Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.

Copper-Catalyzed Regioselective Sulfonylcyanation of Vinylarenes

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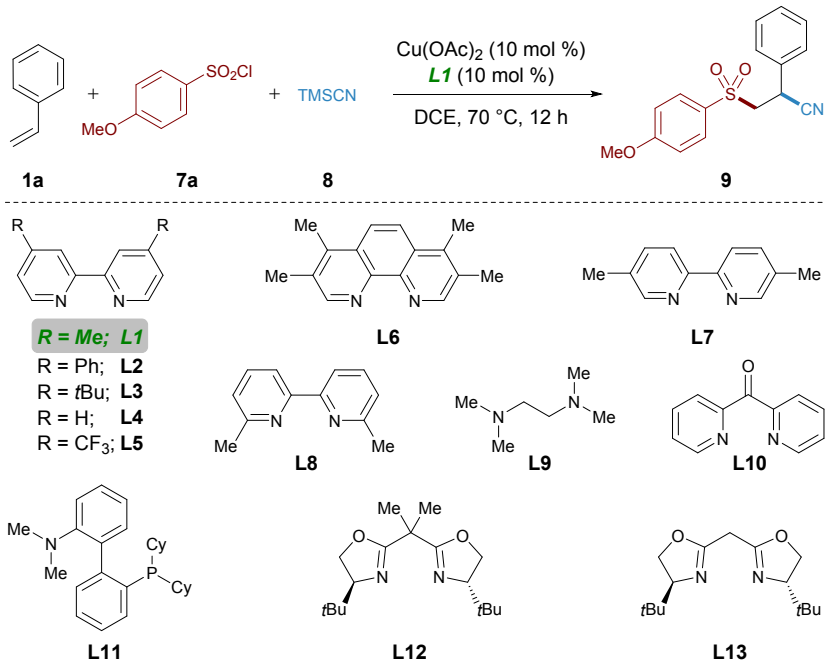
Contents

General Remarks

Catalytic reactions were carried out in Schlenk tubes under an argon atmosphere using pre-dried glassware. Anhydrous 1,2-DCE was dried and obtained from commercial sources. The following starting materials and copper catalysts were synthesized according to previously described methods: Vinylarenes **2j**,[1] **2k**,[2] **32**.[3] Other chemicals were obtained from commercial sources and were used without further purification. Yields refer to isolated compounds, estimated to be > 95% pure as determined by ^{1}H-NMR. Chromatography: Merck silica gel 60 (40-63 µm). NMR: Spectra were recorded on Bruker Avance III 400 in the solvent indicated; chemical shifts (δ) are given in ppm. All IR spectra were recorded on a Shimadzu IRTracer-100. High resolution mass spectrometry (HRMS) with Anilent 1200HPLC-6120MS. M. p.: Stuart melting point apparatus SMP3, Barlworld Scientific, values are uncorrected.

Optimization

Table 1. Optimization for copper-catalyzed sulfonylcyanation of styrene 1a.[a]



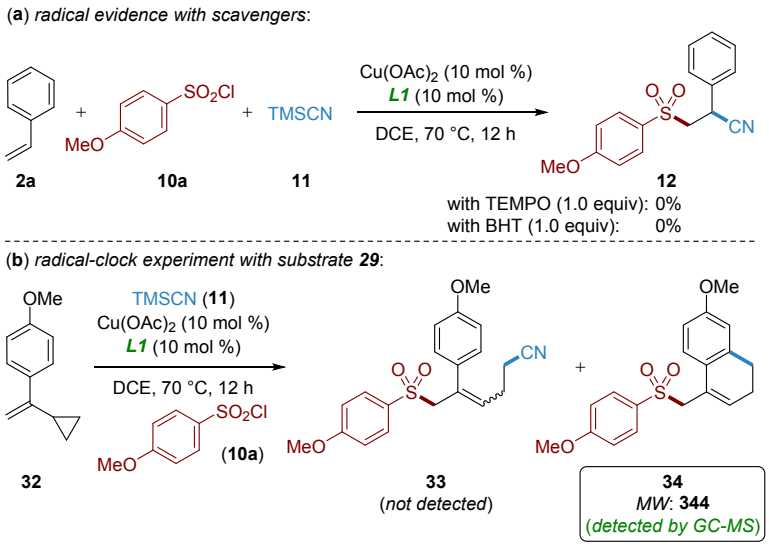
Entry	Modified conditions	Yield (%)[b]
1	CuCl and **L2**	51
2	CuBr and **L2**	45
3	CuI and **L2**	52
4	CuCN and **L2**	49
5	$Cu(MeCN)_4PF_6$ and **L2**	54
6	$CuCl_2$ and **L2**	46
7	$Cu(OTf)_2$ and **L2**	trace
7	$Cu(OAc)_2$ and **L2**	65
8	***none***	***75 (75)***[c]
9	**L3** instead of **L1**	49
10	**L4** instead of **L1**	37
11	**L5** instead of **L1**	18
12	**L6** instead of **L1**	30
13	**L7** instead of **L1**	65
14	**L8** instead of **L1**	trace
15	**L9** instead of **L1**	13
16	**L10** instead of **L1**	13
17	**L11** instead of **L1**	21
18	**L12** instead of **L1**	0
19	**L13** instead of **L1**	0
20	DMF, DCM, THF, or MeCN instead of DCE	28; 40; 42; 46
21	Without [Cu]	0
22	Without ligand	trace

[a] General reaction conditions: **1a** (0.2 mmol), **7a** (0.3 mmol), **8** (0.3 mmol), $Cu(OAc)_2$ (10 mol %), **L1** (10 mol %), anhydrous DCE (1.0 mL), under Ar, 70 ˚C, 12 h. [b] Isolated yield. [c] with $Cu(MeCN)_4PF_6$ (10 mol %). DCE = 1,2-dichloroethane; DMF = *N,N*-dimethylformamide;

DCM = dichloromethane; THF = tetrahydrofuran.

Additional Expeiments:

S1. Mechanistic studies:



Scheme S1. Mechanistic studies

procedures for scheme S1a:

A suspension of vinylarene **2a** (26 mg, 0.25 mmol, 1.00 equiv), arylsulfonyl chloride **10a** (0.38 mmol, 1.50 equiv), TMSCN **11** (0.38 mmol, 1.50 equiv), $Cu(OAc)_2$ (4.5 mg, 10.0 mol %), 4,4'-dimethyl-2,2'-bipyridine (4.6 mg, 10.0 mol %) and TEMPO or BHT (0.25 mmol) in anhydrous 1,2-DCE (1.0 mL) was stirred at 70 °C for 12 h under an atmosphere of Ar. At ambient temperature, the reaction mixture was analyzed by GC-MS.

These experiments demonstrated that no desired product **12** can be observed when stoichiometric TEMPO was added into the catalytic system, as was also observed in the presence of 1.0 equivalents of BHT. Only starting material **2a** can be detected in all these reactions.

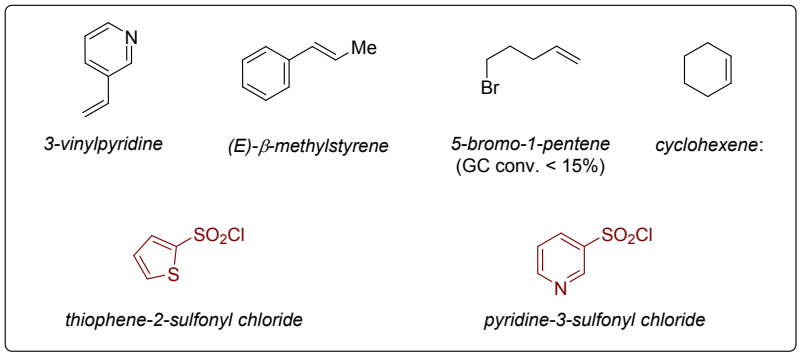
procedures for scheme S1b:

A suspension of vinylarene **32** (44 mg, 0.25 mmol, 1.00 equiv), arylsulfonyl chloride **10a** (0.38 mmol, 1.50 equiv), TMSCN **11** (0.38 mmol, 1.50 equiv), $Cu(OAc)_2$ (4.5 mg, 10.0 mol %) and 4,4'-dimethyl-2,2'-bipyridine (4.6 mg, 10.0 mol %) in anhydrous 1,2-DCE (1.0 mL) was stirred at 70 °C for 12 h under an atmosphere of Ar. At ambient temperature, the reaction mixture was analyzed by GC-MS.

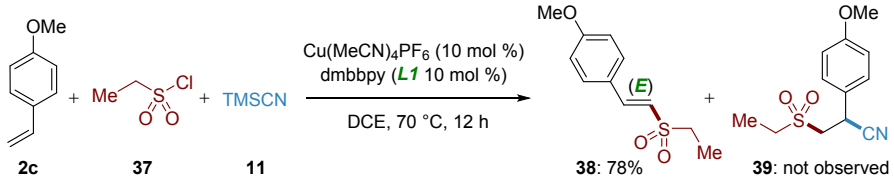
These experiments demonstrated that the ring-opened sulfonylonylcyanation product **33** was not observed, while the ring-closing compound **34** was be detected by GC and GC-MS (MW: 344).

S2. Unsuccessful substrates and Heck-type coupling reaction with ethanesulfonyl chloride:

(**a**) *Unsuccessful substrates* :



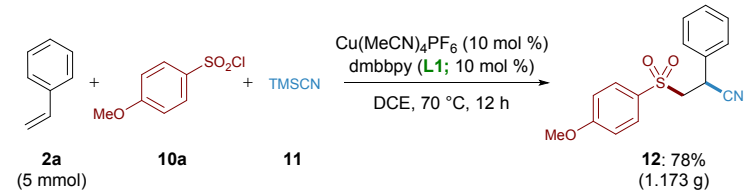
(**b**) *with ethanesulfonyl chloride*:



Scheme S2. Additional experiments with different alkenes and sulfonyl chlorides.

S3. Gram-scale reaction:

(**a**) *gram-scale reaction*:



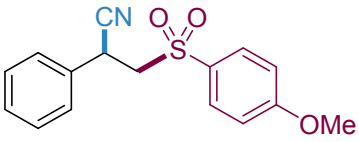
Scheme S3. Gram-scale reaction.

procedures for scheme S3:

A suspension of vinylarene **2a** (520 mg, 5 mmol), arylsulfonyl chloride **10a** (1.545 g, 7.5 mmol), TMSCN **11** (743 mg, 7.5 mmol), $Cu(MeCN)_2PF_6$ (187 mg, 10.0 mol %) and 4,4'-dimethyl-2,2'-bipyridine (92 mg, 10.0 mol %) in anhydrous 1,2-DCE (10 mL) was stirred at 70 °C for 12 h under an atmosphere of Ar. At ambient temperature, the solvent was evaporated *in vacuo* and the remaining residue was purified by column chromatography on silica gel (*n*-

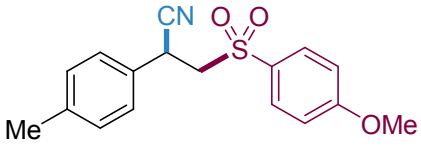
hexane/EtOAc 8:1) to yield products **12** (1.173g, 78%).

Representative Procedure: A suspension of vinylarene **2** (0.25 mmol, 1.00 equiv), arylsulfonyl chloride **10** (0.38 mmol, 1.50 equiv), TMSCN **11** (0.38 mmol, 1.50 equiv), $Cu(OAc)_2$ (4.5 mg, 10.0 mol %) and 4,4'-dimethyl-2,2'-bipyridine (4.6 mg, 10.0 mol %) in anhydrous 1,2-DCE (1.0 mL) was stirred at 70 °C for 12 h under an atmosphere of Ar. At ambient temperature, the solvent was evaporated *in vacuo* and the remaining residue was purified by column chromatography on silica gel (*n*-hexane/EtOAc) to yield products **12**–**31, 35, 38**.



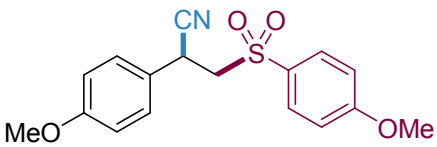
3-[(4-Methoxyphenyl)sulfonyl]-2-phenylpropanenitrile (12)

The general procedure was followed using **2a** (26 mg, 0.25 mmol), **10a** (77.3 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **12** (57 mg, 75%) as a white solid. M. p. = 77–79 °C. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 7.88 – 7.81 (m, 2H), 7.39 – 7.27 (m, 5H), 7.06 – 6.97 (m, 2H), 4.38 (dd, *J* = 9.5, 4.4 Hz, 1H), 3.88 (s, 3H), 3.74 (dd, *J* = 14.4, 9.6 Hz, 1H), 3.43 (dd, *J* = 14.5, 4.4 Hz, 1H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 164.4, 133.1, 130.6, 130.5, 129.6, 129.0, 127.4, 118.1, 114.8, 60.2, 55.8, 32.1. IR (ATR): 2922, 1592, 1258 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{16}H_{16}NO_3S^+$ [M+H$^+$] 302.0845, found 302.0842 [M+H$^+$].



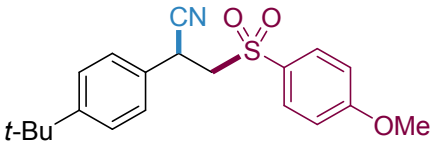
3-[(4-Methoxyphenyl)sulfonyl]-2-(*p*-tolyl)propanenitrile (13)

The general procedure was followed using **2b** (29.5mg, 0.25 mmol), **10a** (77.3 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **13** (56.8 mg, 72%) as a white solid. M. p. = 102–103 °C. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 7.84 (d, *J* = 8.8 Hz, 2H), 7.18 (d, *J* = 8.5 Hz, 2H), 7.15 (d, *J* = 8.5 Hz, 2H), 7.02 (d, *J* = 8.9 Hz, 2H), 4.33 (dd, *J* = 9.5, 4.5 Hz, 1H), 3.88 (s, 3H), 3.71 (dd, *J* = 14.4, 9.5 Hz, 1H), 3.41 (dd, *J* = 14.5, 4.5 Hz, 1H), 2.33 (s, 3H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 164.3, 139.0, 130.5, 130.1, 130.0, 129.6, 127.2, 118.2, 114.7, 60.2, 55.7, 31.8, 21.0. IR (ATR): 2919, 1593, 1260, 1134 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{17}H_{18}NO_3S^+$ [M+H$^+$] 316.1002, found 316.1007 [M+H$^+$].



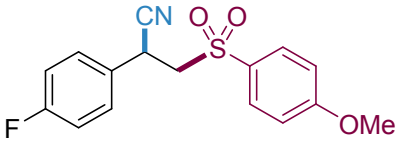
2-(4-Methoxyphenyl)-3-((4-methoxyphenyl)sulfonyl)propanenitrile (14)

The general procedure was followed using **2c** (33.5 mg, 0.25 mmol), **10a** (77.3 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **14** (61.4 mg, 74%) as a white solid. M. p. = 81–82 °C. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 7.82 (d, *J* = 8.9 Hz, 2H), 7.20 (d, *J* = 8.7 Hz, 2H), 7.01 (d, *J* = 8.9 Hz, 2H), 6.85 (d, *J* = 8.7 Hz, 2H), 4.33 (dd, *J* = 9.3, 4.7 Hz, 1H), 3.88 (s, 3H), 3.78 (d, *J* = 4.7 Hz, 3H), 3.72 (dd, *J* = 14.4, 9.3 Hz, 1H), 3.42 (dd, *J* = 14.4, 4.8 Hz, 1H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 164.3, 159.9, 130.5, 129.6, 128.6, 124.8, 118.4, 114.8, 114.7, 60.2, 55.8, 55.4, 31.4. IR (ATR): 2919, 1509, 1251, 1025 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{17}H_{18}NO_4S^+$ [M+H$^+$] 332.0951, found 332.0945 [M+H$^+$].



2-[4-(*Tert*-butyl)phenyl]-3-[(4-methoxyphenyl)sulfonyl]propanenitrile (15)

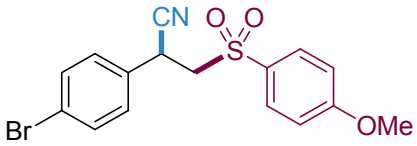
The general procedure was followed using **2d** (40.06mg, 0.25 mmol), **10a** (77.3 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **15** (52.7 mg, 59%) as a white solid. M. p. = 93–94 °C. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 7.87 – 7.79 (m, 2H), 7.36 (d, *J* = 8.4 Hz, 2H), 7.21 (d, *J* = 8.4 Hz, 2H), 7.04 – 6.97 (m, 2H), 4.35 (dd, *J* = 9.5, 4.5 Hz, 1H), 3.88 (s, 3H), 3.73 (dd, *J* = 14.5, 9.5 Hz, 1H), 3.45 (dd, *J* = 14.5, 4.5 Hz, 1H), 1.29 (s, 9H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 164.3, 152.2, 130.5, 129.9, 129.7, 127.0, 126.5, 118.2, 114.7, 60.2, 55.7, 34.6, 31.7, 31.1. IR (ATR): 2956, 1602, 1139 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{20}H_{24}NO_3S^+$ [M+H$^+$] 358.1471, found 358.1463 [M+H$^+$].



2-(4-Fluorophenyl)-3-[(4-methoxyphenyl)sulfonyl]propanenitrile (16)

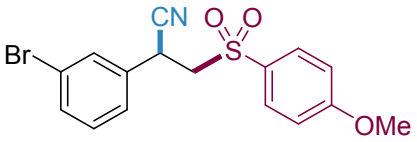
The general procedure was followed using **2e** (30.5mg, 0.25 mmol), **10a** (77.3 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **16** (37 mg, 46%) as a colorless solid. M. p. = 76–78 °C. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 7.87 – 7.80 (m, 2H), 7.35 – 7.27 (m, 2H), 7.10 – 6.99 (m, 4H), 4.39 (dd, *J* = 9.0, 5.0 Hz, 1H), 3.89 (s, 3H), 3.72 (dd, *J* = 14.4, 9.0 Hz, 1H), 3.43 (dd, *J* = 14.4, 5.0 Hz, 1H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 164.5, 162.9 (d, $J_{C\text{-}F}$ = 249.5 Hz), 130.5, 129.6, 129.3 (d, $J_{C\text{-}F}$ =

8.5 Hz), 128.9 (d, J_{C-F} = 3.4 Hz), 117.9, 116.6 (d, J_{C-F} = 22.1 Hz), 114.8, 60.2, 55.7, 31.5. ^{19}F-NMR ($CDCl_3$, 376 MHz): δ = -111.8. IR (ATR): 2917, 1698, 1222 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{16}H_{15}FNO_3S^+$ [M+H$^+$] 320.0751, found 320.0747 [M+H$^+$].



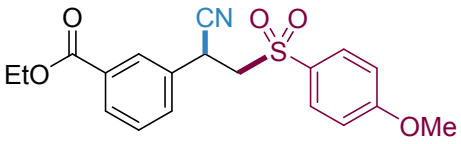
2-(4-Bromophenyl)-3-[(4-methoxyphenyl)sulfonyl]propanenitrile (17)

The general procedure was followed using **2f** (46.0 mg, 0.25 mmol), **10a** (77.3 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **17** (48 mg, 50%) as a colorless solid. M. p. = 79–81 °C. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 7.80 (d, *J* = 8.9 Hz, 2H), 7.49 (d, *J* = 8.4 Hz, 2H), 7.19 (d, *J* = 8.4 Hz, 2H), 7.01 (d, *J* = 8.9 Hz, 2H), 4.37 (dd, *J* = 8.8, 5.2 Hz, 1H), 3.89 (s, 3H), 3.72 (dd, *J* = 14.5, 8.8 Hz, 1H), 3.44 (dd, *J* = 14.5, 5.2 Hz, 1H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 164.4, 132.7, 131.9, 130.5, 129.4, 129.1, 123.3, 117.6, 114.8, 59.8, 55.8, 31.7. IR (ATR): 2919, 1590, 1261, 1128 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{16}H_{15}BrNO_3S^+$ [M+H$^+$] 379.9951, found 379.9954 [M+H$^+$].



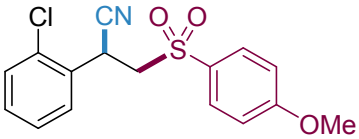
2-(3-Bromophenyl)-3-[(4-methoxyphenyl)sulfonyl]propanenitrile (18)

The general procedure was followed using **2g** (45.8mg, 0.25 mmol), **10a** (77.3 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **18** (47.5 mg, 50%) as a white solid. M. p. = 78–80 °C. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 7.82 (d, *J* = 8.9 Hz, 2H), 7.47 (d, *J* = 7.1 Hz, 1H), 7.43 (s, 1H), 7.27 – 7.22 (m, 2H), 7.02 (d, *J* = 8.8 Hz, 2H), 4.37 (dd, *J* = 8.9, 5.0 Hz, 1H), 3.89 (s, 3H), 3.73 (dd, *J* = 14.4, 9.0 Hz, 1H), 3.45 (dd, *J* = 14.4, 4.9 Hz, 1H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 164.4, 134.9, 132.3, 131.0, 130.8, 130.5, 129.4, 126.1, 123.4, 117.5, 114.8, 114.4, 59.7, 55.8, 31.7. IR (ATR): 2914, 1591, 1254, 1142 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{16}H_{15}BrNO_3S^+$ [M+H$^+$] 379.9951, found 379.9958 [M+H$^+$].



