Electronic Supplementary Information

Enantioselective Intramolecular Cyclization of Alkynyl Esters Catalyzed by Chiral Brønsted Base

Azusa Kondoh,[a] Hoa Thi Quynh Tran,[b] Kyoko Kimura[b] and Masahiro Terada*[a,b]

[a] Research and Analytical Center for Giant Molecules, Graduate School of Science Tohoku University, Aoba-Ku, Sendai 980-8578, Japan
[b] Department of Chemistry, Graduate School of Science, Tohoku University, Aoba-Ku, Sendai 980-8578, Japan

Contents

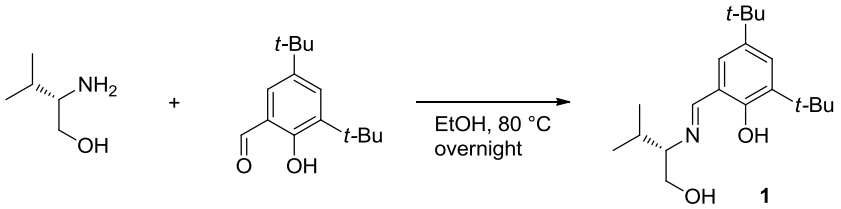
General Information

Unless otherwise noted, the reactions were carried out with dried glassware under argon atmosphere. ^{1}H NMR spectra were recorded on a JEOL JNM-ECA600 (600 MHz) spectrometer. Chemical shifts are reported in ppm from the solvent resonance or tetramethylsilane (TMS) as the internal standard ($CDCl_3$: 7.26 ppm, TMS: 0.00 ppm). Data are reported as follows: chemical shift, integration, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), and coupling constants (Hz). ^{13}C NMR spectra were recorded on a JEOL JNM-ECA600 (150 MHz) spectrometer with complete proton decoupling. Chemical shifts are reported in ppm from the solvent resonance as the internal standard ($CDCl_3$: 77.0 ppm). Analytical thin layer chromatography (TLC) was performed on Merck precoated TLC plates (silica gel 60 GF_{254}, 0.25 mm). Flash column chromatography was performed on silica gel 60N (spherical, neutral, 40-50 μm; Kanto Chemical Co., Inc.). High-performance liquid chromatography (HPLC) was performed on a Jasco equipped with a variable wavelength detector using Daicel chiral column (0.46 × 25 cm). Optical rotations were measured on a Jasco P-1020 digital polarimeter with a sodium lamp and reported as follows; $[\alpha]^{T\,^{\circ}C}_{D}$ (*c* = g/100 mL, solvent). High resolution mass spectra analysis was performed on a Bruker Daltonics solariX 9.4T FT-ICR-MS spectrometer at the Instrumental Analysis Center for Chemistry, Graduate School of Science, Tohoku University.

Materials: Unless otherwise noted, materials were purchased from Wako Pure Chemical Industries, Ltd., Tokyo Chemical Industry Co., LTD., Aldrich Inc., and other commercial suppliers and were used without purification. Dichloromethane, tetrahydrofuran and toluene were supplied from Kanto Chemical Co., Inc. as "Dehydrated solvent system". Other solvents were purchased from commercial suppliers as dehydrated solvents, and used under argon atmosphere.

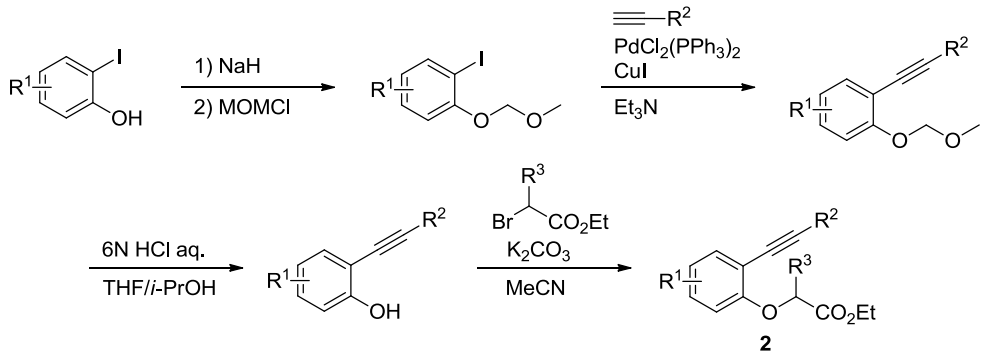
Experimental Procedure

Procedure for Preparation of Chiral Schiff Base 1



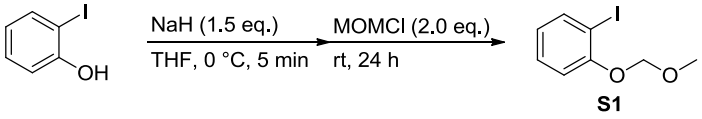
3,5-Di-*tert*-butylsalicylaldehyde (0.23 g, 1.0 mmol) was added to a solution of L-Valinol (0.11 mL, 1.0 mmol) in EtOH (1.0 mL). The resulting mixture was stirred at 80 °C for overnight. Then, solvent was removed under reduced pressure. After purification by flash column chromatography, the pure Schiff base **1a** was obtained (0.30 g, 0.94 mmol, 94%) as a yellow solid.

Procedure for Preparation of Alkynyl Ester 2



Alkynyl esters **2** were synthesized according to the procedure described in the literature.[1] Synthesis of **2a** is representative.

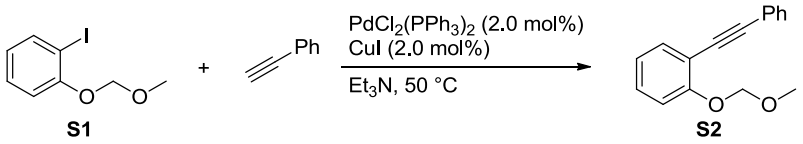
*Synthesis of **S1***



2-iodophenol (2.2 g, 10 mmol) was added portionwise to a suspension of NaH (0.60 g, 15 mmol) in THF (50 mL) at 0 ^{o}C. After stirred for 5 min, chloromethyl methyl ether (1.5 mL, 20 mmol) was added. The reaction mixture was then allowed to warm to room temperature, and further stirred for 24 h. The reaction was quenched with H_2O at 0 ^{o}C, and the product was extracted with Et_2O. The combined organic layer was washed with H_2O (x2) and brine, dried over Na_2SO_4, filtered, and concentrated. The residue was purified by flash column chromatography (AcOEt/ Hexane = 1/25) to afford **S1** (2.31 g, 87% yield) as a colorless oil.

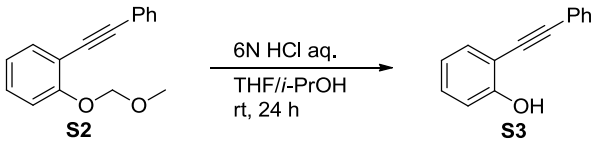
[1] A. Fürstner and P. W. Davies, *J. Am. Chem. Soc.*, 2005, **127**, 15024.

*Synthesis of **S2***



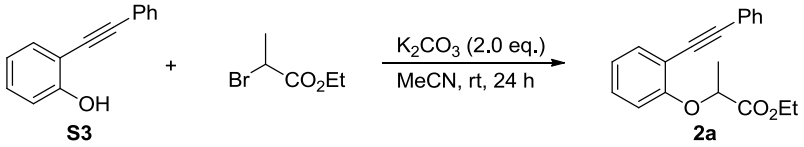
$PdCl_2(PPh_3)_2$ (70 mg, 0.10 mmol) and CuI (19 mg, 0.10 mmol) were added to a solution of **S1** (1.3 g, 5.0 mmol) and phenylacetylene (0.55 mL, 5.0 mmol) in triethylamine (33 mL). The resulting mixture was stirred at 50 °C until the reaction was completed as determined by TLC. Then, the mixture was cooled to room temperature. AcOEt was added to the mixture, and the mixture was filtrated through a pad of celite. After concentrated and purified by flash column chromatography (Et_2O/ Hexane = 1/10), **S2** was obtained (1.1 g, 4.8 mmol, 96%) as a colorless oil.

*Synthesis of **S3***



To a solution of **S2** (1.1 g, 4.5 mmol) in a mixture of THF (4.5 mL) and isopropanol (4.5 mL) was added dropwise 2.0 mL of 6N HCl aq. The reaction was stirred for 24 h. The reaction mixture was extracted with Et_2O and the combined organic layer was washed with H_2O and brine, dried over Na_2SO_4, filtered, and concentrated. The purification of the crude mixture by flash column chromatography (Et_2O t/ Hexane = 1/10) provided S**3** (0.80 g, 4.1 mmol, 92%) as a colorless oil.

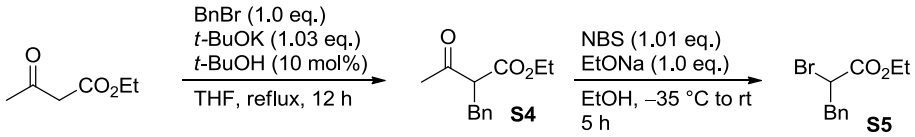
*Synthesis of **2a***



To a solution of S**3** (0.78 g, 4.0 mmol) in acetonitrile (4.0 mL) was added K_2CO_3 (1.1 g, 8.0 mmol). After stirring for 5 min ethyl 2-bromopropionate (0.60 mL, 4.8 mmol) was added to the reaction mixture. The mixture was further stirred for 24 h and then extracted with Et_2O. The combined organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated. The purification by flash column chromatography (Et_2O / Hexane = 1/10) followed by recrystallization from hexane afforded **2a** (0.94 g, 3.2 mmol, 80%) as a white solid.

For the synthesis of **2m** and **2n**, the corresponding ethyl α-bromoacetate derivatives were prepared as follows.

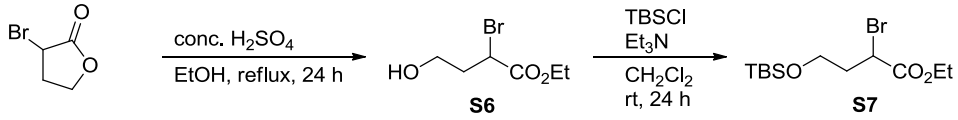
*Synthesis of **S5***[2,3]



To a solution of potassium *tert*-butoxide (1.3 g, 10.3 mmol) in THF (25 mL) were added ethyl acetoacetate (1.3 mL, 10 mmol) and *tert*-butanol (0.10 mL, 1.0 mmol) at 0 °C. After stirring for 30 min, benzyl bromide (1.2 mL, 10 mmol) was added. The resulting mixture was then heated at reflux for 12 h. After cooled to room temperature, the reaction was quenched with H_2O, and sat. aq. $NaHCO_3$ was added. The mixture was extracted with Et_2O. The combined organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated. After purification by flash column chromatography (AcOEt/Hexane = 1/15), **S4** was obtained (1.62g, 7.4 mmol, 74%) as a colorless oil.

To a solution of sodium ethoxide (0.50 g, 7.4 mmol) in ethanol (12 mL) were slowly added **S4** (1.6 g, 7.4 mmol) and *N*-bromosuccinimide (1.3 g, 7.4 mmol) at −35 °C. The mixture was allowed to warm to room temperature and stirred for 5 h. The reaction was quenched with H_2O, and then the product was extracted with Et_2O. The combined organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated. After purification by flash column chromatography (Et_2O /Hexane = 1/25), **S5** was obtained (1.2 g, 4.5 mmol, 62%) as a colorless oil.

*Synthesis of **S7***[4,5]

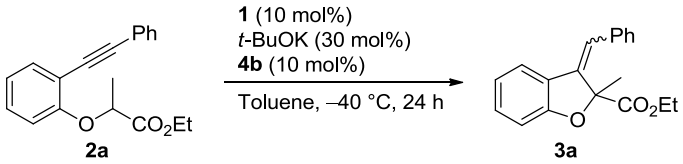


To a solution of α-bromo-γ-butyrolactone (1.8 mL, 16 mmol) in ethanol (16 mL) at 0 °C was added dropwise 4.0 mL of conc. H_2SO_4. After stirring at room temperature for 5 min, the resulted mixture was allowed to be heated at reflux for 24 h. Then, the reaction mixture was cooled to room temperature and brought to pH 3 with sat. aq. $NaHCO_3$, followed by extraction with AcOEt. The combined organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated. After purification by a short-pass column chromatography (AcOEt/Hexane = 1/4), a mixture of **S6** and α-bromo-γ-butyrolactone was obtained (ratio = ca. 3 : 1).

The mixture thus obtained was dissolved in CH_2Cl_2 (30 mL). Then, triethylamine (2.9 mL, 40 mmol) and *tert*-butyl(chloro)dimethylsilane (4.8 g, 32 mmol) were added to the solution at 0 °C. After stirring for 24 h at room temperature, the mixture was extracted with CH_2Cl_2. The combined organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated. The crude product was purified by flash column chromatography (AcOEt/Hexane = 1/15) to provide **S7** (2. 2 g, 6.8 mmol, 43% over 2 steps) as a colorless oil.

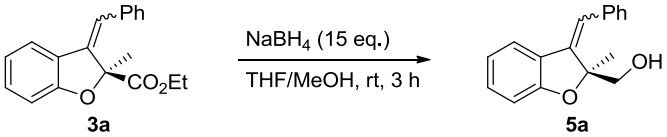
[2] H.-S. Lee, J.-S. Park, B. M. Kim, and S. H. Gellman, *J. Org. Chem.*, 2003, **68**, 1575.
[3] G. Mignani, D. Morel and F. Grass, *Tetrahedron Lett.*, 1987, **28**, 5505.
[4] A. Banerji, D. Bandyopadhyay and K. A. Siddhanta, *Phytochemistry*, 1987, **26**, 3345.
[5] K. Kanai, H. Wakabayashi and T. Honda, *Org. Lett.*, 2000, **2**, 2549.

Typical Procedure for Enantioselective Intramolecular Cyclization



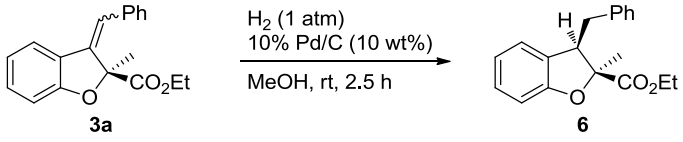
The reaction of **2a** is representative (Table 1, entry 17). To a solution of **1** (6.4 mg, 0.020 mmol) and 1,1-diphenylethanol (**4b**, 4.0 mg, 0.020 mmol) in toluene (0.60 mL) was added a solution of *t*-BuOK in THF (1.0 *M*, 60 μL, 0.060 mmol). The mixture was stirred for 10 min at room temperature. Then, the mixture was cooled to −40 ^{o}C. After stirring for 5 min, a solution of **2a** (59 mg, 0.20 mmol) in toluene (0.40 mL) was added. The resulting mixture was stirred at −40 ^{o}C for 24 h. The reaction was quenched with sat. aq. NH_4Cl, and then extracted with AcOEt. The combined organic layer was dried over Na_2SO_4, filtered, and concentrated. The crude product was purified by flash column chromatography (Et_2O /Hexane = 1/25) to afford **3a** (53 mg, 0.18 mmol, 90%) as a colorless oil. The *E*/*Z* ratio was determined by ^{1}H NMR analysis after purification by flash column chromatography. The enantiomeric excess was calculated by HPLC analysis for *Z* isomer.

Procedure for Transformation of 3 into 5 (Scheme 2a)



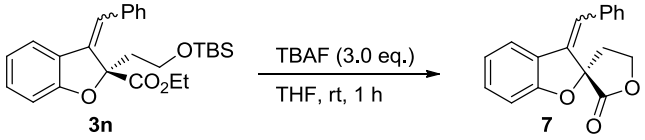
The reaction of **3a** is representative. $NaBH_4$ (0.11 g, 3.0 mmol) was added portionwise to a solution of **3a** (90% ee, 59 mg, 0.20 mmol) in a mixture of THF (0.50 mL) and methanol (0.50 mL) at 0 ^{o}C. The mixture was allowed to warm to room temperature, and then stirred for additional 3 h. The reaction was quenched with sat. aq. NH_4Cl, and the product was extracted with AcOEt. The combined organic layer was dried over Na_2SO_4, filtered, and concentrated. Purification of the crude mixture by flash column chromatography (AcOEt/Hexane = 1/10) provided **5a** (46 mg, 0.18 mmol, 90%, 90% ee) as a white solid.

Procedure for Hydrogenation of 3a into 6 (Scheme 2b)



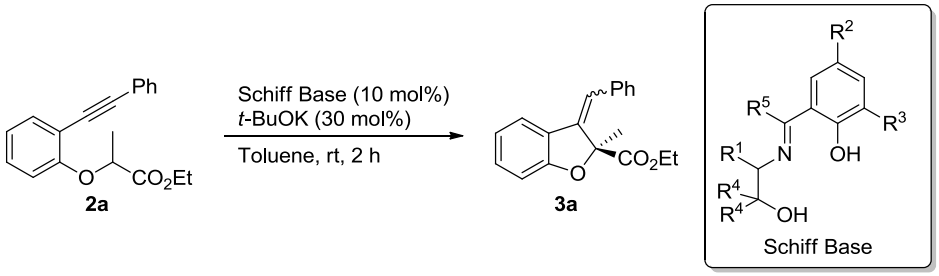
A mixture of **3a** (90% ee, 59 mg, 0.20 mmol), 10% Pd/C (10 wt %, 11 mg) in MeOH (1.0 mL) was vigorously stirred at room temperature under hydrogen atmosphere (balloon, 1 atm) for 2.5 h. The reaction mixture was filtered through a thick pad of Celite, and the filtrate was concentrated. After purification by flash column chromatography (Et_2O /Hexane = 1/25), **6** was obtained (54 mg, 91%, dr = >95:5, 90% ee) as a white solid. The ratio of diastereomers was determined by ^{1}H NMR analysis after flash column chromatography and the enantiomeric excess was calculated by HPLC analysis for the major diastereomer.

Procedure for Hydrogenation of 3n into 7 (Scheme 2c)



To a solution of **3n** (78% ee, 73 mg, 0.15 mmol) in THF (0.75 mL) was added a solution of tetrabutylammonium fluoride in THF (1.0 *M*, 0.45 mL, 0.45 mmol). The mixture was stirred at room temperature for 1 h. The reaction was quenched with sat. aq. $NaHCO_3$, and then the product was extracted with AcOEt. The combined organic layer was dried over Na_2SO_4, filtered, and concentrated. The residue was purified by flash column chromatography (Et_2O /Hexane = 1/8) to afford **7** (37 mg, 0.13 mmol, 90%, 77% ee) as a white solid.

Screening of Chiral Schiff Bases

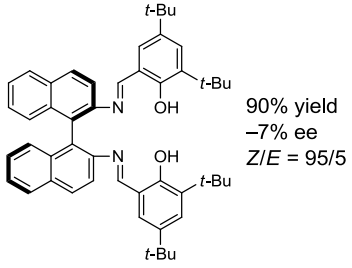


Entry	R^1	R^2	R^3	R^4	R^5	Yield (%)[a]	*Z*/*E* [a]	%ee (*Z*)[b]
1	*i*-Pr	*t*-Bu	*t*-Bu	H	H	84	95/5	53
2	Ph	*t*-Bu	*t*-Bu	H	H	82	>95/5	28
3	*i*-Pr	H	*t*-Bu	H	H	90	>95/5	59
4	*i*-Pr	H	*i*-Pr	H	H	88	94/6	14
5	*i*-Pr	H	H	H	H	92	>95/5	6
6	*i*-Pr	H	Ph	H	H	86	95/5	0
7	*i*-Pr	H	Ph_3Si	H	H	83	93/7	3
8	*i*-Pr	H	*i*-Pr_3Si	H	H	81	>95/5	49
9[c,]	*i*-Pr	*t*-Bu	*t*-Bu	Ph	H	75	>95/5	6
10	*i*-Pr	*t*-Bu	*t*-Bu	H	Ph	89	94/6	9

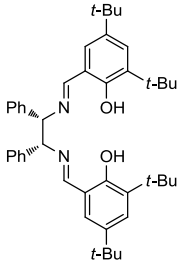
[a] Determined by ^{1}H NMR analysis after column chromatography.

[b] Enantiomeric excess was determined by chiral stationary phase HPLC analysis for *Z* isomer.

[c] The reaction was conducted for 6 h.



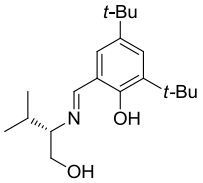
90% yield
–7% ee
Z/*E* = 95/5



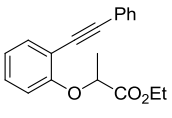
75% yield
1% ee
Z/*E* = 95/5

Analytical Data

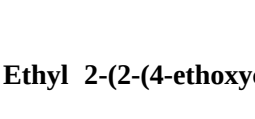
(*S*)-2,4-di-*tert*-butyl-6-{(1-hydroxy-3-methylbutan-2-ylimino)methyl}phenol (**1**): yellow solid; ^{1}H NMR (600 MHz, $CDCl_3$) δ 0.95 (3H, d, J = 6.6 Hz), 0.97 (3H, d, J = 6.6 Hz), 1.31 (9H, s), 1.45 (9H, s), 1.94 (1H, dqq, J = 6.6, 6.6, 6.6 Hz), 3.03 (1H, ddd, J = 9.0, 6.6, 3.6 Hz), 3.76-3.78 (1H, m), 3.82-3.85 (1H, m), 7.13 (1H, d, J = 2.4 Hz), 7.40 (1H, d, J = 2.4 Hz), 8.38 (1H, s); ^{13}C NMR (150 MHz, $CDCl_3$) δ 18.8, 19.8, 29.4, 30.1, 31.5, 34.1, 35.0, 64.7, 77.9, 117.7, 126.1, 127.1, 136.7, 140.2, 158.1, 167.1.



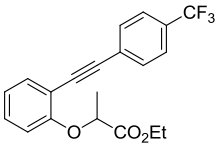
Ethyl 2-(2-phenylethynylphenoxy)propanoate (**2a**): white solid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 1.25 (3H, dd, J = 7.2, 7.2 Hz), 1.70 (3H, d, J = 6.6 Hz), 4.20 (1H, dq, J = 10.8, 7.2 Hz), 4.23 (1H, dq, J = 10.8, 7.2 Hz), 4.86 (1H, q, J = 6.6 Hz), 6.87 (1H, dd, J = 8.4, 1.2 Hz), 6.99 (1H, ddd, J = 7.8, 7.2, 1.2 Hz), 7.23-7.26 (1H, m), 7.31-7.36 (3H, m), 7.50 (1H, dd, J = 7.2, 1.8 Hz), 7.53-7.55 (2H, m); ^{13}C NMR (150 MHz, $CDCl_3$) δ 14.1, 18.6, 61.2, 74.5, 85.6, 93.8, 114.3, 115.2, 122.0, 123.6, 128.1, 128.2, 129.4, 131.5, 133.5, 158.4, 171.9; IR (ATR) 2985, 2219, 1750, 1733, 1497, 1482, 1444, 1275, 1236, 1194, 1131, 1094, 1046, 948, 860 cm^{-1}; HRMS (ESI) Calcd for $C_{19}H_{18}NaO_3$ $[M+Na]^+$ 317.1148, Found 317.1148.



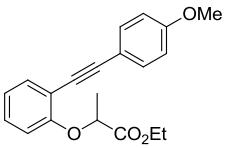
Ethyl 2-(2-(4-ethoxycarbonyl)phenylethylphenoxy)propanoate (**2b**): colorless liquid; ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.25 (3H, dd, J = 7.2, 7.2 Hz), 1.40 (3H, dd, J = 7.2, 6.6 Hz), 1.70 (3H, d, J = 6.6 Hz), 4.21 (1H, dq, J = 10.8, 7.2 Hz), 4.24 (1H, dq, J = 10.8, 7.2 Hz), 4.38 (2H, q, J = 7.2 Hz), 4.84 (1H, q, J = 6.6 Hz), 6.85 (1H, d, J = 9.0 Hz), 6.99 (1H, ddd, J = 7.8, 7.2, 0.6 Hz), 7.26-7.29 (1H, m), 7.51 (1H, dd, J = 7.8, 1.8 Hz), 7.59 (2H, d, J = 8.4 Hz), 8.02 (2H, d, J = 8.4 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ 14.1, 14.3, 18.5, 61.1, 61.3, 74.1, 88.6, 93.0, 113.5, 114.5, 121.8, 128.2, 129.4, 129.6, 130.0, 131.3, 133.6, 158.5, 166.1, 171.8; IR (ATR) 2983, 2938, 2218, 1752, 1714, 1605, 1595, 1485, 1446, 1367, 1268, 1240, 1195, 1175, 1095, 1018, 948, 858 cm^{-1}; HRMS (ESI) Calcd for $C_{22}H_{22}NaO_5$ $[M+Na]^+$ 389.1359, Found 389.1359.



Ethyl 2-(2-(4-trifluoromethylphenyl)ethynylphenoxy)propanoate (**2c**): white solid; ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.25 (3H, dd, J = 7.2, 7.2 Hz), 1.70 (3H, d, J = 6.6 Hz), 4.21 (1H, dq, J = 10.8, 7.2 Hz), 4.24 (1H, dq, J = 10.8, 7.2 Hz), 4.84 (1H, q, J = 6.6 Hz), 6.84 (1H, d, J = 8.4 Hz), 6.99 (1H, ddd, J = 7.8, 7.2, 0.6 Hz), 7.28 (1H, ddd, J = 8.4, 7.8, 1.8 Hz), 7.51 (1H, dd, J = 7.2, 1.8 Hz), 7.59 (2H, d, J = 7.8 Hz), 7.63 (2H, d, J = 7.8 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ 14.0, 18.5, 61.3, 74.2, 88.2, 92.3, 113.4, 114.5, 121.8, 124.0 (q, J = 270 Hz), 125.2 (q, J = 3 Hz), 127.5, 129.7 (q, J = 32 Hz), 130.1, 131.7, 133.6, 158.6, 171.8; IR (ATR) 2989, 2939, 2221, 1752, 1732, 1614, 1487, 1448, 1321, 1277, 1197, 1166, 1125, 1105, 1065, 1015, 949, 842 cm^{-1}; HRMS (ESI) Calcd for $C_{20}H_{17}F_3NaO_3$ $[M+Na]^+$ 385.1022, Found 385.1022.

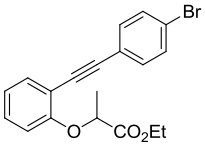


Ethyl 2-(2-(4-methoxyphenyl)ethynylphenoxy)propanoate (**2d**): colorless liquid; ^{1}H NMR (600 MHz, $CDCl_3$) δ



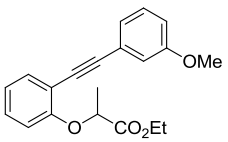
1.24 (3H, dd, *J* = 7.2, 6.6 Hz), 1.69 (3H, d, *J* = 6.6 Hz), 3.82 (3H, s), 4.20 (1H, dq, *J* = 10.8, 7.2 Hz), 4.22 (1H, dq, *J* = 10.8, 7.2 Hz), 4.85 (1H, q, *J* = 6.6 Hz), 6.86-6.88 (3H, m), 6.98 (1H, dd, *J* = 7.2, 7.2 Hz), 7.20-7.23 (1H, m), 7.46-7.48 (3H, m); ^{13}C NMR (150 MHz, $CDCl_3$) δ 14.1, 18.6, 55.3, 61.2, 74.5, 84.2, 93.8, 113.9, 114.7, 115.4, 115.8, 122.0, 129.1, 133.0, 133.3, 158.3, 159.5, 172.0; IR (neat) 2985, 2938, 2838, 2216, 1720, 1606, 1733, 1510, 1487, 1446, 1286, 1246, 1195, 1131, 1106, 1028, 948, 832 cm^{-1}; HRMS (ESI) Calcd for $C_{20}H_{20}NaO_4$ $[M+Na]^+$ 347.1254, Found 347.1254.

Ethyl 2-(2-(4-bromophenyl)ethynylphenoxy)propanoate (**2e**): colorless liquid; ^{1}H NMR (600 MHz, $CDCl_3$) δ



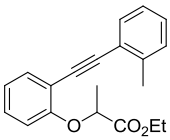
1.25 (3H, dd, *J* = 7.2, 7.2 Hz), 1.69 (3H, d, *J* = 6.6 Hz), 4.19 (1H, dq, *J* = 10.8, 7.2 Hz), 4.22 (1H, dq, *J* = 10.8, 7.2 Hz), 4.83 (1H, q, *J* = 6.6 Hz), 6.84 (1H, d, *J* = 9.0 Hz), 6.99 (1H, dd, *J* = 7.8, 7.2 Hz), 7.26 (1H, ddd, *J* = 7.8, 7.8, 1.8 Hz), 7.40 (2H, d, *J* = 9.0 Hz), 7.46 (2H, d, *J* = 9.0 Hz), 7.48 (1H, dd, *J* = 7.8, 1.8 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ 14.1, 18.5, 61.2, 74.2, 86.8, 92.6, 113.8, 114.7, 121.9, 122.3, 122.6, 129.7, 131.5, 132.9, 133.4, 158.4, 171.8; IR (ATR) 2985, 2938, 2220, 1751, 1733, 1496, 1481, 1446, 1278, 1238, 1196, 1132, 1095, 1069, 1010, 948, 824 cm^{-1}; HRMS (ESI) Calcd for $C_{19}H_{17}BrNaO_3$ $[M+Na]^+$ 395.0253, Found 395.0253.

Ethyl 2-(2-(3-methoxyphenyl)ethynylphenoxy)propanoate (**2f**): colorless liquid; ^{1}H NMR (600 MHz, $CDCl_3$) δ

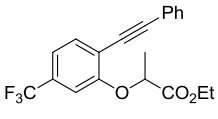


1.25 (3H, dd, *J* = 7.2, 6.6 Hz), 1.69 (3H, d, *J* = 6.6 Hz), 3.83 (3H, s), 4.20 (1H, dq, *J* = 10.8, 7.2 Hz), 4.23 (1H, dq, *J* = 10.8, 7.2 Hz), 4.85 (1H, q, *J* = 6.6 Hz), 6.86 (1H, d, *J* = 8.4 Hz), 6.89 (1H, ddd, *J* = 8.4, 2.4, 0.6 Hz), 6.99 (1H, ddd, *J* = 7.8, 7.2, 0.6 Hz), 7.08 (1H, dd, *J* = 2.4, 1.2 Hz), 7.14 (1H, dt, *J* = 7.2, 0.6 Hz), 7.23-7.27 (2H, m), 7.50 (1H, dd, *J* = 7.8, 1.8 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ 14.1, 18.6, 55.2, 61.2, 74.4, 85.4, 93.7, 114.2, 114.7, 115.1, 116.4, 121.9, 124.1, 124.6, 129.3, 129.5, 133.5, 158.4, 159.3, 171.9; IR (ATR) 2985, 2938, 2210, 1750, 1733, 1594, 1574, 1495, 1447, 1282, 1242, 1195, 1138, 1094, 1045, 949, 930, 856, 810 cm^{-1}; HRMS (ESI) Calcd for $C_{20}H_{20}NaO_4$ $[M+Na]^+$ 347.1254, Found 347.1254.

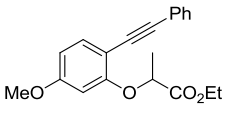
Ethyl 2-(2-(2-methylphenylethynyl)phenoxy)propanoate (**2g**): colorless liquid; ^{1}H NMR (600 MHz, $CDCl_3$) δ



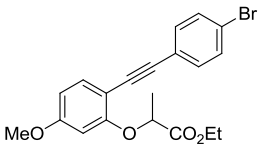
1.24 (3H, dd, *J* = 7.2, 6.6 Hz), 1.68 (3H, d, *J* = 7.2 Hz), 2.55 (3H, s), 7.20 (1H, dq, *J* = 10.8, 7.2 Hz), 7.23 (1H, dq, *J* = 10.8, 7.2 Hz), 4.86 (1H, q, *J* = 6.6 Hz), 6.82 (1H, d, *J* = 7.8 Hz), 6.98 (1H, ddd, *J* = 7.2, 7.2, 0.6 Hz), 7.14-7.19 (1H, m), 7.22-7.24 (3H, m), 7.50-7.52 (2H, m); ^{13}C NMR (150 MHz, $CDCl_3$) δ 14.1, 18.6, 20.8, 61.2, 73.8, 89.6, 92.7, 113.8, 114.1, 121.6, 123.4, 125.4, 128.1, 129.29, 129.34, 131.7, 133.4, 140.2, 158.1, 171.9; IR (ATR) 2985, 2938, 2214, 1752, 1732, 1495, 1479, 1446, 1274, 1236, 1192, 1132, 1098, 1045, 946, 861 cm^{-1}; HRMS (ESI) Calcd for $C_{20}H_{20}NaO_3$ $[M+Na]^+$ 331.1305, Found 331.1305.

Ethyl 2-(2-(phenylethynyl)-5-(trifluoromethyl)phenoxy)propanoate (2h): colorless liquid; ^{1}H NMR (600 MHz, 

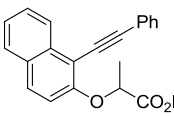
$CDCl_3$) δ 1.24 (3H, t, J = 7.2 Hz), 1.72 (3H, d, J = 6.6 Hz), 4.22 (1H, q, J = 7.2 Hz), 4.89 (1H, q, J = 6.6 Hz), 7.07 (1H, s), 7.23 (1H, dd, J = 7.8, 0.6 Hz), 7.34-7.36 (3H, m), 7.54-7.56 (2H, m), 7.58 (1H, d, J = 7.8 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ 14.0, 18.4, 61.5, 74.4, 84.3, 96.0, 111.5, 118.0, 118.5, 122.9, 123.6 (q, J = 270 Hz), 128.4, 128.7, 130.9 (q, J = 32 Hz), 131.7, 133.7, 158.3, 171.2; IR (ATR) 2988, 2940, 2220, 1752, 1423, 1326, 1269, 1236, 1196, 1170, 1123, 964, 859, 829 cm^{-1}; HRMS (ESI) Calcd for $C_{20}H_{17}F_3NaO_3$ $[M+Na]^+$ 385.1022, Found 385.1022.

