

Supporting information:

A highly efficient heterogeneous copper-catalyzed Chan-Lam coupling reaction of sulfonyl azides with arylboronic acids leading to *N*-arylsulfonamides

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The spectral data of *N*-arylsulfonamides 3a-3c':

4-Methyl-*N*-phenylbenzenesulfonamide 3a.¹ White solid, mp 102-103 °C. ¹H NMR (400 MHz, CDCl₃): δ 7.69 (d, *J* = 8.0 Hz, 2H), 7.25-7.19 (m, 5H), 7.10-7.06 (m, 3H), 2.36 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 143.9, 136.6, 136.0, 129.7, 129.3, 127.3, 125.2, 121.4, 21.5.

4-Methyl-*N*-(*p*-tolyl)benzenesulfonamide 3b.¹ White solid, mp 116-117 °C. ¹H NMR (400 MHz, CDCl₃): δ 7.65 (d, *J* = 8.0 Hz, 2H), 7.20 (d, *J* = 7.6 Hz, 2H), 7.03-6.94 (m, 5H), 2.36 (s, 3H), 2.26 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 143.7, 136.1, 135.3, 133.8, 129.8, 129.6, 127.3, 122.2, 21.5, 20.8.

***N*-(4-Methoxyphenyl)-4-methylbenzenesulfonamide 3c.**¹ White solid, mp 113-114

°C. ¹H NMR (400 MHz, CDCl₃): δ 7.61 (d, *J* = 8.0 Hz, 2H), 7.19 (d, *J* = 8.0 Hz, 2H), 7.10 (s, 1H), 6.99 (d, *J* = 9.2 Hz, 2H), 6.73 (d, *J* = 8.8 Hz, 2H), 3.73 (s, 3H), 2.36 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 157.8, 143.7, 136.0, 129.6, 129.1, 127.3, 125.2, 114.4, 55.4, 21.5.

***N*-(4-Chlorophenyl)-4-methylbenzenesulfonamide 3d.**¹ Pale yellow solid, mp 118-119 °C. ¹H NMR (400 MHz, CDCl₃): δ 7.68 (d, *J* = 8.4 Hz, 2H), 7.49 (s, 1H), 7.23 (d, *J* = 8.4 Hz, 2H), 7.17 (d, *J* = 8.8 Hz, 2H), 7.04 (d, *J* = 8.8 Hz, 2H), 2.37 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 144.2, 135.6, 135.2, 130.8, 129.8, 129.4, 127.3, 122.8, 21.6.

***N*-(4-Bromophenyl)-4-methylbenzenesulfonamide 3e.**² Pale yellow solid, mp 146-148 °C. ¹H NMR (400 MHz, CDCl₃): δ 7.73 (s, 1H), 7.70 (d, *J* = 7.6 Hz, 2H), 7.29 (d, *J* = 8.0 Hz, 2H), 7.21 (d, *J* = 8.0 Hz, 2H), 6.99 (d, *J* = 8.0 Hz, 2H), 2.35 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 144.2, 135.9, 135.7, 132.3, 129.8, 127.3, 122.9, 118.3, 21.6.

***N*-(4-Fluorophenyl)-4-methylbenzenesulfonamide 3f.** White solid, mp 79-80 °C. ¹H NMR (400 MHz, CDCl₃): δ 7.65 (d, *J* = 6.8 Hz, 2H), 7.44 (m, 1H), 7.22 (d, *J* = 7.6 Hz, 2H), 7.07 (m, 2H), 6.91 (t, *J* = 7.6 Hz, 2H), 2.37 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 160.8 (d, ¹*J*_{C-F} = 249.9 Hz), 144.1, 135.6, 132.4 (d, ⁴*J*_{C-F} = 2.2 Hz), 129.7, 127.3, 122.4 (d, ³*J*_{C-F} = 8.4 Hz), 116.1 (d, ²*J*_{C-F} = 22.6 Hz), 21.6. Anal. Calcd. for C₁₃H₁₂FNO₂S: C, 58.85; H, 4.56; N, 5.28; S, 12.09. Found: C, 58.59; H, 4.37; N, 5.45; S, 11.84.

***N*-(Biphenyl-4-yl)-4-methylbenzenesulfonamide 3g.** White solid, mp 157-158 °C.

¹H NMR (400 MHz, CDCl₃): δ 7.73 (d, *J* = 7.6 Hz, 2H), 7.49 (d, *J* = 7.6 Hz, 2H), 7.44 (d, *J* = 8.4 Hz, 2H), 7.41-7.36 (m, 3H), 7.30 (t, *J* = 7.2 Hz, 1H), 7.22 (d, *J* = 7.6 Hz, 2H), 7.16 (d, *J* = 8.0 Hz, 2H), 2.35 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 144.0, 140.1, 138.1, 136.2, 135.9, 129.7, 128.8, 127.9, 127.4, 127.3, 126.8, 121.7, 21.5. Anal. Calcd. for C₁₉H₁₇NO₂S: C, 70.56; H, 5.30; N, 4.33; S, 9.91. Found: C, 70.37; H, 5.48; N, 4.16; S, 9.66.

***N*-(3-Methoxyphenyl)-4-methylbenzenesulfonamide 3h.**³ White solid, mp 86-87 °C.

¹H NMR (400 MHz, CDCl₃): δ 7.73 (d, *J* = 8.0 Hz, 2H), 7.65 (s, 1H), 7.19 (d, *J* = 8.0 Hz, 2H), 7.08 (t, *J* = 8.4 Hz, 1H), 6.73 (s, 1H), 6.67 (d, *J* = 7.6 Hz, 1H), 6.59 (d, *J* = 8.4 Hz, 1H), 3.69 (s, 3H), 2.33 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 160.2, 143.9, 138.0, 136.0, 130.0, 129.7, 127.3, 113.1, 110.7, 106.6, 55.3, 21.5.

***N*-(3,5-Dimethylphenyl)-4-methylbenzenesulfonamide 3i.**³ White solid, mp 90-91

°C. NMR (400 MHz, CDCl₃): δ 7.71 (d, *J* = 7.6 Hz, 2H), 7.26 (s, 1H), 7.21 (d, *J* = 7.6 Hz, 2H), 6.72 (s, 2H), 6.70 (s, 1H), 2.35 (s, 3H), 2.19 (s, 6H); ¹³C NMR (100 MHz, CDCl₃): δ 143.7, 139.0, 136.5, 136.3, 129.6, 127.3, 126.8, 118.8, 21.5, 21.2.

4-Methyl-*N*-(4-vinylphenyl)benzenesulfonamide 3j.³ White solid, mp 80-82 °C. ¹H

NMR (400 MHz, CDCl₃): δ 7.65 (d, *J* = 6.4 Hz, 2H), 7.29-7.21 (m, 4H), 7.02 (d, *J* = 6.4 Hz, 2H), 6.68-6.58 (m, 2H), 5.66 (d, *J* = 16.8 Hz, 1H), 5.20 (d, *J* = 10.8 Hz, 1H), 2.38 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 144.0, 136.0, 135.9, 135.8, 134.8, 129.7, 127.3, 127.2, 121.6, 113.8, 21.5.

4-Methyl-*N*-(*o*-tolyl)benzenesulfonamide 3k.¹ White solid, mp 105-107 °C. ¹H

NMR (400 MHz, CDCl₃): δ 7.62 (d, *J* = 8.0 Hz, 2H), 7.31 (d, *J* = 8.0 Hz, 1H), 7.21 (d,

$J = 8.0$ Hz, 2H), 7.14-7.07 (m, 3H), 6.61 (s, 1H), 2.38 (s, 3H), 2.01 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3): δ 143.8, 136.7, 134.5, 131.4, 130.8, 129.6, 127.2, 126.9, 126.2, 124.3, 21.5, 17.6.

***N*-(2-Methoxyphenyl)-4-methylbenzenesulfonamide 3l.**² White solid, mp 125-126 °C. ^1H NMR (400 MHz, CDCl_3): δ 7.64 (d, $J = 8.0$ Hz, 2H), 7.52 (d, $J = 8.0$ Hz, 1H), 7.18 (d, $J = 8.0$ Hz, 2H), 7.04-7.00 (m, 2H), 6.89 (t, $J = 7.6$ Hz, 1H), 6.73 (d, $J = 8.0$ Hz, 1H), 3.64 (s, 3H), 2.35 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3): δ 149.4, 143.6, 136.3, 129.3, 127.3, 126.0, 125.2, 121.1, 121.0, 110.6, 55.6, 21.5.

4-Methyl-*N*-(naphthalen-1-yl)benzenesulfonamide 3m.¹ White solid, mp 141-142 °C. ^1H NMR (400 MHz, CDCl_3): δ 7.88 (d, $J = 7.6$ Hz, 1H), 7.78 (d, $J = 6.8$ Hz, 1H), 7.70-7.63 (m, 3H), 7.43-7.25 (m, 5H), 7.13 (d, $J = 8.0$ Hz, 2H), 2.31 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3): δ 143.8, 136.4, 134.2, 131.5, 129.6, 128.9, 128.4, 127.4, 127.1, 126.6, 126.3, 125.4, 122.6, 121.6, 21.5.

4-Methyl-*N*-(naphthalen-2-yl)benzenesulfonamide 3n.³ White solid, mp 157-158 °C. ^1H NMR (400 MHz, CDCl_3): δ 7.75-7.68 (m, 5H), 7.61 (s, 1H), 7.56 (s, 1H), 7.43-7.36 (m, 2H), 7.26 (d, $J = 8.8$ Hz, 1H), 7.16 (d, $J = 7.6$ Hz, 2H), 2.30 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3): δ 144.0, 135.9, 134.2, 133.7, 131.0, 129.8, 129.4, 127.7, 127.5, 127.3, 126.7, 125.5, 120.9, 118.1, 21.6.

4-Methyl-*N*-(thiophen-3-yl)benzenesulfonamide 3o.³ White solid, mp 110-111 °C. ^1H NMR (400 MHz, CDCl_3): δ 7.67 (d, $J = 8.0$ Hz, 2H), 7.23 (d, $J = 7.6$ Hz, 2H), 7.16 (t, $J = 4.0$ Hz, 1H), 7.09 (s, 1H), 6.87-6.83 (m, 2H), 2.38 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3): δ 143.9, 136.0, 134.3, 129.6, 127.3, 125.6, 123.3, 113.9, 21.5.

***N*-Phenylmethanesulfonamide 3p.**⁴ White solid, mp 99-100 °C. ¹H NMR (400 MHz, CDCl₃): δ 7.35 (t, *J* = 8.0 Hz, 2H), 7.24 (d, *J* = 8.0 Hz, 2H), 7.19 (t, *J* = 7.4 Hz, 1H), 6.97 (s, 1H), 3.01 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 136.9, 129.7, 125.4, 120.9, 39.2.

***N-p*-Tolylmethanesulfonamide 3q.**⁴ White solid, mp 103-104 °C. ¹H NMR (400 MHz, CDCl₃): δ 7.15 (s, 4H), 7.00 (s, 1H), 2.98 (s, 3H), 2.33 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 135.6, 134.0, 130.2, 121.6, 38.9, 20.9.

***N*-(4-Methoxyphenyl)methanesulfonamide 3r.**⁵ White solid, mp 113-114 °C. ¹H NMR (400 MHz, CDCl₃): δ 7.22 (d, *J* = 8.8 Hz, 2H), 6.93 (br, 1H), 6.88 (d, *J* = 8.8 Hz, 2H), 3.80 (s, 3H), 2.96 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 158.0, 129.2, 124.7, 114.8, 55.5, 38.7.

***N*-(4-Chlorophenyl)methanesulfonamide 3s.**⁵ White solid, mp 122-124 °C. ¹H NMR (400 MHz, CDCl₃): δ 7.32 (d, *J* = 8.8 Hz, 2H), 7.18 (d, *J* = 8.4 Hz, 2H), 6.88 (br, 1H), 3.01 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 135.2, 131.1, 129.8, 122.2, 39.5.

4-Methoxy-*N*-phenylbenzenesulfonamide 3t.⁶ White solid, mp 107-108 °C. ¹H NMR (400 MHz, CDCl₃): δ 7.74 (d, *J* = 8.8 Hz, 2H), 7.29 (br, 1H), 7.22 (t, *J* = 8.0 Hz, 2H), 7.11-7.06 (m, 3H), 6.88 (d, *J* = 8.4 Hz, 2H), 3.80 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 163.1, 136.7, 130.5, 129.5, 129.3, 125.2, 121.4, 114.2, 55.6.

4-Methoxy-*N*-(4-methoxyphenyl)benzenesulfonamide 3u.⁶ White solid, mp 100-101 °C. ¹H NMR (400 MHz, CDCl₃): δ 7.65 (d, *J* = 9.2 Hz, 2H), 6.99 (d, *J* = 8.8 Hz, 2H), 6.87 (d, *J* = 8.8 Hz, 2H), 6.84 (br, 1H), 6.75 (d, *J* = 8.8 Hz, 2H), 3.82 (s, 3H),

3.75 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3): δ 163.0, 157.8, 130.5, 129.5, 129.1, 125.3, 114.4, 114.1, 55.6, 55.4.

***N*-(4-Chlorophenyl)-4-methoxybenzenesulfonamide 3v.** White solid, mp 97-99 °C.

^1H NMR (400 MHz, CDCl_3): δ 7.73 (d, $J = 8.8$ Hz, 2H), 7.47 (s, 1H), 7.18 (d, $J = 8.8$ Hz, 2H), 7.04 (d, $J = 8.4$ Hz, 2H), 6.89 (d, $J = 8.4$ Hz, 2H), 3.82 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3): δ 163.3, 135.3, 130.7, 130.0, 129.5, 129.4, 122.8, 114.3, 55.6.

Anal. Calcd. for $\text{C}_{13}\text{H}_{12}\text{ClNO}_3\text{S}$: C, 52.44; H, 4.06; N, 4.70; S, 10.77. Found: C, 52.57; H, 4.25; N, 4.53; S, 10.56.

4-Nitro-*N*-phenylbenzenesulfonamide 3w.⁷ Yellow solid, mp 135-136 °C. ^1H NMR (400 MHz, DMSO): δ 10.60 (s, 1H), 8.38 (d, $J = 8.4$ Hz, 2H), 8.02 (d, $J = 8.4$ Hz, 2H), 7.27 (t, $J = 7.4$ Hz, 2H), 7.13 (d, $J = 7.6$ Hz, 2H), 7.09 (t, $J = 7.2$ Hz, 1H); ^{13}C NMR (100 MHz, DMSO): δ 150.3, 145.4, 137.4, 129.8, 128.7, 125.2, 125.1, 121.2.

4-Nitro-*N*-(*p*-tolyl)benzenesulfonamide 3x.⁷ Yellow solid, mp 179-180 °C. ^1H NMR (400 MHz, DMSO): δ 10.42 (br, 1H), 8.36 (d, $J = 8.8$ Hz, 2H), 7.97 (d, $J = 8.8$ Hz, 2H), 7.05 (d, $J = 8.4$ Hz, 2H), 6.99 (d, $J = 8.4$ Hz, 2H), 2.18 (s, 3H); ^{13}C NMR (100 MHz, DMSO): δ 150.2, 145.5, 134.7, 134.6, 130.2, 128.7, 125.0, 121.8, 20.8.

***N*-(4-Methoxyphenyl)-4-nitrobenzenesulfonamide 3y.**⁷ Yellow solid, mp 182-183 °C. ^1H NMR (400 MHz, DMSO): δ 10.23 (s, 1H), 8.37 (d, $J = 8.4$ Hz, 2H), 7.93 (d, $J = 8.4$ Hz, 2H), 7.00 (d, $J = 8.4$ Hz, 2H), 6.83 (d, $J = 8.0$ Hz, 2H), 3.68 (s, 3H); ^{13}C NMR (100 MHz, DMSO): δ 157.5, 150.2, 145.4, 129.7, 128.8, 125.0, 124.6, 114.9, 55.7.

***N*-(4-Chlorophenyl)-4-nitrobenzenesulfonamide 3z.**⁷ Yellow solid, mp 189-190 °C.

¹H NMR (400 MHz, DMSO): δ 10.74 (br, 1H), 8.39 (d, *J* = 6.8 Hz, 2H), 8.00 (d, *J* = 6.8 Hz, 2H), 7.33 (d, *J* = 6.8 Hz, 2H), 7.13 (d, *J* = 6.8 Hz, 2H); ¹³C NMR (100 MHz, DMSO): δ 150.4, 145.0, 136.4, 129.8, 129.5, 128.7, 125.2, 122.8.

***N*-Phenylnaphthalene-2-sulfonamide 3a'**. White solid, mp 133-134 °C. ¹H NMR (400 MHz, CDCl₃): δ 8.41 (s, 1H), 7.87-7.79 (m, 4H), 7.62-7.52 (m, 2H), 7.50 (s, 1H), 7.21-7.12 (m, 4H), 7.05 (t, *J* = 7.2 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃): δ 136.4, 135.9, 134.9, 132.0, 129.5, 129.4, 129.3, 129.0, 127.9, 127.6, 125.4, 122.3, 121.6. Anal. Calcd. for C₁₆H₁₃NO₂S: C, 67.82; H, 4.62; N, 4.94; S, 11.32. Found: C, 67.58; H, 4.35; N, 4.67; S, 11.14.

***N*-(4-Methoxyphenyl)naphthalene-2-sulfonamide 3b'**. Yellow liquid. ¹H NMR (400 MHz, CDCl₃): δ 8.29 (s, 1H), 7.89-7.85 (m, 3H), 7.72 (dd, *J* = 8.6, 1.8 Hz, 1H), 7.64-7.54 (m, 2H), 7.00 (d, *J* = 8.8 Hz, 2H), 6.86 (s, 1H), 6.72 (d, *J* = 8.8 Hz, 2H), 3.72 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 158.1, 136.0, 134.9, 132.1, 129.3, 129.2, 128.9, 128.7, 127.9, 127.5, 125.7, 122.5, 114.5, 55.4. Anal. Calcd. for C₁₇H₁₅NO₃S: C, 65.16; H, 4.82; N, 4.47; S, 10.23. Found: C, 65.28; H, 4.57; N, 4.25; S, 10.06.

***N*-(4-Fluorophenyl)naphthalene-2-sulfonamide 3c'**. White solid, mp 106-108 °C. ¹H NMR (400 MHz, CDCl₃): δ 8.34 (s, 1H), 7.90-7.85 (m, 3H), 7.77 (dd, *J* = 8.8, 1.6 Hz, 1H), 7.65-7.55 (m, 2H), 7.43 (s, 1H), 7.11-7.07 (m, 2H), 6.88 (t, *J* = 8.6 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃): δ 160.8 (d, *J*_{C-F} = 250.1 Hz), 135.7, 135.5, 135.0, 132.1 (d, *J*_{C-F} = 19.6 Hz), 129.5, 129.3, 129.1, 129.0, 127.9, 127.7, 124.7 (d, *J*_{C-F} = 8.5 Hz), 122.2, 116.2 (d, *J*_{C-F} = 22.5 Hz). Anal. Calcd. for C₁₆H₁₂FNO₂S: C, 63.77; H, 4.01; N, 4.65; S, 10.64. Found: C, 63.53; H, 3.88; N, 4.41; S, 10.37.

4-Chloro-*N*-phenylbenzenesulfonamide 3d'.³ White solid, mp 104-105 °C. ¹H NMR (400 MHz, CDCl₃): δ 7.72 (d, *J* = 8.4 Hz, 2H), 7.39 (d, *J* = 8.4 Hz, 2H); 7.27-7.22 (m, 3H), 7.15-7.08 (m, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 139.7, 137.4, 136.1, 129.5, 129.4, 128.7, 125.8, 121.9.

4-Chloro-*N*-(4-chlorophenyl)benzenesulfonamide 3e'. White solid, mp 146-147 °C. ¹H NMR (400 MHz, CDCl₃): δ 7.71 (d, *J* = 8.8 Hz, 2H), 7.42 (d, *J* = 8.8 Hz, 2H), 7.28 (s, 1H), 7.22 (d, *J* = 8.8 Hz, 2H), 7.03 (d, *J* = 8.8 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃): δ 140.0, 137.0, 134.6, 131.5, 129.6, 129.5, 128.7, 123.3. Anal. Calcd. for C₁₂H₉Cl₂NO₂S: C, 47.70; H, 3.00; N, 4.64; S, 10.61. Found: C, 47.43; H, 3.11; N, 4.39; S, 10.43.

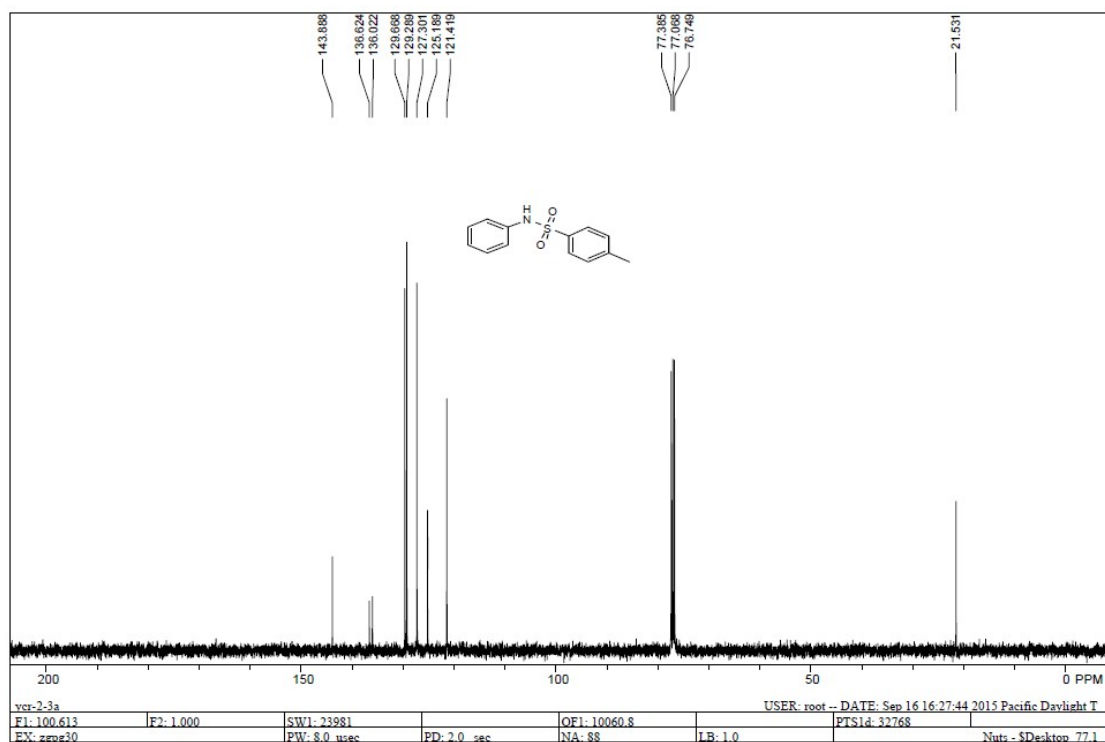
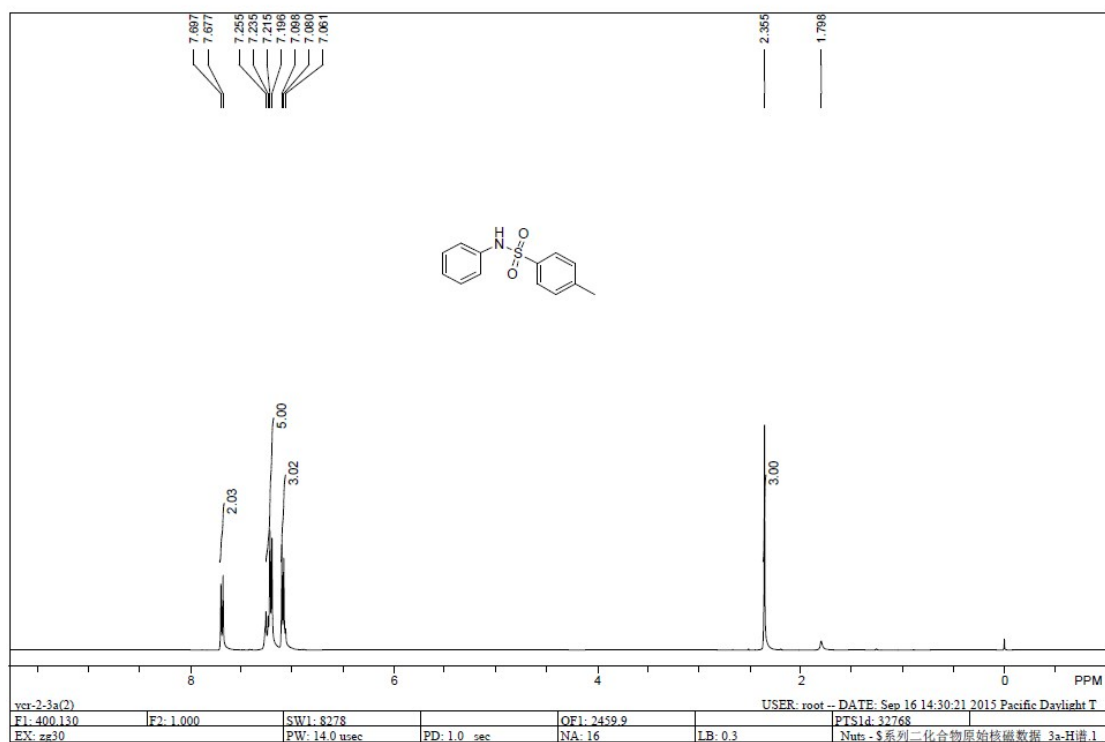
4-Chloro-*N*-(4-methoxyphenyl)benzenesulfonamide 3f'. White solid, mp 141-142 °C. ¹H NMR (400 MHz, CDCl₃): δ 7.64 (d, *J* = 8.4 Hz, 2H), 7.39 (d, *J* = 8.4 Hz, 2H), 6.99 (d, *J* = 8.8 Hz, 2H), 6.93 (s, 1H), 6.77 (d, *J* = 8.8 Hz, 2H), 3.76 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 158.2, 139.4, 137.4, 129.3, 128.8, 128.4, 125.7, 114.6, 55.5. Anal. Calcd. for C₁₃H₁₂ClNO₃S: C, 52.44; H, 4.06; N, 4.70; S, 10.77. Found: C, 52.23; H, 3.79; N, 4.56; S, 10.58.

