# Supporting Information

## *for*

# Palladacycles Derived from Arylphosphinamides for Mild Suzuki-Miyaura Cross-Couplings

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## Contents

## General Information

Unless otherwise stated, all starting materials were obtained from commercial supplies and used as received. Palladacyclic complex **3** were synthesized following the reported procedure.[1] The $^{1}H$ NMR spectra were recorded at 300, 400 MHz in $CDCl_3$ and the $^{13}C$ NMR spectra were recorded at 101 MHz in $CDCl_3$ or DMSO-$d_6$ with TMS as internal standard. All shifts are given in ppm. All coupling constants (*J* values) were reported in Hertz (Hz). Column chromatography was performed on silica gel with 100–200 mesh.

## Experimental procedures

**General procedure for cross-coupling under nitrogen atmosphere**:

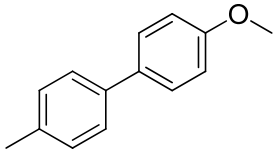
To a Schlenk tube equipped with a magnetic bar was charged solid aryl bromide or triflate (0.5 mmol), boronic acid (0.75 mmol), **3a** (1.0 mol%), anhydrous $K_3PO_4$ (1.5 mmol). The tube was then evacuated under vacuum and backfilled with $N_2$. EtOH (3.0 mL) was injected *via* syringe (the aryl bromide or triflate (0.5 mmol) was also added at this stage if it is liquid). The reaction mixture was stirred at rt or 50 $^{o}C$ until the arylbromide or triflate had disappeared as monitored by TLC. The reaction mixture was poured into water (30 mL) and then extracted with $CH_2Cl_2$ (20 mL × 3). The combined organic layer was dried over anhydrous $Na_2SO_4$, filtered and concentrated to dryness. The crude material was purified by flash chromatography on silica gel using a mixture of hexane and $CH_2Cl_2$ as eluents to give the desired cross-coupled products.

**General procedure for cross-coupling under air atmosphere**:

To a Schlenk tube equipped with a magnetic bar was charged solid aryl bromide or triflate (0.5 mmol), boronic acid (0.75 mmol), **3a** (1.0 mol%), anhydrous $K_3PO_4$ (1.5 mmol). EtOH (3.0 mL) was injected *via* syringe and the tube was sealed with a screw cap. The reaction mixture was stirred at rt until the arylbromide or triflate had disappeared as monitored by TLC. The reaction mixture was poured into water (30 mL) and then extracted with $CH_2Cl_2$ (20 mL × 3). The combined organic layer was dried over anhydrous $Na_2SO_4$, filtered and concentrated to dryness. The crude material was purified by flash chromatography on silica gel using a mixture of hexane and $CH_2Cl_2$ as eluents to give the desired cross-coupled products.

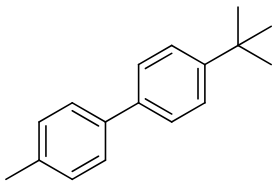
## Product characterization

**4-methoxy-4'-methyl-1,1'-biphenyl (7a)**[2]



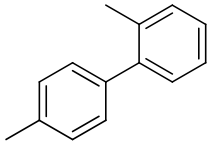
$^{1}H$ NMR (300 MHz, $CDCl_3$) δ 7.53 (d, *J* = 9.0 Hz, 2H), 7.47 (d, *J* = 9.0 Hz, 2H), 7.25 (d, *J* = 9.0 Hz, 2H), 6.99 (d, *J* = 9.0 Hz, 2H), 3.87 (s, 3H), 2.40 (s, 3H).

**4-(*tert*-butyl)-4'-methyl-1,1'-biphenyl (7b)**[3,4]



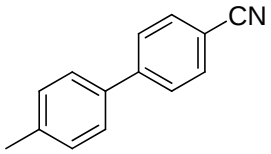
$^1$H NMR (300 MHz, $CDCl_3$) δ 7.57–7.44 (m, 6H), 7.27–7.23 (m, 2H), 2.41 (s, 3H), 1.38 (s, 9H).

**2,4'-dimethyl-1,1'-biphenyl (7c)**[5]



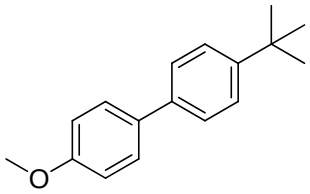
$^1$H NMR (300 MHz, $CDCl_3$) δ 7.30–7.22 (m, 8H), 2.43 (s, 3H), 2.30 (s, 3H).

**4'-methyl-[1,1'-biphenyl]-4-carbonitrile (7d)**[4]



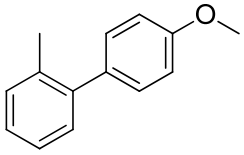

$^1$H NMR (300 MHz, $CDCl_3$) δ 7.75–7.66 (m, 4H), 7.52 (d, *J* = 9.0 Hz, 2H), 7.31 (d, *J* = 9.0 Hz, 2H), 2.43 (s, 3H).

**4-(*tert*-butyl)-4'-methoxy-1,1'-biphenyl (7e)**[3]



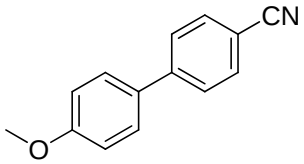

$^1$H NMR (300 MHz, $CDCl_3$) δ 7.57–7.44 (m, 6H), 7.01–6.96 (m, 2H), 3.87 (s, 3H), 1.38 (s, 9H).

**4'-methoxy-2-methyl-1,1'-biphenyl (7f)**[6,7]



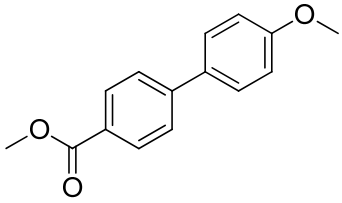

$^1$H NMR (300 MHz, $CDCl_3$) δ 7.33–7.25 (m, 6H), 7.03–6.96 (m, 2H), 3.89 (s, 3H), 2.32 (s, 3H).

**4'-methoxy-[1,1'-biphenyl]-4-carbonitrile (7g)**[8]



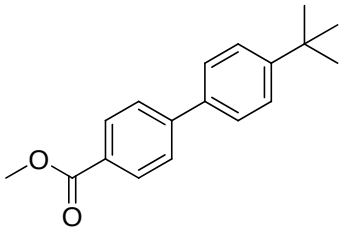

$^1$H NMR (300 MHz, $CDCl_3$) δ 7.74–7.63 (m, 4H), 7.58–7.53 (m, 2H), 7.06–6.99 (m, 2H), 3.89 (s, 3H).

**methyl 4'-methoxy-[1,1'-biphenyl]-4-carboxylate (7h)**[2,8,9]



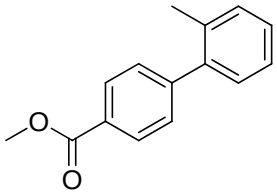

$^1$H NMR (300 MHz, $CDCl_3$) δ 8.10 (d, *J* = 9.0 Hz, 2H), 7.65–7.59 (m, 4H), 7.02 (d, *J* = 9.0 Hz, 2H), 3.95 (s, 3H), 3.88 (s, 3H).

**methyl 4'-(tert-butyl)-[1,1'-biphenyl]-4-carboxylate (7i)**[10]



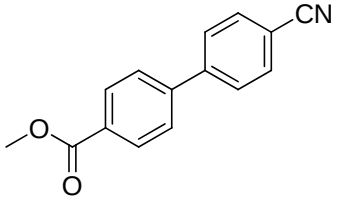

$^1$H NMR (300 MHz, $CDCl_3$) δ 8.12 (d, *J* = 9.0 Hz, 2H), 7.68 (d, *J* = 9.0 Hz, 2H), 7.60 (d, *J* = 9.0 Hz, 2H), 7.52 (d, *J* = 9.0 Hz, 2H), 3.96 (s, 3H), 1.39 (s, 9H).

**methyl 2'-methyl-[1,1'-biphenyl]-4-carboxylate (7j)**[8]




$^1$H NMR (400 MHz, $CDCl_3$) δ 8.06 (d, *J* = 9.0 Hz, 2H), 7.37 (d, *J* = 9.0 Hz, 2H), 7.27–7.18 (m, 4H), 3.92 (s, 3H), 2.24 (s, 3H).

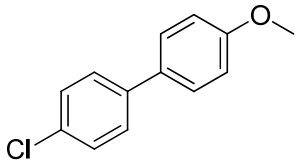
**methyl 4'-cyano-[1,1'-biphenyl]-4-carboxylate (7k)**[8,9]




$^1$H NMR (300 MHz, $CDCl_3$) δ 8.19 (d, *J* = 9.0 Hz, 2H), 7.81–7.71 (m, 4H), 7.68 (d, *J*

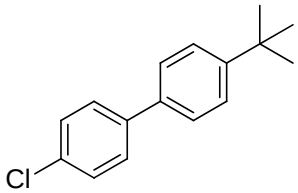
= 9.0 Hz, 2H), 3.97 (s, 3H).

**4-chloro-4'-methoxy-1,1'-biphenyl (7l)**[11]



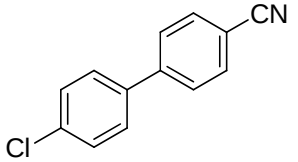

$^1$H NMR (300 MHz, $CDCl_3$) δ 7.54–7.46 (m, 4H), 7.43–7.36 (m, 2H), 7.02–6.96 (m, 2H), 3.87 (s, 3H).

**4-(tert-butyl)-4'-chloro-1,1'-biphenyl (7m)**



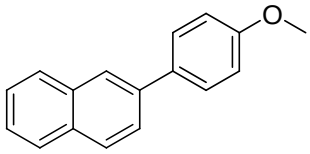

$^1$H NMR (300 MHz, $CDCl_3$) δ 7.56–7.45 (m, 6H), 7.43–7.37 (m, 2H), 1.38 (s, 9H).
$^1$H NMR (300 MHz, CDCl3) δ 7.56–7.45 (m, 6H), 7.43–7.37 (m, 2H), 1.38 (s, 9H).
$^{13}$C NMR (101 MHz, CDCl3) δ 150.6, 139.4, 136.9, 132.9, 128.7, 128.1, 126.5, 125.7, 34.5, 31.2.

**4'-chloro-[1,1'-biphenyl]-4-carbonitrile (7n)**[9]



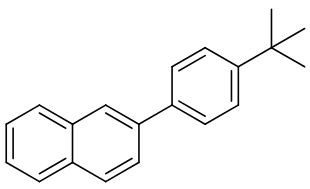

$^1$H NMR (300 MHz, $CDCl_3$) δ 7.78–7.64 (m, 4H), 7.57–7.45 (m, 4H).

**2-(4-methoxyphenyl)naphthalene (7o)**[2,4,6,7]



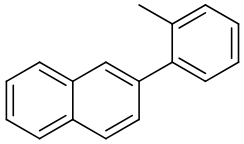

$^1$H NMR (300 MHz, $CDCl_3$) δ 8.01 (s, 1H), 7.94–7.84 (m, 3H), 7.78–7.65 (m, 3H), 7.55–7.45 (m, 2H), 7.05 (d, *J* = 9.0 Hz, 2H), 3.90 (s, 3H).

**2-(4-(tert-butyl)phenyl)naphthalene (7p)**[3]



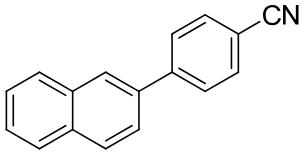
$^1$H NMR (300 MHz, $CDCl_3$) δ 8.06 (s, 1H), 7.95–7.85 (m, 3H), 7.80–7.75 (m, 1H), 7.70 (d, *J* = 9.0 Hz, 2H), 7.57–7.46 (m, 4H), 1.41 (s, 9H).

**2-(o-tolyl)naphthalene (7q)**[2,6]



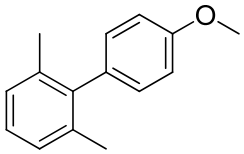
$^1$H NMR (400 MHz, $CDCl_3$) δ 7.91–7.84 (m, 3H), 7.77 (s, 1H), 7.53–7.45 (m, 3H), 7.35–7.25 (m, 4H), 2.31 (s, 3H).

**4-(naphthalen-2-yl)benzonitrile (7r)**[12]



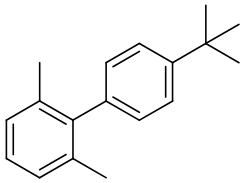

$^1$H NMR (300 MHz, $CDCl_3$) δ 8.08 (s, 1H), 8.00–7.70 (m, 8H), 7.60–7.54 (m, 2H).

**4'-methoxy-2,6-dimethyl-1,1'-biphenyl (7s)**[7]



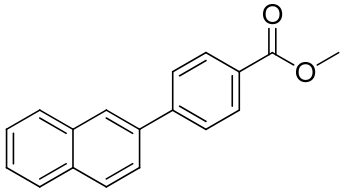

$^1$H NMR (300 MHz, $CDCl_3$) δ 7.18–7.05 (m, 5H), 6.98 (d, *J* = 6 Hz, 2H), 3.88 (s, 3H), 2.06 (s, 6H).

**4'-(tert-butyl)-2,6-dimethyl-1,1'-biphenyl (7t)**[13]



$^1$H NMR (300 MHz, $CDCl_3$) δ 7.46–7.41 (m, 2H), 7.21–7.05 (m, 5H), 2.06 (s, 6H), 1.39 (s, 9H).

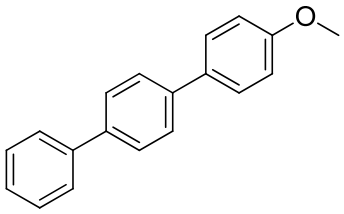
**methyl 4-(naphthalen-2-yl)benzoate (7u)**[6]




$^1$H NMR (300 MHz, CDCl3) δ 8.20–8.09 (m, 3H), 7.99–7.87 (m, 3H), 7.85–7.76 (m,

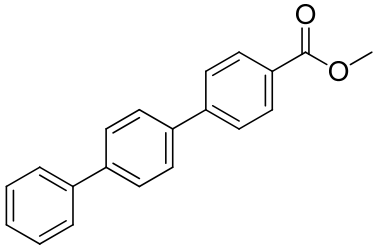
3H), 7.59–7.50 (m, 2H), 3.98 (s, 3H).

**4-methoxy-1,1':4',1''-terphenyl (7v)** [2,7]



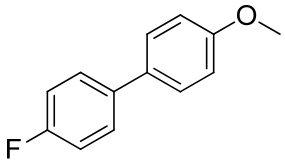
$^1$H NMR (300 MHz, CDCl3) δ 7.70–7.57 (m, 8H), 7.52–7.44 (m, 2H), 7.41–7.34 (m, 1H), 7.02 (d, *J* = 6.0 Hz, 2H), 3.89 (s, 3 H).

**methyl [1,1':4',1''-terphenyl]-4-carboxylate (7w)** [14]



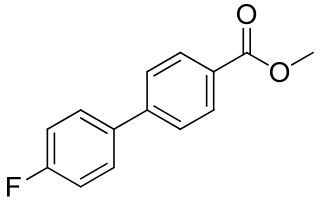
$^1$H NMR (300 MHz, CDCl3) δ 8.15 (d, J = 9.0 Hz, 2H), 7.77–7.64 (m, 8H), 7.54–7.45 (m, 2H), 7.45–7.36 (m, 1H), 3.97 (s, 3H).

**4-fluoro-4'-methoxy-1,1'-biphenyl (7x)**[2,6,11]



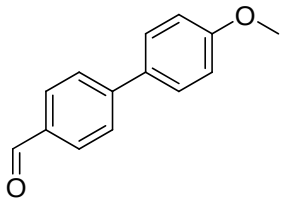
$^1$H NMR (300 MHz, CDCl3) δ 7.55–7.46 (m, 4H), 7.16–7.06 (m, 2H), 7.00 (d, *J* = 9.0 Hz, 2H), 3.87 (s, 3H).

**methyl 4'-fluoro-[1,1'-biphenyl]-4-carboxylate (7y)**[2]



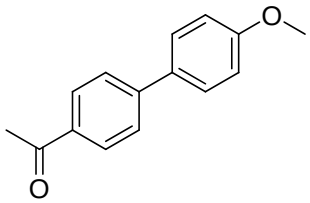
$^1$H NMR (300 MHz, $CDCl_3$) δ 8.14–8.10 (m, 2H), 7.65–7.58 (m, 4H), 7.21–7.13 (m, 2H), 3.96 (s, 3H).

**4'-methoxy-[1,1'-biphenyl]-4-carbaldehyde (7z)**[15]



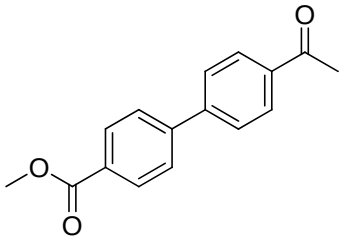
$^1$H NMR (300 MHz, $CDCl_3$) δ 10.06 (s, 1H), 7.95 (d, *J* = 9.0 Hz, 2H), 7.74 (d, *J* = 9.0 Hz, 2H), 7.62 (d, *J* = 9.0 Hz, 2H), 7.04 (d, *J* = 9.0 Hz, 2H), 3.89 (s, 3H).

**1-(4'-methoxy-[1,1'-biphenyl]-4-yl)ethanone (7aa)**[2]



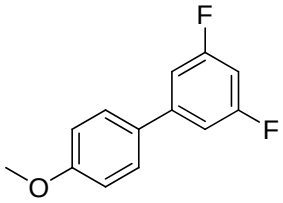
$^1$H NMR (300 MHz, $CDCl_3$) δ 8.03 (d, *J* = 9.0 Hz, 2H), 7.67 (d, *J* = 9.0 Hz, 2H), 7.61 (d, *J* = 9.0 Hz, 2H), 7.03 (d, *J* = 9.0 Hz, 2H), 3.89 (s, 3H), 2.65 (s, 3H).

**methyl 4'-acetyl-[1,1'-biphenyl]-4-carboxylate (7ab)**[9]



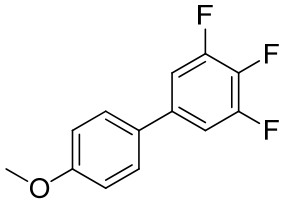
$^1$H NMR (400 MHz, $CDCl_3$) δ 8.14 (d, *J* = 6.0 Hz, 2H), 8.06 (d, *J* = 6.0 Hz, 2H), 7.71 (t, *J* = 6.0 Hz, 4H), 3.95 (s, 3H), 2.65 (s, 3H).

**3,5-difluoro-4'-methoxy-1,1'-biphenyl (10a)**[16]



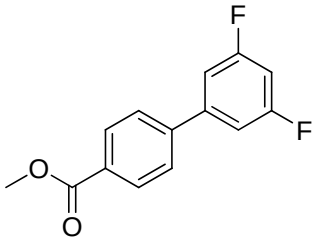
$^1$H NMR (300 MHz, $CDCl_3$) δ 7.51 (d, *J* = 9.0 Hz, 2H), 7.13–6.96 (m, 4H), 6.80–6.69 (m, 1H), 3.87 (s, 3H).

**3,4,5-trifluoro-4'-methoxy-1,1'-biphenyl (10b)**[17]



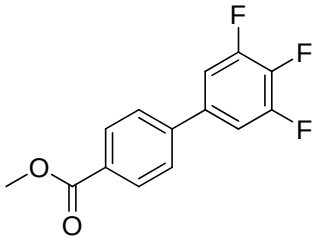
$^1$H NMR (300 MHz, $CDCl_3$) δ 7.45 (d, *J* = 9.0 Hz, 2H), 7.20–7.09 (m, 2H), 7.00 (d, *J* = 9.0 Hz, 2H), 3.87 (s, 3H).

**methyl 3',5'-difluoro-[1,1'-biphenyl]-4-carboxylate (10c)**



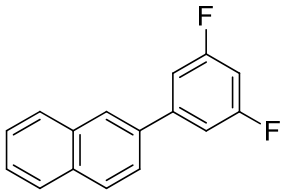

$^1$H NMR (300 MHz, $CDCl_3$) δ 8.14 (d, J = 9.0 Hz, 2H), 7.64 (d, *J* = 9.0 Hz, 2H), 7.20–7.10 (m, 2H), 6.90-6.80 (m, 1H), 3.97 (s, 3H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 166.6, 163.4 (dd, *J* = 13.1, 249.5 Hz), 143.3 (t, *J* = 10.1 Hz), 143.1, 130.3, 130.1, 127.0, 110.2 (dd, *J* = 7.1, 19.2 Hz), 103.35 (t, *J* = 25.3 Hz), 52.2.

**methyl 3',4',5'-trifluoro-[1,1'-biphenyl]-4-carboxylate (10d)**



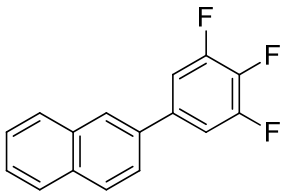

$^1$H NMR (300 MHz, $CDCl_3$) δ 8.14 (d, *J* = 9.0 Hz, 2H), 7.59 (d, *J* = 9.0 Hz, 2H), 7.29–7.20 (m, 2H), 3.97 (s, 3H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 166.5, 151.5 (dd, *J* = 4.0, 9.1, 252.5 Hz), 142.4, 139.8 (td, *J* = 15.2, 254.5 hz), 136.1, 130.3, 130.1, 126.8, 111.3 (dd, *J* = 6.1, 16.2 Hz), 52.2.

**2-(3,5-difluorophenyl)naphthalene (10e)**



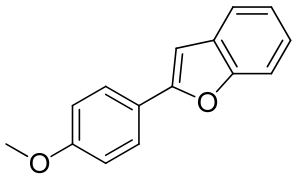

$^1$H NMR (300 MHz, $CDCl_3$) δ 8.07–7.86 (m, 4H), 7.74–7.65 (m, 1H), 7.60–7.50 (m, 2H), 7.29–7.20 (m,2H), 6.88–6.77 (m, 1H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 162.9 (dd, *J* = 14.1, 249.5 Hz), 144.0 (t, *J* = 10.1 Hz), 135.7, 133.0, 132.7, 128.4, 127.9, 127.2, 126.2, 126.1, 125.7, 124.4, 109.7 (dd, *J* = 7.1, 18.2 Hz), 102.1 (t, *J* = 25.3 Hz).

**2-(3,4,5-trifluorophenyl)naphthalene (10f)**



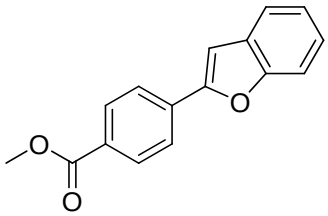

$^{1}$H NMR (300 MHz, $CDCl_3$) δ 8.00–7.86 (m, 4H), 7.67–7.51 (m, 3H), 7.39–7.30 (m, 2H). $^{13}$C NMR (101 MHz, $CDCl_3$) δ 151.0 (ddd, *J* = 4.0, 10.1, 251.5 Hz), 138.8 (td, *J* = 15.2, 253.5 Hz), 136.8, 135.0, 133.0, 132.5, 128.5, 127.8, 127.2, 126.3, 126.2, 125.5, 124.1, 110.8 (dd, *J* = 6.1, 17.2 Hz).

**2-(4-methoxyphenyl)benzofuran (11a)**[18]



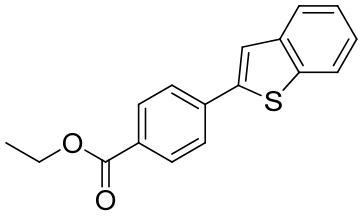

$^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.77 (d, *J* = 6.0 Hz, 2H), 7.54–7.45 (m, 2H), 7.26–7.15 (m, 2H), 6.95 (d, *J* = 6.0 Hz, 2H), 6.86 (s, 1H), 3.83 (s, 3H).

**methyl 4-(benzofuran-2-yl)benzoate (11b)**[19]



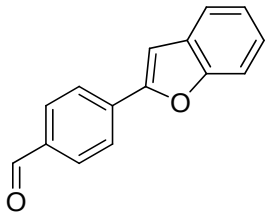

$^{1}$H NMR (400 MHz, $CDCl_3$) δ 8.14 (d, *J* = 9.0 Hz, 2H), 7.95 (d, *J* = 9.0 Hz, 2H), 7.66–7.53 (m, 2H), 7.38–7.25 (m, 2H), 7.18 (s, 1H), 3.96 (s, 3H).

