Supporting Information

Direct Thiocarbamation of Imidazoheterocycles via Dual C-H Sulfurization

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Ri-Yuan Tang*

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1. General Information

^{1}H and ^{13}C NMR spectra were measured on a Bruker Avance-Ⅲ 600 instrument (600MHz for ^{1}H, 151 MHz for ^{13}C NMR spectroscopy) using $CDCl_3$ or DMSO-d_6 as the solvent. Chemical shifts for ^{1}H and ^{13}C NMR were referred to internal Me_4Si (0 ppm) as the standard. The following abbreviations (or combinations thereof) were used to explain chemical shift (δ ppm), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), integration, and coupling constants (*J*) in hertz (Hz). IR spectra were measured on a Nicolet IS10. Mass spectra were measured on an Agilent GC-MS-5975C Plus spectrometer (EI). LCMS (ESI) analysis was measured on an AB Sciex API3200. HRMS (ESI) analysis was measured on a Thermo Scientific LTQ Orbitrap XL.

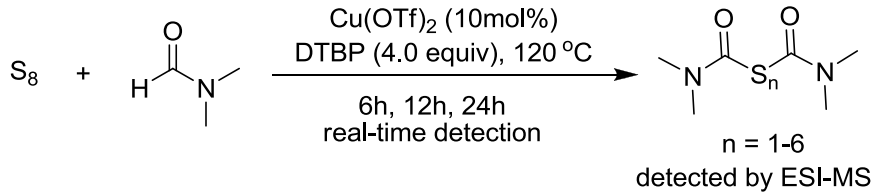
2. Typical Experimental Procedure

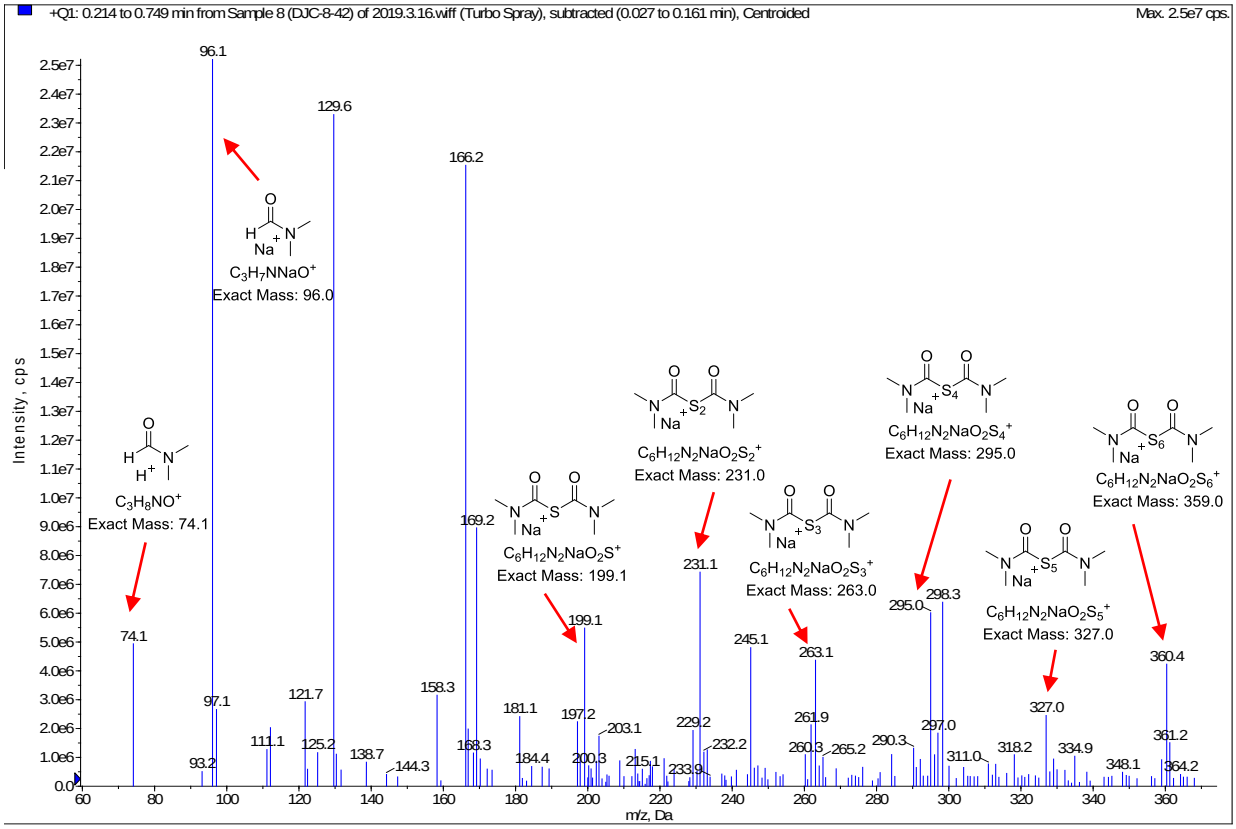
2.1 General experimental procedure for the synthesis of thiocarbamates: A 15-ml sealed tube (with a Teflon cap) equipped with a magnetic stir bar was charged with 2-phenylimidazo[1,2-*a*]pyridine (0.20 mmol), S (0.40 mmol, 2.0 equiv.), $Cu(OTf)_2$ (0.02 mmol, 10 mol%), DTBP (0.8 mmol, 4.0 equiv.) and NBS (0.06 mmol, 30mol%). DMF (1.0 ml) was added to the mixture. The tube was then capped and submerged into an oil bath pre-heated to 120 ^{o}C. The reaction was stirred for 24 h and cooled to room temperature. The crude reaction mixture was then diluted with EtOAc (5 ml) and filtered through a short pad of Celite. The sealed tube and Celite pad were washed with an additional 20 ml of EtOAc. The filtrate was concentrated *in vacuo*, and the resulting residue was purified by flash column chromatography using hexanes and EtOAc as the eluent. (a 50-mL sealed tube was used for gram-scale reaction)

2.2 ESI-MS detection for dicarbamoyl polysulfides

ESI-MS detection conditions: It was measured on an AB Sciex API3200AB instrument. Scan mode: positive ion mode (+Q1); Declustering Potential (DP): 25 (PSI); Curtain Gas: 25 (PSI); Temperature: 600 °C; IS: 5500V; Syringe flow rate: 2mL/min; mobile phase: EtOH.

Operational procedure: the reaction mixture was sampled (50 μL) after reaction for 6, 12, and 24 hours, respectively. The samples were diluted by CH_3OH (3 mL), and filtered by organic membrane (0.22 μm). The filtrate was then quickly injected to ESI-MS analysis.

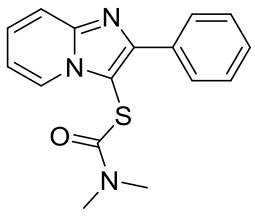




Scheme S1: ESI-MS spectra for dicarbamoyl polysulfides

3. Characterization Data for Products 3-28

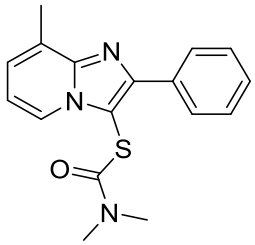
S-2-phenylimidazo[1,2-*a*]pyridin-3-yl dimethylcarbamothioate (3) [1]



White solid, mp: 172.1 – 174.4 °C. 78% yield (46 mg, Petroleum : Ethyl acetate=1 : 1). ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.24 (d, *J* = 6.7 Hz, 1H), 8.06 (d, *J* = 7.5 Hz, 2H), 7.70 (d, *J* = 8.9 Hz, 1H), 7.47 (t, *J* = 7.5 Hz, 2H), 7.40 (t, *J* = 7.2 Hz, 1H), 7.36 – 7.30 (m, 1H), 6.92 (t, *J* = 6.7 Hz, 1H), 3.21 (s, 3H), 3.02 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 164.0, 151.9, 147.3, 133.6, 128.9, 128.3,

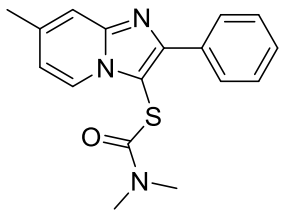
128.2, 126.4, 124.7, 117.6, 112.8, 103.9, 37.1. LRMS (EI, 70eV) m/z (%): 297 (21), 225 (20), 181 (9), 78 (30), 72 (100).

_S_-8-methyl-2-phenylimidazo[1,2-_a_]pyridin-3-yl dimethylcarbamothioate (4) [1]



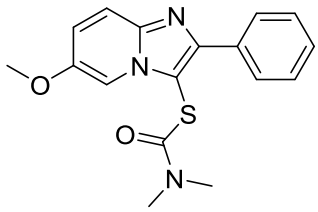
Yellow solid, mp: 152.5 – 153.8 °C. 59% yield (37 mg, Petroleum : Ethyl acetate=1.5 : 1). ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.12 (d, *J* = 6.6 Hz, 1H), 8.03 (d, *J* = 7.5 Hz, 2H), 7.47 (t, *J* = 7.5 Hz, 2H), 7.39 (t, *J* = 7.2 Hz, 1H), 7.12 (d, *J* = 6.6 Hz, 1H), 6.85 (t, *J* = 6.7 Hz, 1H), 3.22 (s, 3H), 3.03 (s, 3H), 2.70 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 164.2, 151.6, 147.6, 133.9, 129.0, 128.2, 128.1, 127.6, 125.2, 122.5, 112.8, 104.1, 37.1, 16.8. LRMS (EI, 70 eV) m/z (%): 311(26), 239 (29), 195 (8), 92 (24), 72 (100).

_S_-(7-methyl-2-phenylimidazo[1,2-a]pyridin-3-yl) dimethylcarbamothioate (5)



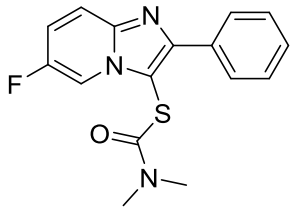
Light yellow solid, mp: 148.6–150.4 °C. 66% yield (41 mg, Petroleum : Ethyl acetate=1 : 1).^{1}H NMR (600 MHz, DMSO-d_6) δ 8.28 – 8.23 (m, 1H), 8.05 – 7.99 (m, 2H), 7.52 – 7.44 (m, 3H), 7.42 – 7.36 (m, 1H), 6.91 (dd, *J* = 7.0, 1.6 Hz, 1H), 3.17 (s, 3H), 2.91 (s, 3H), 2.41 (s, 3H). ^{13}C NMR (151 MHz, DMSO) δ 162.8, 150.3, 146.9, 137.7, 133.6, 128.3, 128.2, 128.0, 124.4, 115.5, 115.3, 103.2, 36.8, 36.7, 20.7. IR (KBr, cm^{-1}): 2974, 2943, 2856, 1665, 1471, 1445, 1355, 1257, 1096, 857, 775, 756. LRMS (EI, 70 eV) m/z (%): 311(26), 239 (29), 195 (8), 92 (24), 72 (100). HRMS (ESI) m/z calcd for $C_{17}H_{18}N_3OS^+$ $(M+H)^+$ 312.1165, found 312.1168.

_S_-6-methoxy-2-phenylimidazo[1,2-_a_]pyridin-3-yl dimethylcarbamothioate (6) [1]



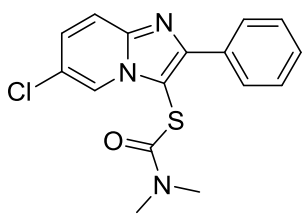
White solid, mp: 139.9 – 141.9 °C. 40% yield (26 mg, Petroleum : Ethyl acetate=1 : 1). ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.05 – 8.03 (m, 3H), 7.46 (t, *J* = 7.6 Hz, 2H), 7.38 (t, *J* = 7.4 Hz, 1H), 6.99 (d, *J* = 2.2 Hz, 1H), 6.63 (dd, *J* = 7.4, 2.4 Hz, 1H), 3.90 (s, 3H), 3.22 (s, 3H), 3.03 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 162.9, 158.3, 149.4, 147.6, 132.9, 131.0, 128.6, 127.2, 123.8, 106.6, 101.3, 93.9, 54.5, 36.0. LRMS (EI, 70 eV) m/z (%): 327 (35), 255 (93), 240 (18), 211 (12), 108 (46), 93 (10), 72 (100).

_S_-(6-fluoro-2-phenylimidazo[1,2-*a*]pyridin-3-yl) dimethylcarbamothioate (7)



Brown solid, mp: 89.1–91.0 °C. 60% yield (38 mg, Petroleum : Ethyl acetate=1 : 1). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.19 – 8.14 (m, 1H), 8.04 – 7.99 (m, 2H), 7.68 (dd, *J* = 9.7, 4.9 Hz, 1H), 7.46 (t, *J* = 7.5 Hz, 2H), 7.39 (t, *J* = 7.4 Hz, 1H), 7.25 – 7.99 (m, 1H), 3.21 (s, 3H), 3.02 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 163.4, 153.6 (d, $J_{C\text{-}F}$ = 238.4 Hz, 1C), 152.9, 144.8, 133.3, 128.7, 128.5, 128.3, 118.2 (d, $J_{C\text{-}F}$ = 24.6 Hz, 1C), 118.1 (d, $J_{C\text{-}F}$ = 9.0 Hz, 1C), 111.7 (d, $J_{C\text{-}F}$ = 41.1 Hz, 1C), 105.6, 37.2, 37.1. IR (KBr, cm^{-1}): 2979, 2919, 2857, 1670, 1521, 1456, 1365, 1339, 1156, 850, 797. LRMS (EI, 70 eV) m/z (%): 315(18), 243 (12), 199 (13), 96 (27), 72 (100). HRMS (ESI) m/z calcd for $C_{16}H_{15}FN_3OS^+$ $(M+H)^+$ 316.0914, found 316.0916.

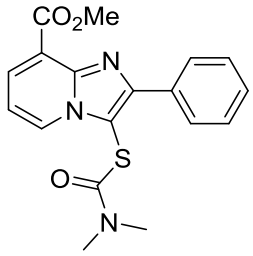
_S_-(6-chloro-2-phenylimidazo[1,2-*a*]pyridin-3-yl) dimethylcarbamothioate (8)



White solid, mp: 93.5–94.7 °C. 47% yield (31 mg, Petroleum : Ethyl acetate=1 : 1). ^{1}H NMR (600

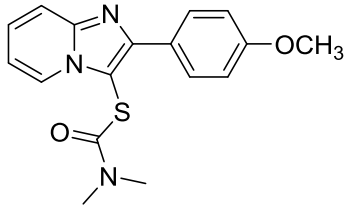
MHz, DMSO-d_6) δ 8.60 (d, J = 1.9 Hz, 1H), 8.04 – 8.00 (m, 2H), 7.77 (d, J = 9.4 Hz, 1H), 7.54 – 7.45 (m, 3H), 7.42 (s, 1H), 3.17 (s, 3H), 2.92 (s, 3H). ^{13}C NMR (151 MHz, DMSO) δ 162.3, 151.1, 144.9, 133.0, 128.6, 128.4, 128.1, 127.8, 123.2, 120.3, 117.9, 105.4, 36.9, 36.7. IR (KBr, cm^{-1}): 2966, 2931, 2848, 1671, 1430, 1350, 1244, 1212, 1171, 1094, 1021, 844, 799. LRMS (EI, 70 eV) m/z (%): 331(13), 259 (8), 215 (7), 112 (18), 72 (100). HRMS (ESI) m/z calcd for $C_{16}H_{15}ClN_3OS^+$ $(M+H)^+$ 332.0619, found 332.0621.

methyl 3-((dimethylcarbamoyl)thio)-2-phenylimidazo[1,2-*a*]pyridine-8-carboxylate (9)



Light yellow oil. 35% yield (25 mg, Petroleum : Ethyl acetate=1 : 1). ^{1}H NMR (600 MHz, Chloroform-d) δ 8.39 (dd, J = 6.8, 1.3 Hz, 1H), 8.12 – 8.04 (m, 3H), 7.44 (d, J = 8.3 Hz, 2H), 7.37 (t, J = 7.0 Hz, 1H), 6.96 (t, J = 7.0 Hz, 1H), 4.04 (s, 3H), 3.17 (s, 3H), 2.97 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 165.0, 163.5, 152.8, 144.8, 133.4, 131.0, 129.2, 128.7, 128.6, 128.2, 119.8, 111.6, 105.1, 52.8, 52.7, 37.2. IR (KBr, cm^{-1}): 3010, 2925, 2828, 1765, 1668, 1533, 1438, 1355, 1252, 1214, 1183, 1093, 1021, 958, 831, 774. HRMS (ESI) m/z calcd for $C_{18}H_{18}N_3O_3S^+$ $(M+H)^+$ 356.1063, found 356.1065.

