Synthesis of difluoromethylated diarylmethanes via $Fe(OTf)_3$-catalyzed Friedel–Crafts reaction of 2,2-difluoro-1-arylethyl phosphates

Yoshihiko Yamamoto,* Tomoya Takase, Eisuke Kuroyanagi, and Takeshi Yasui

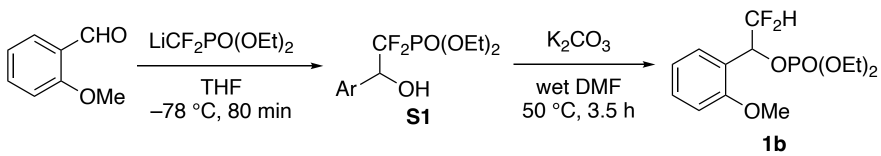
Department of Basic Medicinal Sciences, Graduate School of Pharmaceutical Sciences, Nagoya University, Chikusa, Nagoya 464-8601

yamamoto-yoshi@ps.nagoya-u.ac.jp

Supporting Information

General Information. All air- and moisture sensitive reactions were performed under an argon atmosphere in dried glassware. Analytical thin layer chromatography was performed using 0.25 mm silica gel plate (Merck TLC Silica gel 60 F_{254}). Column chromatography was performed on silica gel (Cica silica gel 60N) with eluents specified below. NMR spectra were recorded for samples in deuterated solvents specified below at 25 °C. ^{1}H NMR chemical shifts are reported in terms of chemical shift (δ, ppm) relative to the singlet at δ 7.26 or 5.32 ppm for chloroform and dichloromethane, respectively. ^{13}C NMR spectra were fully decoupled and are reported in terms of chemical shift (δ, ppm) relative to the triplet at δ 77.0 ppm for $CDCl_3$ or the septet at δ 49.0 ppm for CD_3OD. ^{19}F NMR spectra are reported in terms of chemical shift (δ, ppm) relative to the singlet at δ −63.7 ppm for α,α,α-trifluorotoluene as an external standard. ^{31}P NMR spectra are reported in terms of chemical shift (δ, ppm) relative to the singlet at δ 0 ppm for 85% H_3PO_4 as an external standard. Splitting patterns are designated as follows: s, singlet; d, doublet; t, triplet; q, quartet; quint, quintet; sext, sextet; m, multiplet. Coupling constants are reported in Hz. High resolution mass spectra (HRMS) were obtained on an ESI- or DART-TOF mass spectrometer. $CF_2HPO(OEt)_2$, aromatic compounds, and dry solvents were purchased and used as received. Nitromethane was dried over MS 4Å. Benzylic phosphates **1a**,**l**, **10a**,**b** and alcohols **4** and **6** were reported in the literature.[1]

Preparation of Difluoromethyl-Substituted Benzylic Phosphates.



Representative procedure; Synthesis of 1b: To a solution of ${}^{i}Pr_2NH$ (0.84 mL, 6.0 mmol) in THF (10 mL) was added dropwise ${}^{n}BuLi$ (15 w/w% in hexane, 4.0 mL, 6.0 mmol) at –78 °C, and the resultant mixture was stirred for 20 minutes. To this solution was added dropwise diethyl difluoromethylphosphonate (0.95 mL, 6.0 mmol), and the reaction mixture was stirred at –78 °C for 30 minutes. To the resultant mixture was added a solution of *o*-methoxybenzaldehyde (0.61 mL, 5.0 mmol) in THF (10 mL), and the reaction mixture was stirred at –78 °C for 80 min. The reaction was quenched by adding sat. aq. NH_4Cl (10 mL). The aqueous phase was extracted with EtOAc (3×10 mL). The

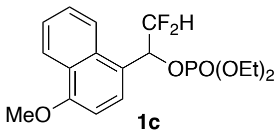
[1] (a) R. Waschbümsch, M. Samadi, P. Savignac, *J. Organomet. Chem.* **1997**, *529*, 267-278. (b) B. T. Ramanjaneyyulu, S. Vidyacharan, S. J. Yim, D.-P. Kim, *Eur. J. Org. Chem.* **2019**, 7730-7734. (c) A. Baeza, C. Nájera, J. M. Sansano, *ARKIVOC* **2005** (ix), 353-363. (d) Y. Zhao, W. Huang, J. Zheng, J. Hu, *Org. Lett.* **2011**, *13*, 5342-5345. (e) L. S. Dobson, G. Pattison, *Chem. Commun.* **2016**, *52*, 11116-11119.

combined organic extract was washed with brine (10 mL), and dried over anhydrous Na_2SO_4. The solvents were evaporated *in vacuo*, and the resultant colorless solid (crude **S1**) was used without purification in the next step.

According to the report,[2] phospha-Brook rearrangement was carried out as follows. A solution of the crude product (**S1**) obtained as above, K_2CO_3 (2.76 g, 20 mmol) in DMF/H_2O (25 mL/2.5 mL) was stirred at 50 °C for 3.5 h. The reaction was quenched by adding sat. aq. NH_4Cl (10 mL). The aqueous phase was extracted with Hexane/AcOEt (4:1, 3×10 mL). The combined organic extract was washed with H_2O (10 mL) and brine (10 mL) and dried over anhydrous Na_2SO_4. The solvents were evaporated *in vacuo,* and the obtained crude product was purified by silica gel column chromatography (hexane/AcOEt 5:1~1:1) to afford **1b** (1.20 g, 74%) as a yellow oil. This procedure was applied to *p*-methoxybenzophenone to produce dephosphorylated product **6**.

Analytical data for 1b: ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ 7.47 (d, 1H, *J* = 7.6 Hz), 7.38–7.33 (m, 1H), 7.01 (t, 1H, *J* = 7.6 Hz), 6.91 (d, 1H, *J* = 8.0 Hz), 5.99 (td, 1H, *J* = 54.8, 2.4 Hz), 5.95–5.82 (m, 1H), 4.20–3.91 (m, 4H), 3.85 (s, 3H), 1.29 (t, 3H, *J* = 6.6 Hz), 1.21 (t, 3H, *J* = 7.2 Hz); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 156.5, 130.5, 128.5, 121.5, 120.8, 113.4 (td, *J* = 245.0, 8.6 Hz), 110.9, 72.5 (ddd, *J* = 26.7, 22.9, 3.8 Hz), 64.1 (d, *J* = 5.7 Hz), 63.9 (d, *J* = 5.8 Hz), 55.5, 15.8; ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –127.7 (dd, *J* = 277.1, 57.9 Hz, 1F), –132.0 (dd, *J* = 277.1, 57.9 Hz, 1F); ^{31}P NMR (161 MHz, $CDCl_3$, 25 °C) δ –0.97; HRMS (DART) *m/z* $[M+H]^+$ calcd for $C_{13}H_{20}F_2O_5P$ 325.1016, found 325.0993.

Analytical data for 1c: 1.29 g, 69%; yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$,



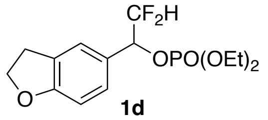
1c

25 °C): δ 8.34 (d, 1H, *J* = 8.0 Hz), 8.07 (d, 1H, *J* = 8.8 Hz), 7.61 (d, 1H, *J* = 7.6 Hz), 7.57 (ddd, 1H, *J* = 8.8, 6.8, 2.0 Hz), 7.50 (ddd, 1H, *J* = 8.4, 6.8, 1.6 Hz), 6.83 (d, 1H, *J* = 7.6 Hz), 6.13 (td, 1H, *J* = 55.6, 4.8 Hz), 6.06 (ddd, 1H, *J* = 19.4, 10.0, 4.0 Hz), 4.16–3.80 (m, 4H), 3.99 (s, 3H), 1.22 (td, 3H, *J* = 7.0, 0.8 Hz), 1.07 (td, 3H, *J* = 7.0, 0.8 Hz); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 156.6, 131.7, 127.4, 127.3, 125.6, 125.3, 122.7, 122.6, 120.7, 114.0 (td, *J* = 245.5, 9.5 Hz), 102.9, 75.4 (t, *J* = 26.7 Hz), 64.1 (d, *J* = 5.7 Hz), 63.9 (d, *J* = 5.7 Hz), 55.5, 15.8 (d, *J* = 10.5 Hz), 15.7 (d, *J* = 7.6 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –126.1 (dd, *J* = 288.8, 57.9 Hz, 1F), –127.0 (dd, *J* = 288.8, 57.9 Hz, 1F); ^{31}P NMR (161 MHz, $CDCl_3$, 25 °C) δ –1.02; HRMS (DART) *m/z* $[M+NH_4]^+$ calcd for $C_{17}H_{25}F_2NO_5P$ 392.1438, found 392.1427.

---

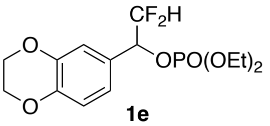
[2] P. Beier, R. Pohl, A. V. Alexandrova, *Synthesis* **2009**, 957-962.

Analytical data for 1d: 1.36 g, 81%; yellow oil; ^{1}H NMR (400 MHz, CD_3OD, 25 °C): δ 7.33 (s, 1H), 7.20 (d, 1H, *J* = 8.0 Hz), 6.77 (d, 1H, *J* = 8.4 Hz), 6.05 (td, 1H, *J* = 54.8, 4.4 Hz), 5.34–5.25 (m, 1H), 4.58 (t, 2H, *J* = 8.8 Hz), 4.17–3.99 (m, 2H), 3.94 (quint, 2H, *J* = 7.2 Hz), 3.23 (t, 2H, *J* = 8.8 Hz), 1.28 (td, 3H, *J* = 7.0, 0.8 Hz), 1.17 (td, 3H, *J* = 7.2, 0.8 Hz); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 161.2, 128.1, 127.6, 124.8, 124.6, 113.9 (td, *J* = 245.1, 9.5 Hz), 109.3, 77.3 (t, *J* = 30 Hz), 71.5, 64.1 (d, *J* = 5.7 Hz), 64.0 (d, *J* = 5.7 Hz), 29.4, 15.93 (d, *J* = 7.6 Hz), 15.85 (d, *J* = 6.7 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –127.4 (dd, *J* = 288.8, 57.9 Hz, 1F), –128.8 (dd, *J* = 288.8, 57.9 Hz, 1F); ^{31}P NMR (161 MHz, $CDCl_3$, 25 °C) δ –1.13; HRMS (DART) *m/z* $[M+H]^+$ calcd for $C_{14}H_{20}F_2O_5P$ 337.1016, found 337.1043.



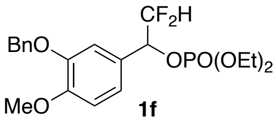
1d

Analytical data for 1e: 1.46 g, 83%; yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ 6.95 (d, 1H, *J* = 1.6 Hz), 6.90 (dd, 1H, *J* = 8.4, 1.6 Hz), 6.88 (d, 1H, *J* = 8.0 Hz), 5.86 (td, 1H, *J* = 55.2, 4.8 Hz), 5.27 (ddd, 1H, *J* = 20.2, 10.0, 4.0 Hz), 4.27 (s, 4H), 4.20–3.89 (m, 4H), 1.30 (td, 3H, *J* = 7.0, 0.8 Hz), 1.21 (td, 3H, *J* = 7.0, 0.8 Hz); ^{13}C NMR (100 MHz, CD_3OD, 25 °C): δ 146.3, 145.2, 127.3, 122.1, 118.5, 118.0, 115.5 (td, *J* = 243.6, 9.5 Hz), 78.9 (ddd, *J* = 29.6, 21.9, 4.8 Hz), 65.73 (d, *J* = 6.7 Hz), 65.68, 65.60 (d, *J* = 5.8 Hz), 65.58, 16.23 (d, *J* = 6.7 Hz), 16.16 (d, *J* = 6.7 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –127.5 (dd, *J* = 288.8, 57.9 Hz, 1F), –128.8 (dd, *J* = 288.8, 57.9 Hz, 1F); ^{31}P NMR (161 MHz, $CDCl_3$, 25 °C) δ –1.13; HRMS (DART) *m/z* $[M+H]^+$ calcd for $C_{14}H_{20}F_2O_6P$ 353.0966, found 353.0984.



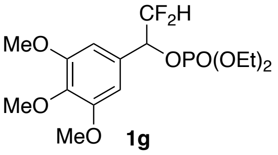
1e

Analytical data for 1f: 1.69 g, 78%; yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ 7.44 (d, 2H, *J* = 7.2 Hz), 7.39–7.34 (m, 2H), 7.32–7.27 (m, 1H), 7.01–6.98 (m, 1H), 6.98 (s, 1H), 6.90 (d, 2H, *J* = 8.8 Hz), 5.82 (td, 1H, *J* = 55.2, 4.0 Hz), 5.28 (ddd, 1H, *J* = 23.0, 10.0, 4.0 Hz), 5.17 (d, 1H, *J* = 12.0 Hz), 5.13 (d, 1H, *J* = 12.4 Hz), 4.15–3.94 (m, 2H), 3.92–3.80 (m, 2H), 3.90 (s, 3H), 1.27 (td, 3H, *J* = 7.2, 1.2 Hz), 1.15 (td, 3H, *J* = 7.2, 1.2 Hz); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 152.4, 149.6, 138.4, 129.5, 129.0, 128.8, 126.7, 122.8, 115.5 (td, *J* = 243.2, 9.5 Hz), 115.0, 113.0, 79.0 (ddd, *J* = 28.6, 24.8, 4.8 Hz), 72.1, 67.7 (d, *J* = 5.8 Hz), 65.5 (d, *J* = 5.7 Hz), 56.5, 16.24 (d, *J* = 6.6 Hz), 16.18 (d, *J* = 6.7 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –127.6 (dd, *J* = 288.8, 57.9 Hz, 1F), –129.2 (dd, *J* = 288.8, 57.9 Hz, 1F); ^{31}P NMR (161 MHz, $CDCl_3$, 25 °C) δ –1.13; HRMS (DART) *m/z* $[M+NH_4]^+$ calcd for $C_{20}H_{29}F_2NO_6P$ 448.1701, found 448.1695.



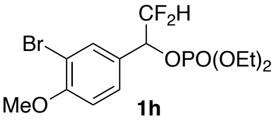
1f

Analytical data for 1g: 1.31 g, 68%; yellow oil; ^{1}H NMR (400 MHz, CDCl$_3$, 25 °C): δ 6.64 (s, 2H), 5.87 (td, 1H, J = 55.2, 4.0 Hz), 5.31 (ddd, 1H, J = 20.0, 10.0, 4.0 Hz), 4.22–3.92 (m, 4H), 3.87 (s, 6H), 3.86 (s, 3H), 1.31 (t, 3H, J = 7.2 Hz), 1.22 (t, 3H, J = 7.0 Hz); ^{13}C NMR (100 MHz, CD$_3$OD, 25 °C): δ 154.8, 140.2, 130.3, 115.5 (td, J = 243.9, 10.0 Hz), 106.3, 79.2 (ddd, J = 28.1, 23.8, 4.7 Hz), 67.3 (d, J = 5.7 Hz), 65.7 (d, J = 5.8 Hz), 61.1, 56.7, 16.3 (d, J = 3.8 Hz), 16.2 (d, J = 3.9 Hz); ^{19}F NMR (376 MHz, CDCl$_3$, 25 °C): δ –127.5 (dd, J = 285.8, 71.4 Hz, 1F), –128.8 (dd, J = 285.8, 71.4 Hz, 1F); ^{31}P NMR (161 MHz, CDCl$_3$, 25 °C) δ –1.02; HRMS (DART) *m/z* [M+NH$_4$]$^+$ calcd for $C_{15}H_{27}F_2NO_7P$ 402.1493, found 402.1472.



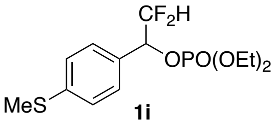
1g

Analytical data for 1h: 1.65 g, 82%; yellow oil; ^{1}H NMR (400 MHz, CDCl$_3$, 25 °C): δ 7.63 (d, 1H, J = 2.0 Hz), 7.35 (dd, 1H, J = 8.8, 2.4 Hz), 6.92 (d, 1H, J = 8.4 Hz), 5.87 (td, 1H, J = 55.2, 4.0 Hz), 5.31 (ddd, 1H, J = 20.6, 9.6, 4.0 Hz), 4.21–3.90 (m, 4H), 3.92 (s, 3H), 1.31 (td, 3H, J = 7.2, 0.8 Hz), 1.21 (td, 3H, J = 7.0, 1.2 Hz); ^{13}C NMR (100 MHz, CD$_3$OD, 25 °C): δ 158.5, 133.8, 129.9, 127.7, 115.3 (td, J = 243.6, 9.5 Hz), 113.1, 112.6, 78.1 (td, J = 25.8, 4.8 Hz), 65.8 (d, J = 5.7 Hz), 65.7 (d, J = 6.7 Hz), 56.8, 16.24 (d, J = 5.7 Hz), 16.19 (d, J = 5.7 Hz); ^{19}F NMR (376 MHz, CDCl$_3$, 25 °C): δ –127.4 (dd, J = 286.1, 71.4 Hz, 1F), –128.8 (dd, J = 286.1, 71.4 Hz, 1F); ^{31}P NMR (161 MHz, CDCl$_3$, 25 °C) δ –1.18; HRMS (DART) *m/z* [M+NH$_4$]$^+$ calcd for $C_{13}H_{22}BrF_2NO_5P$ 420.0387, found 420.0389.



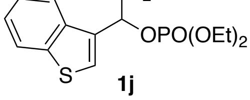
1h

Analytical data for 1i: 1.49 g, 88%; yellow oil; ^{1}H NMR (400 MHz, CD$_3$OD, 25 °C): δ 7.40 (d, 2H, J = 8.4 Hz), 7.32 (d, 2H, J = 8.4 Hz), 6.08 (td, 1H, J = 55.0, 4.0 Hz), 5.36 (ddd, 1H, J = 20.8, 9.6, 4.0 Hz), 4.18–4.01 (m, 2H), 3.96 (quint, 2H, J = 7.4 Hz), 2.50 (s, 3H), 1.28 (t, 3H, J = 7.0 Hz), 1.18 (t, 3H, J = 7.0 Hz); ^{13}C NMR (100 MHz, CD$_3$OD, 25 °C): δ 142.7, 130.7, 129.5, 127.1, 115.5 (td, J = 244.1, 9.5 Hz), 78.9 (td, J = 26.0, 5.2 Hz), 64.8 (d, J = 5.8 Hz), 65.7 (d, J = 6.7 Hz), 16.24 (d, J = 6.6 Hz), 16.17 (d, J = 6.7 Hz), 15.2; ^{19}F NMR (376 MHz, CDCl$_3$, 25 °C): δ –127.4 (dd, J = 288.8, 57.9 Hz, 1F), –129.6 (dd, J = 288.8, 57.9 Hz, 1F); ^{31}P NMR (161 MHz, CDCl$_3$, 25 °C) δ –1.13; HRMS (DART) *m/z* [M+NH$_4$]$^+$ calcd for $C_{13}H_{23}F_2NO_4PS$ 358.1054, found 358.1051.



1i

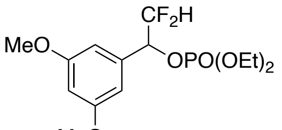
Analytical data for 1j: 1.46 g, 83%; yellow oil; ^{1}H NMR (400 MHz, CDCl$_3$, 25 °C): δ 7.95 (d, 1H, J = 7.2 Hz), 7.88 (dd, 1H, J = 7.2, 1.6 Hz), 7.66 (s, 1H), 7.46–7.38 (m, 2H), 6.11 (td, 1H, J = 55.2, 4.0 Hz), 5.82



1j

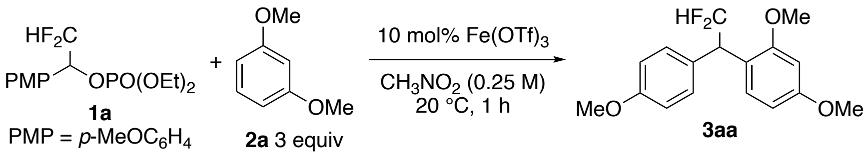
(ddd, 1H, *J* = 20.2, 10.0, 4.0 Hz), 4.21–3.83 (m, 4H), 1.28 (td, 3H, *J* = 7.0, 0.8 Hz), 1.09 (td, 3H, *J* = 6.8, 0.8 Hz); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 140.4, 136.8, 128.0, 127.8, 127.9, 124.6, 122.9, 122.4, 113.4 (td, *J* = 246.0, 8.6 Hz), 73.3 (ddd, *J* = 27.2, 4.8 Hz), 64.3 (d, *J* = 5.7 Hz), 64.1 (d, *J* = 5.7 Hz), 15.9 (d, *J* = 7.6 Hz), 15.7 (d, *J* = 6.7 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –126.4 (dd, *J* = 288.8, 57.9 Hz, 1F), –128.8 (dd, *J* = 288.8, 57.9 Hz, 1F); ^{31}P NMR (161 MHz, $CDCl_3$, 25 °C) δ –1.08; HRMS (DART) *m/z* $[M+H]^+$ calcd for $C_{14}H_{18}F_2O_4PS$ 351.0632, found 351.0607.

Analytical data for 1k: 1.61 g, 91%; yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ 6.57 (d, 2H, *J* = 2.0 Hz), 6.48 (t, 1H, *J* = 2.2 Hz), 5.86 (td, 1H, *J* = 55.2, 4.8 Hz), 5.31 (ddd, 1H, *J* = 20.0, 10.0, 4.0 Hz), 4.21–3.91 (m, 4H), 3.80 (s, 6H), 1.30 (td, 3H, *J* = 7.0, 0.8 Hz), 1.22 (td, 3H, *J* = 6.8, 0.8 Hz); ^{13}C NMR (100 MHz, CD_3OD, 25 °C): δ 162.6, 136.5, 113.8 (ddd, *J* = 245.1, 242.2, 9.6 Hz), 106.8, 102.3, 79.1 (ddd, *J* = 28.1, 23.8, 4.7 Hz), 65.8 (d, *J* = 6.7 Hz), 65.7 (d, *J* = 5.8 Hz), 55.9, 16.24 (d, *J* = 6.6 Hz), 16.18 (d, *J* = 4.8 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –127.5 (dd, *J* = 288.8, 46.2 Hz, 1F), –128.8 (dd, *J* = 288.8, 46.2 Hz, 1F); ^{31}P NMR (161 MHz, $CDCl_3$, 25 °C) δ –1.19; HRMS (DART) *m/z* $[M+H]^+$ calcd for $C_{14}H_{22}F_2O_6P$ 355.1122, found 355.1150.



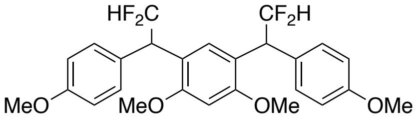
1k

Friedel–Crafts Reaction of Difluoromethylated Benzylic Phosphates



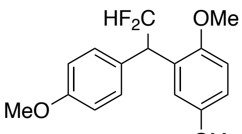
Representative procedure A. Reaction of 1a with 2a (Table 1, entry 10): To a solution of **1a** (100.6 mg, 0.31 mmol) and **2a** (116 μL, 0.90 mmol) in dry $MeNO_2$ (1.2 mL) was added $Fe(OTf)_3$ (14.7 mg, 0.029 mmol) at ambient temperature. The reaction mixture was stirred at 20 °C under an Ar atmosphere for 1 h. The reaction progress was monitored by TLC analysis. The reaction was quenched by adding H_2O (5 mL). The aqueous phase was extracted with AcOEt (3×5 mL). The combined organic extract was washed with brine (5 mL) and dried over anhydrous Na_2SO_4. The solvents were evaporated *in vacuo,* and the obtained crude product was purified by silica gel column chromatography (hexane/AcOEt 15:1~3:1) to afford **3aa** (83.3 mg, 87%) as a colorless oil: ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ 7.24 (d, 2H, *J* = 8.4 Hz), 7.20 (d, 1H, *J* = 7.6 Hz), 6.84 (d, 2H, *J* = 8.8 Hz), 6.50–6.46 (m, 1H), 6.47 (s, 1H), 6.30 (td, 1H, *J* = 56.6, 4.4 Hz), 4.70 (ddd, 1H, *J* = 20.2, 12.4, 4.4 Hz), 3.80 (s, 3H), 3.78 (s, 6H); ^{13}C NMR (100 MHz, CDCl$_3$, 25 °C): δ 160.1, 158.6, 158.0, 130.2, 129.9, 129.3, 118.7, 117.2 (t, J = 242.2 Hz), 113.7, 104.3, 98.9, 55.5, 55.3, 55.2, 47.3 (t, J = 21.5 Hz); ^{19}F NMR (376 MHz, CDCl$_3$, 25 °C): δ –117.5 (dd, 1F, J = 277.5, 57.9 Hz), –120.5 (ddd, 1F, J = 277.5, 57.9, 23.3 Hz); HRMS (DART) *m/z* [M+H]$^+$ calcd for $C_{17}H_{19}F_2O_3$ 309.1302, found 309.1326.

Small amounts of 2:1 adduct **S2** was formed as a mixture of diastereomers under conditions shown in Table 1, entries 3,4,7, and 10.



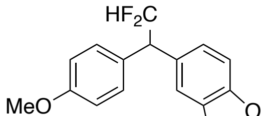
S2

Analytical data for S2: colorless oil; ^{1}H NMR (400 MHz, CDCl$_3$, 25 °C): δ 7.26 (s, 1H), 7.21 and 7.18 (d, 2H+2H, J = 8.8 Hz), 6.84 and 6.82 (d, 2H+2H, J = 8.8 Hz), 6.46 (s, 1H), 6.29 and 6.26 (td, 1H and 1H, J = 56.2, 4.8 Hz), 4.67 (ddd, 2H, J = 24.2, 12.0, 6.0 Hz), 3.802 (s, 3H), 3.796 (s, 3H), 3.78 (s, 6H); ^{19}F NMR (376 MHz, CDCl$_3$, 25 °C): δ –117.3 and –117.4 (dd, 1F, J = 277.5, 57.9 Hz), –120.25 and –120.31 (ddd, 1F, J = 277.5, 57.9, 22.9 Hz); HRMS (DART) *m/z* [M+H]$^+$ calcd for $C_{26}H_{27}F_4O_4$ 479.1846, found 479.1844.



3ab

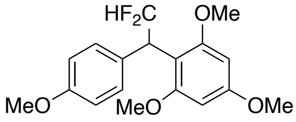
Analytical data for 3ab: 66.9 mg, 75%; colorless oil; ^{1}H NMR (400 MHz, CDCl$_3$, 25 °C): δ 7.26 (d, 2H, J = 8.8 Hz), 6.90–6.75 (m, 5H), 6.33 (td, 1H, J = 56.6, 4.4 Hz), 4.75 (ddd, 1H, J = 20.2, 12.4, 4.4 Hz), 3.77 (s, 3H), 3.74 (s, 6H); ^{13}C NMR (100 MHz, CDCl$_3$, 25 °C): δ 158.7, 153.5, 151.2, 130.2, 128.7, 127.4, 117.0 (t, J = 242.2 Hz), 116.2, 113.8, 112.2, 112.0, 56.1, 55.6, 55.1, 48.1 (t, J = 21.5 Hz); ^{19}F NMR (376 MHz, CDCl$_3$, 25 °C): δ –117.5 (dd, 1F, J = 277.5, 57.9 Hz), –120.4 (ddd, 1F, J = 277.5, 57.9, 22.9 Hz); HRMS (DART) *m/z* [M+NH$_4$]$^+$ calcd for $C_{17}H_{22}F_2NO_3$ 326.1568, found 326.1571.



3ac

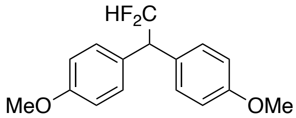
Analytical data for 3ac: 78.1 mg, 87%; colorless oil; ^{1}H NMR (400 MHz, CDCl$_3$, 25 °C): δ 7.21 (d, 2H, J = 8.8 Hz), 6.88 (d, 2H, J = 8.8 Hz), 6.77 (s, 3H), 6.21 (td, 1H, J = 56.0, 4.0 Hz), 5.94 (s, 2H), 4.27 (td, 1H, J = 16.0, 4.0 Hz), 3.80 (s, 3H); ^{13}C NMR (100 MHz, CDCl$_3$, 25 °C): δ 158.8, 147.8, 146.8, 131.0, 129.9, 129.2, 122.2, 116.9 (t, J = 243.2 Hz), 114.0, 109.4 108.2, 101.0, 55.1, 53.7 (t, J = 20.5 Hz); ^{19}F NMR (376 MHz, CDCl$_3$, 25 °C): δ –119.2 (d, 2F, J = 69.6 Hz); HRMS (DART) *m/z* [M+NH$_4$]$^+$ calcd for $C_{16}H_{18}F_2NO_3$ 310.1255, found 310.1274.

Analytical data for 3ad: 92.3 mg, 88%; colorless solid (mp 91.3–91.9 °C); ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ 7.27 (d, 2H, *J* = 8.8 Hz), 6.80 (d, 2H, *J* = 8.8 Hz), 6.68 (ddd, 1H, *J* = 60.6, 56.8, 8.0 Hz), 6.15 (s, 2H), 4.85 (dt, 1H, *J* = 18.8, 7.6 Hz), 3.80 (s, 9H), 3.76 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 160.4, 158.7, 158.3, 130.5 (d, *J* = 9.6 Hz), 129.8, 117.7 (t, *J* = 240.3 Hz), 113.6, 108.2 (d, *J* = 9.5 Hz), 91.1, 55.8, 55.3, 55.1, 45.4 (t, *J* = 23.9 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –115.4 (ddd, 1F, *J* = 277.5, 57.9 Hz), –118.2 (dd, 1F, *J* = 277.5, 57.9 Hz); HRMS (DART) *m/z* $[M+H]^+$ calcd for $C_{18}H_{21}F_2O_4$ 339.1408, found 339.1412.



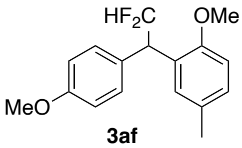
3ad

Analytical data for 3ae: 77.7 mg, 89%; colorless solid (mp 65.1–66.7 °C); ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ 7.21 (d, 4H, *J* = 8.8 Hz), 6.87 (d, 4H, *J* = 8.8 Hz), 6.23 (td, 1H, *J* = 56.0, 4.0 Hz), 4.31 (dt, 1H, *J* = 16.0, 4.0 Hz), 3.79 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 158.7, 129.9, 129.4, 117.0 (t, *J* = 242.7 Hz), 114.0, 55.1, 53.3 (t, *J* = 20.5 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –119.1 (d, 1F, *J* = 23.3 Hz), –119.2 (d, 1F, *J* = 23.3 Hz); HRMS (DART) *m/z* $[M+H]^+$ calcd for $C_{16}H_{17}F_2O_2$ 279.1197, found 279.1203.



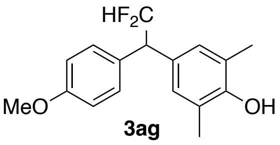
3ae

Analytical data for 3af: 66.5 mg, 72%; colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ 7.26 (d, 2H, *J* = 8.8 Hz), 7.09 (d, 1H, *J* = 1.6 Hz), 7.05 (dd, 1H, *J* = 8.8, 2.4 Hz), 6.84 (d, 2H, *J* = 8.4 Hz), 6.79 (d, 1H, *J* = 8.8 Hz), 6.35 (td, 1H, *J* = 56.6, 5.2 Hz), 4.73 (ddd, 1H, *J* = 20.2, 12.0, 4.8 Hz), 3.78 (s, 3H), 3.771 (s, 3H), 2.28 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 158.6, 154.9, 130.3, 130.1, 129.9, 129.1, 128.8, 126.0, 117.2 (t, *J* = 242.2 Hz), 113.8, 111.1, 55.7, 55.2, 48.2 (t, *J* = 21.0 Hz), 20.6; ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –117.3 (dd, 1F, *J* = 277.5, 57.9 Hz), –120.3 (ddd, 1F, *J* = 277.5, 57.9, 23.3 Hz); HRMS (DART) *m/z* $[M+NH_4]^+$ calcd for $C_{17}H_{22}F_2NO_2$ 310.1619, found 310.1649.



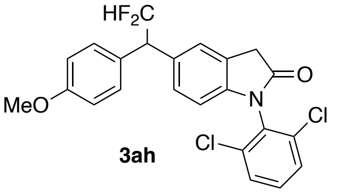
3af

Analytical data for 3ag: 85.9 mg, 93%; yellow solid (mp 93.2–94.5 °C); ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ 7.22 (d, 2H, *J* = 8.4 Hz), 6.90 (s, 2H), 6.87 (d, 2H, *J* = 8.4 Hz), 6.22 (td, 1H, *J* = 56.0, 4.0 Hz), 4.58 (s, 1H), 4.23 (dt, 1H, *J* = 16.0, 4.0 Hz), 3.80 (s, 3H), 2.23 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 158.7, 151.4, 129.9, 129.6, 129.0, 128.9, 123.2, 117.1 (t, *J* = 242.7 Hz), 114.0, 55.2, 53.4 (t, *J* = 20.5 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –118.5 (dd, 1F, *J* = 277.5, 57.9 Hz), –119.4 (dd, 1F, *J* = 277.5, 57.9 Hz); HRMS (DART) *m/z* $[M+H]^+$ calcd for $C_{17}H_{19}F_2O_2$ 292.1275, found 292.1277.



