# Supporting Information

## Synthesis of Pyrazoles through Copper-Catalyzed Three-Component Coupling of Aldehydes, Alkynes, and *p*-Toluenesulfonylhydrazide

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# I. General Information

Unless otherwise noted, all reagents were obtained commercially and used without further purification. All reaction mixtures were stirred with a magnetic bar in flame-dried glassware.

**Chromatography**

Thin layer chromatography (TLC) was performed on Huanghai pre-coated glass-backed TLC plates and visualized by UV lamp (254 nm). Column chromatography on silica gel (300-400 mesh) was carried out using Technical Grade 60-90 $^{o}$C v/v petroleum ether (distillated prior to use) and Analytical Grade EtOAc (without further purification). Concentration under reduced pressure was performed by rotary evaporation. Purified compounds were further addressed under high vacuum (3-5 mmHg). Yields referred to chromatographically purified compounds.

**Nuclear Magnetic Resonance Spectra**

$^{1}$H and $^{13}$C spectra were recorded on a Bruker AV-400 spectrometer. Chemical shifts were reported in ppm. $^{1}$H-NMR spectra were referenced to TMS in $CDCl_3$ (0 ppm) or DMSO -*d6* (2.50 ppm), and $^{13}$C-NMR spectra were referenced to $CDCl_3$ (77.0 ppm) or DMSO -*d6* (39.5 ppm). All $^{13}$C-NMR spectra were measured with complete proton decoupling. Peak multiplicities were designated by the following abbreviations: s, singlet; d, doublet; t, triplet; m, multiplet; brs, broad singlet and *J*, coupling constant in Hz.

**Melting points**

Melting points were measured on a Bűchi Melting Point B-540 Apparatus using open glass capillaries and are uncorrected.

**IR Spectra**

IR spectra were recorded on a Nicolet AVATER FTIR360 spectrometer as thin film. Absorptions were given in wavenumbers (cm$^{-1}$).

**Mass Spectroscopy**

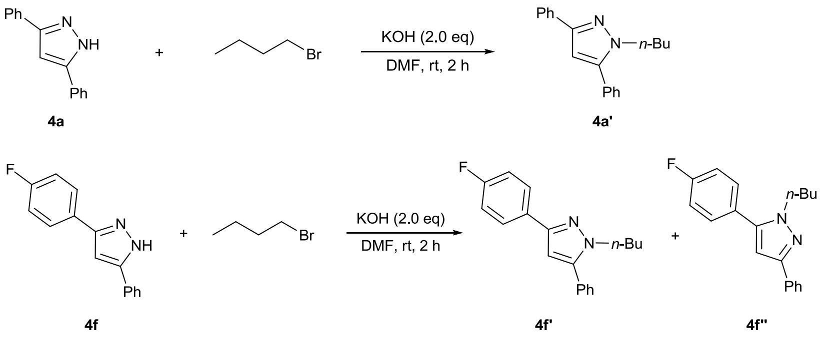
MS measurements were performed on Bruker Reflex III mass spectrometer.

**High resolution mass spectroscopy**

Data were obtained via Ultra-high Resolution Hybrid Qh-Fourier Transform Mass Spectrometer (En Apex ultra 7.0 FT-MS) operated by Department of Chemistry, Xiamen University.

# II. Spectroscopic Analysis

Because of the dynamic tautomeric forms of the NH-pyrazoles, their $^{13}$C NMR spectra are unusual as normal organic compounds show. They often exhibit concentration and solvent-dependent NMR spectra (see the reference "M. T. Chenon, C. Coupry, D. M. Grant , R. J. Pugmire, *J. Org. Chem.*, **1977**, *42*, 659." for more detailes). The biggest effect can be seen in the $^{13}$C NMR spectra is that the C-3, C-5 and α-carbons appears as very broad signals that unresolved from the baseline. In other words, these carbons are missing from the spectra. To circumvent this issue, derivatization such as alkylation has been adopted to provide spectra where all carbons can be found.



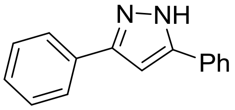
The derivatization of **4a** and **4f**

For example, compound **4a** and **4f** was treated with KOH and *n*-BuBr (1-bromobutane) in DMF at room temperature to readily generate the corresponding 1-butyl-3,5-diphenyl-1*H*-pyrazole (**4a'**), 1-butyl-3-(4-fluorophenyl)-5-phenyl-1*H*-pyrazole (**4f'**) and 1-butyl-5-(4-fluorophenyl)-3-phenyl-1*H*-pyrazole (**4f''**) in nearly quantitative yield (**4f'** and **4f''** were produced as a mixture which could not be seperated by column chromatography, and the isomers ratio is 3:5). These compounds are well dissolved in CDCl$_3$ (**4a** and **4f** are insoluble in CDCl$_3$), and analyzed by $^{13}$C NMR to give $^{13}$C spectra that provide sharp signals with all of the carbons being found (see the supporting information for more details). The two examples are provided as additional supports for characterization of the pyrazole products via $^{13}$C NMR.

# III. Experimental

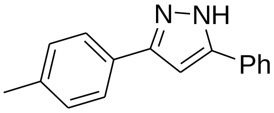
General procedure for the synthesis of pyrazoles: To a flame-dried 5-mL flask equipped with a magnetic bar, aldehyde **1** (0.5 mmol, 1.0 equiv.), *p*-toluenesulfonylhydrazide **2** (0.6 mmol, 1.2 equiv.), alkyne **3** (1.5 mmol, 3.0 equiv.), chlorobenzene (3 mL) and Cu (OTf)$_2$ (0.1 mmol) were added successively. The mixture was stirred at rt until the **2** was dissolved, then heated to reflux for an appropriate time, and monitored periodically by TLC. Upon completion, the product was purified by column chromatography on silica gel to afford **4**.

# IV. Spectral data of Substituted Pyrazoles



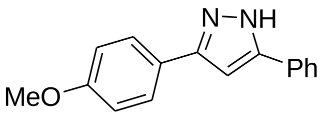
**4a**

**3,5-Diphenyl-1*H*-pyrazole (4a):**[1-5] To a flame-dried 5-mL flask equipped with a magnetic bar, benzaldehyde (0.5 mmol, 1.0 equiv.), *p*-toluenesulfonylhydrazide (0.6 mmol, 1.2 equiv.), phenylacetylene (1.5 mmol, 3.0 equiv.), chlorobenzene (3 mL) and Cu $(OTf)_2$ (0.1 mmol) were added successively. The mixture was stirred at rt until the **2** was dissolved, then heated to reflux for an appropriate time, and monitored periodically by TLC. Upon completion, the product (**4a)** was purified by column chromatography on silica gel to afford a white solid in 60% yield (mp 190-192 $^{o}$C). **$^1$H-NMR** (400 MHz, DMSO): $\delta$ 7.17 (s, 1H), 7.31-7.35 (m, 2H), 7.43-7.46 (m, 4H), 7.84 (m, 4H), 13.39 (brs, 1H); **$^{13}$C-NMR** (100 MHz, DMSO): $\delta$ 99.6, 125.2, 128.8; **IR** (film): 3417, 3101, 1610 1494 cm$^{-1}$; **ESI-MS**: calc. for $C_{15}H_{12}N_2$ $[M+H]^+$: m/z = 221.1; found: 221.3.



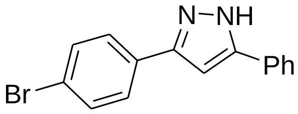
**4b**

**3-(4-Methylphenyl)-5-phenyl-1*H*-Pyrazole (4b):**[3,4,6] To a flame-dried 5-mL flask equipped with a magnetic bar, 4-methylbenzaldehyde (0.5 mmol, 1.0 equiv.), *p*-toluenesulfonylhydrazide (0.6 mmol, 1.2 equiv.), phenylacetylene (1.5 mmol, 3.0 equiv.), chlorobenzene (3 mL) and Cu $(OTf)_2$ (0.1 mmol) were added successively. The mixture was stirred at rt until the **2** was dissolved, then heated to reflux for an appropriate time, and monitored periodically by TLC. Upon completion, the product (**4b**) was purified by column chromatography on silica gel to afford a white solid in 61% yield (mp 162-164 $^{o}$C). **$^1$H-NMR** (400 MHz, DMSO): $\delta$ 2.32 (s, 3H), 7.12 (s, 1H), 7.24-7.45 (m, 5H), 7.72 (d, 2H, $J$ = 6.4 Hz), 7.84 (d, 2H, $J$ = 6.0 Hz)， 13.3 (brs, 1H); **$^{13}$C-NMR** (100 MHz, DMSO): $\delta$ 20.8, 99.3, 125.1, 125.2, 128.3, 128.8, 129.4; **IR** (film): 3421, 3021, 1608, 1508 cm$^{-1}$; **ESI-MS**: calc. for $C_{16}H_{14}N_2$ $[M+H]^+$: $m/z$ = 235.1; found: 235.3.



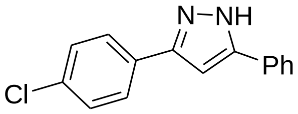
**4c**

**3-(4-Methoxyphenyl)-5-phenyl-1*H*-pyrazole (4c):**[1] To a flame-dried 5-mL flask equipped with a magnetic bar, 4-methoxybenzaldehyde (0.5 mmol, 1.0 equiv.), *p*-toluenesulfonylhydrazide (0.6 mmol, 1.2 equiv.), phenylacetylene (1.5 mmol, 3.0 equiv.), chlorobenzene (3 mL) and Cu (OTf)$_2$ (0.1 mmol) were added successively. The mixture was stirred at rt until the **2** was dissolved, then heated to reflux for an appropriate time, and monitored periodically by TLC. Upon completion, the product (**4c**) was purified by column chromatography on silica gel to afford a white solid in 62% yield (mp 145-146 $^{o}$C). **$^1$H-NMR** (400 MHz, DMSO): $\delta$ 3.78 (s, 3H), 7.02 (s, 2H), 7.06 (s, 1H), 7.32-7.43 (m, 3H), 7.71-7.82 (m, 4H), 13.23(brs, 1H); **$^{13}$C-NMR** (100 MHz, DMSO): $\delta$ 55.6, 99.2, 114.8, 125.5, 126.9, 129.2; **IR** (film): 3350, 3102, 1613, 1509, 1252 cm$^{-1}$; **ESI-MS**: calc. for $C_{16}H_{12}N_2O$ $[M+H]^+$: *m/z* = 251.1; found: 251.3.



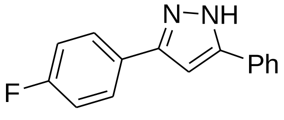
**4d**

**3-(4-Bromophenyl)-5-phenyl-1*H*-Pyrazole (4d):**[4] To a flame-dried 5-mL flask equipped with a magnetic bar, 4-bromobenzaldehyde (0.5 mmol, 1.0 equiv.), *p*-toluenesulfonylhydrazide (0.6 mmol, 1.2 equiv.), phenylacetylene (1.5 mmol, 3.0 equiv.), chlorobenzene (3 mL) and Cu (OTf)$_2$ (0.1 mmol) were added successively. The mixture was stirred at rt until the **2** was dissolved, then heated to reflux for an appropriate time, and monitored periodically by TLC. Upon completion, the product (**4d**) was purified by column chromatography on silica gel to afford a white solid in 55% yield (mp 217-219 $^{o}$C). **$^1$H-NMR** (400 MHz, DMSO): $\delta$ 7.19 (s, 1H), 7.34-7.45 (m, 3H), 7.56-7.63 (m, 2H), 7.73-7.81 (m, 4H), 13.46(brs, 1H); **$^{13}$C-NMR** (100 MHz, DMSO): $\delta$ 99.9, 125.2, 127.2, 128.4, 129.0, 129.4, 131.5, 131.7; **IR** (film): 3345, 3142, 1623, 1512 cm$^{-1}$; **ESI-MS**: calc. for $C_{15}H_{11}N_2Br$ $[M+H]^+$: *m/z* = 299.0, 301.0; found: 299.1, 301.2.



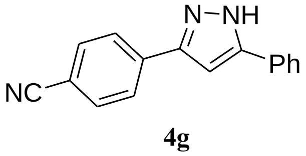
**4e**

**3-(4-Chlorophenyl)-5-phenyl- 1*H*-Pyrazole (4e):**[3,4] To a flame-dried 5-mL flask equipped with a magnetic bar, 4-chlorobenzaldehyde (0.5 mmol, 1.0 equiv.), *p*-toluenesulfonylhydrazide (0.6 mmol, 1.2 equiv.), phenylacetylene (1.5 mmol, 3.0 equiv.), chlorobenzene (3 mL) and Cu $(OTf)_2$ (0.1 mmol) were added successively. The mixture was stirred at rt until the **2** was dissolved, then heated to reflux for an appropriate time, and monitored periodically by TLC. Upon completion, the product (**4e**) was purified by column chromatography on silica gel to afford a white solid in 55% yield (mp 216-218 $^{o}$C). **$^{1}$H-NMR** (400 MHz, DMSO): *δ* 7.20 (s, 1H), 7.32-7.49 (m, 5H), 7.82-7.86 (m, 4H), 13.44(brs, 1H); **$^{13}$C-NMR** (100 MHz, DMSO): *δ* 99.9, 125.1, 126.8, 128.9; **IR** (film): 3340, 3143, 1618, 1490 cm$^{-1}$; **ESI-MS**: calc. for $C_{15}H_{11}N_2Cl$ $[M+H]^+$: *m/z* = 255.1; found: 255.2.



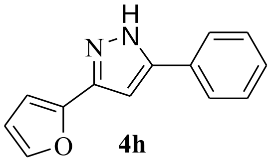
**4f**

**3-(4-Fluorophenyl)-5-phenyl- 1*H*-Pyrazole (4f):**[3,4] To a flame-dried 5-mL flask equipped with a magnetic bar, 4-fluorobenzaldehyde (0.5 mmol, 1.0 equiv.), *p*-toluenesulfonylhydrazide (0.6 mmol, 1.2 equiv.), phenylacetylene (1.5 mmol, 3.0 equiv.), chlorobenzene (3 mL) and Cu $(OTf)_2$ (0.1 mmol) were added successively. The mixture was stirred at rt until the **2** was dissolved, then heated to reflux for an appropriate time, and monitored periodically by TLC. Upon completion, the product (**4f**) was purified by column chromatography on silica gel to afford a white solid in 57% yield (mp 167-169 $^{o}$C). **$^{1}$H-NMR** (400 MHz, DMSO): *δ* 7.15 (s, 1H), 7.27-7.37 (m, 4H), 7.43-7.46 (m, 2H), 7.83-7.88 (m, 3H), 13.39(brs, 1H); **$^{13}$C-NMR** (100 MHz, DMSO): *δ* 100.0, 116.2, 125.6, 127.6, 128.0, 129.2, 131.5; **IR** (film): 3321, 3118, 1606, 1520 cm$^{-1}$; **ESI-MS**: calc. for $C_{15}H_{11}N_2F$ $[M+H]^+$: *m/z* = 239.1; found: 239.2.



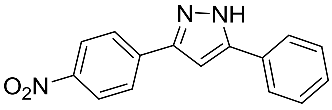
**4g**

**4-(5-Phenyl-1*H*-pyrazol-3-yl)benzonitrile (4g):**[5] To a flame-dried 5-mL flask equipped with a magnetic bar, 4-formylbenzonitrile (0.5 mmol, 1.0 equiv.), *p*-toluenesulfonylhydrazide (0.6 mmol, 1.2 equiv.), phenylacetylene (1.5 mmol, 3.0 equiv.), chlorobenzene (3 mL) and Cu $(OTf)_2$ (0.1 mmol) were added successively. The mixture was stirred at rt until the **2** was dissolved, then heated to reflux for an appropriate time, and monitored periodically by TLC. Upon completion, the product (**4g**) was purified by column chromatography on silica gel to afford a yellow oil in 32% yield. **$^1$H-NMR** (400 MHz, DMSO): *δ* 7.34 (s, 1H), 7.41-7.44 (m, 3H), 7.66-7.87 (m, 5H), 8.04 (s, 1H), 13.65 (brs, 1H); **$^{13}$C-NMR** (100 MHz, DMSO): *δ* 100.8, 110.5, 118.8, 125.3, 125.7, 127.0, 128.3, 128.5, 128.9, 129.9,132.6,146.9, 157.8; **IR** (film): 3335, 3120, 2223, 1608, 1497 cm$^{-1}$; **ESI-MS**: calc. for $C_{16}H_{11}N_3$ $[M+H]^+$: *m/z* (%) = 246.1; found: 246.3.



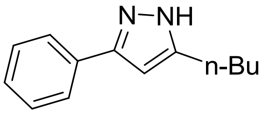
**4h**

**3-(Furan-2-yl)-5-phenyl-1*H*-pyrazole (4h):**[2] To a flame-dried 5-mL flask equipped with a magnetic bar, furan-2-carbaldehyde (0.5 mmol, 1.0 equiv.), *p*-toluenesulfonylhydrazide (0.6 mmol, 1.2 equiv), phenylacetylene (1.5 mmol, 3.0 equiv.), chlorobenzene (3 mL) and Cu $(OTf)_2$ (0.1 mmol) were added successively. The mixture was stirred at rt until the **2** was dissolved, then heated to reflux for an appropriate time, and monitored periodically by TLC. Upon completion, the product (**4h**) was purified by column chromatography on silica gel to afford a yellow solid in 30% yield (mp 172-173 °C). **$^1$H-NMR** (400 MHz, $CDCl_3$): *δ* 6.49 (dd, 1H, *J* = 3.2, 1.6 Hz), 6.67 (d, 1H, *J* = 3.2 Hz), 6.78 (d, 1H, *J* = 1.6 Hz), 7.31-7.46 (m, 4H), 7.72 (d, 2H, *J* = 7.2 Hz); **$^{13}$C-NMR** (100 MHz, $CDCl_3$): *δ* 99.4, 106.6, 111.4, 125.7, 128.4, 128.9, 129.5, 142.1, 146.7, 148.2; **IR** (film): 3371, 3054, 1609, 1596 cm$^{-1}$; **ESI-MS**: calc. for $C_{13}H_{10}N_2O$ $[M+H]^+$: *m/z* (%) = 211.1; found: 211.2.