**ethyl 4-(benzo[b]thiophen-2-yl)benzoate (11c)**[20]



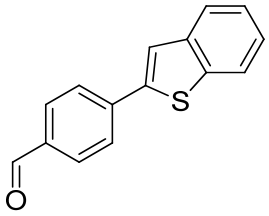

$^{1}$H NMR (400 MHz, $CDCl_3$) δ 8.12 (d, *J* = 9.0 Hz, 2H), 7.89–7.76 (m, 4H), 7.68 (s, 1H), 7.43–7.33 (m, 2H), 4.43 (q, *J* = 6.0 Hz, 2H), 1.44 (t, *J* = 6.0 Hz, 3H).

**4-(benzofuran-2-yl)benzaldehyde (11d)**[21]



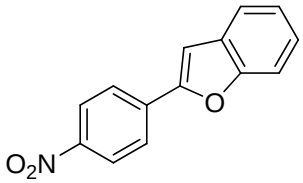
$^1$H NMR (300 MHz, $CDCl_3$) δ 10.06 (s, 1H), 8.05 (d, *J* = 9.0 Hz, 2H), 7.98 (d, *J* = 9.0 Hz, 2H), 7.68–7.55 (m, 2H), 7.40–7.25 (m, 2H), 7.23 (s, 1H).

**4-(benzo[b]thiophen-2-yl)benzaldehyde (11e)**[22]



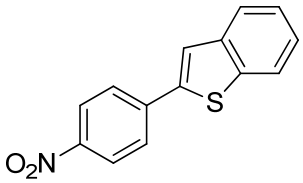
$^1$H NMR (300 MHz, $CDCl_3$) δ 10.06 (s, 1H), 7.98–7.82 (m, 6H), 7.73 (s, 1H), 7.44–7.35 (m, 2H).

**2-(4-nitrophenyl)benzofuran (11f)**[18]



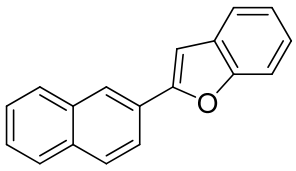
$^1$H NMR (300 MHz, $CDCl_3$) δ 8.34 (d, *J* = 9.0 Hz, 2H), 8.03 (d, *J* = 9.0 Hz, 2H), 7.70–7.55 (m, 2H), 7.43–7.25 (m, 3H).

**2-(4-nitrophenyl)benzo[b]thiophene (11g)**[23]



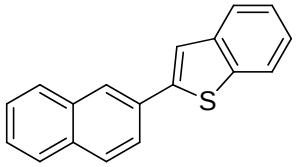
$^1$H NMR (300 MHz, $CDCl_3$) δ 8.32 (d, *J* = 9.0 Hz, 2H), 7.91–7.83 (m, 4H), 7.74 (s, 1H), 7.46–7.37 (m, 2H).

**2-(naphthalen-2-yl)benzofuran (11h)**[6,24]



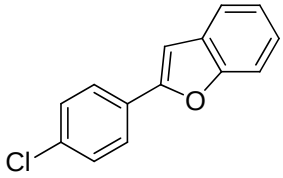
$^1$H NMR (300 MHz, $CDCl_3$) δ 8.40 (s, 1H), 7.98–7.85 (m, 4H), 7.66–7.48 (m, 4H), 7.37–7.24 (m, 2H), 7.17 (s, 1H).

**2-(naphthalen-2-yl)benzo[b]thiophene (11i)**[20]



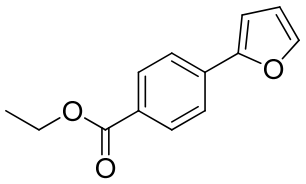

$^1$H NMR (300 MHz, $CDCl_3$) δ 8.17 (s, 1H), 7.94–7.81 (m, 6H), 7.70 (s, 1H), 7.58–7.48 (m, 2H), 7.43–7.33 (m, 2H).

**2-(4-chlorophenyl)benzofuran (11j)**[24]



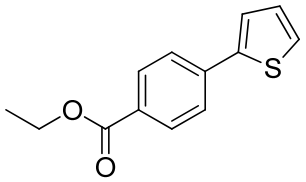

$^1$H NMR (300 MHz, $CDCl_3$) δ 7.82 (d, *J* = 9.0 Hz, 2H), 7.64-7.51 (m, 2H), 7.44 (d, *J* = 9.0 Hz, 2H), 7.35-7.22 (m, 2H), 7.04 (s, 1H).

**ethyl 4-(furan-2-yl)benzoate (11k)**[5,25,26]



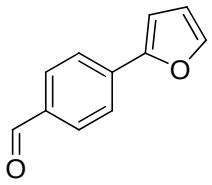

$^1$H NMR (400 MHz, $CDCl_3$) δ 8.07 (d, *J* = 8.0 Hz, 2H), 7.74 (d, *J* = 8.0 Hz, 2H), 7.55–7.53 (m, 1H), 6.81–6.78 (m, 1H), 6.55–6.50 (m, 1H), 4.40 (q, *J* = 8.0 Hz, 2H), 1.42 (t, *J* = 8.0 Hz, 3H).

**ethyl 4-(thiophen-2-yl)benzoate (11l)**[5,26]



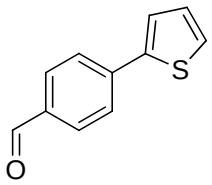

$^1$H NMR (400 MHz, $CDCl_3$) δ 8.07 (d, *J* = 9.0 Hz, 2H), 7.69 (d, *J* = 9.0 Hz, 2H), 7.45–7.36 (m, 2H), 7.16–7.11 (m, 1H), 4.40 (q, *J* = 6.0 Hz, 2H), 1.43 (t, *J* = 6.0Hz, 3H).

**4-(furan-2-yl)benzaldehyde (11m)**[25]



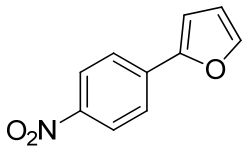
$^1$H NMR (300 MHz, $CDCl_3$) δ 10.01 (s, 1H), 7.92 (d, *J* = 9.0 Hz, 2H), 7.84 (d, *J* = 9.0 Hz, 2H), 7.58–7.56 (m, 1H), 6.88–6.86 (m, 1H), 6.57–6.53 (m, 1H).

**4-(thiophen-2-yl)benzaldehyde (11n)**[23]



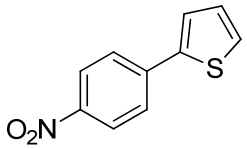
$^1$H NMR (300 MHz, $CDCl_3$) δ 10.02 (s, 1H), 7.91 (d, *J* = 6.0 Hz, 2H), 7.79 (d, *J* = 6.0 Hz, 2H), 7.50–7.47 (m, 1H), 7.44–7.40 (m, 1H), 7.18–7.13 (m, 1H).

**2-(4-nitrophenyl)furan (11o)**[25]



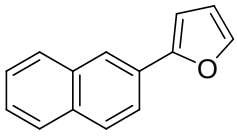
$^1$H NMR (300 MHz, $CDCl_3$) δ 8.27 (d, *J* = 9.0 Hz, 2H), 7.82 (d, *J* = 9.0 Hz, 2H), 7.61–7.58 (m, 1H), 6.92–6.88 (m, 1H), 6.59–6.56 (m, 1H).

**2-(4-nitrophenyl)thiophene (11p)**[26]



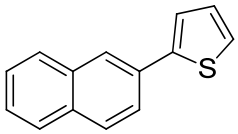
$^1$H NMR (300 MHz, $CDCl_3$) δ 8.26 (d, *J* = 9.0 Hz, 2H), 7.77 (d, *J* = 9.0 Hz, 2H), 7.51–7.44 (m, 2H), 7.20–7.15 (m, 1H).

**2-(naphthalen-2-yl)furan (11q)**[6]



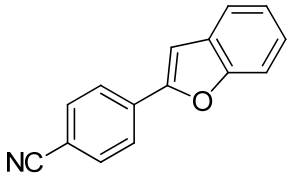
$^1$H NMR (400 MHz, $CDCl_3$) δ 8.15 (s, 1H), 7.88–7.75 (m, 4H), 7.54–7.42 (m, 3H), 6.79–6.76 (m, 1H), 6.54–6.51 (m, 1H).

**2-(naphthalen-2-yl)thiophene (11r)**[27]




$^1$H NMR (300 MHz, $CDCl_3$) δ 8.15 (s, 1H), 7.88–7.75 (m, 4H), 7.54–7.42 (m, 3H), 6.79–6.76 (m, 1H), 6.54–6.51 (m, 1H).

**4-(benzofuran-2-yl)benzonitrile (11s)**[18,25]




$^1$H NMR (300 MHz, $CDCl_3$) δ 7.98 (d, *J* = 9.0 Hz, 2H), 7.75 (d, *J* = 9.0 Hz, 2H), 7.68–7.53 (m, 2H), 7.41–7.28 (m, 2H), 7.20 (s, 1H).

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## Spectra of coupling products

