

Facile One-Pot Synthesis of 4, 5-Disubstituted 1, 2, 3-(NH)-Triazoles through Sonogashira Coupling/1, 3-Dipolar Cycloaddition of Acid Chlorides, Terminal Acetylenes and Sodium Azide

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I . General Remarks:

Column chromatography was carried out on silica gel. ^1H NMR spectra were recorded on 300 or 400 MHz in CDCl_3 and ^{13}C NMR spectra were recorded on 50, 75 or 100 MHz in CDCl_3 , Acetone- D_6 or Dimethyl Sulfoxide- D_6 using TMS as internal standard. IR spectra were recorded on a FT-IR spectrometer and only major peaks are reported in cm^{-1} . Melting points were determined on a microscopic apparatus and were uncorrected. All new products were further characterized by ESI HRMS, EI MS or element analysis; copies of their ^1H NMR and ^{13}C NMR spectra are provided. Commercially available reagents and solvents were used without further purification.

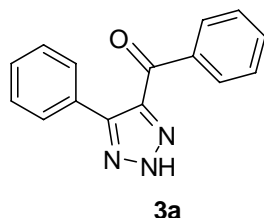
General Procedure for the preparation of 4,5-disubstituted-1,2,3-(NH)-triazoles. Synthesis of NH-triazole (3a):

All reactions were performed on a 0.5 mmol scale relative to 1a. A round-bottom sidearm flask (10 mL) containing $\text{PdCl}_2(\text{PPh}_3)_2$ (0.005 mmol), CuI (0.01 mmol) was subjected to the Schlenk-line procedures of evacuation and purging of N_2 for three cycles. Phenyl acetylene (0.5 mmol), benzoyl chloride (0.5 mmol) and 3 equiv Et_3N (1.5 mmol) was successively added, and the flask was put into ultrasonic (32 KHz, 160 W) to react at room temperature for 1h, then the flask was took out; NaN_3 (39mg, 0.6 mmol) and 1 mL DMSO were added to the mixture and the reaction continued at rt for one more hour. Following, to the reaction mixture was added water (2 mL), 20% HCl solution (1 mL) and extracted with ether (3×10 mL). The combined organic phases were washed with brine (2×5 mL), dried over anhydrous MgSO_4 and concentrated in vacuo. The residue was subjected to flash column chromatography with hexanes/EtOAc (5/1) as eluent to obtain the desired 3a (122.0 mg, 98% yield).

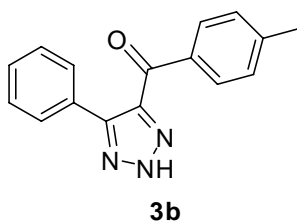
General Procedure for S_NAr reaction of triazole with 1-chloro-4-nitrobenzene. Synthesis of the regioselective 1,4,5-trisubstituted-1, 2, 3-(NH)-triazoles (5a):

All reactions were performed on a 0.5 mmol scale relative to 3a. NH-triazole (3a) (0.5 mmol, 125 mg), 1-chloro-4-nitrobenzene (0.75 mmol, 118 mg), potassium carbonate (1 mmol, 138 mg) and DMSO (1 mL) were added to a round-bottom sidearm flask (10 mL). Then the reaction mixture was heated up to 90°C and reacted for 50 hours. After cool, to the reaction mixture was added water (2 mL), 20% HCl solution (1 mL) and extracted with ethyl acetate (3 × 10 mL). The combined organic phases were washed with brine (10 mL), dried over anhydrous MgSO₄ and concentrated in vacuo. The residue was subjected to flash column chromatography with hexanes/EtOAc (20/1) as eluent to obtain the desired 5a (111.0 mg, 60% yield).

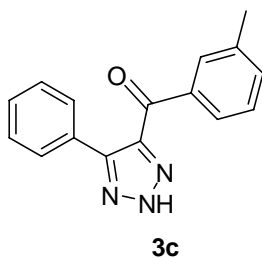
II. Spectral data of the compounds:



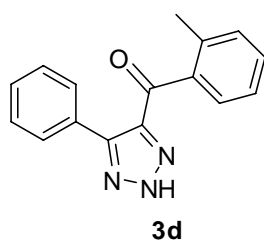
Phenyl(5-phenyl-2H-1,2,3-triazol-4-yl)methanone (3a): 3a was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as off-white solid (yield 98%). mp: 113-115 °C. IR (cm⁻¹): 3443.88, 2922.76, 1655.93. ¹H NMR (300 MHz, CDCl₃), δ 8.03 (d, *J* = 6.9 Hz, 2H), 7.66-7.69 (m, 2H), 7.55 (t, *J* = 7.4 Hz, 1H), 7.30-7.44 (m, 5H). ¹³C NMR (75 MHz, CDCl₃): 188.21, 145.68, 140.77, 136.82, 133.46, 130.41, 129.64, 128.69, 128.49, 128.27, 127.33. ESI HRMS: calcd. for C₁₅H₁₂N₃O [M+H]⁺: 250.0975, found: 250.0977.



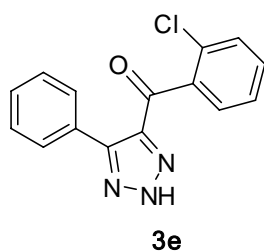
(5-phenyl-2H-1,2,3-triazol-4-yl)(p-tolyl)methanone (3b): **3b** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as off-white solid (yield 99%), mp: 115-117 °C. IR (cm⁻¹): 3157.11, 2998.32, 1707.48, 1657.63. ¹H NMR (300 MHz, CDCl₃): δ 7.92 (d, *J* = 8.4 Hz, 2H), 7.62-7.65 (m, 2H), 7.24-7.31 (m, 3H), 7.17 (d, *J* = 7.8 Hz, 2H), 2.35 (s, 3H). ¹³C NMR (75 MHz, CDCl₃): 187.95, 145.27, 144.43, 140.79, 134.27, 130.56, 129.41, 128.95, 128.59, 128.37, 127.47, 21.59. ESI HRMS: calcd. for C₁₆H₁₄N₃O[M+H]⁺: 264.1131, found: 264.1133.



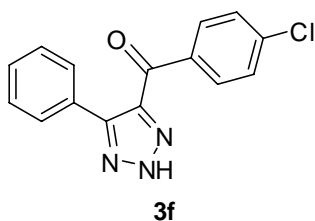
(5-phenyl-2H-1,2,3-triazol-4-yl)(m-tolyl)methanone (3c): **3c** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as colourless viscous oil (98%). IR (cm⁻¹): 3157.53, 2994.87, 1656.62. ¹H NMR (300 MHz, CDCl₃): δ 7.82 (s, 2H), 7.66-7.68 (m, 2H), 7.26-7.37 (m, 5H), 2.34(s, 3H). ¹³C NMR (75 MHz, CDCl₃): δ 188.53, 145.25, 140.63, 138.05, 136.77, 134.25, 130.72, 129.51, 128.60, 128.40, 128.11, 127.70, 127.27, 21.11. ESI HRMS: calcd. for C₁₆H₁₄N₃O [M+H]⁺: 264.1131, found: 264.1135.



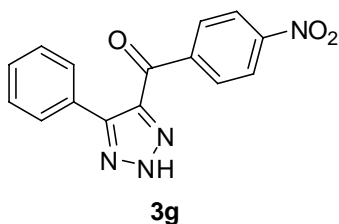
(5-phenyl-2H-1,2,3-triazol-4-yl)(o-tolyl)methanone (3d): **3d** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as off-white solid (99%), mp: 88-90 °C. IR (cm⁻¹): 3147.68, 3096.25, 2989.49, 1662.61. ¹H NMR (300 MHz, CDCl₃), δ 7.69-7.71 (m, 2H), 7.45 (d, *J* = 7.5 Hz, 1H), 7.30-7.38 (m, 4H), 7.21 (d, *J* = 7.8 Hz, 1H), 7.13 (t, *J* = 7.4 Hz, 1H), 2.40 (s, 3H). ¹³C NMR (75 MHz, CDCl₃): δ 190.93, 144.93, 141.22, 137.76, 137.54, 131.28, 131.16, 130.00, 129.69, 128.71, 128.38, 126.95, 125.14, 20.29. ESI HRMS: calcd. for C₁₆H₁₄N₃O [M+H]⁺: 264.1131, found: 264.1133.



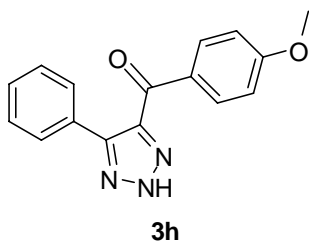
(2-chlorophenyl)(5-phenyl-2H-1,2,3-triazol-4-yl)methanone (3e): **3e** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as colourless viscous oil (93%). IR (cm⁻¹): 3156.93, 2918.76, 1608.67. ¹H NMR (300 MHz, CDCl₃): δ 7.77 (d, *J* = 6.3 Hz, 2H), 7.22-7.46 (m, 7H). ¹³C NMR (75 MHz, CDCl₃), δ 188.29, 144.97, 140.94, 138.31, 131.65, 131.58, 130.01, 129.91, 129.68, 128.86, 128.40, 126.70, 126.48. ESI HRMS: calcd. for C₁₅H₁₁ClN₃O [M+H]⁺: 284.0585, found: 284.0587.



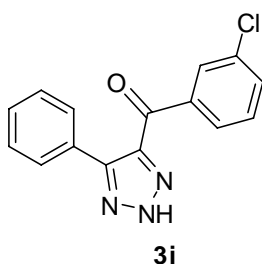
(4-chlorophenyl)(5-phenyl-2H-1,2,3-triazol-4-yl)methanone (3f): **3f** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as off-white solid (99%), mp: 132-134 °C. IR (cm⁻¹): 3139.51, 3086.48, 1653.44. ¹H NMR (300 MHz, CDCl₃), δ 8.06 (d, *J* = 8.1 Hz, 2H), 7.73 (t, *J* = 3.8 Hz, 2H), 7.43-7.51(m, 5H). ¹³C NMR (100 MHz, Acetone-D₆): δ 187.12, 139.69, 137.03, 132.84, 130.09, 129.60, 129.52, 129.24, 129.14, 128.97. ESI HRMS: calcd. for C₁₅H₁₁ClN₃O [M+H]⁺: 284.0585, found: 284.0587.



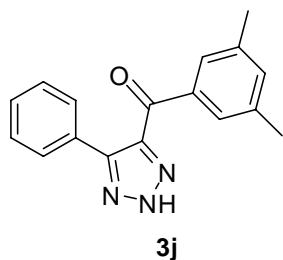
(4-nitrophenyl)(5-phenyl-2H-1,2,3-triazol-4-yl)methanone (3g): **3g** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as green-yellow solid (83%), mp: 150-152 °C. IR (cm⁻¹): 3251.39, 3147.95, 1660.67. ¹H NMR (300 MHz, CDCl₃), δ 8.34 (s, 4H), 7.81-7.84 (m, 2H), 7.49-7.51(m, 3H). ¹³C NMR (75 MHz, D-DMSO): 186.13, 149.66, 142.50, 140.52, 131.41, 129.76, 128.95, 128.48, 127.06, 123.54, 123.38. ESI HRMS: calcd. for C₁₅H₁₁N₄O₃ [M+H]⁺: 295.0826, found: 295.0830.



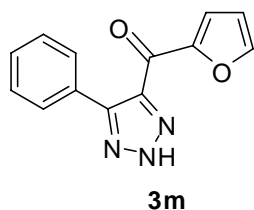
(4-methoxyphenyl)(5-phenyl-2H-1,2,3-triazol-4-yl)methanone (3h): **3h** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as colourless viscous oil (85%). IR (cm⁻¹): 3426.30, 3175.11, 1657.06, 1596.90. ¹H NMR (300 MHz, CDCl₃), δ 8.06 (d, *J* = 8.7 Hz, 2H), 7.66-7.69 (m, 2H), 7.30-7.34 (m, 3H), 6.881 (d, *J* = 9.0 Hz, 2H), 3.83 (s, 3H). ¹³C NMR (75 MHz, CDCl₃): 186.78, 164.02, 145.48, 140.98, 130.03, 129.63, 129.45, 128.61, 128.50, 127.67, 113.65, 55.47. ESI HRMS: calcd. for C₁₆H₁₄N₃O₂ [M+H]⁺: 280.1081, found: 280.1078.



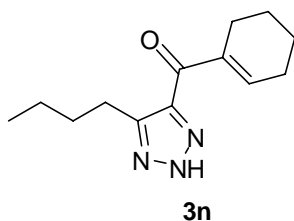
(3-chlorophenyl)(5-phenyl-2H-1,2,3-triazol-4-yl)methanone (3i): **3i** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as off-white solid (98%). mp: 109-111 °C. IR (cm⁻¹): 3154.16, 2916.52, 1660.20. ¹H NMR (300 MHz, CDCl₃), δ 8.11 (s, 1H), 8.00 (d, *J* = 7.8 Hz, 1H), 7.76 (t, *J* = 3.6 Hz, 2H), 7.56-7.59 (m, 1H), 7.39-7.55 (m, 4H). ¹³C NMR (50 MHz, Acetone-D₆): δ 186.95, 142.00, 140.32, 134.72, 133.71, 133.63, 130.93, 130.90, 130.27, 129.76, 129.64, 129.23, 129.06. ESI HRMS: calcd. for C₁₅H₁₁ClN₃O [M+H]⁺: 284.0585, found: 284.0589.



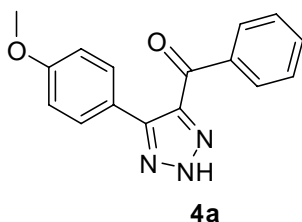
(3,5-dimethylphenyl)(5-phenyl-2H-1,2,3-triazol-4-yl)methanone (3j): **3j** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as colourless viscous oil (98%). IR (cm^{-1}): 3155.43, 2999.57, 1656.80, 1600.17. ^1H NMR (300 MHz, CDCl_3), δ 7.69-7.72 (m, 2H), 7.62 (s, 2H), 7.34-7.38 (m, 3H), 7.20 (s, 1H), 2.31 (s, 6H). ^{13}C NMR (75 MHz, CDCl_3): δ 188.74, 145.21, 140.70, 137.91, 136.86, 135.19, 129.44, 128.60, 128.39, 128.14, 127.45, 21.02. ESI HRMS: calcd. for $\text{C}_{17}\text{H}_{16}\text{N}_3\text{O}$ $[\text{M}+\text{H}]^+$: 278.1288, found: 278.1289.



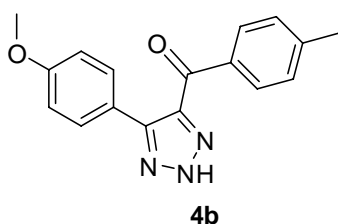
Furan-2-yl(5-phenyl-2H-1,2,3-triazol-4-yl)methanone (3m): **3m** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as off-white solid (97%), mp: 133-135 °C. IR (cm^{-1}): 3145.21, 2997.48, 1628.46. ^1H NMR (300 MHz, CDCl_3): δ 7.79-7.83 (m, 3H), 7.69 (s, 1H), 7.36-7.43 (m, 3H), 6.6 (dd, $J = 3.5$ Hz, 1.7 Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3): 174.21, 151.32, 148.07, 145.21, 139.93, 129.69, 128.93, 128.28, 127.04, 123.46, 112.62. ESI HRMS: calcd. for $\text{C}_{13}\text{H}_{10}\text{N}_3\text{O}_2$ $[\text{M}+\text{H}]^+$: 240.0768, found: 240.0764.



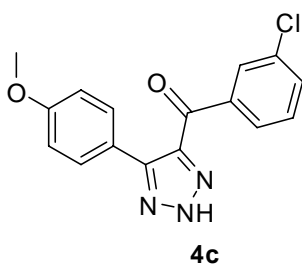
(5-butyl-2H-1,2,3-triazol-4-yl)(cyclohexenyl)methanone (3n): **3n** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as colourless viscous oil (88%), IR (cm⁻¹): 3172.6, 2932.6, 1633.7. ¹H NMR (300 MHz, CDCl₃): δ 7.40 (s, 1H), 2.98 (t, *J* = 6.5 Hz, 2H), 2.42 (s, 2H), 2.33 (t, *J* = 2.9 Hz, 2H), 1.63-1.74 (m, 6H), 1.34-1.41 (m, 2H), 9.12 (t, *J* = 7.4 Hz, 3H). ¹³C NMR (75 MHz, CDCl₃): 189.07, 146.03, 141.97, 138.83, 138.50, 30.77, 26.38, 24.30, 23.57, 22.37, 21.91, 21.50, 13.65. EI-MS: *m/z* = 233 [M]⁺, 204 [M – N₂-H]⁺ Anal. Calcd. For C₁₃H₁₉N₃O: C, 66.92; H, 8.21; N, 18.01. Found: C, 66.88; H, 8.22; N, 18.03..



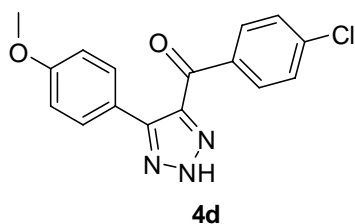
(5-(4-methoxyphenyl)-2H-1,2,3-triazol-4-yl)(phenyl)methanone (4a): **4a** was purified by flash chromatography (hexane-EtOAc, v/v 5/1) as off-white solid (99%), mp: 126-128 °C. IR (cm⁻¹): 3161.11, 3000.70, 1655.99, 1612.64. ¹H NMR (300 MHz, CDCl₃), δ 8.05 (d, *J* = 7.2Hz, 2H), 7.66 (d, *J* = 8.7 Hz, 2H), 7.52-7.58 (m, 1H), 7.42 (t, *J* = 7.5 Hz, 2H), 6.84 (d, *J* = 8.7 Hz, 2H), 3.77 (s, 3H). ¹³C NMR (75 MHz, CDCl₃): δ 188.27, 160.59, 144.82, 140.31, 137.06, 133.25, 130.40, 130.18, 128.19, 119.20, 113.88, 55.17. ESI HRMS: calcd. for C₁₆H₁₄N₃O₂ [M+H]⁺: 280.1081, found: 280.1074.



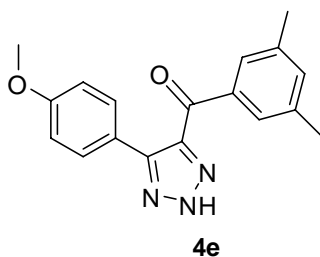
(5-(4-methoxyphenyl)-2H-1,2,3-triazol-4-yl)(p-tolyl)methanone (4b): **4b** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as off-white solid (98%), mp: 91-93 °C. IR (cm⁻¹): 3163.40, 2923.93, 1651.73, 1608.75. ¹H NMR (300 MHz, CDCl₃): δ 7.97 (d, *J* = 8.4 Hz, 2H), 7.66 (d, *J* = 8.7 Hz, 2H), 7.22 (d, *J* = 8.1 Hz, 2H), 6.84 (d, *J* = 8.7 Hz, 2H), 3.78 (s, 3H), 2.38 (s, 3H). ¹³C NMR (75 MHz, CDCl₃): δ 187.95, 160.52, 144.77, 144.27, 140.49, 134.52, 130.61, 130.14, 128.95, 119.49, 113.87, 55.17, 21.64. ESI HRMS: calcd. for C₁₇H₁₆N₃O₂ [M+H]⁺: 294.1237, found: 294.1237.



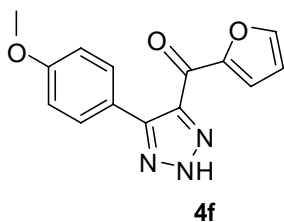
(3-chlorophenyl)(5-(4-methoxyphenyl)-2H-1,2,3-triazol-4-yl)methanone (4c): **4c** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as off-white solid (98%), mp: 119-121 °C. IR (cm⁻¹): 3159.64, 2925.07, 1658.31, 1612.38. ¹H NMR (300 MHz, CDCl₃): δ 8.09 (s, 1H), 7.99 (d, *J* = 7.5 Hz, 1H), 7.71 (d, *J* = 9.0 Hz, 2H), 7.53-7.57 (m, 1H), 7.40 (t, *J* = 8.0, 1H), 6.92 (d, *J* = 9.3 Hz, 2H), 3.83 (s, 3H). ¹³C NMR (75 MHz, D-DMSO): δ 185.63, 160.05, 144.49, 139.40, 137.86, 133.60, 132.25, 129.45, 128.93, 128.72, 127.79, 118.09, 113.19, 54.44. ESI HRMS: calcd. for C₁₆H₁₃ClN₃O₂ [M+H]⁺: 314.0691, found: 314.0696.



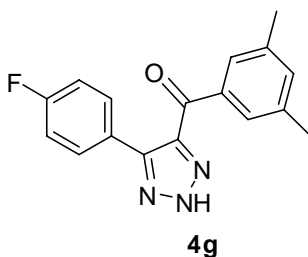
(4-chlorophenyl)(5-(4-methoxyphenyl)-2H-1,2,3-triazol-4-yl)methanone (4d): **4d** was purified by flash chromatography (hexane-EtOAc, v/v 5/1) as off-white solid (98%), mp: 167-169 °C. IR (cm⁻¹): 3420.01, 2924.35, 1658.76, 1610.98. ¹H NMR (300 MHz, CDCl₃): δ 8.10 (d, *J* = 7.8 Hz, 2H), 7.76 (d, *J* = 8.7 Hz, 2H), 7.46 (d, *J* = 8.1 Hz, 2H), 6.98 (d, *J* = 8.1 Hz, 2H), 3.86 (s, 3H). ¹³C NMR (75 MHz, DMSO): δ 186.31, 160.27, 144.22, 140.09, 138.09, 136.09, 132.04, 130.26, 128.48, 119.88, 113.91, 55.29. ESI HRMS: calcd. for C₁₆H₁₃ClN₃O₂ [M+H]⁺: 314.0691, found: 314.0690.



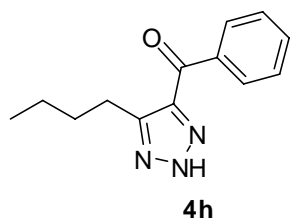
(3,5-dimethylphenyl)(5-(4-methoxyphenyl)-2H-1,2,3-triazol-4-yl)methanone (4e): **4e** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as off-white solid (98%), mp: 147-149 °C. IR (cm⁻¹): 3164.56, 2918.24, 1654.38, 1608.96. ¹H NMR (300 MHz, CDCl₃): δ 7.72 (d, *J* = 9.0Hz, 2H), 7.66 (s, 2H), 7.22 (s, 1H), 6.92 (d, *J* = 8.7Hz, 2H), 3.83 (s, 3H), 2.35 (s, 6H). ¹³C NMR (75 MHz, CDCl₃): δ 189.11, 160.86, 144.90, 140.71, 138.20, 137.47, 135.37, 130.41, 128.46, 119.72, 114.16, 55.49, 21.37. ESI HRMS: calcd. for C₁₈H₁₈N₃O₂ [M+H]⁺: 308.1394, found: 308.1395.



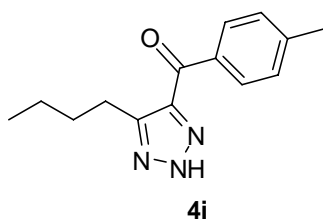
Furan-2-yl(5-(4-methoxyphenyl)-2H-1,2,3-triazol-4-yl)methanone (4f): **4f** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as off-white solid (94%), mp: 148-150 °C. IR (cm⁻¹): 3148.17, 2919.11, 1619.99. ¹H NMR (300 MHz, CDCl₃): δ 7.85 (s, 1H), 7.79 (d, *J* = 7.5 Hz, 2H), 7.69 (s, 1H), 6.89 (d, *J* = 7.5 Hz, 2H), 6.59 (m, 1H), 3.80 (s, 3H). ¹³C NMR (75 MHz, CDCl₃): δ 174.14, 160.79, 151.50, 147.94, 144.77, 139.65, 130.51, 123.26, 119.02, 113.81, 112.60, 55.22. ESI HRMS: calcd. for C₁₄H₁₂N₃O₃ [M+H]⁺: 270.0871, found: 270.0873.



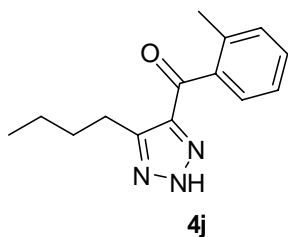
3,5-dimethylphenyl(5-(4-fluorophenyl)-2H-1,2,3-triazol-4-yl)methanone (4g): **4g** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as off-white solid (98%), mp: 161-163 °C. IR (cm⁻¹): 3171.40, 2992.21, 1632.09, 1599.16. ¹H NMR (400 MHz, Acetone-D₆): δ 7.91 (s, 2H), 7.69 (s, 2H), 7.30 (s, 1H), 7.22 (t, *J* = 8.0 Hz, 2H), 4.35 (s, 6H). ¹³C NMR (100 MHz, Acetone-D₆): δ 189.01, 165.36, 162.90, 138.81, 138.61, 135.66, 131.87, 131.78, 128.96, 116.23, 116.02, 21.25. EI-MS: *m/z* = 295 [M]⁺, 266 [M – N₂-H]⁺. Anal. Calcd. For C₁₇H₁₄FN₃O: C, 69.14; H, 4.78; N, 14.23. Found: C, 69.16; H, 4.77; N, 14.20..



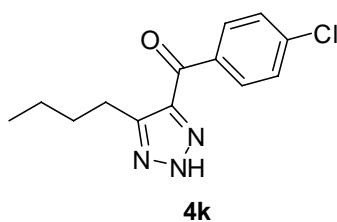
(5-butyl-2H-1,2,3-triazol-4-yl)(phenyl)methanone (4h): **4h** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as off-white solid (90%), mp: 63-65 °C. IR (cm⁻¹): 3166.93, 2959.70, 1652.11. ¹H NMR (300 MHz, CDCl₃): δ 8.23 (d, *J* = 7.2 Hz, 2H), 7.59 (t, *J* = 7.1 Hz, 1H), 7.48 (t, *J* = 7.5 Hz, 2H), 3.06 (t, *J* = 7.7 Hz, 2H), 1.62-1.72 (m, 2H), 1.27-1.39 (m, 2H), 0.86 (t, *J* = 7.4 Hz, 3H). ¹³C NMR (75 MHz, CDCl₃): δ 188.14, 146.95, 141.76, 137.28, 133.06, 130.27, 128.26, 30.50, 24.16, 22.28, 13.58. ESI HRMS: calcd. for C₁₃H₁₆N₃O[M+H]⁺: 230.1288, found: 230.1281.



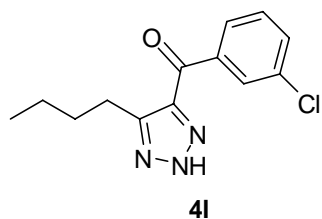
(5-butyl-2H-1,2,3-triazol-4-yl)(p-tolyl)methanone (4i): **4i** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as off-white solid (94%), mp: 86-88 °C. IR (cm⁻¹): 3170.52, 2929.19, 1647.37, 1605.95. ¹H NMR (300 MHz, CDCl₃): δ 8.15 (d, *J* = 8.1 Hz, 2H), 7.27 (d, *J* = 8.1 Hz, 2H), 3.04 (t, *J* = 7.8 Hz, 2H), 2.40 (s, 3H), 1.61-1.71 (m, 2H), 1.26-1.38 (m, 2H), 0.85 (t, *J* = 7.4 Hz, 3H). ¹³C NMR (75 MHz, CDCl₃): δ 187.84, 147.00, 143.96, 141.82, 134.65, 130.42, 128.95, 30.52, 24.1, 22.25, 21.57, 13.55. ESI HRMS: calcd. for C₁₄H₁₈N₃O [M+H]⁺: 244.1444, found: 244.1450.



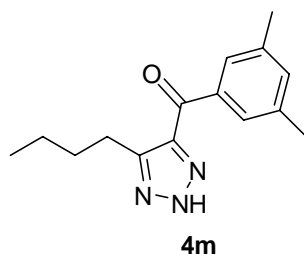
(5-butyl-2H-1,2,3-triazol-4-yl)(o-tolyl)methanone (4j): **4j** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as colourless viscous oil (92%). IR (cm⁻¹): 3158.93, 3096.31, 1658.86. ¹H NMR (300 MHz, CDCl₃): δ 7.55 (d, *J* = 7.8 Hz, 1H), 7.36 (t, *J* = 7.4 Hz, 1H), 7.19-7.24 (m, 2H), 2.95 (t, *J* = 7.7 Hz, 2H), 2.40 (s, 3H), 1.55-1.66 (m, 2H), 1.24-1.36 (m, 2H), 0.85 (t, *J* = 7.4 Hz, 3H). ¹³C NMR (75 MHz, CDCl₃): 191.63, 146.30, 142.10, 138.07, 137.02, 131.12, 130.87, 129.31, 125.19, 30.48, 23.91, 22.21, 20.08, 13.57. ESI HRMS: calcd. for C₁₄H₁₈N₃O[M+H]⁺: 244.1444, found: 244.1446.



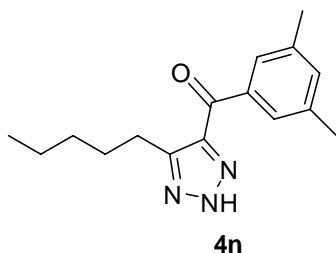
(5-butyl-2H-1,2,3-triazol-4-yl)(4-chlorophenyl)methanone (4k): **4k** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as off-white solid (95%), mp: 73-75 °C. IR (cm⁻¹): 3170.46, 2931.19, 1701.21, 1684.09. ¹H NMR (300 MHz, CDCl₃): δ 8.26 (d, *J* = 8.4 Hz, 2H), 7.48 (d, *J* = 8.7 Hz, 2H), 3.11 (t, *J* = 7.7 Hz, 2H), 1.68-1.78 (m, 2H), 1.25-1.45 (m, 2H), 0.94 (t, *J* = 7.4 Hz, 3H). ¹³C NMR (75 MHz, CDCl₃): δ 186.42, 147.65, 141.80, 139.55, 135.54, 131.81, 128.58, 30.46, 24.36, 22.36, 13.65. ESI HRMS: calcd. for C₁₃H₁₅ClN₃O[M+H]⁺: 264.0898, found: 264.0900.



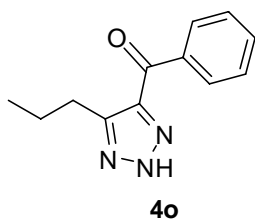
(5-butyl-2H-1,2,3-triazol-4-yl)(3-chlorophenyl)methanone (4l): **4l** was purified by flash chromatography (hexane-EtOAc, v/v 5/1) as colourless viscous oil (95%). IR (cm⁻¹): 3166.30, 3100.88, 1652.99. ¹H NMR(300 MHz, CDCl₃): δ 8.26 (s, 1H), 8.17 (d, *J* = 8.1 Hz, 1H), 7.57 (dd, *J* = 6.9, 1.2 Hz, 1H), 7.42-7.47 (m, 1H), 3.11 (t, *J* = 7.7 Hz, 2H), 1.67-1.77 (m, 2H), 1.32-1.44 (m, 2H), 0.88-0.93 (t, *J* = 7.7 Hz, 3H). ¹³C NMR (75 MHz, CDCl₃): δ 186.29, 147.64, 141.60, 138.78, 134.42, 132.87, 130.29, 129.59, 128.45, 30.42, 24.28, 22.33, 13.62. ESI HRMS: calcd. for C₁₃H₁₅ClN₃O[M+H]⁺: 264.0898, found: 264.0900.



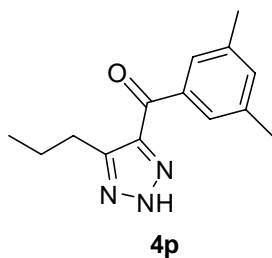
(5-butyl-2H-1,2,3-triazol-4-yl)(3,5-dimethylphenyl)methanone (4m): **4m** was purified by flash chromatography (hexane-EtOAc, v/v 5/1) as colourless viscous oil (96%). IR (cm⁻¹): 3164.34, 2959.37, 1650.11, 1600.22. ¹H NMR (300 MHz, CDCl₃): δ 7.80 (s, 2H), 7.22 (s, 1H), 3.03 (t, *J* = 7.7 Hz, 2H), 2.36 (s, 6H), 1.60-1.70 (m, 2H), 1.26-1.39 (m, 2H), 0.87 (t, *J* = 7.4 Hz, 3H). ¹³C NMR (75 MHz, CDCl₃): δ 189.08, 147.20, 142.22, 138.35, 137.86, 135.18, 128.37, 30.9, 24.50, 22.69, 21.55, 13.98. ESI HRMS: calcd. for C₁₅H₂₀N₃O [M+H]⁺: 258.1601, found: 258.1600.



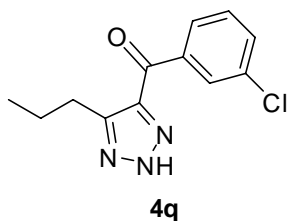
(3,5-dimethylphenyl)(5-pentyl-2H-1,2,3-triazol-4-yl)methanone (4n): **4n** was purified by flash chromatography (hexane-EtOAc, v/v 5/1) as off-white solid (95%), mp: 69-71 °C. IR (cm⁻¹): 3166.33, 2928.03, 1651.21, 1600.33. ¹H NMR (300 MHz, CDCl₃): δ 7.80 (s, 2H), 7.22 (s, 1H), 3.03 (t, *J* = 7.7 Hz, 2H), 2.36 (s, 6H), 1.68 (s, 2H), 1.28 (t, *J* = 3.5 Hz, 4H), 0.83 (t, *J* = 3.5 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃): δ 188.61, 147.12, 141.94, 137.92, 137.47, 134.76, 127.98, 31.33, 28.21, 24.38, 22.17, 21.16, 13.82. ESI HRMS: calcd. for C₁₆H₂₂N₃O [M+H]⁺: 272.1757, found: 272.1763.



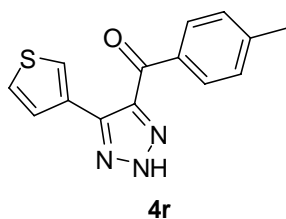
Phenyl(5-propyl-2H-1,2,3-triazol-4-yl)methanone (4o): **4o** was purified by flash chromatography (hexane-EtOAc, v/v 5/1) as off-white solid, mp: 87-89 °C (88%). IR (cm⁻¹): 3167.55, 2964.85, 1652.09. ¹H NMR (300 MHz, CDCl₃): δ 8.23 (d, *J* = 8.1 Hz, 2H), 7.59 (t, *J* = 7.8 Hz, 1H), 7.49 (t, *J* = 8.0 Hz, 2H), 3.04 (t, *J* = 4.7 Hz, 2H), 1.69-1.76 (m, 2H), 0.92 (t, *J* = 7.4 Hz, 3H). ¹³C NMR (75 MHz, CDCl₃): δ 188.10, 146.89, 141.82, 137.32, 132.98, 130.28, 128.23, 26.27, 21.83, 13.67. ESI HRMS: calcd. for C₁₂H₁₄N₃O [M+H]⁺: 216.1131, found: 216.1125.



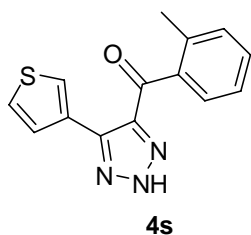
(3,5-dimethylphenyl)(5-propyl-2H-1,2,3-triazol-4-yl)methanone (4p): **4p** was purified by flash chromatography (hexane-EtOAc, v/v 5/1) as off-white solid (90%), mp: 79-81 °C. IR (cm⁻¹): 3166.38, 2926.84, 1650.11. ¹H NMR (300 MHz, CDCl₃): δ 7.81 (s, 2H), 7.23 (s, 1H), 3.03 (t, *J* = 7.7 Hz, 2H), 2.37 (s, 6H), 1.68-1.80 (m, 2H), 0.95 (t, *J* = 7.4 Hz, 3H). ¹³C NMR (75 MHz, CDCl₃): δ 188.49, 146.98, 142.03, 137.91, 137.47, 134.75, 128.01, 26.36, 21.90, 21.20, 13.71. ESI HRMS: calcd. for C₁₄H₁₈N₃O [M+H]⁺: 244.1444, found: 244.1449.



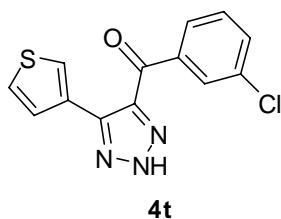
(3-chlorophenyl)(5-propyl-2H-1,2,3-triazol-4-yl)methanone (4q): **4q** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as off-white solid (90%), mp: 66-68 °C. IR (cm⁻¹): 3165.79, 2965.73, 1652.60. ¹H NMR (300 MHz, CDCl₃): δ 8.26 (s, 1H), 8.16 (d, *J* = 8.1 Hz, 1H), 7.56 (d, *J* = 8.1 Hz, 1H), 7.44 (t, *J* = 8.0 Hz, 1H), 3.07 (t, *J* = 7.7 Hz, 2H), 1.69-1.79 (m, 2H), 0.95 (t, *J* = 7.4 Hz, 3H). ¹³C NMR (75 MHz, CDCl₃): δ 186.23, 147.56, 141.76, 138.79, 134.46, 132.92, 130.36, 129.63, 128.47, 26.46, 21.77, 13.75. ESI HRMS: calcd. for C₁₂H₁₃ClN₃O [M+H]⁺: 250.0742, found: 250.0741.



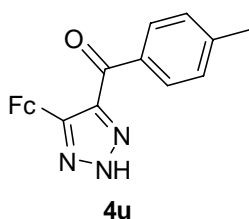
(5-(thiophen-3-yl)-2H-1,2,3-triazol-4-yl)(p-tolyl)methanone (4r): **4r** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as off-white solid (97%), mp: 137-139 °C. IR (cm⁻¹): 3128.84, 2922.78, 1651.52, 1605.55. ¹H NMR (300 MHz, CDCl₃): δ 8.18 (d, *J* = 3.0 Hz, 1H), 7.95 (d, *J* = 8.1 Hz, 2H), 7.52 (d, *J* = 5.1 Hz, 1H), 7.27-7.30 (m, 1H), 7.21 (d, *J* = 8.4 Hz, 2H), 2.37 (s, 3H). ¹³C NMR (75 MHz, CDCl₃): δ 187.84, 144.36, 140.95, 140.77, 134.63, 130.59, 129.01, 127.67, 127.45, 127.29, 126.01, 21.67. ESI HRMS: calcd. for C₁₄H₁₂N₃OS [M+H]⁺: 270.0696, found: 270.0702.