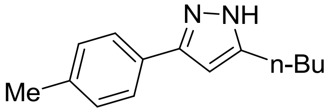
**4i**

**3-(4-nitrophenyl)-5-phenyl-1H-pyrazole (4i)**: [9] To a flame-dried 5-mL flask equipped with a magnetic bar, 4-nitrobenzaldehyde (0.5 mmol, 1.0 equiv.), *p*-toluenesulfonylhydrazide (0.6 mmol, 1.2 equiv.), phenylacetylene (1.5 mmol, 3.0 equiv.), chlorobenzene (3 mL) and Cu $(OTf)_2$ (0.1 mmol) were added successively. The mixture was stirred at rt until the **2** was dissolved, then heated to reflux for an appropriate time, and monitored periodically by TLC. Upon completion, the product (**4i**) was purified directly by column chromatography on silica gel to afford a white solid in 38% yield (mp 278-279 °C). **$^1$H-NMR** (400 MHz, DMSO): δ 7.27-7.60 (m, 4H), 7.84-8.31 (m, 6H), 13.72 (brs, 1H); **$^{13}$C-NMR** (100 MHz, DMSO): δ 101.0, 123.2, 124.1, 125.3, 125.2, 125.6, 125.8, 127.0, 128.9,,146.4, 150.7; **IR** (film): 3190, 2920,1644, 1515, 1457, 1330,1299 cm-1; **ESI-MS**: calc. for $C_{15}H_{11}N_3O_2$ [M+H]+: m/z (%) = 265.1; found: 265.2.



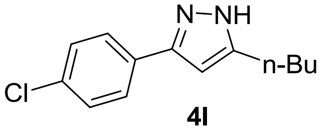
**4j**

**5-Butyl-3-phenyl-1*H*-pyrazole (4j):**[7] To a flame-dried 25-mL sealed tube equipped with a magnetic bar, benzaldehyde (0.5 mmol, 1.0 equiv.), *p*-toluenesulfonylhydrazide (0.6 mmol, 1.2 equiv.), hex-1-yne (1.5 mmol, 3.0 equiv.) , chlorobenzene (3 mL) and Cu $(OTf)_2$ (0.1 mmol) were added successively. The mixture was stirred at rt until the **2** was dissolved, then heated to reflux for an appropriate time, and monitored periodically by TLC. Upon completion, the product (**4j**) was purified by column chromatography on silica gel to afford a yellow oil in 51% yield. **$^1$H-NMR** (400 MHz, DMSO): *δ* 0.91 (t, 3H, *J* = 7.6 Hz), 1.29-1.35 (m, 2H), 1.57-1.61 (m, 2H), 2.59 (t, 2H, *J* = 7.6 Hz), 6.44 (s, 1H), 7.25 (t, 1H, *J* = 7.6 Hz), 7.37 (dd, 2H, *J* = 7.6, 7.6 Hz), 7.75 (t, 2H, *J* = 7.6 Hz) ; **$^{13}$C-NMR** (100 MHz, DMSO): *δ* 13.7, 21.8, 31.1, 100.3, 125.0, 127.3, 128.7; **IR** (film): 3421, 3101, 1620, 1514 cm$^{-1}$; **HRMS**(ESI): calc. for $C_{13}H_{16}N_2$ $[M+H]^+$: *m/z* (%) = 201.1392; found: 201.1384.



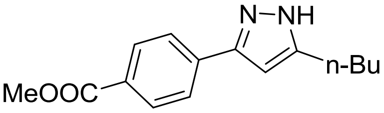
**4k**

**5-Butyl-3-p-tolyl-1*H*-pyrazole (4k):** To a flame-dried 25-mL sealed tube equipped with a magnetic bar, 4-methylbenzaldehyde (0.5 mmol, 1.0 equiv.), *p*-toluenesulfonylhydrazide (0.6 mmol, 1.2 equiv.), hex-1-yne (1.5 mmol, 3.0 equiv.) , chlorobenzene (3 mL) and Cu $(OTf)_2$ (0.1 mmol) were added successively. The mixture was stirred at rt until the **2** was dissolved, then heated to reflux for an appropriate time, and monitored periodically by TLC. Upon completion, the product (**4k**) was purified by column chromatography on silica gel to afford a yellow oil in 56% yield. **$^1$H-NMR** (400 MHz, $CDCl_3$) *δ* 0.90 (t, 3H, *J* = 7.6 Hz), 1.30-1.37 (m, 2H), 1.59-1.63 (m, 2H), 2.36 (s, 3H), 2.59 (t, 2H, *J* = 7.6 Hz), 6.32 (s, 1H), 7.16 (d, 2H, *J* = 8.0 Hz), 7.62 (d, 2H, *J* = 8.0 Hz); **$^{13}$C-NMR** (100 MHz, $CDCl_3$): *δ* 13.7, 21.2, 22.3, 26.1, 31.3, 100.6, 125.6, 129.2, 137.4; **IR** (film): 3420, 3092, 1598, 1517 cm$^{-1}$; **HRMS**(ESI): calc. for $C_{14}H_{18}N_2$ [M+H]$^+$: *m/z* (%) = 215.1548; found: 215.1541.



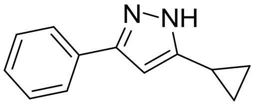
**4l**

**5-Butyl-3-(4-chlorophenyl)-1*H*-pyrazole (4l):**[6] To a flame-dried 25-mL sealed tube equipped with a magnetic bar, 4-chlorobenzaldehyde (0.5 mmol, 1.0 equiv.), *p*-toluenesulfonylhydrazide (0.6 mmol, 1.2 equiv.), hex-1-yne (1.5 mmol, 3.0 equiv.) , chlorobenzene (3 mL) and Cu $(OTf)_2$ (0.1 mmol) were added successively. The mixture was stirred at rt until the **2** was dissolved, then heated to reflux for an appropriate time, and monitored periodically by TLC. Upon completion, the product (**4l**) was purified by column chromatography on silica gel to afford a colorless crystal in 42% yield (mp 65-66 °C); **$^1$H-NMR** (400 MHz, DMSO): $\delta$ 0.90 (t, 3H, *J* = 7.2 Hz), 1.29-1.34 (m, 2H), 1.56-1.62 (m, 2H), 2.59 (t, 2H, *J* = 7.2 Hz), 6.46 (s, 1H), 7.41 (d, 2H, *J* = 8.4 Hz), 7.37 (d, 2H, *J* = 8.4 Hz), 12.66 (brs, 1H) ; **$^{13}$C-NMR** (100 MHz, DMSO): $\delta$ 13.7, 21.8, 31.1, 100.3, 126.7, 128.7; **IR** (film): 3417, 3116, 1643, 1510 cm$^{-1}$; **ESI-MS**: calc. for $C_{13}H_{15}N_2Cl$ [M+H]$^+$: *m/z* (%) = 235.1; found: 235.1.



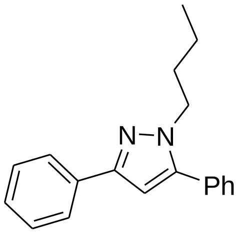
**4m**

**Methyl 4-(5-butyl-1*H*-pyrazol-3-yl)benzoate (4m):** To a flame-dried 25-mL sealed tube equipped with a magnetic bar, methyl 4-formylbenzoate (0.5 mmol, 1.0 equiv.), *p*-toluenesulfonylhydrazide (0.6 mmol, 1.2 equiv.), hex-1-yne (1.5 mmol, 3.0 equiv.) , chlorobenzene (3 mL) and Cu $(OTf)_2$ (0.1 mmol) were added successively. The mixture was stirred at rt until the **2** was dissolved, then heated to reflux for an appropriate time, and monitored periodically by TLC. Upon completion, the product (**4m**) was purified by column chromatography on silica gel to afford a white solid in 35% yield (mp 87-89 °C). **$^1$H-NMR** (400 MHz, $CDCl_3$): $\delta$ 0.87 (t, 3H, *J* = 7.6 Hz), 1.28-1.33 (m, 2H), 1.55-1.63 (m, 2H), 2.59 (t, 2H, *J* = 7.6 Hz), 3.91 (s, 3H), 6.39 (s, 1H), 7.78 (d, 2H, *J* = 8.4 Hz), 8.00 (d, 2H, *J* = 8.4 Hz); **$^{13}$C-NMR** (100MHz, $CDCl_3$): $\delta$ 13.7, 22.2, 25.8, 31.2, 52.0, 101.5, 125.4, 129.0, 130.0, 137.3, 147.4, 149.5, 166.9; **IR** (film): 3322, 3002, 1772, 1604, 1095 cm$^{-1}$; **HRMS**(ESI): calc. for $C_{15}H_{18}N_2O_2$ [M+H]$^+$: *m/z* (%) = 259.1447; found: 259.1442.



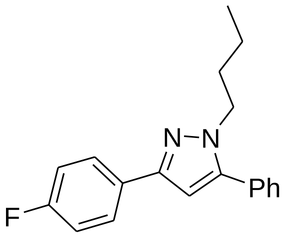
**4n**

**5-Cyclopropyl-3-phenyl-1*H*-pyrazole (4n)**:[8] To a flame-dried 25-mL sealed tube equipped with a magnetic bar, benzaldehyde (0.5 mmol, 1.0 equiv.), *p*-toluenesulfonylhydrazide (0.6 mmol, 1.2 equiv.), ethynylcyclopropane (1.5 mmol, 3.0 equiv.), chlorobenzene (3 mL) and Cu (OTf)$_2$ (0.1 mmol) were added successively. The mixture was stirred at rt until the **2** was dissolved, then heated to reflux for an appropriate time, and monitored periodically by TLC. Upon completion, the product (**4n**) was purified by column chromatography on silica gel to afford a white solid in 45% yield (mp 96-98 °C). **$^1$H-NMR** (400 MHz, CDCl$_3$): $\delta$ 0.72-0.73 (m, 2H), 0.83-0.88 (m, 2H), 1.80-1.87 (m, 1H), 6.16 (s, 1H), 7.23-7.26 (m, 1H), 7.29-7.32 (m, 2H), 7.65-7.67 (m, 2H); **$^{13}$C-NMR** (100 MHz, CDCl$_3$): $\delta$ 7.5, 7.8, 98.6, 125.7, 127.7, 128.6, 132.2, 149.1, 150.8; **IR** (film): 3404, 3130, 1600, 1503 cm$^{-1}$; **ESI-MS**: calc. for $C_{12}H_{12}N_2$ [M+H]$^+$: *m/z* (%) = 185.1; found: 185.2.



**4a´**

**1-butyl-3,5-diphenyl-1*H*-pyrazole (4a´)**: To a flame-dried flask (10 mL) equipped with a magnetic stirring bar, the pyraozle **4a** (1.0 mmol, 1.0 equiv.), KOH (2.0 mmol, 2.0 equiv.), and DMF (5 mL) were successively added. The mixture was stirred at rt for 1 hour. Subsequently, *n*-BuBr (1-bromobutane) (1.2 mmol, 1.0 equiv) was added dropwise. The mixture was stirred at rt for another hour, and monitored periodically by the TLC. Upon completion of the reaction, the solvent was removed under reduced pressure, and the residue was purified by column chromatography on silica gel to afford **4a'** as a yellow oil in nearly quantitative yield. **$^1$H-NMR** (400 MHz, CDCl$_3$): $\delta$ 0.88 (t, 3H, *J*=7.6 Hz), 1.24-1.32 (m, 2H), 1.83-1.90 (m, 2H), 4.16-4.20 (m, 2H), 6.60 (s, 1H), 7.31-7.34 (m, 1H), 7.41-7.51 (m,7H), 7.88 (d, 2H, $J$=7.6 Hz); **$^{13}$C-NMR** (100 MHz, $CDCl_3$): $\delta$ 13.6, 19.8, 32.6, 49.4, 103.2, 125.5, 127.4, 128.4, 128.5, 128.6, 128.9, 131.0, 133.6, 144.8, 150.4; **IR** (film): 3178, 1610, 1514 $cm^{-1}$; **HRMS**(ESI): calc. for $C_{19}H_{20}N_2$ $[M+H]^+$: $m/z$ (%) = 277.1705; found: 277.1704.



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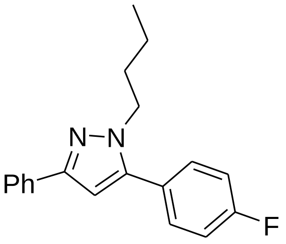

**4f´**

**4f´´**

**1-butyl-3-(4-fluorophenyl)-5-phenyl-1H-pyrazole(4f′) and 1-butyl-5-(4-fluoropheyl)-3-Phenyl-1H-pyrazole(4f″ )**: To a flame-dried flask (10 mL) equipped with a magnetic stirring bar, the pyraozle **4f** (1.0 mmol, 1.0 equiv.), KOH (2.0 mmol, 2.0 equiv.), and DMF (5 mL) were successively added. The mixture was stirred at rt for 1 hour. Subsequently, *n*-BuBr (1-bromobutane) (1.2 mmol, 1.0 equiv.) was added dropwise. The mixture was stirred at rt for another hour, and monitored periodically by the TLC. Upon completion of the reaction, the solvent was removed under reduced pressure, and the residue was purified by column chromatography on silica gel to afford **4f'** and **4f''** (a mixture of isomers, and the isomers ratio is 3:5) as a yellow oil in nearly quantitative yield. **$^1$H-NMR** (400 MHz, $CDCl_3$): $\delta$ 0.86 (t, 4.96H, $J$ =7.2 Hz), 1.25-1.31 (m, 3.26H), 1.83-1.84 (m, 3.61H), 4.10-4.16 (m, 3.42H), 6.52 (s, 1H), 6.55 (s, 0.65H), 7.08-7.12 (m, 2.31H), 7.15-7.19 (m, 1.5H), 7.31-7.48 (m, 8.32H), 7.80-7.86 (m, 3.24H); **$^{13}$C-NMR** (100 MHz, $CDCl_3$): $\delta$ 13.6, 19.8, 32.7, 49.4, 49.5, 103.1, 103.3, 115.5 ($^2J_{CF}$ = 22 Hz), 115.8 ($^2J_{CF}$ = 22 Hz), 125.6, 127.2 ($^3J_{CF}$ = 8Hz), 127.6, 128.5, 128.6, 128.7, 128.9, 129.7, 129.9, 130.8 ($^3J_{CF}$ = 8Hz), 131.0, 133.6, 143.8, 145.0, 149.6, 150.5, 162.5($^1J_{CF}$ = 244 Hz), 162.8($^1J_{CF}$ = 244 Hz); **IR** (film): 3180, 1608, 1509, 1329 $cm^{-1}$; **HRMS**(ESI): calc. for $C_{19}H_{19}FN_2$ $[M+H]^+$: $m/z$ (%) = 295.1611; found: 295.1604.