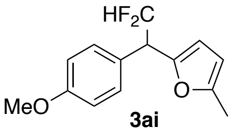
3ag

Analytical data for 3ah: 81.0 mg, 61%; colorless oil; ^{1}H NMR (400 MHz, CD_2Cl_2, 25 °C): δ 7.54 (d, 2H, *J* = 8.4 Hz), 7.42 (t, 1H, *J* = 8.0 Hz), 7.29 (s, 1H), 7.25 (d, 2H, *J* = 8.4 Hz), 7.15 (d, 1H, *J* = 8.0 Hz), 6.89 (d, 2H, *J* = 8.4 Hz), 6.37 (d, 1H, *J* = 8.0 Hz), 6.29 (td, 1H, *J* = 56.0, 4.0 Hz), 4.35 (dt, 1H, *J* = 16.4, 4.0 Hz), 3.78 (s, 3H), 3.73 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 173.4, 158.8, 142.5, 135.3, 132.0, 130.8, 130.2, 129.9, 128.9, 128.6, 125.4, 124.6, 116.8 (t, *J* = 243.2 Hz), 114.1, 109.0, 55.1, 53.8 (t, *J* = 20.5 Hz), 35.6; ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –119.0 (dd, 1F, *J* = 277.5, 57.9 Hz), –120.1 (dd, 1F, *J* = 277.5, 57.9 Hz); HRMS (DART) *m/z* $[M+H]^+$ calcd for $C_{23}H_{18}Cl_2F_2NO_2$ 448.0683, found 448.0663.



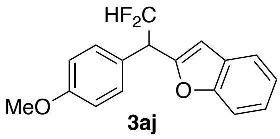
3ah

Analytical data for 3ai: 64.1 mg, 86%; yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ 7.25 (d, 2H, *J* = 8.0 Hz), 6.88 (d, 2H, *J* = 8.8 Hz), 6.15 (td, 1H, *J* = 56.2, 4.4 Hz), 6.13 (d, 1H, *J* = 4.0 Hz), 5.92 (d, 1H, *J* = 4.0 Hz), 4.34 (ddd, 1H, *J* = 16.8, 12.8, 4.0 Hz), 3.80 (s, 3H), 2.26 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 159.2, 152.0, 148.6 (t, *J* = 4.8 Hz), 130.3, 126.6, 115.7 (t, *J* = 244.1 Hz), 114.0, 108.8, 106.2, 55.2, 49.0 (t, *J* = 22.0 Hz), 13.5; ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –119.4 (dd, 1F, *J* = 277.5, 34.6 Hz), –121.4 (dd, 1F, *J* = 277.1, 57.9 Hz); HRMS (DART) *m/z* $[M+NH_4]^+$ calcd for $C_{14}H_{18}F_2NO_2$ 270.1306, found 270.1324.



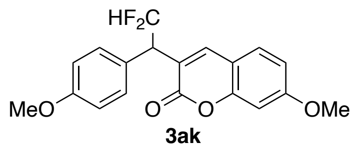
3ai

Analytical data for 3aj: 79.1 mg, 87%; yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ 7.55 (dd, 1H, *J* = 7.6, 1.6 Hz), 7.45 (d, 1H, *J* = 8.0 Hz), 7.33 (d, 2H, *J* = 8.8 Hz), 7.30–7.21 (m, 2H), 6.92 (d, 2H, *J* = 8.8 Hz), 6.69 (s, 1H), 6.32 (td, 1H, *J* = 55.8, 4.4 Hz), 4.55 (ddd, 1H, *J* = 16.6, 12.8, 4.0 Hz), 3.81 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 159.5, 154.8, 153.4, 130.4, 128.1, 125.7, 124.2, 122.9, 120.9, 115.4 (t, *J* = 244.1 Hz), 114.2, 111.1, 105.2, 55.2, 49.4 (t, *J* = 21.9 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –119.5 (dd, 1F, *J* = 277.5, 57.9 Hz), –121.1 (dd, 1F, *J* = 277.5, 57.9 Hz); HRMS (DART) *m/z* $[M+H]^+$ calcd for $C_{17}H_{15}F_2O_2$ 289.1040, found 289.1047.



3aj

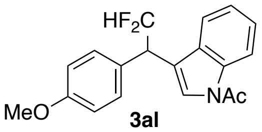
Analytical data for 3ak: 54.5 mg, 51%; colorless paste; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ 7.66 (s, 1H), 7.36 (d, 2H, *J* = 8.8 Hz), 7.35 (d, 1H, *J* = 8.4 Hz), 6.90 (d, 2H, *J* = 8.8 Hz), 6.85 (dd, 1H, *J* = 8.8, 2.4 Hz), 6.81 (d, 1H, *J* = 2.4 Hz), 6.44 (td, 1H, *J* = 56.0, 4.0 Hz), 4.55 (ddd, 1H, *J* = 18.4, 14.4, 4.0 Hz), 3.87 (s, 3H), 3.80 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 162.7, 161.3, 159.3, 155.0, 141.3,



3ak

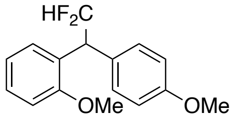
130.3, 128.9, 126.6, 121.9, 116.1 (t, J = 243.2 Hz), 114.2, 112.8, 112.5, 100.4, 55.8, 55.2, 49.1 (t, J = 21.9 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –119.7 (dd, 1F, J = 277.5, 57.9 Hz), –120.7 (dd, 1F, J = 277.5, 57.9 Hz); HRMS (DART) *m/z* $[M+H]^+$ calcd for $C_{19}H_{17}F_2O_4$ 347.1095, found 347.1093.

Analytical data for 3al: 54.1 mg, 56%; colorless oil; ^{1}H NMR (400 MHz, CD_2Cl_2, 25 °C): δ 8.41 (d, 1H, J = 8.4 Hz), 7.54 (s, 1H), 7.35–7.27 (m, 4H), 7.19 (t, 1H, J = 7.4 Hz), 6.89 (d, 2H, J = 8.4 Hz), 6.32 (td, 1H, J = 56.0, 3.2 Hz), 4.63 (td, 1H, J = 16.4, 3.2 Hz), 3.78 (s, 3H), 2.66 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 168.5, 159.3, 135.7, 130.2, 129.7, 126.9, 125.5, 123.6, 123.0, 119.3, 117.8, 116.6 (t, J = 246.5 Hz), 116.5, 114.1, 55.2, 46.1 (t, J = 21.0 Hz), 24.0; ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –119.6 (d, 2F, J = 57.9 Hz); HRMS (DART) *m/z* $[M+H]^+$ calcd for $C_{19}H_{18}F_2NO_2$ 330.1306, found 330.1310.



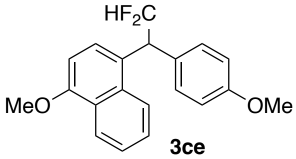
3al

Analytical data for 3be: 73.7 mg, 80%; yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ 7.30 (dd, 1H, J = 8.0, 1.6 Hz), 7.26 (d, 2H, J = 8.8 Hz), 6.96 (dd, 1H, J = 7.2, 1.2 Hz), 6.89 (d, 1H, J = 8.0 Hz), 6.84 (d, 2H, J = 8.8 Hz), 6.35 (td, 1H, J = 56.4, 4.8 Hz), 4.79 (ddd, 1H, J = 20.2, 12.4, 4.8 Hz), 3.80 (s, 3H), 3.78 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 158.6, 156.9, 130.3, 129.3, 128.9, 128.5, 126.3, 120.7, 117.1 (t, J = 242.2 Hz), 113.7, 111.0, 55.5, 55.1, 47.9 (t, J = 21.0 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –117.4 (dd, 1F, J = 277.1, 34.6 Hz), –120.5 (ddd, 1F, J = 277.5, 57.5, 22.9 Hz); HRMS (DART) *m/z* $[M+NH_4]^+$ calcd for $C_{16}H_{20}F_2NO_2$ 296.1462, found 296.1454.



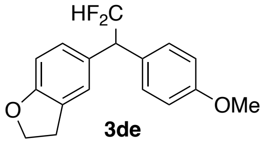
3be

Analytical data for 3ce: 72.8 mg, 74%; yellow oil; ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ 8.33–8.29 (m, 1H), 7.87–7.84 (m, 1H), 7.49 (d, 1H, J = 8.4 Hz), 7.47–7.44 (m, 2H), 7.25 (d, 2H, J = 8.4 Hz), 6.85–6.81 (m, 3H), 6.43 (td, 1H, J = 56.0, 4.0 Hz), 5.04 (ddd, 1H, J = 18.0, 13.2, 4.0 Hz), 4.01 (s, 3H), 3.75 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 158.8, 155.0, 132.5, 130.3, 128.9, 126.9, 126.2, 125.4, 125.3, 125.0, 123.2, 122.7, 117.3 (t, J = 242.7 Hz), 113.9, 102.9, 55.4, 55.1, 49.3 (t, J = 21.0 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –116.0 (dd, 1F, J = 277.1, 57.9 Hz), –120.4 (ddd, 1F, J = 277.5, 57.9 Hz); HRMS (DART) *m/z* $[M+H]^+$ calcd for $C_{20}H_{19}F_2O_2$ 329.1353, found 329.1374.



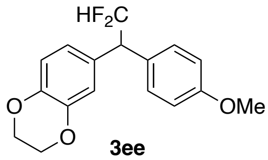
3ce

Analytical data for 3de: 86.6 mg, 90%; colorless oil; ^{1}H NMR (400 MHz, CD_2Cl_2, 25 °C): δ 7.22 (d, 2H, *J* = 8.8 Hz), 7.11 (s, 1H), 7.02 (d, 1H, *J* = 8.0 Hz), 6.87 (d, 2H, *J* = 8.8 Hz), 6.74 (d, 1H, *J* = 8.4 Hz), 6.22 (td, 1H, *J* = 56.0, 4.0 Hz), 4.55 (t, 2H, *J* = 8.6 Hz), 4.29 (td, 1H, *J* = 16.0, 4.8 Hz), 3.79 (s, 3H), 3.18 (t, 2H, *J* = 8.8 Hz); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 159.3, 158.7, 129.9, 129.5, 129.2, 128.6, 127.5, 125.4, 117.1 (t, *J* = 242.2 Hz), 113.8, 109.1, 71.2, 55.1, 53.6 (t, *J* = 20.5 Hz), 29.6; ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –119.1 (d, 2F, *J* = 57.9 Hz); HRMS (DART) *m/z* $[M+NH_4]^+$ calcd for $C_{17}H_{20}F_2NO_2$ 308.1462, found 308.1451.



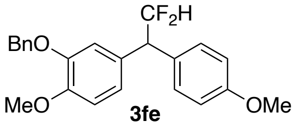
3de

Analytical data for 3ee: 80.6 mg, 86%; yellow oil; ^{1}H NMR (400 MHz, CD_2Cl_2, 25 °C): δ 7.21 (d, 2H, *J* = 8.8 Hz), 6.87 (d, 2H, *J* = 8.4 Hz), 6.82 (d, 1H, *J* = 8.8 Hz), 6.81 (d, 1H, *J* = 2.8 Hz), 6.76 (d, 1H, *J* = 8.4, 2.4 Hz), 6.21 (td, 1H, *J* = 56.0, 4.0 Hz), 4.24 (td, 1H, *J* = 16.0, 4.0 Hz), 4.24 (s, 4H), 3.79 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 158.8, 143.4, 142.8, 130.5, 130.0, 129.2, 121.9, 117.8, 117.3, 116.9 (t, *J* = 242.7 Hz), 114.0, 64.3, 55.2, 53.5 (t, *J* = 20.5 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –119.2 (d, 2F, *J* = 57.9 Hz); HRMS (DART) *m/z* $[M+NH_4]^+$ calcd for $C_{17}H_{20}F_2NO_2$ 324.1411, found 324.1430.



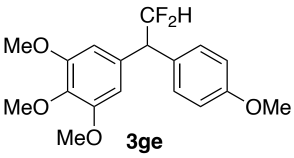
3ee

Analytical data for 3fe: 72.6 mg, 65%; colorless oil; ^{1}H NMR (400 MHz, CD_2Cl_2, 25 °C): δ 7.40–7.28 (m, 5H), 7.11 (d, 2H, *J* = 8.8 Hz), 6.85–6.82 (m, 3H), 6.81 (d, 2H, *J* = 7.2 Hz), 6.15 (td, 1H, *J* = 56.0, 4.0 Hz), 5.12 (d, 1H, *J* = 12.4 Hz), 5.09 (d, 1H, *J* = 12.4 Hz), 4.23 (td, 1H, *J* = 16.0, 4.0 Hz), 3.87 (s, 3H), 3.80 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 158.7, 149.0, 147.9, 136.9, 129.9, 129.6, 129.1, 128.5, 127.8, 127.4, 121.8, 117.0 (t, *J* = 243.2 Hz), 115.4, 114.0, 111.7, 60.7, 56.0, 55.1, 54.2 (t, *J* = 20.5 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –119.0 (t, 1F, *J* = 22.9 Hz), –119.1 (t, 1F, *J* = 22.9 Hz); HRMS (DART) *m/z* $[M+NH_4]^+$ calcd for $C_{23}H_{26}F_2NO_3$ 402.1881, found 402.1890.



3fe

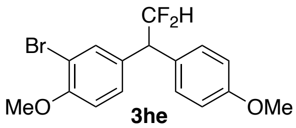
Analytical data for 3ge: 64.7 mg, 61%; colorless oil; ^{1}H NMR (400 MHz, CD_2Cl_2, 25 °C): δ 7.23 (d, 2H, *J* = 8.8 Hz), 6.89 (d, 2H, *J* = 8.8 Hz), 6.50 (s, 2H), 6.24 (td, 1H, *J* = 56.0, 4.0 Hz), 4.29 (td, 1H, *J* = 16.4, 4.0 Hz), 3.832 (s, 3H), 3.826 (s, 6H), 3.80 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 158.9, 153.2, 137.2, 132.8, 129.9, 128.8, 116.8 (t, *J* = 243.1 Hz), 114.0, 106.1, 71.1, 55.9, 55.2, 53.5 (t, *J* = 20.5 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –118.4 (dd, 1F, *J* = 276.0, 57.9 Hz), –119.2 (dd, 1F, *J* = 276.0,



3ge

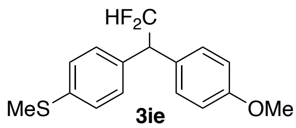
57.9 Hz); HRMS (DART) m/z $[M+H]^+$ calcd for $C_{18}H_{21}F_2O_4$ 339.1408, found 339.1394.

Analytical data for 3he:[3] 114.9 mg, 93%; colorless oil; ^{1}H NMR (400 MHz, CD_2Cl_2, 25 °C): δ 7.45 (d, 1H, J = 1.6 Hz), 7.22–7.15 (m, 3H), 6.87 (d, 2H, J = 8.8 Hz), 6.85 (d, 1H, J = 8.4 Hz), 6.20 (td, 1H, J = 56.0, 4.0 Hz), 4.27 (td, 1H, J = 16.0, 4.0 Hz), 3.87 (s, 3H), 3.79 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 158.9, 155.1, 133.7, 130.7, 129.9, 129.1, 128.6, 116.6 (t, J = 243.7 Hz), 114.1, 111.8, 111.7, 56.1, 55.1, 52.9 (t, J = 21.0 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –118.6 (dd, 1F, J = 277.5, 57.9 Hz), –119.8 (dd, 1F, J = 277.5, 57.9 Hz).



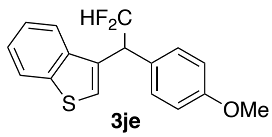
3he

Analytical data for 3ie:[3] 83.6 mg, quant; colorless oil; ^{1}H NMR (400 MHz, CD_2Cl_2, 25 °C): δ 7.24–7.17 (m, 6H), 6.87 (d, 2H, J = 8.8 Hz), 6.24 (td, 1H, J = 56.0, 4.0 Hz), 4.32 (td, 1H, J = 16.0, 4.0 Hz), 3.79 (s, 3H), 2.47 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 158.8, 133.6, 134.0, 130.0, 129.3, 129.0, 126.6, 116.8 (t, J = 243.2 Hz), 114.0, 55.1, 53.6 (t, J = 20.5 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –119.1 (d, 1F, J = 57.5 Hz), –119.2 (d, 1F, J = 57.5 Hz).



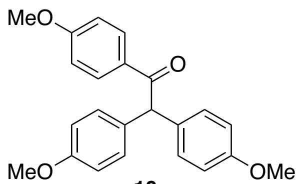
3ie

Analytical data for 3je: 85.1 mg, 96%; yellow oil; ^{1}H NMR (400 MHz, CD_2Cl_2, 25 °C): δ 7.86 (d, 1H, J = 8.0 Hz), 7.53 (d, 1H, J = 6.8 Hz), 7.50 (s, 1H), 7.34–7.27 (m, 2H), 7.24 (d, 2H, J = 8.8 Hz), 6.85 (d, 2H, J = 8.4 Hz), 6.33 (td, 1H, J = 56.0, 4.0 Hz), 4.72 (ddd, 1H, J = 17.8, 14.4, 4.0 Hz), 3.77 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 159.2, 140.0, 138.4, 131.1, 130.3, 127.0, 124.5, 124.2, 123.4, 122.7, 121.9, 116.6 (t, J = 243.6 Hz), 114.0, 55.1, 48.5 (t, J = 21.5 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –118.1 (d, 1F, J = 277.1, 57.9 Hz), –120.7 (d, 1F, J = 277.1, 57.9 Hz); HRMS (DART) m/z $[M+NH_4]^+$ calcd for $C_{17}H_{18}F_2NOS$ 322.1077, found 322.1090.



3je

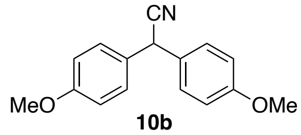
Analytical data for 10a:[4] 67.0 mg, 85%; colorless oil; ^{1}H NMR (400 MHz, CD_2Cl_2, 25 °C): δ 7.98 (d, 2H, J = 8.8 Hz), 7.17 (d, 4H, J = 8.8 Hz), 6.88 (d, 2H, J = 8.8 Hz), 7.24 (d, 2H, J = 8.8 Hz), 6.85 (d, 4H, J = 8.8 Hz), 5.89 (s, 1H), 3.83 (s, 3H), 3.77 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 197.2, 163.3, 158.5, 131.8, 131.2, 130.0, 129.7, 114.0, 113.7, 57.3, 55.4, 55.2.

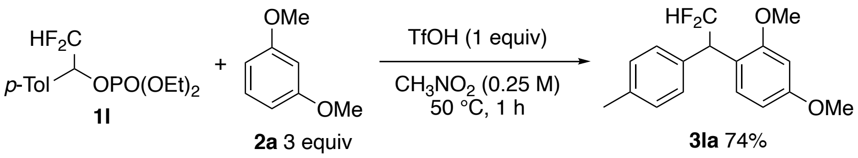


10a

[3] C. Kuang, X. Zhou, Q. Xie, C. Ni, Y. Gu, J. Hu, *Org. Lett.* **2020**, *22*, 8670-8675.
[4] R. Parnes, H. Reiss, D. Pappo, *J. Org. Chem.* **2018**, *83*, 723-732.

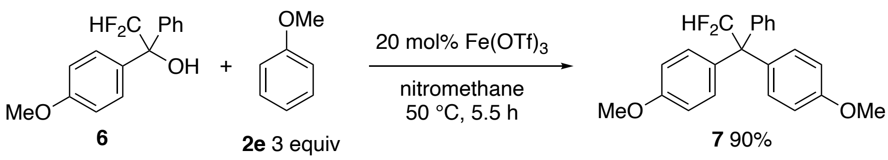
Analytical data for 10b:[5] 42.9 mg, 79%; colorless solid (mp 153.0–155.2 °C); ^{1}H NMR (400 MHz, CD_2Cl_2, 25 °C): δ 7.24 (d, 4H, *J* = 8.8 Hz), 6.88 (d, 4H, *J* = 8.8 Hz), 5.05 (s, 1H), 3.80 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 159.3, 128.8, 128.2, 120.1, 114.4, 55.3, 41.0.





Representative procedure B. Reaction of 1l with 2a: To a solution of **1l** (92.0 mg, 0.30 mmol) and **2a** (120 μL, 0.93 mmol) in dry $MeNO_2$ (1.2 mL) was added TfOH (26 μL, 0.3 mmol) at ambient temperature. The reaction mixture was stirred at 50 °C under an Ar atmosphere for 1 h. The reaction progress was monitored by TLC analysis. The reaction was quenched by adding H_2O (5 mL). The aqueous phase was extracted with AcOEt (3×5 mL). The combined organic extract was washed with brine (1×5 mL) and dried over anhydrous Na_2SO_4. The solvents were evaporated *in vacuo,* and the obtained crude product was purified by silica gel column chromatography (hexane/AcOEt 50:1~30:1) to afford **3la** (64.4 mg, 74%) as a colorless oil: ^{1}H NMR (400 MHz, CD_2Cl_2, 25 °C): δ 7.25–7.17 (m, 3H), 7.12 (d, 2H, *J* = 7.6 Hz), 6.53–6.47 (m, 2H), 6.36 (td, 1H, *J* = 56.8, 4.4 Hz), 4.70 (ddd, 1H, *J* = 16.0, 12.8, 4.8 Hz), 3.78 (s, 6H), 2.31 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 160.1, 158.0, 136.7, 134.3, 129.9, 129.1, 129.0, 118.6, 117.2 (t, *J* = 242.2 Hz), 104.3, 98.9, 55.5, 55.3, 47.7 (t, *J* = 21.5 Hz), 21.0; ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –117.6 (dd, 1F, *J* = 277.1, 57.9 Hz), –120.2 (ddd, 1F, *J* = 277.1, 57.9, 23.3 Hz); HRMS (DART) *m/z* $[M+H]^+$ calcd for $C_{17}H_{19}F_2O_2$ 293.1353, found 293.1373.

Synthesis of Triarylmethane 7.

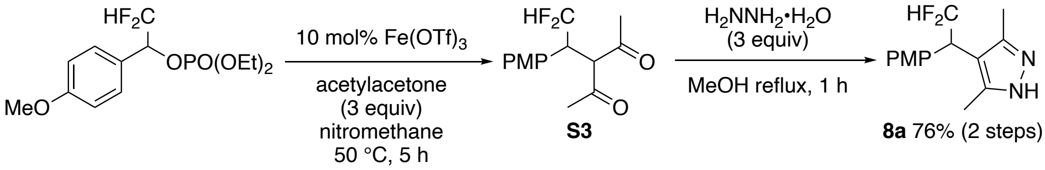


In a similar manner with representative procedure A, benzhydrol **6** (78.2 mg, 0.30 mmol), anisole (100 μL, 0.92 mmol), and $Fe(OTf)_3$ (29.8 mg, 0.059 mmol) was stirred in nitromethane (1.2 mL) at 50 °C for 5.5 h to afford triarylmethane **7** (94.5 mg, 90%) as a colorless solid (mp 99.8–102.5 °C): ^{1}H NMR (400 MHz, CD_2Cl_2, 25 °C): δ 7.35–7.27 (m, 3H), 7.13 (d, 2H,

[5] V. V. Tumanov, A. A. Tishkov, H. Mayr, *Angew. Chem. Int. Ed.* **2007**, *46*, 3563-3566.

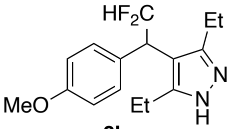
J = 8.0 Hz), 7.03 (d, 4H, J = 8.8 Hz), 6.84 (d, 4H, J = 8.8 Hz), 6.79 (t, 1H, J = 55.2 Hz), 3.79 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 158.4, 142.1, 133.7, 131.0, 129.7, 128.1, 127.1, 119.2 (t, J = 248.4 Hz), 113.4, 60.6 (t, J = 18.6 Hz), 55.2; ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –117.2 (d, 2F, J = 57.9 Hz); HRMS (DART) *m/z* $[M+NH_4]^+$ calcd for $C_{22}H_{24}F_2NO_2$ 372.1775, found 372.1784.

Synthesis of Pyrazoles 8.



To a solution of **1a** (103.0 mg, 0.317 mmol) and acetylacetone (92 μL, 0.90 mmol) in dry $MeNO_2$ (1.2 mL) was added $Fe(OTf)_3$ (18 mg, 0.036 mmol) at ambient temperature. The reaction mixture was stirred at 50 °C under an Ar atmosphere for 5 h. The reaction was quenched by adding H_2O (5 mL). The aqueous phase was extracted with AcOEt (3×5 mL). The combined organic extract was washed with brine (5 mL) and dried over anhydrous Na_2SO_4. The solvents were evaporated *in vacuo,* and the obtained crude materials were filtered through a pad of silica gel and the filtrate was concentrated in vacuo. To the solution of the crude product **S3** in MeOH (0.75 mL) was added H_2NNH_2•H_2O (44 μL, 0.90 mmol) and the reaction mixture was stirred at 80 °C for 1 h. The reaction mixture was concentrated *in vacuo*, and the crude product was purified by silica gel column chromatography (hexane/AcOEt 3:1 then AcOEt/MeOH 19:1) to afford **8a** (64.1 mg, 76%) as a colorless oil: ^1H NMR (400 MHz, $CDCl_3$, 25 °C): δ 11.1 (br s, 1H), 7.18 (d, 2H, J = 8.8 Hz), 6.86 (d, 2H, J = 8.8 Hz), 6.28 (td, 1H, J = 56.2, 4.8 Hz), 4.34 (td, 1H, J = 16.4, 4.4 Hz), 3.79 (s, 3H), 2.15 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 158.5, 143.1, 129.4, 128.7, 116.8 (t, J = 242.2 Hz), 113.8, 111.3, 55.1, 44.4 (t, J = 21.5 Hz), 11.6; ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –117.7 (ddd, 1F, J = 277.5, 57.9, 23.3 Hz), –118.5 (dd, 1F, J = 277.5, 57.9 Hz); HRMS (DART) *m/z* $[M+H]^+$ calcd for $C_{14}H_{17}F_2N_2O$ 267.1309, found 267.1310.

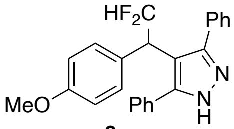
Analytical data for 8b: 76.8 mg, 82%; yellow oil; ^1H NMR (400 MHz, $CDCl_3$, 25 °C): δ 9.55 (br s, 1H), 7.17 (d, 2H, J = 8.4 Hz), 6.84 (d, 2H, J = 8.4 Hz), 6.27 (td, 1H, J = 56.2, 4.8 Hz), 4.37 (td, 1H, J = 16.2, 4.8 Hz), 3.80 (s, 3H), 2.52 (sept, J = 7.6 Hz, 4H), 1.15 (t, 6H, J = 7.8 Hz); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 158.4, 148.4, 129.3, 128.9, 116.7 (t, J = 242.2 Hz), 113.7, 109.7 (t, J = 3.7 Hz), 55.1, 44.1 (t, J = 21.9 Hz), 19.3, 13.2;



8b

^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –117.2 (ddd, 1F, *J* = 277.1, 57.9, 22.9 Hz), –118.0 (ddd, 1F, *J* = 277.1, 57.9, 22.9 Hz); HRMS (DART) *m/z* $[M+H]^+$ calcd for $C_{16}H_{21}F_2N_2O$ 295.1622, found 295.1620.

Analytical data for 8c: 75.6 mg, 60%; colorless solid (mp 68.8–73.4 °C); ^{1}H NMR (400 MHz, $CDCl_3$, 25 °C): δ 11.25 (br s, 1H), 7.38–7.28 (m, 10H), 7.08 (d, 2H, *J* = 8.4 Hz), 6.80 (d, 2H, *J* = 8.8 Hz), 6.27 (td, 1H, *J* = 56.4, 7.2 Hz), 4.55 (ddd, 1H, *J* = 16.6, 9.6, 7.2 Hz), 3.79 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$, 25 °C): δ 158.6, 147.2 (br s), 129.9, 129.8, 129.6, 129.0, 128.6, 128.5, 116.3 (t, *J* = 241.7 Hz), 113.9, 112.5, 112.4, 55.2, 45.0 (t, *J* = 22.4 Hz); ^{19}F NMR (376 MHz, $CDCl_3$, 25 °C): δ –115.2 (dd, 1F, *J* = 277.5, 57.9 Hz), –116.7 (dd, 1F, *J* = 277.5, 57.9 Hz); HRMS (DART) *m/z* $[M+H]^+$ calcd for $C_{24}H_{21}F_2N_2O$ 391.1622, found 391.1641.



8c

DFT Calculations

The Gaussian 16 program package was used for all calculations.[63] The geometries of the stationary points were fully optimized using the Becke's three-parameter hybrid density functional method (B3LYP)[7] with the 6-31G(d)[8] basis sets for all elements. The D3 version of Grimme's dispersion with Becke-Johnson damping[9] was used for empirical dispersion correction. The vibrational frequencies and the thermal correction to Gibbs free energy (TCGFE) including the zero-point energy were calculated at the same level of theory. Single-point energies for geometries obtained using the above method were

---

[6] Gaussian 16, Revision A.03, M. J. Frisch, G. W. Trucks, H. B. Schlegel, G. E. Scuseria, M. A. Robb, J. R. Cheeseman, G. Scalmani, V. Barone, G. A. Petersson, H. Nakatsuji, X. Li, M. Caricato, A. V. Marenich, J. Bloino, B. G. Janesko, R. Gomperts, B. Mennucci, H. P. Hratchian, J. V. Ortiz, A. F. Izmaylov, J. L. Sonnenberg, D. Williams-Young, F. Ding, F. Lipparini, F. Egidi, J. Goings, B. Peng, A. Petrone, T. Henderson, D. Ranasinghe, V. G. Zakrzewski, J. Gao, N. Rega, G. Zheng, W. Liang, M. Hada, M. Ehara, K. Toyota, R. Fukuda, J. Hasegawa, M. Ishida, T. Nakajima, Y. Honda, O. Kitao, H. Nakai, T. Vreven, K. Throssell, J. A. Montgomery, Jr., J. E. Peralta, F. Ogliaro, M. J. Bearpark, J. J. Heyd, E. N. Brothers, K. N. Kudin, V. N. Staroverov, T. A. Keith, R. Kobayashi, J. Normand, K. Raghavachari, A. P. Rendell, J. C. Burant, S. S. Iyengar, J. Tomasi, M. Cossi, J. M. Millam, M. Klene, C. Adamo, R. Cammi, J. W. Ochterski, R. L. Martin, K. Morokuma, O. Farkas, J. B. Foresman, and D. J. Fox, Gaussian, Inc., Wallingford CT, 2016.

[7] (a) W. Kohn, A. D. Becke, R. G. Parr, *J. Phys. Chem.* **1996**, *100*, 12974-12980. (b) P. J. Stephen, F. J. Devlin, C. F. Chabalowski, M. Frisch, *J. Phys. Chem.* **1994**, *98*, 11623-11627. (c) A. D. Becke, *J. Chem. Phys.* **1993**, *98*, 5648-5652. (d) C. Lee, W. Yang, R. G. Parr, *Phys. Rev. B* **1988**, *37*, 785-789.

[8] (a) W. J. Hehre, R. Ditchfield, J. A. Pople, *J. Chem. Phys.* **1972**, *56*, 2257-2261. (b) P. C. Hariharan, J. A. Pople, *Theor. Chim. Acta* **1973**, *28*, 213-222. (c) M. M. Fracl, W. J. Pietro, W. J. Hehre, J. S. Binkley, M. S. Gordon, D. J. DeFrees, J. A. Pople, *J. Chem. Phys.* **1982**, *77*, 3654-3665.

[9] S. Grimme, S. Ehrlich, L. Goerigk, *J. Comp. Chem.* **2011**, *32*, 1456-1465.

calculated at the same level of theory using the 6-311++G(d,p) basis sets[10] for all elements. The GD3BJ dispersion correction (D3) was also employed for the single-point energy calculations. To examine the solvent effect, the above geometry optimizations and single-point energy calculations were performed using the SMD model[11] with $MeNO_2$ as the solvent. CYLview (Ver. 1.0b)[12] was used for the visualization of the optimized structures. The obtained results are summarized in Table S1 and Figure S1.

Table S1. Summary of theoretical calculations.

Model	TCGFE/au	SMD Energy/au	ΔG/au	ΔG_{rel}/kcal mol^{-1}
***ortho*-Int**	0.126121	–623.285244	–623.159123	+5.4
***meta*-Int**	0.125390	–623.271310	–623.145920	+13.7
***para*-Int**	0.126293	–623.293975	–623.167682	0.0

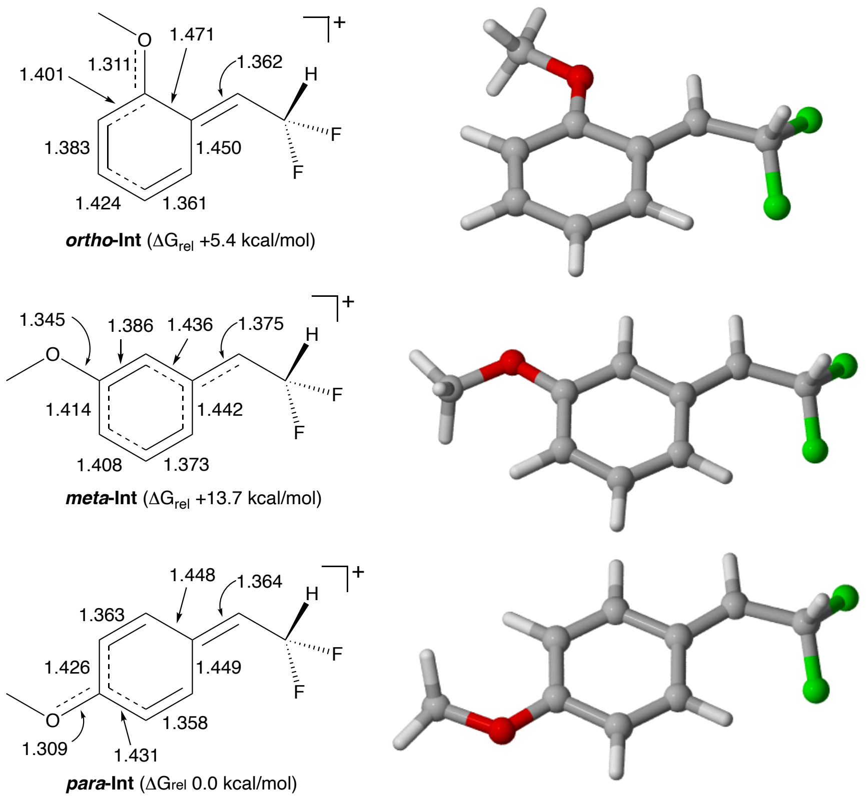


Figure S1. Calculated structures of cationic intermediates with interatomic distances (Å).

