

Palladium-Catalyzed C-H Arylation of (Benzo)oxazoles or (Benzo)thiazoles with Aryltrimethylammonium Triflates

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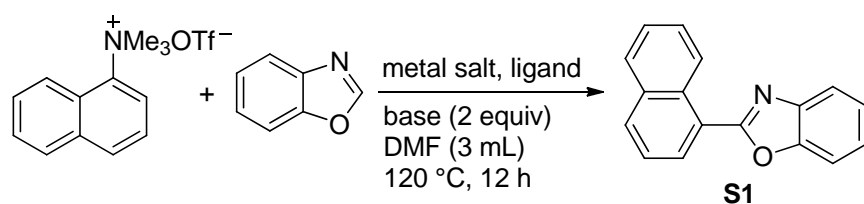
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Table S1. The optimization of reaction conditions^a

| entry | metal salt (mol %) | ligand (mol %) | base | yield (%) ^b |
|-------------------|--|---|---------------------------------|------------------------|
| 1 | Ni(COD) ₂ (10) | dcype (10) | NaOtBu | trace |
| 2 | Ni(COD) ₂ (10) | PCy ₃ (20) | NaOtBu | 7 |
| 3 | Ni(COD) ₂ (10) | IPr·HCl (20) | NaOtBu | 24 |
| 4 | Pd(OAc) ₂ (10) | dcype (10) | NaOtBu | 54 |
| 5 | Pd(OAc) ₂ (10) | dppm (10) | NaOtBu | trace |
| 6 | Pd(OAc) ₂ (10) | dppe (10) | NaOtBu | 36 |
| 7 | Pd(OAc) ₂ (10) | dppb (10) | NaOtBu | 58 |
| 8 | Pd(OAc) ₂ (10) | dppp (10) | NaOtBu | 15 |
| 9 | Pd(OAc) ₂ (10) | Xantphos (10) | NaOtBu | 10 |
| 10 | Pd(OAc) ₂ (10) | DPEphos (10) | NaOtBu | 32 |
| 11 | Pd(OAc) ₂ (10) | Xphos (20) | NaOtBu | 24 |
| 12 | Pd(OAc) ₂ (10) | P(<i>t</i> Bu) ₃ ·HBF ₄ (20) | NaOtBu | 75 |
| 13 | Pd(OAc) ₂ (10) | PCy ₃ (20) | NaOtBu | 91 |
| 14 | Pd(OAc) ₂ (10) | IPr·HCl (20) | NaOtBu | 92 |
| 15 | Pd(OAc) ₂ (10) | IMes·HCl (20) | NaOtBu | 33 |
| 16 | PdCl ₂ (10) | PCy ₃ (20) | NaOtBu | 80 |
| 17 | Pd ₂ (dba) ₃ (5) | PCy ₃ (20) | NaOtBu | 95 |
| 18 | [Pd(π-allyl)Cl] ₂ (5) | PCy ₃ (20) | NaOtBu | 95 |
| 19 | [Pd(π-allyl)Cl] ₂ (5) | PCy ₃ (20) | LiOtBu | 90 |
| 20 | [Pd(π-allyl)Cl] ₂ (5) | PCy ₃ (20) | Cs ₂ CO ₃ | trace |
| 21 | [Pd(π-allyl)Cl] ₂ (5) | PCy ₃ (20) | K ₃ PO ₄ | 42 |
| 22 ^c | [Pd(π-allyl)Cl] ₂ (5) | PCy ₃ (20) | NaOtBu | 60 |
| 23 ^d | [Pd(π-allyl)Cl] ₂ (5) | PCy ₃ (20) | NaOtBu | 90 |
| 24 | [Pd(π-allyl)Cl] ₂ (2.5) | PCy ₃ (10) | NaOtBu | 92 |
| 25 | [Pd(π-allyl)Cl] ₂ (2.5) | IPr·HCl (10) | NaOtBu | 89 |
| 26 ^e | [Pd(π-allyl)Cl] ₂ (2.5) | PCy ₃ (10) | NaOtBu | 97 |
| 27 ^{e,f} | [Pd(π-allyl)Cl] ₂ (2.5) | PCy ₃ (10) | NaOtBu | 80 |
| 28 ^{e,g} | [Pd(π-allyl)Cl] ₂ (2.5) | PCy ₃ (10) | NaOtBu | 45 |
| 29 ^e | – | – | NaOtBu | trace |

^a Unless otherwise specified, the reactions were carried out according to the conditions indicated by the above equation; 0.5 mmol of 1-naphthyltrimethylammonium triflate and 0.75 mmol of benzoxazole were employed. ^b Isolated Yield. ^c Toluene was used as solvent. ^d 1,4-Dioxane was used as solvent. ^e 0.5 mmol of benzoxazole and 0.75 mmol of 1-naphthyltrimethylammonium triflate were employed. ^f 1-Naphthyltrimethylammonium iodide was used to replace 1-naphthyltrimethylammonium triflate. ^g 1-Naphthyltrimethylammonium tetrafluoroborate was used to replace 1-naphthyltrimethylammonium triflate.

Experimental procedures and spectral data

All reactions were performed under nitrogen atmosphere using standard Schlenk and vacuum line techniques. Toluene and 1,4-dioxane were distilled under nitrogen over sodium and degassed prior to use. DMF was dried over 4 Å molecular sieve, fractionally distilled under reduced pressure and stored under nitrogen atmosphere. $[\text{Pd}(\pi\text{-allyl})\text{Cl}]_2$ was purchased from Sinocompound Catalysts Co., Ltd. PCy_3 and methyl triflate were purchased from Sigma-Aldrich and Acros Organics, respectively, and used as received. CDCl_3 was purchased from Cambridge Isotope Laboratories and used as received. Aryldimethylamines were obtained from commercial vendors and purified by distillation under reduced pressure or recrystallization prior to use. Phenyltrimethylammonium triflate,¹ 2-methylphenyltrimethylammonium triflate,¹ 4-(trifluoromethyl)phenyltrimethylammonium triflate,¹ 4-cyanophenyltrimethylammonium triflate,¹ 2-pyridyltrimethylammonium triflate,¹ 1-naphthyltrimethylammonium triflate,² 2-naphthyltrimethylammonium triflate,² 4-(diethylcarbamoyl)phenyltrimethylammonium triflate,² 2-methoxyphenyltrimethylammonium triflate,³ 3-methoxyphenyltrimethylammonium triflate,³ 4-methoxyphenyltrimethylammonium triflate,⁴ and 4-benzoylphenyltrimethylammonium triflate⁴ were prepared according to reported procedures. The other aryltrimethylammonium triflates were prepared according to a similar procedure. All other chemicals were obtained from commercial vendors and used as received. NMR spectra were recorded on a Bruker Avance III 400 spectrometer at ambient temperature. The chemical shifts of the ^1H NMR spectra were referenced to TMS and the chemical shifts of the ^{13}C NMR spectra were referenced to internal solvent resonances. High-resolution mass spectra (HR-MS) were acquired on a Thermo Orbital XL ETD mass spectrometer.

Synthesis of unknown aryltrimethylammonium triflates

1. Synthesis of 2-anthryltrimethylammonium triflate (S2)

To a dry Schlenk tube was charged *N,N*-dimethylaminoanthracene⁵ (1.0 g, 4.52 mmol) and CH_2Cl_2 (15 mL). To the stirred solution was added dropwise methyl triflate (1 mL, 8.84 mmol) at 0 °C. The solution was warmed to room temperature and stirred overnight. Volatiles were removed in vacuo. The residue was washed with Et_2O (2×10 mL), filtered and dried under vacuum to give 2-anthryltrimethylammonium triflate as a yellow solid (1.54 g, 89%). ^1H NMR (400 MHz, DMSO-d_6): δ 3.76 (s, 9H), 7.61-7.66 (m, 2H), 8.11-8.23 (m, 3H), 8.40 (d, $J = 9.6$ Hz, 1H), 8.66 (d, $J = 2.4$ Hz, 1H), 8.75 (s, 1H), 8.80 (s, 1H). ^{13}C NMR (101 MHz, DMSO-d_6): δ 56.04, 117.65, 119.39, 120.70 (q, $J = 323.5$ Hz), 126.46, 126.70,

126.85, 128.07, 128.21, 128.26, 129.41, 129.77, 131.10, 132.00, 132.32, 143.57. HR-MS: m/z 236.14273 $[M-OTf]^+$, calcd for $C_{17}H_{18}N$ 236.14338.

2. Synthesis of 4-methylphenyltrimethylammonium triflate (**S3**)

The same procedure as above was used to prepare 4-methylphenyltrimethylammonium triflate. Thus, *N,N*,4-trimethylaniline (1.45 mL, 10.05 mmol) was reacted with methyl triflate (2.3 mL, 20.32 mmol) in CH_2Cl_2 (20 mL) at room temperature for about 12 h to afford, after similar workup, 4-methylphenyltrimethylammonium triflate as a white solid (2.75 g, 92%). 1H NMR (400 MHz, $CDCl_3$): δ 2.38 (s, 3H), 3.68 (s, 9H), 7.36 (d, $J = 9.2$ Hz, 2H), 7.68 (d, $J = 9.2$ Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 20.88, 57.43, 119.38, 120.81 (q, $J = 321.2$ Hz), 131.29, 141.24, 144.63. HR-MS: m/z 150.12726 $[M-OTf]^+$, calcd for $C_{10}H_{16}N$ 150.12773.

3. Synthesis of 4-methoxy-1-naphthyltrimethylammonium triflate (**S4**)

*Synthesis of 4-methoxy-N,N-dimethylnaphthalen-1-amine:*⁶ To a three-necked flask was charged 1-methoxy-4-nitronaphthalene (1.01 g, 4.97 mmol), 10% Pd/C (0.3 g), and EtOH (20 mL). The mixture was stirred overnight under 1 atm of H_2 at room temperature. The resultant mixture was filtered to remove Pd/C and the filtrate was concentrated by rotary evaporation to give a crude product of 4-methoxynaphthalen-1-amine (0.85 g). The amine was mixed with THF (35 mL) and $NaBH_4$ (1.33 g, 35.15 mmol). The resulting slurry was added into a stirred mixture of 3 M H_2SO_4 (4 mL) and 40% aqueous formaldehyde (2.3 mL, 30 mmol) at a rate compatible with temperature control (-10 °C to 20 °C). Then the mixture was made strongly basic with solid NaOH. The supernatant solution was decanted (and saved), the residue was treated with H_2O (50 mL), and the resultant mixture was extracted with Et_2O (3×60 mL). The organic phases were combined, washed with saturated NaCl solution (50 mL), and dried with Na_2SO_4 . The Na_2SO_4 was removed by filtration and the filtrate was concentrated. The residue was purified by column chromatography on silica gel (eluent:) to afford 4-methoxy-*N,N*-dimethylnaphthalen-1-amine as a colorless oil (0.30 g, 30% overall yield). 1H NMR (400 MHz, $CDCl_3$): δ 2.83 (s, 6H), 3.96 (s, 3H), 6.72 (d, $J = 8.0$ Hz, 1H), 7.01 (d, $J = 8.0$ Hz, 1H), 7.45-7.54 (m, 2H), 8.21-8.26 (m, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 45.72, 55.71, 103.48, 114.01, 122.41, 123.85, 125.32, 126.04, 126.66, 130.04, 144.24, 151.74. HR-MS: m/z calcd for

Synthesis of 4-methoxy-1-naphthyltrimethylammonium triflate: To a dry Schlenk tube was charged 4-methoxy-*N,N*-dimethylnaphthalen-1-amine (0.26 g, 1.29 mmol) and CH_2Cl_2 (5 mL). To the stirred solution was added dropwise methyl triflate (0.3 mL, 2.65 mmol) at 0 °C.

The solution was warmed to room temperature and stirred overnight. Volatiles were removed in vacuo. The residue was washed with Et₂O (2 × 3 mL), filtered and dried under vacuum to give 4-methoxy-1-naphthyltrimethylammonium triflate as a white solid (0.45 g, 94%). ¹H NMR (400 MHz, DMSO-d₆): δ 3.88 (s, 9H), 4.06 (s, 3H), 7.08 (d, *J* = 8.8 Hz, 1H), 7.72 (t, *J* = 7.4 Hz, 1H), 7.80-7.84 (m, 1H), 8.03 (d, *J* = 8.8 Hz, 1H), 8.43 (dd, *J* = 1.2, 8.4 Hz, 1H), 8.57 (d, *J* = 9.2 Hz, 1H). ¹³C NMR (101 MHz, CDCl₃): δ 56.37, 57.23, 102.49, 120.71 (q, *J* = 323.6 Hz), 121.03, 123.27, 123.58, 124.68, 126.14, 126.42, 128.45, 134.08, 156.41. HR-MS: *m/z*

4. Synthesis of 4-(dimethylamino)phenyltrimethylammonium triflate (**S5**)

The same procedure as for synthesis of 2-anthryltrimethylammonium triflate was employed. Thus, reaction of *N*¹,*N*¹,*N*⁴,*N*⁴-tetramethylbenzene-1,4-diamine (0.82 g, 4.99 mmol) with MeOTf (0.57 mL, 5.03 mmol) in CH₂Cl₂ (20 mL) at room temperature afforded, after similar workup, 4-(dimethylamino)phenyltrimethylammonium triflate as a brown powder (1.25 g, 76%). ¹H NMR (400 MHz, CDCl₃): δ 2.98 (s, 6H), 3.61 (s, 9H), 6.71 (d, *J* = 9.5 Hz, 2H), 7.57 (d, *J* = 9.5 Hz, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 40.21, 57.56, 112.35, 120.16, 120.84 (q, *J* = 319.8 Hz), 135.35, 150.88. HR-MS: *m/z* [M-OTf]⁺, calcd for

General procedure for reaction of azoles or thiazoles with aryltrimethylammonium triflates

Azoles or thiazoles (0.5 mmol), aryltrimethylammonium triflates (0.75 mmol), NaOtBu (1 mmol), [Pd(π -allyl)Cl]₂ (2.5-5.0 mol %), PCy₃ (10-20 mol %), and DMF (3 mL) were successively added into a Schlenk tube. After stirring at 120 °C for 12 h, water (15 mL) was added. The resulting mixture was extracted with Et₂O (3×15 mL). The combined organic phases were dried over MgSO₄, concentrated by rotary evaporation and purified by column chromatography on silica gel.

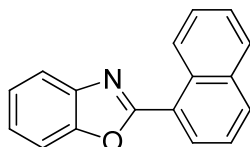
The one-pot reaction for the C-H arylation of benzoxazole

To a stirred solution of *N,N*-dimethylnaphthalen-1-amine (128.5 mg, 0.75 mmol) in CH₂Cl₂ (2 mL) was added dropwise methyl trifluoromethanesulfonate (0.094 mL, 0.83 mmol) at 0 °C. Then the solution was stirred for 5 h at room temperature. Volatiles were removed in vacuo. Benzoxazole (59.6 mg, 0.5 mmol), NaOtBu (96.1 mg, 1 mmol), [Pd(π -allyl)Cl]₂ (4.6 mg, 2.5 mol %), PCy₃ (15.4 μ L, 10 mol %), and DMF (3 mL) were successively added into the Schlenk tube. After stirring at 120 °C for 12 h, water (15 mL) was added. The resulting

mixture was extracted with Et₂O (3×15 mL). The combined organic phases were dried over MgSO₄, concentrated by rotary evaporation and purified by column chromatography on silica gel to give 2-(naphthalen-1-yl)benzoxazole as a white solid (112.6 mg, 92%).

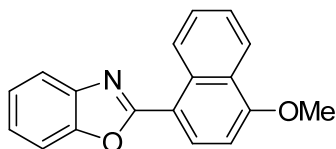
Spectral data for the cross-coupling products

1. 2-(Naphthalen-1-yl)benzoxazole (**S1**)⁷



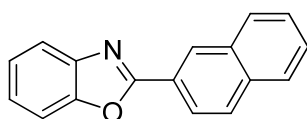
Eluent: petroleum ether/ethyl acetate = 100:1. White solid; yield 119 mg (97%). ¹H NMR (400 MHz, CDCl₃): δ 7.37-7.42 (m, 2H), 7.56-7.65 (m, 3H), 7.68-7.73 (m, 1H), 7.86-7.90 (m, 1H), 7.92-7.94 (m, 1H), 8.02 (d, *J* = 8 Hz, 1H), 8.43 (dd, *J* = 1.2, 7.2 Hz, 1H), 9.47 (dd, *J* = 0.8, 8.4 Hz, 1H). ¹³C NMR (101 MHz, CDCl₃): δ 110.64, 120.42, 123.77, 124.63, 125.07, 125.41, 126.43, 126.59, 128.05, 128.80, 129.46, 130.84, 132.43, 134.11, 142.46, 150.32, 162.95.

2. 2-(4-Methoxynaphthalen-1-yl)benzoxazole (**1**)



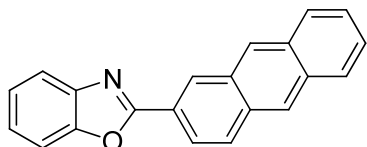
Eluent: petroleum ether/ethyl acetate = 60:1. Light yellow solid, yield 112.9 mg (82%); mp: 88-90 °C. ¹H NMR (400 MHz, CDCl₃): δ 3.91 (s, 3H), 6.75 (d, *J* = 8.4 Hz, 1H), 7.20-7.27 (m, 2H), 7.43-7.49 (m, 2H), 7.58-7.63 (m, 1H), 7.71-7.76 (m, 1H), 8.24 (d, *J* = 8.4 Hz, 1H), 8.25 (d, *J* = 8.4 Hz, 1H), 9.40 (d, *J* = 8.4 Hz, 1H). ¹³C NMR (101 MHz, CDCl₃): 55.82, 103.27, 110.34, 116.07, 119.97, 122.49, 124.37, 124.82, 125.85, 125.88, 126.19, 128.45, 130.59, 131.88, 142.59, 150.08, 158.51, 163.23. HR-MS: *m/z* 276.10175 [M+H]⁺, calcd for C₁₈H₁₄O₂N 276.10191.

3. 2-(Naphthalen-2-yl)benzoxazole (**2**)⁸



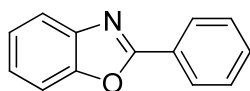
Eluent: petroleum ether/ethyl acetate = 100:1. White solid; yield 79.6 mg (65%). ^1H NMR (400 MHz, CDCl_3): δ 7.33-7.39 (m, 2H), 7.50-7.56 (m, 2H), 7.57-7.62 (m, 1H), 7.79-7.87 (m, 2H), 7.92-7.96 (m, 2H), 8.29 (dd, $J = 1.6, 8.4$ Hz, 1H), 8.73 (s, 1H). ^{13}C NMR (101 MHz, CDCl_3): δ 110.64, 120.08, 123.99, 124.42, 124.68, 125.21, 126.92, 127.81, 127.94, 128.17, 128.80, 128.99, 133.01, 134.78, 142.29, 150.90, 163.22.

4. 2-(Anthracen-2-yl)benzoxazole (**3**)⁹



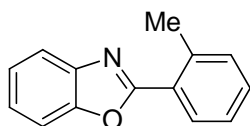
Eluent: petroleum ether/ethyl acetate = 100:1. Light yellow solid; yield 88.4 mg (60%). ^1H NMR (400 MHz, CDCl_3): δ 7.37-7.41 (m, 2H), 7.49-7.54 (m, 2H), 7.62-7.66 (m, 1H), 7.81-7.85 (m, 1H), 8.01-8.06 (m, 2H), 8.12 (d, $J = 9.2$ Hz, 1H), 8.27 (dd, $J = 1.6, 8.8$ Hz, 1H), 8.45 (s, 1H), 8.57 (s, 1H), 8.94 (s, 1H). ^{13}C NMR (101 MHz, CDCl_3): δ 110.74, 120.18, 123.18, 123.93, 124.80, 125.38, 126.11, 126.54, 126.58, 128.19, 128.37, 128.53, 129.05, 129.27, 130.91, 132.19, 132.34, 132.96, 142.40, 151.01, 163.35.

5. 2-Phenylbenzoxazole (**4**)¹⁰



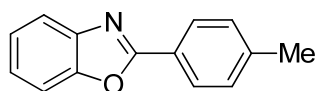
Eluent: petroleum ether/ethyl acetate = 100:1. White solid; yield 41.8 mg (43%). ^1H NMR (400 MHz, CDCl_3): δ 7.22-7.27 (m, 2H), 7.40-7.44 (m, 3H), 7.45-7.50 (m, 1H), 7.66-7.70 (m, 1H), 8.14-8.18 (m, 2H). ^{13}C NMR (101 MHz, CDCl_3): δ 110.69, 120.12, 124.68, 125.20, 127.27, 127.72, 129.00, 131.61, 142.22, 150.86, 163.14.

6. 2-*o*-Tolylbenzoxazole (**5**)¹¹



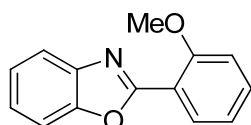
Eluent: petroleum ether/ethyl acetate = 100:1. White solid; yield 84.8 mg (81%). ^1H NMR (400 MHz, CDCl_3): δ 2.72 (s, 3H), 7.22-7.33 (m, 5H), 7.46-7.51 (m, 1H), 7.69-7.73 (m, 1H), 8.06-8.09 (m, 1H). ^{13}C NMR (101 MHz, CDCl_3): δ 22.32, 110.58, 120.26, 124.47, 125.11, 126.17, 126.35, 130.05, 131.00, 131.90, 138.96, 142.26, 150.41, 163.51.

7. 2-(*p*-Tolyl)benzoxazole (**6**)¹²



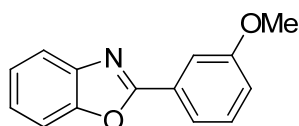
Eluent: petroleum ether/ethyl acetate = 100:1. White solid; yield 45 mg (43%). ¹H NMR (400 MHz, CDCl₃): δ 2.43 (s, 3H), 7.31-7.36 (m, 4H), 7.55-7.59 (m, 1H), 7.73-7.78 (m, 1H), 8.14 (d, *J* = 8.4 Hz, 2H). ¹³C NMR (101 MHz, CDCl₃): 21.79, 110.62, 119.94, 124.48, 124.60, 124.99, 127.70, 129.77, 142.19, 142.26, 150.78, 163.41.

8. 2-(2-Methoxyphenyl)benzoxazole (**7**)¹³



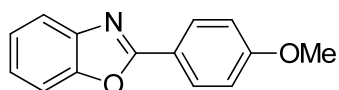
Eluent: petroleum ether/ethyl acetate = 60:1. Pale yellow oil; yield 25.7 mg (23%). ¹H NMR (400 MHz, CDCl₃): δ 4.03 (s, 3H), 7.08-7.13 (m, 2H), 7.32-7.37 (m, 2H), 7.49-7.53 (m, 1H), 7.56-7.61 (m, 1H), 7.80-7.84 (m, 1H), 8.14 (dd, *J* = 1.6, 7.6 Hz, 1H). ¹³C NMR (101 MHz, CDCl₃): δ 56.35, 110.58, 112.20, 116.33, 120.37, 120.85, 124.40, 125.06, 131.44, 132.89, 142.29, 150.47, 158.60, 161.69.

9. 2-(3-Methoxyphenyl)benzoxazole (**8**)¹⁴



Eluent: petroleum ether/ethyl acetate = 60:1. Pale yellow solid; yield 37.1 mg (33%). ¹H NMR (400 MHz, CDCl₃): δ 3.91 (s, 3H), 7.08 (d, *J* = 8.0 Hz, 1H), 7.33-7.38 (m, 2H), 7.42 (t, *J* = 8.0 Hz, 1H), 7.56-7.60 (m, 1H), 7.76-7.80 (m, 2H), 7.85 (d, *J* = 7.6 Hz, 1H). ¹³C NMR (101 MHz, CDCl₃): δ 55.63, 110.72, 112.03, 118.45, 120.13, 120.24, 124.72, 125.28, 128.46, 130.12, 142.17, 150.87, 160.06, 163.08.

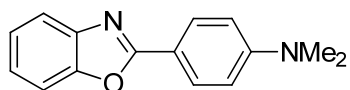
10. 2-(4-Methoxyphenyl)benzoxazole (**9**)¹⁵



Eluent: petroleum ether/ethyl acetate = 60:1. Pale yellow solid; yield 39.5 mg (35%). ¹H NMR (400 MHz, CDCl₃): δ 3.86 (s, 3H), 7.01 (d, *J* = 9.2 Hz, 2H), 7.28-7.35 (m, 2H), 7.52-7.56 (m, 1H), 7.71-7.76 (m, 1H), 8.19 (d, *J* = 9.2 Hz, 2H). ¹³C NMR (101 MHz, CDCl₃):

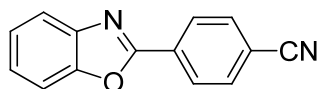
δ 55.53, 110.47, 114.45, 119.71, 124.51, 124.68, 129.48, 142.38, 150.77, 162.41, 163.26.

11. 4-(benzoxazol-2-yl)-*N,N*-dimethylaniline (**10**)¹⁶



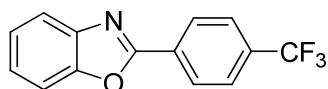
Eluent: petroleum ether/ethyl acetate = 50:1. White solid; yield 47.4 mg (40%). ¹H NMR (400 MHz, CDCl₃): δ 3.05 (s, 6H), 6.76 (d, J = 9.2 Hz, 2H), 7.24-7.32 (m, 2H), 7.50-7.52 (m, 1H), 7.68-7.70 (m, 1H), 8.10 (d, J = 9.2 Hz, 2H). ¹³C NMR (101 MHz, CDCl₃): δ 40.23, 110.21, 111.67, 114.26, 119.20, 124.00, 124.25, 129.19, 142.72, 150.67, 152.49, 164.31.

