

“One pot” regiospecific synthesis of polysubstituted pyrroles from benzylamines and ynones under metal free conditions

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Context

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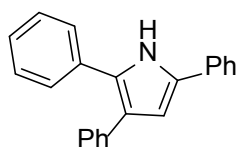
General information:

Unless otherwise stated, all solvents were purchased from commercial suppliers and used without further purification. The α,β -ynones **2** were prepared according to the literatures.¹⁻³ Silica gel was purchased from Qing Dao Hai Yang Chemical Industry Co. ^1H and ^{13}C NMR spectra were measured on a 400 MHz Bruker spectrometer (^1H 400 MHz, ^{13}C 100 MHz), using CDCl_3 as the solvent with tetramethylsilane (TMS) as the internal standard at room temperature. HRMS-ESI spectra were obtained on Agilent 6450 spectrometer. IR data were recorded on a Nicolet iS10 spectrometer.

General Procedure for Synthesis of Polysubstituted Pyrroles

Benzylamines **1** (1 mmol), α,β -ynones **2** (1 mmol) and K_3PO_4 (1 eq), DMSO 2 mL, were added to a 5-mL Schlenk tube equipped with magnetic stirring. The mixture was stirred at ambient temperature. After completion of Michael addition (monitored by TLC), the mixture was heated to $140\text{ }^\circ\text{C}$, and stirred under nitrogen atmosphere. After completing reaction, the mixture was diluted with ethyl acetate (10 mL) and washed with brine ($3 \times 10\text{ mL}$). The organic phase was dried over anhydrous Na_2SO_4 and filtered. The solvents were evaporated and the residue was purified by silica gel column chromatography with DCM/petroleum ether (1:8) as the eluent to afford the products pyrroles **4**.

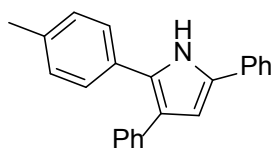
Spectroscopic data for products **4**



2,3,5-Triphenyl-1H-pyrrole⁴ **4aa**

White crystalline solid: mp $140\text{--}142\text{ }^\circ\text{C}$

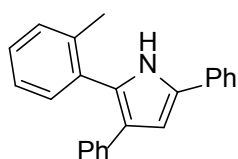
^1H NMR (400 MHz, CDCl_3) δ 8.37 (s, 1H), 7.52 (d, $J = 7.8\text{ Hz}$, 2H), 7.43-7.17 (m, 13H), 6.72-6.66 (m, 1H); ^{13}C NMR (100 MHz, CDCl_3) δ 136.3, 133.1, 132.2, 129.3, 129.0, 128.7, 128.4, 128.3, 127.5, 127.0, 126.5, 125.9, 123.8, 123.8, 108.6.



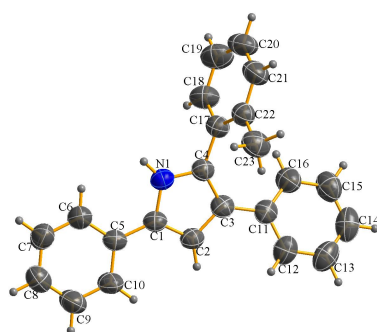
3,5-Diphenyl-2-p-tolyl-1H-pyrrole⁵ **4ba**

White crystalline solid: mp $118\text{--}120\text{ }^\circ\text{C}$

^1H NMR (400 MHz, CDCl_3) δ 8.35 (s, 1H), 7.53 (d, J = 6.7 Hz, 2H), 7.45-7.03 (m, 12H), 6.69 (s, 1H), 2.36 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 136.8, 136.5, 132.3, 131.9, 130.2, 129.4, 129.0, 128.4, 128.3, 127.4, 126.4, 125.8, 123.7, 123.4, 108.5, 21.2.



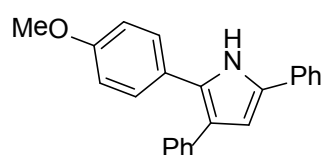
3,5-Diphenyl-2-o-tolyl-1H-pyrrole **4ca**



CCDC 957208

White crystalline solid: mp 155-156 °C

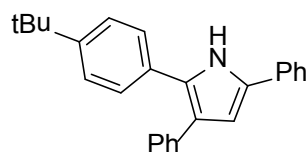
^1H NMR (400 MHz, CDCl_3) δ 8.42-8.16 (m, 1H), 7.61-7.47 (m, 2H), 7.45-7.05 (m, 12H), 6.82 (d, J = 2.9 Hz, 1H), 2.08 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 137.7, 136.4, 133.3, 132.4, 131.7, 130.7, 130.6, 129.0, 129.0, 128.3, 128.3, 126.8, 126.4, 126.0, 125.5, 124.0, 123.6, 106.2, 20.1; $\nu_{\text{max}}(\text{KBr})/\text{cm}^{-1}$ = 3421, 1607, 1599, 1488, 759, 695, 549; HRMS (ESI) m/z calcd for $\text{C}_{23}\text{H}_{19}\text{N}$ (MH^+) 310.1511, found 310.1597.



2-(4-Methoxyphenyl)-3,5-diphenyl-1H-pyrrole **4da**

White crystalline solid: mp 115-156 °C

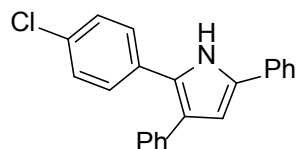
^1H NMR (400 MHz, CDCl_3) δ 8.32 (s, 1H), 8.00-6.96 (m, 12H), 6.86 (d, J = 8.5 Hz, 2H), 6.68 (s, 1H), 3.81 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 158.8, 136.5, 132.3, 128.9, 128.3, 126.3, 125.7, 123.7, 123.0, 114.2, 108.2, 55.24.



2-(4-Tert-butylphenyl)-3,5-diphenyl-1H-pyrrole **4ea**

White crystalline solid: mp 139-140 °C

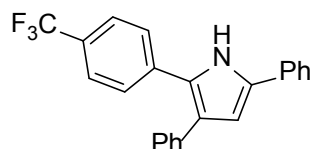
^1H NMR (400 MHz, CDCl_3) δ 8.39 (s, 1H), 7.71-7.07 (m, 14H), 6.73 (s, 1H), 1.42-1.28 (m, 9H); ^{13}C NMR (100 MHz, CDCl_3) δ 150.0, 136.6, 132.3, 131.9, 130.2, 129.4, 129.0, 128.4, 128.3, 127.1, 126.4, 125.8, 125.6, 123.7, 123.5, 108.5, 34.6, 31.3; $\nu_{\text{max}}(\text{KBr})/\text{cm}^{-1} = 3412, 2959, 1602, 1488, 1261, 837, 757, 696, 551$; HRMS (ESI) m/z calcd for $\text{C}_{26}\text{H}_{25}\text{N}$ (MH^+) 352.2021, found 352.2067.



2-(4-Chlorophenyl)-3,5-diphenyl-1H-pyrrole **4fa**

White crystalline solid: mp 86-88 °C

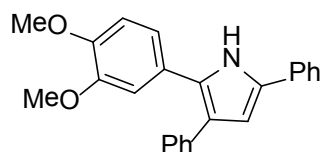
^1H NMR (400 MHz, CDCl_3) δ 8.36 (s, 1H), 7.55 (d, $J = 7.6$ Hz, 2H), 7.47-7.06 (m, 12H), 6.69 (s, 1H); ^{13}C NMR (100 MHz, CDCl_3) δ 136.1, 132.7, 132.1, 131.6, 129.0, 129.0, 128.6, 128.5, 128.06, 126.8, 126.2, 124.4, 123.9, 108.9; $\nu_{\text{max}}(\text{KBr})/\text{cm}^{-1} = 3423, 1603, 1484, 1266, 1093, 831, 760, 697, 538, 504$; HRMS (ESI) m/z calcd for $\text{C}_{22}\text{H}_{16}\text{ClN}$ (MH^+) 330.1005, found 330.1051.



3,5-Diphenyl-2-(4-(trifluoromethyl)phenyl)-1H-pyrrole⁷ **4ga**

White crystalline solid: mp 115-117 °C

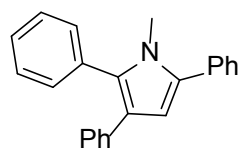
^1H NMR (400 MHz, CDCl_3) δ 8.44 (s, 1H), 7.72-7.20 (m, 14H), 6.70 (s, 1H); ^{13}C NMR (100 MHz, CDCl_3) δ 136.4, 135.9, 133.3, 131.9, 129.0, 128.6, 128.5, 128.31, 127.53, 127.1, 127.0, 126.5, 125.7 (q, $J = 3.7$ Hz), 125.5, 124.0, 109.3.



2-(3,4-Dimethoxyphenyl)-3,5-diphenyl-1H-pyrrole⁸ **4ha**

White crystalline solid: mp 186-187 °C

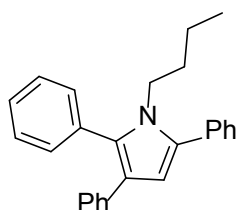
^1H NMR (400 MHz, CDCl_3) δ 8.44 (s, 1H), 8.02-6.37 (m, 14H), 3.90 (s, 3H), 3.65 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 148.81, 148.17, 136.42, 132.25, 128.92, 128.46, 128.22, 126.45, 125.85, 123.76, 123.70, 123.23, 119.42, 111.48, 108.24, 55.85, 55.62.



1-Methyl-2,3,5-triphenyl-1H-pyrrole⁹ **4ia**

White crystalline solid: mp 177-179 °C

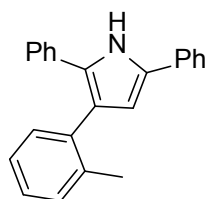
^1H NMR (400 MHz, CDCl_3) δ 7.56-7.29 (m, 10H), 7.26-7.13 (m, 4H), 7.12-7.05 (m, 1H), 6.50 (s, 1H), 3.47 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 136.4, 135.7, 133.4, 133.1, 132.5, 131.2, 128.9, 128.6, 128.5, 128.1, 127.9, 127.6, 127.0, 125.2, 122.9, 108.9, 33.8.



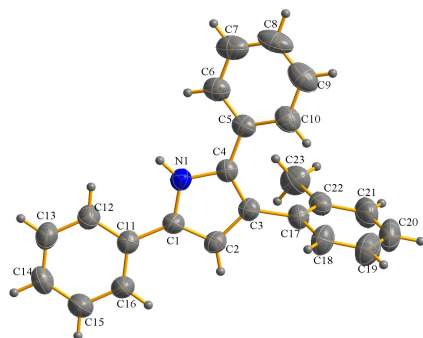
1-Butyl-2,3,5-triphenyl-1H-pyrrole¹⁰ **4ja**

White crystalline solid: mp 105-106 °C

^1H NMR (400 MHz, CDCl_3) δ 7.51 (dd, J = 5.1, 3.0 Hz, 2H), 7.48-7.26 (m, 8H), 7.22-7.11 (m, 4H), 7.06 (ddd, J = 23.2, 9.9, 8.5 Hz, 1H), 6.52-6.38 (m, 1H), 3.92 (t, J = 6.8 Hz, 2H), 1.25-1.13 (m, 2H), 0.94-0.81 (m, 2H), 0.54 (ddd, J = 7.3, 4.2, 0.9 Hz, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 136.4, 135.1, 134.0, 133.5, 131.9, 131.3, 129.0, 128.5, 128.4, 128.0, 127.7, 127.5, 127.0, 125.0, 122.8, 109.4, 44.6, 32.8, 19.4, 13.3.



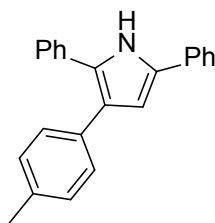
2,5-Diphenyl-3-o-tolyl-1H-pyrrole¹¹ **4ab**



CCDC 957206

White crystalline solid: mp 137-138 °C

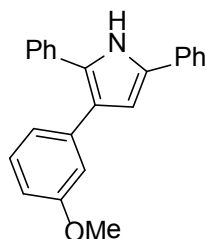
^1H NMR (400 MHz, CDCl_3) δ 8.50 (s, 1H), 7.69-7.06 (m, 14H), 6.55 (s, 1H), 2.14 (d, J = 2.9 Hz, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 136.8, 136.5, 133.1, 132.3, 131.7, 130.8, 130.1, 129.4, 129.0, 128.7, 126.8, 126.4, 126.3, 125.7, 125.6, 123.7, 110.1, 20.3.



2,5-Diphenyl-3-p-tolyl-1H-pyrrole¹¹ **4ac**

White crystalline solid: mp 138-139 °C

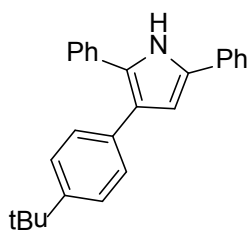
¹H NMR (400 MHz, CDCl₃) δ 8.39 (s, 1H), 7.56 (d, *J* = 7.6 Hz, 2H), 7.48-7.20 (m, 10H), 7.13 (d, *J* = 7.6 Hz, 2H), 6.70 (s, 1H), 2.37 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 135.5, 134.6, 133.4, 133.2, 132.3, 129.1, 129.0, 128.7, 128.3, 128.3, 127.5, 126.9, 126.5, 123.9, 123.8, 108.7, 21.2.



3-(3-Methoxyphenyl)-2,5-diphenyl-1H-pyrrole **4ad**

White crystalline solid: mp 97-99 °C

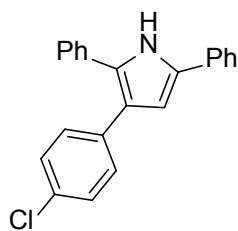
¹H NMR (400 MHz, CDCl₃) δ 8.44 (s, 1H), 7.85-7.17 (m, 12H), 7.10-6.95 (m, 2H), 6.79 (ddd, *J* = 13.6, 7.7, 5.9 Hz, 1H), 6.73 (d, *J* = 2.8 Hz, 1H), 3.73 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 159.5, 137.7, 133.0, 132.2, 129.4, 129.2, 128.9, 128.6, 127.6, 127.0, 126.5, 123.8, 123.6, 120.9, 113.6, 111.9, 108.5, 55.1; *v*_{max}(KBr)/cm⁻¹ = 3455, 1607, 1484, 1260, 1207, 1043, 763, 694, 517; HRMS (ESI) *m/z* calcd for C₂₃H₁₉NO (MH⁺) 326.1500, found 326.1544.



3-(4-Tert-butylphenyl)-2,5-diphenyl-1H-pyrrole **4ae**

White crystalline solid: mp 107-109 °C

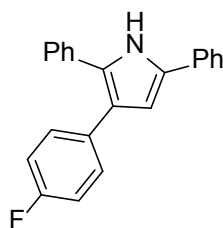
¹H NMR (400 MHz, CDCl₃) δ 8.53-8.24 (m, 1H), 7.56 (d, *J* = 7.6 Hz, 2H), 7.51-7.05 (m, 12H), 6.72 (d, *J* = 2.8 Hz, 1H), 1.37 (dd, *J* = 6.2, 0.7 Hz, 9H); ¹³C NMR (100 MHz, CDCl₃) δ 148.7, 133.3, 132.3, 132.1, 129.1, 128.9, 128.7, 127.9, 127.9, 127.5, 126.9, 126.4, 125.2, 123.7, 123.7, 108.6, 34.4, 31.4; *v*_{max}(KBr)/cm⁻¹ = 3425, 2962, 1604, 1487, 1263, 764, 697, 532; HRMS (ESI) *m/z* calcd for C₂₆H₂₅N (MH⁺) 352.2021, found 352.2066.



3-(4-Chlorophenyl)-2,5-diphenyl-1H-pyrrole **4af**

White crystalline solid: mp 142-144 °C

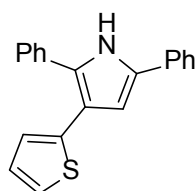
¹H NMR (400 MHz, CDCl₃) δ 8.41 (s, 1H), 7.53 (d, *J* = 7.4 Hz, 2H), 7.43-7.16 (m, 12H), 6.67 (dd, *J* = 17.3, 2.6 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 134.9, 132.8, 131.6, 129.6, 129.0, 128.8, 128.5, 128.4, 128.30, 127.5, 127.2, 126.7, 125.9, 123.8, 122.5, 108.3; *v*_{max}(KBr)/cm⁻¹ = 3410, 1604, 1485, 1093, 835, 763, 504; HRMS (ESI) *m/z* calcd for C₂₂H₁₆ClN (MH⁺) 330.1005, found 330.1036.



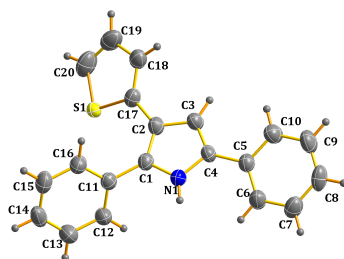
3-(4-Fluorophenyl)-2,5-diphenyl-1H-pyrrole **4ag**

White crystalline solid: mp 157-159 °C

¹H NMR (400 MHz, CDCl₃) δ 8.53-8.30 (m, 1H), 7.59-7.51 (m, 2H), 7.47-7.23 (m, 10H), 7.10-6.93 (m, 2H), 6.66 (d, *J* = 2.8 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 161.5 (d, *J* = 244.5 Hz), 132.4 (d, *J* = 3.4 Hz), 132.3, 132.1, 129.9 (d, *J* = 7.6 Hz), 129.2, 129.0, 128.8, 127.4, 127.0, 126.6, 123.8, 122.8, 115.3, 115.1, 108.5; *v*_{max}(KBr)/cm⁻¹ = 3439, 3060, 1606, 1508, 1489, 1208, 1157, 842, 761, 564; HRMS (ESI) *m/z* calcd for C₂₂H₁₆FN (MH⁺) 314.1300, found 314.1336.



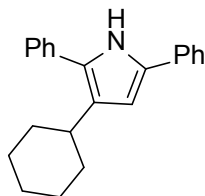
2,5-Diphenyl-3-(thiophen-2-yl)-1H-pyrrole **4ah**



CDCC 957400

White crystalline solid: mp 89-90 °C

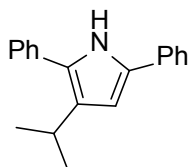
^1H NMR (400 MHz, CDCl_3) δ 8.50-8.25 (m, 1H), 7.64-7.05 (m, 11H), 7.05-6.83 (m, 2H), 6.71 (dd, J = 6.1, 2.9 Hz, 1H); ^{13}C NMR (100 MHz, CDCl_3) δ 138.6, 132.6, 132.1, 131.9, 129.7, 129.0, 128.7, 128.0, 127.5, 127.2, 126.7, 124.0, 123.8, 123.3, 116.8, 108.6; $\nu_{\text{max}}(\text{KBr})/\text{cm}^{-1}$ = 3414, 1604, 1066, 837, 808, 764, 694, 546; HRMS (ESI) m/z calcd for $\text{C}_{20}\text{H}_{15}\text{NS}$ (MH^+) 302.0959, found 302.0997.



1-Cyclohexyl-2,5-diphenyl-1H-pyrrole¹¹ **4ai**

White crystalline solid: mp 105-106 °C

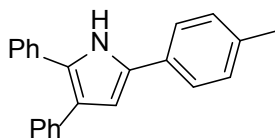
^1H NMR (400 MHz, CDCl_3) δ 8.41-8.01 (m, 1H), 7.83-7.08 (m, 10H), 6.55 (dd, J = 13.3, 2.7 Hz, 1H), 2.76 (ddd, J = 11.7, 7.7, 3.3 Hz, 1H), 2.04-1.26 (m, 10H); ^{13}C NMR (100 MHz, CDCl_3) δ 133.7, 132.6, 131.6, 129.7, 128.8, 128.8, 128.6, 127.2, 126.4, 126.0, 123.5, 105.9, 35.4, 35.2, 26.9, 26.3.



3-Isopropyl-2,5-diphenyl-1H-pyrrole **4aj**

White crystalline solid: mp 105-106 °C

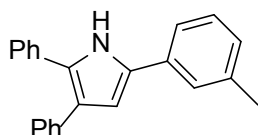
^1H NMR (400 MHz, CDCl_3) δ 8.17 (s, 1H), 7.56-7.39 (m, 6H), 7.35 (t, J = 7.7 Hz, 2H), 7.28 (t, J = 6.9 Hz, 1H), 7.19 (d, J = 7.3 Hz, 1H), 6.55 (d, J = 2.4 Hz, 1H), 3.14 (dq, J = 13.1, 6.5 Hz, 1H), 1.28 (d, J = 6.8 Hz, 6H); ^{13}C NMR (100 MHz, CDCl_3) δ 133.6, 132.6, 131.7, 130.6, 128.8, 128.8, 127.2, 126.5, 126.1, 123.6, 105.2, 25.2, 24.7; HRMS (ESI) m/z calcd for $\text{C}_{19}\text{H}_{19}\text{N}$ (MH^+) 262.1551, found 262.1589.



2,3-Diphenyl-5-p-tolyl-1H-pyrrole¹² **4ak**

White crystalline solid: mp 129-131 °C

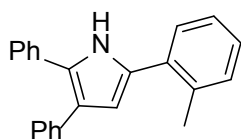
^1H NMR (400 MHz, CDCl_3) δ 8.50-8.19 (m, 1H), 7.80-6.86 (m, 14H), 6.67 (d, J = 6.5 Hz, 1H), 2.39 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 136.4, 136.3, 133.2, 132.5, 129.7, 129.5, 128.7, 128.4, 128.3, 128.3, 127.5, 126.9, 125.9, 123.8, 123.8, 108.1, 21.2.



