SUPPORTING INFORMATION

Metal-free alkene oxy- and amino-perfluoroalkylations via carbocation formation by using perfluoro acid anhydrides: unique reactivity between styrenes and perfluoro diacyl peroxides

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1. General Experimental

General: Reactions were conducted in a dry vessel under a positive pressure of nitrogen gas by using a nitrogen-filled balloon. Analytical thin-layer chromatography (TLC) was performed on glass plates coated with 0.25 mm 230–400 mesh silica gel (Merck, Silica gel 60 F_{254}) containing a fluorescent indicator. Visualization was accomplished by means of ultraviolet irradiation at 254 nm and/or by spraying an ethanolic solution of 12-molybdo(VI)phosphoric acid as a developing agent. Flash column chromatography was performed using Silica gel N-60 (spherical, neutral, 40–50 μm, Kanto Chemical Co., Inc. (Kanto)) as described by Still *et al*.[1]

Instrumentation:

NMR analysis

NMR spectra were recorded at room temperature on a JEOL JNM-ECS-400 NMR spectrometer at 400 MHz for ^{1}H, 100 MHz for ^{13}C, and 376 MHz for ^{19}F. The proton chemical shift values are reported in parts per million (ppm, δ scale) downfield from tetramethylsilane and referenced to the proton resonance of $CHCl_3$ (δ 7.26). The carbon chemical shift values are reported in parts per million (ppm, δ scale) downfield from tetramethylsilane and referenced to the carbon resonance of $CDCl_3$ (δ 77.16). The fluorine chemical shift values are reported in parts per million (ppm, δ scale) with $CFCl_3$ (δ 0.00) as an external standard. *J* values are reported in hertz (Hz). The data are presented in the following order: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet and/or multiple resonances, and br = broad), coupling constant and signal area integration in natural numbers.

IR analysis

Infrared spectra were measured on a Thermo Nicolet iS5. Only diagnostic absorptions are listed.

HRMS analysis

ESI-MS spectra were measured on a Bruker micrOTOF-QII-RSL. The samples were diluted with MeOH for measurement. EI-MS was taken on a JEOL JMS-T100GCV gas chromatograph time-of-flight mass spectrometer. The samples were diluted with $CHCl_3$ for measurement.

Solvents: Anhydrous dichloromethane was purchased from Kanto Chemical Co., Inc.

Materials: Reagents were purchased from Wako Pure Chemical Industries, Ltd. Tokyo

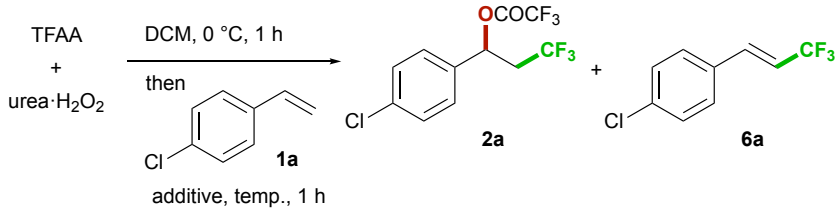
[1]W. C. Still, M. Kahn, A. Mitra, *J. Org. Chem.,* 1978, **43**, 2923.

Chemical Industry Co., Ltd. and Sigma-Aldrich Inc. Known alkenes **3a**[2] and **12**[3] were prepared according to the cited literature.

2. Additional Results

Optimization of the reaction conditions

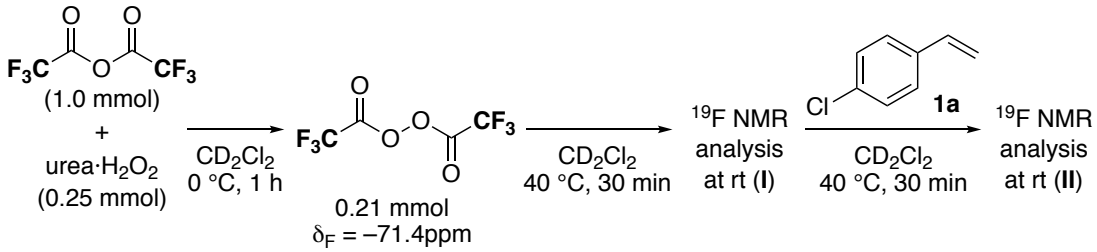
Table S1. Optimization of the conditions for the synthesis of 2a[a]



Entry	TFAA/urea·H_2O_2 (equiv.)	Temp. (°C)	Additive	Yield (%)[b]		Recovery of **1a** (%)[c]
				2a	**6a**	
1	4.0/1.2	0	–	0	0	94
2	4.0/1.2	25	–	38	3	32
3	4.0/1.2	40	–	60	5	14
4	6.0/1.2	40	–	44	4	15
5	8.0/2.2	40	–	74	4	0
6	8.0/2.2	40	TFA (0.4 equiv.)	75	4	0
7	8.0/2.2	40	TFA (1.0 equiv)	75	3	0
8	10/2.5	40	–	85(80)[d]	4	0
9	12/3.0	40	–	81	3	0
10	10/3.5	40	–	83	3	0

[a]The reactions were conducted on 0.20 mmol scale. [b]The yields were estimated by means of ^{19}F NMR analysis, with α,α,α-trifluorotoluene as an internal standard. [c]The recovery of **1a** was estimated by means of ^{1}H NMR analysis, with 1,1,2,2-tetrachloroethane as an internal standard. [d]Yield in parenthesis is the isolated yield.

^{19}F NMR monitoring:



Trifluoroacetic anhydride (0.14 mL, 1.0 mmol) was slowly added to a suspension of urea · H_2O_2 (24 mg, 0.25 mmol) in CD_2Cl_2 (0.6 mL) in a Schlenk tube at 0 °C, and the mixture

[2]L. Zhou, J. Chen, C. K. Tan, Y.-Y. Yeung, *J. Am. Chem. Soc.*, 2011, **133**, 9164.
[3]Y. Arai, R. Tomita, G. Ando, T. Koike, M. Akita, *Chem. Eur. J.*, 2016, **22**, 1262.

was stirred for 1 h. The obtained colorless solution containing bis(trifluoroacetyl)peroxide (BTFAP) was transferred to a valve NMR tube containing α,α,α-trifluorotoluene (13 mg, 0.09 mmol) as an internal standard under a N_2 atmosphere. The ^{19}F NMR spectrum of the sample was measured at room temperature, and 0.21 mmol of the peroxide was found to have been formed. After the measurement, the NMR sample was warmed to 40 °C on an oil bath. After 30 min, ^{19}F NMR measurement was conducted at room temperature (**I**) (Figure S1); and no change of the spectral signals or integration values was observed. Then, styrene **1a** (14 mg, 0.10 mmol) was added to the sample solution at room temperature, and the mixture was warmed to 40 °C on an oil bath. After 30 min, the ^{19}F NMR spectrum of the sample was measured at room temperature (**II**); the results indicated the presence of 0.09 mmol (86% yield based on **1a**) of oxy-trifluoromethylation product **2a** and 0.10 mmol of BTFAP. This shows that styrene is essential for decomposition of BTFAP and CF_3 radical generation.

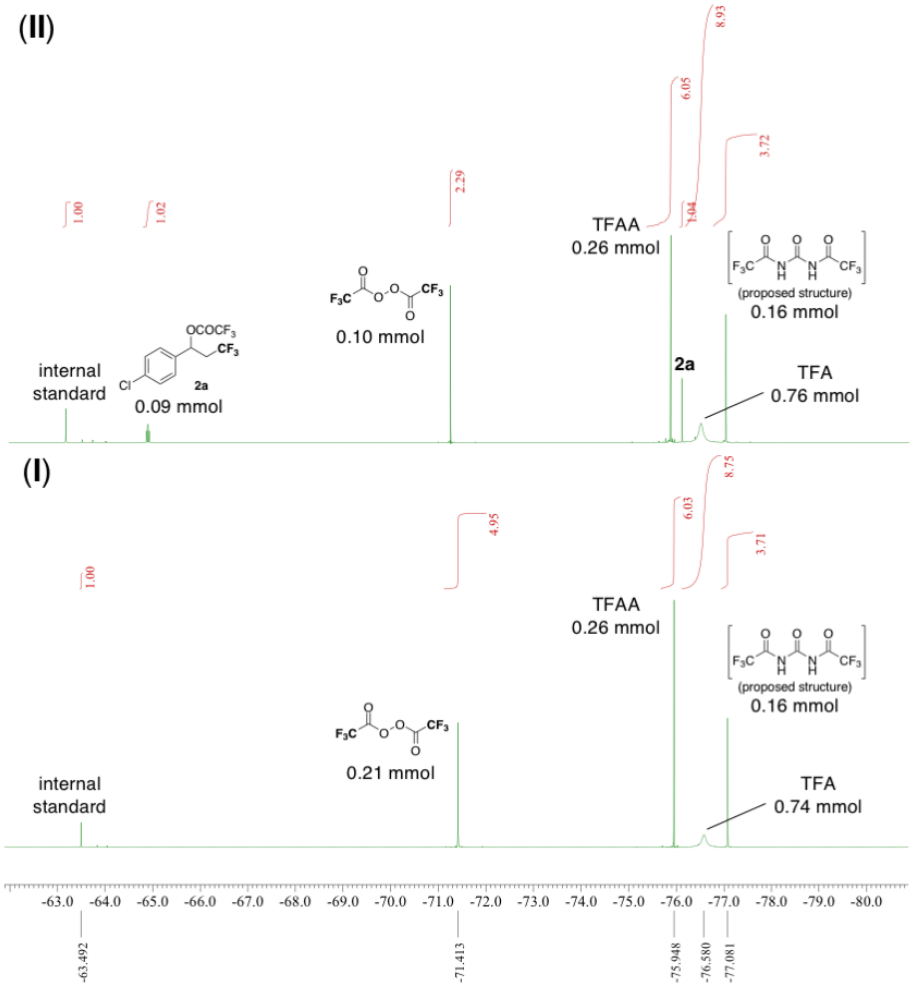
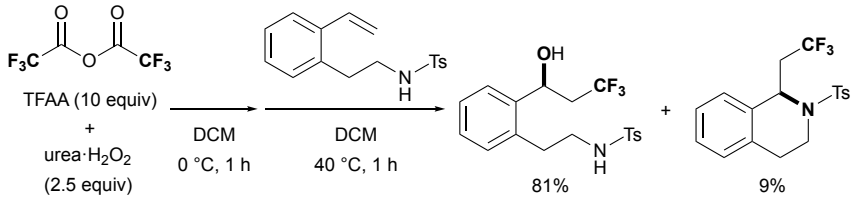


Figure S1. ^{19}F NMR monitoring of the decomposition of BTFAP

***Reaction of N-(2-vinylphenethyl)-p-toluenesulfonamide*:**



To a suspension of urea·H_2O_2 (47 mg, 0.50 mmol) in DCM (1 mL) trifluoroacetic anhydride (0.28 mL, 2.0 mmol) was slowly added at 0 °C. After stirring for 1 h, *N*-(2-vinylphenethyl)-*p*-toluenesulfonamide (60 mg, 0.20 mmol) was added. Then, the mixture was immediately warmed to 40 °C, further stirred for 3 h, then diluted with Et_2O (5 mL), quenched with saturated K_2CO_3 solution at 0 °C, again stirred for 20 min. The phases were separated and the aqueous layer was extracted with Et_2O (2 x 5 mL). The combined organic phase was dried over Na_2SO_4, filtered and concentrated *in vacuo*. Purification of the crude product by column chromatography on silica gel afforded *N*-(2-(3,3,3-trifluoro-1-hydroxypropyl)phenethyl)-*p*-toluenesulfonamide (63 mg, 81% yield) and 2-tosyl-1-(2,2,2-trifluoroethyl)-1,2,3,4-tetrahydroisoquinoline (7 mg, 9%).

<N-(2-(3,3,3-trifluoro-1-hydroxypropyl)phenethyl)-p-toluenesulfonamide>

^{1}H NMR (400 MHz, $CDCl_3$)

2.28–2.43 (m, 2H), 2.40 (s, 3H), 2.56–2.72 (m, 1H), 2.80 (ddd, *J* = 14.0, 6.9, 6.7 Hz, 1H), 2.89 (ddd, *J* = 14.0, 7.0, 6.9 Hz, 1H), 3.14 (ddd, *J* = 13.0, 7.0, 6.9 Hz), 3.22 (ddd, *J* = 13.0, 6.9, 6.7 Hz, 1H), 4.85–5.10 (br, 1H), 5.24 (dd, *J* = 8.9, 3.3 Hz, 1H), 7.07 (d, *J* = 7.5 Hz, 1H), 7.18–7.29 (overlap, 4H), 7.41 (d, *J* = 7.5 Hz, 1H), 7.63 (d, *J* = 7.9 Hz, 2H)

^{13}C NMR (100 MHz, $CDCl_3$)

21.6, 32.2, 42.2 (q, *J* = 27 Hz). 44.2, 64.9 (q, *J* = 2.9 Hz), 126.0 (q, *J* = 277 Hz), 126.4, 127.1 (2C), 127.7, 128.7, 129.9 (2C), 130.3, 134.9, 136.8, 140.5, 143.7.

^{19}F NMR (376 MHz, $CDCl_3$)

–63.7 (t, *J* = 10.1 Hz)

IR (neat, cm^{-1})

3287, 1325, 1260, 1156, 1093, 815, 761, 662.

HRMS-ESI (*m*/*z*)

$[M+Na]^+$ calcd. for $C_{18}H_{20}F_3NO_3SNa$, 410.1008; found, 410.1009.

<2-Tosyl-1-(2,2,2-trifluoroethyl)-1,2,3,4-tetrahydroisoquinoline>

^{1}H NMR (400 MHz, $CDCl_3$)

2.35 (s, 3H), 2.41–2.56 (m, 1H), 2.56–2.82 (m, 3H), 3.48 (ddd, *J* = 14.2, 10.3,

5.3 Hz, 1H), 3.77 (dddd, J = 14.2, 6.4, 3.7, 0.9 Hz, 1H), 5.42 (dd, J = 8.4, 5.1 Hz, 1H), 6.96 (d, J = 7.0 Hz, 1H), 7.08 (dd, J = 7.0, 1.8 Hz, 1H), 7.12–7.18 (m, 4H), 7.63 (d, J = 8.3 Hz, 2H)

^{13}C NMR (100 MHz, $CDCl_3$)

21.6, 26.3, 39.3, 41.3 (q, J = 27 Hz), 51.1 (q, J = 2.9 Hz), 125.3 (q, J = 278 Hz), 126.7, 127.0, 127.4 (2C), 127.8, 129.3, 129.6 (2C), 133.3, 134.4, 137.0, 143.6.

^{19}F NMR (376 MHz, $CDCl_3$)

–63.3 (t, J = 11.6 Hz)

IR (neat, cm^{-1})

1339, 1266, 1165, 1091, 941, 815, 734, 659.

HRMS-ESI (m/z)

$[M+H]^+$ calcd. for $C_{18}H_{19}F_3NO_2S$, 370.1083; found, 370.1090.

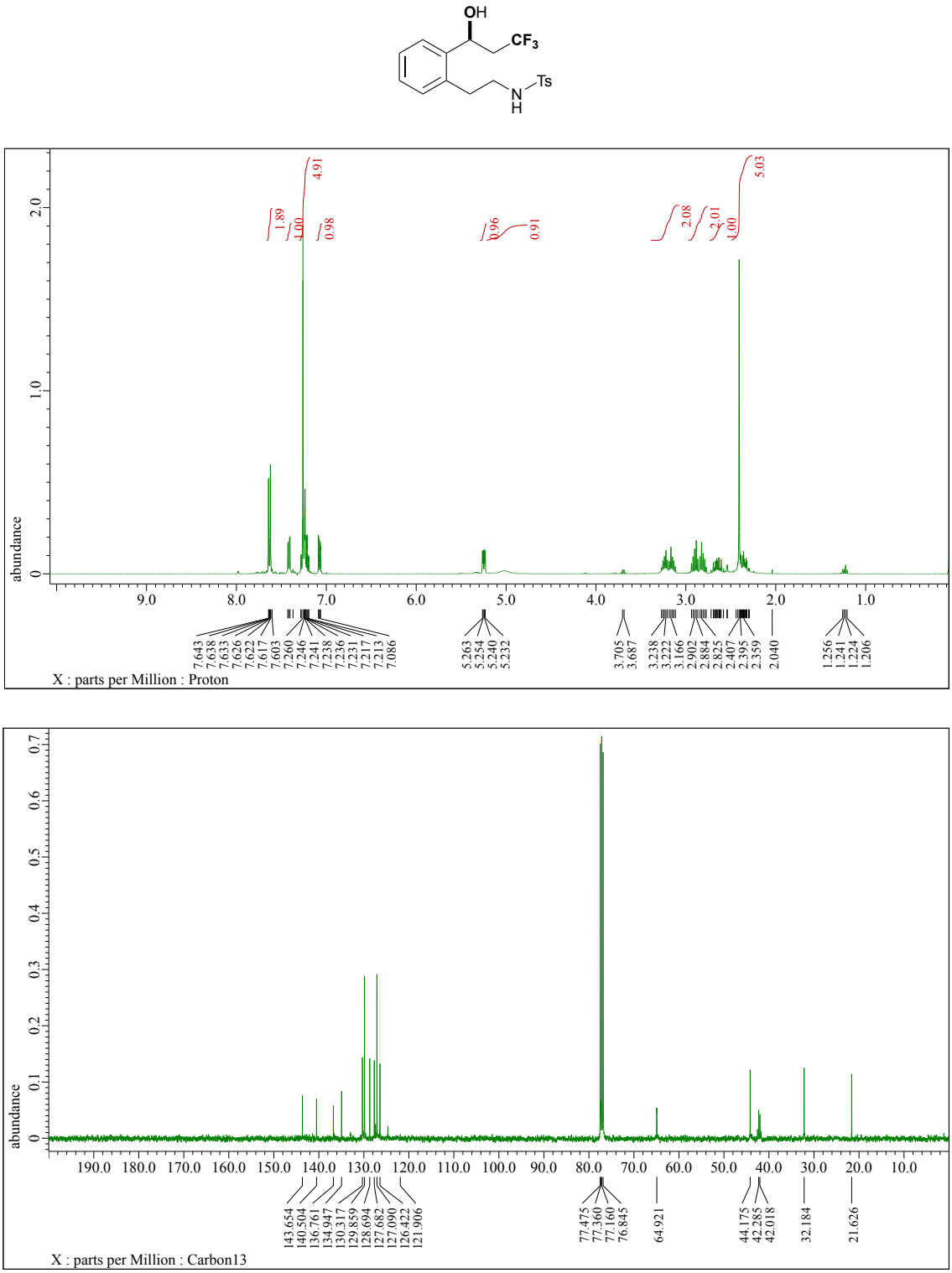


Figure S2. NMR spectra of *N*-(2-(3,3,3-trifluoro-1-hydroxypropyl)phenethyl)-*p*-toluenesulfonamide

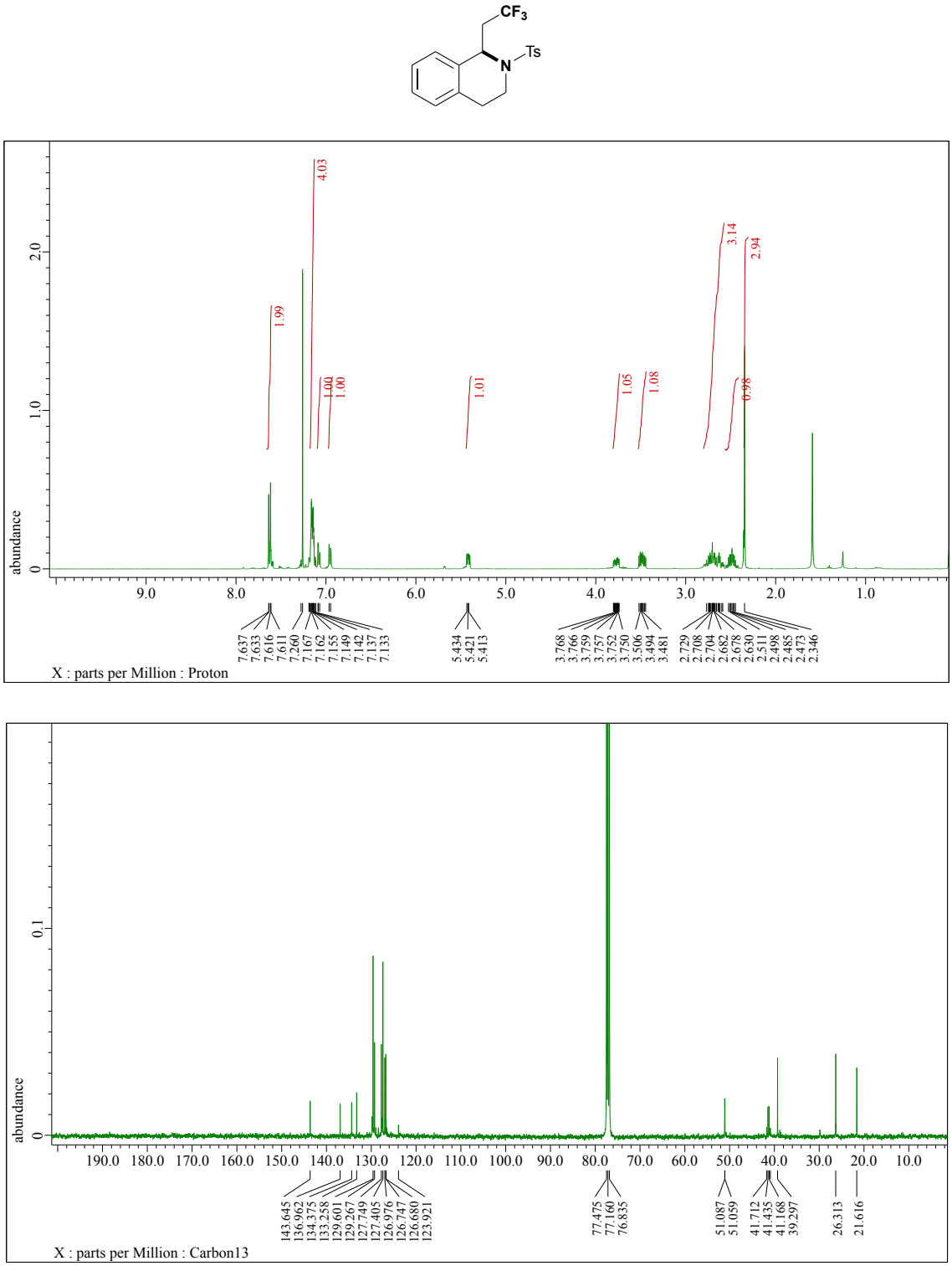
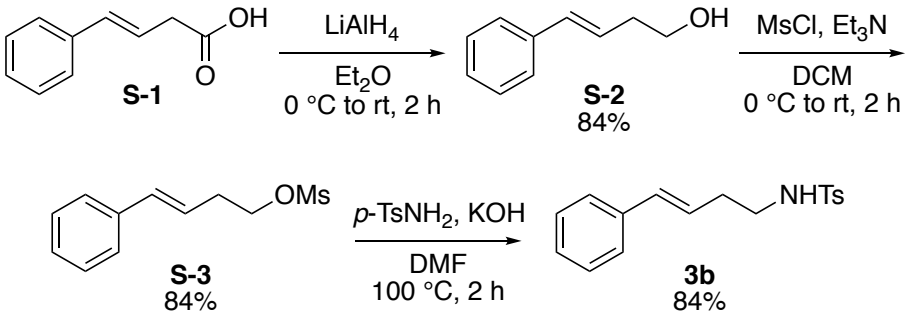


Figure S3. NMR spectra of *2-Tosyl-(2,2,2-trifluoroethyl)-1,2,3,4-tetrahydro-isoquinoline*

3. Experimental procedures

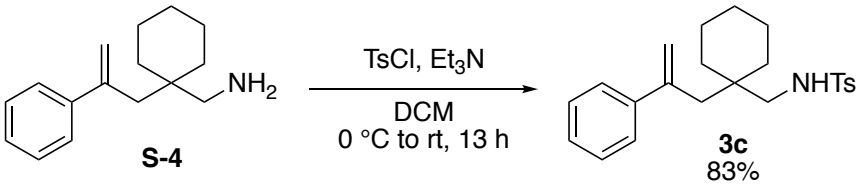
Preparation of aminoalkene 3b



Substrate **3b** was synthesized according to the literature procedure for preparing **3a**.[2] A solution of carboxylic acid **S-1** (2.0 g, 12 mmol) in dry Et_2O (15 mL) was added dropwise to a suspension of lithium aluminum hydride (0.9 g, 24 mmol) in dry Et_2O (35 mL) at 0 °C. The mixture was stirred at room temperature for 2 h, and then the reaction was quenched by careful and sequential addition of H_2O (7 mL) and 2 M NaOH solution (7 mL) at 0 °C. The resulting suspension was filtered through a Celite pad and the filtrate was dried over Na_2SO_4, filtered and concentrated *in vacuo* to provide **S-2** (1.5 g, 84% yield) as a yellow oil. Methanesulfonyl chloride (0.97 mL, 13 mmol) was added dropwise to a solution of **S-2** (1.5 g, 10 mmol) and triethylamine (1.9 mL, 14 mmol) in dry DCM (30 mL) at 0 °C. The solution was stirred at 0 °C for 10 min, then warmed to room temperature, and stirred further for 1 h. The reaction mixture was diluted with DCM (10 mL) and washed with 1 M HCl aqueous solution (40 mL), saturated $NaHCO_3$ solution (40 mL) and brine (40 mL). The organic phase was dried over Na_2SO_4, filtered and concentrated *in vacuo*. Purification by means of column chromatography (SiO_2; EtOAc/hexane = 20/80) provided **S-3** (2.2 g, 93% yield) as a yellow oil. A solution of *p*-toluenesulfonamide (4.4 g, 26 mmol) and potassium hydroxide (1.4 g, 26 mmol) in dry DMF (70 mL) was heated to 100 °C for 0.5 h. Then a solution of **S-3** (2.1 g, 13 mmol) in dry DMF (40 mL) was added dropwise. The mixture was stirred at 100 °C for 2 h, cooled to room temperature, quenched with water (80 mL), and extracted with Et_2O (3 x 60 mL). The combined organic phase was washed with water (60 mL) and brine (60 mL), dried over Na_2SO_4, filtered and concentrated *in vacuo*. Purification of the residue by means of column chromatography (SiO_2; EtOAc/hexane = 20/80) provided **3b** (2.0 g, 64% yield) as a colorless oil, whose spectroscopic data matched reported values.[4]

[4] J. Ciesielski, G. Dequirez, P. Retailleau, V. Gandon, P. Dauban, *Chem. Eur, J*. 2016, **22**, 9338.

Preparation of aminoalkene 3c



S-4 **3c** 83%

p-Toluenesulfonyl chloride (0.46 mg, 2.4 mmol) was added to a solution of **S-4**[5] (0.50 g, 2.2 mmol) and triethylamine (0.6 mL, 4.4 mmol) in dry DCM (9 mL) at 0 °C. The reaction mixture was stirred at room temperature overnight, then diluted with DCM (10 mL) and washed with 1 M HCl aqueous solution (2 x 15 mL). The organic phase was dried over Na_2SO_4, filtered and concentrated *in vacuo* to give a yellow oil. Purification by column chromatography (SiO_2; EtOAc/hexane = 10/90) provided **3c** (0.70 g, 83% yield) as a white solid.

^{1}H NMR (400 MHz, $CDCl_3$)

1.21–1.45 (overlap, 10H), 2.42 (s, 3H), 2.49 (s, 2H), 2.50 (d, *J* = 7.6 Hz, 2H), 3.93 (t, *J* = 7.6 Hz, 1H), 5.03 (d, *J* = 1.6 Hz, 1H), 5.17 (d, *J* = 1.6 Hz, 1H), 7.22 (d, *J* = 8.4 Hz, 2H), 7.27–7.33 (overlap, 5H), 7.39 (d, *J* = 8.4 Hz, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

21.5 (2C), 21.6, 26.1, 33.9 (2C), 37.6, 42.5, 48.6, 118.0, 126.5 (2C), 127.0 (2C), 127.7, 128.9 (2C), 129.6 (2C), 136.9, 143.1, 143.8, 146.0.

IR (neat, cm^{-1})

3284, 1454, 1415, 1325, 1161, 1093, 1071, 906, 813, 779, 705, 662.

HRMS-ESI (*m*/*z*)

$[M+Na]^+$ calcd. for $C_{23}H_{29}NO_2SNa$, 406.1817; found, 406.1818.

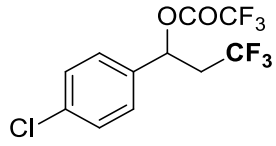
Oxy- and amino-perfluoroalkylation of alkenes: general procedure

To a suspension of urea·H_2O_2 (47 mg, 0.50 mmol) in DCM (1 mL) perfluoro acid anhydride (2.0 mmol) was slowly added at 0 °C. After stirring for 1 h, styrene (0.20 mmol) was added. Then, the mixture was immediately warmed to 40 °C, further stirred for 1 h, then diluted with Et_2O (5 mL), quenched with saturated K_2CO_3 solution at 0 °C, again stirred for 20 min. The phases were separated and the aqueous layer was extracted with Et_2O (2 x 5 mL).[6] The combined organic phase was dried over Na_2SO_4, filtered and

[5] J.-S. Lin, P. Yu, L. Huang, P. Zhang, B. Tan, X.-Y. Liu, *Angew. Chem. Int. Ed.*, 2015, **54**, 7847.
[6] The combined organic phase was checked with XploSens PS® to confirm the absence of peroxide, and the water phase was treated with saturated $Na_2S_2O_3$ to decompose H_2O_2.

concentrated *in vacuo*. Purification of the crude product by column chromatography on silica gel afforded the target compound.

Synthesis of 1-(4-chlorophenyl)-3,3,3-trifluoropropyl 2,2,2-trifluoroacetate (2a):



The reaction was carried out according to the general procedure. The target compound **2a** was obtained as a colorless oil (51 mg, 80% yield) after purification by column chromatography (SiO_2; 100% hexane).

^{1}H NMR (400 MHz, $CDCl_3$)

2.62 (dqd, *J* = 15.7, 10.1, 2.8 Hz, 1H), 2.95 (m, 1H), 6.18 (dd, *J* = 7.6, 2.8 Hz, 1H), 7.33 (d, *J* = 6.8 Hz, 2H), 7.41 (d, *J* = 6.8 Hz, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

40.1 (q, *J* = 29 Hz), 73.0 (q, *J* = 2.9 Hz), 114.4 (q, *J* = 285 Hz), 124.7 (q, *J* = 277 Hz), 128.0 (2C), 129.7 (2C), 134.5, 136.1, 156.2 (q, *J* = 43 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–64.3 (t, *J* = 10.1 Hz, 3F), –75.2 (s, 3F).

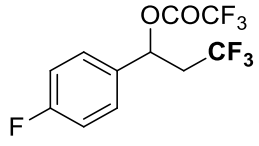
IR (neat, cm^{-1})

1793, 1495, 1392, 1378, 1338, 1323, 1283, 1253, 1226, 1143, 1130, 1096, 1064, 1016, 828, 819, 668.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{11}H_7ClF_6O_2$, 320.0039; found, 320.0027.

Synthesis of 1-(4-fluorophenyl)-3,3,3-trifluoropropyl 2,2,2-trifluoroacetate (2b):



The reaction was carried out according to the general procedure. The target compound **2b** was obtained as a yellow oil (54 mg, 88% yield) after purification by column chromatography (SiO_2; 100% hexane).

Procedure for gram-scale synthesis: To a suspension of urea·H_2O_2 (3.9 g, 41 mmol) in DCM (82 mL), trifluoroacetic anhydride (23.1 mL, 164 mmol) was slowly added at 0 °C. After stirring for 1 h, 4-fluorostyrene (2.0 g, 16 mmol) was added. The mixture was immediately warmed to 40 °C and stirred for further 1 h. After dilution with DCM (50 mL), the reaction was quenched with saturated K_2CO_3 solution at 0 °C for 20 min. The phases were separated and the aqueous layer was extracted with DCM (2 x 50 mL).[6] The

combined organic phase was dried over Na_2SO_4, filtered and concentrated *in vacuo* to give pure **2b** (4.7 g, 93%) as a yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$)

2.62 (dqd, *J* = 15.5, 10.1, 3.6 Hz, 1H), 2.96 (m, 1H), 6.20 (dd, *J* = 9.6, 3.6 Hz, 1H), 7.12 (m, 2H), 7.39 (m, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

40.2 (q, *J* = 29 Hz), 73.1 (q, *J* = 2.8 Hz), 114.4 (q, *J* = 285 Hz), 116.5 (d, *J* = 22 Hz, 2C), 124.7 (q, *J* = 277 Hz), 128.7 (d, *J* = 8.6 Hz, 2C), 132.0 (d, *J* = 3.9 Hz), 156.2 (q, *J* = 43 Hz), 163.5 (d, *J* = 249 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–64.3 (t, *J* = 10.1 Hz, 3F), –75.2 (s, 3F), –110.6 (m, 1F).

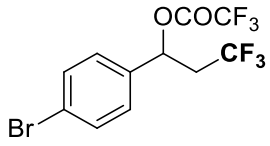
IR (neat, cm^{-1})

1791, 1515, 1340, 1229, 1129, 1098, 1064, 831, 771, 735.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{11}H_7F_7O_2$, 304.0334; found, 304.0312.

Synthesis of 1-(4-bromophenyl)-3,3,3-trifluoropropyl 2,2,2-trifluoroacetate (2c):



The reaction was carried out according to the general procedure. The target compound **2c** was obtained as a colorless oil (56 mg, 77% yield) after purification by column chromatography (SiO_2; 100% hexane).

^{1}H NMR (400 MHz, $CDCl_3$)

2.62 (dqd, *J* = 15.6, 10.1, 3.6 Hz, 1H), 2.95 (m, 1H), 6.17 (dd, *J* = 9.6, 3.6 Hz, 1H), 7.27 (d, *J* = 8.4 Hz, 2H), 7.57 (d, *J* = 8.4 Hz, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

40.1 (q, *J* = 29 Hz), 73.1 (q, *J* = 3.8 Hz), 114.4 (q, *J* = 285 Hz), 124.2, 124.7 (q, *J* = 277 Hz), 128.2 (2C), 132.7 (2C), 135.1, 156.2 (q, *J* = 43 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–64.3 (t, *J* = 10.1 Hz, 3F), –75.2 (s, 3F).

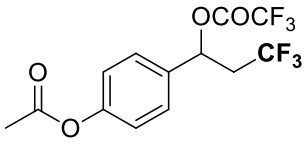
IR (neat, cm^{-1})

1791, 1491, 1377, 1338, 1253, 1225, 1129, 1102, 1075, 1013, 816, 735, 668.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{11}H_7BrF_6O_2$, 363.9534; found, 363.9506.

Synthesis of 1-(4-acetoxyphenyl)-3,3,3-trifluoropropyl 2,2,2-trifluoroacetate (2d):



The reaction was carried out according to the general procedure. The target compound **2d** was obtained as a colorless oil (69 mg, quantitative yield) after purification by column chromatography (SiO_2; EtOAc/hexane = 5/95).

^{1}H NMR (400 MHz, $CDCl_3$)

2.31 (s, 3H), 2.62 (dqd, *J* = 15.6, 10.1, 3.2 Hz, 1H), 2.96 (m, 1H), 6.23 (dd, *J* = 10.0, 3.2 Hz, 1H), 7.16 (d, *J* = 8.4 Hz, 2H), 7.41 (d, *J* = 8.4 Hz, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

21.2, 40.2 (q, *J* = 29 Hz), 73.0 (q, *J* = 3.0 Hz), 114.4 (q, *J* = 285 Hz), 122.7 (2C), 124.8 (q, *J* = 277 Hz), 127.8 (2C), 133.6, 151.7, 156.2 (q, *J* = 43 Hz), 169.3.

^{19}F NMR (376 MHz, $CDCl_3$)

–64.5 (t, *J* = 10.1 Hz, 3F), –75.2 (s, 3F).

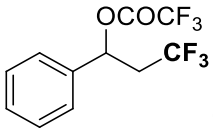
IR (neat, cm^{-1})

1791, 1770, 1374, 1341, 1258, 1216, 1199, 1130, 1104, 1064, 1018, 913, 800, 774, 631.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{13}H_{10}F_6O_4$, 344.0483; found, 344.0447.

Synthesis of 3,3,3-trifluoro-1-phenylpropyl 2,2,2-trifluoroacetate (2e):



The reaction was carried out according to the general procedure. The target compound **2e** was obtained as a colorless oil (90% yield based on ^{1}H and ^{19}F NMR).[7] The crude product was purified by column chromatography (SiO_2; 100% hexane) to obtain an analytical sample (11 mg).

^{1}H NMR (400 MHz, $CDCl_3$)

2.63 (dqd, *J* = 15.5, 10.1, 3.2 Hz, 1H), 2.98 (m, 1H), 6.23 (dd, *J* = 9.6, 3.2 Hz, 1H), 7.37–7.45 (overlap, 5H).

^{13}C NMR (100 MHz, $CDCl_3$)

40.3 (q, *J* = 29 Hz), 73.7 (q, *J* = 2.9 Hz), 114.5 (q, *J* = 284 Hz), 124.8 (q, *J* =

[7]Compound **2e** appeared to be volatile, hampering full isolation.

276 Hz), 126.5 (2C), 129.4 (2C), 129.9, 136.2, 156.3 (q, J = 44 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–64.4 (d, J = 10.1 Hz, 3F), –75.2 (s, 3F).

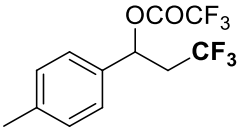
IR (neat, cm^{-1})

1791, 1347, 1332, 1254, 1226, 1129, 1077, 1062, 773, 763, 734, 698, 668, 609.

HRMS-EI (m/z)

[M] calcd. for $C_{11}H_8F_6O_2$, 286.0428; found, 286.0417.

Synthesis of 1-(4-methylphenyl)-3,3,3-trifluoropropyl 2,2,2-trifluoroacetate (2f):



The reaction was carried out according to the general procedure. The target compound **2f** was obtained as a colorless oil (43 mg, 72% yield) after purification by column chromatography (SiO_2; 100% hexane).

^{1}H NMR (400 MHz, $CDCl_3$)

2.37 (s, 3H), 2.61 (dqd, J = 15.6, 10.1, 3.6 Hz, 1H), 2.96 (m, 1H), 6.19 (dd, J = 9.6, 3.6 Hz, 1H), 7.22 (m, 2H), 7.27 (m, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

21.4, 40.2 (q, J = 29 Hz), 73.7 (q, J = 3.8 Hz), 114.5 (q, J = 285 Hz), 124.9 (q, J = 277 Hz), 126.5 (2C), 130.0 (2C), 133.2, 140.1, 156.3 (q, J = 43 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–64.4 (t, J = 10.1 Hz, 3F), –75.2 (s, 3F).