12. 4-(Benzoxazol-2-yl)benzonitrile (**11**)¹⁷



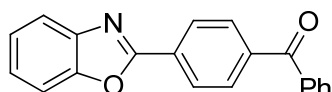
Eluent: petroleum ether/ethyl acetate = 50:1. White solid; yield 68 mg (62%). ¹H NMR (400 MHz, CDCl₃): δ 7.38-7.44 (m, 2H), 7.59-7.64 (m, 1H), 7.80-7.82 (m, 3H), 8.35 (d, J = 8.4 Hz, 2H). ¹³C NMR (101 MHz, CDCl₃): δ 111.00, 114.86, 118.28, 120.70, 125.25, 126.29, 128.07, 131.24, 132.80, 141.99, 151.02, 161.03.

13. 2-(4-(Trifluoromethyl)phenyl)benzoxazole (**12**)¹⁸



Eluent: petroleum ether/ethyl acetate = 100:1. White solid; yield 96 mg (73%). ¹H NMR (400 MHz, CDCl₃): δ 7.36-7.43 (m, 2H), 7.58-7.64 (m, 1H), 7.77-7.83 (m, 3H), 8.38 (d, J = 8.4 Hz, 2H). ¹³C NMR (101 MHz, CDCl₃): δ 110.95, 120.55, 123.88 (q, J = 273.5 Hz), 125.10, 125.97, 126.08 (q, J = 3.8 Hz), 128.00, 130.57, 133.12 (q, J = 32.8 Hz), 142.04, 151.00, 161.62. ¹⁹F NMR (376 MHz, CDCl₃): δ -62.99 (s).

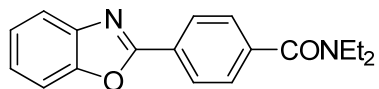
14. (4-(Benzoxazol-2-yl)phenyl)(phenyl)methanone (**13**)⁸



Eluent: petroleum ether/ethyl acetate = 60:1. White solid; yield 119.5 mg (80%). ¹H NMR (400 MHz, CDCl₃): δ 7.34-7.40 (m, 2H), 7.47-7.52 (m, 2H), 7.56-7.63 (m, 2H), 7.76-7.84 (m, 3H), 7.93 (d, J = 8.4 Hz, 2H), 8.34 (d, J = 8.4 Hz, 2H). ¹³C NMR (101 MHz, CDCl₃): δ

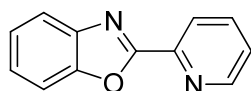
110.84, 120.42, 124.95, 125.80, 127.48, 128.52, 130.11, 130.51, 130.54, 132.87, 137.19, 139.86, 142.09, 150.94, 161.96, 195.86.

15. 4-(Benzoxazol-2-yl)-*N,N*-diethylbenzamide (**14**)⁹



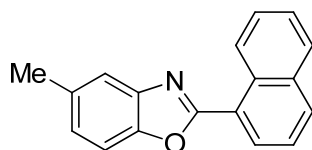
Eluent: petroleum ether/ethyl acetate = 10:1. Yellow-brown solid; yield 126.1 mg (86%). ¹H NMR (400 MHz, CDCl₃): δ 1.10 (s, 3H), 1.24 (s, 3H), 3.25 (s, 2H), 3.54 (s, 2H), 7.31-7.37 (m, 2H), 7.51 (d, *J* = 8.4 Hz, 2H), 7.54-7.58 (m, 1H), 7.73-7.78 (m, 1H), 8.27 (d, *J* = 8.4 Hz, 2H). ¹³C NMR (101 MHz, CDCl₃): δ 12.97, 14.31, 39.45, 43.38, 110.73, 120.21, 124.80, 125.48, 126.99, 127.78, 127.85, 140.17, 142.08, 150.85, 162.31, 170.35.

16. 2-(Pyridin-2-yl)benzoxazole (**15**)⁷



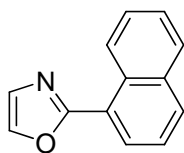
Eluent: petroleum ether/ethyl acetate = 30:1. Pale yellow solid; yield 80.5 mg (82%). ¹H NMR (400 MHz, CDCl₃): δ 7.36-7.46 (m, 3H), 7.65-7.69 (m, 1H), 7.80-7.86 (m, 1H), 7.89 (dt, *J* = 1.6, 7.6 Hz, 1H), 8.36 (d, *J* = 8 Hz, 1H), 8.82 (d, *J* = 4.4 Hz, 1H). ¹³C NMR (101 MHz, CDCl₃): δ 111.29, 120.69, 123.49, 124.99, 125.62, 126.10, 137.14, 141.82, 146.10, 150.35, 151.09, 161.49.

17. 5-Methyl-2-(naphthalen-1-yl)benzoxazole (**16**)



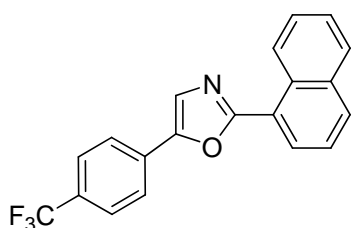
Eluent: petroleum ether/ethyl acetate = 100:1. Light yellow solid; yield 79 mg (61%); mp: 114-116 °C. ¹H NMR (400 MHz, CDCl₃): δ 2.51 (s, 3H), 7.18-7.21 (m, 1H), 7.50 (d, *J* = 8.4 Hz, 1H), 7.55-7.60 (m, 2H), 7.65-7.67 (m, 1H), 7.67-7.72 (m, 1H), 7.90-7.93 (m, 1H), 8.01 (d, *J* = 8.4 Hz, 1H), 8.40 (dd, *J* = 1.4, 7.4 Hz, 1H), 9.43-9.46 (m, 1H). ¹³C NMR (101 MHz, CDCl₃): δ 21.69, 109.99, 120.30, 123.94, 125.06, 126.46, 126.51, 126.54, 127.97, 128.76, 129.33, 130.82, 132.27, 134.09, 134.42, 142.65, 148.57, 163.04. HR-MS: *m/z* 260.10669 [M+H]⁺, calcd for C₁₈H₁₄ON 260.10699.

18. 2-(Naphthalen-1-yl)oxazole (**17**)¹⁹



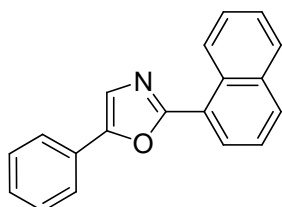
Eluent: petroleum ether/ethyl acetate = 100:1. Pale yellow oil; yield 86.6 mg (89%). ¹H NMR (400 MHz, CDCl₃): δ 7.35 (s, 1H), 7.49-7.54 (m, 2H), 7.60-7.65 (m, 1H), 7.76 (s, 1H), 7.87 (d, *J* = 8.2 Hz, 1H), 7.92 (d, *J* = 8.2 Hz, 1H), 8.17 (d, *J* = 7.3 Hz, 1H), 9.26 (d, *J* = 8.4 Hz, 1H). ¹³C NMR (101 MHz, CDCl₃): δ 124.08, 125.02, 126.22, 126.35, 127.60, 127.91, 128.44, 128.61, 130.23, 131.25, 133.99, 138.42, 161.88.

19. 2-(Naphthalen-1-yl)-5-(4-(trifluoromethyl)phenyl)oxazole (**18**)⁹



Eluent: petroleum ether/ethyl acetate = 60:1. Pale yellow solid; yield 105.4 mg (62%). ¹H NMR (400 MHz, CDCl₃): δ 7.50-7.55 (m, 2H), 7.60 (s, 1H), 7.61-7.65 (m, 3H), 7.75 (d, *J* = 8.2 Hz, 2H), 7.86 (d, *J* = 8.1 Hz, 1H), 7.92 (d, *J* = 8.2 Hz, 1H), 8.24 (d, *J* = 8.1 Hz, 1H), 9.30 (d, *J* = 8.6 Hz, 1H). ¹³C NMR (101 MHz, CDCl₃): δ 122.72, 123.51, 124.08 (q, *J* = 273 Hz), 124.33, 125.02, 125.24, 126.04 (q, *J* = 3.8 Hz), 126.14, 126.48, 127.82, 128.03, 128.75, 130.08 (q, *J* = 32.8 Hz), 130.22, 131.20, 131.68, 134.05, 149.50, 161.87. ¹⁹F NMR (376 MHz, CDCl₃) δ -62.63.

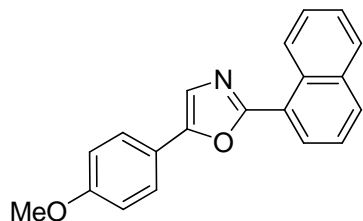
20. 2-(Naphthalen-1-yl)-5-phenyloxazole (**19**)²⁰



Eluent: petroleum ether/ethyl acetate = 60:1. White solid; yield 88.3 mg (65%). ¹H NMR (400 MHz, CDCl₃): δ 7.35 (t, *J* = 7.4 Hz, 1H), 7.46 (t, *J* = 7.7 Hz, 2H), 7.54-7.59 (m, 3H), 7.64-7.68 (m, 1H), 7.77 (d, *J* = 7.4 Hz, 2H), 7.91 (d, *J* = 8.1 Hz, 1H), 7.96 (d, *J* = 8.2 Hz, 1H), 8.29 (d, *J* = 7.3 Hz, 1H), 9.33 (d, *J* = 8.6 Hz, 1H). ¹³C NMR (101 MHz, CDCl₃): δ 123.59,

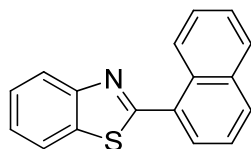
124.05, 124.45, 125.11, 126.30, 126.43, 127.72, 127.89, 128.15, 128.64, 128.71, 129.11, 130.30, 131.31, 134.10, 151.10, 161.18.

21. 5-(4-Methoxyphenyl)-2-(naphthalen-1-yl)oxazole (**20**)



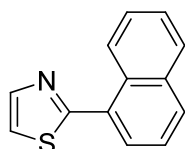
Eluent: petroleum ether/ethyl acetate = 60:1. Light yellow solid; yield 96.2 mg (64%) ; mp: 96-98 °C. ¹H NMR (400 MHz, CDCl₃): δ 3.82 (s, 3H), 6.96 (d, *J* = 9.2 Hz, 2H), 7.44 (s, 1H), 7.52-7.56 (m, 2H), 7.62-7.69 (m, 3H), 7.88 (d, *J* = 8 Hz, 1H), 7.93 (d, *J* = 8 Hz, 1H), 8.26 (dd, *J* = 1.1, 7.6 Hz, 1H), 9.33 (d, *J* = 8.7 Hz, 1H). ¹³C NMR (101 MHz, CDCl₃): 55.45, 114.54, 120.96, 122.08, 124.15, 125.09, 125.96, 126.35, 126.36, 127.61, 127.66, 128.66, 130.25, 131.05, 134.08, 151.13, 159.97, 160.53. HR-MS: *m/z* 302.11743 [M+H]⁺, calcd for C₂₀H₁₆O₂N 302.11756.

22. 2-(Naphthalen-1-yl)benzothiazole (**21**)²¹



Eluent: petroleum ether/ethyl acetate = 100:1. Light yellow solid; yield 126.5 mg (97%). ¹H NMR (400 MHz, CDCl₃): δ 7.43-7.47 (m, 1H), 7.53-7.59 (m, 3H), 7.60-7.64 (m, 1H), 7.92-8.00 (m, 4H), 8.18-8.21 (m, 1H), 8.91-8.94 (m, 1H). ¹³C NMR (101 MHz, CDCl₃): δ 121.51, 123.68, 125.10, 125.41, 126.01, 126.39, 126.63, 127.75, 128.52, 129.44, 130.77, 130.95, 131.19, 134.13, 135.57, 154.28, 167.71.

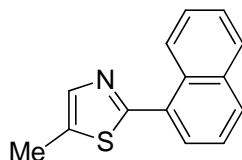
23. 2-(Naphthalen-1-yl)thiazole (**22**)²²



Eluent: petroleum ether/ethyl acetate = 100:1. Light yellow oil; yield 56.1 mg (53%). ¹H NMR (400 MHz, CDCl₃): δ 7.45 (d, *J* = 3.2 Hz, 1H), 7.50-7.60 (m, 3H), 7.81 (dd, *J* = 1.2, 6.8 Hz, 1H), 7.89-7.92 (m, 1H), 7.94 (d, *J* = 8.4 Hz, 1H), 8.03 (d, *J* = 3.6 Hz, 1H), 8.75-8.78 (m,

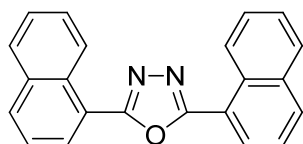
1H). ^{13}C NMR (101 MHz, CDCl_3): δ 119.85, 125.16, 125.89, 126.50, 127.45, 128.46, 128.76, 130.51, 130.71, 130.90, 134.11, 143.64, 167.79.

24. 5-Methyl-2-(naphthalen-1-yl)thiazole (**23**)



Eluent: petroleum ether/ethyl acetate = 100:1. Light yellow solid; yield 48.5 mg (43%); mp: 80-82 °C. ^1H NMR (400 MHz, CDCl_3): δ 2.56 (s, 3H), 7.48-7.61 (m, 3H), 7.68 (s, 1H), 7.78 (d, $J = 7.2$ Hz, 1H), 7.91 (t, $J = 7.1$ Hz, 2H), 8.85 (d, $J = 8.5$ Hz, 1H). ^{13}C NMR (101 MHz, CDCl_3): δ 12.03, 125.09, 125.98, 126.34, 127.25, 128.34, 128.37, 130.11, 130.65, 131.17, 134.09, 134.62, 141.44, 166.03. HR-MS: m/z 226.06827 $[\text{M}+\text{H}]^+$, calcd for $\text{C}_{14}\text{H}_{12}\text{NS}$ 226.06850.

25. 2,5-Di(naphthalen-1-yl)-1,3,4-oxadiazole (**24**)²³



Eluent: petroleum ether/ethyl acetate = 60:1. Light yellow solid; yield 67.5 mg (42%). ^1H NMR (400 MHz, CDCl_3): δ 7.56-7.61 (m, 4H), 7.68-7.73 (m, 2H), 7.90-7.93 (m, 2H), 8.02 (d, $J = 8.2$ Hz, 2H), 8.28 (dd, $J = 1.2, 7.3$ Hz, 2H), 9.37 (dd, $J = 0.9, 8.6$ Hz, 2H). ^{13}C NMR (101 MHz, CDCl_3): δ 120.52, 125.01, 126.41, 126.85, 128.32, 128.60, 128.82, 130.26, 132.77, 134.00, 164.26.

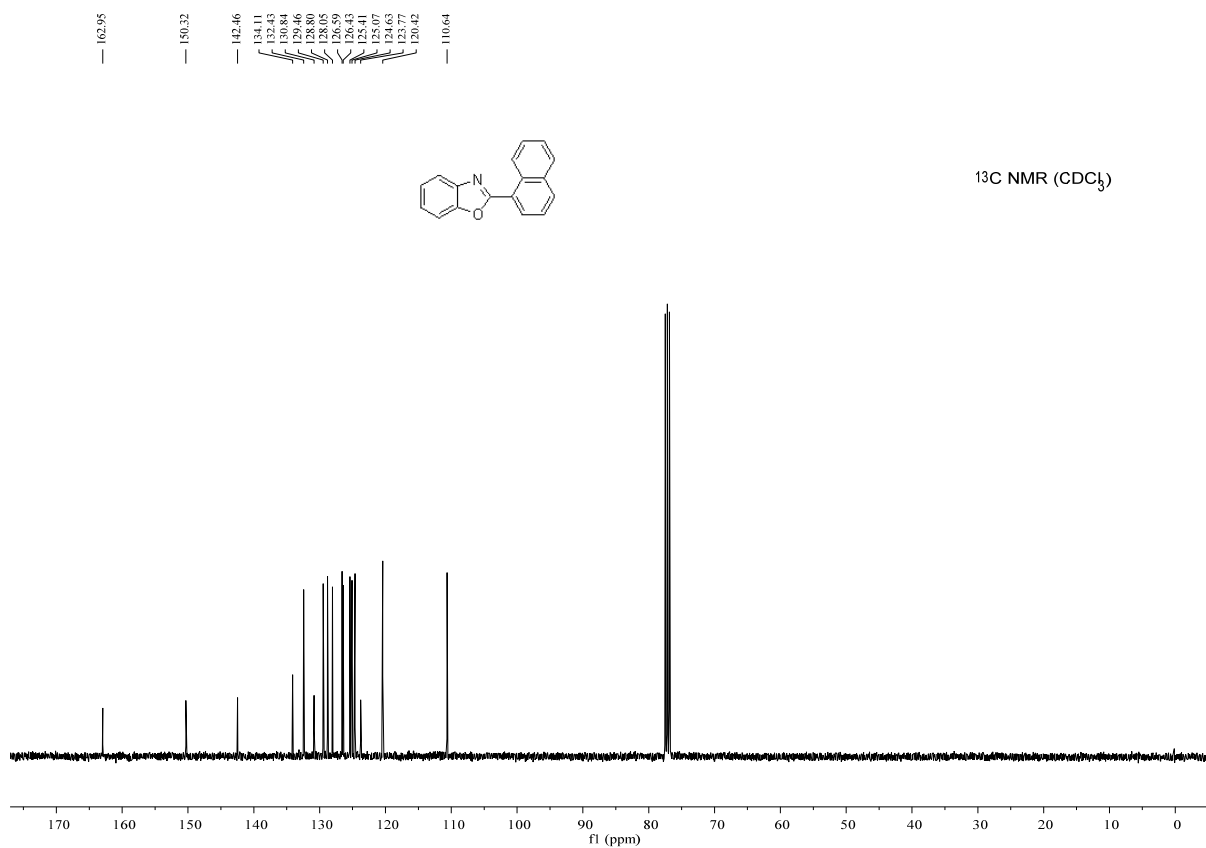
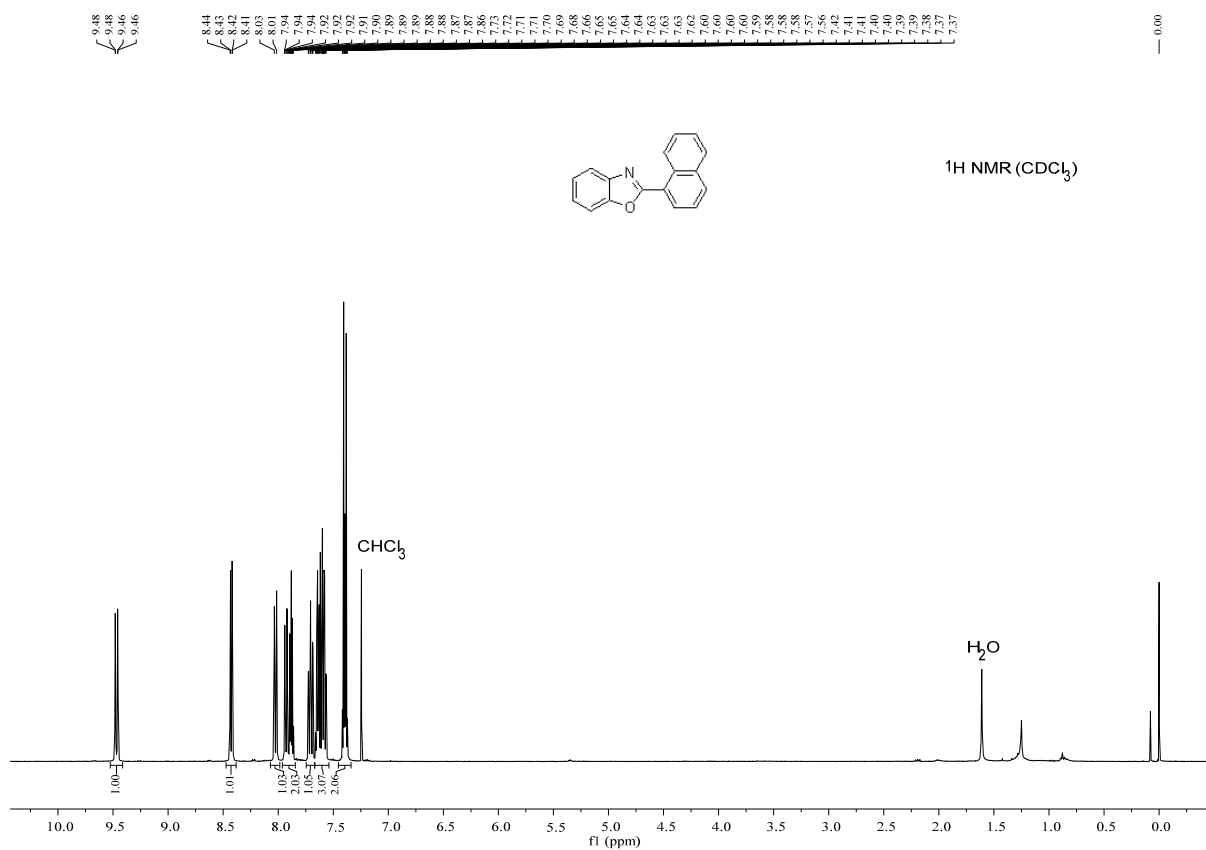
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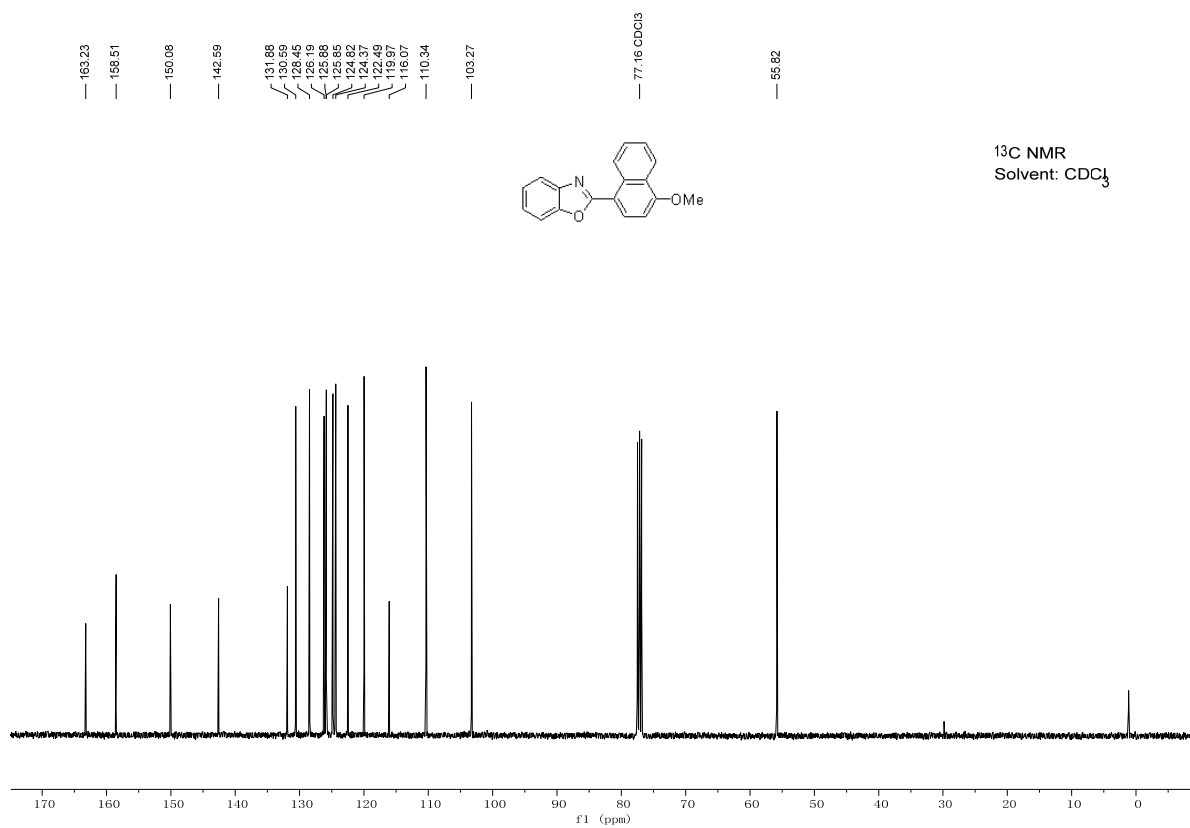
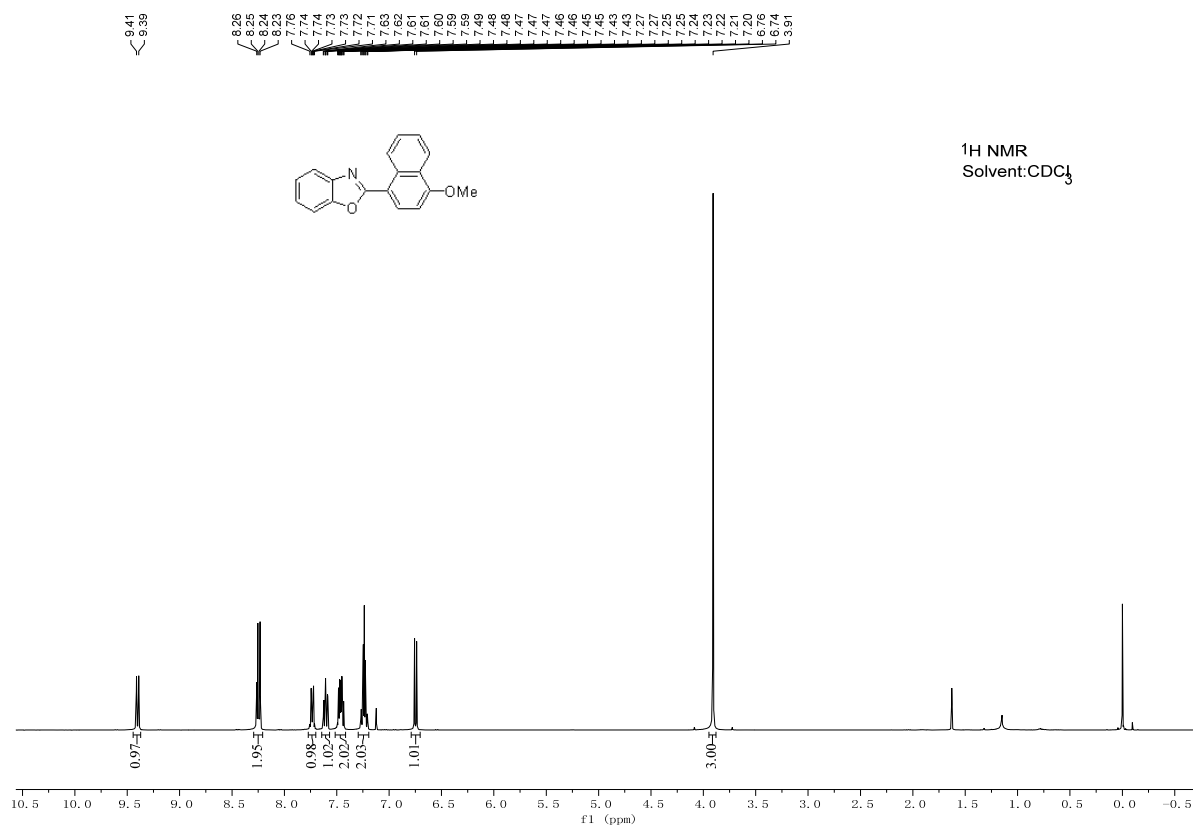
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Copies of NMR spectra for the cross-coupling products

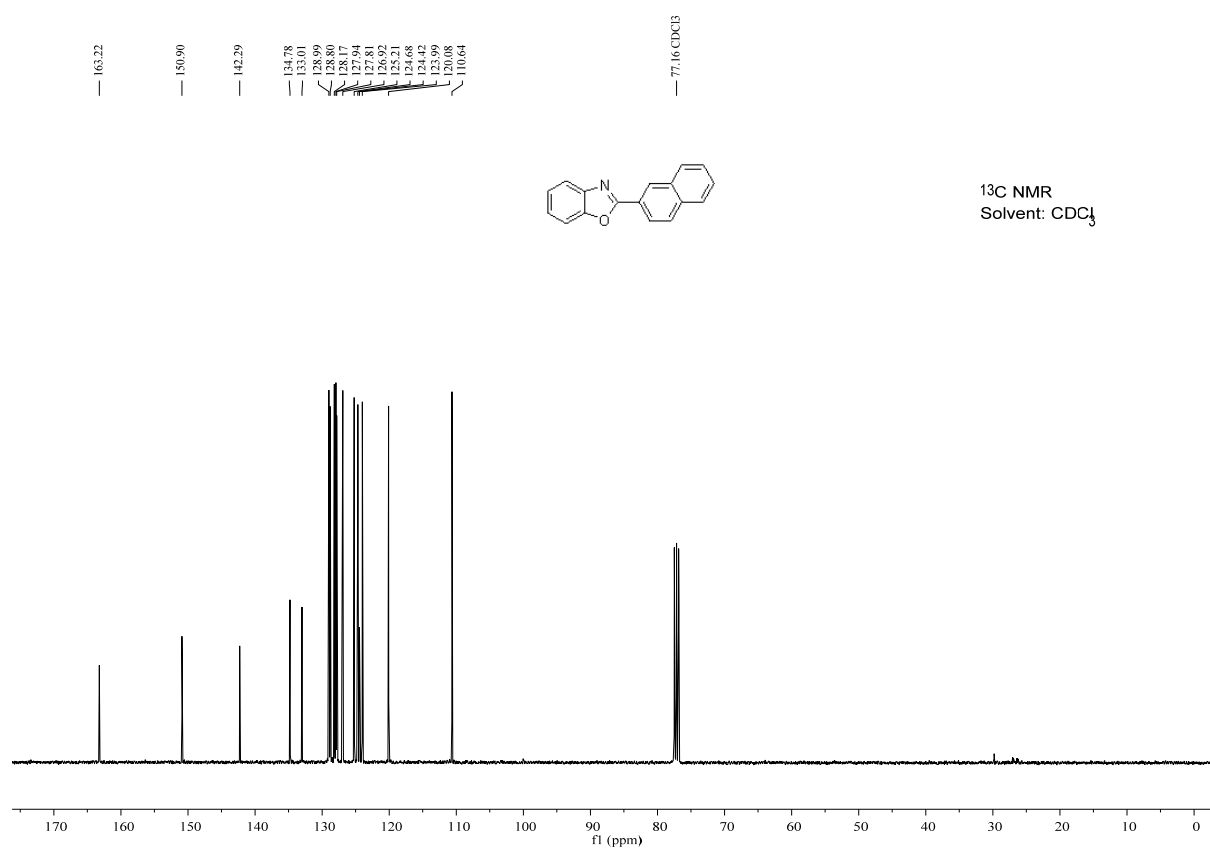
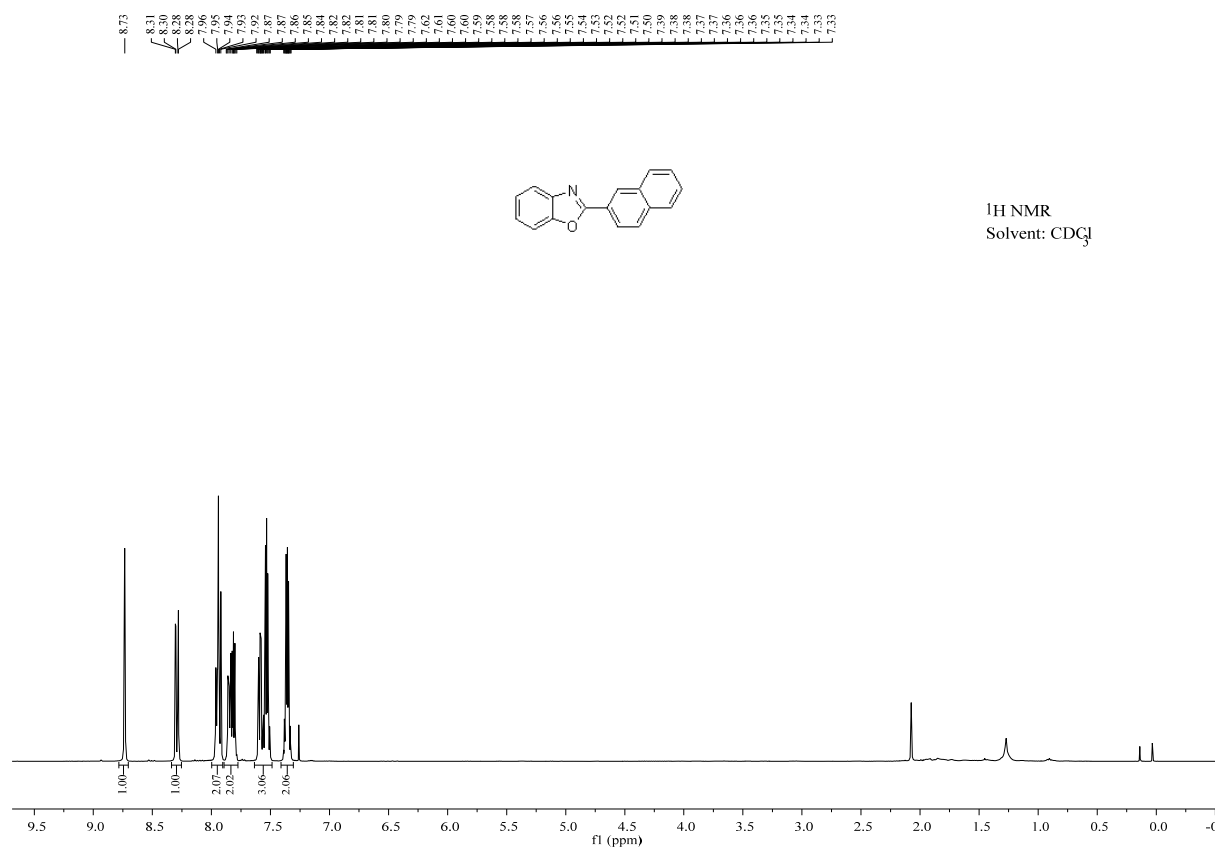
1. 2-(Naphthalen-1-yl)benzoxazole (S1)



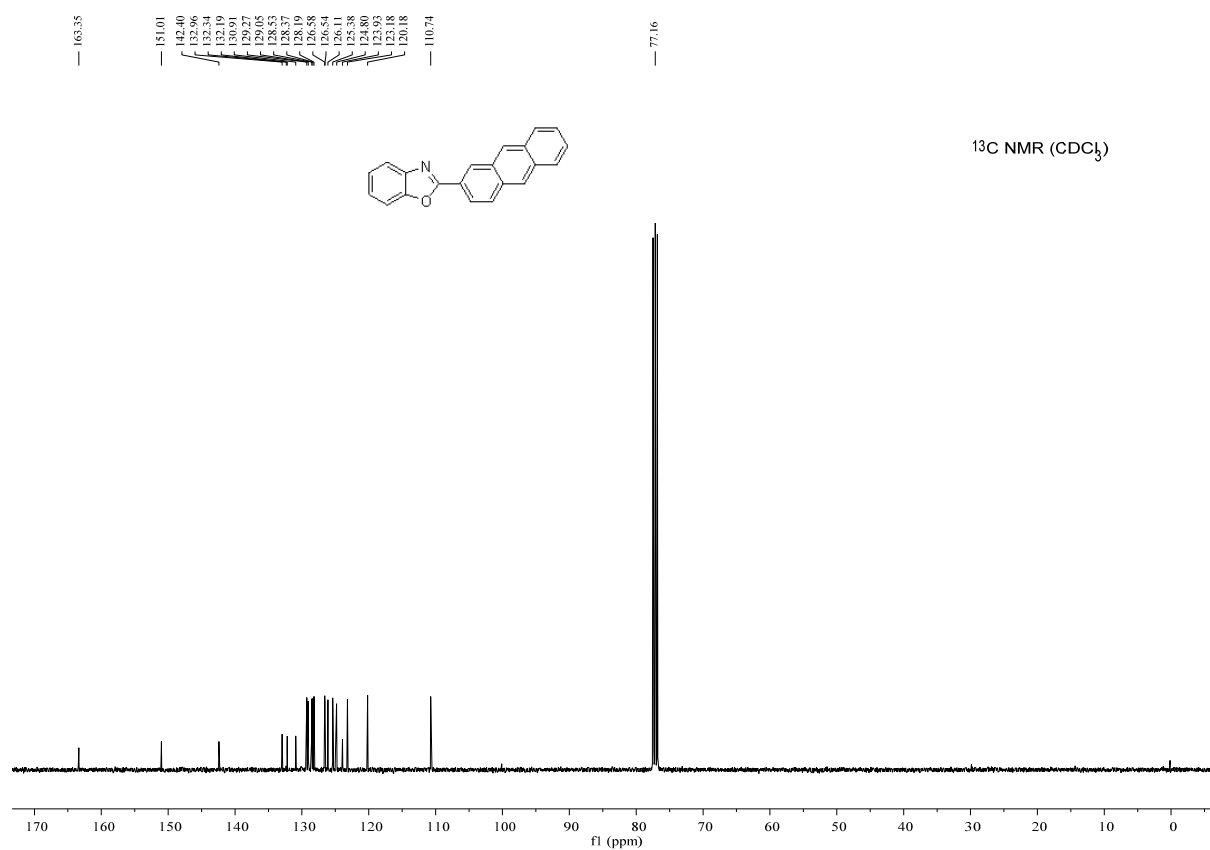
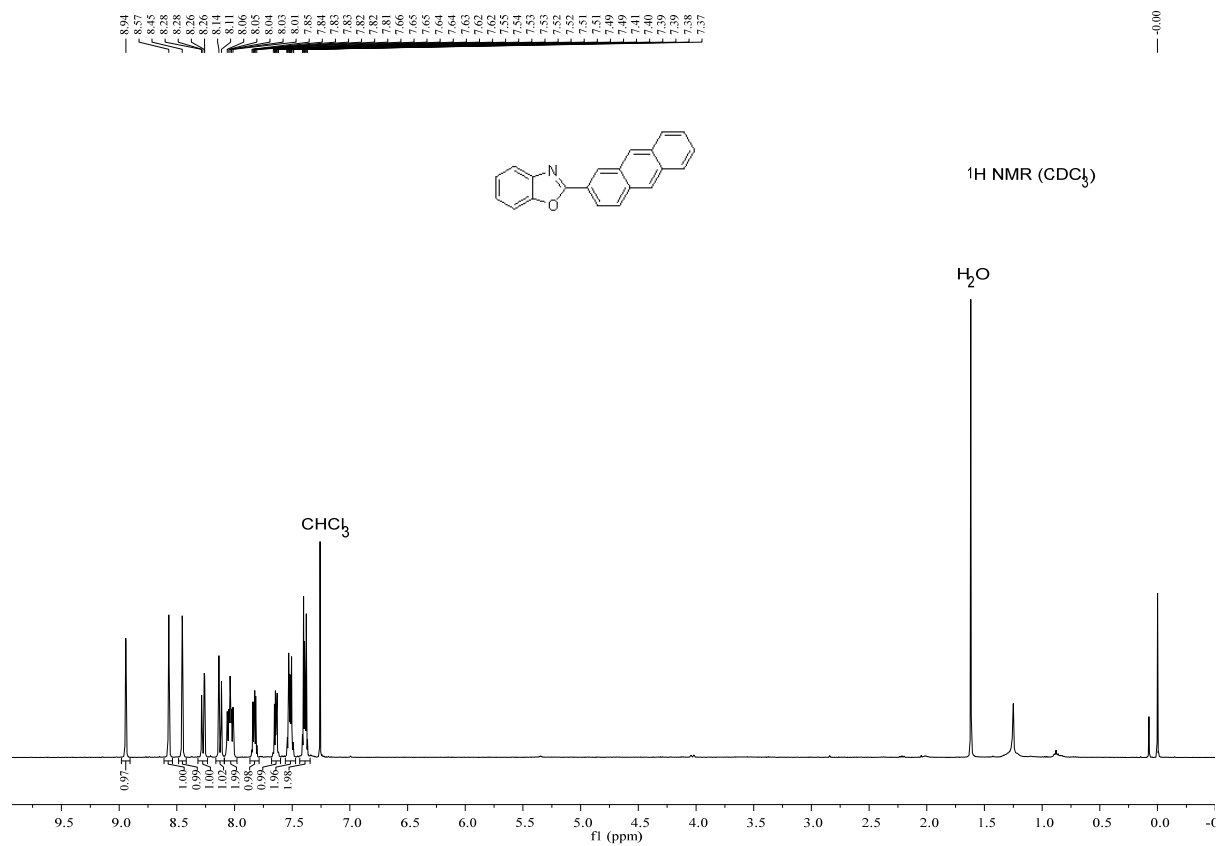
2. 2-(4-Methoxynaphthalen-1-yl)benzoxazole (1)



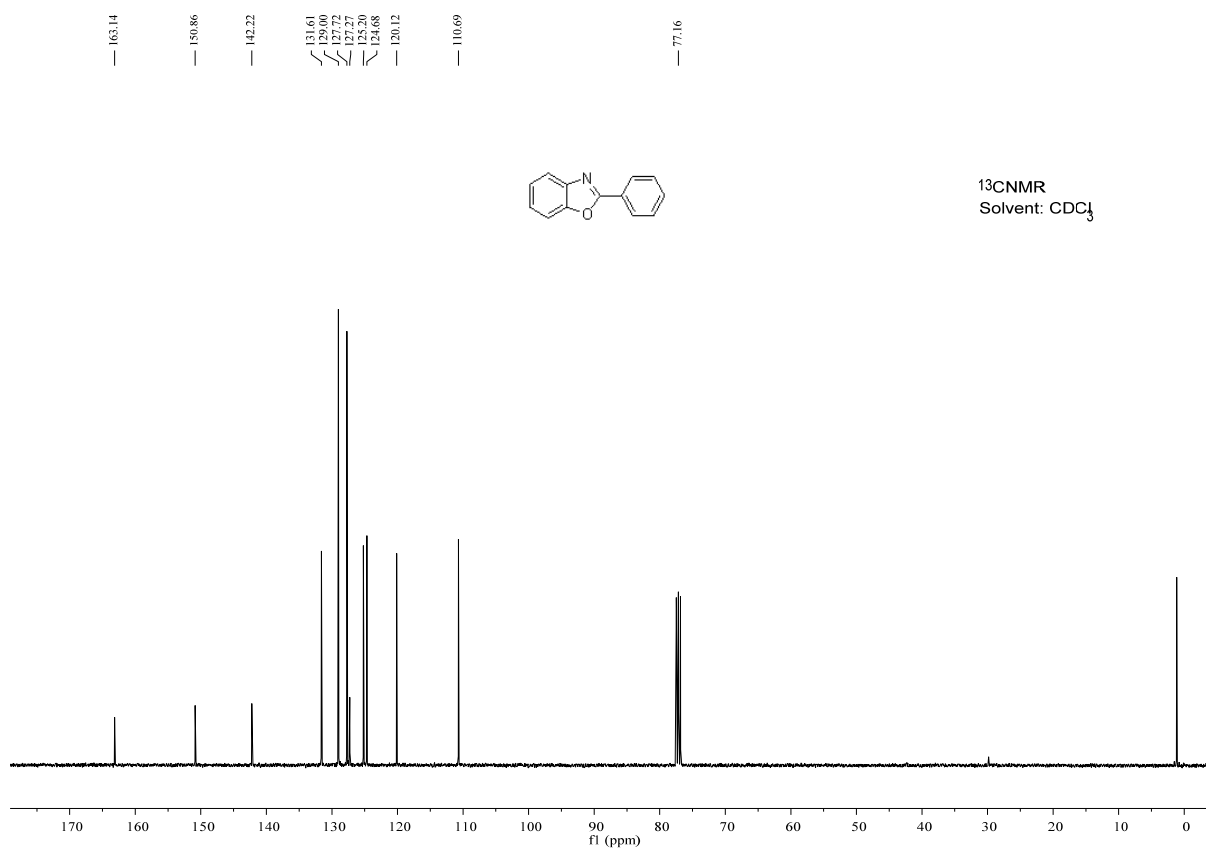
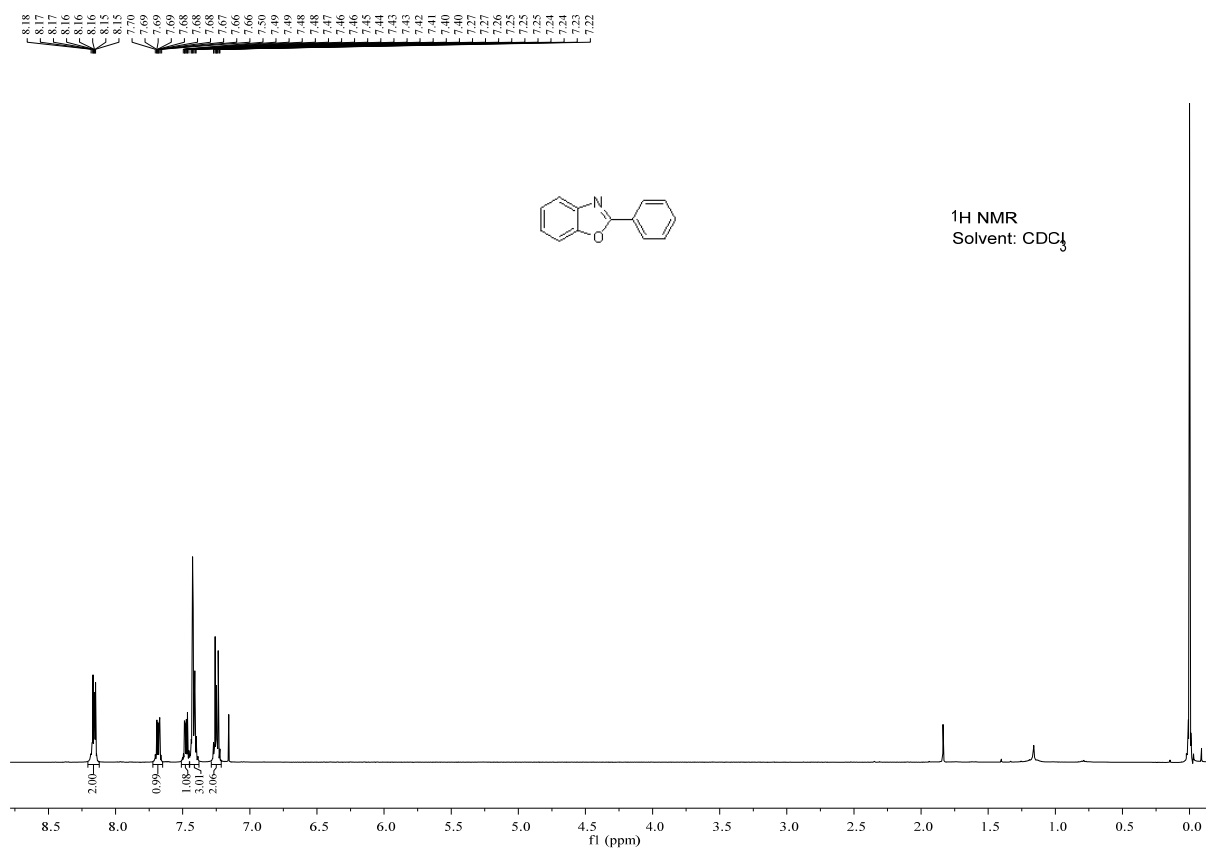
3. 2-(Naphthalen-2-yl)benzoxazole (2)



