Modular Approach to 9-Monosubstituted Fluorene Derivatives Using Mo^{V} Reagents

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Supporting Information

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General remarks

All reagents were used of analytical grades. Solvents were desiccated if necessary by standard methods.[1] Flash chromatography was performed on silica gel (40–60 μm, Merck, Darmstadt, Germany) by using mixtures of cyclohexane with ethyl acetate or dichloromethane with methanol as eluents. For thin-layer chromatography, silica gel 60 sheets (F_{254}, Merck, Darmstadt, Germany) were applied. Novel compounds were characterized by ^{1}H NMR and ^{13}C NMR, in addition to high resolution mass spectrometry. Copies of the ^{1}H and ^{13}C NMR are attached. ^{1}H and ^{13}C NMR spectra were recorded at 25 °C using a Bruker Avance III HD 300, Avance II 400 or Avance III 600 instrument (Analytische Messtechnik, Karlsruhe, Germany). All ^{1}H NMR experiments are reported in δ units, parts per million (ppm) downfield from tetramethylsilane (internal standard) and were referenced to the signal for residual d_6-*N*,*N*-dimethylformamide (8.03 ppm) or d_2-acetonitrile (1.94 ppm) in the deuterated solvent. All ^{13}C NMR spectra are reported in ppm relative to deuterated *N*,*N*-dimethylformamide (163.15 ppm) or deuterated acetonitrile (1.32 ppm) and were obtained by ^{1}H decoupling. FD mass spectra were performed on a MAT 95 (Thermo Finnigan, Bremen, Germany) apparatus and ESI high resolution mass spectra were obtained by using a QTof Ultima 3 (Waters, Milford, Massachusetts) instrument.

Synthesis and characterization of the products

Reaction route A:

General protocol of the Knoevenagel-Doebner reaction (A I)

A solution of the benzaldehyde **3** (1.0 eq.), malonic acid (3.0 eq.) and piperidine (0.5 eq.) in pyridine was stirred at 115 °C until the evolution of CO_2 has stopped. Subsequently, the solvent was evaporated and the crude product was suspended in an aqueous 1% HCl solution (100 mL). The suspension was stored at 4 °C overnight and the product was filtered off and washed with cyclohexane to yield the product without further purification.

General protocol of the acid catalyzed 1,4-addition of veratrole (A II)

A solution of the cinnamic acid **4** (1.0 eq.) and veratrole (1.5–2.1 eq.) in trifluoroacetic acid was heated at 72 °C for the given time (3–96 h). Subsequently, the trifluoroacetic acid was distilled off and an aqueous saturated solution of sodium bicarbonate was added to the residue. The aqueous layer was washed with diethylether and acidified with conc. HCl. The mixture was then extracted with dichloromethane, dried over $MgSO_4$ and the solvent was evaporated. The crude product was purified as described below.

General protocol of the esterification of the diphenyl propionic acids (A III)

A solution of the diphenyl propionic acid **12** (1.0 eq.) in anhydrous methanol was treated by thionyl chloride (6.0 eq.) at 0 °C, stirred at room temperature for 16 h and then heated to 65 °C for 6 h under argon atmosphere. Subsequently, a saturated aqueous solution of sodium bicarbonate was added and the mixture was extracted by dichloromethane, dried over $MgSO_4$ and the solvent was evaporated. The crude product was purified as described below.

Reaction route B:

General protocol of the Horner-Wadsworth-Emmons reaction (B I)

A solution of the benzaldehyde **3** (1.0 eq.) in anhydrous tetrahydrofurane (THF, 50 mL) was treated with diethylcyanomethylphosphonate (1.1 eq.) and KO^{t}Bu (1.1 eq.) at 0 °C and stirred for one hour at this temperature and then over night at room temperature under argon atmosphere. Subsequently, water (100 mL) was added and the mixture was extracted by dichloromethane (3×50 mL), dried over $MgSO_4$ and the solvent was evaporated. The crude product was purified as described below.

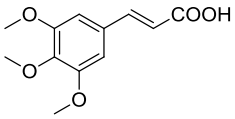
General protocol of the acid catalyzed 1,4-addition of veratrole (B II)

A solution of the cinnamic nitrile **5** (1.0 eq.) and veratrole (1.5–5 eq.) in trifluoroacetic acid was heated to 72 °C for the given time (3–100 h). Subsequently, the trifluoroacetic acid was distilled off and an aqueous saturated solution of sodium bicarbonate was added to the residue. The aqueous layer was then extracted by dichloromethane, dried over $MgSO_4$ and the solvent was evaporated. The crude product was purified as described below.

General protocol of the oxidative coupling reaction using Mo^{V} reagents (C)

A solution of the precursor **6**, **7**, or **8** (1.0 eq.) in anhydrous dichloromethane was treated with $MoCl_5$ (3.0 eq.) or $MoCl_3HFIP_2$ (3.0 eq.)[2] and stirred for the given time (15 min – 6 h) at room temperature under argon atmosphere. Subsequently, an aqueous saturated solution of sodium bicarbonate was added and it was stirred for another 5 minutes. The mixture was extracted with dichloromethane, dried over $MgSO_4$ and the solvent was evaporated. The crude product was purified as described below.

3,4,5-Trimethoxycinnamic acid 4a

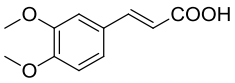


According to the protocol for the Knoevenagel-Doebner reaction (A I), 3,4,5-trimethoxybenzaldehyde (4.00 g, 20.4 mmol) was treated with malonic acid (6.36 g, 61.2 mmol) and piperidine (0.87 g, 10.2 mmol) in pyridine (40 mL) to yield compound **4a** as a colorless solid (4.81 g, 99%).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.70 (d, *J* = 15.9 Hz, 1H), 6.78 (s, 2H), 6.36 (d, *J* = 15.9 Hz, 1H), 3.89 (s, 6H), 3.88 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 172.4, 153.6, 147.1, 140.6, 129.6, 116.6, 105.6, 61.1, 56.3.

All analytic data match to the reported data.[3]

3,4-Dimethoxycinnamic acid 4b

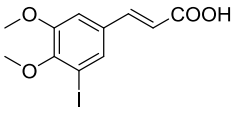


According to the protocol for the Knoevenagel-Doebner reaction (A I), 3,4-dimethoxybenzaldehyde (11.30 g, 68.0 mmol) was treated with malonic acid (20.90 g, 200.8 mmol) and piperidine (2.84 g, 33.3 mmol) in pyridine (120 mL) to yield compound **4b** as a colorless solid (13.97 g, 99%).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 10.71 (bs, 1H), 7.70 (d, *J* = 15.9 Hz, 1H), 7.12 (dd, *J* = 8.3, 1.9 Hz, 1H), 7.07 (d, *J* = 1.9 Hz, 1H), 6.87 (d, *J* = 8.3 Hz, 1H), 6.33 (d, *J* = 15.9 Hz, 1H), 3.91 (s, 6H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 172.7, 151.5, 149.3, 146.5, 127.3, 123.1, 115.7, 111.1, 109.8, 56.1, 56.0.

All analytic data match to the reported data.[4]

4,5-Dimethoxy-3-iodocinnamic acid 4c

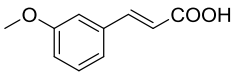


According to the protocol for the Knoevenagel-Doebner reaction (A I), 4,5-dimethoxy-3-iodobenzaldehyde (1.00 g, 3.4 mmol) was treated with malonic acid (1.07 g, 10.3 mmol) and piperidine (0.15 g, 1.7 mmol) in pyridine (10 mL) to yield compound **4d** as a colorless solid (1.04 g, 91%).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.66 (d, *J* = 15.8 Hz, 1H), 7.58 (d, *J* = 1.9 Hz, 1H), 7.06 (d, *J* = 1.9 Hz, 1H), 6.37 (d, *J* = 15.8 Hz, 1H), 3.92 (s, 3H), 3.89 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 172.0, 152.8, 151.2, 145.3, 132.1, 131.4, 117.6, 111.9, 92.9, 60.8, 56.2.

All analytic data match to the reported data.[5]

3-Methoxycinnamic acid 4d

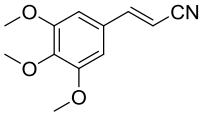


According to the protocol for the Knoevenagel-Doebner reaction (A I), 3-methoxy-benzaldehyde (4.00 g, 29.4 mmol) was treated with malonic acid (9.12 g, 87.6 mmol) and piperidine (1.25 g, 14.7 mmol) in pyridine (40 mL) to yield compound **4d** as a colorless solid (5.01 g, 97%).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 9.80 (bs, 1H), 7.77 (d, *J* = 15.9 Hz, 1H), 7.32 (m, 1H), 7.15 (d, *J* = 7.6 Hz, 1H), 7.07 (m, 1H), 6.97 (ddd, *J* = 8.3, 2.6, 0.8 Hz, 1H), 6.45 (d, *J* = 15.9 Hz, 1H), 3.84 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 172.4, 159.9, 147.1, 135.4, 130.0, 121.1, 117.6, 116.7, 113.1, 55.3.

All analytic data match to the reported data.[6]

3,4,5-Trimethoxycinnamic nitrile 5a

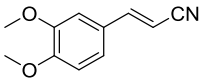


According to the protocol for the Horner-Wadsworth-Emmons reaction (B I), 3,4,5-trimethoxybenzaldehyde (2.00 g, 10.2 mmol) was treated with diethylcyanomethylphosphonate (1.99 g, 11.2 mmol) and KO^{t}Bu (1.08 g, 11.2 mmol). The crude product was purified by flash column chromatography (eluent: cyclohexane/ethyl acetate, 9:1) to yield compound **5a** as a colorless solid (2.00 g, 89%).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.31 (d, *J* = 16.6 Hz, 1H), 6.65 (s, 2H), 5.78 (d, *J* = 16.6 Hz, 1H), 3.88 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 153.7, 150.6, 141.0, 129.1, 118.3, 104.7, 95.5, 61.2, 56.4.

All analytic data match to the reported data.[7]

3,4-Dimethoxycinnamic nitrile 5b

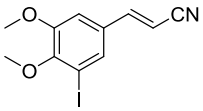


According to the protocol for the Horner-Wadsworth-Emmons reaction (B I), 3,4,5-trimethoxybenzaldehyde (2.00 g, 12.0 mmol) was treated with diethylcyanomethylphosphonate (2.35 g, 13.2 mmol) and KO^{t}Bu (1.27 g, 13.2 mmol). The crude product was purified by flash column chromatography (eluent: cyclohexane/ethyl acetate, 3:1) to yield compound **5b** as a colorless solid (2.09 g, 92%).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.30 (d, *J* = 16.6 Hz, 1H), 7.02 (dd, *J* = 8.4, 2.0 Hz, 1H), 6.92 (d, *J* = 2.0 Hz, 1H), 6.85 (d, *J* = 8.4 Hz, 1H), 5.71 (d, *J* = 16.6 Hz, 1H), 3.90 (s, 3H), 3.89 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 151.9, 150.3, 149.4, 126.6, 122.1, 118.7, 111.1, 108.9, 93.7, 56.1, 56.0.

All analytic data match to the reported data.[8]

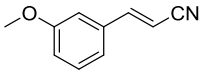
4,5-Dimethoxy-3-iodocinnamic nitrile 5c



According to the protocol for the Horner-Wadsworth-Emmons reaction (B I), 4,5-dimethoxy-3-iodobenzaldehyde (2.00 g, 5.1 mmol) was treated with diethylcyanomethylphosphonate (1.00 g, 5.7 mmol) and KO^{t}Bu (0.54 g, 5.7 mmol). The crude product was purified by flash column chromatography (eluent: cyclohexane/ethyl acetate, 9:1) to yield compound **5c** as a colorless solid (1.49 g, 92%).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.46 (d, *J* = 1.9 Hz, 1H), 7.25 (d, *J* = 16.6 Hz, 1H), 6.91 (d, *J* = 1.9 Hz, 1H), 5.78 (d, *J* = 16.6 Hz, 1H), 3.89 (s, 3H), 3.87 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 152.9, 151.6, 148.7, 131.5, 130.3, 118.0, 111.2, 96.7, 93.1, 60.8, 56.3. HRMS (ESI+) *m/z* calcd for $C_{11}H_{10}NO_2INa$ $[M+Na]^+$ 337.9654, found 337.9659.

3-Methoxycinnamic nitrile 5d

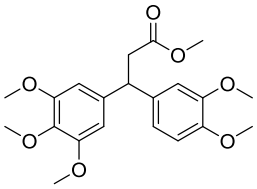


According to the protocol for the Horner-Wadsworth-Emmons reaction (B I), 3-methoxybenzaldehyde (2.00 g, 14.7 mmol) was treated with diethylcyanomethylphosphonate (2.87 g, 16.2 mmol) and KO^{t}Bu (1.57 g, 16.2 mmol). The crude product was purified by flash column chromatography (eluent: cyclohexane/ethyl acetate, 3:1) to yield compound **5d** as a colorless solid (2.12 g, 91%).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.37 (d, *J* = 16.6 Hz, 1H), 7.04 (d, *J* = 7.6 Hz, 1H), 7.00–6.94 (m, 2H), 5.87 (d, *J* = 16.6 Hz, 1H), 3.84 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 160.2, 150.7, 135.0, 134.9, 130.3, 120.1, 117.0, 112.6, 96.8, 55.5.

All analytic data match to the reported data.[9]

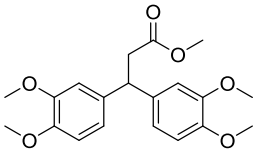
Methyl 3-(3,4-dimethoxyphenyl)-3-(3,4,5-trimethoxyphenyl)propionate 6a



According to the protocol for the esterification of the diphenyl propionic acids (A III), 3-(3,4-dimethoxyphenyl)-3-(3,4,5-trimethoxyphenyl)propionic acid **12a** (500 mg, 1.34 mmol) was treated with thionyl chloride (953 mg, 8.01 mmol) in anhydrous methanol (30 mL). The crude product was purified by flash column chromatography (eluent: cyclohexane/ethyl acetate, 3:1) to yield compound **6a** as a colorless solid (432 mg, 83%).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 6.82–6.74 (m, 3H), 6.43 (s, 2H), 4.44 (t, *J* = 8.0 Hz, 1H), 3.85 (s, 3H), 3.84 (s, 3H), 3.81 (s, 9H), 3.61 (s, 3H) 3.00 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 172.4, 153.3, 153.3, 149.0, 147.9, 139.5, 136.7, 135.9, 119.4, 111.3, 111.2, 104.8, 104.8, 61.0, 56.2, 56.2, 56.0, 56.0, 51.9, 46.9, 41.2. HRMS (ESI+) *m/z* calcd for $C_{21}H_{26}O_7Na$ $[M+Na]^+$ 413.1576, found 413.1558.

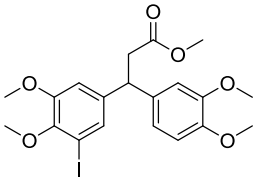
Methyl 3,3-bis(3,4-dimethoxyphenyl)propionate 6b



According to the protocol for the esterification of the diphenyl propionic acids (A III), 3,3-bis(3,4-dimethoxyphenyl)propionic acid **12a** (1.56 g, 4.5 mmol) was treated with thionyl chloride (3.21 g, 27.0 mmol) in dry methanol (70 mL). The crude product was purified by flash column chromatography (eluent: dichloromethane/methanol, 19:1) to yield compound **6a** as a light yellow solid (1.38 g, 85%).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 6.80–6.75 (m, 4H), 6.71 (d, *J* = 1.6 Hz, 2H), 4.45 (t, *J* = 8.0 Hz, 1H), 3.83 (s, 6H), 3.81 (s, 6H), 3.58 (s, 3H), 2.99 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 172.4, 148.9, 147.7, 136.3, 119.3, 111.3, 111.2, 55.9, 51.8, 46.2, 41.2. HRMS (ESI+) *m/z* calcd for $C_{20}H_{24}O_6Na$ $[M+Na]^+$ 383.1471, found 383.1466.

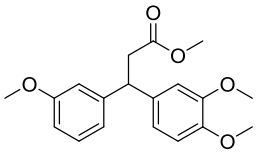
Methyl 3-(4,5-dimethoxy-3-iodophenyl)-3-(3,4-dimethoxyphenyl)propionate 6c



According to the protocol for the esterification of the diphenyl propionic acids (A III), 3-(4,5-dimethoxy-3-iodophenyl)-3-(3,4-dimethoxyphenyl)propionic acid **12c** (400 mg, 0.82 mmol) was treated with thionyl chloride (670 mg, 5.63 mmol) in dry methanol (25 mL). The crude product was purified by flash column chromatography (eluent: cyclohexane/ethyl acetate, 3:1) to yield compound **6c** as a colorless solid (371 mg, 90%).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.19 (d, *J* = 1.9 Hz, 1H), 6.80 (d, *J* = 8.3 Hz, 1H), 6.76 (dd, *J* = 8.3, 1.9 Hz, 1H), 6.70 (d, *J* = 1.6 Hz, 2H), 4.40 (dd, *J* = 7.9, 7.9 Hz, 1H), 3.85 (s, 3H), 3.84 (s, 3H), 3.79 (s, 6H), 3.61 (s, 3H), 3.02–2.92 (each dd, *J* = 15.5, 7.9 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 172.2, 152.6, 149.1, 148.0, 147.7, 141.9, 135.4, 129.2, 119.4, 112.7, 111.3, 111.3, 92.7, 60.5, 56.1, 56.1, 56.0, 52.0, 46.0, 41.0. HRMS (ESI+) *m/z* calcd for $C_{20}H_{23}O_6INa$ $[M+Na]^+$ 509.0437, found 509.0436.

