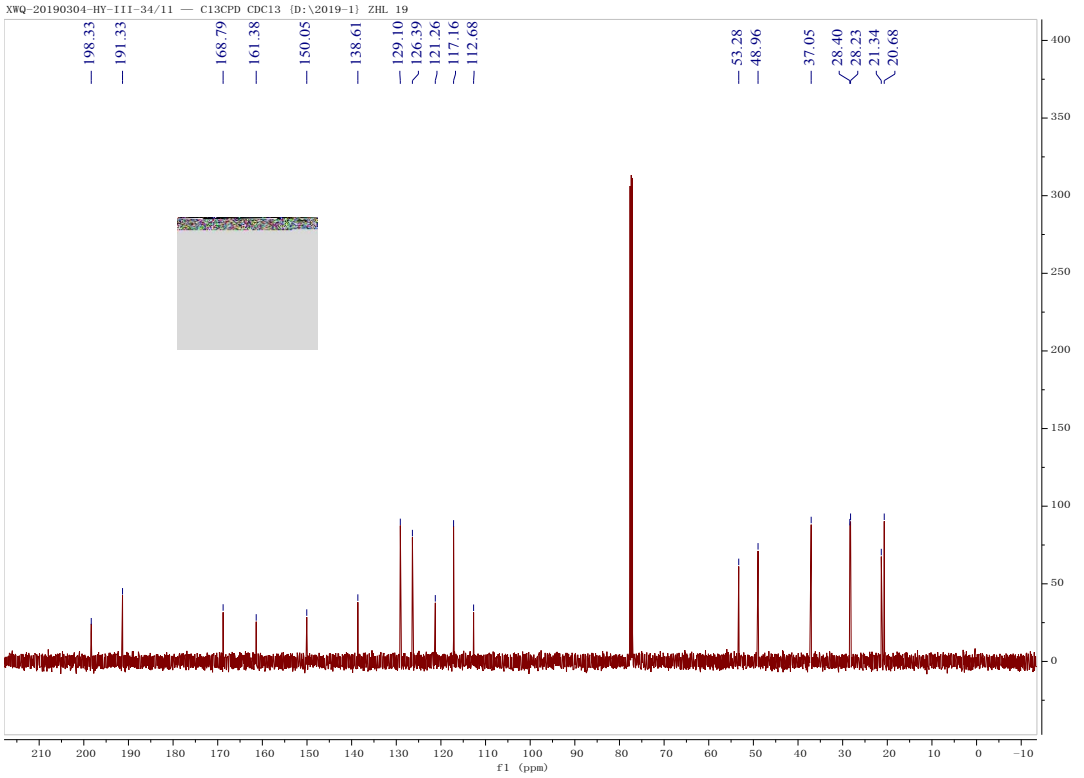

MeO
O
O
O
F
7i
1.04
2.11
1.00
3.04
1.05
1.05
1.11
1.14
1.14
1.19
2.16
f1 (ppm)

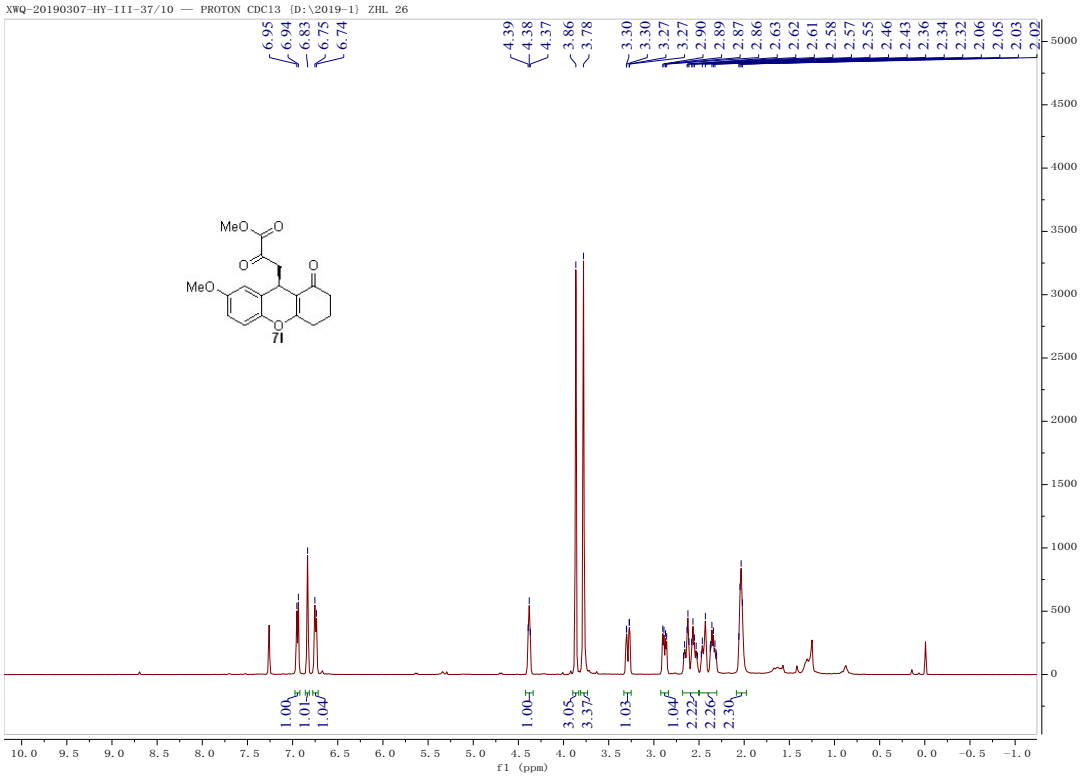

198.10
191.07
168.12
161.29
151.88
149.89
138.81
138.73
126.91
125.25
125.19
124.21
124.18
115.31
115.17
112.74
53.34
48.53
37.05
28.28
28.27
28.01
20.63
f1 (ppm)

