Electronic Supplementary Material (ESI) for ChemComm.

Supporting Information

Aerobic Oxidative α-Arylation of Furans with Boronic Acids via Pd(II)-Catalyzed C–C Bond Cleavage of Primary Furfuryl Alcohols: Sustainable Access to Arylfurans

Guanghao Huang, Lin Lu, Huanfeng Jiang and Biaolin Yin*

Key Laboratory of Functional Molecular Engineering of Guangdong Province,

School of Chemistry and Chemical Engineering, South China University of Technology,

Guangzhou 510640, P. R. China

E-mail: blyin@scut.edu.cn

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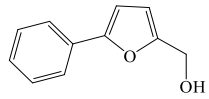
1 General experimental details

All chemicals and solvents were purchased from commercial vendors and used without further purification unless otherwise noted. Analytical TLC was performed with silica gel 60 F254 plates. Column chromatography was performed on silica gel 200-300 mesh and using appropriate solvents as eluent. Melting points were determined using a Stuart SMP10 melting point apparatus. NMR spectra were recorded on a Bruker AV-400 spectrometer (^{1}H NMR at 400 MHz and ^{13}C NMR at 100 MHz). Proton chemical shifts were referenced relative to tetramethylsilane proton signals at δ = 0.00 ppm. Carbon chemical shifts were referenced relative to $CDCl_3$ at δ = 77.16 ppm. Data for ^{1}H NMR are reported as follows: chemical shift (ppm), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, dd = double doublet, dt = double triplet, dq = double quartet, br = broad), coupling constants (Hz), integration. Data for ^{13}C NMR are reported in chemical shift (ppm). Infrared spectra (IR) recorded as KBr disks on a Bruker Tensor 27 FT/IR spectrometer are reported in cm^{-1}. ESI technique was used for the high resolution mass (HRMS) measurements.

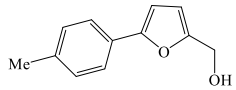
2 Synthesis of the starting materials

(5-Phenylfuran-2-yl)methanol (1a)



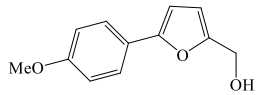
The syntheses of **1a** have been reported previously.[1] Analytical data were consistent with previously reported data.[2] Yellow solid (2.34 g, 85% over two steps). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 – 7.64 (m, 2H), 7.42 – 7.34 (m, 2H), 7.28 – 7.23 (m, 1H), 6.59 (d, J = 3.3 Hz, 1H), 6.37 (d, J = 3.3 Hz, 1H), 4.66 (s, 2H), 1.83 (br, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.2, 153.7, 130.8, 128.8, 127.6, 124.0, 110.1, 105.8, 57.8.

(5-(*p*-Tolyl)furan-2-yl)methanol (1b)



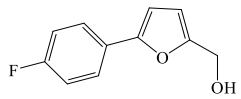
Compound **1b** was prepared in the same manner of **1a**, except that 4-tolylboronic acid was used instead of phenylboronic acid.[1] Analytical data were consistent with previously reported data.[3] White solid (0.82 g, 94% over two steps). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56 (d, J = 8.0 Hz, 2H), 7.18 (d, J = 7.9 Hz, 2H), 6.53 (d, J = 3.2 Hz, 1H), 6.35 (d, J = 3.2 Hz, 1H), 4.65 (s, 2H), 2.35 (s, 3H), 1.89 (br, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.4, 153.3, 137.5, 129.5, 128.1, 123.9, 110.1, 105.1, 57.8, 21.4.

(5-(4-Methoxyphenyl)furan-2-yl)methanol (1c)



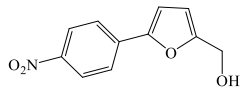
Compound **1c** was prepared in the same manner of **1a**, except that 4-methoxyphenylboronic acid was used instead of phenylboronic acid.[1] Analytical data were consistent with previously reported data.[3] White solid (0.91 g, 94% over two steps). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58 (d, J = 8.8 Hz, 2H), 6.90 (d, J = 8.8 Hz, 2H), 6.44 (d, J = 3.2 Hz, 1H), 6.33 (d, J = 3.2 Hz, 1H), 4.62 (s, 2H), 3.81 (s, 3H), 2.10 (br, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.2, 154.2, 153.0, 125.4, 123.9, 114.2, 110.1, 104.2, 57.7, 55.4.

(5-(4-Fluorophenyl)furan-2-yl)methanol (1d)



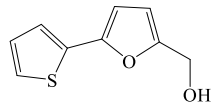
The syntheses of **1d** have been reported previously.[3] Analytical data were consistent with previously reported data.[3] Yellow solid (0.21 g, 24%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 – 7.58 (m, 2H), 7.09 – 7.02 (m, 2H), 6.51 (d, J = 3.3 Hz, 1H), 6.35 (d, J = 3.3 Hz, 1H), 4.64 (s, 2H), 2.05 (br, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.3 (d, $J_{C\text{-}F}$ = 245.6 Hz), 153.7, 153.3, 127.2 (d, $J_{C\text{-}F}$ = 3.3 Hz), 125.7 (d, $J_{C\text{-}F}$ = 8.0 Hz), δ 115.8 (d, $J_{C\text{-}F}$ = 21.8 Hz), 110.1, 105.5 (d, $J_{C\text{-}F}$ = 1.3 Hz), 57.7. ^{19}F NMR (376 MHz, $CDCl_3$) δ -114.12.

(5-(4-Nitrophenyl)furan-2-yl)methanol (1e)



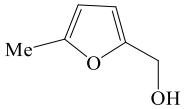
The syntheses of **1e** have been reported previously.[3] Analytical data were consistent with previously reported data.[3] Yellow solid (0.18 g, 17%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.24 (d, J = 8.8 Hz, 2H), 7.78 (d, J = 8.8 Hz, 2H), 6.83 (d, J = 3.3 Hz, 1H), 6.46 (d, J = 3.3 Hz, 1H), 4.71 (s, 2H), 1.84 (br, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.0, 151.8, 146.6, 136.4, 124.5, 124.1, 110.7, 109.9, 57.7.

(5-(Thiophen-2-yl)furan-2-yl)methanol (1f)



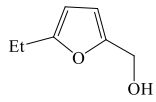
Compound **1f** was prepared in the same manner of **1a**, except that 2-thiopheneboronic acid was used instead of phenylboronic acid.[1] White solid (0.32 g, 39% over two steps). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.26 – 7.24 (m, 1H), 7.23 – 7.19 (m, 1H), 7.02 (dd, J = 5.0, 3.7 Hz, 1H), 6.43 (d, J = 3.3 Hz, 1H), 6.33 (d, J = 3.3 Hz, 1H), 4.62 (s, 2H), 1.97 (br, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.3, 149.6, 133.7, 127.7, 124.4, 122.9, 110.1, 105.9, 57.6. IR (film) 3312, 3048, 2925, 1651, 1423, 1197, 1012, 845, 785 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_9H_8NaO_2S$ $[M+Na]^+$: 203.0137, found: 203.0136.

(5-Methylfuran-2-yl)methanol (1g)



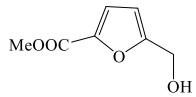
The syntheses of **1g** have been reported previously.[4] Analytical data were consistent with previously reported data.[4] Yellow oil (0.93 g, 84%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.15 (d, J = 3.0 Hz, 1H), 5.90 (d, J = 3.0 Hz, 1H), 4.52 (s, 2H), 2.28 (s, 3H), 2.13 (br, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 152.5, 152.4, 108.8, 106.3, 57.5, 13.6.

(5-Ethylfuran-2-yl)methanol (1h)



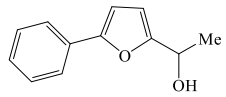
The syntheses of **1h** have been reported previously.[2] Analytical data were consistent with previously reported data.[2] Yellow oil (0.72 g, 34% over two steps). ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.15 (d, J = 2.8 Hz, 1H), 5.91 (br, 1H), 4.51 (s, 2H), 2.67 – 2.50 (m, 3H), 1.22 (t, J = 7.6 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.1, 152.3, 108.5, 104.7, 57.4, 21.4, 12.1.

Methyl 5-(hydroxymethyl)furan-2-carboxylate (1j)



To a DMSO solution of potassium hydroxide (100 mg potassium hydroxide in 5 mL DMSO) was added 5-(hydroxymethyl)furan-2-carboxylic acid (0.38 g, 2.7 mmol). After stirring at room temperature for 5 min, methyl iodide (0.25 g, 1.8 mmol) was added and the mixture stirred for 5 h. Water (30 mL) was added very carefully and the mixture was extracted with EtOAc (3 × 20 mL). The combined organic layers were dried over Na_2SO_4 and concentrated in vacuo, and then was purified by silica gel chromatography (petroleum ether/EtOAc =5:1) to give the title compound **1j** (0.23 g, 80 %) as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.12 (d, J = 3.4 Hz, 1H), 6.41 (d, J = 3.4 Hz, 1H), 4.66 (s, 2H), 3.88 (s, 3H), 2.97 (br, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.4, 158.7, 143.9, 119.1, 109.5, 57.5, 52.1. Analytical data were consistent with previously reported data.[5]

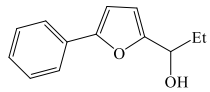
1-(5-Phenylfuran-2-yl)ethan-1-ol (1k)



The syntheses of **1k** have been reported previously.[6] Analytical data were consistent with previously reported data.[6] Yellow oil (0.44 g, 96%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 (d, J = 7.8 Hz, 2H), 7.37 (t, J = 7.6 Hz, 2H), 7.25 (t, J = 7.4 Hz, 1H), 6.58 (d, J = 3.2 Hz, 1H), 6.31 (d, J

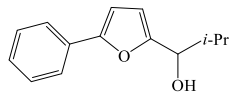
= 3.2 Hz, 1H), 4.99 – 4.87 (m, 1H), 2.10 (br, 1H), 1.59 (d, *J* = 6.6 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.3, 153.4, 130.9, 128.8, 127.5, 123.8, 107.4, 105.6, 63.9, 21.5.

1-(5-Phenylfuran-2-yl)propan-1-ol (1l)



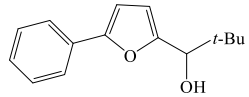
Compound **1l** was prepared in the same manner of **1k**, except that ethylmagnesium bromide was used instead of methylmagnesium bromide.[6] Yellow oil (0.47 g, 88%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, *J* = 7.4 Hz, 2H), 7.36 (t, *J* = 7.7 Hz, 2H), 7.24 (t, *J* = 7.4 Hz, 1H), 6.58 (d, *J* = 3.3 Hz, 1H), 6.31 (d, *J* = 3.3 Hz, 1H), 4.65 (t, *J* = 6.7 Hz, 1H), 2.09 – 1.84 (m, 3H), 0.99 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.4, 153.4, 130.9, 128.8, 127.4, 123.8, 108.2, 105.6, 69.5, 28.8, 10.1. IR (film) 3353, 3068, 2969, 1605, 1455, 1381, 1018, 759 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{13}H_{14}NaO_2$ $[M+Na]^+$: 225.0886, found: 225.0887.

2-Methyl-1-(5-phenylfuran-2-yl)propan-1-ol (1m)



Compound **1m** was prepared in the same manner of **1k**, except that *iso*-propylmagnesium bromide was used instead of methylmagnesium bromide.[6] Yellow oil (0.38 g, 61%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 – 7.61 (m, 2H), 7.36 (t, *J* = 7.7 Hz, 2H), 7.23 (t, *J* = 7.4 Hz, 1H), 6.58 (d, *J* = 3.3 Hz, 1H), 6.30 (d, *J* = 3.3 Hz, 1H), 4.42 (d, *J* = 6.9 Hz, 1H), 2.17 (m, 1H), 2.05 (br, 1H), 1.05 (d, *J* = 6.8 Hz, 3H), 0.92 (d, *J* = 6.8 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.9, 153.3, 131.0, 128.8, 127.4, 123.8, 108.8, 105.6, 73.8, 33.5, 18.9, 18.4. IR (film) 3446, 3021, 2961, 2843, 1611, 1543, 1353, 1019, 759 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{14}H_{16}NaO_2$ $[M+Na]^+$: 239.1043, found: 239.1046.

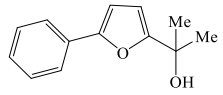
2,2-Dimethyl-1-(5-phenylfuran-2-yl)propan-1-ol (1n)



Compound **1n** was prepared in the same manner of **1k**, except that *tert*-butylmagnesium chloride was used instead of methylmagnesium bromide.[6] Yellow oil (0.27 g, 41%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.63 (d, *J* = 7.4 Hz, 2H), 7.36 (t, *J* = 7.7 Hz, 2H), 7.23 (t, *J* = 7.4 Hz, 1H), 6.58 (d, *J* = 3.3 Hz, 1H), 6.29 (d, *J* = 3.3 Hz, 1H), 4.41 (s, 1H), 2.04 (br, 1H), 1.01 (s, 9H). ^{13}C NMR (100

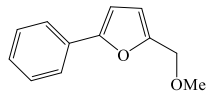
MHz, $CDCl_3$) δ 155.6, 153.0, 131.0, 128.8, 127.3, 123.7, 109.4, 105.5, 76.7, 35.8, 26.0. IR (film) 3447, 3063, 2957, 1650, 1542, 1383, 1204, 1014, 760 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{15}H_{18}NaO_2$ $[M+Na]^+$: 253.1199, found: 253.1196.

2-(5-Phenylfuran-2-yl)propan-2-ol (1o)



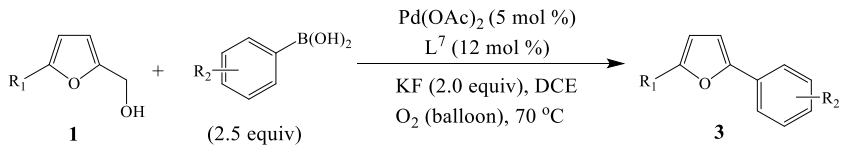
Compounds **1o** were prepared by additions of 5-lithio-2-phenylfuran, prepared by deprotonation of 2-phenylfuran with n-BuLi, to acetone.[7] Yellow oil (0.44 g, 62%). ^1H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, J = 8.0 Hz, 2H), 7.36 (t, J = 7.4 Hz, 2H), 7.24 (t, J = 7.0 Hz, 1H), 6.55 (d, J = 3.1 Hz, 1H), 6.26 (d, J = 3.1 Hz, 1H), 2.16 (br, 1H), 1.64 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.9, 153.0, 131.0, 128.8, 127.4, 123.8, 105.9, 105.6, 69.1, 28.9. IR (film) 3337, 3068, 2976, 1607, 1453, 1206, 1024, 759 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{13}H_{14}NaO_2$ $[M+Na]^+$: 225.0886, found: 225.0884.

2-(Methoxymethyl)-5-phenylfuran (1p)



To a suspension of sodium hydride (60% in mineral oil, 0.19 g, 4.4 mmol) in 10 mL of anhydrous THF under N_2 was carefully added a solution of (5-phenylfuran-2-yl)methanol (**1a**, 0.5 g, 2.9 mmol) in 5 mL of anhydrous THF. After stirring at room temperature for 5 min, methyl iodide (0.82 g, 5.8 mmol) was added and the mixture stirred for 12 h. Water (15 mL) was added very carefully and the mixture concentrated in vacuo to remove the THF. The remaining aqueous mixture was extracted with EtOAc (3 × 30 mL). The combined organic layers were dried over Na_2SO_4 and concentrated in vacuo, and then was purified by silica gel chromatography (petroleum ether/EtOAc =20:1) to give the title compound **1p** (0.48 g, 93 %) as a red oil. ^1H NMR (400 MHz, $CDCl_3$) δ 7.67 (d, J = 8.1 Hz, 2H), 7.36 (t, J = 7.7 Hz, 2H), 7.24 (t, J = 7.3 Hz, 1H), 6.59 (d, J = 3.3 Hz, 1H), 6.39 (d, J = 3.3 Hz, 1H), 4.44 (s, 2H), 3.39 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.4, 151.4, 130.9, 128.7, 127.5, 124.0, 111.6, 105.7, 66.6, 57.9. Analytical data were consistent with previously reported data.[8]

3 General procedure for the synthesis of arylfurans 3

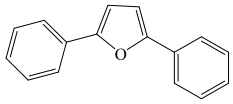


1 (2.5 equiv) **3**

General procedure: **1** (0.5 mmol) was added to an 25-mL dried Schlenk tube charged with aryl boronic acids (1.25 mmol), $Pd(OAc)_2$ (5 mol %, 5.6 mg), **L**^{7} (12 mol %, 11.0 mg), KF (1.0 mmol, 58.0 mg), and 1,2-dichloroethane (1.5 mL). The mixture was stirred at 70 ℃ for 15 h under O_2 atmosphere (in balloon), and then was cooled down to room temperature. The resultant mixture was evaporated in vacuum and further isolated by flash chromatography on silica gel with petroleum ether to give the pure product **3**.

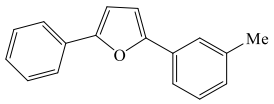
4 Data for arylfurans 3

2,5-Diphenylfuran (3a)



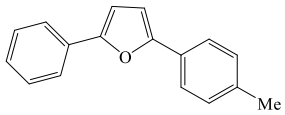
White solid (76.1 mg, 69%), mp: 86-87 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.74 – 7.68 (m, 4H), 7.40 – 7.32 (m, 4H), 7.26 – 7.19 (m, 2H), 6.68 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.5, 130.9, 128.9, 127.5, 123.9, 107.4. IR (film) 3039, 1602, 1534, 1474, 1270, 1018, 794 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{16}H_{13}O$ $[M+H]^+$: 221.0961, found: 221.0963.

2-Phenyl-5-(*m*-tolyl)furan (3b)



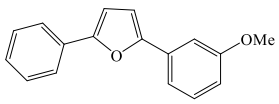
White solid (80.5 mg, 68%), mp: 82-83 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.73 (d, J = 7.5 Hz, 2H), 7.61 – 7.50 (m, 2H), 7.38 (t, J = 7.7 Hz, 2H), 7.32 – 7.21 (m, 2H), 7.07 (d, J = 7.4 Hz, 1H), 6.77 – 6.64 (m, 2H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.7, 153.4, 138.4, 131.0, 130.8, 128.8, 128.7, 128.3, 127.4, 124.5, 123.8, 121.0, 107.3, 107.2, 21.6. IR (film) 3046, 2959, 1602, 1533, 1478, 1271, 1022, 772 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{17}H_{15}O$ $[M+H]^+$: 235.1117, found: 235.1115.

2-Phenyl-5-(*p*-tolyl)furan (3c)



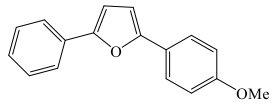
White solid (73.8 mg, 64%), mp: 109-110 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.75 – 7.70 (m, 2H), 7.62 (d, J = 8.2 Hz, 2H), 7.38 (t, J = 7.7 Hz, 2H), 7.24 (t, J = 7.4 Hz, 1H), 7.19 (d, J = 8.2 Hz, 2H), 6.70 (d, J = 3.5 Hz, 1H), 6.65 (d, J = 3.5 Hz, 1H), 2.35 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.8, 153.1, 137.3, 131.0, 129.5, 128.8, 128.3, 127.3, 123.8, 123.8, 107.3, 106.6, 21.4. IR (film) 3027, 2926, 1595, 1482, 1273, 1021, 791 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{17}H_{15}O$ $[M+H]^+$: 235.1117, found: 235.1113.

2-(3-Methoxyphenyl)-5-phenylfuran (3d)



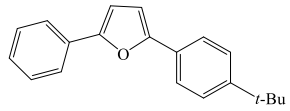
White solid (86.6 mg, 70%), mp: 83-84 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71 (d, J = 7.7 Hz, 2H), 7.36 (t, J = 7.6 Hz, 2H), 7.33 – 7.19 (m, 4H), 6.79 (d, J = 7.6 Hz, 1H), 6.68 (br, 2H), 3.81 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.0, 153.4, 153.2, 132.1, 130.8, 129.9, 128.8, 127.5, 123.8, 116.5, 113.0, 109.4, 107.7, 107.3, 55.3. IR (film) 3122, 3067, 2956, 1596, 1476, 1284, 1219, 1031, 840, 766 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{17}H_{15}O_2$ $[M+H]^+$: 251.1067, found: 251.1065.

2-(4-Methoxyphenyl)-5-phenylfuran (3e)



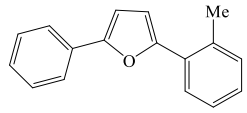
White solid (81.8 mg, 66%), mp: 121-122 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71 (d, J = 7.6 Hz, 2H), 7.65 (d, J = 8.5 Hz, 2H), 7.37 (t, J = 7.5 Hz, 2H), 7.23 (t, J = 7.4 Hz, 1H), 6.92 (d, J = 8.5 Hz, 2H), 6.68 (d, J = 3.3 Hz, 1H), 6.56 (d, J = 3.3 Hz, 1H), 3.80 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.2, 153.6, 152.8, 131.0, 128.8, 127.2, 125.3, 124.0, 123.7, 114.3, 107.3, 105.8, 55.4. IR (film) 3123, 2961, 1607, 1533, 1490, 1246, 1023, 830, 756 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{17}H_{14}O_2$ $[M]^+$: 250.0988, found: 250.0993.

2-(4-(*tert*-Butyl)phenyl)-5-phenylfuran (3f)



White solid (82.0 mg, 60%), mp: 105-107 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.73 (d, J = 7.6 Hz, 2H), 7.66 (d, J = 8.4 Hz, 2H), 7.44 – 7.34 (m, 4H), 7.24 (t, J = 7.4 Hz, 1H), 6.70 (d, J = 3.4 Hz, 1H), 6.66 (d, J = 3.4 Hz, 1H), 1.33 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.7, 153.1, 150.6, 131.0, 128.8, 128.2, 127.3, 125.8, 123.8, 123.7, 107.3, 106.8, 34.8, 31.4. IR (film) 3118, 2964, 1604, 1490, 1408, 1269, 1022, 831, 795 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{20}H_{21}O$ $[M+H]^+$: 277.1587, found: 277.1586.

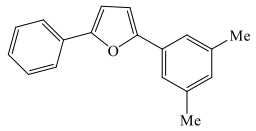
2-Phenyl-5-(*o*-tolyl)furan (3g)



White solid (35.7 mg, 31%), mp: 49-51 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.78 (d, J = 7.4 Hz, 1H), 7.73 (d, J = 7.5 Hz, 2H), 7.39 (t, J = 7.5 Hz, 2H), 7.30 – 7.19 (m, 4H), 6.77 – 6.72 (m, 1H), 6.64 – 6.60 (m, 1H), 2.56 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.2, 153.1, 134.6, 131.4, 130.9, 130.2, 128.9, 127.6, 127.4, 127.0, 126.2, 123.8, 110.8, 107.1, 22.2. IR (film) 3064, 2962,

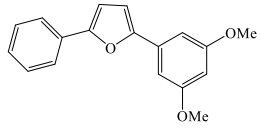
1604, 1481, 1204, 1029, 831, 791 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{17}H_{15}O$ $[M+H]^+$: 235.1117, found: 235.1113.

2-(3,5-Dimethylphenyl)-5-phenylfuran (3h)



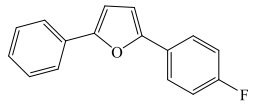
White solid (88.6 mg, 71%), mp: 62-63 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 7.72 (d, J = 7.7 Hz, 2H), 7.41 – 7.32 (m, 4H), 7.22 (t, J = 7.0 Hz, 1H), 6.88 (s, 1H), 6.69 – 6.66 (m, 1H), 6.66 – 6.64 (m, 1H), 2.34 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.8, 153.2, 138.3, 131.0, 130.8, 129.3, 128.8, 127.3, 123.8, 121.7, 107.3, 107.1, 21.5. IR (film) 3034, 2920, 1602, 1533, 1475, 1273, 1026, 849, 794 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{18}H_{17}O$ $[M+H]^+$: 249.1274, found: 249.1280.

2-(3,5-Dimethoxyphenyl)-5-phenylfuran (3i)



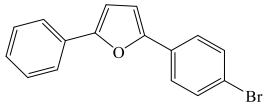
White solid (91.9 mg, 66%), mp: 63-64 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 7.71 (d, J = 7.7 Hz, 2H), 7.37 (t, J = 7.5 Hz, 2H), 7.24 (t, J = 7.3 Hz, 1H), 6.89 (s, 2H), 6.68 (s, 2H), 6.38 (s, 1H), 3.81 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.2, 153.4, 153.2, 132.5, 130.7, 128.8, 127.5, 123.8, 107.9, 107.3, 102.0, 99.7, 55.4. IR (film) 3119, 3070, 2948, 1603, 1470, 1210, 1058, 838, 795 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{18}H_{17}O_3$ $[M+H]^+$: 281.1172, found: 281.1176.

2-(4-Fluorophenyl)-5-phenylfuran (3j)



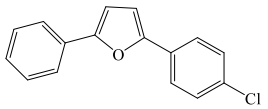
White solid (65.2 mg, 55%), mp: 108-109 °C. ^1H NMR (400 MHz, $CDCl_3$) δ 7.73 – 7.62 (m, 4H), 7.37 (t, J = 7.7 Hz, 2H), 7.24 (t, J = 7.3 Hz, 1H), 7.05 (t, J = 8.6 Hz, 2H), 6.67 (d, J = 3.4 Hz, 1H), 6.60 (d, J = 3.4 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.2 (d, J_{C-H} = 245.5 Hz), 153.5, 152.6, 130.8, 128.8, 127.5, 127.3 (d, J_{C-H} = 3.2 Hz), 125.5 (d, J_{C-H} = 8.0 Hz), 123.8, 115.8 (d, J_{C-H} = 21.8 Hz), 107.3, 107.0 (d, J_{C-H} = 1.3 Hz). ^{19}F NMR (376 MHz, $CDCl_3$) δ -114.1. IR (film) 3125, 3071, 1611, 1483, 1229, 1019, 836, 793 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{16}H_{12}FO$ $[M+H]^+$: 239.0867, found: 239.0862.

2-(4-Bromophenyl)-5-phenylfuran (3k)



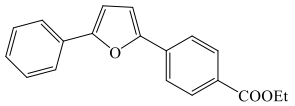
White solid (85.6 mg, 58%), mp: 128-129 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 (d, J = 7.9 Hz, 2H), 7.54 (d, J = 8.5 Hz, 2H), 7.47 (d, J = 8.5 Hz, 2H), 7.37 (t, J = 7.6 Hz, 2H), 7.25 (t, J = 7.4 Hz, 1H), 6.67 (br, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.8, 152.3, 131.9, 130.6, 129.7, 128.8, 127.6, 125.2, 123.9, 121.1, 107.9, 107.4. IR (film) 3126, 3073, 1527, 1464, 1016, 826, 791 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{16}H_{12}BrO$ $[M+H]^+$: 299.0066, found: 299.0066.

2-(4-Chlorophenyl)-5-phenylfuran (3l)



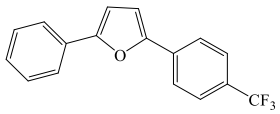
White solid (42.1 mg, 33%), mp: 126-128 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 (d, J = 7.5 Hz, 2H), 7.64 (d, J = 8.5 Hz, 2H), 7.40 (t, J = 7.7 Hz, 2H), 7.35 (d, J = 8.5 Hz, 2H), 7.27 (t, J = 7.4 Hz, 1H), 6.71 (d, J = 3.5 Hz, 1H), 6.70 (d, J = 3.5 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.8, 152.4, 133.1, 130.7, 129.4, 129.1, 128.9, 127.7, 125.0, 123.9, 107.8, 107.4. IR (film) 3081, 1527, 1472, 1103, 1019, 831, 793 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{16}H_{12}ClO$ $[M+H]^+$: 255.0571, found: 255.0550.

Ethyl 4-(5-phenylfuran-2-yl)benzoate (3m)



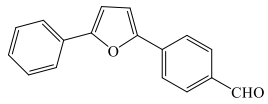
Yellow solid (64.1 mg, 44%), mp: 86-88 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10 – 8.04 (m, 2H), 7.75 (t, J = 7.9 Hz, 4H), 7.41 (t, J = 7.7 Hz, 2H), 7.29 (t, J = 7.4 Hz, 1H), 6.84 (d, J = 3.5 Hz, 1H), 6.75 (d, J = 3.5 Hz, 1H), 4.38 (q, J = 7.1 Hz, 2H), 1.40 (t, J = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.4, 154.5, 152.4, 134.6, 130.5, 130.2, 129.6, 128.9, 127.9, 124.0, 123.3, 109.6, 107.6, 61.1, 14.5. IR (film) 3124, 2976, 1708, 1605, 1465, 1269, 1020, 854, 760 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{19}H_{17}O_3$ $[M+H]^+$: 293.1172, found: 293.1170.

2-Phenyl-5-(4-(trifluoromethyl)phenyl)furan (3n)



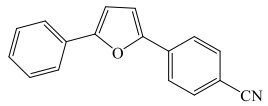
White solid (30.2 mg, 21%), mp: 133-135 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.80 (d, J = 8.2 Hz, 2H), 7.75 (d, J = 7.9 Hz, 2H), 7.63 (d, J = 8.2 Hz, 2H), 7.42 (t, J = 7.6 Hz, 2H), 7.30 (t, J = 7.1 Hz, 1H), 6.83 (d, J = 3.4 Hz, 1H), 6.75 (d, J = 3.4 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.6, 151.9, 134.0, 130.5, 129.0 (q, J_{C-H} = 32.3 Hz), 128.9, 128.0, 125.9 (q, J_{C-H} = 3.8 Hz), 124.4 (q, J_{C-H} = 270.2 Hz), 124.1, 123.8, 109.4, 107.5. ^{19}F NMR (376 MHz, $CDCl_3$) δ -62.4. IR (film) 3124, 1608, 1527, 1330, 1163, 843, 795 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{17}H_{12}F_3O$ $[M+H]^+$: 289.0835, found: 289.0832.

4-(5-Phenylfuran-2-yl)benzaldehyde (3o)



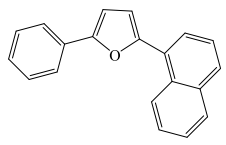
Yellow solid (21.5 mg, 18%), mp: 110-112 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.97 (s, 1H), 7.88 (d, J = 8.3 Hz, 2H), 7.84 (d, J = 8.3 Hz, 2H), 7.75 (d, J = 7.7 Hz, 2H), 7.42 (t, J = 7.7 Hz, 2H), 7.30 (t, J = 7.3 Hz, 1H), 6.90 (d, J = 3.5 Hz, 1H), 6.76 (d, J = 3.5 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.6, 155.1, 151.9, 136.0, 134.9, 130.5, 130.3, 128.9, 128.1, 124.1, 123.8, 110.6, 107.8. IR (film) 3124, 2733, 1692, 1599, 1212, 1021, 832, 798 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{17}H_{13}O_2$ $[M+H]^+$: 249.0910, found: 249.0908.

4-(5-Phenylfuran-2-yl)benzonitrile (3p)



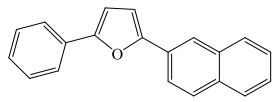
Yellow solid (10.8 mg, 9%), mp: 122-125 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.80 (d, J = 8.4 Hz, 2H), 7.75 (d, J = 7.7 Hz, 2H), 7.67 (d, J = 8.4 Hz, 2H), 7.43 (t, J = 7.6 Hz, 2H), 7.32 (t, J = 7.4 Hz, 1H), 6.90 (d, J = 3.5 Hz, 1H), 6.78 (d, J = 3.5 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.2, 151.4, 134.6, 132.8, 130.2, 129.0, 128.3, 124.2, 123.9, 119.2, 110.6, 110.2, 107.8. IR (film) 3118, 2219, 1526, 1464, 1270, 1016, 837, 794 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{17}H_{11}NNaO$ $[M+Na]^+$: 268.0733, found: 268.0740.

2-(Naphthalen-1-yl)-5-phenylfuran (3r)



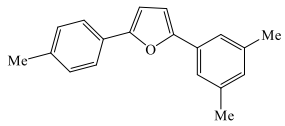
White solid (38.1 mg, 29%), mp: 40-42 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.51 (d, J = 8.2 Hz, 1H), 7.90 – 7.85 (m, 1H), 7.81 (dd, J = 6.9, 6.1 Hz, 2H), 7.77 (d, J = 7.5 Hz, 2H), 7.57 – 7.47 (m, 3H), 7.40 (t, J = 7.7 Hz, 2H), 7.26 (t, J = 7.4 Hz, 1H), 6.82 (d, J = 3.4 Hz, 1H), 6.79 (d, J = 3.4 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.9, 153.1, 134.1, 131.0, 130.4, 128.9, 128.7, 128.7, 128.6, 127.5, 126.8, 126.2, 126.1, 125.7, 125.5, 123.9, 111.6, 107.1. IR (film) 3051, 1601, 1516, 1482, 1392, 1203, 1027, 782 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{20}H_{15}O$ $[M+H]^+$: 271.1117, found: 271.1121.

2-(Naphthalen-2-yl)-5-phenylfuran (3s)



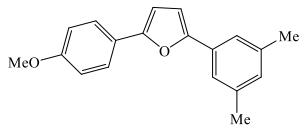
White solid (68.5 mg, 52%), mp: 136-137 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.21 (s, 1H), 7.92 – 7.76 (m, 6H), 7.53 – 7.39 (m, 4H), 7.29 (t, J = 7.3 Hz, 1H), 6.86 (d, J = 3.3 Hz, 1H), 6.78 (d, J = 3.3 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.8, 153.6, 133.7, 132.8, 130.9, 128.9, 128.6, 128.3, 128.2, 127.9, 127.6, 126.7, 126.0, 124.0, 122.4, 122.1, 108.1, 107.6. IR (film) 3121, 1601, 1526, 1463, 1269, 1017, 791 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{20}H_{15}O$ $[M+H]^+$: 271.1117, found: 271.1115.