2,3-Diphenyl-5-m-tolyl-1H-pyrrole 4al

White crystalline solid: mp 105-107 °C

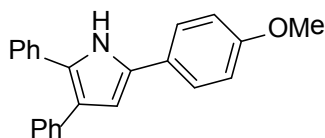
^1H NMR (400 MHz, CDCl_3) δ 8.29 (d, $J = 46.1$ Hz, 1H), 7.43 – 7.15 (m, 13H), 7.04 (d, $J = 6.7$ Hz, 1H), 6.72 – 6.62 (m, 1H), 2.38 (d, $J = 4.5$ Hz, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 138.5, 136.3, 133.1, 132.3, 132.1, 129.1, 128.9, 128.7, 128.4, 128.3, 127.4, 127.3, 126.9, 125.9, 124.5, 123.8, 120.9, 108.5, 21.5; $\nu_{\text{max}}(\text{KBr})/\text{cm}^{-1} = 3409, 2956, 1601, 1521, 1447, 764, 698$; HRMS (ESI) m/z calcd for $\text{C}_{23}\text{H}_{19}\text{N}$ (MH^+) 310.1551, found 310.1594.



2,3-Diphenyl-5-o-tolyl-1H-pyrrole 4am

White crystalline solid: mp 131-132 °C

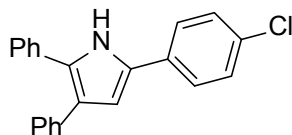
^1H NMR (400 MHz, CDCl_3) δ 8.19 (d, $J = 46.2$ Hz, 1H), 7.46-7.18 (m, 14H), 6.52 (d, $J = 2.3$ Hz, 1H), 2.56 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 136.6, 135.1, 133.2, 132.2, 131.6, 131.2, 128.7, 128.6, 128.4, 128.3, 127.6, 127.4, 127.0, 126.8, 126.2, 125.8, 123.0, 111.5, 21.4; $\nu_{\text{max}}(\text{KBr})/\text{cm}^{-1} = 3424, 3057, 1602, 1480, 763, 698, 577$; HRMS (ESI) m/z calcd for $\text{C}_{23}\text{H}_{19}\text{N}$ (MH^+) 310.1551, found 310.1595.



5-(4-Methoxyphenyl)-2,3-diphenyl-1H-pyrrole¹³ 4an

White crystalline solid: mp 183-184 °C

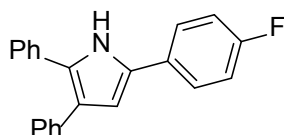
^1H NMR (400 MHz, CDCl_3) δ 8.30 (s, 1H), 7.51-7.16 (m, 12H), 6.94 (d, $J = 7.7$ Hz, 2H), 6.58 (s, 1H), 3.82 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 158.5, 133.2, 132.30, 128.7, 128.4, 128.3, 127.4, 126.8, 125.8, 125.6, 125.2, 123.7, 114.4, 107.6, 55.3.



5-(4-Chlorophenyl)-2,3-diphenyl-1H-pyrrole¹² 4ao

White crystalline solid: mp 118-120 °C

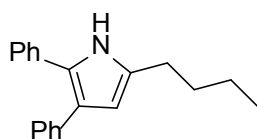
^1H NMR (400 MHz, CDCl_3) δ 8.32 (s, 1H), 7.51-7.16 (m, 14H), 6.79-6.59 (m, 1H); ^{13}C NMR (100 MHz, CDCl_3) δ 136.1, 132.9, 132.0, 131.1, 130.7, 129.7, 129.1, 128.7, 128.4, 128.4, 127.9, 127.1, 126.0, 124.9, 124.0 109.0.



5-(4-Fluorophenyl)-2,3-diphenyl-1H-pyrrole⁷ **4ap**

White crystalline solid: mp 128-129 °C

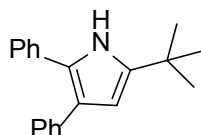
¹H NMR (400 MHz, CDCl₃) δ 8.43-8.21 (m, 1H), 7.53-7.43 (m, 2H), 7.43-7.15 (m, 10H), 7.13-7.04 (m, 2H), 6.62 (t, *J* = 2.7 Hz, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 161.7 (d, *J* = 246.2 Hz), 136.2, 133.0, 131.4, 129.3, 128.7, 128.6, 128.4, 128.3 (d, *J* = 1.0 Hz), 127.5, 127.0, 126.0, 125.5 (d, *J* = 7.9 Hz), 123.8, 115.9, 108.8.



5-Butyl-2,3-diphenyl-1H-pyrrole **4aq**

Brown oil.

¹H NMR (400 MHz, CDCl₃) δ 7.99-7.74 (m, 1H), 7.36-7.11 (m, 10H), 6.10 (d, *J* = 2.9 Hz, 1H), 2.62 (t, *J* = 7.7 Hz, 2H), 1.66 (dt, *J* = 15.3, 7.5 Hz, 2H), 1.43 (dq, *J* = 14.5, 7.4 Hz, 2H), 0.95 (t, *J* = 7.4 Hz, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 136.9, 133.6, 133.3, 128.5, 128.3, 128.6, 127.2, 126.4, 125.5, 122.0, 107.9, 31.6, 27.4, 22.5, 13.9; *v*_{max}(KBr)/cm⁻¹ = 3419, 2956, 1601, 1521, 1447, 764, 698; HRMS (ESI) *m/z* calcd for C₂₀H₂₁N (MH⁺) 276.1708, found 276.1756.



5-(tert-Butyl)-2,3-diphenyl-1H-pyrrole **4ar**

Brown oil.

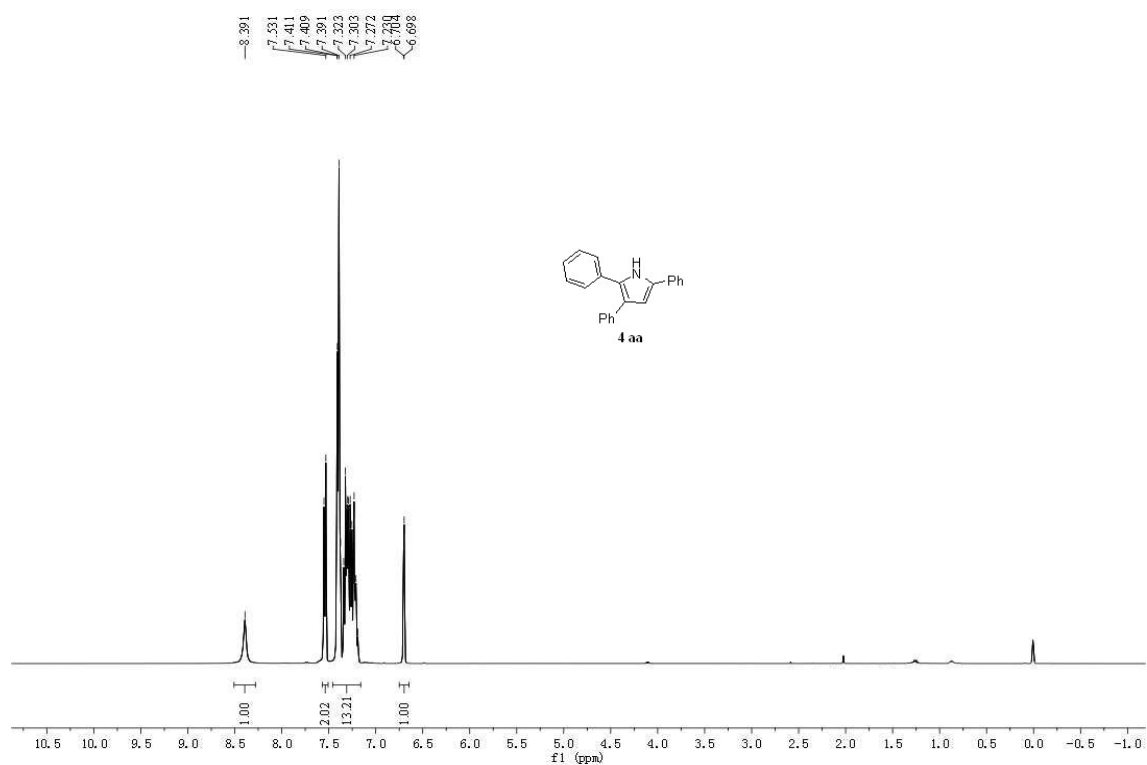
¹H NMR (400 MHz, CDCl₃) δ 7.95 (d, *J* = 8.7 Hz, 1H), 7.38-7.32 (m, 4H), 7.31-7.27 (m, 2H), 7.25-7.18 (m, 3H), 7.18-7.12 (m, 1H), 6.17-6.10 (m, 1H), 1.38-1.36 (m, 9H); ¹³C NMR (100 MHz, CDCl₃) δ 142.3, 136.9, 133.8, 128.6, 128.3, 128.2, 127.4, 126.4, 126.4, 125.5, 121.6, 105.6, 31.4, 30.5; *v*_{max}(KBr)/cm⁻¹ = 3415, 2965, 1604, 1492, 764, 697, 524; HRMS (ESI) *m/z* calcd for C₂₀H₂₁N (MH⁺) 276.1708, found 276.1748.

References:

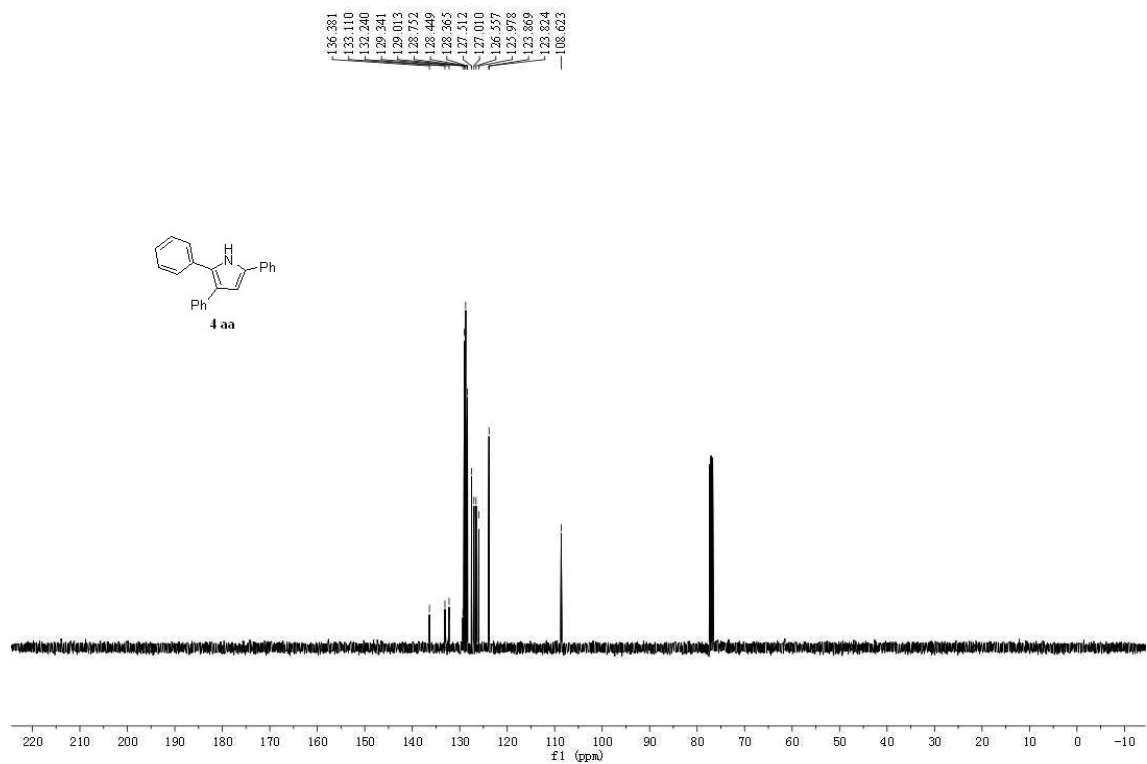
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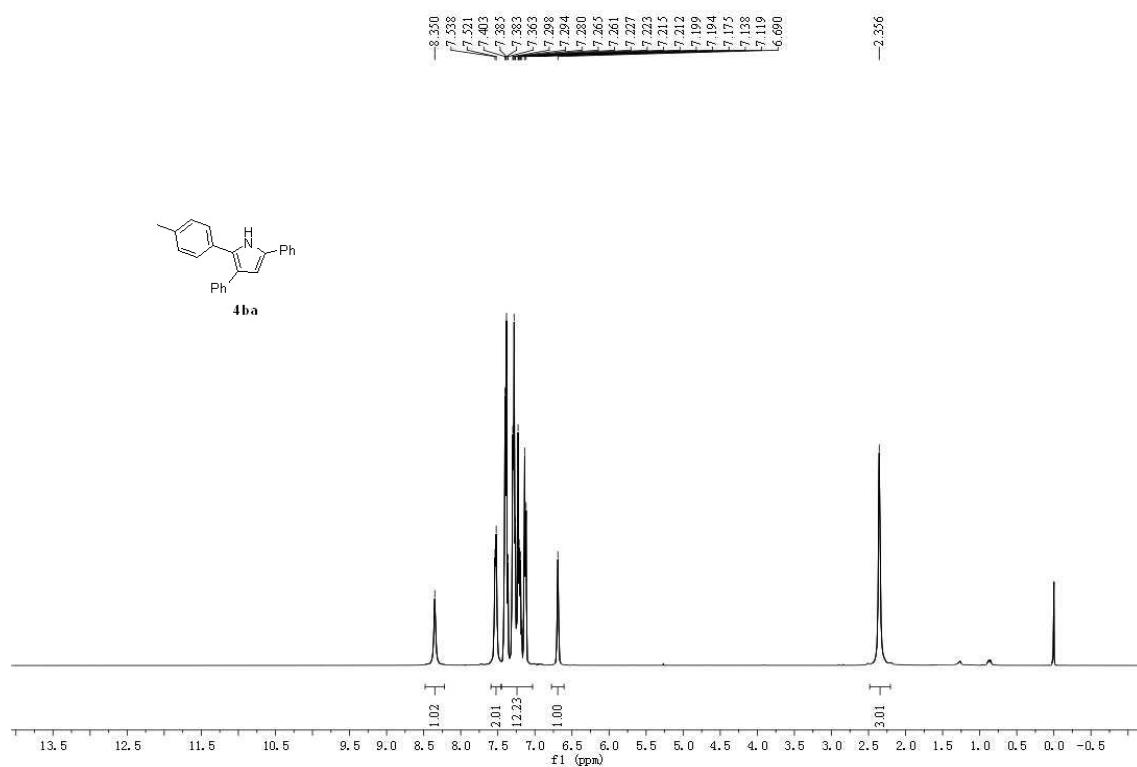
^1H NMR spectrum of product **4aa**