---

[10] (a) R. Krishnan, J. S. Binkley, R. Seeger, J. A. Pople, *J. Chem. Phys.* **1980**, *72*, 650-654. (b) A. D. McLean, G. S. Chandler, *J. Chem. Phys.* **1980**, *72*, 5639-5648. (c) M. J. Frisch, J. A. Pople, J. S. Binkley, *J. Chem. Phys.* **1984**, *80*, 3265-3269. (d) T. Clark, J. Chandrasekhar, G. W. Spitznagel, P. v. R. Schleyer, *J. Comp. Chem.* **1983**, *4*, 294-301.

[11] A. V. Marenich, C. J. Cramer, D. G. Truhlar, *J. Phys. Chem. B* **2009**, *113*, 6378-6396.

[12] CYLview, 1.0b; Legault, C. Y., Université de Sherbrooke, 2009 (http://www.cylview.org).

Cartesian coordinates

21

***ortho*-Int**

C	−0.443000	1.047400	0.068300
C	−0.197300	0.554000	1.356300
C	0.988200	1.008200	2.099500
C	1.865200	1.971100	1.461900
C	1.595500	2.426800	0.208100
C	0.437800	1.962300	−0.479300
H	−1.309600	0.723000	−0.492300
H	2.741700	2.308300	1.997800
H	2.252500	3.139600	−0.276600
H	0.237500	2.339800	−1.477600
C	1.209200	0.491000	3.340000
H	0.532500	−0.265500	3.726600
C	2.364400	0.787200	4.252200
H	3.242200	0.187300	3.986800
F	2.713600	2.110600	4.227200
F	1.996800	0.486300	5.532700
O	−0.968600	−0.305400	1.977700
C	−2.163300	−0.816700	1.334000
H	−2.600000	−1.499200	2.060900
H	−2.848500	0.006400	1.119700
H	−1.892800	−1.350200	0.419800

21

***meta*-Int**

C	−2.084800	1.424400	2.519100
C	−1.120400	0.693100	3.193400
C	0.215700	1.199900	3.330200
C	0.562300	2.473600	2.750900
C	−0.407500	3.175400	2.077700
C	−1.716300	2.670200	1.961700
H	−1.374500	−0.267100	3.629500
H	1.569400	2.855000	2.836400
H	−0.176600	4.132900	1.624400

H	-2.450400	3.260200	1.425300
C	1.102300	0.415000	4.029300
H	0.762600	-0.552600	4.392700
C	2.554200	0.668200	4.307300
H	3.165300	0.238100	3.503200
F	2.880600	0.063200	5.486600
F	2.848900	1.995100	4.426500
O	-3.315500	0.886900	2.441300
C	-4.341500	1.615500	1.750100
H	-5.234300	0.994200	1.822300
H	-4.525400	2.583500	2.228900
H	-4.077000	1.760800	0.697200

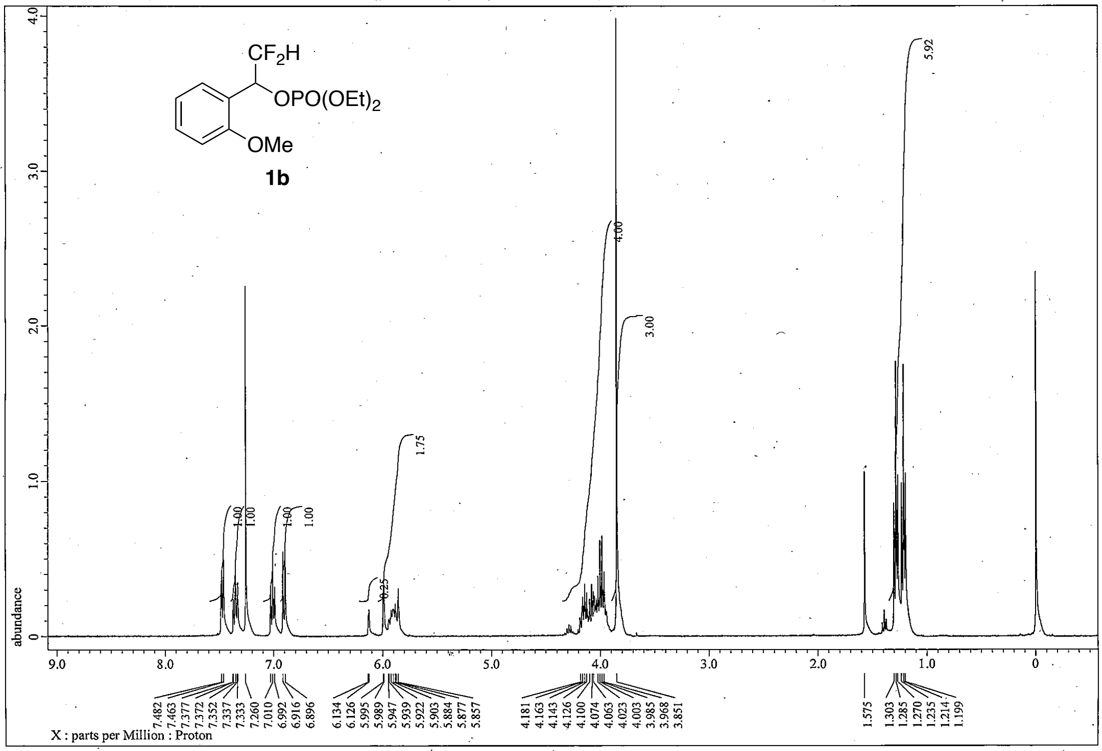
21

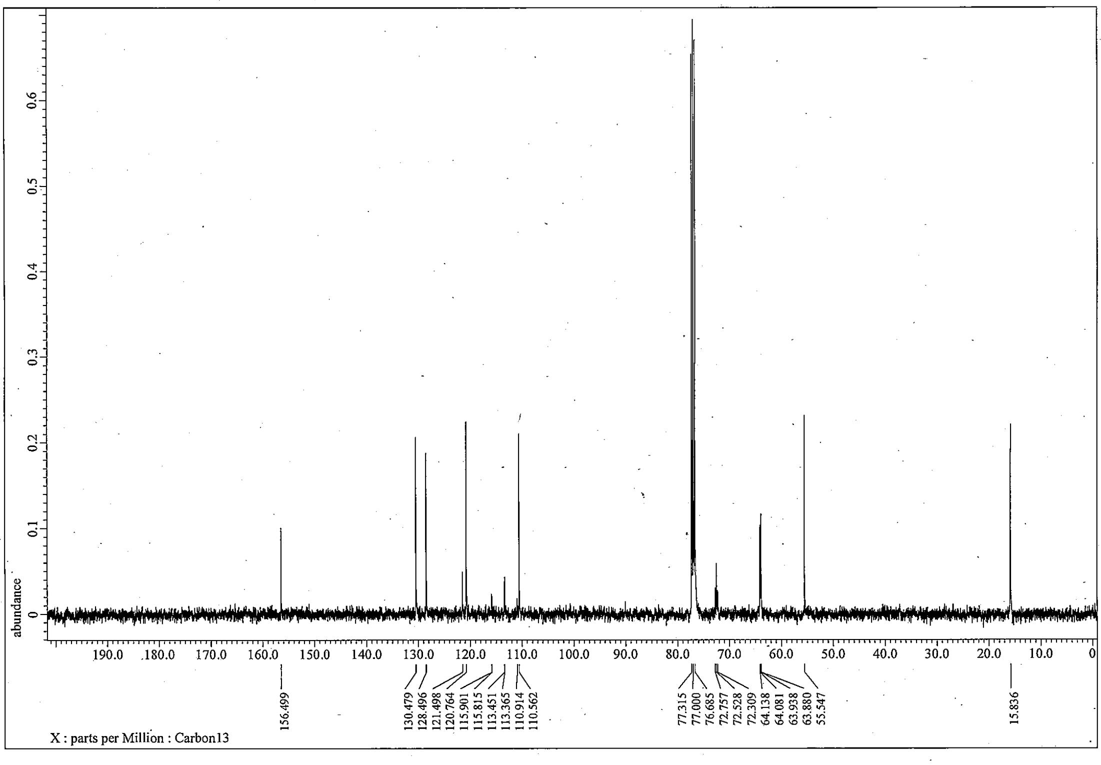
***para*-Int**

C	0.161300	0.467000	-0.213500
C	0.143200	0.548700	1.209600
C	1.278400	0.240200	1.897200
C	2.494300	-0.157100	1.218300
C	2.477500	-0.224200	-0.229400
C	1.344000	0.073700	-0.916000
H	-0.756300	0.846700	1.732300
H	1.291200	0.291800	2.981100
H	3.370000	-0.525400	-0.760600
H	1.300600	0.022600	-1.998000
C	3.581000	-0.449500	1.988800
H	3.479300	-0.412100	3.070700
C	4.931700	-0.908000	1.524600
H	4.958600	-1.994200	1.382200
F	5.303500	-0.306100	0.351500
F	5.858500	-0.567200	2.470300
O	-0.871100	0.732500	-0.973200
C	-2.137000	1.136400	-0.388100
H	-2.801800	1.282500	-1.237500
H	-2.514100	0.344300	0.262400
H	-2.009800	2.070400	0.163700

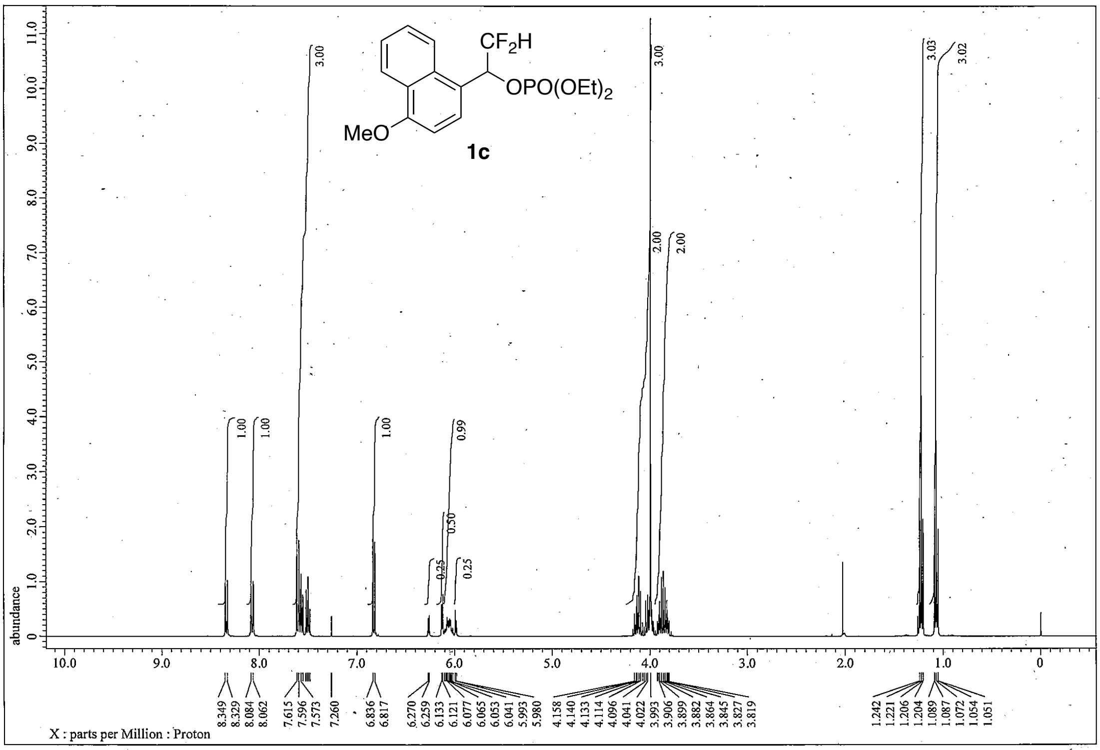
NMR Charts

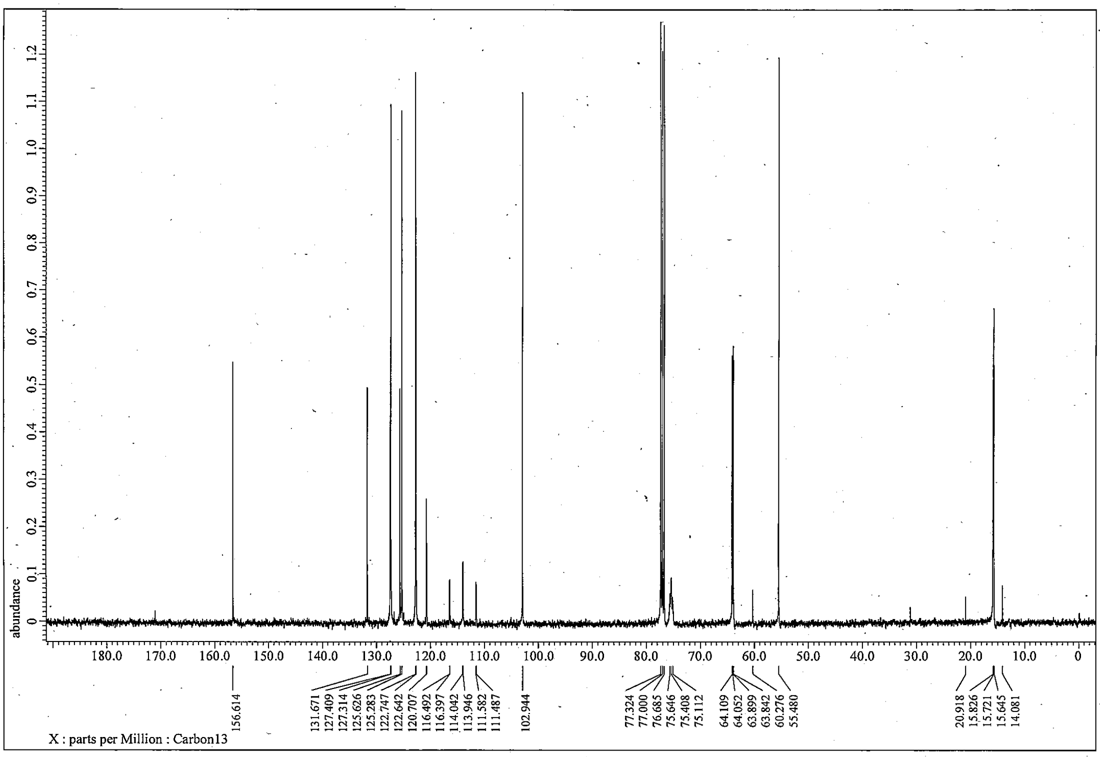
1b: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$)



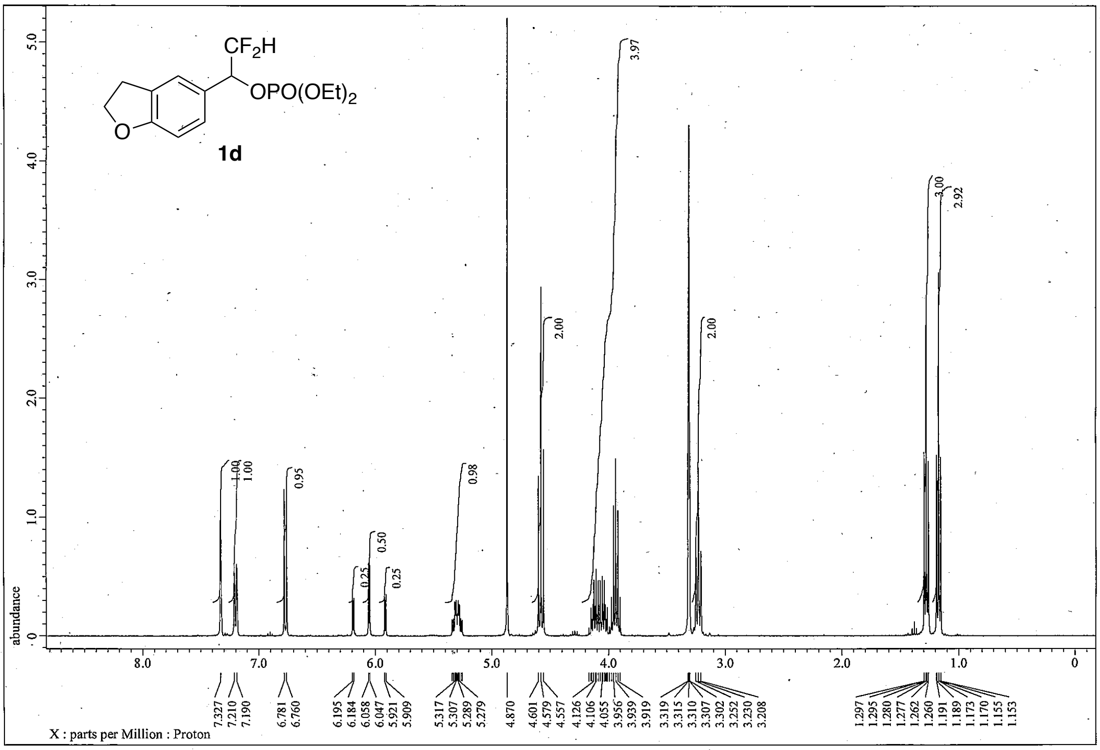


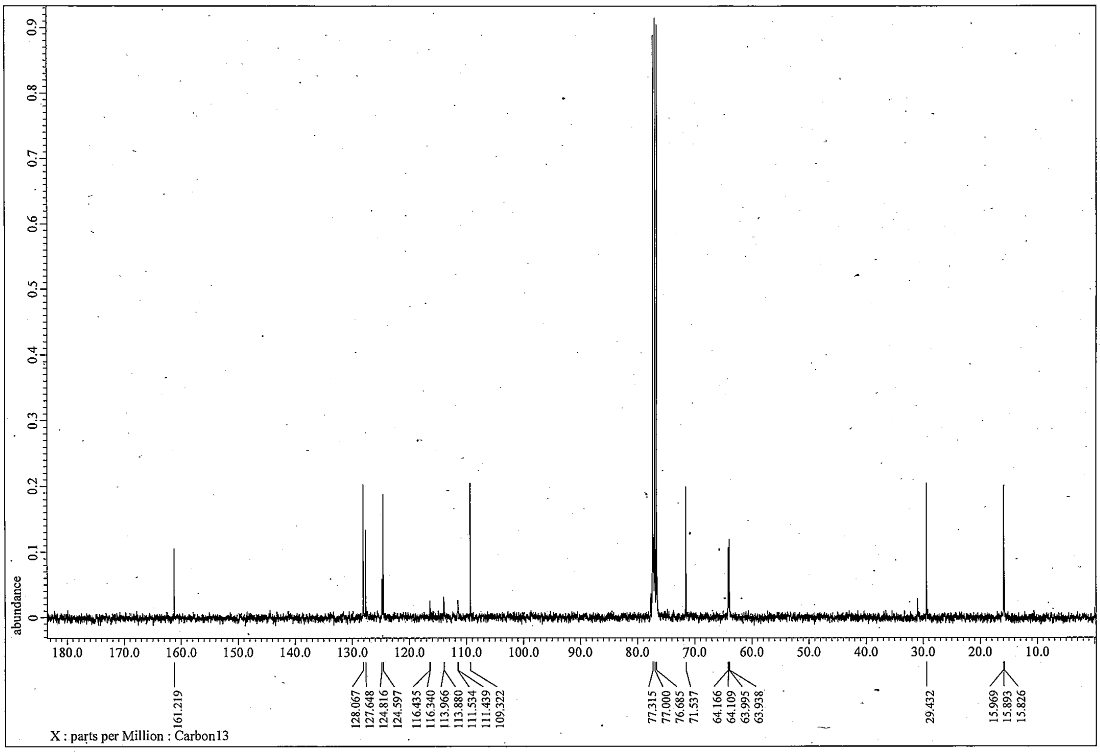
1c: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$)



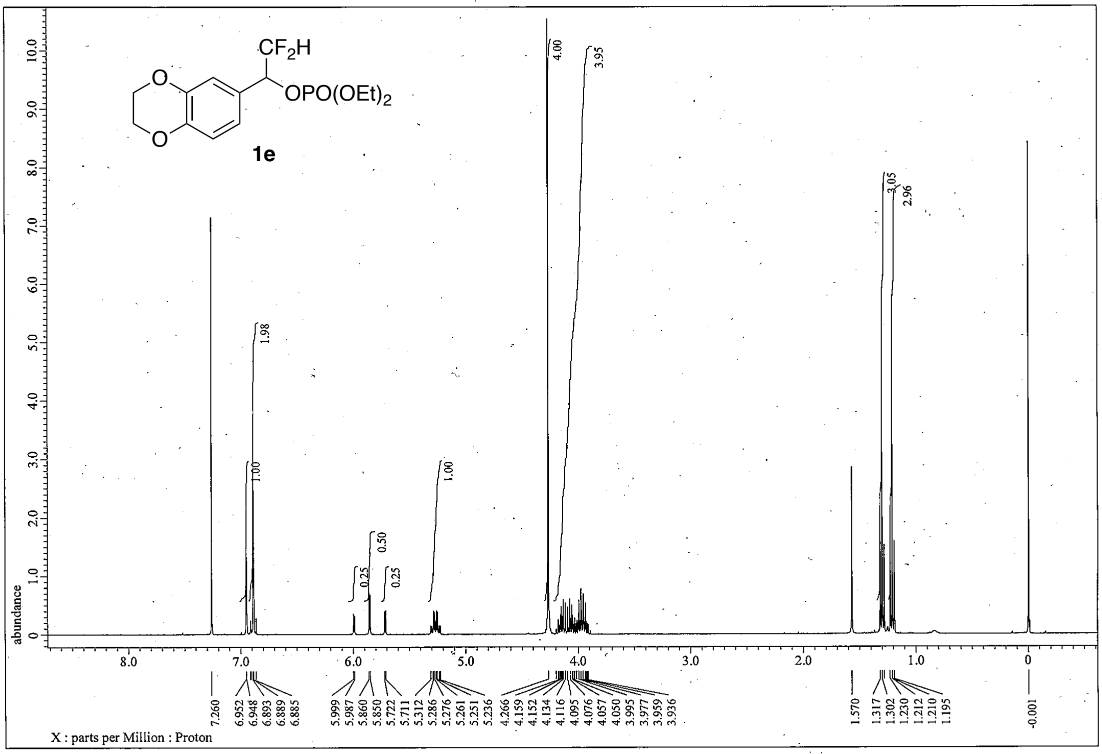


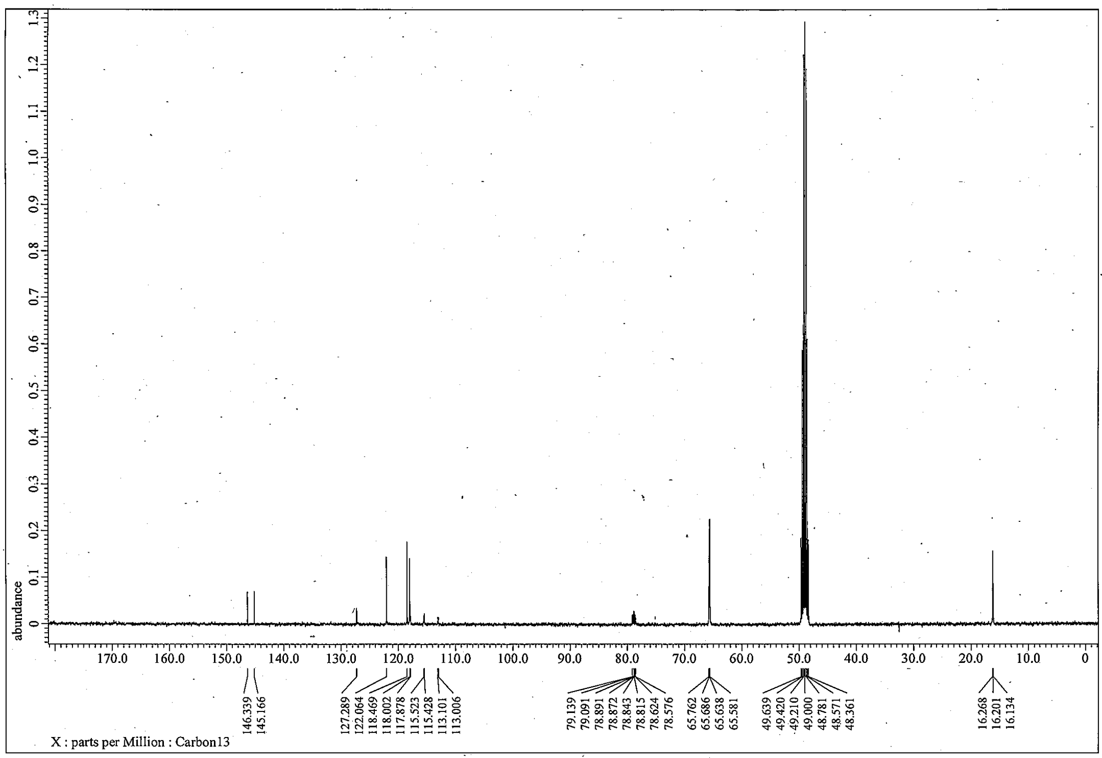
1d: ^{1}H NMR (400 MHz, CD_3OD)/$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$)



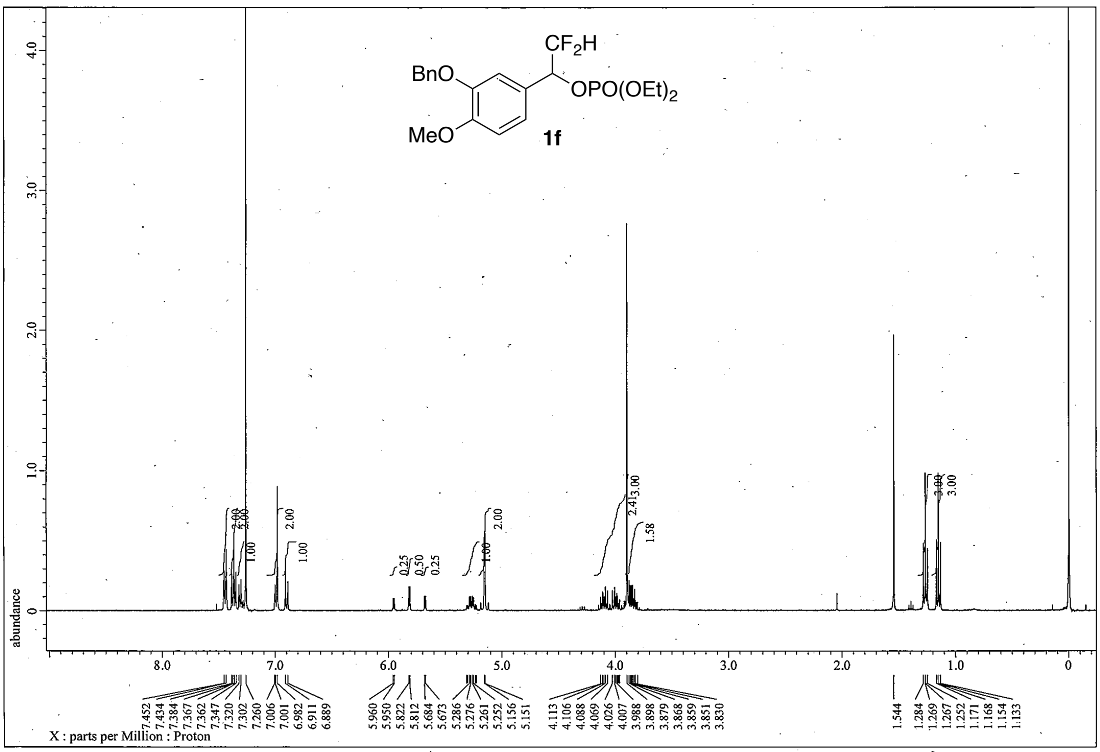


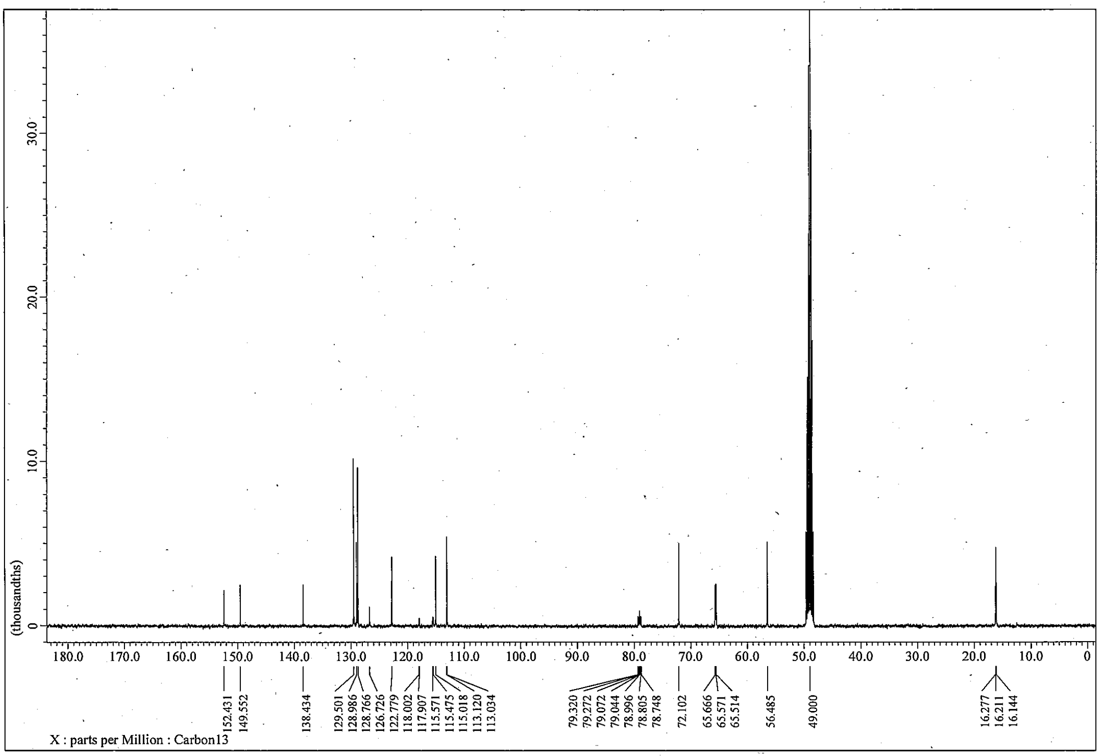
1e: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^1H\}$ NMR (100 MHz, CD_3OD)



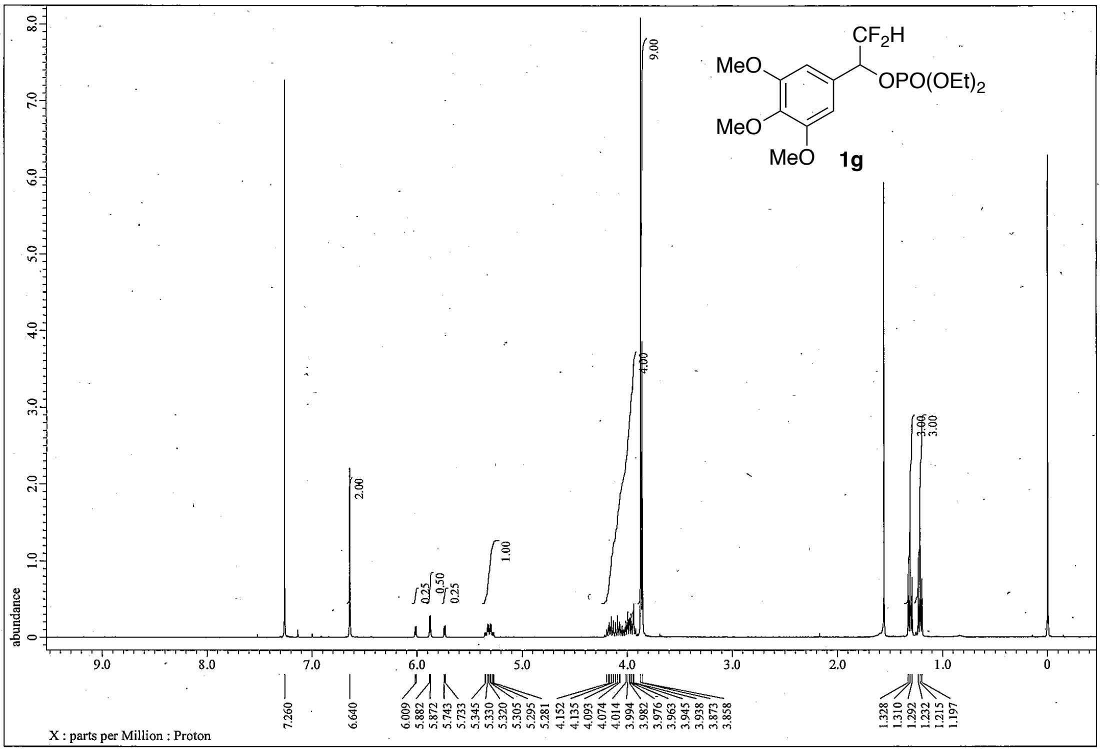


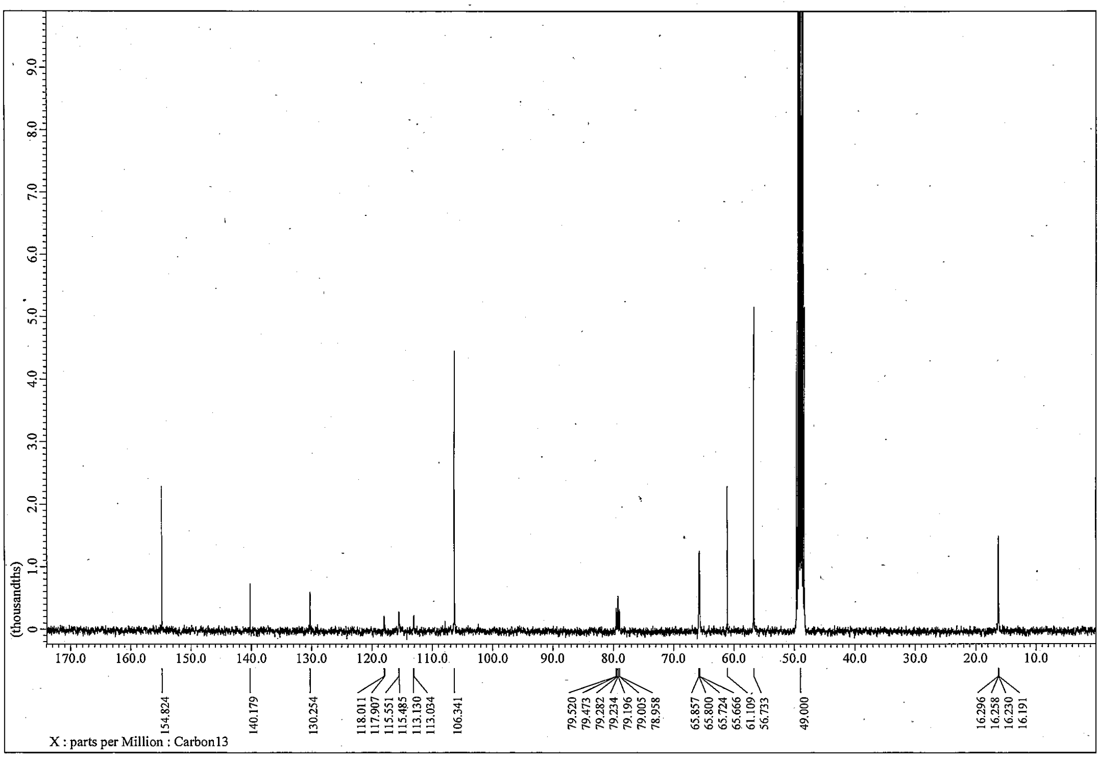
1f: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$)