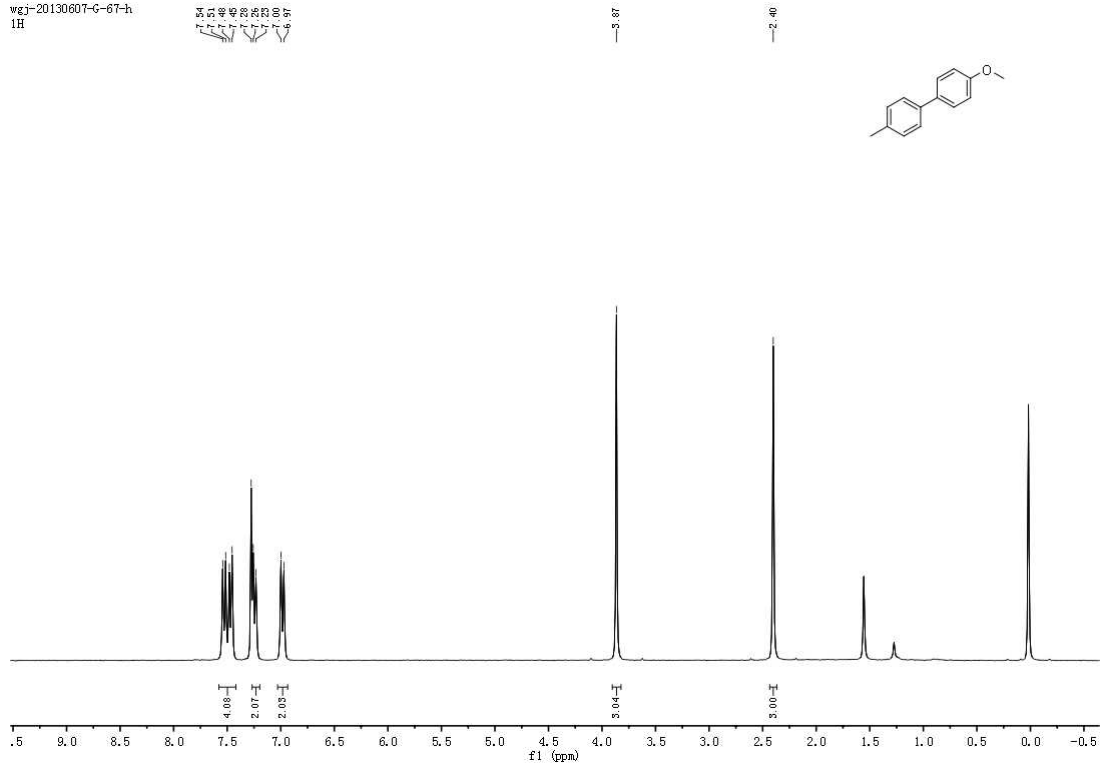


**Figure S1.** $^{1}$H -NMR spectra of **7a**

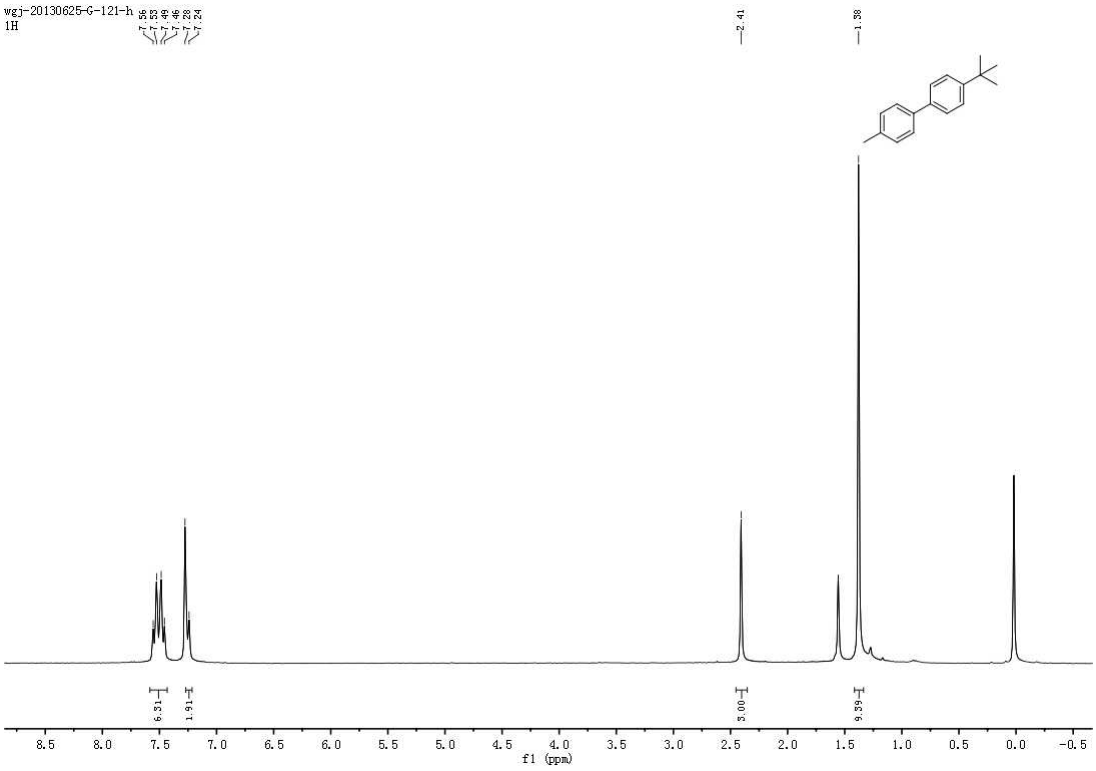


**Figure S2.** $^{1}$H -NMR spectra of **7b**

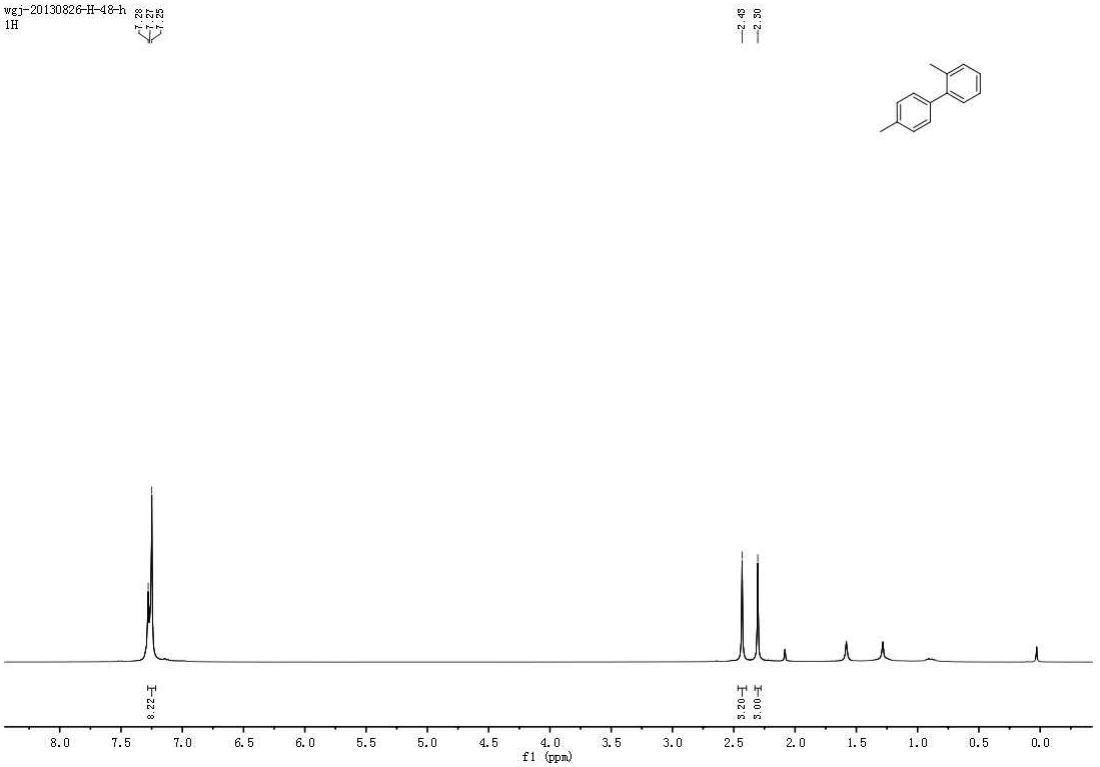


**Figure S3.** $^{1}$H -NMR spectra of **7c**

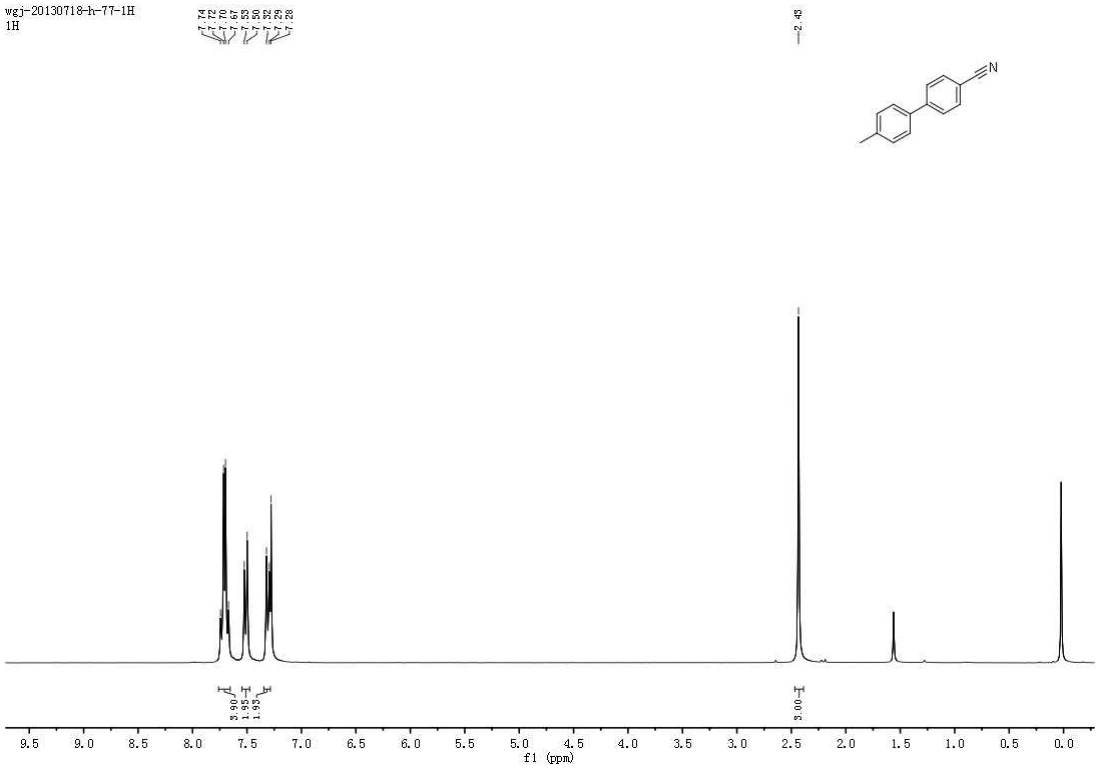


**Figure S4.** $^{1}$H -NMR spectra of **7d**

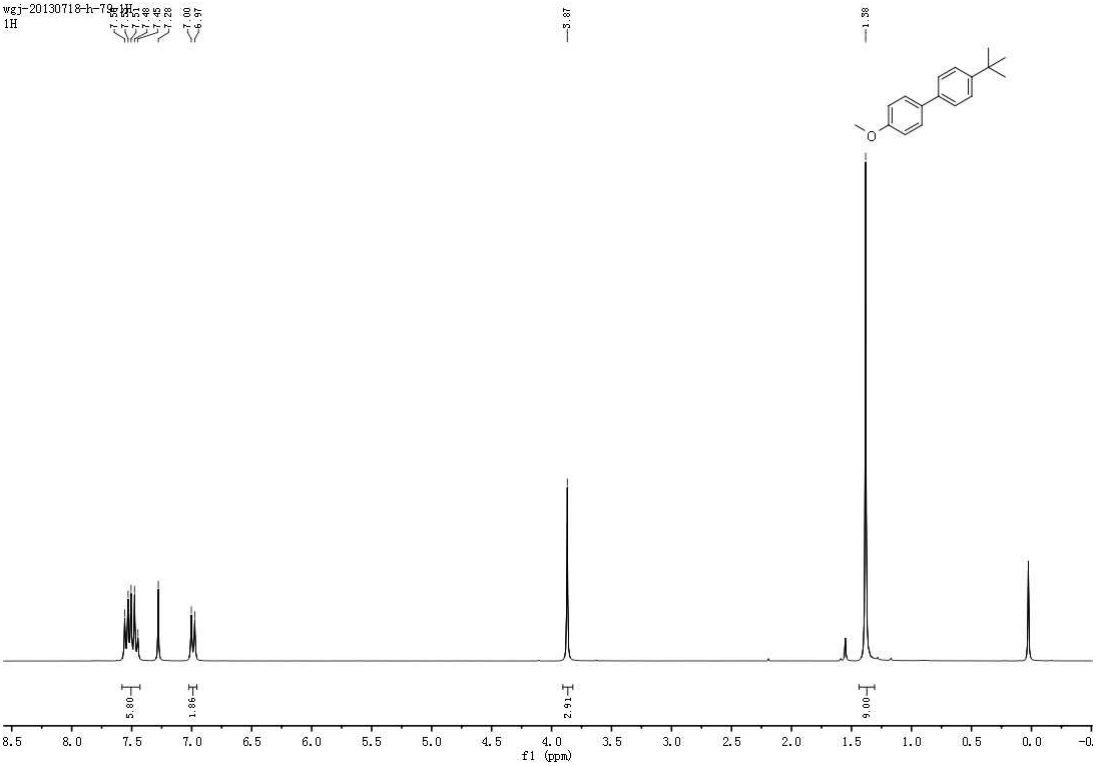


**Figure S5.** $^{1}$H -NMR spectra of **7e**

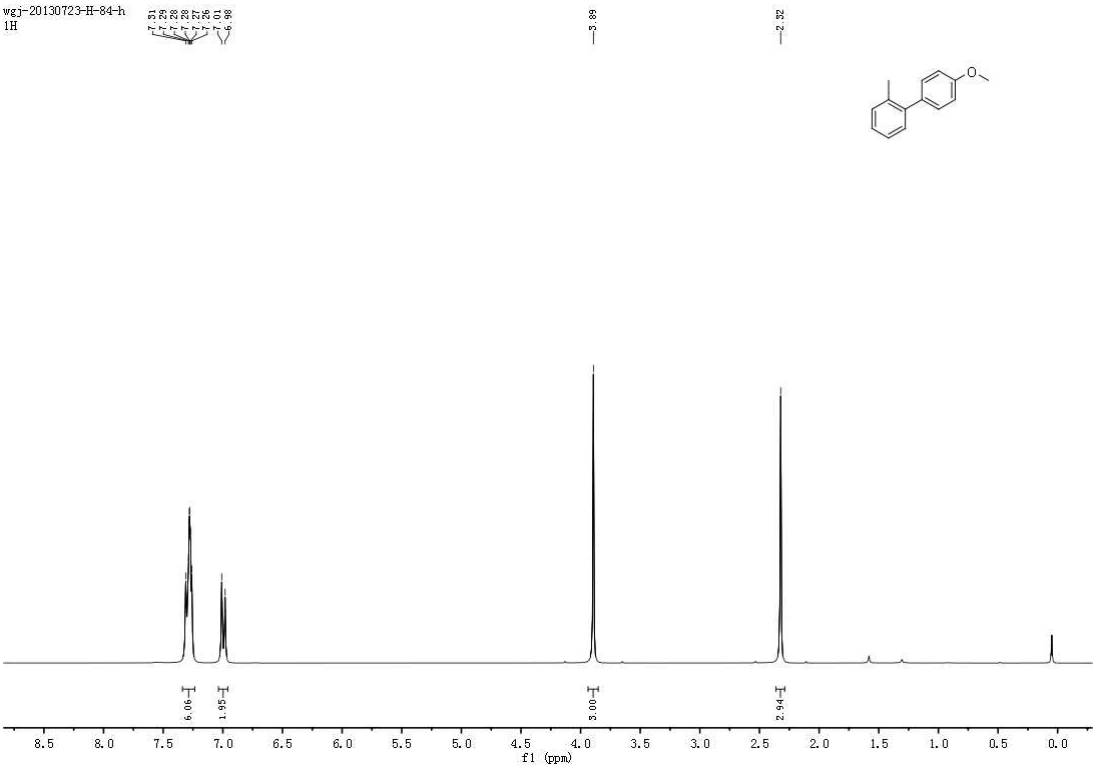


**Figure S6.** $^{1}$H -NMR spectra of **7f**

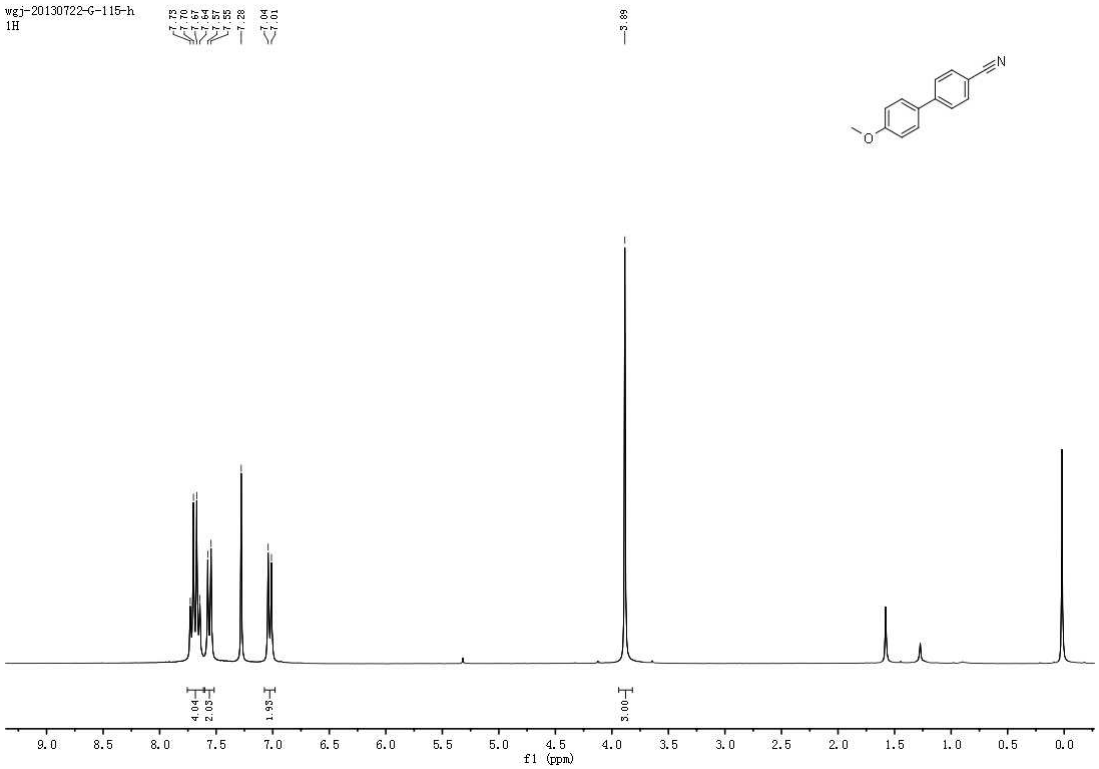


**Figure S7.** $^{1}$H -NMR spectra of **7g**

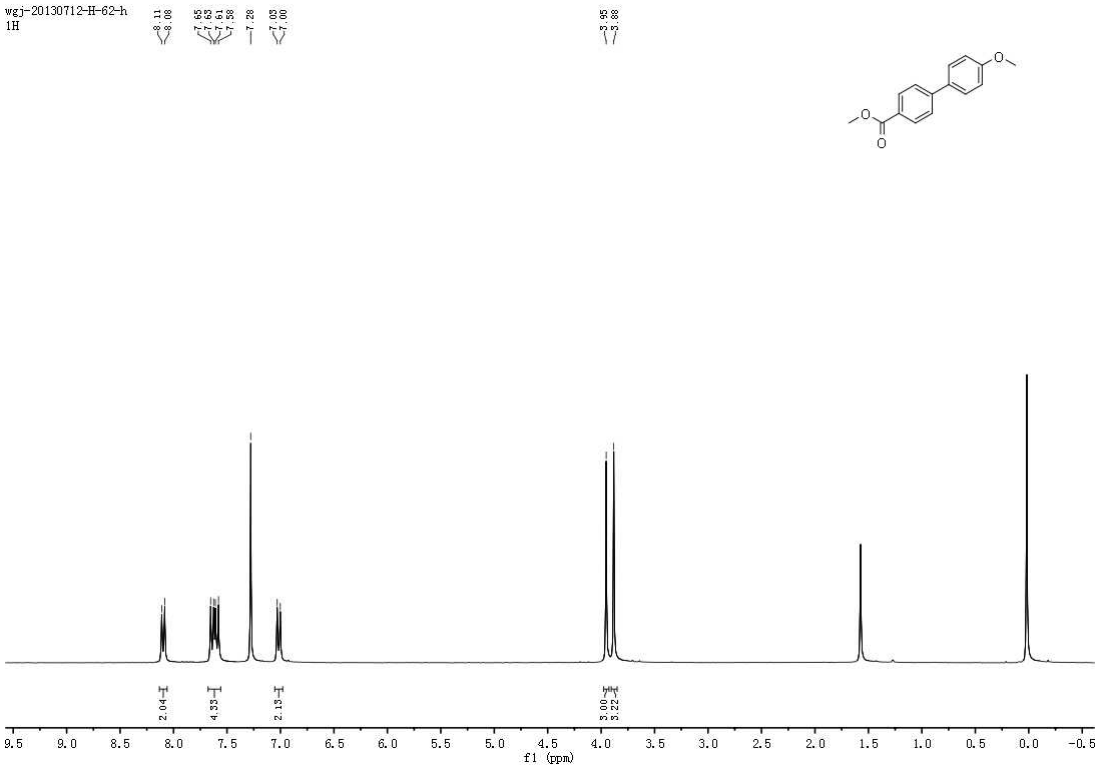


**Figure S8.** $^{1}$H -NMR spectra of **7h**

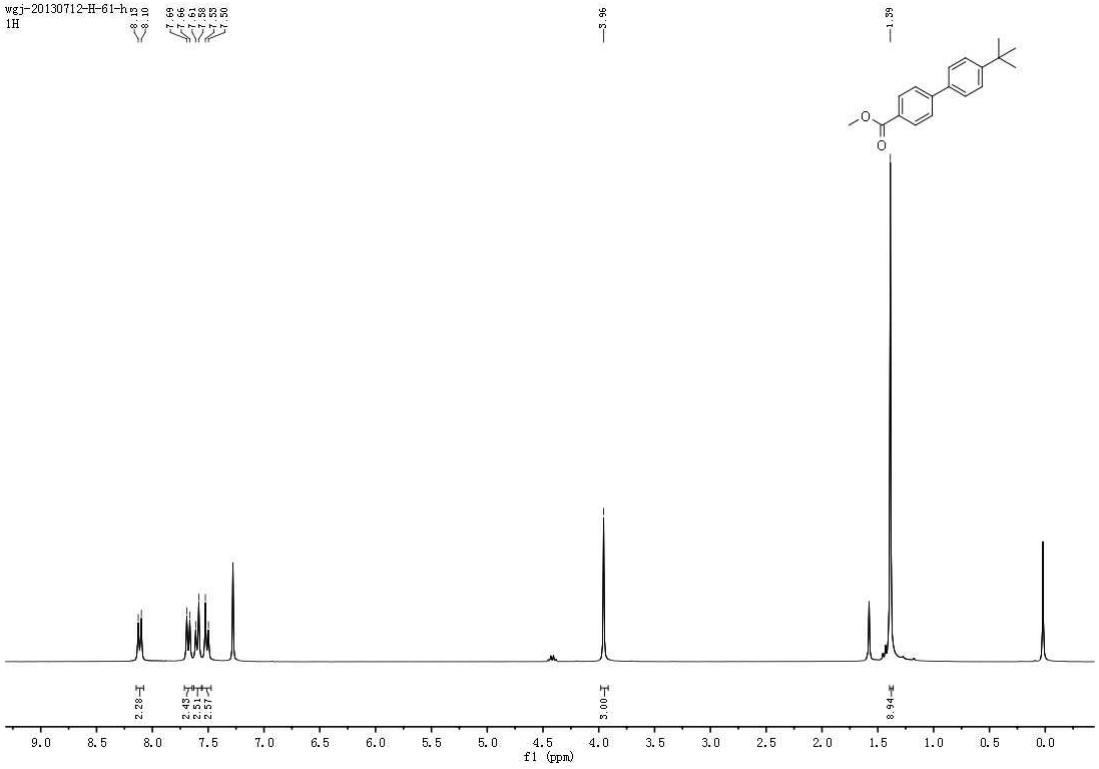


**Figure S9.** $^{1}$H -NMR spectra of **7i**

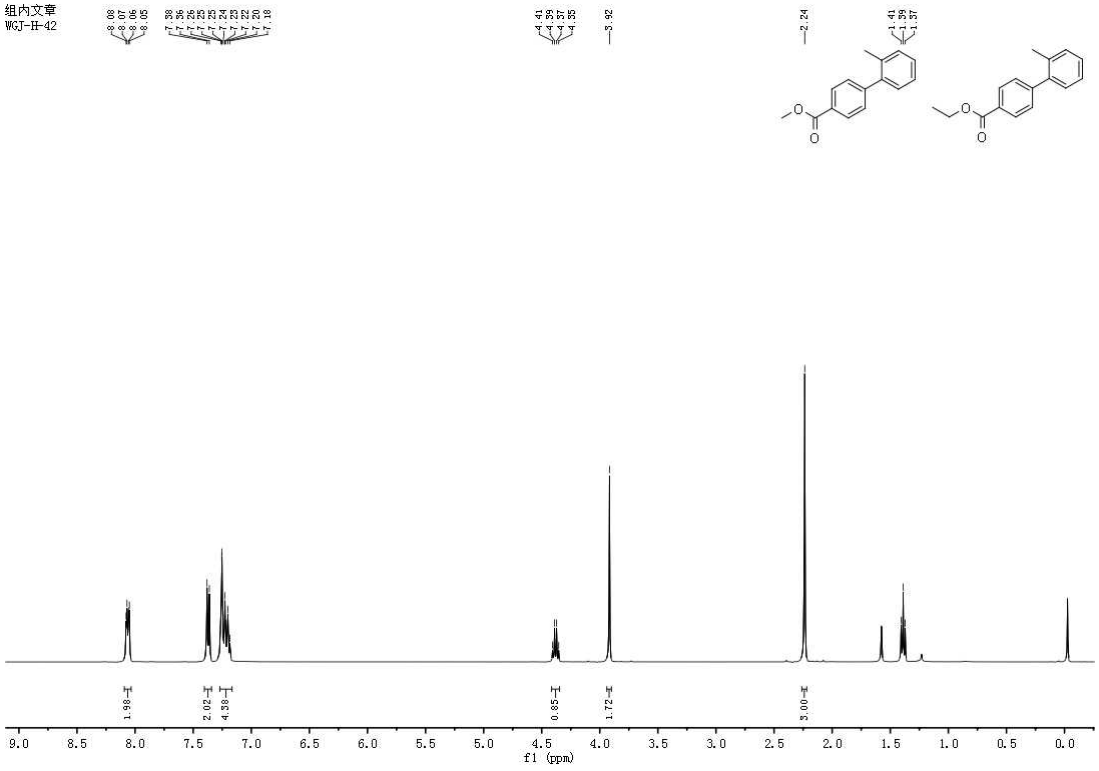