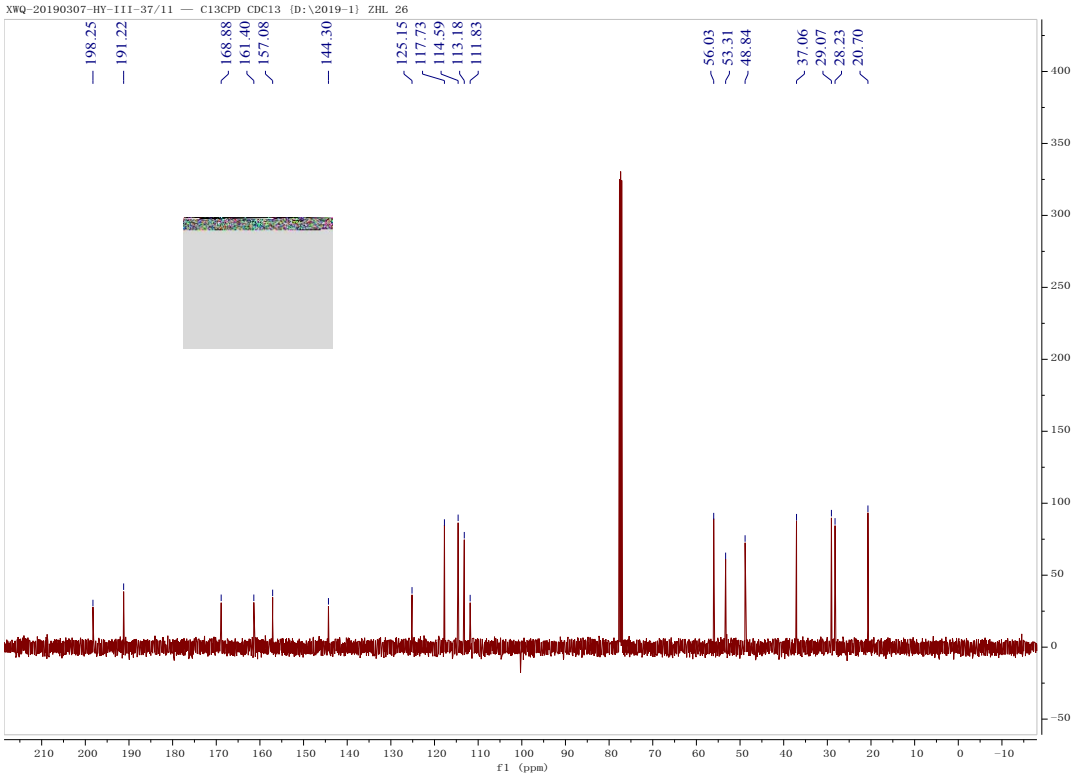

XWQ-20180710-GYQ-V-88/10 — PROTON CDC13 {D:\2018-1} ZHL 5
7.12
7.00
6.98
6.90
6.89
4.37
4.35
4.34
3.86
3.29
3.28
3.26
3.25
2.87
2.86
2.84
2.83
2.64
2.63
2.62
2.56
2.55
2.44
2.42
2.42
2.35
2.34
2.30
2.06
2.04
2.03
2.02
2.01
MeO
O
O
O
Me
7j
1.00
1.03
1.02
1.00
3.04
1.04
1.04
1.11
1.13
1.13
1.01
3.28
2.18
f1 (ppm)

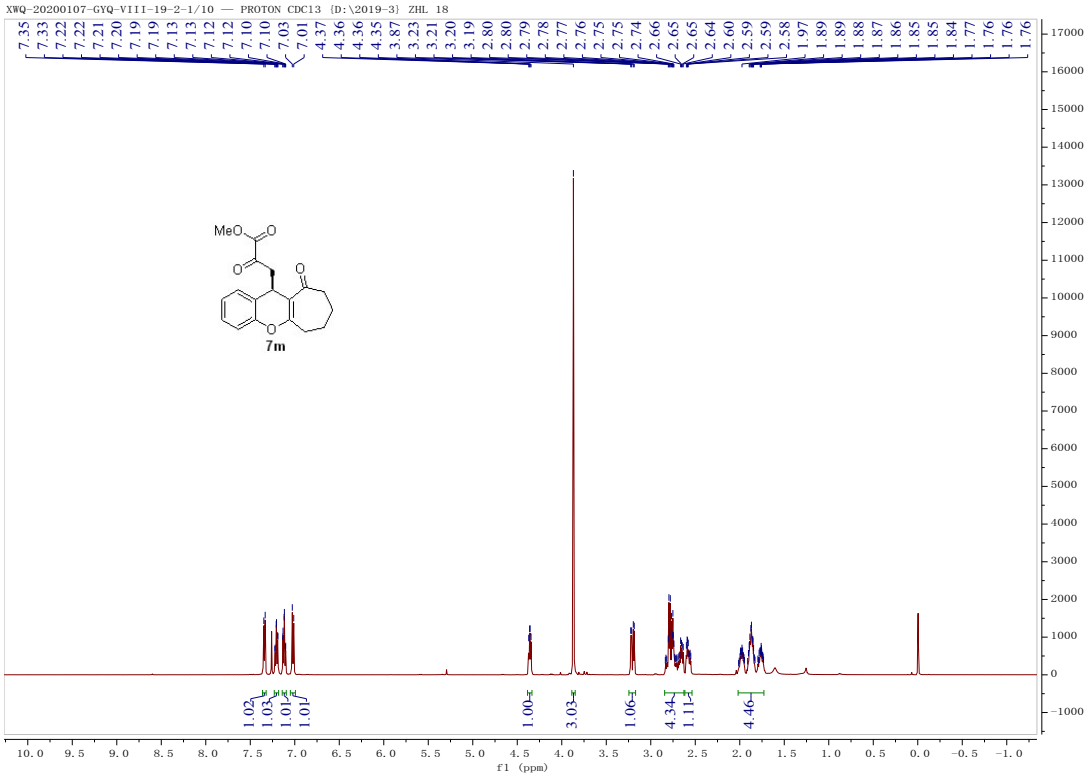

XWQ-20180710-GYQ-V-88/11 — C13CPD CDC13 {D:\2018-1} ZHL 5
198.31
191.19
168.82
161.41
148.17
135.17
129.57
129.03
124.00
116.52
112.46
53.25
49.03
37.03
28.72
28.22
21.08
20.68
f1 (ppm)

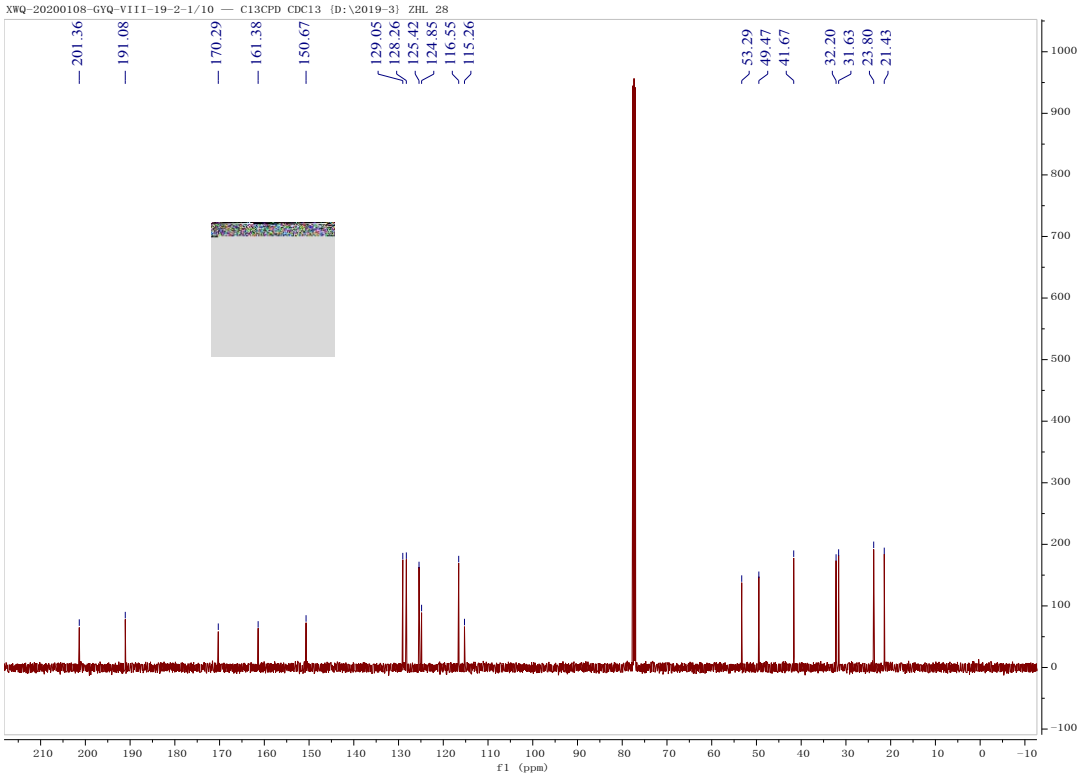

XWQ-20190304-HY-III-34/10 — PROTON CDC13 {D:\2019-1} ZHL 19
7.21
7.19
6.93
6.92
6.83
4.38
4.36
4.35
3.85
3.28
3.27
3.25
3.24
MeO
Me
7k
1.00
1.01
0.97
0.97
2.98
1.01
1.01
4.30
3.34
2.07
f1 (ppm)