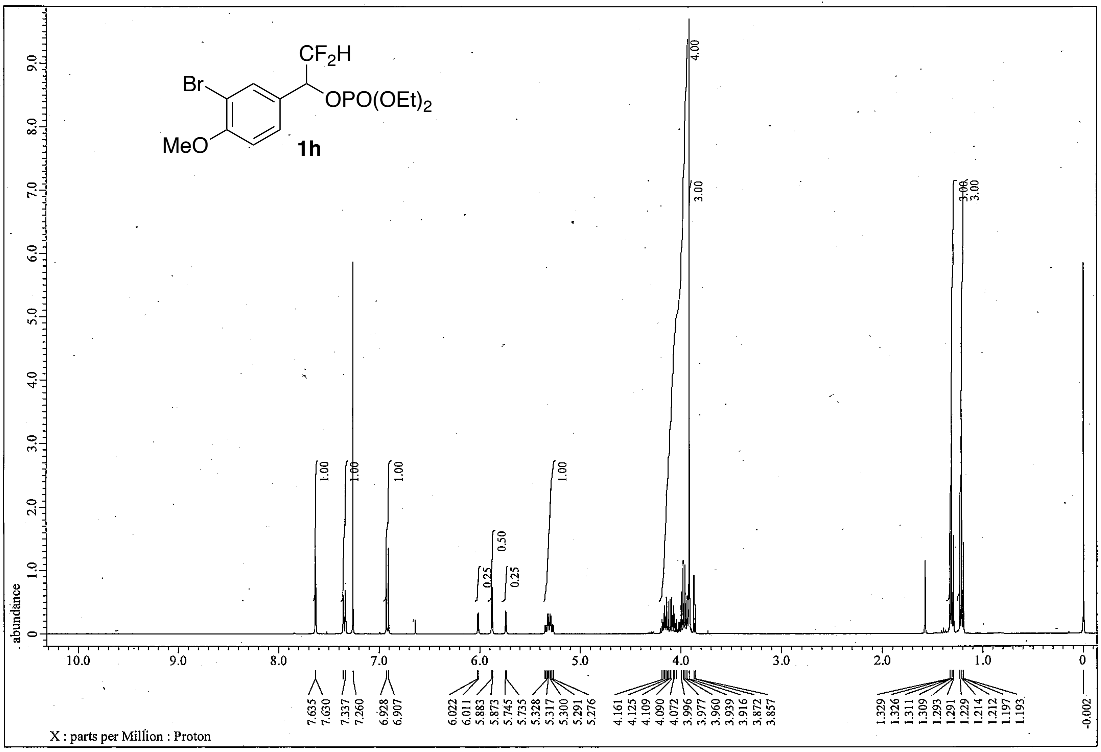


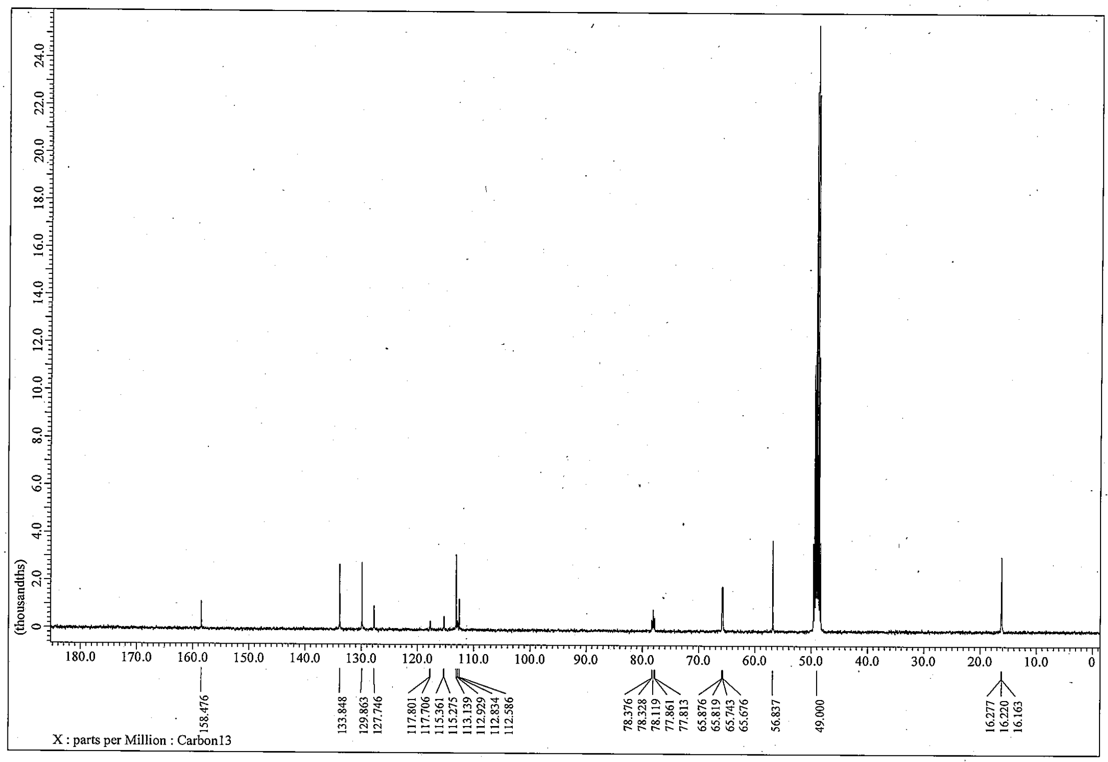
1g: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^{1}H\}$ NMR (100 MHz, CD_3OD)



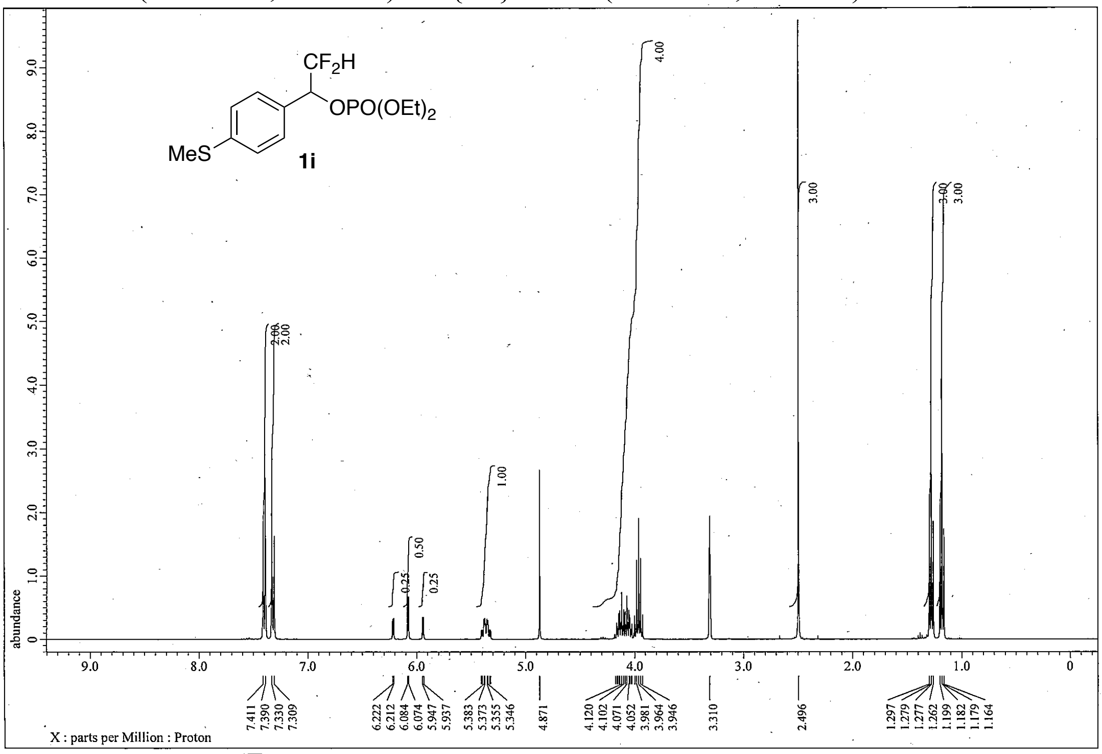


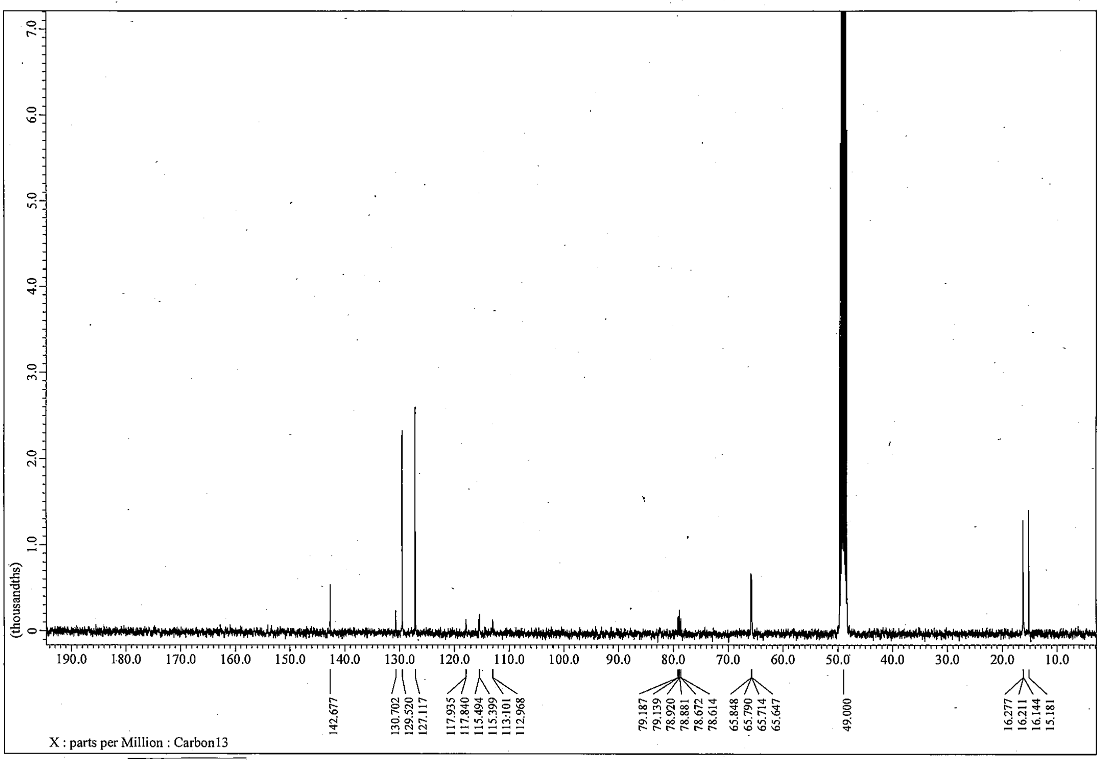
1h: ^{1}H NMR (400 MHz, CDCl$_3$)/^{13}C{^{1}H} NMR (100 MHz, CD$_3$OD)



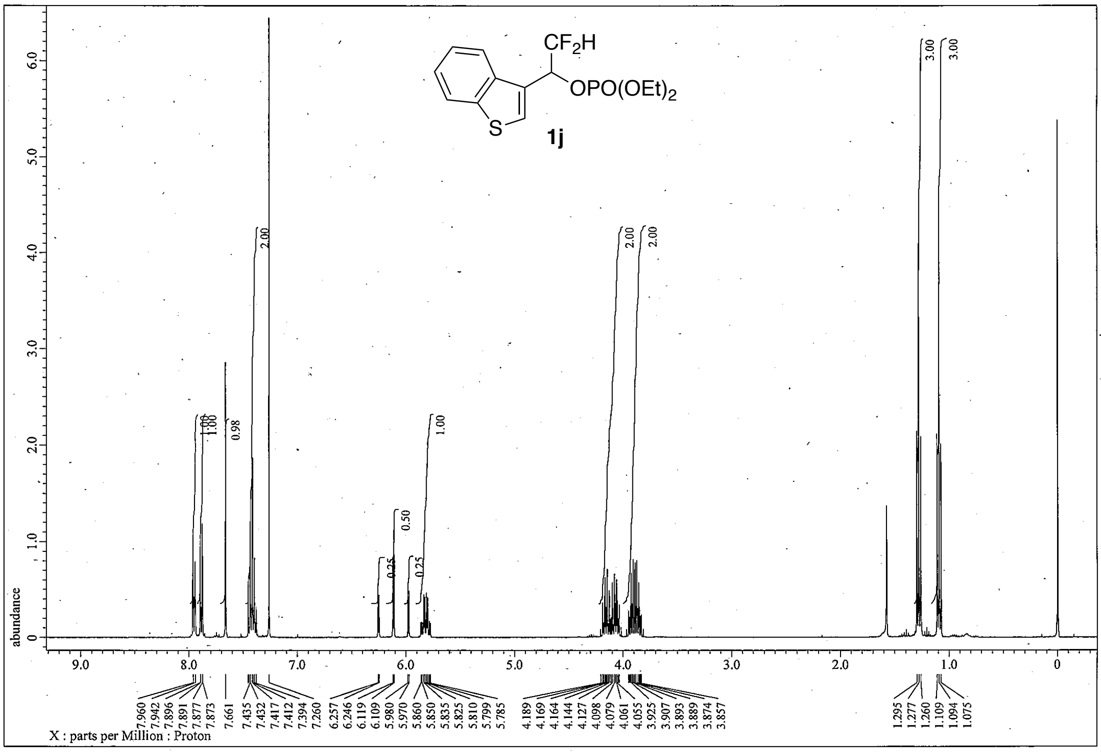


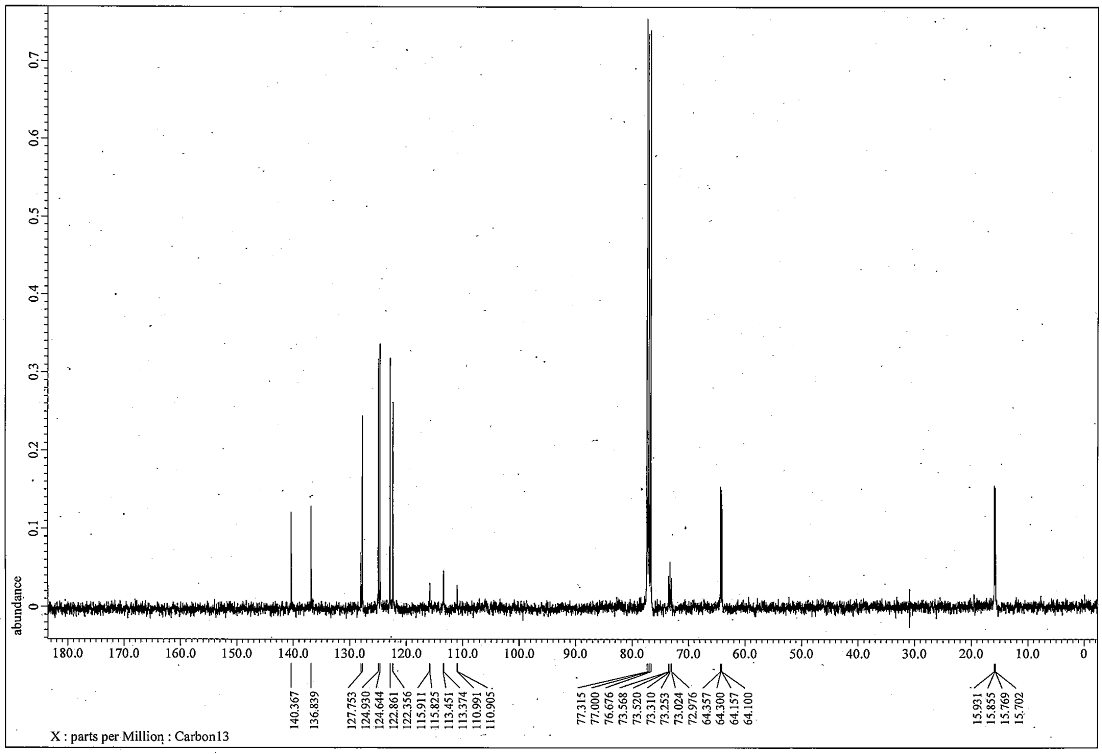
1i: ^{1}H NMR (400 MHz, CD_3OD)/$^{13}C\{^1H\}$ NMR (100 MHz, CD_3OD)



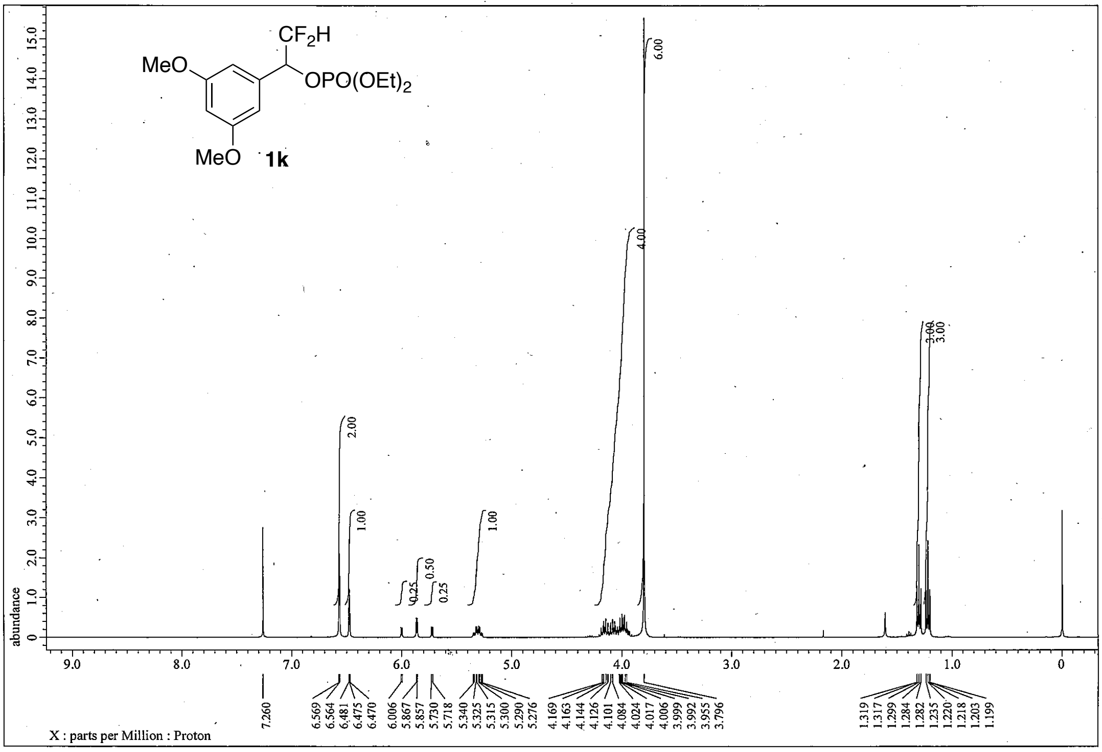


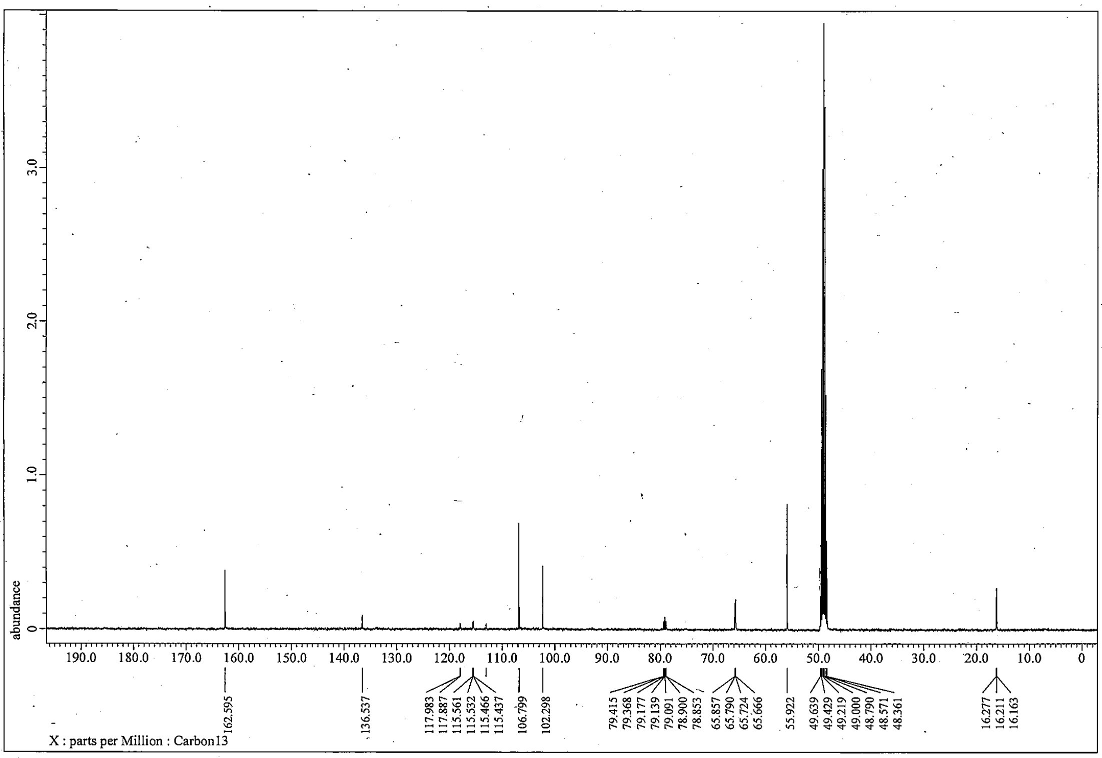
1j: ^{1}H NMR (400 MHz, $CDCl_3$)/^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$)



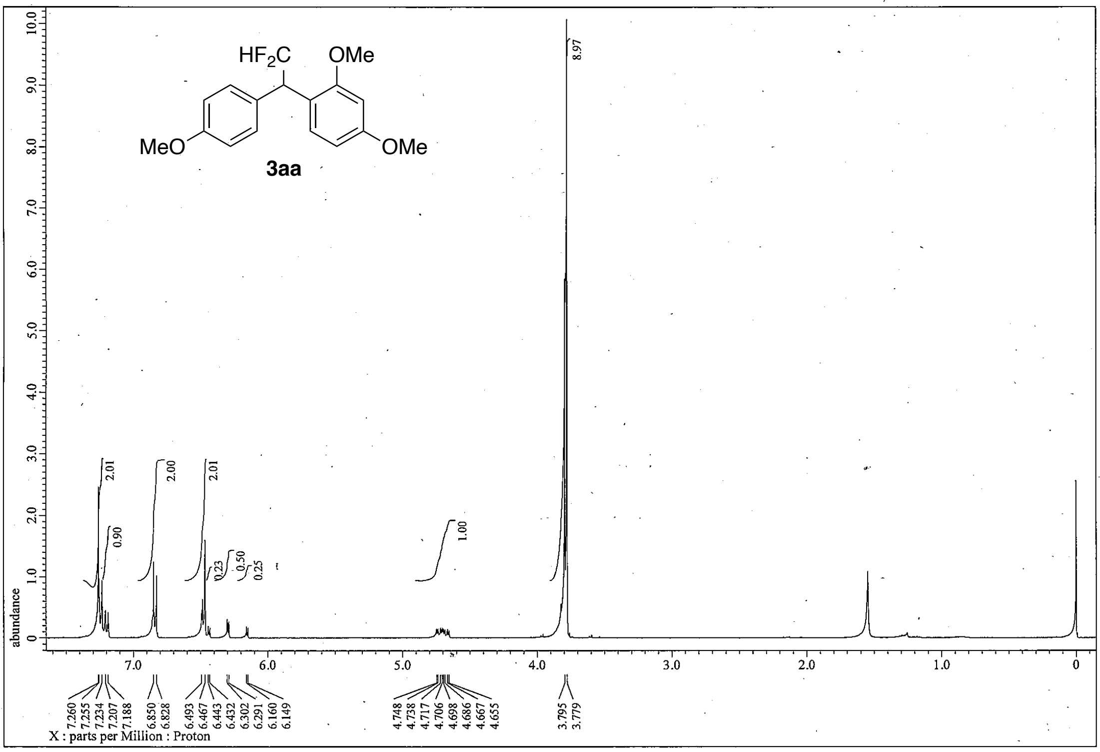


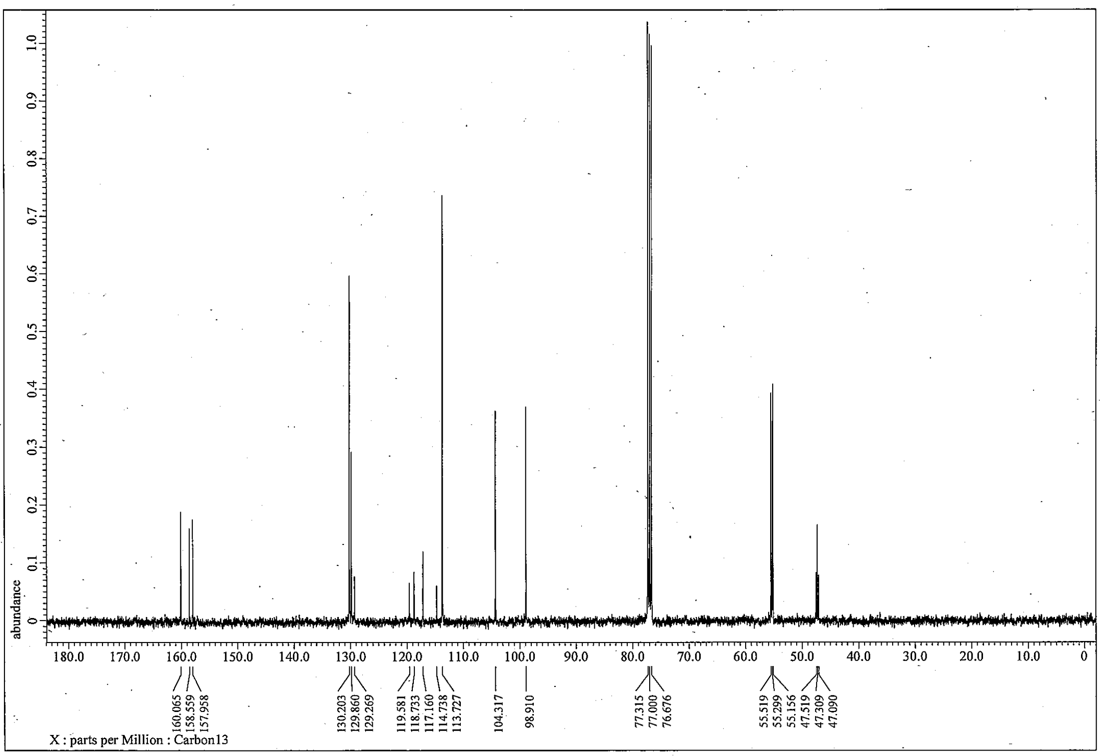
1k: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$)



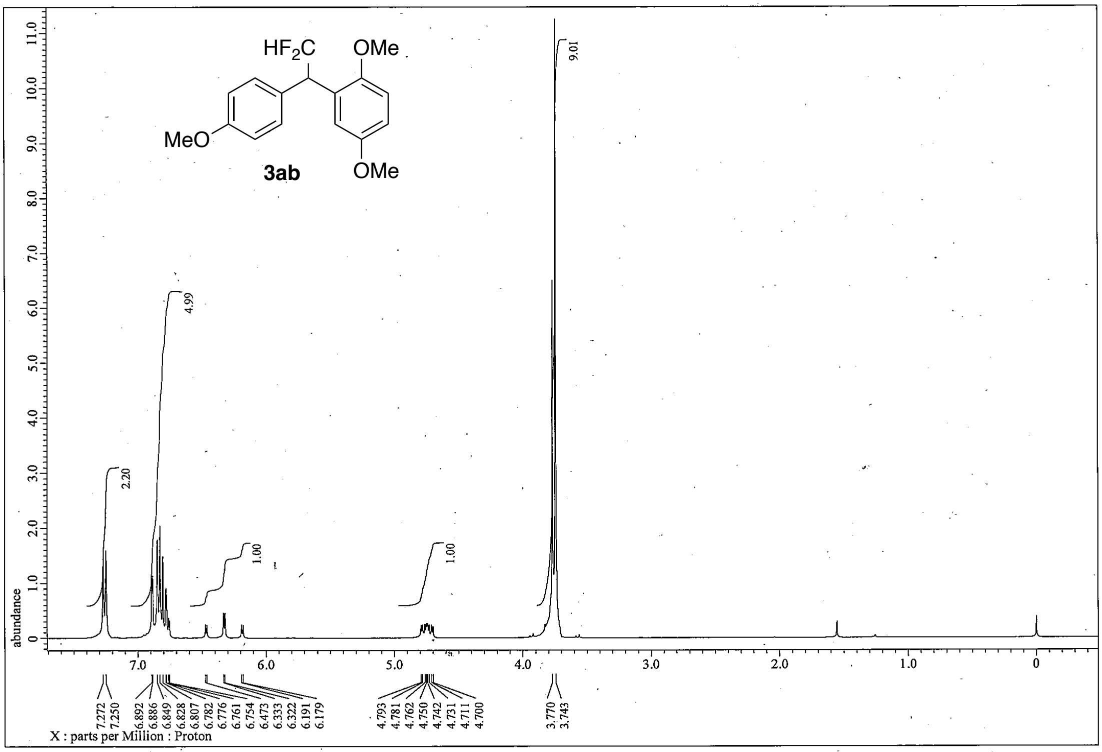


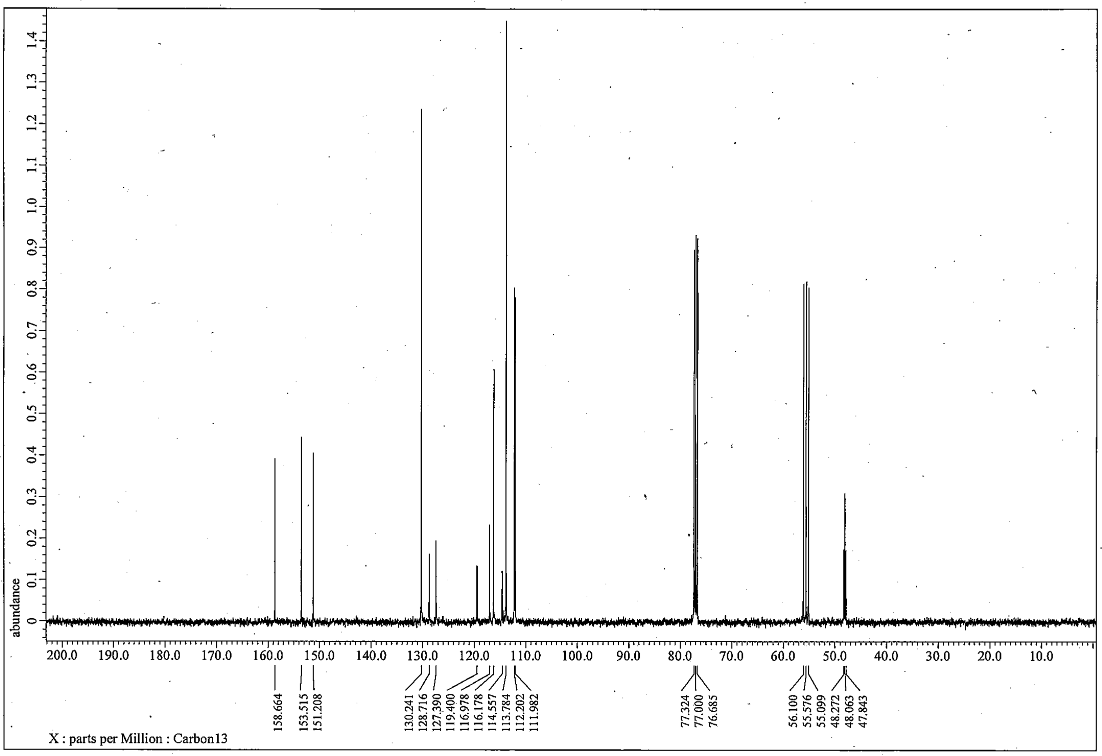
3aa: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$)



