Supporting Information

Phosphine-Catalyzed Sequential (2+3)/(2+4) Annulation of γ Vinyl Allenoates: Access to the Synthesis of Chromeno[4,3-b]pyrroles

Xiaohu Li[†], You Huang[*,†]

[†]State Key Laboratory and Institute of Elemento-Organic Chemistry, College of Chemistry, Nankai University, Tianjin 300071, China

Email: hyou@nankai.edu.cn

Table of Contents

1. General Information.....S1

2. Optimization of Reaction Conditions S2

3. General Procedure of Starting Materials.....S3

4. General Procedure for New Products 3.....S4

5. Primary Attempt on Asymmetric Edition in the Presence of Chiral Phosphine Catalysts S5

6. Scale-up Experiment and Transformations of New Product S8

7. Control and Deuterium-labeling Experiments S9

8. Characterization Data of New Substrates 1 .....S12

9. Characterization Data of New Products 3.....S15

10. Spectra S28

11. X-Ray Crystallography Data of 3aa.....S59

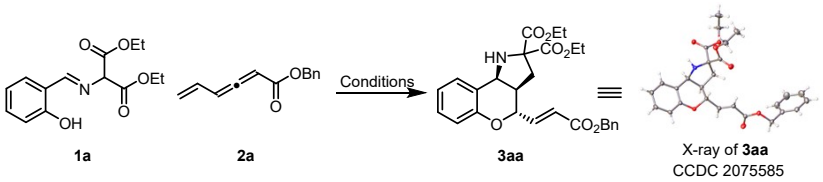
12. References.....S60

1. General Information

Commercial reagents and solvents were used as received without further purification, unless otherwise stated. Dry CH_2Cl_2 was distilled over calcium hydride. Unless otherwise specified, reactions at 25 °C have been performed using the pre-heated water-bath or the pre-heated oil-bath maintained at 25 °C. Yields referred to isolated compounds through preparative TLC. ^{1}H NMR, ^{13}C NMR spectra were recorded on a Bruker Avance 400 (400 MHz) spectrometer. And ^{19}F NMR were reported on a Bruker Avance (376 MHz) spectrometer. Chemical shifts for protons are reported in ppm and are referenced to the NMR solvent peak ($CDCl_3$: δ 7.26 ppm, DMSO-d_6: δ 2.50 ppm). Chemical shifts for carbons are reported in ppm and are referenced to the carbon resonances of the NMR solvent peak ($CDCl_3$: δ 77.06 ppm, DMSO-d_6: δ 39.50 ppm). Multiplicity was indicated as follows: s (singlet), d (doublet), t (triplet), q (quartet), dd (doublet of doublet), brs (broad singlet) and m (multiplet). Enantiomeric excesses of the diene carboxylates products were determined by Agilent 6890 chiral-phase high performance liquid chromatography (HPLC) or LabAlliance PC2001, using chiralcel AD-H, OD-H, and ID-H. High resolution mass spectrometry (HRMS) were obtained on Q Exactive Focus or Agilent 6520 Q-TOF LC/MS with ESI resource. Melting points were measured on a RY-I apparatus and reported uncorrected.

2. Optimization of Reaction Conditions

S-Table 1 Optimization of the Reaction Conditionsa[a].

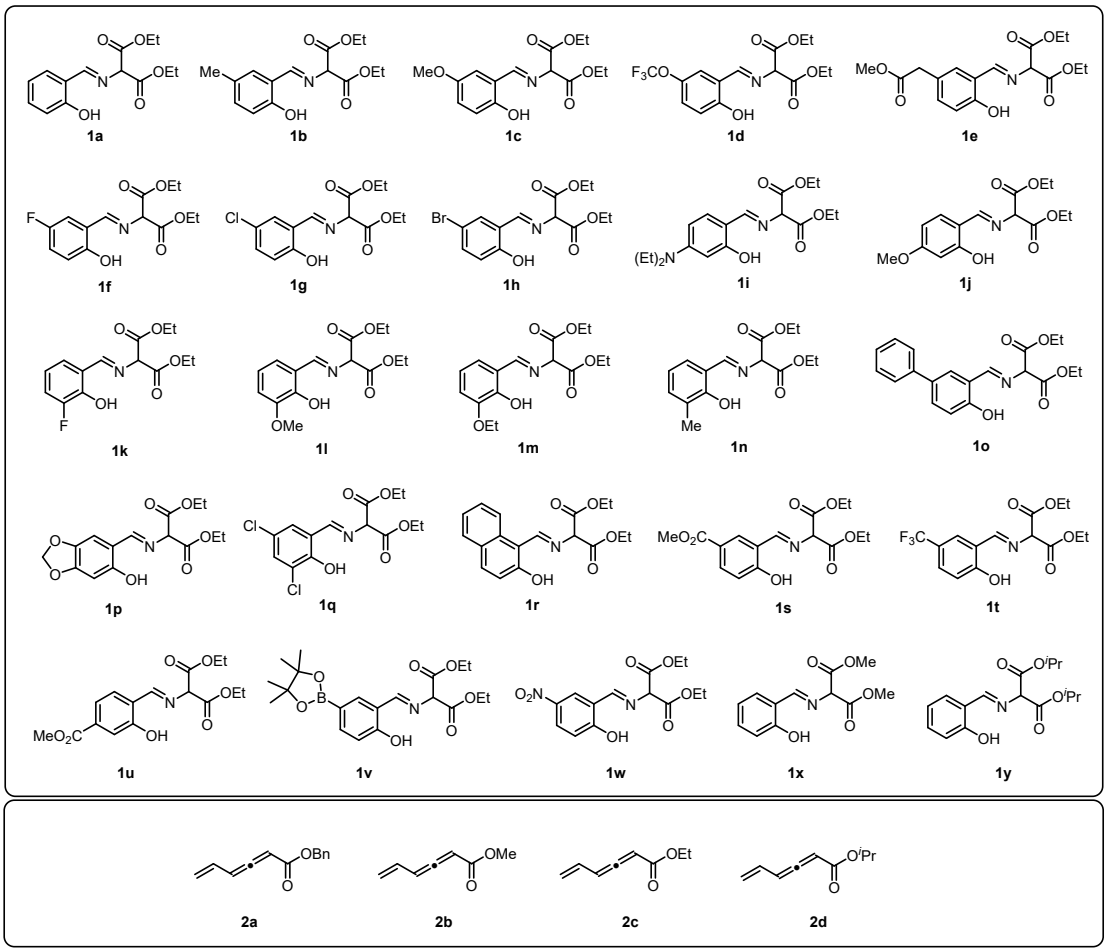


Entry	Catalyst	Additive	Solvent	Yield[b] (%)	dr[c]
1	PPh_3	-	toluene	50	>20:1
2	$(p\text{-}FC_6H_4)_3P$	-	toluene	69	>20:1
3	$(p\text{-}MeOC_6H_4)_3P$	-	toluene	43	>20:1
4	$EtPPh_2$	-	toluene	35	>20:1
5	Cy_3P	-	toluene	trace	-
6	Bu_3P	-	toluene	trace	-
7	$(p\text{-}FC_6H_4)_3P$	PhCOONa	toluene	trace	-
8	$(p\text{-}FC_6H_4)_3P$	PhOH	toluene	70	>20:1
9	$(p\text{-}FC_6H_4)_3P$	CH_3COOH	toluene	77	>20:1
10	**$(p\text{-}FC_6H_4)_3P$**	**PhCOOH**	**toluene**	**82**	**>20:1**
11	$(p\text{-}FC_6H_4)_3P$	CF_3COOH	toluene	18	>20:1
12	$(p\text{-}FC_6H_4)_3P$	PhCOOH	CH_2Cl_2	48	>20:1
13	$(p\text{-}FC_6H_4)_3P$	PhCOOH	$HCCl_3$	53	>20:1
14	$(p\text{-}FC_6H_4)_3P$	PhCOOH	THF	40	>20:1

[a]Reaction conditions: 0.10 mmol **1a** (1.0 equiv.), 0.25 mmol **2a** (2.5 equiv.), catalyst (30 mol%) in solvent (1.0 mL) at 25°C. [b]Yield of isolated. [c]dr determined by ^1H NMR.

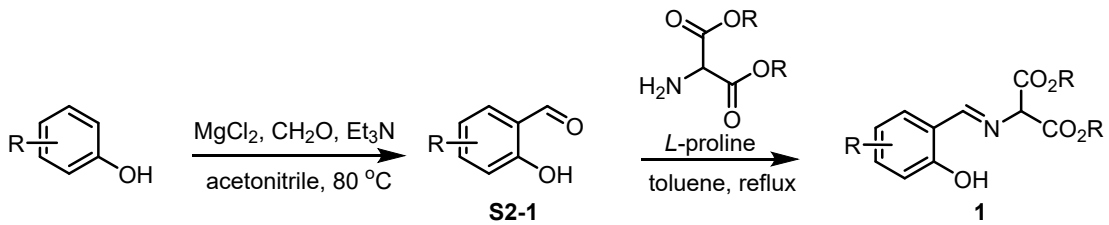
3. General Procedure of Starting Materials

3.1. The substrates examined in this report.



The aldimine esters **1a**[1a], **1b**[1b], **1c**[1c], **1f**[1d], **1g**[1a], **1h**[1a], **1i**[1b], **1j**[1a], **1l**[1c], **1m**[1b], **1n**[1d], **1q**[1b], **1r**[1b], **1w**[1a], **and 1x**[1e] are known compounds, and their NMR data were identical with the literature. The substrates were prepared according to the reported literature procedures. γ-Vinyl Allenoates were prepared following the synthetic method describes in our previous work[2].

3.2. General Procedure for aldimine esters 1:

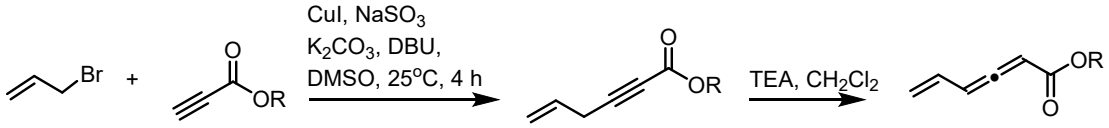


Compound **S2-1** was prepared following the synthetic method described previously[3] and directly used for the following reaction.

A 50 mL Single-port flask was charged with substituted salicylaldehydes (1.0 equiv), aminomalonate (1.2-2.0 equiv), *L*-proline (0.2 equiv) and toluene (20 mL). The mixture was stirred at reflux for 2-4 hours until the complete consumption of the starting materials monitored by TLC. Then the reaction mixture

was concentrated under reduced pressure and the residue was purified by a silica gel column chromatography (petroleum ether: ethyl acetate = 10:1) to afford the product **1**.

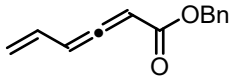
3.3. General Procedure for γ-Vinyl Allenoates:



S2-2 **2**

To an oven-dried 50 mL glass vial was added compound K_2CO_3 (1.0 equiv), Na_2SO_3 (0.5 equiv), CuI (0.1 equiv), and DMSO, then corresponding propynoic acid ester (1.0 equiv) and 3-bromoprop-1-ene (1.5 equiv) were added with stirring under argon atmosphere. The resulting mixture was stirred at 25 ºC for 4 hours. Then the mixture was colded down to 0 °C by ice-water bath, diluted by cold water, and extracted using methyl tertiary-butyl ether (MTBE) three times. The combined organic phase was washed with water and brine in turn. The volatile solvent was removed under reduced pressure and the residue was purified by flash chromatography (petroleum ether: ethyl acetate = 20:1) to afford the product **S2-2** as a pale yellow oil.

To a stirred solution of compound **S2-2** (1.0 equiv) in anhydrous CH_2Cl_2 was added trimethylamine (0.2 equiv) at 25 °C, and the mixture was stirred for 2 h under argon atmosphere. Then the reaction mixture was concentrated under reduced pressure and the residue was used directly for the next step without further purification. **2a-d** are known compounds, the data of the compound **2a** is given as follows.

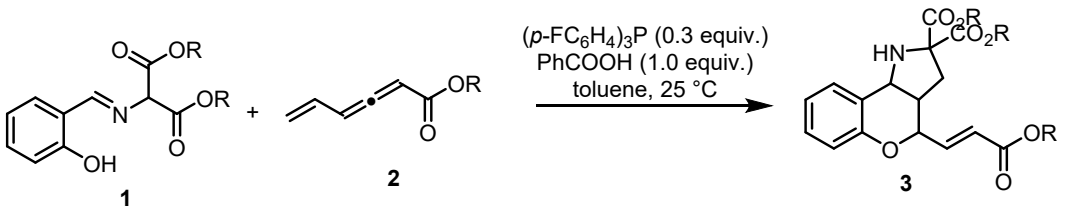


2a

Pale yellow oil

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.31 (m, 5H), 6.29 (dd, *J* = 10.4, 6.0 Hz, 1H), 6.25 – 6.13 (m, 1H), 5.85 (d, *J* = 5.7 Hz, 1H), 5.34 (d, *J* = 16.5 Hz, 1H), 5.21 – 5.14 (m, 3H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 216.36, 164.94, 135.86, 128.97, 128.56, 128.14, 119.35, 98.54, 89.63, 66.69. **IR (KBr, cm^{-1}):** 2987, 1944, 1718, 1650, 1261, 1152, 989, 913, 750, 698. **HRMS (ESI):** m/z calcd for $C_{13}H_{13}O_2$ ($[M+H]^+$): 201.0910; found: 201.0909.

4. General Procedure for New Products 3

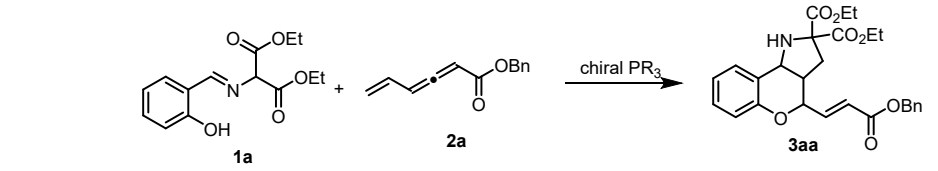


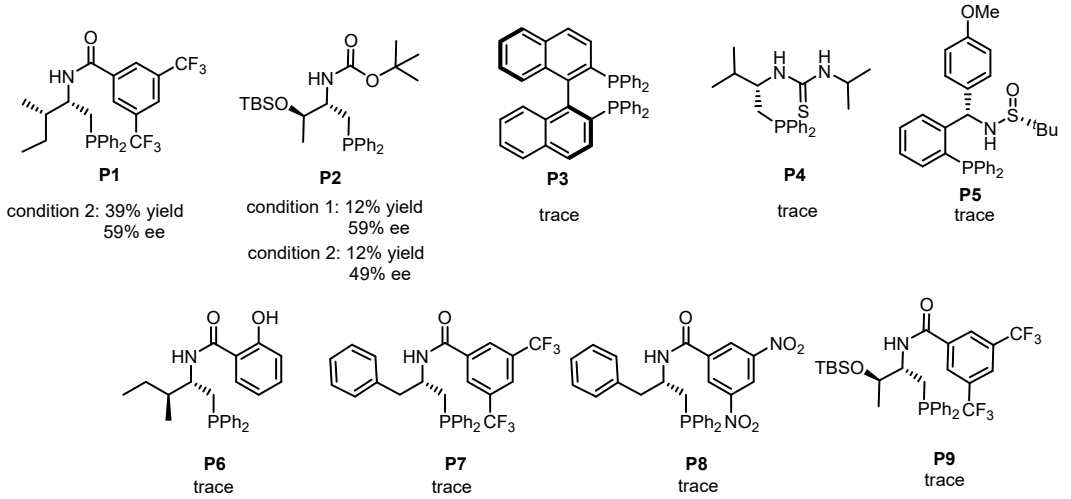
To an oven-dried 10 mL glass vial was added compound **1** (0.1 mmol), allenoate **2** (0.25 mmol), PhCOOH (0.1 mmol), $(p\text{-}FC_6H_4)_3P$ (0.3 equiv) and 1.0 mL of toluene. The resulting mixture was stirred at 25 ºC for 2-4 hours until the complete consumption of the starting materials monitored by TLC. After

removal of toluene, the residue was diluted with ethyl acetate (2.0 mL) and washed with brine. The volatile was removed under reduced pressure and the residue was purified by preparative TLC (petroleum ether: ethyl acetate = 5:1) to afford **3.**

5. Primary Attempt on Asymmetric Edition in the Presence of Chiral Phosphine Catalysts

S-Scheme 1. Primary attempt on asymmetric edition

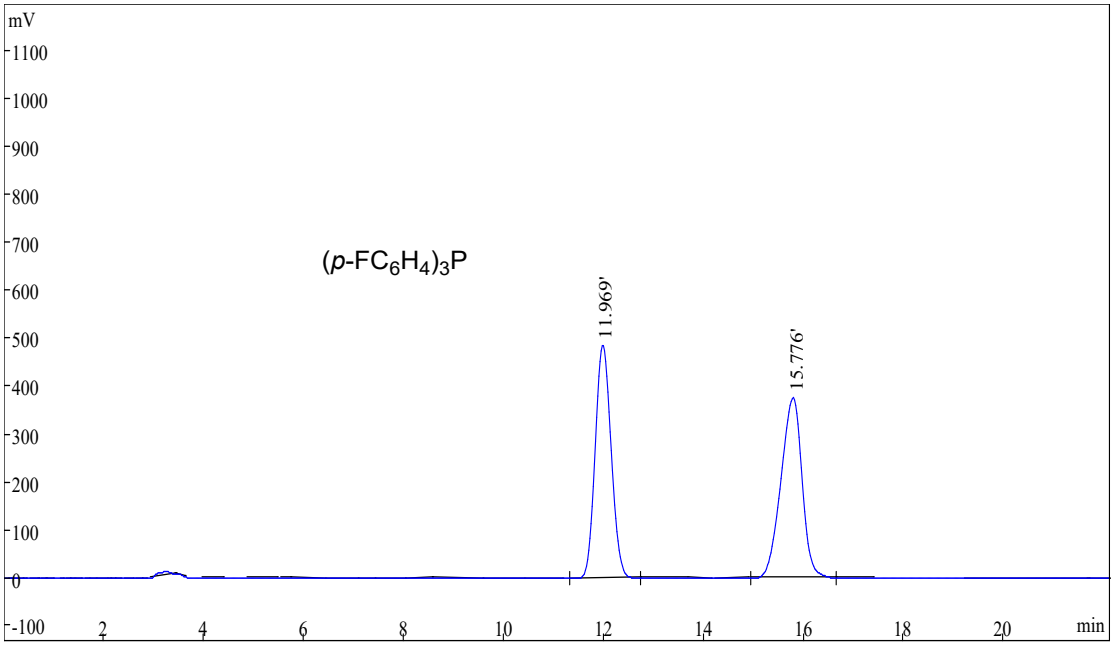




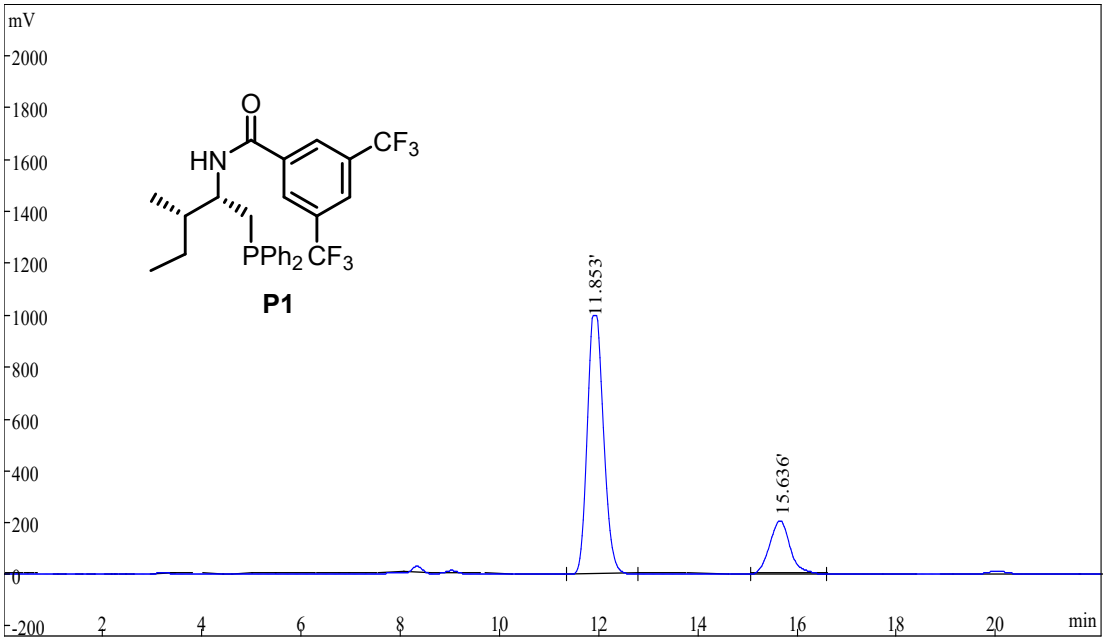
Conditions 1: **1a** (0.1 mmol), **2a** (0.25 mmol), catalyst (10 mol %), PhCOOH (0.1mmol), toluene (1.0 mL), 25°C, 24 h.

Conditions 2: **1a** (0.1 mmol), **2a** (0.25 mmol), catalyst (10 mol %), PhCOOH (0.1mmol), $HCCl_3$ (1.0 mL), 0°C, 48 h.

HPLC conditions: Chiralcel AD-H, λ = 220 nm, hexanes : iPrOH = 85 : 15, flow rate = 1.0 mL/min

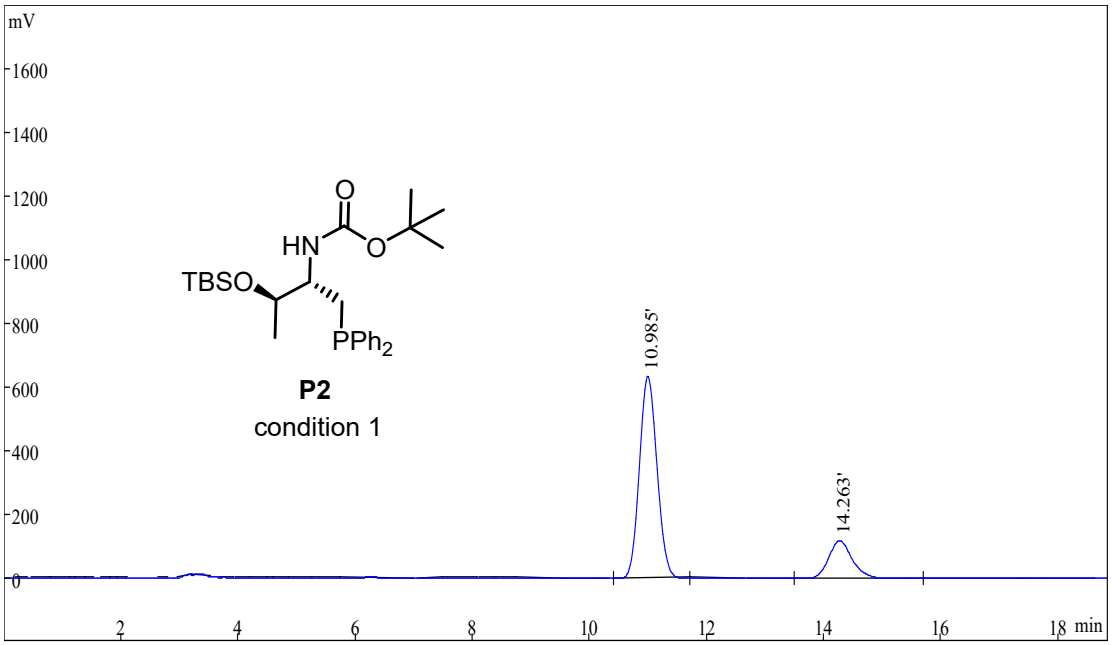


Rank	Time	Area%	Area	Height
1	11.969	49.41	10848899	488799
2	15.776	50.59	11105926	376957
Total		100	21954825	865756



Rank	Time	Area%	Area	Height
1	11.853	79.4	22951416	997287

2	15.636	20.6	5956079	206432
Total		100	28907495	1203719



Rank	Time	Area%	Area	Height
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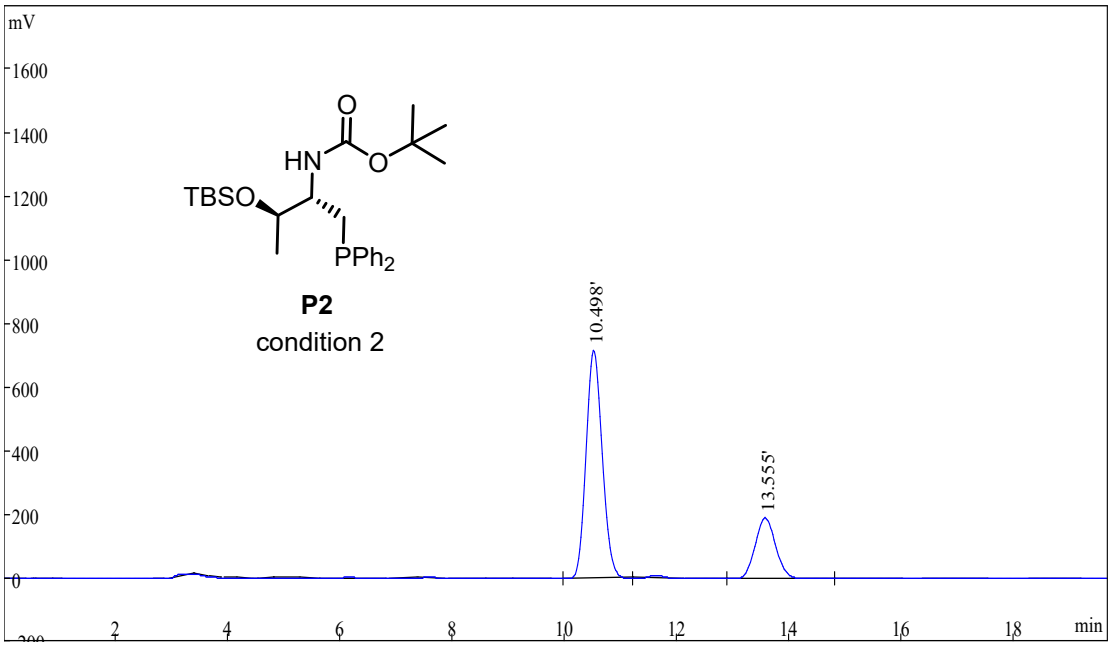
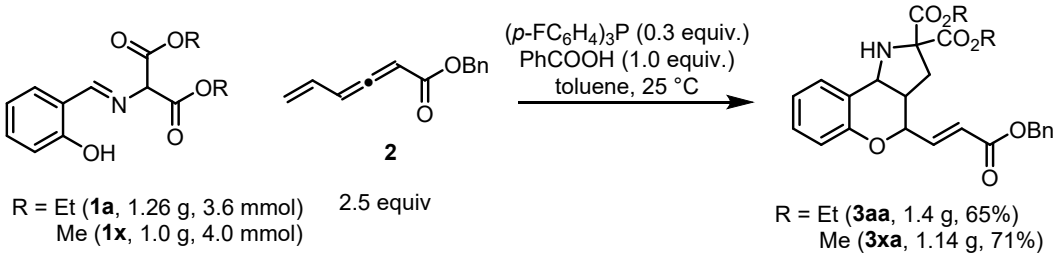
2	14.263	20.3	3384152	119110
Total		100	16666810	753923



Rank	Time	Area%	Area	Height
1	10.498	74.54	14442262	718492
2	13.555	25.46	4932770	192287
Total		100	19375032	910779

6. Scale-up Experiment and Transformations of New Product

6.1 Scale-up Experiment of the new products 3aa and 3xa



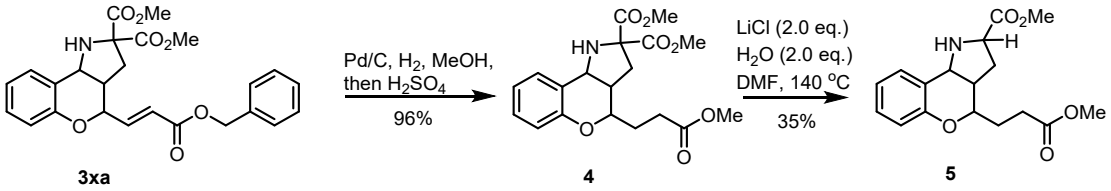
R = Et (**1a**, 1.26 g, 3.6 mmol)
Me (**1x**, 1.0 g, 4.0 mmol)

2.5 equiv

R = Et (**3aa**, 1.4 g, 65%)
Me (**3xa**, 1.14 g, 71%)

A 100 mL flask equipped with a stirring bar was charged with compound **1a or 1x** (1.0 equiv), PhCOOH (0.1 mmol), **2a** (2.5 equiv) and (p-FC_6H_4)$_3$P (0.3 equiv) and toluene (30.0 mL). The resulting suspension was stirred at 25 ºC until the complete consumption of the starting materials monitored by TLC. The mixture was quenched with saturated aqueous $NaHCO_3$ (30 mL), and extracted with ethyl acetate (25 mL×3). The combined organic phase was washed with brine, dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The residue was purified by silica gel flash column chromatography (petroleum ether: ethyl acetate = 10:1) to afford crude product which was recrystallized from CH_2Cl_2 and n-hexane afforded the analytically pure product as white solid.

6.2 Transformations of the new product and spectral data



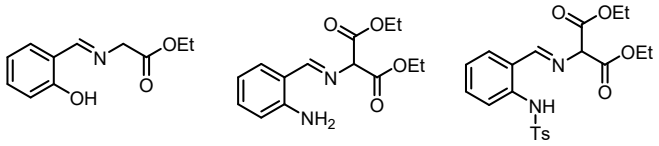
A mixture of 3xa (400 mg, 0.89 mmol), and 10% Pd-C catalyst (40 mg) in MeOH (20 mL) was stirred at 25 °C under hydrogen atmosphere (hydrogen balloon) until the complete consumption of the starting materials monitored by TLC. After the Pd-C catalyst was filtered off, two drops of con. H_2SO_4 was added and the mixture was stirred at 25 °C for 5 h. Then the reaction was quenched with saturated aqueous $NaHCO_3$ (20 mL), extracted extracted with ethyl acetate (20 mL×3). The organic phase was washed with brine and dried by anhydrous Na_2SO_4 and concentrated under reduced pressure to give compound **4** (colorless oil, 320 mg, 96% yield)**,** which was pure enough and used for the next step without further purification. **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.32 – 7.26 (m, 1H), 7.16 (t, J = 7.6 Hz, 1H), 6.92 (t, J = 7.3 Hz, 1H), 6.85 (d, J = 8.1 Hz, 1H), 4.22 (s, 1H), 3.82 (s, 3H), 3.74 – 3.67 (m, 6H), 3.22 (brs, 1H), 2.76 – 2.62 (m, 2H), 2.62 – 2.43 (m, 2H), 2.29 – 2.13 (m, 2H), 1.88 (m , 1H). **^{13}C NMR**

(101 MHz, $CDCl_3$) δ 173.80, 172.42, 170.72, 153.93, 129.81, 128.80, 122.53, 120.97, 117.00, 74.07, 70.70, 55.60, 53.23, 53.16, 51.63, 40.27, 35.04, 30.09, 27.87. **IR (KBr, cm^{-1}):** 3338, 2953, 2853, 1737, 1584, 1448, 1357, 1269, 1240, 1133, 1072, 1016, 945, 755. **HRMS (ESI):** m/z calcd for $C_{19}H_{24}NO_7$ ($[M+H]^+$): 378.1547; found: 378.1546.

In a 10 mL glass vial, to the solution of compound **4** (50 mg, 0.13 mmol) in dry DMF (1.0 mL) was added LiCl (11.2 mg, 0.26 mmol) and H_2O (2.4 mg, 0.13 mmol) at room temperature. The reaction mixture was purged with argon three times and then placed in a pre-heated oil bath at 140°C until the complete consumption of the starting materials monitored by TLC (about 40 min). The mixture was cold down to room temperature, diluted by H_2O (3.0 mL), extracted with ethyl acetate (5 mL×3). The organic phase was washed with brine and dried by anhydrous Na_2SO_4 and concentrated under reduced pressure to give a residue, which was purified by preparative TLC (petroleum ether: ethyl acetate = 2:1) to give compound **5** (white solid, 35% yield, m.p. 66-68°C). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 7.32 (d, *J* = 6.9 Hz, 1H), 7.16 (t, *J* = 7.2 Hz, 1H), 6.93 (t, *J* = 6.8 Hz, 1H), 6.85 (d, *J* = 7.8 Hz, 1H), 4.23 (d, *J* = 5.5 Hz, 1H), 3.88 (s, 1H), 3.77 (s, 3H), 3.69 (s, 4H), 2.73 – 2.50 (m, 3H), 2.39 – 2.22 (m, 2H), 2.20 – 2.07 (m, 2H), 1.95 – 1.79 (m, 1H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 173.89, 129.84, 128.51, 123.79, 121.18, 116.96, 74.71, 57.73, 54.66, 52.29, 51.68, 40.49, 32.23, 30.06, 28.17. **IR (KBr, cm^{-1}):** 2921, 2855, 1732, 1582, 1450, 1363, 1267, 1228, 1119, 1086, 1019, 752. **HRMS (ESI):** m/z calcd for $C_{17}H_{22}NO_5$ ($[M+H]^+$): 320.1492; found: 320.1488.

7. Control and Deuterium-labeling Experiments

7.1. Substrates of control experiments



The compound **6** was known compounds, and its NMR data were identical with the literature[4]. The substrates were prepared according to the reported literature procedures. **7a** and **7b** were prepared according to the general procedure for aldimine esters 1.

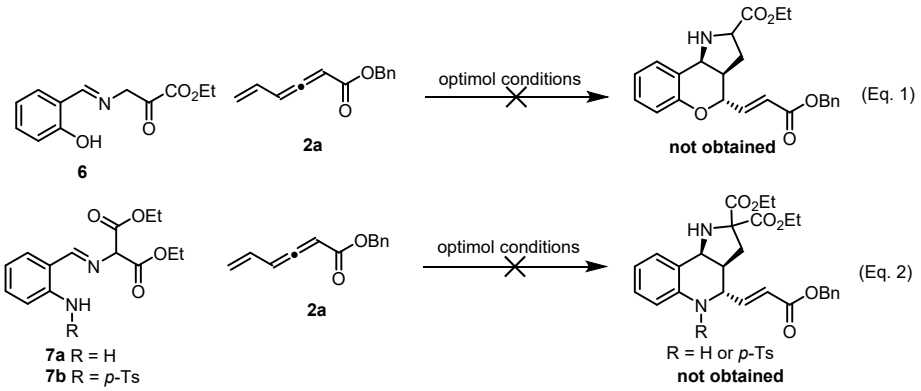
7a was synthesized from the condensation of 2-aminobenzaldehyde (540 mg, 4.5 mmol) and diethyl aminomalonate (1.17 g, 6.7 mmol) and obtained as yellow oil (400 mg, 32% yield).**^{1}H NMR (400 MHz, $CDCl_3$)** δ 8.39 (s, 1H), 7.23 (dd, *J* = 7.9, 1.5 Hz, 1H), 7.20 – 7.15 (m, 1H), 6.70 – 6.63 (m, 2H), 6.44 (brs, 2H), 4.74 (s, 1H), 4.27 (qd, *J* = 7.1, 2.4 Hz, 4H), 1.30 (t, *J* = 7.1 Hz, 6H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 169.29, 167.19, 149.10, 134.22, 132.06, 116.68, 115.85, 115.75, 75.20, 62.01, 14.07. **IR (KBr, cm^{-1}):** 2984, 2938, 1753, 1630, 1558, 1492, 1273, 1216, 1158, 1095, 1028, 751. **HRMS (ESI):** m/z calcd for $C_{14}H_{19}N_2O_4$ ($[M+H]^+$): 279.1339; found: 279.1335.