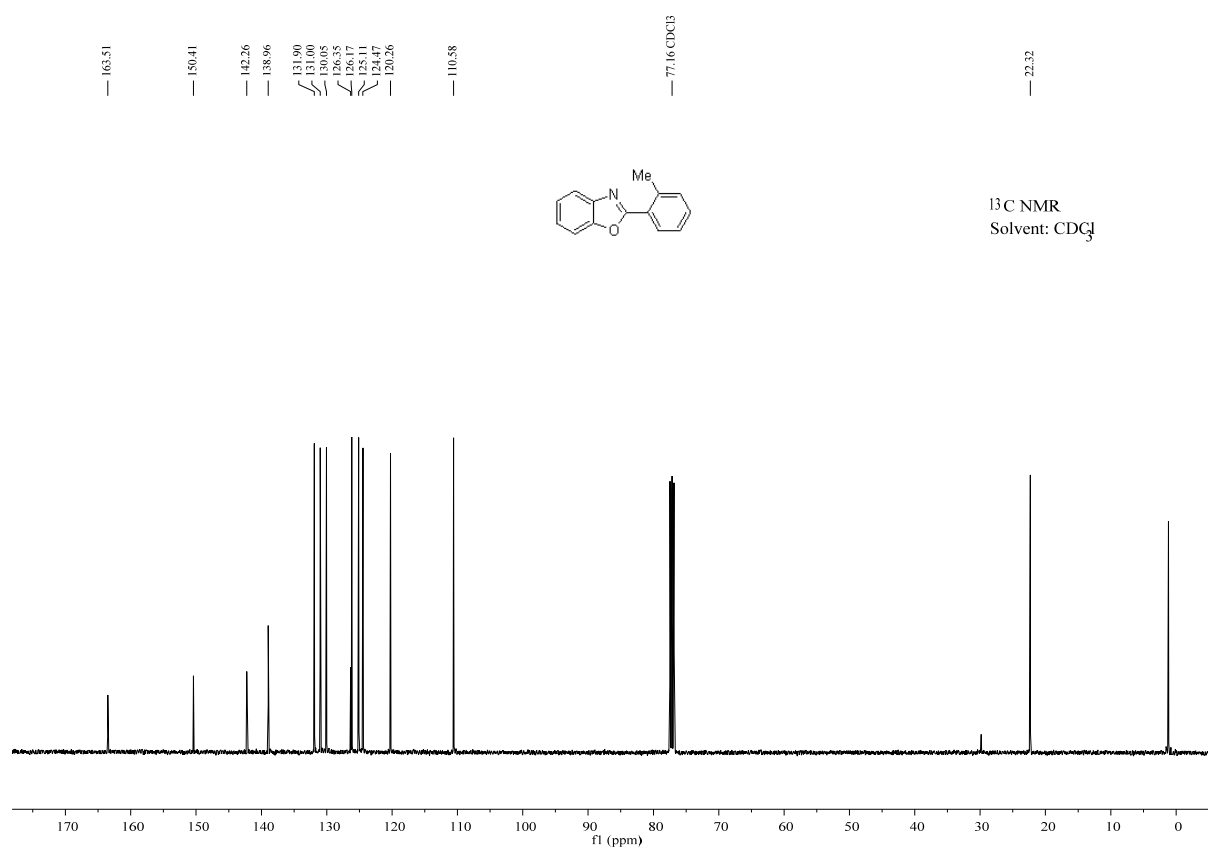
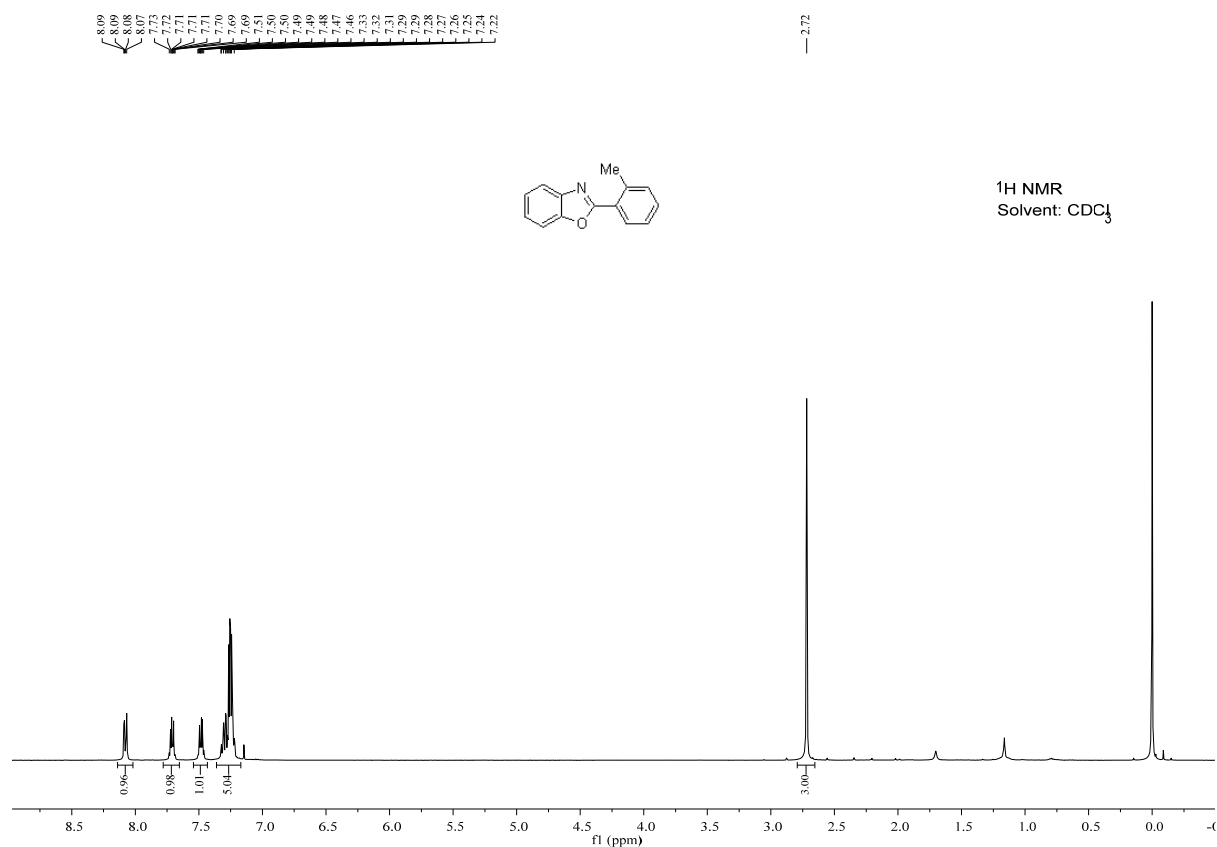
4. 2-(Anthracen-2-yl)benzoxazole (3)



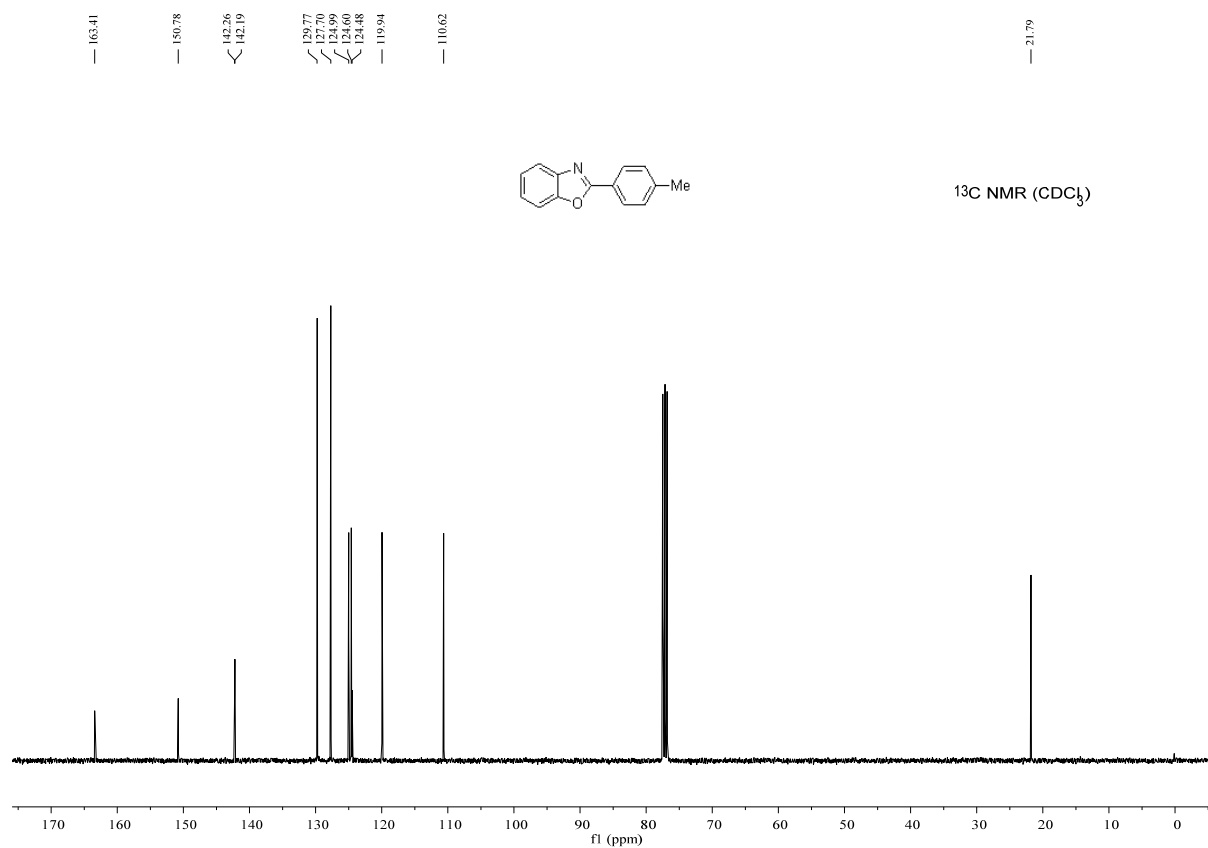
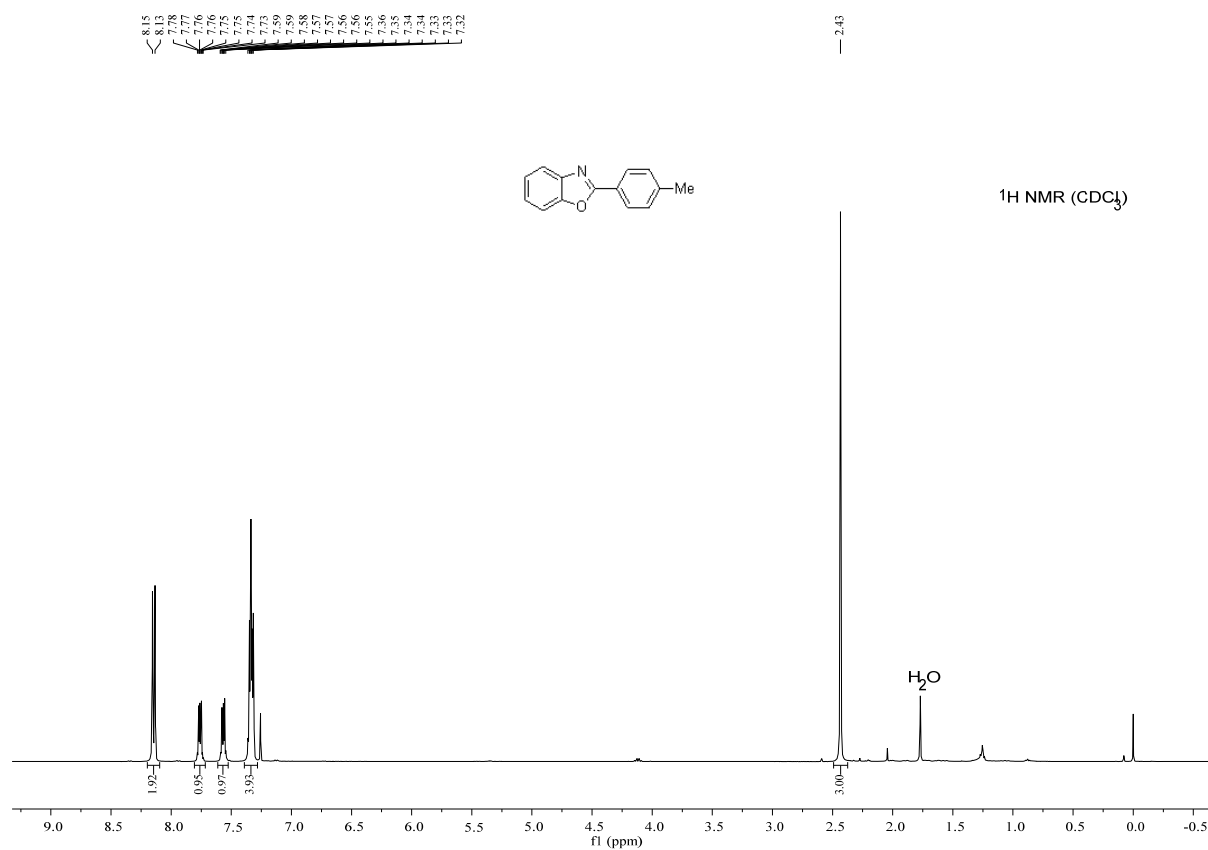
5. 2-Phenylbenzoxazole (4)



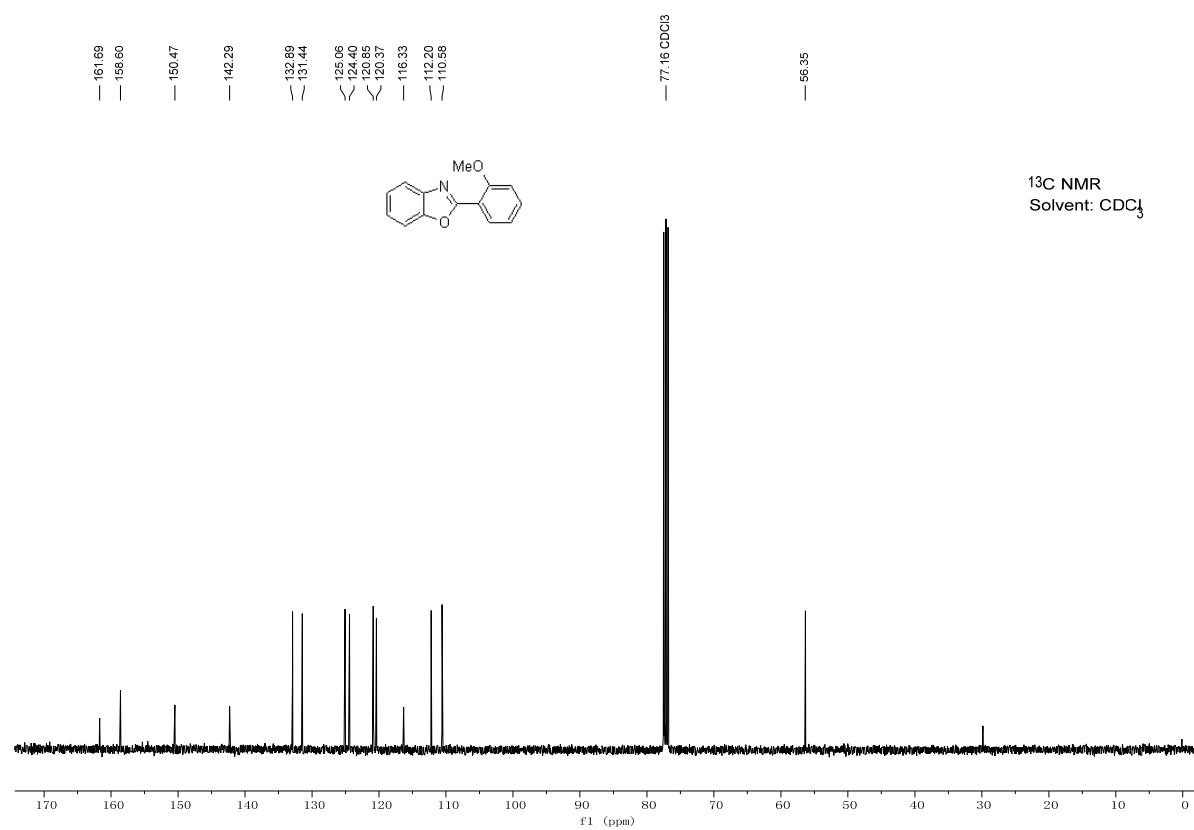
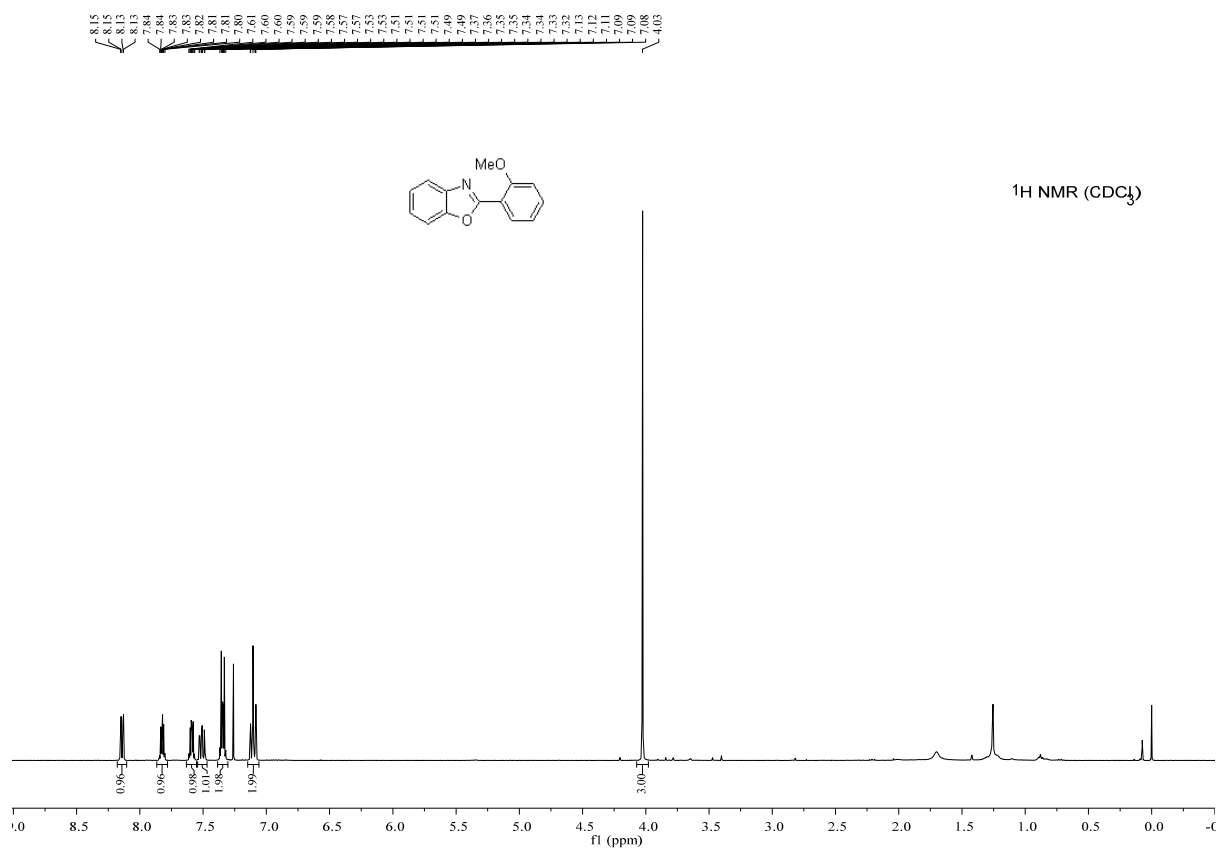
6. 2-*o*-Tolylbenzoxazole (5)



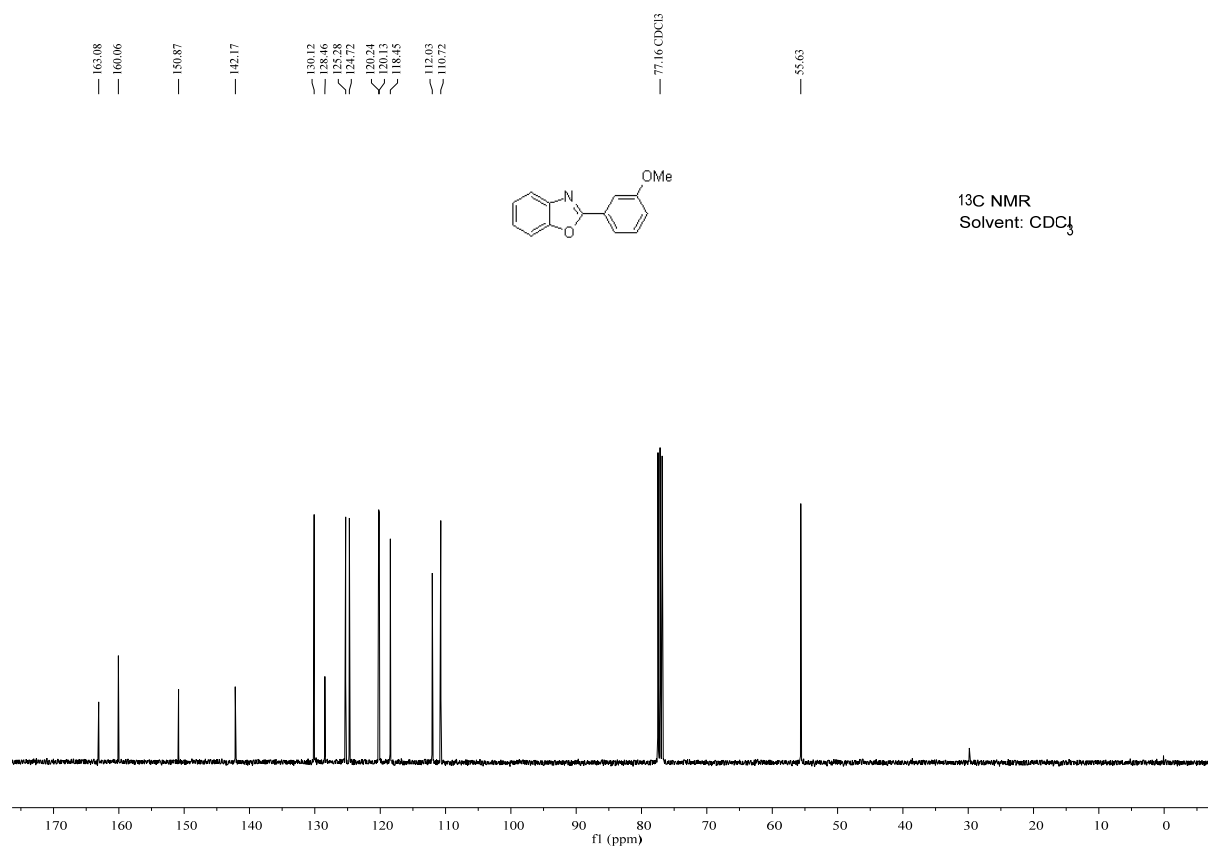
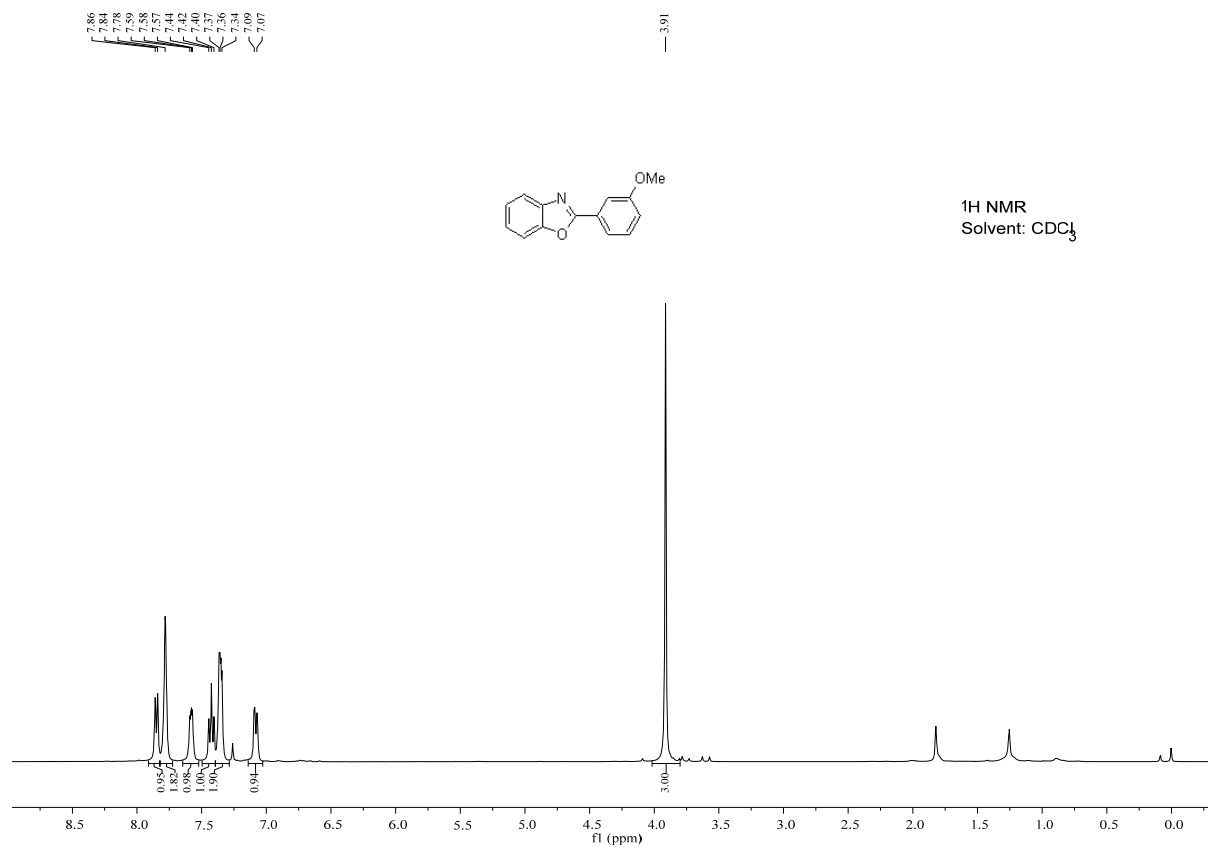
7. 2-(*p*-Tolyl)benzoxazole (**6**)