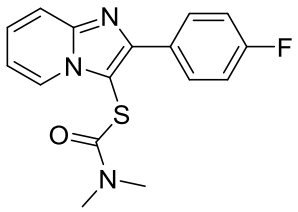
***S*-2-(4-methoxyphenyl)imidazo[1,2-*a*]pyridin-3-yl dimethylcarbamothioate (10) [1]**



White solid, mp: 138.4 – 139.6 °C. 60% yield (39 mg, Petroleum : Ethyl acetate=1 : 1). ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.22 (d, J = 6.8 Hz, 1H), 8.02 (d, J = 8.7 Hz, 2H), 7.67 (d, J = 8.9 Hz, 1H), 7.34 – 7.28 (m, 1H), 7.00 (d, J = 8.7 Hz, 2H), 6.90 (t, J = 6.7 Hz, 1H), 3.86 (s, 3H), 3.22 (s, 3H), 3.02 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 164.2, 159.8, 151.8, 147.3, 130.0, 126.3, 126.2, 124.6, 117.4, 113.7, 112.7, 103.0, 55.3, 37.1. LRMS (EI, 70eV) m/z (%): 327 (28), 255 (31), 240 (9), 211

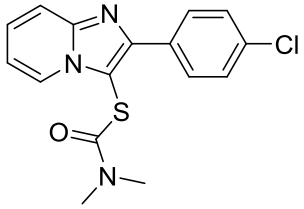
(10), 78 (33), 72 (100).

_S_-2-(4-fluorophenyl)imidazo[1,2-_a_]pyridin-3-yl dimethylcarbamothioate (11) [1]



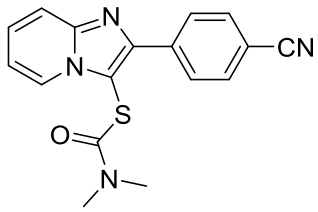
Light yellow solid, mp: 163.7 – 165.5 °C. 50% yield (36 mg, Petroleum : Ethyl acetate=1 : 1). ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.24 (d, J = 6.8 Hz, 1H), 8.05 (dd, J = 8.7, 5.6 Hz, 2H), 7.70 (d, J = 9.0 Hz, 1H), 7.36 – 7.33 (m, 1H), 7.16 (t, J = 8.7 Hz, 2H), 6.94 (t, J = 6.6 Hz, 1H), 3.23 (s, 3H), 3.04 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 163.8, 163.0 (d, J_{C-F} = 248.0 Hz, 1C), 151.1, 147.3, 133.6 (d, J_{C-F} = 8.2 Hz, 2C), 129.8, 126. 6, 124.7, 117.6, 115.2 (d, J_{C-F} = 21.5 Hz, 2C), 112.9, 103.7, 37.1. LRMS (EI, 70eV) m/z (%): 315 (17), 243 (15), 78 (28), 72 (100).

_S_-2-(4-chlorophenyl)imidazo[1,2-_a_]pyridin-3-yl dimethylcarbamothioate (12)



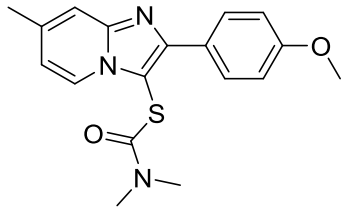
Light yellow solid, mp: 178.4–179.2 °C. 45% yield (30 mg, Petroleum : Ethyl acetate=1 : 1). ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.24 (d, J = 6.8 Hz, 1H), 8.04 – 7.99 (m, 2H), 7.70 (d, J = 9.0 Hz, 1H), 7.46 – 7.41 (m, 2H), 7.34 (td, J = 6.8, 1.1 Hz, 1H), 6.93 (td, J = 6.8, 0.9 Hz, 1H), 3.22 (s, 3H), 3.02 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 163.7, 150.7, 147.3, 134.4, 132.1, 130.1, 128.5, 126.7, 124.7, 117.6, 113.0, 104.2, 37.1. IR (KBr, cm^{-1}): 2966, 2931, 2848, 1671, 1485, 1374, 1341, 1220, 1063, 847, 799. LRMS (EI, 70 eV) m/z (%): 331(13), 259 (6), 224 (10), 78 (30), 72 (100). HRMS (ESI) m/z calcd for $C_{16}H_{15}ClN_3OS^+$ $(M+H)^+$ 332.0619, found 332.0623.

_S_-2-(4-cyanophenyl)imidazo[1,2-_a_]pyridin-3-yl dimethylcarbamothioate (13)



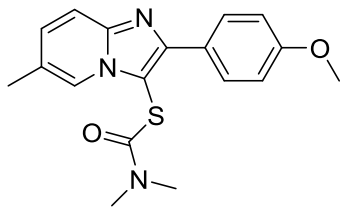
Light yellow solid, mp: 207.8–209.0 °C. 19% yield (12 mg, Petroleum : Ethyl acetate = 2 : 3). ^{1}H NMR (600 MHz, $CDCl_3$) δ 8.25 (d, *J* = 6.8 Hz, 1H), 8.21 (d, *J* = 8.2 Hz, 2H), 7.77 – 7.67 (m, 3H), 7.37 ((t, *J* = 6.8 Hz, 1H), 6.97 (t, *J* = 6.7 Hz, 1H), 3.23 (s, 3H), 3.02 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 163.3, 149.6, 147.5, 138.1, 132.1, 129.2, 127.1, 124.8, 119.0, 117.9, 113.4, 111.7, 105.4, 37.3, 37.2. IR (KBr, cm^{-1}): 2978, 2922, 2856, 2222, 1680, 1504, 1452, 1339, 1249, 1098, 894, 779. HRMS (ESI) m/z calcd for $C_{17}H_{15}N_4OS^+$ $(M+H)^+$ 323.0961, found 323.0965.

_S_-(2-(4-methoxyphenyl)-7-methylimidazo[1,2-*a*]pyridin-3-yl) dimethylcarbamothioate (14) [1]



Brown solid, mp: 166.5–168.8 °C. 63% yield (43 mg, Petroleum : Ethyl acetate = 1 : 1). ^{1}H NMR (600 MHz, DMSO-d_6) δ 8.23 (d, *J* = 6.9 Hz, 1H), 7.98 – 7.95 (m, 2H), 7.46 (s, 1H), 7.06 – 7.01 (m, 2H), 6.89 (dd, *J* = 7.0, 1.5 Hz, 1H), 3.80 (s, 3H), 3.17 (s, 3H), 2.91 (s, 3H), 2.40 (s, 3H). ^{13}C NMR (151 MHz, DMSO) δ 162.9, 159.4, 150.3, 146.8, 137.6, 129.3, 126.0, 124.3, 115.3, 115.1, 113.8, 102.1, 55.2, 36.8, 36.7, 20.7. LRMS (EI, 70 eV) m/z (%): 341(47), 169 (100), 225 (14), 92 (37), 72 (94), 65 (15).

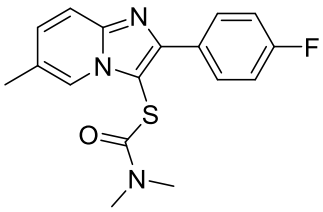
_S_-(2-(4-methoxyphenyl)-6-methylimidazo[1,2-*a*]pyridin-3-yl) dimethylcarbamothioate (15) [1]



Brown solid, mp: 121.5–124.2 °C. 69% yield (47 mg, Petroleum : Ethyl acetate = 1 : 1). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.01 – 7.93 (m, 3H), 7.57 (d, *J* = 9.0 Hz, 1H), 7.15 (dd, *J* = 9.1, 1.4 Hz, 1H), 6.98 (d, *J* = 8.8 Hz, 2H), 3.85 (s, 3H), 3.22 (s, 3H), 3.03 (s, 3H), 2.37 (s, 3H). ^{13}C NMR

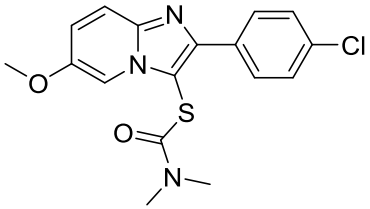
(151 MHz, $CDCl_3$) δ 164.3, 159.7, 151.6, 146.3, 130.0, 129.4, 126.3, 122.4, 122.3, 116.7, 113.7, 102.5, 55.3, 37.1, 18.4. LRMS (EI, 70 eV) m/z (%): 341 (43), 269 (65), 254 (13), 225(12), 92 (32), 72 (100), 65 (16).

_S_-(2-(4-fluorophenyl)-6-methylimidazo[1,2-*a*]pyridin-3-yl) dimethylcarbamothioate (16) [1]



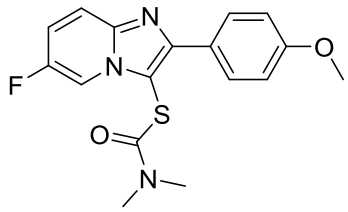
Light yellow solid, mp: 162.1–163.0 °C. 63% yield (42 mg, Petroleum : Ethyl acetate = 1 : 1). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.02-7.98 (m, 3H), 7.57 (d, *J* = 9.1 Hz, 1H), 7.17 (d, *J* = 1.5 Hz, 1H), 7.16 – 7.09 (m, 2H), 3.21 (s, 3H), 3.02 (s, 3H), 2.37 (s, 3H). ^{13}C NMR (151 MHz, CDCl3) δ 163.9, 162.8 (d, $J_{C\text{-}F}$ = 247.7 Hz, 1C), 150.8, 146.2, 130.3 (d, $J_{C\text{-}F}$ = 8.2 Hz, 2C), 129.9, 129.5, 122.6, 122.3, 116.7, 115.0 (d, $J_{C\text{-}F}$ = 21.4 Hz, 2C), 103.1, 37.1, 37.0, 18.3. LRMS (EI, 70eV) m/z (%): 329 (19), 257 (21), 92 (23), 72 (100), 65 (11).

_S_-(2-(4-chlorophenyl)-6-methoxyimidazo[1,2-*a*]pyridin-3-yl) dimethylcarbamothioate (17) [1]



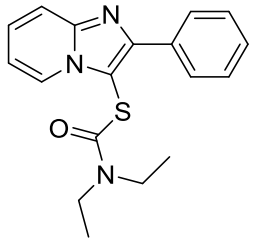
White solid, mp: 228.0–230.6 °C. 56% yield (41 mg, Petroleum : Ethyl acetate = 1 : 1). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.02 (d, *J* = 7.5 Hz, 1H), 7.98 (d, *J* = 8.5 Hz, 2H), 7.41 (d, *J* = 8.5 Hz, 2H), 6.96 (d, *J* = 2.0 Hz, 1H), 6.62 (dd, *J* = 7.4, 2.3 Hz, 1H), 3.88 (s, 3H), 3.20 (s, 3H), 3.02 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 164.1, 159.5, 150.6, 148.8, 134.2, 132.2, 129.8, 128.4, 125.1, 107.8, 102.5, 95.2, 55.7, 37.2, 37.1. LRMS (EI, 70 eV) m/z (%): 361 (15), 289(24), 253 (15), 108 (31), 72 (100).

_S_-(6-fluoro-2-(4-methoxyphenyl)imidazo[1,2-*a*]pyridin-3-yl) dimethylcarbamothioate (18) [1]



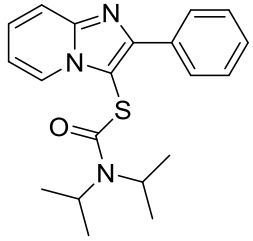
Light yellow solid, mp: 134.8–137.0 °C. 45% yield (31 mg, Petroleum : Ethyl acetate = 1 : 1). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.13 (s, 1H), 7.97 (d, *J* = 8.4 Hz, 2H), 7.62 (dd, *J* = 9.3, 4.7 Hz, 1H), 7.24 – 7.17 (m, 1H), 6.98 (d, *J* = 8.4 Hz, 2H), 3.85 (s, 3H), 3.20 (s, 3H), 3.01 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 163.5, 159.9, 153.5 (d, $J_{C\text{-}F}$ = 237.7 Hz, 1C), 144.8, 129.9, 125.9, 118.1, 117.9, 117.7 (d, $J_{C\text{-}F}$ = 8.7 Hz, 1C), 113.7, 111.6 (d, $J_{C\text{-}F}$ = 41.6 Hz, 1C), 104.7, 99.9, 55.2, 37.2, 37.1. LRMS (EI, 70 eV) m/z (%): 345 (19), 273 (13), 229 (11), 96 (22), 72 (100).

_S_-(2-phenylimidazo[1,2-*a*]pyridin-3-yl) diethylcarbamothioate (19)



Brown oil. 66% yield (43 mg, Petroleum : Ethyl acetate=2 : 1). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.29 – 8.21 (m, 1H), 8.09 – 8.02 (m, 2H), 7.77 (d, *J* = 8.9 Hz, 1H), 7.46 (t, *J* = 8.3 Hz, 2H), 7.42 – 7.33 (m, 2H), 6.96 (td, *J* = 6.8, 1.1 Hz, 1H), 3.53 (q, *J* = 7.2 Hz, 2H), 3.41 (q, *J* = 7.8 Hz, 2H), 1.36 (t, *J* = 7.2 Hz, 3H), 1.16 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 162.7, 150.8, 146.7, 132.9, 128.9, 128.6, 128.3, 127.1, 124.8, 117.2, 113.3, 104.8, 42.8, 42.7, 14.2, 13.2. IR (KBr, cm^{-1}): 2972, 2922, 2851, 1669, 1466, 1406, 1343, 1245, 1214, 1114, 849, 757. HRMS (ESI) m/z calcd for $C_{18}H_{20}N_3OS^+$ $(M+H)^+$ 326.1322, found 326.1321.

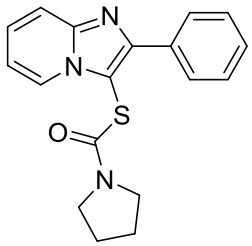
_S_-(2-phenylimidazo[1,2-*a*]pyridin-3-yl) diisopropylcarbamothioate (20)



Light yellow solid. mp: 143.0–144.0 °C. 67% yield (47 mg, Petroleum : Ethyl acetate = 2 : 1). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.24 (dt, *J* = 6.8, 1.0 Hz, 1H), 8.06 (dt, *J* = 8.1, 1.8 Hz, 2H),

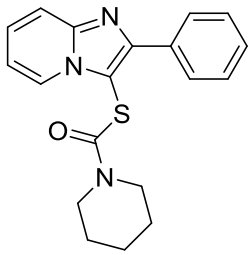
7.69 (d, *J* = 9.0 Hz, 1H), 7.46 (t, *J* = 7.6 Hz, 2H), 7.42 – 7.36 (m, 1H), 7.34 – 7.28 (m, 1H), 6.92 (td, *J* = 6.8, 1.1 Hz, 1H), 4.32 (brs, 1H), 3.55 (brs, 1H), 1.37 (brs, 6H), 1.36 (brs, 6H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 161.2, 151.7, 147.3, 133.9, 128.8, 128.2, 128.1, 126.2, 124.7, 117.6, 112.7, 105.1, 50.4, 47.9, 20.7. IR (KBr, cm^{-1}): 3037, 2971, 2926, 2850, 1670, 1631, 1420, 1342, 1275, 1205, 1032, 807, 752. HRMS (ESI) m/z calcd for $C_{20}H_{24}N_3OS^+$ $(M+H)^+$ 354.1635, found 354.1631.

_S_-(2-phenylimidazo[1,2-*a*]pyridin-3-yl) pyrrolidine-1-carbothioate (21) [1]



White solid, mp: 164.2–166.0 °C. 45% yield (29 mg, Petroleum : Ethyl acetate = 1 : 1). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.36 – 8.22 (m, 1H), 8.17 – 8.01 (m, 2H), 7.71 (d, *J* = 7.0 Hz, 1H), 7.47 (s, 2H), 7.43 – 7.30 (m, 2H), 6.93 (s, 1H), 3.64 (brs, 2H), 3.53 (brs, 2H), 2.07 (brs, 2H), 1.94 (brs, 2H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 161.5, 151.7, 147.3, 133.7, 128.9, 128.3, 128.2, 126.4, 124.8, 117.6, 112.8, 104.2, 47.6, 46.4, 25.8, 24.5. LRMS (EI, 70eV) m/z (%): 323 (15), 225 (17), 98 (100), 78 (37), 55 (36).