2-(3,5-Dimethylphenyl)-5-(*p*-tolyl)furan (3t)



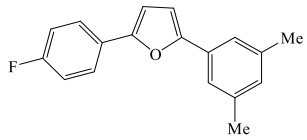
White solid (99.0 mg, 76%), mp: 123-124 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 – 7.59 (m, 2H), 7.35 (s, 2H), 7.18 (d, J = 7.0 Hz, 2H), 6.88 (s, 1H), 6.71 – 6.58 (m, 2H), 2.34 (br, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.5, 153.4, 138.3, 137.2, 130.8, 129.5, 129.1, 128.3, 123.8, 121.6, 107.1, 106.6, 21.5, 21.4. IR (film) 3119, 2920, 1602, 1492, 1209, 1022, 833, 779 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{19}H_{19}O$ $[M+H]^+$: 263.1430, found: 263.1429.

2-(3,5-Dimethylphenyl)-5-(4-methoxyphenyl)furan (3u)



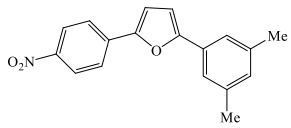
White solid (113.1 mg, 82%), mp: 107-108 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, J = 8.7 Hz, 2H), 7.34 (s, 2H), 6.91 (d, J = 8.7 Hz, 2H), 6.88 (s, 1H), 6.65 (d, J = 3.4 Hz, 1H), 6.55 (d, J = 3.4 Hz, 1H), 3.79 (s, 3H), 2.34 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.1, 153.3, 153.1, 138.3, 130.9, 129.0, 125.2, 124.1, 121.5, 114.3, 107.1, 105.7, 55.4, 21.5. IR (film) 3126, 2953, 1604, 1491, 1291, 1030, 836, 781 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{19}H_{19}O_2$ $[M+H]^+$: 279.1380, found: 279.1378.

2-(3,5-Dimethylphenyl)-5-(4-fluorophenyl)furan (3v)



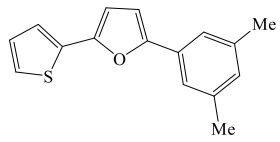
White solid (82.3 mg, 62%), mp: 91-93 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71 – 7.64 (m, 2H), 7.33 (s, 2H), 7.10 – 7.03 (m, 2H), 6.89 (s, 1H), 6.65 (d, J = 3.4 Hz, 1H), 6.60 (d, J = 3.4 Hz, 1H), 2.34 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.2 (d, $J_{C\text{-}H}$ = 245.5 Hz), 153.9, 152.4, 138.4, 130.7, 129.4, 127.4 (d, $J_{C\text{-}H}$ = 3.3 Hz), 125.5 (d, $J_{C\text{-}H}$ = 8.0 Hz), 121.7, 115.8 (d, $J_{C\text{-}H}$ = 21.8 Hz), 107.1, 107.0, 21.5; IR (film) 3115, 2919, 1605, 1494, 1233, 1024, 848, 790 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{18}H_{15}FO$ $[M]^+$: 266.1107, found: 266.1105.

2-(3,5-Dimethylphenyl)-5-(4-nitrophenyl)furan (3w)



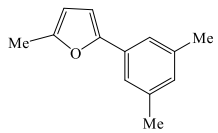
Yellow solid (94.0 mg, 63%), mp: 141-143 °C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.20 (d, J = 8.8 Hz, 2H), 7.77 (d, J = 8.8 Hz, 2H), 7.34 (s, 2H), 6.95 (s, 1H), 6.89 (d, J = 3.5 Hz, 1H), 6.72 (d, J = 3.5 Hz, 1H), 2.37 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.1, 150.8, 146.2, 138.5, 136.4, 130.2, 129.9, 124.4, 123.7, 122.0, 111.5, 107.8, 21.5. IR (film) 3113, 2919, 2842, 1596, 1464, 1335, 1027, 847, 782 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{18}H_{15}NNaO_3$ $[M+Na]^+$: 316.0944, found: 316.0949.

2-(3,5-Dimethylphenyl)-5-(thiophen-2-yl)furan (3x)



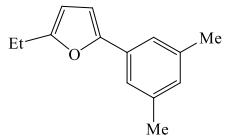
White solid (59.2 mg, 47%), mp: 57-58 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 (s, 2H), 7.30 (d, J = 3.5 Hz, 1H), 7.19 (d, J = 5.0 Hz, 1H), 7.02 (dd, J = 5.0, 3.5 Hz, 1H), 6.89 (s, 1H), 6.63 (d, J = 3.4 Hz, 1H), 6.53 (d, J = 3.4 Hz, 1H), 2.34 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.4, 148.9, 138.3, 134.0, 130.5, 129.4, 127.8, 124.1, 122.6, 121.7, 107.3, 107.1, 21.5. IR (film) 3121, 2917, 1605, 1493, 1386, 1198, 1016, 846, 780 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{16}H_{14}OS$ $[M]^+$: 254.0765, found: 254.0759.

2-(3,5-Dimethylphenyl)-5-methylfuran (3y)



Yellow oil (39.9 mg, 43%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25 (s, 2H), 6.84 (s, 1H), 6.48 (d, J = 3.1 Hz, 1H), 6.01 (d, J = 3.1 Hz, 1H), 2.34 (s, 3H), 2.31 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 152.7, 151.7, 138.2, 131.2, 128.7, 121.3, 107.7, 105.7, 21.5, 13.8. IR (film) 3110, 2920, 1603, 1451, 1381, 1212, 1023, 845, 780 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{13}H_{15}O$ $[M+H]^+$: 187.1117, found: 187.1115.

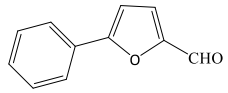
2-(3,5-Dimethylphenyl)-5-ethylfuran (3z)



Yellow oil (26.9 mg, 27%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25 (s, 2H), 6.83 (s, 1H), 6.48 (d, J = 3.2 Hz, 1H), 6.01 (d, J = 3.2 Hz, 1H), 2.69 (q, J = 7.5 Hz, 2H), 2.30 (s, 6H), 1.26 (t, J = 7.6 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.5, 152.6, 138.1, 131.3, 128.7, 121.3, 106.1, 105.5, 21.6, 21.4, 12.3. IR (film) 3108, 2926, 1602, 1551, 1376, 1203, 1014, 846, 781 cm^{-1}. HRMS (ESI) *m/z* Calcd for $C_{14}H_{17}O$ $[M+H]^+$: 201.1274, found: 201.1273.

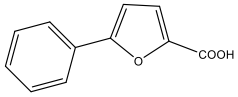
5 Data for 4 and 5

5-Phenylfuran-2-carbaldehyde (4)



Yellow oil (4.8 mg, 5%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.63 (s, 1H), 7.80 (d, J = 7.2 Hz, 2H), 7.46 – 7.35 (m, 3H), 7.31 (d, J = 3.7 Hz, 1H), 6.82 (d, J = 3.7 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 177.2, 159.4, 152.0, 129.7, 128.9, 125.3, 107.7. Analytical data were consistent with previously reported data.[9]

5-Phenylfuran-2-carboxylic acid (5)



Compounds **5** were prepared by hydrolysis of methyl 5-phenylfuran-2-carboxylate, prepared by Suzuki coupling of methyl 5-bromofuran-2-carboxylate with phenylboronic acid. White solid (117.0 mg, 70%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.45 (s, 1H), 7.81 (d, J = 7.7 Hz, 2H), 7.50 – 7.32 (m, 4H), 6.78 (d, J = 3.5 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 163.6, 158.9, 143.0, 129.4, 129.4, 129.0, 125.2, 122.3, 107.4. Analytical data were consistent with previously reported data.[10]

6 Full list of references

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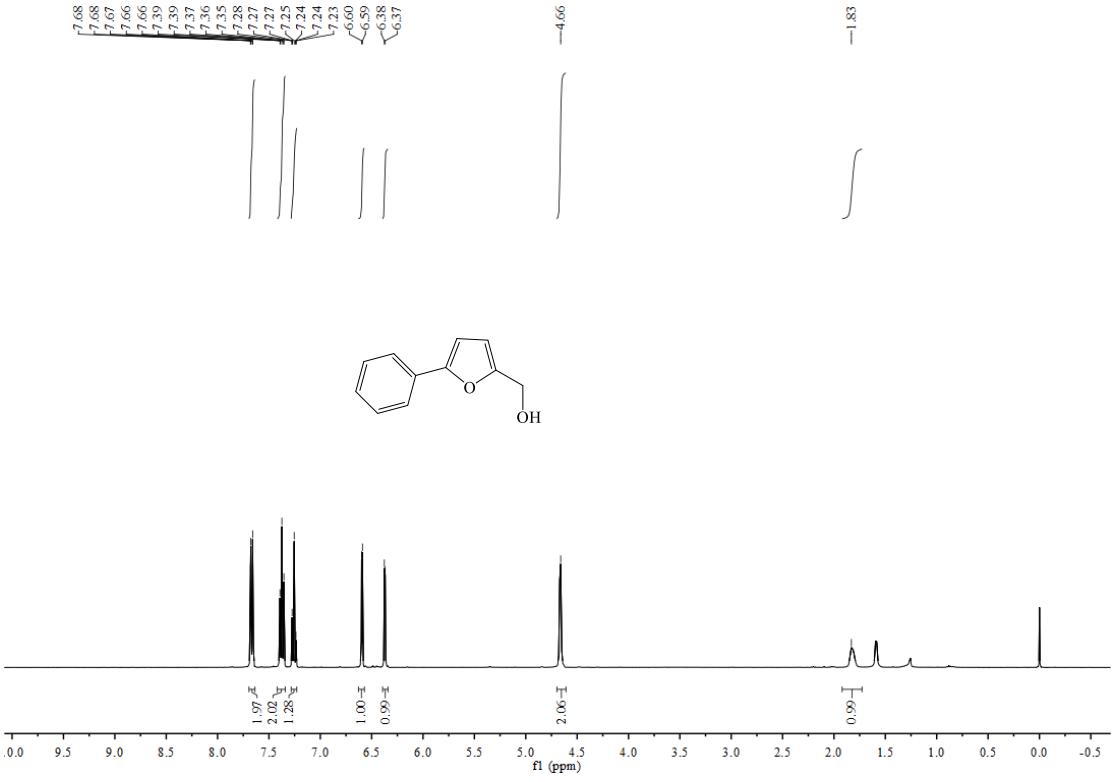
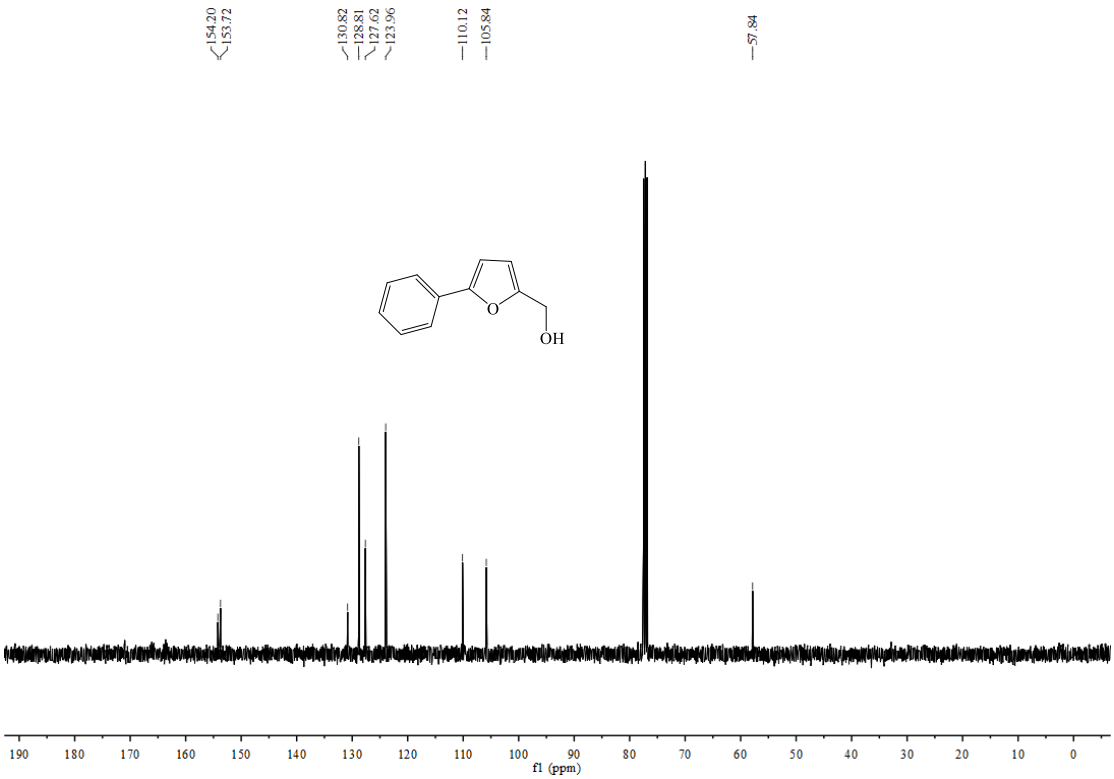
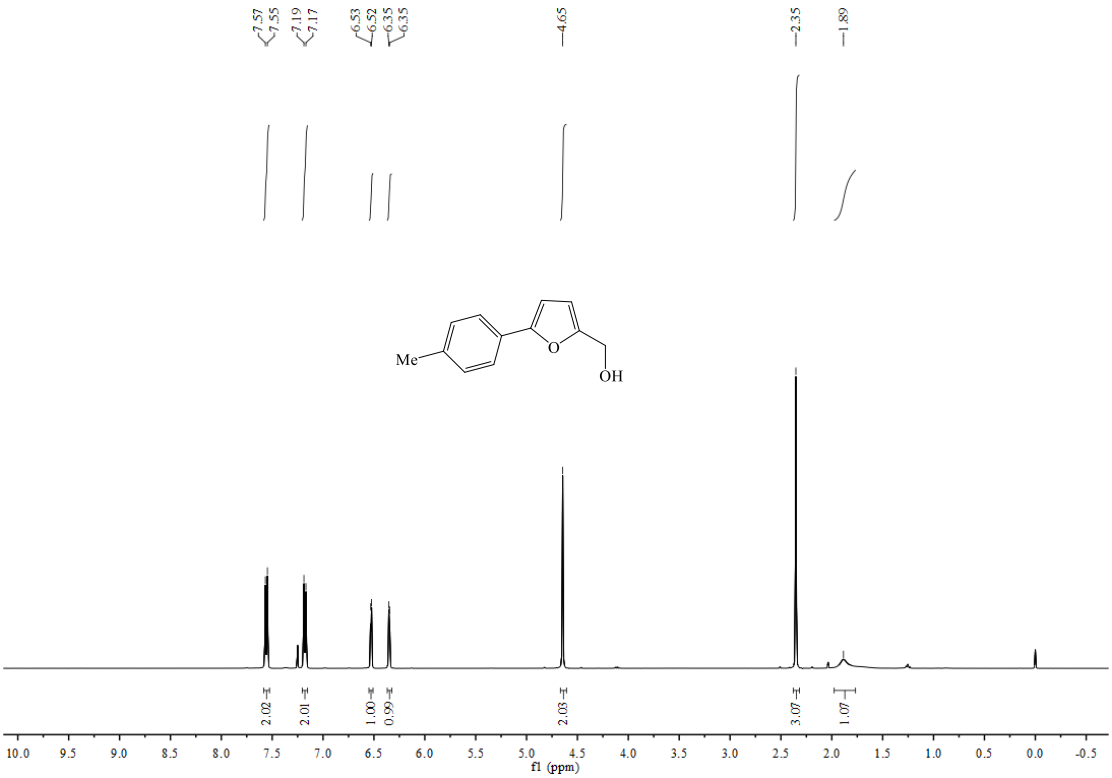
7 NMR charts of starting materials