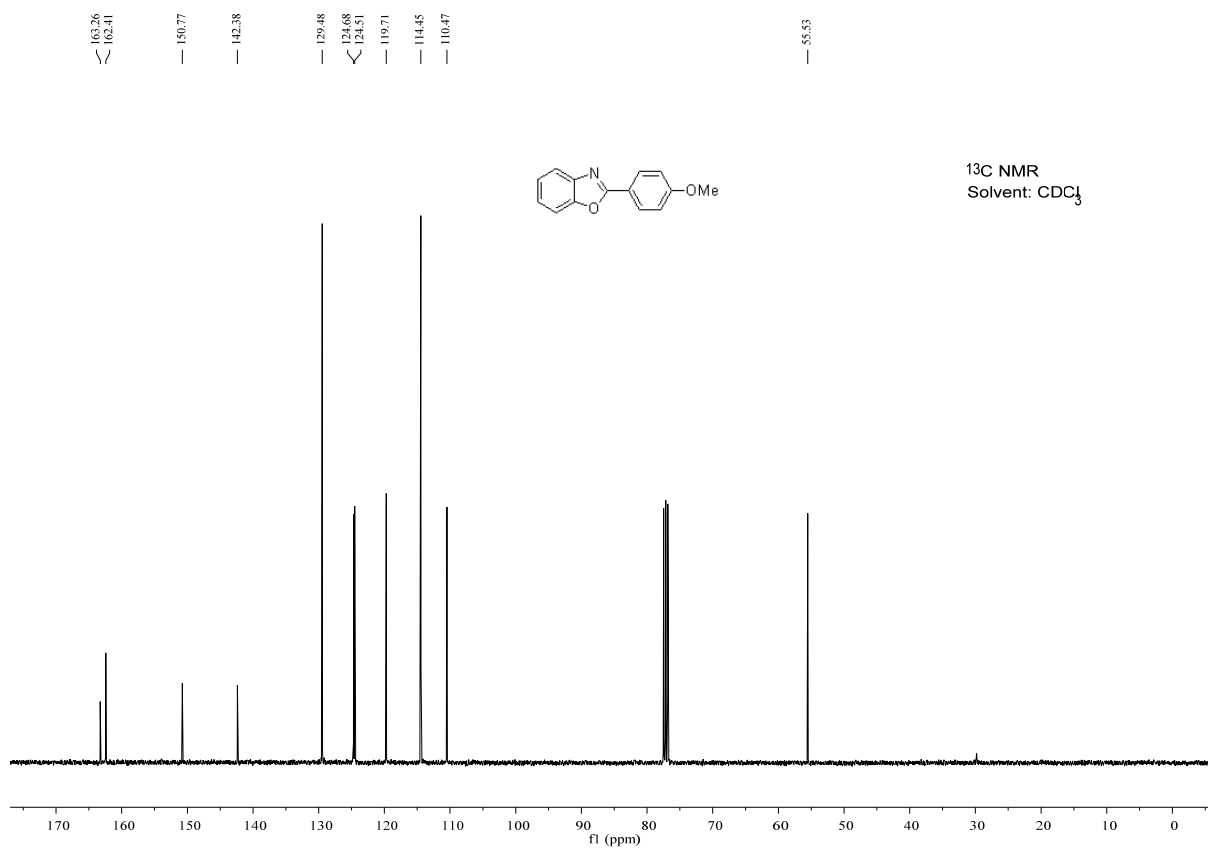
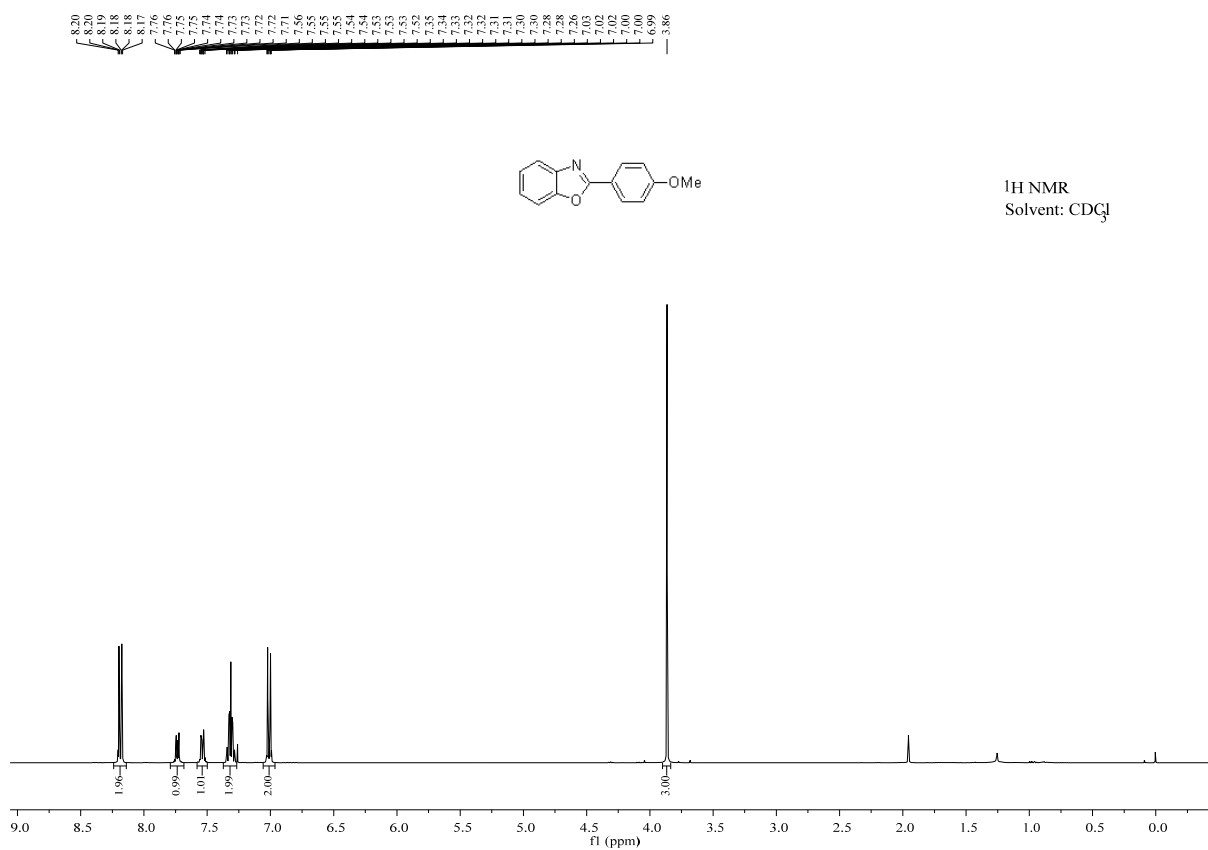
8. 2-(2-Methoxyphenyl)benzoxazole (7)



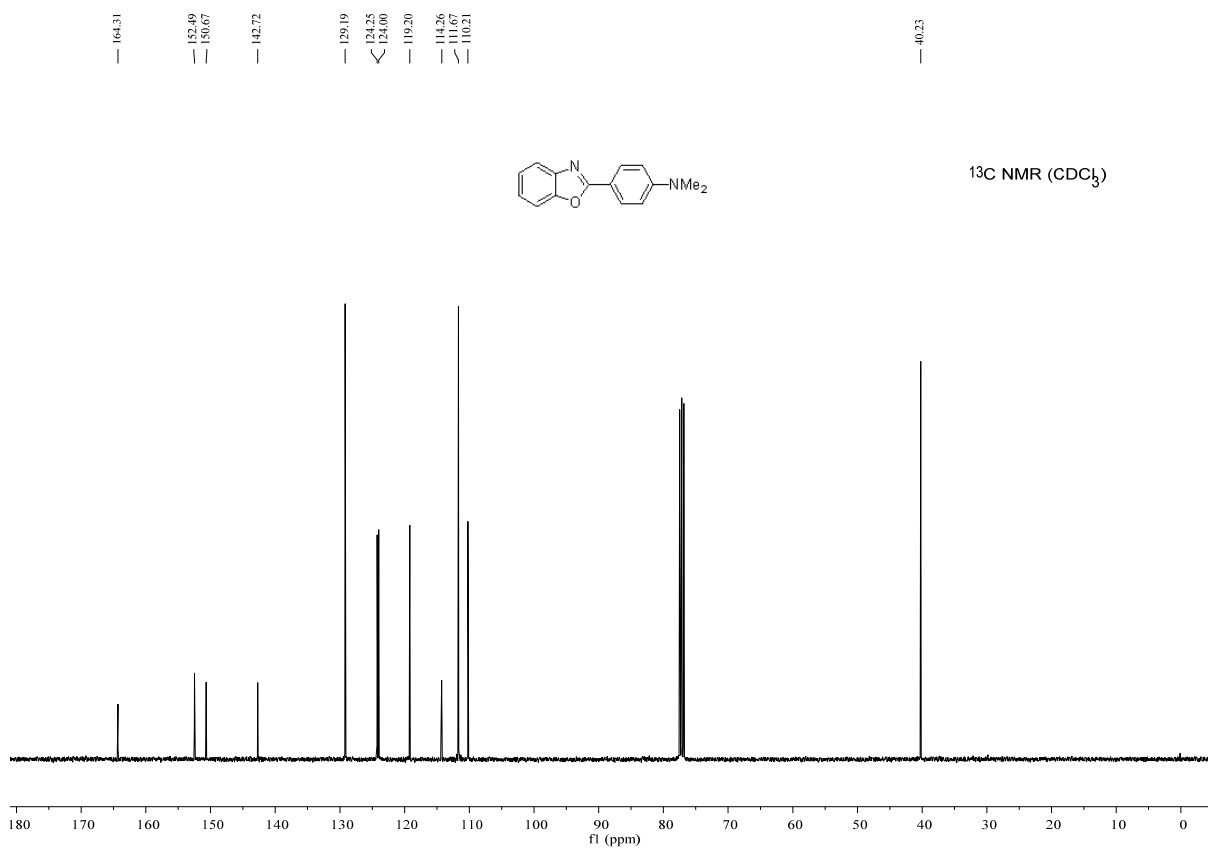
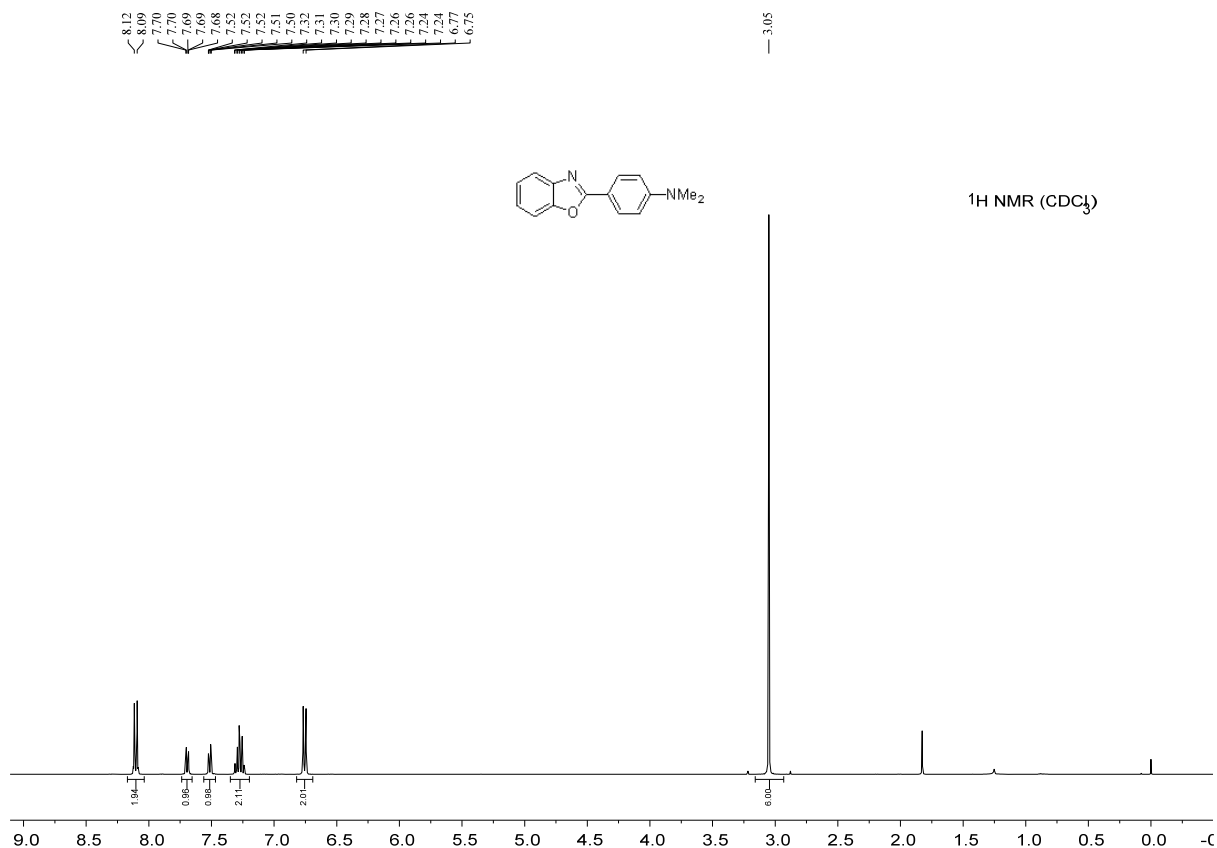
9. 2-(3-Methoxyphenyl)benzoxazole (**8**)



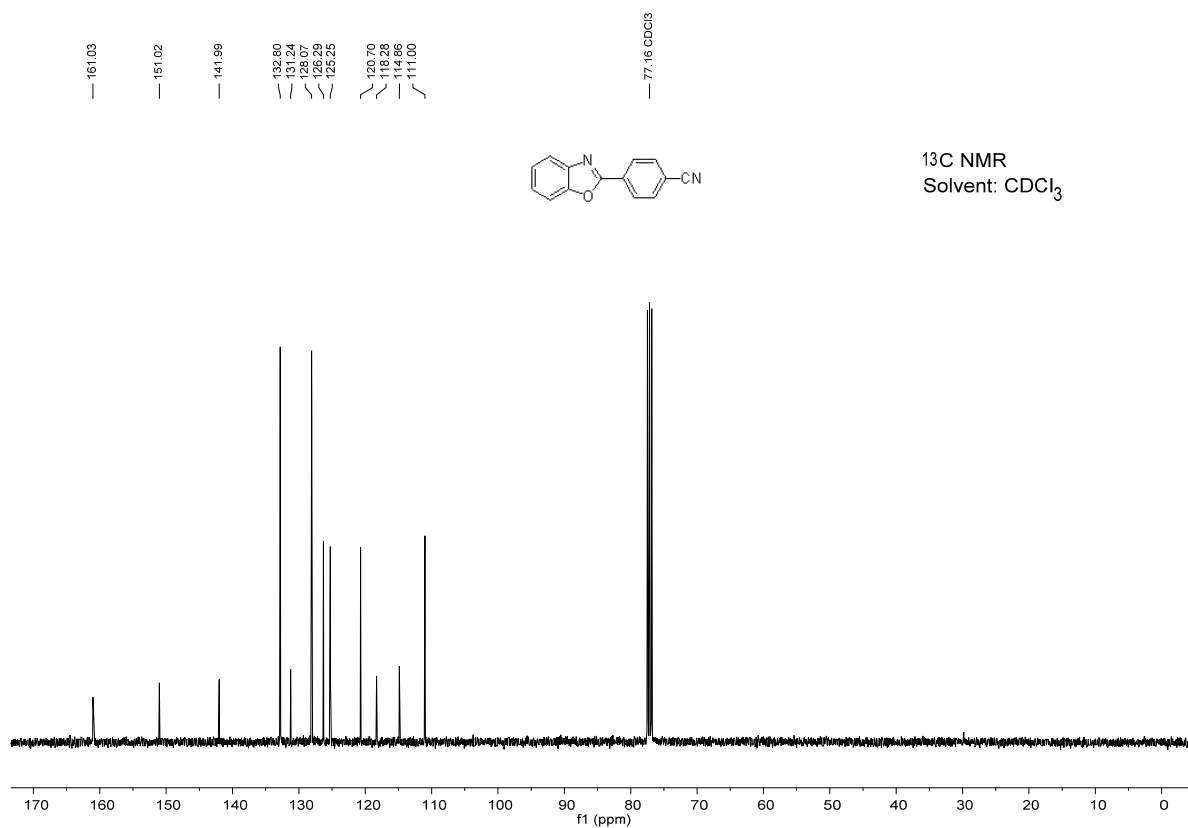
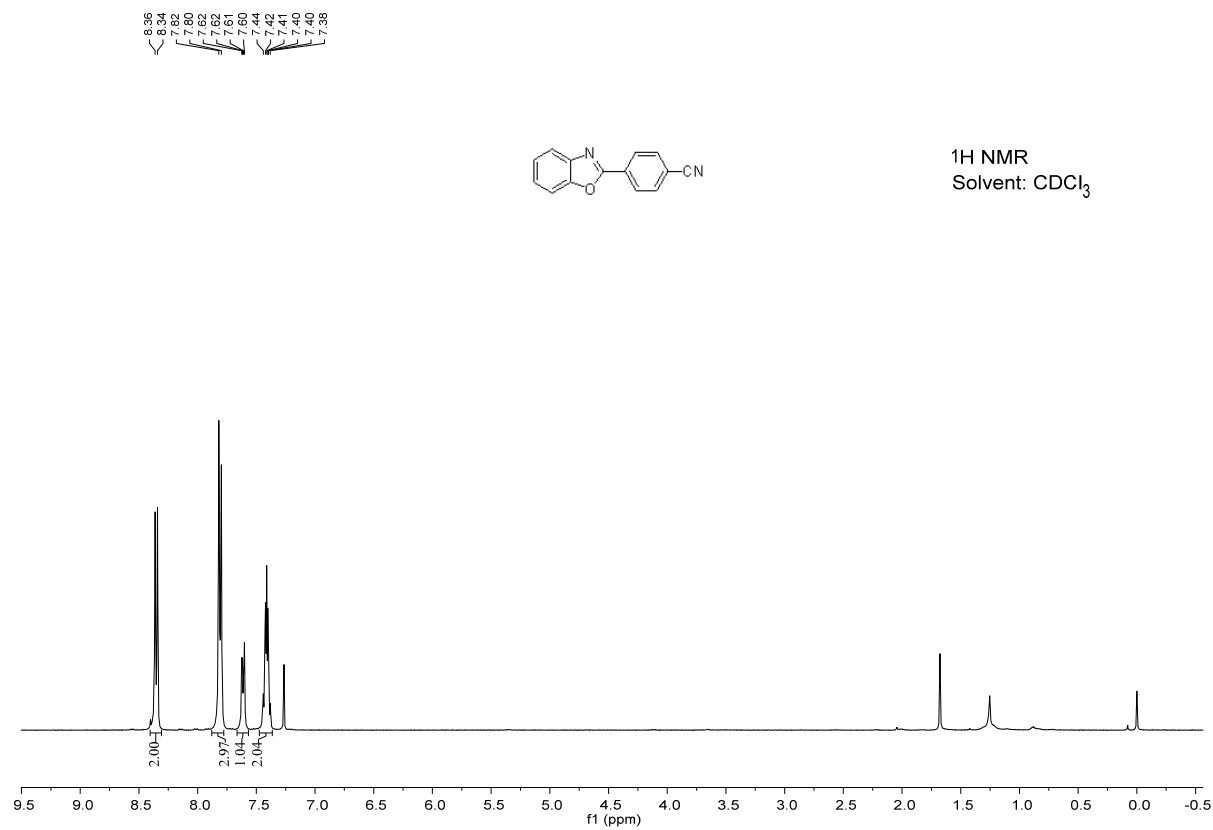
10. 2-(4-Methoxyphenyl)benzoxazole (9)



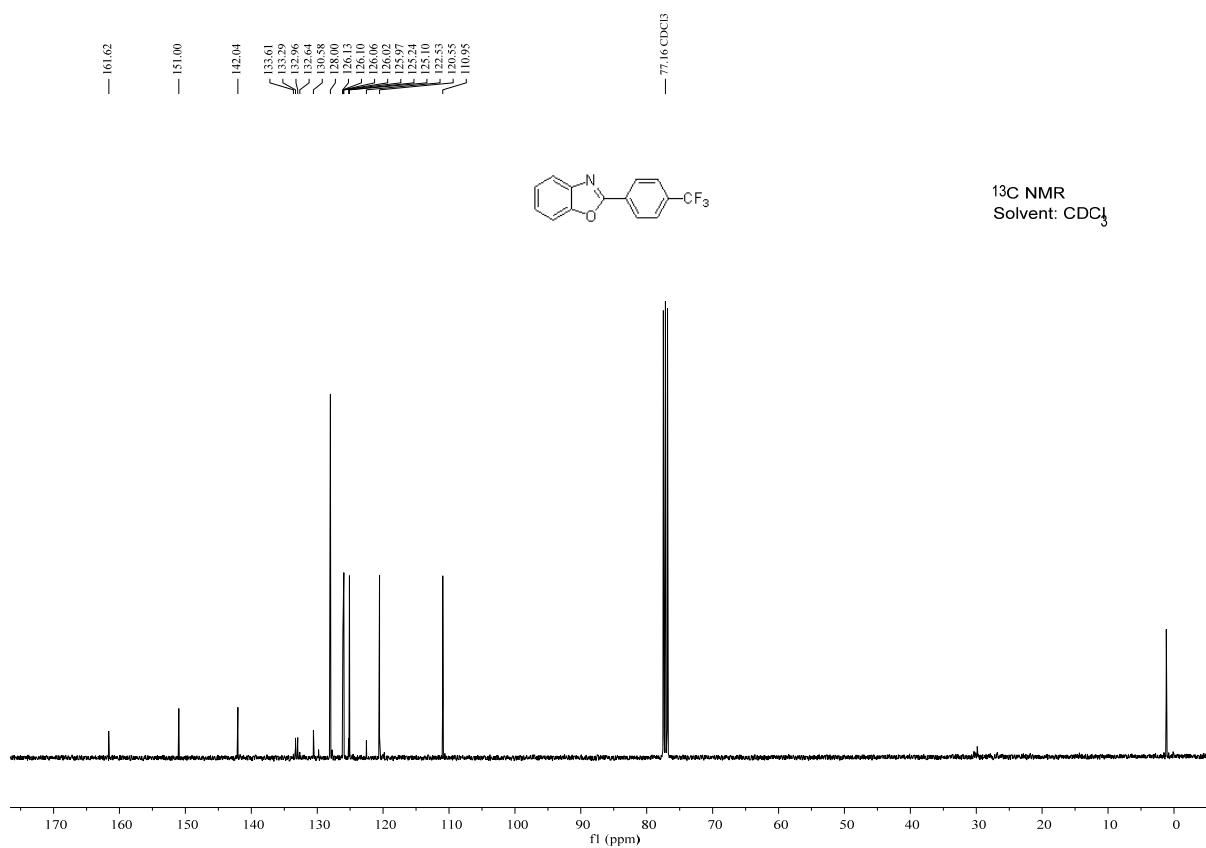
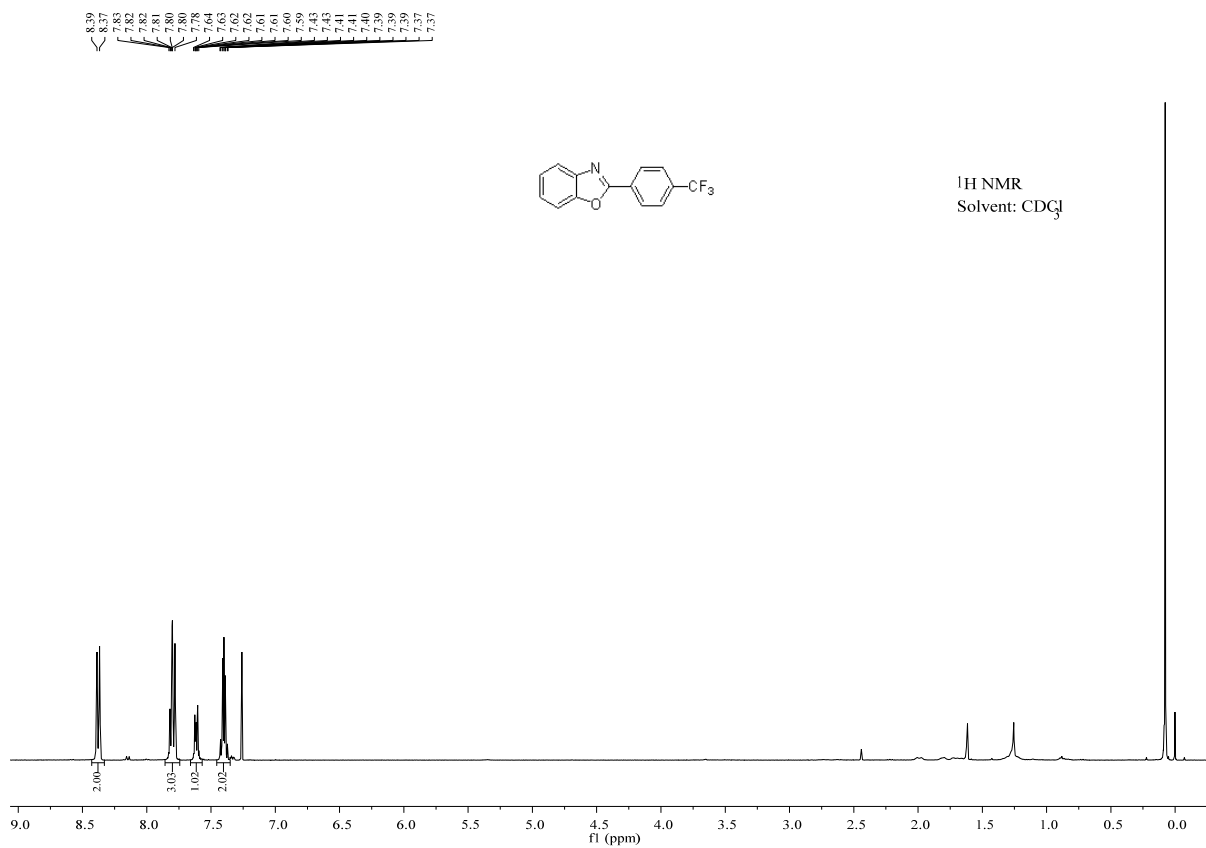
11. 4-(benzoxazol-2-yl)-*N,N*-dimethylaniline (**10**)



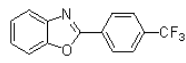
12. 4-(Benzoxazol-2-yl)benzonitrile (**11**)