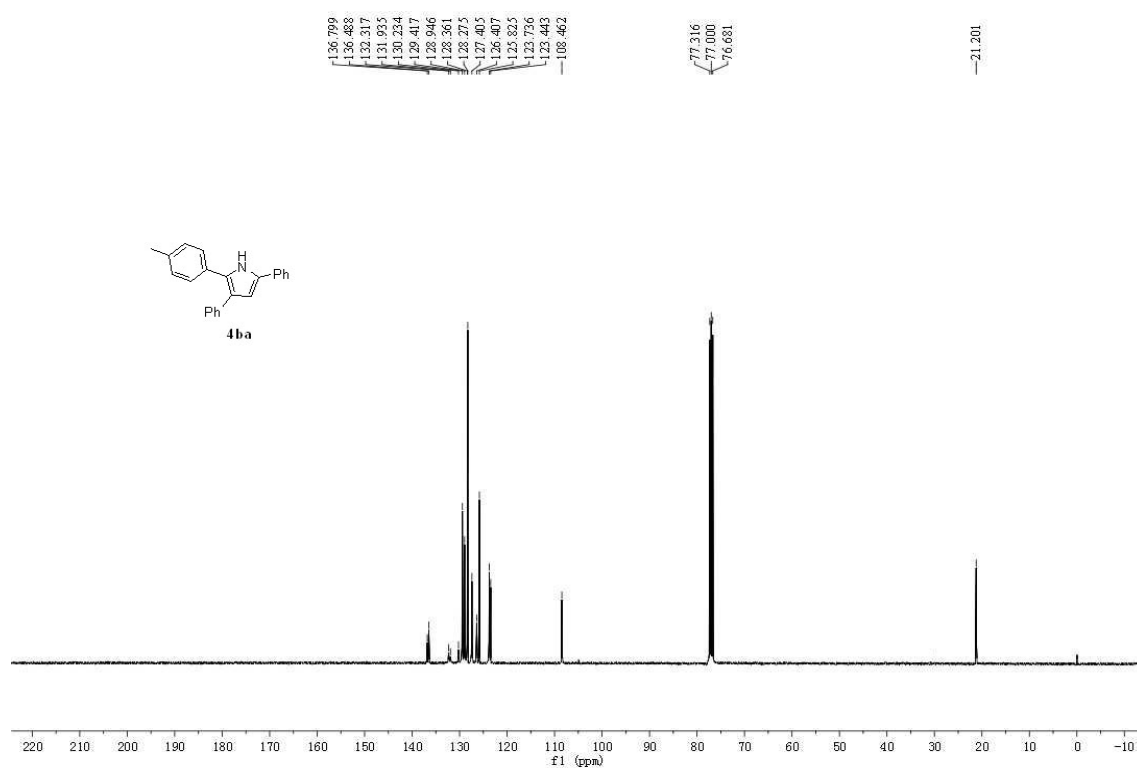
^{13}C NMR spectrum of product **4aa**



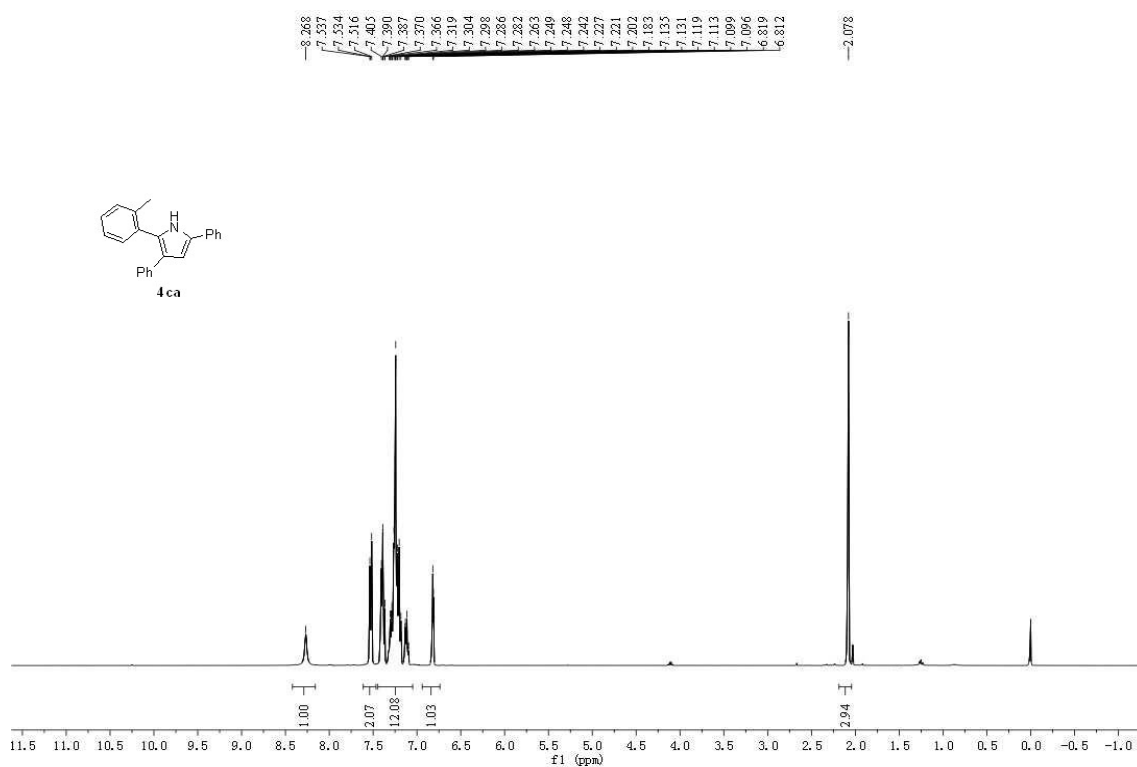
¹H NMR spectrum of product **4ba**



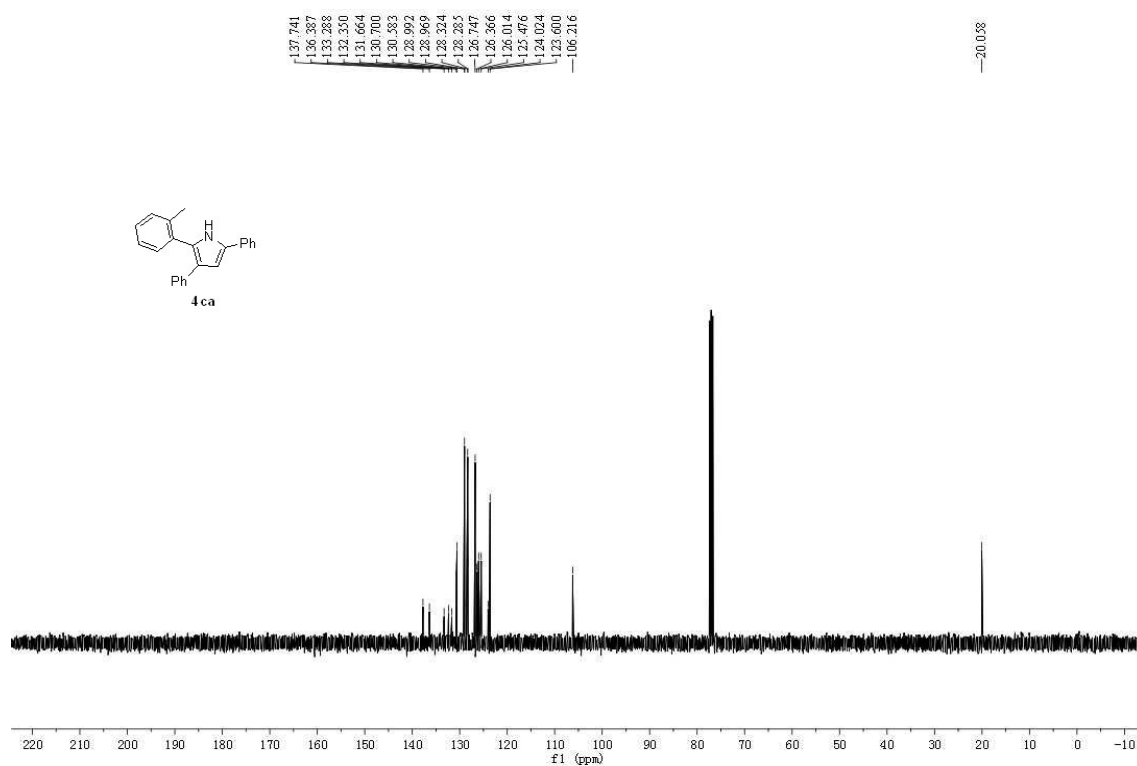
¹³C NMR spectrum of product **4ba**



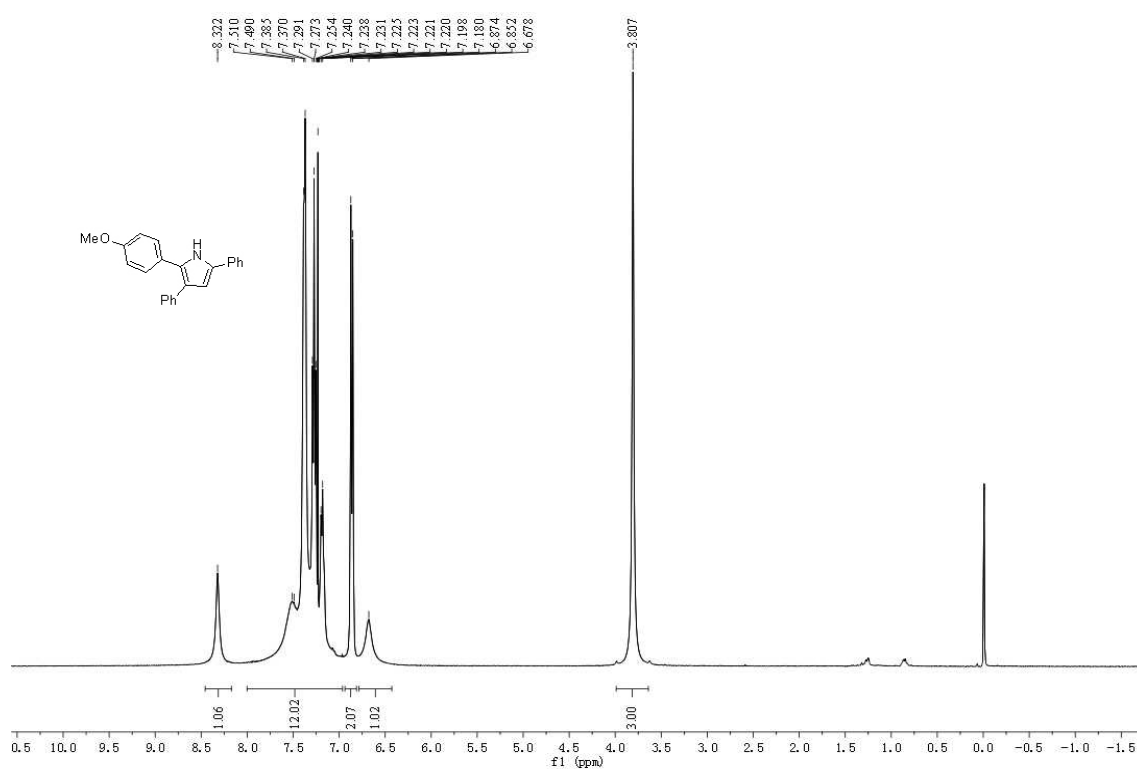
¹H NMR spectrum of product **4ca**



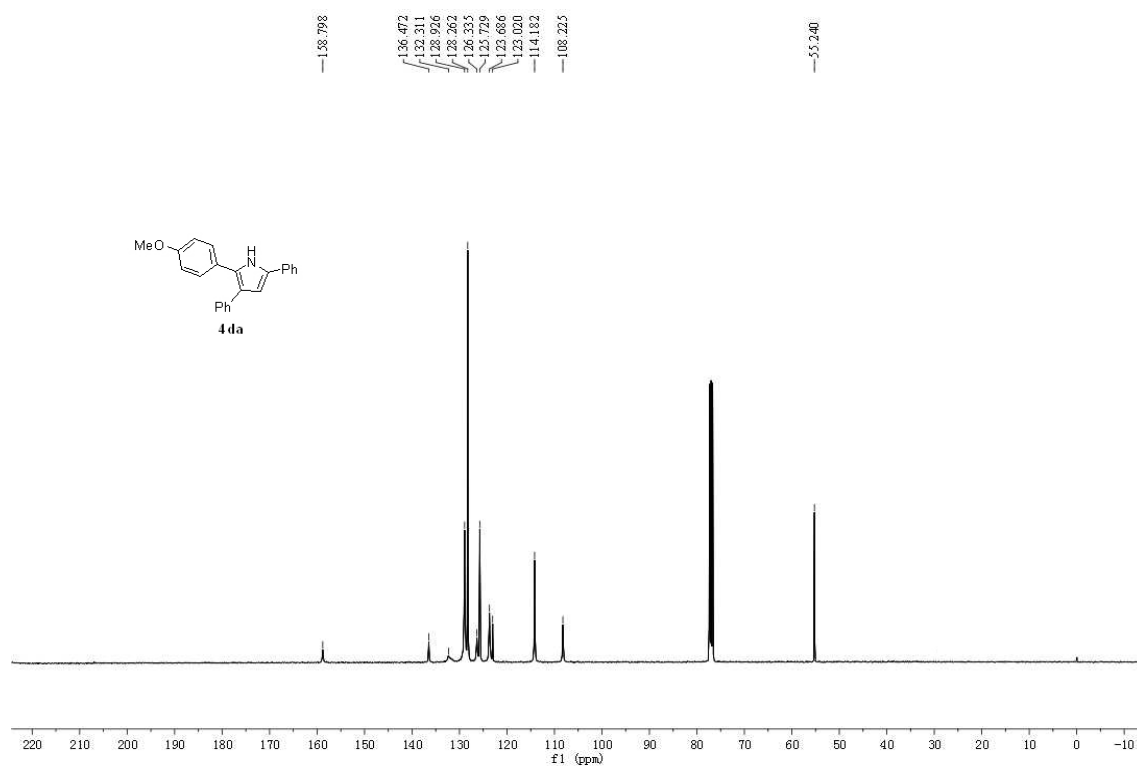
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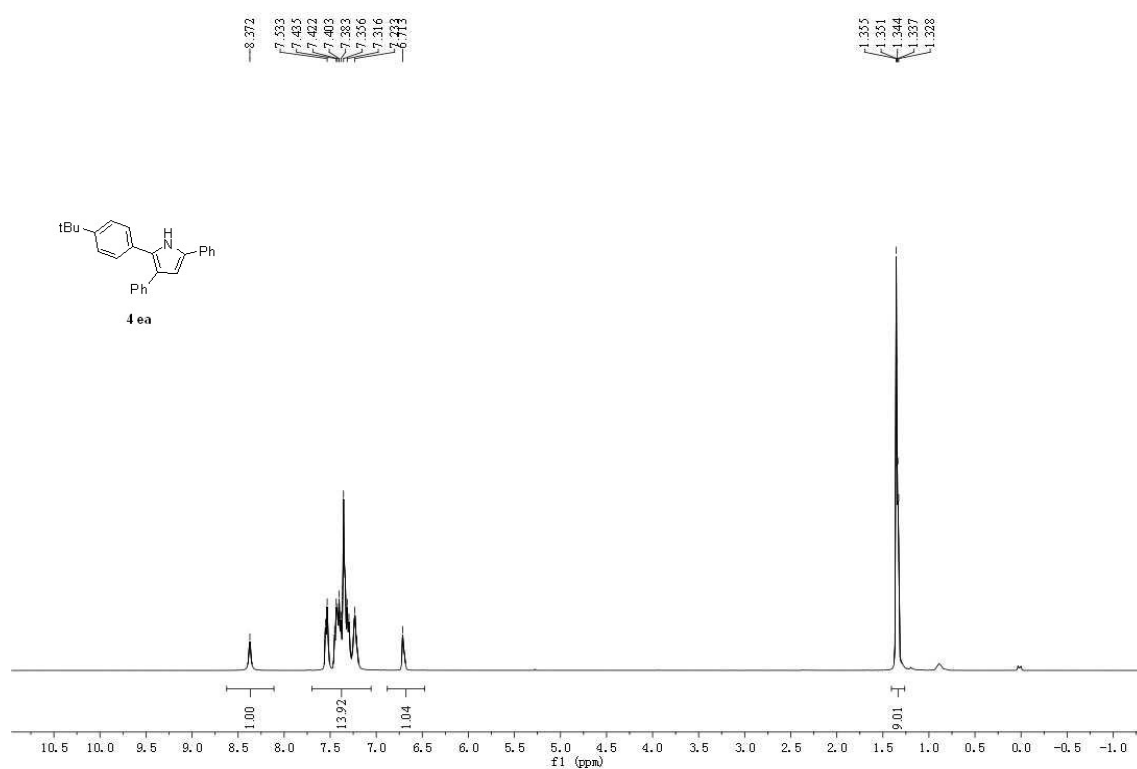
¹H NMR spectrum of product **4da**