2-Methyl-6*H*-dibenzo[*c,e*][1,2]thiazine 5,5-dioxide 4a.³ White solid, mp 162-164 °C. ¹H NMR (400 MHz, CDCl₃): δ 7.99 (d, *J* = 8.0 Hz, 1H), 7.89 (d, *J* = 8.0 Hz, 1H), 7.78 (s, 1H), 7.42-7.36 (m, 2H), 7.32-7.28 (m, 1H), 7.23 (br, 1H), 7.12 (d, *J* = 8.0 Hz, 1H), 2.52 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 143.1, 135.6, 132.4, 132.3, 130.2, 129.1, 125.8, 125.3, 125.0, 123.0, 122.1, 120.6, 22.0.

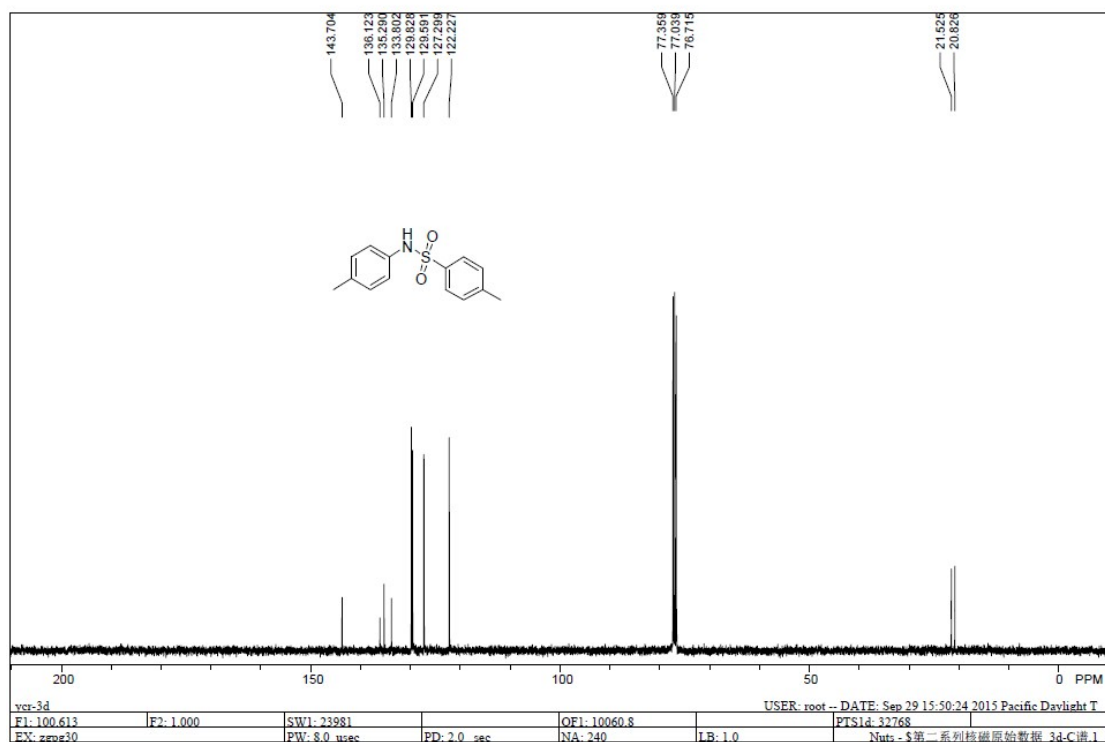
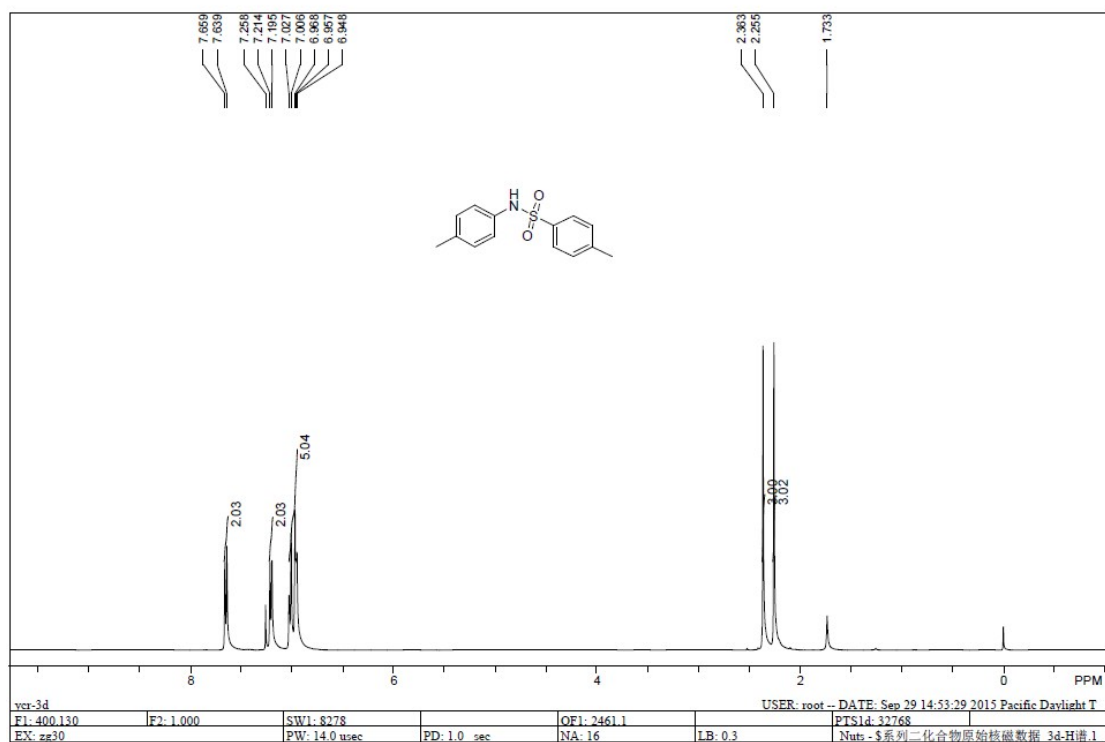
References

- 1 W. Zhang, J. Xie, B. Rao and M. Luo, *J. Org. Chem.*, 2015, **80**, 3504-3511.
- 2 Y.-C. Teo and F.-F. Yong, *Synlett*, 2011, 837-843.
- 3 S.-Y. Moon, J. Nam, K. Rathwell and W.-S. Kim, *Org. Lett.*, 2014, **16**, 338-341.
- 4 R. Lis and A. J. Marisca, *J. Org. Chem.*, 1987, **52**, 4377-4379.
- 5 B. R. Rosen, J. C. Ruble, T. J. Beauchamp and A. Navarro, *Org. Lett.*, 2011, **13**, 2564-2567.
- 6 T. Kato, I. Okamoto, A. Tanatani, T. Hatano, M. Uchiyama, H. Kagechika, H. Masu, K. Katagiri, M. Tominaga, K. Yamaguchi and I. Azumaya, *Org. Lett.*, 2006, **8**, 5017-5020.
- 7 A. L. Pera, A. Leggio and A. Liguori, *Tetrahedron*, 2006, **62**, 6100-6106.

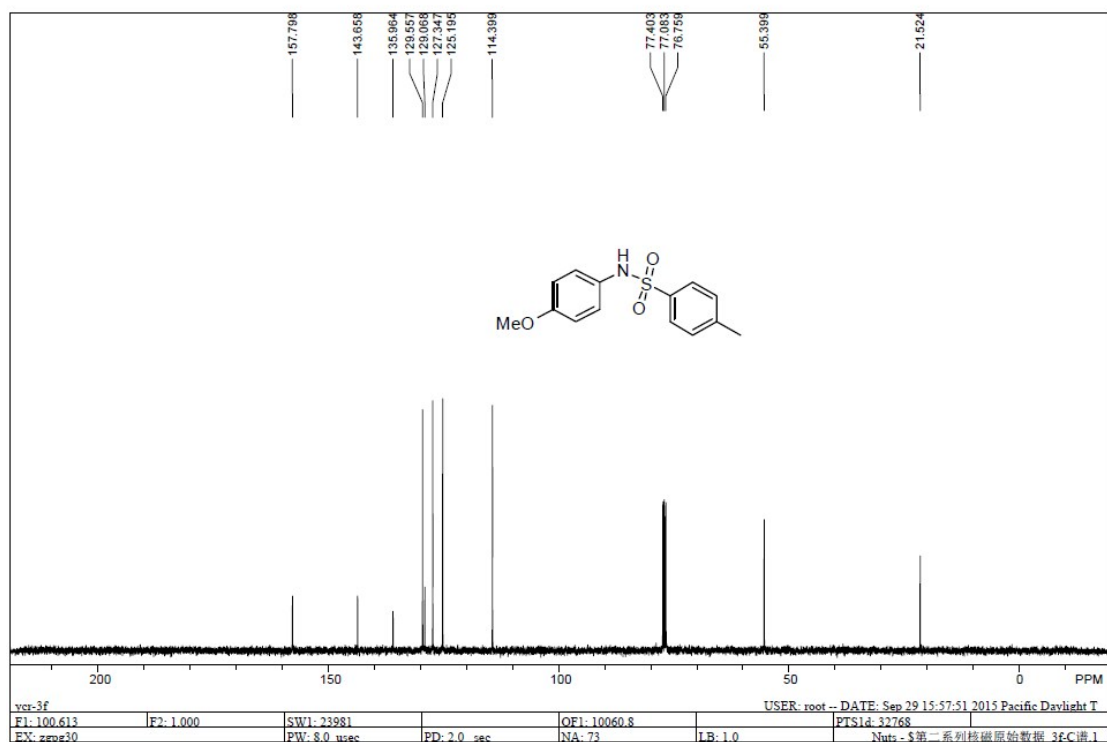
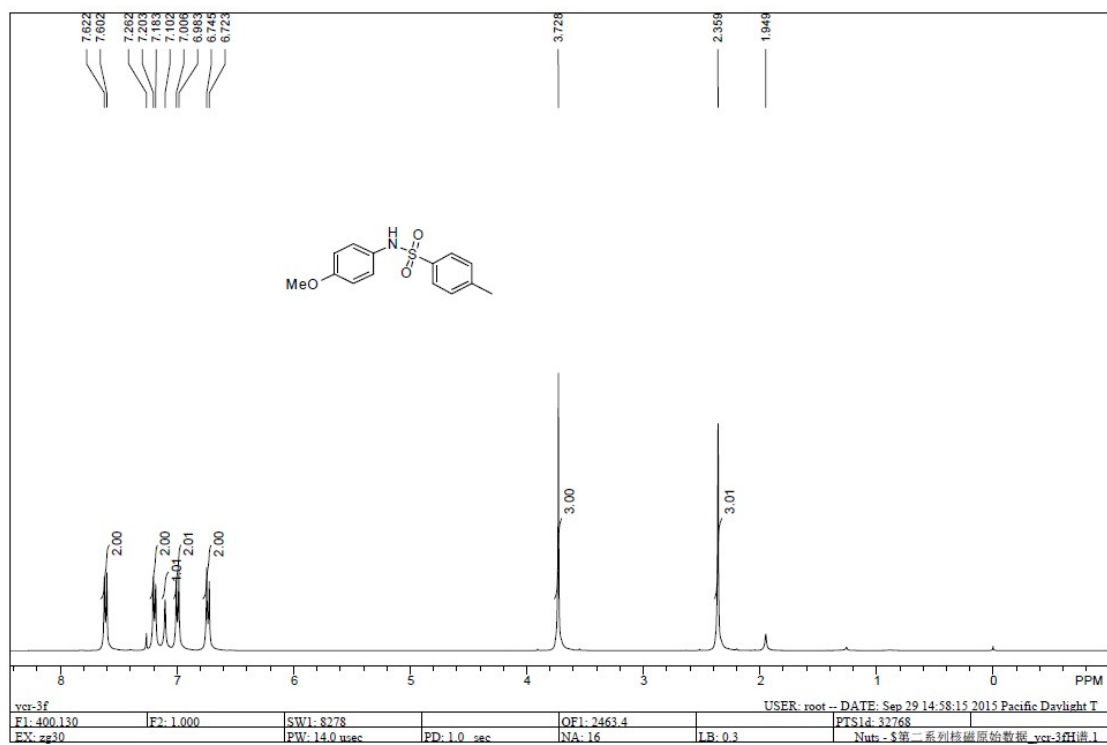
^1H NMR and ^{13}C NMR spectra of compounds 3a-3f and 4a.



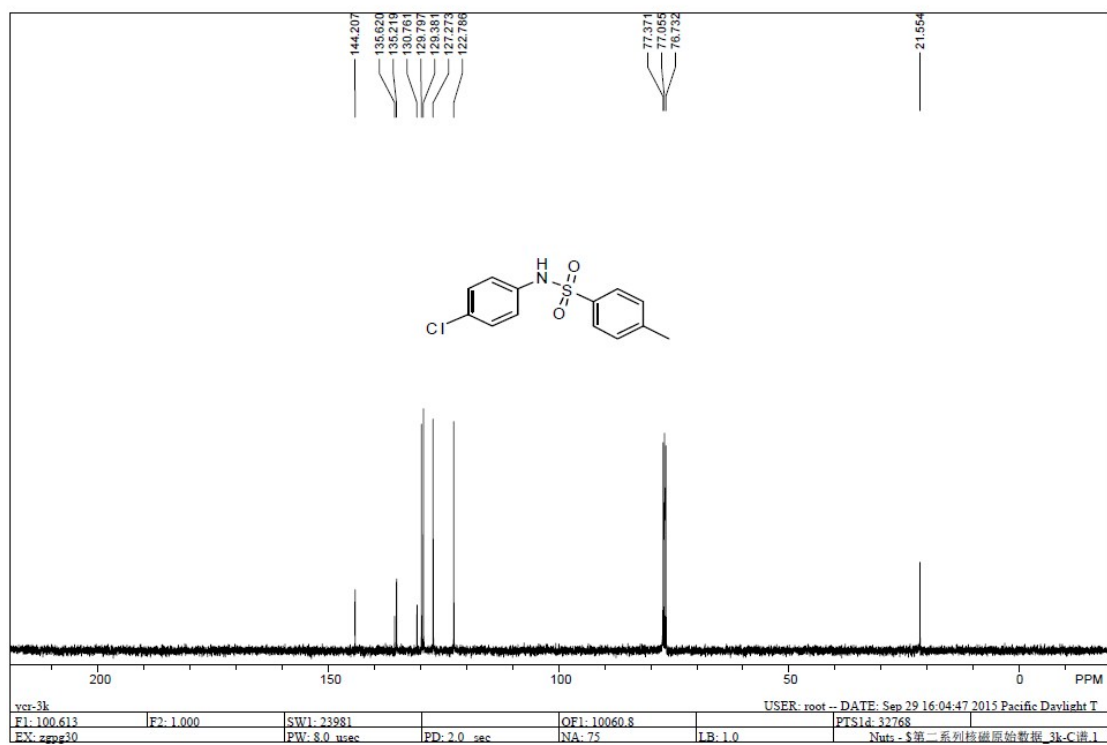
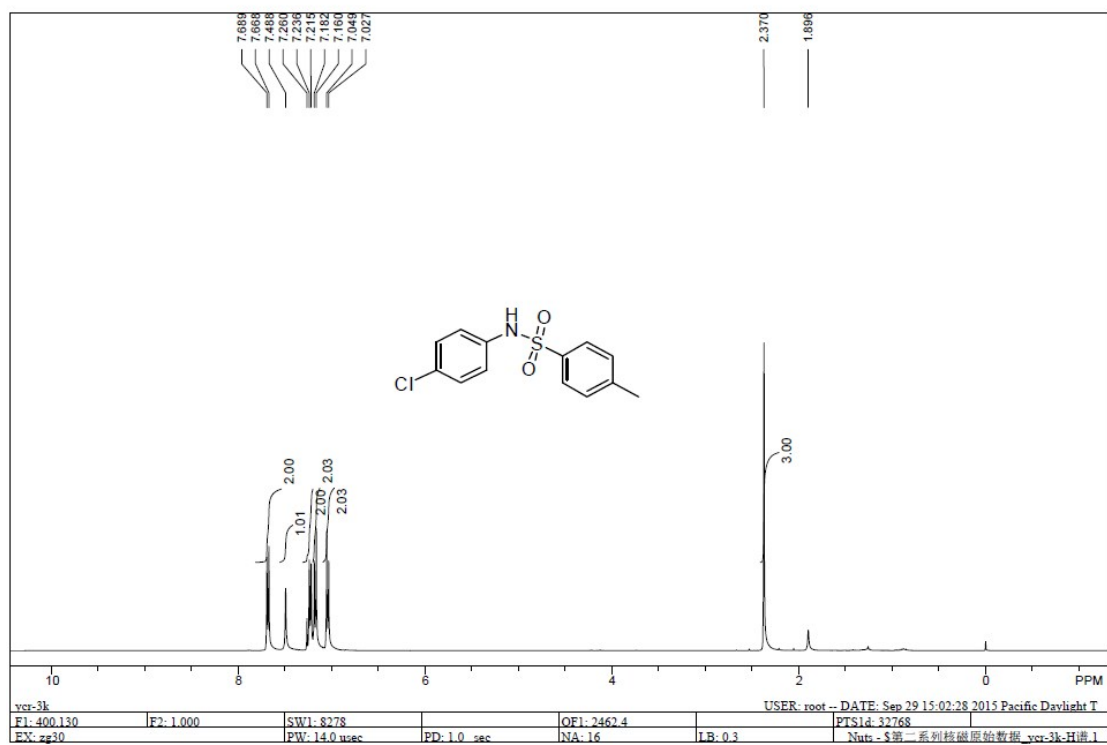
¹H NMR and ¹³C NMR spectra of compound **3a**



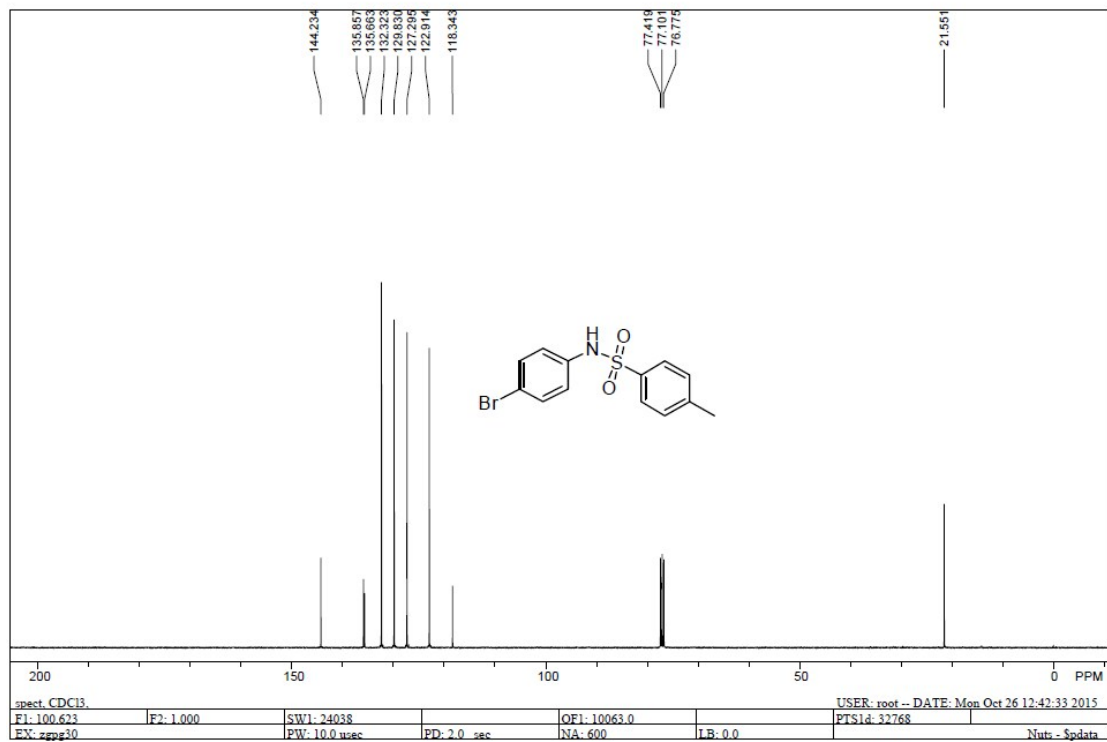
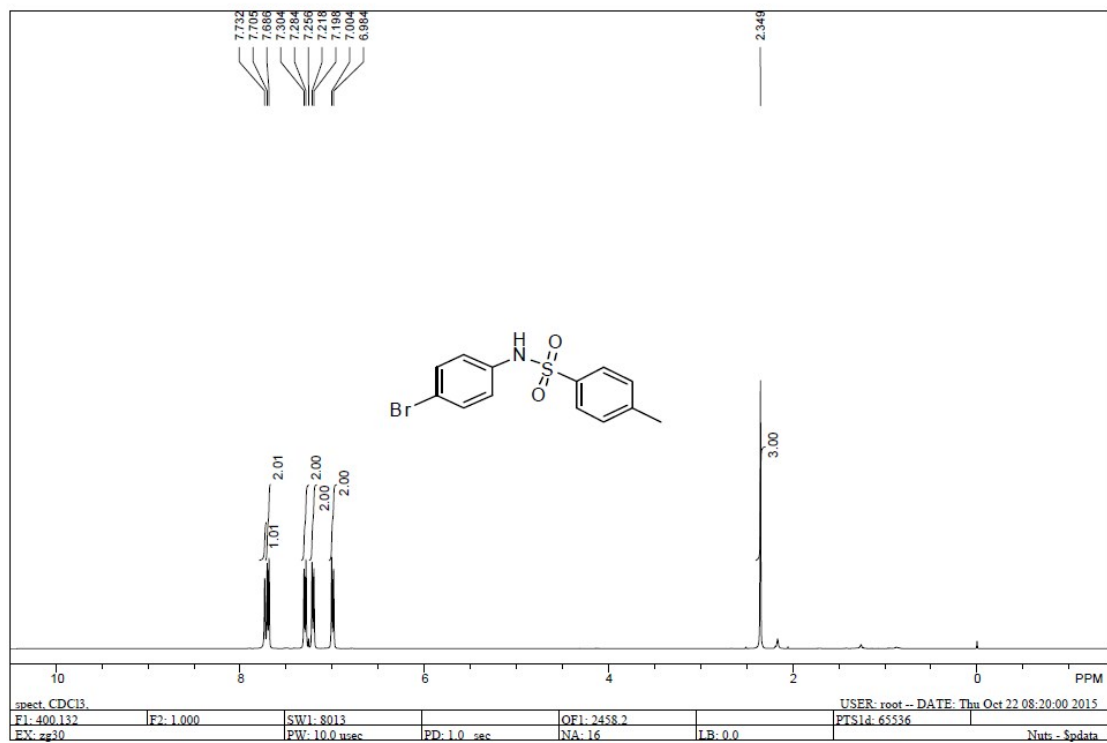
¹H NMR and ¹³C NMR spectra of compound 3b