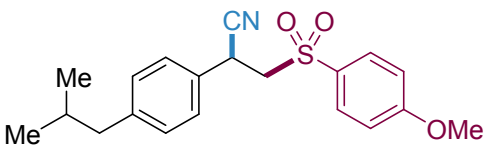
Ethyl 3-[1-cyano-2-(4-methoxyphenylsulfonyl)ethyl]benzoate (**19**)

The general procedure was followed using **2h** (45.8mg, 0.25 mmol), **10a** (77.3 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **19** (58 mg, 62%) as a colorless solid. M. p. = 91–93 °C. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 8.05 (dt, *J* = 7.6, 1.4 Hz, 1H), 7.97 (t, *J* = 1.7 Hz, 1H), 7.89 – 7.82 (m, 2H), 7.56 (dt, *J* = 7.7, 1.5 Hz, 1H), 7.49 (t, *J* = 7.7 Hz, 1H), 7.07 – 7.01 (m, 2H), 4.47 (dd, *J* = 9.2, 4.9 Hz, 1H), 4.41 (q, *J* = 7.1 Hz, 2H), 3.91 (s, 3H), 3.78 (dd, *J* = 14.4, 9.2 Hz, 1H), 3.50 (dd, *J* = 14.4, 4.9 Hz, 1H), 1.43 (t, *J* = 7.1 Hz, 3H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 165.5, 164.5, 133.4, 131.9, 131.8, 130.6, 130.3, 129.8, 129.4, 128.5, 117.7, 114.8, 61.5, 59.8, 55.8, 32.1, 14.4. IR (ATR): 2921, 1584, 1251, 1149 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{19}H_{20}NO_5S^+$ [M+H$^+$] 374.1062, found 374.1065 [M+H$^+$].



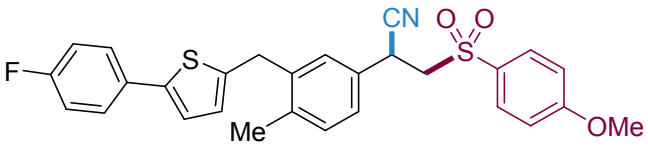
2-(2-Chlorophenyl)-3-[(4-methoxyphenyl)sulfonyl]propanenitrile (20)

The general procedure was followed using **2i** (35 mg, 0.25 mmol), **10a** (77.3 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **20** (45.4 mg, 54%) as a colorless solid. M. p. = 93–95 °C. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 7.89 (d, *J* = 8.9 Hz, 2H), 7.53 (dd, *J* = 6.0, 3.3 Hz, 1H), 7.34 (ddd, *J* = 9.3, 4.9, 2.4 Hz, 3H), 7.04 (d, *J* = 8.9 Hz, 2H), 4.71 (dd, *J* = 10.1, 3.8 Hz, 1H), 3.90 (s, 3H), 3.66 (dd, *J* = 14.5, 10.1 Hz, 1H), 3.49 (dd, *J* = 14.5, 3.8 Hz, 1H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 164.4, 132.6, 130.7, 130.6, 130.4, 130.4, 129.4, 129.3, 128.0, 117.2, 114.7, 114.4, 57.8, 55.8, 55.7, 30.2. IR (ATR): 2916, 1646, 1589, 1257, 1141 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{16}H_{15}ClNO_3S^+$ [M+H$^+$] 336.0456, found 336.0464 [M+H$^+$].



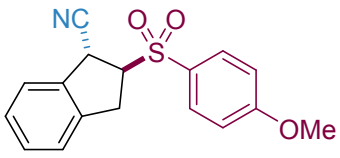
2-(4-Isobutylphenyl)-3-(4-methoxyphenylsulfonyl)propanenitrile (21)

The general procedure was followed using **2j** (40 mg, 0.25 mmol), **10a** (77.3 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol), $Cu(MeCN)_4PF_6$–dmbbpy (10 mol %) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **21** (66 mg, 74%) as a colorless solid. M. p. = 84–86 °C. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 7.86 – 7.79 (m, 2H), 7.20 – 7.15 (m, 2H), 7.10 (d, J = 8.2 Hz, 2H), 7.02 – 6.97 (m, 2H), 4.32 (dd, J = 9.6, 4.4 Hz, 1H), 3.86 (s, 3H), 3.70 (dd, J = 14.5, 9.6 Hz, 1H), 3.41 (dd, J = 14.5, 4.4 Hz, 1H), 2.42 (d, J = 7.2 Hz, 2H), 1.80 (dp, J = 13.6, 6.8 Hz, 1H), 0.86 (d, J = 6.6 Hz, 6H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 164.3, 142.8, 130.6, 130.3, 130.2, 129.7, 127.0, 118.2, 114.7, 60.3, 55.7, 44.9, 31.8, 30.1, 22.2, 22.2. IR (ATR): 2919, 1583, 1257, 1139 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{20}H_{24}NO_3S^+$ [M+H$^+$] 358.1477, found 358.1473 [M+H$^+$].



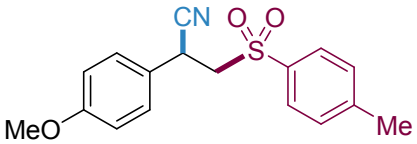
2-{3-[(5-(4-Fluorophenyl)thiophen-2-yl)methyl]-4-methylphenyl}-3-(4-methoxyphenylsulfonyl)propanenitrile (22)

The general procedure was followed using **2k** (77 mg, 0.25 mmol), **10a** (77.3 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol), $Cu(MeCN)_4PF_6$–dmbbpy (20 mol %) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **22** (61 mg, 48%) as a colorless solid. M. p. = 157–159 °C. ^{1}H-NMR (DMSO-d_6, 600 MHz): δ = 7.78 – 7.73 (m, 2H), 7.58 – 7.53 (m, 2H), 7.28 – 7.24 (m, 2H), 7.21 – 7.14 (m, 3H), 7.11 (d, J = 7.9 Hz, 1H), 7.08 – 7.04 (m, 2H), 6.76 (d, J = 3.6 Hz, 1H), 4.49 (dd, J = 9.2, 5.0 Hz, 1H), 4.21 (dd, J = 14.5, 9.3 Hz, 1H), 4.06 (s, 2H), 3.84 – 3.77 (m, 4H), 2.22 (s, 3H). ^{13}C-NMR (DMSO-d_6, 150 MHz): δ = 163.9, 161.83 (d, J_{C-F} = 244.6 Hz), 143.2, 140.8, 139.4, 136.9, 131.8, 131.3, 130.9 (d, J_{C-F} = 3.2 Hz), 130.7, 130.6, 129.3, 127.4 (d, J_{C-F} = 8.1 Hz), 127.0, 126.6, 123.9, 123.9, 119.6, 116.4 (d, J_{C-F} = 21.8 Hz), 114.9, 57.3, 56.3, 33.6, 30.9, 19.1. ^{19}F-NMR (DMSO-d_6, 376 MHz) δ -115.05 (tt, J = 8.9, 5.4 Hz). IR (ATR): 2932, 1579, 1265, 1156 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{28}H_{25}FNO_3S_2^+$ [M+H$^+$] 506.1260, found 506.1266 [M+H$^+$].



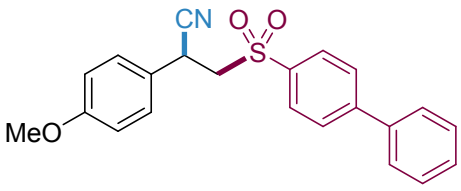
(*trans*)-2-[(4-Methoxyphenyl)sulfonyl]-2,3-dihydro-1*H*-indene-1-carbonitrile (23)

The general procedure was followed using **2l** (29 mg, 0.25 mmol), **10a** (77.3 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol), $Cu(MeCN)_4PF_6$–dmbbpy (10 mol %) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **22** (61 mg, 82%; *dr* > 20:1) as a colorless solid. M. p. = 65–67 °C. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 7.88 (d, *J* = 8.9 Hz, 2H), 7.37 – 7.15 (m, 4H), 7.05 (d, *J* = 8.9 Hz, 2H), 4.60 (d, *J* = 8.7 Hz, 1H), 4.21 (q, *J* = 8.8 Hz, 1H), 3.87 (s, 3H), 3.50 (dd, *J* = 16.5, 8.8 Hz, 1H), 3.29 (dd, *J* = 16.5, 9.0 Hz, 1H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 164.6, 138.8, 134.7, 130.9, 129.5, 128.5, 128.3, 125.1, 124.3, 118.4, 115.1, 67.5, 55.9, 36.6, 32.6. IR (ATR): 2935, 1587, 1274, 1166 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{17}H_{16}NO_3S^+$ [M+H$^+$] 314.0851, found 314.0857 [M+H$^+$].



2-(4-Methoxyphenyl)-3-tosylpropanenitrile (24)

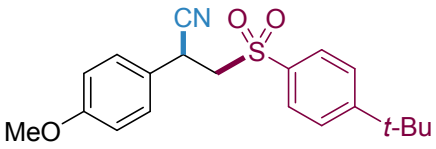
The general procedure was followed using **2c** (34 mg, 0.25 mmol), **10b** (72 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **24** (43 mg, 54%) as a colorless solid. M. p. = 71–72 °C. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 7.78 (d, *J* = 8.3 Hz, 2H), 7.36 (d, *J* = 8.1 Hz, 2H), 7.23 – 7.15 (m, 2H), 6.90 – 6.81 (m, 2H), 4.33 (dd, *J* = 9.2, 4.8 Hz, 1H), 3.78 (s, 3H), 3.72 (dd, *J* = 14.5, 9.2 Hz, 1H), 3.42 (dd, *J* = 14.5, 4.8 Hz, 1H), 2.45 (s, 3H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 160.0, 145.6, 135.4, 130.1, 128.6, 128.3, 124.8, 118.2, 114.9, 60.1, 55.4, 31.3, 21.6. IR (ATR): 2923, 1513, 1245,1035 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{17}H_{18}NO_3S^+$ [M+H$^+$] 316.1002, found 316.1009 [M+H$^+$].



3-[(1,1'-Biphenyl)-4-ylsulfonyl]-2-(4-methoxyphenyl)propanenitrile (25)

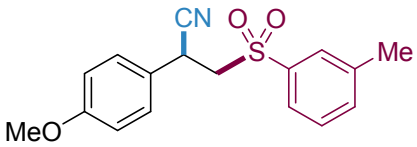
The general procedure was followed using **2c** (34 mg, 0.25 mmol), **10c** (96 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **25** (50 mg, 53%) as a white solid. M. p. = 54–56 °C. ^{1}H-NMR

($CDCl_3$, 400 MHz): δ = 7.93 (d, J = 8.5 Hz, 2H), 7.73 (d, J = 8.5 Hz, 2H), 7.63 – 7.55 (m, 2H), 7.45 (ddd, J = 10.9, 9.8, 5.6 Hz, 3H), 7.21 (d, J = 8.7 Hz, 2H), 6.84 (d, J = 8.7 Hz, 2H), 4.38 (dd, J = 8.7, 5.3 Hz, 1H), 3.77 (dd, J = 14.5, 8.6 Hz, 1H), 3.75 (s, 3H), 3.51 (dd, J = 14.5, 5.3 Hz, 1H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 160.1, 147.3, 138.9, 136.9, 129.1, 128.8, 128.7, 128.7, 128.0, 127.4, 124.7, 118.2, 114.9, 60.1, 55.3, 31.4. IR (ATR): 2920, 1630, 1136 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{22}H_{20}NO_3S^+$ [M+H$^+$] 378.1158, found 378.1153 [M+H$^+$].



3-{[4-(*Tert*-butyl)phenyl]sulfonyl}-2-(4-methoxyphenyl)propanenitrile (26)

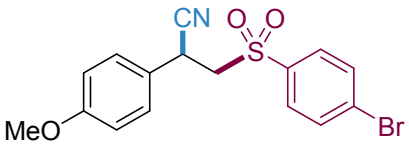
The general procedure was followed using **2c** (34 mg, 0.25 mmol), **10d** (88 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **26** (36 mg, 40%) as a white solid. M. p. = 58–60 °C. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 7.79 (d, J = 8.6 Hz, 2H), 7.55 (d, J = 8.6 Hz, 2H), 7.20 (d, J = 8.7 Hz, 2H), 6.84 (d, J = 8.8 Hz, 2H), 4.36 (dd, J = 8.6, 5.3 Hz, 1H), 3.78 (s, 3H), 3.74 – 3.68 (m, 1H), 3.45 (dd, J = 14.4, 5.3 Hz, 1H), 1.34 (s, 9H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 160.0, 158.5, 135.4, 128.6, 128.0, 126.5, 124.7, 118.2, 114.8, 60.0, 55.3, 35.3, 31.3, 31.0. IR (ATR): 2919, 1645, 1512, 1248 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{20}H_{24}NO_3S^+$ [M+H$^+$] 358.1471, found 358.1467 [M+H$^+$].



2-(4-Methoxyphenyl)-3-(*m*-tolylsulfonyl)propanenitrile (27)

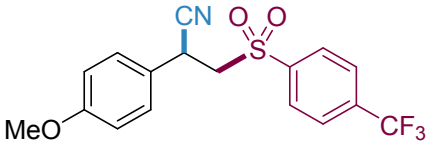
The general procedure was followed using **2c** (34 mg, 0.25 mmol), **10e** (72 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **27** (32 mg, 40%); or [$Cu(MeCN)_4PF_6$–dmbbpy (20 mol %); 42 mg, 53%] as a white solid. M. p. = 79–81 °C. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 7.99 (dd, J = 8.0, 1.1 Hz, 1H), 7.55 (td, J = 7.5, 1.3 Hz, 1H), 7.37 (dd, J = 16.5, 7.9 Hz, 2H), 7.21 (d, J = 8.7 Hz, 2H), 6.86 (d, J = 8.8 Hz, 2H), 4.35 (dd, J = 9.0, 4.8 Hz, 1H), 3.79 (s, 3H), 3.78 - 3.72 (m, 1H), 3.46 (dd, J = 14.5, 4.8 Hz, 1H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 160.0, 138.0, 136.4, 134.4, 132.9, 130.5,

128.5, 126.9, 124.8, 118.1, 114.9, 59.2, 55.3, 31.3, 20.3. IR (ATR): 2913, 1643, 1513, 1123 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{17}H_{18}NO_3S^+$ [M+H$^+$] 316.1002, found 316.1008 [M+H$^+$].



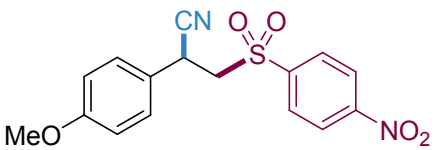
3-[(4-Bromophenyl)sulfonyl]-2-(4-methoxyphenyl)propanenitrile (28)

The general procedure was followed using **2c** (34 mg, 0.25 mmol), **10f** (97 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **28** (52.3 mg, 55%) as a white solid. M. p. = 102–103 °C. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 7.81 – 7.62 (m, 4H), 7.18 (d, J = 8.7 Hz, 2H), 6.92 – 6.80 (m, 2H), 4.35 (dd, J = 8.9, 5.3 Hz, 1H), 3.79 (s, 3H), 3.77 – 3.68 (m, 1H), 3.49 (dd, J = 14.6, 5.3 Hz, 1H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 160.1, 137.5, 132.8, 129.8, 129.7, 128.7, 124.3, 118.1, 114.9, 59.8, 55.4, 31.3. IR (ATR): 2917, 1716, 1511, 1244 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{16}H_{15}BrNO_3S^+$ [M+H$^+$] 379.9951, found 379.9945 [M+H$^+$].



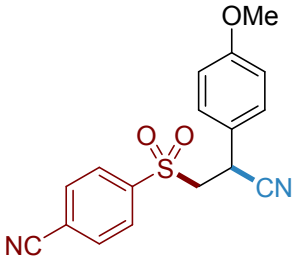
2-(4-Methoxyphenyl)-3-{[4-(trifluoromethyl)phenyl]sulfonyl}propanenitrile (29)

The general procedure was followed using **2c** (34 mg, 0.25 mmol), **10g** (93 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **29** (47 mg, 51%) as a white solid. M. p. = 92–93 °C .^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 7.99 (d, J = 8.2 Hz, 2H), 7.80 (d, J = 8.3 Hz, 2H), 7.18 (d, J = 8.7 Hz, 2H), 6.83 (d, J = 8.8 Hz, 2H), 4.39 (dd, J = 8.5, 5.7 Hz, 1H), 3.78 (s, 3H), 3.77 - 3.73 (m, 1H), 3.54 (dd, J = 14.7, 5.7 Hz, 1H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 160.3, 142.1, 136.0 (q, $J_{C\text{-}F}$ = 33.0 Hz), 128.9, 128.7, 126.6 (q, $J_{C\text{-}F}$ = 3.5 Hz), 124.0, 123.0 (q, $J_{C\text{-}F}$ = 273.2 Hz), 117.9, 115.0, 59.9, 55.3, 31.4. ^{19}F-NMR ($CDCl_3$, 376 MHz): δ = -63.3. IR (ATR): 2919, 1509, 1331, 1063 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{17}H_{15}F_3NO_3S^+$ [M+H$^+$] 370.0719, found 370.0716 [M+H$^+$].



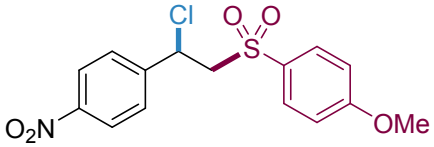
2-(4-Methoxyphenyl)-3-[(4-nitrophenyl)sulfonyl]propanenitrile (30)

The general procedure was followed using **2c** (34 mg, 0.25 mmol), **10h** (84 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **30** (56.3 mg, 65%) as a white solid. M. p. = 74–76 °C. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 8.38 (d, J = 8.9 Hz, 2H), 8.07 (d, J = 8.8 Hz, 2H), 7.19 (d, J = 8.7 Hz, 2H), 6.85 (d, J = 8.8 Hz, 2H), 4.40 (dd, J = 8.8, 5.4 Hz, 1H), 3.80 (dd, J = 14.8, 8.6 Hz, 1H), 3.78 (s, 1H), 3.57 (dd, J = 14.7, 5.4 Hz, 1H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 160.3, 151.1, 144.0, 129.8, 128.7, 124.5, 123.8, 117.7, 115.0, 59.9, 55.4, 31.4. IR (ATR): 2912, 1645, 1525, 1346 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{16}H_{15}N_2O_5S^+$ [M+H$^+$] 347.0696, found 347.0693 [M+H$^+$].



4-{[2-Cyano-2-(4-methoxyphenyl)ethyl]sulfonyl}benzonitrile (31)

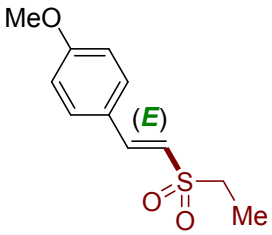
The general procedure was followed using **2c** (34 mg, 0.25 mmol), **10i** (77 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 8:1) yielded **31** (21 mg, 25%) or [$Cu(MeCN)_4PF_6$–dmbbpy (20 mol %); 30 mg, 37%] as a white solid. M. p. = 78–80 °C. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 7.99 (d, J = 8.5 Hz, 2H),7.85 (d, J = 8.5 Hz, 2H), 7.19 (d, J = 8.7 Hz, 2H), 6.85 (d, J = 8.7 Hz, 2H), 4.38 (dd, J = 8.9, 5.4 Hz, 1H), 3.80 (s, 3H), 3.74 (dd, J = 17.8, 8.9 Hz, 1H), 3.53 (dd, J = 14.7, 5.4 Hz, 1H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 160.3, 142.6, 133.2, 129.1, 128.7, 123.9, 118.2, 117.8, 116.8, 115.0, 60.1, 55.5, 31.5. IR (ATR): 2918, 1627, 1542, 1287 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{17}H_{15}N_2O_3S^+$ [M+H$^+$] 327.0803, found 327.0802 [M+H$^+$].



3-[(4-Methoxyphenyl)sulfonyl]-2-(4-nitrophenyl)propanenitrile (35)

The general procedure was followed using **2m** (37.3mg, 0.25 mmol), **10a** (77.3 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol), $Cu(MeCN)_4PF_6$–dmbbpy (20 mol %) for 12 h. Purification

by column chromatography (*n*-hexane/EtOAc 10:1) yielded **35** (54 mg, 60%) as a white solid. M. p. =76–77 °C. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 8.15 (d, *J* = 8.8 Hz, 2H), 7.69 – 7.63 (m, 2H), 7.50 (d, *J* = 8.7 Hz, 2H), 6.95 – 6.88 (m, 2H), 5.40 (dd, *J* = 7.9, 6.2 Hz, 1H), 3.93 (dd, *J* = 14.6, 6.1 Hz, 1H), 3.85 (s, 3H), 3.84 (dd, *J* = 14.6, 7.9 Hz, 1H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 164.2, 148.1, 145.2, 130.3, 130.3, 128.4, 124.0, 114.5, 63.9, 53.6, 29.7. IR (ATR): 2917, 1646, 1509, 1246 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{15}H_{15}ClNO_5S^+$ [M+H$^+$] 356.0359, found 356.0354 [M+H$^+$].