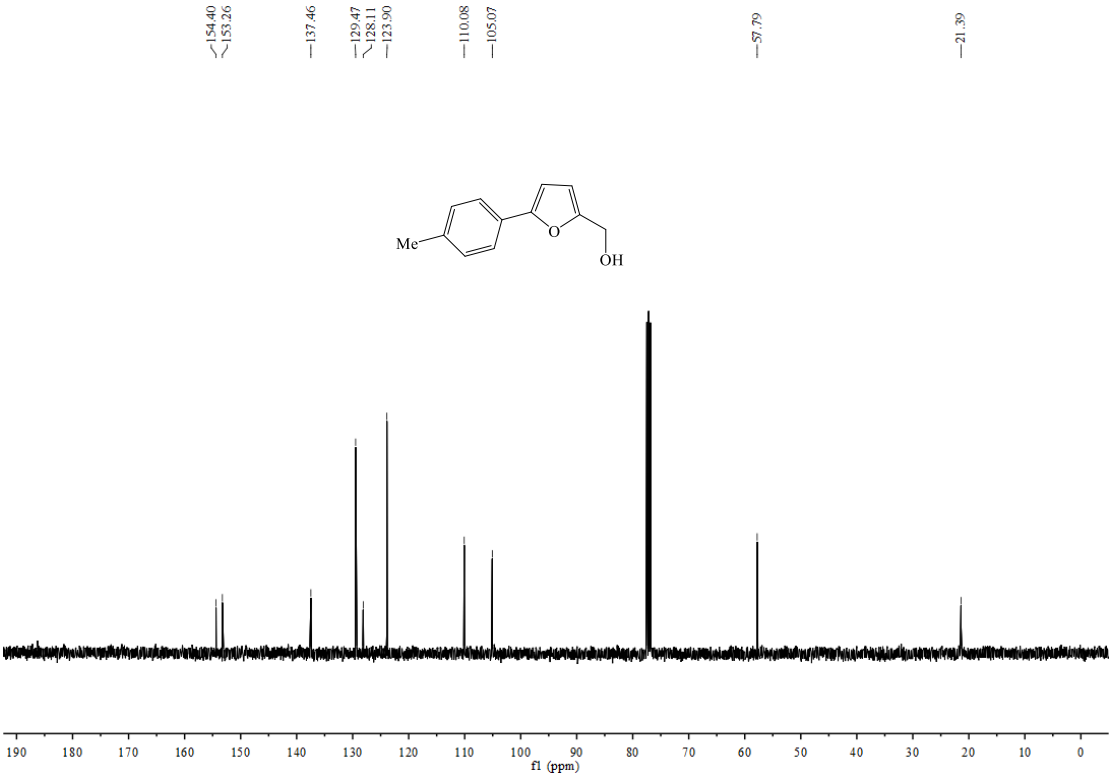
^{1}H NMR spectrum of **1a**



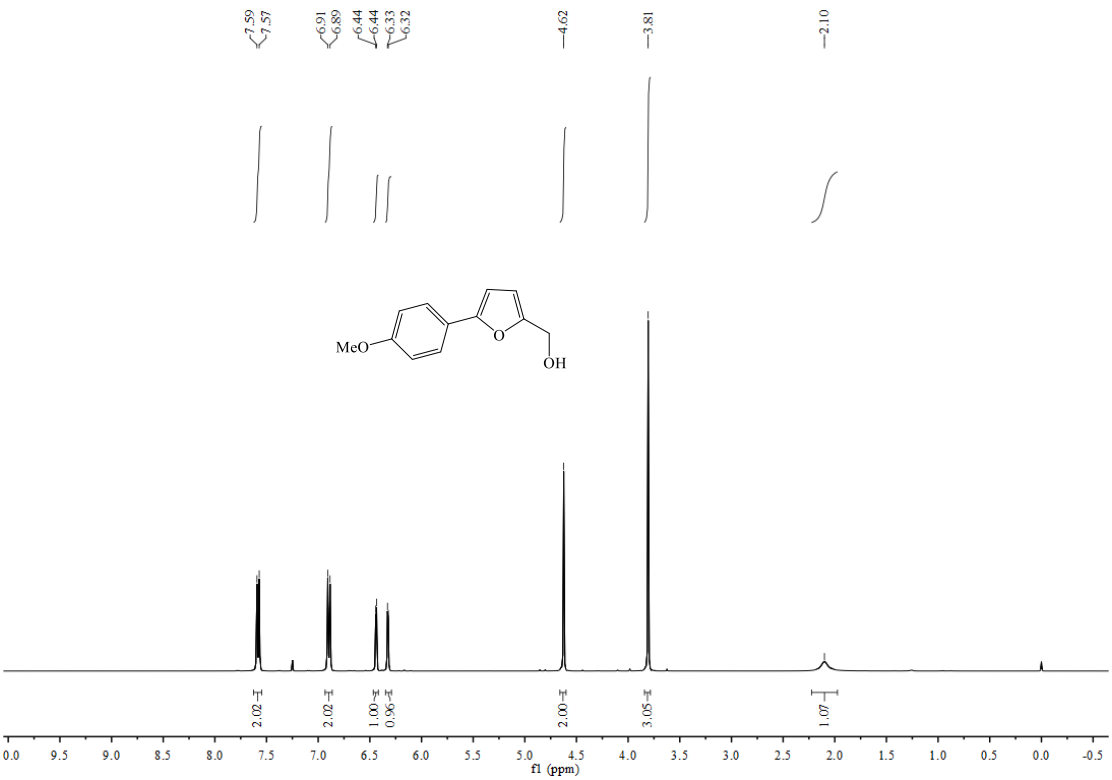
^{13}C NMR spectrum of **1a**



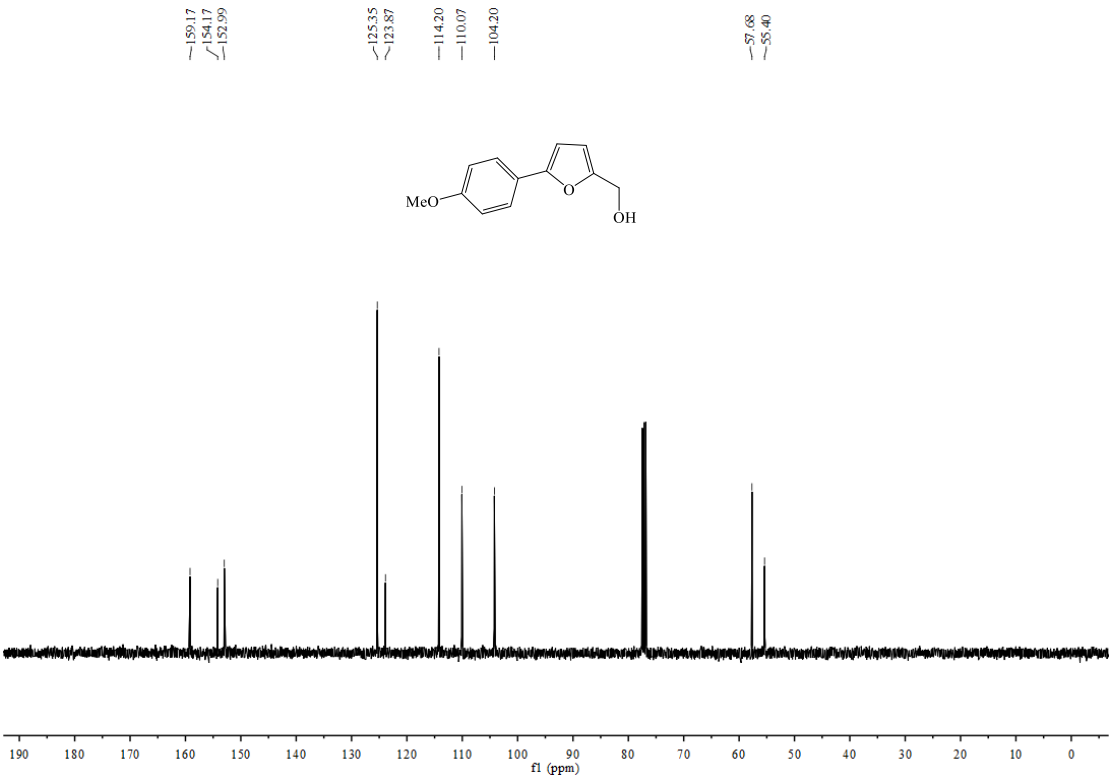
^{1}H NMR spectrum of **1b**



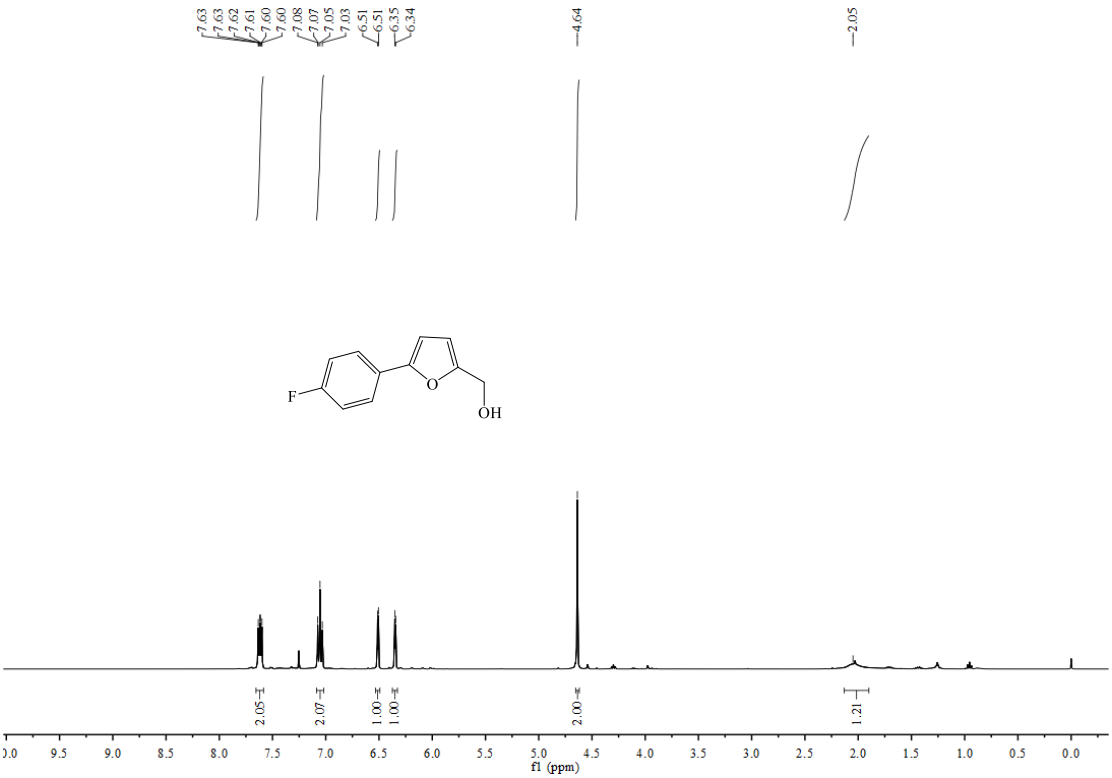
^{13}C NMR spectrum of **1b**



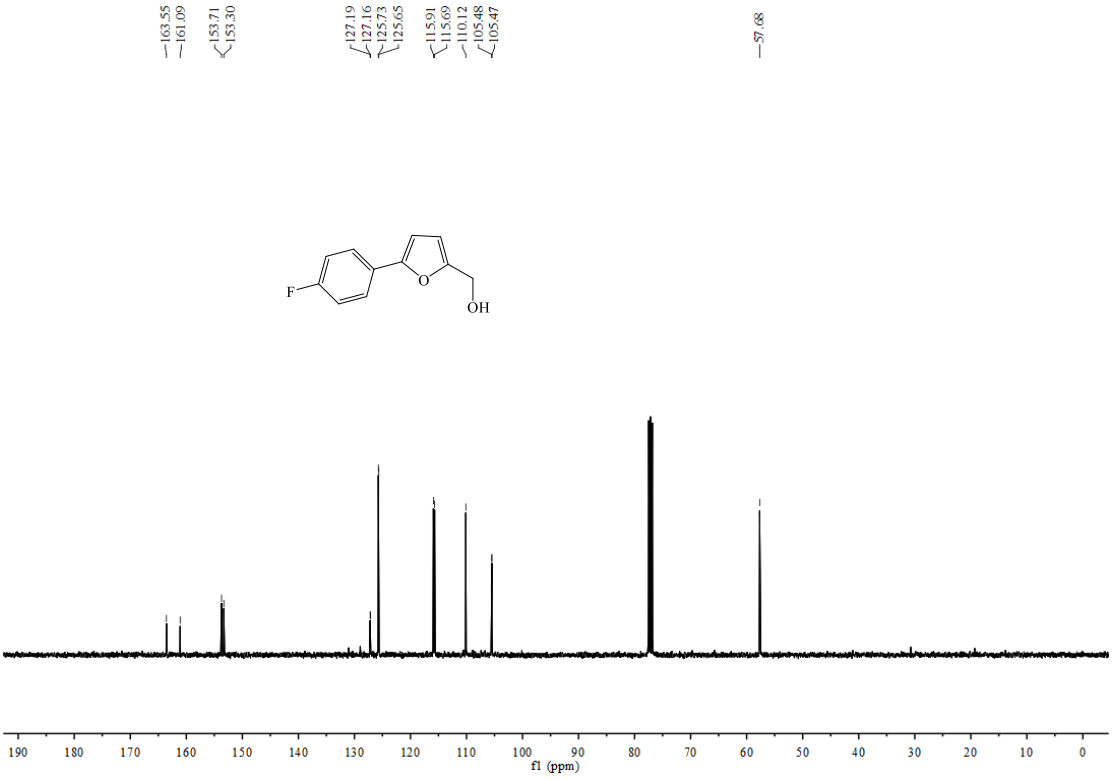
^{1}H NMR spectrum of **1c**



^{13}C NMR spectrum of **1c**

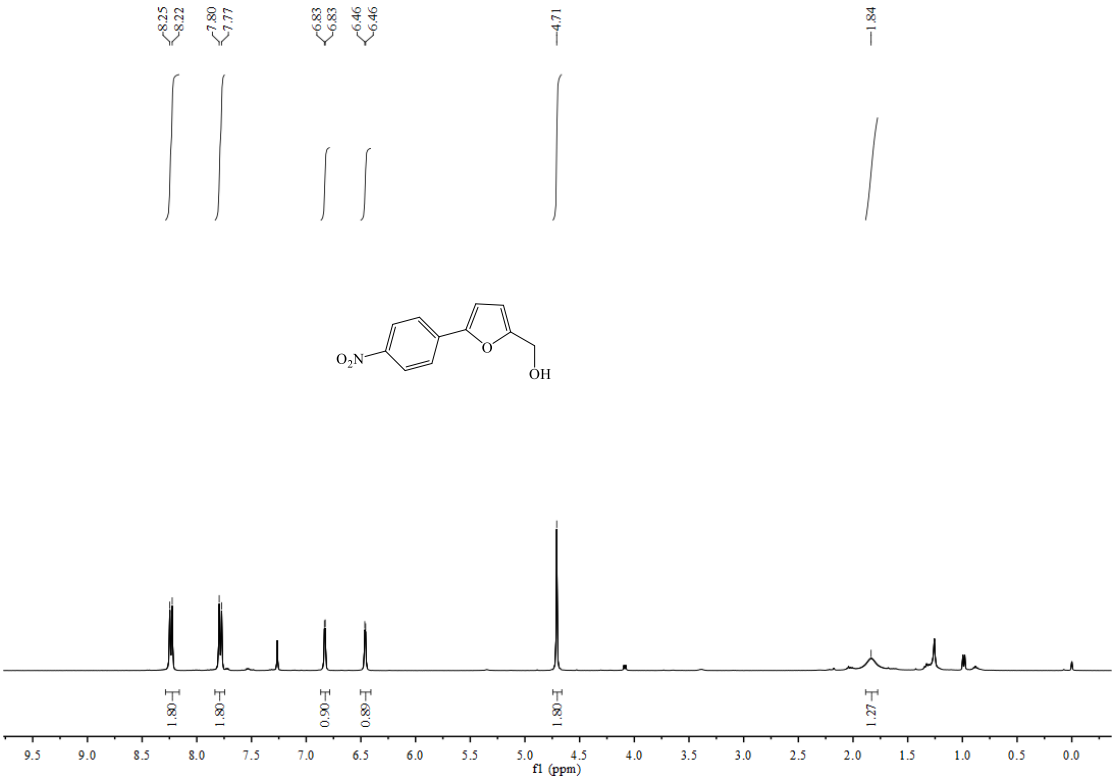


^{1}H NMR spectrum of **1d**

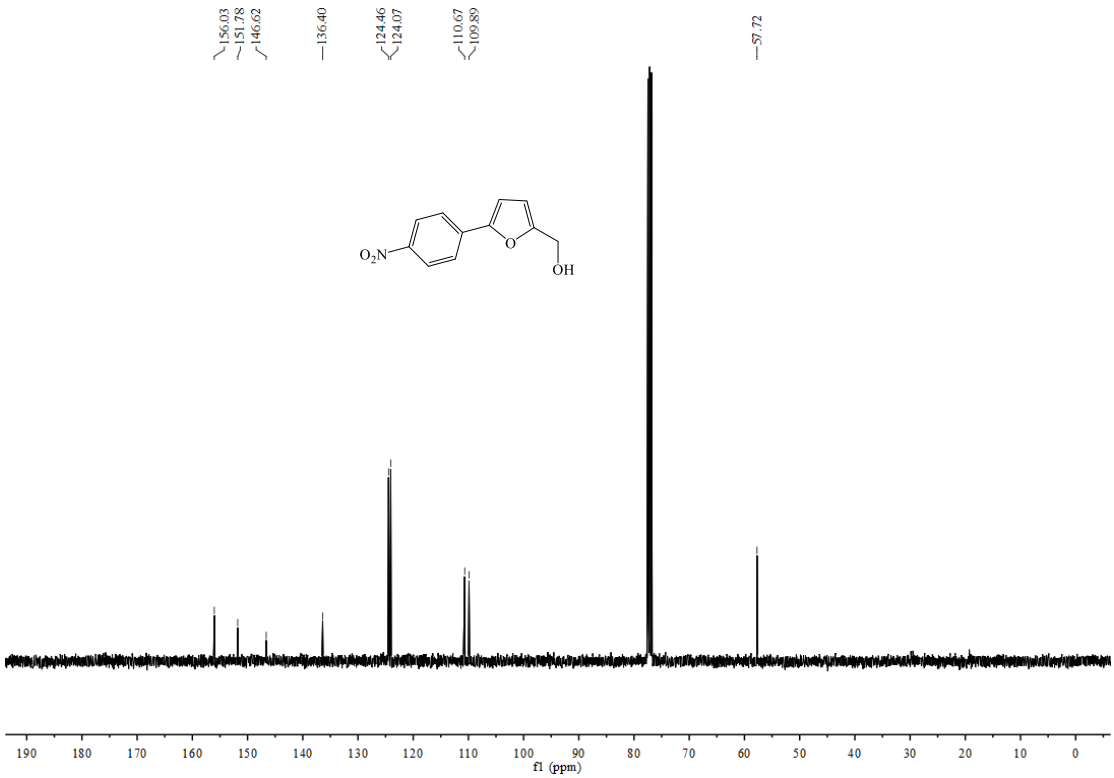


^{13}C NMR spectrum of **1d**

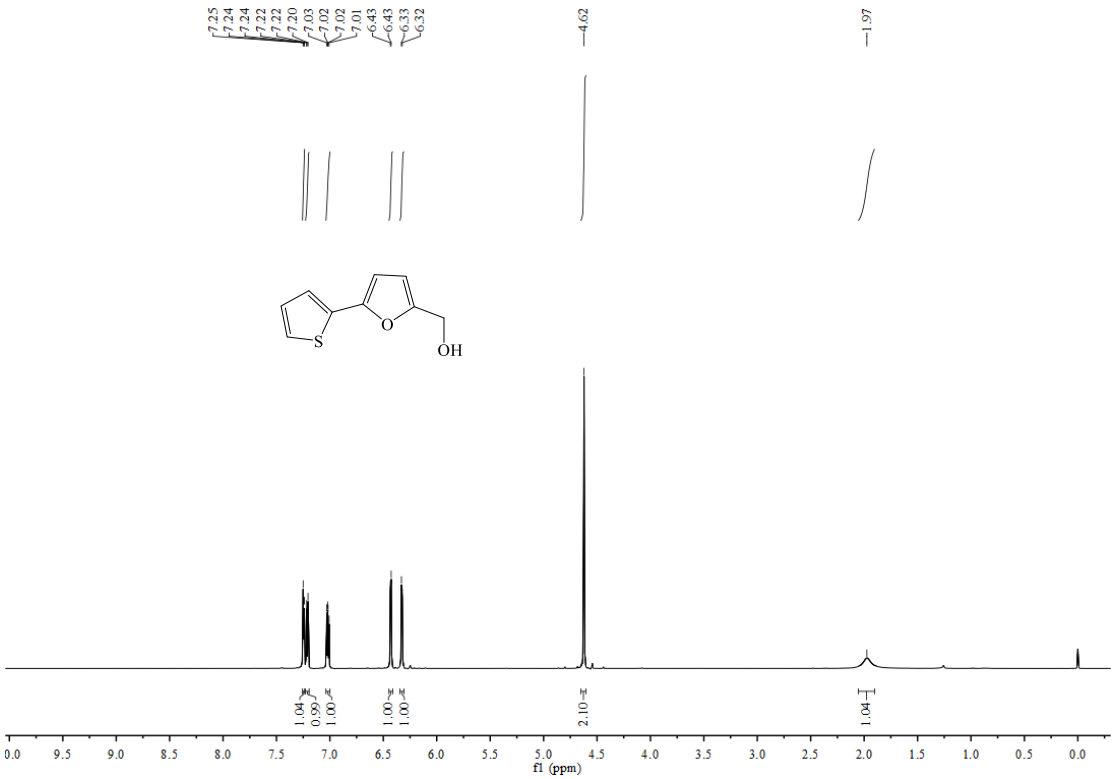
^{19}F NMR spectrum of **1d**



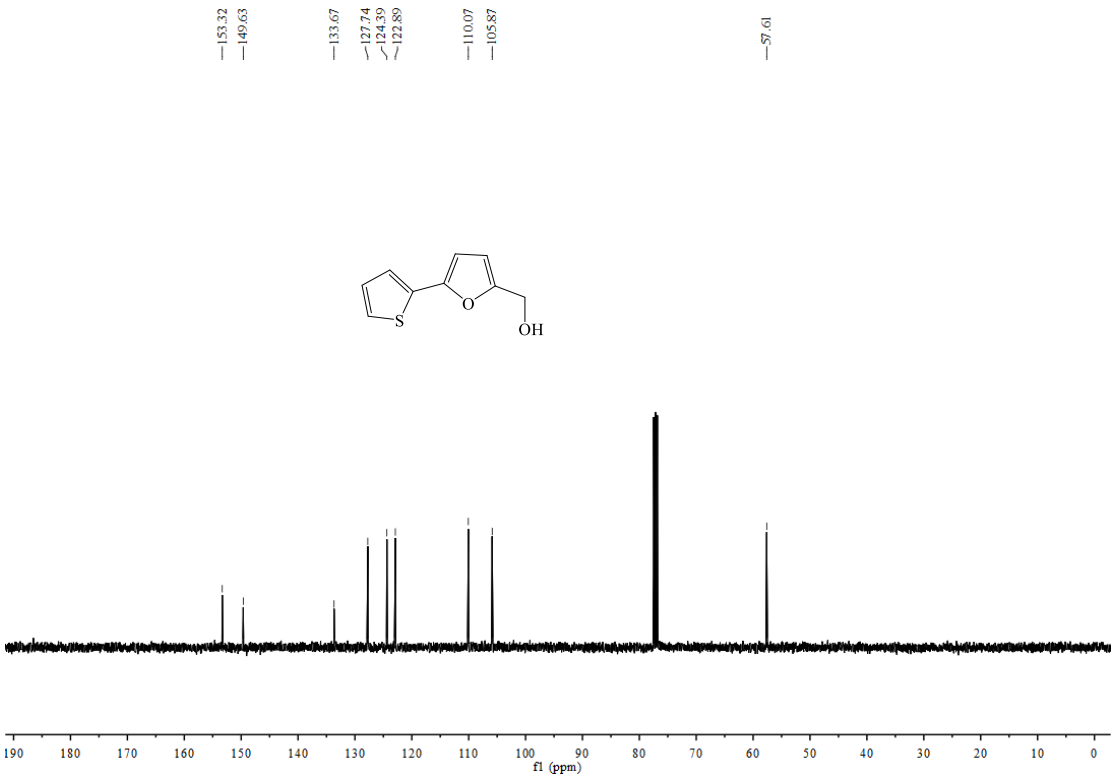
^{1}H NMR spectrum of **1e**



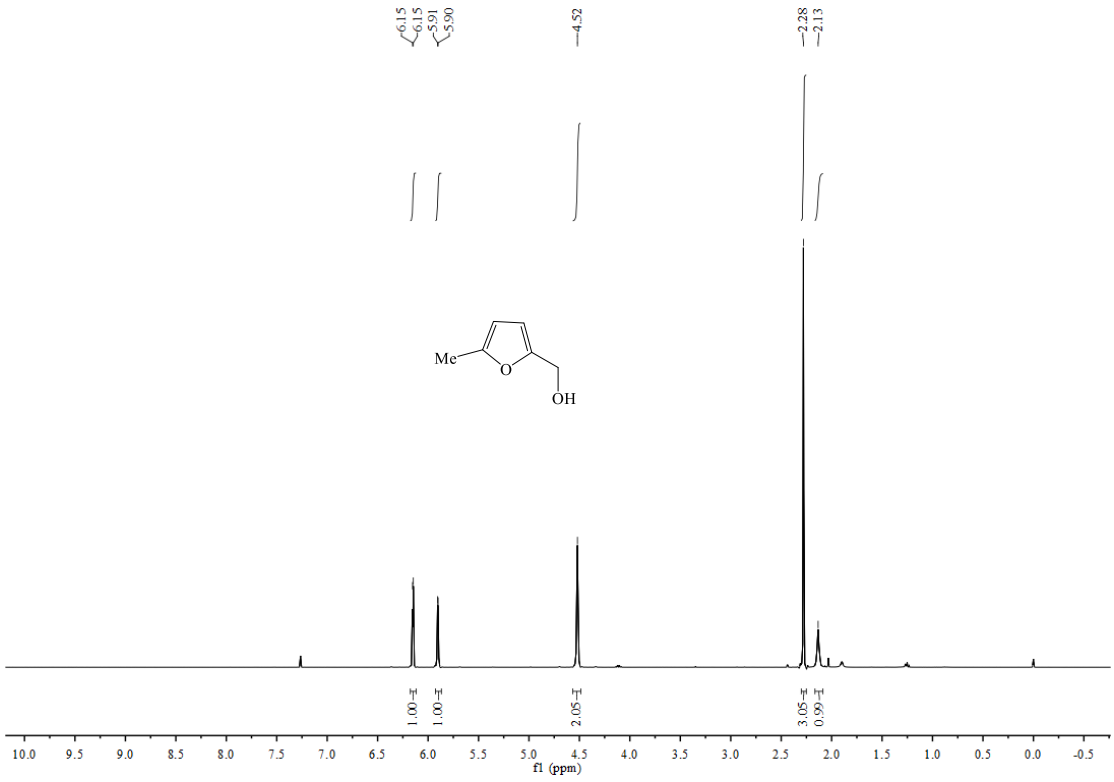
^{13}C NMR spectrum of **1e**



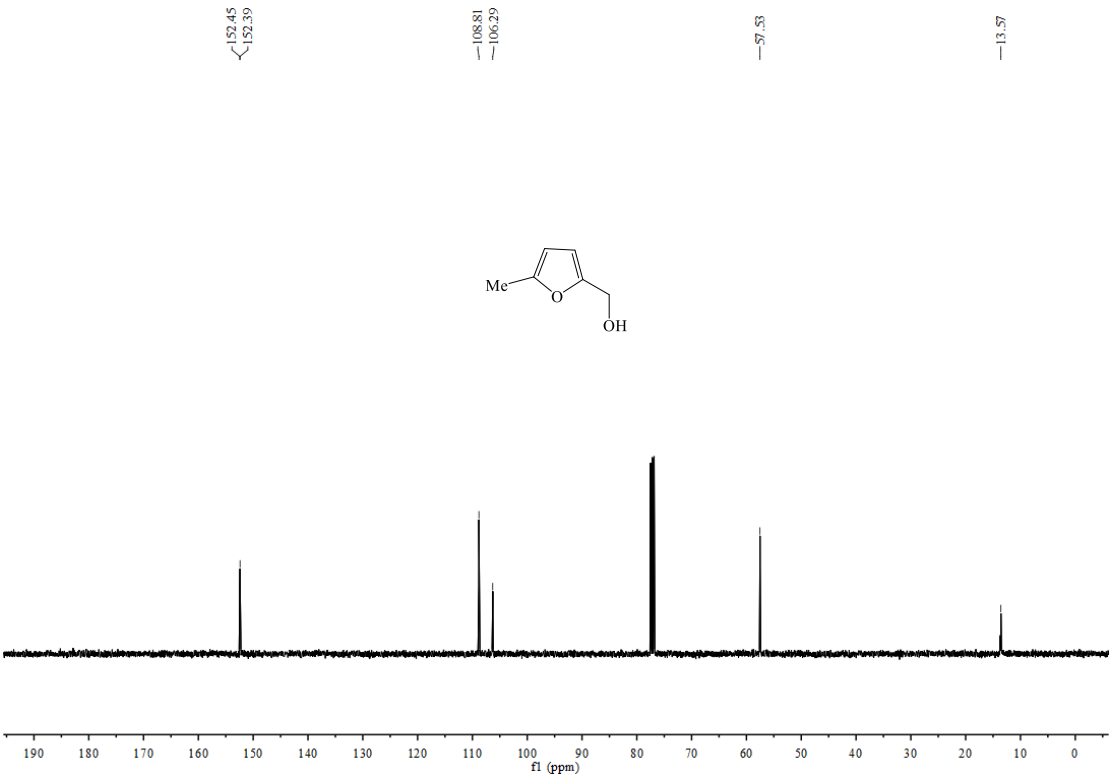
^{1}H NMR spectrum of **1f**



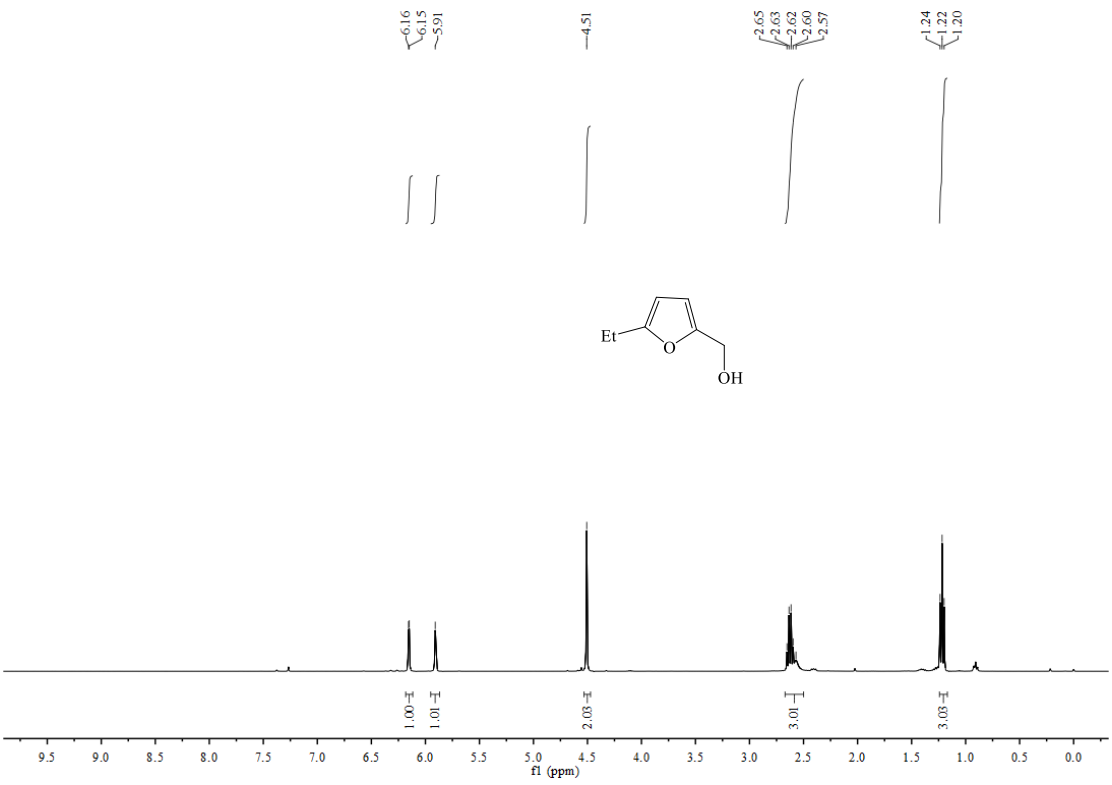
^{13}C NMR spectrum of **1f**



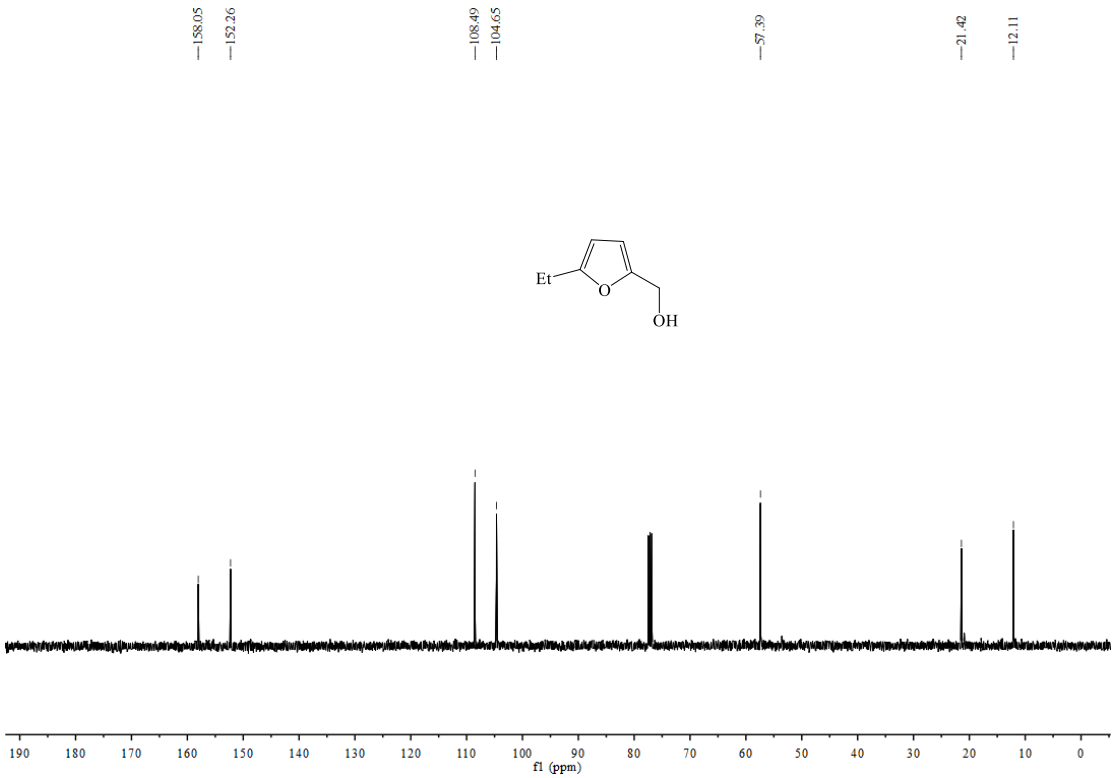
^{1}H NMR spectrum of **1g**