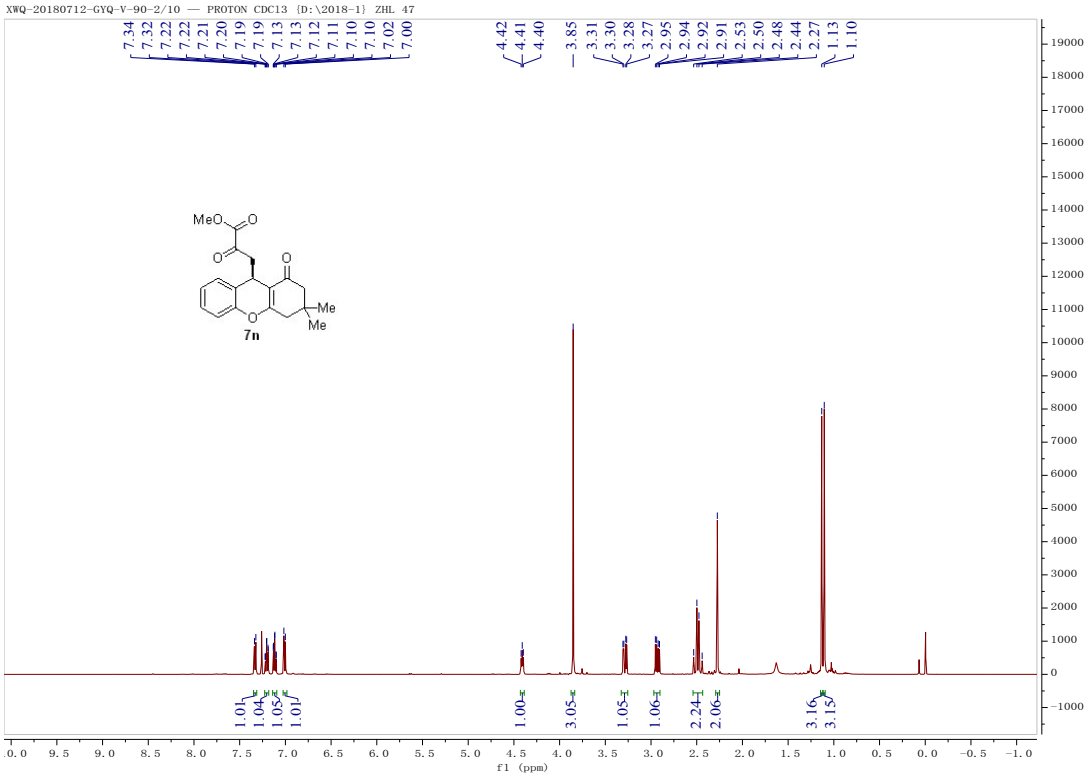

XWQ-20190304-HY-III-34/11 — C13CPD CDC13 {D:\2019-1} ZHL 19
198.33
191.33
168.79
161.38
150.05
138.61
129.10
126.39
121.26
117.16
112.68
53.28
48.96
37.05
28.40
28.23
21.34
20.68
f1 (ppm)

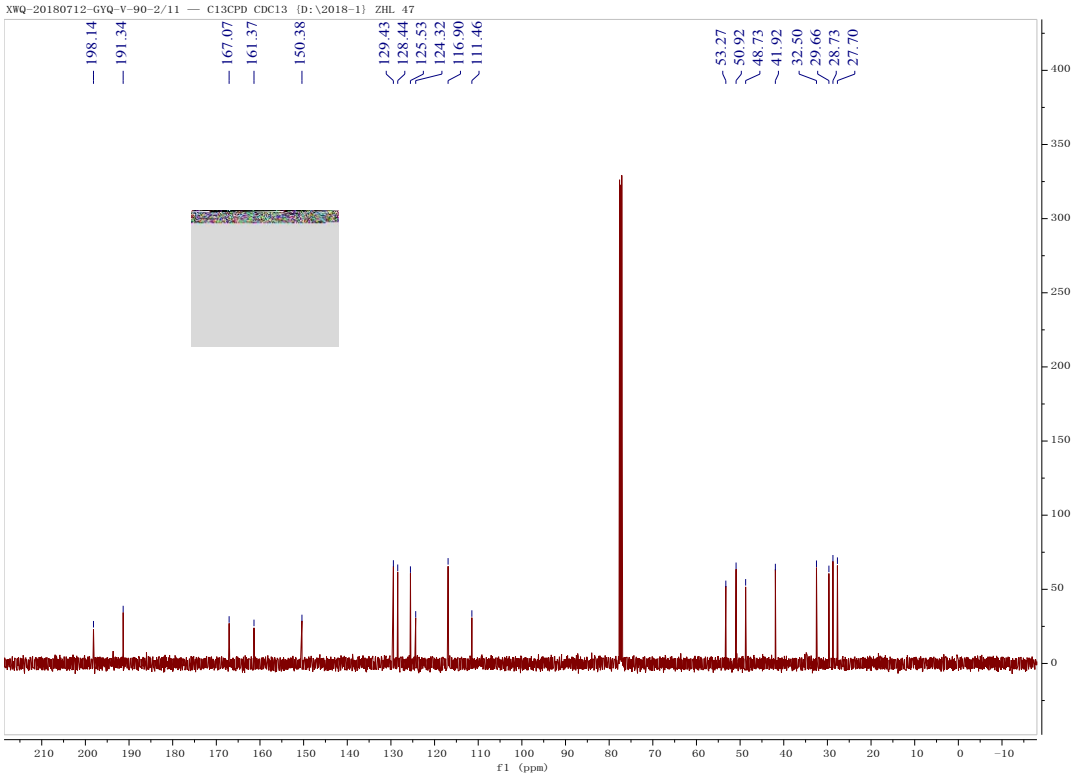

XWQ-20190307-HY-III-37/10 — PROTON CDC13 {D:\2019-1} ZHL 26
6.95
6.94
6.83
6.75
6.74
4.39
4.38
4.37
3.86
3.78
3.30
3.30
3.27
3.27
2.90
2.89
2.87
2.86
2.63
2.62
2.61
2.58
2.57
2.55
2.46
2.43
2.36
2.34
2.32
2.06
2.05
2.03
2.02
MeO
O
O
MeO
O
71
1.00
1.01
1.04
1.00
3.05
3.37
1.03
1.04
2.22
2.26
2.30
f1 (ppm)