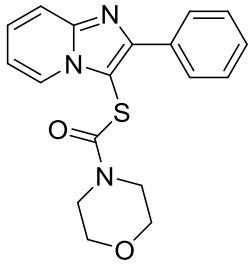
_S_-(2-phenylimidazo[1,2-*a*]pyridin-3-yl) piperidine-1-carbothioate (22)



Light yellow solid, mp: 49.7–50.5 °C. 35% yield (24 mg, Petroleum : Ethyl acetate = 2 : 3). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.26 (d, *J* = 6.8 Hz, 1H), 8.09 – 8.04 (m, 2H), 7.74 (d, *J* = 8.9 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 2H), 7.43 – 7.38 (m, 1H), 7.37 – 7.31 (m, 1H), 6.98 – 6.92 (m, 1H), 3.64 (brs, 2H), 3.57 (brs, 2H), 1.73 (brs, 4H), 1.63 (brs, 2H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 162.5, 151.7, 147.3, 133.5, 128.9, 128.4, 128.2, 126.5, 124.7, 117.6, 112.9, 104.2, 47.4, 45.6, 26.3, 25.6,

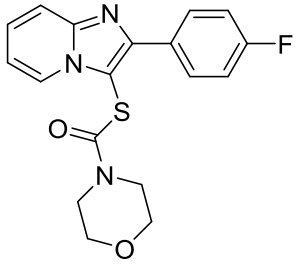
24.4. IR (KBr, cm^{-1}): 2926, 2855, 1670, 1408, 1344, 1240, 1209, 1123, 998, 757. HRMS (ESI) m/z calcd for $C_{19}H_{20}N_3OS^+$ $(M+H)^+$ 338.1322, found 338.1323.

_S_-(2-phenylimidazo[1,2-*a*]pyridin-3-yl) morpholine-4-carbothioate (23)



Yellow solid, mp: 44.2–45.0 °C. 39% yield (26 mg, Petroleum : Ethyl acetate = 2 : 3). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.22 (d, *J* = 6.7 Hz, 1H), 8.05 – 8.00 (m, 2H), 7.73 (d, *J* = 9.0 Hz, 1H), 7.47 (t, *J* = 7.6 Hz, 2H), 7.43 – 7.38 (m, 1H), 7.37 – 7.30 (m, 1H), 6.93 (t, *J* = 6.8 Hz, 1H), 3.73 (brs, 4H), 3.66 (brs, 4H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 163.3, 152.1, 147.4, 133.4, 128.8, 128.5, 128.3, 126.7, 124.6, 117.6, 113.0, 103.1, 66.6, 46.3, 44.6. IR (KBr, cm^{-1}): 2961, 2924, 2854, 1671, 1406, 1344, 1271, 1212, 1113, 1015, 831, 776. HRMS (ESI) m/z calcd for $C_{18}H_{18}N_3O_2S^+$ $(M+H)^+$ 340.1114, found 340.1112.

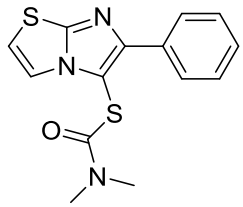
_S_-(2-(4-fluorophenyl)imidazo[1,2-*a*]pyridin-3-yl) morpholine-4-carbothioate (24)



Yellow solid, mp: 145.9–147.5 °C. 55% yield (39 mg, Petroleum : Ethyl acetate = 2 : 3). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.22 (dt, *J* = 6.8, 1.2 Hz, 1H), 8.05 – 8.00 (m, 2H), 7.69 (dt, *J* = 8.9, 1.1 Hz, 1H), 7.36 – 7.30 (m, 1H), 7.18 – 7.12 (m, 2H), 6.93 (td, *J* = 6.8, 1.1 Hz, 1H), 3.74 (brs, 4H), 3.67 (brs, 4H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 163.2, 163.0 (d, $J_{C\text{-}F}$ = 247.0 Hz, 1C), 151.3, 147.4, 130.5 (d, $J_{C\text{-}F}$ = 8.7 Hz, 2C), 129.7 (d, $J_{C\text{-}F}$ = 2.8 Hz, 1C), 126.7, 124.6, 117.6, 115.3 (d, $J_{C\text{-}F}$ = 21.7 Hz, 2C), 113.0, 102.8, 66.6, 46.3, 44.6. IR (KBr, cm^{-1}): 2967, 2921, 2855, 1670, 1471, 1407, 1345, 1271, 1216, 1115, 1016, 842, 754. LRMS (EI, 70 eV) m/z (%): 357(18), 243 (19),

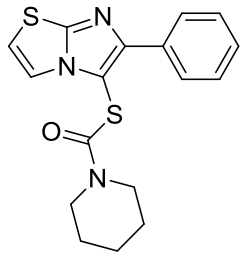
199 (8), 114 (100), 78 (44), 70 (60). HRMS (ESI) m/z calcd for $C_{18}H_{17}FN_3O_2S^+$ $(M+H)^+$ 358.1020, found 358.1023.

_S_-(6-phenylimidazo[2,1-_b_]thiazol-5-yl) dimethylcarbamothioate (25) [1]



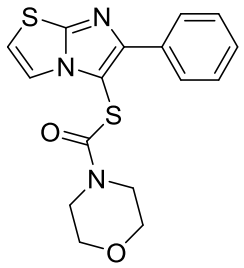
Brown solid, mp: 156.2–158.8 °C. 34% yield (21 mg, Petroleum : Ethyl acetate = 1 : 1). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.95 (d, *J* = 7.9 Hz, 2H), 7.42 (t, *J* = 7.1 Hz, 3H), 7.34 (t, *J* = 7.3 Hz, 1H), 6.88 (d, *J* = 4.2 Hz, 1H), 3.17 (s, 3H), 3.02 (s, 3H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 164.4, 152.9, 151.7, 133.6, 128.2, 128.1, 128.0, 118.4, 112.6, 104.9, 37.2, 37.1. LRMS (EI, 70eV) m/z (%): 303 (16), 187 (13), 77 (8), 72 (100).

_S_-(6-phenylimidazo[2,1-_b_]thiazol-5-yl) piperidine-1-carbothioate (26)



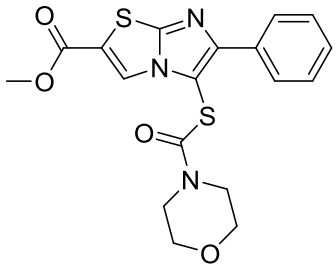
Yellow solid, mp: 49.0–49.8 °C. 33% yield (23 mg, Petroleum : Ethyl acetate = 2 : 3). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.96 (d, *J* = 7.2 Hz, 2H), 7.43 – 7.41 (m, 3H), 7.34 (t, *J* = 7.4 Hz, 1H), 6.86 (d, *J* = 4.4 Hz, 1H), 3.56 (brs, 4H), 1.69 (brs, 4H), 1.60 (brs, 2H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 162.9, 153.0, 151.7, 133.8, 128.2, 128.0, 127.9, 118.5, 112.5, 105.0, 47.3, 45.6, 26.2, 25.5, 24.4. IR (KBr, cm^{-1}): 2960, 2923, 2854, 1665, 1436, 1407, 1240, 1207, 1122, 1023, 852, 816. HRMS (ESI) m/z calcd for $C_{17}H_{18}N_3OS_2^+$ $(M+H)^+$ 344.0886, found 344.0883.

_S_-(6-phenylimidazo[2,1-_b_]thiazol-5-yl) morpholine-4-carbothioate (27)



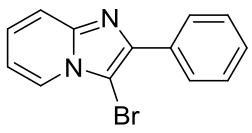
Light yellow solid, mp: 50.9–52.0 °C. 29% yield (20 mg, Petroleum : Ethyl acetate = 1 : 1). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.97 – 7.93 (m, 2H), 7.46 – 7.41 (m, 3H), 7.36 (t, *J* = 7.4 Hz, 1H), 6.88 (d, *J* = 4.5 Hz, 1H), 3.75 (brs, 4H), 3.65 – 3.61 (m, 4H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 163.7, 153.3, 151.9, 133.6, 128.3, 128.1, 128.0, 118.3, 112.8, 103.9, 66.5, 46.4, 44.7. IR (KBr, cm^{-1}): 2959, 2923, 2853, 1667, 1438, 1212, 1113, 1017, 832, 772. HRMS (ESI) m/z calcd for $C_{16}H_{16}N_3O_2S_2^+$ $(M+H)^+$ 346.0678, found 346.0679.

methyl 5-((morpholine-4-carbonyl)thio)-6-phenylimidazo[2,1-*b*]thiazole-2-carboxylate (28)



Light yellow solid, mp: 174.9–177.5 °C. 40% yield (32 mg, Petroleum : Ethyl acetate = 1 : 2). ^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.14 (s, 1H), 7.95 (d, *J* = 7.3 Hz, 2H), 7.44 (t, *J* = 7.6 Hz, 2H), 7.38 (t, *J* = 7.3 Hz, 1H), 3.94 (s, 3H), 3.77 (brs, 4H), 3.68 – 3.59 (m, 4H). ^{13}C NMR (151 MHz, $CDCl_3$) δ 163.1, 161.5, 154.4, 152.6, 132.9, 128.6, 128.4, 128.1, 124.4, 121.4, 104.8, 66.5, 52.8, 46.3, 44.7. IR (KBr, cm^{-1}): 2970, 2921, 2852, 1714, 1633, 1404, 1269, 1110, 1049, 828, 805. HRMS (ESI) m/z calcd for $C_{18}H_{18}N_3O_4S_2^+$ $(M+H)^+$ 404.0733, found 404.0731.

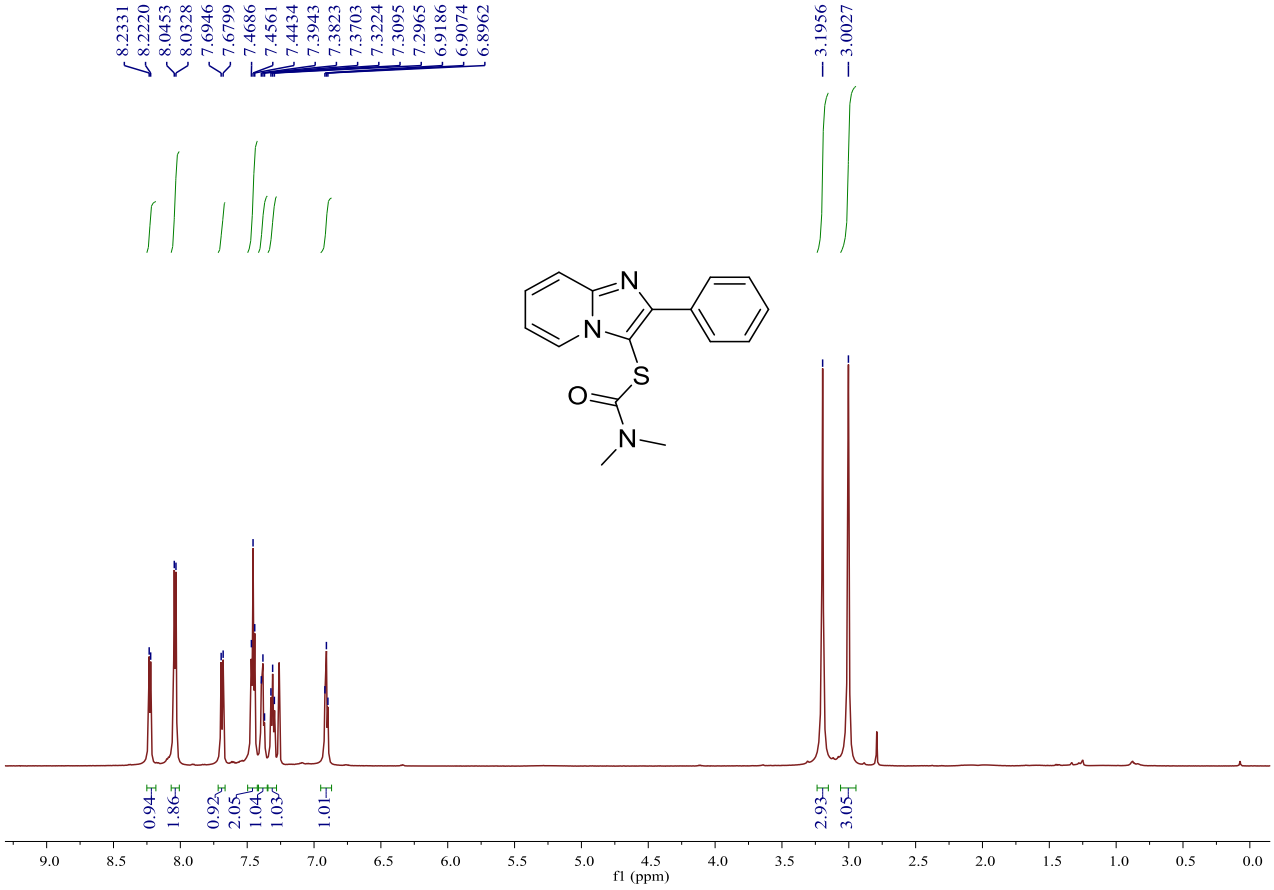
3-bromo-2-phenylimidazo[1,2-*a*]pyridine (30)[2]

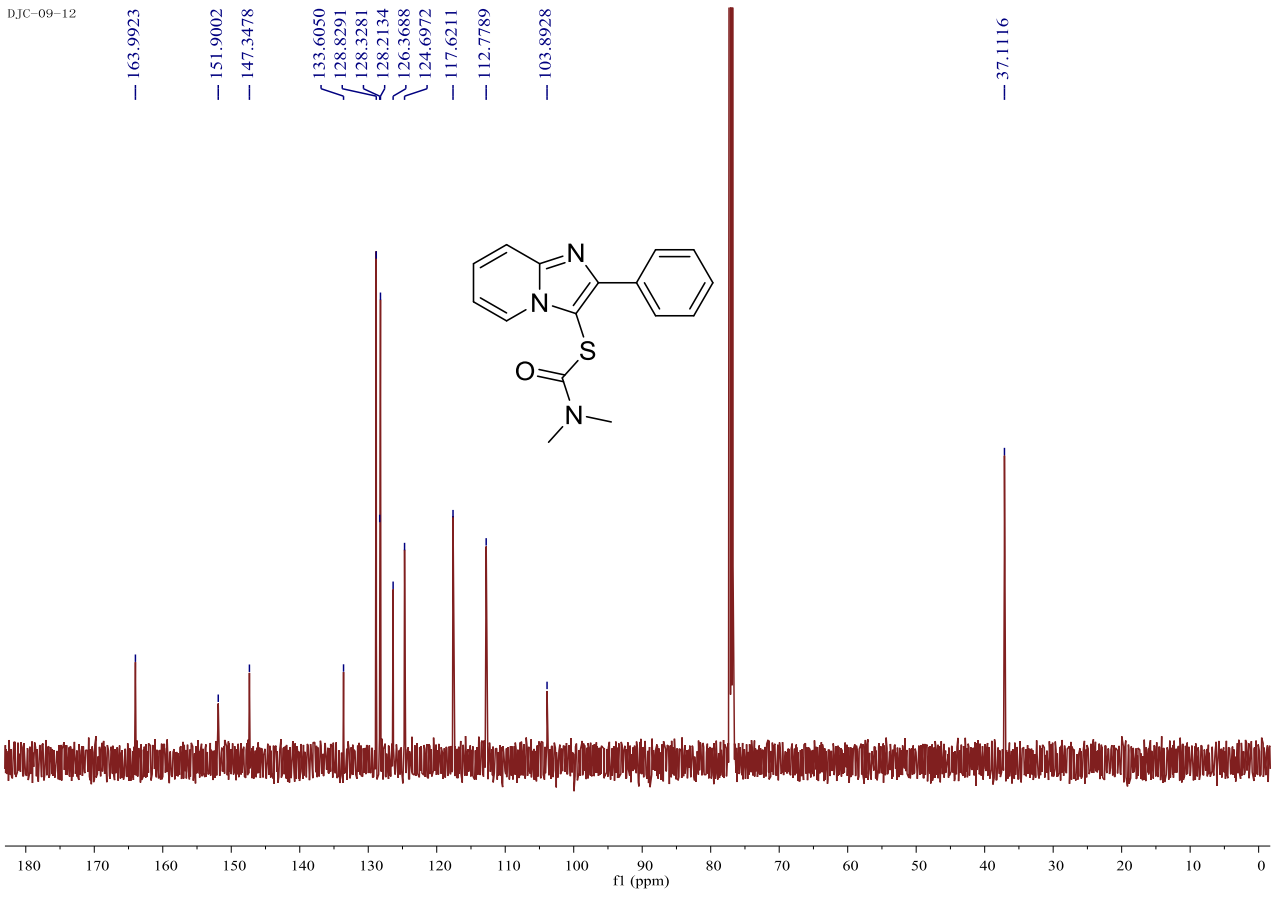


^{1}H NMR (600 MHz, Chloroform-*d*) δ 8.16 – 8.11 (m, 3H), 7.62 (d, *J* = 9.0 Hz, 1H), 7.48 (t, *J* = 7.7 Hz, 2H), 7.41 – 7.36 (m, 1H), 7.25 – 7.20 (m, 1H), 6.89 (td, *J* = 6.8, 1.0 Hz, 1H).