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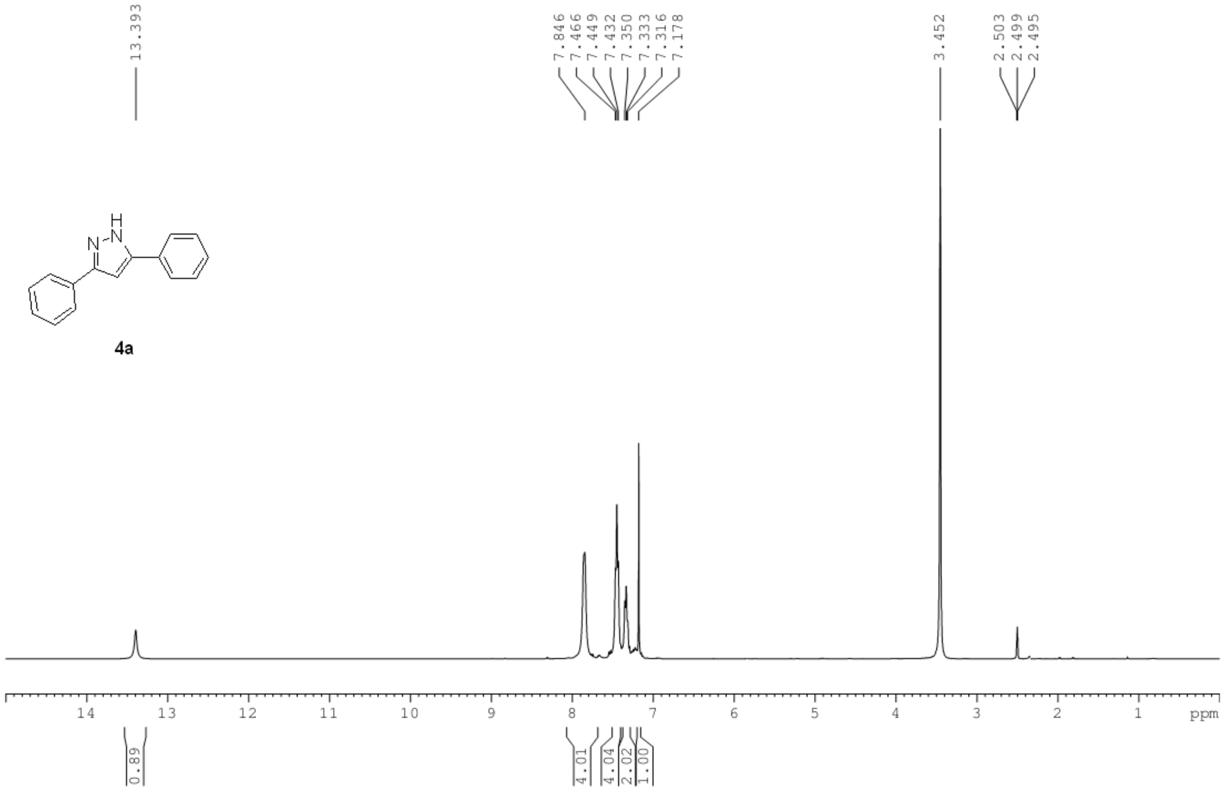
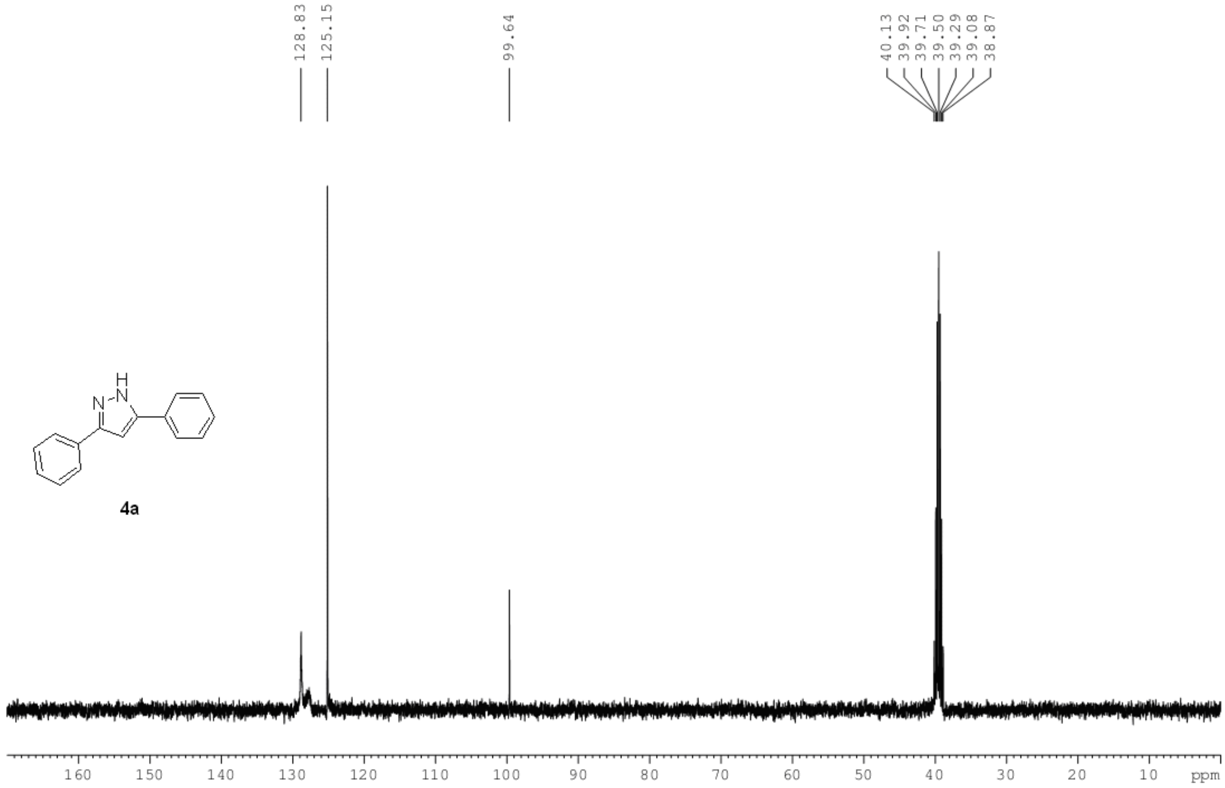
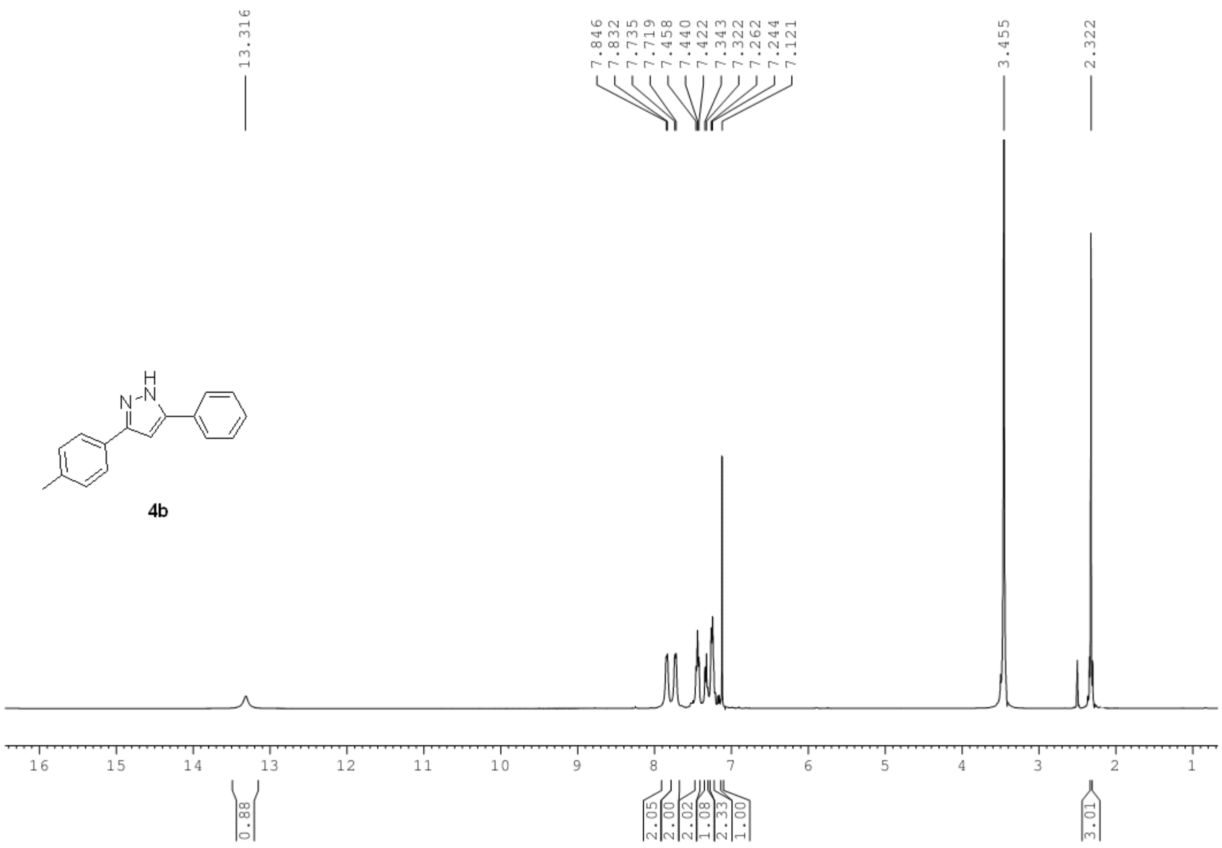
# IV. $^1$H, $^{13}$C-NMR Spectra