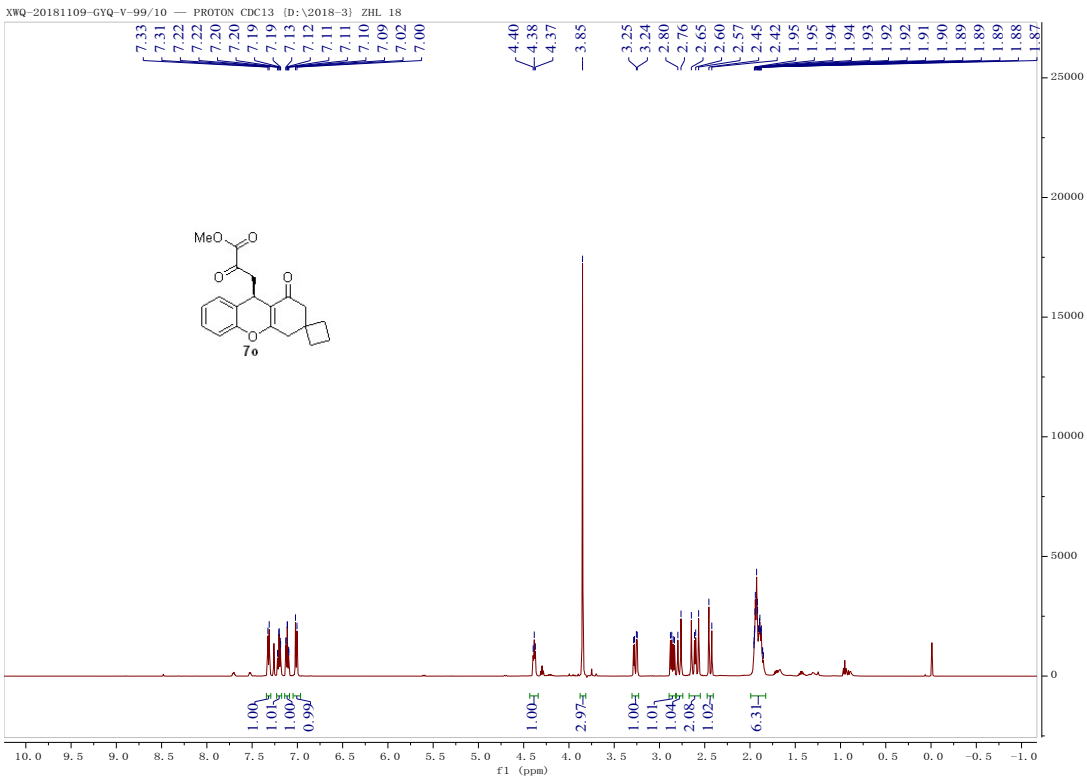

XWQ-20190307-HY-III-37/11 — C13CPD CDC13 {D:\2019-1} ZHL 26
198.25
191.22
168.88
161.40
157.08
144.30
125.15
117.73
114.59
113.18
111.83
56.03
53.31
48.84
37.06
29.07
28.23
20.70
f1 (ppm)

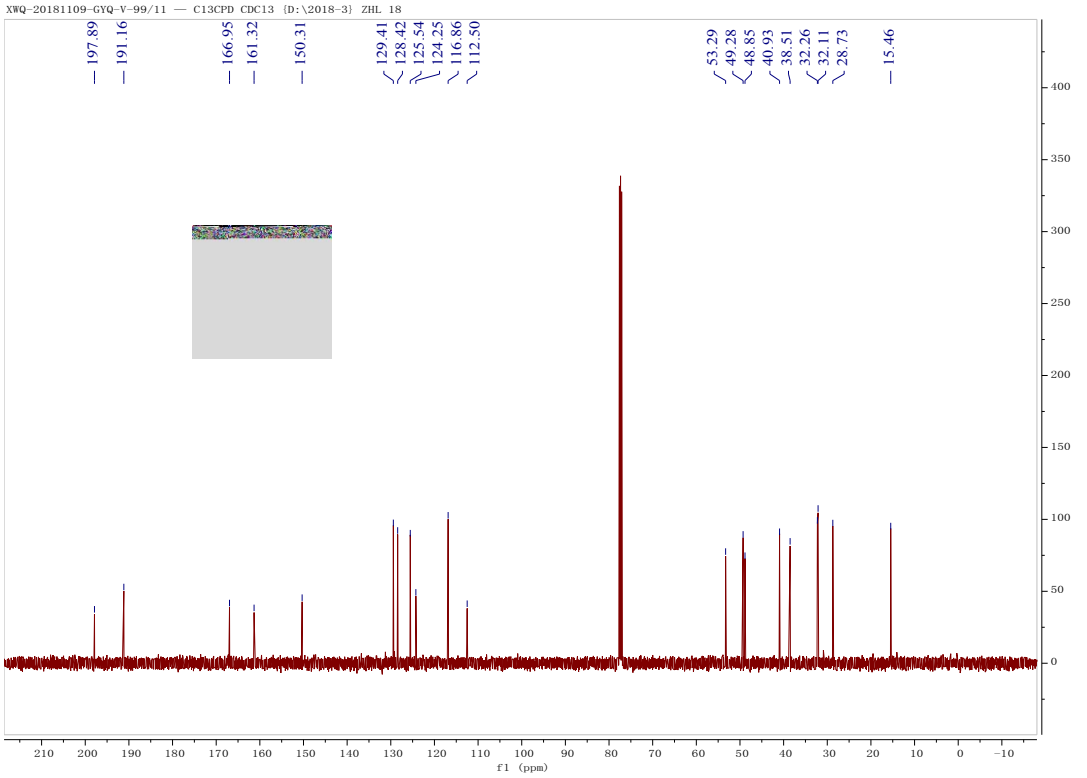

XWQ-20200107-GYQ-VIII-19-2-1/10 — PROTON CDC13 {D:\2019-3} ZHL 18
MeO
O
O
O
O
7m
1.02
1.02
1.01
1.01
1.00
3.03
1.06
4.34
1.11
4.46
f1 (ppm)

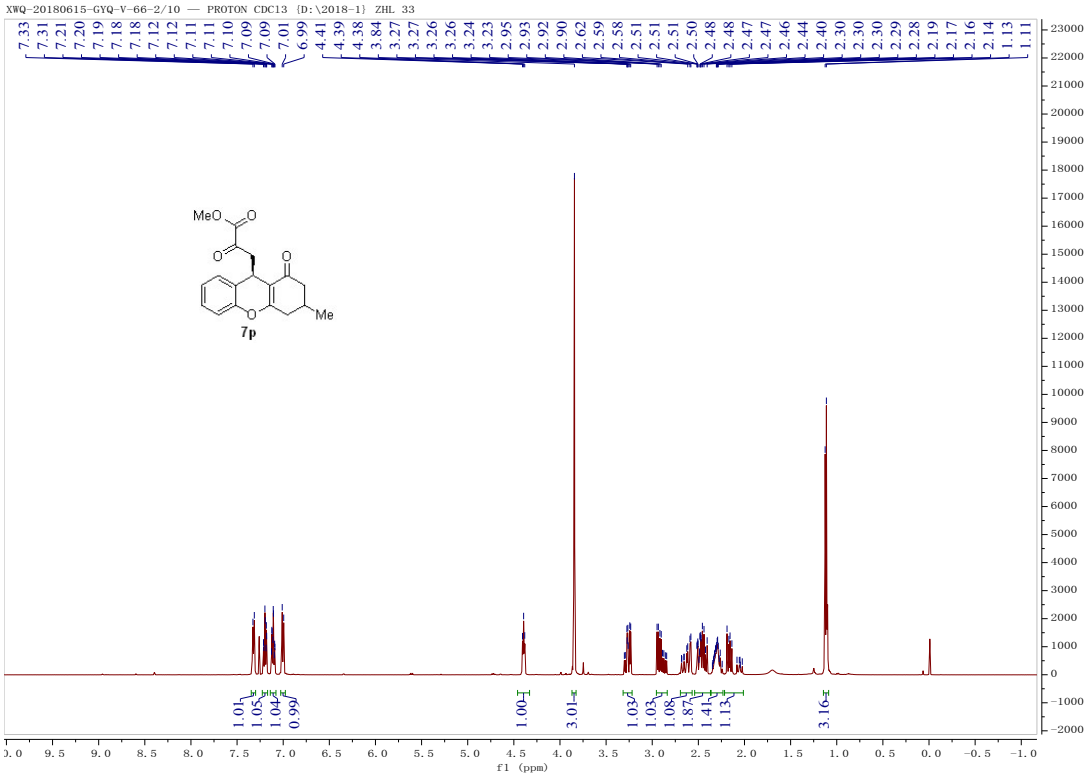

XWQ-20200108-GYQ-VIII-19-2-1/10 — C13CPD CDCl3 {D:\2019-3} ZHL 28
201.36
191.08
170.29
161.38
150.67
129.05
128.26
125.42
124.85
116.55
115.26
53.29
49.47
41.67
32.20
31.63
23.80
21.43
f1 (ppm)