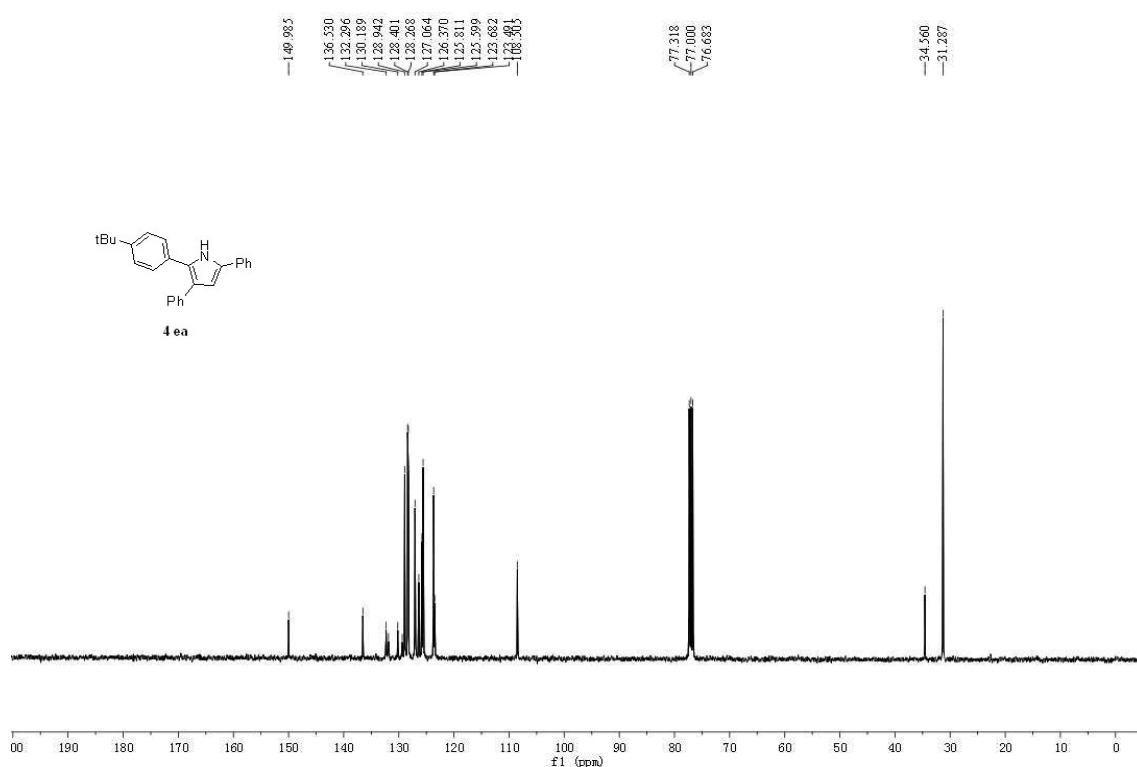
¹³C NMR spectrum of product **4da**



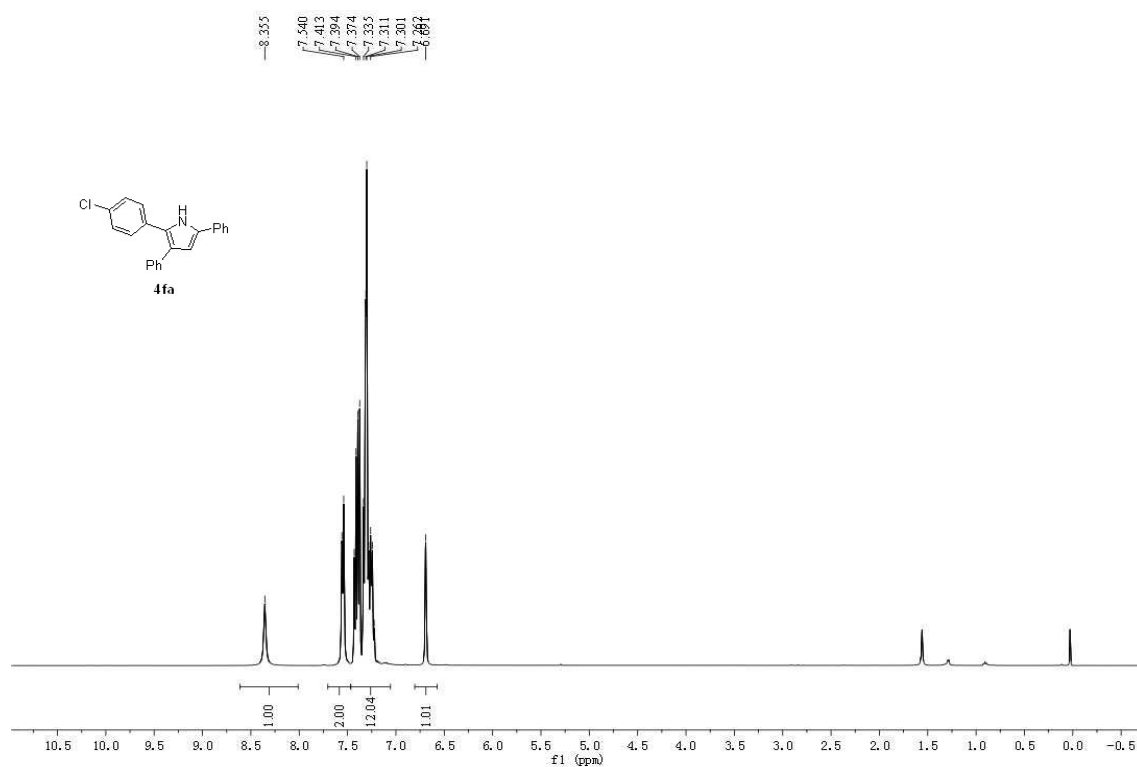
¹H NMR spectrum of product **4ea**



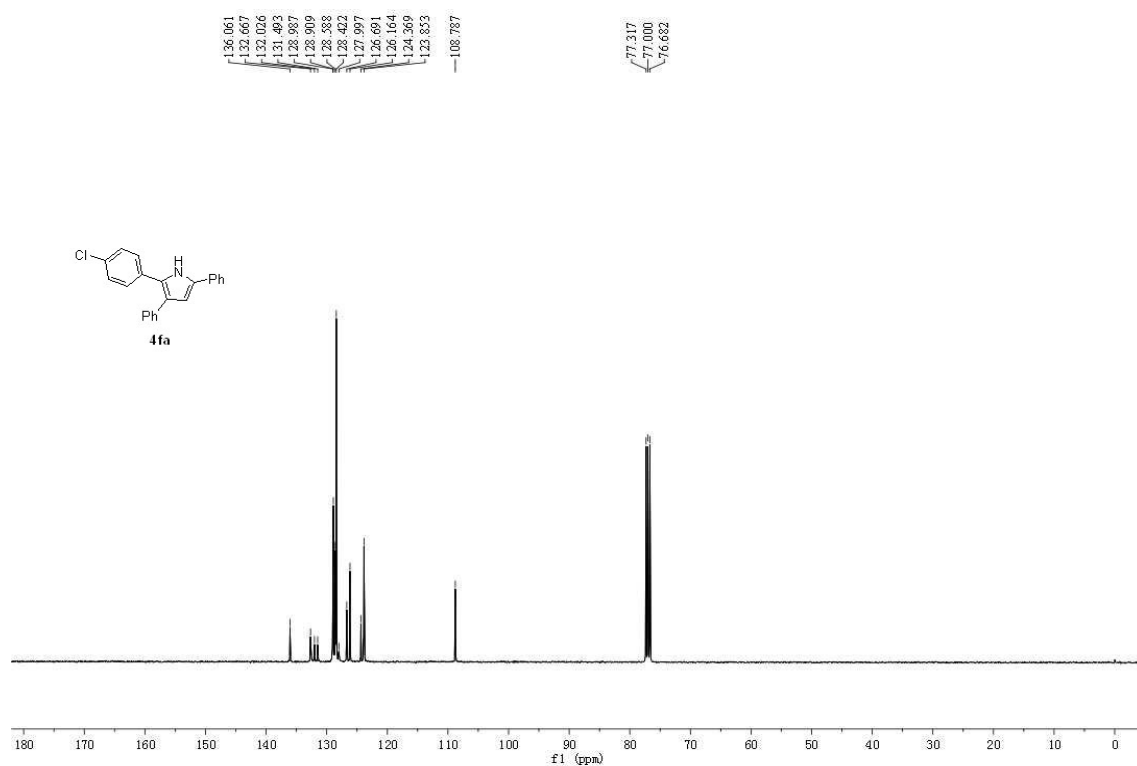
¹³C NMR spectrum of product **4ea**



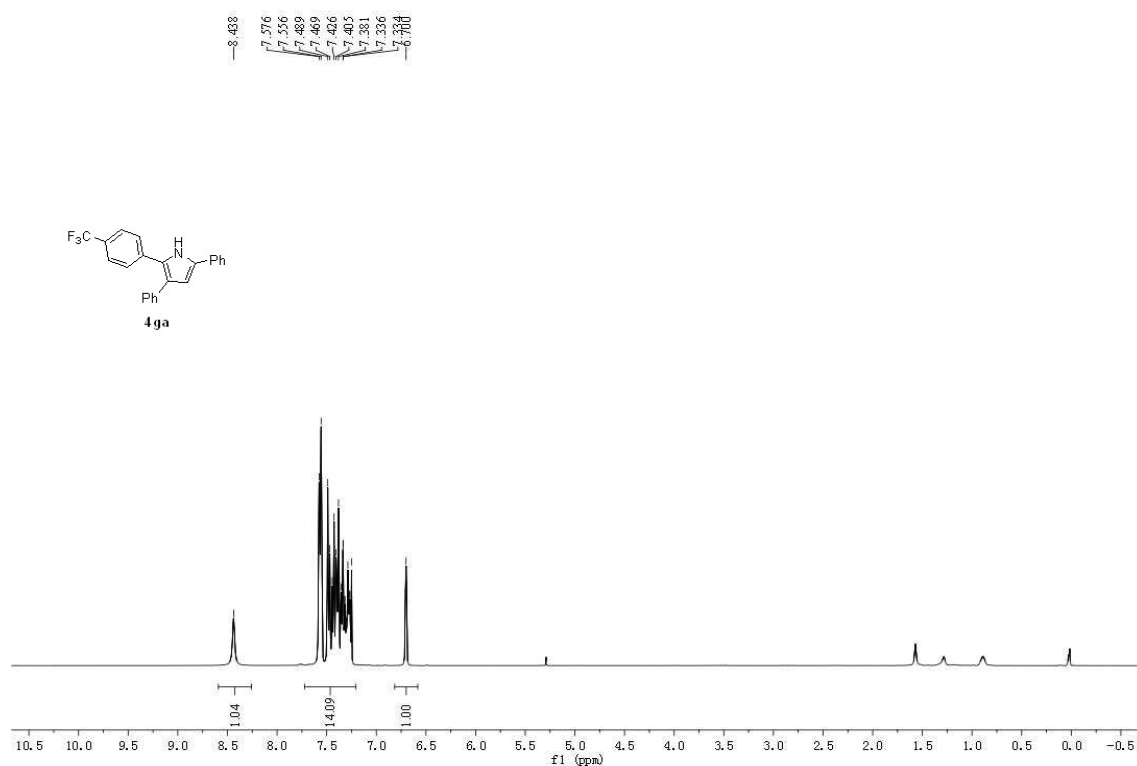
¹H NMR spectrum of product **4fa**



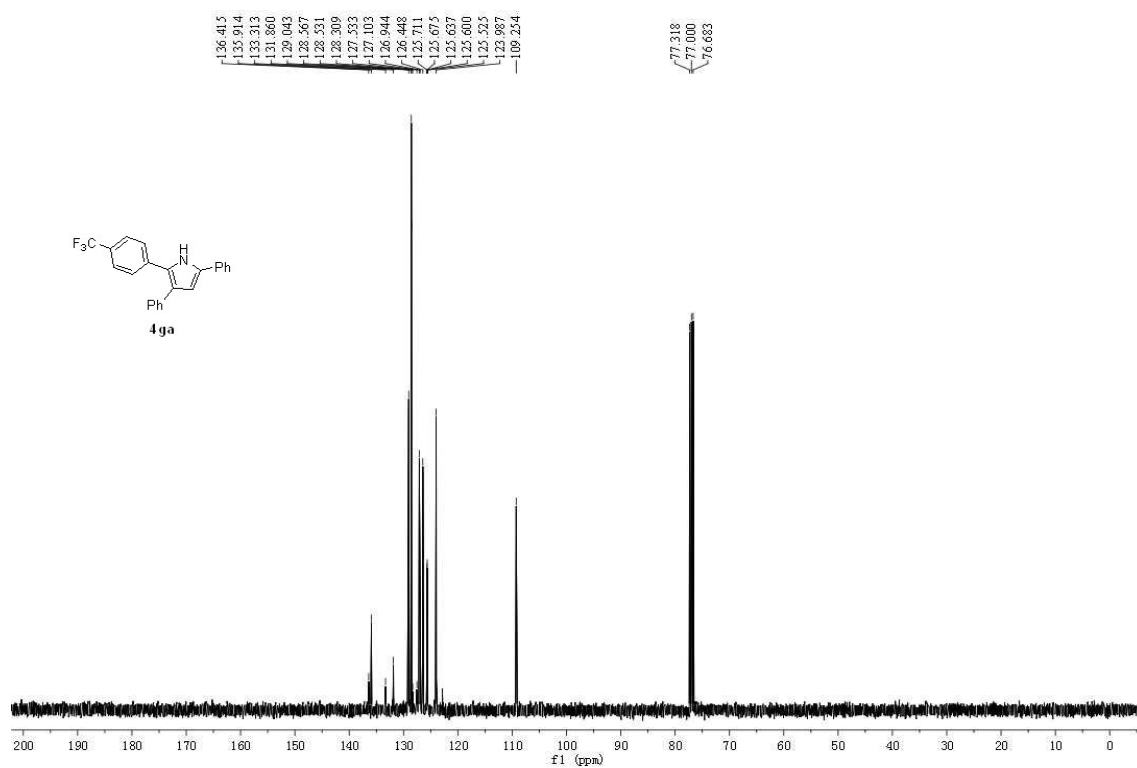
¹³C NMR spectrum of product **4fa**



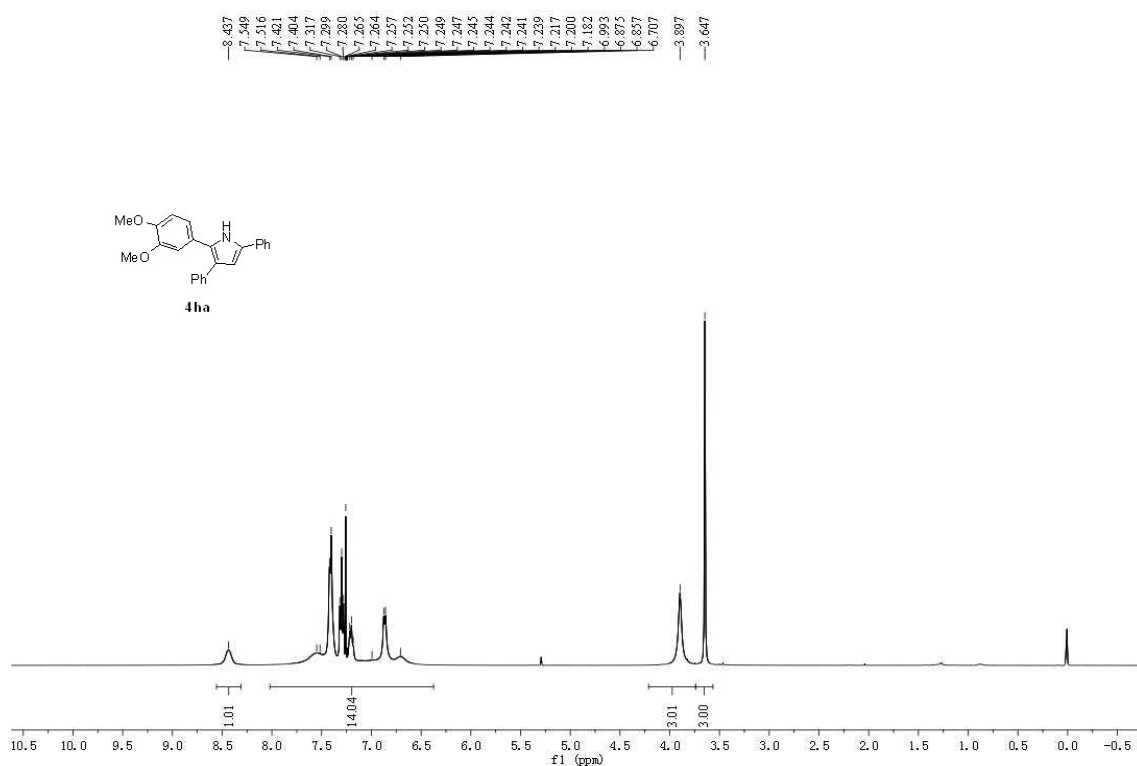
¹H NMR spectrum of product **4ga**



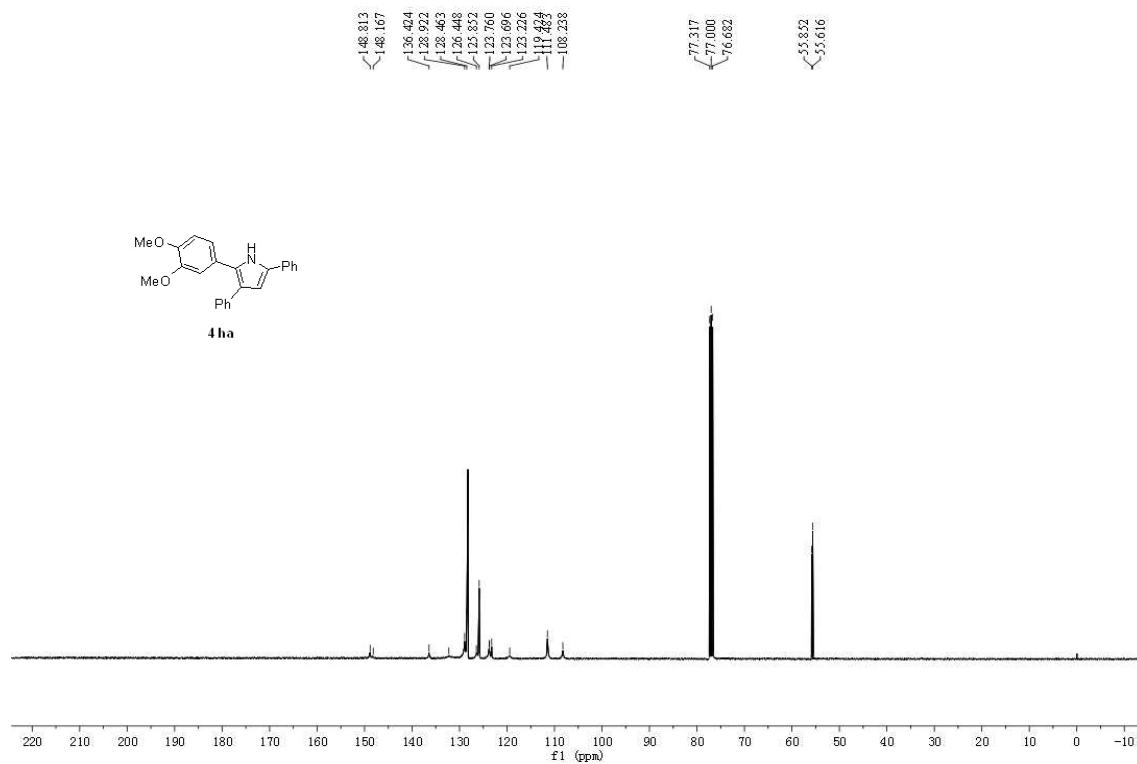
¹³C NMR spectrum of product **4ga**



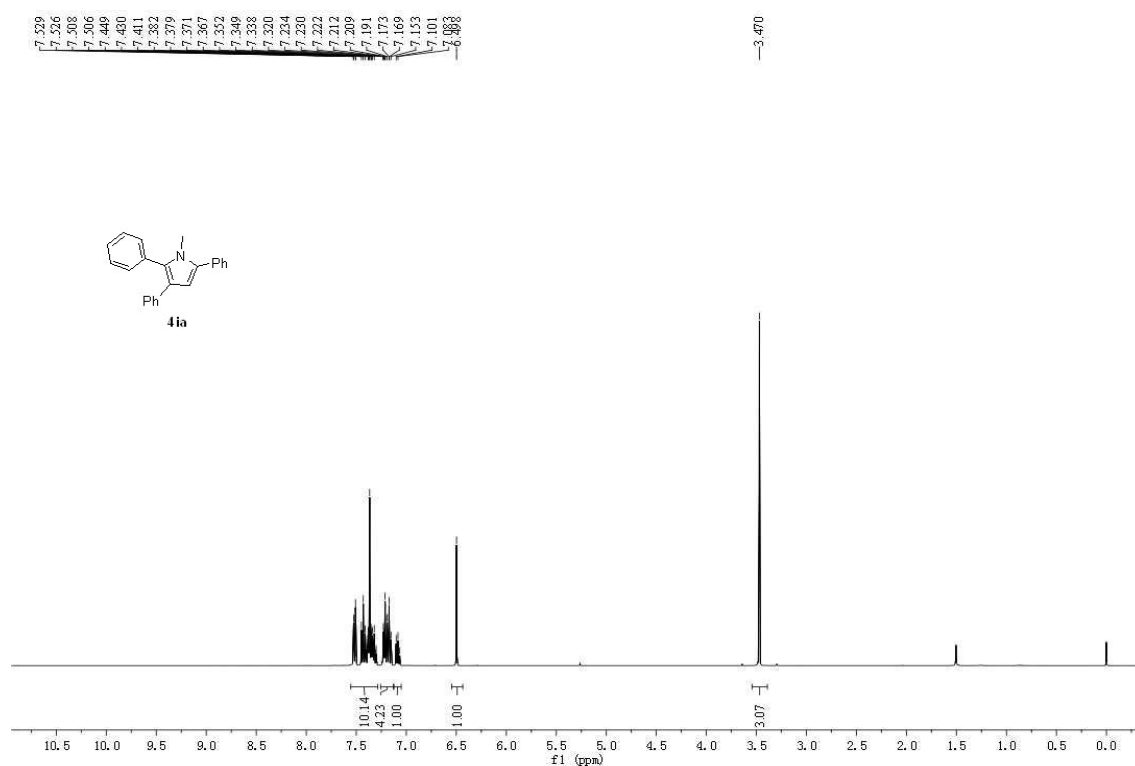
^1H NMR spectrum of product **4ha**



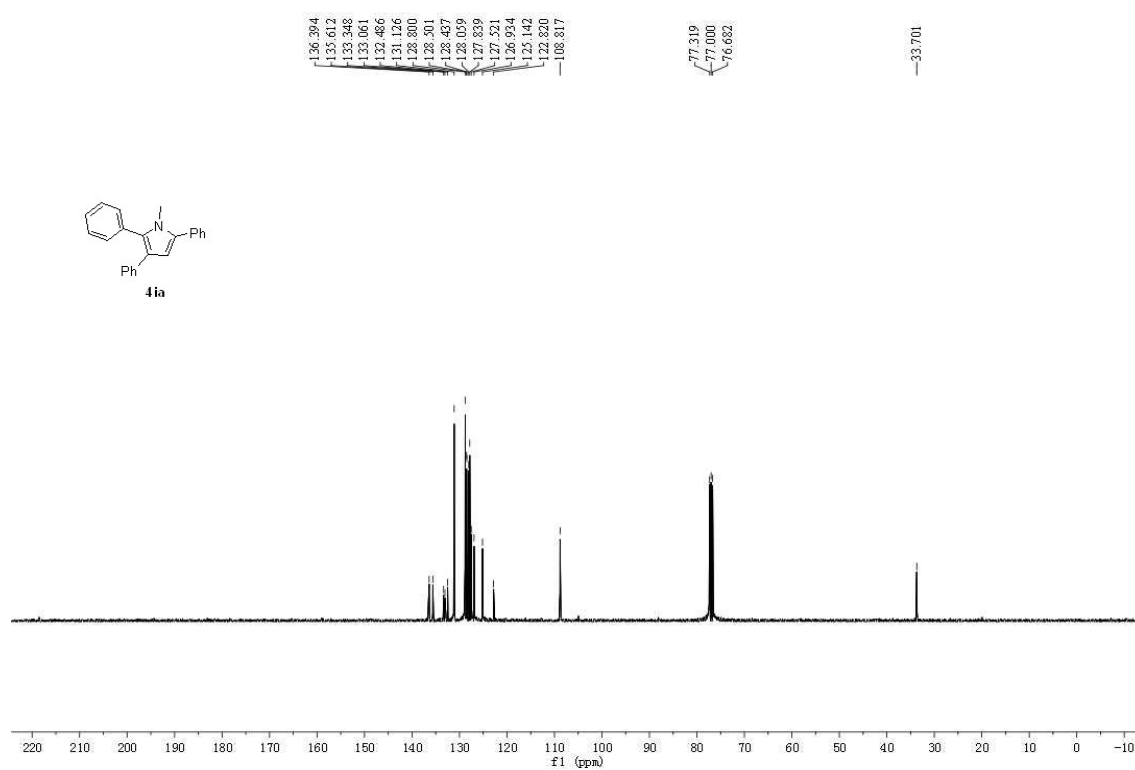
^{13}C NMR spectrum of product **4ha**