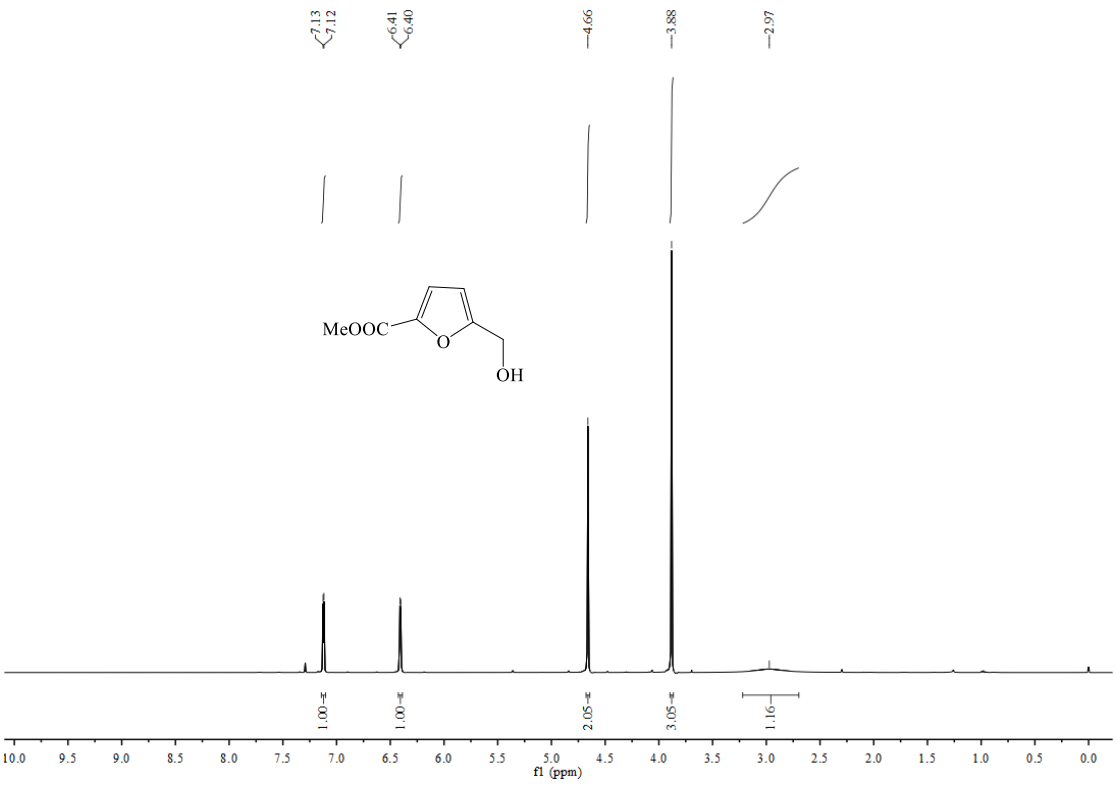
^{13}C NMR spectrum of **1g**



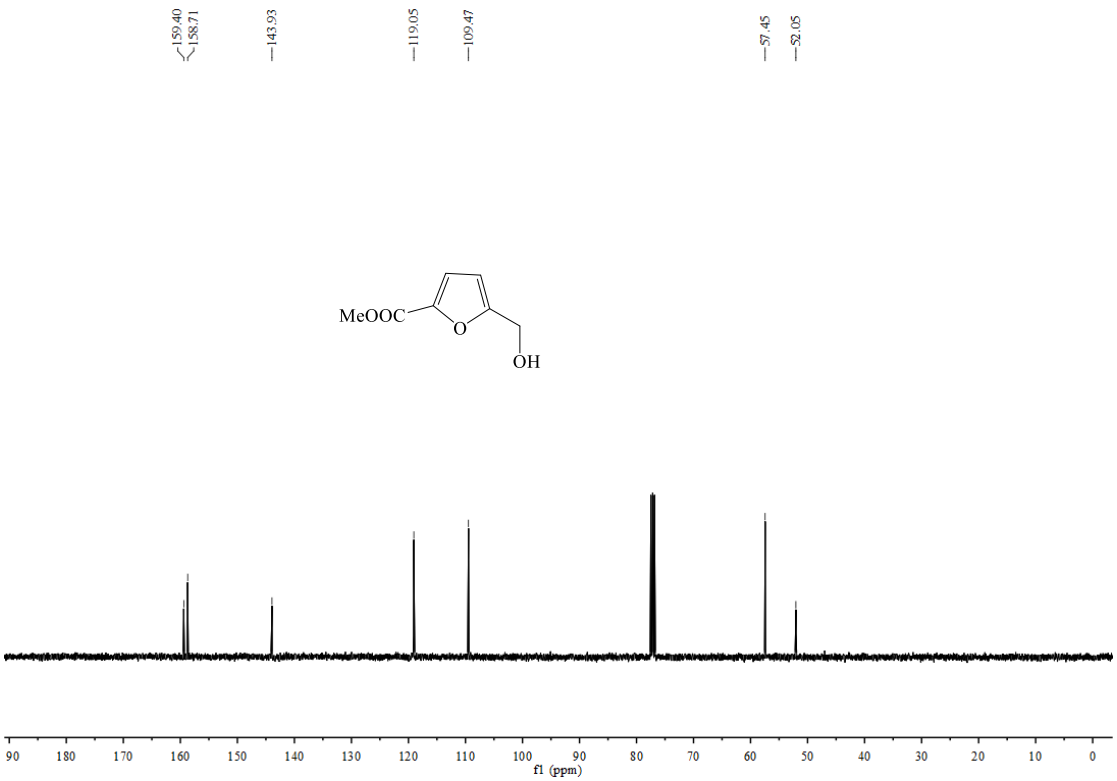
^{1}H NMR spectrum of **1h**



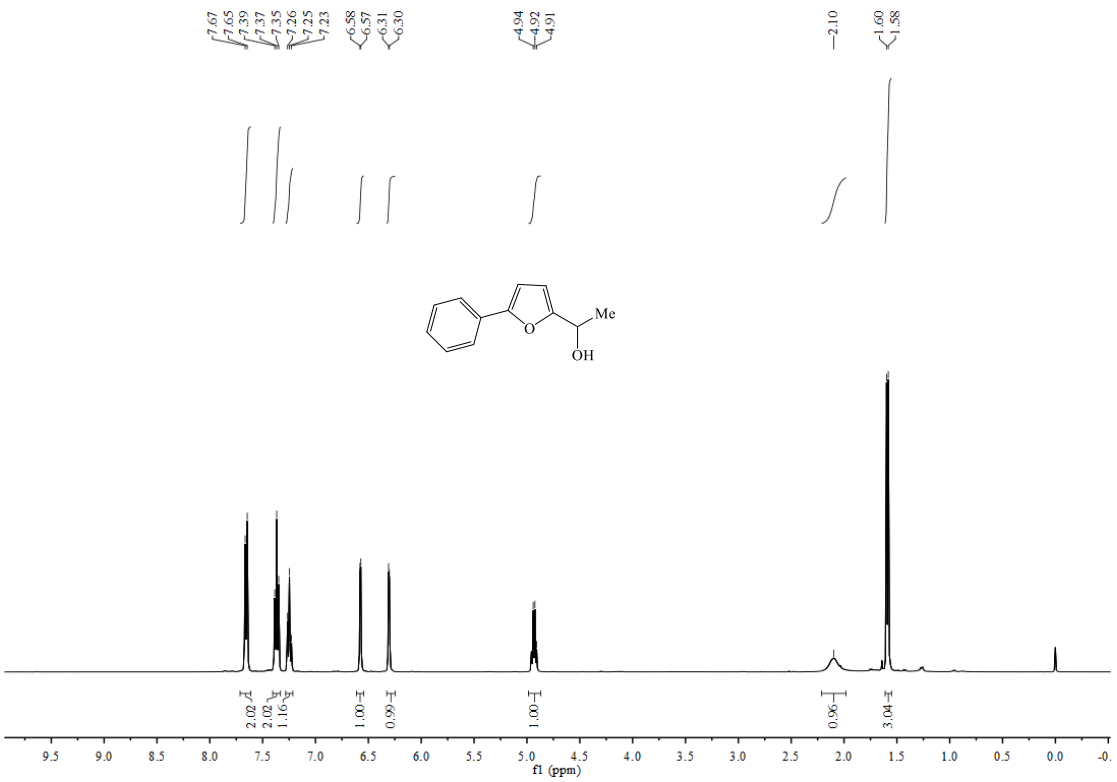
^{13}C NMR spectrum of **1h**



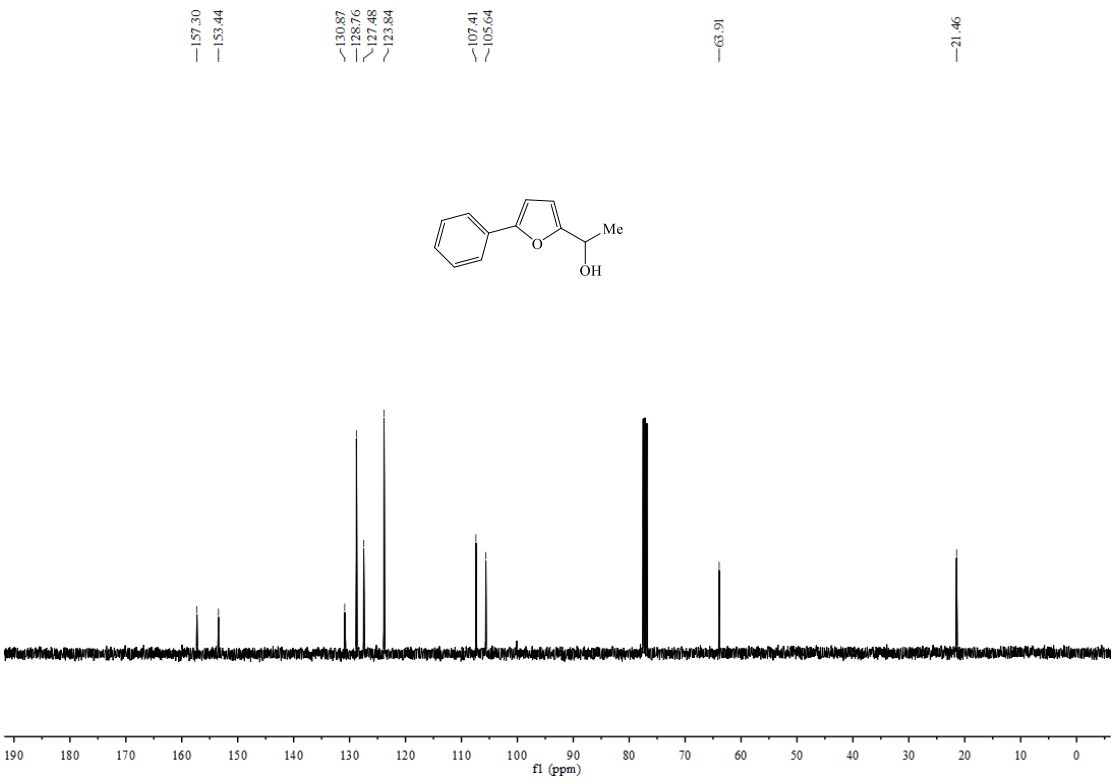
^{1}H NMR spectrum of **1j**



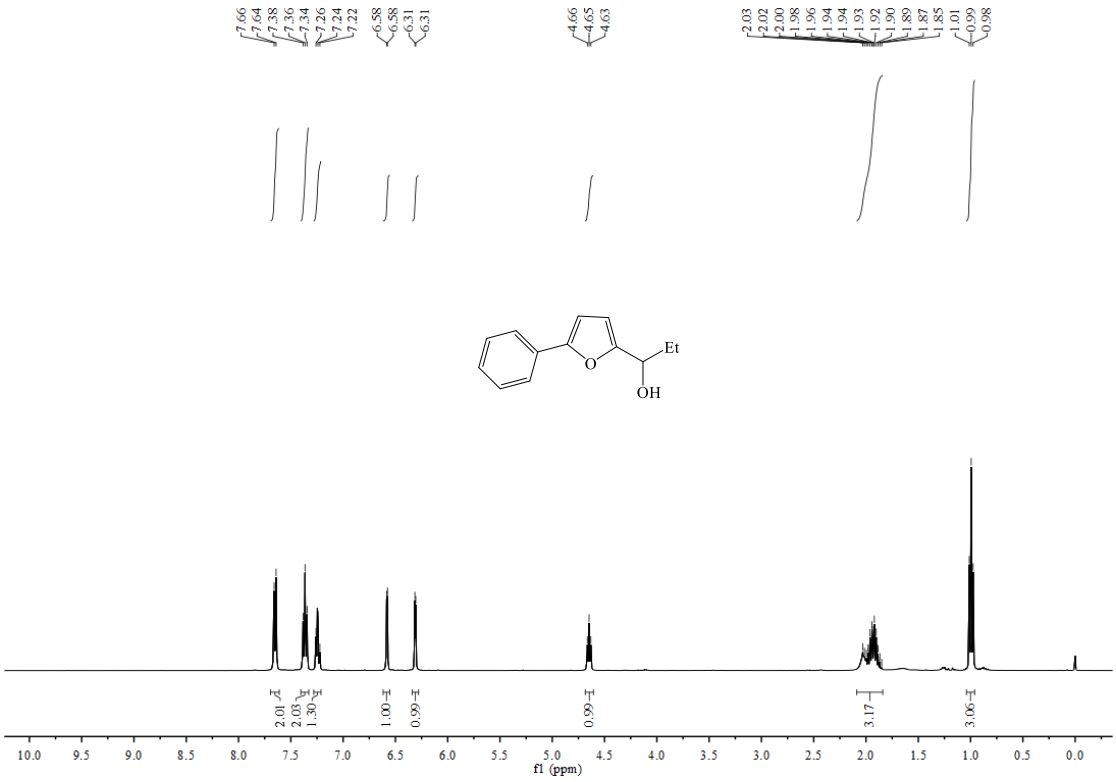
^{13}C NMR spectrum of **1j**



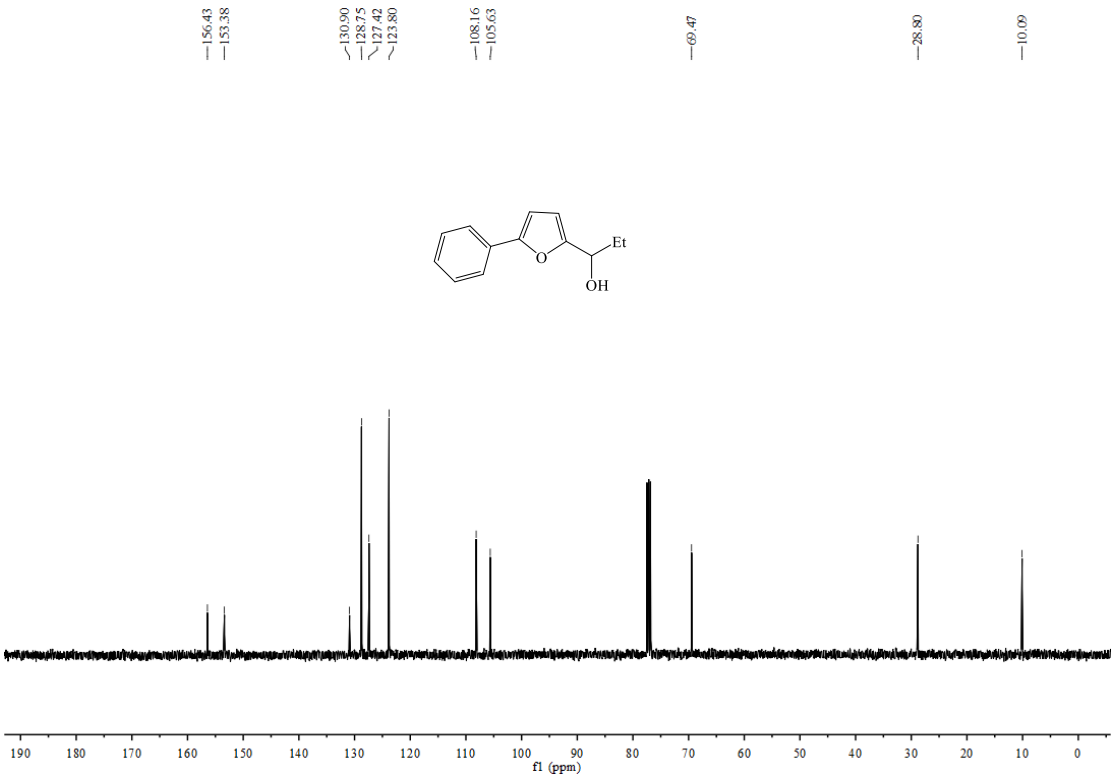
^{1}H NMR spectrum of **1k**



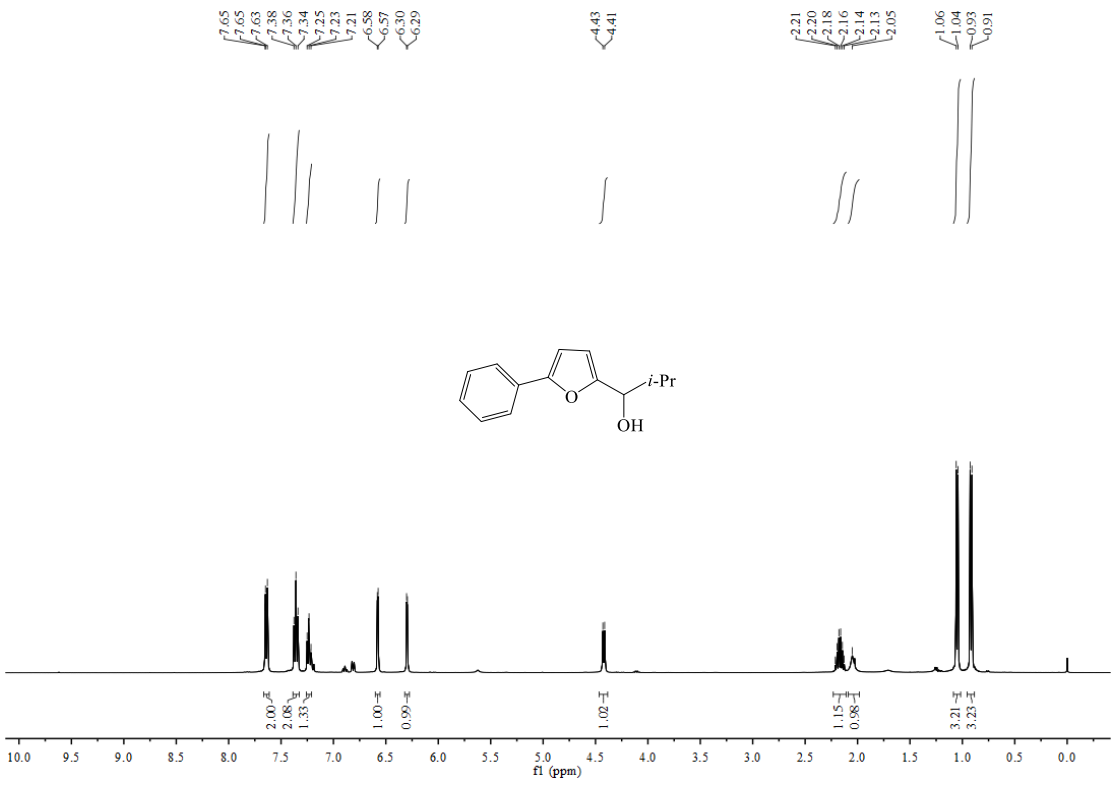
^{13}C NMR spectrum of **1k**



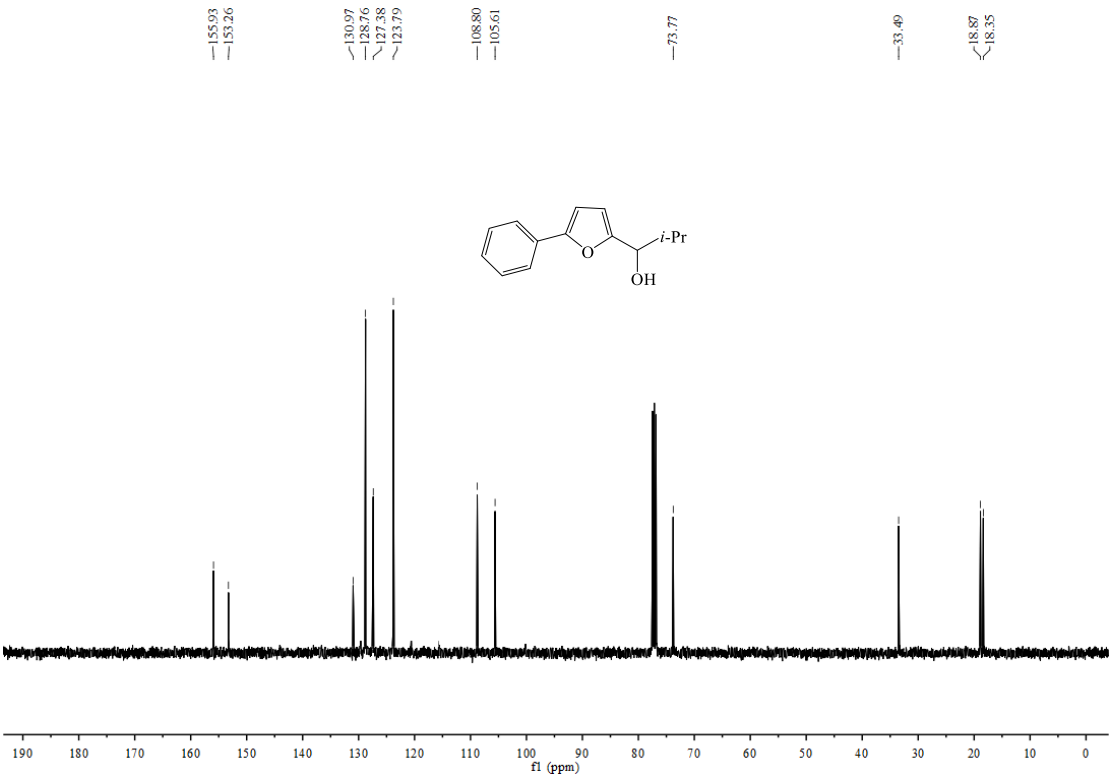
^{1}H NMR spectrum of **1l**



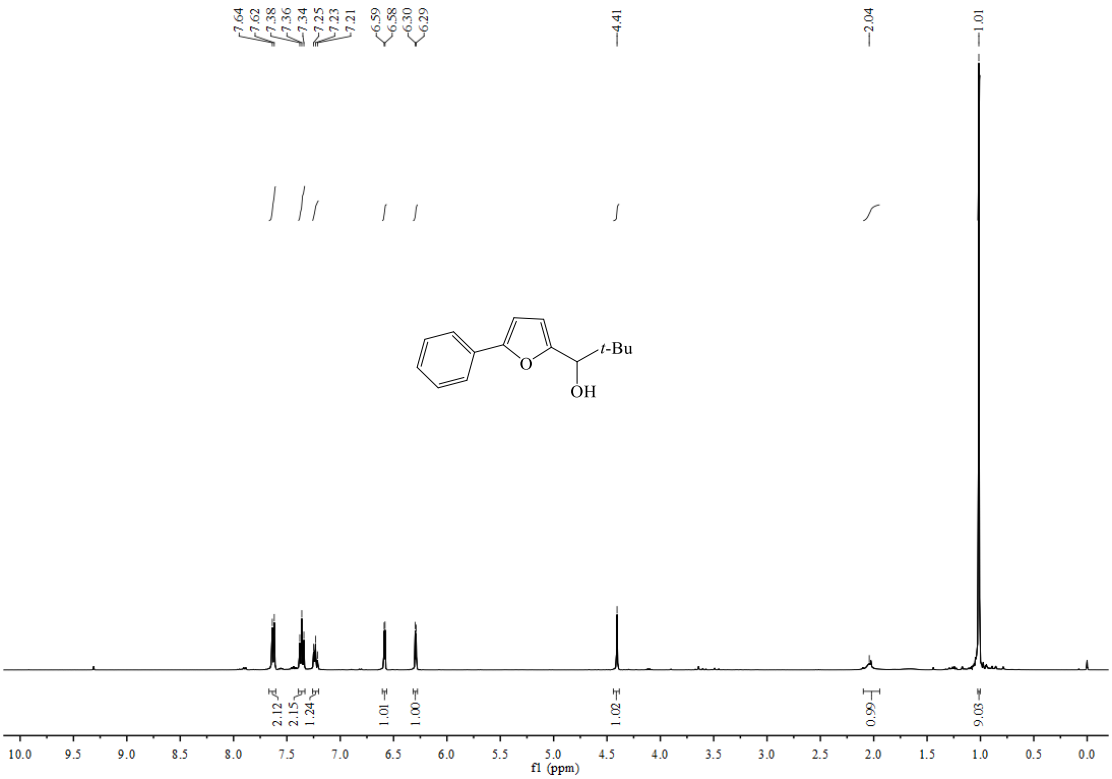
^{13}C NMR spectrum of **1l**



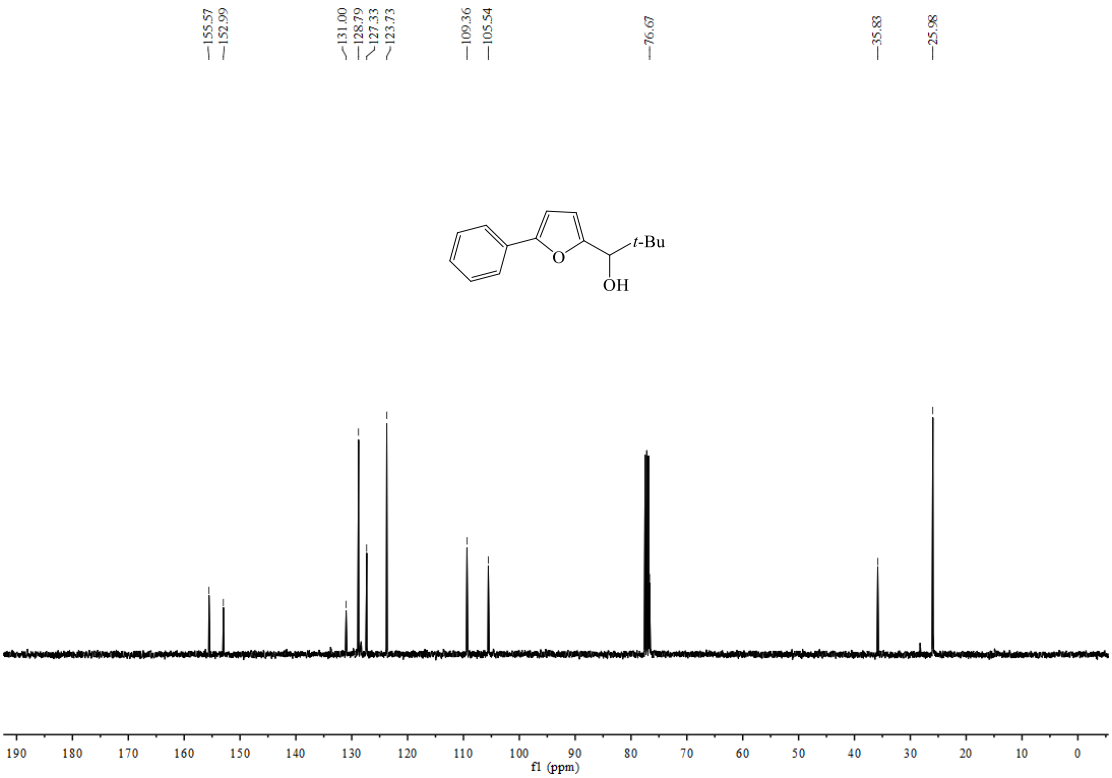
^{1}H NMR spectrum of **1m**



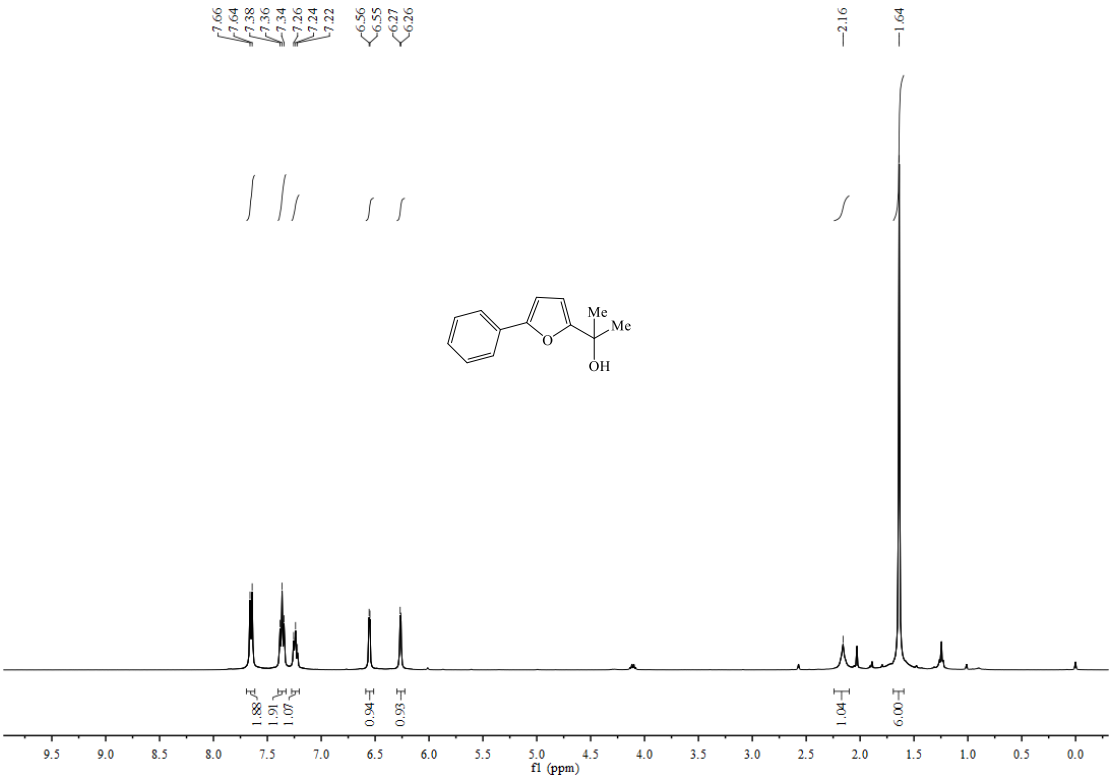
^{13}C NMR spectrum of **1m**



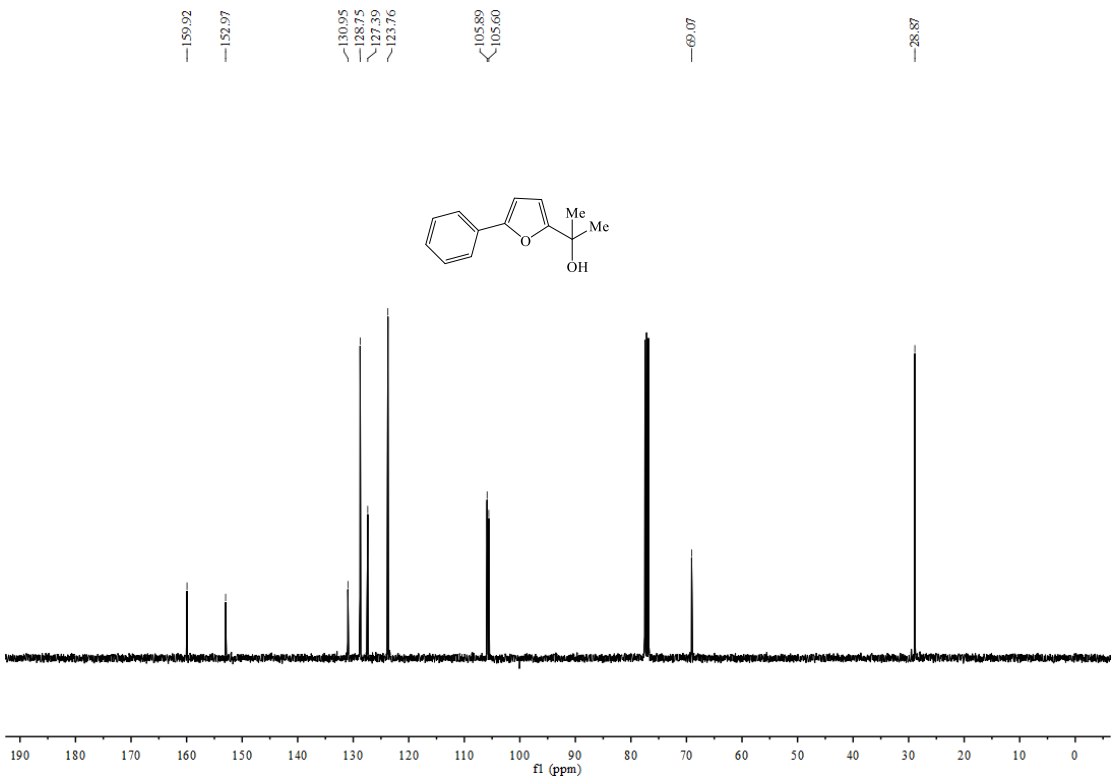
^{1}H NMR spectrum of **1n**



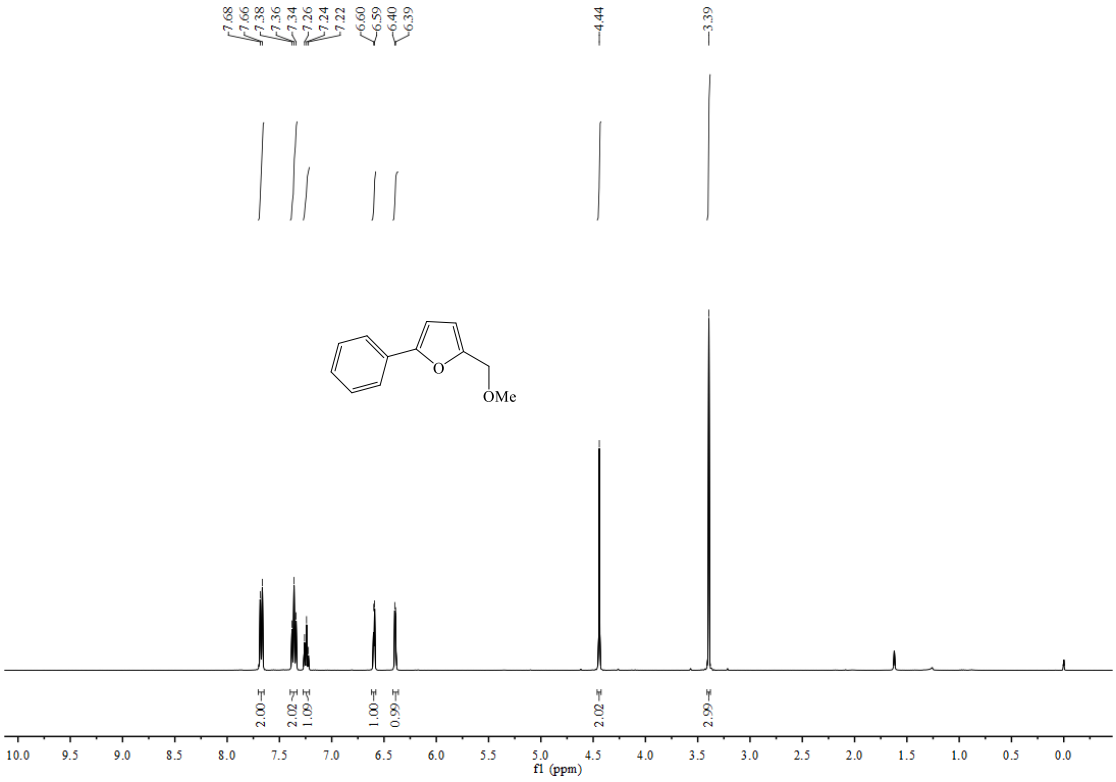
^{13}C NMR spectrum of **1n**



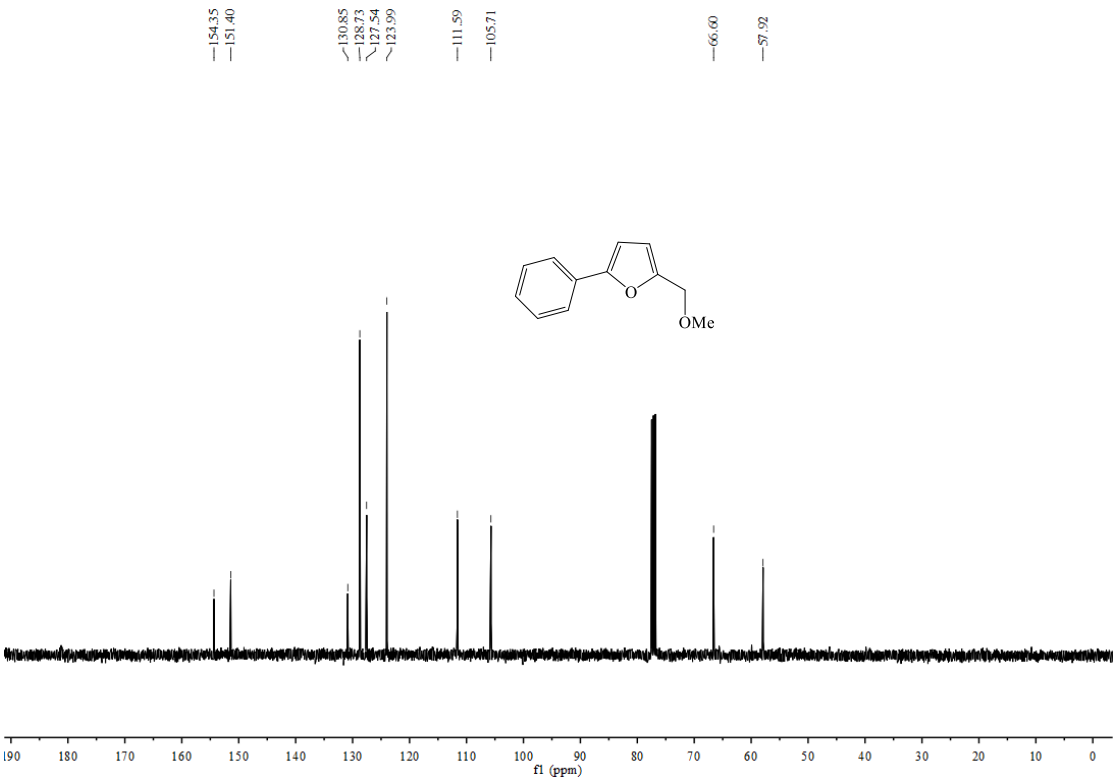
^{1}H NMR spectrum of **1o**