XWQ-20180712-GYQ-V-90-2/10 — PROTON CDCl3 {D:\2018-1} ZHL 47
7.34
7.32
7.22
7.22
7.21
7.20
7.19
7.19
7.13
7.13
7.12
7.11
7.10
7.10
7.02
7.00
4.42
4.41
4.40
3.85
3.31
3.30
3.28
3.27
2.95
2.94
2.92
2.91
2.53
2.50
2.48
2.44
2.27
1.13
1.10
MeO
O
O
O
Me
Me
7n
1.01
1.04
1.05
1.01
1.00
3.05
1.05
1.06
2.24
2.06
3.16
3.15
f1 (ppm)


XWQ-20180712-GYQ-V-90-2/11 — C13CPD CDC13 {D:\2018-1} ZHL 47
198.14
191.34
167.07
161.37
150.38
129.43
128.44
125.53
124.32
116.90
111.46
53.27
50.92
48.73
41.92
32.50
29.66
28.73
27.70
f1 (ppm)


XWQ-20181109-GYQ-V-99/10 — PROTON CDC13 {D:\2018-3} ZHL 18
7.33
7.31
7.22
7.22
7.20
7.20
7.19
7.19
7.13
7.12
7.11
7.11
7.10
7.09
7.02
7.00
4.40
4.38
4.37
3.85
3.25
3.24
2.80
2.76
2.65
2.60
2.57
2.45
2.42
1.95
1.95
1.94
1.94
1.93
1.92
1.92
1.91
1.90
1.89
1.89
1.89
1.88
1.87
MeO
O
O
O
O
7o
1.00
1.01
1.00
0.99
1.00
2.97
1.00
1.01
1.04
2.08
1.02
6.31
f1 (ppm)