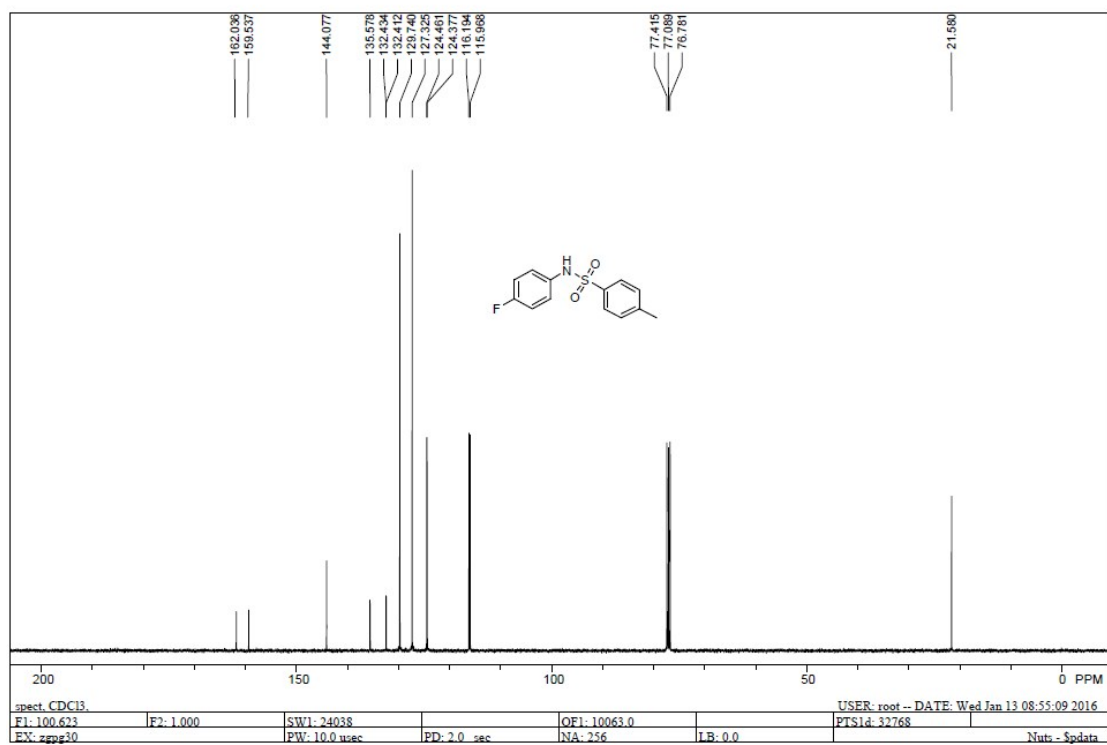
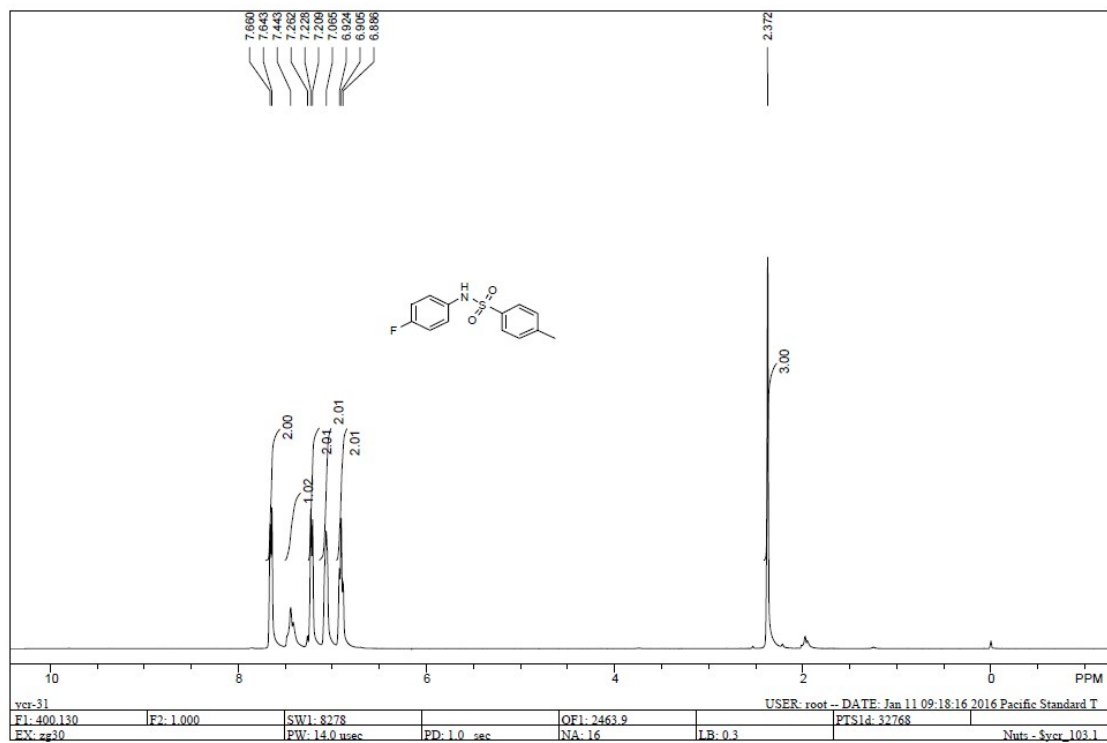
¹H NMR and ¹³C NMR spectra of compound 3c



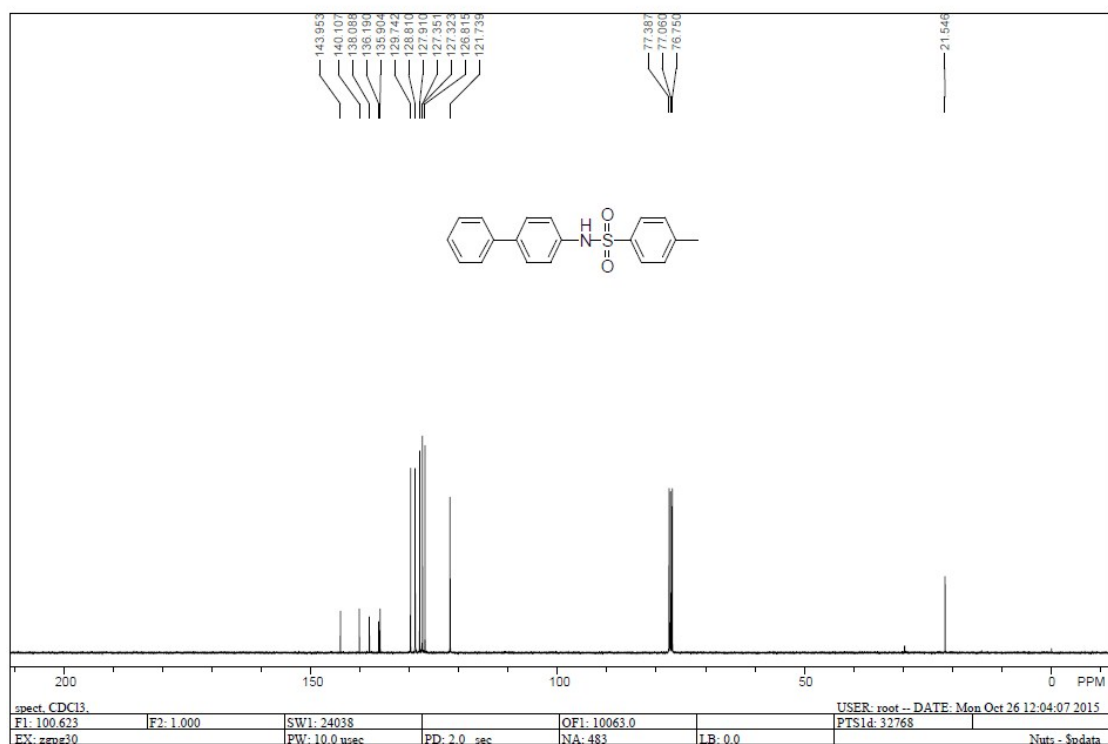
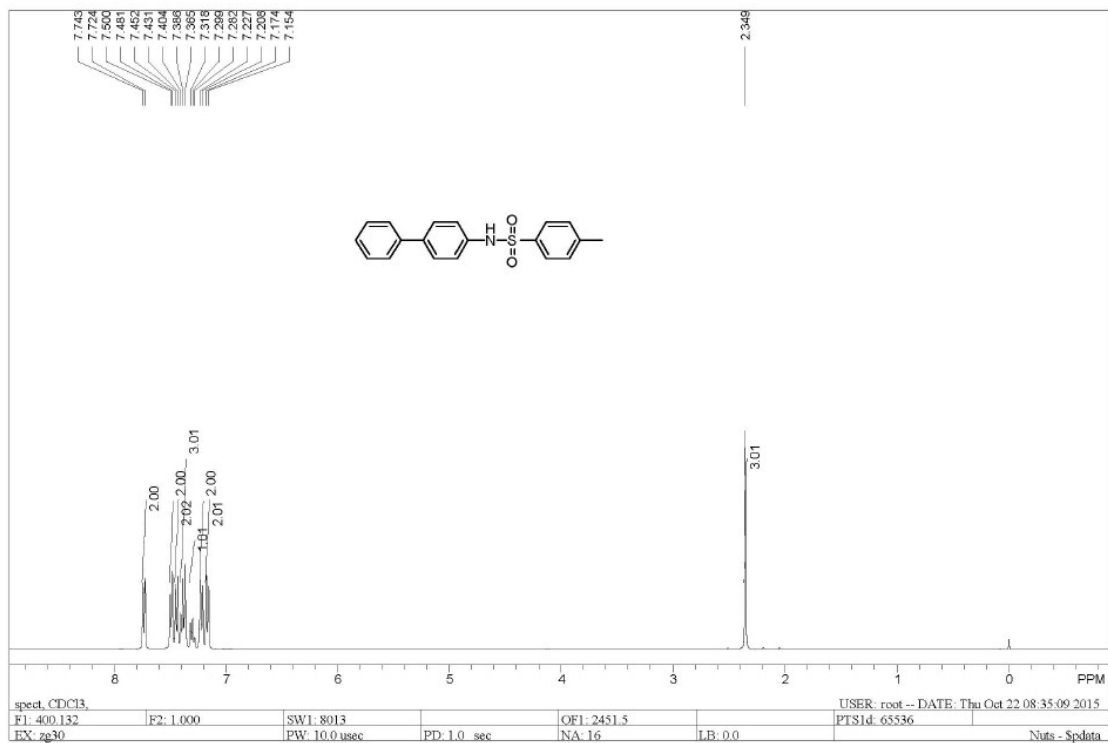
^1H NMR and ^{13}C NMR spectra of compound **3d**



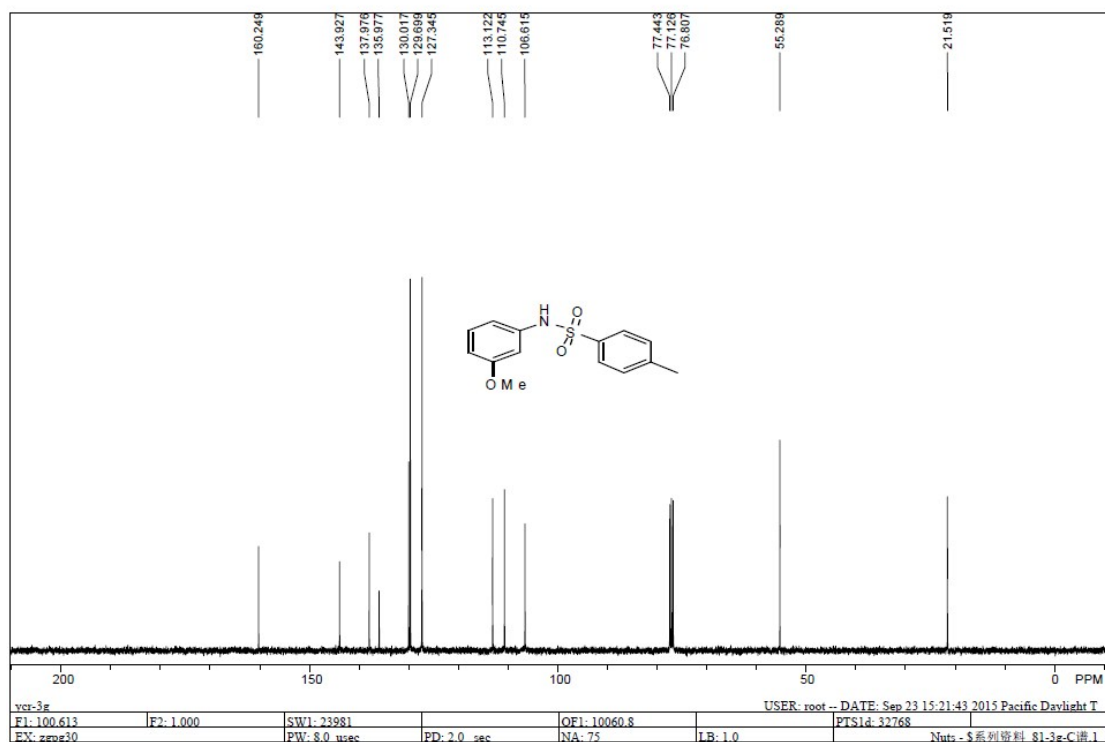
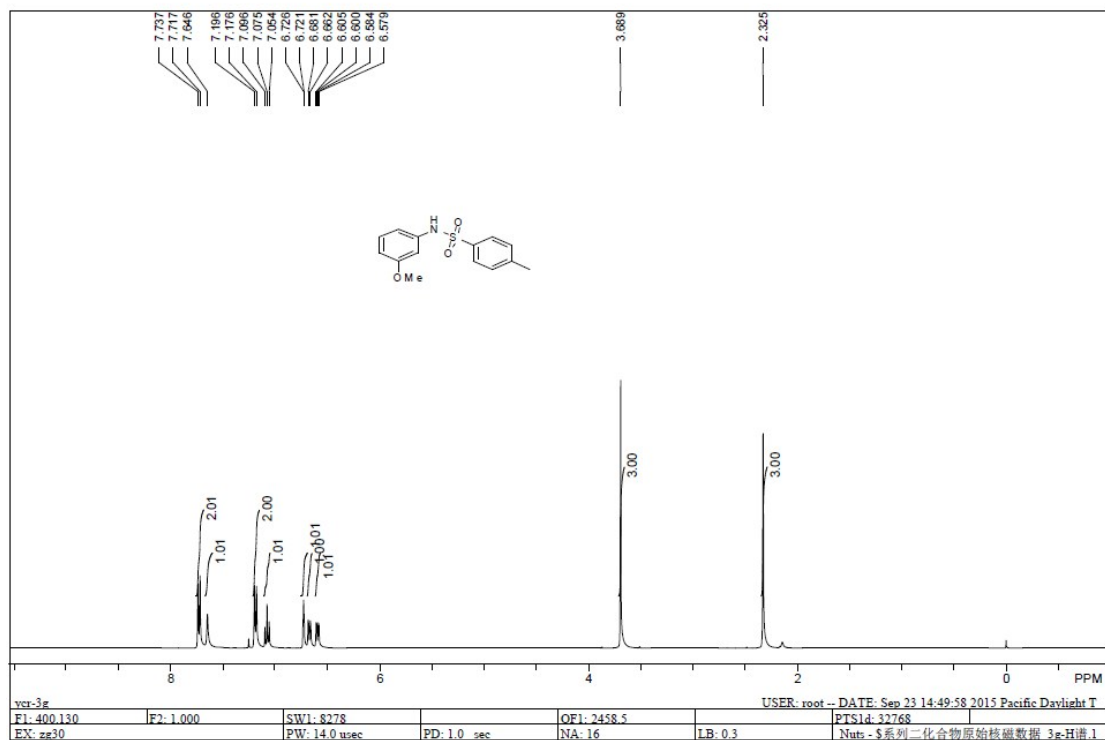
¹H NMR and ¹³C NMR spectra of compound 3e



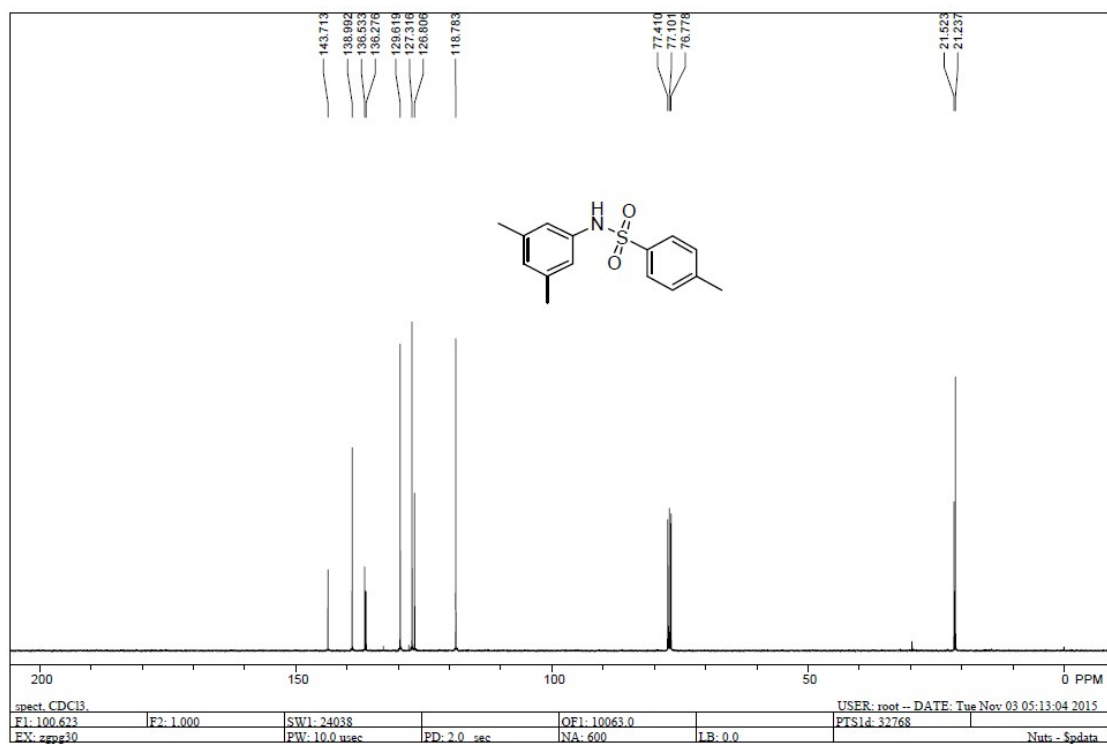
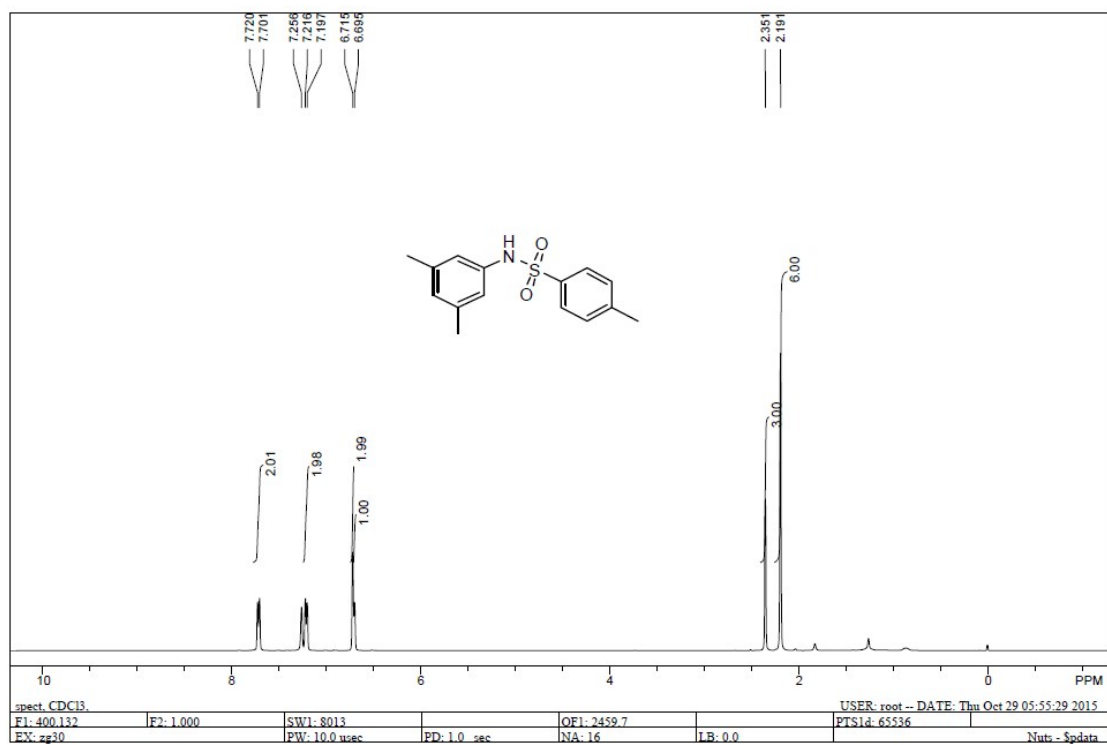
¹H NMR and ¹³C NMR spectra of compound 3f



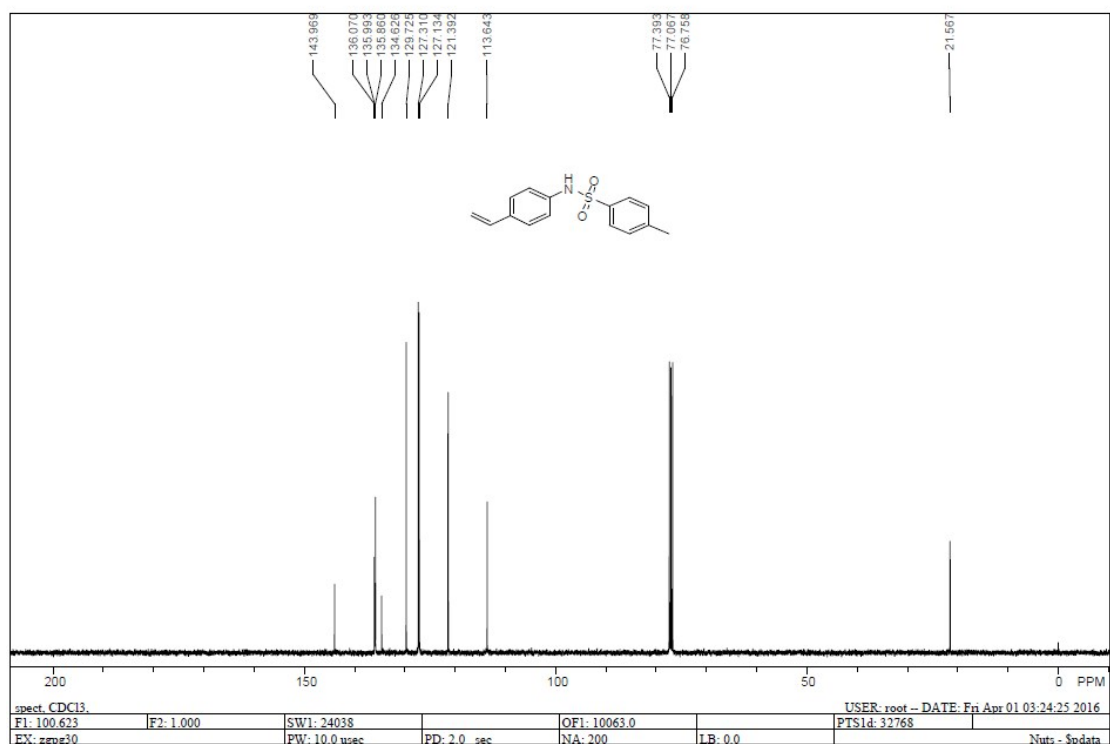
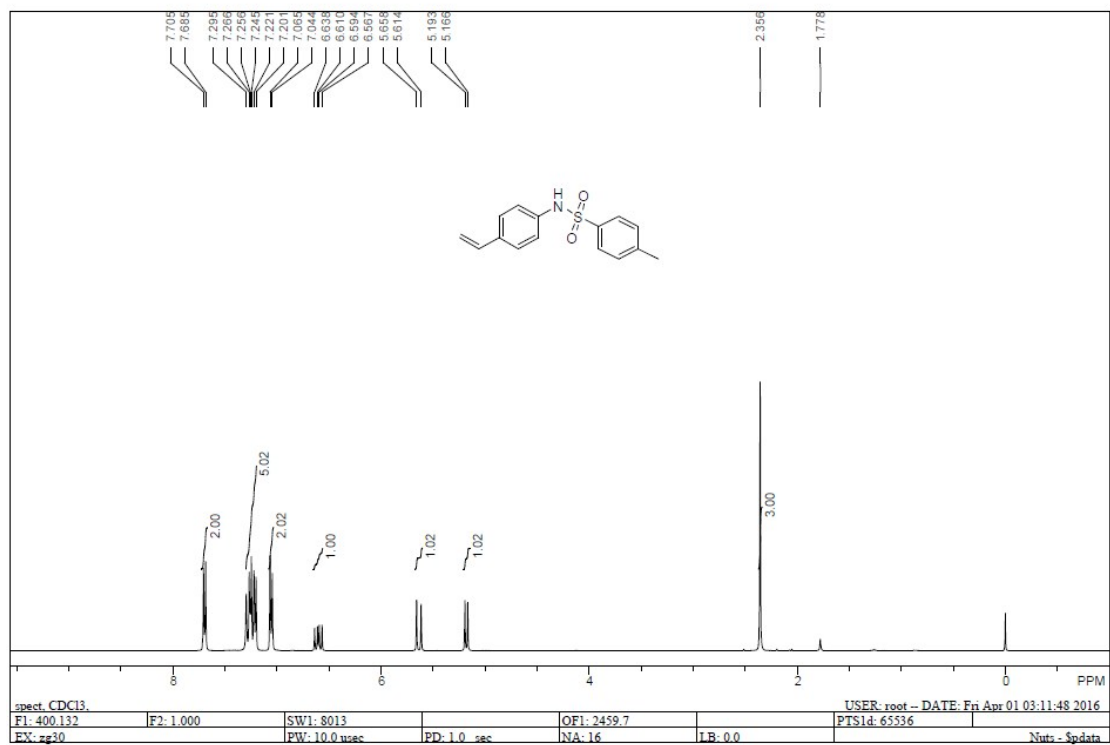
¹H NMR and ¹³C NMR spectra of compound 3g



