

Eco-Friendly Synthesis of 2-Substituted Benzothiazoles Catalyzed by Cetyltrimethyl Ammonium Bromide (CTAB) in Water

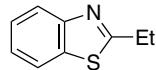
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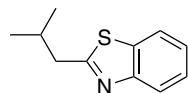
Description of the Products

2-Ethylbenzothiazole (**3a**)¹



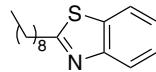
Colorless oil, ¹H NMR (300 MHz, CDCl₃) δ 7.28-8.00 (m, 4H, ArH), 3.10 (q, *J* 7.6 Hz, 2H, CH₂CH₃), 1.43 (t, *J* 7.6 Hz, 3H, CH₂CH₃); ¹³C NMR (75 MHz, CDCl₃) δ 173.6, 153.2, 135.0, 125.9, 124.6, 122.5, 121.5, 27.8, 13.8; MS (ESI): *m/z* (%) 164 ([M+H]⁺, 100).

2-Isobutylbenzothiazole (**3b**)¹



Colorless oil, ¹H NMR (300 MHz, CDCl₃) δ 7.98-8.01 (m, 1H, ArH), 7.84-7.87 (m, 1H, ArH), 7.43-7.48 (m, 1H, ArH), 7.35-7.38 (m, 1H, ArH), 3.00 (d, *J* 7.2 Hz, 2H, CH₂), 2.25 (m, 1H, CH(CH₃)₂), 1.06 (d, *J* 6.6 Hz, 6H, CH(CH₃)₂); ¹³C NMR (75 MHz, CDCl₃) δ 171.3, 153.2, 135.2, 125.8, 124.6, 122.5, 121.4, 43.2, 29.7, 22.4; MS (ESI): *m/z* (%) 192 ([M+H]⁺, 100).

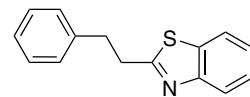
2-Nonylbenzothiazole (**3c**)²



Yellow oil, ¹H NMR (300 MHz, CDCl₃) δ 7.97 (d, *J* 7.7 Hz, 1H, ArH), 7.84 (d, *J* 7.7 Hz, 1H, ArH), 7.42-7.48 (m, 1H, ArH), 7.32-7.37 (m, 1H, ArH), 3.12 (t, *J* 7.8 Hz, 2H, CH₂); 1.83-1.93 (m, 2H, CH₂), 1.27-1.47 (m, 12H, (CH₂)₆), 0.88 (t, *J* 6.9 Hz, 3H, CH₂CH₃); ¹³C NMR (75 MHz, CDCl₃) δ 172.5, 153.2, 135.1, 125.8, 124.6, 122.5, 121.5, 34.4, 31.8,

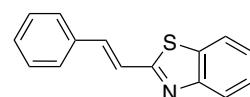
29.8, 29.4, 29.3, 29.3, 29.2, 22.7, 14.1; MS (ESI): *m/z* (%) 262 ([M+H]⁺, 100).

2-Phenethylbenzothiazole (**3d**)³



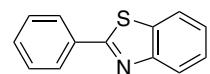
White crystal, mp 54-56 °C (not reported); ¹H NMR (300 MHz, CDCl₃) δ 8.02 (d, *J* 8.0 Hz, 1H, ArH); 7.85 (d, *J* 8.0 Hz, 1H, ArH); 7.22-7.48 (m, 6H, ArH); 3.45 (t, *J* 6.0 Hz, 2H, CH₂); 3.24 (t, *J* 6.0 Hz, 2H, CH₂); ¹³C NMR (75 MHz, CDCl₃) δ 170.9, 153.1, 140.1, 135.1, 128.6, 128.4, 126.4, 126.0, 124.7, 122.5, 121.5, 36.0, 35.5; MS (ESI): *m/z* (%) 240 ([M+H]⁺, 100).

2-Styrylbenzothiazole (**3e**)⁴



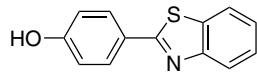
Yellow crystal, mp 110-112 °C (not reported); ¹H NMR (300 MHz, CDCl₃) δ 7.36-7.98 (m, 11H, ArH); ¹³C NMR (75 MHz, CDCl₃) δ 166.9, 153.9, 137.6, 135.4, 134.4, 129.4, 128.9, 127.4, 126.3, 125.3, 123.0, 122.2, 121.5; MS (ESI): *m/z* (%) 238 ([M+H]⁺, 100).

2-Phenylbenzothiazole (**3f**)⁴

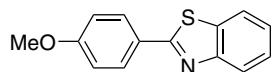


White solid, mp 111-112 °C (113-114 °C)⁴; ¹H NMR (300 MHz, CDCl₃) δ 8.10-8.12 (m, 3H, ArH), 7.91 (d, *J* 7.7 Hz, 1H, ArH), 7.48-7.53 (m, 4H, ArH), 7.40 (d, *J* 7.7 Hz, 1H, ArH); ¹³C NMR (75 MHz, CDCl₃) δ 168.1, 154.1, 135.0, 133.6, 131.0, 129.1, 127.6, 126.3, 125.2, 123.2, 121.6; MS (ESI): *m/z* (%) 212 ([M+H]⁺, 100).

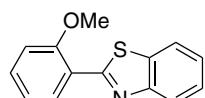
*e-mail: jiuxichen@wzu.edu.cn; huayuewu@wzu.edu.cn

2-(4-Hydroxyphenyl)benzothiazole (3g**)⁴**

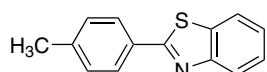
White solid, mp 229-231 °C (227-228 °C)⁴; ¹H NMR (300 MHz, DMSO-*d*₆) δ 7.89-8.06 (m, 4H, ArH), 7.36-7.50 (m, 2H, ArH), 6.90-6.95 (m, 2H, ArH), 3.64 (br s, 1H, OH); ¹³C NMR (75 MHz, CDCl₃) δ 167.9, 170.1, 154.1, 134.5, 129.5, 126.8, 125.3, 124.4, 122.7, 122.5, 116.5; MS (ESI): *m/z* (%) 228 ([M+H]⁺, 100).

2-(4-Methoxyphenyl)benzothiazole (3h**)⁵**

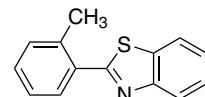
Yellow crystal, mp 120-121 °C (119-121 °C)⁵; ¹H NMR (300 MHz, CDCl₃) δ 8.04-8.07 (m, 3H, ArH), 7.90 (m, 1H, ArH), 7.48 (d, *J* 7.3 Hz, 1H, ArH), 7.37 (d, *J* 7.3 Hz, 1H, ArH), 7.01-7.04 (m, 2H, ArH), 3.90 (s, 3H, OCH₃); ¹³C NMR (75 MHz, CDCl₃) δ 168.0, 162.1, 154.4, 135.1, 129.3, 126.6, 126.4, 125.0, 123.0, 121.7, 114.5, 55.6; MS (ESI): *m/z* (%) 242 ([M+H]⁺, 100).

2-(2-Methoxyphenyl)-benzothiazole (3i**)¹**

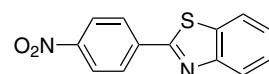
White crystal, mp 120-122 °C (not reported); ¹H NMR (300 MHz, CDCl₃) δ 7.03-8.58 (m, 8H, ArH), 4.03 (s, 3H, OCH₃); ¹³C NMR (75 MHz, CDCl₃) δ 162.8, 156.9, 151.9, 135.8, 131.4, 129.2, 125.6, 124.3, 122.5, 120.9, 120.8, 111.4, 55.4; MS (ESI): *m/z* (%) 242 ([M+H]⁺, 100).

2-(4-Methylphenyl)-benzothiazole (3j**)⁴**

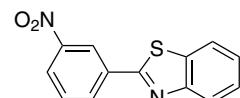
Yellow crystal, mp 85-86 °C (84-85 °C)⁴; ¹H NMR (300 MHz, CDCl₃) δ 8.05 (d, *J* 8.0 Hz, 1H, ArH), 7.97 (d, *J* 8.0 Hz, 2H, ArH), 7.86 (d, *J* 8.0 Hz, 1H, ArH), 7.44-7.46 (m, 1H, ArH), 7.34-7.37 (m, 1H, ArH), 7.27 (d, *J* 8.0 Hz, 1H, ArH), 2.40 (s, 3H, CH₃); ¹³C NMR (75 MHz, CDCl₃) δ 168.2, 154.2, 141.4, 135.0, 131.0, 129.7, 127.5, 126.2, 125.0, 123.0, 121.5, 21.5; MS (ESI): *m/z* (%) 226 ([M+H]⁺, 100).

2-(2-Methylphenyl)-benzothiazole (3k**)¹**

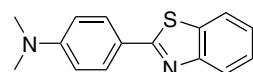
White crystal, mp 53-54 °C (53-54 °C); ¹H NMR (300 MHz, CDCl₃) δ 8.1 (d, *J* 8.0 Hz, 1H, ArH), 7.90 (d, *J* 8.0 Hz, 1H, ArH), 7.75 (d, *J* 7.6 Hz, 1H, ArH), 7.50 (d, *J* 7.6 Hz, 1H, ArH), 7.26-7.41 (m, 4H, ArH), 2.65 (s, 3H, CH₃); ¹³C NMR (75 MHz, CDCl₃) δ 163.1, 157.2, 152.1, 136.1, 131.7, 129.5, 125.8, 124.5, 122.7, 122.2, 121.2, 121.1, 111.6, 55.6; MS (ESI): *m/z* (%) 226 ([M+H]⁺, 100).

2-(4-Nitrophenyl)-benzothiazole (3l**)⁵**

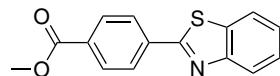
Yellow crystal, mp 231-232 °C (229-230 °C)⁵; ¹H NMR (300 MHz, CDCl₃) δ 7.46-8.38 (m, 8H, ArH); ¹³C NMR (75 MHz, CDCl₃) δ 164.8, 154.1, 149.0, 139.1, 135.5, 128.2, 126.9, 126.2, 124.3, 123.9, 121.8; MS (ESI): *m/z* (%) 257 ([M+H]⁺, 100).

2-(3-Nitrophenyl)-benzothiazole (3m**)⁶**

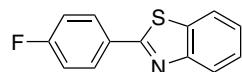
Yellow crystal, mp 185-186 °C (183-185 °C)⁶; ¹H NMR (300 MHz, CDCl₃) δ 7.43-8.95 (m, 8H, ArH); ¹³C NMR (75 MHz, CDCl₃) δ 164.8, 153.8, 148.6, 135.2, 135.1, 132.9, 130.0, 126.8, 126.0, 125.1, 123.7, 122.2, 121.8; MS (ESI): *m/z* (%) 257 ([M+H]⁺, 100).

2-(4-N,N-dimethylaminophenyl)benzothiazole (3n**)⁴**

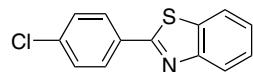
Brown crystal, mp 173-175 °C (176-178 °C)⁴; ¹H NMR (300 MHz, CDCl₃) δ 7.98 (dd, *J* 7.0 Hz, *J* 2.0 Hz, 3H, ArH), 7.83-7.86 (m, 1H, ArH), 7.42-7.45 (m, 1H, ArH), 7.3-7.33 (m, 1H, ArH), 6.74 (dd, *J* 2.0 Hz, *J* 7.0 Hz, 2H, ArH), 3.05 (s, 6H, N(CH₃)₂); ¹³C NMR (75 MHz, CDCl₃) δ 168.8, 154.4, 152.1, 134.5, 128.8, 125.9, 124.1, 122.2, 121.3, 111.6, 40.1; MS (ESI): *m/z* (%) 255 ([M+H]⁺, 100).

2-(4-Methoxycarbonylphenyl) benzothiazole (3o**)⁷**

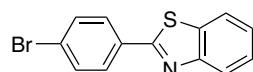
White crystal, mp 166-167 °C (166 °C)⁷; ¹H NMR (300 MHz, CDCl₃) δ 8.07-8.12 (m, 5H, ArH), 7.87-7.89 (m, 1H, ArH), 7.39-7.50 (m, 2H, ArH), 3.94 (s, 3H, OCH₃); ¹³C NMR (75 MHz, CDCl₃) δ 166.4, 166.3, 150.4, 137.3, 135.2, 131.9, 130.1, 127.3, 126.5, 125.6, 123.5, 121.6, 52.25; MS (ESI): *m/z* (%) 270 ([M+H]⁺, 100).

2-(4-Fluorophenyl)benzothiazole (3p**)⁵**

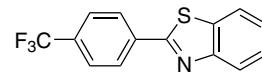
White crystal, mp 98-100 °C (98-99 °C)⁵; ¹H NMR (300 MHz, CDCl₃) δ 8.03-8.07 (m, 3H, ArH), 7.85 (d, *J* 8.0 Hz, 1H, ArH), 7.47 (d, *J* 7.7 Hz, 1H, ArH), 7.35 (d, *J* 7.7 Hz, 1H, ArH), 7.15 (t, *J* 8.0 Hz, 1H, ArH); ¹³C NMR (75 MHz, CDCl₃) δ 166.9, 163.0 (d, ¹*J*_{C-F} 250.3 Hz), 154.3, 135.2, 130.1, 129.7 (d, ³*J*_{C-F} 7.0 Hz), 129.6, 125.4, 123.4 (d, ⁴*J*_{C-F} 2.9 Hz), 121.7, 116.3 (d, ²*J*_{C-F}=22.0 Hz); MS (ESI): *m/z* (%) 230 ([M+H]⁺, 100).

2-(4-Chlorophenyl)benzothiazole (3q**)⁸**

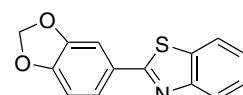
Yellow crystal, mp 113-114°C (113°C)⁸; ¹H NMR (300 MHz, CDCl₃) δ 7.87-8.06 (m, 4H, ArH), 7.35-7.51 (m, 4H, ArH); ¹³C NMR (75 MHz, CDCl₃) δ 166.8, 154.3, 137.2, 135.3, 132.3, 129.5, 128.9, 126.7, 125.6, 123.5, 121.8; MS (ESI): *m/z* (%) 246 ([M+H]⁺, 100), 248 ([M+2+H]⁺, 35).

2-(4-Bromophenyl)benzothiazole (3r**)⁵**

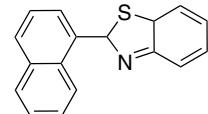
Yellow crystal, mp 131-132 °C (130-131 °C)⁵; ¹H NMR (300 MHz, CDCl₃) δ 7.37-8.08 (m, 8H, ArH); ¹³C NMR (75 MHz, CDCl₃) δ 166.7, 154.1, 135.0, 132.5, 132.2, 128.9, 126.5, 125.5, 125.4, 123.3, 121.6; MS (ESI): *m/z* (%) 291 ([M+H]⁺, 100), 289 ([M+2+H]⁺, 97).

2-(4-(Trifluoromethyl) phenyl) benzothiazole (3s**)⁹**

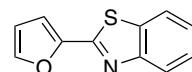
Yellow crystal, mp 160-162 °C (not reported); ¹H NMR (300 MHz, CDCl₃) δ 8.08-8.18 (m, 3H, ArH), 7.90 (d, *J* 8.1 Hz, 1H, ArH), 7.70 (d, *J* 8.1 Hz, 2H, ArH), 7.39-7.754 (m, 2H, ArH); ¹³C NMR (75 MHz, CDCl₃) δ 165.9, 153.9, 136.6, 135.1, 132.3 (q, ²*J*_{C-F} 32.8 Hz, C-CF₃), 127.7, 126.6, 125.8 (q, ³*J*_{C-F} 3.8 Hz, CH-C-CF₃), 125.7, 124.6 (q, ¹*J*_{C-F} 270.1 Hz, CF₃), 123.5, 121.7; MS (ESI): *m/z* (%) 280 ([M+H]⁺, 100).

2-(Benzo[1, 3] dioxol-5-yl)benzothiazole (3t**)⁴**

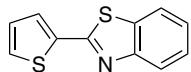
Yellow crystal, mp 125-127 °C (127-128 °C)⁴; ¹H NMR (300 MHz, CDCl₃) δ 8.04 (d, *J* 8.1 Hz, 1H, ArH), 7.90 (d, *J* 8.1 Hz, 1H, ArH), 7.60-7.63 (m, 2H, ArH), 7.46-7.49 (m, 1H, ArH), 7.38-7.41 (m, 1H, ArH), 7.00 (d, *J* 7.8 Hz, 1H, ArH), 6.08 (s, 2H, OCH₂O); ¹³C NMR (75 MHz, CDCl₃) δ 167.5, 154.1, 150.1, 148.4, 134.9, 128.0, 126.2, 124.9, 122.9, 122.5, 121.5, 108.6, 107.5, 101.7; MS (ESI): *m/z* (%) 256 ([M+H]⁺, 100).