(*E*)-1-[2-(Ethylsulfonyl)vinyl]-4-methoxybenzene (38)

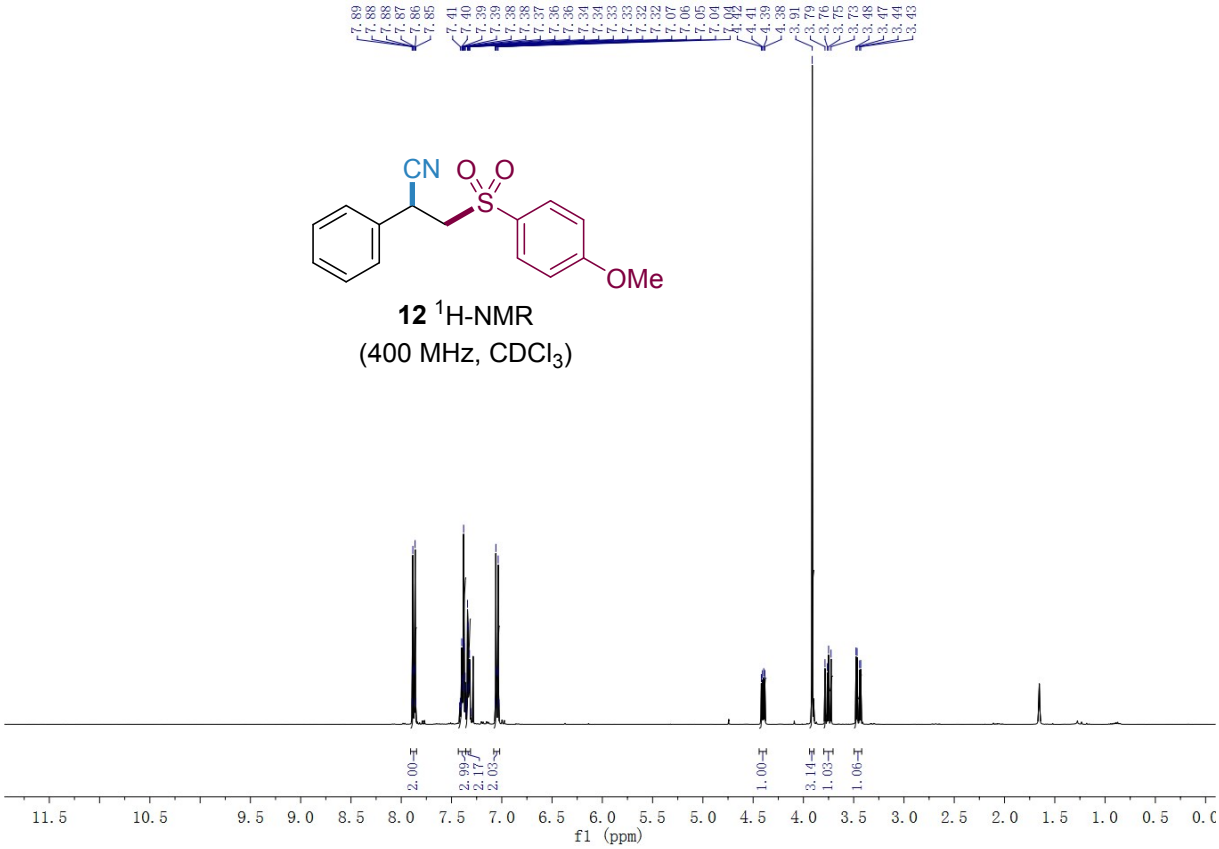
The general procedure was followed using **2c** (34 mg, 0.25 mmol), **37** (49 mg, 0.38 mmol) and TMSCN (**11**, 0.38 mmol), $Cu(MeCN)_4PF_6$–dmbbpy (20 mol %) for 12 h. Purification by column chromatography (*n*-hexane/EtOAc 10:1) yielded **38** (44 mg, 78%) as a colorless oil. ^{1}H-NMR ($CDCl_3$, 400 MHz): δ = 7.52 (d, *J* = 15.4 Hz, 1H), 7.45 (d, *J* = 8.8 Hz, 2H), 6.91 (d, *J* = 8.8 Hz, 2H), 6.64 (d, *J* = 15.4 Hz, 1H), 3.83 (s, 3H), 3.06 (q, *J* = 7.5 Hz, 2H), 1.36 (t, *J* = 7.5 Hz, 3H). ^{13}C-NMR ($CDCl_3$, 100 MHz): δ = 162.2, 144.9, 130.4, 124.9, 121.1, 114.6, 55.5, 49.6, 7.4. IR (ATR): 2932, 1651, 1579, 1237, 966 cm^{-1}. HR-MS (ESI) m/z calcd for $C_{11}H_{15}O_3S^+$ [M+H$^+$] 227.0742, found 227.0746 [M+H$^+$].

Reference:

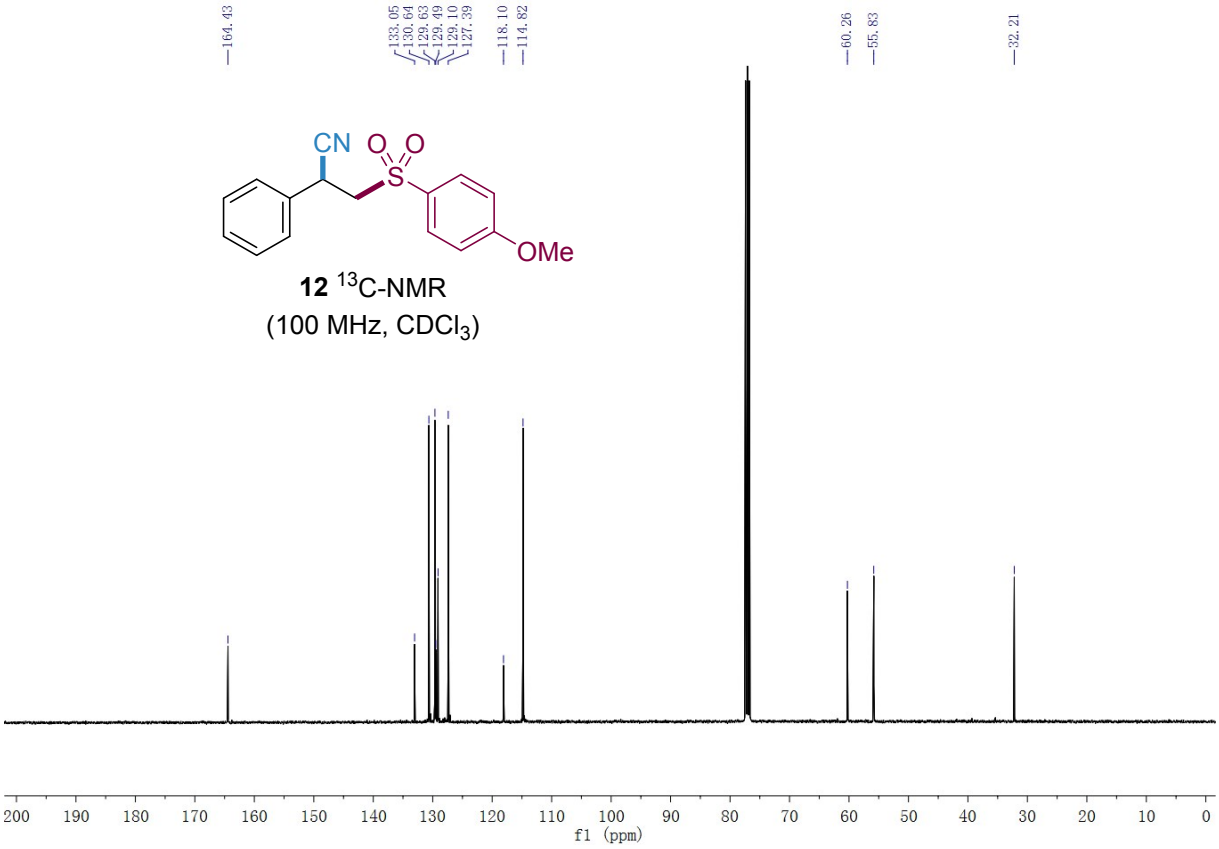
[1] D. Gärtner, A. L. Stein, S. Grupe, J. Arp, A. Jacobi von Wangelin, *Angew. Chem. Int. Ed.* 2015, **54**, 10545.

[2] J. J. Molloy, C. P. Seath, M. J. West, C. McLaughlin, N. J. Fazakerley, A. R. Kennedy, D. J. Nelson, A. J. B. Watson, *J. Am. Chem. Soc*. 2018, **140**, 126–130.

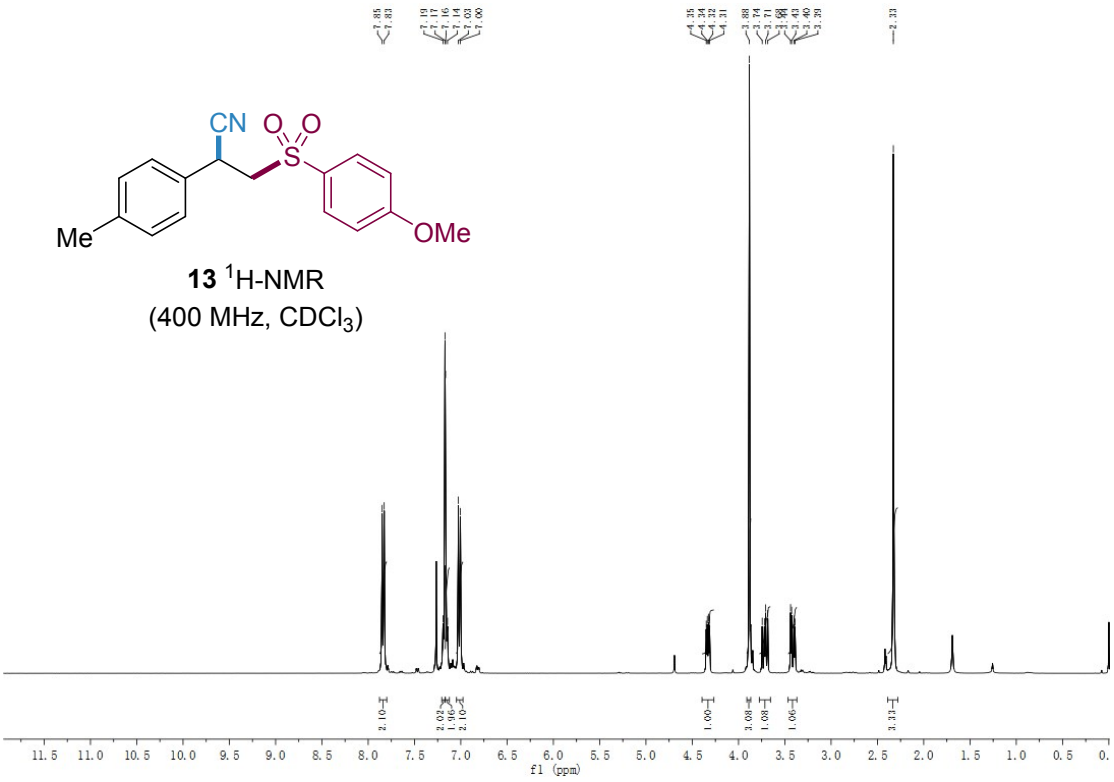
[3] (a) F. H. Lutter, L. Grokenberger, M. S. Hofmayer, P. Knochel, *Chem. Sci*. 2019, **10**, 8241; (b) J. Fei, Z. Wang, Z. Cai, H. Sun, X. Cheng, *Adv. Synth. Catal*. 2015, **357**, 4063.



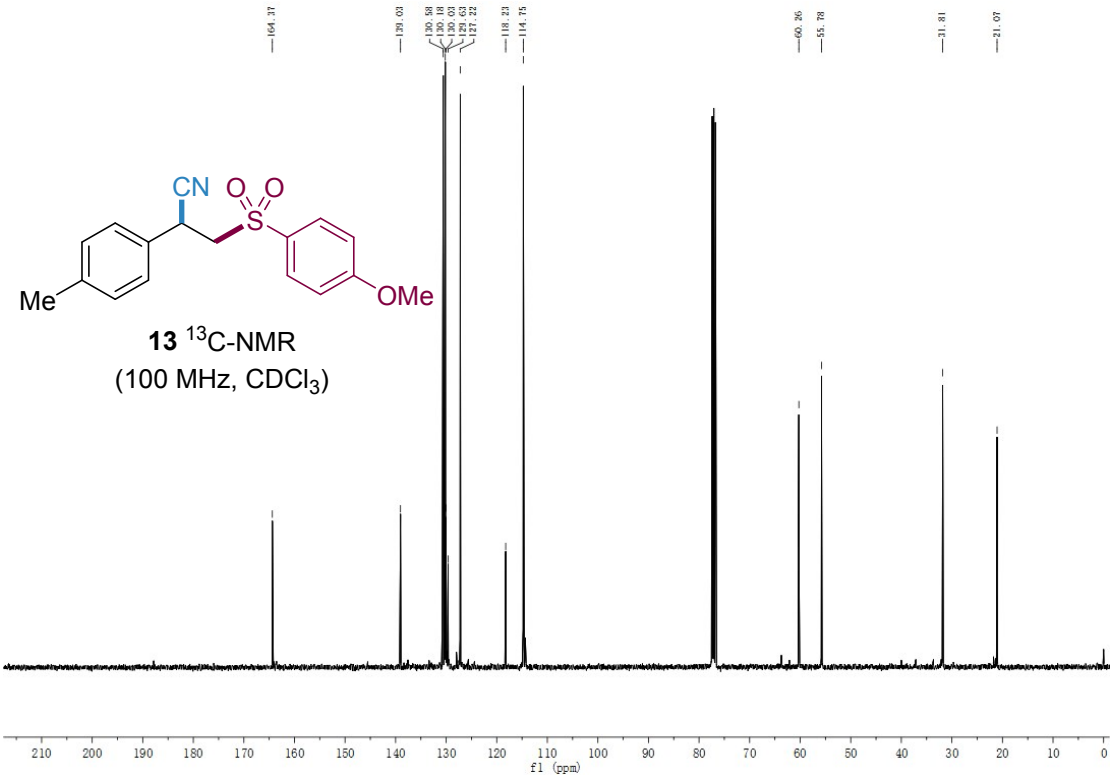
12 ^{1}H-NMR
(400 MHz, $CDCl_3$)



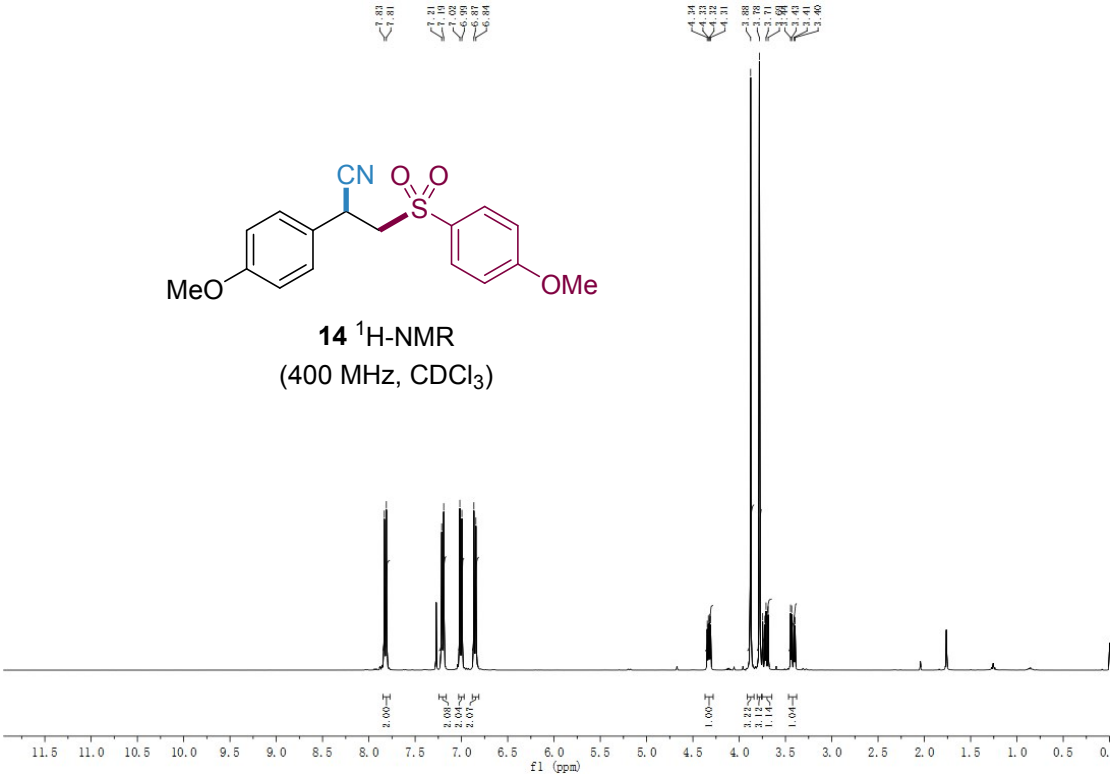
12 ^{13}C-NMR
(100 MHz, $CDCl_3$)



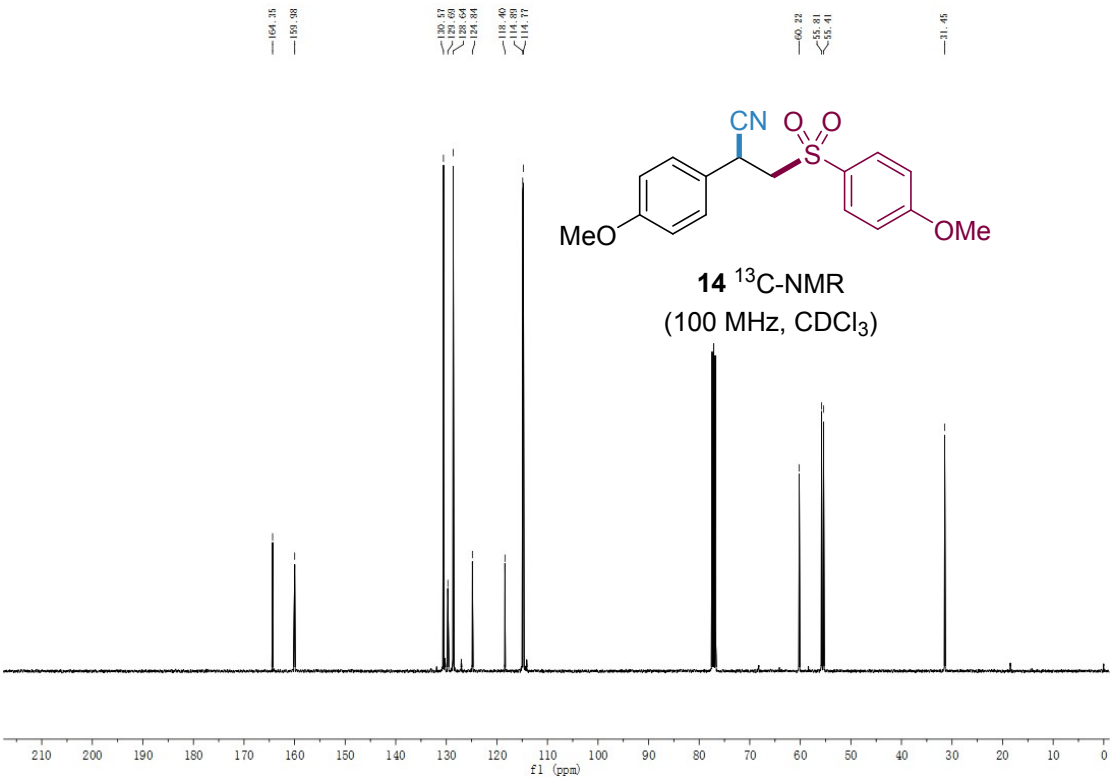
13 ^{1}H-NMR
(400 MHz, $CDCl_3$)



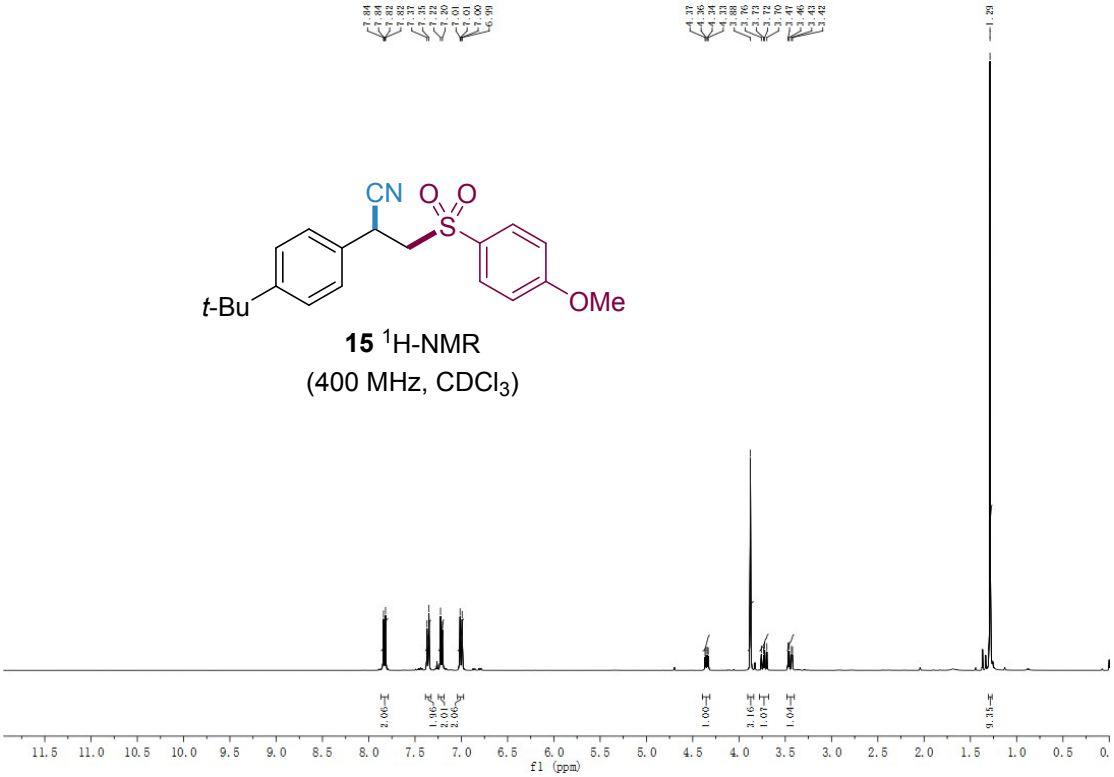
13 ^{13}C-NMR
(100 MHz, $CDCl_3$)