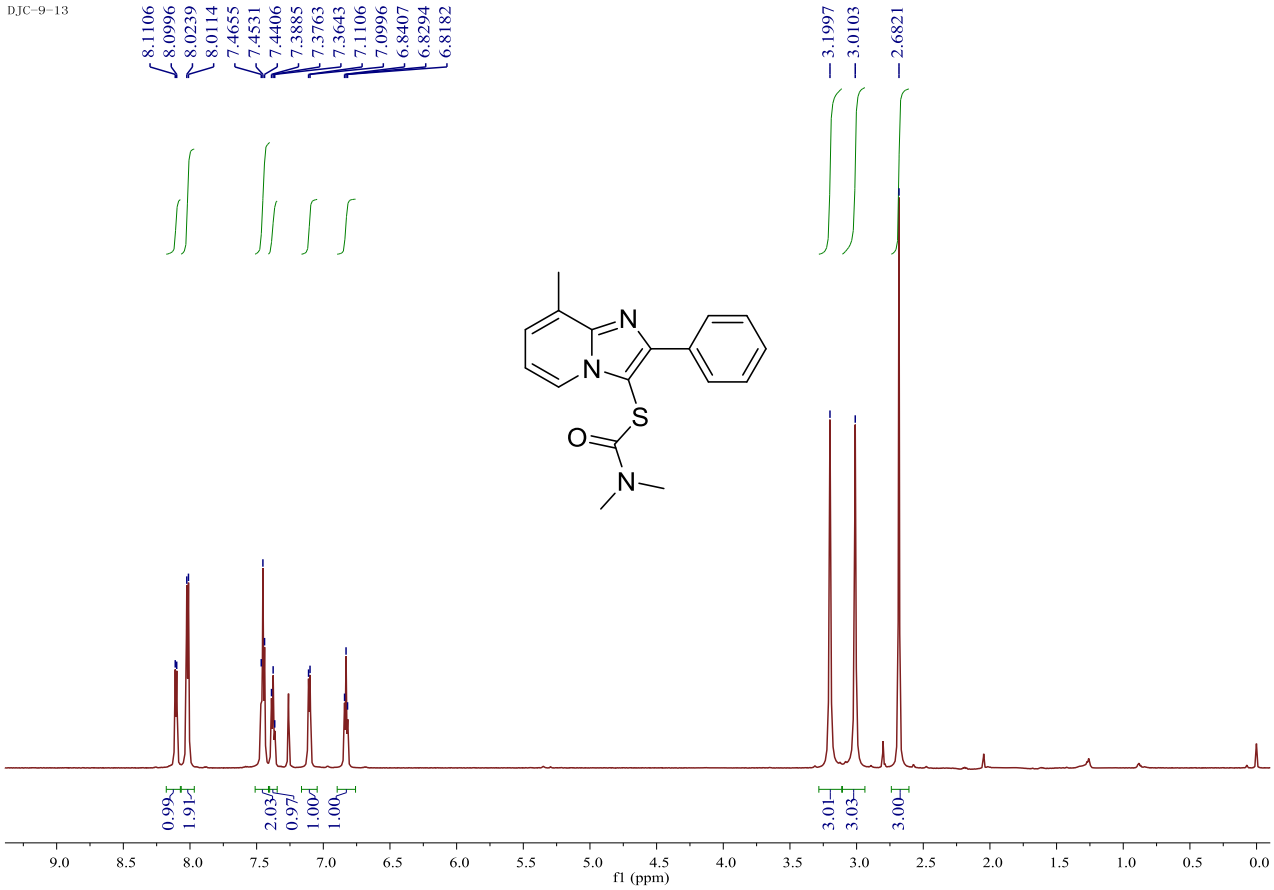
4. NMR spectra

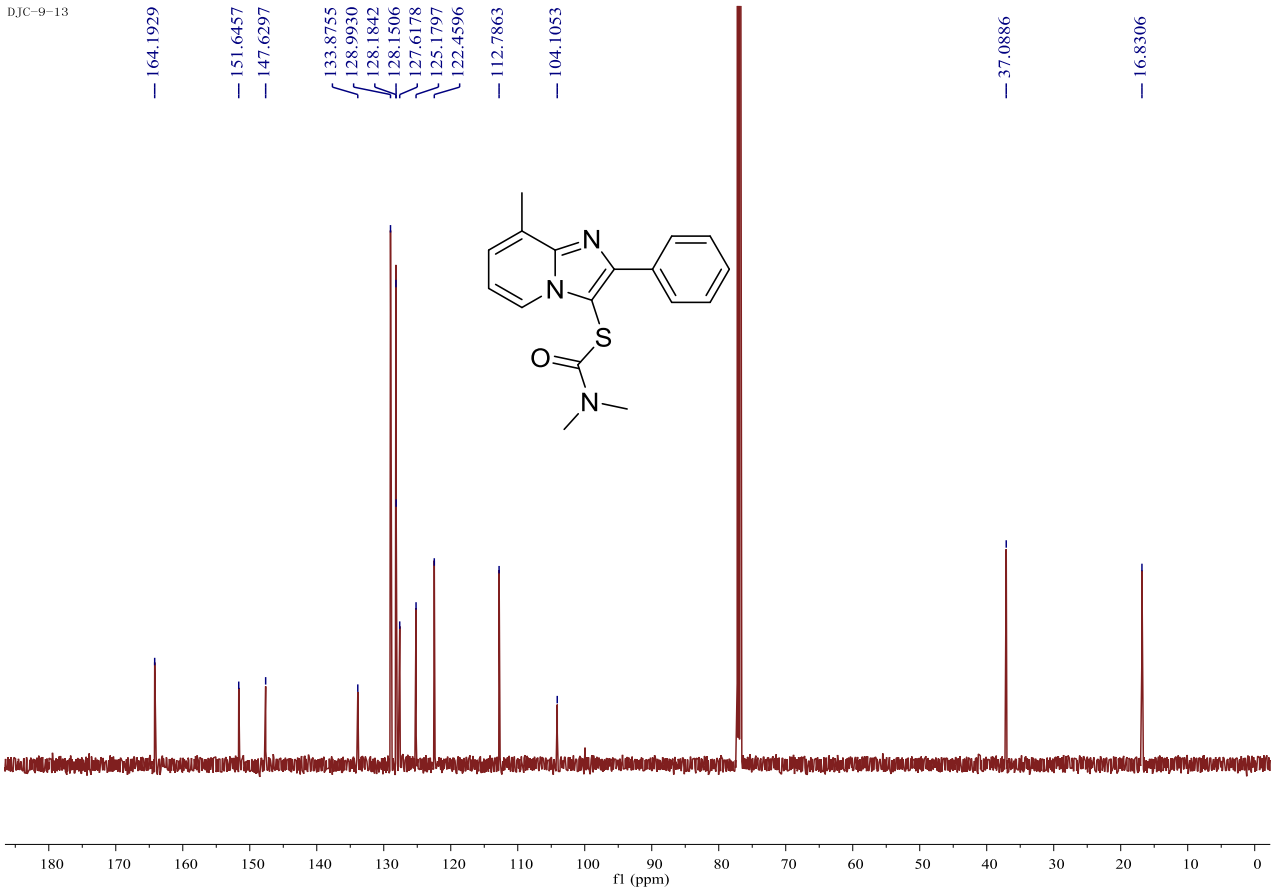
_S_-2-phenylimidazo[1,2-_a_]pyridin-3-yl dimethylcarbamothioate (3)



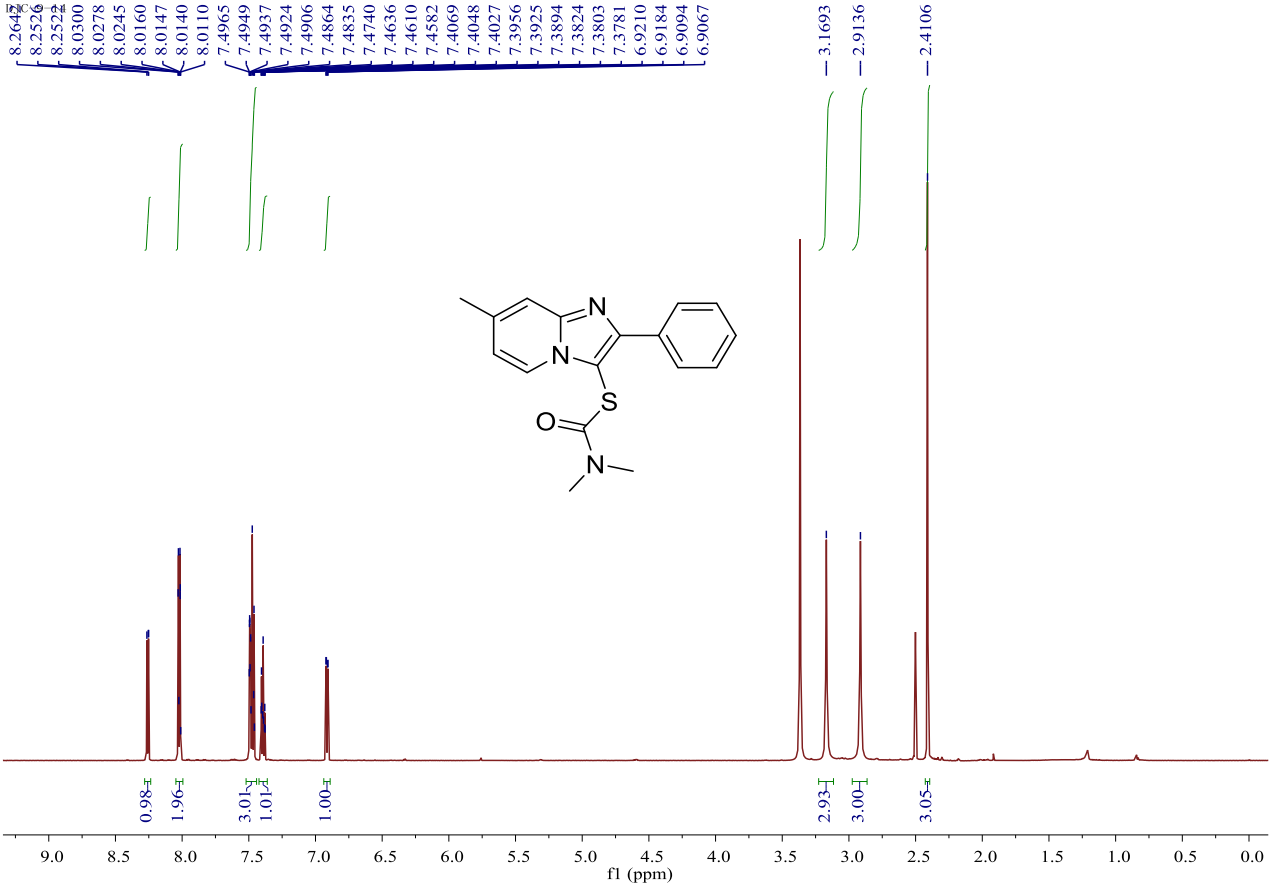


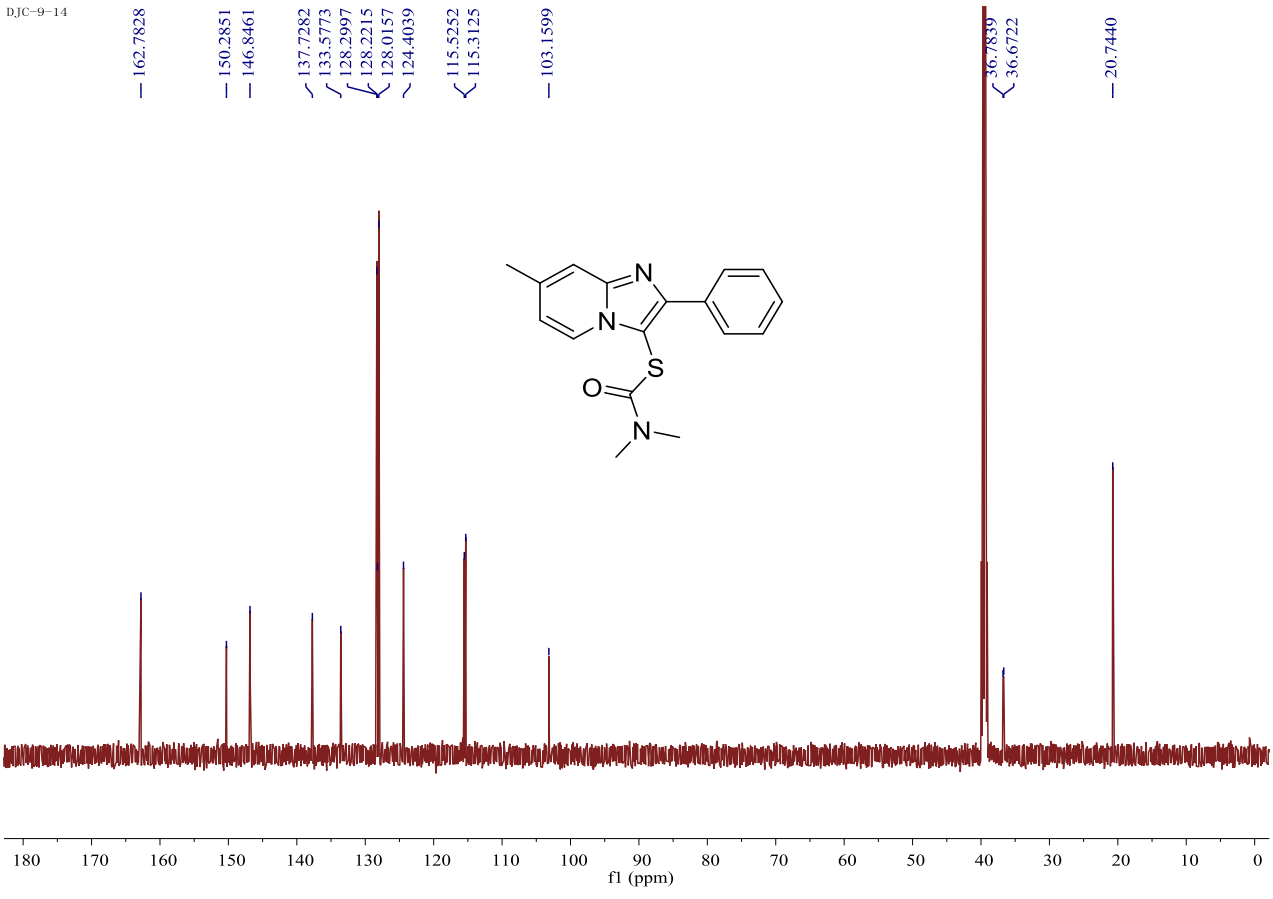
S-8-methyl-2-phenylimidazo[1,2-*a*]pyridin-3-yl dimethylcarbamothioate (4)