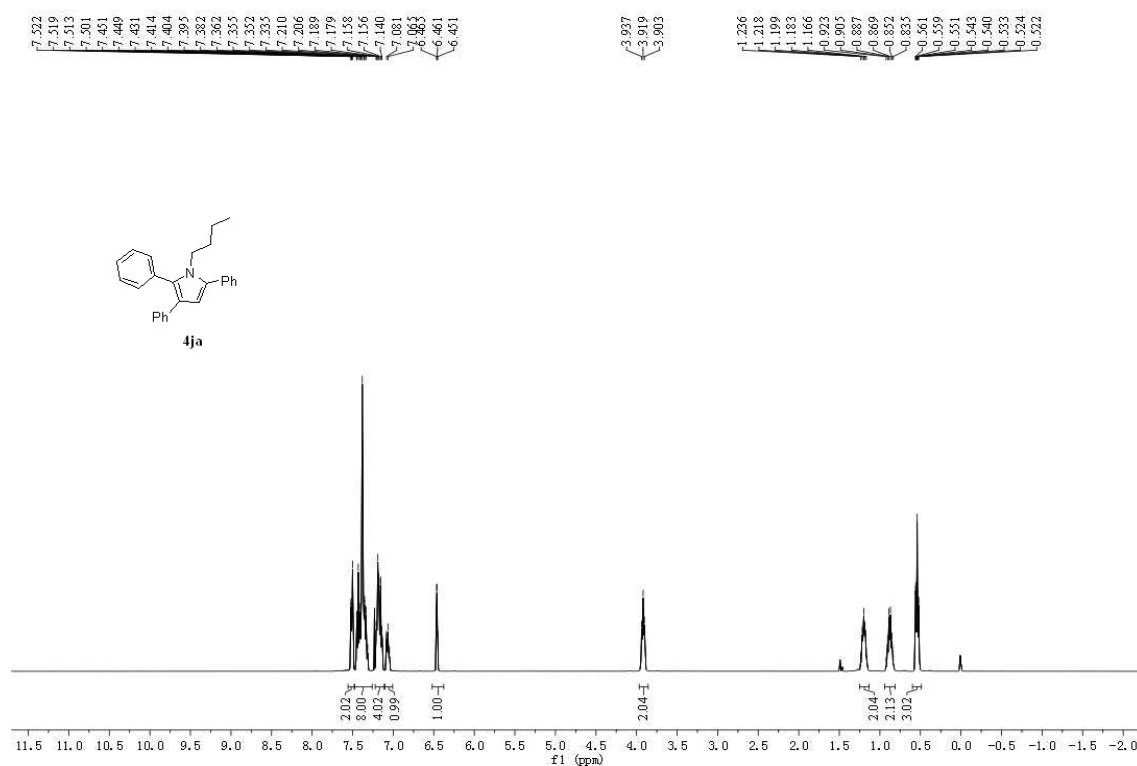
¹H NMR spectrum of product **4ia**



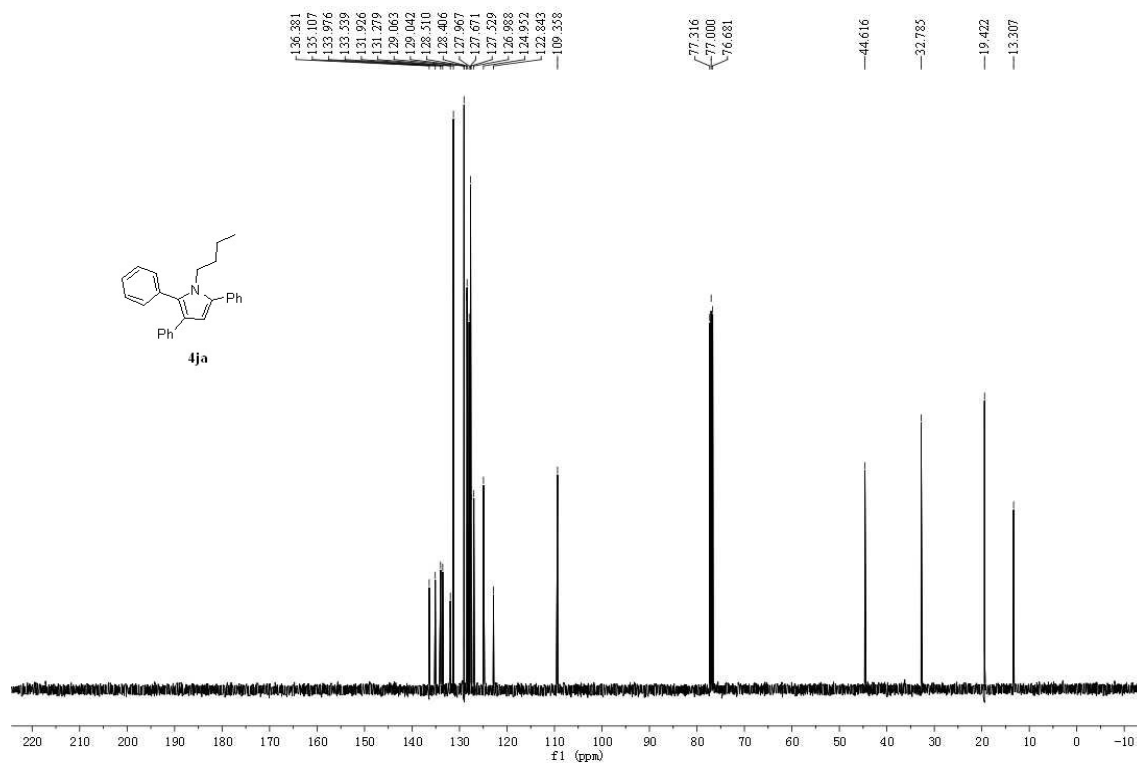
¹³C NMR spectrum of product **4ia**



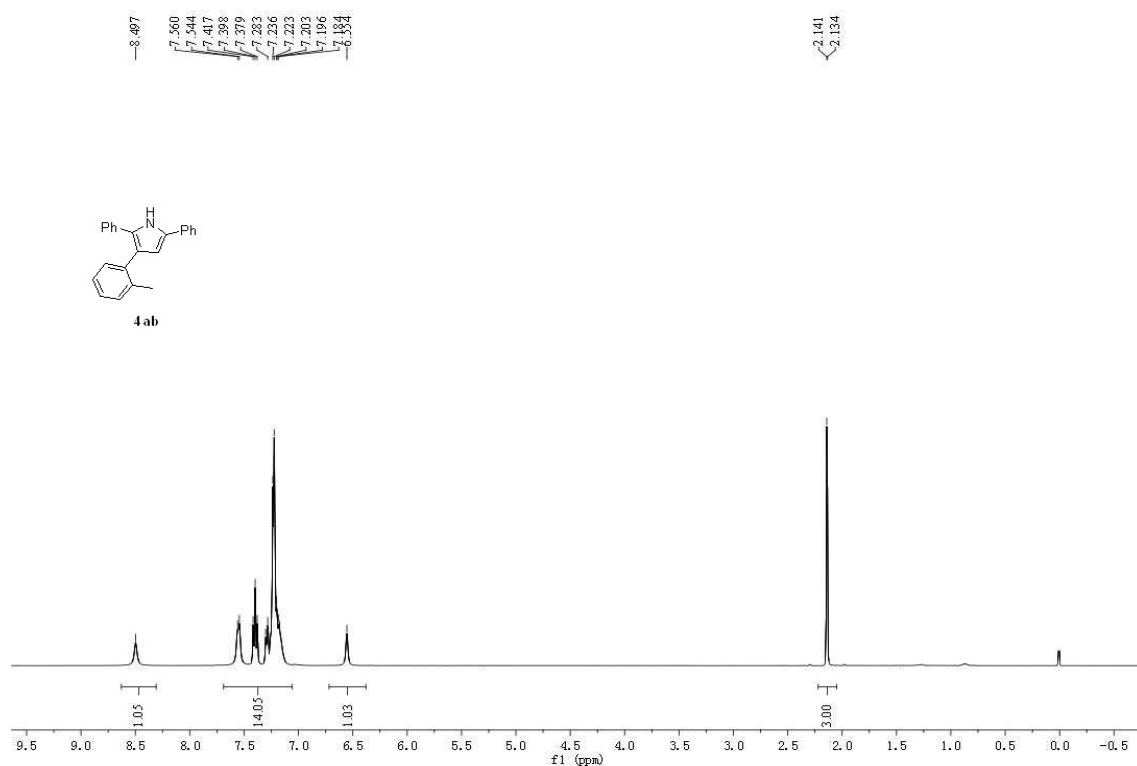
^1H NMR spectrum of product **4ja**



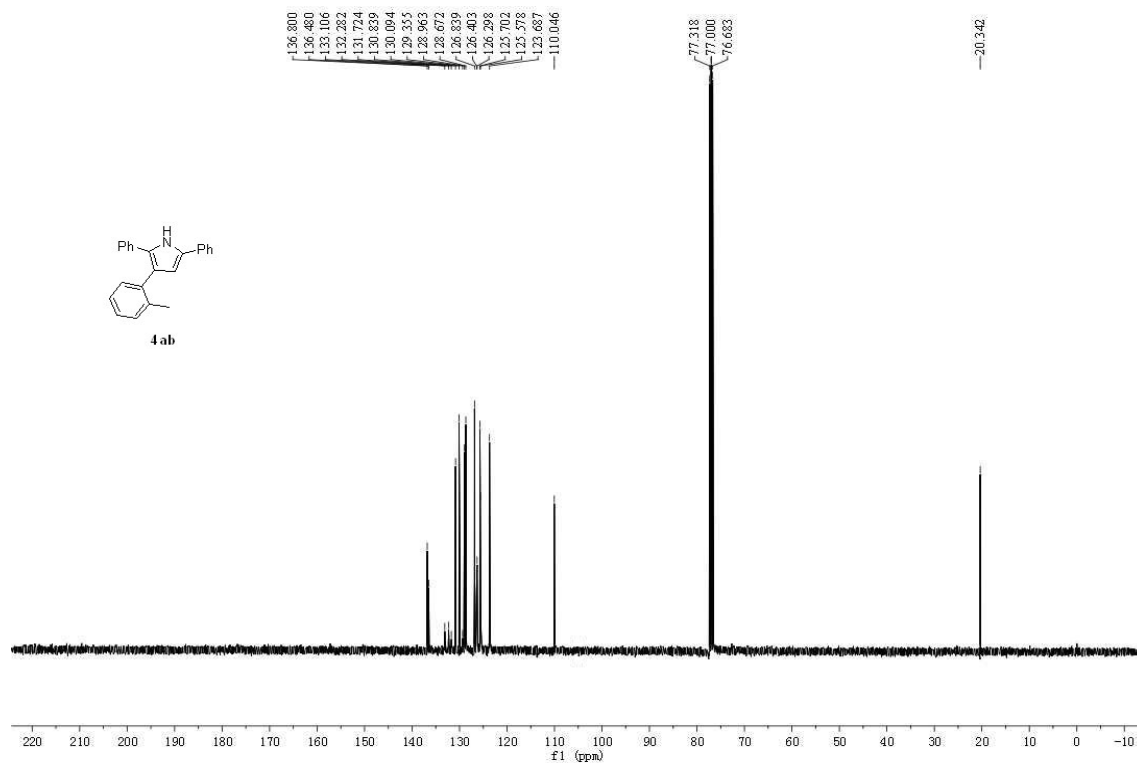
^{13}C NMR spectrum of product **4ja**



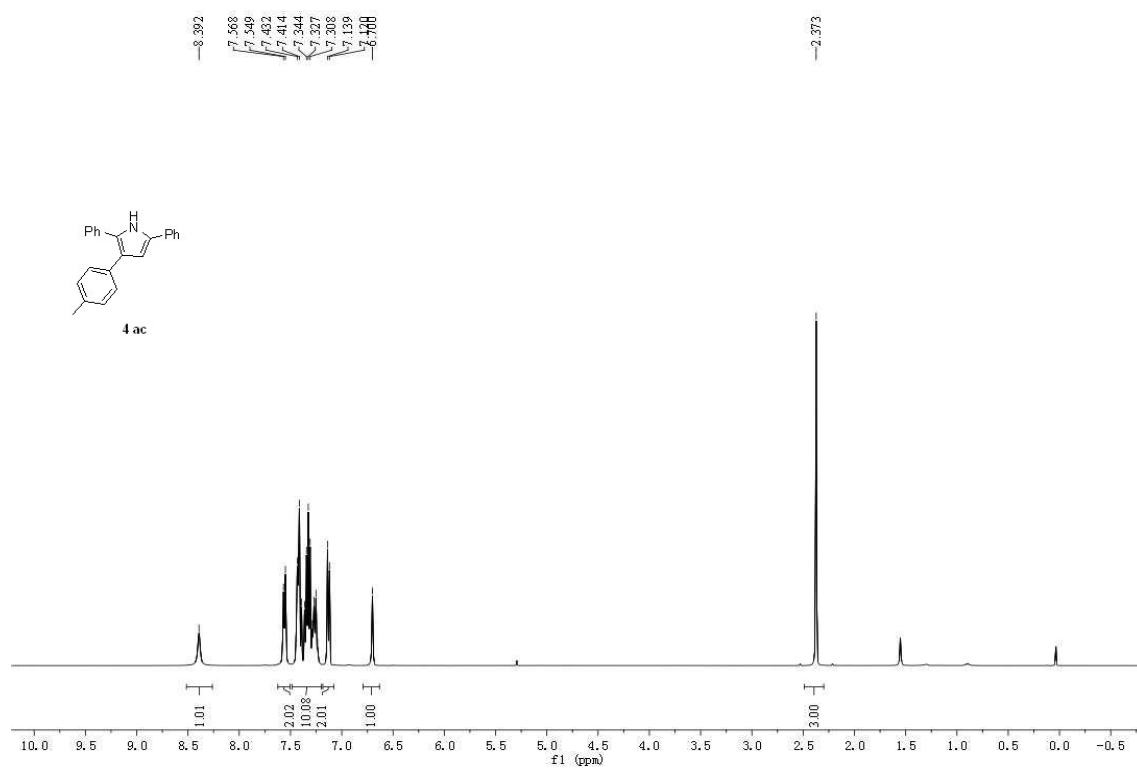
^1H NMR spectrum of product **4ab**



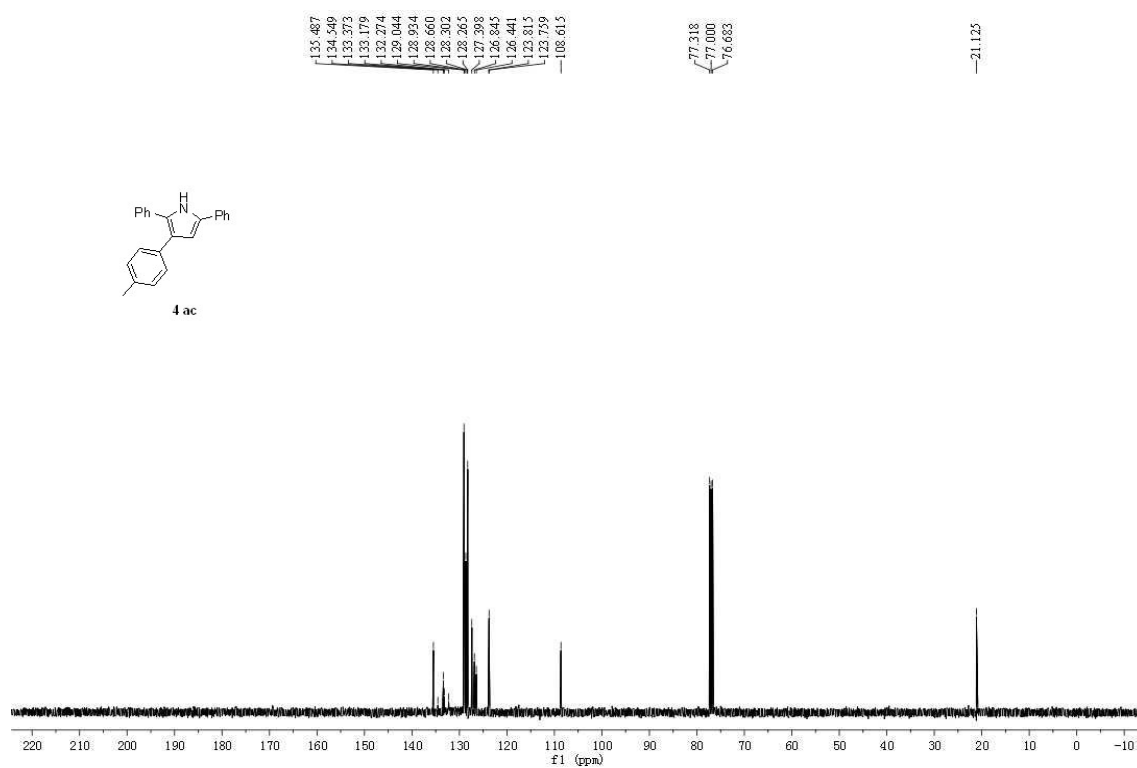
^{13}C NMR spectrum of product **4ab**



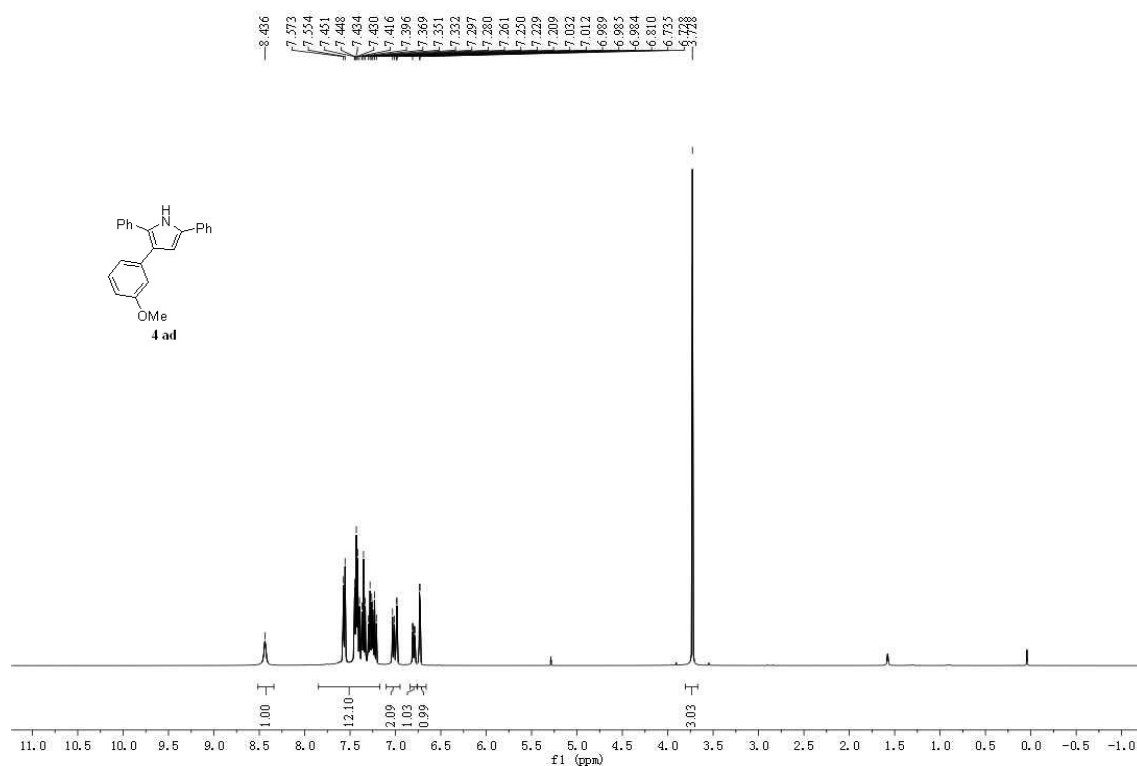
^1H NMR spectrum of product **4ac**



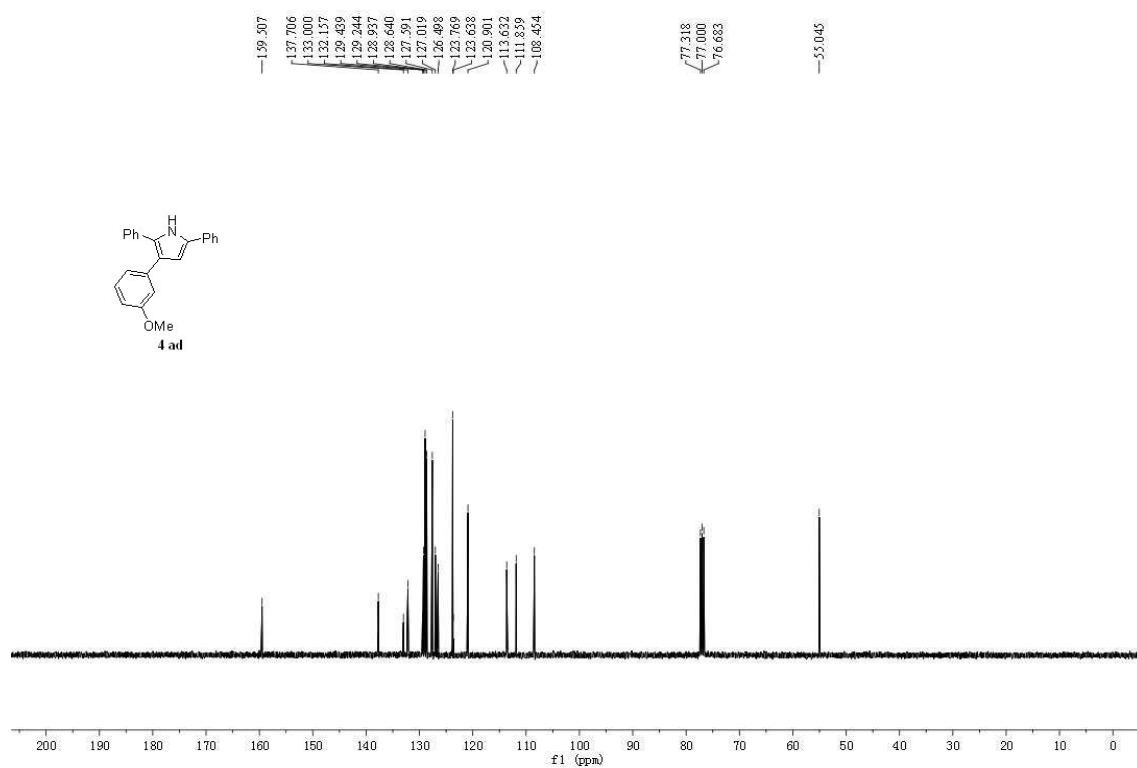
^{13}C NMR spectrum of product **4ac**



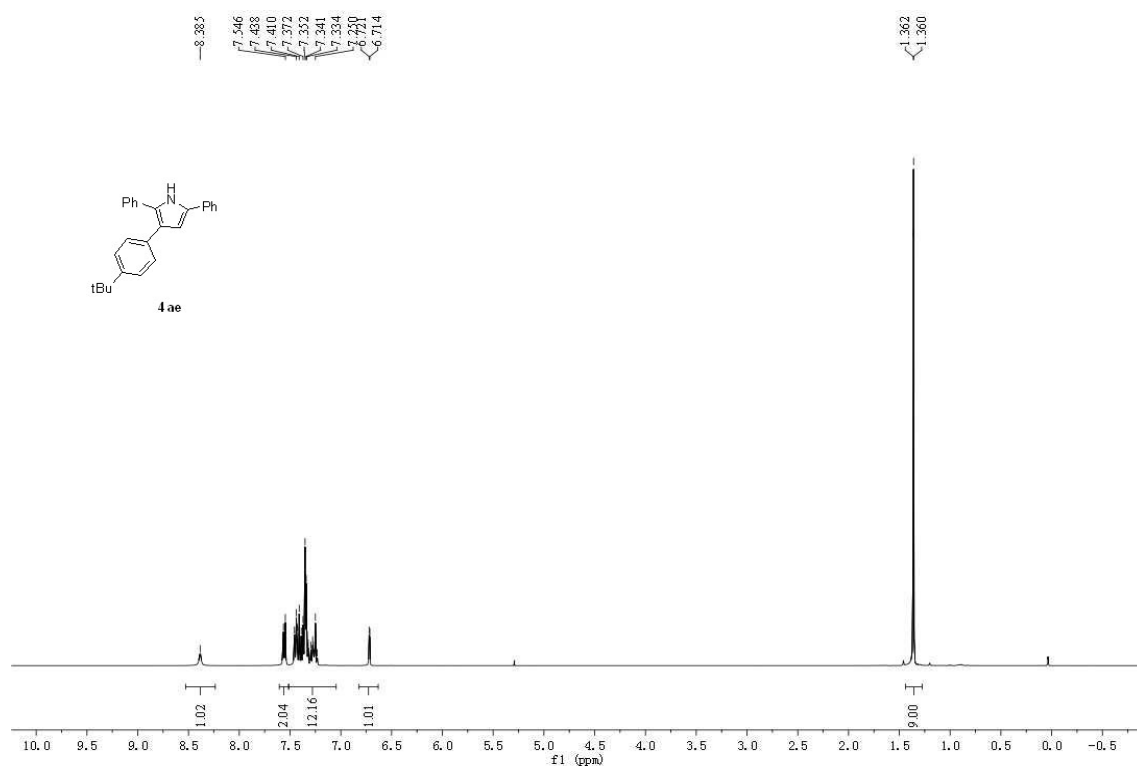