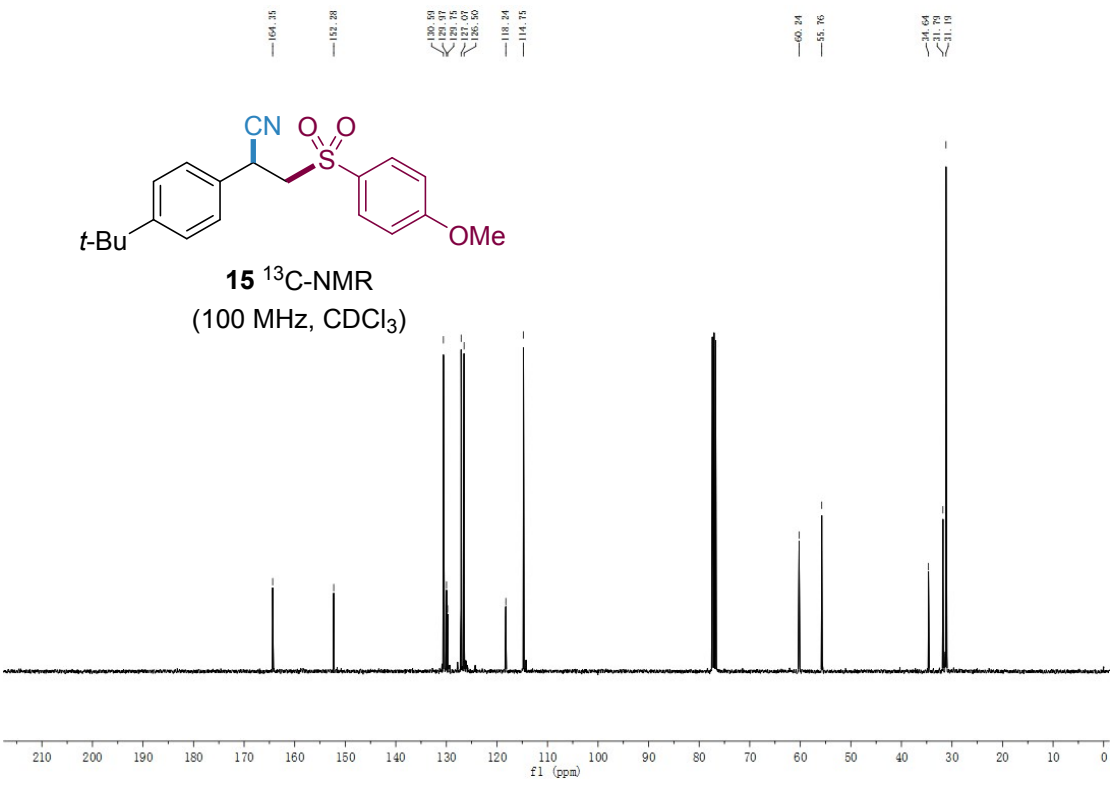
14 ^{1}H-NMR
(400 MHz, $CDCl_3$)



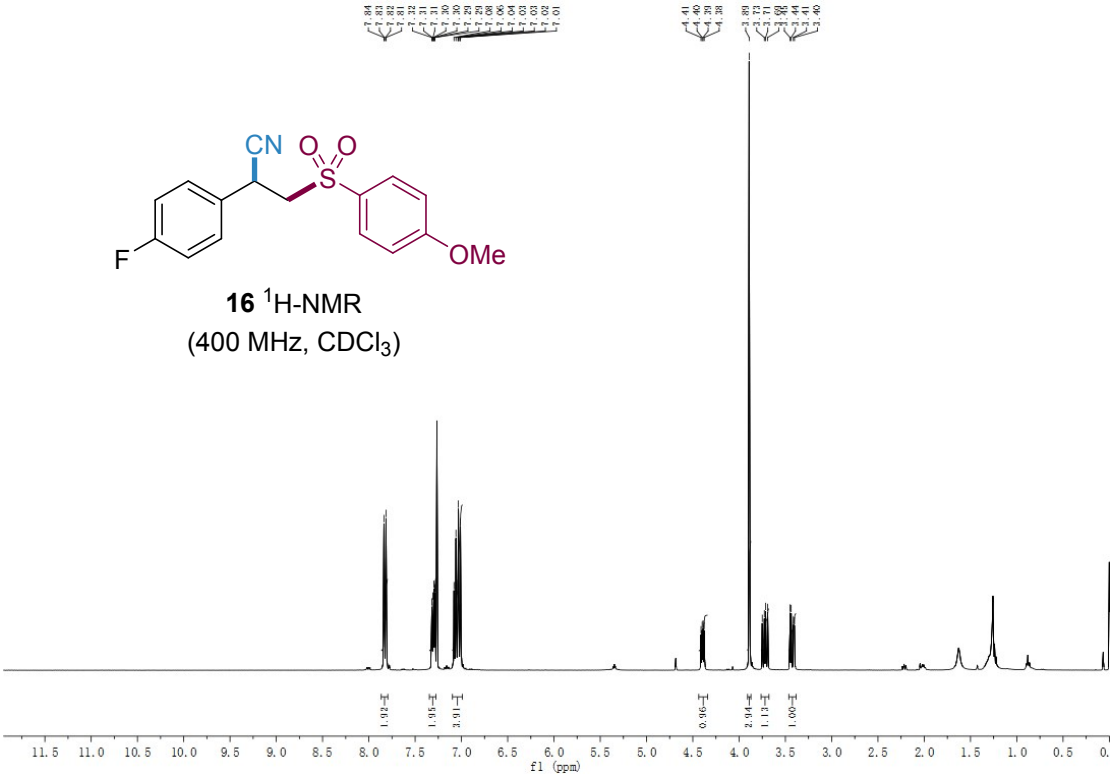
14 ^{13}C-NMR
(100 MHz, $CDCl_3$)



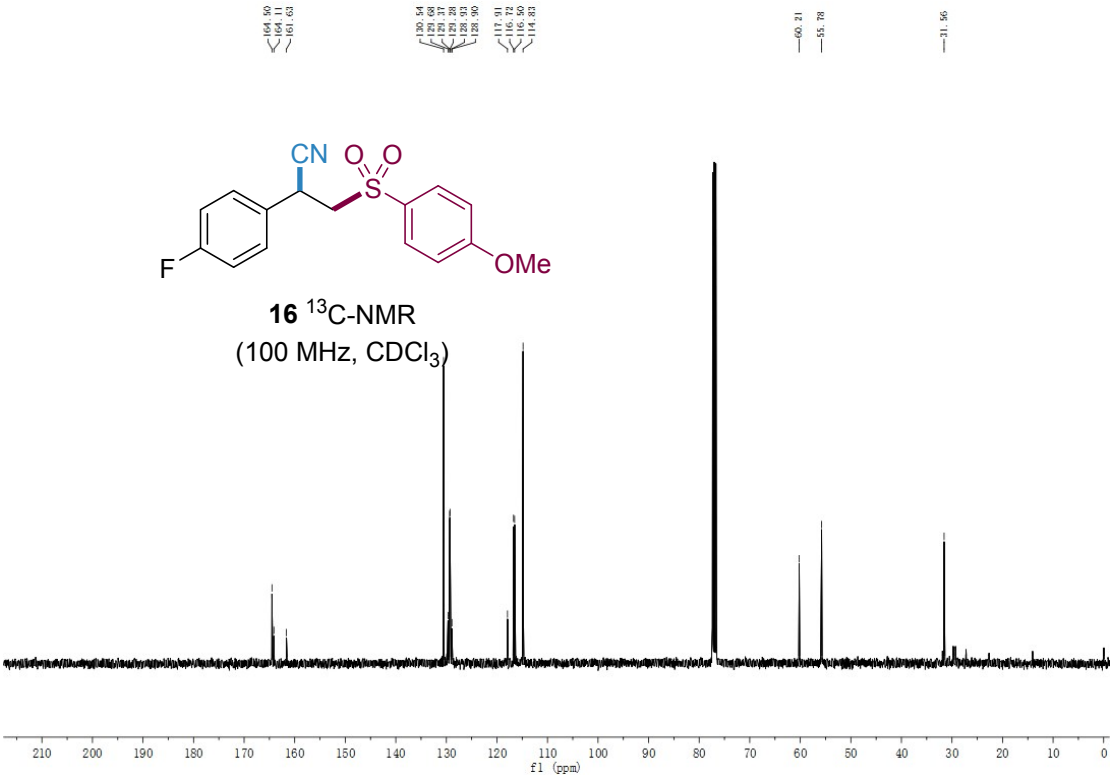
15 ^{1}H-NMR
(400 MHz, $CDCl_3$)



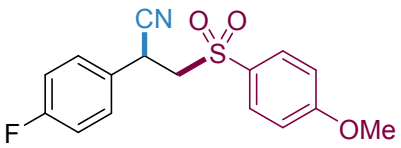
15 ^{13}C-NMR
(100 MHz, $CDCl_3$)



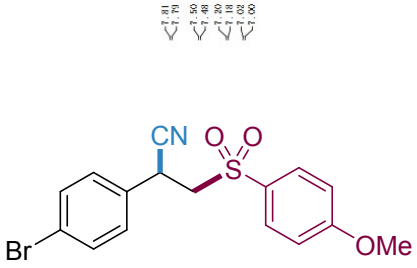
16 ^{1}H-NMR
(400 MHz, $CDCl_3$)



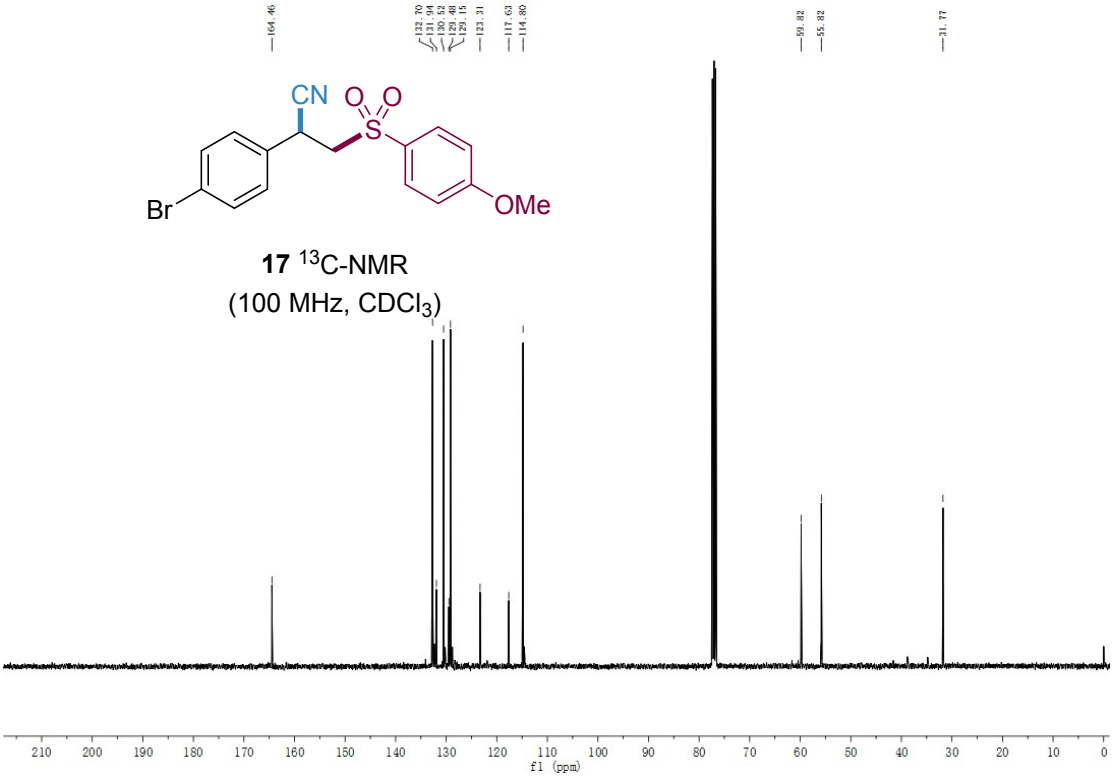
16 ^{13}C-NMR
(100 MHz, $CDCl_3$)



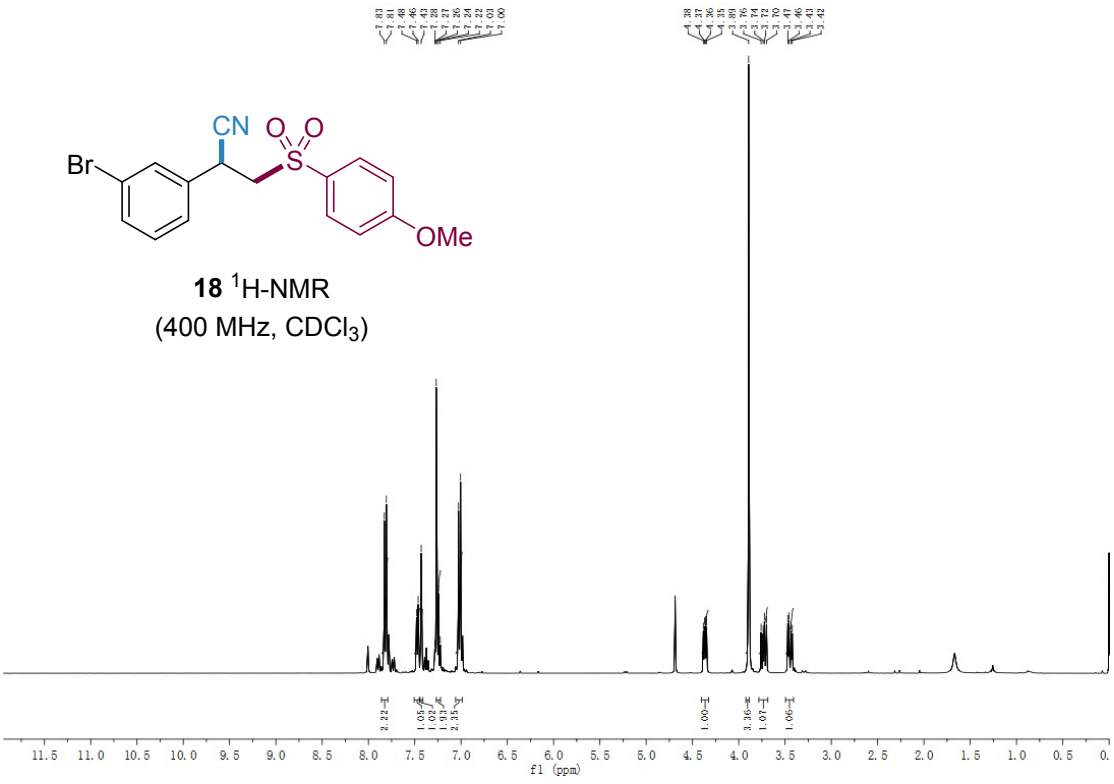
16 ^{19}F-NMR
(376 MHz, $CDCl_3$)



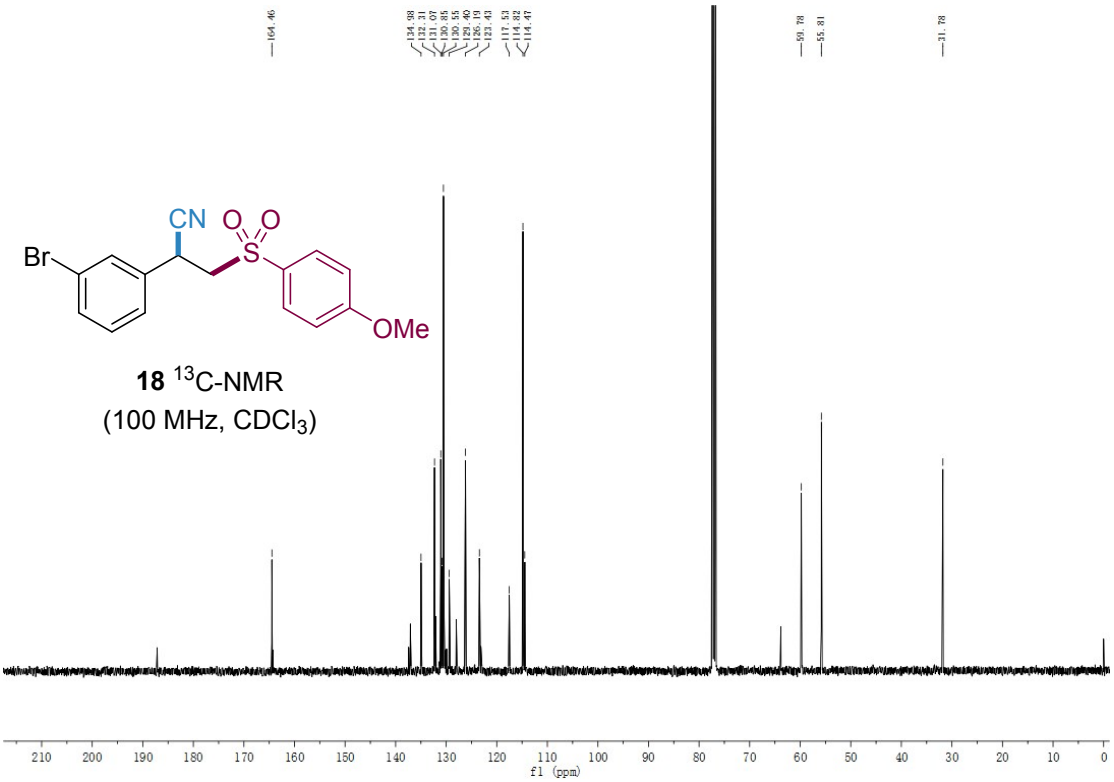
17 ^{1}H-NMR
(400 MHz, $CDCl_3$)



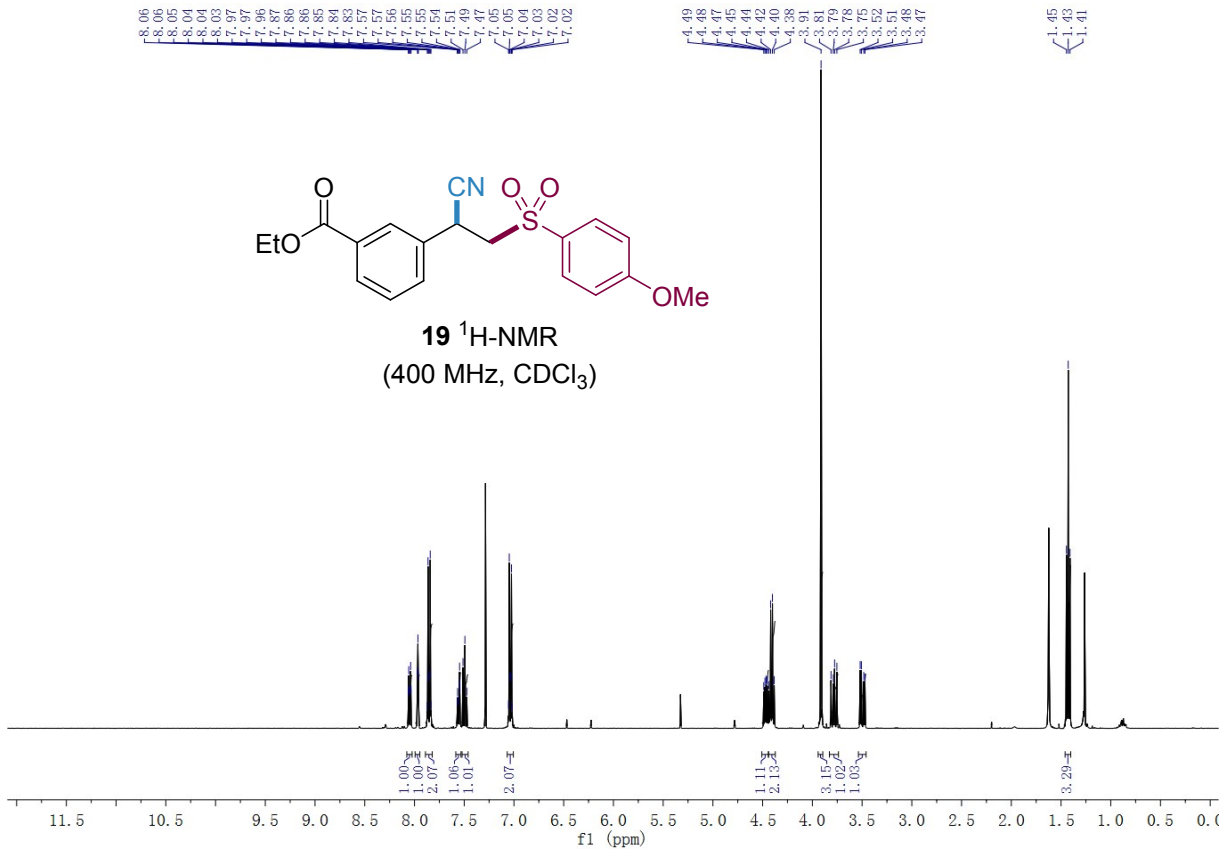
17 ^{13}C-NMR
(100 MHz, $CDCl_3$)