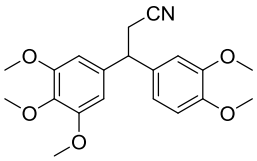
Methyl 3-(3,4-dimethoxyphenyl)-3-(3-methoxyphenyl)propionate 6d



According to the protocol for the esterification of the diphenyl propionic acids (A III), 3-(3,4-dimethoxyphenyl)-3-(3-methoxyphenyl)propionic acid **12d** (250 mg, 0.80 mmol) was treated with thionyl chloride (570 mg, 4.77 mmol) in dry methanol (20 mL). The crude product was purified by flash column chromatography (eluent: cyclohexane/ethyl acetate, 3:1) to yield compound **6d** as a light yellow oil (228 mg, 86%).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.20 (t, *J* = 7.9 Hz, 1H), 6.82 (d, *J* = 7.7 Hz, 1H), 6.80–6.71 (m, 5H), 4.47 (t, *J* = 8.0 Hz, 1H), 3.84 (s, 3H), 3.82 (s, 3H), 3.76 (s, 3H), 3.59 (s, 3H) 3.02 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 172.4, 159.8, 149.0, 147.8, 145.5, 136.0, 129.7, 120.0, 119.4, 113.9, 111.6, 111.3, 111.3, 56.0, 56.0, 55.3, 51.9, 46.7, 40.9. HRMS (ESI+) *m/z* calcd for $C_{19}H_{22}O_5Na$ $[M+Na]^+$ 353.1365, found 353.1369.

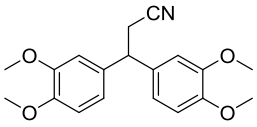
3-(3,4-Dimethoxyphenyl)-3-(3,4,5-trimethoxyphenyl)propionitrile 7a



According to the protocol for the acid catalyzed 1,4-addition of veratrole (B II), 3,4,5-trimethoxycinnamic nitrile **5a** (500 mg, 2.28 mmol) was treated with veratrole (1.55 g, 11.4 mmol) in trifluoroacetic acid (10 mL) for 3 h. The crude product was purified by flash column chromatography (eluent: dichloromethane/methanol, 99:1) to yield compound **7a** as a colorless solid (348 mg, 43%).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 6.84–6.78 (m, 2H), 6.71 (d, *J* = 2.0 Hz, 1H), 6.42 (s, 2H), 4.24 (t, *J* = 7.5 Hz, 1H), 3.85 (s, 3H), 3.82 (s, 3H), 3.81 (s, 3H), 3.80 (s, 6H), 2.98 (d, *J* = 7.5 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 153.4, 153.4, 149.2, 148.4, 137.2, 133.5, 119.3, 119.3, 118.6, 111.3, 111.2, 104.8, 104.8, 60.9, 56.2, 56.2, 56.0, 55.9, 46.9, 24.7. HRMS (ESI+) *m/z* calcd for $C_{20}H_{23}NO_5Na$ $[M+Na]^+$ 380.1474, found 380.1466.

3,3-Bis(3,4-dimethoxyphenyl)propionitrile 7b

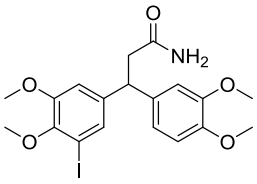


According to the protocol for the acid catalyzed 1,4-addition of veratrole (B II), 3,4,5-trimethoxycinnamic nitrile **5b** (1.00 g, 4.80 mmol) was treated with veratrole (0.98 g, 7.20 mmol) in trifluoroacetic acid (10 mL) for 3 h. The crude product was purified by flash column chromatography (eluent: dichloromethane/methanol, 99:1) to yield compound **7b** as a colorless solid (1.08 g, 67%).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 6.85–6.78 (m, 4H), 6.70 (d, *J* = 1.9 Hz, 2H), 4.28 (t, *J* = 7.5 Hz, 1H), 3.86 (s, 6H), 3.82 (s, 6H), 2.99 (d, *J* = 7.5 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 149.3, 148.4, 134.1, 119.4, 118.7, 111.3, 111.2, 56.1, 56.0, 46.4, 24.9.

All analytic data match to the reported data.[10]

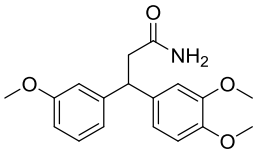
3-(4,5-Dimethoxy-3-iodophenyl)-3-(3,4-dimethoxyphenyl)propionic amide 8a



According to the protocol for the acid catalyzed 1,4-addition of veratrole (B II), 4,5-dimethoxy-3-iodocinnamic nitrile **5c** (600 mg, 1.90 mmol) was treated with veratrole (1.30 g, 9.52 mmol) in trifluoroacetic acid (6 mL) for 20 h. The crude product was purified by flash column chromatography (eluent: cyclohexane/ethyl acetate, 3:1) to yield compound **8a** as a colorless solid (500 mg, 58%).

^{1}H NMR (400 MHz, $(CD_3)_2SO$): δ = 7.31 (bs, 1H), 7.16 (d, *J* = 1.7 Hz, 1H), 7.00 (d, *J* = 1.7 Hz, 1H), 6.90 (d, *J* = 1.8 Hz, 1H), 6.85 (d, *J* = 8.3 Hz, 1H), 6.79–6.74 (m, 2H), 4.33 (t, *J* = 8.0 Hz, 1H), 3.79 (s, 3H), 3.73 (s, 3H), 3.70 (s, 3H), 3.64 (s, 3H), 2.76 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 172.2, 152.0, 148.5, 147.3, 146.4, 143.2, 136.5, 128.4, 119.2, 112.8, 111.9, 111.7, 92.5, 59.7, 55.9, 55.6, 55.5, 45.5, 40.9. HRMS (ESI+) *m/z* calcd for $C_{19}H_{23}NIO_5$ $[M+H]^+$ 472.0621, found 472.0618.

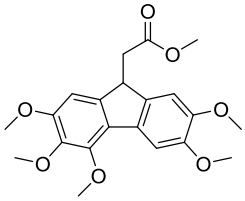
3-(3,4-Dimethoxyphenyl)-3-(3-methoxyphenyl)propionic amide 8b



According to the protocol for the acid catalyzed 1,4-addition of veratrole (B II), 3-methoxycinnamic nitrile **5d** (730 mg, 4.59 mmol) was treated with veratrole (934 mg, 6.86 mmol) in trifluoroacetic acid (10 mL) for 100 h. The crude product was purified by flash column chromatography (eluent: cyclohexane/ethyl acetate, 3:1) to yield compound **8b** as a light yellow solid (341 mg, 25%).

^{1}H NMR (400 MHz, $(CD_3)_2SO$: δ = 7.34 (bs, 1H), 7.18 (t, *J* = 8.1 Hz, 1H), 6.88–6.71 (m, 7H), 4.40 (t, *J* = 8.0 Hz, 1H), 3.72 (s, 3H), 3.71 (s, 3H), 3.69 (s, 3H), 2.80 (d, *J* = 8.0 Hz, 2H). ^{13}C NMR (101 MHz, $(CD_3)_2SO$: δ = 172.4, 159.2, 148.5, 147.2, 146.5, 136.9, 129.3, 119.8, 119.4, 113.6, 111.8, 111.8, 111.0, 55.5, 55.5, 54.9, 46.2, 41.1. HRMS (ESI+) *m/z* calcd for $C_{18}H_{21}NO_4Na$ $[M+Na]^+$ 338.1368, found 338.1379.

9*H*-9-(Methoxycarbonylmethyl)-2,3,4,6,7-pentamethoxyfluorene 9a

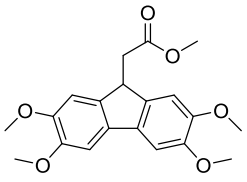


a) $MoCl_5$: According to the protocol for the oxidative coupling reaction using Mo^V reagents (C), 3-(3,4-dimethoxyphenyl)-3-(3,4,5-trimethoxyphenyl)methyl-propionate **6a** (44 mg, 0.11 mmol) was treated with $MoCl_5$ (93 mg, 0.34 mmol) in dichloromethane (20 mL) for 15 min. The crude product was purified by flash column chromatography (eluent: cyclohexane/ethyl acetate, 1:1) to yield compound **9a** as a light yellow solid (25 mg, 57%).

b) $MoCl_3HFIP_2$: According to the protocol for the oxidative coupling reaction using Mo^V reagents (C), 3-(3,4-dimethoxyphenyl)-3-(3,4,5-trimethoxyphenyl)methylpropionate **6a** (50 mg, 0.13 mmol) was treated with $MoCl_3HFIP_2$ (206 mg, 0.38 mmol) in dichloromethane (20 mL) for 15 min. The crude product was purified by flash column chromatography (eluent: cyclohexane/ethyl acetate, 1:1) to yield compound **9a** as a light yellow solid (31 mg, 62%).

^{1}H NMR (400 MHz, CD_3CN): δ = 7.49 (s, 1H), 7.06 (s, 1H), 6.91 (s, 1H), 4.14 (t, *J* = 7.3 Hz, 1H), 3.98 (s, 3H), 3.87 (s, 3H), 3.83 (s, 3H), 3.82 (s, 3H), 3.80 (s, 3H), 3.71 (s, 3H), 2.72 (d, *J* = 7.3 Hz, 2H). ^{13}C NMR (101 MHz, CD_3CN): δ = 173.7, 153.7, 150.0, 149.1, 148.0, 143.6, 142.6, 139.3, 133.2, 127.2, 109.1, 106.7, 105.4, 61.3, 61.3, 56.9, 56.5, 56.5, 52.3, 44.7, 39.2. HRMS (ESI+) *m/z* calcd for $C_{21}H_{25}O_7$ $[M+H]^+$ 389.1600, found 389.1594.

9*H*-9-(Methoxycarbonylmethyl)-2,3,6,7-tetramethoxyfluorene 9b

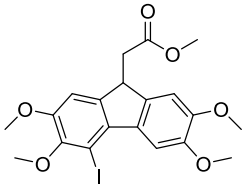


a) $MoCl_5$: According to the protocol for the oxidative coupling reaction using Mo^V reagents (C), 3,3-bis(3,4-dimethoxyphenyl)methylpropionate **6b** (100 mg, 0.28 mmol) was treated with $MoCl_5$ (227 mg, 0.83 mmol) in dichloromethane (25 mL) for 1 h. The crude product was purified by flash column chromatography (eluent: cyclohexane/ethyl acetate, 1:1) to yield compound **9b** as a colorless solid (69 mg, 69%).

b) $MoCl_3HFIP_2$: According to the protocol for the oxidative coupling reaction using Mo^V reagents (C), 3,3-bis(3,4-dimethoxyphenyl)methylpropionate **6b** (100 mg, 0.28 mmol) was treated with $MoCl_3HFIP_2$ (446 mg, 0.83 mmol) in dichloromethane (25 mL) for 1 h. The crude product was purified by flash column chromatography (eluent: cyclohexane/ethyl acetate, 1:1) to yield compound **9b** as a colorless solid (72 mg, 72%).

^{1}H NMR (400 MHz, CD_3CN): δ = 7.33 (s, 2H), 7.09 (s, 2H), 4.14 (t, *J* = 7.3 Hz, 1H), 3.89 (s, 6H), 3.81 (s, 6H), 3.72 (s, 3H), 2.73 (d, *J* = 7.3 Hz, 2H). ^{13}C NMR (151 MHz, CD_3CN): δ = 173.8, 150.3, 149.1, 139.7, 134.7, 109.2, 104.0, 56.6, 56.5, 52.3, 44.2, 39.1. HRMS (ESI+) *m/z* calcd for $C_{20}H_{23}O_6$ $[M+H]^+$ 359.1495, found 359.1504.

9*H*-4-Iodo-9-(methoxycarbonylmethyl)-2,3,6,7-tetramethoxyfluorene 9c

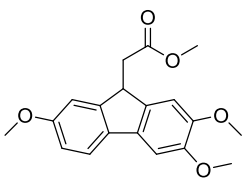


a) $MoCl_5$: According to the protocol for the oxidative coup5ling reaction using Mo^V reagents (C), 3-(4,5-dimethoxy-3-iodophenyl)-3-(3,4-dimethoxyphenyl)methyl-propionate **6c** (50 mg, 0.10 mmol) was treated with $MoCl_5$ (84 mg, 0.31 mmol) in dichloromethane (25 mL) for 1 h. The crude product was purified by flash column chromatography (eluent: cyclohexane/ethyl acetate, 1:1; subsequently toluene/acetonitrile, 9:1) to yield compound **9c** as a colorless solid (40 mg, 80%).

b) $MoCl_3HFIP_2$: According to the protocol for the oxidative coupling reaction using Mo^V reagents (C), 3-(4,5-dimethoxy-3-iodophenyl)-3-(3,4-dimethoxyphenyl)methylpropionate **6c** (50 mg, 0.10 mmol) was treated with $MoCl_3HFIP_2$ (165 mg, 0.31 mmol) in dichloromethane (25 mL) for 1 h. The crude product was purified by flash column chromatography (eluent: cyclohexane/ethyl acetate, 1:1; subsequently toluene/acetonitrile, 9:1) to yield compound **9c** as a colorless solid (39 mg, 78%).

^{1}H NMR (400 MHz, CD_3CN): δ = 8.32 (s, 1H), 7.12 (s, 1H), 7.03 (s, 1H), 4.06 (dd, *J* = 6.9, 6.9 Hz, 1H), 3.87 (s, 3H), 3.85 (s, 3H), 3.81 (s, 3H), 3.77 (s, 3H), 3.69 (s, 3H), 2.79–2.67 (each dd, *J* = 16.2, 6.9 Hz, 1H). ^{13}C NMR (101 MHz, CD_3CN): δ = 173.5, 151.7, 149.6, 148.6, 148.5, 146.1, 140.9, 135.8, 134.4, 110.2, 108.6, 106.1, 86.7, 60.6, 56.8, 56.4, 56.4, 52.3, 43.9, 39.0. HRMS (ESI+) *m/z* calcd for $C_{20}H_{21}IO_6Na$ $[M+Na]^+$ 507.0281, found 507.0272.

9*H*-9-(Methoxycarbonylmethyl)-2,3,7-trimethoxyfluorene 9d



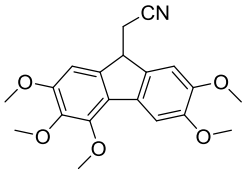
a) $MoCl_5$: According to the protocol for the oxidative coupling reaction using Mo^V reagents (C), 3-(3,4-dimethoxyphenyl)-3-(3-methoxyphenyl)methylpropionate **6d** (40 mg, 0.12 mmol) was treated with $MoCl_5$ (99 mg, 0.36 mmol) in dichloromethane (20 mL) for 1 h. The crude product was purified by flash column chromatography

(eluent: cyclohexane/ethyl acetate, 1:1) to yield compound **9d** as a colorless solid (19 mg, 48%).

b) $MoCl_3HFIP_2$: According to the protocol for the oxidative coupling reaction using Mo^V reagents (C), 3-(3,4-dimethoxyphenyl)-3-(3-methoxyphenyl)methylpropionate **6d** (35 mg, 0.11 mmol) was treated with $MoCl_3HFIP_2$ (171 mg, 0.32 mmol) in dichloromethane (20 mL) for 1 h. The crude product was purified by flash column chromatography (eluent: cyclohexane/ethyl acetate, 1:1) to yield compound **9d** as a colorless solid (17 mg, 49%).

^{1}H NMR (400 MHz, CD_3CN): δ = 7.58 (d, *J* = 8.3 Hz, 1H), 7.28 (s, 1H), 7.07 (s, 1H), 7.06 (d, 1H, *J* = 2.4 Hz), 6.91 (dd, *J* = 8.3, 2.4 Hz, 1H), 4.18 (dd, *J* = 7.2, 7.2 Hz, 1H), 3.87 (s, 3H), 3.81 (s, 3H), 3.80 (s, 3H), 3.71 (s, 3H), 2.80–2.70 (each dd, *J* = 16.2, 7.2 Hz, 1H). ^{13}C NMR (101 MHz, CD_3CN): δ = 173.7, 159.7, 150.4, 149.4, 149.3, 139.1, 135.0, 134.2, 120.6, 113.9, 111.2, 109.3, 104.1, 56.6, 56.6, 56.1, 52.3, 44.3, 39.0. HRMS (ESI+) *m/z* calcd for $C_{19}H_{21}O_5$ $[M+H]^+$ 329.1389, found 329.1399.

9*H*-9-(Cyanomethyl)-2,3,4,6,7-pentamethoxyfluorene 10a

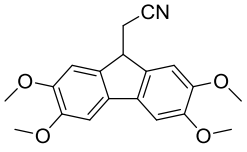


a) $MoCl_5$: According to the protocol for the oxidative coupling reaction using Mo^V reagents (C), 3-(3,4-dimethoxyphenyl)-3-(3,4,5-trimethoxyphenyl)propionitrile **7a** (30 mg, 0.08 mmol) was treated with $MoCl_5$ (69 mg, 0.25 mmol) in dichloromethane (10 mL) for 2 h. The crude product was purified by flash column chromatography (eluent: dichloromethane/methanol, 49:1) to yield compound **10a** as a colorless solid (14 mg, 46%).

b) $MoCl_3HFIP_2$: According to the protocol for the oxidative coupling reaction using Mo^V reagents (C), 3-(3,4-dimethoxyphenyl)-3-(3,4,5-trimethoxyphenyl)propionitrile **7a** (45 mg, 0.13 mmol) was treated with $MoCl_3HFIP_2$ (205 mg, 0.38 mmol) in dichloromethane (15 mL) for 2 h. The crude product was purified by flash column chromatography (eluent: dichloromethane/methanol, 49:1) to yield compound **10a** as a colorless solid (23 mg, 51%).

^{1}H NMR (600 MHz, CD_3CN): δ = 7.52 (s, 1H), 7.21 (s, 1H), 7.07 (s, 1H), 4.03 (dd, *J* = 5.6, 5.6 Hz, 1H), 4.01 (s, 3H), 3.89 (s, 3H), 3.88 (s, 3H), 3.86 (s, 3H), 3.85 (s, 3H), 3.14–3.07 (each dd, *J* = 17.1, 5.6 Hz, 1H). ^{13}C NMR (151 MHz, CD_3CN): δ = 154.0, 150.4, 149.2, 149.1, 143.0, 141.6, 137.2, 133.6, 127.6, 119.2, 108.9, 106.7, 105.4, 61.4, 61.3, 56.9, 56.6, 56.4, 44.1, 22.2. HRMS (ESI+) *m/z* calcd for $C_{20}H_{22}NO_5$ $[M+H]^+$ 356.1498, found 356.1506.

9*H*-9-(Cyanomethyl)-2,3,6,7-tetramethoxyfluorene 10b

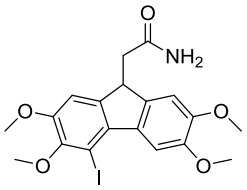


a) $MoCl_5$: According to the protocol for the oxidative coupling reaction using Mo^V reagents (C), 3,3-bis(3,4-dimethoxyphenyl)propionitrile **7b** (35 mg, 0.11 mmol) was treated with $MoCl_5$ (88 mg, 0.32 mmol) in dichloromethane (15 mL) for 2 h. The crude product was purified by flash column chromatography (eluent: dichloromethane/methanol, 49:1) to yield compound **10b** as a colorless solid (21 mg, 60%).

b) $MoCl_3HFIP_2$: According to the protocol for the oxidative coupling reaction using Mo^V reagents (V), 3,3-bis(3,4-dimethoxyphenyl)propionitrile **7b** (80 mg, 0.24 mmol) was treated with $MoCl_3HFIP_2$ (385 mg, 0.72 mmol) in dichloromethane (25 mL) for 2 h. The crude product was purified by flash column chromatography (eluent: dichloromethane/methanol, 49:1) to yield compound **10b** as a colorless solid (46 mg, 58%).

^{1}H NMR (400 MHz, CD_3CN): δ = 7.37 (s, 2H), 7.22 (s, 3H), 4.00 (t, *J* = 5.5 Hz, 1H), 3.91 (s, 6H), 3.86 (s, 6H), 3.10 (d, 2H, *J* = 5.5 Hz). ^{13}C NMR (101 MHz, CD_3CN): δ = 150.8, 149.4, 137.7, 135.2, 119.3, 109.2, 104.1, 56.7, 56.6, 43.6, 22.1. HRMS (ESI+) *m/z* calcd for $C_{19}H_{19}NO_4Na$ $[M+Na]^+$ 348.1212, found 348.1219.

9*H*-9-(Aminocarbonylmethyl)-4-iodo-2,3,6,7-tetramethoxyfluorene 11a

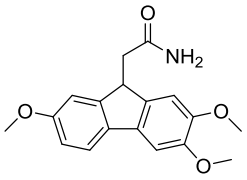


a) $MoCl_5$: According to the protocol for the oxidative coupling reaction using Mo^V reagents (C), 3-(4,5-dimethoxy-3-iodophenyl)-3-(3,4-dimethoxyphenyl)propionic amide **8a** (40 mg, 0.09 mmol) was treated with $MoCl_5$ (70 mg, 0.26 mmol) in dichloromethane (15 mL) for 6 h. The crude product was purified by flash column chromatography (eluent: dichloromethane/methanol, 19:1; subsequently ethyl acetate) to yield compound **11a** as a colorless solid (22 mg, 55%).

b) $MoCl_3HFIP_2$: According to the protocol for the oxidative coupling reaction using Mo^V reagents (C), 3-(4,5-dimethoxy-3-iodophenyl)-3-(3,4-dimethoxyphenyl)propionic amide **8a** (40 mg, 0.09 mmol) was treated with $MoCl_3HFIP_2$ (137 mg, 0.26 mmol) in dichloromethane (15 mL) for 6 h. The crude product was purified by flash column chromatography (eluent: dichloromethane/methanol, 19:1; subsequently ethyl acetate) to yield compound **11a** as a colorless solid (21 mg, 53%).

^{1}H NMR (600 MHz, $(CD_3)_2CDO$): δ = 8.46 (s, 1H), 7.58 (bs, 1H), 7.45 (s, 1H), 7.34 (s, 1H), 7.15 (bs, 1H), 4.31 (dd, *J* = 7.5, 7.5 Hz, 1H), 3.94 (s, 3H), 3.93 (s, 3H), 3.87 (s, 3H), 3.82 (s, 3H), 2.71–2.60 (each dd, *J* = 14.9, 7.5 Hz, 1H). ^{13}C NMR (151 MHz, $(CD_3)_2CDO$): δ = 174.4, 151.9, 149.9, 148.8, 148.6, 147.2, 142.1, 135.8, 134.5, 110.8, 109.5, 106.4, 87.1, 60.7, 56.9, 56.7, 56.6, 44.6, 41.1. HRMS (ESI+) *m/z* calcd for $C_{19}H_{20}NIO_5Na$ $[M+Na]^+$ 492.0284, found 492.0282.

9*H*-9-(Aminocarbonylmethyl)-2,3,7-trimethoxyfluorene 11b

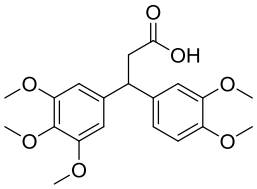


a) $MoCl_5$: According to the protocol for the oxidative coupling reaction using Mo^V reagents (C), 3-(3,4-dimethoxyphenyl)-3-(3-methoxyphenyl)propionic amide **8b** (30 mg, 0.10 mmol) was treated with $MoCl_5$ (84 mg, 0.30 mmol) in dichloromethane (10 mL) for 6 h. The crude product was purified by flash column chromatography (eluent: dichloromethane/methanol, 19:1) to yield a complex product mixture, which was not further purified.

b) $MoCl_3HFIP_2$: According to the protocol for the oxidative coupling reaction using Mo^V reagents (C), 3-(3,4-dimethoxyphenyl)-3-(3-methoxyphenyl)propionic amide **8b** (40 mg, 0.13 mmol) was treated with $MoCl_3HFIP_2$ (220 mg, 0.41 mmol) in dichloromethane (15 mL) for 6 h. The crude product was purified by flash column chromatography (eluent: dichloromethane/methanol, 19:1) to yield compound **11b** as a colorless solid (22 mg, 55%).

^{1}H NMR (400 MHz, CD_3CN): δ = 7.30 (d, *J* = 8.3 Hz, 1H), 6.96 (s, 1H), 6.80 (dd, *J* = 8.3, 2.3 Hz, 1H), 6.77 (s, 1H), 6.72 (d, 1H, *J* = 2.3 Hz), 6.28 (bs, 1H), 5.70 (bs, 1H), 5.15 (t, *J* = 7.6 Hz, 1H), 3.78 (s, 3H), 3.73 (s, 3H), 3.72 (s, 3H), 2.80 (d, 2H, *J* = 7.6 Hz). ^{13}C NMR (101 MHz, CD_3CN): δ = 173.0, 159.6, 149.5, 149.1, 142.4, 132.3, 131.3, 125.9, 125.6, 116.0, 114.1, 113.8, 112.9, 56.7, 56.7, 56.2, 41.1, 40.0. HRMS (ESI+) *m/z* calcd for $C_{18}H_{19}NO_4Na$ $[M+Na]^+$ 336.1212, found 336.1200.

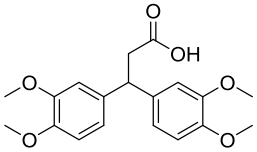
3-(3,4-Dimethoxyphenyl)-3-(3,4,5-trimethoxyphenyl)propionic acid 12a



According to the protocol for the acid catalyzed 1,4-addition of veratrole (B II), 3,4,5-trimethoxycinnamic acid **4a** (1.00 g, 4.20 mmol) was treated with veratrole (860 mg, 6.30 mmol) in trifluoroacetic acid (10 mL) for 3 h to yield compound **12a** as a colorless solid (1.49 g, 95%).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 6.83–6.76 (m, 2H), 6.73 (d, *J* = 1.6 Hz, 1H), 6.43 (s, 2H), 4.41 (t, *J* = 7.9 Hz, 1H), 3.84 (s, 3H), 3.83 (s, 3H), 3.81 (s, 3H), 3.79 (s, 6H), 3.05 (d, *J* = 7.9 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 178.0, 153.2, 153.2, 149.0, 147.9, 139.4, 136.4, 135.5, 119.4, 111.4, 111.3, 104.8, 104.8, 61.0, 56.2, 56.0, 56.0, 46.6, 41.0, 26.8. HRMS (ESI+) *m/z* calcd for $C_{20}H_{24}O_7Na$ $[M+Na]^+$ 399.1420, found 399.1432.

3,3-Bis(3,4-dimethoxyphenyl)propionic acid 12b

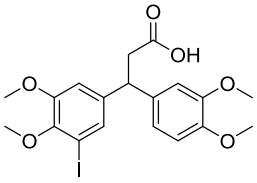


According to the protocol for the acid catalyzed 1,4-addition of veratrole (B II), 3,4,-dimethoxycinnamic acid **4b** (1.00 g, 4.80 mmol) was treated with veratrole (0.98 g, 7.20 mmol) in trifluoroacetic acid (6 mL) for 3 h to yield compound **12b** as a colorless solid (1.24 g, 75%).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.92 (s, 1H), 6.80–6.71 (m, 6H), 4.42 (t, *J* = 7.9 Hz, 1H), 3.83 (s, 6H), 3.80 (s, 6H), 3.02 (d, *J* = 7.9 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 177.8, 149.0, 147.8, 136.1, 119.3, 111.2, 111.2, 55.9, 55.9, 45.9, 41.1.

All analytic data match to the reported data.[11]

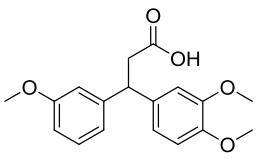
3-(4,5-Dimethoxy-3-iodophenyl)-3-(3,4-dimethoxyphenyl)propionic acid 12c



According to the protocol for the acid catalyzed 1,4-addition of veratrole (B II), 4,5-dimethoxy-3-iodocinnamic acid **4c** (400 mg, 1.20 mmol) was treated with veratrole (350 mg, 2.57 mmol) in trifluoroacetic acid (6 mL) for 18 h. The crude product was purified by flash column chromatography (eluent: cyclohexane/ethyl acetate, 1:4) to yield compound **12c** as a colorless solid (286 mg, 51%).

^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.19 (d, *J* = 1.9 Hz, 1H), 6.81 (d, *J* = 8.3 Hz, 1H), 6.76 (dd, *J* = 8.3, 2.0 Hz, 1H), 6.70 (d, *J* = 2.0 Hz, 2H), 4.38 (dd, *J* = 7.9, 7.9 Hz, 1H), 3.85 (s, 3H), 3.84 (s, 3H), 3.79 (s, 3H), 3.78 (s, 3H), 3.06–2.96 (each dd, *J* = 16.0, 7.9 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 176.7, 152.6, 149.1, 148.0, 147.8, 141.6, 135.1, 129.2, 119.3, 112.7, 111.4, 111.3, 92.8, 60.5, 56.1, 56.1, 56.0, 45.7, 40.7. HRMS (ESI+) *m/z* calcd for $C_{19}H_{21}IO_6Na$ $[M+Na]^+$ 492.0281, found 495.0291.

3-(4,5-Dimethoxy-3-iodophenyl)-3-(3,4-dimethoxyphenyl)propionic acid 12d

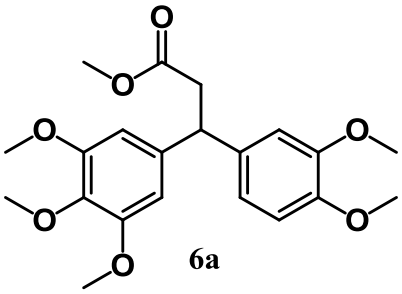


According to the protocol for the acid catalyzed 1,4-addition of veratrole (B II), 3-methoxycinnamic acid **4d** (1.00 g, 5.61 mmol) was treated with veratrole (1.15 g, 8.42 mmol) in trifluoroacetic acid (6 mL) for 96 h. The crude product was purified by flash column chromatography (eluent: cyclohexane/ethyl acetate, 1:1) to yield compound **12d** as a colorless solid (295 mg, 17%).

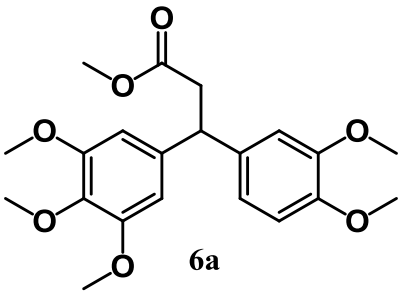
^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.20 (t, *J* = 7.9 Hz, 1H), 7.18 (t, *J* = 8.1 Hz, 1H), 6.82 (d, *J* = 7.7 Hz, 1H), 6.79–6.72 (m, 5H), 4.44 (t, *J* = 7.9 Hz, 1H), 3.83 (s, 3H), 3.81 (s, 3H), 3.76 (s, 3H), 3.04 (d, *J* = 7.9 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ = 177.7, 159.8, 149.0, 147.9, 145.2, 135.7, 129.7, 119.9, 119.4, 113.9, 111.7, 111.3, 111.3, 56.0, 56.0, 55.3, 46.3, 40.7. HRMS (ESI+) *m/z* calcd for $C_{18}H_{20}O_5Na$ $[M+Na]^+$ 339.1208, found 339.1212.