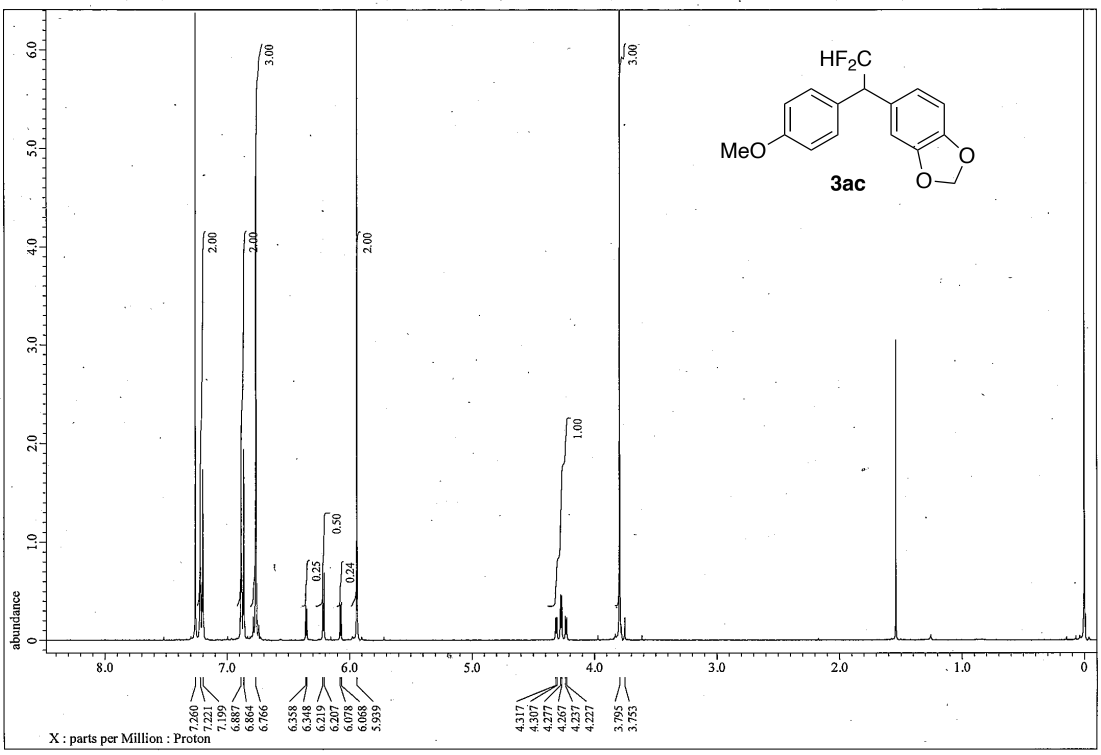


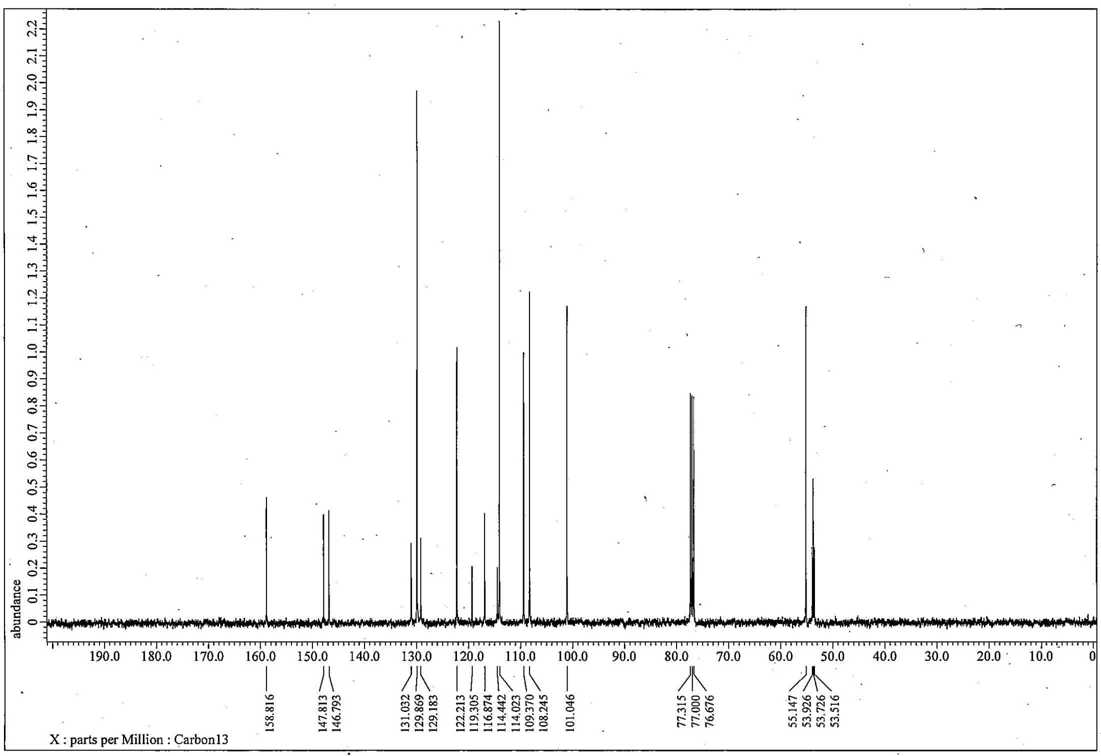
3ab: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$)



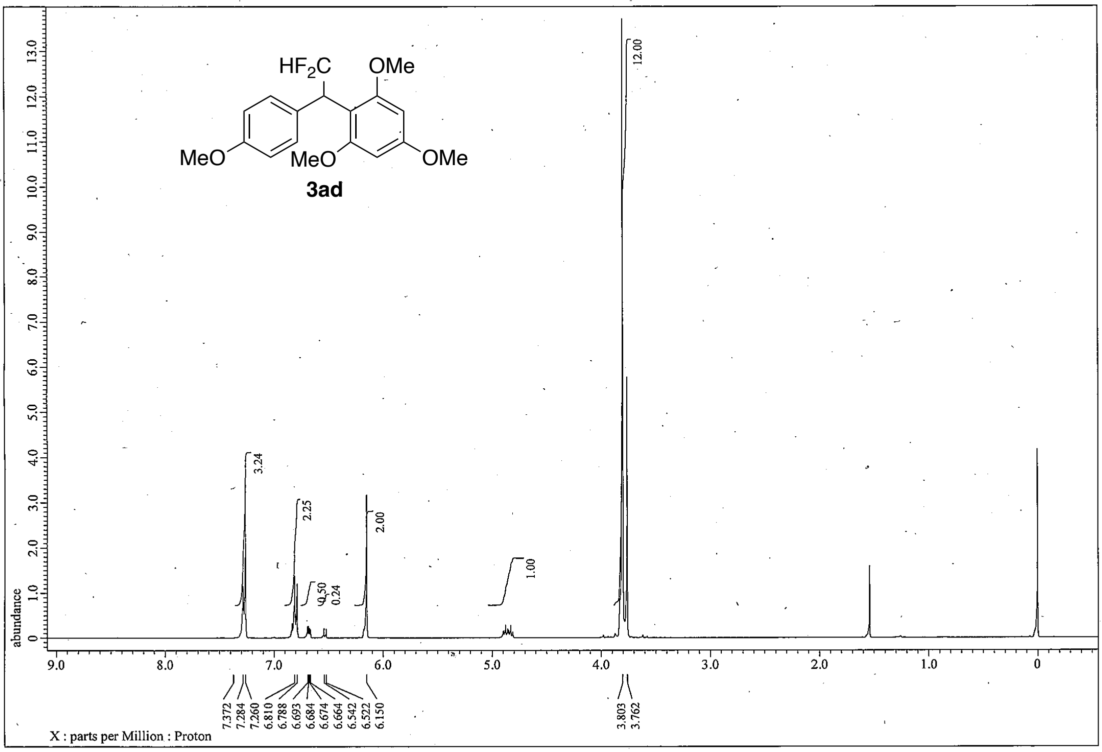


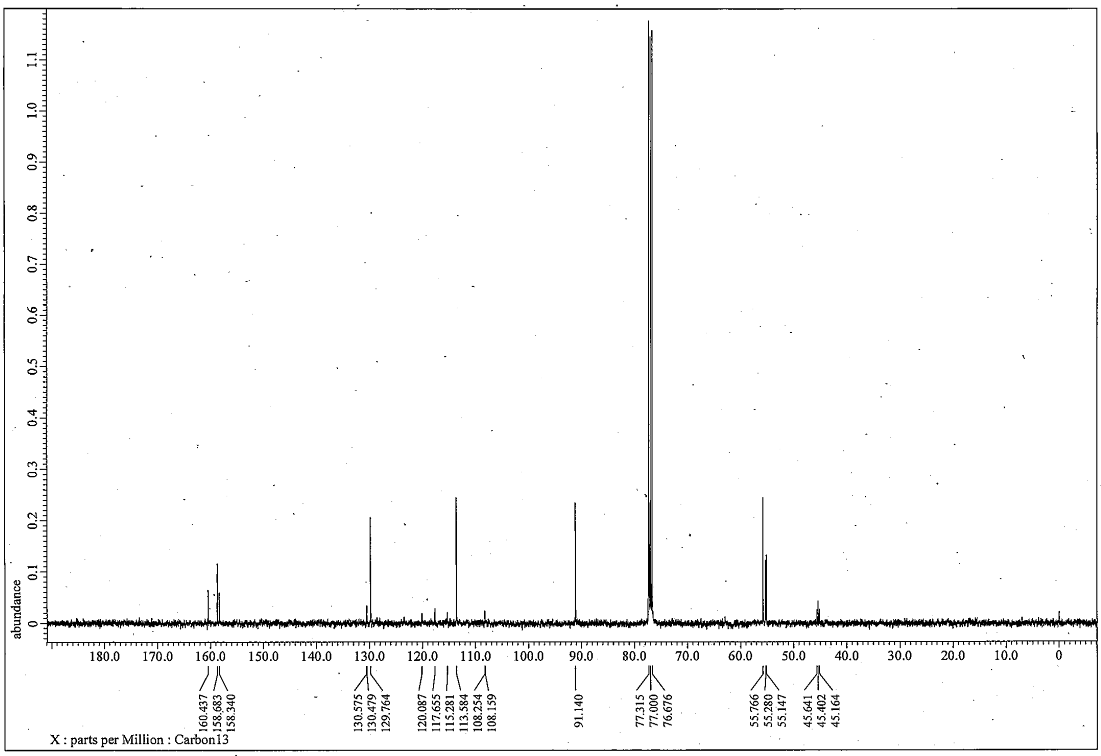
3ac: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$)



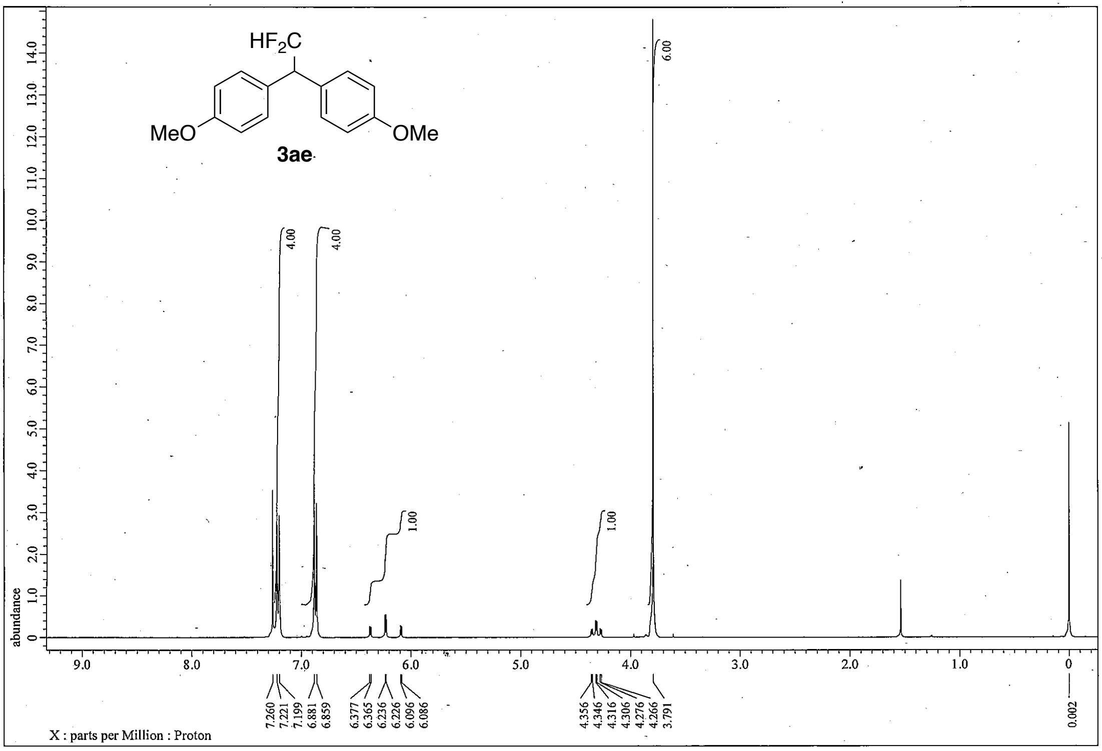


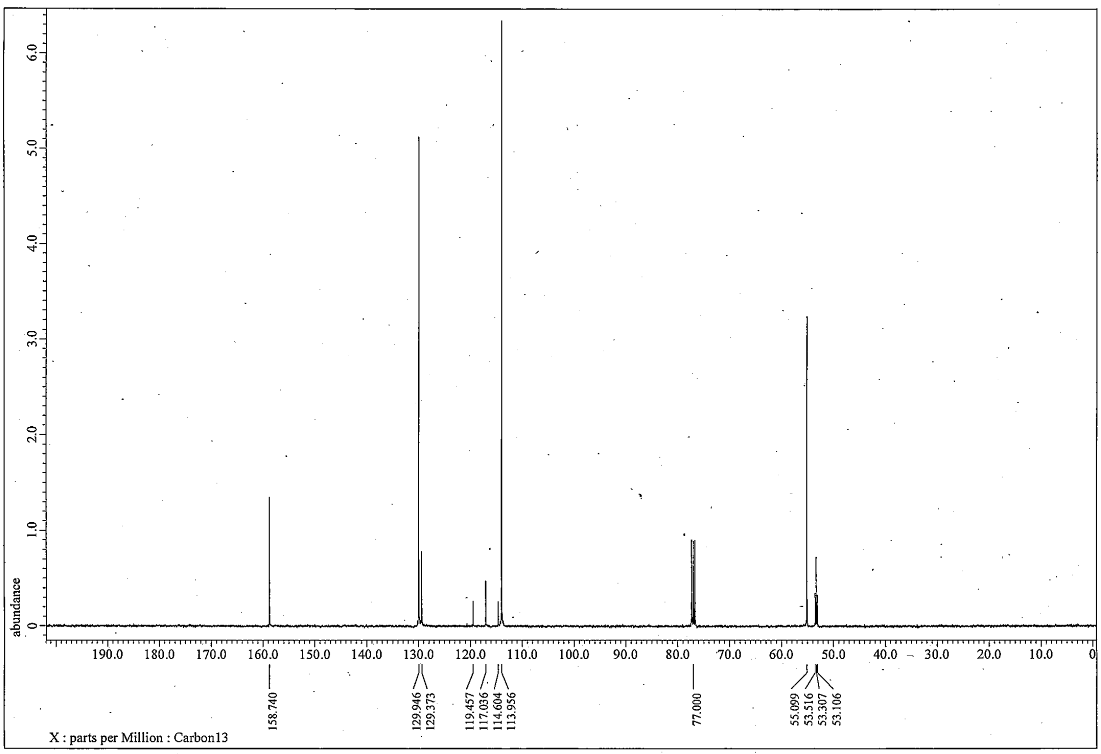
3ad: ^{1}H NMR (400 MHz, CDCl$_3$)/^{13}C{^{1}H} NMR (100 MHz, CDCl$_3$)



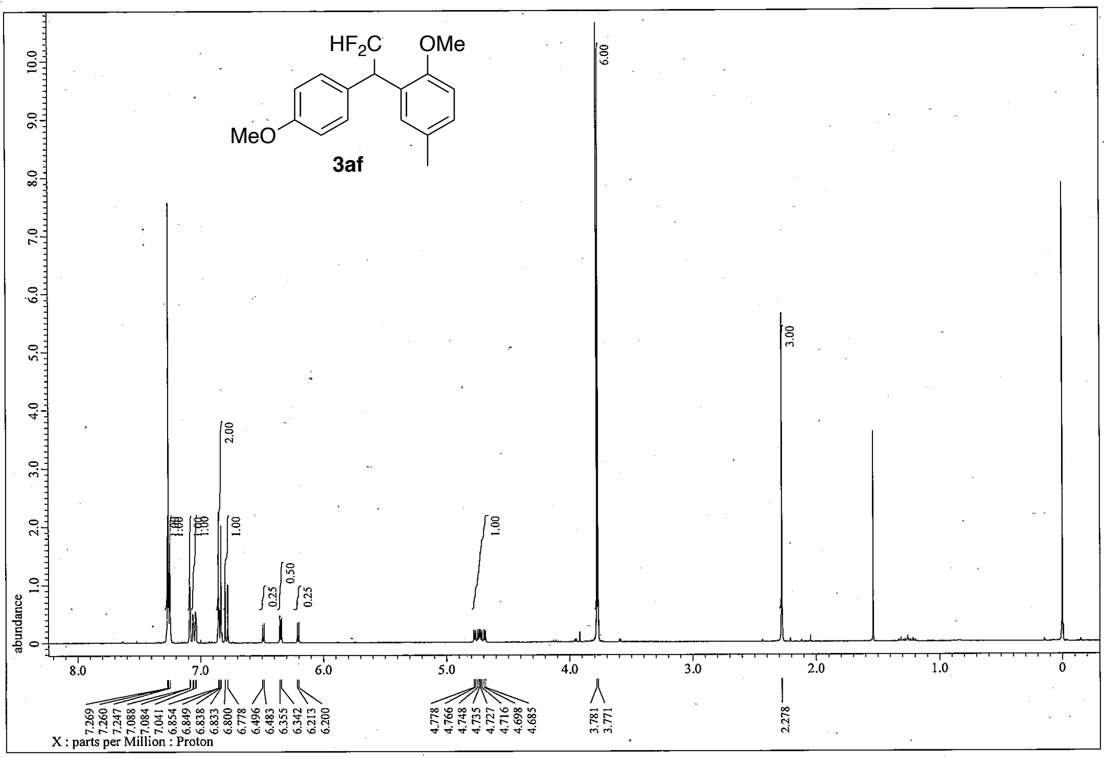


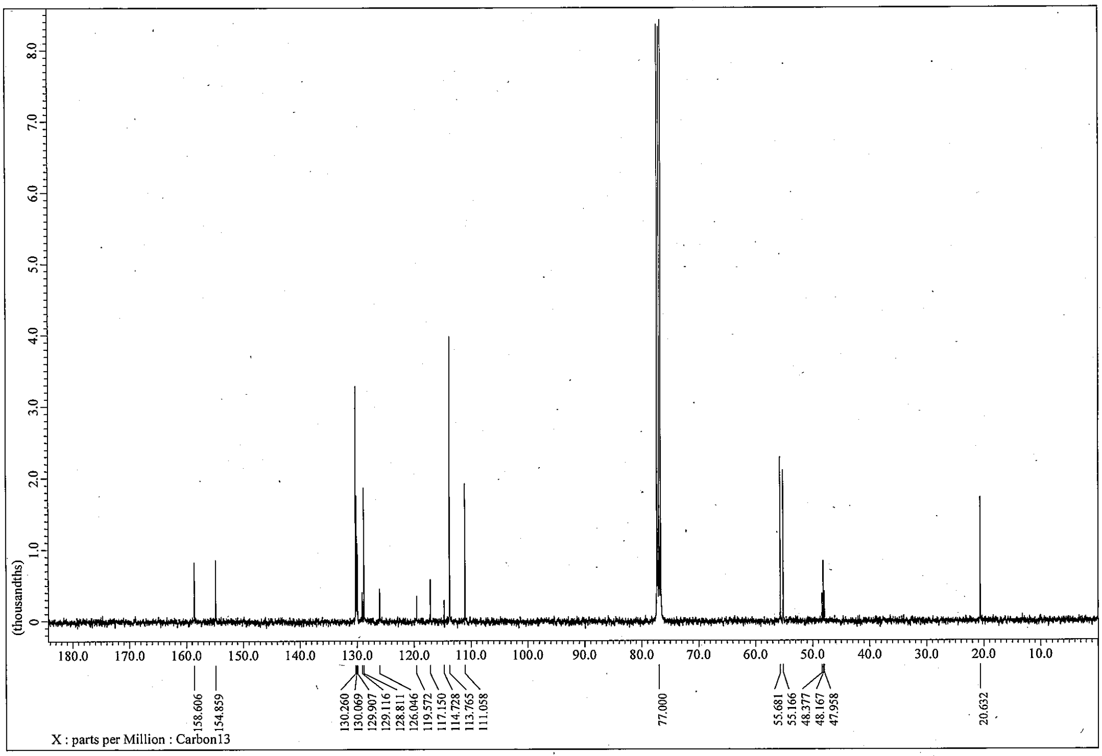
3ae: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$)



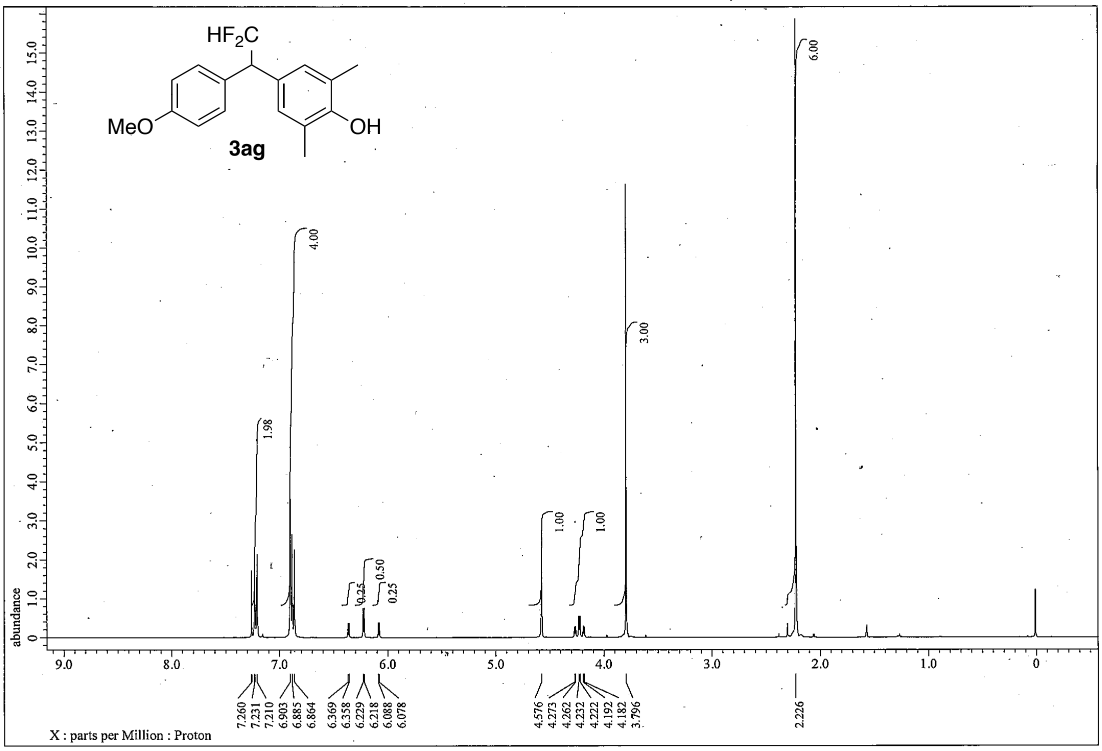


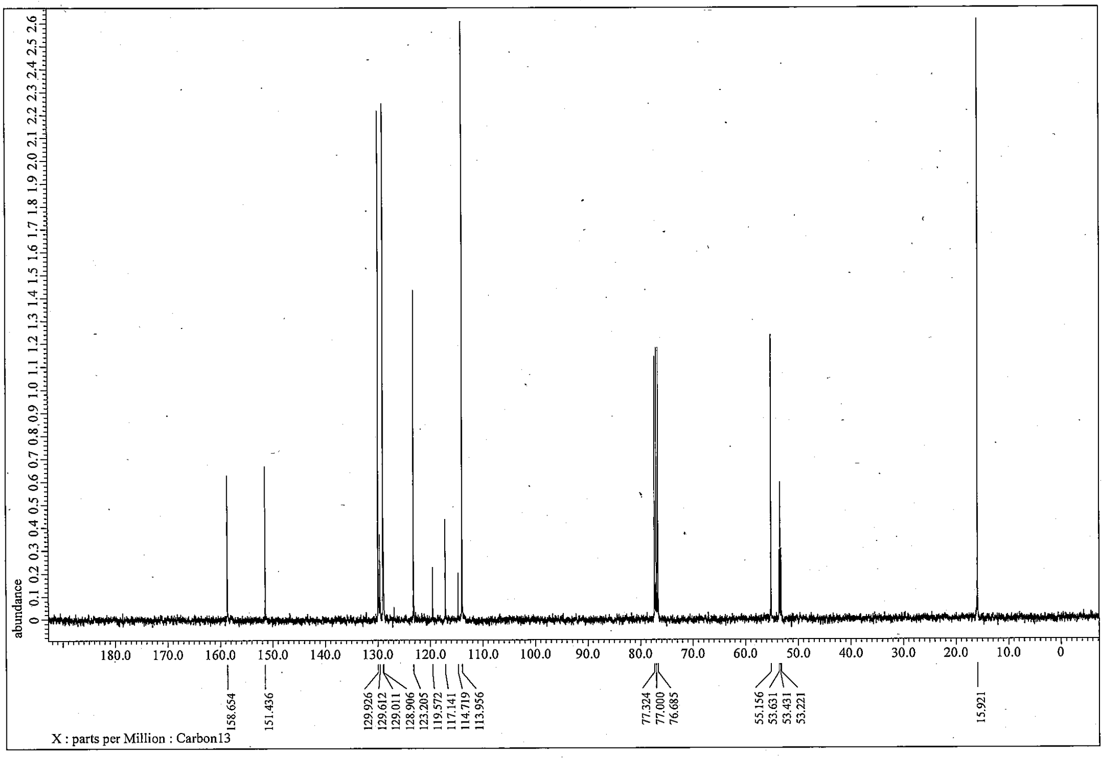
3af: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$)



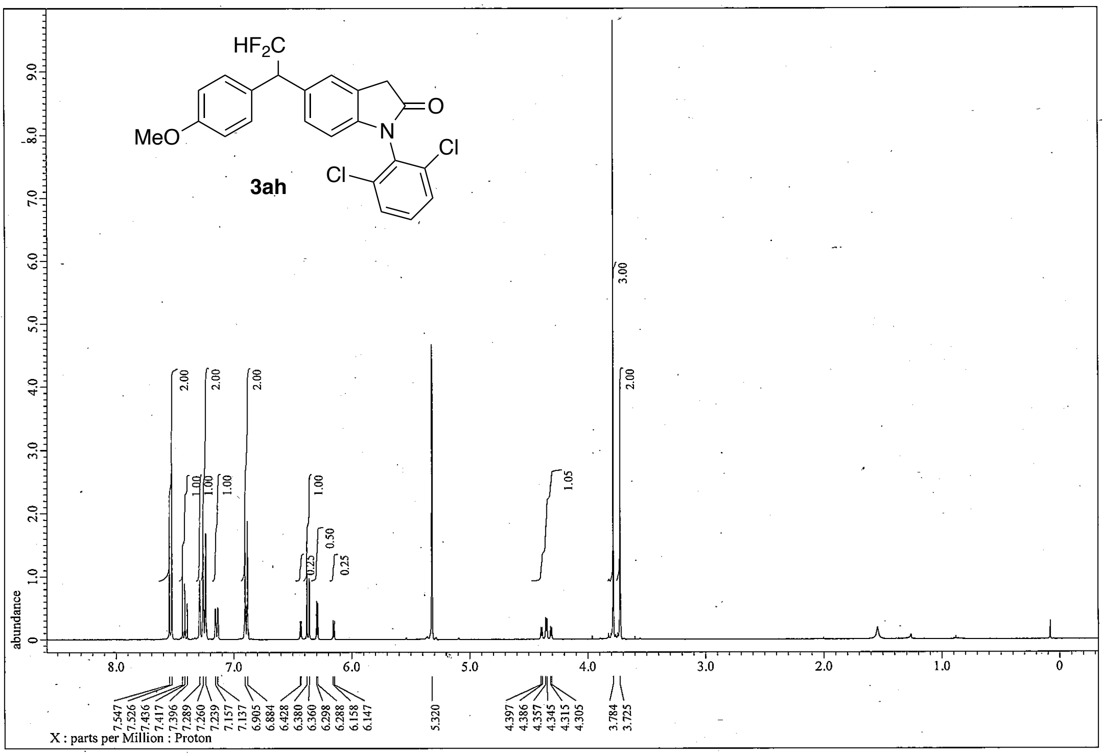


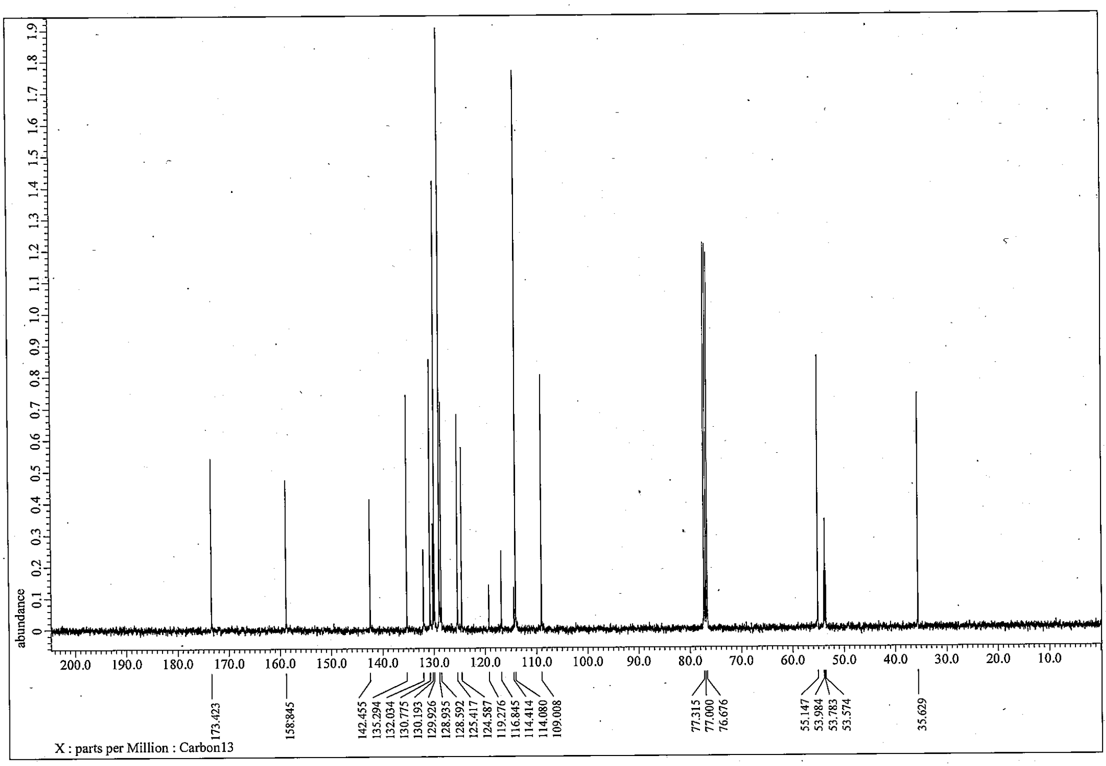
3ag: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$)