2-(Naphthalen-1-yl)benzothiazole (3u**)⁴**

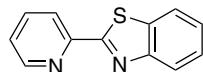
White crystal, mp 125-127°C (126 °C)⁴; ¹H NMR (300 MHz, CDCl₃) δ 8.97 (d, *J* 8.3 Hz, 1H, ArH), 8.23 (d, *J* 7.8 Hz, 1H, ArH), 7.95-8.03 (m, 4H, ArH), 7.58-7.63 (m, 4H, ArH), 7.48-7.56 (m, 1H, ArH); ¹³C NMR (75 MHz, CDCl₃) δ 167.7, 154.2, 135.5, 134.1, 131.1, 130.9, 130.7, 129.5, 128.5, 127.7, 126.6, 126.3, 126.0, 125.3, 125.0, 123.6, 121.5; MS (ESI): *m/z* (%) 264 ([M+H]⁺, 100).

2-(Furan-2-yl)benzothiazole (3v**)⁴**

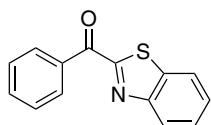
Yellow crystal, mp 102-104 °C (103 °C)⁴; ¹H NMR (300 MHz, CDCl₃) δ 8.05 (d, *J* 8.1 Hz, 1H, ArH), 7.90 (d, *J* 8.1 Hz, 1H, ArH), 7.60 (s, 1H, ArH), 7.46-7.51 (m, 1H, ArH), 7.35-7.40 (m, 1H, ArH), 7.18-7.19 (m, 1H, ArH), 6.59-6.60 (m, 1H, ArH); ¹³C NMR (75 MHz, CDCl₃) δ 157.7, 153.9, 140.9, 144.9, 134.5, 126.6, 125.3, 123.3, 121.7, 112.7, 111.6; MS (ESI): *m/z* (%) 202 ([M+H]⁺, 100).

2-(Thiophen-2-yl)benzothiazole (3w**)¹**

White crystal, mp 99-100 °C (99 °C)¹; ¹H NMR (300 MHz, CDCl₃) δ 8.02-8.05 (m, 1H, ArH), 7.84-7.87 (m, 1H, ArH), 7.66 (dd, *J* 3.6 Hz, *J* 1.2 Hz, 1H, ArH), 7.48-7.52 (m, 2H, ArH), 7.37-7.39 (m, 1H, ArH), 7.14 (m, 1H, ArH); ¹³C NMR (75 MHz, CDCl₃) δ 161.4, 153.7, 137.3, 134.7, 129.3, 128.6, 128.0, 126.4, 125.2, 122.9, 121.4; MS (ESI): *m/z* (%) 218 ([M+H]⁺, 100).

2-(Pyridin-2-yl)benzothiazole (3x**)⁴**

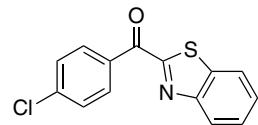
White crystal, mp 136-137 °C (136-137 °C)⁴; ¹H NMR (300 MHz, CDCl₃) δ 8.64-8.65 (m, 1H, ArH), 8.32-8.35 (m, 1H, ArH), 8.05-8.08 (m, 1H, ArH), 7.91-7.93 (m, 1H, ArH), 7.76-7.79 (m, 1H, ArH), 7.32-7.47 (m, 2H, ArH); ¹³C NMR (75 MHz, CDCl₃) δ 169.5, 154.5, 151.6, 149.8, 137.1, 136.3, 126.4, 125.8, 125.4, 123.8, 122.2, 120.9; MS (ESI): *m/z* (%) 213 ([M+H]⁺, 100).

2-Benzoylbenzothiazole (4a**)¹⁰**

Yellow crystal, mp 98-99 °C (98-99 °C)¹⁰; ¹H NMR (300 MHz, CDCl₃) δ 8.55-8.59 (m, 2H, ArH), 8.24-8.27 (m, 1H, ArH), 8.02-8.05 (m, 1H, ArH), 7.54-7.71 (m, 5H, ArH); ¹³C NMR (75 MHz, CDCl₃) δ 185.7, 167.4, 154.2, 137.3, 135.3, 134.2, 131.6, 128.9, 128.0, 127.3, 126.1, 122.5; MS (ESI): *m/z* (%) 240 ([M+H]⁺, 100).

2-(4-Methylbenzoyl)benzothiazole (4b**)¹¹**

Yellow crystal; mp 96-98 °C (not reported); ¹H NMR (300 MHz, CDCl₃) δ 8.47-8.50 (m, 2H, ArH), 8.23-8.26 (m, 1H, ArH), 8.01-8.04 (m, 1H, ArH), 7.52-7.62 (m, 2H, ArH), 7.37 (d, *J* 7.8 Hz, 2H, ArH), 2.47 (s, 3H, CH₃); ¹³C NMR (75 MHz, CDCl₃) δ 184.8, 167.4, 153.8, 145.0, 136.9, 132.3, 131.4, 129.2, 127.4, 126.8, 125.6, 122.1, 21.8; MS (ESI): *m/z* (%) 254 ([M+H]⁺, 100).

2-(4-chlorobenzoyl)benzothiazole (4c**)¹²**

White crystal, mp 100-102°C (102-103°C)¹²; ¹H NMR (CDCl₃, 300 MHz) δ 8.54-8.59 (m, 2H, ArH), 8.23-8.27 (m, 1H, ArH), 8.02-8.05 (m, 1H, ArH), 7.53-7.64 (m, 4H, ArH); ¹³C NMR (75 MHz, CDCl₃) δ 183.9, 166.7, 153.7, 140.5, 137.0, 133.1, 132.7, 128.8, 127.7, 127.0, 125.7, 122.1; MS (ESI): *m/z* (%) 274 ([M+H]⁺, 100), 276 ([M+2+H]⁺, 34).

2-(4-Bromobenzoyl)benzothiazole (4d**)¹¹**

Yellow crystal, mp 123-124 °C (not reported); ¹H NMR (CDCl₃, 300MHz) δ 8.46-8.49 (m, 2H, ArH), 8.23-8.26 (m, 1H, ArH), 8.02-8.07 (m, 1H, ArH), 7.70-7.73 (m, 2H, ArH), 7.56-7.61 (m, 2H, ArH); ¹³C NMR (75 MHz, CDCl₃) δ 184.1, 166.7, 153.8, 137.0, 133.6, 132.7, 131.8, 129.5, 127.8, 127.0, 125.7, 122.2; MS (ESI): *m/z* (%) 317 ([M+H]⁺, 100), 319 ([M+2+H]⁺, 98).

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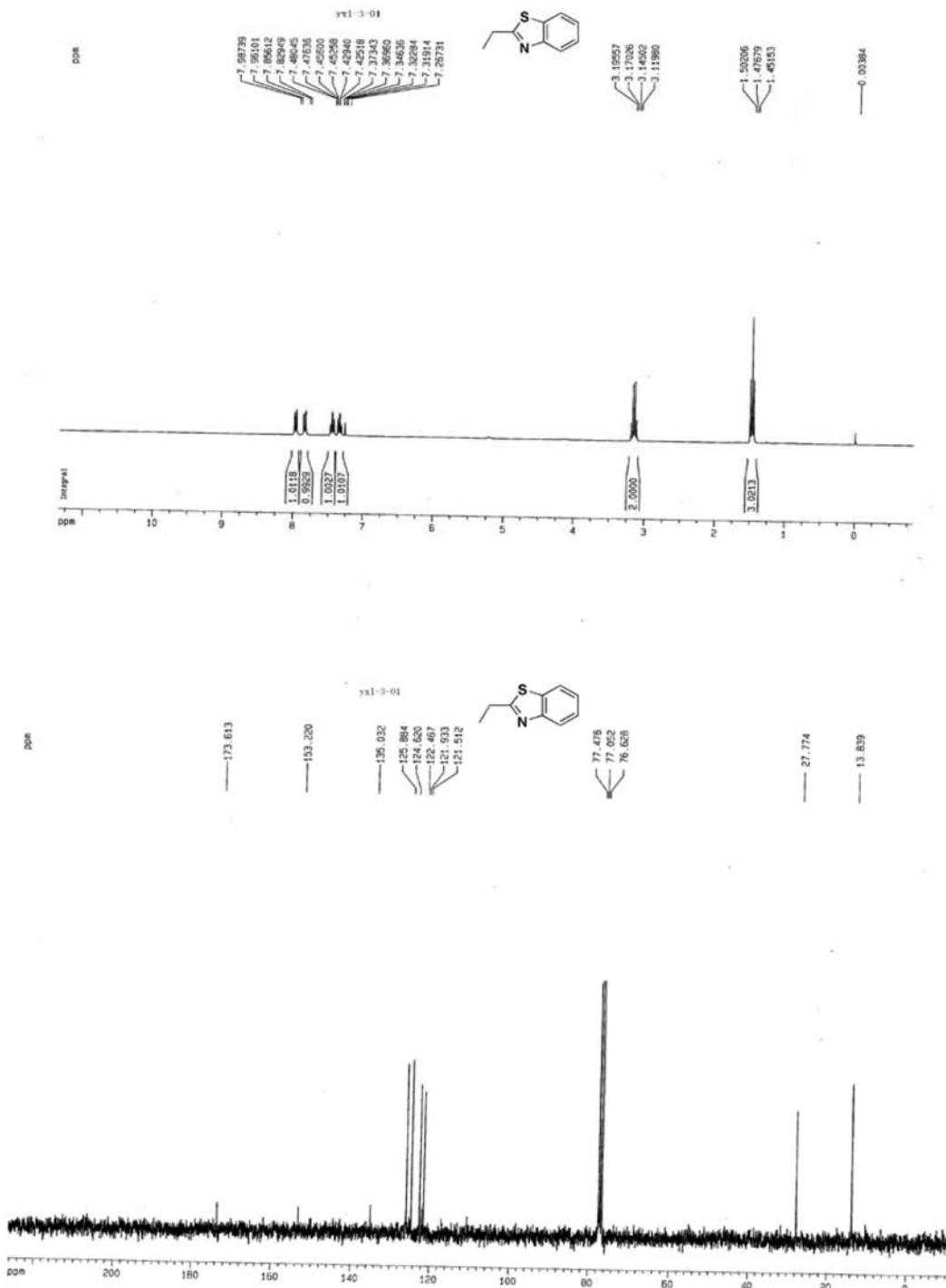


Figure S1. ^1H NMR of **3a** (300 MHz, CDCl_3) and ^{13}C NMR of **3a** (75 MHz, CDCl_3).

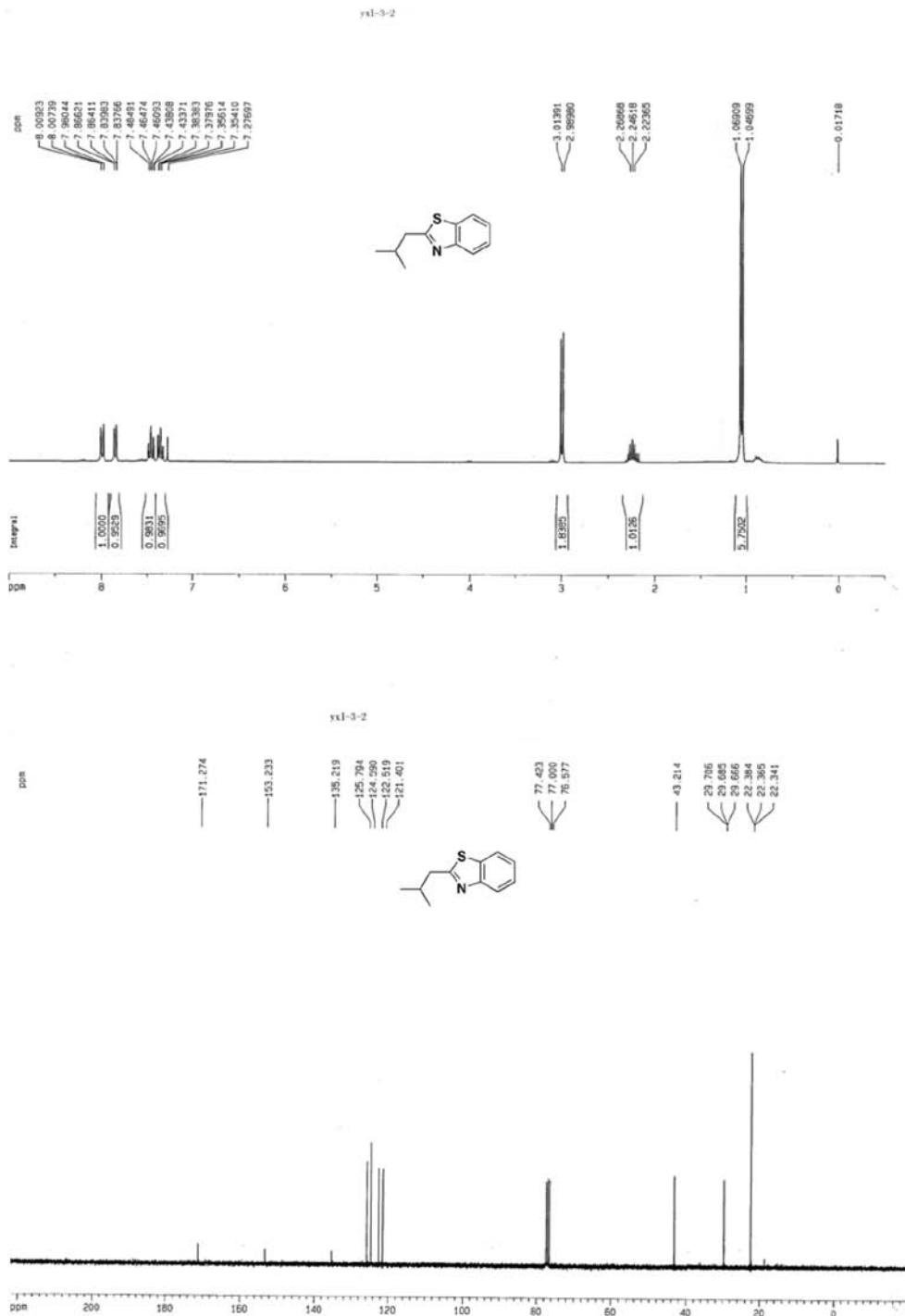


Figure S2. ^1H NMR of **3b** (300 MHz, CDCl_3) and ^{13}C NMR of **3b** (75 MHz, CDCl_3).

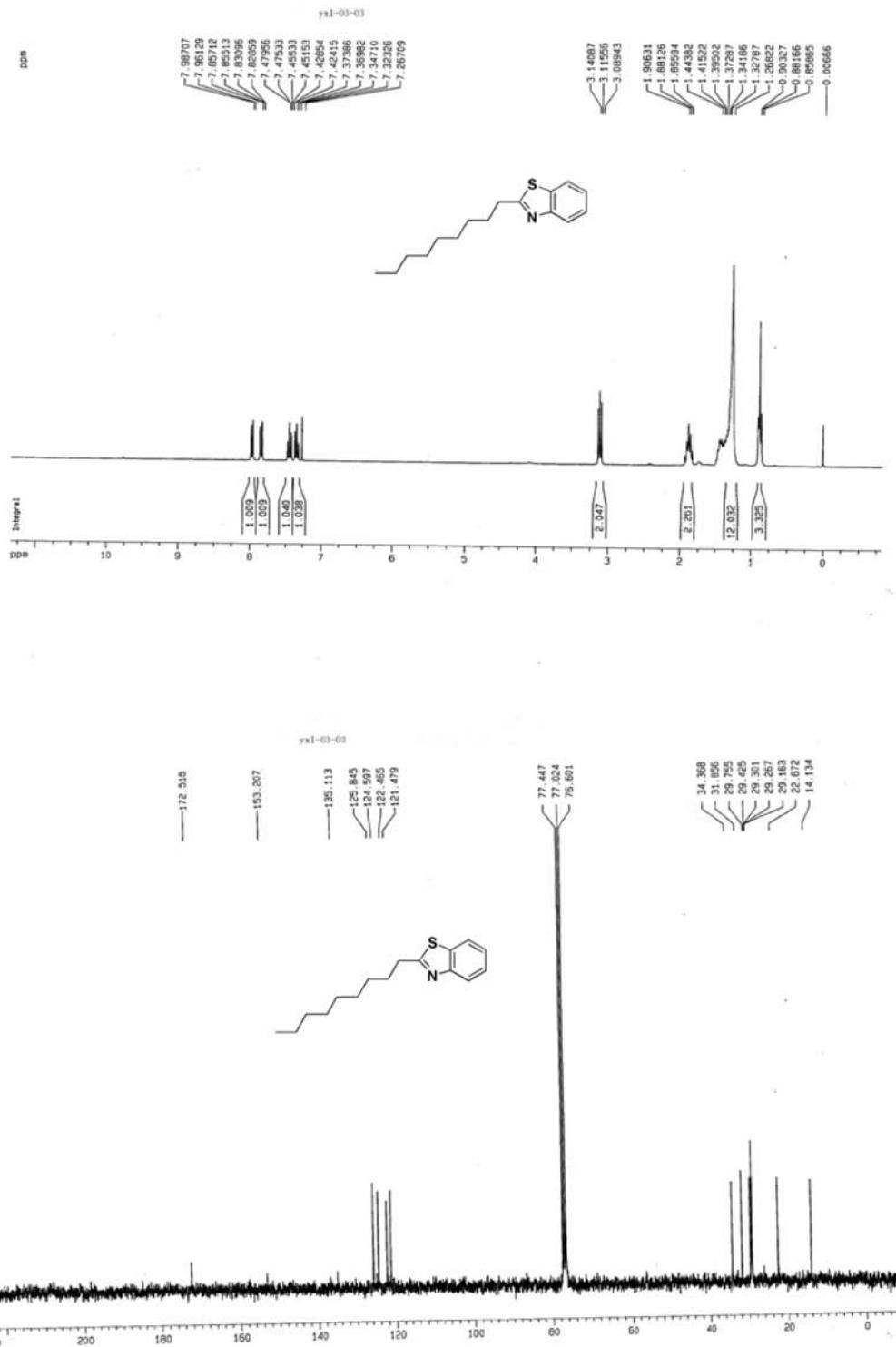


Figure S3. ^1H NMR of **3c** (300 MHz, CDCl_3) and ^{13}C NMR of **3c** (75 MHz, CDCl_3).

