

General procedure for the synthesis of polysubstituted pyrroles derivatives

A mixture of, ethyl acetoacetate, nitromethane, benzaldehyde, aniline and Cu@imine/Fe₃O₄ MNPs was combined with each other at 100°C under solvent-free conditions. The development of the reaction was controlled with TLC (eluent = n-hexane/ethyl acetate, 7:3). At the end of the reaction, 5 ml of hot ethanol was added to the reaction mixture and the catalyst was separated from the solution using a permanent magnetic field. Afterwards, the resultant mixture was rinsed with water and next, recrystallized from ethanol to pure polysubstituted pyrrole derivative.

Spectral data:

(Table 2, Entry 1): Mp: Oil; IR (KBr, cm⁻¹): 3031, 2929, 1697, 1606, 1527, 1495, 1452, 1433, 1411, 1286, 1205, 1183, 1142, 1121, 1064, 1029; ¹H NMR (400 MHz, DMSO-*d*₆) δ: 2.48 (s, 3H), 3.69 (s, 3H), 5.09 (s, 2H), 6.57 (s, 1H), 7.05 (d, 2H), 7.22-7.25 (m, 2H), 7.31 (t, 4H), 7.34-7.36 (m 2H) ppm; ¹³C NMR (100 MHz, DMSO-*d*₆) δ: 11.1, 50.8, 110.8, 120.7, 126.4, 126.8, 127.7, 127.8, 129.2, 129.5, 135.8, 136.5, 136.8, 166.4 ppm.

Table 2, Entry 2): Mp: Oil; IR (KBr, cm⁻¹): 3031, 2949, 2844, 1695, 1521, 1436, 1281, 1211, 1204, 1186, 1141, 1059; ¹H NMR (400 MHz, DMSO-*d*₆) δ: 2.46 (s, 3H), 3.68 (s, 3H), 5.06 (s, 2H), 6.58 (s, 1H), 7.06 (d, 2H), 7.28 (brs, 4H), 7.32-7.38 (m, 3H) ppm; ¹³C NMR (100 MHz, DMSO-*d*₆) δ: 11.6, 50.8, 110.8, 120.9, 125.1, 126.7, 127.8, 128.1, 129.0, 130.7, 132.2, 134.6, 136.6, 136.8, 166.2 ppm.

Table 2, Entry 3): Mp: Oil; IR (KBr, cm⁻¹): 2929, 2341, 1707, 1506, 1439, 1341, 1295, 1175, 1143, 1052; ¹H NMR (400 MHz, DMSO-*d*₆) δ: 2.47 (s, 3H), 3.68 (s, 3H), 5.08 (s, 2H), 6.65 (s, 1H), 7.09 (d, 2H), 7.29-7.37 (m, 3H), 7.50 (d, 2H), 8.17 (d, 2H) ppm; ¹³C NMR (100 MHz, DMSO-*d*₆) δ: 11.6, 29.5, 50.7, 110.6, 121.5, 123.0, 124.6, 126.8, 128.1, 129.4, 129.5, 136.4, 137.8, 143.0, 146.4, 165.9 ppm.

Table 2, Entry 4): Mp: Oil; IR (KBr, cm⁻¹): 3027, 2925, 1699, 1528, 1435, 1282, 1201, 1189, 1146, 1062; ¹H NMR (400 MHz, DMSO-*d*₆) δ: 2.35 (s, 3H), 2.47 (s, 3H), 3.69 (s, 3H), 5.05 (s, 2H), 6.55 (s, 1H), 7.07 (d, 2H), 7.15 (d, 2H), 7.26(d, 1H), 7.30 (d, 2H), 7.35 (d, 2H) ppm; ¹³C NMR (100 MHz, DMSO-*d*₆) δ: 11.8, 21.4, 29.6, 50.8, 110.7, 120.7, 126.2, 126.5, 127.8, 128.4, 129.1, 129.3, 132.7, 135.6, 136.3, 136.8, 166.2 ppm.