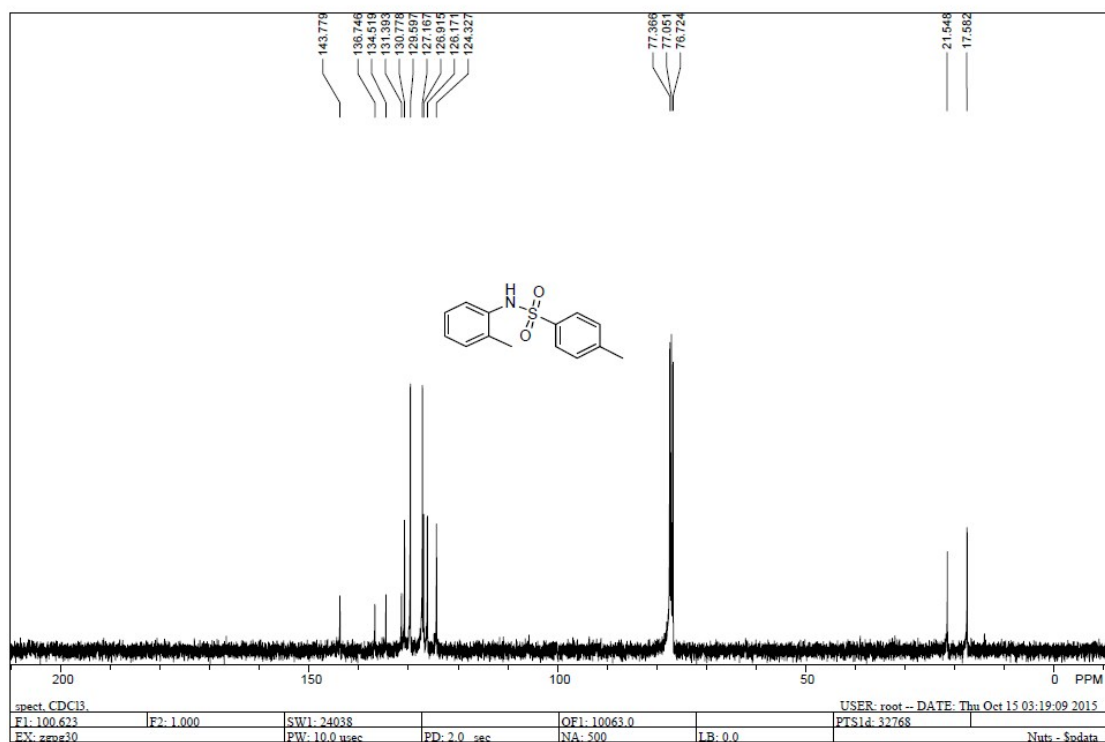
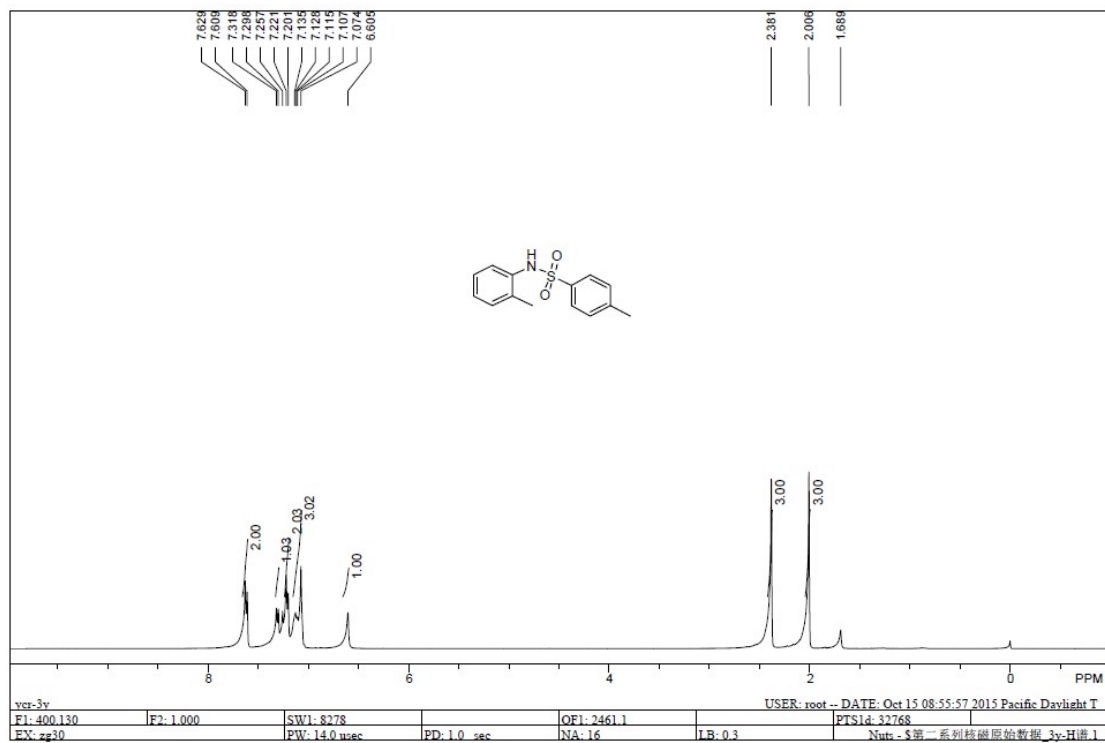
¹H NMR and ¹³C NMR spectra of compound 3h



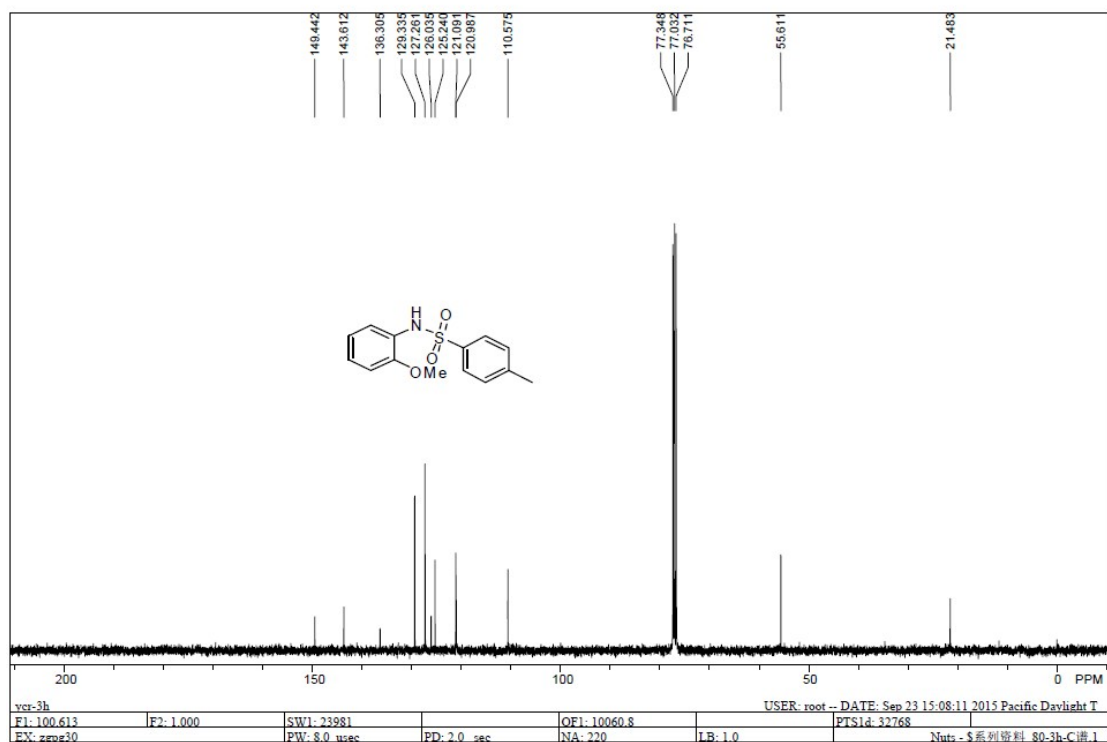
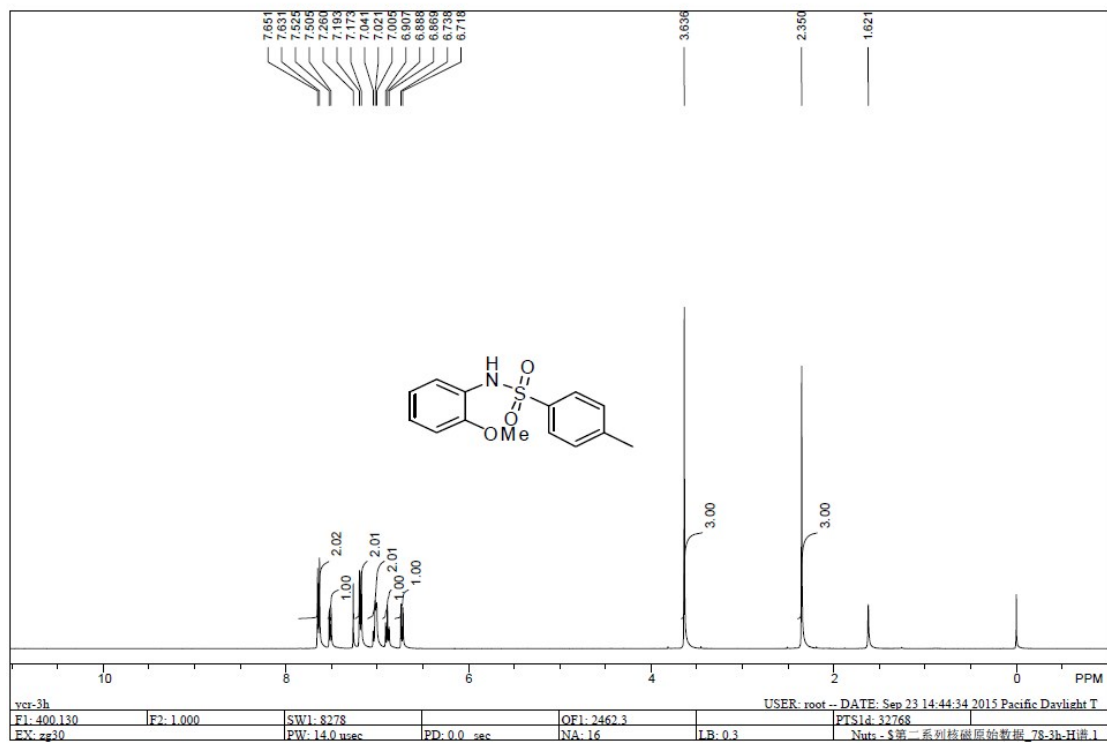
^1H NMR and ^{13}C NMR spectra of compound **3i**



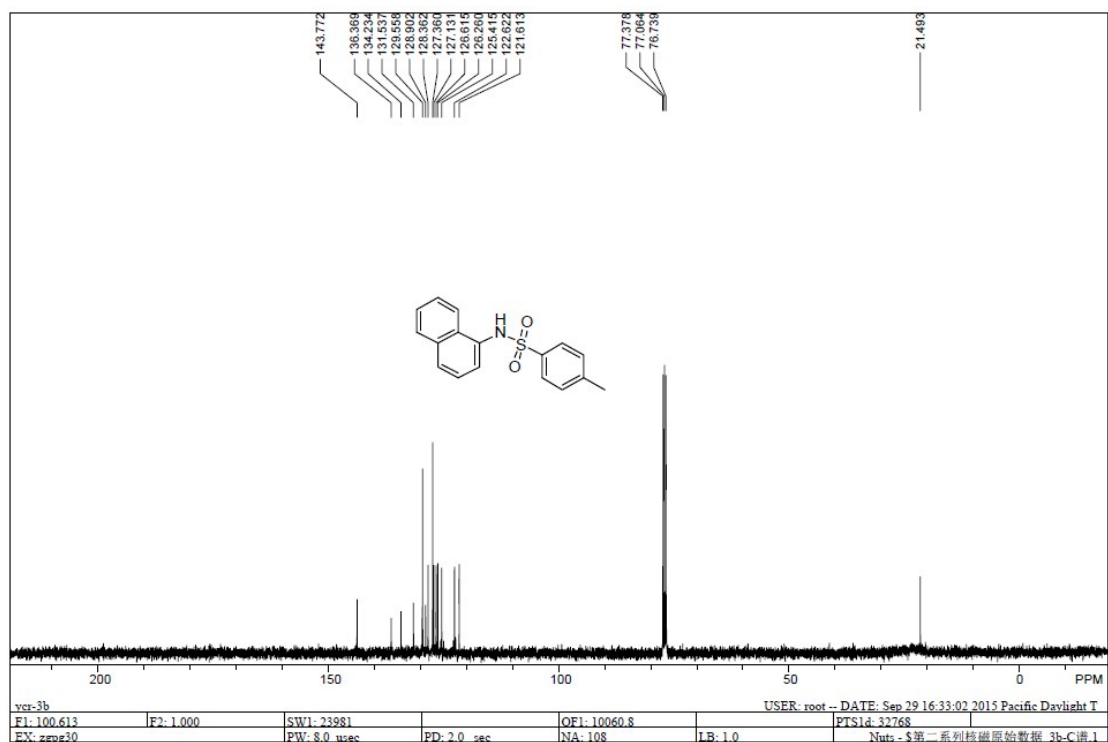
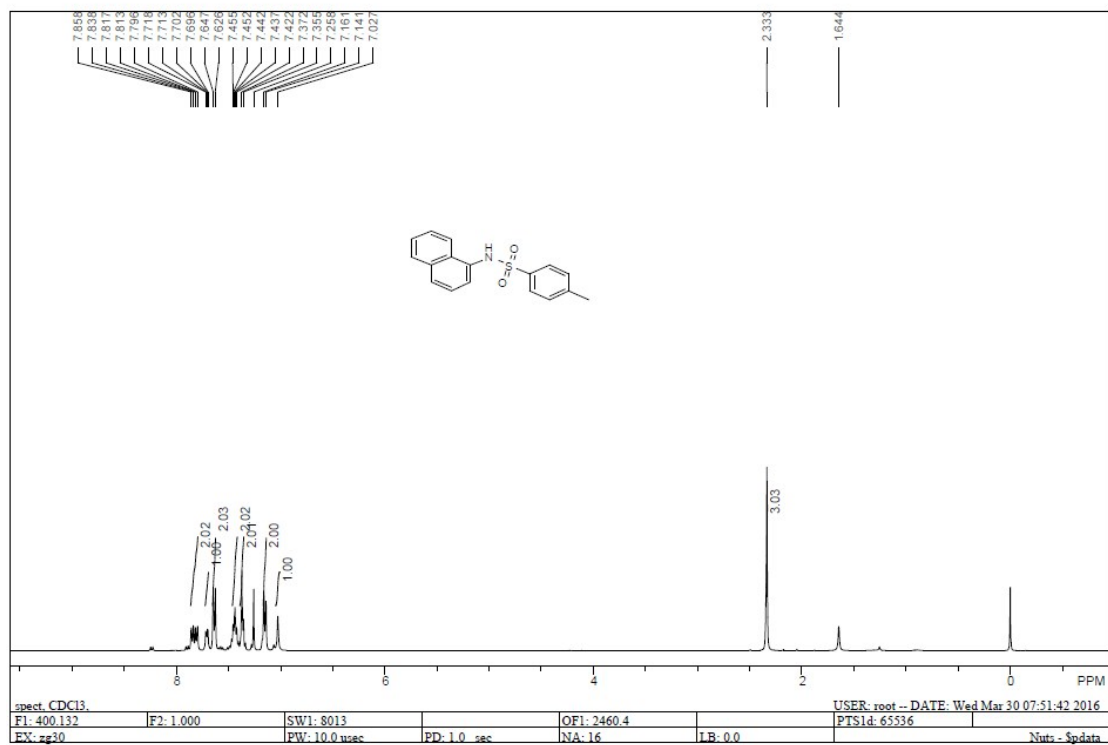
¹H NMR and ¹³C NMR spectra of compound **3j**



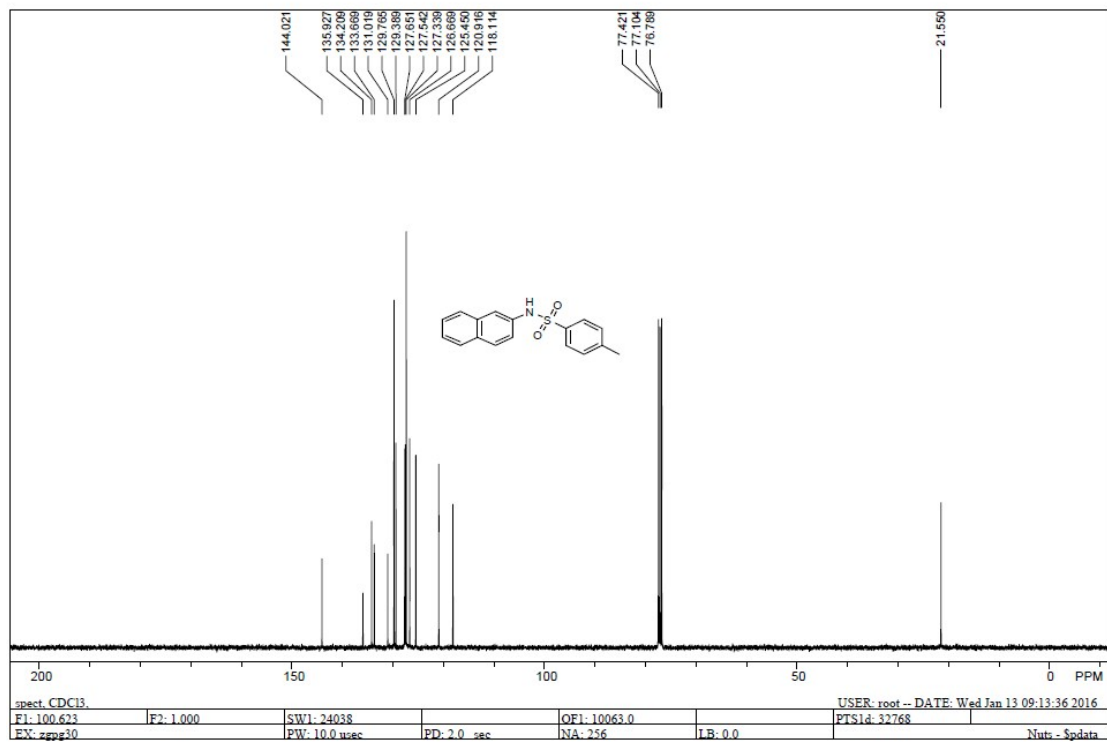
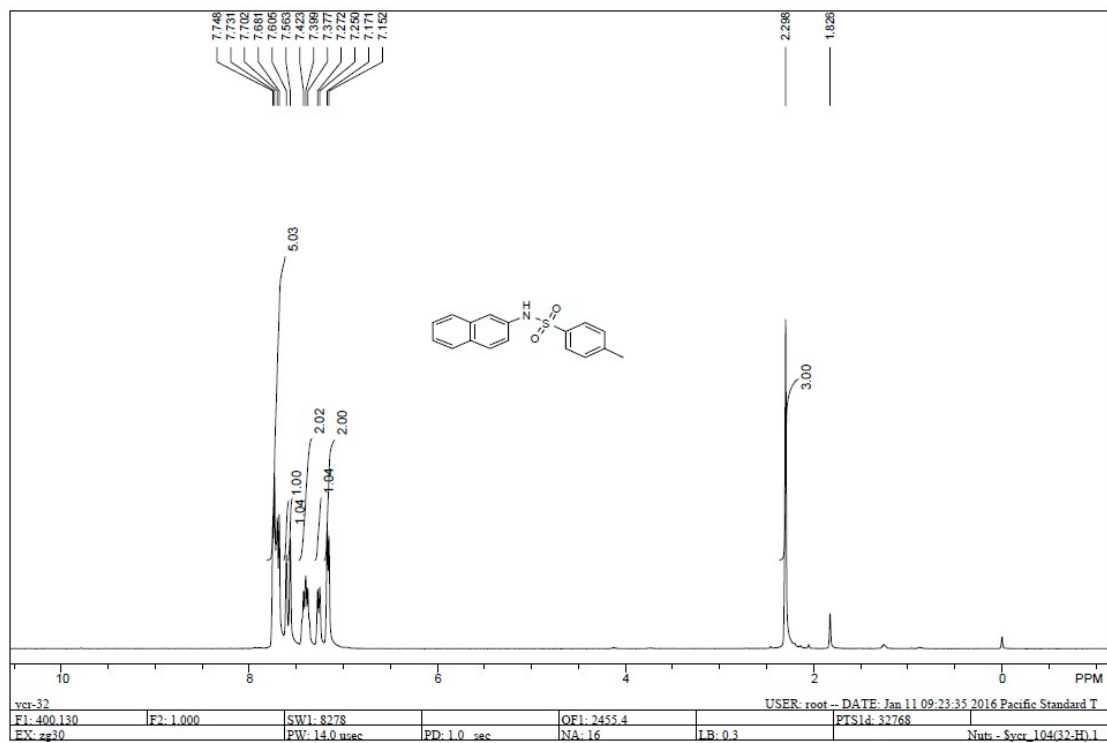
¹H NMR and ¹³C NMR spectra of compound 3k