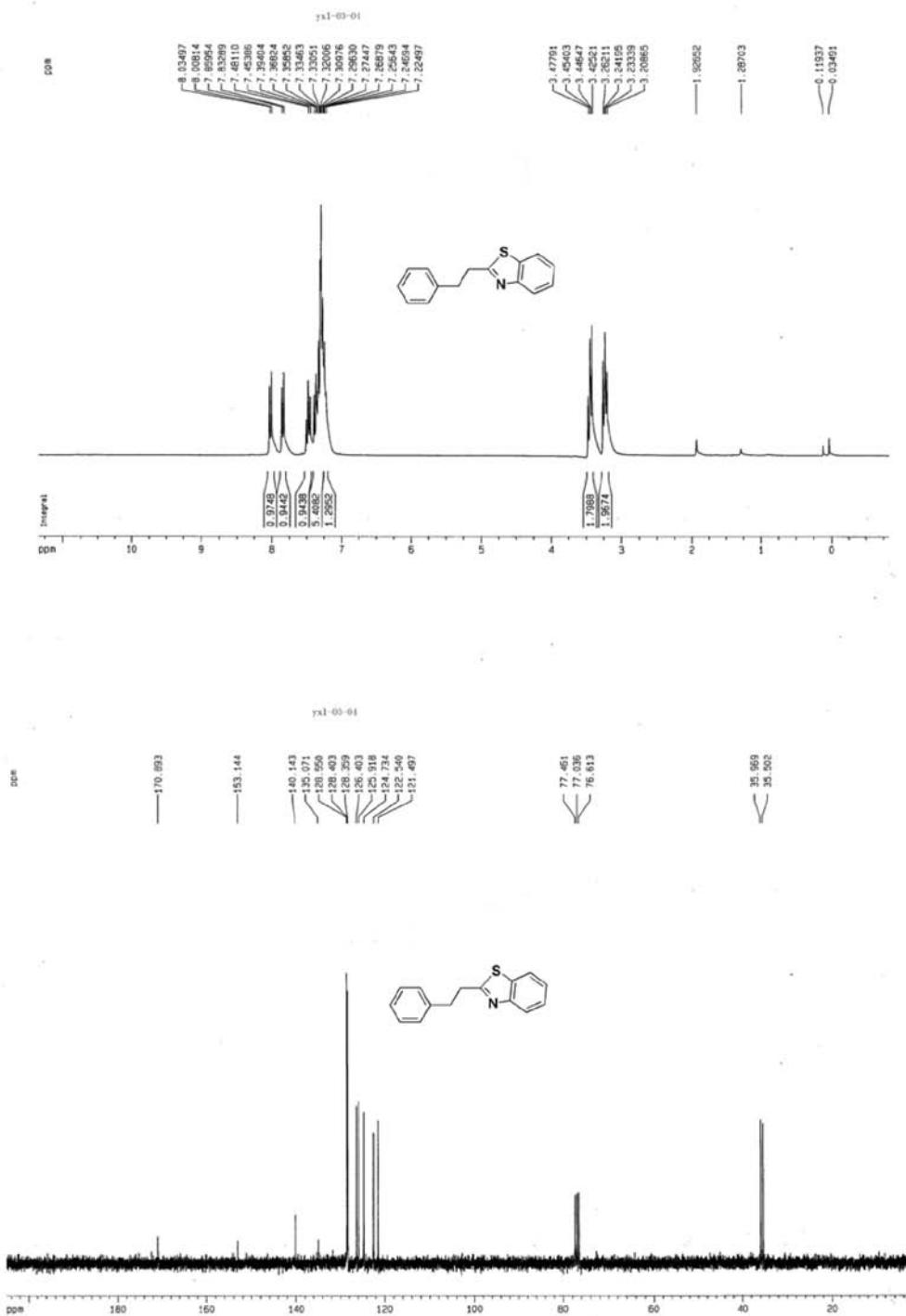


Figure S4. ^1H NMR of **3d** (300 MHz, CDCl_3) and ^{13}C NMR of **3d** (75 MHz, CDCl_3).

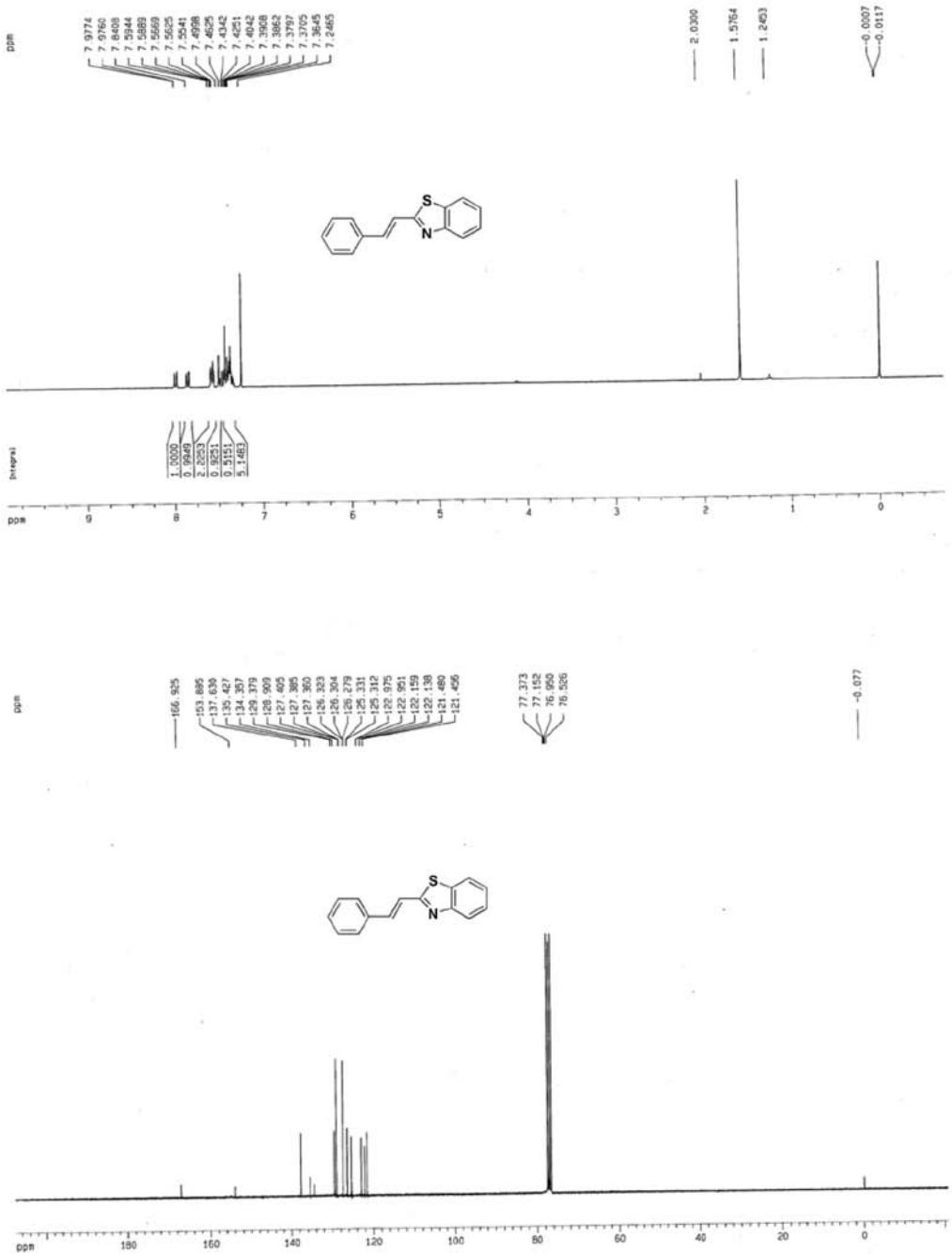


Figure S5. ^1H NMR of **3e** (300 MHz, CDCl_3) and ^{13}C NMR of **3e** (75 MHz, CDCl_3).

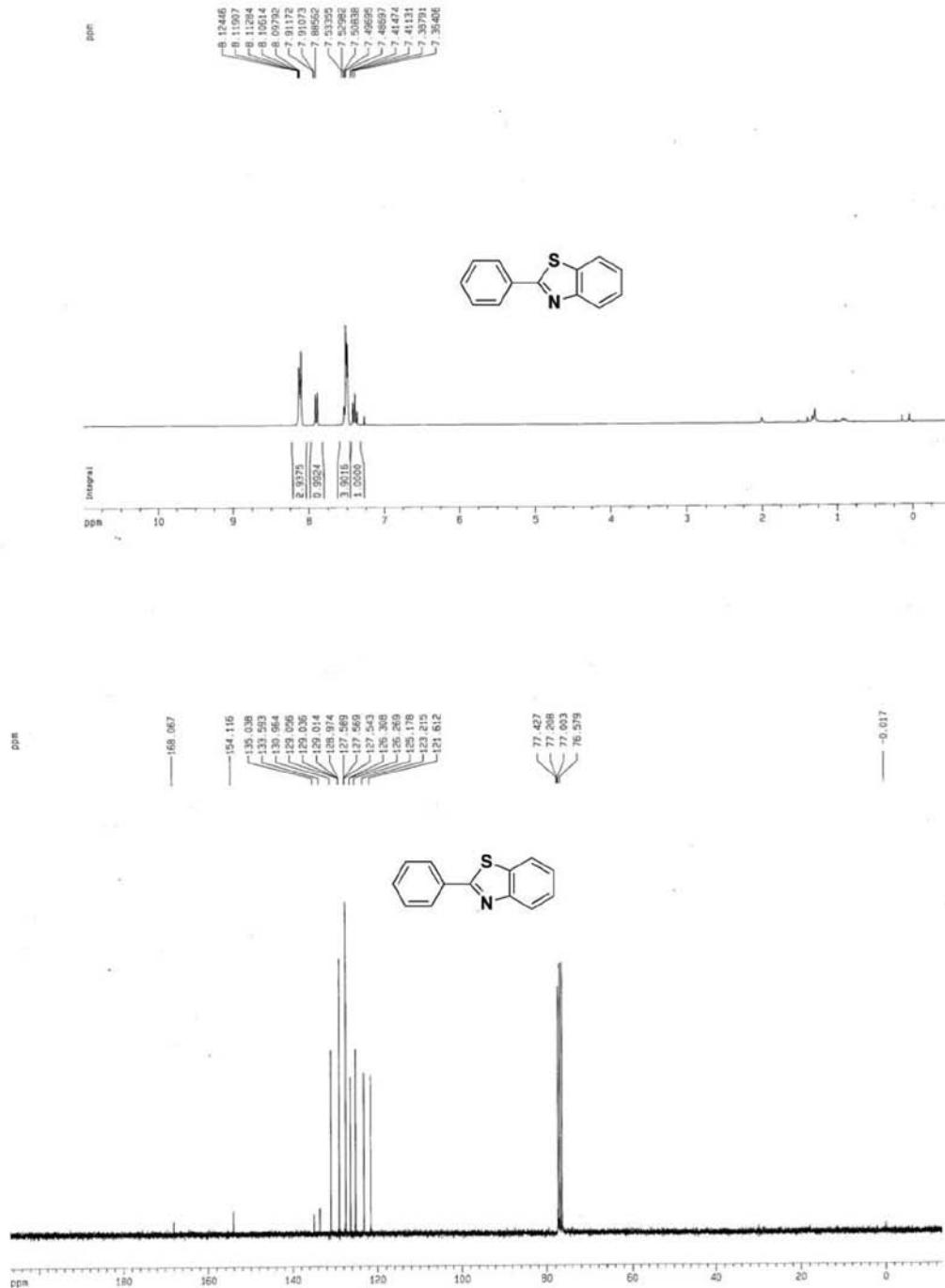


Figure S6. ^1H NMR of **3f**(300 MHz, CDCl_3) and ^{13}C NMR of **3f** (75 MHz, CDCl_3).

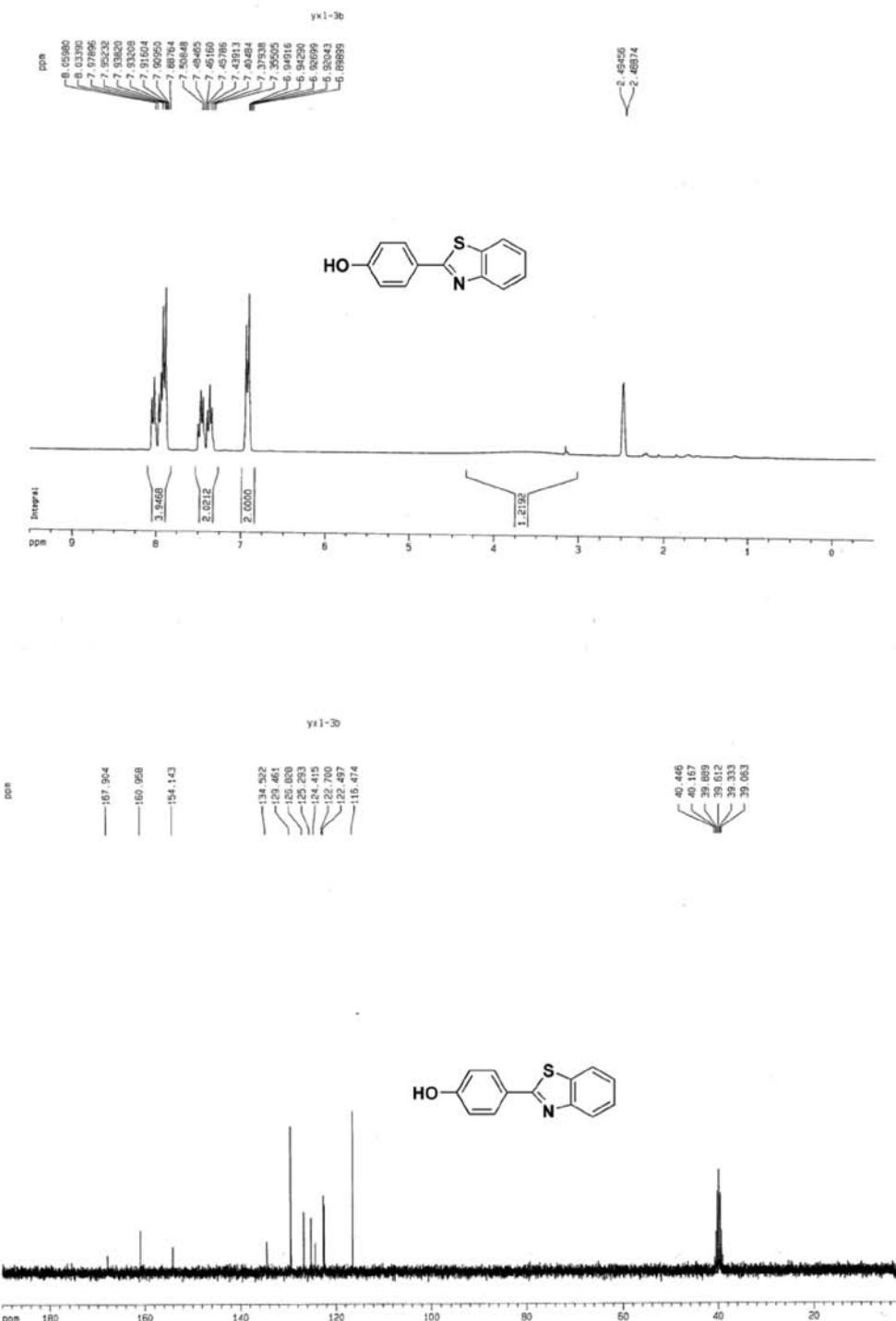


Figure S7. ^1H NMR of **3g** (300 MHz, CDCl_3) and ^{13}C NMR of **3g** (75 MHz, CDCl_3).