^1H NMR spectrum of product **4ad**



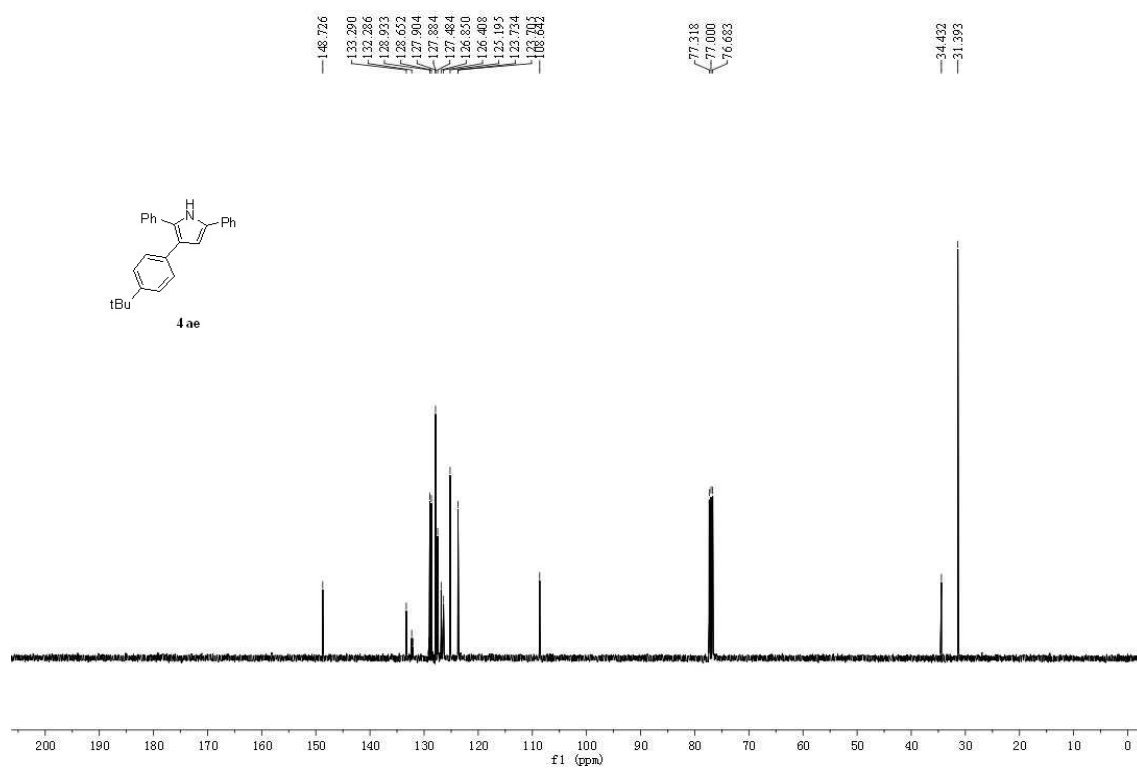
^{13}C NMR spectrum of product **4ad**



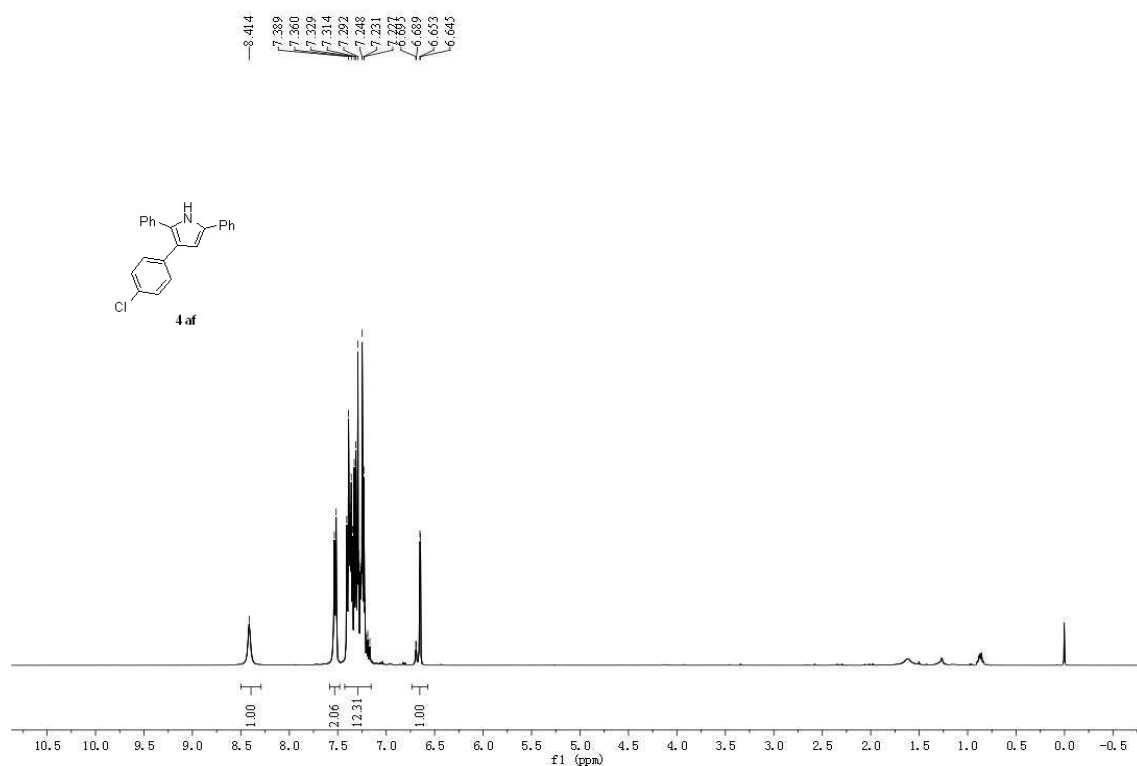
^1H NMR spectrum of product **4ae**



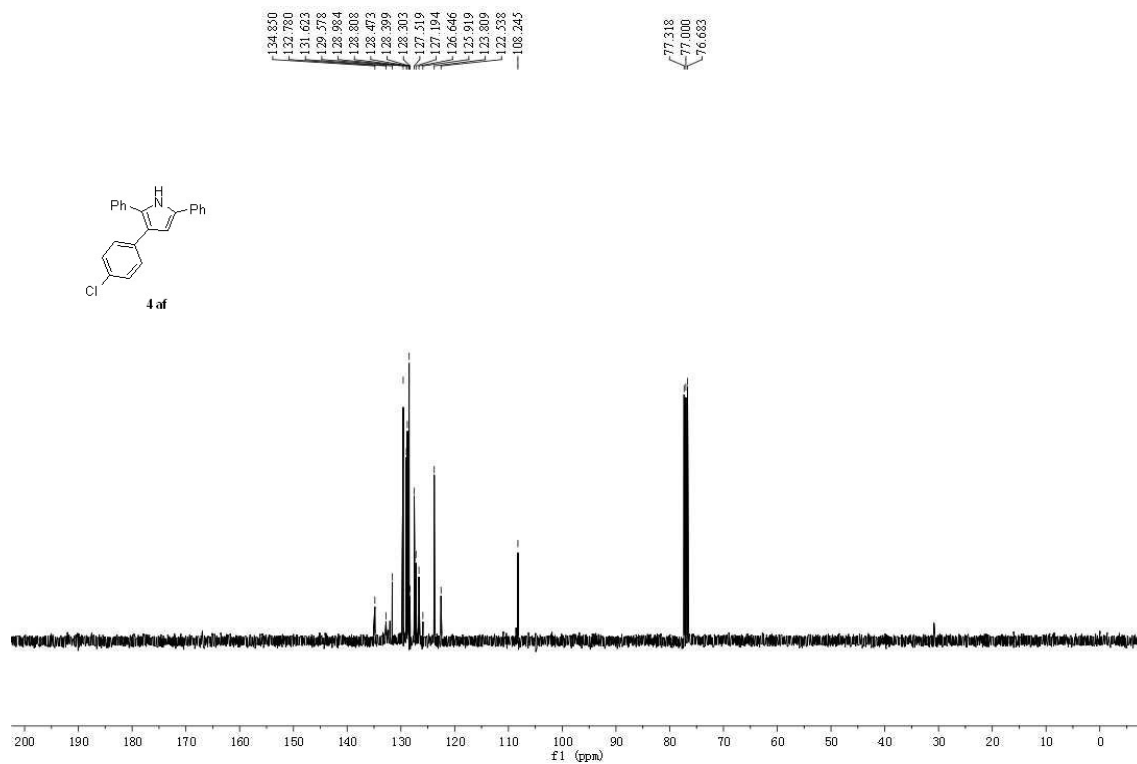
^{13}C NMR spectrum of product **4ae**



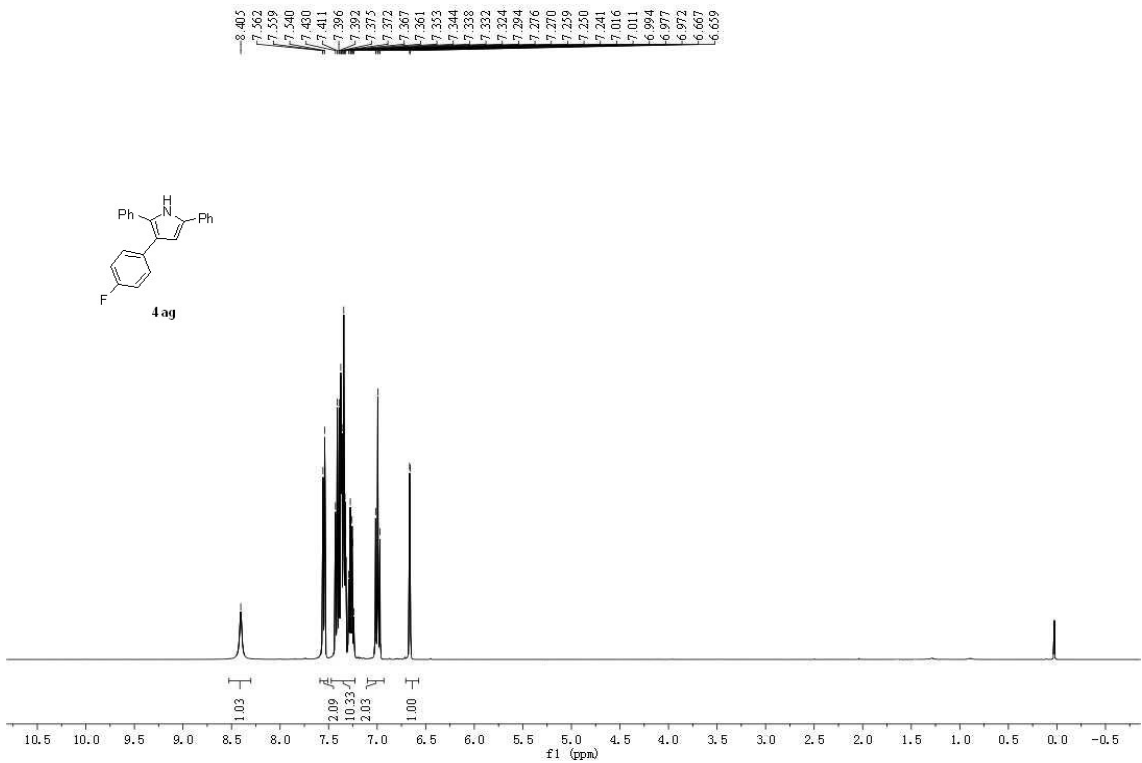
^1H NMR spectrum of product **4af**



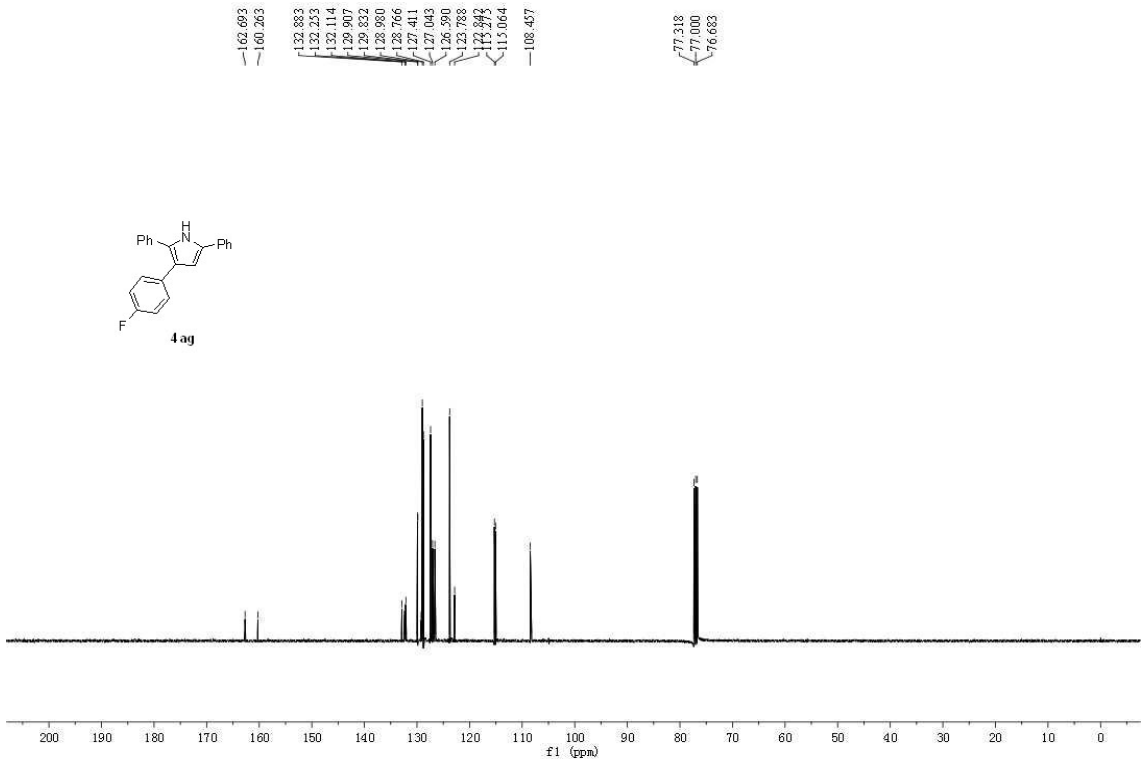
^{13}C NMR spectrum of product **4af**



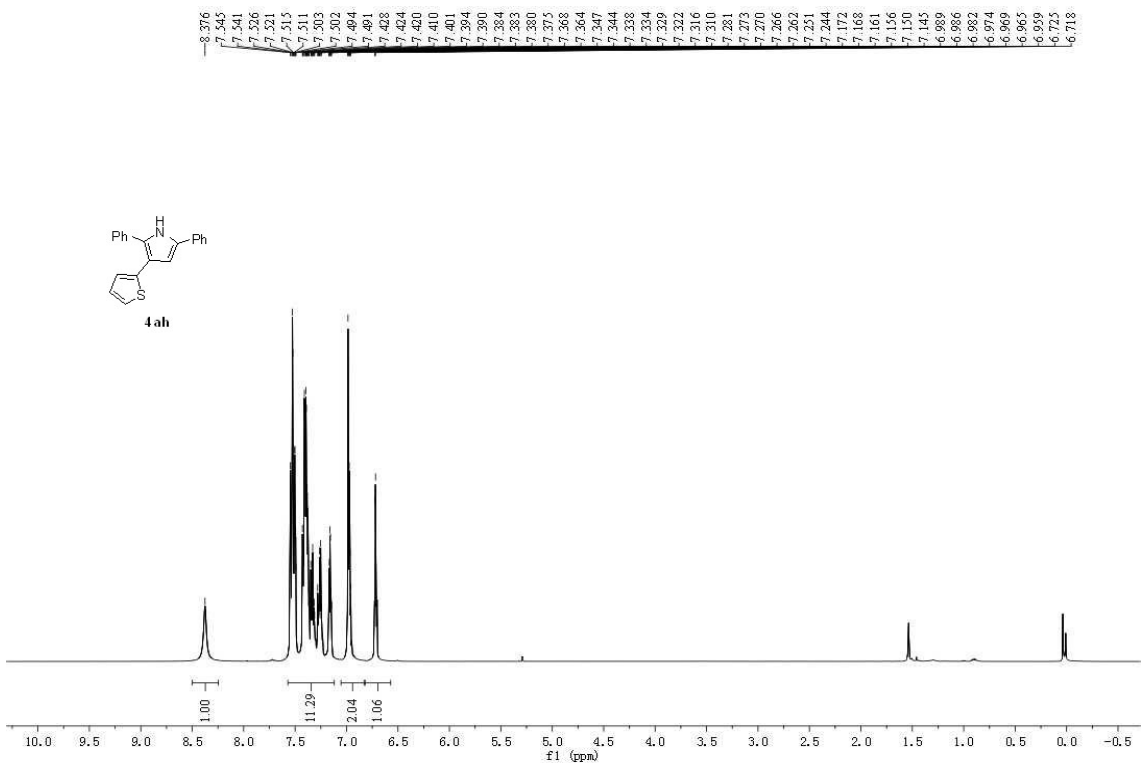
¹H NMR spectrum of product **4ag**



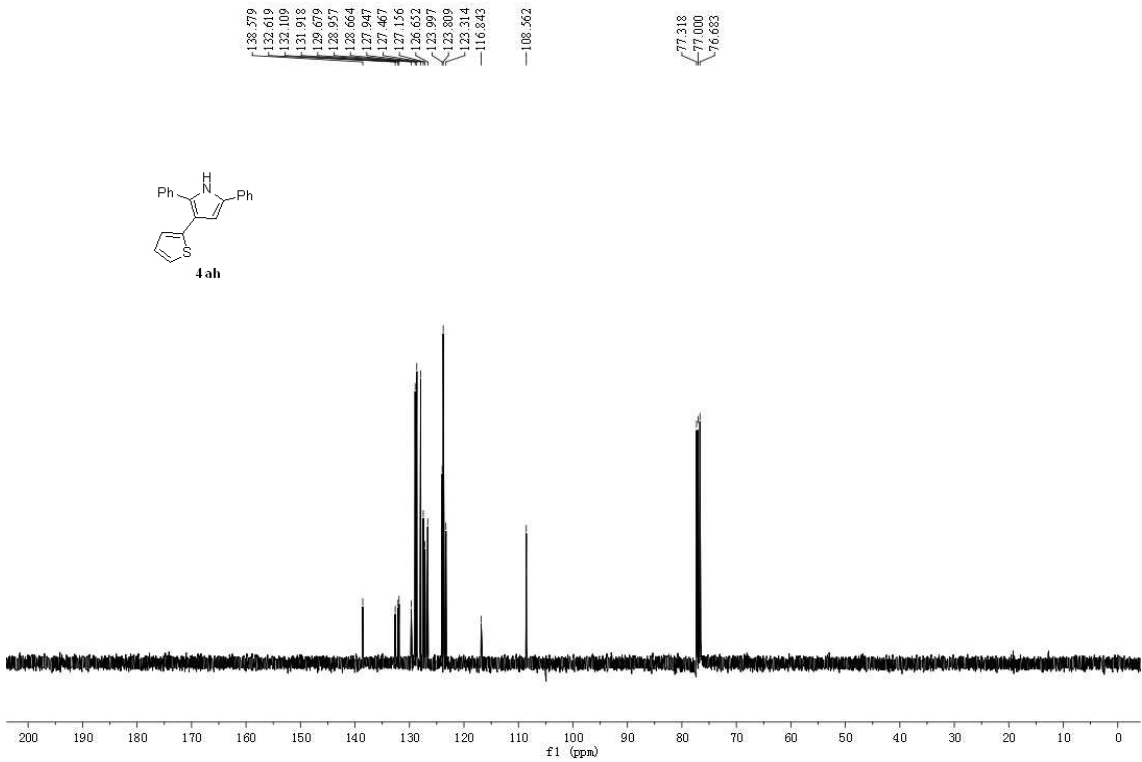
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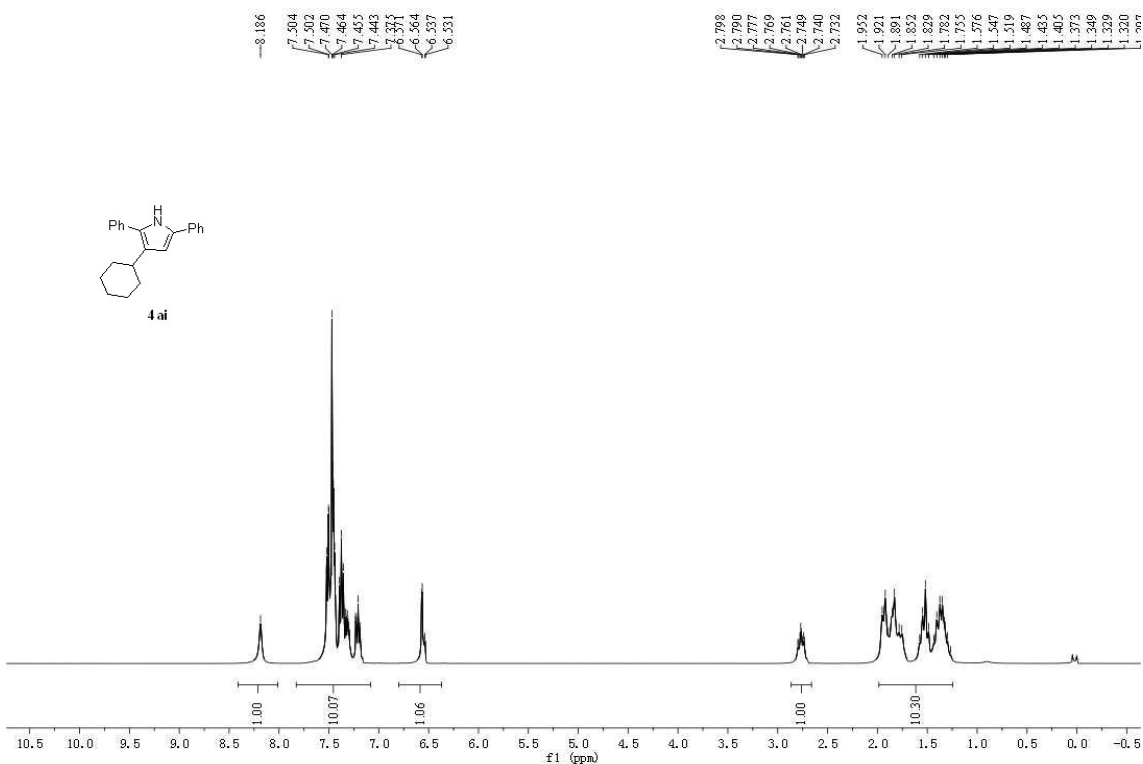
¹H NMR spectrum of product **4ah**