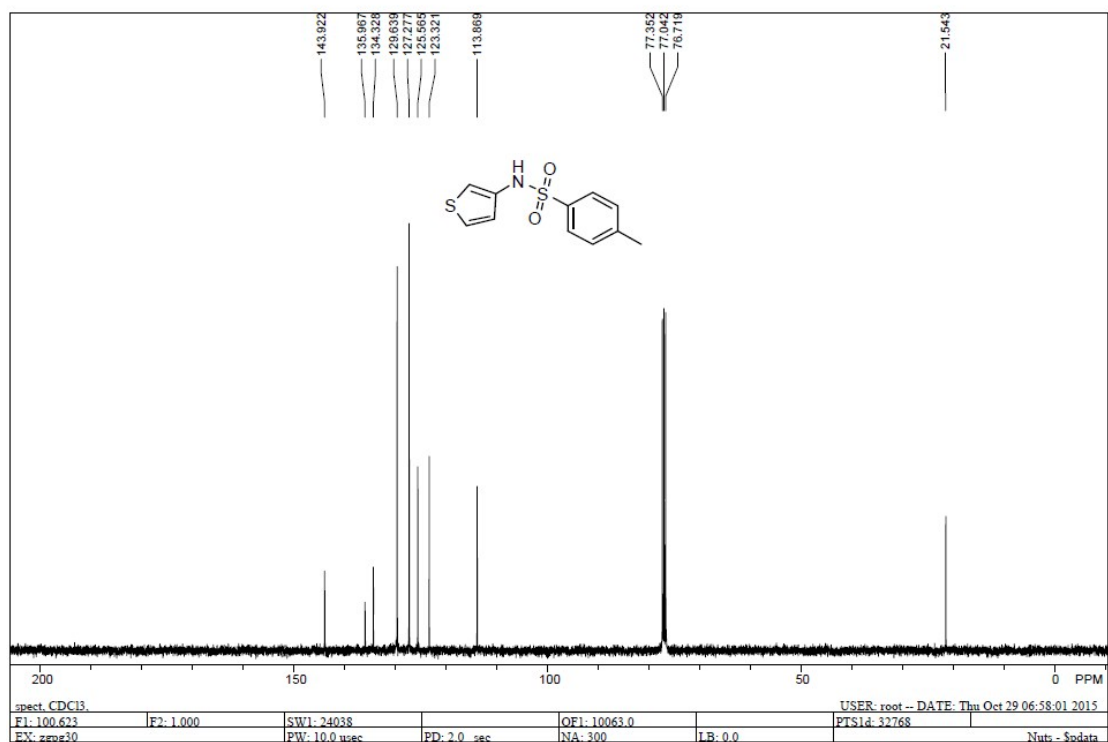
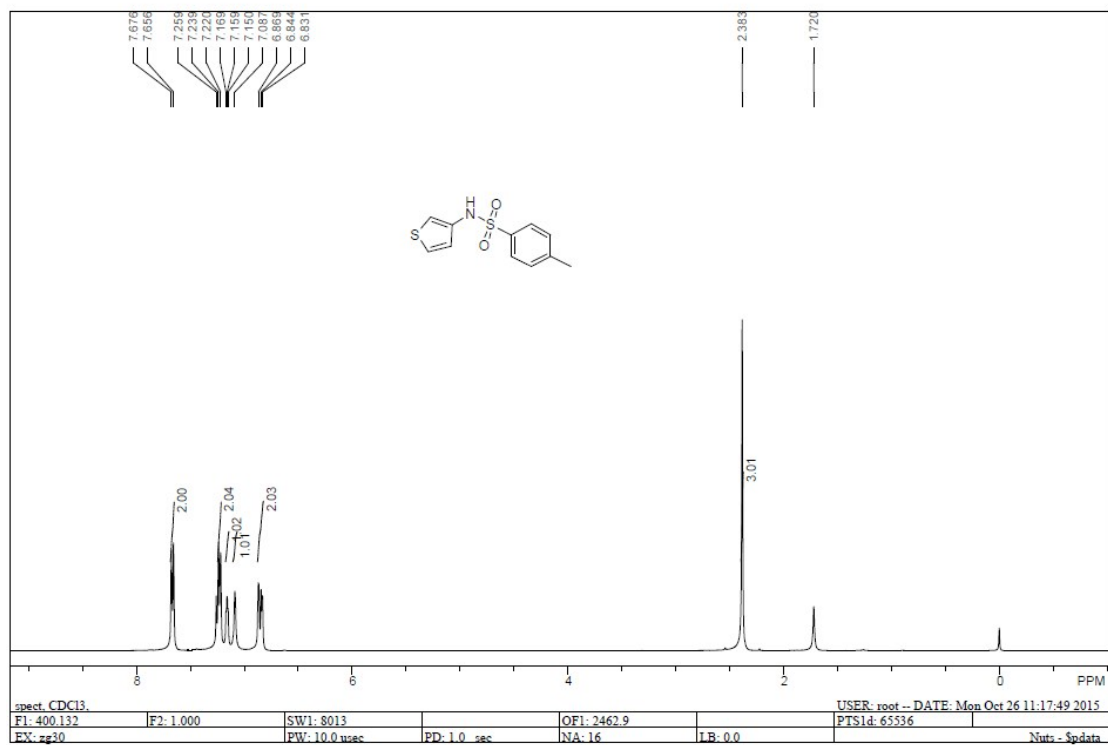
¹H NMR and ¹³C NMR spectra of compound 31



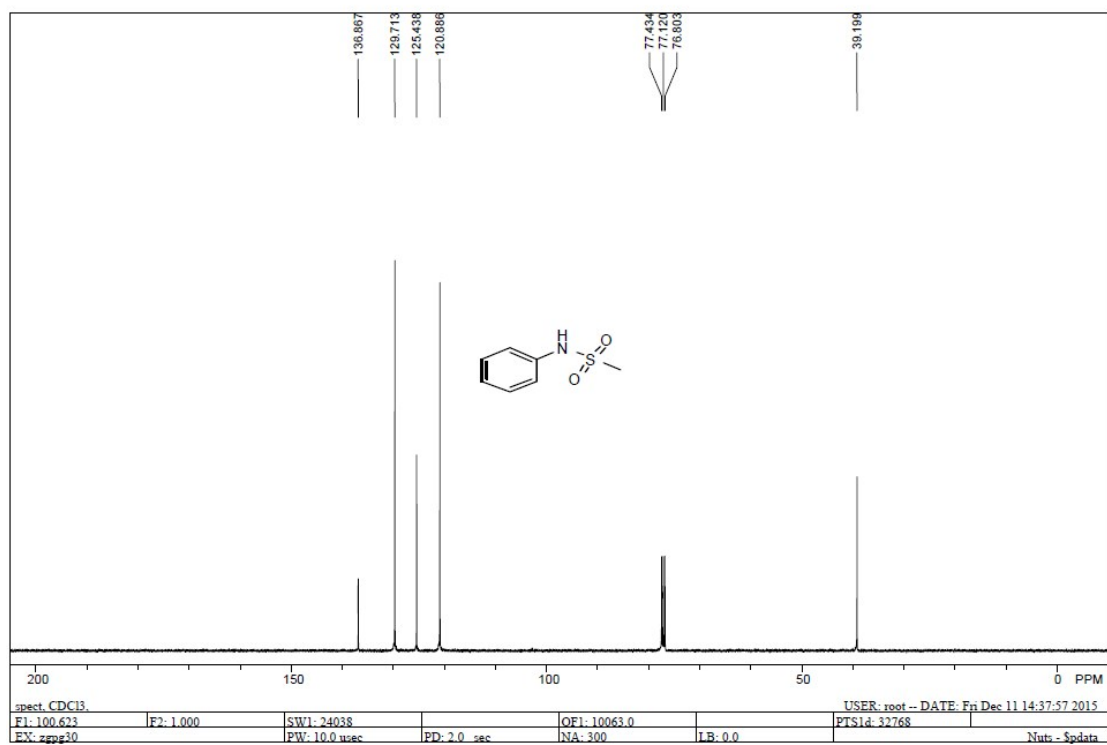
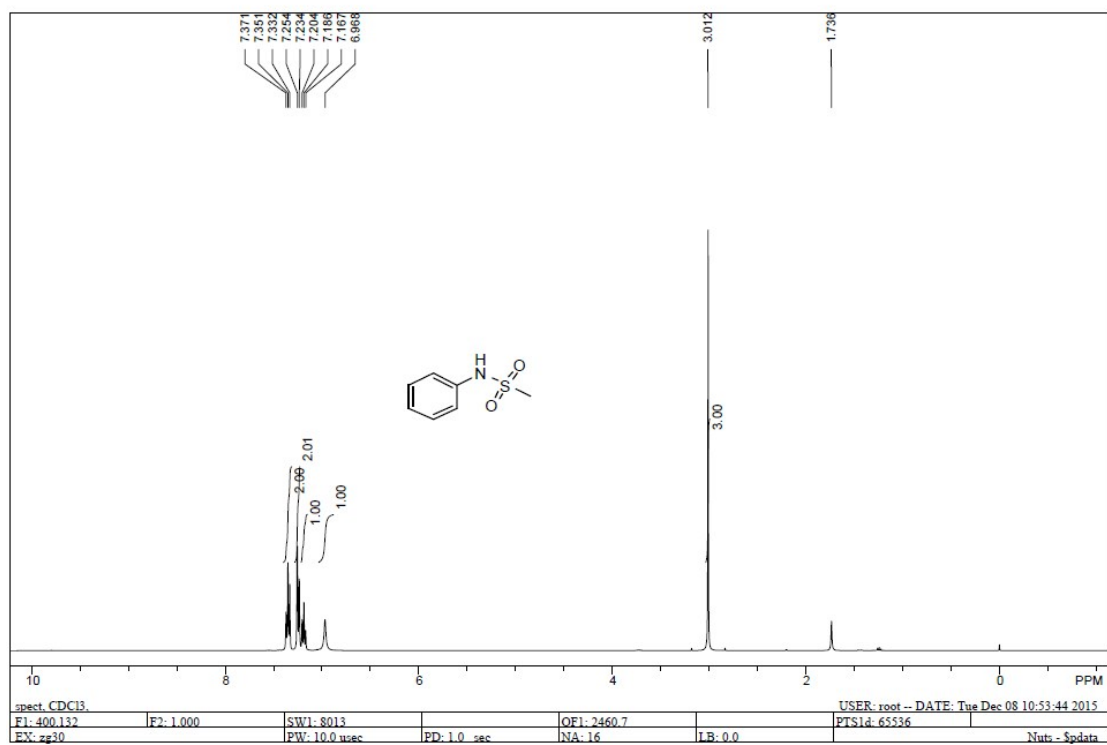
¹H NMR and ¹³C NMR spectra of compound 3m



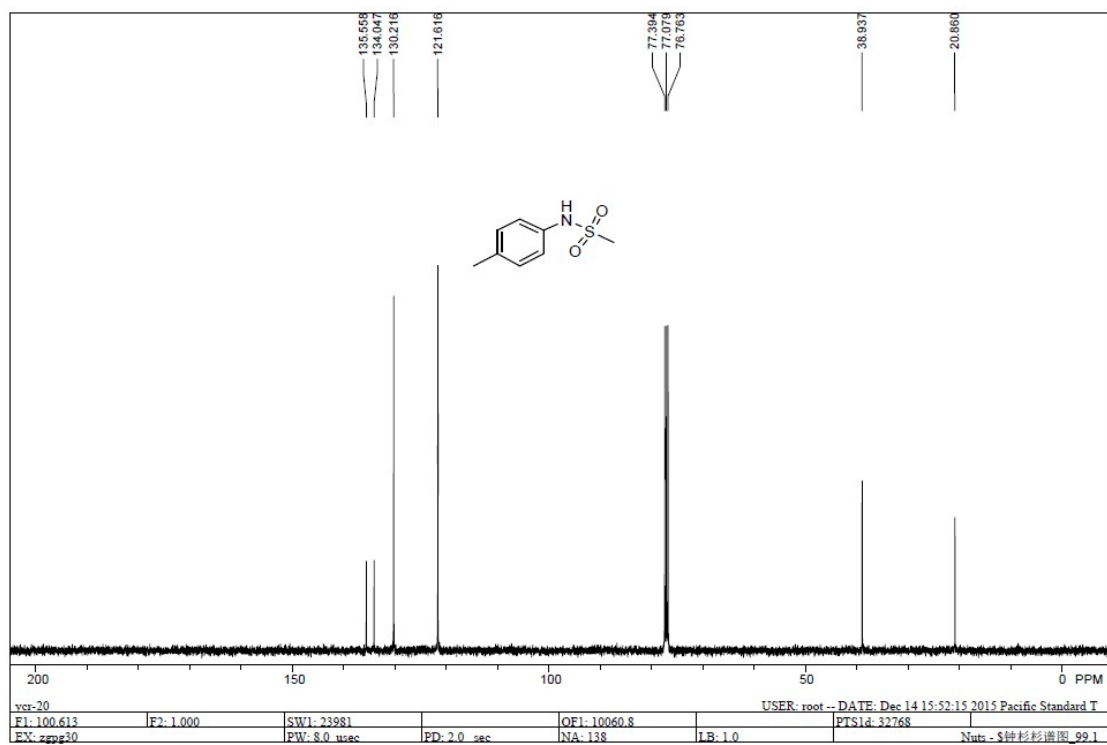
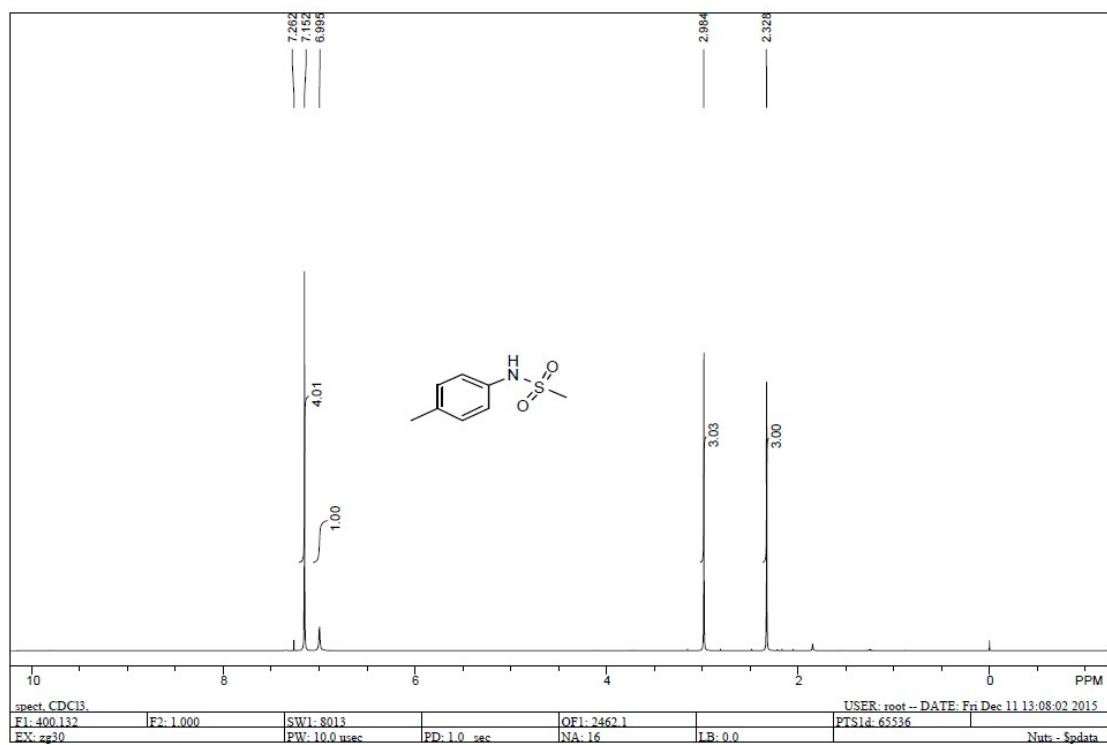
¹H NMR and ¹³C NMR spectra of compound **3n**



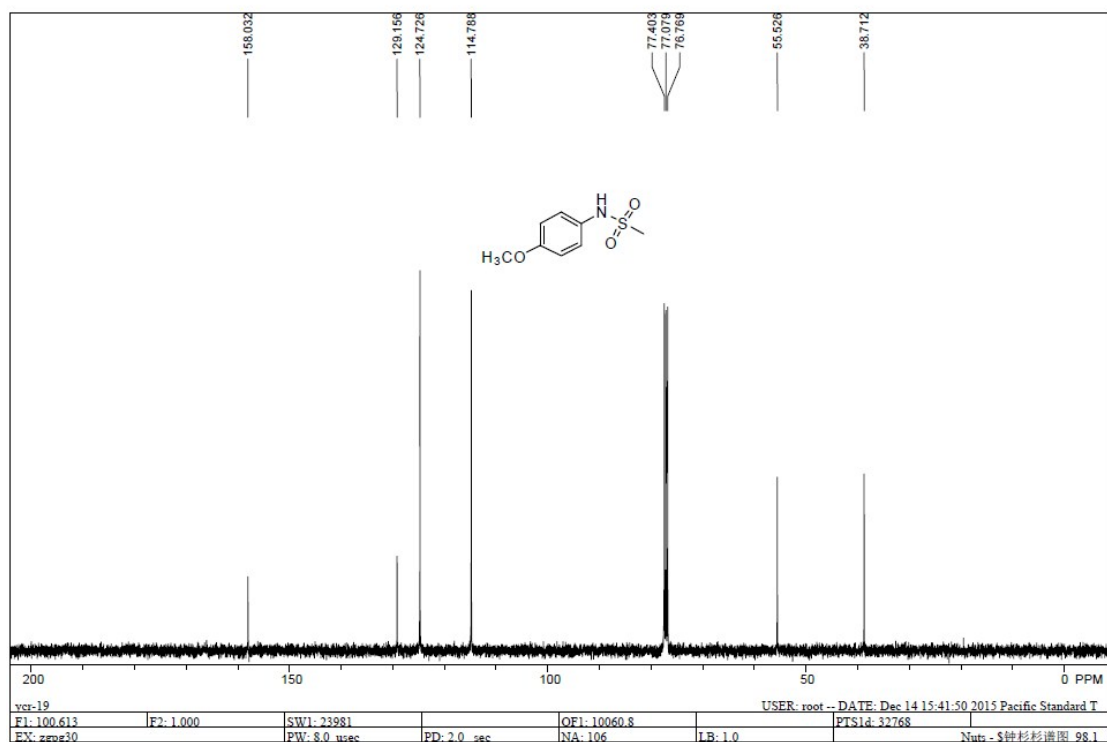
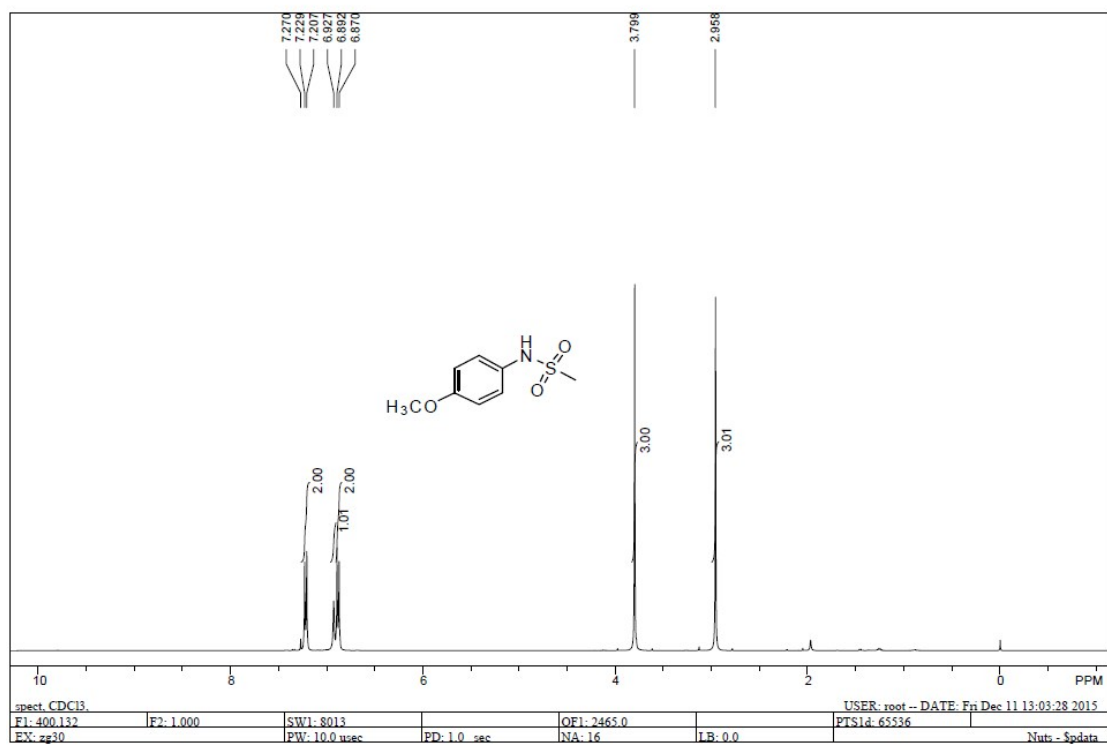
¹H NMR and ¹³C NMR spectra of compound **3o**



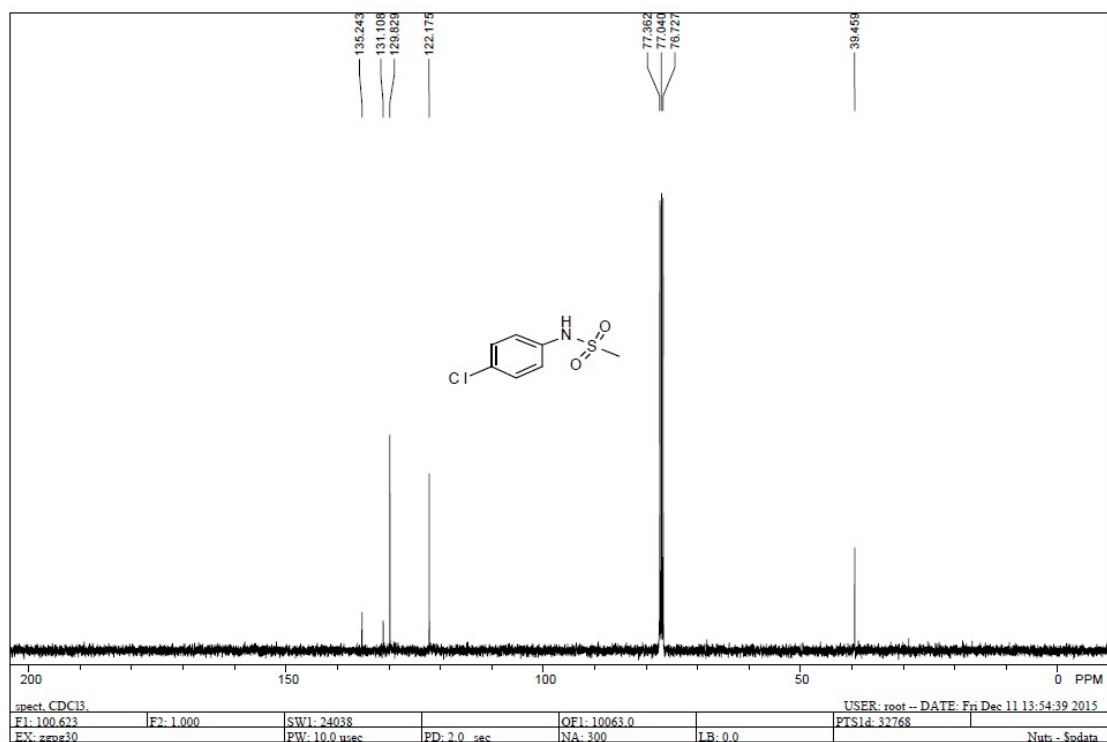
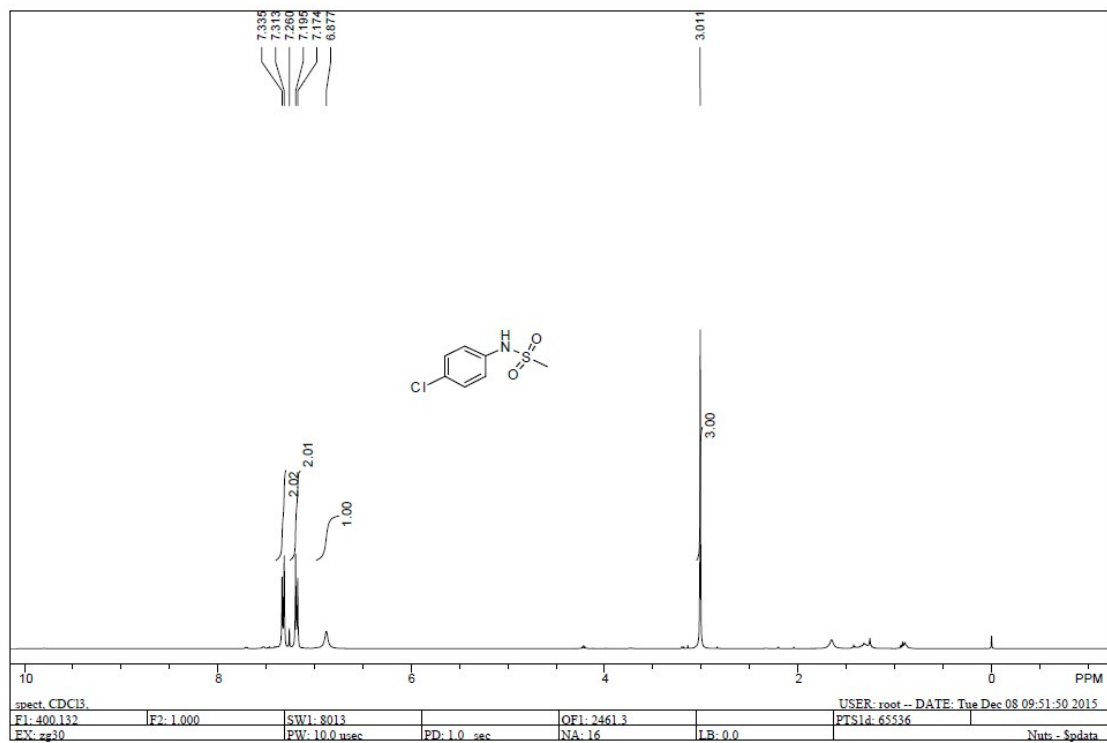
¹H NMR and ¹³C NMR spectra of compound **3p**