7b was synthesized from the condensation of *N*-(2-formylphenyl)-4-methylbenzenesulfonamide (300 mg, 1.1 mmol) and diethyl aminomalonate (248 mg, 1.4 mmol) and obtained as yellow oil (270 mg, 57% yield). **^{1}H NMR (400 MHz, $CDCl_3$)** δ 12.48 (s, 1H), 8.35 (s, 1H), 7.77 (d, *J* = 8.3 Hz, 2H), 7.70 (d, *J* = 8.3 Hz, 1H), 7.34 – 7.27 (m, 2H), 7.18 (d, *J* = 8.1 Hz, 2H), 7.09 – 6.94 (m, 1H), 4.86 (s, 1H), 4.39 – 4.28 (m, 4H), 2.33 (s, 3H), 1.35 (t, *J* = 7.1 Hz, 6H). **^{13}C NMR (101 MHz, $CDCl_3$)** δ 168.84, 166.14, 143.44, 139.57, 136.94, 134.17, 132.47, 129.45, 127.27, 122.47, 120.33, 117.95, 73.48, 62.48, 21.45, 14.03. **IR**

(KBr, cm^{-1}): 2985, 2938, 1740, 1636, 1500, 1338, 1277, 1161, 1092, 1029, 927, 761, 565. **HRMS (ESI):** m/z calcd for $C_{21}H_{25}N_2O_6S$ ([M+H]$^+$): 433.1428; found: 433.1424.

7.2. Control Experiment

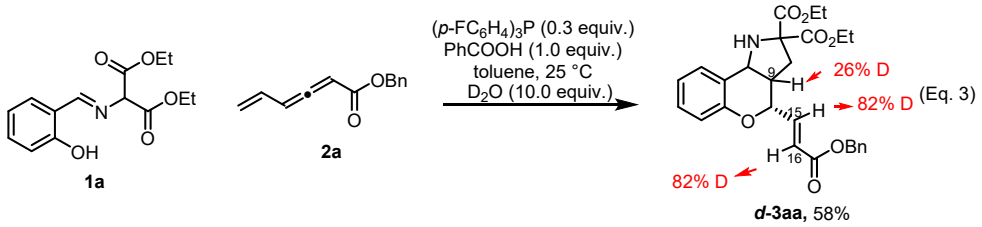
Under the standard conditions, no corresponding product was obtained when allenoate **2a** reacted with ethyl (*E*)-2-[(2-hydroxybenzylidene)amino]acetate **6**, suggesting that malonate moiety is necessary to trigger the reaction. Replacing hydroxyl group with amido group or 4-methyl benzenesulfonamido group (*p*-TsNH), it did not give the desired product, revealing that the hydroxyl group is essential.



6 **2a**

7a R = H
7b R = *p*-Ts

7.3. Deuterium-labeling reaction

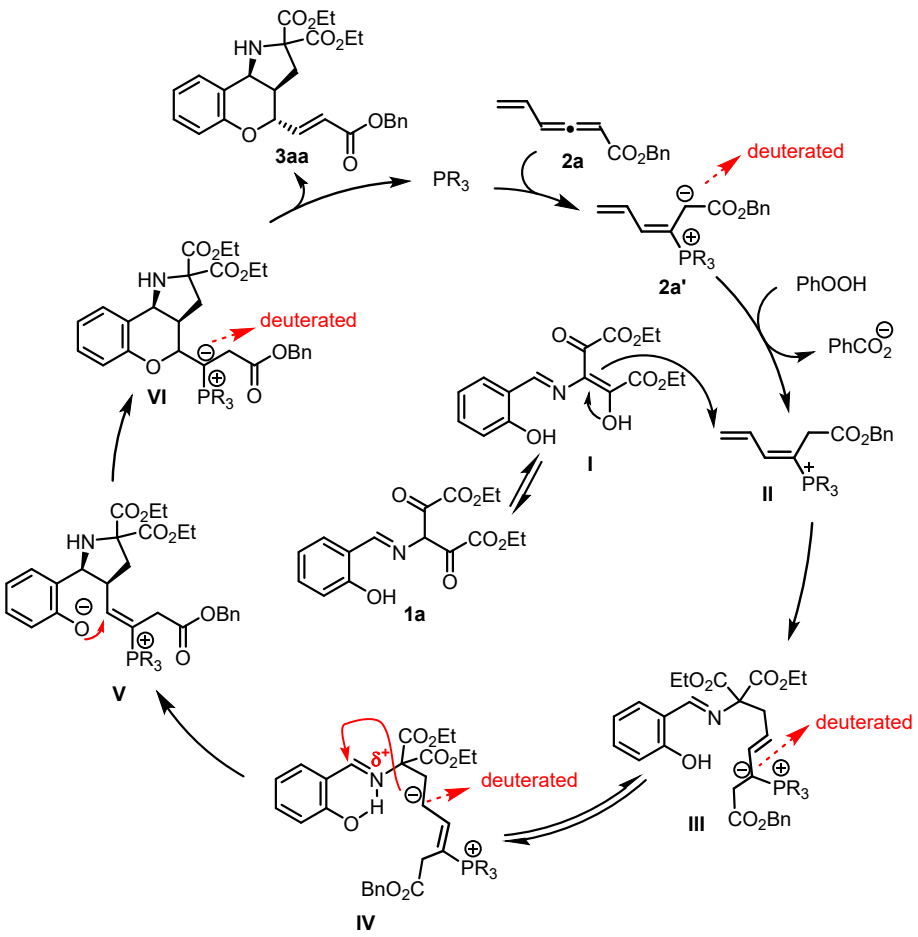


1a **2a**

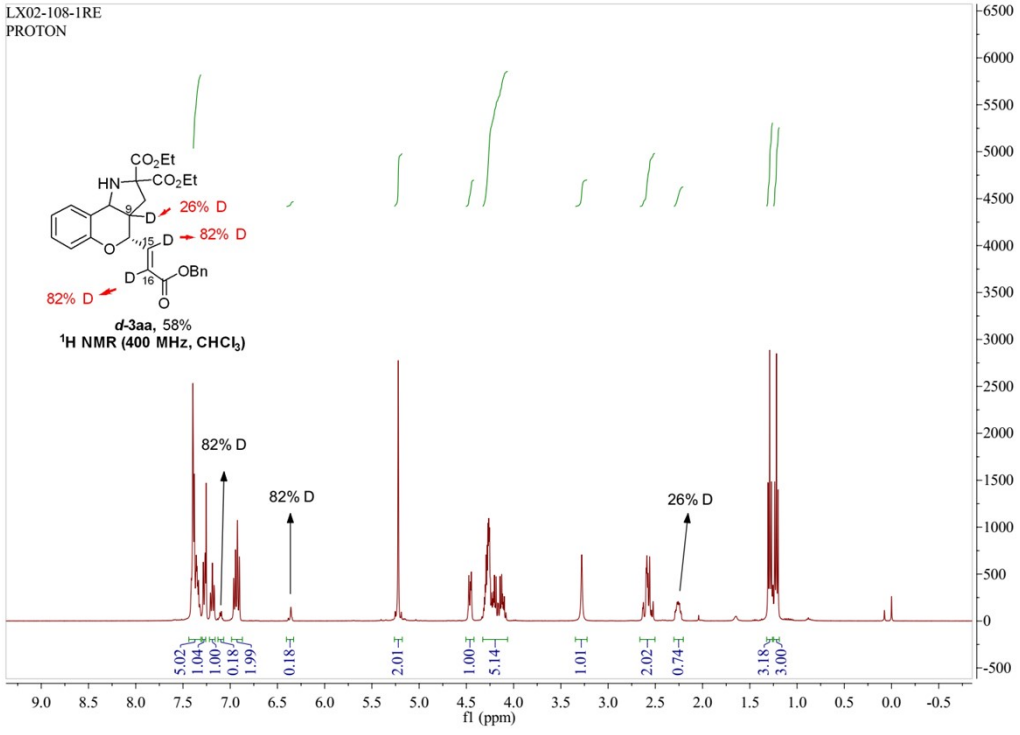
***d*-3aa**, 58%

To an oven-dried 10 mL glass vial was added compound **1** (0.1 mmol), allenoate **2** (0.25 mmol), PhCOOH (0.1 mmol), $(p\text{-}FC_6H_4)_3P$ (0.3 equiv) and 1.0 mL of toluene. Then D_2O (1.0 mmol, 10.0 equiv) was added to the system. The resulting mixture was stirred at 25 ºC for 2 hours until the complete consumption of the starting materials monitored by TLC. After removal of toluene, the residue was diluted with ethyl acetate (2.0 mL) and washed with brine. The volatile was removed under reduced pressure and the residue was purified by preparative TLC (petroleum ether: ethyl acetate = 5:1) to afford ***d*-3aa** (28 mg, 58%).

During annulation reaction catalyzed by nucleophilic phosphine, there may be four active intermediates involving nucleophilic site or carbanion (intermediate **2a'**, **III**, **IV**, **VI**), which would be deuterated in the present of D_2O (**S-Figure 1**). The resonated intermediate **IV** carried out intramolecular addition of the carbon anion to vinyl phosphonium to afford intermediate **V** quickly, so carbanion of C9 site is only deuterated by 26%. The carbanion of C16 could be stabilized by enolization, and The carbanion of C15 can be stabilized by forming ylide with PR_3. Hydrogen and deuterium are therefore more likely to be exchanged at C15 and C16.

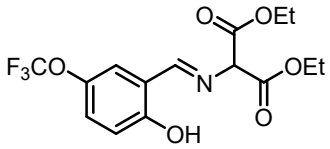


S-Figure 1. The exchange process of hydrogen and deuterium



8. Characterization Data of New Substrates 1

diethyl (*E*)-2-((2-hydroxy-5-(trifluoromethoxy)benzylidene)amino)malonate (1d)



1d was synthesized from the condensation of corresponding substituted salicylaldehyde (400 mg, 1.9 mmol) and diethyl aminomalonate (442 mg, 2.5 mmol) and obtained as yellow oil (304 mg, 43% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 12.76 (s, 1H), 8.47 (s, 1H), 7.26 – 7.18 (m, 2H), 7.00 (d, J = 8.9 Hz, 1H), 4.90 (s, 1H), 4.33 – 4.28 (m, 4H), 1.32 (t, J = 7.1 Hz, 6H)..

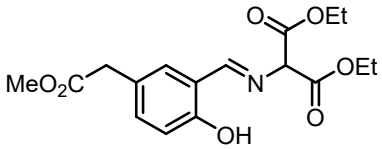
^{13}C NMR (101 MHz, $CDCl_3$) δ 168.69, 165.88, 159.76, 140.86, 126.77, 124.60, 124.43, 120.6 (C-F, $^1J_{C\text{-}F}$ = 256.5 Hz), 118.66, 118.36, 116.76, 100.31, 77.38, 77.06, 76.74, 72.45, 62.59, 14.00.

IR (KBr, cm^{-1}): 2987, 2940, 1742, 1639, 1585, 1492, 1370, 1258, 1217, 1158, 1100, 1029, 802, 751, 606.

^{19}F NMR (377 MHz, $CDCl_3$) δ -58.61 (s).

HRMS (ESI): m/z calcd for $C_{15}H_{17}F_3NO_6$ ([M+H]$^+$): 364.1002; found: 364.0999.

diethyl (*E*)-2-((2-hydroxy-5-(2-methoxy-2-oxoethyl)benzylidene)amino)malonate (1e)



1e was synthesized from the condensation of corresponding substituted salicylaldehyde (500 mg, 2.6 mmol) and diethyl aminomalonate (586 mg, 3.3 mmol) and obtained as yellow solid (723 mg, 80% yield, m.p. 29-31 °C).

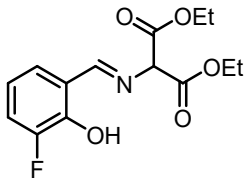
^{1}H NMR (400 MHz, $CDCl_3$) δ 12.63 (s, 1H), 8.45 (s, 1H), 7.33 – 7.18 (m, 2H), 6.95 (d, J = 8.4 Hz, 1H), 4.85 (s, 1H), 4.32 – 4.26 (m, 4H), 3.69 (s, 3H), 3.57 (s, 2H), 1.31 (t, J = 7.1 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.07, 169.57, 166.12, 160.22, 134.41, 132.78, 124.33, 118.41, 117.61, 72.76, 62.42, 52.09, 40.02, 14.01.

IR (KBr, cm^{-1}): 2986, 1739, 1636, 1590, 1493, 1275, 1216, 1160, 1027, 751.

HRMS (ESI): m/z calcd for $C_{17}H_{22}NO_7$ ([M+H]$^+$): 352.1391; found: 352.1386.

diethyl (*E*)-2-((3-fluoro-2-hydroxybenzylidene)amino)malonate (1k)



1k was synthesized from the condensation of corresponding substituted salicylaldehyde (358 mg, 2.6 mmol) and diethyl aminomalonate (895 mg, 5.1 mmol) and obtained as yellow oil (380 mg, 80% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.51 (s, 1H), 7.23 – 7.15 (m, 1H), 7.12 (d, J = 7.8 Hz, 1H), 6.86 – 6.81 (m, 1H), 4.89 (s, 1H), 4.30 (q, J = 7.1 Hz, 4H), 1.32 (t, J = 7.1 Hz, 7H).

^{13}C NMR (101 MHz, $CDCl_3$) δ169.44, 169.41, 165.92, 151.35 (C-F, $^1J_{C\text{-}F}$ = 245.6 Hz), 149.59 (C-F, $^2J_{C\text{-}F}$ = 12.7 Hz), 127.21 (2C, C-F, $^4J_{C\text{-}F}$ = 3.4 Hz), 120.33 (C-F, $^3J_{C\text{-}F}$ = 4.1 Hz), 119.53 (C-F, $^2J_{C\text{-}F}$ = 17.7

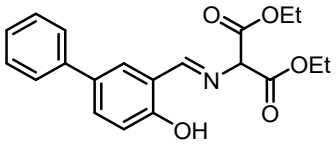
Hz), 118.30 (C-F, $^{3}J_{C\text{-}F}$ = 6.7 Hz), 72.48, 62.56, 14.01.

IR (KBr, cm^{-1}): 2986, 1740, 1634, 1467, 1400, 1370, 1274, 1253, 1220, 1100, 1022, 852, 751.

^{19}F NMR (377 MHz, CDCl$_3$) δ -137.26 – -137.38 (m)

HRMS (ESI): m/z calcd for $C_{14}H_{18}FNO_5$ ([M+H]$^+$): 298.1085; found:298.1082.

diethyl (*E*)-2-(((4-hydroxy-[1,1'-biphenyl]-3-yl)methylene)amino)malonate (1o)



1o was synthesized from the condensation of corresponding substituted salicylaldehyde (400 mg, 2.0 mmol) and diethyl aminomalonate (460 mg, 2.6 mmol) and obtained as yellow solid (710 mg, 99% yield, m.p. 34-36 °C).

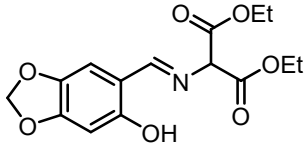
^{1}H NMR (400 MHz, CDCl$_3$) δ 12.73 (s, 1H), 8.54 (s, 1H), 7.60 (dd, *J* = 8.6, 2.3 Hz, 1H), 7.56 – 7.50 (m, 3H), 7.44 – 7.40 (m, 2H), 7.34 – 7.30 (m, 1H), 7.07 (d, *J* = 8.6 Hz, 1H), 4.88 (s, 1H), 4.35 – 4.24 (m, 4H), 1.32 (t, *J* = 7.1 Hz, 6H).

^{13}C NMR (101 MHz, CDCl$_3$) δ 169.84, 166.14, 160.57, 140.04, 132.21, 130.65, 128.85, 126.93, 126.55, 118.63, 117.82, 72.75, 62.45, 14.03.).

IR (KBr, cm^{-1}): 2985, 1739, 1633, 1480, 1370, 1272, 1219, 1179, 1099, 1027, 751, 699.

HRMS (ESI): m/z calcd for $C_{20}H_{22}NO_5$ ([M+H]$^+$): 356.1492; found: 356.1489.

diethyl (*E*)-2-(((6-hydroxybenzo[d][1,3]dioxol-5-yl)methylene)amino)malonate (1p)



1p was synthesized from the condensation of corresponding substituted salicylaldehyde (440 mg, 2.6 mmol) and diethyl aminomalonate (603 mg, 3.4 mmol) and obtained as yellow solid (650 mg, 76% yield, m.p. 57-59 °C).

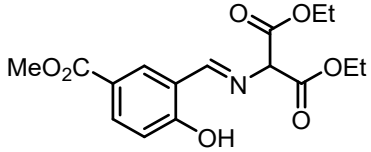
^{1}H NMR (400 MHz, CDCl$_3$) δ 13.33 (s, 1H), 8.27 (s, 1H), 6.65 (s, 1H), 6.48 (s, 1H), 5.94 (s, 2H), 4.80 (s, 1H), 4.36 – 4.21 (m, 4H), 1.31 (t, *J* = 7.1 Hz, 6H).

^{13}C NMR (101 MHz, CDCl$_3$) δ 168.06, 166.34, 160.70, 152.36, 140.42, 110.68, 108.93, 101.57, 98.75, 71.98, 62.36, 14.01.

IR (KBr, cm^{-1}): 2986, 1739, 1638, 1602, 1489, 1364, 1261, 1222, 1165, 1086, 1035, 936, 858, 751.

HRMS (ESI): m/z calcd for $C_{15}H_{18}NO_7$ ([M+H]$^+$): 324.1078; found:. 324.1073

diethyl (*E*)-2-((2-hydroxy-5-(methoxycarbonyl)benzylidene)amino)malonate (1s)



1s was synthesized from the condensation of corresponding substituted salicylaldehyde (300 mg, 1.7 mmol) and diethyl aminomalonate (705 mg, 3.3 mmol) and obtained as yellow solid (560 mg, 100% yield, m.p. 52-54 °C).

^{1}H NMR (400 MHz, CDCl$_3$) δ 13.33 (s, 1H), 8.54 (s, 1H), 8.08 (d, *J* = 1.9 Hz, 1H), 8.04 (dd, *J* = 8.7, 1.5 Hz, 1H), 7.02 (d, *J* = 8.7 Hz, 1H), 4.90 (s, 1H), 4.37 – 4.24 (m, 4H), 3.90 (s, 3H), 1.32 (t, *J* = 7.1 Hz,

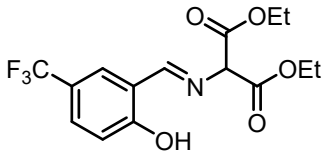
6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.29, 166.20, 165.87, 165.04, 134.67, 134.62, 121.06, 118.01, 117.60, 72.40, 62.57, 52.04, 14.02.

IR (KBr, cm^{-1}): 2987, 1741, 1718, 1634, 1457, 1369, 1275, 1230, 1102, 1029, 751.

HRMS (ESI): m/z calcd for $C_{16}H_{20}NO_7$ ($[M+H]^+$): 338.1234; found: 338.1230.

diethyl (*E*)-2-((2-hydroxy-5-(trifluoromethyl)benzylidene)amino)malonate (1t)



1t was synthesized from the condensation of corresponding substituted salicylaldehyde (340 mg, 1.8 mmol) and diethyl aminomalonate (407 mg, 2.3 mmol) and obtained as yellow oil (441 mg, 71% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 13.22 (s, 1H), 8.55 (s, 1H), 7.62– 7.59 (m, 2H), 7.08 (d, J = 8.4 Hz, 1H), 4.93 (s, 1H), 4.35 – 4.29 (m, 4H), 1.34 (t, J = 7.1 Hz, 6H).

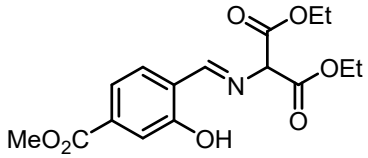
^{13}C NMR (101 MHz, $CDCl_3$) δ 168.94, 165.84, 163.67, 130.05 (C-F, ^{3}J = 3.2 Hz), 129.62 (C-F, ^{3}J = 4.0 Hz), 124.05 (C-F, ^{1}J = 270.9 Hz), 122.12 – 120.42 (m), 118.12, 115.44, 72.28, 62.64, 13.99.

^{19}F NMR (377 MHz, $CDCl_3$) δ -61.70 (s).

IR (KBr, cm^{-1}): 2987, 1742, 1639, 1593, 1502, 1453, 1370, 1323, 1287, 1189, 1117, 1071, 834, 750.

HRMS (ESI): m/z calcd for $C_{15}H_{17}F_3NO_5$ ([M+H]+): 348.1053; found: 348.1049.

diethyl (E)-2-((2-hydroxy-4-(methoxycarbonyl)benzylidene)amino)malonate (1u)



1u was synthesized from the condensation of corresponding substituted salicylaldehyde (140 mg, 0.8 mmol) and diethyl aminomalonate (177 mg, 1.0 mmol) and obtained as yellow solid (170 mg, 65% yield, m.p. 70-72 °C).

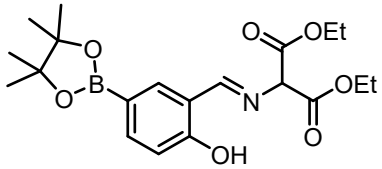
^{1}H NMR (400 MHz, $CDCl_3$) δ 12.71 (s, 1H), 8.54 (s, 1H), 7.65 (s, 1H), 7.57 (d, J = 8.0 Hz, 1H), 7.40 (d, J = 7.9 Hz, 1H), 4.90 (s, 1H), 4.31 (q, J = 7.1 Hz, 4H), 3.93 (d, J = 0.6 Hz, 3H), 1.32 (t, J = 7.1 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.30, 166.34, 165.90, 160.83, 134.20, 132.25, 121.61, 119.64, 118.72, 72.68, 62.61, 52.45, 14.04.

IR (KBr, cm^{-1}): 2987, 1736, 1623, 1562, 1508, 1457, 1382, 1275, 1261, 1092, 1028, 751.

HRMS (ESI): m/z calcd for $C_{16}H_{20}NO_7$ ($[M+H]^+$): 338.1234; found: 338.1230.

diethyl (*E*)-2-((2-hydroxy-5-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)benzylidene) amino)malonate (1v)



1v was synthesized from the condensation of corresponding substituted salicylaldehyde (400 mg, 1.6 mmol) and diethyl aminomalonate (367 mg, 2.1 mmol) and obtained as yellow oil (579 mg, 89% yield).

^{1}H NMR (400 MHz, $CDCl_3$) δ 13.00 (s, 1H), 8.50 (s, 1H), 7.86 – 7.74 (m, 2H), 6.98 (dd, J = 8.0, 1.5

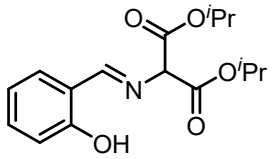
Hz, 1H), 4.85 (s, 1H), 4.29 (q, *J* = 6.8 Hz, 4H), 1.37 – 1.28 (m, 18H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 169.87, 166.11, 163.74, 139.90, 139.84, 118.26, 116.90, 83.78, 72.66, 62.39, 24.87, 14.02.

IR (KBr, cm^{-1}): 2981, 1742, 1632, 1589, 1442, 1365, 1325, 1277, 1148, 1089, 1030, 966, 857, 751.

HRMS (ESI): m/z calcd for $C_{20}H_{29}BNO_7$ ($[M+H]^+$): 406.2032; found: 406.2034.

diisopropyl (*E*)-2-((2-hydroxybenzylidene)amino)malonate (1y)



1y was synthesized from the condensation of corresponding substituted salicylaldehyde (300 mg, 2.5 mmol) and diisopropyl aminomalonate (700 mg, 3.4 mmol) and obtained as yellow solid (501 mg, 66% yield, m.p. 32-34 °C).

^{1}H NMR (400 MHz, $CDCl_3$) δ 12.76 (s, 1H), 8.48 (s, 1H), 7.39 – 7.29 (m, 2H), 6.99 (d, *J* = 8.3 Hz, 1H), 6.90 (t, *J* = 7.5 Hz, 1H), 5.16 – 5.10 (m, 2H), 4.79 (s, 1H), 1.29 (d, *J* = 6.3 Hz, 12H).

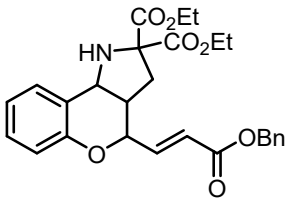
^{13}C NMR (101 MHz, $CDCl_3$) δ 169.62, 165.73, 161.10, 133.31, 132.24, 118.82, 118.60, 117.30, 72.95, 70.17, 21.56, 21.53.

IR (KBr, cm^{-1}): 2985, 1737, 1631, 1458, 1276, 1103, 903, 826, 752.

HRMS (ESI): m/z calcd for $C_{16}H_{22}NO_5$ ($[M+H]^+$): 308.1492; found: 308.1489

9. Characterization Data of New Products 3

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-1,3a,4,9b-tetrahydrochromeno[4,3-*b*]pyrrole -2,2(3*H*)-dicarboxylate (3aa)



White solid (39.5 mg, 82% yield, m.p. 138-140 °C)

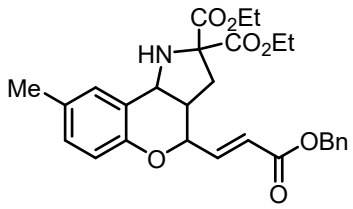
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.33 (m, 4H), 7.27 (d, *J* = 10.6 Hz, 2H), 7.19 (t, *J* = 7.2 Hz, 1H), 7.11 (dd, *J* = 15.7, 5.9 Hz, 1H), 6.94 (dd, *J* = 17.2, 7.9 Hz, 2H), 6.36 (d, *J* = 15.7 Hz, 1H), 5.22 (s, 2H), 4.46 (dd, *J* = 10.2, 5.9 Hz, 1H), 4.35 – 4.06 (m, 5H), 3.28 (s, 1H), 2.67 – 2.49 (m, 2H), 2.26 (s, 1H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.22 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.11, 170.20, 165.87, 153.37, 144.58, 135.79, 129.88, 129.06, 128.58, 128.37, 128.30, 123.50, 122.21, 121.27, 117.09, 73.85, 70.24, 66.48, 62.19, 62.17, 55.71, 39.93, 34.28, 14.06, 13.94.

IR (KBr, cm^{-1}): 3739, 3340, 2923, 2856, 2357, 1728, 1662, 1584, 1457, 1370, 1266, 1232, 1167, 1131, 1094, 1011, 857, 750, 700.

HRMS (ESI): m/z calcd for $C_{27}H_{30}NO_7$ ($[M+H]^+$): 480.2017; found: 480.2014

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-8-methyl-1,3a,4,9b-tetrahydrochromeno[4,3-*b*] pyrrole-2,2(3*H*)-dicarboxylate (3ba)



White solid (44.0 mg, 89% yield, m.p. 93-94 °C)

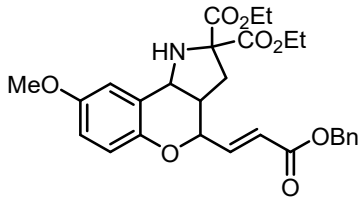
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 – 7.33 (m, 5H), 7.13 (dd, *J* = 14.7, 5.9 Hz, 2H), 7.02 (d, *J* = 8.3 Hz, 1H), 6.84 (d, *J* = 8.2 Hz, 1H), 6.38 (d, *J* = 15.7 Hz, 1H), 5.25 (s, 2H), 4.43 (dd, *J* = 10.6, 5.9 Hz, 1H), 4.35 – 4.10 (m, 5H), 3.29 (s, 1H), 2.60 (d, *J* = 4.8 Hz, 2H), 2.37 – 2.22 (m, 4H), 1.32 (t, *J* = 6.7 Hz, 3H), 1.25 (t, *J* = 6.7 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.11, 170.23, 165.90, 151.17, 144.71, 135.82, 130.60, 130.07, 129.75, 128.58, 128.37, 128.30, 123.44, 121.93, 116.82, 73.93, 70.34, 66.47, 62.18, 62.16, 55.80, 40.13, 34.37, 20.50, 14.08, 13.96.

IR (KBr, cm^{-1}): 3339, 2972, 2927, 2863, 1730, 1663, 1591, 1497, 1455, 1372, 1267, 1230, 1167, 1098, 1012, 856, 818, 753, 700.

HRMS (ESI): m/z calcd for $C_{28}H_{32}NO_7$ ([M+H]+): 494.2173; found: 494.2170

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-8-methoxy-1,3a,4,9b-tetrahydrochromeno [4,3-*b*] pyrrole-2,2(3*H*)-dicarboxylate (3ca)



Yellow solid (43.5 mg, 85% yield, m.p. 100-102 °C)

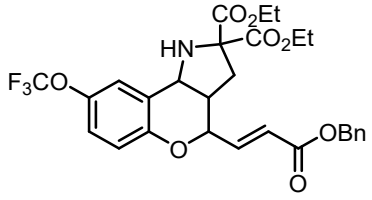
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.31 (m, 5H), 7.09 (dd, *J* = 15.7, 5.9 Hz, 1H), 6.84 (d, *J* = 8.8 Hz, 1H), 6.81 – 6.75 (m, 2H), 6.34 (dd, *J* = 15.7, 1.4 Hz, 1H), 5.26 – 5.18 (m, 2H), 4.40 – 4.36 (m, 1H), 4.33 – 4.08 (m, 5H), 3.76 (s, 3H), 3.29 (s, 1H), 2.58 (t, *J* = 7.6 Hz, 2H), 2.30 – 2.23 (m, 1H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.22 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.10, 170.18, 165.88, 154.03, 147.29, 144.68, 135.80, 128.58, 128.36, 128.30, 123.44, 122.74, 117.91, 115.80, 113.53, 74.05, 70.38, 66.47, 62.23, 62.20, 56.05, 55.80, 40.17, 34.34, 14.07, 13.96.

IR (KBr, cm^{-1}): 3334, 2931, 2846, 1729, 1663, 1495, 1453, 1369, 1269, 1227, 1166, 1097, 1036, 855, 753, 701.

HRMS (ESI): m/z calcd for $C_{28}H_{32}NO_8$ ([M+H]+): 510.2122; found: 510.2123

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-8-(trifluoromethoxy)-1,3a,4,9b-tetrahydro-chromeno[4,3-*b*]pyrrole-2,2(3*H*)-dicarboxylate (3da)



White solid (36.0 mg, 59% yield, m.p. 104-106 °C)

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.44 – 7.31 (m, 5H), 7.15 (s, 1H), 7.12 – 7.03 (m, 2H), 6.91 (d, *J* = 8.9 Hz, 1H), 6.35 (d, *J* = 15.7 Hz, 1H), 5.22 (s, 2H), 4.47 (dd, *J* = 10.3, 5.9 Hz, 1H), 4.35 – 4.07 (m, 5H), 3.29 (brs, 1H), 2.63 (dd, *J* = 14.7, 2.1 Hz, 1H), 2.54 (dd, *J* = 14.7, 7.9 Hz, 1H), 2.32 – 2.19 (m, 1H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.23 (t, *J* = 7.1 Hz, 3H).

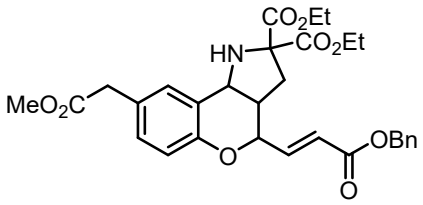
^{13}C NMR (101 MHz, $CDCl_3$) δ 172.00, 170.08, 165.78, 152.00, 144.03, 142.90, 135.80, 128.63, 128.42, 128.37, 123.82, 123.40, 122.52, 122.28, 120.56 (C-F, ^1J = 256.3 Hz), 118.25, 74.19, 70.24, 66.58, 62.34, 62.29, 55.58, 39.73, 34.19, 14.08, 13.96.

^{19}F NMR (376 MHz, $CDCl_3$) δ -58.26 (s).

IR (KBr, cm^{-1}): 3339, 2921, 2857, 2360, 1729, 1657, 1551, 1492, 1455, 1370, 1260, 1215, 1163, 1010, 855, 747, 698.

HRMS (ESI): m/z calcd for $C_{31}H_{39}N_2O_7$ ($[M+H]^+$): 551.2752; found: 551.2748

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-8-(2-methoxy-2-oxoethyl)-1,3a,4,9b-tetrahydrochromeno[4,3-*b*]pyrrole-2,2(3*H*)-dicarboxylate (3ea)



Pale yellow oil (40.9 mg, 74% yield)

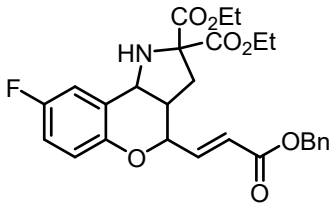
^{1}H NMR (400 MHz, $CDCl_3$) δ7.43 – 7.30 (m, 5H), 7.20 (s, 1H), 7.14 – 7.05 (m, 2H), 6.87 (d, *J* = 8.4 Hz, 1H), 6.36 (d, *J* = 15.7 Hz, 1H), 5.22 (s, 2H), 4.43 (dd, *J* = 10.6, 5.9 Hz, 1H), 4.34 – 4.06 (m, 5H), 3.68 (s, 3H), 3.54 (s, 2H), 3.28 (br, 1H), 2.65 – 2.51 (m, 2H), 2.25 (brs, 1H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.22 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.11, 172.05, 170.19, 165.84, 152.61, 144.46, 135.83, 130.60, 130.01, 128.59, 128.37, 128.31, 126.76, 123.58, 122.30, 117.29, 73.98, 70.29, 66.49, 62.20, 55.72, 52.03, 40.33, 39.96, 34.32, 14.08, 13.96.

IR (KBr, cm^{-1}): 3340, 2949, 2856, 1731, 1662, 1497, 1448, 1369, 1263, 1164, 1011, 855, 739, 700.

HRMS (ESI): m/z calcd for $C_{30}H_{34}NO_9$ ($[M+H]^+$): 552.2228; found: 552.2224.

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-8-fluoro-1,3a,4,9b-tetrahydrochromeno[4,3-*b*]pyrrole-2,2(3*H*)-dicarboxylate (3fa)



Yellow solid (38.0 mg, 76% yield, m.p. 89-90 °C)

^{1}H NMR (400 MHz, $CDCl_3$) δ7.45 – 7.29 (m, 5H), 7.08 (dd, *J* = 15.7, 5.8 Hz, 1H), 6.98 (dd, *J* = 8.4, 2.2 Hz, 1H), 6.93 – 6.82 (m, 2H), 6.34 (d, *J* = 15.7 Hz, 1H), 5.22 (s, 2H), 4.42 (dd, *J* = 10.2, 5.8 Hz, 1H), 4.34 – 4.18 (m, 4H), 4.18 – 4.08 (m, 1H), 3.28 (s, 1H), 2.64 – 2.49 (m, 2H), 2.32 – 2.21 (m, 1H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.22 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.97, 170.11, 165.81, 157.20 (C-F, ^1J = 239.8 Hz), 149.40 (C-F, ^4J = 1.9 Hz), 144.30, 135.80, 128.60, 128.39, 128.34, 123.61, 123.47 (C-F, ^3J = 7.2 Hz), 118.22 (C-F, ^3J =

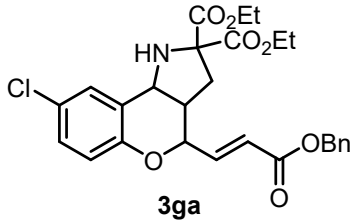
8.0 Hz), 115.97 (C-F, ^2J = 23.3 Hz), 115.64 (C-F, ^2J = 22.8 Hz)., 74.15, 70.29, 66.53, 62.28, 62.24, 55.66, 39.87, 34.21, 14.07, 13.95.