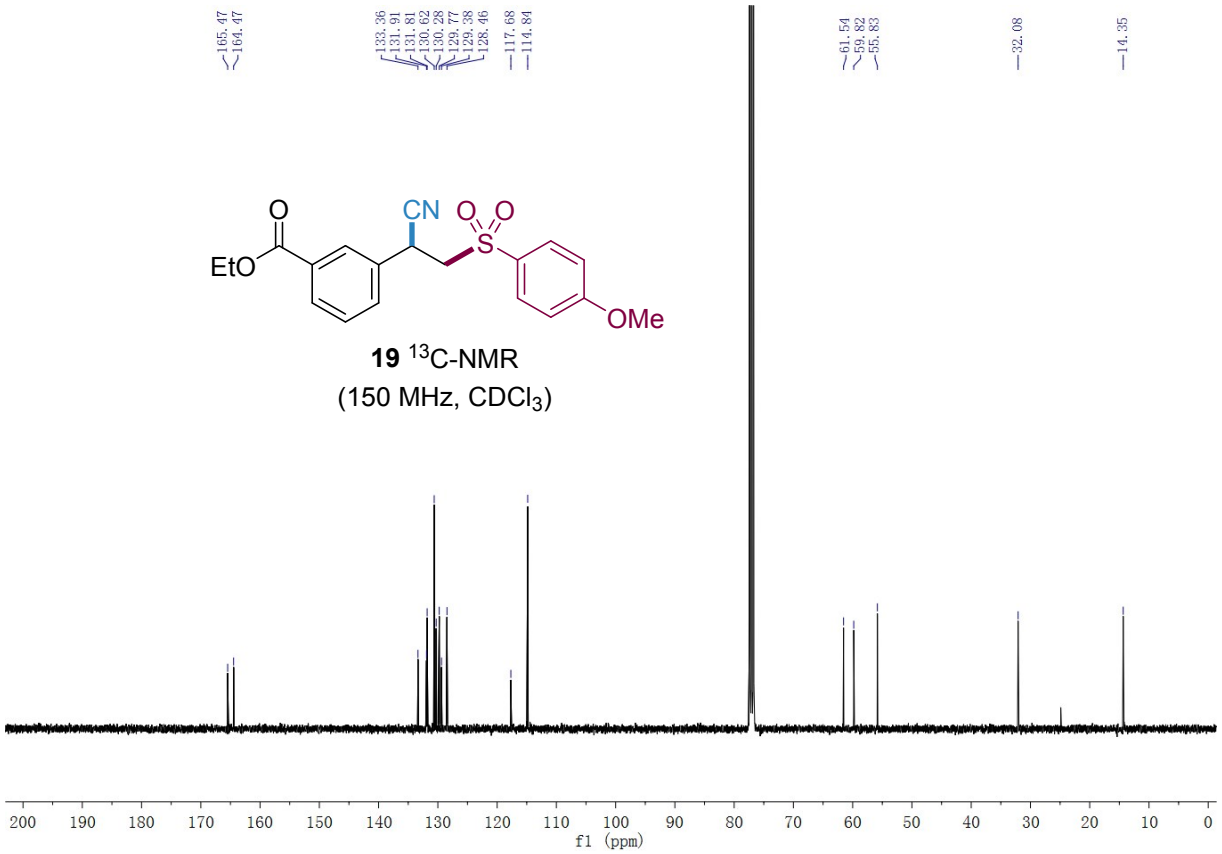
18 ^{1}H-NMR
(400 MHz, $CDCl_3$)



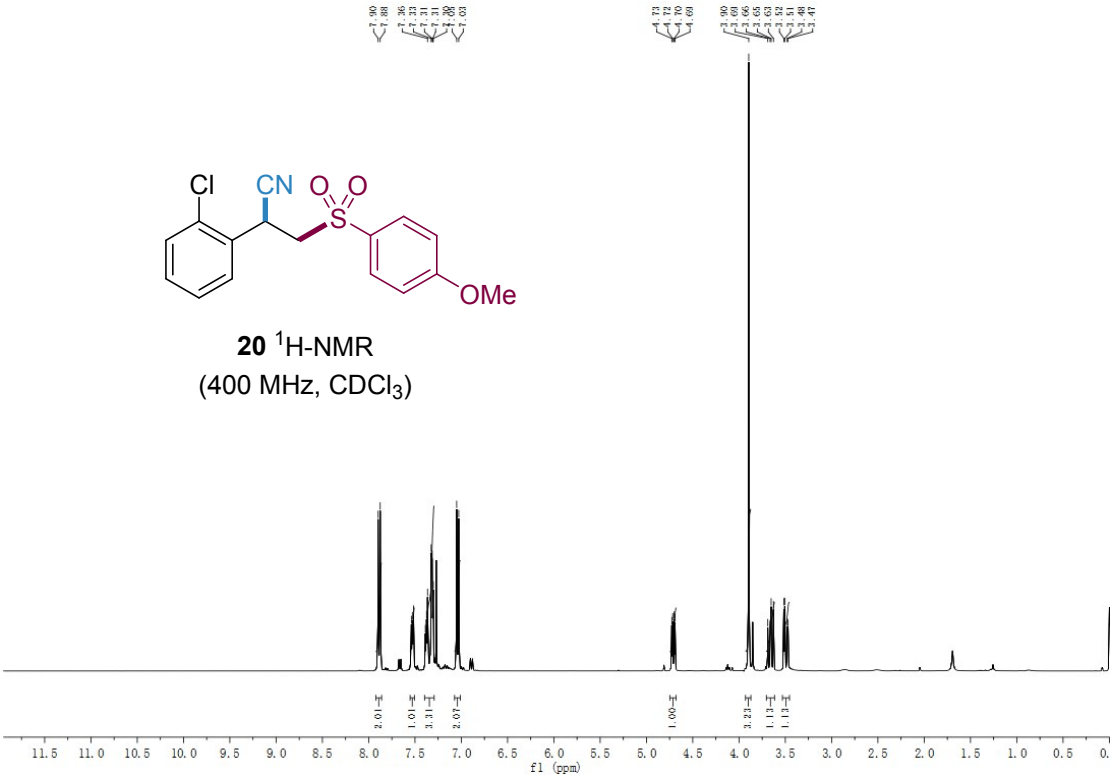
18 ^{13}C-NMR
(100 MHz, $CDCl_3$)



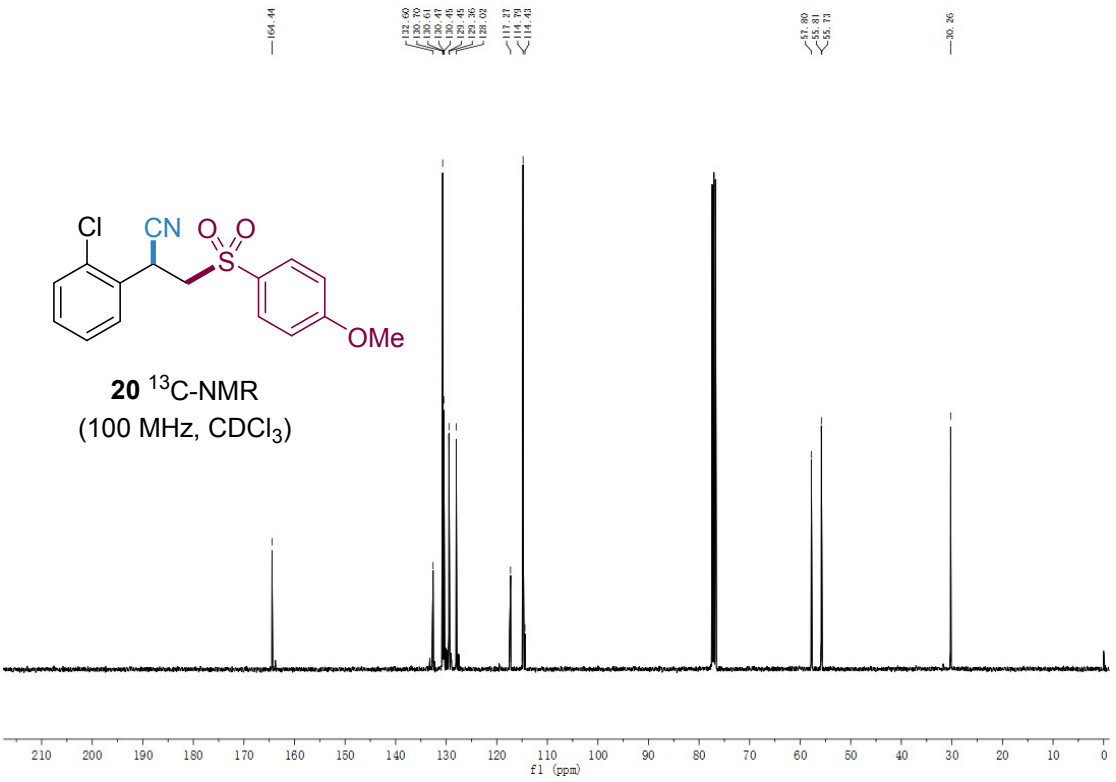
19 ^{1}H-NMR
(400 MHz, $CDCl_3$)



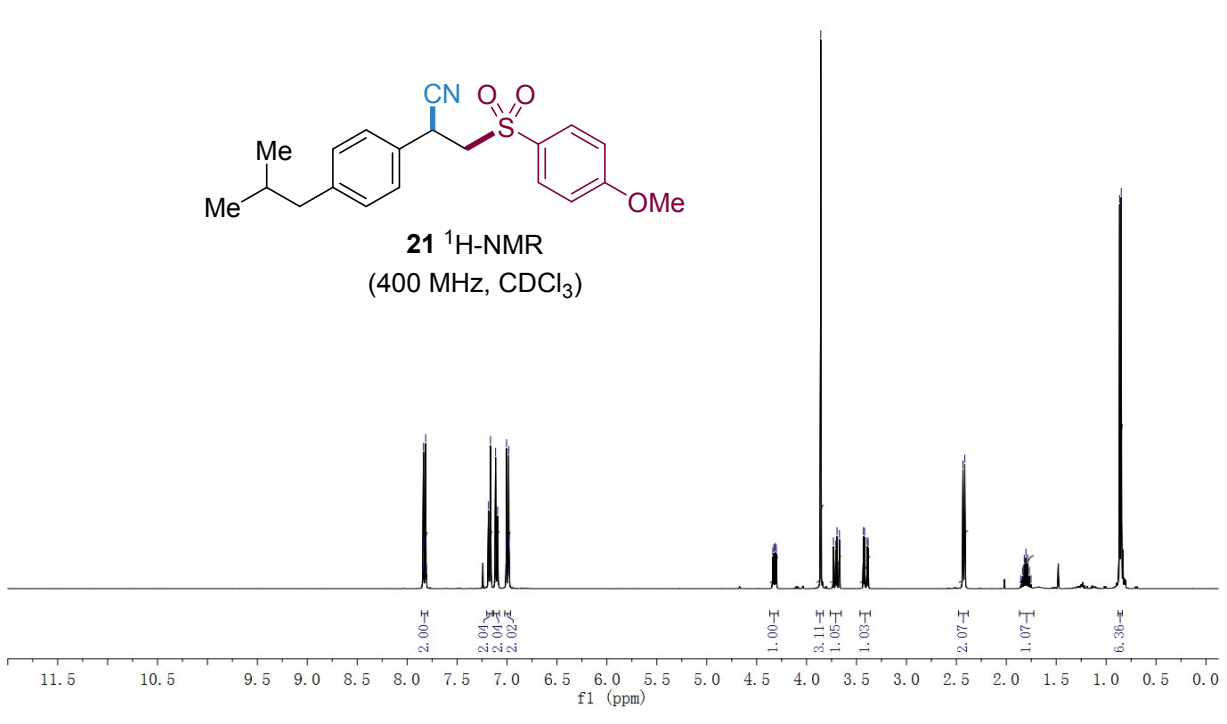
19 ^{13}C-NMR
(150 MHz, $CDCl_3$)



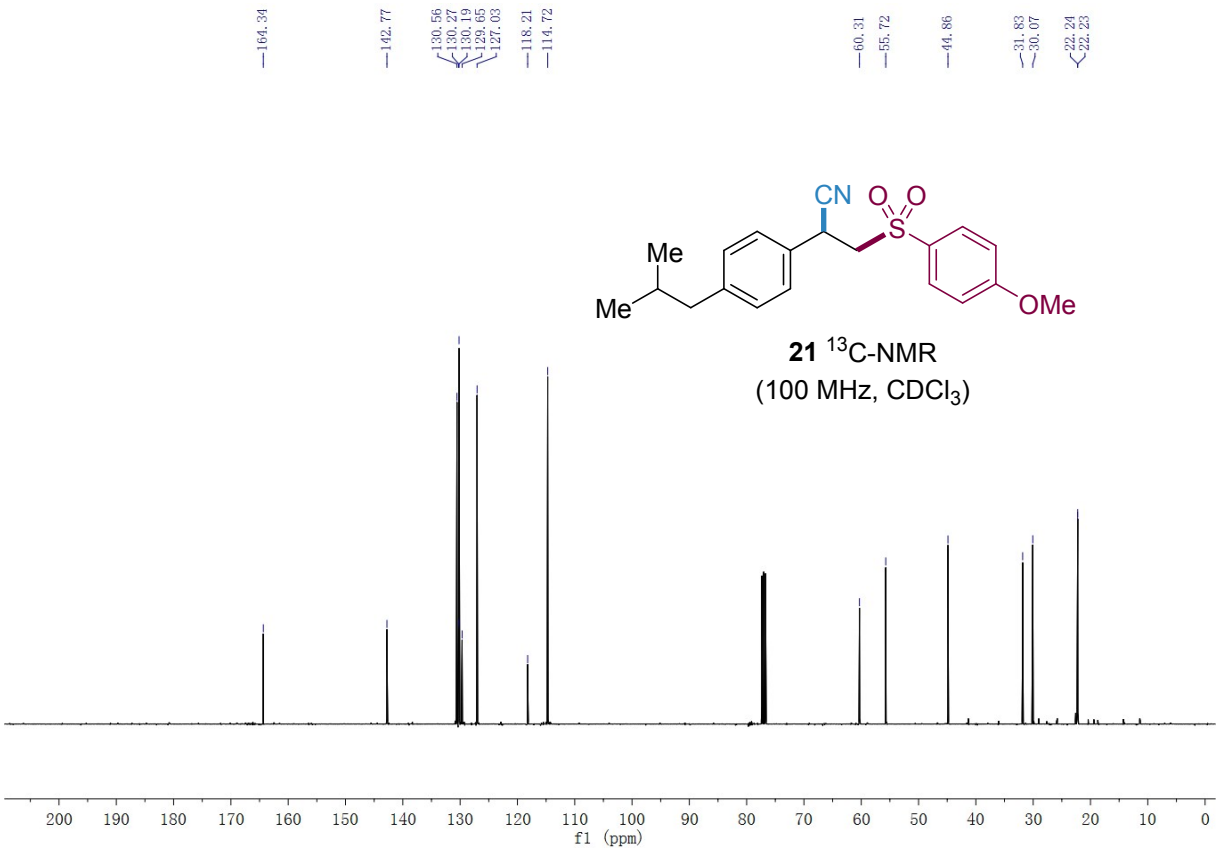
20 ^{1}H-NMR
(400 MHz, $CDCl_3$)



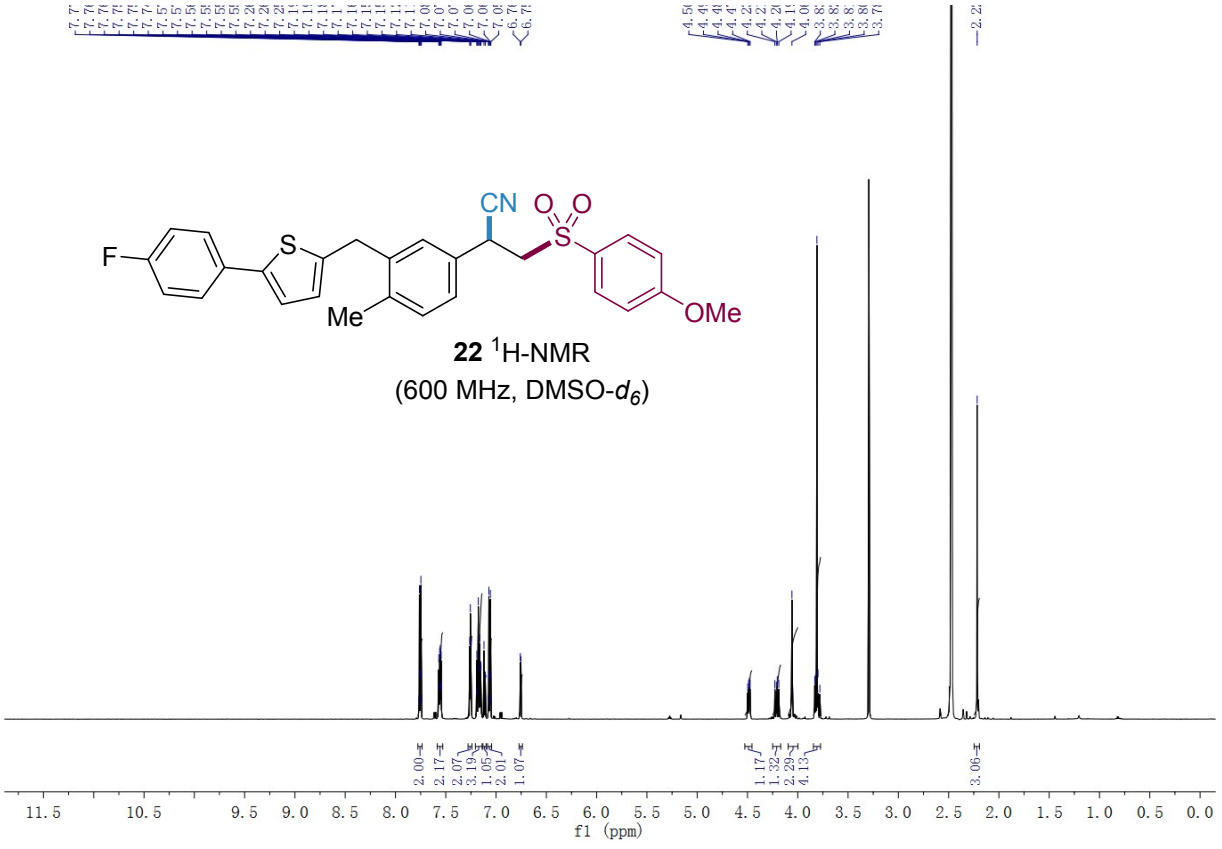
20 ^{13}C-NMR
(100 MHz, $CDCl_3$)



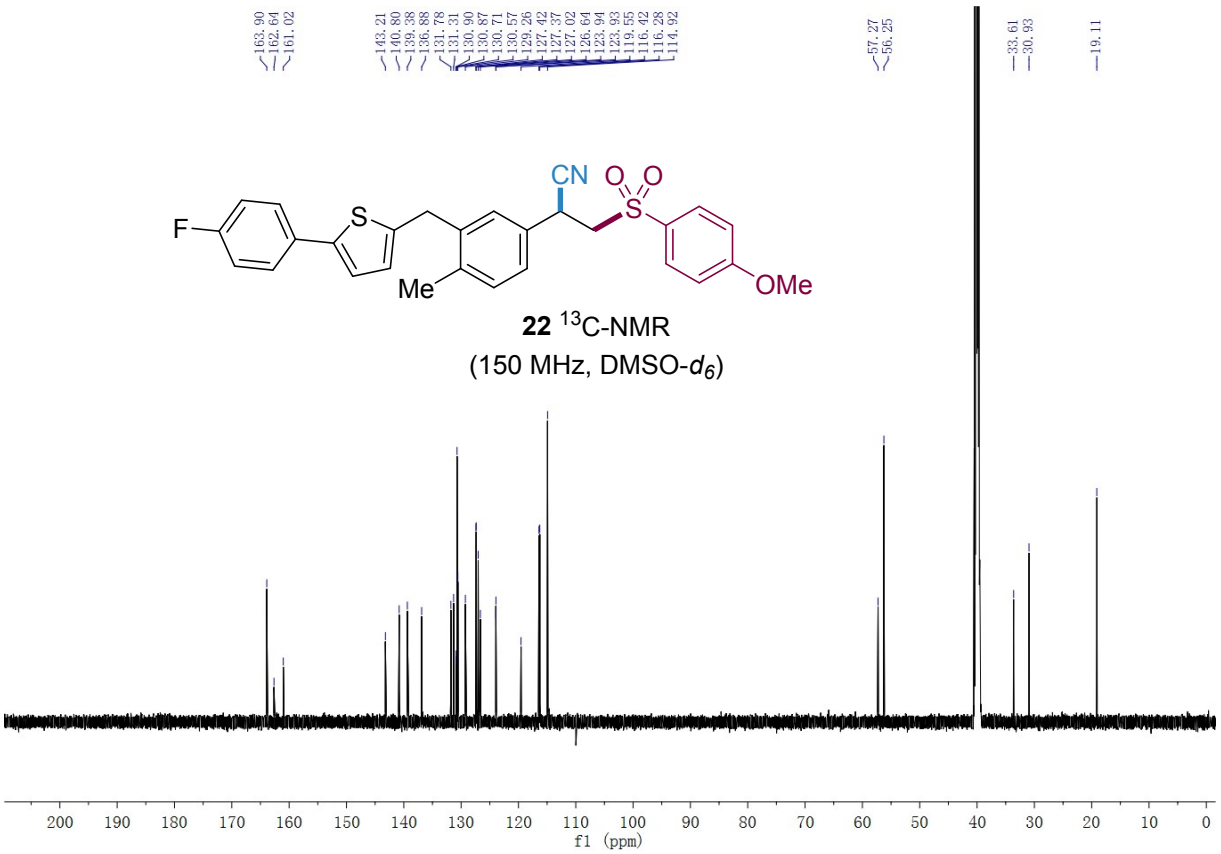
21 ^{1}H-NMR
(400 MHz, $CDCl_3$)



21 ^{13}C-NMR
(100 MHz, $CDCl_3$)

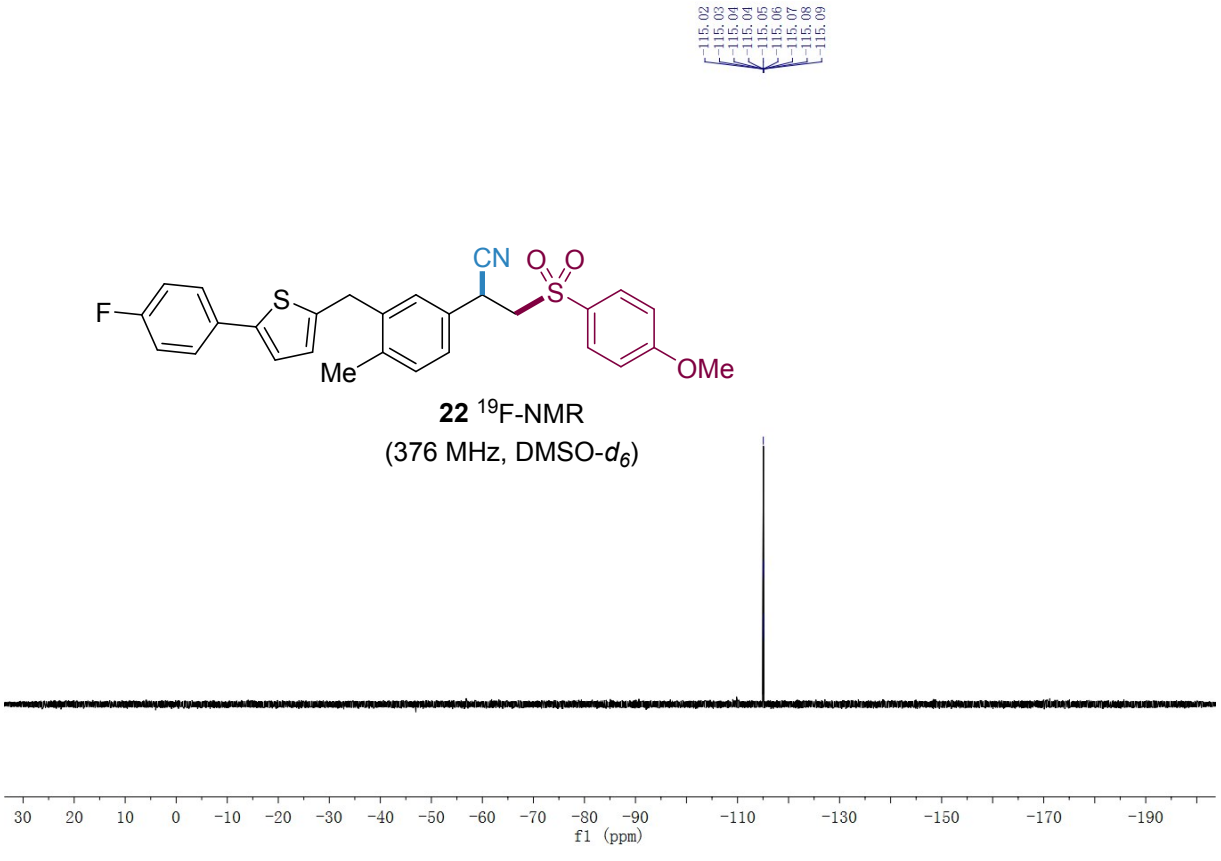


22 ^{1}H-NMR
(600 MHz, DMSO-d_6)



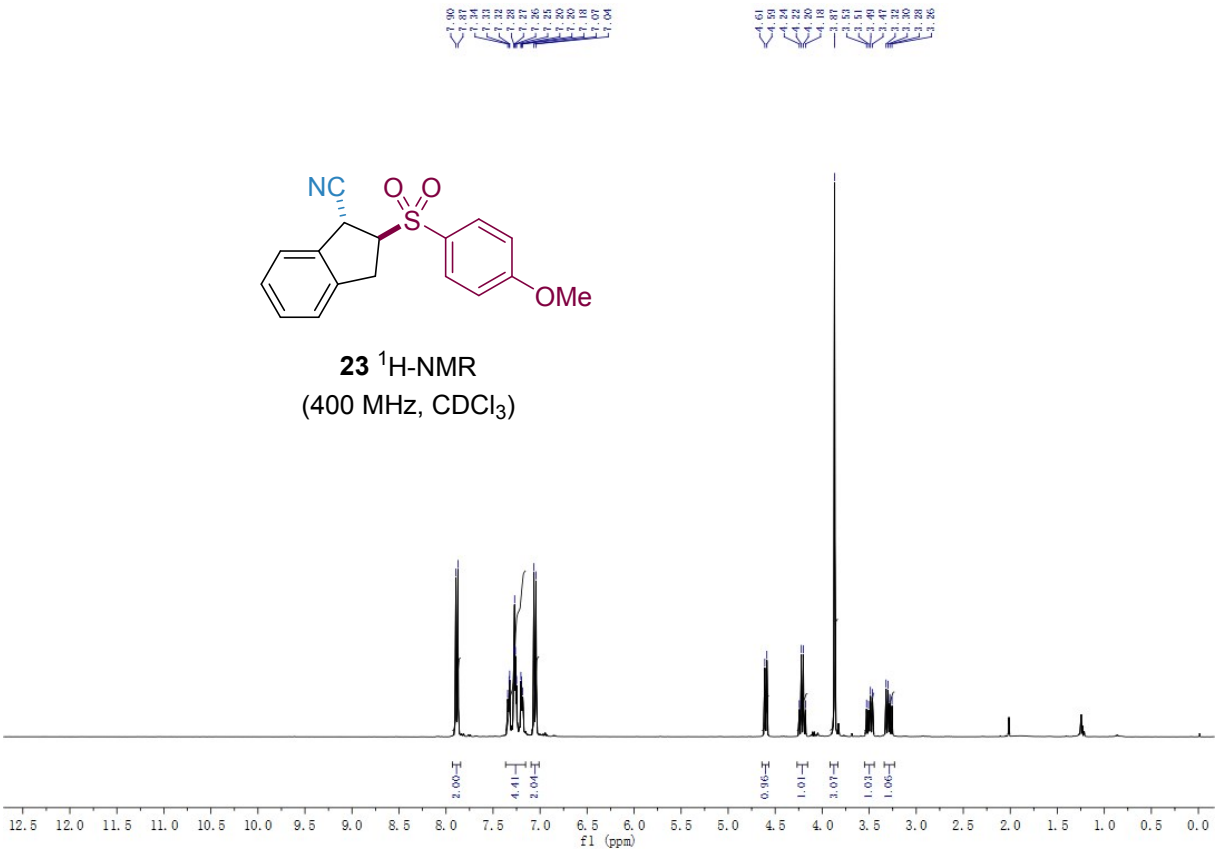
22 ^{13}C-NMR

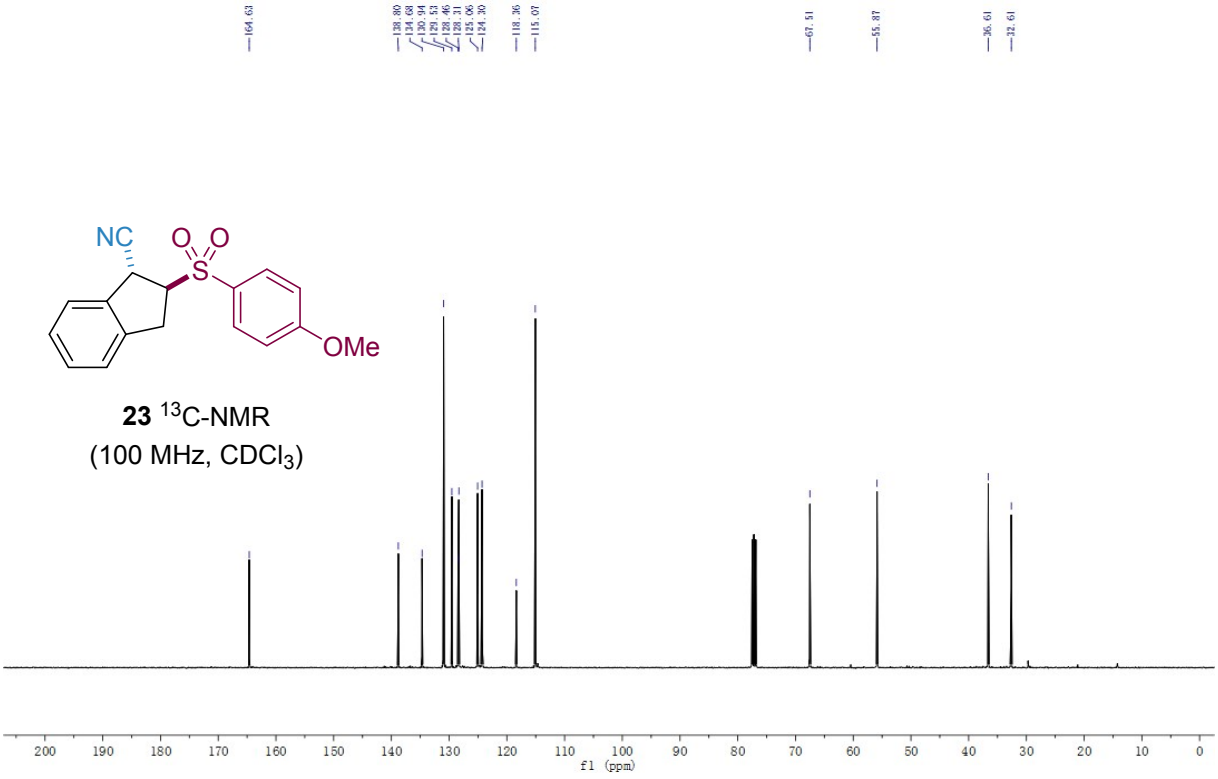
(150 MHz, DMSO-d_6)

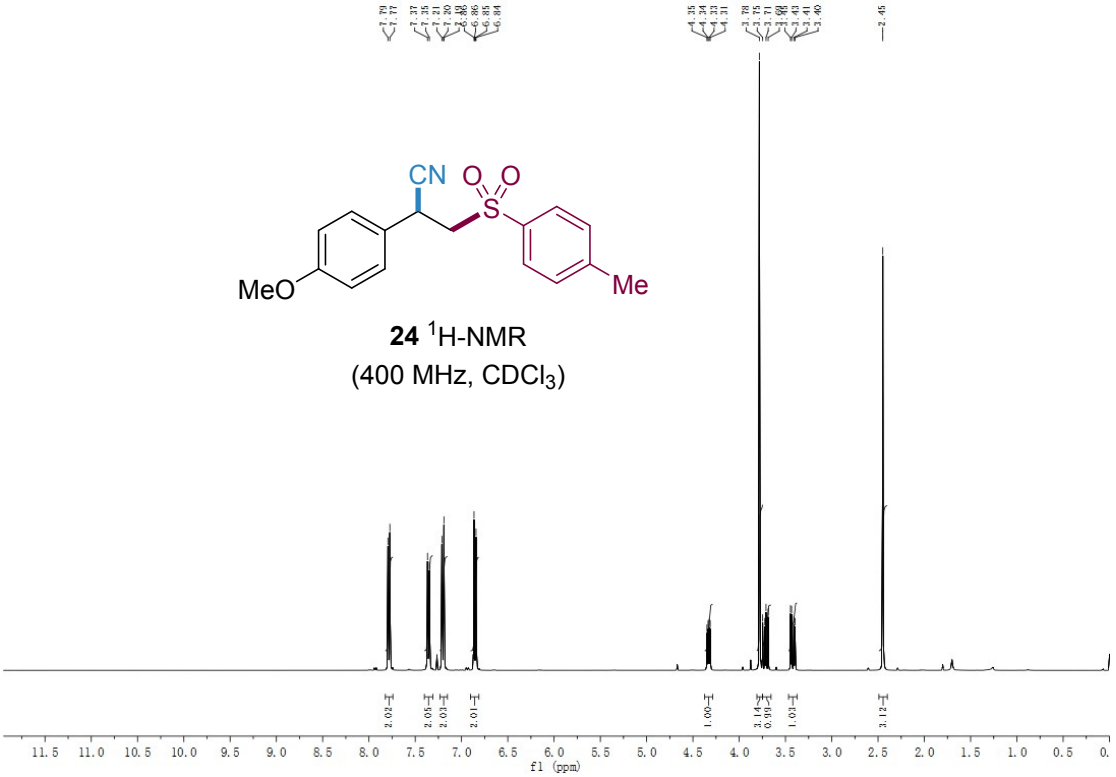


22 ^{19}F-NMR

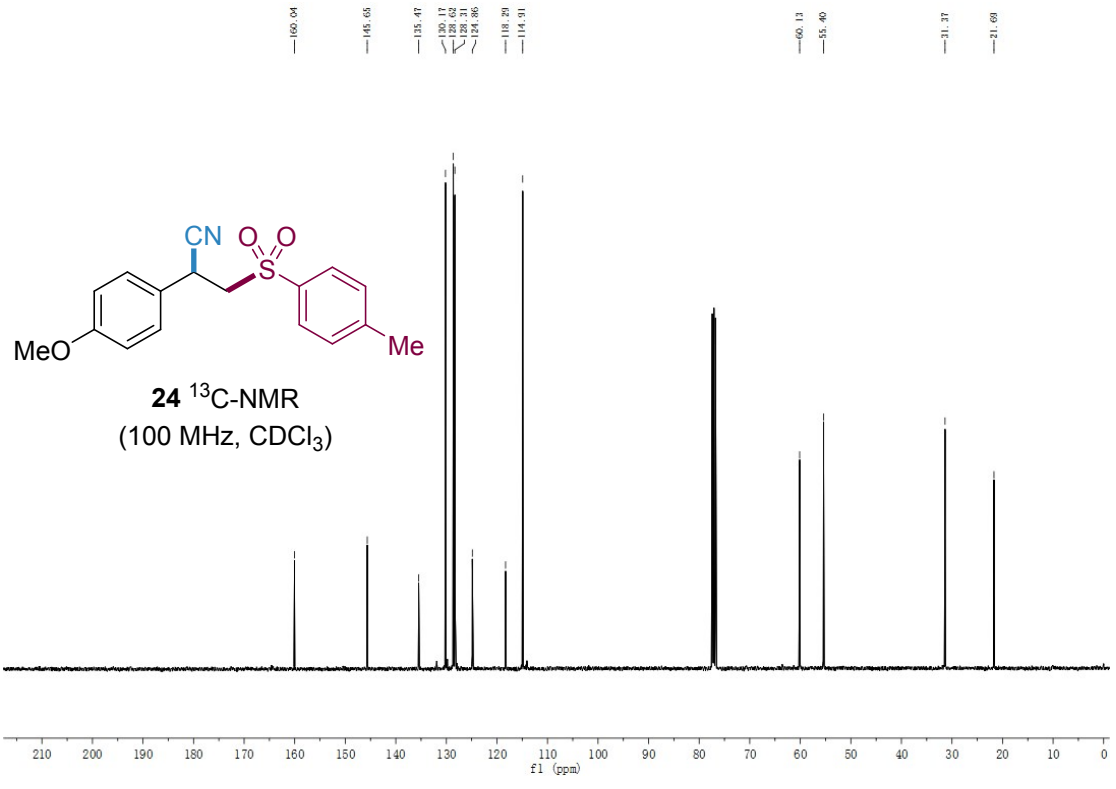
(376 MHz, DMSO-d_6)


NC
O
O
S
OMe
23 1H-NMR
(400 MHz, CDCl3)
f1 (ppm)

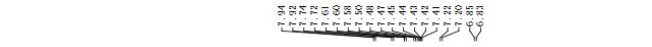

NC
O
O
S
OMe
23 13C-NMR
(100 MHz, CDCl3)
f1 (ppm)

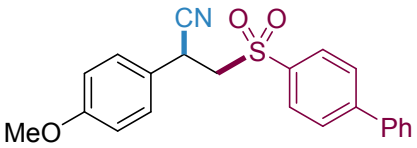


24 ^{1}H-NMR
(400 MHz, $CDCl_3$)

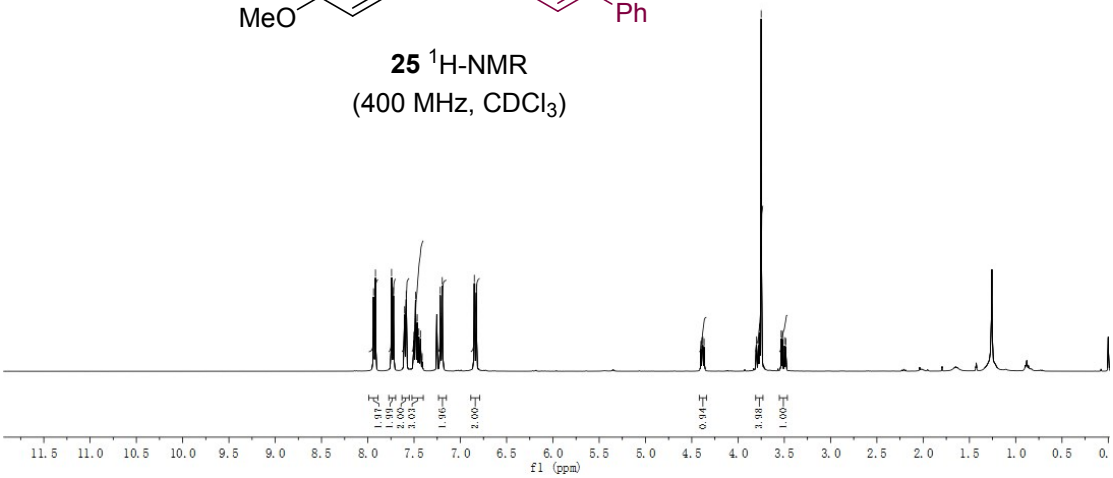


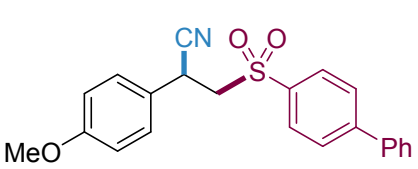
24 ^{13}C-NMR
(100 MHz, $CDCl_3$)



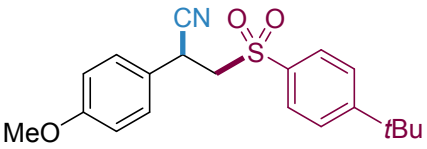


25 ^{1}H-NMR
(400 MHz, $CDCl_3$)

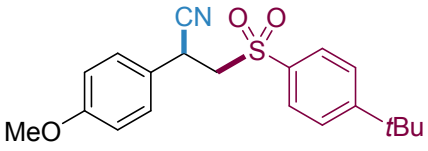




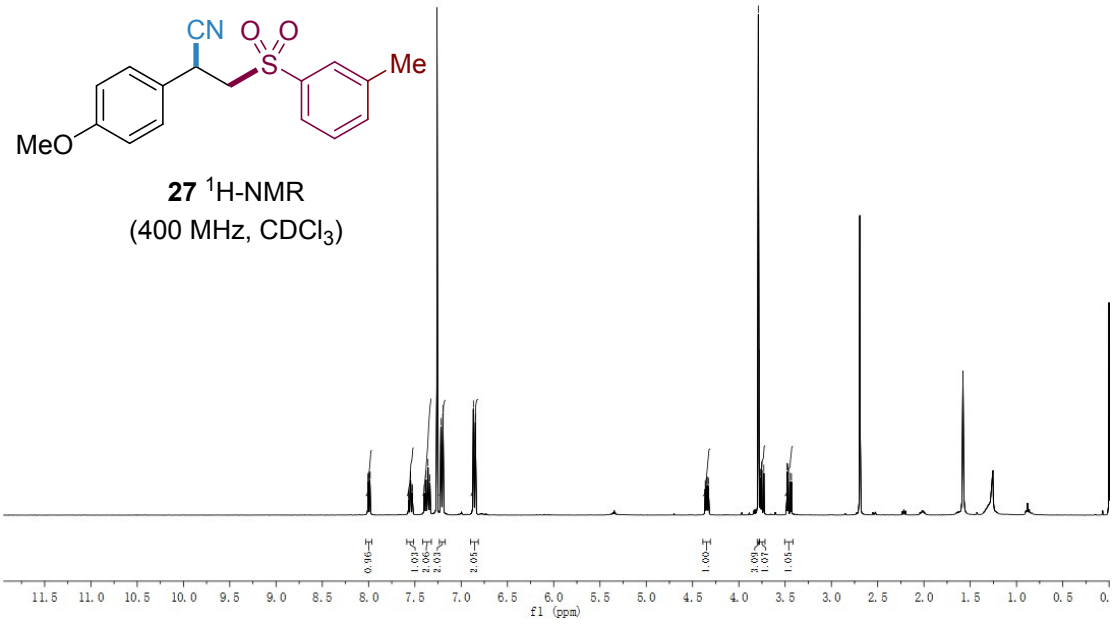
25 ^{13}C-NMR
(100 MHz, $CDCl_3$)