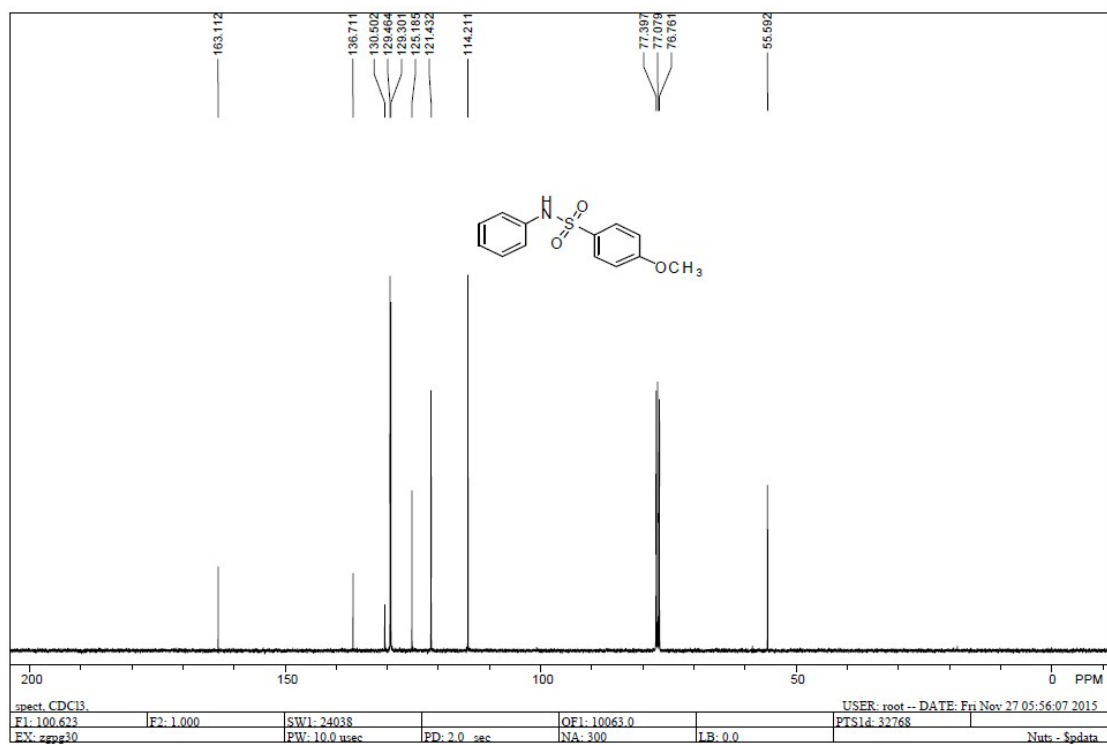
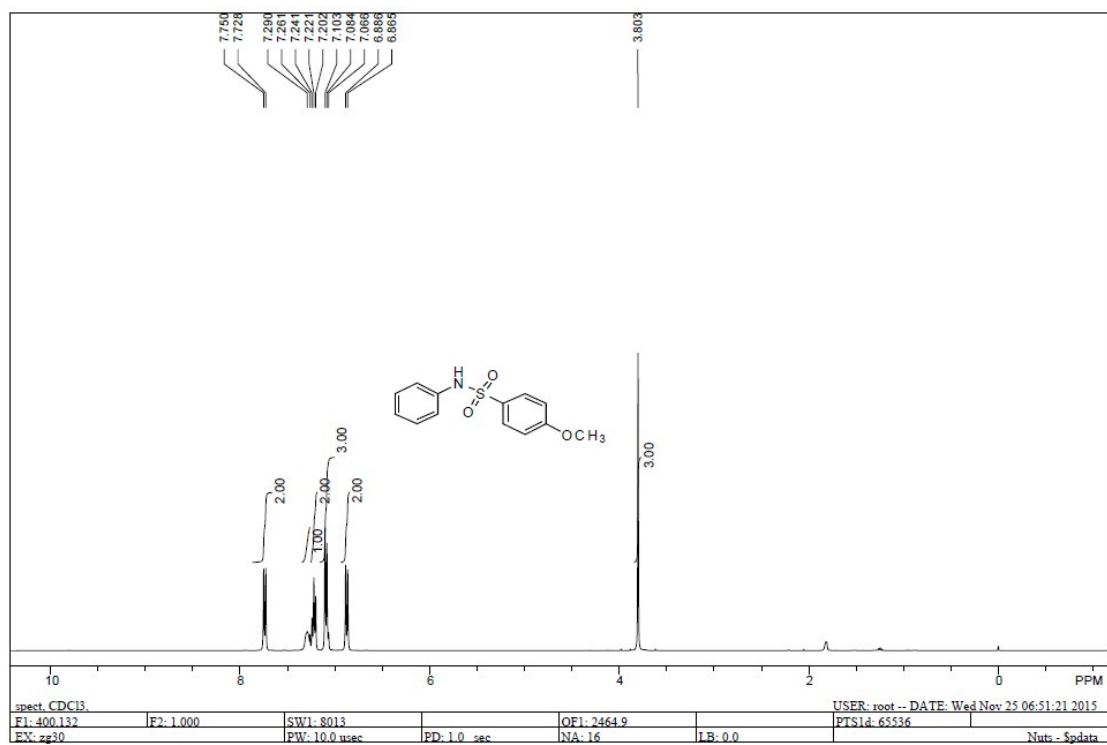
^1H NMR and ^{13}C NMR spectra of compound **3q**



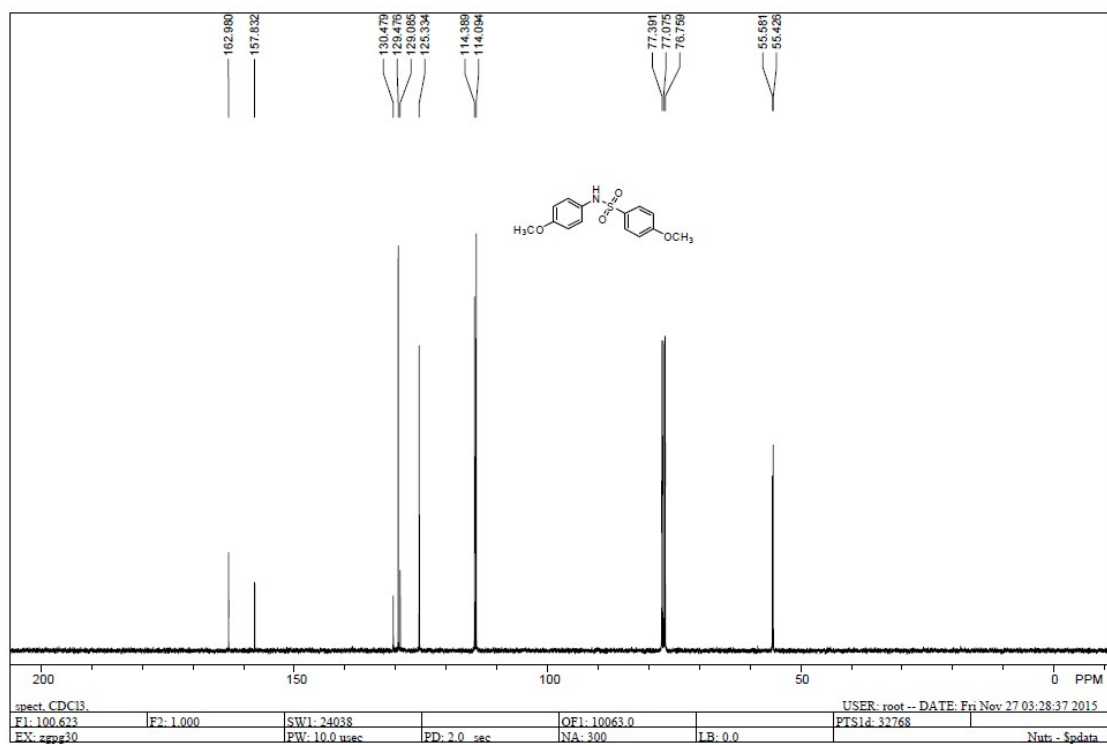
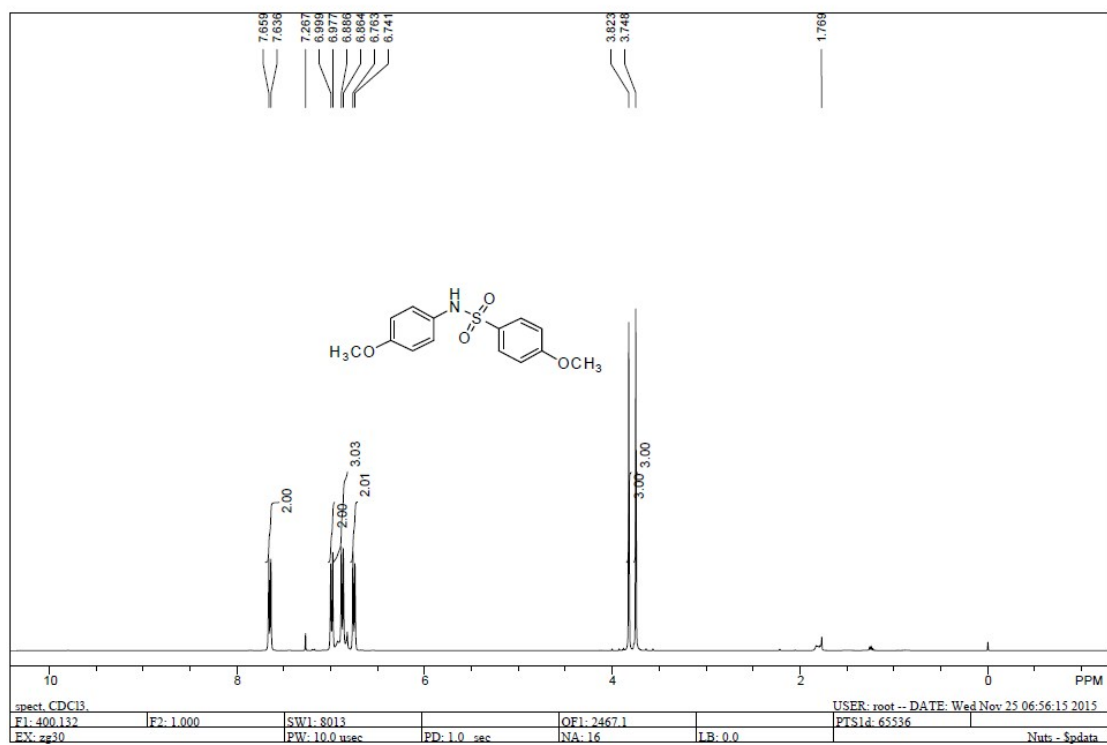
^1H NMR and ^{13}C NMR spectra of compound **3r**



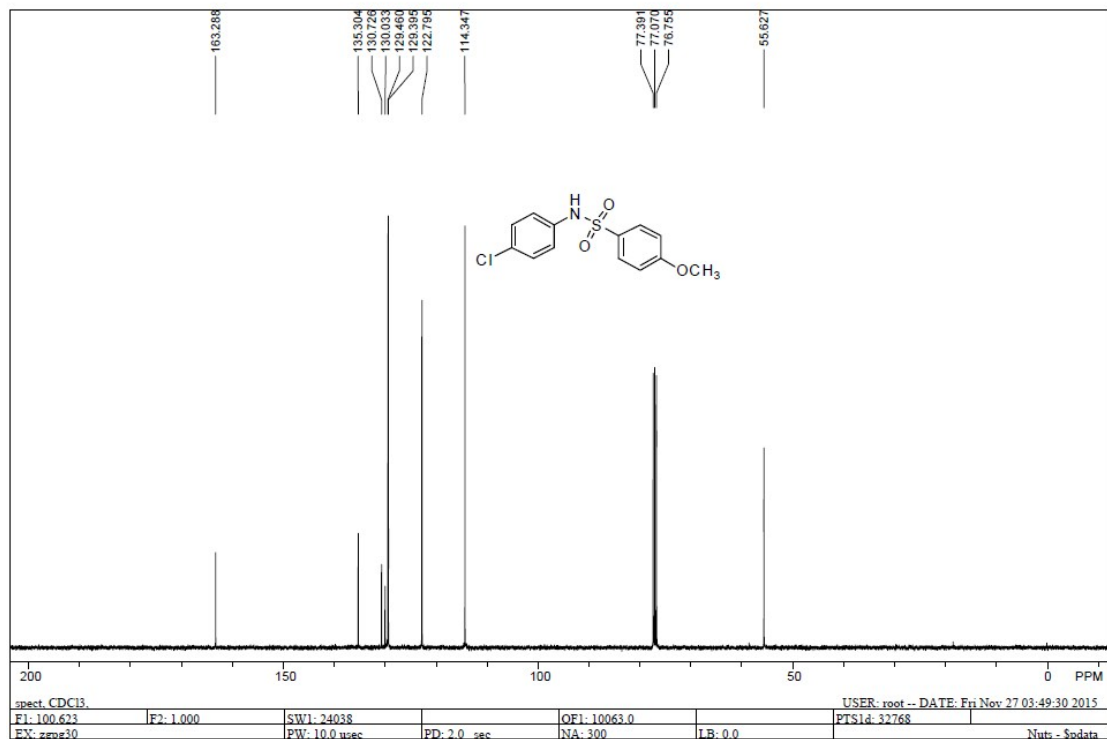
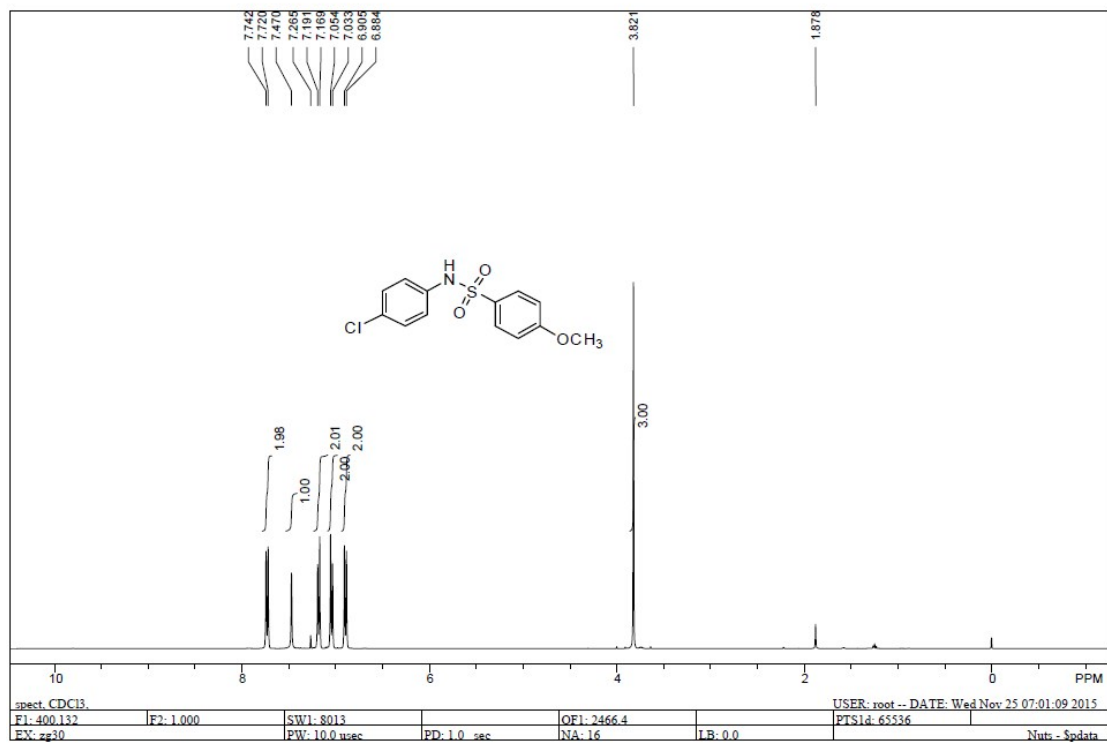
^1H NMR and ^{13}C NMR spectra of compound **3s**



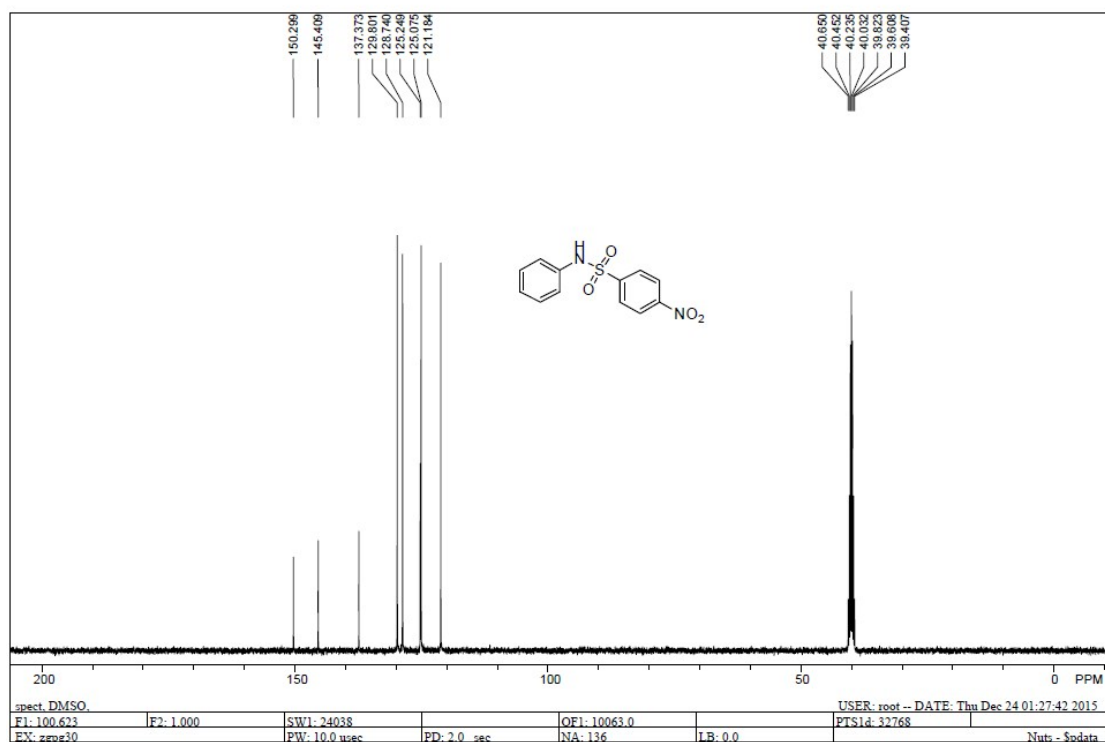
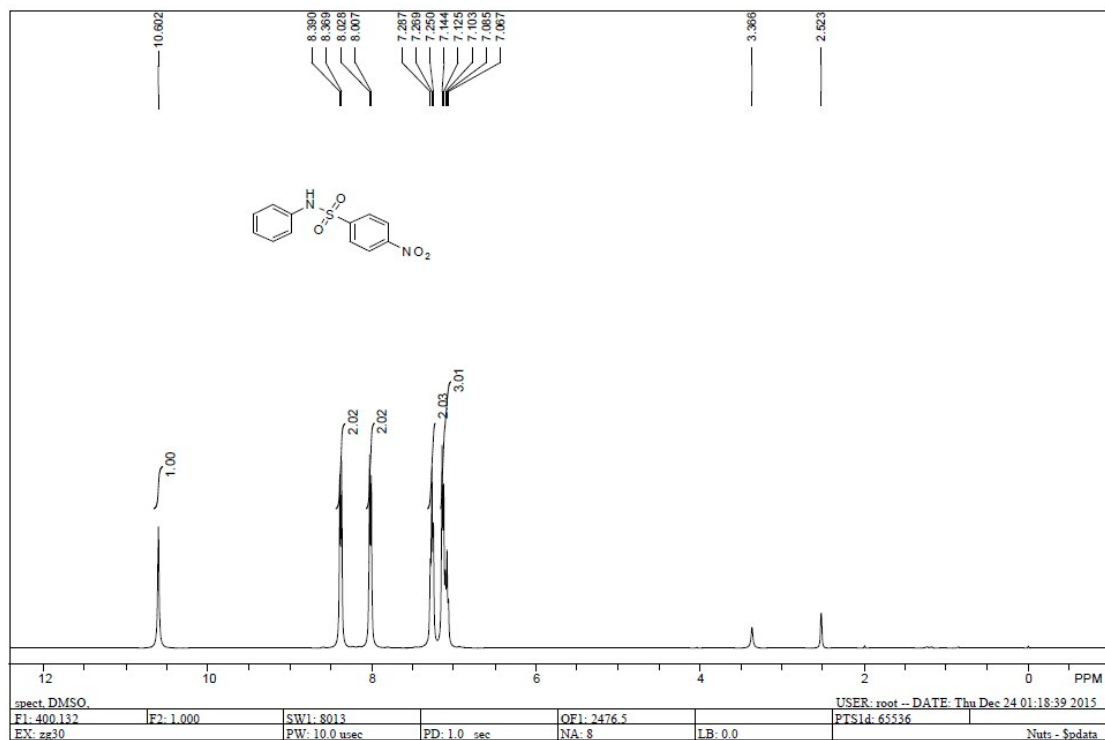
¹H NMR and ¹³C NMR spectra of compound 3t



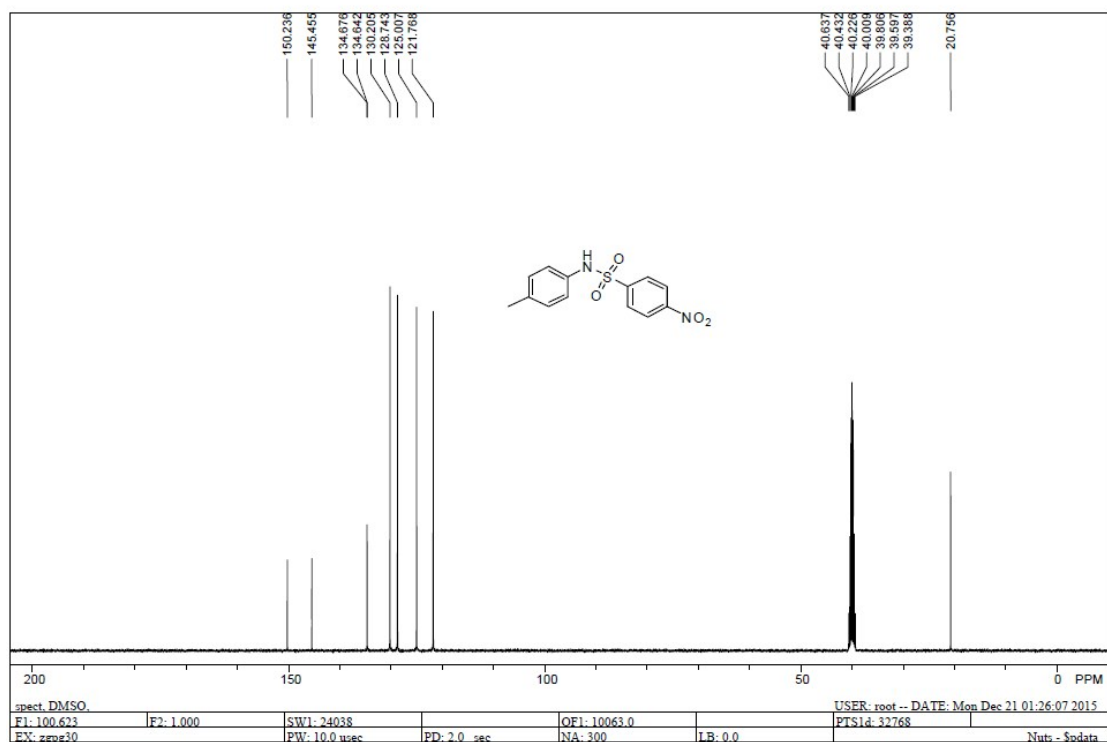
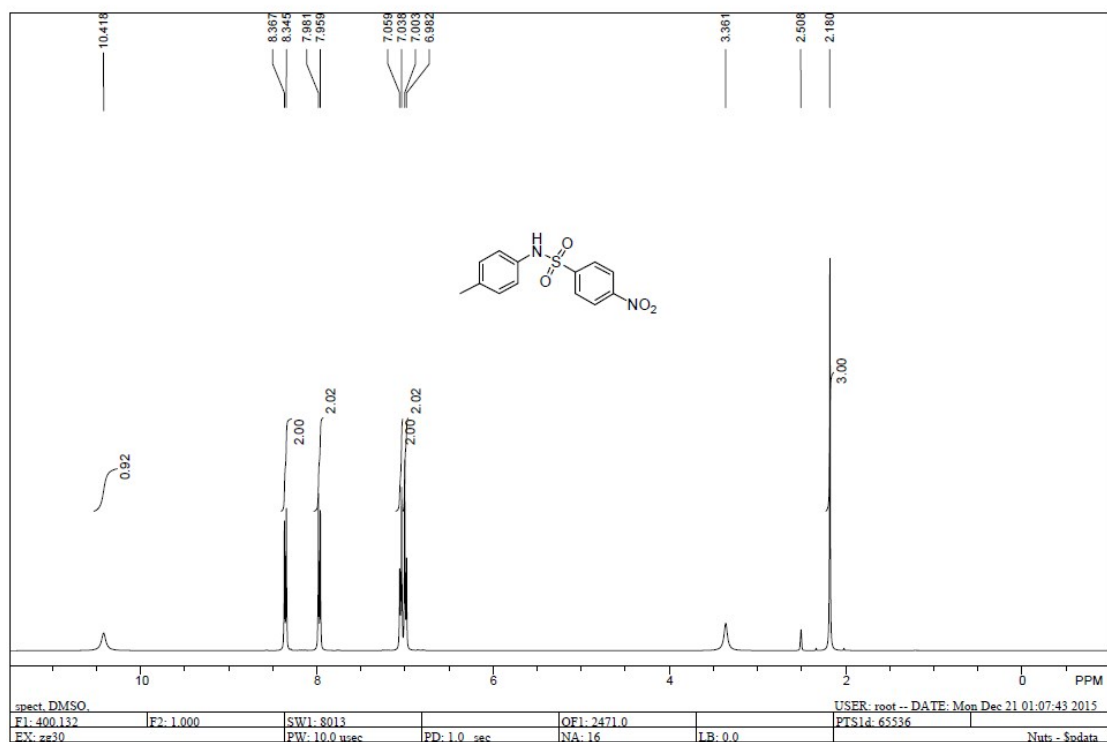
¹H NMR and ¹³C NMR spectra of compound **3u**