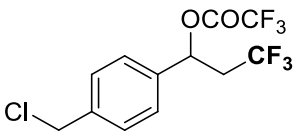
IR (neat, cm^{-1})

1791, 1378, 1324, 1254, 1227, 1130, 1058, 813, 733, 668, 652.

HRMS-EI (m/z)

[M] calcd. for $C_{12}H_{10}F_6O_2$, 300.0585; found, 300.0566.

Synthesis of 1-(2-(chloromethyl)phenyl)-3,3,3-trifluoropropyl 2,2,2-trifluoroacetate (2g):



The reaction was carried out according to the general procedure. The target compound **2g** was obtained as a colorless oil (50 mg, 75% yield) after purification by column chromatography (SiO_2; 100% hexane).

^{1}H NMR (400 MHz, $CDCl_3$)

2.62 (dqd, *J* = 15.6, 10.1, 3.5 Hz, 1H), 2.96 (m, 1H), 4.59 (s, 2H), 6.22 (dd, *J* = 9.7, 3.5 Hz, 1H), 7.38 (d, *J* = 8.4 Hz, 2H), 7.46 (d, *J* = 8.4 Hz, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

40.2 (q, *J* = 29 Hz), 45.5, 73.3 (q, *J* = 2.9 Hz), 114.4 (q, *J* = 284 Hz), 124.8 (q, *J* = 277 Hz), 126.9 (2C), 129.6 (2C), 136.3, 139.4, 156.2 (q, *J* = 43 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–64.3 (t, *J* = 10.1 Hz, 3F), –75.1 (s, 3F).

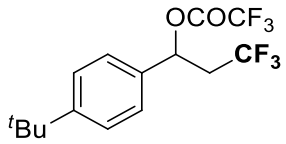
IR (neat, cm^{-1})

1791, 1340, 1314, 1275, 1254, 1227, 1130, 1063, 832, 789, 734, 684, 668, 658.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{12}H_9ClF_6O_2$, 334.0195; found, 334.0179.

Synthesis of 1-(4-(*tert*-butyl)phenyl)-3,3,3-trifluoropropyl 2,2,2-trifluoroacetate (2h):



The reaction was carried out according to the general procedure. The target compound **2h** was obtained as a colorless oil (60 mg, 87% yield) after purification by column chromatography (SiO_2; 100% hexane).

^{1}H NMR (400 MHz, $CDCl_3$)

1.32 (s, 9H), 2.61 (dqd, *J* = 15.6, 10.1, 3.2 Hz, 1H), 2.97 (m, 1H), 6.23 (dd, *J* = 9.6, 3.2 Hz, 1H), 7.31 (d, *J* = 8.4 Hz, 2H), 7.43 (d, *J* = 8.4 Hz, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

31.3 (3C), 34.9, 40.2 (q, *J* = 29 Hz), 73.6 (q, *J* = 2.9 Hz), 114.5 (q, *J* = 285 Hz), 124.9 (q, *J* = 277 Hz), 126.2 (2C), 126.3 (2C), 133.2, 153.2, 156.3 (q, *J* = 43 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–64.5 (t, *J* = 10.1 Hz, 3F), –75.2 (s, 3F).

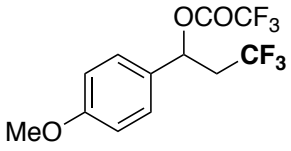
IR (neat, cm^{-1})

1791, 1394, 1367, 1340, 1253, 1224, 1132, 1063, 830, 820, 774, 733, 639.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{15}H_{16}F_6O_2$, 342.1054; found, 342.1029.

Synthesis of 1-(4-methoxyphenyl)-3,3,3-trifluoropropyl 2,2,2-trifluoroacetate (2i):



To a suspension of urea·H_2O_2 (47 mg, 0.50 mmol) in DCM (1 mL), trifluoroacetic anhydride (0.28 mL, 2.0 mmol) was slowly added at 0 °C. After stirring for 1 h, Cs_2CO_3 (326 mg, 1.0 mmol) was added, followed by styrene **1i** (27 mg, 0.20 mmol). The mixture was stirred for further 10 min. After addition of Et_2O (5 mL), the reaction was quenched with saturated K_2CO_3 solution at 0 °C for 20 min. The phases were separated and the aqueous layer was extracted with Et_2O (2 x 5 mL). The combined organic phase was dried over Na_2SO_4, filtered and concentrated *in vacuo*. Purification of the crude product by column chromatography on silica gel (SiO_2; EtOAc/hexane = 10/90) afforded the target product **2i** as a colorless oil (24 mg, 38% yield).

^{1}H NMR (400 MHz, $CDCl_3$)

2.61 (dqd, *J* = 15.5, 10.1, 3.6 Hz, 1H), 2.96 (m, 1H), 3.82 (s, 3H), 6.18 (dd, *J* = 9.5, 3.6 Hz, 1H), 6.93 (d, *J* = 8.8 Hz, 2H), 7.32 (d, *J* = 8.8 Hz, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

40.1 (q, *J* = 29 Hz), 55.5, 73.6 (q, *J* = 2.9 Hz), 114.5 (q, *J* = 286 Hz), 114.7 (2C), 124.9 (q, *J* = 277 Hz), 128.1, 128.3 (2C), 156.3 (q, *J* = 43 Hz), 160.8.

^{19}F NMR (376 MHz, $CDCl_3$)

–64.4 (t, *J* = 10.1 Hz, 3F), –75.2 (s, 3F).

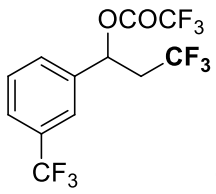
IR (neat, cm^{-1})

2924, 2853, 1791, 1617, 1506, 1308, 1279, 1226, 1131, 1063, 1033, 829.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{12}H_{10}F_6O_3$, 316.0534; found, 316.0544.

Synthesis of 1-(3-(trifluoromethyl)phenyl)-3,3,3-trifluoropropyl 2,2,2-trifluoroacetate (2j):



The reaction was carried out in DCE at 60 °C for the second step, but otherwise according to the general procedure. The target compound **2j** was obtained as a colorless oil (52 mg, 74% yield) after purification by column chromatography (SiO_2; 100% hexane).

^{1}H NMR (400 MHz, $CDCl_3$)

2.66 (dqd, *J* = 15.5, 10.1, 3.6 Hz, 1H), 2.99 (m, 1H), 6.27 (dd, *J* = 9.6, 3.6 Hz, 1H), 7.59 (m, 2H), 7.64 (br, 1H), 7.69 (m, 1H).

^{13}C NMR (100 MHz, $CDCl_3$)

40.2 (q, *J* = 29 Hz), 72.9 (q, *J* = 2.9 Hz), 114.4 (q, *J* = 285 Hz), 123.6 (q, *J* = 272 Hz), 123.3 (q, *J* = 3.8 Hz), 124.6 (q, *J* = 277 Hz), 126.9 (q, *J* = 3.7 Hz), 129.9, 130.2, 132.0 (q, *J* = 32 Hz), 137.1, 156.2 (q, *J* = 43 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–62.8 (s, 3F), –64.2 (t, *J* = 10.1 Hz, 3F), –75.1 (s, 3F).

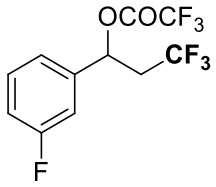
IR (neat, cm^{-1})

1793, 1330, 1252, 1229, 1203, 1128, 1094, 1076, 805, 777, 736, 702, 668.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{12}H_7F_9O_2$, 354.0302; found, 354.0283.

Synthesis of 1-(3-fluorophenyl)-3,3,3-trifluoropropyl 2,2,2-trifluoroacetate (2k):



The reaction was carried out in DCE at 60 °C for the second step, but otherwise according to the general procedure. The target compound **2k** was obtained as a colorless oil (47 mg, 78% yield) after purification by column chromatography (SiO_2; 100% hexane).

^{1}H NMR (400 MHz, $CDCl_3$)

2.63 (dqd, *J* = 15.6, 10.1, 3.2 Hz, 1H), 2.95 (m, 1H), 6.20 (dd, *J* = 9.6, 3.2 Hz, 1H), 7.11 (m, 2H), 7.17 (m, 1H), 7.41 (m, 1H).

^{13}C NMR (100 MHz, $CDCl_3$)

40.2 (q, *J* = 29 Hz), 72.9, 113.6 (d, *J* = 22 Hz), 114.4 (q, *J* = 285 Hz), 117.1 (d, *J* = 21 Hz), 122.2 (d, *J* = 2.8 Hz), 124.7 (q, *J* = 277 Hz), 131.2 (d, *J* = 8.7 Hz), 138.4 (d, *J* = 7.7 Hz), 156.2 (q, *J* = 43 Hz), 163.1 (d, *J* = 248 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–64.3 (t, *J* = 10.1 Hz, 3F), –75.1 (s, 3F), –110.6 (m, 1F).

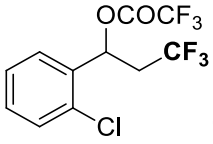
IR (neat, cm^{-1})

1793, 1596, 1491, 1378, 1341, 1258, 1227, 1144, 1127, 1064, 876, 789, 779, 735, 696, 668.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{11}H_7F_7O_2$, 304.0334; found, 304.0314.

Synthesis of 1-(2-chlorophenyl)-3,3,3-trifluoropropyl 2,2,2-trifluoroacetate (2l):



The reaction was carried out according to the general procedure. The target compound **2l** was obtained as a colorless oil (43 mg, 67% yield) after purification by column chromatography (SiO_2; 100% hexane).

^{1}H NMR (400 MHz, $CDCl_3$)

2.64–2.90 (overlap, 2H), 6.64 (dd, *J* = 9.6, 2.8 Hz, 1H), 7.33–7.38 (overlap, 2H), 7.40–7.46 (overlap, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

39.2 (q, *J* = 29 Hz), 70.4 (q, *J* = 3.9 Hz), 114.5 (q, *J* = 285 Hz), 124.8 (q, *J* = 277 Hz), 126.6, 128.0, 130.4, 130.7, 132.0, 134.2, 156.0 (q, *J* = 43 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–64.5 (t, *J* = 10.1 Hz, 3F), –75.1 (s, 3F).

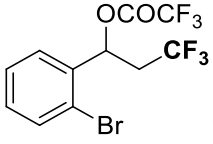
IR (neat, cm^{-1})

1793, 1379, 1344, 1252, 1225, 1134, 1054, 1037, 757, 736, 711, 668, 612.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{11}H_7ClF_6O_2$, 320.0039; found, 320.0017.

Synthesis of 1-(2-bromophenyl)-3,3,3-trifluoropropyl 2,2,2-trifluoroacetate (2m):



The reaction was carried out according to the general procedure. The target compound **2m** was obtained as a colorless oil (54 mg, 74% yield) after purification by column chromatography (SiO_2; 100% hexane).

^{1}H NMR (400 MHz, $CDCl_3$)

2.63–2.88 (overlap, 2H), 6.60 (dd, *J* = 9.6, 2.8 Hz, 1H), 7.22–7.29 (m, 1H), 7.39–7.42 (overlap, 2H), 7.62 (d, *J* = 7.6 Hz, 1H).

^{13}C NMR (100 MHz, $CDCl_3$)

39.3 (q, *J* = 29 Hz), 72.6 (q, *J* = 2.8 Hz), 114.5 (q, *J* = 285 Hz), 121.6, 124.7 (q, *J* = 277 Hz), 126.7, 128.6, 131.0, 133.7, 135.9, 155.9 (q, *J* = 43 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–64.5 (t, J = 10.1 Hz, 3F), –75.1 (s, 3F).

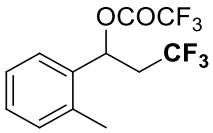
IR (neat, cm^{-1})

1793, 1474, 1438, 1392, 1343, 1314, 1284, 1251, 1225, 1205, 1131, 1065, 1026, 843, 756, 736, 722, 691, 668, 611.

HRMS-EI (m/z)

[M] calcd. for $C_{11}H_7BrF_6O_2$, 363.9534; found, 363.9505.

Synthesis of 1-(2-methylphenyl)-3,3,3-trifluoropropyl 2,2,2-trifluoroacetate (2n):



The reaction was carried out according to the general procedure. The target compound **2n** was obtained as a colorless oil (50 mg, 83% yield) after purification by column chromatography (SiO_2; 100% hexane).

^{1}H NMR (400 MHz, $CDCl_3$)

2.45 (s, 3H), 2.54 (dqd, J = 15.7, 10.1, 3.2, 1H), 2.92 (m, 1H), 6.43 (dd, J = 9.6, 3.2 Hz, 1H), 7.21 (m, 1H), 7.25-7.29 (overlap, 2H), 7.33 (m, 1H).

^{13}C NMR (100 MHz, $CDCl_3$)

19.0, 39.9 (q, J = 29 Hz), 70.7 (q, J = 2.8 Hz), 114.5 (q, J = 285 Hz), 124.9 (q, J = 277 Hz), 125.5, 127.2, 129.6, 131.2, 134.9, 135.1, 156.3 (q, J = 43 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–64.8 (t, J = 10.1 Hz, 3F), –75.2 (s, 3F).

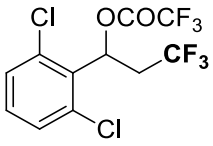
IR (neat, cm^{-1})

1792, 1333, 1252, 1222, 1133, 1099, 1064, 833, 761, 725, 615.

HRMS-EI (m/z)

[M] calcd. for $C_{12}H_{10}F_6O_2$, 300.0585; found, 300.0558.

Synthesis of 1-(2,6-dichlorophenyl)-3,3,3-trifluoropropyl 2,2,2-trifluoroacetate (2o):



The reaction was carried out in DCE at 60 °C for the second step, but otherwise according to the general procedure. The desired compound **2o** was obtained as a colorless oil (53 mg, 75% yield) after purification by column chromatography (SiO_2; 100% hexane).

^{1}H NMR (400 MHz, $CDCl_3$)

2.77 (dqd, *J* = 15.5, 10.1, 4.0 Hz, 1H), 3.40 (m, 1H), 6.91 (dd, *J* = 8.8, 4.0 Hz, 1H), 7.27 (m, 1H), 7.37 (m, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

36.7 (q, *J* = 29 Hz), 70.1 (q, *J* = 2.9 Hz), 114.4 (q, *J* = 285 Hz), 124.9 (q, *J* = 277 Hz), 128.5, 130.7 (2C), 131.3 (2C), 135.6, 156.2 (q, *J* = 43 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–64.8 (d, *J* = 10.1 Hz, 3F), –74.7 (s, 3F).

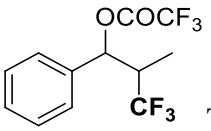
IR (neat, cm^{-1})

1793, 1566, 1441, 1395, 1352, 1318, 1284, 1249, 1226, 1196, 1139, 1093, 1076, 832, 782, 774, 740, 622.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{11}H_6Cl_2F_6O_2$, 353.9649; found, 353.9632.

Synthesis of 3,3,3-trifluoro-2-methyl-1-phenylpropyl 2,2,2-trifluoroacetate (2p):



The reaction was carried out according to the general procedure. The target compound **2p** was obtained as a colorless oil (28 mg, 47% yield, *anti*:*syn* = 2:1) after purification by column chromatography (SiO_2; 100% hexane).[8]

^{1}H NMR (400 MHz, $CDCl_3$)

anti-isomer: 1.22 (d, *J* = 7.2 Hz, 3H), 2.68 (m, 1H), 6.36 (d, *J* = 3.2 Hz, 1H), 7.29 (m, 2H), 7.35–7.44 (overlap, 3H).

syn-isomer: 0.94 (d, *J* = 7.2 Hz, 3H), 2.93 (m, 1H), 5.97 (d, *J* = 9.6 Hz, 1H), 7.35–7.44 (overlap, 5H).

^{13}C NMR (100 MHz, $CDCl_3$)

anti-isomer: 7.0, 44.3 (q, *J* = 26 Hz), 75.6 (q, *J* = 2.8 Hz), 114.5 (q, *J* = 284 Hz), 125.7 (2C), 126.5 (q, *J* = 279 Hz), 129.1 (2C), 129.2, 135.8, 156.1 (q, *J* = 43 Hz).

syn-isomer: 10.7, 42.7 (q, *J* = 26 Hz), 78.1, 114.5 (q, *J* = 284 Hz), 126.7 (q, *J* = 279 Hz), 127.6 (2C), 129.2 (2C), 129.9, 135.0, 156.1 (q, *J* = 43 Hz).

[8]The stereochemistry was determined by comparison of ^{19}F NMR signals to those reported for the alcohols after hydrolysis of the products. For **2p**, **2r**, **2t** (a) Y. Yasu, T. Koike, M. Akita, *Angew. Chem. Int. Ed.*, 2012, **51**, 9567: For **2s**, (b) Y. Yang, Y. Liu, Y. Jiang, Y. Zhang, D. A. Vicic, *J. Org. Chem.*, 2015, **80**, 6639.

^{19}F NMR (376 MHz, $CDCl_3$)

anti-isomer: –70.7 (d, *J* = 8.6 Hz, 3F), –75.1 (s, 3F).

syn-isomer: –69.6 (d, *J* = 8.6 Hz, 3F), –75.3 (s, 3F).

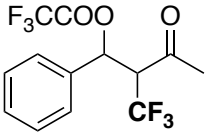
IR (neat, cm^{-1})

1791, 1378, 1348, 1328, 1263, 1226, 1156, 1133, 1076, 1019, 773, 753, 732, 700, 668, 612.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{12}H_{10}F_6O_2$, 300.0585; found, 300.0566.

Synthesis of 3-oxo-1-phenyl-2-(trifluoromethyl)butyl 2,2,2-trifluoroacetate (2q):



The reaction was carried out in DCE at 60 °C for the second step, but otherwise according to the general procedure. The target compound **2q** was obtained as a yellow oil (26 mg, 38% yield, *anti/syn* = 2:1) after purification by column chromatography (SiO_2; EtOAc/hexane = 5/95).[9]

^{1}H NMR (400 MHz, $CDCl_3$)

anti-isomer: 2.41 (s, 3H), 4.00 (m, 1H), 6.37 (d, *J* = 9.6 Hz, 1H), 7.42 (overlap, 5H).

syn-isomer: 1.95 (s, 3H), 4.07 (m, 1H), 6.36 (d, *J* = 10.8 Hz, 1H), 7.42 (overlap, 5H).

^{13}C NMR (100 MHz, $CDCl_3$)

anti-isomer: 32.3, 59.9 (q, *J* = 25 Hz), 76.5 (q, *J* = 1.9 Hz), 114.3 (q, *J* = 285 Hz), 122.6 (q, *J* = 279 Hz), 127.4 (2C), 129.3 (2C), 130.3, 133.8, 155.3 (q, *J* = 43 Hz), 198.3.

syn-isomer: 32.7, 60.0 (q, *J* = 25 Hz), 75.4, 114.3 (q, *J* = 285 Hz), 122.6 (q, *J*

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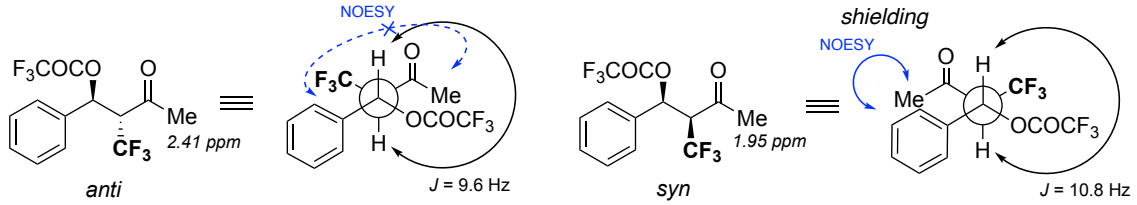
[9]The stereochemistry was determined by comparison of ^{1}H NMR chemical shifts of the methyl groups due to magnetic shielding by the phenyl groups of each diastereomers, where the conformations were confirmed by NOESY correction as shown in the following scheme. In addition, relative chemical shifts of diastereomers of **2q** are similar to those of diastereomers of 3,3,3-trifluoro-2-methyl-1-phenylpropanol (ref 8a).



= 279 Hz), 127.7 (2C), 128.5, 129.5 (2C), 130.5, 155.3 (q, *J* = 43 Hz), 198.1.

^{19}F NMR (376 MHz, $CDCl_3$)

anti-isomer: –63.0 (d, *J* = 7.2 Hz, 3F), –75.1 (s, 3F).

syn-isomer: –63.9 (d, *J* = 7.2 Hz, 3F), –75.2 (s, 3F).

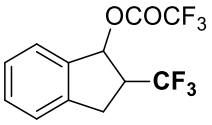
IR (neat, cm^{-1})

1799, 1734, 1363, 1344, 1328, 1260, 1231, 1207, 1171, 1143, 1017, 798, 698, 668.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{13}H_{10}F_6O_3$, 328.0534; found, 328.0502.

Synthesis of 2-(trifluoromethyl)-2,3-dihydro-1*H*-inden-1-yl 2,2,2-trifluoroacetate (2r):



The reaction was carried out according to the general procedure. The target compound **2r** was obtained as a colorless oil (38 mg, 60% yield, *trans*:*cis* = 8:1) after purification by column chromatography (SiO_2; 100% hexane).[8]

^{1}H NMR (400 MHz, $CDCl_3$)

trans-isomer: 3.16 (dd, *J* = 16.0, 6.4 Hz, 1H), 3.35 (m, 1H), 3.43 (dd, *J* = 16.0, 8.8 Hz, 1H), 6.68 (d, *J* = 4.8 Hz, 1H), 7.30–7.37 (overlap, 3H), 7.41 (m, 1H).

cis-isomer: 3.16 (dd, *J* = 15.3, 7.8 Hz, 1H), 3.35 (m, 1H), 3.47 (dd, *J* = 15.3, 9.0 Hz, 1H), 6.53 (d, *J* = 6.0 Hz, 1H), 7.32–7.36 (overlap, 2H),7.43 (m, 1H), 7.50 (m, 1H).

^{13}C NMR (100 MHz, $CDCl_3$)

trans-isomer: 30.8 (q, *J* = 1.9 Hz), 49.1 (q, *J* = 28 Hz), 80.8 (q, *J* = 2.9 Hz), 114.6 (q, *J* = 285 Hz), 125.2, 125.4, 126.6 (q, *J* = 277 Hz), 128.3, 130.7, 137.0, 140.8, 157.2 (q, *J* = 43 Hz).

cis-isomer: 30.8 (q, *J* = 1.9 Hz), 46.7 (q, *J* = 29 Hz), 78.4 (q, *J* = 1.9 Hz), 114.5 (q, *J* = 286 Hz), 125.3, 125.5 (q, *J* = 277 Hz), 126.5, 128.2, 131.1, 136.8, 142.3, 157.0 (q, *J* = 43 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

trans-isomer: –70.7 (d, *J* = 8.6 Hz, 3F), –74.9 (s, 3F).

cis-isomer: –66.0 (d, *J* = 8.6 Hz, 3F), –75.1 (s, 3F).

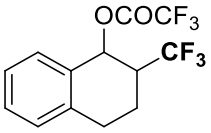
IR (neat, cm^{-1})

1788, 1375, 1332, 1269, 1226, 1145, 1118, 927, 774, 751, 692, 617.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{12}H_8F_6O_2$, 298.0428; found, 298.0401.

Synthesis of 2-(trifluoromethyl)-1,2,3,4-tetrahydronaphthalene-1-yl 2,2,2-trifluoroacetate (2s):



The reaction was carried out according to the general procedure. The target compound **2s** was obtained as a colorless oil (46 mg, 73% yield, *trans*:*cis* = 2:1) after purification by column chromatography (SiO_2; 100% hexane).[8]

^{1}H NMR (400 MHz, $CDCl_3$)

trans-isomer: 1.90 (m, 1H), 2.31 (m, 1H), 2.81–3.02 (overlap, 3H), 6.50 (d, *J* = 8.0 Hz, 1H), 7.17–7.20 (overlap, 2H), 7.24–7.32 (overlap, 2H).

cis-isomer: 2.16 (m. 1H), 2.26 (m, 1H), 2.70 (m, 1H), 2.96 (m, 1H), 3.13 (dd, *J* = 17.6, 6.0 Hz, 1H), 6.50 (d, *J* = 8.0 Hz, 1H), 7.23 (d, *J* = 6.8 Hz, 2H), 7.36 (m, 1H), 7.42 (d, *J* = 8.0 Hz, 1H).

^{13}C NMR (100 MHz, $CDCl_3$)

trans-isomer: 21.3 (q, *J* = 2.9 Hz), 27.3, 44.3 (q, *J* = 27 Hz), 72.6 (q, *J* = 1.9 Hz), 114.6 (q, *J* = 285 Hz), 126.5 (q, *J* = 278 Hz), 127.4, 128.2, 129.0, 129.4, 131.0, 137.3, 157.4 (q, *J* = 42 Hz).

cis-isomer: 17.1, 27.8, 43.4 (q, *J* = 28 Hz), 70.8 (q, *J* = 2.8 Hz), 114.6 (q, *J* = 285 Hz), 126.5 (q, *J* = 278 Hz), 127.2, 129.5, 130.4, 130.8 (2C), 136.6, 157.4 (q, *J* = 42 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

trans-isomer: –71.0 (d, *J* = 8.6 Hz, 3F), –75.1 (s, 3F).

cis-isomer: –69.5 (d, *J* = 8.6 Hz, 3F), –75.2 (s, 3F).

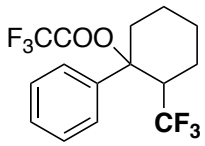
IR (neat, cm^{-1})

1787, 1324, 1263, 1224, 1148, 1128, 902, 830, 771, 750, 668.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{13}H_{10}F_6O_2$, 312.0585; found, 312.0563.

Synthesis of 1-phenyl-2-(trifluoromethyl)cyclohexyl 2,2,2-trifluoroacetate (2t):



The reaction was carried out according to the general procedure. The desired compound **2t** was obtained as a colorless oil (40 mg, 59% yield, *trans*:*cis* = 1:2) after purification by column chromatography (SiO_2; 100% hexane).[8]

^{1}H NMR (400 MHz, $CDCl_3$)

cis-isomer: 1.78 (m, 2H), 2.13–2.39 (overlap, 5H), 3.87–3.97 (overlap, 2H), 7.36–7.47 (overlap, 3H), 7.69 (m, 2H).

trans-isomer: 1.97 (m, 2H), 2.13-2.39 (overlap, 3H), 2.51 (m, 1H), 2.98 (m, 1H), 3.64 (m, 2H), 7.36–7.47 (overlap, 5H).

^{13}C NMR (100 MHz, $CDCl_3$)

cis-isomer: 19.5, 21.6, 22.3, 23.1, 46.8 (q, J = 26 Hz), 87.1, 114.3 (q, J = 286 Hz), 125.4 (q, J = 278 Hz), 126.8 (2C), 128.2 (2C), 129.0, 134.4, 156.1 (q, J = 43 Hz).

trans-isomer: 21.0, 24.1, 27.5, 34.5, 46.1 (q, J = 24 Hz), 87.9, 114.4 (q, J = 286 Hz), 125.4 (q, J = 278 Hz), 126.4 (2C), 128.6 (2C), 129.2, 136.1, 156.1 (q, J = 43 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

cis-isomer: –65.2 (d, J = 8.6 Hz, 3F), –75.6 (s, 3F).

trans-isomer: –64.2 (d, J = 7.1 Hz, 3F), –75.2 (s, 3F).

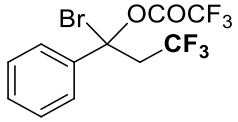
IR (neat, cm^{-1})

1778, 1364, 1335, 1290, 1264, 1227, 1151, 1131, 1076, 986, 891, 838, 774, 764, 744, 706, 686, 638.

HRMS-EI (m/z)

[M] calcd. for $C_{15}H_{14}F_6O_2$, 340.0898; found, 340.0881.

Synthesis of 1-bromo-3,3,3-trifluoro-1-phenylpropyl 2,2,2-trifluoroacetate (2u):



The reaction was carried out according to the general procedure. The target compound **2u** was obtained as a colorless oil (58 mg, 80% yield) after purification by column chromatography (SiO_2; 100% hexane).

^{1}H NMR (400 MHz, $CDCl_3$)

3.53 (dq, J = 15.6, 9.3 Hz, 1H), 4.18 (dq, J = 15.6, 9.3 Hz, 1H), 7.40–7.48 (overlap, 3H), 7.60 (m, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

47.7 (q, J = 29 Hz), 87.0 (q, J = 1.9 Hz), 114.0 (q, J = 285 Hz), 123.2 (q, J = 278 Hz), 125.0 (2C), 129.0 (2C), 130.2, 139.2, 153.9 (q, J = 44 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–61.7 (t, J = 9.3 Hz, 3F), –75.2 (s, 3F).

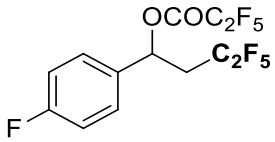
IR (neat, cm^{-1})

1805, 1365, 1349, 1257, 1226, 1178, 1120, 874, 838, 799, 767, 735, 721, 690, 668, 624, 617.

HRMS-EI (m/z)

[M] calcd. for $C_9H_7F_3O$ (degradation product), 188.0449; found, 188.0432.

Synthesis of 1-(4-fluorophenyl)-3,3,4,4,4-pentafluorobutyl 2,2,3,3,3-pentafluoropropanoate (2b'):



The reaction was carried out according to the general procedure. The target compound **2b'** was obtained as a colorless oil (75 mg, 93% yield) after purification by column chromatography (SiO_2; 100% hexane).

^{1}H NMR (400 MHz, $CDCl_3$)

2.53 (m, 1H), 2.91 (m, 1H), 6.32 (dd, J = 9.6, 3.2 Hz, 1H), 7.12 (m, 2H), 7.39 (m, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

37.1 (t, J = 21 Hz), 72.6 (br s), 100.0–130.0 (m, 4C),[10] 116.5 (d, J = 22 Hz, 2C), 128.5 (d, J = 8.6 Hz, 2C), 132.4 (d, J = 3.8 Hz), 157.1 (t, J = 30 Hz), 163.5 (d, J = 249 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–82.6 (m, 3F), –85.7 (m, 3F), –110.4 (m, 1F), –117.4 (m, 2F), –121.7 (m, 2F).

IR (neat, cm^{-1})

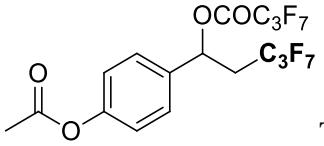
1785, 1516, 1300, 1194, 1152, 1130, 1098, 1071, 1032, 838, 737, 668.

HRMS-EI (m/z)

[10]The carbons of perfluoroalkyl groups could not be assigned because of low intensity of signals, their complex coupling, and overlap due to large J values.

[M] calcd. for $C_{13}H_7F_{11}O_2$, 404.0270; found, 404.0248.

Synthesis of 1-(4-acetoxyphenyl)-3,3,4,4,5,5,5-heptafluoropentyl 2,2,3,3,4,4,4-heptafluorobutyrate (2d"):



The reaction was carried out according to the general procedure. The desired compound **2d"** was obtained as a white solid (105 mg, quantitative yield) after purification by column chromatography (SiO_2; EtOAc/hexane = 5/95).

^{1}H NMR (400 MHz, $CDCl_3$)

2.31 (s, 3H), 2.57 (m, 1H), 2.94 (m, 1H), 6.36 (dd, *J* = 9.6, 2.8 Hz, 1H), 7.17 (d, *J* = 8.8 Hz, 2H), 7.42 (d, *J* = 8.8 Hz, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)[10]

21.2, 37.1 (t, *J* = 22 Hz), 72.7, 100.0–130.0 (m, 6C),[10] 122.7 (2C), 127.8 (2C), 133.9, 151.8, 157.1 (t, *J* = 30 Hz), 169.4.

^{19}F NMR (376 MHz, $CDCl_3$)

–80.2 (m, 3F), –80.6 (m, 3F), –114.4 (m, 2F), –119.2 (m, 2F), –126.7 (m, 2F), –127.7 (m, 2F).

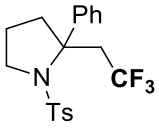
IR (neat, cm^{-1})

1783, 1354, 1301, 1217, 1147, 1117, 1083, 970, 939, 919, 725.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{17}H_{10}F_{14}O_4$, 544.0356; found, 544.0310.

Synthesis of 2-phenyl-1-tosyl-2-(2,2,2-trifluoroethyl)pyrrolidine (4a):



The reaction was carried out for 3 h at the second step, but otherwise according to the general procedure. The target compound **4a** was obtained as a white solid (58 mg, 76% yield) after purification by column chromatography (SiO_2; EtOAc/hexane/Et_3N = 3/96/1).

^{1}H NMR (400 MHz, $CDCl_3$)

1.96 (m, 1H), 2.06 (m, 1H), 2.38 (s, 3H), 2.44 (m, 2H), 3.44 (m, 2H), 3.55 (m, 1H), 3.71 (m, 1H), 7.10 (d, *J* = 8.4 Hz, 2H), 7.19–7.26 (overlap, 5H), 7.30 (m, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

21.6, 23.0, 41.1, 41.9 (q, J = 27 Hz), 49.6, 68.7 (q, J = 1.9 Hz), 126.1 (q, J = 277 Hz), 126.7 (2C), 127.0 (2C), 127.6, 128.3 (2C), 129.3 (2C), 137.5, 142.8, 142.9.

^{19}F NMR (376 MHz, $CDCl_3$)

–58.3 (t, J = 11.6 Hz).

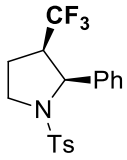
IR (neat, cm^{-1})

1379, 1338, 1304, 1262, 1223, 1154, 1136, 1092, 1040, 974, 912, 813, 757, 733, 699, 659, 614.

HRMS-ESI (m/z)

$[M+Na]^+$ calcd. for $C_{19}H_{20}F_3NO_2SNa$, 406.1065; found, 406.1067.

Synthesis of (2*S*,3*R*)-2-phenyl-1-tosyl-3-(trifluoromethyl)pyrrolidine (4b):



The reaction was carried out according to the general procedure. The target compound **4b** was obtained as a colorless oil (28 mg, 37% yield) after purification by column chromatography (SiO_2; EtOAc/hexane/Et_3N = 10/89/1).[11]

^{1}H NMR (400 MHz, $CDCl_3$)

1.96 (dddd, J = 13.6, 7.4, 4.5, 4.5 Hz, 1H), 2.22 (dddd, J = 13.6, 8.0, 8.0, 8.0 Hz, 1H), 2.43 (s, 3H), 2.76 (m, 1H), 3.52 (m, 1H), 3.74 (m, 1H), 4.87 (d, J = 3.6 Hz, 1H), 7.27–7.30 (overlap, 3H), 7.31–7.35 (overlap, 4H), 7.62 (d, J = 8.4 Hz, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

21.7, 24.5, 48.4, 52.7 (q, J = 27 Hz), 63.0 (q, J = 1.9 Hz), 126.2 (2C), 126.6 (q, J = 274 Hz), 127.7 (2C), 128.0, 128.9 (2C), 129.7 (2C), 134.4, 141.6, 143.9.

^{19}F NMR (376 MHz, $CDCl_3$)

–70.7 (d, J = 8.7 Hz).

IR (neat, cm^{-1})

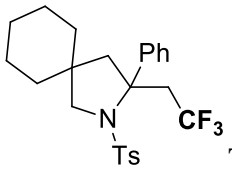
1394, 1351, 1268, 1236, 1161, 1128, 1097, 1024, 1012, 815, 801, 783, 756, 700, 668, 619.

HRMS-ESI (m/z)

[11]The analytic and spectroscopic data matched reported values: Y. Wang, M. Jiang, J.-T. Liu, *Adv. Synth. Catal.*, 2016, **358**, 1322.

[M+Na]$^+$ calcd. for $C_{18}H_{18}F_3NNaO_2S$, 392.0908; found, 392.0910.

Synthesis of 3-phenyl-2-tosyl-3-(2,2,2-trifluoroethyl)-2-azaspiro[4.5]decane (4c):



The reaction was carried out for 3 h for the second step, but otherwise according to the general procedure, on a 0.10 mmol scale. The target compound **4c** was obtained as a white solid (39 mg, 86% yield) after purification by column chromatography (SiO_2; EtOAc/hexane/Et_3N = 5/94/1). An analytical sample was obtained by crystallization from EtOAc.

^{1}H NMR (400 MHz, $CDCl_3$)

1.27–1.61 (overlap, 10H), 2.36 (s, 3H), 2.39 (d, *J* = 14.4 Hz, 1H), 2.46 (d, *J* = 14.4 Hz, 1H), 3.07 (dq, *J* = 16.1, 11.5 Hz, 1H), 3.14 (d, *J* = 9.6 Hz, 1H), 3.56 (d, *J* = 9.6 Hz, 1H), 4.01 (dq, *J* = 16.0, 11.2 Hz, 1H), 7.06 (d, *J* = 8.4 Hz, 2H), 7.14–7.22 (overlap, 5H), 7.32 (d, *J* = 8.4 Hz, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

21.6, 23.3, 23.8, 25.8, 37.1, 37.5, 40.6, 44.1 (q, *J* = 27 Hz), 51.6, 59.6, 69.0 (q, *J* = 1.9 Hz), 125.7 (q, *J* = 277 Hz), 127.0 (2C), 127.3 (2C), 127.6, 128.1 (2C), 129.2 (2C), 136.8, 142.2, 142.8.

^{19}F NMR (376 MHz, $CDCl_3$)

–56.3 (t, *J* = 11.5 Hz).

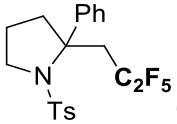
IR (neat, cm^{-1})

1448, 1340, 1257, 1212, 1156, 1121, 1090, 1054, 1034, 984, 925, 906, 813, 762, 732, 698, 661.

HRMS-ESI (*m*/*z*)

[M+Na]$^+$ calcd. for $C_{24}H_{28}F_3NNaO_2S$, 474.1691; found, 474.1689.

Synthesis of 2-phenyl-1-tosyl-2-(2,2,3,3,3-pentafluoropropyl)pyrrolidine (4a'):



The reaction was carried out for 3 h for the second step, but otherwise according to the general procedure. The target compound **4a'** was obtained as a white solid (55 mg, 63% yield) after purification by column chromatography (SiO_2; EtOAc/hexane/Et_3N = 3/96/1).

^{1}H NMR (400 MHz, $CDCl_3$)

1.99 (m, 1H), 2.10 (m, 1H), 2.37 (s, 3H), 2.53 (m, 2H), 3.19 (m, 1H), 3.49-3.64 (overlap, 2H), 3.74 (m, 1H), 7.08 (d, *J* = 8.4 Hz, 2H), 7.17–7.24 (overlap, 5H), 7.30 (m, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)[10]

21.6, 23.3, 37.8 (t, *J* = 19 Hz), 41.2, 49.5, 69.2, 110.0–130.0 (m, 2C),[10] 126.8 (2C), 126.9 (2C), 127.6, 128.3 (2C), 129.2 (2C), 137.5, 142.5, 142.9.