Ethyl 2-(5-methoxy-2-(phenylethynyl)phenoxy)propanoate (2i): yellowish liquid; ^{1}H NMR (600 MHz, $CDCl_3$) δ 

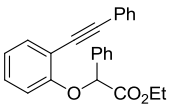
1.25 (3H, dd, J = 7.2, 7.2 Hz), 1.69 (3H, d, J = 6.6 Hz), 3.78 (3H, s), 4.20 (1H, dq, J = 10.8, 7.2 Hz), 4.23 (1H, dq, J = 10.8, 7.2 Hz), 4.85 (1H, q, J = 6.6 Hz), 6.44 (1H, d, J = 2.4 Hz), 6.54 (1H, dd, J = 8.4, 2.4 Hz), 7.28-7.34 (3H, m), 7.41 (1H, d, J = 9.0 Hz), 7.51 (2H, m); ^{13}C NMR (150 MHz, $CDCl_3$) δ 14.1, 18.6, 55.4, 61.2, 74.5, 85.7, 92.4, 102.5, 106.7, 107.2, 123.9, 127.8, 128.2, 131.3, 134.2, 159.6, 160.8, 171.8; IR (ATR) 2984, 2938, 2215, 1751, 1733, 1609, 1595, 1506, 1442, 1297, 1201, 1169, 1131, 1113, 1041, 983, 915, 832 cm^{-1}; HRMS (ESI) Calcd for $C_{20}H_{20}NaO_4$ $[M+Na]^+$ 347.1254, Found 347.1254.

Ethyl 2-(2-((4-bromophenyl)ethynyl)-5-methoxyphenoxy)propanoate (2j): white solid; ^{1}H NMR (600 MHz, 

$CDCl_3$) δ 1.25 (3H, dd, J = 7.2, 7.2 Hz), 1.68 (3H, d, J = 6.6 Hz), 3.78 (3H, s), 4.21 (1H, dq, J = 10.8, 7.2 Hz), 4.24 (1H, dq, J = 10.8, 7.2 Hz), 4.82 (1H, q, J = 6.6 Hz), 6.42 (1H, d, J = 2.4 Hz), 6.53 (1H, dd, J = 8.4, 2.4 Hz), 7.35-7.38 (2H, m), 7.40 (1H, d, J = 8.4 Hz), 7.44-7.46 (2H, m); ^{13}C NMR (150 MHz, $CDCl_3$) δ 14.1, 18.6, 55.4, 61.3, 74.3, 86.9, 91.3, 102.0, 106.2, 107.0, 121.8, 122.9, 131.5, 132.8, 134.2, 159.6, 161.0, 171.7; IR (ATR) 2984, 2937, 2215, 1751, 1733, 1607, 1507, 1443, 1428, 1297, 1253, 1200, 1168, 1112, 1093, 1040, 1009, 915, 822 cm^{-1}; HRMS (ESI) Calcd for $C_{20}H_{19}BrNaO_4$ $[M+Na]^+$ 425.0359, Found 425.0359.

Ethyl 2-((1-(phenylethynyl)naphthalen-2-yl)oxy)propanoate (2k): white solid; ^{1}H NMR (600 MHz, $CDCl_3$) δ 

1.23 (3H, dd, J = 7.2, 7.2 Hz), 1.75 (3H, d, J = 7.2 Hz), 4.19 (1H, dq, J = 10.8, 7.2 Hz), 4.22 (1H, dq, J = 10.8, 7.2 Hz), 5.08 (1H, q, J = 7.2) Hz), 7.22 (1H, d, J = 9.0 Hz), 7.34-7.40 (3H, m), 7.42 (1H, ddd, J = 7.8, 7.8, 1.2 Hz), 7.56 (1H, ddd, J = 7.8, 7.8, 1.2 Hz), 7.64-7.67 (2H, m), 7.75 (1H, d, J = 9.0 Hz), 7.78 (1H, d, J = 8.4 Hz), 8.34 (1H, d, J = 8.4 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ 14.1, 18.8, 61.2, 75.6, 83.7, 99.4, 109.3, 117.6, 123.7, 124.9, 125.6, 127.2, 128.1, 128.2, 128.3, 129.5, 129.8, 131.5, 134.4, 157.5, 172.0; IR (ATR) 3059, 2985, 2938, 2207, 1750, 1590, 1507, 1491, 1465, 1442, 1267, 1234, 1198, 976, 914, 863 cm^{-1}; HRMS (ESI) Calcd for $C_{23}H_{20}NaO_3$ $[M+Na]^+$ 367.1305, Found 367.1304.

Ethyl 2-phenyl-2-(2-phenylethynylphenoxy)acetate (**2l**): white solid; ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.18 (3H, dd, 

J = 7.2, 7.2 Hz), 4.16 (1H, dq, J = 10.8, 7.2 Hz), 4.19 (1H, dq, J = 10.8, 7.2 Hz), 5.75 (1H, s), 6.87 (1H, d, J = 7.8 Hz), 7.00 (1H, ddd, J = 7.8, 7.2, 1.2 Hz), 7.23 (1H, ddd, J = 8.4, 7.8, 1.8 Hz), 7.31-7.41 (6H, m), 7.50-7.53 (3H, m), 7.70 (2H, m); ^{13}C NMR (150 MHz, $CDCl_3$) δ 13.9, 61.5,

79.6, 85.6, 94.2, 114.4, 114.6, 122.0, 123.6, 126.9, 128.1, 128.2, 128.5, 128.8, 129.4, 131.5, 133.3, 135.5, 158.0, 169.7; IR (ATR) 3063, 3033, 2981, 2219, 1752, 1733, 1496, 1481, 1448, 1277, 1235, 1203, 1179, 1108, 1057, 1027, 916, 817 cm^{-1}; HRMS (ESI) Calcd for $C_{24}H_{20}NaO_3$ $[M+Na]^+$ 379.1305, Found 379.1304.

Ethyl 3-phenyl-2-(2-phenylethynylphenoxy)propanoate (**2m**): white solid; ^1H NMR (600 MHz, $CDCl_3$) δ 1.16 (3H, t, J = 7.2 Hz), 3.30 (1H, dd, J = 13.8, 4.2 Hz), 3.36 (1H, dd, J = 13.8, 7.8 Hz), 4.16 (2H, q, J = 7.2 Hz), 4.87 (1H, dd, J = 7.8, 4.2 Hz), 6.69 (1H, d, J = 8.4 Hz), 6.94 (1H, dd, J = 7.8, 7.2 Hz), 7.18-7.22 (4H, m), 7.33-7.39 (3H, m), 7.43 (2H, dd, J = 7.8, 2.4 Hz), 7.48 (1H, dd, J = 7.8, 1.2 Hz), 7.58 (2H, dd, J = 7.2, 1.2 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ 14.0, 39.1, 61.3, 78.4, 85.9, 93.6, 113.1, 113.6, 121.5, 123.7, 126.9, 128.1, 128.2, 128.3, 129.4, 129.9, 131.5, 133.6, 136.1, 158.3, 170.7; IR (ATR) 3063, 3030, 2980, 2933, 2220, 1752, 1731, 1496, 1482, 1444, 1279, 1235, 1186, 1107, 1027, 915, 855 cm^{-1}; HRMS (ESI) Calcd for $C_{25}H_{22}NaO_3$ $[M+Na]^+$ 393.1461, Found 393.1461.

Ethyl 4-((*tert*-butyldimethylsilyl)oxy)-3-(2-(phenylethynylphenoxy)butanoate (**2n**): colorless liquid; ^1H NMR (600 MHz, $CDCl_3$) δ -0.06 (3H, s), -0.01 (3H, s), 0.82 (9H, s), 1.25 (3H, dd, J = 7.2, 7.2 Hz), 2.22-2.25 (2H, m), 3.88 (1H, ddd, J = 9.6, 5.4, 5.4 Hz), 4.00 (1H, ddd, J = 9.6, 7.8, 6.0 Hz), 4.21 (1H, dq, J = 10.8, 7.2 Hz), 4.24 (1H, dq, J = 10.8, 7.2 Hz), 4.88 (1H, dd, J = 7.2, 5.4 Hz), 6.80 (1H, d, J = 8.4 Hz), 6.95 (1H, ddd, J = 7.8, 7.2, 0.6 Hz), 7.23 (1H, ddd, J = 9.0, 8.4, 1.8 Hz), 7.29-7.35 (3H, m), 7.48 (1H, dd, J = 7.8, 1.8 Hz), 7.51-7.53 (2H, m); ^{13}C NMR (150 MHz, $CDCl_3$) δ -5.6, -5.5, 14.1, 18.2, 25.8, 35.8, 58.4, 61.2, 74.4, 85.8, 93.5, 113.3, 113.6, 121.3, 123.8 128.0, 128.2, 129.4, 131.5 133.4, 158.7, 171.7; IR (ATR) 2955, 2928, 2856, 2220, 1755, 1734, 1497, 1483, 1450, 1277, 1250, 1187, 1026, 955, 834 cm^{-1}; HRMS (ESI) Calcd for $C_{26}H_{34}NaO_3$ $[M+Na]^+$ 461.2119, Found 461.2118.

(*Z*)-Ethyl 3-benzylidene-2-methyl-2,3-dihydrobenzofuran-2-carboxylate (**3a**): colorless liquid; HPLC analysis Chiralpak IC-3 (hexane/*i*-PrOH = 95/5, 1.0 mL/min, 254 nm, 30 °C); 6.0 (minor), 6.9 (major) min; 92% ee, $[\alpha]_D^{25}$ = +411 (c = 0.99, $CHCl_3$); ^1H NMR (500 MHz, $CDCl_3$) δ 1.15 (3H, dd, J = 7.2, 7.2 Hz), 1.70 (3H, s), 4.14 (1H, dq, J = 10.8, 7.2 Hz), 4.20 (1H, dq, J = 10.8, 7.2 Hz), 6.87 (1H, d, J = 8.4 Hz), 6.98 (1H, ddd, J = 7.8, 7.2, 0.6 Hz), 7.00 (1H, s), 7.22-7.28 (4H, m), 7.34 (2H, dd, J = 7.2, 7.2 Hz), 7.48 (1H, dd, J = 7.8, 0.6 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ 13.8, 20.7, 62.0, 89.3, 110.5, 119.8, 120.3, 121.3, 127.1, 127.4, 128.4, 128.6, 130.3, 135.5, 140.5, 160.3, 169.8; IR (ATR) 2983, 2938, 1735, 1595, 1464, 1252, 1127, 1075, 1017, 911, 858 cm^{-1}; HRMS (ESI) Calcd for $C_{19}H_{18}NaO_3$ $[M+Na]^+$ 317.1148, Found 317.1148.

(*E*)-Ethyl 3-benzylidene-2-methyl-2,3-dihydrobenzofuran-2-carboxylate (**3a**): white solid; ^1H NMR (500 MHz, $CDCl_3$) δ 1.27 (3H, t, J = 7.2 Hz), 1.84 (3H, s), 4.25 (2H, q, J = 7.2 Hz), 6.67 (1H, s), 6.70 (1H, ddd, J = 7.8, 7.8, 0.6 Hz), 6.94 (1H, d J = 7.8 Hz), 7.19 (1H, ddd, J = 7.8, 7.8, 1.2 Hz), 7.22 (1H, d, J = 7.8 Hz), 7.30-7.33 (1H, m), 7.37-7.42 (4H, m); ^{13}C NMR (150 MHz, $CDCl_3$) δ 14.0, 25.1, 61.9, 89.2, 110.7, 120.7, 121.7, 122.9, 123.9, 127.6, 128.4, 128.5, 130.9, 136.4, 140.4, 162.3, 171.2; IR (ATR) 2982, 2935, 1734, 1462, 1252, 1117, 1092, 1021, 982, 936, 859 cm^{-1}; HRMS (ESI) Calcd for $C_{19}H_{18}NaO_3$ $[M+Na]^+$ 317.1148, Found 317.1148.

(*Z*)-Ethyl 3-(4-ethoxycarbonylbenzylidene)-2-methyl-2,3-dihydrobenzofuran-2-carboxylate (**3b**): colorless liquid; HPLC analysis Chiralpak AD-3 (hexane/*i*-PrOH = 98/2, 1.0 mL/min, 254 nm, 30 °C); 13.3 (major), 29.6 (minor) min; 33% ee, $[\alpha]_D^{25}$ = +135 (c = 1.06 , $CDCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.16 (3H, dd, *J* = 7.2, 7.2 Hz), 1.40 (3H, t, *J* = 7.2 Hz), 1.71 (3H, s), 4.16 (1H, dq, *J* = 10.8, 7.2 Hz), 4.21 (1H, dq, *J* = 10.8, 7.2 Hz), 4.38 (2H, q, *J* = 7.2 Hz), 6.89 (1H, d, *J* = 7.8 Hz), 6.99 (1H, dd, *J* = 7.2, 7.2 Hz), 6.99 (1H, s), 7.26 (1H, dd, *J* = 7.2, 7.2 Hz), 7.35 (2H, d, *J* = 8.4 Hz), 7.49 (1H, d, *J* = 7.2 Hz), 8.01 (2H, d, *J* = 8.4 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ 13.9, 14.3, 20.7, 61.0, 62.1, 89.4, 110.7, 118.7, 120.6, 121.5, 126.8, 128.5, 129.7, 130.9, 140.0, 142.5, 160.6, 166.2, 169.6; IR (ATR) 2982, 2938, 1738, 1713, 1465, 1269, 1101, 1018, 913, 889, 854 cm^{-1}; HRMS (ESI) Calcd for $C_{22}H_{22}NaO_5$ $[M+Na]^+$ 389.1359, Found 389.1359.

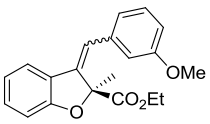
(*Z*)-Ethyl 2-methyl-3-(4-trifluoromethylbenzylidene)-2,3-dihydrobenzofuran-2-carboxylate (**3c**): colorless liquid; HPLC analysis Chiralpak AD-3 (hexane/*i*-PrOH = 90/10, 1.0 mL/min, 254 nm, 30 °C); 4.5 (major), 6.6 (minor) min; 53% ee, $[\alpha]_D^{25}$ = +223 (c = 1.01 , $CDCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.15 (3H, dd, *J* = 7.2, 7.2 Hz), 1.69 (3H, s), 4.15 (1H, dq, *J* = 10.8, 7.2 Hz), 4.21 (1H, dq, *J* = 10.8, 7.2 Hz), 6.90 (1H, d, *J* = 8.4 Hz), 6.99 (1H, s), 7.00 (1H, ddd, *J* = 7.2, 7.2, 0.6 Hz), 7.27 (1H, dd, *J* = 8.4, 7.2, 1.2 Hz), 7.40 (2H, d, *J* = 8.4 Hz), 7.49 (1H, dd, *J* = 7.8, 1.2 Hz), 7.59 (2H, d, *J* = 8.4 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ 13.8, 20.7, 62.2, 89.2, 110.7, 118.1, 124.0 (q, *J* = 270 Hz), 125.3, (q, *J* = 4 Hz), 125.3, 125.4, 126.6, 128.8, 129.1 (q, *J* = 32 Hz), 131.0, 142.6, 160.6, 169.6; IR (ATR) 2986, 2940, 1738, 1466, 1320, 1254, 1165, 1118, 1066, 1017, 914, 858 cm^{-1}; HRMS (ESI) Calcd for $C_{20}H_{17}F_3NaO_3$ $[M+Na]^+$ 385.1022, Found 385.1022.

(*Z*)-Ethyl 3-(4-methoxybenzylidene)-2-methyl-2,3-dihydrobenzofuran-2-carboxylate (**3d**): yellowish liquid; HPLC analysis Chiralpak AD-3 (hexane/*i*-PrOH = 90/10, 1.0 mL/min, 254 nm, 30 °C); 9.2 (major), 10.2 (minor) min; 85% ee, $[\alpha]_D^{20}$ = +375 (c = 1.02 , $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.14 (3H, dd, *J* = 7.2, 7.2 Hz), 1.73 (3H, s), 3.81 (3H, s), 4.15 (1H, dq, *J* = 10.8, 7.2 Hz), 4.20 (1H, dq, *J* = 10.8, 7.2 Hz), 6.85 (1H, d, *J* = 8.4 Hz), 6.87 (2H, d, *J* = 9.0 Hz), 6.92 (1H, s), 6.95 (1H, ddd, *J* = 7.8, 7.2, 0.6 Hz), 7.20 (1H, ddd, *J* = 7.8, 7.8, 1.2 Hz), 7.23 (2H, d, *J* = 8.4 Hz), 7.44 (1H, dd, *J* = 7.2, 0.6 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ 13.9, 20.5, 55.2, 62.9, 89.3, 110.3, 113.9, 119.6, 120.0, 121.2, 127.6, 128.0, 129.9, 130.0, 138.6, 158.9, 160.0, 170.0; IR (ATR) 2982, 2937, 2837, 1733, 1510, 1464, 1249, 1180, 1127, 1031, 912, 883, 863, 826 cm^{-1}; HRMS (ESI) Calcd for $C_{20}H_{20}NaO_4$ $[M+Na]^+$ 347.1254, Found 347.1254.

(*Z*)-Ethyl 3-(4-bromobenzylidene)-2-methyl-2,3-dihydrobenzofuran-2-carboxylate (**3e**): colorless liquid; HPLC analysis Chiralpak AD-3 (hexane/*i*-PrOH = 95/05, 1.0 mL/min, 254 nm, 30 °C); 8.0 (major), 10.2 (minor) min; 85% ee, $[\alpha]_D^{20}$ = +363 (c = 1.08 , $CDCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.15 (3H, dd, *J* = 7.2, 7.2 Hz), 1.69 (3H, s), 4.14 (1H, dq, *J* = 10.8, 7.2 Hz), 4.19 (1H, dq, *J* = 10.8, 7.2 Hz), 6.87 (1H, d, *J* = 9.0 Hz), 6.90 (1H, s), 6.97 (1H, ddd, *J* = 7.8, 7.2, 0.6 Hz), 7.16 (2H, d, *J* = 9.0 Hz), 7.24 (1H, ddd, *J* = 7.8, 7.8, 1.2 Hz), 7.44-7.47 (3H, m); ^{13}C NMR (150 MHz, $CDCl_3$) δ 13.9, 20.7, 62.1, 89.3, 110.6, 118.5, 120.4, 121.3, 121.4, 126.9, 130.2, 130.7, 131.6, 134.4, 141.2, 160.4, 169.7; IR (ATR) 2982, 2938, 1735, 1488, 1464, 1253, 1126, 1076, 1009, 913, 858, 813 cm^{-1}; HRMS (ESI) Calcd for $C_{19}H_{17}BrNaO_3$

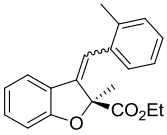
$[M+Na]^+$ 395.0253, Found 395.0253.

(*Z*)-Ethyl 3-(3-methoxybenzylidene)-2-methyl-2,3-dihydrobenzofuran-2-carboxylate (**3f**): colorless liquid;



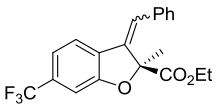
HPLC analysis Chiralpak AD-3 (hexane/*i*-PrOH = 90/10, 1.0 mL/min, 254 nm, 30 °C); 7.2 (minor), 14.1 (major) min; 87% ee, $[\alpha]_D^{25}$ = +333 (c = 1.00, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.15 (3H, dd, *J* = 7.2, 7.2 Hz), 1.73 (3H, s), 3.81 (3H, s), 4.15 (1H, dq, *J* = 10.8, 7.2 Hz), 4.20 (1H, dq, *J* = 10.8, 7.2 Hz), 6.81 (1H, dd, *J* = 8.4, 1.2 Hz), 6.84 (1H, s), 6.87 (1H, d, *J* = 8.4 Hz), 6.96 (1H, s), 6.97 (1H, ddd, *J* = 7.8, 7.8, 0.6 Hz) 7.23 (1H, ddd, *J* = 7.2, 7.2, 1.2 Hz), 7.24 (1H, dd, *J* = 7.8, 7.8 Hz), 7.46 (1H, d, *J* = 8.4 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ 13.8, 20.6, 55.2, 62.0, 89.3, 110.5, 113.4, 113.5, 119.7, 120.3, 121.29, 121.34, 127.1, 129.4, 130.4, 136.7, 140.5, 159.6, 160.3, 169.8; IR (neat) 2991, 2938, 2835, 1735, 1594, 1464, 1247, 1127, 1078, 1017, 908, 854 cm^{-1}; HRMS (ESI) Calcd for $C_{20}H_{20}NaO_4$ $[M+Na]^+$ 347.1254, Found 347.1254.

(*Z*)-Ethyl 2-methyl-3-(2-methylbenzylidene)-2,3-dihydrobenzofuran-2-carboxylate (**3g**): colorless liquid;



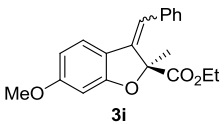
HPLC analysis Chiralpak IA-3 (hexane/*i*-PrOH = 98/2, 1.0 mL/min, 254 nm, 30 °C); 6.0 (minor), 7.2 (major) min; 81% ee, $[\alpha]_D^{25}$ = +275 (c = 1.00, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.17 (3H, dd, *J* = 7.2, 7.2 Hz), 1.50 (3H, s), 2.27 (3H, s), 4.08 (1H, dq, *J* = 10.8, 7.2 Hz), 4.15 (1H, dq, *J* = 10.8, 7.2 Hz), 6.89 (1H, d, *J* = 8.4 Hz), 6.99 (1H, dd, *J* = 7.8, 7.2 Hz), 7.01 (1H, s), 7.08 (1H, d, *J* = 7.8 Hz), 7.14 (1H, ddd, *J* = 7.2, 7.2, 1.2 Hz), 7.18-7.26 (3H, m), 7.50 (1H, d, *J* = 7.8 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ 13.8, 20.2, 21.3, 61.8, 89.0, 110.5, 119.1, 120.5, 121.2, 125.5, 126.5, 127.8, 128.2, 129.7, 130.3, 135.1, 136.8, 141.2, 160.5, 169.9; IR (ATR) 2983, 2938, 1464, 1251, 1127, 1112, 1079, 1018, 913, 858 cm^{-1}HRMS (ESI) Calcd for $C_{20}H_{20}NaO_3$ $[M+Na]^+$ 331.1305. Found 331.1304.

(*Z*)-Ethyl 3-benzylidene-2-methyl-6-(trifluoromethyl)-2,3-dihydrobenzofuran-2-carboxylate (**3h**): colorless



liquid; HPLC analysis Chiralpak IA-3 (hexane/*i*-PrOH = 90/10, 1.0 mL/min, 254 nm, 30 °C); 4.3 (major), 10.3 (minor) min; 79% ee, $[\alpha]_D^{25}$ = +291 (c = 0.98, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.16 (3H, dd, *J* = 7.2, 7.2 Hz), 1.72 (3H, s), 4.16 (1H, dq, *J* = 10.8, 7.2 Hz), 4.21 (1H, dq, *J* = 10.8, 7.2 Hz), 7.10 (1H×2, s), 7.24 (1H, dd, *J* = 7.8, 0.6 Hz), 7.28 (2H, d, *J* = 7.8 Hz), 7.29 (1H, t, *J* = 6.6 Hz), 7.36 (2H, dd, *J* = 7.8, 6.6 Hz), 7.54 (1H, d, *J* = 7.8 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ 13.8, 20.6, 62.2, 90.3, 107.7 (q, *J* = 4 Hz), 118.4, 118.5, 120.5, 122.6, 123.9 (q, *J* = 270 Hz), 128.0, 128.5, 128.7, 130.8, 132.1 (q, *J* = 33 Hz), 134.8, 138.9, 160.1; IR (ATR) 2987, 2941, 1739, 1437, 1322, 1264, 1165, 1119, 1053, 934, 868, 820 cm^{-1}; HRMS (ESI) Calcd for $C_{20}H_{17}F_3NaO_3$ $[M+Na]^+$ 385.1022, Found 385.1022.

(*Z*)-Ethyl 3-benzylidene-2-methyl-6-methoxy-2,3-dihydrobenzofuran-2-carboxylate (**3i**): yellowish liquid;

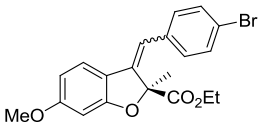


3i

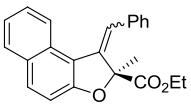
HPLC analysis Chiralpak IC-3 (hexane/*i*-PrOH = 98/2, 1.0 mL/min, 254 nm, 30 °C); 15.5 (minor), 19.4 (major) min; 89% ee, $[\alpha]_D^{24}$ = +308 (c = 0.71, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.16 (3H, dd, *J* = 7.2, 7.2 Hz), 1.70 (3H, s), 3.82 (3H, s), 4.15 (1H, dq, *J* = 10.8, 7.2 Hz), 4.21 (1H, dq, *J* = 10.8, 7.2 Hz), 6.44 (1H, d, *J* = 2.4 Hz), 6.56 (1H, dd, *J* = 8.4, 2.4 Hz), 6.82 (1H, s), 7.23 (1H, t, *J* = 7.2 Hz), 7.25 (2H, d, *J* = 7.8 Hz), 7.32 (1H, dd, *J* = 7.8, 7.2 Hz), 7.36 (1H, d, *J* = 8.4 Hz); ^{13}C NMR (150

MHz, $CDCl_3$) δ 13.9, 20.7, 55.5, 62.0, 90.2, 95.9, 108.4, 117.3, 119.9, 120.9, 127.0, 128.3, 128.5, 135.8, 140.0, 161.7, 162.3, 169.8; IR (ATR) 2982, 2939, 2837, 1736, 1616, 1593, 1498, 1445, 1285, 1158, 1127, 1080, 1027, 957, 826 cm^{-1}; HRMS (ESI) Calcd for $C_{20}H_{20}NaO_4$ $[M+Na]^+$ 347.1254, Found 347.1254.

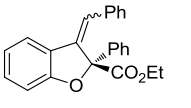
(*Z*)-Ethyl 3-(4-bromobenzylidene)-6-methoxy-2-methyl-2,3-dihydrobenzofuran-2-carboxylate (**3j**): colorless liquid; HPLC analysis Chiralpak AD-3 (hexane/*i*-PrOH = 96/4, 1.0 mL/min, 254 nm, 30 °C); 11.3 (minor), 14.4 (major) min; 92% ee, $[\alpha]_D^{25}$ = +333 (c = 1.03, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.17 (3H, dd, *J* = 7.2, 7.2 Hz), 1.68 (3H, s), 3.81 (3H, s), 4.15 (1H, dq, *J* = 10.8, 7.2 Hz), 4.21 (1H, dq, *J* = 10.8, 7.2 Hz), 6.43 (1H, d, *J* = 8.4 Hz), 6.55 (1H, dd, *J* = 8.4, 1.8 Hz), 6.72 (1H, s), 7.13 (2H, d, *J* = 8.4 Hz), 7.34 (1H, d, *J* = 8.4 Hz), 7.44 (2H, d, *J* = 8.4 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ 13.9, 20.7, 55.6, 62.1, 90.1, 95.9, 108.6, 116.0, 119.6, 120.8, 120.9, 130.1, 131.5, 134.7, 140.9, 161.9, 162.6, 169.7; IR (ATR) 2983, 2939, 2837, 1737, 1615, 1594, 1497, 1285, 1264, 1159, 1128, 1078, 1026, 957, 824 cm^{-1}; HRMS (ESI) Calcd for $C_{20}H_{19}BrNaO_4$ $[M+Na]^+$ 425.0359, Found 425.0359.



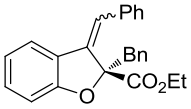
(*Z*)-Ethyl 1-benzylidene-2-methyl-1,2-dihydronaphtho[2,1-b]furan-2-carboxylate (**3k**): bright yellow liquid; HPLC analysis Chiralpak IC-3 (hexane/*i*-PrOH = 95/5, 1.0 mL/min, 254 nm, 30 °C); 7.4 (major), 13.5 (minor) min; 93% ee, $[\alpha]_D^{20}$ = +313 (c = 1.03, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.10 (3H, dd, *J* = 7.2, 7.2 Hz), 1.72 (3H, s), 4.04 (1H, dq, *J* = 11.4, 7.2 Hz), 4.07 (1H, dq, *J* = 11.4, 7.2 Hz), 7.14 (1H, d, *J* = 9.0 Hz), 7.27 (1H, t, *J* = 7.2 Hz), 7.30 (2H, d, *J* = 7.2 Hz), 7.35 (2H, dd, *J* = 7.2, 7.2 Hz), 7.39 (1H, ddd, *J* = 7.2, 7.2, 1.2 Hz), 7.57 (1H, s), 7.58 (1H, ddd, *J* = 7.2, 7.2, 1.2 Hz), 7.76 (1H, d, *J* = 9.0 Hz), 7.86 (1H, d, *J* = 7.8 Hz), 8.37 (1H, d, *J* = 7.8 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ 13.7, 22.2, 61.9, 89.6, 112.5, 117.1, 122.2, 122.4, 123.5, 127.2, 127.9, 128.2, 128.7, 129.4, 129.7, 130.3, 132.3, 136.7, 143.1, 160.1, 169.8; IR (ATR) 3058, 2984, 2937, 1739, 1702, 1631, 1581, 1522, 1462, 1447, 1374, 1258, 1125, 1082, 1007, 932, 859, 822 cm^{-1}; HRMS (ESI) Calcd for $C_{23}H_{20}NaO_3$ $[M+Na]^+$ 367.1305, Found 367.1304.



(*Z*)-Ethyl 3-benzylidene-2-phenyl-2,3-dihydrobenzofuran-2-carboxylate (**3l**): white solid; HPLC analysis Chiralpak IA-3 (hexane/*i*-PrOH = 90/10, 1.0 mL/min, 254 nm, 30 °C); 10.4 (major), 12.1 (minor) min; 48% ee, $[\alpha]_D^{25}$ = -167 (c = 1.02, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 0.96 (3H, dd, *J* = 7.2, 7.2 Hz), 4.05 (1H, dq, *J* = 10.8, 7.2 Hz), 4.14 (1H, dq, *J* = 10.8, 7.2 Hz), 6.88 (1H, d, *J* = 8.4 Hz), 7.00 (1H, dd, *J* = 7.8, 7.2 Hz), 7.12-7.16 (3H, m), 7.19-7.24 (3H, m), 7.27 (1H, s), 7.30-7.35 (3H, m), 7.57-7.60 (3H, m); ^{13}C NMR (150 MHz, $CDCl_3$) δ 13.6, 62.2, 93.2, 110.6, 120.1, 121.5, 123.1, 127.4, 127.5, 127.9, 128.2, 128.6, 129.0, 129.6, 130.4, 134.7, 15.7, 136.9, 159.6, 168.4; IR (ATR) 3059, 3027, 2980, 1735, 1460, 1447, 1234, 1019, 971, 928, 861 cm^{-1}; HRMS (ESI) Calcd for $C_{24}H_{20}NaO_3$ $[M+Na]^+$ 379.1305, Found 379.1304.

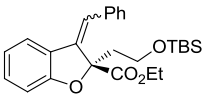


(*Z*)-Ethyl 2-benzyl-3-benzylidene-2,3-dihydrobenzofuran-2-carboxylate (**3m**): colorless liquid; HPLC analysis Chiralpak IC-3 (hexane/*i*-PrOH = 98/2, 1.0 mL/min, 254 nm, 30 °C); 7.6 (minor), 8.2 (major) min; 84% ee, $[\alpha]_D^{25}$ = +80 (c = 0.87, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.16 (3H, dd, *J* = 7.2, 7.2 Hz), 3.37 (1H, d, *J* = 14.4 Hz), 3.59 (1H, d, *J* = 14.4 Hz), 4.18 (1H, dq, *J* = 10.8, 7.2 Hz),



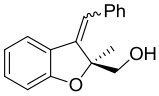
4.24 (1H, dq, *J* = 10.8, 7.2 Hz), 6.78 (1H, d, *J* = 8.4 Hz), 6.80 (1H, dd, *J* = 7.2, 7.2 Hz), 6.97 (1H, s), 6.98-7.03 (5H, m), 7.09 (1H, ddd, *J* = 7.8, 7.8, 1.2 Hz), 7.25 (1H, d, *J* =7.8 Hz), 7.28-7.31 (1H, m), 7.38-7.41 (4H, m); ^{13}C NMR (150 MHz, $CDCl_3$) δ 13.9, 38.0, 62.1, 91.4, 109.9, 119.9, 120.3, 121.0, 126.4, 127.4, 127.5, 127.9, 128.5, 128.8, 130.1, 130.6, 134.8, 135.7, 138.3, 160.6, 169.8; IR (ATR) 3061, 3029, 2980, 1734, 1464, 1262, 1244, 1051, 938, 910, 876 cm^{-1}; HRMS (ESI) Calcd for $C_{25}H_{22}NaO_3$ $[M+Na]^+$ 393.1461, Found 393.1461.

(*Z*)-Ethyl 3-benzylidene-2-(2-((*tert*-butyldimethylsilyl)oxy)ethyl)-2,3-dihydrobenzofuran-2-carboxylate (**3n**):



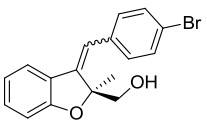
colorless liquid; HPLC analysis Chiralpak IA-3 (hexane/*i*-PrOH = 98.5/1.5, 1.0 mL/min, 254 nm, 30 °C); 5.5 (minor), 11.5 (major) min; 80% ee, $[\alpha]_D^{25}$ = +172 (c = 1.13, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ -0.17 (3H, s), -0.14 (3H, s), 0.76 (9H, s), 1.15 (3H, dd, *J* = 7.2, 7.2 Hz), 2.37 (1H, ddd, *J* = 15.0, 9.6, 6.0 Hz), 2.49 (1H, ddd, *J* = 15.0, 9.0, 5.4 Hz), 3.59 (1H, ddd, *J* = 10.2, 9.0, 6.0 Hz), 3.64 (1H, ddd, *J* = 10.2, 9.6, 5.4 Hz), 4.12 (1H, dq, *J* = 10.8, 7.2 Hz), 4.19 (1H, dq, *J* = 10.8, 7.2 Hz), 6.87 (1H, d, *J* = 8.4 Hz), 6.96 (1H, ddd, *J* = 7.2, 7.2, 0.6 Hz), 7.04 (1H, s) 7.22 (2H, ddd, *J* = 7.2, 7.2, 1.8 Hz) 7.24-7.27 (m, 2H), 7.30-7.35 (4H, m), 7.45 (1H, dd, *J* = 7.8, 0.6 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ -5.62, -5.58, 13.8, 18.1, 25.8, 36.1, 58.4, 61.9, 90.3, 110.2, 120.2, 120.4, 121.2, 127.4 (2C), 128.3, 128.7, 130.3, 135.5, 138.4, 160.9, 169.6; IR (ATR) 2954, 2928, 2856, 1464, 1249, 1218, 1084, 1028, 940, 834 cm^{-1}; HRMS (ESI) Calcd for $C_{26}H_{34}NaO_4Si$ $[M+Na]^+$ 461.2119, Found 461.2118.