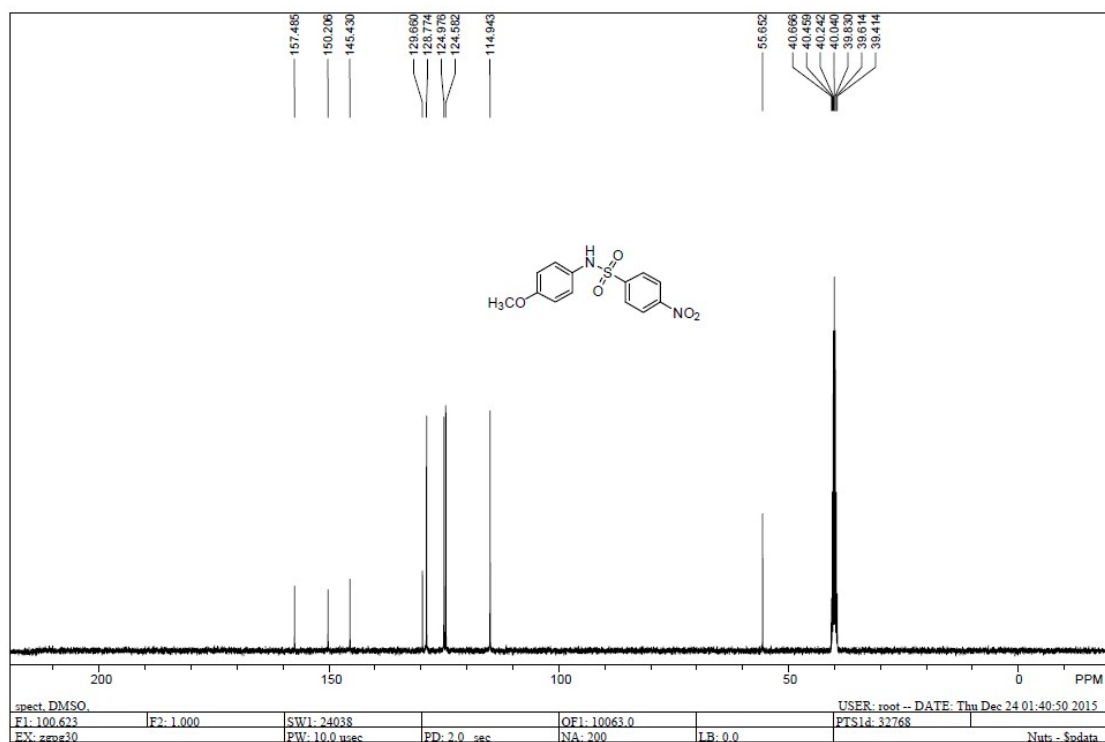
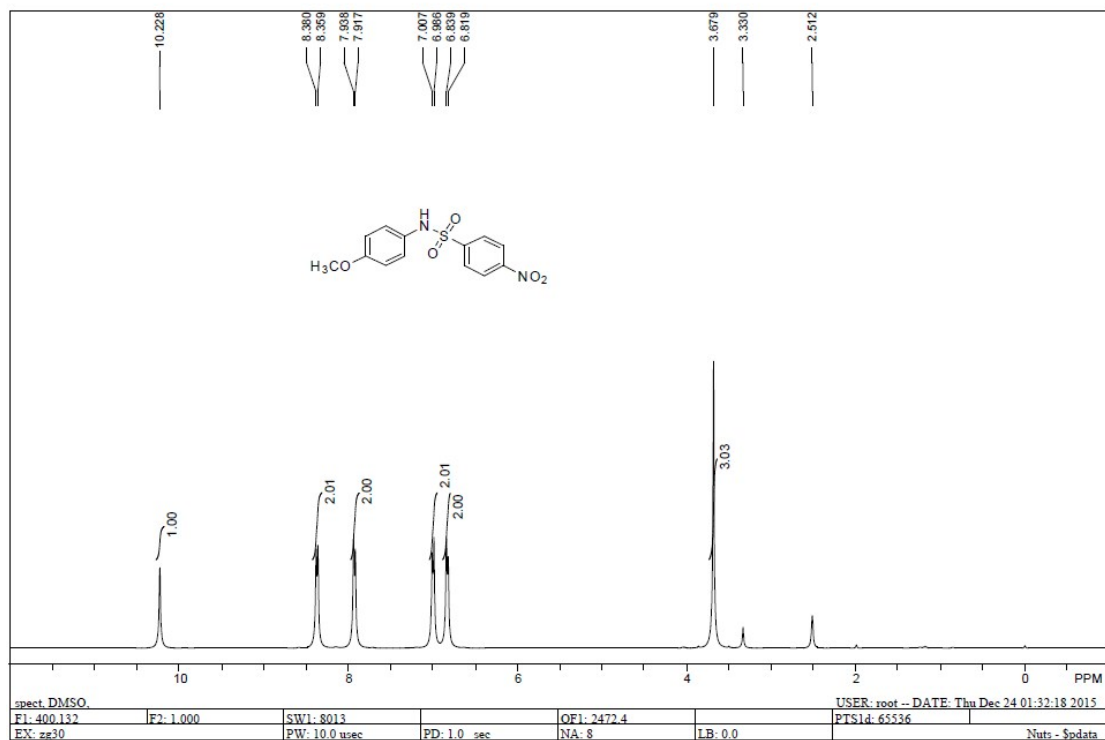
¹H NMR and ¹³C NMR spectra of compound **3v**



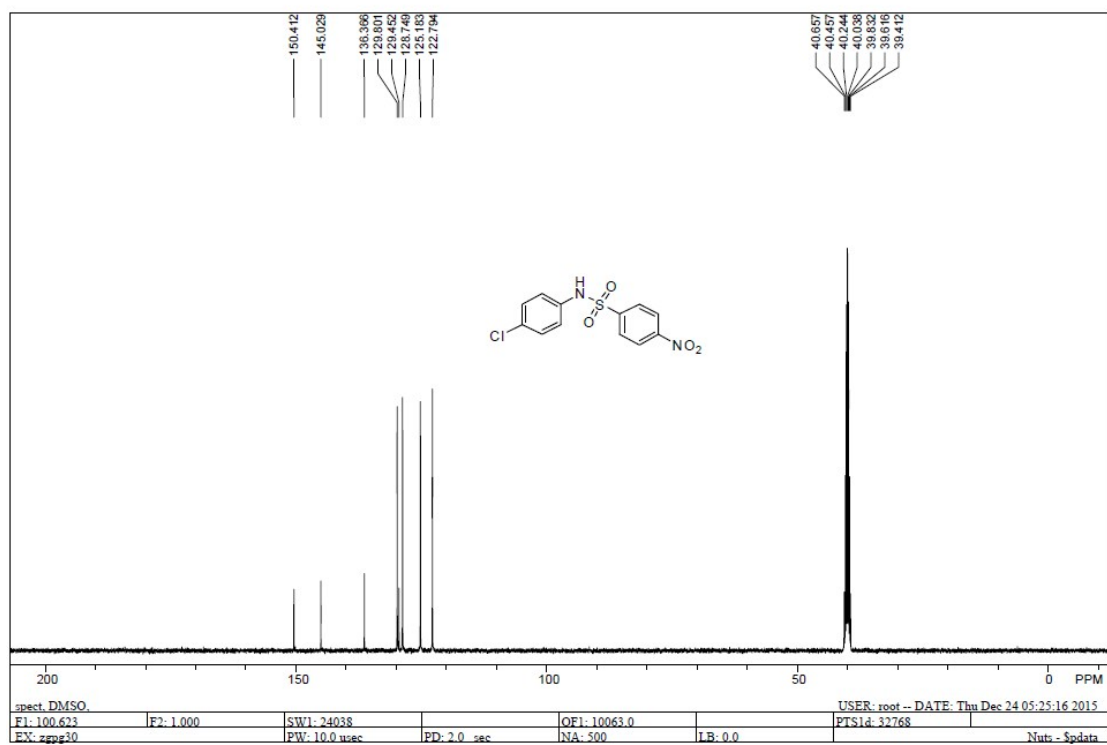
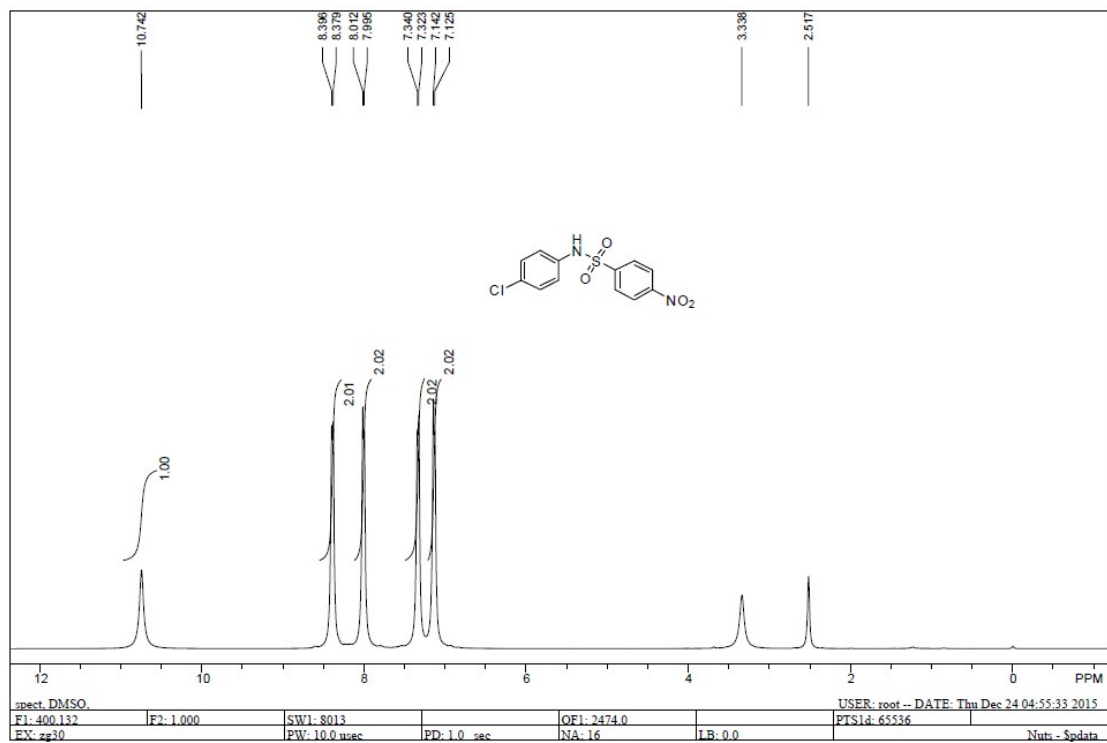
¹H NMR and ¹³C NMR spectra of compound **3w**



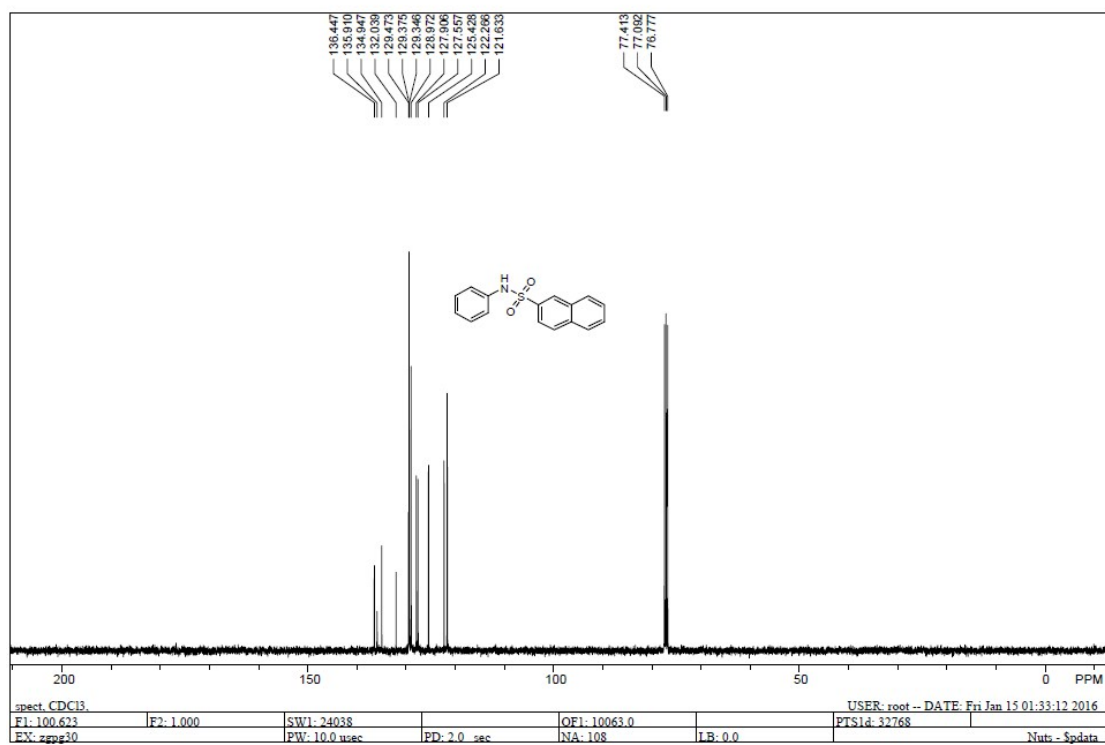
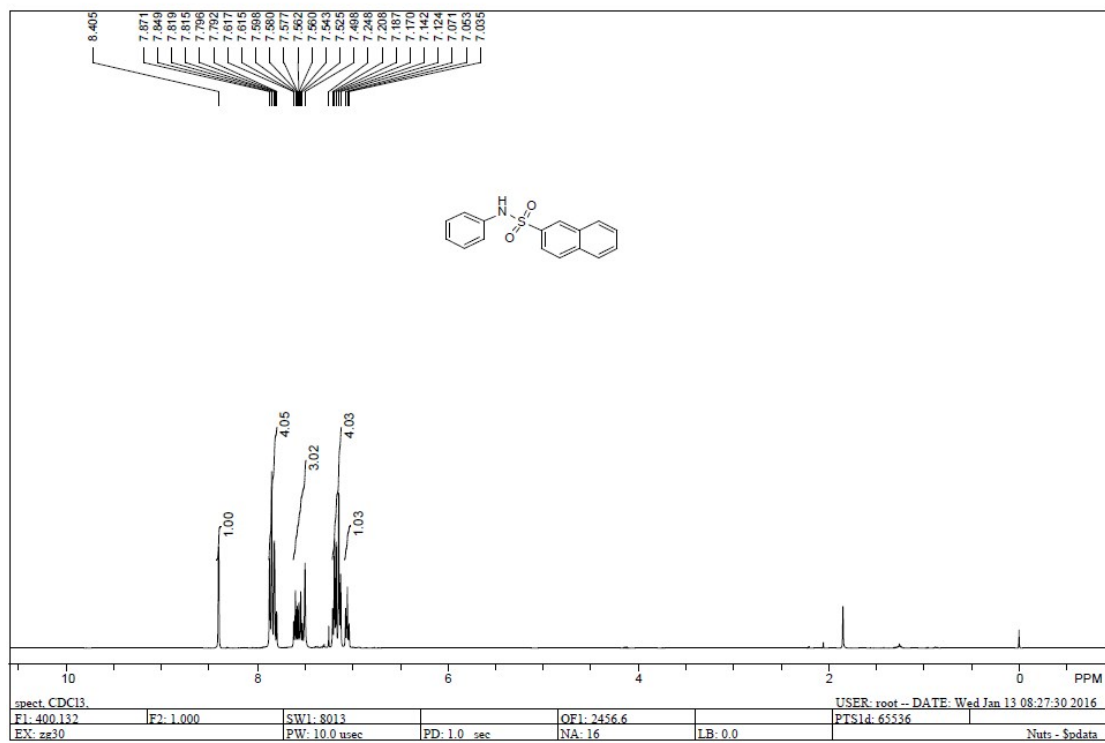
¹H NMR and ¹³C NMR spectra of compound **3x**



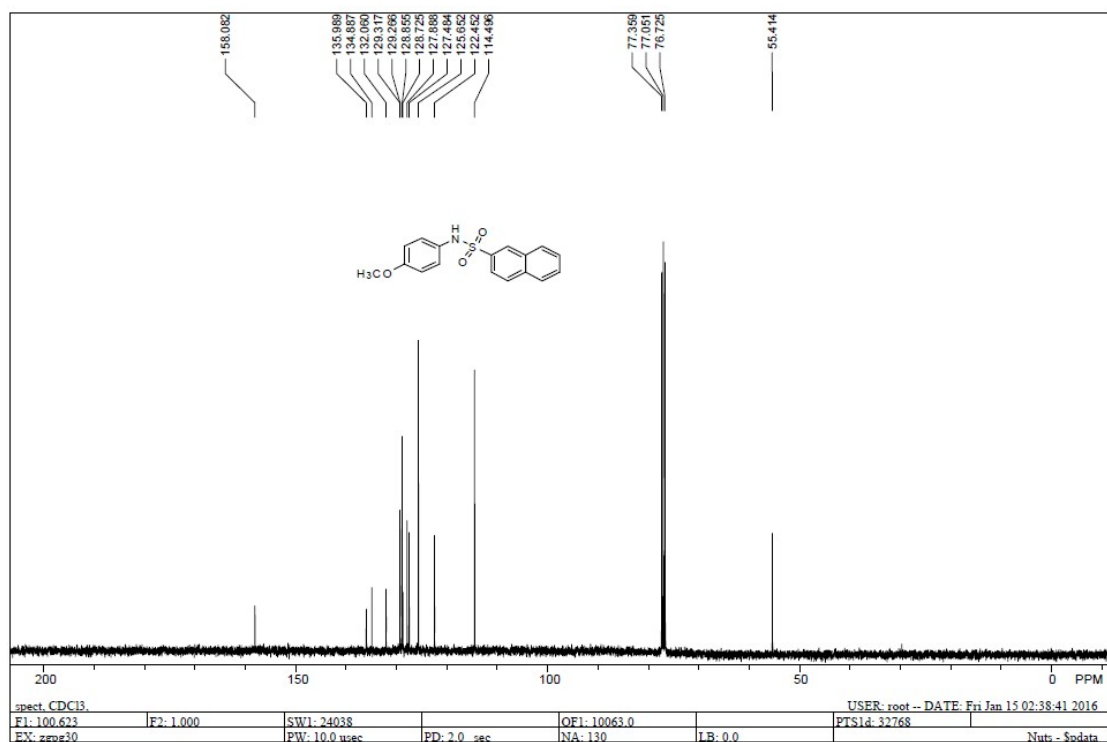
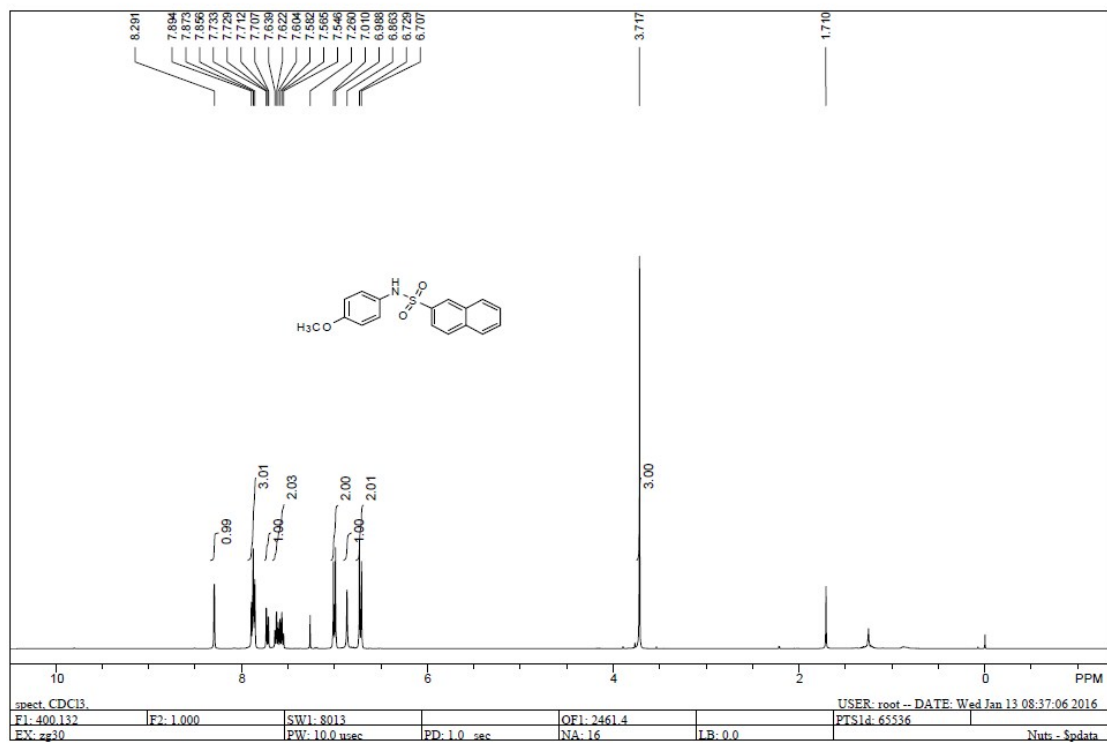
^1H NMR and ^{13}C NMR spectra of compound **3y**