XWQ-20181109-GYQ-V-99/11 — C13CPD CDC13 {D:\2018-3} ZHL 18
197.89
191.16
166.95
161.32
150.31
129.41
128.42
125.54
124.25
116.86
112.50
53.29
49.28
48.85
40.93
38.51
32.26
32.11
28.73
15.46
f1 (ppm)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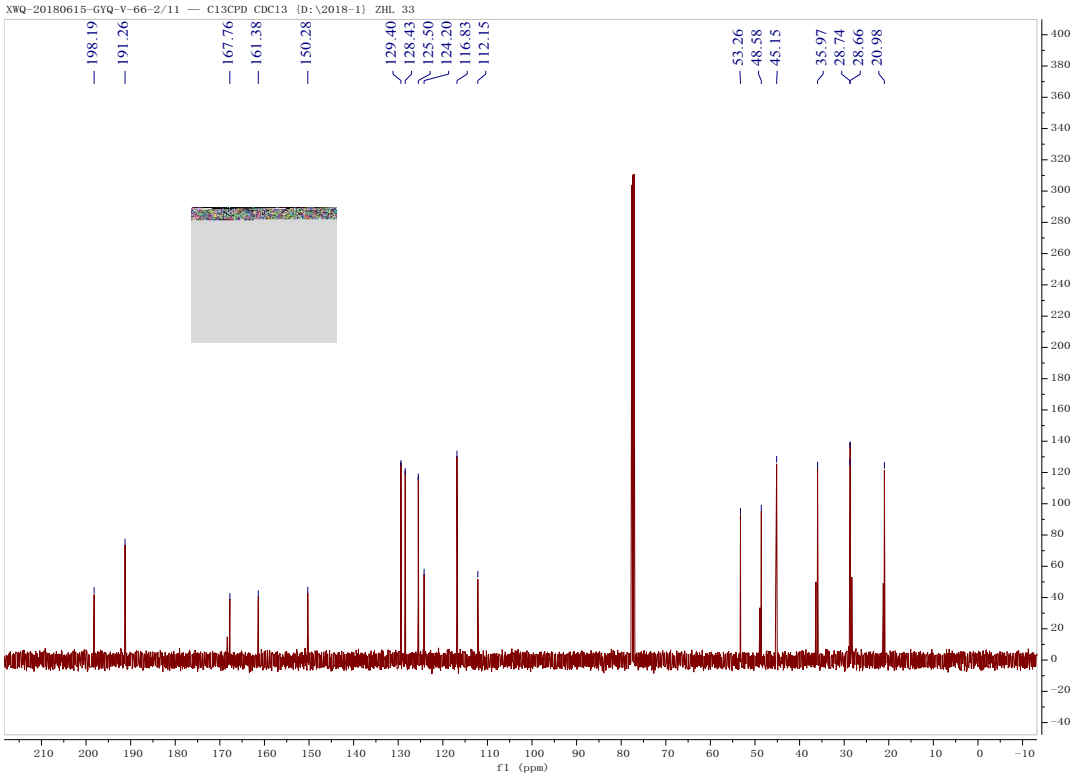
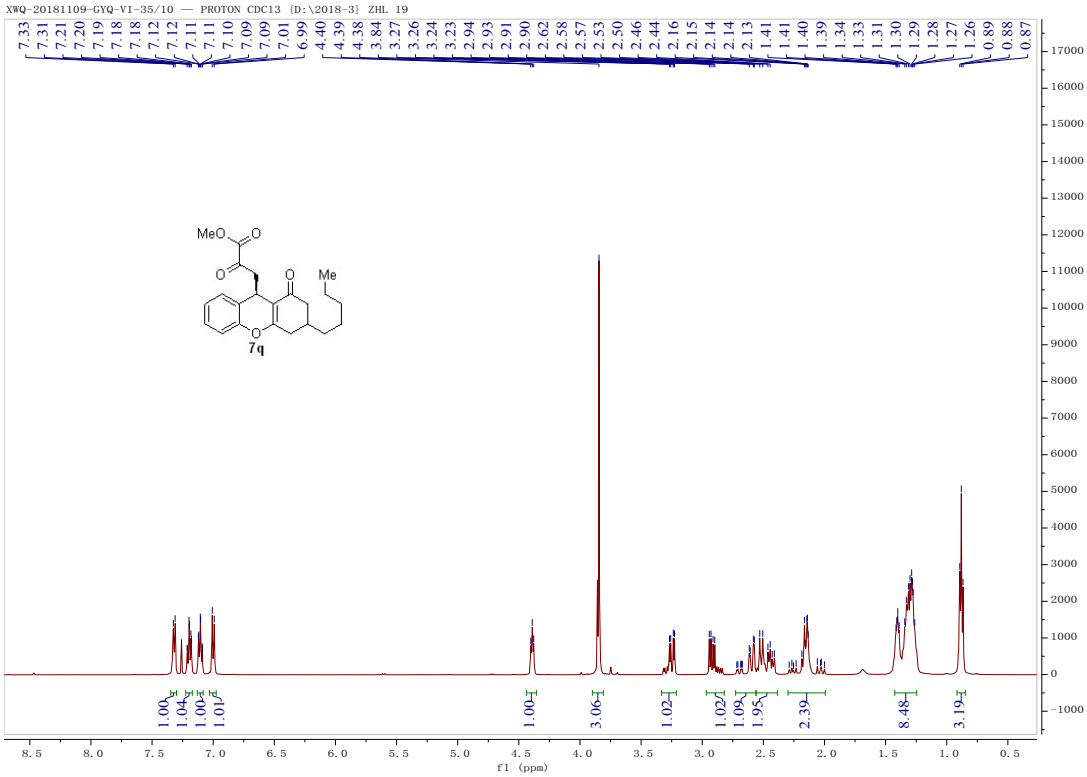
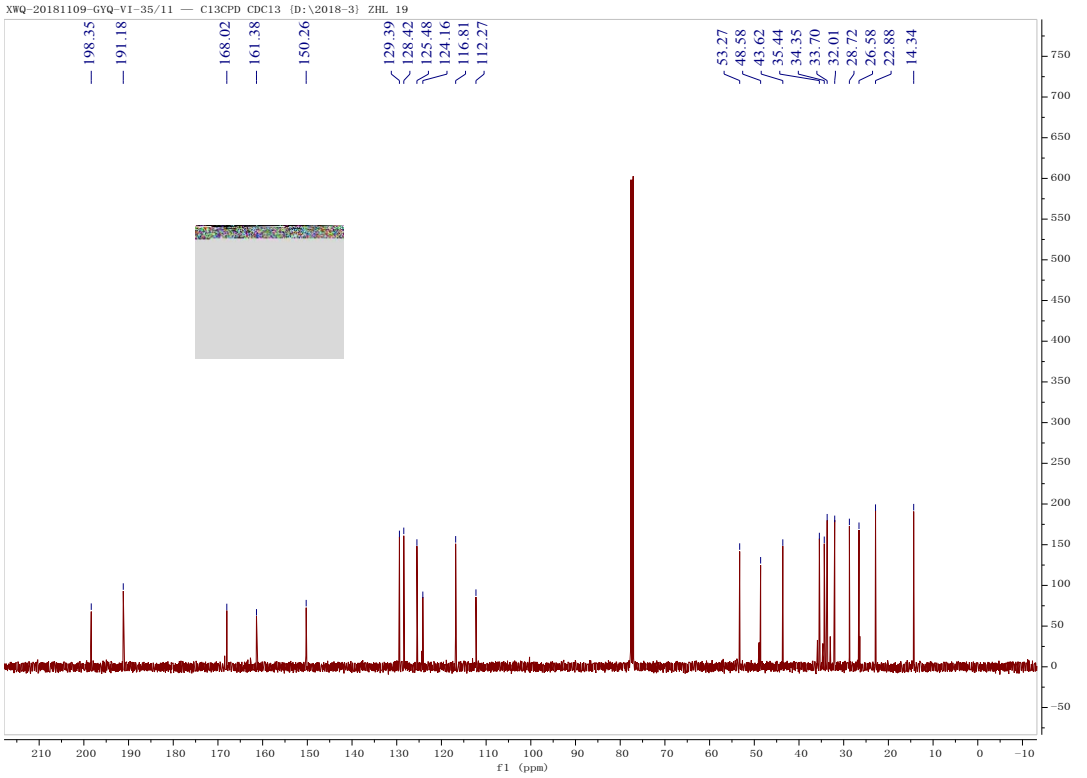
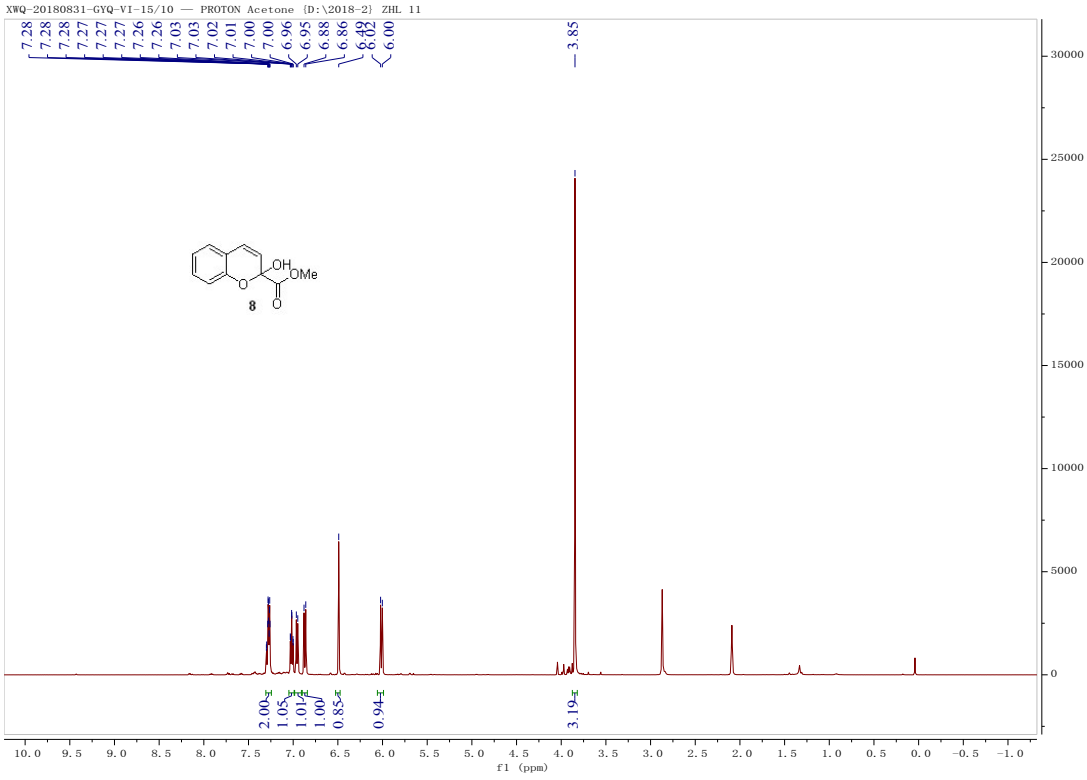
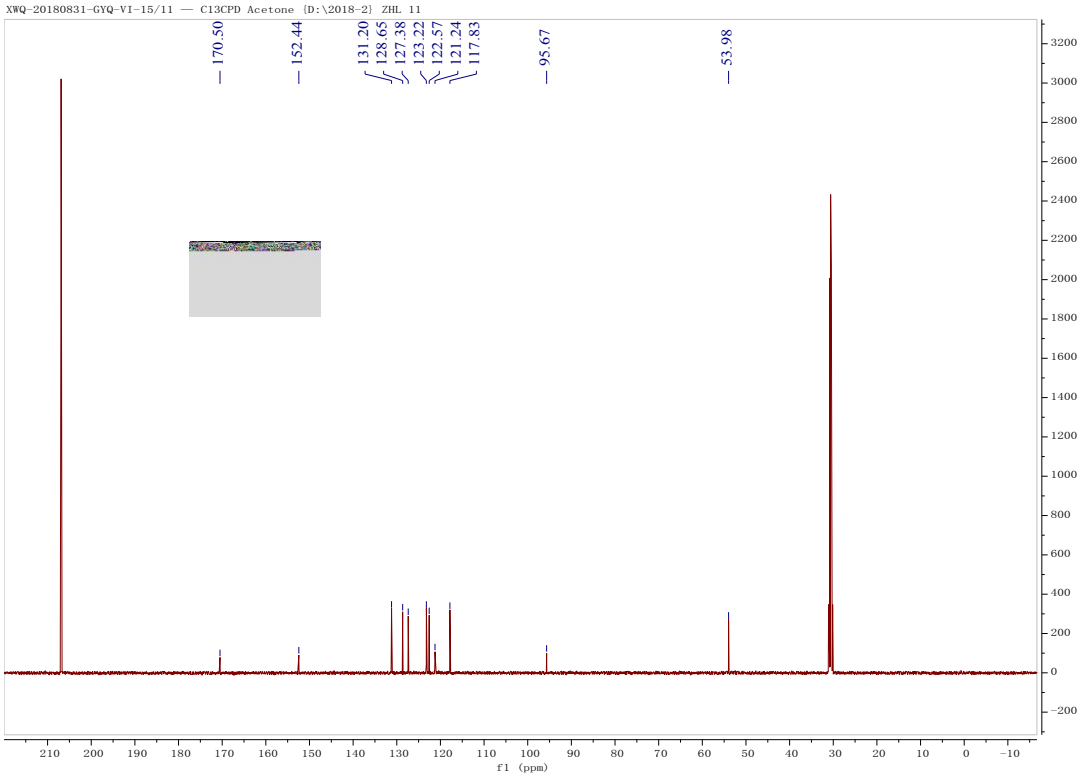
O
O
O
Me
7p
1.01
1.05
1.04
0.99
1.00
3.01
1.03
1.08
1.87
1.41
1.13
3.16
f1 (ppm)