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N
4b
16
15
14
13
12
11
10
9
8
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3
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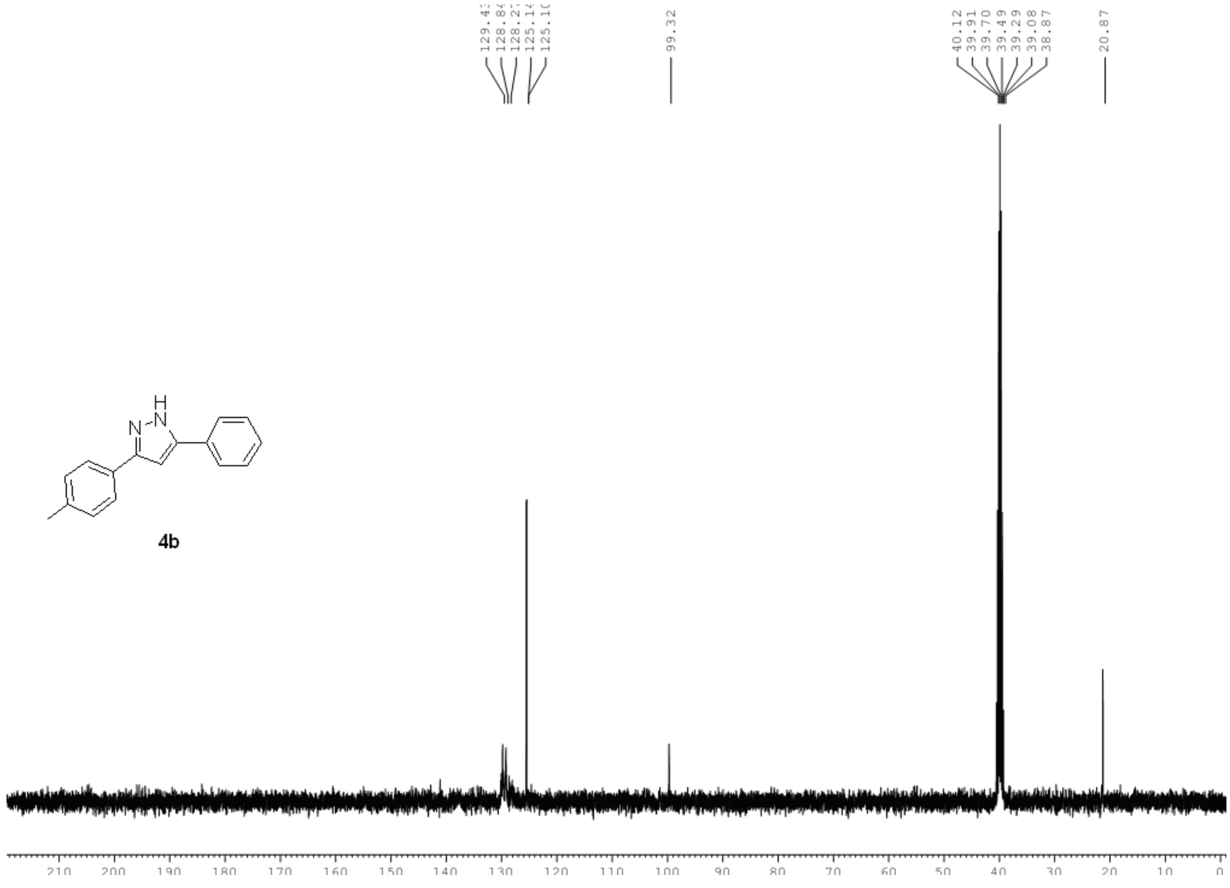
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N
N
4b
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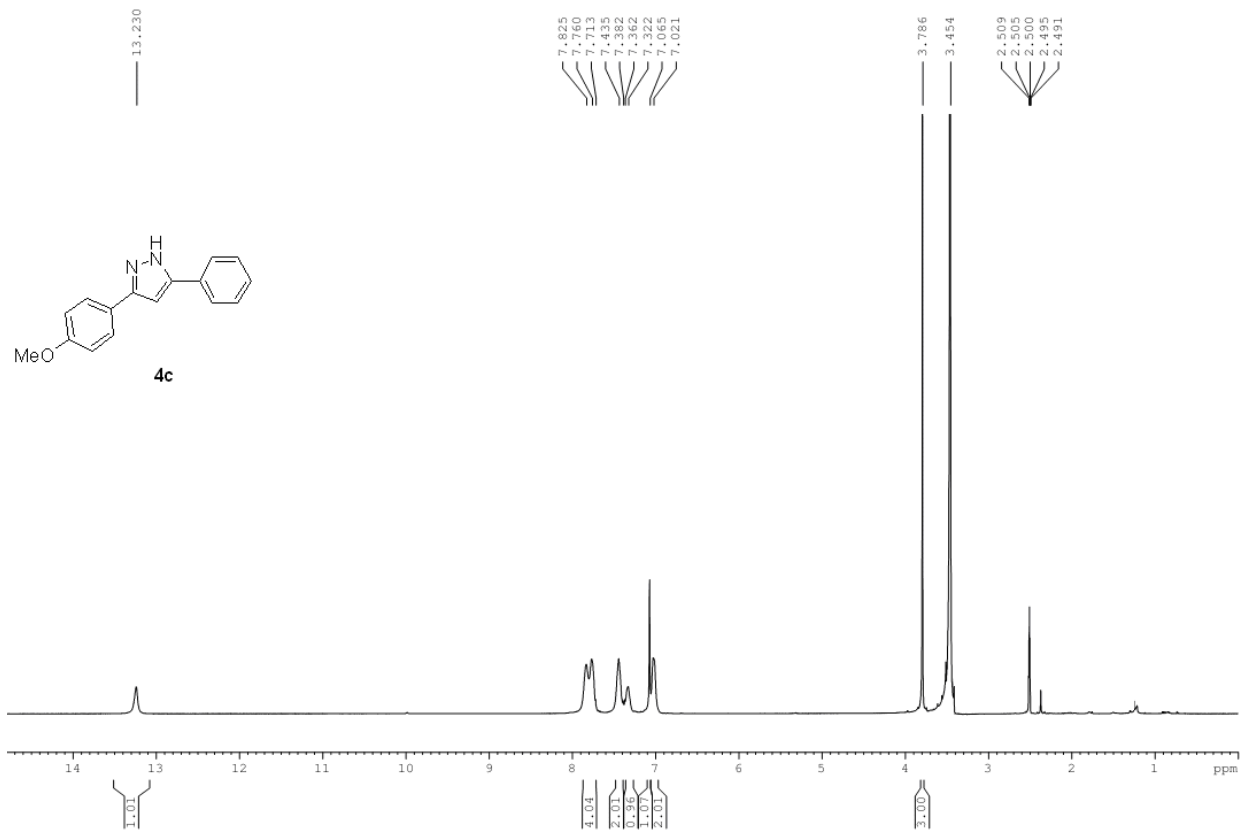
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2.491
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N
H
4c
14
13
12
11
10
9
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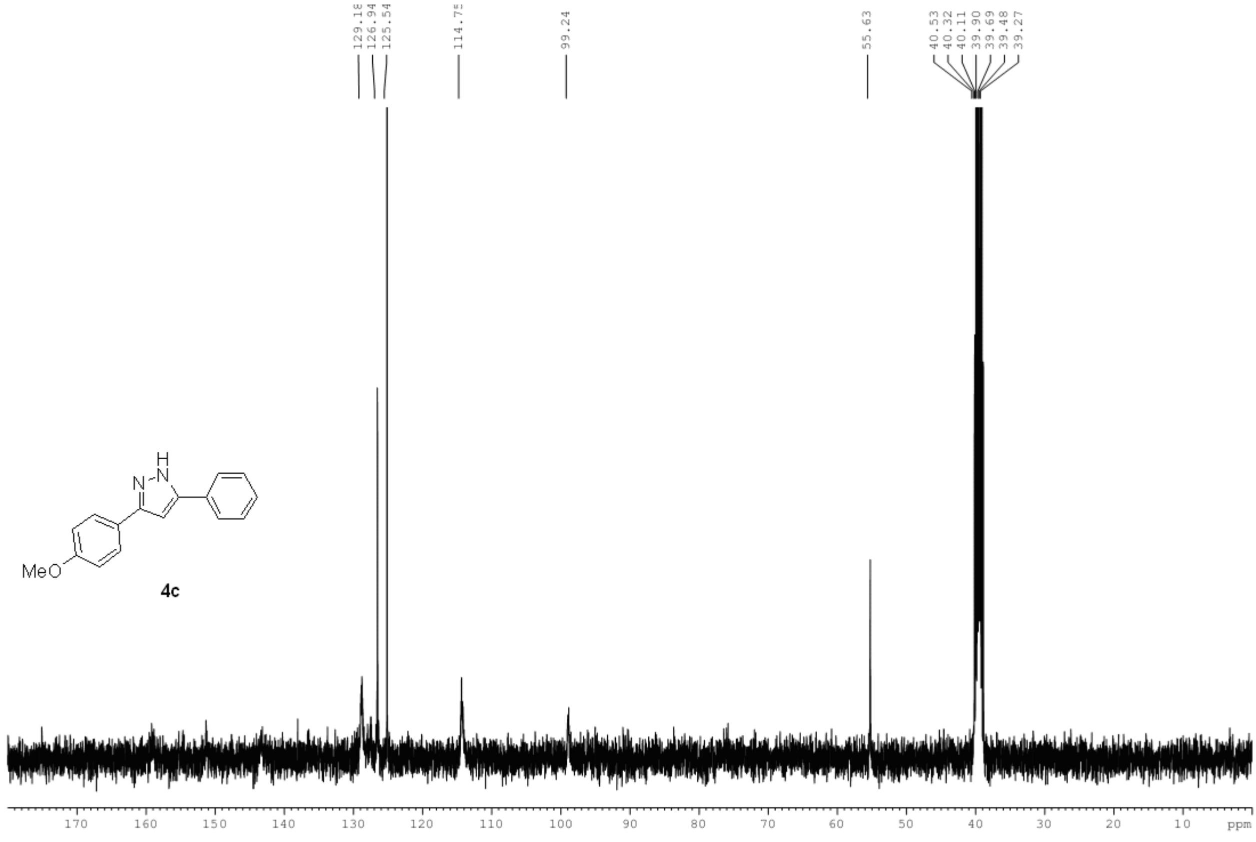
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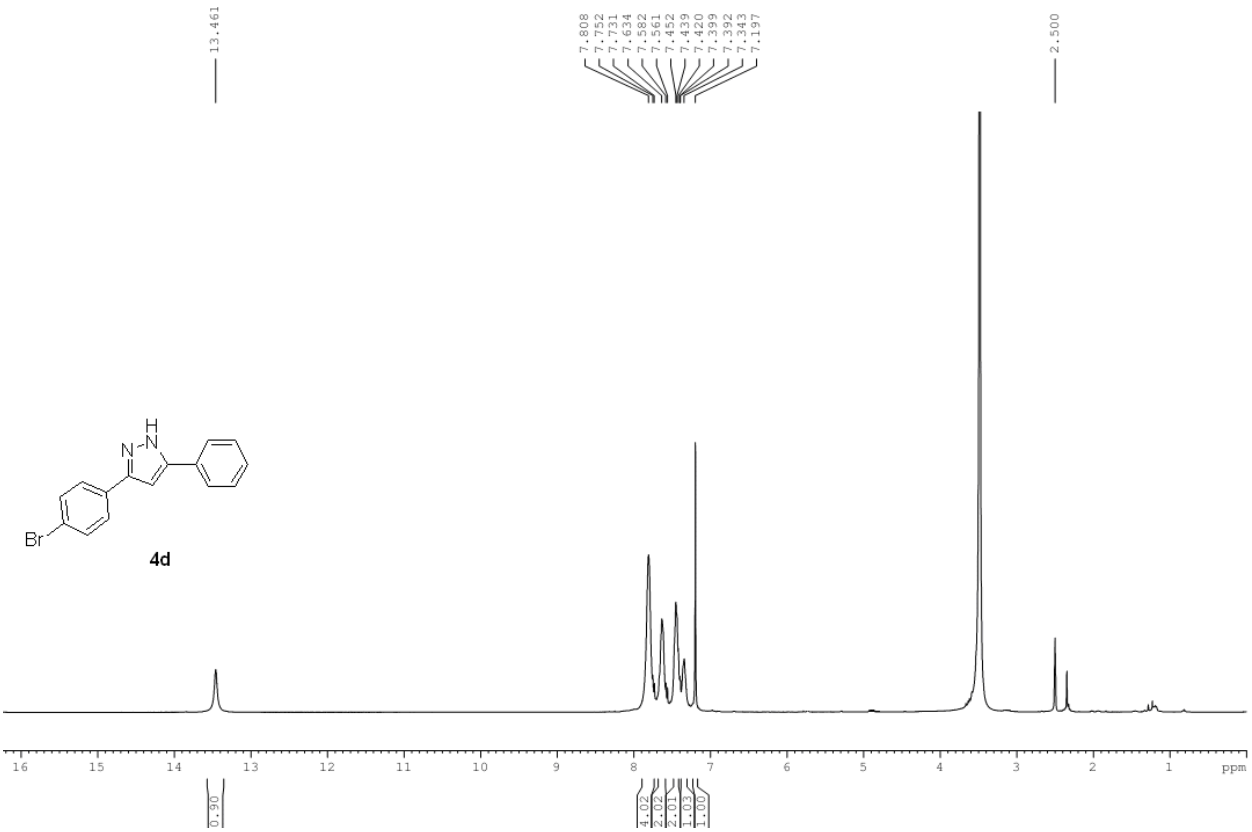
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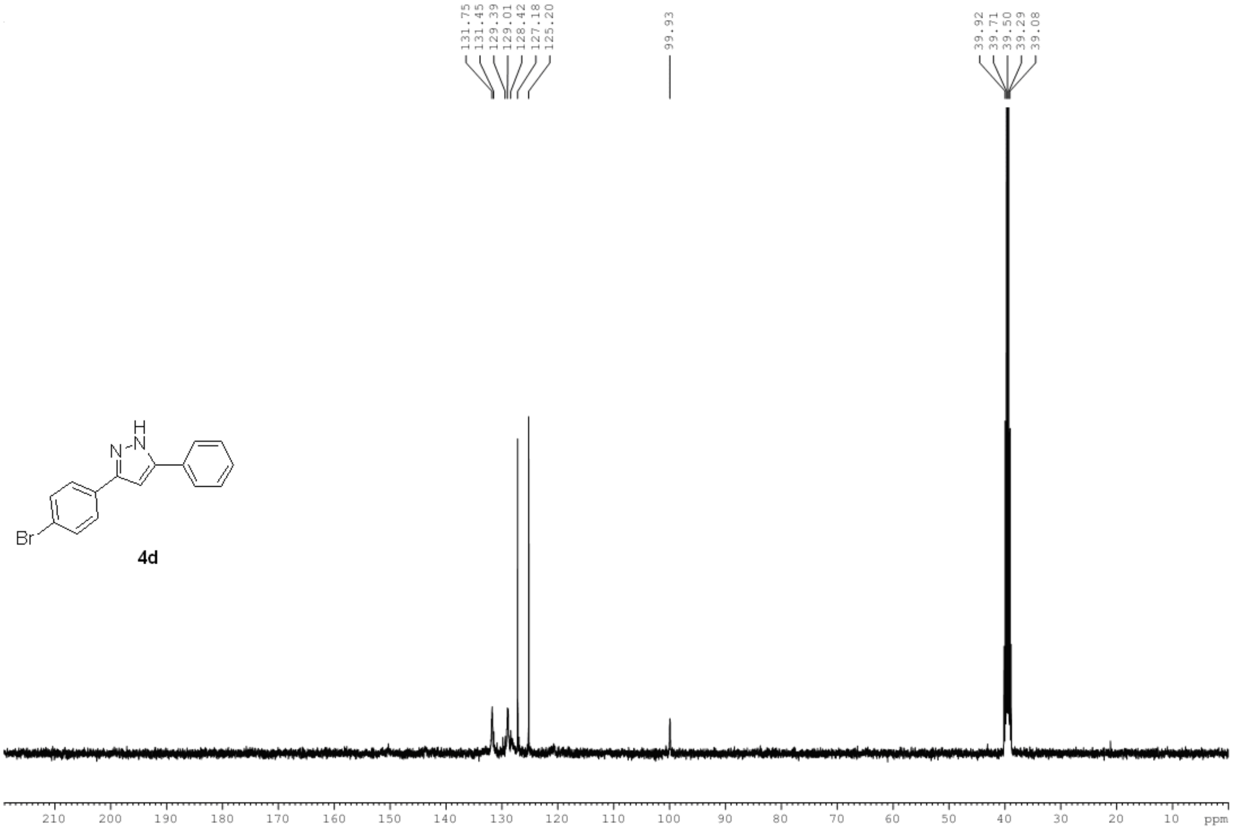
4d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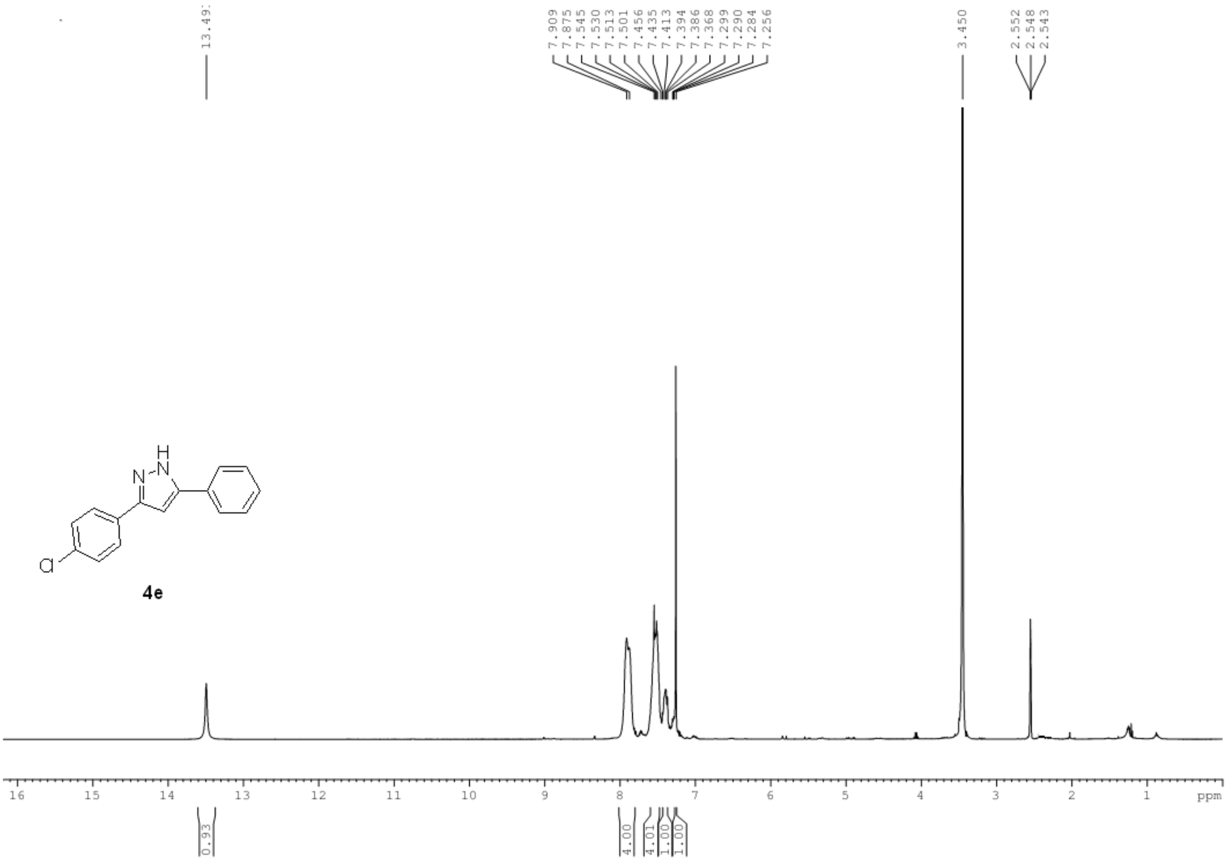
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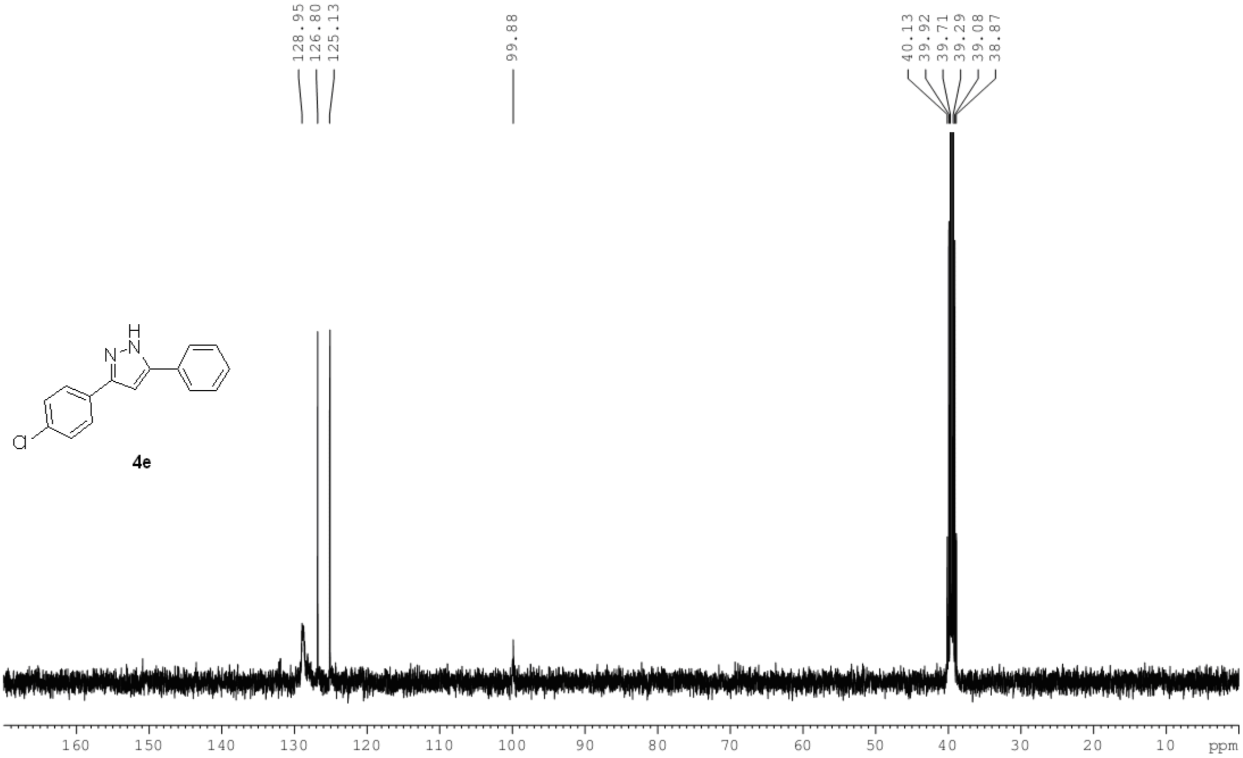
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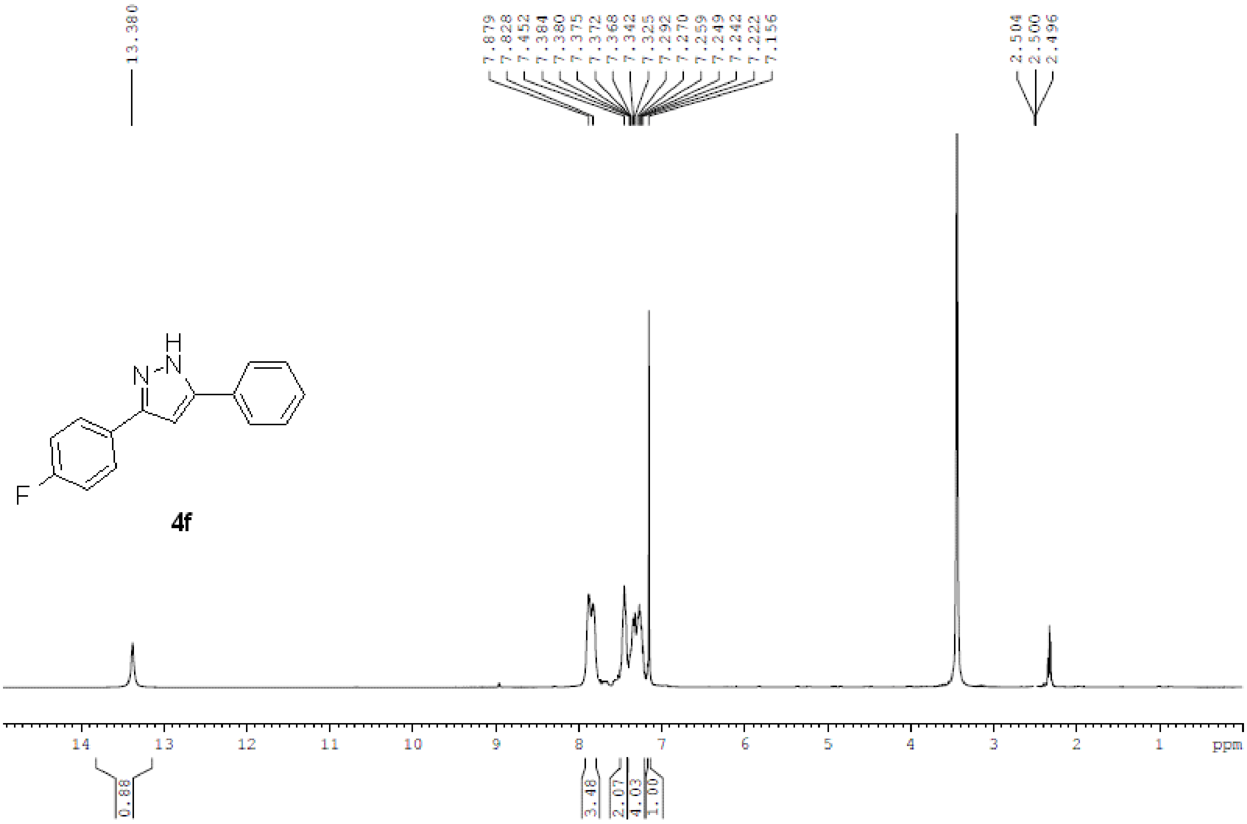
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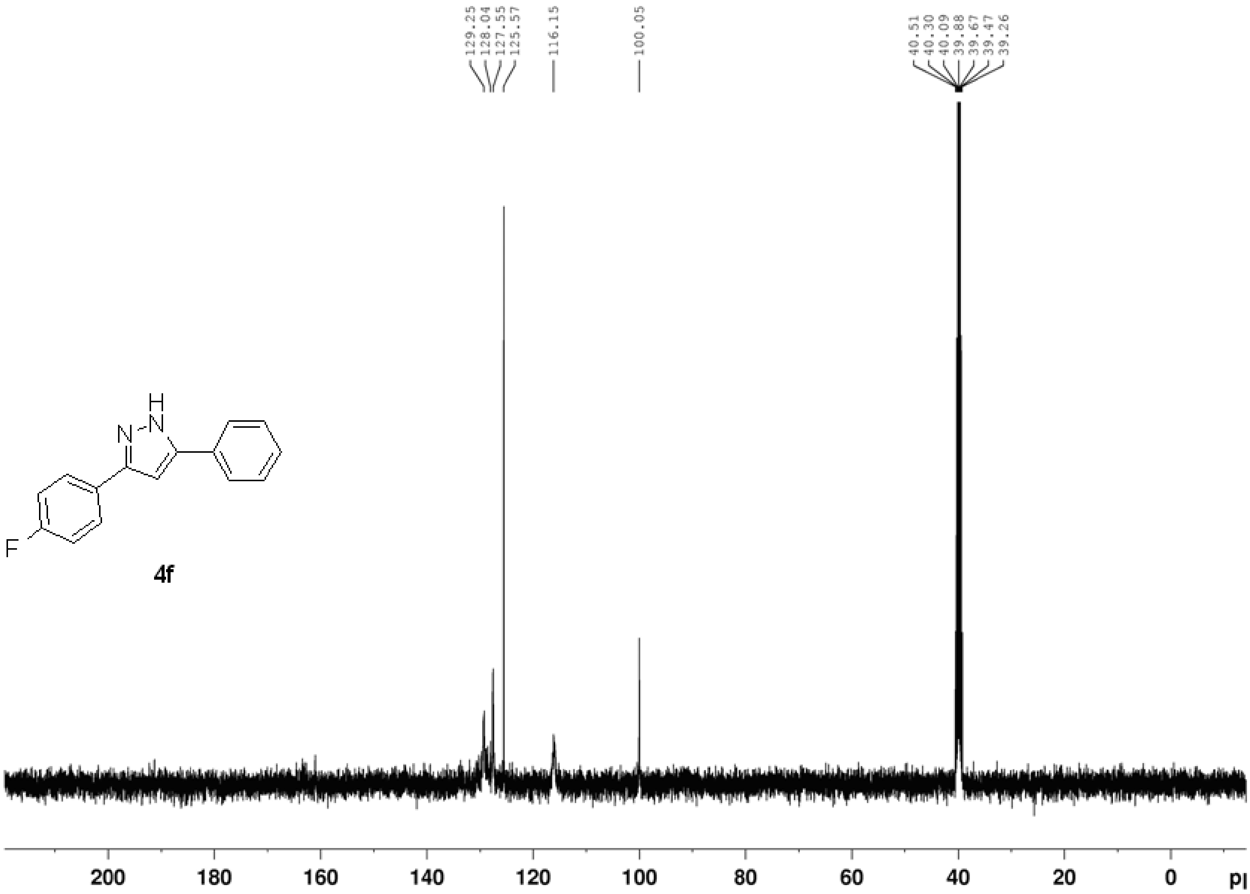
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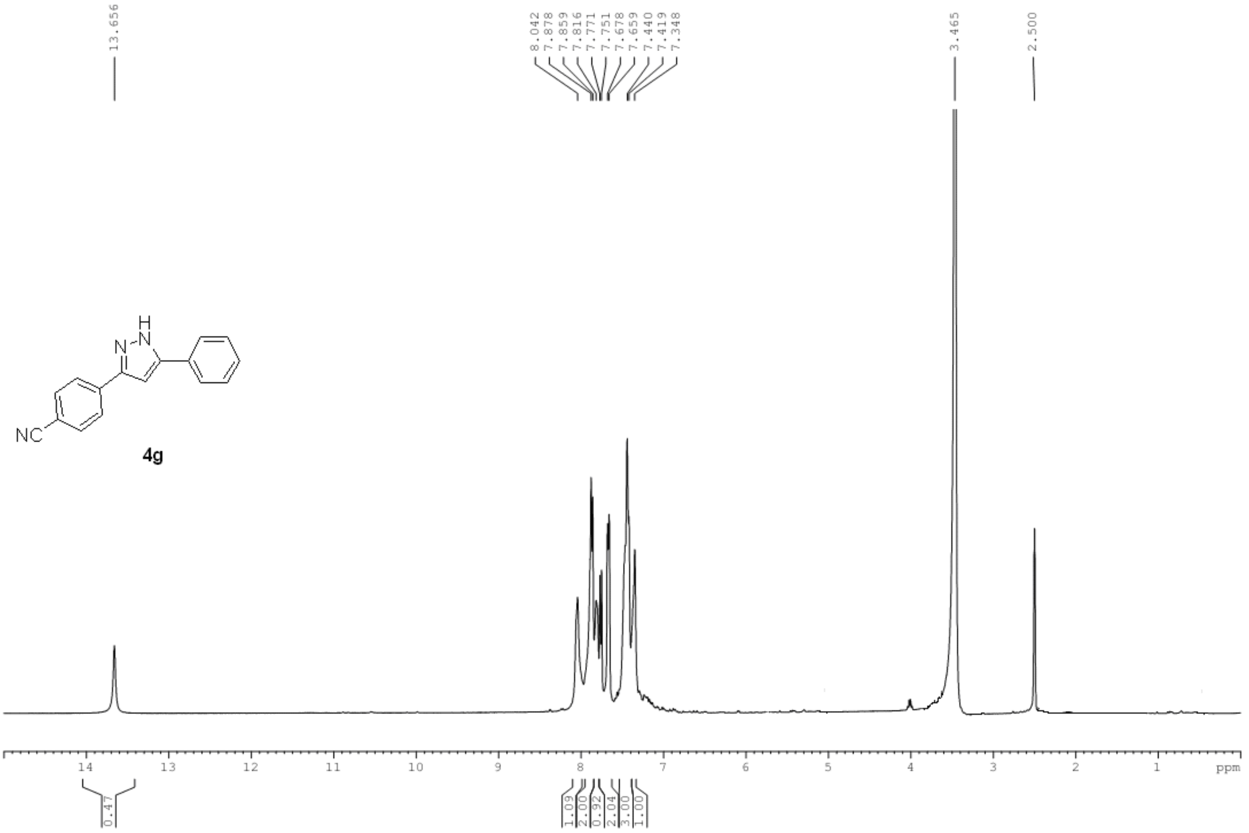
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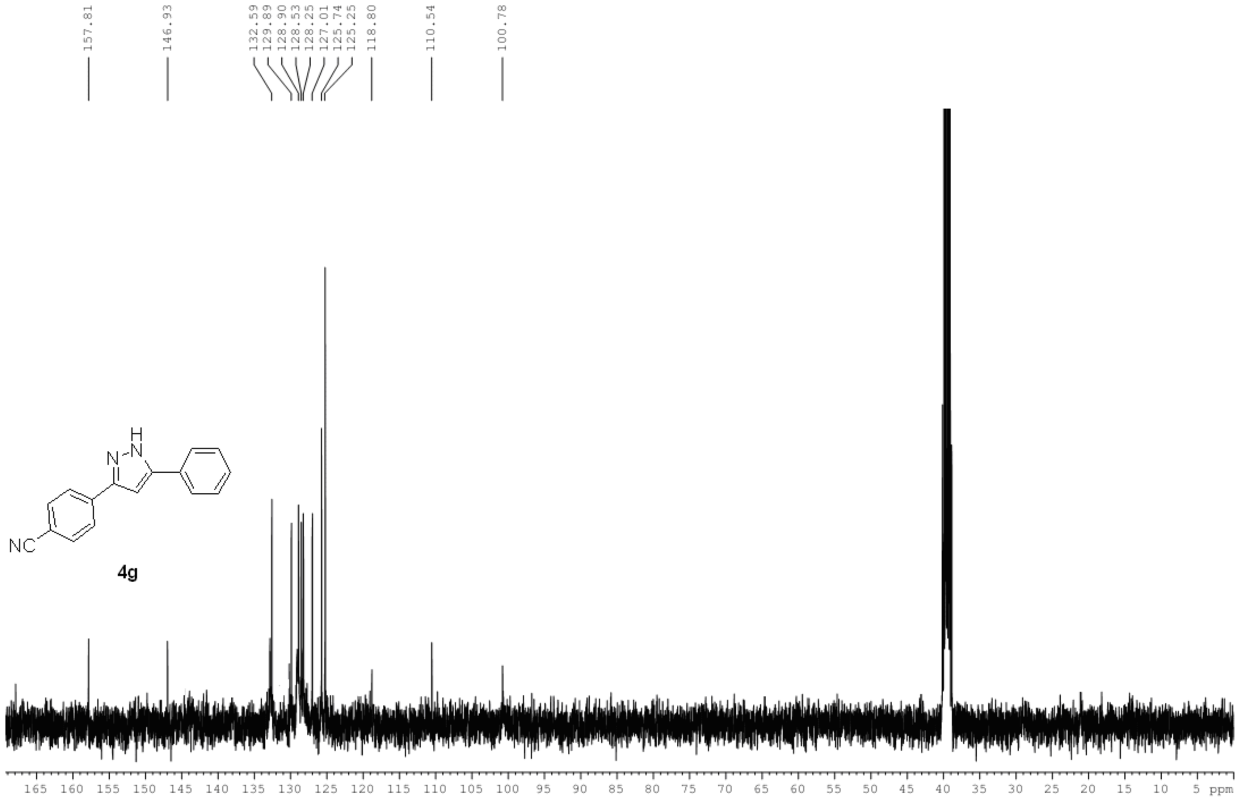
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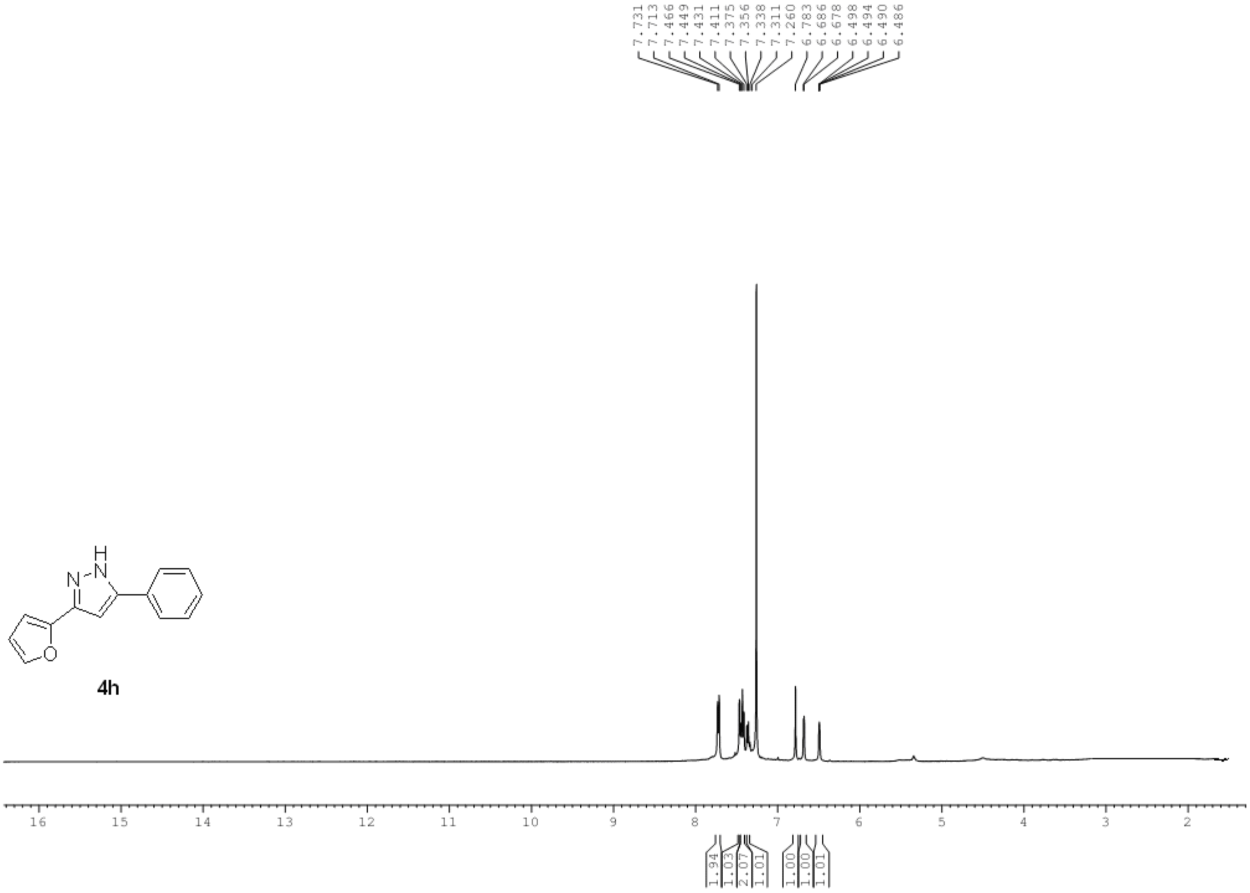
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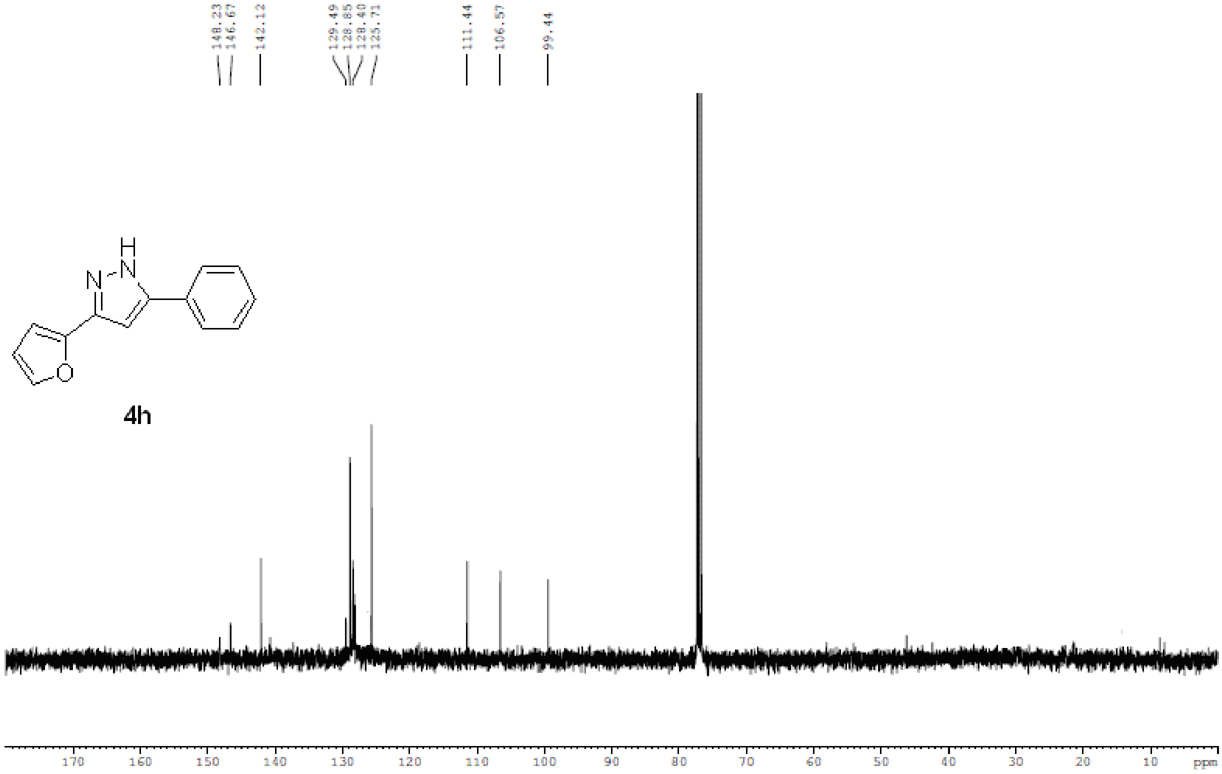