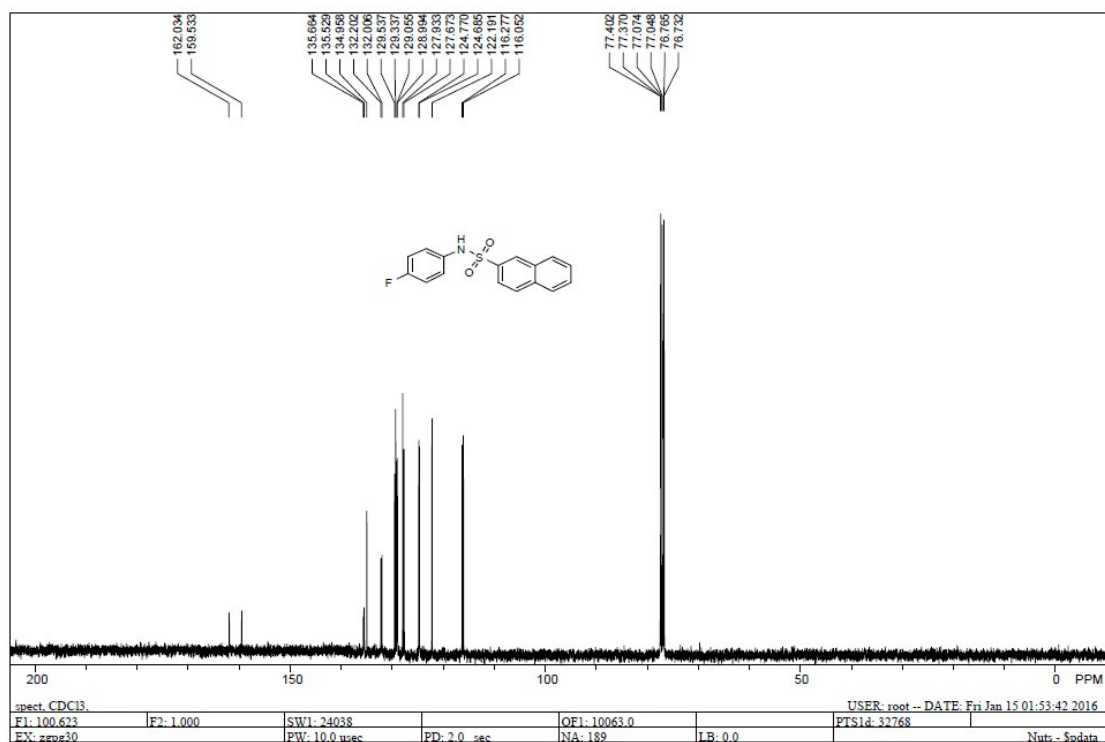
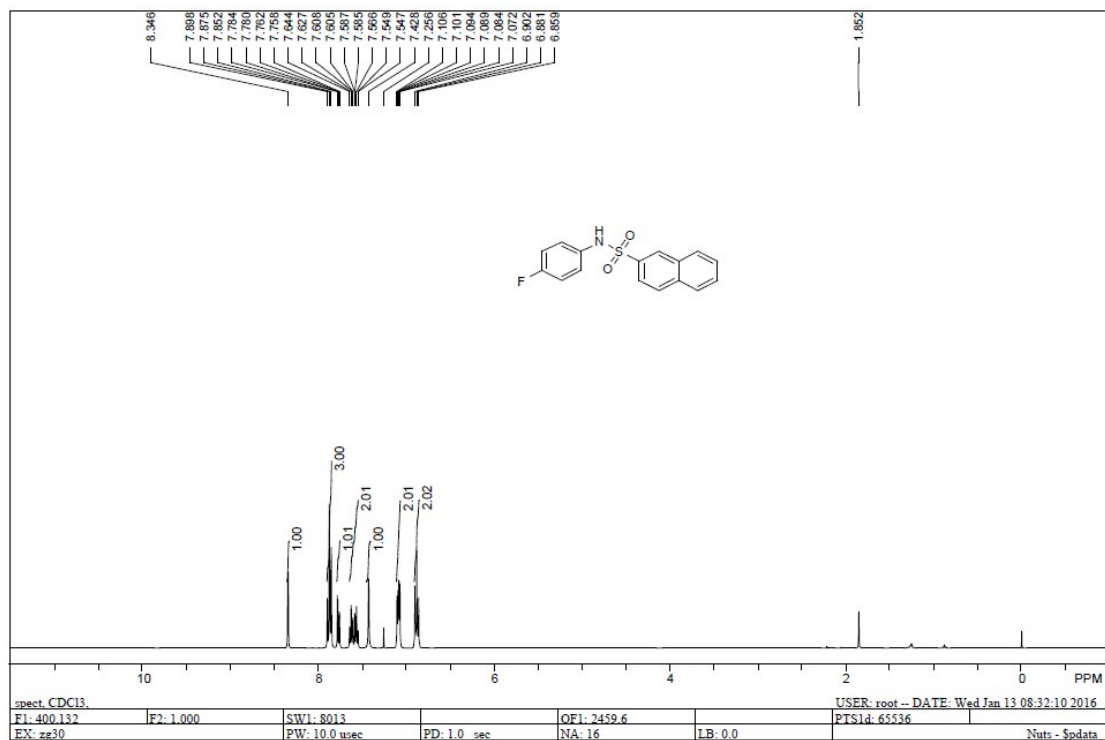
^1H NMR and ^{13}C NMR spectra of compound **3z**



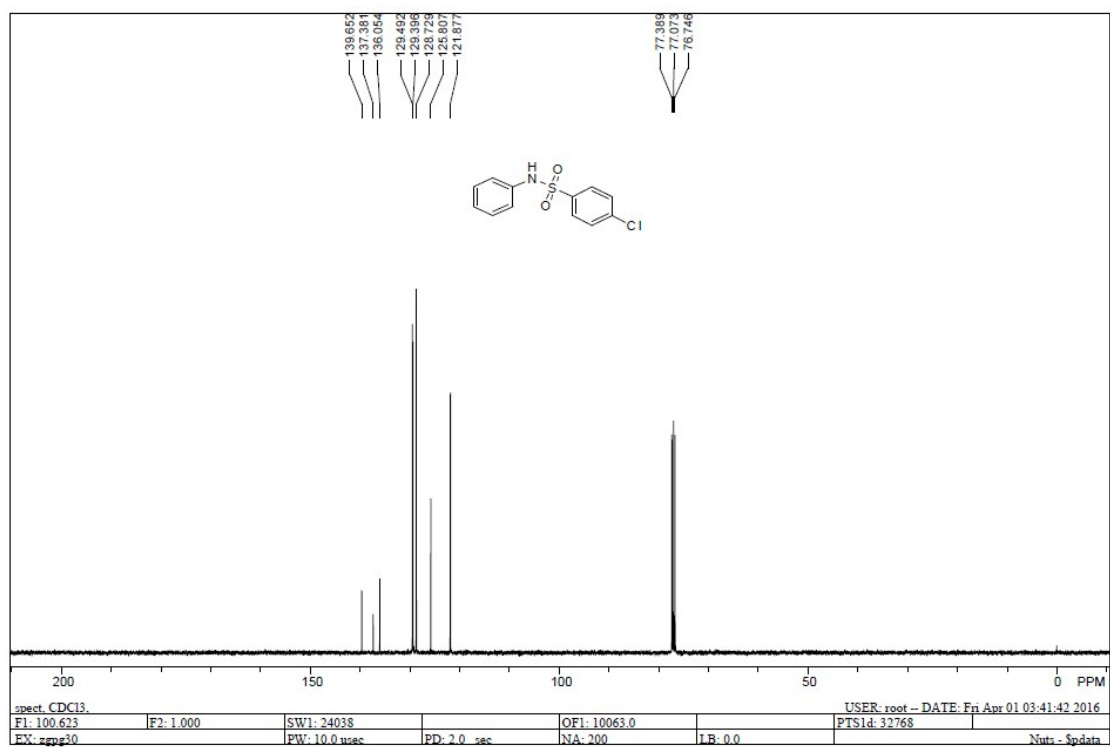
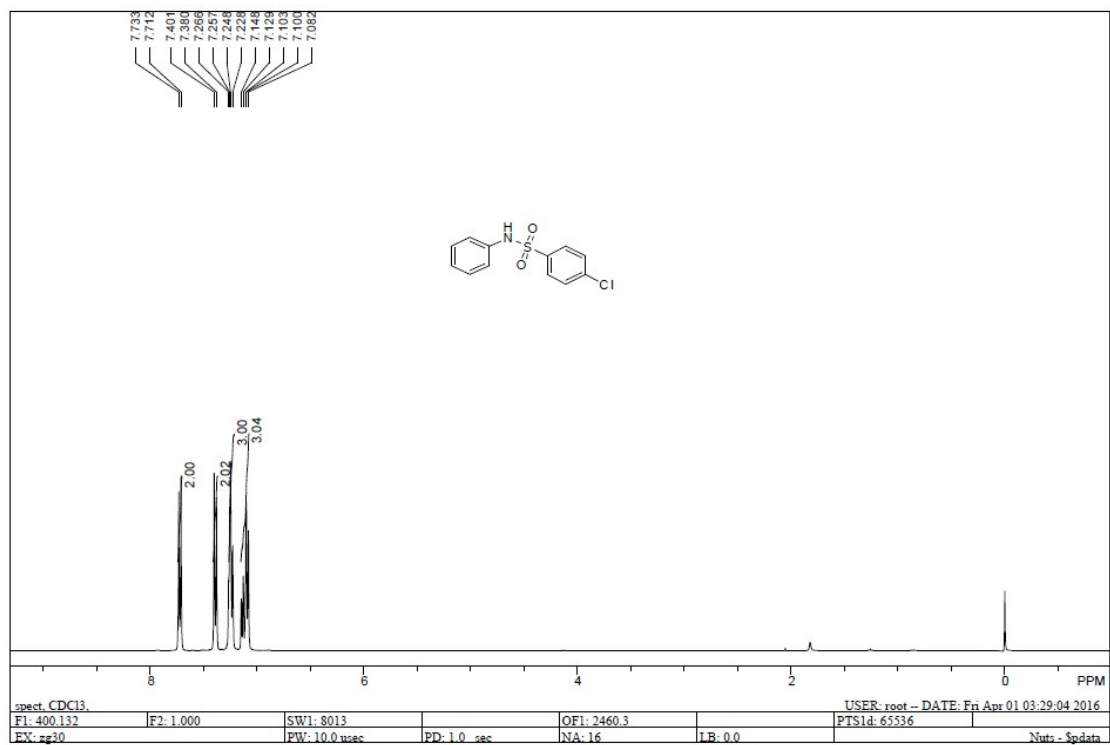
¹H NMR and ¹³C NMR spectra of compound 3a'



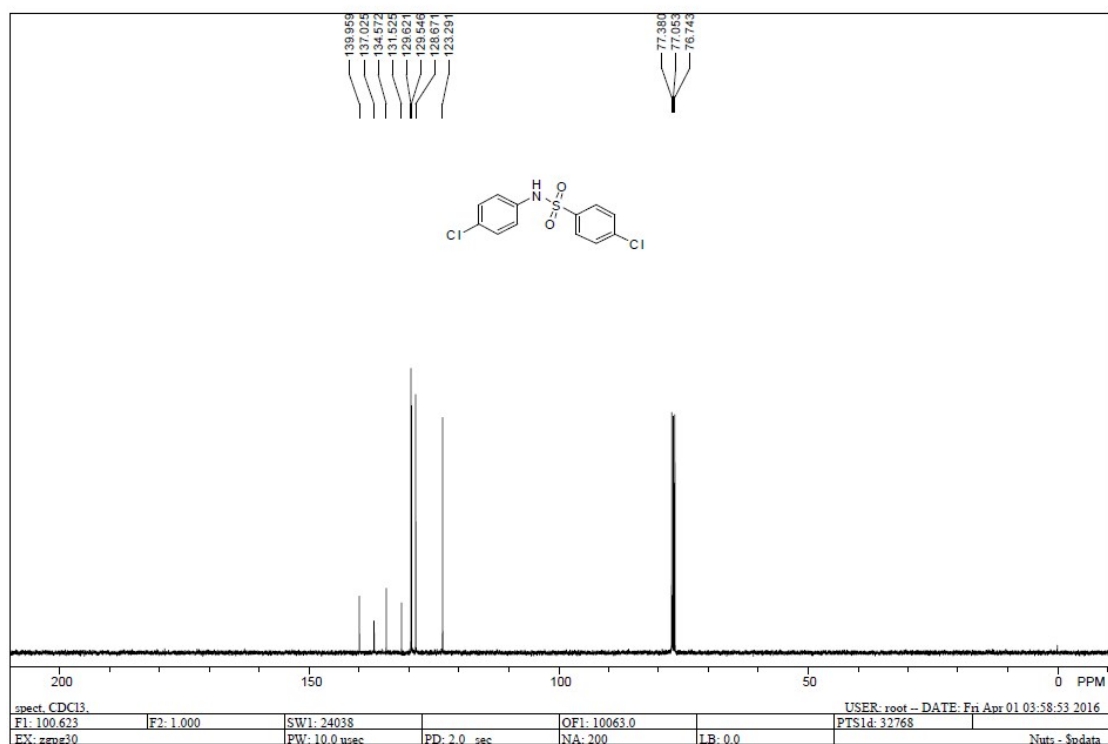
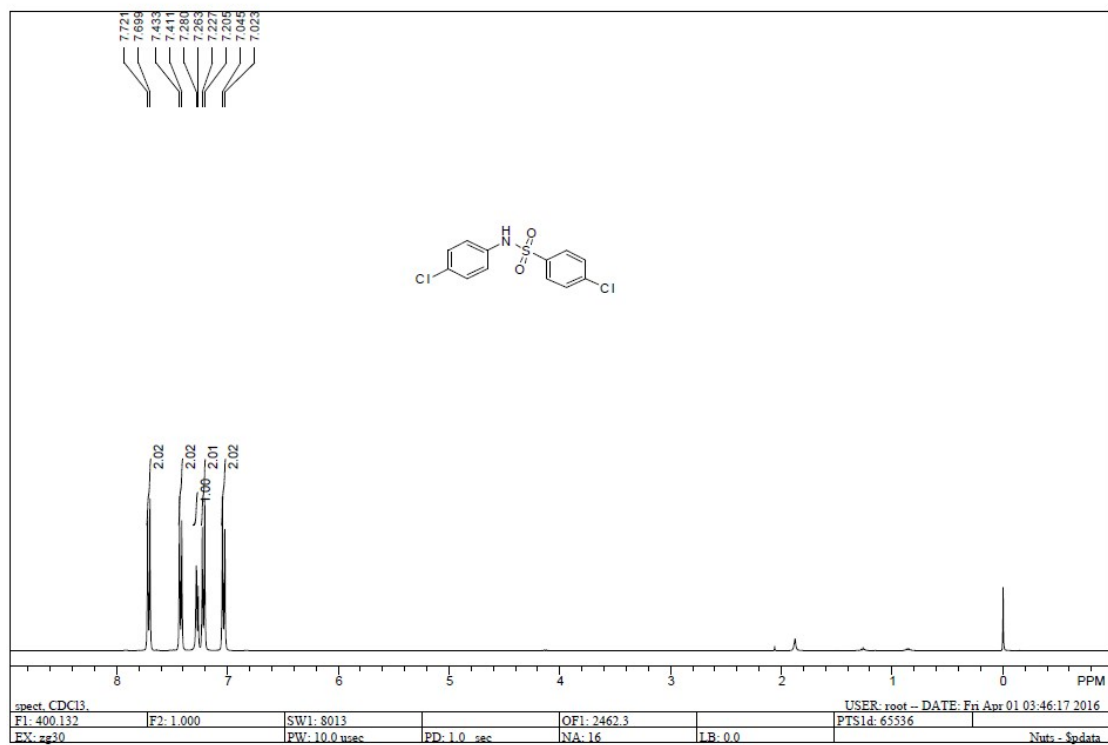
¹H NMR and ¹³C NMR spectra of compound **3b'**



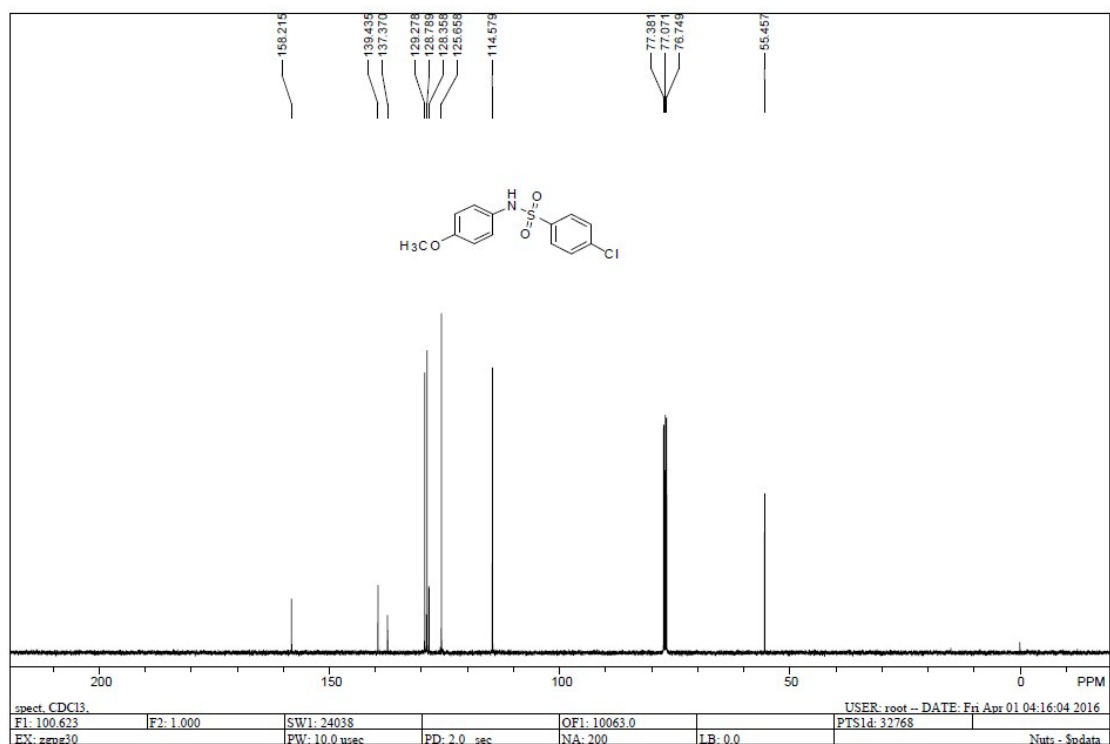
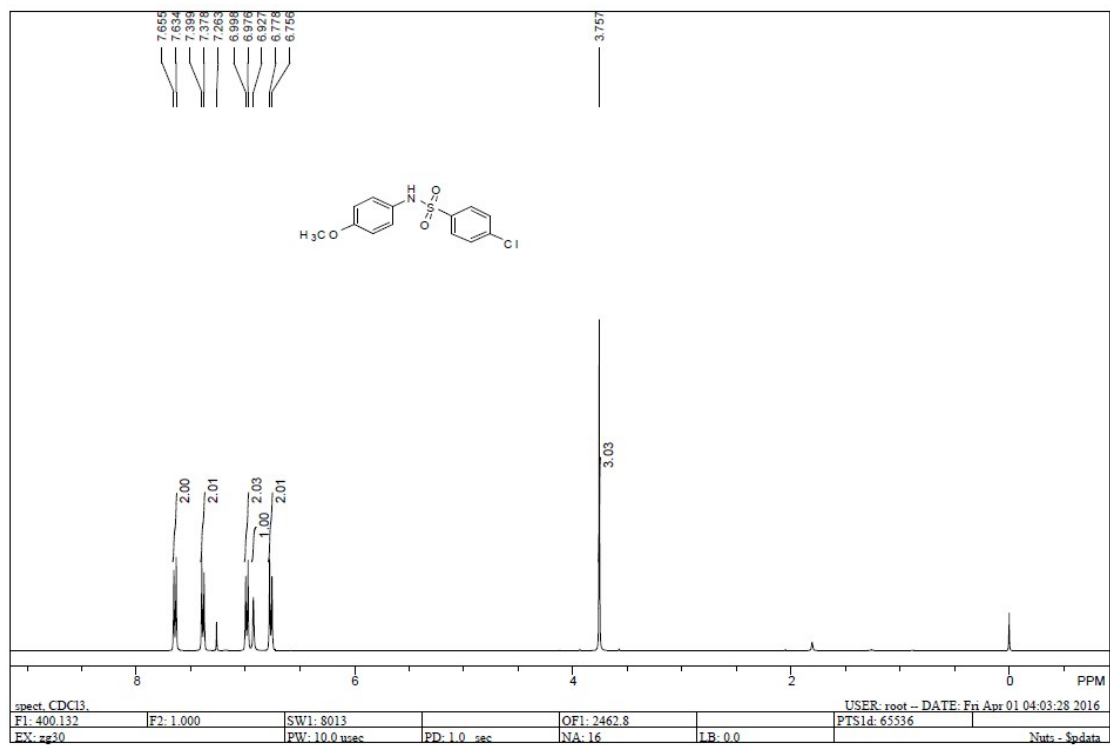
¹H NMR and ¹³C NMR spectra of compound 3c'



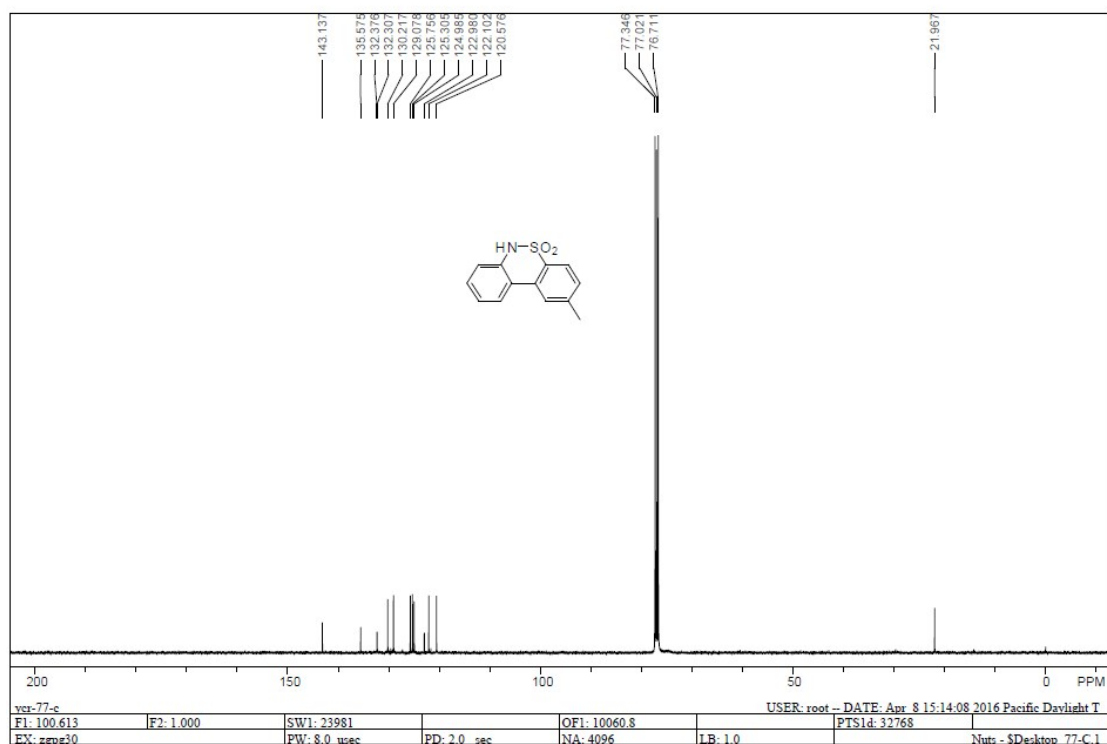
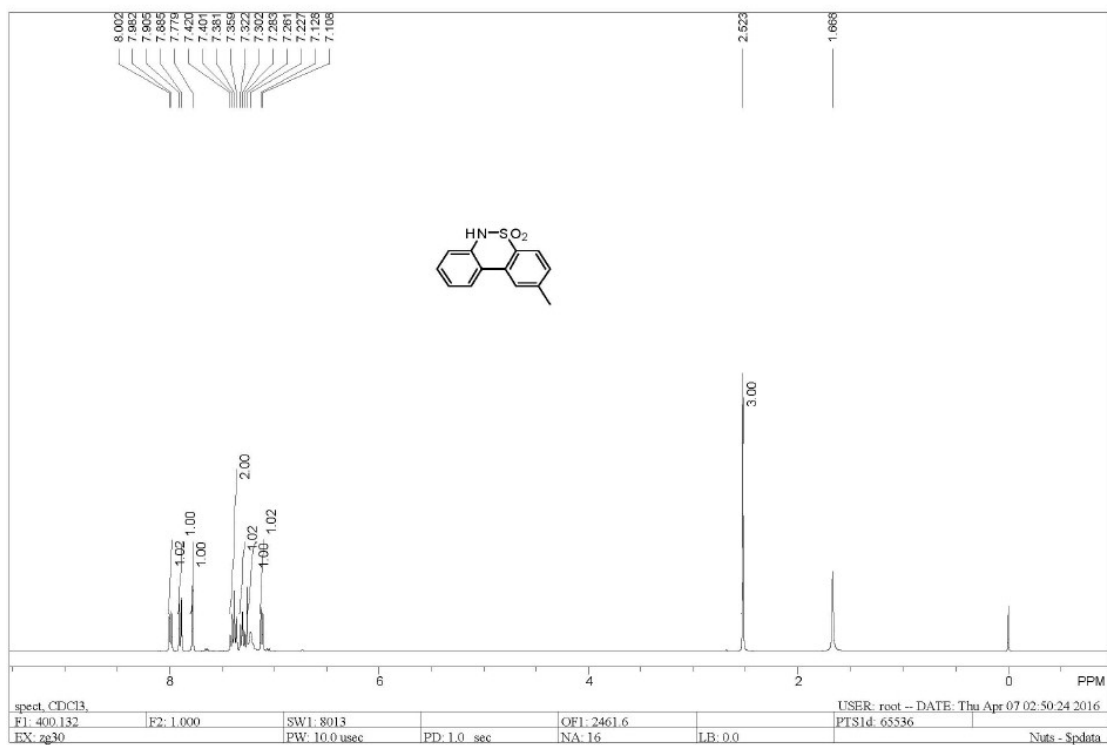
^1H NMR and ^{13}C NMR spectra of compound **3d'**



¹H NMR and ¹³C NMR spectra of compound 3e'



¹H NMR and ¹³C NMR spectra of compound 3f



¹H NMR and ¹³C NMR spectra of compound 4a