^{13}C NMR spectrum of **1o**

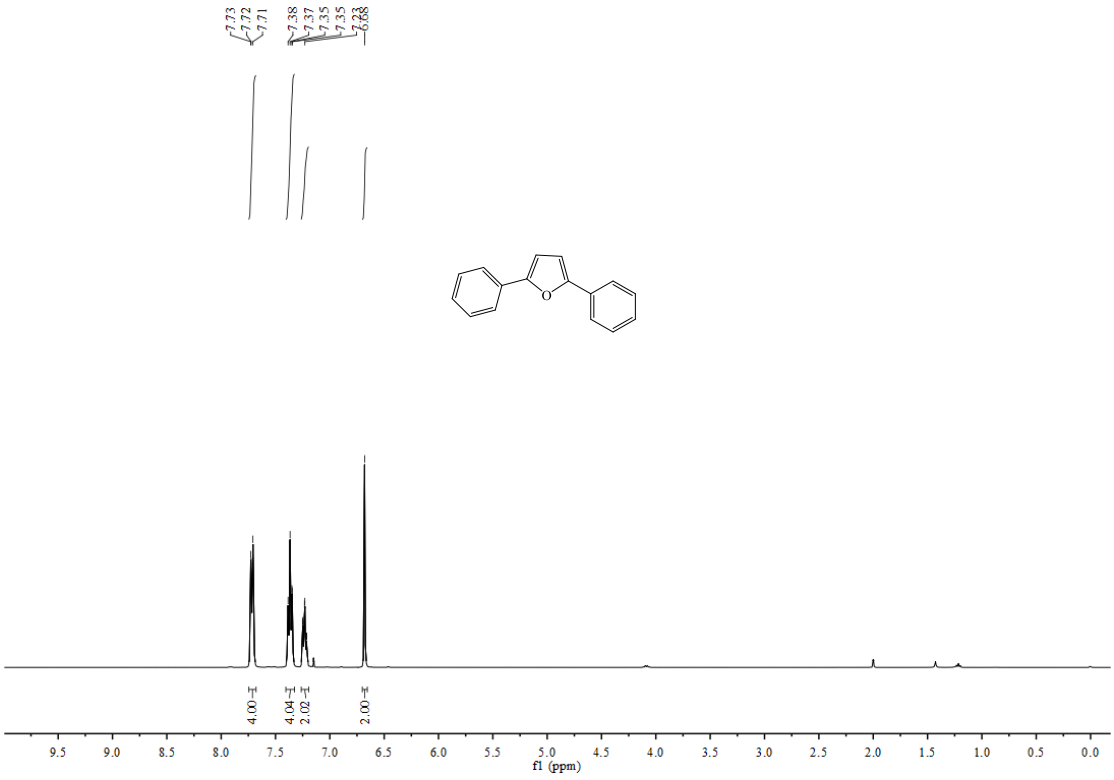


^{1}H NMR spectrum of **1p**

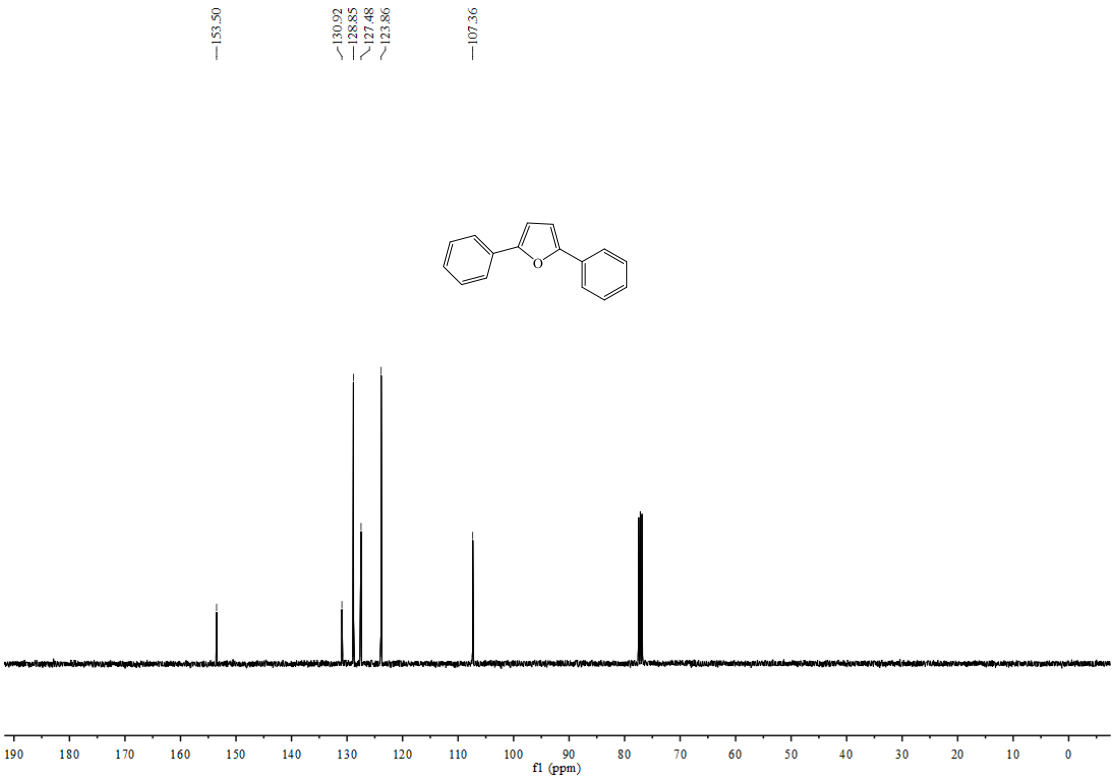


^{13}C NMR spectrum of **1p**

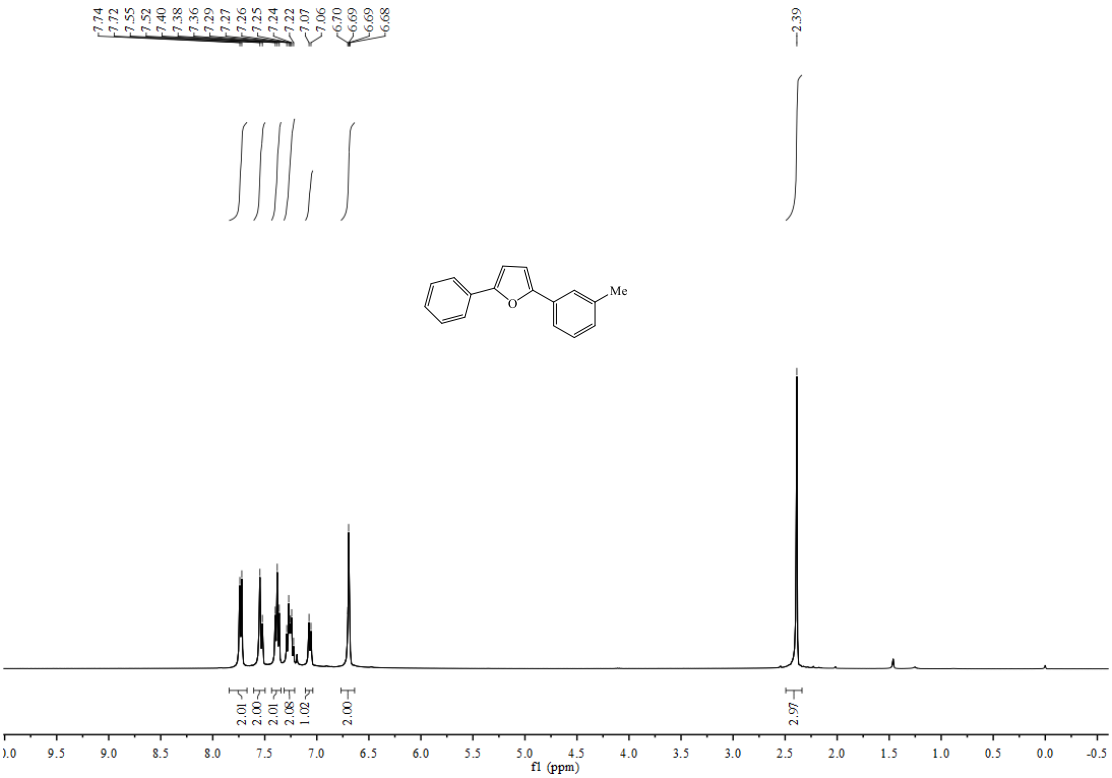
NMR charts of arylfurans 3



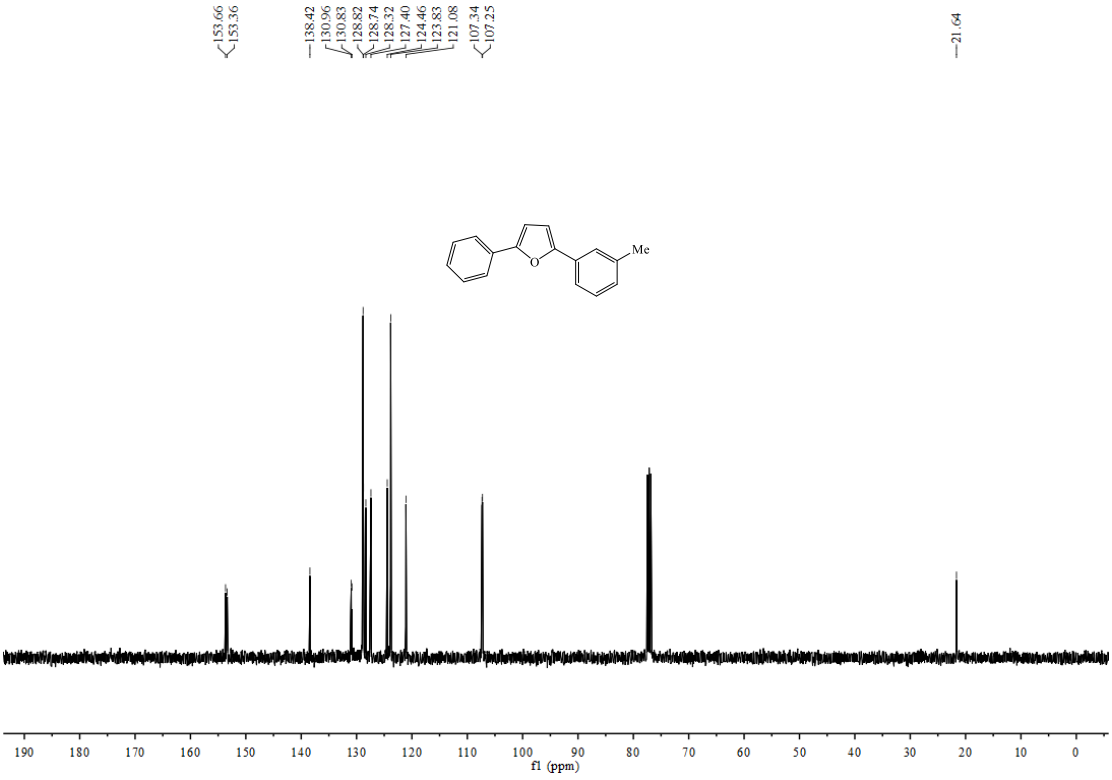
^{1}H NMR spectrum of **3a**



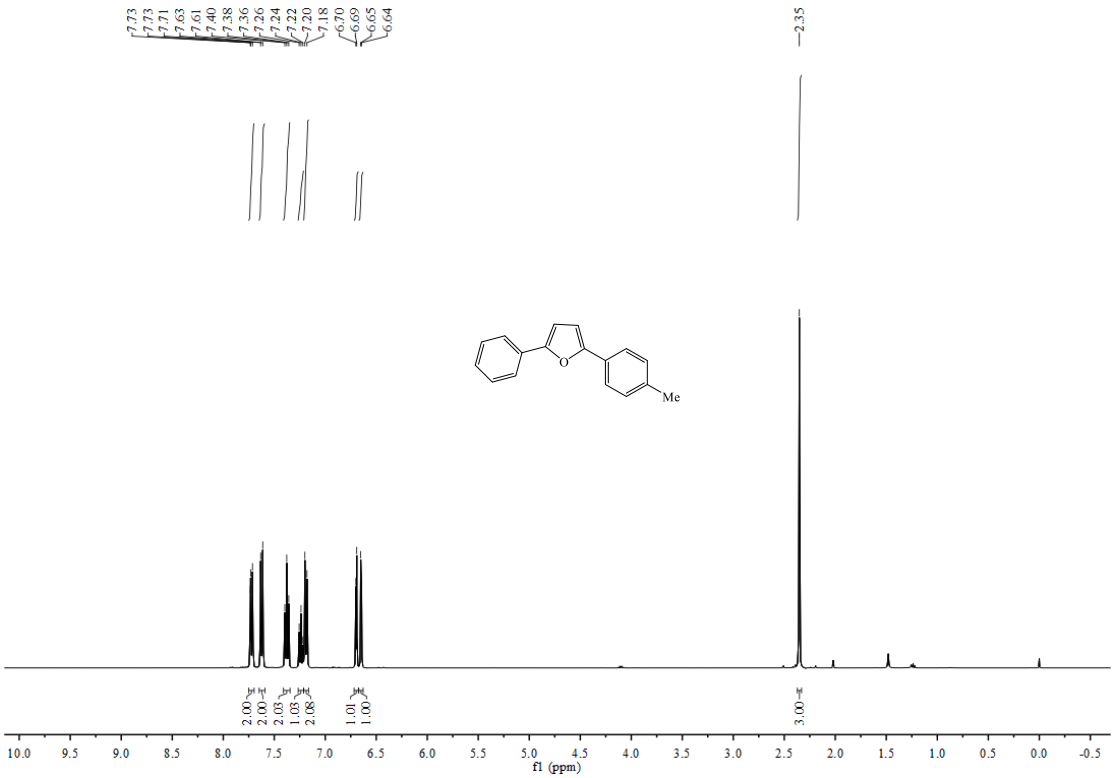
^{13}C NMR spectrum of **3a**



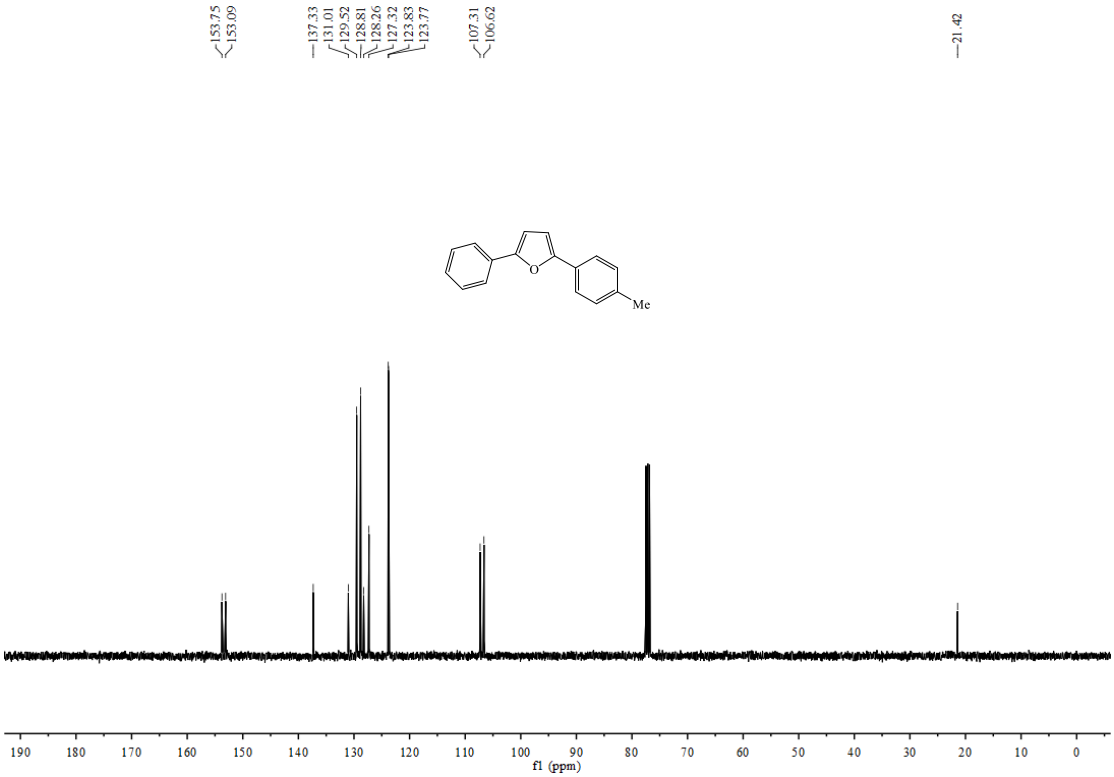
^{1}H NMR spectrum of **3b**



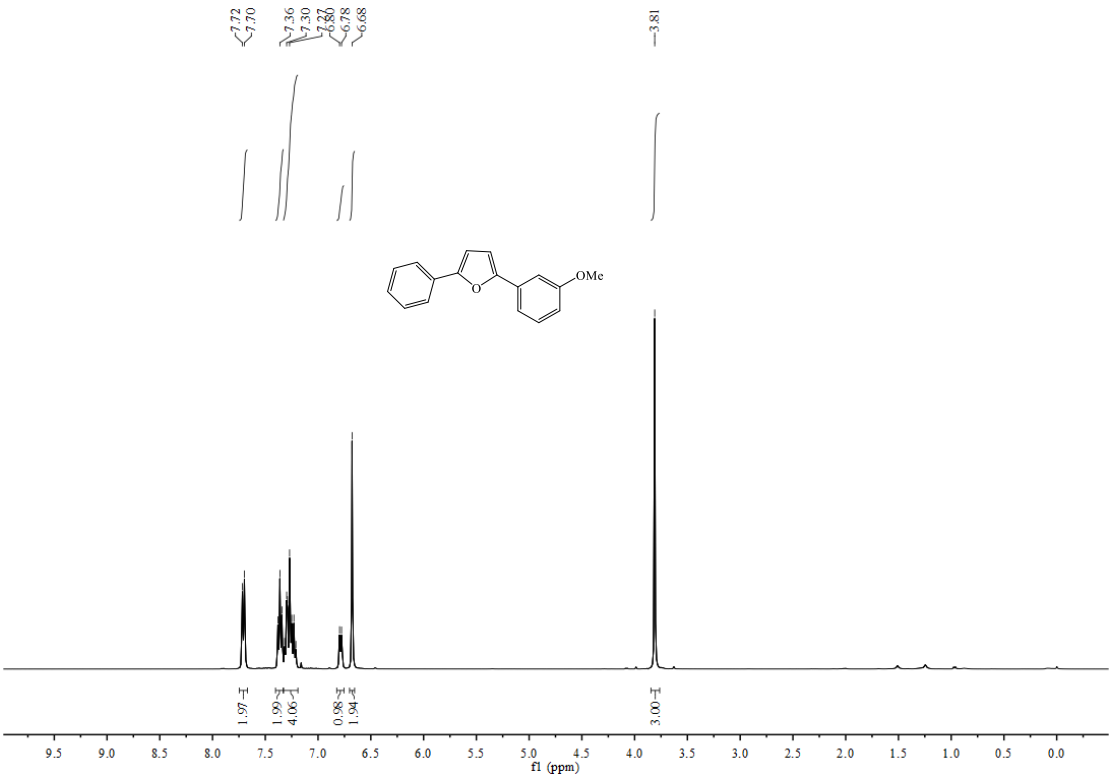
^{13}C NMR spectrum of **3b**



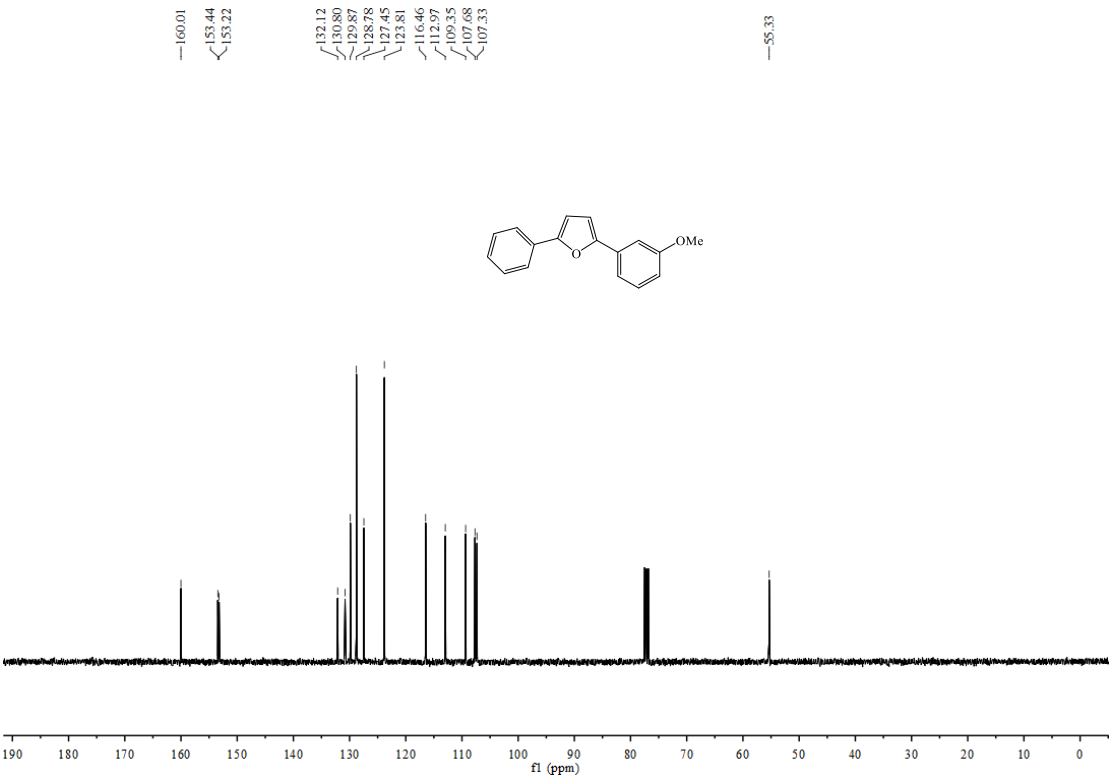
^{1}H NMR spectrum of **3c**



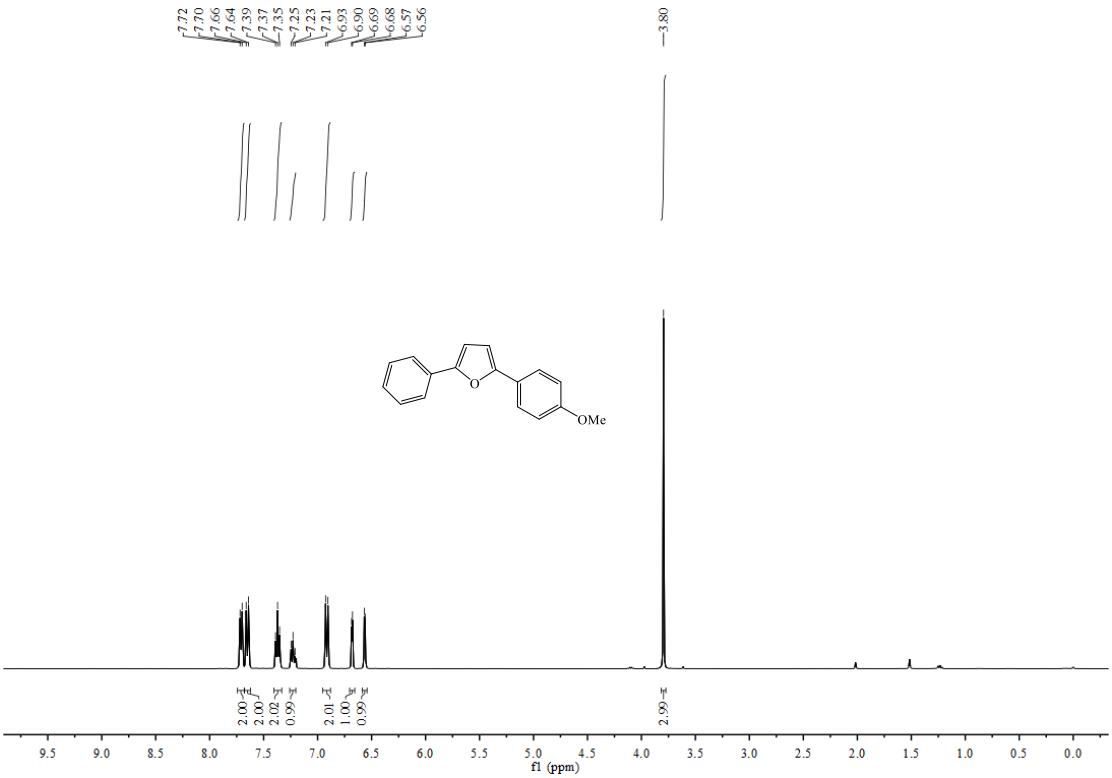
^{13}C NMR spectrum of **3c**



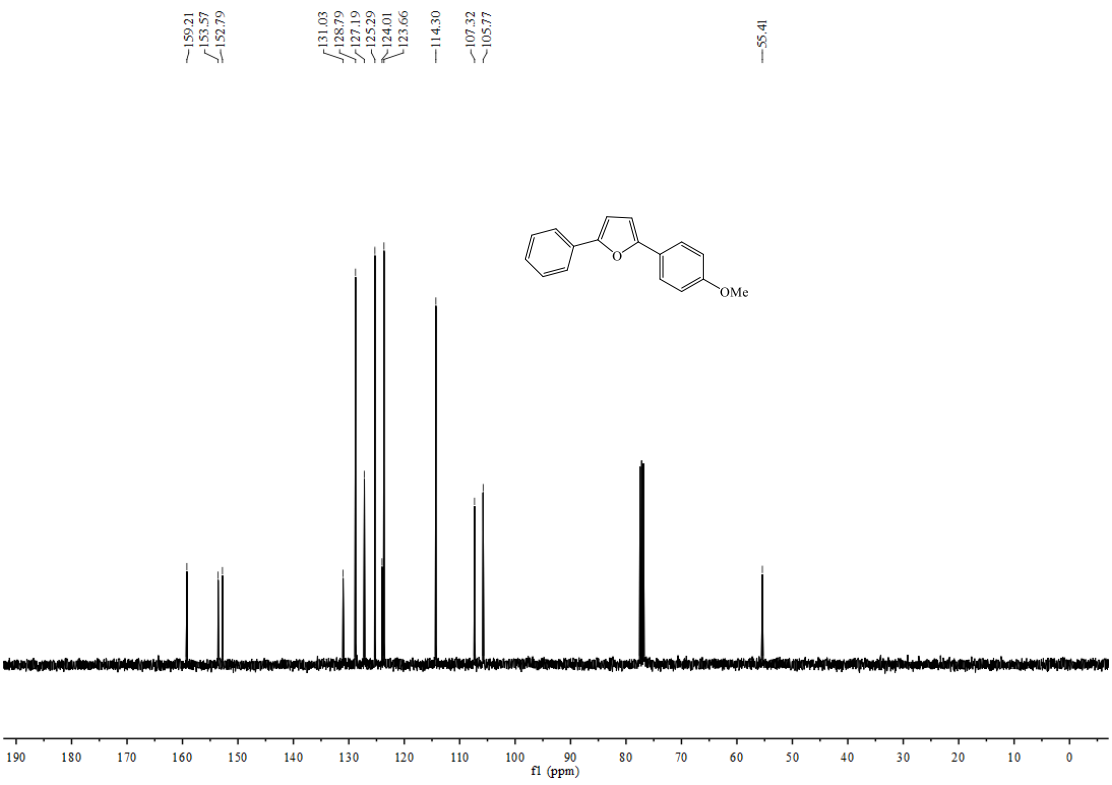
^{1}H NMR spectrum of **3d**



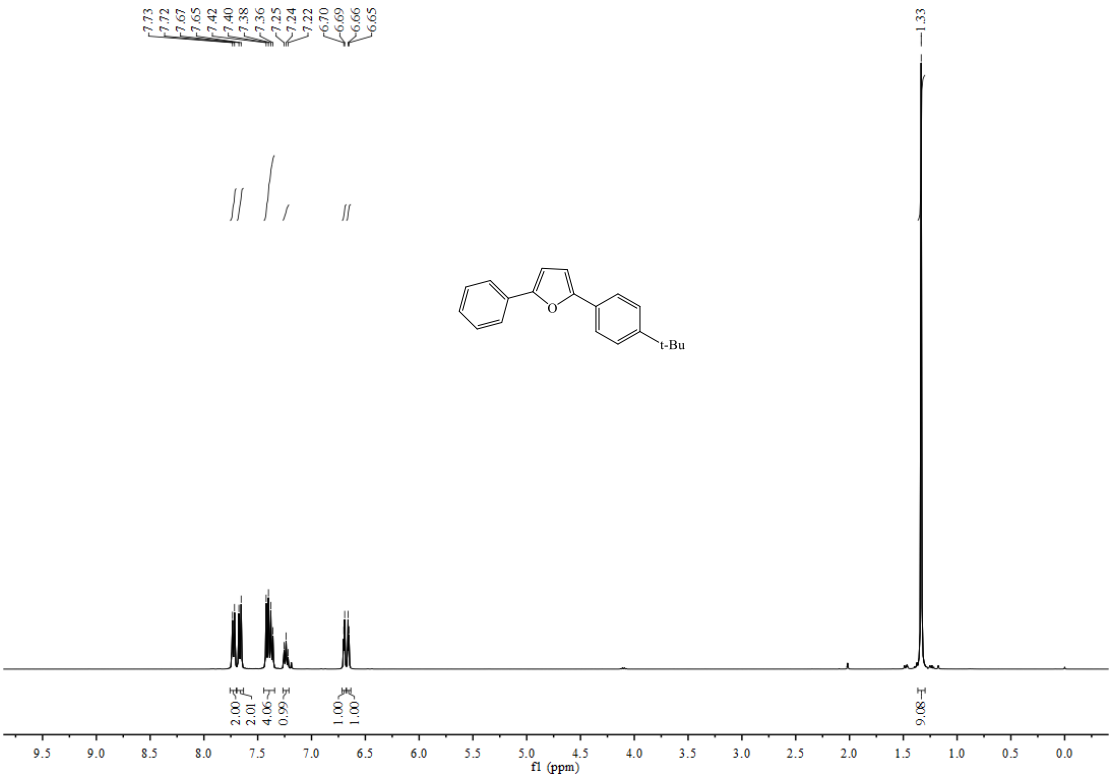
^{13}C NMR spectrum of **3d**



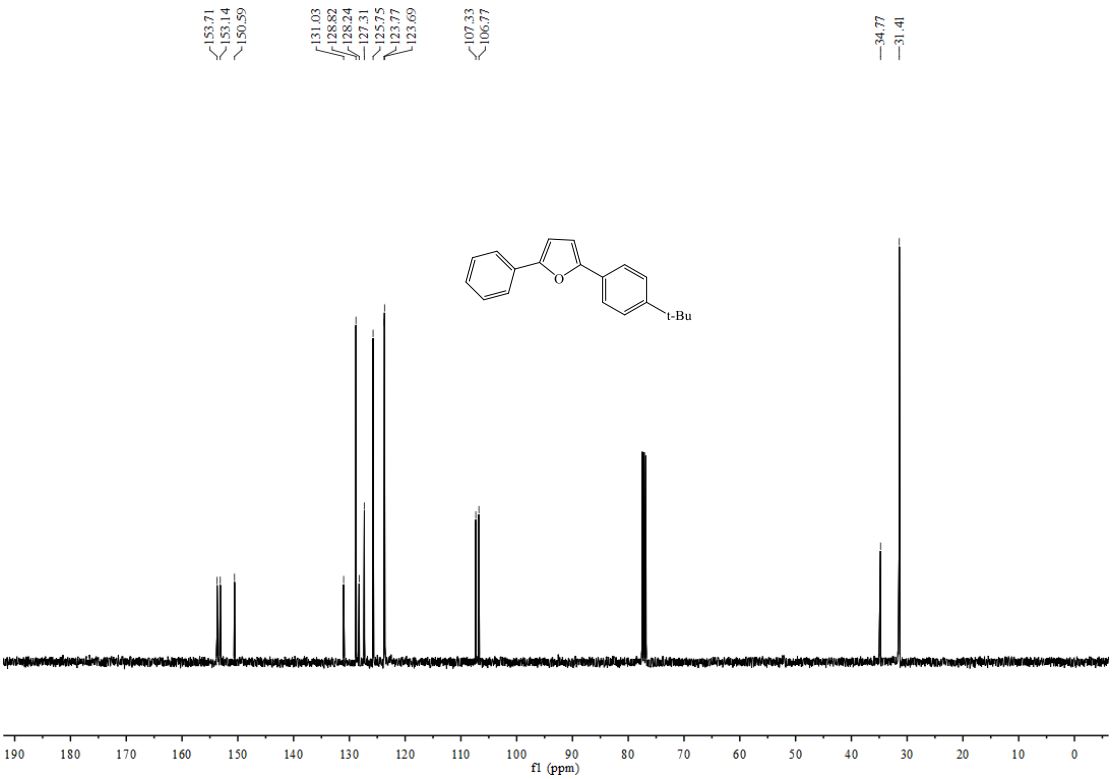
^{1}H NMR spectrum of **3e**



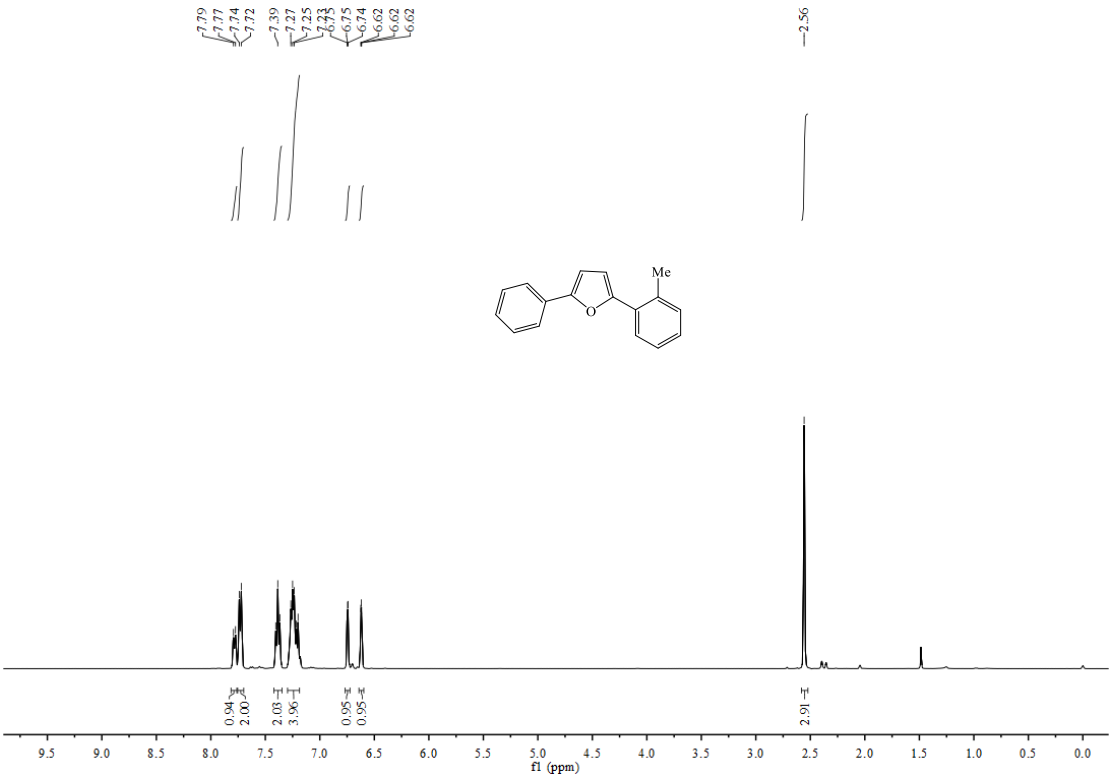
^{13}C NMR spectrum of **3e**