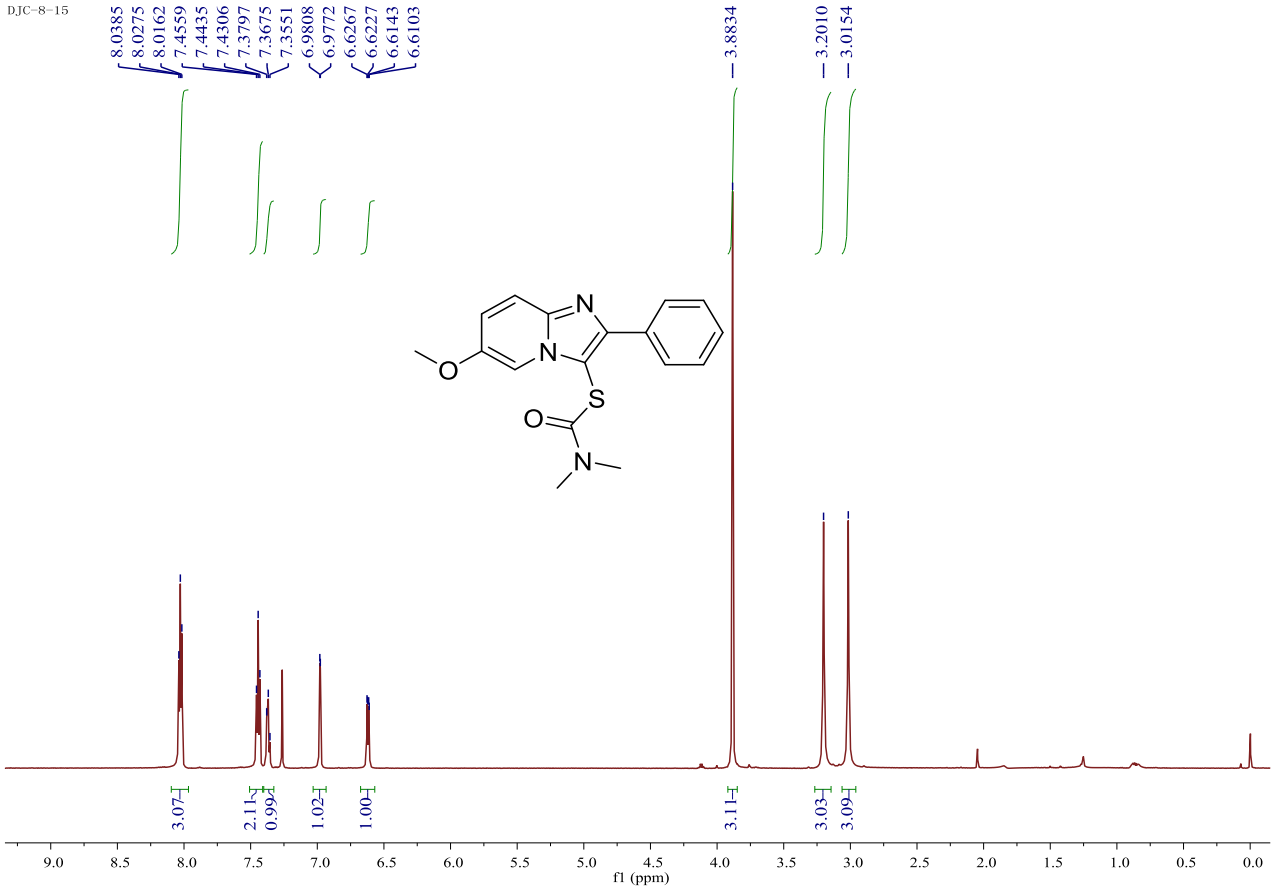


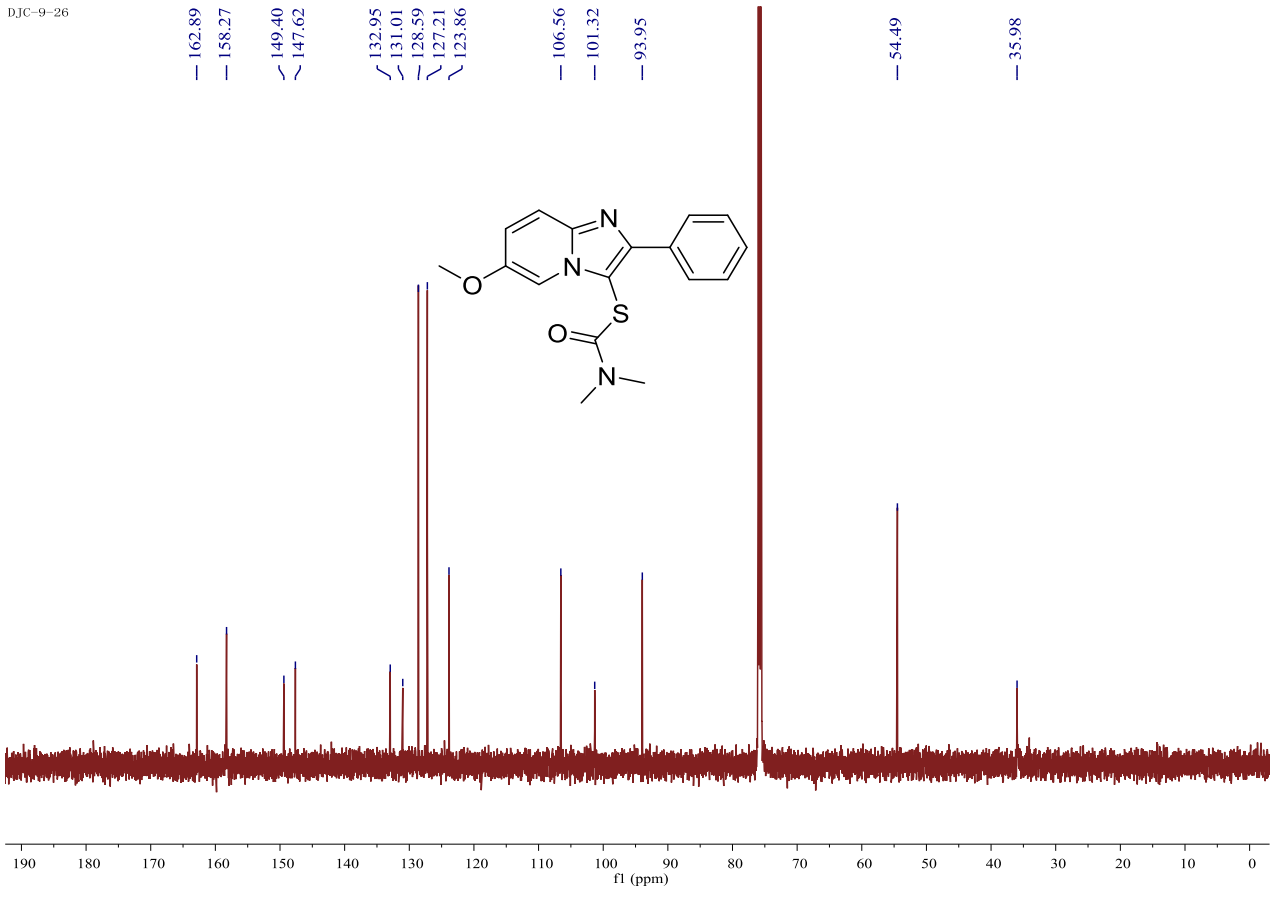
S-(7-methyl-2-phenylimidazo[1,2-a]pyridin-3-yl) dimethylcarbamothioate (5)



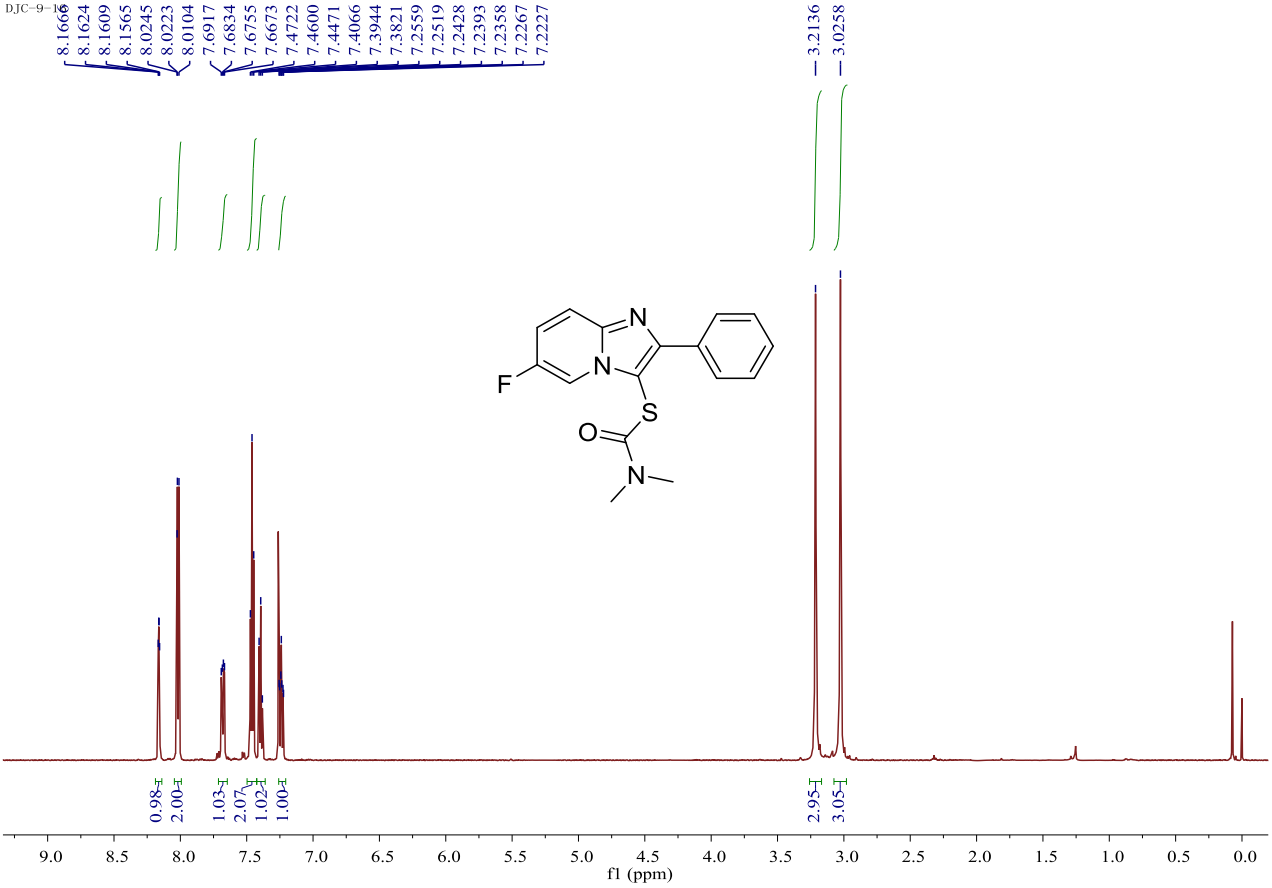


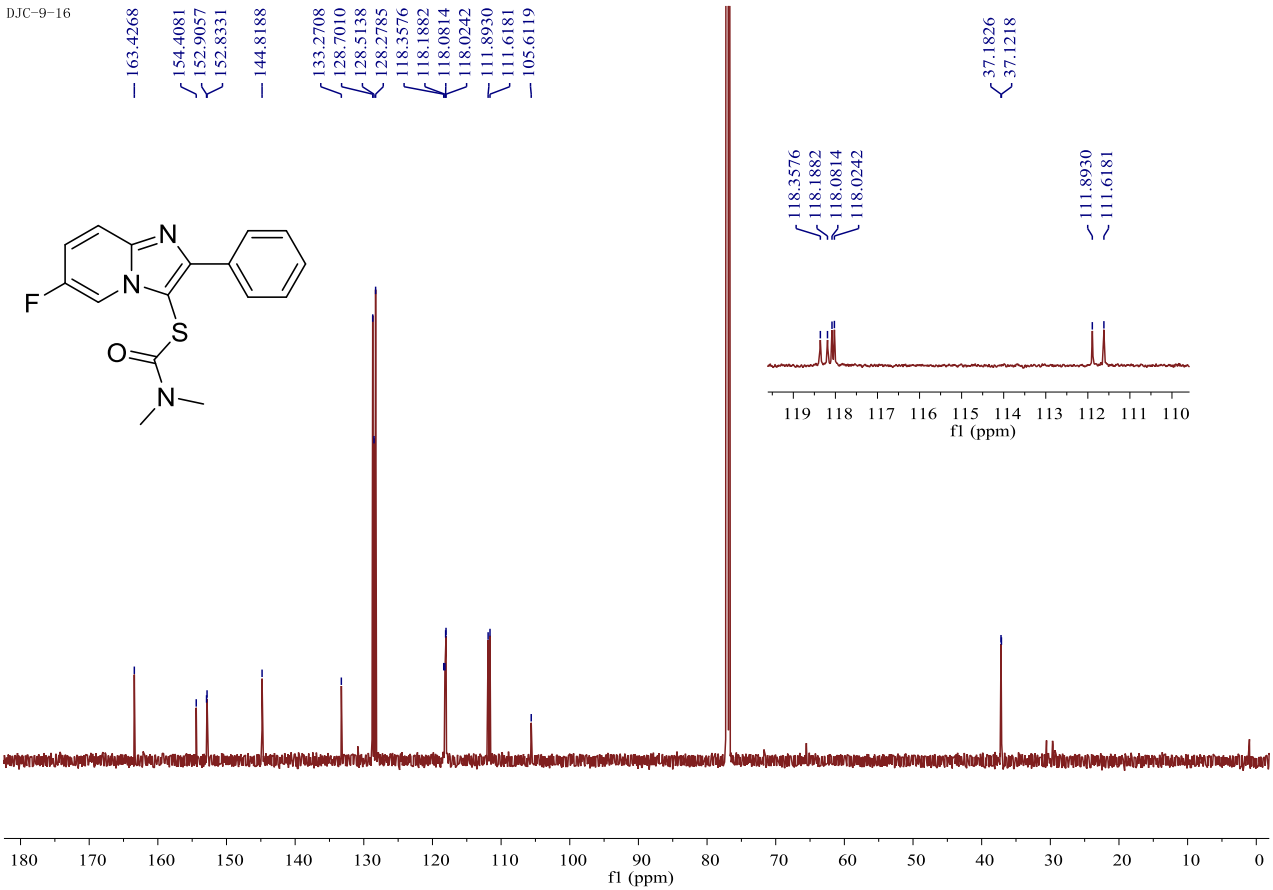
S-6-methoxy-2-phenylimidazo[1,2-*a*]pyridin-3-yl dimethylcarbamothioate (6)