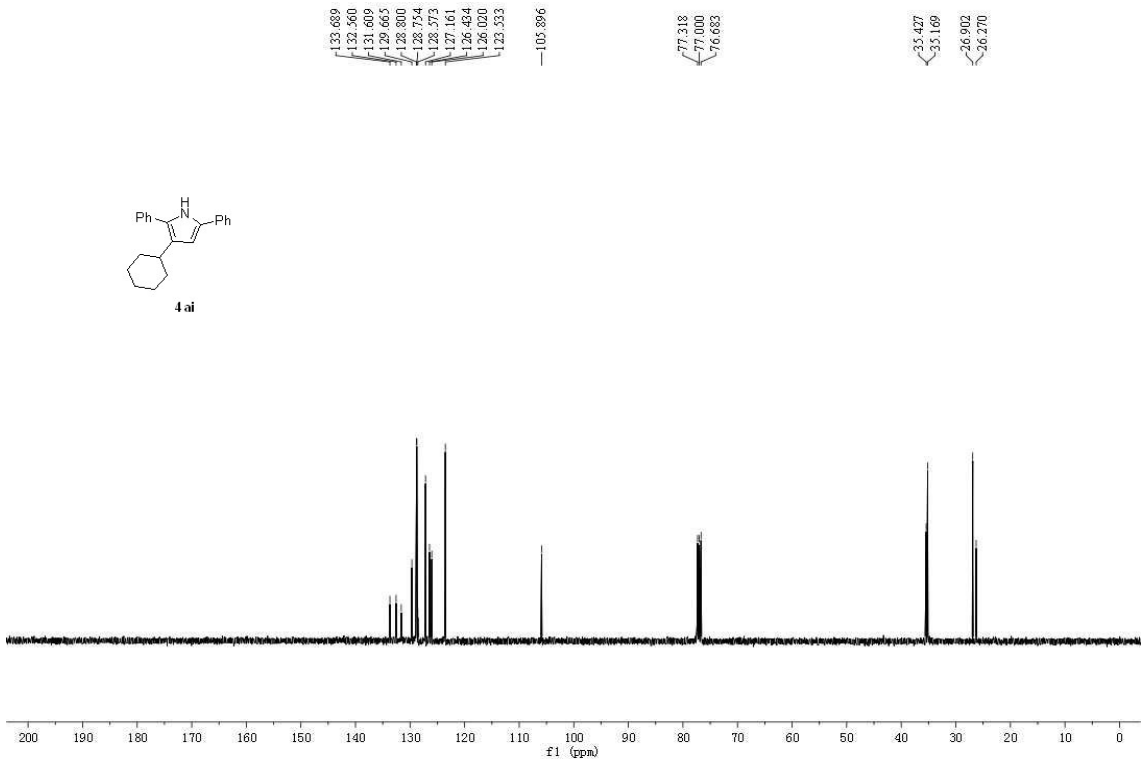
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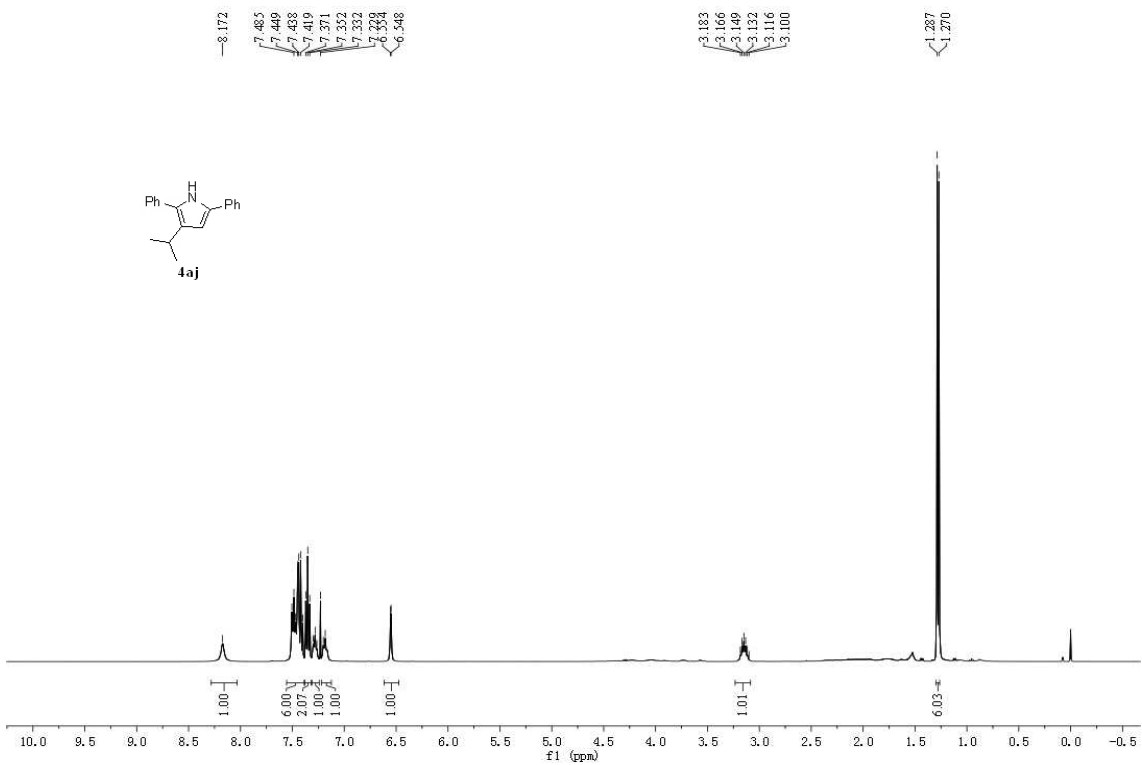
¹H NMR spectrum of product **4ai**