(*Z*)-(3-Benzylidene-2-methyl-2,3-dihydrobenzofuran-2-yl)methanol (5a): white solid; HPLC analysis Chiralpak



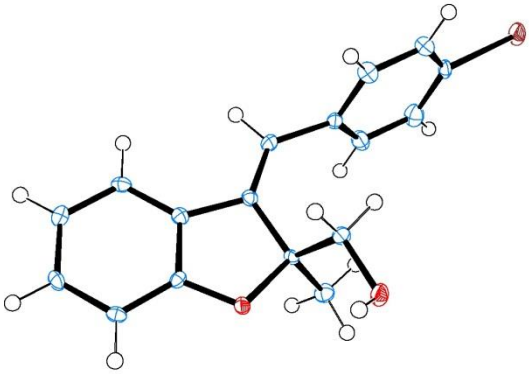
IC-3 (hexane/*i*-PrOH = 96/4, 1.0 mL/min, 254 nm, 30 °C); 14.0 (major), 17.8 (minor) min; 90% ee, $[\alpha]_D^{25}$ = +64 (c = 1.20, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.49 (3H, s), 1.85 (1H, br), 3.63 (1H, dd, *J* = 12.0, 6.6 Hz), 3.67 (1H, dd, *J* = 12.0, 7.8 Hz), 6.84 (1H, d, *J* = 7.8 Hz), 6.94 (1H, ddd, *J* = 7.2, 7.2, 1.2 Hz), 7.13 (1H, s), 7.22 (1H, ddd, *J* = 7.2, 7.2, 0.6 Hz), 7.28 (1H, t, *J* = 7.2 Hz), 7.29 (2H, d, *J* = 7.8 H), 7.34 (1H, dd, *J* = 7.8, 7.2 Hz), 7.45 (1H, dd, *J* = 7.8, 0.6 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ 22.2, 67.7, 91.8, 110.4, 118.9, 120.5, 130.8, 127.2, 128.1, 128.8, 130.3, 136.1, 141.4, 160.1; IR (ATR) 3449, 3052, 2983, 2932, 2869, 1596, 1491, 1466, 1322, 1261, 1053, 926, 905, 867 cm^{-1}; HRMS (ESI) Calcd for $C_{17}H_{16}NaO_2$ $[M+Na]^+$ 275.1042, Found 275.1043.

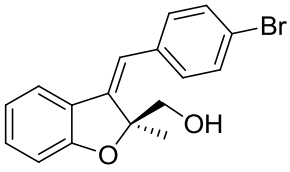
(*Z*)-(3-(4-Bromobenzylidene)-2-methyl-2,3-dihydrobenzofuran-2-yl)methanol (5e): white solid; HPLC analysis



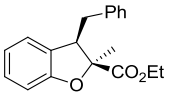
Chiralpak IA-3 (hexane/*i*-PrOH = 96/04, 1.0 mL/min, 254 nm, 30 °C); 23.7 (major), 28.5 (minor) min; 85% ee, $[\alpha]_D^{25}$ = +52 (c = 1.01, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.41 (3H, s), 1.80-1.95 (1H, br), 3.60 (dd, *J* = 12.0, 6.0 Hz, 1H), 3.66 (dd, *J* = 12.0, 7.2 Hz, 1H), 6.85 (1H, d, *J* = 7.8 Hz), 6.94 (1H, dd, *J* = 7.8, 7.2 Hz), 7.01 (1H, s), 7.17 (2H, d, *J* = 8.4 Hz), 7.23 (1H, dd, *J* = 7.8, 7.2 Hz), 7.44 (1H, d, *J* = 7.2 Hz), 7.47 (2H, d, *J* = 8.4 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ 22.2, 67.7, 91.7, 110.5, 117.5, 120.6, 120.9, 121.3, 126.9, 130.55, 130.62, 131.3, 135.1, 142.2, 160.2; IR (neat) 3421, 2982, 2932, 2869, 1595, 1486, 1465, 1321, 1261, 1070, 1054, 1011, 912, 869 cm^{-1}; HRMS (ESI) Calcd for $C_{17}H_{15}BrNaO_2$ $[M+Na]^+$ 353.0148. Found 353. 0148; CCDC No. 1431742.

Figure S1. ORTEP diagram of **5e**.



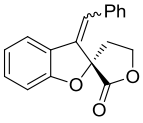


Ethyl 3-benzyl-2-methyl-2,3-dihydrobenzofuran-2-carboxylate (6a): white solid, dr = 21 : 1; HPLC analysis



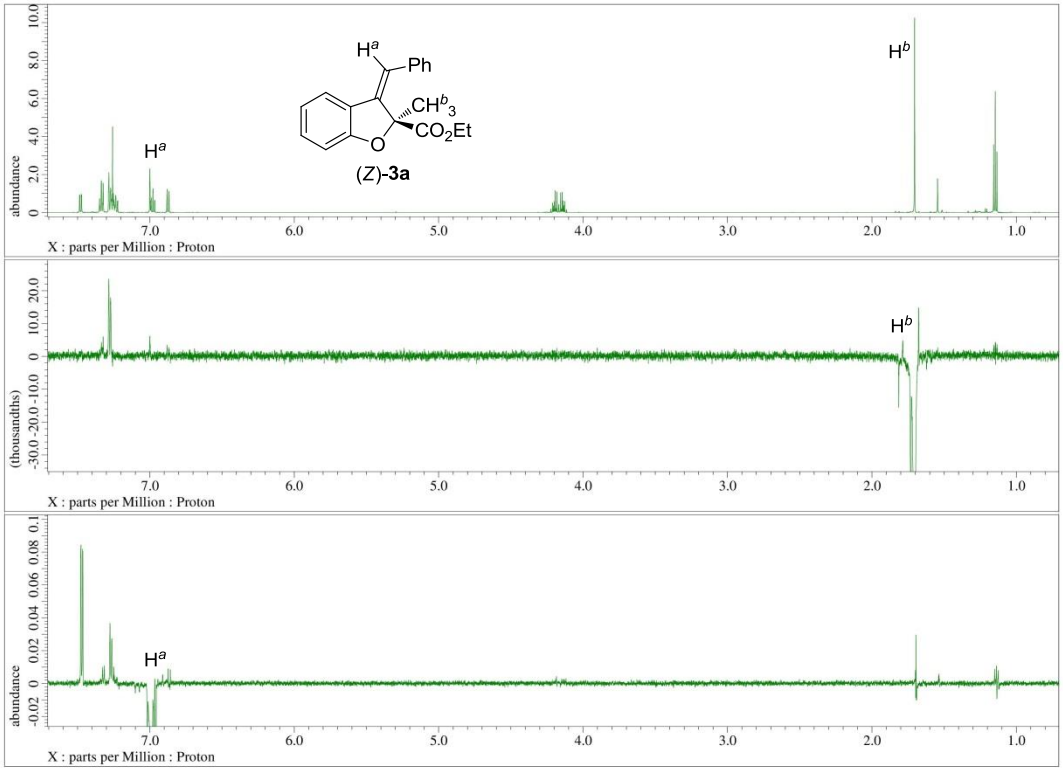
Chiralpak IB-3 (hexane/*i*-PrOH = 98/02, 1.0 mL/min, 254 nm, 30 °C); 5.5 (major), 7.5 (minor) min; 90% ee, $[\alpha]_D^{25}$ = -133 (c = 1.13, $CHCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 1.31 (3H, dd, *J* = 7.2, 7.2 Hz), 1.66 (3H, s), 2.58 (1H, dd, *J* = 13.2, 11.4 Hz), 3.07 (1H, dd, *J* = 13.2, 4.8 Hz), 3.53 (1H, dd, *J* = 11.4, 4.8 Hz), 4.23 (1H, dq, *J* = 10.8, 7.2 Hz), 4.32 (1H, dq, *J* = 10.8, 7.2 Hz), 6.29 (1H, d, *J* = 7.2 Hz), 6.66 (1H, ddd, *J* = 7.8, 7.8, 1.2 Hz), 6.87 (1H, d, *J* = 7.8 Hz), 7.10 (2H, d, *J* = 8.4 Hz), 7.12 (1H, ddd, *J* = 7.8, 7.8, 1.2 Hz), 7.23-7.26 (1H, m), 7.30 (2H, dd, *J* = 7.2, 7.2 Hz); ^{13}C NMR (150 MHz, $CDCl_3$) δ 14.2, 24.5, 37.4, 53.0, 61.5, 90.4, 110.1, 120.3, 125.5, 126.5, 128.3, 128.4, 128.6, 129.5, 138.3, 157.9, 171.4; IR (ATR) 3029, 2981, 1733, 1478, 1461, 1244, 1123, 1084, 1018, 930, 859 cm^{-1}; HRMS (ESI) Calcd for $C_{19}H_{20}NaO_3$ $[M+Na]^+$ 319.1305, Found 319.1305.

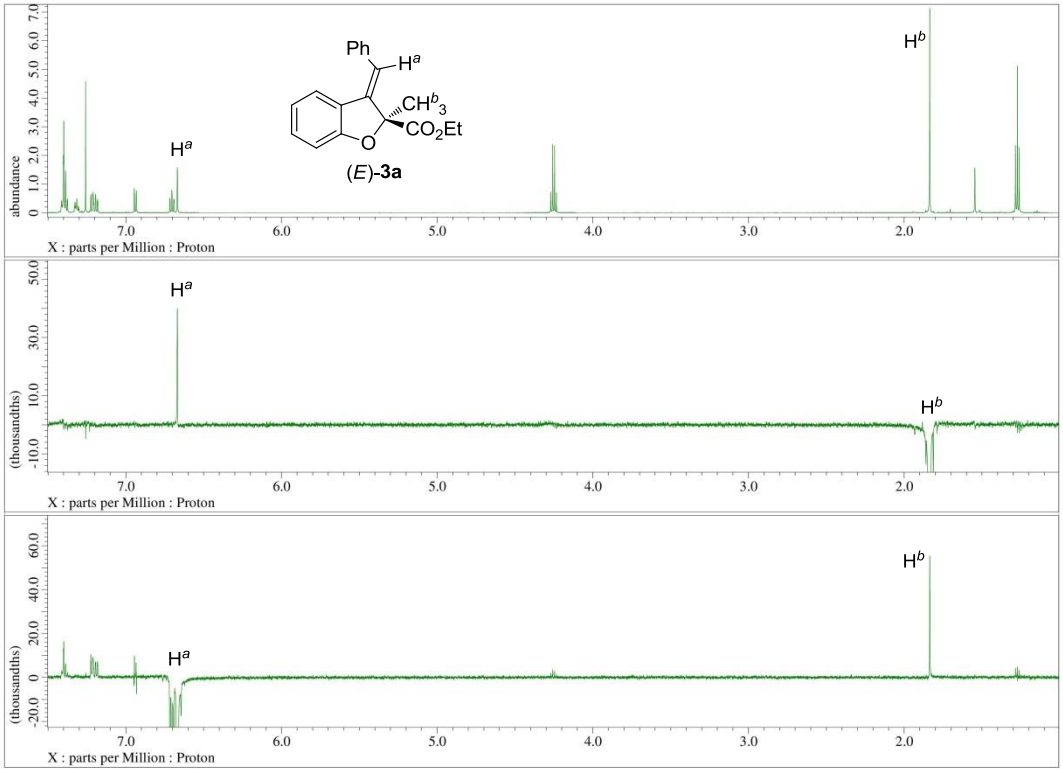
(*Z*)-3-Benzylidene-4',5'-dihydro-2'H,3H-spiro[benzofuran-2,3'-furan]-2'-one (**7**): colorless liquid; HPLC



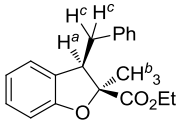
analysis Chiralpak AD-3 (hexane/*i*-PrOH = 85/15, 1.0 mL/min, 254 nm, 30 °C); 10.1 (minor), 17.7 (major) min; 77% ee, $[\alpha]_D^{25}$ = +535 (c = 1.01, $CDCl_3$); ^{1}H NMR (600 MHz, $CDCl_3$) δ 2.37 (1H, ddd, *J* = 14.4, 7.2, 2.4 Hz), 2.60 (1H, ddd, *J* = 14.4, 9.0, 9.0 Hz), 4.01 (1H, ddd, *J* = 9.0, 9.0, 2.4 Hz), 4.42 (1H, ddd, *J* = 9.0, 9.0, 7.2 Hz), 6.87 (1H, d, *J* = 7.8 Hz), 7.00 (1H, ddd, *J* = 7.8, 7.2, 0.6 Hz), 7.19 (1H, s), 7.23-7.27 (3H, m), 7.29 (1H, t, *J* = 7.2 Hz), 7.37 (2H, dd, *J* = 7.8, 7.2 Hz), 7.48-7.50 (1H, m); ^{13}C NMR (150 MHz, $CDCl_3$) δ 32.3, 66.0, 88.0, 110.5, 120.4, 121.0, 121.9, 126.4, 127.8, 128.4, 128.8, 130.8, 135.4, 137.5, 159.8, 173.1; IR (ATR) 3054, 3024, 2922, 1775, 1464, 1173, 1020, 957, 932, 859 cm^{-1}; HRMS (ESI) Calcd for $C_{18}H_{14}NaO_3$ $[M+Na]^+$ 301.0835, Found 301.0835.

NOE Analysis of 3a

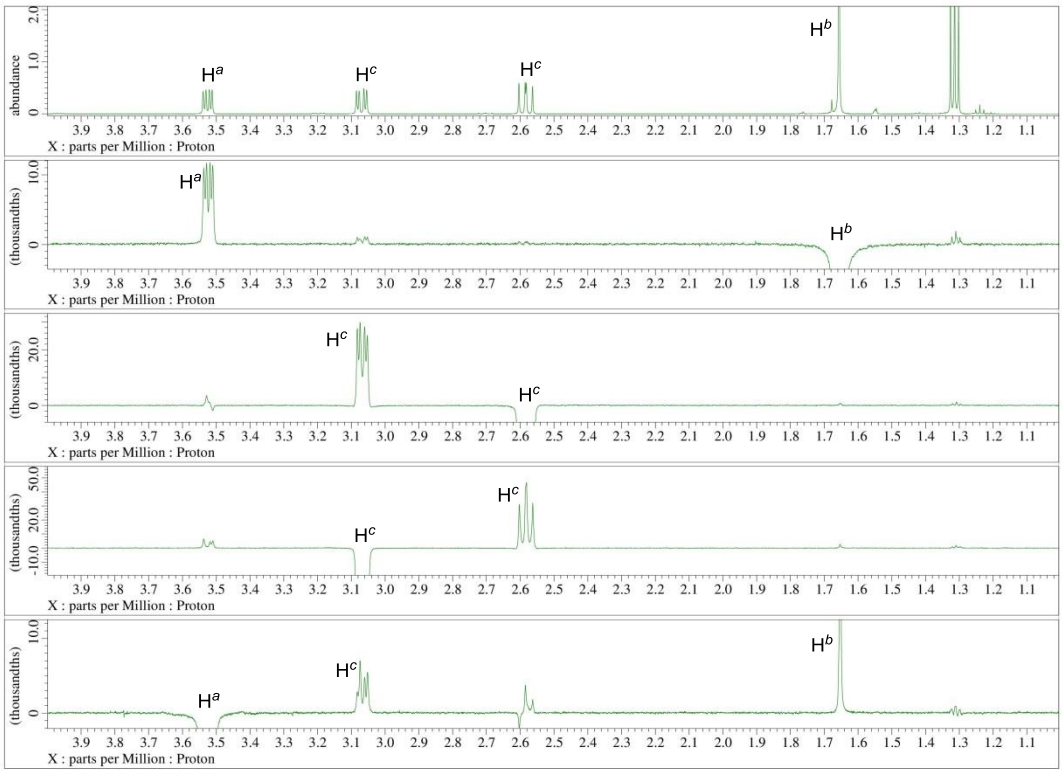


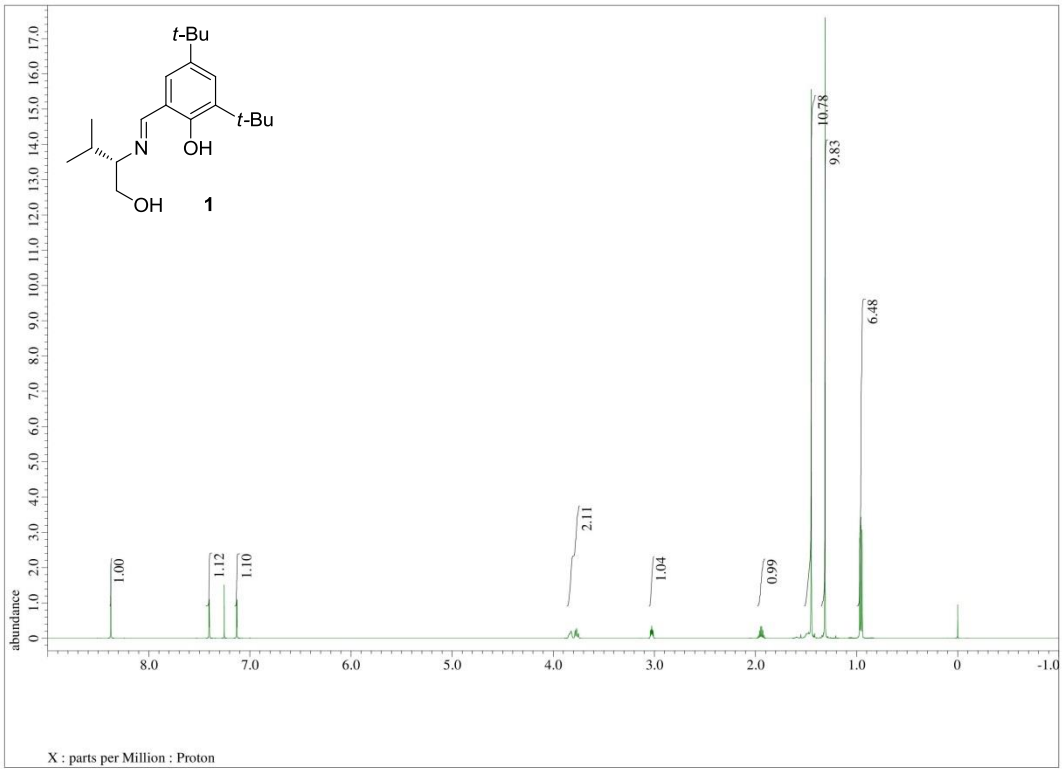


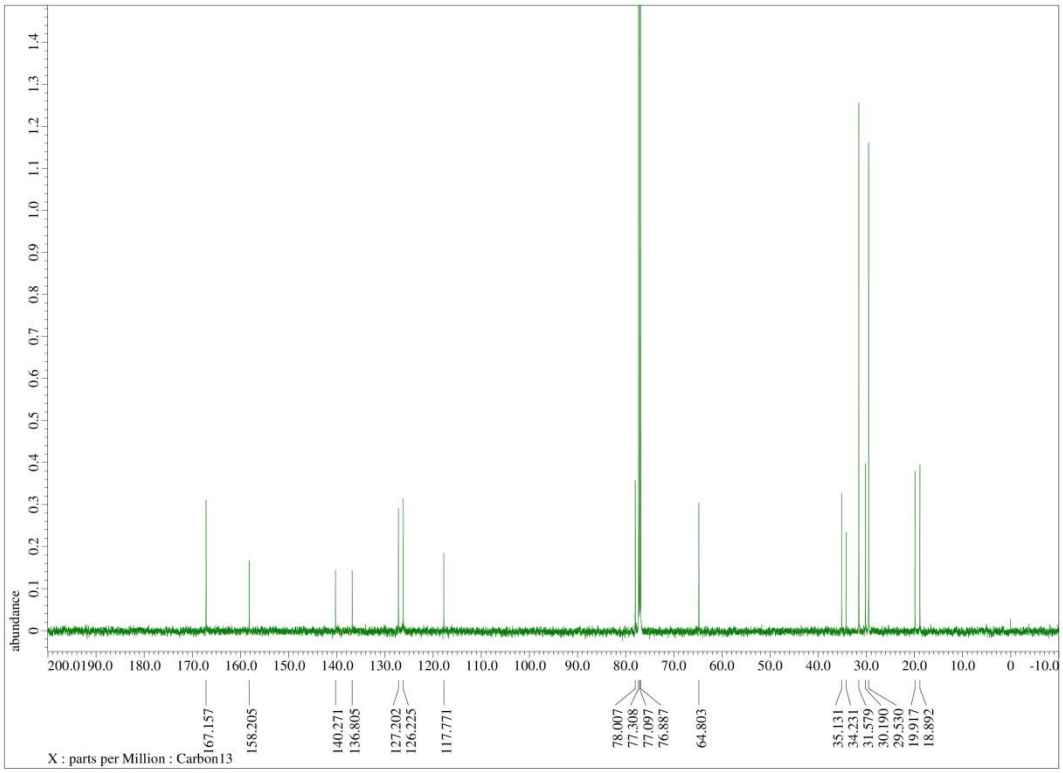
NOE Analysis of 6a

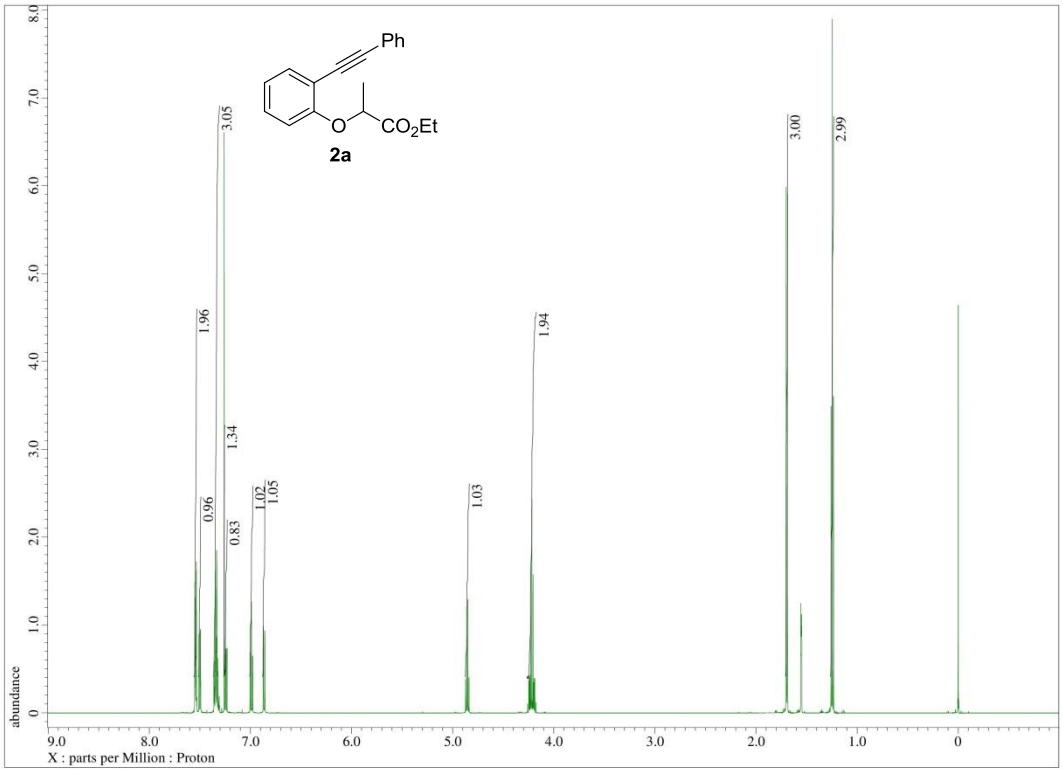


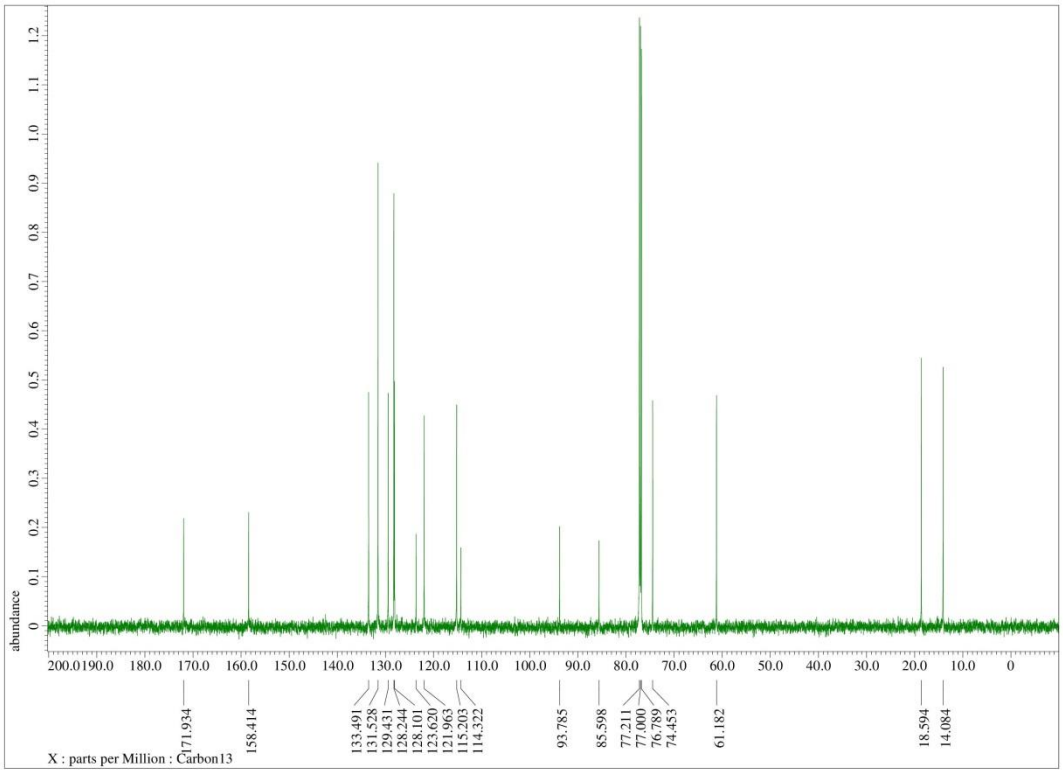
6a

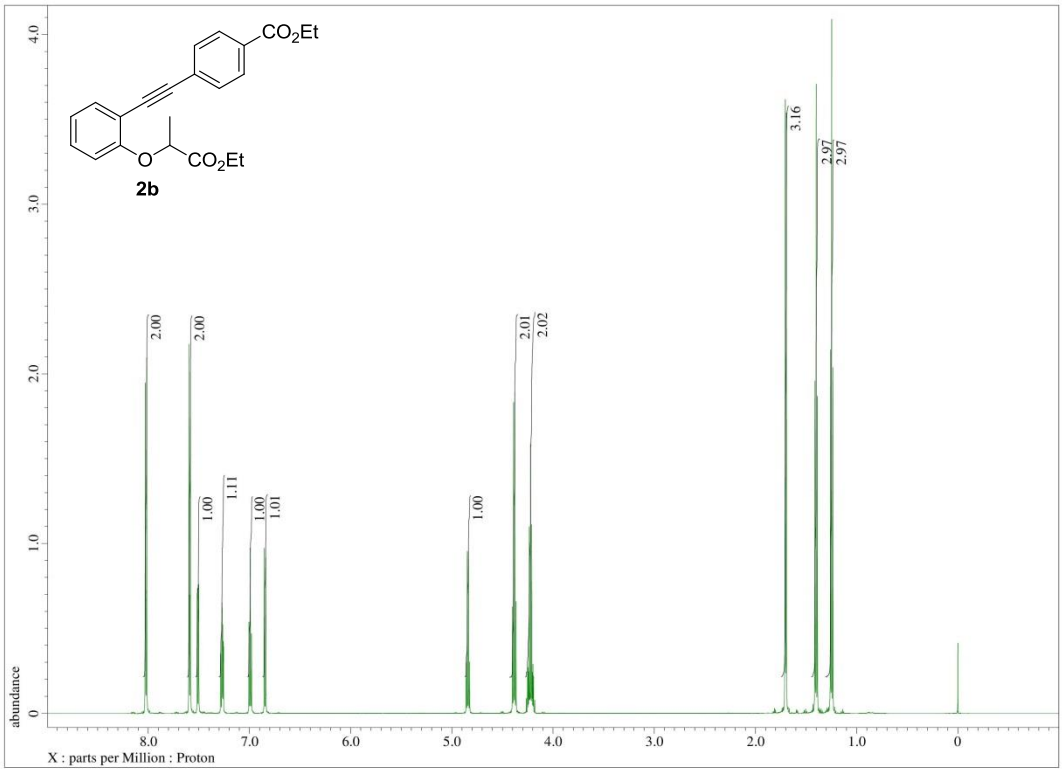


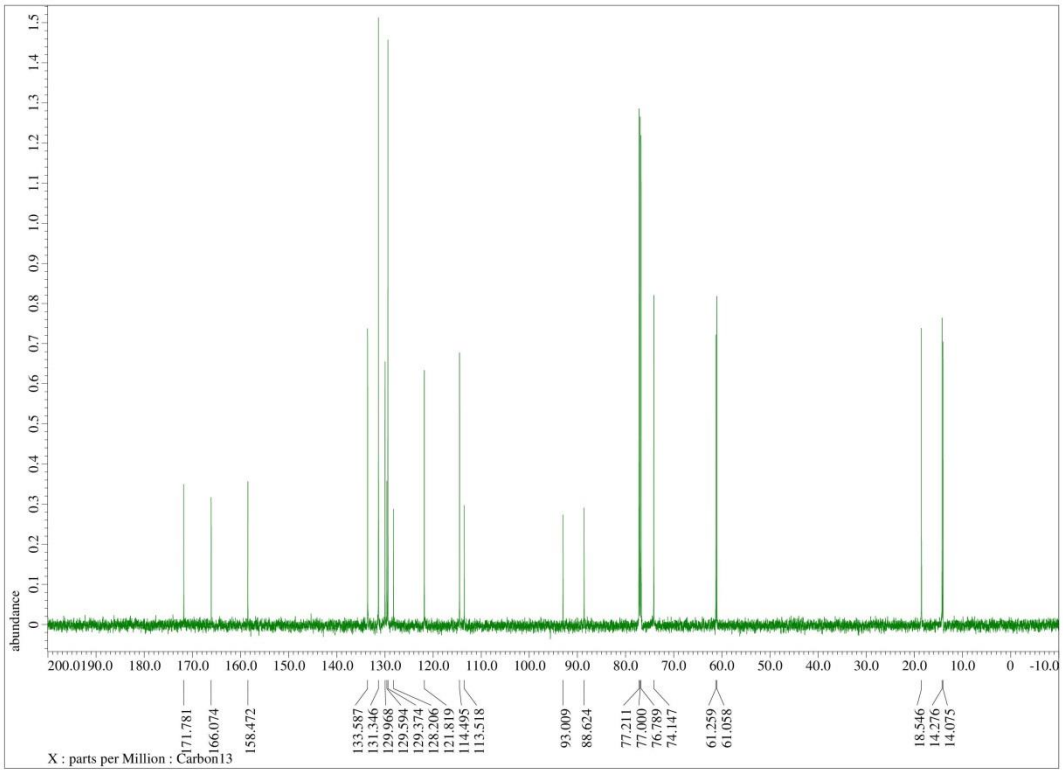

t-Bu
t-Bu
N
OH
OH
1
abundance
1.00
1.12
1.10
2.11
1.04
0.99
10.78
9.83
6.48
X : parts per Million : Proton

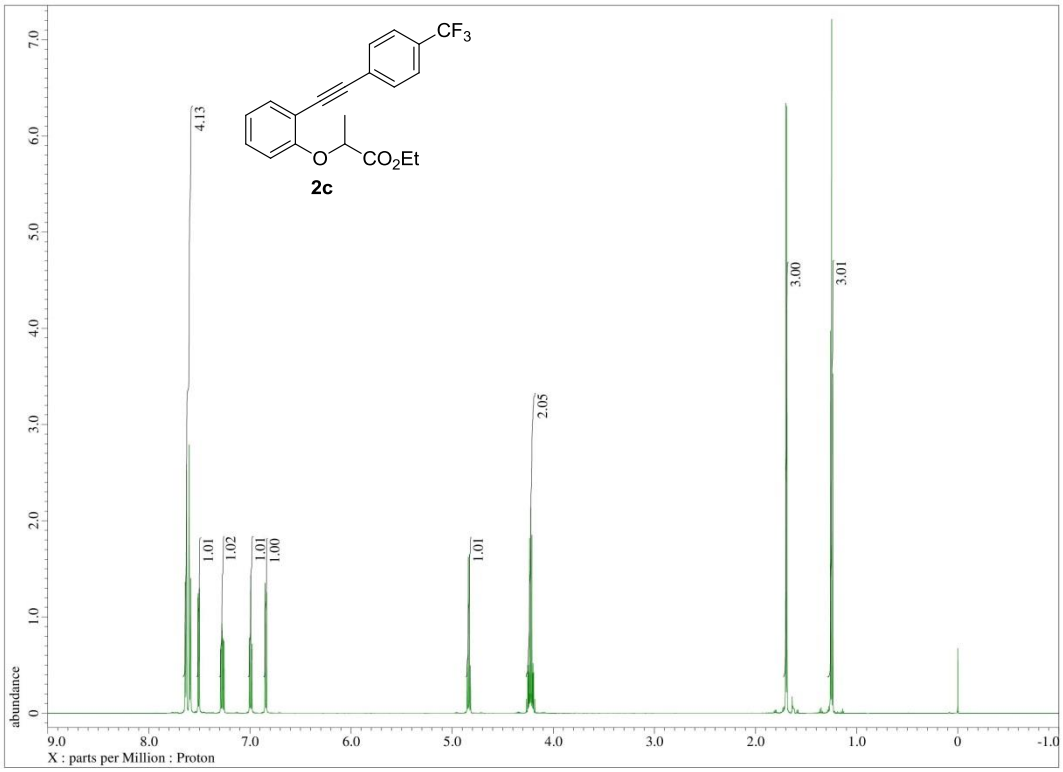

abundance
167.157
158.205
140.271
136.805
127.202
126.225
117.771
78.007
77.308
77.097
76.887
64.803
35.131
34.231
31.579
30.190
29.530
19.917
18.892
X : parts per Million : Carbon13

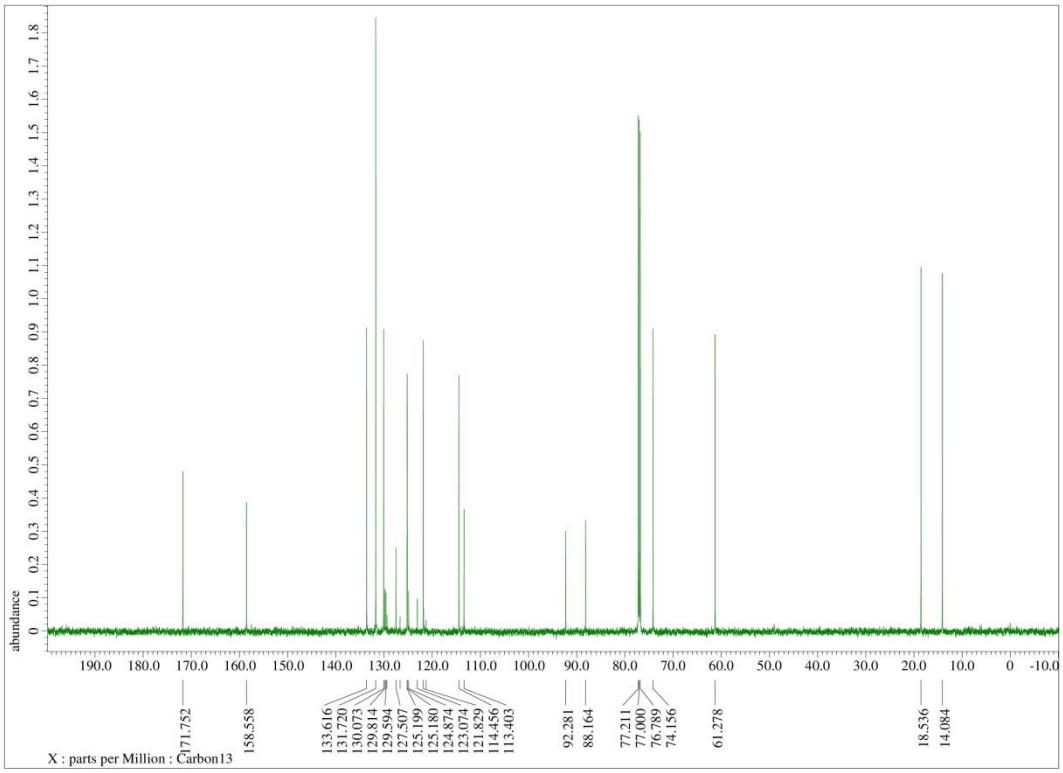

Ph
O
CO2Et
2a
1.96
0.96
3.05
1.34
0.83
1.02
1.05
1.03
1.94
3.00
2.99
abundance
X : parts per Million : Proton

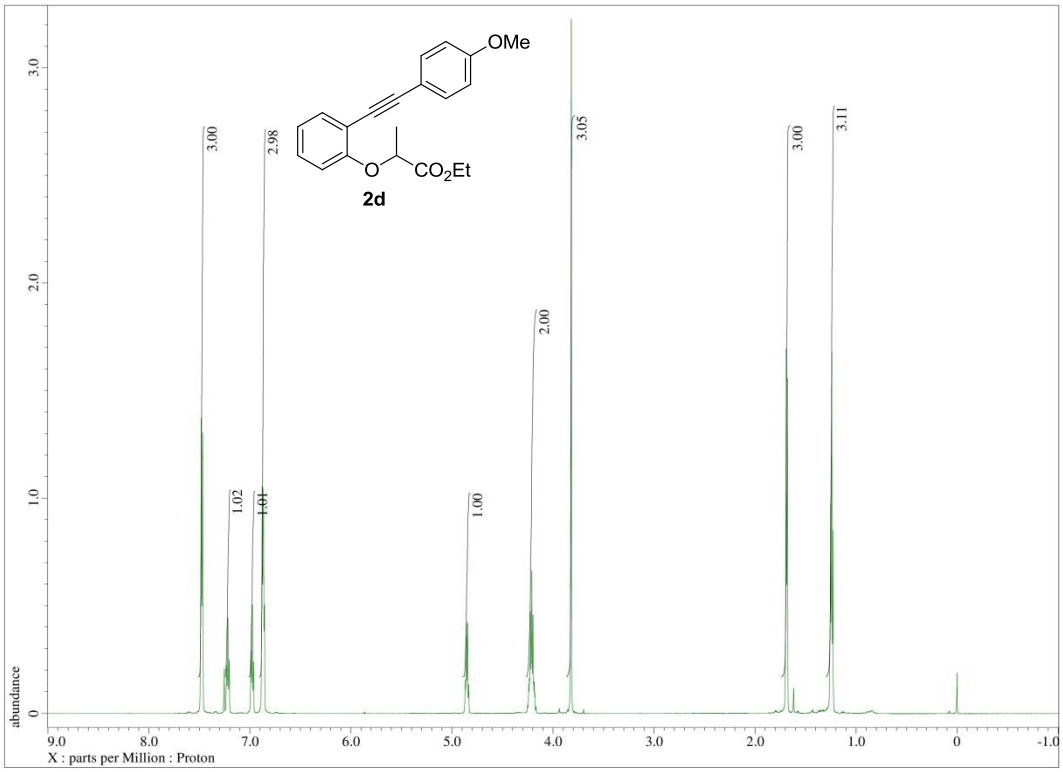

abundance
171.934
158.414
133.491
131.528
129.431
128.244
128.101
123.620
121.963
115.203
114.322
93.785
85.598
77.211
77.000
76.789
74.453
61.182
18.594
14.084
X : parts per Million : Carbon13

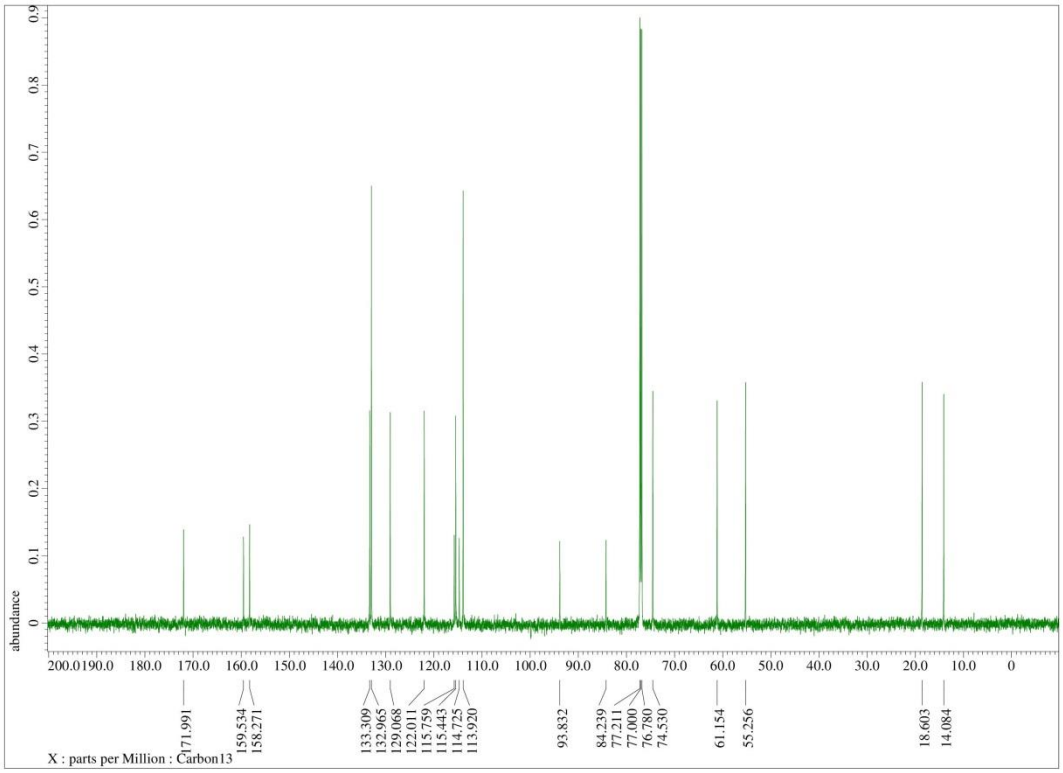

CO2Et
O
CO2Et
2b
abundance
X : parts per Million : Proton
2.00
2.00
1.00
1.11
1.00
1.01
1.00
2.01
2.02
3.16
2.97
2.97

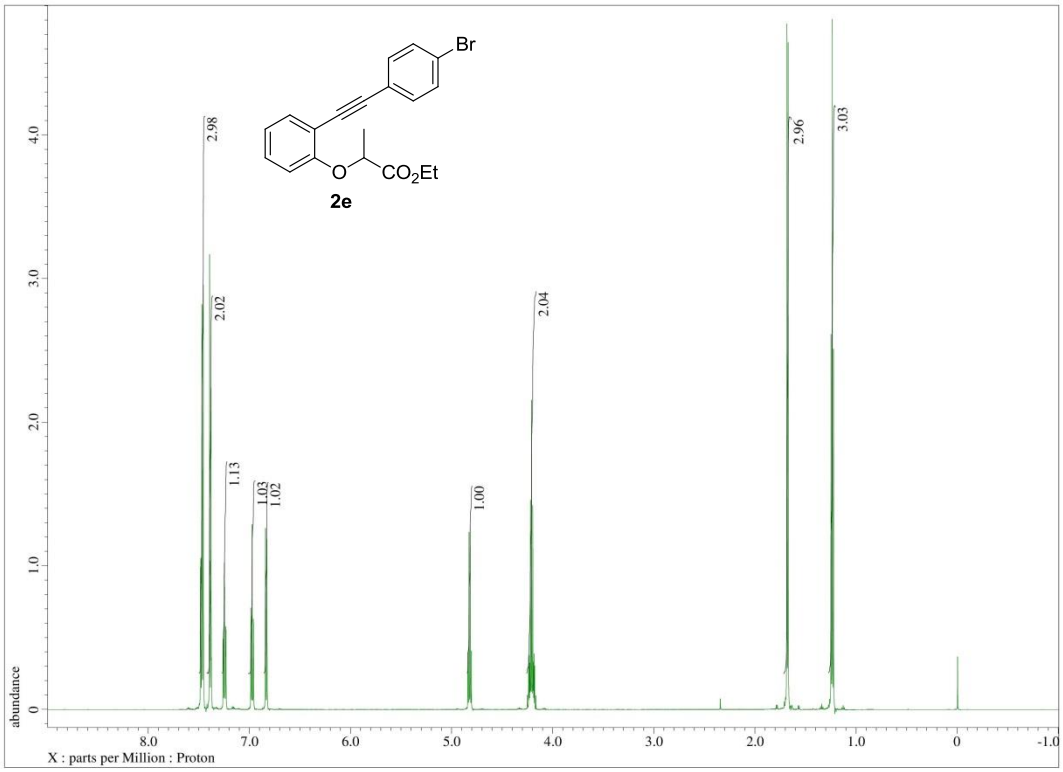

abundance
X : parts per Million : Carbon13
171.781
166.074
158.472
133.587
131.346
129.968
129.594
129.374
128.206
121.819
114.495
113.518
93.009
88.624
77.211
77.000
76.789
74.147
61.259
61.058
18.546
14.276
14.075

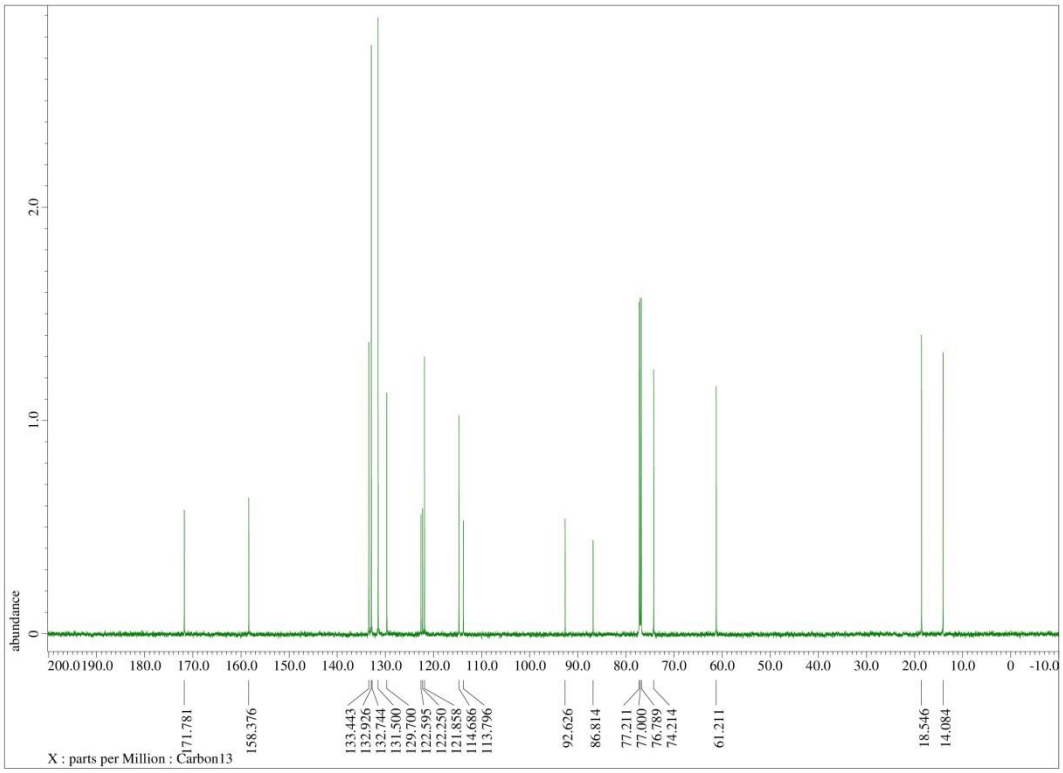

CF3
O
CO2Et
2c
4.13
1.01
1.02
1.01
1.00
1.01
2.05
3.00
3.01
abundance
X : parts per Million : Proton

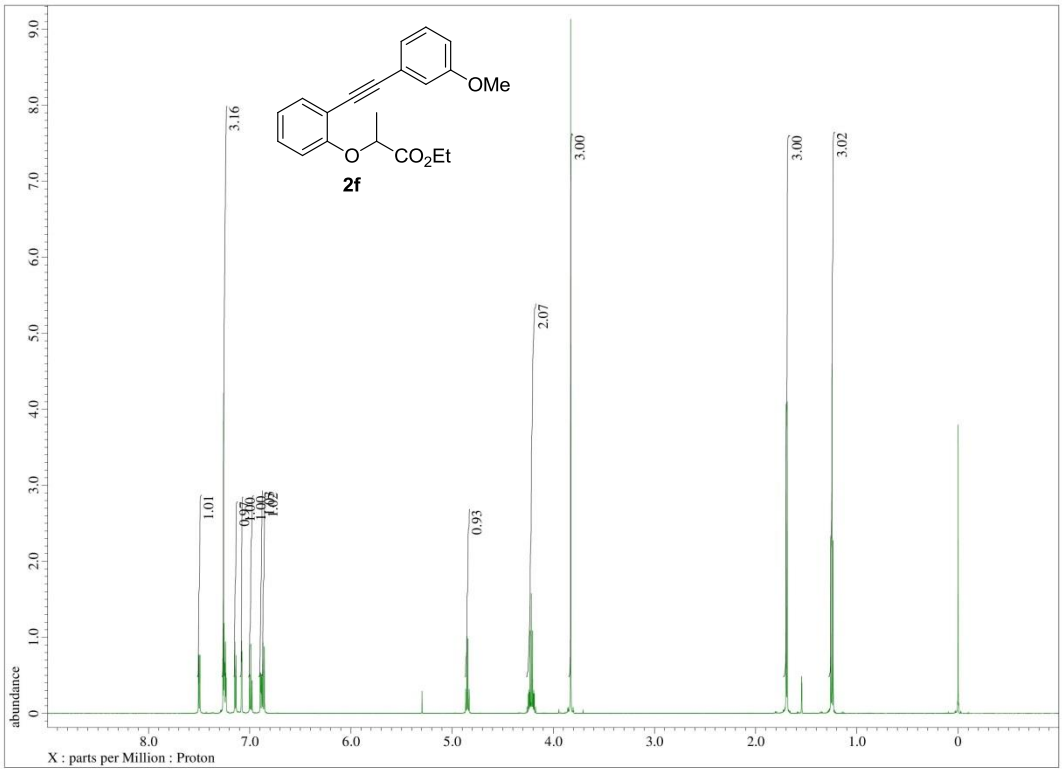

abundance
X : parts per Million : Carbon13
171.752
158.558
133.616
131.720
130.073
129.814
129.594
127.507
125.199
125.180
124.874
123.074
121.829
114.456
113.403
92.281
88.164
77.211
77.000
76.789
74.156
61.278
18.536
14.084

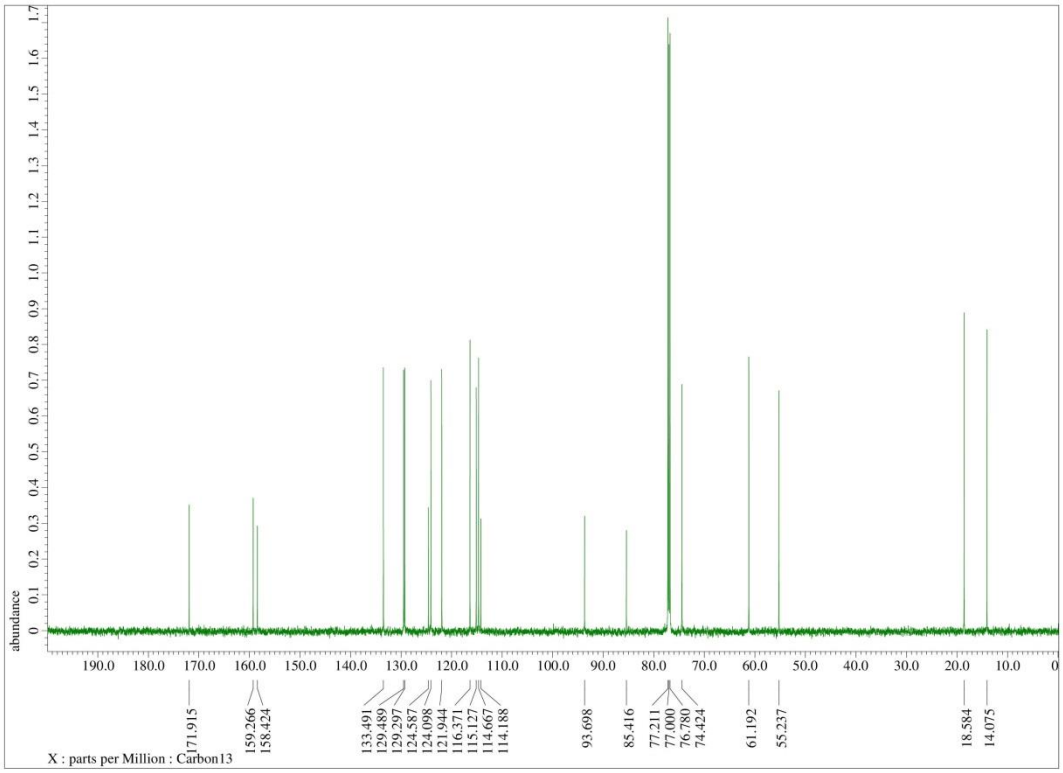

OMe
O
CO2Et
2d
3.00
2.98
1.02
1.01
1.00
2.00
3.05
3.00
3.11
abundance
X : parts per Million : Proton

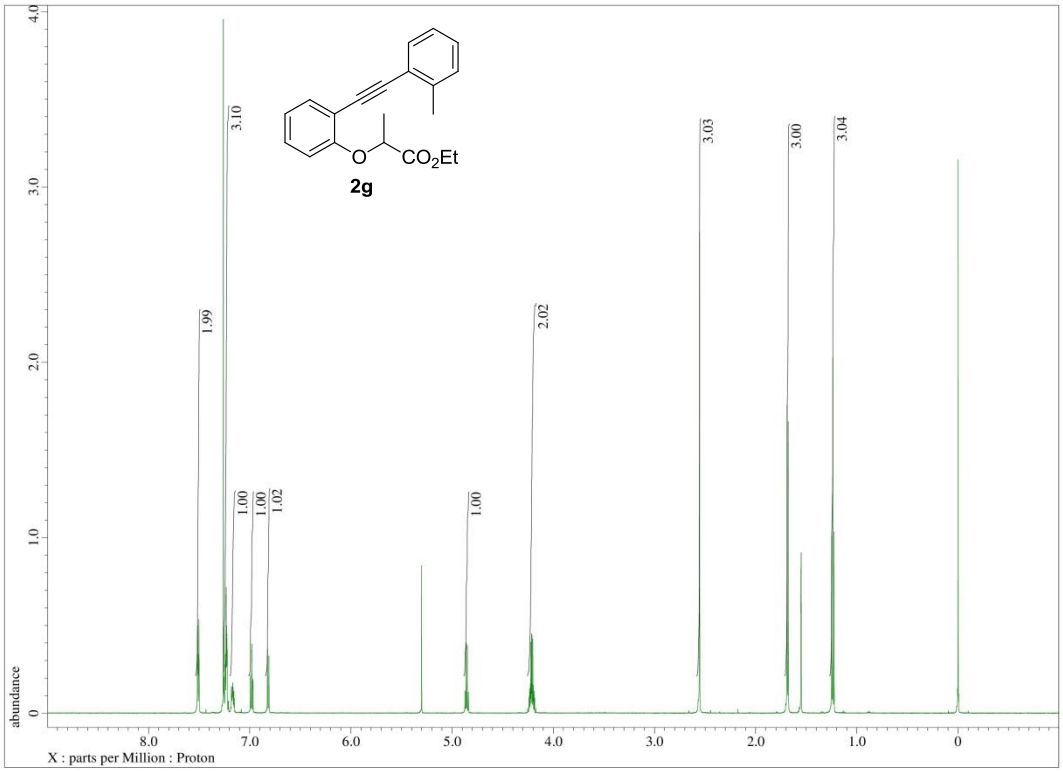

abundance
X : parts per Million : Carbon13
171.991
159.534
158.271
133.309
132.965
129.068
122.011
115.759
115.443
114.725
113.920
93.832
84.239
77.211
77.000
76.780
74.530
61.154
55.256
18.603
14.084

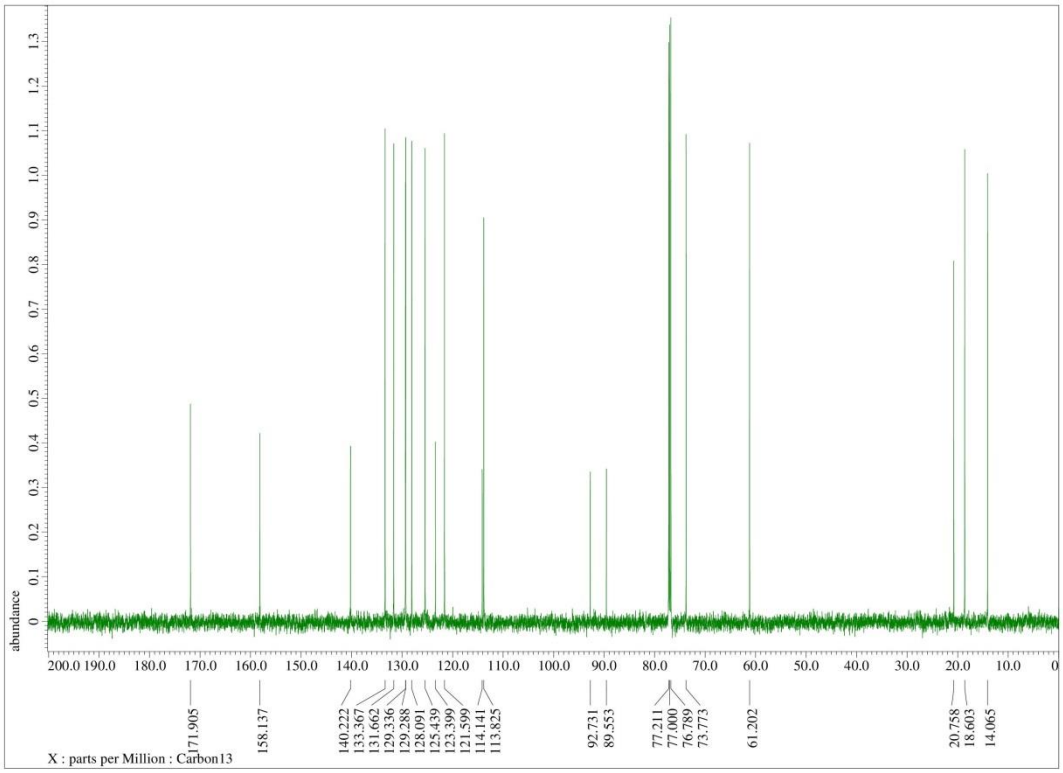

Br
O
CO2Et
2e
2.98
2.02
1.13
1.03
1.02
1.00
2.04
2.96
3.03
abundance
X : parts per Million : Proton

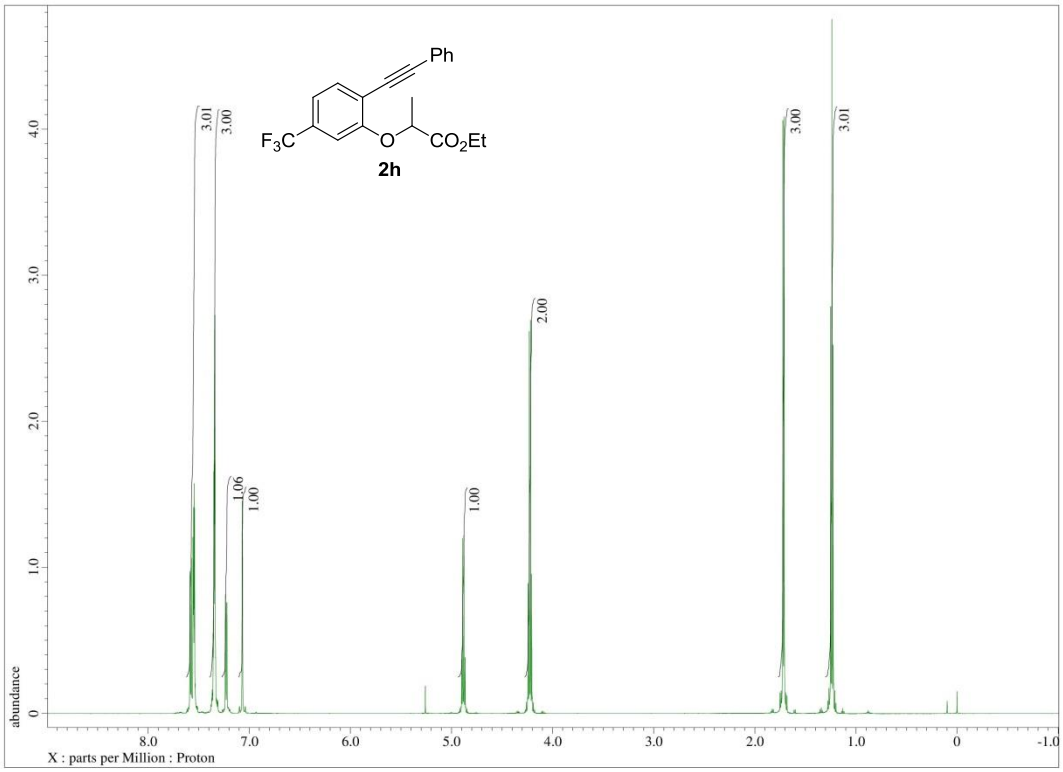

abundance
171.781
158.376
133.443
132.926
132.744
131.500
129.700
122.595
122.250
121.858
114.686
113.796
92.626
86.814
77.211
77.000
76.789
74.214
61.211
18.546
14.084
X : parts per Million : Carbon13

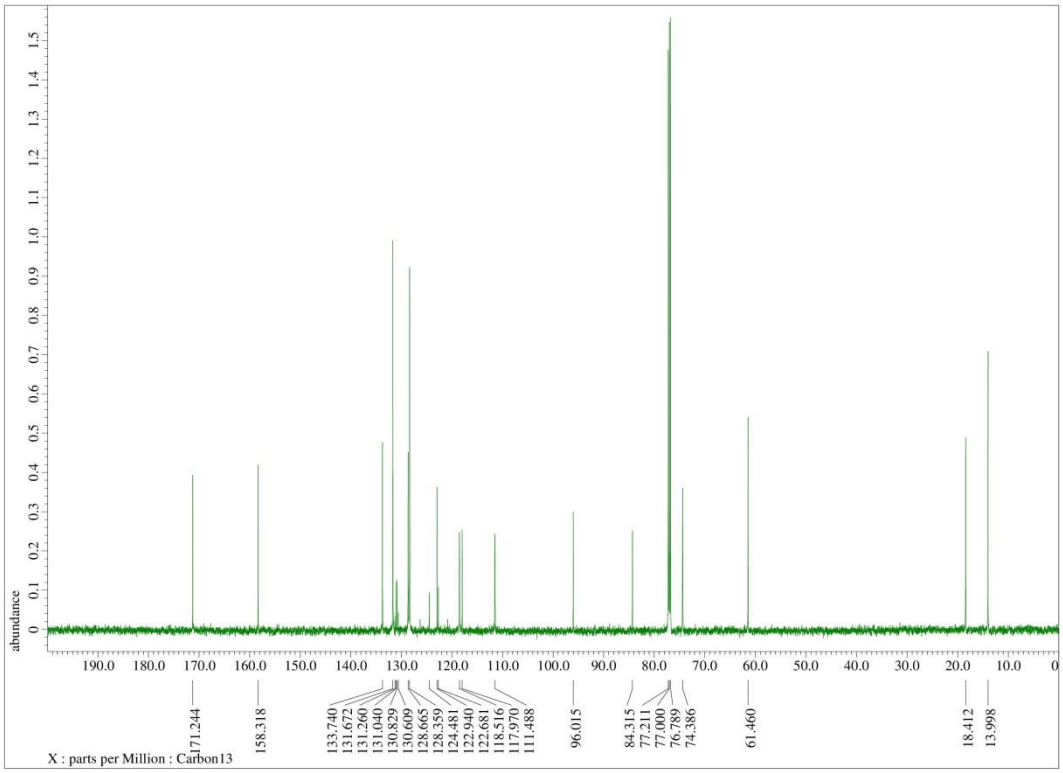

OMe
O
CO2Et
2f
3.16
3.00
3.00
3.02
2.07
1.01
0.93
abundance
X : parts per Million : Proton

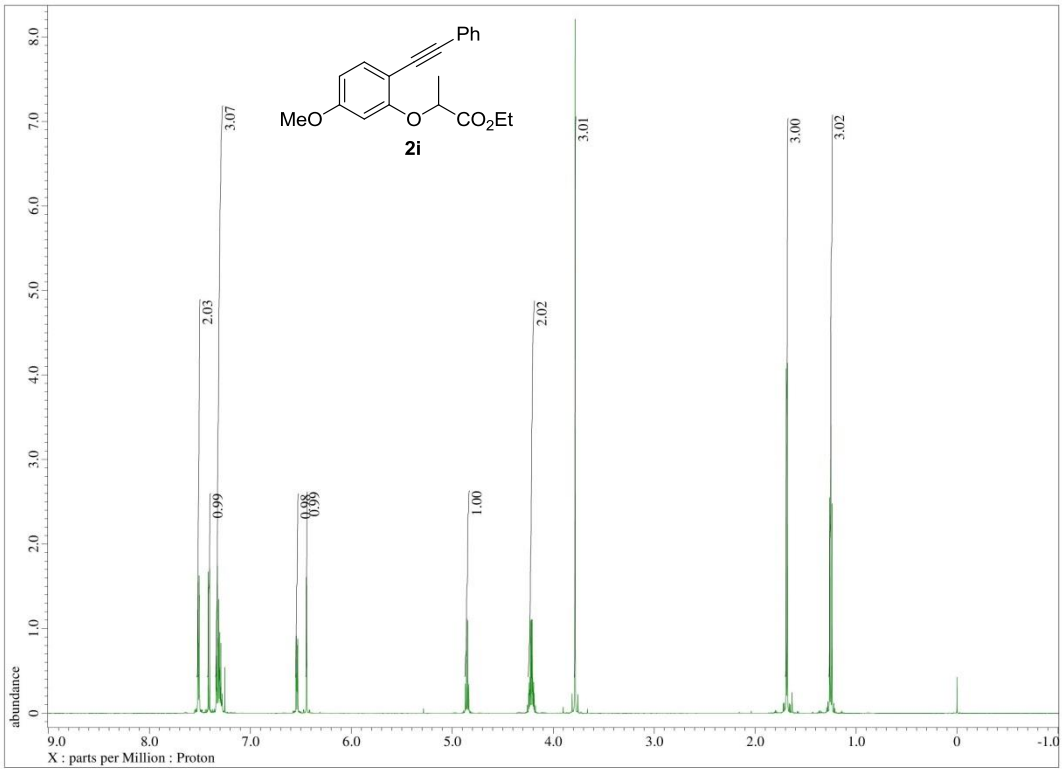

abundance
171.915
159.266
158.424
133.491
129.489
129.297
124.587
124.098
121.944
116.371
115.127
114.667
114.188
93.698
85.416
77.211
77.000
76.780
74.424
61.192
55.237
18.584
14.075
X : parts per Million : Carbon13