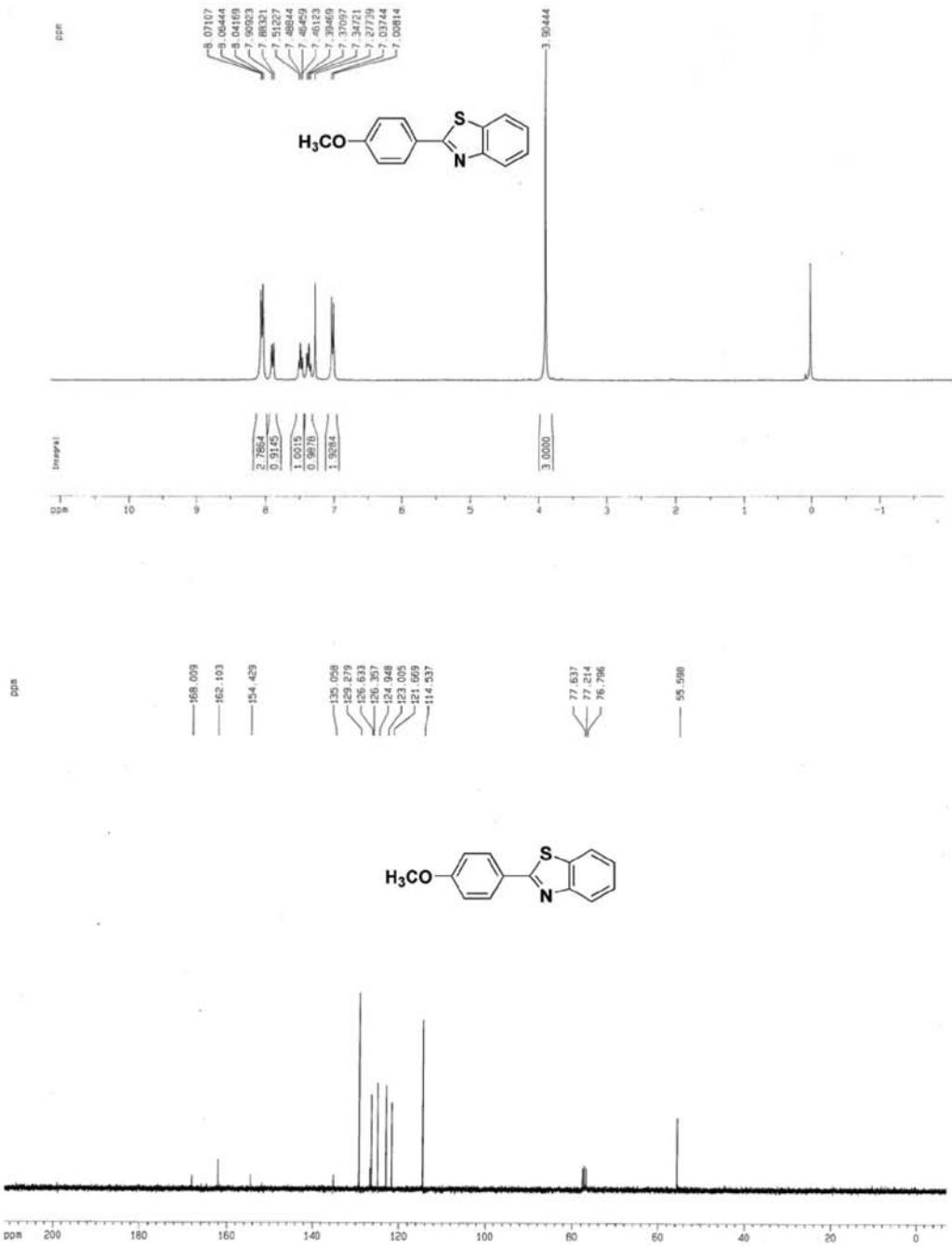


Figure S8. ^1H NMR of **3h** (300 MHz, CDCl_3) and ^{13}C NMR of **3h** (75 MHz, CDCl_3).

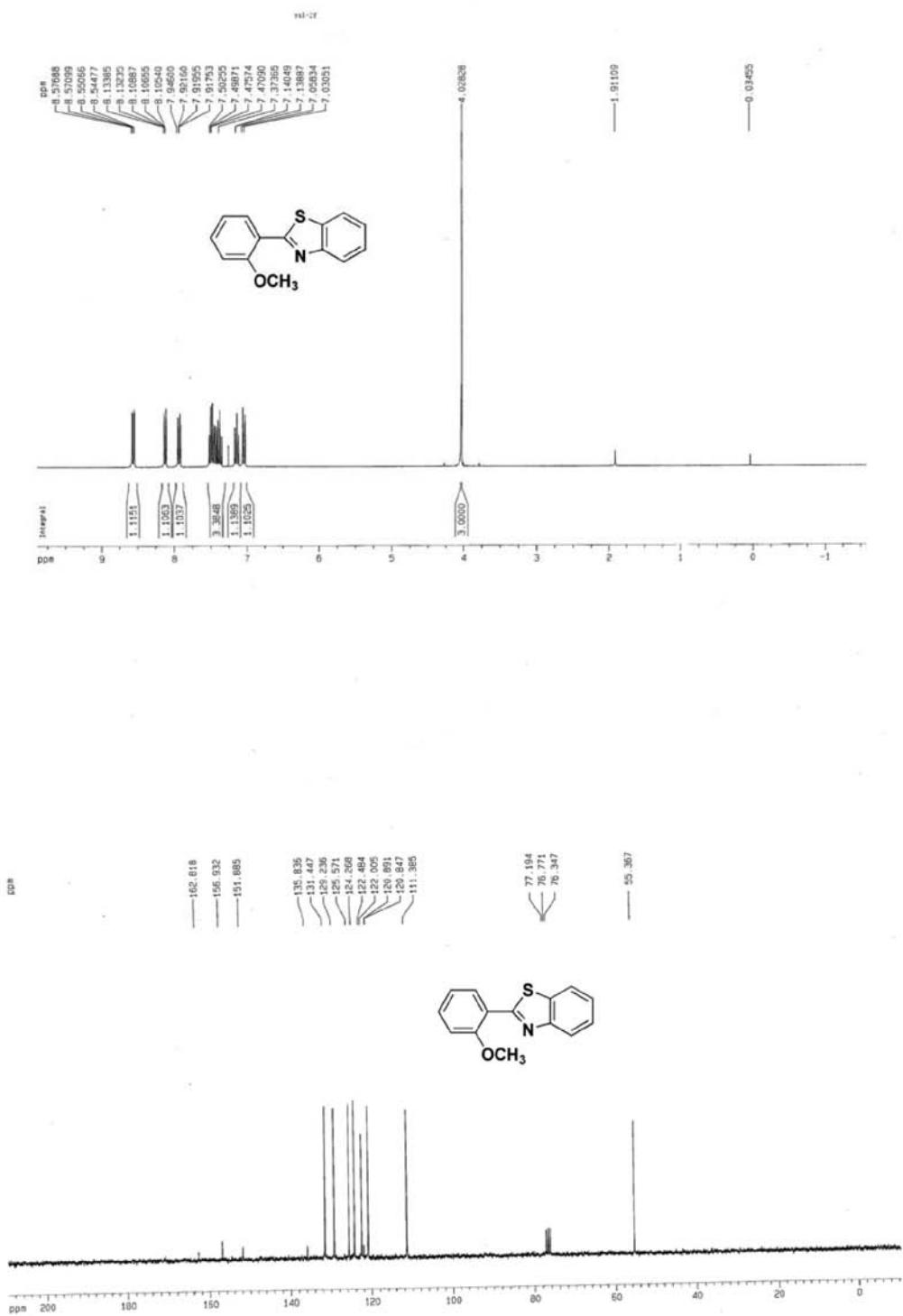


Figure S9. ¹H NMR of **3i** (300 MHz, CDCl₃) and ¹³C NMR of **3i** (75 MHz, CDCl₃).

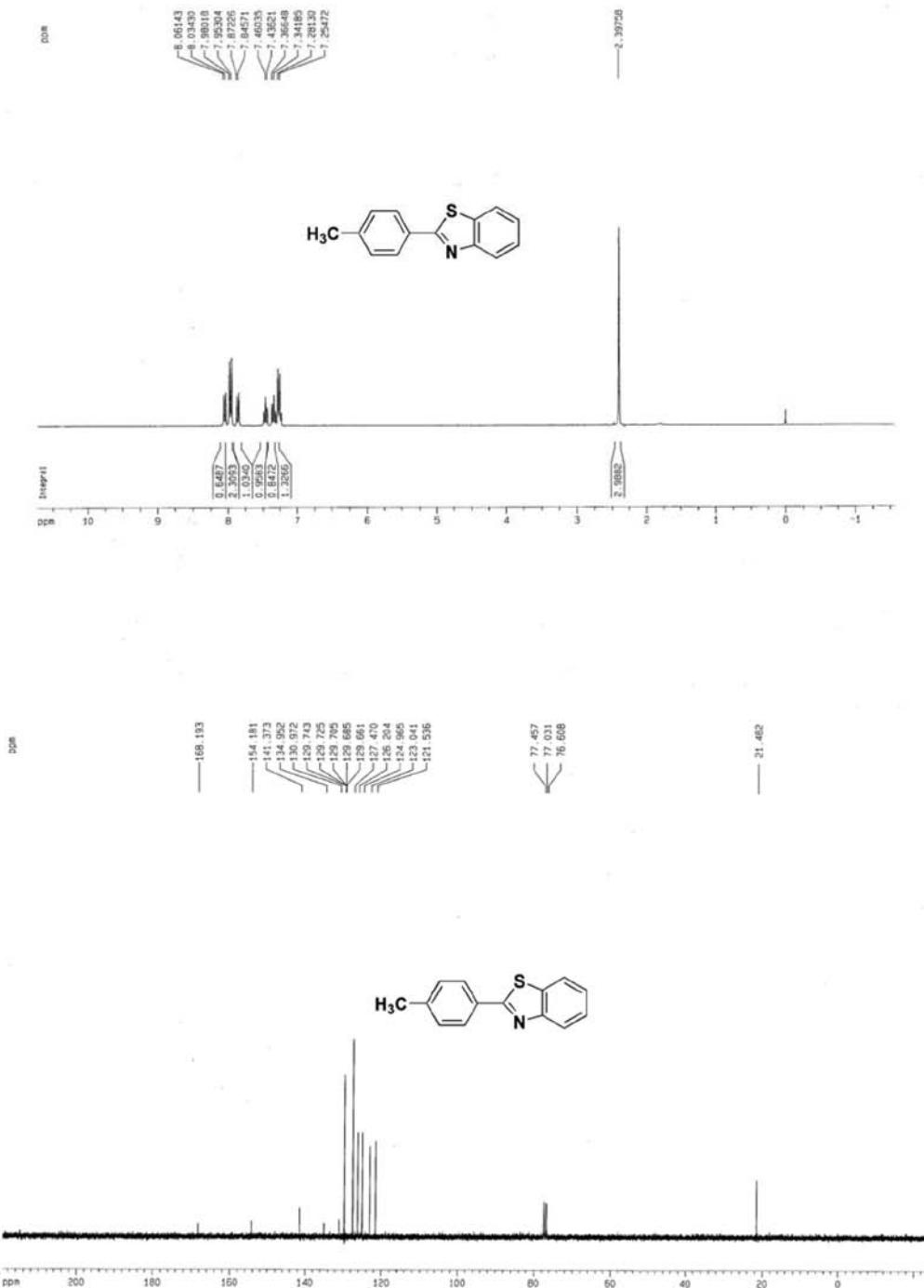


Figure S10. ^1H NMR of **3j** (300 MHz, CDCl_3) and ^{13}C NMR of **3j** (75 MHz, CDCl_3).

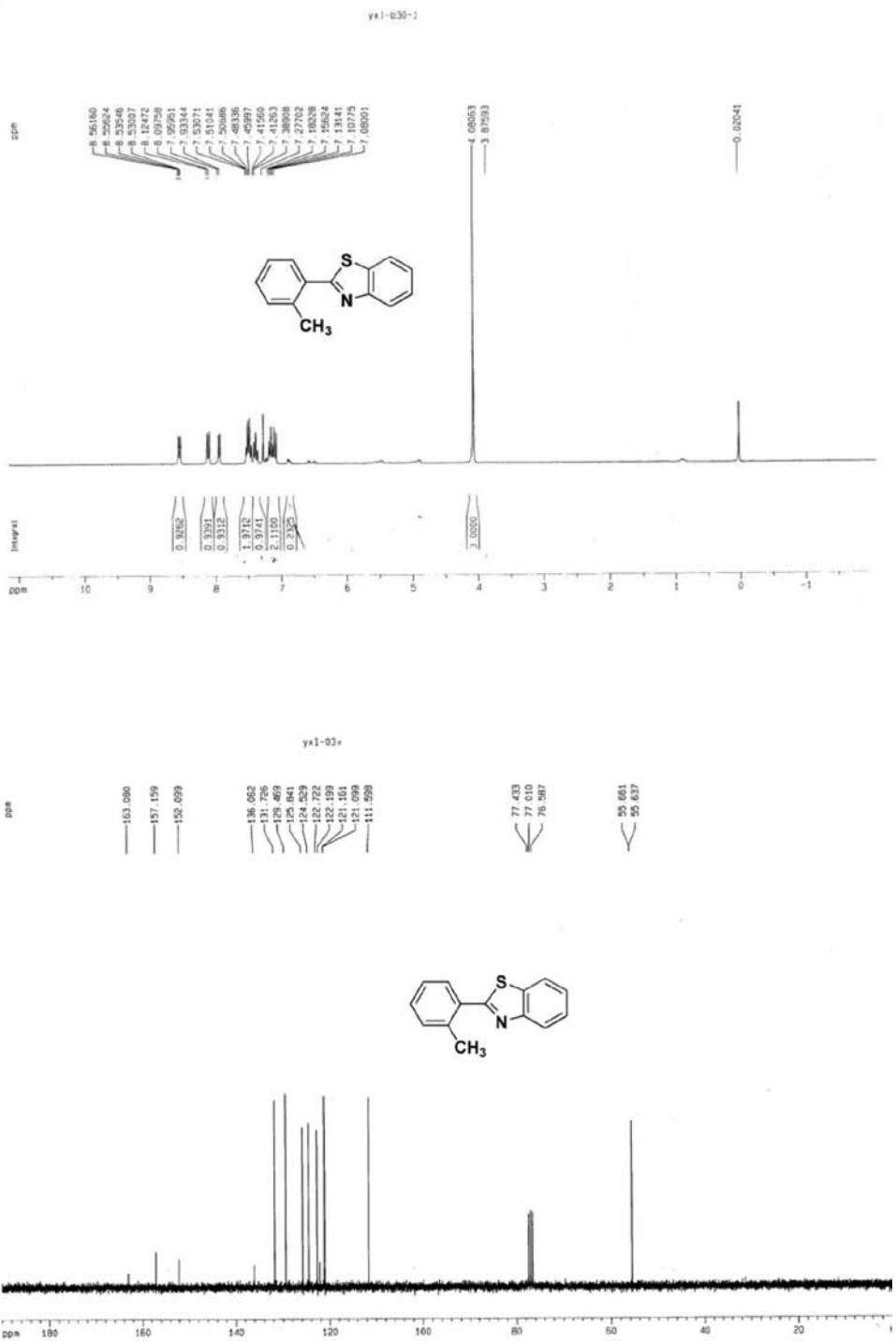


Figure S11. ¹H NMR of **3k** (300 MHz, CDCl₃) and ¹³C NMR of **3k** (75 MHz, CDCl₃).