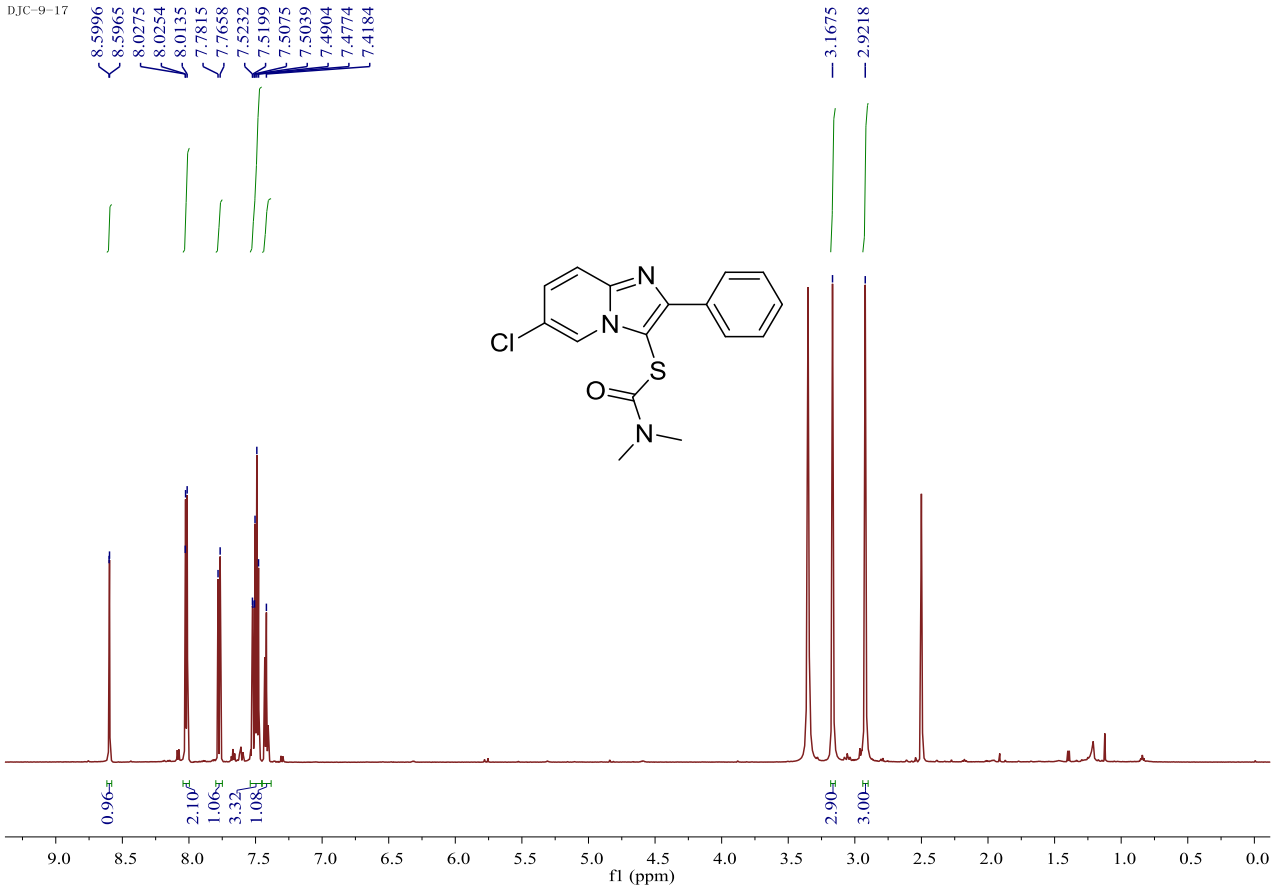


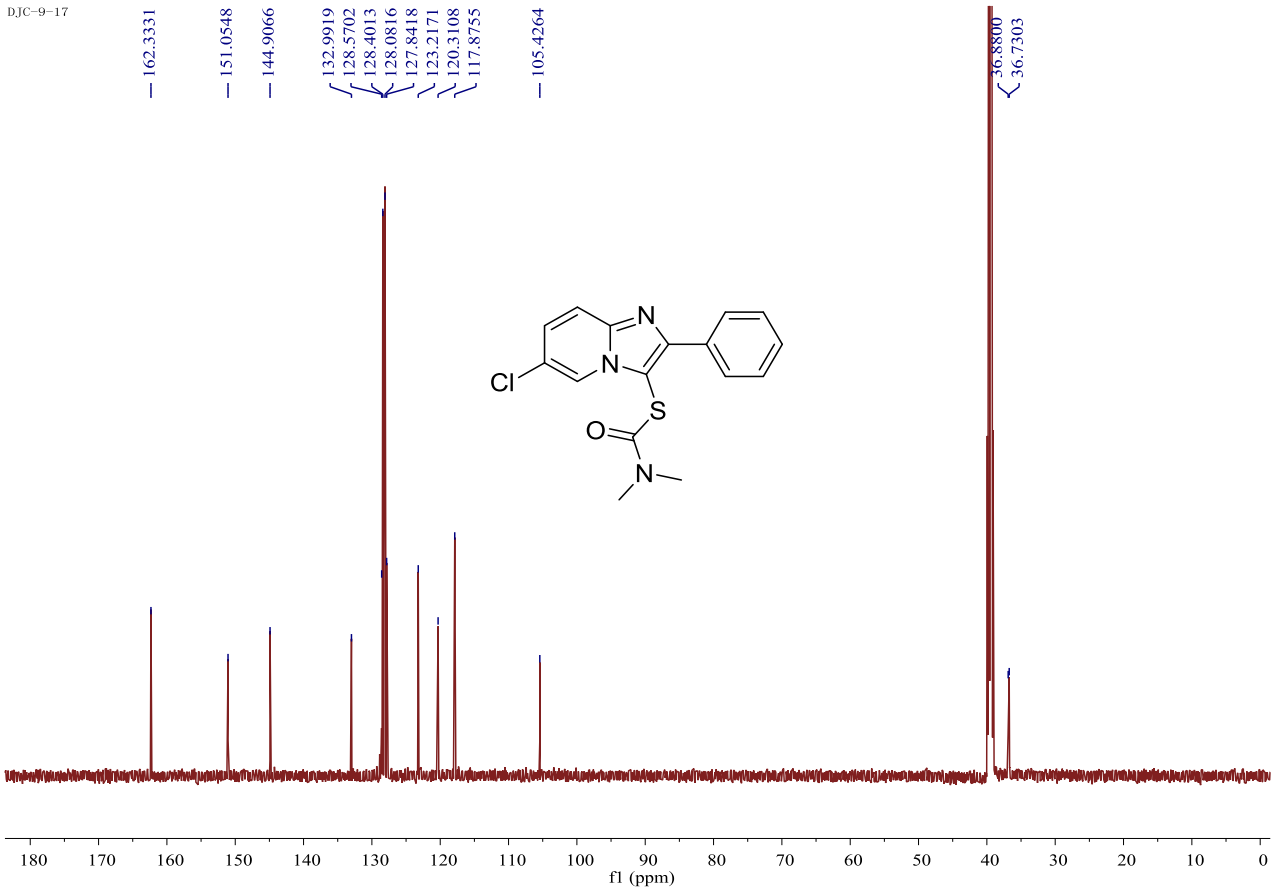
S-(6-fluoro-2-phenylimidazo[1,2-*a*]pyridin-3-yl) dimethylcarbamothioate (7)



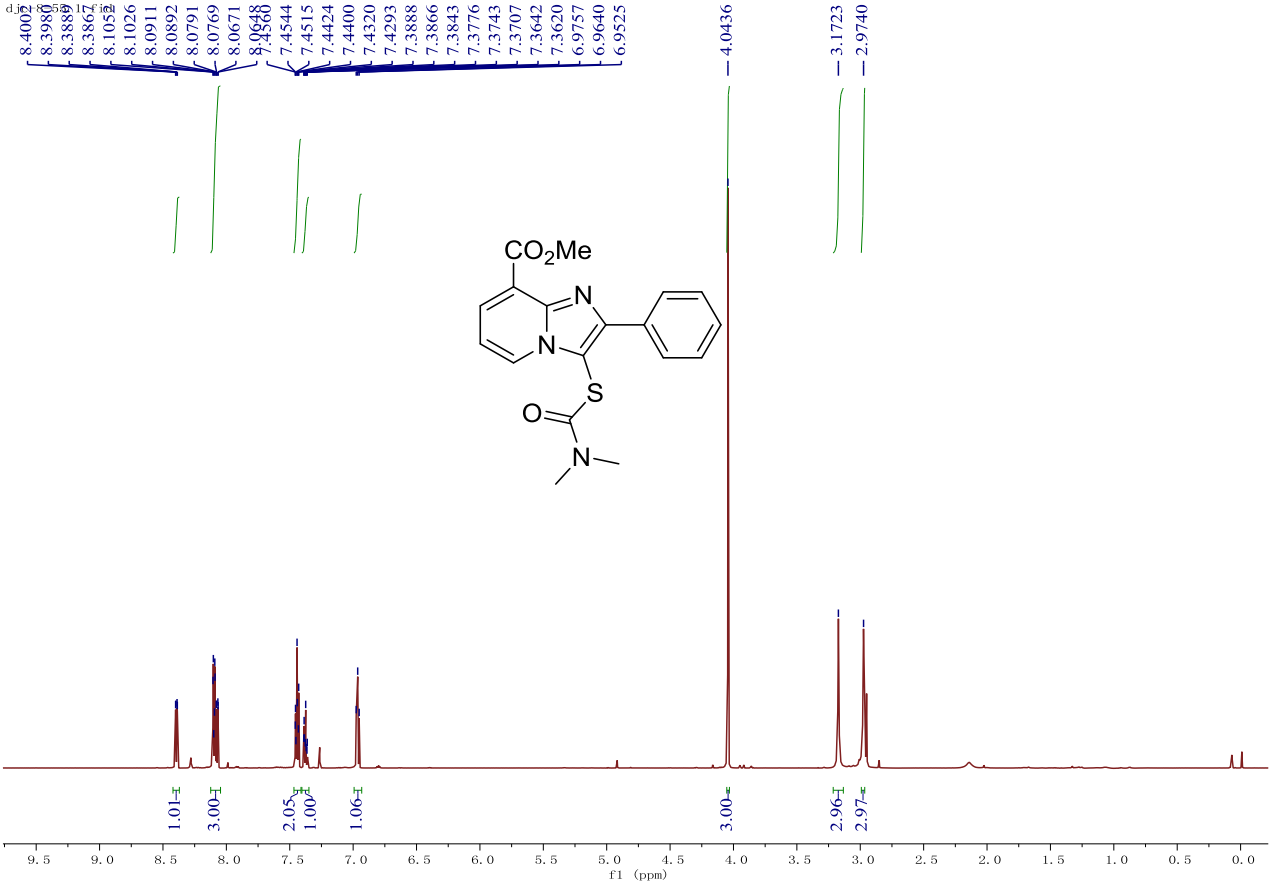


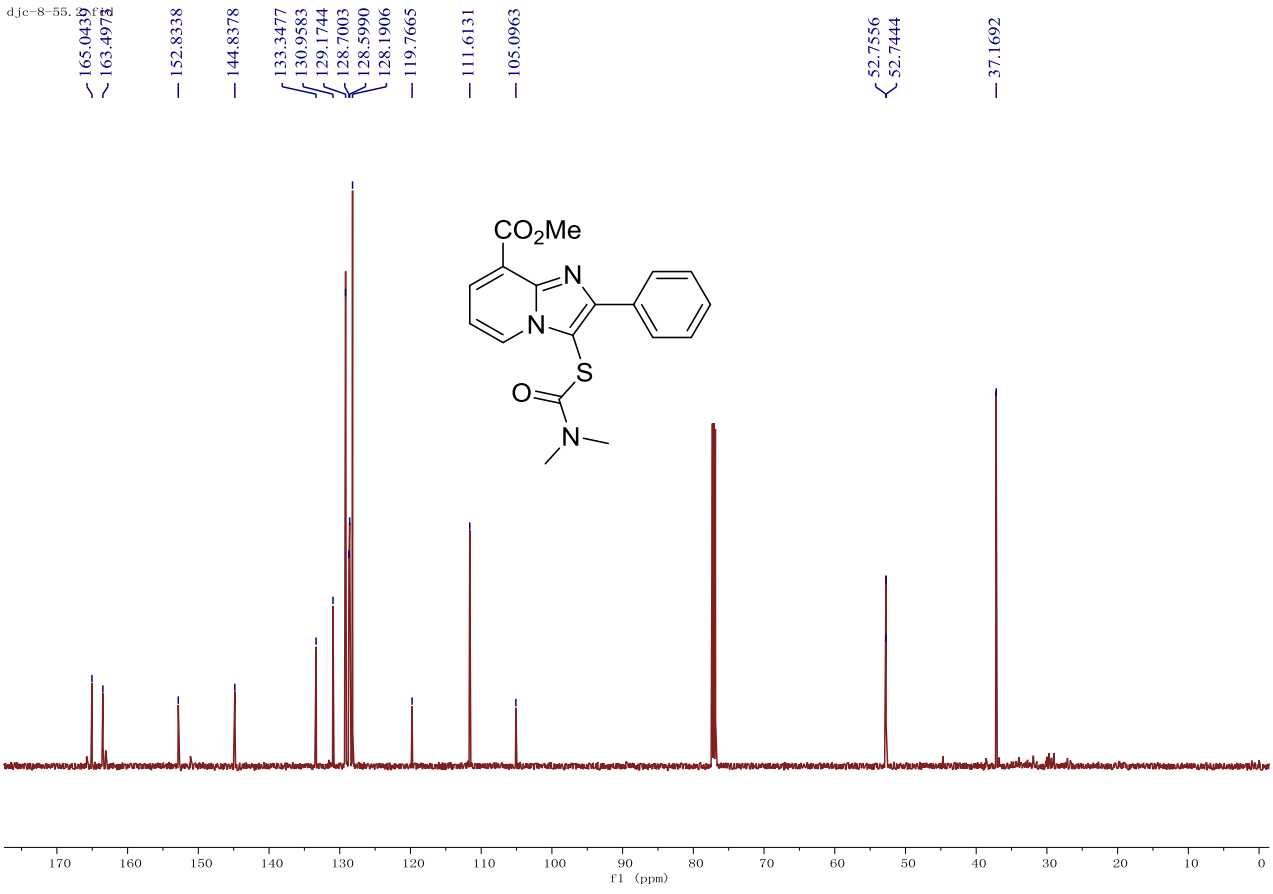
_S_-(6-chloro-2-phenylimidazo[1,2-_a_]pyridin-3-yl) dimethylcarbamothioate (8)