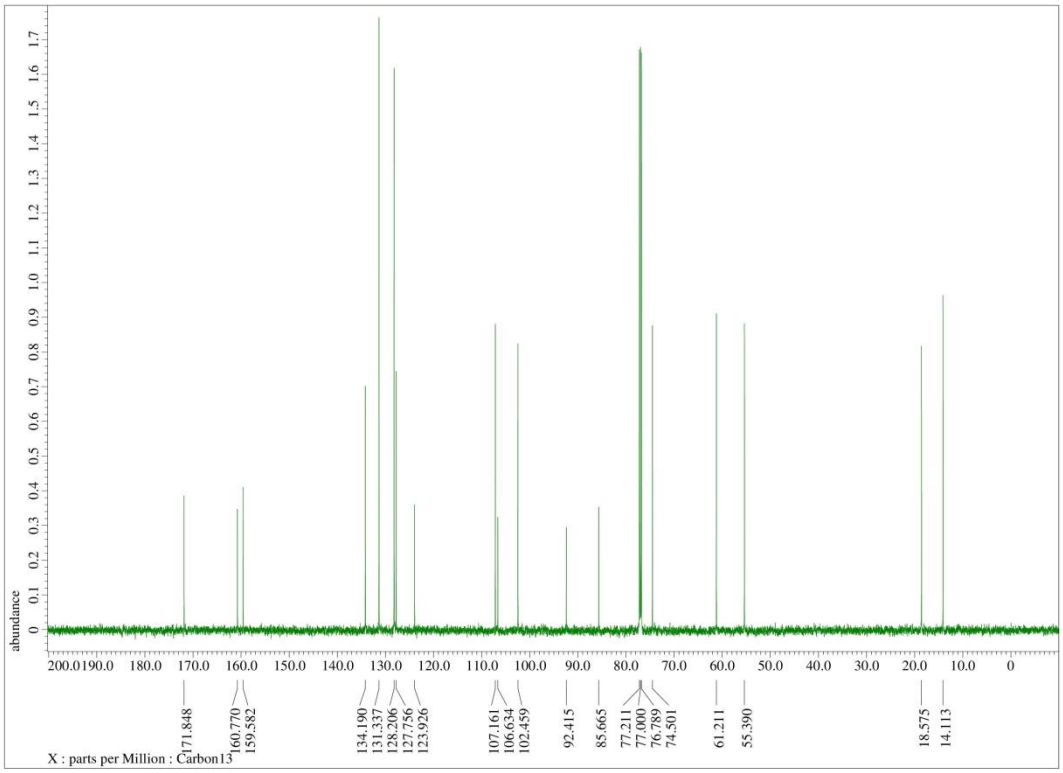

2g
O
CO2Et
1.99
3.10
1.00
1.00
1.02
1.00
2.02
3.03
3.00
3.04
abundance
X : parts per Million : Proton

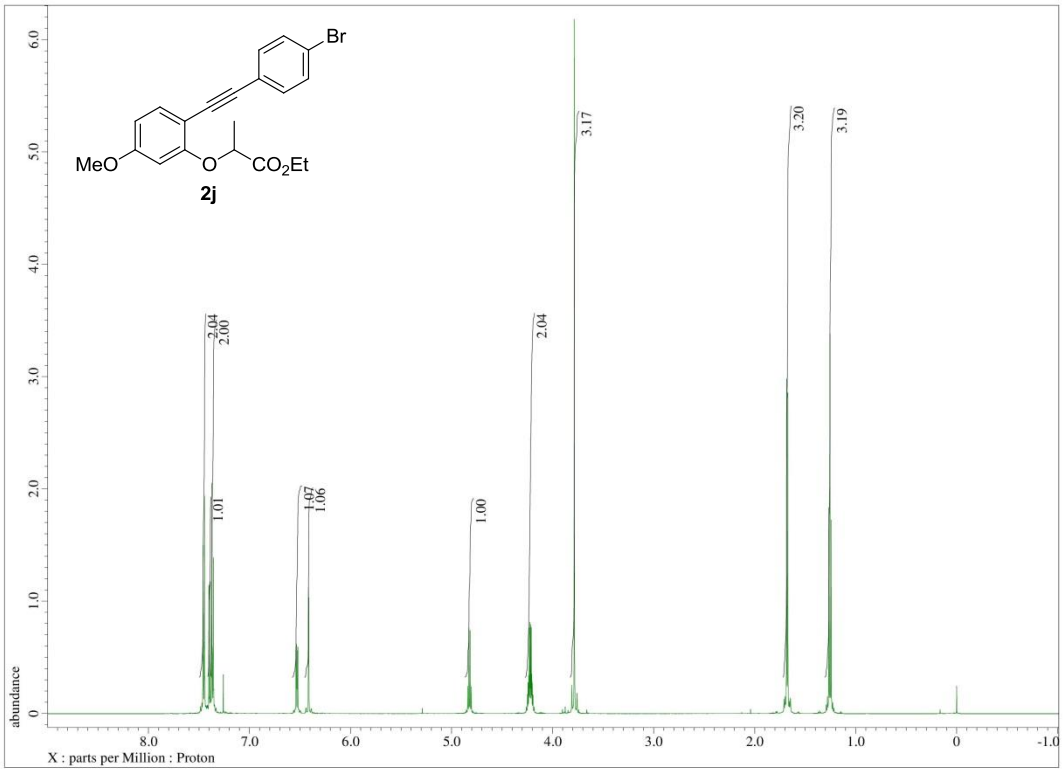

abundance
X : parts per Million : Carbon13
171.905
158.137
140.222
133.367
131.662
129.336
129.288
128.091
125.439
123.399
121.599
114.141
113.825
92.731
89.553
77.211
77.000
76.789
73.773
61.202
20.758
18.603
14.065

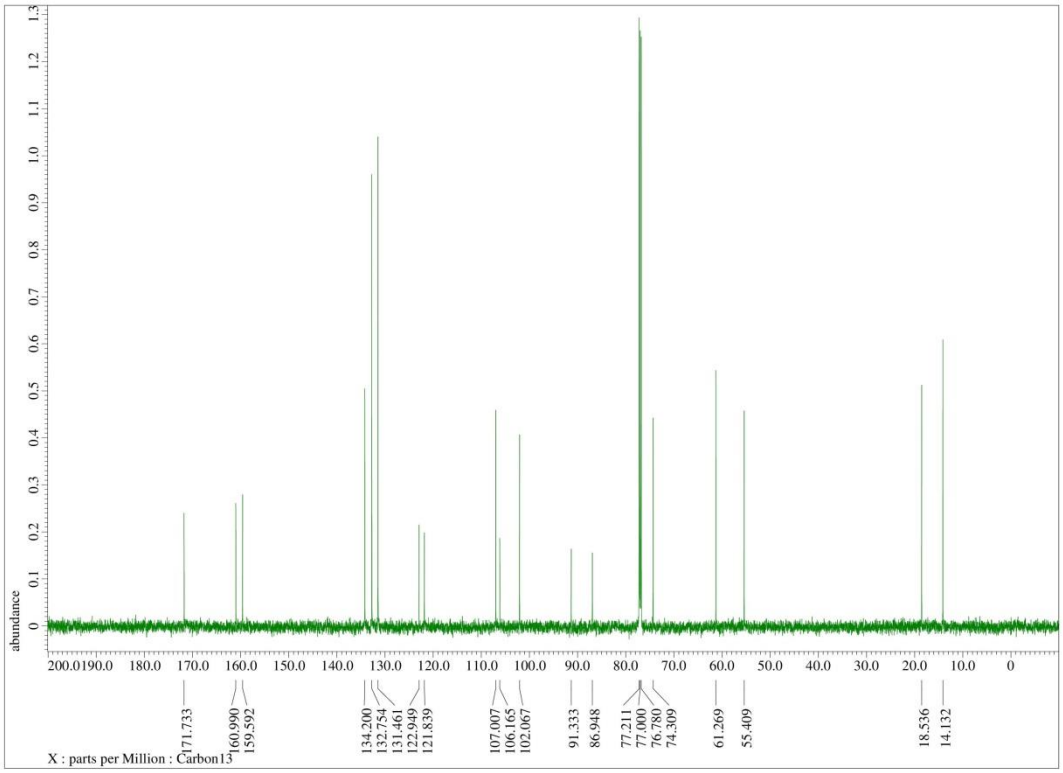

Ph
F3C
O
CO2Et
2h
3.01
3.00
1.06
1.00
1.00
2.00
3.00
3.01
abundance
X : parts per Million : Proton

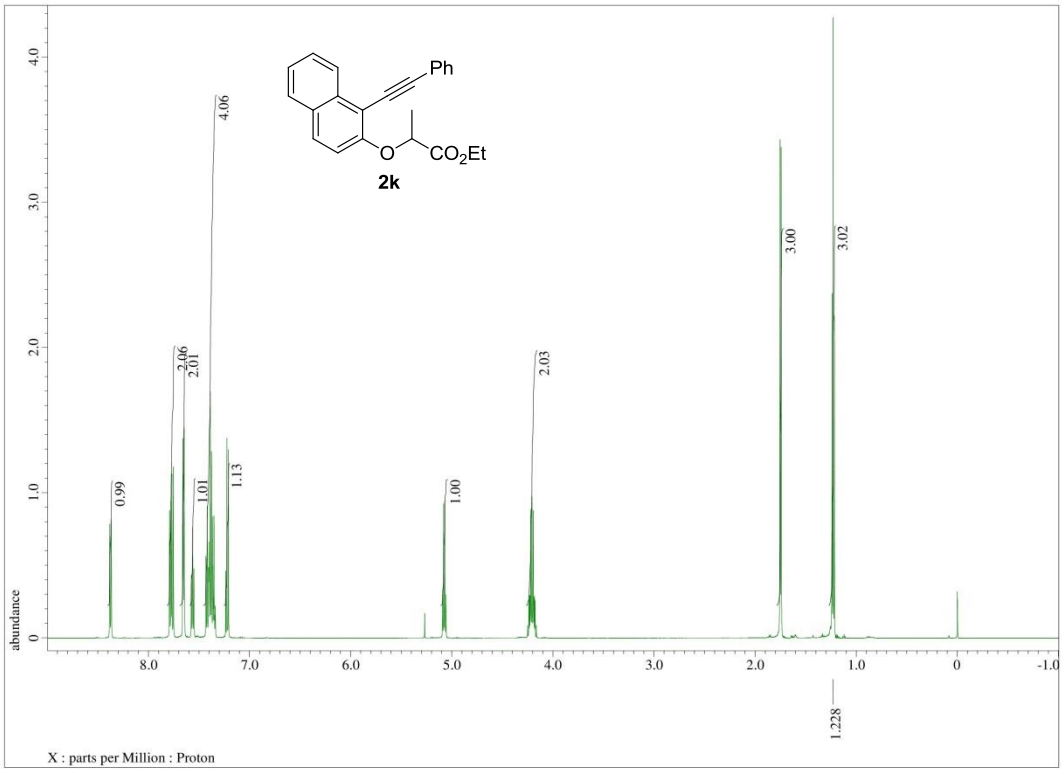

abundance
X : parts per Million : Carbon13
171.244
158.318
133.740
131.672
131.260
131.040
130.829
130.609
128.665
128.359
124.481
122.940
122.681
118.516
117.970
111.488
96.015
84.315
77.211
77.000
76.789
74.386
61.460
18.412
13.998

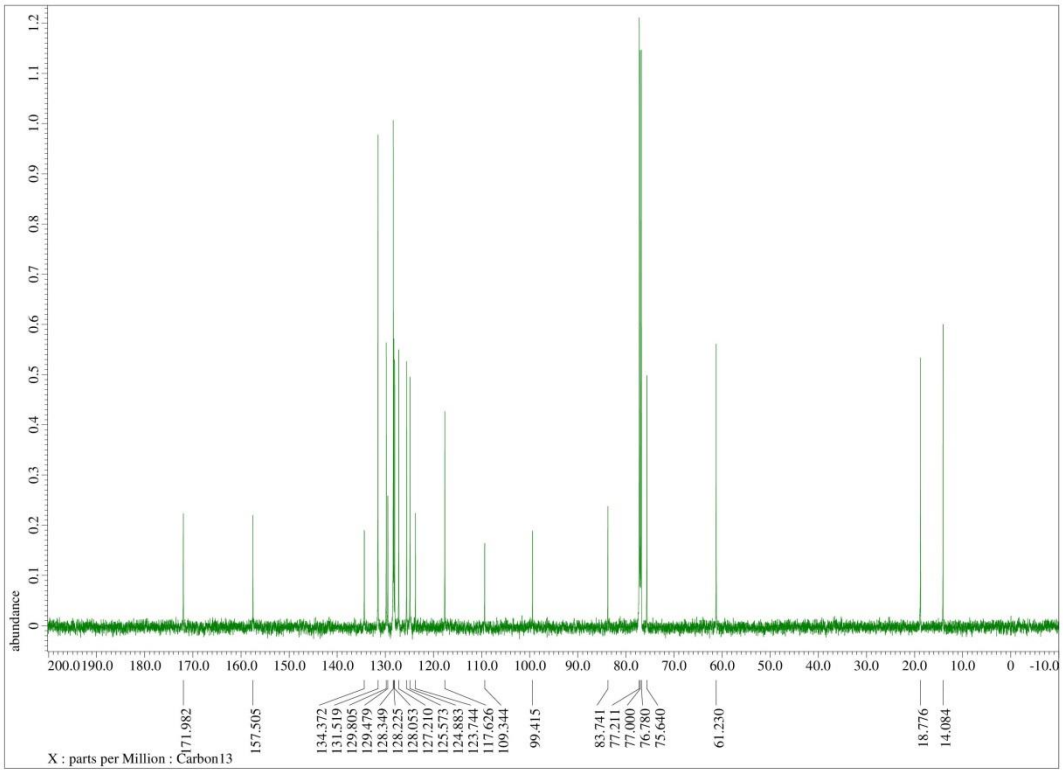

Ph
MeO
O
CO2Et
2i
3.07
2.03
0.99
0.98
0.99
1.00
2.02
3.01
3.00
3.02
abundance
X : parts per Million : Proton

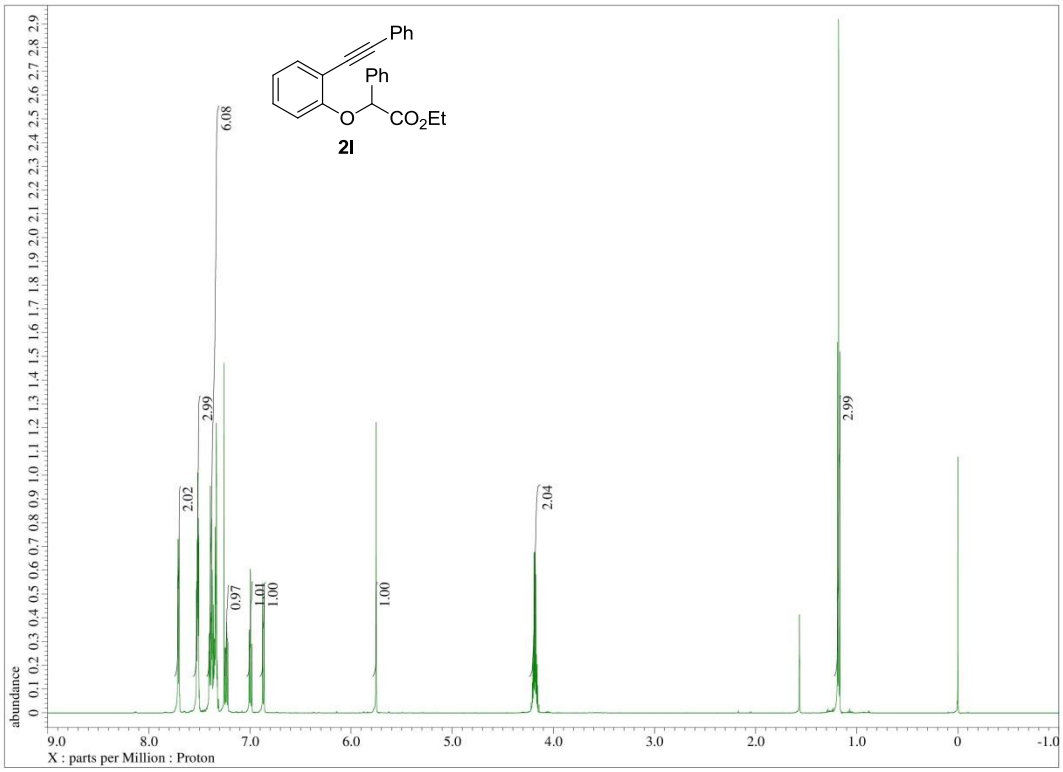

abundance
171.848
160.770
159.582
134.190
131.337
128.206
127.756
123.926
107.161
106.634
102.459
92.415
85.665
77.211
77.000
76.789
74.501
61.211
55.390
18.575
14.113
X : parts per Million : Carbon13

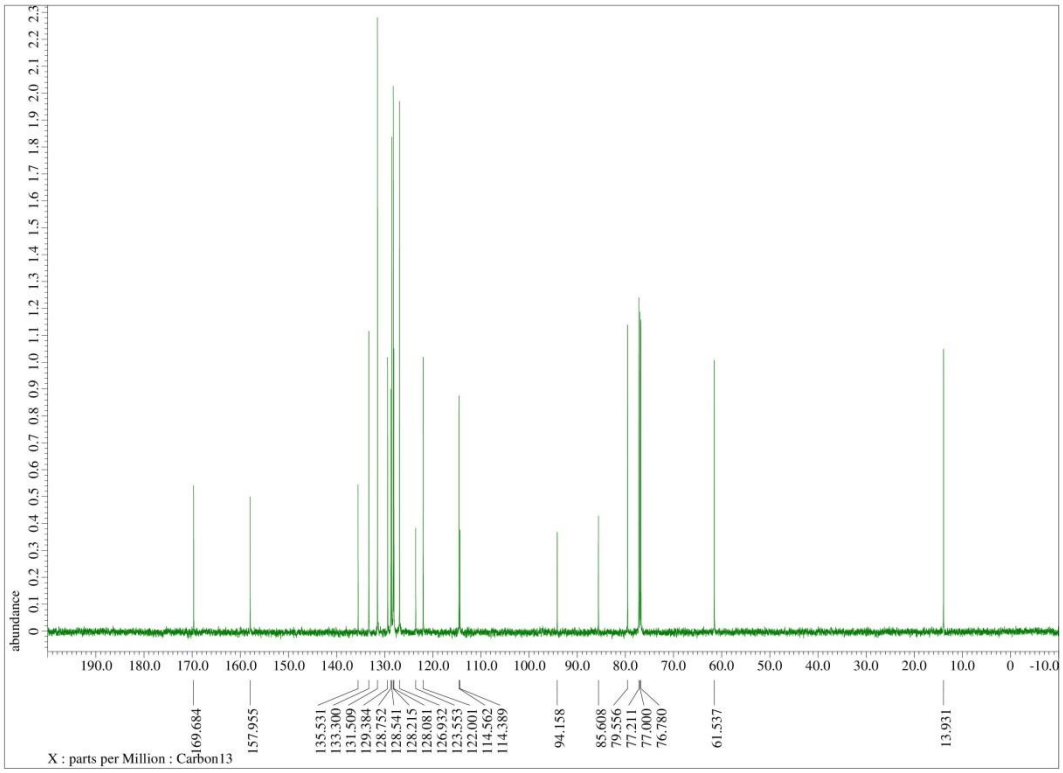

Br
MeO
O
CO2Et
2j
abundance
X : parts per Million : Proton
2.04
2.00
1.01
1.07
1.06
1.00
2.04
3.17
3.20
3.19

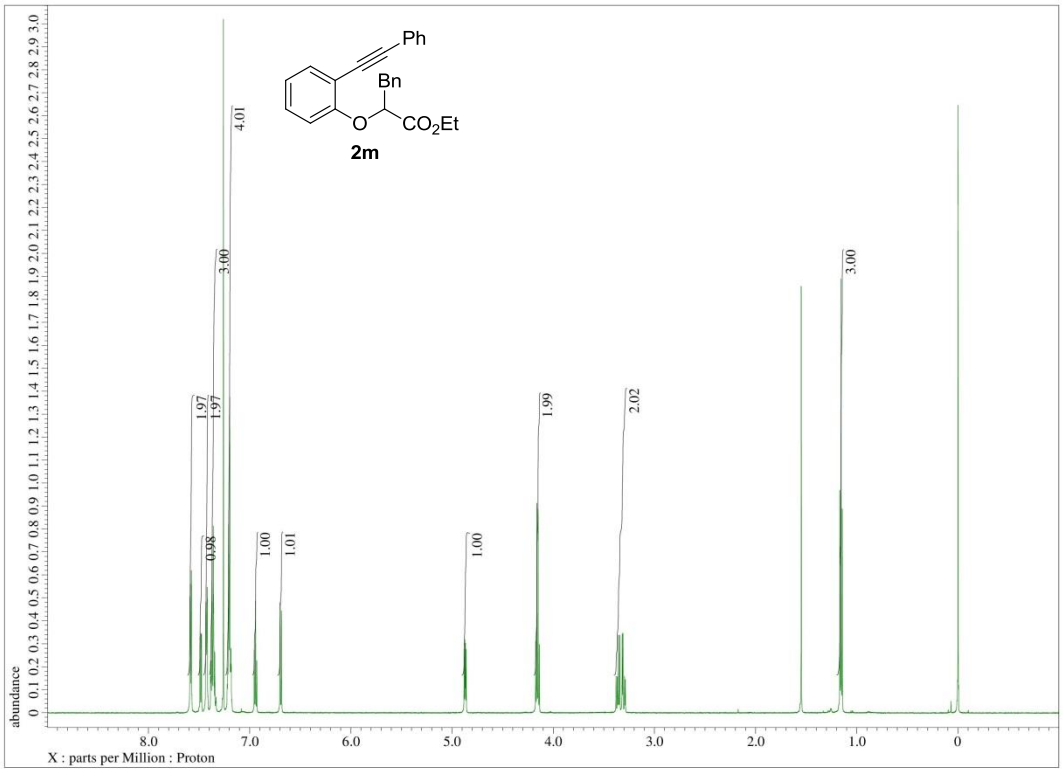

abundance
X : parts per Million : Carbon13
171.733
160.990
159.592
134.200
132.754
131.461
122.949
121.839
107.007
106.165
102.067
91.333
86.948
77.211
77.000
76.780
74.309
61.269
55.409
18.536
14.132

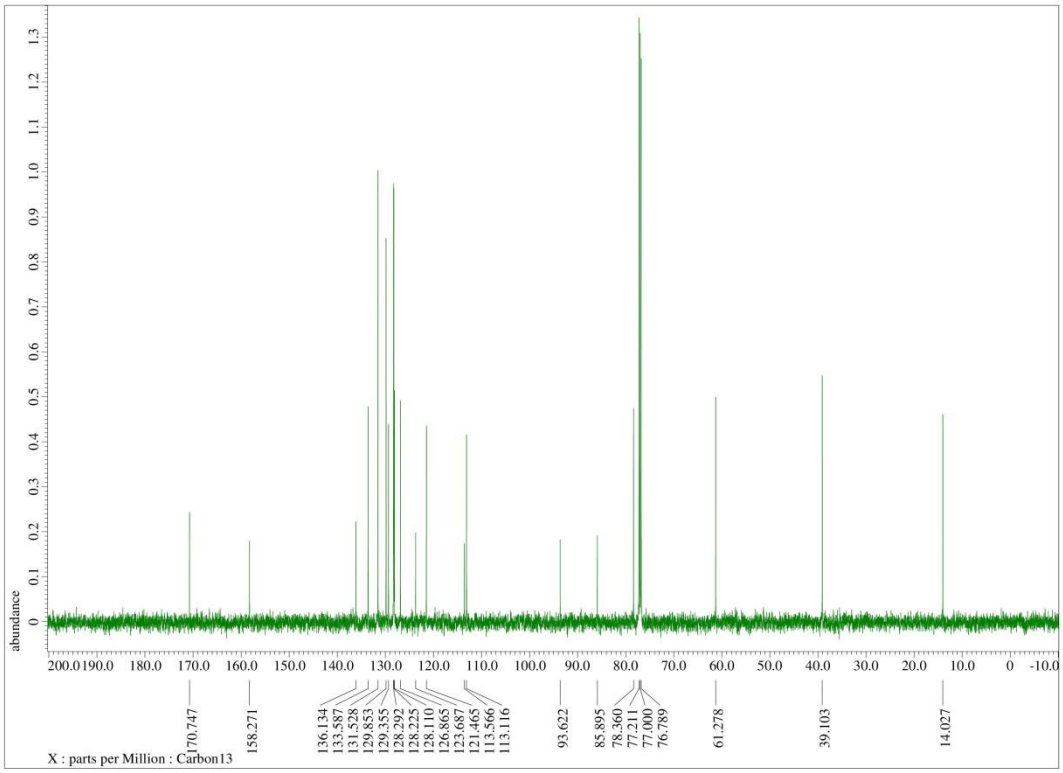

Ph
O
CO2Et
2k
4.06
2.06
2.01
1.01
1.13
0.99
1.00
2.03
3.00
3.02
1.228
abundance
X : parts per Million : Proton

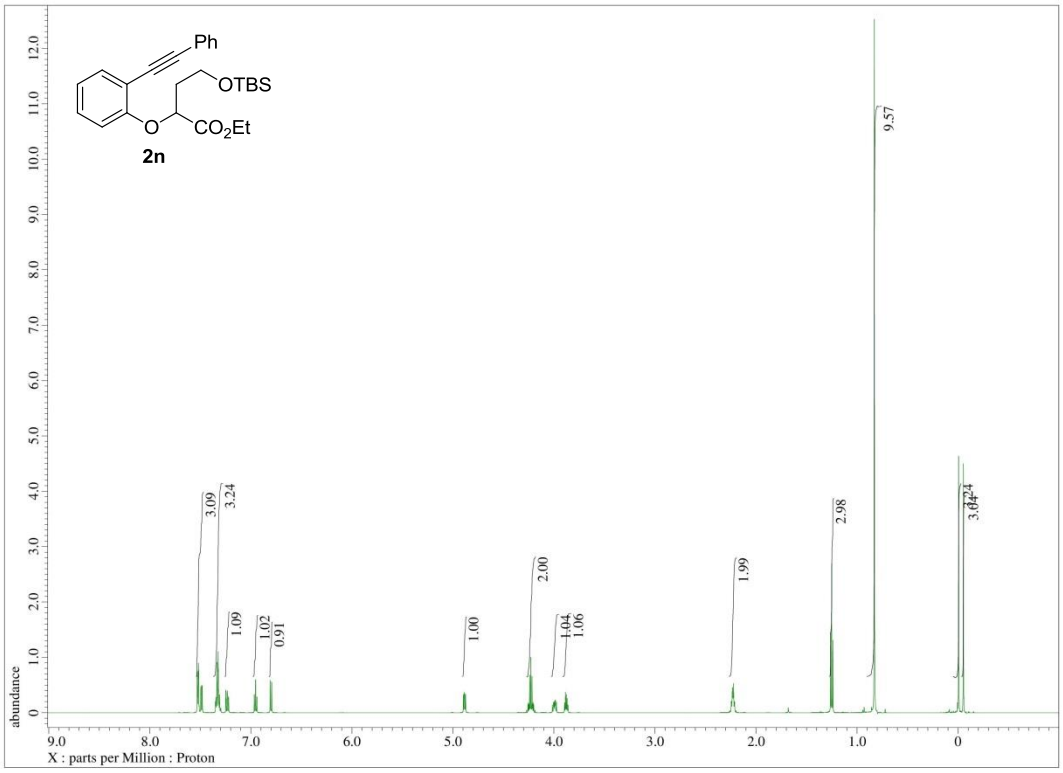

171.982
157.505
134.372
131.519
129.805
129.479
128.349
128.225
128.053
127.210
125.573
124.883
123.744
117.626
109.344
99.415
83.741
77.211
77.000
76.780
75.640
61.230
18.776
14.084
abundance
X : parts per Million : Carbon13

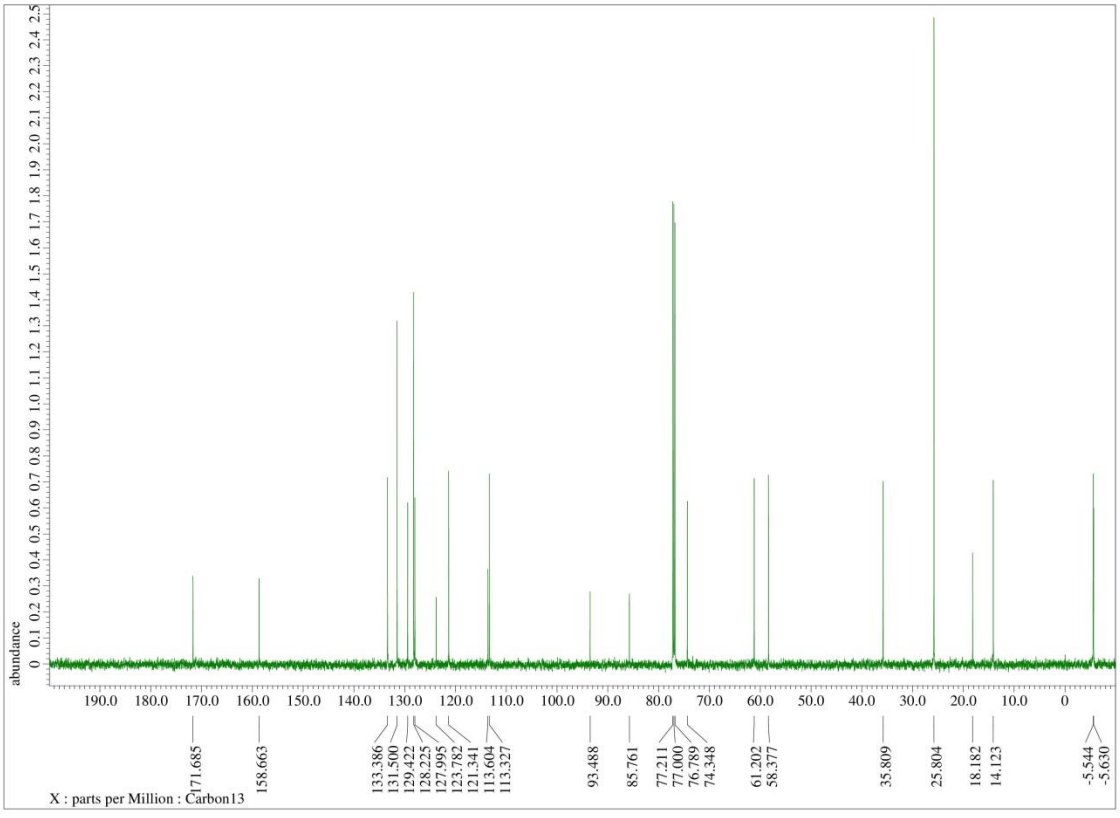

Ph
Ph
O
CO2Et
2l
6.08
2.99
2.02
0.97
1.01
1.00
1.00
2.04
2.99
abundance
X : parts per Million : Proton

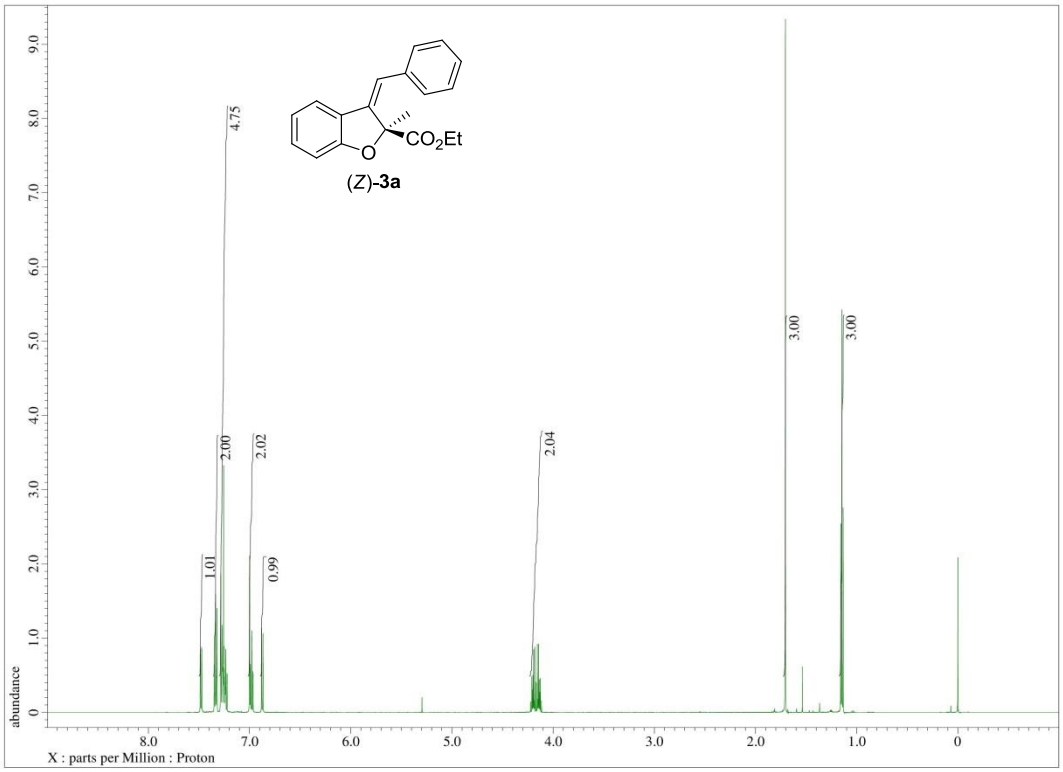

abundance
169.684
157.955
135.531
133.300
131.509
129.384
128.752
128.541
128.215
128.081
126.932
123.553
122.001
114.562
114.389
94.158
85.608
79.556
77.211
77.000
76.780
61.537
13.931
X : parts per Million : Carbon13