^{19}F NMR (376 MHz, $CDCl_3$) δ -122.52 (dd, J = 12.8, 7.8 Hz).

IR (KBr, cm^{-1}): 3339, 2978, 2932, 2860, 2359, 1729, 1663, 1492, 1451, 1370, 1268, 1224, 1164, 1095, 1011, 858, 814, 752, 700.

HRMS (ESI): m/z calcd for $C_{27}H_{29}FNO_7$ ([M+H]$^+$): 498.1923; found: 498.1921.

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-8-chloro-1,3a,4,9b-tetrahydrochromeno[4,3-*b*] pyrrole-2,2(3*H*)-dicarboxylate (3ga)



3ga

Yellow solid (42.6 mg, 83% yield, m.p. 115-117 °C)

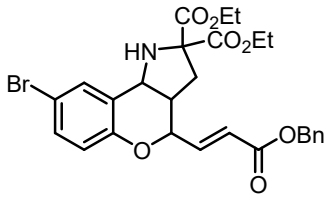
^{1}H NMR (400 MHz, $CDCl_3$) δ7.44 – 7.31 (m, 5H), 7.27 (s, 1H), 7.14 (dd, J = 8.7, 2.4 Hz, 1H), 7.08 (dd, J = 15.7, 5.8 Hz, 1H), 6.85 (d, J = 8.7 Hz, 1H), 6.35 (d, J = 15.7 Hz, 1H), 5.22 (s, 2H), 4.44 (dd, J = 10.4, 5.9 Hz, 1H), 4.35 – 4.08 (m, 6H), 3.29 (s, 1H), 2.61 (dd, J = 14.7, 2.5 Hz, 1H), 2.53 (dd, J = 14.7, 7.8 Hz, 1H), 2.30 – 2.20 (m, 1H), 1.29 (t, J = 7.1 Hz, 3H), 1.22 (t, J = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.95, 170.10, 165.79, 152.01, 144.11, 135.76, 129.49, 129.08, 128.62, 128.41, 128.36, 126.03, 123.88, 123.72, 118.55, 74.10, 70.21, 66.57, 62.32, 62.27, 55.44, 39.75, 34.17, 14.09, 13.97.

IR (KBr, cm^{-1}): 3741, 2983, 2360, 1728, 1664, 1482, 1370, 1267, 1172, 1134, 1096, 1011, 859, 752, 705.

HRMS (ESI): m/z calcd for $C_{27}H_{28}ClNO_7$ ([M+H]$^+$): 514.1627; found: 514.1625.

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-8-bromo-1,3a,4,9b-tetrahydrochromeno[4,3-*b*] pyrrole-2,2(3*H*)-dicarboxylate (3ha)



Pale yellow solid (47.0 mg, 84% yield, m.p. 133-135 °C)

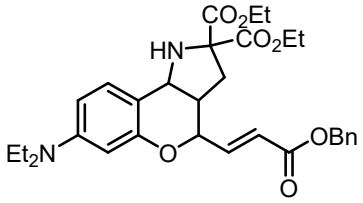
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.33 (m, 6H), 7.30 – 7.26 (m, 1H), 7.07 (dd, J = 15.7, 5.9 Hz, 1H), 6.80 (d, J = 8.7 Hz, 1H), 6.34 (dd, J = 15.7, 1.2 Hz, 1H), 5.22 (s, 2H), 4.44 (dd, J = 9.8, 5.9 Hz, 1H), 4.32 – 4.18 (m, 4H), 4.18 – 4.08 (m, 1H), 3.28 (brs, 1H), 2.61 (dd, J = 14.7, 2.6 Hz, 1H), 2.53 (dd, J = 14.7, 7.8 Hz, 1H), 2.30 – 2.19 (m, 1H), 1.29 (t, J = 7.1 Hz, 3H), 1.22 (t, J = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.95, 170.10, 165.79, 152.55, 144.08, 135.76, 132.46, 131.96, 128.62, 128.42, 128.37, 124.45, 123.75, 119.00, 113.31, 74.08, 70.21, 66.58, 62.33, 62.29, 55.38, 39.74, 34.17, 14.10, 13.98.

IR (KBr, cm^{-1}):3329, 3033, 2923, 2861, 2362, 1728, 1576, 1475, 1371, 1264, 1176, 1133, 1099, 1010, 855, 739, 698.

HRMS (ESI): m/z calcd for $C_{27}H_{29}BrNO_7$ ([M+H]$^+$): 558.1122; found: 558.1121.

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-7-(diethylamino)-1,3a,4,9b-tetrahydro chromeno[4,3-*b*]pyrrole-2,2(3*H*)-dicarboxylate (3ia)



Brown solid (43.9 mg, 80% yield, m.p. 103-105 °C)

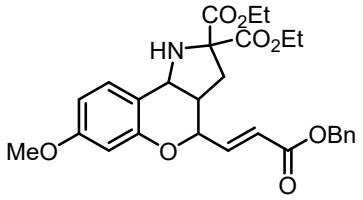
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 – 7.30 (m, 5H), 7.15 – 7.06 (m, 2H), 6.42 – 6.28 (m, 2H), 6.19 (d, *J* = 2.1 Hz, 1H), 5.22 (s, 2H), 4.43 (dd, *J* = 10.7, 6.1 Hz, 1H), 4.30 – 4.09 (m, 5H), 3.30 (q, *J* = 7.0 Hz, 4H), 3.17 (brs, 1H), 2.55 (d, *J* = 4.9 Hz, 2H), 2.20 (td, *J* = 10.2, 5.0 Hz, 1H), 1.28 (t, *J* = 7.1 Hz, 3H), 1.22 (t, *J* = 7.1 Hz, 3H), 1.12 (t, *J* = 7.0 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.30, 170.43, 165.94, 154.48, 148.69, 145.04, 135.90, 130.45, 128.58, 128.38, 128.29, 123.48, 109.08, 105.92, 99.09, 73.94, 70.48, 66.44, 62.06, 55.68, 44.41, 40.44, 34.45, 14.08, 13.99, 12.59.

IR (KBr, cm^{-1}):3338, 2972, 2929, 1729, 1623, 1563, 1516, 1454, 1363, 1267, 1207, 1127, 1015, 749, 701.

HRMS (ESI): m/z calcd for $C_{31}H_{39}N_2O_7$ ($[M+H]^+$): 551.2752; found: 551.2748.

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-7-methoxy-1,3a,4,9b-tetrahydrochromeno [4,3-*b*]pyrrole-2,2(3*H*)-dicarboxylate (3ja)



White solid (40.6 mg, 80% yield, m.p. 82-84°C)

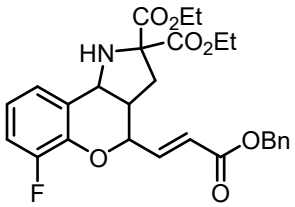
^{1}H NMR (400 MHz, $CDCl_3$) δ7.42 – 7.30 (m, 5H), 7.19 (d, *J* = 8.4 Hz, 1H), 7.12 (dd, *J* = 15.6, 5.8 Hz, 1H), 6.56 (d, *J* = 8.3 Hz, 1H), 6.49 (s, 1H), 6.38 (d, *J* = 15.7 Hz, 1H), 5.25 (s, 2H), 4.49 (dd, *J* = 10.3, 6.0 Hz, 1H), 4.36 – 4.10 (m, 5H), 3.78 (s, 3H), 3.25 (brs, 1H), 2.67 – 2.51 (m, 2H), 2.26 (br, 1H), 1.31 (t, *J* = 7.1 Hz, 3H), 1.25 (t, *J* = 7.0 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.15, 170.30, 165.86, 160.29, 154.36, 144.57, 135.81, 130.53, 128.59, 128.38, 128.32, 123.55, 114.49, 108.56, 101.54, 73.96, 70.31, 66.50, 62.17, 55.45, 55.35, 40.03, 34.27, 14.07, 13.97.

IR (KBr, cm^{-1}): 3335, 2930, 2848, 1729, 1664, 1620, 1585, 1503, 1452, 1369, 1268, 1196, 1163, 1127, 1033, 850, 749, 701.

HRMS (ESI): m/z calcd for $C_{28}H_{32}NO_8$ ($[M+H]^+$): 510.2122; found: 510.2122.

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-6-fluoro-1,3a,4,9b-tetrahydrochromeno[4,3-*b*] pyrrole-2,2(3*H*)-dicarboxylate (3ka)



White solid (37.9 mg, 76% yield, m.p. 84-85°C)

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.46 – 7.33 (m, 5H), 7.13 (dd, *J* = 15.7, 6.0 Hz, 1H), 7.07 (d, *J* = 7.6 Hz, 1H), 7.05 – 6.98 (m, 1H), 6.90 (td, *J* = 7.9, 4.9 Hz, 1H), 6.42 (d, *J* = 15.6 Hz, 1H), 5.25 (s, 2H), 4.54 (dd, *J* = 10.3, 6.0 Hz, 1H), 4.37 – 4.20 (m, 4H), 4.16 (m, 1H), 3.32 (brs, 1H), 2.67 (dd, *J* = 14.7, 2.2 Hz, 1H), 2.57 (dd, *J* = 14.7, 7.9 Hz, 1H), 2.37 – 2.28 (m, 1H), 1.32 (t, *J* = 7.1 Hz, 3H), 1.25 (t, *J* = 7.1 Hz, 3H).

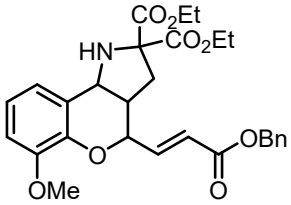
^{13}C NMR (101 MHz, $CDCl_3$) δ 172.06, 170.09, 165.78, 151.47 (C-F, ^1J = 246.8 Hz), 143.80, 141.79 (C-F, ^2J = 11.3 Hz), 135.76, 128.60, 128.42, 128.34, 124.84, 124.72 (C-F, ^3J = 3.6 Hz), 124.03, 120.85 (C-F, ^3J = 7.0 Hz), 115.45 (C-F, ^2J = 17.8 Hz), 74.26, 70.14, 66.56, 62.29, 62.26, 55.28, 39.74, 34.17, 14.07, 13.96.

^{19}F NMR (376 MHz, $CDCl_3$) δ -135.11 (dd, *J* = 10.7, 4.7 Hz).

IR (KBr, cm^{-1}): 3335, 2976, 2929, 2860, 2358, 1729, 1663, 1590, 1483, 1372, 1267, 1227, 1170, 1132, 1096, 1026, 990, 858, 753.

HRMS (ESI): m/z calcd for $C_{27}H_{29}FNO_7$ ($[M+H]^+$): 498.1923; found: 498.1922.

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-6-methoxy-1,3a,4,9b-tetrahydrochromeno [4,3-*b*]pyrrole-2,2(3*H*)-dicarboxylate (3la)



Yellow oil (37.0 mg, 73% yield)

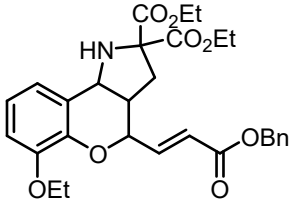
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.42 – 7.30 (m, 5H), 7.11 (dd, *J* = 15.7, 6.4 Hz, 1H), 6.93 – 6.86 (m, 2H), 6.83 – 6.76 (m, 1H), 6.36 (dd, *J* = 15.7, 1.2 Hz, 1H), 5.21 (s, 2H), 4.50 (dd, *J* = 9.5, 6.5 Hz, 1H), 4.32 – 4.06 (m, 5H), 3.84 (s, 3H), 3.30 (brs, 1H), 2.64 – 2.49 (m, 2H), 2.31 (tdd, *J* = 10.4, 6.4, 3.7 Hz, 1H), 1.28 (t, *J* = 7.1 Hz, 3H), 1.21 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.10, 170.21, 165.77, 148.53, 144.36, 142.83, 135.80, 128.57, 128.37, 128.29, 124.09, 123.20, 121.40, 121.00, 110.93, 74.42, 70.24, 66.46, 62.16, 62.14, 56.03, 55.46, 39.74, 34.28, 14.06, 13.94.

IR (KBr, cm^{-1}): 2926, 2849, 1727, 1584, 1479, 1456, 1371, 1266, 1225, 1169, 1090, 1022, 984, 858, 754.

HRMS (ESI): m/z calcd for $C_{28}H_{32}NO_8$ ($[M+H]^+$): 510.2122; found: 510.2123.

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-6-ethoxy-1,3a,4,9b-tetrahydrochromeno[4,3-*b*] pyrrole-2,2(3*H*)-dicarboxylate (3ma)



Yellow oil (34.0 mg, 65% yield)

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.30 (m, 5H), 7.13 (dd, *J* = 15.7, 6.1 Hz, 1H), 6.91 – 6.84 (m, 2H), 6.79 (dd, *J* = 6.6, 3.0 Hz, 1H), 6.35 (dd, *J* = 15.7, 1.2 Hz, 1H), 5.27 – 5.15 (m, 2H), 4.49 (dd, *J* = 9.7, 6.6 Hz, 1H), 4.32 – 4.22 (m, 3H), 4.22 – 4.02 (m, 4H), 3.28 (s, 1H), 2.65 – 2.49 (m, 2H), 2.35 –

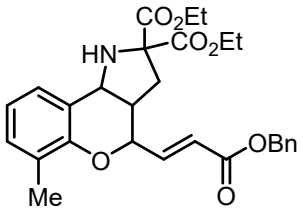
2.26 (m, 1H), 1.42 (t, *J* = 7.0 Hz, 3H), 1.28 (t, *J* = 7.1 Hz, 3H), 1.21 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.11, 170.24, 165.90, 147.80, 144.63, 143.30, 135.86, 128.58, 128.36, 128.29, 123.71, 123.35, 121.52, 120.97, 112.89, 74.29, 70.27, 66.45, 64.70, 62.17, 62.15, 55.57, 39.80, 34.32, 14.84, 14.07, 13.96.

IR (KBr, cm^{-1}): 3338, 2976, 2927, 1729, 1662, 1586, 1477, 1373, 1265, 1224, 1169, 1088, 1028, 992, 858, 789, 738, 700.

HRMS (ESI): m/z calcd for $C_{29}H_{34}NO_8$ ($[M+H]^+$): 524.2179; found: 524.2280.

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-6-methyl-1,3a,4,9b-tetrahydrochromeno[4,3-*b*] pyrrole-2,2(3*H*)-dicarboxylate (3na)



White solid (36.9 mg, 80% yield, m.p. 83-85°C)

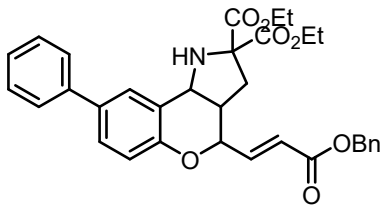
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.44 – 7.31 (m, 5H), 7.17 (dd, *J* = 15.6, 5.4 Hz, 1H), 7.12 (d, *J* = 7.3 Hz, 1H), 7.05 (d, *J* = 7.2 Hz, 1H), 6.85 (t, *J* = 7.5 Hz, 1H), 6.37 (dd, *J* = 15.6, 1.4 Hz, 1H), 5.29 – 5.16 (m, 2H), 4.51 – 4.42 (m, 1H), 4.31 – 4.07 (m, 5H), 3.27 (s, 1H), 2.64 (dd, *J* = 14.7, 2.3 Hz, 1H), 2.56 (dd, *J* = 14.7, 7.7 Hz, 1H), 2.28 – 2.16 (m, 4H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.22 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.16, 170.24, 166.05, 151.48, 145.07, 135.83, 130.11, 128.59, 128.44, 128.32, 127.32, 126.42, 122.83, 121.58, 120.68, 73.65, 70.22, 66.49, 62.16, 56.04, 39.97, 34.32, 16.05, 14.07, 13.95.

IR (KBr, cm^{-1}): 3337, 2957, 2924, 2851, 1731, 1661, 1596, 1471, 1368, 1266, 1218, 1167, 1131, 1018, 982, 857, 750, 698.

HRMS (ESI): m/z calcd for $C_{28}H_{32}NO_7$ ($[M+H]^+$): 494.2173; found: 494.2171.

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-8-phenyl-1,3a,4,9b-tetrahydrochromeno[4,3-*b*] pyrrole-2,2(3*H*)-dicarboxylate (3oa)



Yellow oil (42.9 mg, 77% yield)

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.59 – 7.49 (m, 3H), 7.45 – 7.30 (m, 9H), 7.13 (dd, *J* = 15.6, 5.7 Hz, 1H), 6.99 (d, *J* = 8.4 Hz, 1H), 6.39 (d, *J* = 15.6 Hz, 1H), 5.23 (s, 2H), 4.50 (dd, *J* = 10.1, 6.0 Hz, 1H), 4.36 – 4.09 (m, 5H), 3.35 (brs, 1H), 2.64 (d, *J* = 14.3 Hz, 1H), 2.57 (dd, *J* = 14.6, 7.8 Hz, 1H), 2.29 (s, 1H), 1.29 (t, *J* = 7.0 Hz, 3H), 1.22 (t, *J* = 7.0 Hz, 3H).

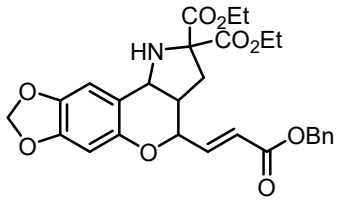
^{13}C NMR (101 MHz, $CDCl_3$) δ 172.13, 170.20, 165.86, 153.00, 144.48, 140.55, 135.84, 134.56, 128.73, 128.60, 128.50, 128.39, 128.33, 127.87, 126.86, 126.81, 123.64, 122.51, 117.50, 74.09, 70.33, 66.52, 62.23, 55.91, 40.07, 34.33, 14.09, 13.96.

IR (KBr, cm^{-1}): 3337, 2971, 2927, 2860, 1729, 1664, 1602, 1482, 1452, 1371, 1264, 1173, 1134, 1098,

1011, 854, 755, 699.

HRMS (ESI): m/z calcd for $C_{33}H_{34}NO_7$ ($[M+H]^+$): 556.2330; found: 556.2330.

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-1,3a,4,10b-tetrahydro-[1,3]dioxolo[4',5':6,7] chromeno[4,3-*b*]pyrrole-2,2(3*H*)-dicarboxylate (3pa)



Pale yellow solid (39.5 mg, 75% yield, m.p. 138-141°C)

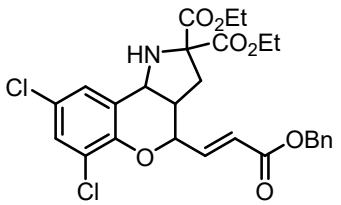
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.44 – 7.31 (m, 5H), 7.07 (dd, *J* = 15.7, 5.7 Hz, 1H), 6.70 (s, 1H), 6.43 (s, 1H), 6.32 (d, *J* = 15.7 Hz, 1H), 5.88 (d, *J* = 10.5 Hz, 2H), 5.21 (s, 2H), 4.36 (dd, *J* = 10.4, 5.9 Hz, 1H), 4.32 – 4.08 (m, 5H), 3.22 (brs, 1H),2.59 – 2.55 (m, 2H), 2.23 – 2.19 (m, 1H), 1.28 (t, *J* = 7.0 Hz, 3H), 1.22 (t, *J* = 7.0 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.06, 170.29, 165.86, 148.40, 147.90, 144.53, 142.26, 135.84, 128.60, 128.38, 128.33, 123.49, 114.12, 108.10, 101.15, 98.82, 74.15, 70.33, 66.50, 62.20, 56.01, 40.05, 34.30, 14.08, 13.98.

IR (KBr, cm^{-1}): 2920, 2860, 2359, 1726, 1477, 1450, 1365, 1266, 1158, 1031, 936, 854, 743, 701.

HRMS (ESI): m/z calcd for $C_{28}H_{30}NO_9$ ($[M+H]^+$): 524.1915; found: 524.1912.

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-6,8-dichloro-1,3a,4,9b-tetrahydrochromeno [4,3-*b*]pyrrole-2,2(3*H*)-dicarboxylate (3qa)



Pale yellow solid (45.0 mg, 82% yield, m.p. 78-80°C)

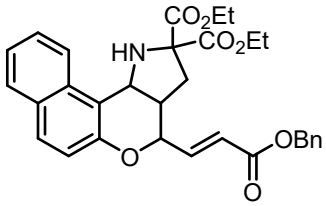
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 – 7.34 (m, 5H), 7.30 (d, *J* = 2.3 Hz, 1H), 7.21 (d, *J* = 2.3 Hz, 1H), 7.13 (dd, *J* = 15.6, 5.4 Hz, 1H), 6.43 (d, *J* = 15.7 Hz, 1H), 5.31 – 5.20 (m, 2H), 4.57 (dd, *J* = 10.4, 5.4 Hz, 1H), 4.33 – 4.12 (m, 5H), 3.32 (brs, 1H), 2.68 (dd, *J* = 14.7, 2.3 Hz, 1H), 2.56 (dd, *J* = 14.7, 7.9 Hz, 1H), 2.36 – 2.25 (m, 1H), 1.31 (t, *J* = 7.1 Hz, 3H), 1.25 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.85, 169.96, 165.77, 148.12, 143.38, 135.78, 129.29, 128.62, 128.46, 128.37, 128.01, 125.80, 125.10, 123.86, 122.94, 77.38, 74.66, 70.16, 66.61, 62.37, 62.32, 55.54, 39.77, 34.08, 14.08, 13.96.

IR (KBr, cm^{-1}):3339, 2924, 2857, 1728, 1661, 1577, 1459, 1370, 1271, 1238, 1195, 1094, 1013, 857, 699.

HRMS (ESI): m/z calcd for $C_{27}H_{28}Cl_2NO_7$ ($[M+H]^+$): 548.1237; found: 548.1237.

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-1,3a,4,11c-tetrahydrobenzo[5,6]chromeno [4,3-*b*]pyrrole-2,2(3*H*)-dicarboxylate (3ra)



White solid (51 mg, 96% yield, m.p. 92-93°C)

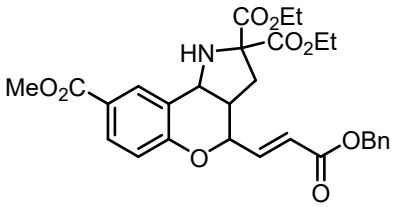
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.07 (d, *J* = 8.4 Hz, 1H), 7.76 (d, *J* = 8.0 Hz, 1H), 7.69 (d, *J* = 8.9 Hz, 1H), 7.56 (t, *J* = 7.3 Hz, 1H), 7.45 – 7.31 (m, 6H), 7.18 (dd, *J* = 15.7, 6.0 Hz, 1H), 7.11 (d, *J* = 8.9 Hz, 1H), 6.43 (dd, *J* = 15.7, 1.0 Hz, 1H), 5.29 – 5.19 (m, 2H), 4.69 (d, *J* = 4.5 Hz, 1H), 4.62 (dd, *J* = 10.6, 6.1 Hz, 1H), 4.43 – 4.27 (m, 2H), 4.22 (dq, *J* = 10.8, 7.1 Hz, 1H), 4.11 (dq, *J* = 10.8, 7.1 Hz, 1H), 3.66 (brs, 1H), 2.75 (d, *J* = 14.7 Hz, 1H), 2.61 (dd, *J* = 14.8, 8.0 Hz, 1H), 2.35 – 2.23 (m, 1H), 1.34 (t, *J* = 7.1 Hz, 3H), 1.21 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.61, 170.11, 165.91, 151.36, 144.51, 135.84, 133.12, 129.69, 129.29, 128.61, 128.40, 128.33, 127.32, 123.80, 123.76, 122.13, 118.57, 114.12, 73.92, 70.23, 66.53, 62.28, 62.23, 53.53, 39.35, 33.81, 14.15, 13.97.

IR (KBr, cm^{-1}): 2974, 2930, 2861, 1728, 1613, 1596, 1509, 1456, 1379, 1270, 1231, 1170, 1130, 1095, 984, 855, 819, 751, 700.

HRMS (ESI): m/z calcd for $C_{31}H_{32}NO_7$ ($[M+H]^+$): 530.2173; found: 530.2172.

2,2-diethyl 8-methyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-1,3a,4,9b-tetrahydrochromeno [4,3-*b*]pyrrole-2,2,8(3*H*)-tricarboxylate (3sa)



White solid (37.3 mg, 69% yield, m.p. 148-150°C)

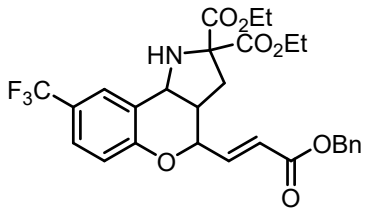
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (s, 1H), 7.94 – 7.83 (m, 1H), 7.40 – 7.83 (m, 5H), 7.13 – 7.06 (m, 1H), 6.95 – 6.92 (m, 1H), 6.38 (d, *J* = 15.7 Hz, 1H), 5.23 (s, 2H), 4.55 (dd, *J* = 10.5, 5.6 Hz, 1H), 4.43 – 4.11 (m, 5H), 3.88 (s, 3H), 3.34 (brs, 1H), 2.66 (d, *J* = 14.8 Hz, 1H), 2.55 – 2.50 (m, 1H), 2.31 – 2.19 (m, 1H), 1.33 – 1.26 (m, 3H), 1.24 – 1.18 (m, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.01, 170.07, 166.58, 165.74, 157.43, 143.87, 135.77, 132.14, 130.73, 128.61, 128.40, 128.35, 123.88, 123.12, 122.10, 117.16, 74.30, 70.10, 66.57, 62.28, 62.22, 55.44, 51.95, 39.53, 34.11, 14.09, 13.94.

IR (KBr, cm^{-1}): 3338, 2925, 2856, 1724, 1664, 1616, 1588, 1493, 1443, 1372, 1257, 1189, 1128, 1029, 991, 854, 730, 701.

HRMS (ESI): m/z calcd for $C_{29}H_{32}NO_9$ ($[M+H]^+$): 538.2072; found: 538.2070.

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-8-(trifluoromethyl)-1,3a,4,9b-tetrahydro-chromeno [4,3-*b*]pyrrole-2,2(3*H*)-dicarboxylate (3ta)



Yellow solid (29.5 mg, 54% yield, m.p. 123-125°C)

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56 (s, 1H), 7.45 – 7.36 (m, 6H), 7.09 (dd, *J* = 15.6, 5.7 Hz, 1H), 6.99 (d, *J* = 8.5 Hz, 1H), 6.37 (d, *J* = 15.7 Hz, 1H), 5.23 (s, 2H), 4.53 (dd, *J* = 10.0, 5.8 Hz, 1H), 4.37 – 4.06 (m, 5H), 3.34 (brs, 1H), 2.66 (d, *J* = 14.7 Hz, 1H), 2.54 (dd, *J* = 14.6, 8.0 Hz, 1H), 2.27 (br, 1H), 1.30 (t, *J* = 7.0 Hz, 3H), 1.22 (t, *J* = 7.0 Hz, 3H).

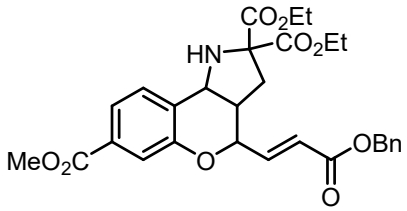
^{13}C NMR (101 MHz, $CDCl_3$) δ 171.96, 170.07, 165.72, 156.10, 143.77, 135.77, 128.63, 128.43, 128.38, 127.45 (C-F, ^3J = 3.7 Hz), 126.27– 126.16 (m), 124.21 (C-F, ^1J = 271.3 Hz), 123.95, 123.49 (C-F, ^2J = 32.9 Hz), 122.57, 117.62, 77.38, 77.06, 76.74, 74.23, 70.17, 66.61, 62.37, 62.30, 55.40, 39.68, 34.18, 14.08, 13.95.

19F NMR (376 MHz, CDCl3) δ -61.59.

IR (KBr, cm^{-1}): 3338, 2925, 2858, 1730, 1663, 1625, 1593, 1502, 1455, 1373, 1328, 1265, 1167, 1119, 1027, 907, 845, 739, 696, 623.

HRMS (ESI): m/z calcd for $C_{28}H_{29}F_3NO_7$ ([M+H]$^+$): 548.1891; found: 548.1887.

2,2-diethyl 7-methyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-1,3a,4,9b-tetrahydrochromeno [4,3-*b*]pyrrole-2,2,7(3*H*)-tricarboxylate (3ua)



Pale yellow solid (43 mg, 80% yield, m.p. 89-92°C)

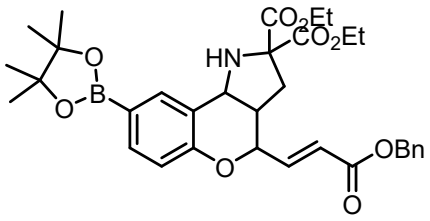
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 – 7.57 (m, 2H), 7.43 – 7.31 (m, 6H), 7.10 (dd, *J* = 15.7, 5.7 Hz, 1H), 6.36 (dd, *J* = 15.7, 1.2 Hz, 1H), 5.23 (s, 2H), 4.49 (dd, *J* = 10.3, 5.7 Hz, 1H), 4.35 – 4.08 (m, 5H), 3.89 (s, 3H), 3.32 (brs, 1H), 2.63 (dd, *J* = 14.7, 2.7 Hz, 1H), 2.55 (dd, *J* = 14.7, 7.7 Hz, 1H), 2.37 – 2.23 (m, 1H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.22 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.98, 170.08, 166.52, 165.80, 153.33, 144.11, 135.79, 130.96, 129.94, 128.60, 128.38, 128.33, 127.17, 123.65, 122.19, 118.52, 74.10, 70.24, 66.54, 62.30, 62.25, 55.51, 52.19, 39.82, 34.21, 14.08, 13.95.

IR (KBr, cm^{-1}): 3331, 2951, 2924, 2856, 1727, 1579, 1441, 1372, 1277, 1223, 1174, 1099, 1011, 905, 856, 750, 703.

HRMS (ESI): m/z calcd for $C_{29}H_{32}NO_9$ ([M+H]$^+$): 538.2072; found: 538.2070.

diethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-8-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl) -1,3a,4,9b-tetrahydrochromeno[4,3-*b*]pyrrole-2,2(3*H*)-dicarboxylate (3va)



Yellow solid (18 mg, 30% yield, m.p. 114-116°C)

When added PhCOONa (1.0 equiv) and PhCOOH (1.0 equiv) to reaction mixture as buffer, it was up to 25 mg (41% yield).

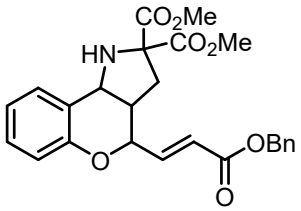
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.77 (s, 1H), 7.64 (d, *J* = 8.1 Hz, 1H), 7.44 – 7.32 (m, 5H), 7.11 (dd, *J* = 15.7, 5.8 Hz, 1H), 6.91 (d, *J* = 8.1 Hz, 1H), 6.38 (d, *J* = 15.7 Hz, 1H), 5.23 (s, 2H), 4.50 (dd, *J* = 10.4, 5.9 Hz, 1H), 4.35 – 4.04 (m, 5H), 3.32 (brs, 1H), 2.64 (d, *J* = 14.6 Hz, 1H), 2.52 (dd, *J* = 14.6, 7.9 Hz, 1H), 2.24 (s, 1H), 1.33 (d, *J* = 10.5 Hz, 12H), 1.24 (dd, *J* = 23.6, 6.8 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.13, 170.20, 165.90, 156.23, 144.46, 137.05, 135.78, 128.61, 128.38, 128.32, 123.63, 121.77, 116.61, 83.72, 74.08, 70.22, 66.51, 62.17, 62.11, 55.57, 39.85, 34.25, 24.88, 14.12, 13.98.

IR (KBr, cm^{-1}): 3345, 2966, 2923, 2856, 1729, 1660, 1612, 1580, 1456, 1359, 1255, 1236, 1138, 1095, 1010, 856, 790, 697.

HRMS (ESI): m/z calcd for $C_{33}H_{41}BNO_9$ ([M+H]$^+$): 606.2869; found: 606.2873.

dimethyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-1,3a,4,9b-tetrahydrochromeno[4,3-*b*] pyrrole-2,2(3*H*)-dicarboxylate (3xa)



White solid (36.0 mg, 80% yield, m.p. 131-134°C)

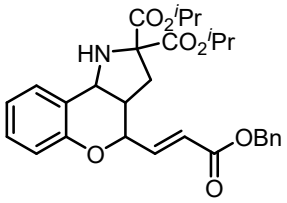
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 – 7.32 (m, 5H), 7.28 (dd, *J* = 7.6, 1.5 Hz, 2H), 7.23 – 7.16 (m, 1H), 7.10 (dd, *J* = 15.7, 5.9 Hz, 1H), 6.97 – 6.91 (m, 2H), 6.35 (dd, *J* = 15.7, 1.4 Hz, 1H), 5.23 (s, 2H), 4.49 – 4.40 (m, 1H), 4.26 (d, *J* = 5.5 Hz, 1H), 3.82 (s, 3H), 3.72 (s, 3H), 3.29 (brs, 1H), 2.63 – 2.55 (m, 2H), 3.21– 3.24 (m, 1H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.53, 170.64, 165.90, 153.38, 144.50, 135.82, 129.86, 129.15, 128.62, 128.41, 128.35, 123.58, 122.12, 121.37, 117.16, 73.87, 70.22, 66.53, 55.71, 53.31, 53.26, 39.96, 34.48.

IR (KBr, cm^{-1}):3338, 2981, 2958, 2930, 2365, 2343, 1732, 1586, 1489, 1459, 1265, 1225, 1195, 1167, 1130, 1098, 1048, 1009, 860, 755, 698.

HRMS (ESI): m/z calcd for $C_{25}H_{26}NO_7$ ([M+H]$^+$): 452.1704; found: 452.1700.

diisopropyl (*E*)-4-(3-(benzyloxy)-3-oxoprop-1-en-1-yl)-1,3a,4,9b-tetrahydrochromeno[4,3-*b*] pyrrole-2,2(3*H*)-dicarboxylate (3ya)



Yellow oil (34.6 mg, 68% yield)

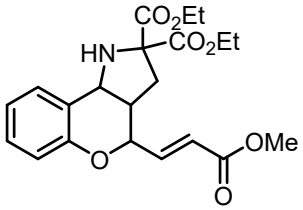
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 – 7.31 (m, 5H), 7.30 – 7.25 (m, 1H), 7.19 (t, *J* = 7.7 Hz, 1H), 7.15 – 7.07 (m, 1H), 6.98 – 6.88 (m, 2H), 6.37 (d, 1H), 5.22 (s, 2H), 5.18 – 5.07 (m, 1H), 5.03 – 4.93 (m, 1H), 4.48 (dd, *J* = 10.5, 6.0 Hz, 1H), 4.26 (d, *J* = 4.5 Hz, 1H), 3.24 (brs, 1H), 2.61 (d, *J* = 14.7 Hz, 1H), 2.49 (dd, *J* = 14.1, 8.5 Hz, 1H), 2.31 – 2.18 (m, 1H), 1.30 – 1.18 (m, 12H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 171.77, 169.73, 165.89, 153.45, 144.71, 135.84, 129.92, 129.00, 128.59, 128.39, 128.30, 123.48, 122.41, 121.20, 117.06, 73.93, 70.27, 69.78, 66.47, 55.72, 39.89, 34.21, 21.62, 21.50.