^{19}F NMR (376 MHz, $CDCl_3$)

–86.2 (m, 3F), –113.6 (m, 2F).

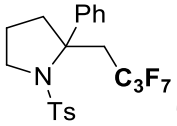
IR (neat, cm^{-1})

1341, 1198, 1155, 1134, 1093, 1056, 1020, 1008, 814, 755, 727, 699, 688, 659.

HRMS-ESI (*m*/*z*)

$[M+Na]^+$ calcd. for $C_{20}H_{20}F_5NO_2SNa$, 456.1033; found, 456.1032.

Synthesis of 2-phenyl-1-tosyl-2-(2,2,3,3,3-pentafluoropropyl)pyrrolidine (4a"):



The reaction was carried out for 3 h for the second step, but otherwise according to the general procedure, on a 0.10 mmol scale. The target compound **4a"** was obtained as a white solid (32 mg, 65% yield) after purification by column chromatography (SiO_2; EtOAc/hexane/Et_3N = 5/94/1).

^{1}H NMR (400 MHz, $CDCl_3$)

1.99 (m, 1H), 2.09 (m, 1H), 2.37 (s, 3H), 2.53 (m, 2H), 3.20 (m, 1H), 3.52 (m, 1H), 3.63 (m, 1H), 3.73 (m, 1H), 7.08 (d, *J* = 8.4 Hz, 2H), 7.18–7.24 (overlap, 5H), 7.32 (m, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)[10]

21.6, 23.3, 37.7 (t, *J* = 19 Hz), 41.1, 49.5, 69.3, 100.0–130.0 (m, 3C),[10] 126.8 (2C), 126.9 (2C), 127.6, 128.3 (2C), 129.2 (2C), 137.5, 142.4, 142.9.

^{19}F NMR (376 MHz, $CDCl_3$)

–79.9 (m, 3F), –110.2 (m, 2F), –127.4 (m, 2F).

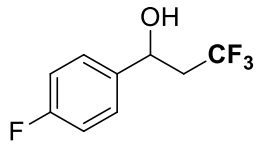
IR (neat, cm^{-1})

1340, 1224, 1174, 1155, 1133, 1112, 1092, 1035, 911, 813, 755, 735, 699, 687, 666.

HRMS-ESI (*m*/*z*)

[M+Na]$^+$ calcd. for $C_{21}H_{20}F_7NNaO_2S$, 506.1001; found, 506.0999.

Synthesis of 1-(4-fluorophenyl)-3,3,3-trifluoropropan-1-ol (5b):



A solution of **2b** (100 mg, 0.33 mmol) in DME (1 mL) was cooled to 0 °C. 1,8-Diazabicyclo[5.4.0]undec-5-ene (DBU) (54 μL, 0.36 mmol) was added dropwise and the solution was stirred for 10 min at 0 °C.[12] The reaction mixture was then quenched with saturated NH_4Cl solution (2 mL) and extracted with Et_2O (3 x 5 mL). Filtration of the combined organic phase through a silica pad, followed by evaporation *in vacuo* gave a colorless oil. The crude product was purified by column chromatography (SiO_2; EtOAc/hexane = 10/90), providing the target compound **5b** as a colorless oil (41 mg, 96% yield).

^{1}H NMR (400 MHz, $CDCl_3$)

2.14 (br s, 1H), 2.43 (m, 1H), 2.62 (m, 1H), 5.08 (dd, *J* = 8.8, 3.6 Hz, 1H), 7.07 (t, *J* = 8.8 Hz, 2H), 7.36 (m, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

43.1 (q, *J* = 27 Hz), 68.3 (q, *J* = 2.9 Hz), 115.9 (d, *J* = 22 Hz, 2C), 125.9 (q, *J* = 277 Hz), 127.6 (d, *J* = 8.6 Hz, 2C), 138.2 (d, *J* = 2.9 Hz), 162.7 (d, *J* = 246 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–63.6 (t, *J* = 10.1 Hz, 3F), –113.5 (m, 1F).

IR (neat, cm^{-1})

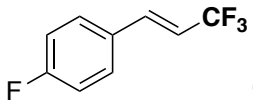
3404, 1607, 1511, 1431, 1375, 1326, 1259, 1227, 1202, 1131, 1093, 1015, 860, 841, 827, 800, 669, 652.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_9H_8F_4O$, 208.0511; found, 208.0503.

[12]Moisture in DBU and/or DME may participate in the reaction.

Synthesis of (*E*)-β-trifluoromethyl-3-fluorostyrene (6b):



To a 0.07 M THF solution of KHMDS (0.4 mmol) was added **2b** (30.4 mg, 0.1 mmol) at –78 °C. The reaction mixture was stirred for 3.5 h, then quenched with saturated NH_4Cl solution (2 mL), and extracted with Et_2O (3 x 5 mL). The combined organic phase was dried over Na_2SO_4 and gently evaporated under vacuum (200 mmHg, 20 °C). The crude product was purified by means of column chromatography (SiO_2; 100% hexane) providing the desired compound **6b** as a colorless oil (12 mg, 63% yield).[13]

^{1}H NMR (400 MHz, $CDCl_3$)

6.13 (dq, *J* = 16.1, 6.5 Hz, 1H), 7.05–7.16 (m, 3H), 7.42–7.47 (m, 2H).

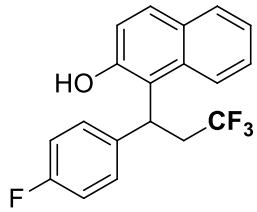
^{13}C NMR (100 MHz, $CDCl_3$)

115.8 (q, *J* = 32 Hz), 116.2 (d, *J* = 34.6 Hz, 2C), 123.7 (q, *J* = 269 Hz), 129.5 (d, *J* = 8.7 Hz, 2C), 129.8 (d, *J* = 3.9 Hz), 136.6 (q, *J* = 6.7 Hz), 163.9 (d, *J* = 250 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–63.2 (d, *J* = 6.5 Hz, 3F), –110.2 (m, 1F).

Synthesis of 1-(3,3,3-trifluoro-1-(4-fluorophenyl)propyl)naphthalene-2-ol (7b):



2-Naphthol (47 mg, 0.33 mmol) and trifluoromethanesulfonic acid (3 μL, 20 mol%) were added to a solution of **2b** (50 mg, 0.16 mmol) in HFIP (1.6 mL) under nitrogen in a Schlenk tube. The resulting solution was stirred at room temperature for 4 h, and then evaporated *in vacuo*. Purification by column chromatography (SiO_2; EtOAc/hexane = 10/90) provided the target compound **7b** as a white solid (37 mg, 68% yield).

^{1}H NMR (400 MHz, $CDCl_3$)

2.96 (m, 2H), 4.44 (t, *J* = 7.2 Hz, 1H), 4.91 (br, 1H), 6.99 (t, *J* = 8.8 Hz, 2H), 7.08–7.11 (overlap, 2H), 7.22-7.26 (overlap, 3H), 7.60–7.62 (overlap, 2H),

[13]The spectroscopic data obtained were in agreement with literature data: L. He, X. Yang, G. C. Tsui, *J. Org. Chem.*, 2017, *82*, 6192.

7.71 (m, 1H).

^{13}C NMR (100 MHz, $CDCl_3$)

39.7 (q, J = 27 Hz), 44.3 (q, J = 2.8 Hz), 109.5, 115.7 (d, J = 22 Hz, 2C), 118.3, 125.6, 126.4 (q, J = 277 Hz), 126.7, 127.3, 129.0, 129.3 (d, J = 8.7 Hz, 2C), 129.9, 133.6, 137.8, 138.5 (d, J = 2.8 Hz), 153.6, 161.8 (d, J = 245 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–63.4 (t, J = 10.1 Hz, 3F), –115.9 (m, 1F).

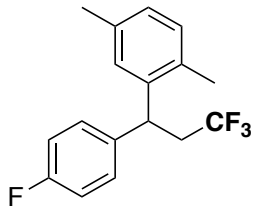
IR (neat, cm^{-1})

3340, 1607, 1508, 1379, 1265, 1226, 1174, 1160, 1133, 1107, 1088, 861, 833, 820, 668, 653.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{19}H_{14}F_4O$, 334.0981; found, 334.0969.

Synthesis of 1,4-dimethyl-2-(3,3,3-trifluoro-1-(4-fluorophenyl)propyl)benzene (8b):



p-Xylene (31 μL, 0.25 mmol) and trifluoromethanesulfonic acid (1.5 μL, 20 mol%) were added to a solution of **2b** (25 mg, 0.08 mmol) in HFIP (0.8 mL) under nitrogen in a Schlenk tube. The resulting solution was stirred at room temperature for 3 h, and then evaporated *in vacuo*. Purification by column chromatography (SiO_2; 100% hexane) provided the target compound **8b** as a colorless oil (22 mg, 92% yield).

^{1}H NMR (400 MHz, $CDCl_3$)

2.27 (s, 3H), 2.34 (s, 3H), 2.84 (m, 2H), 4.51 (t, J = 7.2 Hz, 1H), 6.95–7.01 (overlap, 3H), 7.03–7.05 (overlap, 2H), 7.20 (m, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

19.4, 21.4, 39.9, 40.0 (q, J = 27 Hz), 115.5 (d, J = 21 Hz, 2C), 126.6 (q, J = 277 Hz), 127.0, 127.7, 129.6 (d, J = 7.7 Hz, 2C), 131.0, 132.7, 135.9, 138.0 (d, J = 2.9 Hz), 140.5, 161.6 (d, J = 245 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–63.6 (t, J = 10.1 Hz, 3F), –116.1 (m, 1F).

IR (neat, cm^{-1})

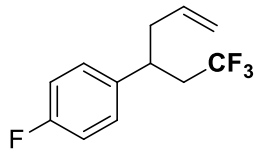
1605, 1509, 1441, 1376, 1318, 1290, 1263, 1229, 1159, 1133, 1085, 1015, 837,

813, 784, 667, 620.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{17}H_{16}F_4$, 296.1188; found, 296.1176.

Synthesis of 1-fluoro-4-(1,1,1-trifluorohex-5-en-3-yl)benzene (9b):



Allyltrimethylsilane (78 μL, 0.49 mmol) and **2b** (100 mg, 0.33 mmol) were added to a solution of tris(pentafluorophenyl)borane (17 mg, 10 mol%) in DCM (1 mL) under nitrogen. The resulting solution was stirred at room temperature for 48 h, then passed through a silica gel pad and concentrated under *vacuo*. Purification of the residue by column chromatography (SiO_2; 100% hexane) provided the target compound **9b** as a colorless oil (48 mg, 63% yield).

^{1}H NMR (400 MHz, $CDCl_3$)

2.29–2.55 (overlap, 4H), 3.02 (m, 1H), 5.02 (overlap, 2H), 5.60 (m, 1H), 7.00 (t, J = 8.8 Hz, 2H), 7.13 (m, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

39.0 (q, J = 1.9 Hz), 39.5 (q, J = 27 Hz), 41.1, 115.5 (d, J = 21 Hz, 2C), 117.8, 126.7 (q, J = 277 Hz), 128.9 (d, J = 7.6 Hz, 2C), 135.1, 138.6 (d, J = 2.9 Hz), 161.8 (d, J = 244 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

–63.5 (t, J = 10.1 Hz, 3F), –116.0 (m, 1F).

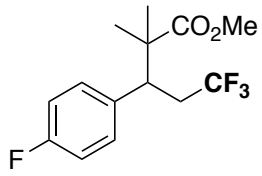
IR (neat, cm^{-1})

1606, 1512, 1378, 1256, 1226, 1161, 1143, 1122, 1093, 1053, 1015, 994, 920, 830, 742, 723, 668, 644, 626.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{12}H_{12}F_4$, 232.0875; found, 232.0866.

Synthesis of methyl 5,5,5-trifluoro-3-(4-fluorophenyl)-2,2-dimethylpentanoate (10b):



Methyl trimethylsilyl dimethylketene acetal (100 μL, 0.49 mmol) and **2b** (50 mg, 0.16 mmol) were added to a solution of tris(pentafluorophenyl)borane (8.4 mg, 10 mol%) in DCM (0.6 mL). The resulting solution was stirred at reflux for 6 h, passed through a silica gel pad and concentrated *in vacuo*. Purification of the residue by column chromatography (SiO_2; EtOAc/hexane = 1/99) provided the target compound **10b** as a colorless oil (24 mg, 52% yield).

^{1}H NMR (400 MHz, $CDCl_3$)

1.08 (s, 3H), 1.15 (s, 3H), 2.42 (m, 1H), 2.62 (m, 1H), 3.27 (dd, *J* = 11.2, 2.0 Hz, 1H), 3.67 (s, 3H), 7.00 (t, *J* = 8.8 Hz, 2H), 7.14 (m, 2H).

^{13}C NMR (100 MHz, $CDCl_3$)

21.5, 24.4, 35.7 (q, *J* = 27 Hz), 46.3 (q, *J* = 1.9 Hz), 46.6, 52.2, 115.2 (d, *J* = 21 Hz, 2C), 126.8 (q, *J* = 277 Hz), 130.7 (d, *J* = 7.7 Hz, 2C), 134.5 (d, *J* = 3.8 Hz), 162.2 (d, *J* = 245 Hz), 177.0.

^{19}F NMR (376 MHz, $CDCl_3$)

–64.0 (t, *J* = 10.1 Hz, 3F), –115.3 (m, 1F).

IR (neat, cm^{-1})

1729, 1512, 1436, 1392, 1325, 1303, 1294, 1256, 1227, 1192, 1138, 1125, 1113, 1090, 1051, 1015, 840, 827, 799, 633.

HRMS-EI (*m*/*z*)

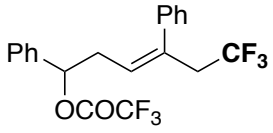
[M] calcd. for $C_{14}H_{16}F_4O_2$, 292.1086; found, 292.1071.

TEMPO trapping test (Scheme 7b)

The reaction was carried out according to the general procedure with the addition of TEMPO (1 equiv. versus the styrene) before the substrate. For neutralization, saturated K_2CO_3 solution (1.5 mL) was added in addition to 0.5 M $NaHCO_3$ solution in order to recover TEMPO derivatives completely. The yields of the oxytrifluoromethylated products shown in Scheme 7b were estimated based on ^{19}F NMR analysis of the crude product.[14]

[14]The structures of **11** and **5a** were identified by comparison of the spectral data with literature values after rough isolation by means of column chromatography: (a) Y. Li, A. Studer, *Angew. Chem. Int. Ed.*, 2012, **51**, 8221. (b) Y. Yasu, T. Koike, M. Akita, *Angew. Chem. Int. Ed.*, 2012, **51**, 9567.

***Radical probe test using 12 (Scheme 8)*:**



The reaction of **12** was carried out according to the general procedure (the ^{19}F NMR spectrum of the crude product is shown in Figure S4). Compound **13** was isolated as a colorless oil (25 mg, 31% yield, *E*/*Z* = 4/96) after purification by column chromatography (SiO_2; EtOAc/hexane = 4/96). Stereochemistry of isomers was determined by means of a NOESY experiment.

^{1}H NMR (400 MHz, $CDCl_3$)

Z-isomer: 2.84 (m, 1H), 3.01 (m, 1H), 3.16–3.36 (m, 2H), 5.87 (t, *J* = 7.9 Hz, 1H), 6.00 (dd, *J* = 7.9, 5.8 Hz, 1H), 7.20–7.48 (m, 10H).

E-isomer: 2.52–2.63 (m, 1H), 2.65–2.77 (m, 1H), 3.08 (overlap, 2H), 5.68 (t, *J* = 7.3 Hz, 1H), 5.90 (overlap, 1H), 7.20–7.48 (m, 10H).

^{13}C NMR (100 MHz, $CDCl_3$; *Z*-isomer)

35.0 (q, *J* = 29.9 Hz), 36.0, 79.6, 114.6 (q, *J* = 286 Hz), 125.8 (q, *J* = 278 Hz), 126.5 (2C), 126.6 (2C), 127.9, 128.6, 128.7 (2C), 129.1 (2C), 129.3, 133.9 (q, *J* = 2.9 Hz), 137.4, 141.5, 156.8 (q, *J* = 43 Hz).

^{19}F NMR (376 MHz, $CDCl_3$)

Z-isomer: –63.4 (t, *J* = 10.1 Hz, 3F), –75.0 (s, 3F).

E-isomer: –64.4 (t, *J* = 10.1 Hz, 3F), –175.0 (s, 3F).

IR (neat, cm^{-1})

3067, 1784, 1496, 1457, 1383, 1331, 1253, 1223, 1153, 1113, 759, 698.

HRMS-EI (*m*/*z*)

[M] calcd. for $C_{20}H_{16}F_6O_2$, 402.1054; found, 402.1061.

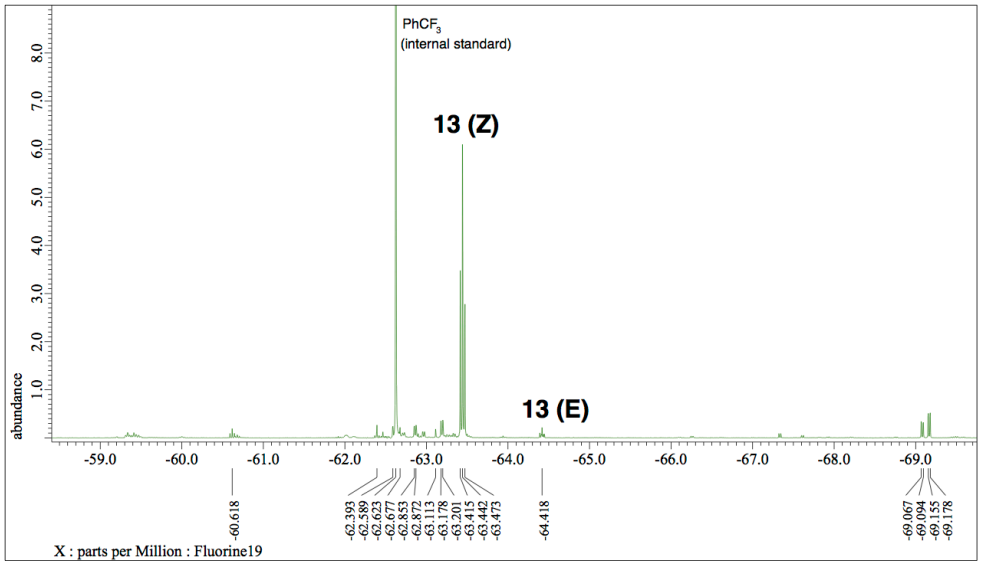
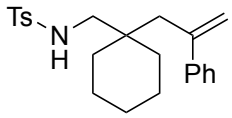
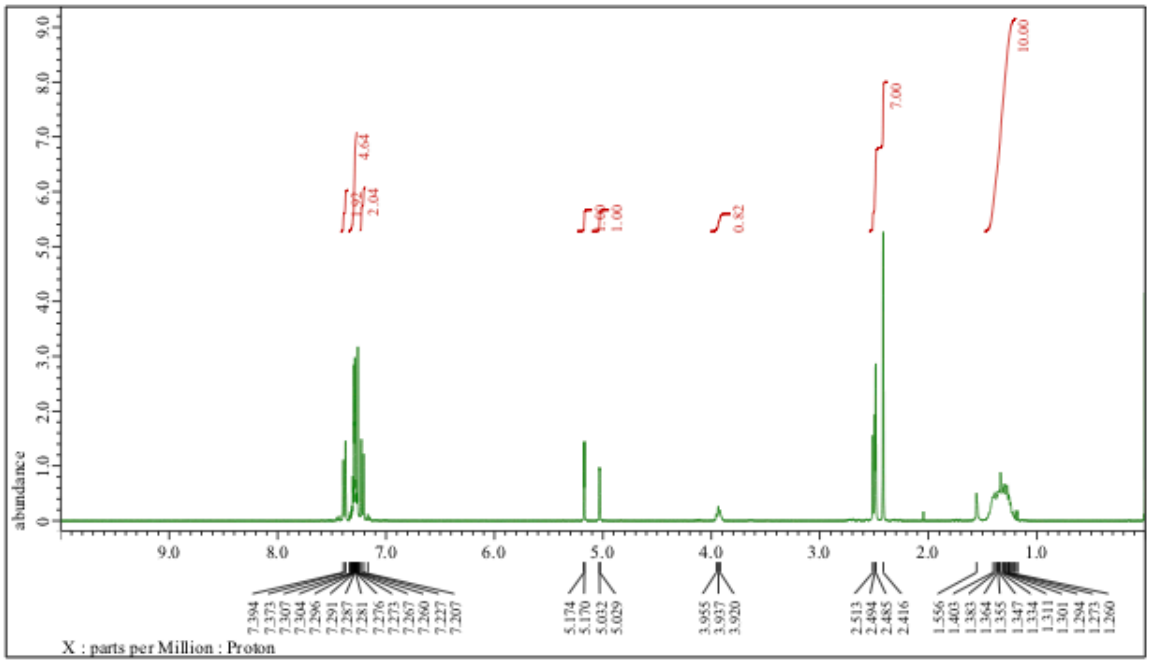


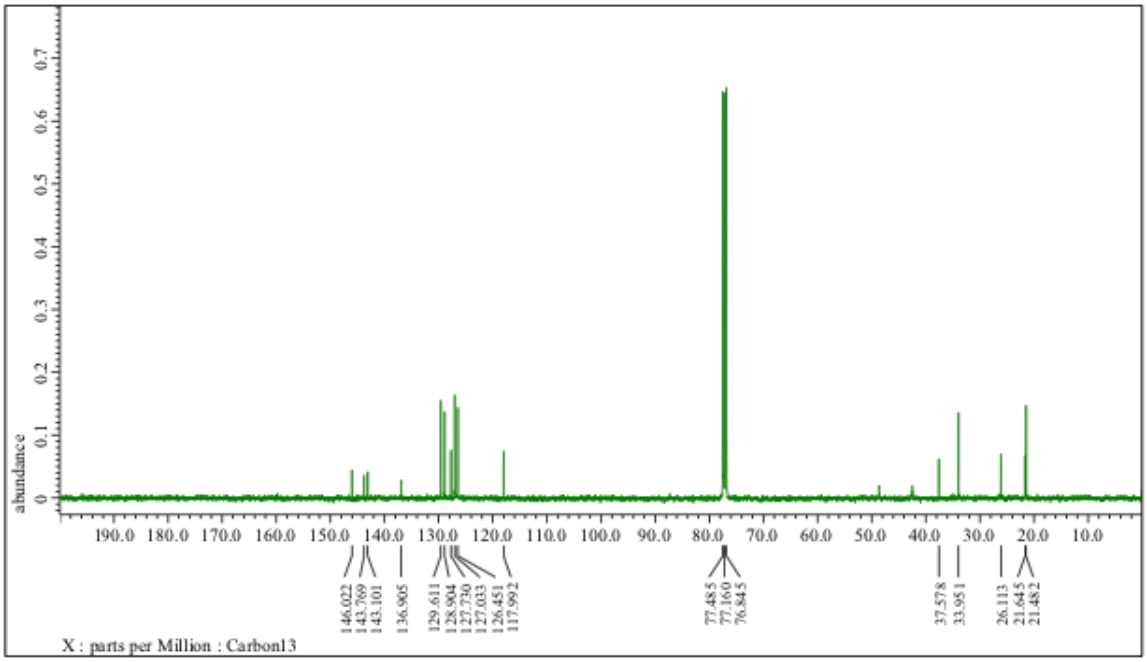
Figure S4. ^{19}F NMR spectrum of the crude product of the radical probe experiment using 12

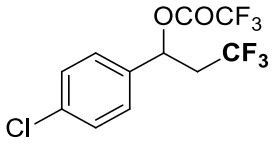
4. ^{1}H and ^{13}C NMR spectra of new compounds



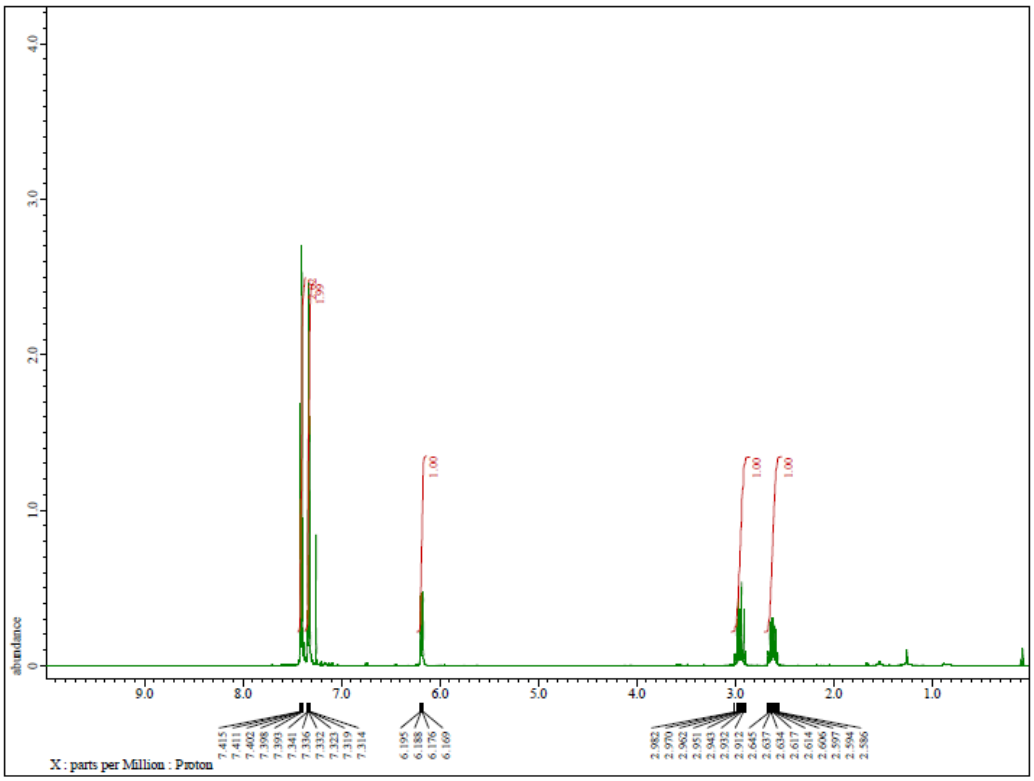
(**3c**)

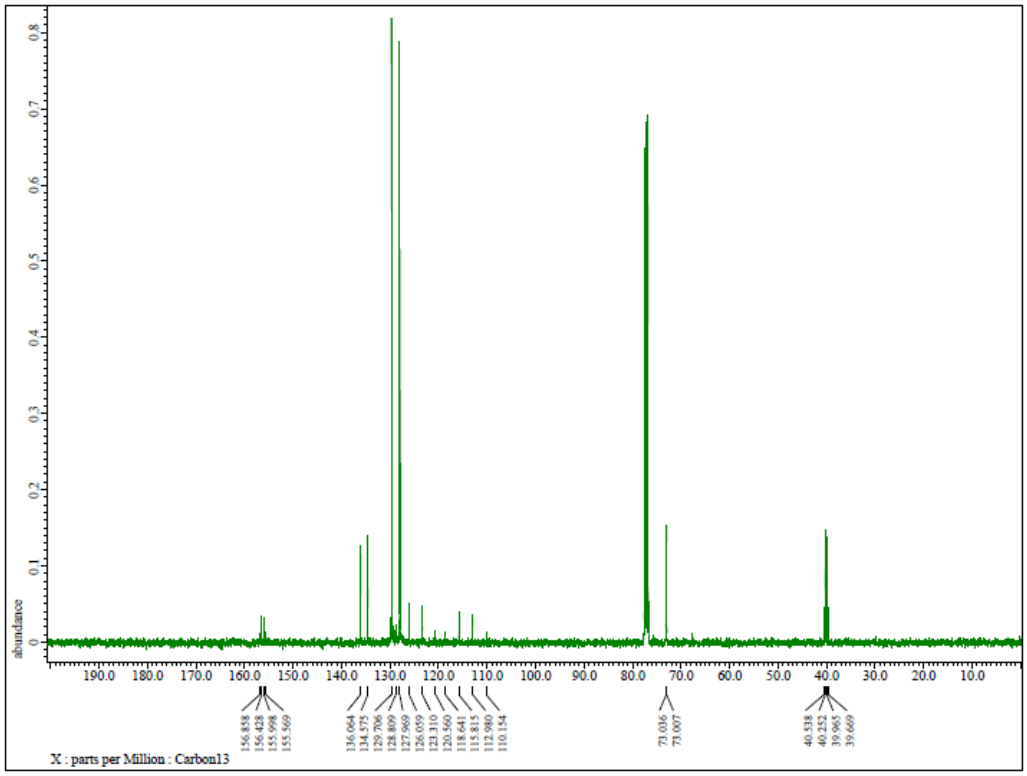


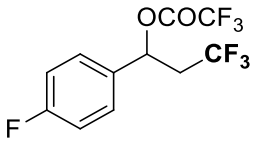



OCOCF3
CF3
Cl

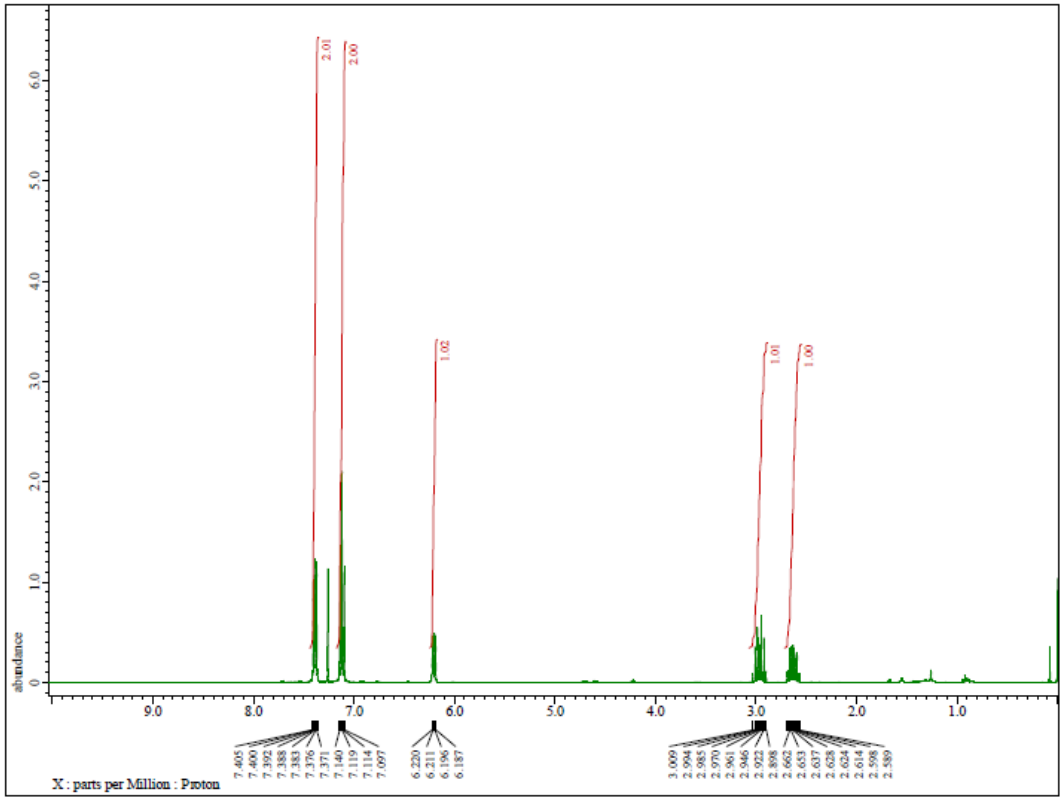
(**2a**)

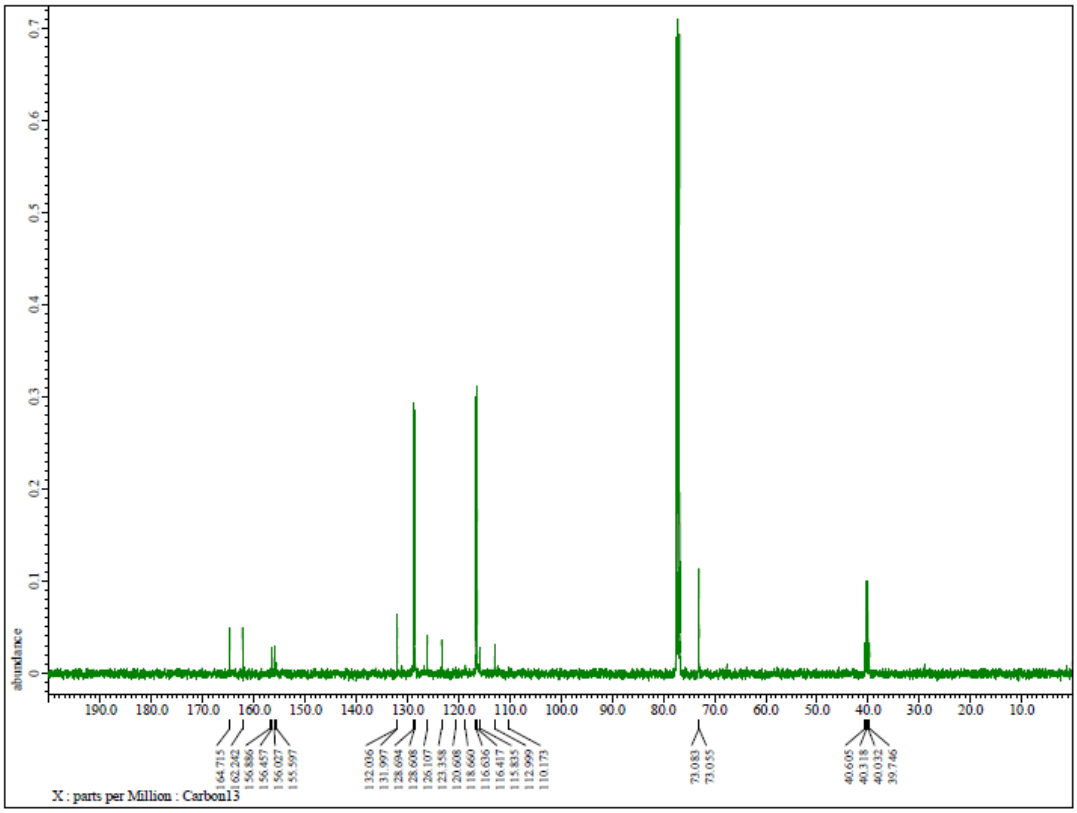

abundance
X : parts per Million : Proton

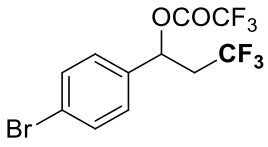

abundance
X : parts per Million : Carbon13


OCOCF3
CF3
F

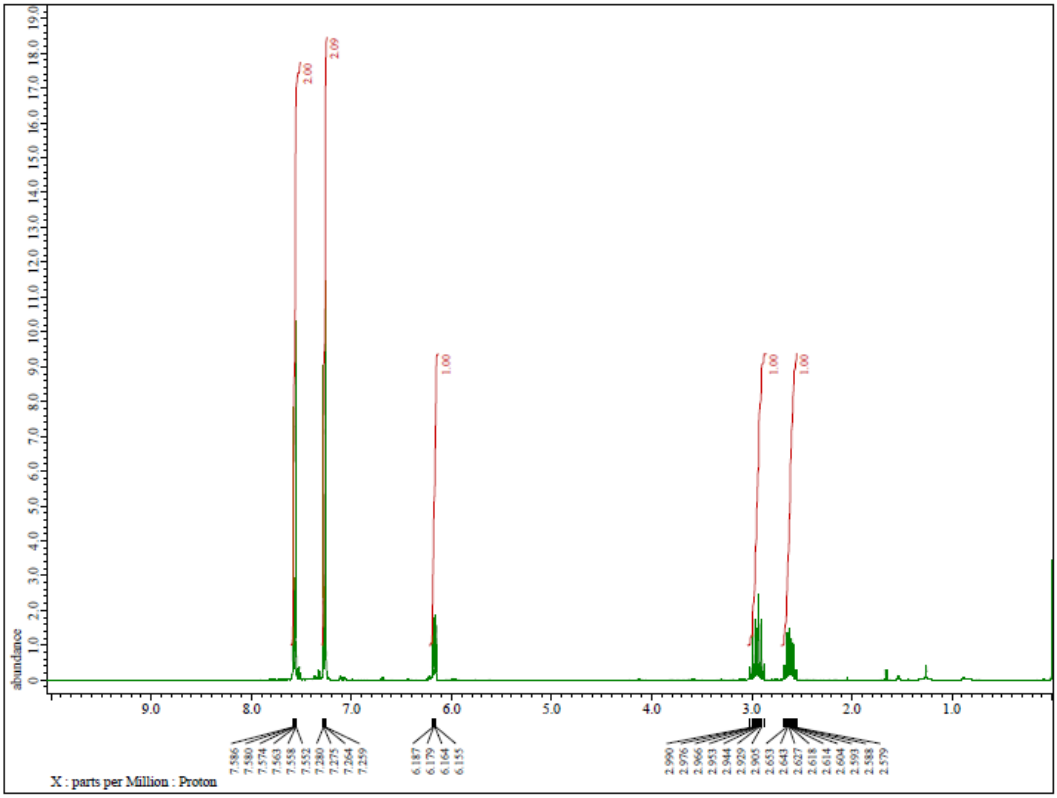
(**2b**)