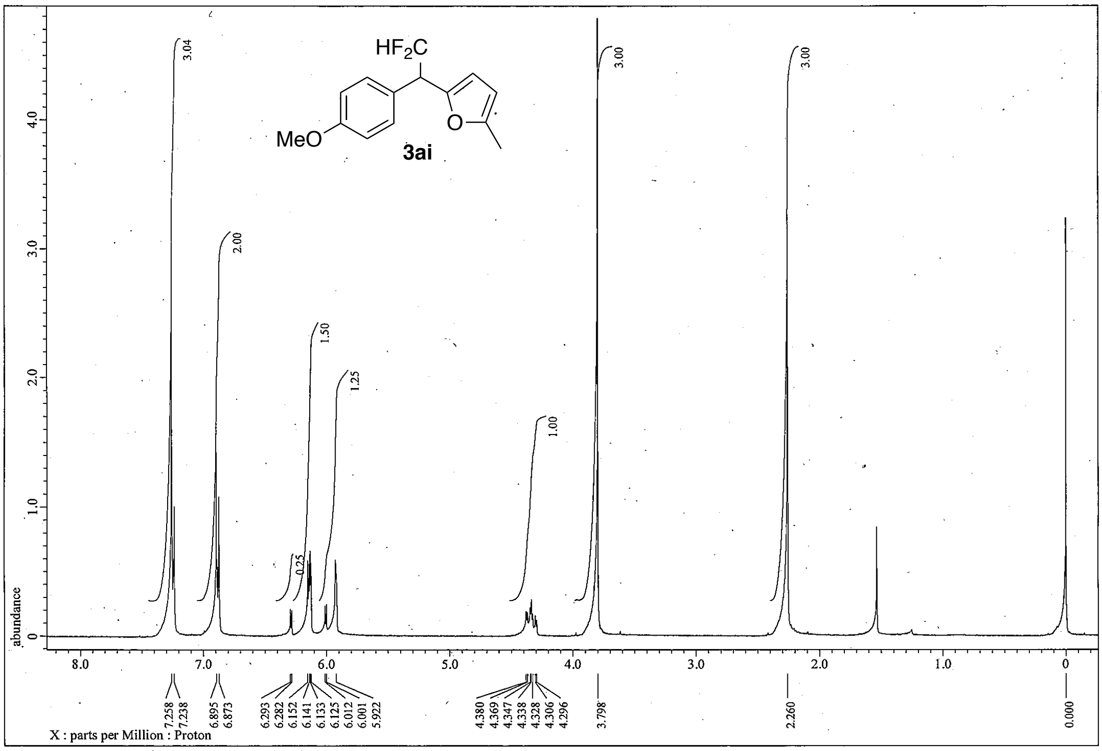


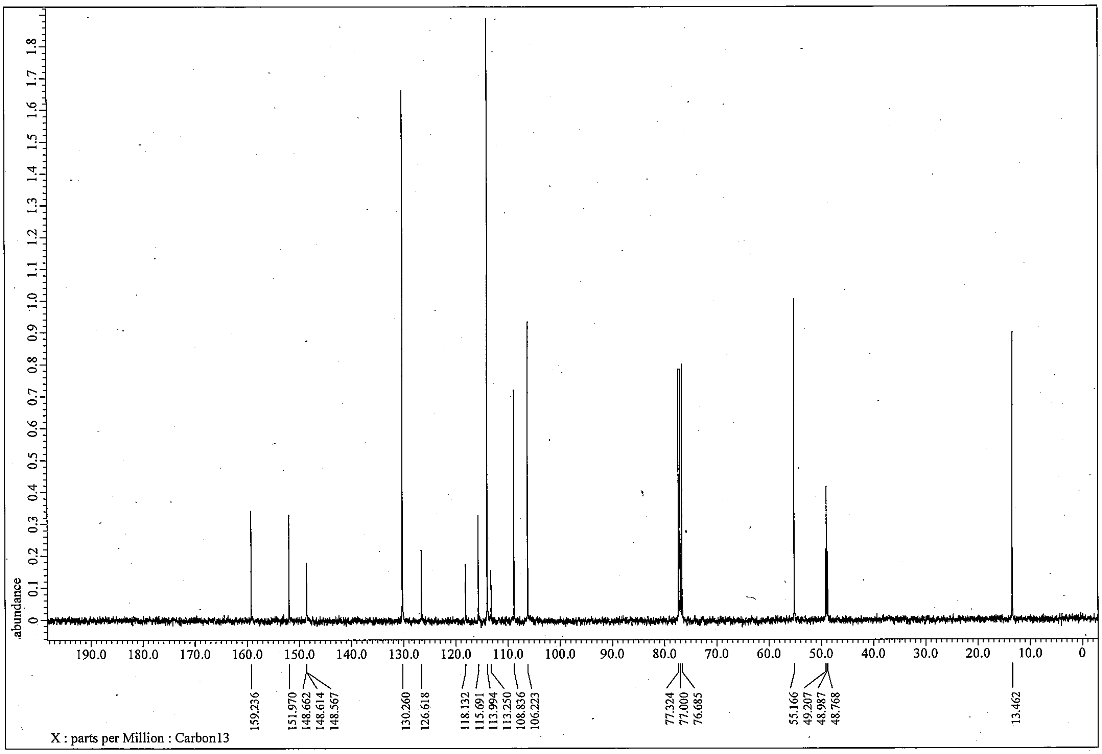
3ah: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$)



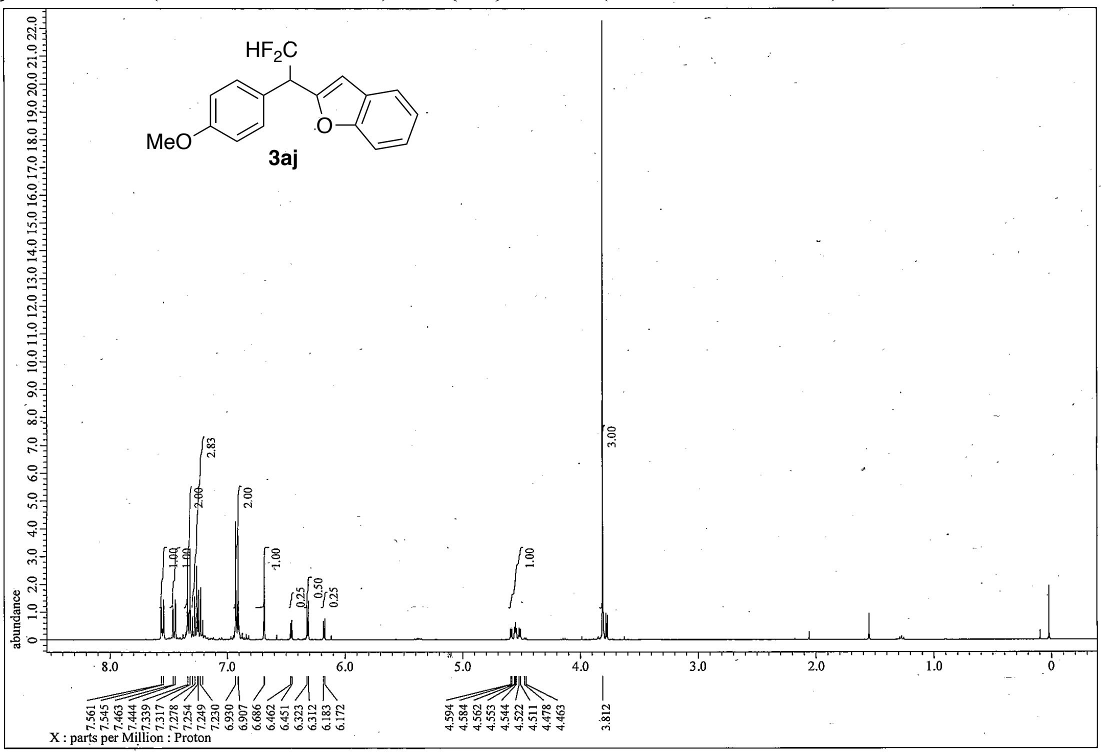


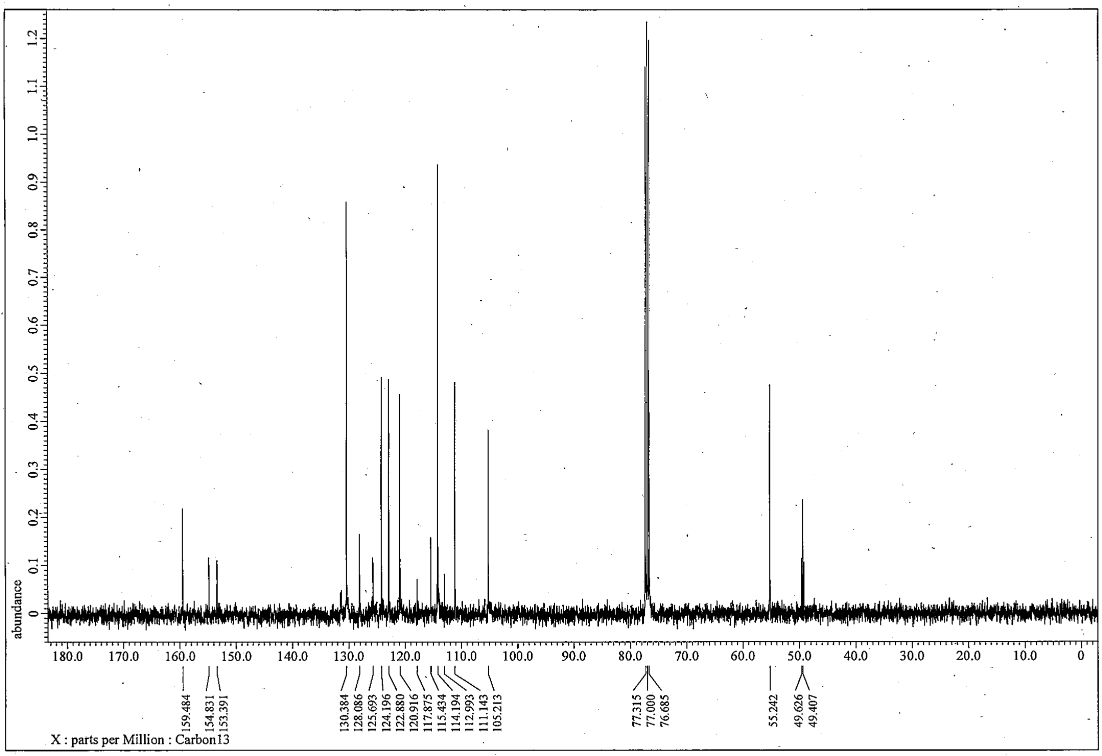
3ai: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$)



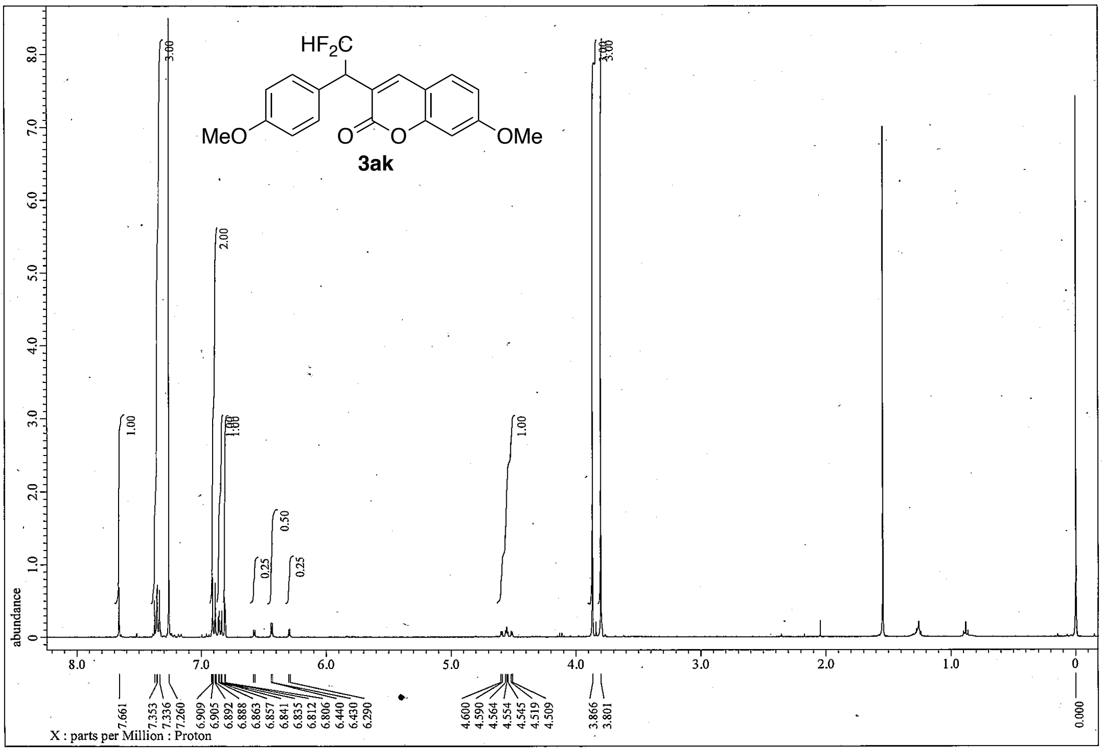


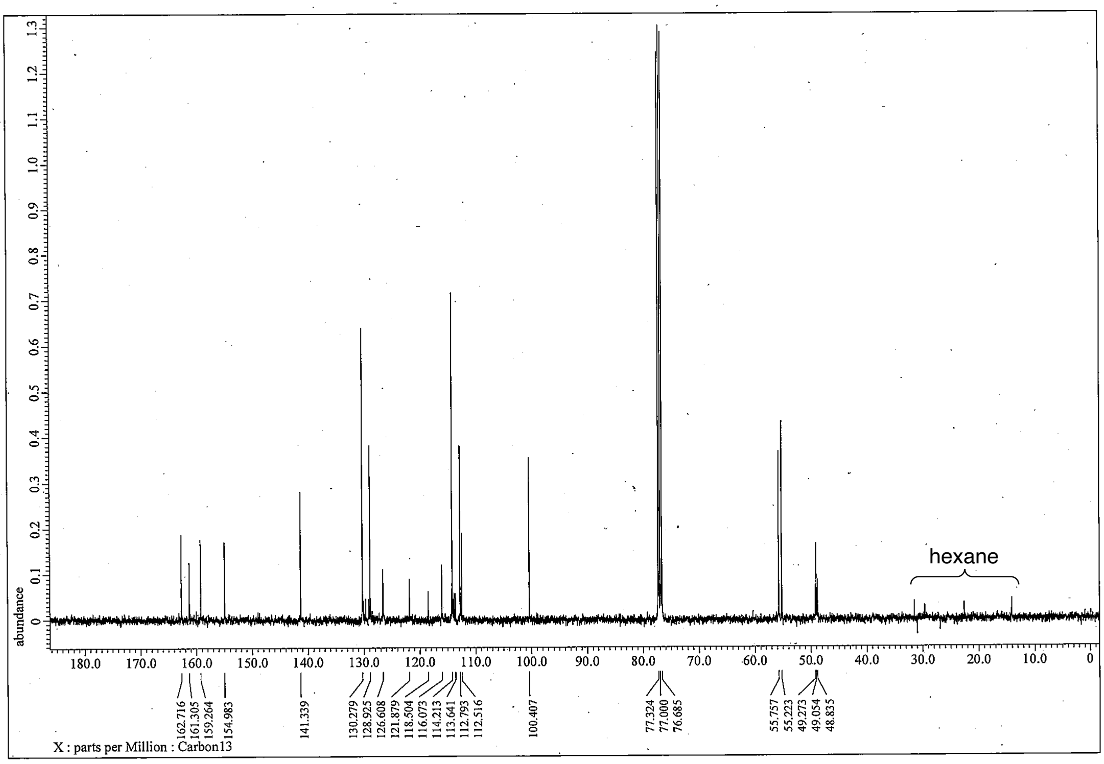
3aj: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$)



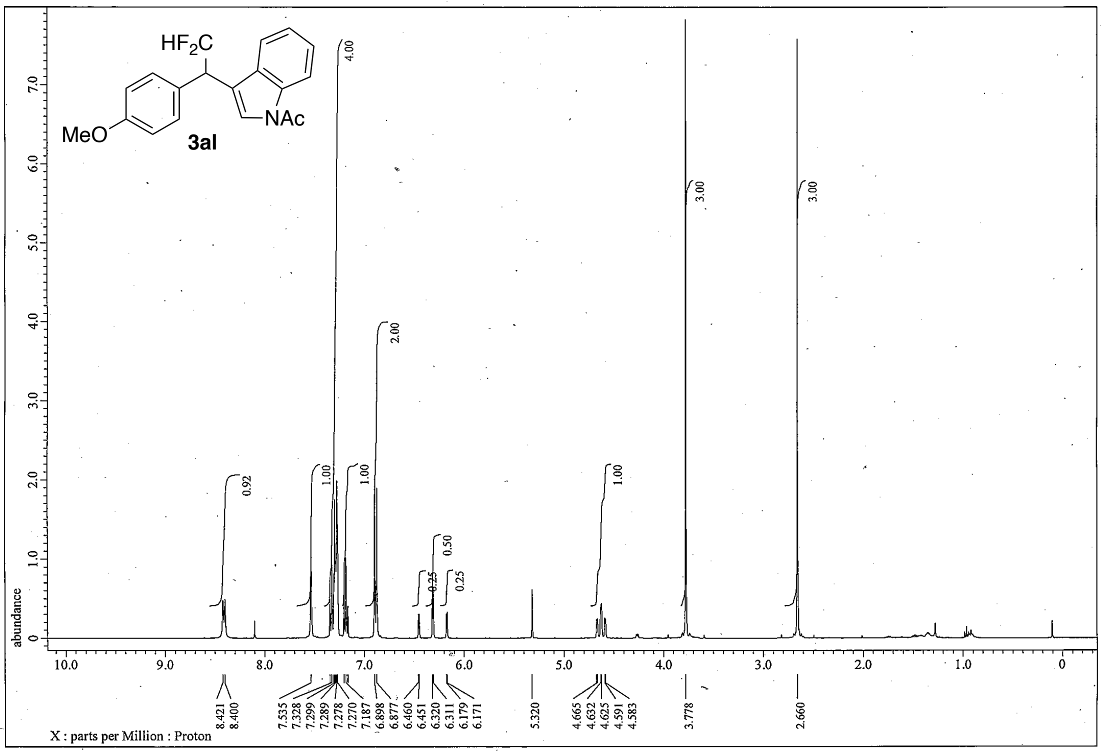


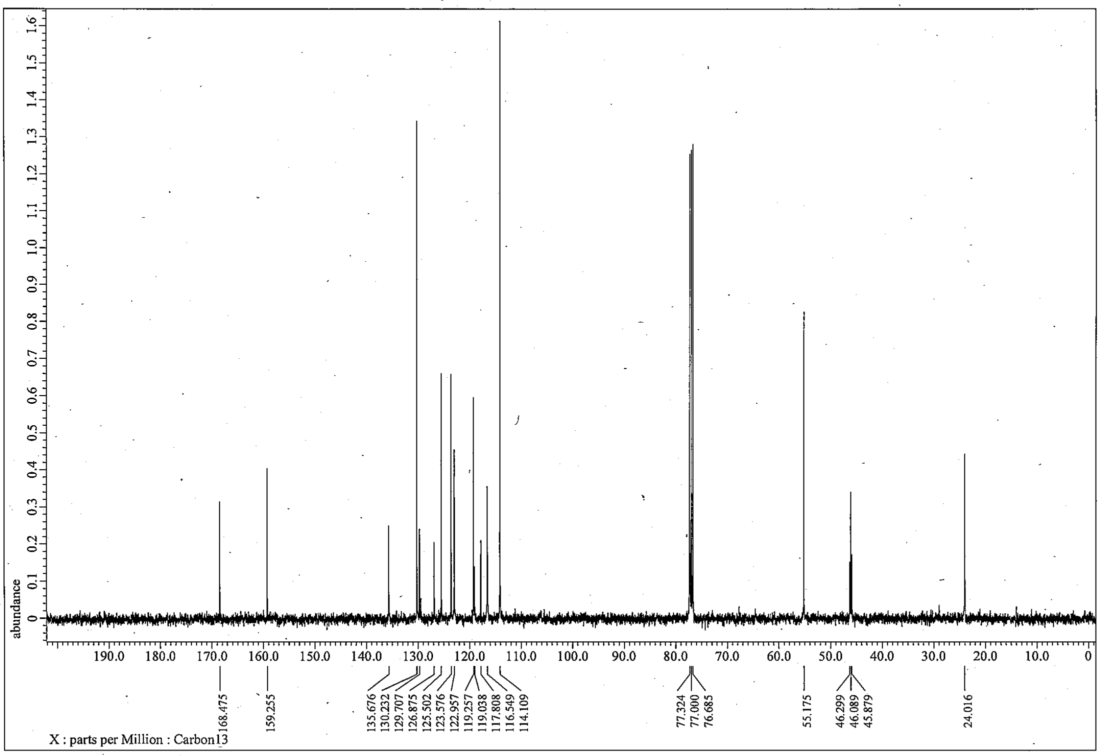
3ak: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$)



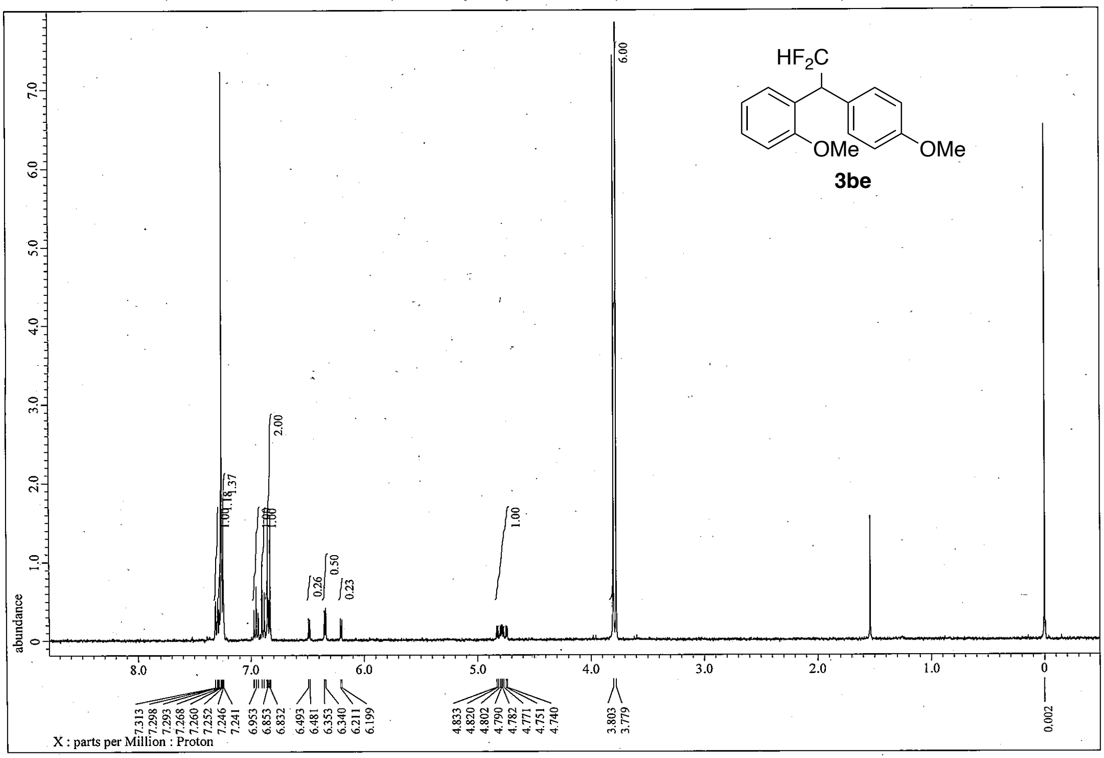


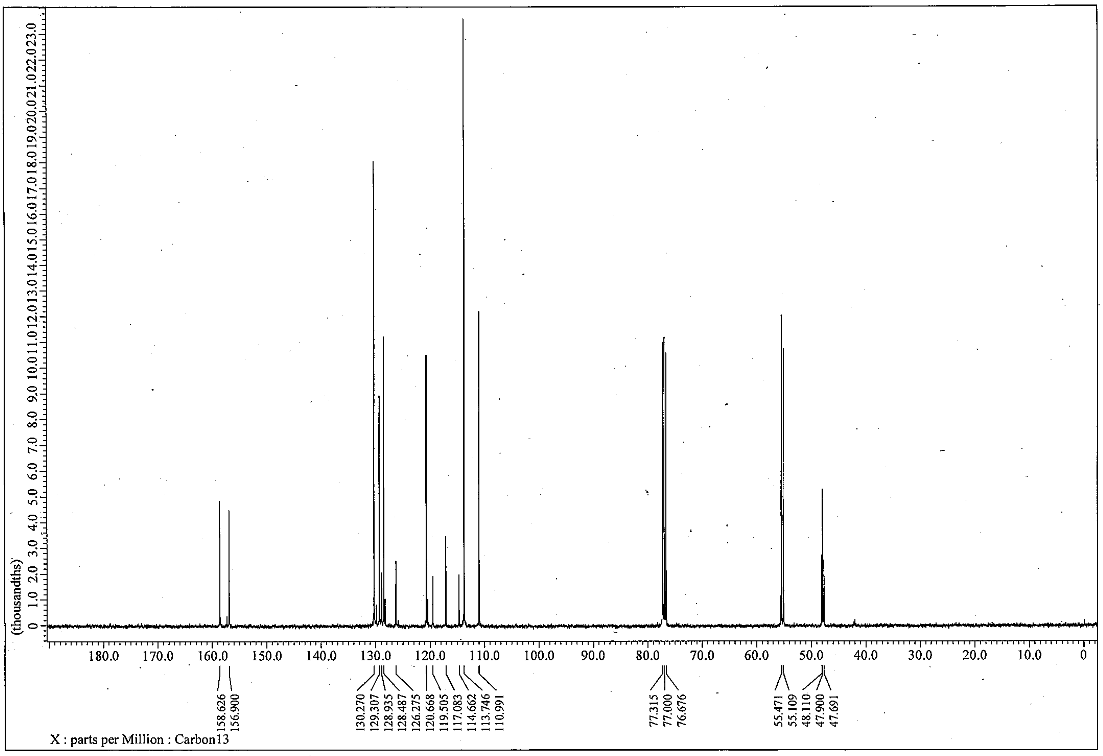
3al: ^{1}H NMR (400 MHz, CD_2Cl_2)/^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$)



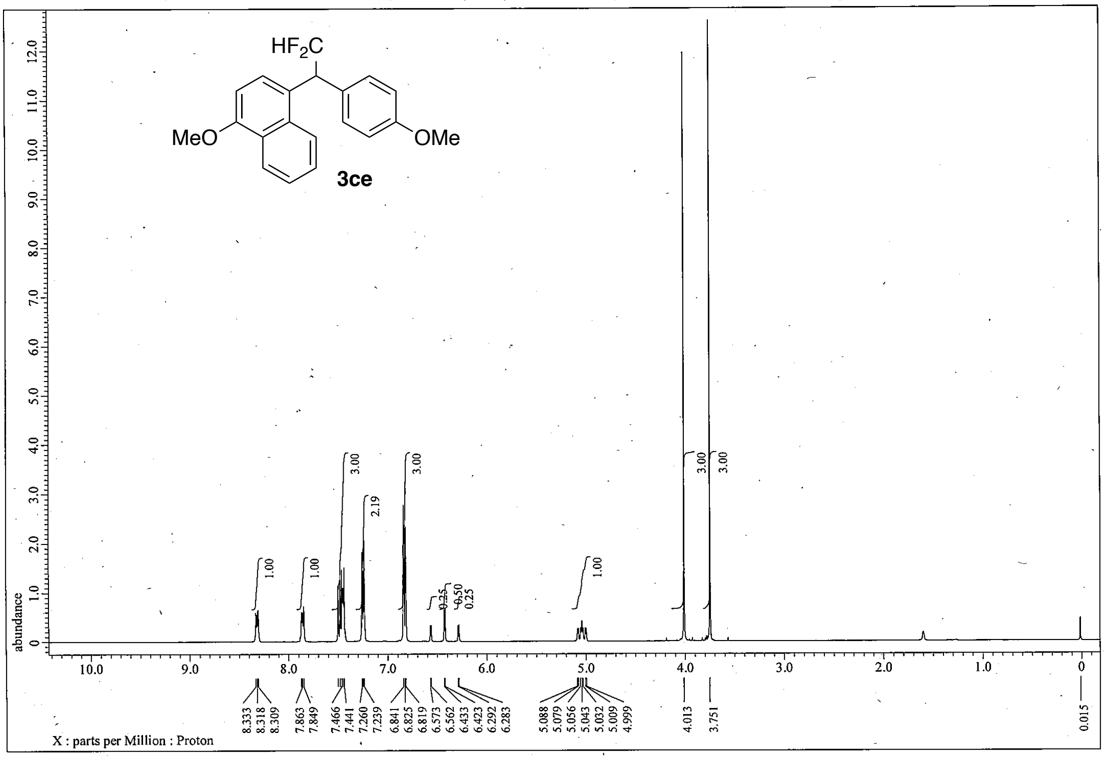


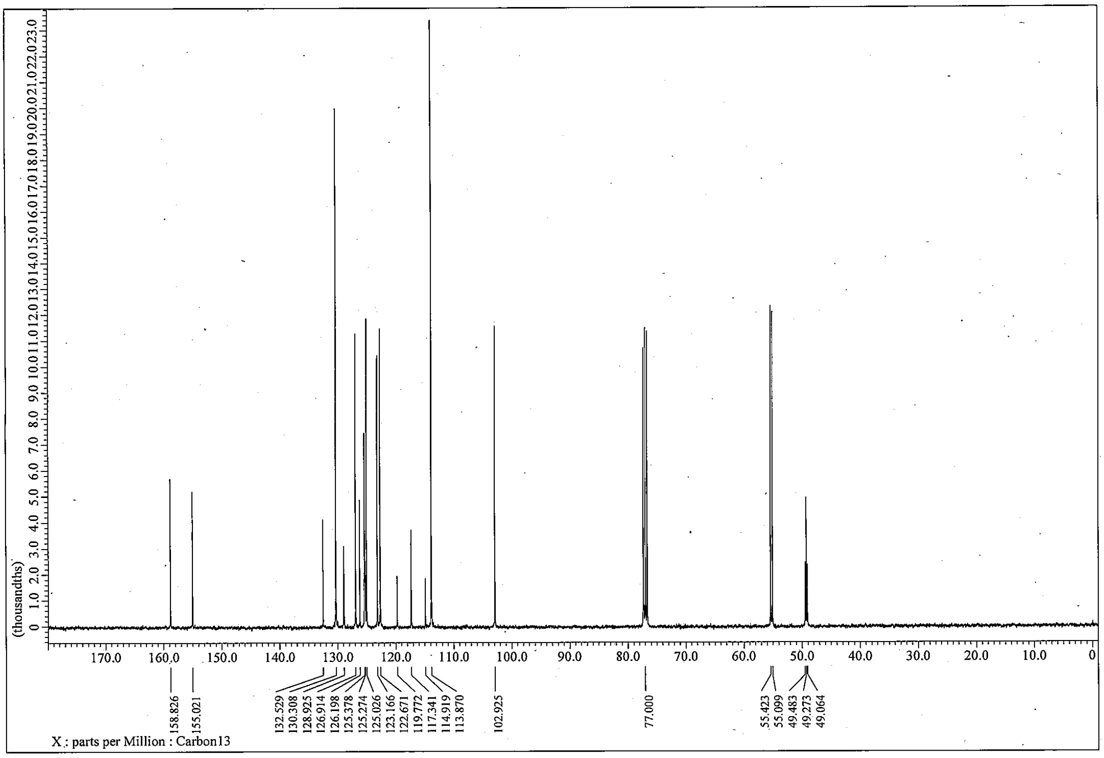
3be: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$)



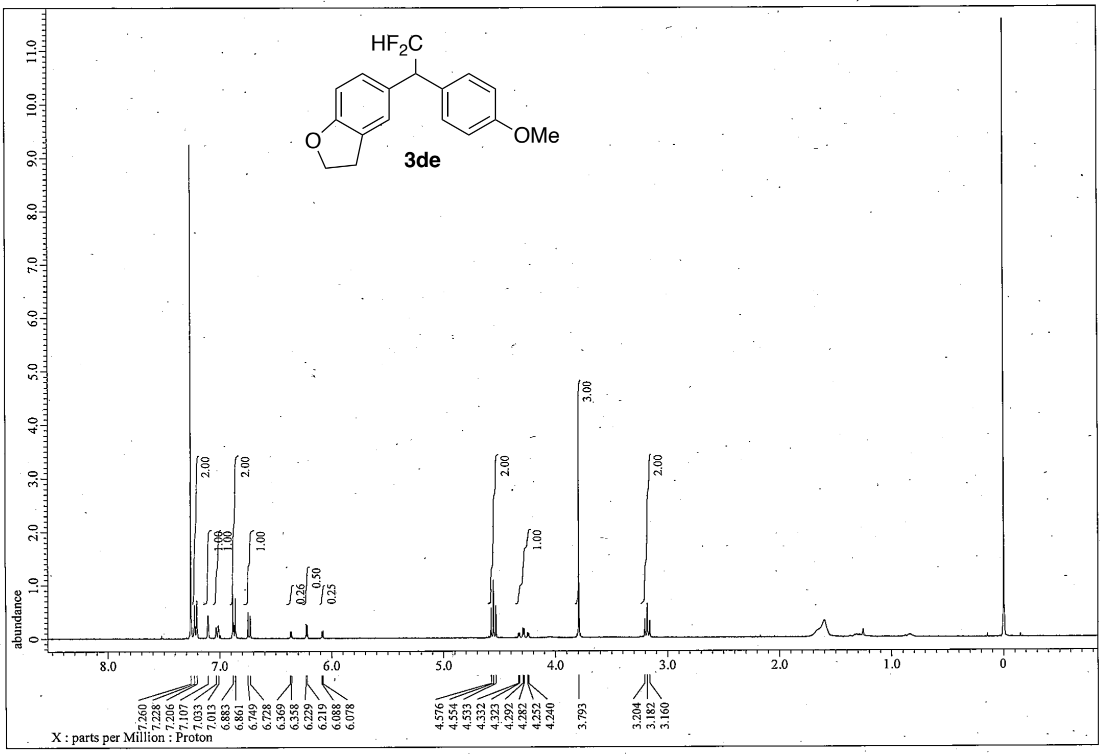


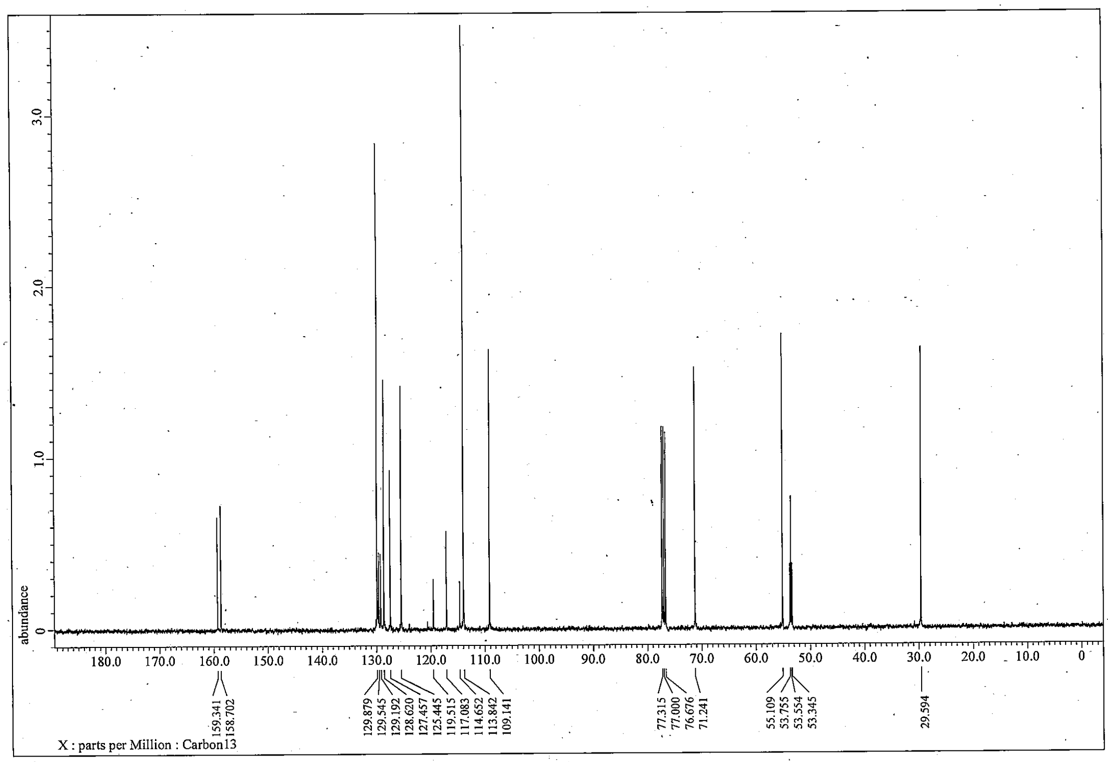
3ce: ^{1}H NMR (400 MHz, CDCl$_3$)/^{13}C{^{1}H} NMR (100 MHz, CDCl$_3$)



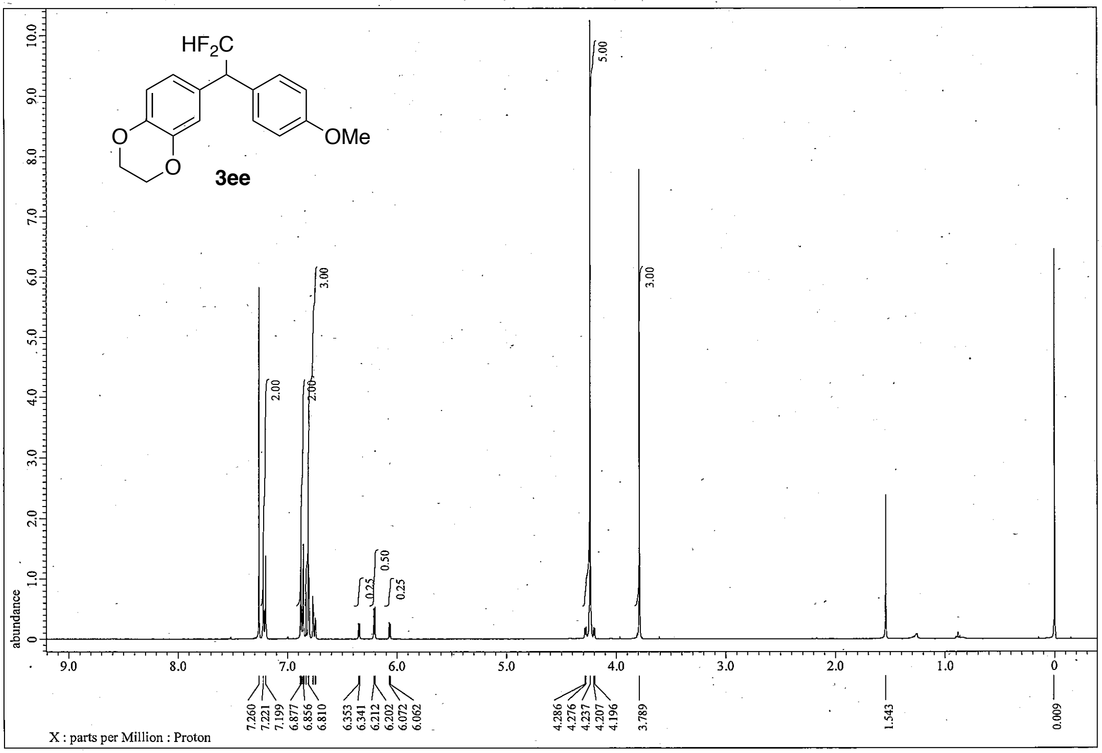


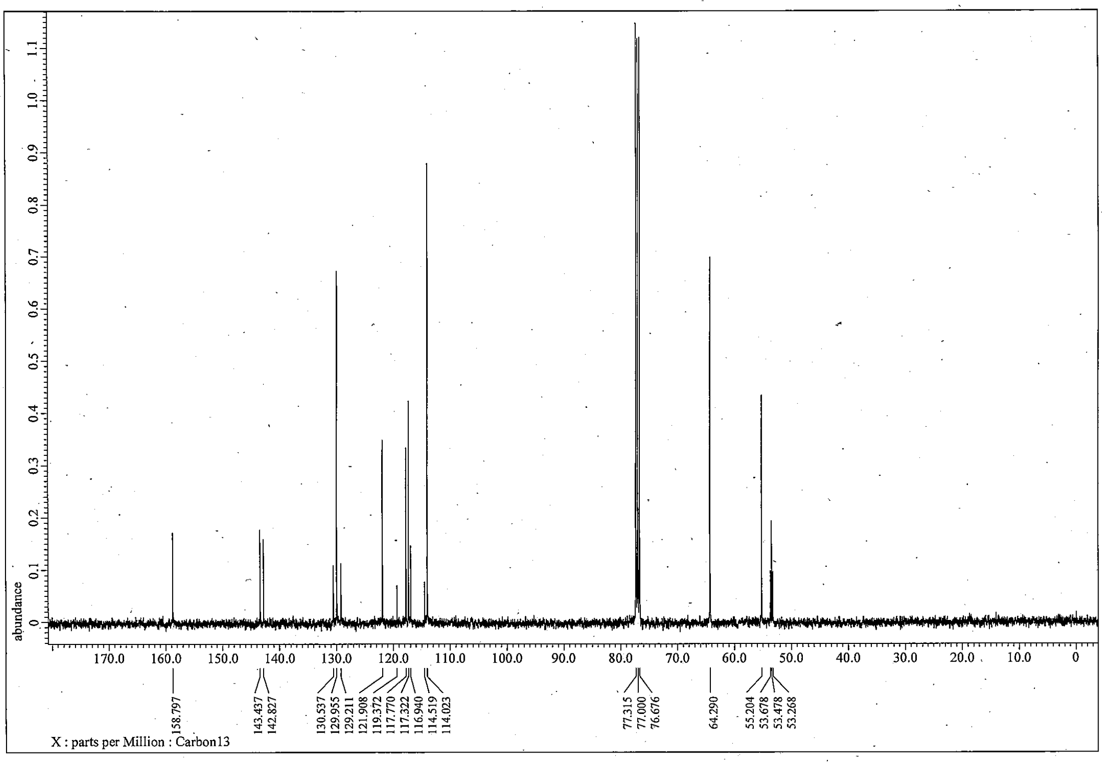
3de: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$)



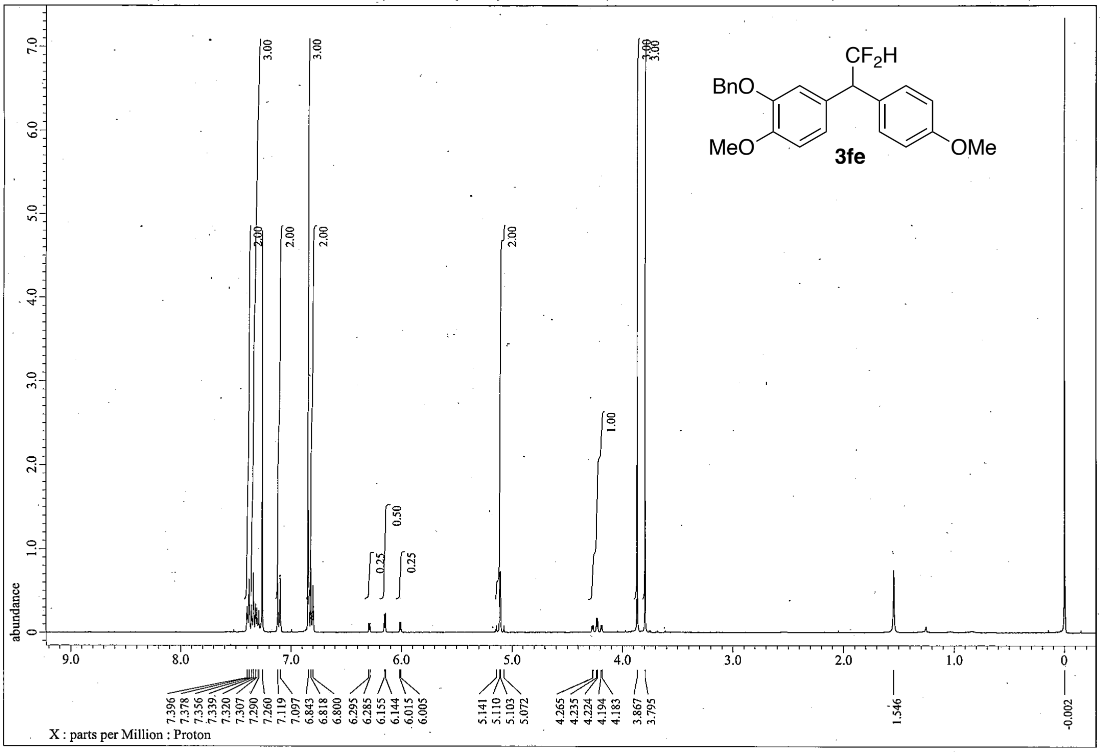


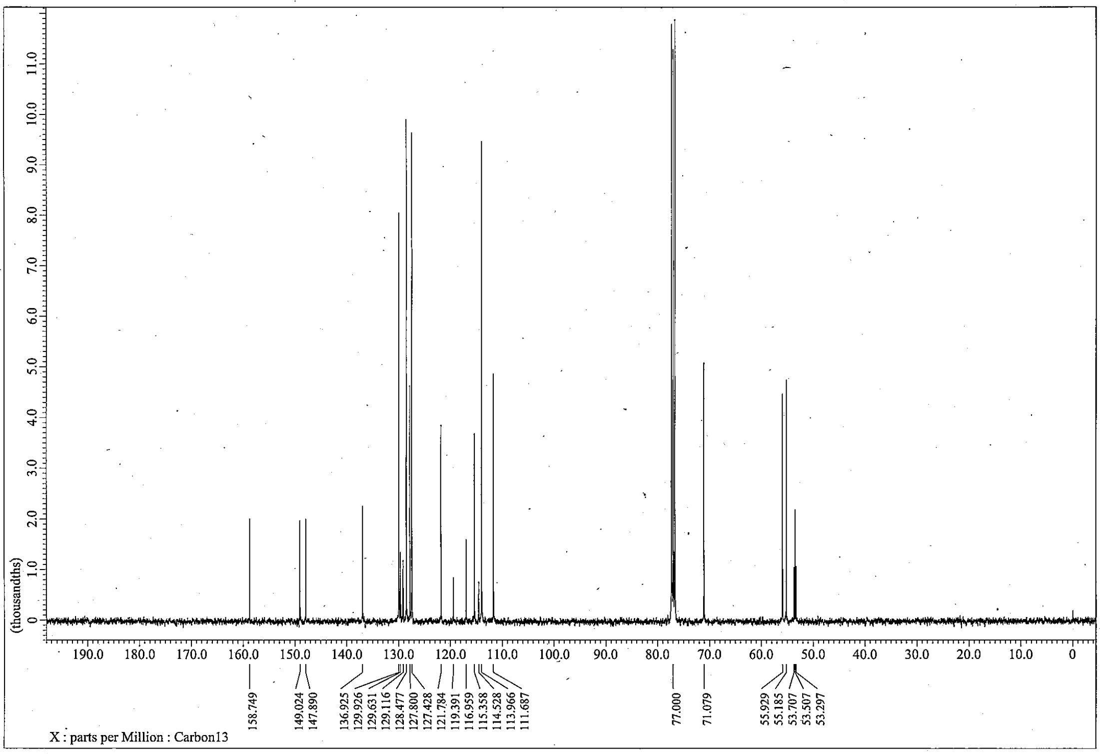
3ee: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$)



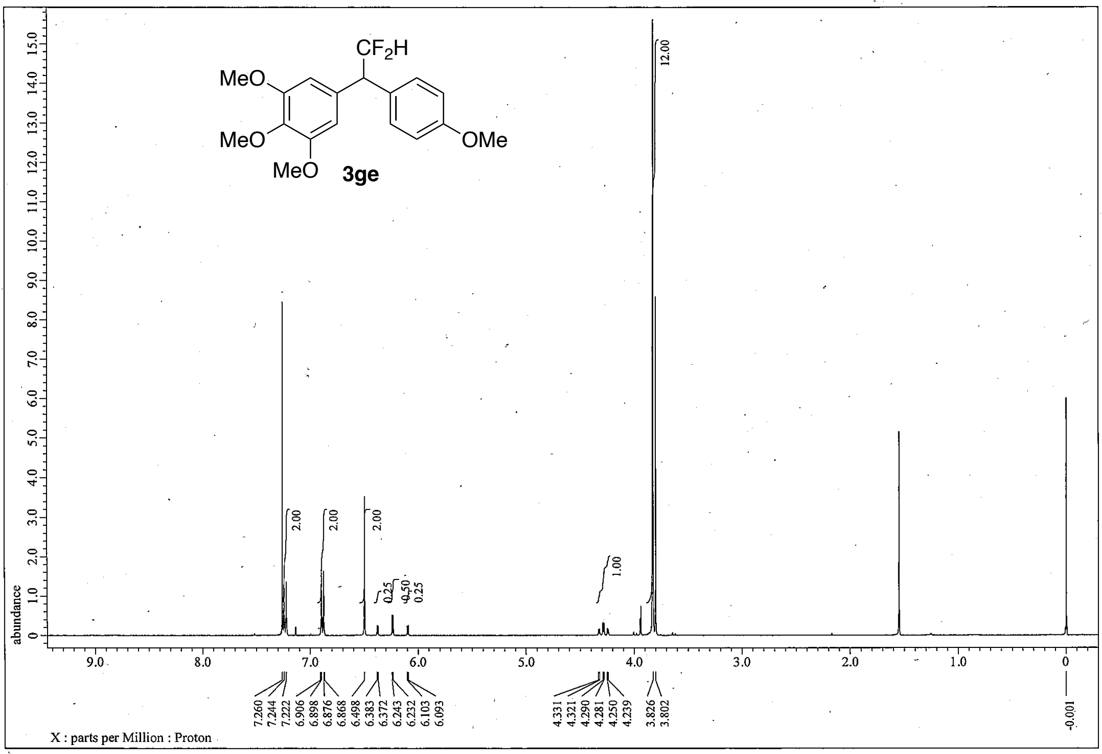


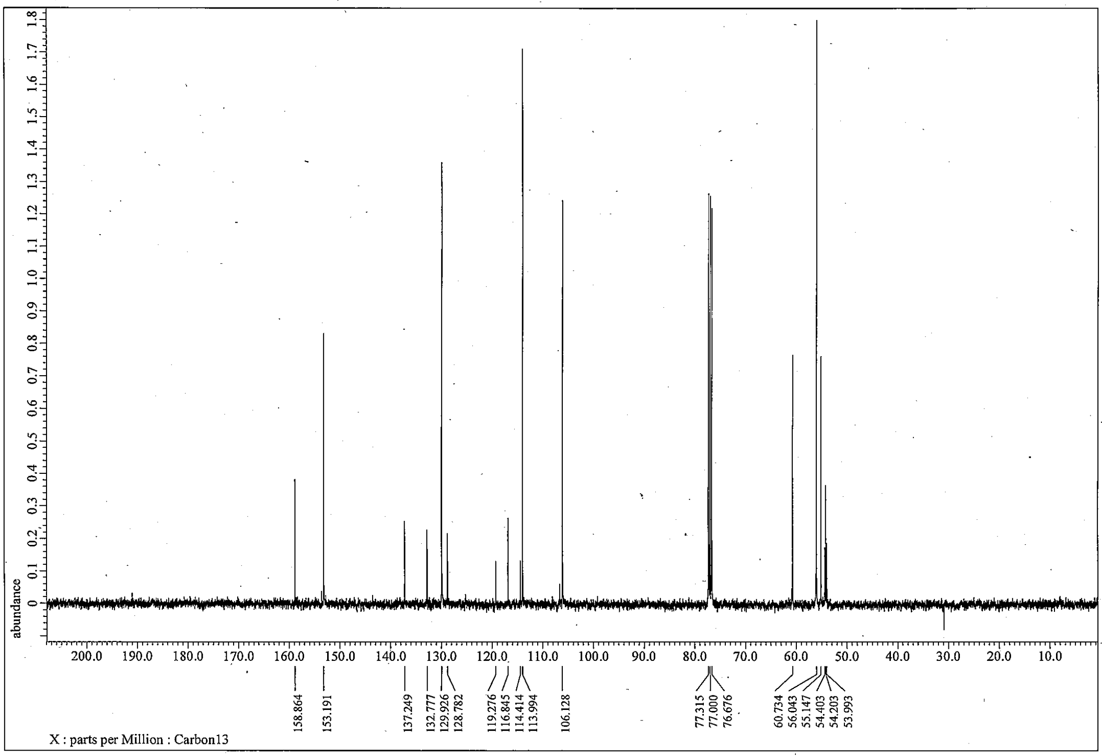
3fe: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$)



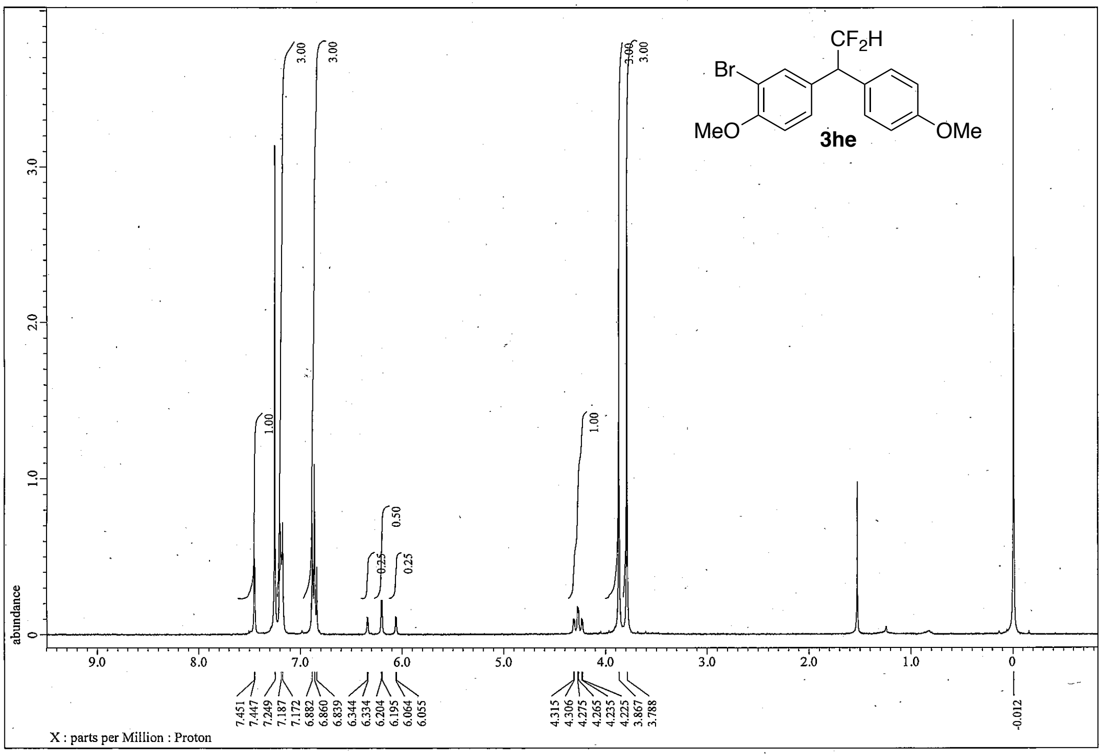


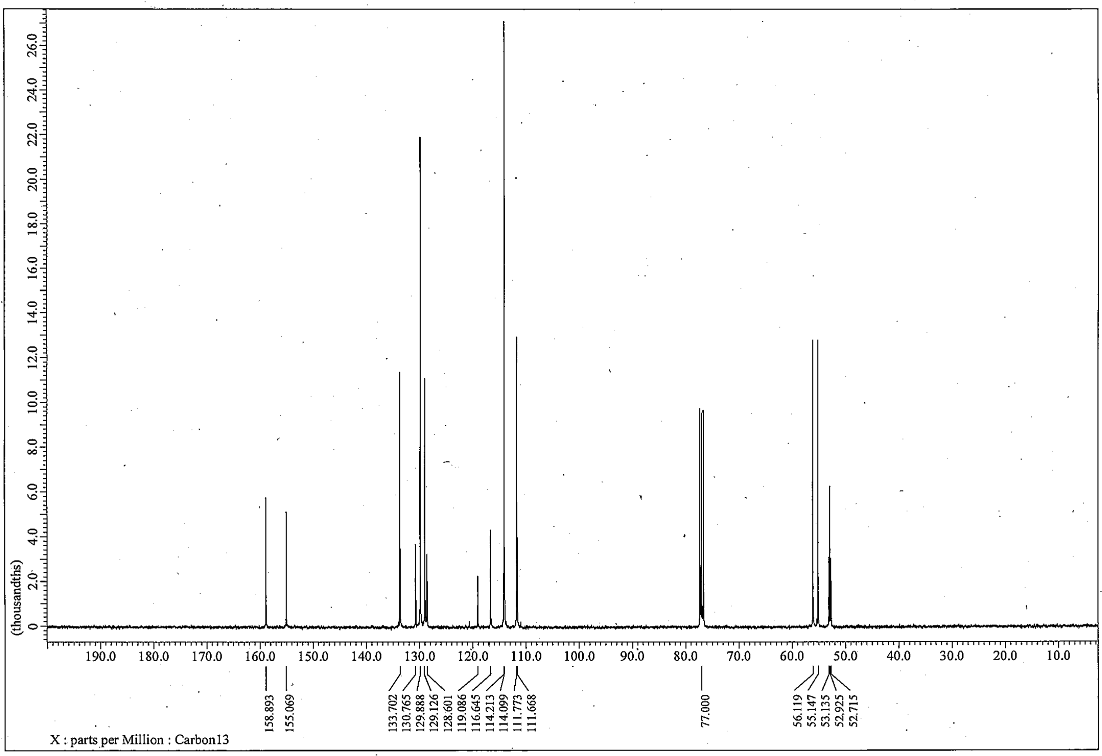
3ge: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$)



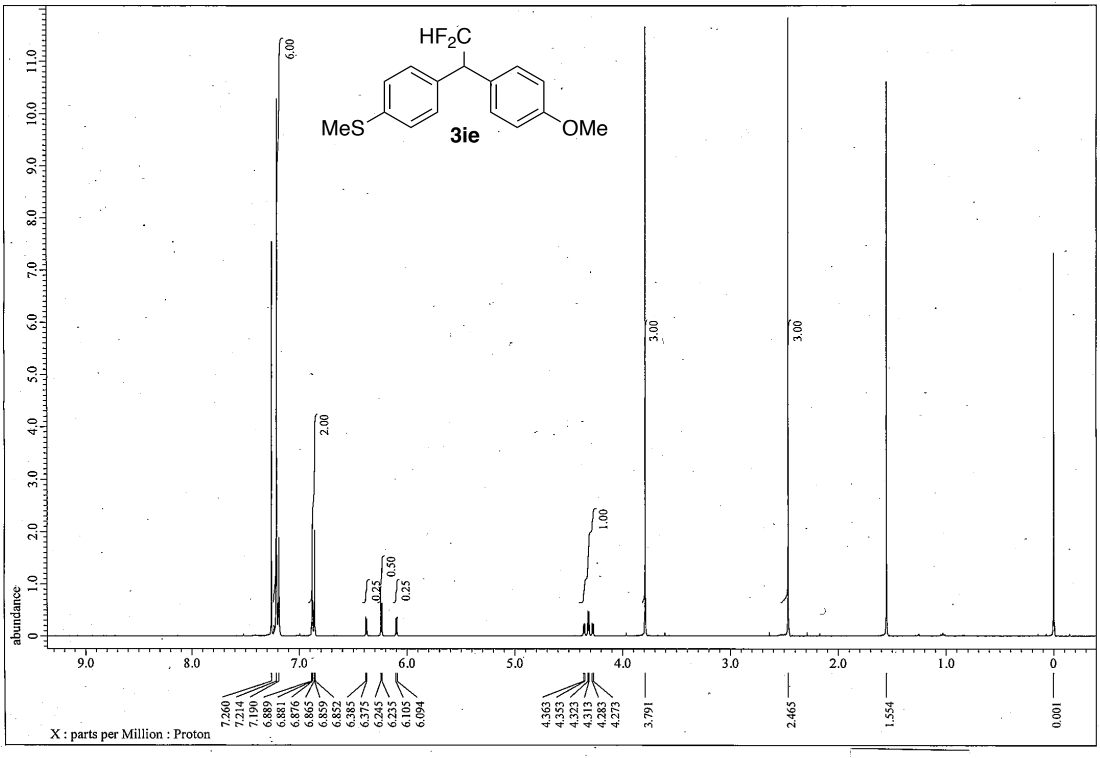


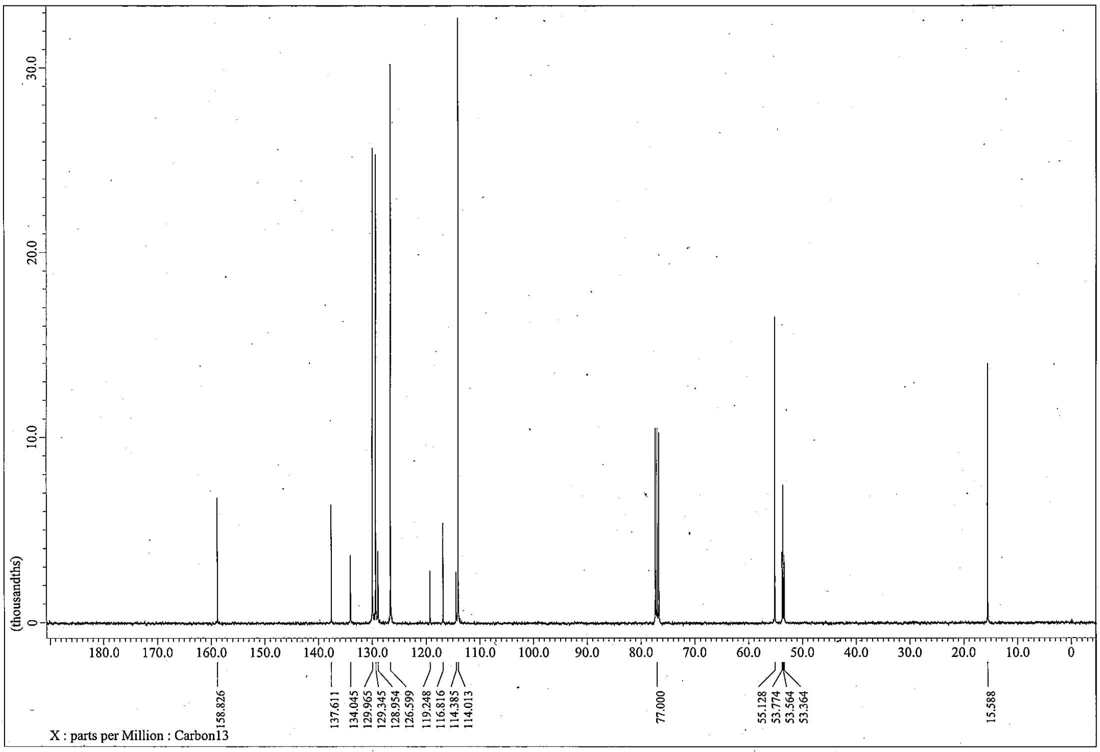
3he: ^{1}H NMR (400 MHz, CDCl$_3$)/^{13}C{^{1}H} NMR (100 MHz, CDCl$_3$)



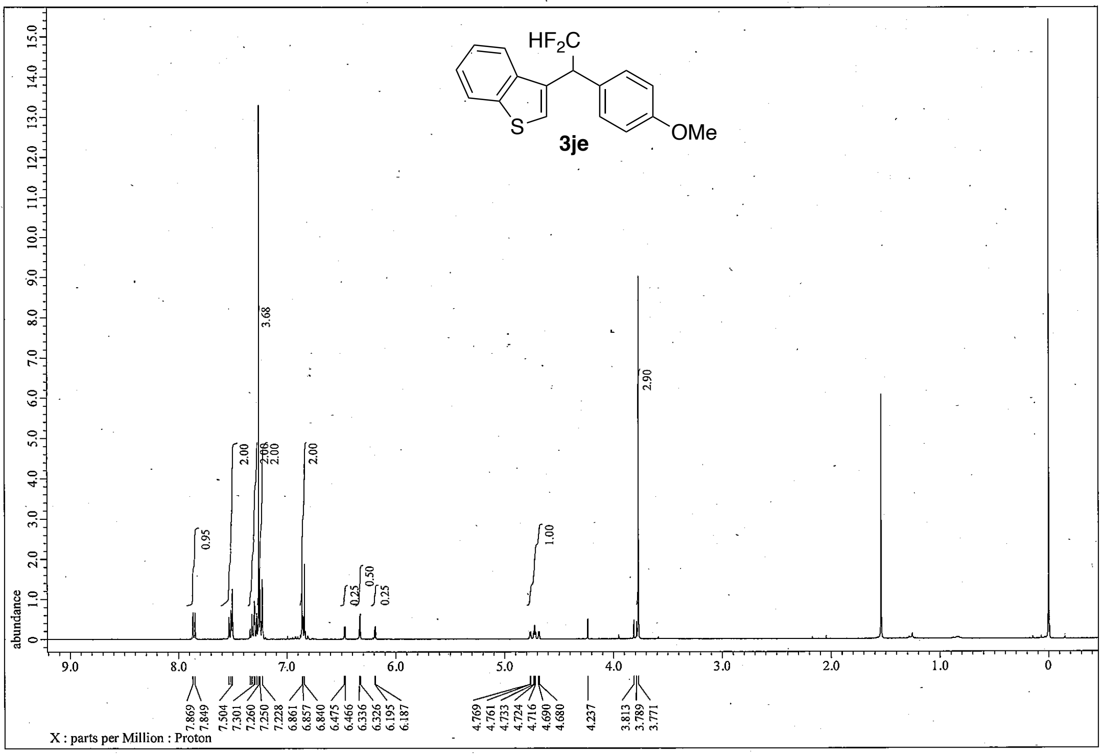


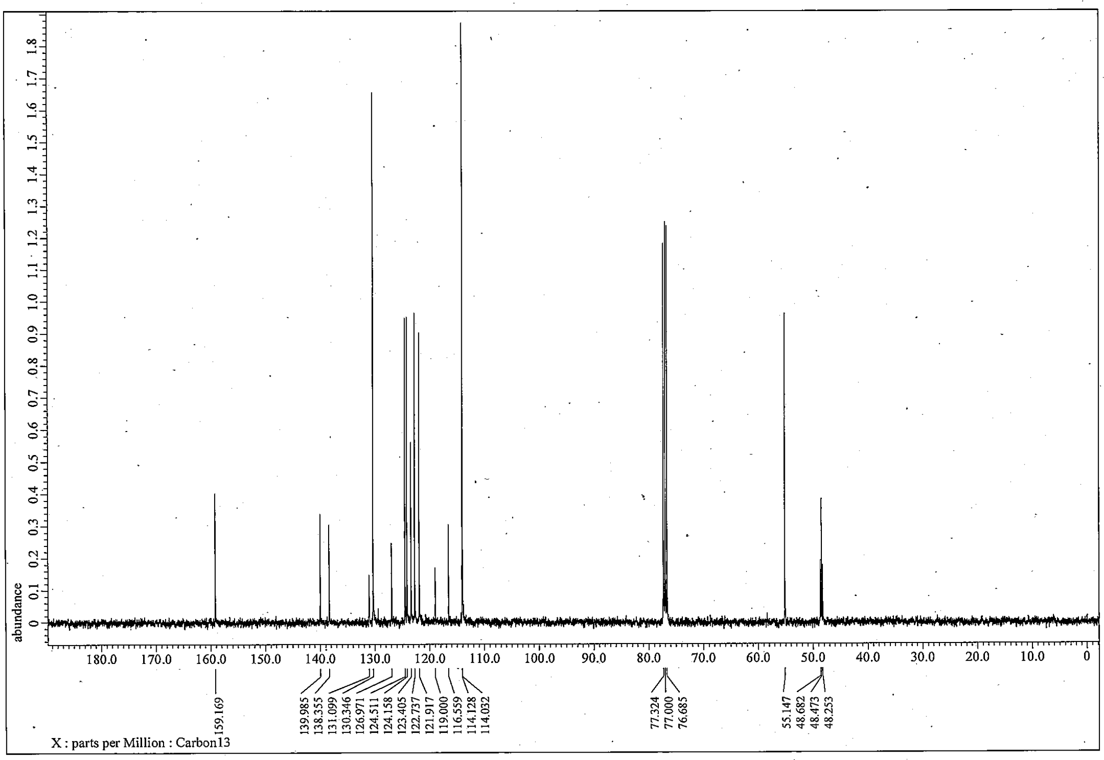
3ie: ^{1}H NMR (400 MHz, $CDCl_3$)/^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$)