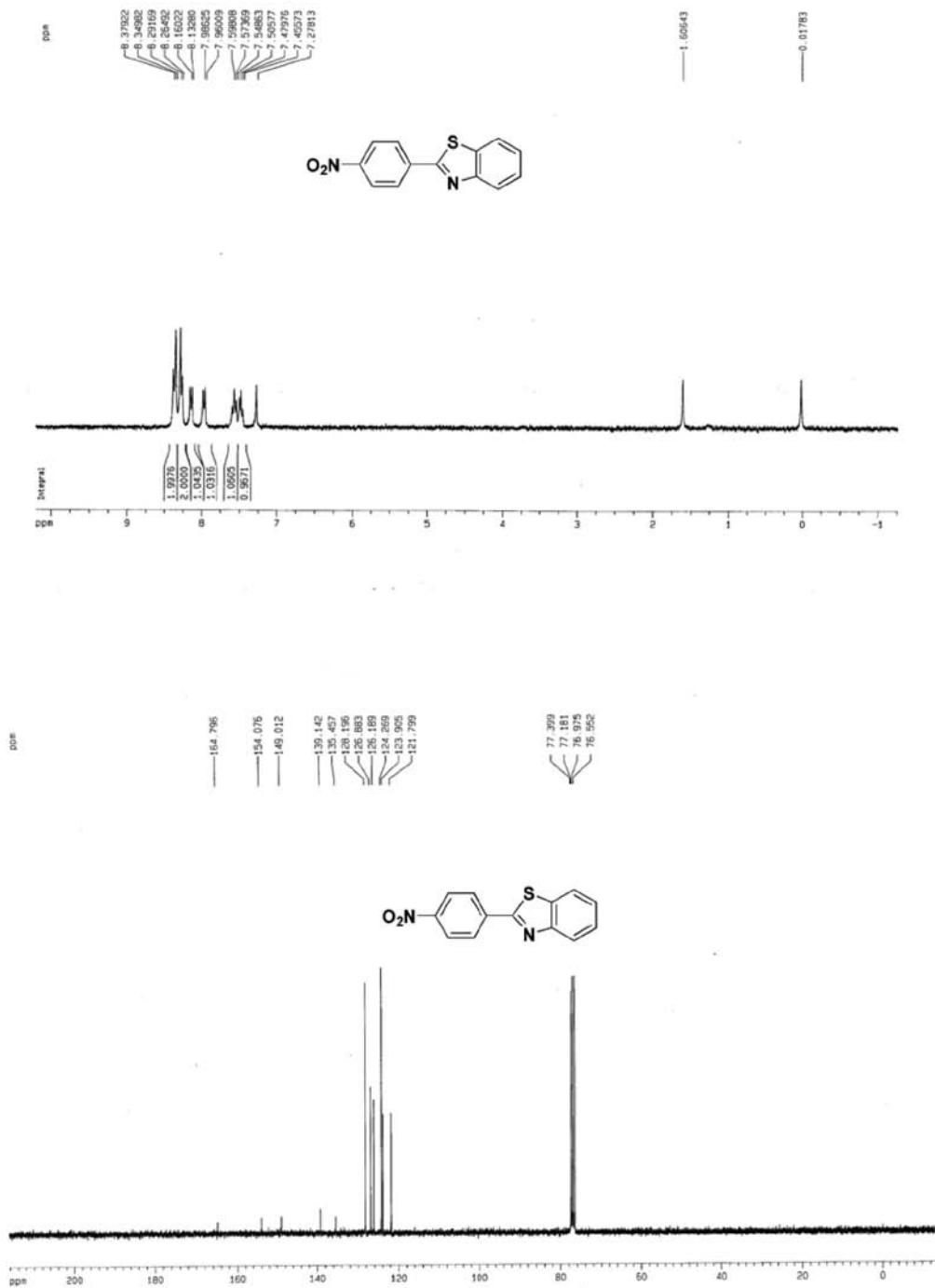


Figure S12. ¹H NMR of **3l** (300 MHz, CDCl₃) and ¹³C NMR of **3l** (75 MHz, CDCl₃).

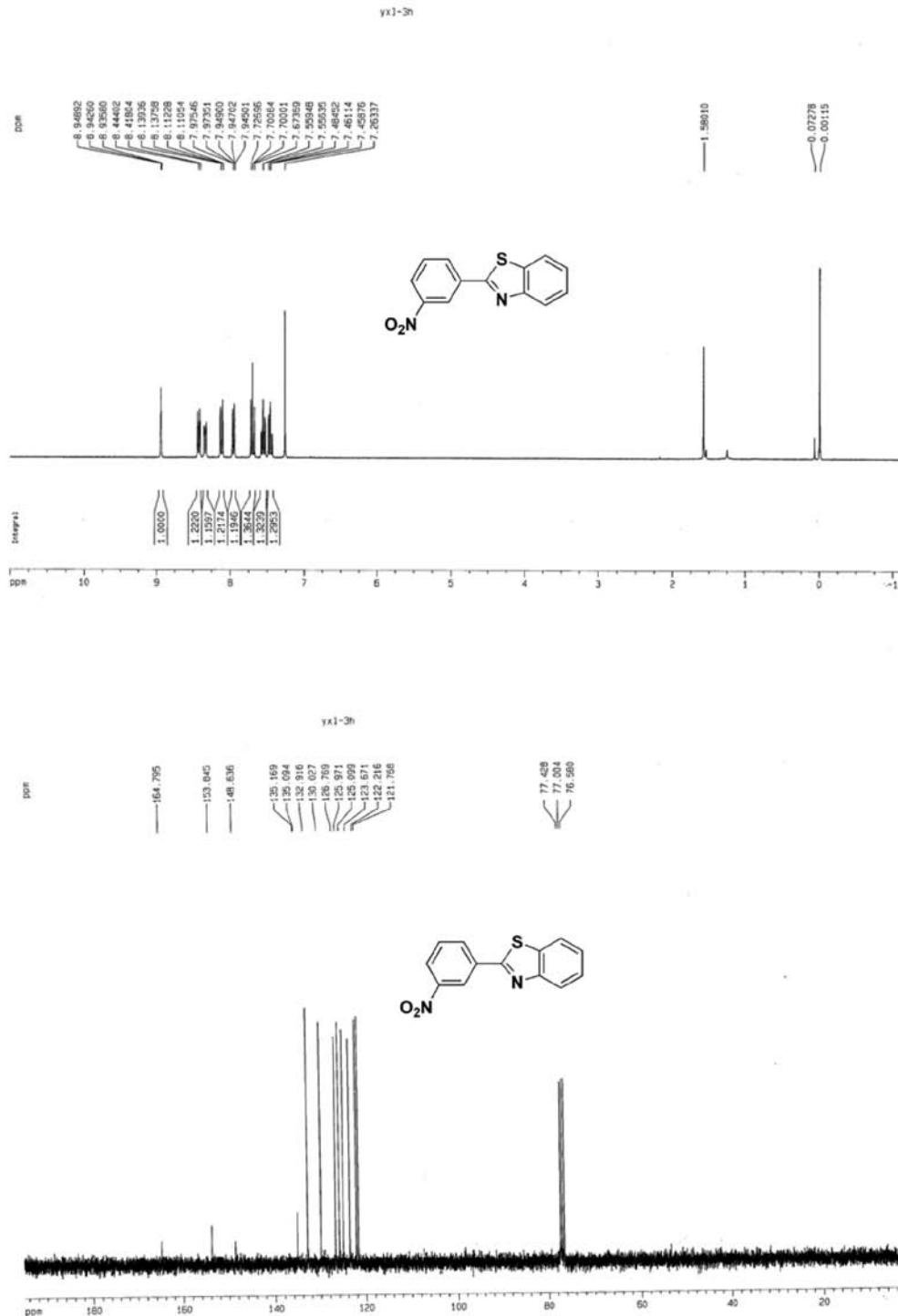


Figure S13. ¹H NMR of **3m** (300 MHz, CDCl₃) and ¹³C NMR of **3m** (75 MHz, CDCl₃).

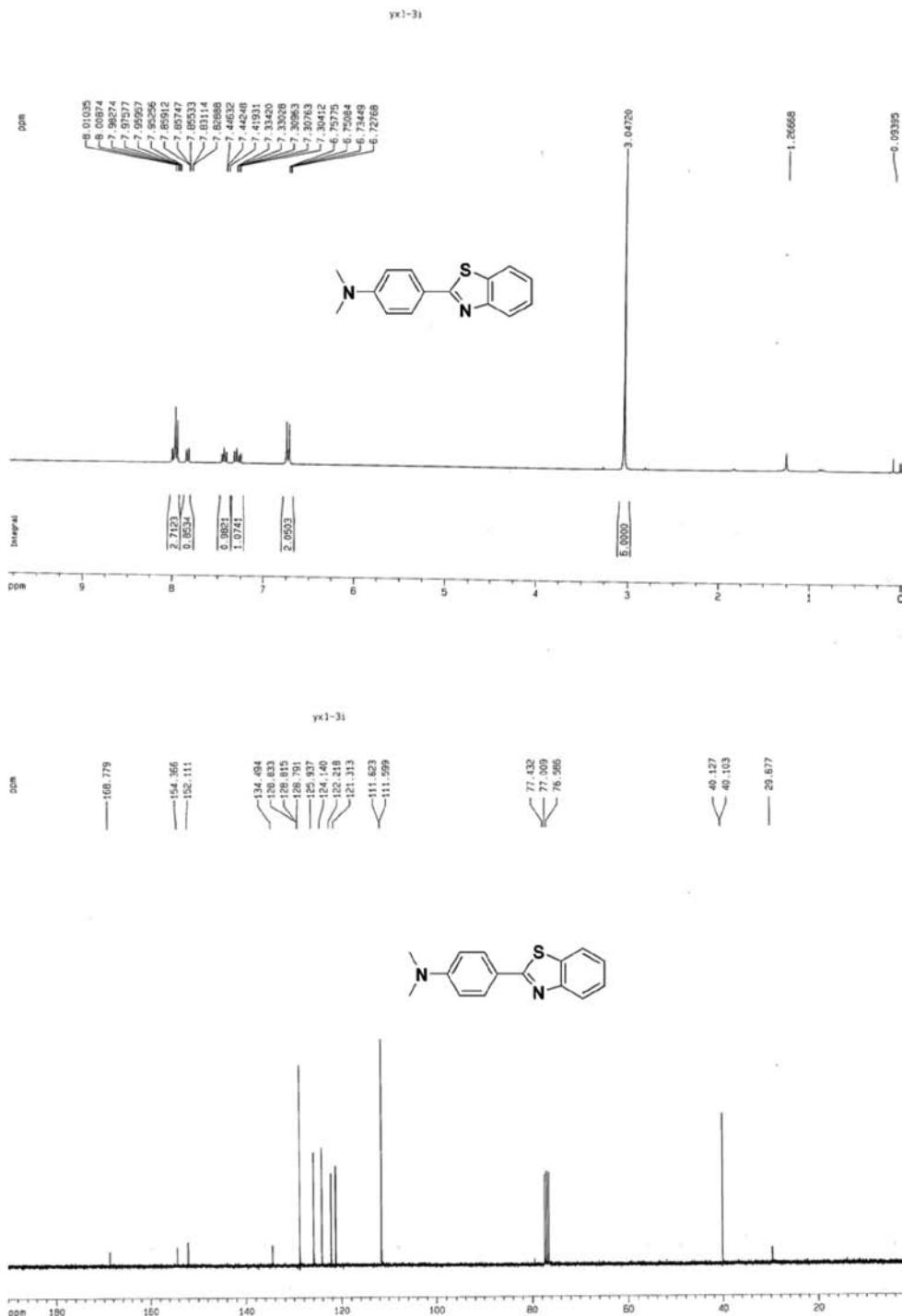


Figure S14. ¹H NMR of **3n** (300 MHz, CDCl₃) and ¹³C NMR of **3n** (75 MHz, CDCl₃).

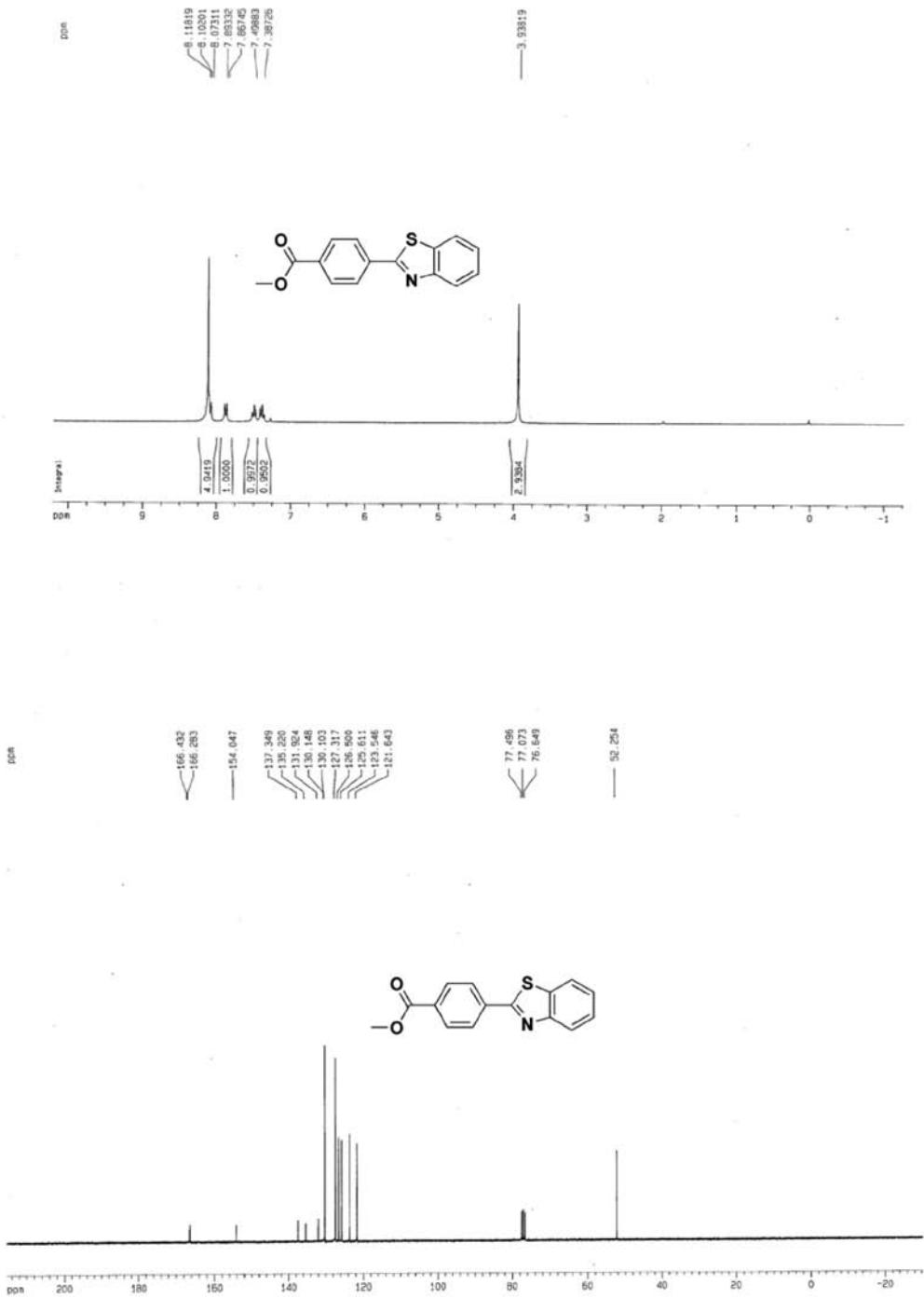


Figure S15. ¹H NMR of **3o** (300 MHz, CDCl₃) and ¹³C NMR of **3o** (75 MHz, CDCl₃).