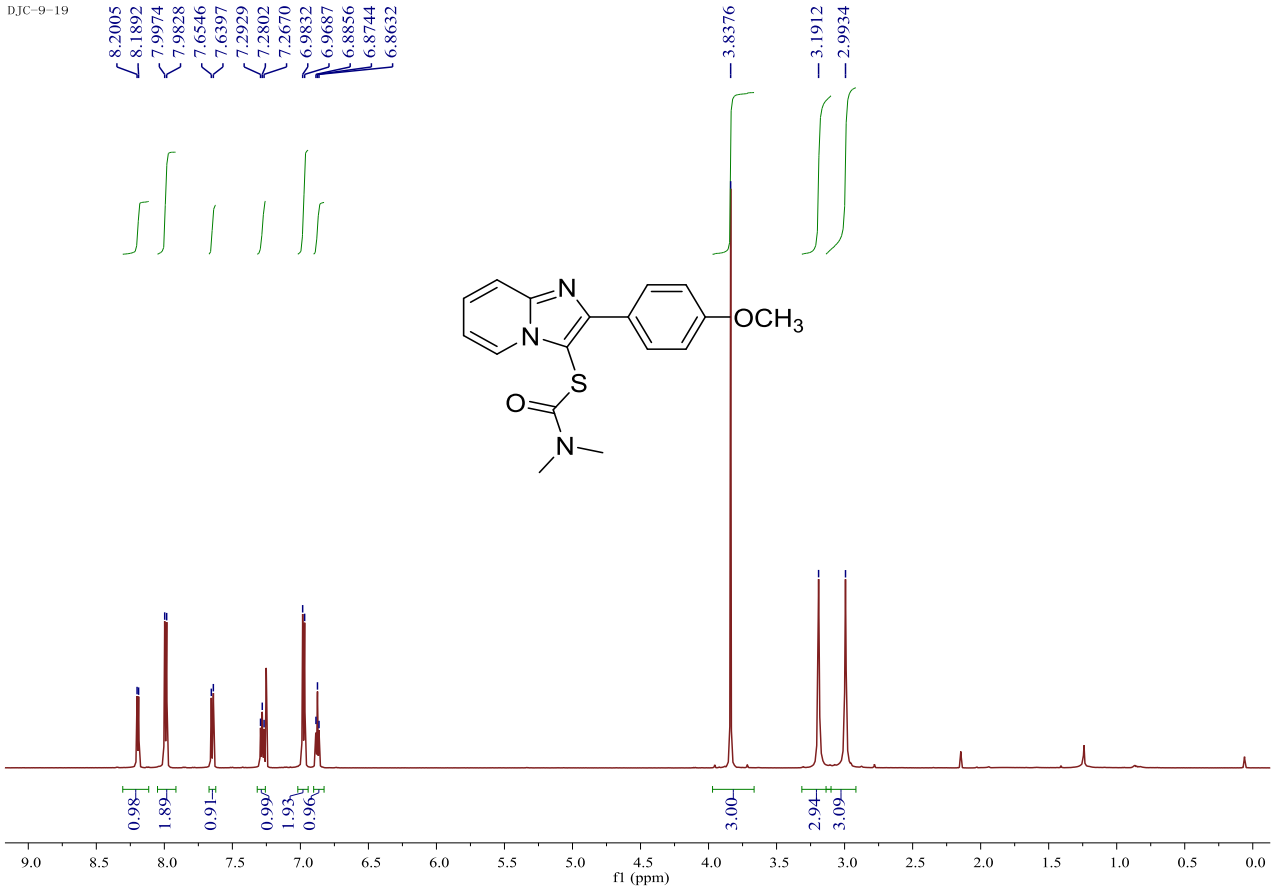


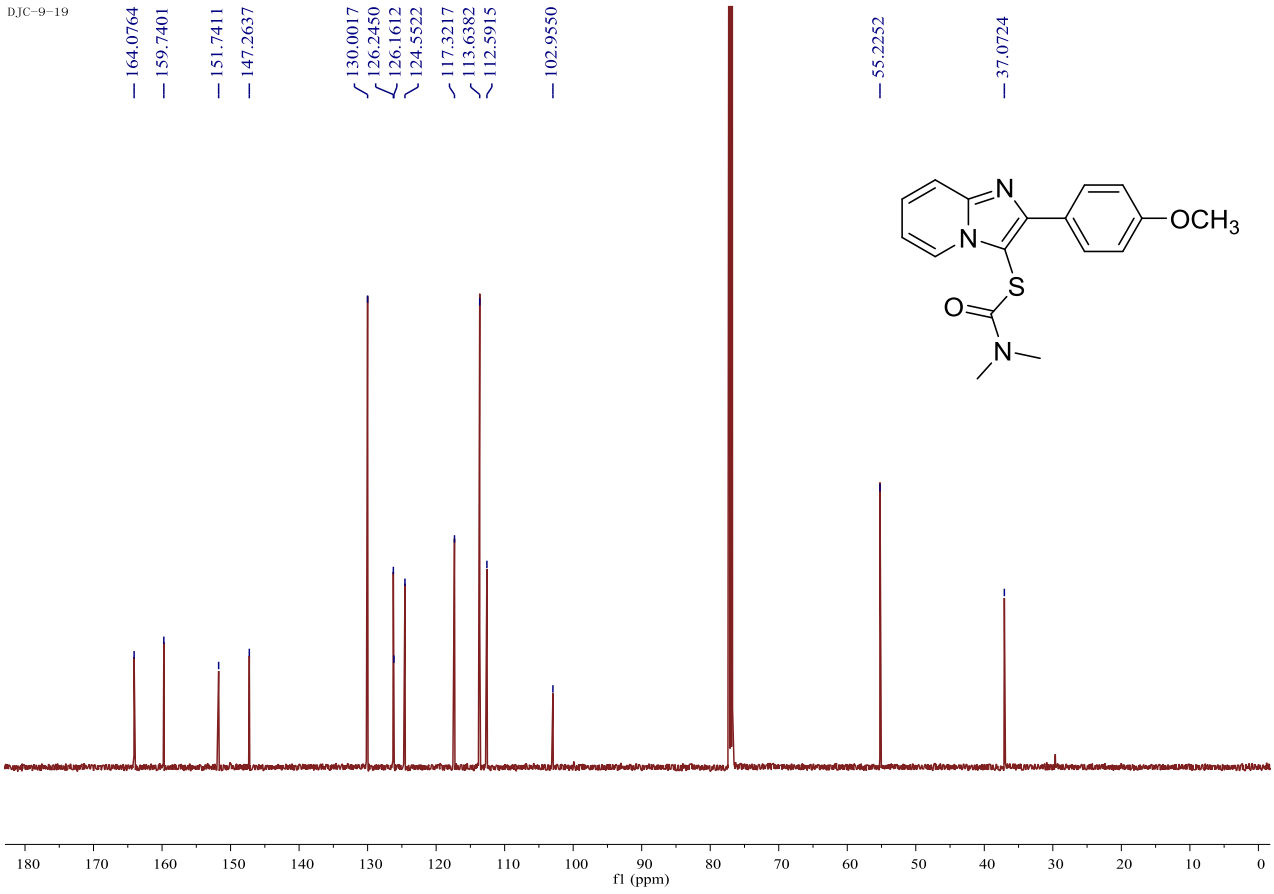
methyl 3-((dimethylcarbamoyl)thio)-2-phenylimidazo[1,2-*a*]pyridine-8-carboxylate (9)



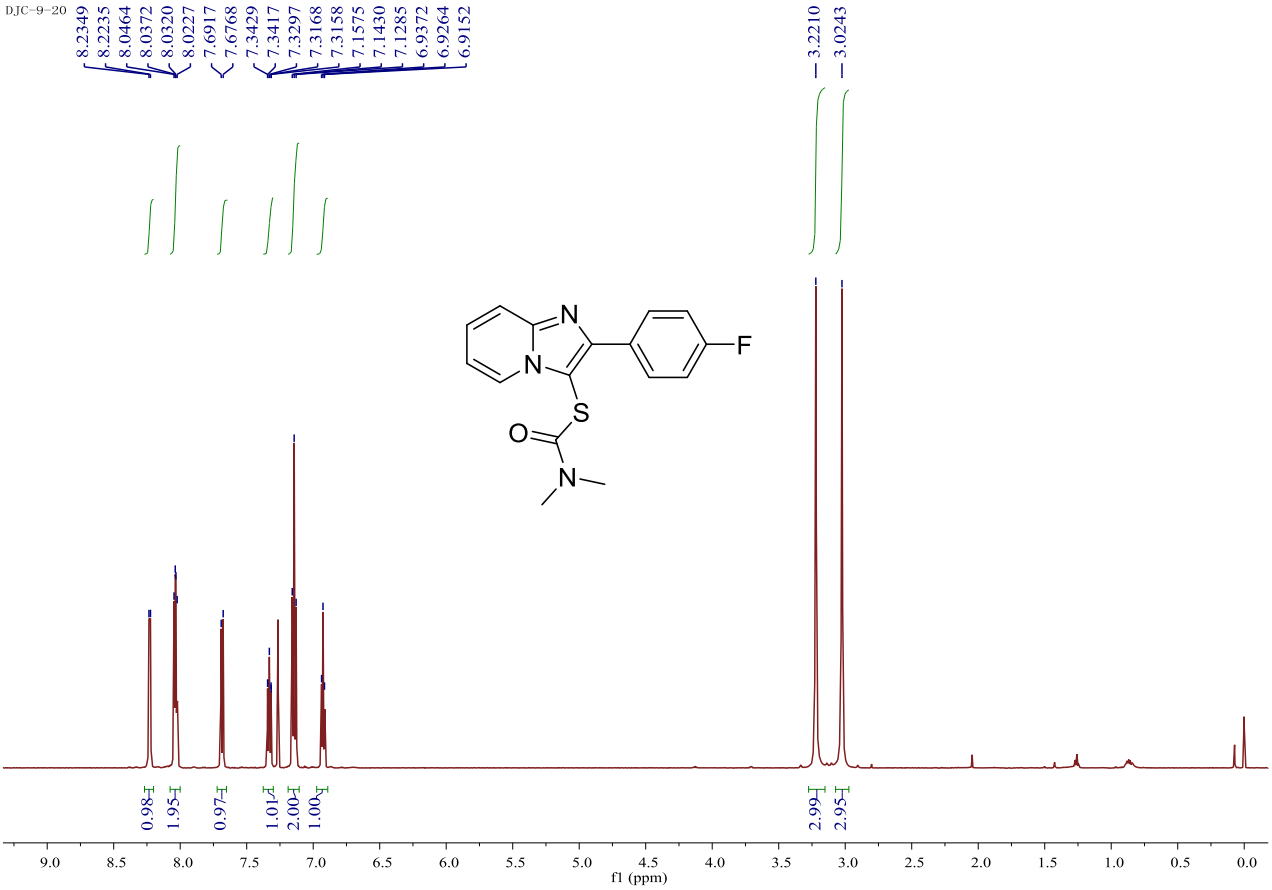


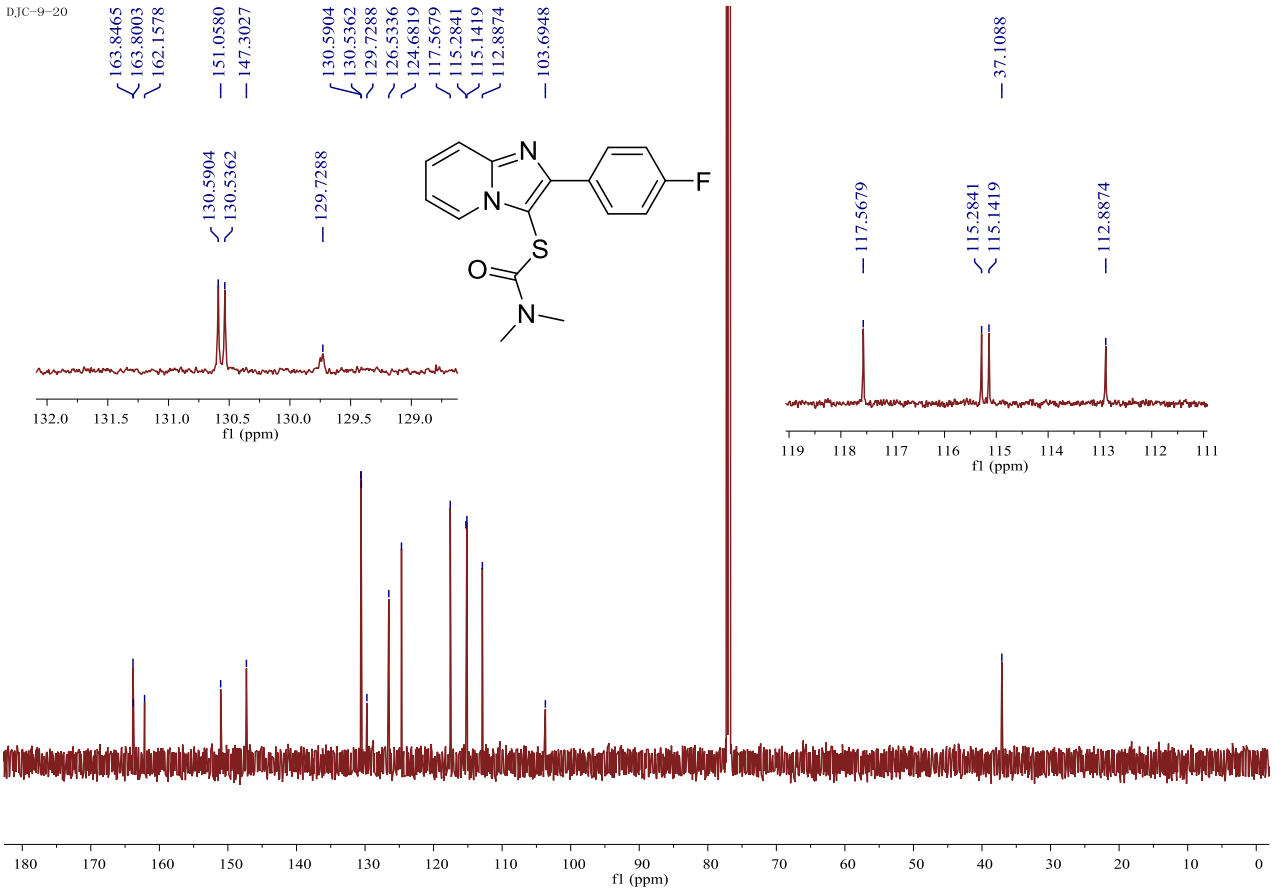
S-2-(4-methoxyphenyl)imidazo[1,2-*a*]pyridin-3-yl dimethylcarbamothioate (10)



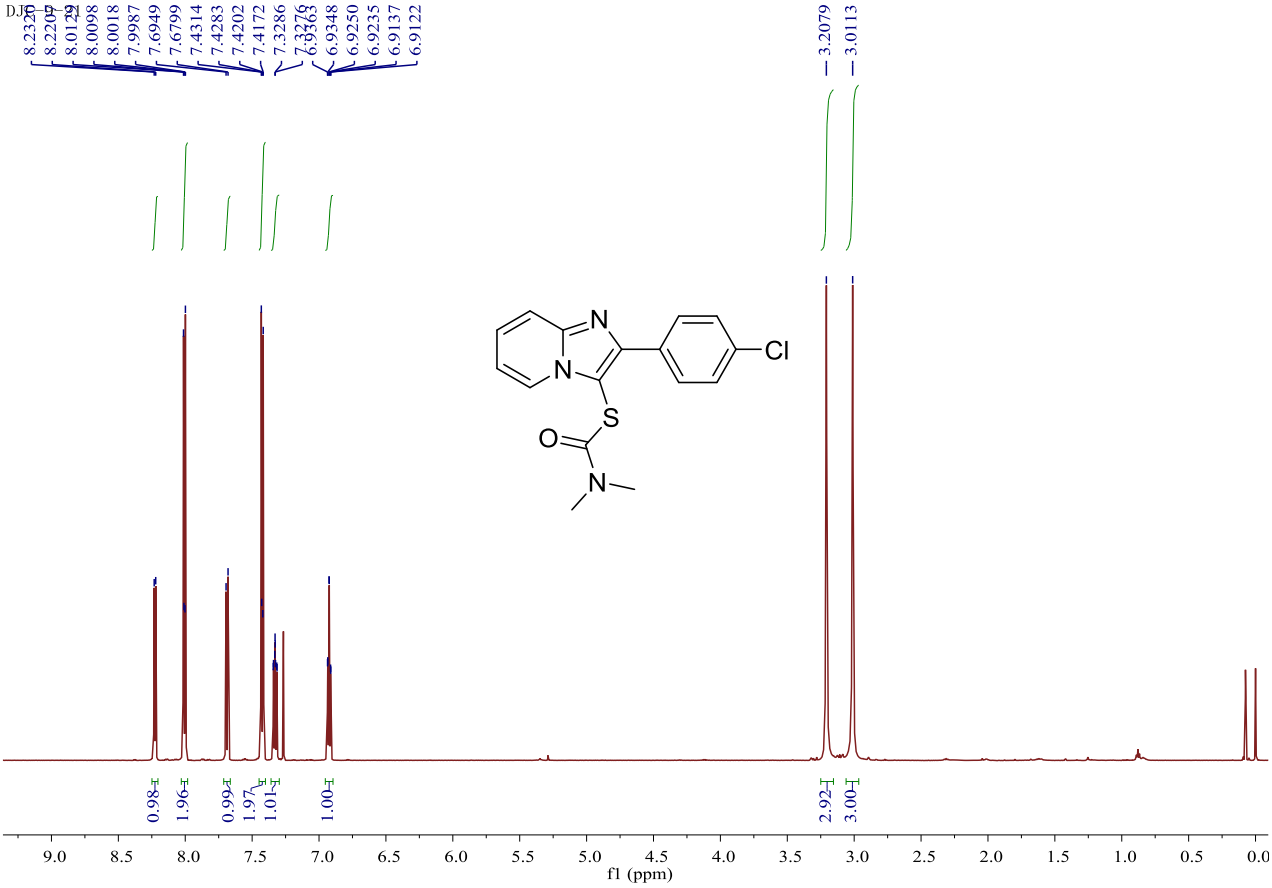


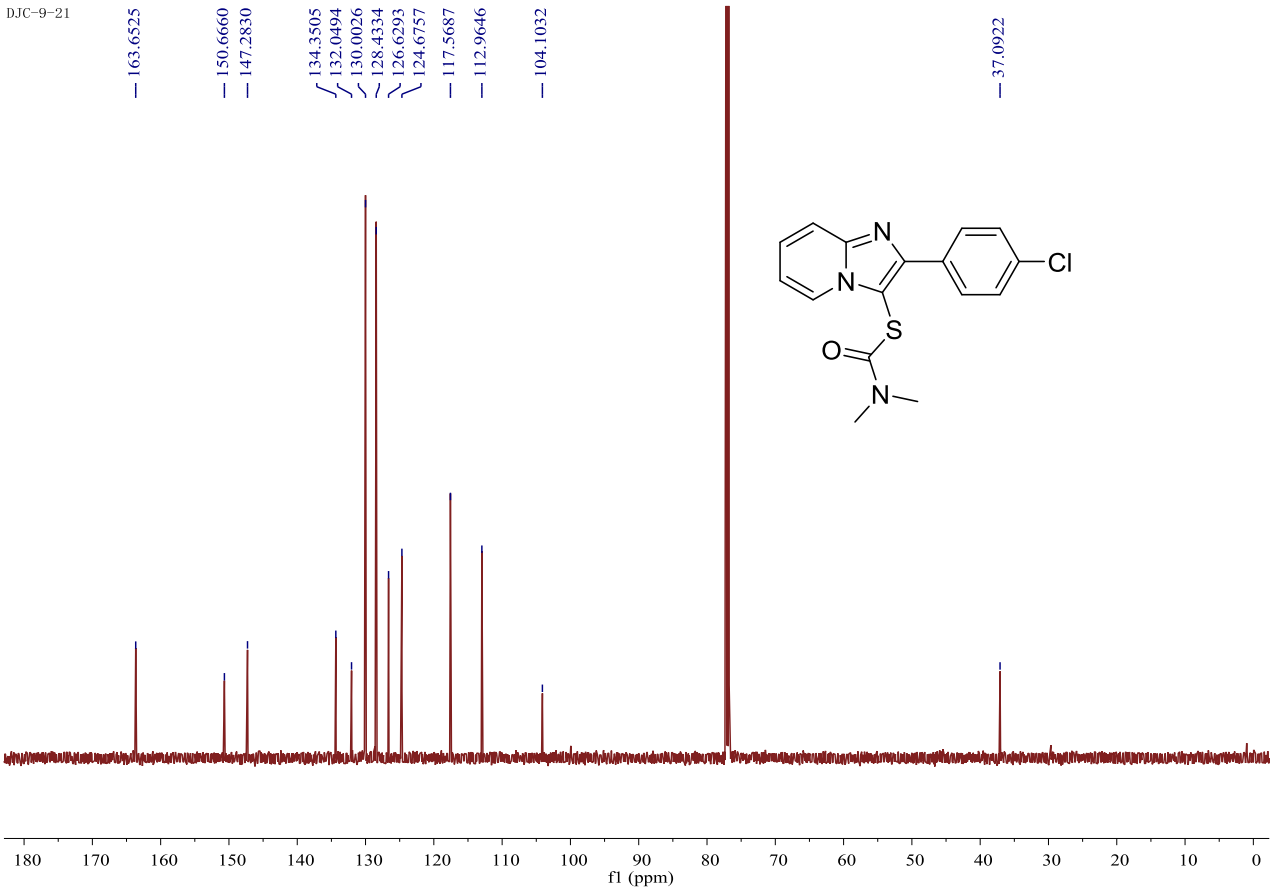
_S_-2-(4-fluorophenyl)imidazo[1,2-*a*]pyridin-3-yl dimethylcarbamothioate (11)