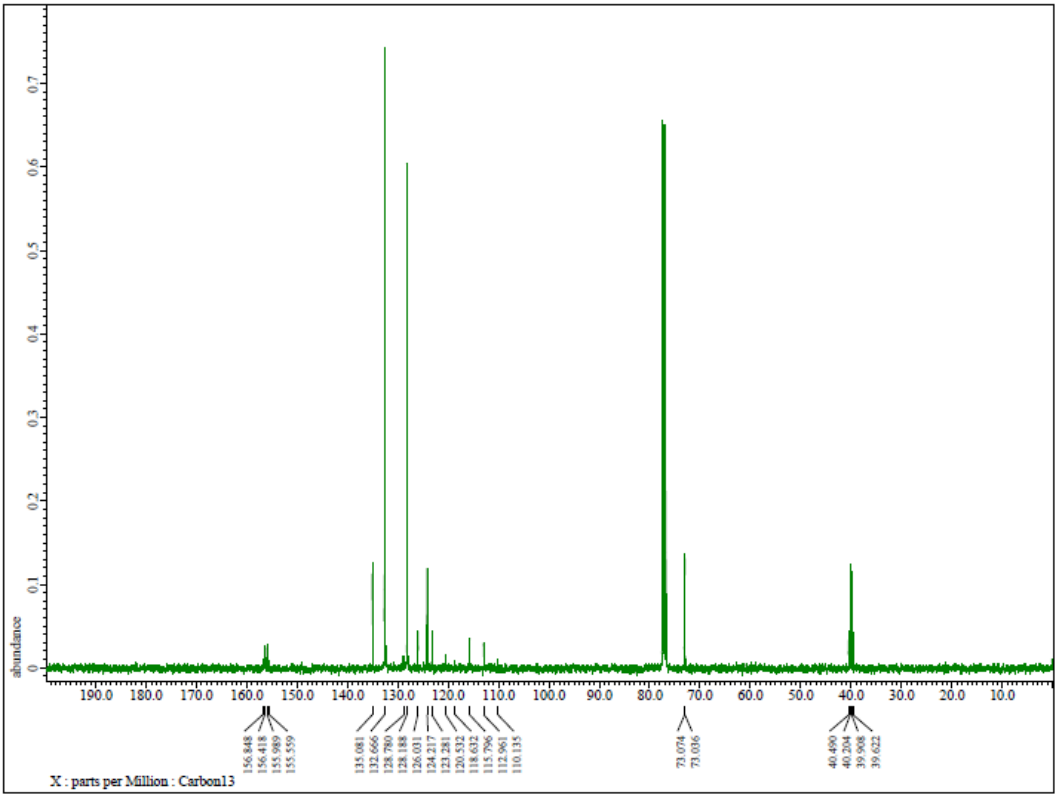

abundance
X : parts per Million : Proton

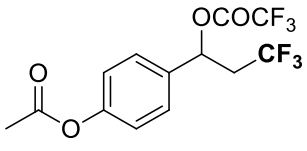

abundance
X : parts per Million : Carbon13


OCOCF3
CF3
Br

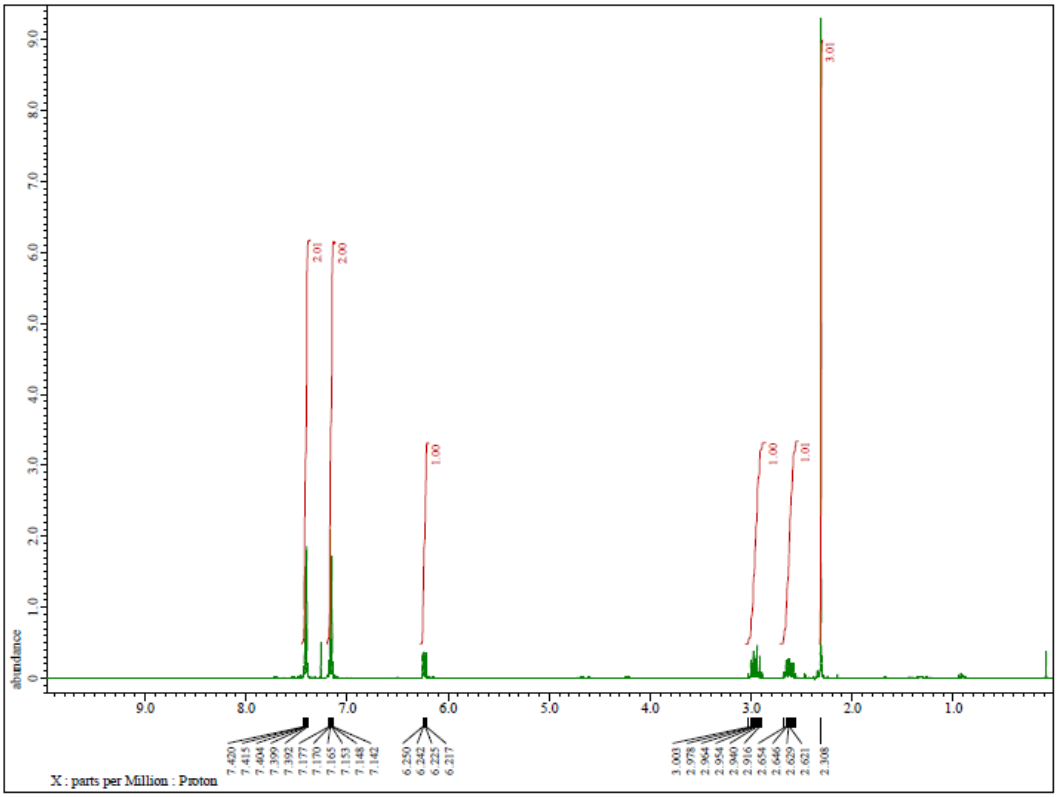
(**2c**)

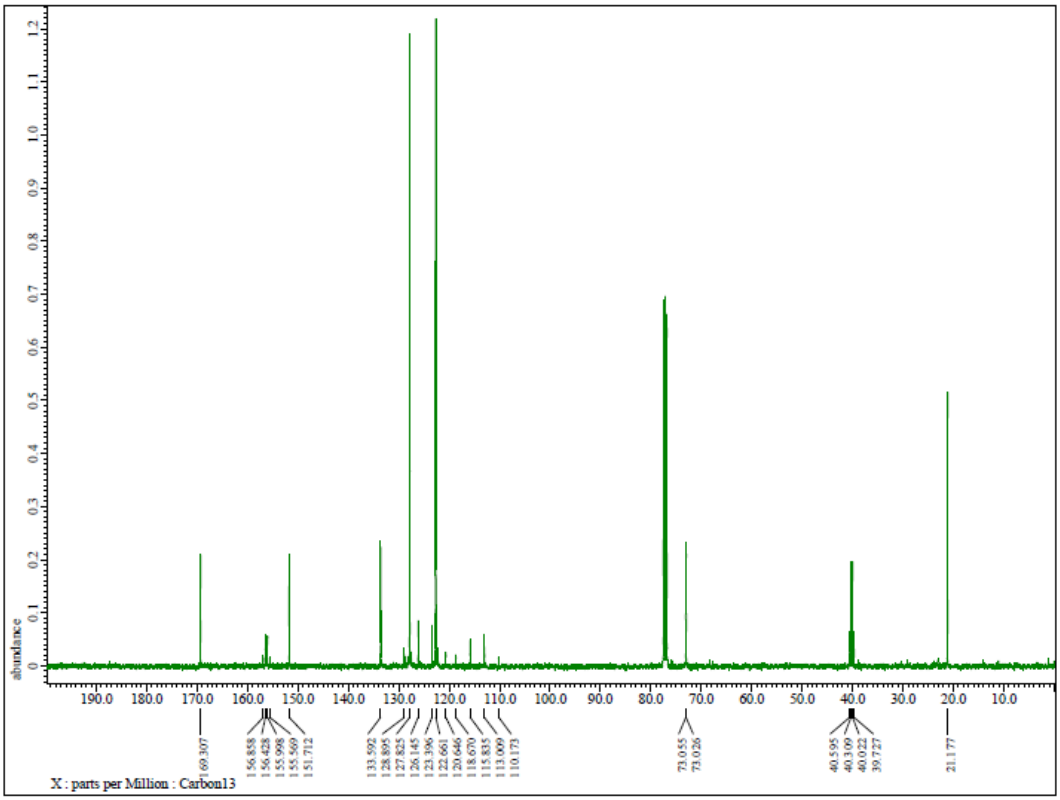

abundance
X : parts per Million : Proton

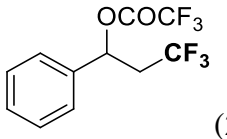

abundance
X : parts per Million : Carbon13


OCOCF3
CF3
O
O

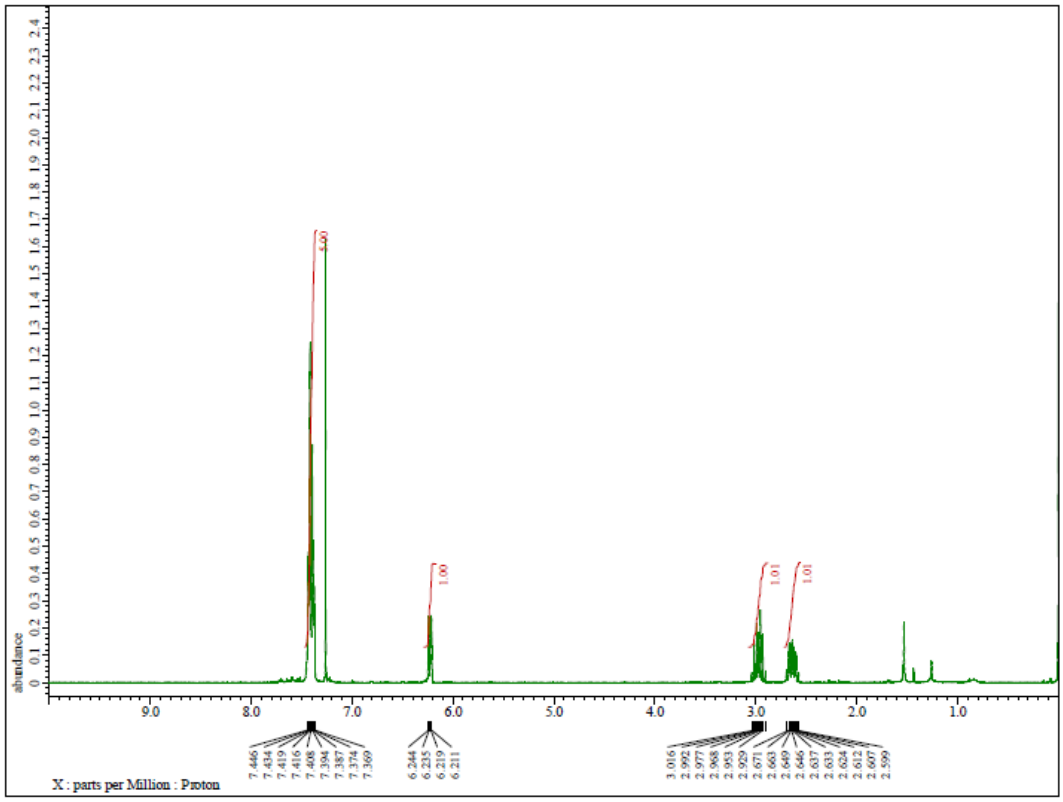
(**2d**)

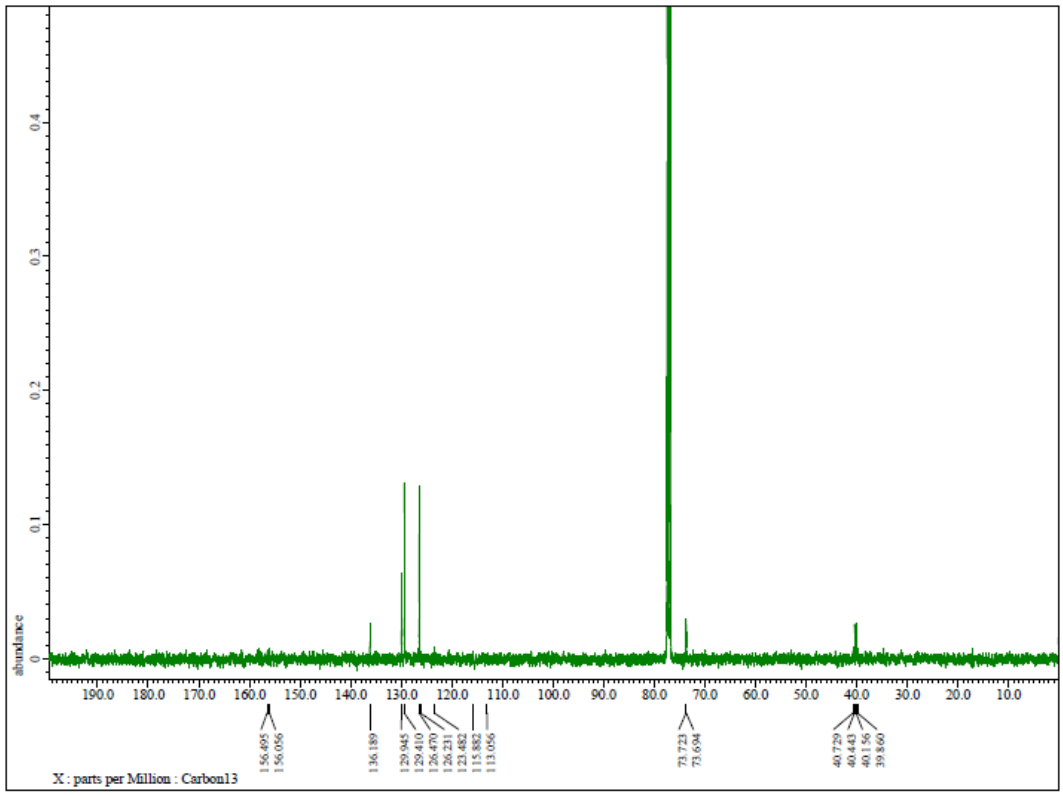

abundance
X : parts per Million : Proton

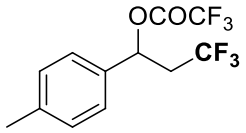

abundance
X : parts per Million : Carbon13


OCOCF3
CF3

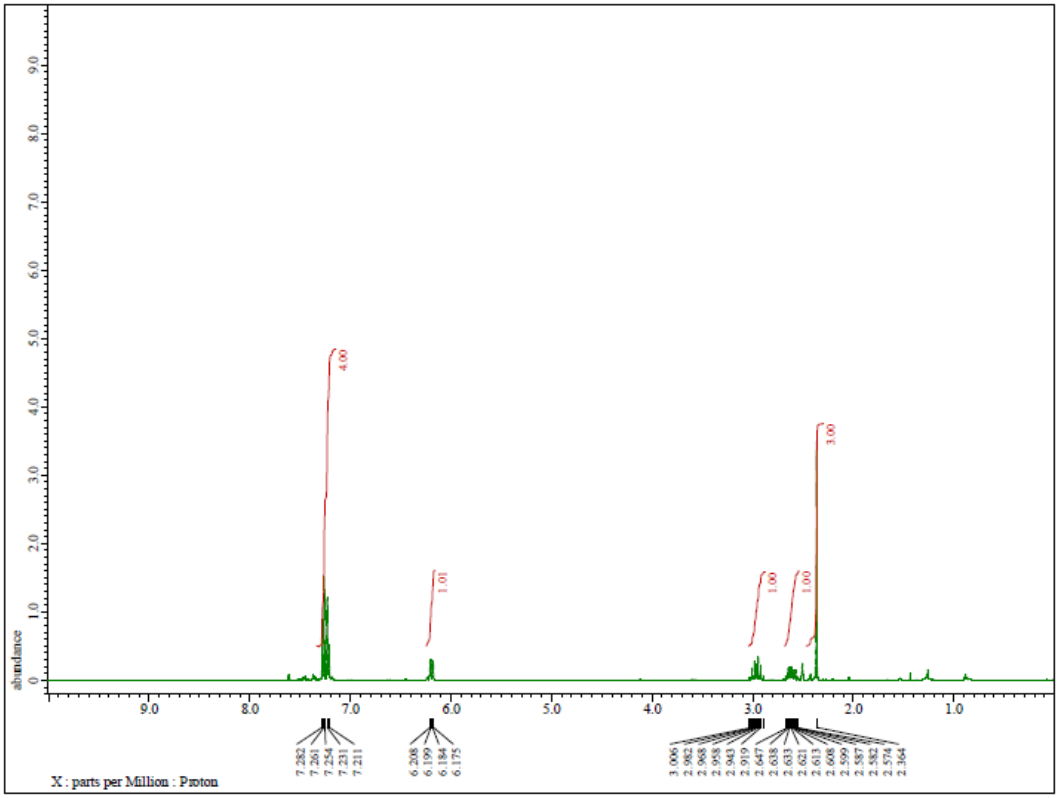
(**2e**)

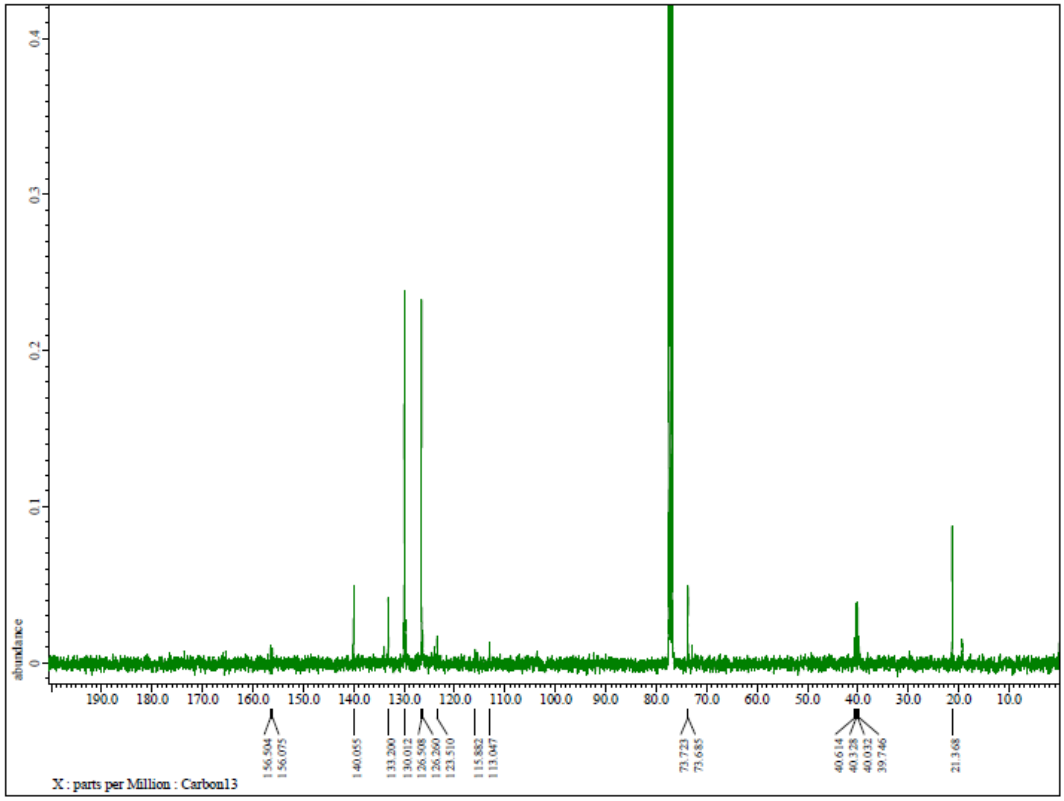

abundance
X : parts per Million : Proton

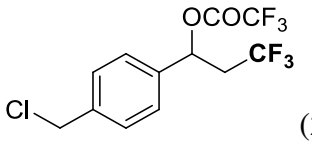

abundance
X : parts per Million : Carbon13


OCOCF3
CF3

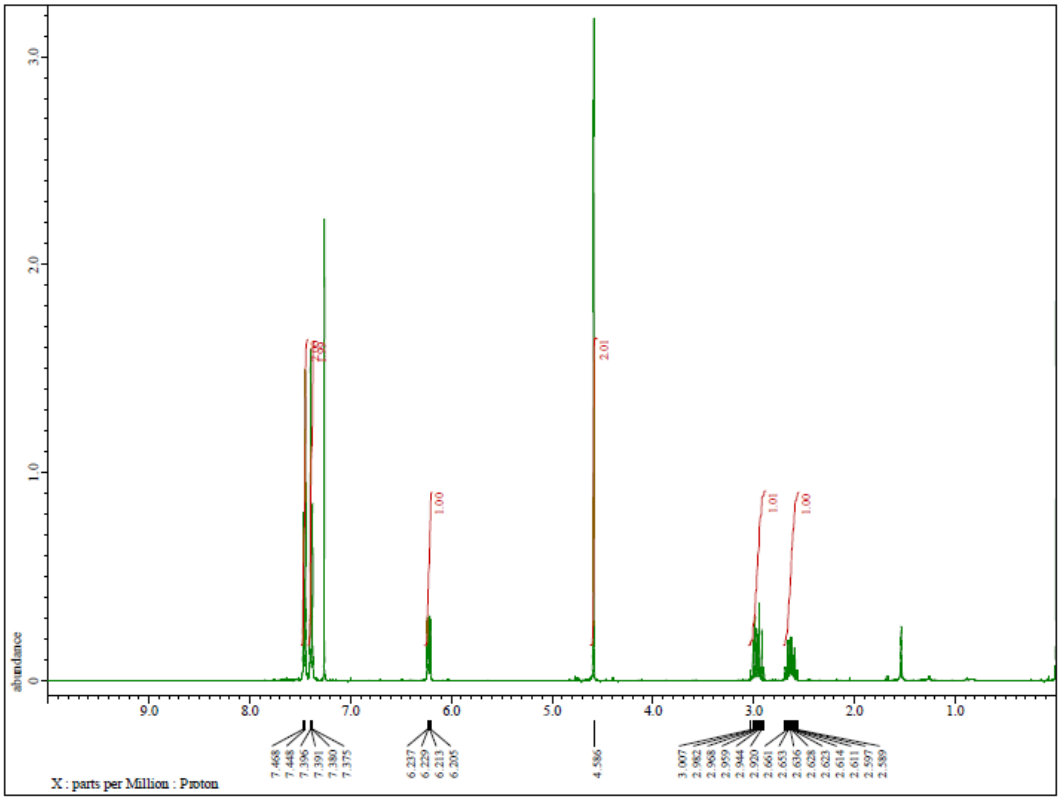
(**2f**)

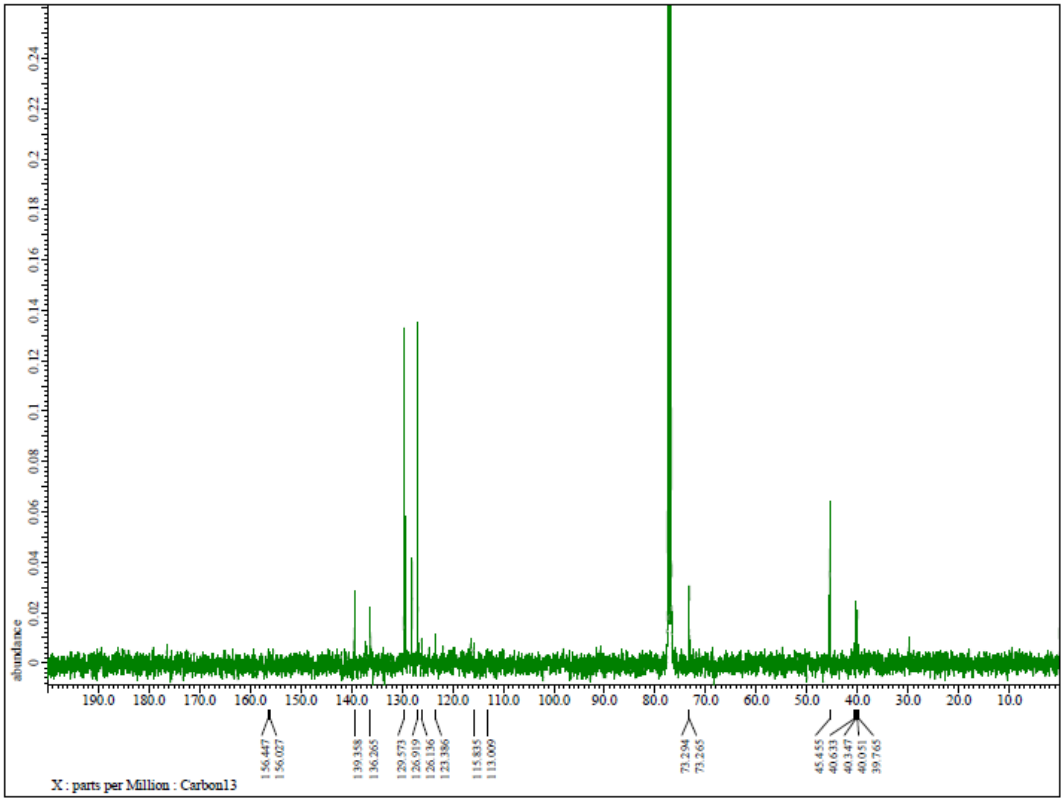

abundance
4.00
1.01
1.00
1.00
3.00
X : parts per Million : Proton

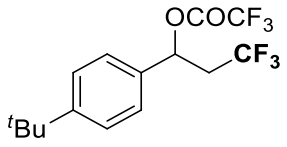

abundance
X : parts per Million : Carbon13


OCOCF3
CF3
Cl

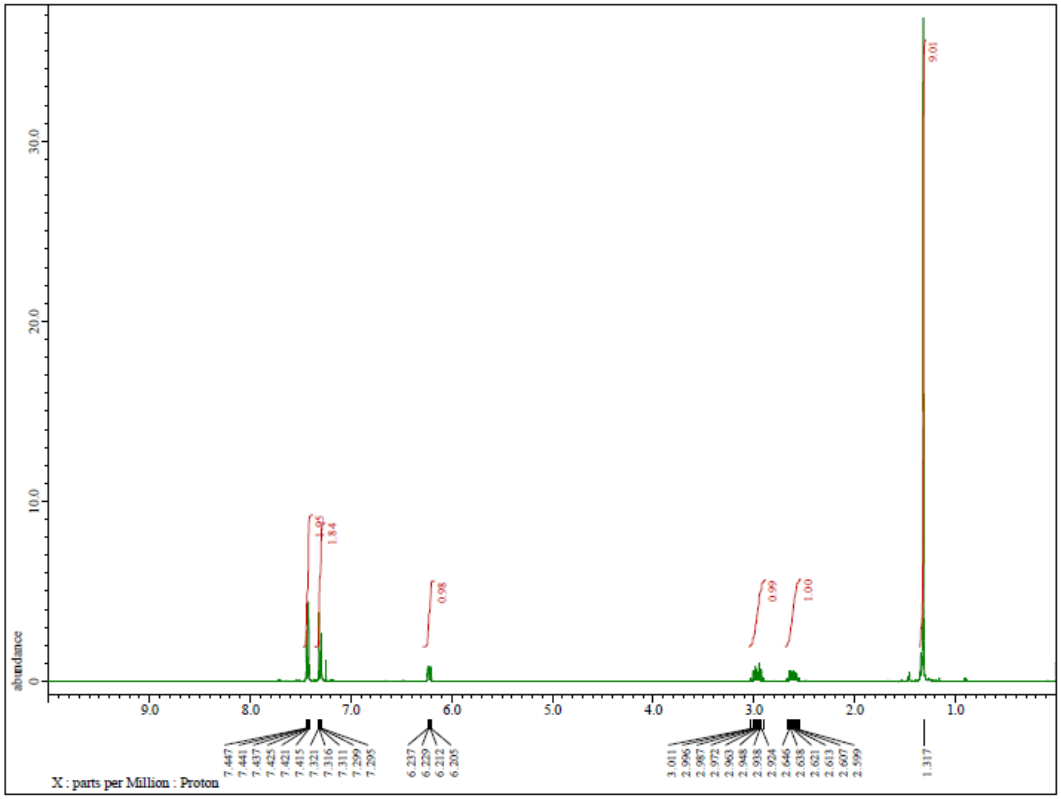
(**2g**)

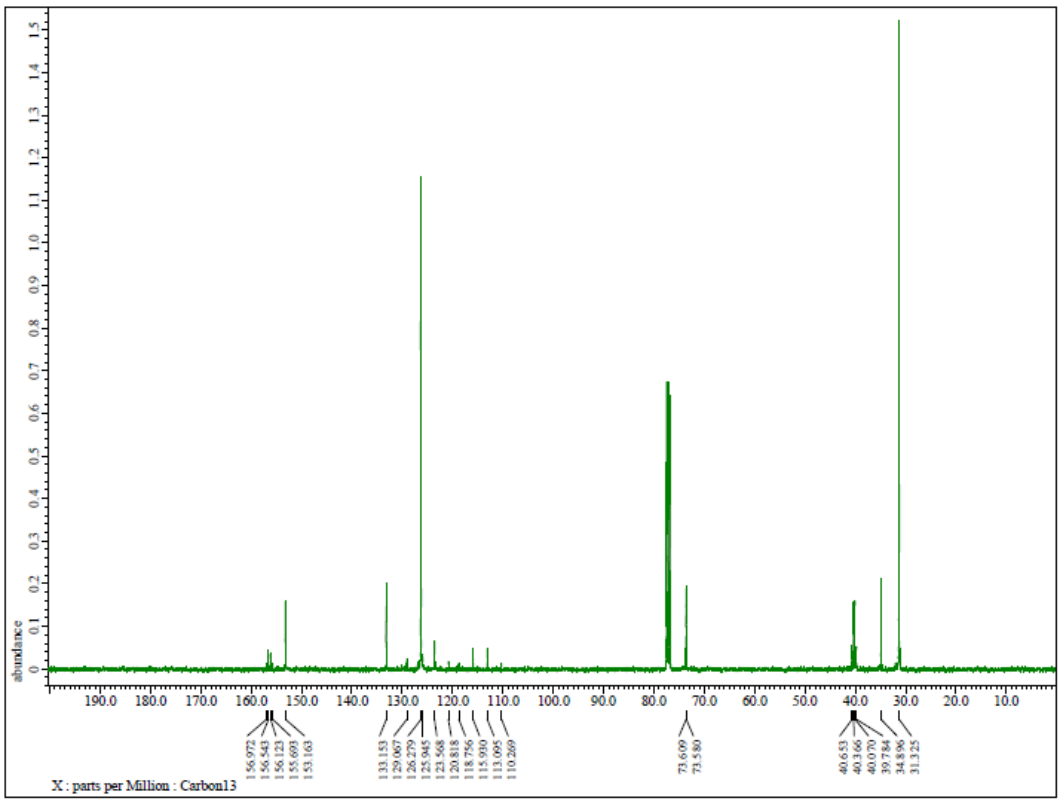

abundance
X : parts per Million : Proton

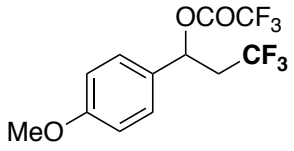

abundance
X : parts per Million : Carbon13


OCOCF3
CF3
tBu

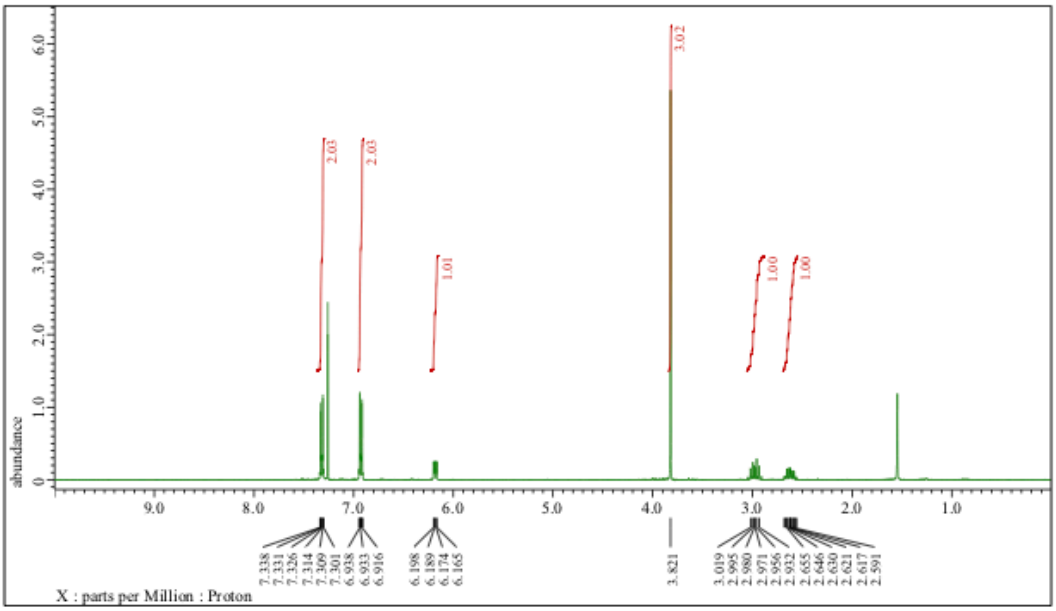
(**2h**)

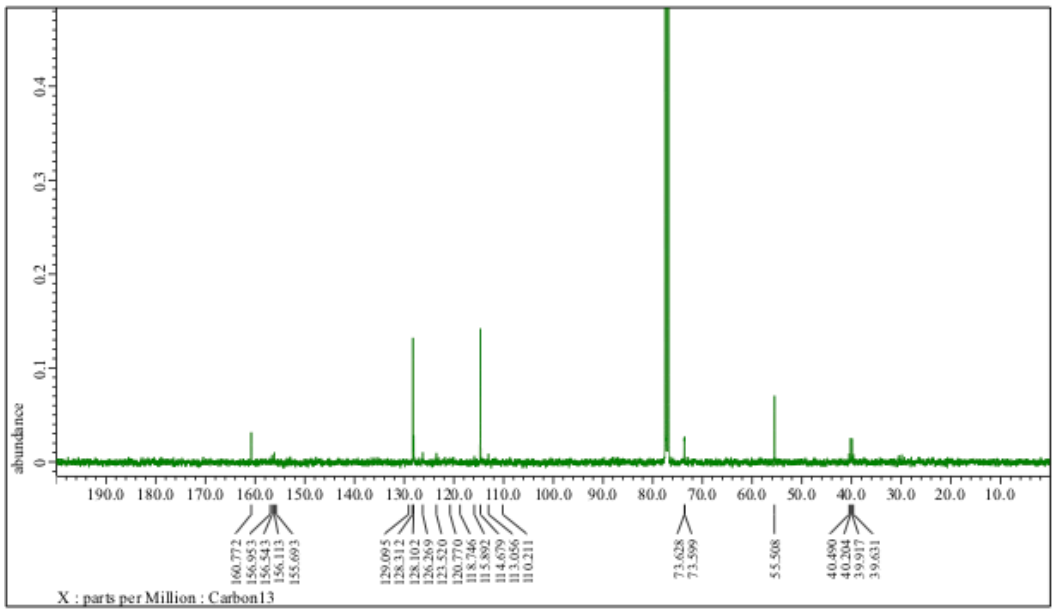

abundance
X : parts per Million : Proton

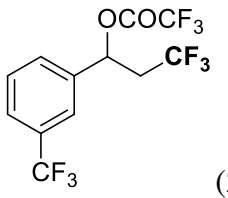

abundance
X : parts per Million : Carbon13


OCOCF3
CF3
MeO

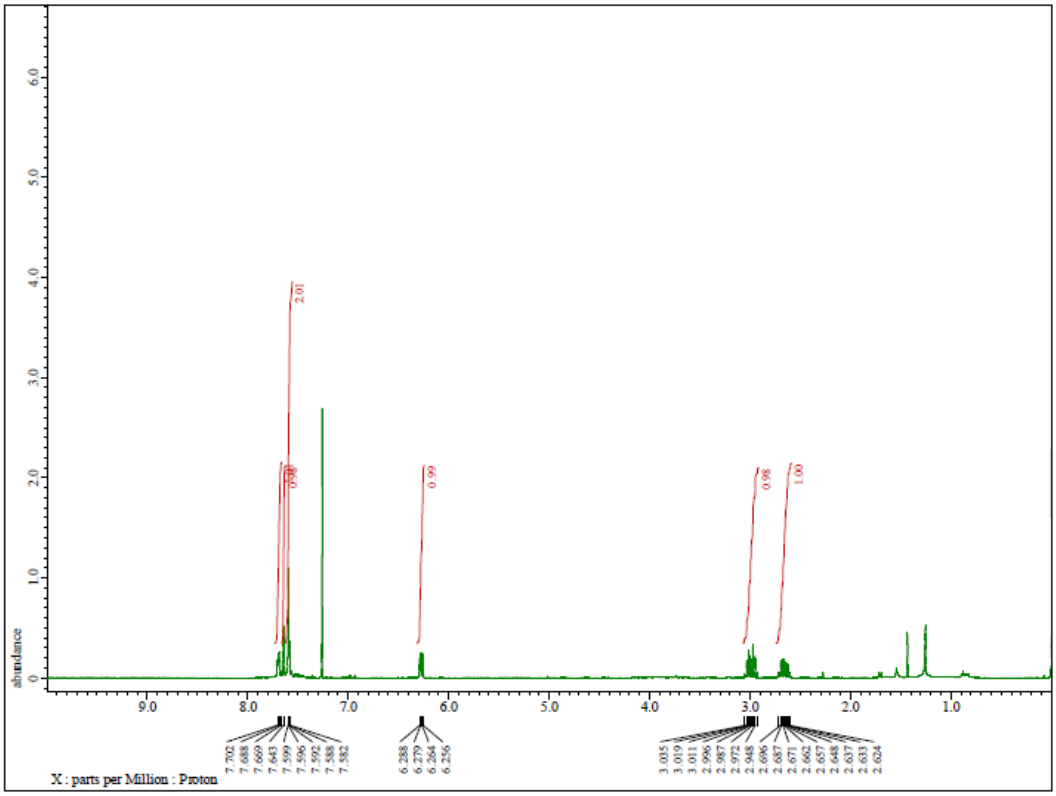
(**2i**)