Table 2, Entry 5): Mp: Oil; IR (KBr, cm⁻¹): 2947, 2836, 1697, 1605, 1522, 1439, 1287, 1246, 1205, 1180, 1145, 1064, 1032; ¹H NMR (400 MHz, DMSO-*d*₆) δ: 2.47 (s, 3H), 3.69 (s, 3H), 3.83 (s, 3H), 5.07 (s, 2H), 6.54 (s, 1H), 6.87 (d, 2H), 7.05 (d, 2H), 7.28-7.33 (m, 5H) ppm; ¹³C NMR

(100 MHz, DMSO- d_6) δ : 11.6, 50.7, 55.3, 110.9, 113.1, 120.5, 125.8, 126.5, 127.8, 128.5, 129.1, 130.4, 136.4, 136.8, 158.4, 166.2 ppm.

Table 2, Entry 6): Mp: 128-131°C; IR (KBr, cm^{-1}): 2926, 2854, 1700, 1603, 1524, 1493, 1438, 1363, 1281, 1208, 1188, 1131, 1079; ^1H NMR (400 MHz, DMSO- d_6) δ : 2.35 (s, 3H), 3.74 (s, 3H), 4.98 (s, 2H), 6.35 (dd, 1H), 6.64 (dd, 1H), 6.88 (s, 1H), 6.99 (d, 2H), 7.16-7.28 (m, 4H) ppm; ^{13}C NMR (100 MHz, DMSO- d_6) δ : 11.8, 29.7, 50.6, 107.1, 109.9, 111.5, 115.8, 120.6, 126.5, 127.9, 128.2, 129.4, 136.5, 136.7, 140.3, 149.6, 165.8 ppm.

Table 2, Entry 7): Mp: 120-123°C; IR (KBr, cm^{-1}): 2926, 2851, 1699, 1528, 1497, 1437, 1410, 1372, 1263, 1181, 1125, 1106, 1075; ^1H NMR (400 MHz, DMSO- d_6) δ : 2.36 (s, 3H), 3.63 (s, 3H), 4.92 (s, 2H), 6.63 (s, 1H), 6.91 (dd, 1H), 6.95 (d, 2H), 7.05 (dd, 1H), 7.09 (d, 1H), 7.15-7.25 (m, 3H) ppm; ^{13}C NMR (100 MHz, DMSO- d_6) δ : 11.6, 29.7, 50.9, 111.3, 118.7, 121.4, 123.8, 125.5, 126.6, 126.8, 128.2, 129.3, 136.5, 137.3, 137.5, 166.2 ppm.

Table 2, Entry 8): Mp: Oil; IR (KBr, cm^{-1}): 3033, 2982, 2930, 1695, 1526, 1490, 1424, 1384, 1282, 1202, 1184, 1145, 1090, 1016; ^1H NMR (400 MHz, DMSO- d_6) δ : 1.16 (t, 3H), 2.47 (s, 3H), 4.16 (q, 2H), 5.03 (s, 2H), 6.54 (s, 1H), 7.04 (d, 2H), 7.26-7.34 (m, 7H) ppm; ^{13}C NMR (100 MHz, DMSO- d_6) δ : 11.8, 14.4, 50.5, 59.9, 111.2, 120.8, 125.1, 126.6, 127.5, 128.1, 129.3, 130.7, 132.2, 134.5, 136.9, 136.8, 165.9 ppm.

Table 2, Entry 9): Mp: Oil; IR (KBr, cm^{-1}): 2928, 2342, 1707, 1507, 1438, 1341, 1295, 1177, 1143, 1050; ^1H NMR (400 MHz, DMSO- d_6) δ : 1.23 (t, 3H), 2.48 (s, 3H), 4.24 (q, 2H), 5.07 (s, 2H), 6.65 (s, 1H), 7.03 (d, 2H), 7.35-7.24 (m, 3H), 7.54 (d, 2H), 8.11 (d, 2H) ppm; ^{13}C NMR (100 MHz, DMSO- d_6) δ : 11.7, 14.4, 29.9, 57.8, 110.8, 121.7, 123.3, 124.5, 126.6, 128.3, 129.4, 129.8, 136.5, 137.4, 143.2, 146.5, 165.8 ppm.