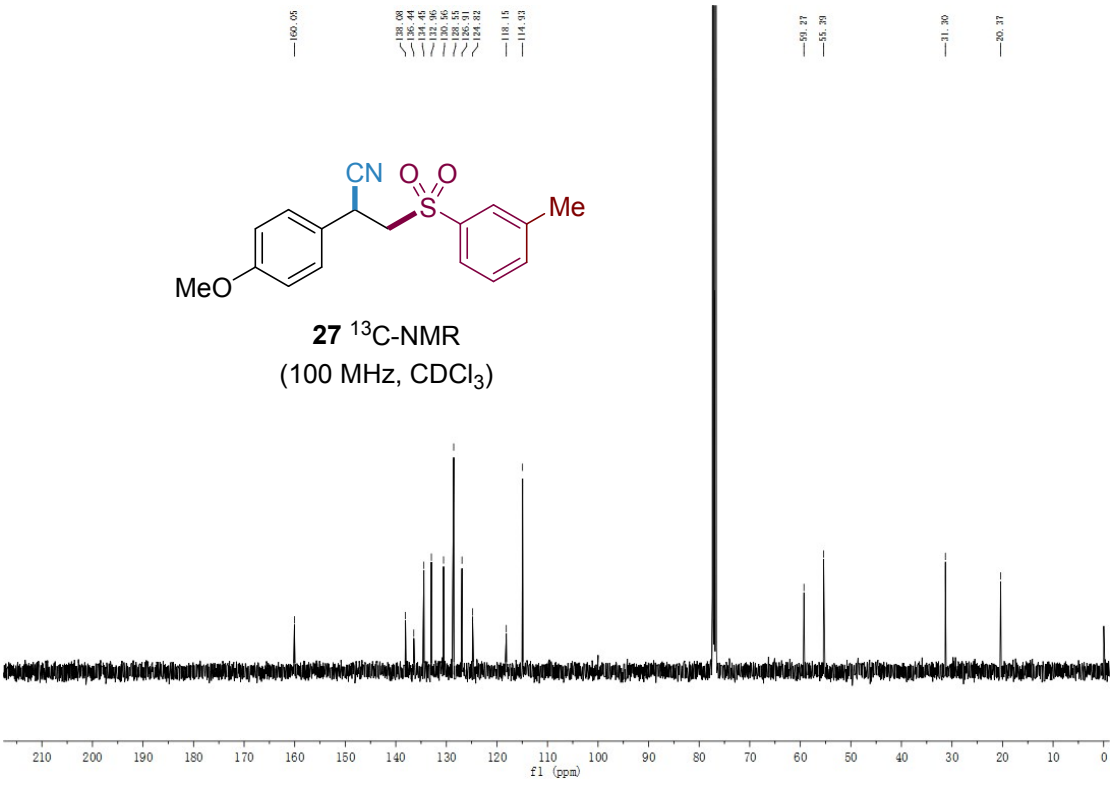
26 ^{1}H-NMR
(400 MHz, $CDCl_3$)



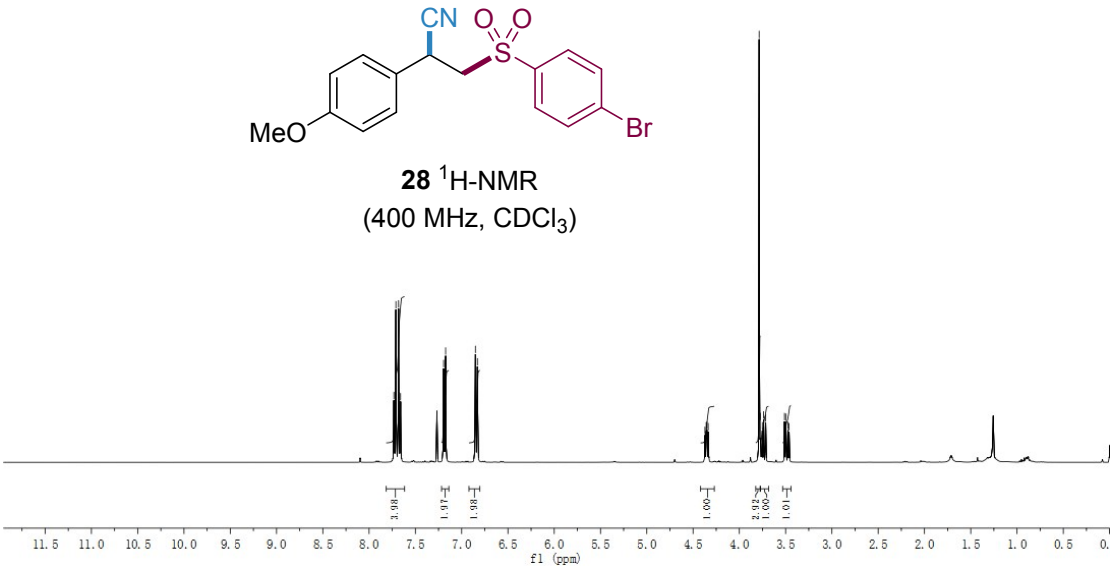
26 ^{13}C-NMR
(100 MHz, $CDCl_3$)

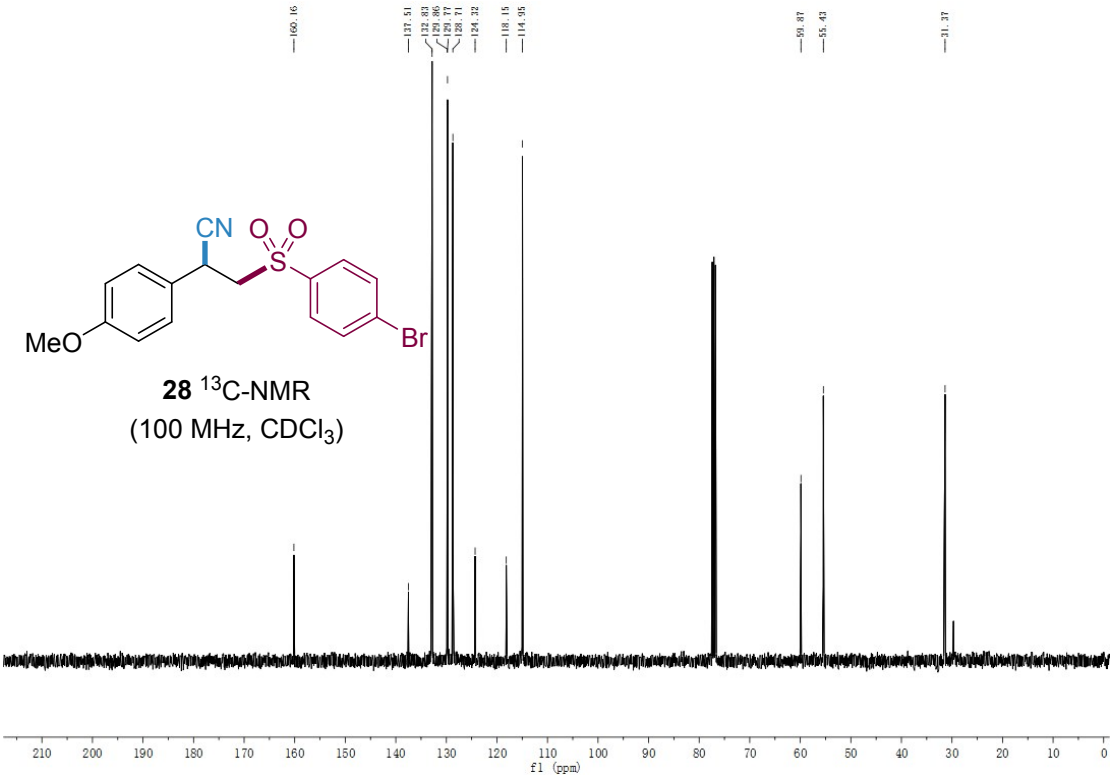


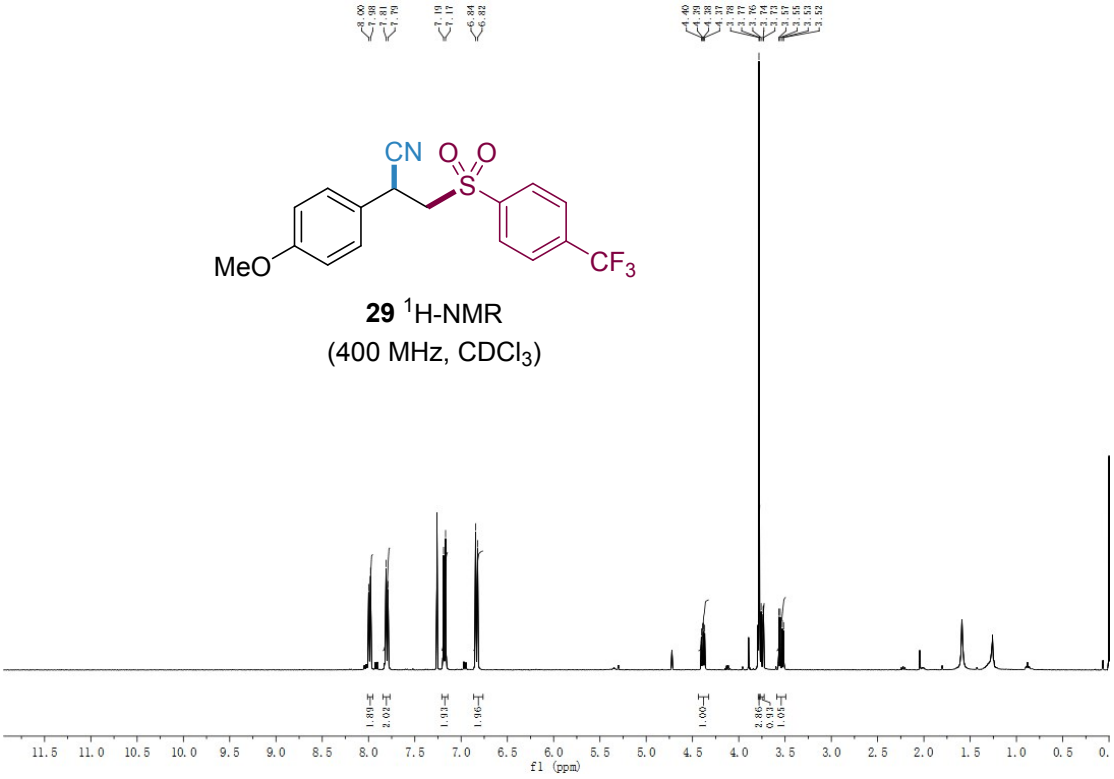
27 ^{1}H-NMR
(400 MHz, $CDCl_3$)



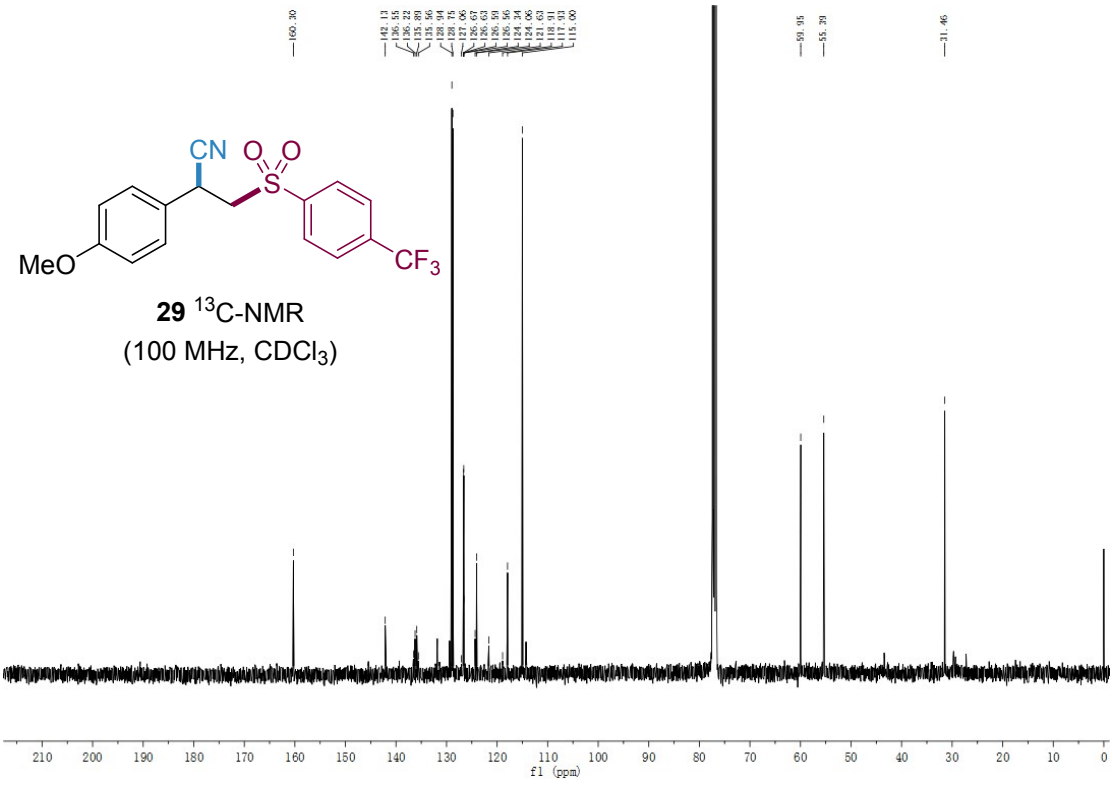
27 ^{13}C-NMR
(100 MHz, $CDCl_3$)


CN
O
O
S
MeO
Br
28 1H-NMR
(400 MHz, CDCl3)
f1 (ppm)

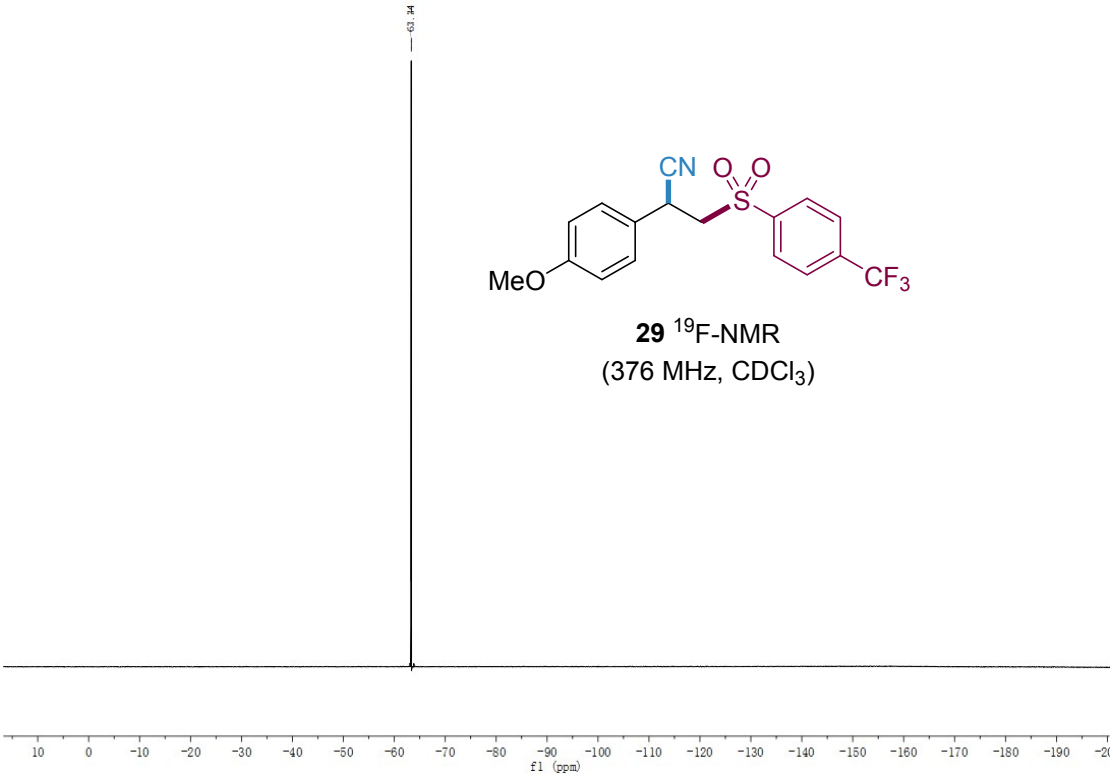

CN
O
O
S
MeO
Br
28 13C-NMR
(100 MHz, CDCl3)
f1 (ppm)



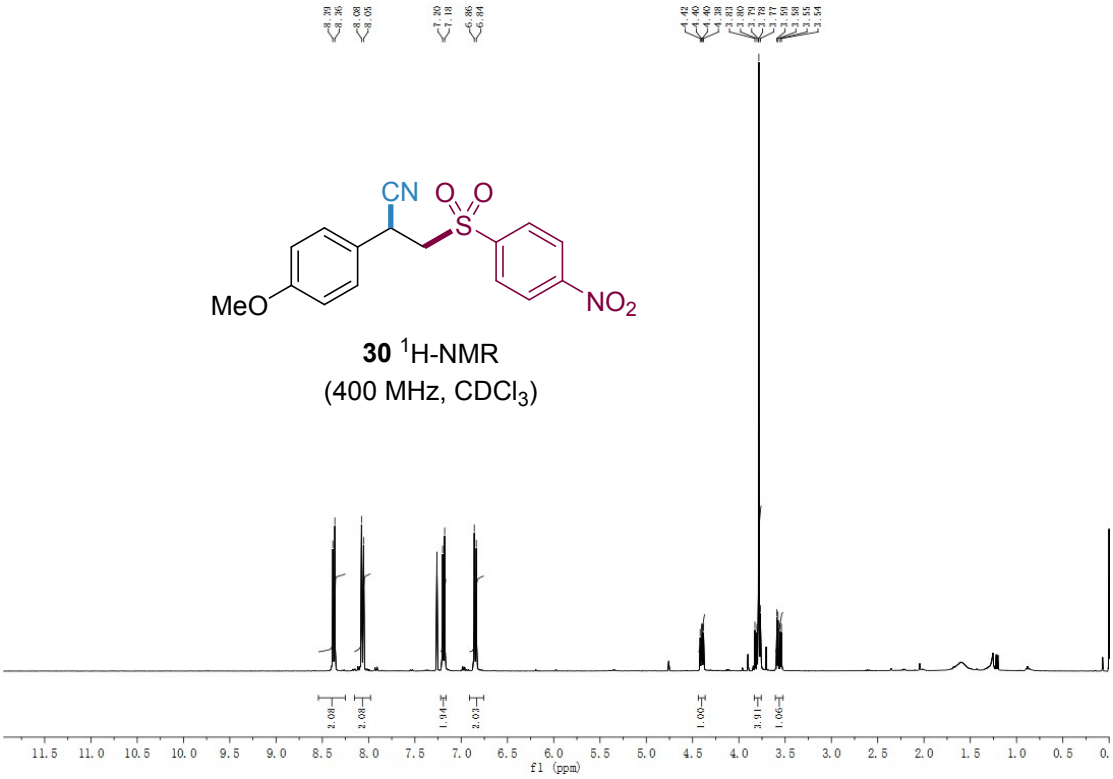
29 ^{1}H-NMR
(400 MHz, $CDCl_3$)



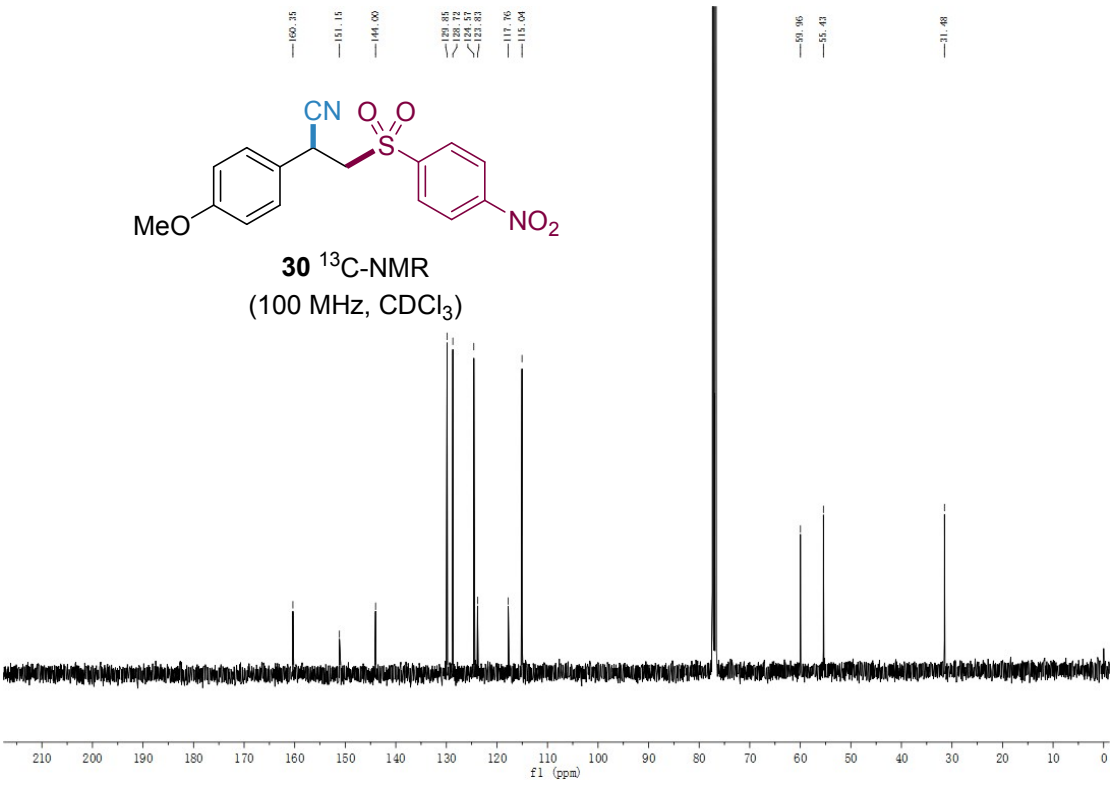
29 ^{13}C-NMR
(100 MHz, $CDCl_3$)