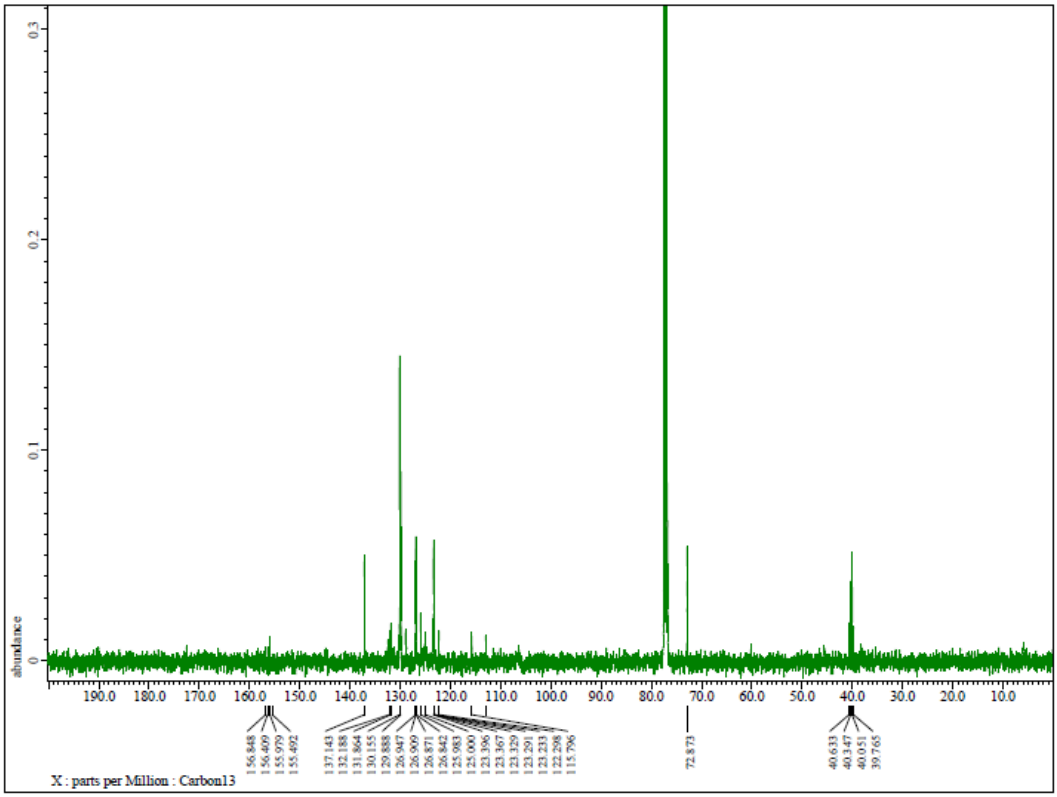

abundance
X : parts per Million : Proton

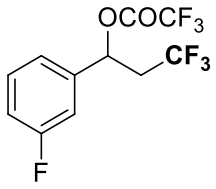

abundance
X : parts per Million : Carbon13


OCOCF3
CF3
CF3

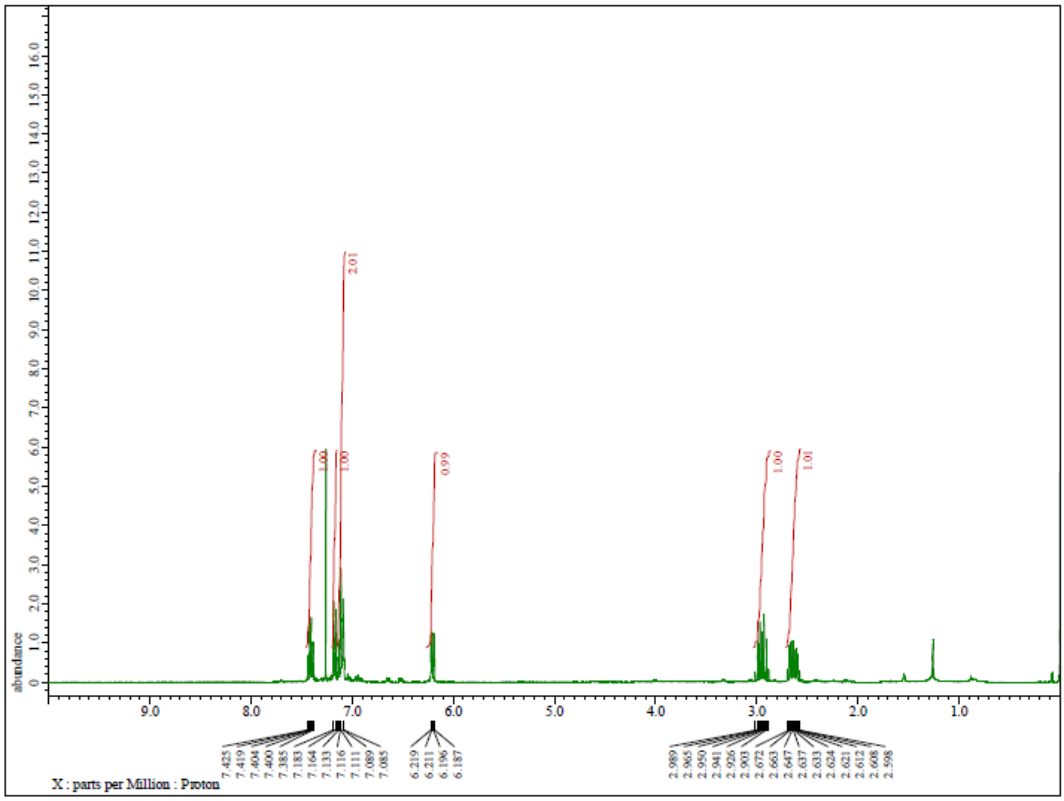
(**2j**)

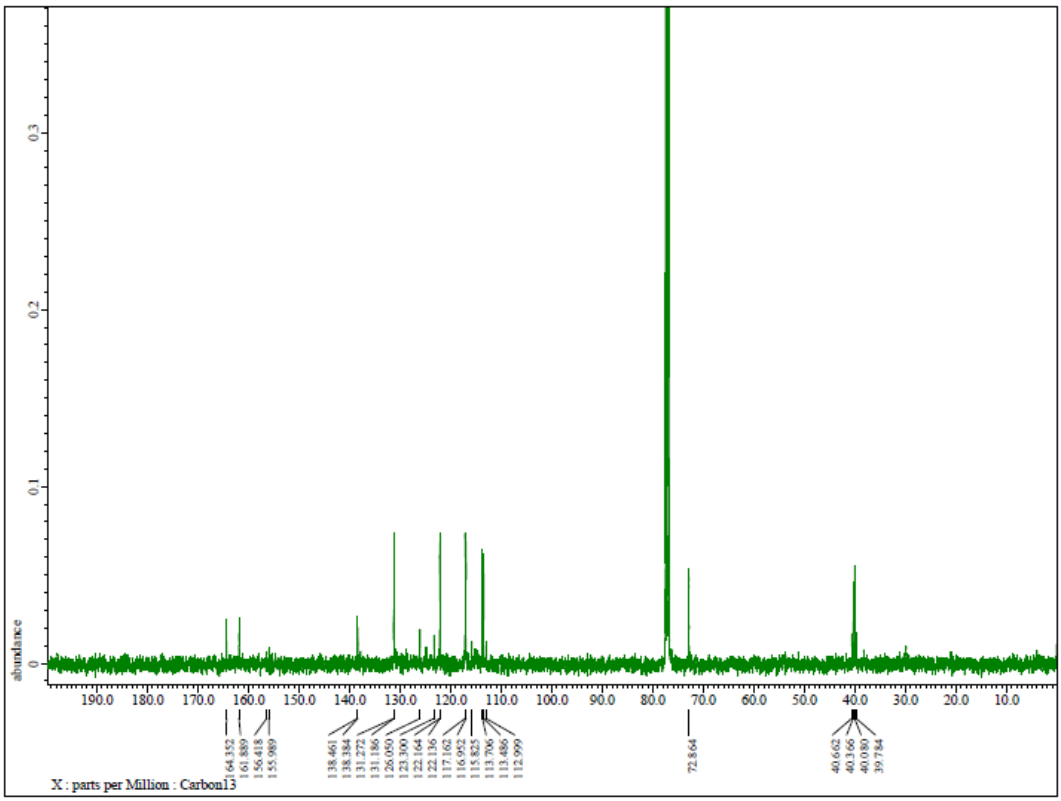

abundance
X : parts per Million : Proton

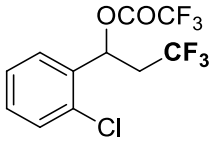

abundance
X : parts per Million : Carbon13


OCOCF3
CF3
F

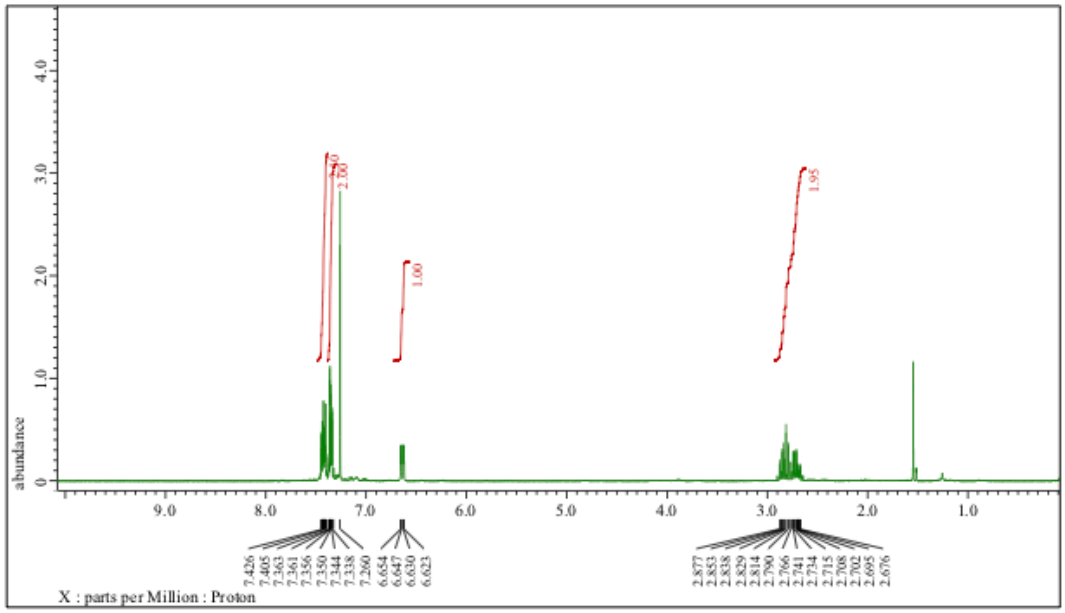
(**2k**)

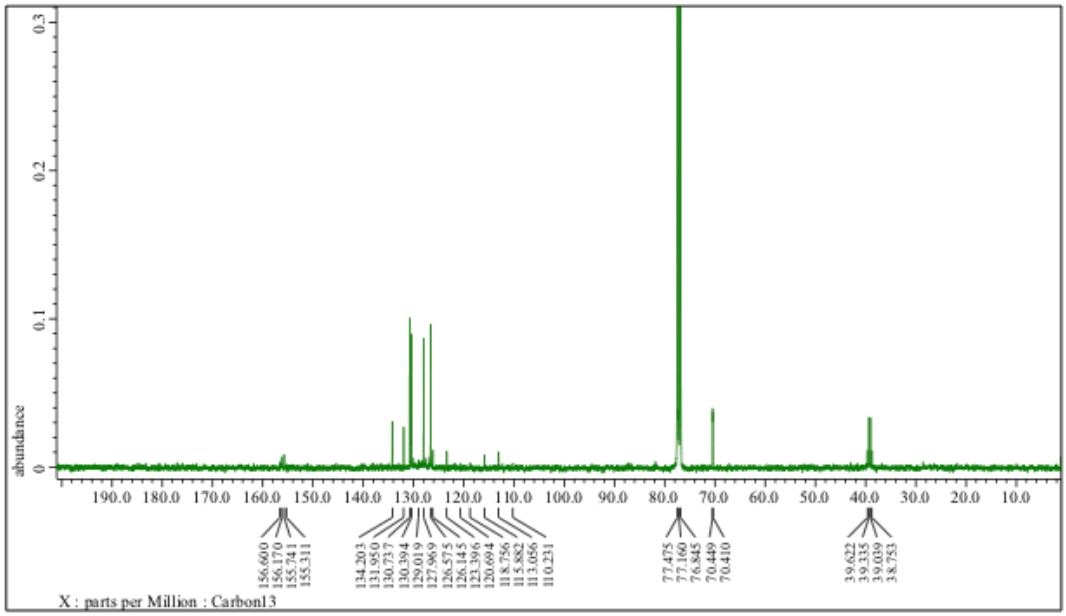

abundance
X : parts per Million : Proton

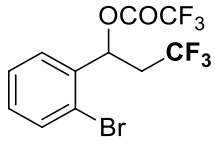

abundance
X : parts per Million : Carbon13


OCOCF3
CF3
Cl

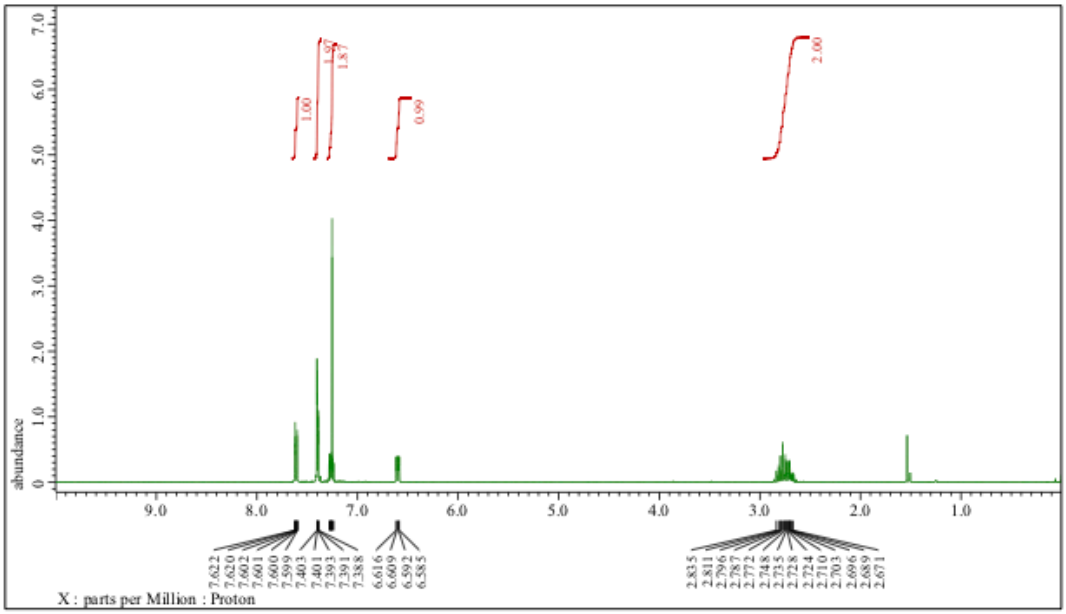
(**2l**)

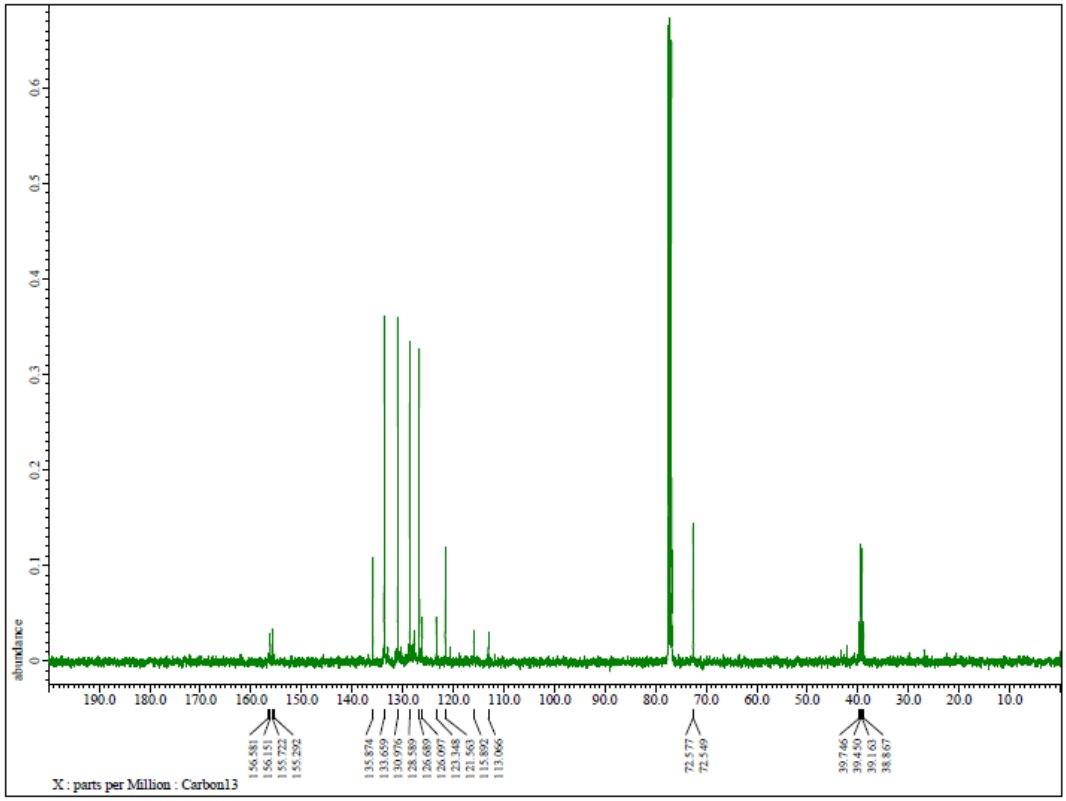

abundance
X : parts per Million : Proton

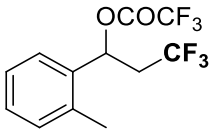

abundance
X : parts per Million : Carbon13


OCOCF3
CF3
Br

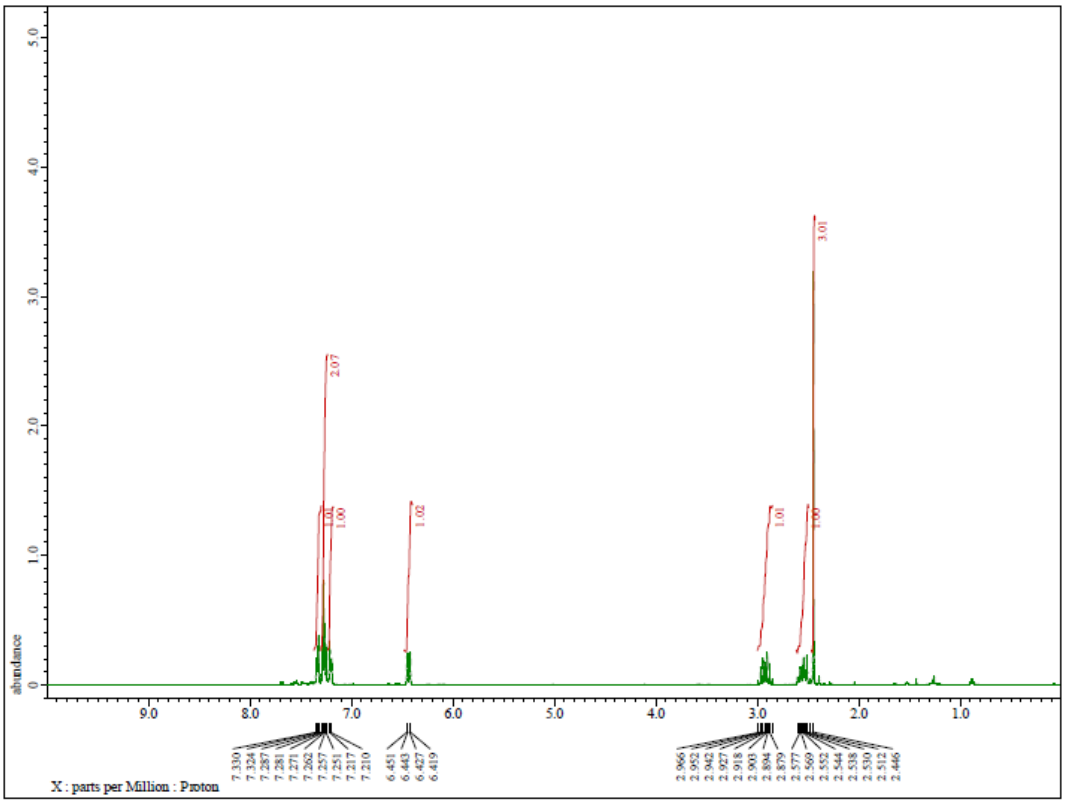
(**2m**)

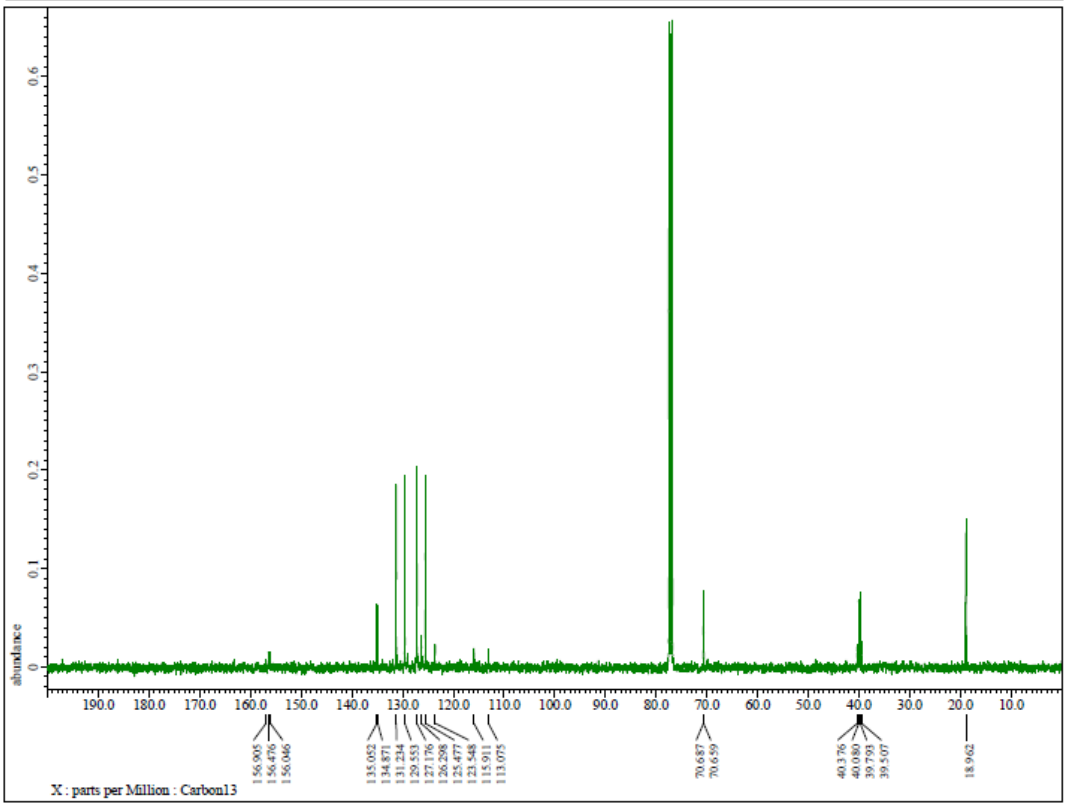

abundance
X : parts per Million : Proton

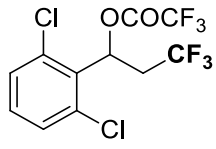

abundance
X : parts per Million : Carbon13


OCOCF3
CF3

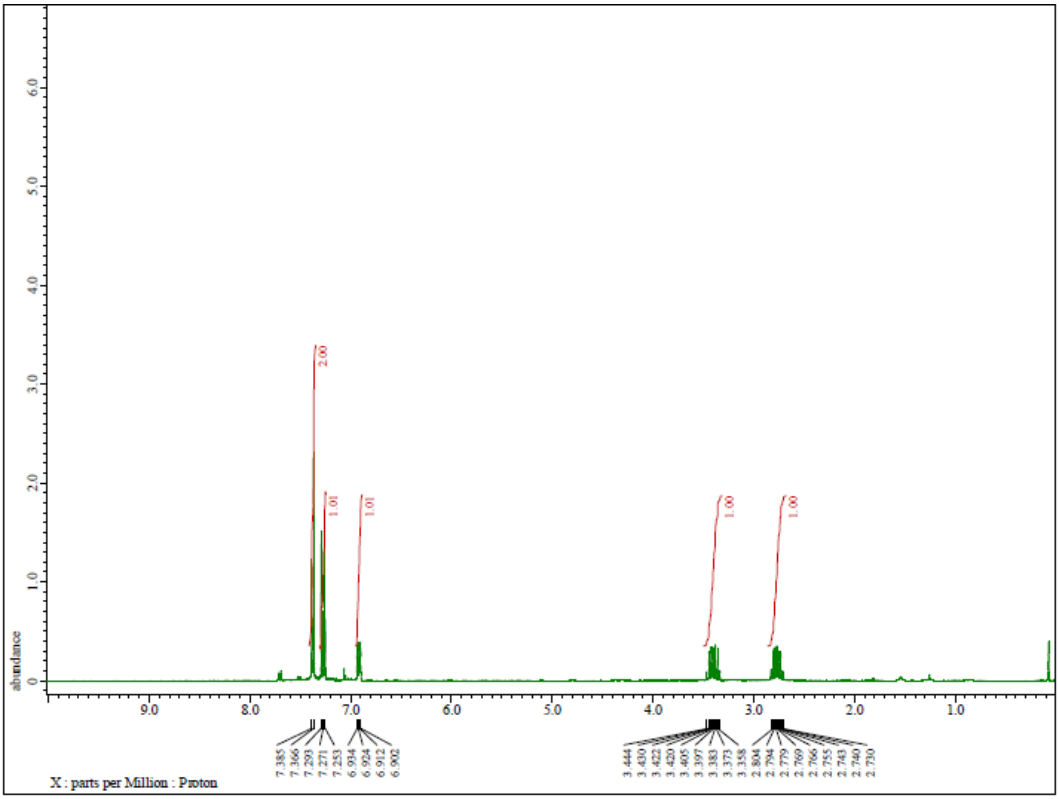
(**2n**)

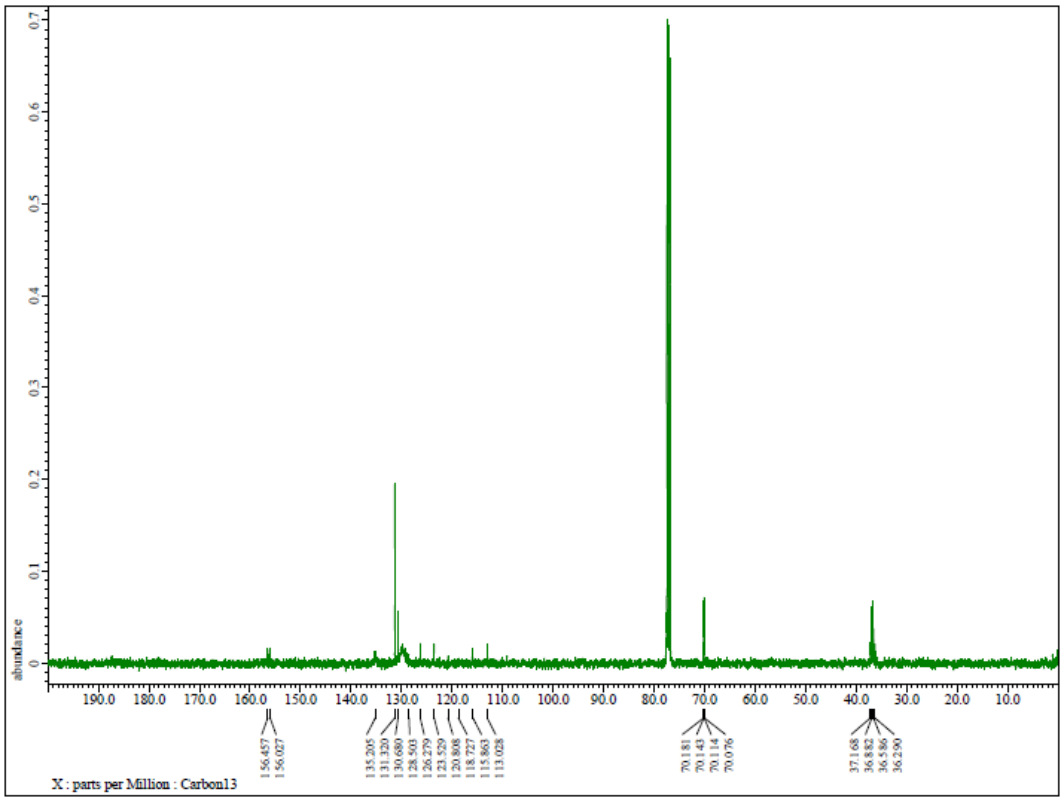

abundance
X : parts per Million : Proton

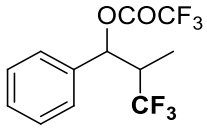

abundance
X : parts per Million : Carbon13


Cl
OCOCF3
CF3
Cl

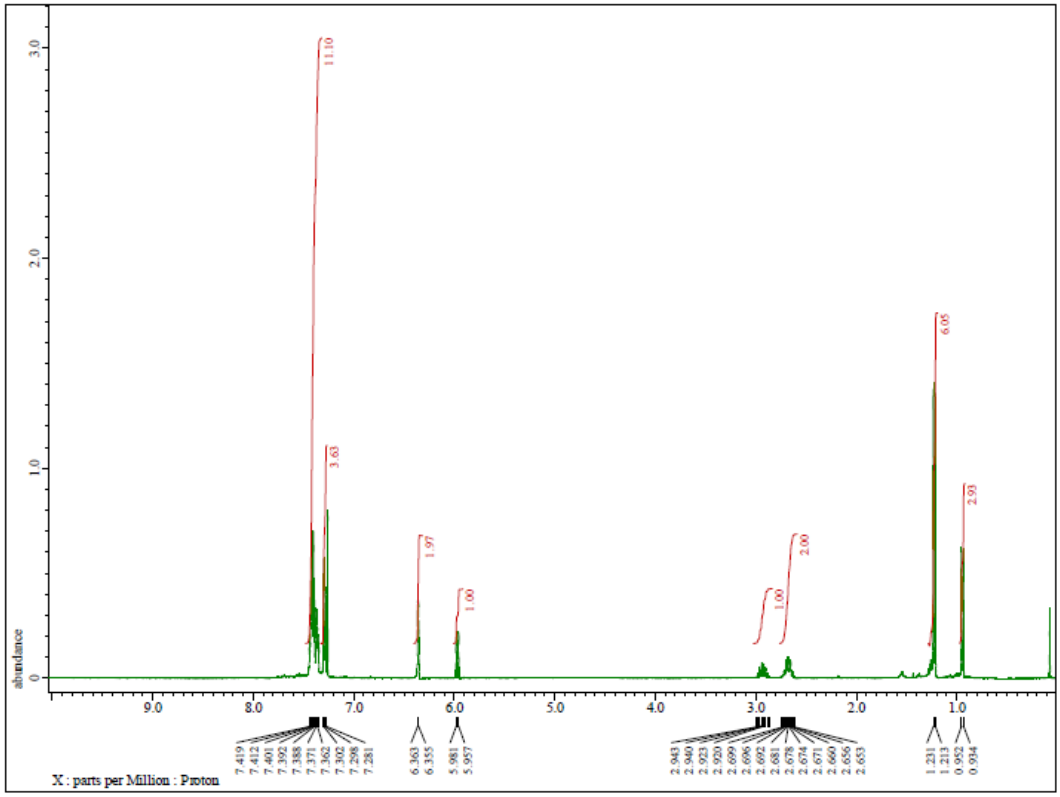
(**2o**)

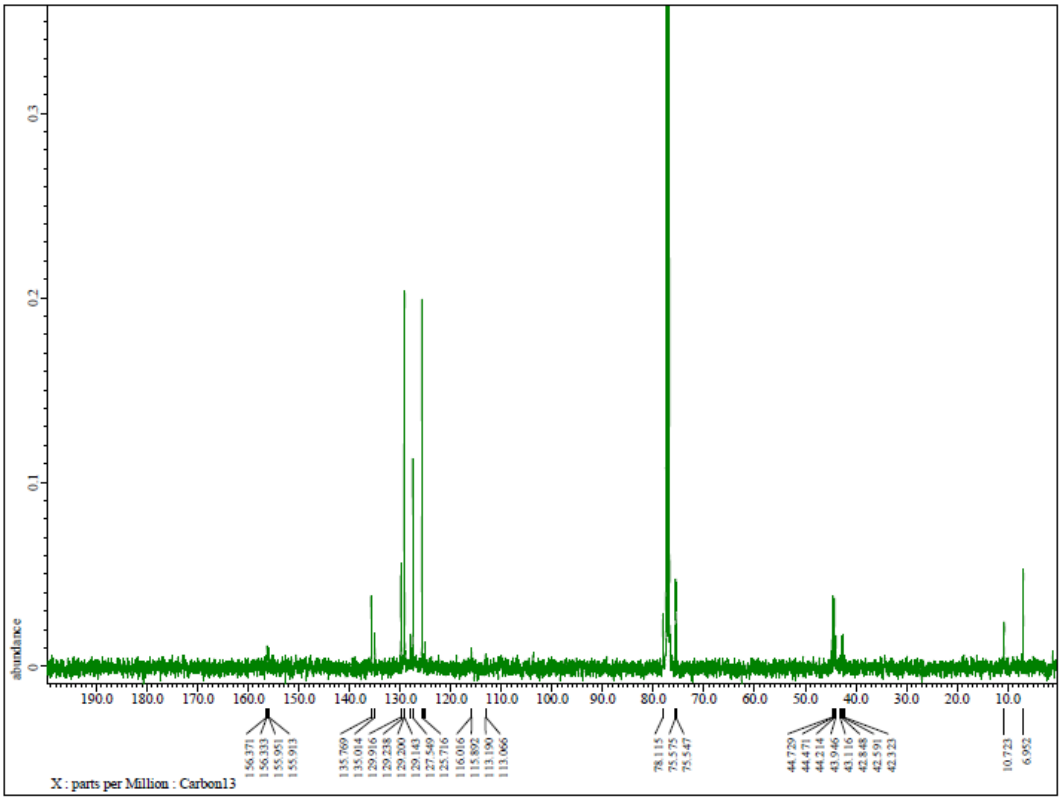

abundance
X : parts per Million : Proton

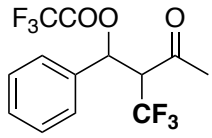

abundance
X : parts per Million : Carbon13


OCOCF3
CF3

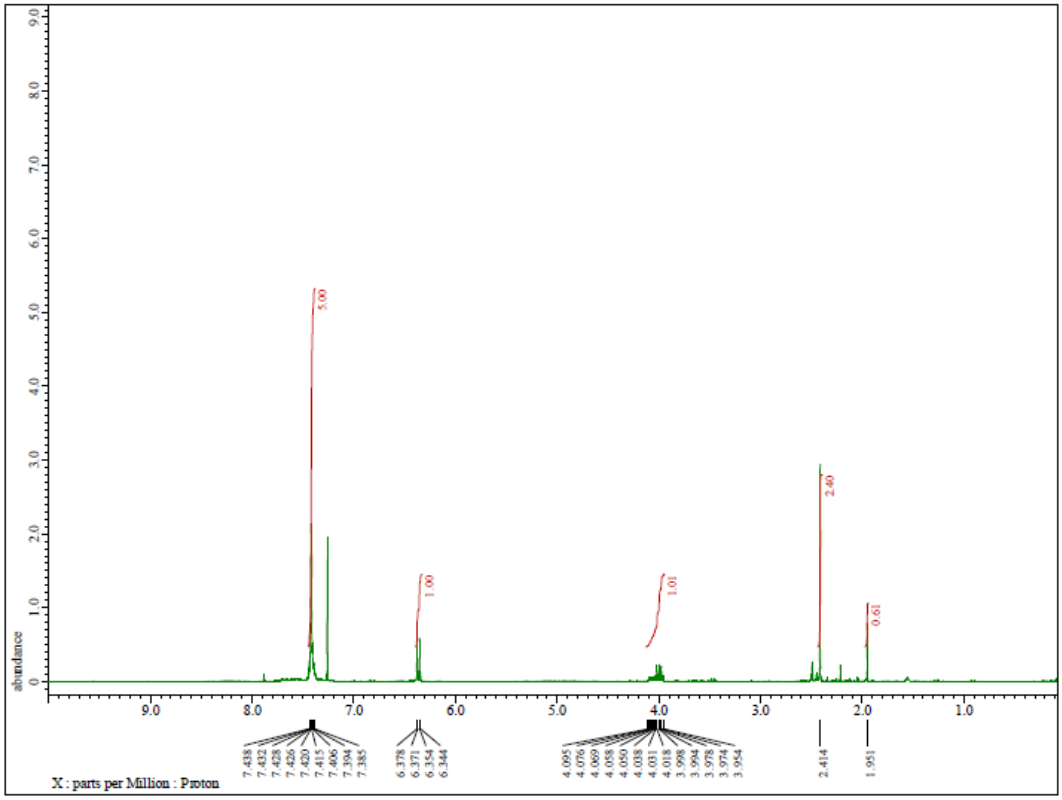
(2p)

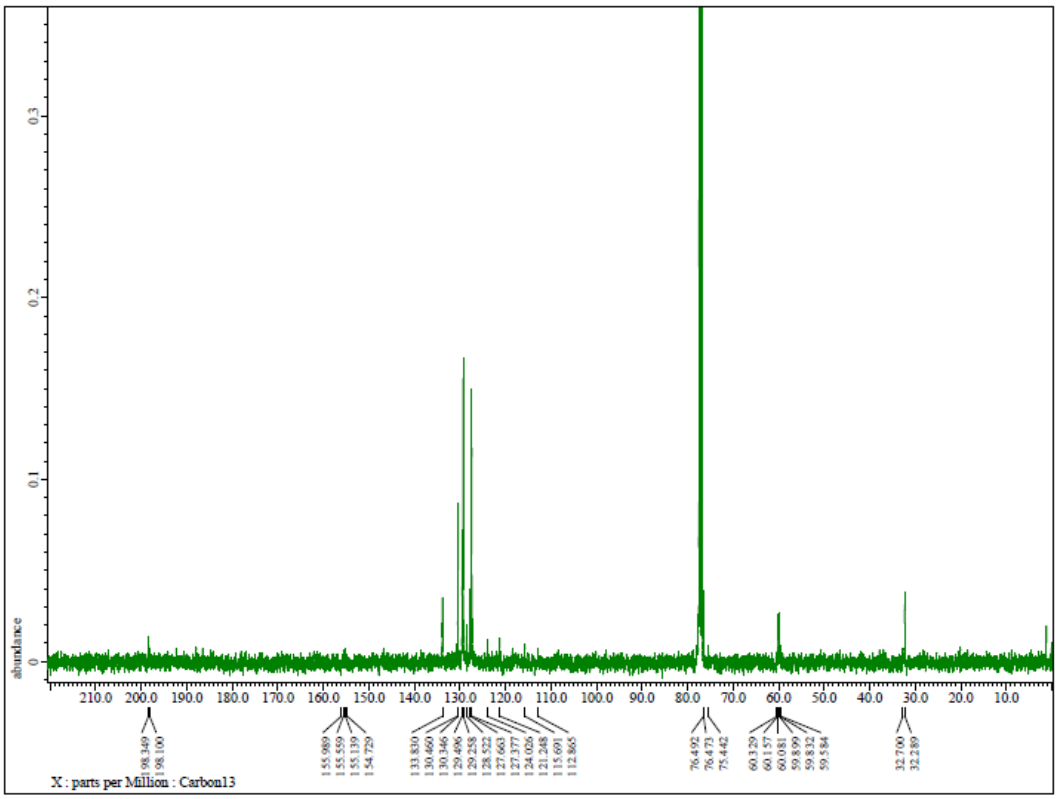

abundance
X : parts per Million : Proton

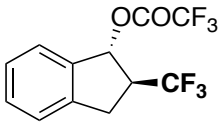

abundance
X : parts per Million : Carbon13


F3CCOO
O
CF3

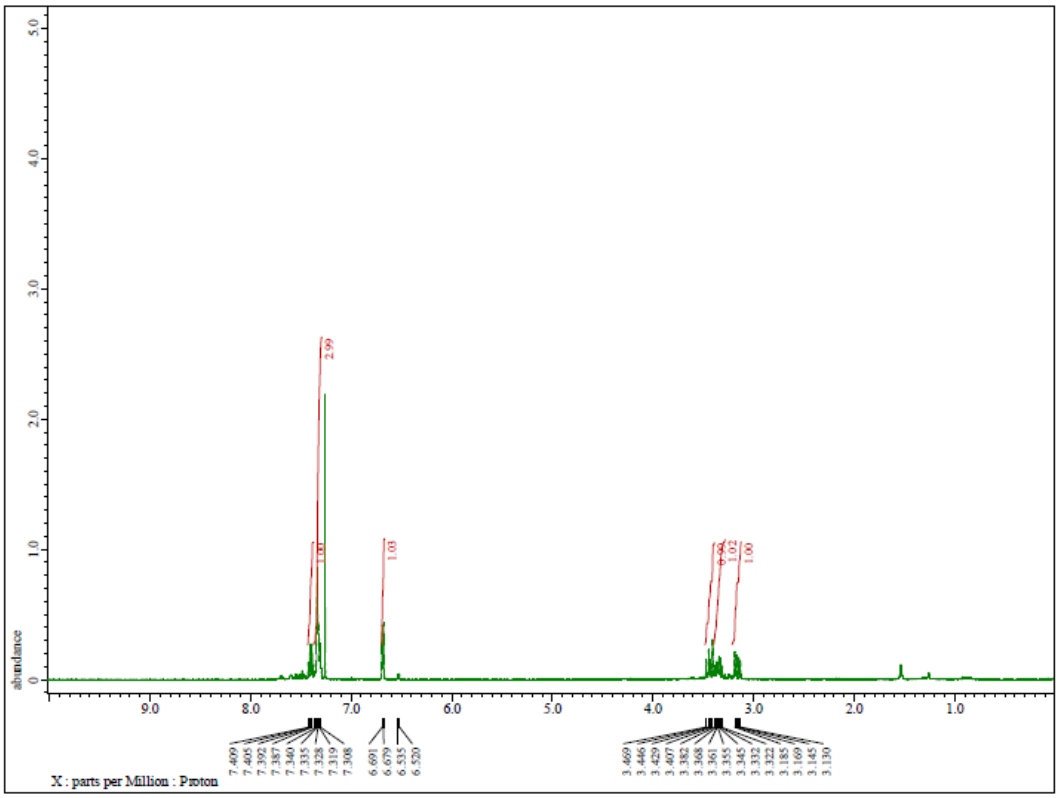
(2q)