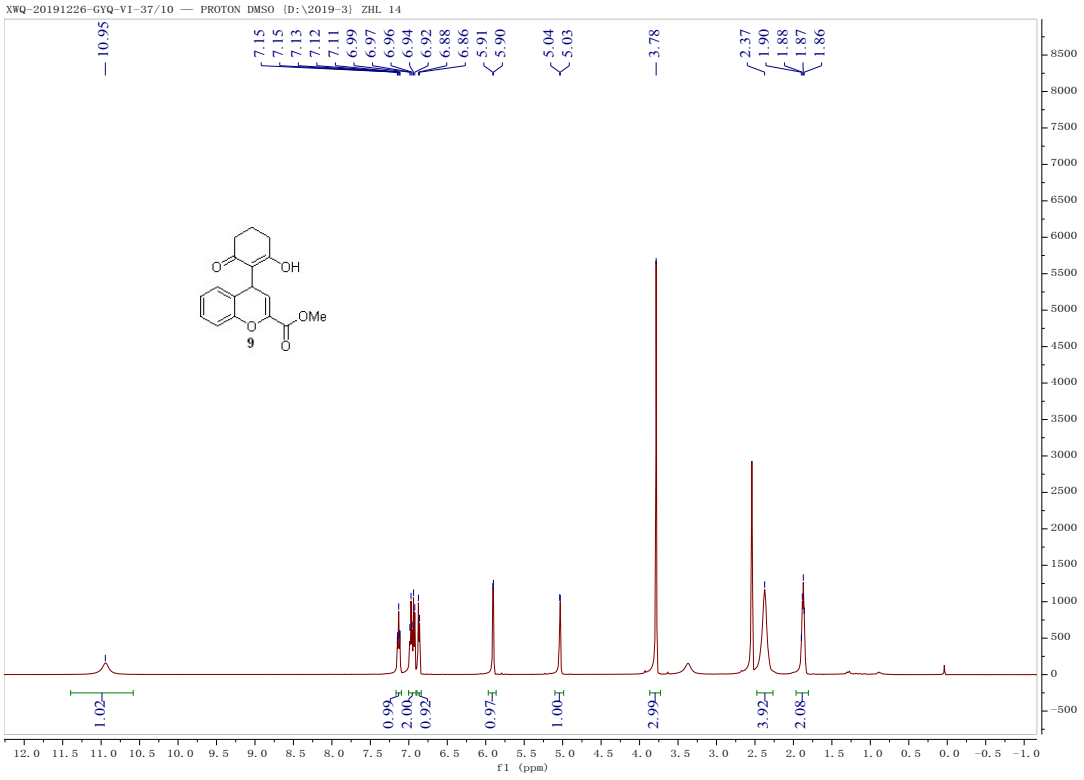

XWQ-20180615-GYQ-V-66-2/11 — C13CPD CDC13 {D:\2018-1} ZHL 33
198.19
191.26
167.76
161.38
150.28
129.40
128.43
125.50
124.20
116.83
112.15
53.26
48.58
45.15
35.97
28.74
28.66
20.98
f1 (ppm)

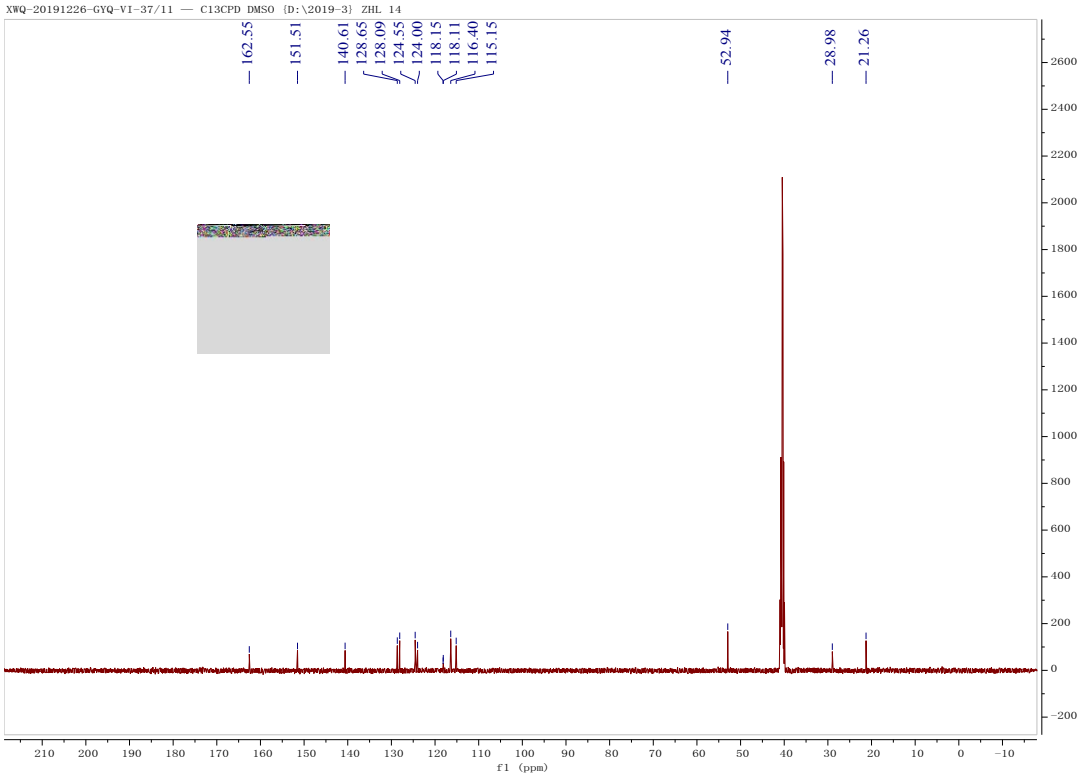

XWQ-20181109-GYQ-VI-35/10 — PROTON CDC13 {D:\2018-3} ZHL 19
MeO
O
O
O
Me
O
7q
1.00
1.04
1.00
1.01
1.00
3.06
1.02
1.02
1.09
1.95
2.39
8.48
3.19
f1 (ppm)

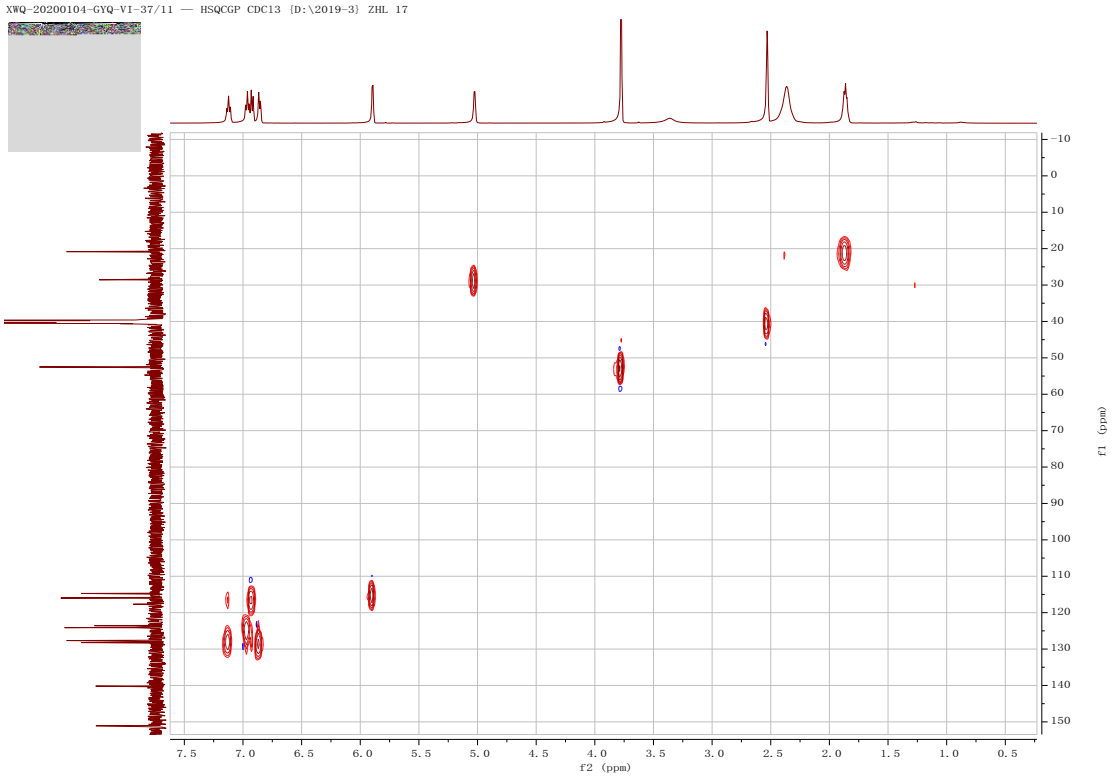

XWQ-20181109-GYQ-VI-35/11 — C13CPD CDC13 {D:\2018-3} ZHL 19
198.35
191.18
168.02
161.38
150.26
129.39
128.42
125.48
124.16
116.81
112.27
53.27
48.58
43.62
35.44
34.35
33.70
32.01
28.72
26.58
22.88
14.34
f1 (ppm)


XWQ-20180831-GYQ-VI-15/10 — PROTON Acetone {D:\2018-2} ZHL 11
7.28
7.28
7.28
7.27
7.27
7.27
7.26
7.26
7.03
7.03
7.02
7.01
7.00
7.00
6.96
6.95
6.88
6.86
6.49
6.02
6.00
3.85
OH
OMe
O
O
8
2.00
1.05
1.01
1.00
0.85
0.94
3.19
f1 (ppm)


XWQ-20180831-GYQ-VI-15/11 — C13CPD Acetone {D:\2018-2} ZHL 11
170.50
152.44
131.20
128.65
127.38
123.22
122.57
121.24
117.83
95.67
53.98
f1 (ppm)


XWQ-20191226-GYQ-VI-37/10 — PROTON DMSO {D:\2019-3} ZHL 14
10.95
7.15
7.15
7.13
7.12
7.11
6.99
6.97
6.96
6.94
6.92
6.88
6.86
5.91
5.90
5.04
5.03
3.78
2.37
1.90
1.88
1.87
1.86
OH
OMe
O
9
1.02
0.99
2.00
0.92
0.97
1.00
2.99
3.92
2.08
f1 (ppm)


XWQ-20191226-GYQ-VI-37/11 — C13CPD DMSO {D:\2019-3} ZHL 14
162.55
151.51
140.61
128.65
128.09
124.55
124.00
118.15
118.11
116.40
115.15
52.94
28.98
21.26
f1 (ppm)


XWQ-20200104-GYQ-VI-37/11 — HSQCGP CDC13 {D:\2019-3} ZHL 17
f2 (ppm)
f1 (ppm)

10. OTEP Drawing of 7a

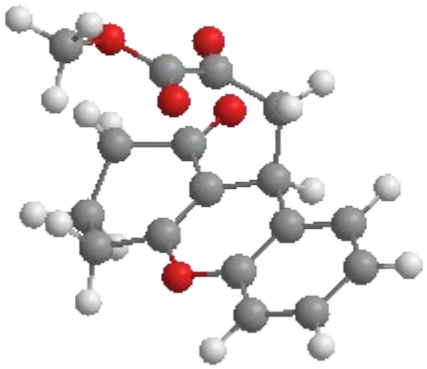


Figure S1

Table 1 Crystal data and structure refinement for compound 7a.

Identification code	**7a**
Empirical formula	$C_{17}H_{16}O_5$
Formula weight	300.30
Temperature/K	150.0
Wavelength	1.54178 A
Crystal system, space group	Orthorhombic, P2(1)2(1)2(1)
Unit cell dimensions	a = 9.4100(4) Å alpha = 90 deg. b = 10.2293(4) Å beta = 90 deg. c = 14.7811(6) Å gamma = 90 deg.
Volume	1422.79(10) A^3
Z, Calculated density	4, 1.402 g/cm^3
Absorption coefficient	0.860 mm^-1
F(000)	632.0
Crystal size	0.20 x 0.15 x 0.10 mm^3
Theta range for data collection	5.573 to 79.002 deg.
Limiting indices	-11<=h<=11, -13<=k<=13, -18<=l<=18
Reflections collected / unique	27882 / 3044 [R(int) = 0.0711]
Completeness to theta = 79.002	99.3 %
Absorption correction	None
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	2946 / 0 / 200
Goodness-of-fit on F^2	1.113
Final R indices [I>2sigma(I)]	R_1 = 0.0315, wR_2 = 0.0894
R indices (all data)	R_1 = 0.0359, wR_2 = 0.0981
Absolute structure parameter	0.07(7)
Extinction coefficient	n/a
Largest diff. peak and hole	0.283 and -0.292 e.A^-3