**Figure S10.** $^{1}$H -NMR spectra of **7j**

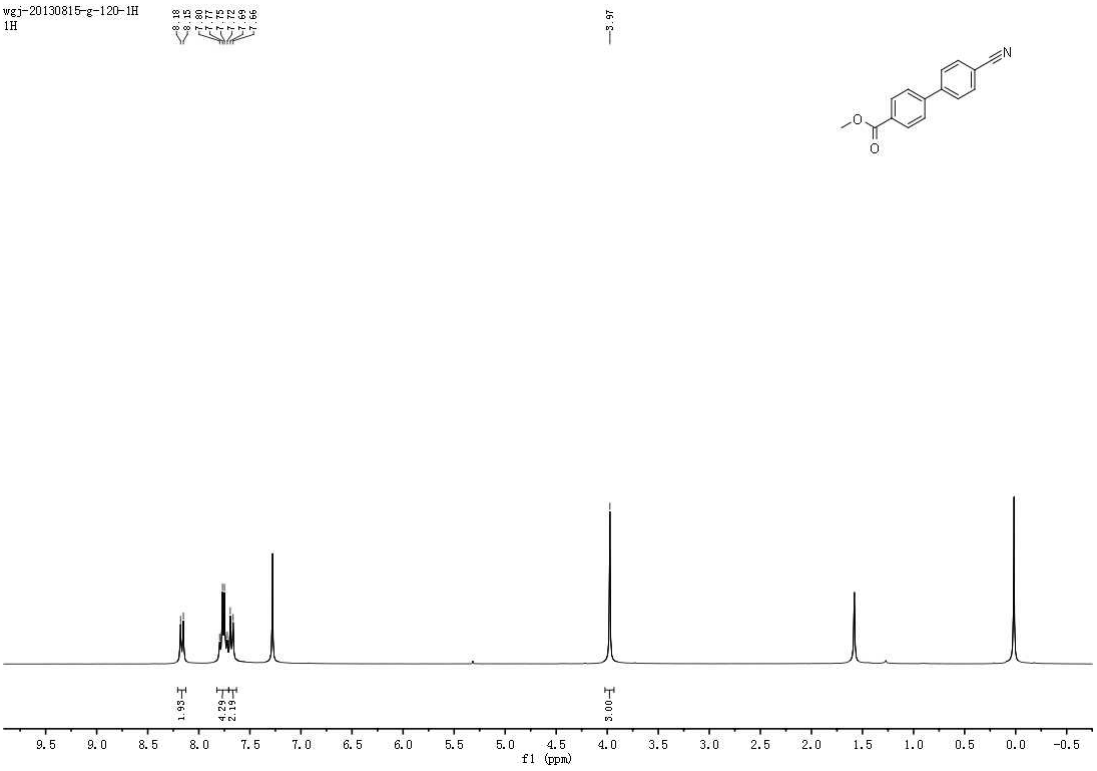


**Figure S11.** $^{1}$H -NMR spectra of **7k**

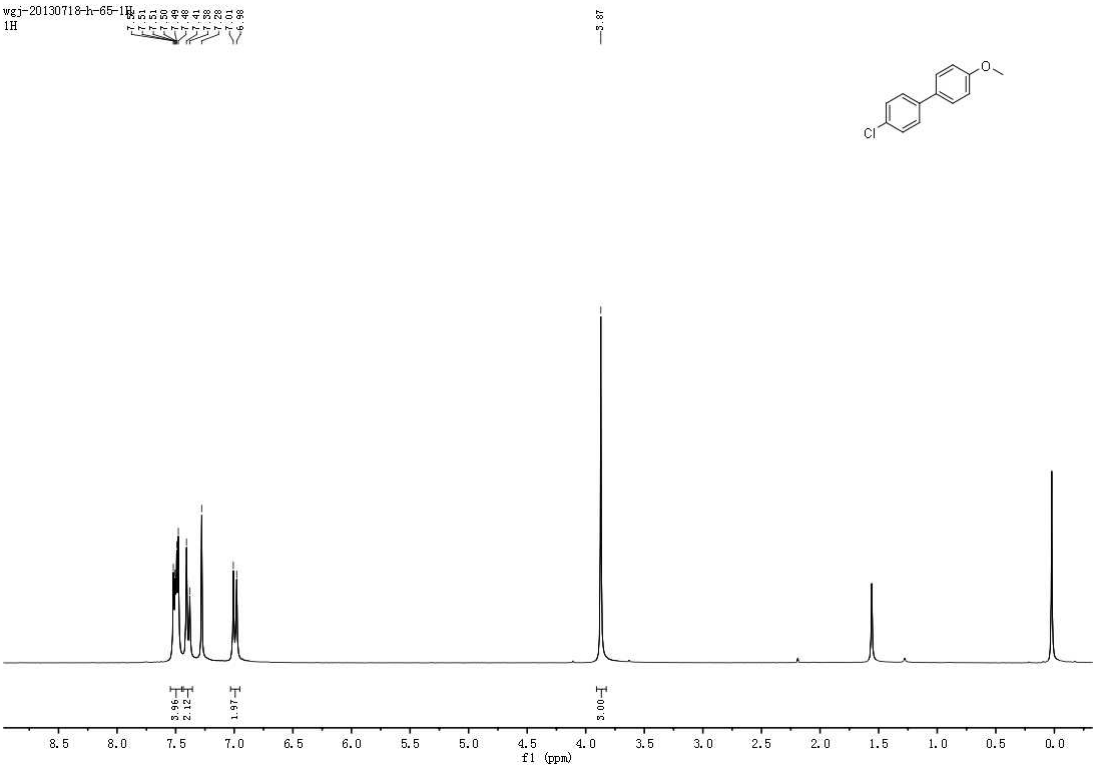


**Figure S12.** $^{1}$H -NMR spectra of **7l**

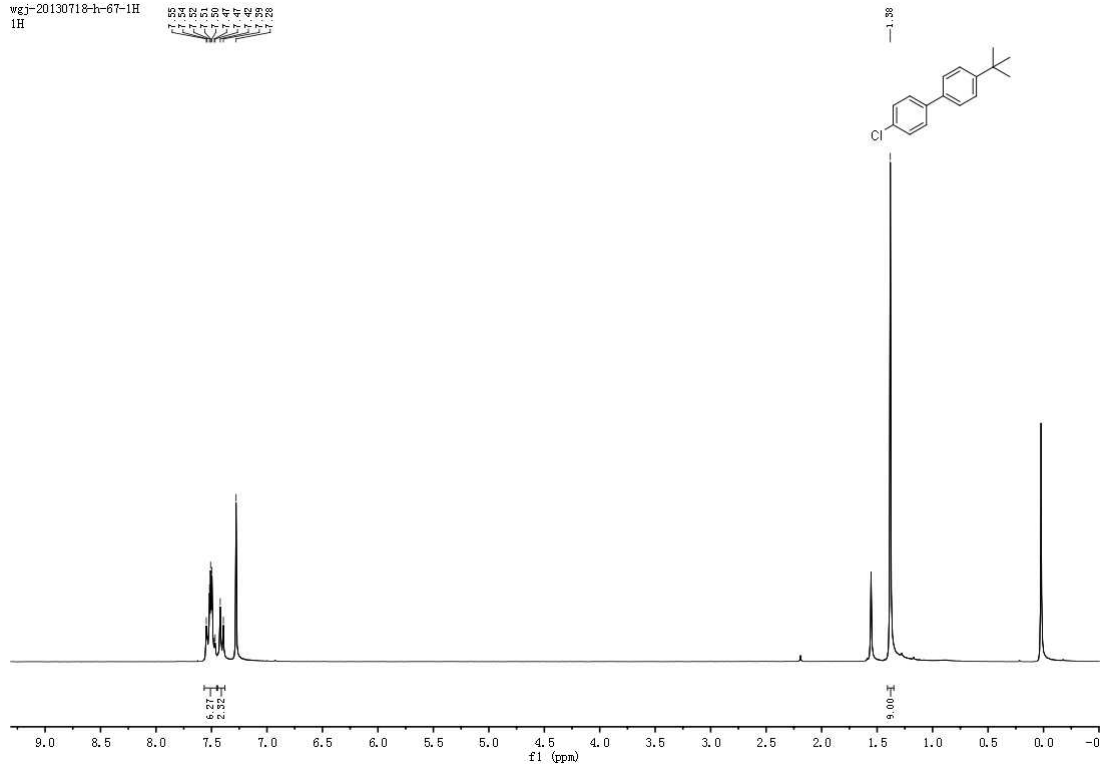


**Figure S13.** $^{1}$H -NMR spectra of **7m**

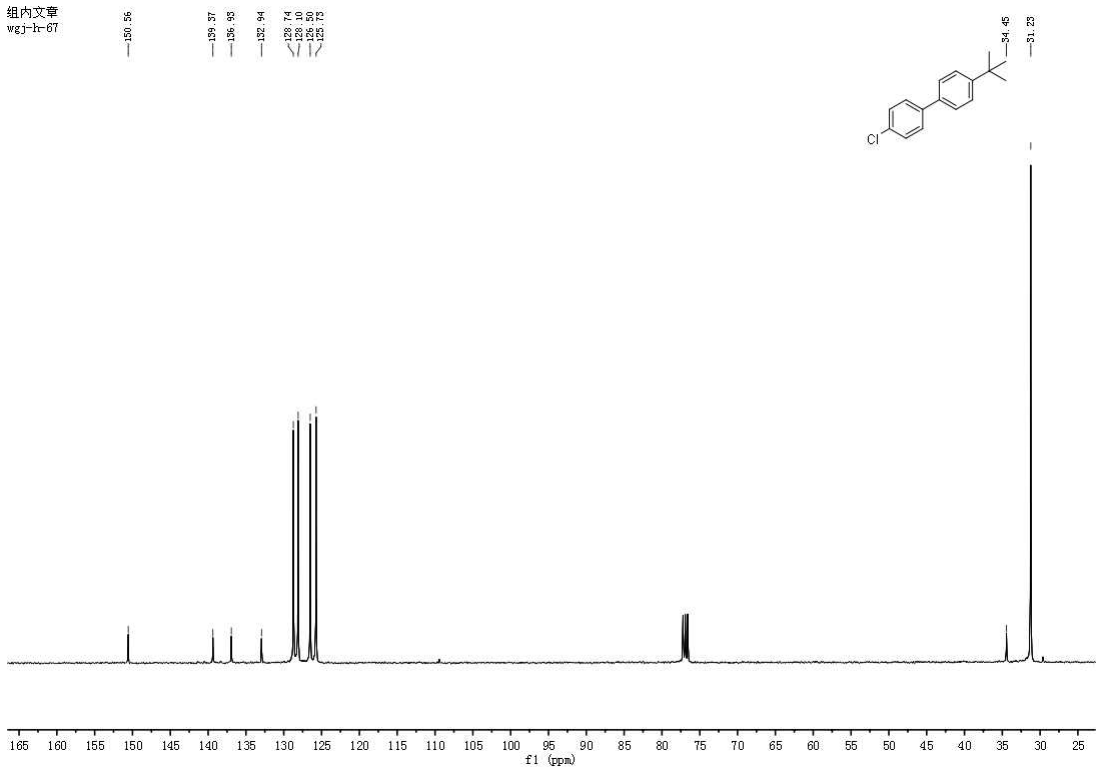


**Figure S14.** $^{13}$C -NMR spectra of **7m**

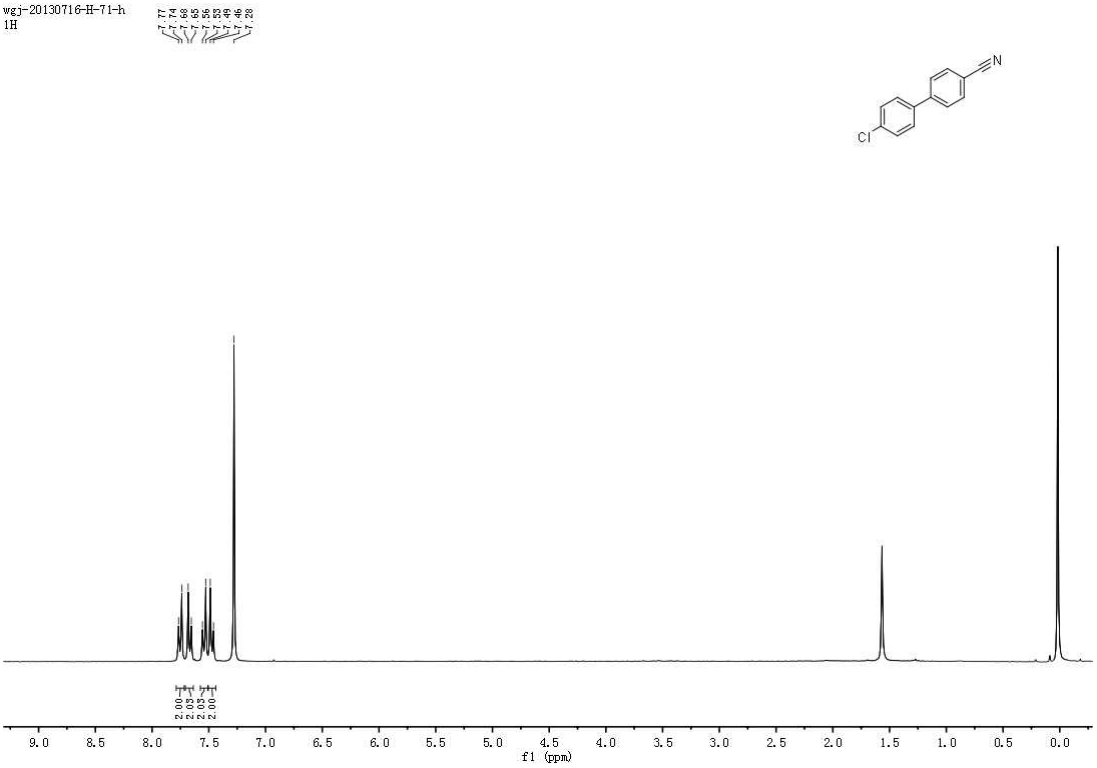


**Figure S15.** $^{1}$H -NMR spectra of **7n**

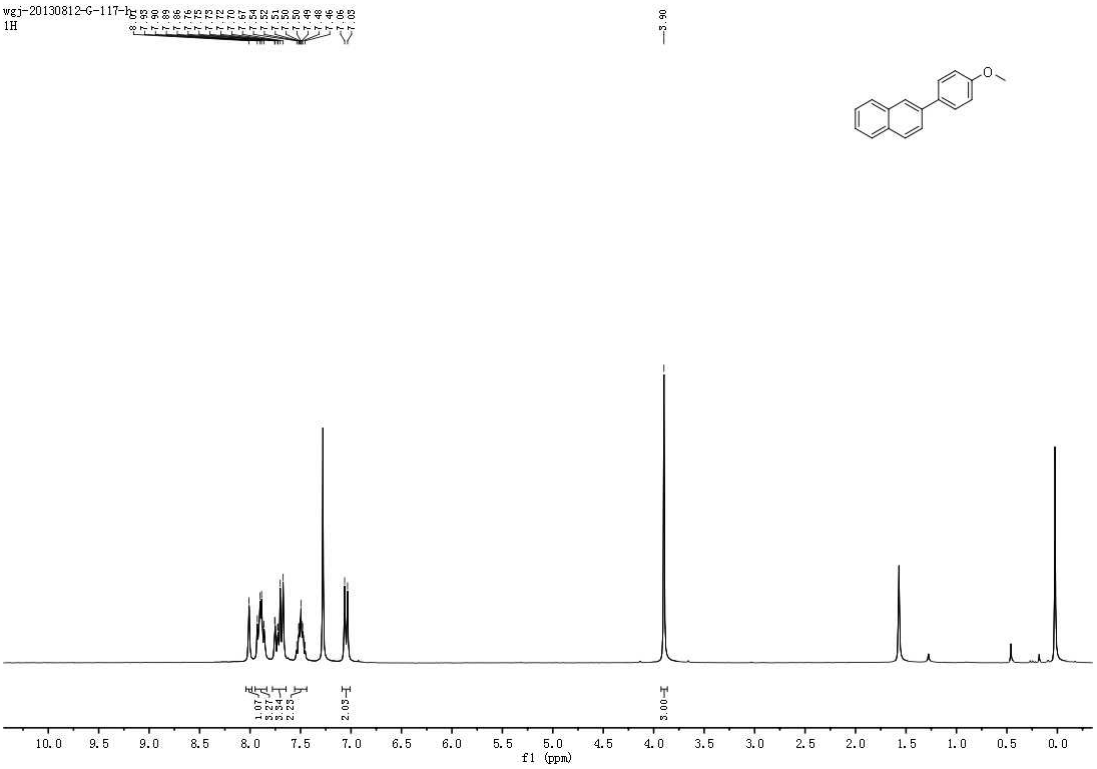


**Figure S16.** $^{1}$H -NMR spectra of **7o**

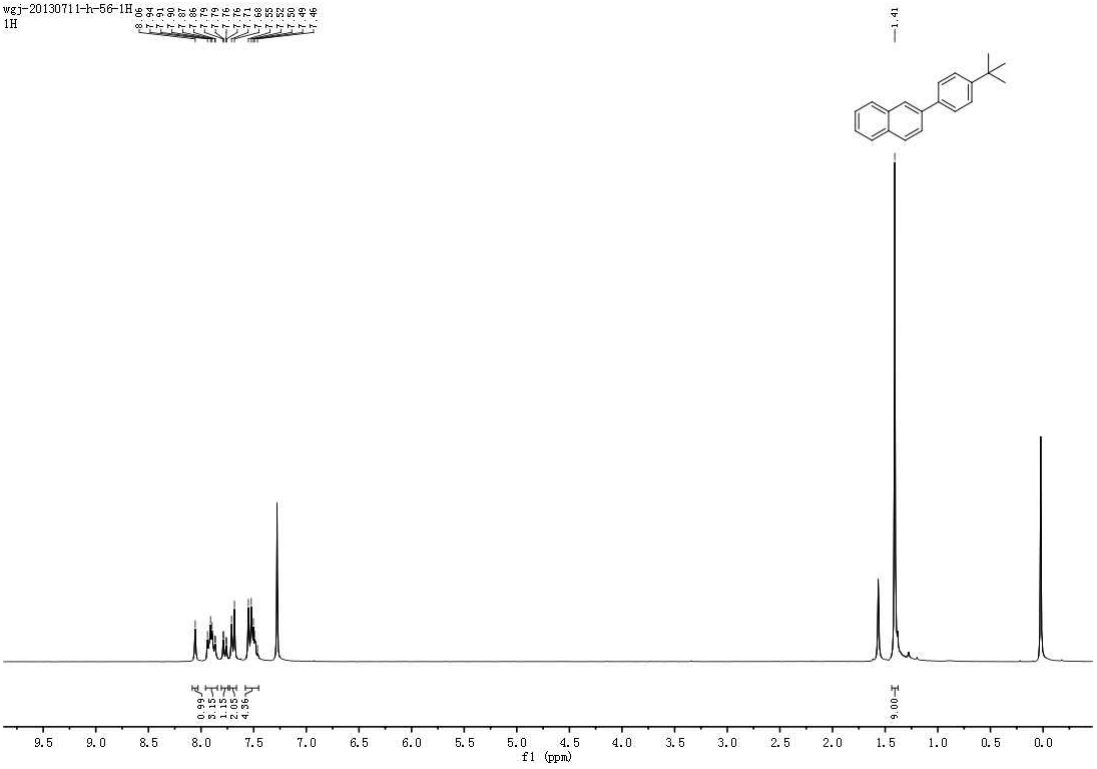


**Figure S17.** $^{1}$H -NMR spectra of **7p**

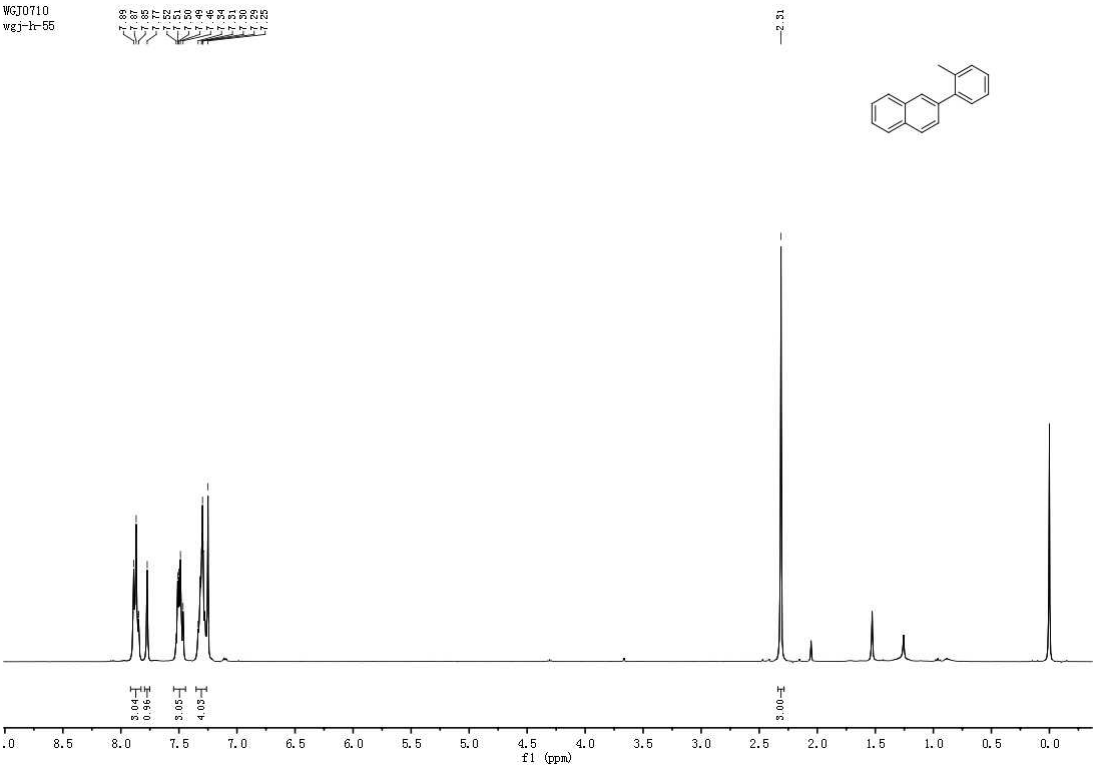


**Figure S18.** $^{1}$H -NMR spectra of **7q**

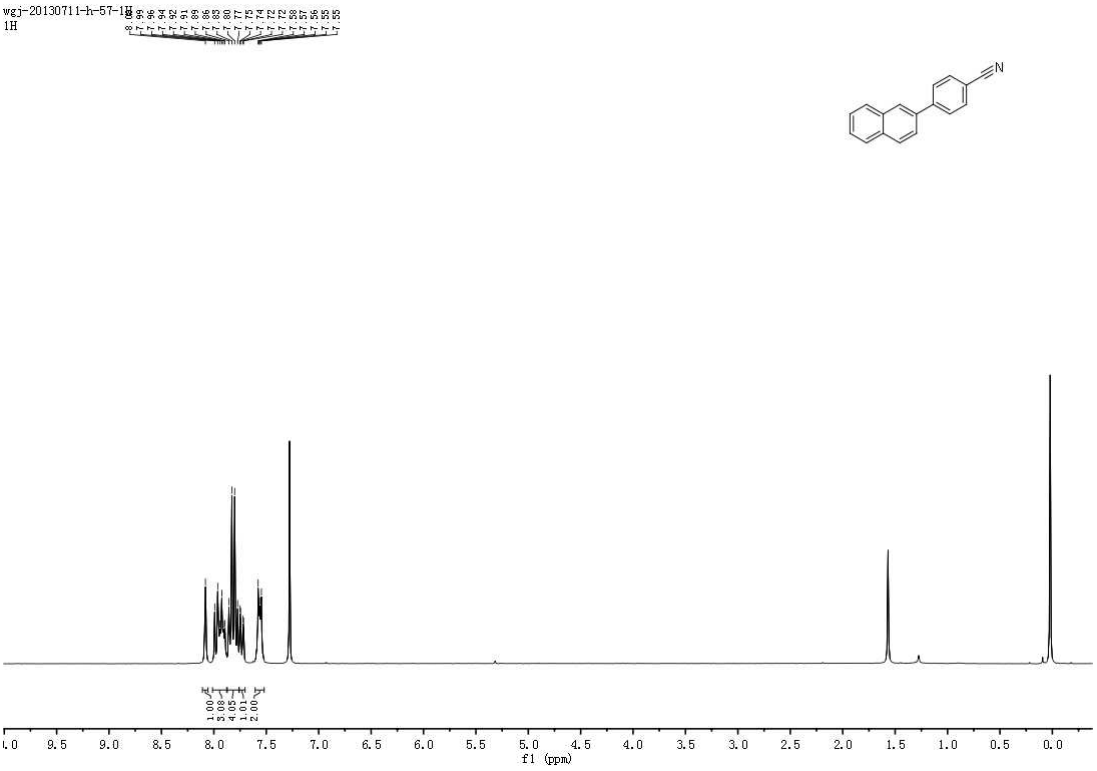


**Figure S19.** $^{1}$H -NMR spectra of **7r**

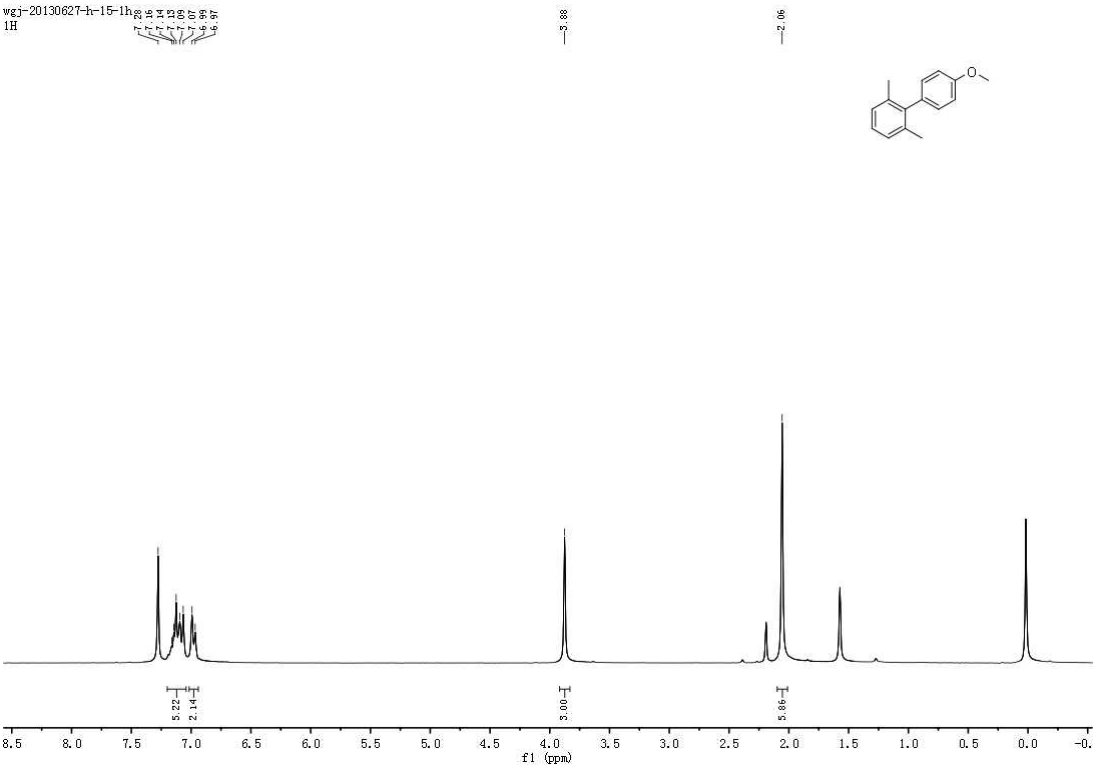