NMR spectra

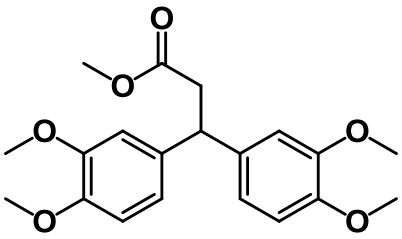
^{1}H NMR, 400 MHz, $CDCl_3$



^{13}C NMR, 101 MHz, $CDCl_3$

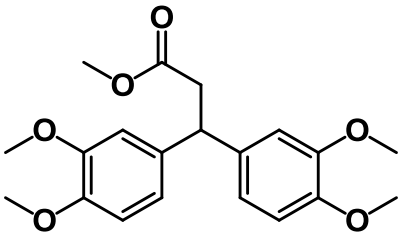


^{1}H NMR, 400 MHz, $CDCl_3$

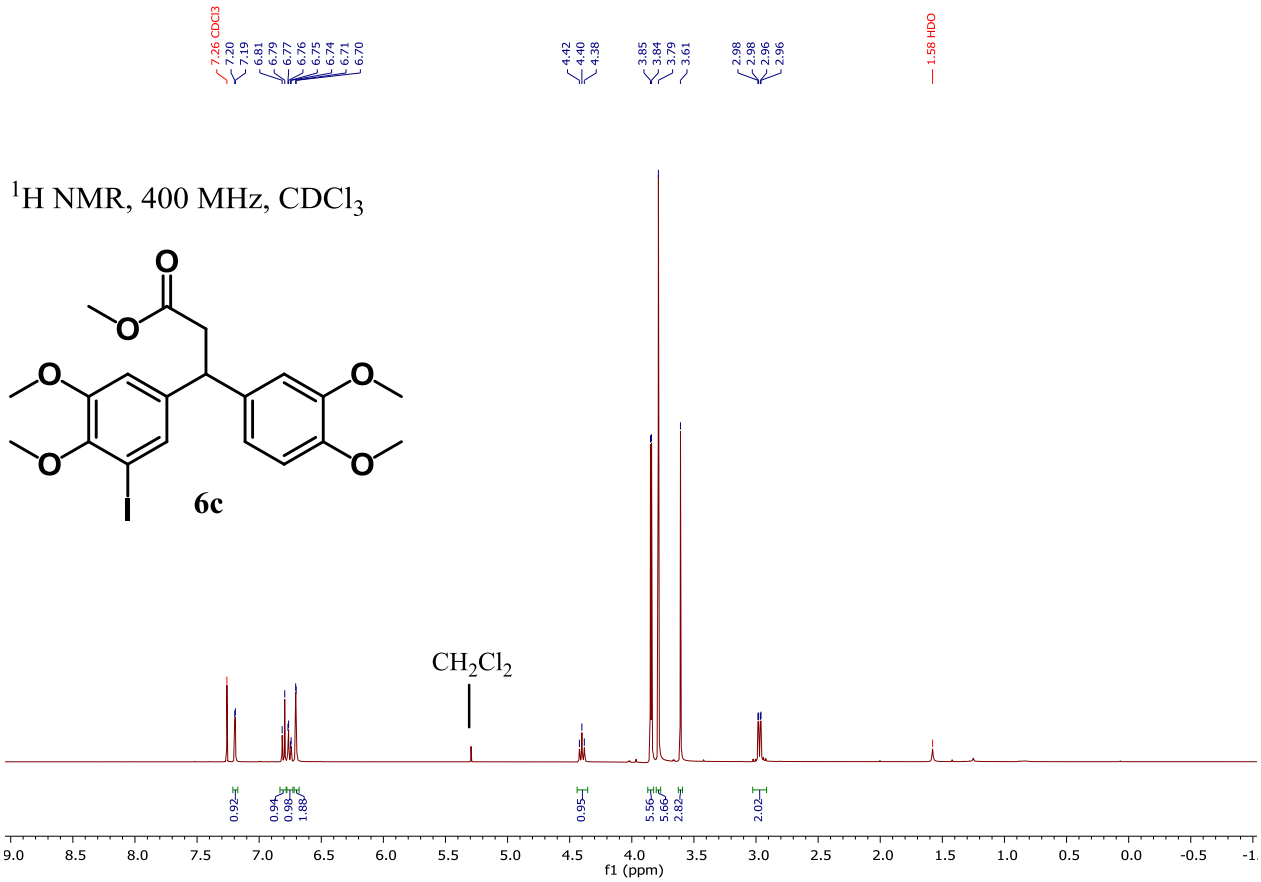


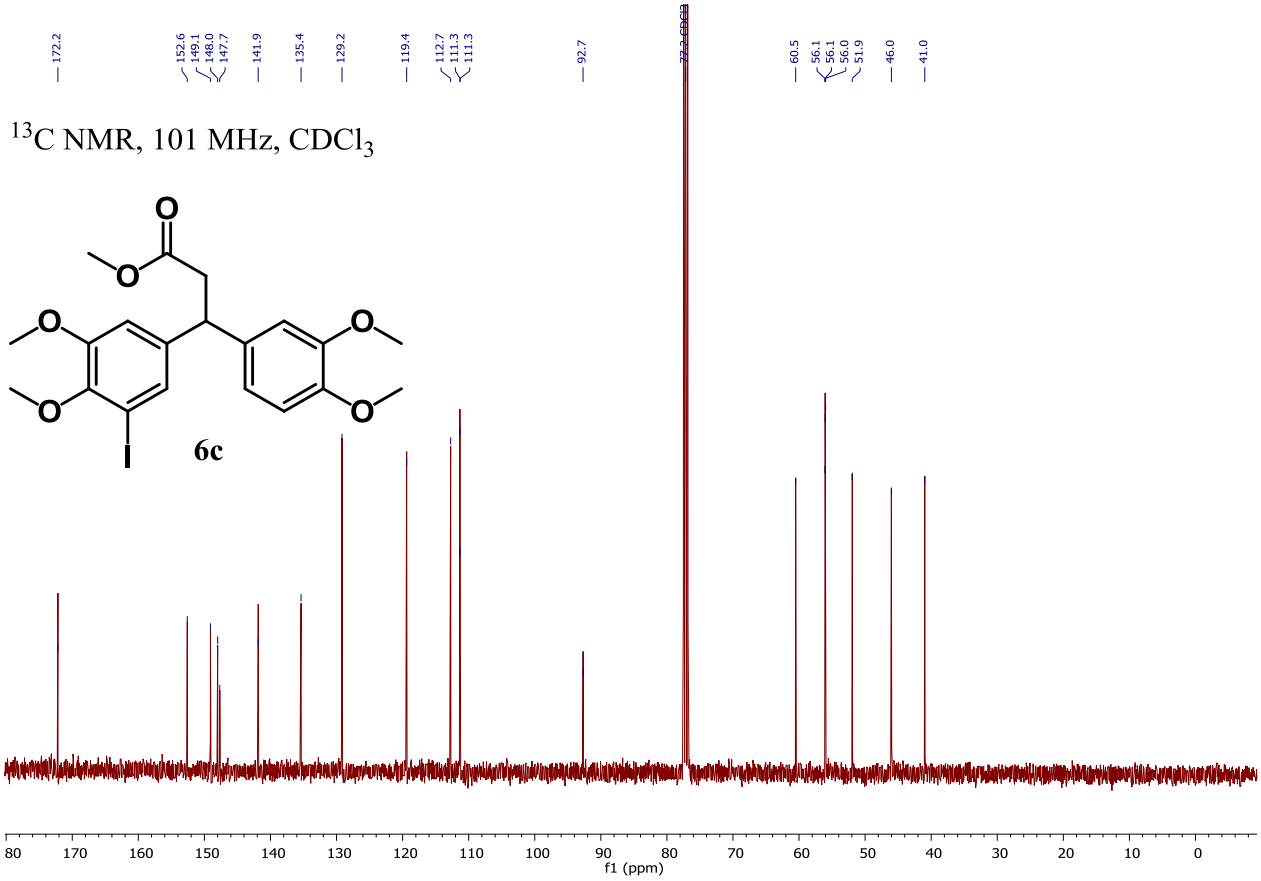
6b

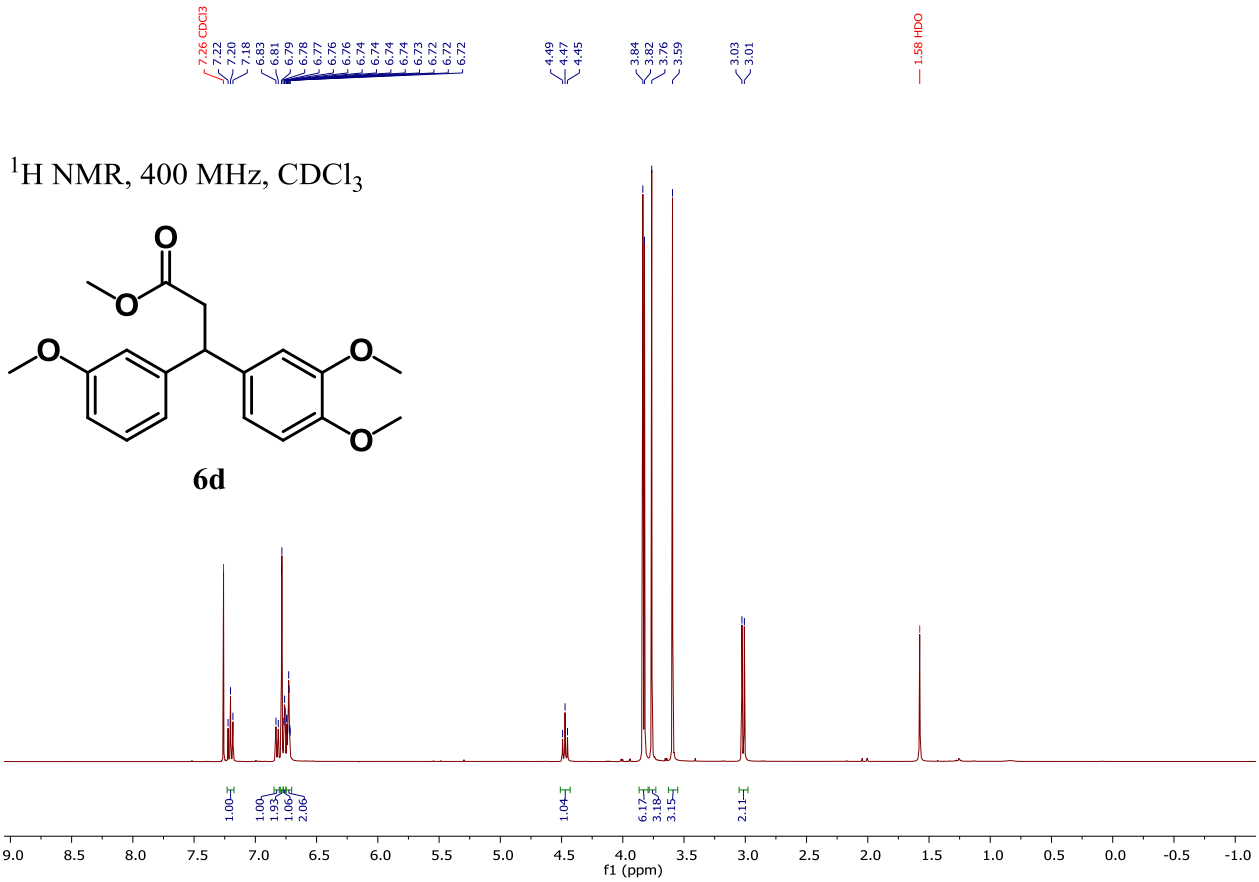
^{13}C NMR, 101 MHz, $CDCl_3$

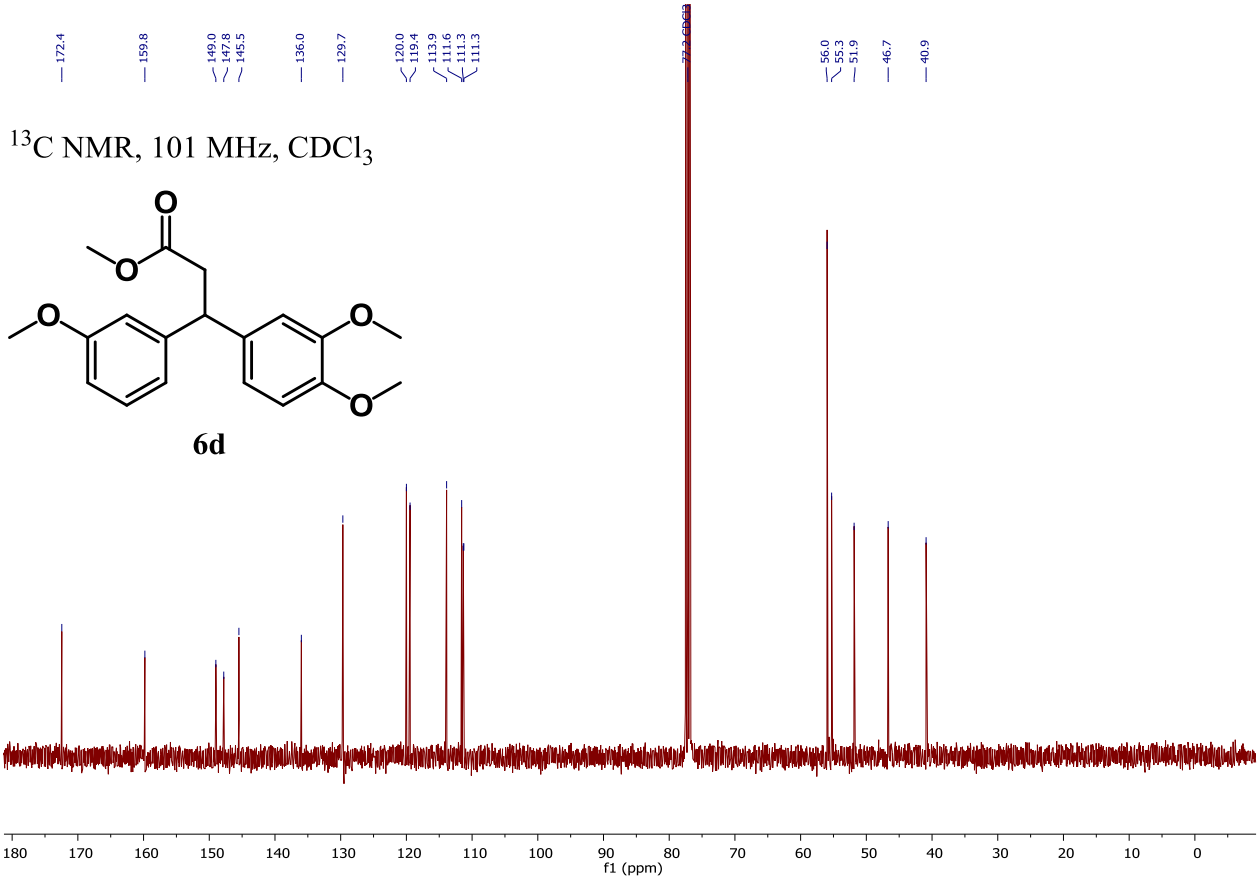


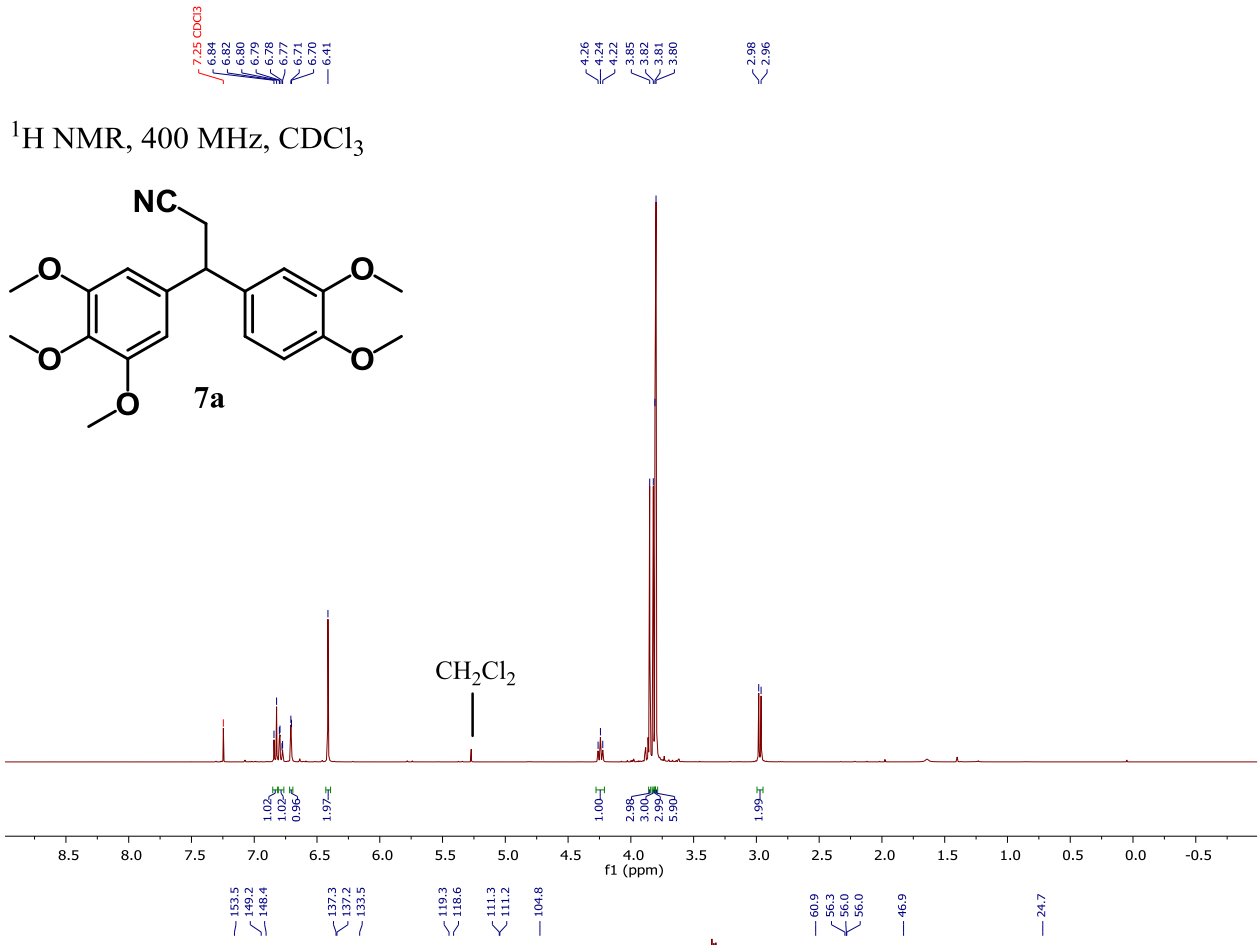
6b


7.26 CDCl3
7.20
7.19
6.81
6.79
6.77
6.76
6.75
6.74
6.71
6.70
4.42
4.40
4.38
3.85
3.84
3.79
3.61
2.98
2.98
2.96
2.96
1.58 HDO
^{1}H NMR, 400 MHz, $CDCl_3$
6c
CH_2Cl_2
0.92
0.94
0.98
1.88
0.95
5.56
5.66
2.82
2.02
f1 (ppm)

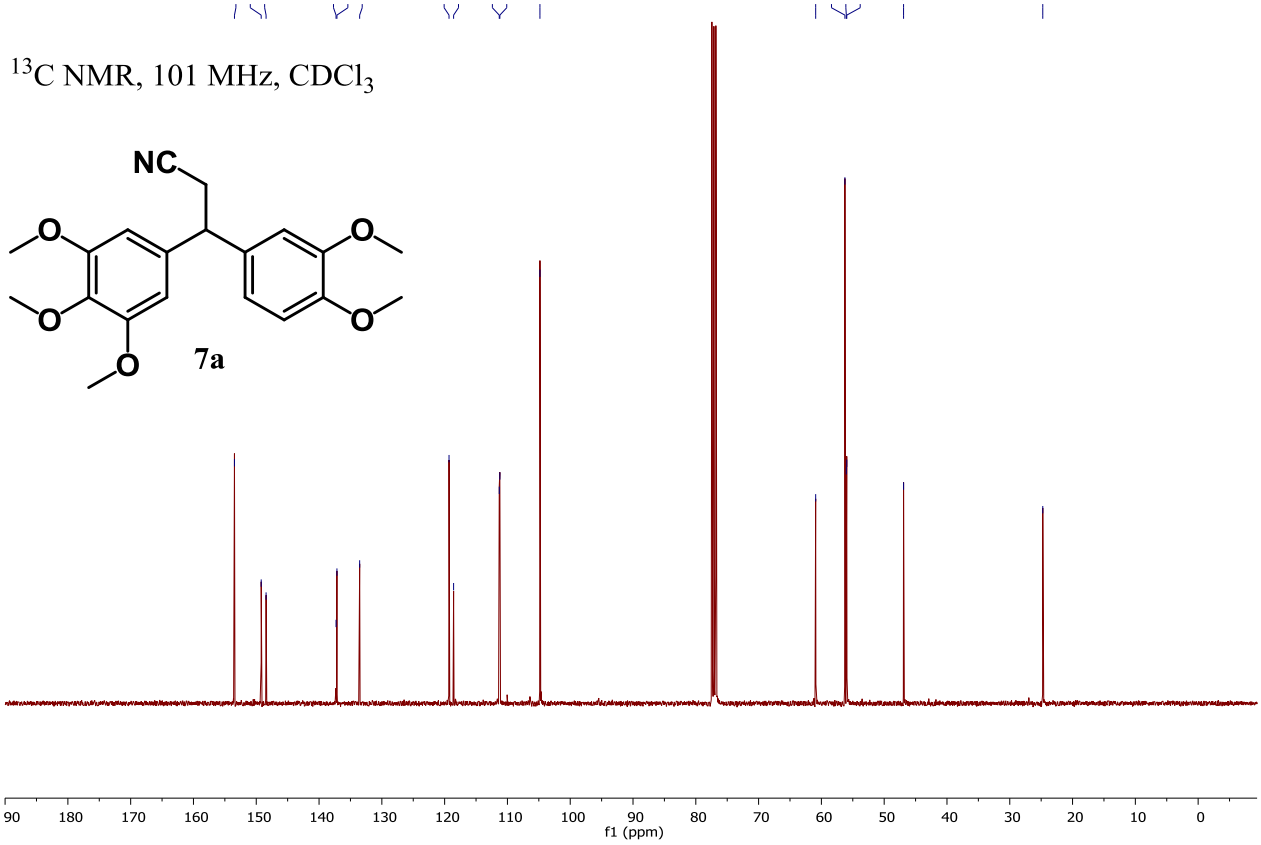

172.2
152.6
149.1
148.0
147.7
141.9
135.4
129.2
119.4
112.7
111.3
111.3
92.7
77.2 CDCl3
60.5
56.1
56.1
56.0
51.9
46.0
41.0
^{13}C NMR, 101 MHz, $CDCl_3$
6c
f1 (ppm)