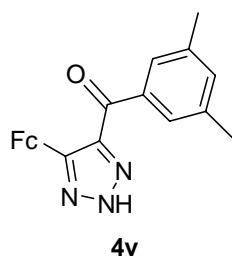
(5-(thiophen-3-yl)-2H-1,2,3-triazol-4-yl)(o-tolyl)methanone (4s): **4s** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as colourless viscous oil (98%). IR (cm⁻¹): 3123.21, 2966.69, 1660.97. ¹H NMR (300 MHz, CDCl₃): δ 8.35 (s, 1H), 7.60 (d, *J* = 5.1 Hz, 1H), 7.46 (d, *J* = 18.6 Hz, 1H), 7.33-7.39 (m, 2H), 7.16-7.23 (m, 2H), 2.41 (s, 3H). ¹³C NMR (75 MHz, CDCl₃): δ 191.06, 141.26, 140.58, 138.16, 137.45, 131.17, 131.13, 129.68, 128.49, 127.93, 127.41, 126.08, 125.21, 20.24. ESI HRMS: calcd. for C₁₄H₁₂N₃OS [M+H]⁺: 270.0696, found: 270.0698.



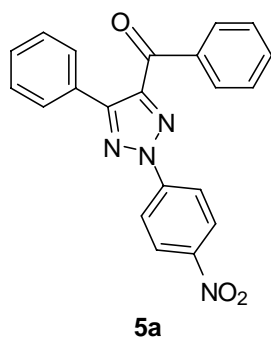
(3-chlorophenyl)(5-(thiophen-3-yl)-2H-1,2,3-triazol-4-yl)methanone (4t): **4t** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as off-white solid (97%), mp: 122-124 °C. IR (cm⁻¹): 3085.61, 2919.50, 1656.39. ¹H NMR (300 MHz, CDCl₃): δ 8.33 (s, 1H), 8.12 (s, 1H), 8.01 (d, *J* = 7.8 Hz, 1H), 7.56-7.74 (m, 2H), 7.39-7.46 (m, 2H). ¹³C NMR (75 MHz, CDCl₃): δ 186.38, 141.44, 140.58, 138.81, 134.50, 133.14, 130.36, 129.61, 128.58, 128.02, 127.37, 127.14, 126.37. ESI HRMS: calcd. for C₁₃H₉ClN₃OS [M+H]⁺: 290.0149, found: 290.0146.



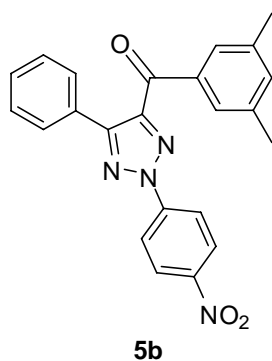
(4u): **4u** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as purple-red solid (93%), mp: 68-70 °C. IR (cm⁻¹): 3099.82, 2911.74, 1704.05, 1652.73. ¹H NMR (300 MHz, CDCl₃): δ 8.08 (d, *J* = 7.5 Hz, 2H), 7.26 (d, *J* = 8.1 Hz, 2H), 5.11 (s, 2H), 4.36 (s, 2H), 4.04 (s, 5H), 2.39 (s, 3H). ¹³C NMR (75 MHz, CDCl₃): δ 187.60, 144.03, 140.66, 135.13, 130.59, 129.03, 70.25, 69.86, 69.48, 21.69. EI-MS: *m/z* = 371 [M]⁺, 342[M - N₂-H]⁺. Anal. Calcd. for C₂₀H₁₇FeN₃O: C, 64.71; H, 4.62; N, 11.32. Found: C, 64.69; H, 4.59; N, 11.28.



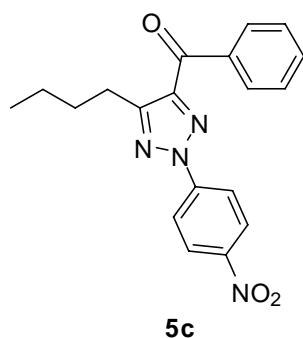
(4v): **4v** was purified by flash chromatography (Hexane-EtOAc, v/v 5/1) as purple-red solid (95%), mp: 79-81 °C. IR (cm⁻¹): 3098.40, 2915.70, 1654.48, 1600.13. ¹H NMR (300 MHz, CDCl₃): δ 7.72 (s, 2H), 7.20 (s, 1H), 5.06 (s, 2H), 4.36 (s, 2H), 4.05 (s, 5H), 2.34 (s, 6H). ¹³C NMR (75 MHz, CDCl₃): δ 188.41, 144.28, 140.67, 137.94, 137.84, 134.89, 128.11, 70.19, 69.87, 69.40, 21.23. EI-MS: m/z = 385 [M]⁺, 356 [M – N₂–H]⁺. Anal. Calcd. for C₂₁H₁₉FeN₃O: C, 65.47; H, 4.97; N, 10.91. Found: C, 65.49; H, 4.99; N, 10.90.



(2-(4-nitrophenyl)-5-phenyl-2H-1,2,3-triazol-4-yl)(phenyl)methanone (5a): **5a** was purified by flash chromatography (Hexane-EtOAc, v/v 20/1) as green-yellow solid (60%), mp: 145-147 °C. IR (cm⁻¹): 3074.59, 2918.34, 1652.74, 1593.64. ¹H NMR (400 MHz, CDCl₃): δ 8.33-8.35 (m, 4H), 8.11-8.13 (m, 2H), 7.87-7.90 (m, 2H), 7.64-7.67 (m, 1H), 7.44-7.54 (m, 5H). ¹³C NMR (100 MHz, CDCl₃): δ 187.45, 151.34, 146.89, 144.36, 143.09, 136.65, 133.90, 130.44, 129.82, 128.69, 128.58, 128.56, 128.52, 125.20, 119.50. EI-MS: m/z = 370 [M]⁺. Anal. Calcd. For C₂₁H₁₄N₄O₃: C, 68.10; H, 3.81; N, 15.13. Found: C, 68.14; H, 3.79; N, 15.15.



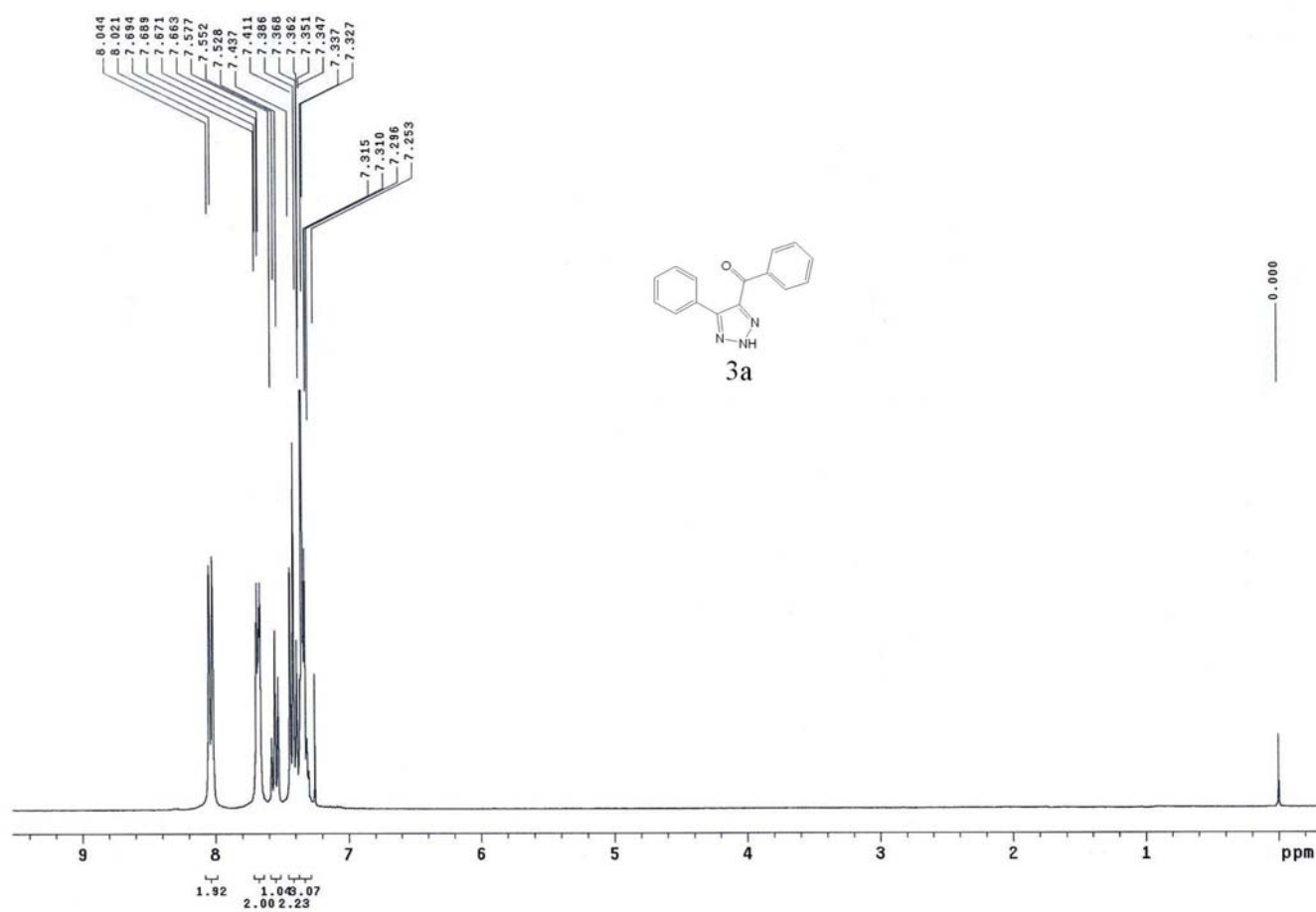
(3,5-dimethylphenyl)(2-(4-nitrophenyl)-5-phenyl-2H-1,2,3-triazol-4-yl)methanone (5b): **5b** was purified by flash chromatography (Hexane-EtOAc, v/v 20/1) as green-yellow solid (70%), mp: 160-162 °C. IR (cm⁻¹): 3118.78, 2920.88, 1668.42, 1595.49. ¹H NMR (400 MHz, CDCl₃): δ 8.35-8.41 (m, 4H), 7.85-7.87 (m, 2H), 7.69 (s, 2H), 7.44 (t, *J* = 3.2 Hz, 3H), 7.29 (s, 1H), 2.38 (s, 6H). ¹³C NMR (100 MHz, CDCl₃): δ 188.15, 151.01, 146.85, 144.79, 143.22, 138.28, 136.68, 135.78, 129.75, 128.65, 128.59, 128.21, 125.23, 119.49, 21.21. ESI HRMS: calcd. for C₂₃H₁₉N₄O₃[M+H]⁺: 399.1452, found: 399.1454.

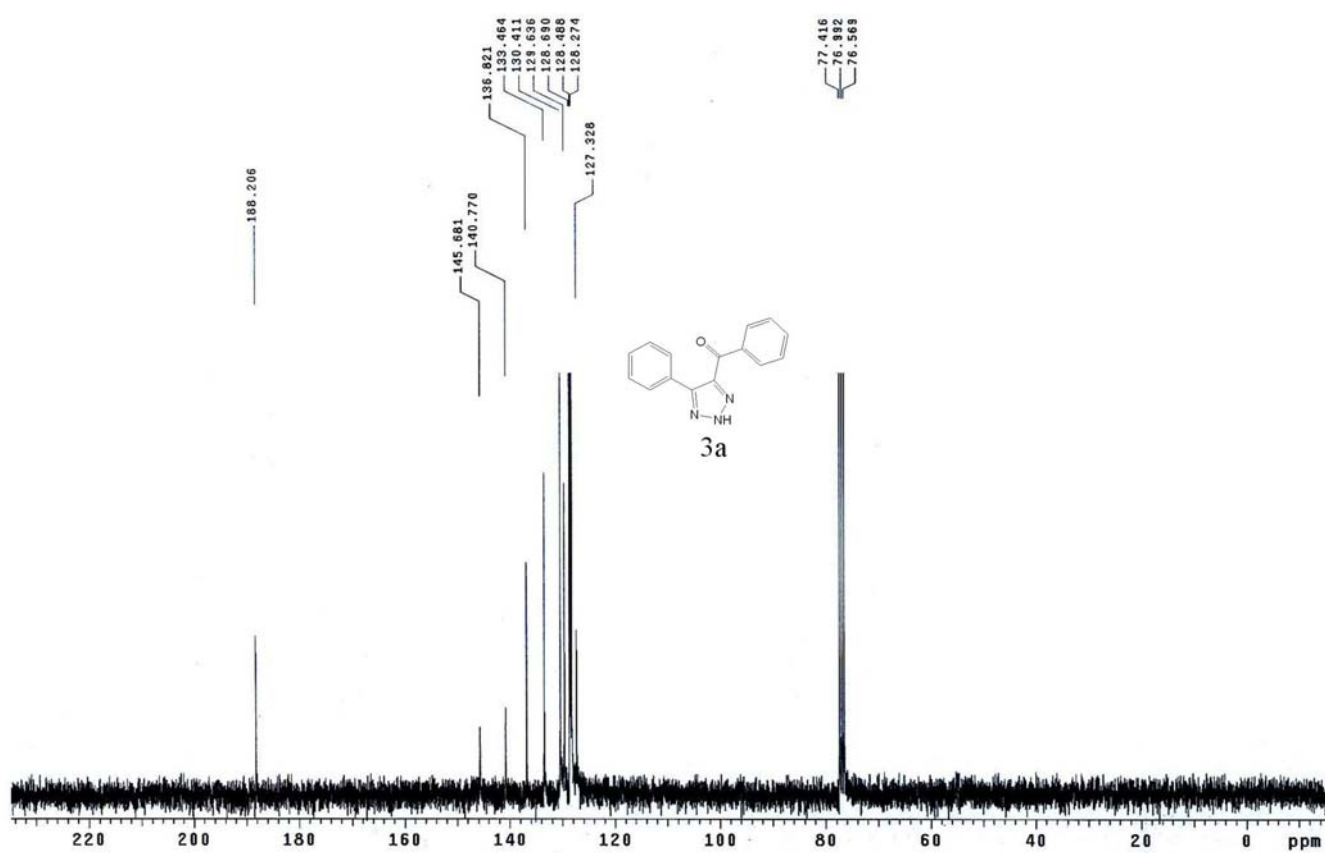


(5-butyl-2-(4-nitrophenyl)-2H-1,2,3-triazol-4-yl)(phenyl)methanone (5c): **5c** was purified by flash chromatography (Hexane-EtOAc, v/v 20/1) as green-yellow solid (85%), mp: 91-93 °C. IR (cm⁻¹): 3120.39, 2956.82, 1647.69, 1592.42. ¹H NMR (400 MHz, CDCl₃): δ 8.38 (dd, *J* = 1.8, 7.4 Hz, 2H), 8.24-8.31 (m, 4H), 7.66 (t, *J* = 7.4 Hz, 1H), 7.55 (t, *J* = 7.6 Hz, 2H), 3.11 (t, *J* = 7.8 Hz, 2H), 1.76-1.83 (m, 2H), 1.44-1.53 (m, 2H), 0.99 (t, *J* = 7.2 Hz, 3H). ¹³C NMR (100 MHz, CDCl₃): δ 186.84, 155.28, 146.73, 144.65, 143.28, 136.96, 133.40, 130.33, 128.41, 125.16, 119.40, 30.52, 25.84, 22.49, 13.81. EI-MS: *m/z* = 350 [M]⁺. Anal. Calcd for C₁₉H₁₈N₄O₃: C, 65.13; H, 5.18; N, 15.99. Found: C, 65.10; H, 5.23; N, 15.60.

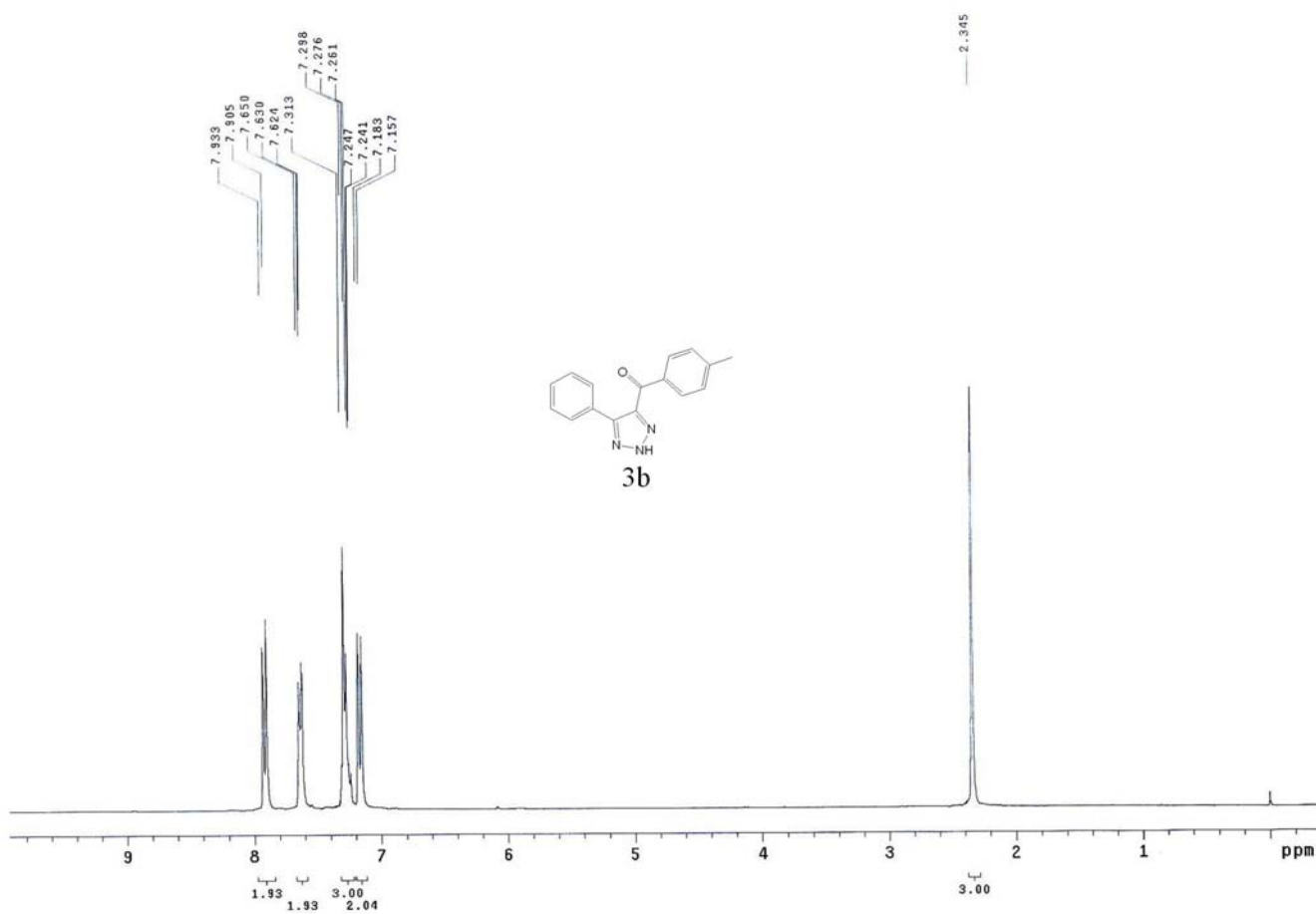
III. ^1H and ^{13}C NMR spectra of selected compounds:

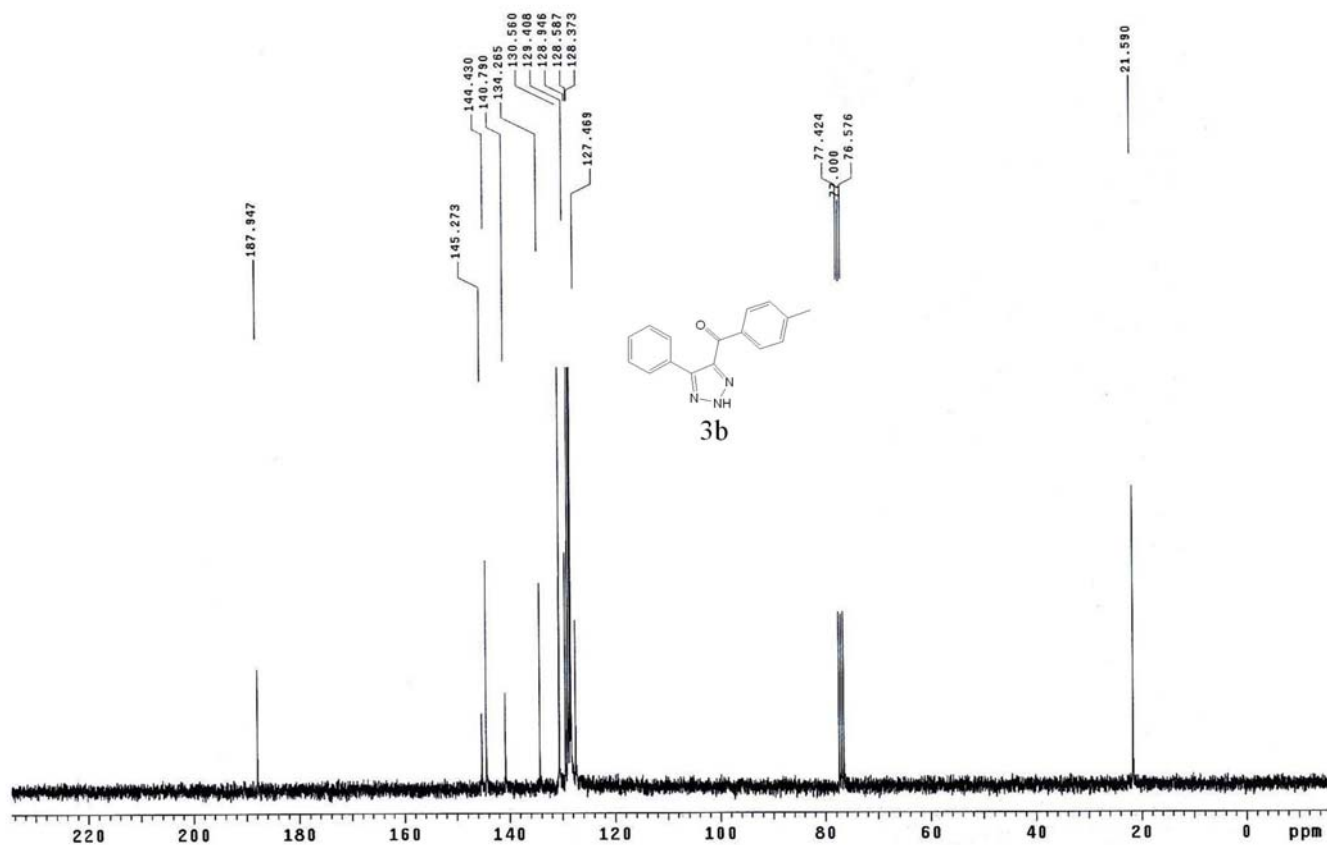
3a:



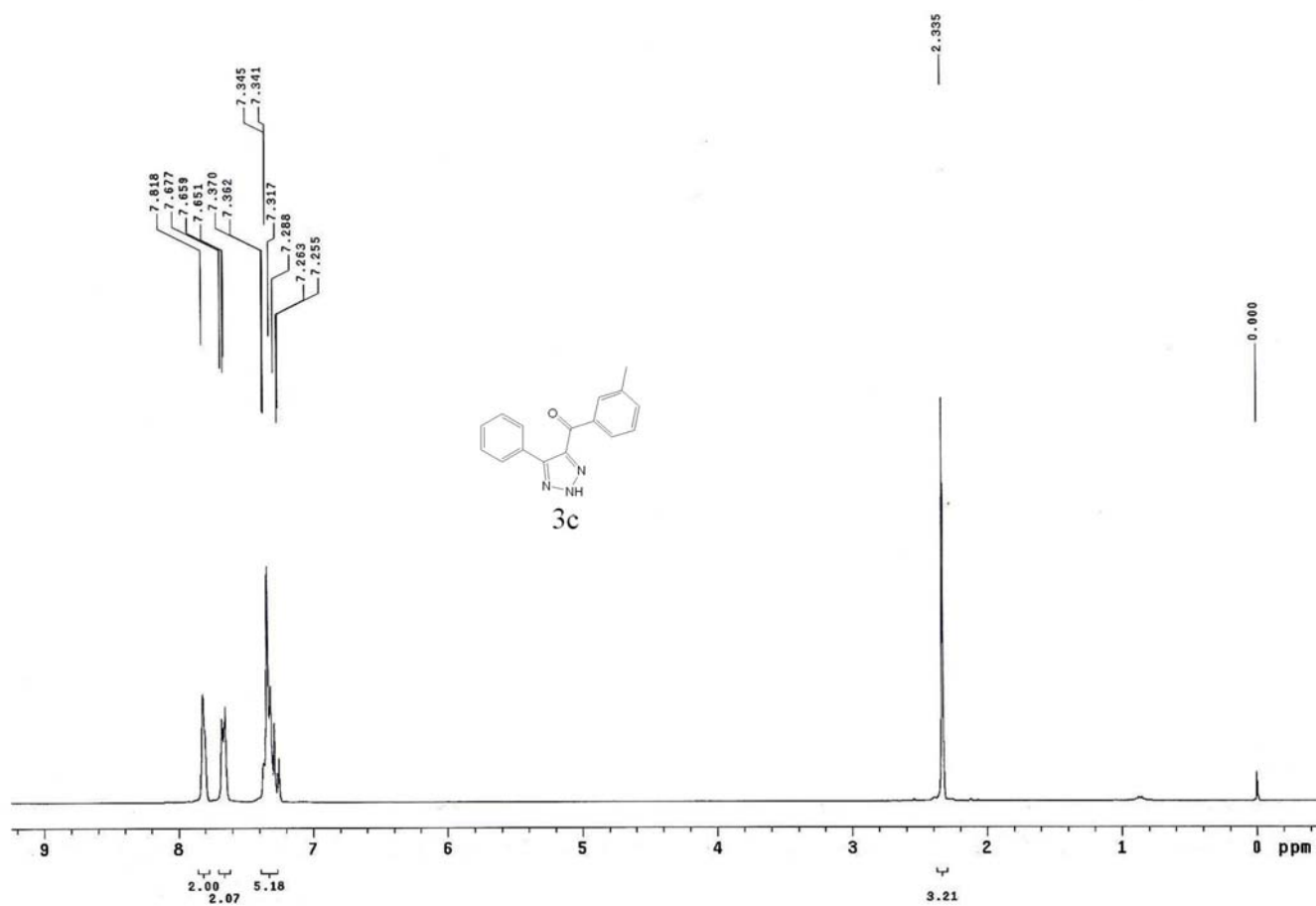


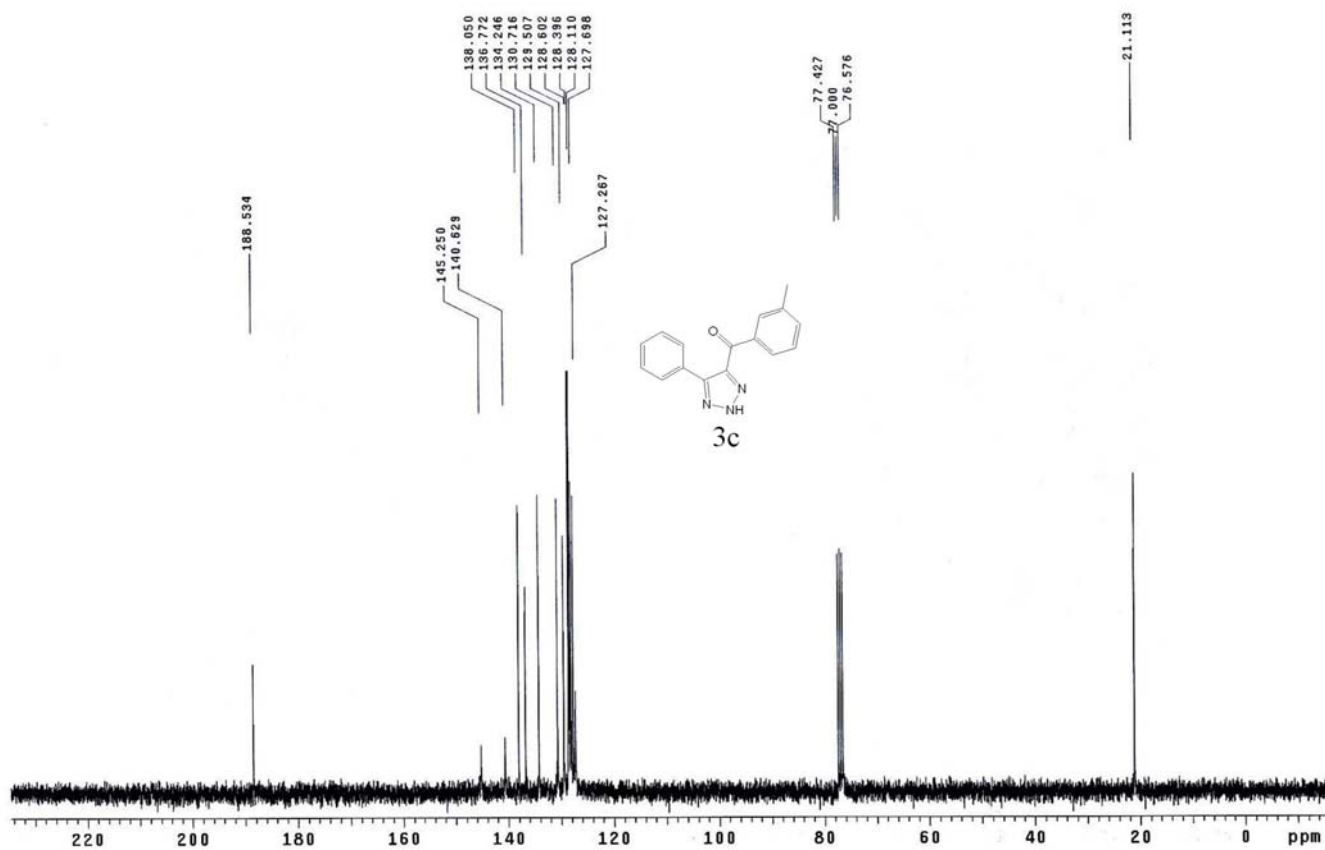
3b:



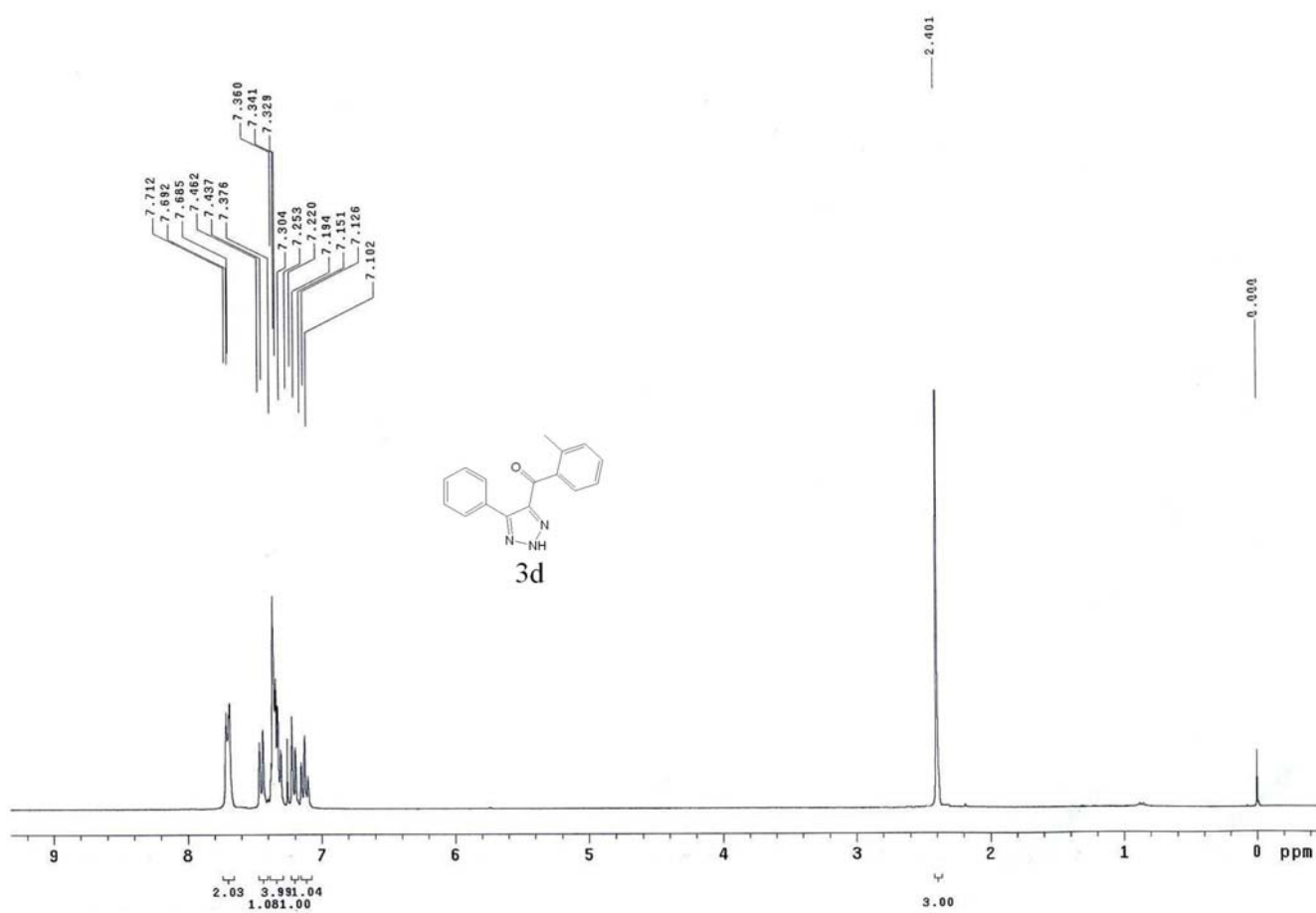


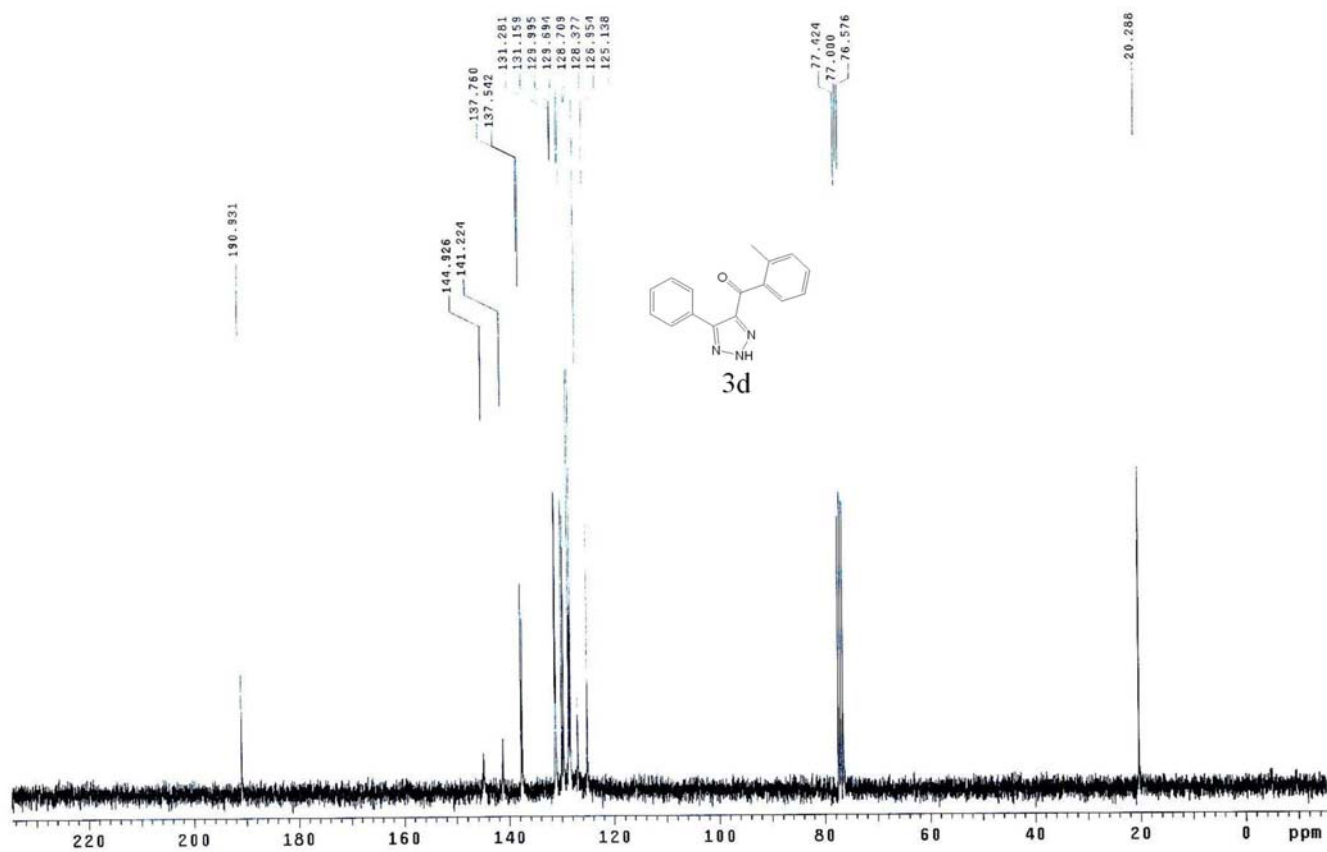
3c:



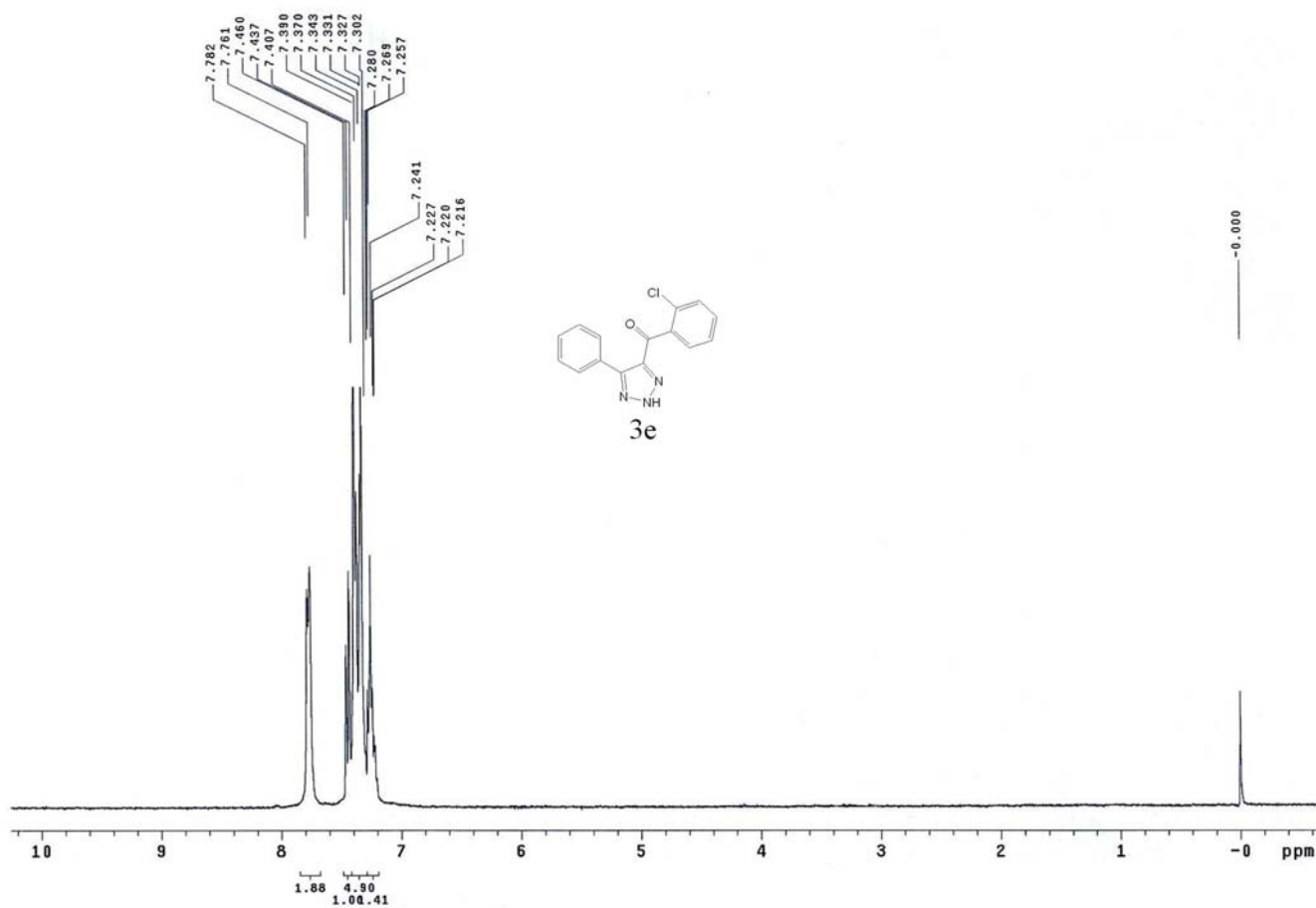


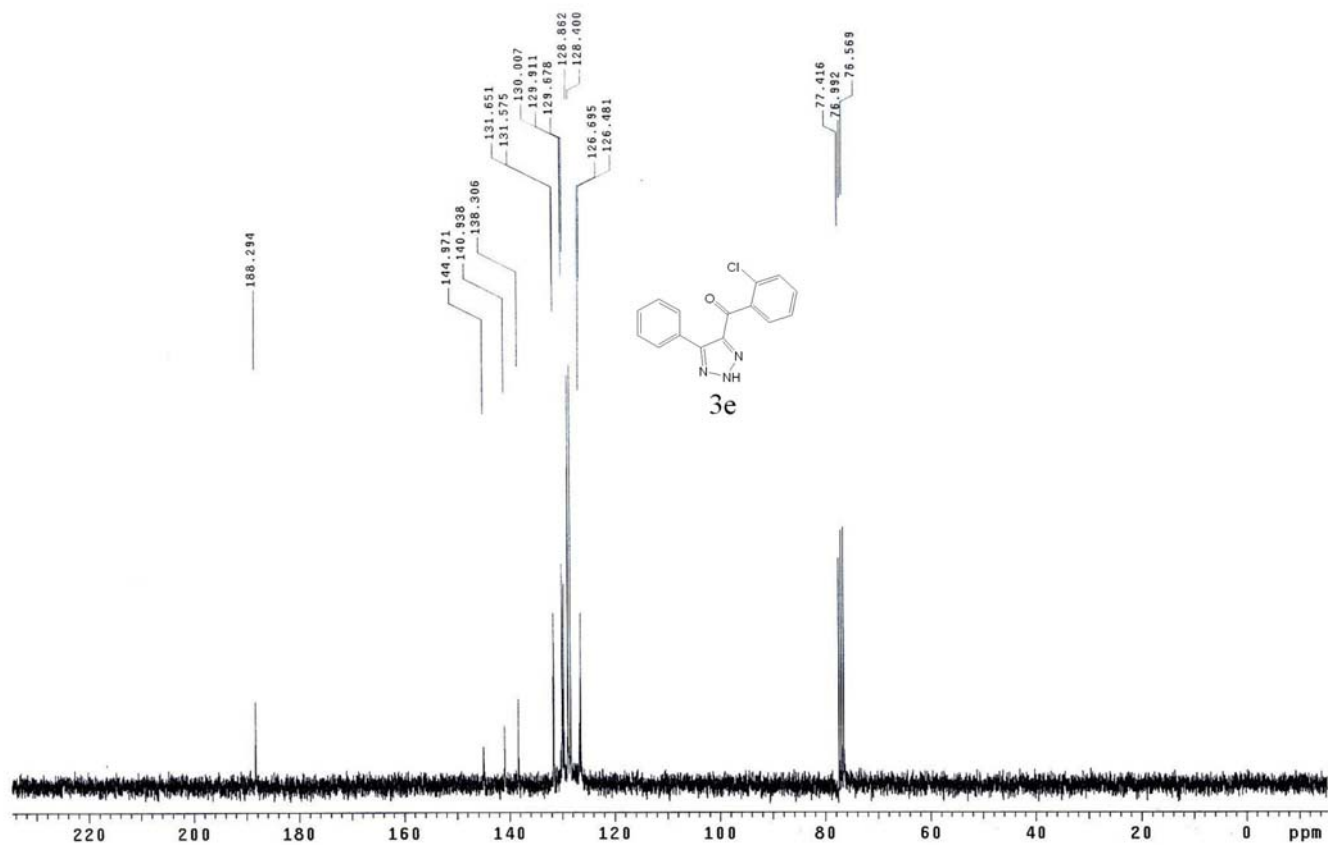
3d:



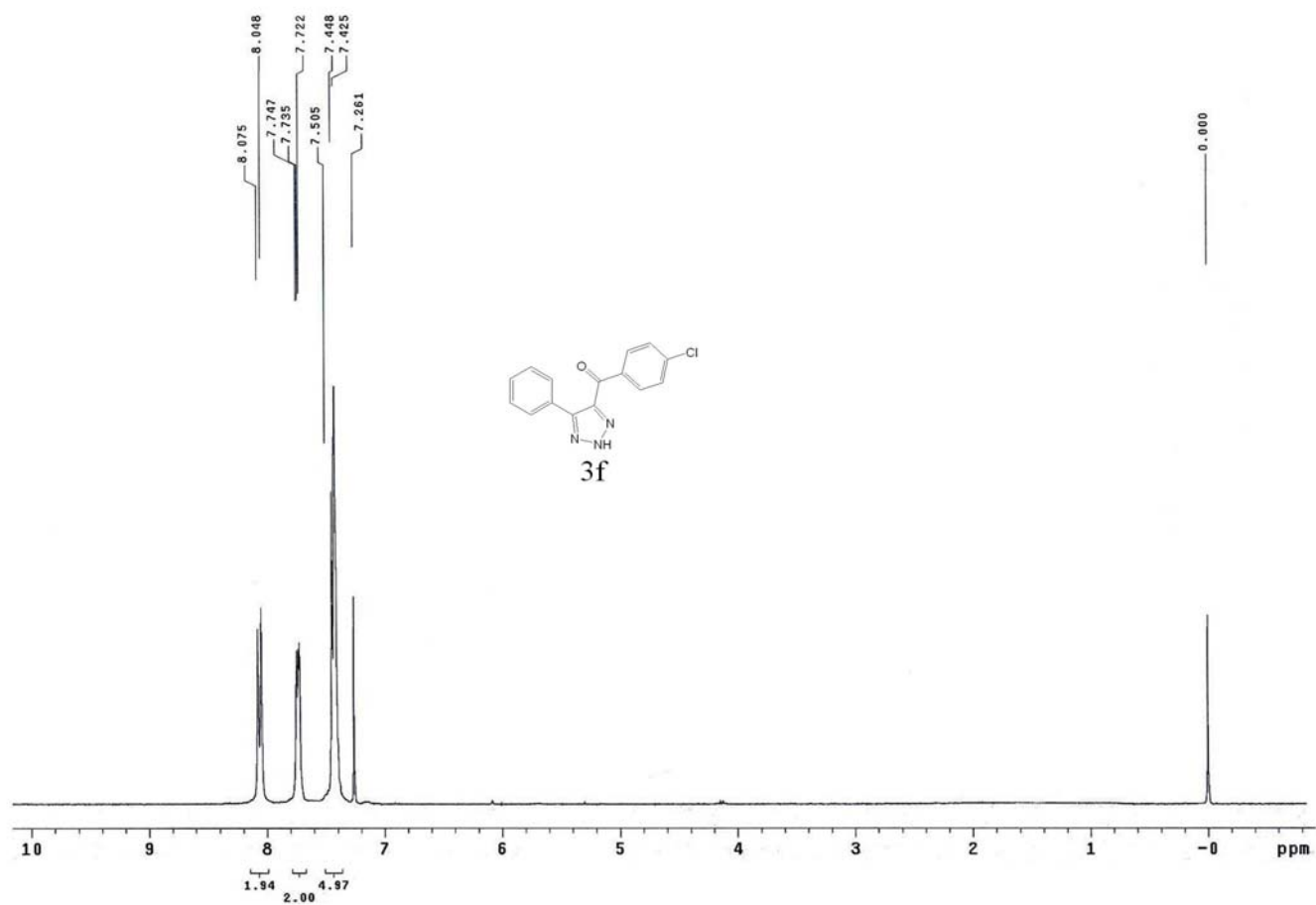


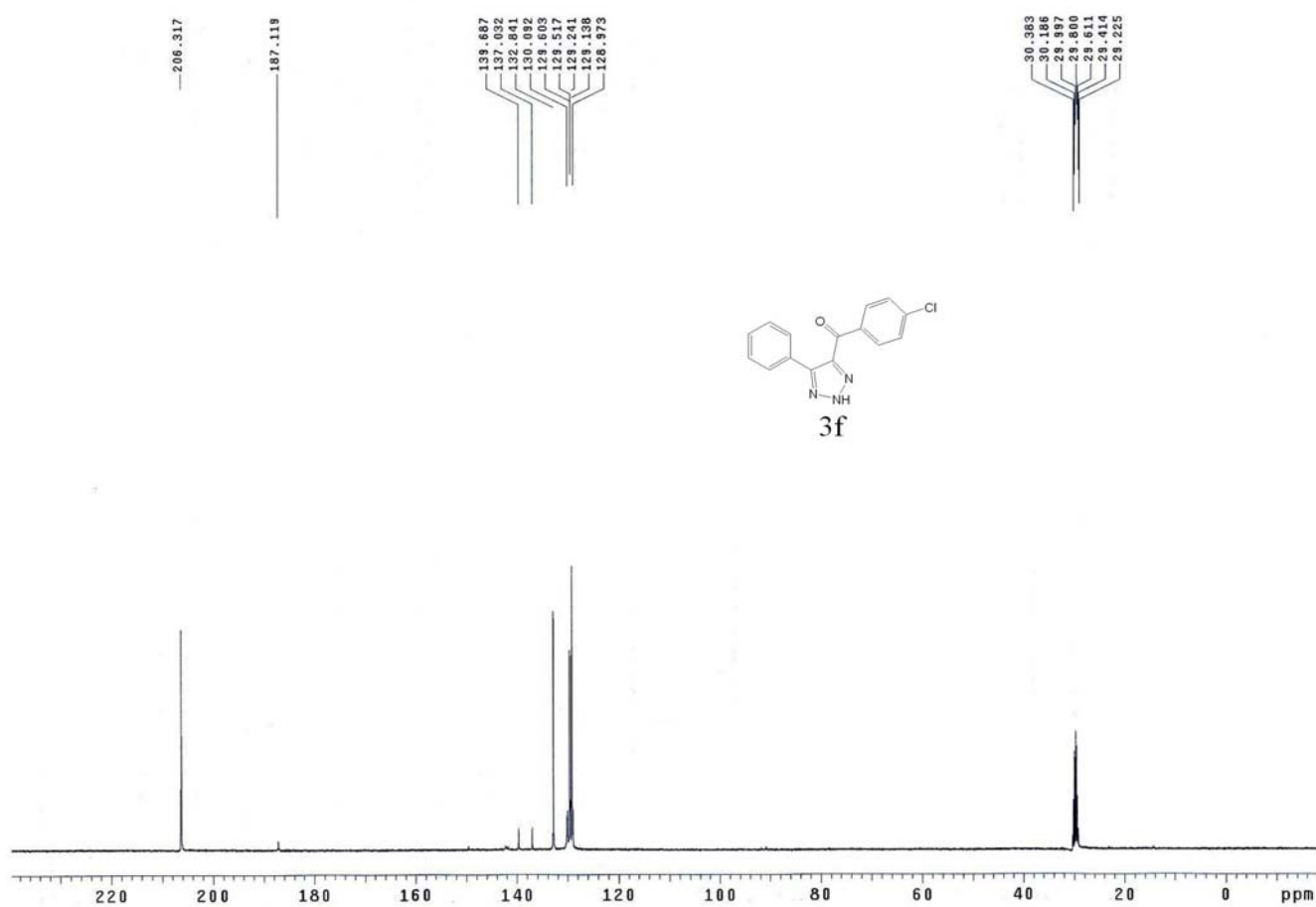
3e:



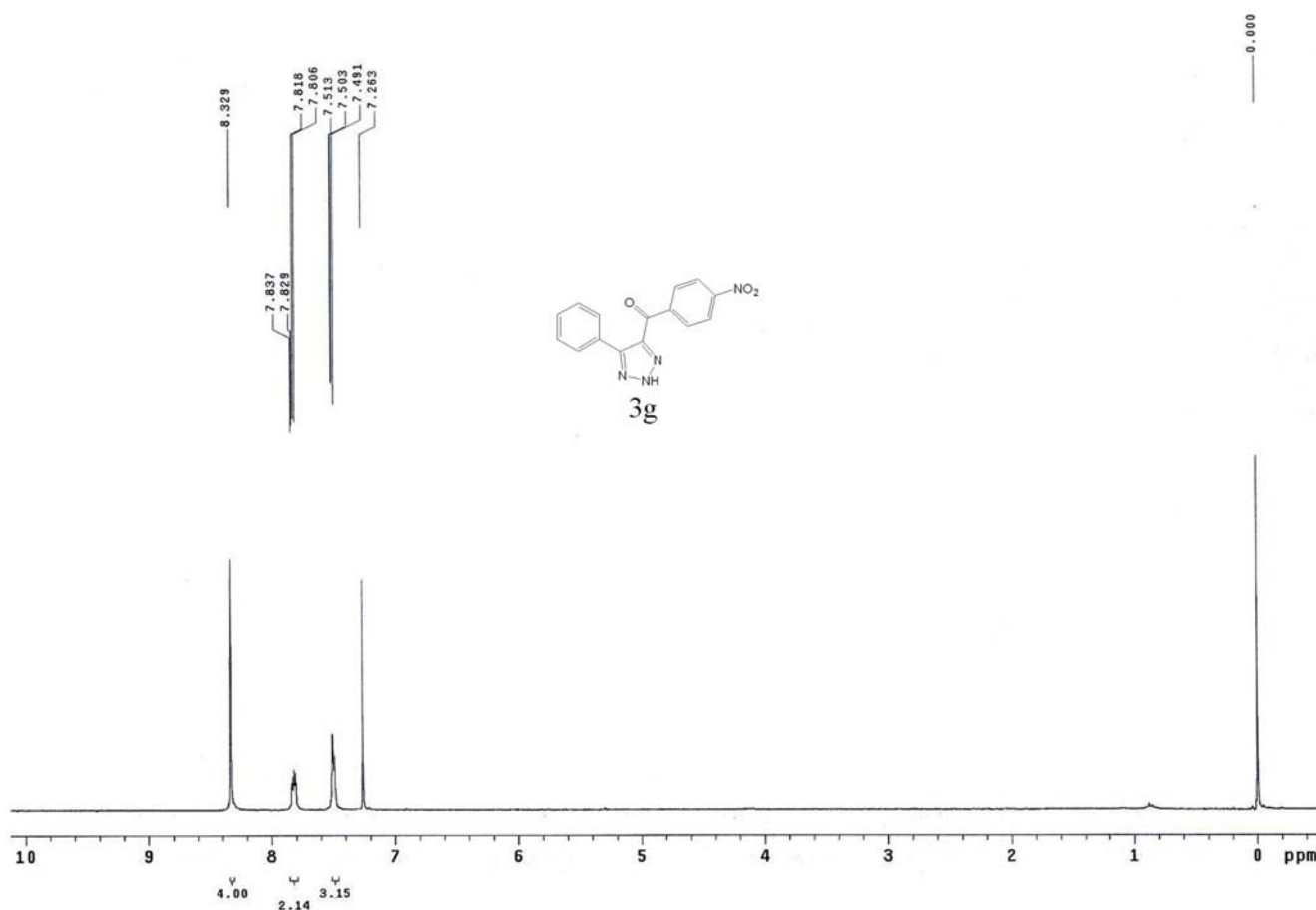


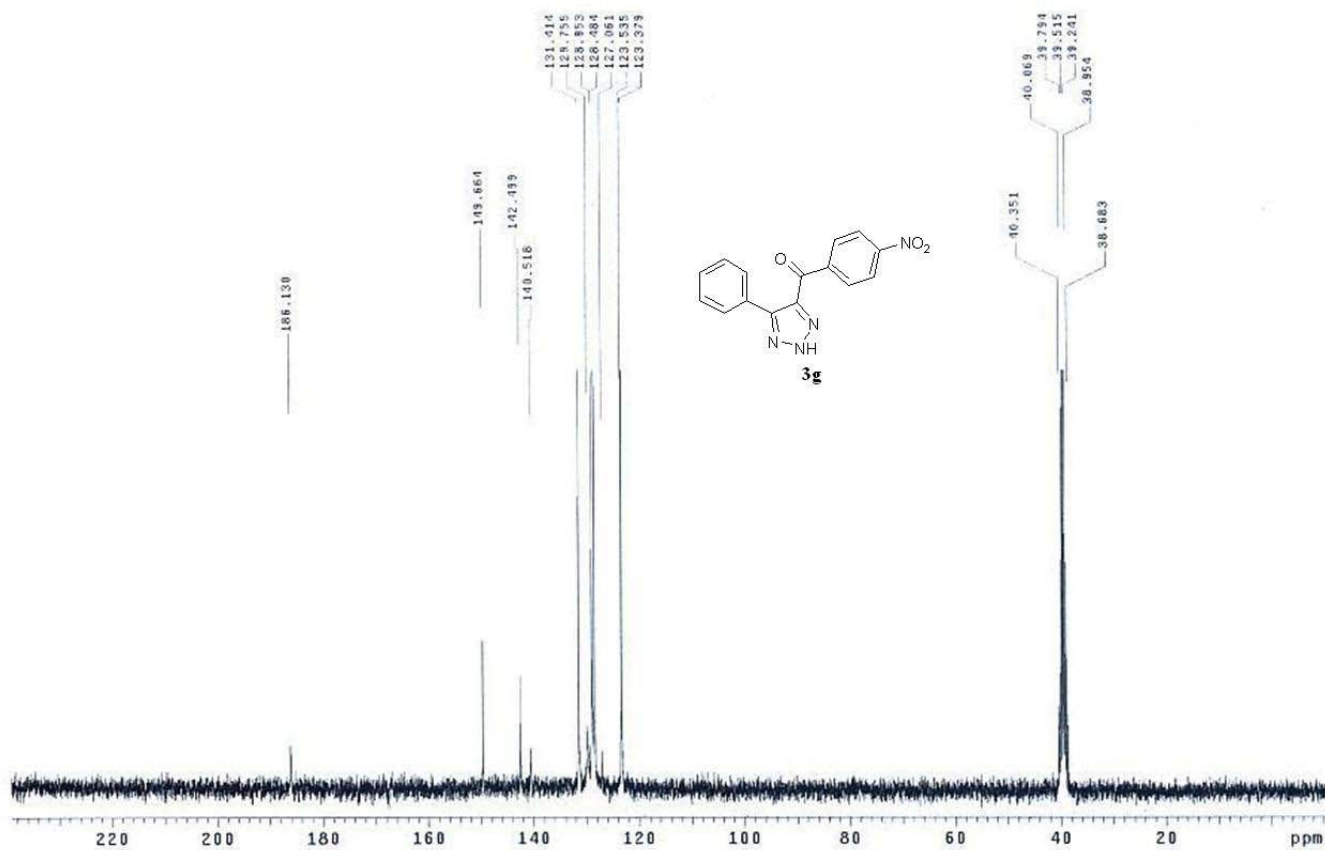
3f:



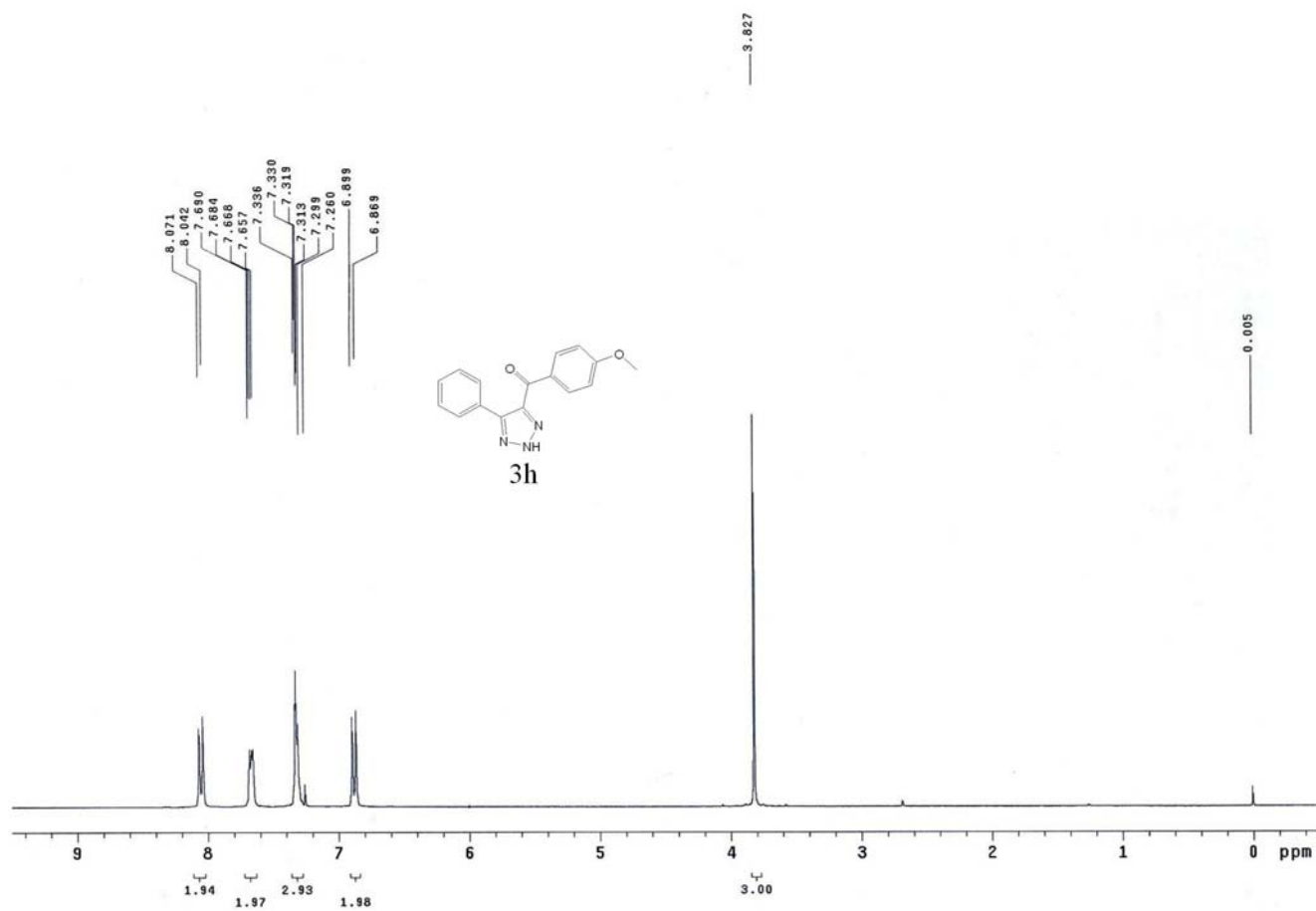


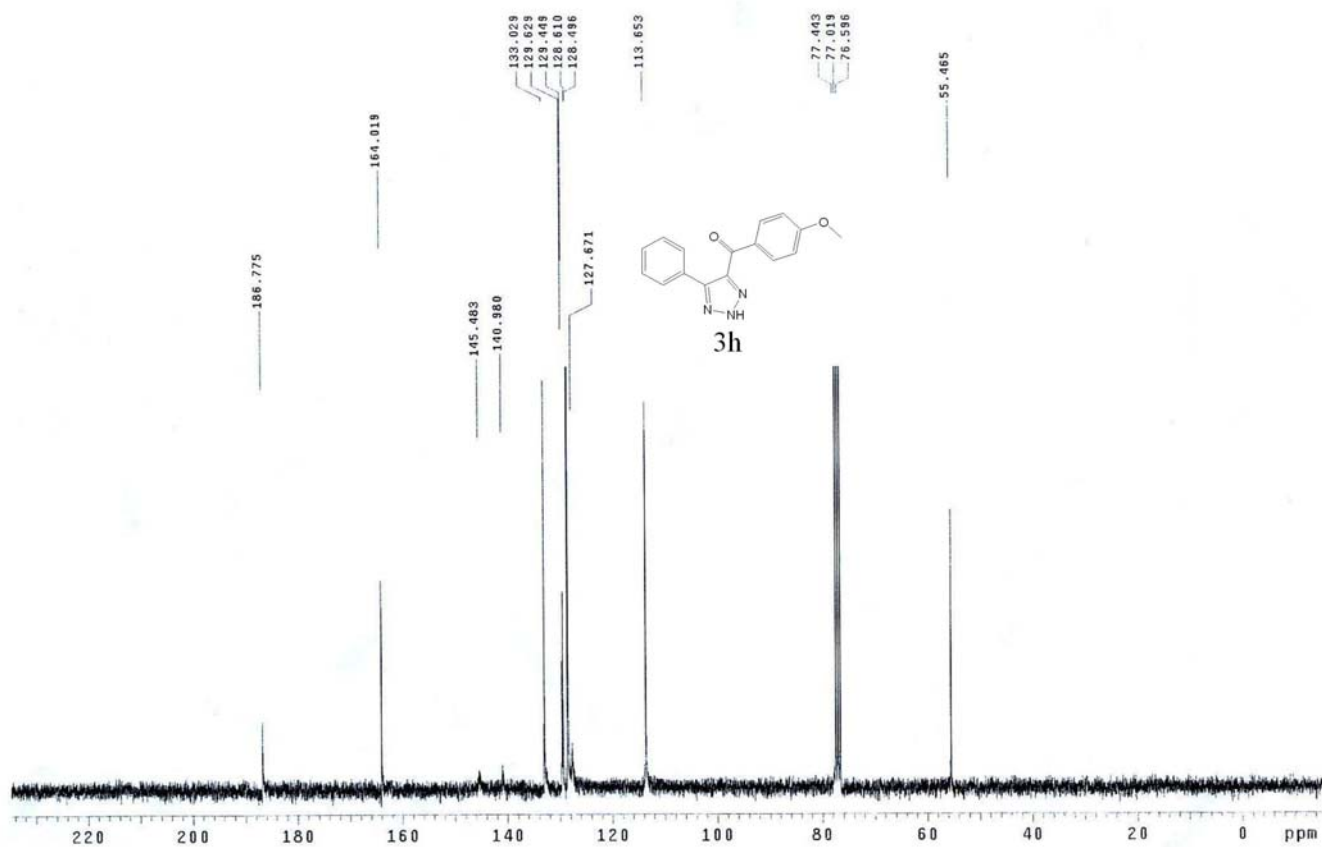
3g:



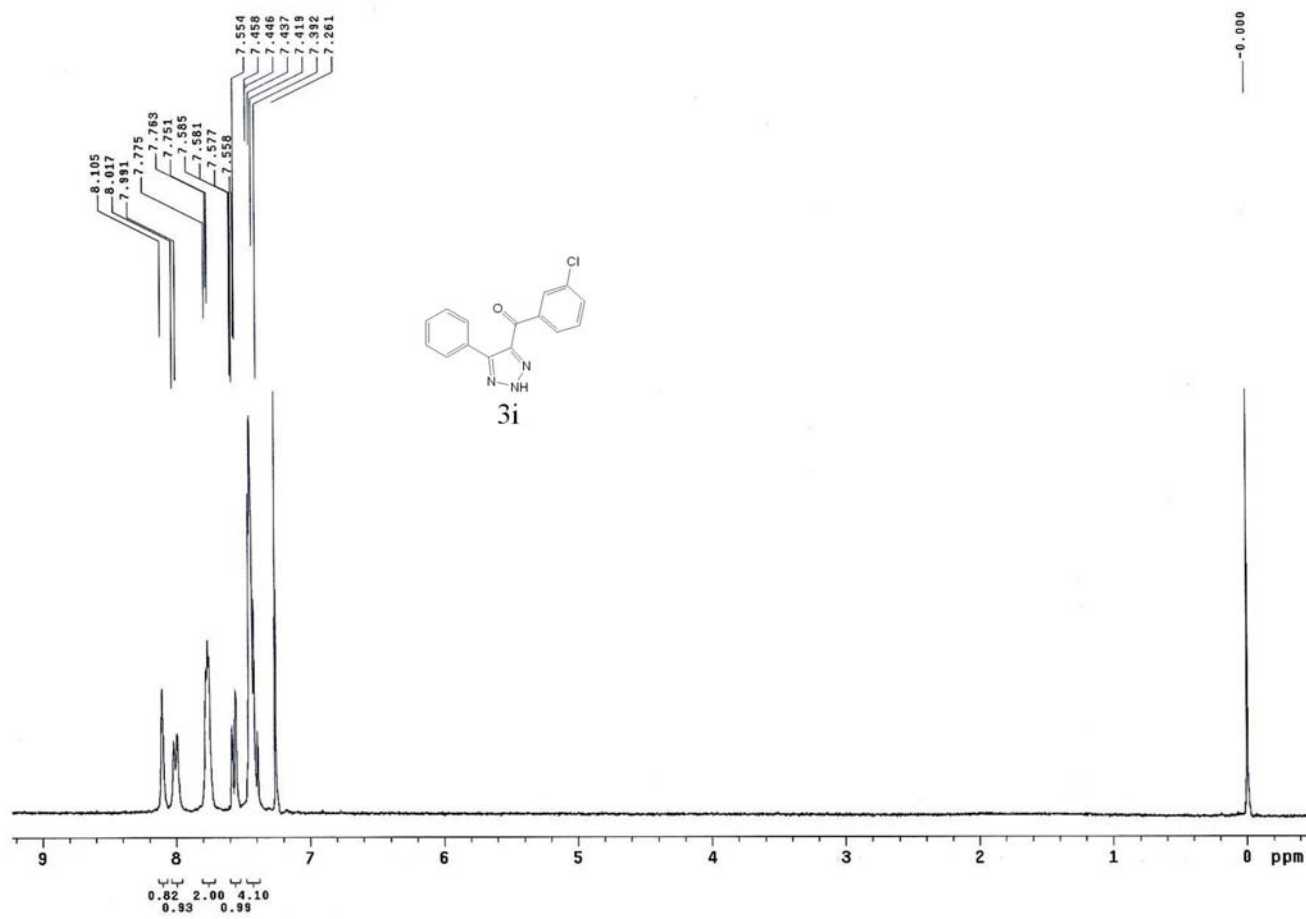


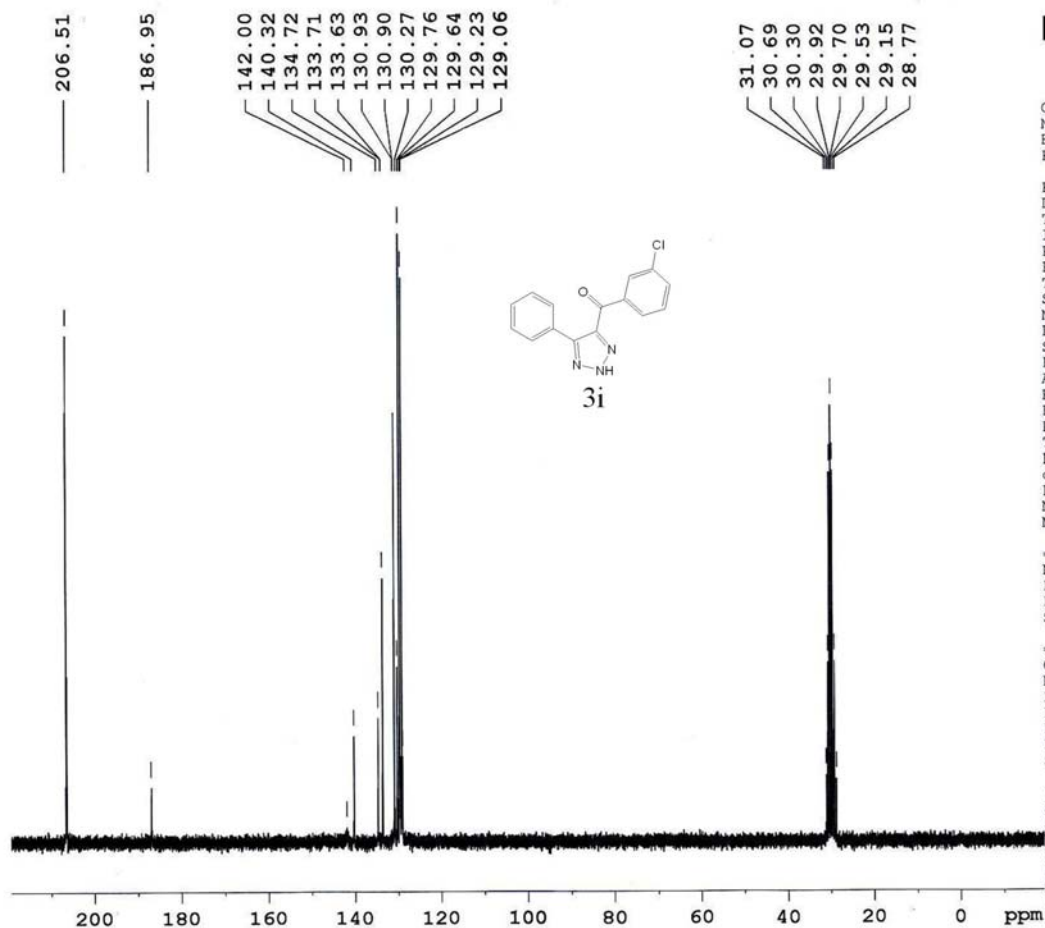
3h:





3i:





Current Data Parameters
NAME lijihui-C
EXPNO 4
PROCNO 1

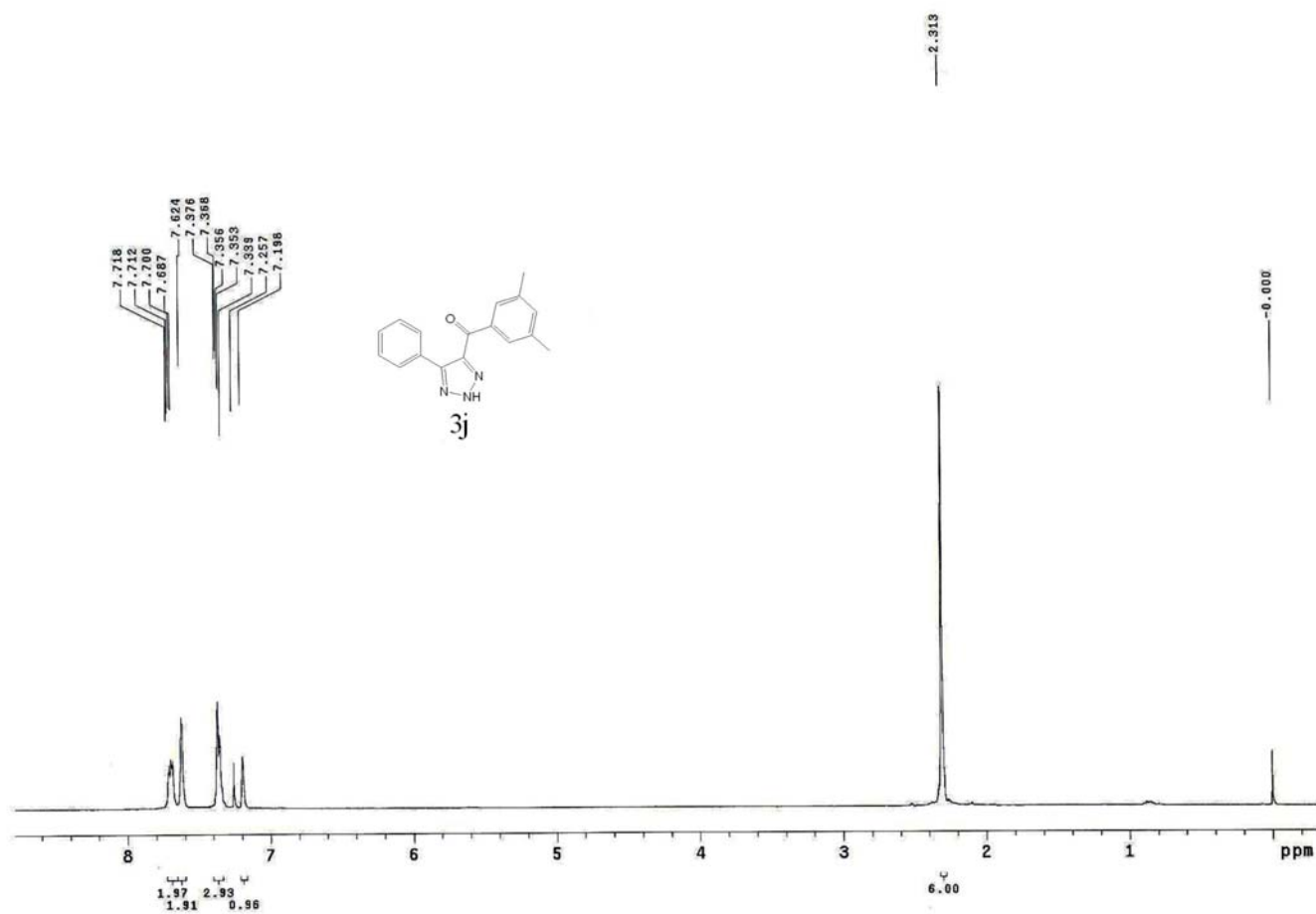
F2 - Acquisition Parameters
Date 20090330
Time 12.25
INSTRUM drx200
PROBHD 5 mm Dual 13C/
PULPROG zgpg30
TD 32768
SOLVENT Acetone
NS 1024
DS 0
SWH 12562.814 Hz
FIDRES 0.383387 Hz
AQ 1.3042164 sec
RG 1625.5
DW 39.800 usec
DE 6.00 usec
TE 0.0 K
D1 2.00000000 sec
d11 0.03000000 sec
DELTA 1.89999998 sec
MCREST 0.00000000 sec
MCWRK 0.01500000 sec