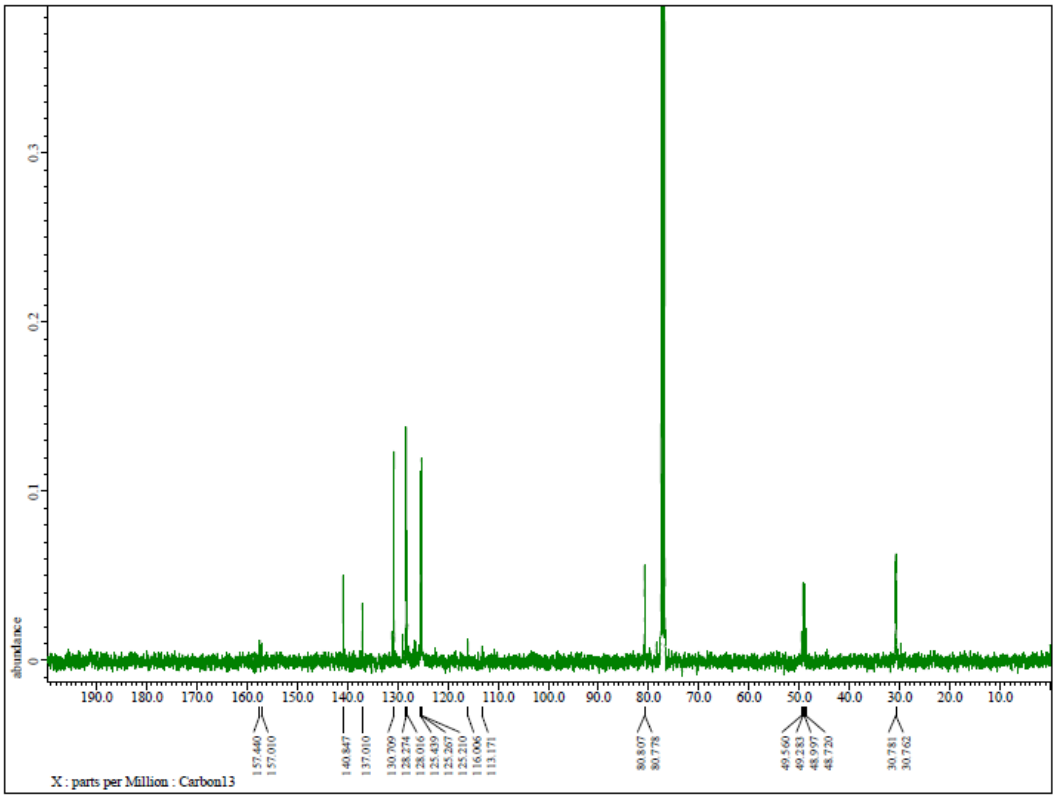

abundance
X : parts per Million : Proton

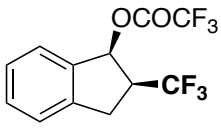

abundance
X : parts per Million : Carbon13



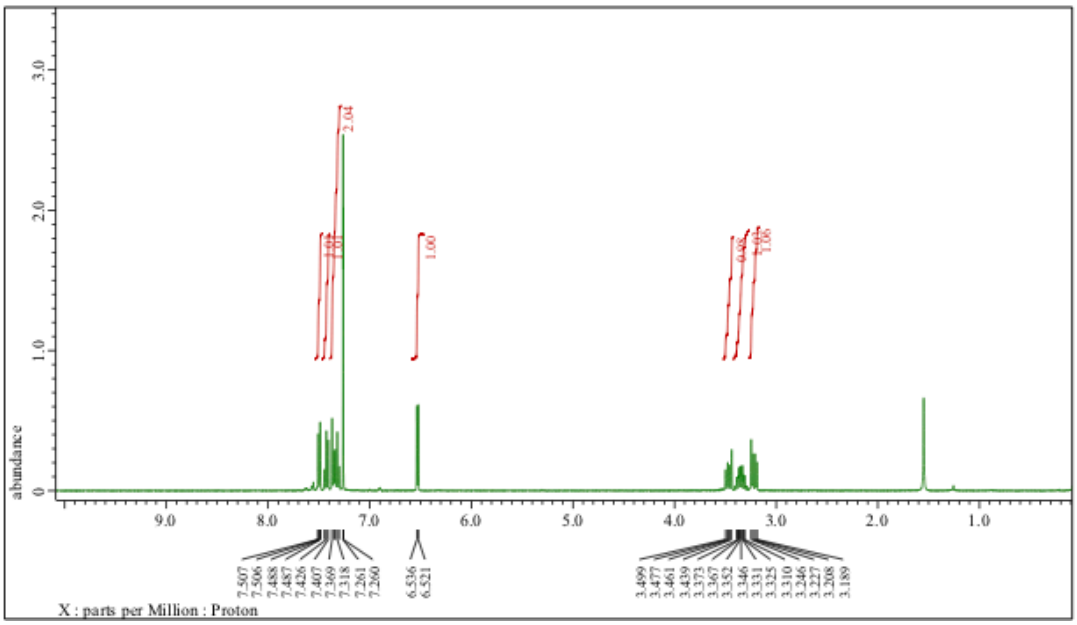
(**2r**, *anti*-isomer)

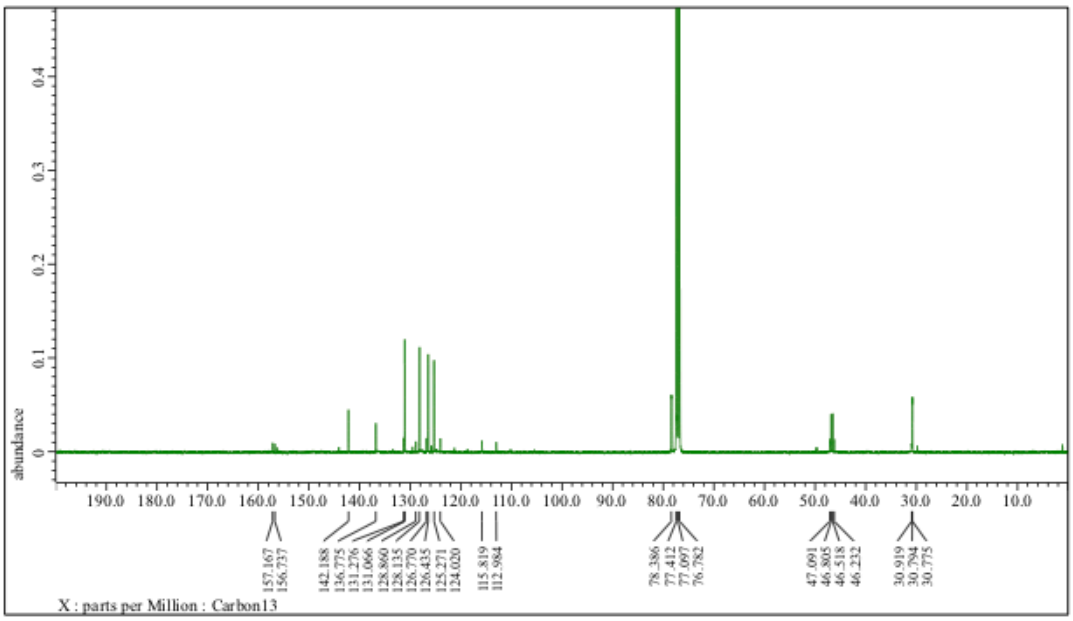


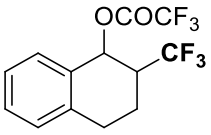




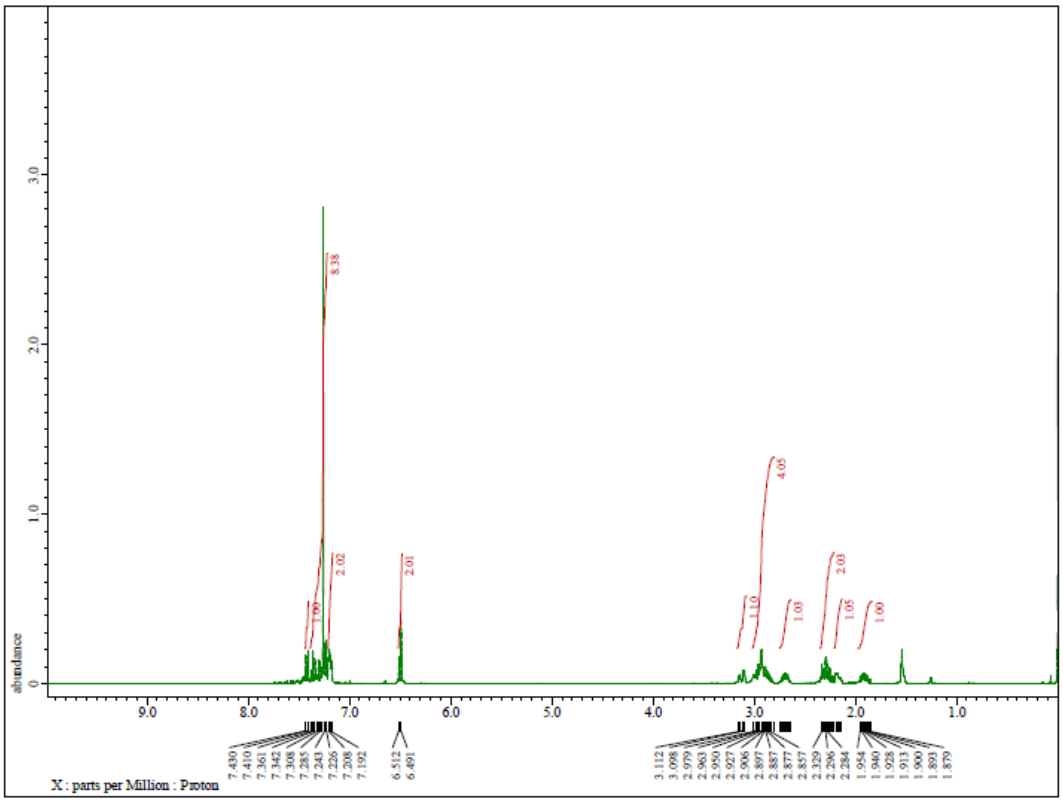
(**2r**, *syn*-isomer)

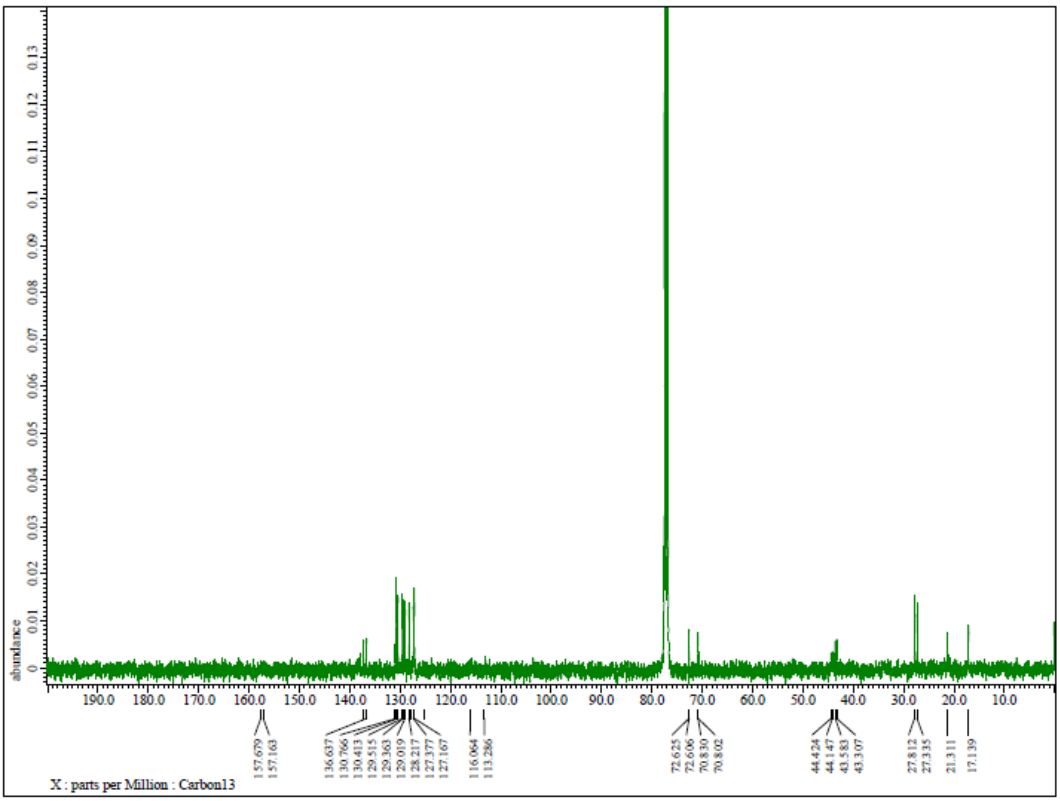


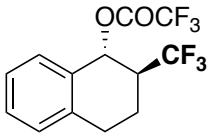




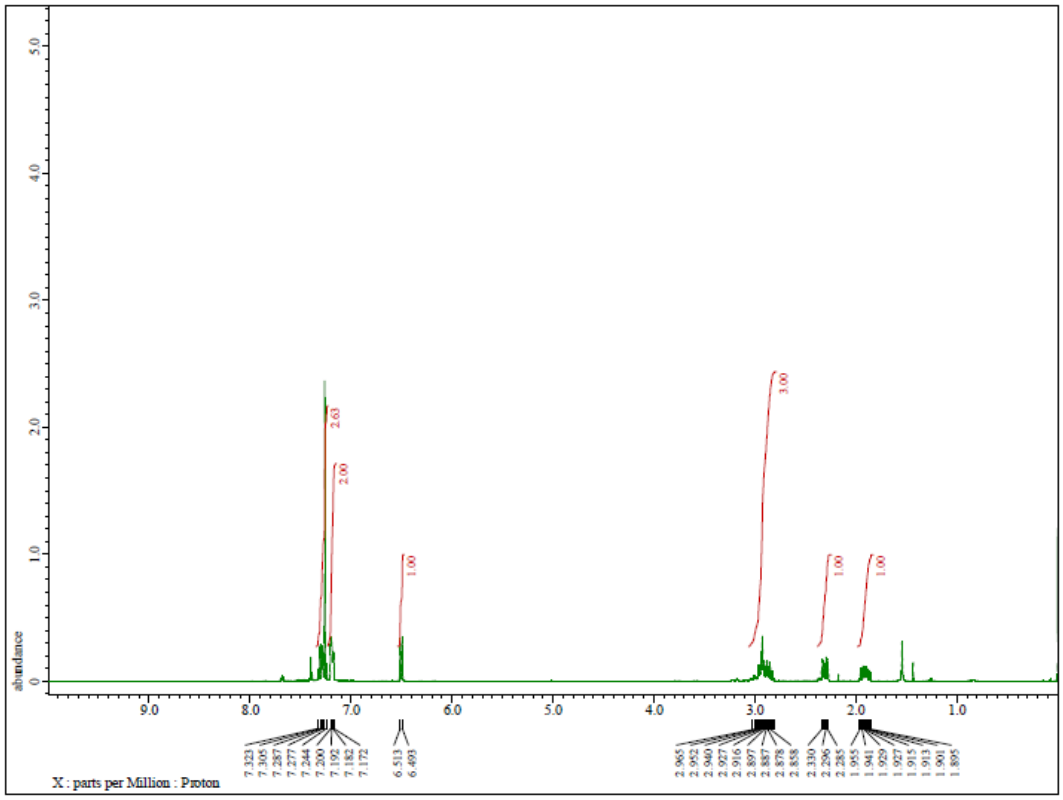
(**2s**, diastereomixture)

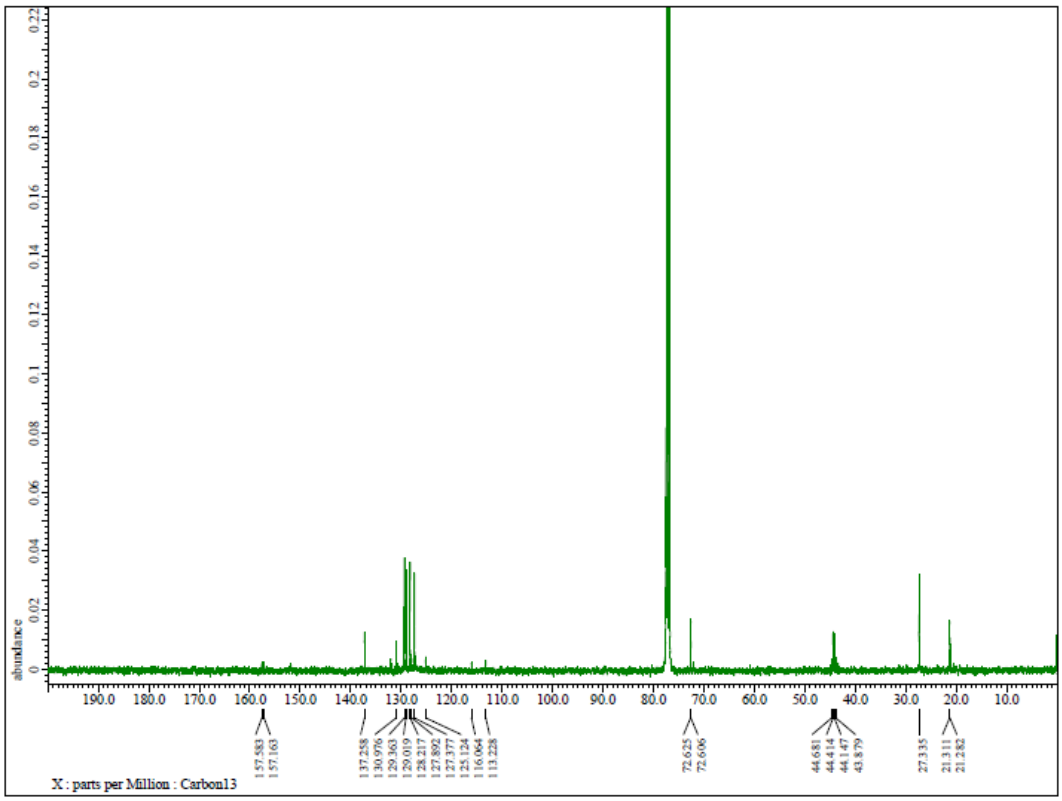


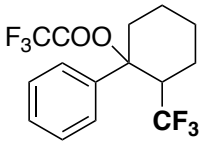




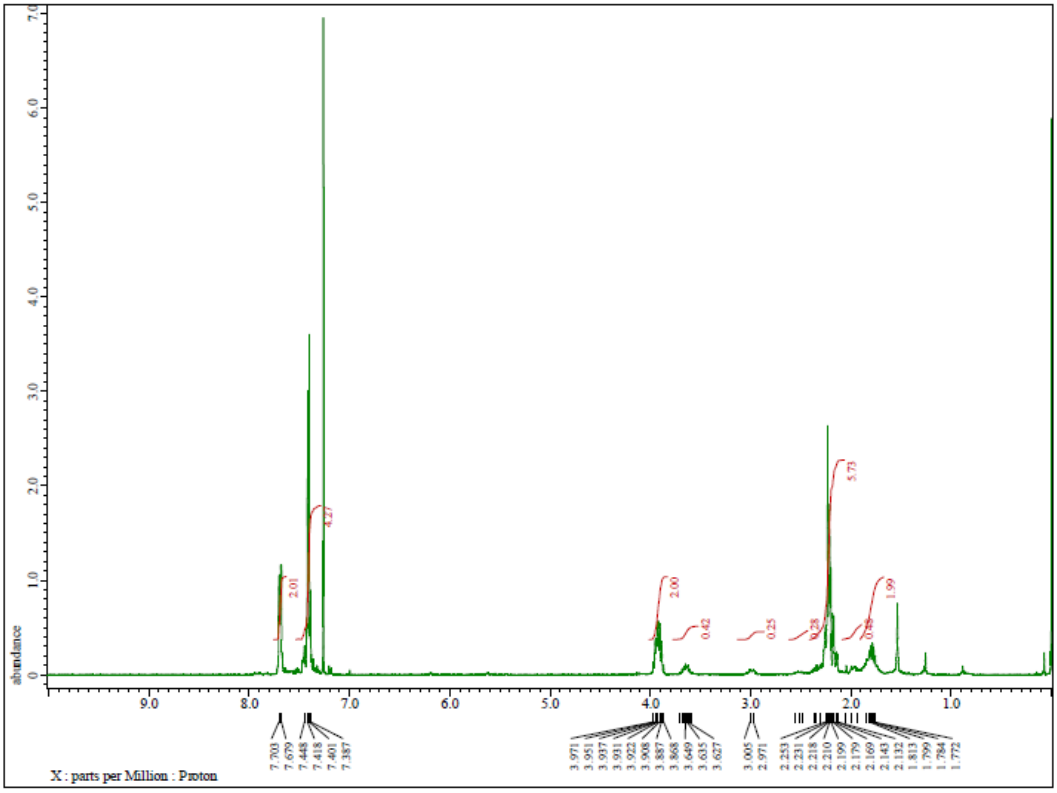
(**2s**, *anti*-isomer)

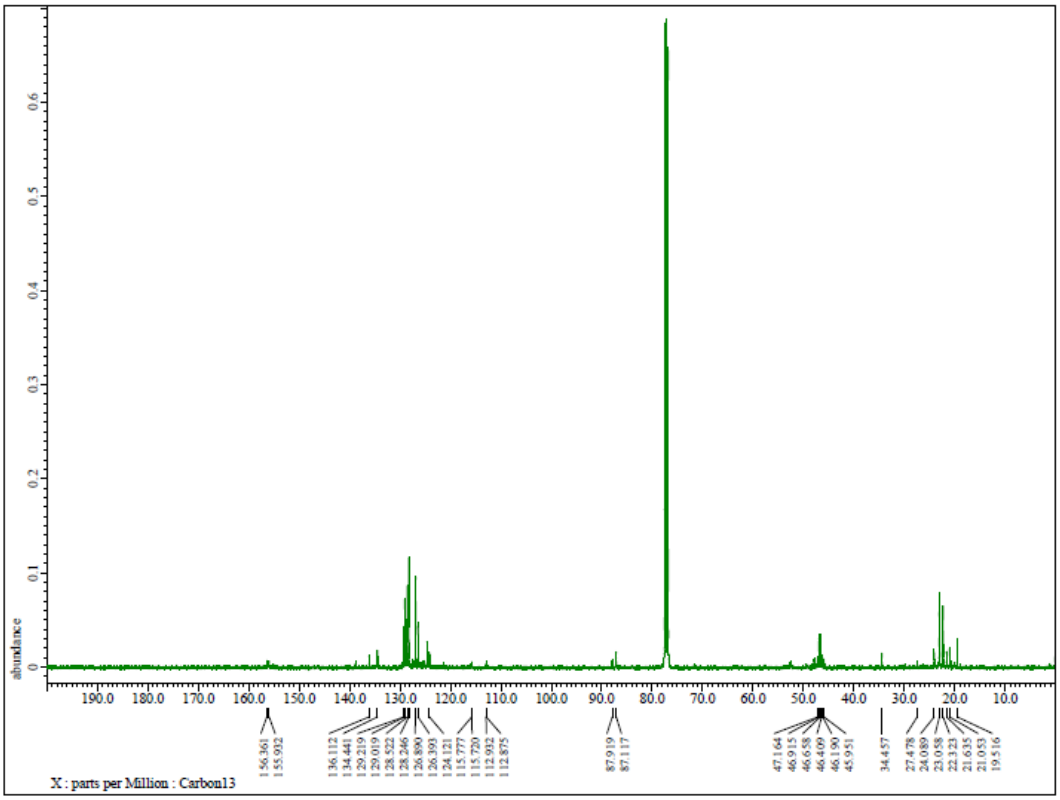


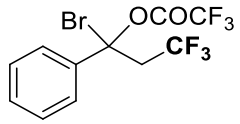



F3CCOO
CF3

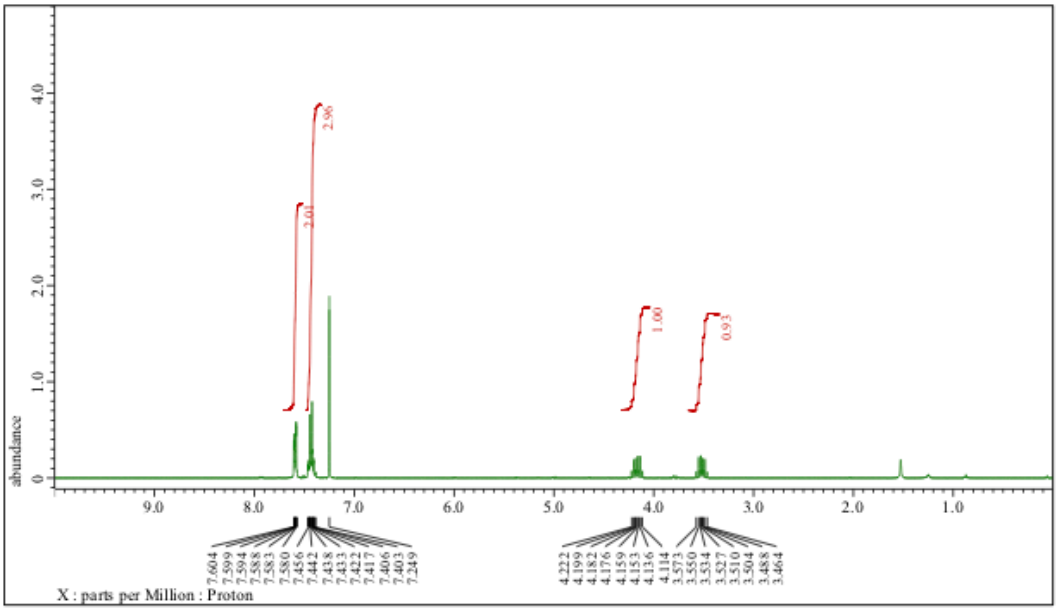
(**2t**)

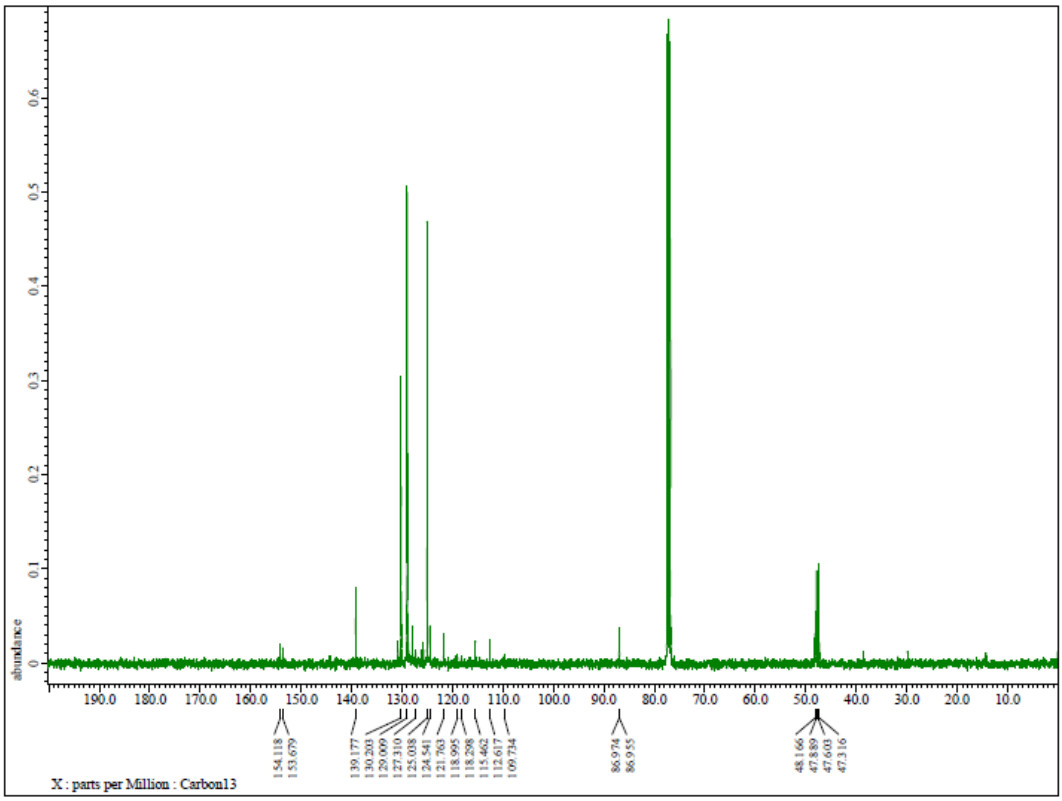

abundance
X : parts per Million : Proton

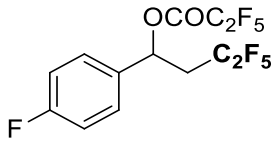

abundance
X : parts per Million : Carbon13


Br
OCOCF3
CF3

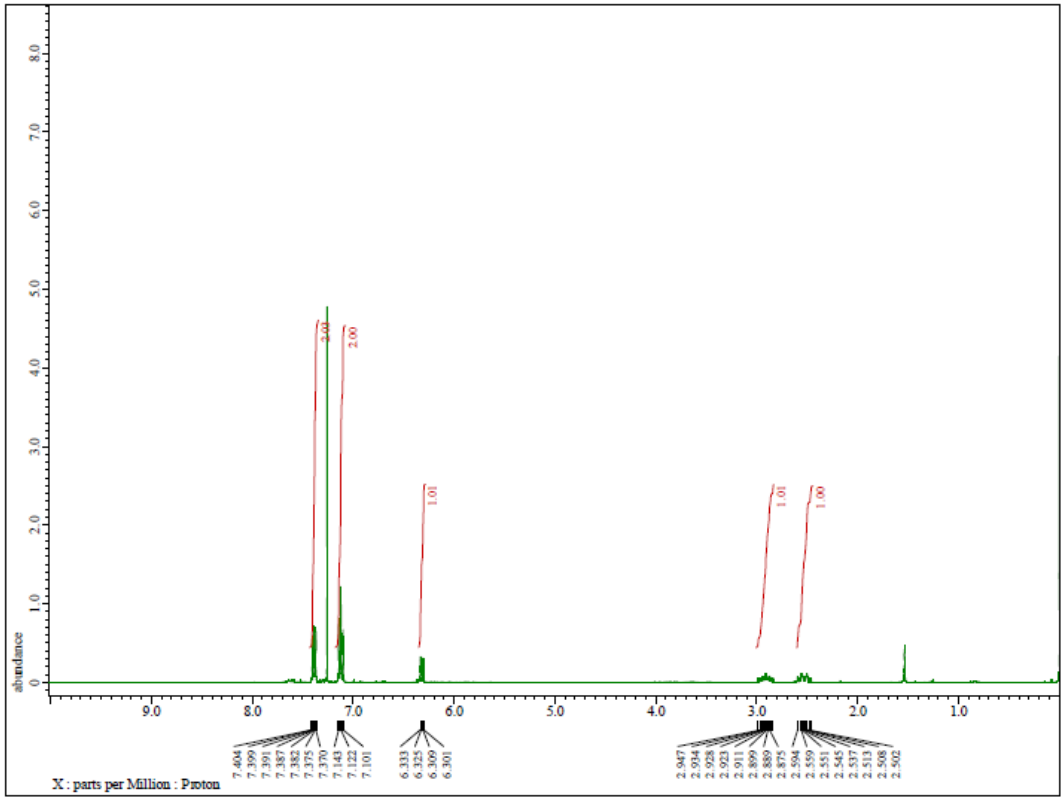
(**2u**)


abundance
2.96
2.03
1.00
0.93
X : parts per Million : Proton


abundance
X : parts per Million : Carbon13


OCOC2F5
C2F5
F

(**2b'**)


abundance
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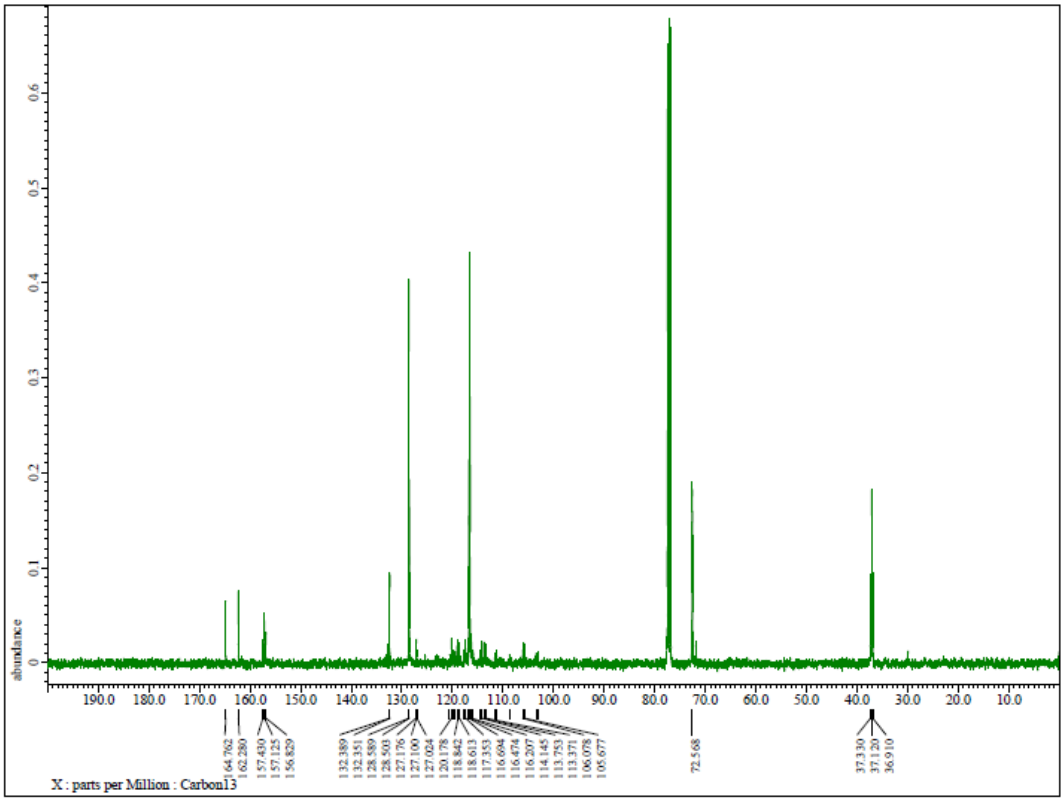
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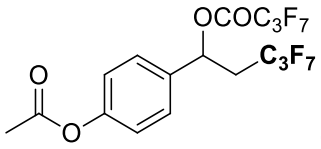
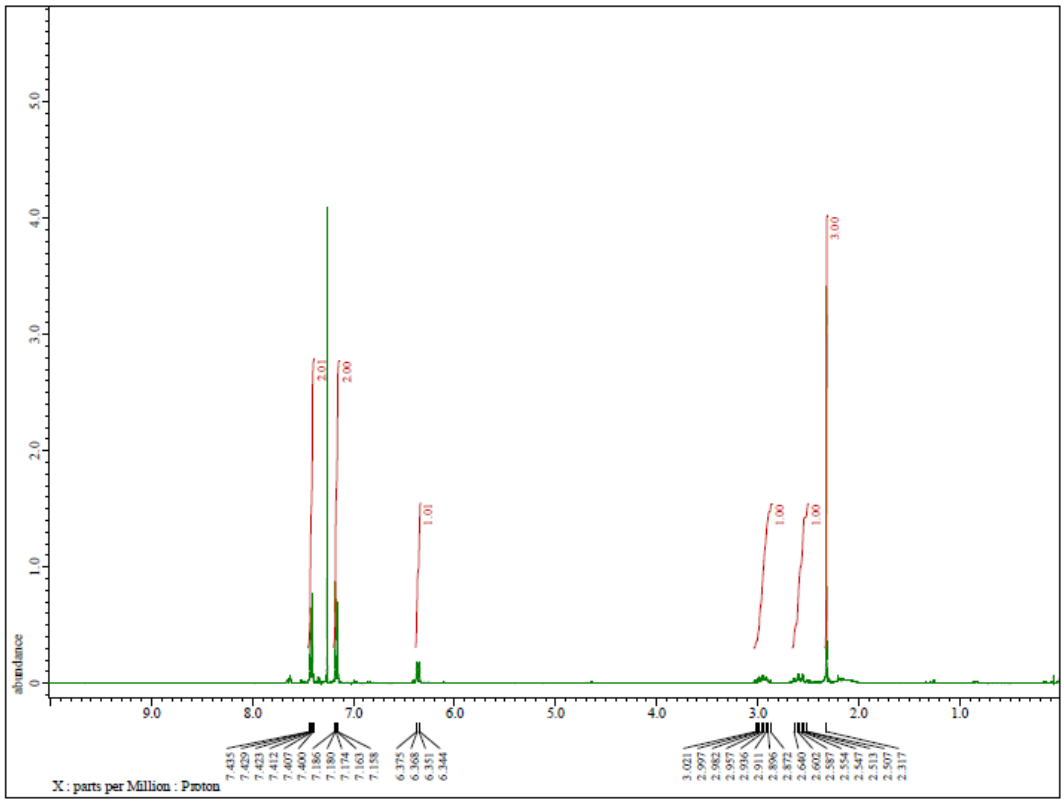
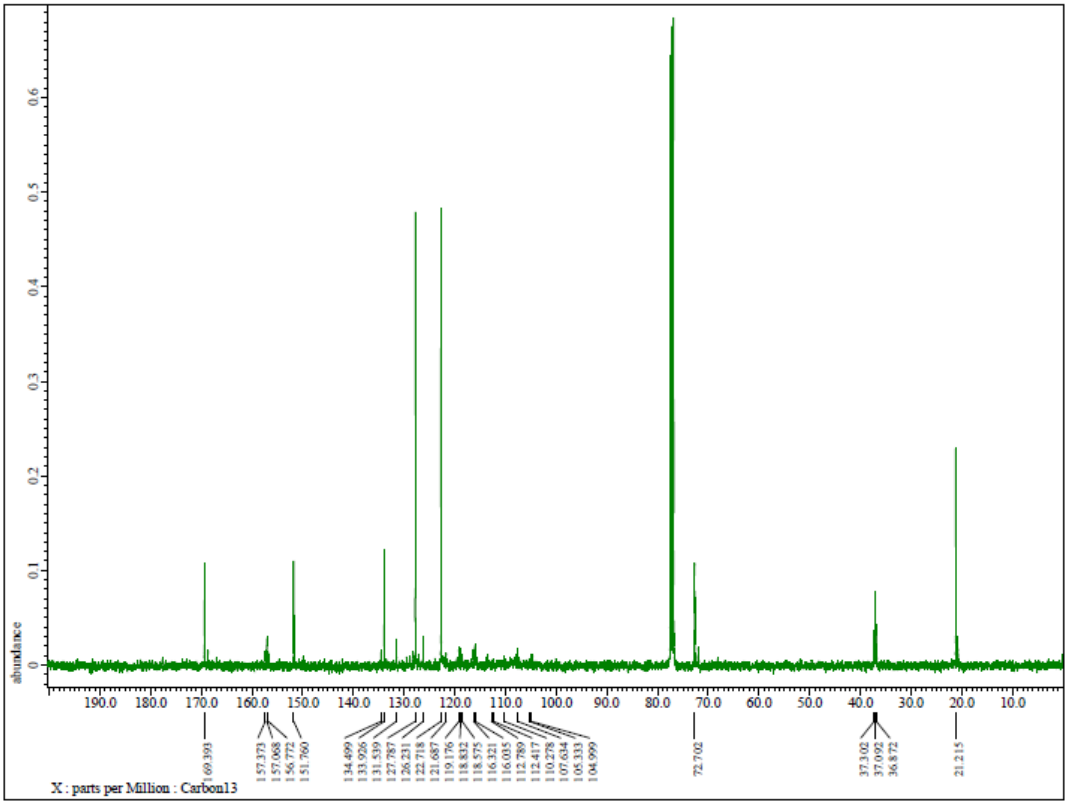