**Figure S20.** $^{1}$H -NMR spectra of **7s**

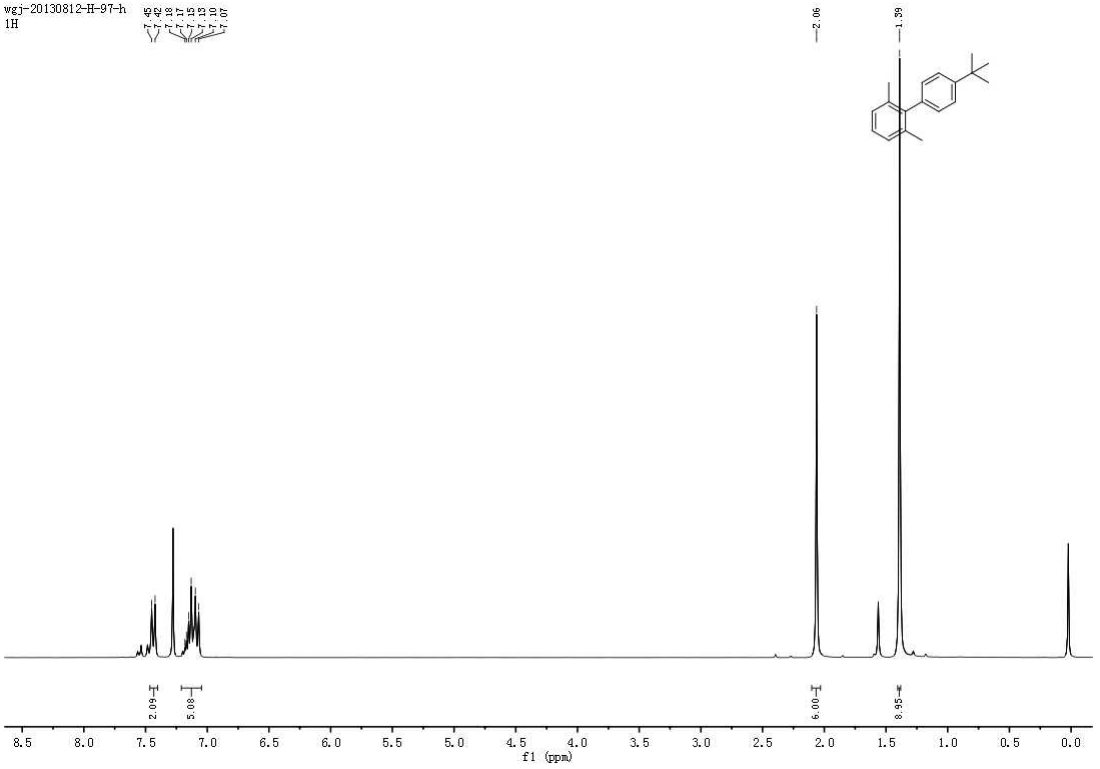


**Figure S21.** $^{1}$H -NMR spectra of **7t**

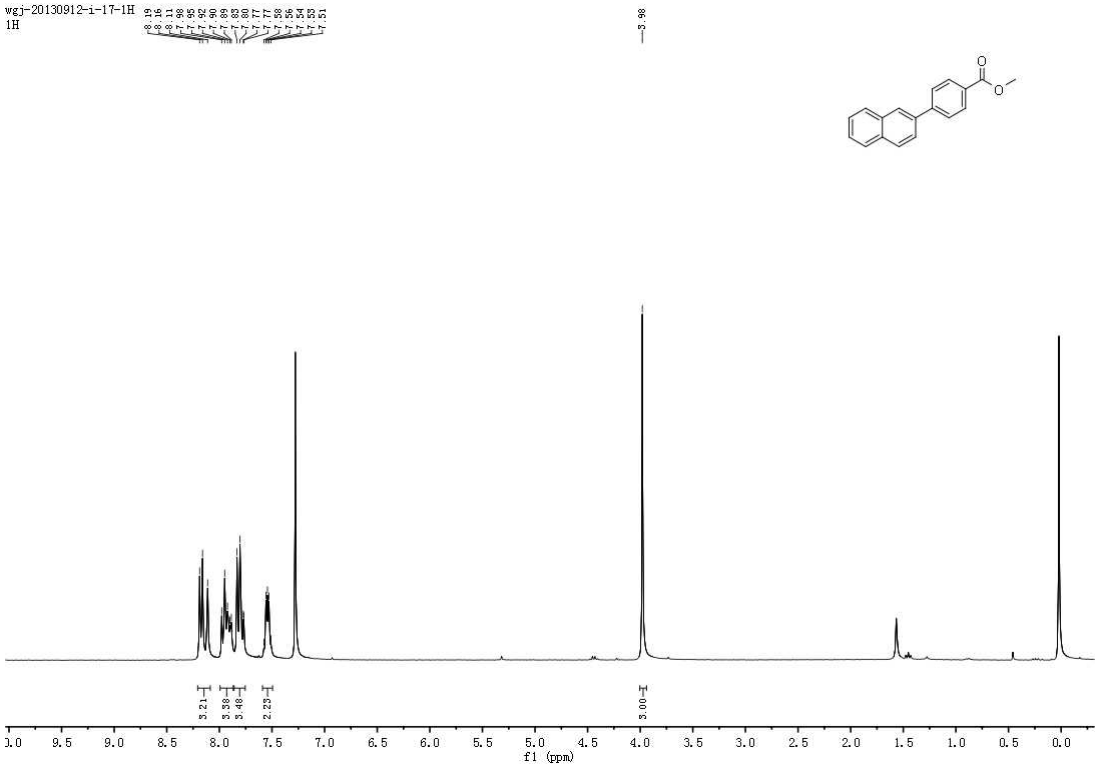


**Figure S22.** $^{1}$H -NMR spectra of **7u**

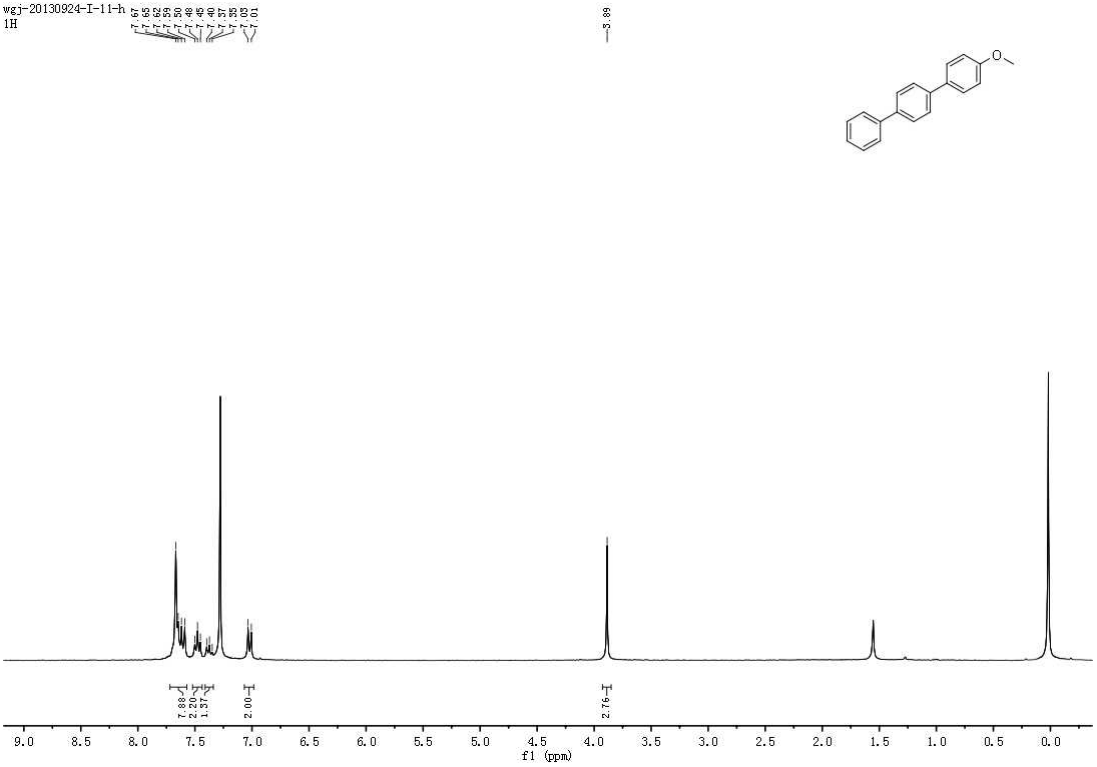


**Figure S23.** $^{1}$H -NMR spectra of **7v**

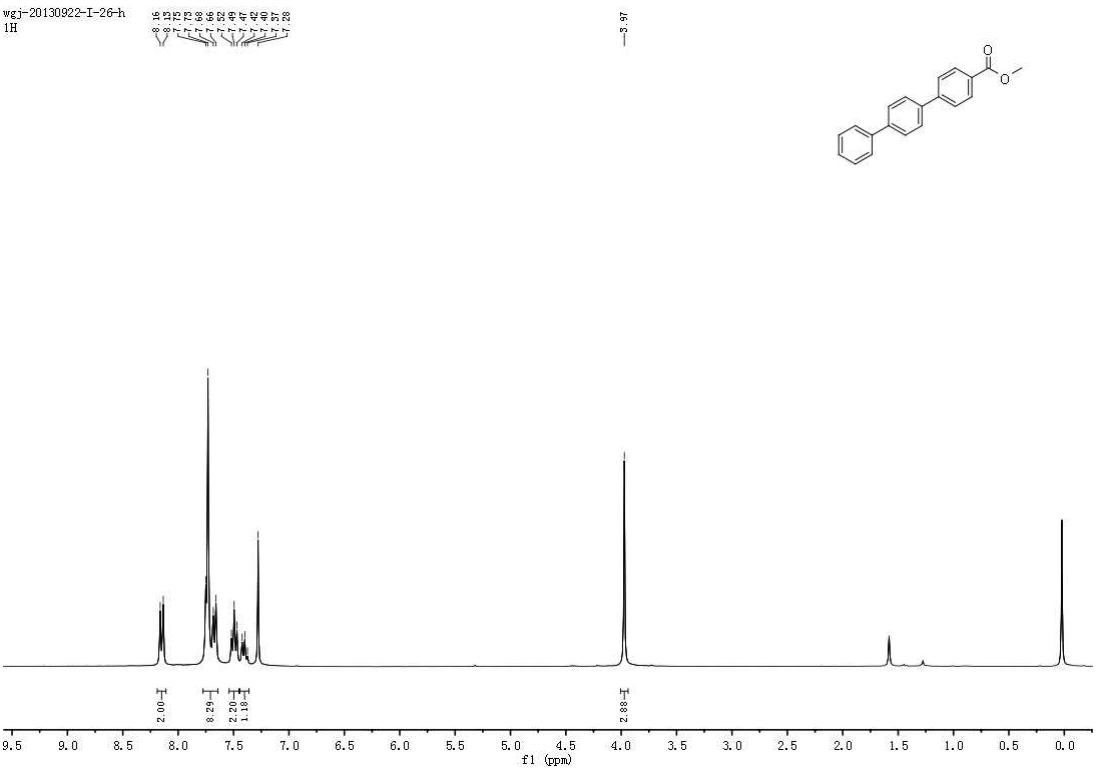


**Figure S24.** $^{1}$H -NMR spectra of **7w**

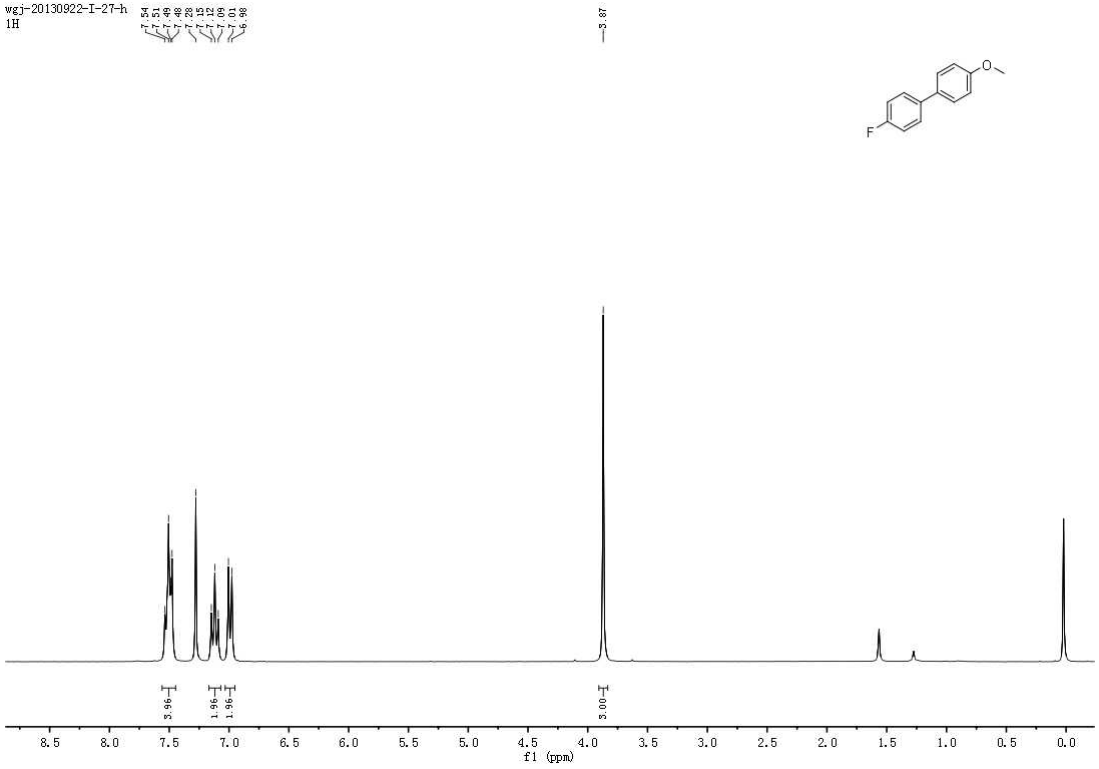


**Figure S25.** $^{1}$H -NMR spectra of **7x**

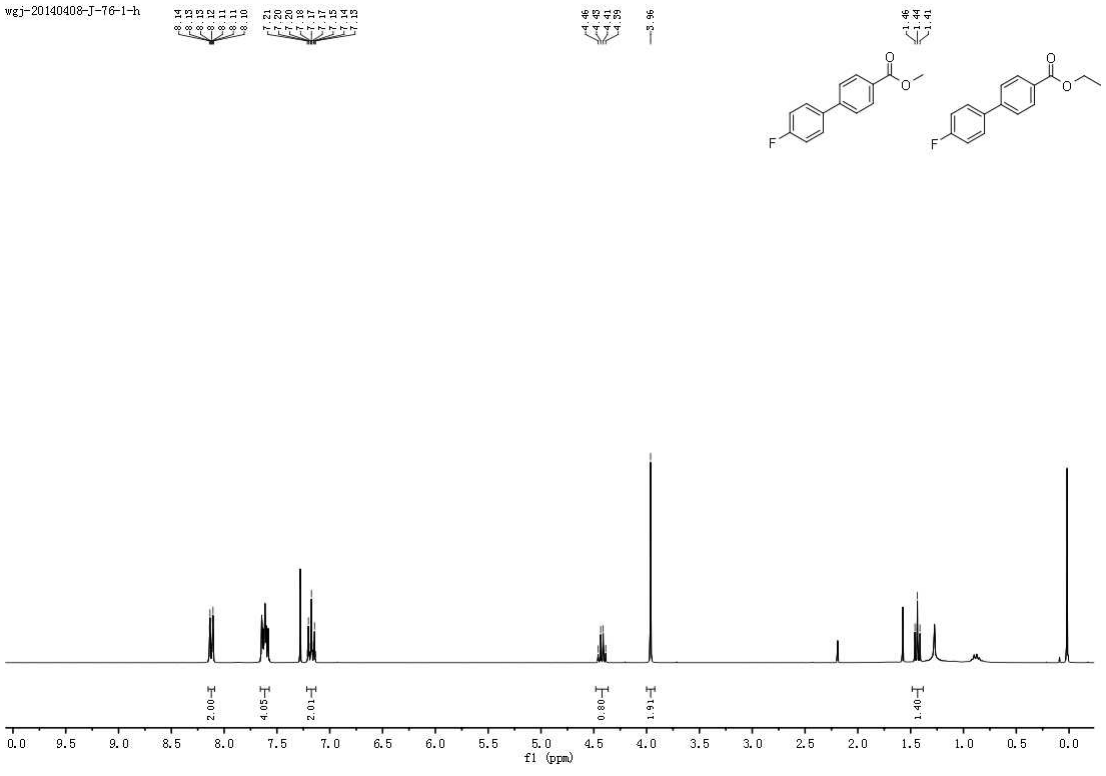


**Figure S26.** $^{1}$H -NMR spectra of **7y**

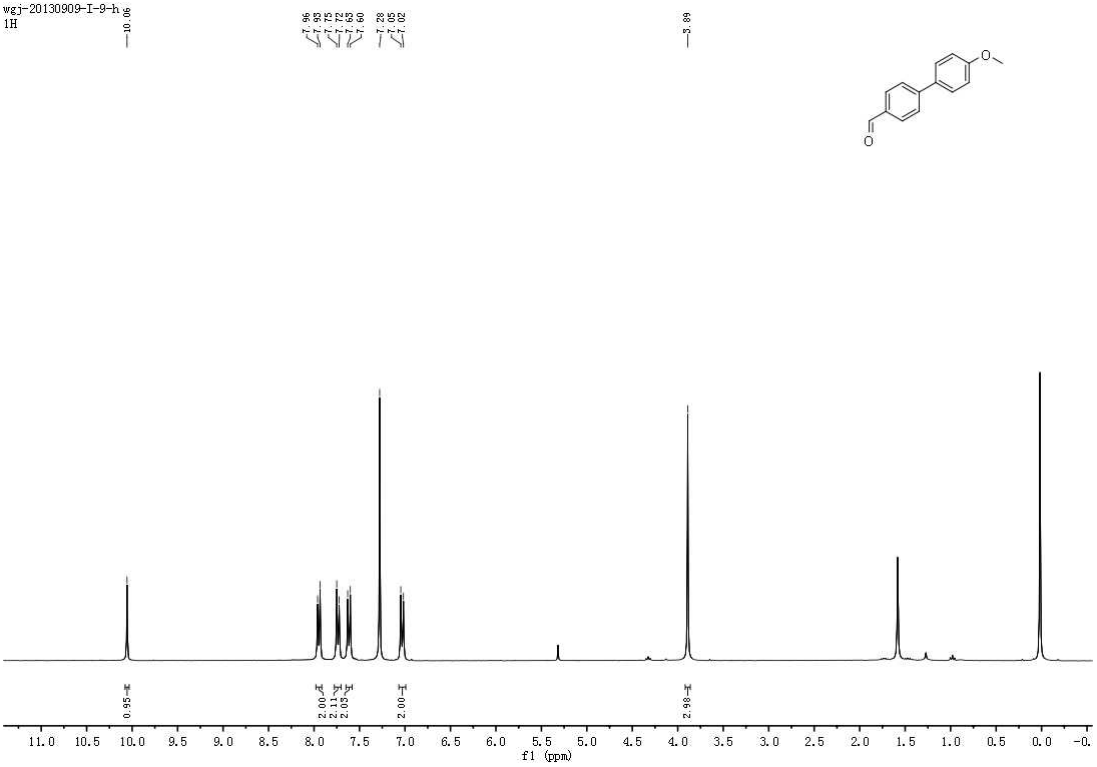


**Figure S27.** $^{1}$H -NMR spectra of **7z**

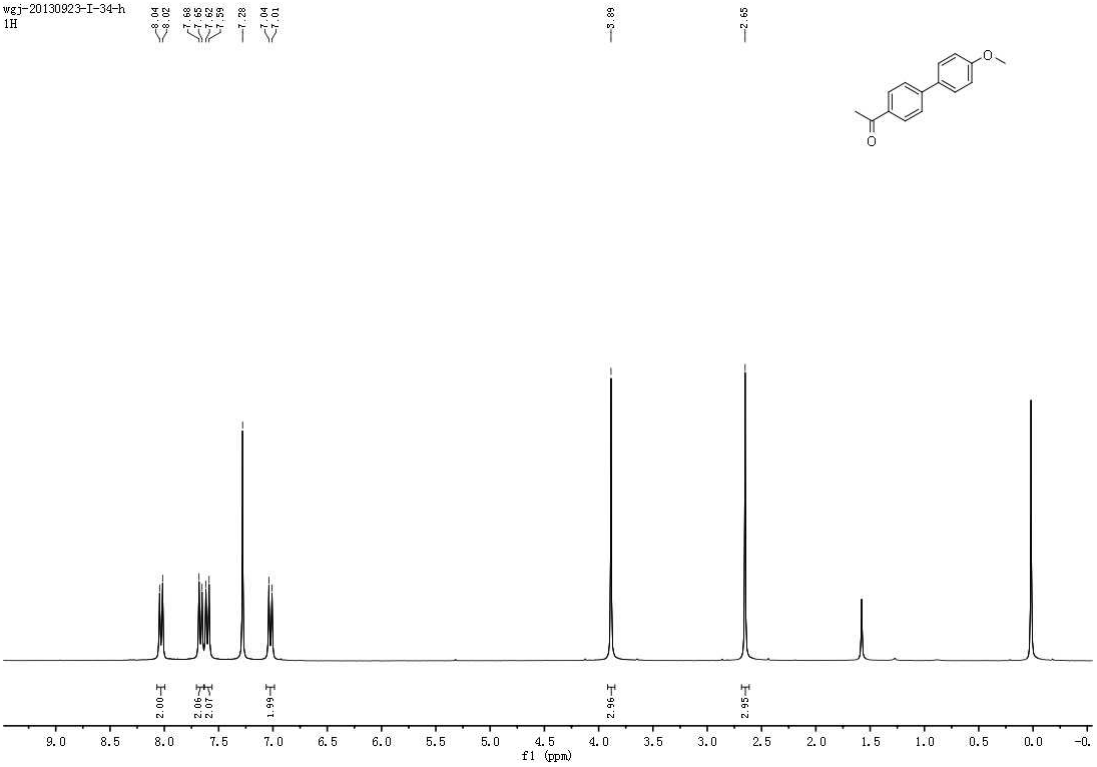


**Figure S28.** $^{1}$H -NMR spectra of **7aa**

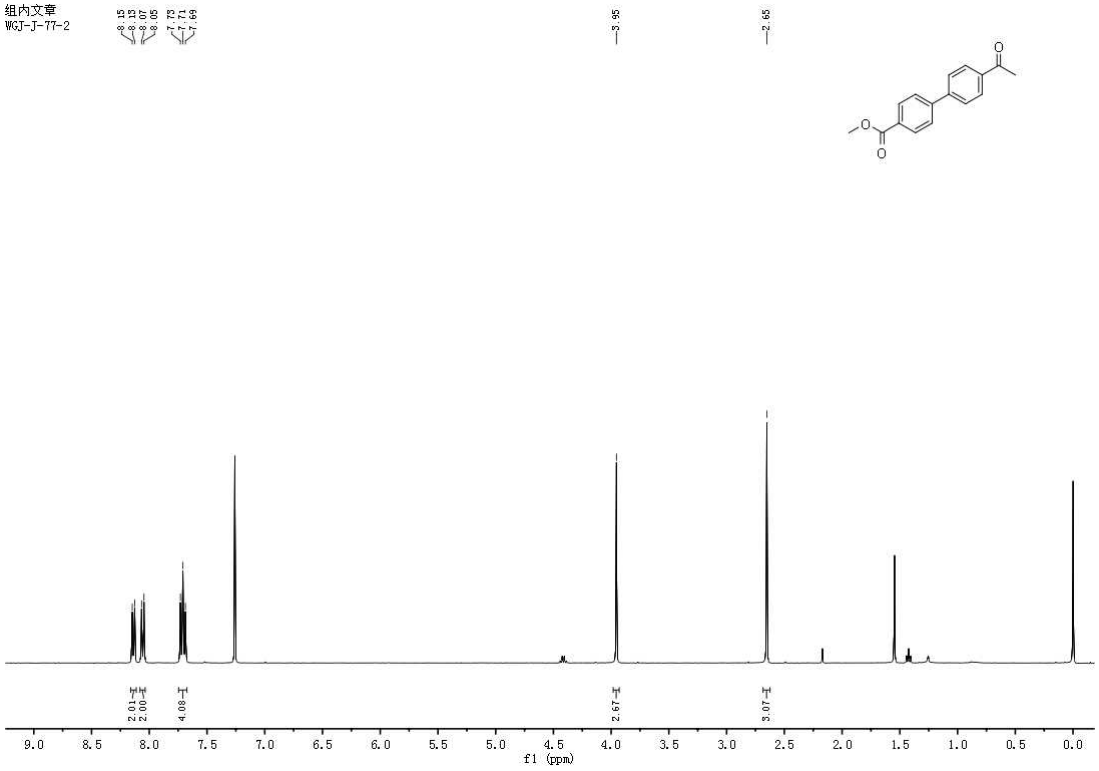


**Figure S29.** $^{1}$H -NMR spectra of **7ab**

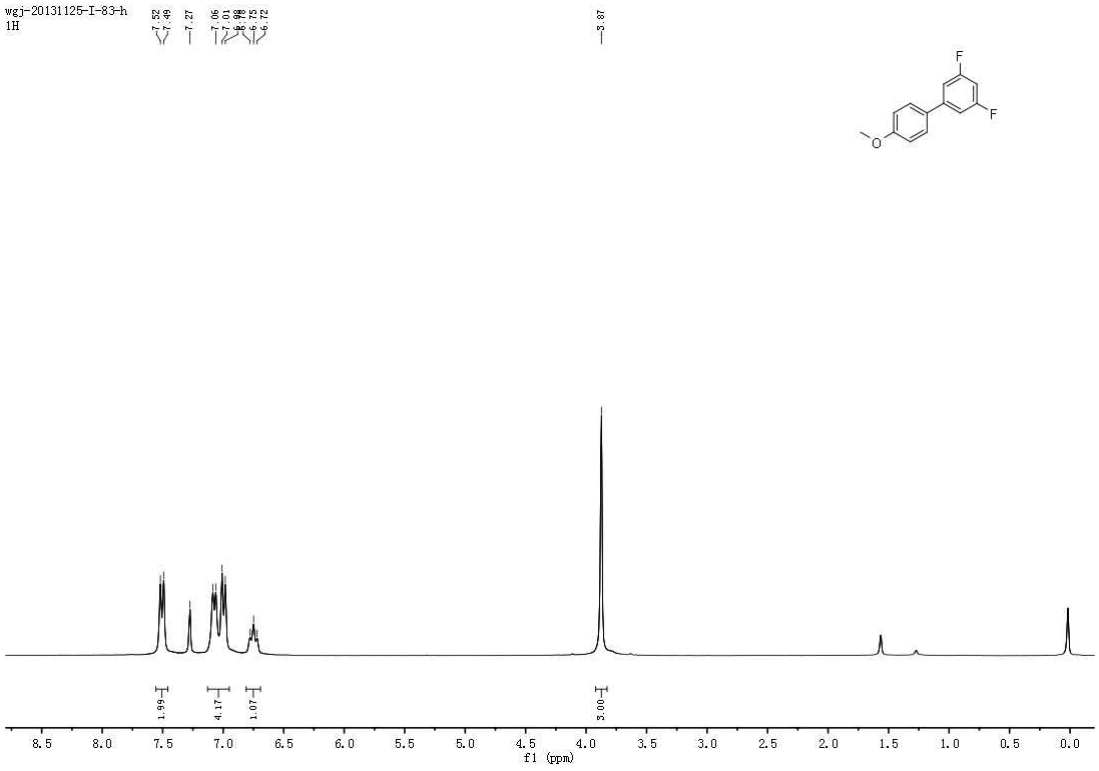