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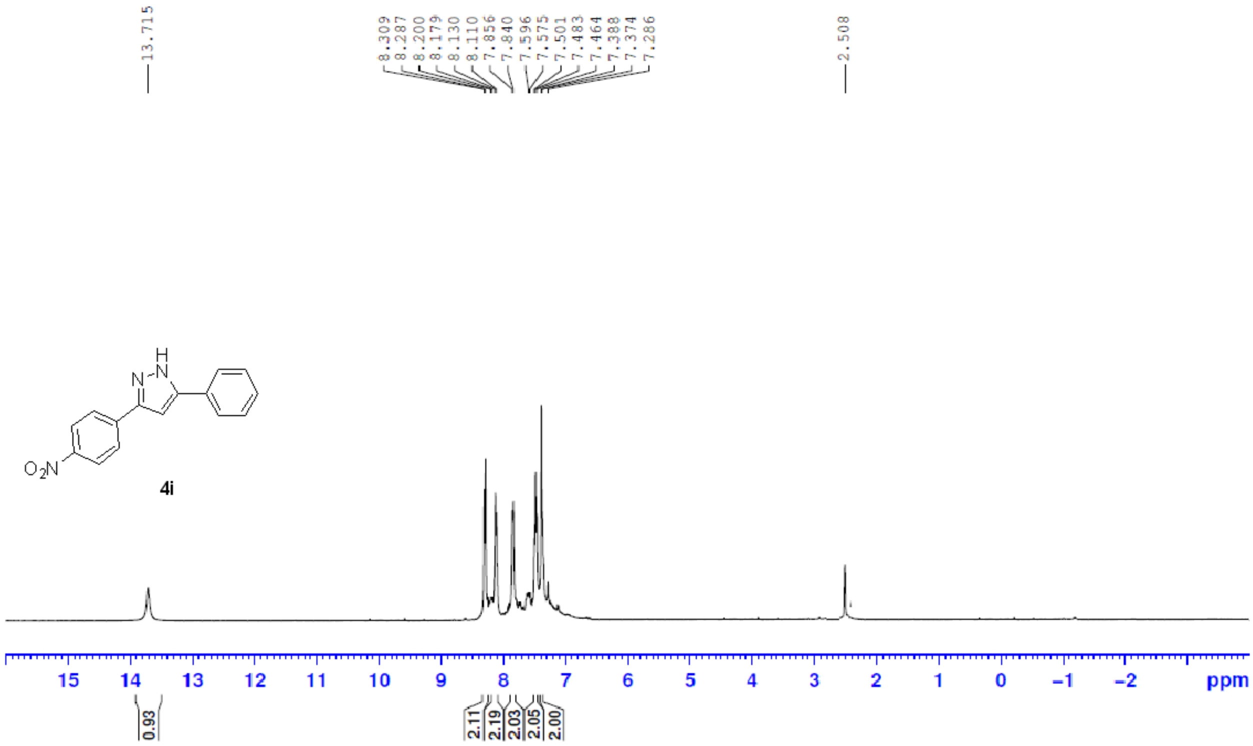
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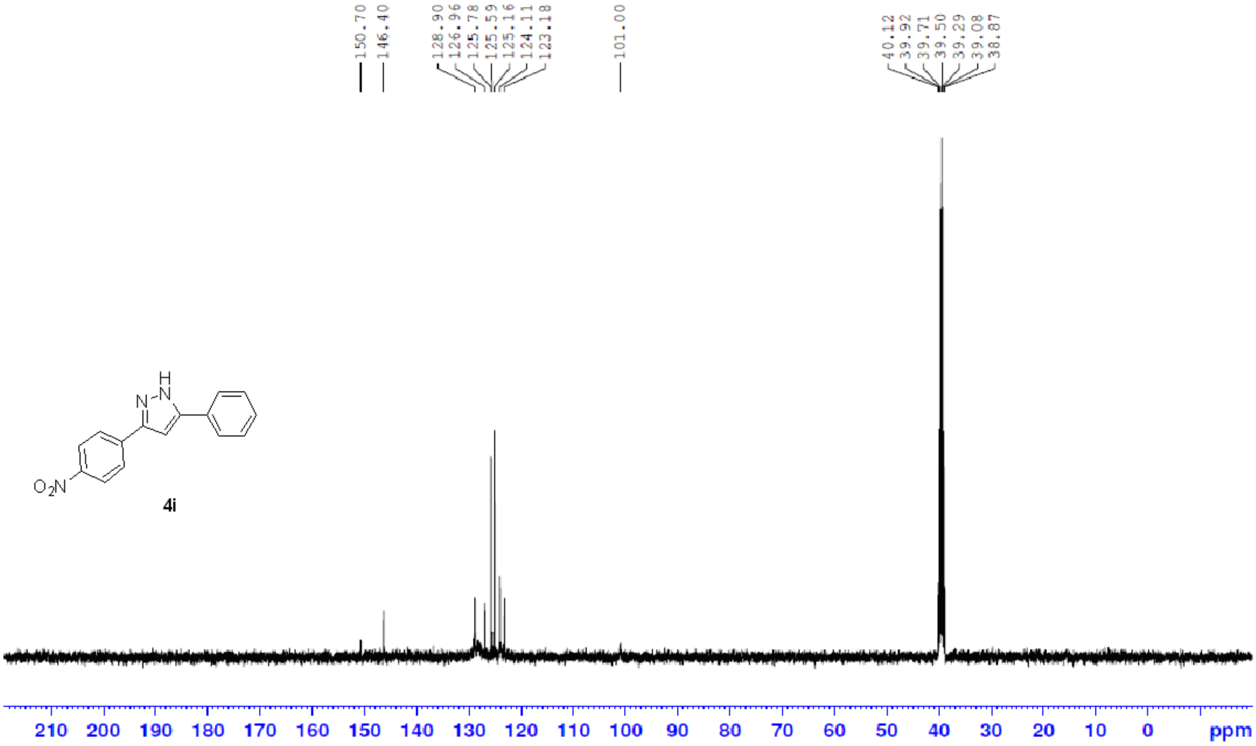
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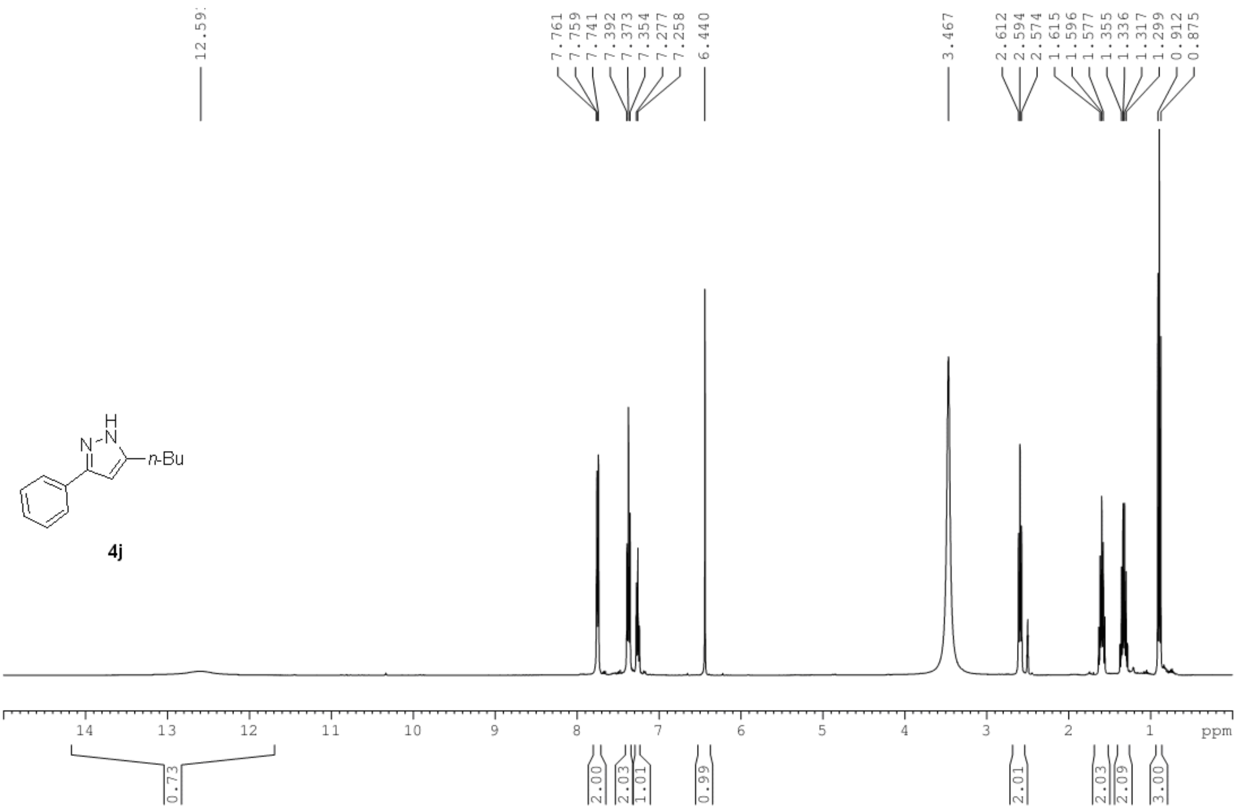
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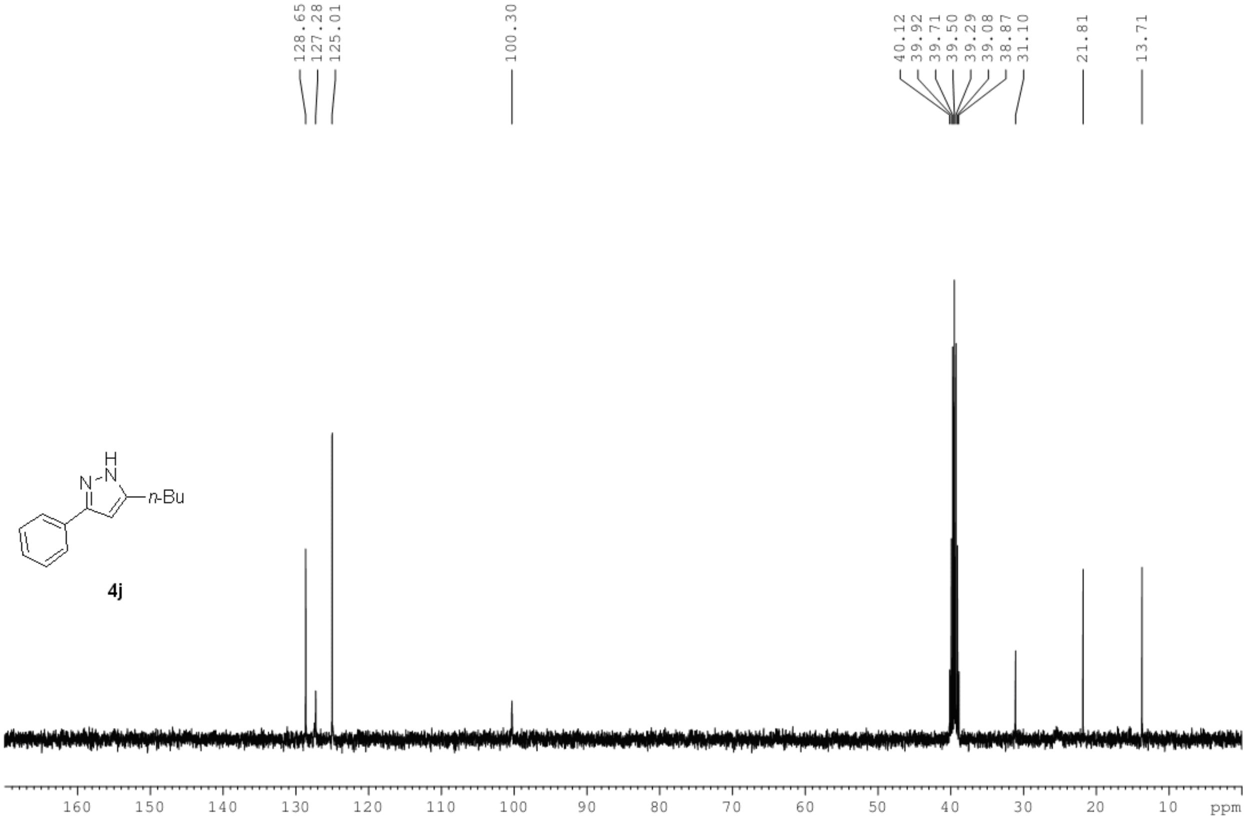
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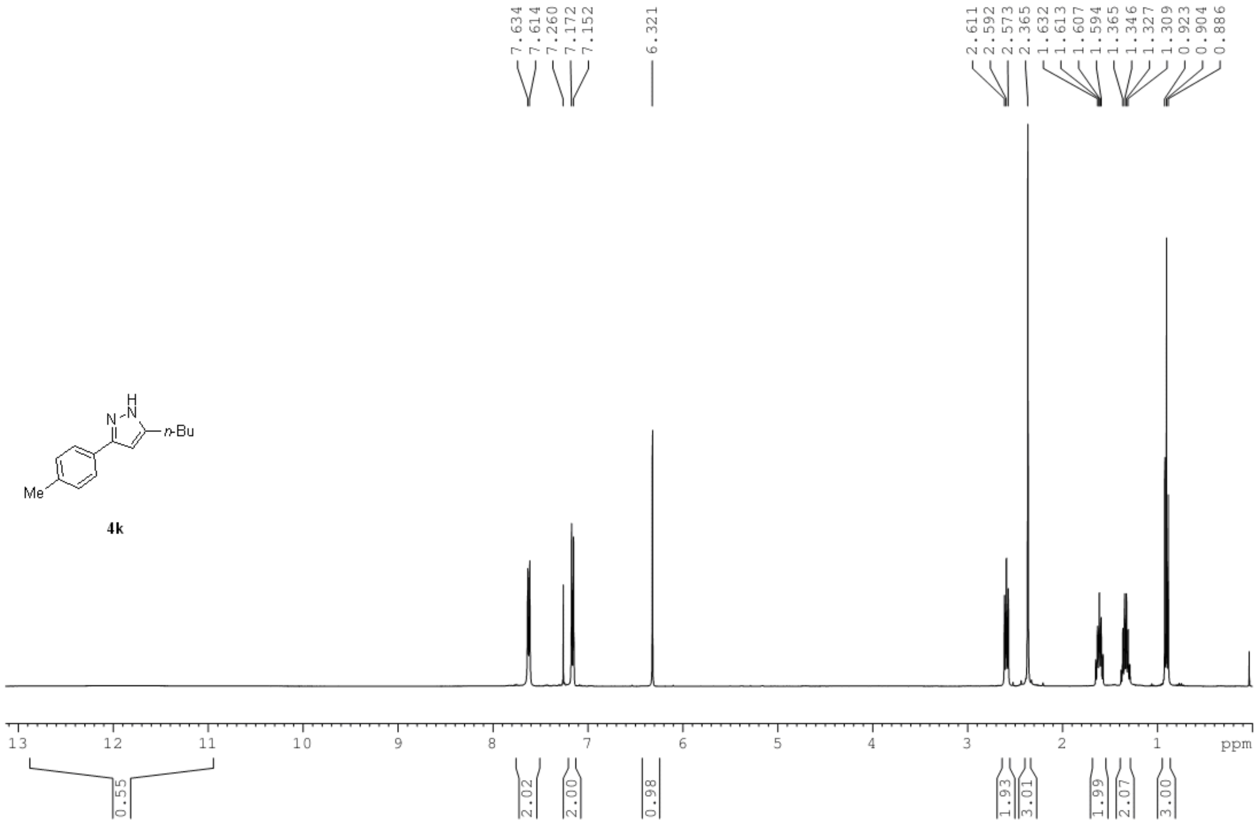
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1.365
1.346
1.327
1.309
0.923
0.904
0.886
N
N
H
n-Bu
Me
4k
13
12
11
10
9
8
7
6
5
4
3
2
1
ppm
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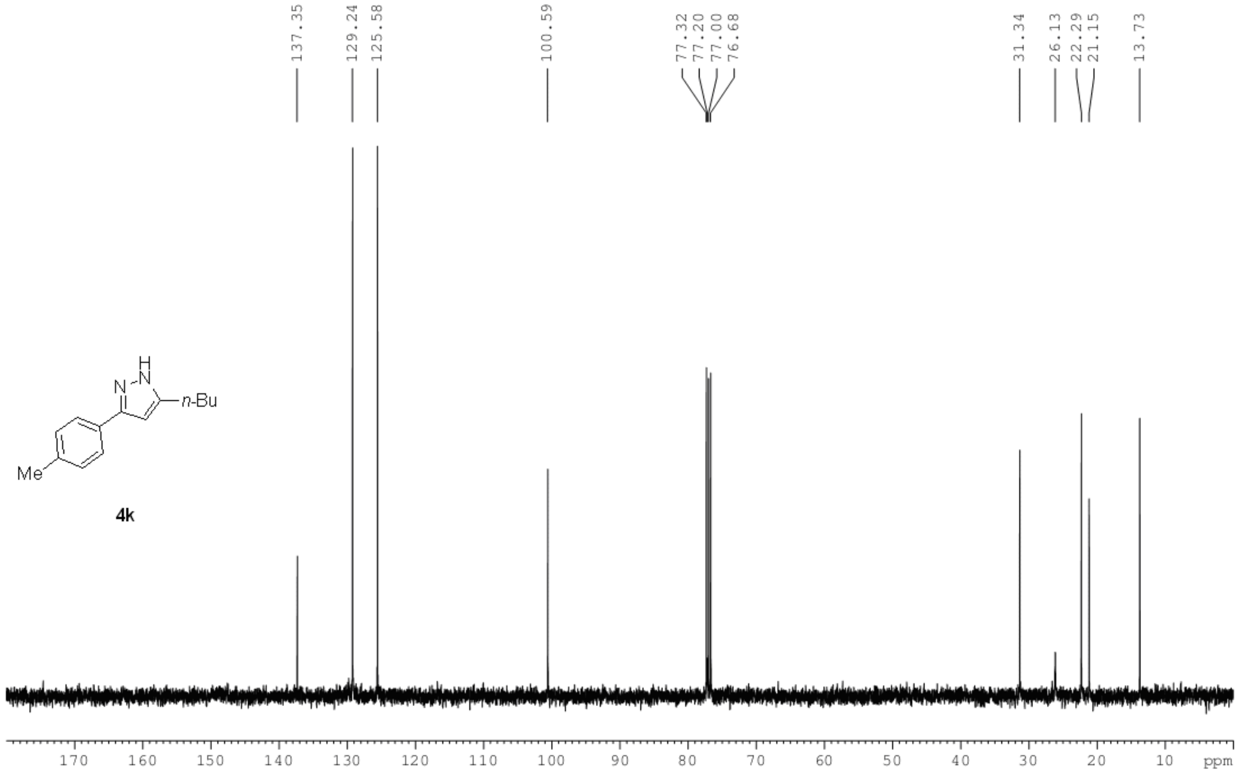
2.00
0.98
1.93
3.01
1.99
2.07
3.00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129.24
125.58
100.59
77.32
77.20
77.00
76.68
31.34
26.13
22.29
21.15
13.73
N
N
H
n-Bu
Me
4k
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160
150
140
130
120
110
100
90
80
70
60
50
40
30
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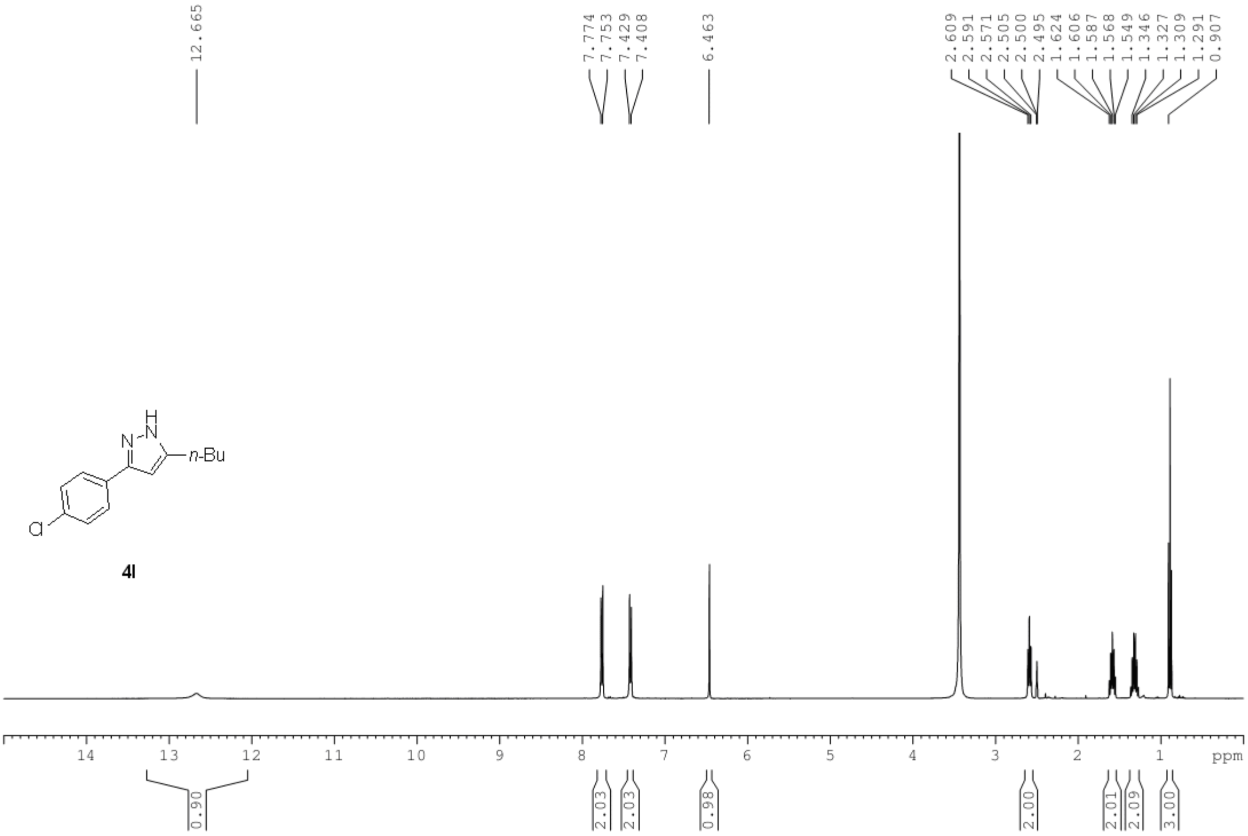
10
ppm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7.774
7.753
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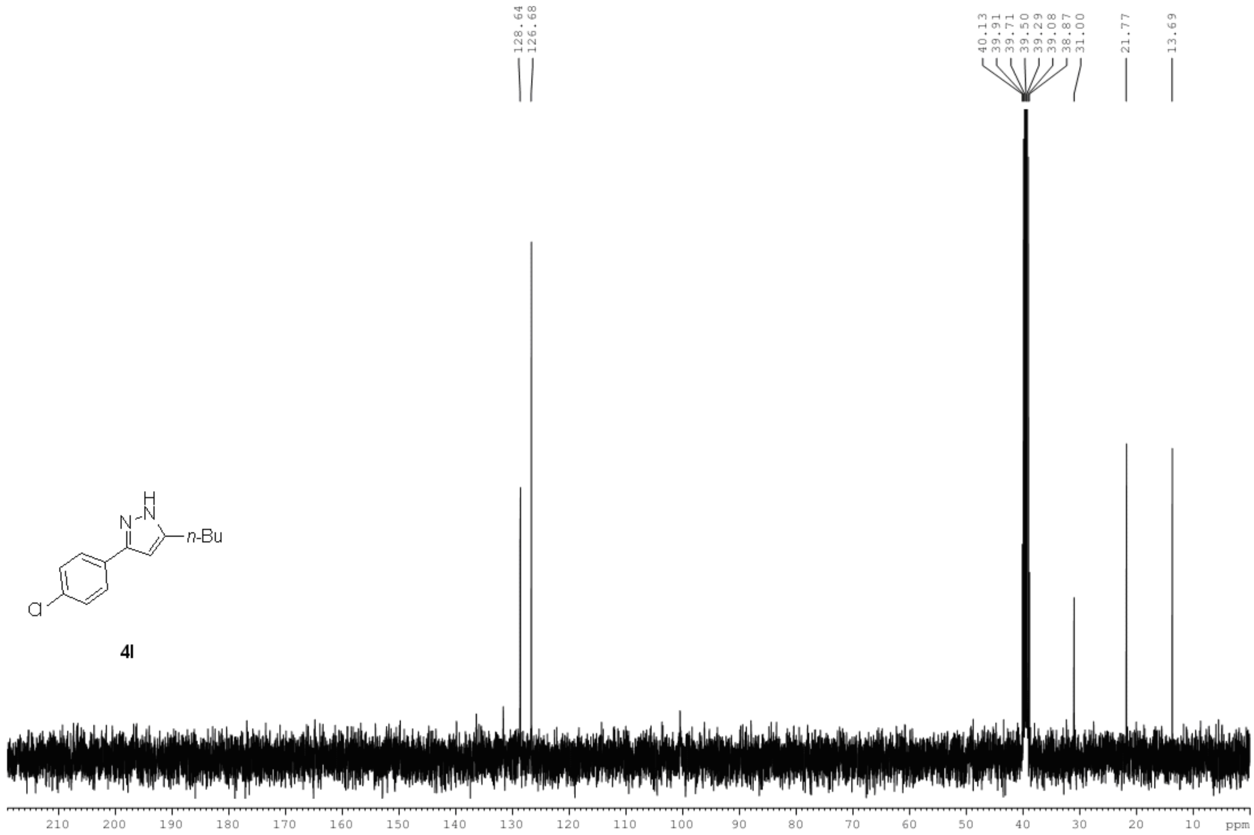
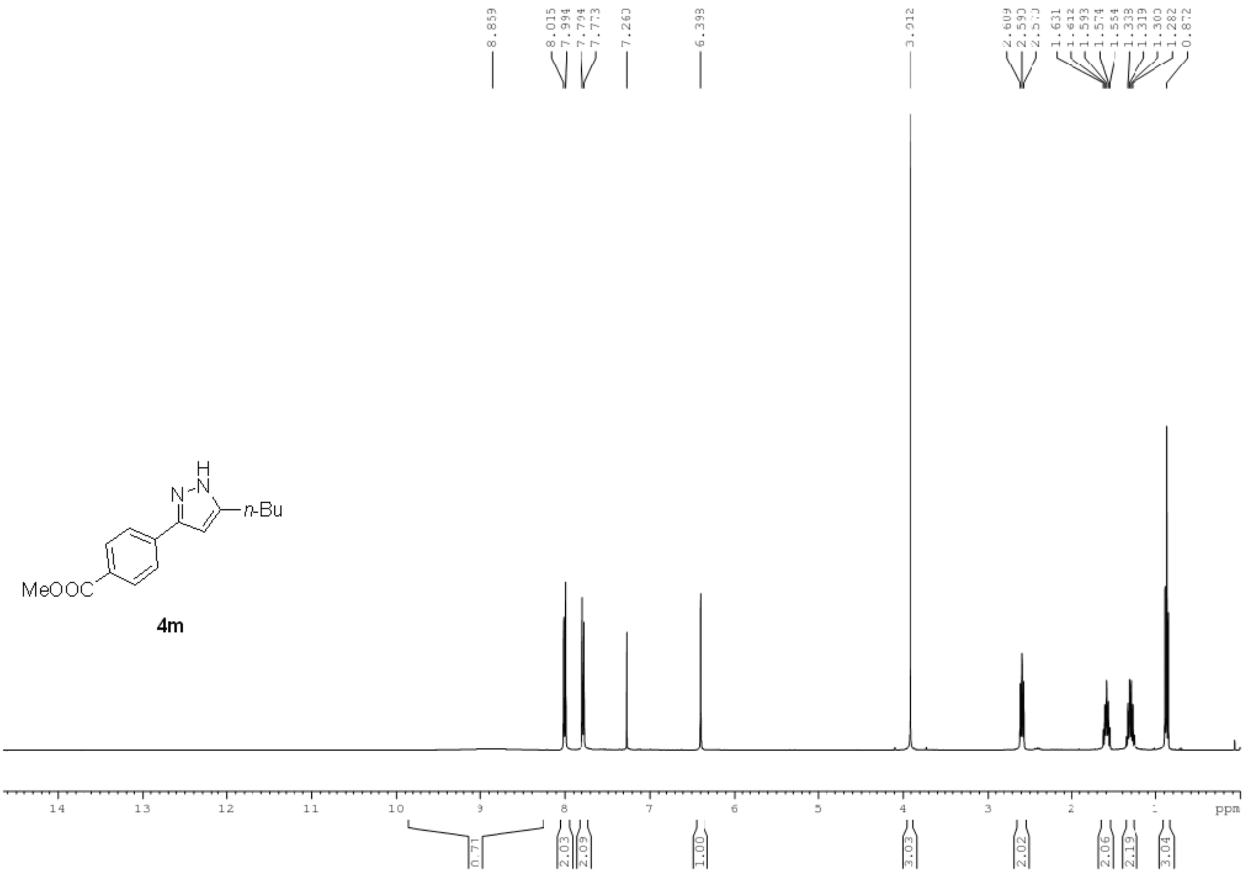
7.408
6.463
2.609
2.591
2.571
2.505
2.500
2.495
1.624
1.606
1.587
1.568
1.549
1.346
1.327
1.309
1.291
0.907
N
H
N
n-Bu
Cl
4l
14
13
12
11
10
9
8
7
6
5
4
3
2
1
ppm
0.90
2.03
2.03
0.98
2.00
2.01
2.09
3.00