OCOC3F7
C3F7
O
O

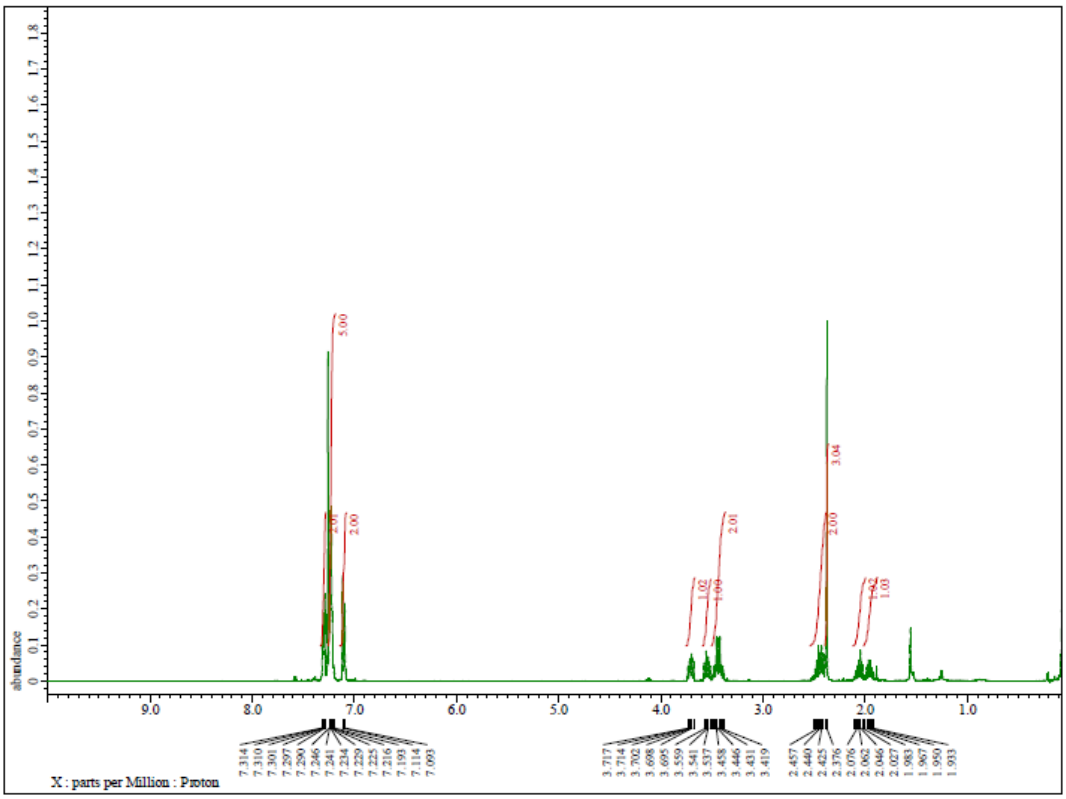
(**2d”**)

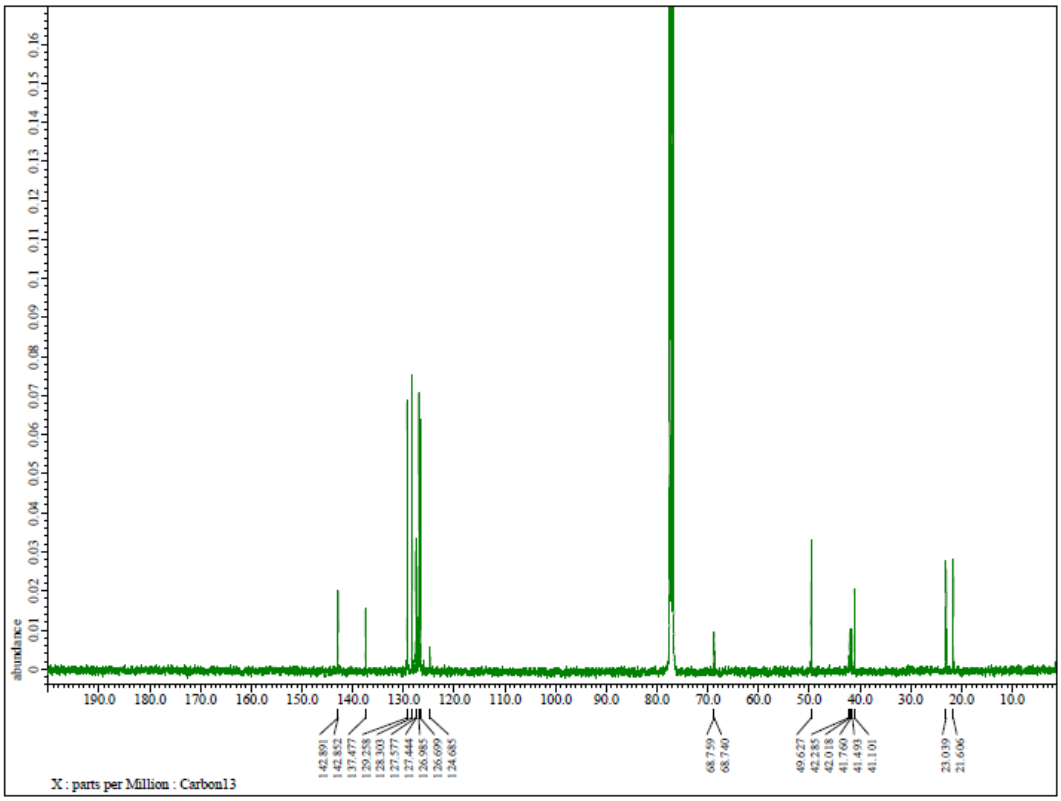

abundance
X : parts per Million : Proton


abundance
X : parts per Million : Carbon13


Ph
N
Ts
CF3

(4a)


abundance
X : parts per Million : Proton


abundance
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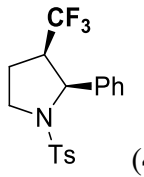
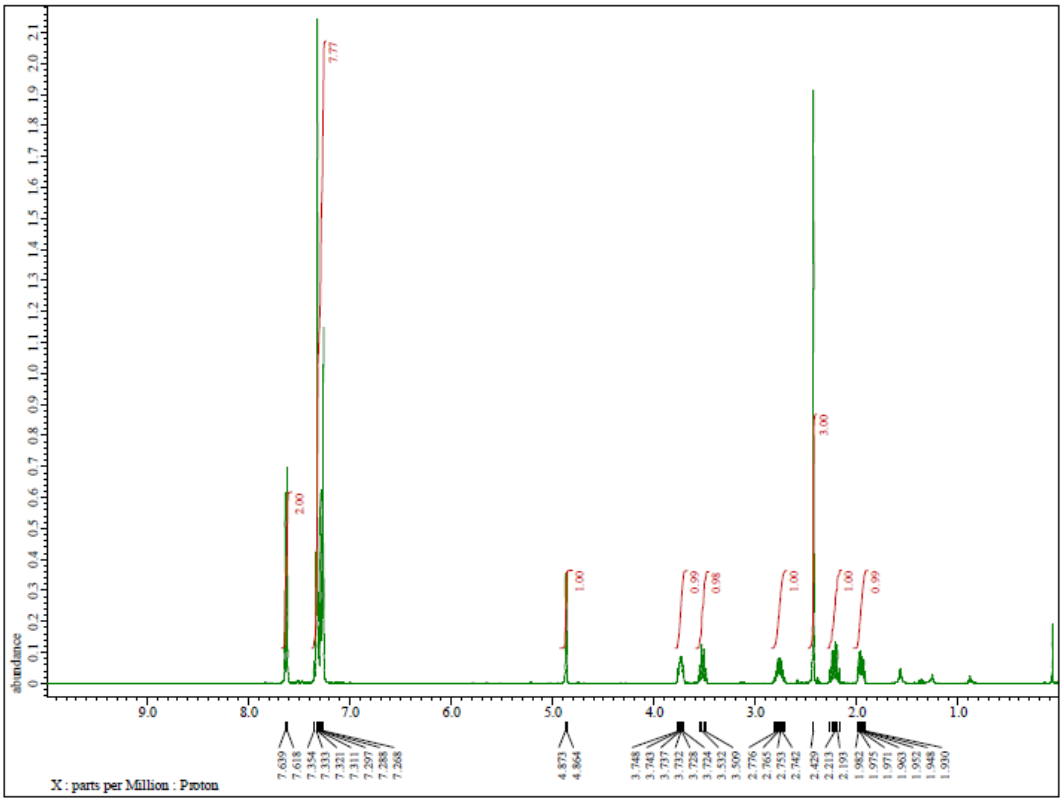

CF3
Ph
N
Ts

(**4b**)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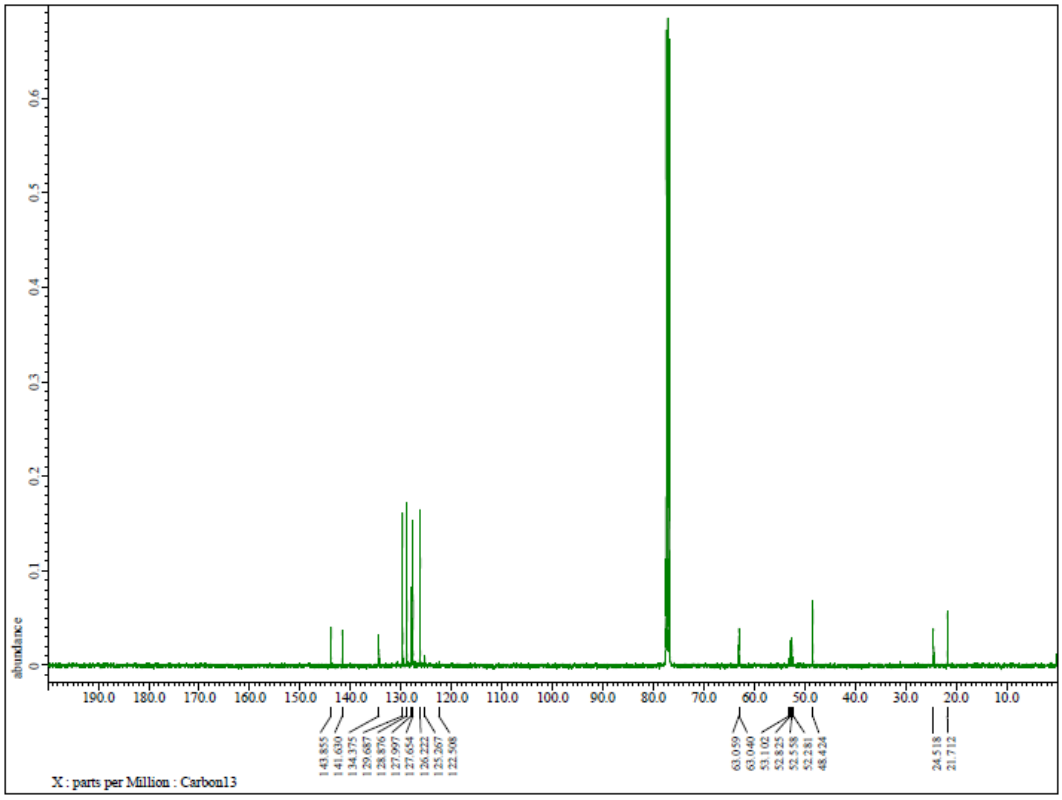
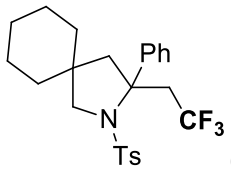
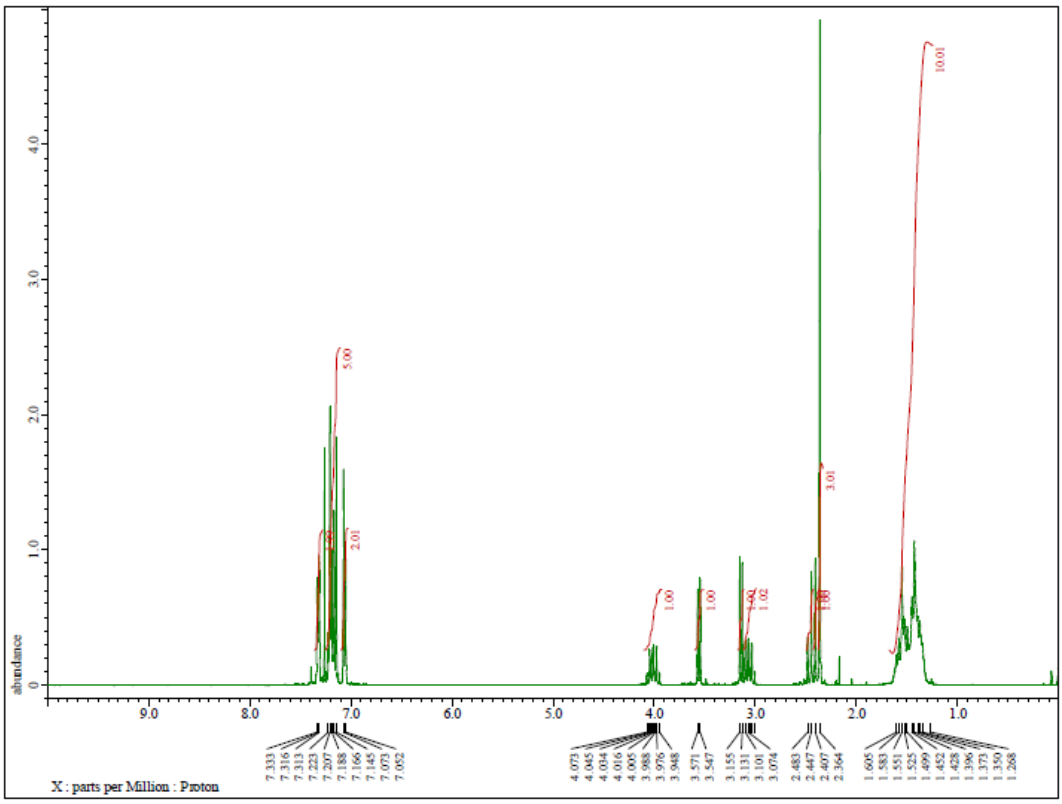
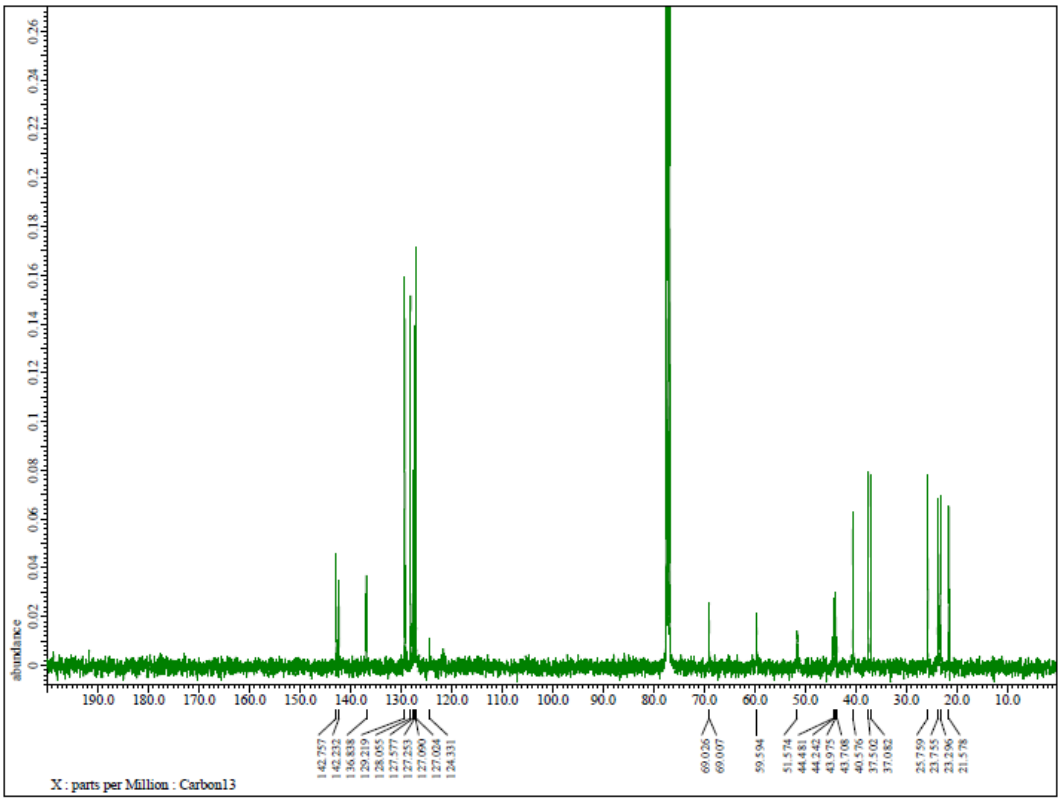
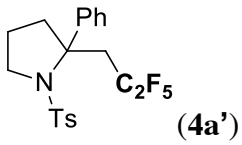

abundance
X : parts per Million : Carbon13


Ph
N
CF3
Ts

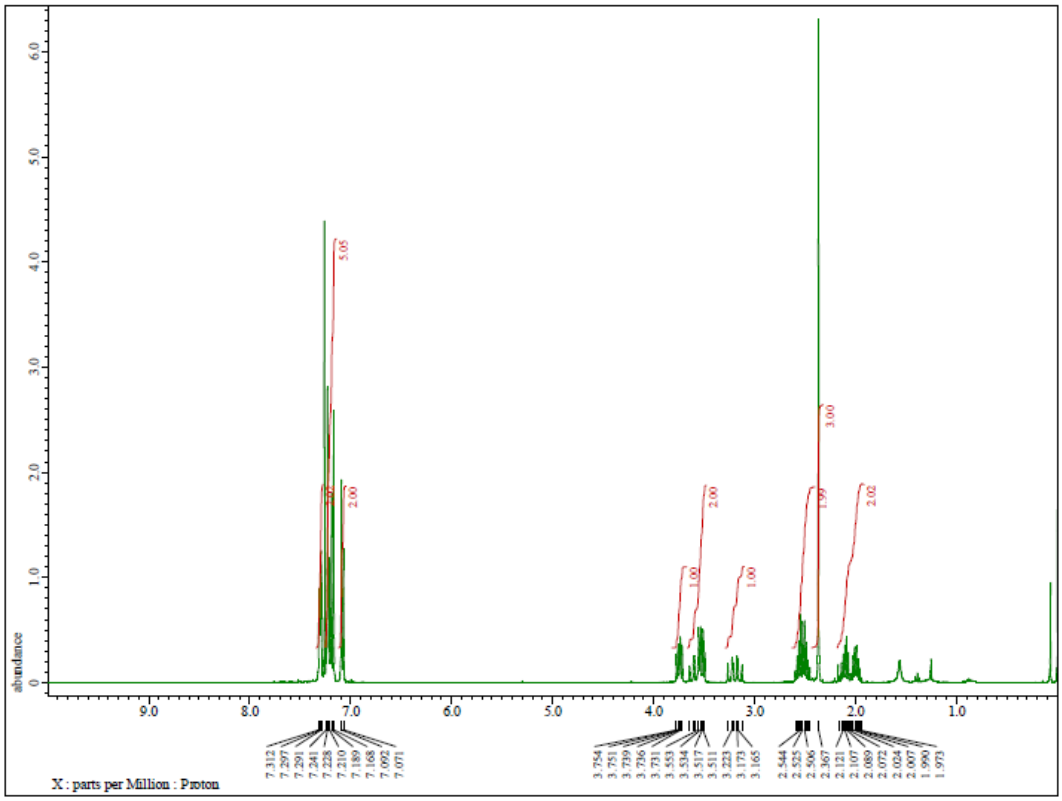
(**4c**)

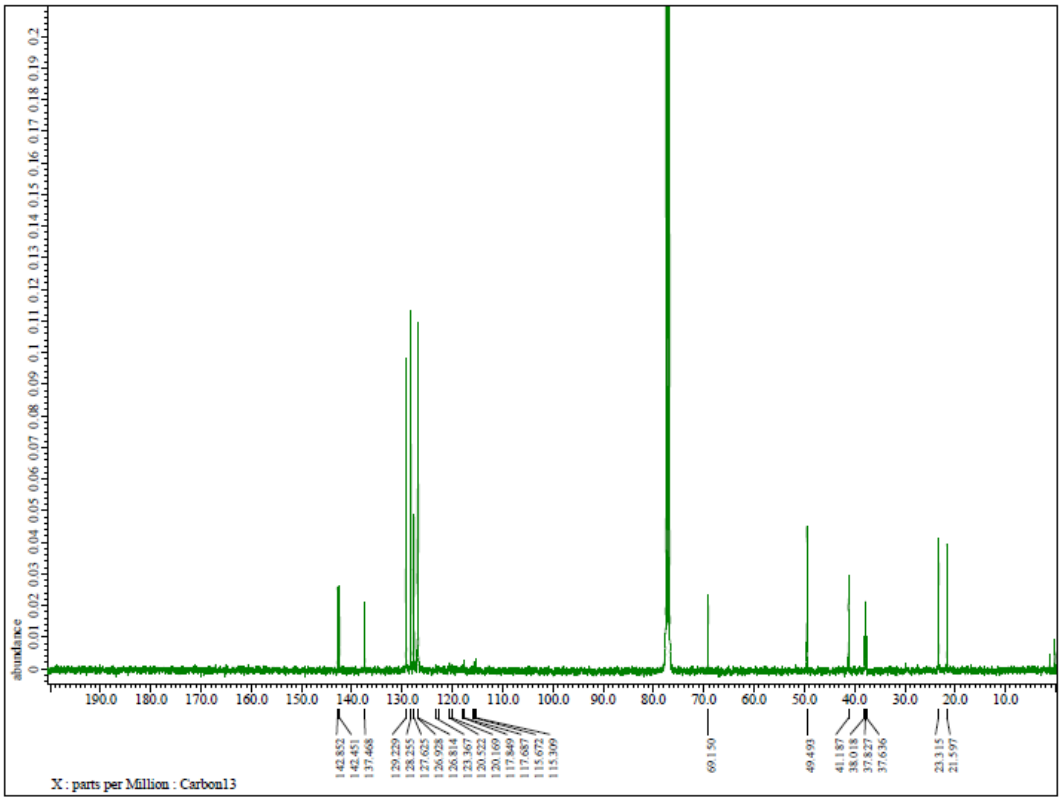

abundance
X : parts per Million : Proton

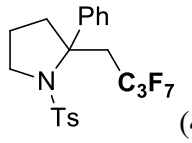

abundance
X : parts per Million : Carbon13


Ph
N
Ts
C_2F_5

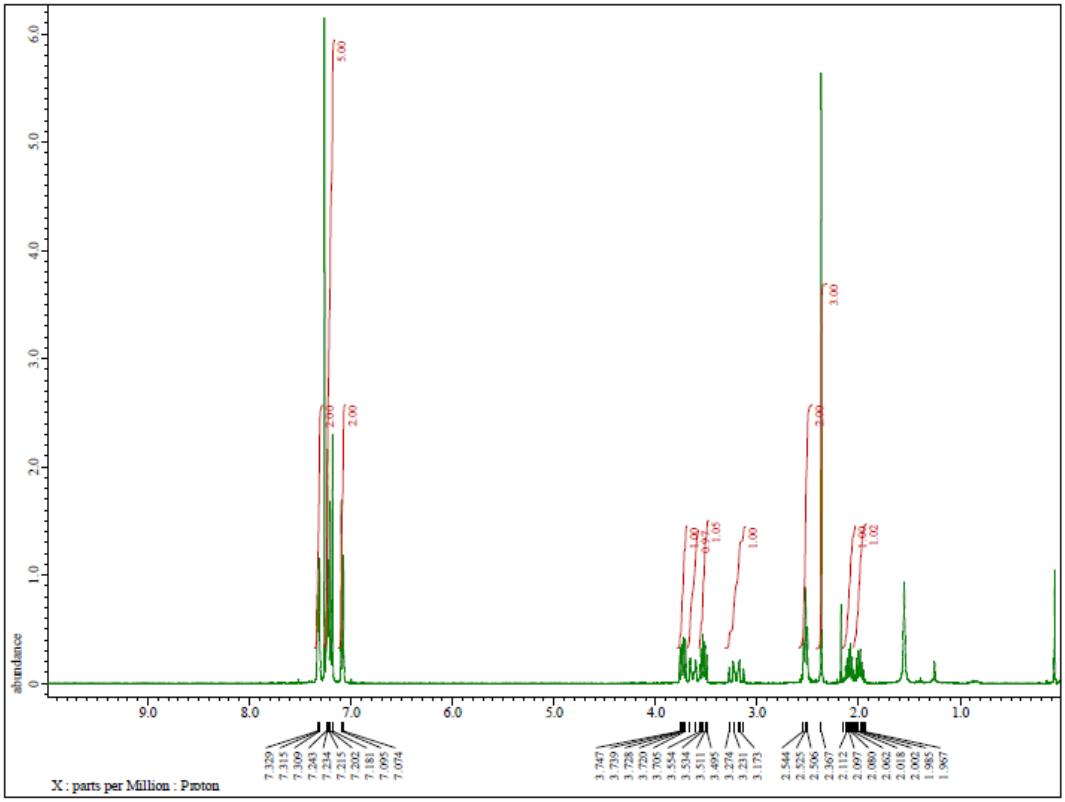
(4a')

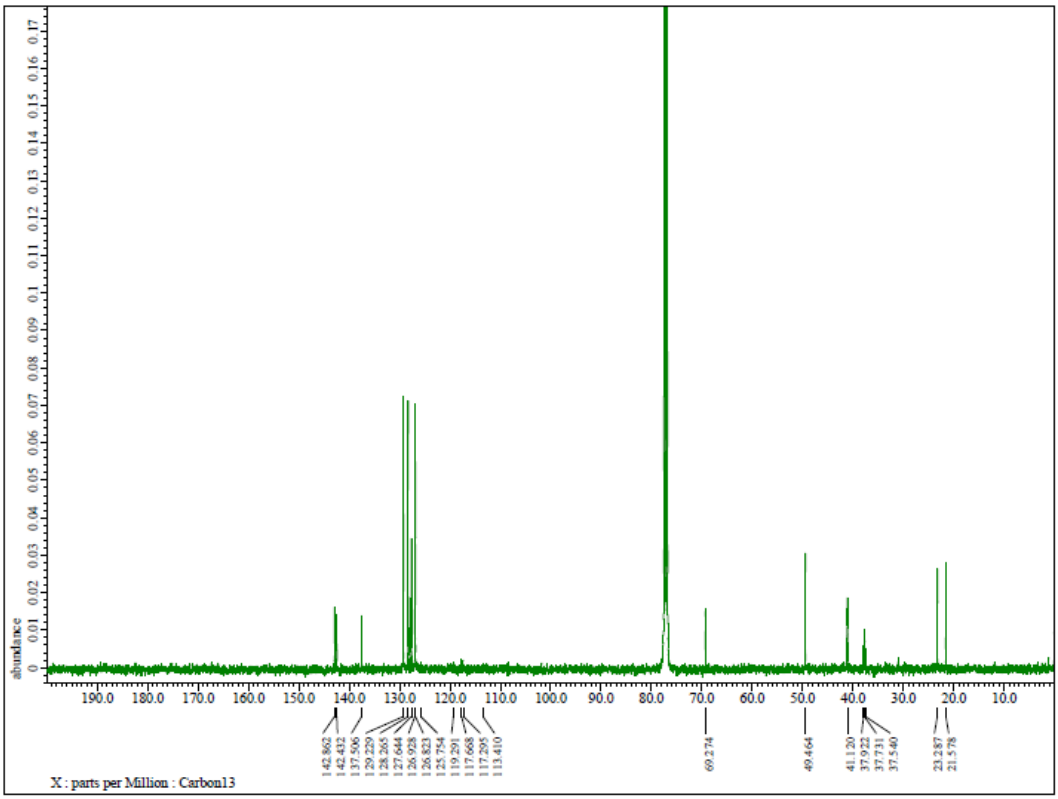

abundance
X : parts per Million : Proton

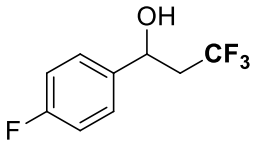

abundance
X : parts per Million : Carbon13


Ph
N
Ts
C_3F_7

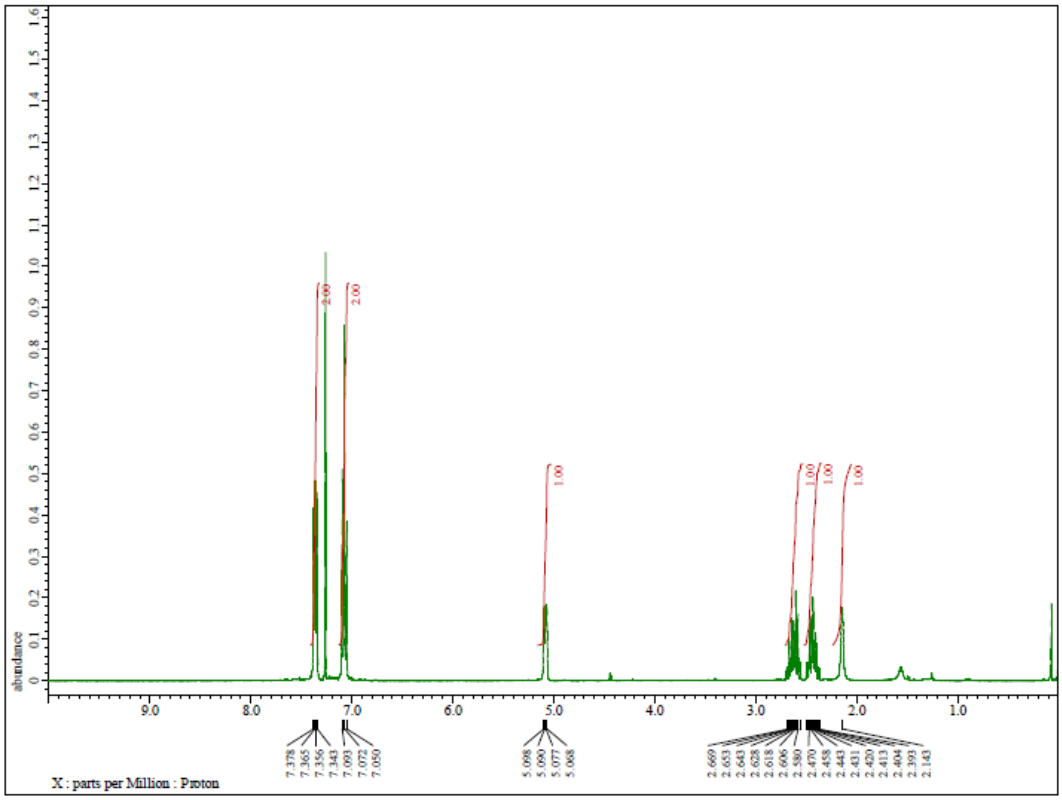
(4a")

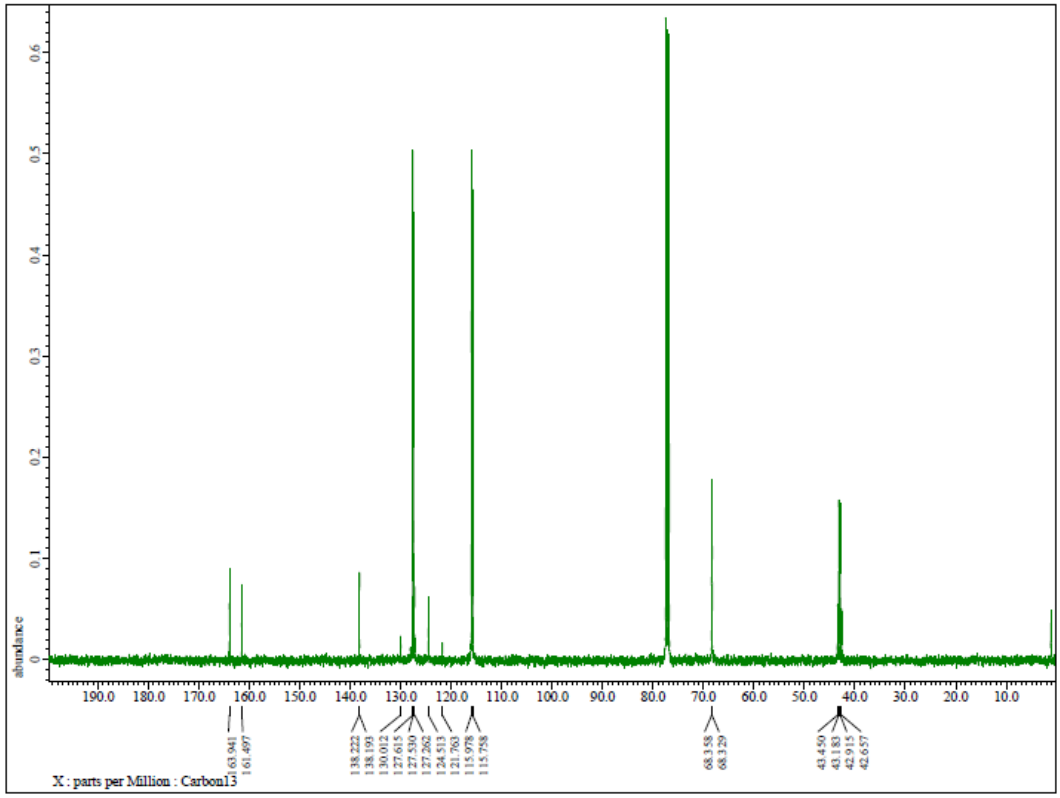

abundance
X : parts per Million : Proton

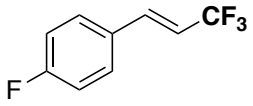

abundance
X : parts per Million : Carbon13


OH
CF3
F

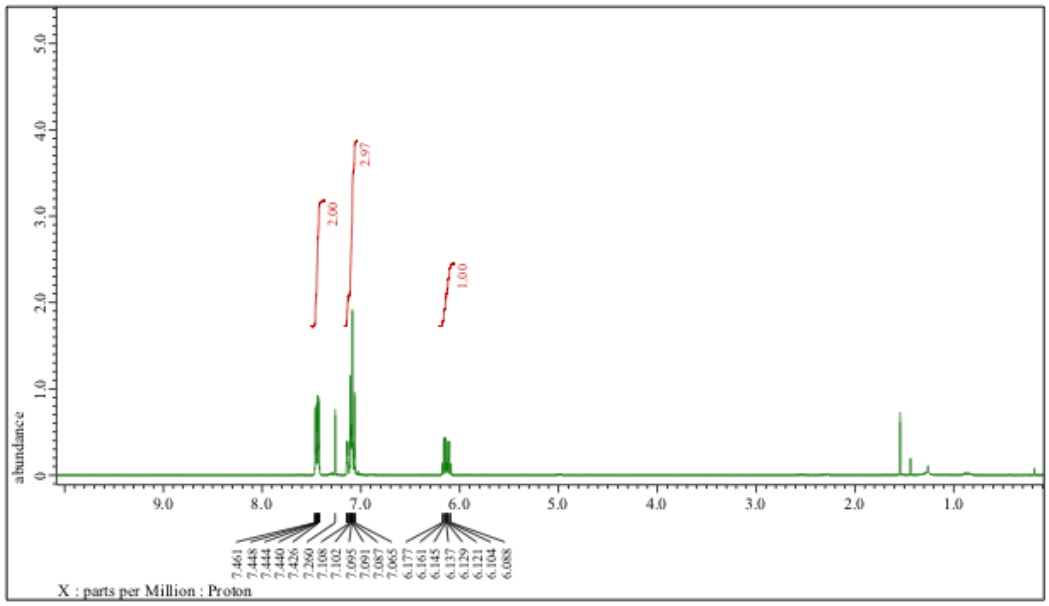
(**5b**)