**Figure S30.** $^{1}$H -NMR spectra of **10a**

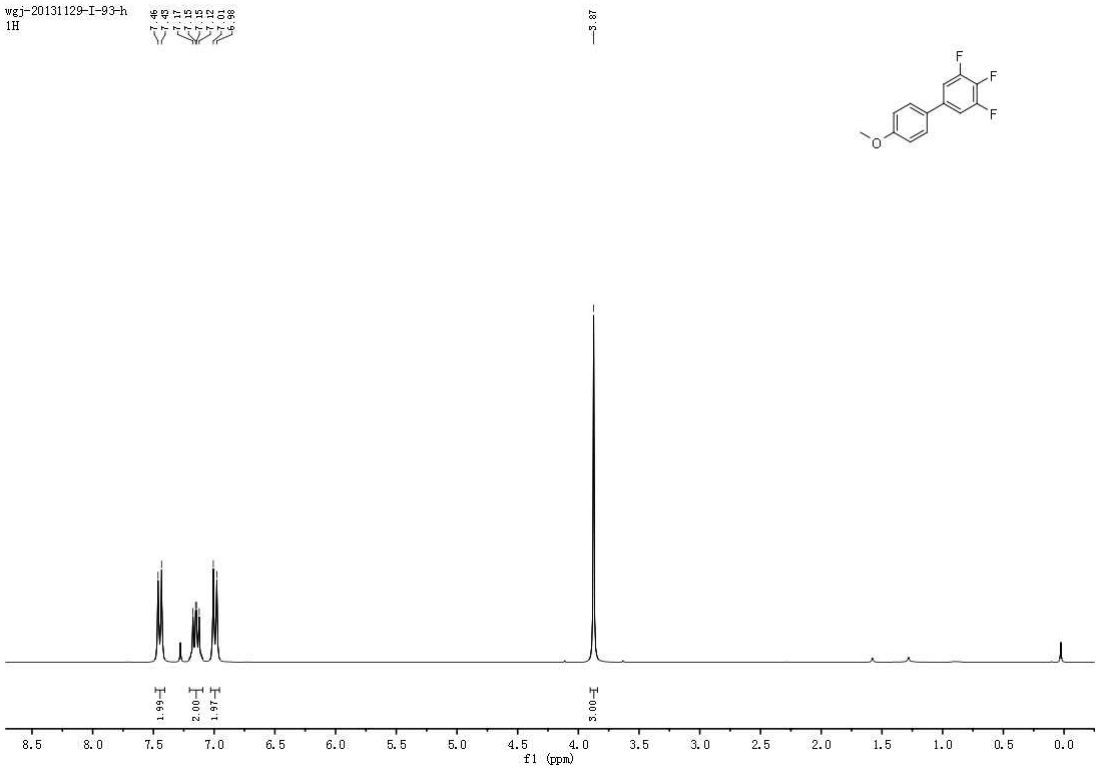


**Figure S31.** $^{1}$H -NMR spectra of **10b**

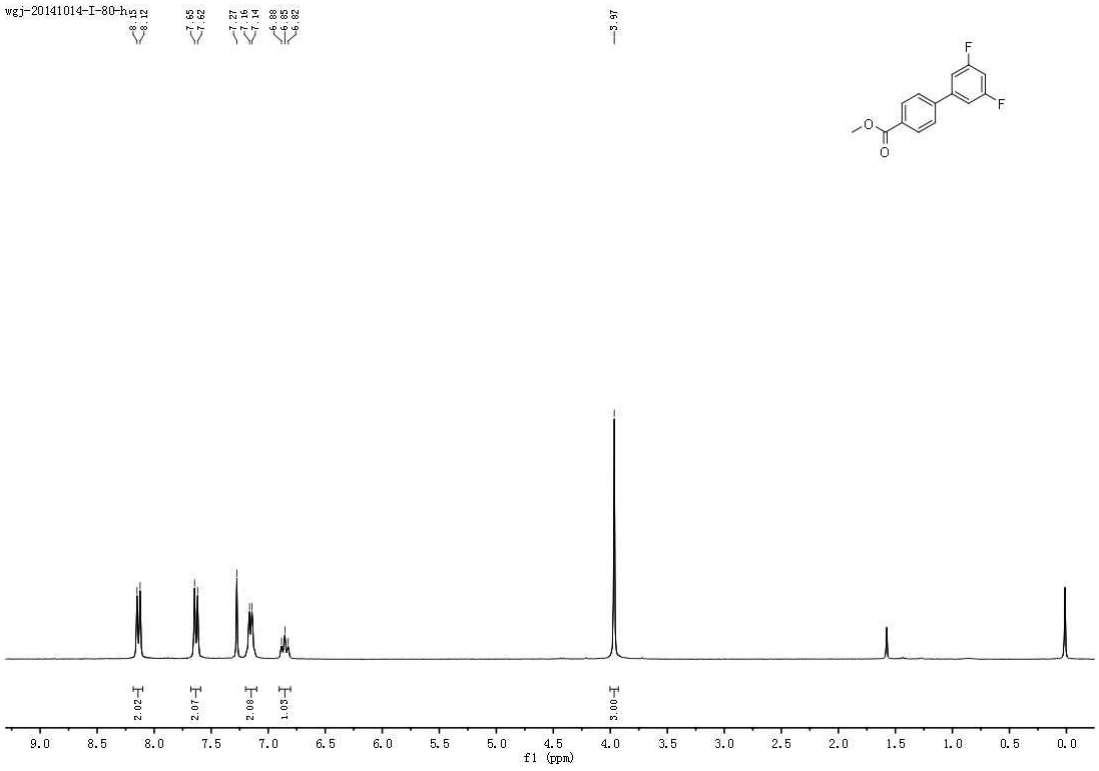


**Figure S32.** $^{1}$H -NMR spectra of **10c**

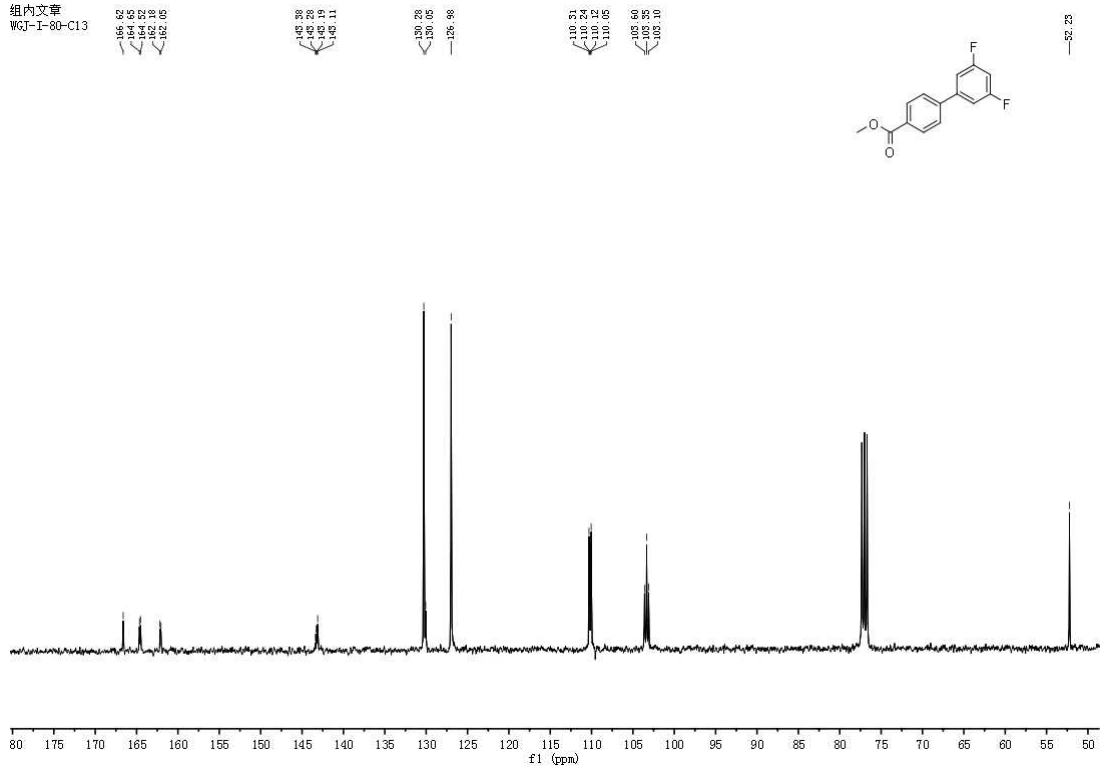


**Figure S33.** $^{13}$C -NMR spectra of **10c**

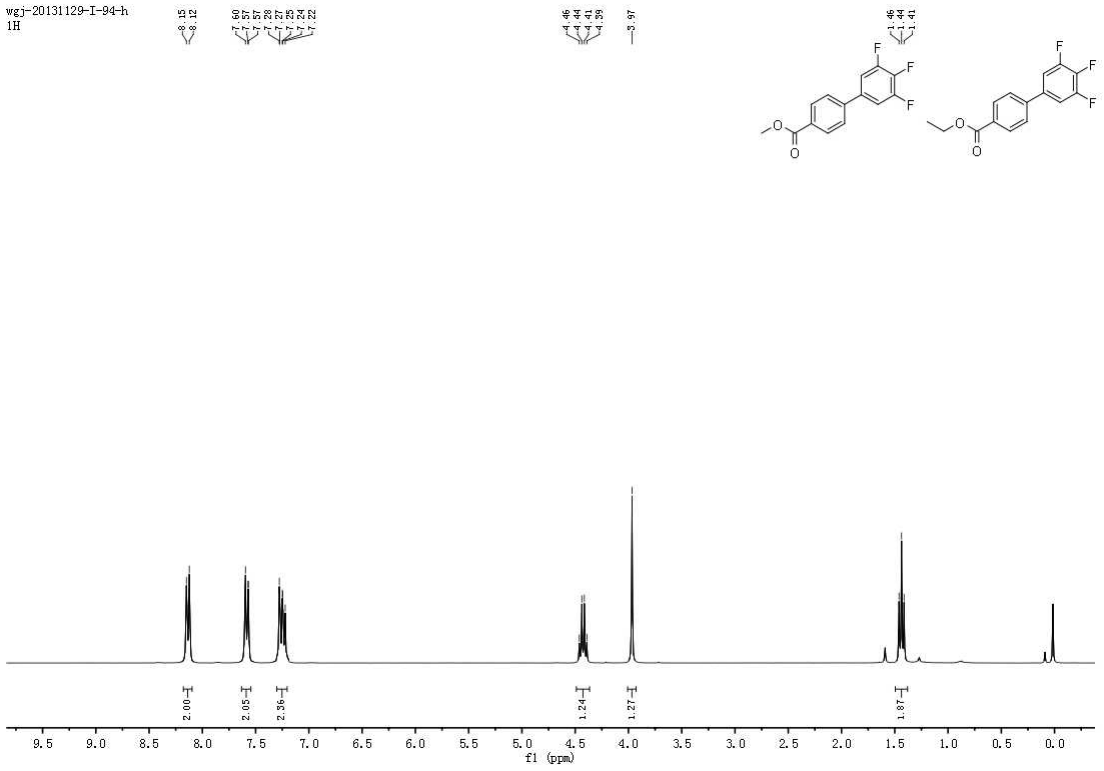


**Figure S34.** $^{1}$H -NMR spectra of **10d**

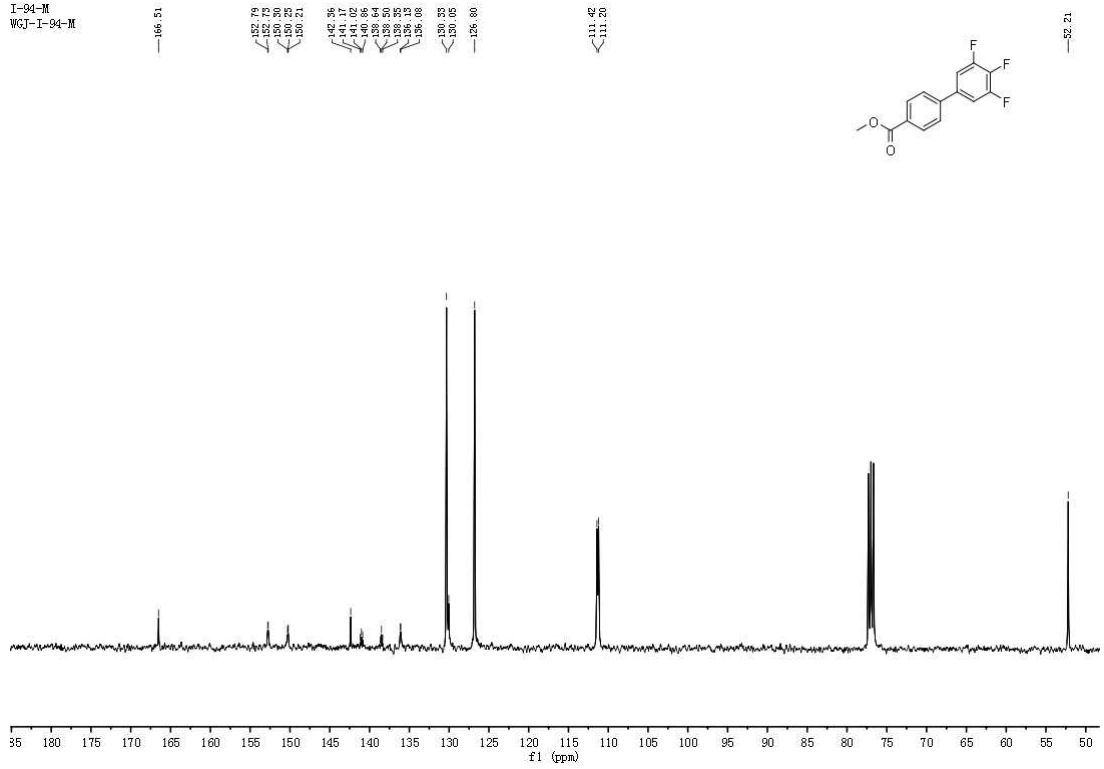


**Figure S35.** $^{13}$C -NMR spectra of **10d**

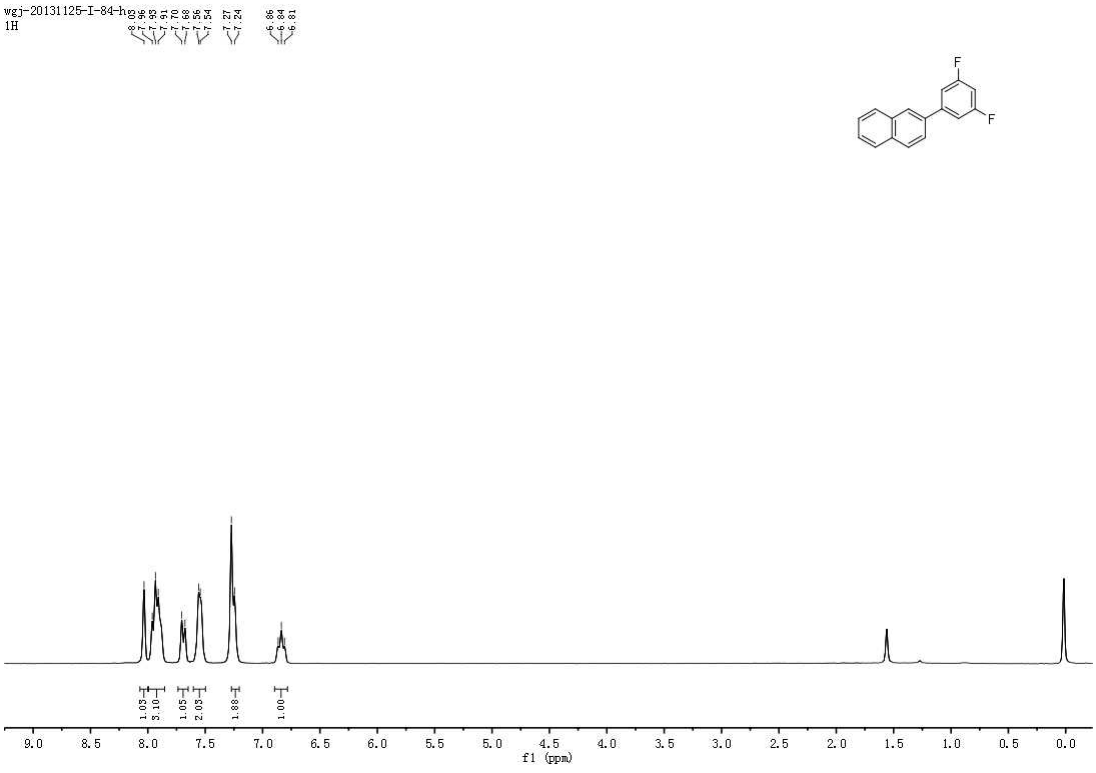


**Figure S36.** $^{1}$H -NMR spectra of **10e**

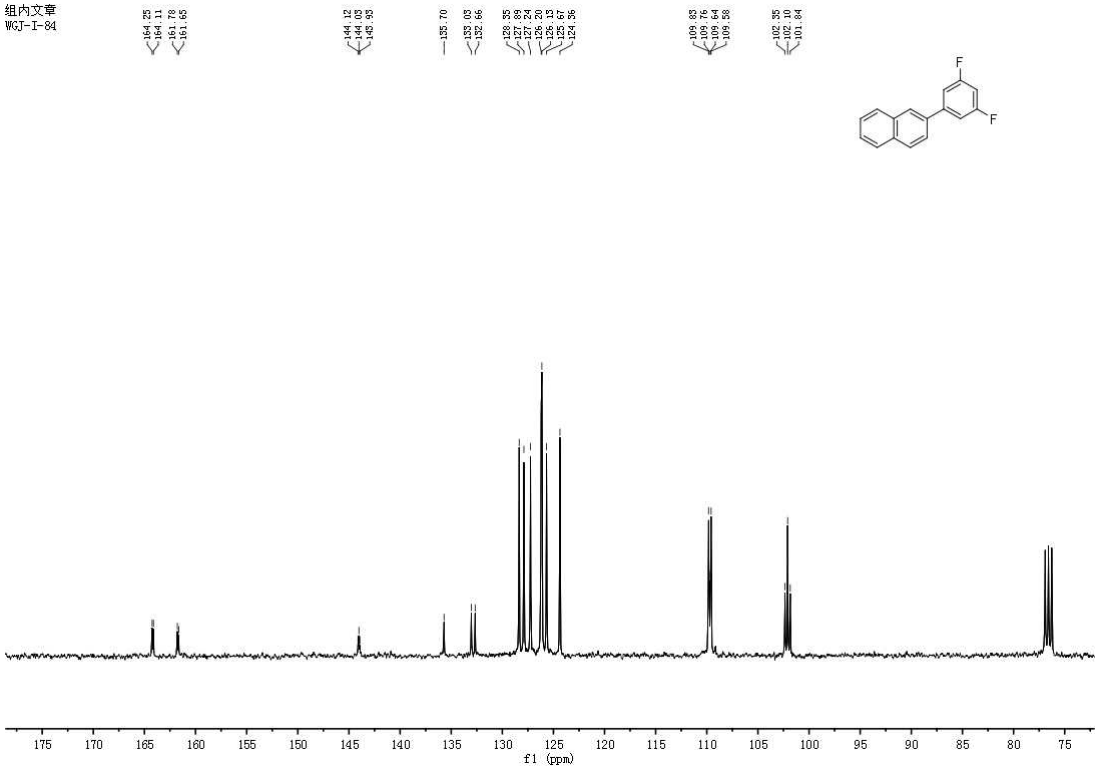


**Figure S37.** $^{13}$C -NMR spectra of **10e**

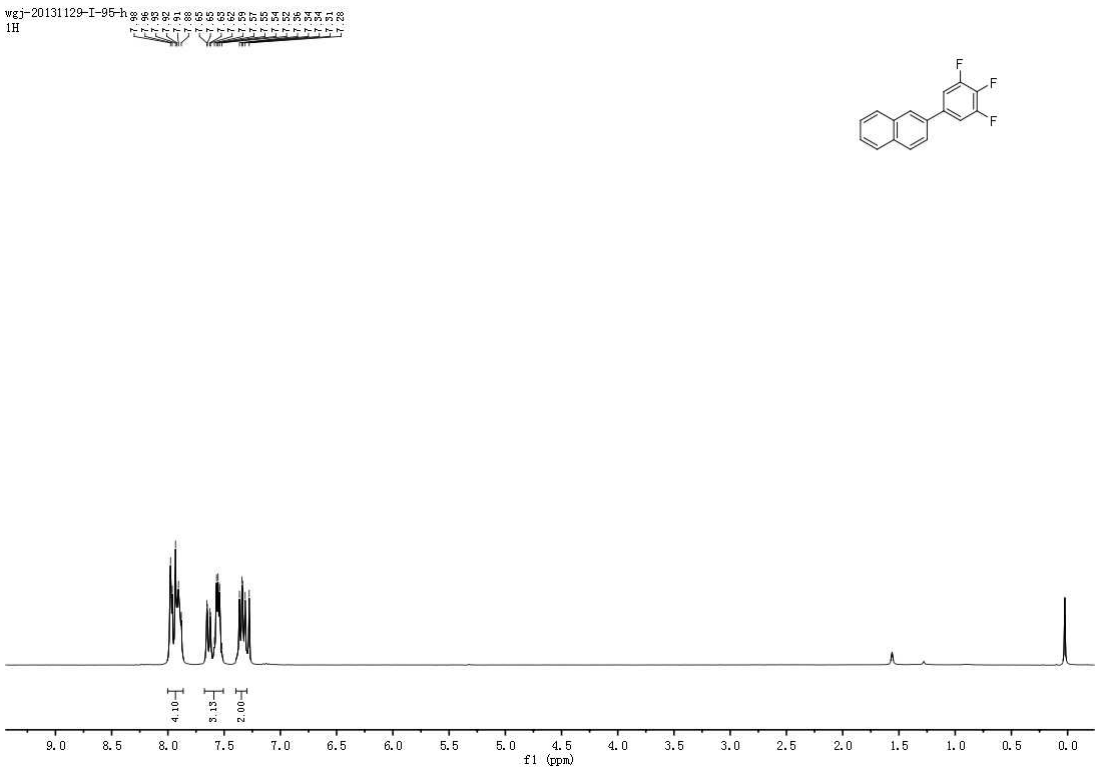


**Figure S38.** $^{1}$H -NMR spectra of **10f**

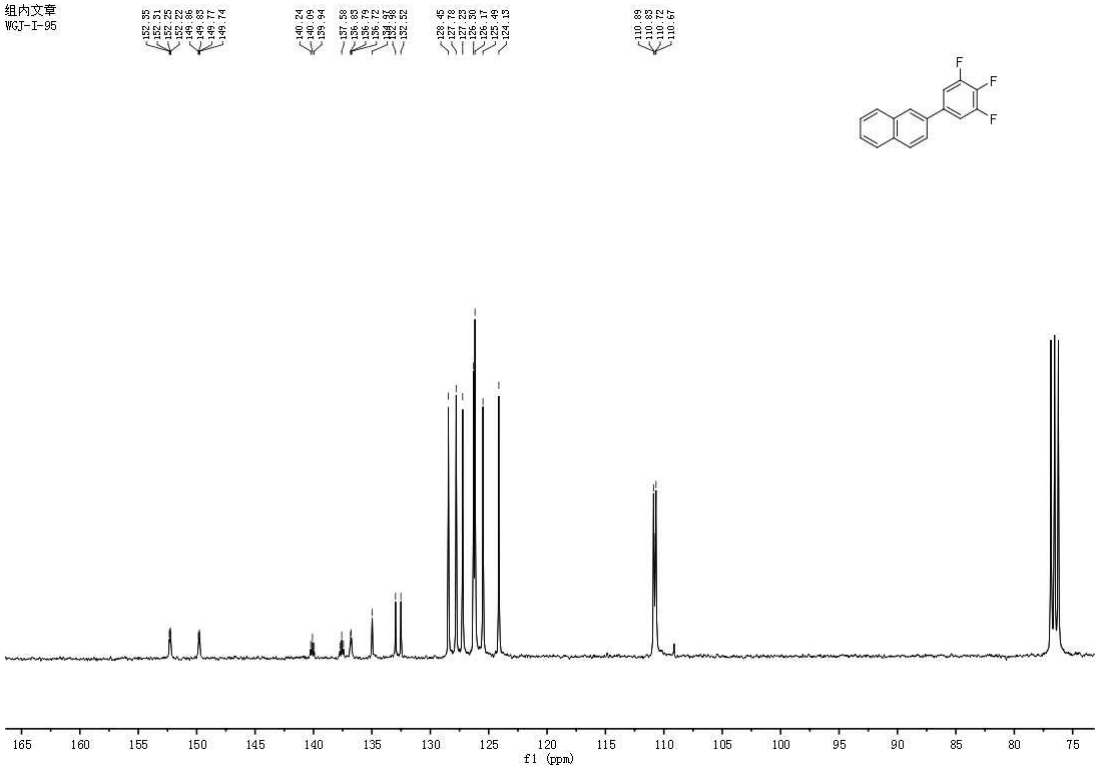