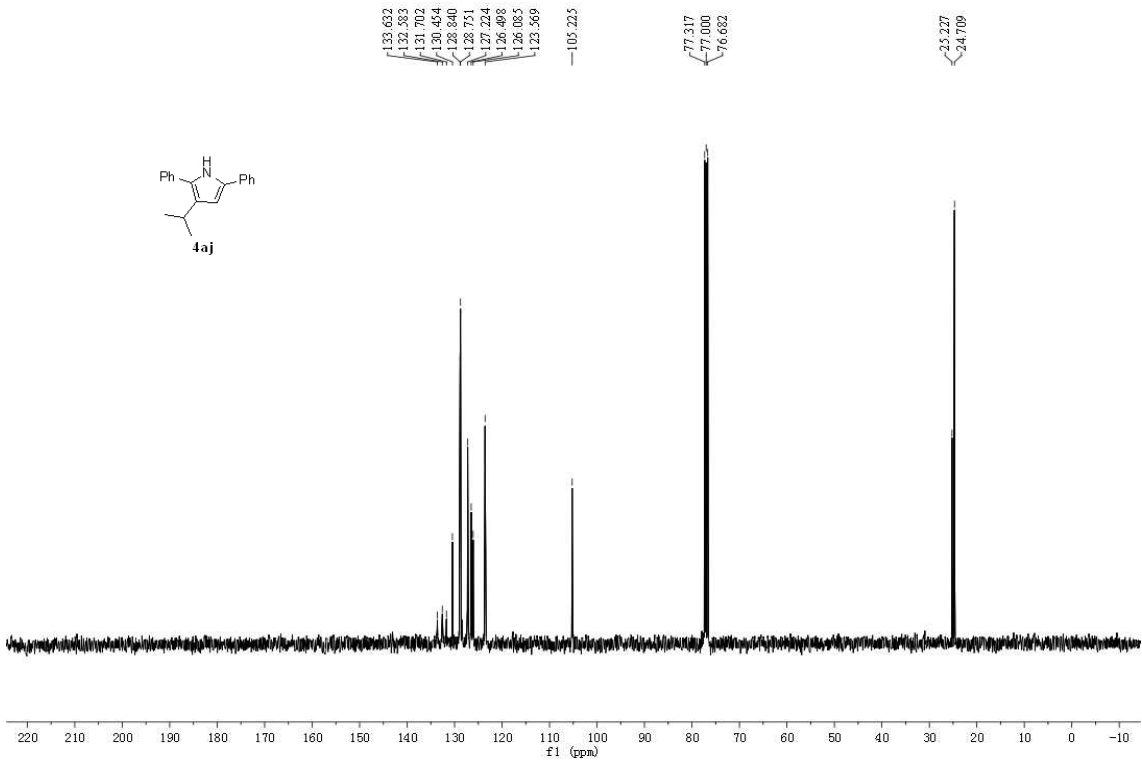
¹³C NMR spectrum of product **4ai**



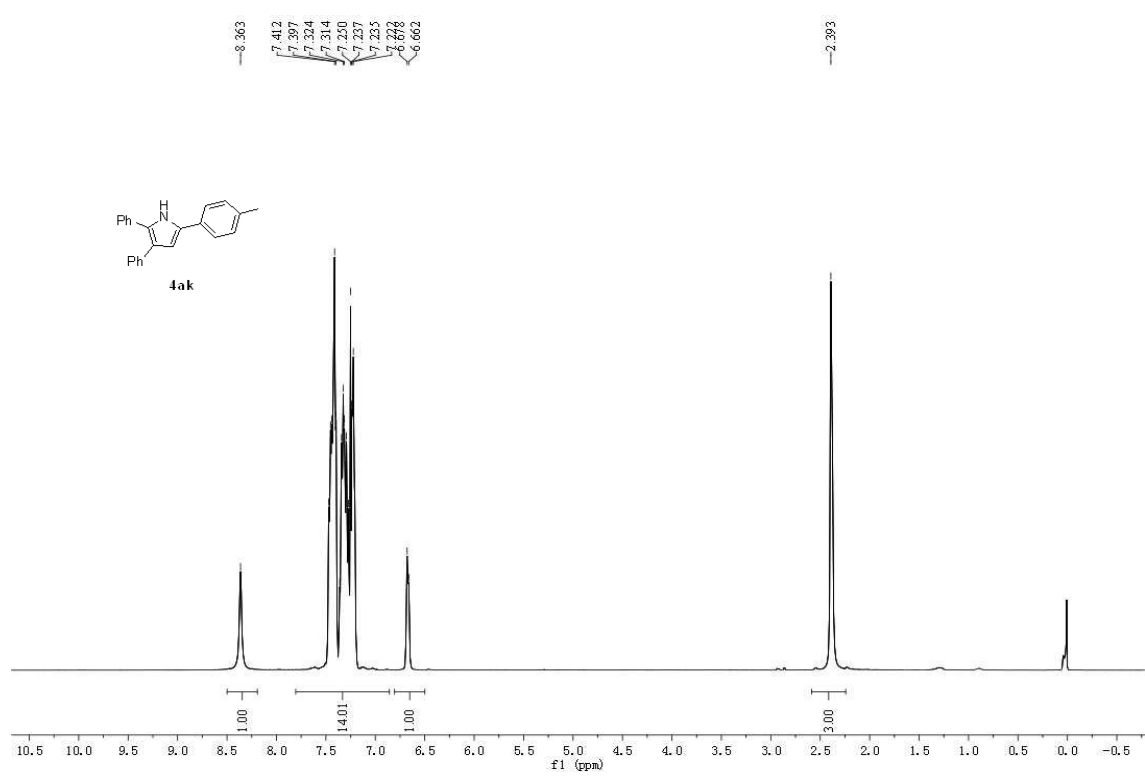
¹H NMR spectrum of product **4aj**



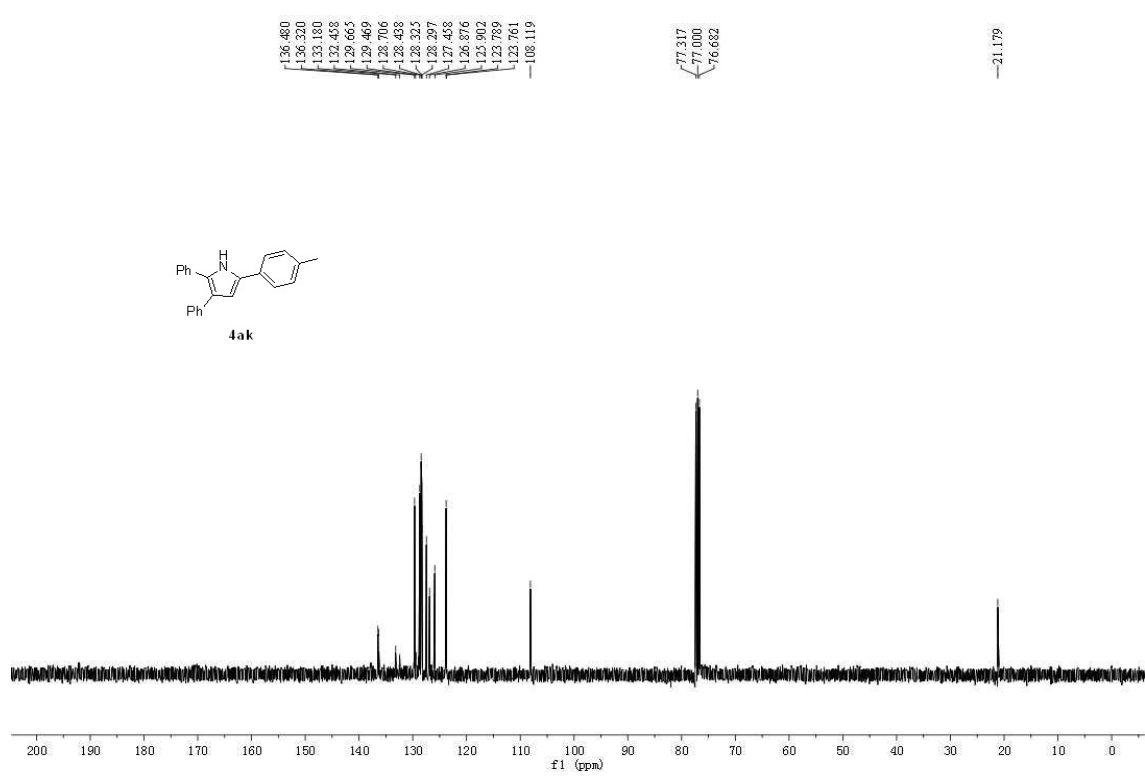
¹³C NMR spectrum of product **4aj**



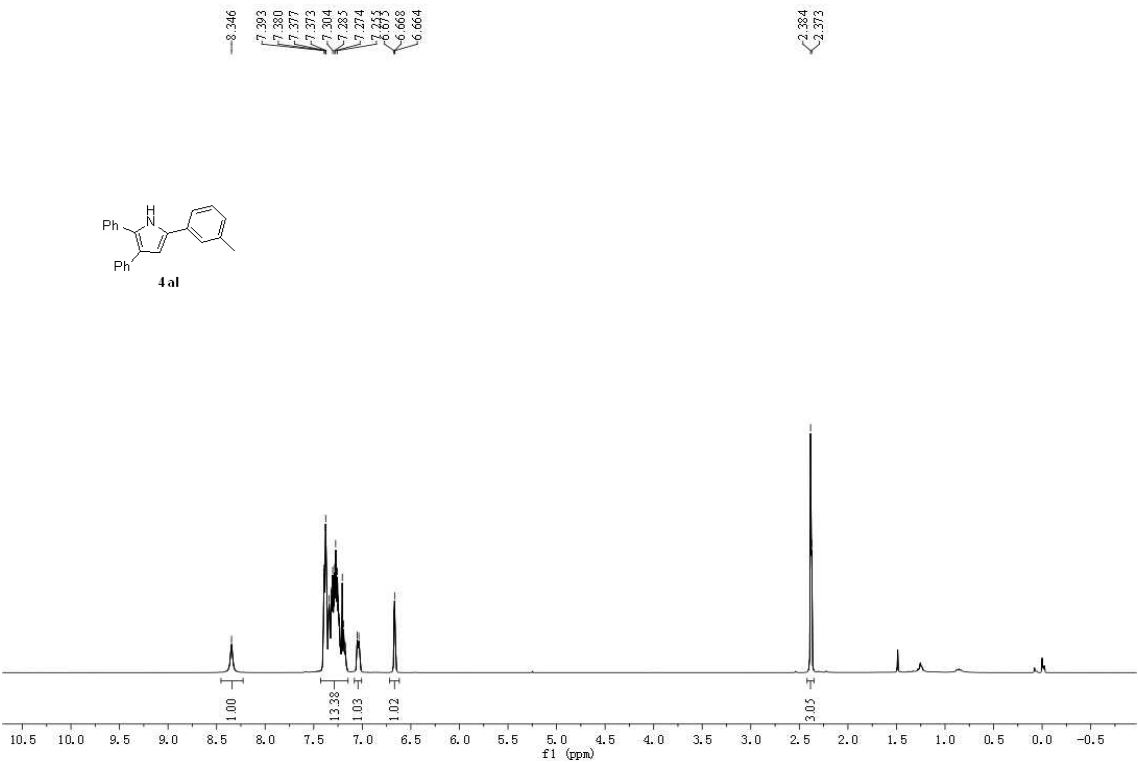
¹H NMR spectrum of product **4ak**



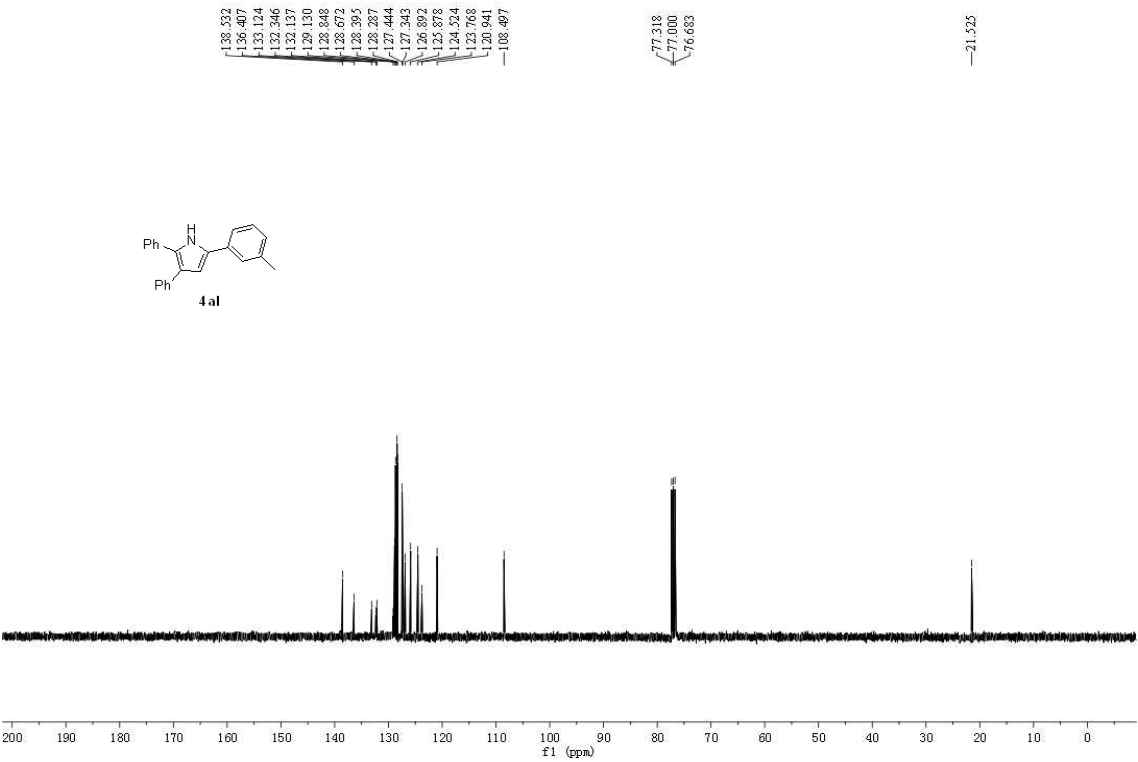
¹³C NMR spectrum of product **4ak**



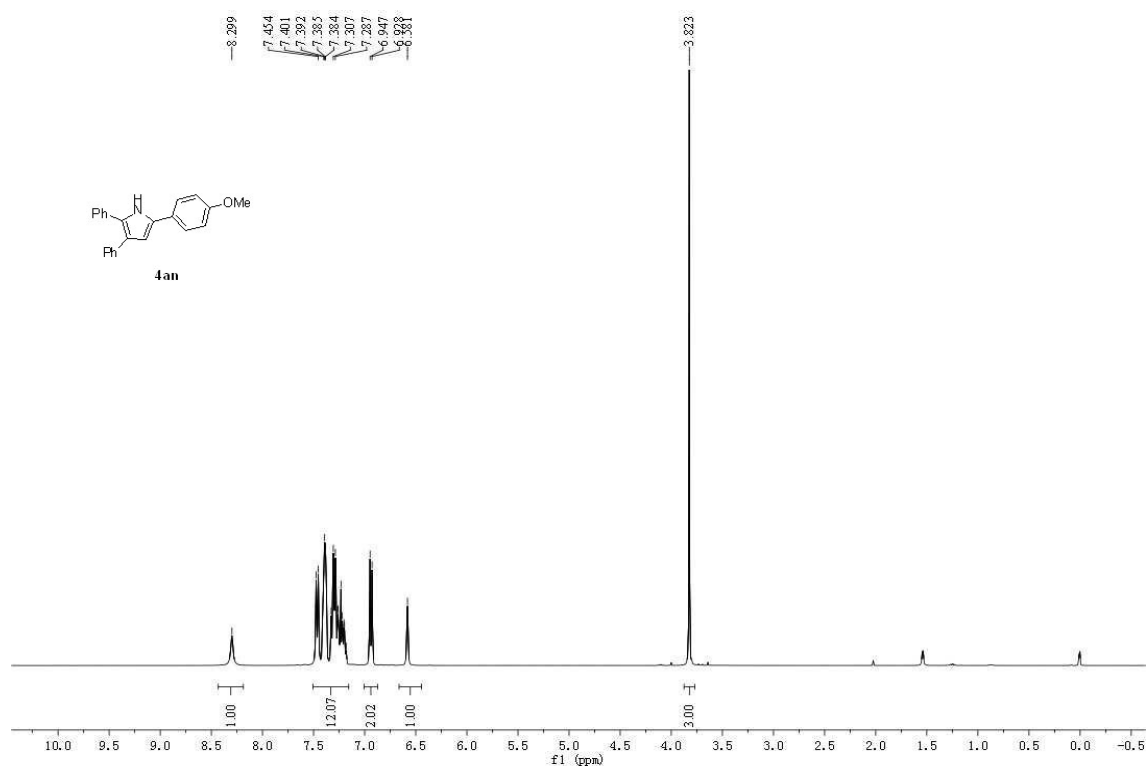
¹H NMR spectrum of product **4al**



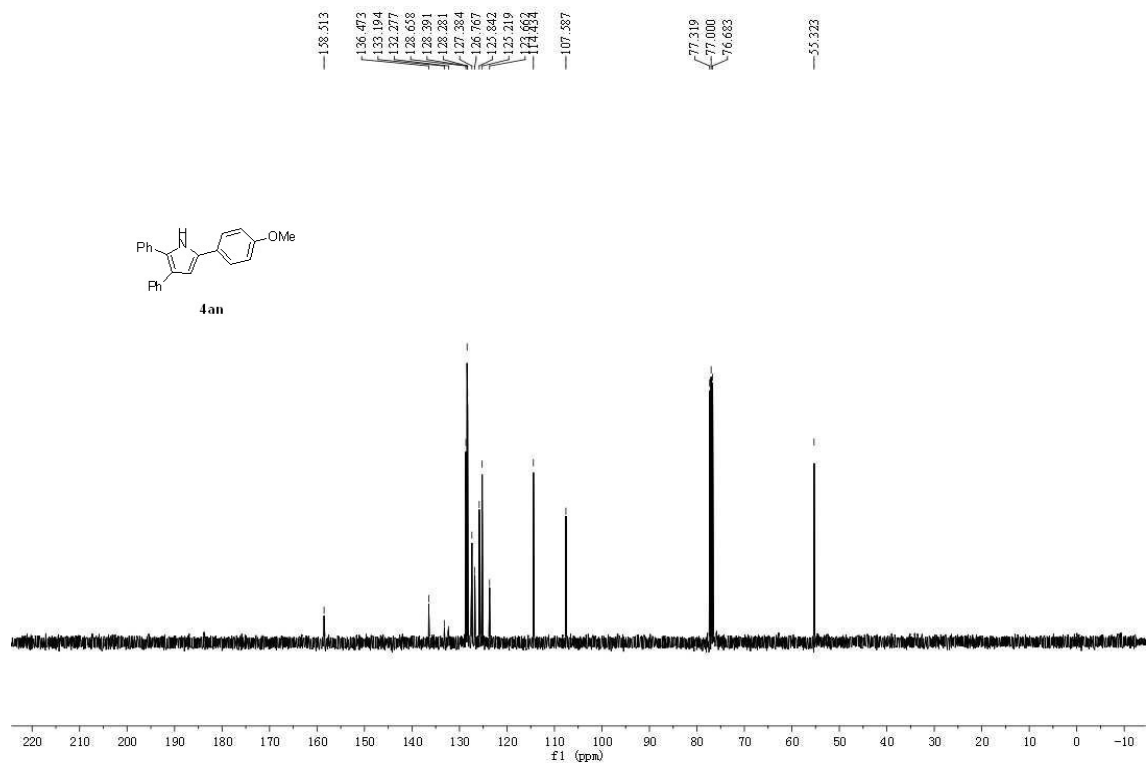
¹³C NMR spectrum of product **4al**



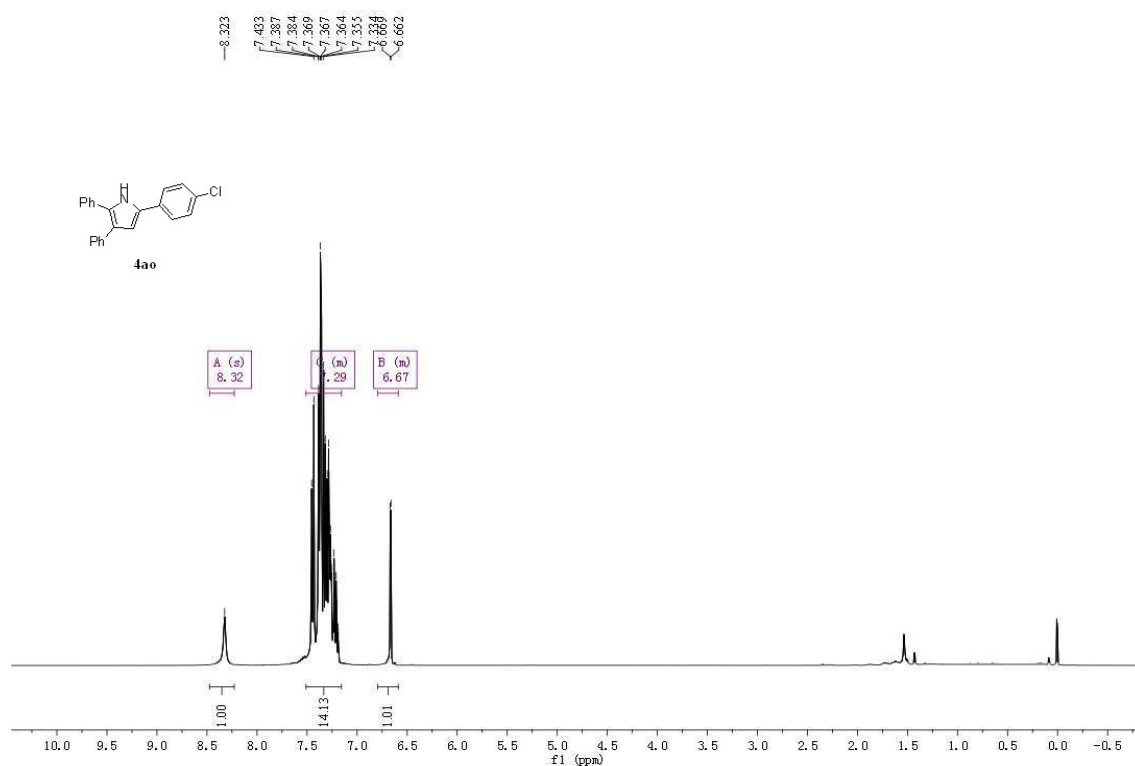
^1H NMR spectrum of product **4an**



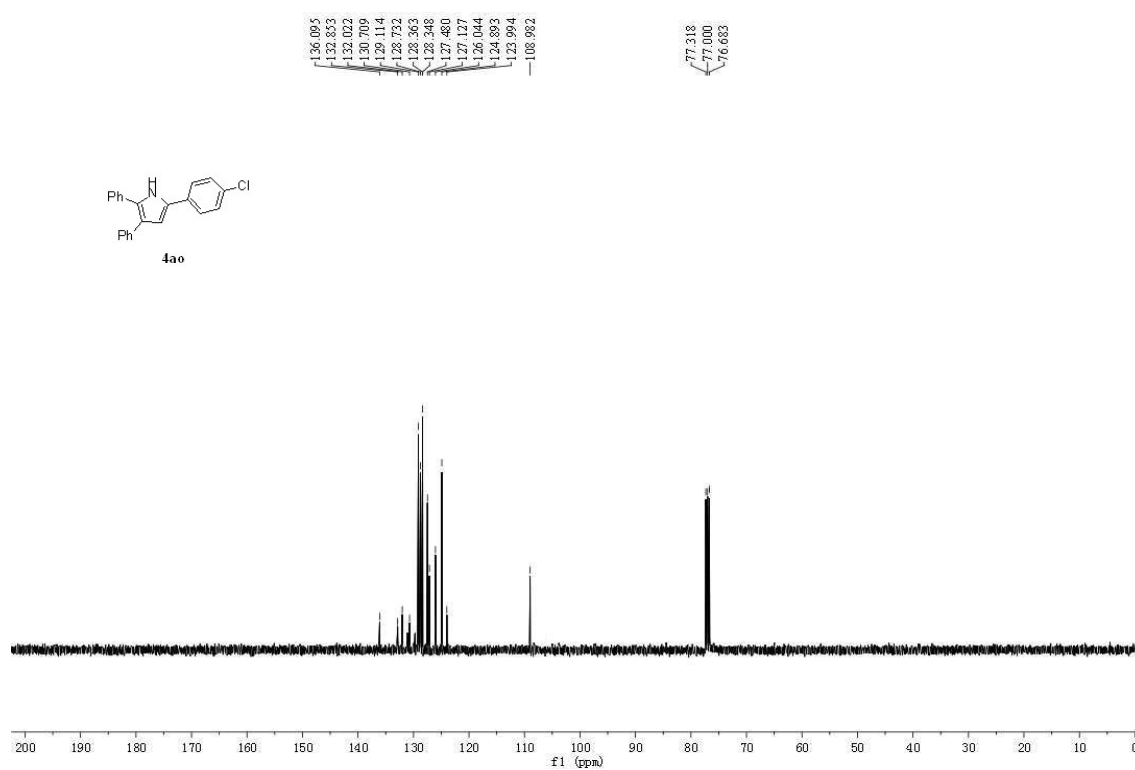
^{13}C NMR spectrum of product **4an**



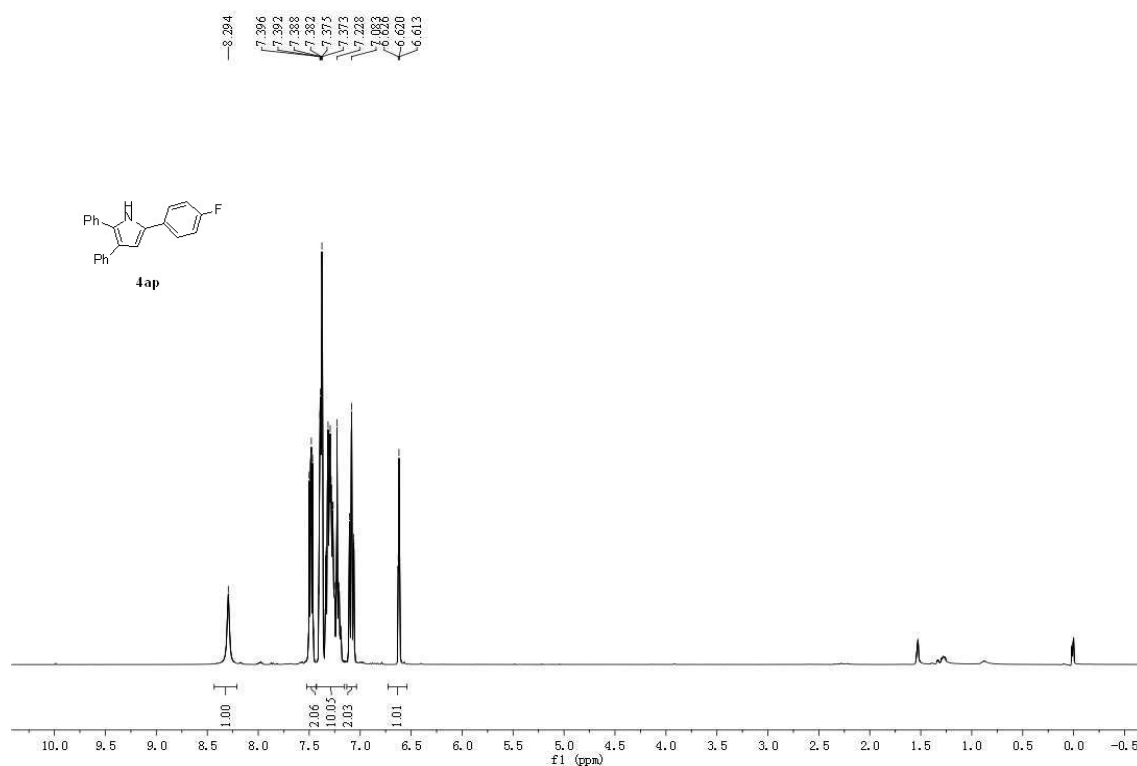
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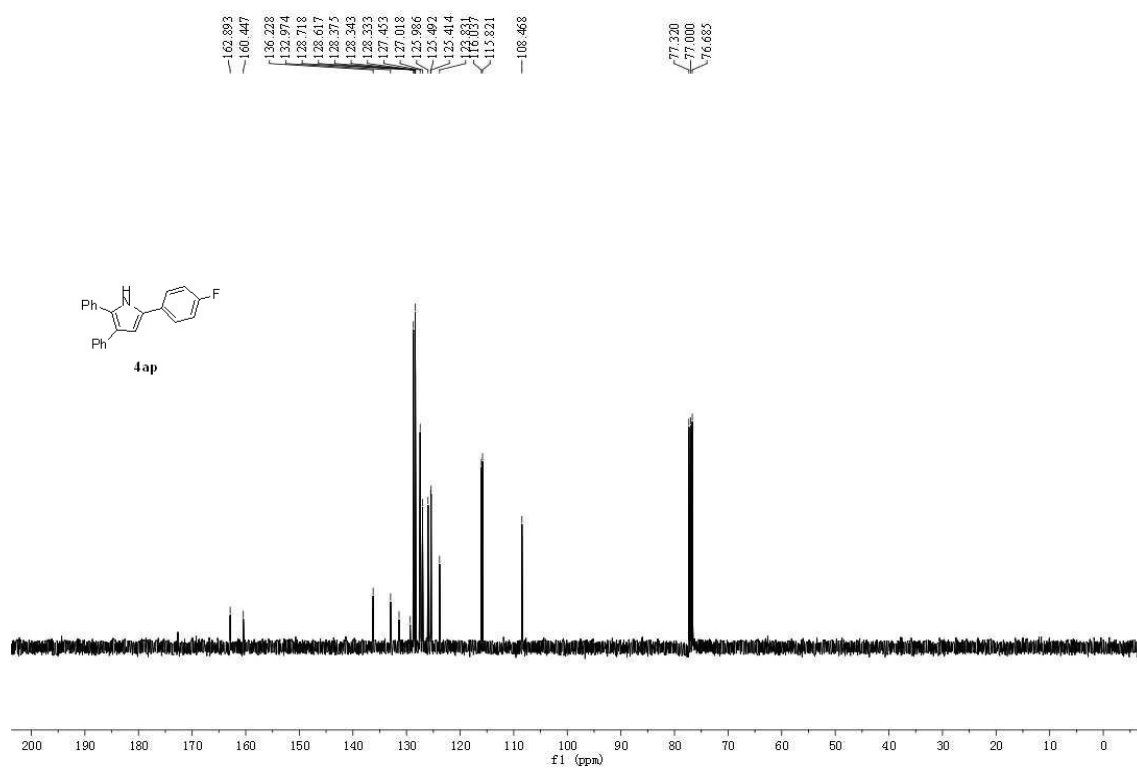
¹³C NMR spectrum of product **4ao**



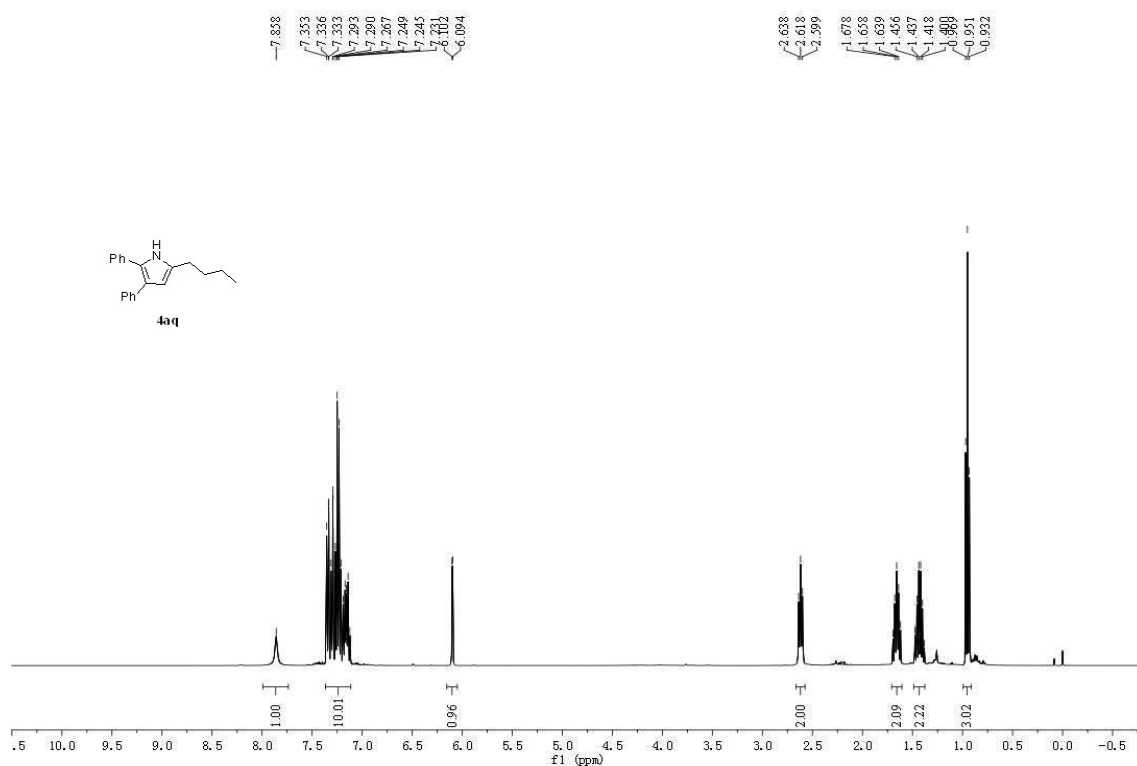
^1H NMR spectrum of product **4ap**



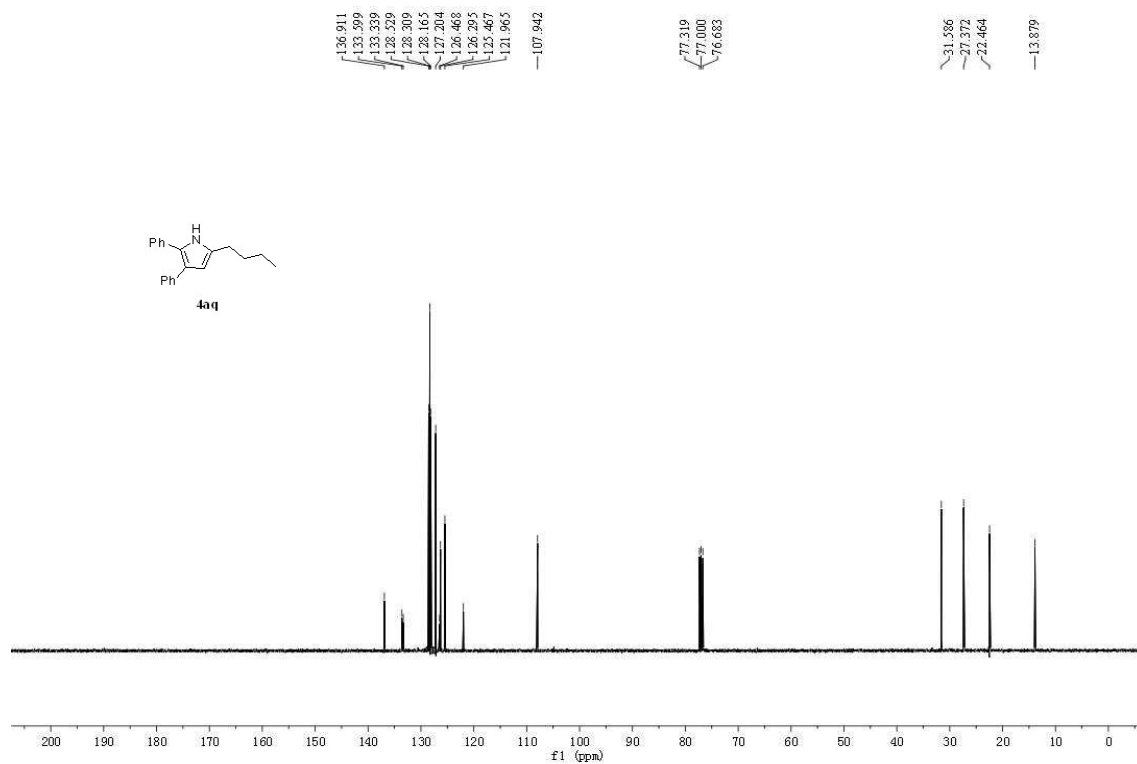
^{13}C NMR spectrum of product **4ap**



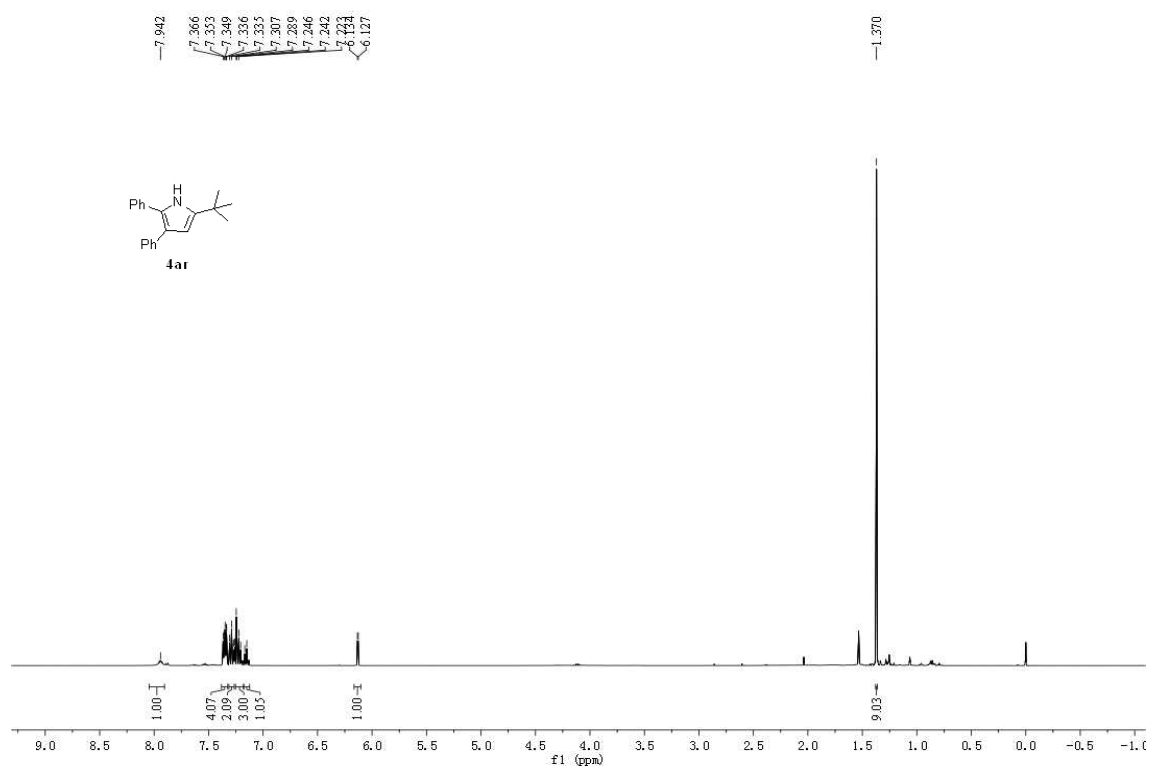
^1H NMR spectrum of product **4aq**



^{13}C NMR spectrum of product **4aq**



¹H NMR spectrum of product **4ar**



¹³C NMR spectrum of product **4ar**