7.26 CDCl3
7.22
7.20
7.18
6.83
6.81
6.79
6.78
6.77
6.76
6.76
6.74
6.74
6.74
6.73
6.72
6.72
6.72
4.49
4.47
4.45
3.84
3.82
3.76
3.59
3.03
3.01
1.58 HDO
1H NMR, 400 MHz, CDCl3
6d
1.00
1.00
1.93
1.06
2.06
1.04
6.17
3.18
3.15
2.11
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
f1 (ppm)


172.4
159.8
149.0
147.8
145.5
136.0
129.7
120.0
119.4
113.9
111.6
111.3
111.3
77.3 CDCl3
56.0
55.3
51.9
46.7
40.9
13C NMR, 101 MHz, CDCl3
6d
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

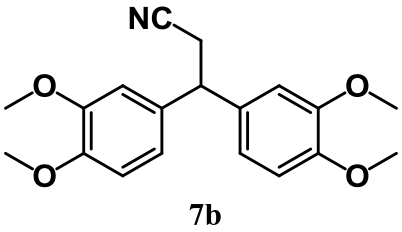


^{1}H NMR, 400 MHz, $CDCl_3$

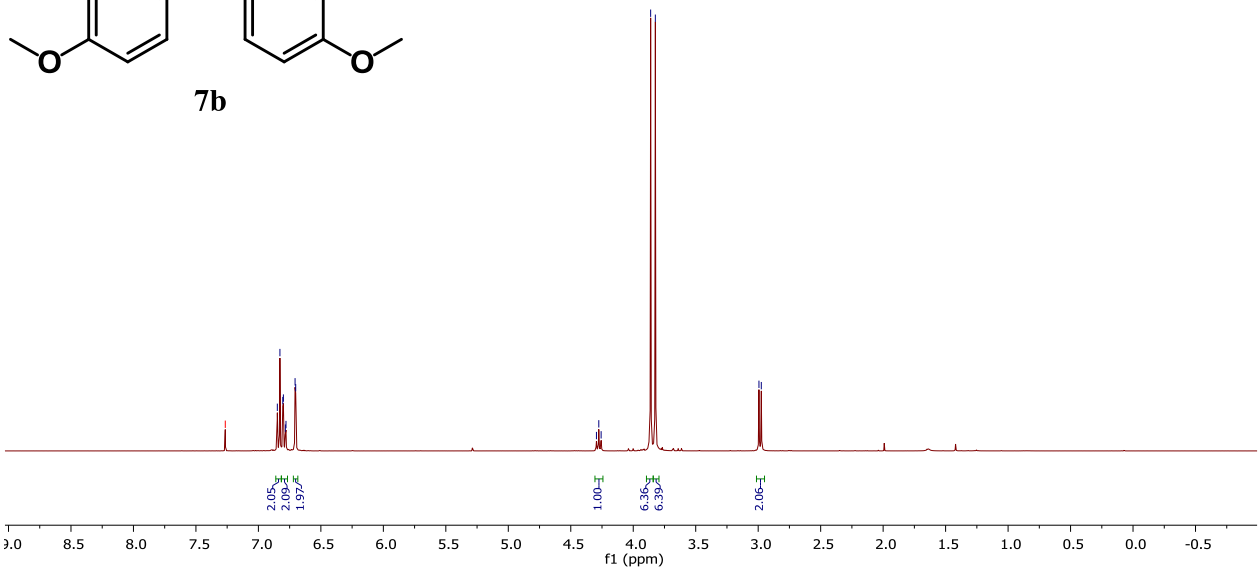


^{13}C NMR, 101 MHz, $CDCl_3$

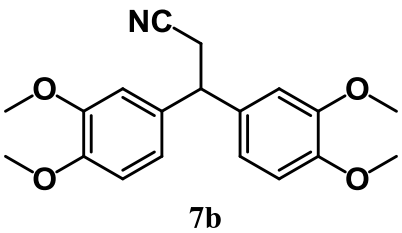
^{1}H NMR, 400 MHz, $CDCl_3$



7b

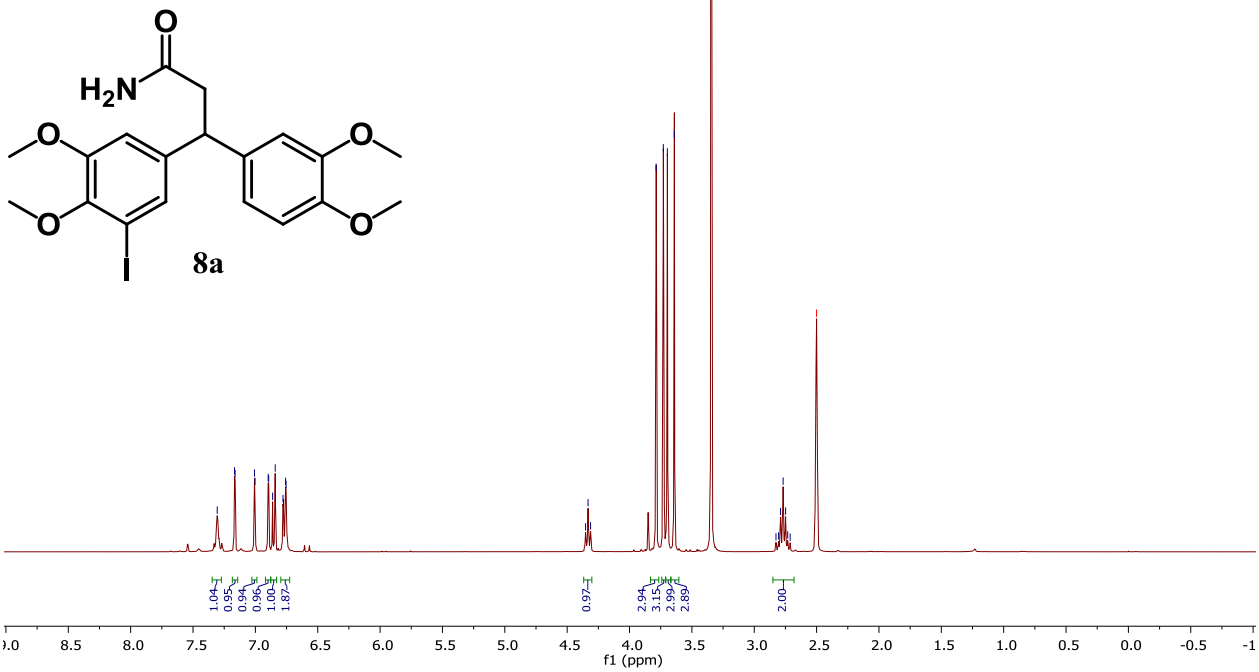


^{13}C NMR, 101 MHz, $CDCl_3$



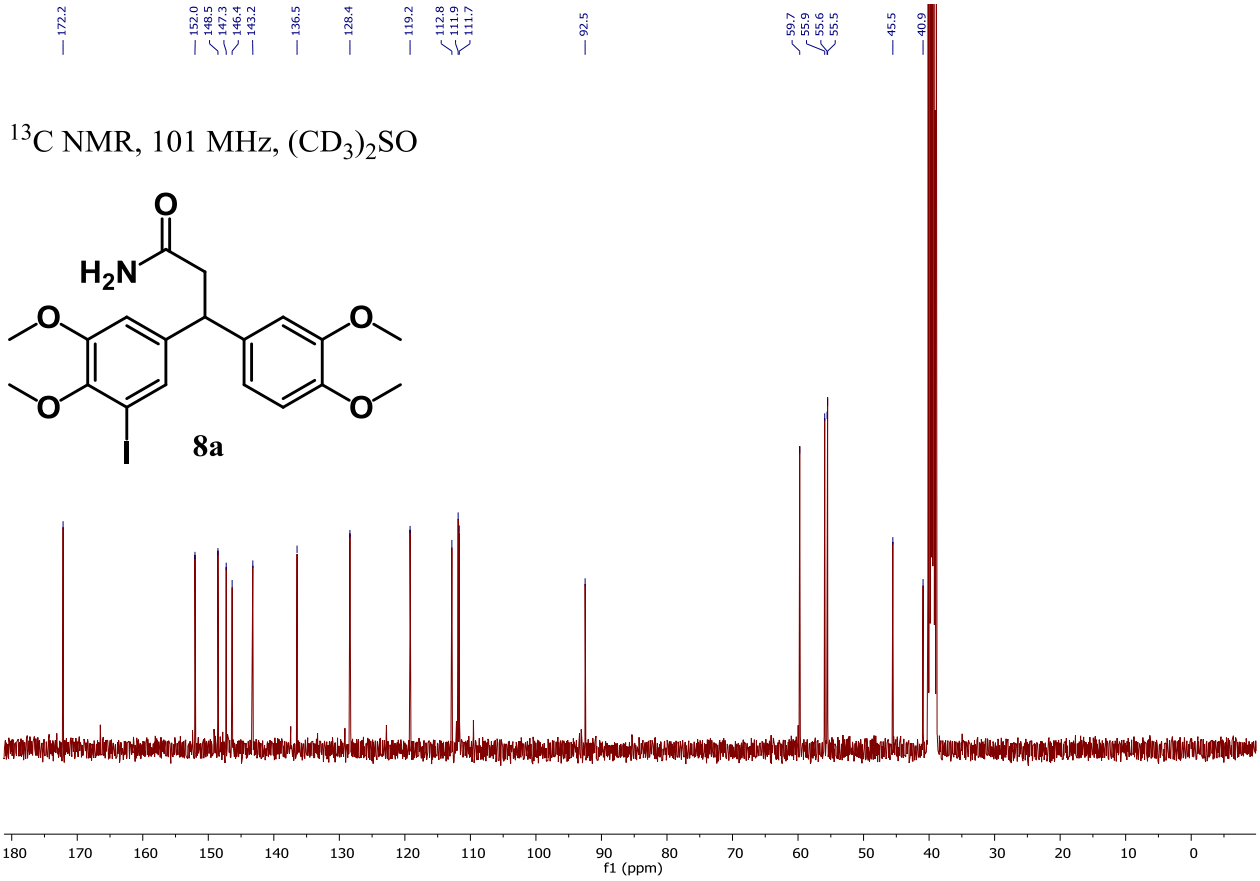