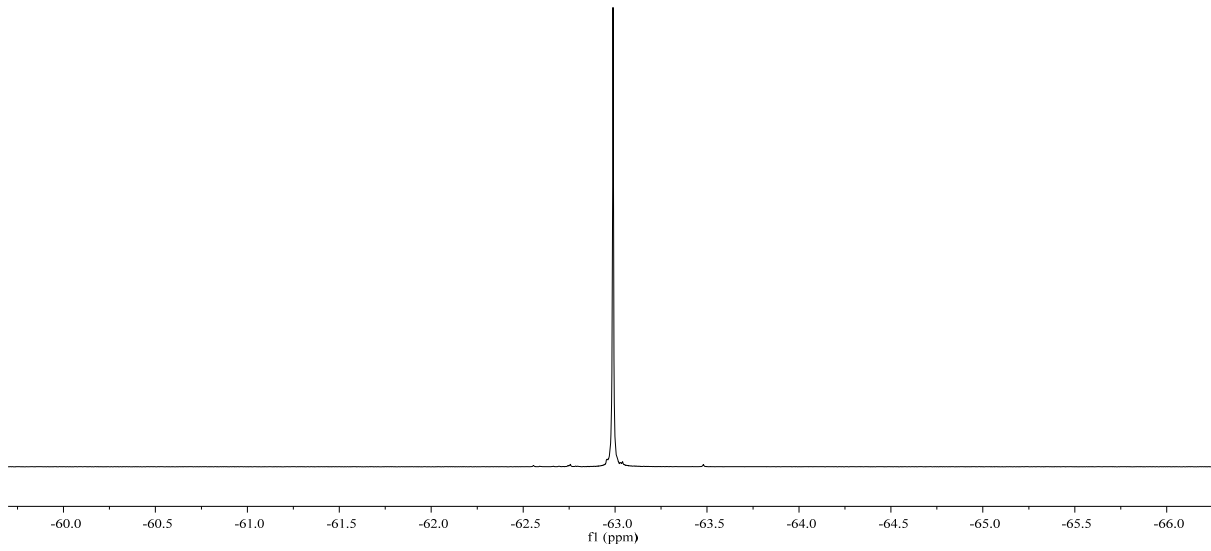
13. 2-(4-(Trifluoromethyl)phenyl)benzoxazole (12)



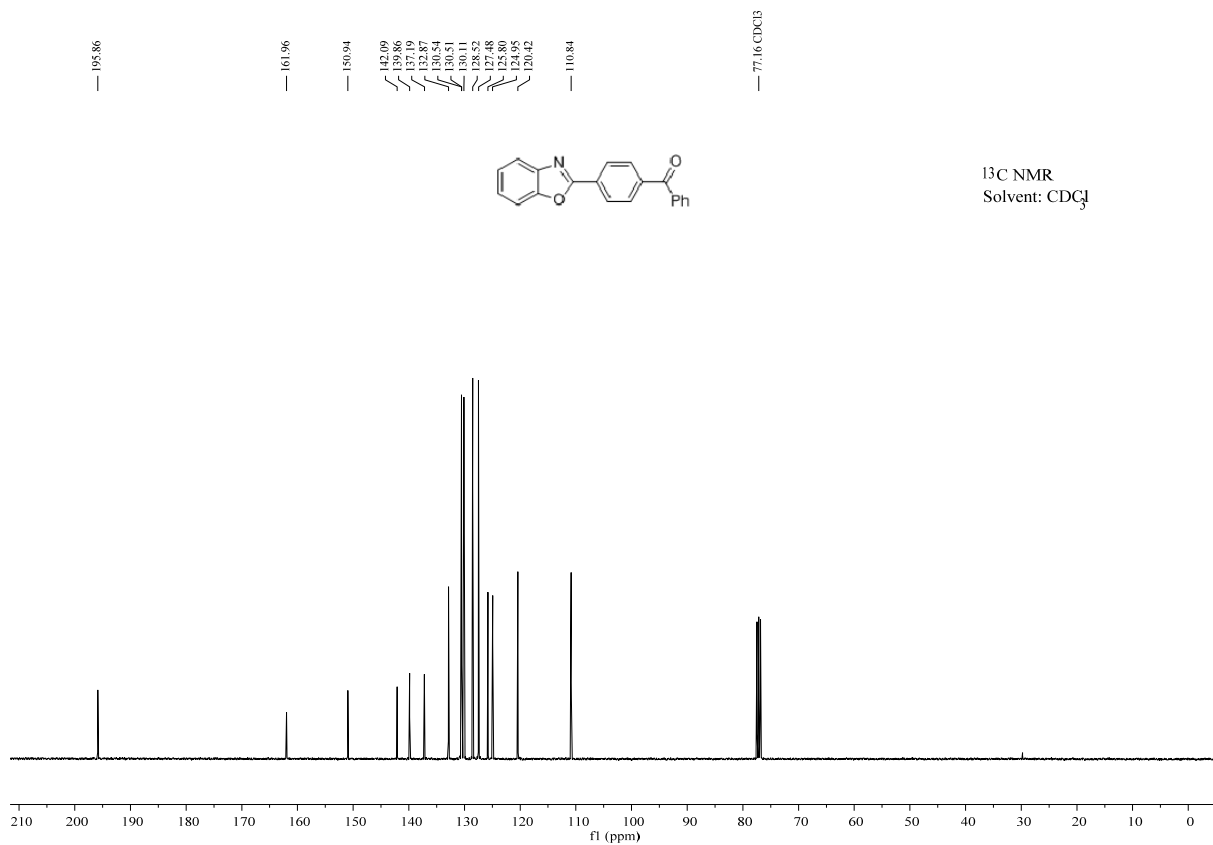
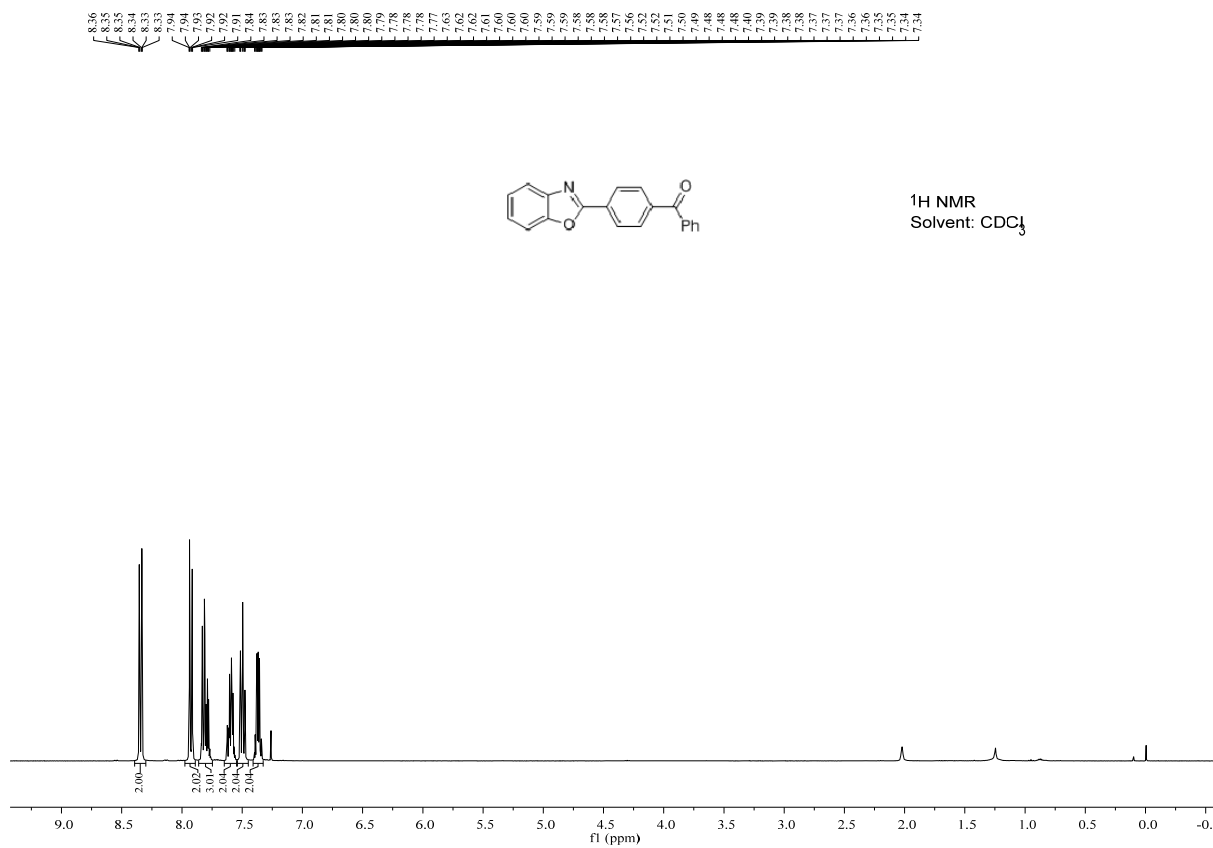
-62.99



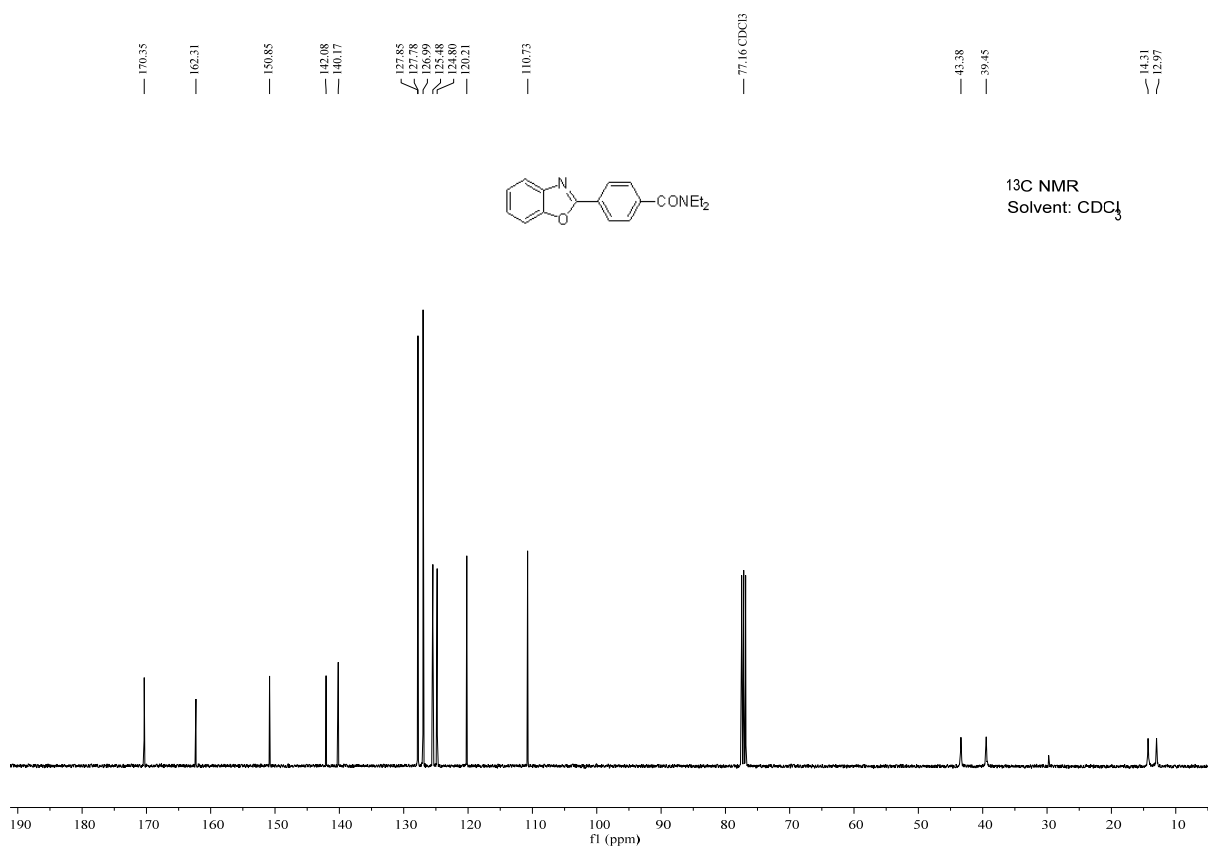
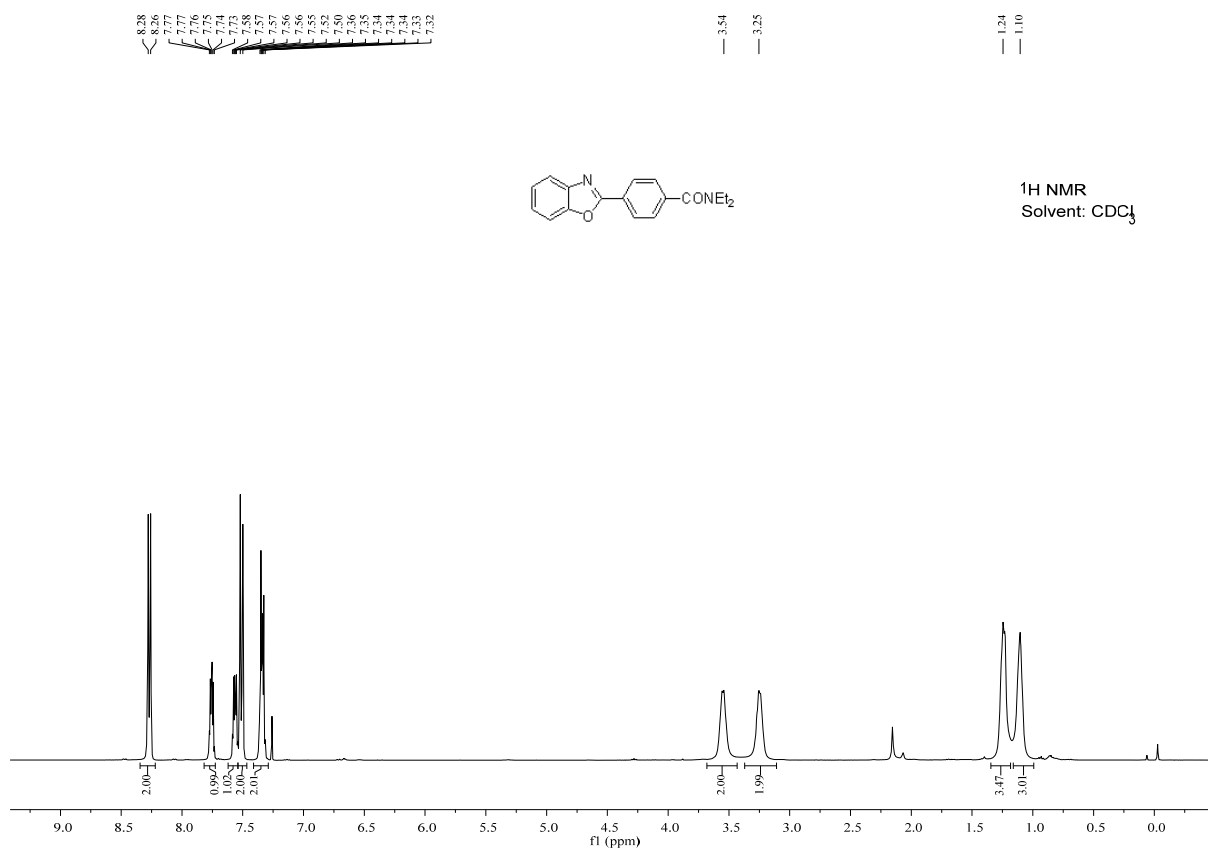
¹⁹F NMR
Solvent: CDCl₃



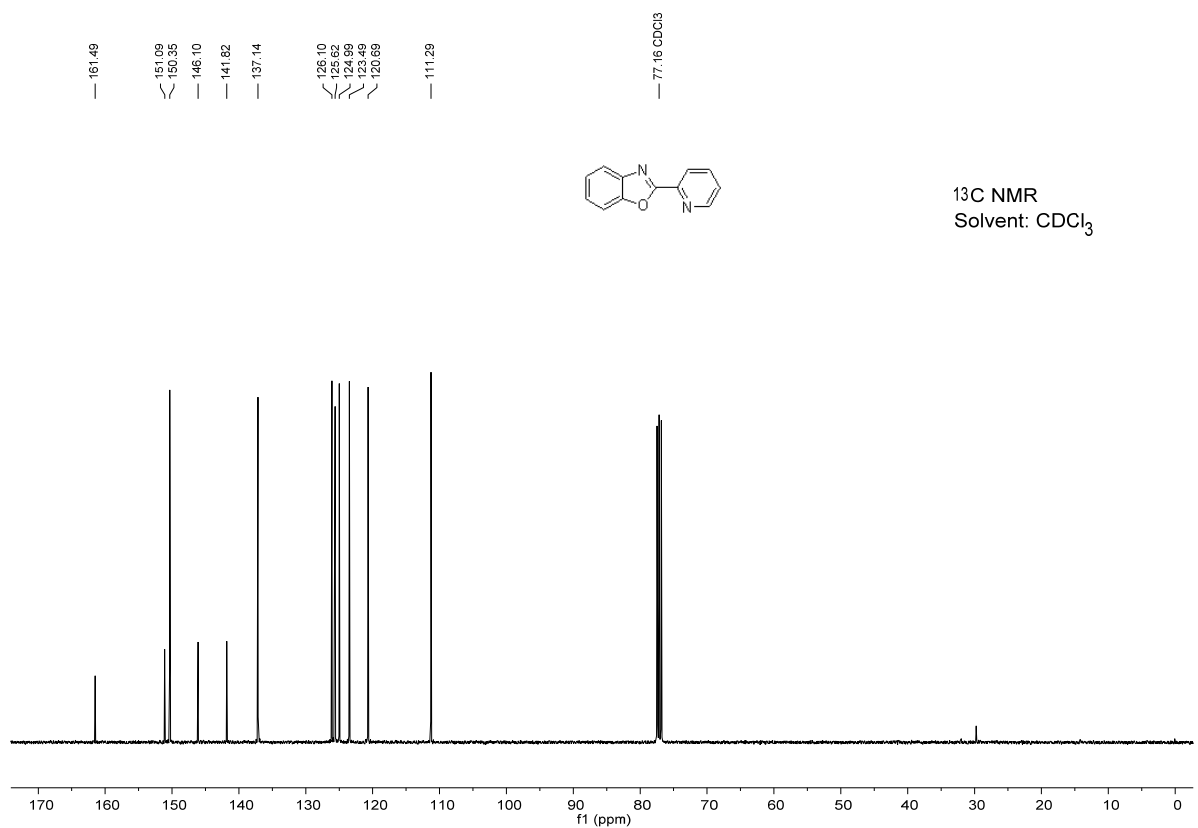
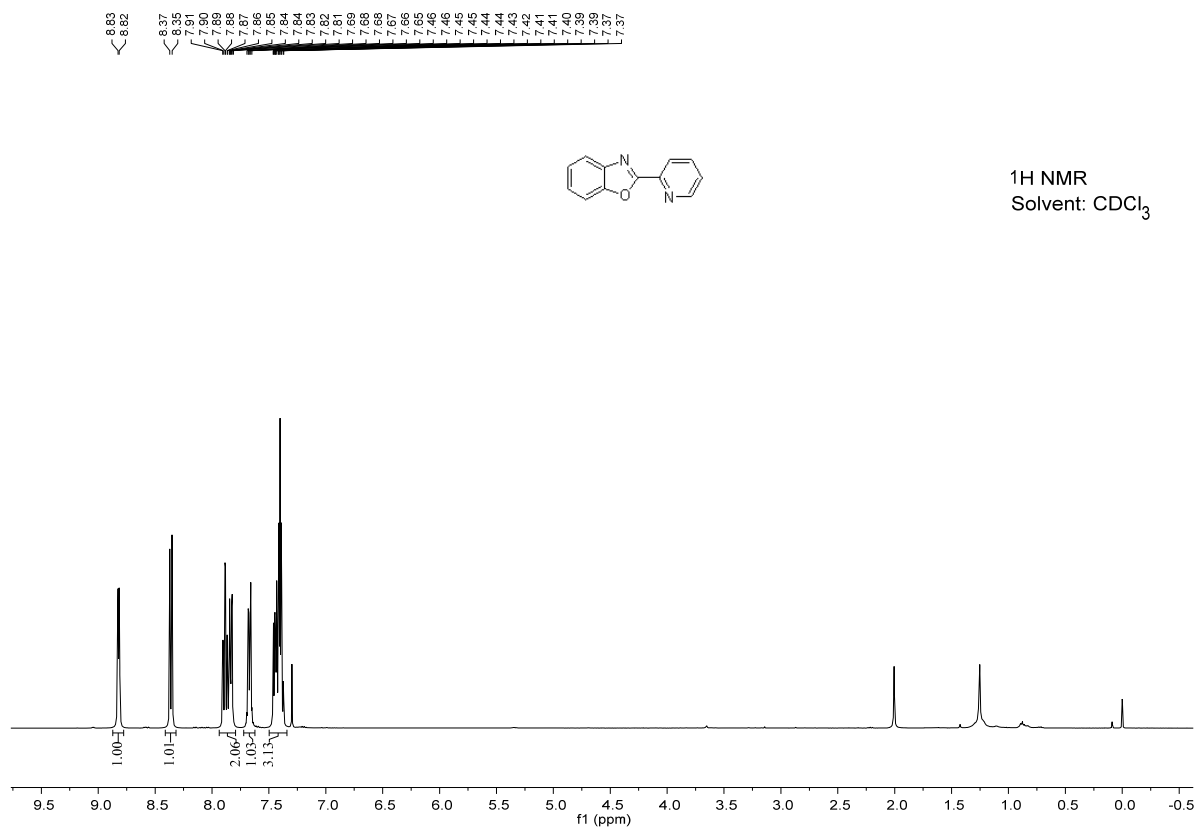
14. (4-(Benzoxazol-2-yl)phenyl)(phenyl)methanone (**13**)



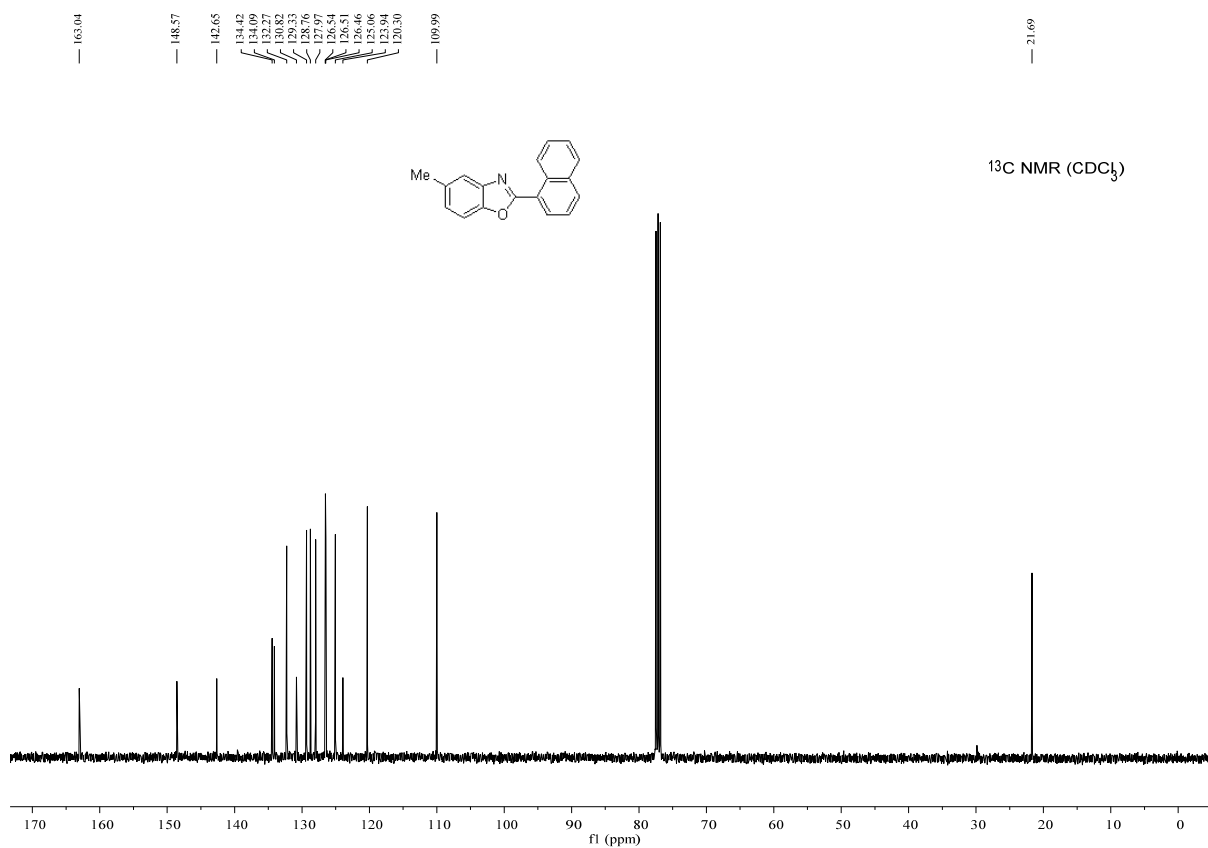
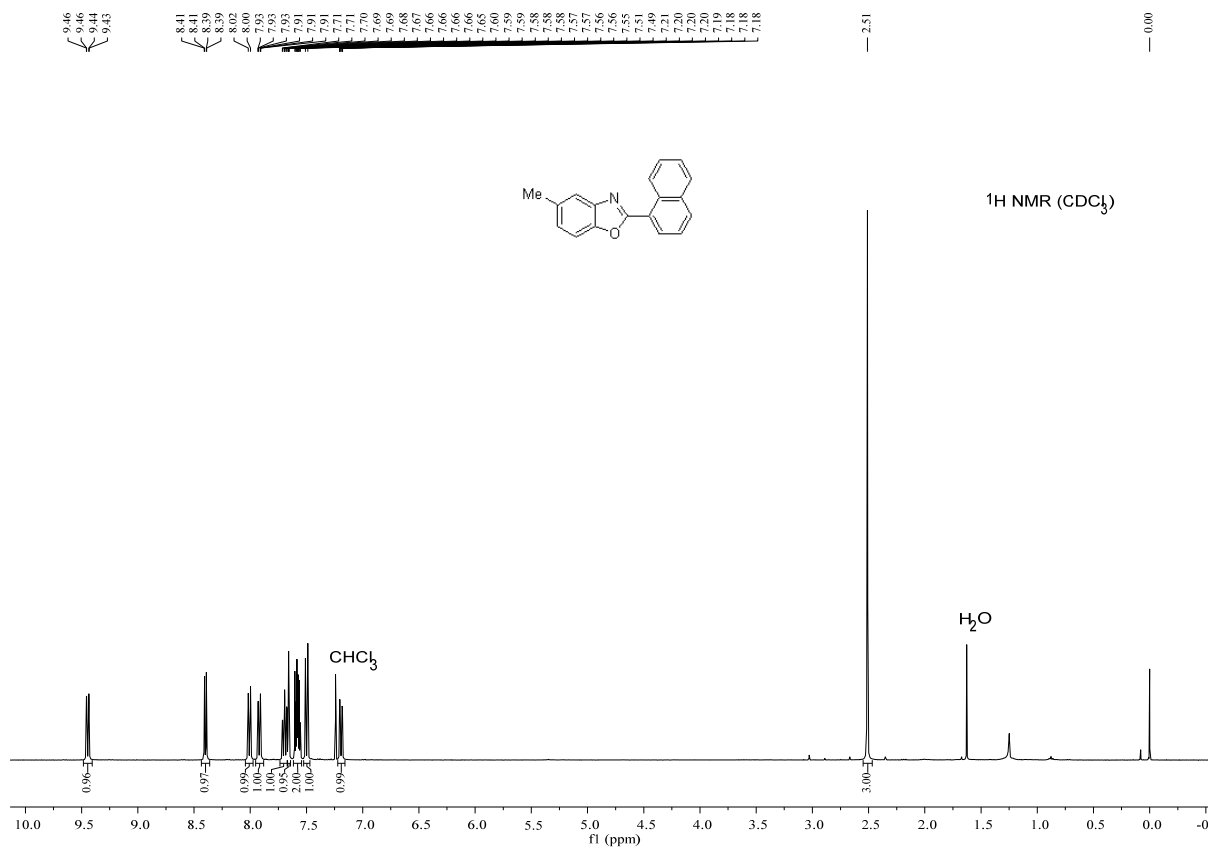
15. 4-(Benzoxazol-2-yl)-*N,N*-diethylbenzamide (**14**)