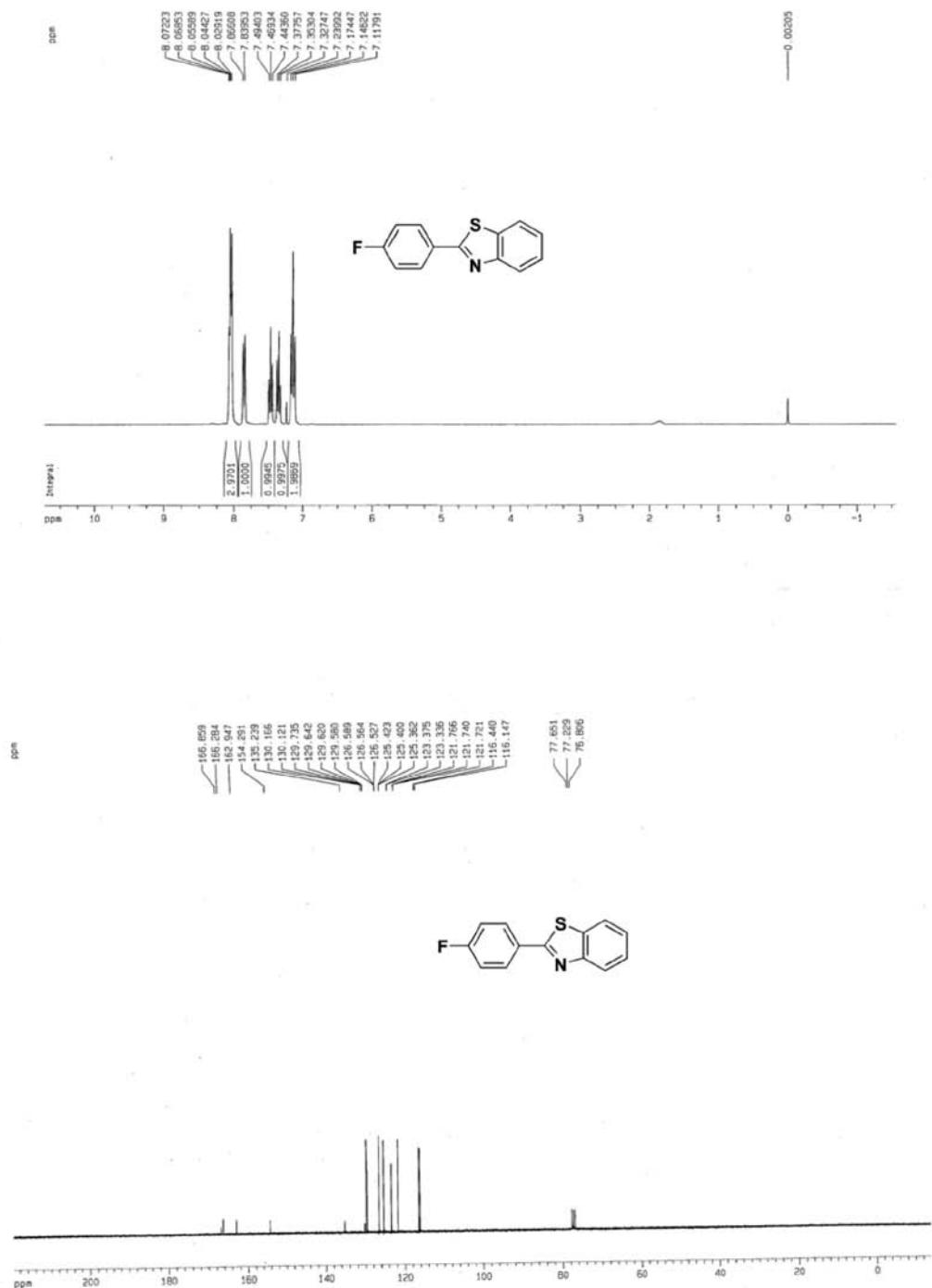


Figure S16. ^1H NMR of **3p** (300 MHz, CDCl_3) and ^{13}C NMR of **3p** (75 MHz, CDCl_3).

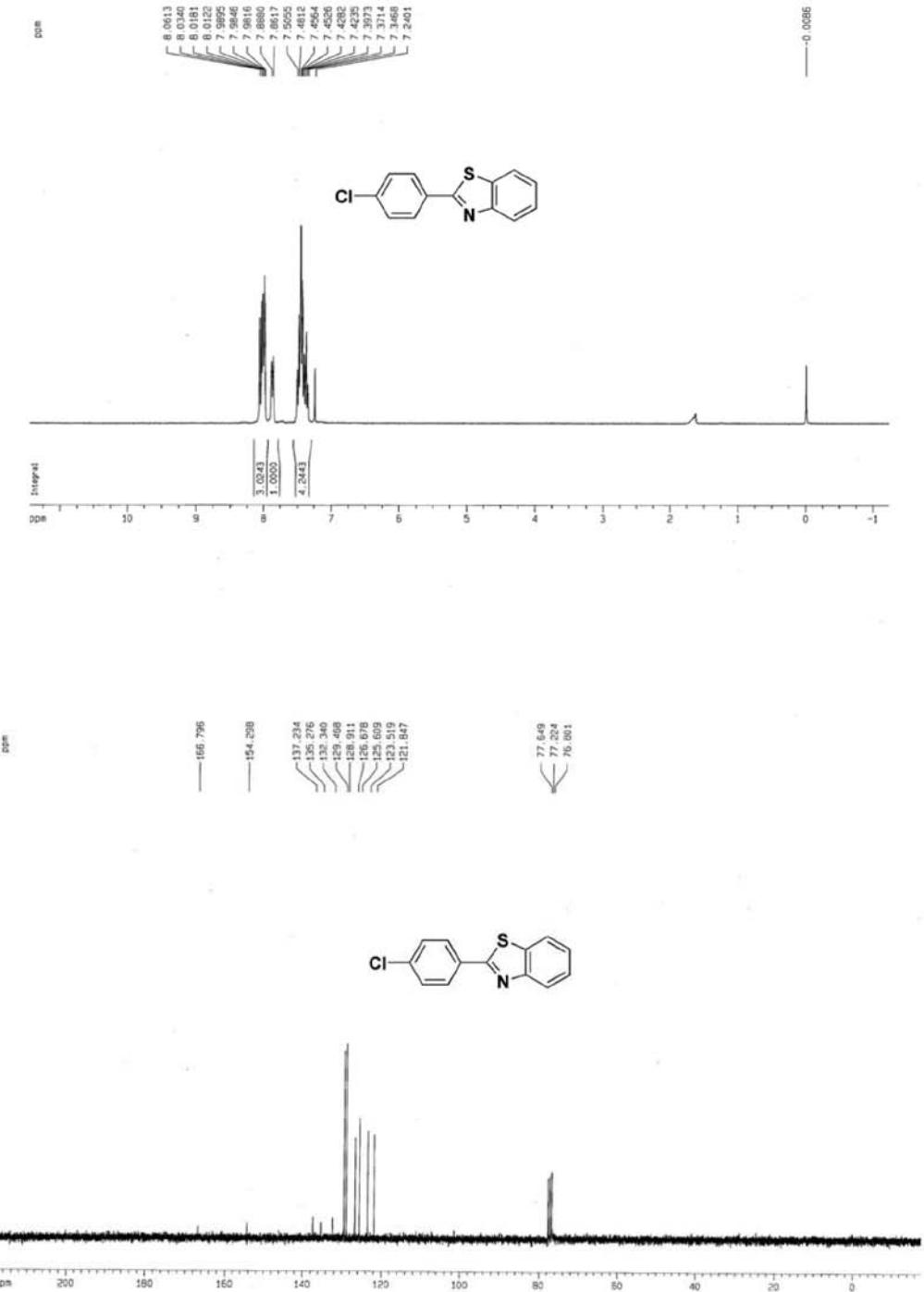


Figure S17. ¹H NMR of **3q**(300 MHz, CDCl₃) and ¹³C NMR of **3q** (75 MHz, CDCl₃).

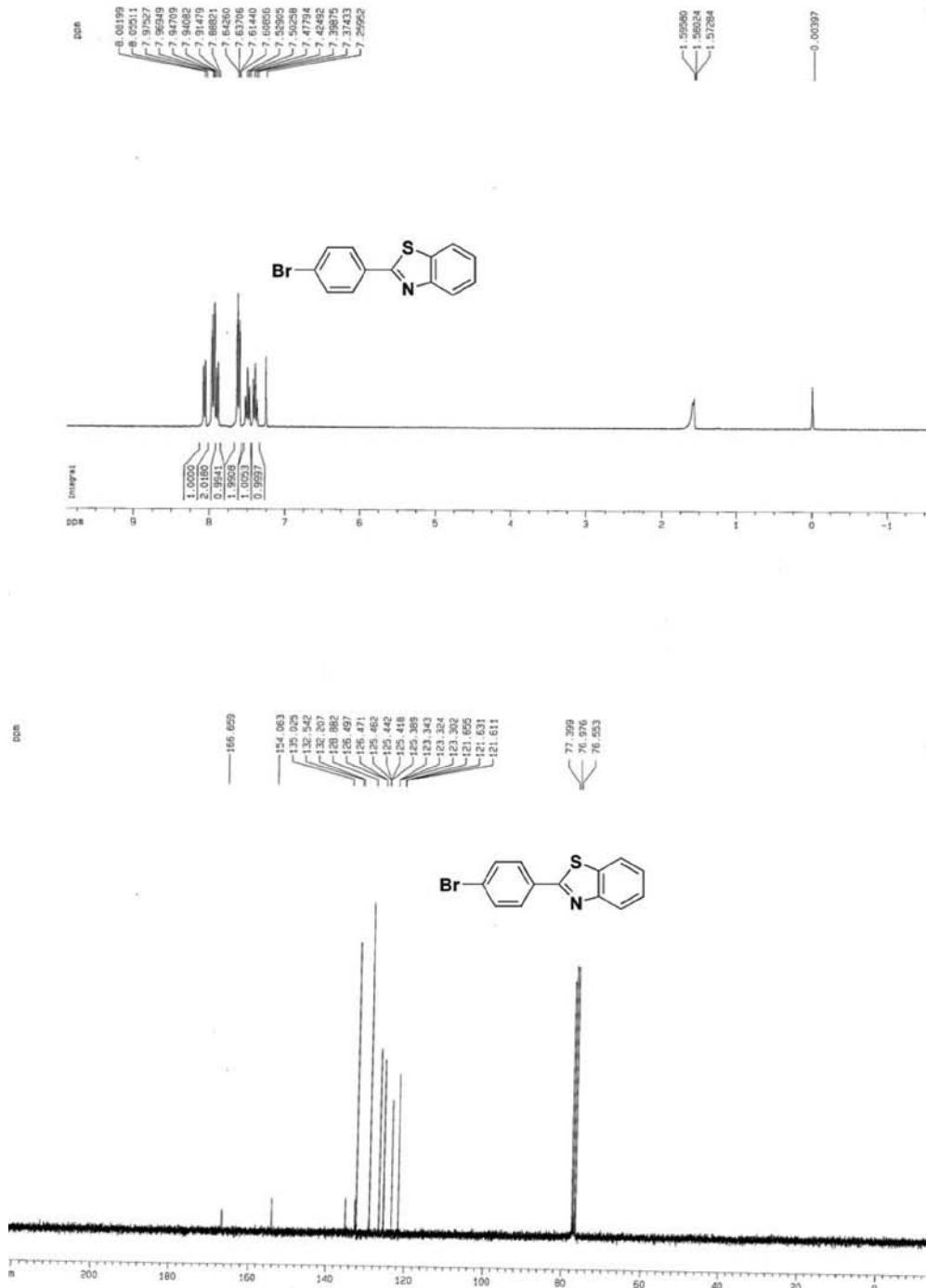


Figure S18. ^1H NMR of **3r** (300 MHz, CDCl_3) and ^{13}C NMR of **3r** (75 MHz, CDCl_3).

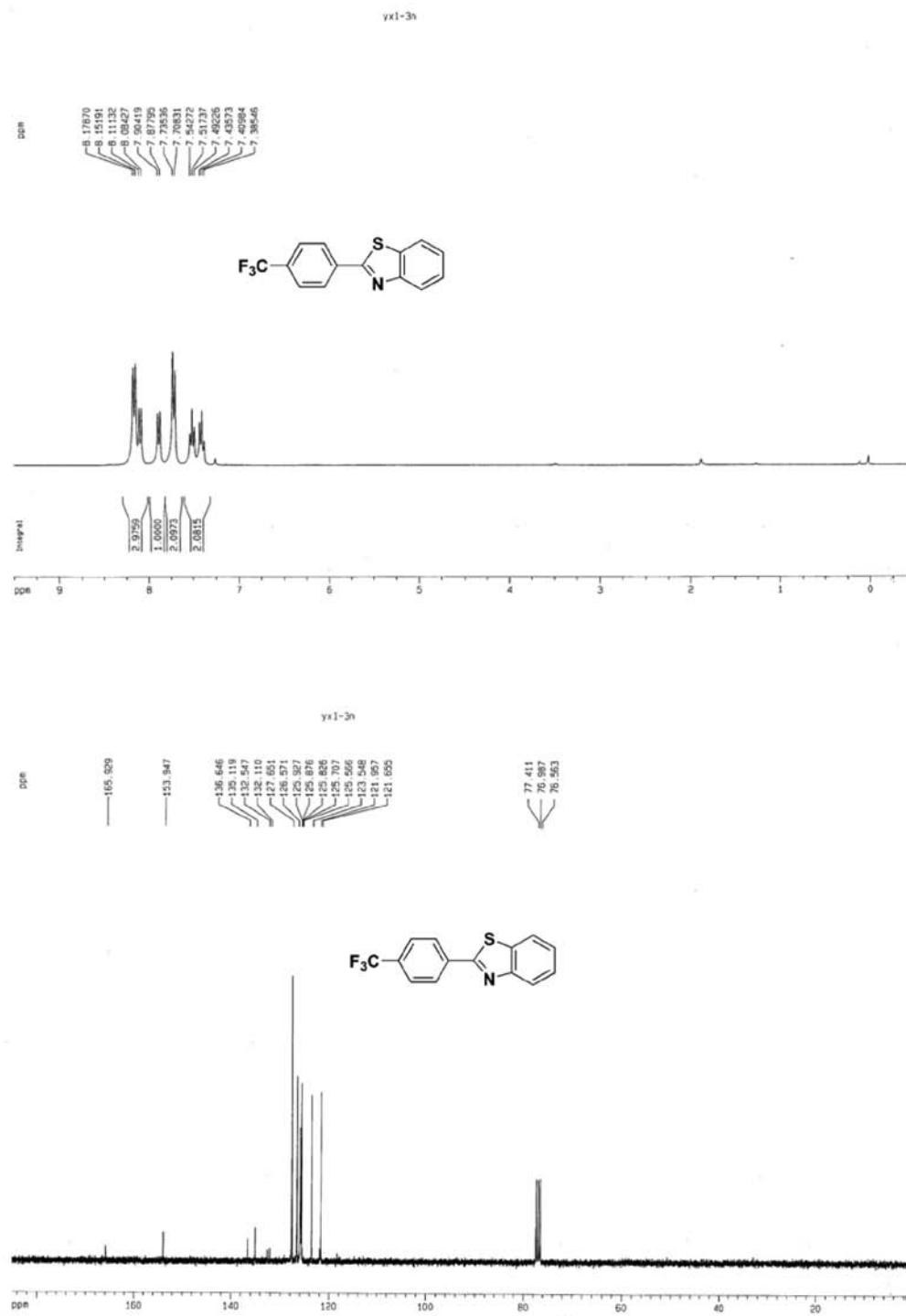


Figure S19. ^1H NMR of **3s** (300 MHz, CDCl_3) and ^{13}C NMR of **3s** (75 MHz, CDCl_3).

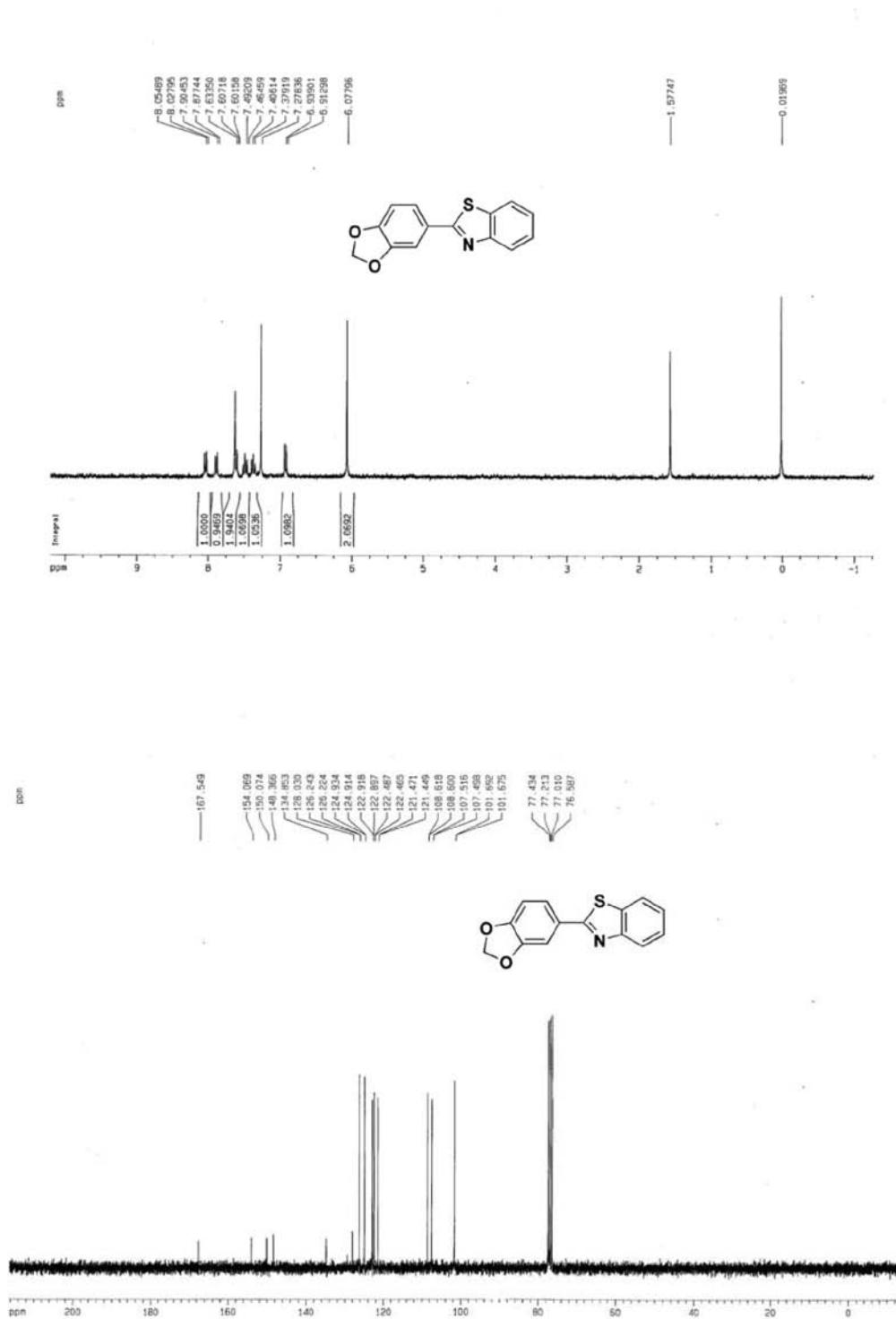


Figure S20. ^1H NMR of **3t** (300 MHz, CDCl_3) and ^{13}C NMR of **3t** (75 MHz, CDCl_3).