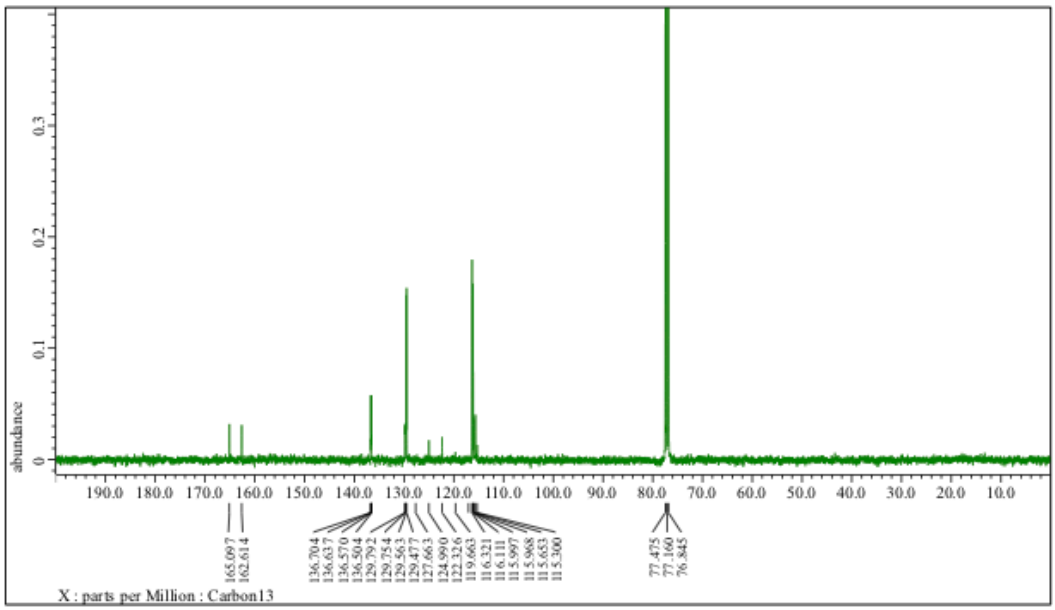

abundance
X : parts per Million : Proton

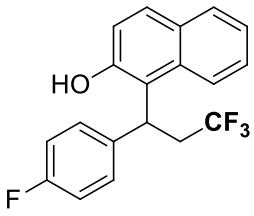

abundance
X : parts per Million : Carbon13


CF3
F

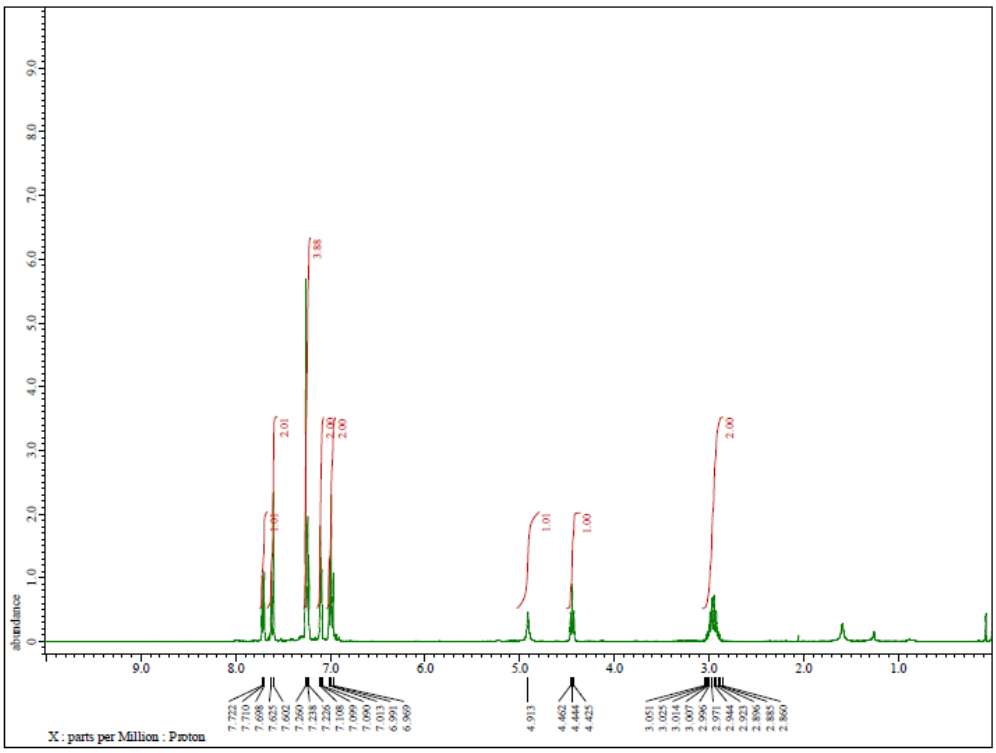
(**6b**)

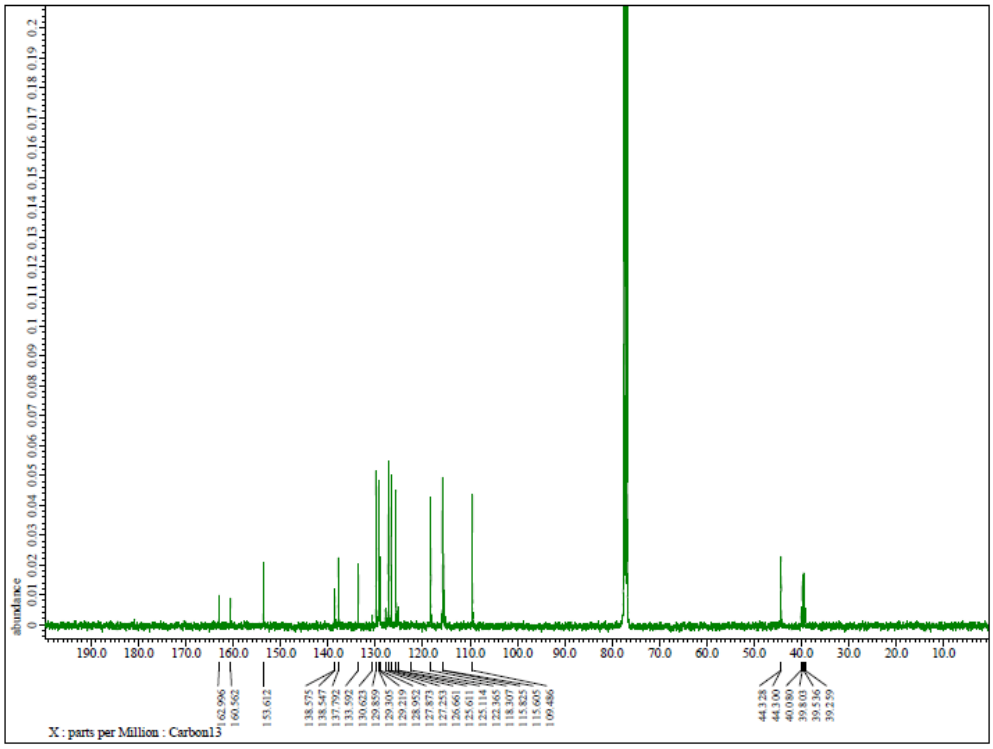

abundance
2.00
2.97
1.00
X : parts per Million : Proton

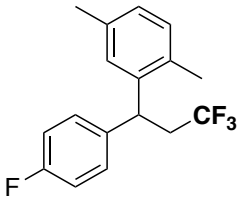

abundance
X : parts per Million : Carbon13


HO
CF3
F

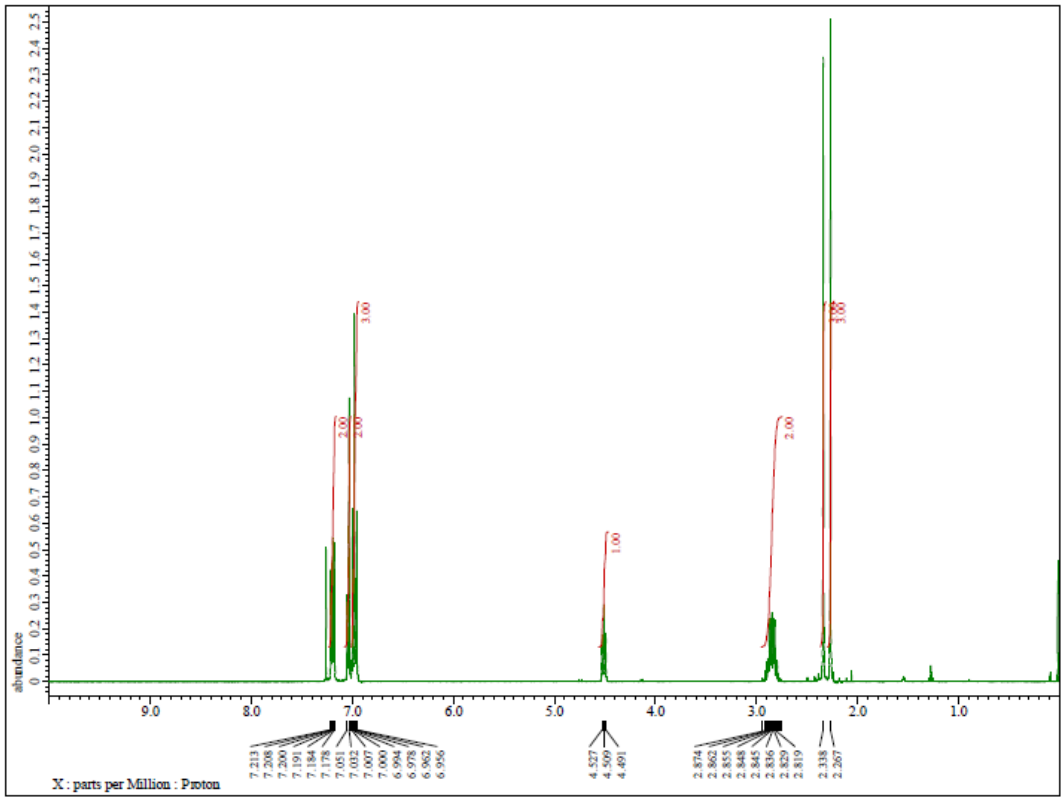
(**7b**)

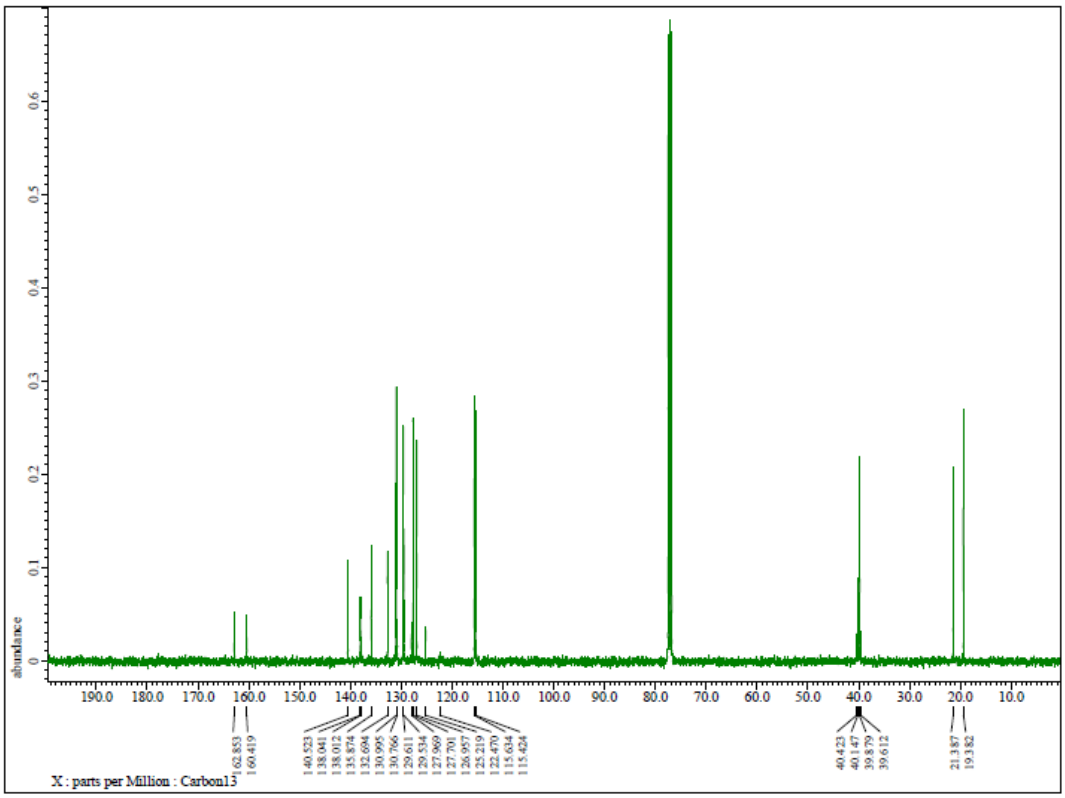

abundance
X : parts per Million : Proton

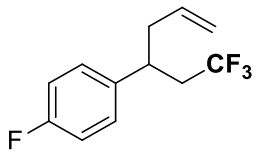

abundance
X : parts per Million : Carbon13


CF3
F

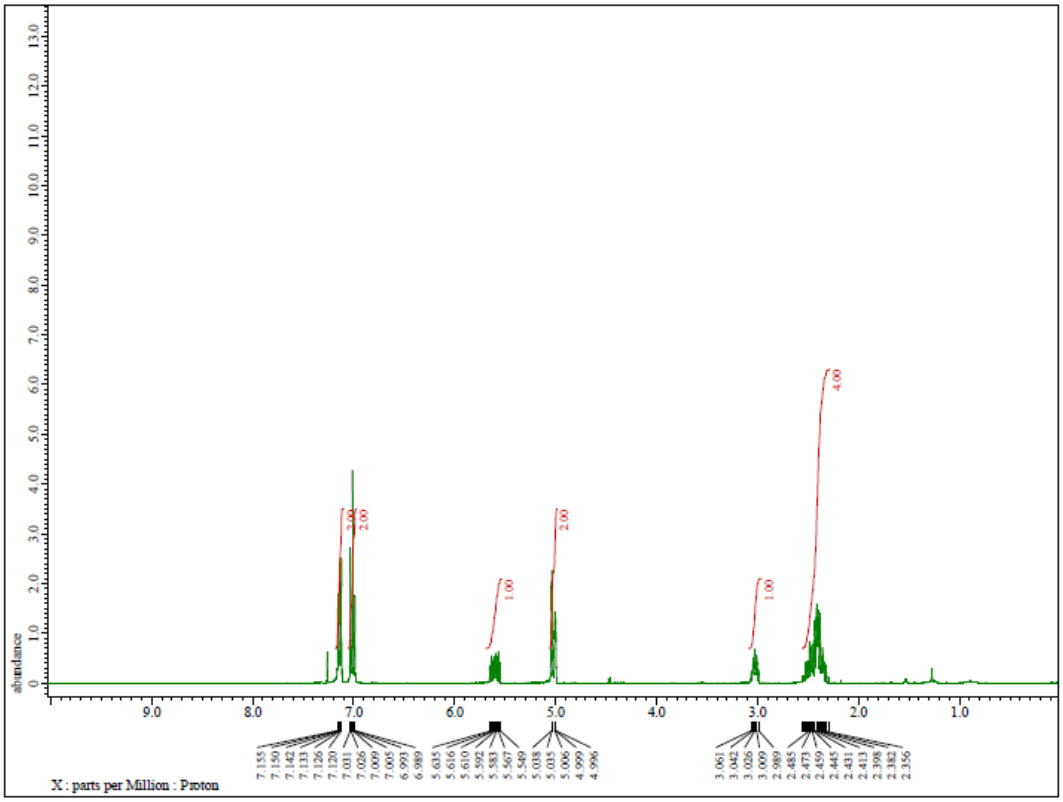
(**8b**)

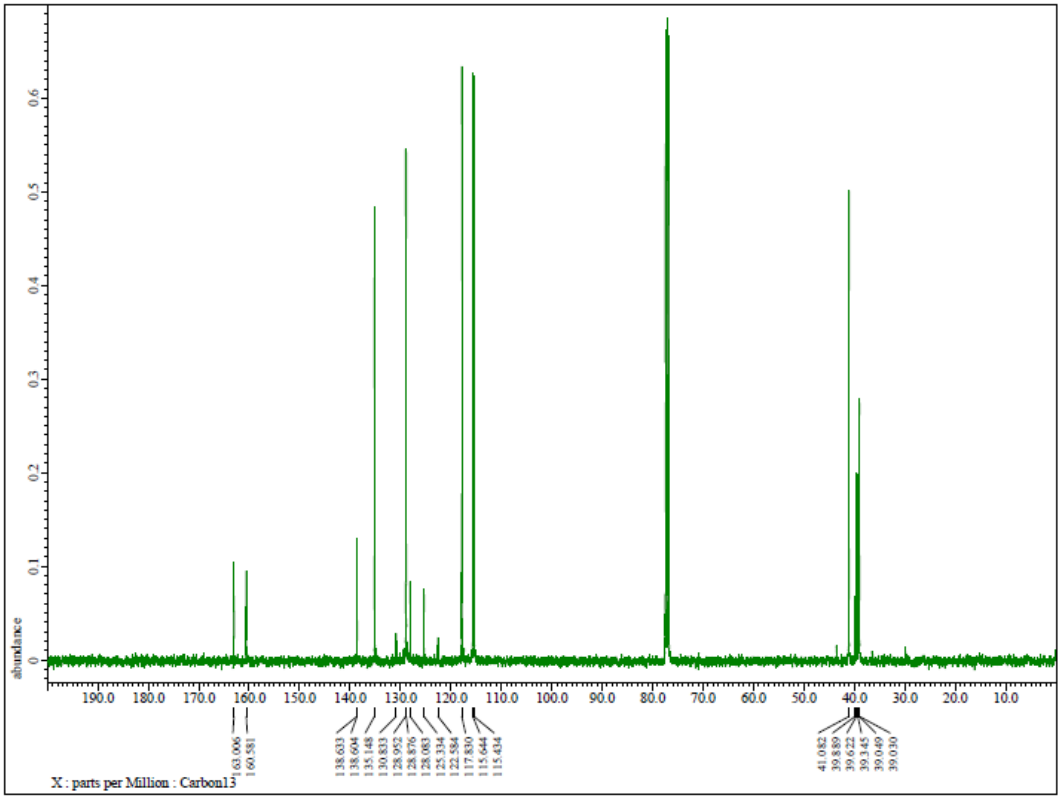

abundance
X : parts per Million : Proton

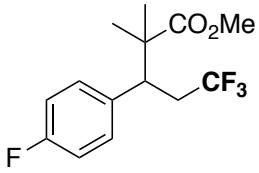

abundance
X : parts per Million : Carbon13


CF3
F

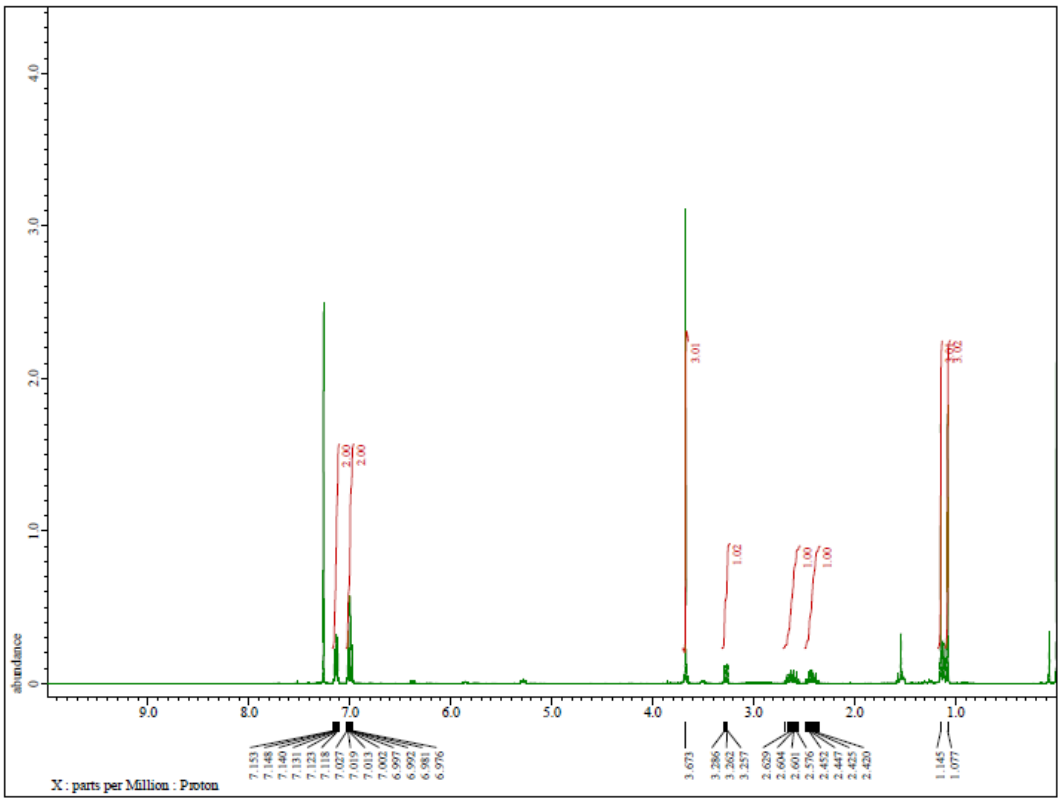
(**9b**)

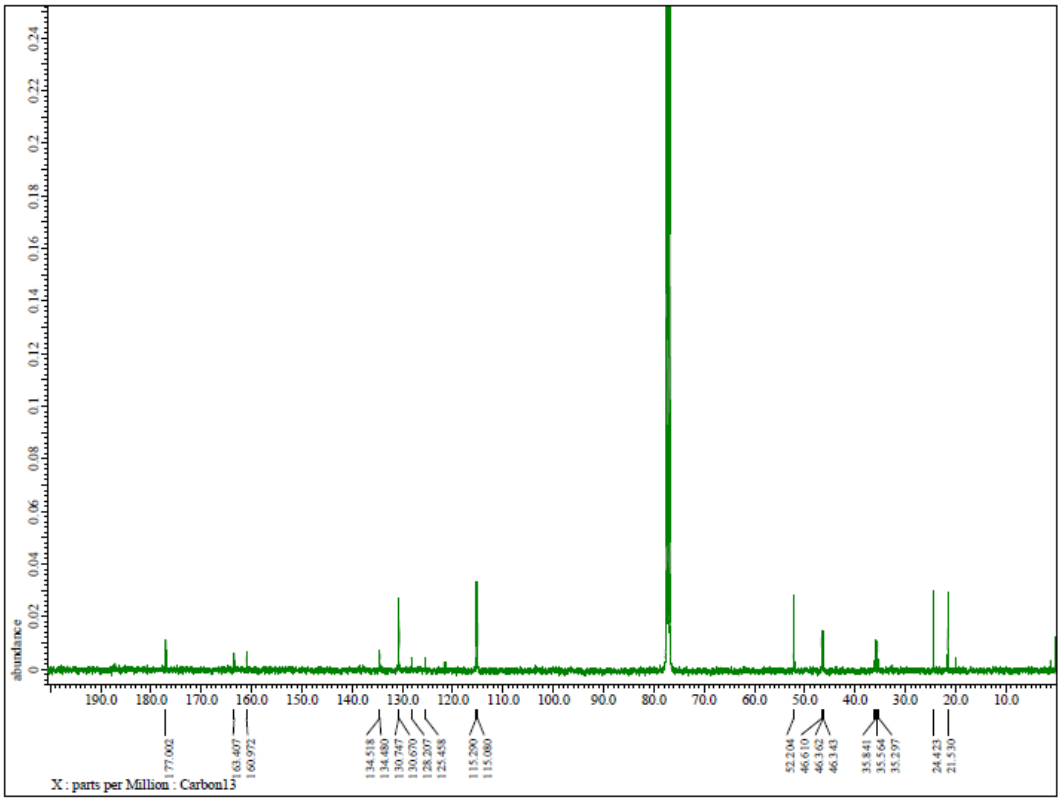

abundance
X : parts per Million : Proton

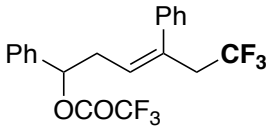

abundance
X : parts per Million : Carbon13


CO2Me
CF3
F

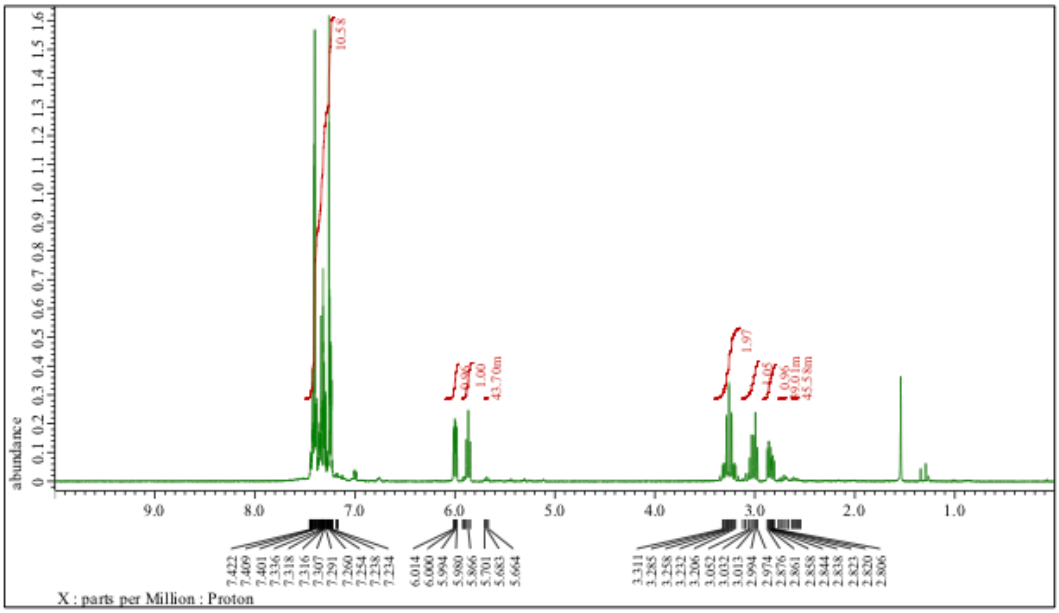
(**10b**)

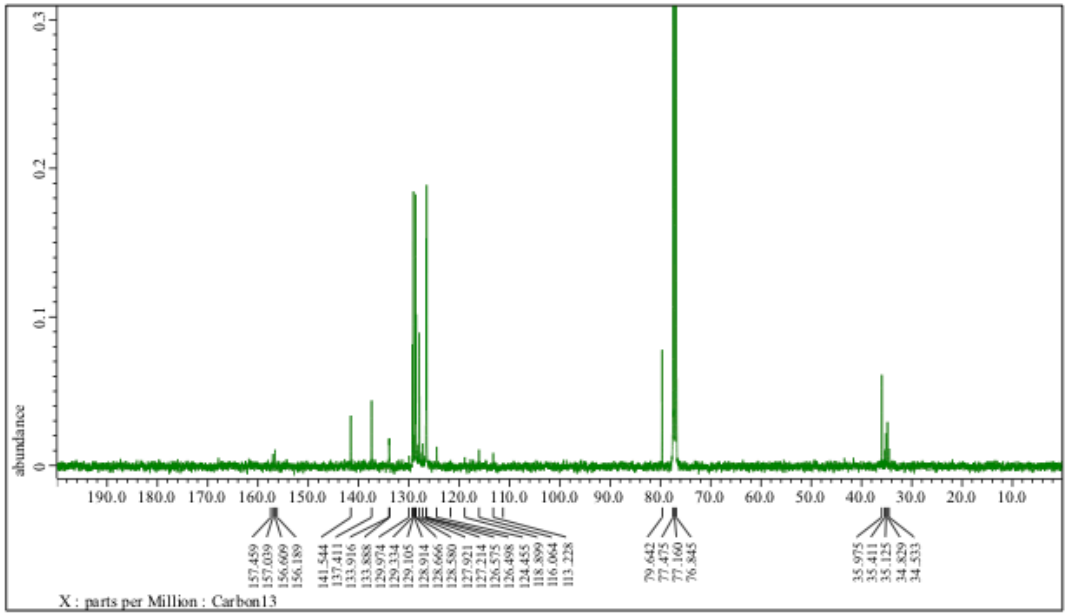

abundance
X : parts per Million : Proton


abundance
X : parts per Million : Carbon13


Ph
Ph
CF3
OCOCF3

(**13**)


abundance
X : parts per Million : Proton


abundance
X : parts per Million : Carbon13

5. Computational details:

DFT calculations were conducted with Gaussian 16 series[13] of programs. The structures were optimized at the UB3LYP level of theory, and 6-31+G(d,p) basis set was used. The single-point energy calculation was performed using UMPWB1K/6-311+G(2df,2p), except that LanL2DZ was used for Cu. The CPCM solvation model (dichloromethane) was used to reflect the solvent effect. The free energies described in this work were estimated from the ZPEs from UMPWB1K with thermal corrections by using vibrational analysis at the UB3LYP level of theory. No imaginary frequencies for intermediates and one imaginary frequency for the transition state were observed. The reaction pathway from the transition state was confirmed by IRC calculation and the vibration mode of the imaginary frequency. DFT calculations were conducted according to the literature procedure reported by Houk and Buchwald.[15] The activation energy ($\Delta G^{\ddagger}$) of SET was estimated according to the Marcus equation with parameters as shown in Scheme S1 (n = 1.424, ε= 8.93 for CH_2Cl_2).

$$\Delta^{\ddagger}G = \left(\lambda/4\right)\left(1 + \Delta G/\lambda\right)^2$$

$$\lambda \approx 332 \times \left(\frac{1}{2r_A} + \frac{1}{2r_B} - \frac{1}{R}\right)\left(\frac{1}{n^2} - \frac{1}{\varepsilon}\right)$$; reorganization energy (kcal/mol)

ΔG; reaction energy (kcal/mol)

r; radius of molecules (Å)

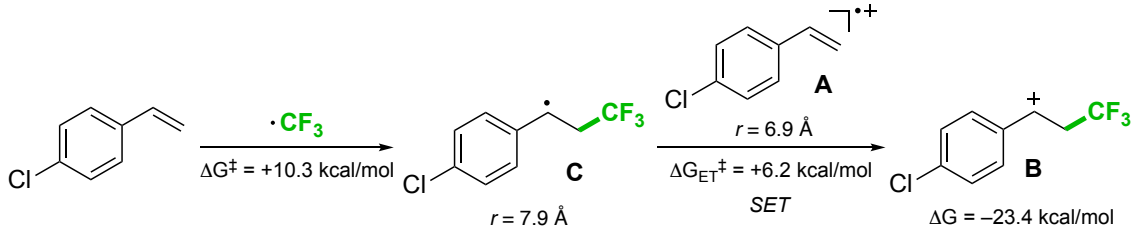
$R = r_A + r_B$ (Å)

n; index of refraction

ε; dielectric constant

[13]M. J. Frisch, G. W. Trucks, H. B. Schlegel, G. E. Scuseria, M. A. Robb, J. R. Cheeseman, G. Scalmani, V. Barone, B. Mennucci, G. A. Petersson, H. Nakatsuji, M. Caricato, X. Li, H. P. Hratchian, A. F. Izmaylov, J. Bloino, G. Zheng, J. L. Sonnenberg, M. Hada, M. Ehara, K. Toyota, R. Fukuda, J. Hasegawa, M. Ishida, T. Nakajima, Y. Honda, O. Kitao, H. Nakai, T. Vreven, J. A. Montgomery, Jr., J. E. Peralta, F. Ogliaro, M. Bearpark, J. J. Heyd, E. Brothers, K. N. Kudin, V. N. Staroverov, R. Kobayashi, J. Normand, K. Raghavachari, A. Rendell, J. C. Burant, S. S. Iyengar, J. Tomasi, M. Cossi, N. Rega, J. M. Millam, M. Klene, J. E. Knox, J. B. Cross, V. Bakken, C. Adamo, J. Jaramillo, R. Gomperts, R. E. Stratmann, O. Yazyev, A. J. Austin, R. Cammi, C. Pomelli, J. W. Ochterski, R. L. Martin, K. Morokuma, V. G. Zakrzewski, G. A. Voth, P. Salvador, J. J. Dannenberg, S. Dapprich, A. D. Daniels, O. Farkas, J. B. Foresman, J. V. Ortiz, J. Cioslowski, and D. J. Fox, *Gaussian 09,* Revision A.02; Gaussian, Inc.: Wallingford CT, 2009.

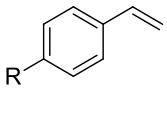
[15]G. O. Jones, P. Liu, K. N. Houk, S. L. Buchwald, *J. Am. Chem. Soc.* **2010**, *132*, 6205.



Scheme S1. Estimation of activation energies of pathway b

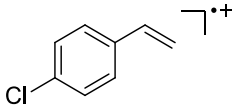
HOMO and LUMO levels

Table S2. HOMO levels of styrenes



R	HOMO (eV)
OMe	-5.90
Me	-6.20
Cl	-6.41
CF_3	-6.74
Benzene	-7.90

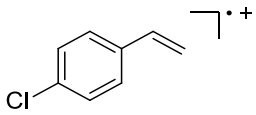
Table S3. LUMO levels of potential oxidants

Oxidant	LUMO (eV)
BTFAP	-2.35
	-6.26
$Cu^{II}(O_2CCF_3)_2$	-5.09

Cartesian coordinates and energies

E (UMPWB1K) = -337.5780555
Sum electronic and thermal free energies = -337.5930245
Charge = 0 Multiplicity = 2

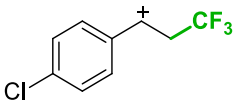
C	0.00027	0.00002	0.32655
F	-0.97128	0.80219	-0.07254
F	-0.20919	-1.24218	-0.07256
F	1.18029	0.43998	-0.0726



A

E (UMPWB1K) = -769.0158561
Sum electronic and thermal free energies = -768.9261741
Charge = 1 Multiplicity = 2

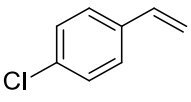
C	1.42252	0.23852	0.00001
C	0.57961	1.39434	0.
C	-0.78631	1.27451	0.
C	-1.3553	-0.01927	0.
C	-0.55418	-1.18497	0.00001
C	0.80961	-1.0561	0.00002
H	1.03617	2.3765	-0.00001
H	-1.42954	2.14396	-0.00001
H	-1.02559	-2.15832	0.00001
H	1.4217	-1.9473	0.00002
C	2.83359	0.43103	0.00001
H	3.1796	1.45969	0.00005
C	3.77812	-0.56229	-0.00003
H	3.52819	-1.61556	-0.00006
H	4.83112	-0.31	-0.00001
Cl	-3.05339	-0.17904	-0.00001



B

E (UMPWB1K) = -1106.7106645
Sum electronic and thermal free energies = -1106.609694
Charge = 1 Multiplicity = 1

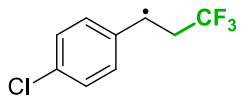
C	-0.29953	0.30696	-0.27609
C	-1.17376	1.4372	-0.11899
C	-2.52621	1.26734	0.02967
C	-3.04496	-0.04189	0.02514
C	-2.22233	-1.18008	-0.12686
C	-0.87142	-1.01036	-0.2733
H	-0.748	2.43311	-0.11909
H	-3.19105	2.1113	0.1505
H	-2.66637	-2.16586	-0.12209
H	-0.23909	-1.88042	-0.38431
C	2.12478	-0.44394	-0.65391
H	2.38109	-0.3976	-1.72298
H	1.84108	-1.46965	-0.42615
C	3.40535	-0.11391	0.11101
F	3.20734	-0.15482	1.44154
F	4.36873	-0.9964	-0.18483
F	3.86597	1.11412	-0.18731
C	1.04941	0.54931	-0.42355
H	1.36743	1.58918	-0.40279
Cl	-4.72774	-0.26529	0.21433



E (UMPWB1K) = -769.2528712

Sum electronic and thermal free energies =
-769.1628782
Charge = 0 Multiplicity = 1

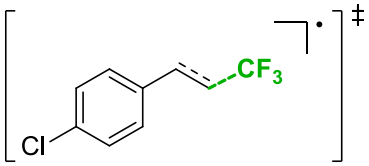
C	1.43138	0.2244	0.
C	0.60427	1.35892	-0.00001
C	-0.7848	1.25226	0.
C	-1.36045	-0.01378	0.
C	-0.57187	-1.16404	-0.00001
C	0.81241	-1.03787	0.
H	1.05481	2.34574	-0.00001
H	-1.40707	2.13801	0.00001
H	-1.0352	-2.14251	0.
H	1.41268	-1.93972	0.
C	2.89089	0.40833	0.
H	3.2127	1.4475	0.
C	3.83258	-0.54305	0.00001
H	3.60103	-1.60251	0.00001
H	4.88375	-0.28021	0.00001
Cl	-3.10878	-0.16926	0.



C

E (UMPWB1K) = -1106.9066534
Sum electronic and thermal free energies =
-1106.809183
Charge = 0 Multiplicity = 2

C	-0.32724	0.29685	-0.08624
C	-1.21224	1.41426	-0.04175
C	-2.58472	1.25326	0.00583
C	-3.12201	-0.03893	0.00909
C	-2.29462	-1.16413	-0.03571
C	-0.91979	-0.99918	-0.08256
H	-0.79455	2.41505	-0.04432
H	-3.24024	2.11419	0.04043
H	-2.72835	-2.15615	-0.03425
H	-0.29349	-1.88225	-0.11971
C	2.07819	-0.5953	-0.19484
H	2.07475	-1.09997	-1.17027
H	1.88767	-1.36999	0.55549
C	3.49338	-0.11023	0.0328
F	3.65503	0.46257	1.24566
F	4.37898	-1.12694	-0.03948
F	3.87861	0.80811	-0.88116
C	1.06597	0.50708	-0.1334
H	1.42628	1.52922	-0.15608
Cl	-4.85924	-0.24858	0.06848



E (UMPWB1K) = -1106.830502
Sum electronic and thermal free energies =
-1106.739551
Charge = 0 Multiplicity = 2

C	0.97264	1.5888	0.42454
H	1.13352	2.45224	-0.2164
C	1.98636	1.20047	1.22651
H	2.89919	1.7809	1.27636
H	1.89439	0.38633	1.93578
C	3.39066	-0.48217	-0.23904
F	4.21128	-1.16372	0.55658
F	4.0917	0.21389	-1.12814
F	2.56251	-1.31362	-0.86046
C	-0.34486	0.96562	0.29283
C	-1.27535	1.52662	-0.5993
C	-0.73695	-0.17386	1.02032
C	-2.54651	0.98426	-0.76578
H	-0.99863	2.40462	-1.17297
C	-2.00117	-0.72823	0.86578
H	-0.05106	-0.63948	1.71748
C	-2.89779	-0.14216	-0.02825
H	-3.25114	1.42911	-1.45659
H	-2.29052	-1.60513	1.43074
Cl	-4.49454	-0.83963	-0.22423