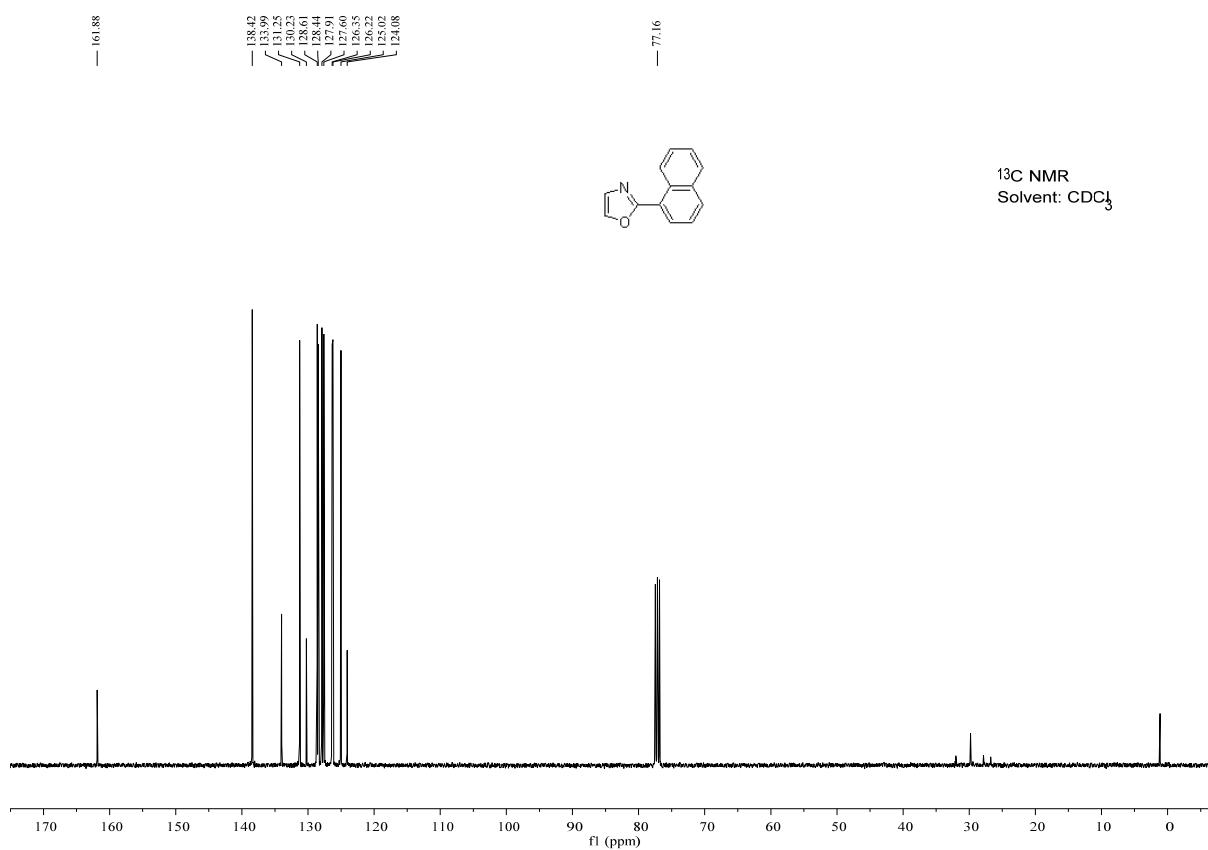
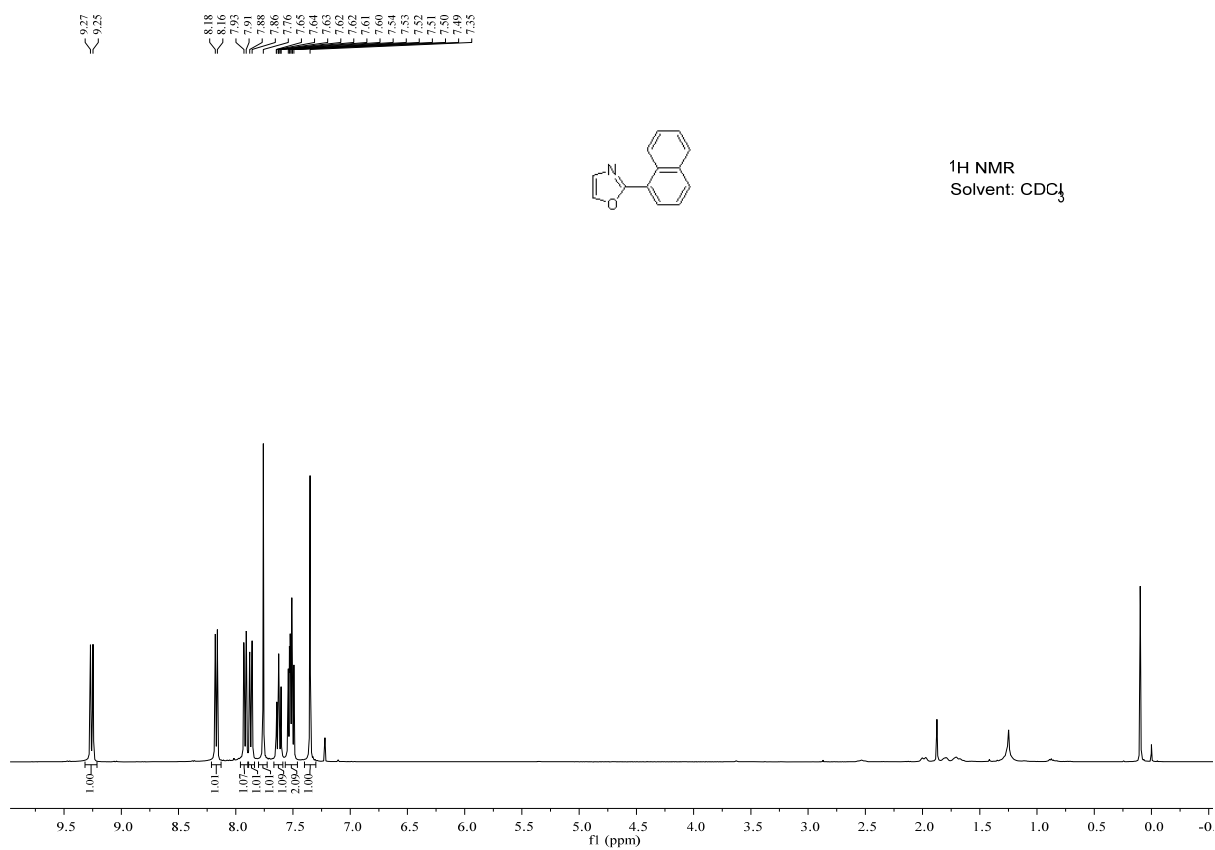
16. 2-(Pyridin-2-yl)benzoxazole (15)



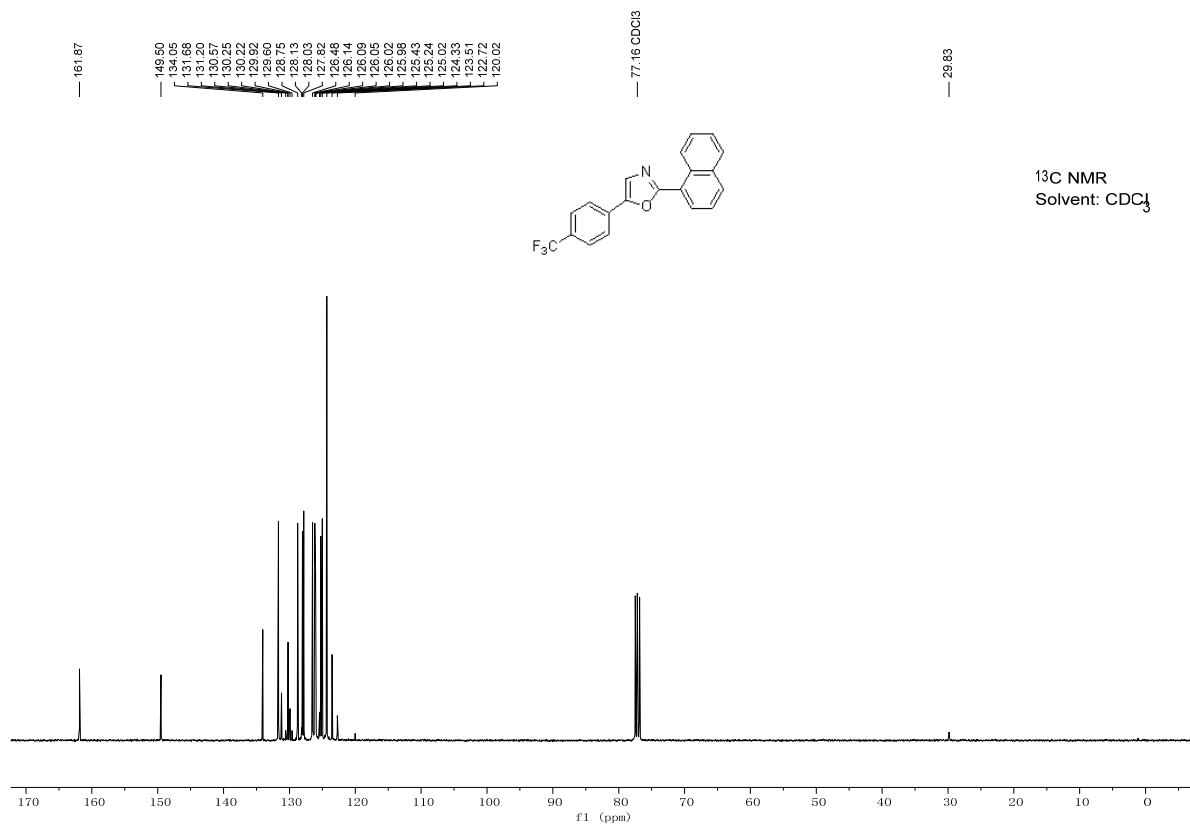
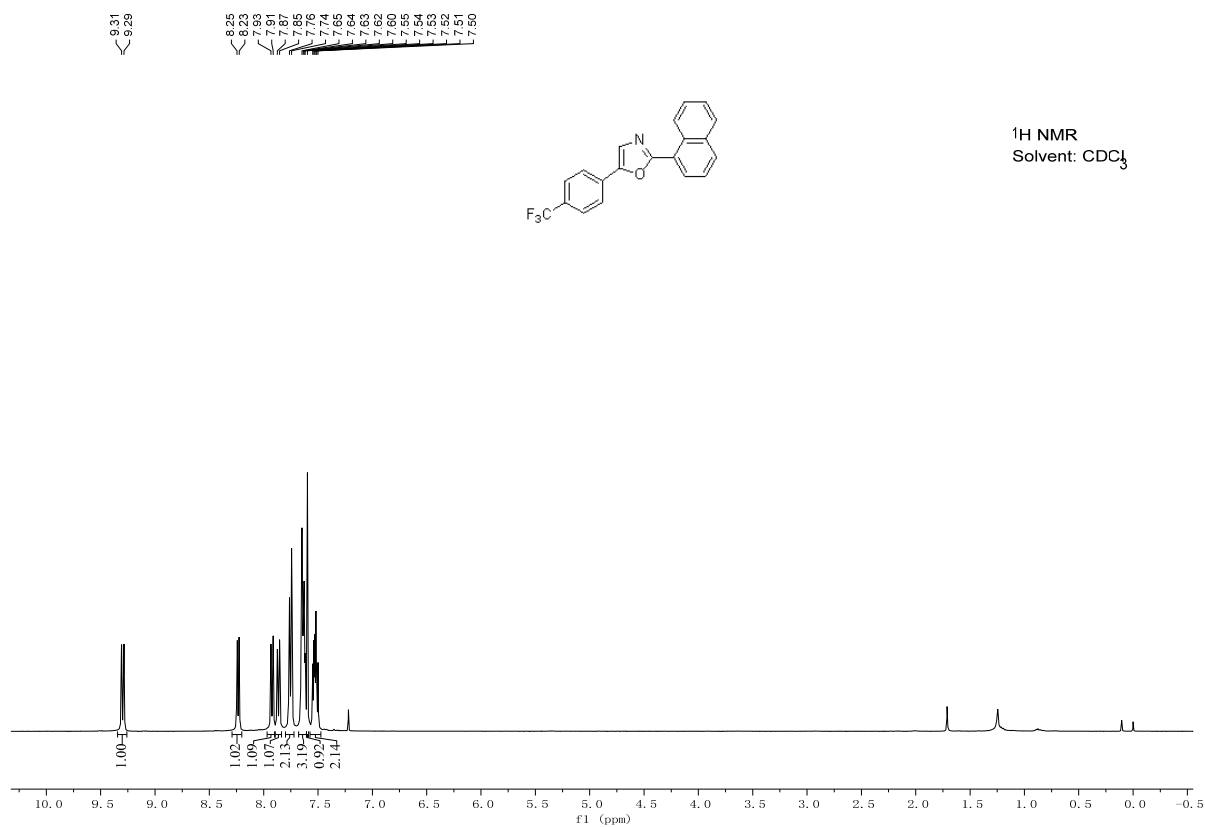
17. 5-Methyl-2-(naphthalen-1-yl)benzoxazole (16)

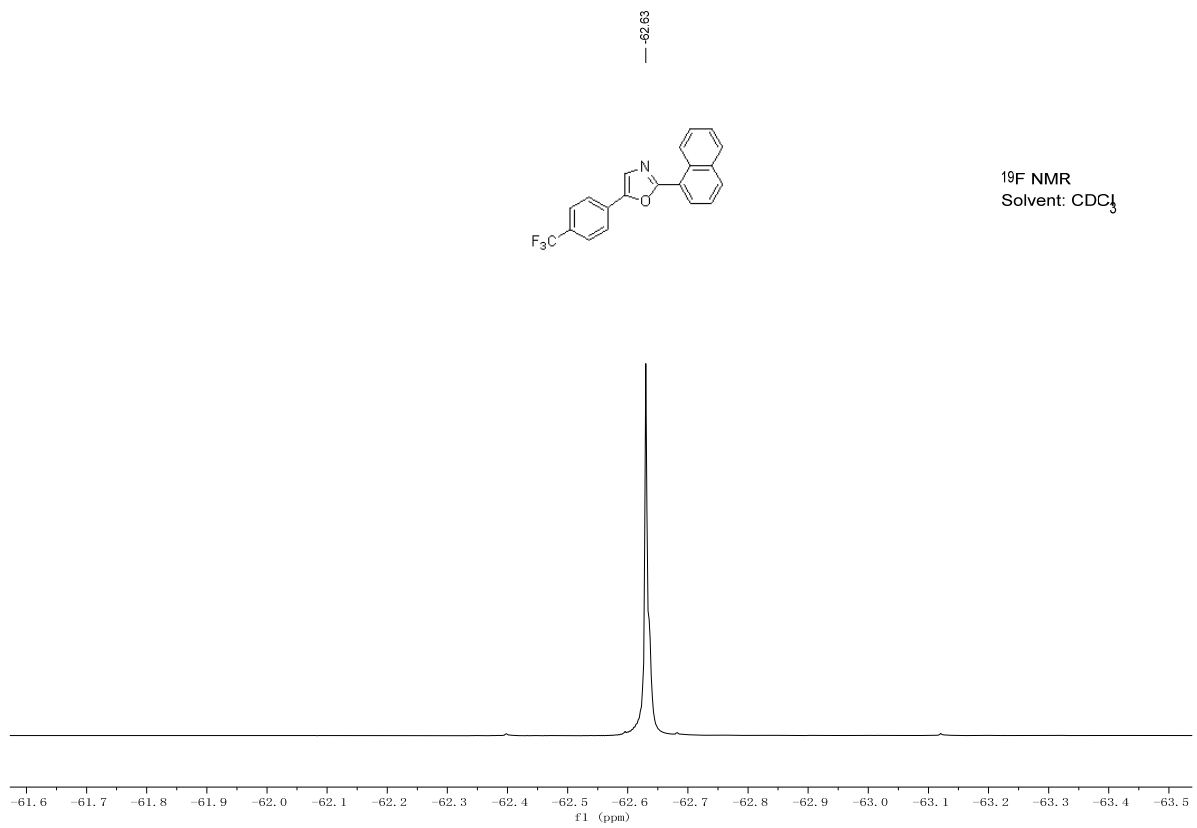


18. 2-(Naphthalen-1-yl)oxazole (17)

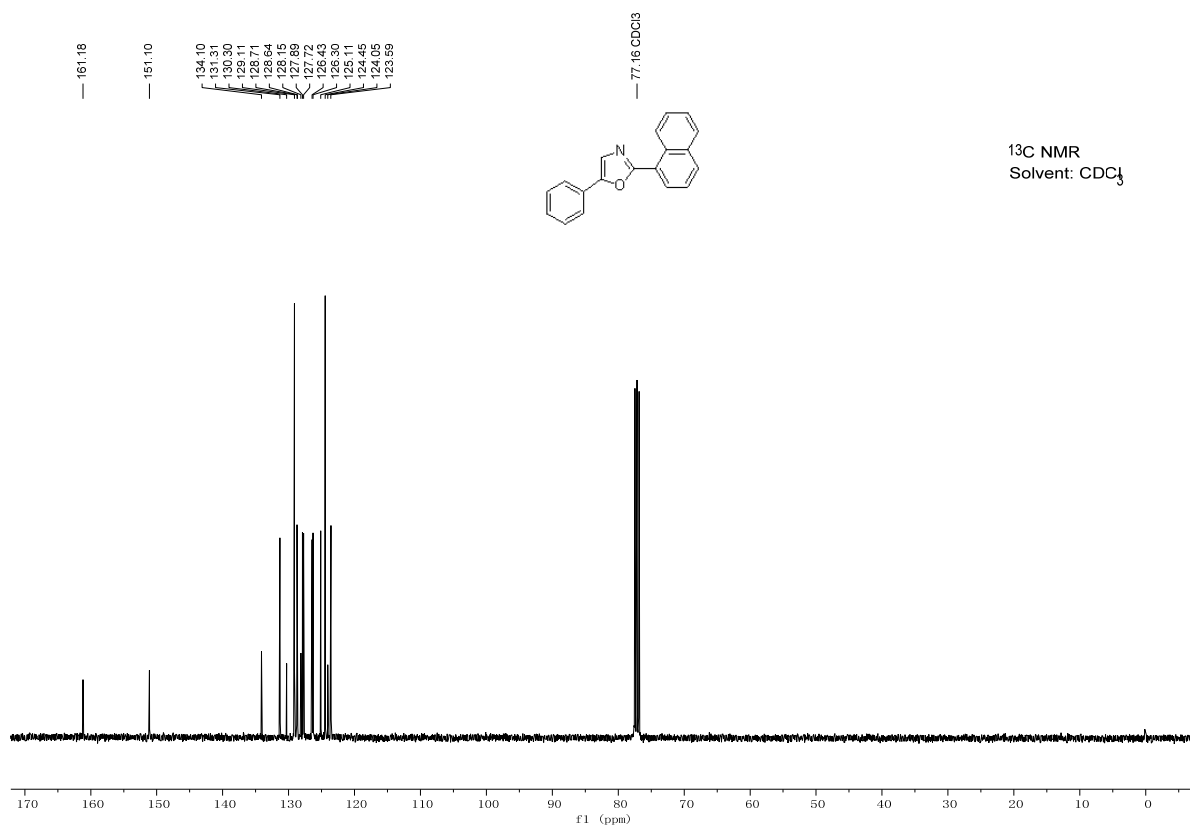
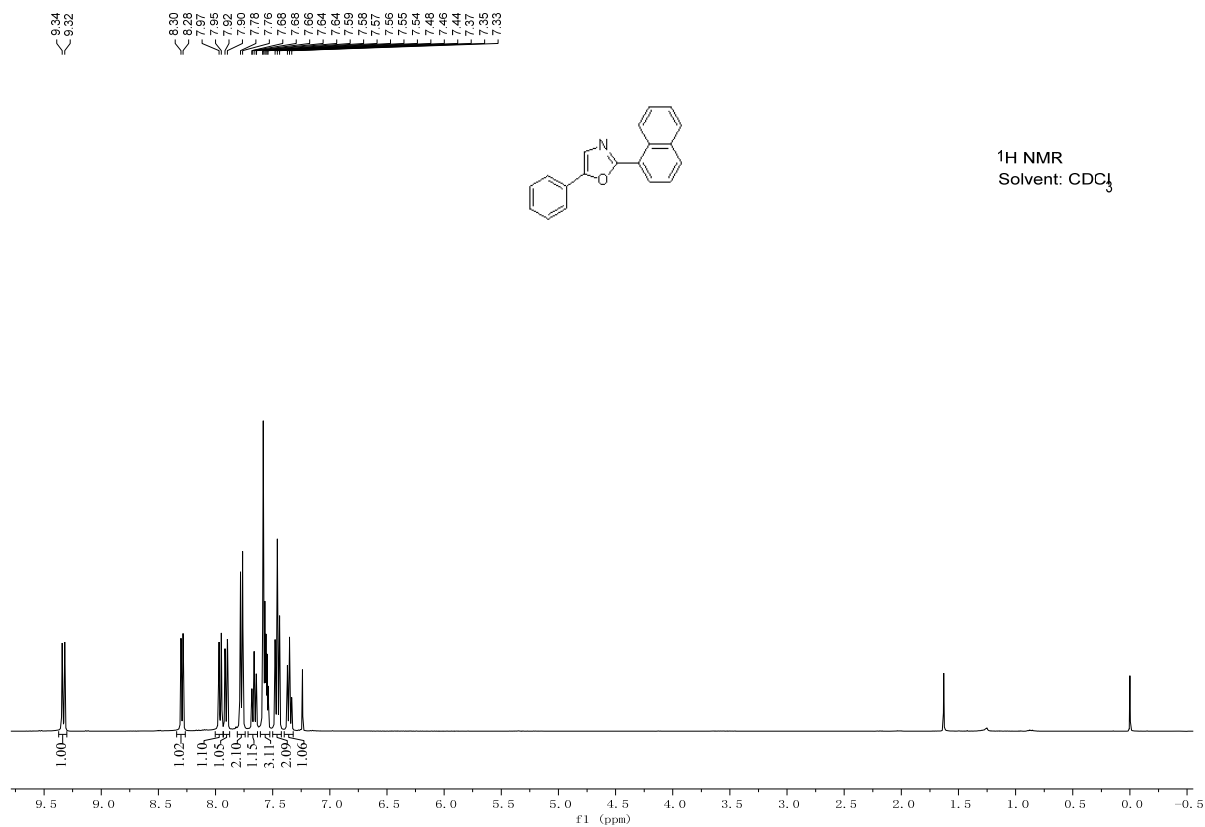


19. 2-(Naphthalen-1-yl)-5-(4-(trifluoromethyl)phenyl)oxazole (**18**)