**Figure S39.** $^{13}$C -NMR spectra of **10f**

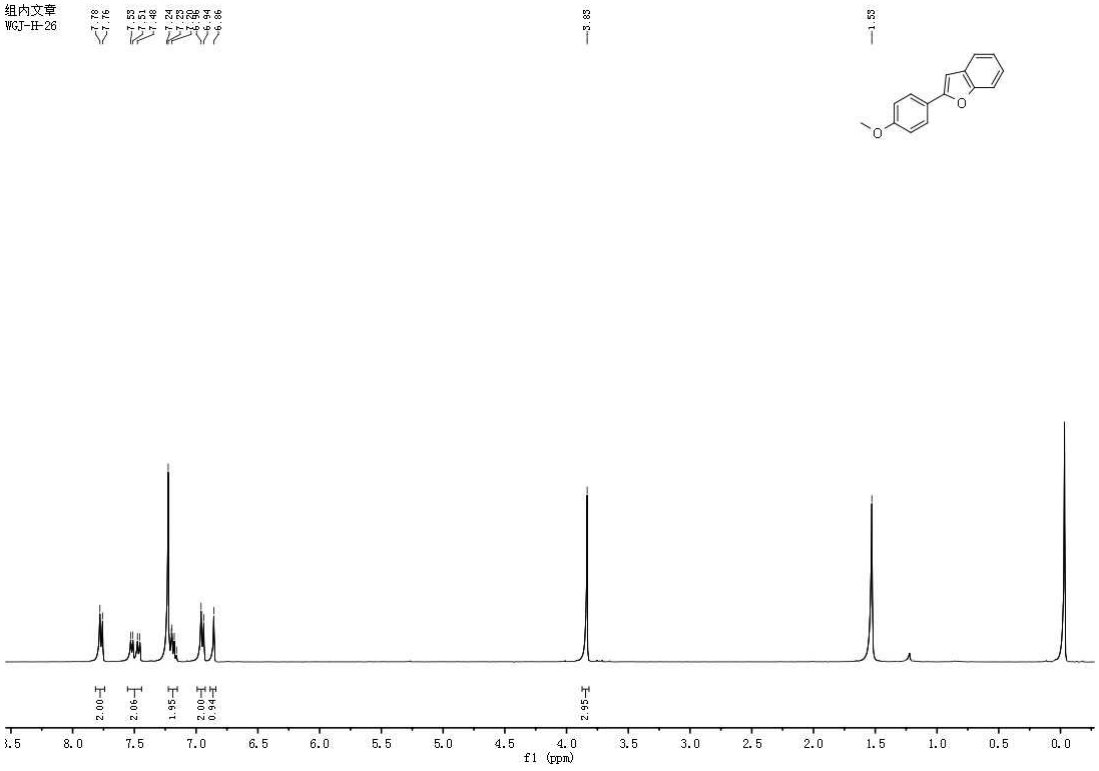


**Figure S40.** $^{1}$H -NMR spectra of **11a**

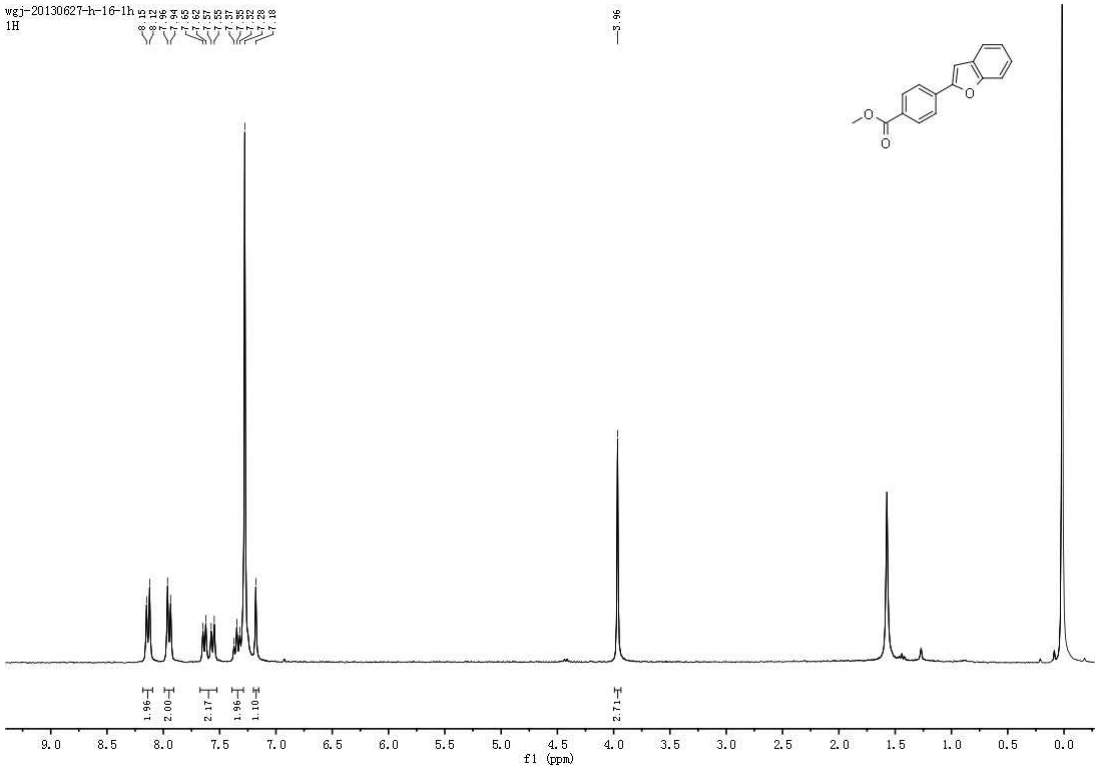


**Figure S41.** $^{1}$H -NMR spectra of **11b**

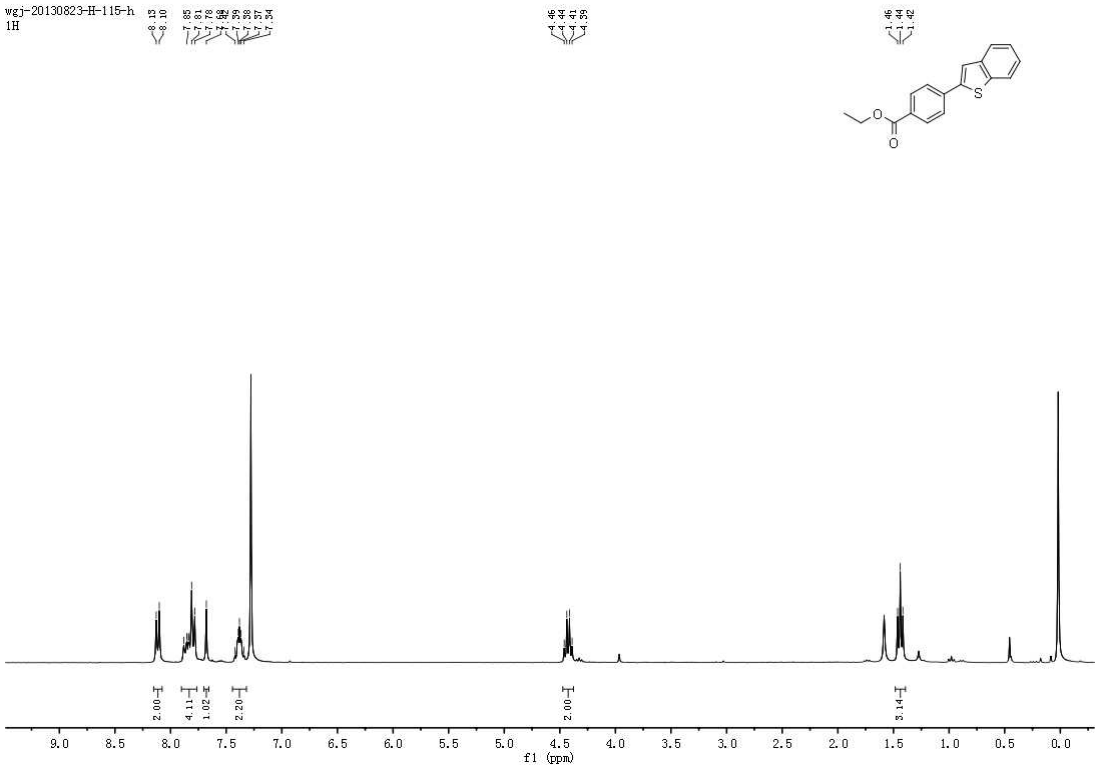


**Figure S42.** $^{1}$H -NMR spectra of **11c**

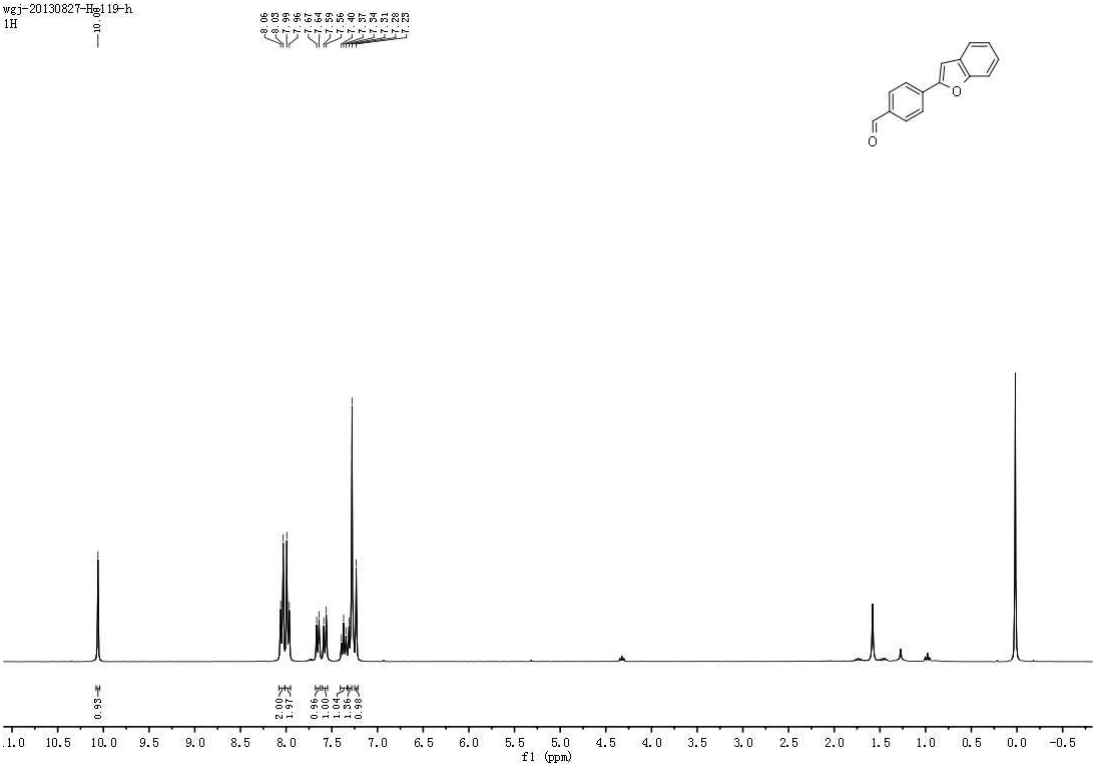


**Figure S43.** $^{1}$H -NMR spectra of **11d**

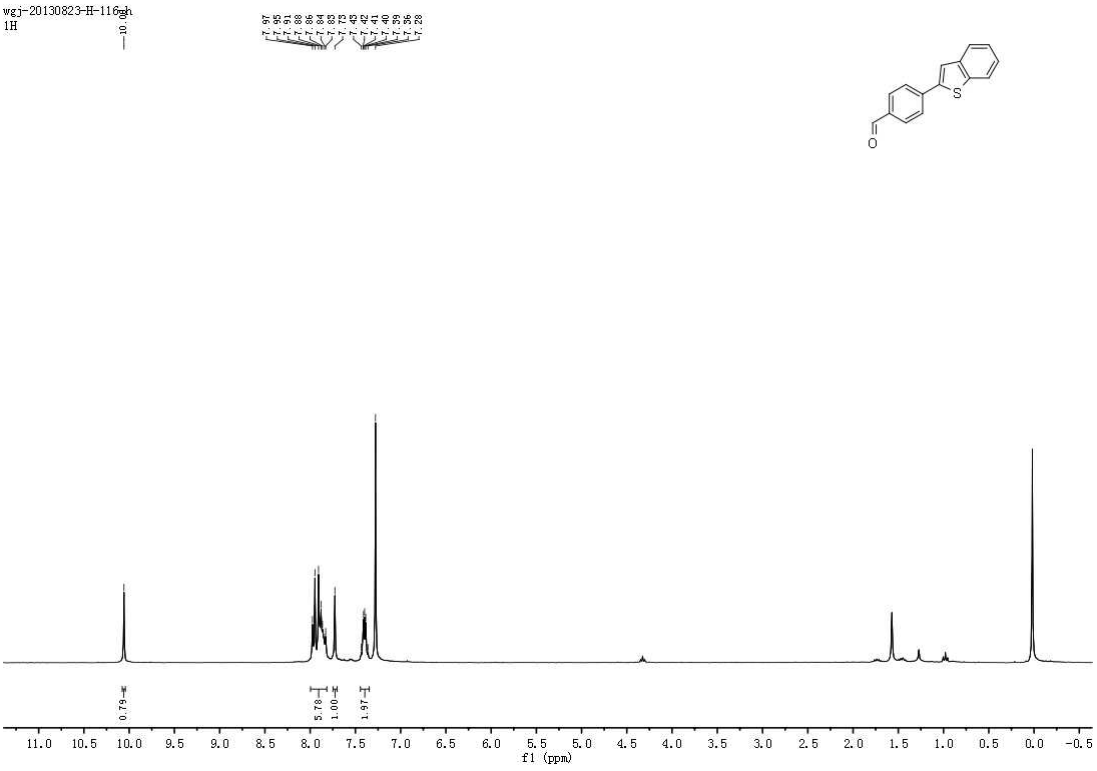


**Figure S44.** $^{1}$H -NMR spectra of **11e**

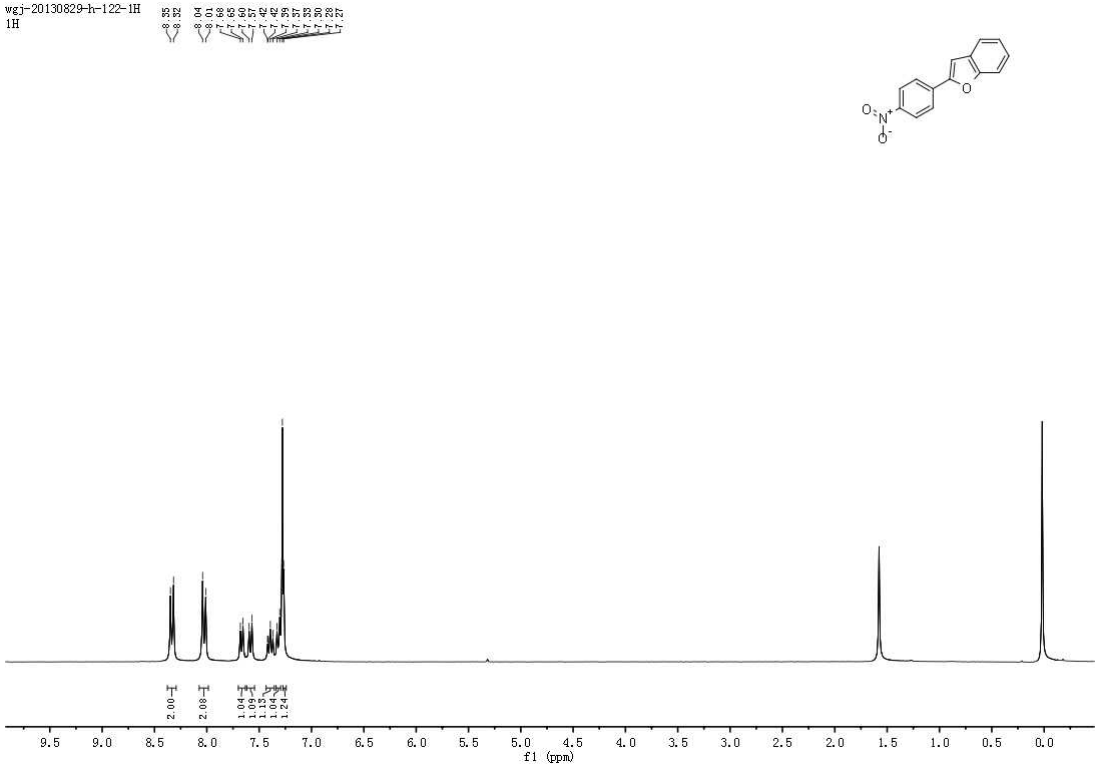


**Figure S45.** $^{1}$H -NMR spectra of **11f**

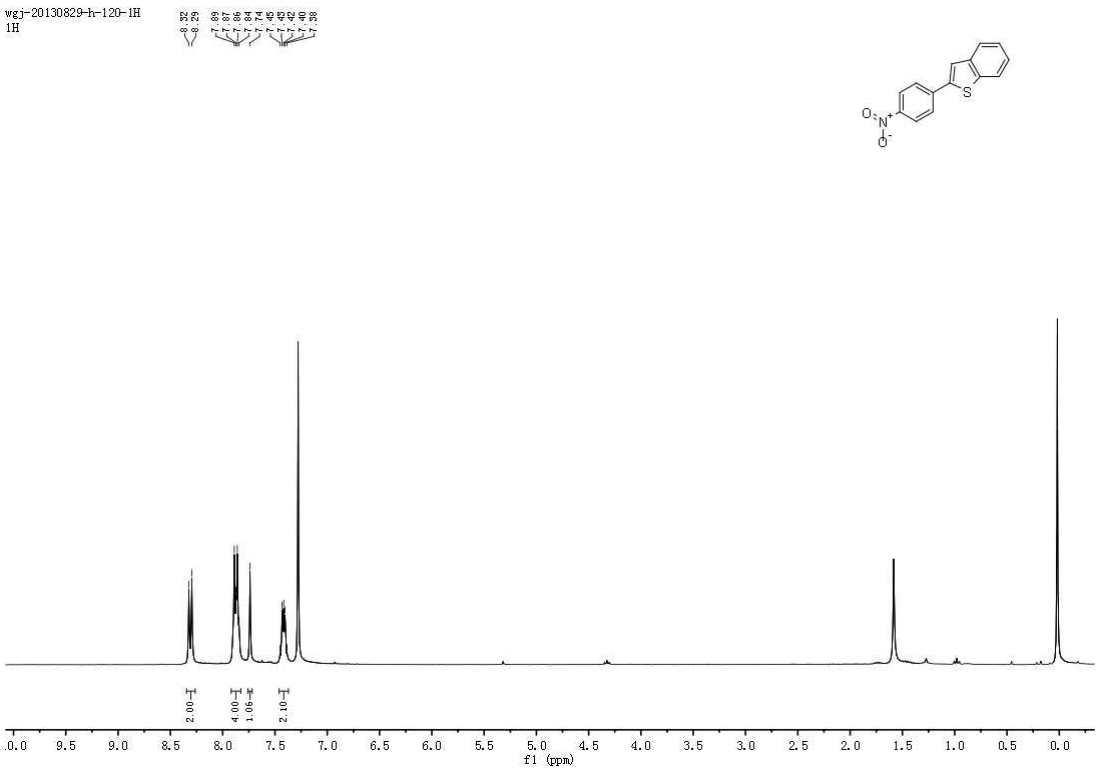


**Figure S46.** $^{1}$H -NMR spectra of **11g**

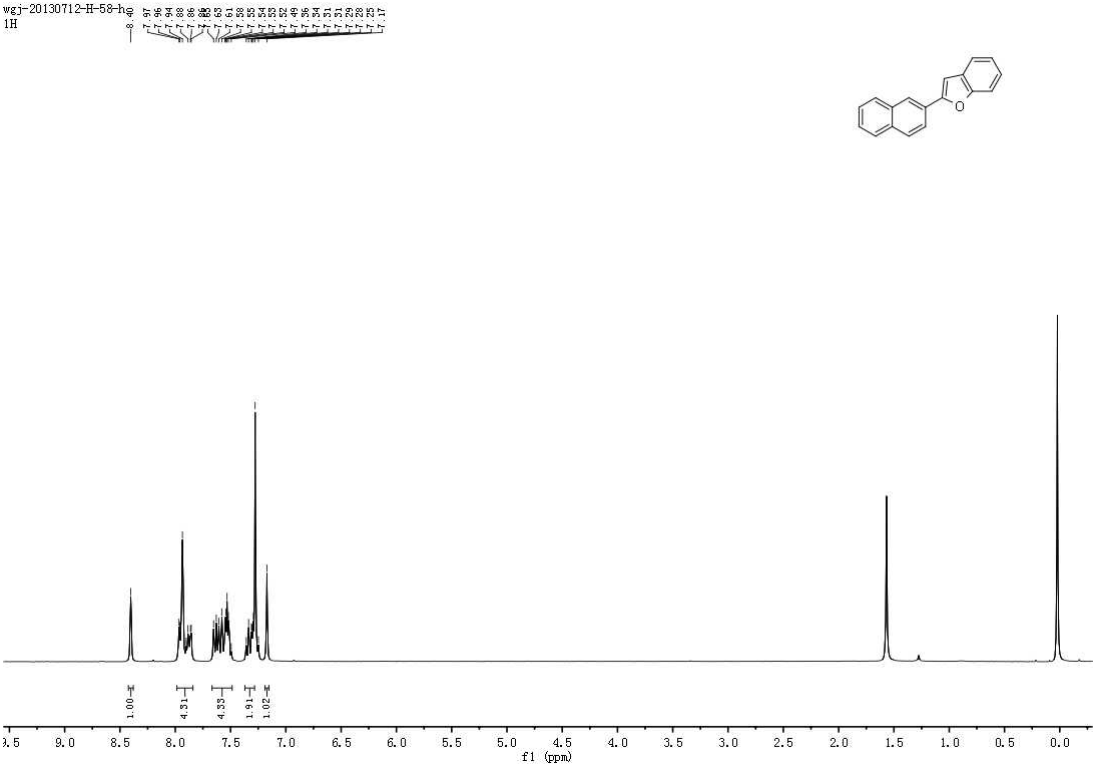


**Figure S47.** $^{1}$H -NMR spectra of **11h**

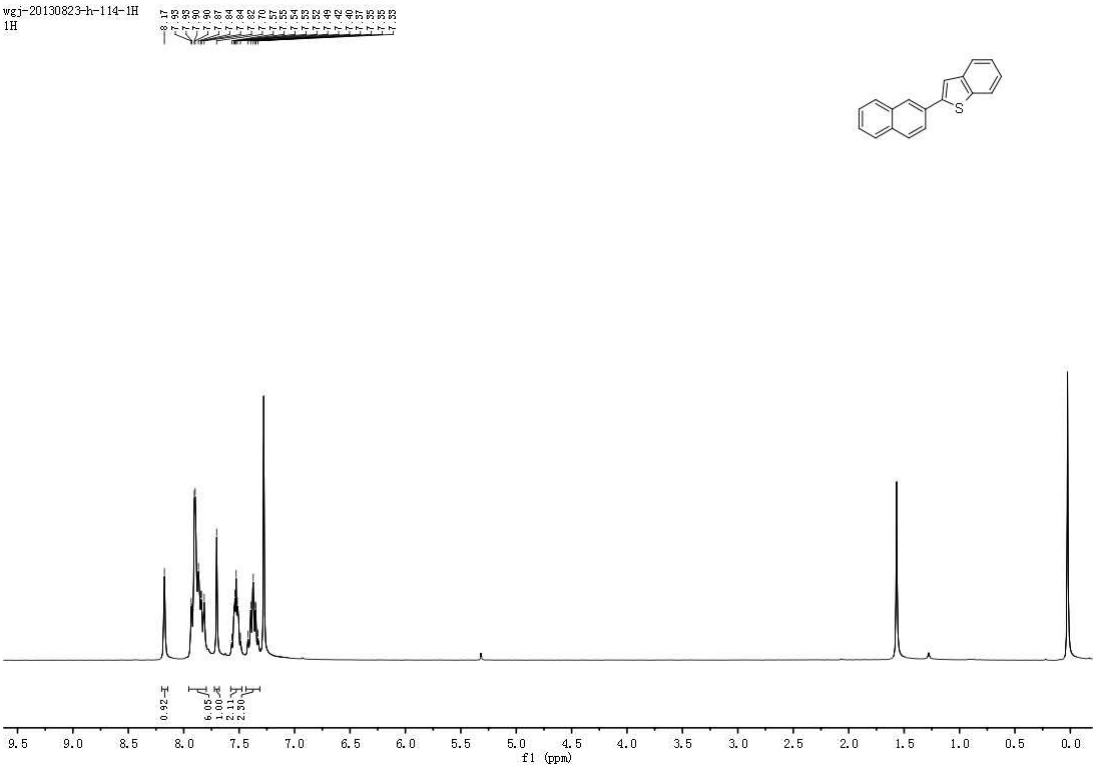


**Figure S48.** $^{1}$H -NMR spectra of **11i**

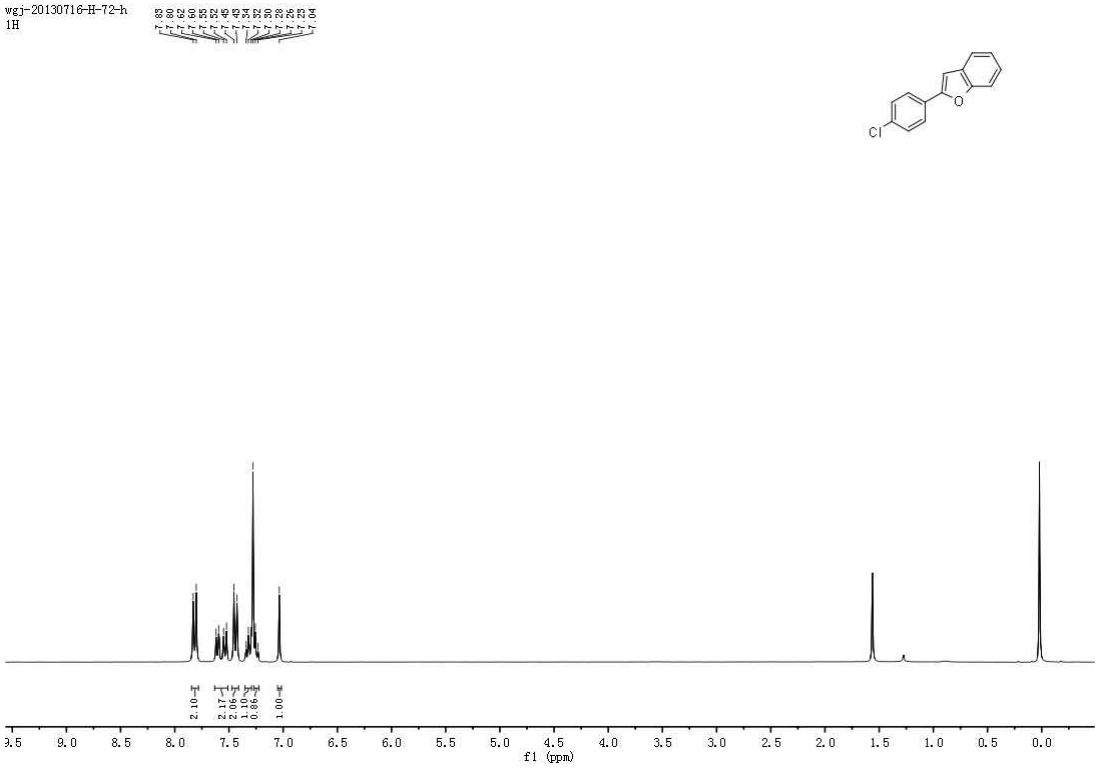