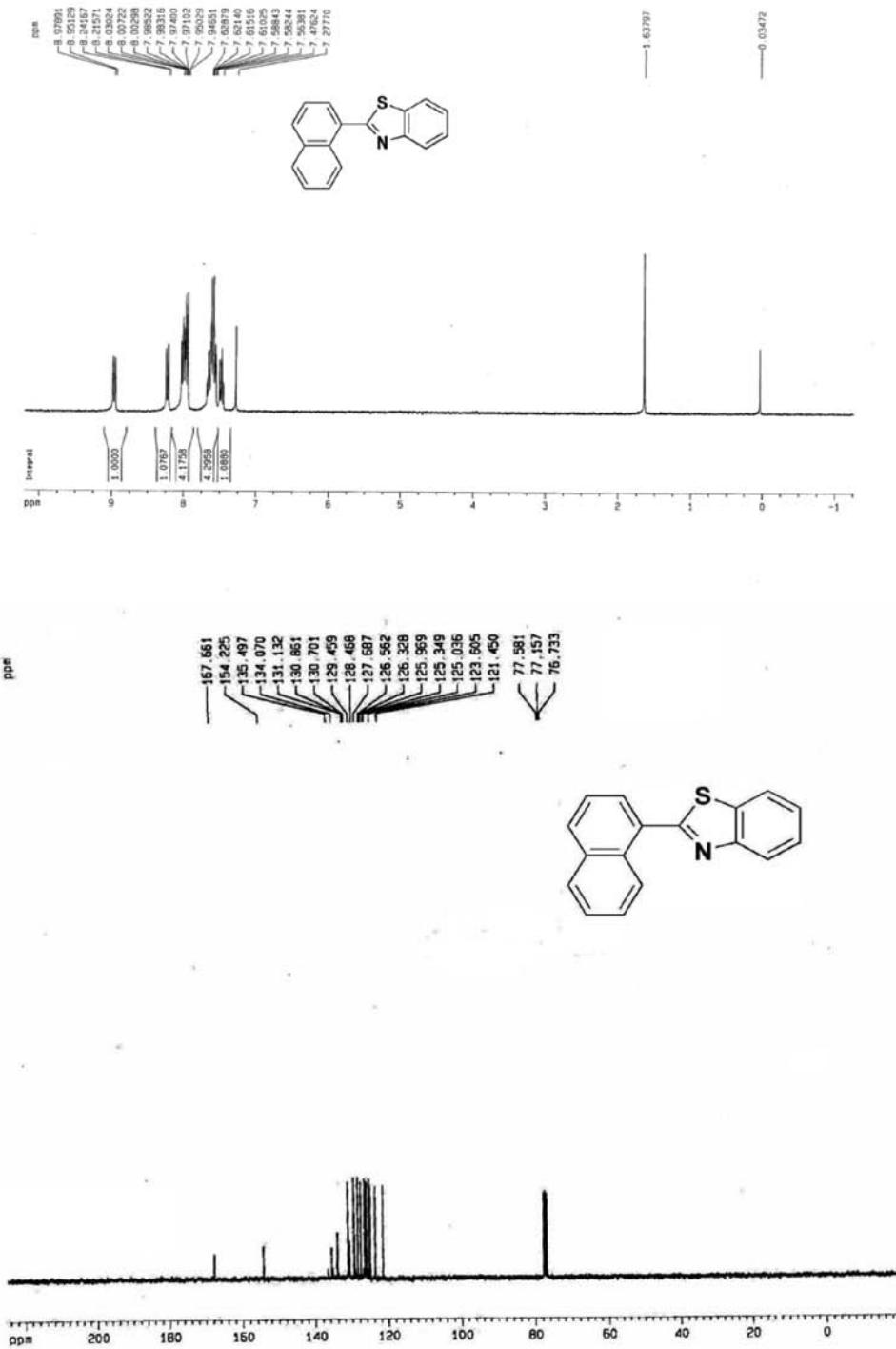


Figure S21. ¹H NMR of **3u** (300 MHz, CDCl₃) and ¹³C NMR of **3u** (75 MHz, CDCl₃).

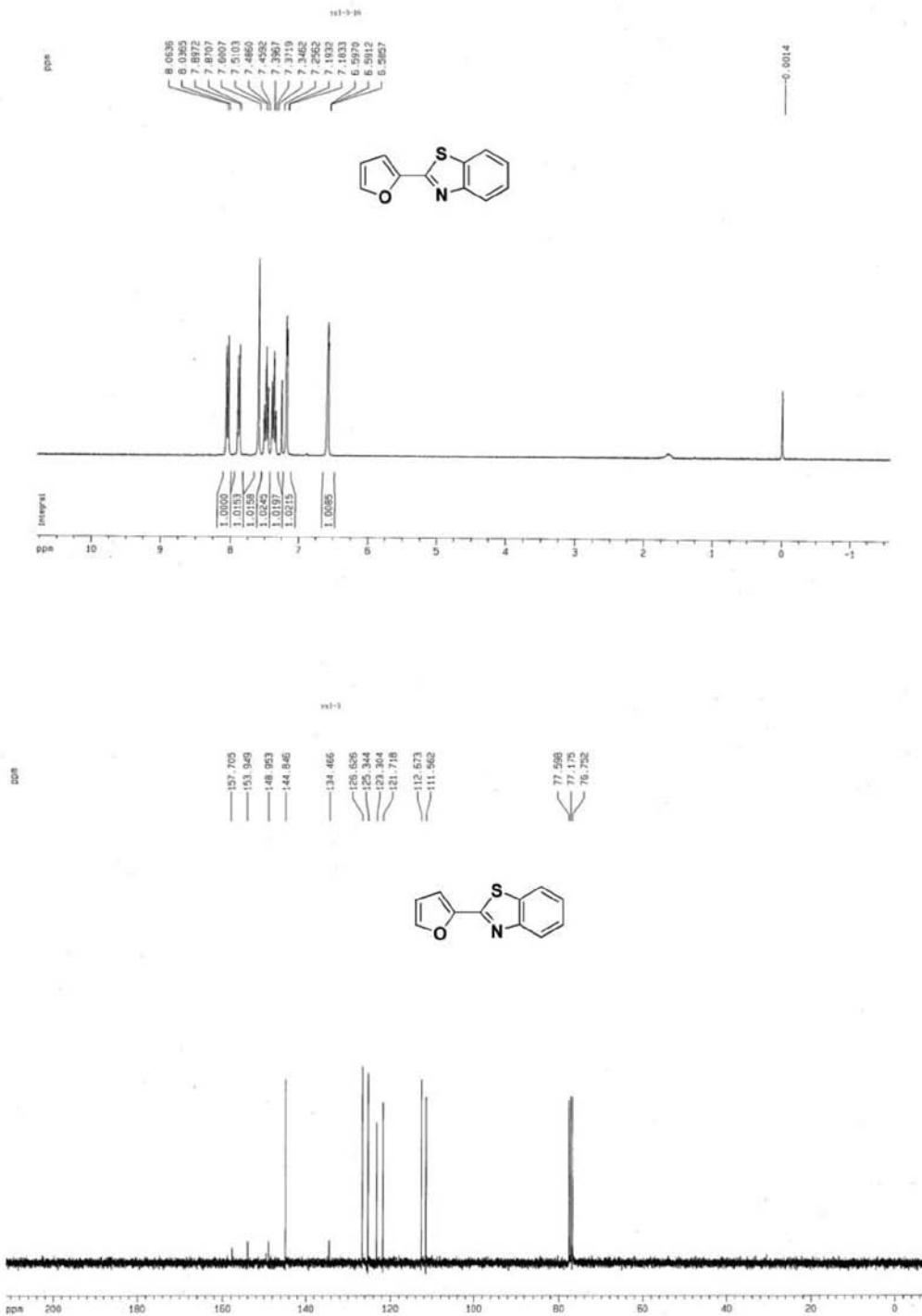


Figure S22. ^1H NMR of **3v** (300 MHz, CDCl_3) and ^{13}C NMR of **3v** (75 MHz, CDCl_3).

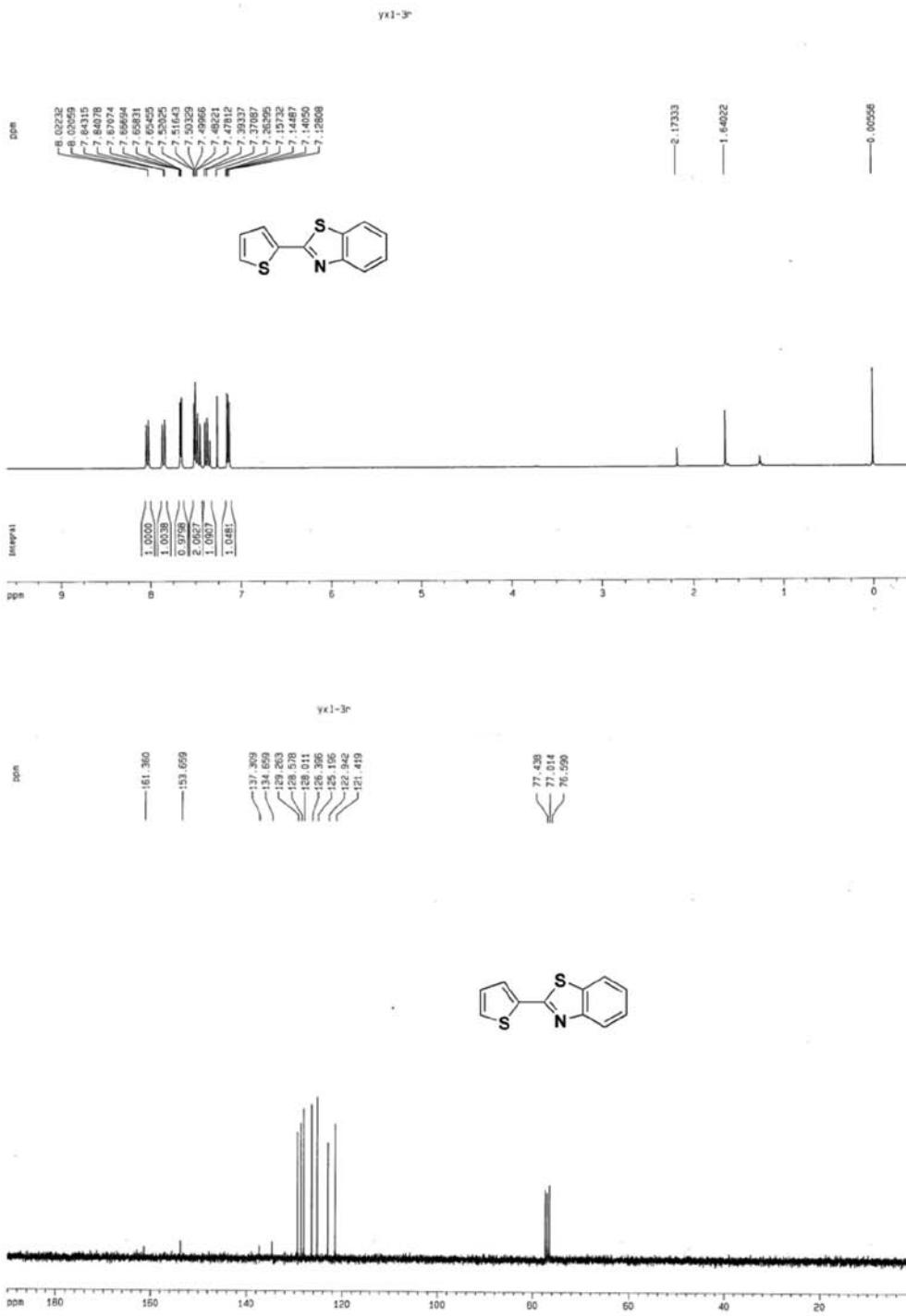


Figure S23. ^1H NMR of **3w** (300 MHz, CDCl_3) and ^{13}C NMR of **3w** (75 MHz, CDCl_3).

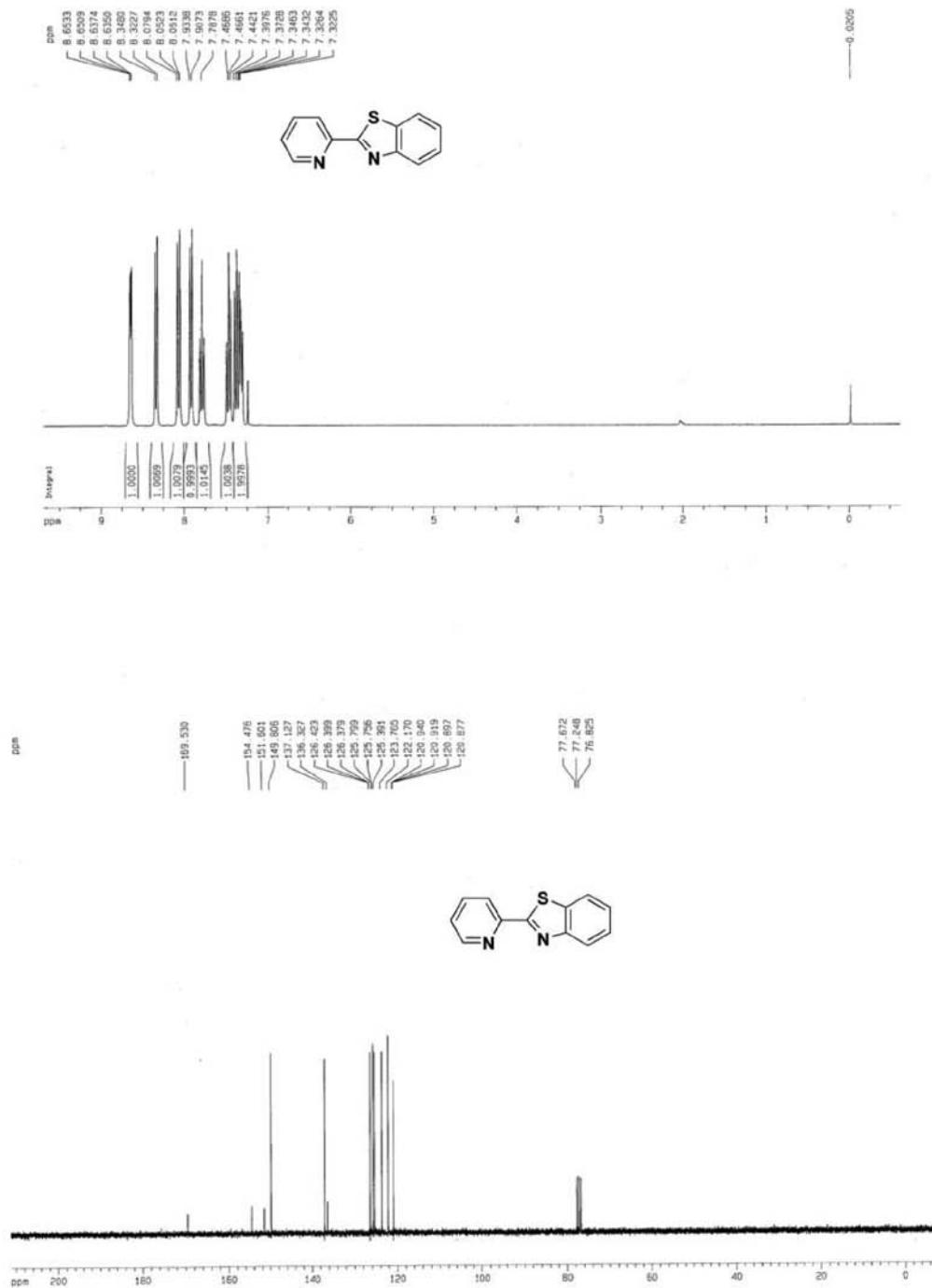


Figure S24. ^1H NMR of **3x** (300 MHz, CDCl_3) and ^{13}C NMR of **3x** (75 MHz, CDCl_3).