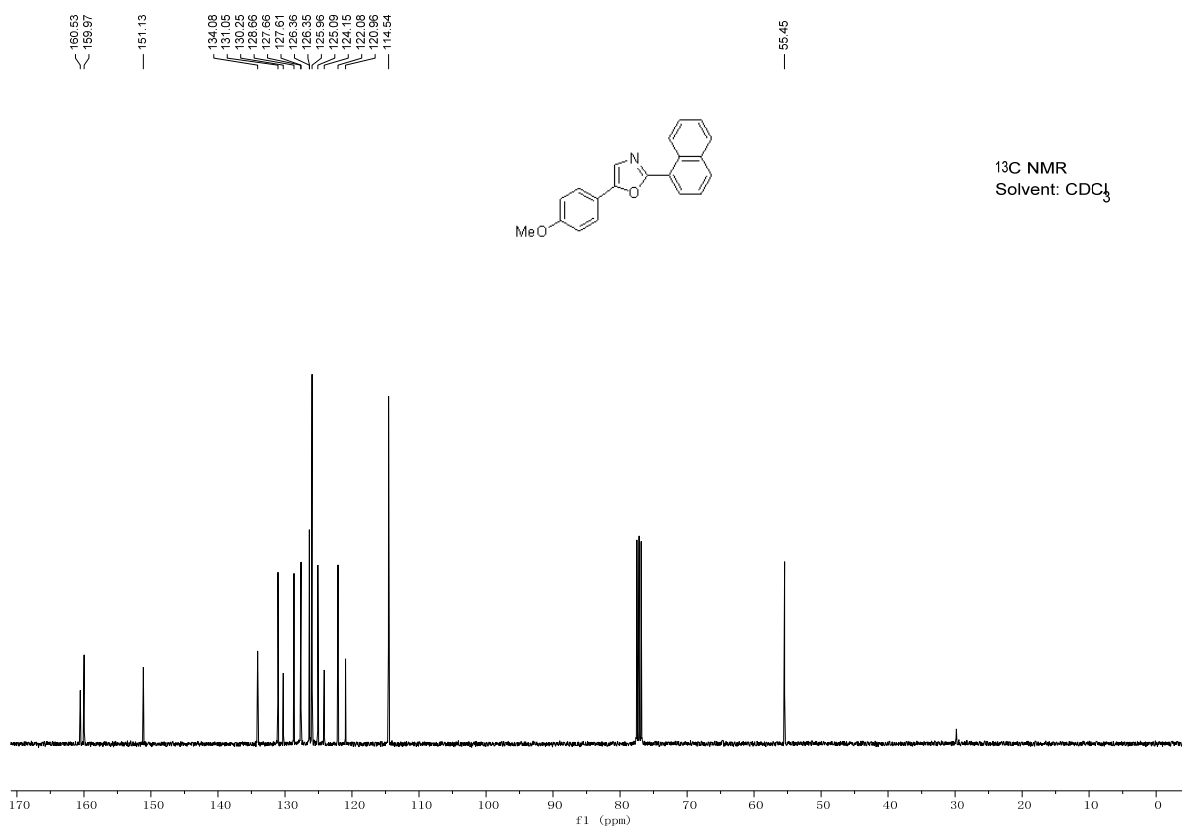
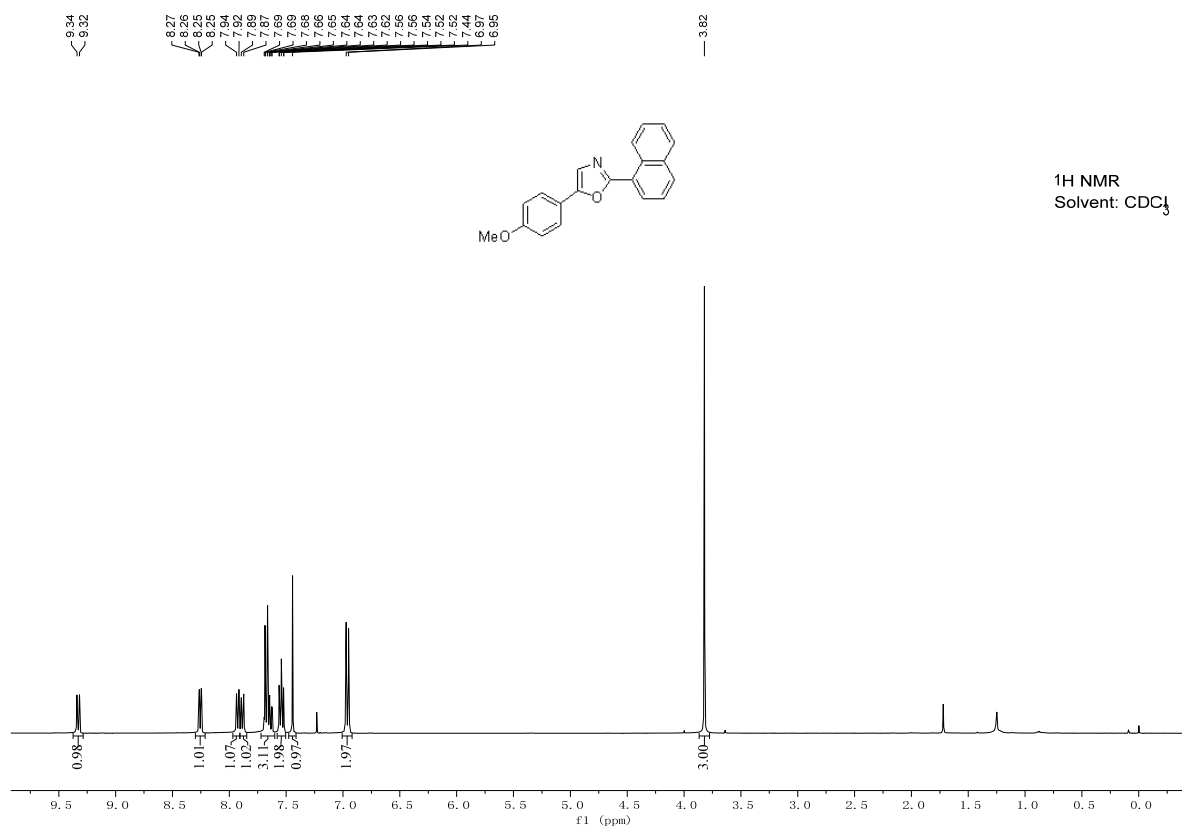




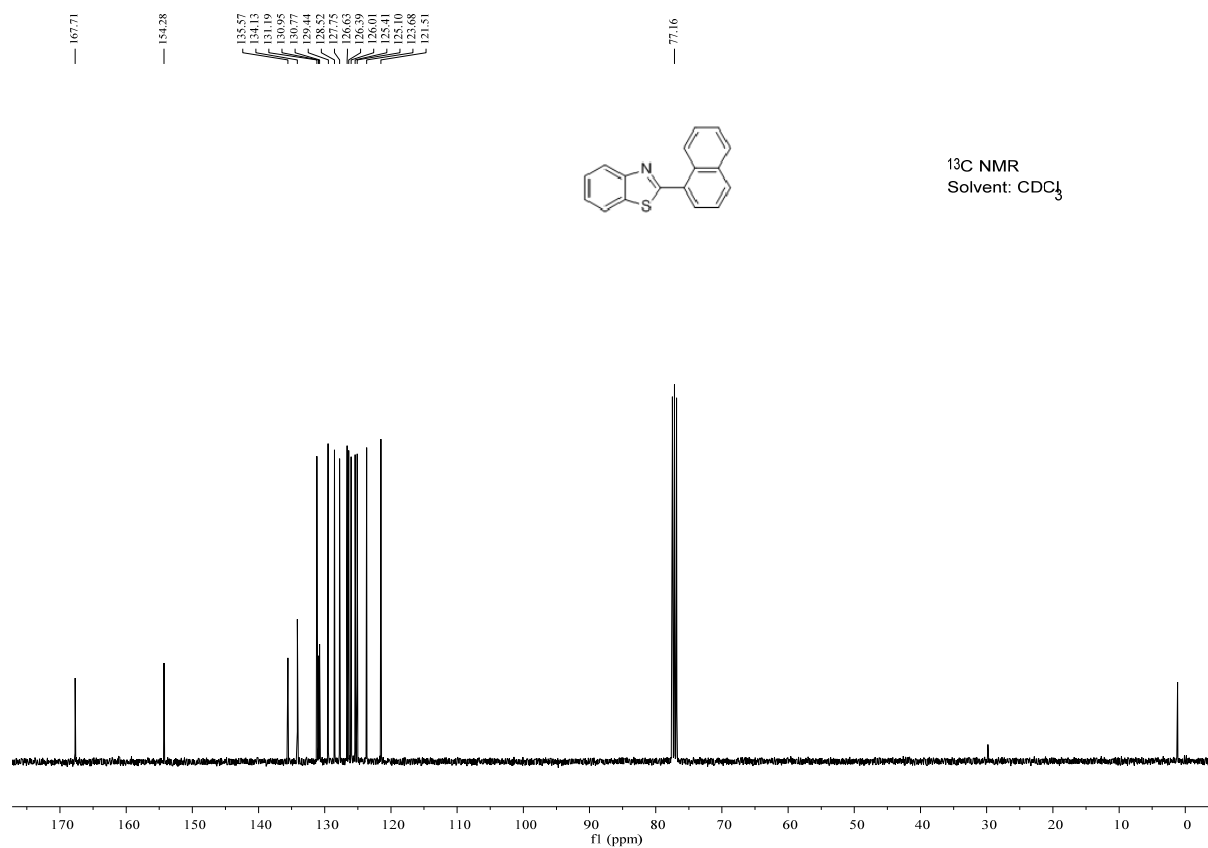
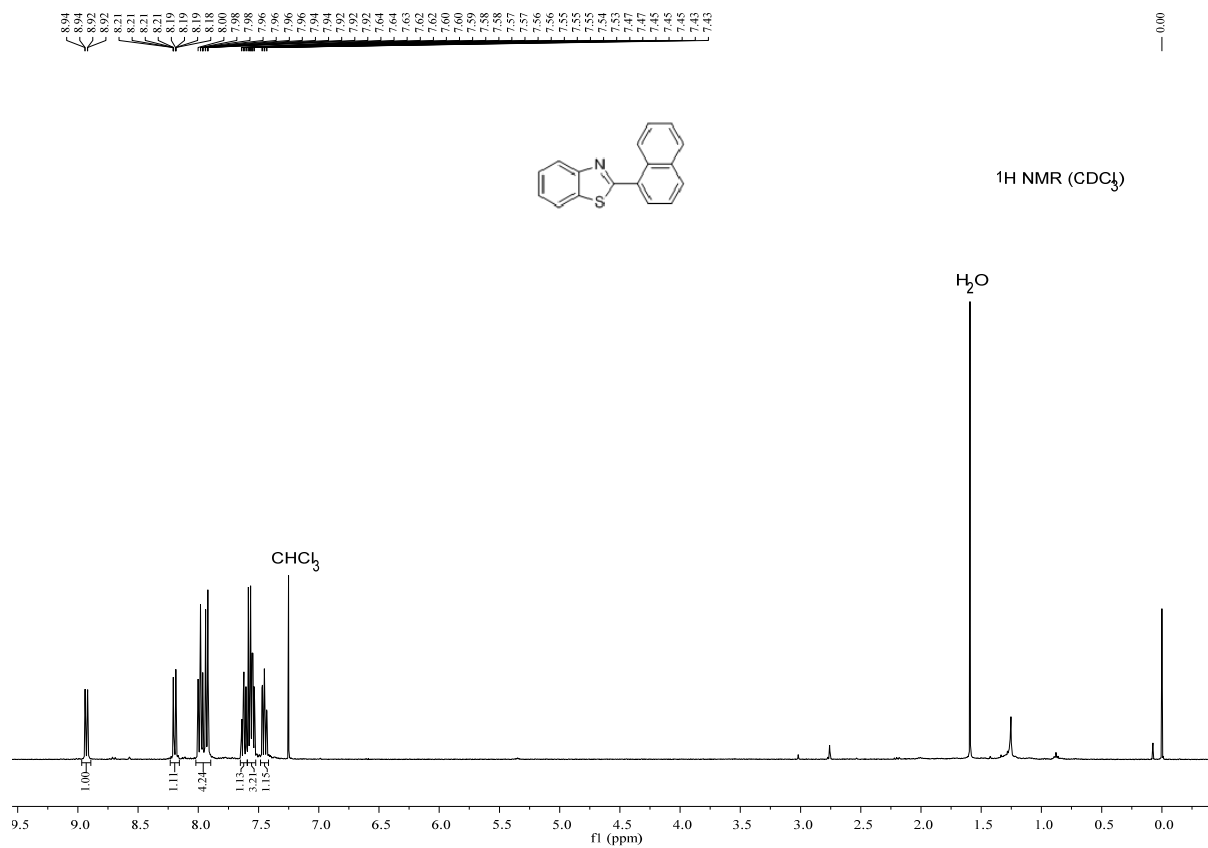
20. 2-(Naphthalen-1-yl)-5-phenyloxazole (19)



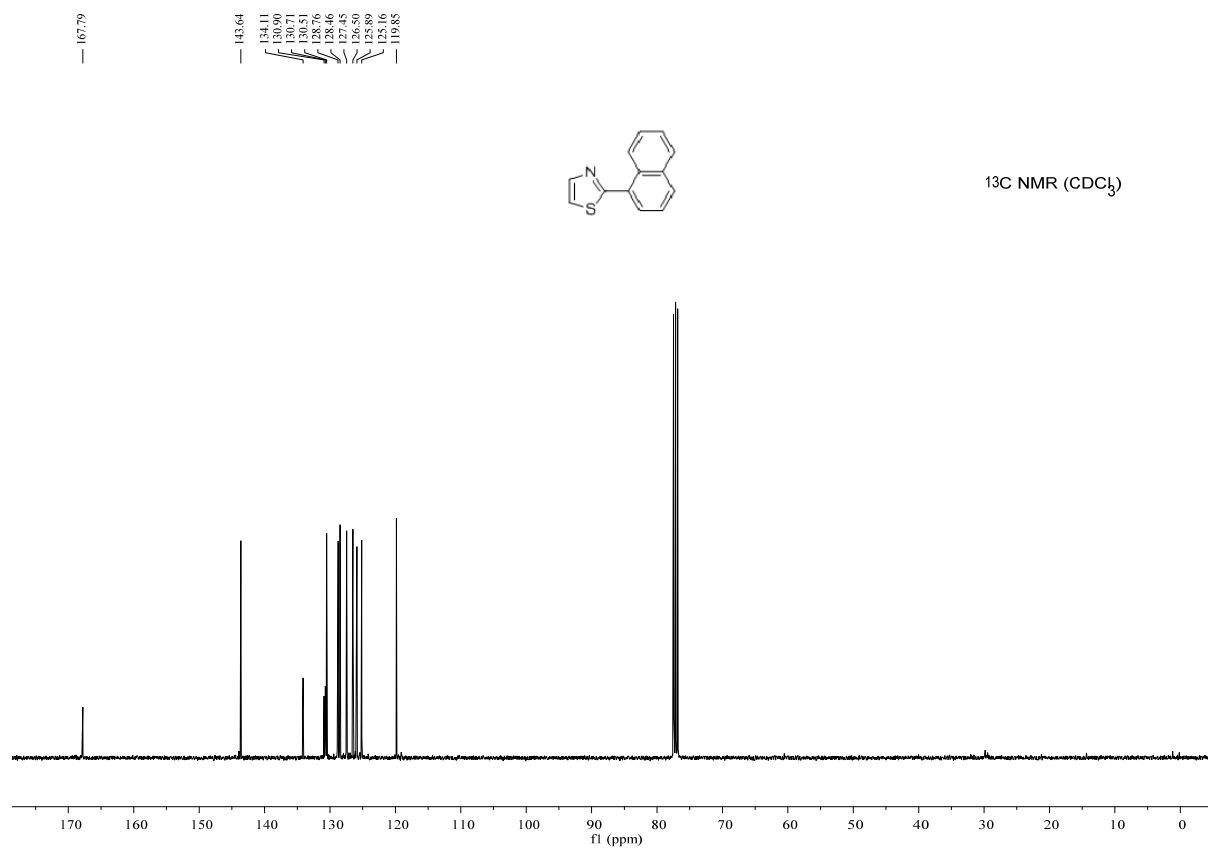
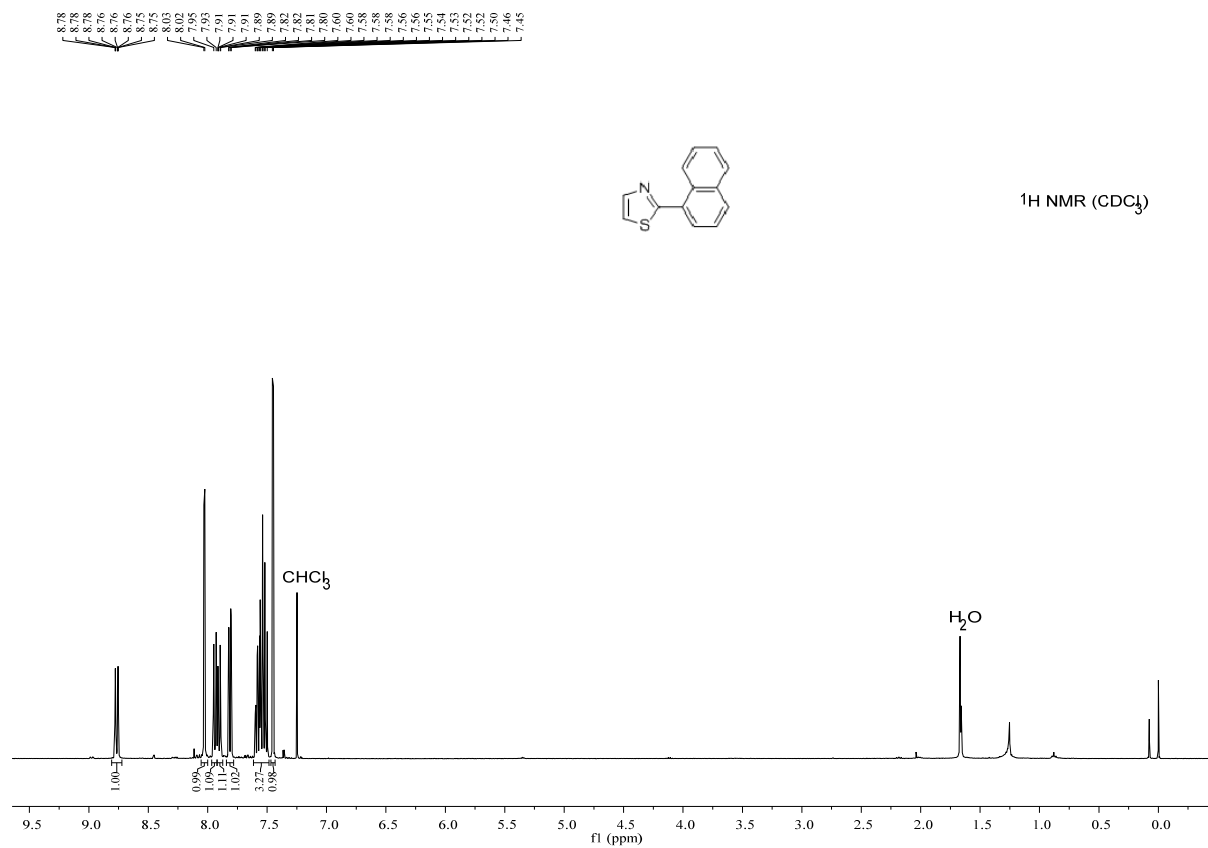
21. 5-(4-Methoxyphenyl)-2-(naphthalen-1-yl)oxazole (20)



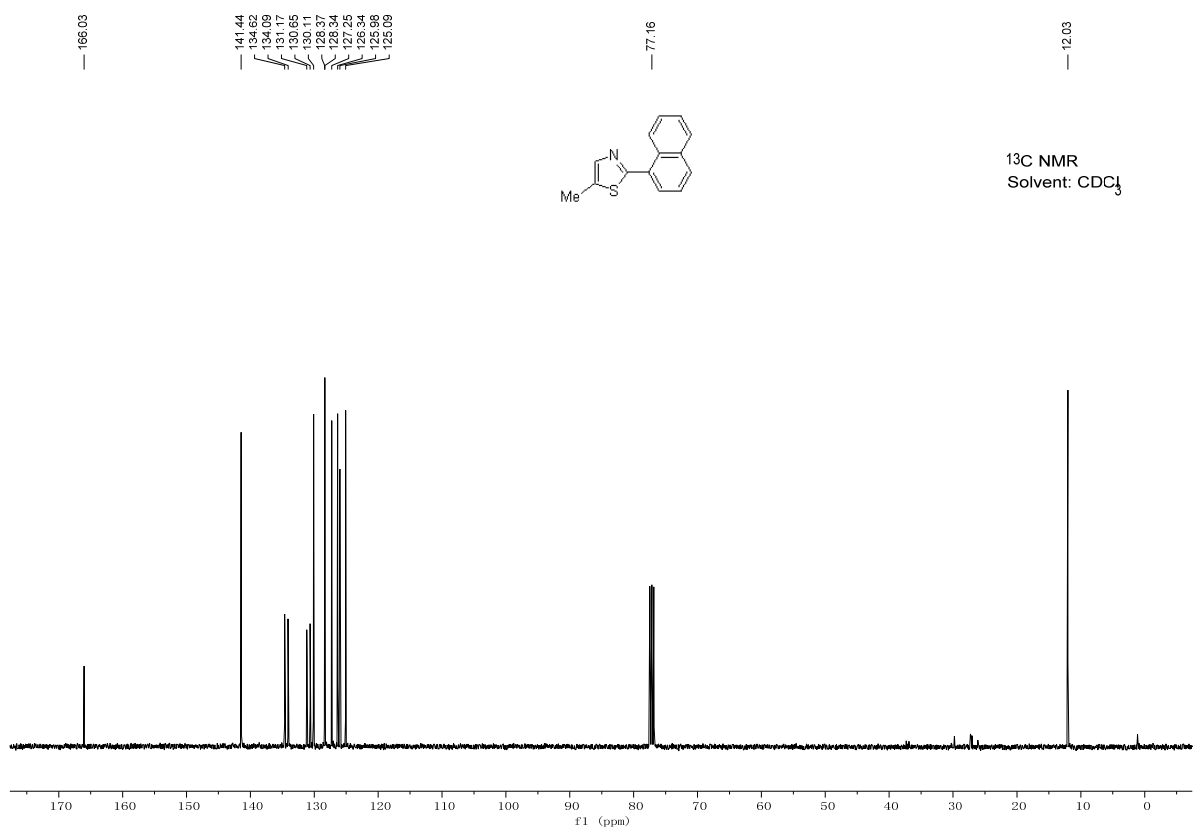
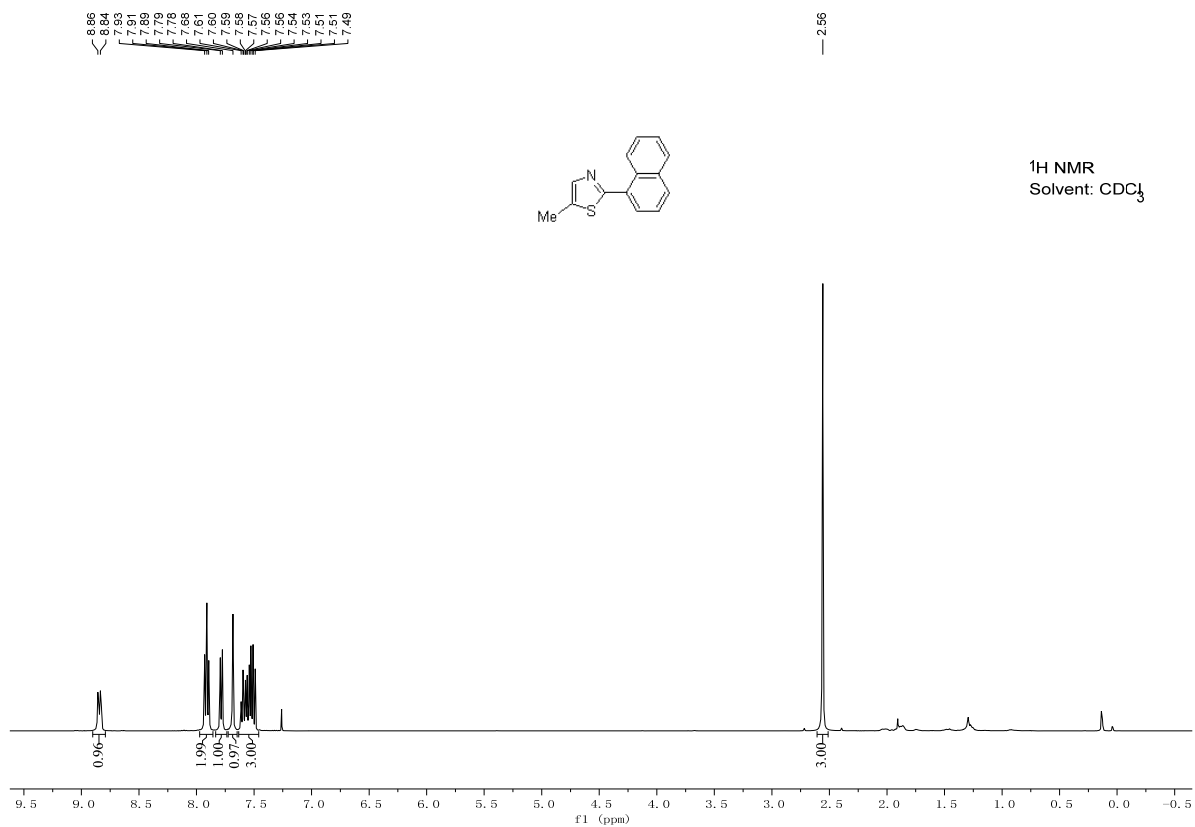
22. 2-(Naphthalen-1-yl)benzothiazole (21)



23. 2-(Naphthalen-1-yl)thiazole (22)



24. 5-Methyl-2-(naphthalen-1-yl)thiazole (**23**)



25. 2,5-Di(naphthalen-1-yl)-1,3,4-oxadiazole (**24**)