128.64
126.68
40.13
39.91
39.71
39.50
39.29
39.08
38.87
31.00
21.77
13.69
N
H
N
n-Bu
Cl
4l
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm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7.994
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7.260
6.398
3.912
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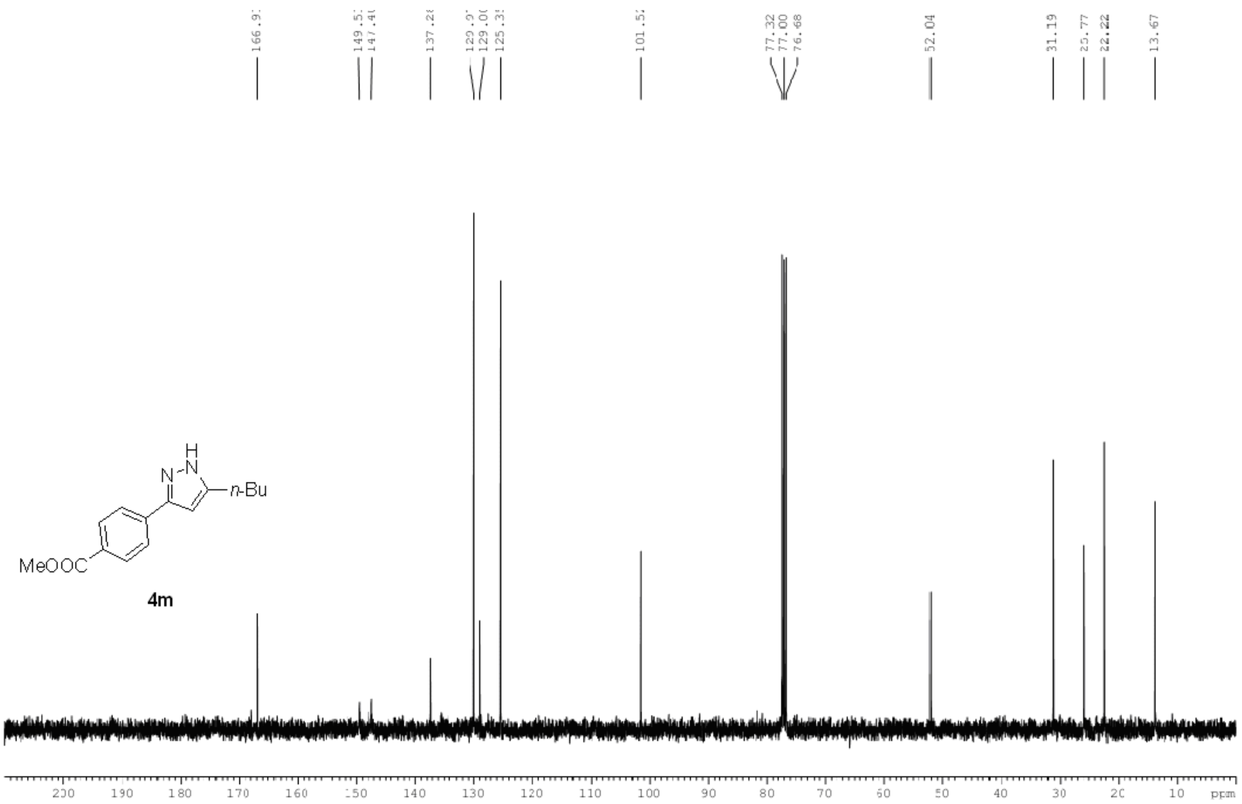
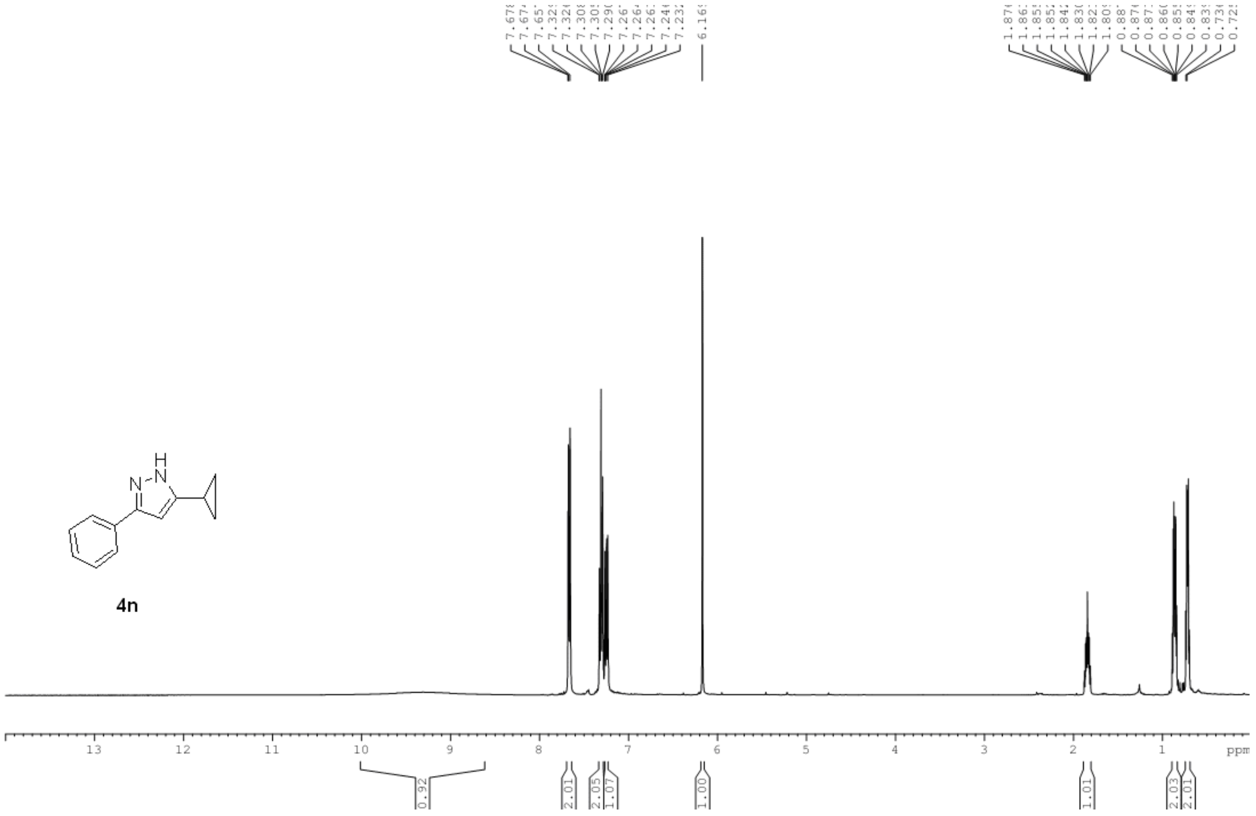
2.590
2.570
1.631
1.612
1.593
1.574
1.554
1.338
1.319
1.300
1.282
0.872
N
N
H
n-Bu
MeOOC
4m
14
13
12
11
10
9
8
7
6
5
4
3
2
1
ppm
0.71
2.03
2.09
1.00
3.03
2.02
2.06
2.19
3.04


166.9
149.5
147.40
137.2
129.9
129.0
125.3
101.5
77.32
77.00
76.68
52.04
31.19
25.77
22.22
13.67
N
N
H
n-Bu
MeOOC
4m
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm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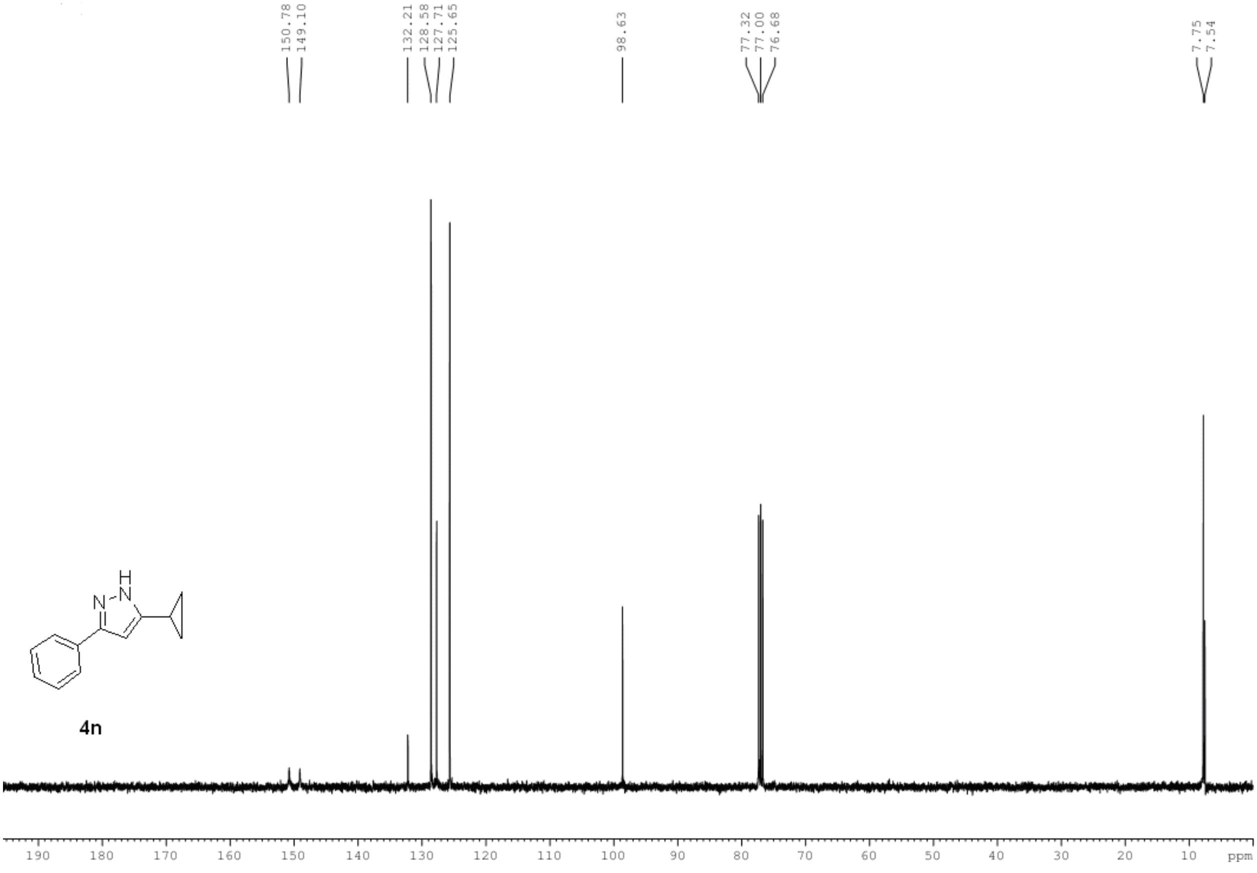
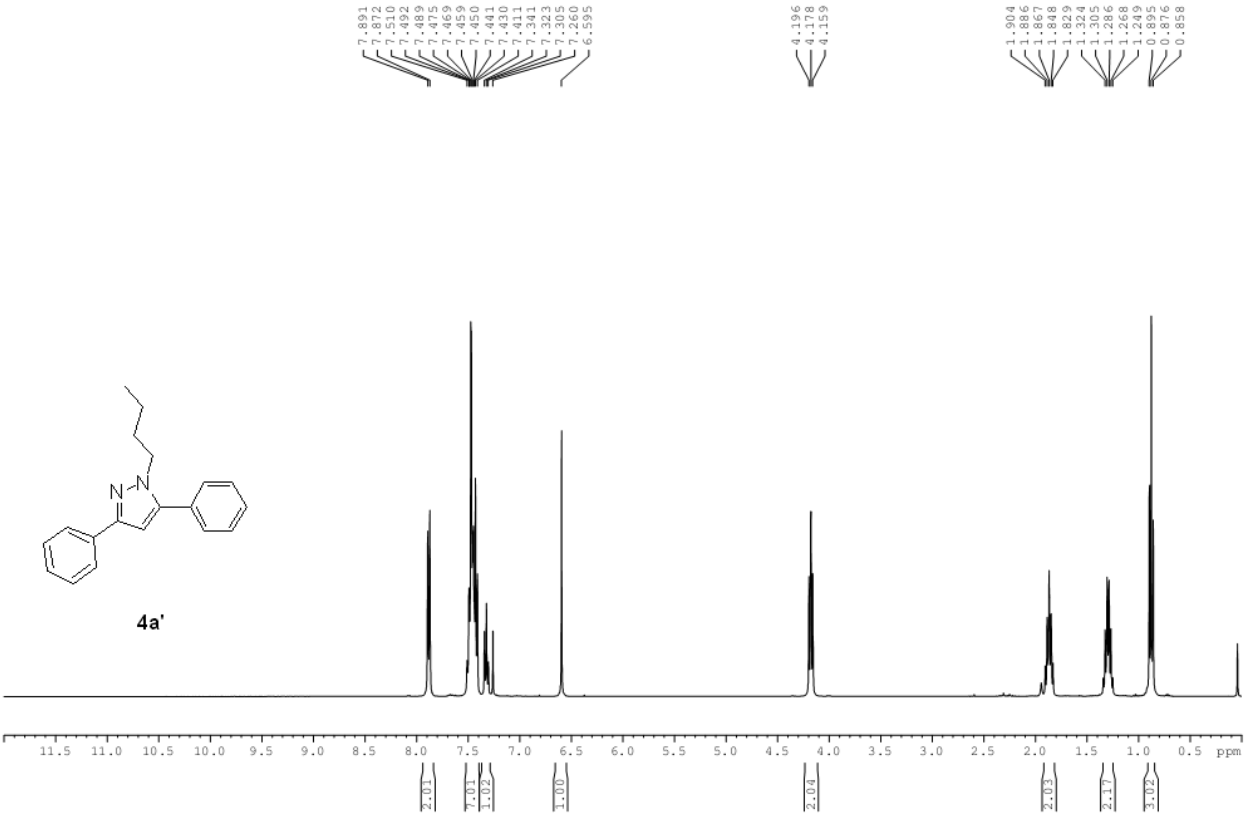
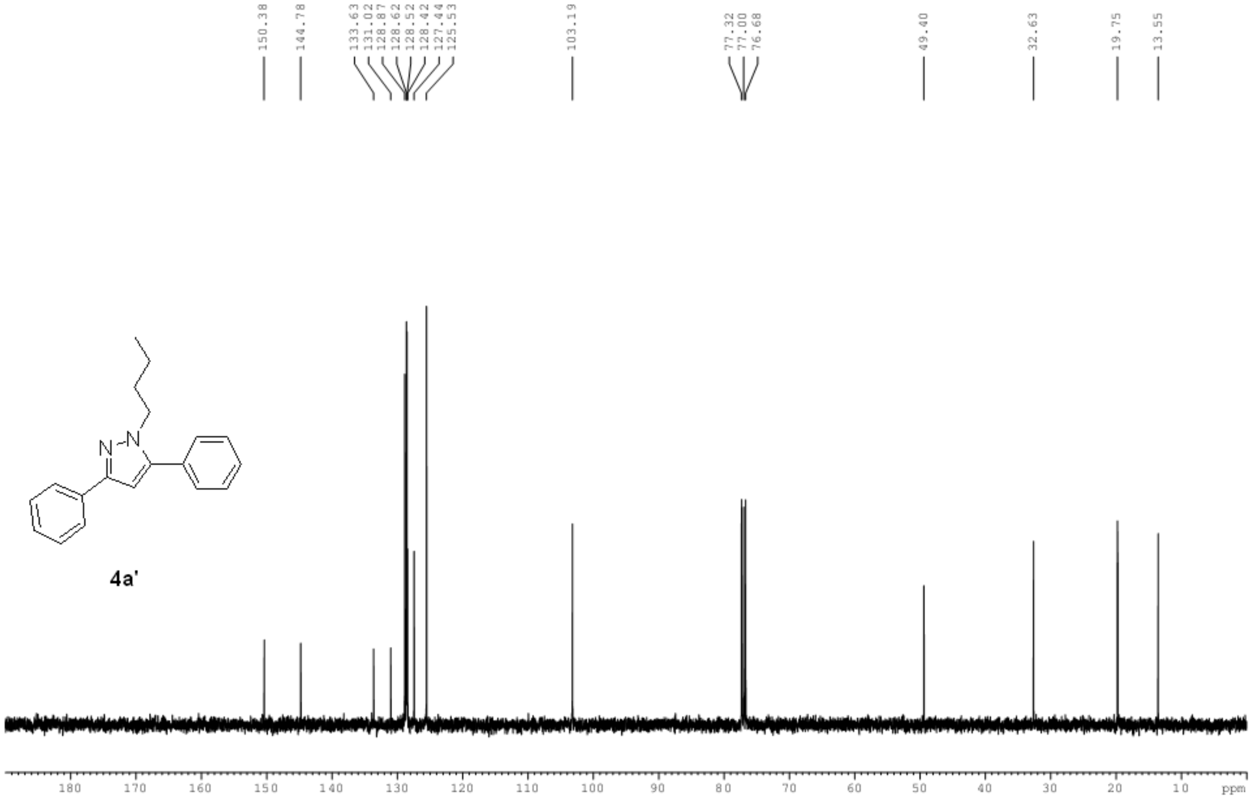
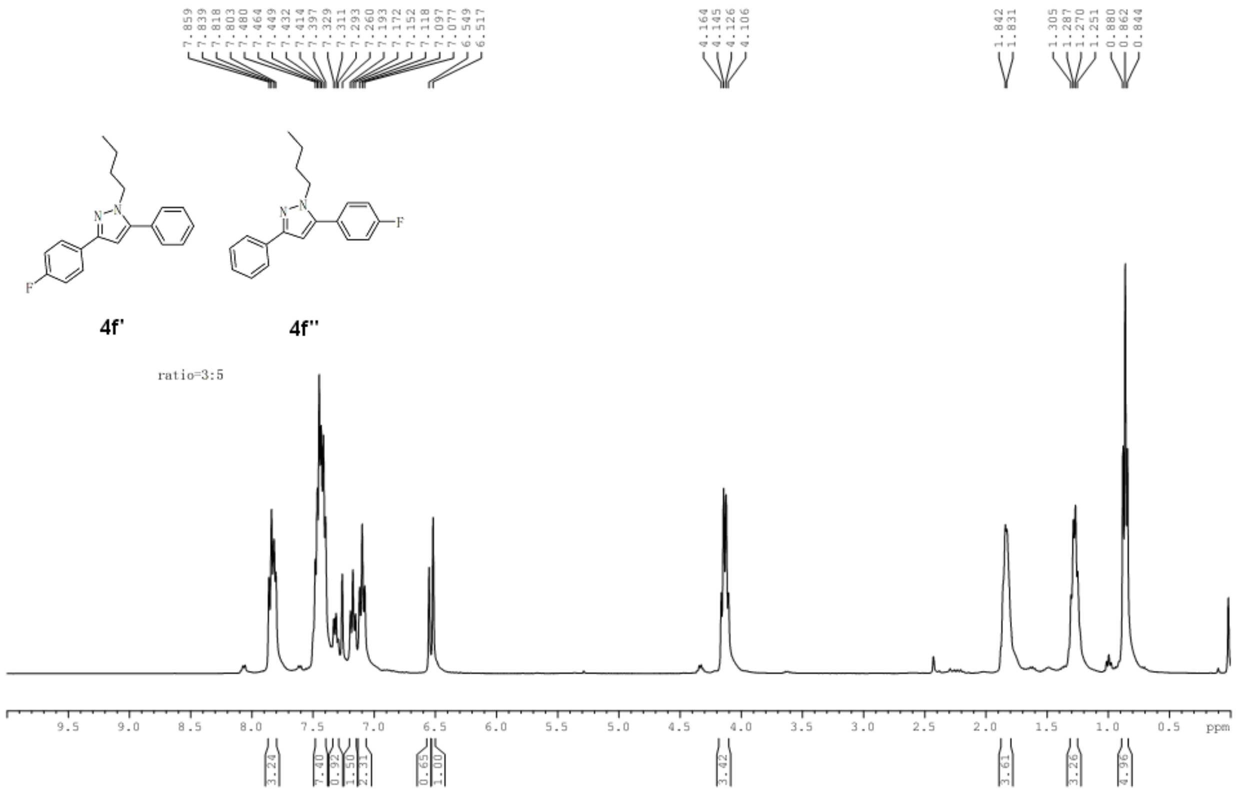
7.67
7.65
7.32
7.32
7.30
7.30
7.29
7.26
7.26
7.26
7.24
7.23
6.16
1.87
1.86
1.85
1.85
1.84
1.83
1.82
1.80
0.88
0.87
0.87
0.86
0.85
0.84
0.83
0.73
0.72
N
N
H
4n
13
12
11
10
9
8
7
6
5
4
3
2
1
ppm
0.92
2.01
2.05
1.07
1.00
1.01
2.03
2.01


150.78
149.10
132.21
128.58
127.71
125.65
98.63
77.32
77.00
76.68
7.75
7.54
N
N
H
4n
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm


7.891
7.872
7.510
7.492
7.489
7.475
7.469
7.459
7.450
7.441
7.430
7.411
7.341
7.323
7.305
7.260
6.595
4.196
4.178
4.159
1.904
1.886
1.867
1.848
1.829
1.324
1.305
1.286
1.268
1.249
0.895
0.876
0.858
N
N
4a'
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
2.01
7.01
1.02
1.00
2.04
2.03
2.17
3.02


150.38
144.78
133.63
131.02
128.87
128.62
128.52
128.42
127.44
125.53
103.19
77.32
77.00
76.68
49.40
32.63
19.75
13.55
N
N
4a'
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm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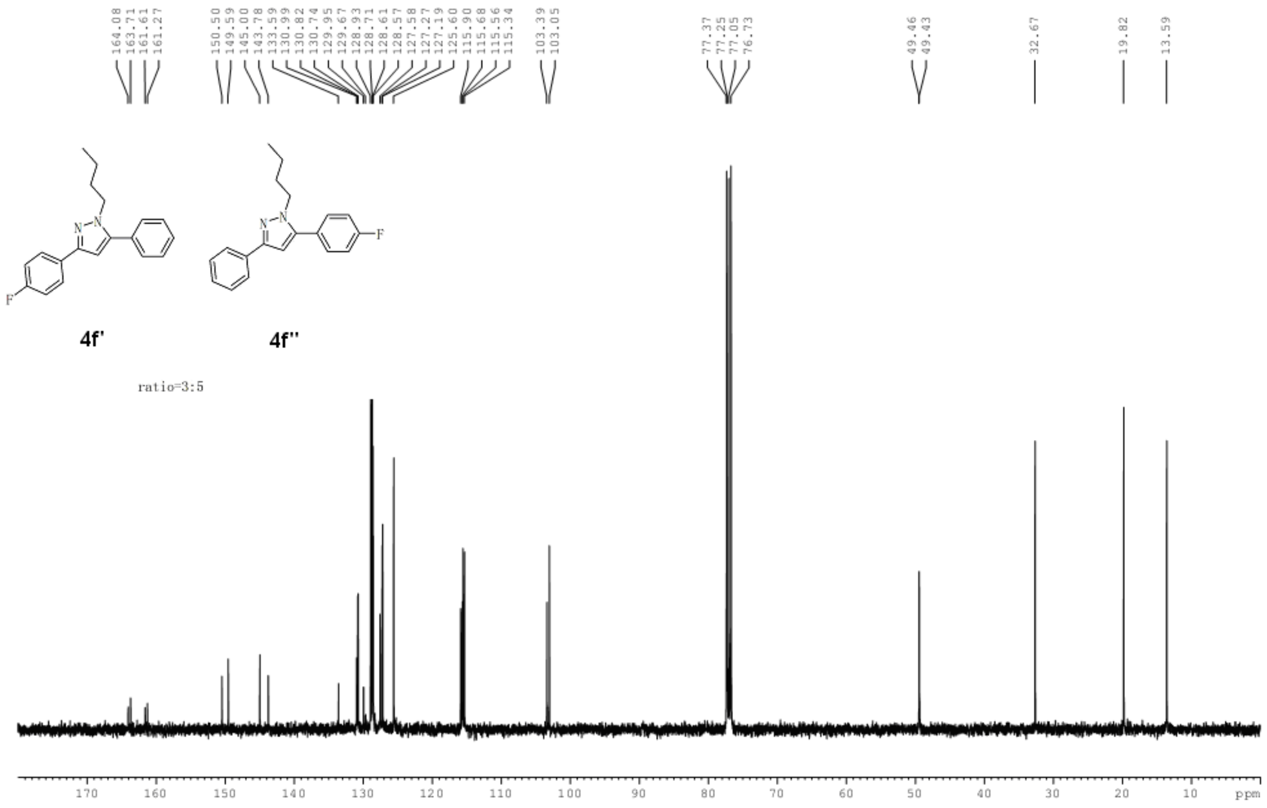
7.818
7.803
7.480
7.464
7.449
7.432
7.414
7.397
7.329
7.311
7.293
7.260
7.193
7.172
7.152
7.118
7.097
7.077
6.549
6.517
4.164
4.145
4.126
4.106
1.842
1.831
1.305
1.287
1.270
1.251
0.880
0.862
0.844
N
N
F
N
N
F
4f'
4f''
ratio=3:5
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
ppm
3.24
7.40
0.92
1.50
2.31
0.65
1.00
3.42
3.61
3.26
4.96


164.08
163.71
161.61
161.27
150.50
149.59
145.00
143.78
133.59
130.99
130.82
130.74
129.95
129.67
128.93
128.71
128.61
128.57
127.58
127.27
127.19
125.60
115.90
115.68
115.56
115.34
103.39
103.05
77.37
77.25
77.05
76.73
49.46
49.43
32.67
19.82
13.59
N
N
F
N
N
F
4f'
4f''
ratio=3:5
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
ppm