7b

^{1}H NMR, 400 MHz, $(CD_3)_2SO$



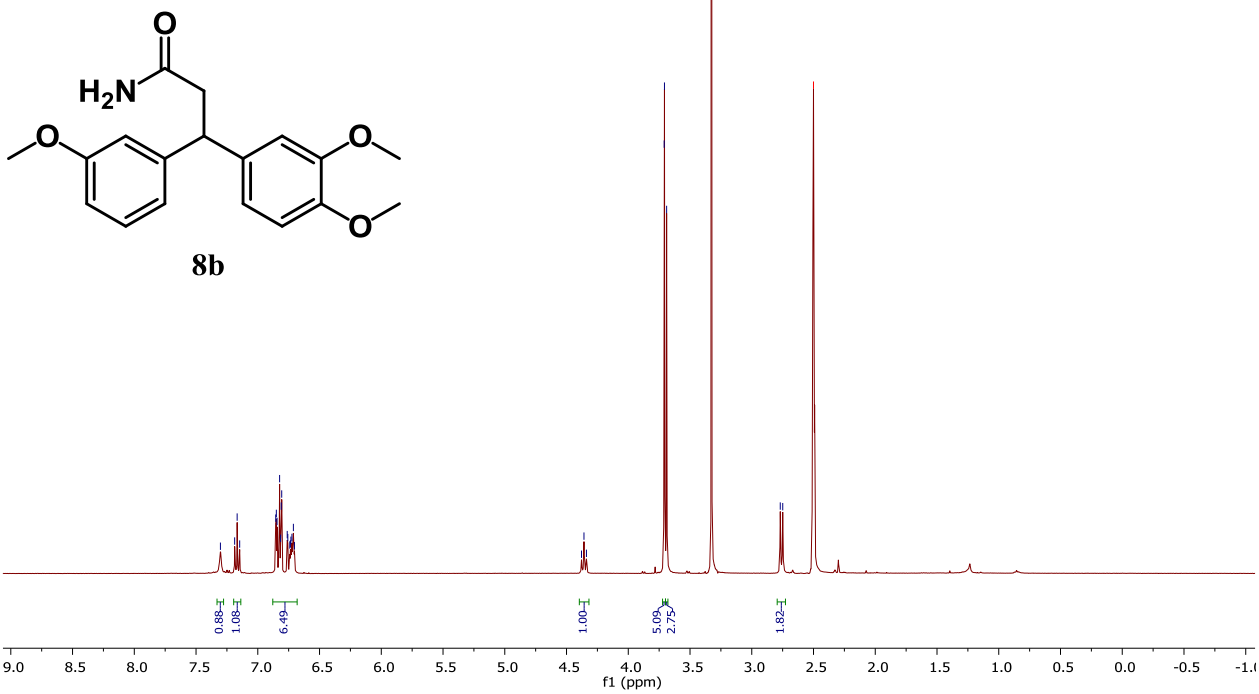
8a

^{13}C NMR, 101 MHz, $(CD_3)_2SO$



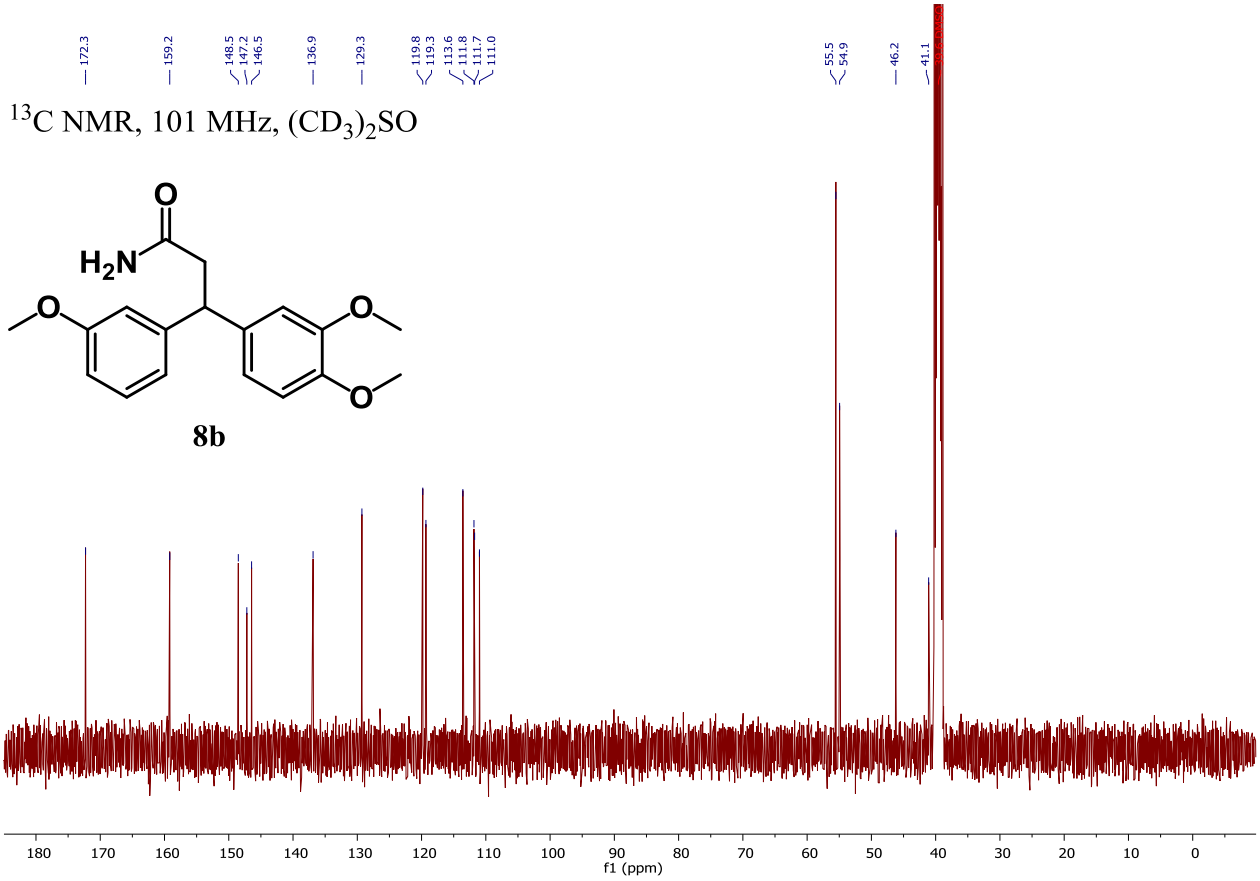
8a

^{1}H NMR, 400 MHz, $(CD_3)_2SO$



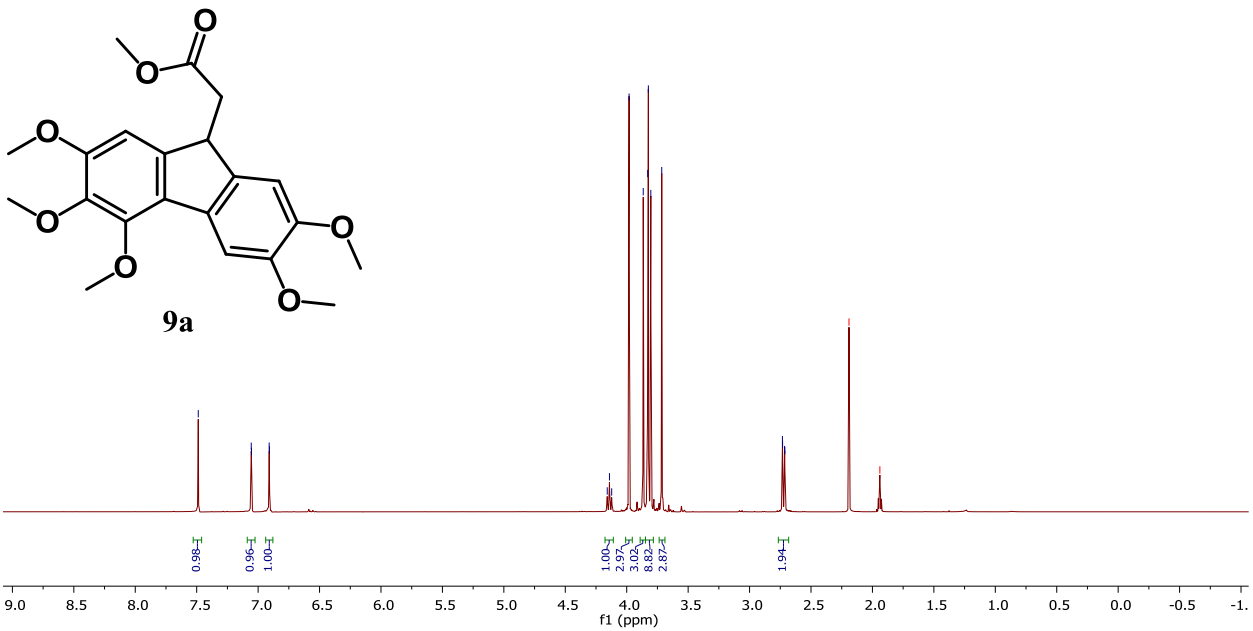
8b

^{13}C NMR, 101 MHz, $(CD_3)_2SO$



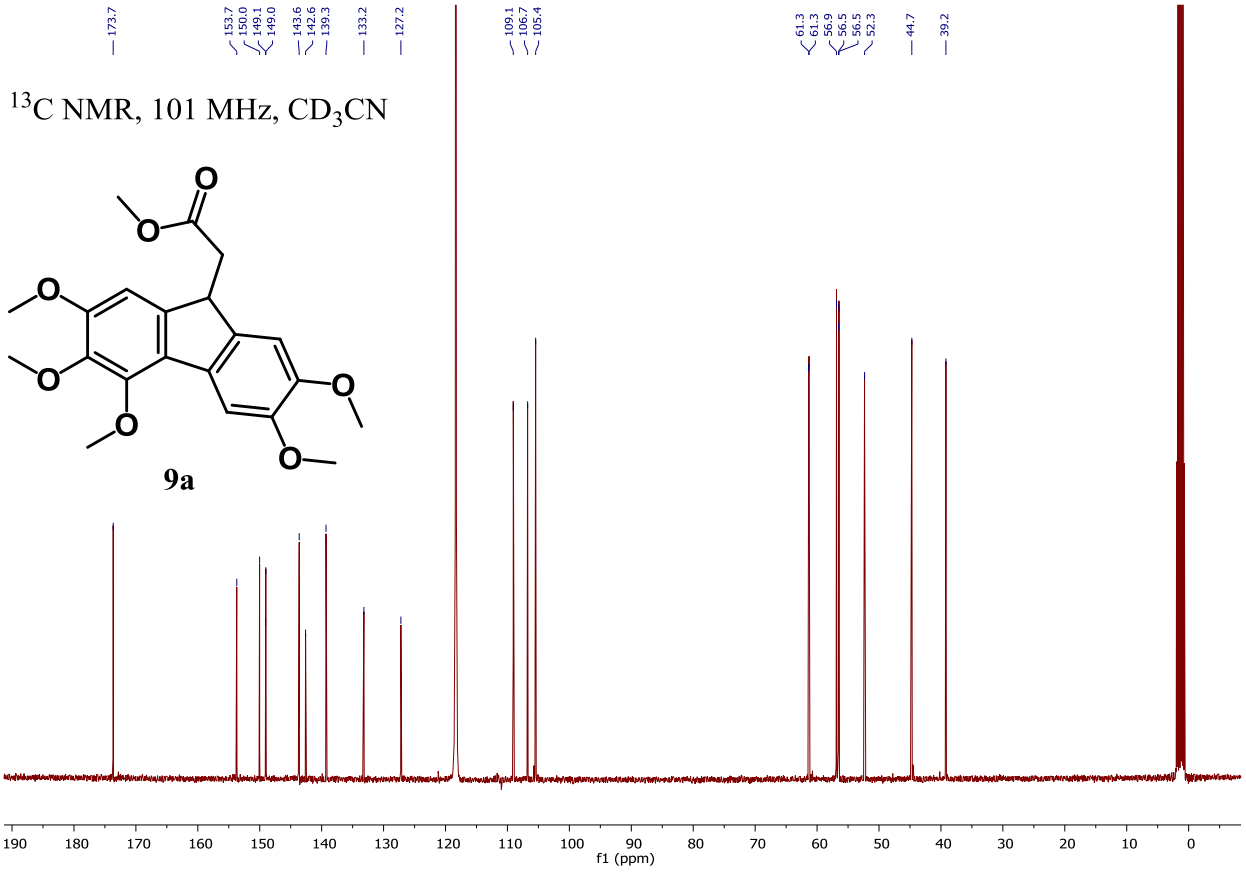
8b

^{1}H NMR, 400 MHz, CD_3CN

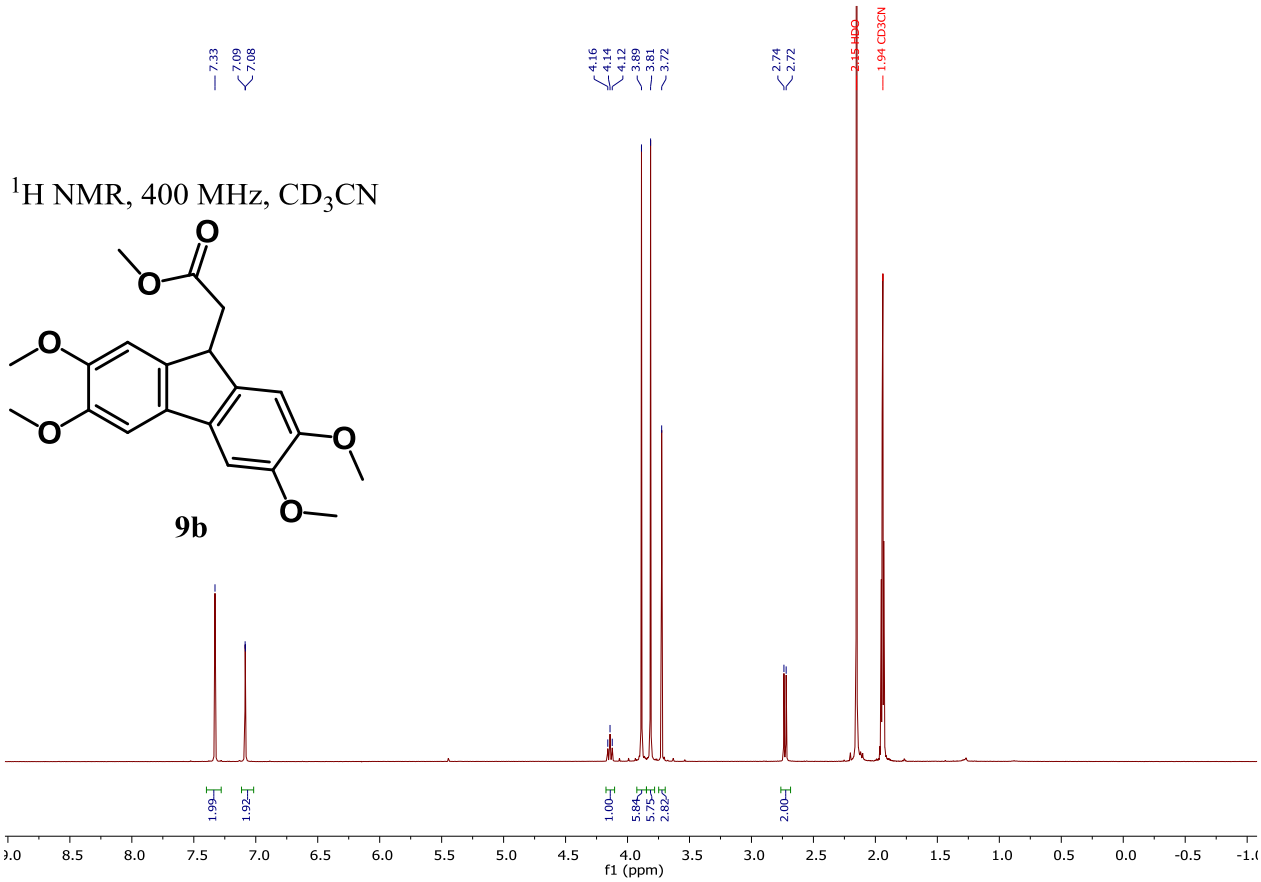


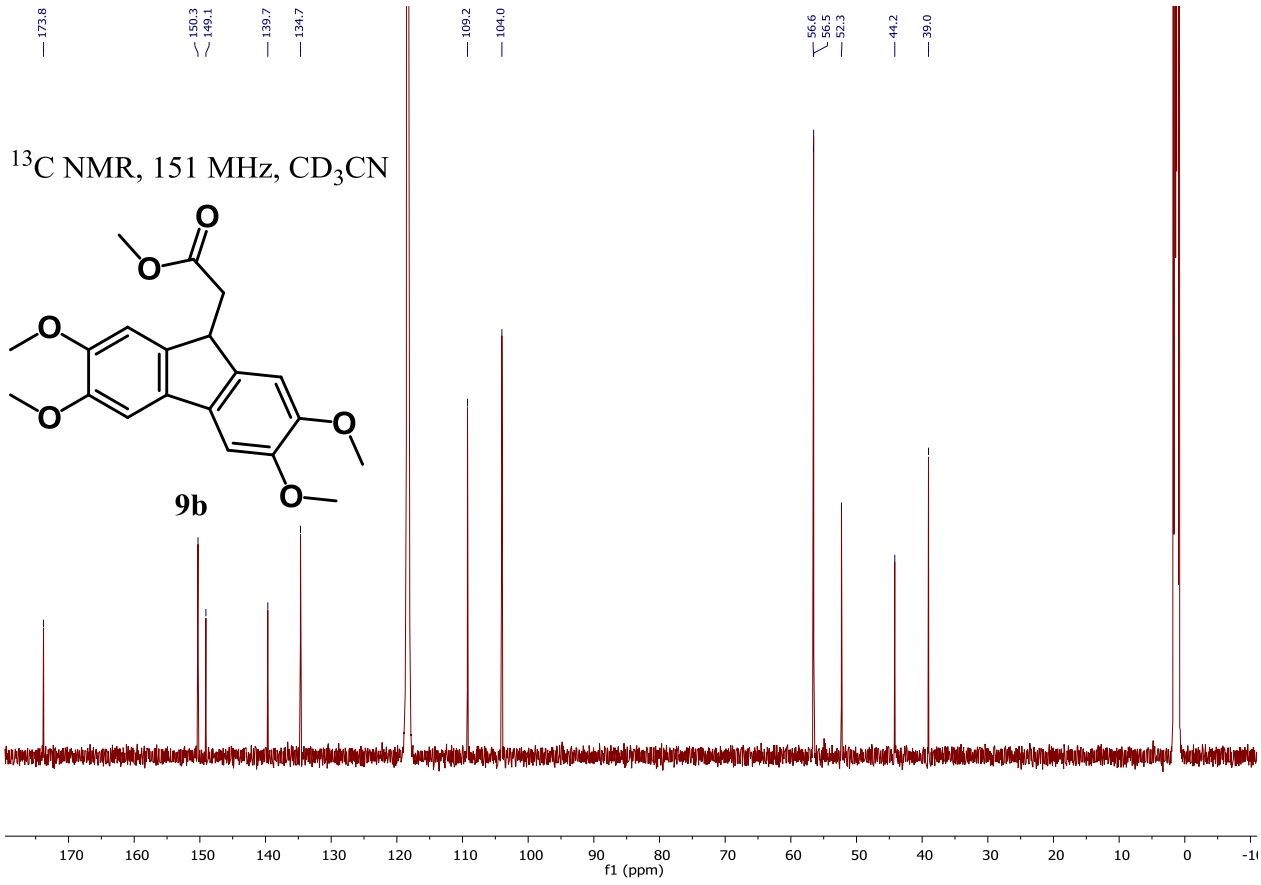
9a

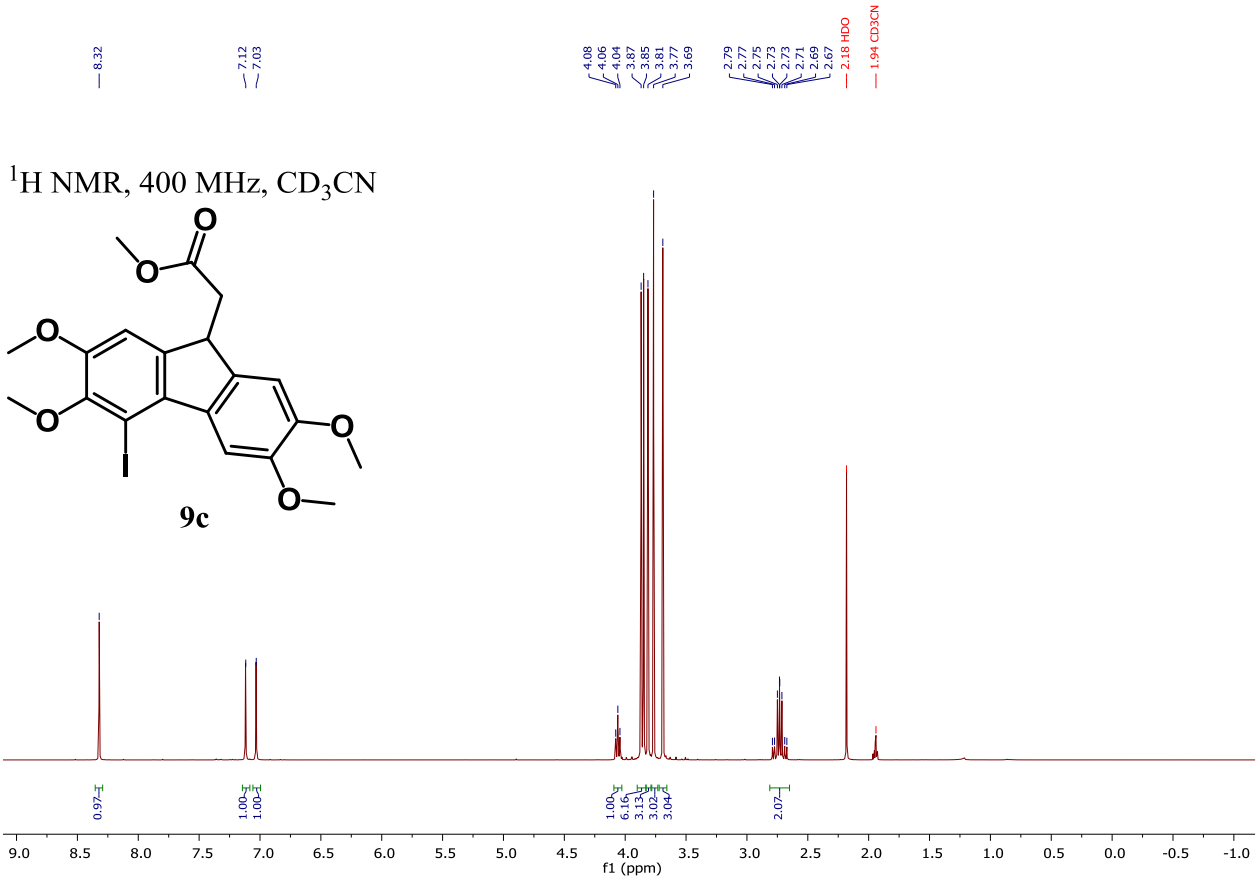
^{13}C NMR, 101 MHz, CD_3CN



9a

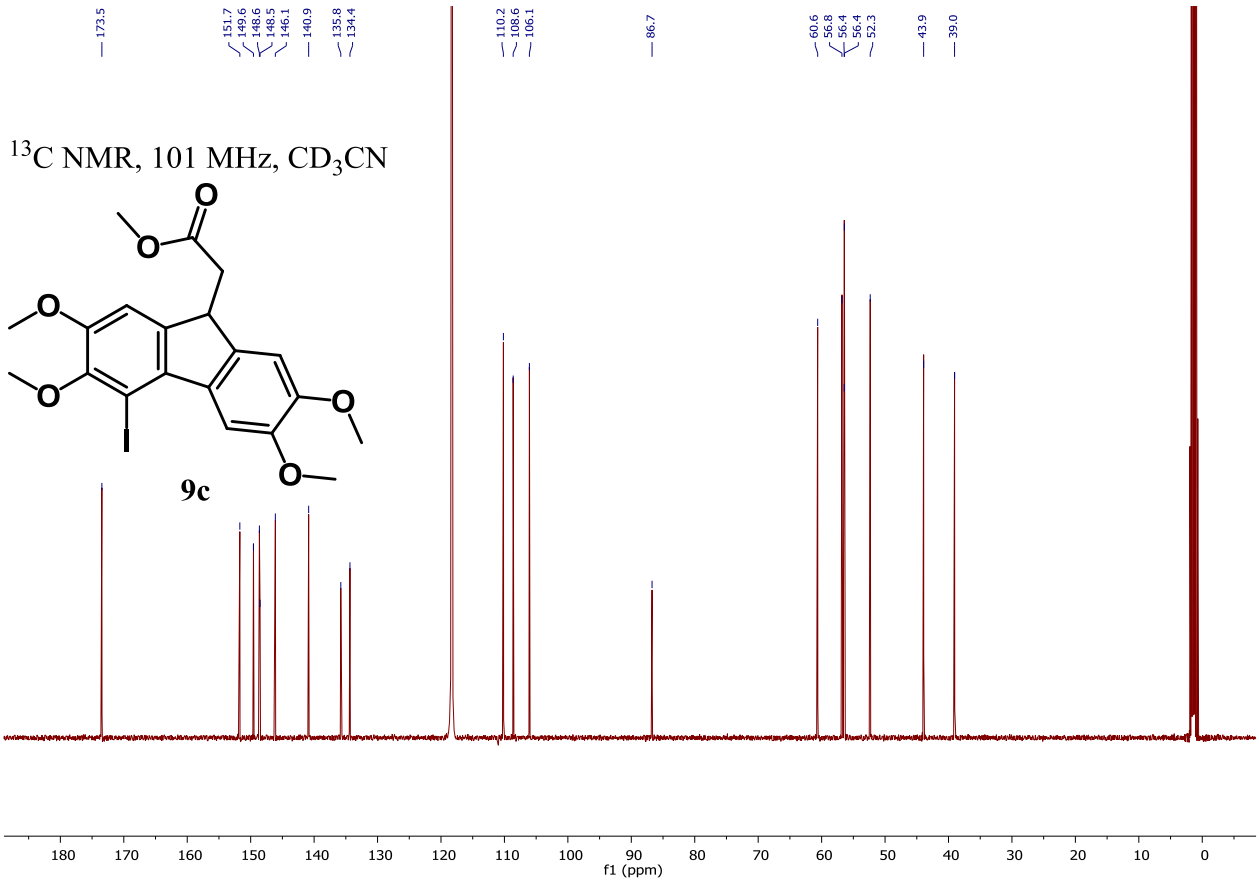

7.33
7.09
7.08
4.16
4.14
4.12
3.89
3.81
3.72
2.74
2.72
2.15 HDO
1.94 CD3CN
1H NMR, 400 MHz, CD3CN
9b
1.99
1.92
1.00
5.84
5.75
2.82
2.00
f1 (ppm)


173.8
150.3
149.1
139.7
134.7
109.2
104.0
56.6
56.5
52.3
44.2
39.0
13C NMR, 151 MHz, CD3CN
9b
f1 (ppm)