IR (KBr, cm^{-1}): 2979, 2931, 1727, 1584, 1458, 1374, 1271, 1167, 1101, 1040, 990, 909, 856, 754, 703.

HRMS (ESI): m/z calcd for $C_{29}H_{34}NO_7$ ($[M+H]^+$): 508.2330; found: 508.2333.

diethyl (*E*)-4-(3-methoxy-3-oxoprop-1-en-1-yl)-1,3a,4,9b-tetrahydrochromeno[4,3-*b*]pyrrole-2,2(3*H*)-dicarboxylate (3ab)



White solid (24.0 mg, 60% yield, m.p. 85-87°C)

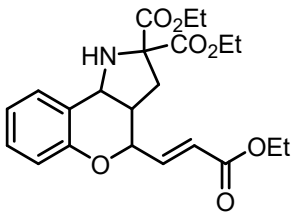
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28 (d, *J* = 7.9 Hz, 1H), 7.20 (t, *J* = 7.6 Hz, 1H), 7.07 (dd, *J* = 15.7, 5.9 Hz, 1H), 7.02 – 6.87 (m, 2H), 6.32 (d, *J* = 15.7 Hz, 1H), 4.46 (dd, *J* = 10.4, 6.0 Hz, 1H), 4.35 – 4.07 (m, 5H), 3.78 (s, 3H), 3.29 (brs, 1H), 2.63 (dd, *J* = 14.6, 2.0 Hz, 1H), 2.55 (dd, *J* = 14.7, 7.7 Hz, 1H), 2.31 – 2.20 (m, 1H), 1.26 (dt, *J* = 25.7, 7.1 Hz, 6H).

^{13}C NMR (101 MHz, $CDCl_3$) δ 172.17, 170.25, 166.53, 153.43, 144.27, 129.91, 129.08, 123.45, 122.28, 121.30, 117.13, 73.88, 70.27, 62.19, 55.76, 51.78, 40.01, 34.29, 14.09, 13.98.

IR (KBr, cm^{-1}): 3337, 2948, 2857, 1730, 1665, 1584, 1453, 1363, 1269, 1189, 1131, 1096, 1038, 1014, 857, 751, 705.

HRMS (ESI): m/z calcd for $C_{21}H_{26}NO_7$ ($[M+H]^+$): 404.1704; found: 404.1699.

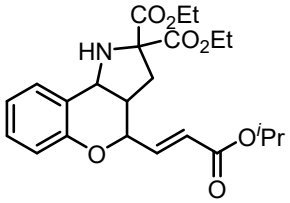
diethyl (E)-4-(3-ethoxy-3-oxoprop-1-en-1-yl)-1,3a,4,9b-tetrahydrochromeno[4,3-b]pyrrole-2,2(3H)-dicarboxylate (3ac)



Colorless oil (19.0 mg, 52% yield)

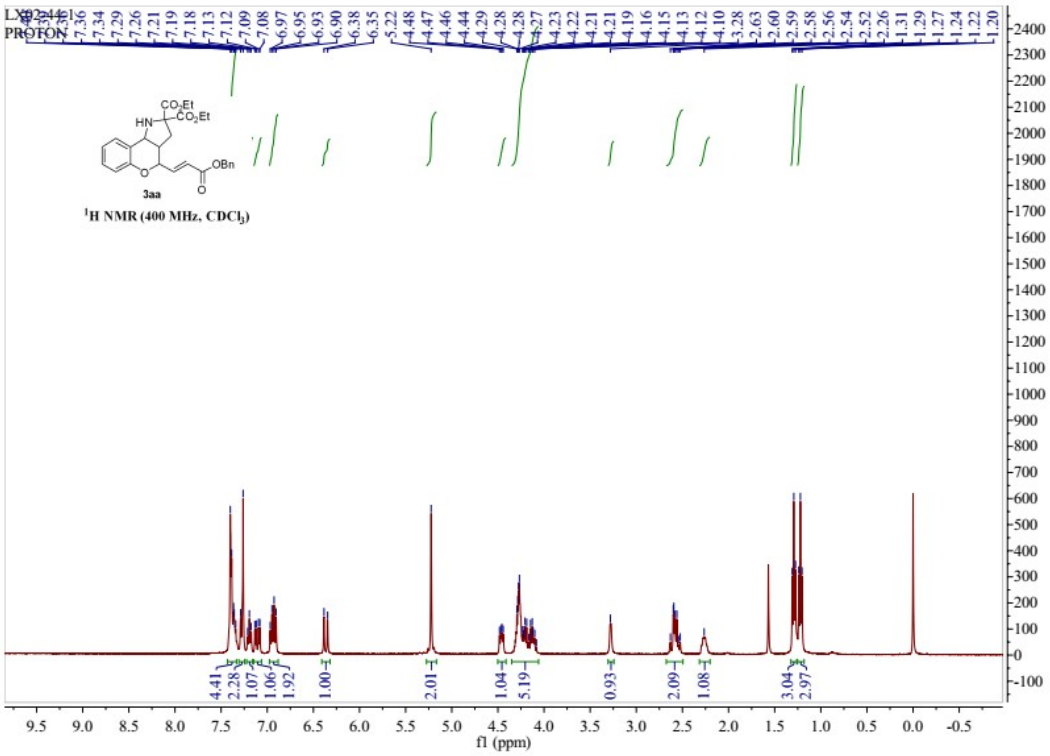
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28 (d, *J* = 7.6 Hz, 1H), 7.20 (t, *J* = 7.4 Hz, 1H), 7.06 (dd, *J* = 15.6, 5.8 Hz, 1H), 6.99 – 6.88 (m, 2H), 6.31 (d, *J* = 15.7 Hz, 1H), 4.46 (dd, *J* = 10.1, 6.0 Hz, 1H), 4.35 – 4.17 (m, 6H), 4.17 – 4.09 (m, 1H), 3.29 (brs, 1H), 2.70 – 2.49 (m, 2H), 2.28 (br, 1H), 1.38 – 1.18 (m, 9H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 172.17, 170.25, 166.09, 153.46, 143.90, 129.91, 129.08, 123.96, 122.27, 121.28, 117.13, 73.93, 70.28, 62.21, 60.66, 55.75, 39.97, 34.31, 14.28, 14.10, 13.98.
IR (KBr, cm^{-1}): 3331, 2978, 2927, 2861, 1728, 1666, 1585, 1474, 1458, 1368, 1268, 1233, 1186, 1131, 1096, 1037, 859, 753.
HRMS (ESI): m/z calcd for $C_{22}H_{28}NO_7$ ($[M+H]^+$): 418.1860; found: 418.1857.

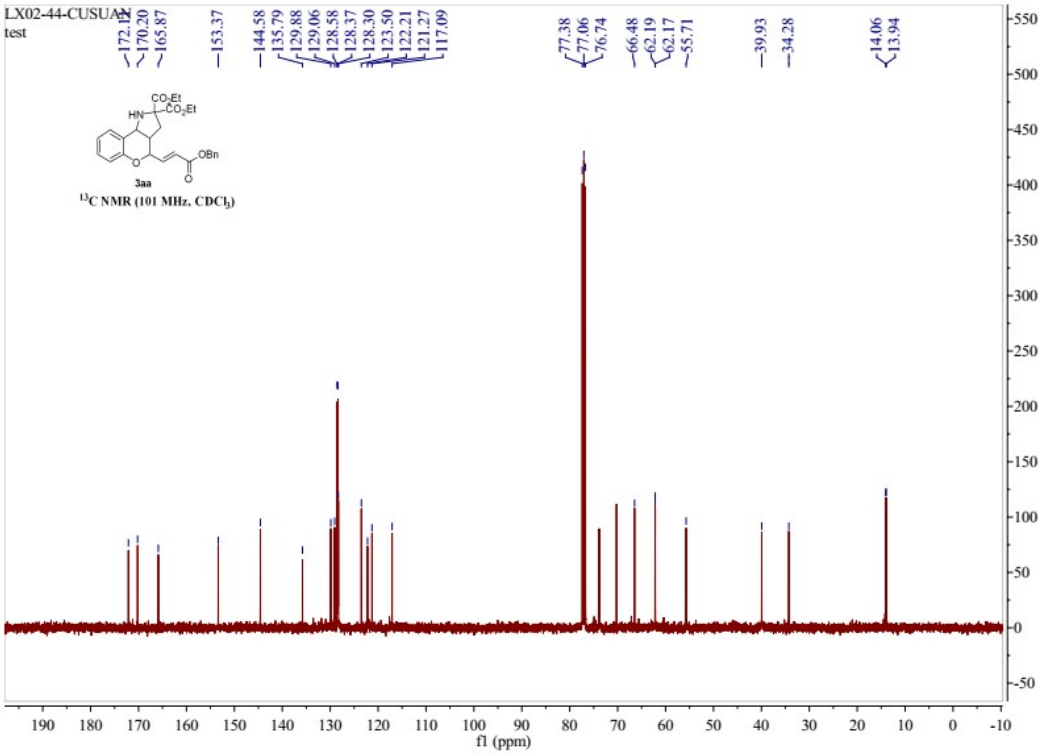
diethyl (E)-4-(3-isopropoxy-3-oxoprop-1-en-1-yl)-1,3a,4,9b-tetrahydrochromeno[4,3-b]pyrrole-2,2(3H)-dicarboxylate (3ad)

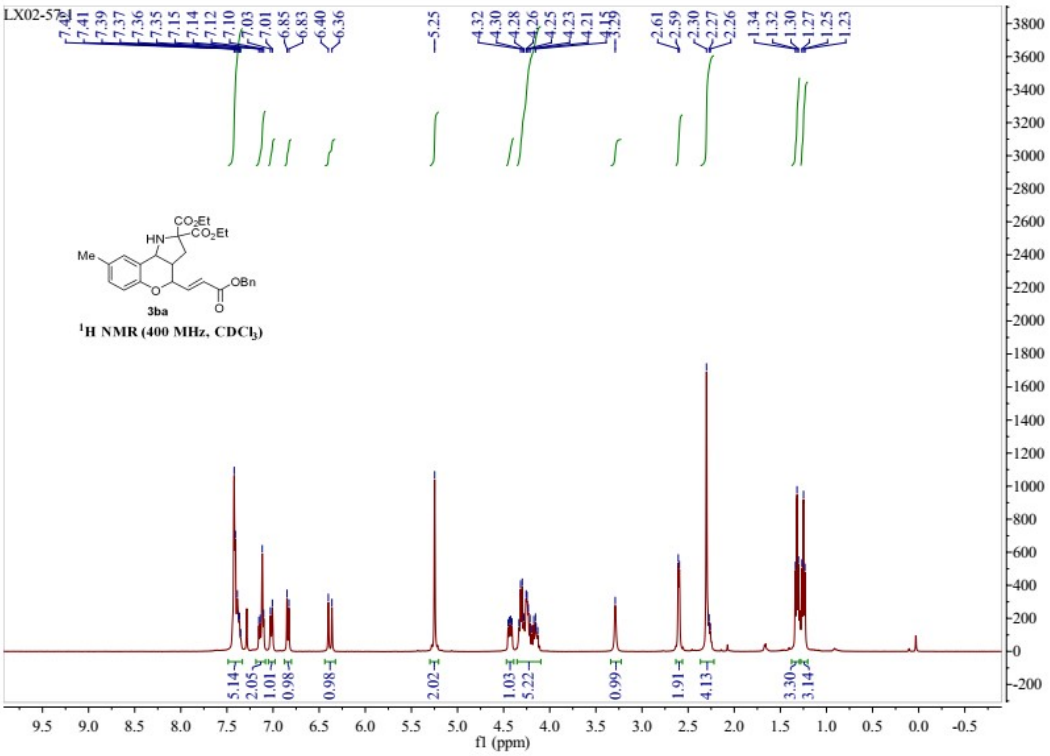


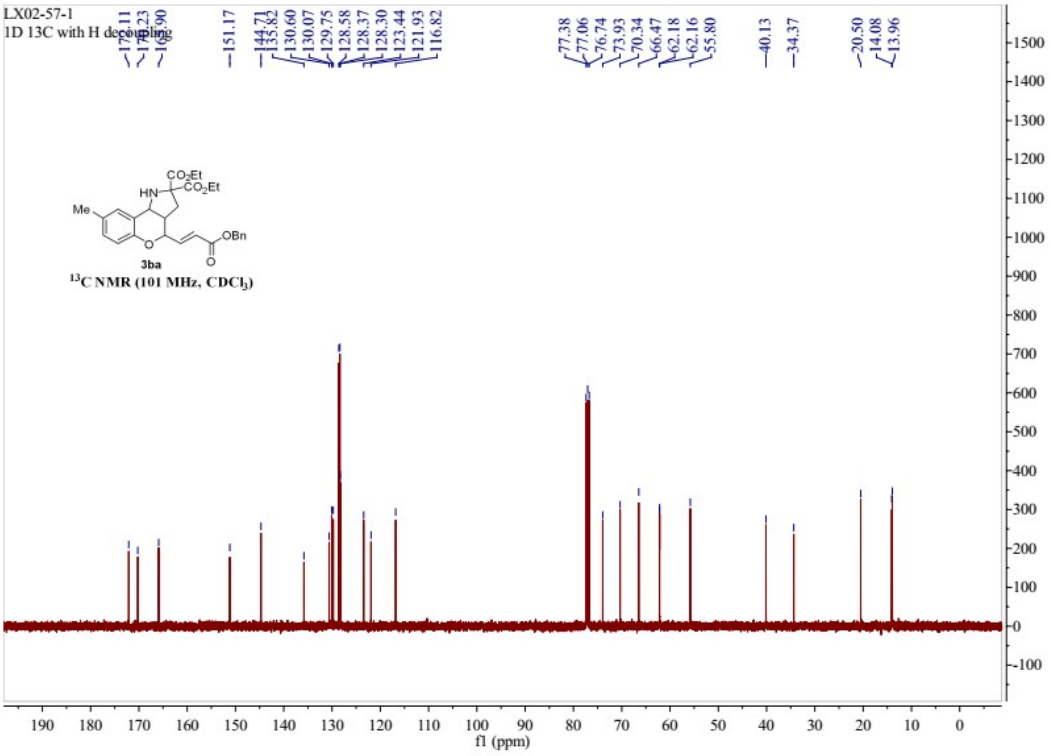
White solid (24.6.0 mg, 65% yield, m.p. 60-62°C)
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.30 (d, *J* = 7.7 Hz, 1H), 7.21 (t, *J* = 7.3 Hz, 1H), 7.05 (dd, *J* = 15.6, 5.8 Hz, 1H), 7.00 – 6.88 (m, 2H), 6.30 (d, *J* = 15.6 Hz, 1H), 5.20 – 5.06 (m, 1H), 4.46 (dd, *J* = 9.7, 6.0 Hz, 1H), 4.37 – 4.10 (m, 5H), 3.30 (brs, 1H), 2.71 – 2.51 (m, 2H), 2.29 (br, 1H), 1.37 – 1.22 (m, 12H).
^{13}C NMR (101 MHz, $CDCl_3$) δ 172.17, 170.23, 165.60, 153.46, 143.54, 129.90, 129.07, 124.49, 122.24, 121.25, 117.12, 73.96, 70.27, 68.04, 62.18, 55.73, 39.91, 34.31, 21.88, 14.09, 13.97.
IR (KBr, cm^{-1}): 2977, 2927, 2862, 1727, 1584, 1458, 1367, 1268, 1232, 1186, 1104, 1038, 1016, 988, 908, 858, 749.
HRMS (ESI): m/z calcd for $C_{23}H_{30}NO_7$ ($[M+H]^+$): 432.2017; found: 432.2018.

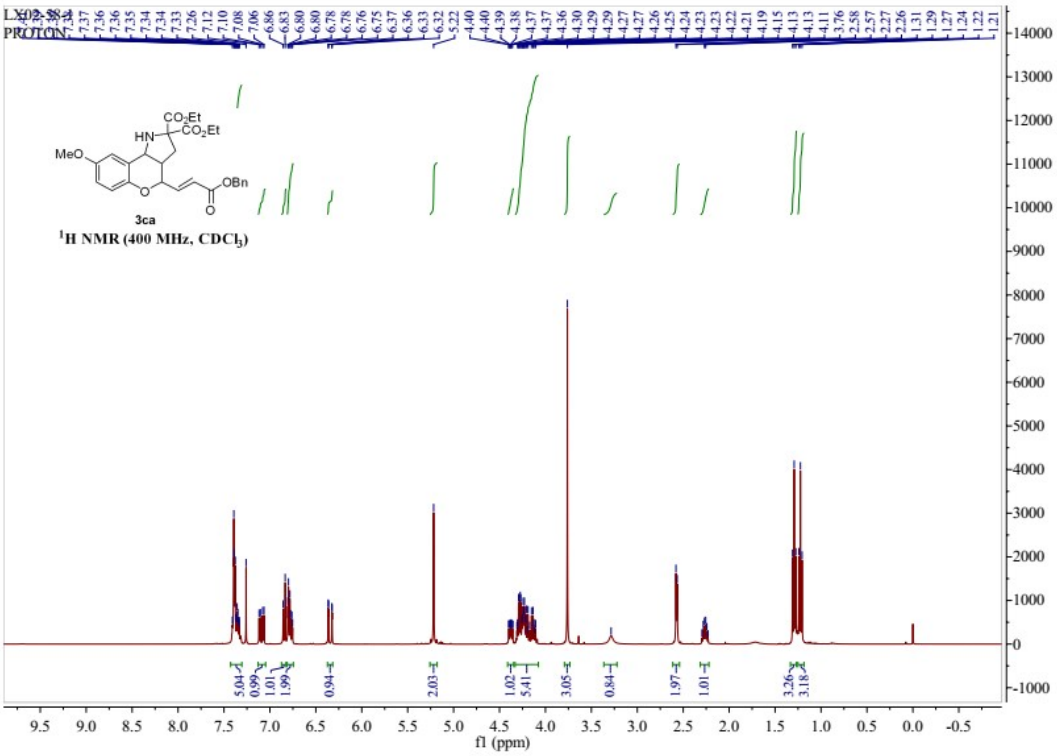
10. Spectra

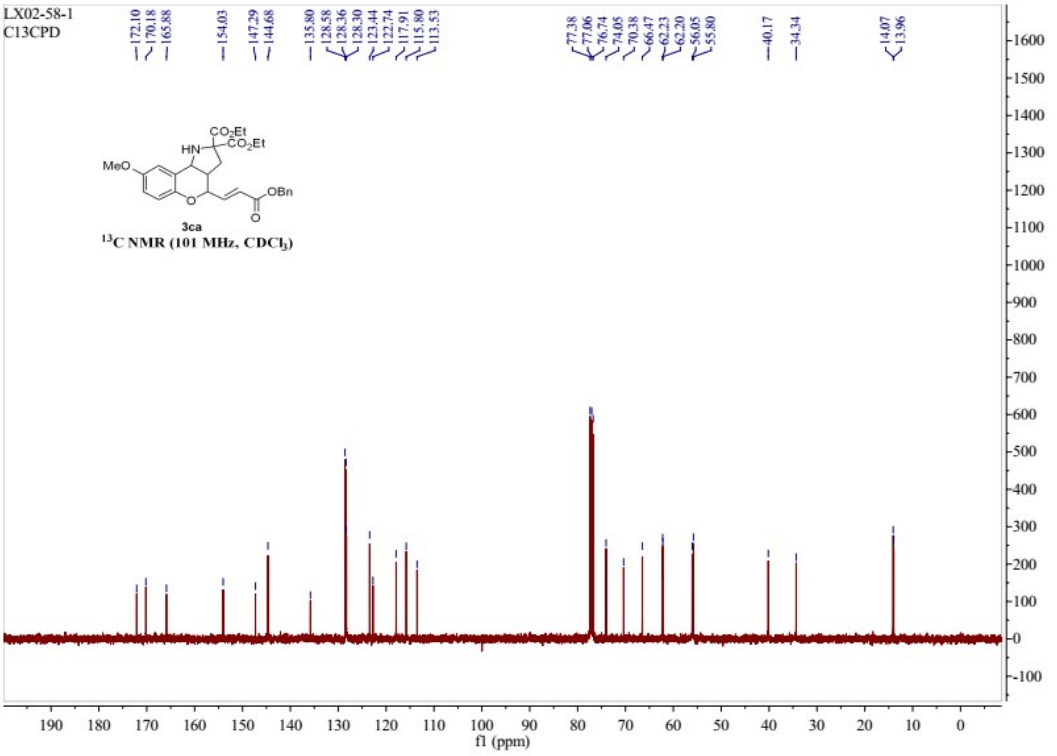

LX02-44-1
PROTON
3aa
^{1}H NMR (400 MHz, CDCl$_3$)
f1 (ppm)

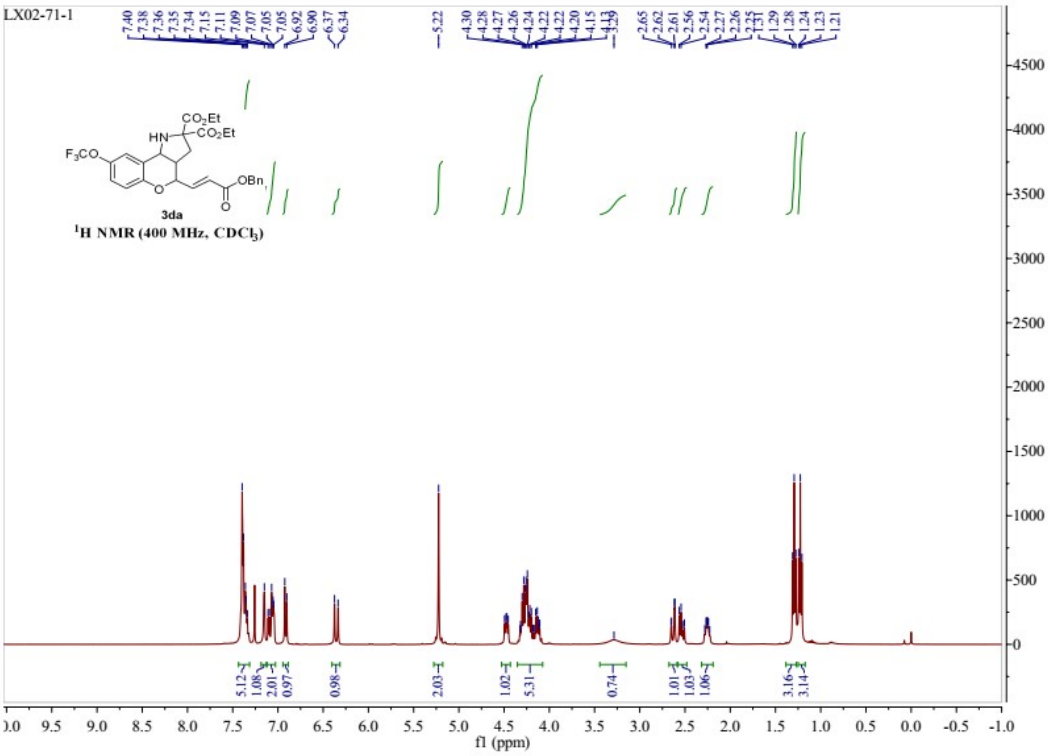

LX02-44-CUSUAL
test
3aa
^{13}C NMR (101 MHz, CDCl$_3$)
f1 (ppm)

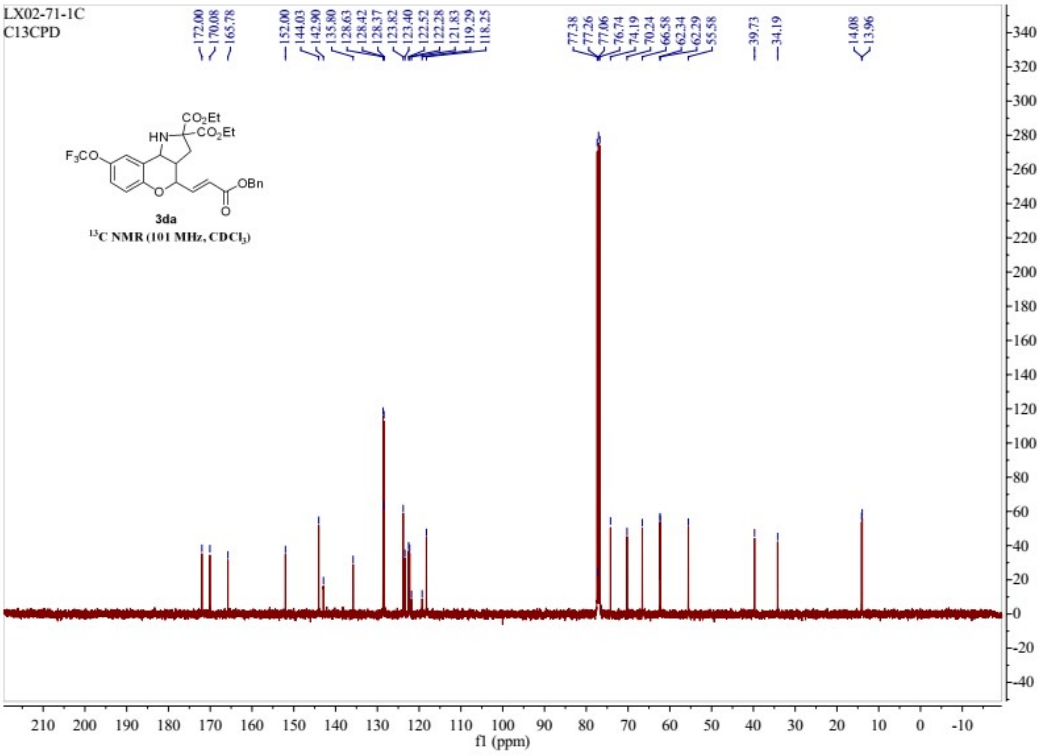

LX02-57-1
7.41
7.39
7.37
7.36
7.35
7.15
7.14
7.12
7.10
7.03
7.01
6.85
6.83
6.40
6.36
5.25
4.32
4.30
4.28
4.26
4.25
4.23
4.21
3.29
2.61
2.59
2.30
2.27
2.26
1.34
1.32
1.30
1.27
1.25
1.23
CO2Et
CO2Et
HN
Me
OBn
O
3ba
1H NMR (400 MHz, CDCl3)
5.14
2.05
1.01
0.98
0.98
2.02
1.03
5.22
0.99
1.91
4.13
3.30
3.14
fl (ppm)

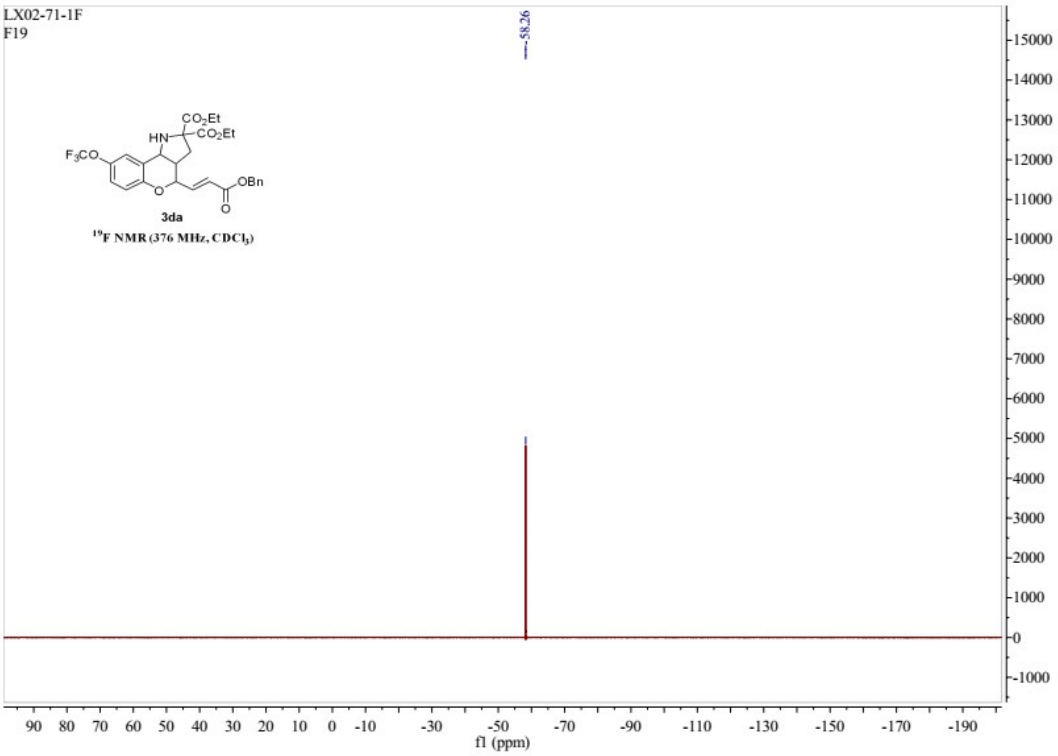

LX02-57-1
1D 13C with H decoupling
171.11
170.23
169.90
151.17
144.71
135.82
130.60
130.07
129.75
128.58
128.37
128.30
123.44
121.93
116.82
77.38
77.06
76.74
73.93
70.34
66.47
62.18
62.16
55.80
40.13
34.37
20.50
14.08
13.96
CO2Et
CO2Et
HN
Me
OBn
O
3ba
13C NMR (101 MHz, CDCl3)
fl (ppm)

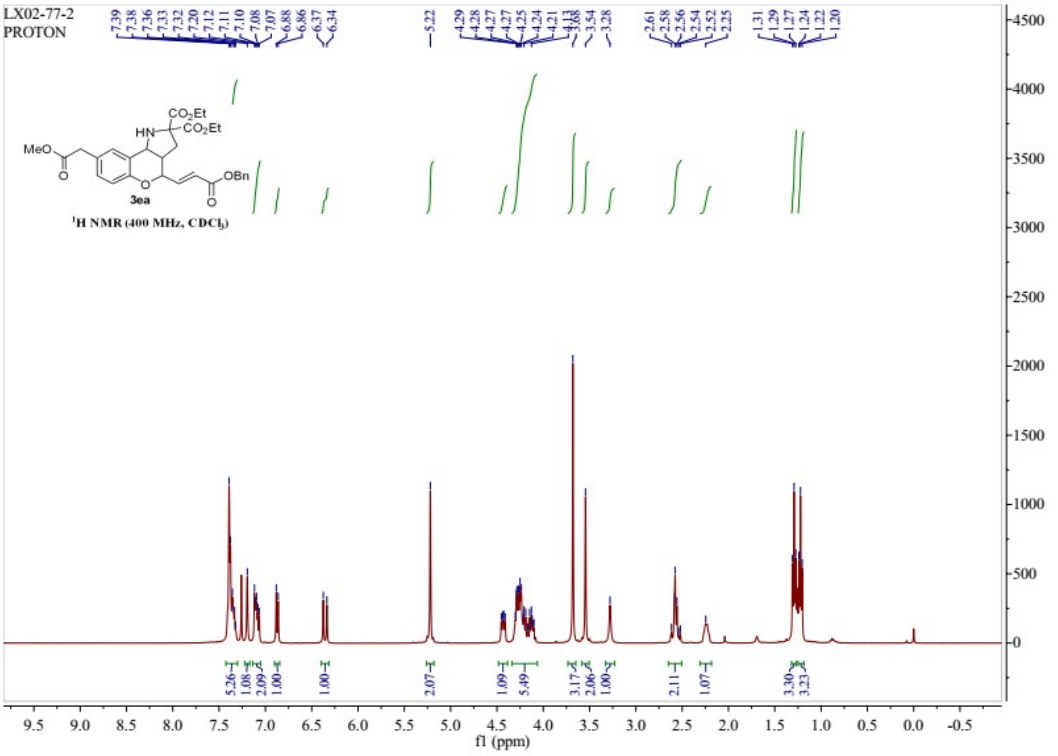

LX02-58-1
PROTON
3ca
^{1}H NMR (400 MHz, $CDCl_3$)
fl (ppm)

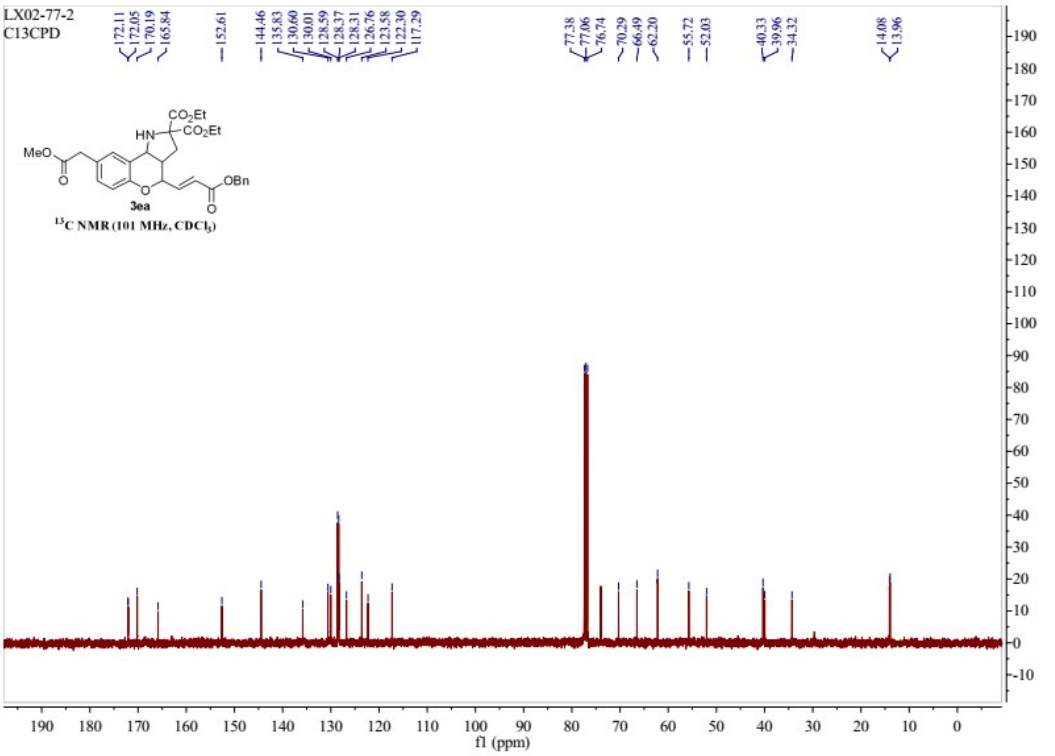

LX02-58-1
C13CPD
3ca
^{13}C NMR (101 MHz, $CDCl_3$)
fl (ppm)

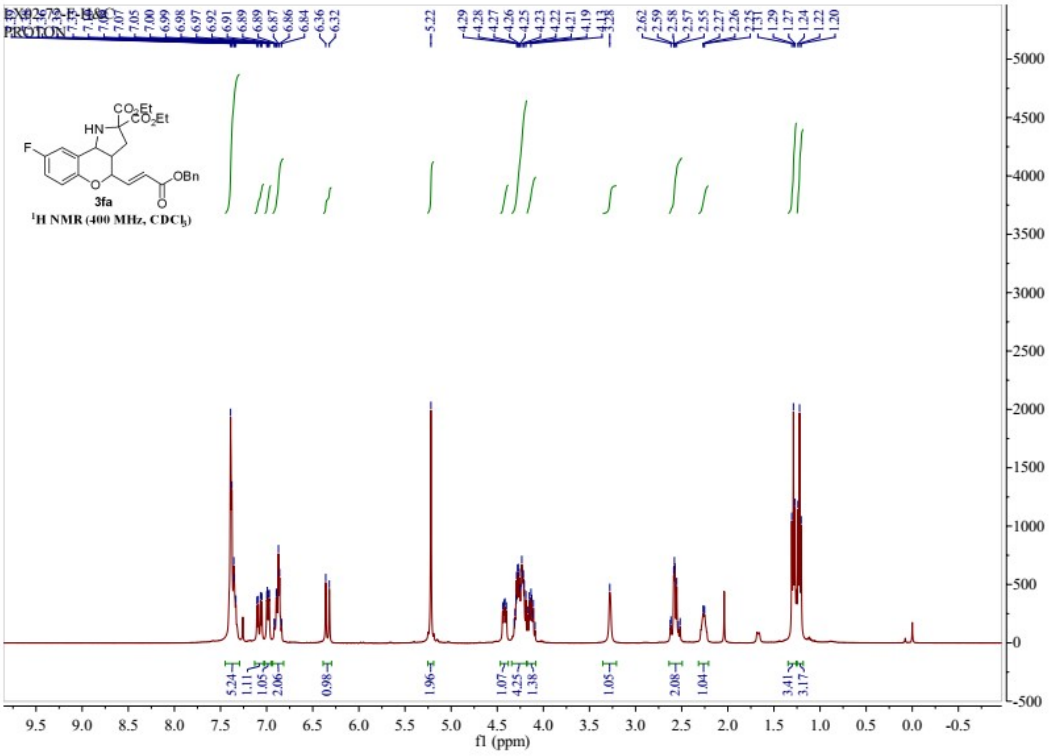

LX02-71-1
3da
^{1}H NMR (400 MHz, CDCl$_3$)
f1 (ppm)

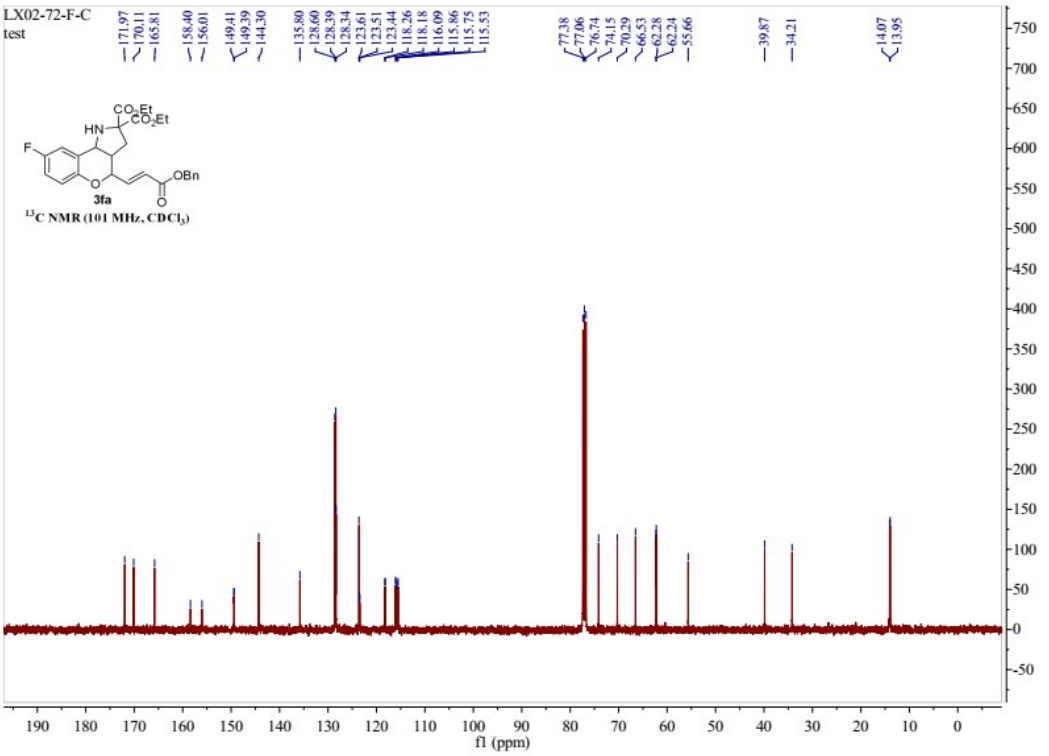

LX02-71-1C
C13CPD
3da
^{13}C NMR (101 MHz, CDCl$_3$)
f1 (ppm)

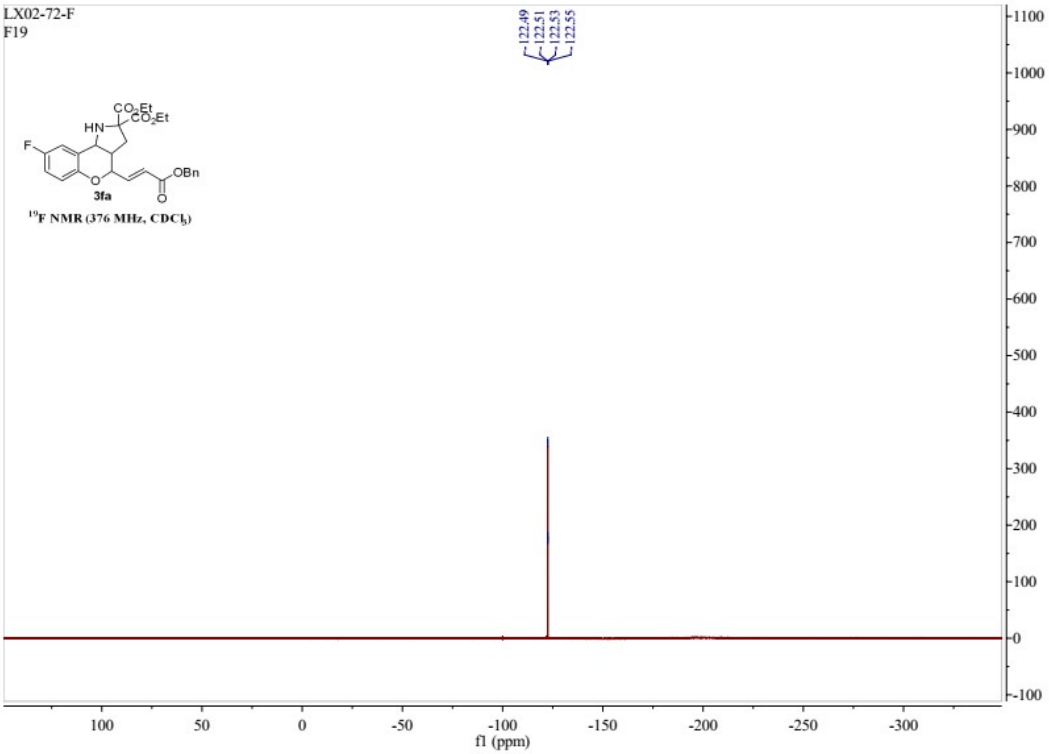

LX02-71-1F
F19
-58.26
3da
^{19}F NMR (376 MHz, CDCl$_3$)
f1 (ppm)

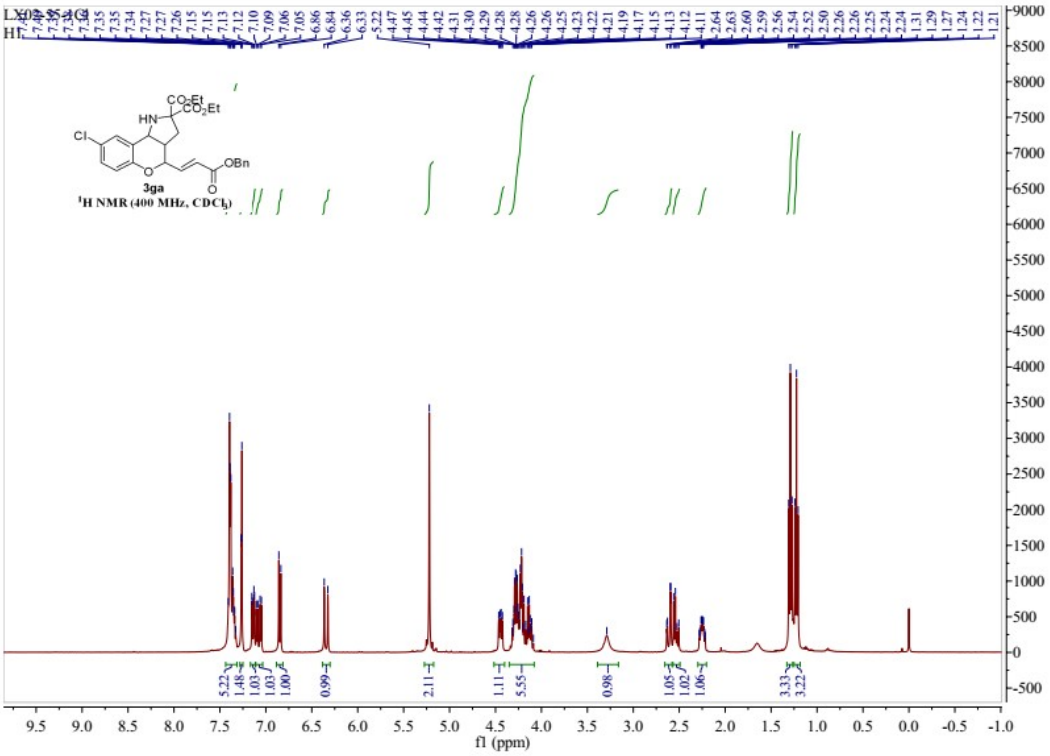

LX02-77-2
PROTON
3ea
^{1}H NMR (400 MHz, CDCl$_3$)
f1 (ppm)

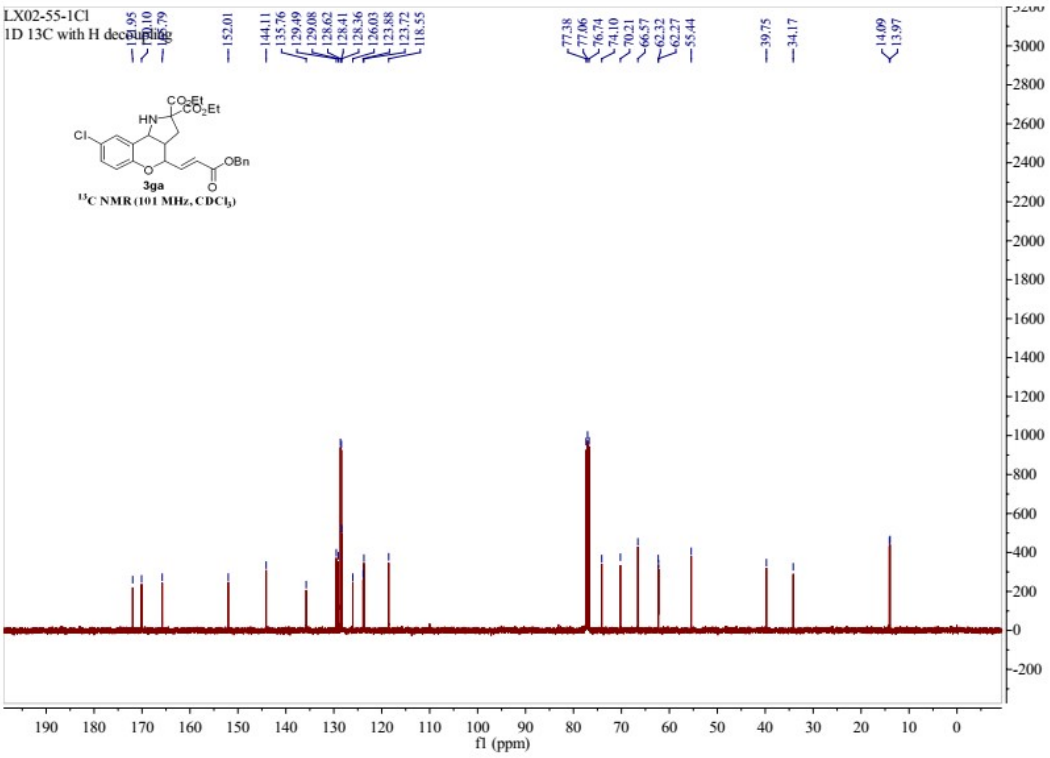

LX02-77-2
C13CPD
3ea
^{13}C NMR (101 MHz, CDCl$_3$)
f1 (ppm)

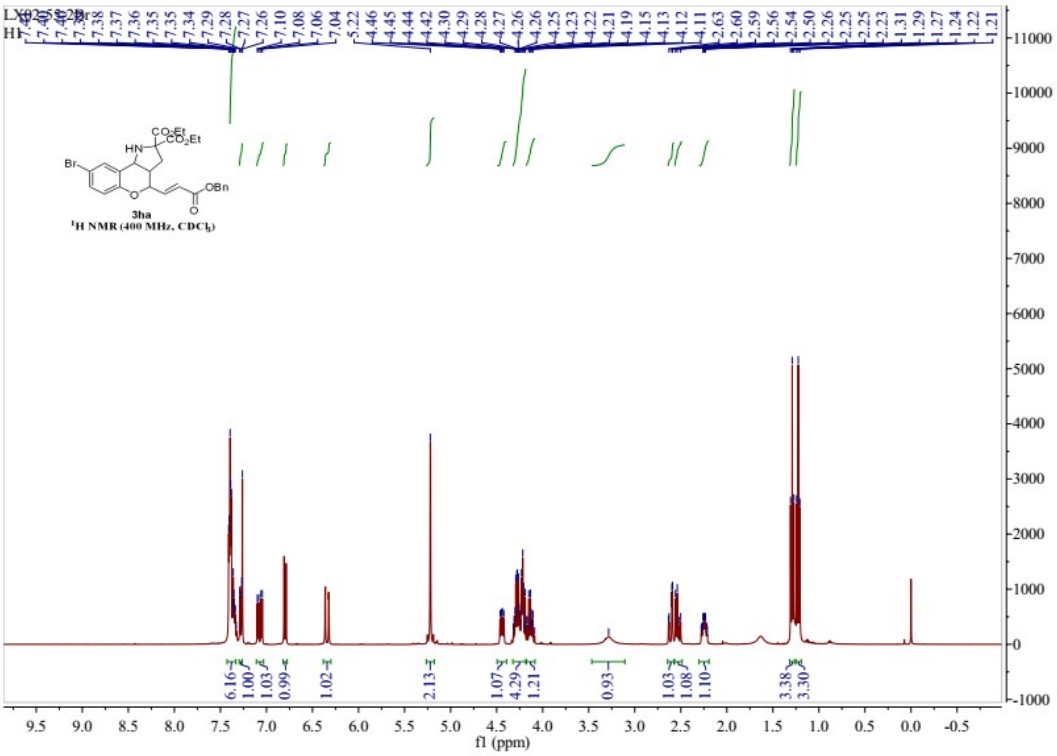

PROTON
3fa
^{1}H NMR (400 MHz, CDCl$_3$)
f1 (ppm)

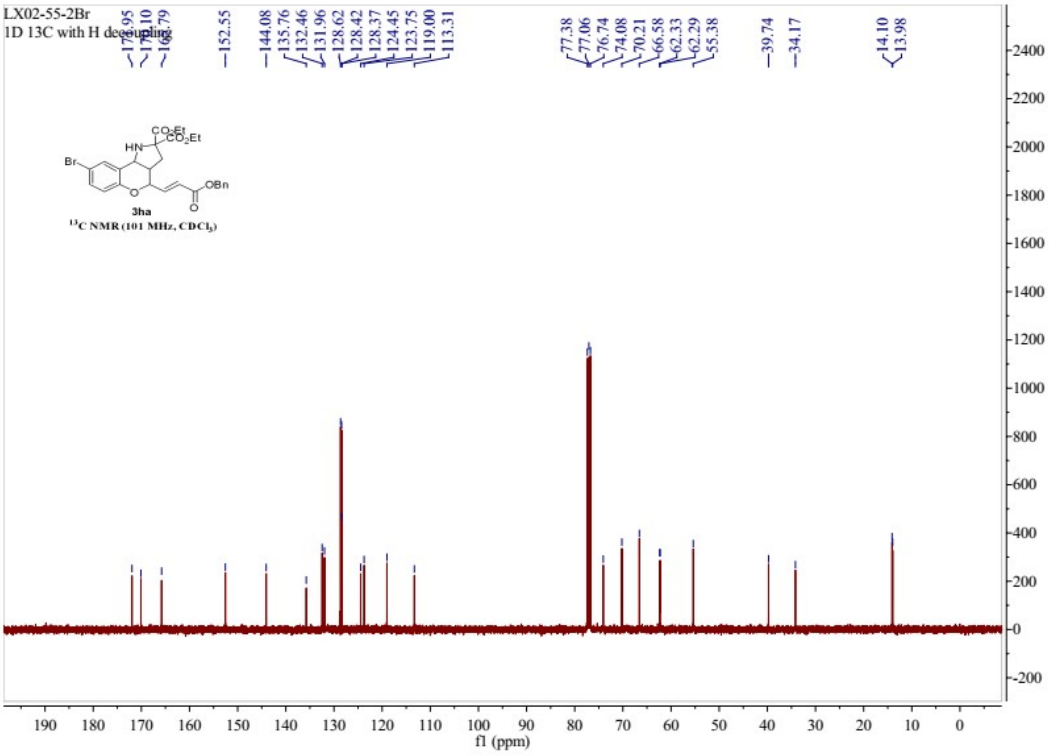

LX02-72-F-C
test
171.97
170.11
165.81
158.40
156.01
149.41
149.39
144.30
135.80
128.60
128.39
128.34
123.61
123.51
123.44
118.26
118.18
116.09
115.86
115.75
115.53
77.38
77.06
76.74
74.15
70.29
66.53
62.28
62.24
55.66
39.87
34.21
14.07
13.95
3fa
^{13}C NMR (101 MHz, CDCl$_3$)
fl (ppm)

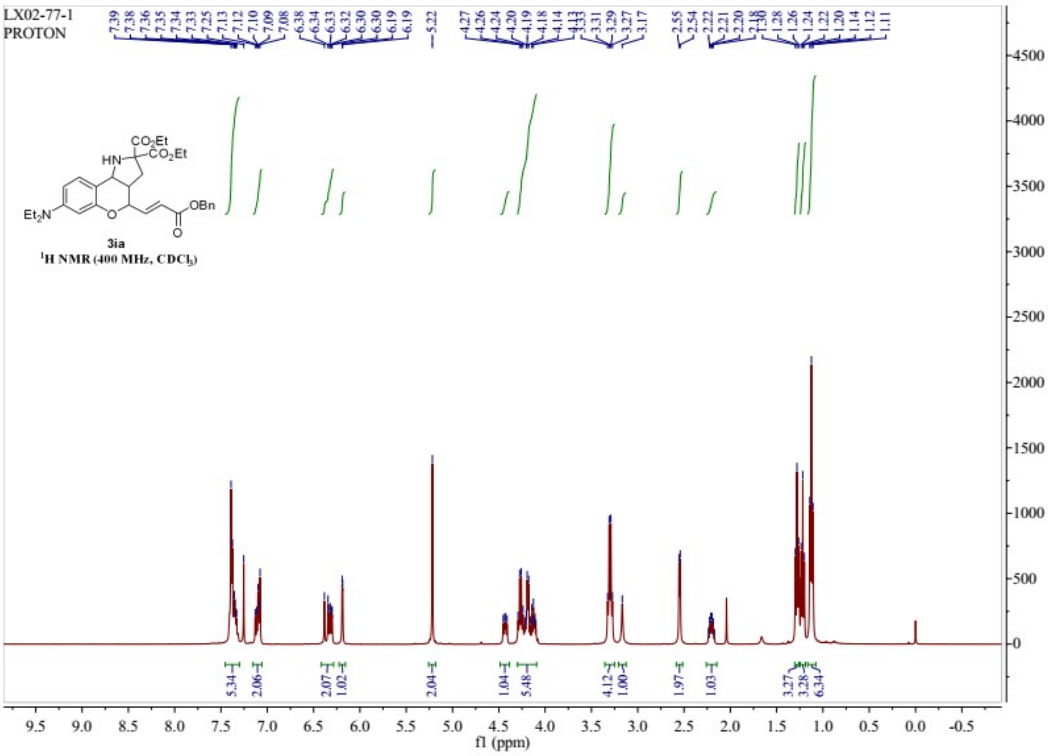

LX02-72-F
F19
122.49
122.51
122.53
122.55
3fa
^{19}F NMR (376 MHz, CDCl$_3$)
fl (ppm)

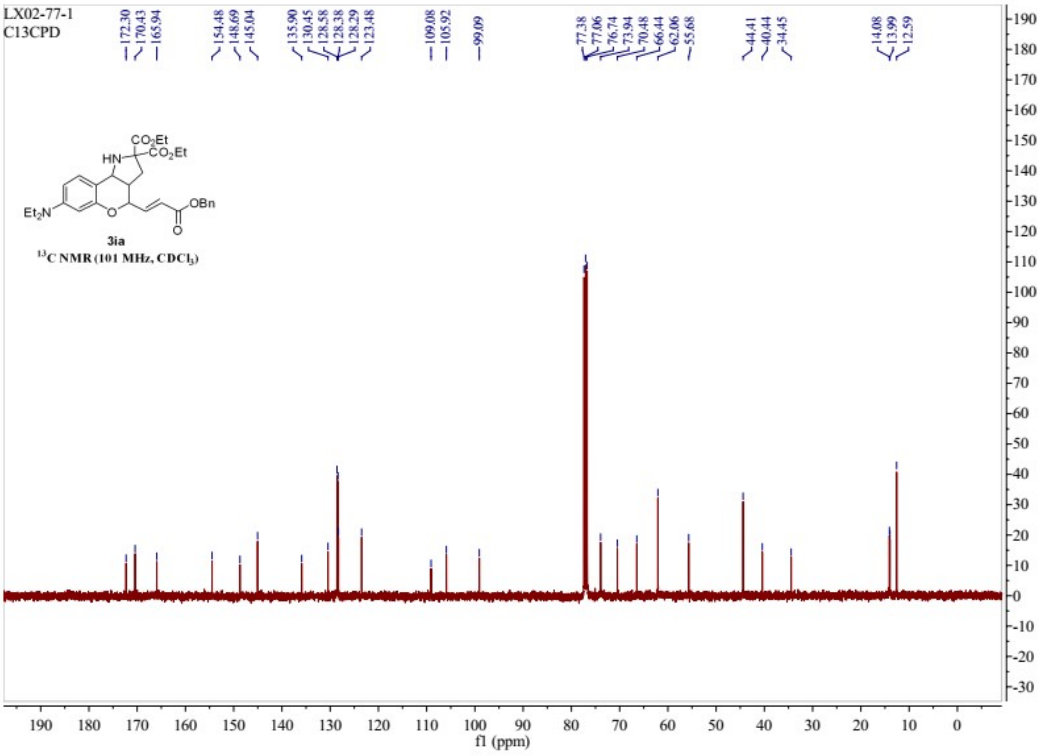

3ga
^{1}H NMR (400 MHz, CDCl$_3$)
f1 (ppm)

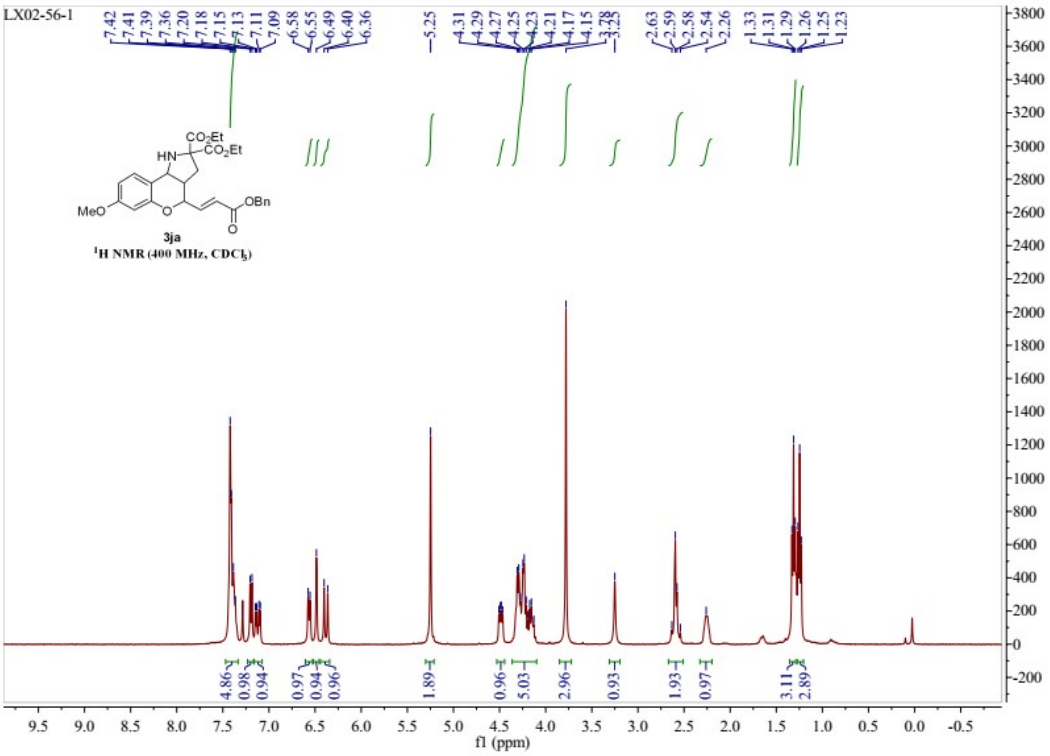

LX02-55-1C1
1D 13C with H decoupling
3ga
^{13}C NMR (101 MHz, CDCl$_3$)
f1 (ppm)

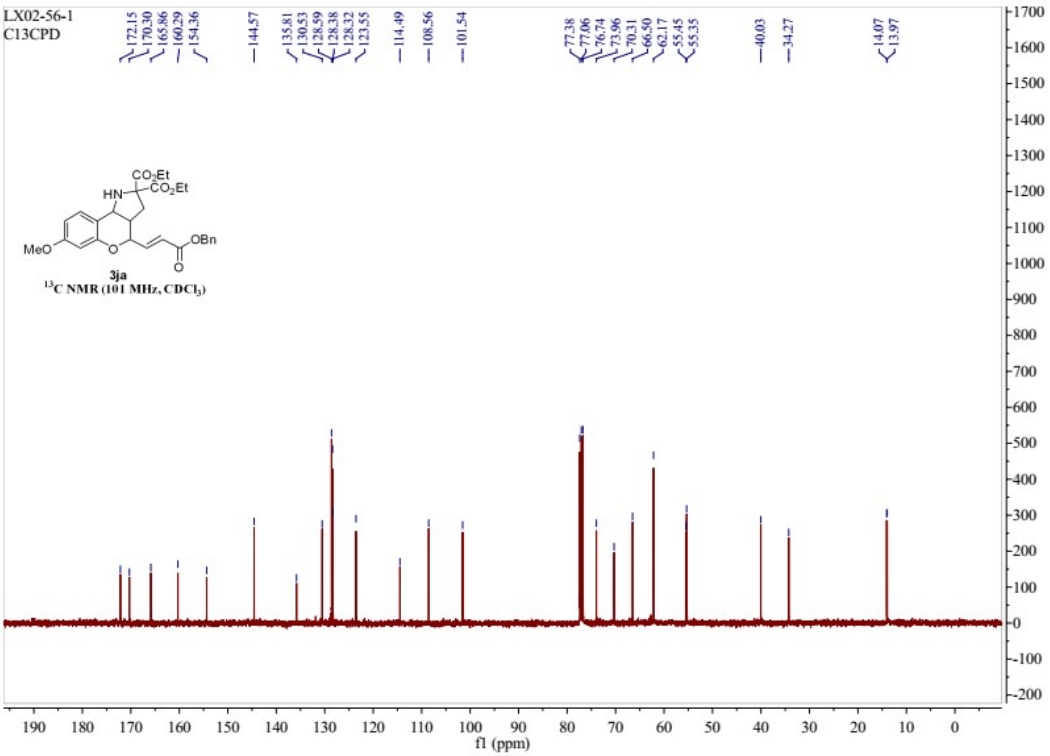

LX02-55-2Br
1H
3ha
1H NMR (400 MHz, CDCl3)
fl (ppm)

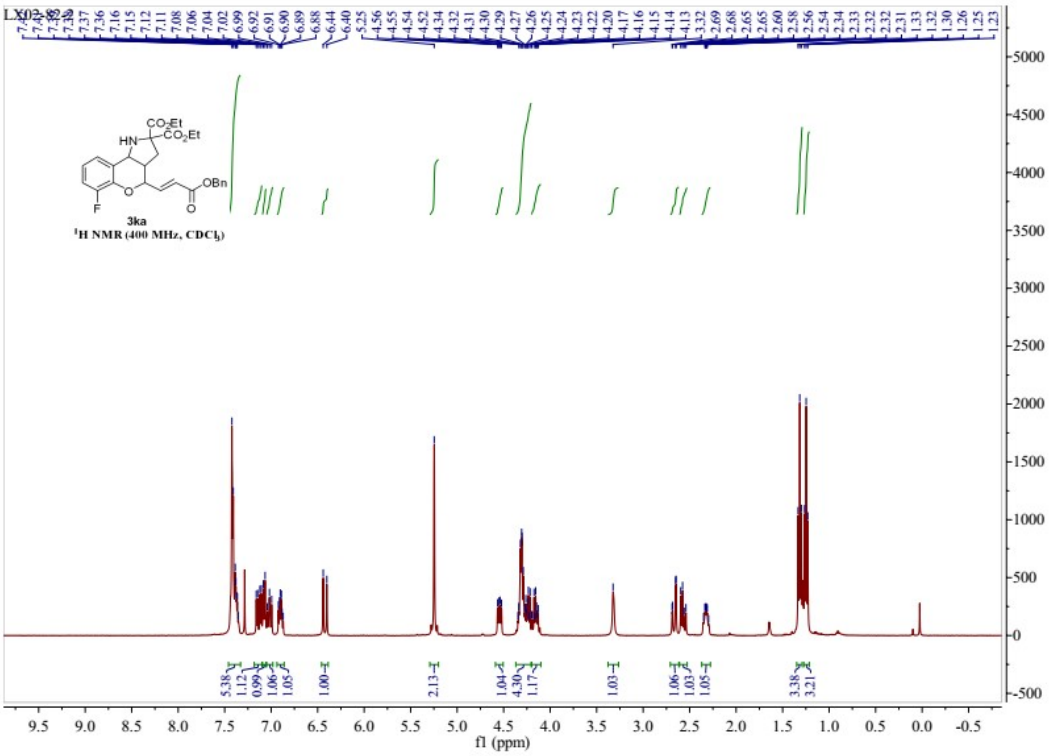

LX02-55-2Br
1D 13C with H decoupling
3ha
13C NMR (101 MHz, CDCl3)
fl (ppm)

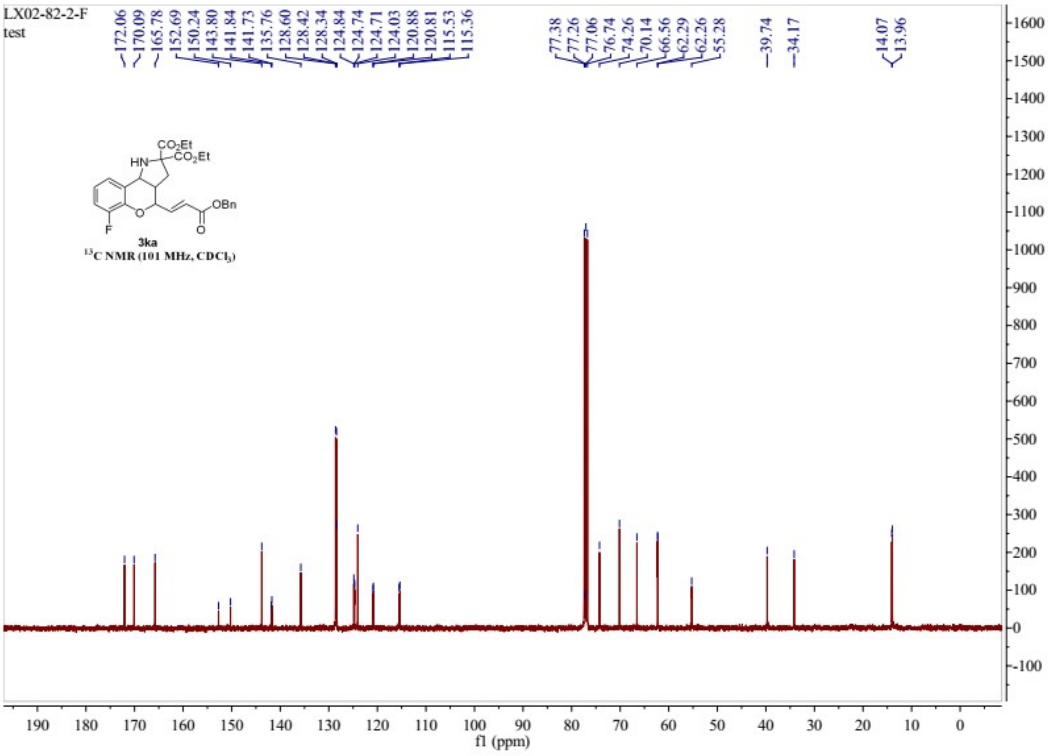

LX02-77-1
PROTON
3ia
^{1}H NMR (400 MHz, CDCl$_3$)
f1 (ppm)

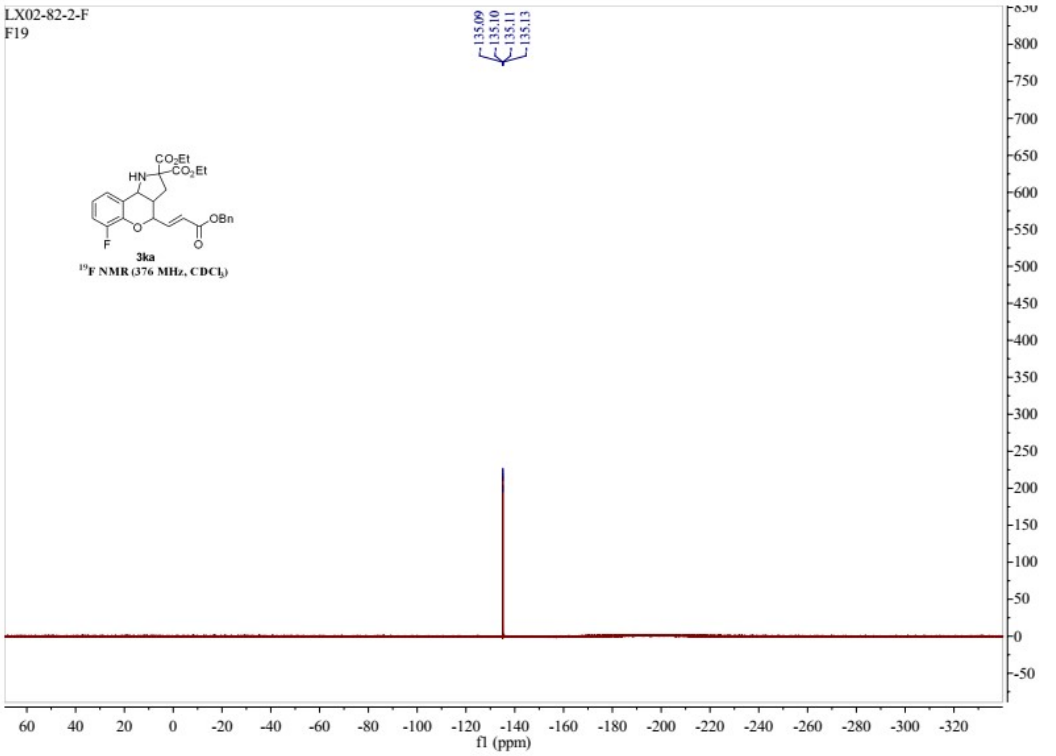

LX02-77-1
C13CPD
3ia
^{13}C NMR (101 MHz, CDCl$_3$)
f1 (ppm)