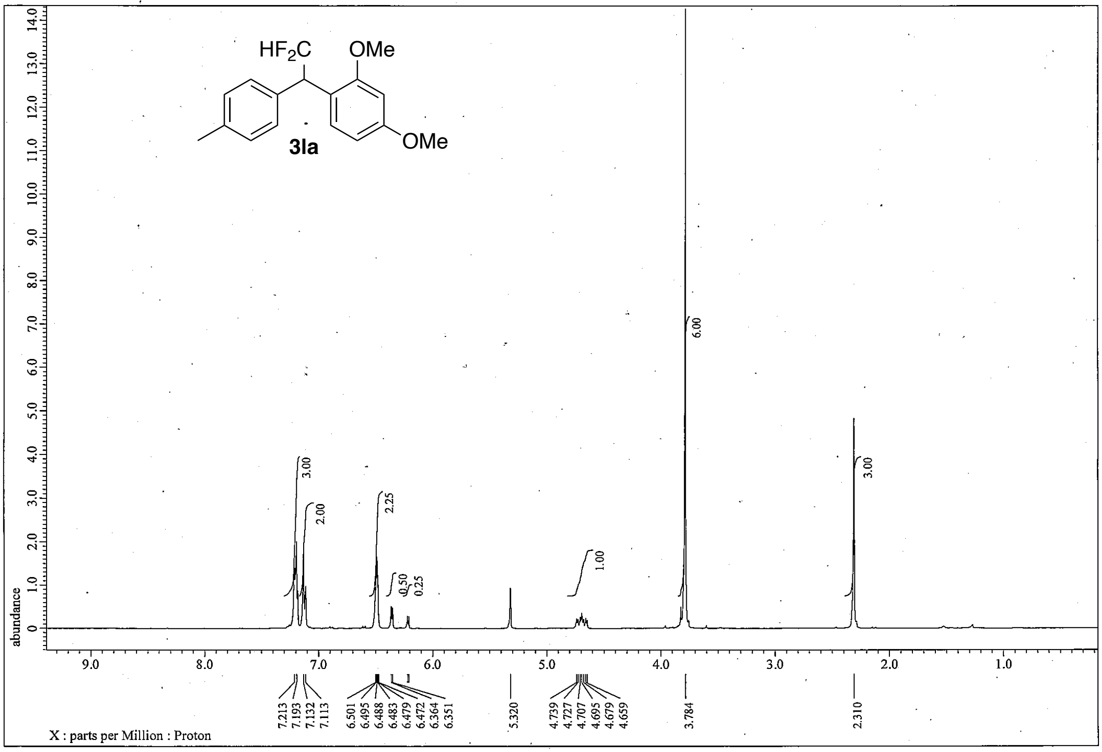


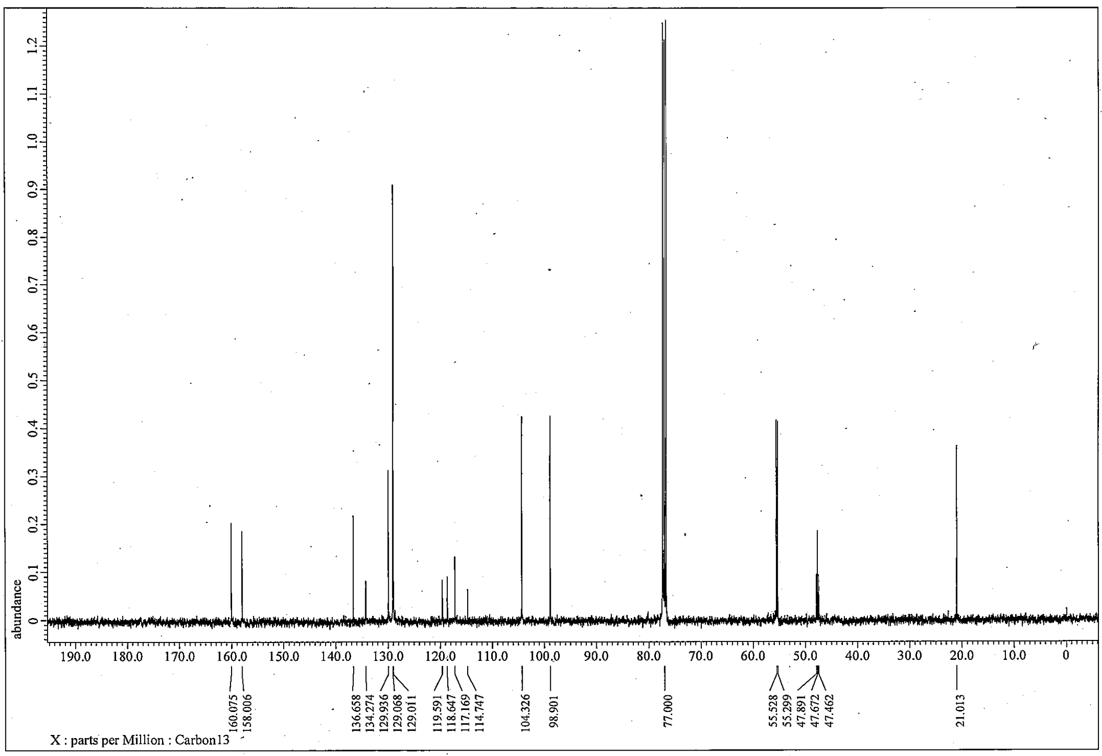
3je: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$)



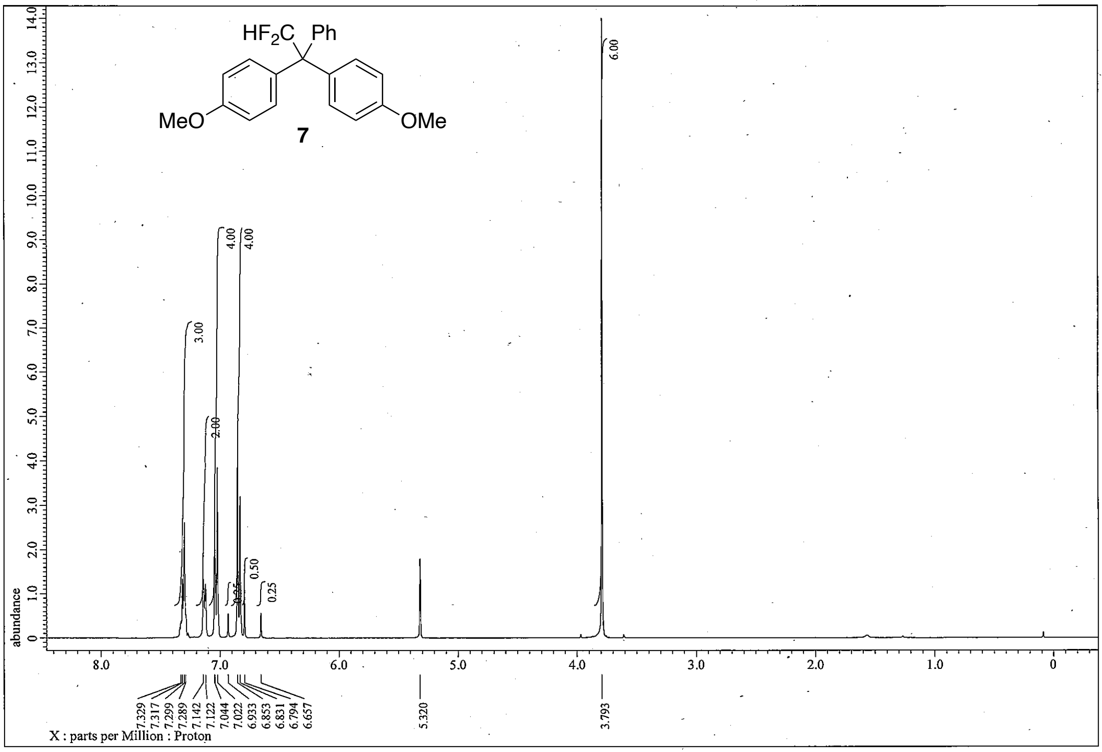


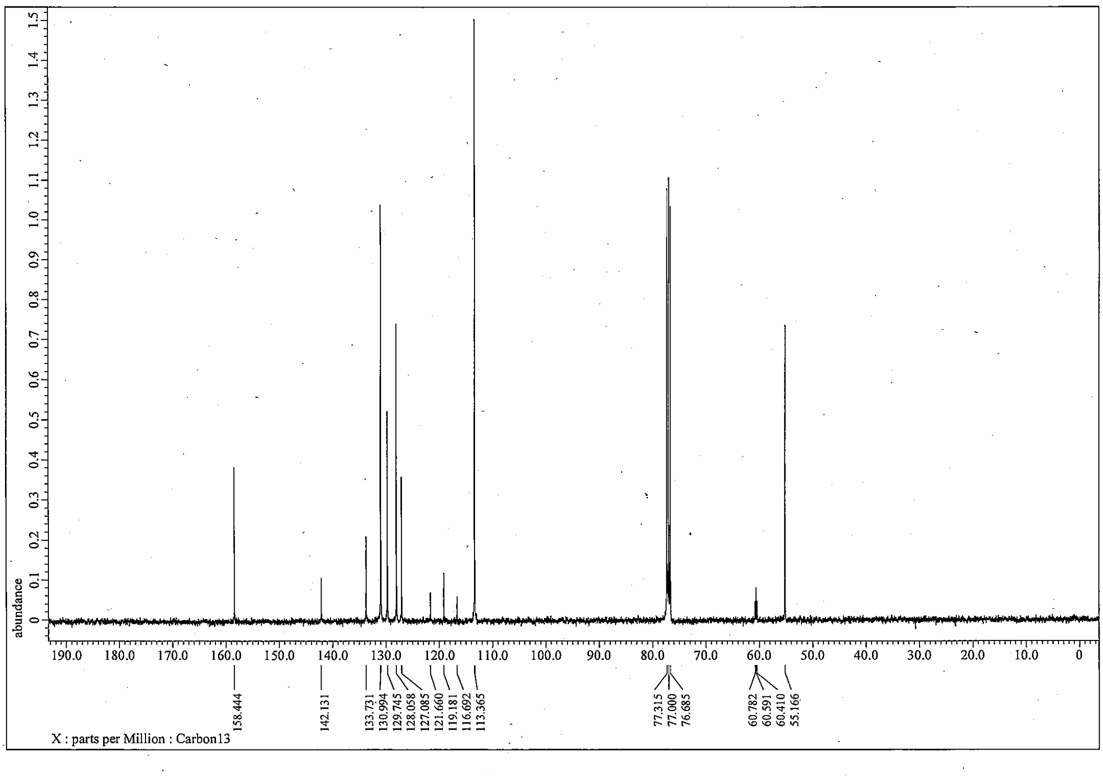
3la: ^{1}H NMR (400 MHz, CD_2Cl_2)/$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$)



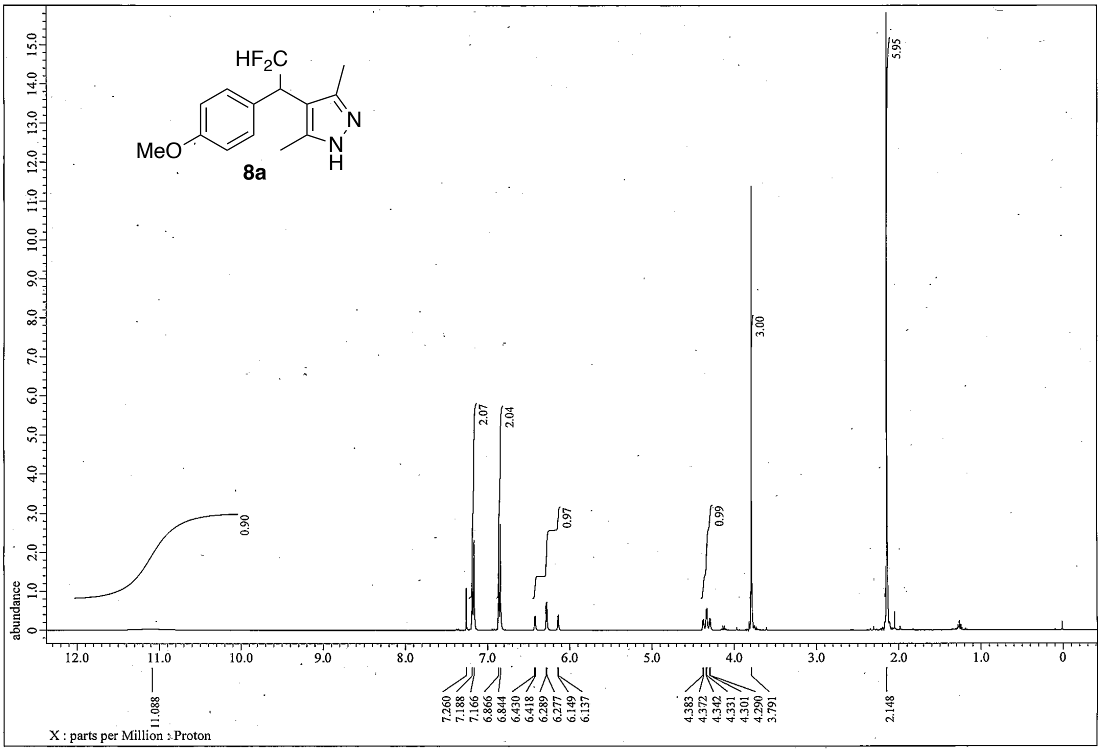


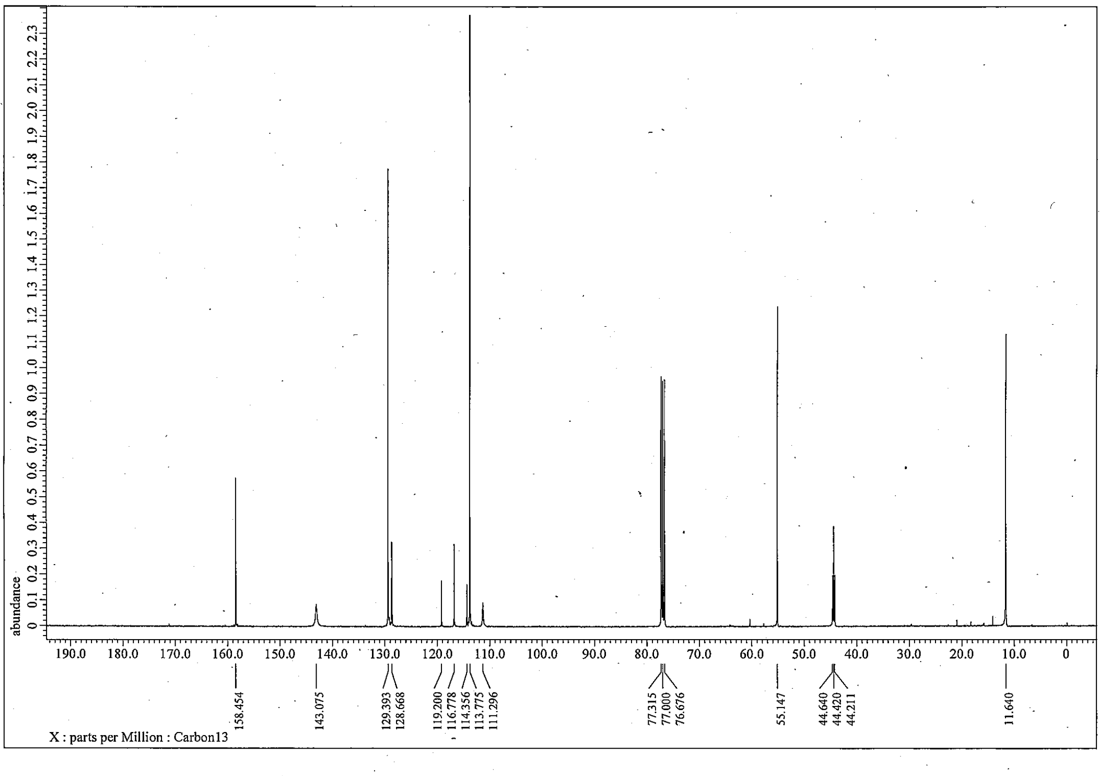
7: ^{1}H NMR (400 MHz, CD_2Cl_2)/$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$)



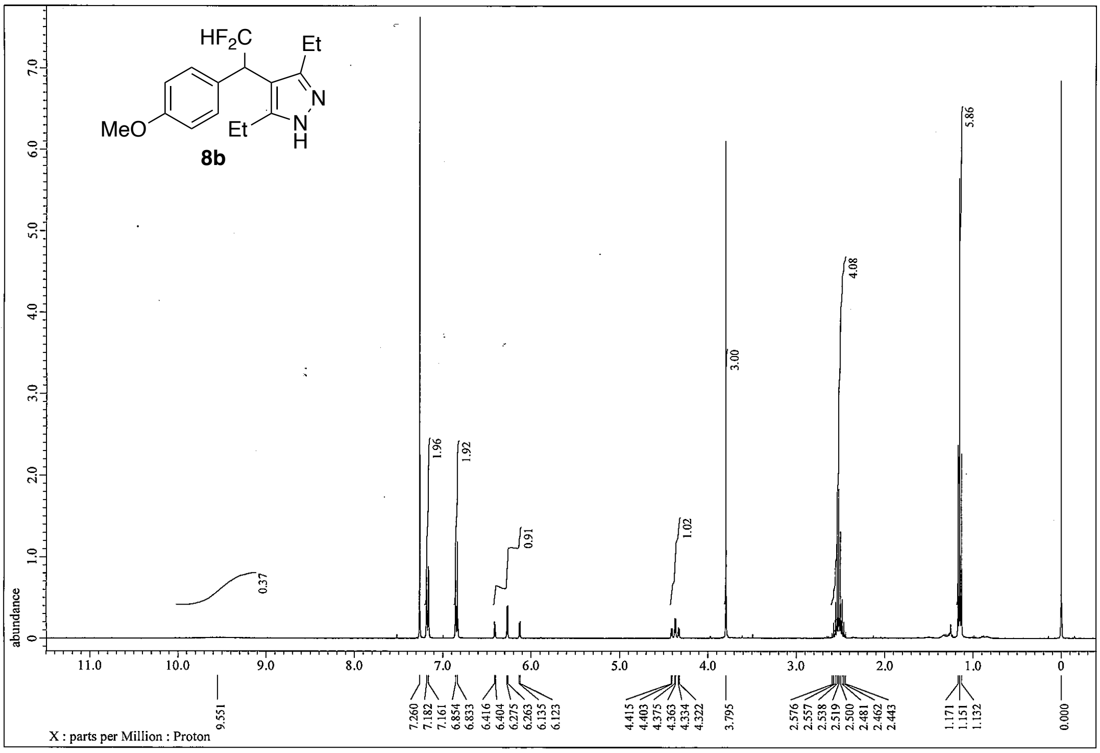


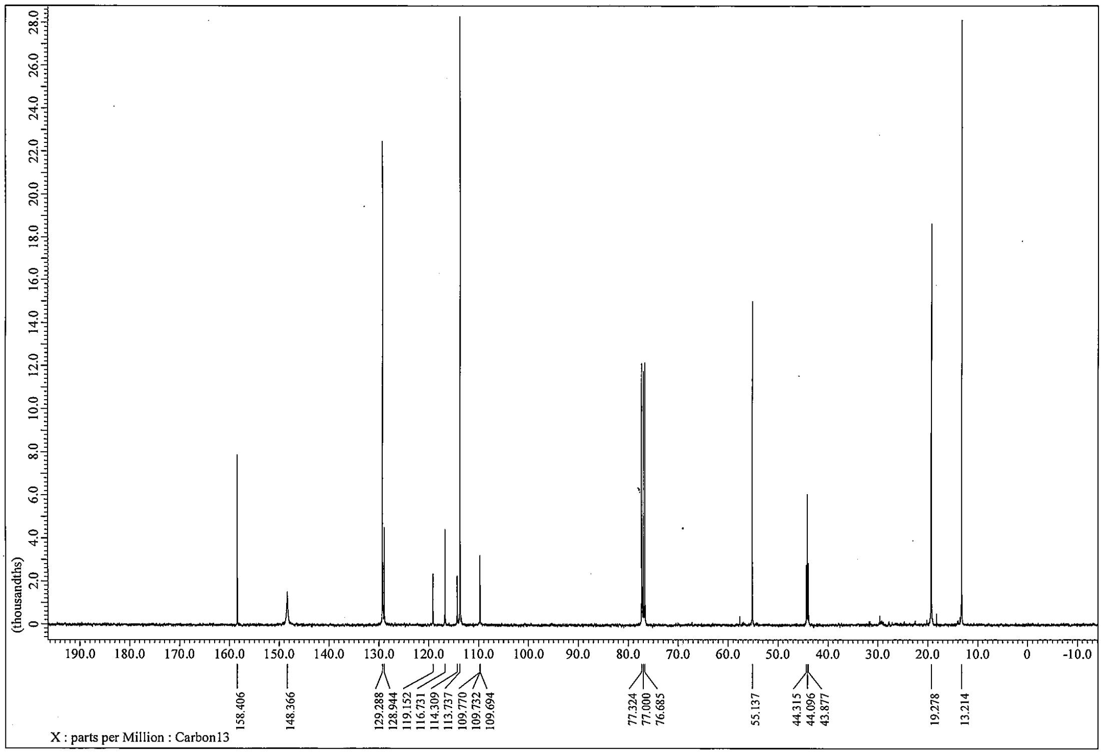
8a: ^{1}H NMR (400 MHz, $CDCl_3$)/^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$)



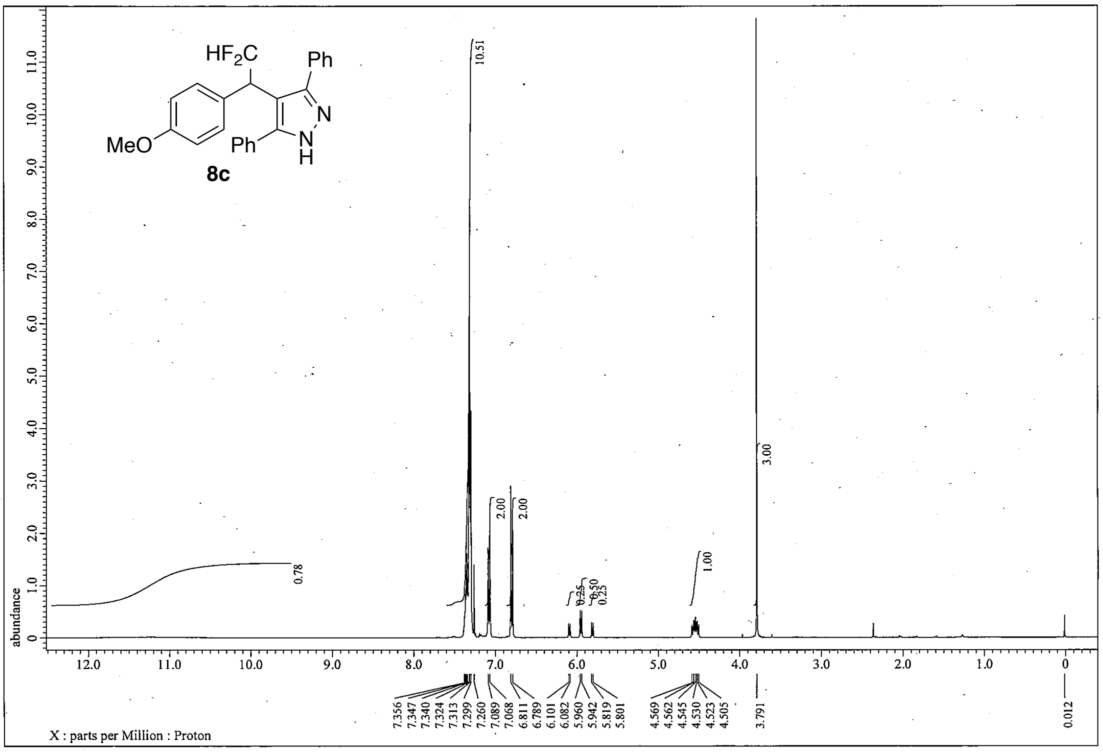


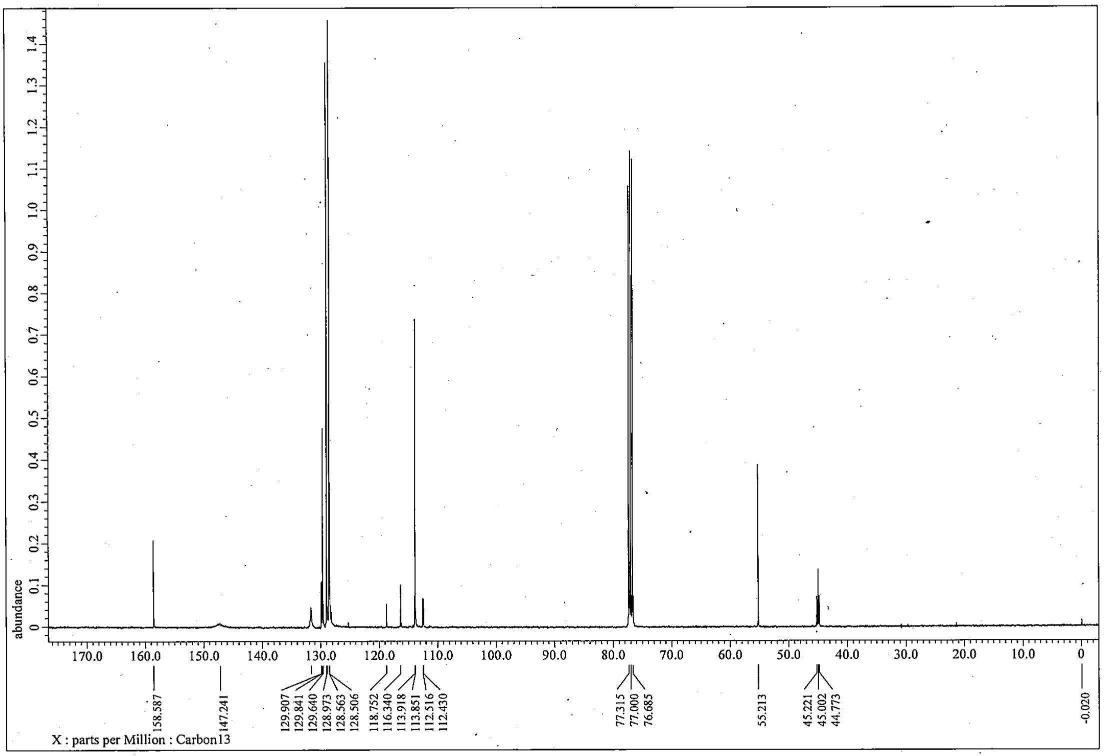
8b: ^{1}H NMR (400 MHz, $CDCl_3$)/^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$)



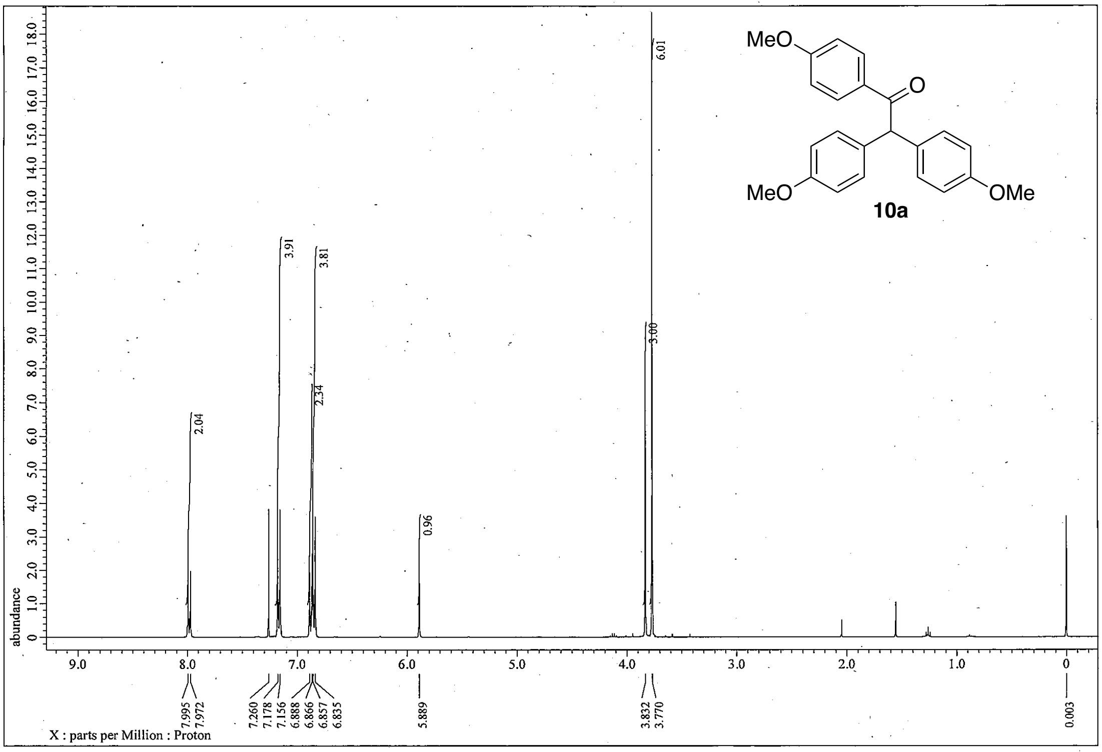


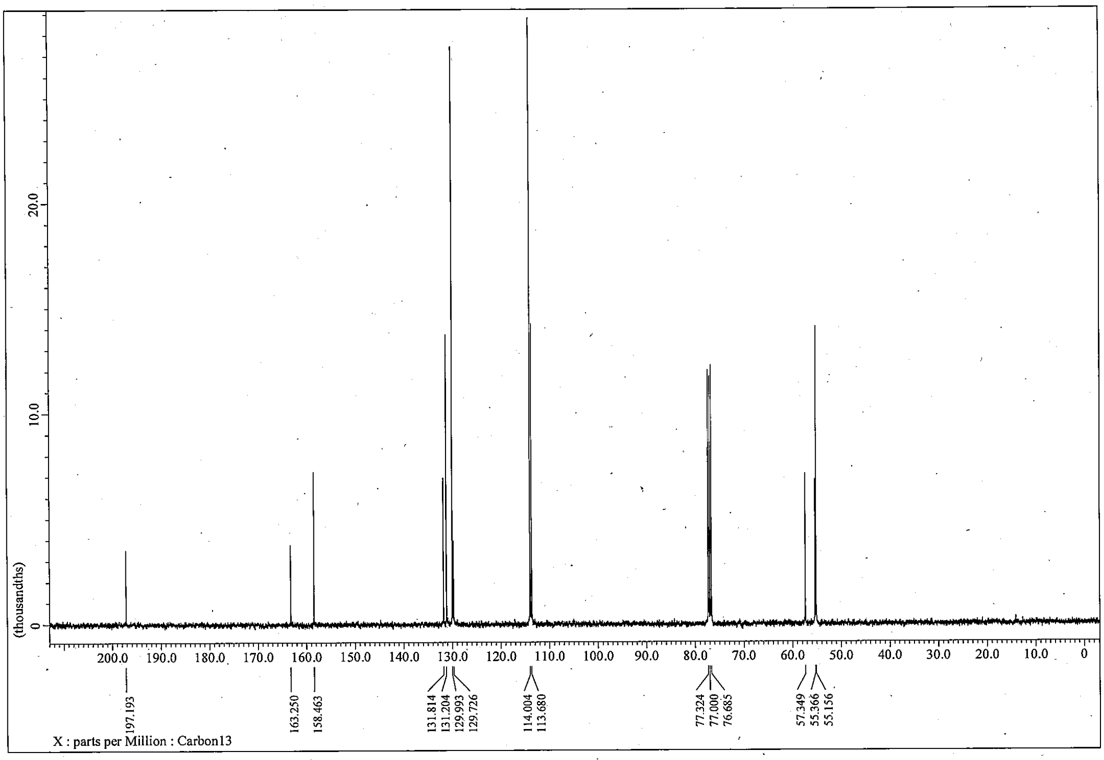
8c: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^{1}H\}$ NMR (100 MHz, $CDCl_3$)





10a: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$)





10b: ^{1}H NMR (400 MHz, $CDCl_3$)/$^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$)