Table 2, Entry 10): Mp: Oil; IR (KBr, cm^{-1}): 3028, 2926, 1699, 1526, 1437, 1281, 1203, 1189, 1145, 1069; ^1H NMR (400 MHz, DMSO- d_6) δ : 1.22 (t, 3H), 2.37 (s, 3H), 2.47 (s, 3H), 4.21 (q, 2H), 5.07 (s, 2H), 6.57 (s, 1H), 7.06 (d, 2H), 7.11 (d, 2H), 7.26 (d, 1H), 7.31 (d, 2H), 7.35 (d, 2H) ppm; ^{13}C NMR (100 MHz, DMSO- d_6) δ : 11.7, 14.2, 21.3, 29.5, 50.6, 59.3, 110.9, 120.5, 126.2, 126.7, 128.9, 128.4, 129.0, 129.1, 130.9, 132.6, 132.3, 134.5, 165.7 ppm.

Table 2, Entry 11): Mp: Oil; IR (KBr, cm^{-1}): 2946, 2834, 1698, 1606, 1521, 1438, 1283, 1246, 1205, 1178, 1142, 1065, 1032; ^1H NMR (400 MHz, DMSO- d_6) δ : 1.21 (t, 3H), 2.47 (s, 3H), 3.68 (s, 3H), 4.20 (q, 2H), 5.06 (s, 2H), 6.55 (s, 1H), 6.88 (d, 2H), 7.07 (d, 2H), 7.26-7.32 (m, 5H)

ppm; ^{13}C NMR (100 MHz, $\text{DMSO-}d_6$) δ : 11.6, 14.2, 50.6, 53.2, 110.7, 113.1, 120.2, 125.8, 126.6, 127.8, 128.4, 129.2, 130.1, 136.4, 136.9, 158.5, 166.3 ppm.

Table 2, Entry 12): Mp: Oil; IR (KBr, cm^{-1}): 3051, 2982, 1693, 1598, 1515, 1386, 1225, 754; ^1H NMR (400 MHz, $\text{DMSO-}d_6$) δ : 1.16 (t, 3H), 2.47 (s, 3H), 4.20 (q, 2H), 6.72 (s, 1H), 7.27-7.29 (m, 1H), 7.31-7.34 (m, 5H), 7.41-7.45 (m, 3H), 7.48-7.51 (m, 2H) ppm; ^{13}C NMR (100 MHz, $\text{DMSO-}d_6$) δ : 12.6, 14.2, 59.4, 111.7, 120.8, 126.2, 126.5, 127.4, 128.2, 129.6, 129.8, 135.4, 136.2, 139.1, 165.4 ppm.

Table 2, Entry 13): Mp: 126-128°C; IR (KBr, cm^{-1}): 3033, 2978, 2926, 1693, 1527, 1485, 1421, 1384, 1282, 1207, 1185, 1146, 1087, 1016; ^1H NMR (400 MHz, $\text{DMSO-}d_6$) δ : 1.14 (t, 3H), 2.45 (s, 3H), 4.16 (q, 2H), 6.54 (s, 1H), 7.06 (d, 2H), 7.24-7.33 (m, 7H) ppm; ^{13}C NMR (100 MHz, $\text{DMSO-}d_6$) δ : 14.4, 50.8, 59.7, 111.0, 120.6, 125.3, 126.8, 127.7, 128.0, 129.2, 130.7, 132.0, 134.5, 136.7, 136.8, 165.6 ppm.

Table 2, Entry 14): Mp: 119-122°C; IR (KBr, cm^{-1}): 2982, 2953, 2865, 1720, 1495; ^1H NMR (400 MHz, $\text{DMSO-}d_6$) δ : 1.22 (t, 3H), 1.65 (s, 3H), 2.15 (s, 3H), 3.79 (q, 2H), 7.40 (d, 4H), 7.70 (d, 1H), 7.75 (s, 1H), 7.78 (d, 1H), 7.90 (d, 2H) ppm; ^{13}C NMR (100 MHz, $\text{DMSO-}d_6$) δ : 28.2, 31.5, 35.9, 45.4, 115.4, 119.7, 122.8, 124.1, 128.0, 131.2, 133.3, 137.2, 138.9, 148.5, 152.6, 157.4, 161.1, 164.3, 167.4, 169.2, 180.0 ppm.

Table 2, Entry 15): Mp: 128-131°C; IR (KBr, cm^{-1}): 2926, 2855, 1708, 1517, 1484, 1441, 1417, 1295, 1198, 1189, 1151, 1073; ^1H NMR (400 MHz, $\text{DMSO-}d_6$) δ : 1.24 (t, 3H), 2.48 (s, 3H), 3.82 (s, 3H), 4.23 (q, 2H), 6.69 (s, 1H), 6.93-6.99 (d, 2H), 7.22-7.25 (dd, 2H), 7.27-7.30 (d, 2H), 7.34-7.37 (d, 2H) ppm; ^{13}C NMR (100 MHz, $\text{DMSO-}d_6$) δ : 12.8, 14.0, 53.5, 59.6, 110.7, 114.5, 121.3, 125.4, 127.5, 127.9, 130.5, 131.8, 132.3, 134.4, 137.8, 159.2, 166.5 ppm.

Table 2, Entry 16): Mp: 106-109°C; IR (KBr, cm^{-1}): 2935, 2882, 1714, 1597, 1520, 1445; ^1H NMR (400 MHz, $\text{DMSO-}d_6$) δ : 1.27 (t, 3H), 1.89 (s, 3H), 3.37 (q, 2H), 3.72 (s, 3H), 7.16 (d, 2H), 7.29 (d, 2H), 7.36 (d, 2H), 7.61 (t, 1H), 7.88 (d, 2H), 8.12 (s, 1H) ppm; ^{13}C NMR (100 MHz, $\text{DMSO-}d_6$) δ : 44.1, 115.6, 119.4, 123.2, 124.1, 127.5, 128.4, 129.3, 131.1, 140.8, 145.7, 149.4, 152.5, 155.7, 159.8, 164.5, 167.2, 179.4 ppm.

General procedure for the synthesis of 1,2,4,5-tetrasubstituted imidazoles derivatives.

A mixture of, benzil, benzylamine, benzaldehyde, ammonium acetate and Cu@imine/Fe₃O₄ MNPs was combined with each other at 80°C under solvent-free conditions. The development of the reaction was controlled with TLC (eluent = n-hexane/ethyl acetate, 7:3). At the end of the reaction, 5 ml of hot ethanol was added to the reaction mixture and the catalyst was separated from the solution using a permanent magnetic field. Afterwards, the resultant mixture was rinsed with water and next, recrystallized from ethanol to pure 1,2,4,5-tetrasubstituted imidazole derivative.

Spectral data:

(Table 4, Entry1): Mp: 215-217°C; IR (KBr, cm⁻¹): 3351, 2872, 2298, 1640, 1221; ¹H NMR (400 MHz, DMSO-*d*₆) δ: 7.09 (d, 2H), 7.20 (m, 2H), 7.24-7.38 (m, 12H), 7.52 (m, 2H), 7.71 (d, 2H) ppm; ¹³C NMR (100 MHz, DMSO-*d*₆) δ: 126.6, 127.4, 127.8, 128.1, 128.2, 128.4, 128.6, 128.8, 129.1, 130.3, 130.5, 130.7, 131.1, 134.2, 136.1, 136.5, 146.7 ppm.

(Table 4, Entry 2): Mp: 150-152°C; IR (KBr, cm⁻¹): 3051, 1604, 1506, 1064; ¹H NMR (400 MHz, DMSO-*d*₆) δ: 7.12-7.33 (m, 17H), 7.45 (d, 2H) ppm; ¹³C NMR (100 MHz, DMSO-*d*₆) δ: 127.2, 127.4, 127.6, 128.1, 128.3, 129.4, 129.7, 129.9, 130.2, 131.3, 132.5, 133.4, 133.6, 145.1, 149.5 ppm.

(Table 4, Entry3): Mp: 254-257°C; IR (KBr, cm⁻¹): 1596, 1579; ¹H NMR (400 MHz, DMSO-*d*₆) δ: 7.26-7.70 (m, 16H), 7.82-8.17 (m, 4H) ppm; ¹³C NMR (100 MHz, DMSO-*d*₆) δ: 123.0, 125.1, 126.2, 128.2, 128.4, 128.6, 128.8, 128.9, 129.8, 130.6, 133.1, 134.5, 137.3, 137.5, 144.6, 153.2 ppm.

(Table 4, Entry 4): Mp: 186-188°C; IR (KBr, cm⁻¹): 3064, 1589, 1490; ¹H NMR (400 MHz, DMSO-*d*₆) δ: 2.23 (s, 3H), 7.05 (d, 2H), 7.06–7.43 (m, 15H), 7.45 (d, 2H) ppm; ¹³C NMR (100 MHz, DMSO-*d*₆) δ: 21.3, 126.9, 127.0, 128.1, 128.7, 128.8, 128.9, 129.0, 129.5, 130.7, 131.3, 131.5, 134.8, 137.1, 138.2, 146.5 ppm.

(Table 4, Entry 5): Mp: 170-172°C; IR (KBr, cm⁻¹): 3059, 2955, 1604, 1575, 1483; ¹H NMR (400 MHz, DMSO-*d*₆) δ: 3.78 (s, 3H), 6.77 (d, 2H), 7.01-7.35 (m, 15H), 7.62 (d, 2H) ppm; ¹³C NMR (100 MHz, DMSO-*d*₆) δ: 55.1, 113.5, 126.3, 127.2, 127.5, 128.1, 128.4, 128.6, 129.3, 130.1, 130.5, 131.4, 134.6, 137.5, 146.8, 159.7 ppm.

(Table 4, Entry 6): Mp: 258-260°C; IR (KBr, cm⁻¹): 3043, 1615, 1579; ¹H NMR (400 MHz, DMSO-*d*₆) δ: 3.62 (s, 6H), 6.86 (d, 2H), 7.16-7.32 (m, 16H) ppm; ¹³C NMR (100 MHz, DMSO-

d_6) δ : 55.7, 112.8, 115.7, 121.3, 122.1, 122.4, 123.7, 126.8, 128.6, 130.2, 130.4, 132.3, 132.5, 150.2, 152.7, 153.1 ppm.

(Table 4, Entry 7): Mp: 258-260°C; IR (KBr, cm^{-1}): 3027, 1599, 1478; ^1H NMR (400 MHz, DMSO- d_6) δ : 0.52 (t, 3H), 1.33 (m, 2H), 3.82 (t, 2H), 7.11-7.56 (m, 13H), 7.69 (d, 2H) ppm; ^{13}C NMR (100 MHz, DMSO- d_6) δ : 11.4, 24.1, 53.5, 121.4, 122.9, 124.1, 125.3, 126.4, 126.8, 128.3, 128.7, 130.2, 132.6, 156.5 ppm.

(Table 4, Entry 8): Mp: 258-260°C; IR (KBr, cm^{-1}): 3026, 1644, 1488; ^1H NMR (400 MHz, DMSO- d_6) δ : 0.52 (t, 3H), 1.35 (m, 2H), 3.82 (t, 2H), 7.16-7.31 (m, 12H), 7.33 (d, 2H) ppm; ^{13}C NMR (100 MHz, DMSO- d_6) δ : 11.6, 24.3, 53.6, 121.4, 122.8, 124.2, 125.9, 126.3, 127.1, 128.5, 129.2, 130.3, 132.7, 135.5, 156.3 ppm

(Table 4, Entry 9): Mp: 258-260°C; IR (KBr, cm^{-1}): 3052, 2927, 1595, 1515; ^1H NMR (400 MHz, DMSO- d_6) δ : 0.64 (t, 3H), 1.42-1.47 (m, 2H), 3.92-3.96 (t, 2H), 7.15-7.22 (d, 3H), 7.45 (d, 2H), 7.52 (m, 5H), 7.93 (d, 2H), 8.36 (t, 3H) ppm; ^{13}C NMR (100 MHz, DMSO- d_6) δ : 11.5, 23.7, 51.6, 121.2, 109.5, 116.0, 118.7, 119.0, 119.4, 120.7, 122.2, 123.7, 127.5, 127.8, 128.1, 129.4, 132.8, 134.3, 135.5, 136.8, 140.5, 157.1, 165.8 ppm.

(Table 4, Entry 10): Mp: 258-260°C; IR (KBr, cm^{-1}): 3075, 2964, 1601, 1539, 1511; ^1H NMR (400 MHz, DMSO- d_6) δ : 0.63 (t, 3H), 1.48 (m, 2H), 4.05 (t, 2H), 7.17-7.22 (d, 3H), 7.54-7.57 (m, 7H), 7.85 (d, 1H), 8.26 (d, 1H), 8.33 (s, 1H), 8.64 (d, 1H) ppm; ^{13}C NMR (100 MHz, DMSO- d_6) δ : 10.2, 23.7, 46.5, 123.1, 123.3, 126.4, 126.6, 128.1, 129.2, 130.4, 131.1, 131.3, 131.5, 133.6, 134.7, 134.9, 137.8, 144.5, 148.2 ppm.

(Table 4, Entry 11): Mp: 258-260°C; IR (KBr, cm^{-1}): 3029, 1621, 1495; ^1H NMR (400 MHz, DMSO- d_6) δ : 0.53 (t, 3H), 1.31 (m, 2H), 2.52 (s, 3H), 3.83 (t, 2H), 7.11-7.34 (m, 12H), 7.52 (d, 2H) ppm; ^{13}C NMR (100 MHz, DMSO- d_6) δ : 11.4, 22.1, 24.3, 53.5, 121.2, 122.8, 124.1, 125.2, 126.3, 127.1, 127.5, 128.6, 130.3, 130.8, 133.2, 142.5, 156.3 ppm.

(Table 4, Entry 12): Mp: 258-260°C; IR (KBr, cm^{-1}): 3053, 2965, 1603, 1505; ^1H NMR (400 MHz, DMSO- d_6) δ : 1.12 (t, 3H), 2.55 (q, 2H), 7.15 (d, 1H), 7.24 (d, 2H), 7.30 (m, 4H), 7.35-7.39 (m, 3H), 7.44-7.46 (m, 3H), 7.54-7.56 (m, 4H), 8.05-8.08 (t, 2H) ppm; ^{13}C NMR (100 MHz, DMSO- d_6) δ : 15.8, 28.3, 121.2, 122.4, 123.7, 126.2, 126.8, 127.6, 128.4, 128.9, 130.5, 132.6, 139.2, 142.8, 154.4 ppm.

(Table 4, Entry 13): Mp: 258-260°C; IR (KBr, cm^{-1}): 3061, 2963, 1607, 1525; ^1H NMR (400 MHz, DMSO- d_6) δ : 1.11 (t, 3H), 2.58 (q, 2H), 3.82 (d, 2H), 7.24-7.26 (m, 4H), 7.31 (t, 3H),

7.47-7.48 (t, 3H), 7.65 (d, 2H), 7.79 (d, 1H), 8.06 (s, 1H), 8.12 (d, 1H) ppm; ^{13}C NMR (100 MHz, $\text{DMSO-}d_6$) δ : 15.7, 28.3, 122.6, 123.4, 126.7, 126.8, 126.9, 127.4, 128.1, 128.4, 128.6, 128.8, 128.9, 129.1, 129.3, 129.4, 129.6, 130.5, 130.6, 130.7, 131.2, 132.4, 132.8, 134.4, 134.6, 134.8, 135.1, 137.3, 137.8, 144.2, 145.7, 148.1 ppm.

(Table 4, Entry 14): Mp: 258-260°C; IR (KBr, cm^{-1}): 3028, 2965, 1601, 1512; ^1H NMR (400 MHz, $\text{DMSO-}d_6$) δ : 1.12 (t, 3H), 2.25 (s, 3H), 2.48-2.55 (q, 2H), 7.05-7.07 (d, 2H), 7.11 (m, 4H), 7.21-7.23 (m, 5H), 7.28 (m, 4H), 7.45-7.69 (t, 3H) ppm; ^{13}C NMR (100 MHz, $\text{DMSO-}d_6$) δ : 15.4, 21.1, 28.1, 126.7, 128.1, 128.5, 128.7, 128.9, 129.1, 131.1, 131.5, 134.7, 135.2, 137.3, 138.1, 144.5, 146.6 ppm.