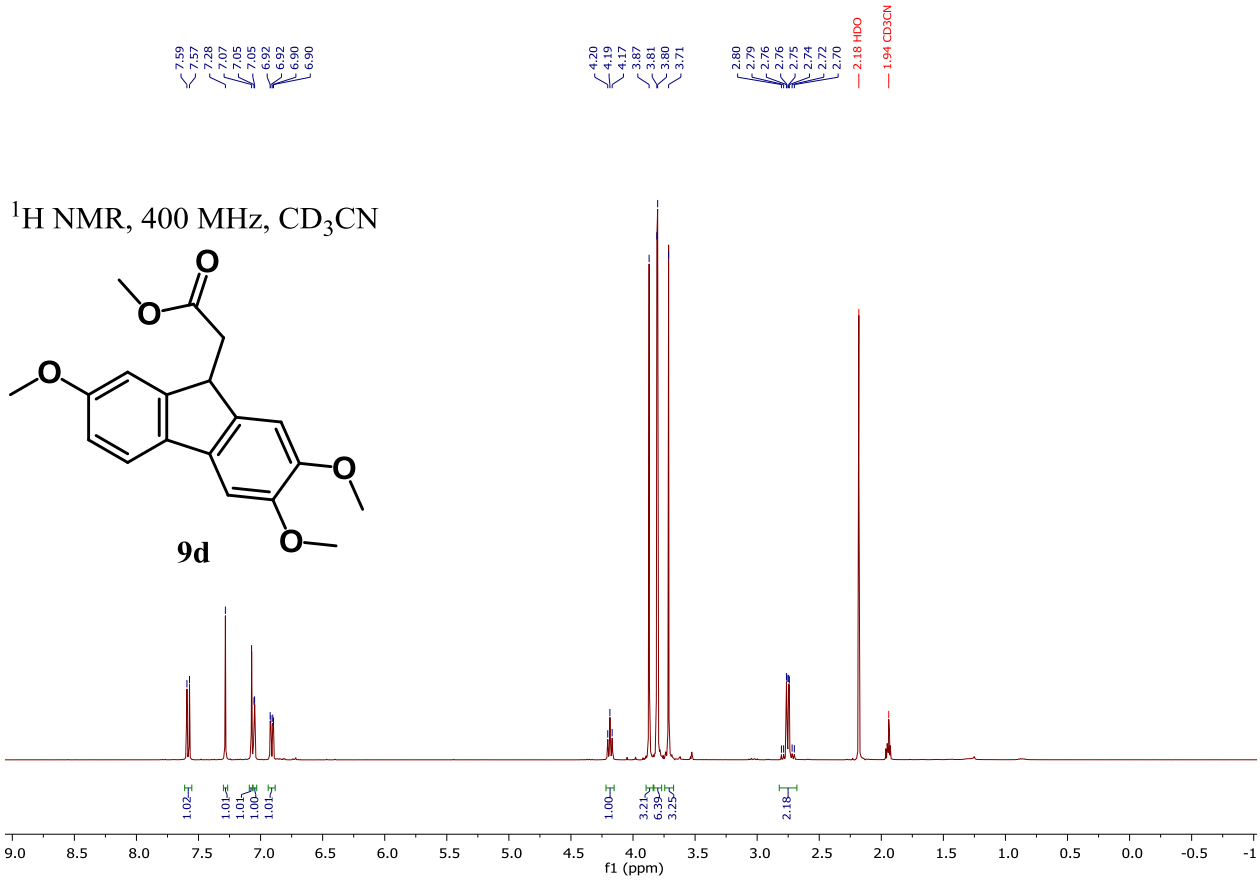
^{1}H NMR, 400 MHz, CD_3CN

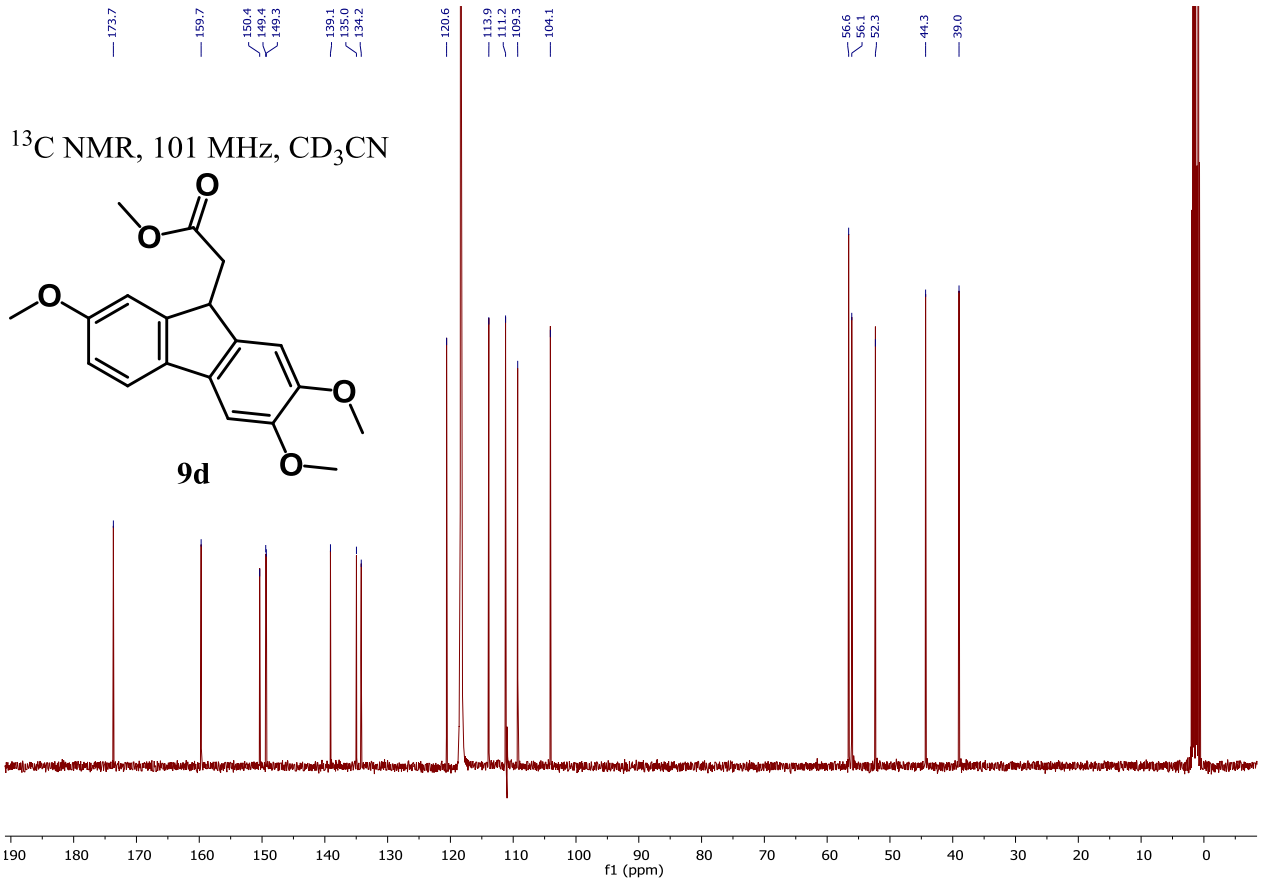
9c

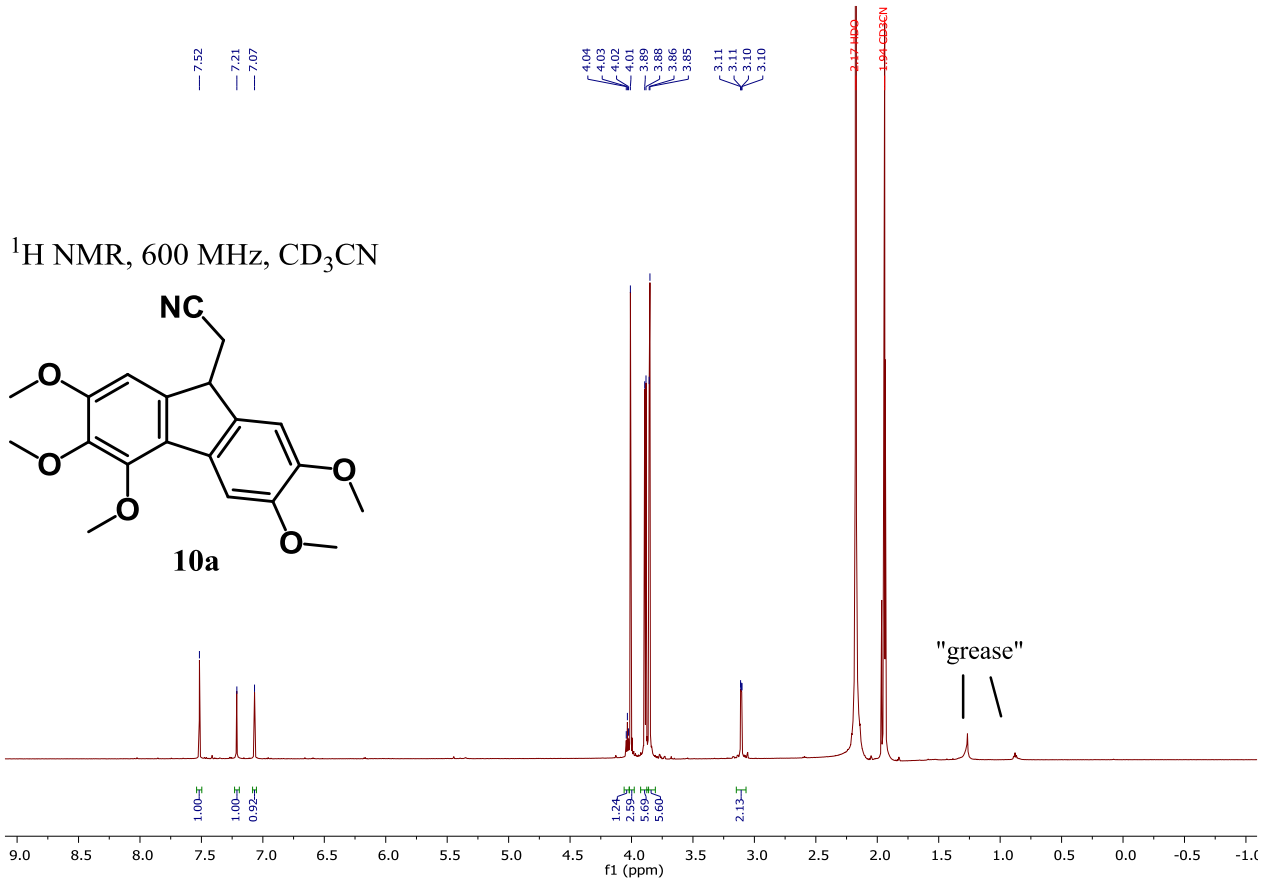


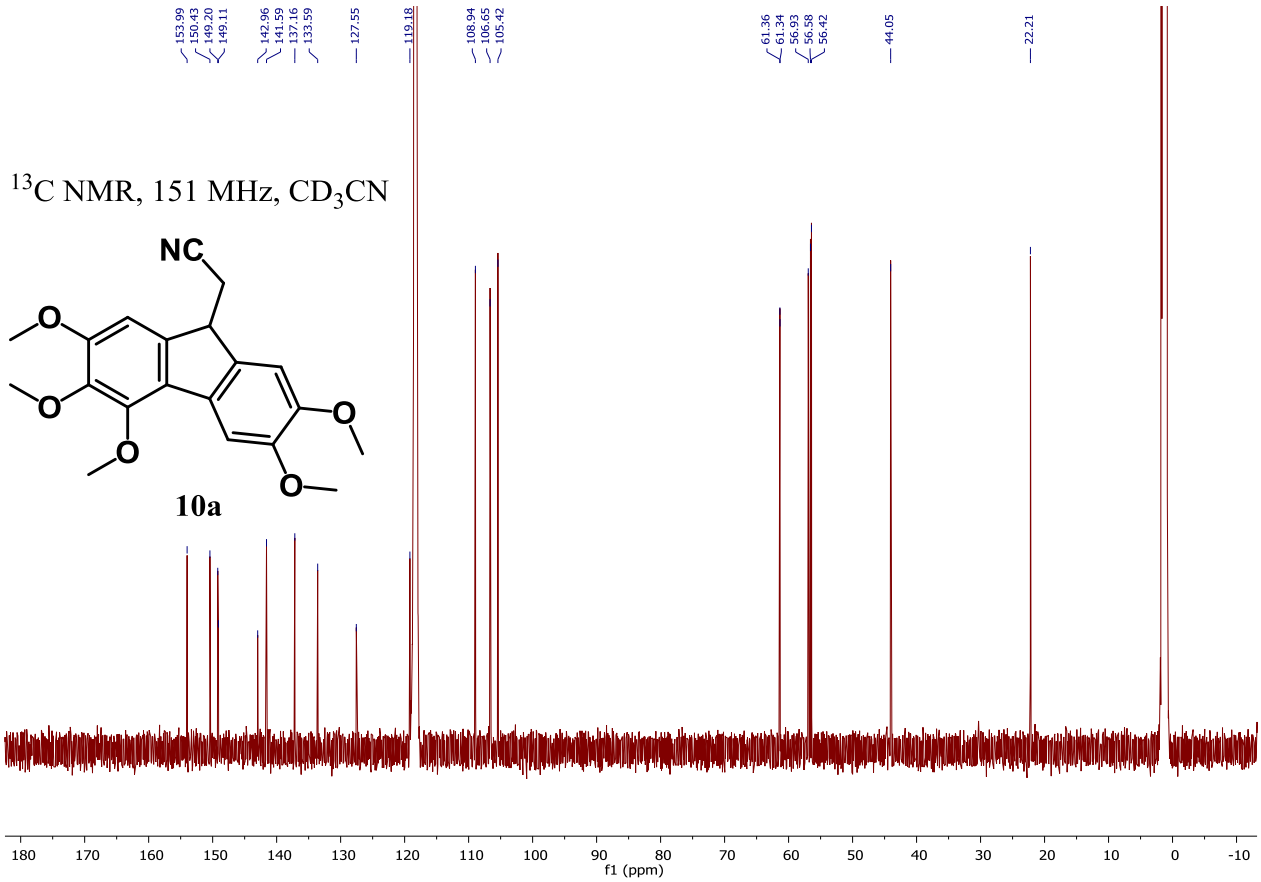
^{13}C NMR, 101 MHz, CD_3CN

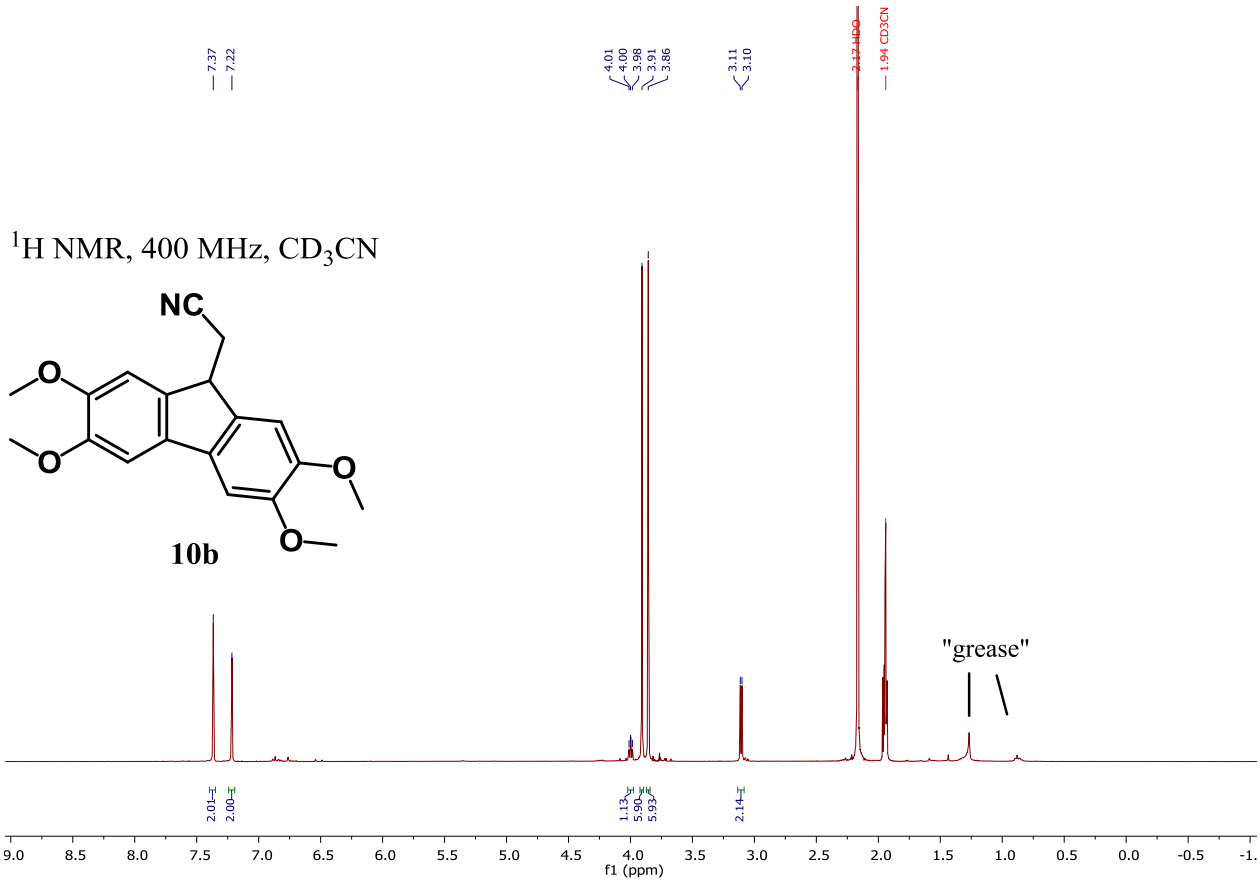
9c

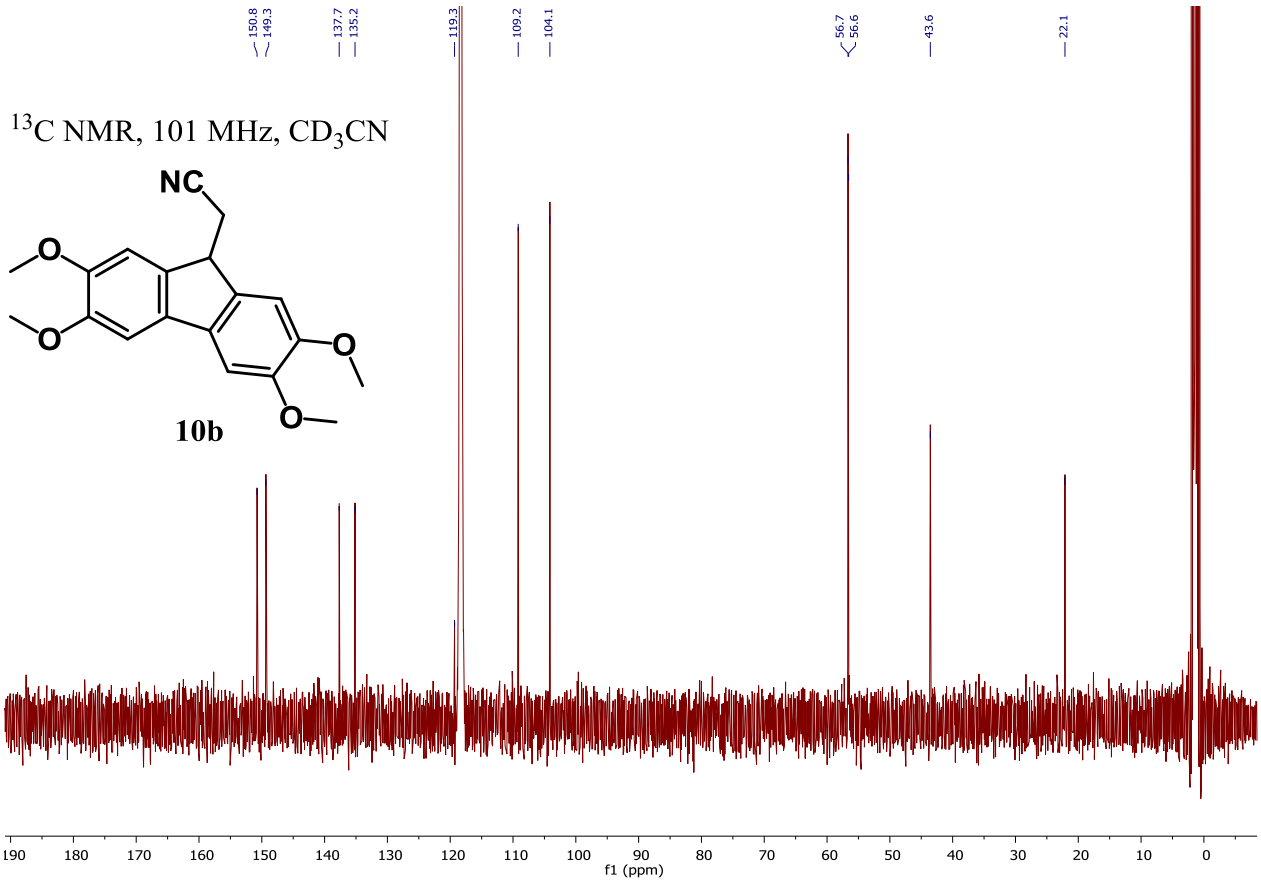

7.59
7.57
7.28
7.07
7.05
7.05
6.92
6.92
6.90
6.90
4.20
4.19
4.17
3.87
3.81
3.80
3.71
2.80
2.79
2.76
2.76
2.75
2.74
2.72
2.70
2.18 HDO
1.94 CD3CN
1H NMR, 400 MHz, CD3CN
9d
1.02
1.01
1.01
1.00
1.01
1.00
3.21
6.39
3.25
2.18
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1
f1 (ppm)


173.7
159.7
150.4
149.4
149.3
139.1
135.0
134.2
120.6
113.9
111.2
109.3
104.1
56.6
56.1
52.3
44.3
39.0
13C NMR, 101 MHz, CD3CN
9d
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

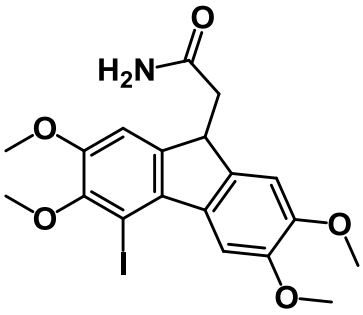

7.52
7.21
7.07
4.04
4.03
4.02
4.01
3.89
3.88
3.86
3.85
3.11
3.11
3.10
3.10
2.17 H2O
1.94 CD3CN
1H NMR, 600 MHz, CD3CN
NC
O
O
O
O
O
10a
"grease"
1.00
1.00
0.92
1.24
2.59
5.69
5.60
2.13
f1 (ppm)


153.99
150.43
149.20
149.11
142.96
141.59
137.16
133.59
127.55
119.18
108.94
106.65
105.42
61.36
61.34
56.93
56.58
56.42
44.05