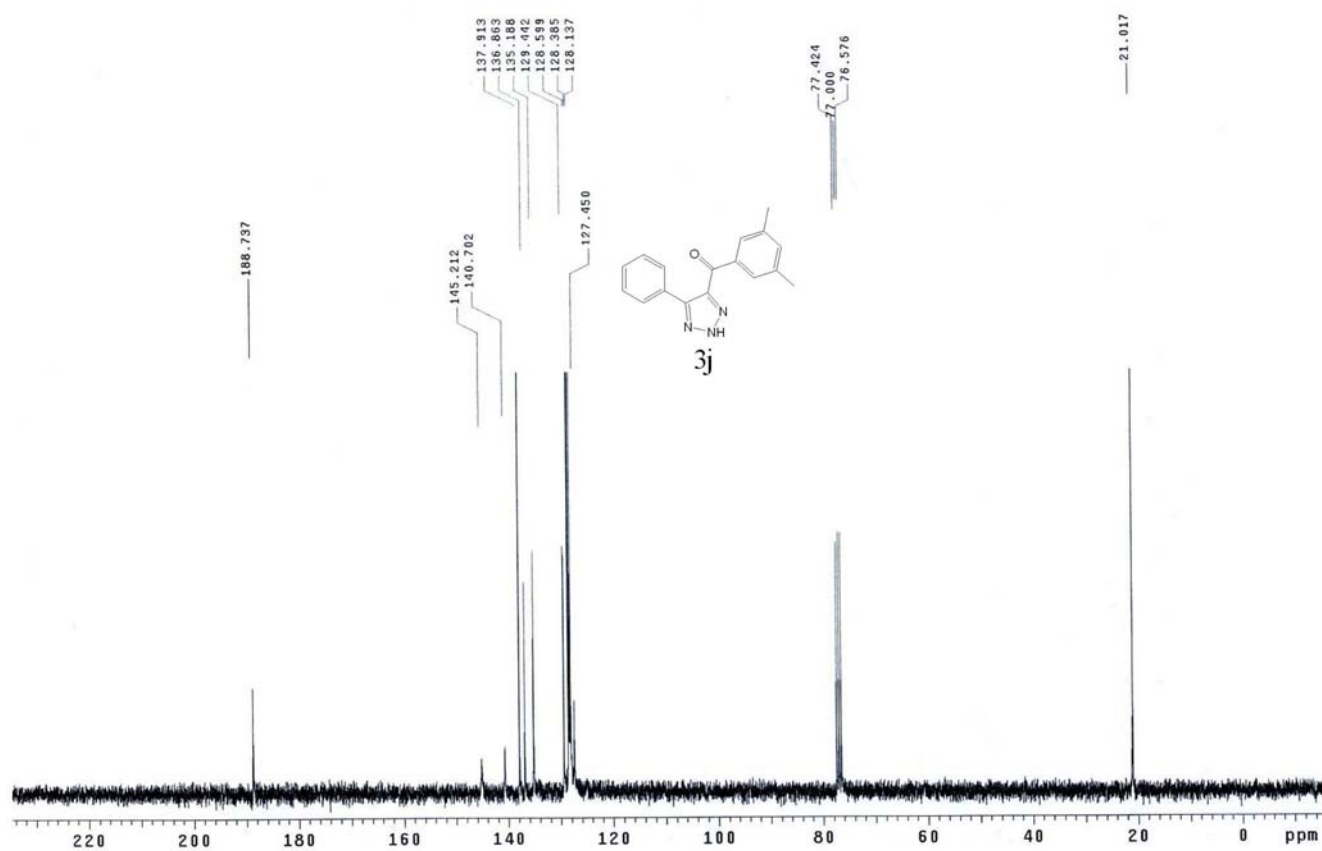
----- CHANNEL f1 -----
NUC1 13C
P1 9.80 usec
PL1 -1.00 dB
SFO1 50.3277608 MHz

----- CHANNEL f2 -----
CPDPRG2 waltz16
NUC2 1H
PCPD2 80.00 usec
PL2 -3.00 dB
PL12 15.24 dB
PL13 15.24 dB
SFO2 200.1310007 MHz

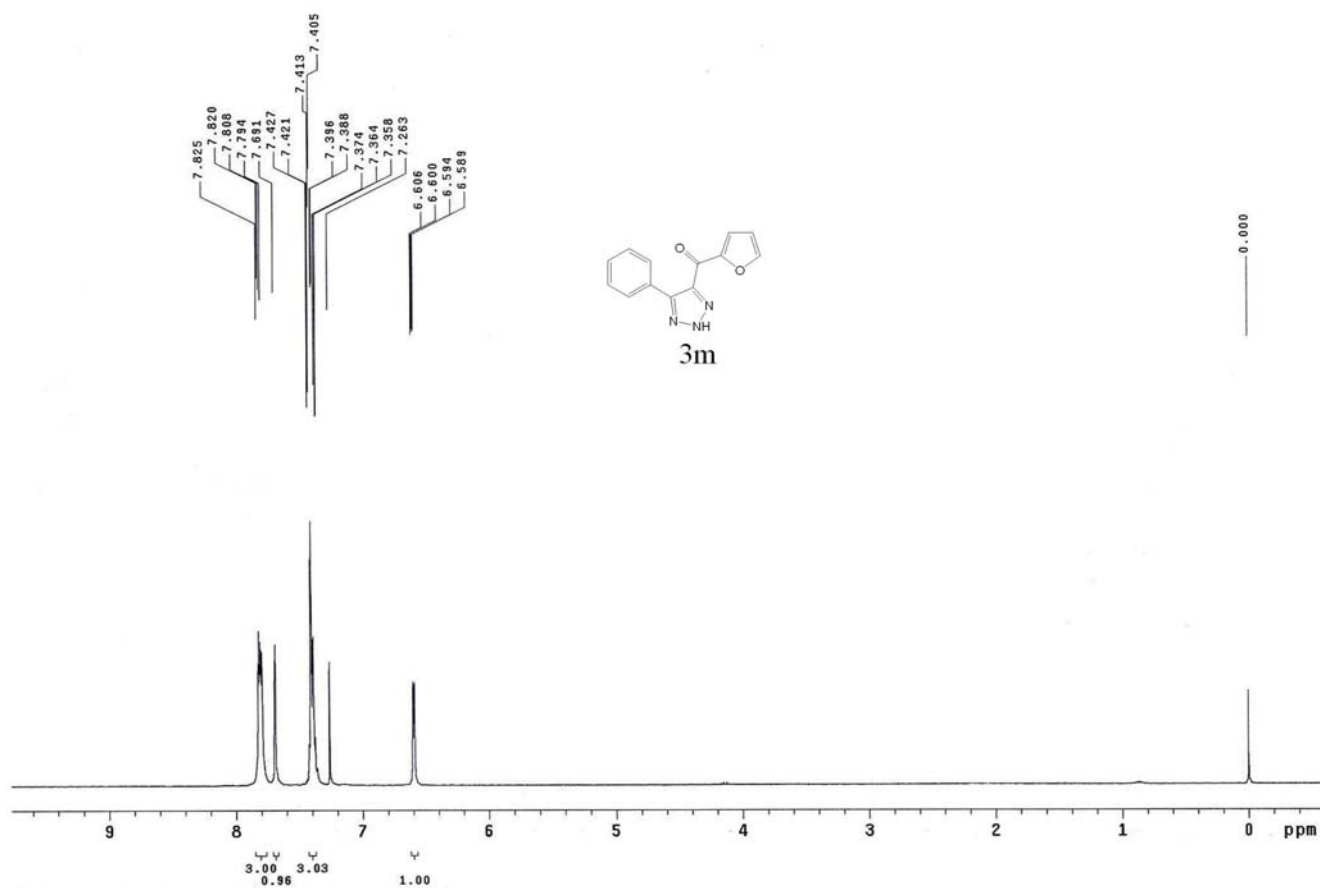
F2 - Processing parameters
SI 32768
SF 50.3226847 MHz
WDW no
SSB 0
LB 0.00 Hz
GB 0
PC 1.00

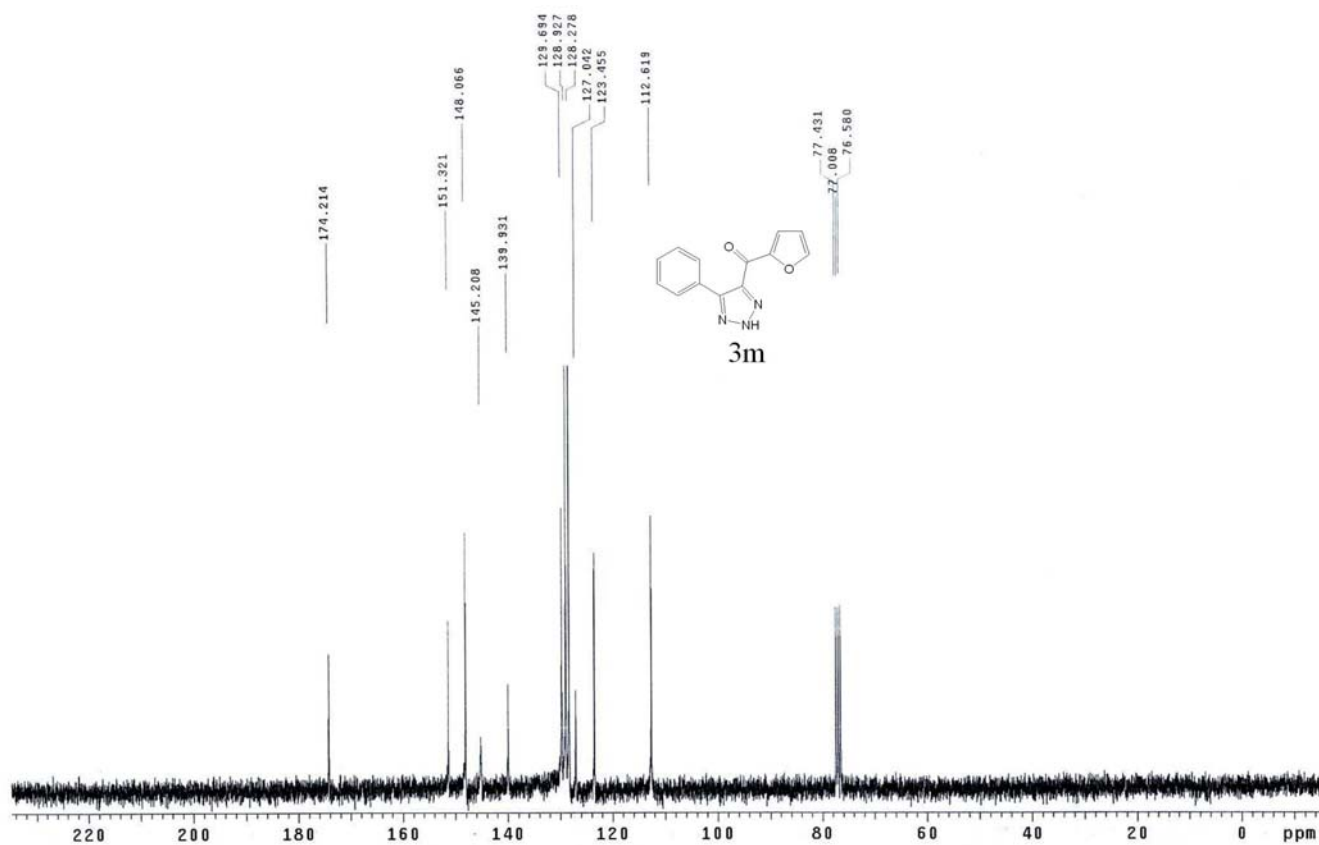
3j:



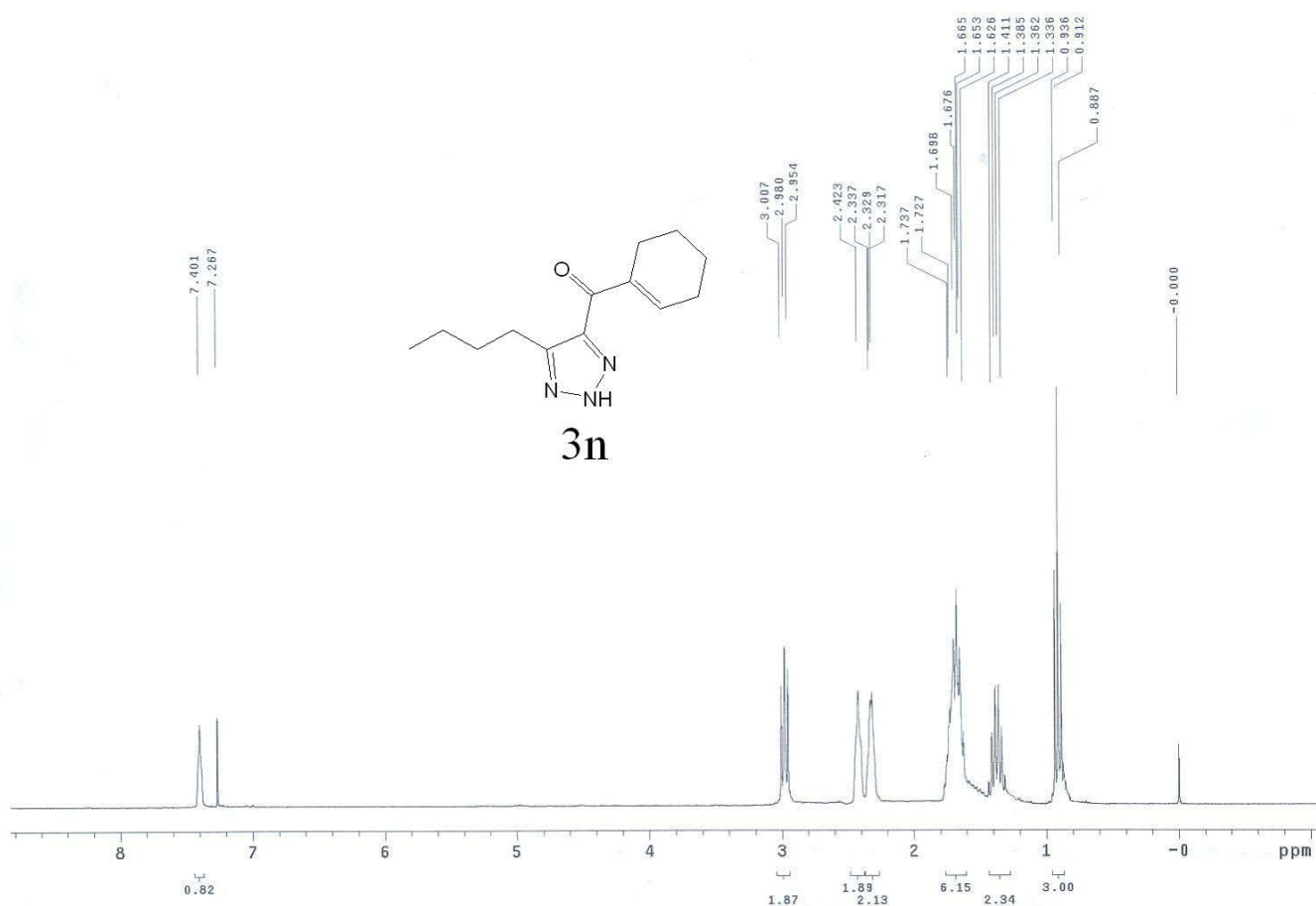


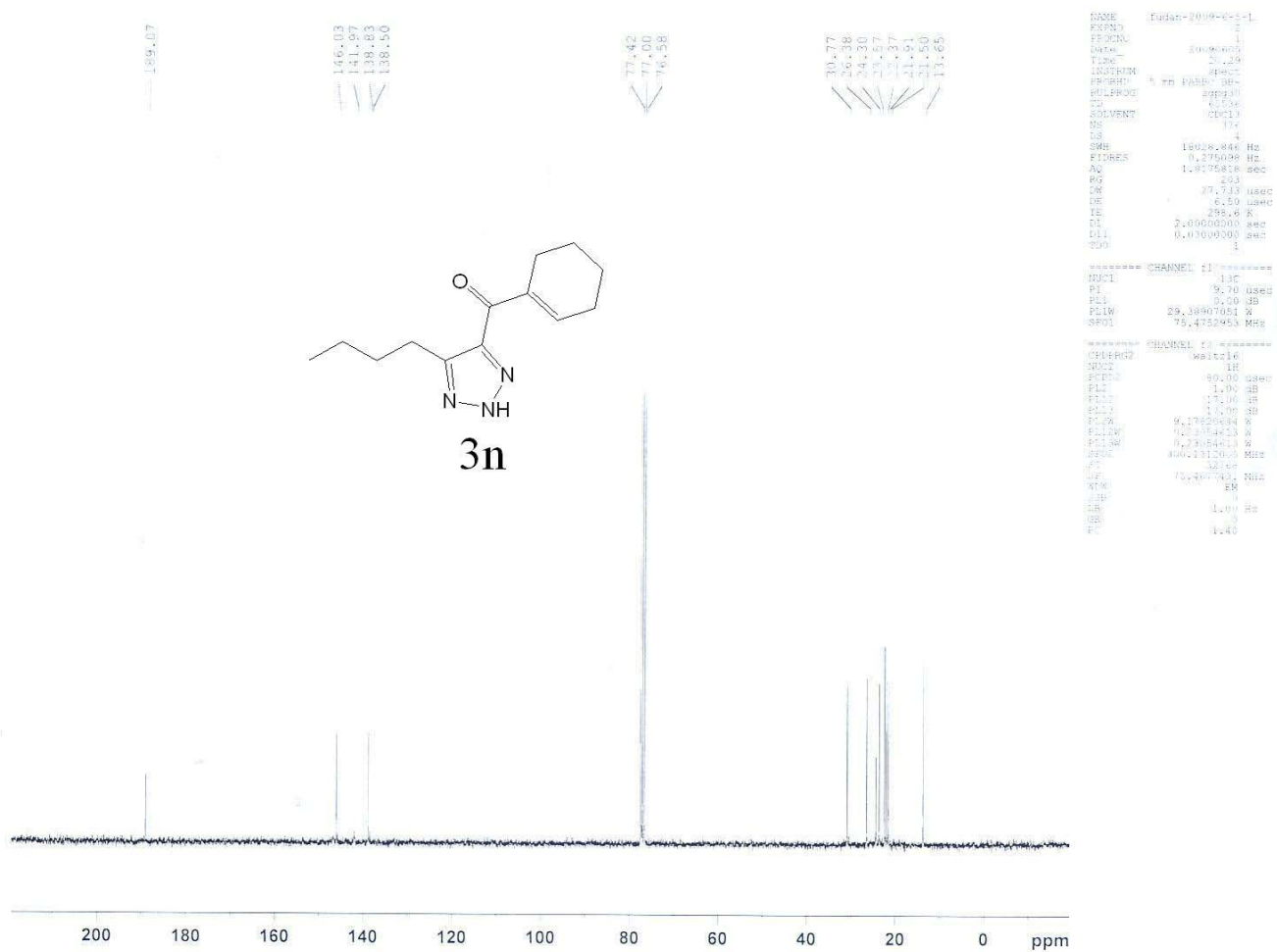
3m:



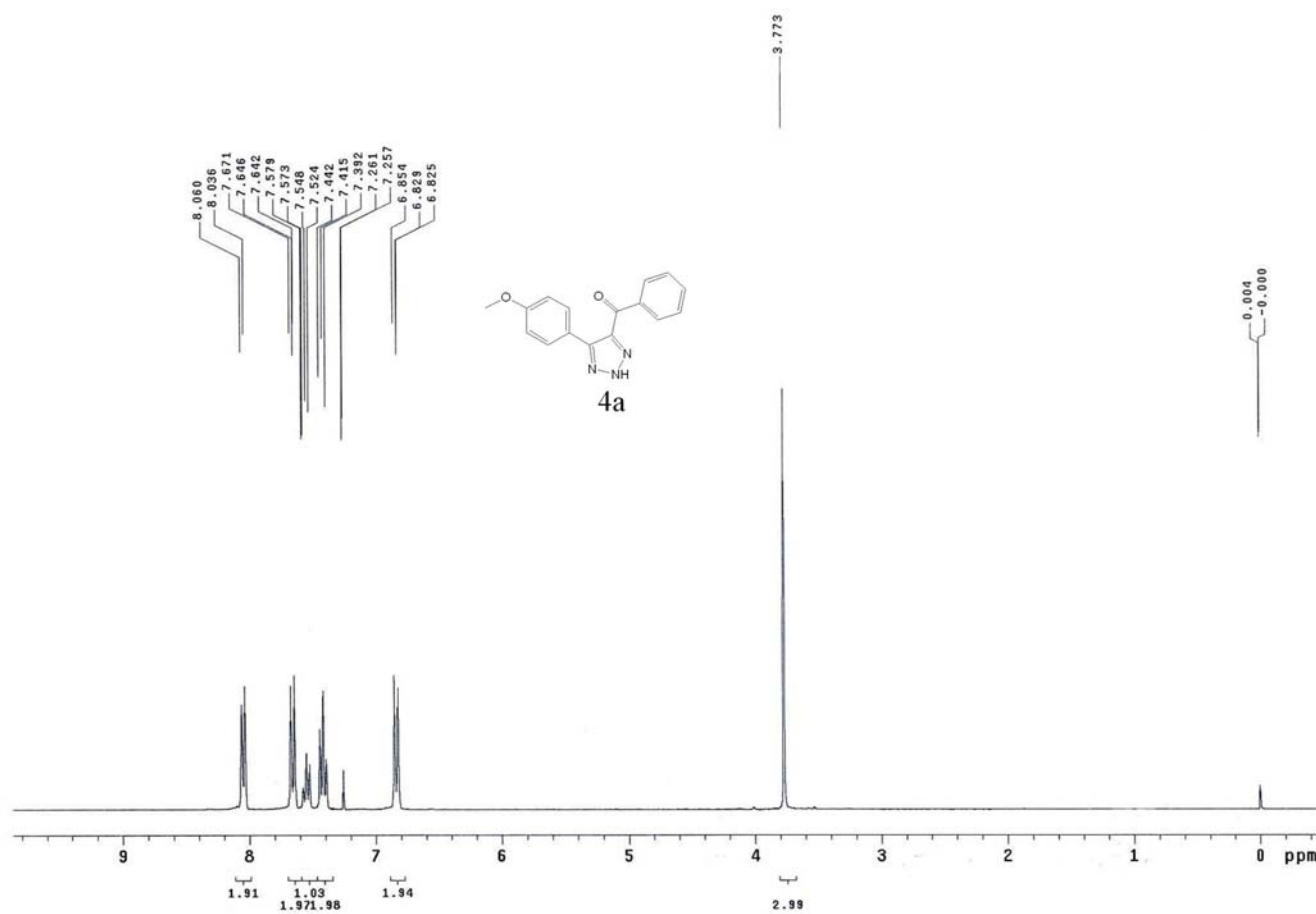


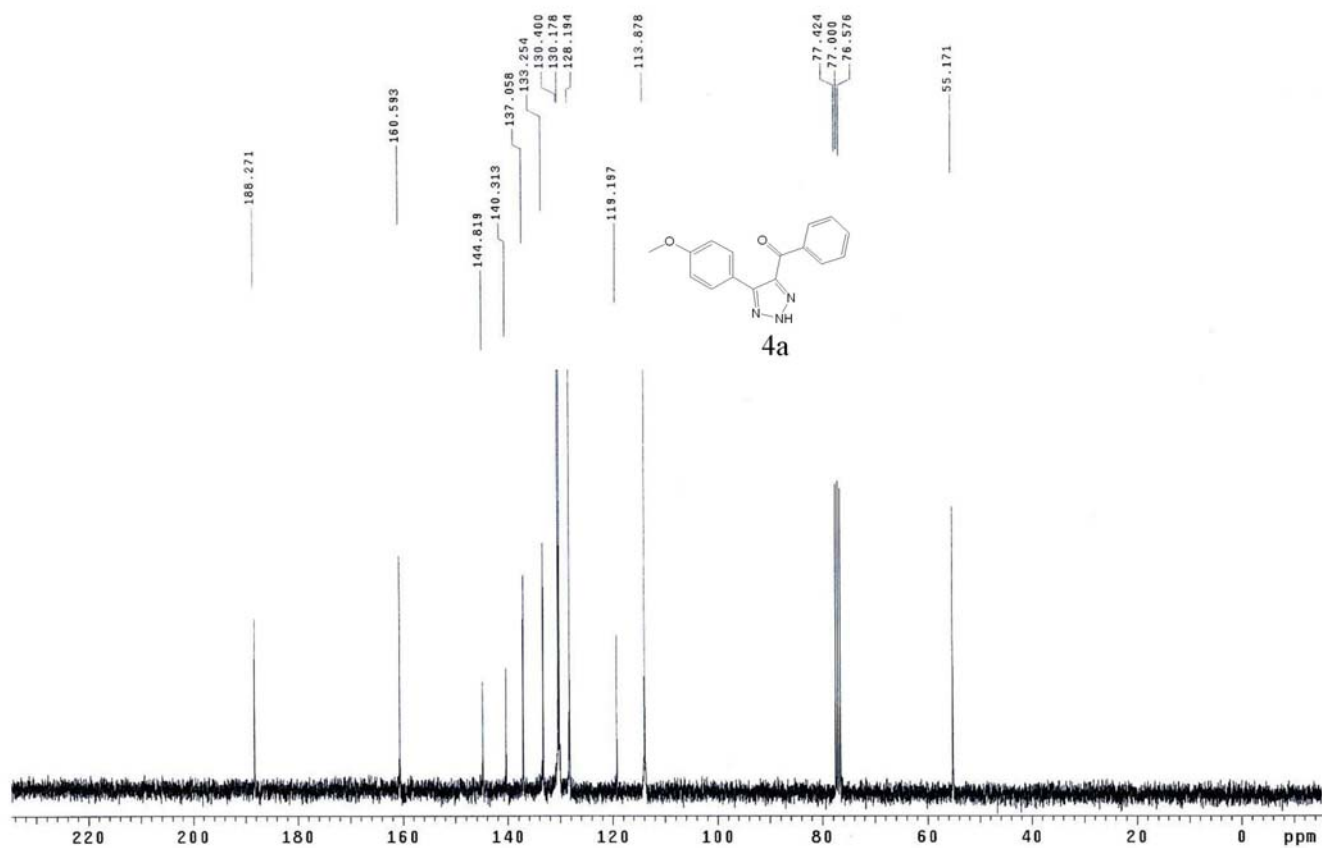
3n



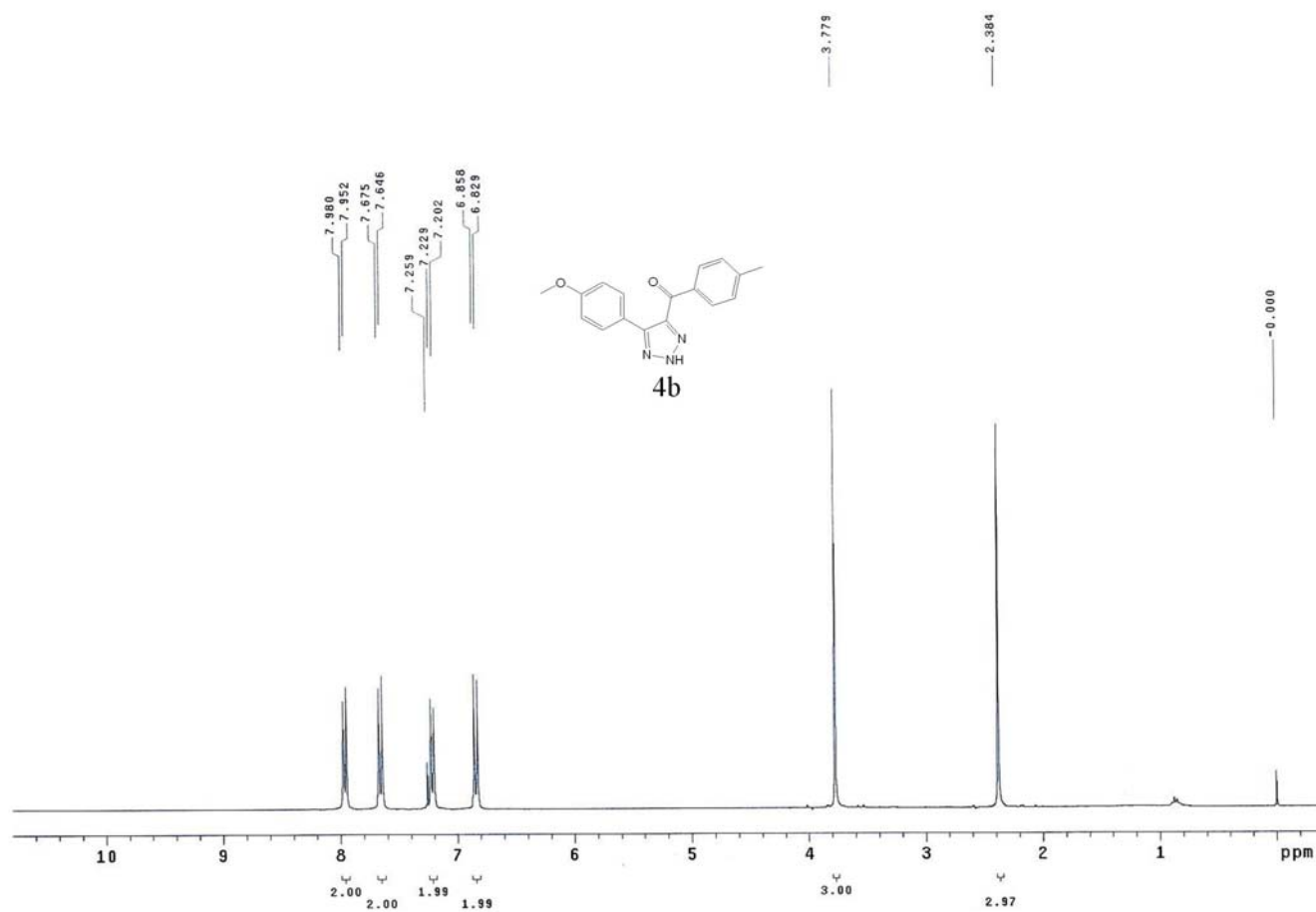


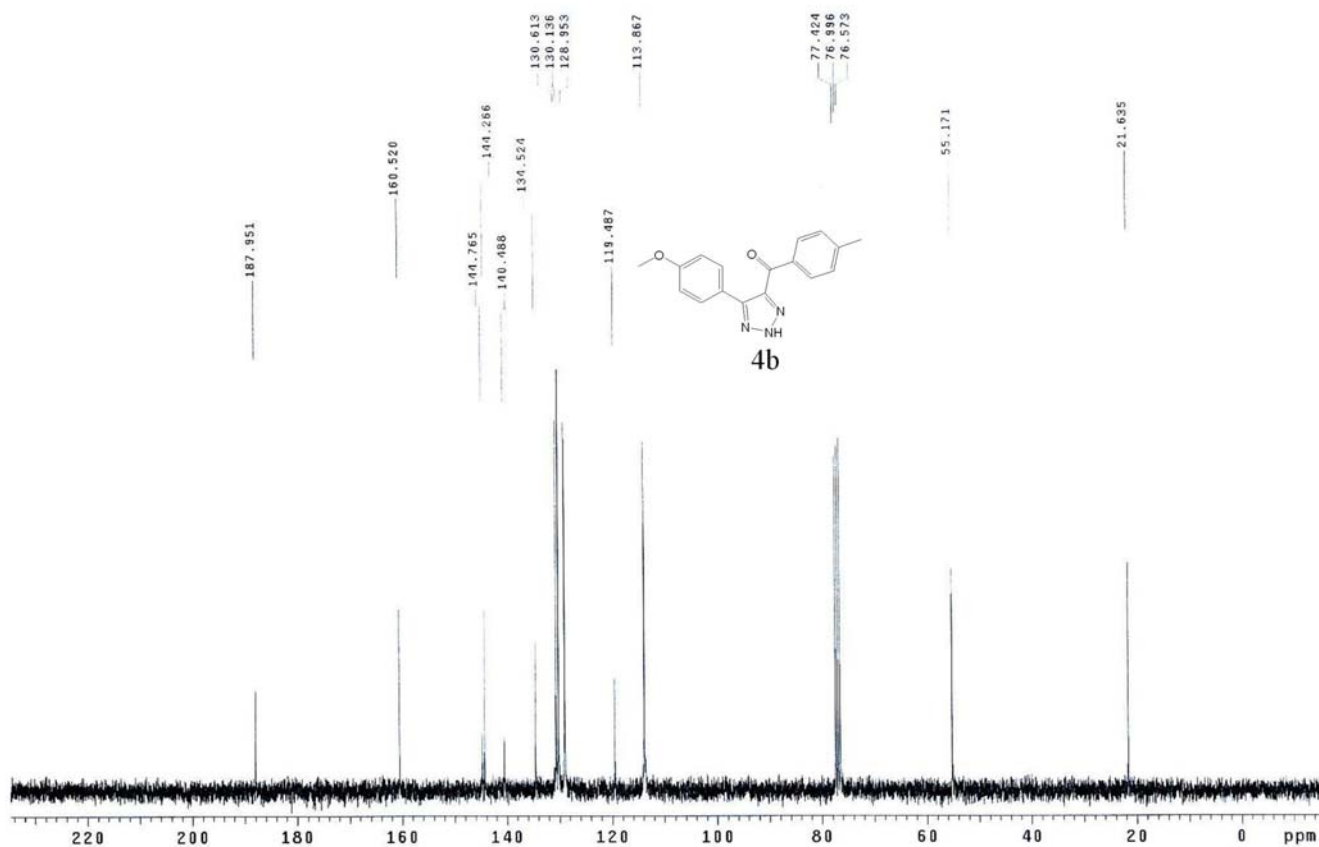
4a:



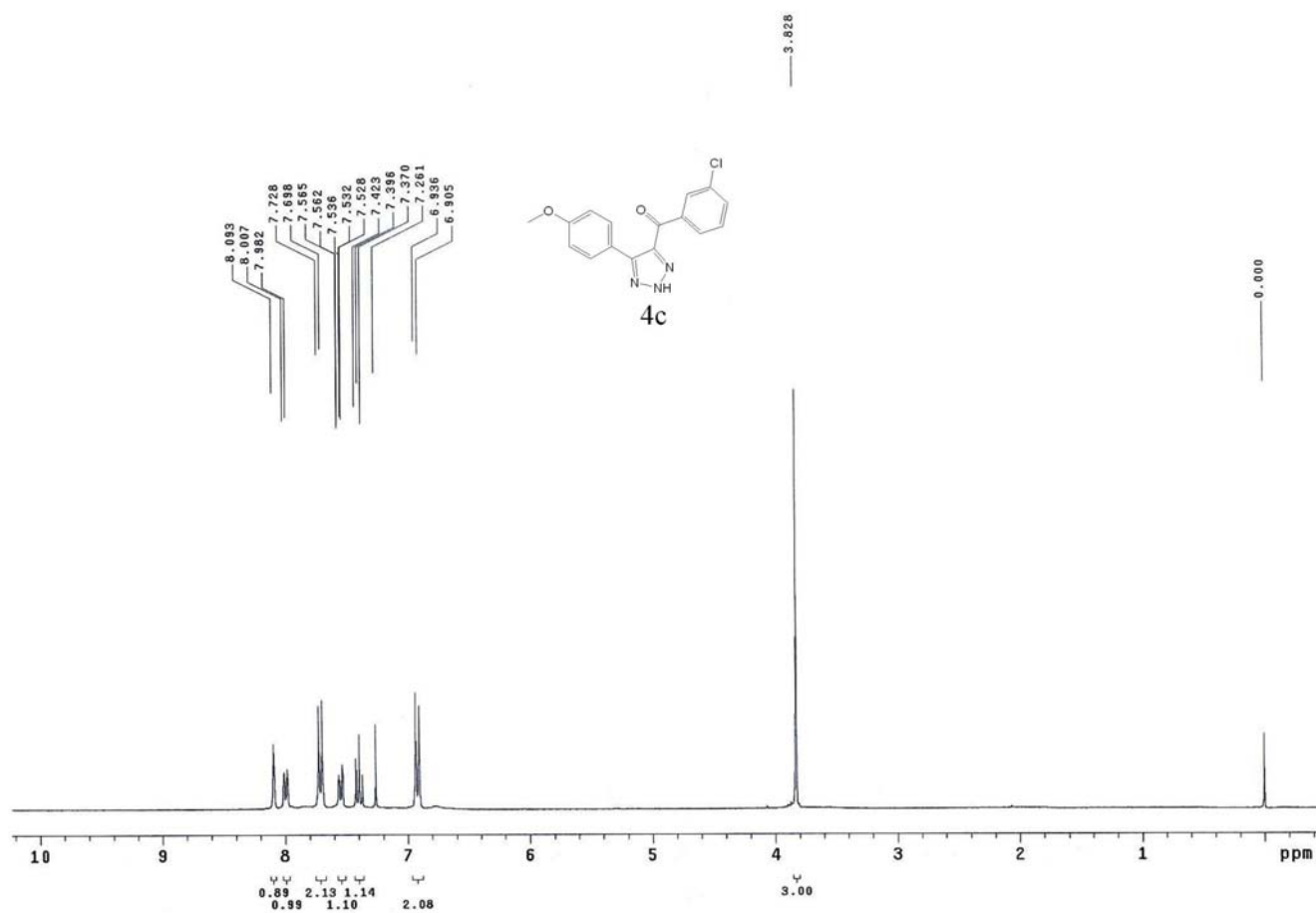


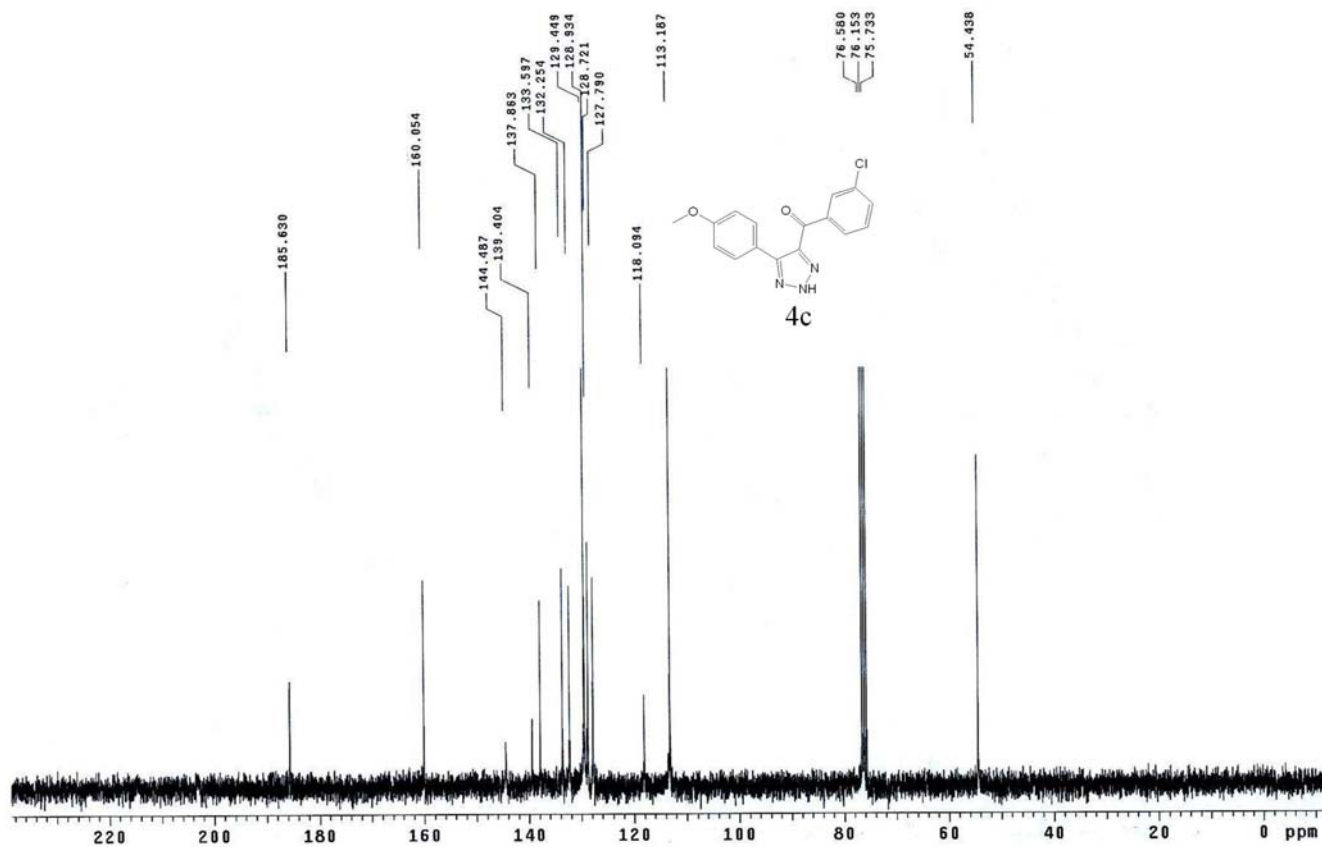
4b:



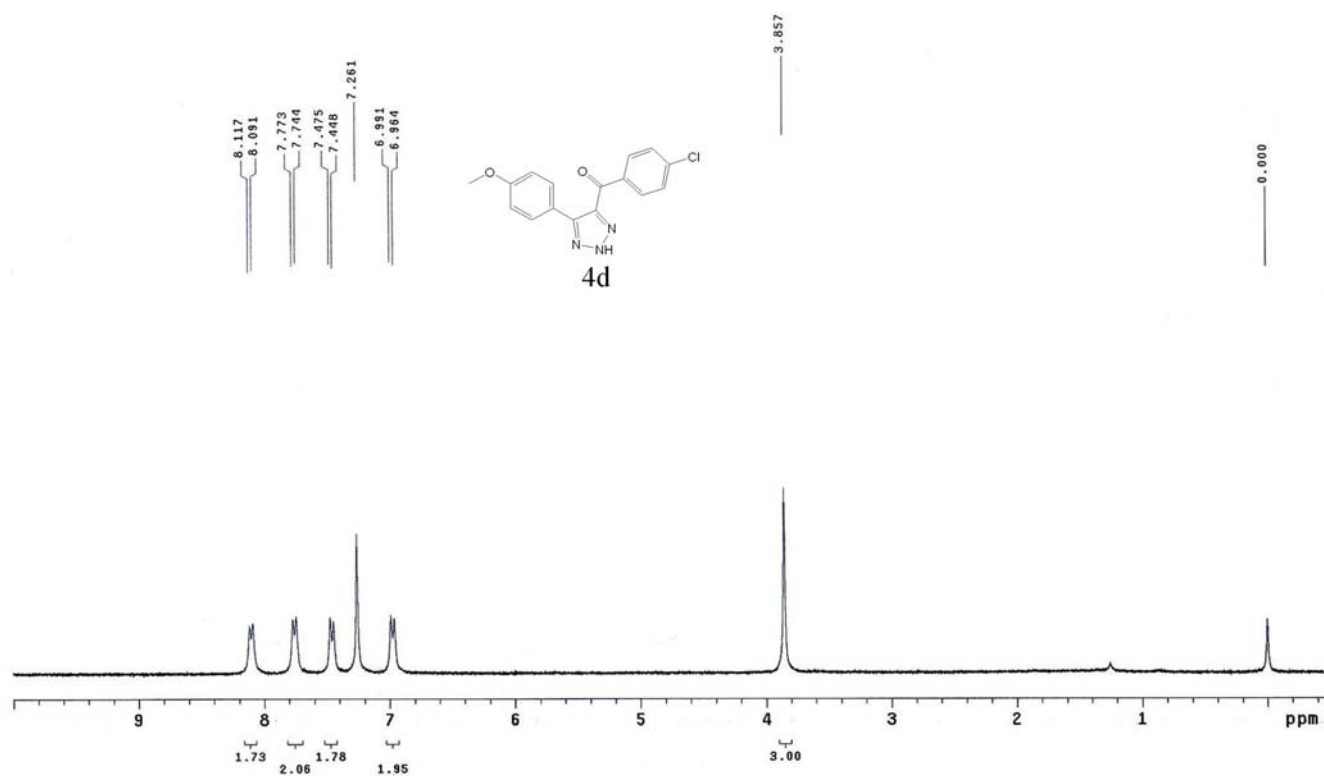


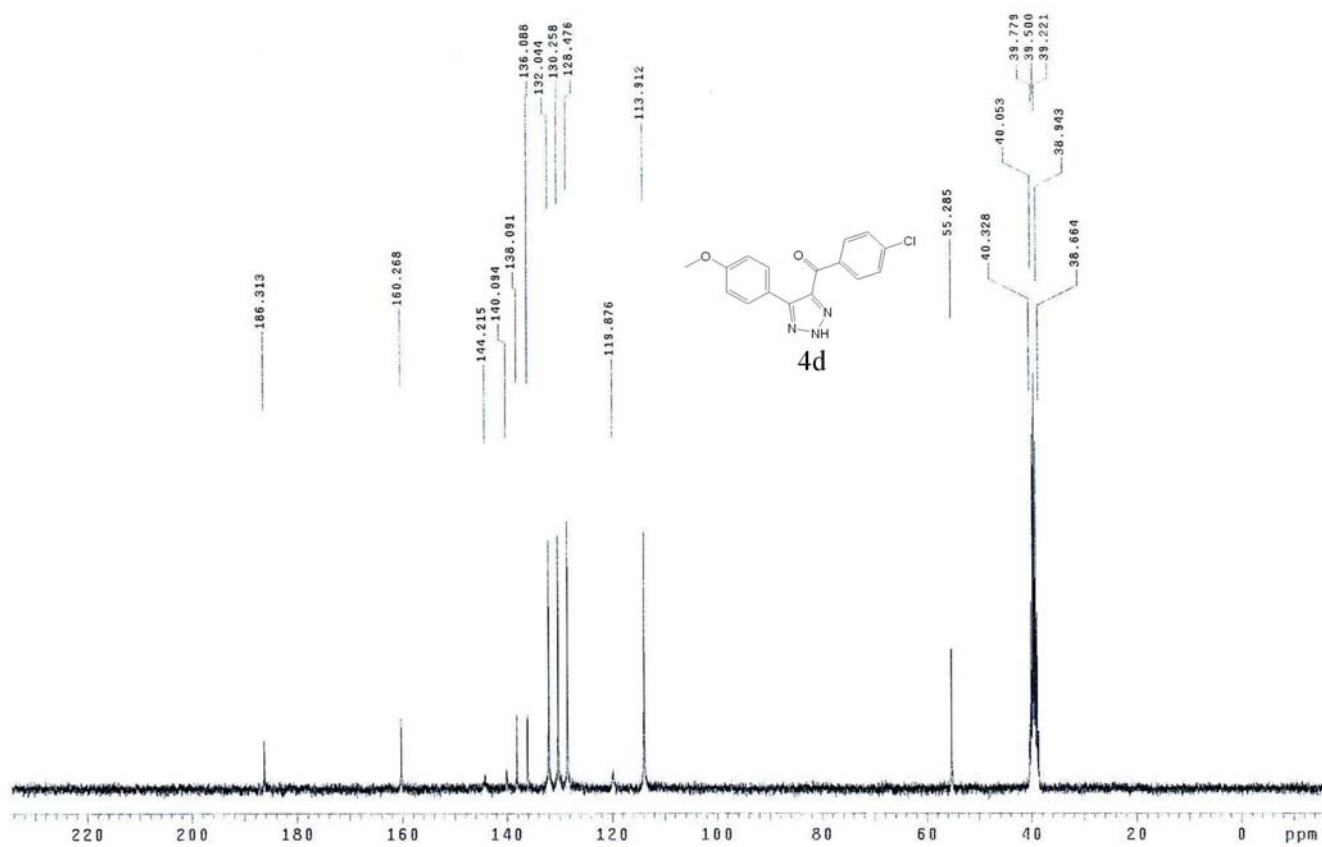
4c:



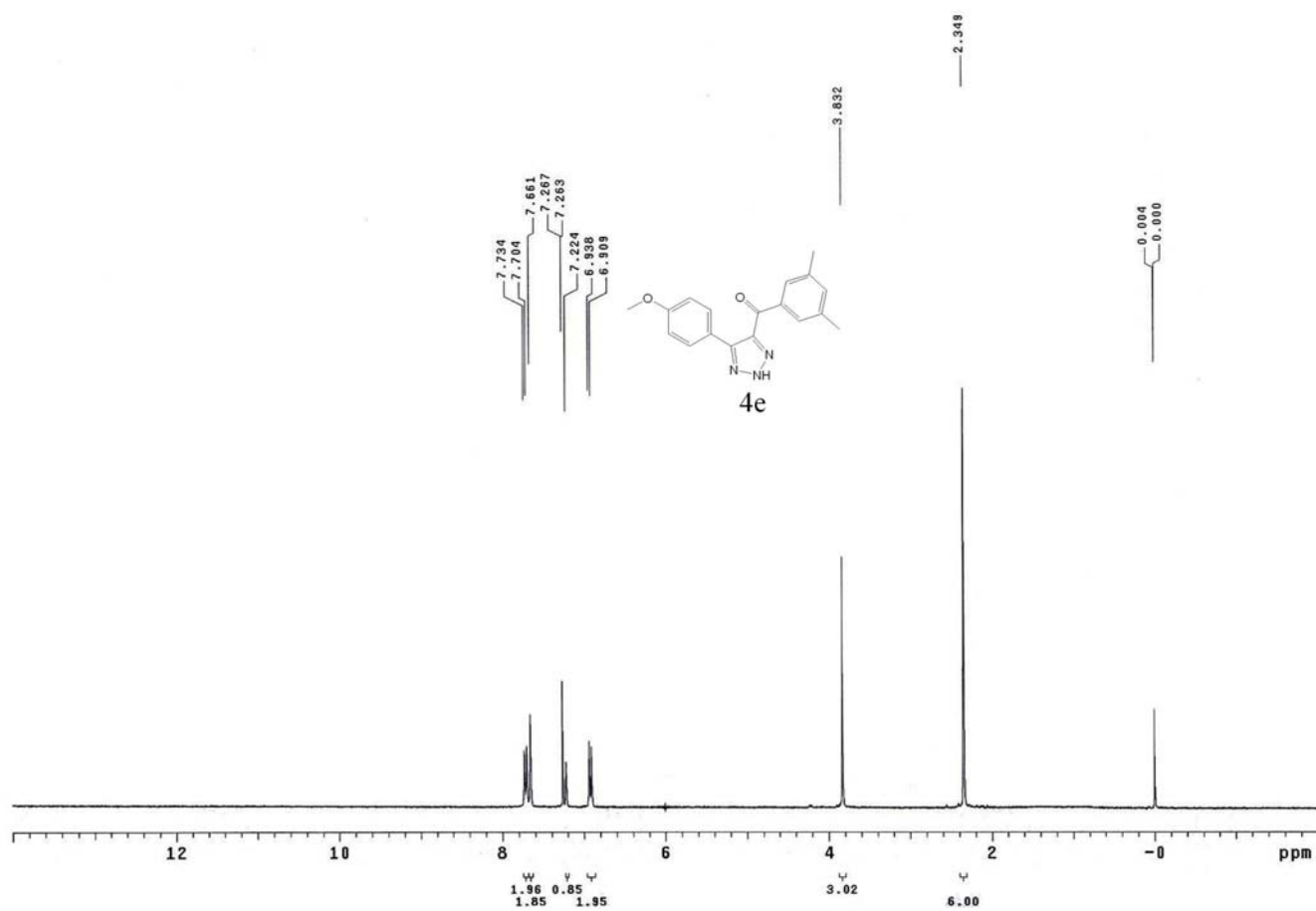


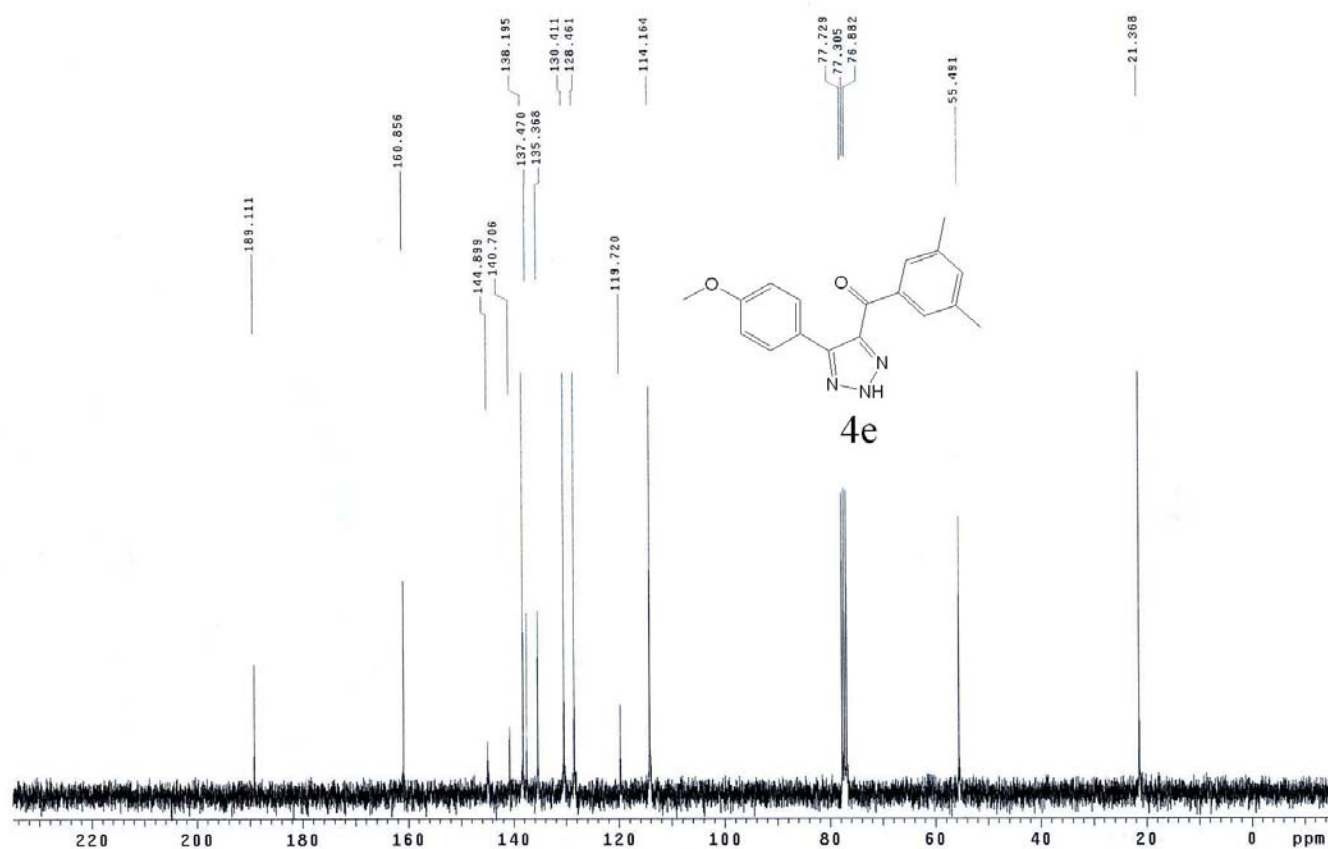
4d:



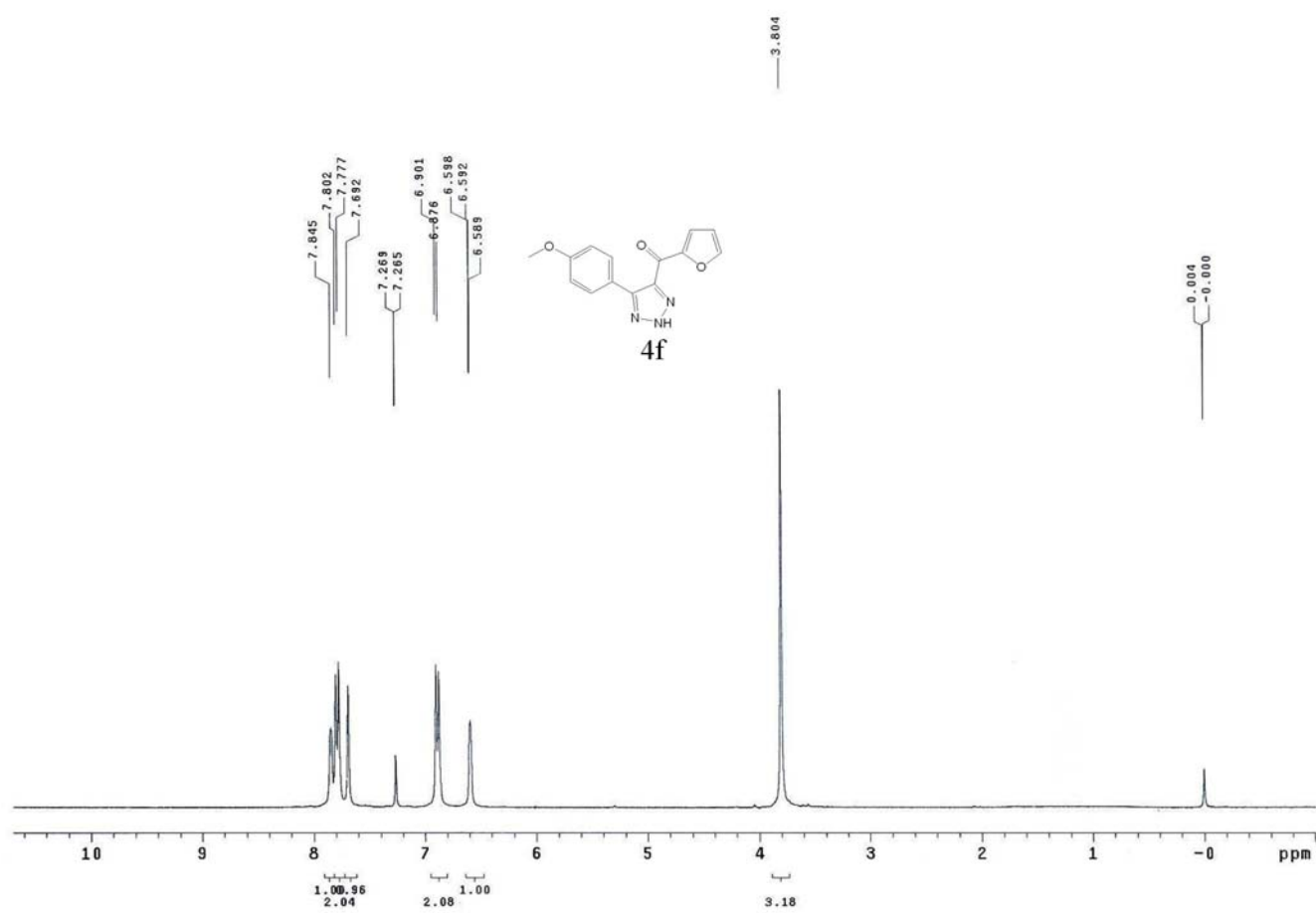


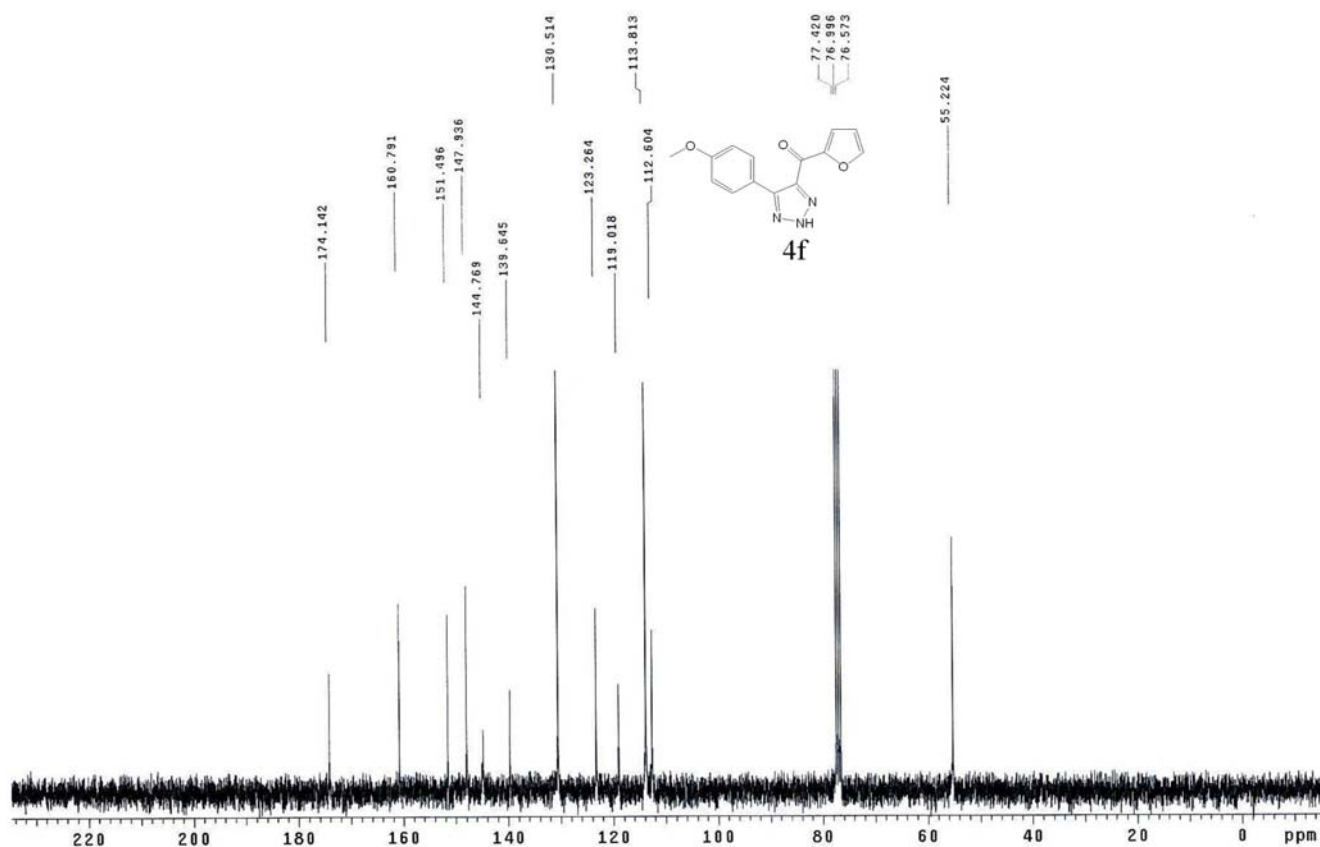
4e:



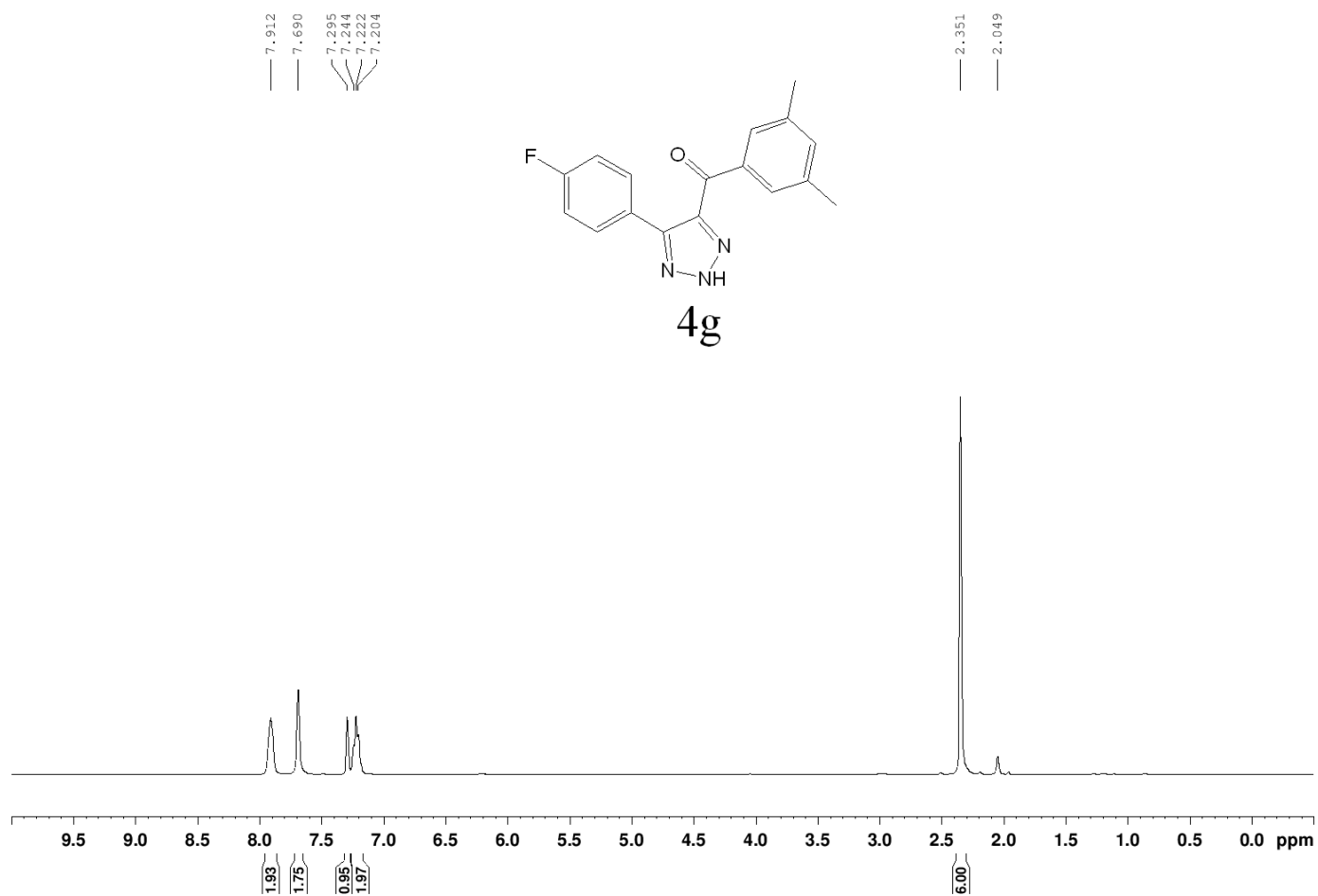


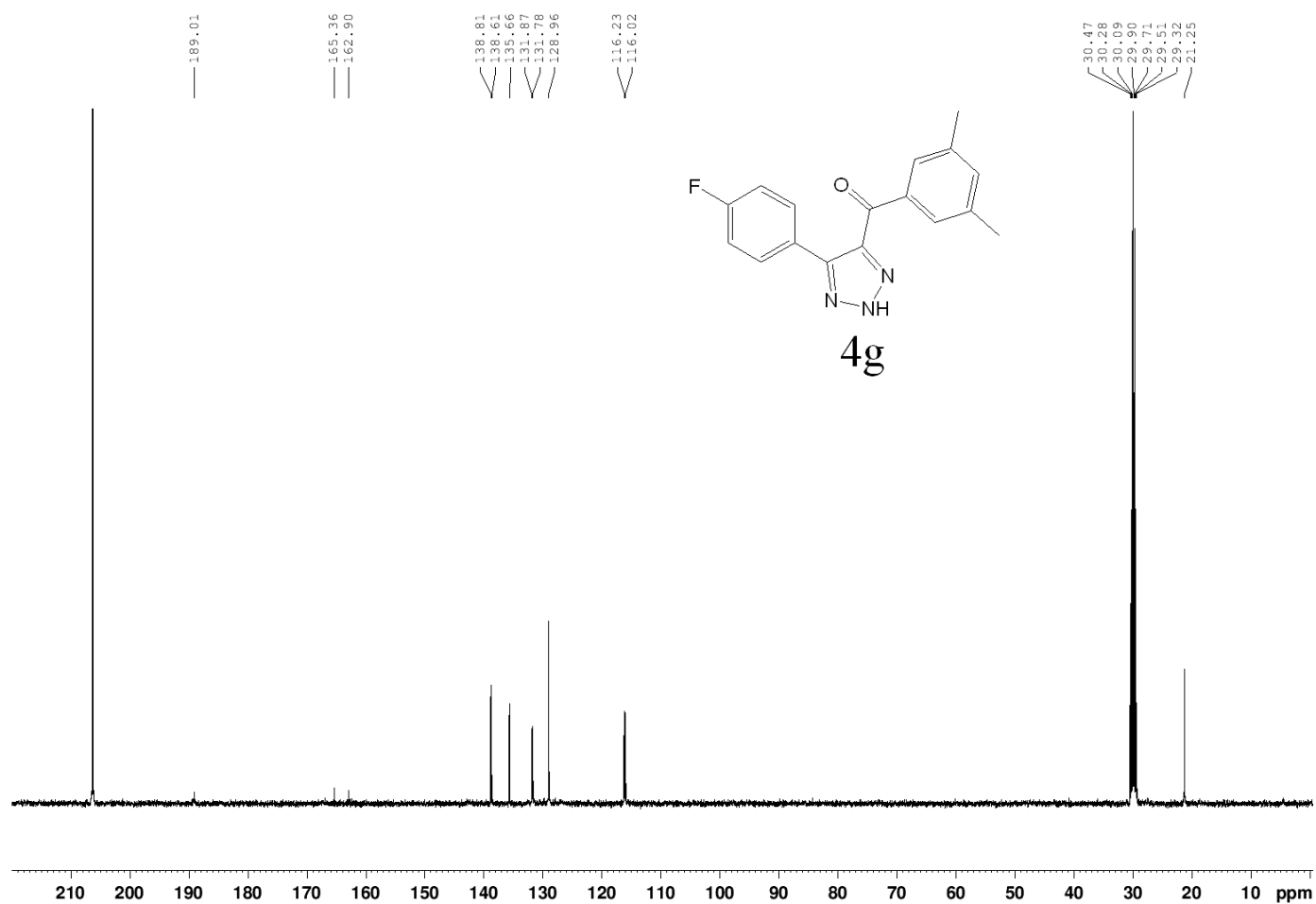
4f:



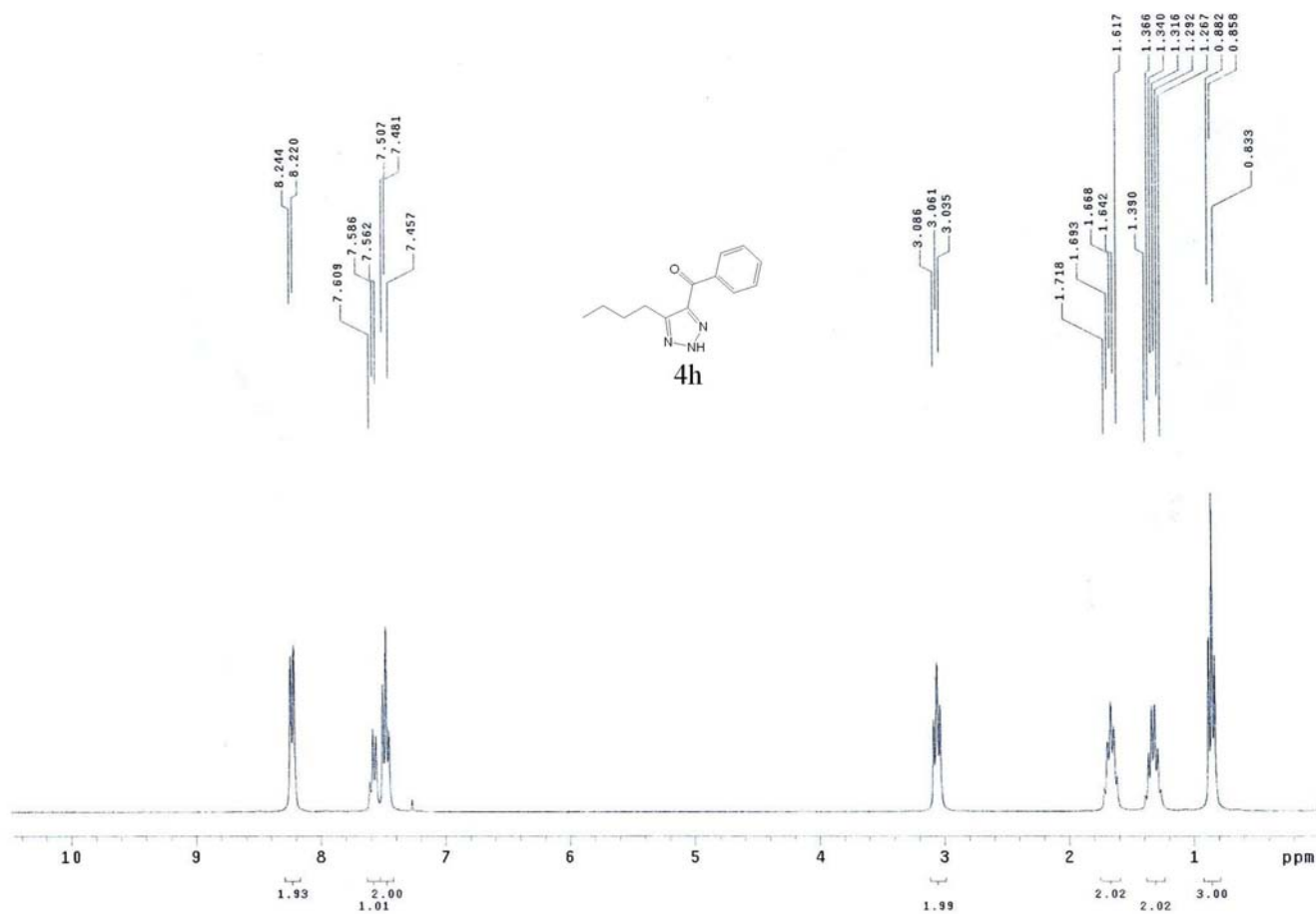


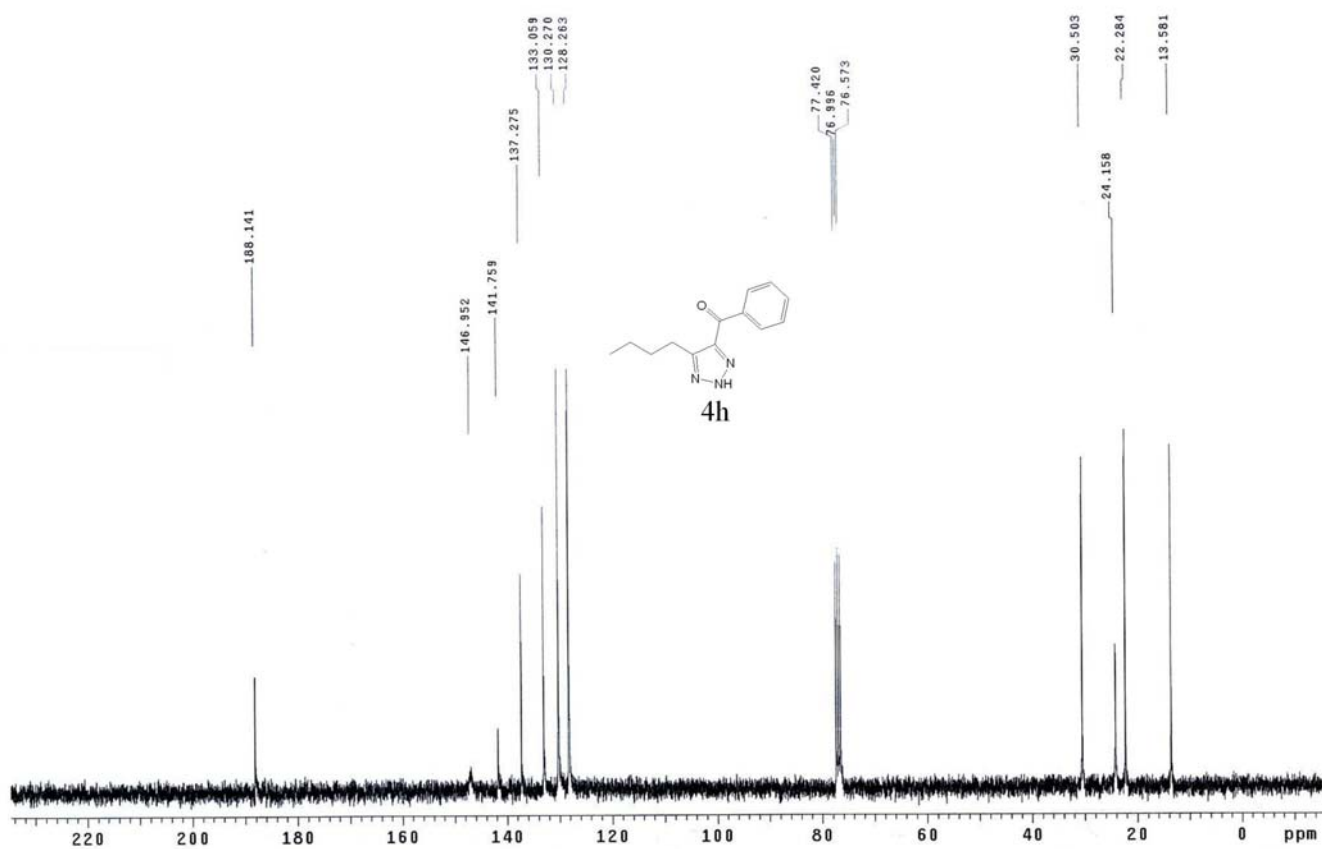
4g:



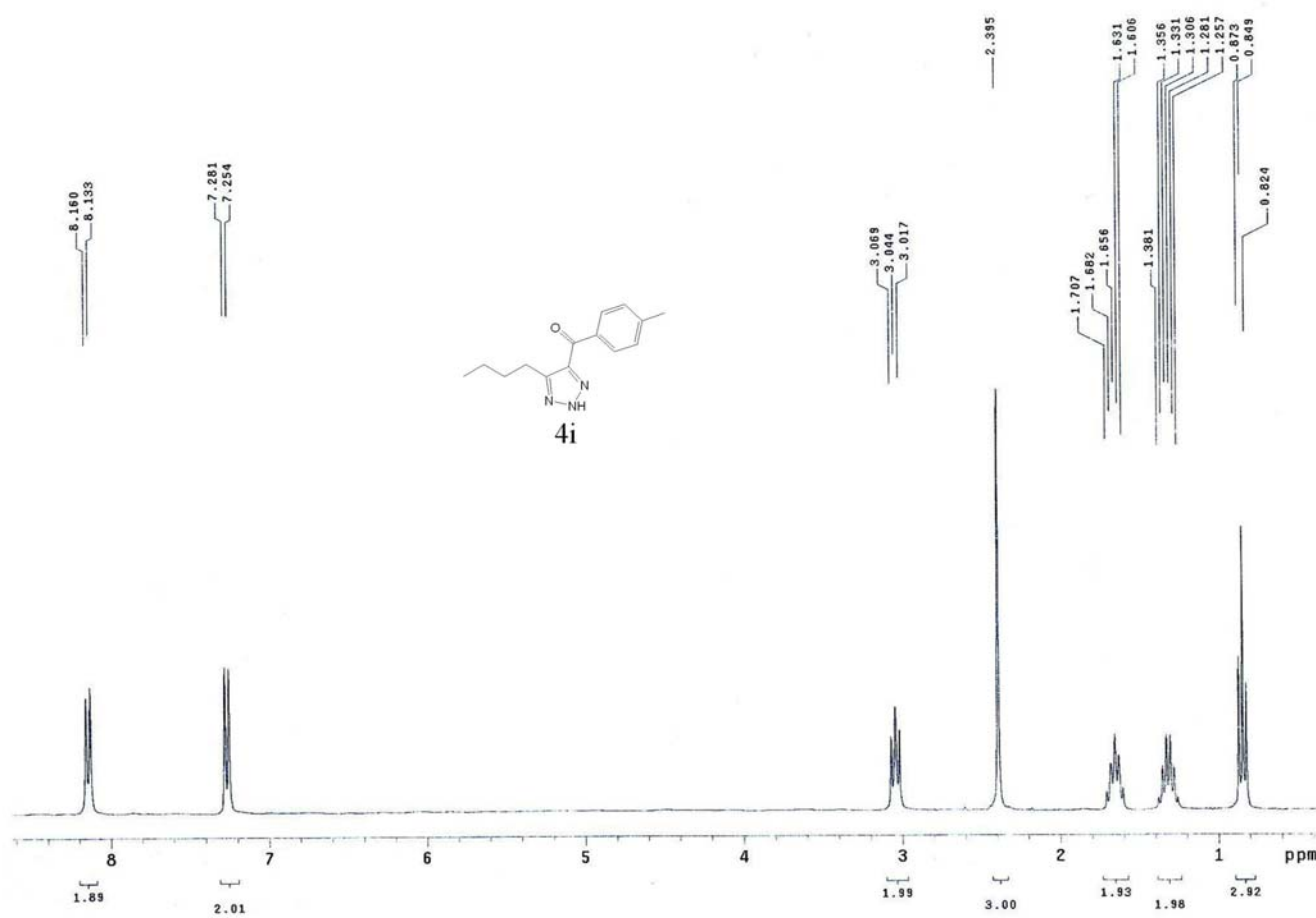


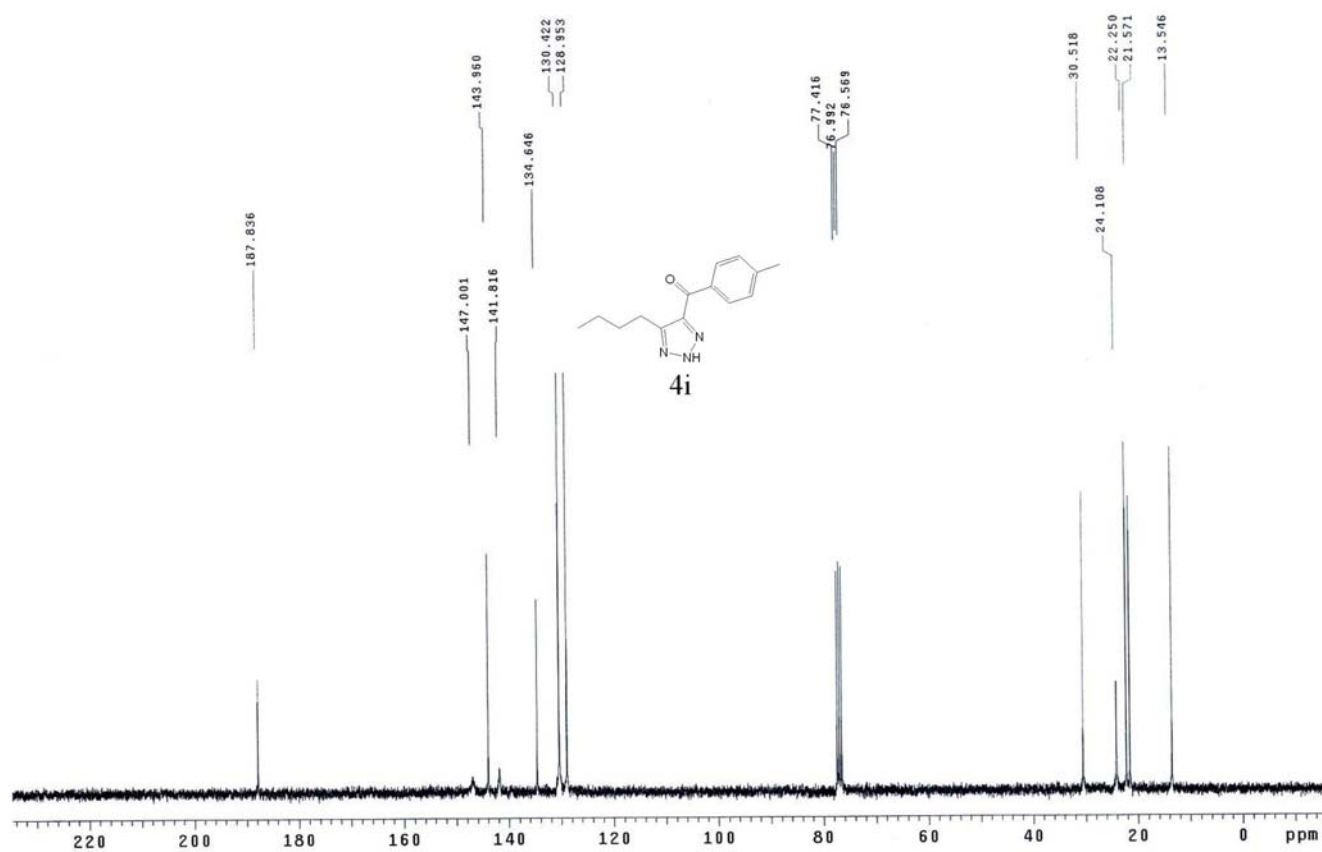
4h:



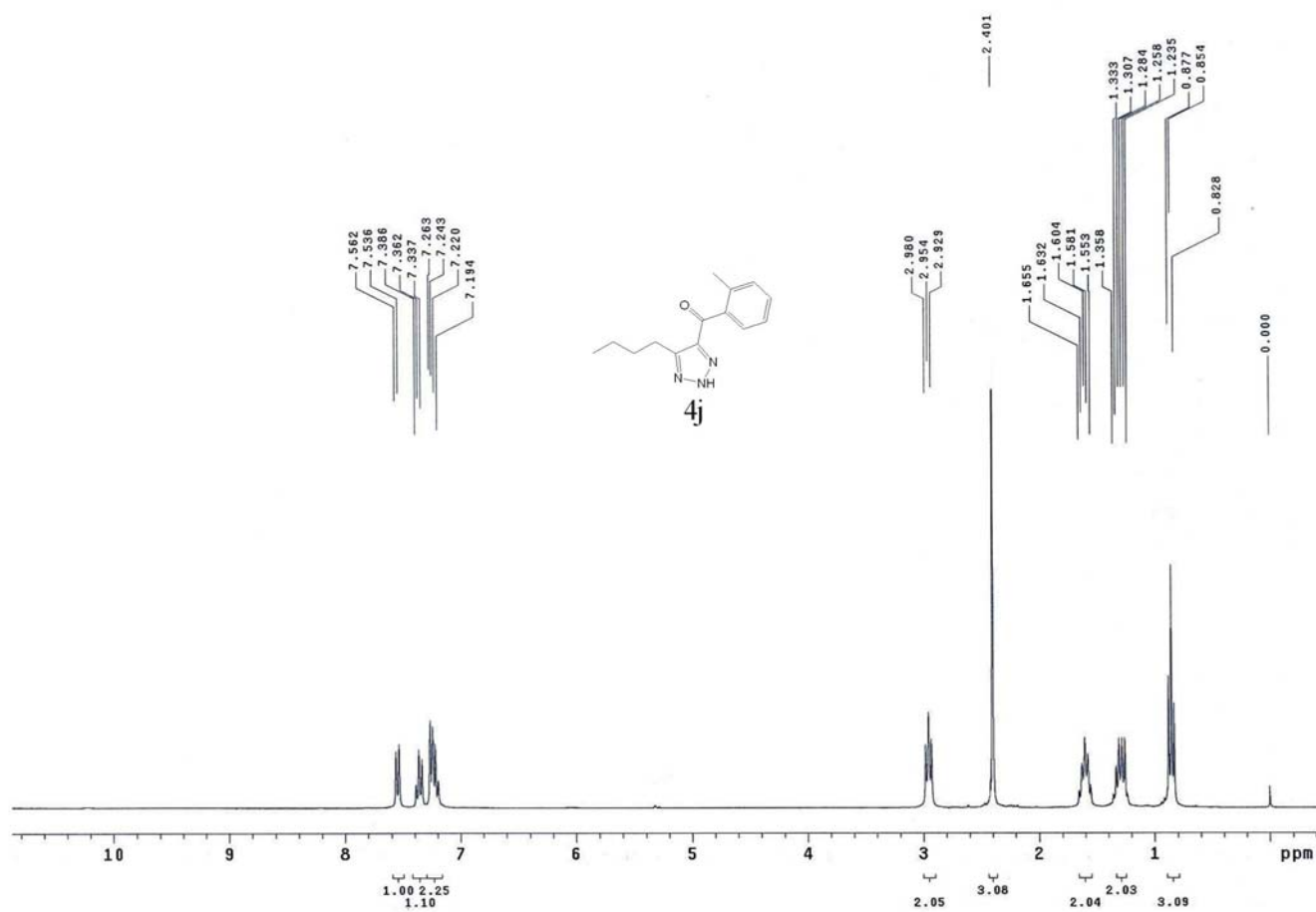


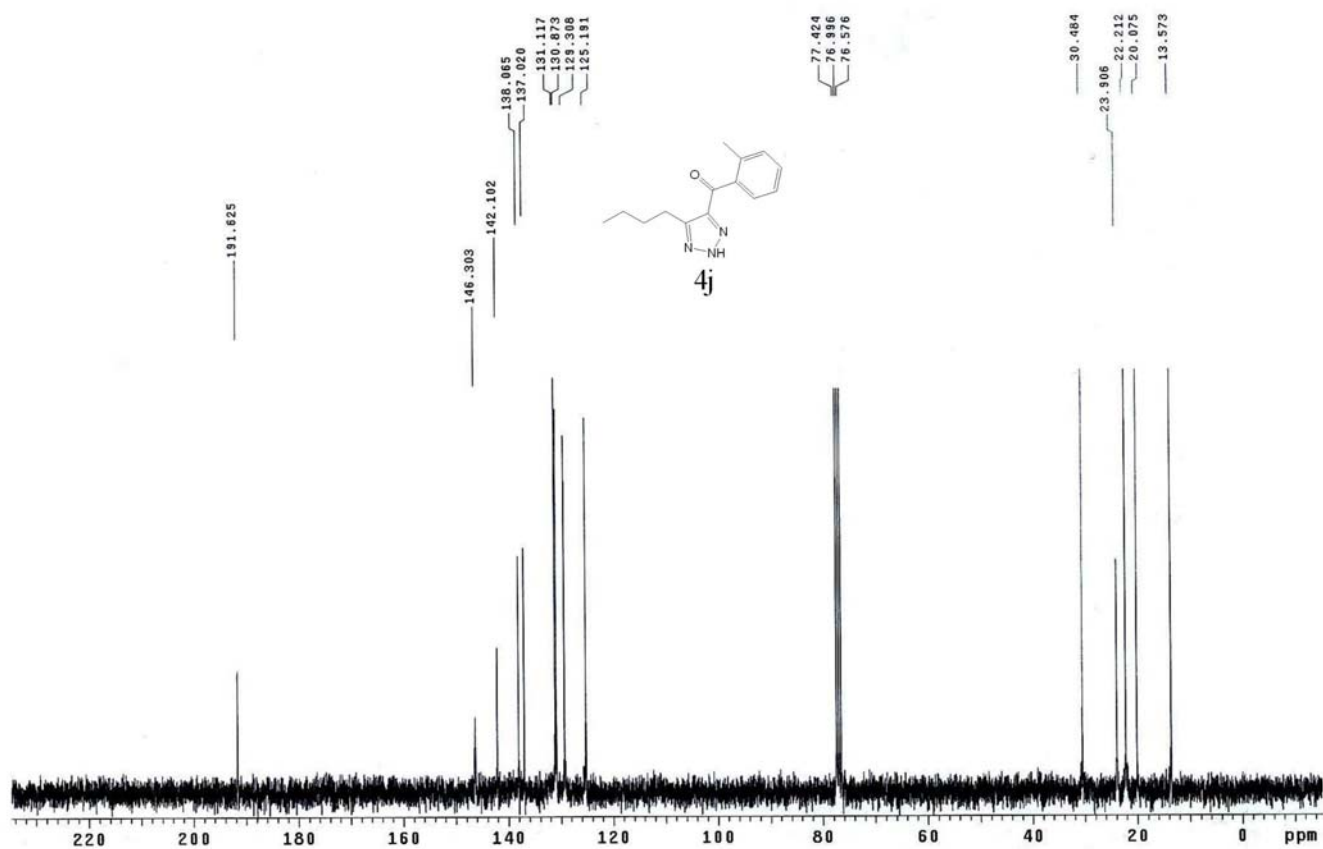
4i:



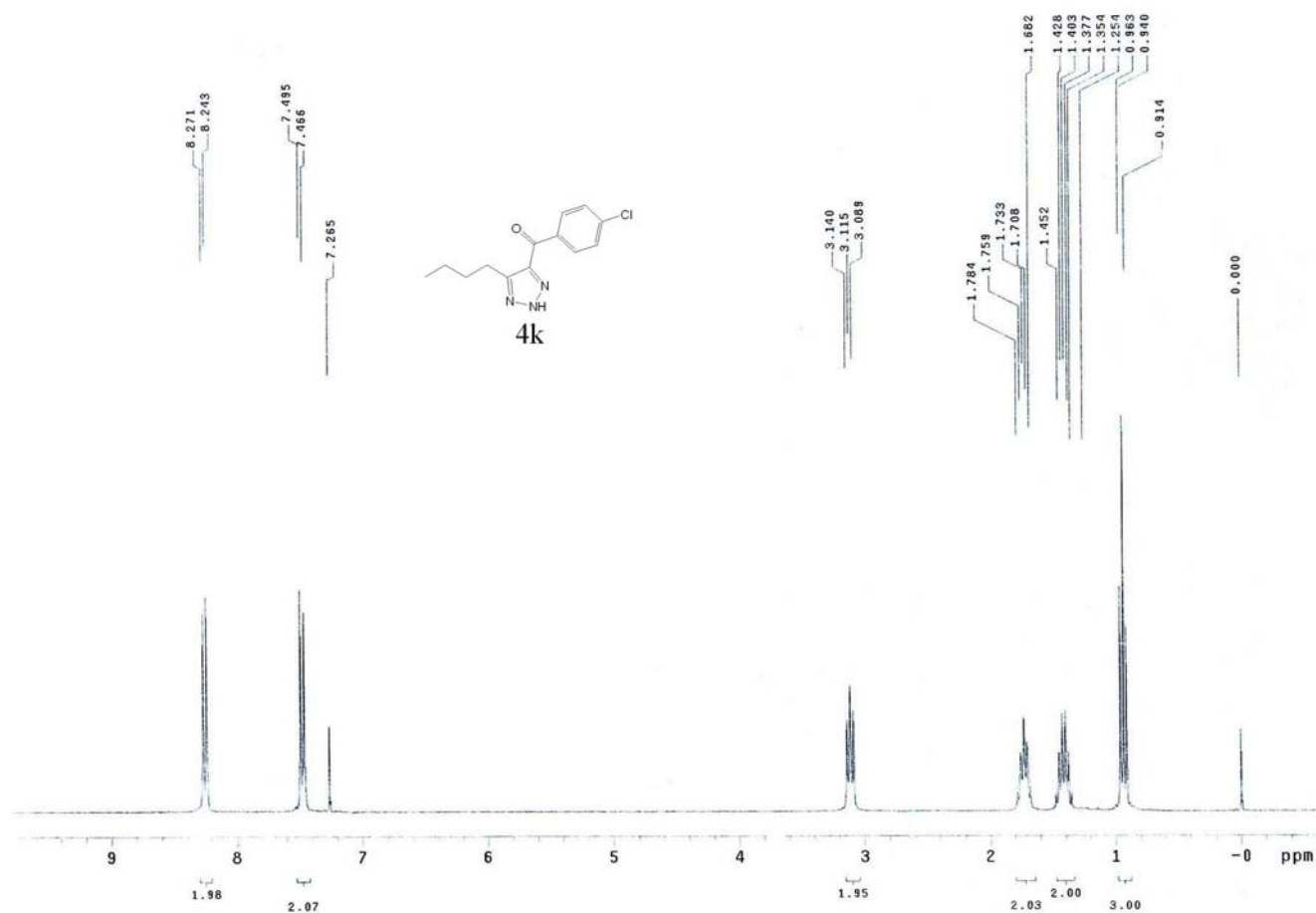


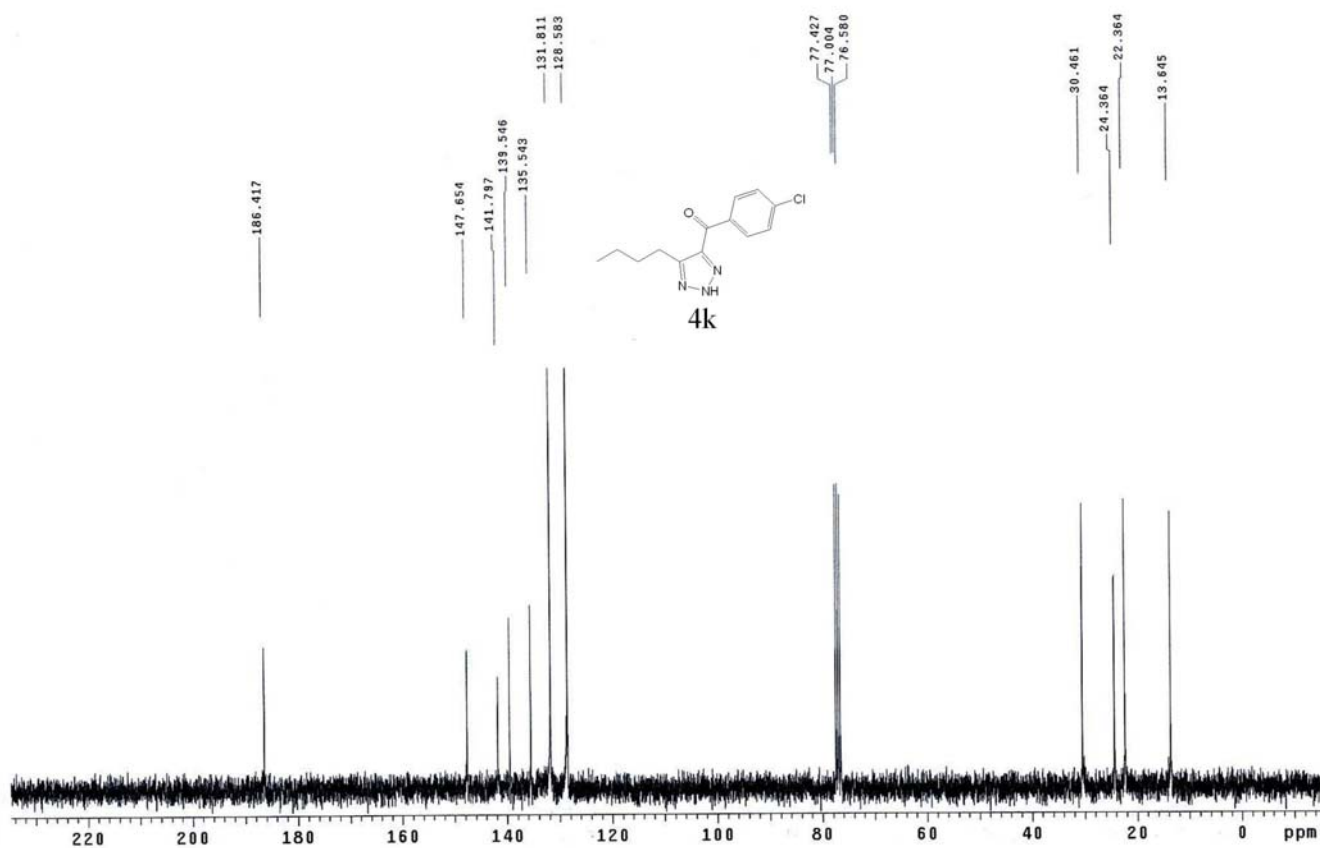
4j:



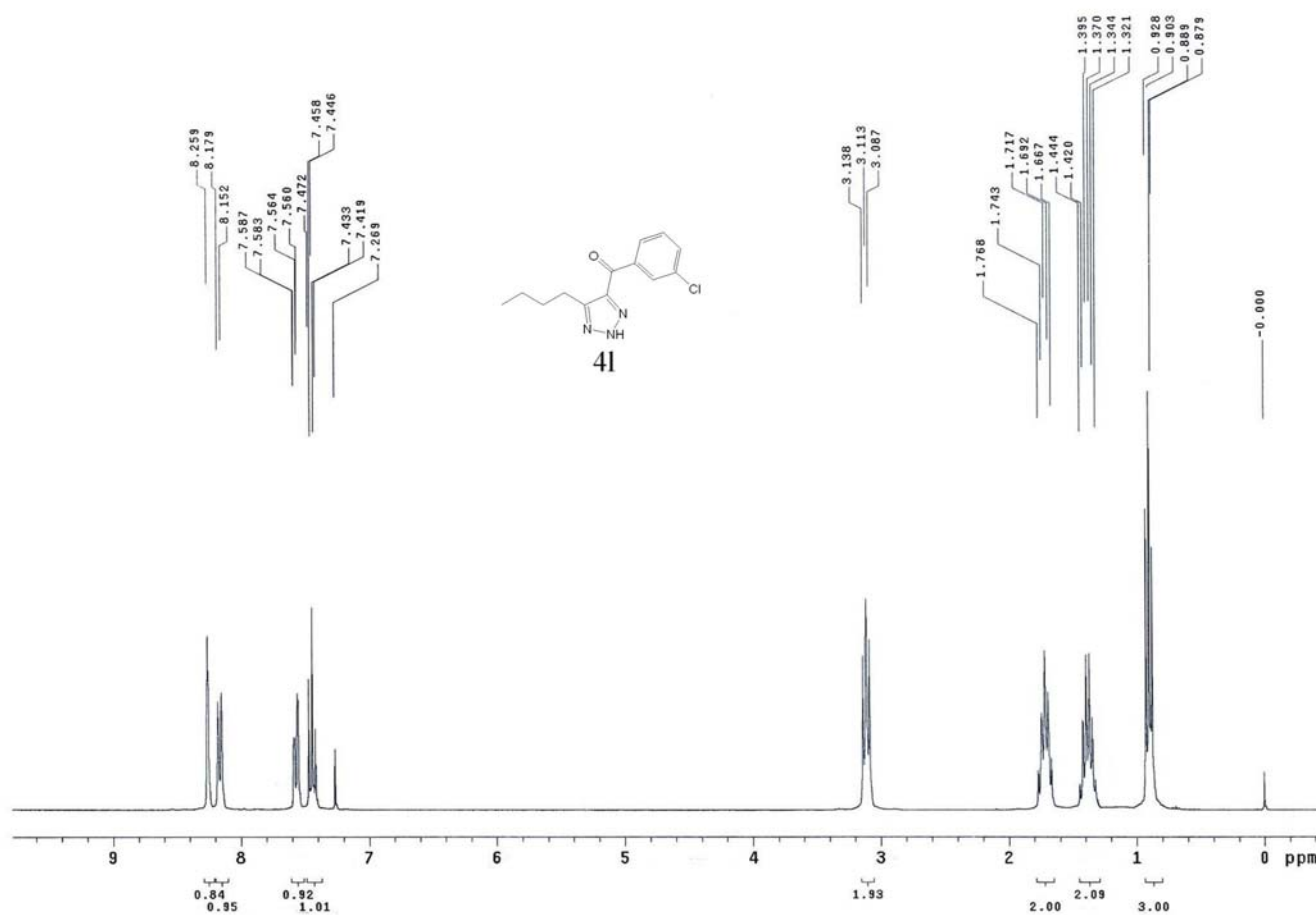


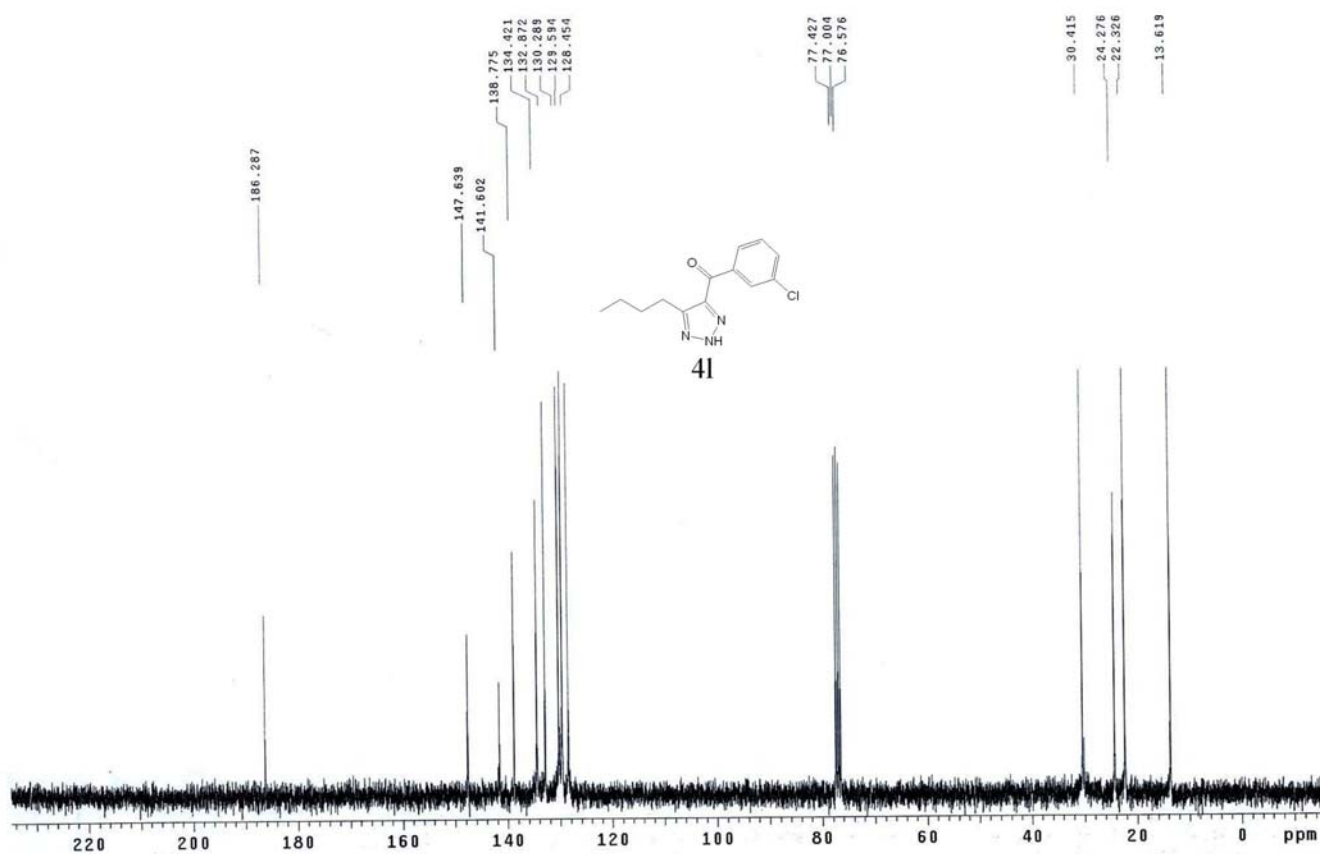
4k:



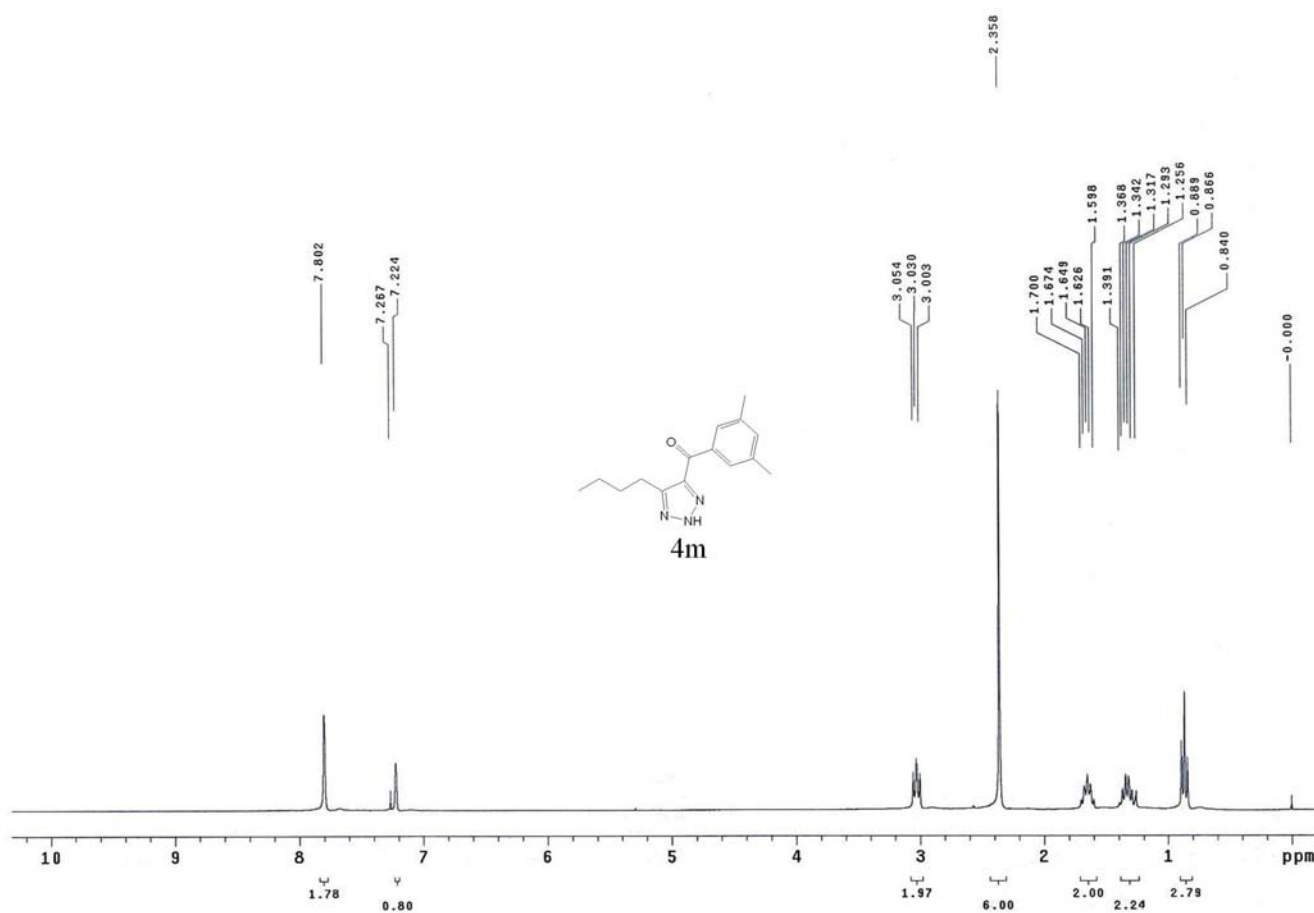


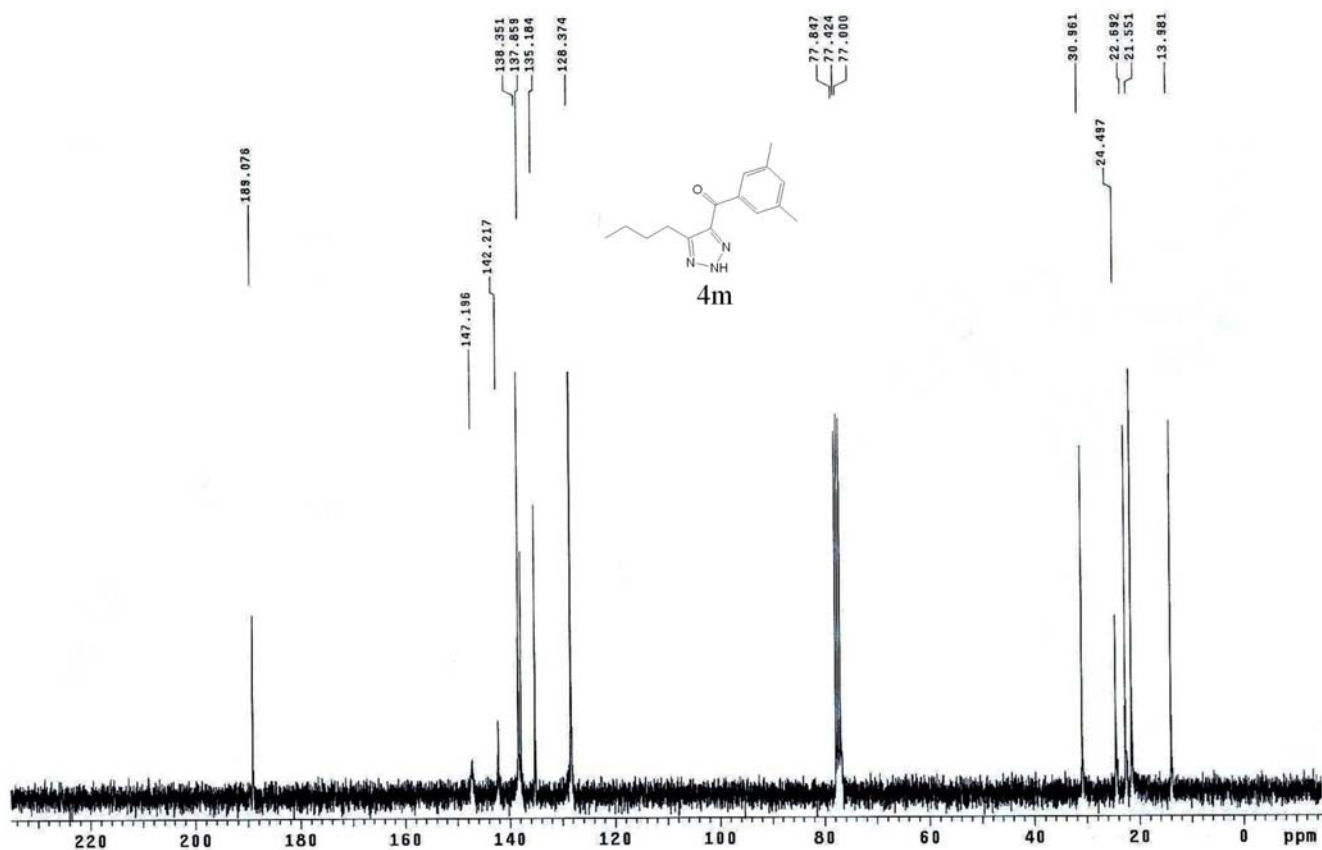
4l:



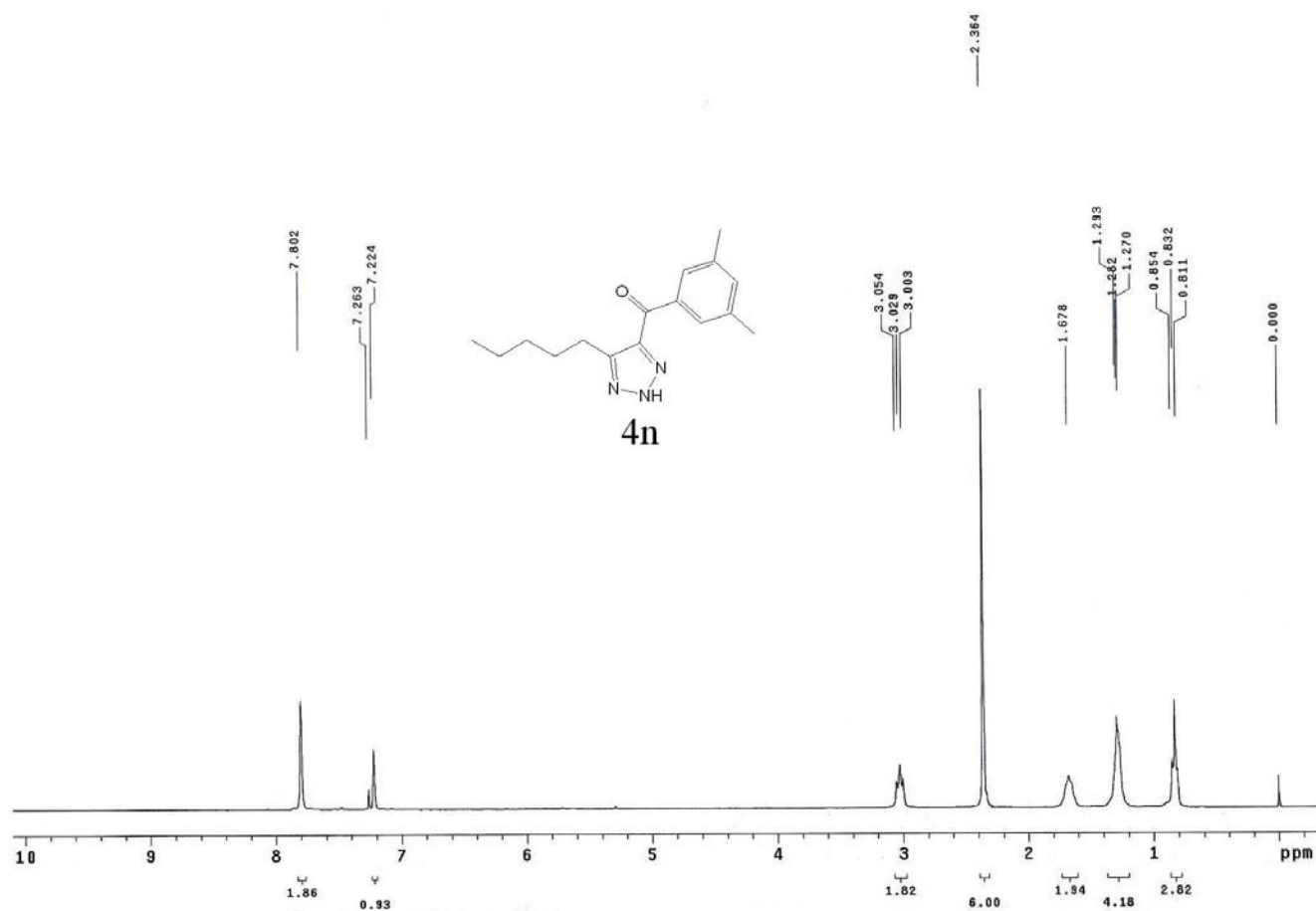


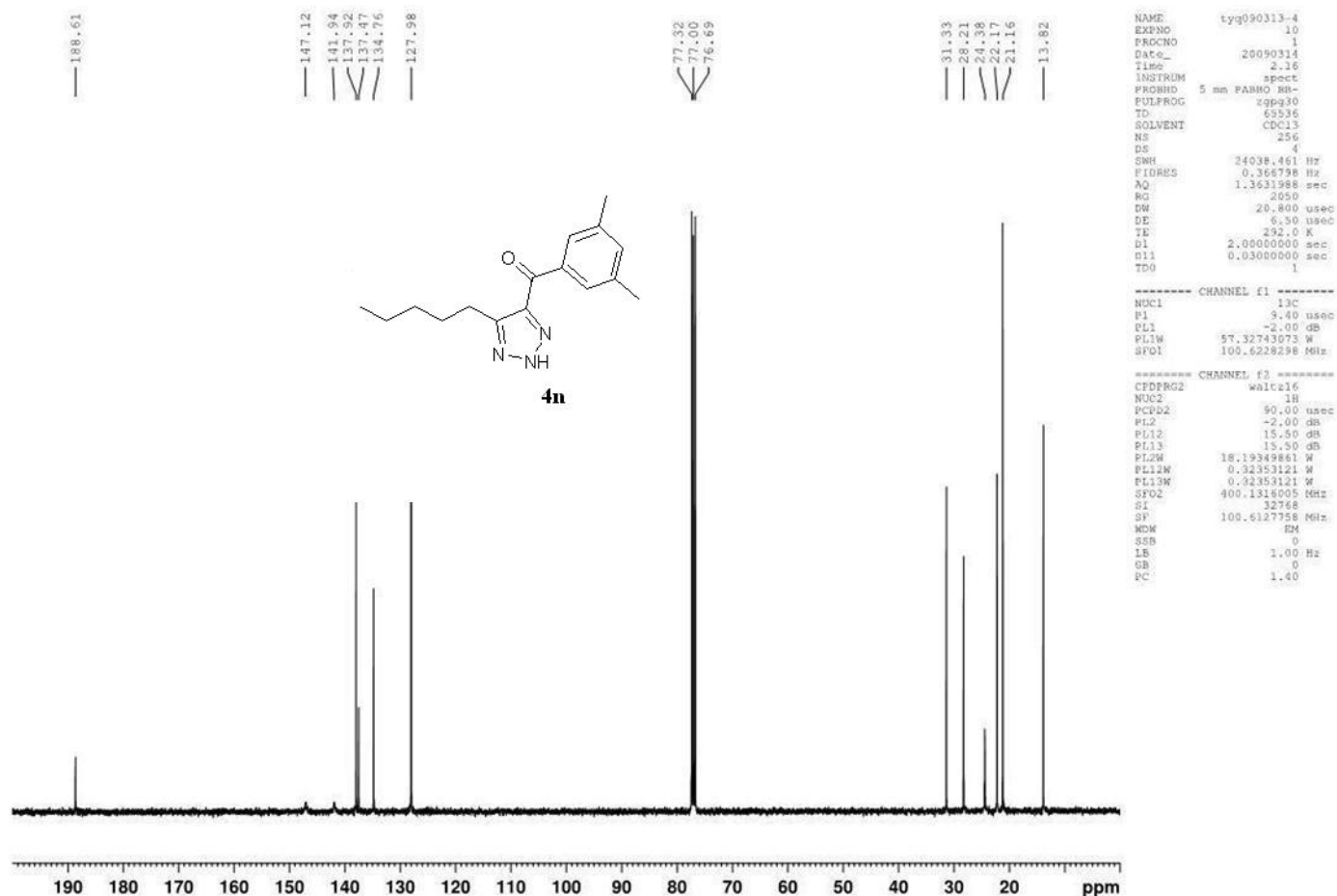
4m:



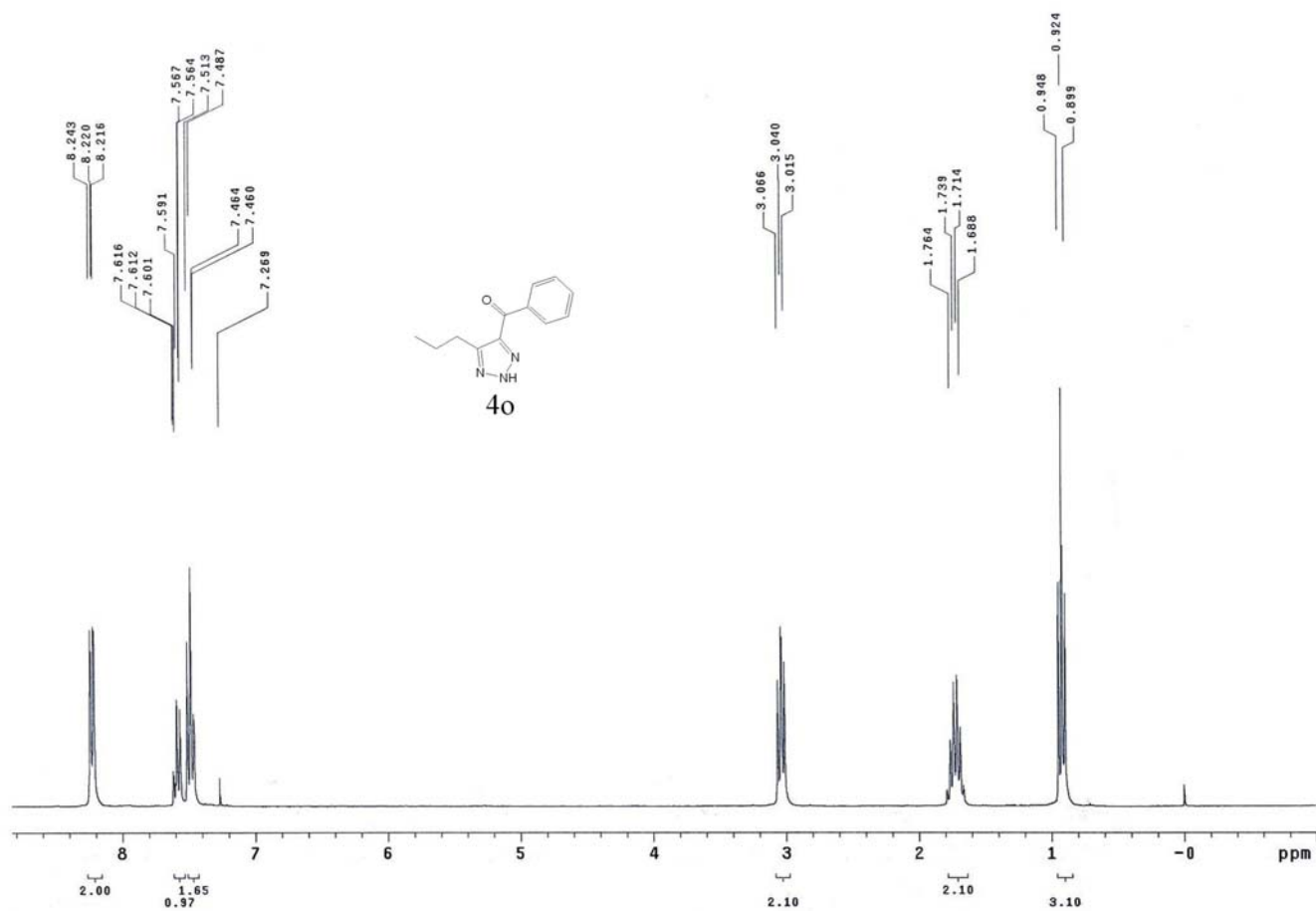


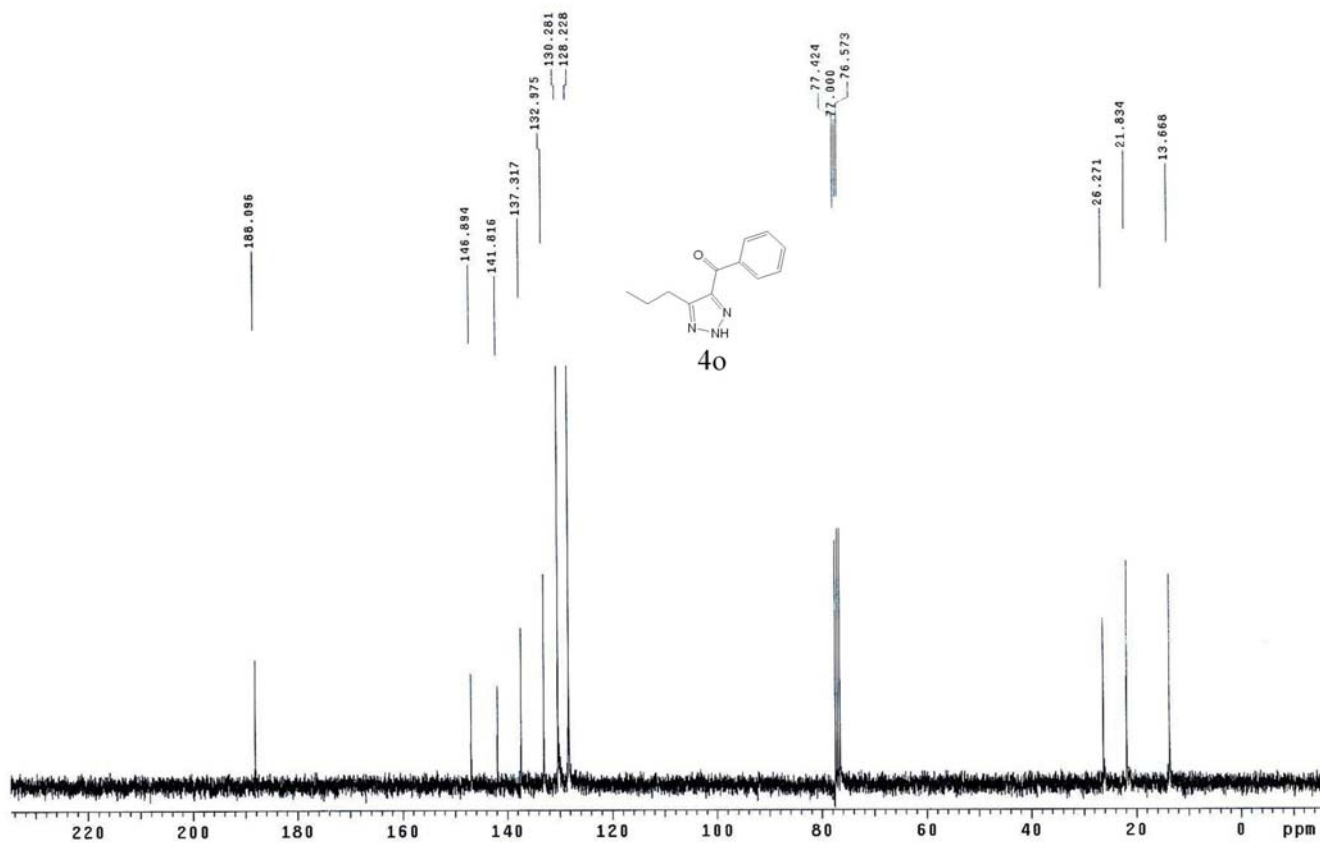
4n:



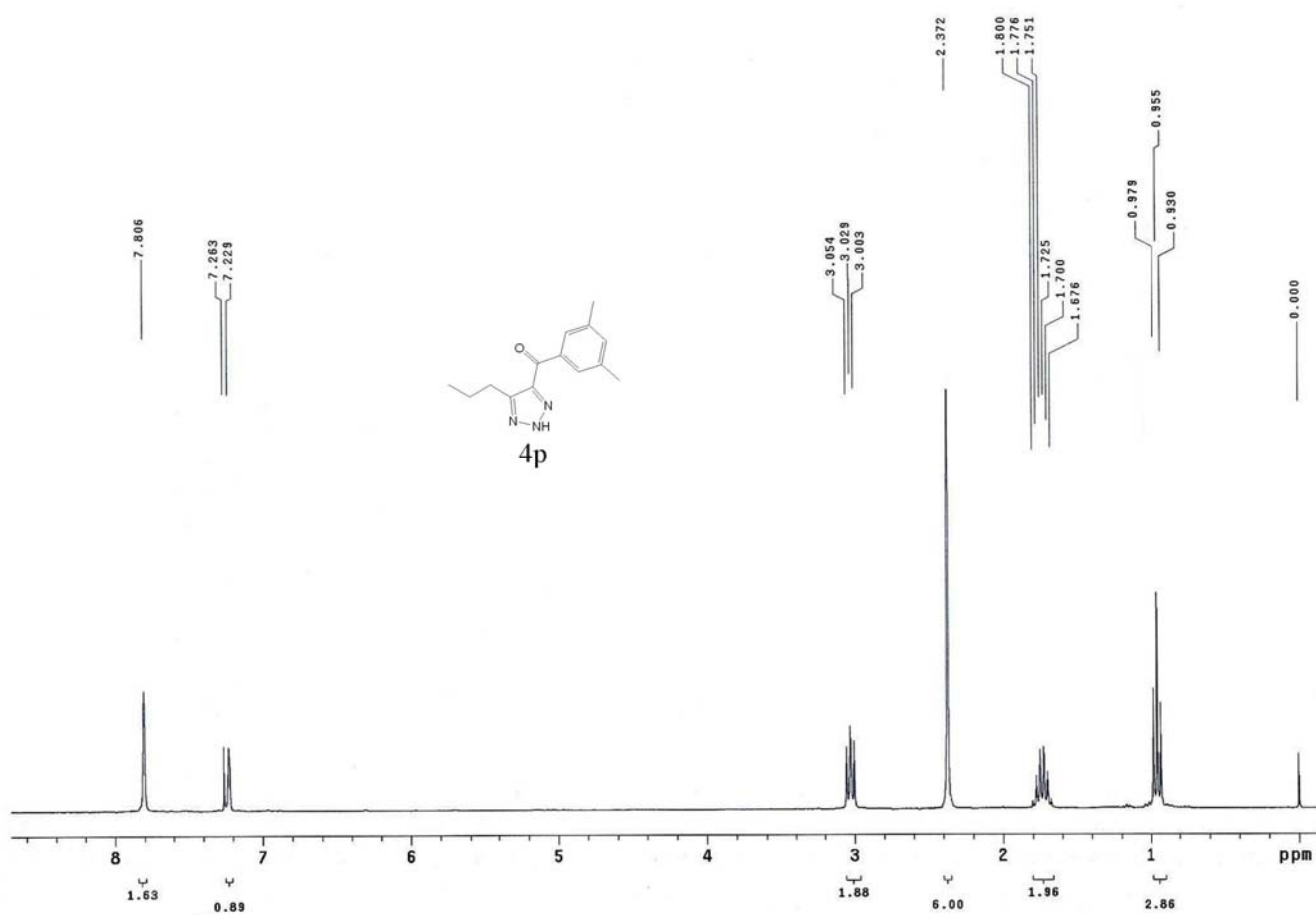


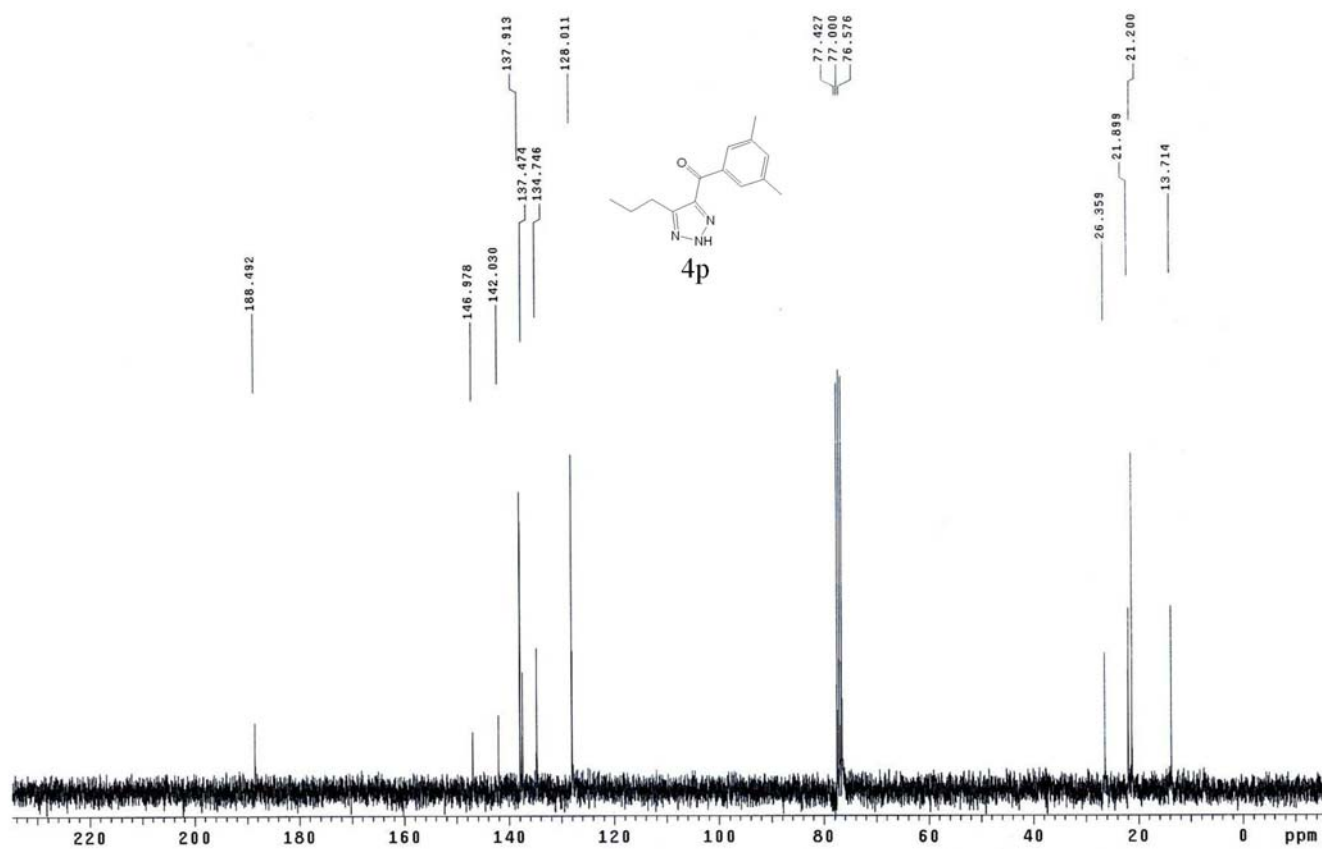
4o:



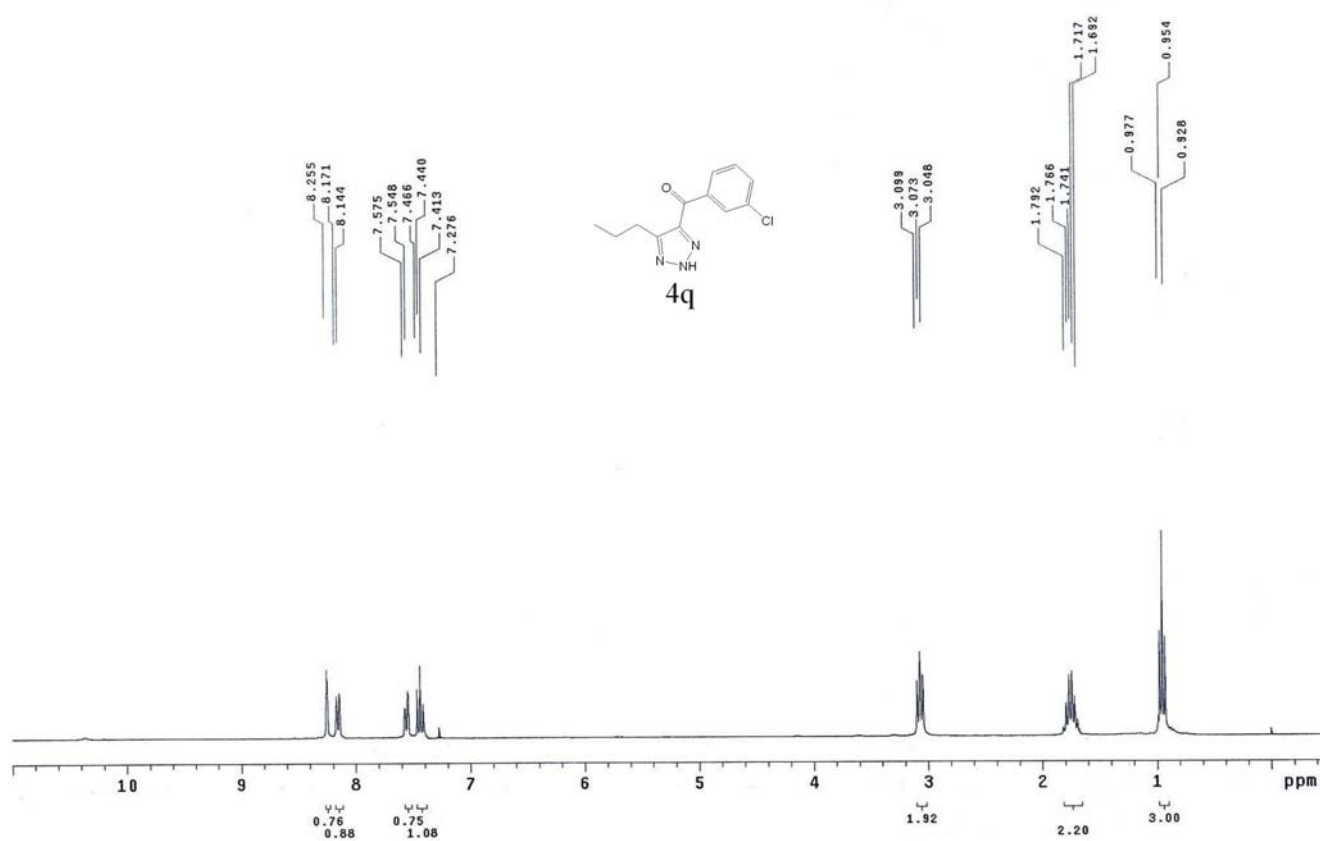


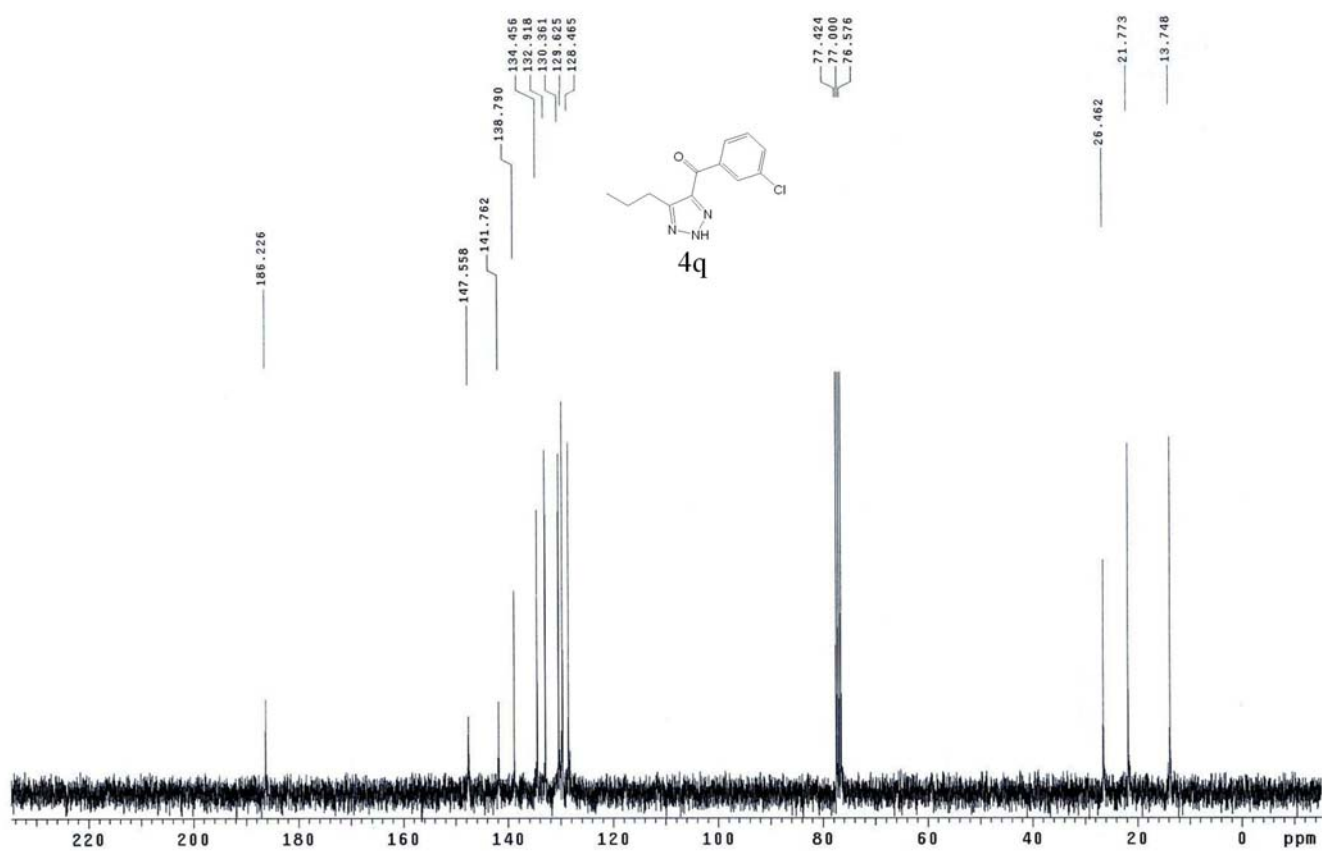
4p:



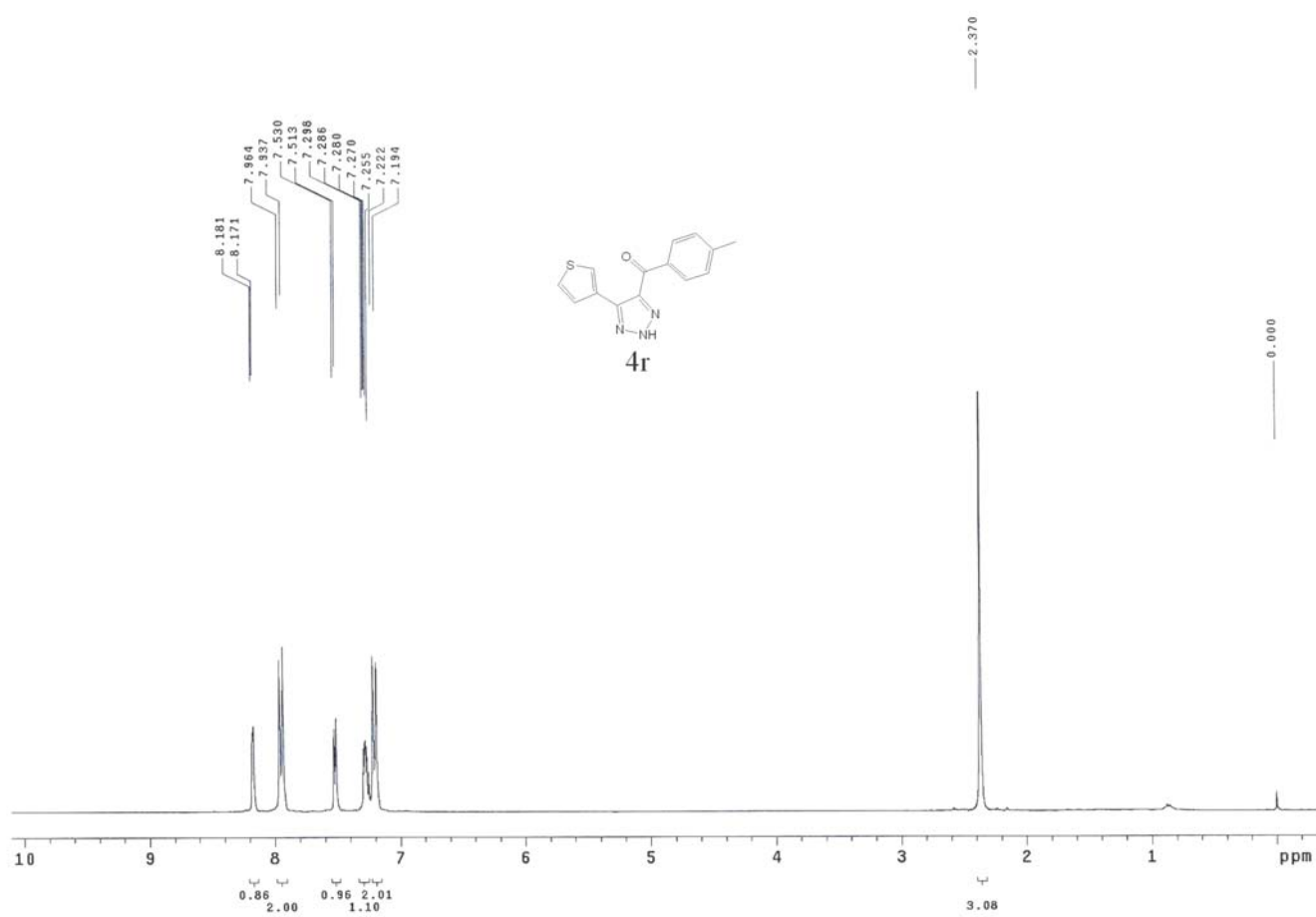


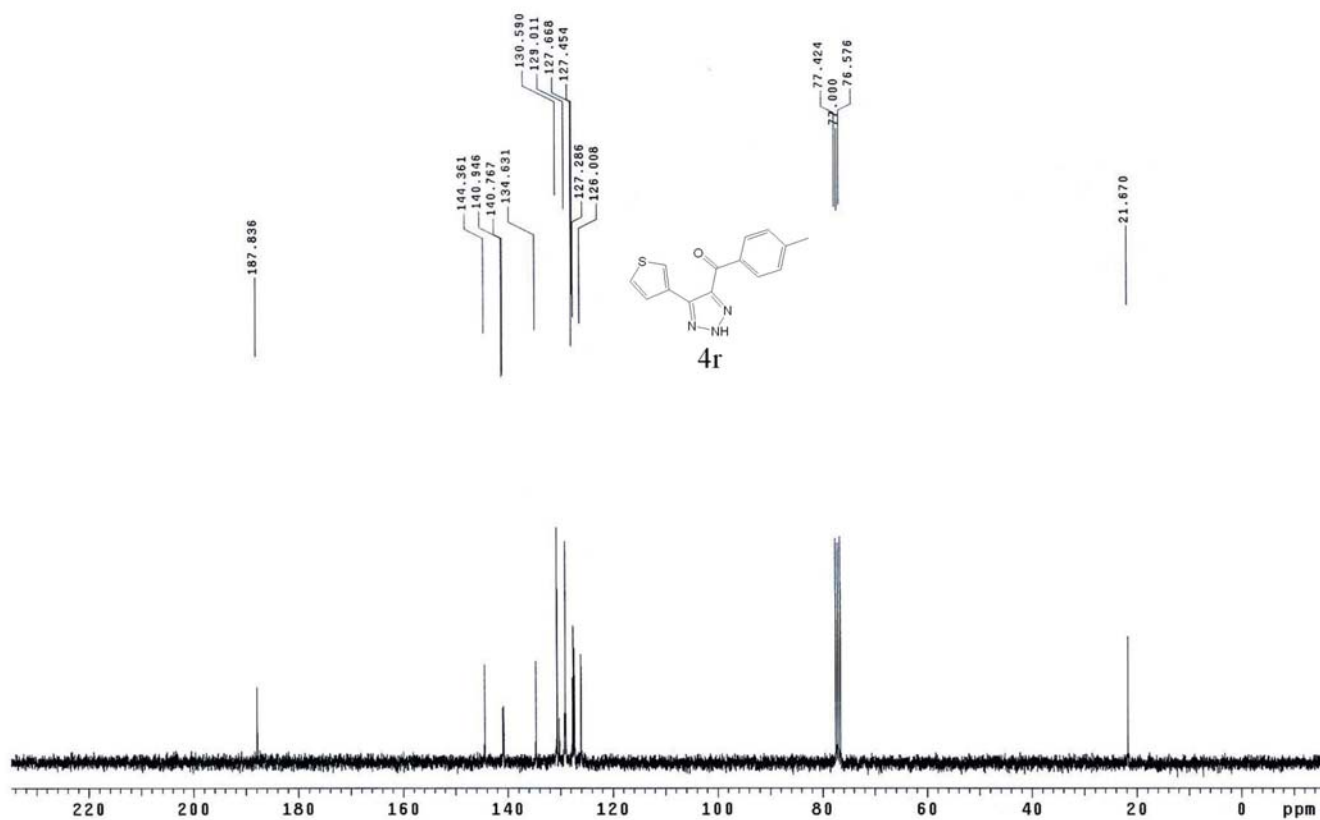
4q:



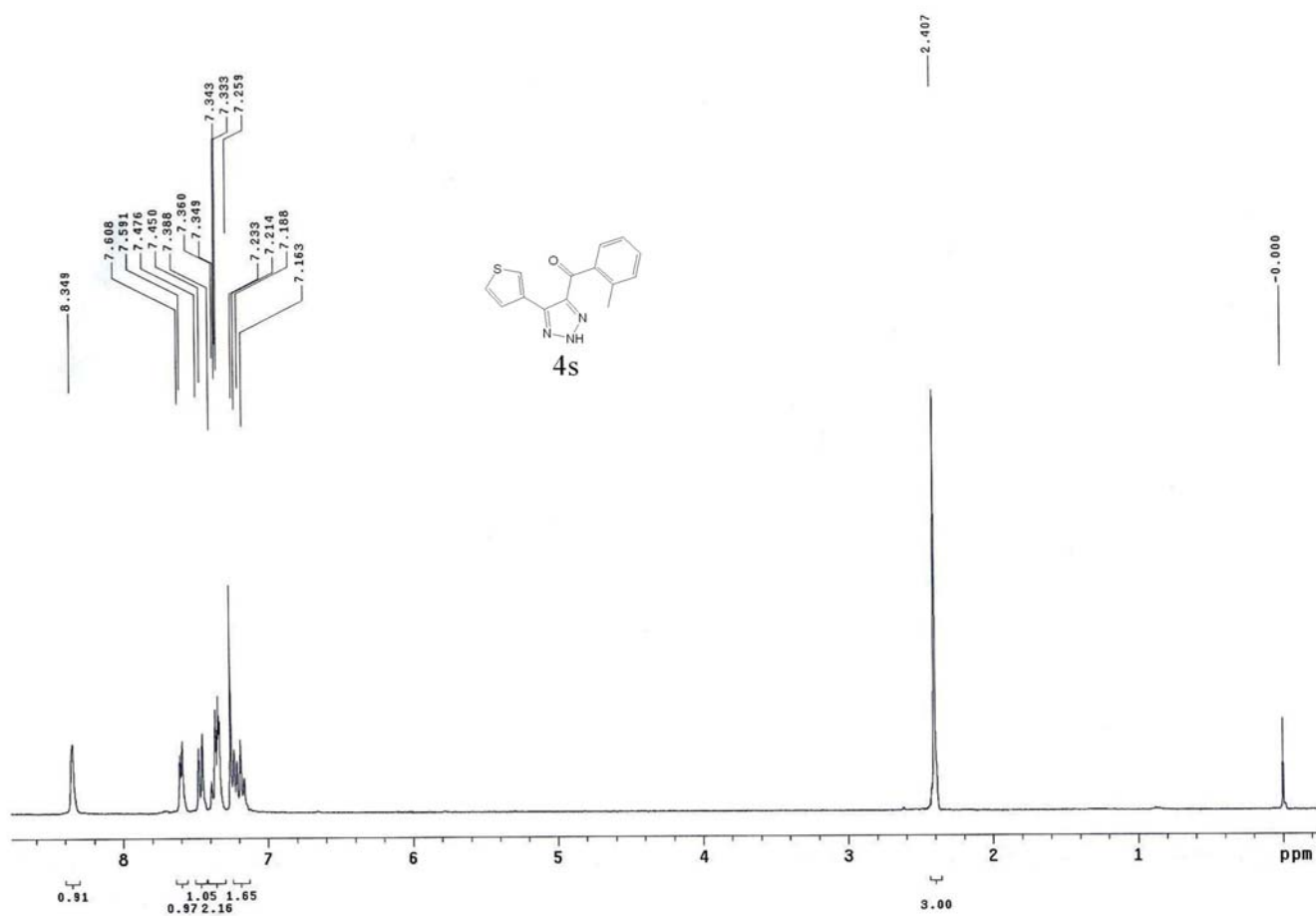


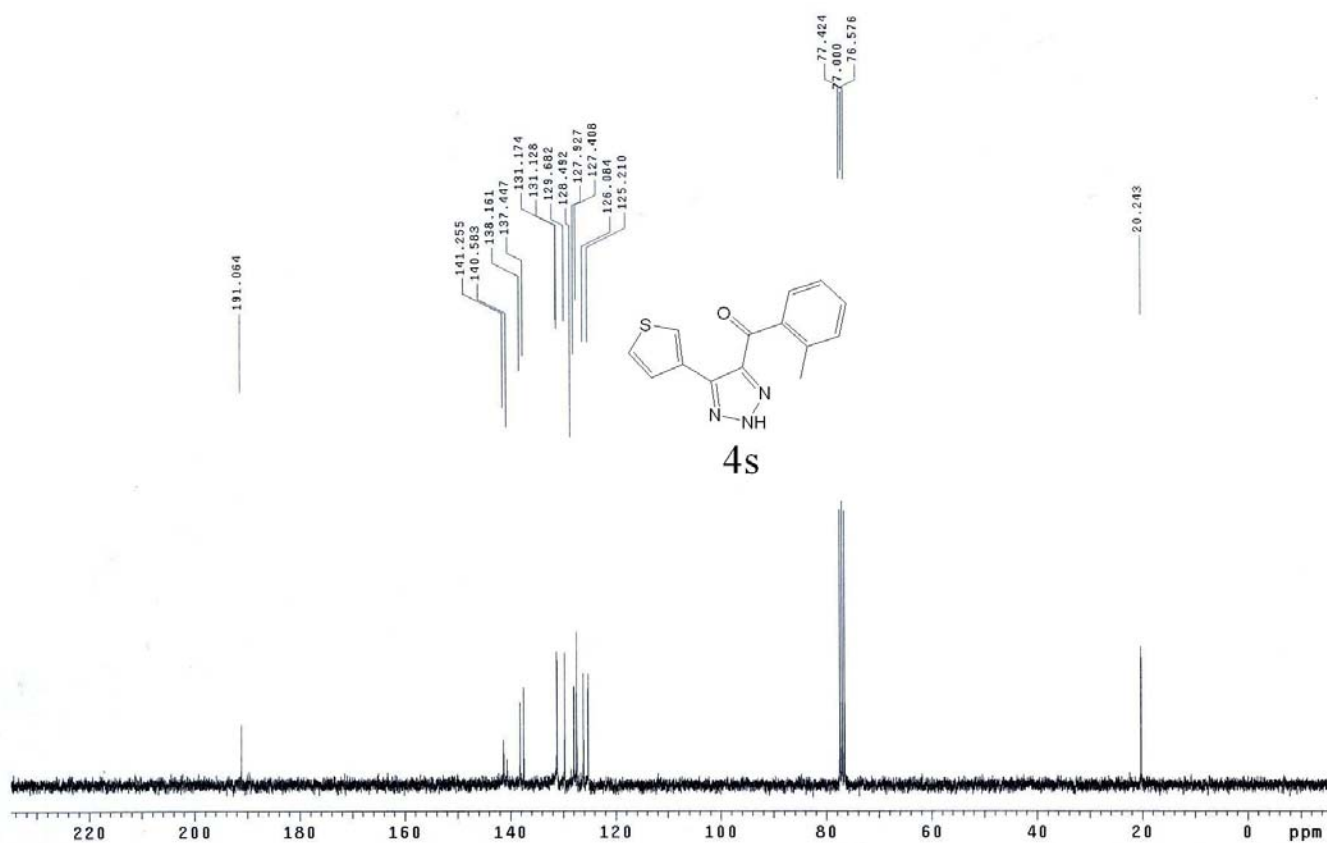
4r:



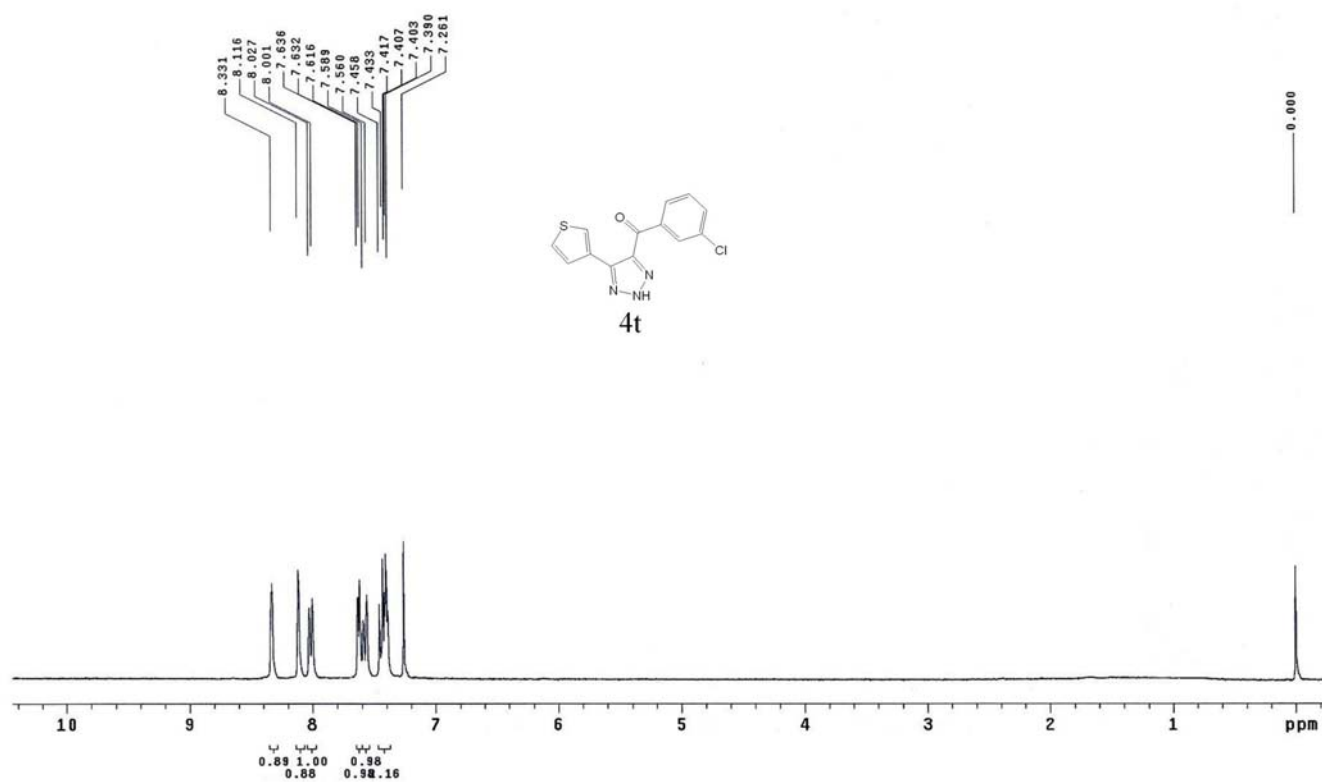


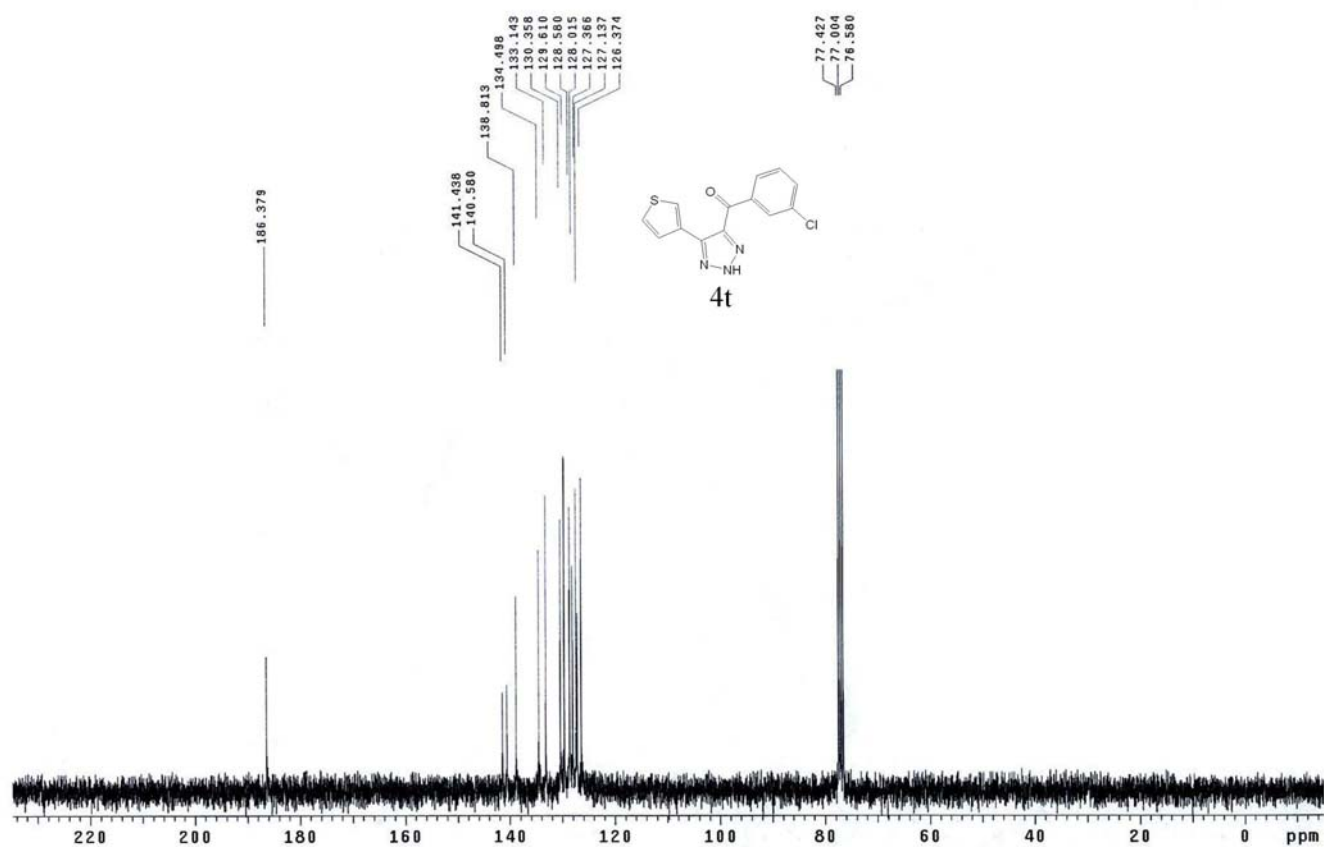
4s:



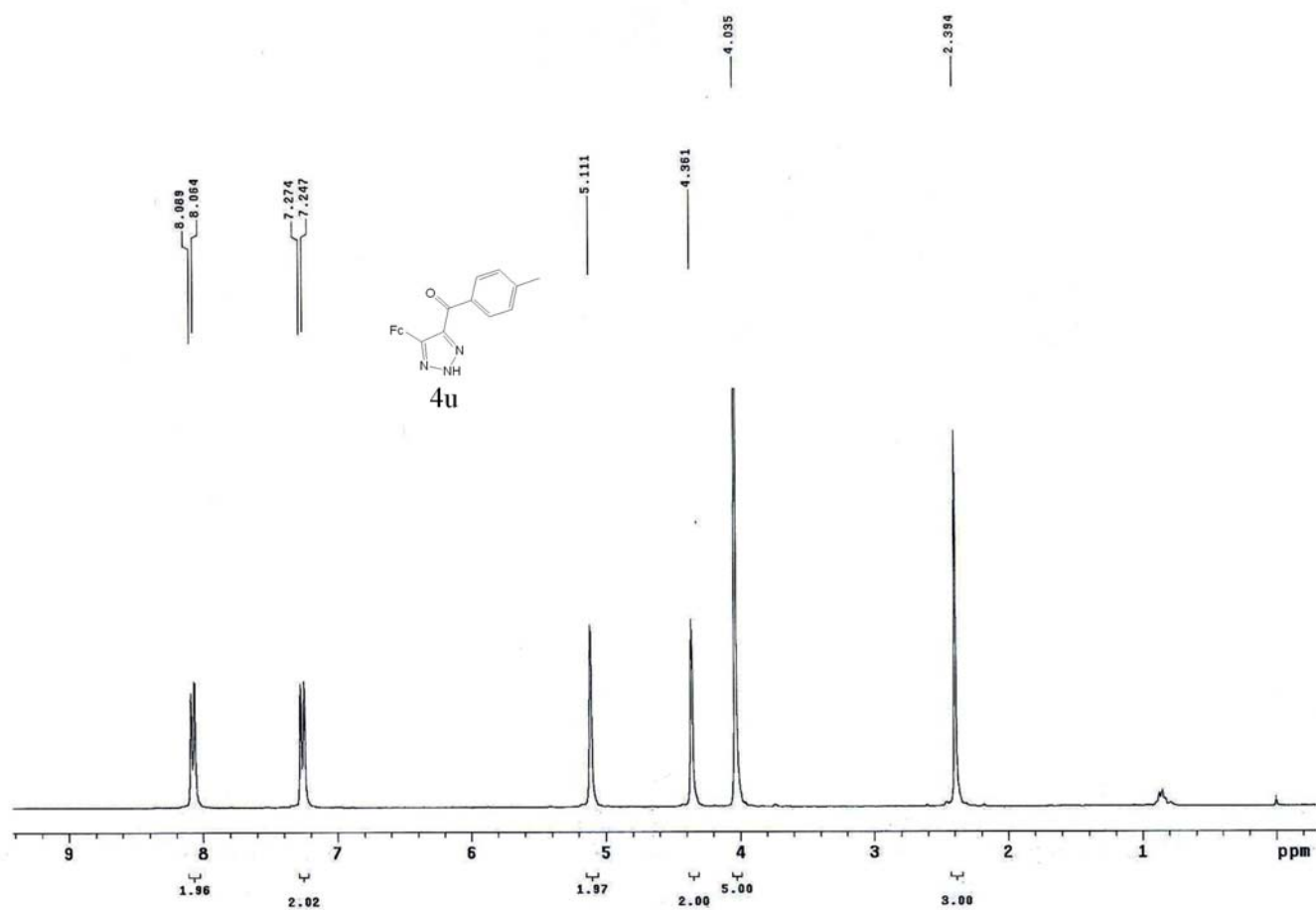


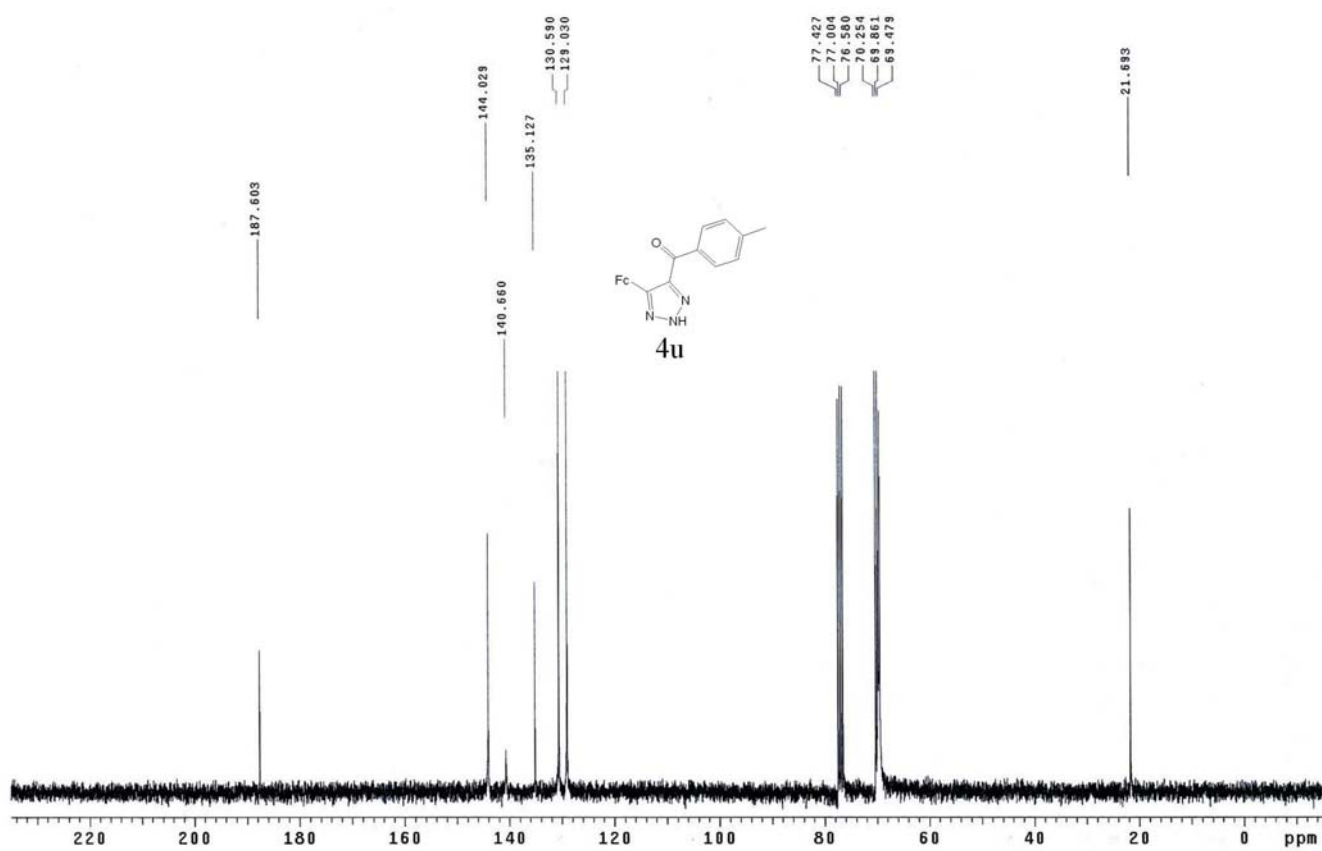
4t:



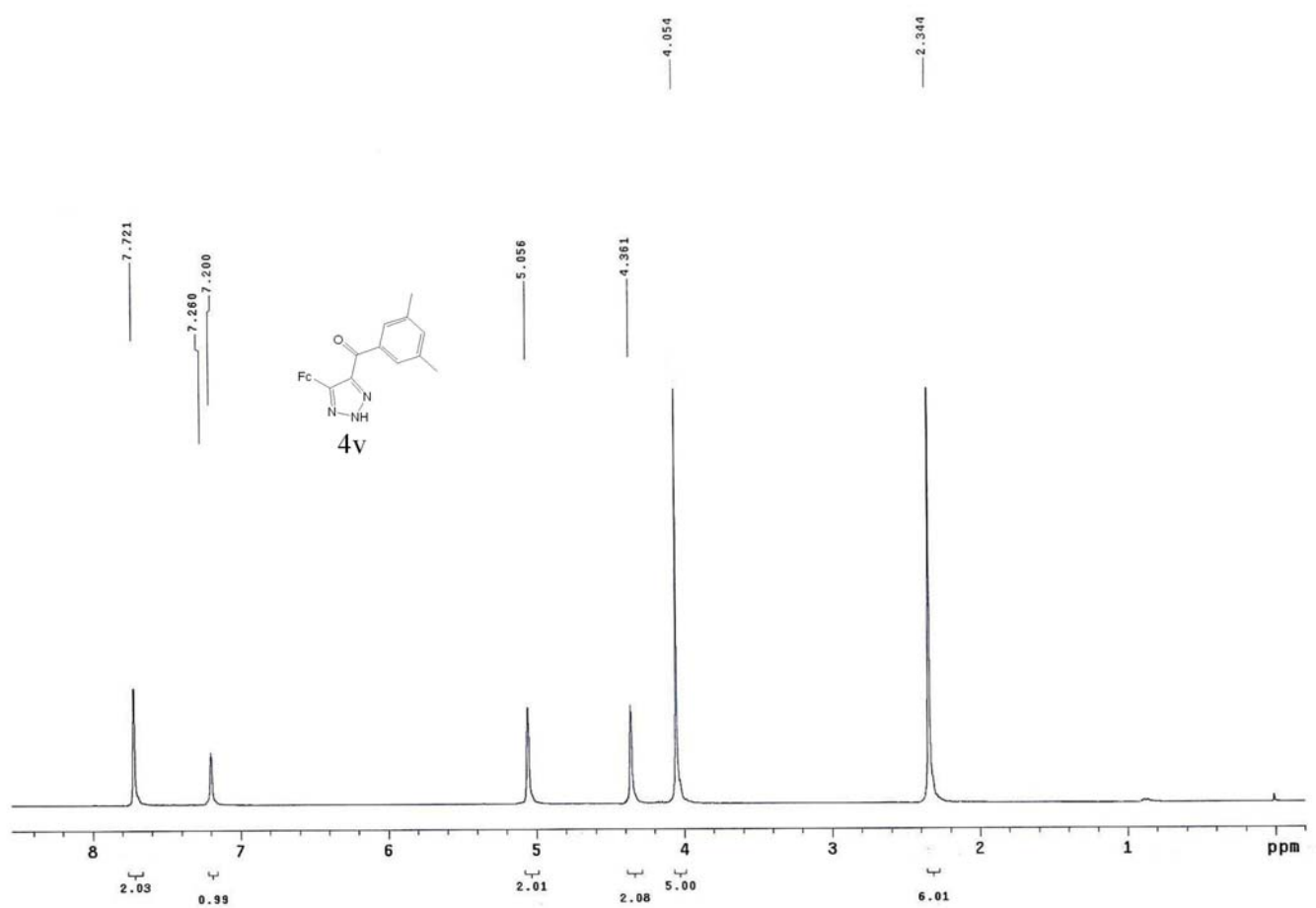


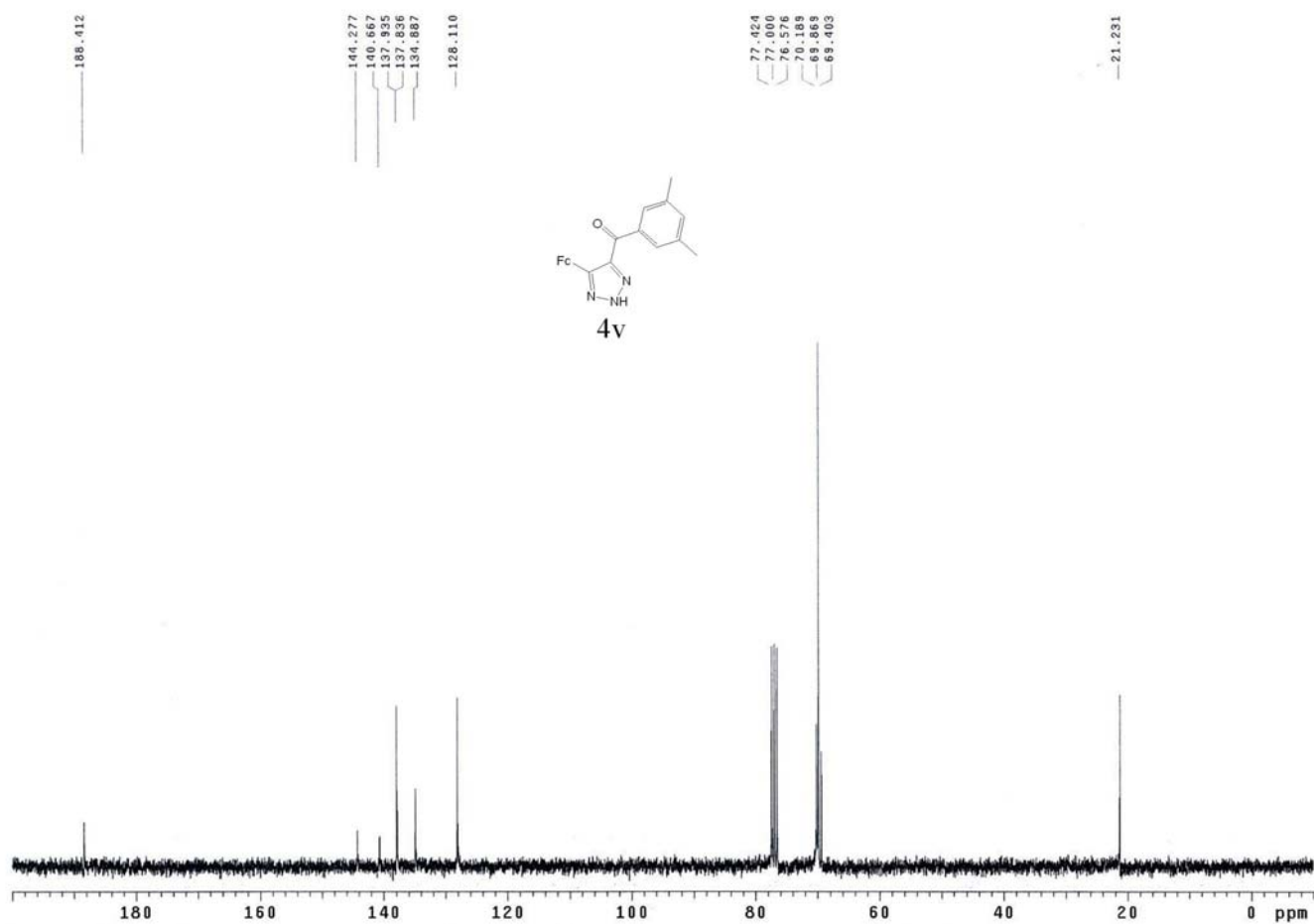
4u:



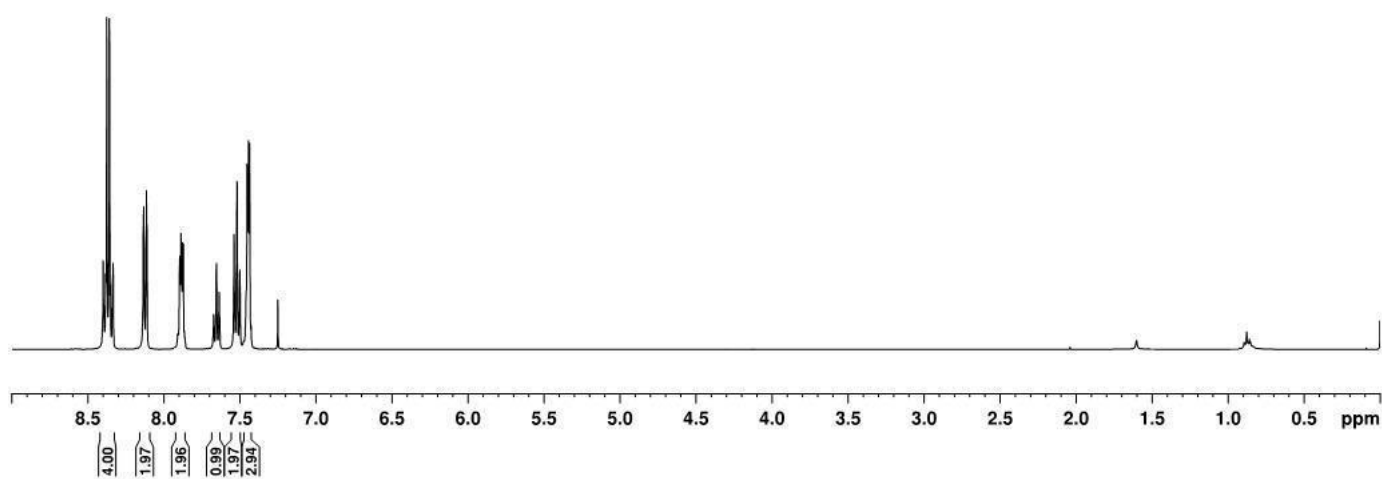
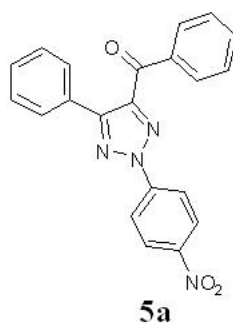
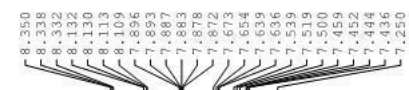


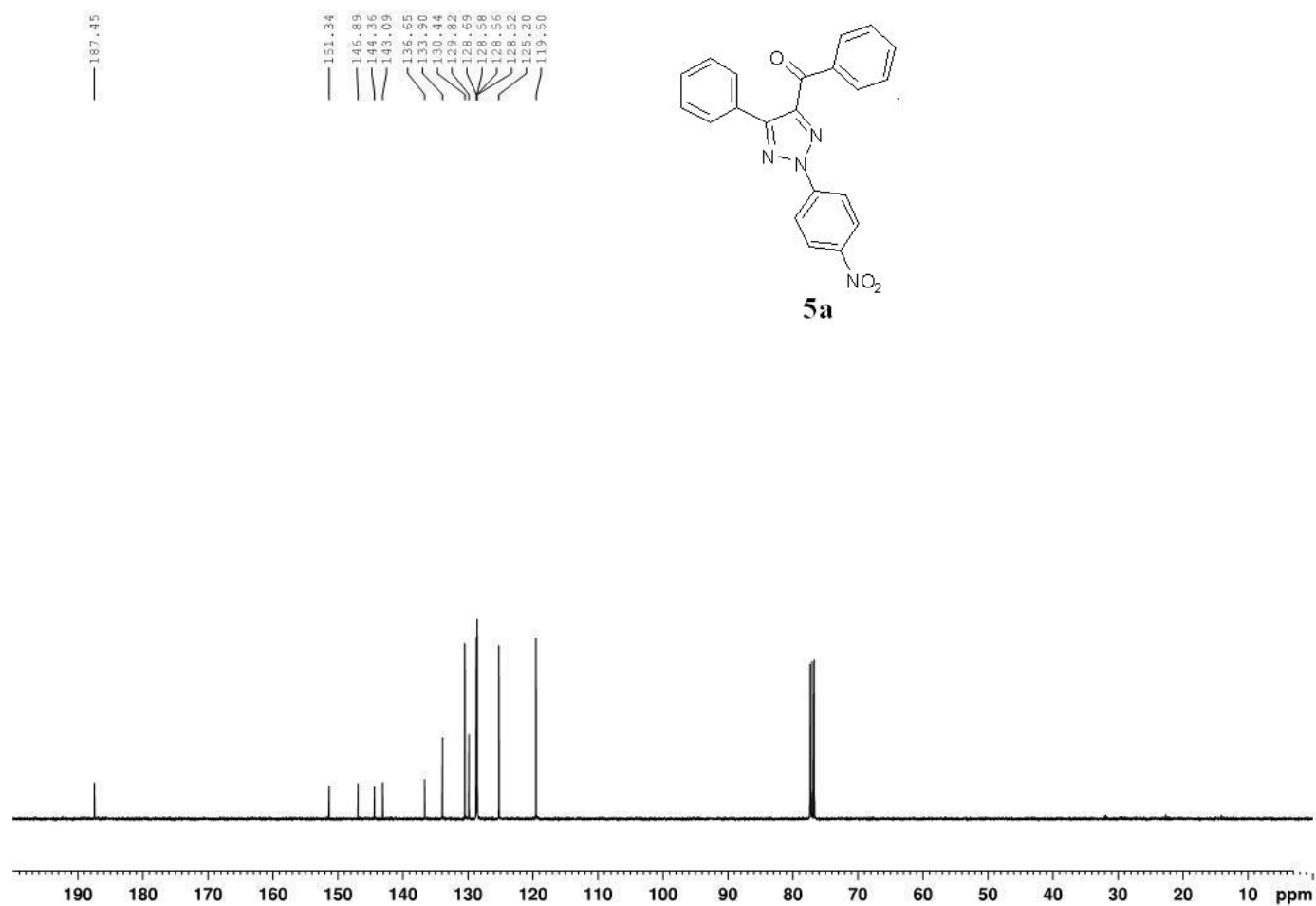
4v:



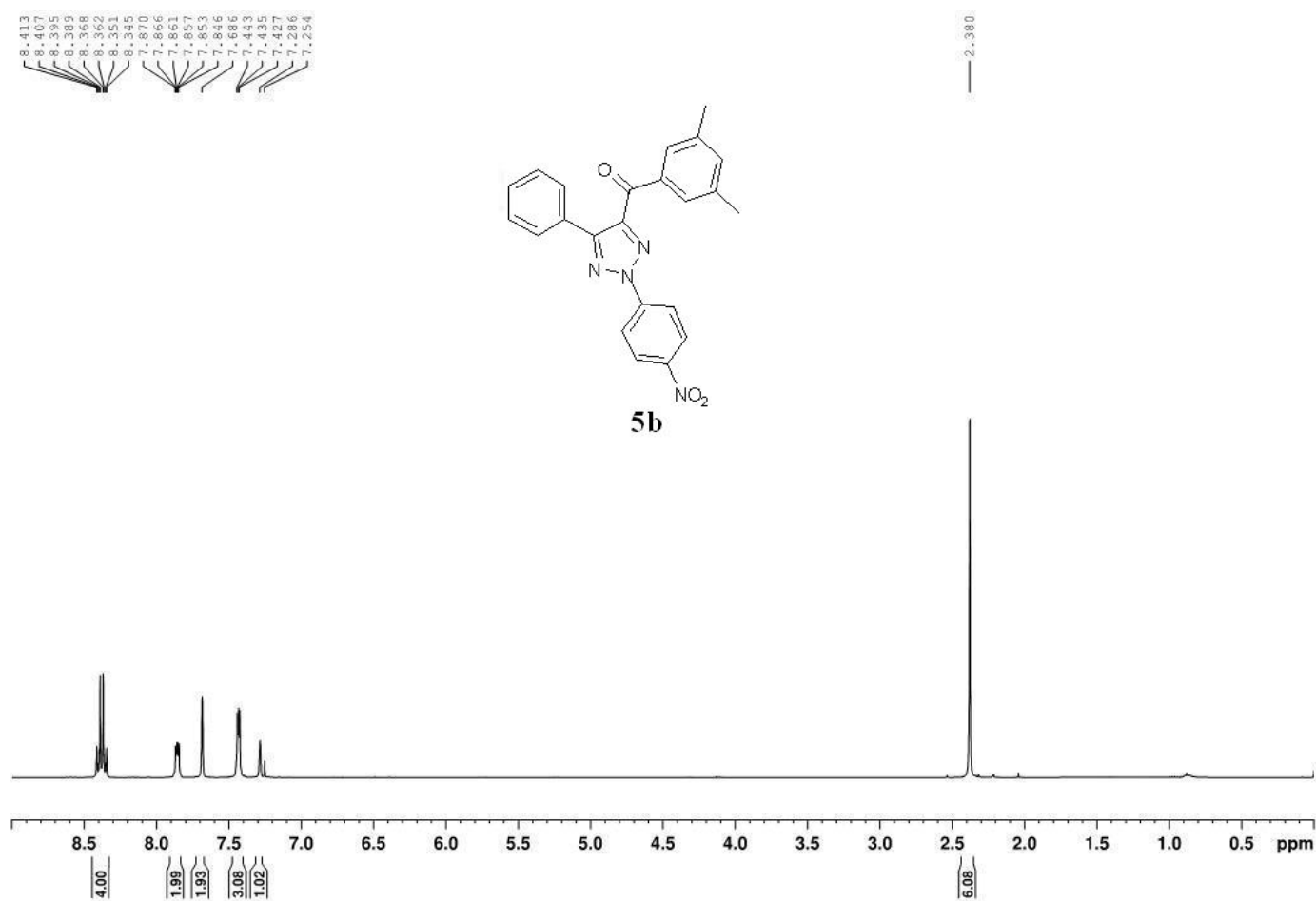


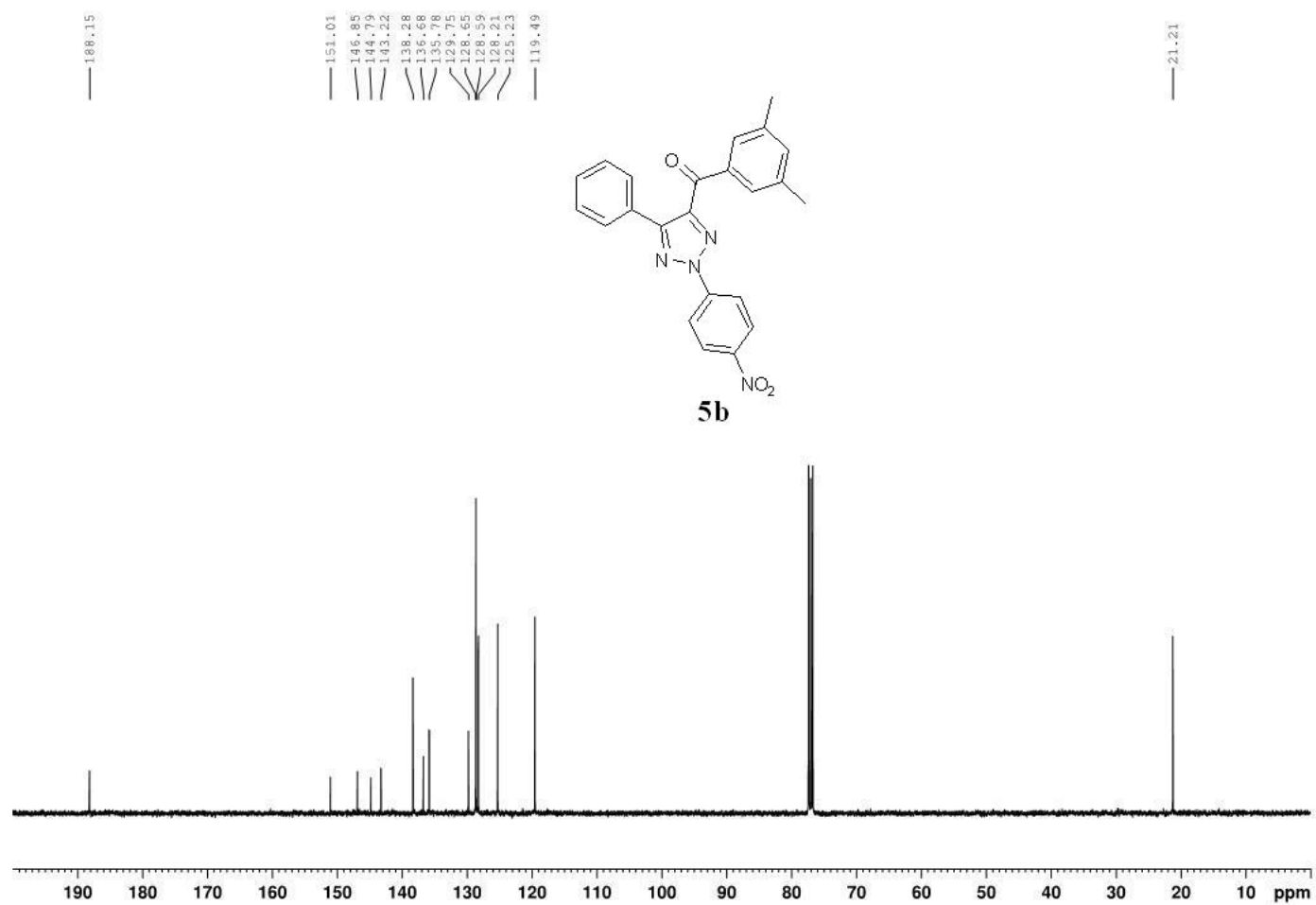
5a:





5b:





5c:

