

# Efficient One-Pot Three-Component Synthesis of Fused Pyridine Derivatives in Ionic Liquid

*Zhibin Huang, Yu Hu, Yao Zhou, Daqing Shi\**

*Key Laboratory of Organic Synthesis of Jiangsu Province, College of Chemistry,  
Chemical Engineering and Materials Science, Soochow University, Suzhou 215123, P.*

*R. China*

[dqshi@suda.edu.cn](mailto:dqshi@suda.edu.cn)

## Contents

Experiment Section.....S3-S26

X-ray crystallographic information..... S27-S28

Copies of  $^1\text{H}$  NMR and  $^{13}\text{C}$  NMR of compounds .....S29-S55

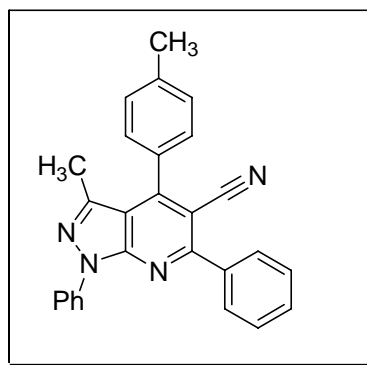
## General Experimental Methods

Commercial solvents and reagents were used as received. Melting points are uncorrected. IR spectra were recorded on Varian F-1000 spectrometer in KBr with absorptions in  $\text{cm}^{-1}$ .  $^1\text{H}$  NMR and  $^{13}\text{C}$  NMR were determined on Varian-300 MHz or Varian-400 MHz spectrometer in  $\text{DMSO}-d_6$  or  $\text{CDCl}_3$  solution.  $J$  values are in Hz. Chemical shifts are expressed in ppm downfield from internal standard TMS. High resolution mass spectra (HRMS) were obtained using a time-of-flight mass spectrometry (TOF-MS) instrument. X-ray crystallographic analysis was performed with a Rigaku Mercury CCD/AFC diffractometer.

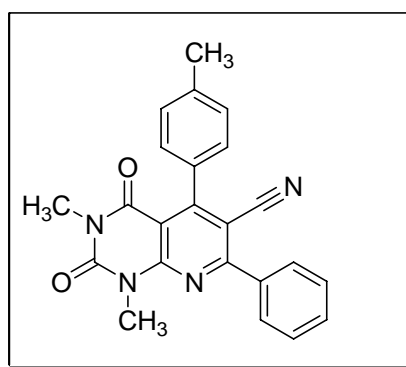
### General procedure for the synthesis of fused pyridines **4** is represented as follows

A dry 50 ml flask was charged with aldehyde **1** (1 mmol), acyl acetonitrile **2** (1 mmol), electron-rich amino heterocycles **3** (1 mmol) and ionic liquid [bmim]Br (2 ml). The mixture was stirred at 80 °C for 4-7 h to complete the reaction (monitored by TLC), then 50 ml water was added. The solid was filtered off and washed with water. The crude product was purified by recrystallization from ethanol to give **4**.

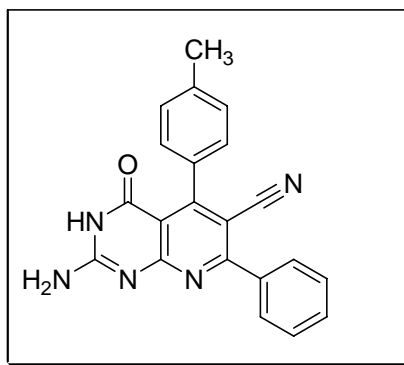
## Characterizations for compounds



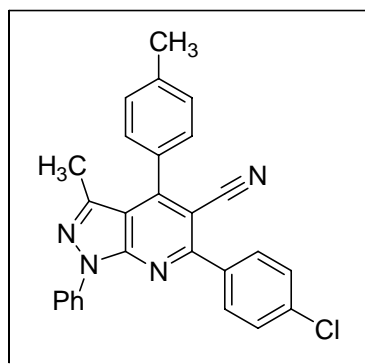
**3-Methyl-1,6-diphenyl-4-(4-methylphenyl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{1,1,1}**: m.p. 210-212 °C. IR (KBr)  $\nu$ : 2221, 1583, 1559, 1506, 1433, 1418, 1385, 1340, 1196, 1176, 1127, 775, 758, 706 cm<sup>-1</sup>; <sup>1</sup>H NMR (DMSO-*d*<sub>6</sub>) ( $\delta$ , ppm): 2.10 (3H, s, CH<sub>3</sub>), 2.46 (3H, s, CH<sub>3</sub>), 7.38 (1H, t, *J* = 7.2 Hz, ArH), 7.45 (2H, d, *J* = 8.0 Hz, ArH), 7.56-7.61 (7H, m, ArH), 7.94-7.96 (2H, m, ArH), 8.22 (2H, d, *J* = 8.4 Hz, ArH). HRMS [Found: *m/z* 400.1688 (M<sup>+</sup>); Calcd for C<sub>27</sub>H<sub>20</sub>N<sub>4</sub> M, 400.1688].



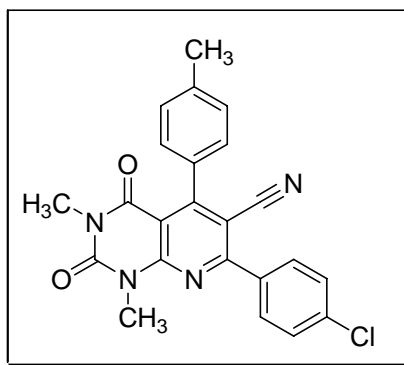
**1,3-Dimethyl-2,4-dioxo-7-phenyl-5-*p*-tolyl-1,2,3,4-tetrahydropyrido[2,3-*d*]pyrimidine-6-carbonitrile 4{1,1,2}**: m.p. >300 °C. IR (KBr)  $\nu$ : 2222, 1713, 1668, 1553, 1478, 1409, 1362, 1286, 1097, 817, 752, 716, 698 cm<sup>-1</sup>; <sup>1</sup>H NMR (DMSO-*d*<sub>6</sub>) ( $\delta$ , ppm): 2.41 (3H, s, CH<sub>3</sub>), 3.17 (3H, s, CH<sub>3</sub>), 3.67 (3H, s, CH<sub>3</sub>), 7.25-7.31 (4H, m, ArH), 7.61-7.62 (3H, m, ArH), 8.00-8.02 (2H, m, ArH). HRMS [Found: *m/z* 382.1435 (M<sup>+</sup>); Calcd for C<sub>23</sub>H<sub>18</sub>N<sub>4</sub>O<sub>2</sub> M, 382.1430].



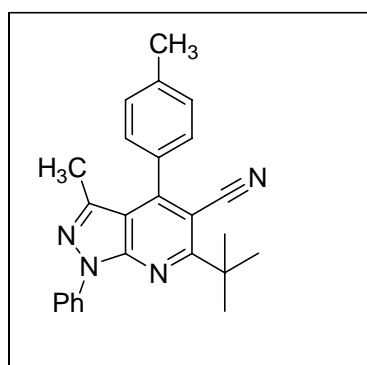
**2-Amino-4-oxo-7-phenyl-5-p-tolyl-3,4-dihydropyrido[2,3-*d*]pyrimidine-6-carbonitrile 4{I,I,4}**: m.p. 249-250°C. IR(KBr)  $\nu$ : 3323, 3060, 2224, 1701, 1665, 1539, 1455, 1431, 1386, 1357, 1280, 1209, 1103, 908, 828, 789, 717, 694  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 2.43 (3H, s,  $\text{CH}_3$ ), 7.28 (5H, s, ArH), 7.58-7.60 (4H, m, ArH+ $\text{NH}_2$ ), 7.89-7.99 (2H, m, ArH), 11.18 (1H, s, NH).  $^{13}\text{C}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 21.65, 108.74, 114.13, 118.04, 128.48, 128.97, 129.69, 130.92, 134.85, 137.99, 138.17, 138.33, 141.37, 156.47, 158.73, 162.98, 164.96. HRMS [Found:  $m/z$  353.1277( $\text{M}^+$ ); Calcd for  $\text{C}_{20}\text{H}_{12}^{35}\text{ClN}_5\text{O}$  M, 353.1277].



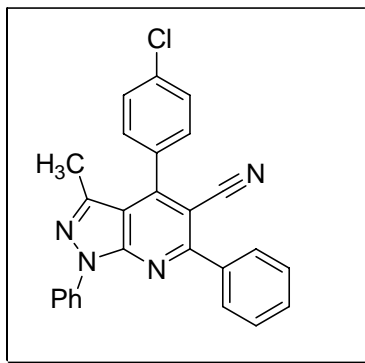
**3-Methyl-1-phenyl-6-(4-chlorophenyl)-4-(4-methylphenyl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{I,2,I}**: m.p. 210-211°C. IR (KBr)  $\nu$ : 2226, 1581, 1558, 1506, 1439, 1421, 1385, 1346, 1174, 1129, 1090, 1017, 841, 803, 756, 741  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 2.10 (3H, s,  $\text{CH}_3$ ), 2.47 (3H, s,  $\text{CH}_3$ ), 7.36-7.40 (1H, m, ArH), 7.46 (2H, d,  $J = 8.0$  Hz, ArH), 7.56-7.59 (4H, m, ArH), 7.68-7.70 (2H, m, ArH), 7.98-8.00 (2H, m, ArH), 8.20 (2H, d,  $J = 8.0$  Hz, ArH). HRMS [Found:  $m/z$  434.1296( $\text{M}^+$ ); Calcd for  $\text{C}_{27}\text{H}_{19}^{35}\text{ClN}_4$  M, 434.1298 ].



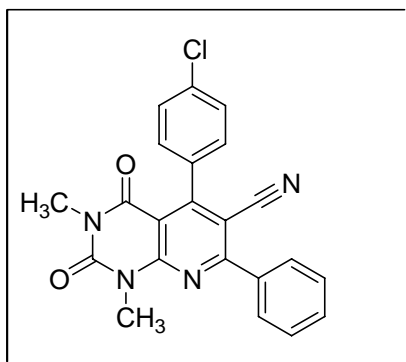
**7-(4-Chlorophenyl)-1,3-dimethyl-2,4-dioxo-5-(4-methylphenyl)-1,2,3,4-tetrahydropyrido[2,3-*d*]pyrimidine-6-carbonitrile 4{1,2,2}**: m.p. >300°C. IR(KBr)  $\nu$ : 2220, 1718, 1670, 1578, 1550, 1496, 1475, 1411, 1363, 1285, 1092, 1012, 844, 812  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 2.44 (3H, s, CH<sub>3</sub>), 3.21 (3H, s, CH<sub>3</sub>), 3.71 (3H, s, CH<sub>3</sub>), 7.28-7.34 (4H, m, ArH), 7.73 (2H, d,  $J$  = 8.0 Hz, ArH), 8.08 (2H, d,  $J$  = 8.4 Hz, ArH). HRMS [Found:  $m/z$  416.1001( $\text{M}^+$ ); Calcd for  $\text{C}_{23}\text{H}_{17}^{35}\text{ClN}_4\text{O}_2$  M, 416.1040].



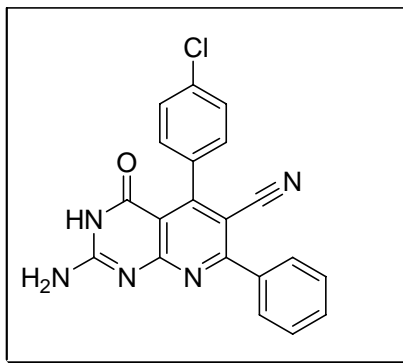
**6-*tert*-Butyl-3-methyl-1-phenyl-4-p-tolyl-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{1,3,1}**: m.p. 197-199 °C. IR (KBr)  $\nu$ : 2997, 2968, 2869, 2218, 1598, 1577, 1559, 1505, 1418, 1385, 1368, 1340, 1196, 1127, 1089, 912, 758, 706  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 1.60 (9H, s, CH<sub>3</sub>), 2.00 (3H, s, CH<sub>3</sub>), 2.48 (3H, s, CH<sub>3</sub>), 7.35-7.44 (5H, m, ArH), 7.55-7.60 (2H, m, ArH), 8.25-8.28 (2H, m, ArH). HRMS [Found:  $m/z$  380.2003 ( $\text{M}^+$ ); Calcd for  $\text{C}_{25}\text{H}_{24}\text{N}_4$  M, 380.2001].



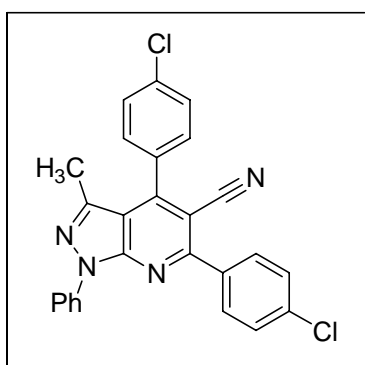
**3-Methyl-1,6-diphenyl-4-(4-chlorophenyl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{2,1,1}**: m.p. 231-233°C. IR (KBr)  $\nu$ : 2221, 1596, 1572, 1506, 1491, 1437, 1343, 1127, 1091, 1017, 839, 774, 757, 705  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{DMSO-}d_6$ ) ( $\delta$ , ppm): 2.18 (3H, s,  $\text{CH}_3$ ), 7.26-7.35 (1H, m, ArH), 7.47-7.60 (9H, m, ArH), 7.99-8.01 (2H, m, ArH), 8.28 (2H, d,  $J = 8.0$  Hz, ArH). HRMS [Found:  $m/z$  420.1143( $\text{M}^+$ ); Calcd for  $\text{C}_{26}\text{H}_{17}^{35}\text{ClN}_4$  M, 420.1142].



**5-(4-Chlorophenyl)-1,3-dimethyl-2,4-dioxo-7-phenyl-1,2,3,4-tetrahydropyrido[2,3-*d*]pyrimidine-6-carbonitrile 4{2,1,2}**: m.p. >300 °C. IR(KBr)  $\nu$ : 2222, 1712, 1666, 1583, 1554, 1495, 1477, 1440, 1410, 1362, 1287, 1087, 1020, 779, 752, 721, 697  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{DMSO-}d_6$ ) ( $\delta$ , ppm): 3.19 (3H, s,  $\text{CH}_3$ ), 3.69 (3H, s,  $\text{CH}_3$ ), 7.43 (2H, dd,  $J_1 = 2.0$  Hz,  $J_2 = 8.4$  Hz, ArH), 7.58 (2H, dd,  $J_1 = 2.0$  Hz,  $J_2 = 8.4$  Hz, ArH), 7.62-7.64 (3H, m, ArH), 8.03 (2H, d,  $J = 7.2$  Hz, ArH). HRMS [Found:  $m/z$  402.0886 ( $\text{M}^+$ ); Calcd for  $\text{C}_{22}\text{H}_{15}^{35}\text{ClN}_4\text{O}_2$  M, 402.0884].

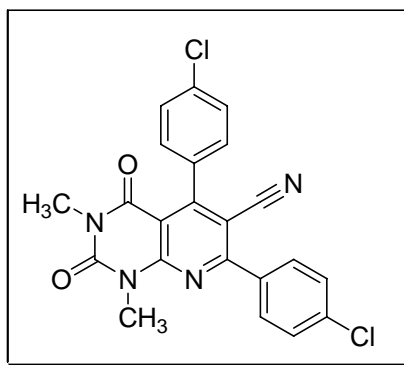


**2-Amino-5-(4-chlorophenyl)-4-oxo-7-phenyl-3,4-dihydropyrido[2,3-*d*]pyrimidine-6-carbonitrile 4{2,1,4}**: m.p. 252-254°C. IR(KBr)  $\nu$ : 3322, 3149, 3059, 2216, 1696, 1668, 1596, 1541, 1487, 1455, 1431, 1386, 1356, 1281, 1214, 1090, 1017, 909, 827, 801, 785, 718  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 7.40-7.43 (2H, m, ArH), 7.50-7.57 (7H, m, ArH+NH<sub>2</sub>), 7.88-7.96 (2H, m, ArH), 11.22 (1H, s, NH). HRMS [Found:  $m/z$  373.0729( $\text{M}^+$ ); Calcd for  $\text{C}_{20}\text{H}_{12}^{35}\text{ClN}_5\text{O}$  M, 373.0730].

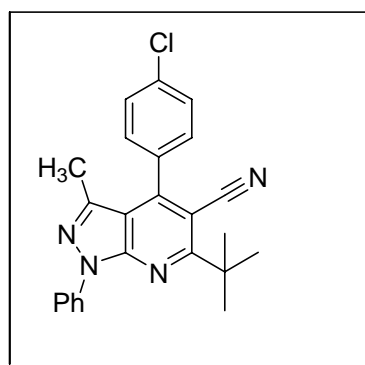


**3-Methyl-1-phenyl-4,6-di-(4-chlorophenyl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{2,2,1}**: m.p. 244-246 °C. IR (KBr)  $\nu$ : 2225, 1595, 1559, 1573, 1507, 1492, 1440, 1420, 1385, 1129, 1087, 1015, 835, 796, 758, 743  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 2.11 (3H, s, CH<sub>3</sub>), 7.37-7.41 (1H, m, ArH), 7.57-7.61 (2H, m, ArH), 7.69-7.74 (6H, m, ArH), 8.00 (2H, d,  $J$  = 8.0 Hz, ArH), 8.20 (2H, d,  $J$  = 8.0 Hz, ArH). HRMS[Found:  $m/z$  454.0759 ( $\text{M}^+$ ); Calcd for  $\text{C}_{26}\text{H}_{16}^{35}\text{Cl}_2\text{N}_4$  M, 454.0752].

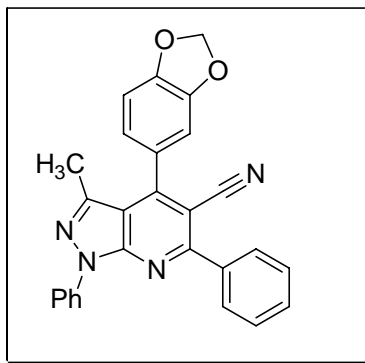




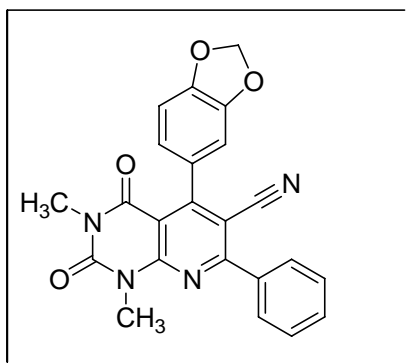
**5,7-Bis(4-chlorophenyl)-1,3-dimethyl-2,4-dioxo-1,2,3,4-tetrahydropyrido[2,3-*d*]pyrimidine-6-carbonitrile 4{2,2,2}**: m.p. > 300°C. IR(KBr)  $\nu$ : 2222, 1717, 1670, 1597, 1557, 1549, 1495, 1475, 1412, 1363, 1287, 1089, 1016, 840, 815, 781, 754  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 3.18 (3H, s, CH<sub>3</sub>), 3.68 (3H, s, CH<sub>3</sub>), 7.41 (2H, d,  $J$  = 8.4 Hz, ArH), 7.57 (2H, d,  $J$  = 8.4 Hz, ArH), 7.70 (2H, d,  $J$  = 8.8 Hz, ArH), 8.05 (2H, d,  $J$  = 8.4 Hz, ArH). HRMS [Found:  $m/z$  436.0490( $\text{M}^+$ ); Calcd for  $\text{C}_{22}\text{H}_{14}^{35}\text{Cl}_2\text{N}_4\text{O}_2$  M, 436.0494].



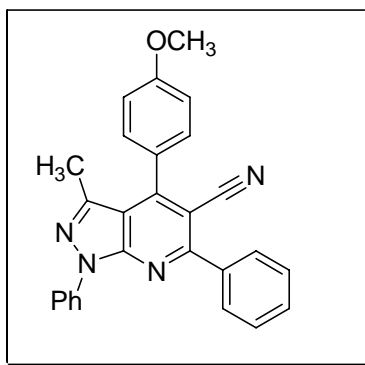
**6-*tert*-Butyl-4-(4-chlorophenyl)-3-methyl-1-phenyl-1*H*-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{2,3,1}**: m.p. 180-182 °C. IR (KBr)  $\nu$ : 2995, 2970, 2871, 2217, 1598, 1577, 1559, 1505, 1490, 1437, 1382, 1326, 1286, 1190, 1108, 1091, 828, 768, 693, 671  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 1.58 (9H, s, CH<sub>3</sub>), 2.00 (3H, s, CH<sub>3</sub>), 7.33-7.36 (1H, m, ArH), 7.52-7.68 (6H, m, ArH), 8.22-8.27 (2H, m, ArH).  $^{13}\text{C}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 14.92, 29.54, 40.47, 100.56, 104.99, 113.18, 120.83, 126.81, 129.23, 129.83, 131.57, 131.67, 133.16, 135.47, 138.96, 144.04, 148.88, 152.59, 170.32. HRMS [Found:  $m/z$  400.1453( $\text{M}^+$ ); Calcd for  $\text{C}_{24}\text{H}_{21}^{35}\text{ClN}_4$  M, 400.1455].



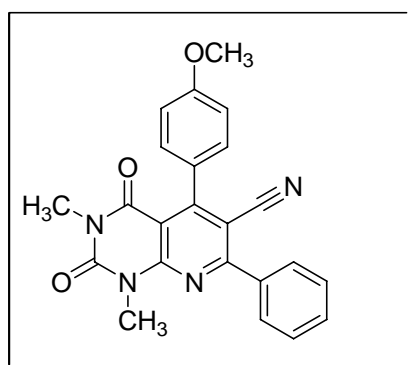
**3-Methyl-1,6-diphenyl-4-(3,4-methylenedioxyphenyl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{3,1,1}**: m.p. 216-218°C. IR (KBr)  $\nu$ : 2220, 1584, 1570, 1506, 1489, 1467, 1442, 1385, 1272, 1236, 1197, 1037, 931, 779, 758, 708  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ ) ( $\delta$ , ppm): 2.25 (3H, s,  $\text{CH}_3$ ), 6.12 (2H, d,  $J = 10.8$  Hz,  $\text{OCH}_2\text{O}$ ), 6.99-7.03 (3H, m, ArH), 7.32 (1H, t,  $J = 7.6$  Hz, ArH), 7.49-7.55 (5H, m, ArH), 7.99-8.01 (2H, m, ArH), 8.29 (2H, d,  $J = 8.0$  Hz, ArH). HRMS [Found:  $m/z$  430.1428( $\text{M}^+$ ); Calcd for  $\text{C}_{27}\text{H}_{18}\text{N}_4\text{O}_2$  M, 430.1430].



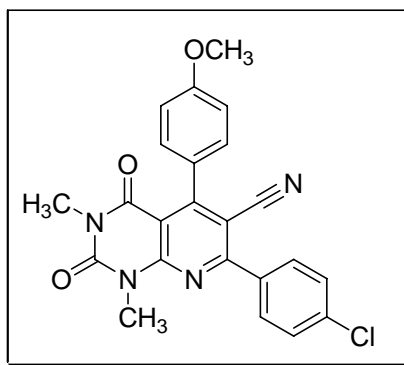
**5-(3,4-Methylenedioxyphenyl)-1,3-dimethyl-2,4-dioxo-7-phenyl-1,2,3,4-tetrahydro-pyrido[2,3-*d*]pyrimidine-6-carbonitrile 4{3,1,2}**: m.p. 269-270 °C. IR(KBr)  $\nu$ : 2223, 1718, 1670, 1554, 1502, 1477, 1439, 1362, 1244, 1080, 1037, 822, 752, 713, 696  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{DMSO}-d_6$ ) ( $\delta$ , ppm): 3.16 (3H, s,  $\text{CH}_3$ ), 3.63 (3H, s,  $\text{CH}_3$ ), 6.10 (2H, s,  $\text{OCH}_2\text{O}$ ), 6.82-6.86 (1H, m, ArH), 6.93-6.95 (1H, m, ArH), 6.98-7.03 (1H, m, ArH), 7.56-7.61 (3H, m, ArH), 7.98-8.00 (2H, m, ArH). HRMS [Found:  $m/z$  412.1179 ( $\text{M}^+$ ); Calcd for  $\text{C}_{23}\text{H}_{16}\text{N}_4\text{O}_4$  M, 412.1172].



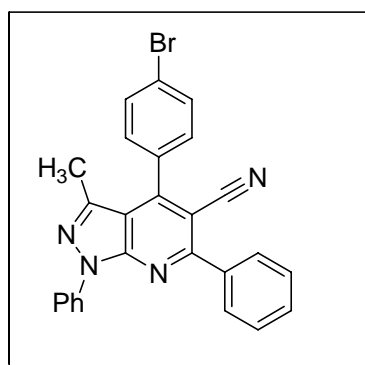
**3-Methyl-1,6-diphenyl-4-(4-methoxyphenyl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{4,*I*,*I*}**: m.p. 206-208 °C. IR (KBr)  $\nu$ : 2220, 1609, 1565, 1513, 1436, 1286, 1250, 1029, 840, 762, 706  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ ) ( $\delta$ , ppm): 2.21 (3H, s,  $\text{CH}_3$ ), 3.92 (3H, s,  $\text{OCH}_3$ ), 7.11 (2H, d,  $J = 8.0$  Hz, ArH), 7.32 (1H, t,  $J = 7.2$  Hz, ArH), 7.40-7.56 (7H, m, ArH), 7.96-8.02 (2H, m, ArH), 8.29 (2H, d,  $J = 8.4$  Hz, ArH). HRMS [Found:  $m/z$  416.1637( $\text{M}^+$ ); Calcd for  $\text{C}_{27}\text{H}_{20}\text{N}_4\text{O}$  M, 416.1637].



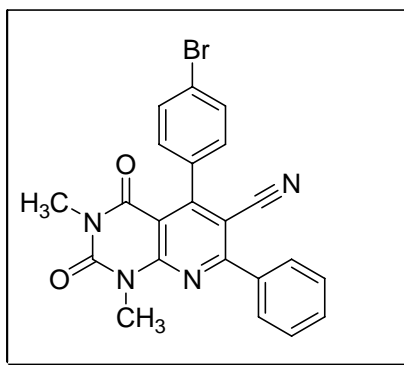
**5-(4-Methoxyphenyl)-1,3-dimethyl-2,4-dioxo-7-phenyl-1,2,3,4-tetrahydropyridine[2,3-*d*]pyrimidine-6-carbonitrile 4{4,*I*,2}**: m.p. 246-248 °C. IR(KBr)  $\nu$ : 2222, 1714, 1668, 1552 1516, 1473, 1441, 1409, 1361, 1253, 1176, 1097, 833, 752  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{DMSO-}d_6$ ) ( $\delta$ , ppm): 3.20 (3H, s,  $\text{CH}_3$ ), 3.69 (3H, s,  $\text{CH}_3$ ), 3.86 (3H, s,  $\text{OCH}_3$ ), 7.06 (2H, d,  $J = 8.8$  Hz, ArH), 7.35 (2H, d,  $J = 8.8$  Hz, ArH), 7.62-7.65 (3H, m, ArH), 8.03 (2H, dd,  $J_1 = 2.0$  Hz,  $J_2 = 7.2$  Hz, ArH). HRMS [Found:  $m/z$  398.1378( $\text{M}^+$ ); Calcd for  $\text{C}_{23}\text{H}_{18}\text{N}_4\text{O}_3$  M, 398.1379].



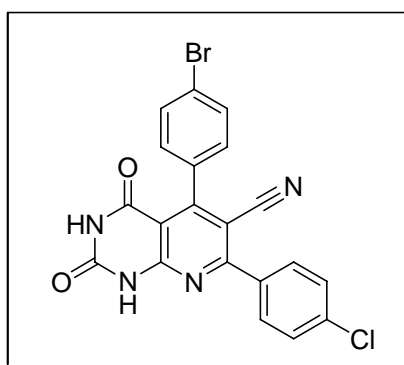
**7-(4-Chlorophenyl)-5-(4-methoxyphenyl)-1,3-dimethyl-2,4-dioxo-1,2,3,4-tetrahydropyrido[2,3-*d*]pyrimidine-6-carbonitrile 4{4,2,2}**: m.p. >300°C. IR(KBr)  $\nu$ : 2221, 1717, 1669, 1610, 1577, 1549, 1515, 1472, 1363, 1298, 1253, 1176, 1092, 1035, 840, 816, 752  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR(DMSO- $d_6$ ) ( $\delta$ , ppm): 3.18 (3H, s, CH<sub>3</sub>), 3.67 (3H, s, CH<sub>3</sub>), 3.85 (3H, s, OCH<sub>3</sub>), 7.04 (2H, d,  $J$  = 8.4 Hz, ArH), 7.32 (2H, d,  $J$  = 8.4 Hz, ArH), 7.69 (2H, d,  $J$  = 8.4 Hz, ArH), 8.04 (2H, d,  $J$  = 8.4 Hz, ArH). HRMS [Found:  $m/z$  432.0988( $\text{M}^+$ ); Calcd for C<sub>23</sub>H<sub>17</sub><sup>35</sup>ClN<sub>4</sub>O<sub>3</sub> M, 432.0989].



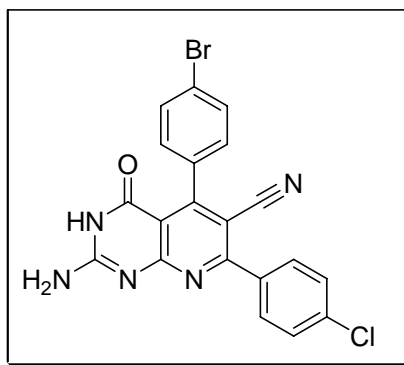
**3-Methyl-1,6-diphenyl-4-(4-bromophenyl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{5,1,1}**: m.p. 244-246 °C. IR (KBr)  $\nu$ : 2223, 1595, 1571, 1507, 1489, 1433, 1340, 1196, 1124, 1012, 834, 774, 753, 699  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (CDCl<sub>3</sub>) ( $\delta$ , ppm): 2.19 (3H, s, CH<sub>3</sub>), 7.33 (1H, t,  $J$  = 7.2 Hz, ArH), 7.42 (2H, d,  $J$  = 8.0 Hz, ArH), 7.50-7.56 (5H, m, ArH), 7.75 (2H, d,  $J$  = 8.0 Hz, ArH), 7.99-8.02 (2H, m, ArH), 8.29 (2H, d,  $J$  = 8.0 Hz, ArH). HRMS [Found:  $m/z$  464.0643( $\text{M}^+$ ); Calcd for C<sub>26</sub>H<sub>17</sub><sup>79</sup>BrN<sub>4</sub> M, 464.0637].



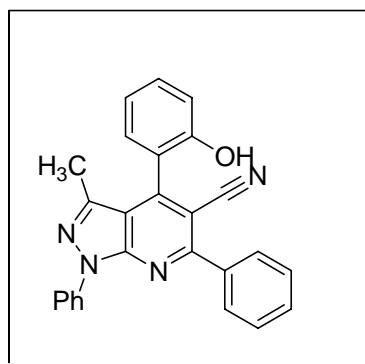
**5-(4-Bromophenyl)-1,3-dimethyl-2,4-dioxo-7-phenyl-1,2,3,4-tetrahydropyrido[2,3-*d*]pyrimidine-6-carbonitrile 4{5,1,2}**: m.p. >300 °C. IR(KBr)  $\nu$ : 2222, 1713, 1666, 1553, 1476, 1410, 1362, 1287, 1072, 1011, 752, 697  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 3.18 (3H, s, CH<sub>3</sub>), 3.69 (3H, s, CH<sub>3</sub>), 7.36 (2H, d,  $J$  = 8.4 Hz, ArH), 7.61-7.64 (3H, m, ArH), 7.71 (2H, d,  $J$  = 8.4 Hz, ArH), 8.01-8.03 (2H, m, ArH). HRMS [Found:  $m/z$  446.0375( $\text{M}^+$ ); Calcd for  $\text{C}_{22}\text{H}_{15}^{79}\text{BrN}_4\text{O}_2$  M, 446.0378].



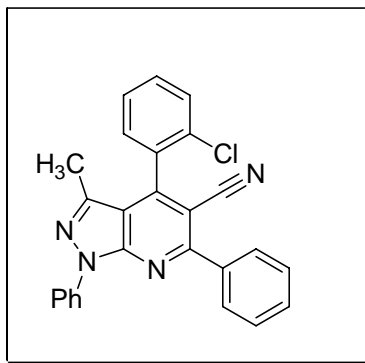
**5-(4-Bromophenyl)-7-(4-chlorophenyl)-2,4-dioxo-1,2,3,4-tetrahydropyrido[2,3-*d*]pyrimidine-6-carbonitrile 4{5,2,3}**: m.p. 177-178°C. IR(KBr)  $\nu$ : 3446, 3177, 2224, 1714, 1641, 1574, 1557, 1490, 1385, 1261, 1204, 1092, 1072, 1010, 833, 815, 750, 705  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 7.31-.36 (2H, m, ArH), 7.63-7.70 (4H, m, ArH), 7.86-7.92 (2H, m, ArH), 11.50 (1H, s, NH), 12.26 (1H, s, NH). HRMS [Found:  $m/z$  451.9676( $\text{M}^+$ ); Calcd for  $\text{C}_{20}\text{H}_{10}^{79}\text{Br}^{35}\text{ClN}_4\text{O}_2$  M, 451.9676].



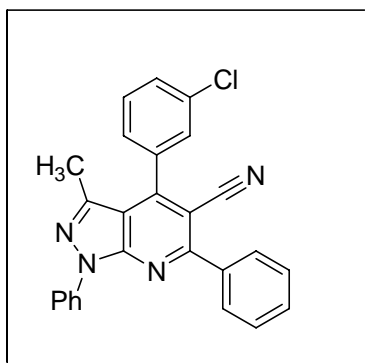
**2-Amino-5-(4-bromophenyl)-7-(4-chlorophenyl)-4-oxo-3,4-dihydropyrido[2,3-*d*]pyrimidine-6-carbonitrile 4{5,2,4}**: m.p. 266-268°C. IR(KBr)  $\nu$ : 3427, 3129, 2216, 1700, 1653, 1593, 1573, 1545, 1484, 1382, 1285, 1214, 1091, 1011, 910, 824, 738  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 7.34 (3H, d,  $J = 8.0$  Hz, ArH), 7.62-7.66 (5H, m, ArH+NH<sub>2</sub>), 7.90 (2H, d,  $J = 8.0$  Hz, ArH), 11.26 (1H, s, NH).  $^{13}\text{C}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 108.76, 117.73, 122.54, 129.15, 130.73, 131.40, 131.53, 131.69, 136.05, 136.15, 136.87, 136.99, 156.61, 157.21, 162.98, 163.62. HRMS [Found:  $m/z$  450.9835( $\text{M}^+$ ); Calcd for  $\text{C}_{20}\text{H}_{11}^{79}\text{Br}^{35}\text{ClN}_5\text{O}$  M, 450.9836].



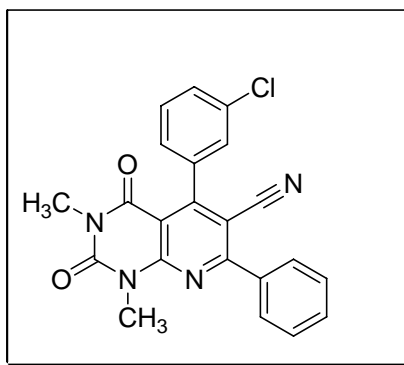
**3-Methyl-1,6-diphenyl-4-(2-hydroxyphenyl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{6,1,1}**: m.p. 204-206 °C. IR (KBr)  $\nu$ : 3330, 2239, 1610, 1583, 1554, 1507, 1434, 1351, 1292, 1128, 1029, 917, 752, 708  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ ) ( $\delta$ , ppm): 2.19 (3H, s, CH<sub>3</sub>), 5.94 (1H, s, OH), 6.93 (1H, d,  $J = 8.0$  Hz, ArH), 7.12 (1H, t,  $J = 7.6$  Hz, ArH), 7.29-7.35 (2H, m, ArH), 7.37-7.42 (1H, m, ArH), 7.48-7.56 (5H, m, ArH), 7.99-8.00 (2H, m, ArH), 8.26 (2H, d,  $J = 8.0$  Hz, ArH). HRMS [Found:  $m/z$  402.1482 ( $\text{M}^+$ ); Calcd for  $\text{C}_{26}\text{H}_{18}\text{N}_4\text{O}$  M, 402.1481].



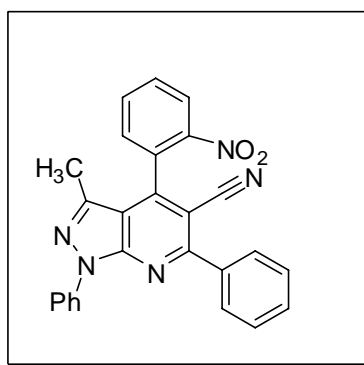
**3-Methyl-1,6-diphenyl-4-(2-chlorophenyl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{7,*I*,*I*}**: m.p. 186-188 °C. IR (KBr)  $\nu$ : 2220, 1596, 1574, 1506, 1434, 1342, 1197, 1128, 1058, 771, 756, 703  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ ) ( $\delta$ , ppm): 2.12 (3H, s,  $\text{CH}_3$ ), 7.33 (1H, t,  $J = 7.6$  Hz, ArH), 7.44 (1H, dd,  $J_1 = 1.6$  Hz,  $J_2 = 7.6$  Hz, ArH), 7.50-7.58 (7H, m, ArH), 7.64 (1H, d,  $J = 8.0$  Hz, ArH), 8.03-8.06 (2H, m, ArH), 8.31 (2H, d,  $J = 8.0$  Hz, ArH). HRMS [Found:  $m/z$  420.1140 ( $\text{M}^+$ ); Calcd for  $\text{C}_{26}\text{H}_{17}^{35}\text{ClN}_4$  M, 420.1142].



**3-Methyl-1,6-diphenyl-4-(3-chlorophenyl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{8,*I*,*I*}**: m.p. 176-178 °C. IR (KBr)  $\nu$ : 2220, 1573, 1559, 1506, 1435, 1383, 1340, 1178, 789, 757, 728, 707  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ ) ( $\delta$ , ppm): 2.17 (3H, s,  $\text{CH}_3$ ), 7.33 (1H, t,  $J = 7.6$  Hz, ArH), 7.43 (1H, d,  $J = 6.8$  Hz, ArH), 7.50-7.57 (8H, m, ArH), 7.99-8.02 (2H, m, ArH), 8.28 (2H, d,  $J = 8.0$  Hz, ArH). HRMS [Found:  $m/z$  420.1144 ( $\text{M}^+$ ); Calcd for  $\text{C}_{26}\text{H}_{17}^{35}\text{ClN}_4$  M, 420.1142].

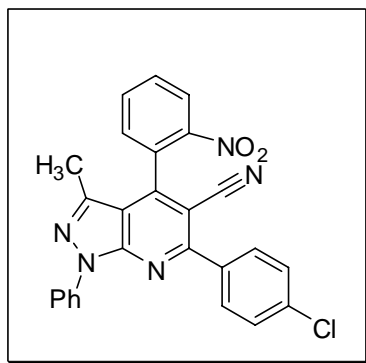


**5-(3-Chlorophenyl)-1,3-dimethyl-2,4-dioxo-7-phenyl-1,2,3,4-tetrahydropyrido[2,3-*d*]pyrimidine-6-carbonitrile 4{8,*I*,2}**: m.p. 270-272 °C. IR(KBr)  $\nu$ : 2225, 1717, 1668, 1557, 1479, 1409, 1394, 1358, 1108, 1019, 818, 781, 750, 706  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 3.19 (3H, s, CH<sub>3</sub>), 3.69 (3H, s, CH<sub>3</sub>), 7.36 (1H, dd,  $J_1 = 1.6$  Hz,  $J_2 = 6.8$  Hz, ArH), 7.51-7.59 (3H, m, ArH), 7.62-7.64 (3H, m, ArH), 8.03-8.04 (2H, m, ArH). HRMS [Found:  $m/z$  402.0884 ( $\text{M}^+$ ); Calcd for  $\text{C}_{22}\text{H}_{15}^{35}\text{ClN}_4\text{O}_2$  M, 402.0884].

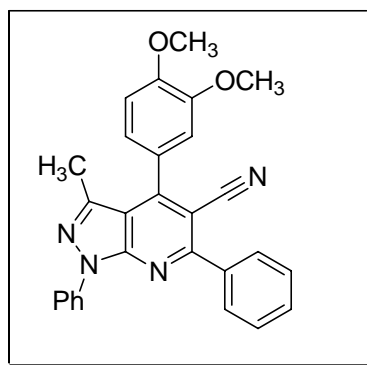


**3-Methyl-1,6-diphenyl-4-(2-nitrophenyl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{9,*I*,*I*}**: m.p. 226-228 °C. IR (KBr)  $\nu$ : 2223, 1575, 1557, 1526, 1503, 1429, 1383, 1345, 1196, 1127, 795, 762, 708  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ ) ( $\delta$ , ppm): 2.03 (3H, s, CH<sub>3</sub>), 7.34 (1H, t,  $J = 7.6$  Hz, ArH), 7.51-7.57 (6H, m, ArH), 7.82 (1H, t,  $J = 8.0$  Hz, ArH), 7.90 (1H, t,  $J = 7.2$  Hz, ArH), 8.02-8.04 (2H, m, ArH), 8.29 (2H, d,  $J = 8.4$  Hz, ArH), 8.41 (1H, d,  $J = 8.4$  Hz, ArH). HRMS [Found:  $m/z$  431.1383 ( $\text{M}^+$ ); Calcd for  $\text{C}_{26}\text{H}_{17}\text{N}_5\text{O}_2$  M, 431.1382].

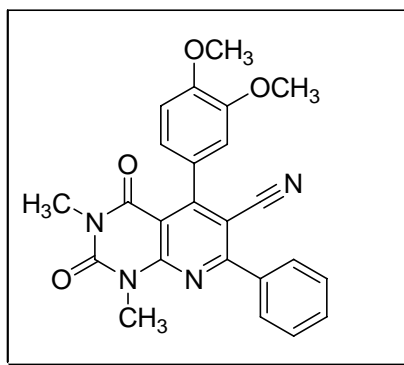




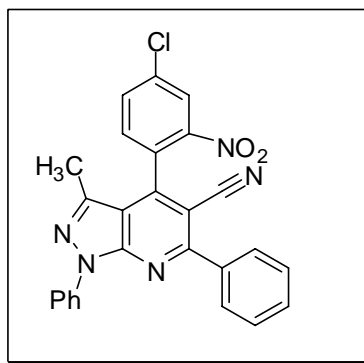
**3-Methyl-1-phenyl-6-(4-chlorophenyl)-4-(2-nitrophenyl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{9,2,1}**: m.p. 201-202 °C. IR (KBr)  $\nu$ : 2223, 1581, 1566, 1524, 1506, 1438, 1345, 1096, 1012, 792, 754  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{DMSO-}d_6$ ) ( $\delta$ , ppm): 2.00 (3H, s,  $\text{CH}_3$ ), 7.39-7.43 (1H, m, ArH), 7.59-7.63 (2H, m, ArH), 7.69-7.72 (2H, m, ArH), 7.86-7.88 (1H, m, ArH), 7.99-8.02 (3H, m, ArH), 8.07-8.11 (1H, m, ArH), 8.22 (2H, d,  $J = 8.0$  Hz, ArH), 8.49 (1H, d,  $J = 8.0$  Hz, ArH).  $^{13}\text{C}$  NMR ( $\text{DMSO-}d_6$ ) ( $\delta$ , ppm): 13.98, 101.34, 113.69, 117.31, 118.35, 121.87, 126.12, 127.48, 128.87, 129.49, 130.07, 131.87, 132.48, 132.77, 135.55, 136.21, 136.66, 138.69, 144.13, 147.60, 150.20, 159.13. HRMS [Found:  $m/z$  465.1005( $\text{M}^+$ ); Calcd for  $\text{C}_{26}\text{H}_{16}^{35}\text{ClN}_5\text{O}_2$  M, 465.0993 ].



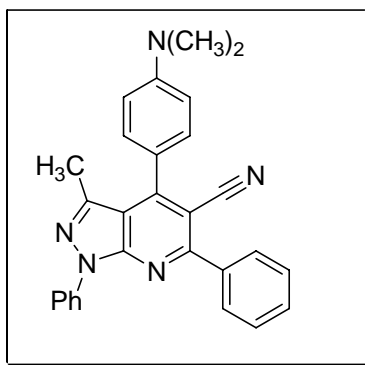
**3-Methyl-1,6-diphenyl-4-(3,4-dimethoxyphenyl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{10,1,1}**: m.p. 192-194 °C. IR (KBr)  $\nu$ : 2221, 1600, 1559, 1515, 1436, 1381, 1340, 1258, 1233, 1139, 1024, 818, 762, 713  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ ) ( $\delta$ , ppm): 2.23 (3H, s,  $\text{CH}_3$ ), 3.95 (3H, s,  $\text{CH}_3\text{O}$ ), 3.99 (3H, s,  $\text{CH}_3\text{O}$ ), 7.04-7.12 (3H, m, ArH), 7.32 (1H, t,  $J = 7.6$  Hz, ArH), 7.49-7.55 (5H, m, ArH), 8.00-8.02 (2H, m, ArH), 8.29 (2H, d,  $J = 8.4$  Hz, ArH). HRMS [Found:  $m/z$  446.1746 ( $\text{M}^+$ ); Calcd for  $\text{C}_{28}\text{H}_{22}\text{N}_4\text{O}_2$  M, 446.1743].



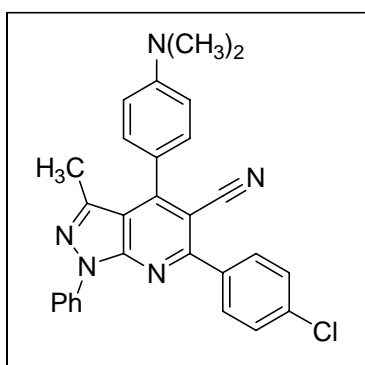
**5-(3,4-Dimethoxyphenyl)-1,3-dimethyl-2,4-dioxo-7-phenyl-1,2,3,4-tetrahydropyrido[2,3-*d*]pyrimidine-6-carbonitrile 4{10,1,2}**: m.p. 226-227 °C. IR(KBr)  $\nu$ : 2223, 1717, 1674, 1564 1517, 1467, 1405, 1351, 1281, 1260, 1138, 1020, 789, 750, 697  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 3.20 (3H, s, CH<sub>3</sub>), 3.68 (3H, s, CH<sub>3</sub>), 3.75 (3H, s, OCH<sub>3</sub>), 3.85 (3H, s, OCH<sub>3</sub>), 6.94 (1H, dd,  $J_1 = 2.0$  Hz,  $J_2 = 8.4$  Hz, ArH), 7.03 (1H, d,  $J = 2.0$  Hz, ArH), 7.07 (1H, d,  $J = 8.4$  Hz, ArH), 7.61-7.64 (3H, m, ArH), 8.01-8.03 (2H, m, ArH).  $^{13}\text{C}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 28.96, 30.77, 104.39, 107.73, 116.95, 127.08, 128.07, 129.29, 129.36, 130.01, 130.66, 131.93, 133.29, 137.02, 139.24, 151.31, 152.84, 157.21, 159.40, 163.52. HRMS [Found:  $m/z$  428.1483( $\text{M}^+$ ); Calcd for C<sub>24</sub>H<sub>20</sub>N<sub>4</sub>O<sub>4</sub> M, 428.1485].



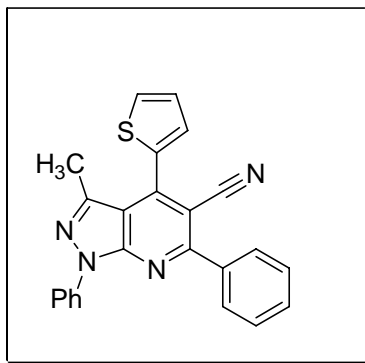
**3-Methyl-1,6-diphenyl-4-(2-nitro-4-chlorophenyl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{11,1,1}**: m.p. 275-276 °C. IR (KBr)  $\nu$ : 2220, 1584, 1563, 1525, 1505, 1435, 1380, 1341, 1295, 1074, 845, 763, 711  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 2.07 (3H, s, CH<sub>3</sub>), 7.39-7.43 (1H, m, ArH), 7.59-7.64 (5H, m, ArH), 7.97-7.99 (2H, m, ArH), 8.10 (1H, dd,  $J_1 = 2.0$  Hz,  $J_2 = 8.8$  Hz, ArH), 8.15 (1H, d,  $J = 2.0$  Hz, ArH), 8.23 (2H, d,  $J = 8.4$  Hz, ArH), 8.52 (1H, d,  $J = 8.8$  Hz, ArH). HRMS [Found:  $m/z$  465.0995 ( $\text{M}^+$ ); Calcd for C<sub>26</sub>H<sub>16</sub><sup>35</sup>ClN<sub>5</sub>O<sub>2</sub> M, 465.0993].



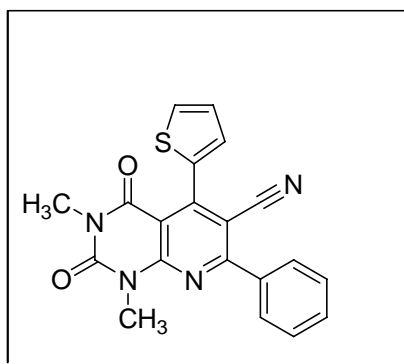
**3-Methyl-1,6-diphenyl-4-(4-dimethylaminophenyl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{12,1,1}**: m.p. 210-212 °C. IR (KBr)  $\nu$ : 2219, 1607, 1564, 1526, 1506, 1436, 1369, 1206, 1171, 969, 824, 796, 757  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{DMSO-}d_6$ ) ( $\delta$ , ppm): 2.22 (3H, s,  $\text{CH}_3$ ), 3.05 (6H, s,  $(\text{CH}_3)_2\text{N}$ ), 6.91 (2H, d,  $J = 8.8$  Hz, ArH), 7.35-7.39 (1H, m, ArH), 7.52-7.60 (7H, m, ArH), 7.93-7.95 (2H, m, ArH), 8.22 (2H, d,  $J = 8.4$  Hz, ArH). HRMS [Found:  $m/z$  429.1960( $\text{M}^+$ ); Calcd for  $\text{C}_{28}\text{H}_{23}\text{N}_5$  M, 429.1953].



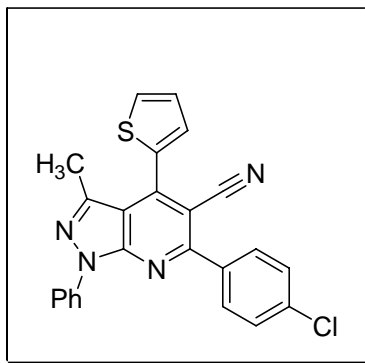
**3-Methyl-1-phenyl-6-(4-chlorophenyl)-4-(4-dimethylaminophenyl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{12,2,1}**: m.p. 265-267 °C. IR (KBr)  $\nu$ : 2220, 1608, 1579, 1564, 1524, 1505, 1493, 1385, 1203, 1090, 836, 794, 745  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{DMSO-}d_6$ ) ( $\delta$ , ppm): 2.23 (3H, s,  $\text{CH}_3$ ), 3.05 (6H, s,  $(\text{CH}_3)_2\text{N}$ ), 6.90-6.93 (2H, m, ArH), 7.36-7.40 (1H, m, ArH), 7.51-7.60 (4H, m, ArH), 7.67-7.69 (2H, m, ArH), 7.96-7.98 (2H, m, ArH), 8.20 (2H, d,  $J = 8.0$  Hz, ArH). HRMS [Found:  $m/z$  463.1576 ( $\text{M}^+$ ); Calcd for  $\text{C}_{28}\text{H}_{22}^{35}\text{ClN}_5$  M, 463.1564].



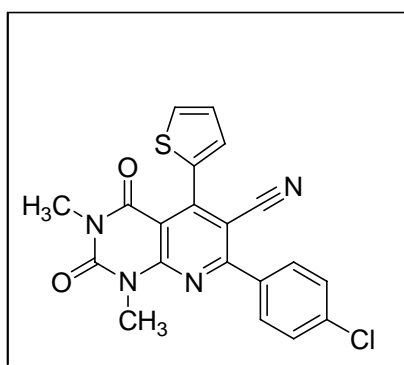
**3-Methyl-1,6-diphenyl-4-(thiophen-2-yl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{13,1,1}**: m.p. 191-192 °C. IR (KBr)  $\nu$ : 2223, 1574, 1558, 1527, 1506, 1487, 1433, 1412, 1349, 1196, 1118, 777, 758, 708  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 2.25 (3H, s, CH<sub>3</sub>), 7.38-7.44 (2H, m, ArH), 7.59-7.64 (6H, m, ArH), 7.96-7.99 (2H, m, ArH), 8.03-8.05 (1H, m, ArH), 8.23 (2H, d,  $J$  = 8.4 Hz, ArH).  $^{13}\text{C}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 14.82, 103.16, 114.58, 117.85, 121.53, 127.14, 128.40, 129.14, 129.88, 130.06, 130.74, 130.86, 131.78, 132.76, 138.15, 138.76, 144.34, 145.95, 150.10, 160.71. HRMS [Found:  $m/z$  392.1095 ( $\text{M}^+$ ); Calcd for C<sub>24</sub>H<sub>16</sub>N<sub>4</sub>S M, 392.1096].



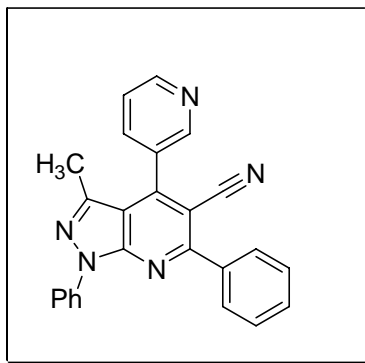
**1,3-Dimethyl-2,4-dioxo-7-phenyl-5-(thiophen-2-yl)-1,2,3,4-tetrahydro-pyrido[2,3-*d*]pyrimidine-6-carbonitrile 4{13,1,2}**: m.p. 257-258 °C. IR(KBr)  $\nu$ : 2220, 1717, 1668, 1554, 1506, 1472, 1442, 1363, 1289, 1236, 854, 817, 777, 752, 693  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR (DMSO- $d_6$ ) ( $\delta$ , ppm): 3.22 (3H, s, CH<sub>3</sub>), 3.68 (3H, s, CH<sub>3</sub>), 7.19-7.23 (2H, m, ArH), 7.60-7.65 (3H, m, ArH), 7.82-7.83 (1H, m, ArH), 8.01-8.03 (2H, m, ArH). HRMS [Found:  $m/z$  374.0838 ( $\text{M}^+$ ); Calcd for C<sub>20</sub>H<sub>14</sub>N<sub>4</sub>O<sub>2</sub>S M, 374.0837].



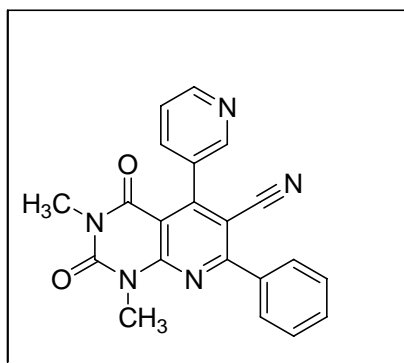
**3-Methyl-1-phenyl-4-(thiophen-2-yl)-6-(4-chlorophenyl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{I3,2,I}**: m.p. 210-212 °C. IR (KBr)  $\nu$ : 2221, 1582, 1558, 1506, 1435, 1347, 1263, 1119, 1093, 1014, 842, 755, 715  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{DMSO-}d_6$ ) ( $\delta$ , ppm): 2.25 (3H, s,  $\text{CH}_3$ ), 7.38-7.44 (2H, m, ArH), 7.58-7.61 (3H, m, ArH), 7.69-7.72 (2H, m, ArH), 7.99-8.05 (3H, m, ArH), 8.19-8.22 (2H, m, ArH). HRMS [Found:  $m/z$  426.0710 ( $\text{M}^+$ ); Calcd for  $\text{C}_{24}\text{H}_{15}^{35}\text{ClN}_4\text{S}$  M, 426.0706].



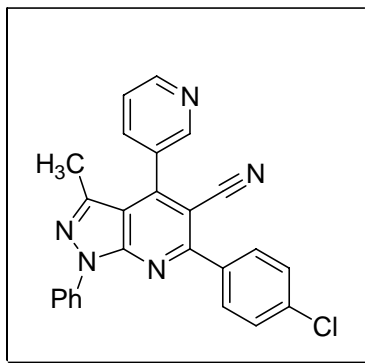
**7-(4-Chlorophenyl)-1,3-dimethyl-2,4-dioxo-5-(thiophen-2-yl)-1,2,3,4-tetrahydropyrido[2,3-*d*]pyrimidine-6-carbonitrile 4{I3,2,2}**: m.p. 275-276°C. IR(KBr)  $\nu$ : 2224, 1722, 1675, 1576, 1550, 1494, 1468, 1393, 1358, 1284, 1225, 1092, 852, 815, 754, 714  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{DMSO-}d_6$ ) ( $\delta$ , ppm): 3.22 (3H, s,  $\text{CH}_3$ ), 3.67 (3H, s,  $\text{CH}_3$ ), 7.19-7.24 (2H, m, ArH), 7.70 (2H, d,  $J = 8.4$  Hz, ArH), 7.83 (1H, d,  $J = 5.2$  Hz), 8.05 (2H, d,  $J = 8.8$  Hz, ArH).  $^{13}\text{C}$  NMR ( $\text{DMSO-}d_6$ ) ( $\delta$ , ppm): 28.97, 30.79, 104.56, 123.61, 129.39, 130.62, 131.98, 133.35, 136.17, 136.98, 148.36, 150.25, 151.30, 152.92, 155.62, 156.52, 159.67, 163.59. HRMS [Found:  $m/z$  408.0446( $\text{M}^+$ ); Calcd for  $\text{C}_{20}\text{H}_{13}^{35}\text{ClN}_4\text{O}_2\text{S}$  M, 408.0448].



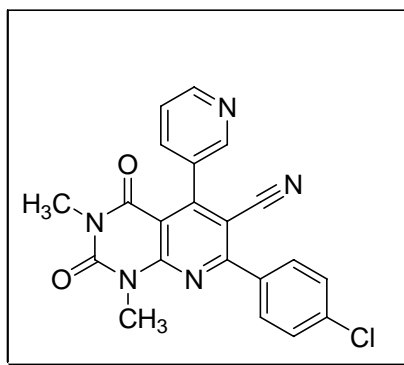
**3-Methyl-1,6-diphenyl-4-(pyridin-3-yl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{14,1,1}**: m.p. 174-176 °C. IR (KBr)  $\nu$ : 2223, 1592, 1575, 1558, 1506, 1495, 1435, 1421, 1385, 1345, 1130, 1025, 912, 777, 757, 709  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{DMSO-}d_6$ ) ( $\delta$ , ppm): 2.14 (3H, s,  $\text{CH}_3$ ), 7.42 (1H, t,  $J = 7.2$  Hz, ArH), 7.60-7.66 (5H, m, ArH), 7.72-7.76 (1H, m, ArH), 8.00-8.02 (2H, m, ArH), 8.21-8.26 (3H, m, ArH), 8.88-8.90 (1H, m, ArH), 8.94-8.96 (1H, m, ArH). HRMS [Found:  $m/z$  387.1484( $\text{M}^+$ ); Calcd for  $\text{C}_{25}\text{H}_{17}\text{N}_5$  M, 387.1484].



**1,3-Dimethyl-2,4-dioxo-7-phenyl-5-(pyridin-3-yl)-1,2,3,4-tetrahydro-pyrido[2,3-*d*]pyrimidine-6-carbonitrile 4{14,1,2}**: m.p. 269-270 °C. IR(KBr)  $\nu$ : 2221, 1716, 1666, 1554, 1505, 1477, 1441, 1411, 1390, 1362, 1289, 1100, 815, 752, 709, 693  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{DMSO-}d_6$ ) ( $\delta$ , ppm): 3.20 (3H, s,  $\text{CH}_3$ ), 3.71 (3H, s,  $\text{CH}_3$ ), 7.54-7.57 (1H, m, ArH), 7.63-7.65 (3H, m, ArH), 7.86-7.88 (1H, m, ArH), 8.04-8.06 (2H, m, ArH), 8.59-8.60 (1H, m, ArH), 8.70 (1H, dd,  $J_1 = 1.6$  Hz,  $J_2 = 8.8$  Hz, ArH). HRMS [Found:  $m/z$  369.1230( $\text{M}^+$ ); Calcd for  $\text{C}_{21}\text{H}_{15}\text{N}_5\text{O}_2$  M, 369.1226].

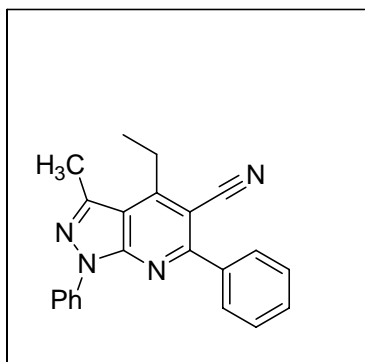


**3-Methyl-1-phenyl-4-(pyridin-3-yl)-6-(4-chlorophenyl)-1H-pyrazolo[3,4-b]pyridine-5-carbonitrile 4{14,2,1}**: m.p. 201-203 °C. IR (KBr)  $\nu$ : 2226, 1593, 1578, 1561, 1505, 1479, 1434, 1418, 1347, 1269, 1178, 1128, 1095, 1017, 911, 838, 789, 759, 740, 692  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{DMSO}-d_6$ ) ( $\delta$ , ppm): 2.14 (3H, s,  $\text{CH}_3$ ), 7.40-7.44 (1H, m, ArH), 7.59-7.63 (2H, m, ArH), 7.71-7.75 (3H, m, ArH), 8.04 (2H, d,  $J = 8.4$  Hz, ArH), 8.20-8.24 (3H, m, ArH), 8.89 (1H, d,  $J = 8.8$  Hz, ArH), 8.93-8.94 (1H, m, ArH).  $^{13}\text{C}$  NMR ( $\text{DMSO}-d_6$ ) ( $\delta$ , ppm): 15.21, 102.31, 114.14, 117.85, 121.54, 124.10, 127.24, 129.33, 129.94, 130.25, 131.89, 136.08, 136.86, 137.59, 138.70, 144.38, 149.48, 149.67, 150.08, 151.80, 159.39. HRMS [Found:  $m/z$  421.1090 ( $\text{M}^+$ ); Calcd for  $\text{C}_{25}\text{H}_{16}^{35}\text{ClN}_5$  M, 421.1094].



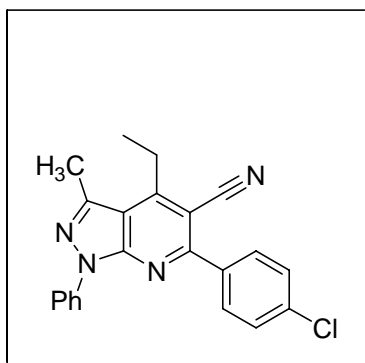
**7-(4-Chlorophenyl)-1,3-dimethyl-2,4-dioxo-5-(pyridin-3-yl)-1,2,3,4-tetrahydro pyrido[2,3-d]pyrimidine-6-carbonitrile 4{14,2,2}**: m.p. 246-248°C. IR(KBr)  $\nu$ : 2222, 1718, 1668, 1577, 1552, 1497, 1476, 1411, 1361, 1285, 1092, 1010, 812, 755, 713  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR( $\text{DMSO}-d_6$ ) ( $\delta$ , ppm): 3.20 (3H, s,  $\text{CH}_3$ ), 3.70 (3H, s,  $\text{CH}_3$ ), 7.54-7.58 (1H, m, ArH), 7.72 (2H, d,  $J = 8.4$  Hz, ArH), 7.85-7.88 (1H, m, ArH), 8.08 (2H, d,  $J = 8.4$  Hz, ArH), 8.59 (1H, s, ArH), 8.69 (1H, d,  $J = 4.8$  Hz, ArH). HRMS

[Found:  $m/z$  403.0836( $M^+$ ); Calcd for  $C_{21}H_{14}^{35}ClN_5O_2$  M, 403.0836].



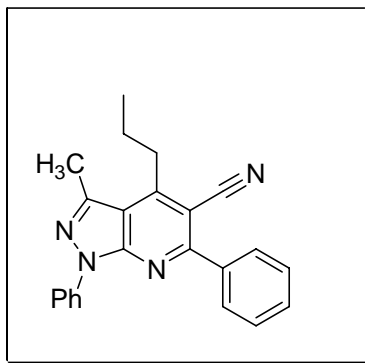
**3-Methyl-1,6-diphenyl-4-ethyl-1H-pyrazolo[3,4-b]pyridine-5-carbonitrile**

**4{15,1,1}**: m.p. 138-139 °C. IR (KBr)  $\nu$ : 2218, 1585, 1555, 1506, 1434, 1416, 1386, 1264, 1113, 754, 704  $cm^{-1}$ ;  $^1H$  NMR ( $CDCl_3$ ) ( $\delta$ , ppm): 1.48 (3H, t,  $J = 7.6$  Hz,  $CH_3$ ), 2.82 (3H, s,  $CH_3$ ), 3.36 (2H, q,  $J = 7.6$  Hz,  $CH_2$ ), 7.29-7.33 (1H, m, ArH), 7.48-7.58 (5H, m, ArH), 7.96-7.98 (2H, m, ArH), 8.26-8.28 (2H, m, ArH). HRMS [Found:  $m/z$  388.1534 ( $M^+$ ); Calcd for  $C_{22}H_{18}N_4$  M, 338.1531].

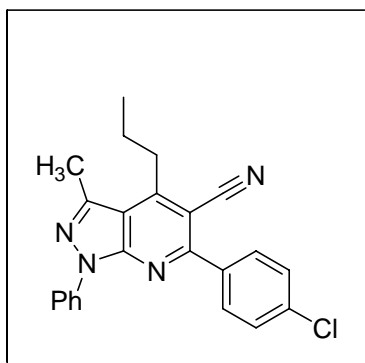


**3-Methyl-1-phenyl-4-ethyl-6-(4-chlorophenyl)-1H-pyrazolo[3,4-b]pyridine-5-carbonitrile 4{15,2,1}**: m.p. 200-202 °C. IR (KBr)  $\nu$ : 2220, 1581, 1558, 1508, 1491, 1416, 1113, 1013, 913, 837, 758  $cm^{-1}$ ;  $^1H$  NMR ( $DMSO-d_6$ ) ( $\delta$ , ppm): 1.36-1.40 (3H, m,  $CH_3$ ), 2.78 (3H, s,  $CH_3$ ), 3.24-3.29 (2H, m,  $CH_2$ ), 7.34-7.38 (1H, m, ArH), 7.54-7.58 (2H, m, ArH), 7.66-7.68 (2H, m, ArH), 7.92-7.94 (2H, m, ArH), 8.16-8.18 (2H, m, ArH). HRMS [Found:  $m/z$  372.1143 ( $M^+$ ); Calcd for  $C_{22}H_{17}^{35}ClN_4$  M, 372.1142 ].

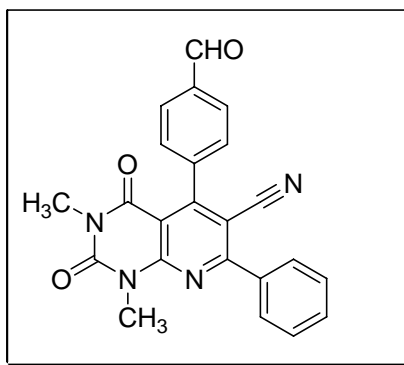




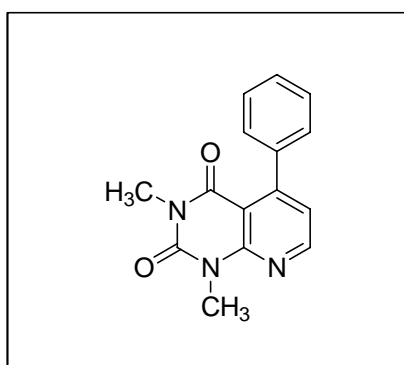
**3-Methyl-1,6-diphenyl-4-propylphenyl-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{16,1,1}**: m.p. 156-158 °C. IR (KBr)  $\nu$ : 2220, 1587, 1559, 1507, 1437, 1419, 1385, 1353, 1030, 772, 749, 703  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{CDCl}_3$ ) ( $\delta$ , ppm): 1.18 (3H, t,  $J = 7.2$  Hz,  $\text{CH}_3$ ), 1.85-1.91 (2H, m,  $\text{CH}_2$ ), 2.81 (3H, s,  $\text{CH}_3$ ), 3.31 (2H, t,  $J = 8.0$  Hz,  $\text{CH}_2$ ), 7.31 (1H, t,  $J = 7.2$  Hz, ArH), 7.48-7.56 (5H, m, ArH), 7.95-7.98 (2H, m, ArH), 8.27 (2H, d,  $J = 8.0$  Hz, ArH). HRMS [Found:  $m/z$  352.1688 ( $\text{M}^+$ ); Calcd for  $\text{C}_{23}\text{H}_{20}\text{N}_4$  M, 352.1688].



**3-Methyl-1-phenyl-4-propyl-6-(4-chlorophenyl)-1H-pyrazolo[3,4-*b*]pyridine-5-carbonitrile 4{16,2,1}**: m.p. 163-164 °C. IR (KBr)  $\nu$ : 2219, 1583, 1558, 1507, 1490, 1416, 1381, 1085, 1012, 838, 794, 756  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{DMSO}-d_6$ ) ( $\delta$ , ppm): 1.10 (3H, t,  $J = 7.2$  Hz,  $\text{CH}_3$ ), 1.76-1.82 (2H, m,  $\text{CH}_2$ ), 2.78 (3H, s,  $\text{CH}_3$ ), 3.23-3.27 (2H, m,  $\text{CH}_2$ ), 7.35-7.39 (1H, m, ArH), 7.54-7.58 (2H, m, ArH), 7.67-7.69 (2H, m, ArH), 7.92-7.94 (2H, m, ArH), 8.18 (2H, d,  $J = 8.4$  Hz, ArH). HRMS [Found:  $m/z$  386.1296 ( $\text{M}^+$ ); Calcd for  $\text{C}_{23}\text{H}_{19}^{35}\text{ClN}_4$  M, 386.1298].



**5-(4-Formylphenyl)-1,3-dimethyl-2,4-dioxo-7-phenyl-1,2,3,4-tetrahydropyrido[2,3-*d*]pyrimidine-6-carbonitrile 4{17,1,2}**: m.p. >300 °C. IR(KBr)  $\nu$ : 2724, 2223, 1716, 1667, 1608, 1557, 1480, 1441, 1410, 1391, 1361, 1287, 1210, 1096, 819, 788, 752 718, 698  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{DMSO-}d_6$ ) ( $\delta$ , ppm): 3.18 (3H, s,  $\text{CH}_3$ ), 3.70 (3H, s,  $\text{CH}_3$ ), 7.61-7.64 (5H, m, ArH), 8.03-8.06 (4H, m, ArH), 10.12 (1H, s, CHO). HRMS [Found:  $m/z$  396.1222( $\text{M}^+$ ); Calcd for  $\text{C}_{23}\text{H}_{16}\text{N}_4\text{O}_3$  M, 396.1222].

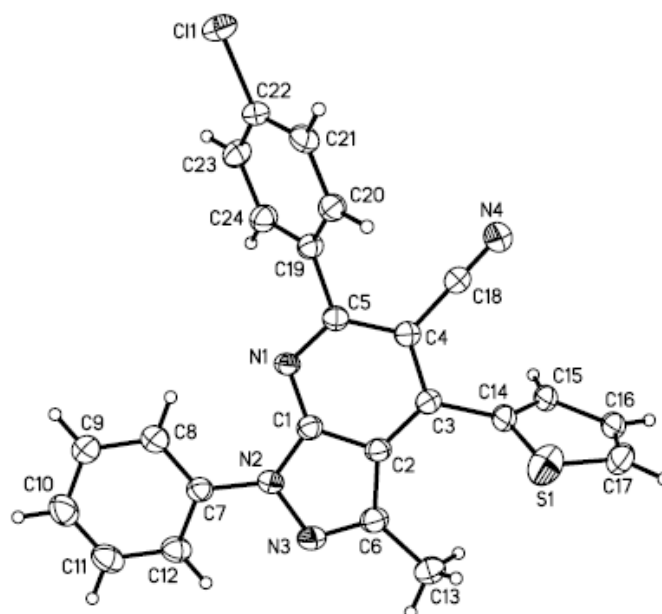


**1,3-Dimethyl-5-phenylpyrido[2,3-*d*]pyrimidine-2,4(1 $H$ ,3 $H$ )-dione 4{18,0,2}**:m.p. 177-178°C. IR(KBr)  $\nu$ : 1717, 1669, 1585, 1551, 1498, 1465, 1422, 1378, 1355, 1283, 1240, 1175, 1003, 844, 762, 719, 703  $\text{cm}^{-1}$ ;  $^1\text{H}$  NMR ( $\text{DMSO-}d_6$ ) ( $\delta$ , ppm): 3.19 (3H, s,  $\text{CH}_3$ ), 3.62 (3H, s,  $\text{CH}_3$ ), 7.09 (1H, d,  $J = 4.8$  Hz, ArH), 7.31-7.32 (2H, m, ArH), 7.40-7.42 (3H, m, ArH), 8.67 (1H, d,  $J = 4.8$  Hz, ArH).

## Crystal structures of compounds

### Crystal data for 4{13,2,1}

$C_{24}H_{15}ClN_4S$ ;  $M=426.91$ , yellow block crystals,  $0.53 \times 0.44 \times 0.40$  mm, Monoclinic, space group  $P2_1/c$ ,  $a = 8.360(2)$  Å,  $b = 10.078(3)$  Å,  $c = 24.344(7)$  Å,  $\alpha = 90^\circ$ ,  $\beta = 91.088(6)^\circ$ ,  $\gamma = 90^\circ$ ,  $V = 2050.6(9)$  Å<sup>3</sup>,  $Z = 4$ ,  $D_c = 1.383$  g·cm<sup>-3</sup>,  $F(000) = 880$ ,  $\mu$  (MoK $\alpha$ ) =  $0.307$  mm<sup>-1</sup>. Intensity data were collected on a diffractometer with graphite monochromated MoK $\alpha$  radiation ( $\lambda = 0.71070$  Å) using  $\omega$  scan mode with  $3.17^\circ < \theta < 25.34^\circ$ . 3744 unique reflections were measured and 3015 reflections with  $I > 2\sigma(I)$  were used in the refinement. The structure was solved by direct methods and expanded using Fourier techniques. The final cycle of full-matrix least squares technique to  $R = 0.1107$  and  $wR = 0.3051$ .



**Figure 1.** ORTEP plot of the molecular structure of compound 4{13,2,1} in crystal

**Table 1.** Bond lengths (Å) for 4{13,2,1}

Bond	Bond Lengths	Bond	Bond Lengths	Bond	Bond Lengths
S(1)-C(17)	1.678(9)	C(2)-C(6)	1.422(8)	C(10)-C(11)	1.331(10)
S(1)-C(14)	1.735(7)	C(3)-C(4)	1.397(8)	C(11)-C(12)	1.393(9)
Cl(1)-C(22)	1.734(6)	C(3)-C(14)	1.510(8)	C(14)-C(15)	1.431(8)

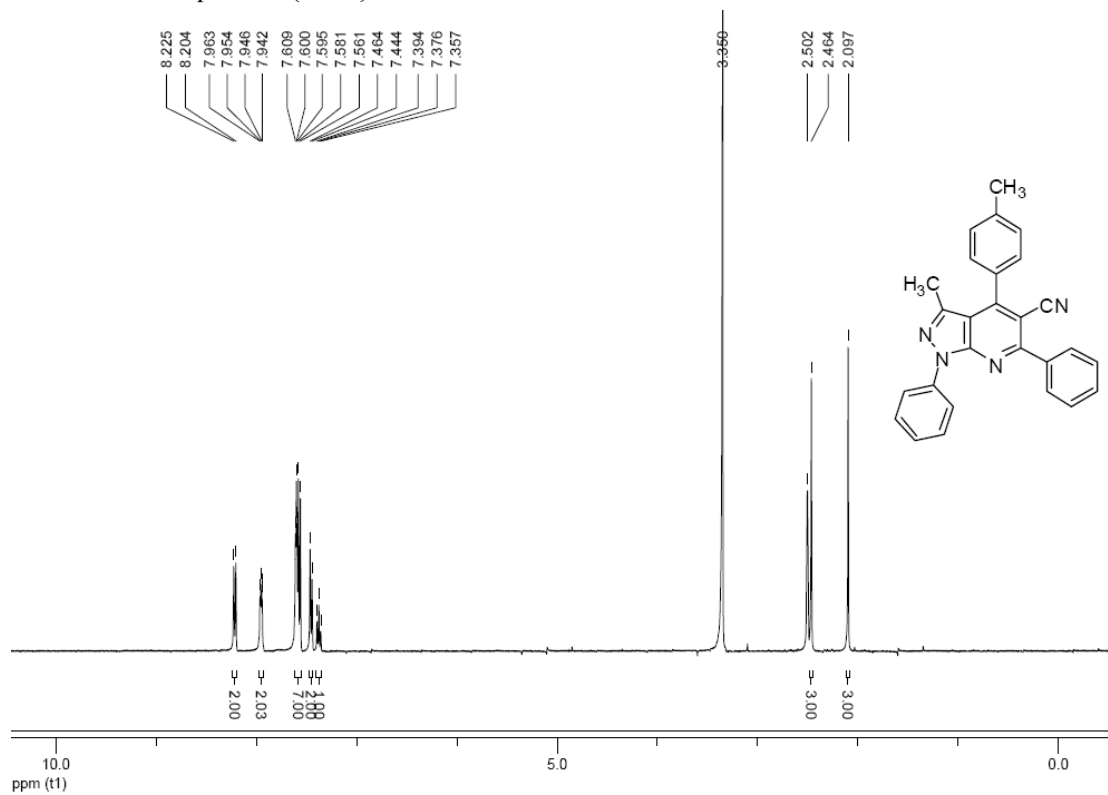
N(1)-C(5)	1.321(7)	C(4)-C(18)	1.427(8)	C(15)-C(16)	1.474(8)
N(1)-C(1)	1.342(7)	C(4)-C(5)	1.427(8)	C(16)-C(17)	1.318(11)
N(2)-C(1)	1.360(7)	C(5)-C(19)	1.494(7)	C(19)-C(20)	1.377(8)
N(2)-N(3)	1.392(7)	C(6)-C(13)	1.497(9)	C(19)-C(24)	1.385(8)
N(2)-C(7)	1.425(7)	C(7)-C(8)	1.362(9)	C(20)-C(21)	1.383(8)
N(3)-C(6)	1.306(8)	C(7)-C(12)	1.379(8)	C(21)-C(22)	1.373(9)
N(4)-C(18)	1.133(8)	C(8)-C(9)	1.388(10)	C(22)-C(23)	1.365(9)
C(1)-C(2)	1.409(8)	C(9)-C(10)	1.368(11)	C(23)-C(24)	1.381(8)
C(2)-C(3)	1.388(8)				

**Table 2.** Bond angles ( $^{\circ}$ ) for **4**{*I*3,2,*I*}

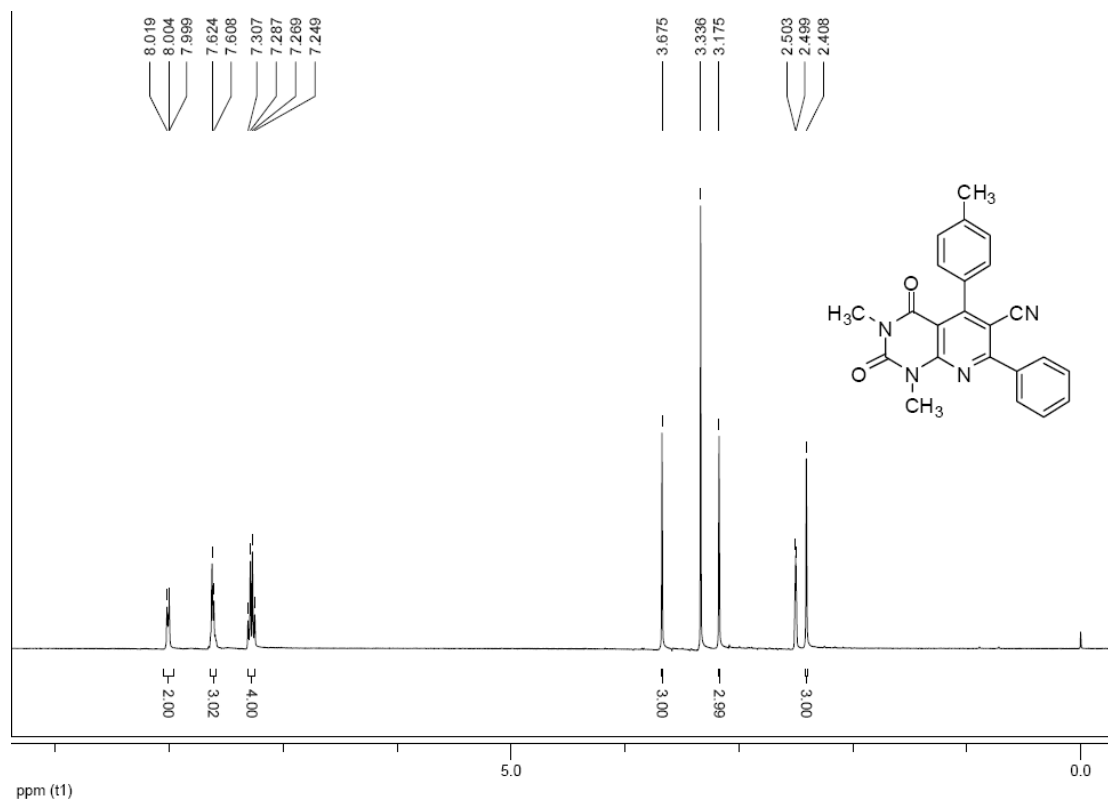
Angles	( $^{\circ}$ )	Angles	( $^{\circ}$ )
C(17)-S(1)-C(14)	88.7(4)	C(8)-C(7)-N(2)	121.7(5)
C(5)-N(1)-C(1)	115.1(5)	C(12)-C(7)-N(2)	118.6(5)
C(1)-N(2)-N(3)	109.6(4)	C(7)-C(8)-C(9)	119.7(6)
C(1)-N(2)-C(7)	132.0(5)	C(10)-C(9)-C(8)	120.3(7)
N(3)-N(2)-C(7)	118.4(4)	C(11)-C(10)-C(9)	119.9(7)
C(6)-N(3)-N(2)	107.7(5)	C(10)-C(11)-C(12)	121.1(6)
N(1)-C(1)-N(2)	126.1(5)	C(7)-C(12)-C(11)	119.2(6)
N(1)-C(1)-C(2)	126.8(5)	C(15)-C(14)-C(3)	126.3(6)
N(2)-C(1)-C(2)	107.1(5)	C(15)-C(14)-S(1)	116.5(5)
C(3)-C(2)-C(1)	117.3(5)	C(3)-C(14)-S(1)	117.2(4)
C(3)-C(2)-C(6)	137.7(5)	C(14)-C(15)-C(16)	103.1(6)
C(1)-C(2)-C(6)	105.0(5)	C(17)-C(16)-C(15)	116.1(6)
C(2)-C(3)-C(4)	117.4(5)	C(16)-C(17)-S(1)	115.6(5)
C(2)-C(3)-C(14)	122.9(5)	N(4)-C(18)-C(4)	178.6(8)
C(4)-C(3)-C(14)	119.6(5)	C(20)-C(19)-C(24)	119.7(5)
C(3)-C(4)-C(18)	120.1(5)	C(20)-C(19)-C(5)	121.3(5)
C(3)-C(4)-C(5)	119.8(5)	C(24)-C(19)-C(5)	119.0(5)
C(18)-C(4)-C(5)	120.0(5)	C(19)-C(20)-C(21)	120.2(6)
N(1)-C(5)-C(4)	123.5(5)	C(23)-C(22)-C(21)	121.2(5)
N(1)-C(5)-C(19)	115.3(5)	C(23)-C(22)-Cl(1)	120.0(5)
C(4)-C(5)-C(19)	121.2(5)	C(22)-C(21)-Cl(1)	118.8(5)
N(3)-C(6)-C(2)	110.5(5)	C(22)-C(23)-C(24)	119.6(6)
N(3)-C(6)-C(13)	119.9(5)	C(23)-C(24)-C(19)	120.1(6)
C(2)-C(6)-C(13)	129.6(6)	C(8)-C(7)-C(12)	119.7(6)

## Copies of $^1\text{H}$ NMR and $^{13}\text{C}$ NMR of compounds

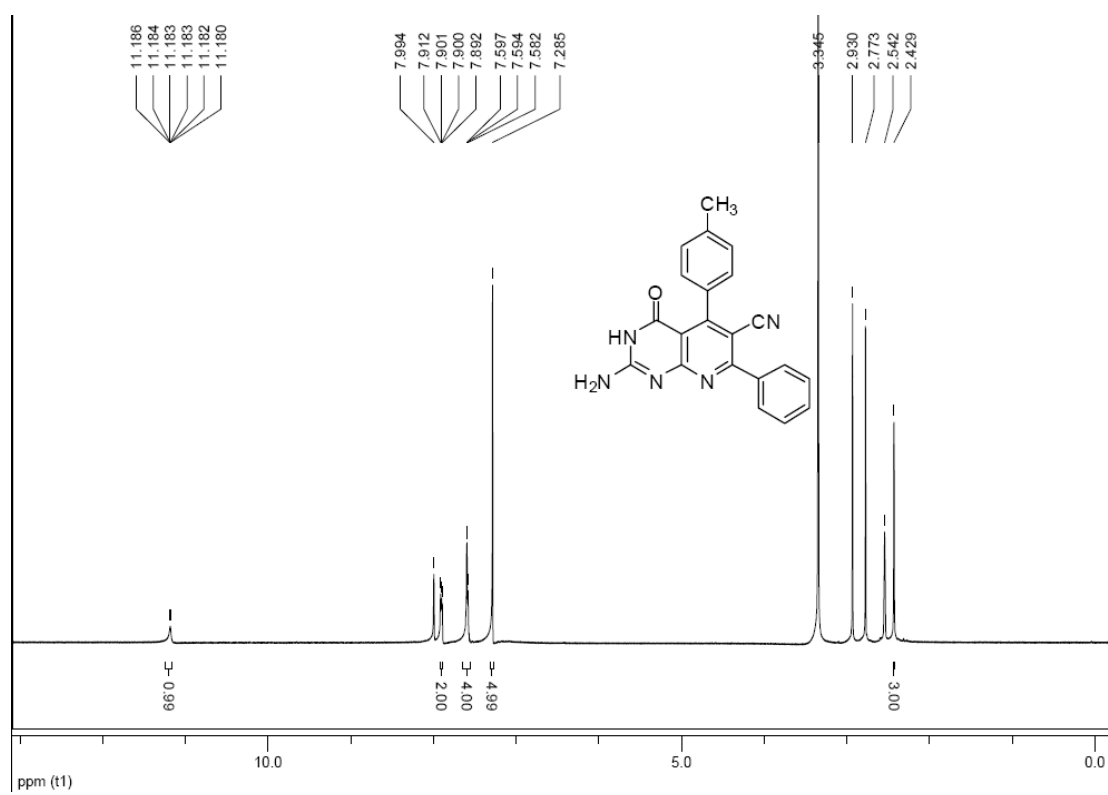
$^1\text{H}$  NMR of compound **4**{*l,l,l*}



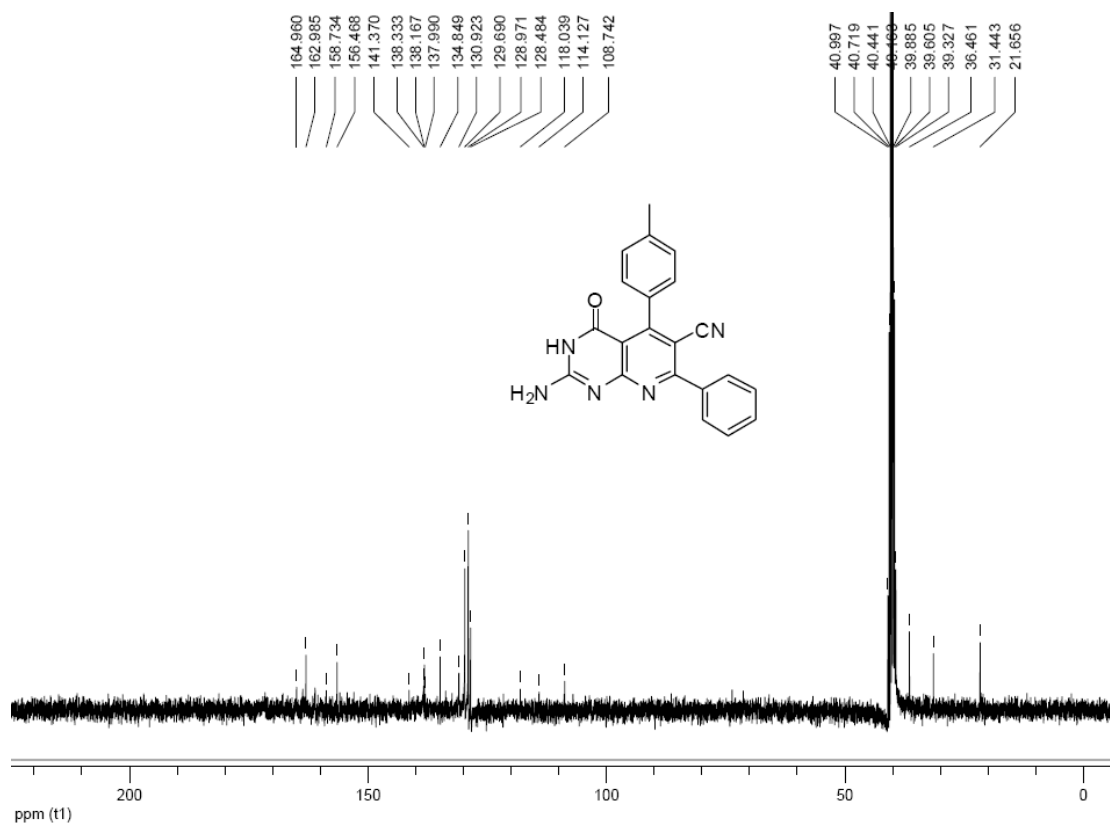
$^1\text{H}$  NMR of compound **4**{*l,l,2*}



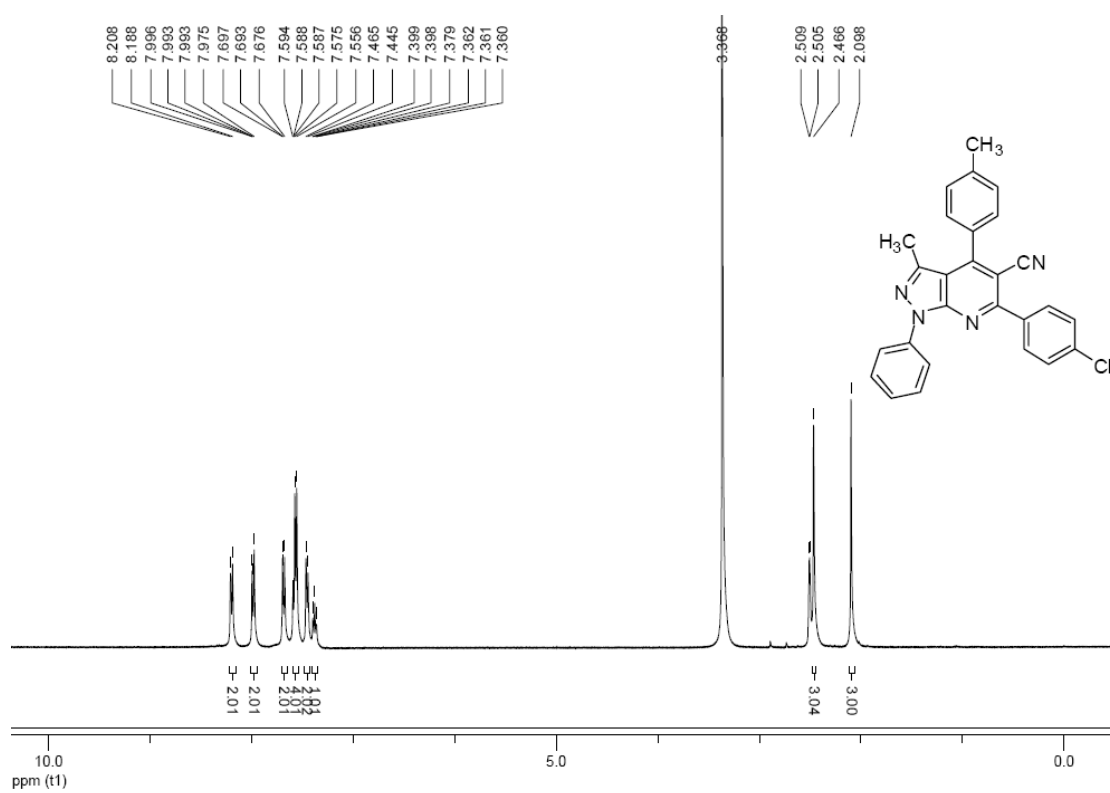
<sup>1</sup>H NMR of compound **4{1,1,4}**



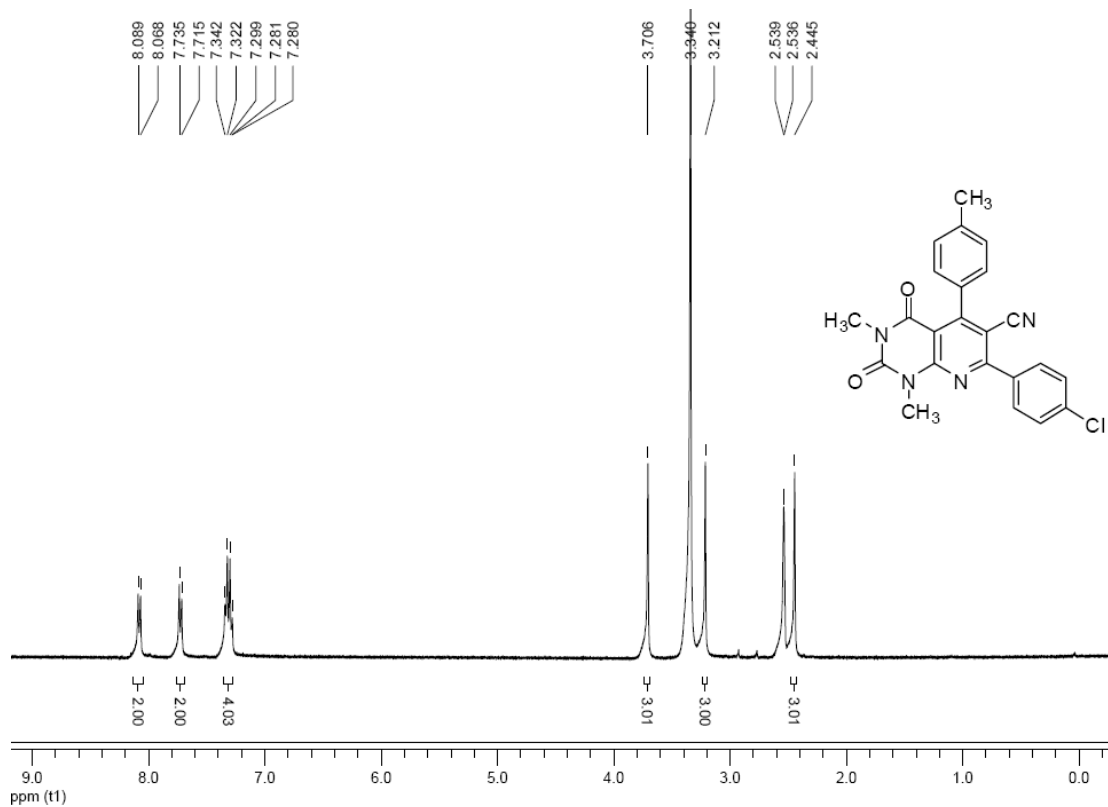
<sup>13</sup>C NMR of compound **4{1,1,4}**



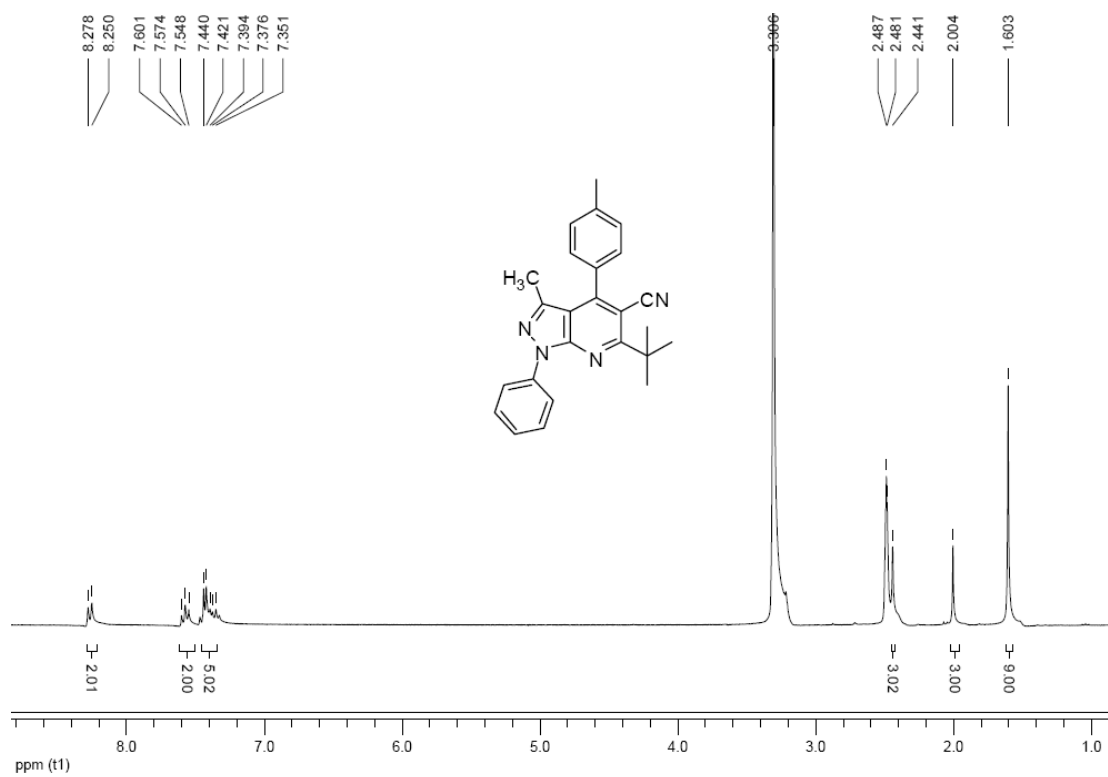
<sup>1</sup>H NMR of compound 4{1,2,1}



<sup>1</sup>H NMR of compound 4{1,2,2}

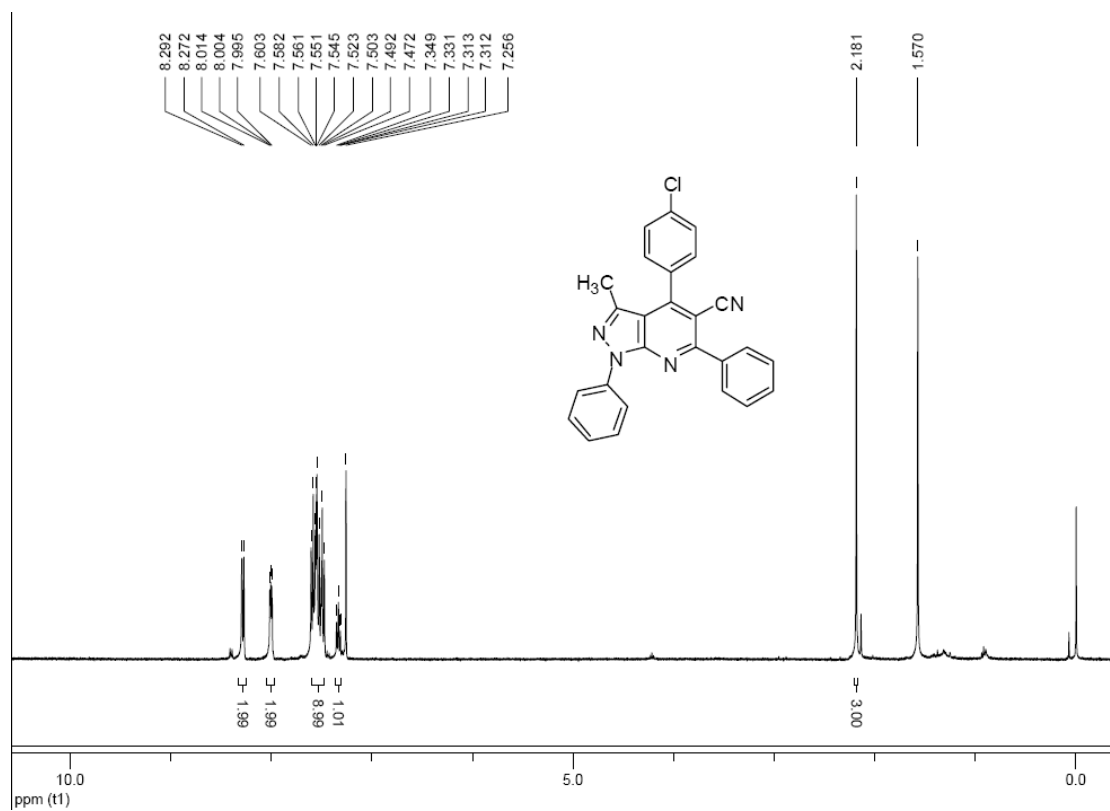


<sup>1</sup>H NMR of compound **4**{1,3,I}

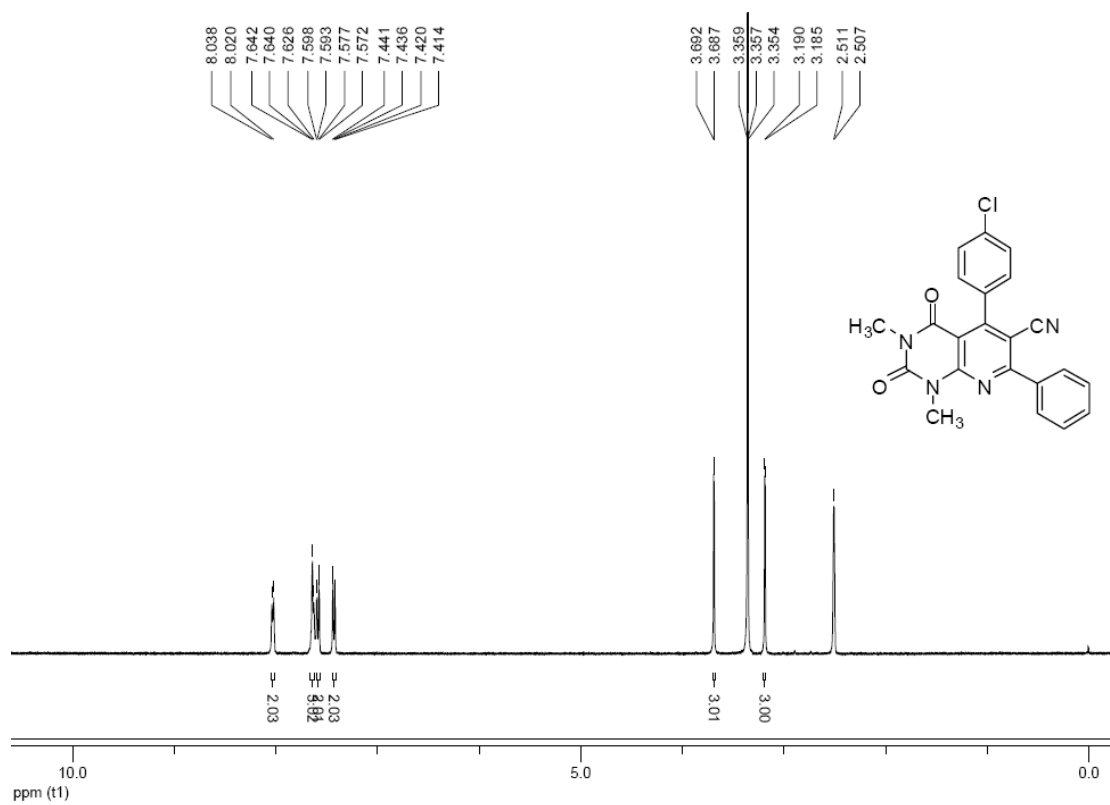


<sup>1</sup>H NMR of compound **4**{2,I,I}



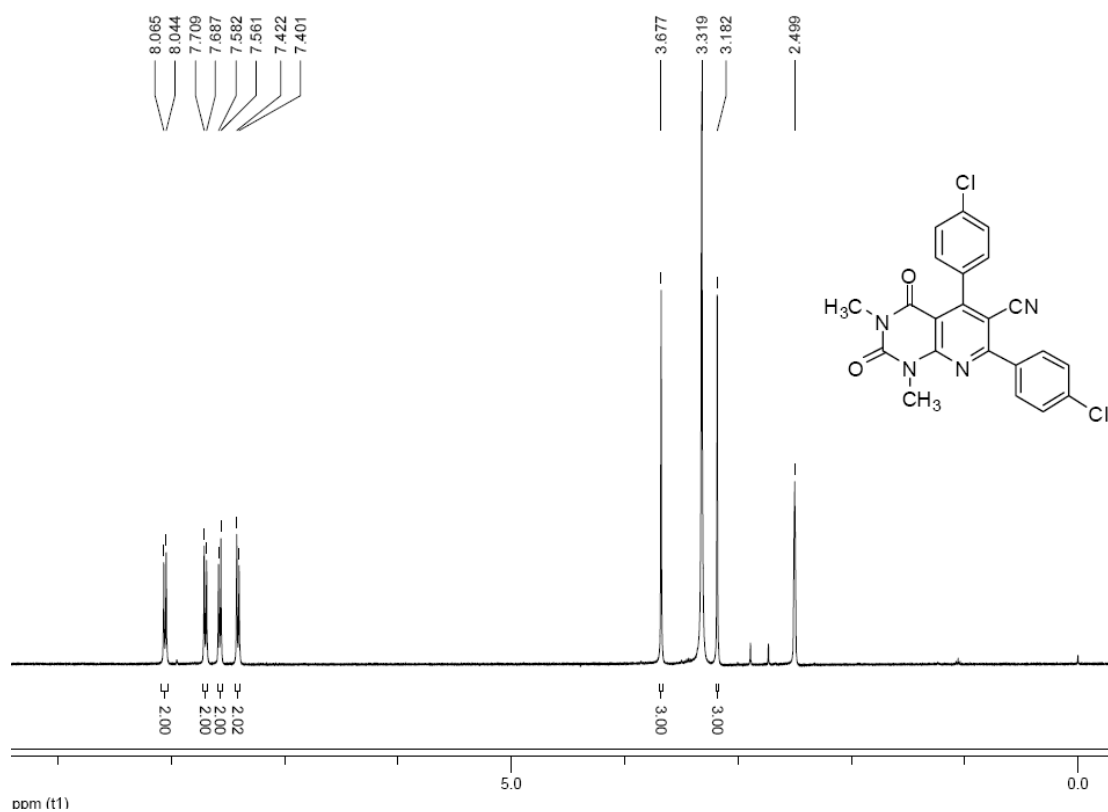


<sup>1</sup>H NMR of compound **4**<sub>{2,1,2}</sub>

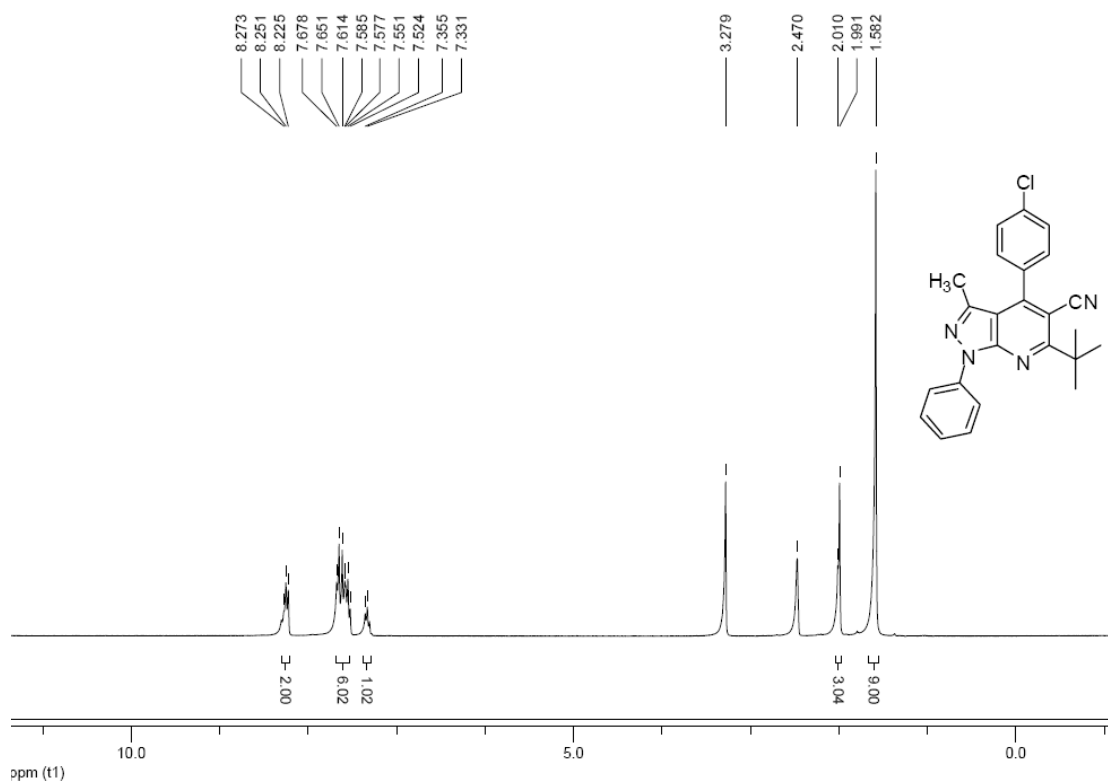


<sup>1</sup>H NMR of compound **4**<sub>{2,1,4}</sub>

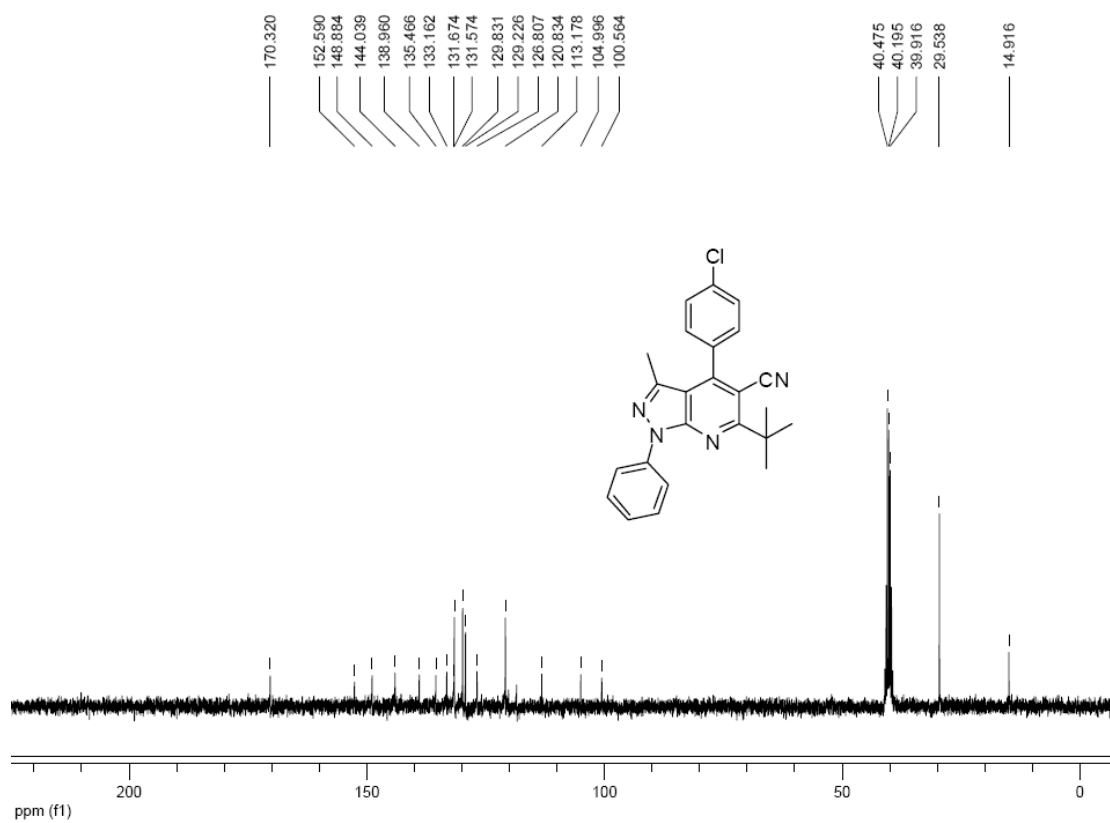




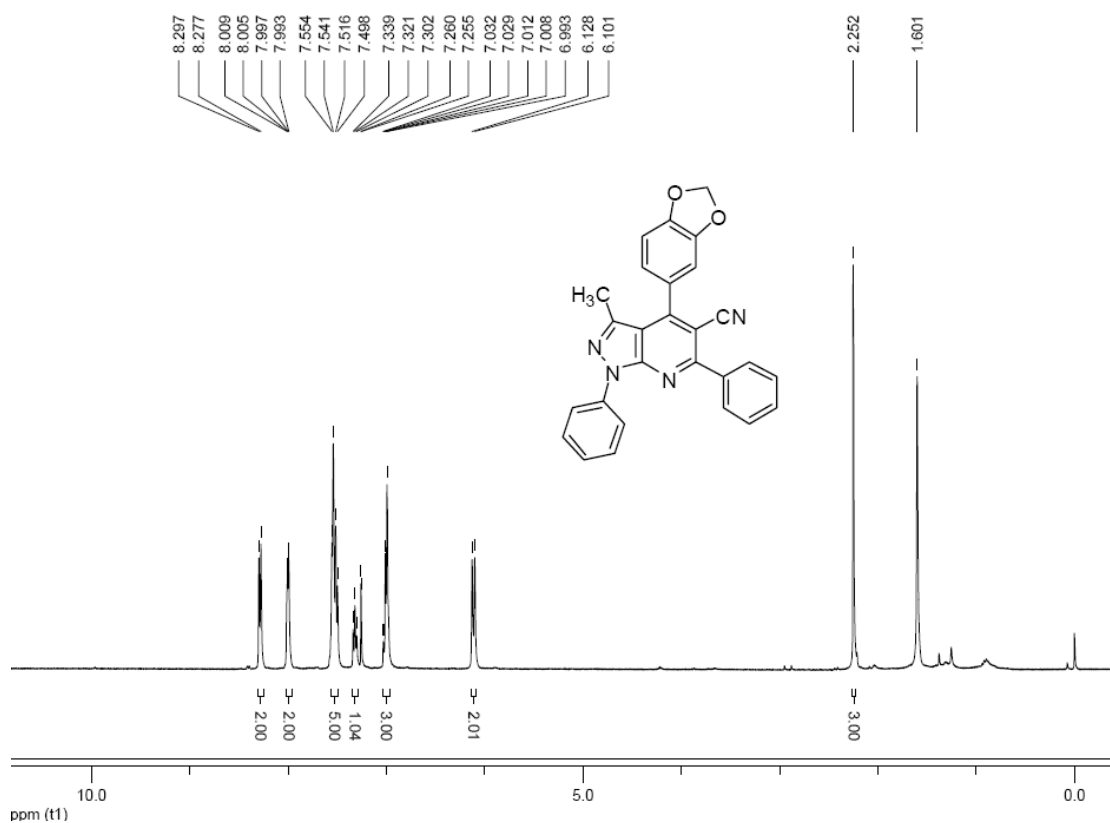
<sup>1</sup>H NMR of compound **4**{2,3,I}



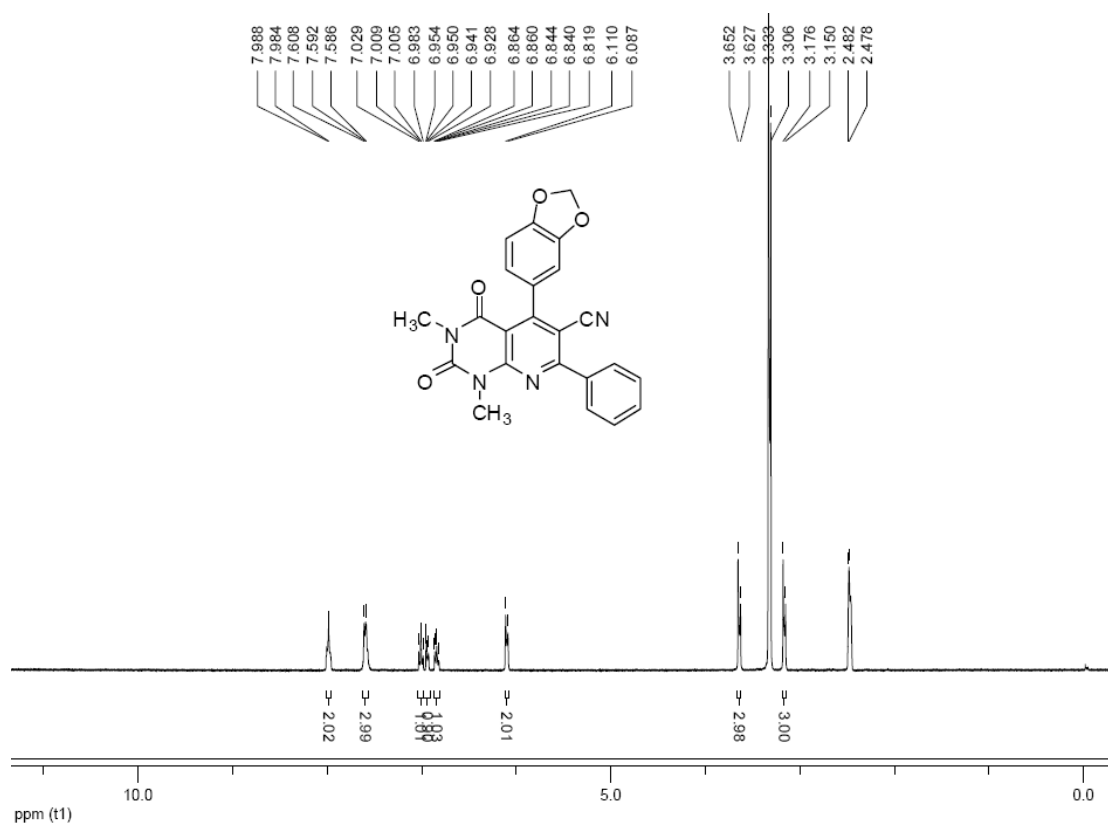
<sup>13</sup>C NMR of compound **4**{2,3,I}



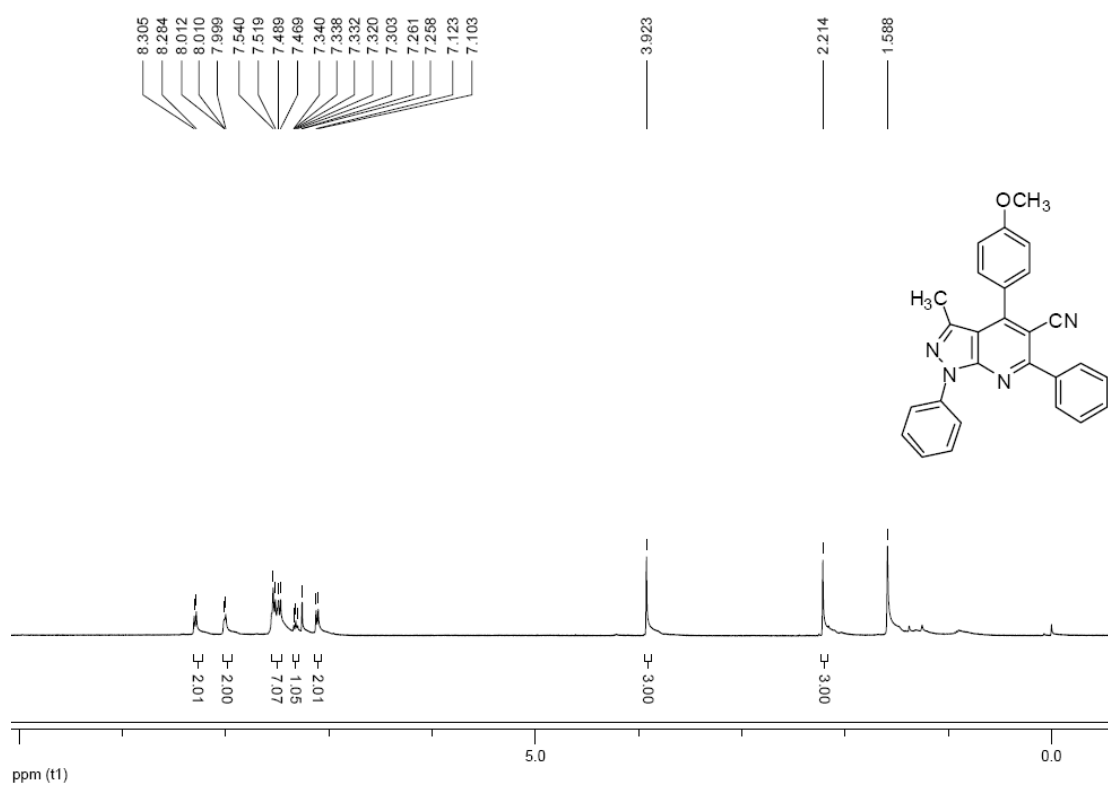
<sup>1</sup>H NMR of compound 4{3,1,1}



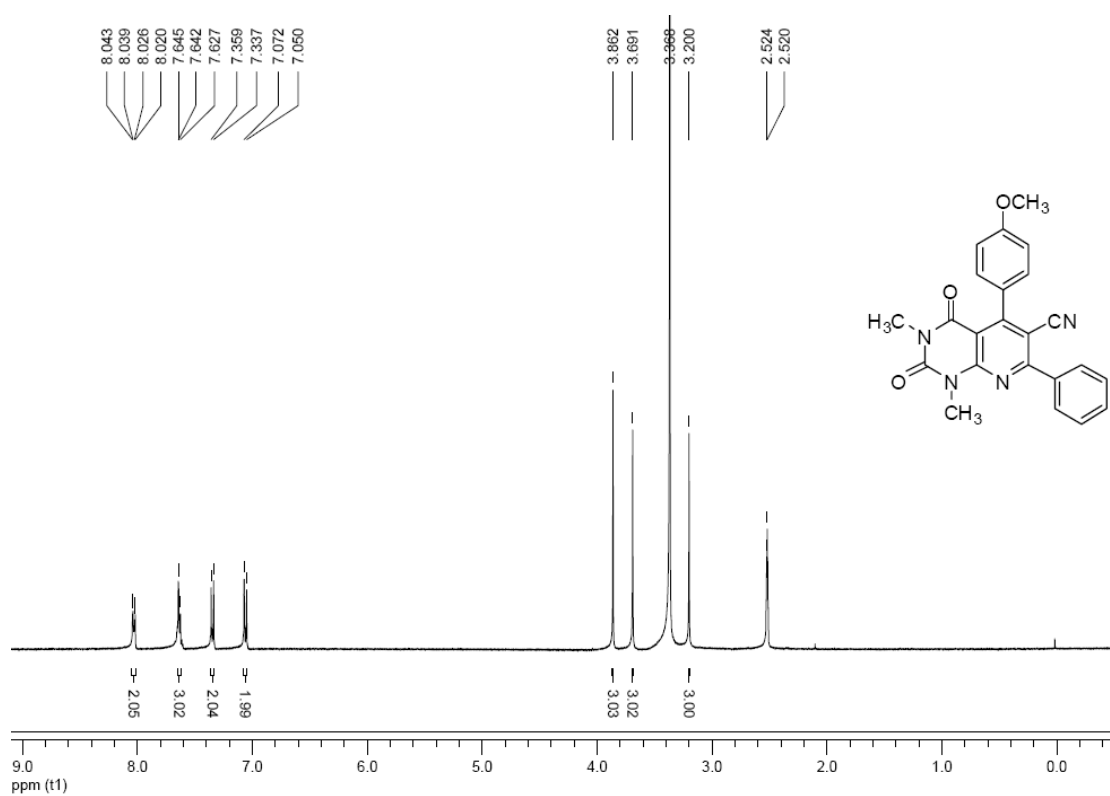
<sup>1</sup>H NMR of compound **4**{3,1,2}



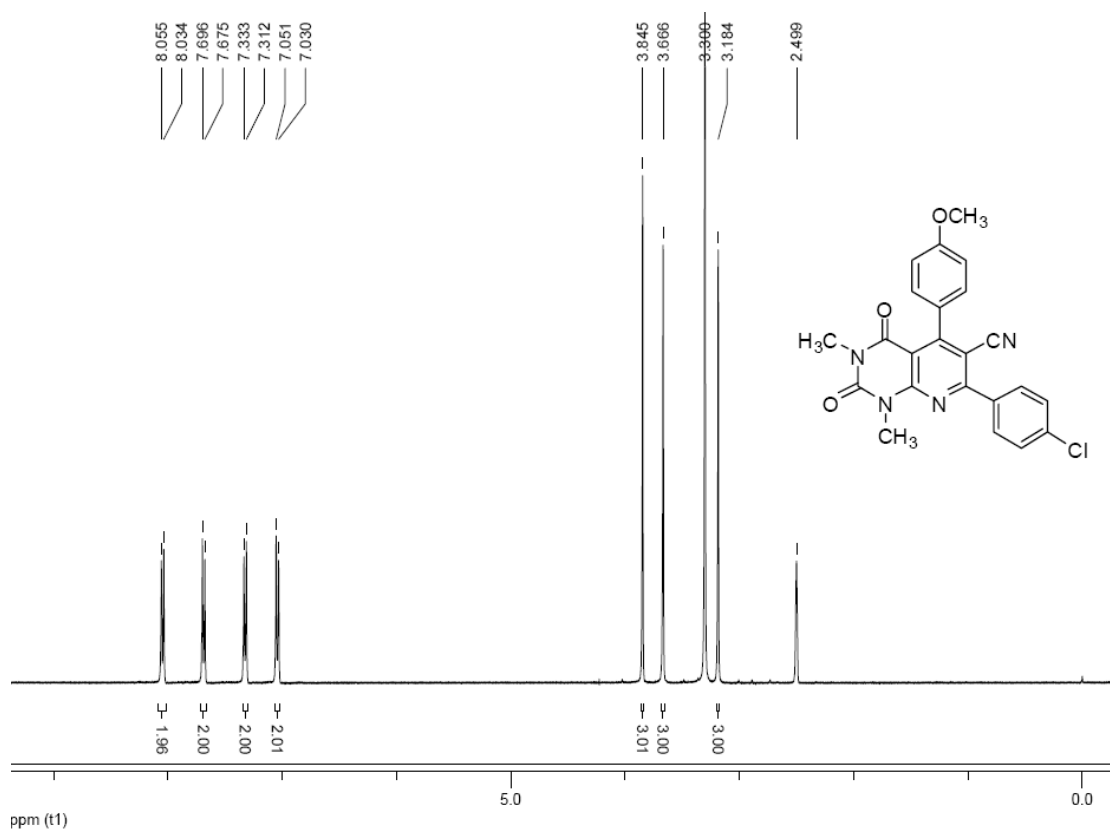
<sup>1</sup>H NMR of compound **4**{4,1,1}



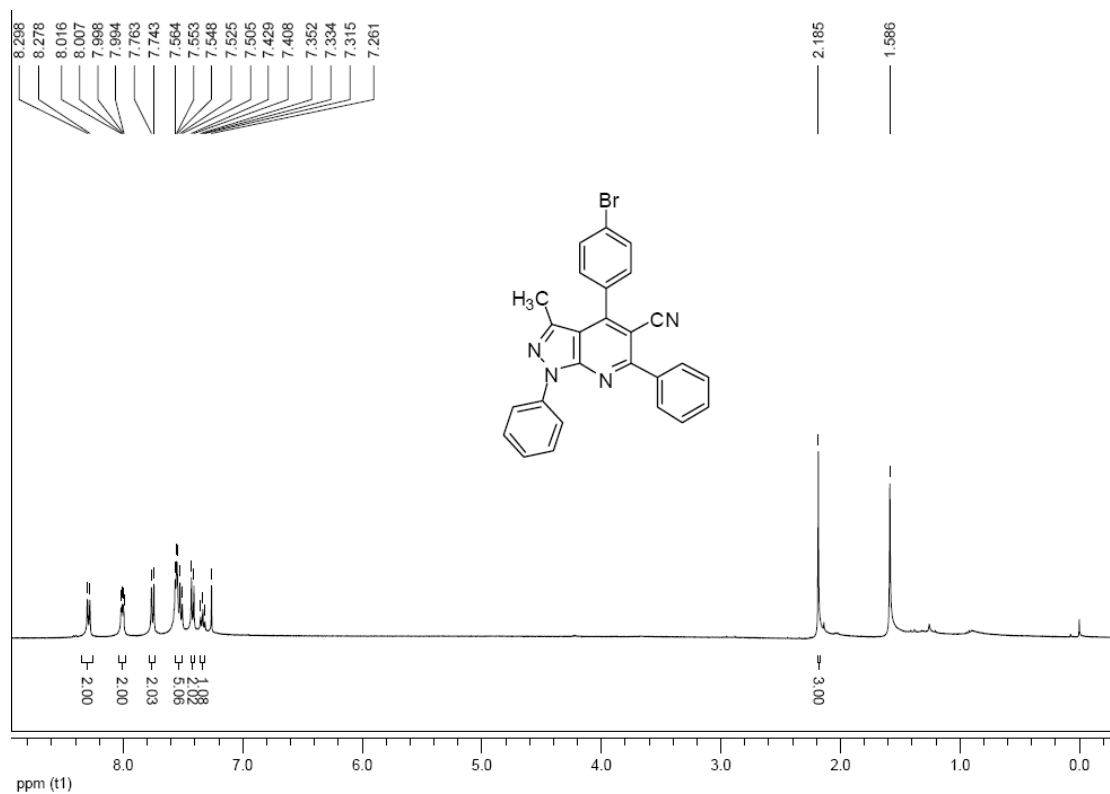
$^1\text{H}$  NMR of compound **4**{4,1,2}



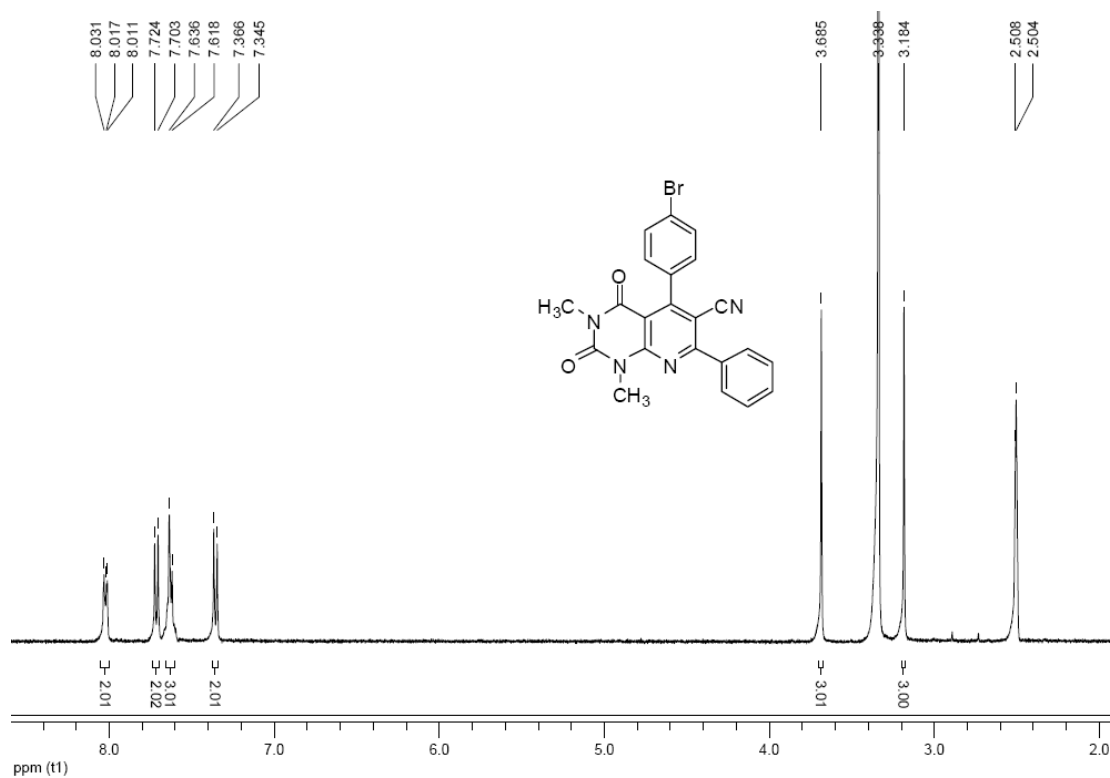
$^1\text{H}$  NMR of compound **4**{4,2,2}



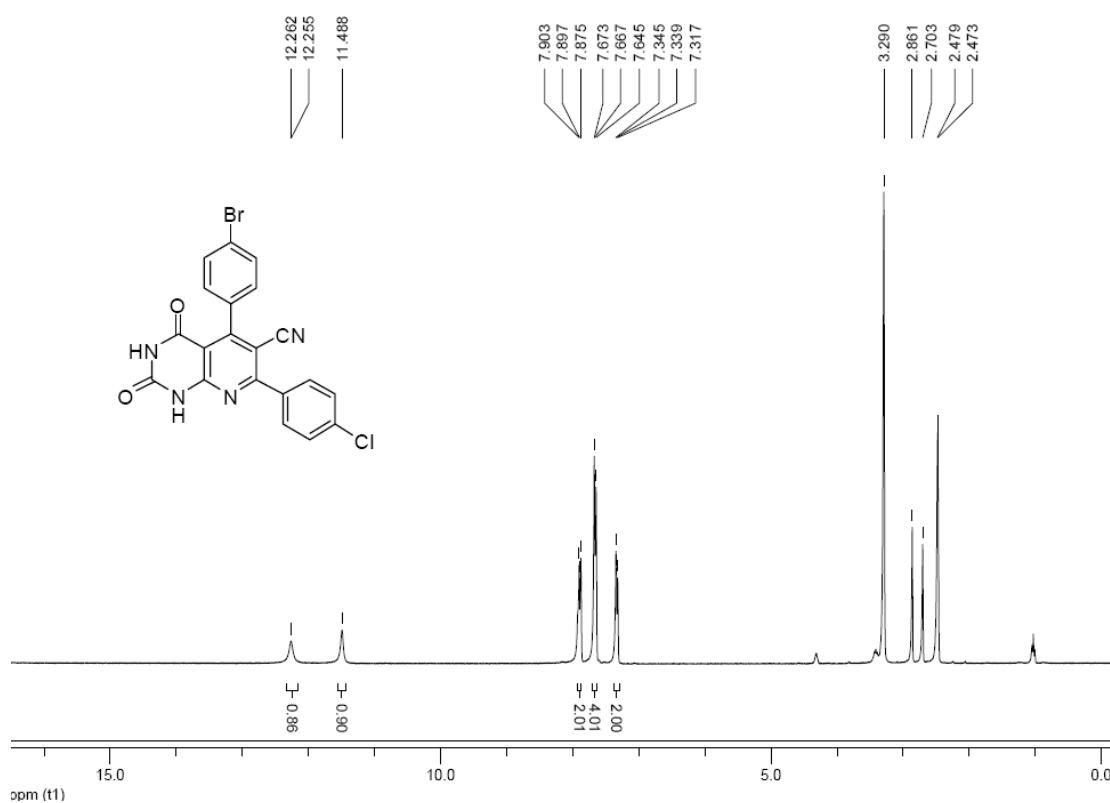
<sup>1</sup>H NMR of compound **4**{5,1,1}



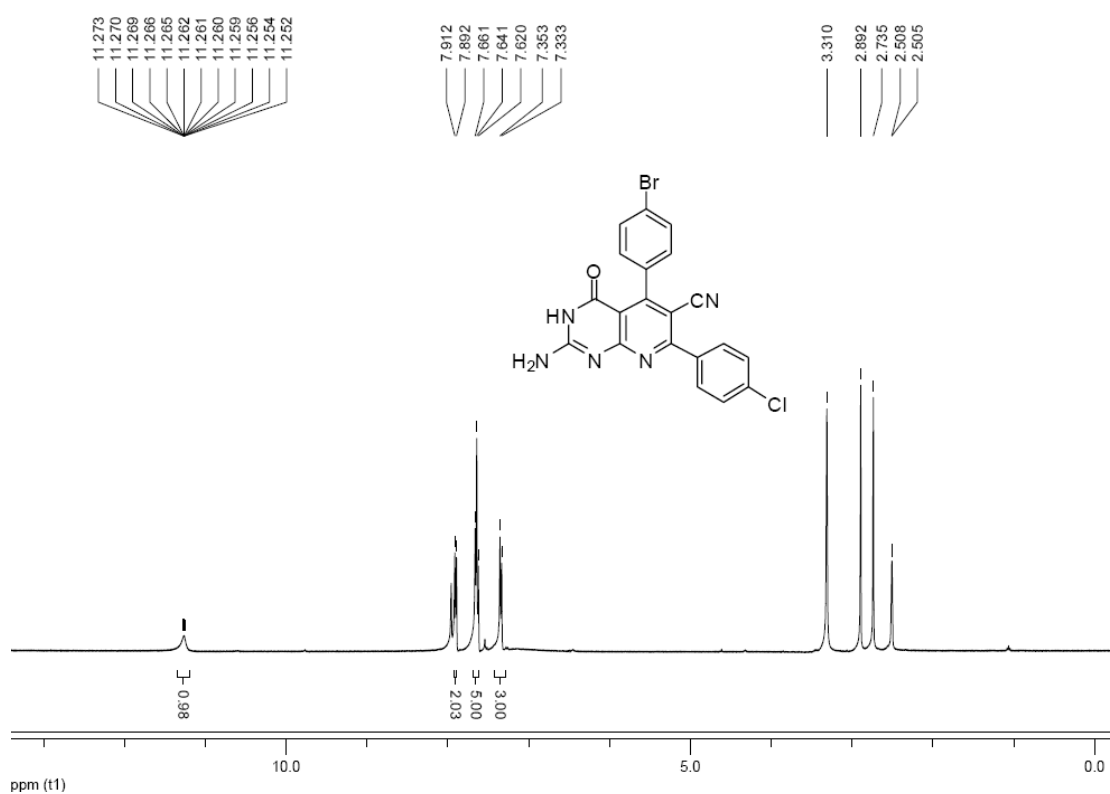
<sup>1</sup>H NMR of compound **4**{5,1,2}



$^1\text{H}$  NMR of compound **4**{5,2,3}

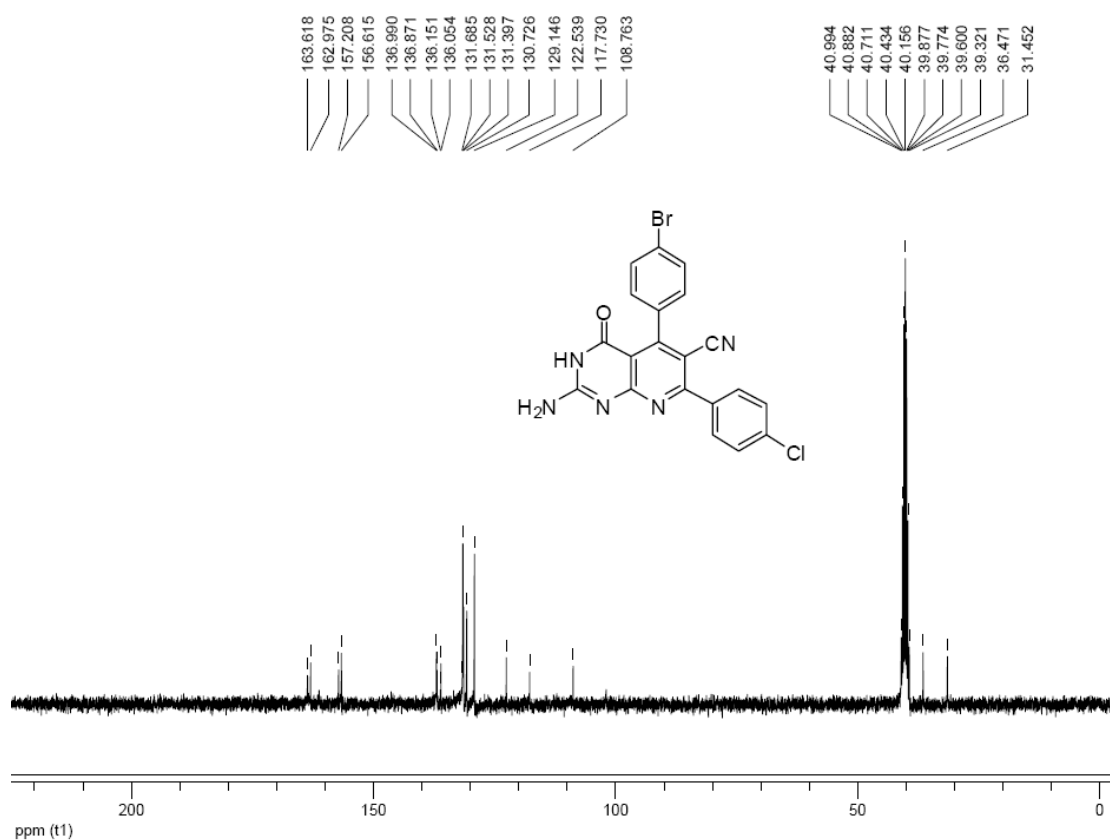


$^1\text{H}$  NMR of compound **4**{5,2,4}

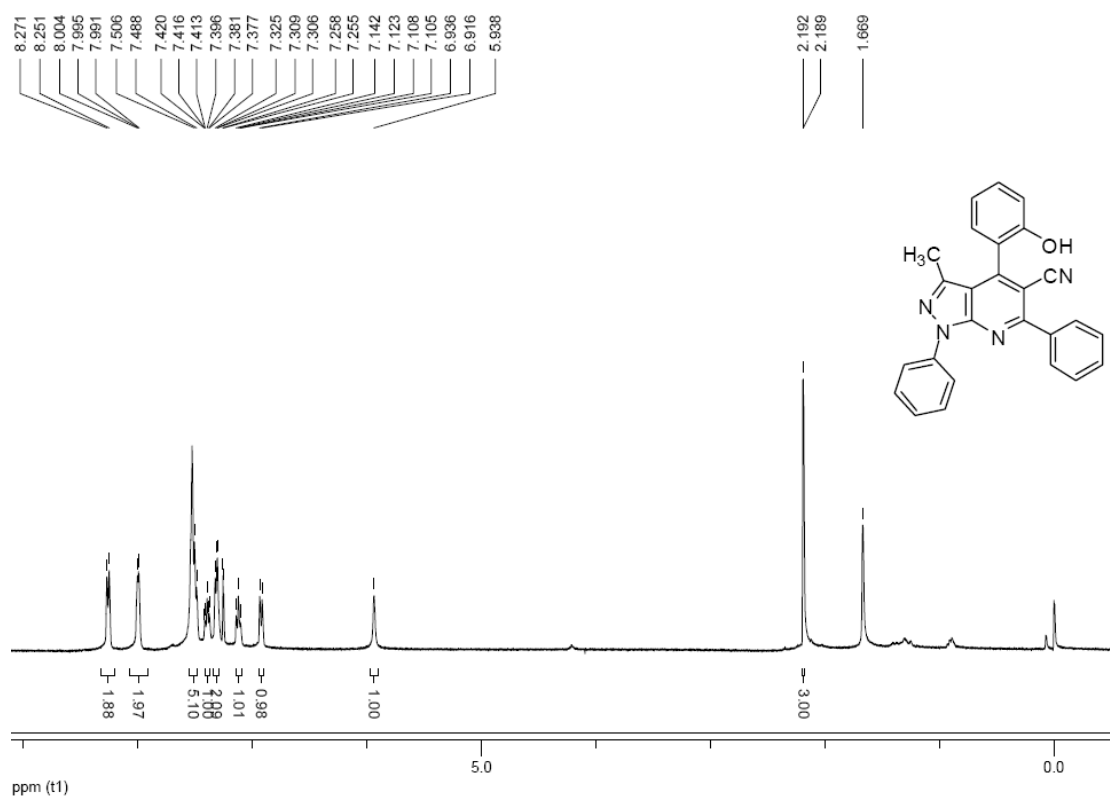




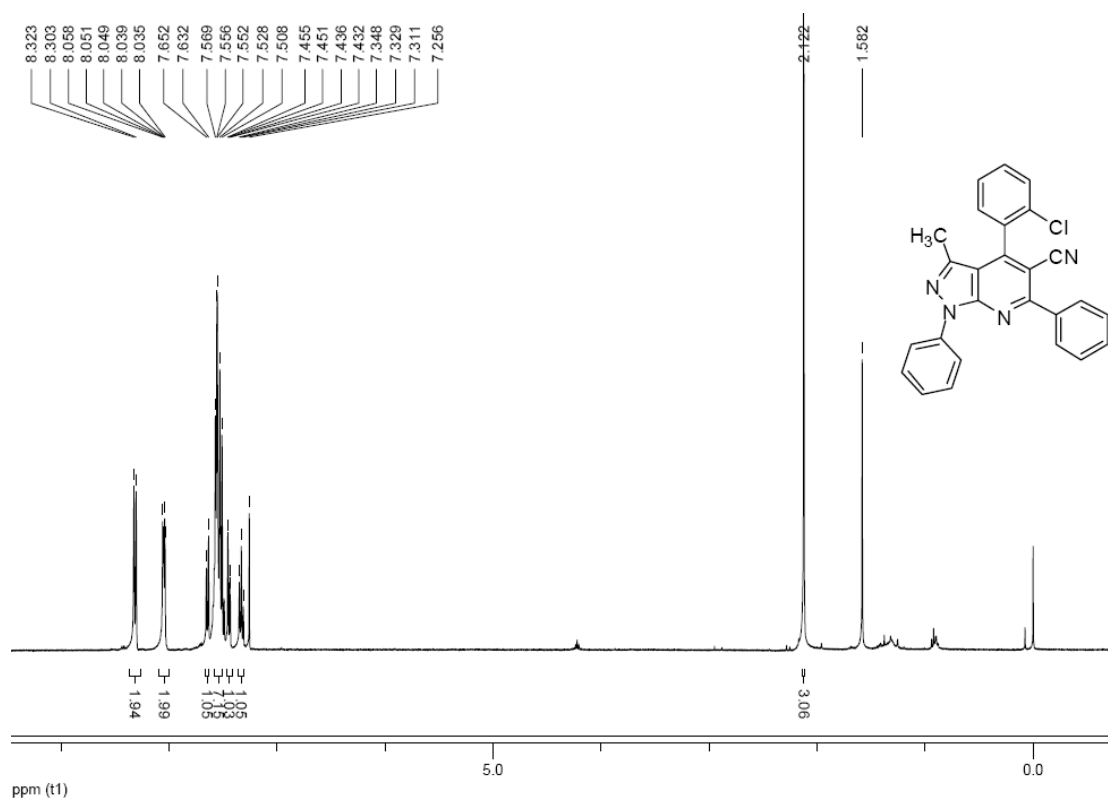
$^{13}\text{C}$  NMR of compound **4**{5,2,4}



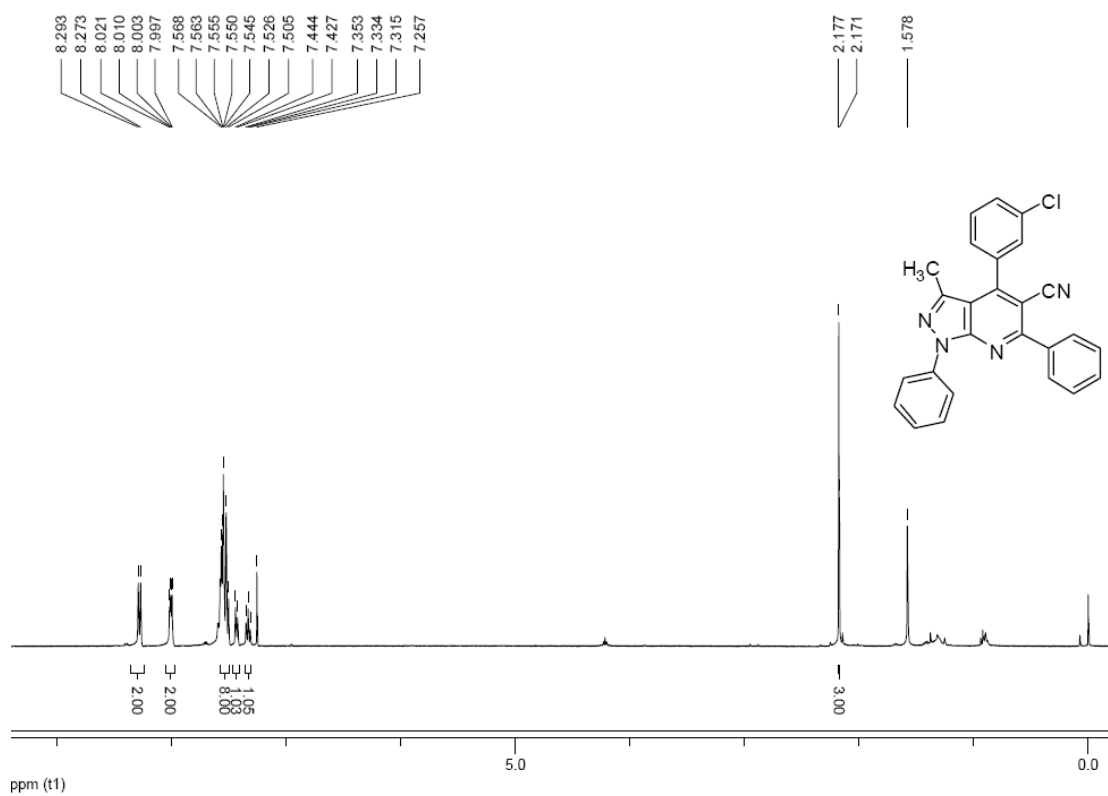
$^1\text{H}$  NMR of compound **4**{6,1,1}



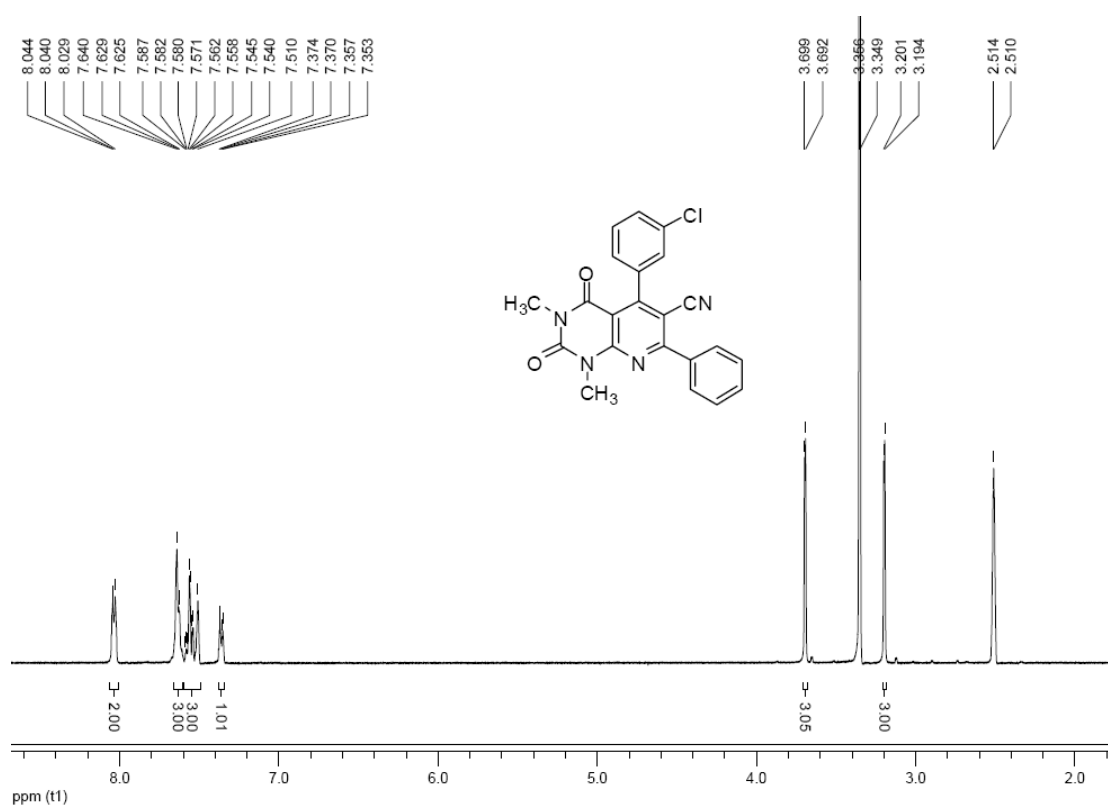
$^1\text{H}$  NMR of compound **4**{7,1,1}



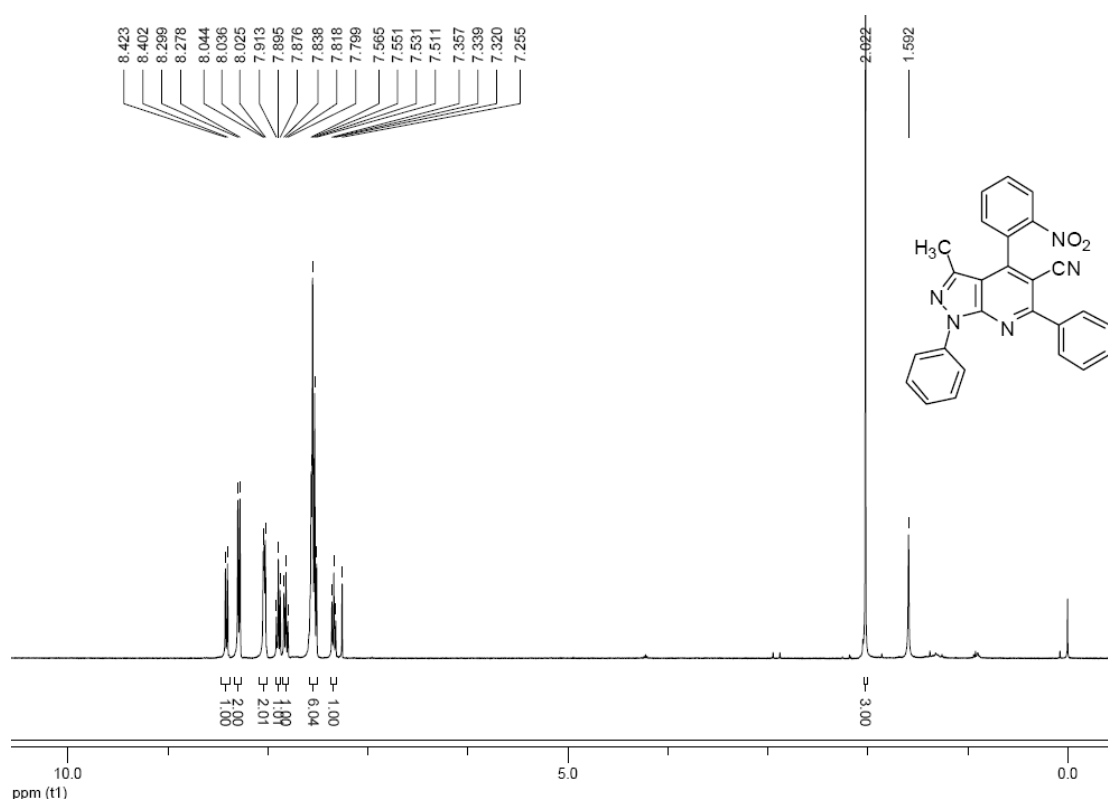
$^1\text{H}$  NMR of compound **4**{8,1,1}



$^1\text{H}$  NMR of compound **4**{8,*I*,2}



$^1\text{H}$  NMR of compound **4**{9,*I*,*I*}

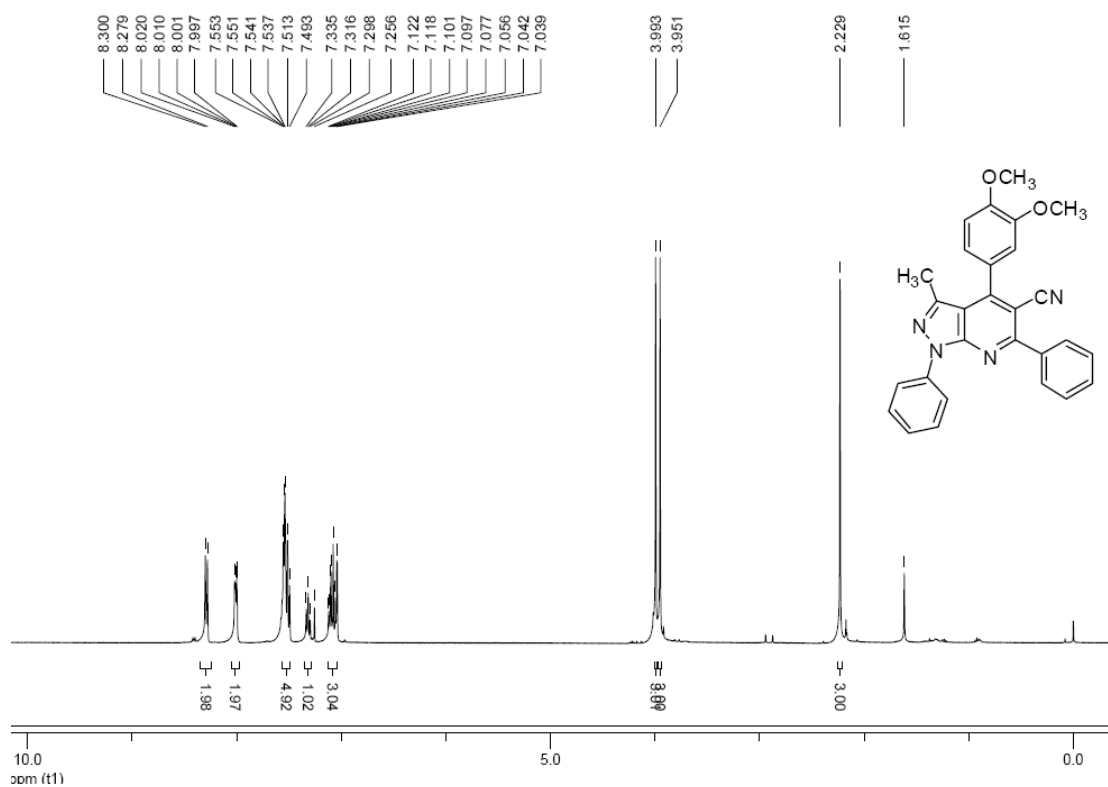


[illegible]

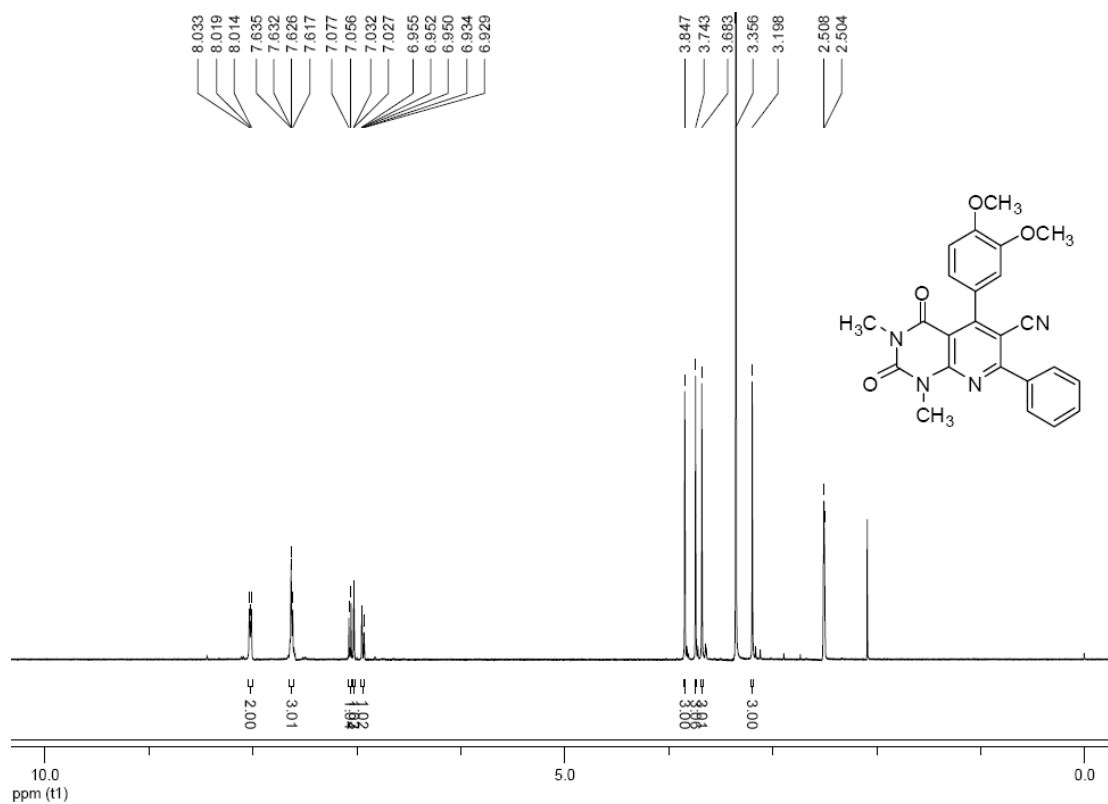
Chemical structure of 1-(4-chlorophenyl)-2-methyl-4-nitro-6-phenyl-1H-benzimidazole-5-carbonitrile is shown above the spectrum.

<sup>13</sup>C NMR peaks (ppm): 159.128, 150.196, 147.603, 144.127, 138.694, 136.660, 136.208, 135.550, 132.768, 132.478, 131.869, 130.069, 129.495, 128.867, 127.476, 126.117, 121.873, 118.348, 117.310, 113.696, 101.337, 40.752, 40.473, 40.194, 39.916, 39.636, 39.362, 13.985.

$^1\text{H}$  NMR of compound **4**{10,1,1}



$^1\text{H}$  NMR of compound **4**{10,1,2}



Chemical structure of compound 10: CN1C(=O)c2c(C#N)c(c3ccccc23)n(C)c1=O (2-cyano-2-((4-methoxyphenyl)amino)-1-methyl-1H-imidazole-3-carbonyl derivative).

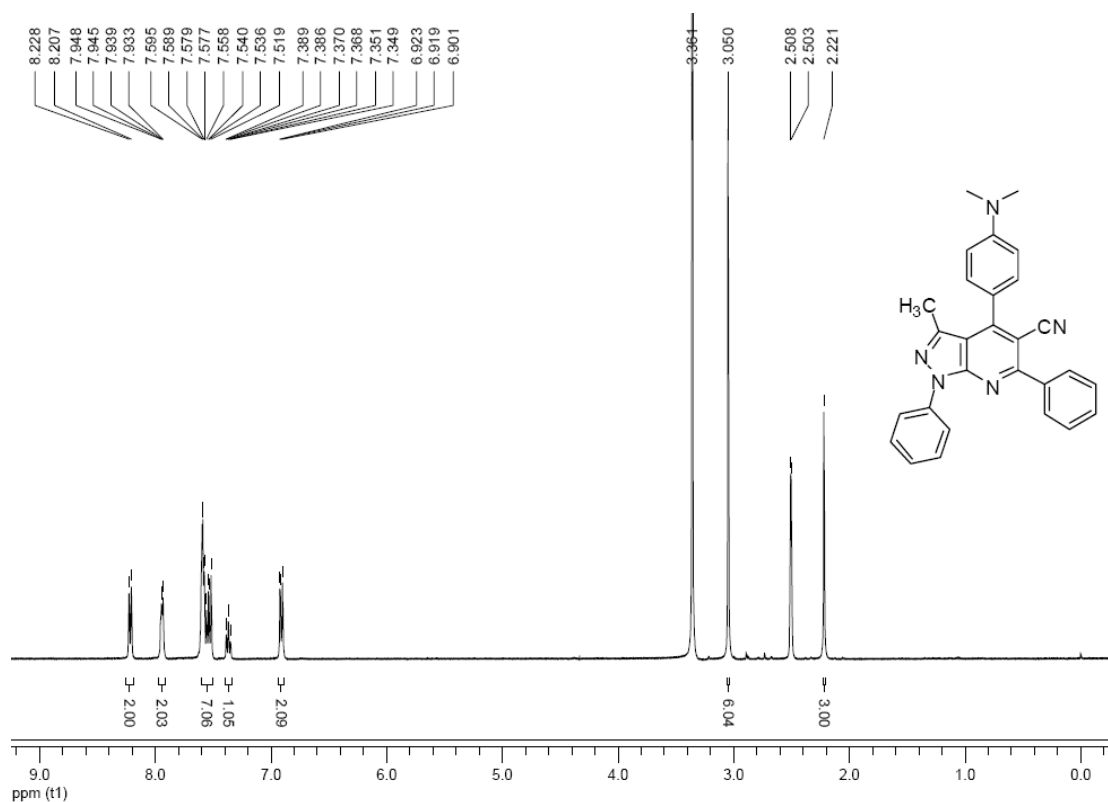
<sup>13</sup>C NMR spectrum (ppm):

- 163.516
- 159.400
- 157.206
- 152.837
- 151.308
- 139.240
- 137.016
- 133.294
- 131.925
- 130.863
- 130.009
- 129.359
- 129.290
- 128.073
- 127.084
- 116.954
- 107.730
- 104.392
- 41.038
- 40.761
- 40.483
- 40.205
- 39.928
- 39.650
- 39.371
- 30.775
- 28.960

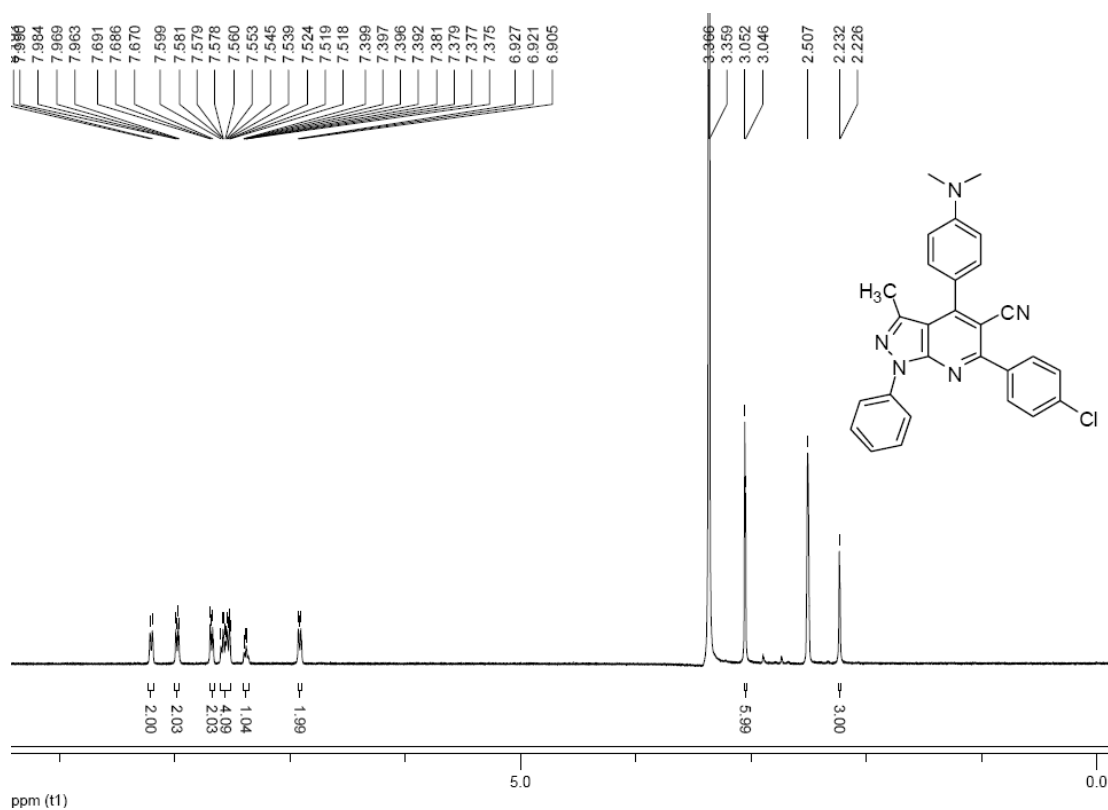
Chemical structure of compound 10: Cc1nc2c(c1)c(cnc2-c3ccccc3)c4ccccc4C#N

<sup>1</sup>H NMR spectrum (CDCl<sub>3</sub>) of compound 10. The x-axis represents chemical shift in ppm (t1), ranging from 0.0 to 10.0. The spectrum shows several peaks, with the following chemical shifts (ppm) labeled above the peaks: 8.527, 8.505, 8.243, 8.222, 8.152, 8.147, 8.111, 8.105, 8.088, 8.083, 7.982, 7.969, 7.963, 7.980, 7.974, 7.968, 7.636, 7.631, 7.624, 7.618, 7.596, 7.434, 7.432, 7.415, 7.397, 7.395, 3.962, 2.506, 2.503, and 2.072. Integration values are shown below the peaks: 0.86, 1.00, 4.99, 1.00, and 3.00.

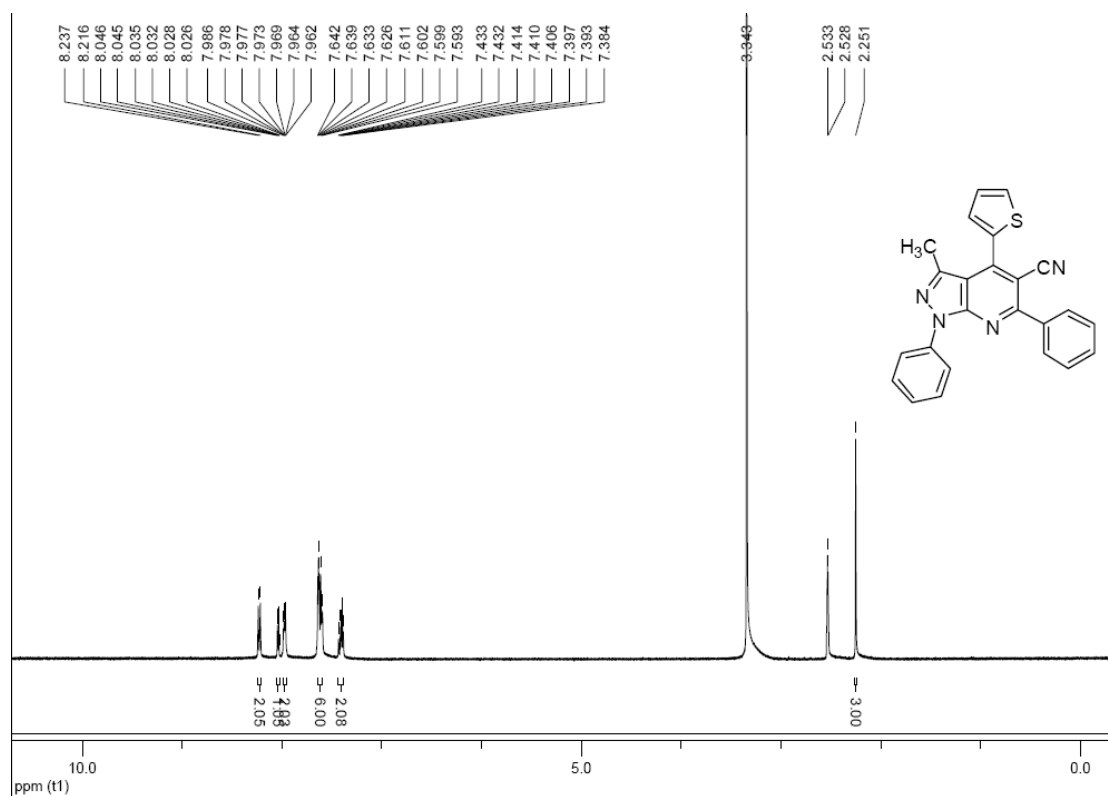
<sup>1</sup>H NMR of compound **4**{12,1,1}



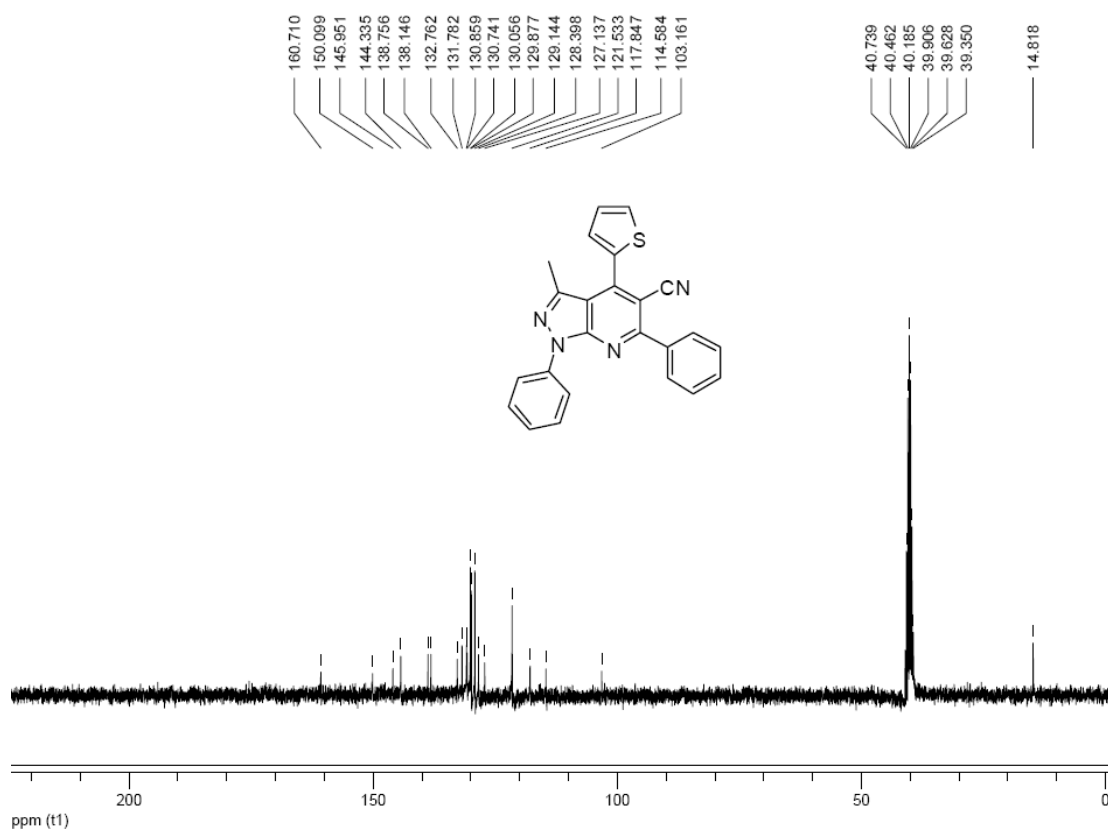
<sup>1</sup>H NMR of compound **4**{12,2,1}



<sup>1</sup>H NMR of compound **4**{13,1,1}

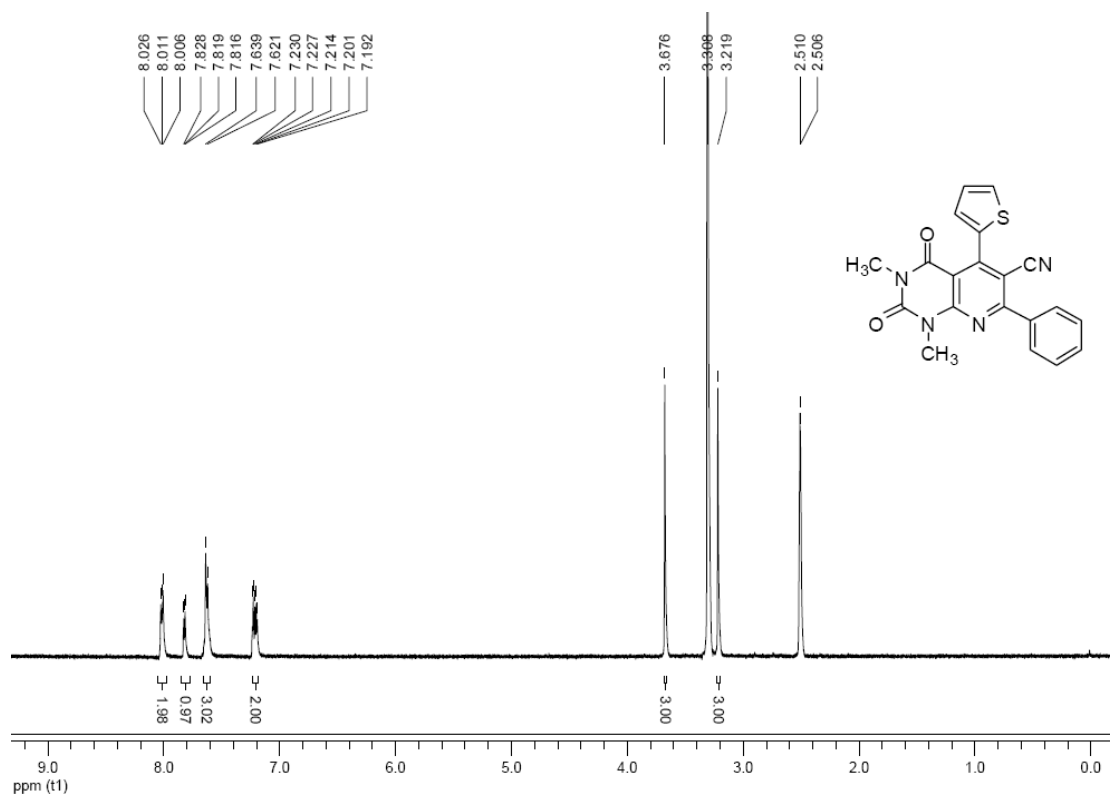


<sup>13</sup>C NMR of compound **4**{13,1,1}

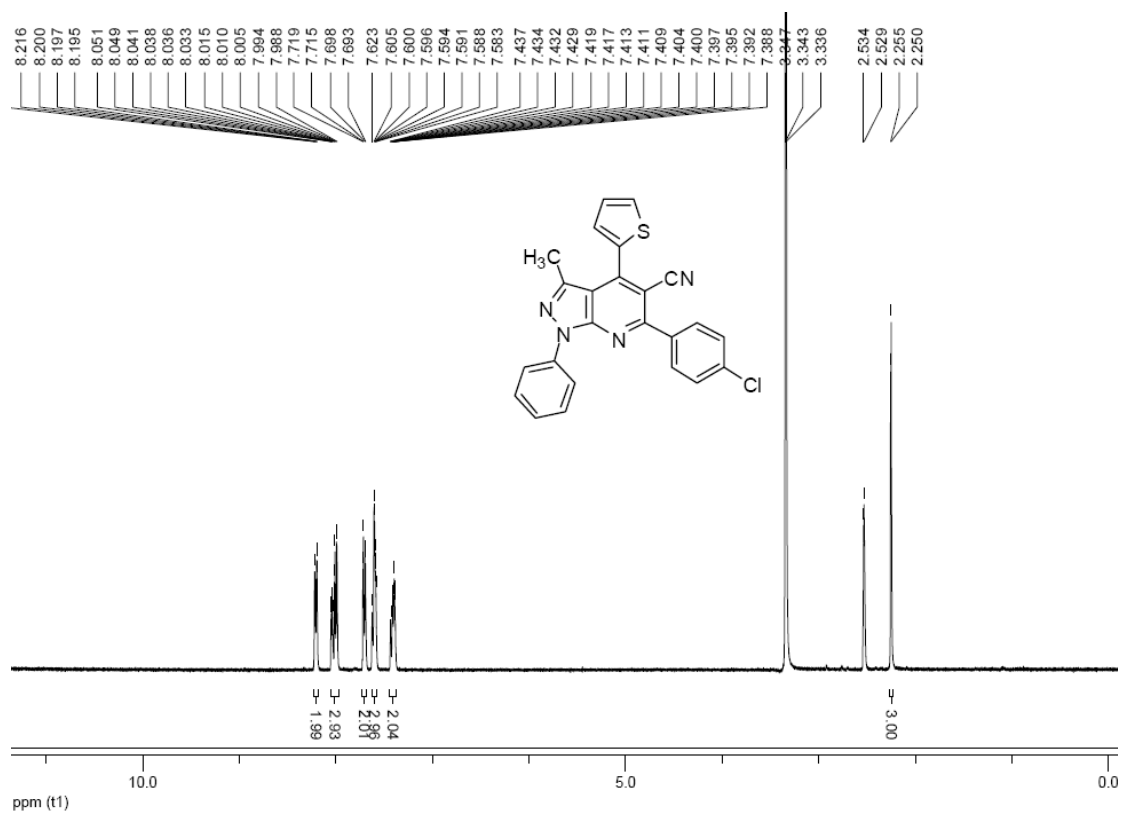




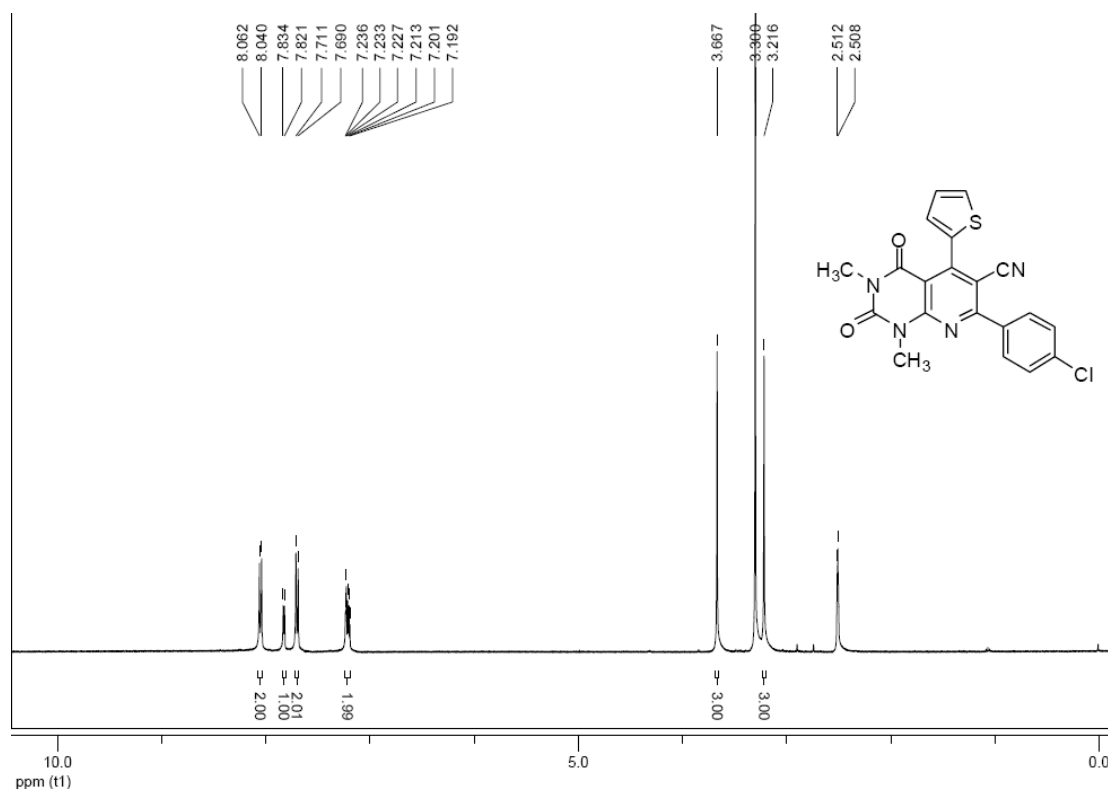
$^1\text{H}$  NMR of compound **4**{13,1,2}



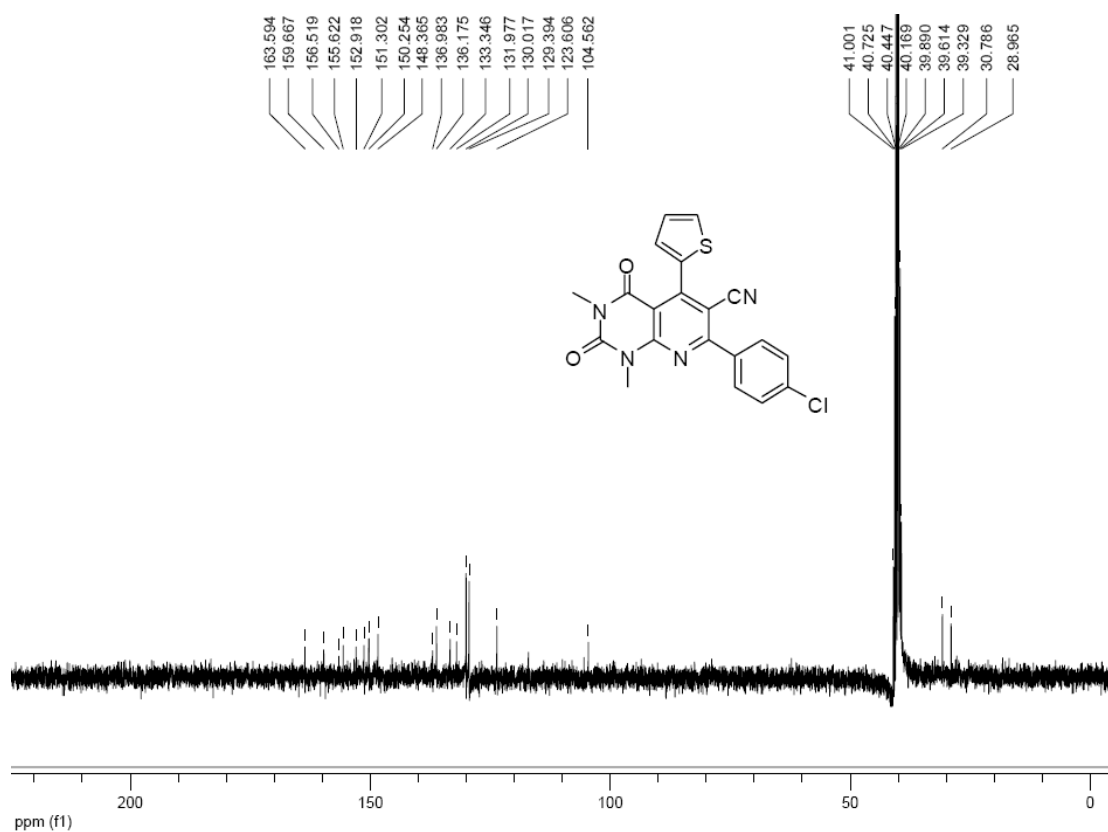
$^1\text{H}$  NMR of compound **4**{13,2,1}



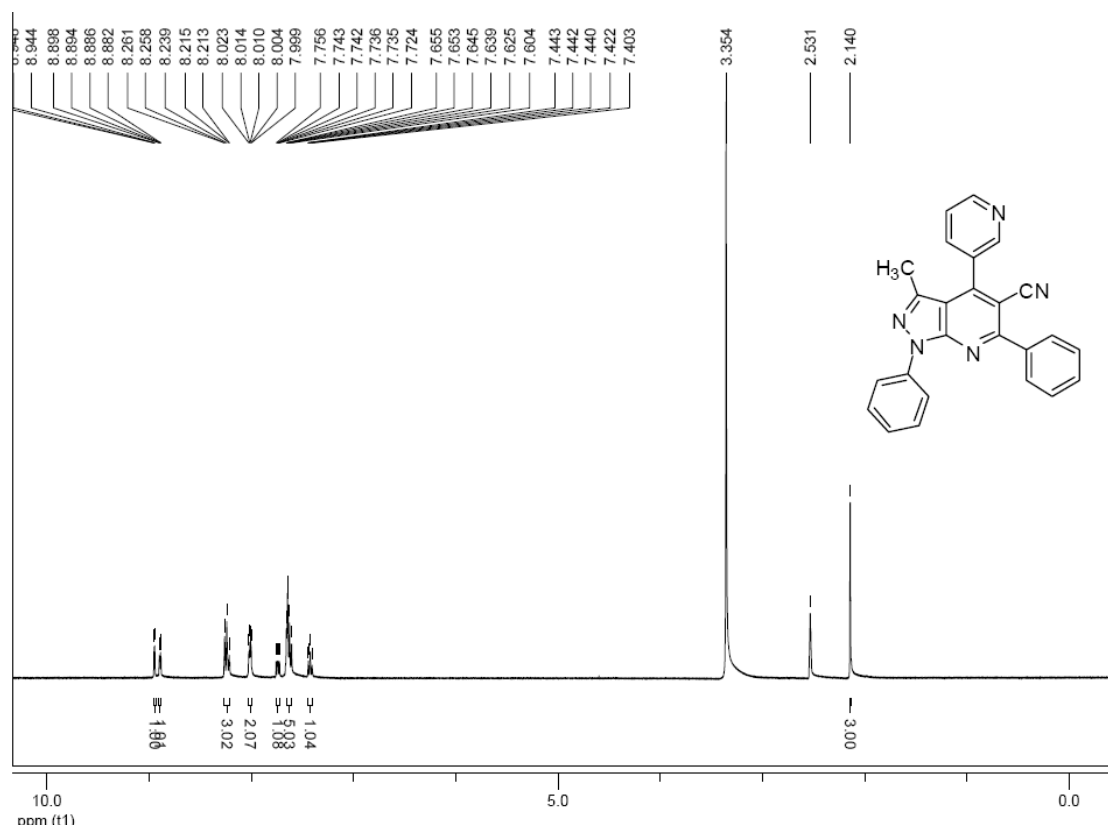
$^1\text{H}$  NMR of compound **4** {13,2,2}



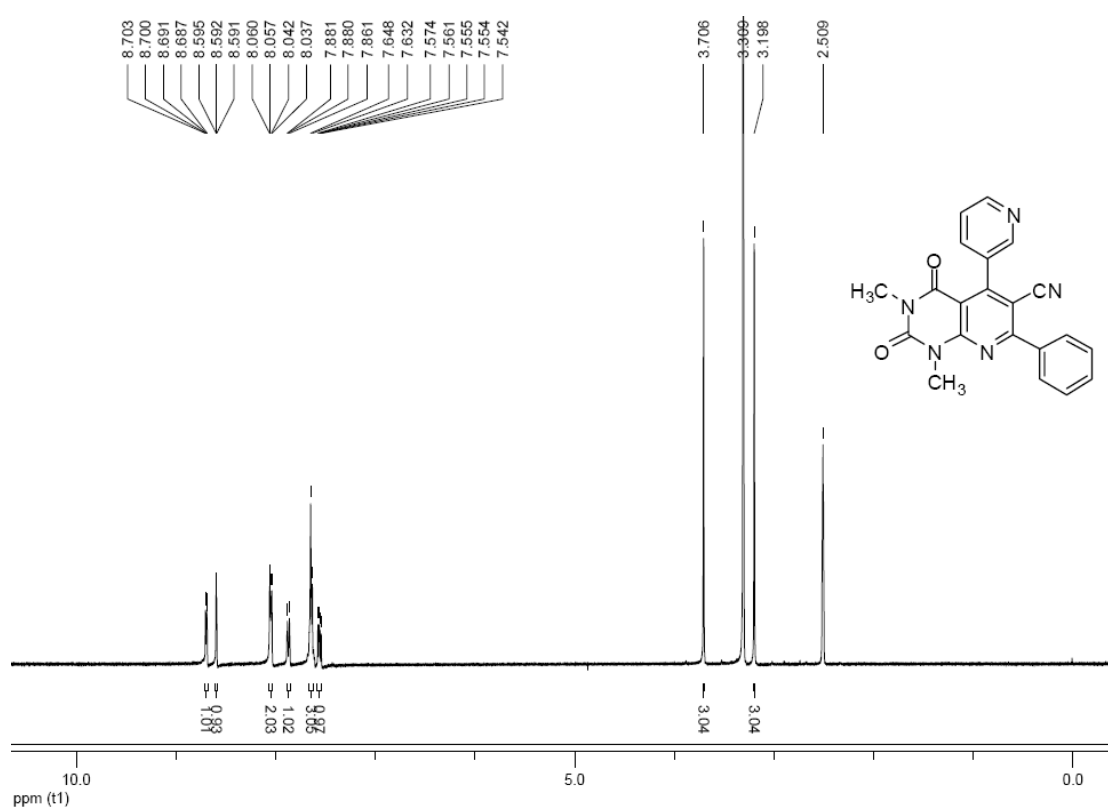
$^{13}\text{C}$  NMR of compound **4** {13,2,2}



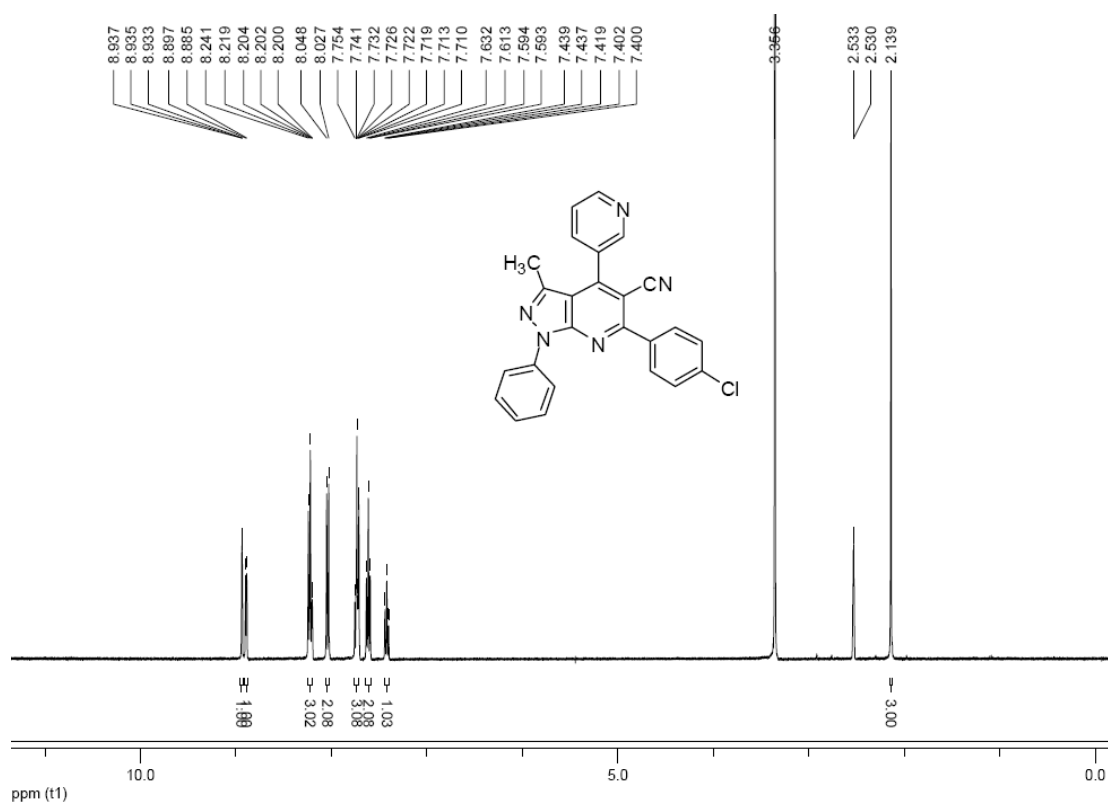
$^1\text{H}$  NMR of compound **4**{14,1,1}



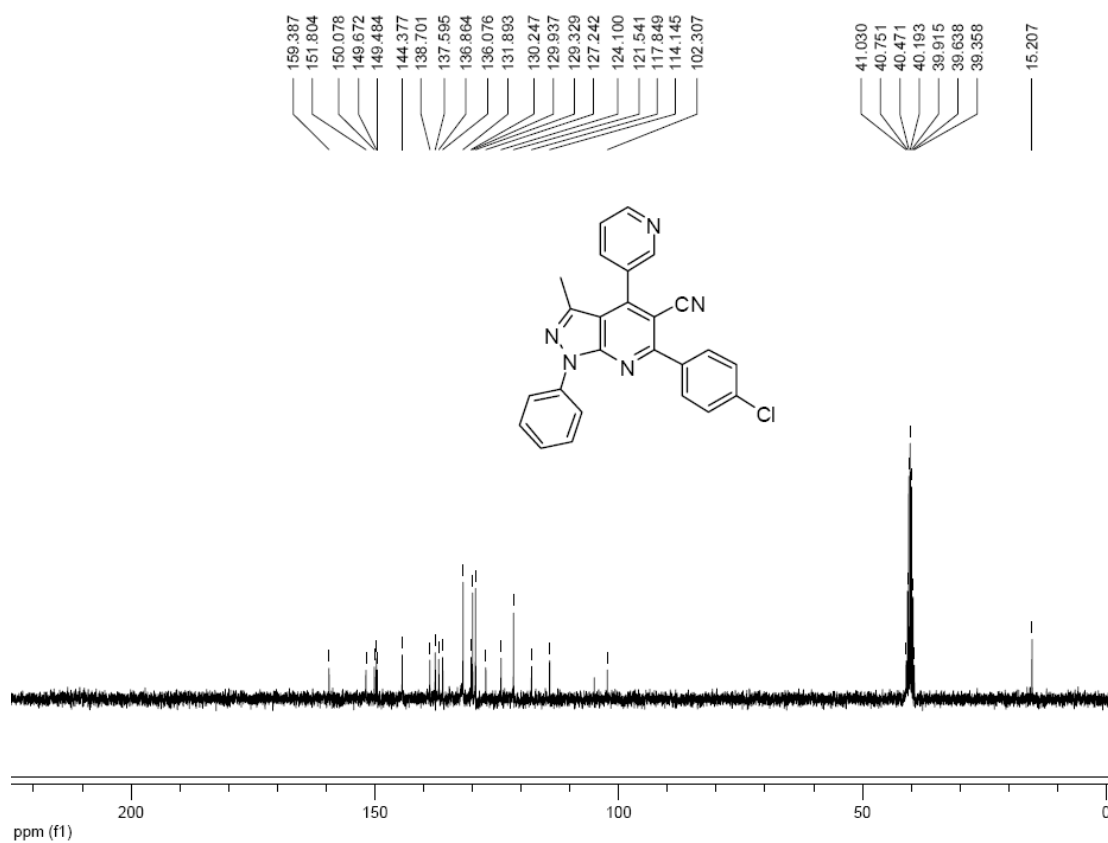
$^1\text{H}$  NMR of compound **4**{14,1,2}



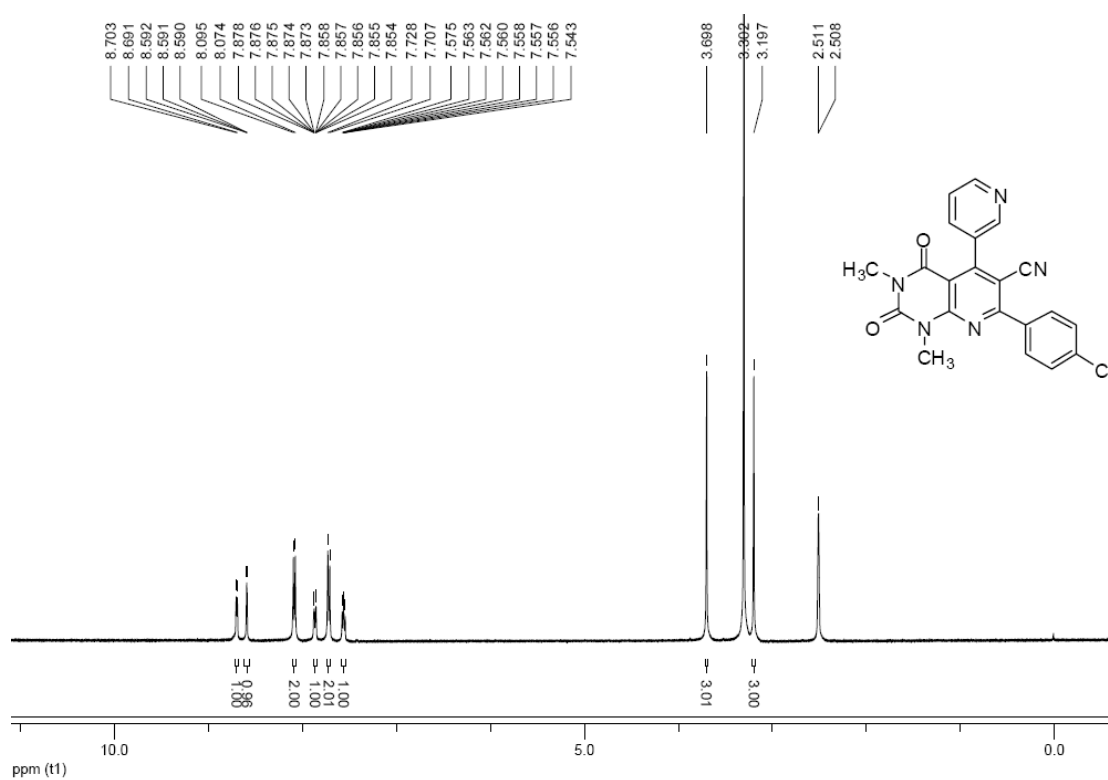
<sup>1</sup>H NMR of compound **4**{1*4*,2,1}



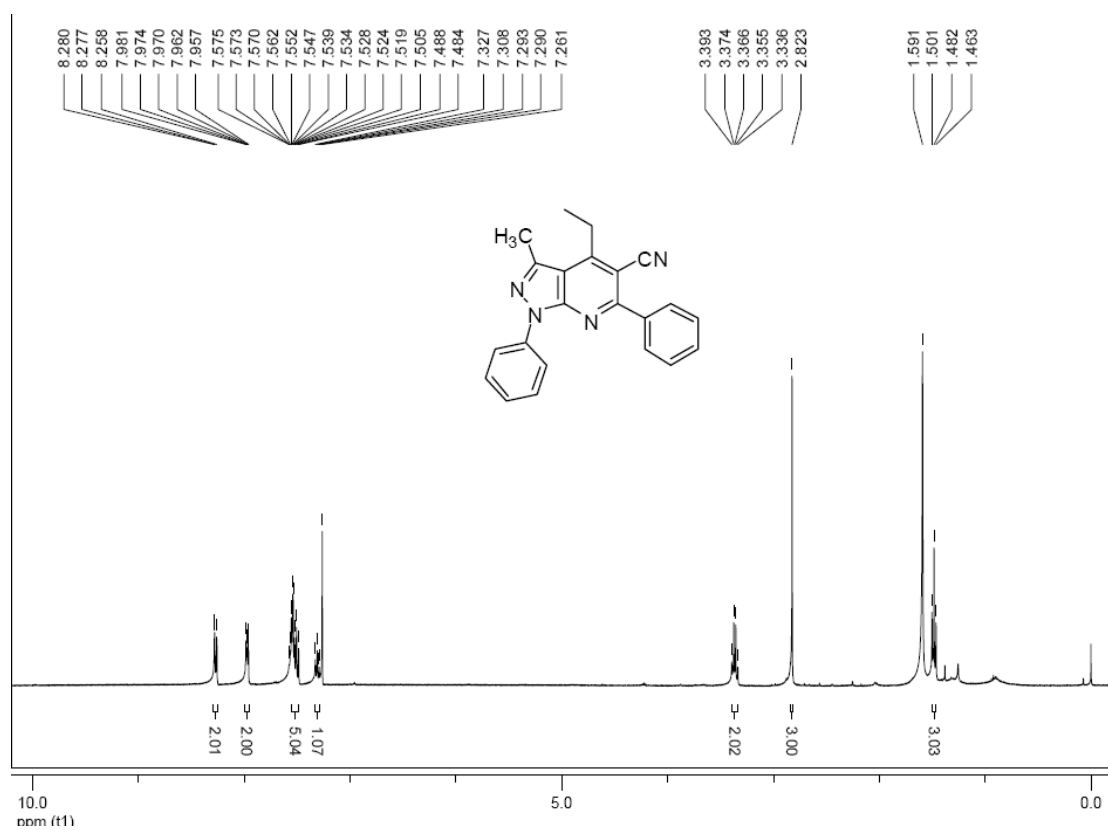
<sup>13</sup>C NMR of compound **4**{1*4*,2,1}



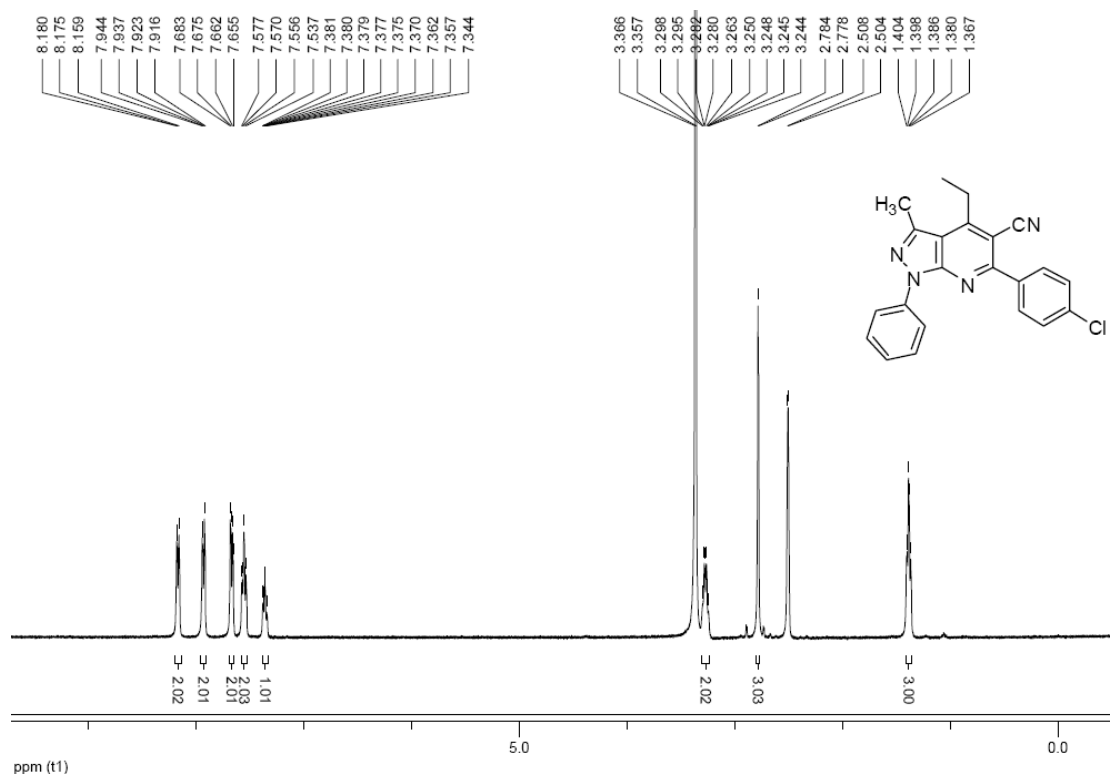
$^1\text{H}$  NMR of compound **4**{14,2,2}



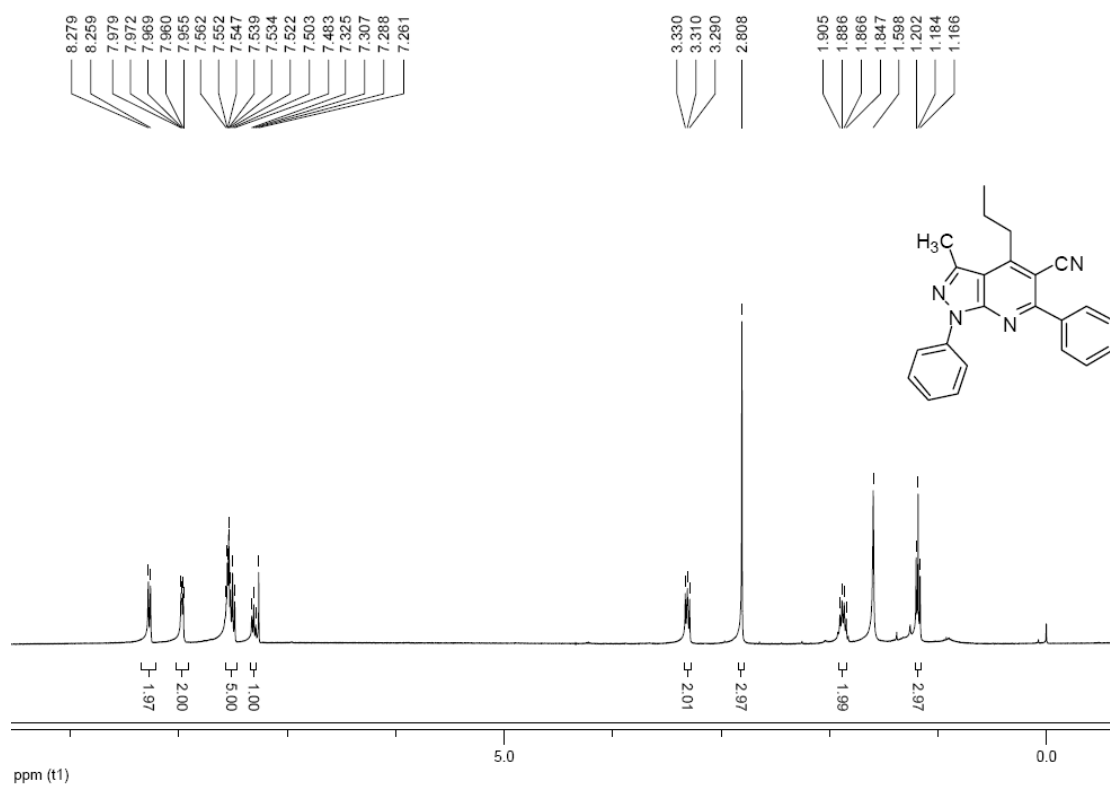
$^1\text{H}$  NMR of compound **4**{15,1,1}



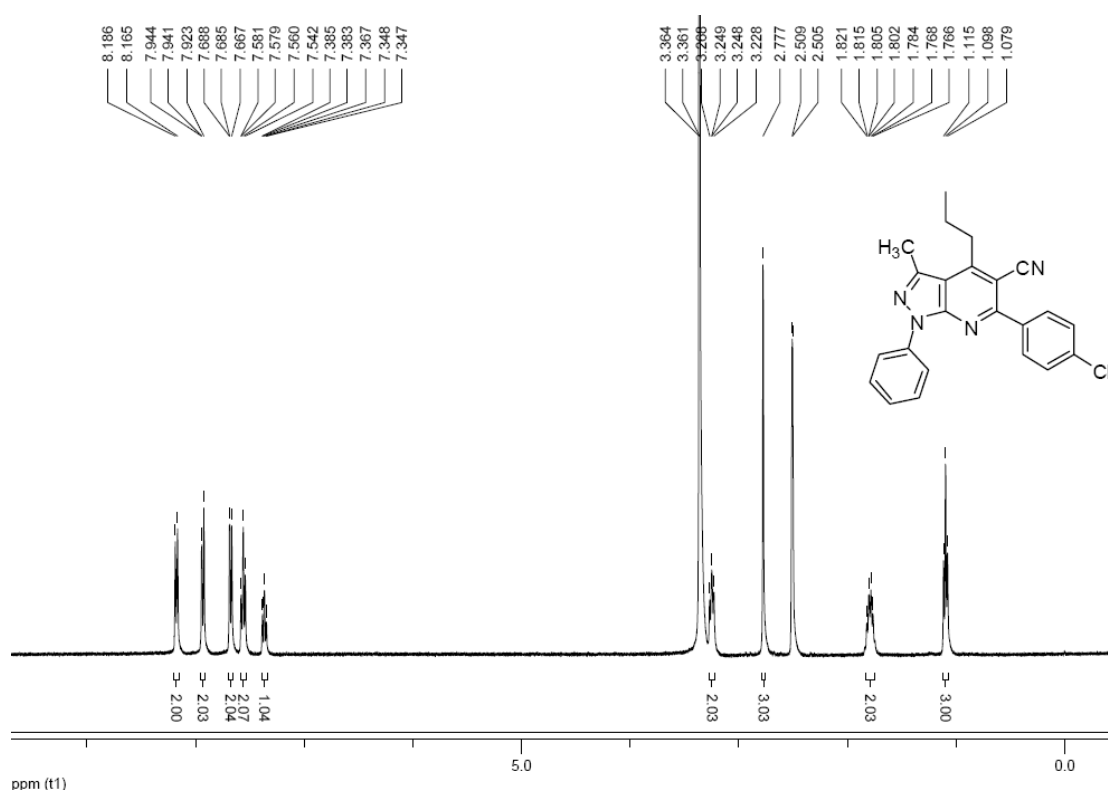
$^1\text{H}$  NMR of compound **4**{15,2,1}



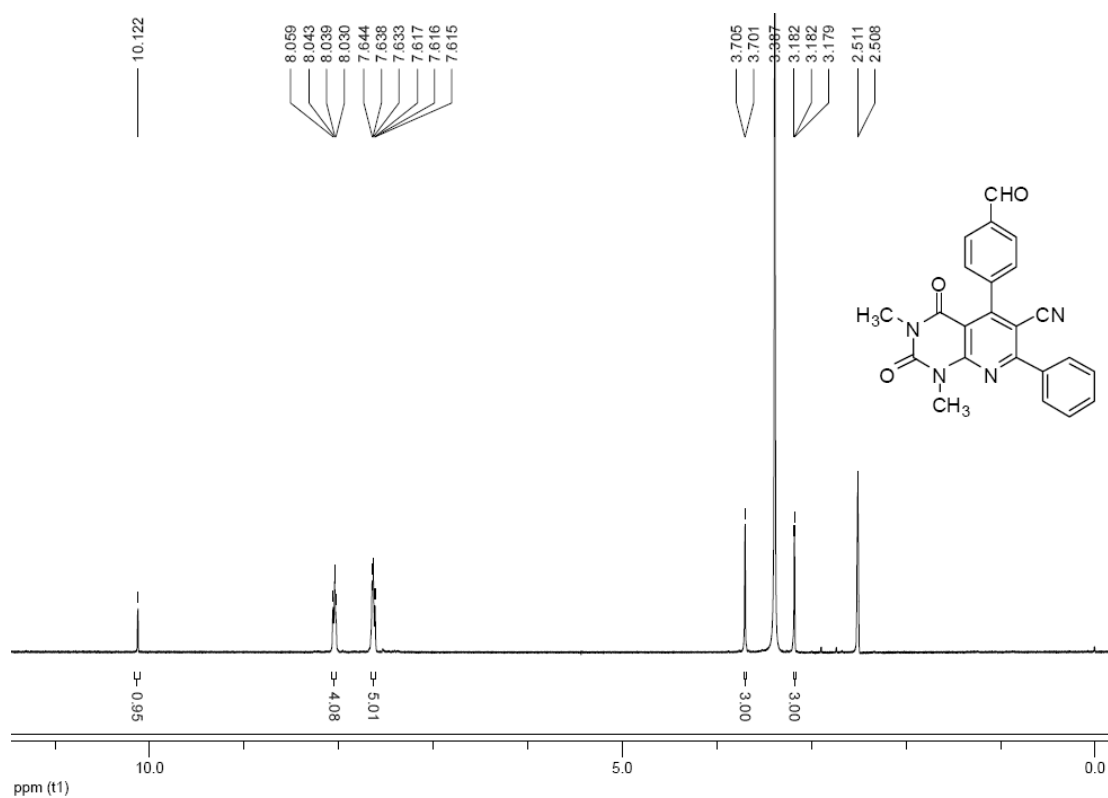
$^1\text{H}$  NMR of compound **4**{16,1,1}



<sup>1</sup>H NMR of compound 4{16,2,1}



<sup>1</sup>H NMR of compound 4{17,1,2}



$^1\text{H}$  NMR of compound **4**<sub>{18,0,2}</sub>