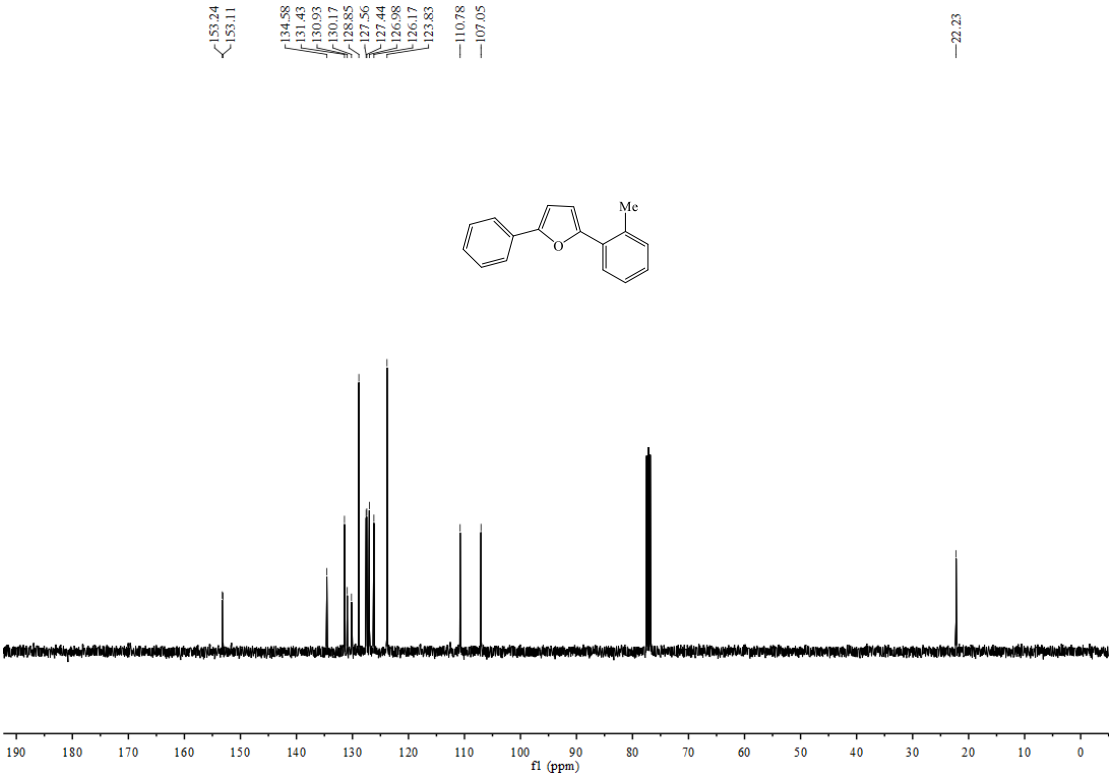
^{1}H NMR spectrum of **3f**



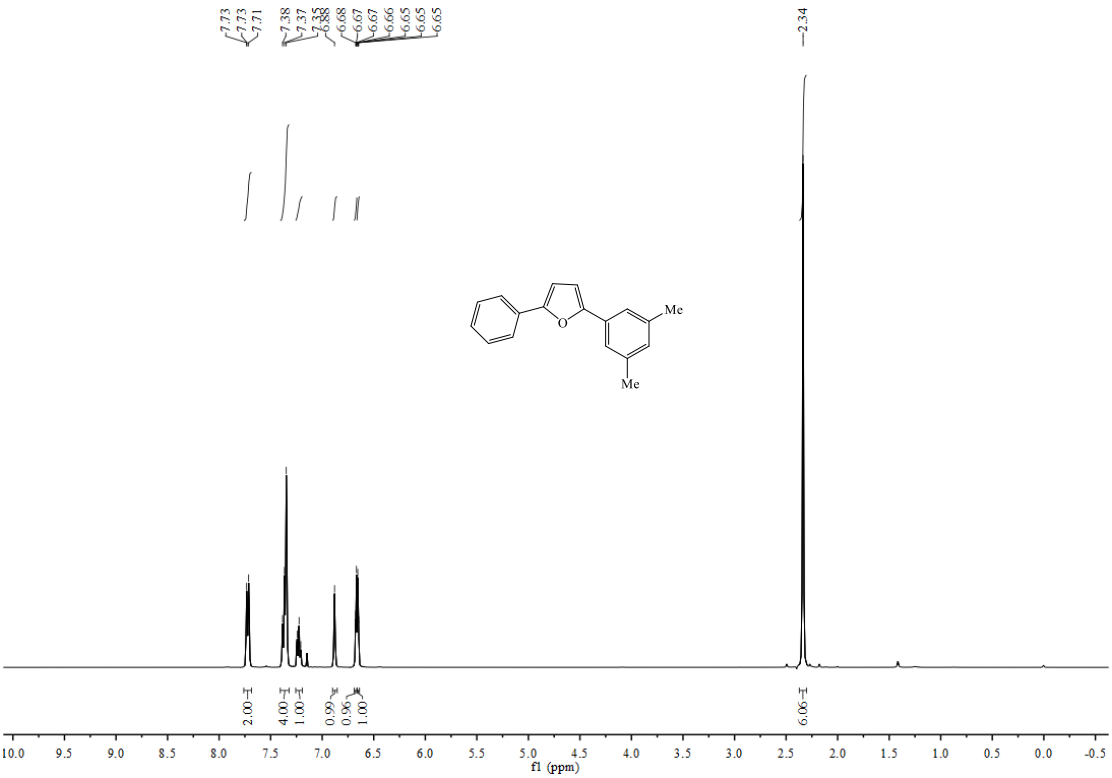
^{13}C NMR spectrum of **3f**



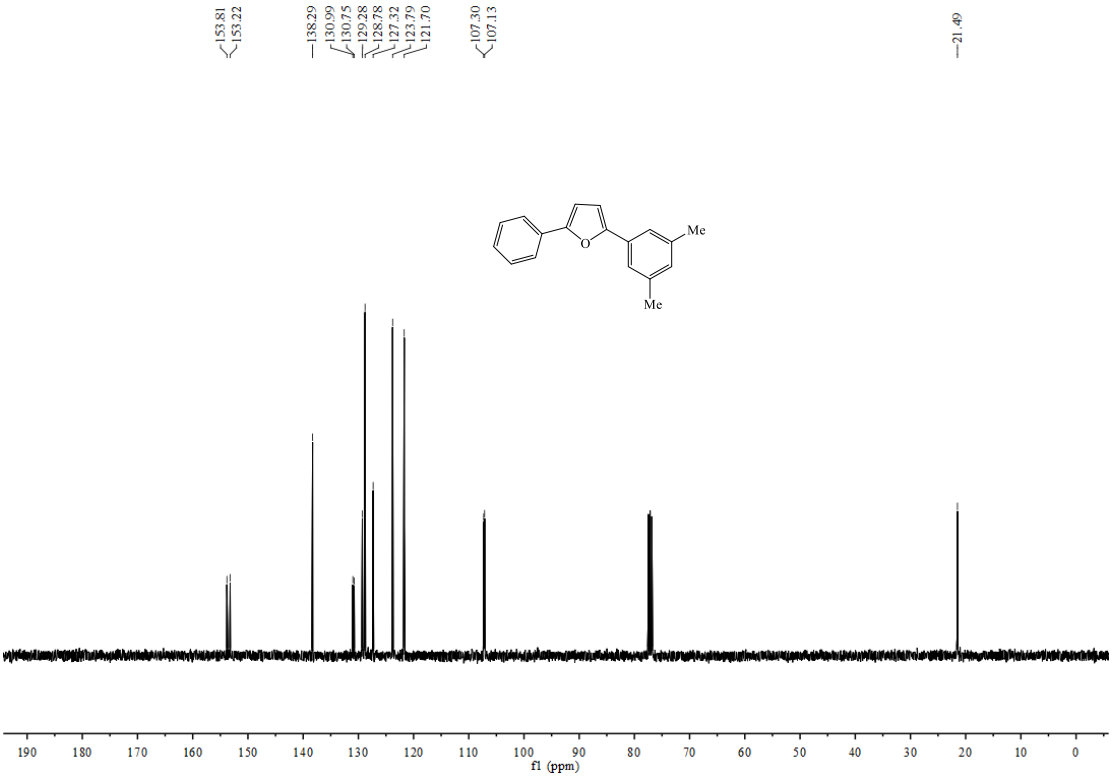
^{1}H NMR spectrum of **3g**



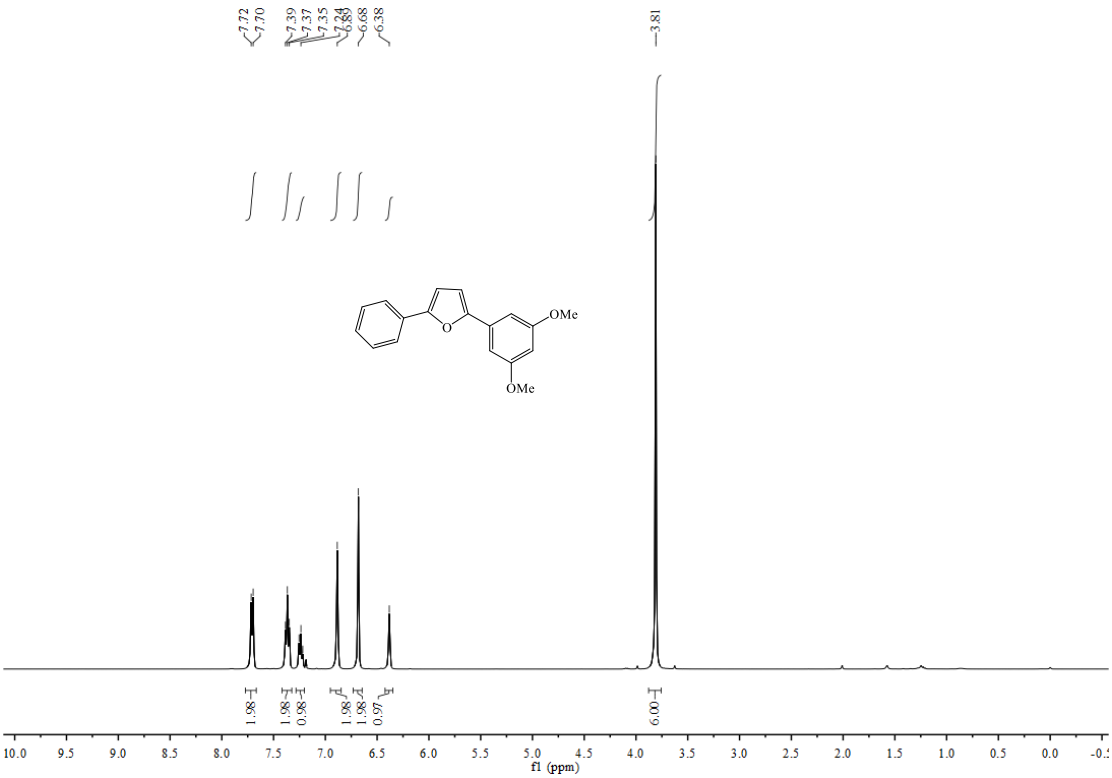
^{13}C NMR spectrum of **3g**



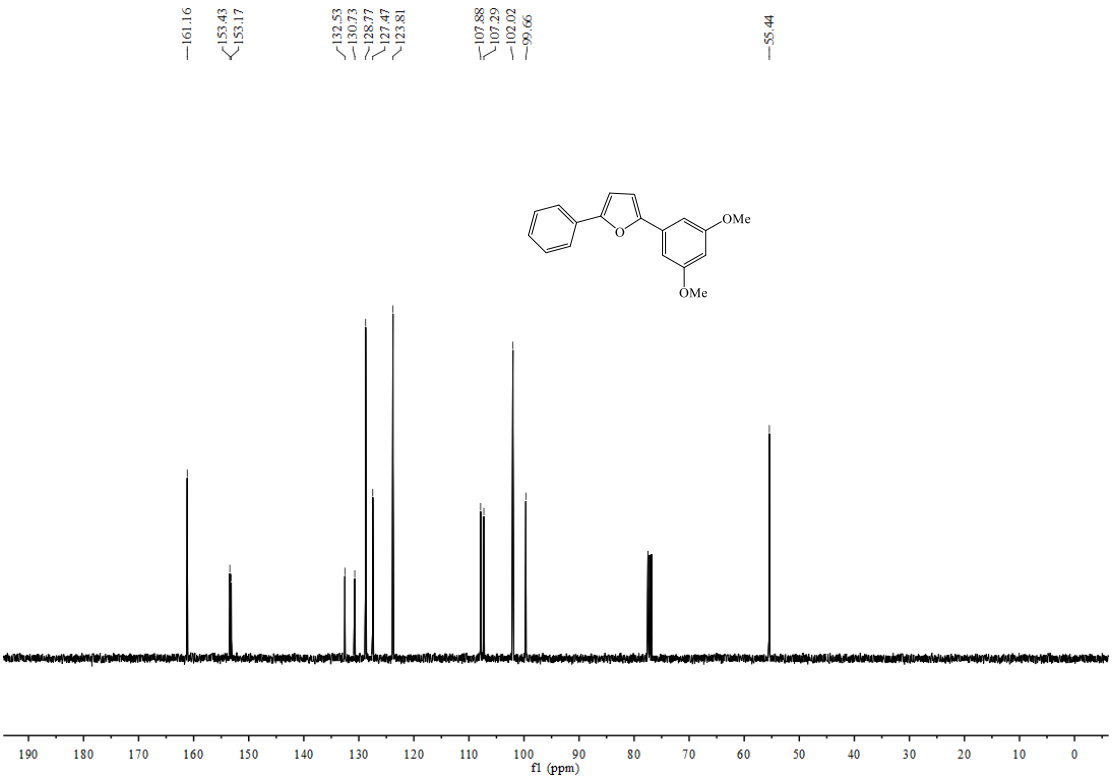
^{1}H NMR spectrum of **3h**



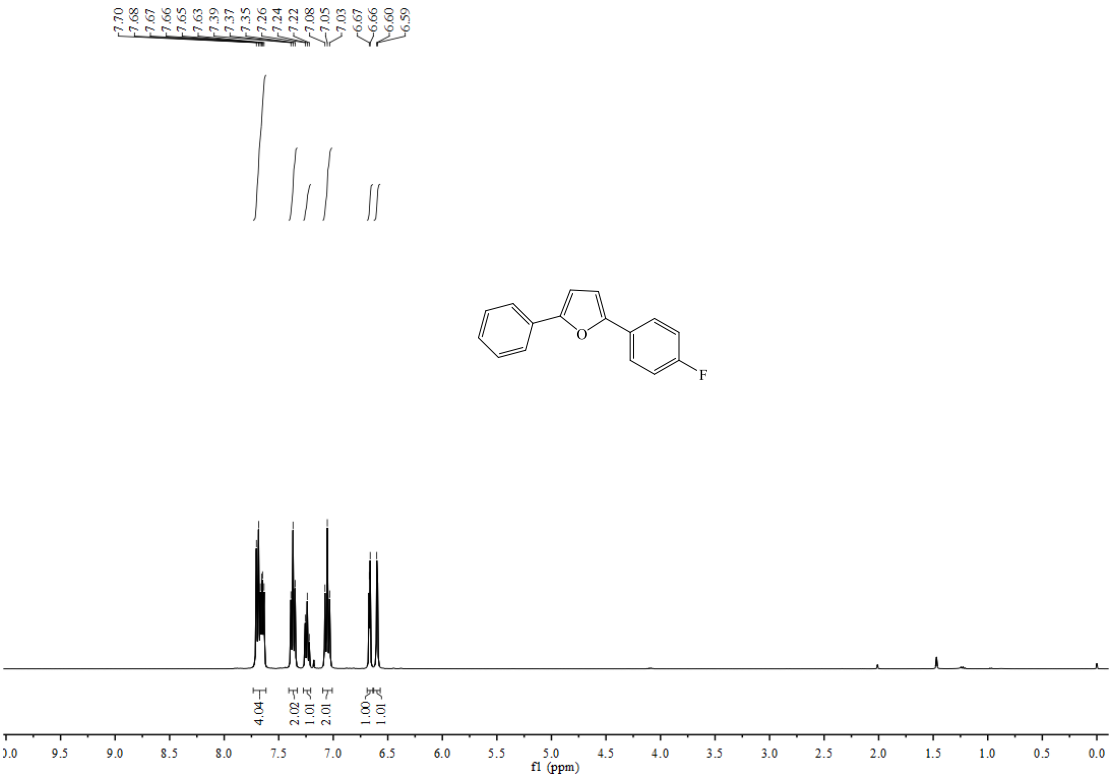
^{13}C NMR spectrum of **3h**



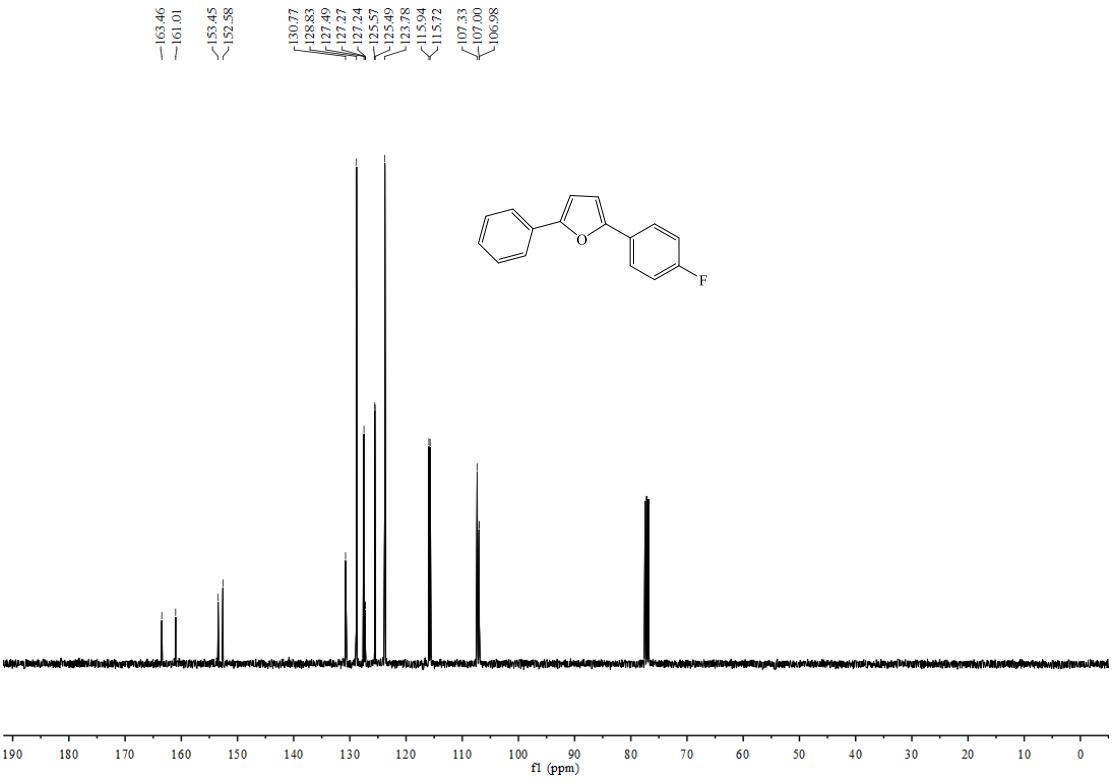
^{1}H NMR spectrum of **3i**



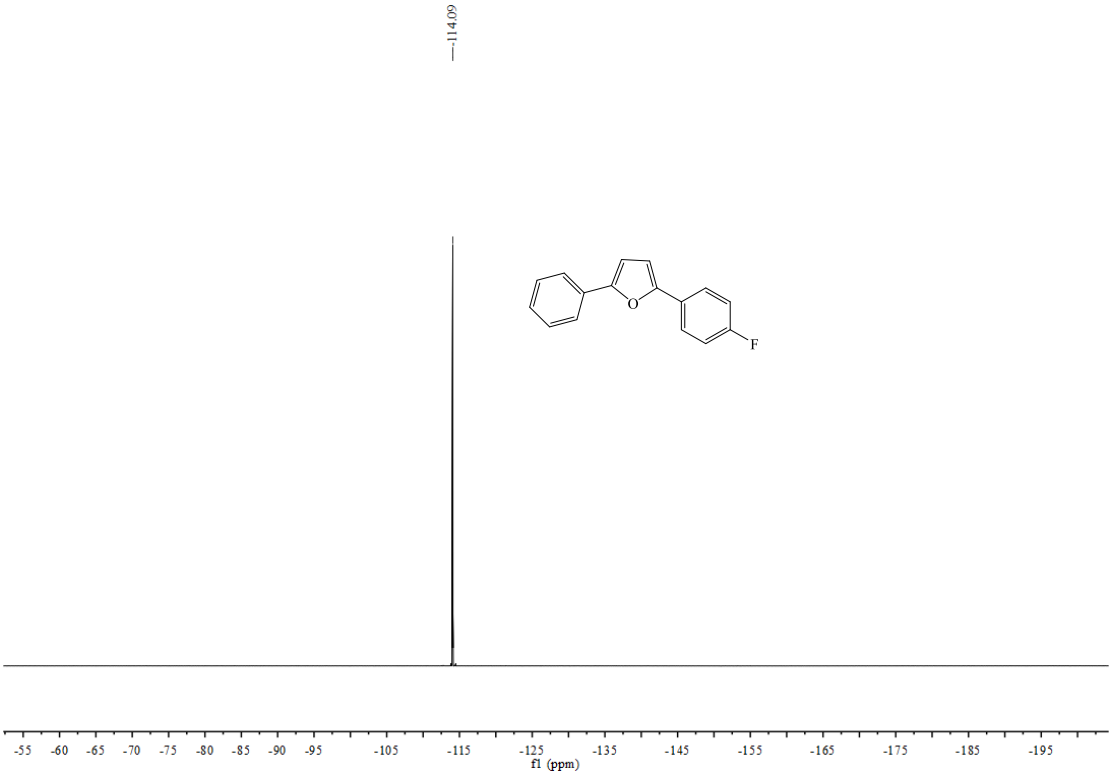
^{13}C NMR spectrum of **3i**



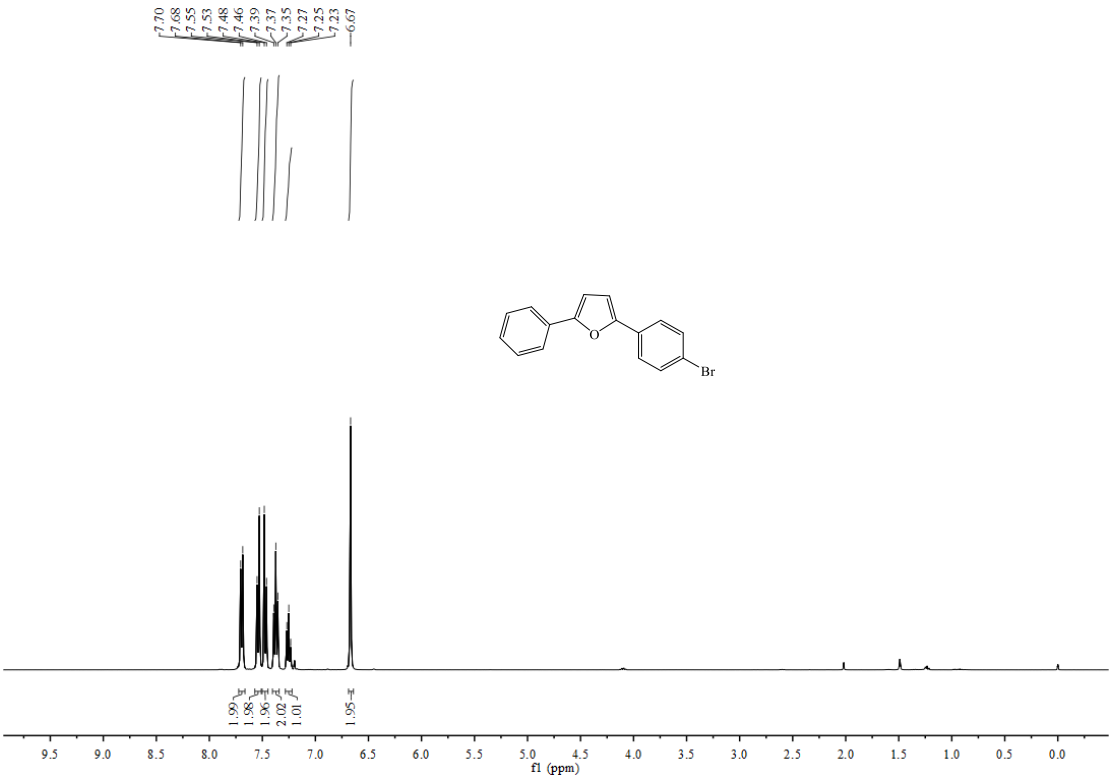
^{1}H NMR spectrum of **3j**



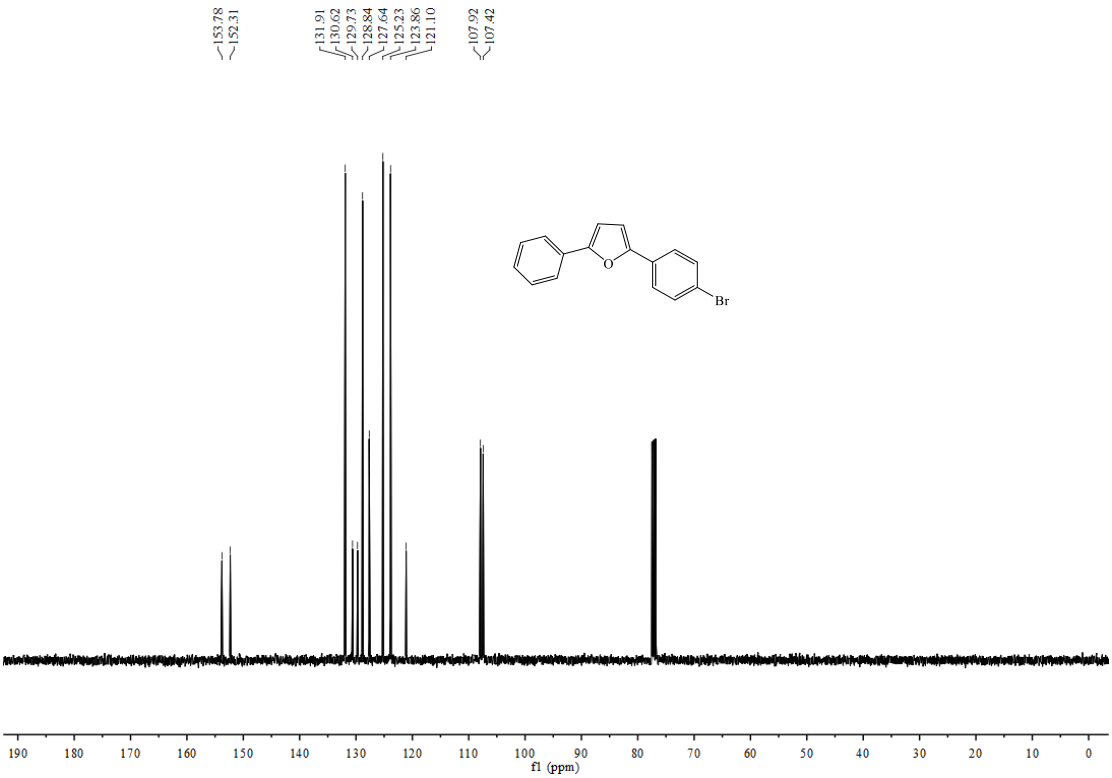
^{13}C NMR spectrum of **3j**



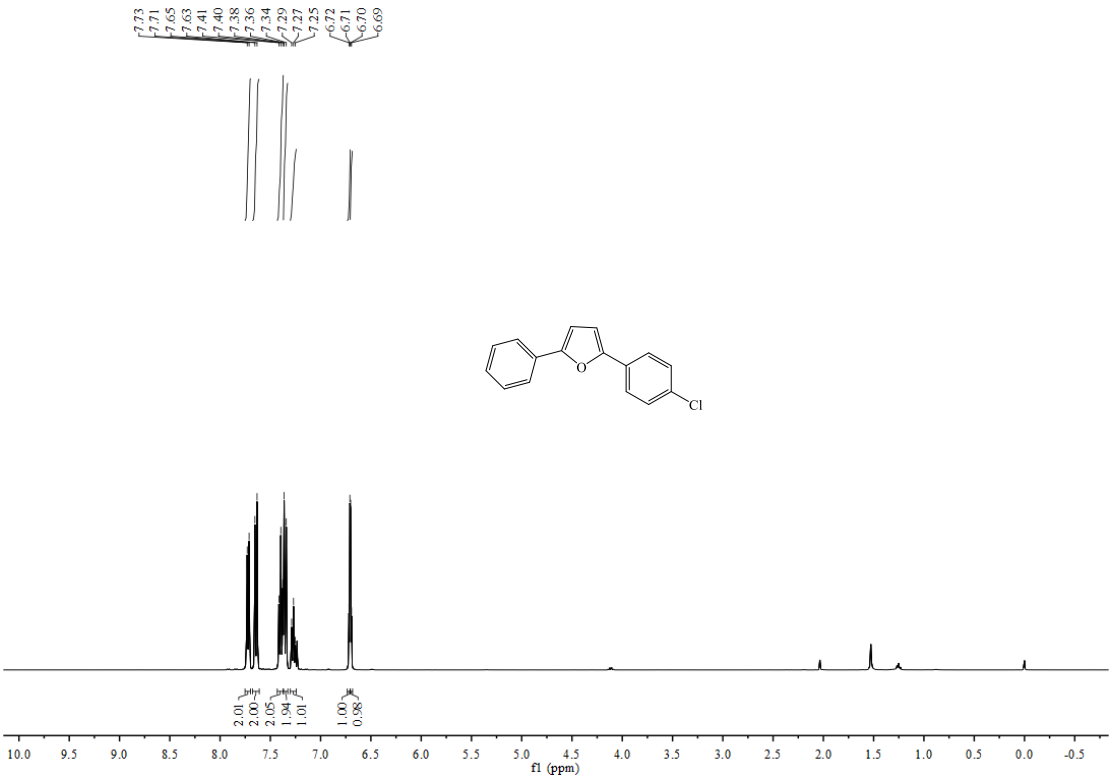
^{19}F NMR spectrum of **3j**



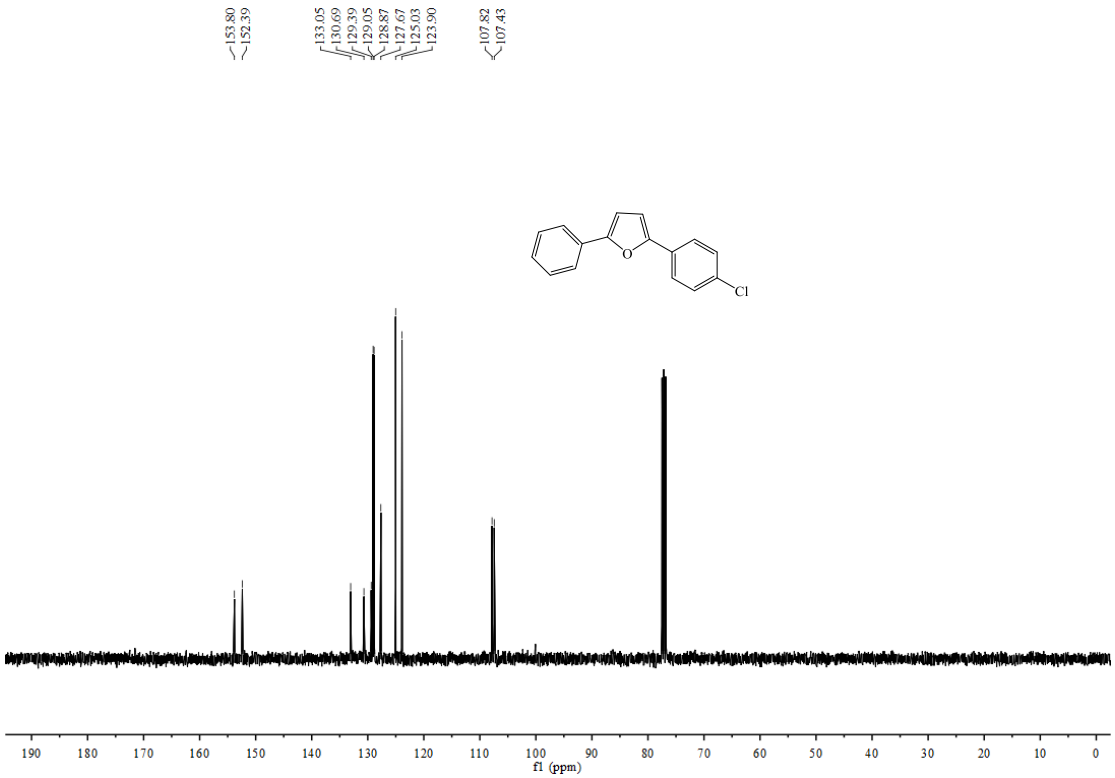
^{1}H NMR spectrum of **3k**



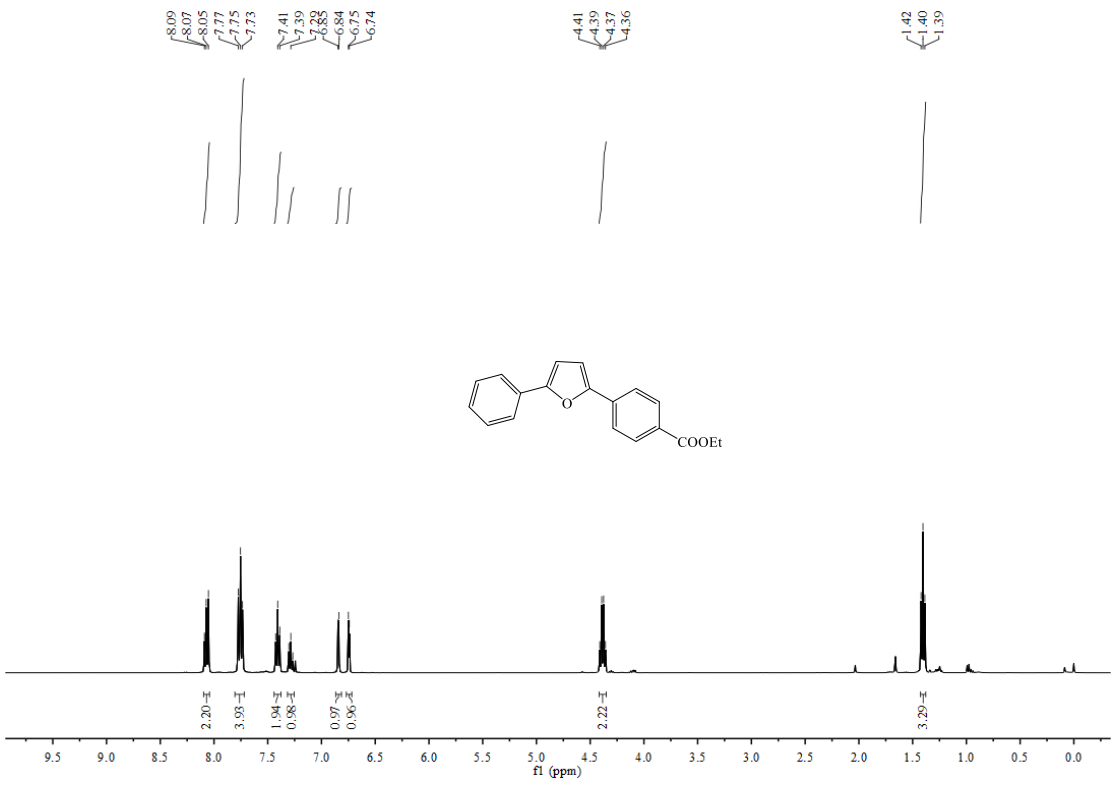
^{13}C NMR spectrum of **3k**



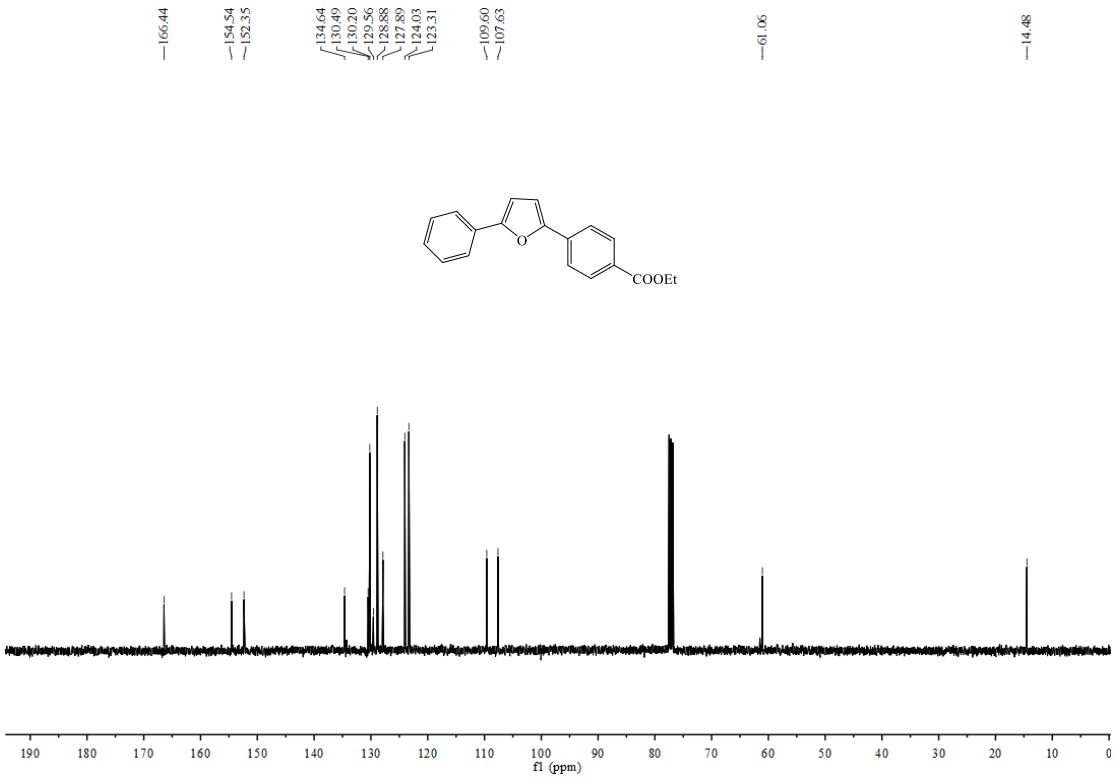
^{1}H NMR spectrum of **3l**