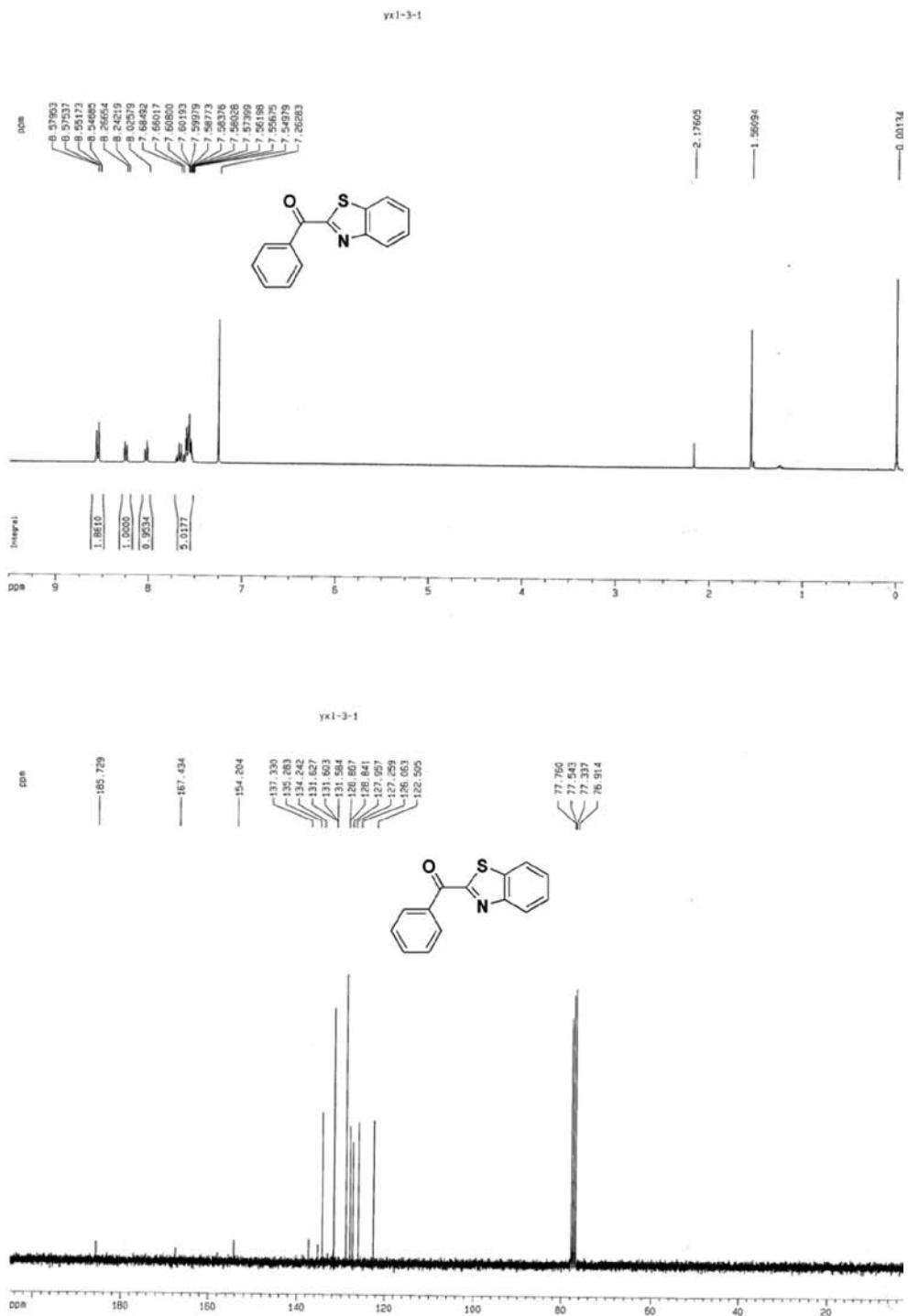


Figure S25. ^1H NMR of **4a** (300 MHz, CDCl_3) and ^{13}C NMR of **4a** (75 MHz, CDCl_3).

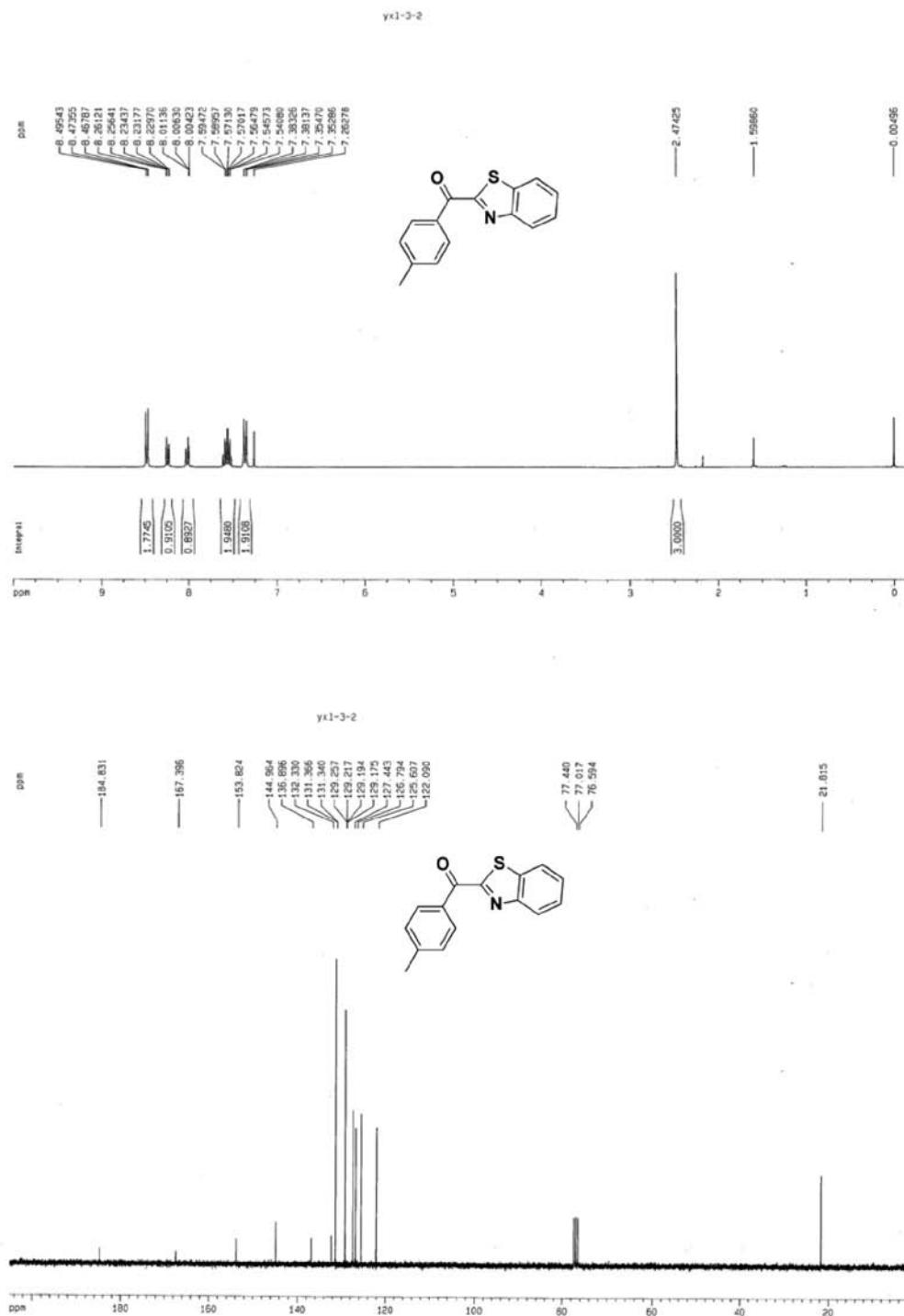


Figure S26. ^1H NMR of **4b** (300 MHz, CDCl_3) and ^{13}C NMR of **4b** (75 MHz, CDCl_3).

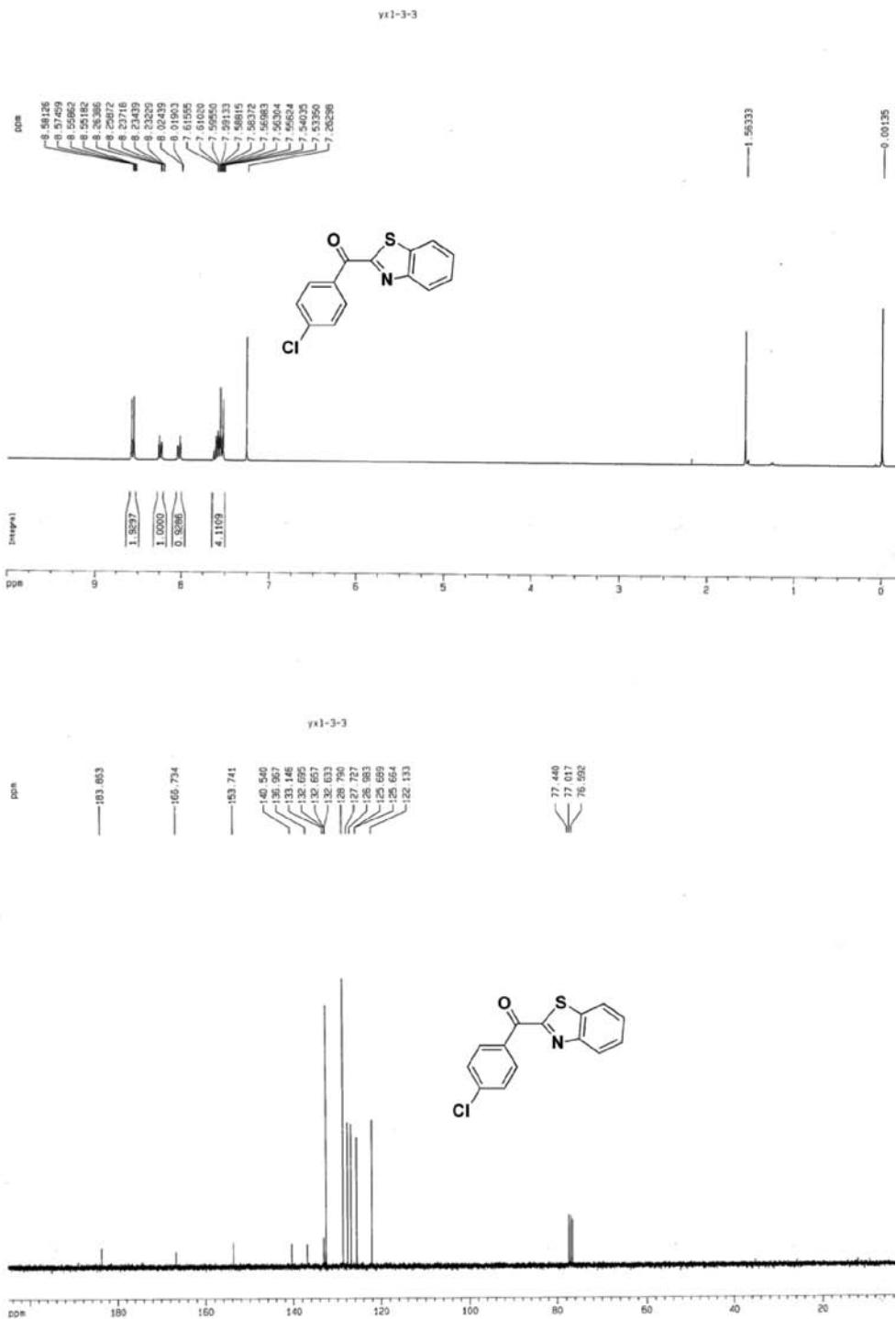


Figure S27. ^1H NMR of **4c** (300 MHz, CDCl_3) and ^{13}C NMR of **4c** (75 MHz, CDCl_3).

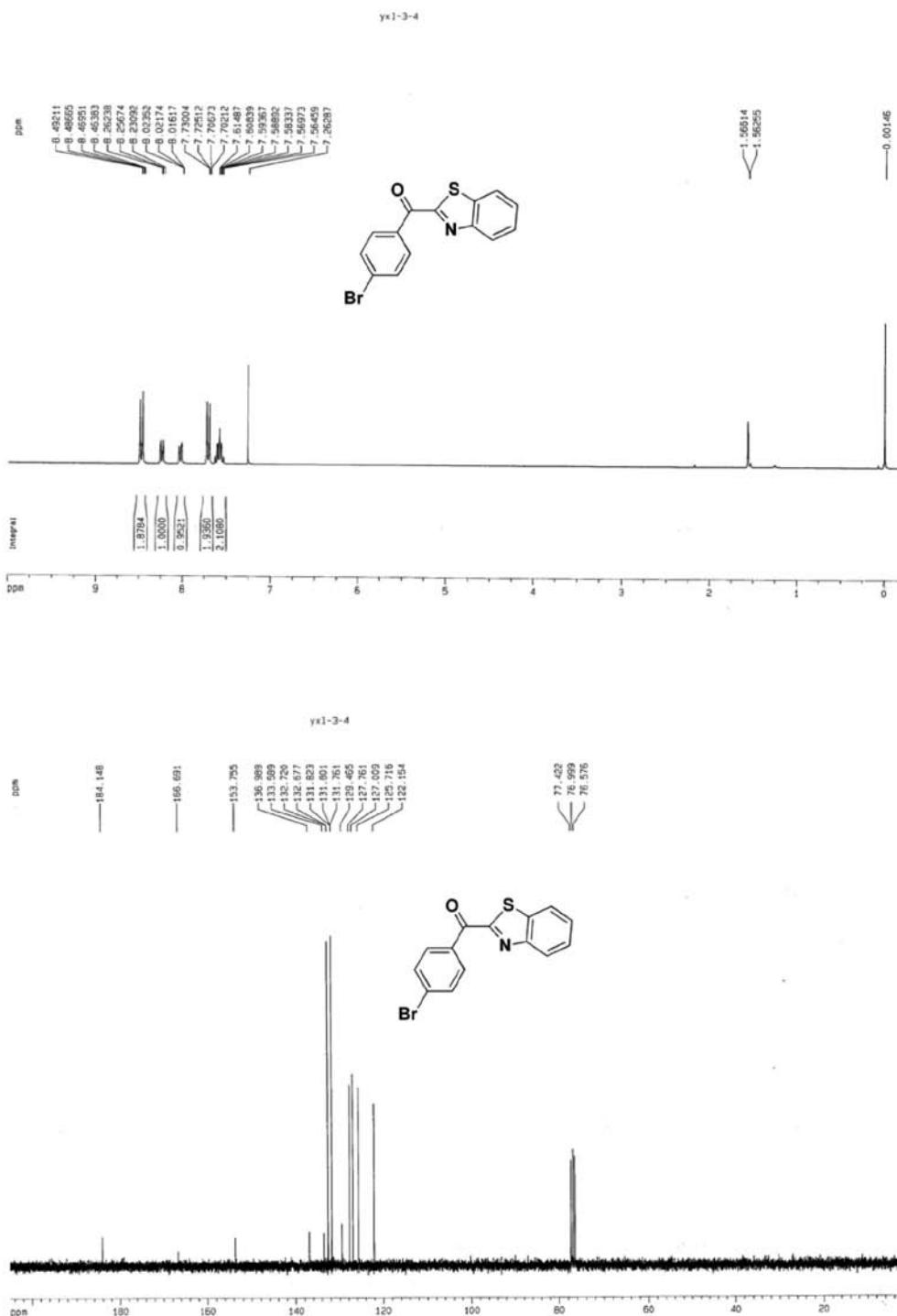


Figure S28. ^1H NMR of **4d** (300 MHz, CDCl_3) and ^{13}C NMR of **4d** (75 MHz, CDCl_3).