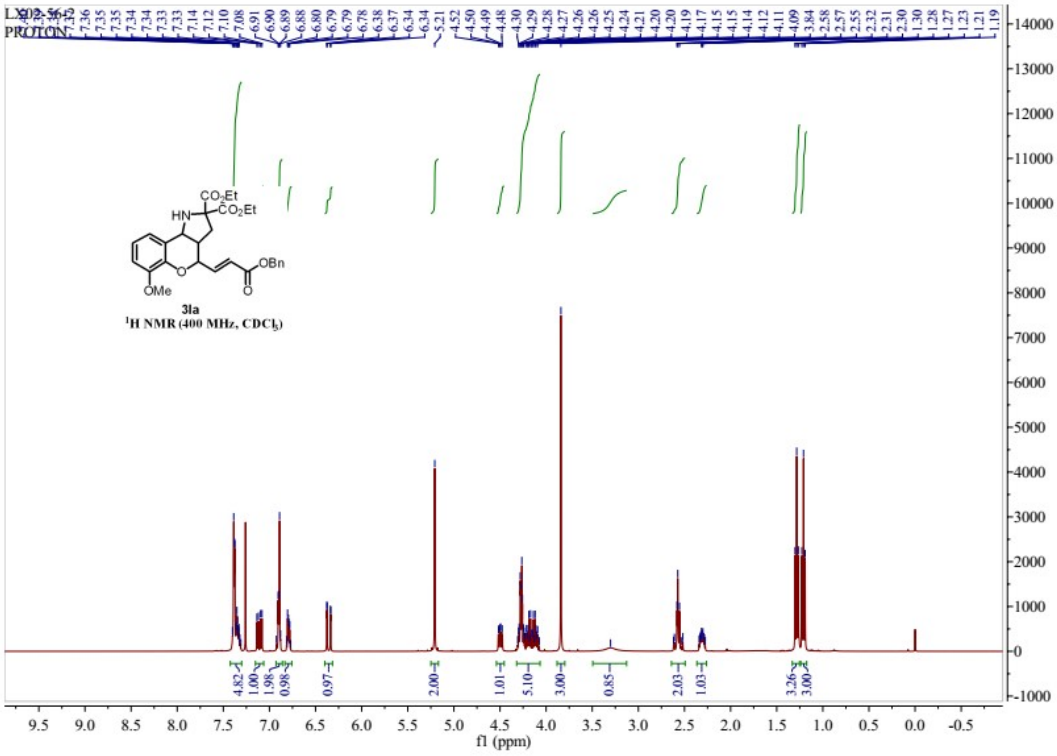

LX02-56-1
7.42
7.41
7.39
7.36
7.20
7.18
7.15
7.13
7.11
7.09
6.58
6.55
6.49
6.40
6.36
5.25
4.31
4.29
4.27
4.25
4.23
4.21
4.17
4.15
3.28
3.25
2.63
2.59
2.58
2.54
2.26
1.33
1.31
1.29
1.26
1.25
1.23
CO2Et
HN
CO2Et
MeO
O
OBn
O
3ja
1H NMR (400 MHz, CDCl3)
4.86
0.98
0.94
0.97
0.94
0.96
1.89
0.96
5.03
2.96
0.93
1.93
0.97
3.11
2.89
f1 (ppm)

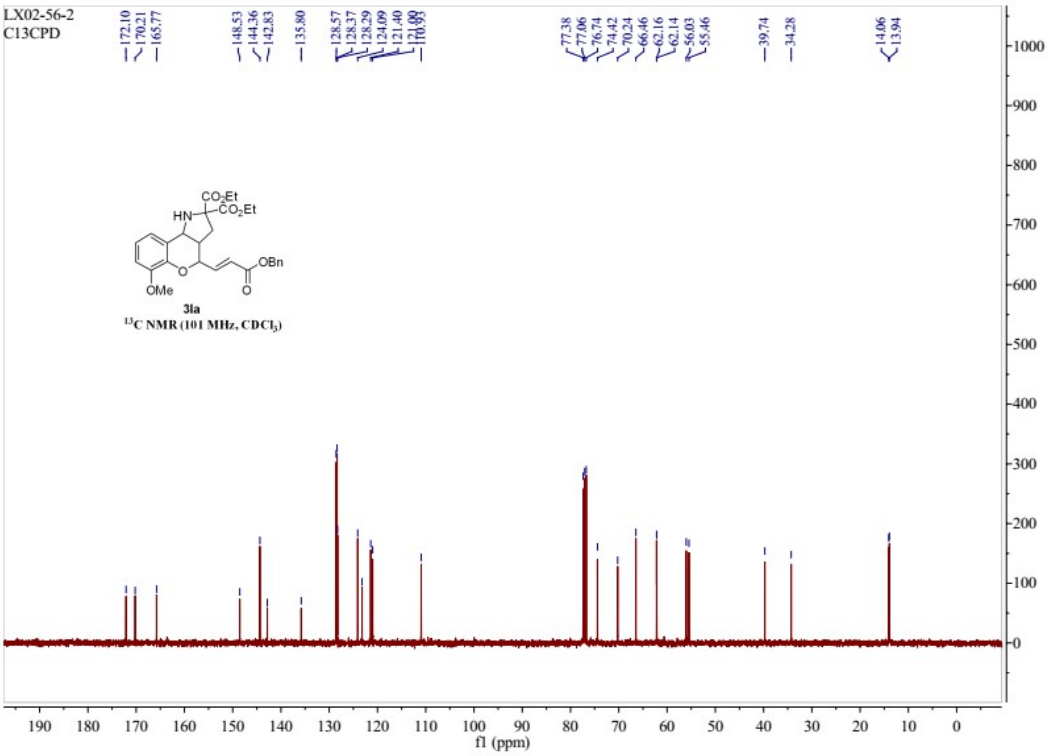

LX02-56-1
C13CPD
172.15
170.30
165.86
160.29
154.36
144.57
135.81
130.53
128.59
128.38
128.32
123.55
114.49
108.56
101.54
77.38
77.06
76.74
73.96
70.31
66.50
62.17
55.45
55.35
40.03
34.27
14.07
13.97
CO2Et
HN
CO2Et
MeO
O
OBn
O
3ja
13C NMR (101 MHz, CDCl3)
f1 (ppm)

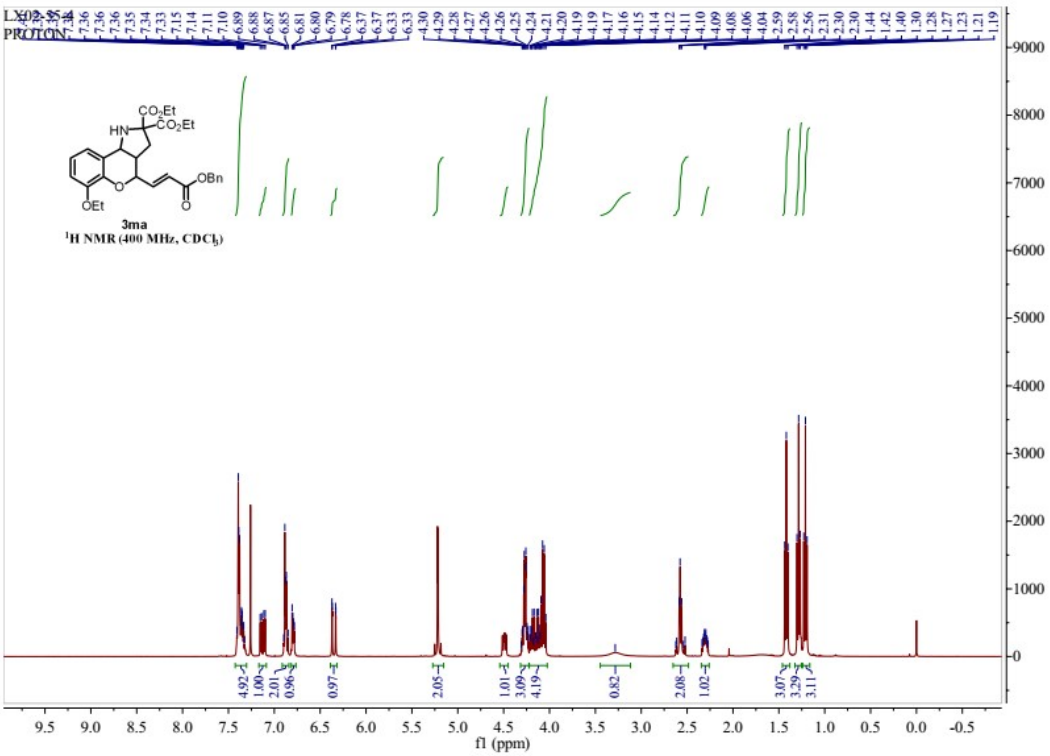

3ka
^{1}H NMR (400 MHz, CDCl$_3$)
f1 (ppm)

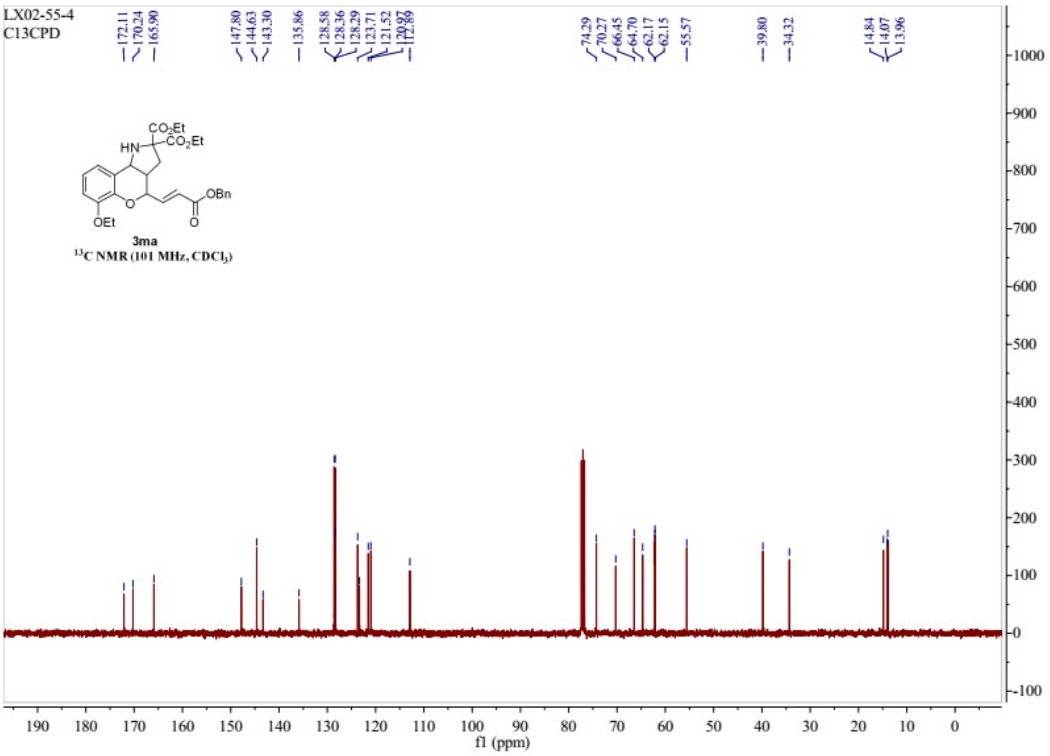

LX02-82-2-F
test
3ka
^{13}C NMR (101 MHz, CDCl$_3$)
f1 (ppm)

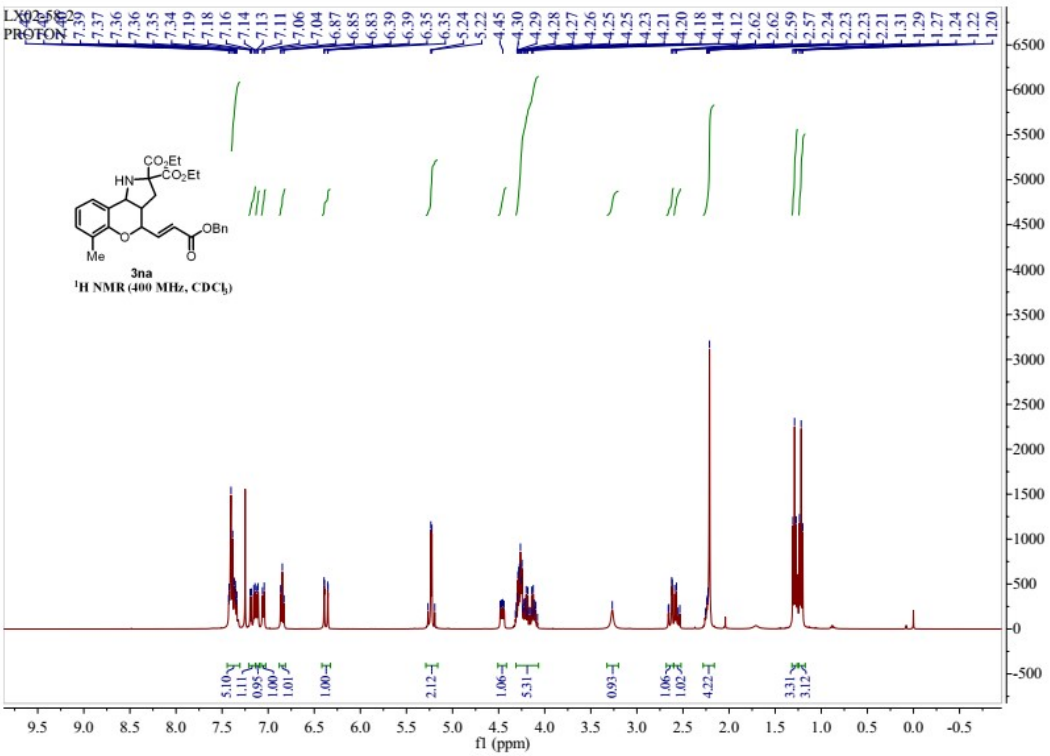

LX02-82-2-F
F19
135.09
135.10
135.11
135.13
CO2Et
CO2Et
HN
OBn
O
F
3ka
19F NMR (376 MHz, CDCl3)
f1 (ppm)

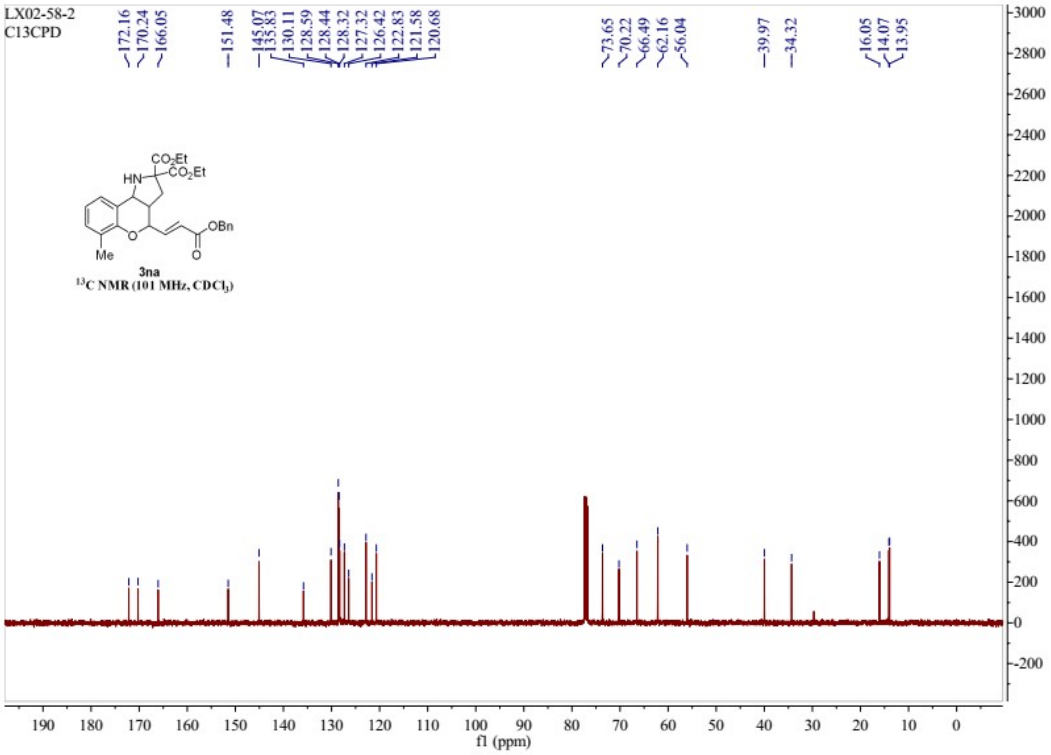

PROTON
CO2Et
CO2Et
HN
OBn
O
OMe
3la
1H NMR (400 MHz, CDCl3)
4.82
1.00
1.98
0.98
0.97
2.00
1.01
5.10
3.00
0.85
2.03
1.03
3.26
3.00
f1 (ppm)

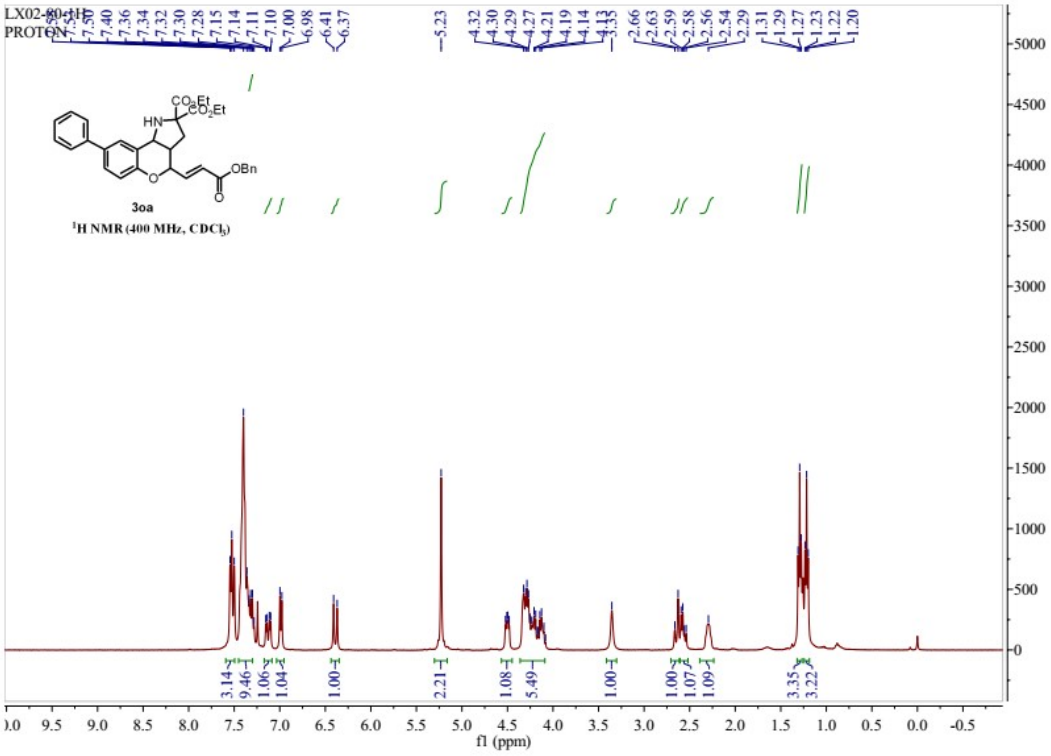

LX02-56-2
C13CPD
172.10
170.21
165.77
148.53
144.36
142.83
135.80
128.57
128.37
128.29
124.09
121.40
110.93
77.38
77.06
76.74
74.42
70.24
66.46
62.16
62.14
56.03
55.46
39.74
34.28
14.06
13.94
CO2Et
CO2Et
HN
OBn
OMe
O
3la
13C NMR (101 MHz, CDCl3)
fl (ppm)

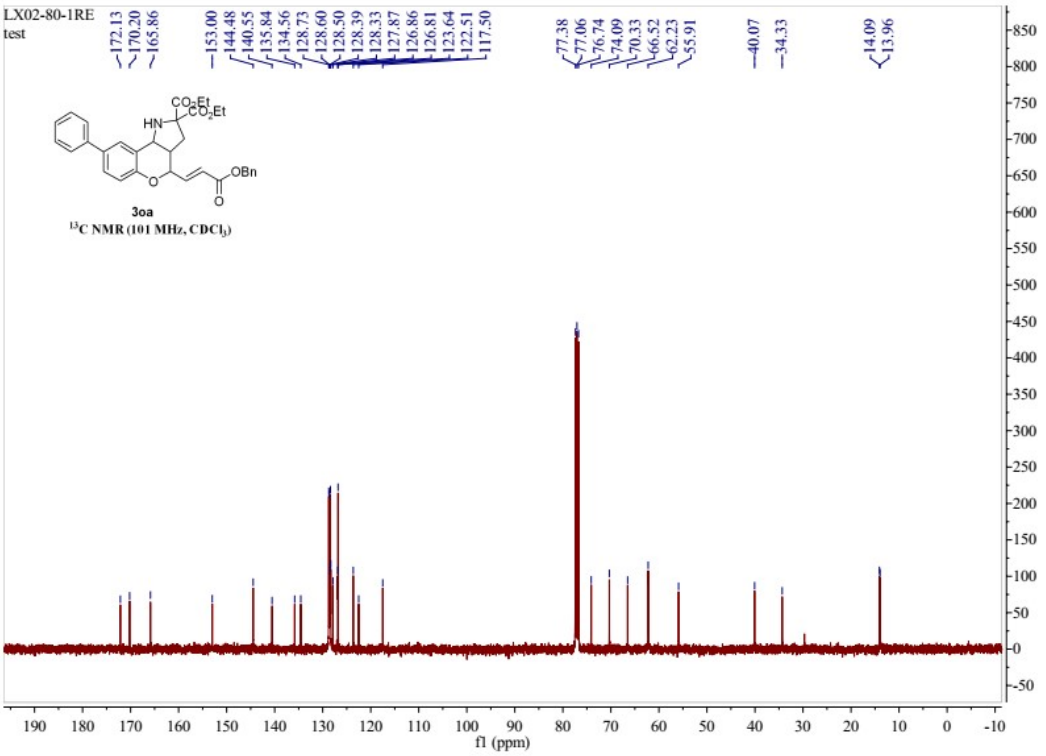

PROTON
CO2Et
CO2Et
HN
OBn
OEt
O
3ma
1H NMR (400 MHz, CDCl3)
4.92
1.00
2.01
0.96
0.97
2.05
1.01
3.09
4.19
0.82
2.08
1.02
3.07
3.29
3.11
fl (ppm)

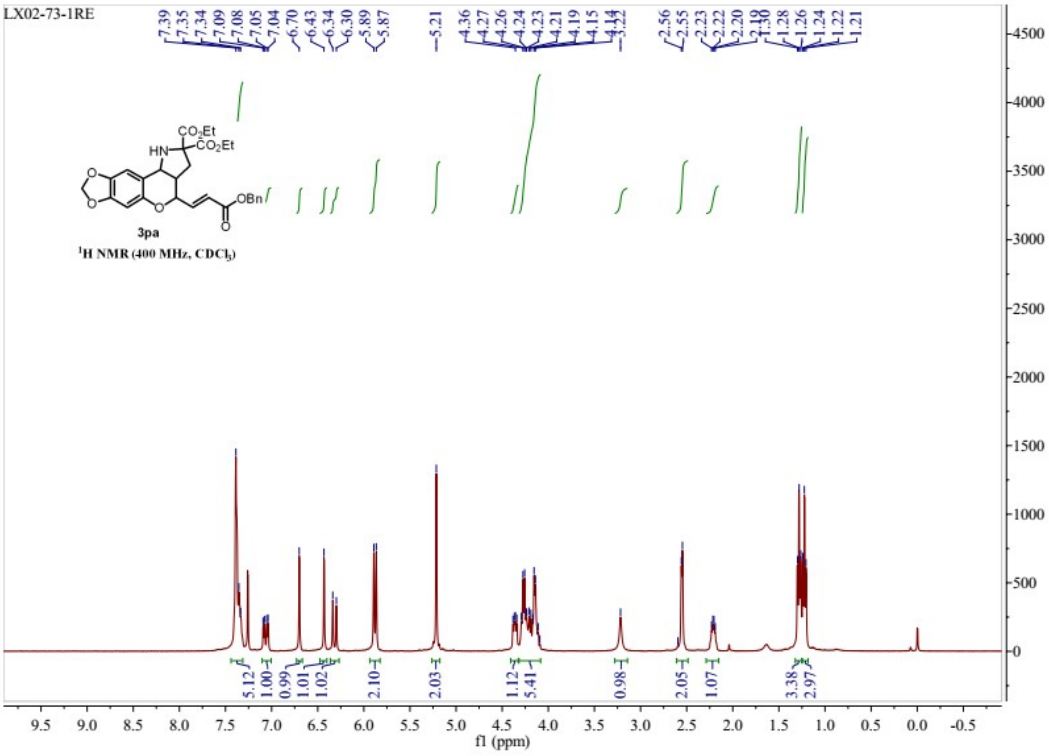

LX02-55-4
C13CPD
172.11
170.24
165.90
147.80
144.63
143.30
135.86
128.58
128.36
128.29
123.71
121.52
120.97
112.88
74.29
70.27
66.45
64.70
62.17
62.15
55.57
39.80
34.32
14.84
14.07
13.96
CO2Et
CO2Et
HN
OBn
OEt
O
3ma
13C NMR (101 MHz, CDCl3)
fl (ppm)

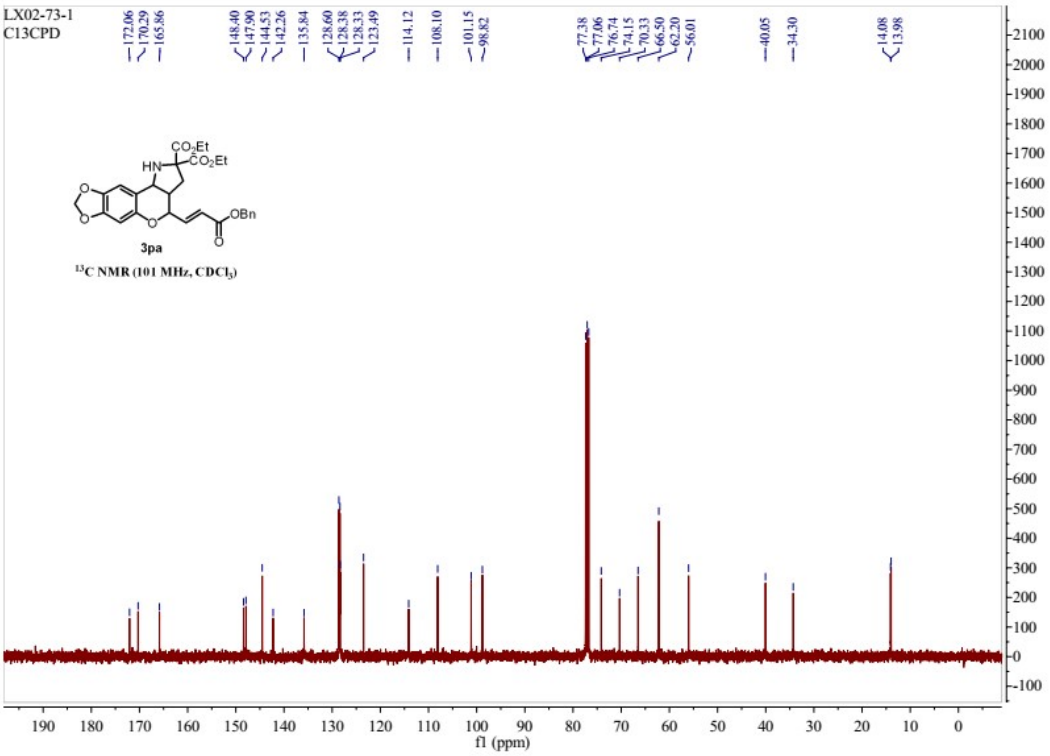

LX02-58-2
PROTON
7.39
7.37
7.36
7.36
7.35
7.34
7.19
7.18
7.16
7.14
7.13
7.11
7.06
7.04
6.87
6.85
6.83
6.39
6.39
6.35
6.35
5.24
5.22
4.45
4.30
4.29
4.28
4.27
4.26
4.25
4.25
4.23
4.21
4.20
4.18
4.14
4.12
2.62
2.62
2.59
2.57
2.24
2.23
2.23
2.21
1.31
1.29
1.27
1.24
1.22
1.20
CO2Et
CO2Et
HN
OBn
Me
O
3na
1H NMR (400 MHz, CDCl3)
5.10
1.11
0.95
1.00
1.01
1.00
2.12
1.06
5.31
0.93
1.06
1.02
4.22
3.31
3.12
fl (ppm)

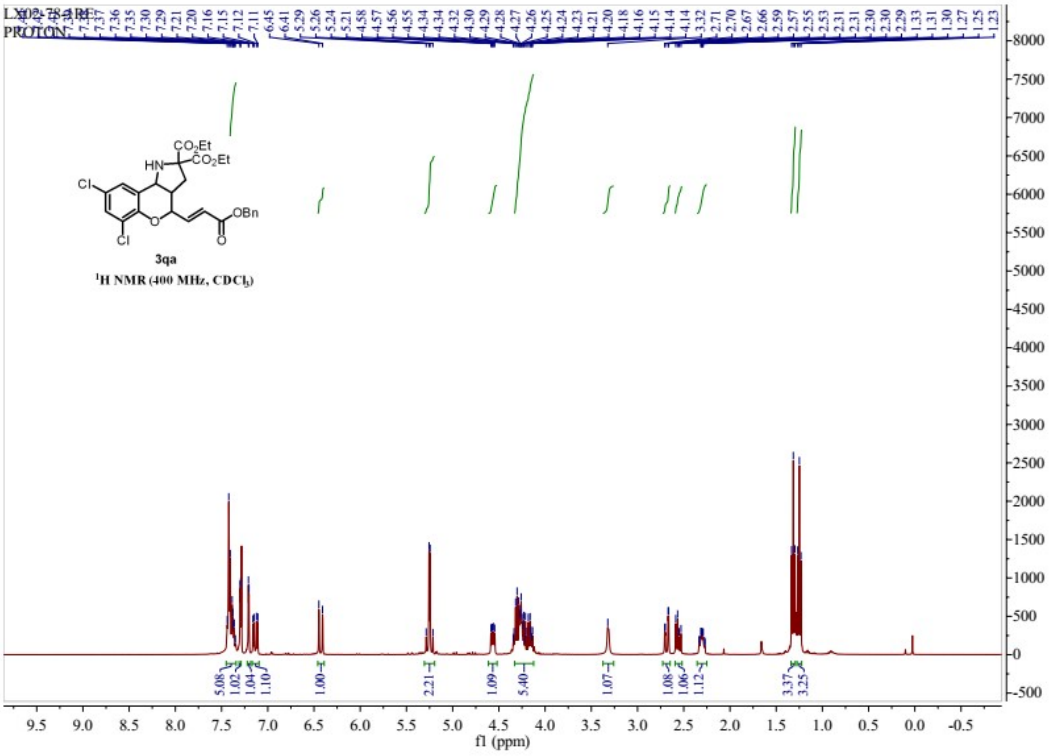

LX02-58-2
C13CPD
172.16
170.24
166.05
151.48
145.07
135.83
130.11
128.59
128.44
128.32
127.32
126.42
122.83
121.58
120.68
73.65
70.22
66.49
62.16
56.04
39.97
34.32
16.05
14.07
13.95
CO2Et
CO2Et
HN
OBn
O
Me
3na
13C NMR (101 MHz, CDCl3)
f1 (ppm)

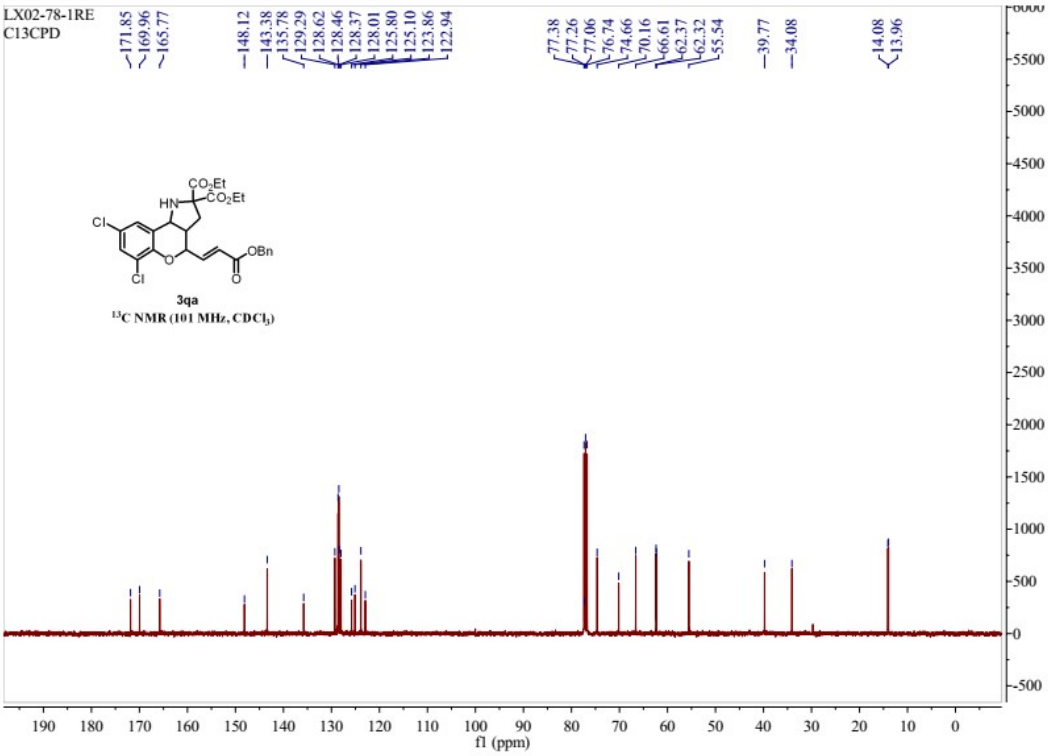

PROTON
7.50
7.40
7.36
7.34
7.32
7.30
7.28
7.15
7.14
7.11
7.10
7.00
6.98
6.41
6.37
5.23
4.32
4.30
4.29
4.27
4.21
4.19
4.14
4.13
3.33
2.66
2.63
2.59
2.58
2.56
2.54
2.29
1.31
1.29
1.27
1.23
1.22
1.20
CO2Et
CO2Et
HN
OBn
O
3oa
1H NMR (400 MHz, CDCl3)
3.14
9.46
1.06
1.04
1.00
2.21
1.08
5.49
1.00
1.00
1.07
1.09
3.35
3.22
f1 (ppm)