**Figure S49.** $^{1}$H -NMR spectra of **11j**

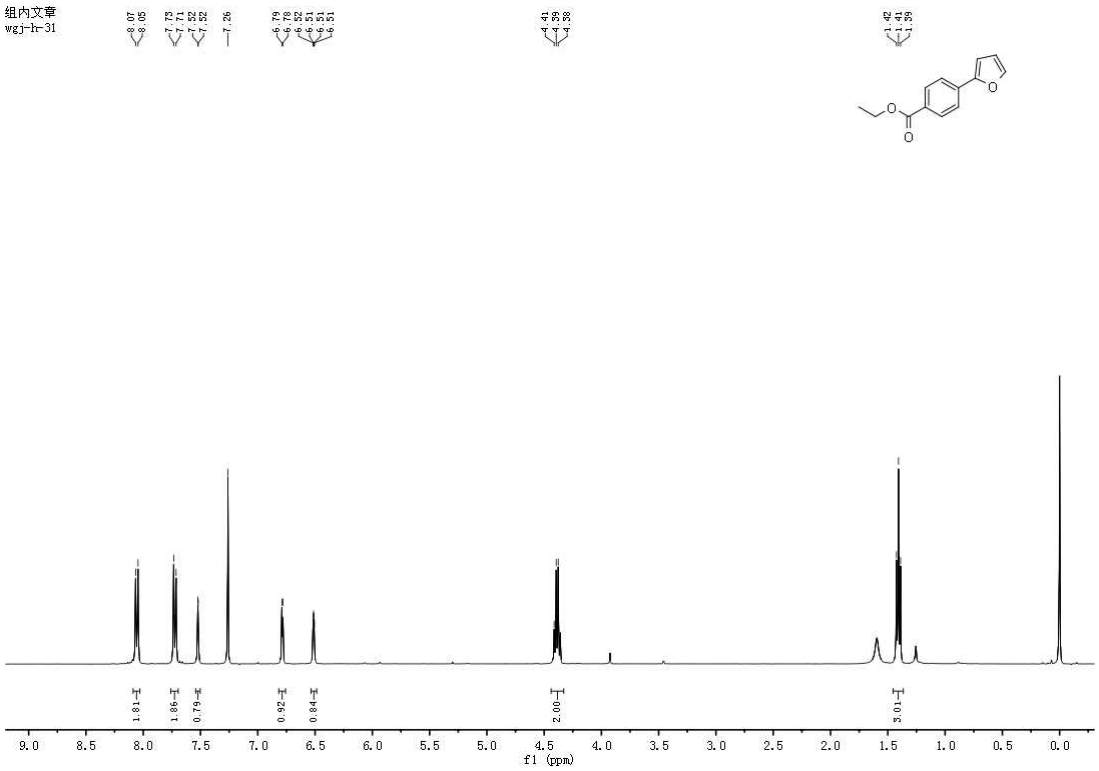


**Figure S50.** $^{1}$H -NMR spectra of **11k**

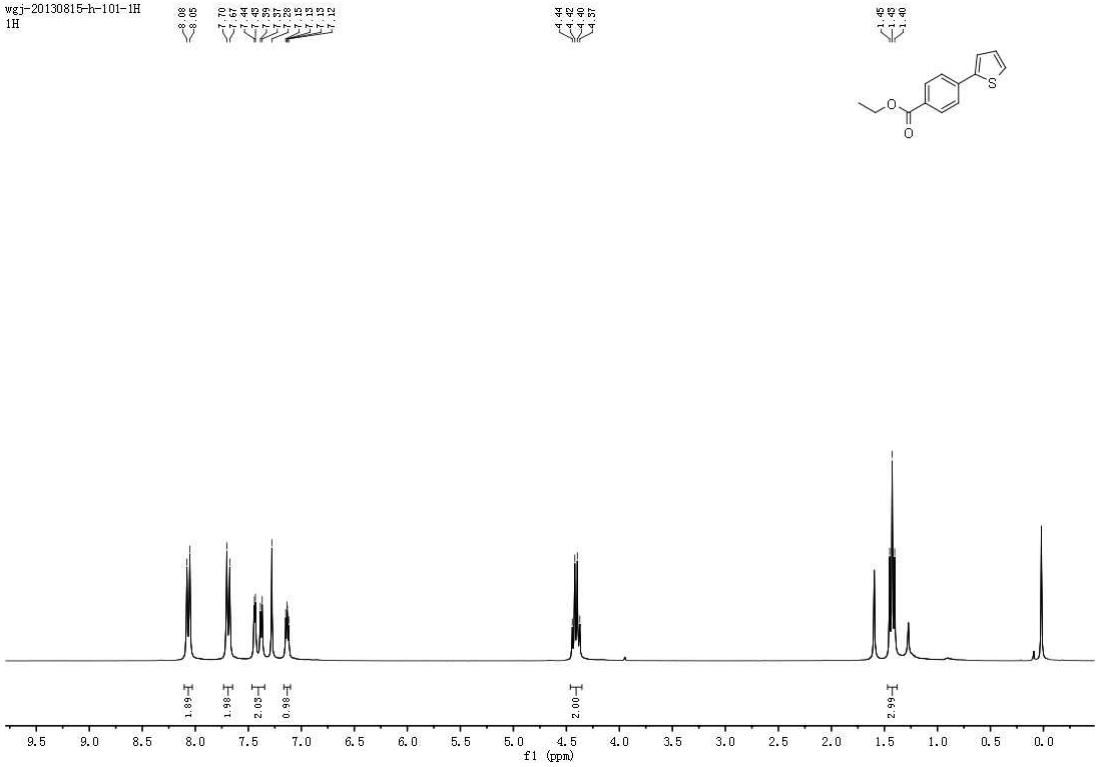


**Figure S51.** $^{1}$H -NMR spectra of **11l**

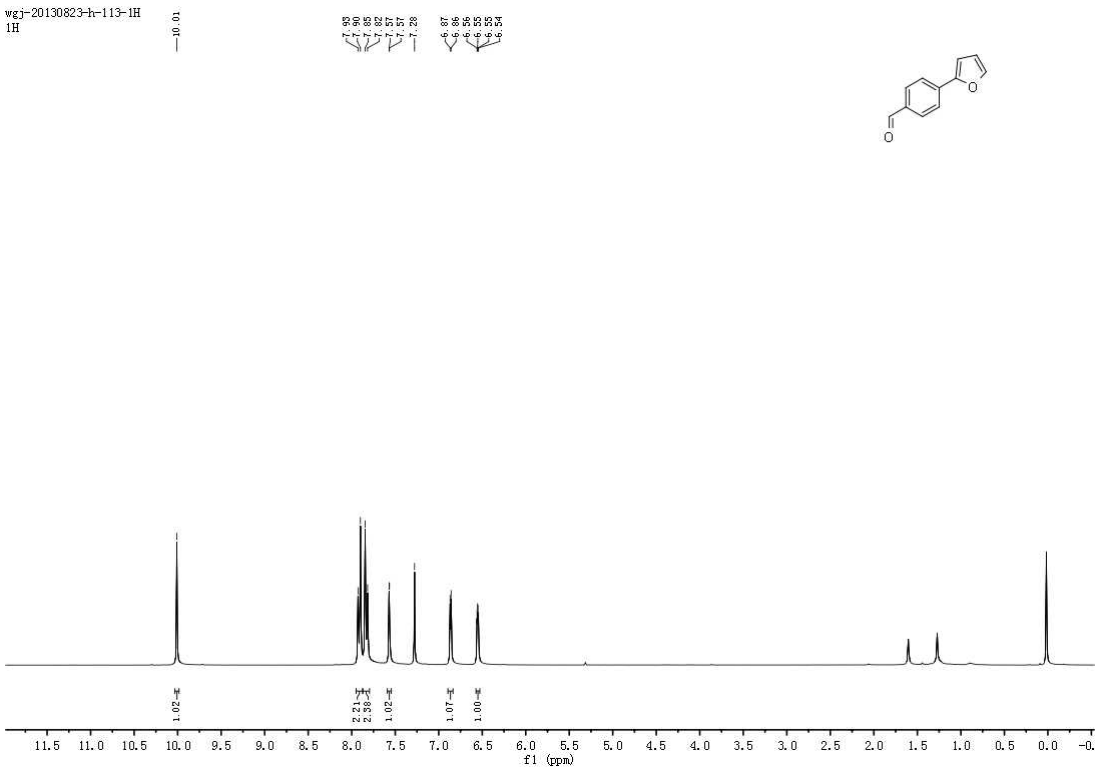


**Figure S52.** $^{1}$H -NMR spectra of **11m**

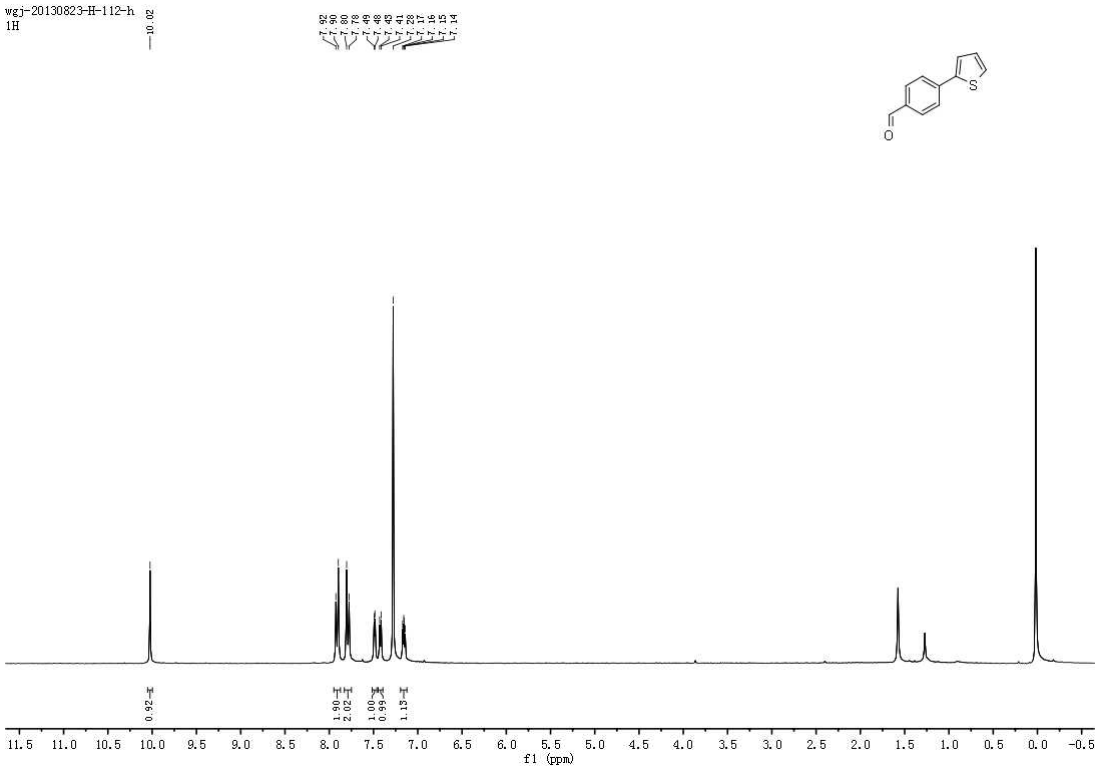


**Figure S53.** $^{1}$H -NMR spectra of **11n**

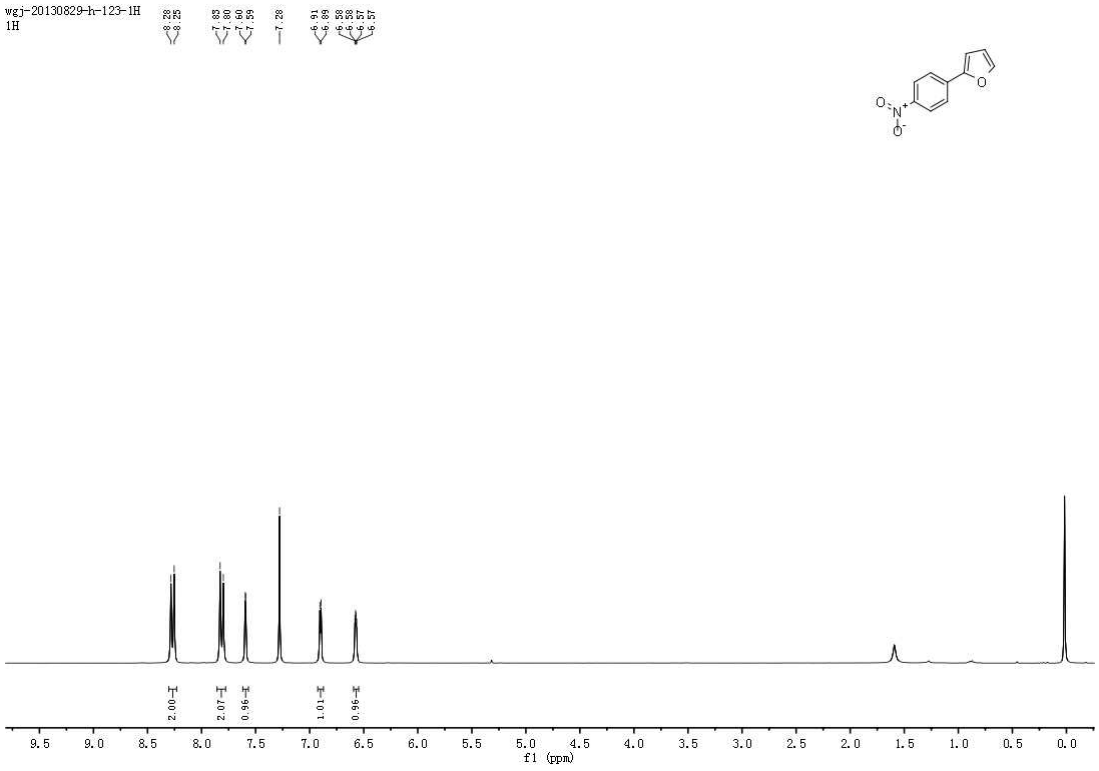


**Figure S54.** $^{1}$H -NMR spectra of **11o**

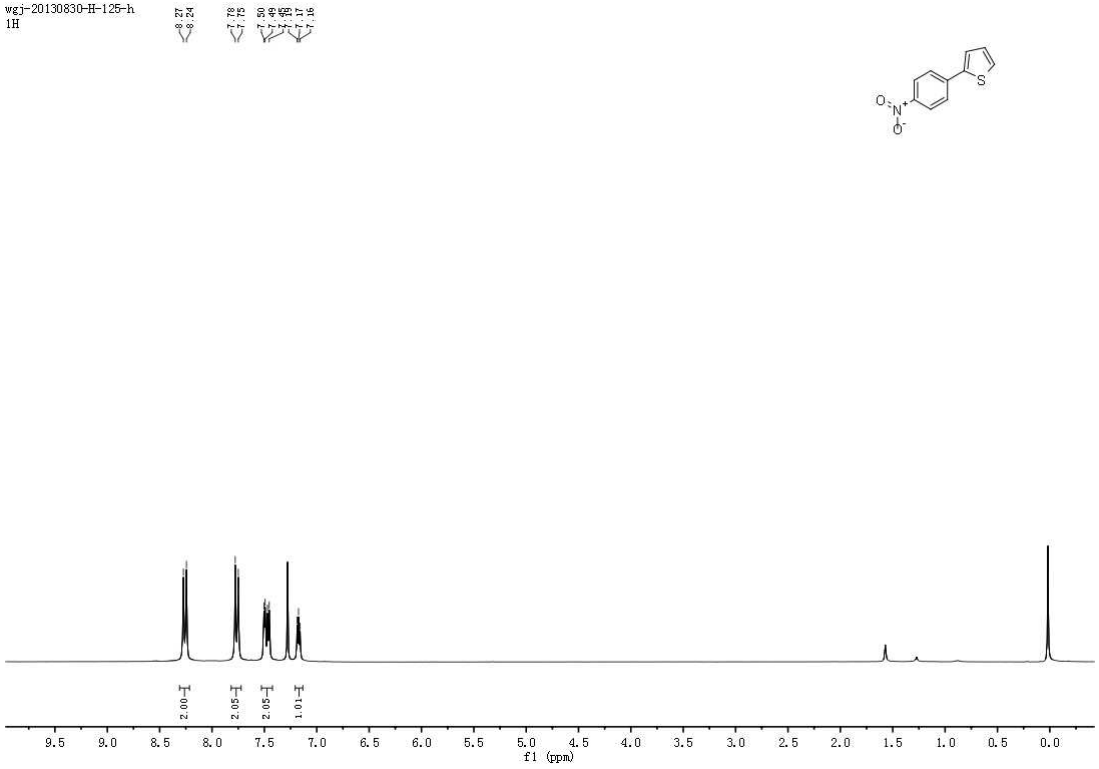


**Figure S55.** $^{1}$H -NMR spectra of **11p**

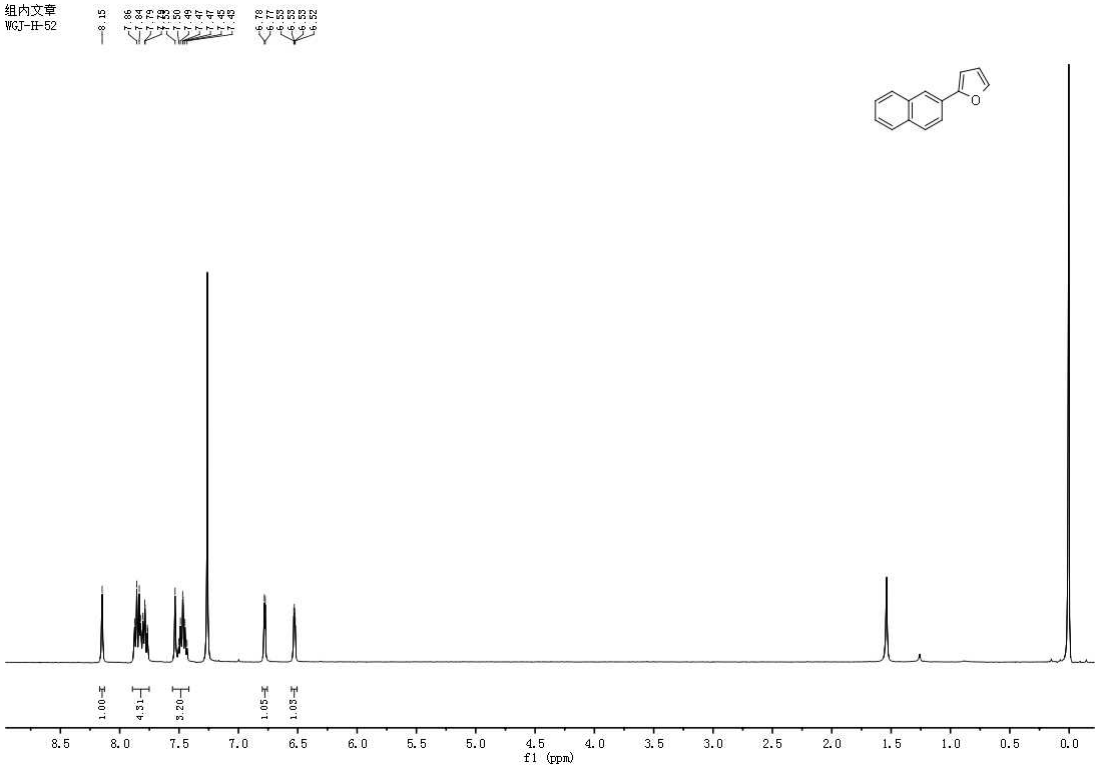


**Figure S56.** $^{1}$H -NMR spectra of **11q**

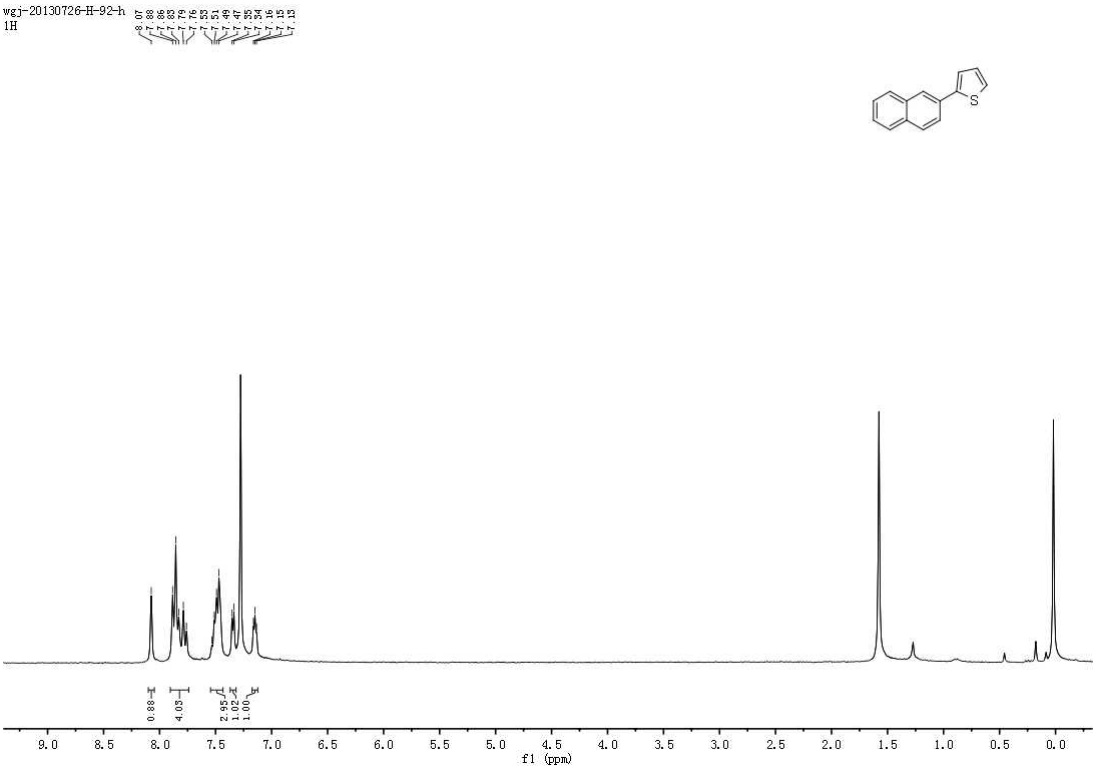


**Figure S57.** $^{1}$H -NMR spectra of **11r**

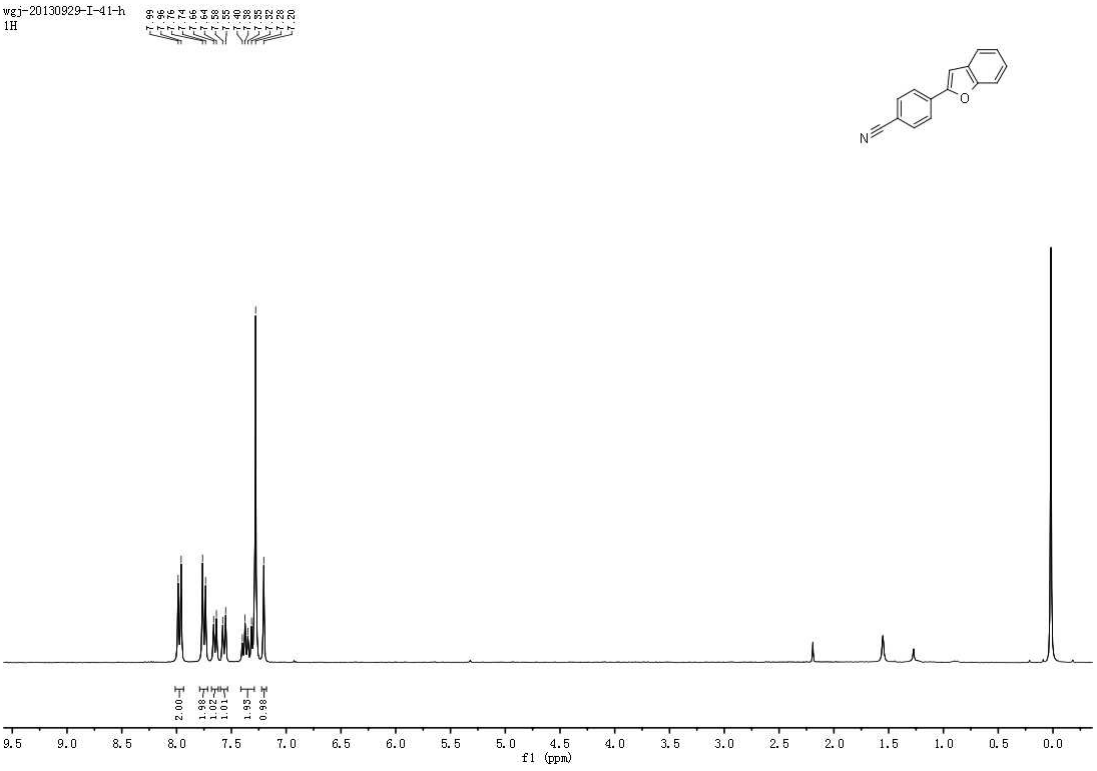


**Figure S58.** $^{1}$H -NMR spectra of **11s**