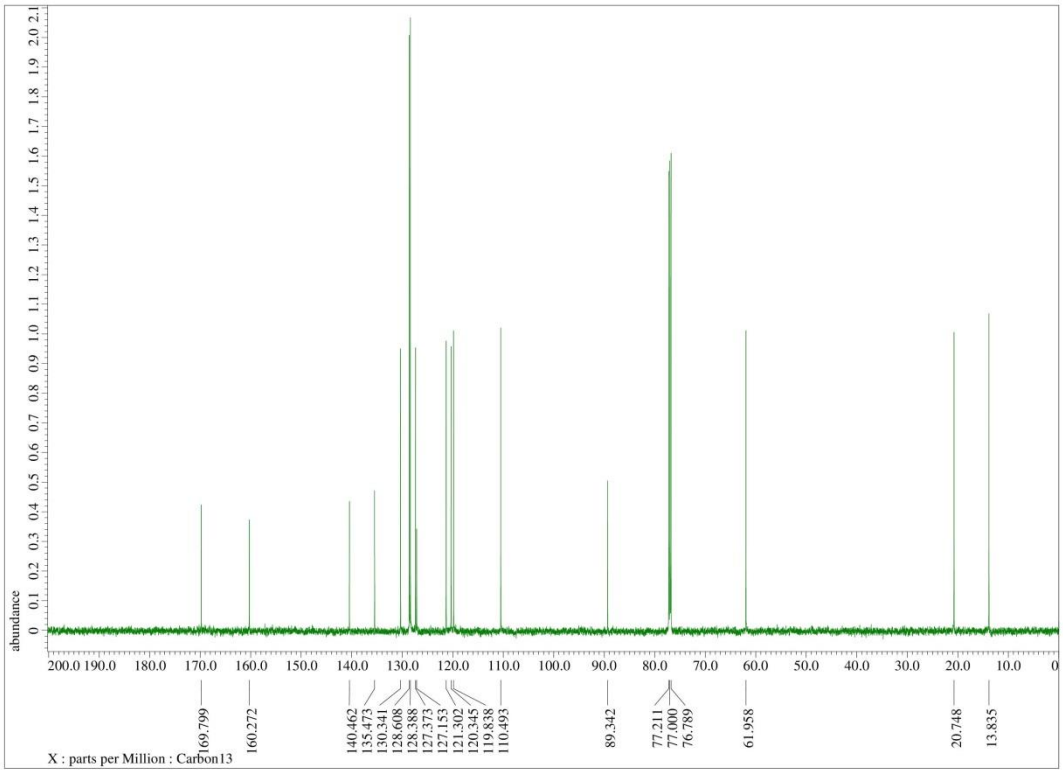

Ph
Bn
O
CO2Et
2m
4.01
3.00
1.97
1.97
1.97
0.98
1.00
1.01
1.00
1.99
2.02
3.00
abundance
X : parts per Million : Proton

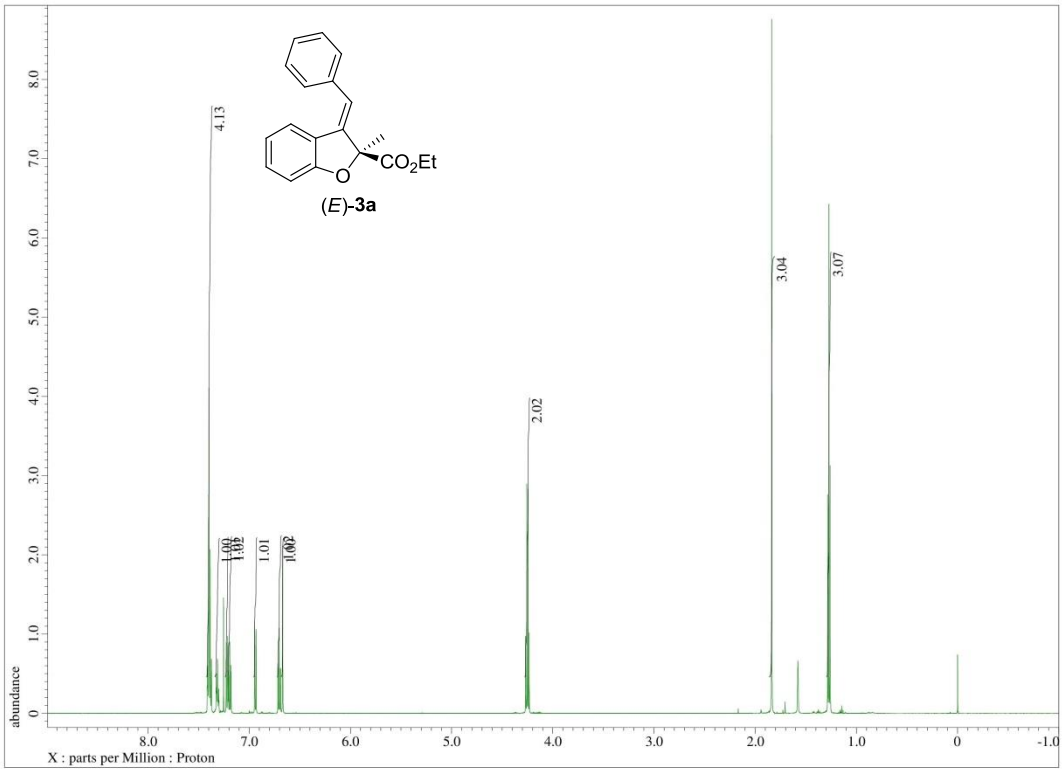

abundance
X : parts per Million : Carbon13
170.747
158.271
136.134
133.587
131.528
129.853
129.355
128.292
128.225
128.110
126.865
123.687
121.465
113.566
113.116
93.622
85.895
78.360
77.211
77.000
76.789
61.278
39.103
14.027


Ph
OTBS
O
CO2Et
2n
abundance
X : parts per Million : Proton
9.57
3.09
3.24
2.98
2.00
1.99
1.09
1.02
0.91
1.00
1.04
1.06

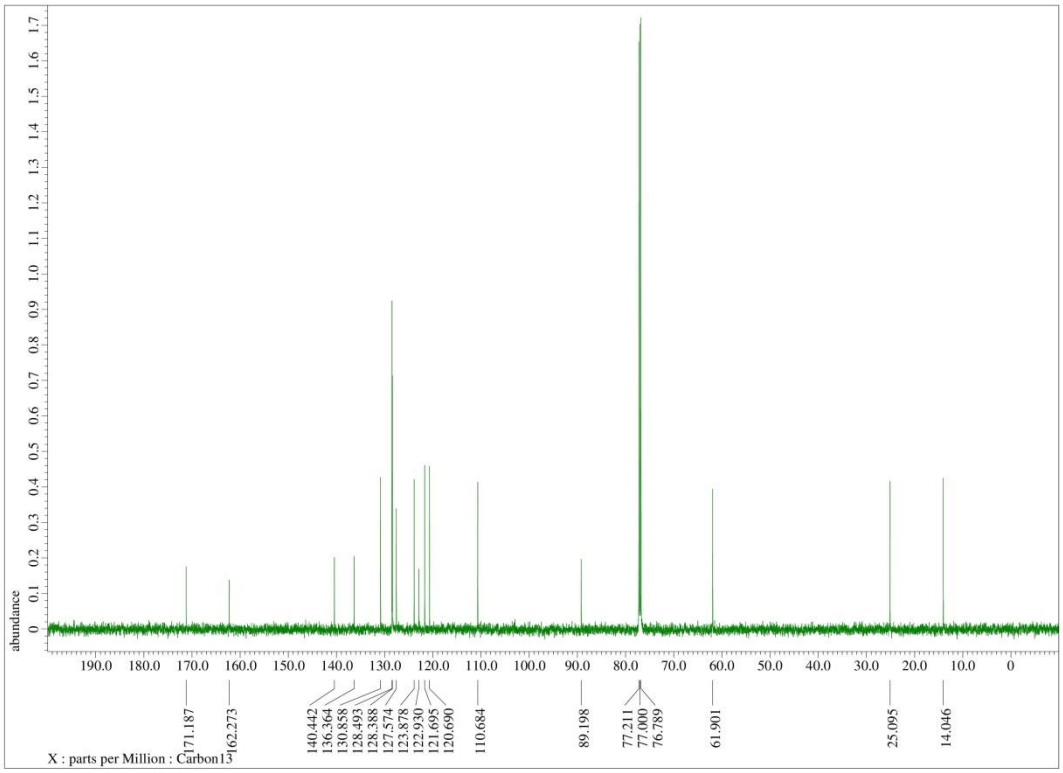

abundance
X : parts per Million : Carbon13
171.685
158.663
133.386
131.500
129.422
128.225
127.995
123.782
121.341
113.604
113.327
93.488
85.761
77.211
77.000
76.789
74.348
61.202
58.377
35.809
25.804
18.182
14.123
-5.544
-5.630

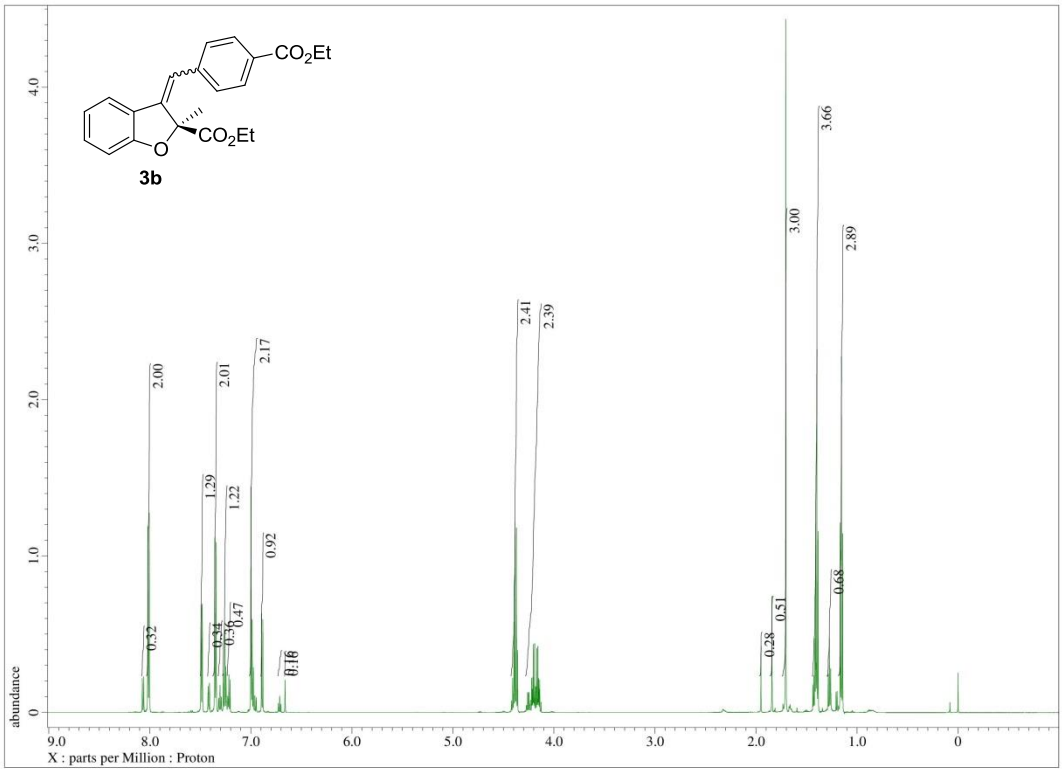

(Z)-3a
CO2Et
O
4.75
2.00
2.02
1.01
0.99
2.04
3.00
3.00
abundance
X : parts per Million : Proton

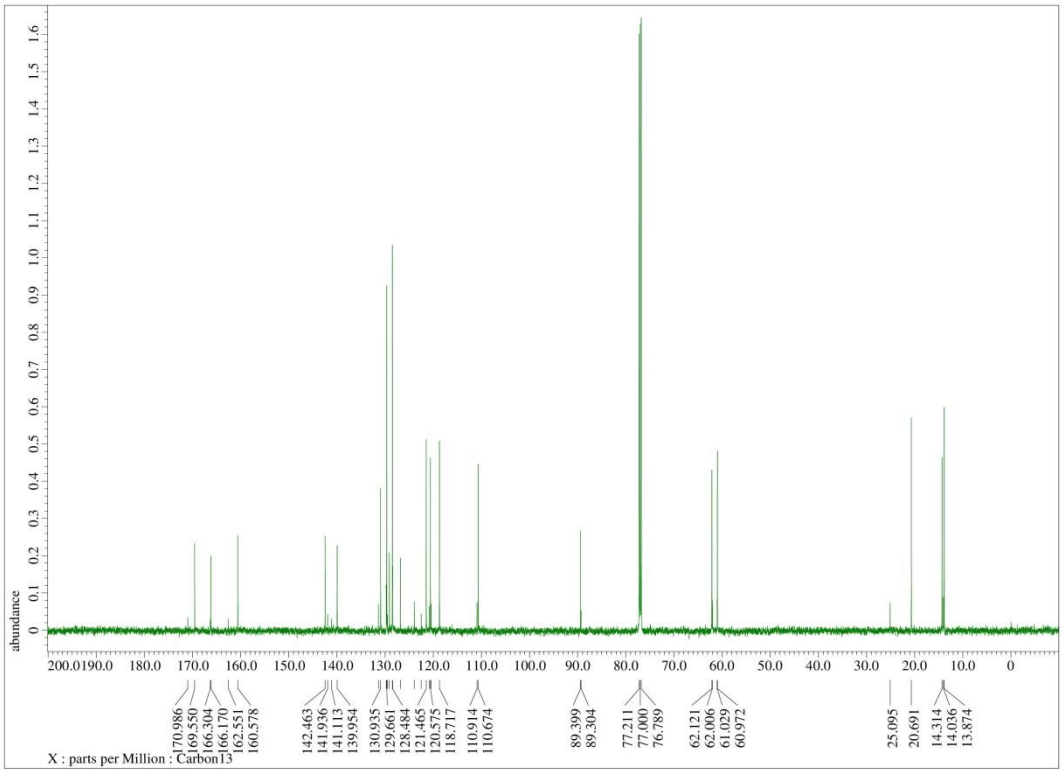

abundance
X : parts per Million : Carbon13
169.799
160.272
140.462
135.473
130.341
128.608
128.388
127.373
127.153
121.302
120.345
119.838
110.493
89.342
77.211
77.000
76.789
61.958
20.748
13.835

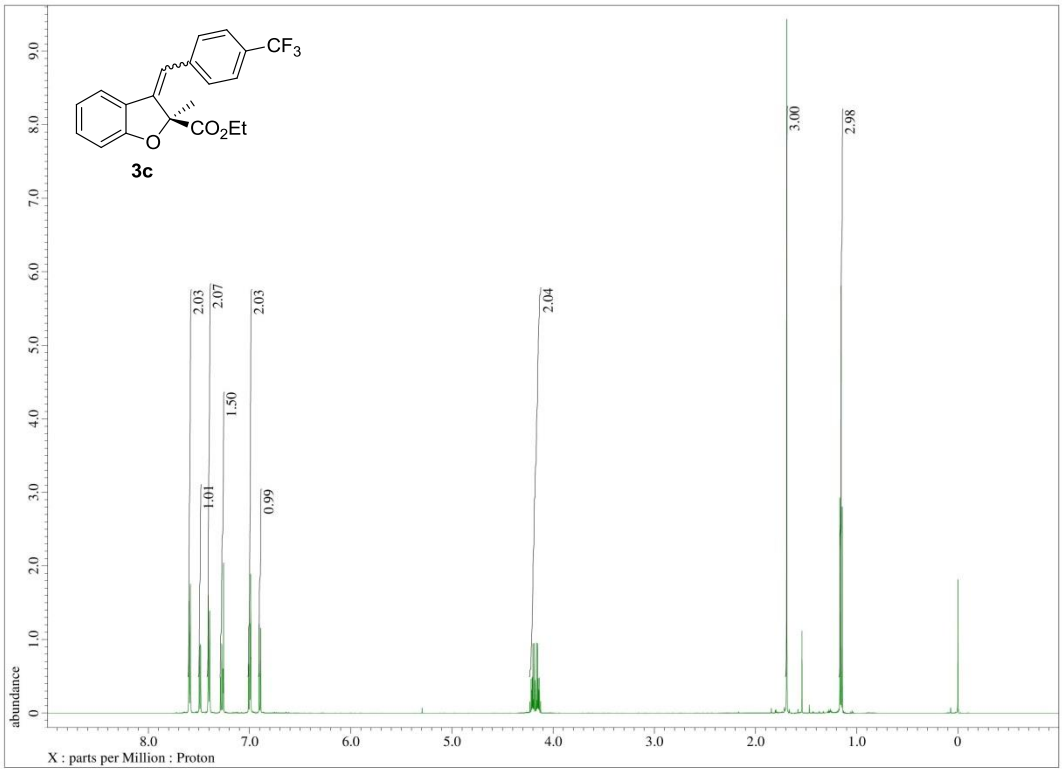

4.13
1.00
1.03
1.01
1.00
2.02
3.04
3.07
abundance
X : parts per Million : Proton

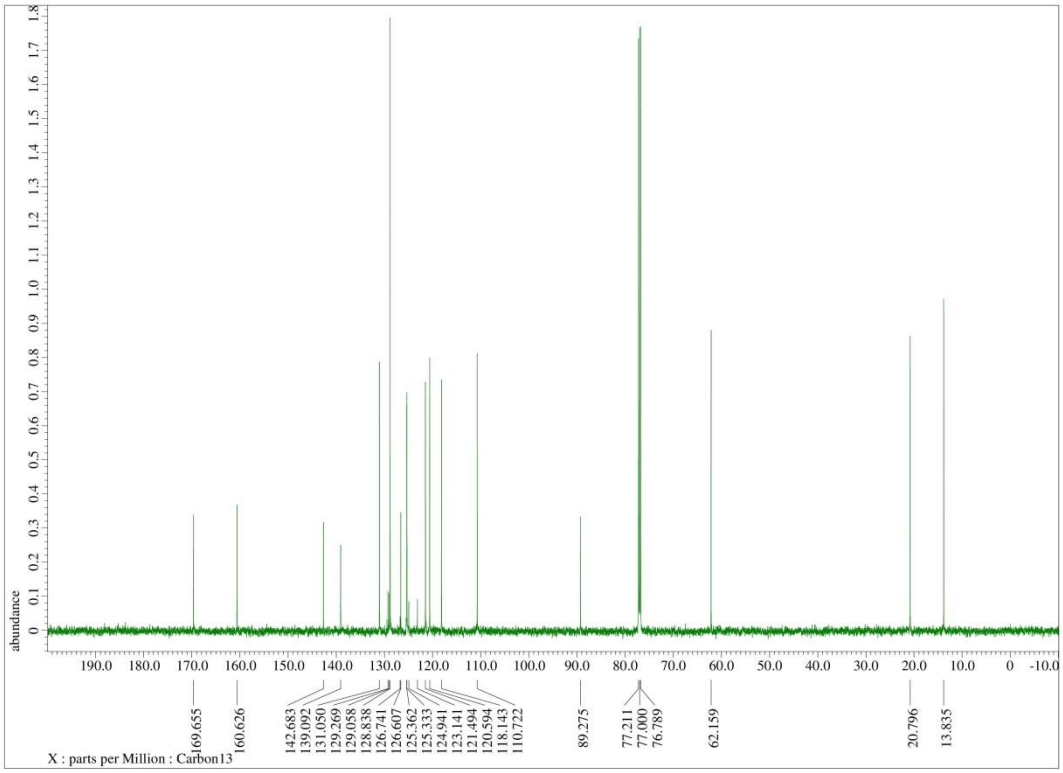
(*E*)-**3a**

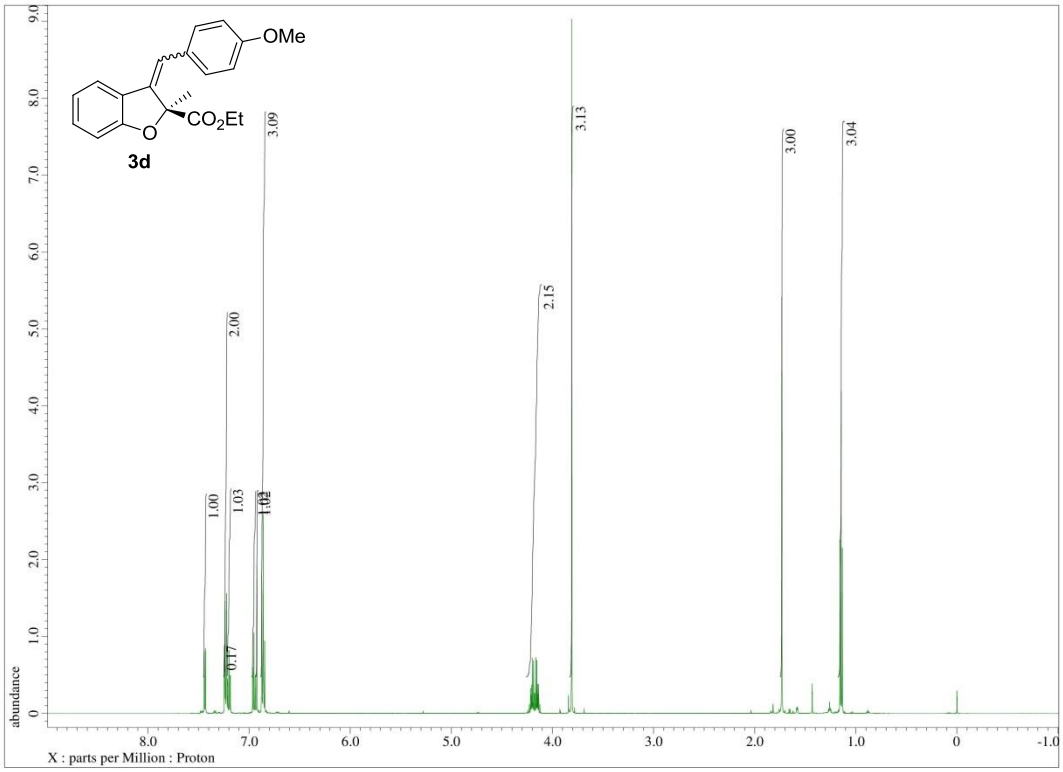

abundance
171.187
162.273
140.442
136.364
130.858
128.493
128.388
127.574
123.878
122.930
121.695
120.690
110.684
89.198
77.211
77.000
76.789
61.901
25.095
14.046
X : parts per Million : Carbon13

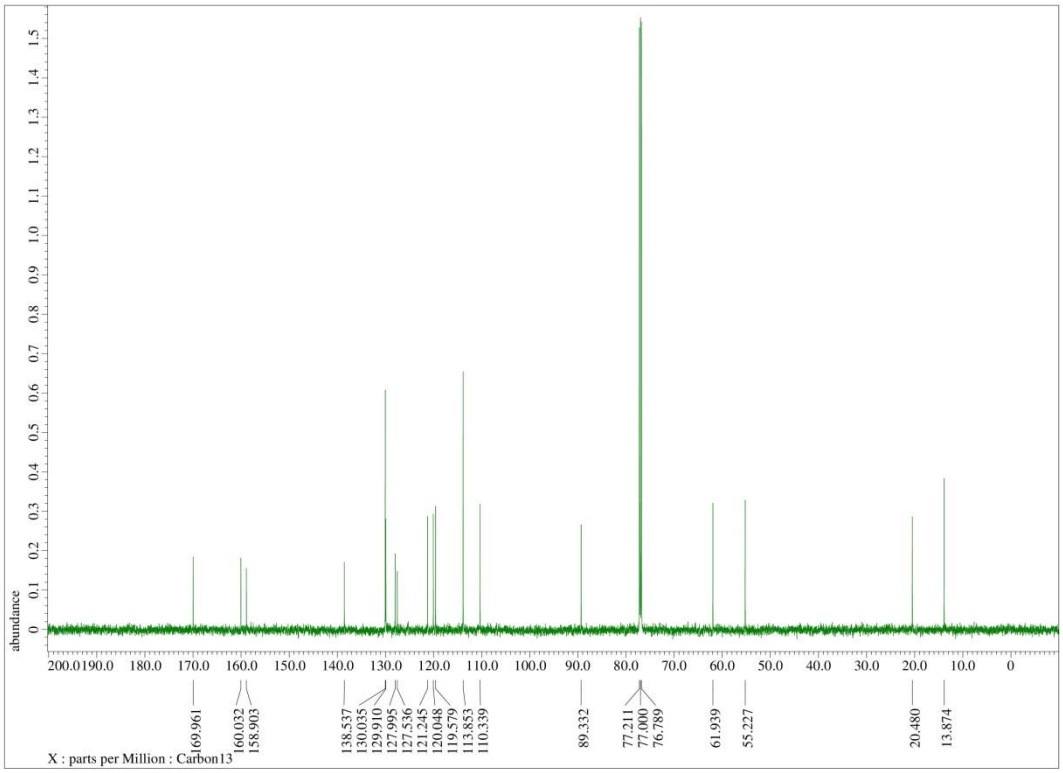

CO2Et
CO2Et
O
3b
abundance
X : parts per Million : Proton
2.00
2.01
2.17
1.29
1.22
0.92
0.47
0.32
2.41
2.39
3.00
3.66
2.89
0.51
0.28
0.68

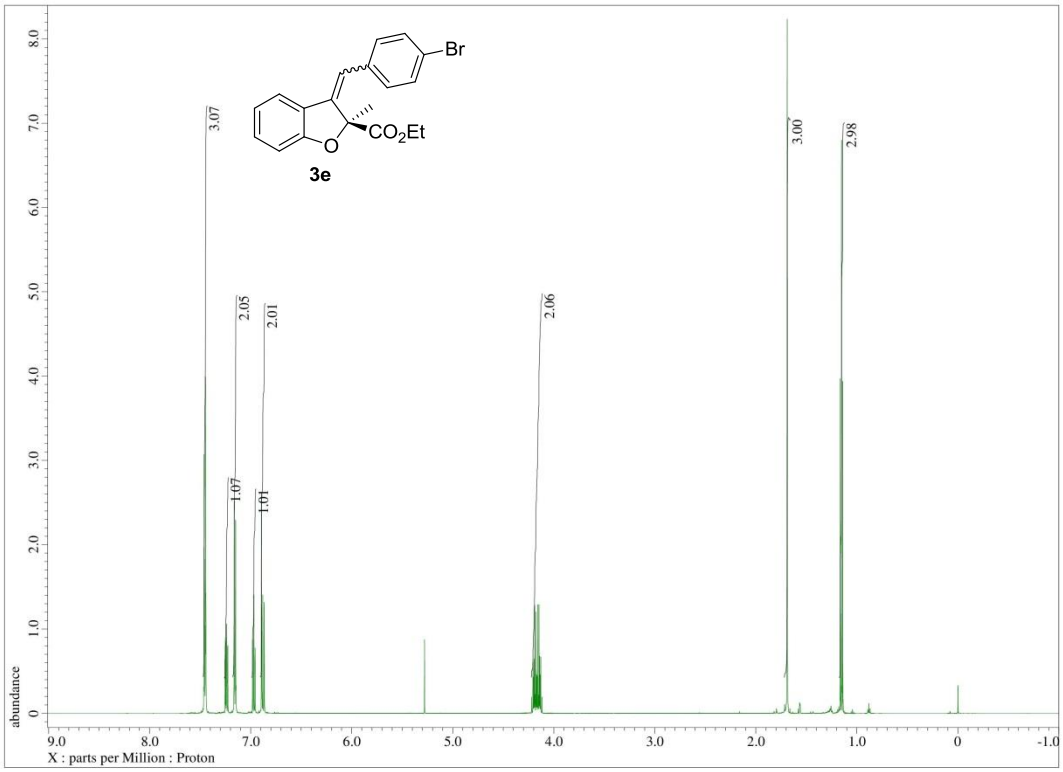

abundance
X : parts per Million : Carbon13
170.986
169.550
166.304
166.170
162.551
160.578
142.463
141.936
141.113
139.954
130.935
129.661
128.484
121.465
120.575
118.717
110.914
110.674
89.399
89.304
77.211
77.000
76.789
62.121
62.006
61.029
60.972
25.095
20.691
14.314
14.036
13.874

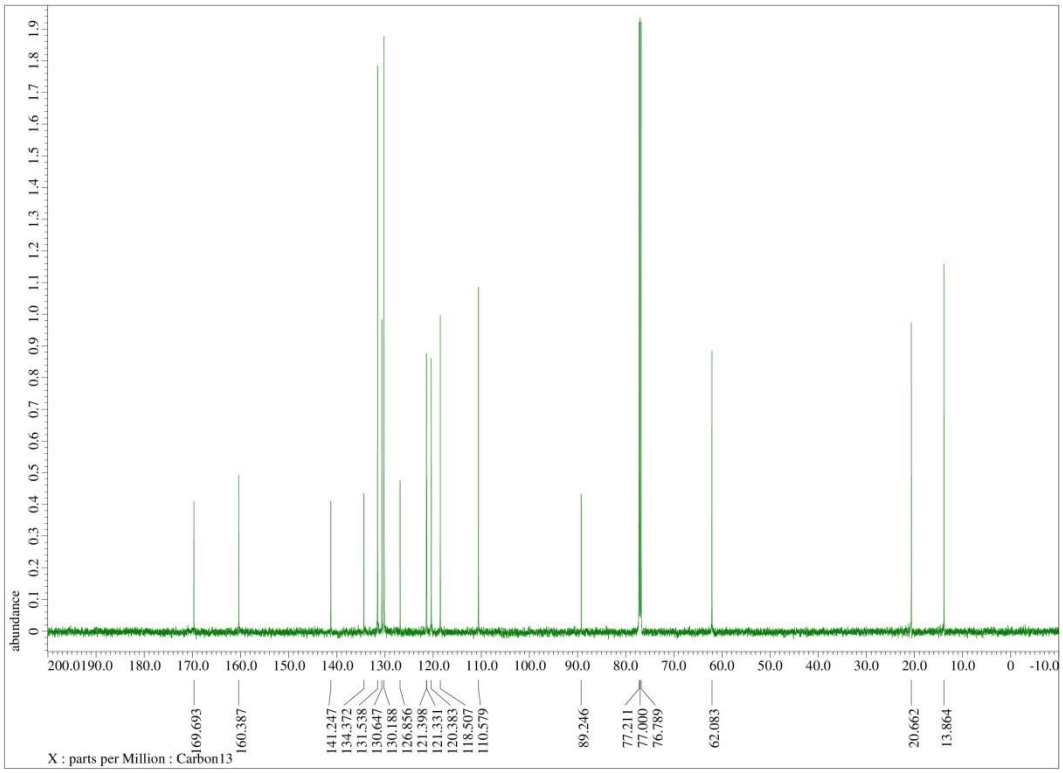

CF3
CO2Et
O
3c
2.03
2.07
2.03
1.50
1.01
0.99
2.04
3.00
2.98
abundance
X : parts per Million : Proton

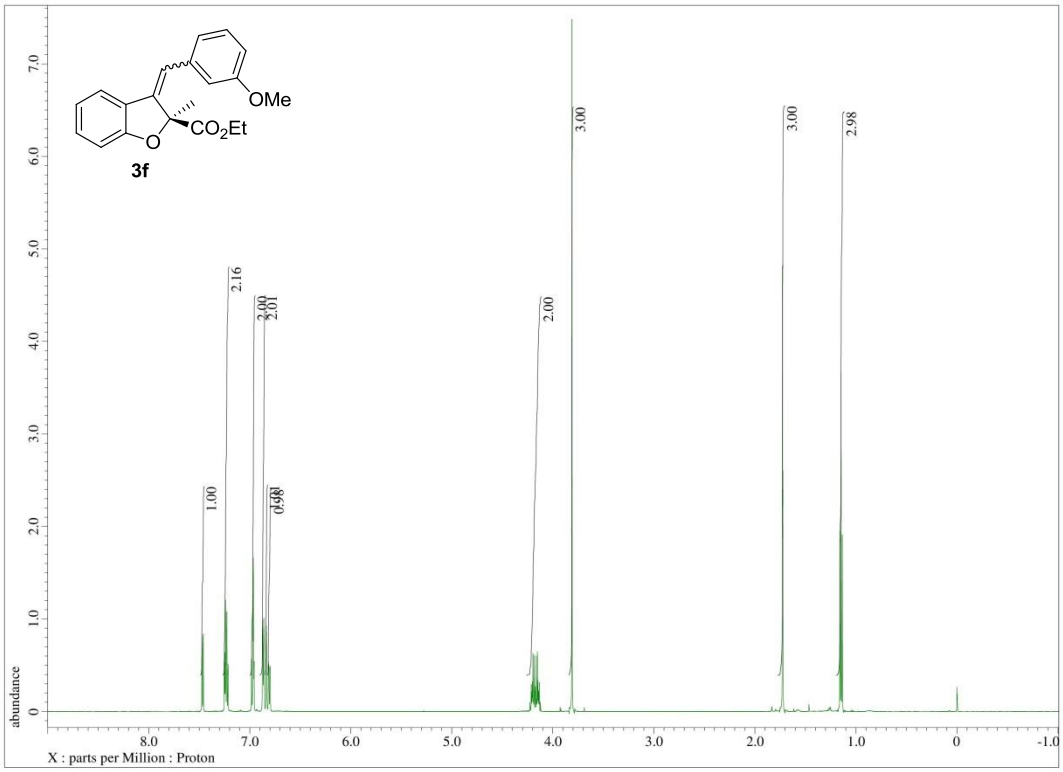

abundance
X : parts per Million : Carbon13
169.655
160.626
142.683
139.092
131.050
129.269
129.058
128.838
126.741
126.607
125.362
125.333
124.941
123.141
121.494
120.594
118.143
110.722
89.275
77.211
77.000
76.789
62.159
20.796
13.835

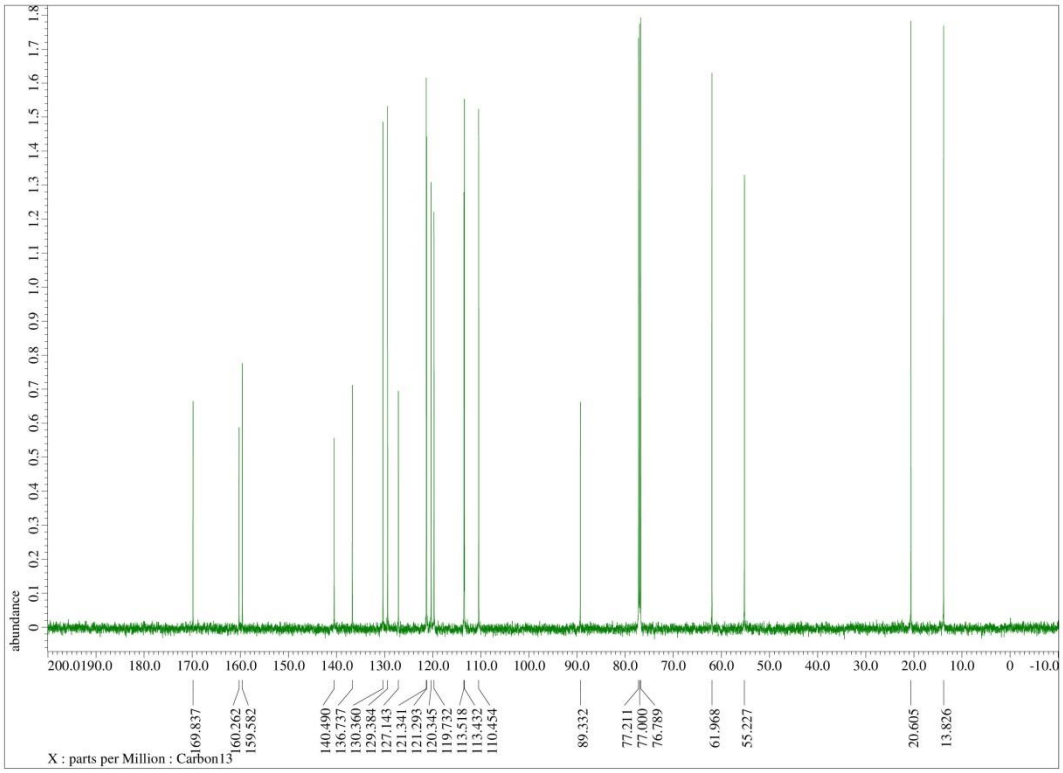

OMe
CO2Et
O
3d
abundance
X : parts per Million : Proton
1.00
2.00
1.03
1.04
3.09
0.17
2.15
3.13
3.00
3.04