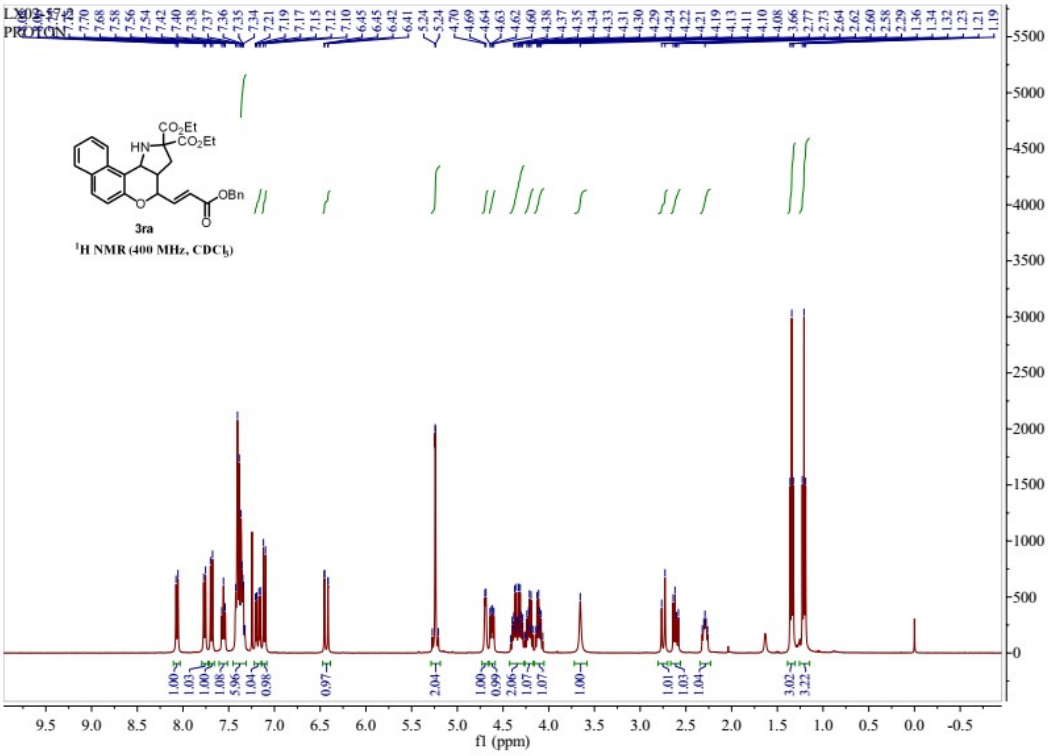

LX02-80-1RE
test
172.13
170.20
165.86
153.00
144.48
140.55
135.84
134.56
128.73
128.60
128.50
128.39
128.33
127.87
126.86
126.81
123.64
122.51
117.50
77.38
77.06
76.74
74.09
70.33
66.52
62.23
55.91
40.07
34.33
14.09
13.96
CO2Et
CO2Et
HN
OBn
O
3oa
13C NMR (101 MHz, CDCl3)
f1 (ppm)

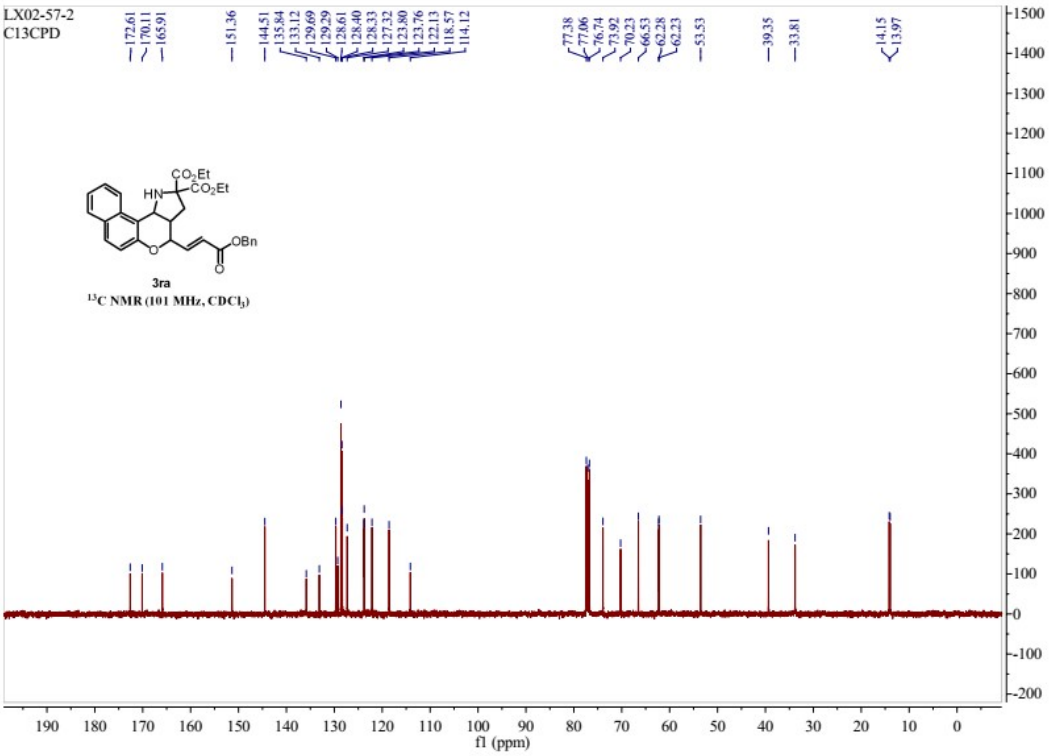

LX02-73-1RE
7.39
7.35
7.34
7.09
7.08
7.05
7.04
6.70
6.43
6.34
6.30
5.89
5.87
5.21
4.36
4.27
4.26
4.24
4.23
4.21
4.19
4.15
4.14
3.22
2.56
2.55
2.23
2.22
2.20
1.28
1.26
1.24
1.22
1.21
CO2Et
CO2Et
HN
OBn
O
3pa
1H NMR (400 MHz, CDCl3)
5.12
1.00
0.99
1.01
1.02
2.10
2.03
1.12
5.41
0.98
2.05
1.07
3.38
2.97
f1 (ppm)

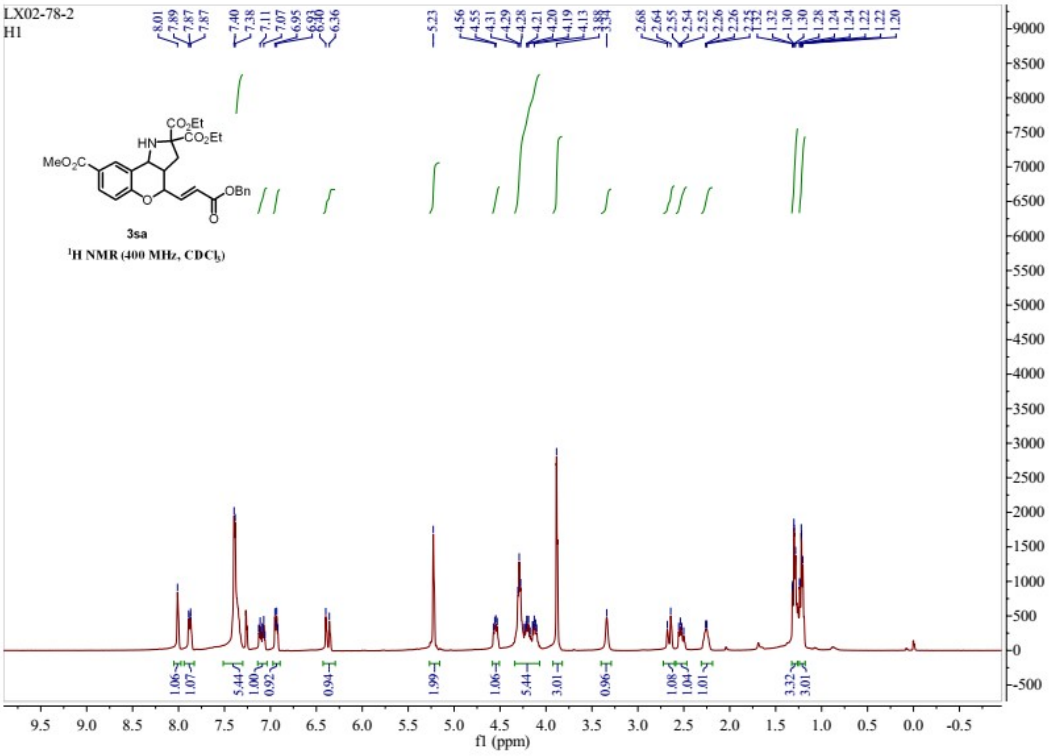

LX02-73-1
C13CPD
3pa
^{13}C NMR (101 MHz, CDCl$_3$)
f1 (ppm)

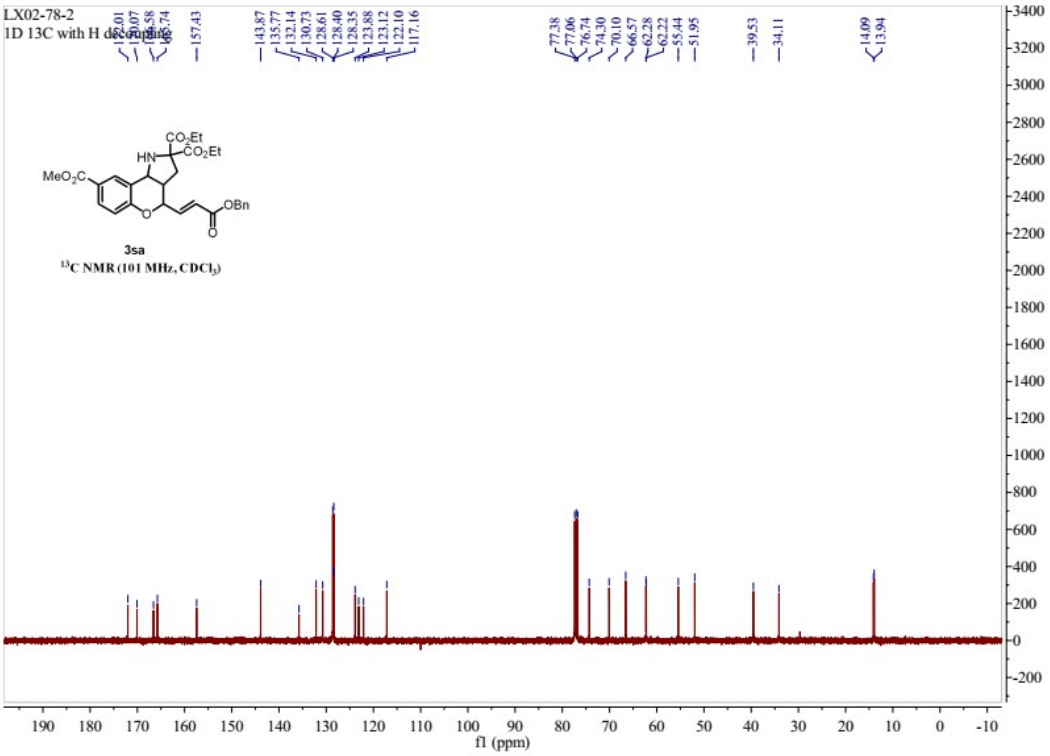

PROTON
3qa
^{1}H NMR (400 MHz, CDCl$_3$)
f1 (ppm)

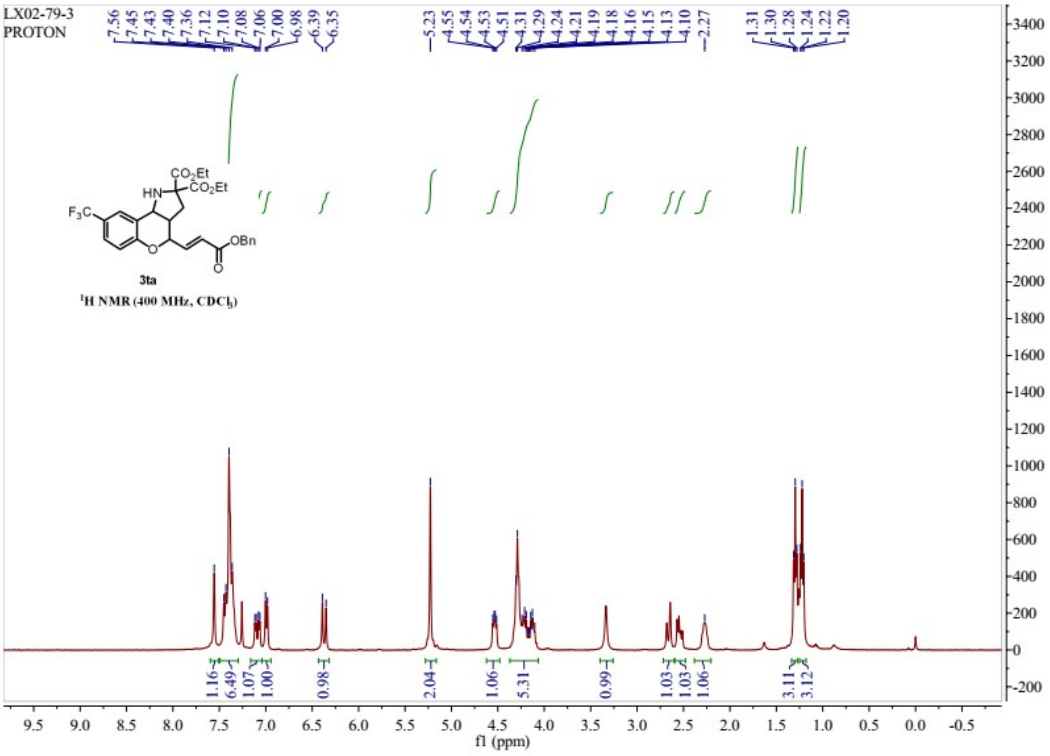

LX02-78-1RE
C13CPD
171.85
169.96
165.77
148.12
143.38
135.78
129.29
128.62
128.46
128.37
128.01
125.80
125.10
123.86
122.94
77.38
77.26
77.06
76.74
74.66
70.16
66.61
62.37
62.32
55.54
39.77
34.08
14.08
13.96
3qa
13C NMR (101 MHz, CDCl3)
f1 (ppm)

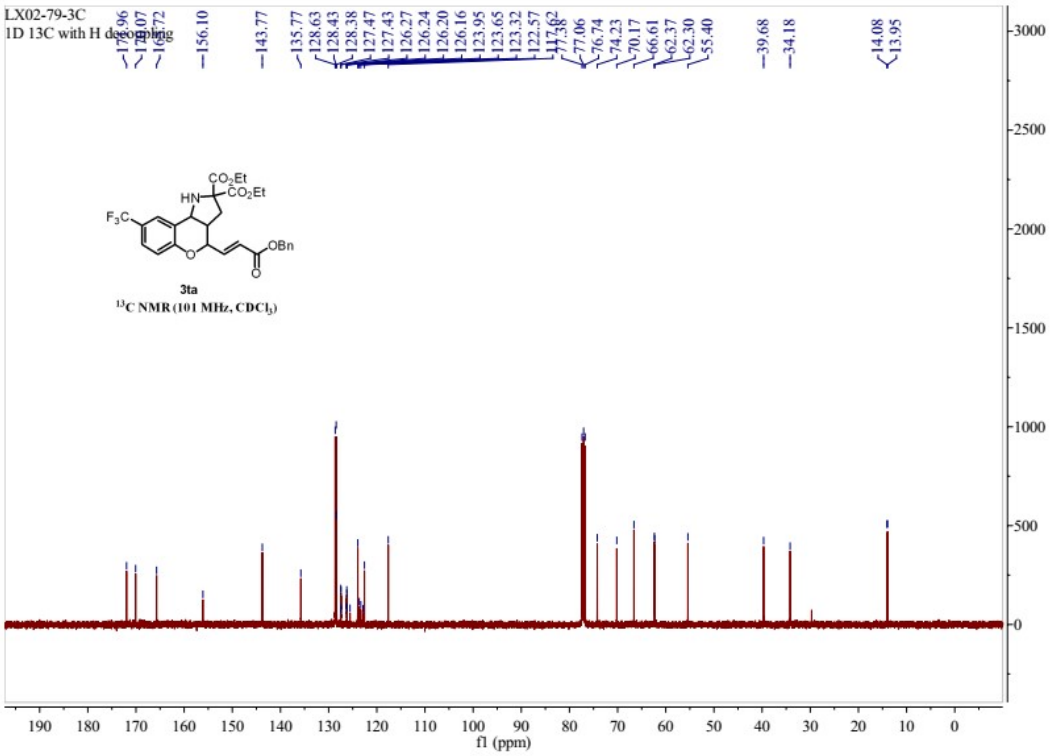

PROTON
3ra
1H NMR (400 MHz, CDCl3)
f1 (ppm)

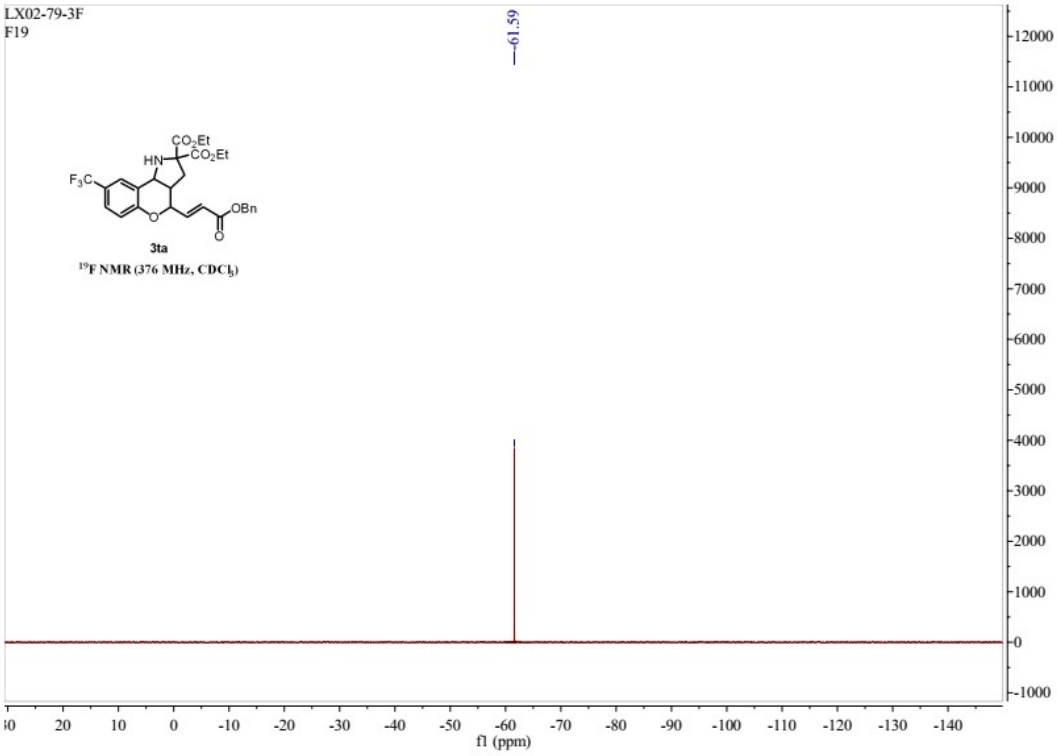

LX02-57-2
C13CPD
172.61
170.11
165.91
151.36
144.51
135.84
133.12
129.69
129.29
128.61
128.40
128.33
127.32
123.80
123.76
122.13
118.57
114.12
77.38
77.06
76.74
73.92
70.23
66.53
62.28
62.23
53.53
39.35
33.81
14.15
13.97
CO2Et
CO2Et
HN
O
OBn
O
3ra
13C NMR (101 MHz, CDCl3)
fl (ppm)

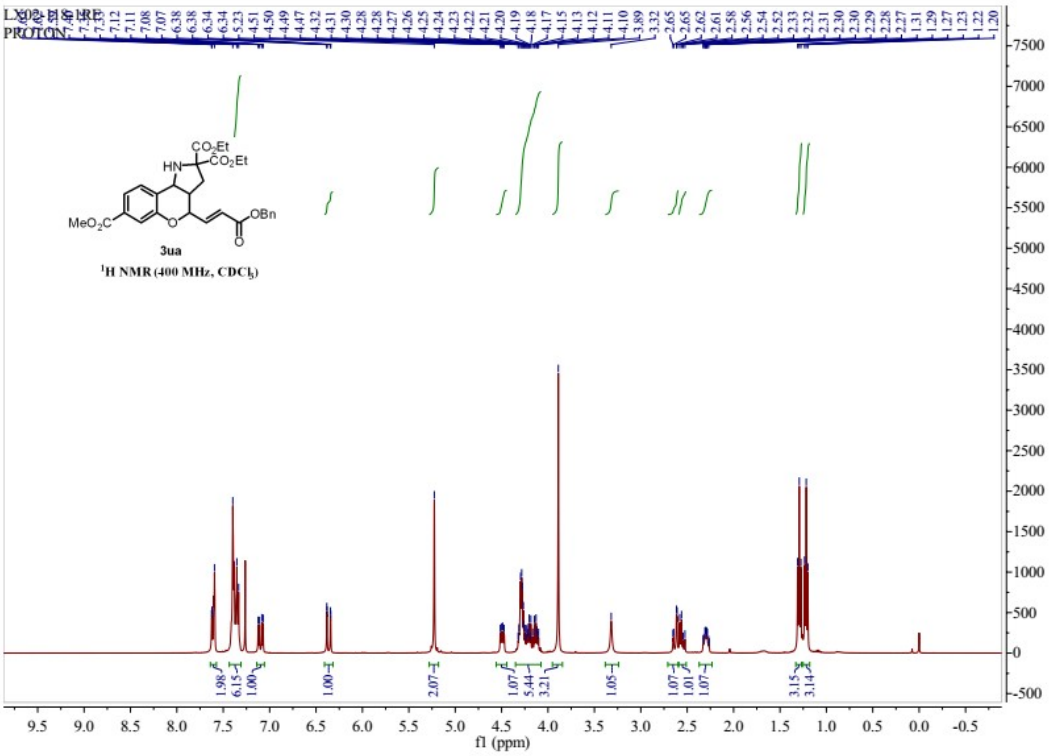

LX02-78-2
H1
8.01
7.89
7.87
7.87
7.40
7.38
7.11
7.07
6.95
6.93
6.40
6.36
5.23
4.56
4.55
4.31
4.29
4.28
4.21
4.20
4.19
4.13
3.88
3.84
2.68
2.64
2.55
2.54
2.52
2.26
2.26
2.25
1.32
1.30
1.30
1.28
1.24
1.24
1.22
1.22
1.20
CO2Et
CO2Et
HN
MeO2C
O
OBn
O
3sa
1H NMR (400 MHz, CDCl3)
1.06
1.07
5.44
1.00
0.92
0.94
1.99
1.06
5.44
3.01
0.96
1.08
1.04
1.01
3.32
3.01
fl (ppm)

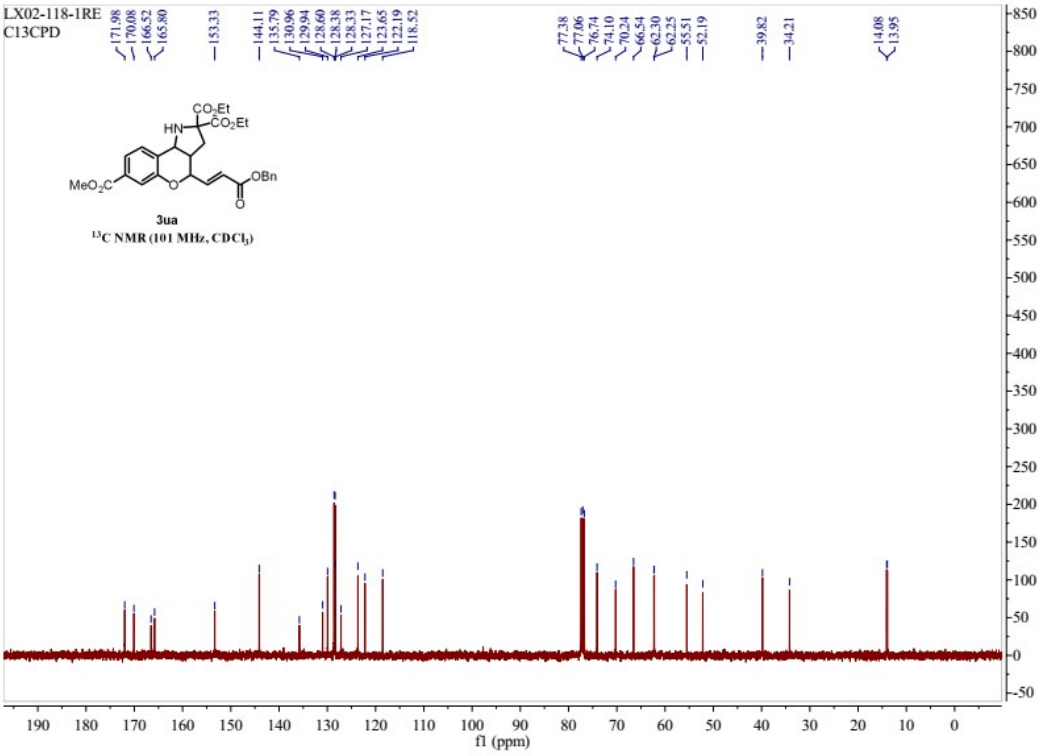

LX02-78-2
1D 13C with H decoupling
157.43
143.87
135.77
132.14
130.73
128.61
128.40
128.35
123.88
123.12
122.10
117.16
77.38
77.06
76.74
74.30
70.10
66.57
62.28
62.22
55.44
51.95
39.53
34.11
14.09
13.94
CO2Et
HN
CO2Et
MeO2C
OBn
O
3sa
13C NMR (101 MHz, CDCl3)
f1 (ppm)

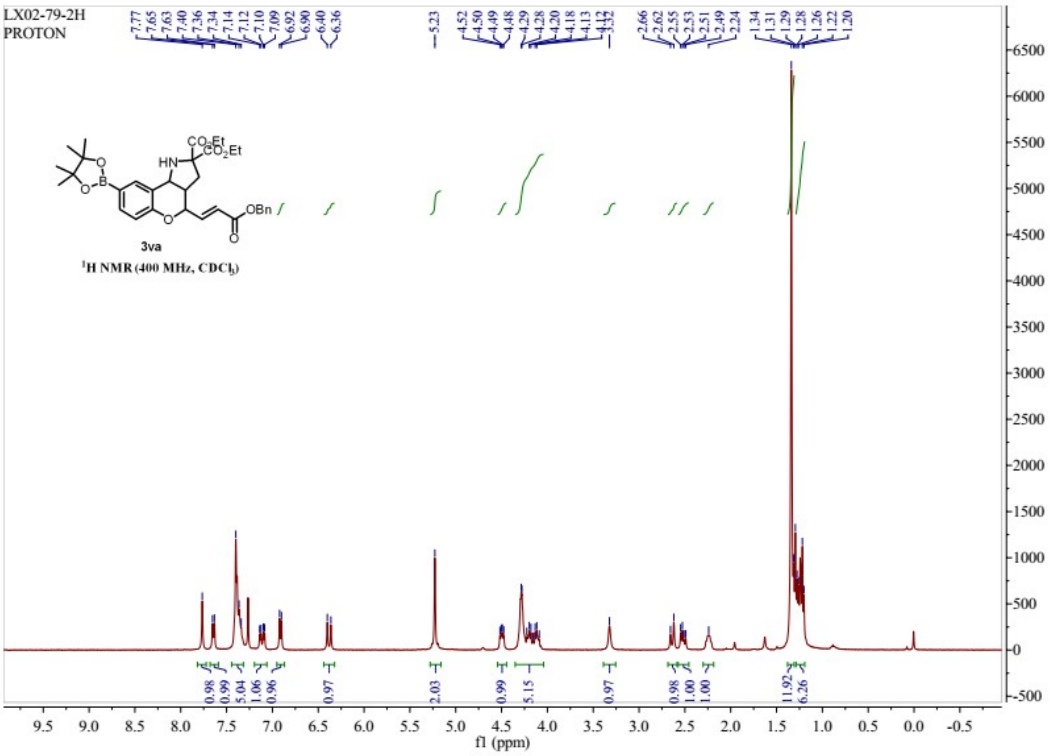

LX02-79-3
PROTON
7.56
7.45
7.43
7.40
7.36
7.12
7.10
7.08
7.06
7.00
6.98
6.39
6.35
5.23
4.55
4.54
4.53
4.51
4.31
4.29
4.24
4.21
4.19
4.18
4.16
4.15
4.13
4.10
2.27
1.31
1.30
1.28
1.24
1.22
1.20
CO2Et
HN
CO2Et
F3C
OBn
O
3ta
1H NMR (400 MHz, CDCl3)
1.16
6.49
1.07
1.00
0.98
2.04
1.06
5.31
0.99
1.03
1.03
1.06
3.11
3.12
f1 (ppm)

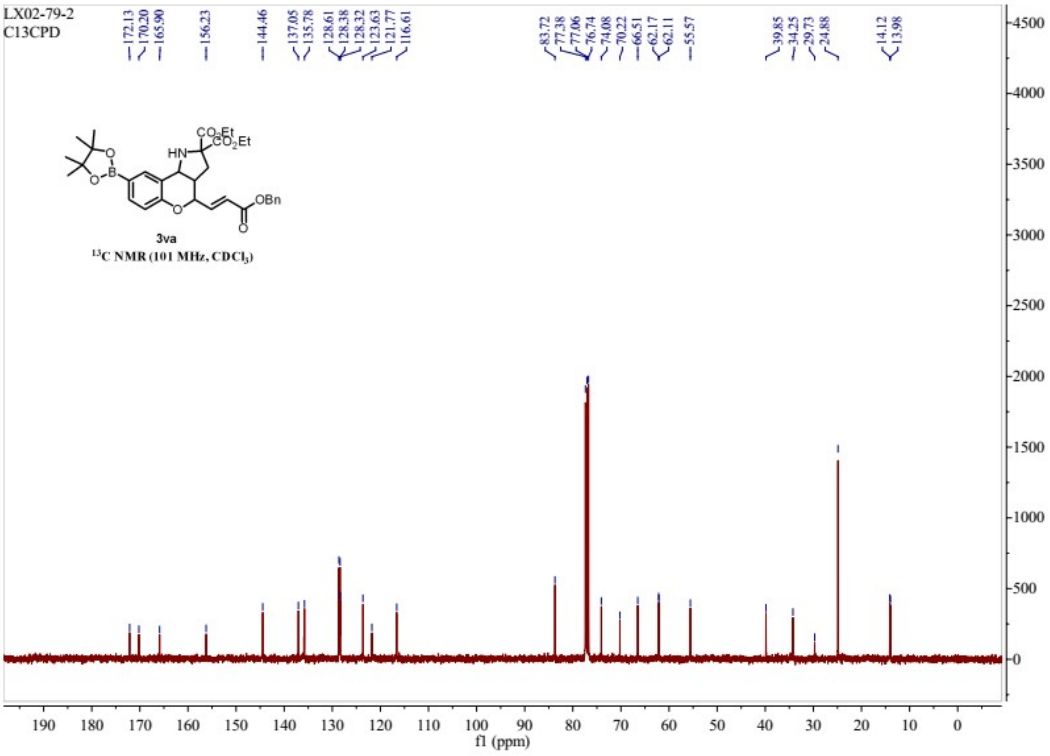

LX02-79-3C
1D 13C with H decoupling
156.10
143.77
135.77
128.63
128.43
128.38
127.47
127.43
126.27
126.24
126.20
126.16
123.95
123.65
123.32
122.57
77.06
76.74
74.23
70.17
66.61
62.37
62.30
55.40
39.68
34.18
14.08
13.95
3ta
13C NMR (101 MHz, CDCl3)
f1 (ppm)

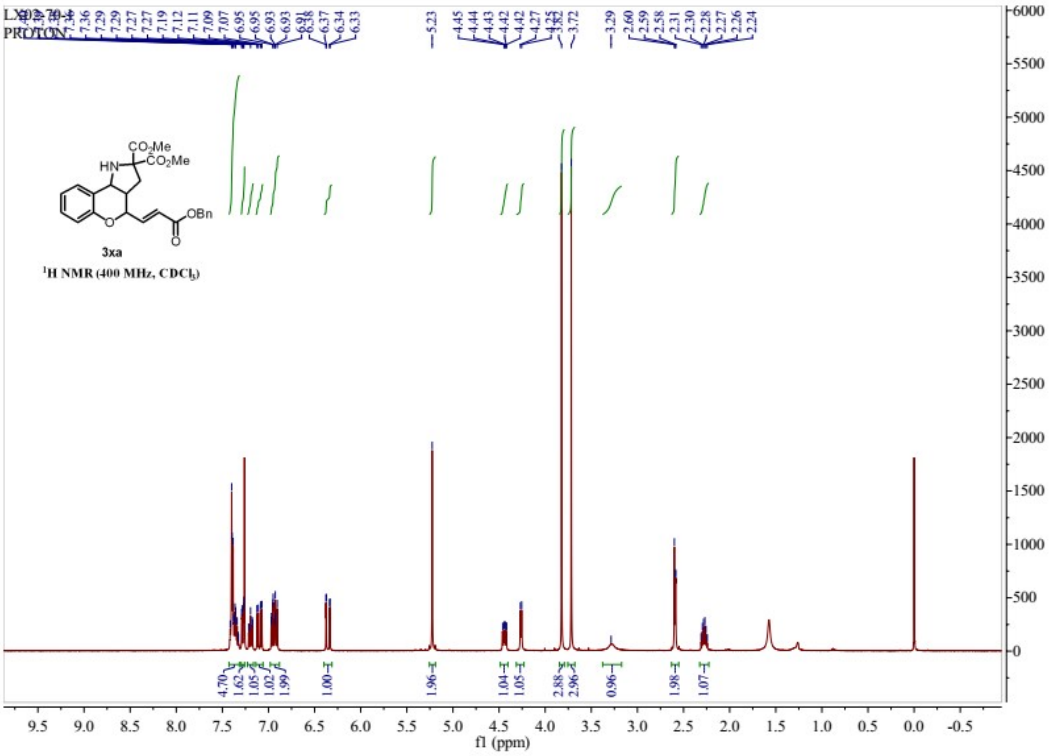

LX02-79-3F
F19
61.59
3ta
19F NMR (376 MHz, CDCl3)
f1 (ppm)

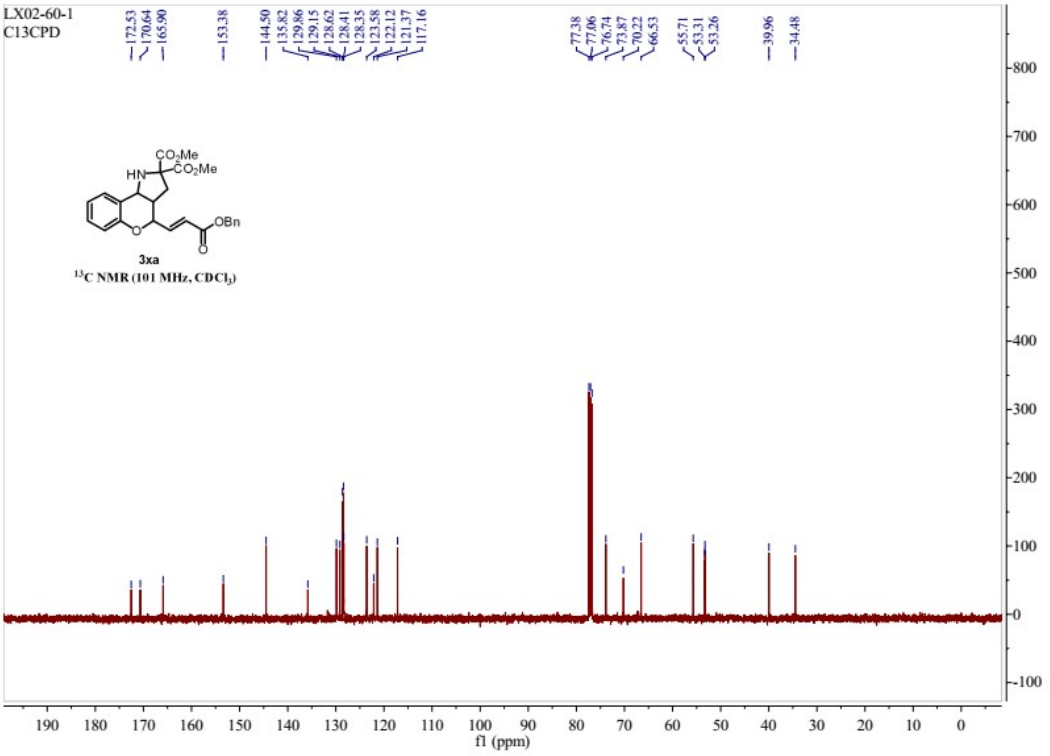

PROTON
3ua
^{1}H NMR (400 MHz, CDCl$_3$)
fl (ppm)