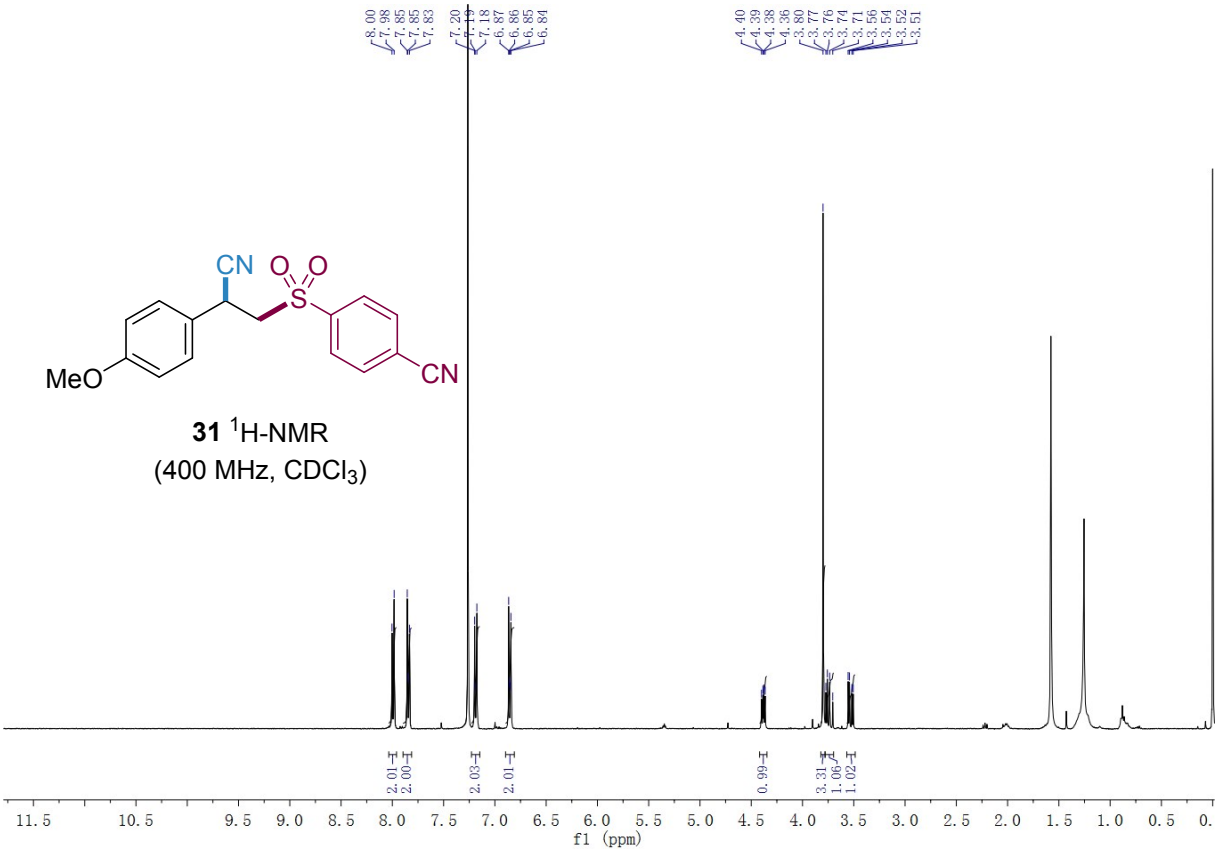
29 ^{19}F-NMR
(376 MHz, $CDCl_3$)



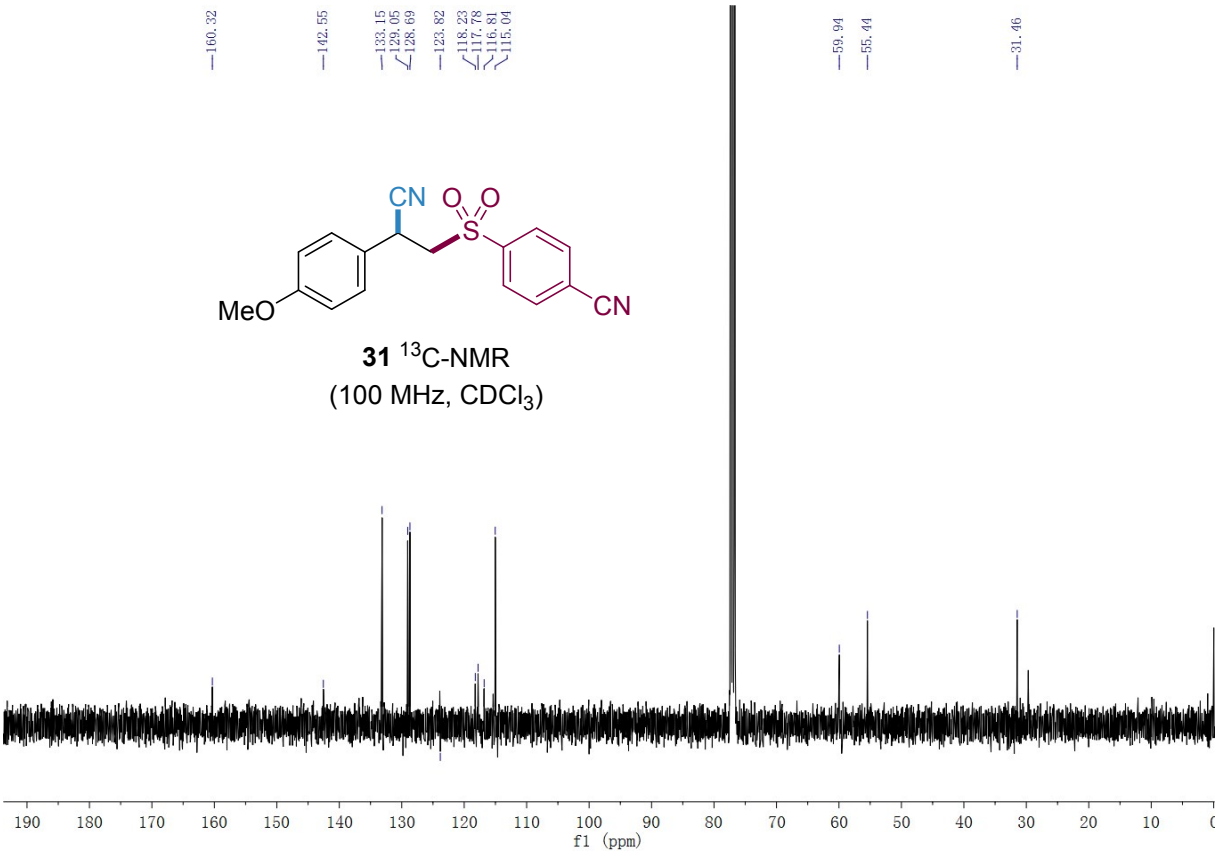
30 ^{1}H-NMR
(400 MHz, $CDCl_3$)



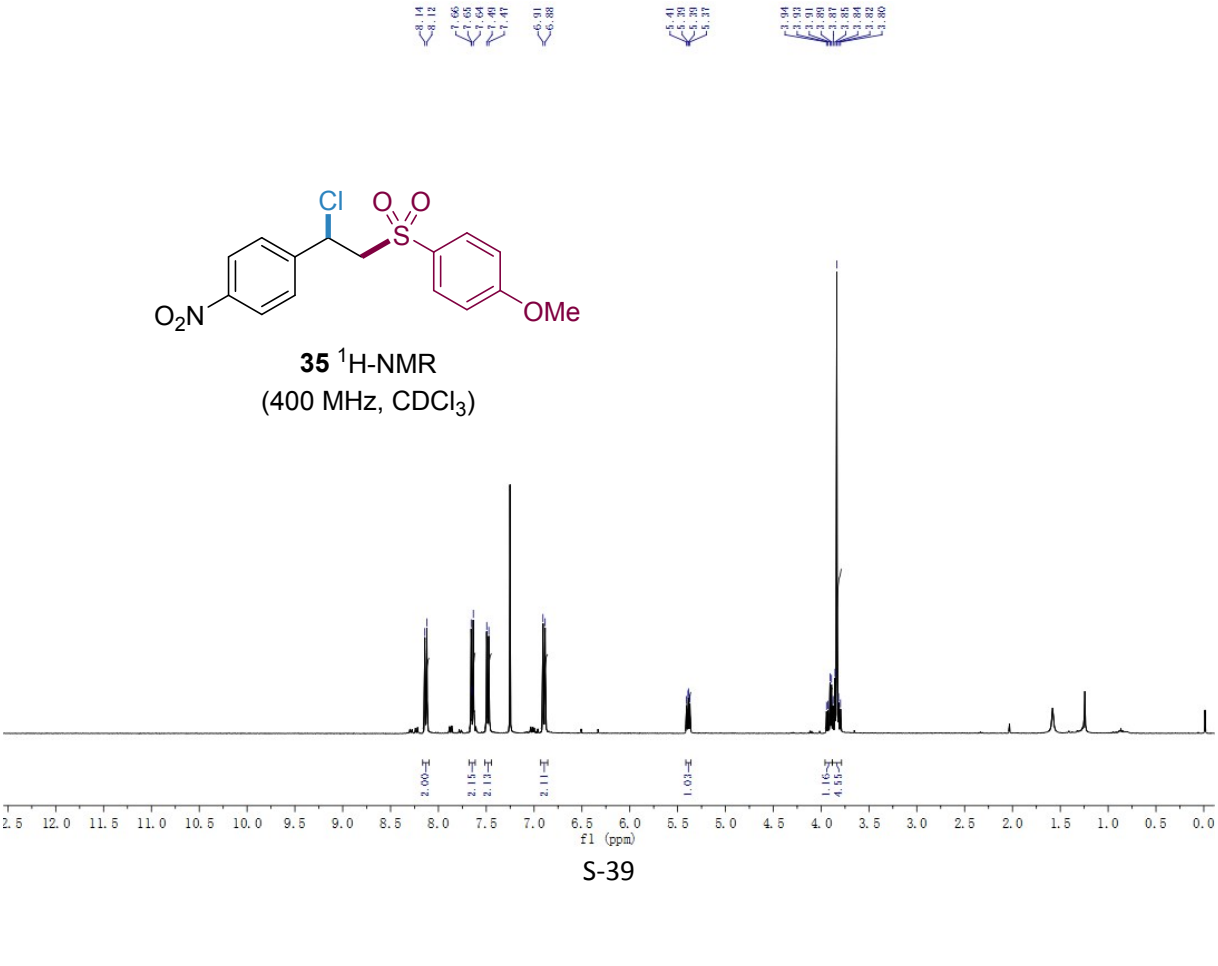
30 ^{13}C-NMR
(100 MHz, $CDCl_3$)



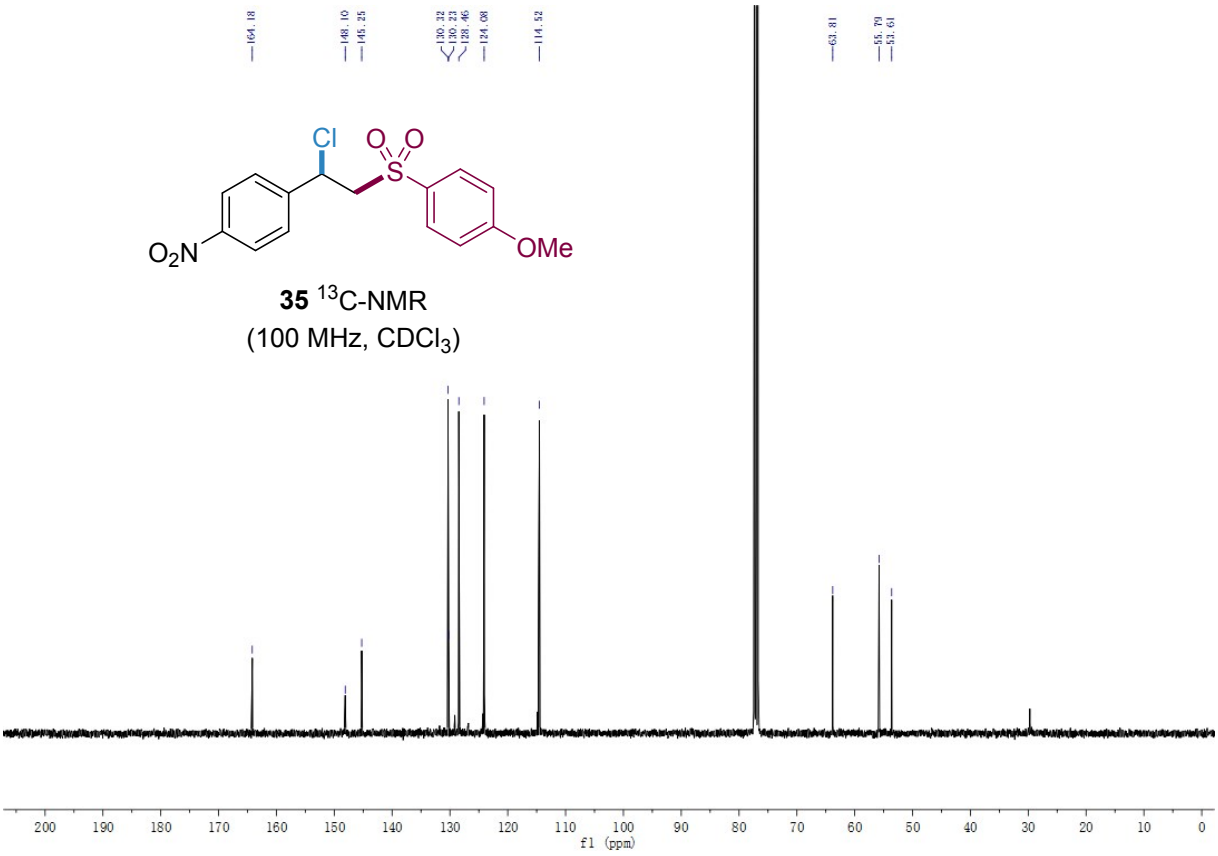
31 ^{1}H-NMR
(400 MHz, $CDCl_3$)



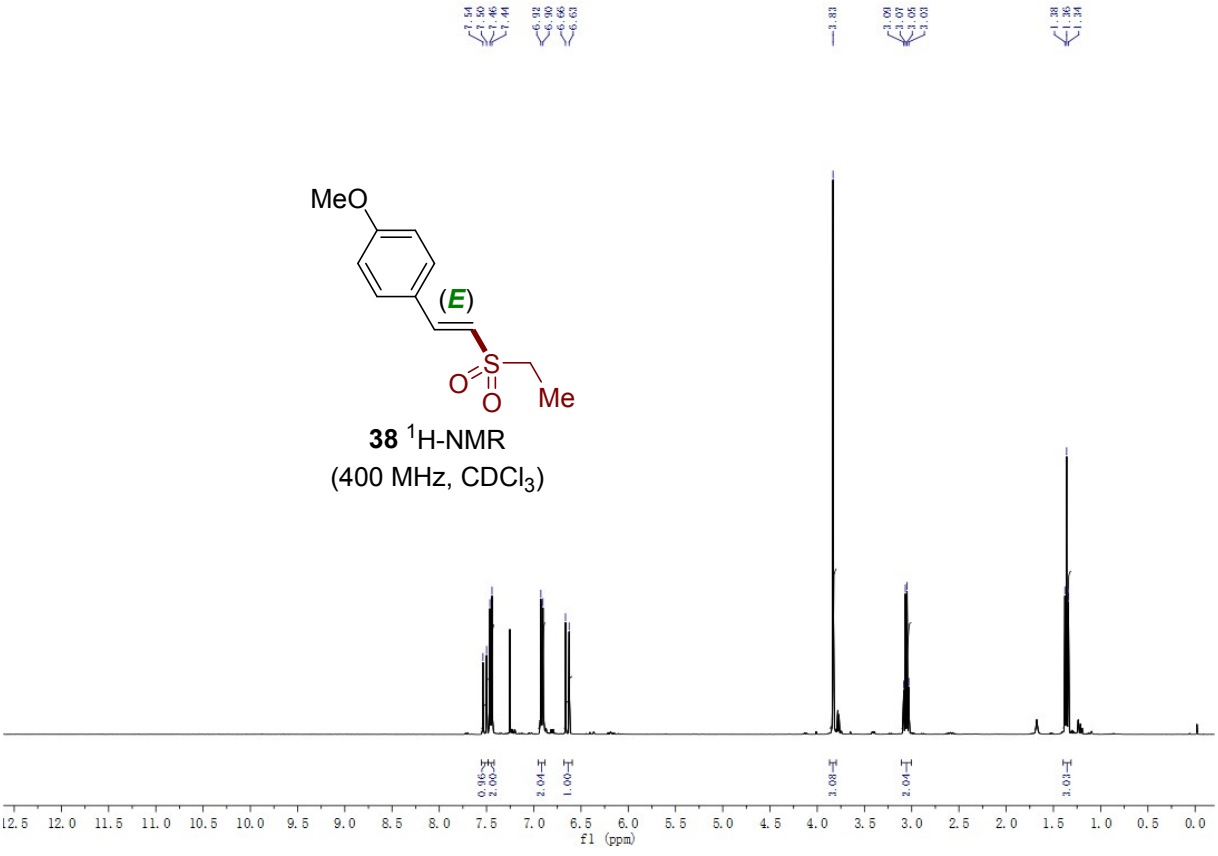
31 ^{13}C-NMR
(100 MHz, $CDCl_3$)



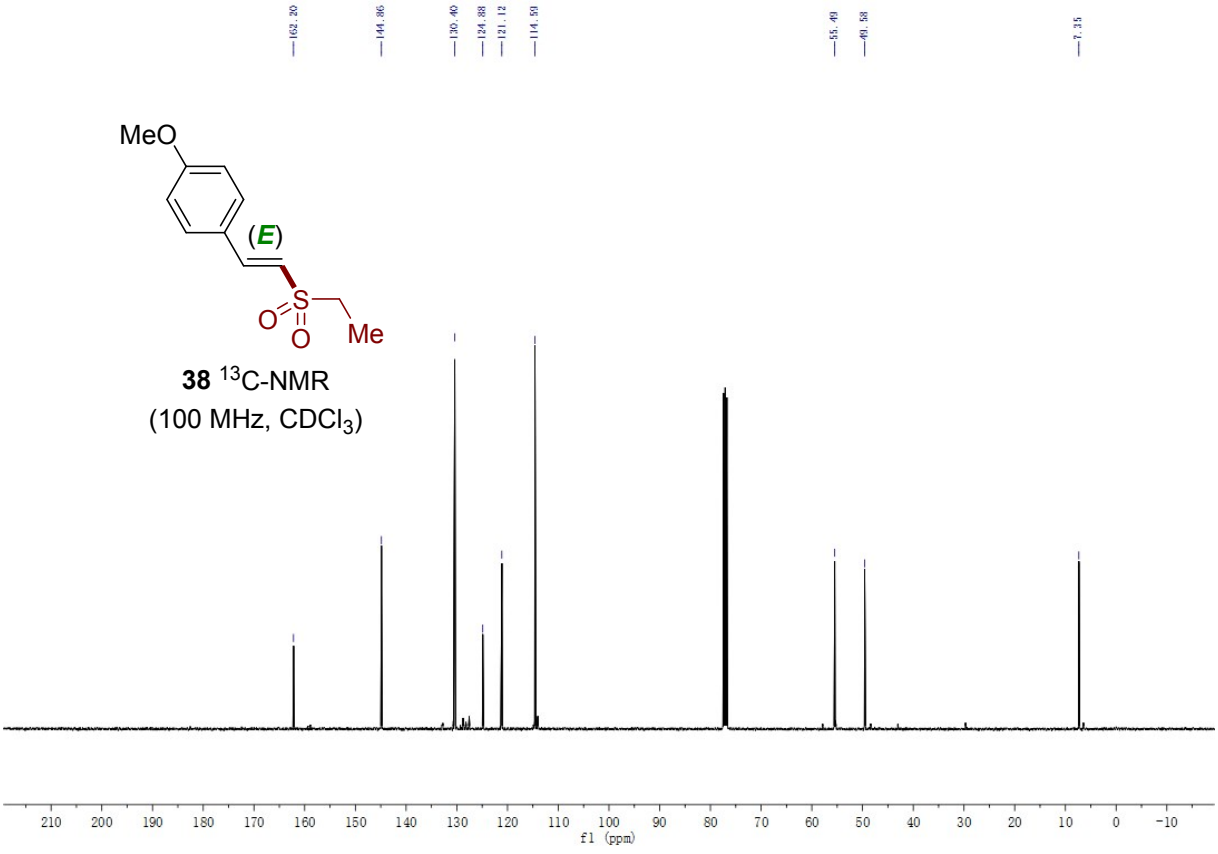
35 ^{1}H-NMR
(400 MHz, $CDCl_3$)



35 ^{13}C-NMR
(100 MHz, $CDCl_3$)



38 ^{1}H-NMR
(400 MHz, $CDCl_3$)



38 ^{13}C-NMR
(100 MHz, $CDCl_3$)