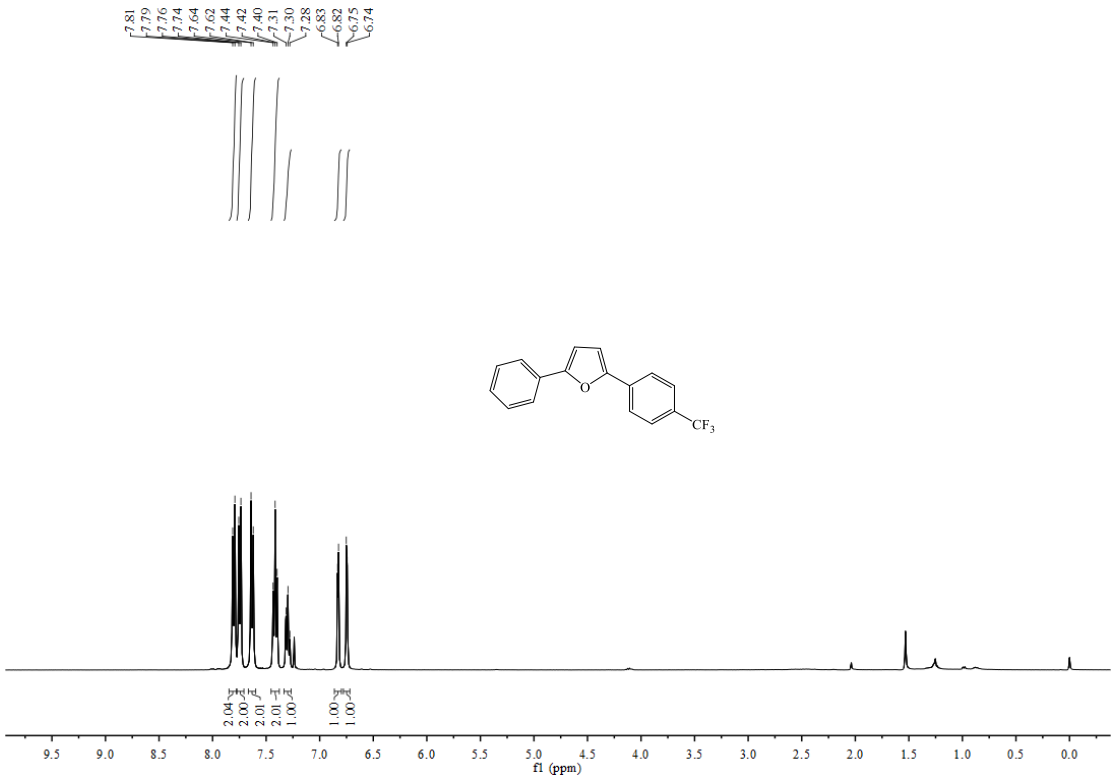
^{13}C NMR spectrum of **3l**



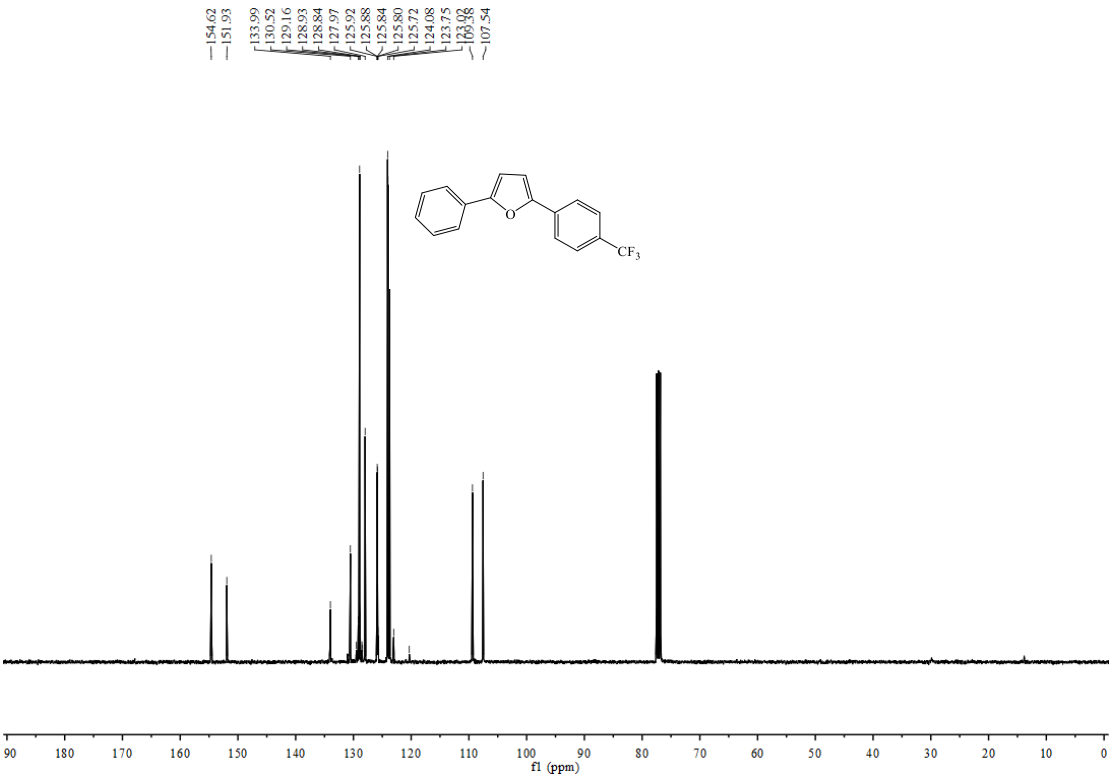
^{1}H NMR spectrum of **3m**



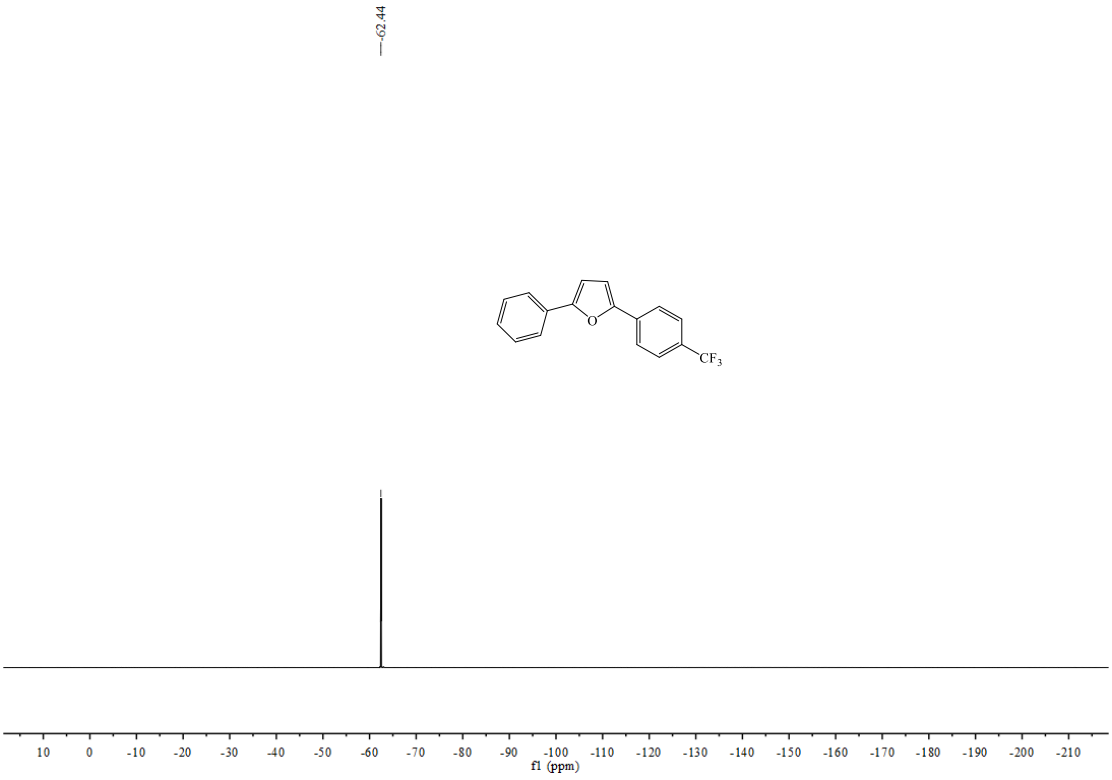
^{13}C NMR spectrum of **3m**



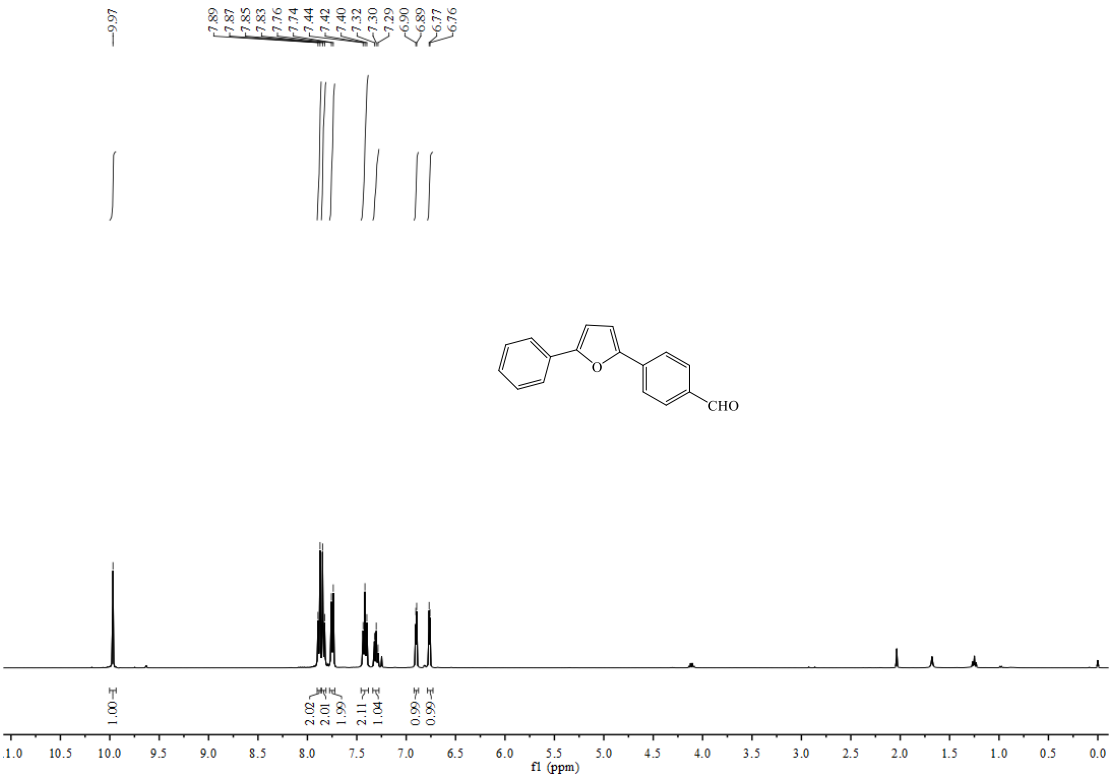
^{1}H NMR spectrum of **3n**



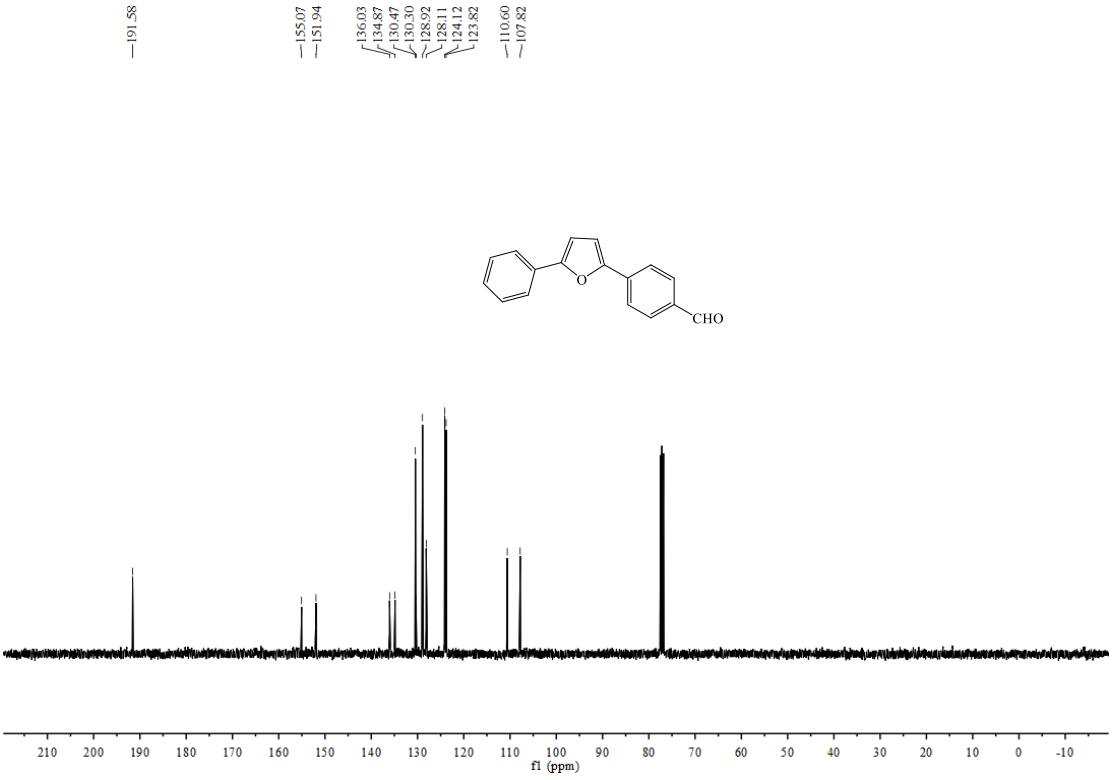
^{13}C NMR spectrum of **3n**



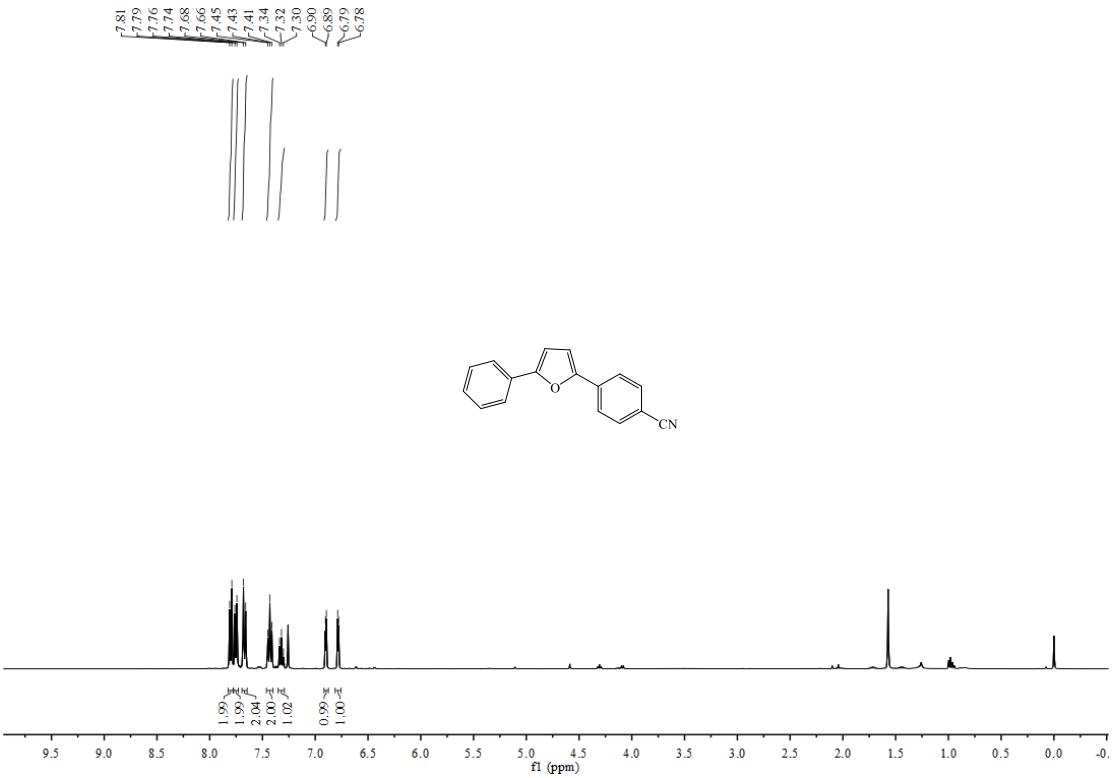
^{19}F NMR spectrum of **3n**



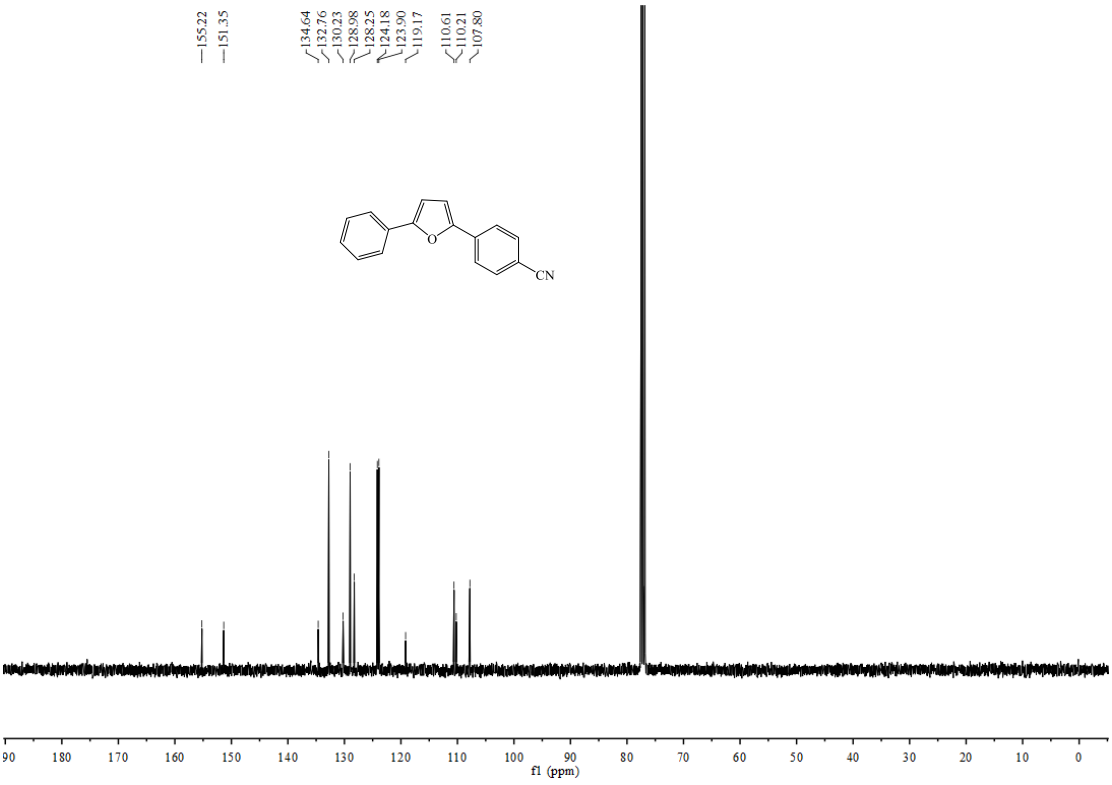
^{1}H NMR spectrum of **3o**



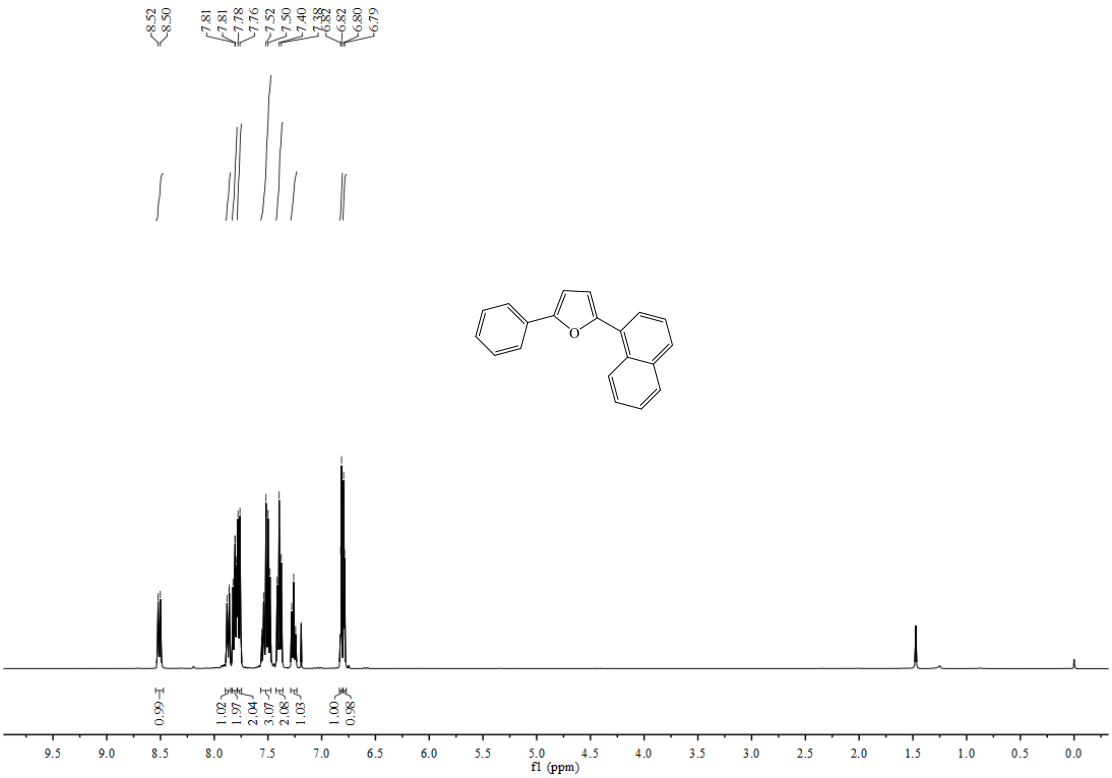
^{13}C NMR spectrum of **3o**



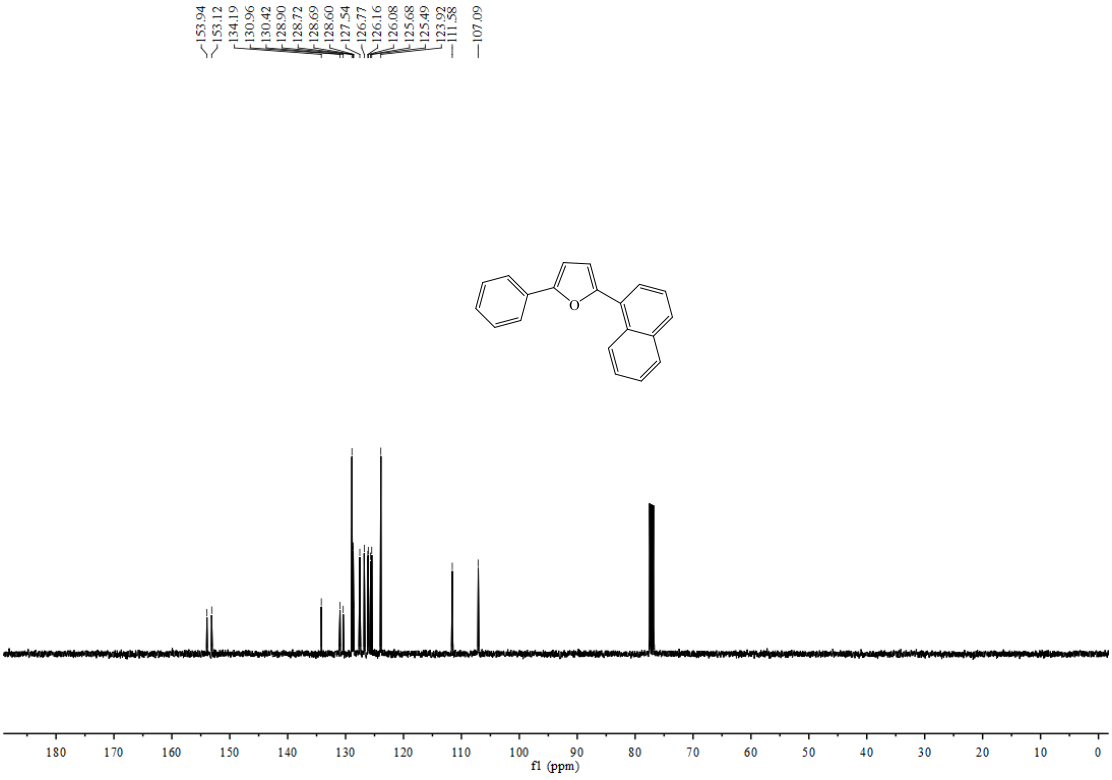
^{1}H NMR spectrum of **3p**



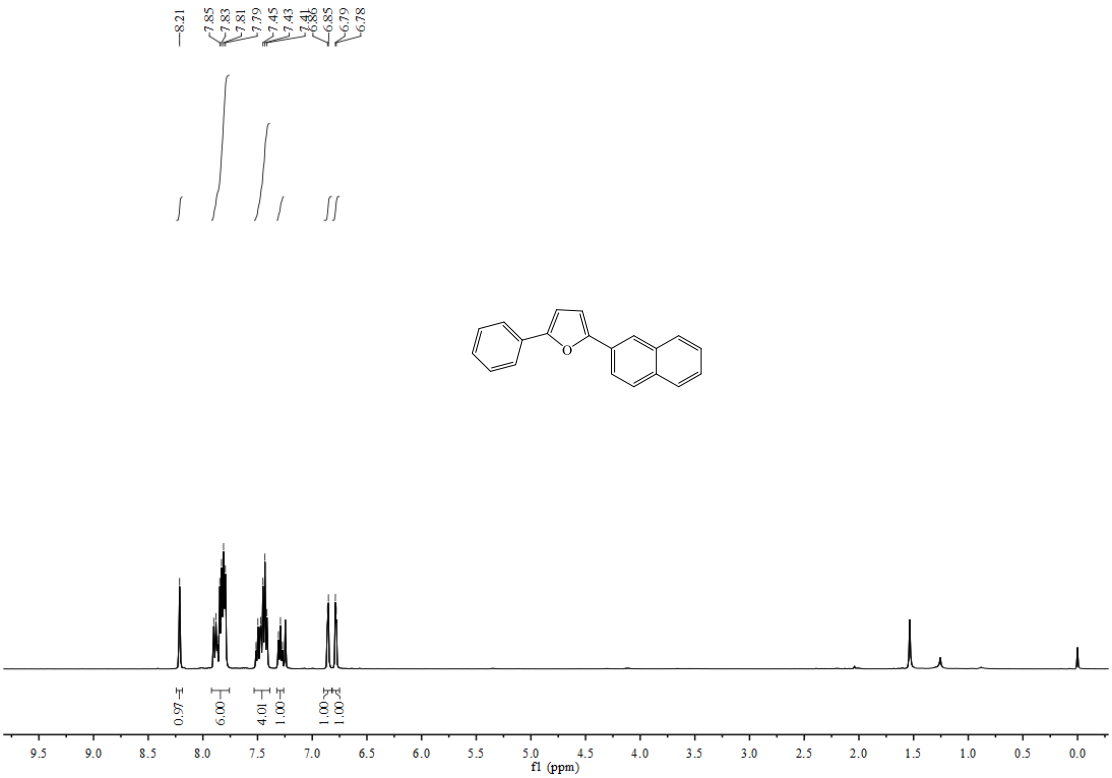
^{13}C NMR spectrum of **3p**



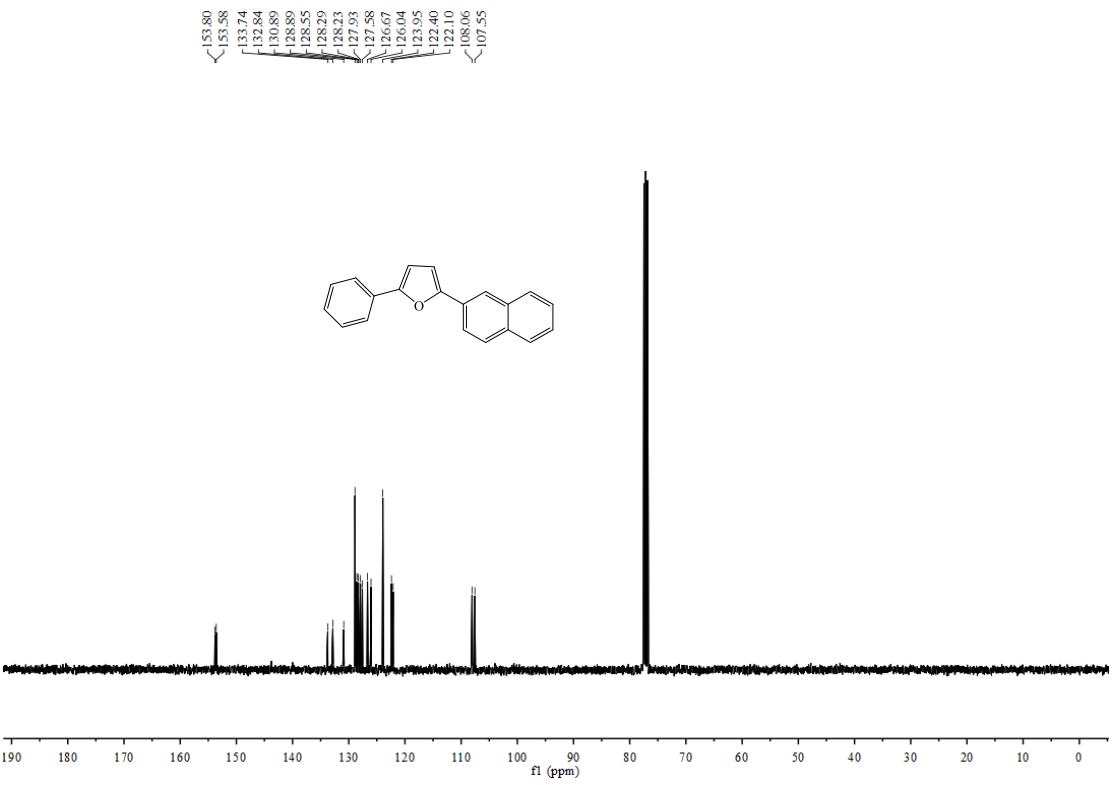
^{1}H NMR spectrum of **3r**



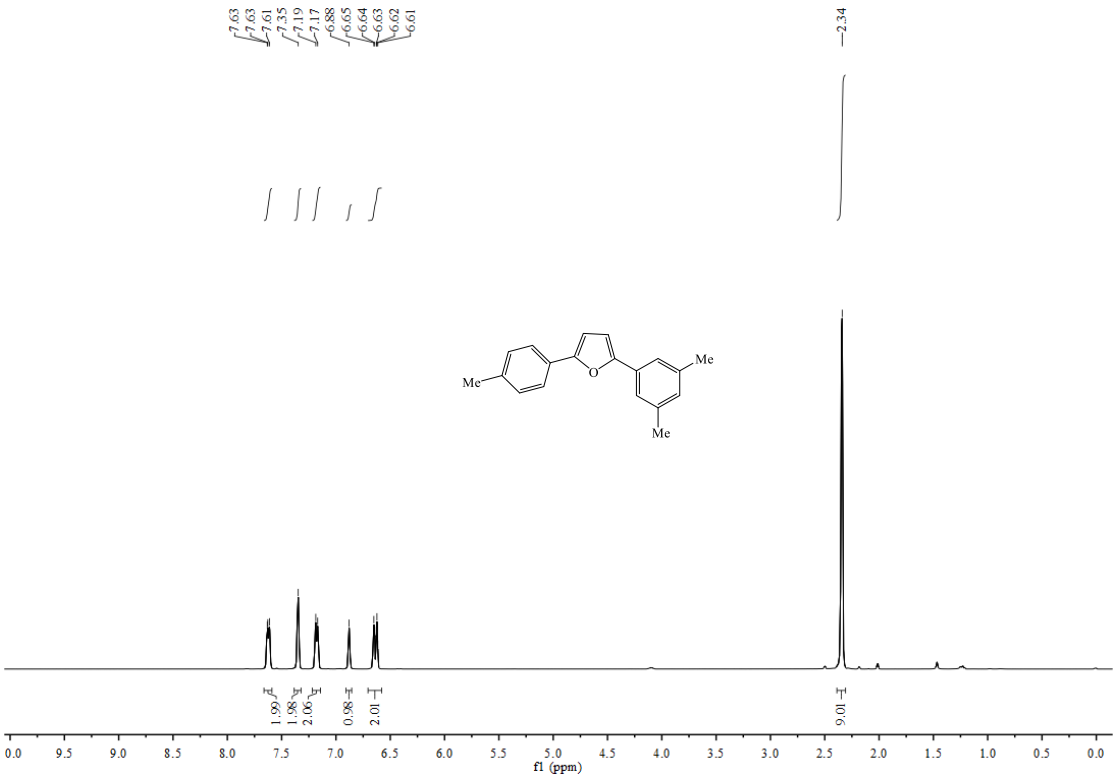
^{13}C NMR spectrum of **3r**



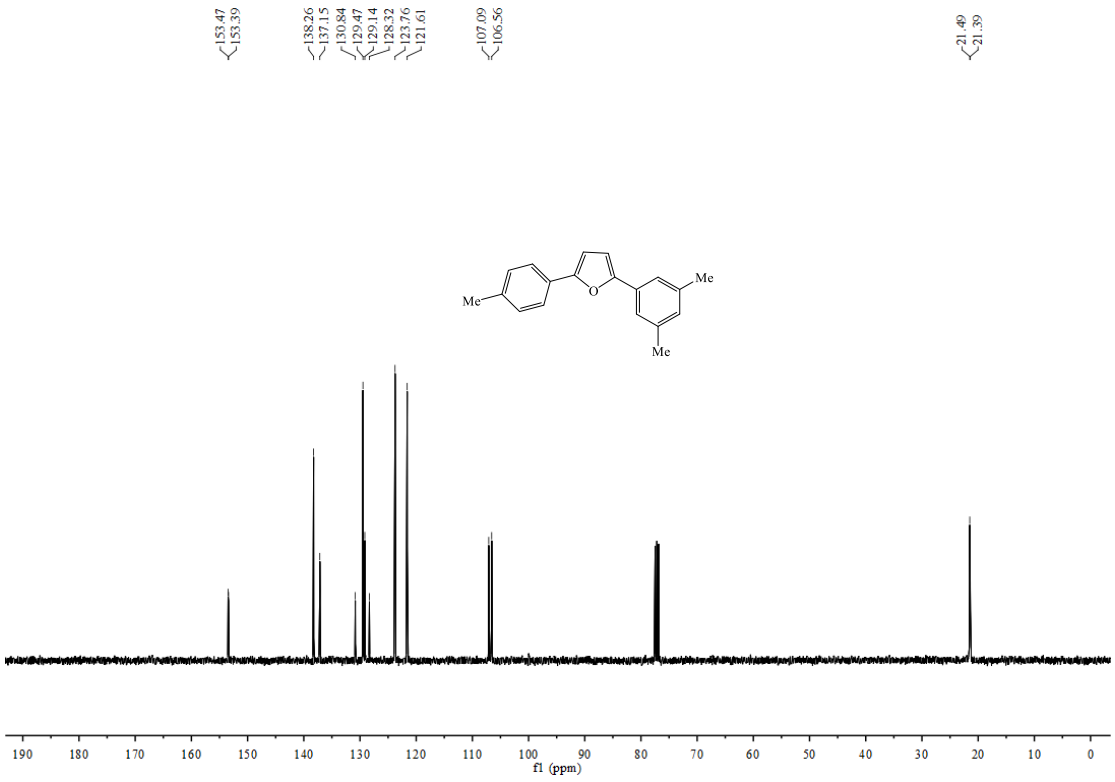
^{1}H NMR spectrum of **3s**



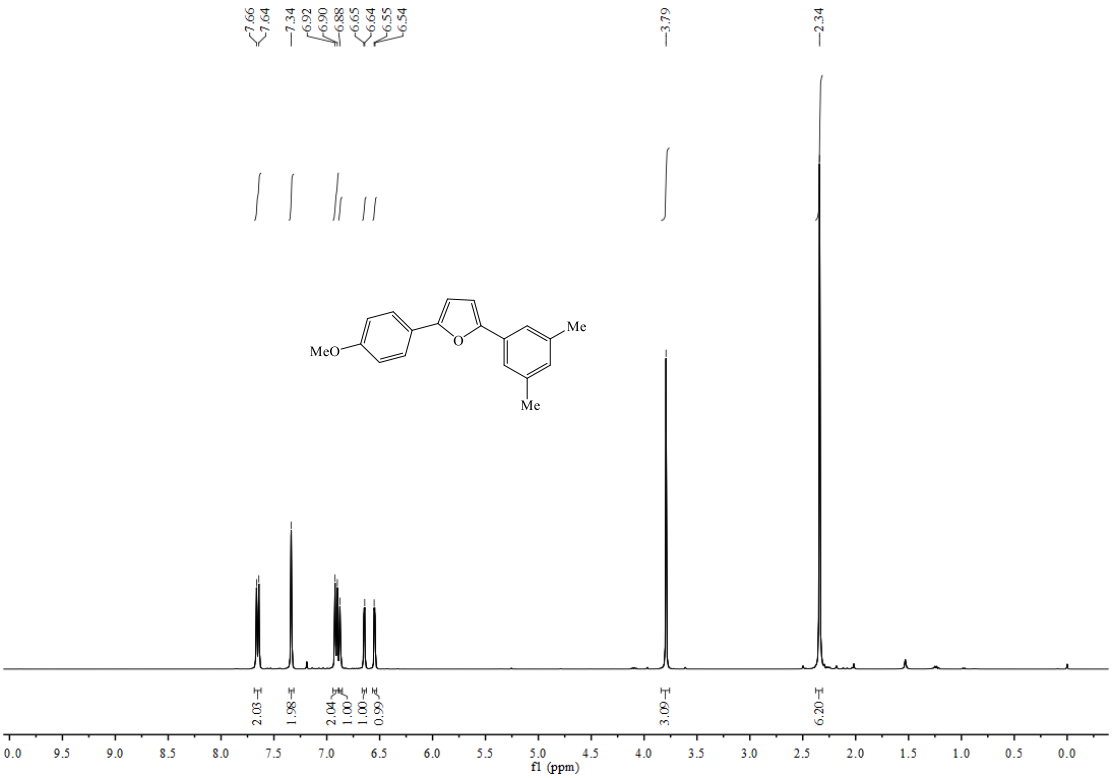