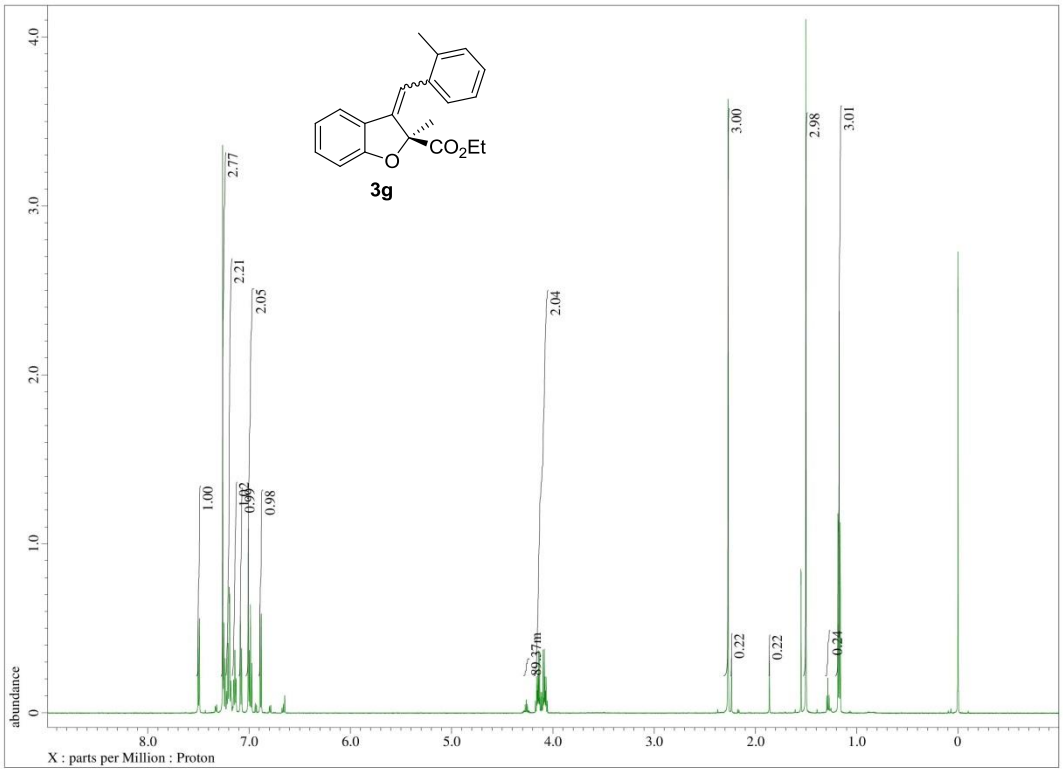

abundance
X : parts per Million : Carbon13
169.961
160.032
158.903
138.537
130.035
129.910
127.995
127.536
121.245
120.048
119.579
113.853
110.339
89.332
77.211
77.000
76.789
61.939
55.227
20.480
13.874

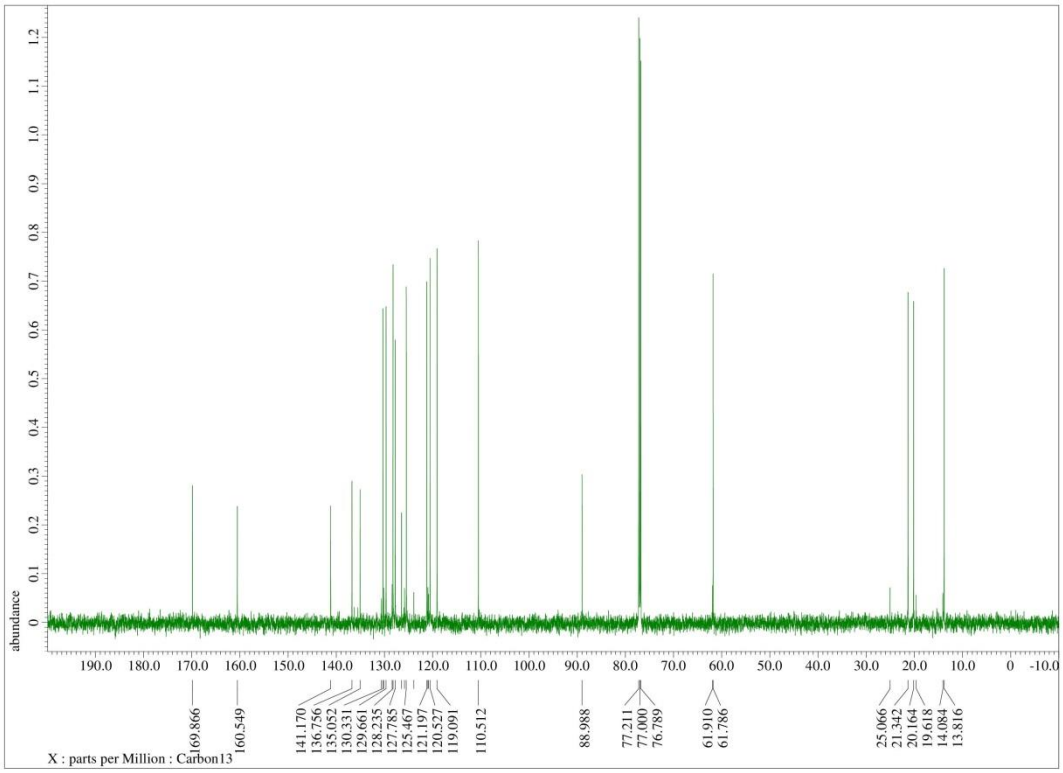

Br
CO2Et
O
3e
3.07
2.05
2.01
1.07
1.01
2.06
3.00
2.98
abundance
X : parts per Million : Proton

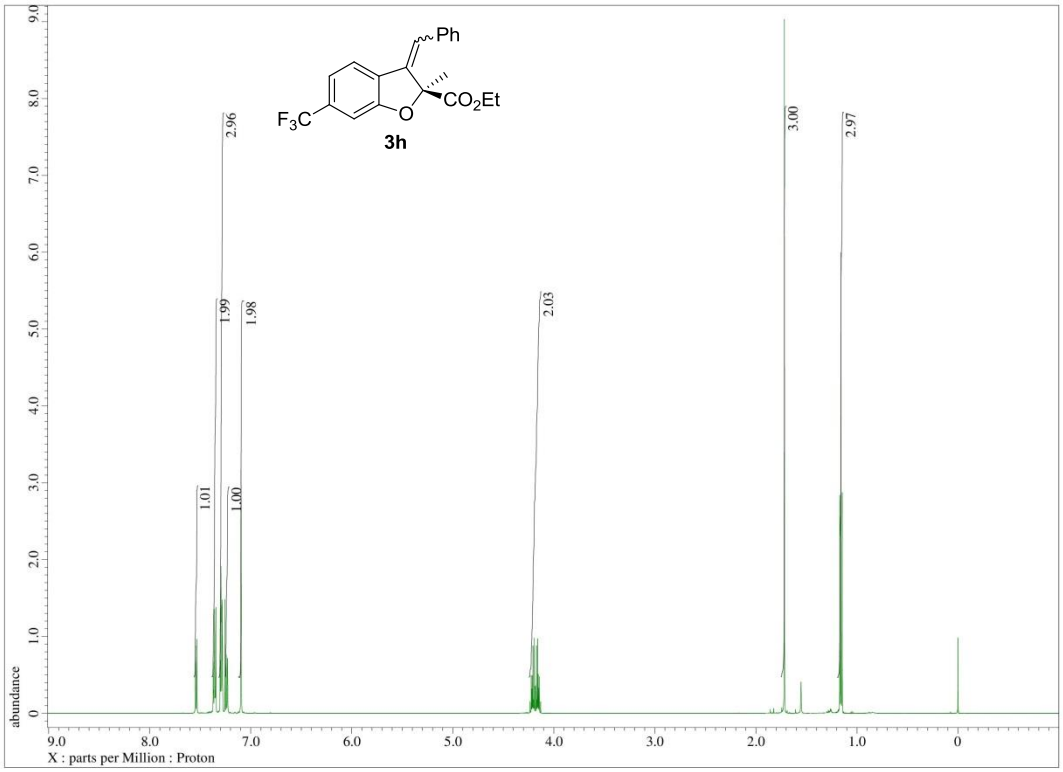

abundance
X : parts per Million : Carbon13
169.693
160.387
141.247
134.372
131.538
130.647
130.188
126.856
121.398
121.331
120.383
118.507
110.579
89.246
77.211
77.000
76.789
62.083
20.662
13.864

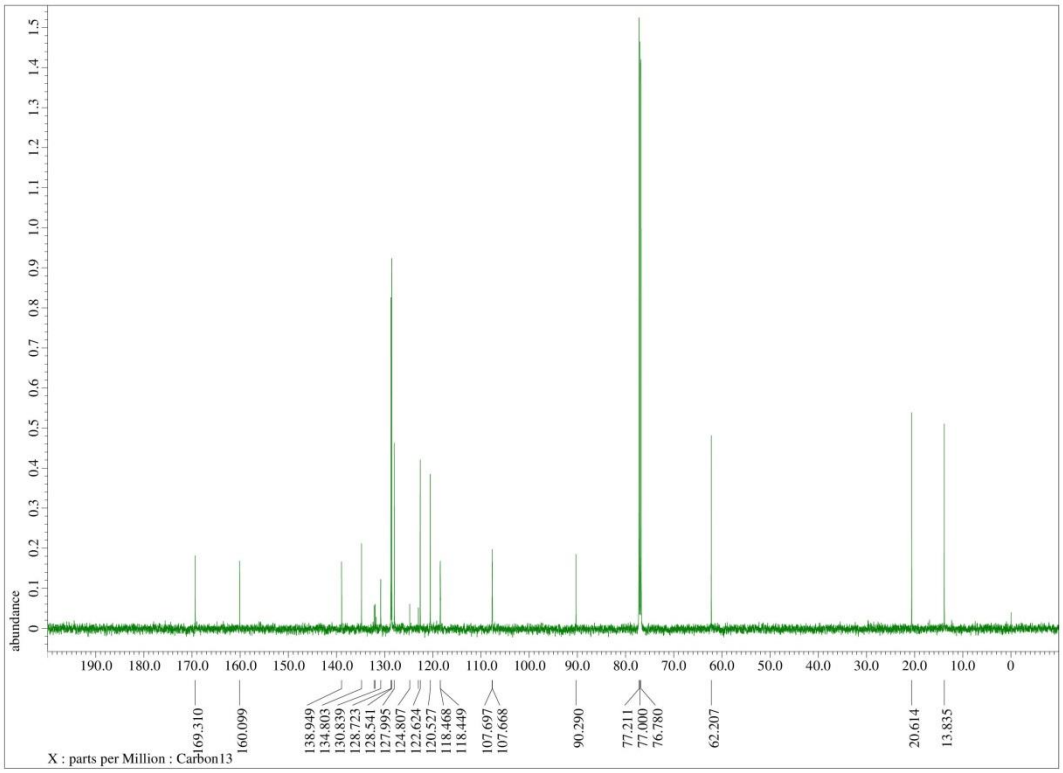

OMe
CO2Et
O
3f
abundance
X : parts per Million : Proton
1.00
2.16
2.00
2.01
2.00
3.00
3.00
2.98

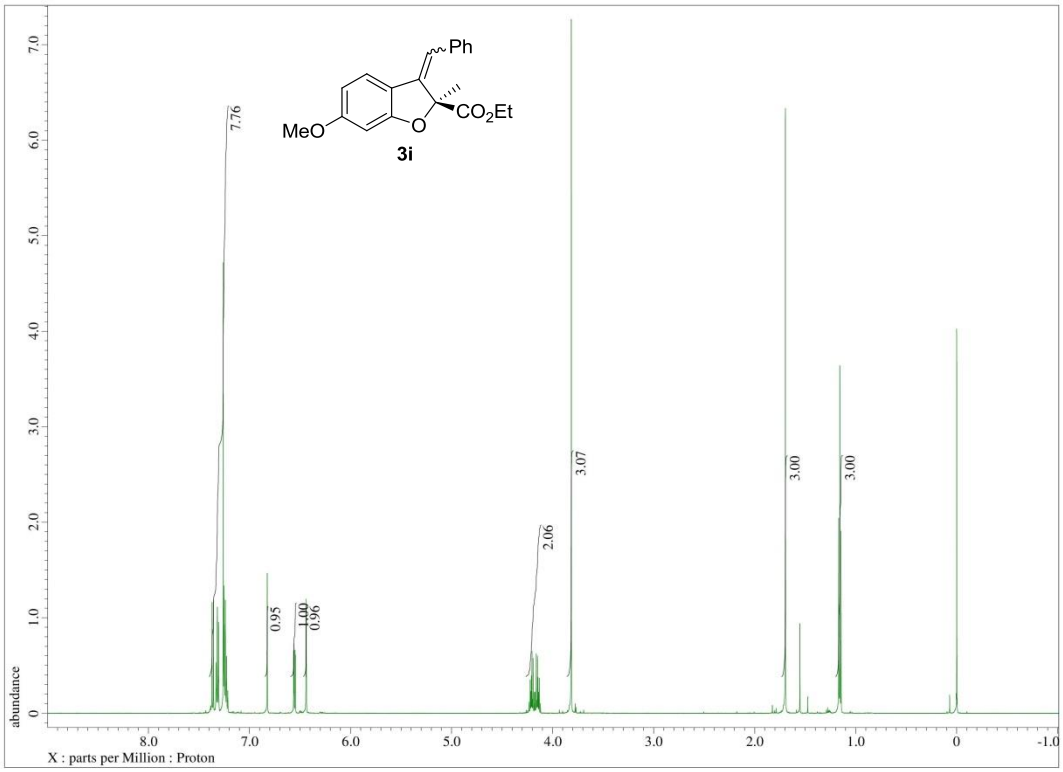

abundance
X : parts per Million : Carbon13
169.837
160.262
159.582
140.490
136.737
130.360
129.384
127.143
121.341
121.293
120.345
119.732
113.518
113.432
110.454
89.332
77.211
77.000
76.789
61.968
55.227
20.605
13.826

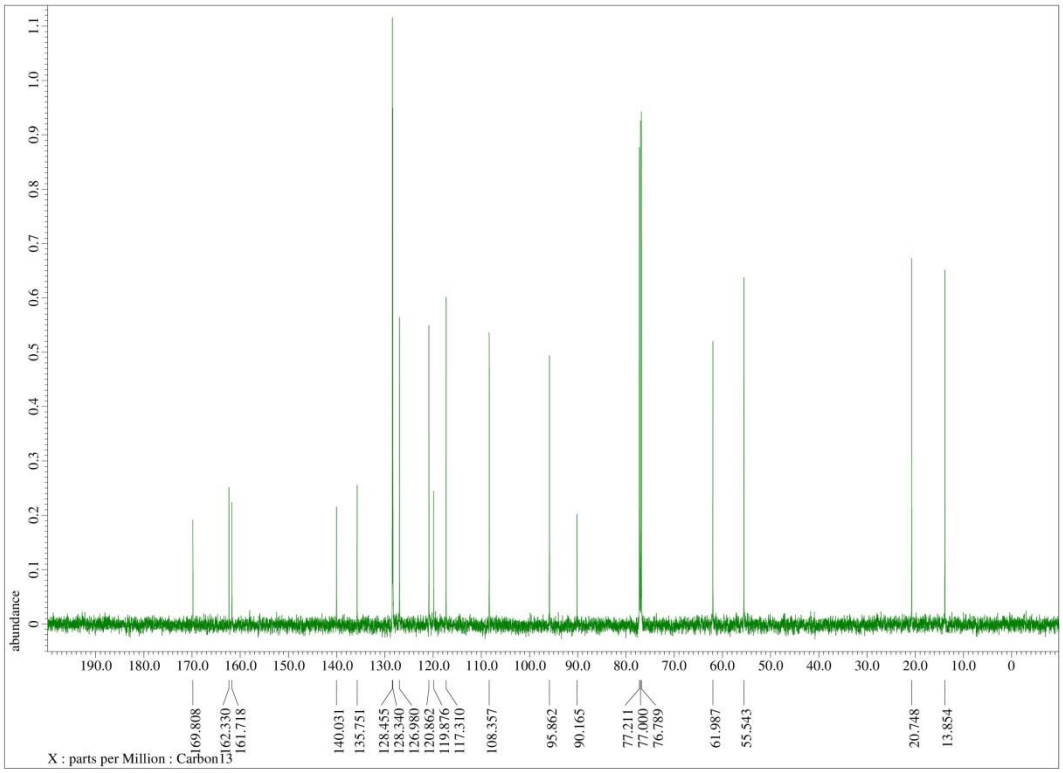

CO2Et
O
3g
abundance
X : parts per Million : Proton
1.00
1.02
0.99
0.98
2.77
2.21
2.05
2.04
89.37m
3.00
0.22
0.22
2.98
3.01
0.24

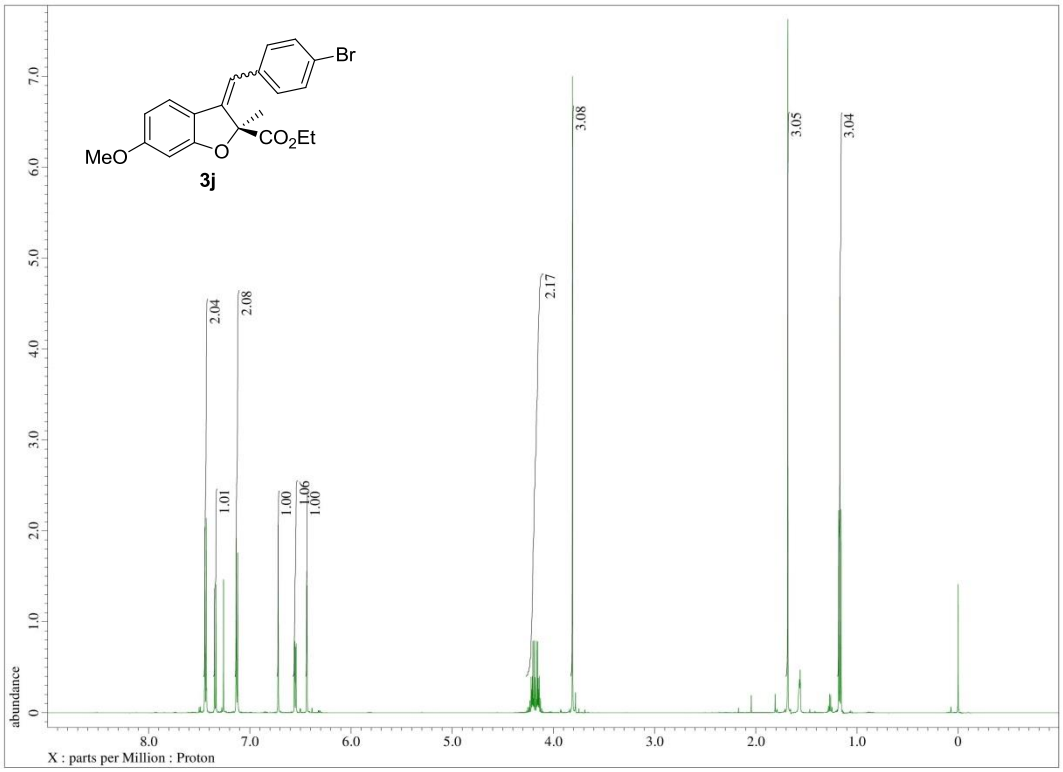

abundance
X : parts per Million : Carbon13
169.866
160.549
141.170
136.756
135.052
130.331
129.661
128.235
127.785
125.467
121.197
120.527
119.091
110.512
88.988
77.211
77.000
76.789
61.910
61.786
25.066
21.342
20.164
19.618
14.084
13.816

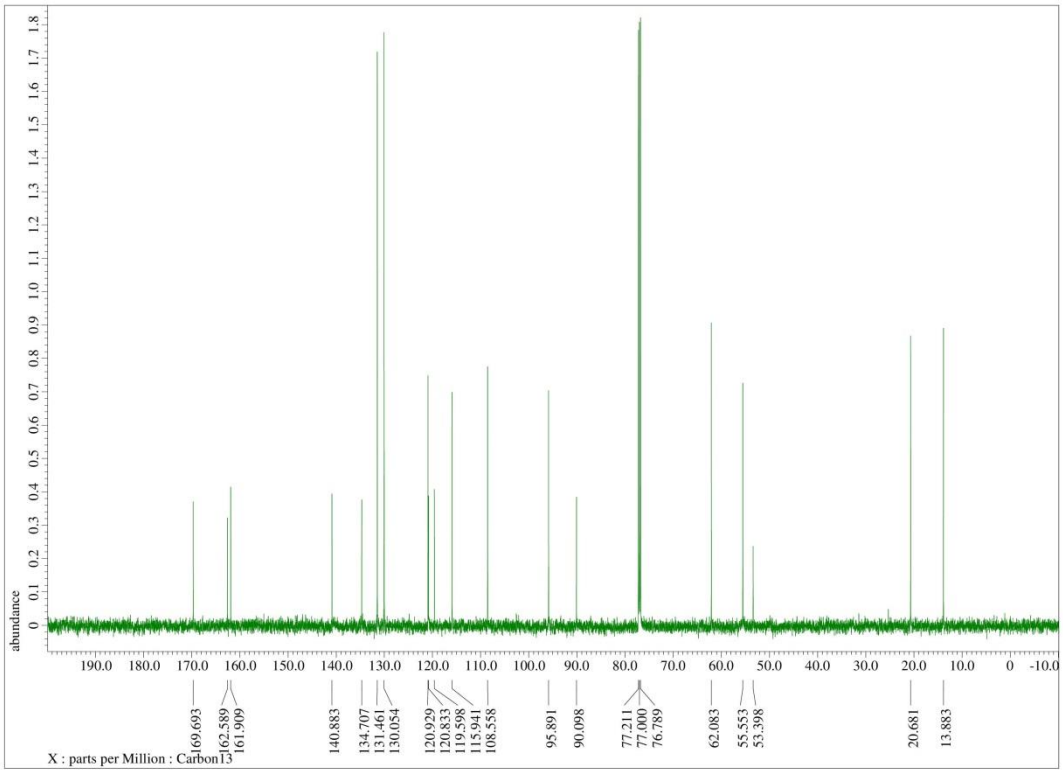

Ph
CO2Et
F3C
O
3h
2.96
1.99
1.98
1.01
1.00
2.03
3.00
2.97
abundance
X : parts per Million : Proton

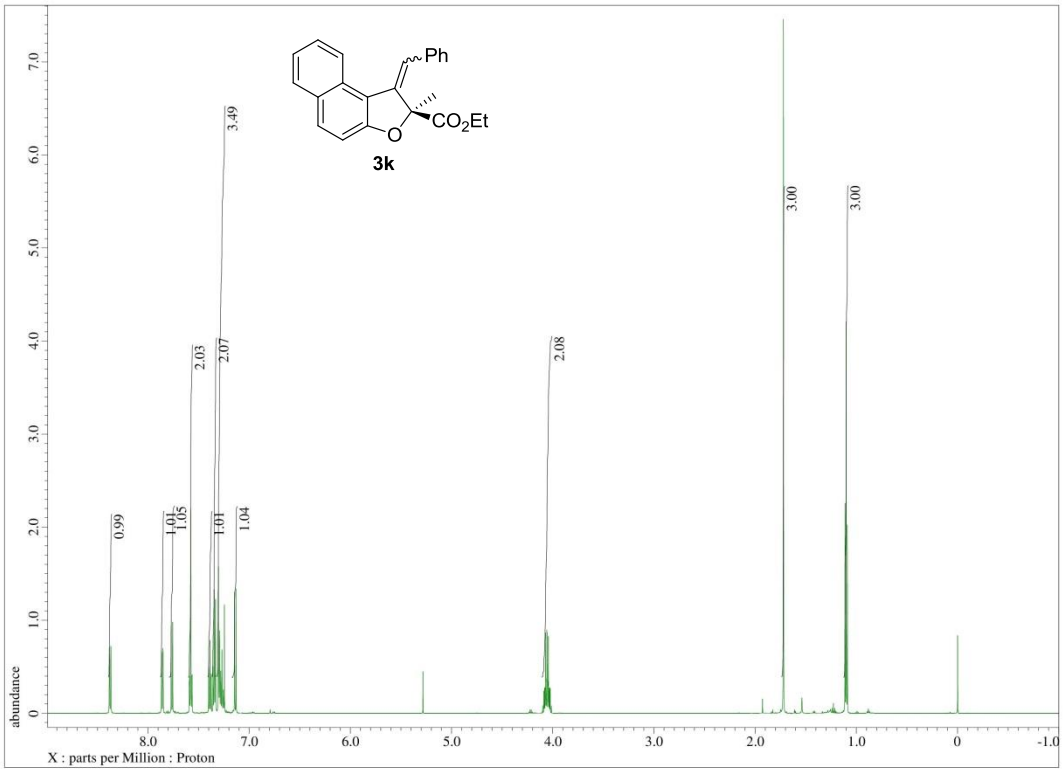

abundance
X : parts per Million : Carbon13
169.310
160.099
138.949
134.803
130.839
128.723
128.541
127.995
124.807
122.624
120.527
118.468
118.449
107.697
107.668
90.290
77.211
77.000
76.780
62.207
20.614
13.835

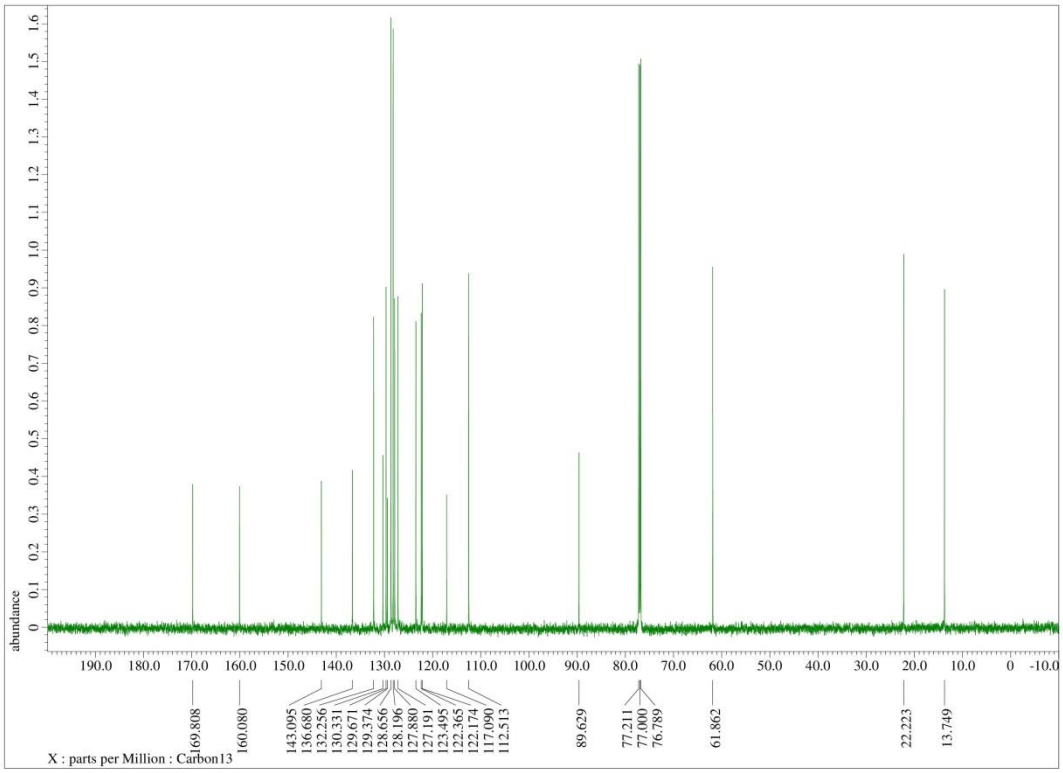

Ph
MeO
O
CO2Et
3i
7.76
0.95
1.00
0.96
2.06
3.07
3.00
3.00
abundance
X : parts per Million : Proton

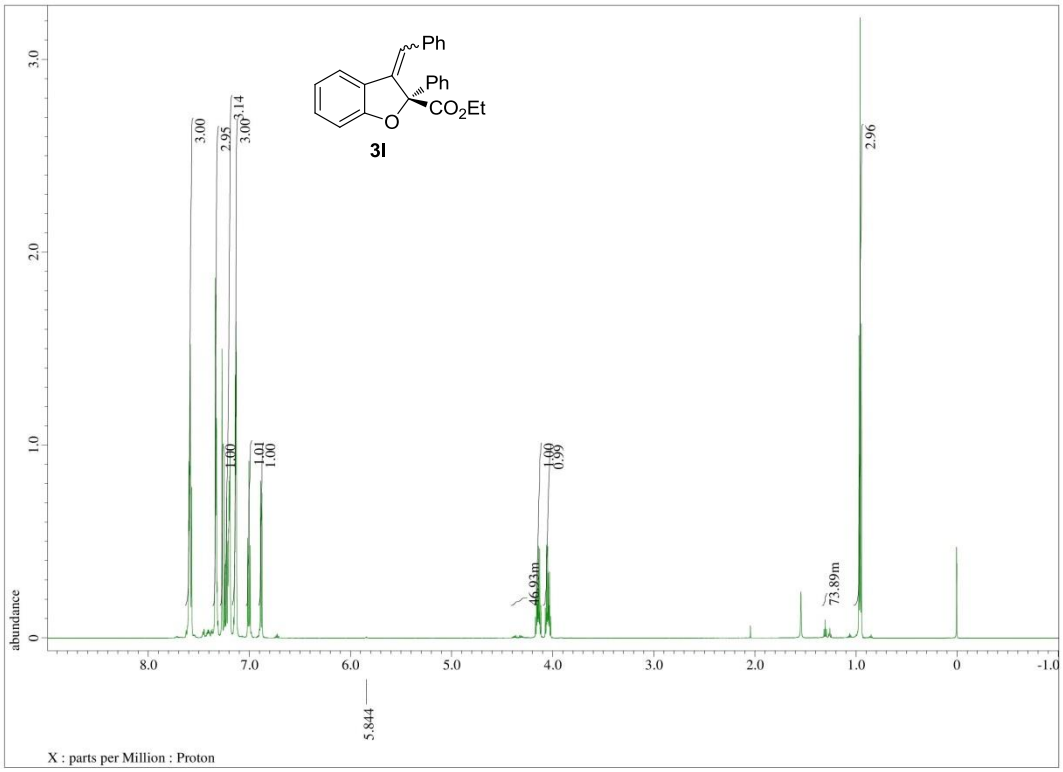

abundance
X : parts per Million : Carbon13
169.808
162.330
161.718
140.031
135.751
128.455
128.340
126.980
120.862
119.876
117.310
108.357
95.862
90.165
77.211
77.000
76.789
61.987
55.543
20.748
13.854

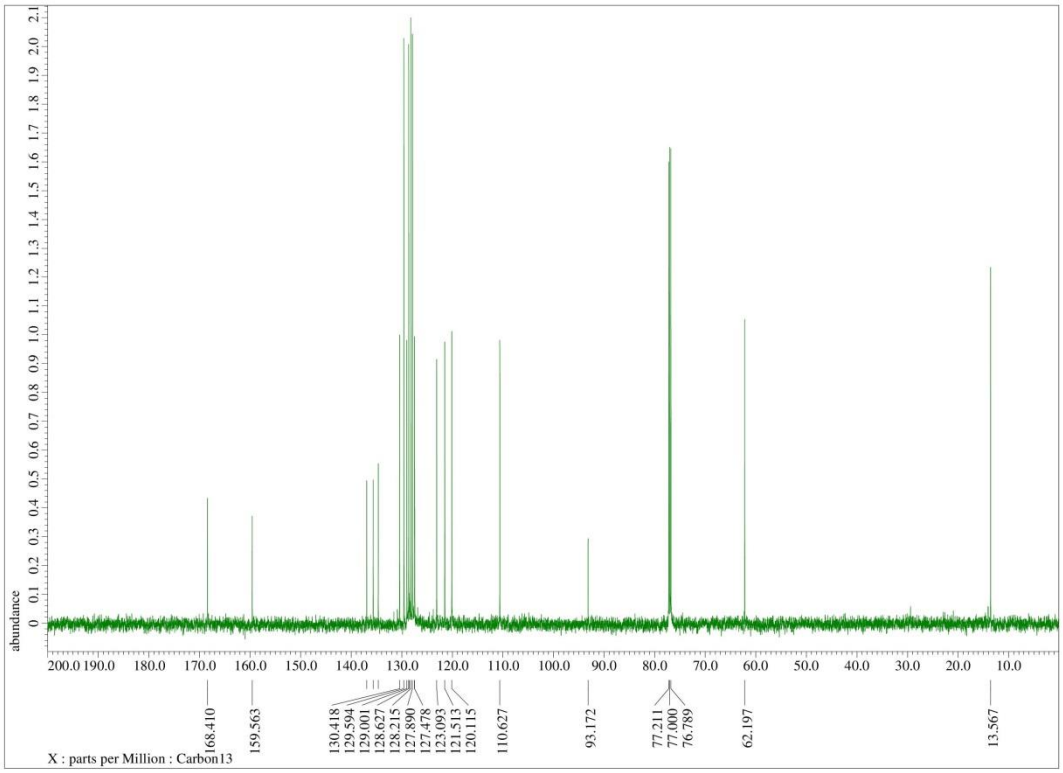

Br
MeO
O
CO2Et
3j
2.04
2.08
1.01
1.00
1.06
1.00
2.17
3.08
3.05
3.04
abundance
X : parts per Million : Proton