22.21
13C NMR, 151 MHz, CD3CN
NC
O
O
O
O
O
10a
f1 (ppm)


7.37
7.22
4.01
4.00
3.98
3.91
3.86
3.11
3.10
2.17 HDO
1.94 CD3CN
^{1}H NMR, 400 MHz, CD_3CN
NC
O
O
O
O
10b
"grease"
2.01
2.00
1.13
5.90
5.93
2.14
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.
f1 (ppm)

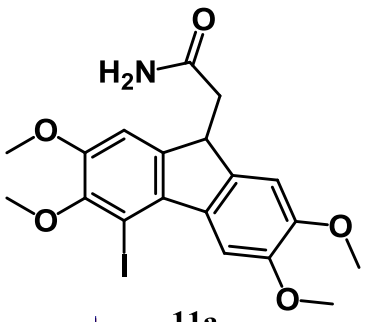

150.8
149.3
137.7
135.2
119.3
109.2
104.1
56.7
56.6
43.6
22.1
^{13}C NMR, 101 MHz, CD_3CN
NC
O
O
O
O
10b
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

^{1}H NMR, 600 MHz, DMF-d$_7$

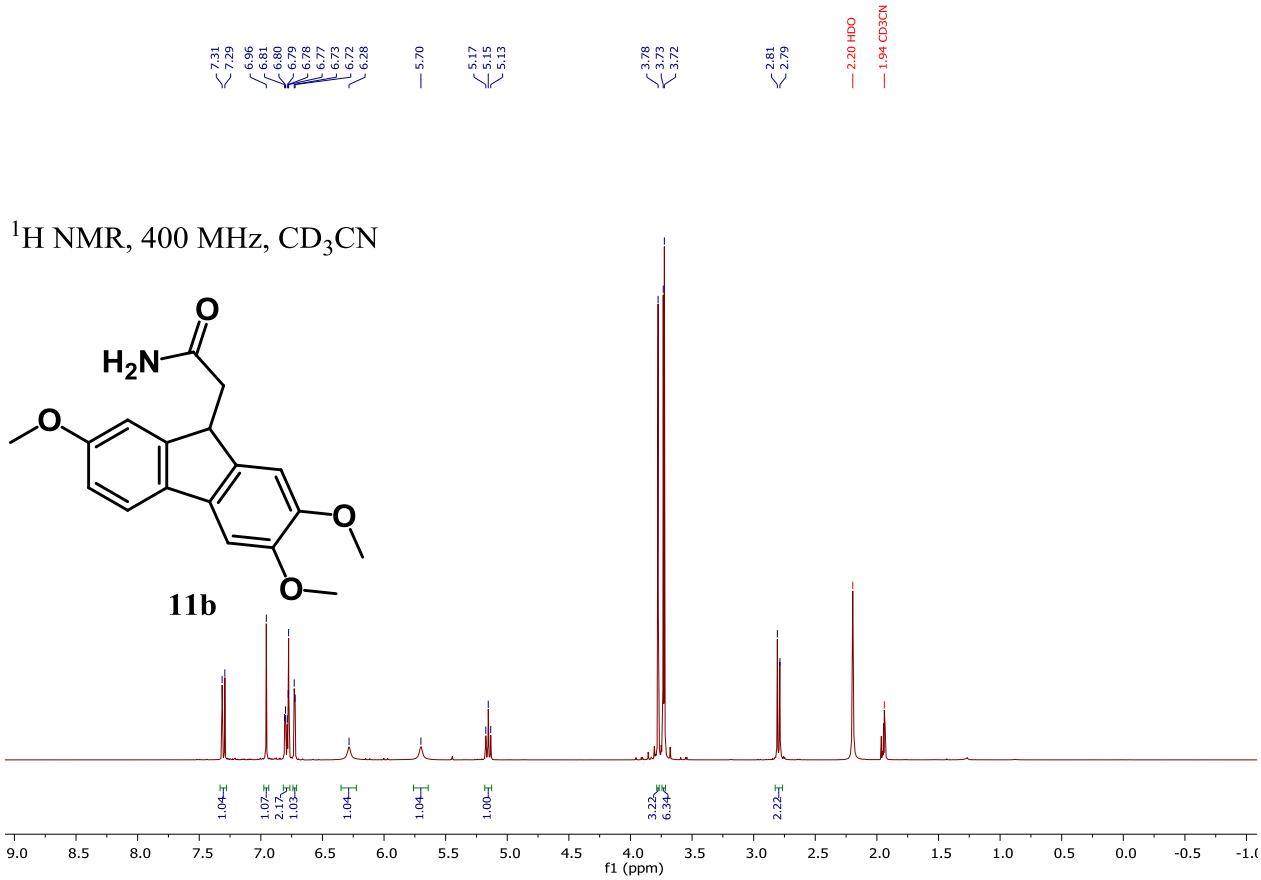


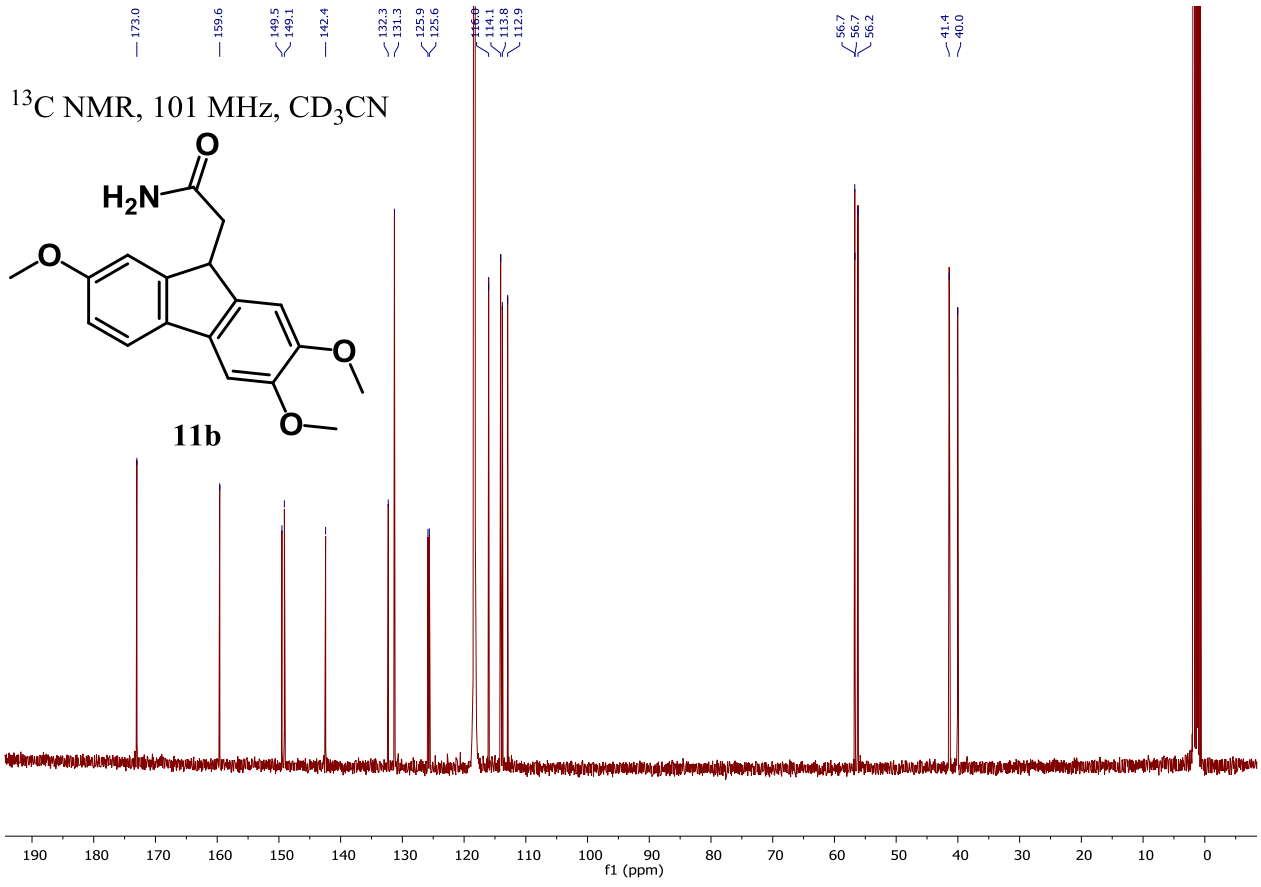
11a

^{13}C NMR, 151 MHz, DMF-d$_7$



11a


7.31
7.29
6.96
6.81
6.80
6.79
6.78
6.77
6.73
6.72
6.28
5.70
5.17
5.15
5.13
3.78
3.73
3.72
2.81
2.79
2.20 HDO
1.94 CD3CN
1H NMR, 400 MHz, CD3CN
O
H2N
O
O
O
11b
1.04
1.07
2.17
1.03
1.04
1.04
1.00
3.22
6.34
2.22
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


173.0
159.6
149.5
149.1
142.4
132.3
131.3
125.9
125.6
116.6
114.1
113.8
112.9
56.7
56.7
56.2
41.4
40.0
13C NMR, 101 MHz, CD3CN
O
H2N
O
O
O
11b
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

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