^{13}C NMR spectrum of **3s**



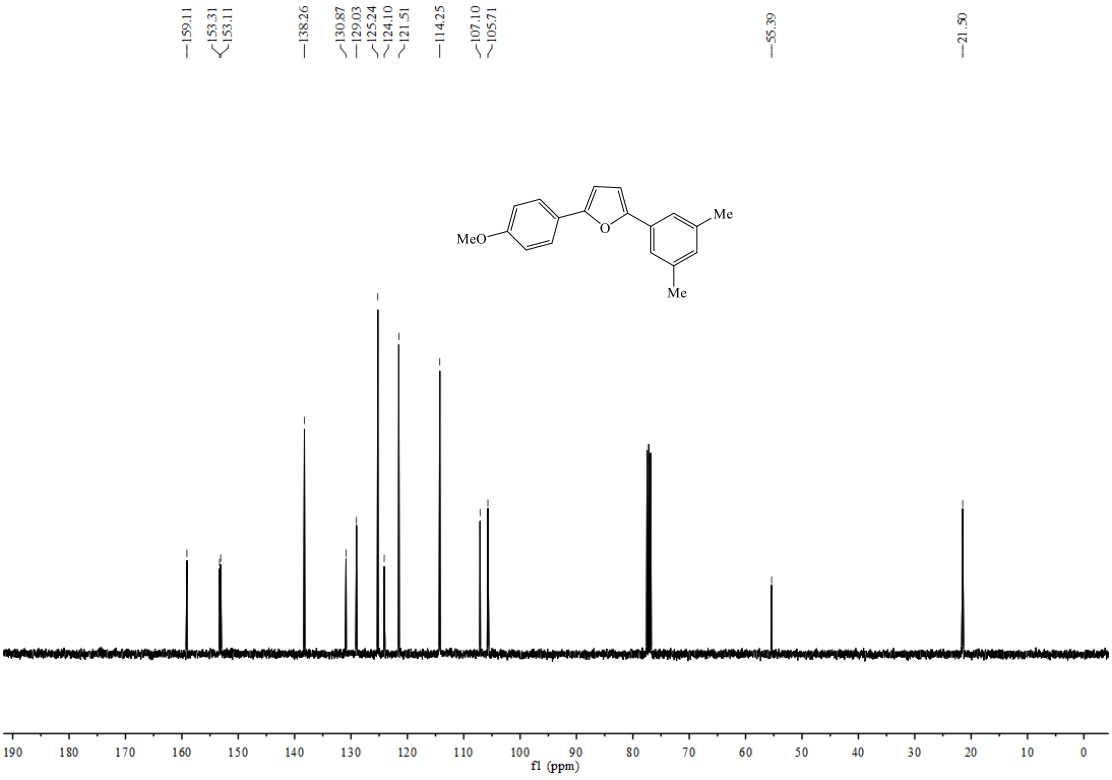
^{1}H NMR spectrum of **3t**



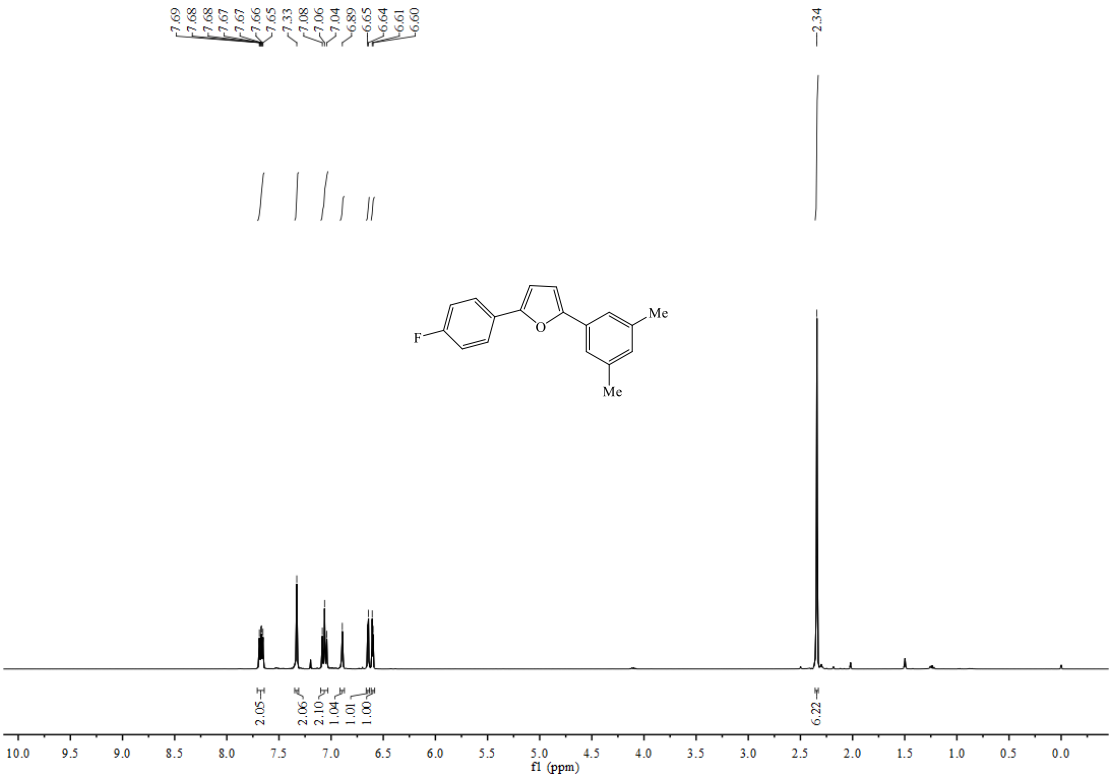
^{13}C NMR spectrum of **3t**



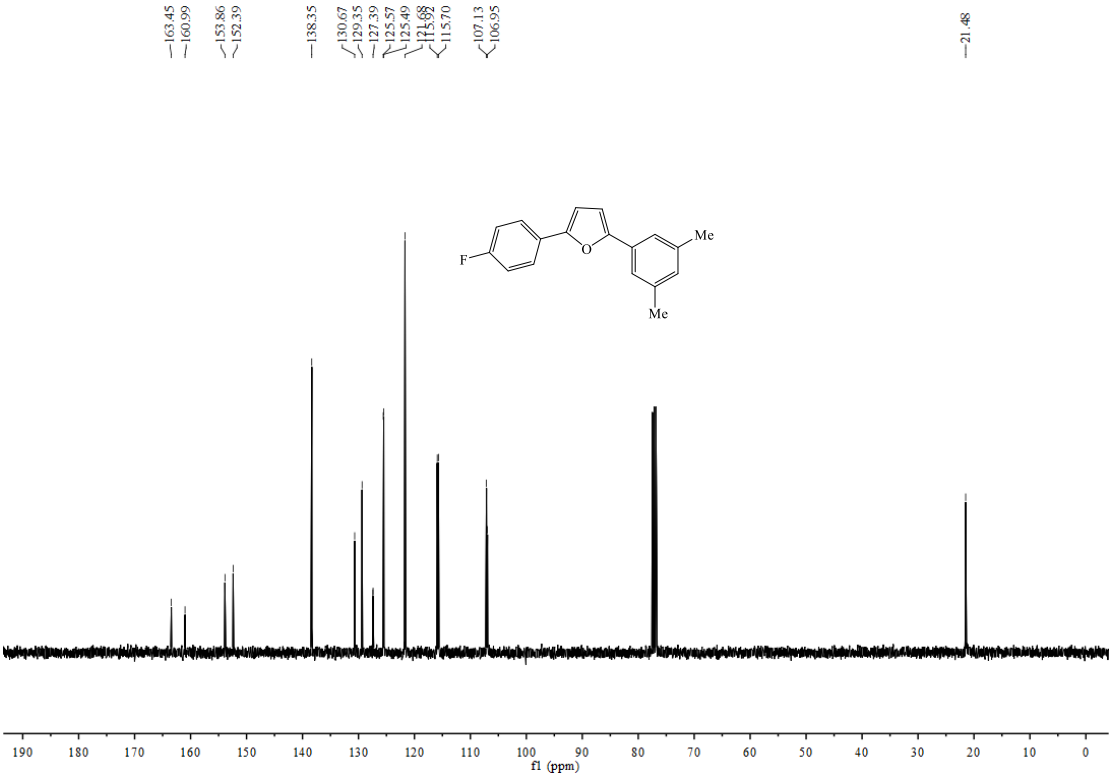
^{1}H NMR spectrum of **3u**



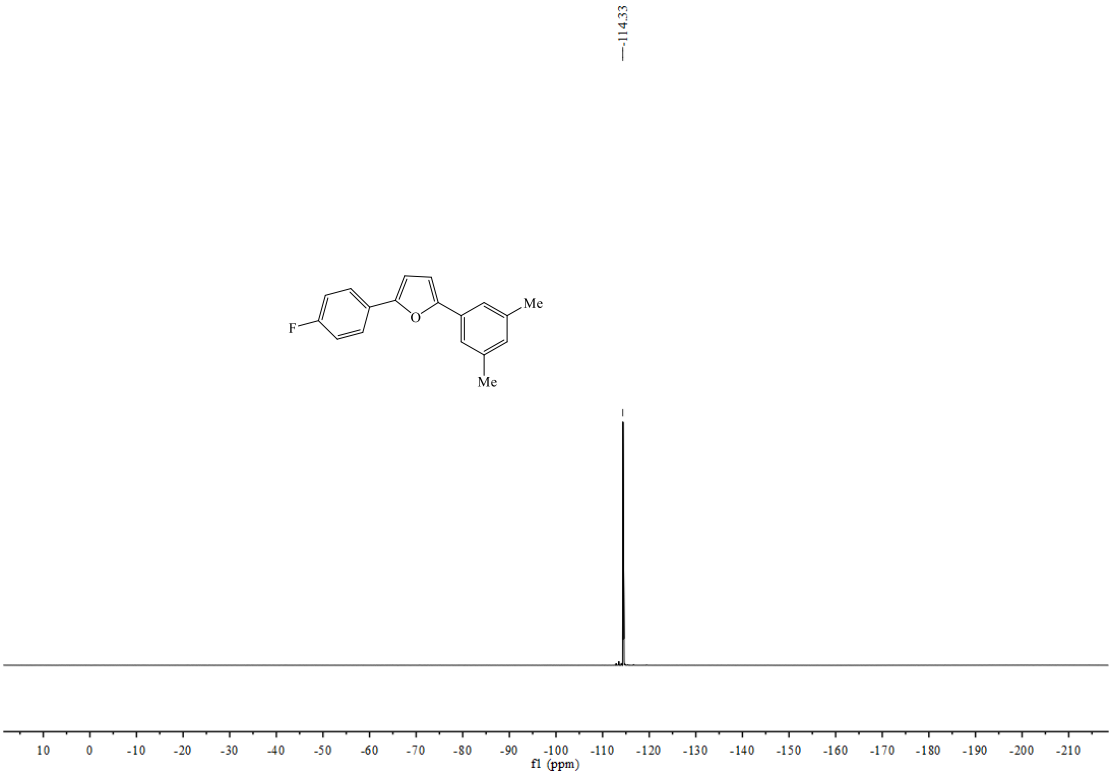
^{13}C NMR spectrum of **3u**



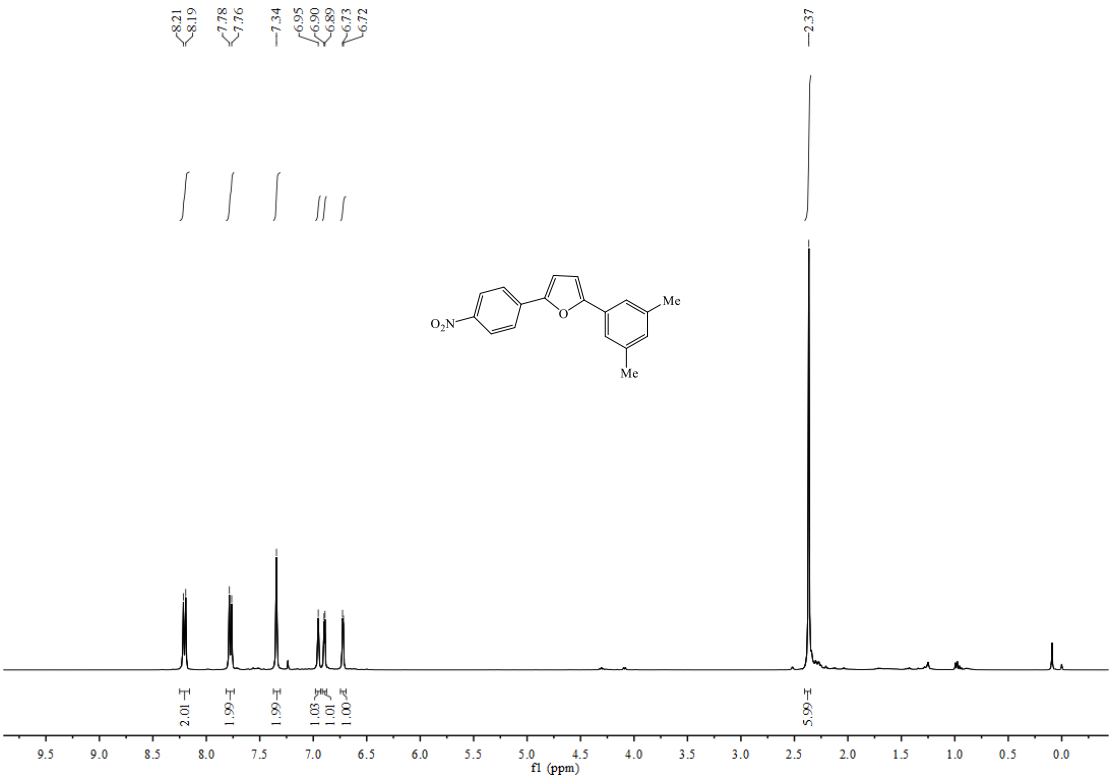
^{1}H NMR spectrum of **3v**



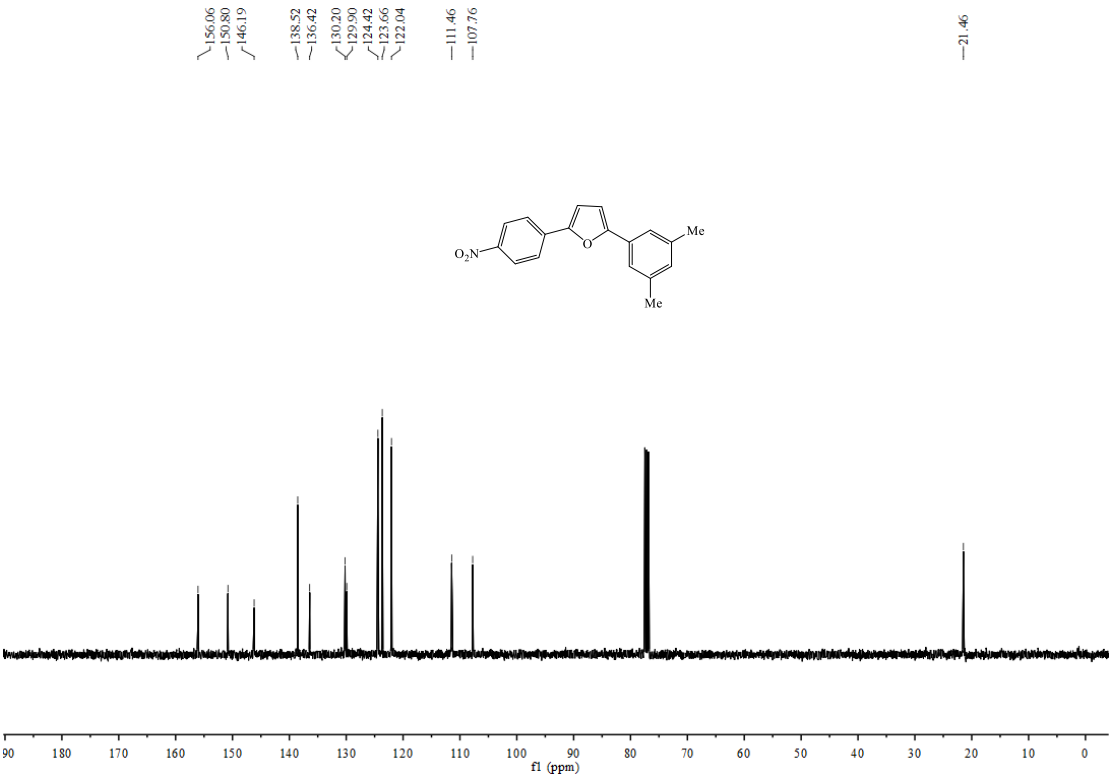
^{13}C NMR spectrum of **3v**



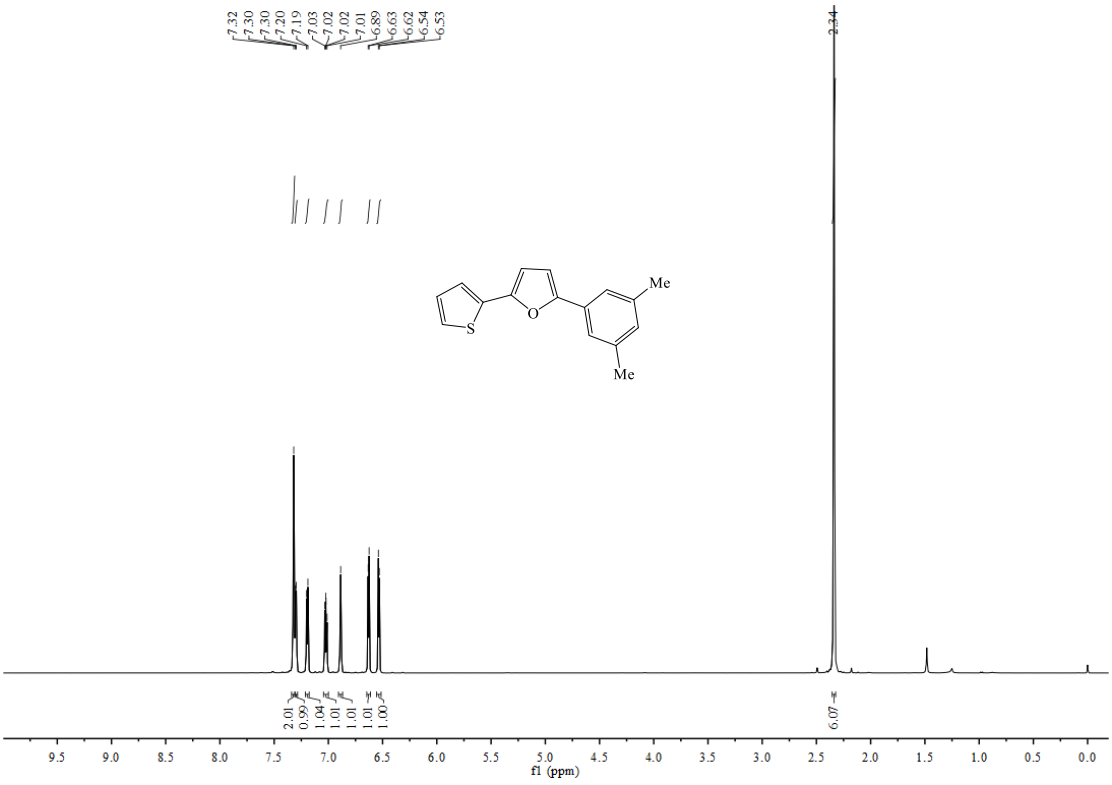
^{19}F NMR spectrum of **3v**



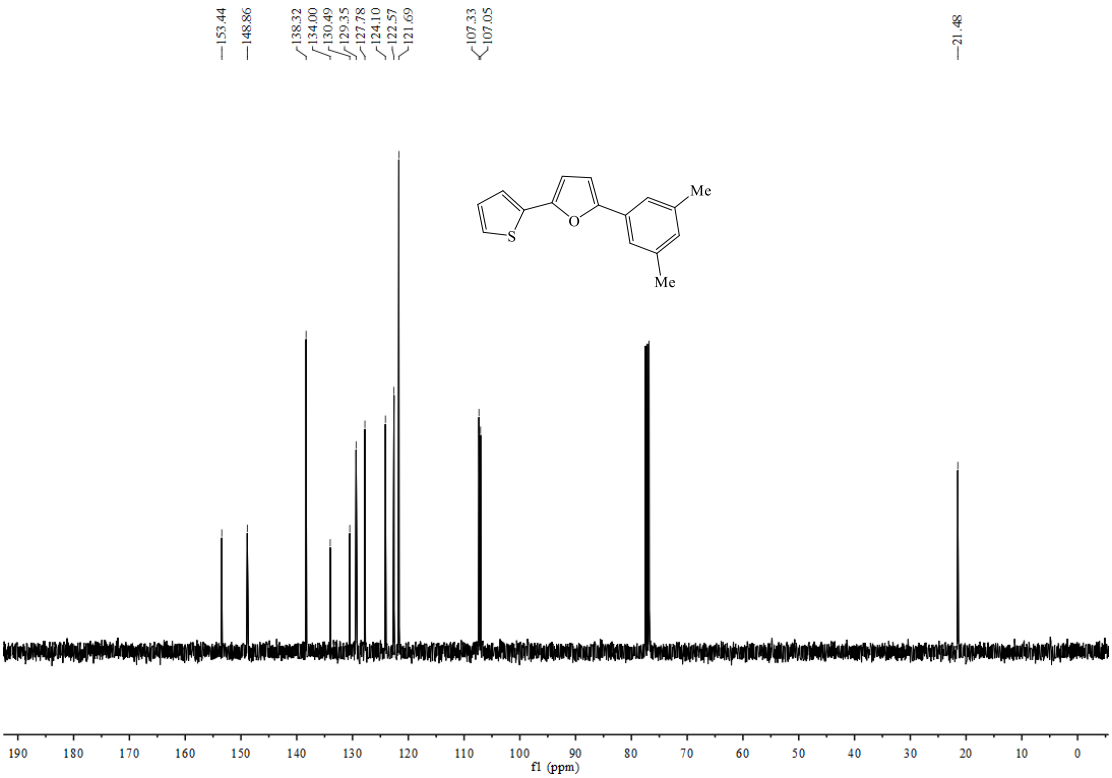
^{1}H NMR spectrum of **3w**



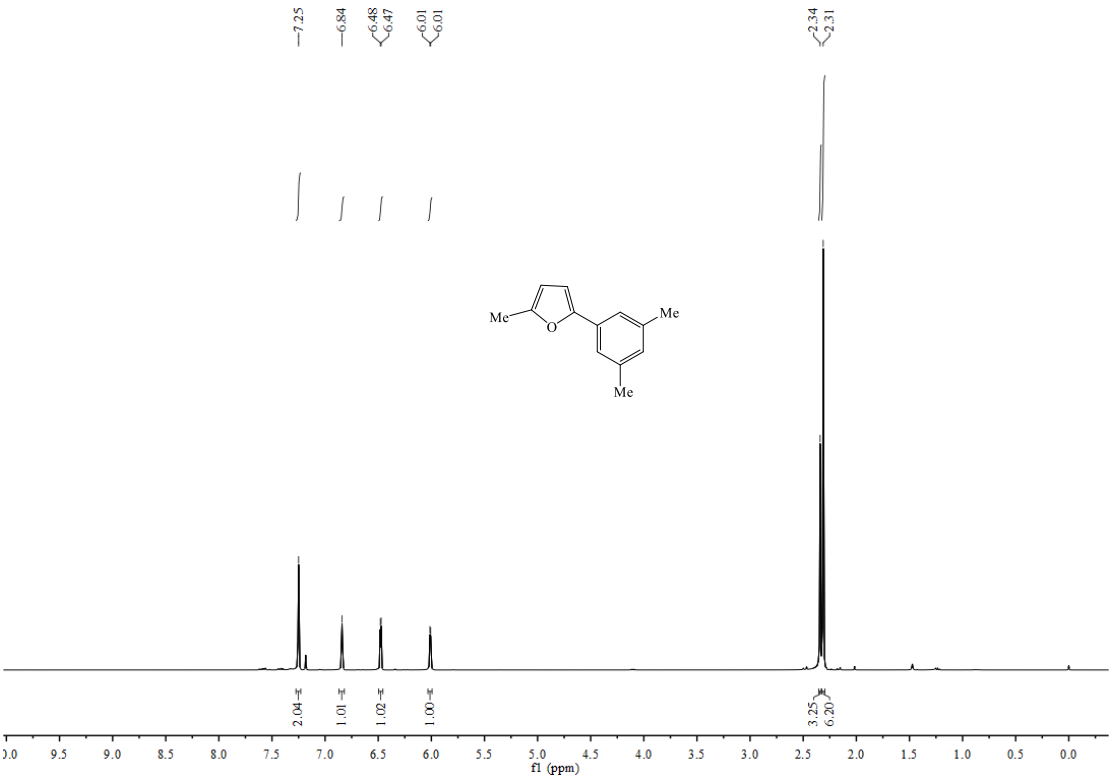
^{13}C NMR spectrum of **3w**



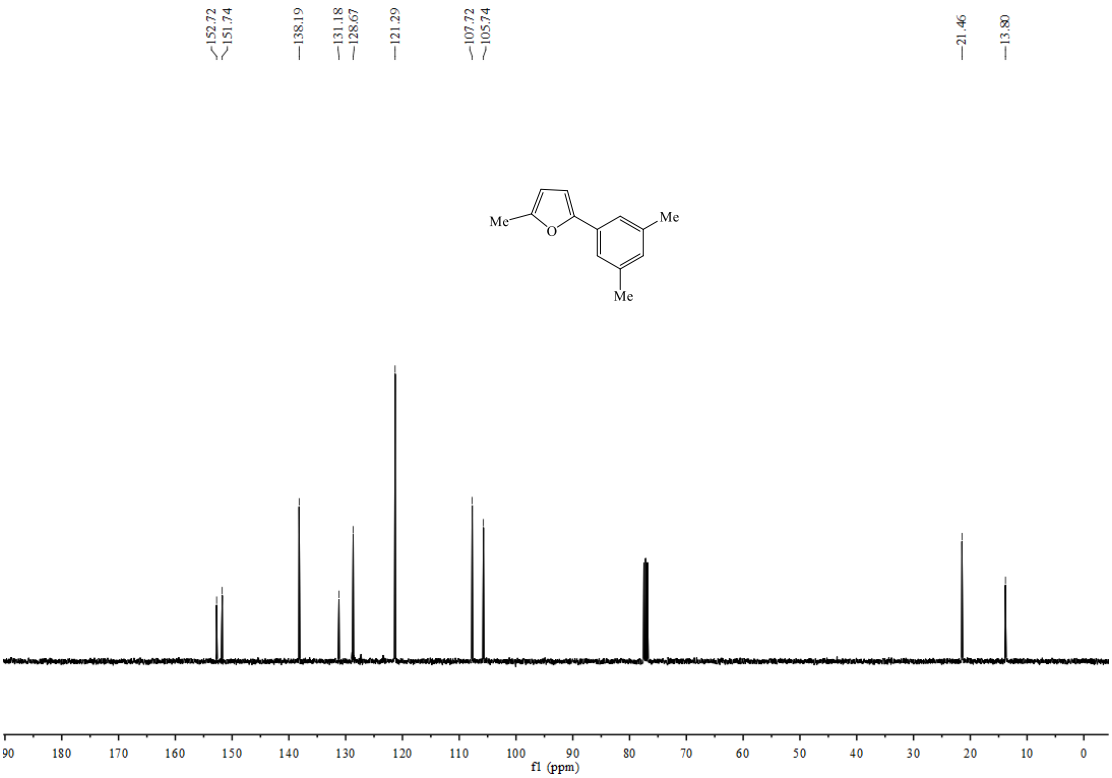
^{1}H NMR spectrum of **3x**



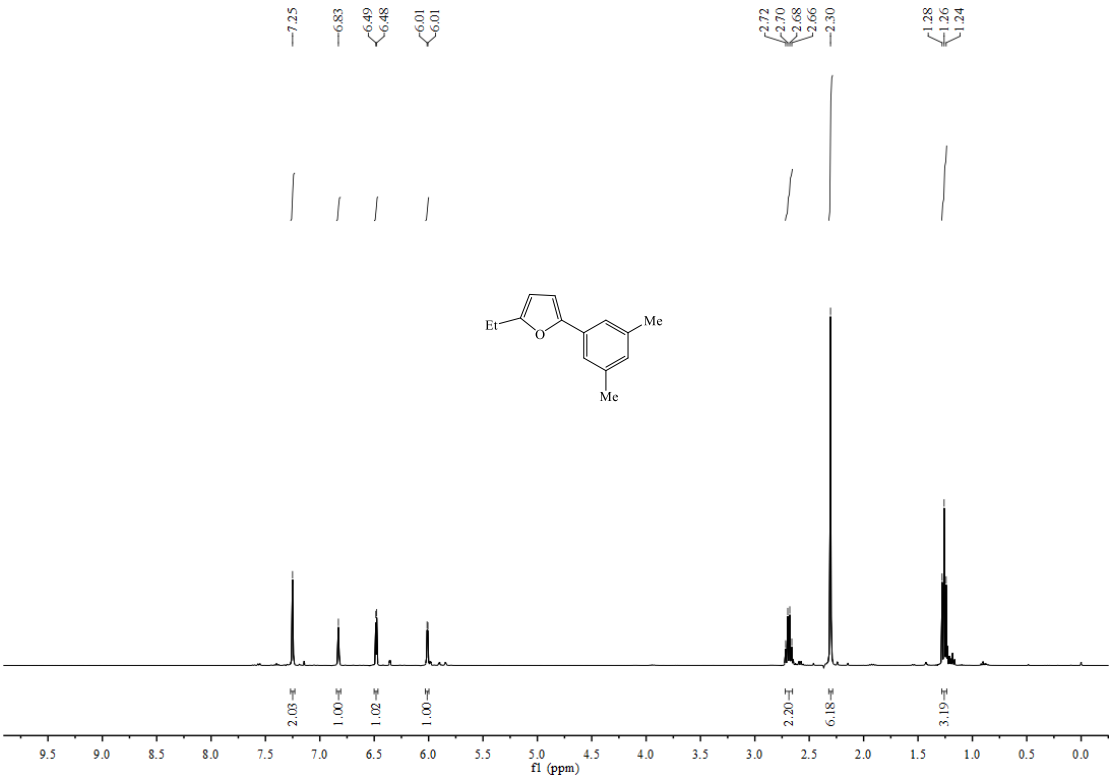
^{13}C NMR spectrum of **3x**



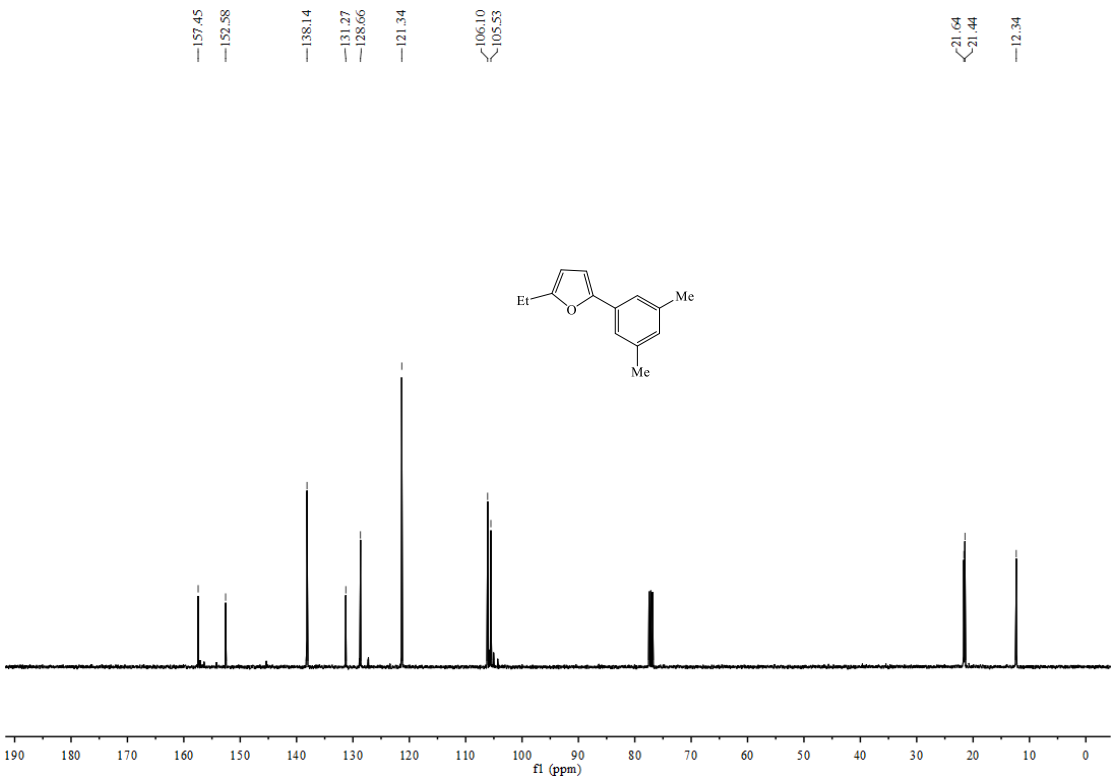
^{1}H NMR spectrum of **3y**



^{13}C NMR spectrum of **3y**



^{1}H NMR spectrum of **3z**



^{13}C NMR spectrum of **3z**