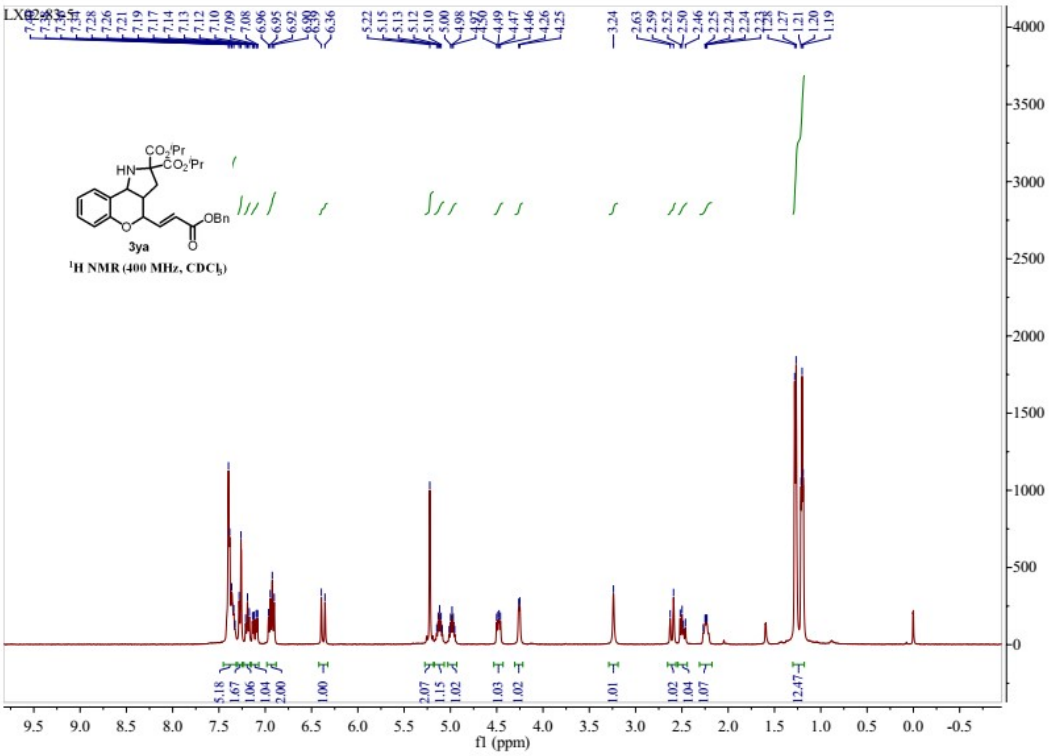

LX02-118-1RE
C13CPD
3ua
^{13}C NMR (101 MHz, CDCl$_3$)
fl (ppm)

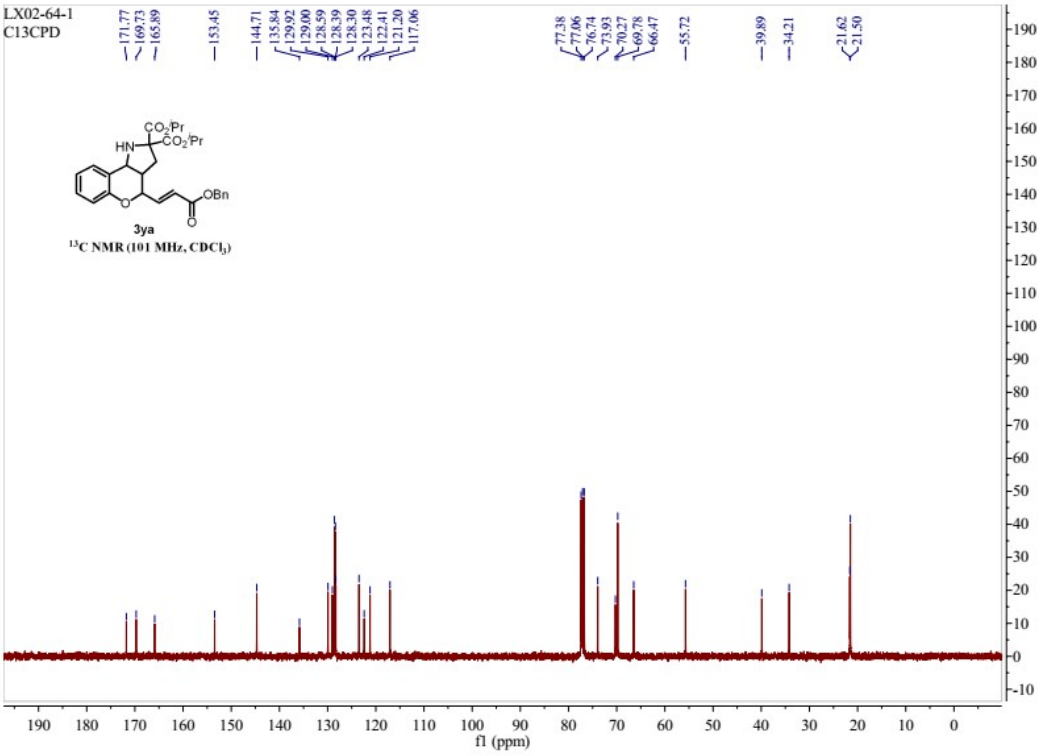

LX02-79-2H
PROTON
3va
^{1}H NMR (400 MHz, $CDCl_3$)
f1 (ppm)

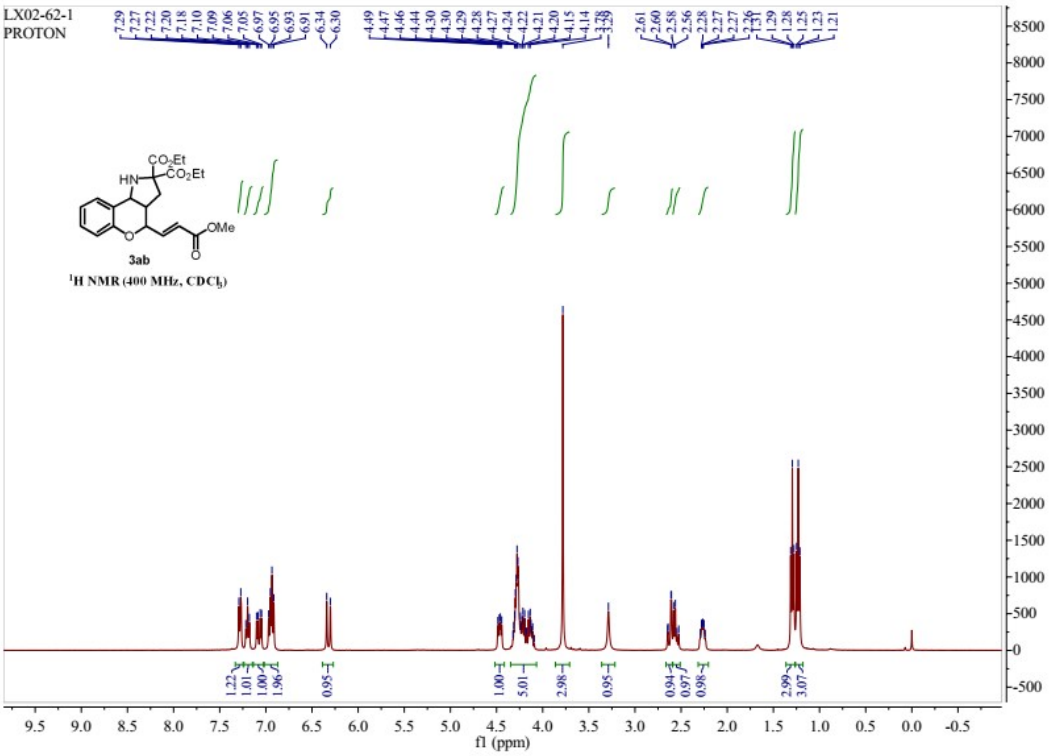

LX02-79-2
C13CPD
3va
^{13}C NMR (101 MHz, $CDCl_3$)
f1 (ppm)

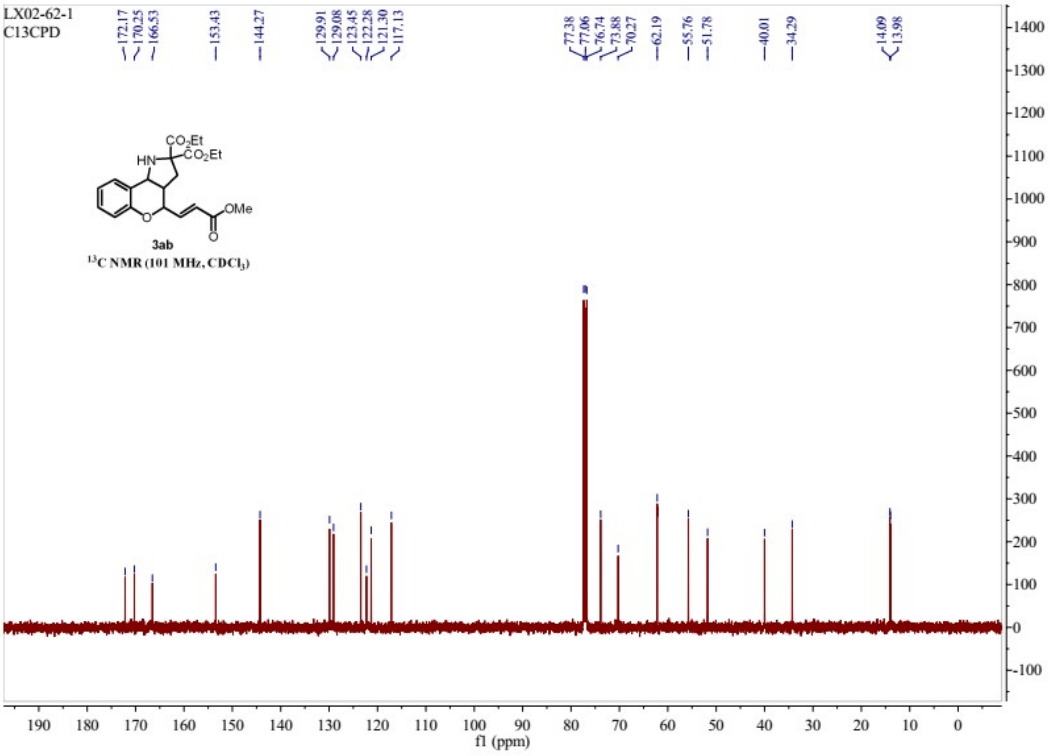

PROTON
3xa
^{1}H NMR (400 MHz, CDCl$_3$)
f1 (ppm)

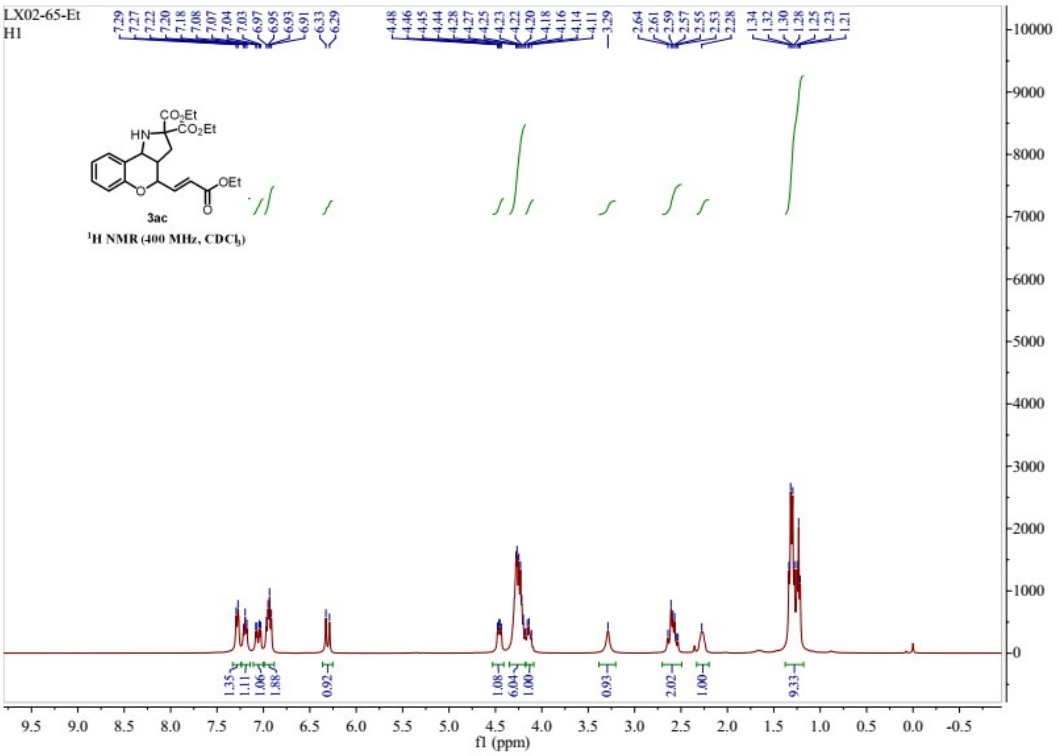

LX02-60-1
C13CPD
3xa
^{13}C NMR (101 MHz, CDCl$_3$)
f1 (ppm)

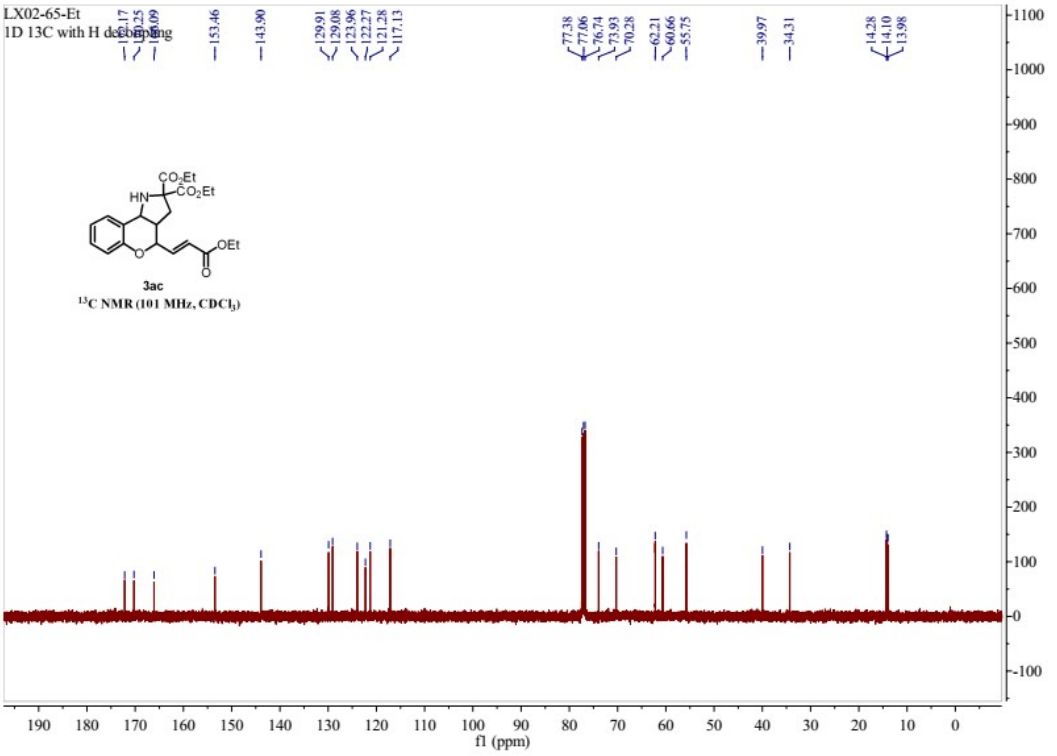

3ya
^{1}H NMR (400 MHz, CDCl$_3$)
fl (ppm)

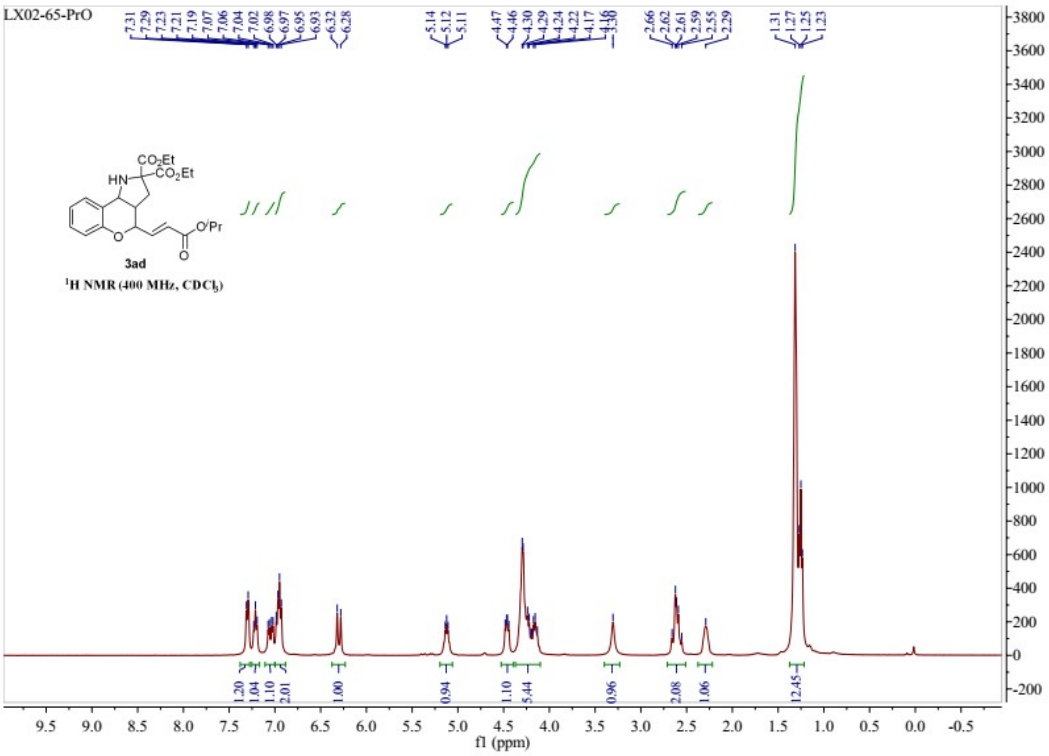

LX02-64-1
C13CPD
3ya
^{13}C NMR (101 MHz, CDCl$_3$)
fl (ppm)

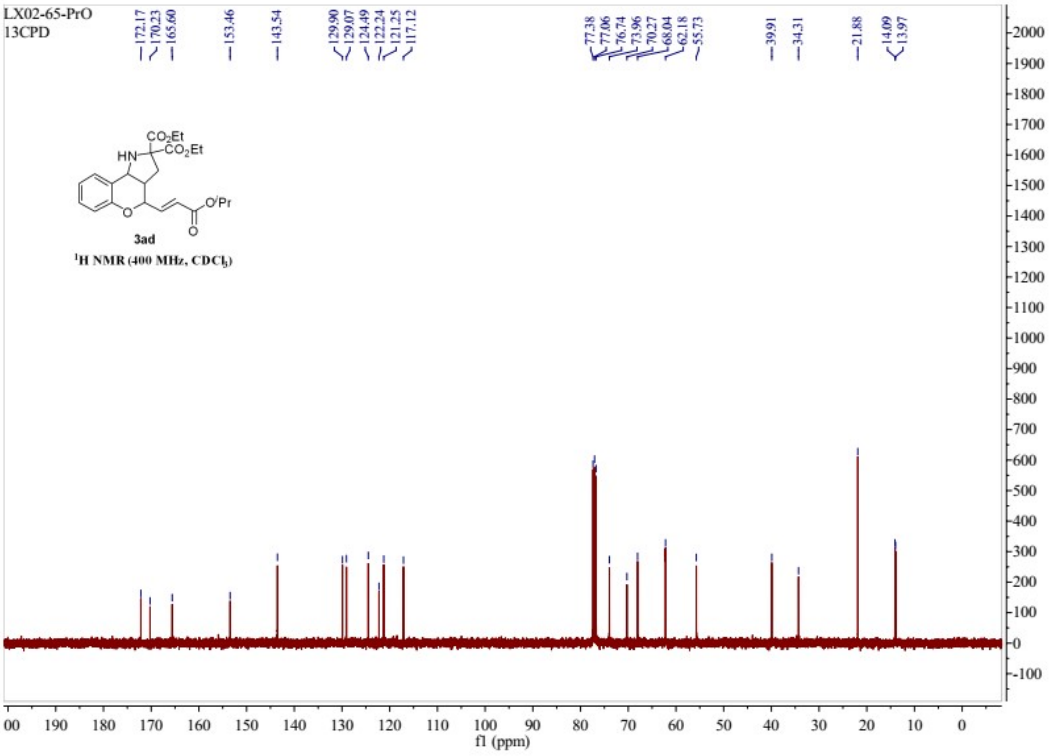

LX02-62-1
PROTON
3ab
^{1}H NMR (400 MHz, CDCl$_3$)
f1 (ppm)

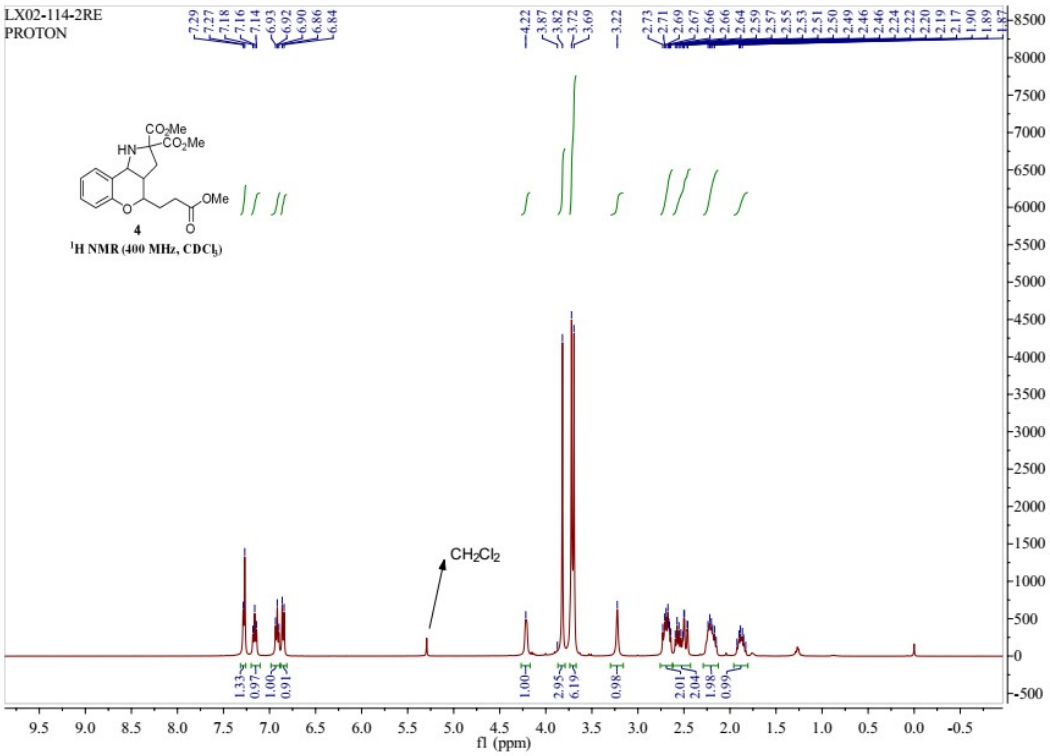

LX02-62-1
C13CPD
3ab
^{13}C NMR (101 MHz, CDCl$_3$)
f1 (ppm)

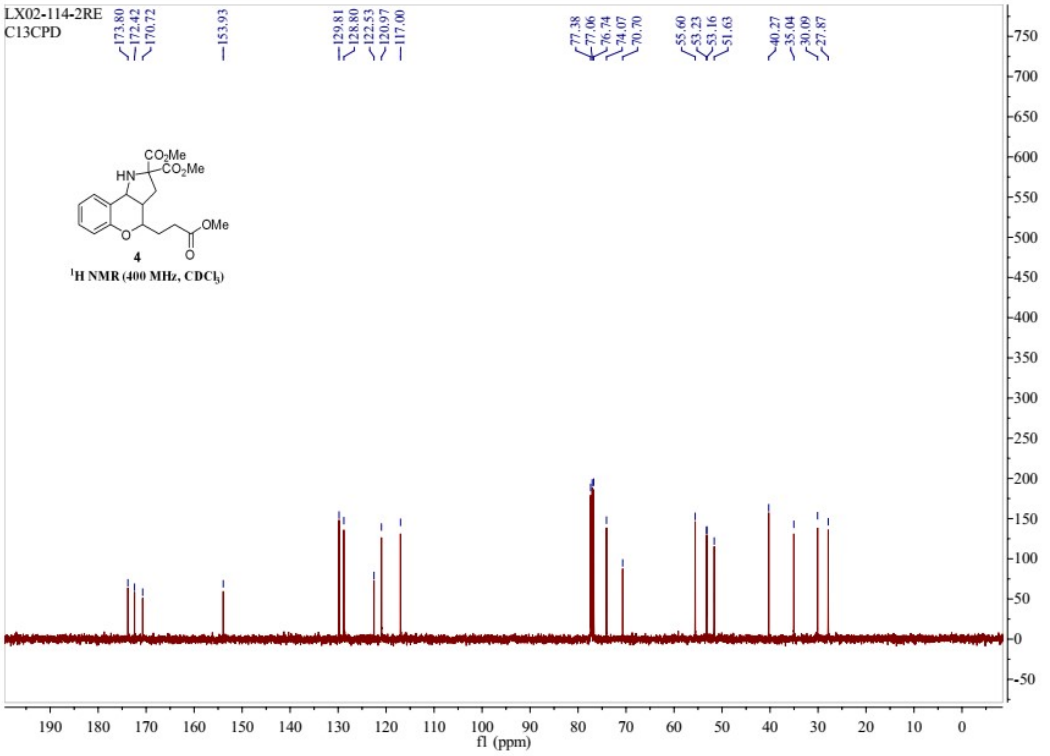

LX02-65-Et
H1
3ac
^{1}H NMR (400 MHz, CDCl$_3$)
f1 (ppm)

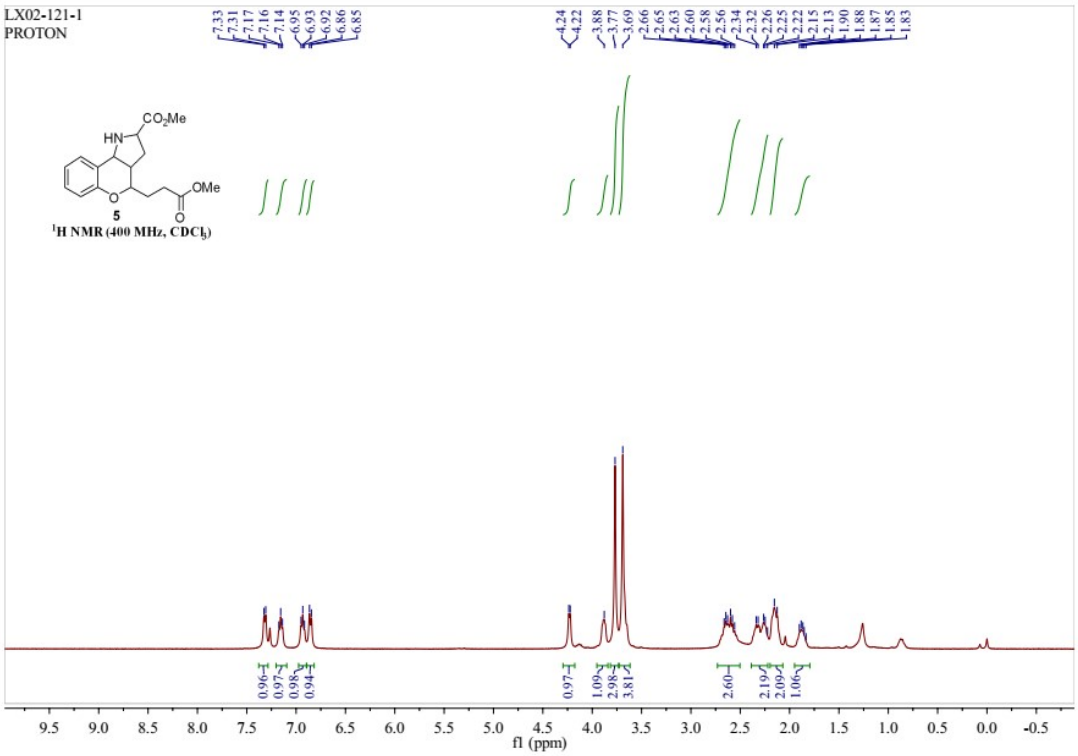

LX02-65-Et
1D 13C with H decoupling
3ac
^{13}C NMR (101 MHz, CDCl$_3$)
f1 (ppm)

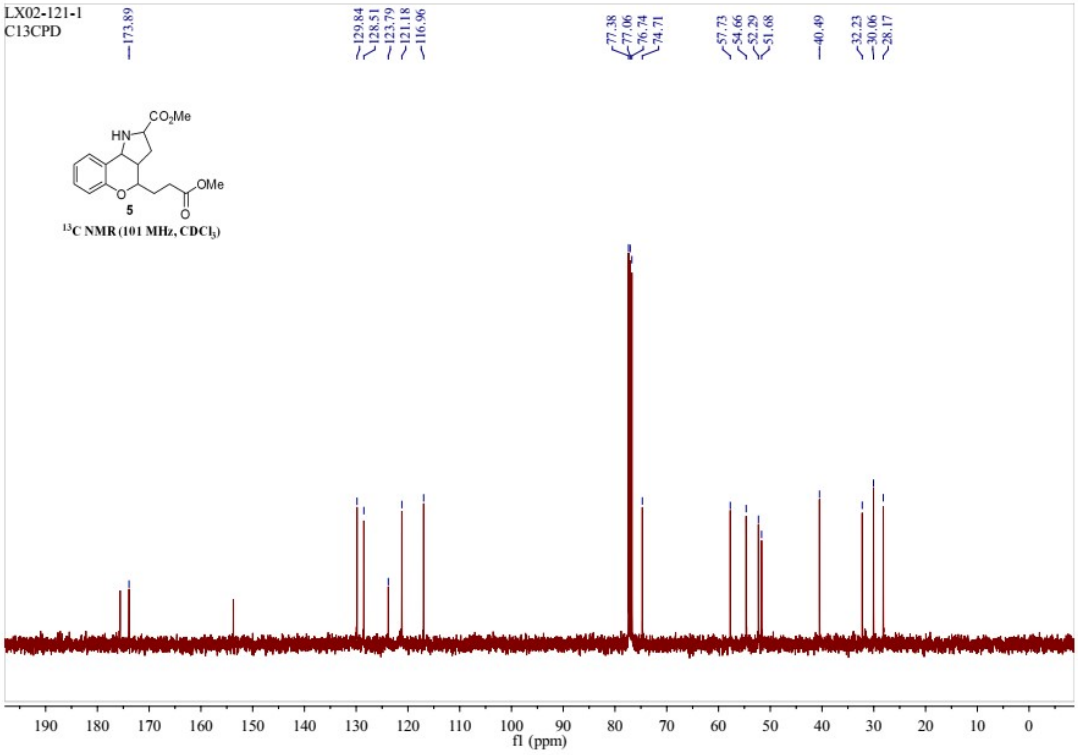

LX02-65-PrO
3ad
^{1}H NMR (400 MHz, CDCl$_3$)
f1 (ppm)


LX02-65-PrO
13CPD
3ad
^{1}H NMR (400 MHz, CDCl$_3$)
f1 (ppm)

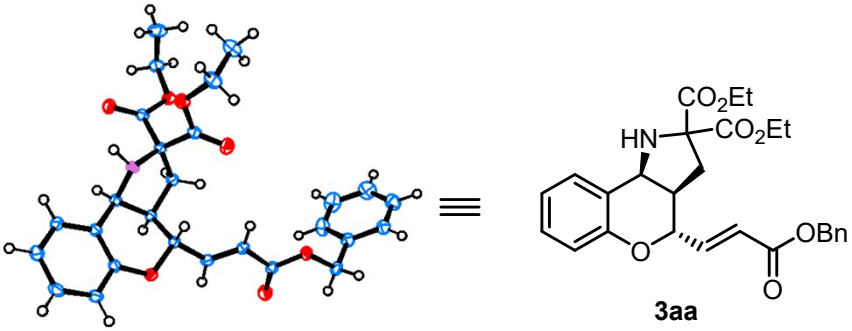

LX02-114-2RE
PROTON
CO2Me
CO2Me
HN
OMe
O
4
1H NMR (400 MHz, CDCl3)
CH2Cl2
f1 (ppm)


LX02-114-2RE
C13CPD
CO2Me
CO2Me
HN
OMe
O
4
1H NMR (400 MHz, CDCl3)
f1 (ppm)


LX02-121-1
PROTON
7.33
7.31
7.17
7.16
7.14
6.95
6.93
6.92
6.86
6.85
4.24
4.22
3.88
3.77
3.69
2.66
2.65
2.63
2.60
2.58
2.56
2.34
2.32
2.26
2.25
2.22
2.15
2.13
1.90
1.88
1.87
1.85
1.83
CO2Me
HN
OMe
O
5
1H NMR (400 MHz, CDCl3)
0.96
0.97
0.98
0.94
0.97
1.09
2.98
3.81
2.60
2.19
2.09
1.06
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


LX02-121-1
C13CPD
173.89
129.84
128.51
123.79
121.18
116.96
77.38
77.06
76.74
74.71
57.73
54.66
52.29
51.68
40.49
32.23
30.06
28.17
CO2Me
HN
OMe
O
5
13C NMR (101 MHz, CDCl3)
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

11. X-Ray Crystallography Data of 3aa



S-Figure 2. ORTEP diagram of 3**aa** (CCDC: 2075585). Thermal ellipsoids are shown at the 50% probability level. A colorless block crystal of **3aa** for X-ray diffraction was obtained by slowly volatilizing a solution of 3aa in hexane/ ethyl acetate (5:1). The X-ray intensity data was measured on a Rigaku 007 Saturn 70 single crystal diffractometer.

S-Table 2. Crystal data and structure refinement for **3aa**.

Identification code	**3aa**
Empirical formula	$C_{27}H_{29}NO_7$
Formula weight	479.51
Temperature/K	113.15
Crystal system	triclinic
Space group	P-1
a/Å	10.7992(6)
b/Å	10.9972(5)
c/Å	11.7181(7)
α/°	93.977(4)
β/°	106.212(5)
γ/°	112.740(5)
Volume/Å^3	1207.49(12)
Z	2
ρ_{calc}g/cm^3	1.319
μ/mm^{-1}	0.095
F(000)	508.0
Crystal size/mm^3	0.18 × 0.16 × 0.15
Radiation	MoKα (λ = 0.71073)
2Θ range for data collection/°	3.694 to 65.7
Index ranges	-15 ≤ h ≤ 16, -16 ≤ k ≤ 15, -17 ≤ l ≤ 17
Reflections collected	18298
Independent reflections	8080 [R_{int} = 0.0326, R_{sigma} = 0.0474]
Data/restraints/parameters	8080/0/323

Goodness-of-fit on F^2	1.038
Final R indexes [I>=2σ (I)]	R_1 = 0.0472, wR_2 = 0.1073
Final R indexes [all data]	R_1 = 0.0664, wR_2 = 0.1182
Largest diff. peak/hole / e $Å^{-3}$	0.38/-0.23

12. References

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