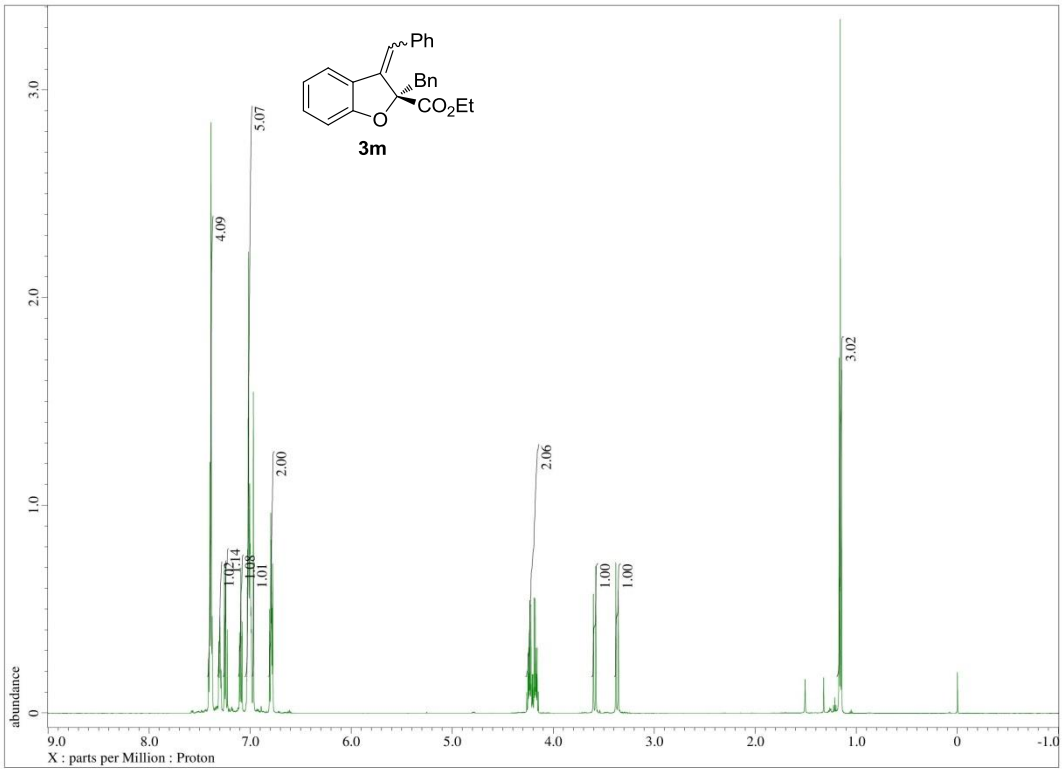

abundance
169.693
162.589
161.909
140.883
134.707
131.461
130.054
120.929
120.833
119.598
115.941
108.558
95.891
90.098
77.211
77.000
76.789
62.083
55.553
53.398
20.681
13.883
X : parts per Million : Carbon13

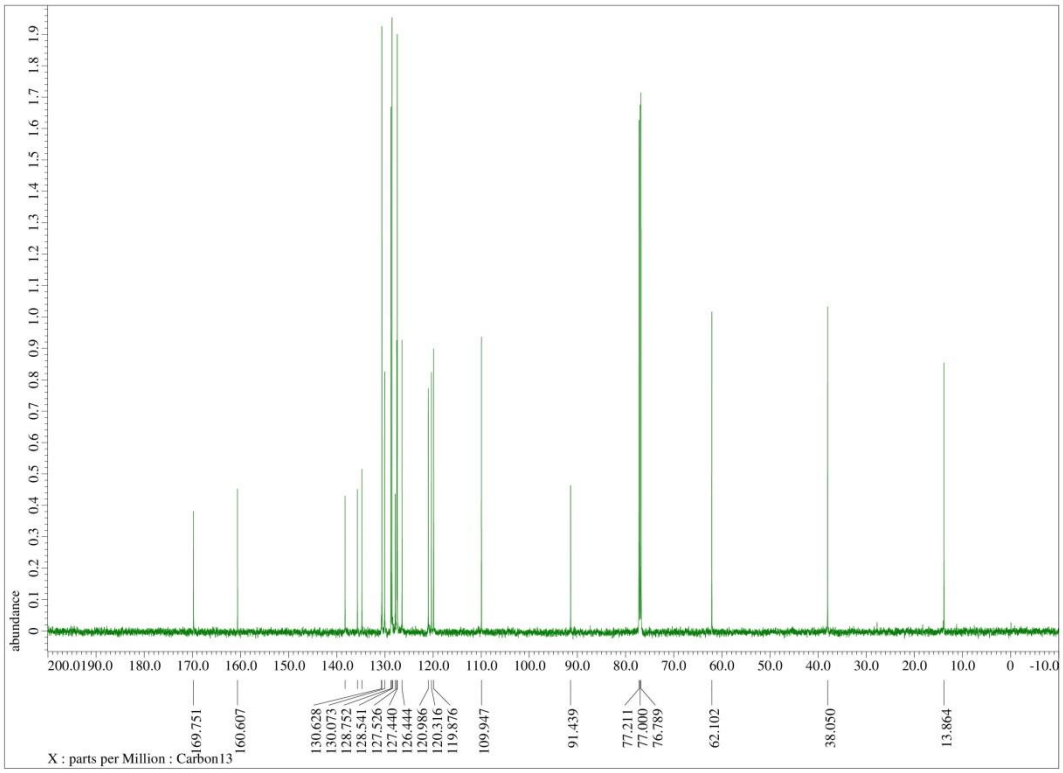

Ph
CO2Et
O
3k
abundance
X : parts per Million : Proton
0.99
1.01
1.05
2.03
3.49
2.07
1.01
1.04
2.08
3.00
3.00

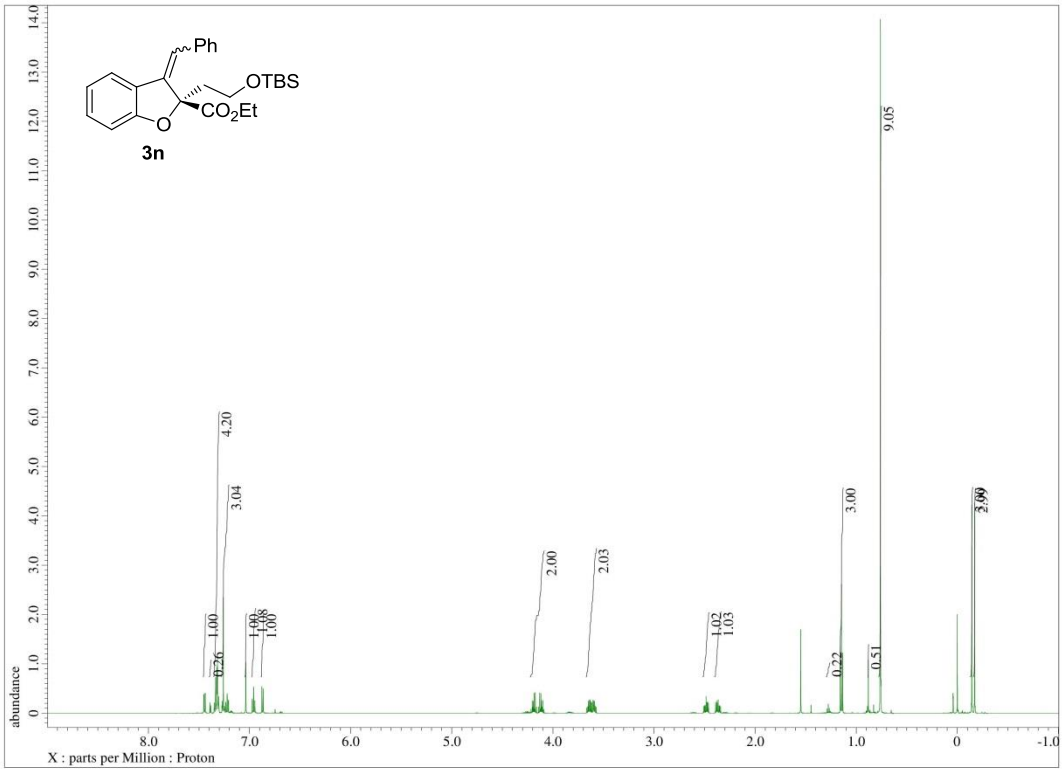

abundance
X : parts per Million : Carbon13
169.808
160.080
143.095
136.680
132.256
130.331
129.671
129.374
128.656
128.196
127.880
127.191
123.495
122.365
122.174
117.090
112.513
89.629
77.211
77.000
76.789
61.862
22.223
13.749

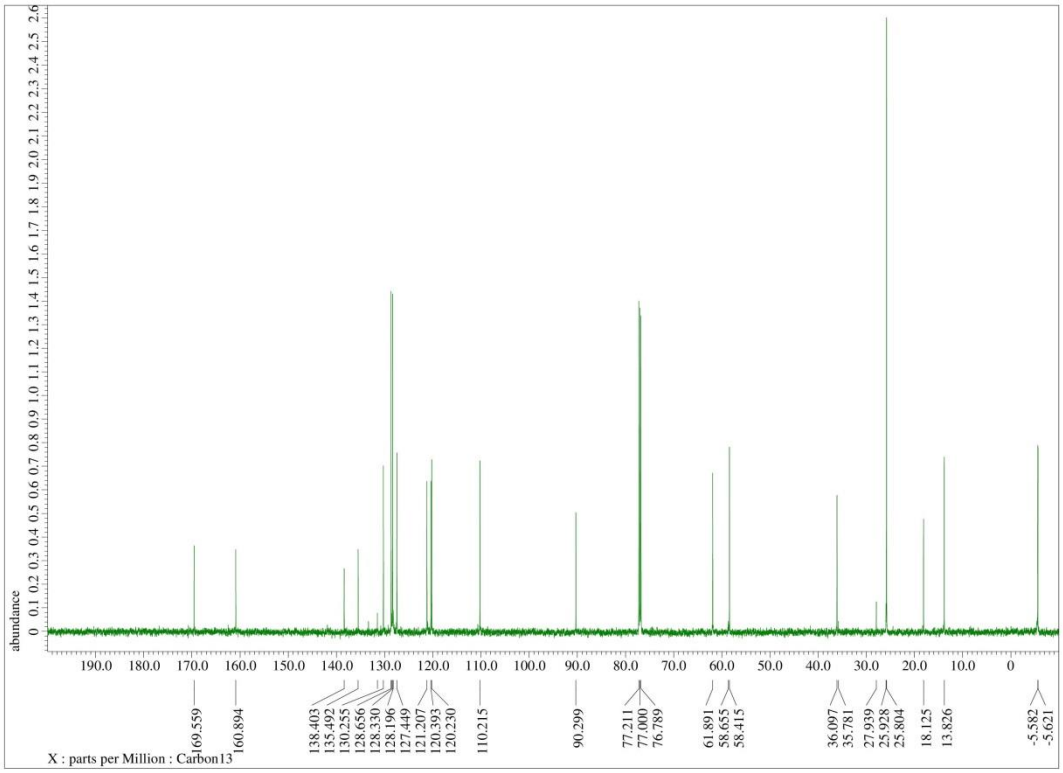

Ph
Ph
CO2Et
O
3l
3.00
2.95
3.14
3.00
1.00
1.01
1.00
1.00
0.99
46.93m
73.89m
2.96
5.844
abundance
X : parts per Million : Proton

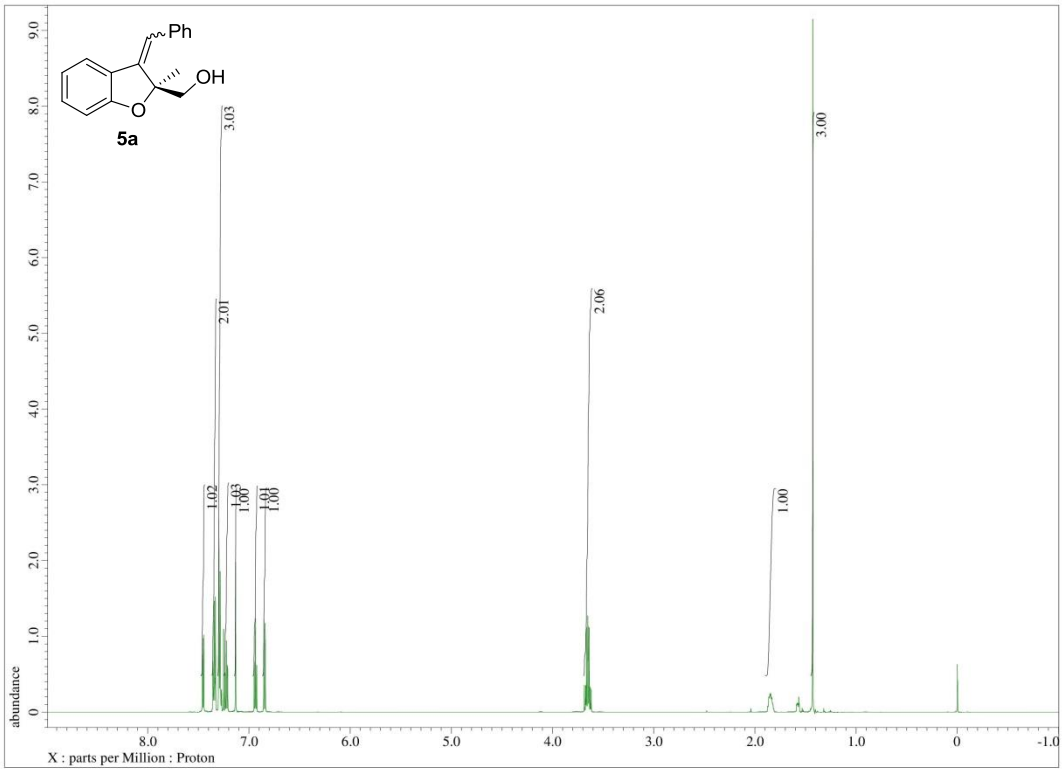

abundance
168.410
159.563
130.418
129.594
129.001
128.627
128.215
127.890
127.478
123.093
121.513
120.115
110.627
93.172
77.211
77.000
76.789
62.197
13.567
X : parts per Million : Carbon13

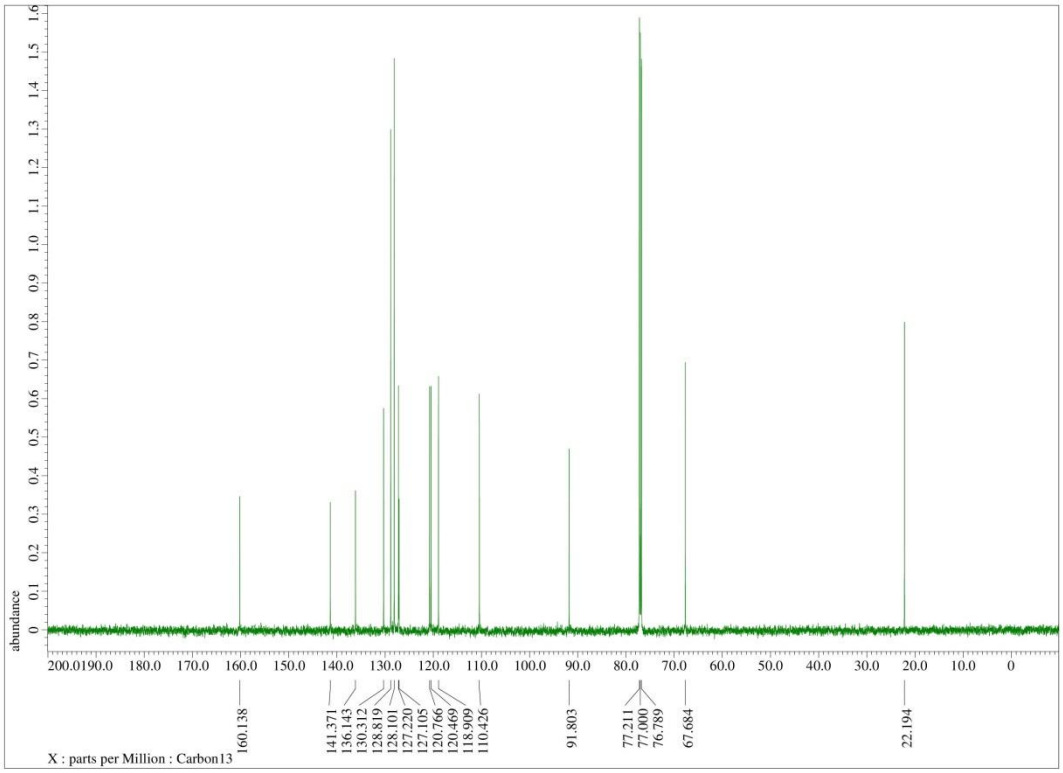

Ph
Bn
CO2Et
O
3m
4.09
5.07
2.00
1.05
1.14
1.08
1.01
2.06
1.00
1.00
3.02
abundance
X : parts per Million : Proton

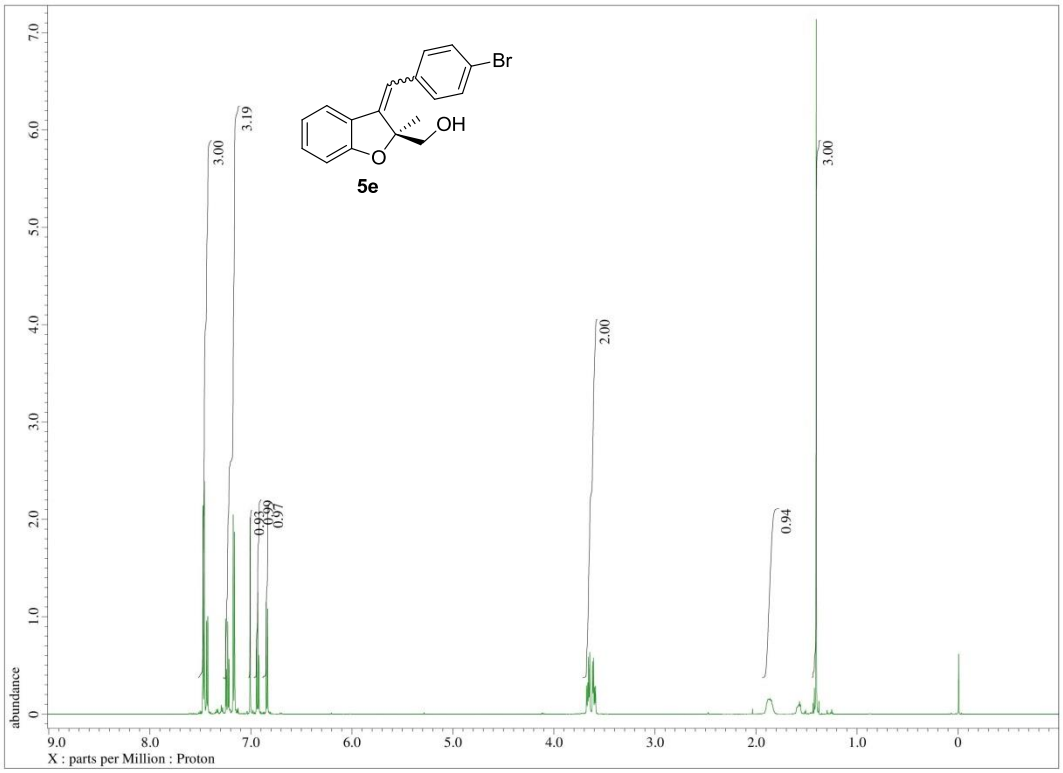

abundance
X : parts per Million : Carbon13
169.751
160.607
130.628
130.073
128.752
128.541
127.526
127.440
126.444
120.986
120.316
119.876
109.947
91.439
77.211
77.000
76.789
62.102
38.050
13.864

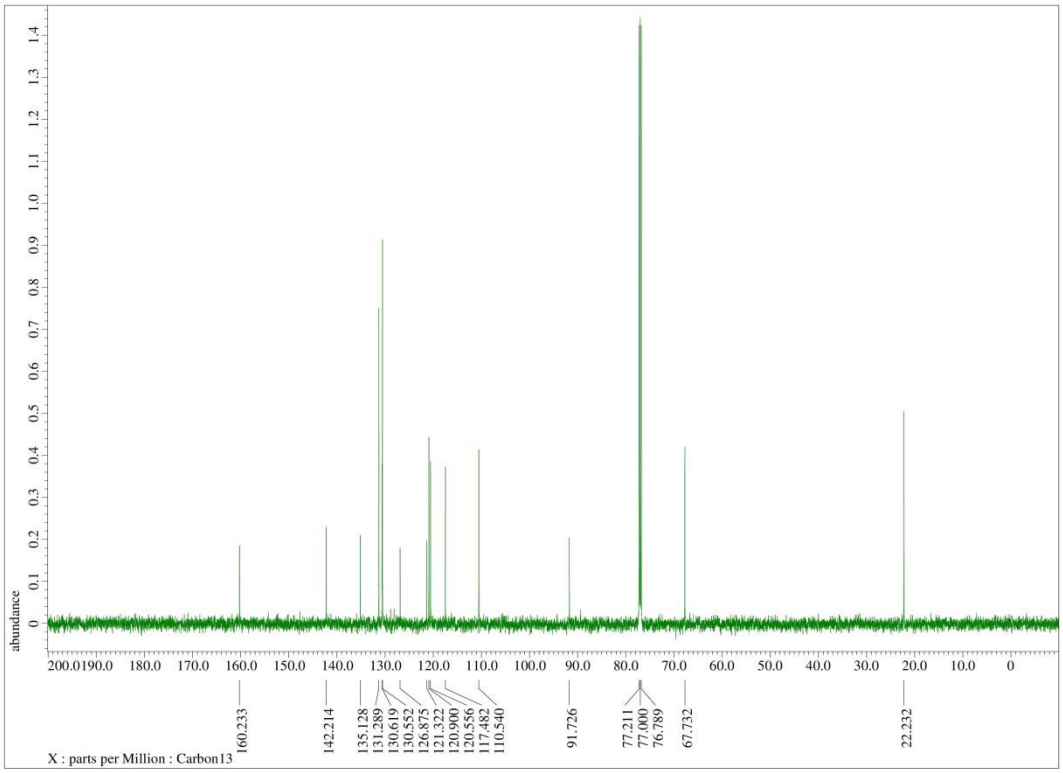

Ph
OTBS
CO2Et
O
3n
abundance
X : parts per Million : Proton
4.20
3.04
2.00
2.03
3.00
9.05
1.00
1.02
1.03
0.22
0.51

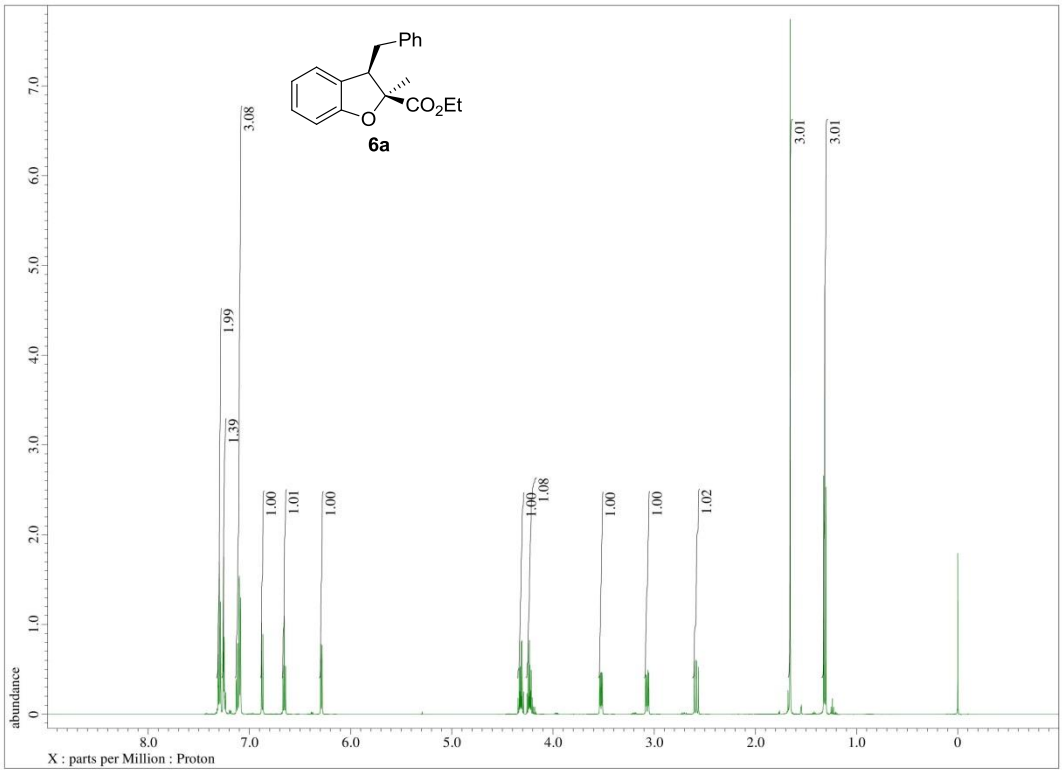

abundance
X : parts per Million : Carbon13
169.559
160.894
138.403
135.492
130.255
128.656
128.330
128.196
127.449
121.207
120.393
120.230
110.215
90.299
77.211
77.000
76.789
61.891
58.655
58.415
36.097
35.781
27.939
25.928
25.804
18.125
13.826
-5.582
-5.621

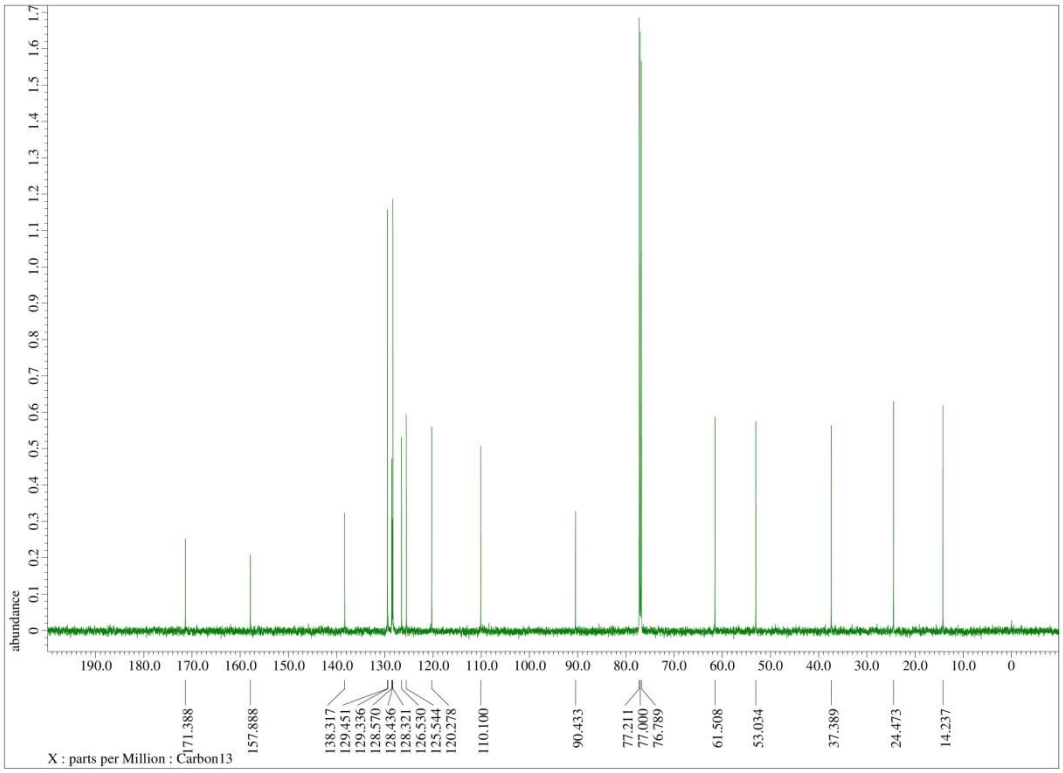

Ph
OH
O
5a
3.03
2.01
1.02
1.03
1.00
1.01
1.00
2.06
1.00
3.00
abundance
X : parts per Million : Proton

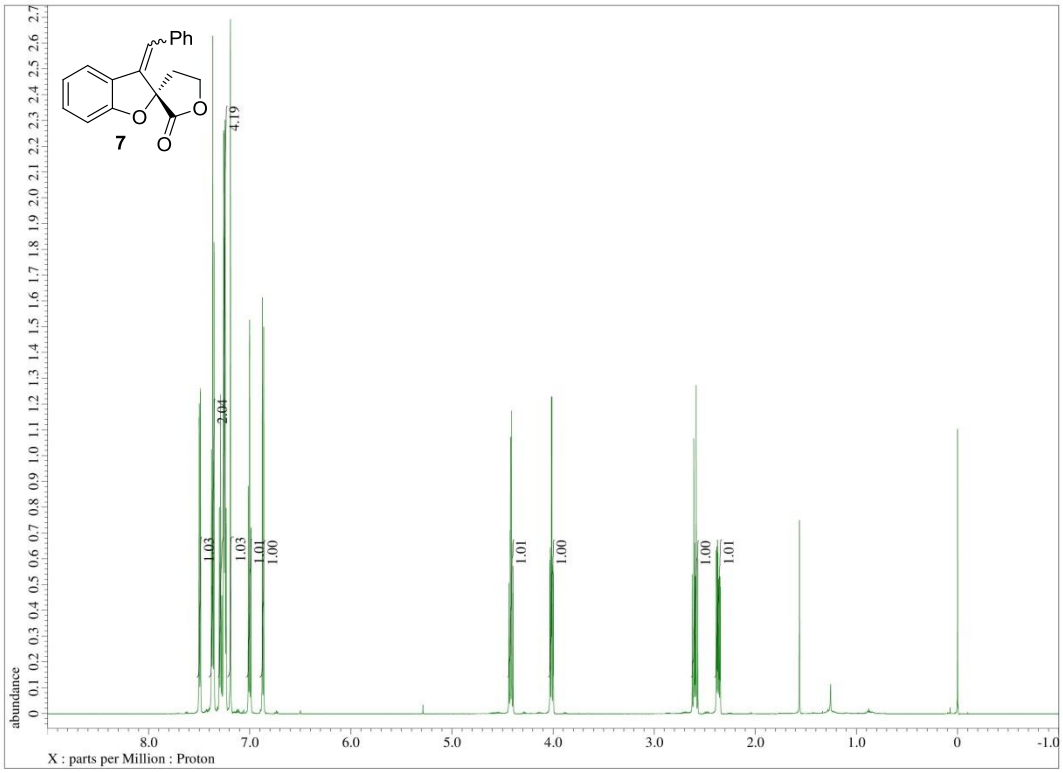

abundance
X : parts per Million : Carbon13
160.138
141.371
136.143
130.312
128.819
128.101
127.220
127.105
120.766
120.469
118.909
110.426
91.803
77.211
77.000
76.789
67.684
22.194

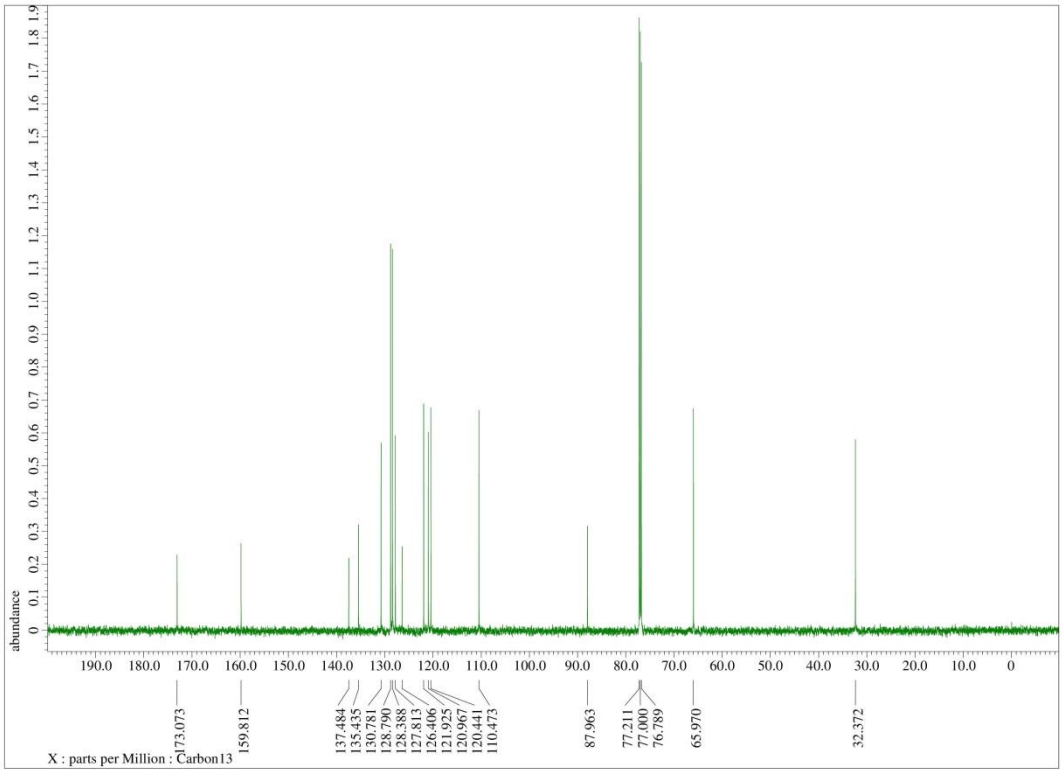

Br
OH
O
5e
3.00
3.19
2.00
0.94
3.00
abundance
X : parts per Million : Proton


abundance
X : parts per Million : Carbon13
160.233
142.214
135.128
131.289
130.619
130.552
126.875
121.322
120.900
120.556
117.482
110.540
91.726
77.211
77.000
76.789
67.732
22.232


Ph
CO2Et
O
6a
3.08
1.99
1.39
1.00
1.01
1.00
1.00
1.08
1.00
1.00
1.02
3.01
3.01
abundance
X : parts per Million : Proton


abundance
171.388
157.888
138.317
129.451
129.336
128.570
128.436
128.321
126.530
125.544
120.278
110.100
90.433
77.211
77.000
76.789
61.508
53.034
37.389
24.473
14.237
X : parts per Million : Carbon13


Ph
O
O
O
7
4.19
3.04
1.03
1.03
1.01
1.00
1.01
1.00
1.00
1.01
abundance
X : parts per Million : Proton


abundance
173.073
159.812
137.484
135.435
130.781
128.790
128.388
127.813
126.406
121.925
120.967
120.441
110.473
87.963
77.211
77.000
76.789
65.970
32.372
X : parts per Million : Carbon13