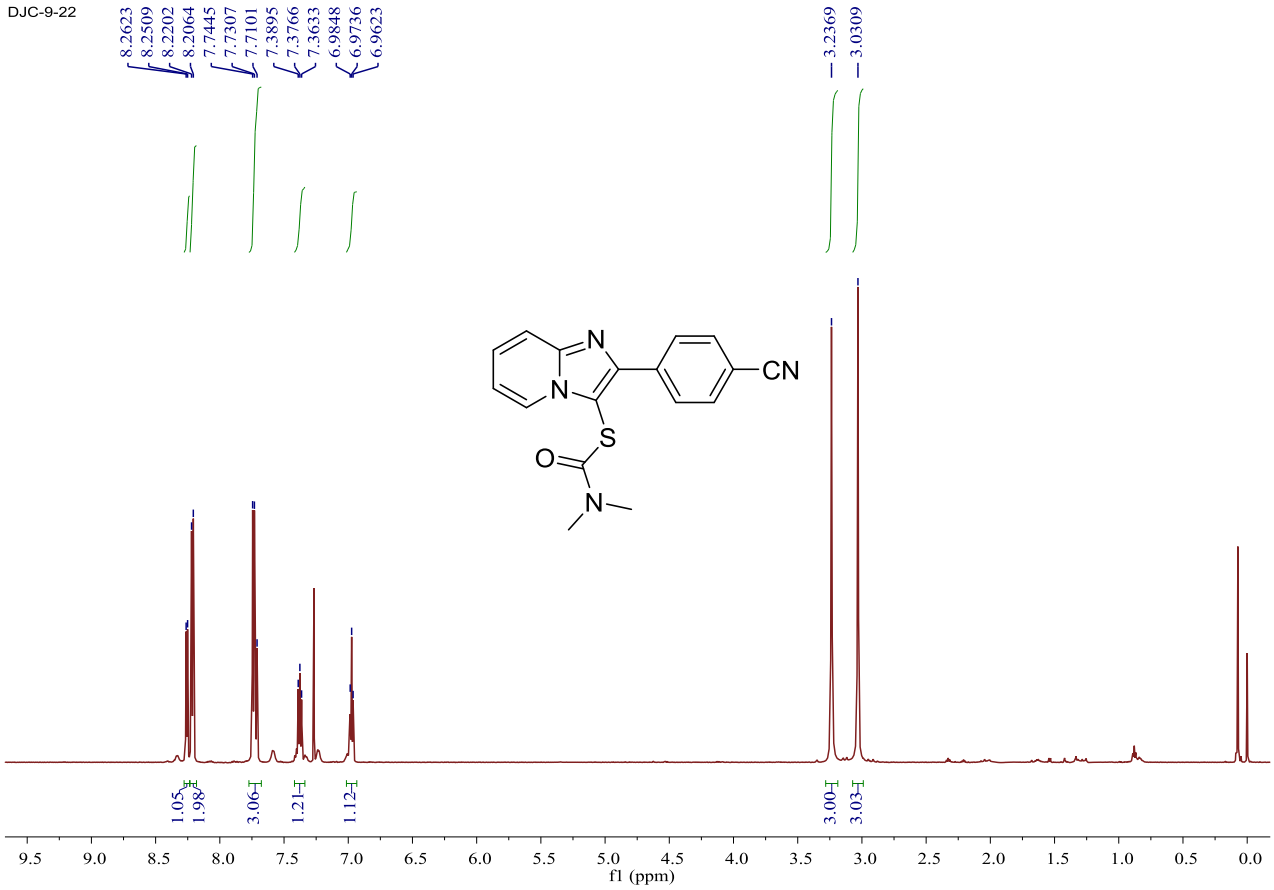


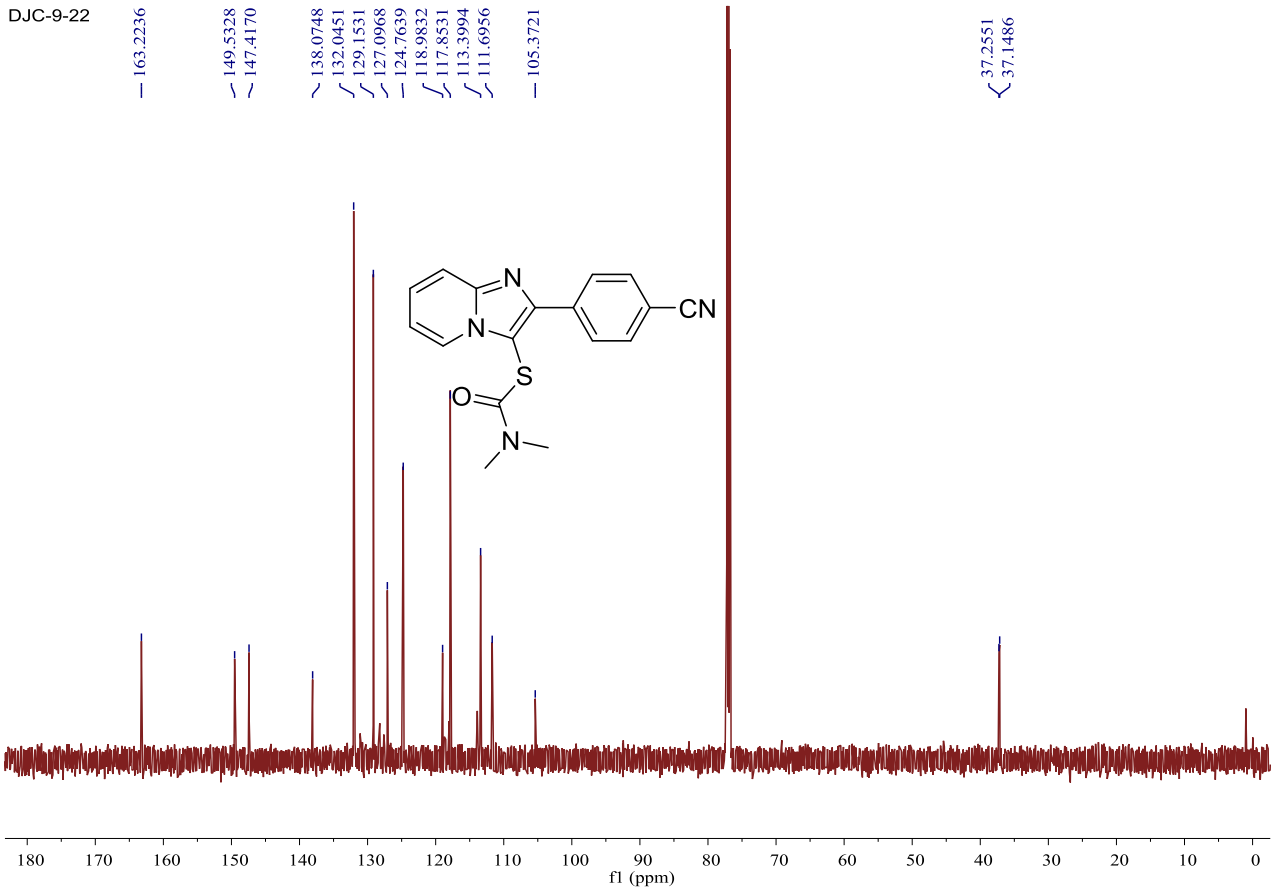
S-2-(4-chlorophenyl)imidazo[1,2-*a*]pyridin-3-yl dimethylcarbamothioate (12)



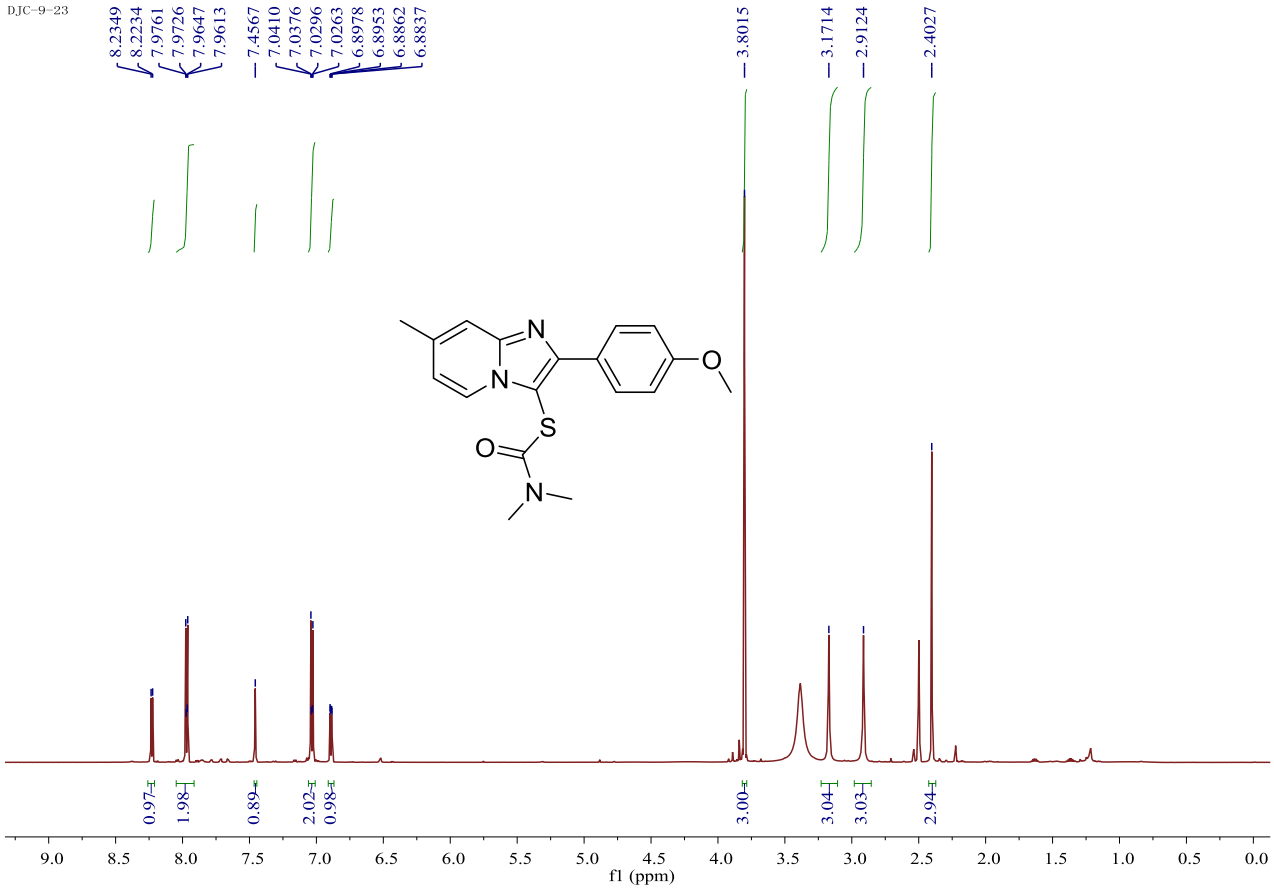


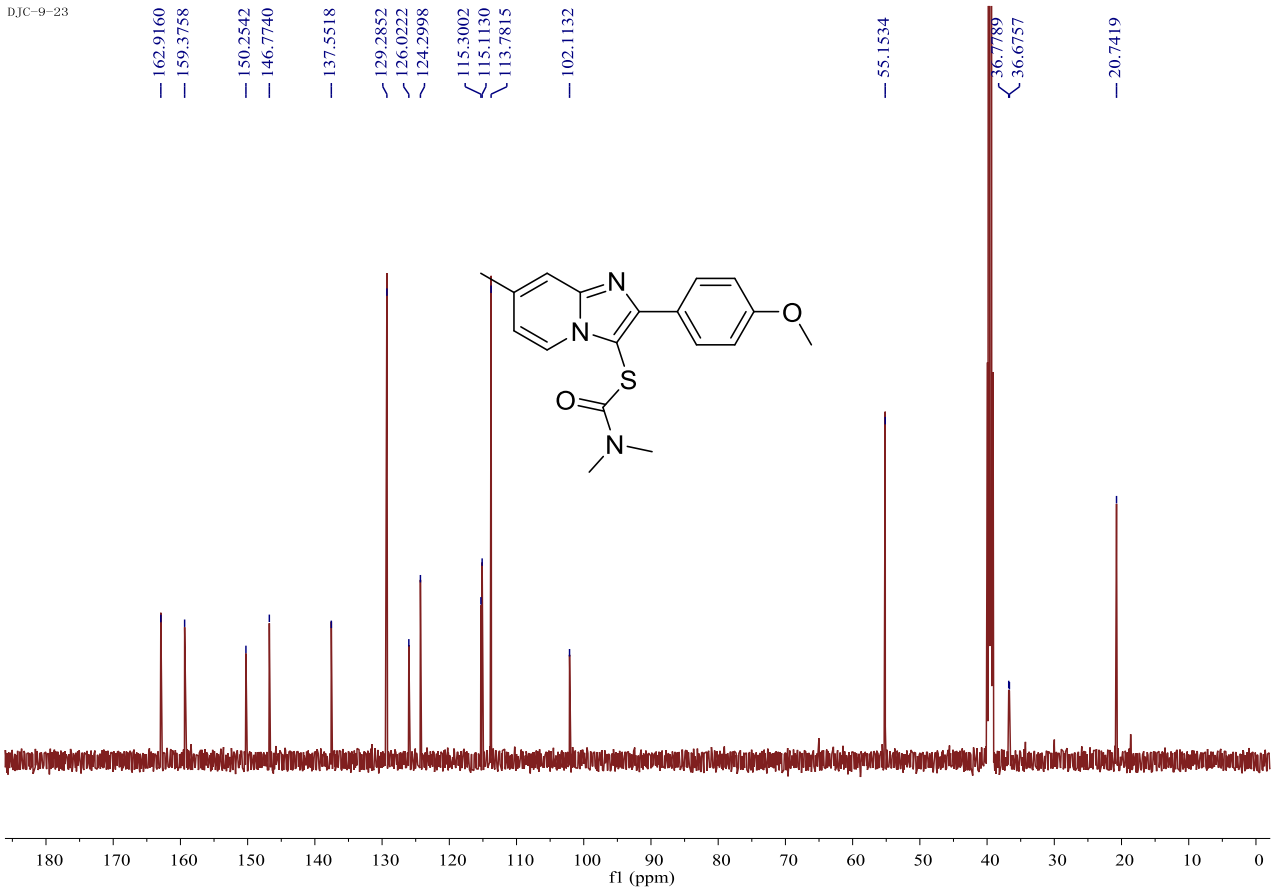
_S_-2-(4-cyanophenyl)imidazo[1,2-_a_]pyridin-3-yl dimethylcarbamothioate (13)



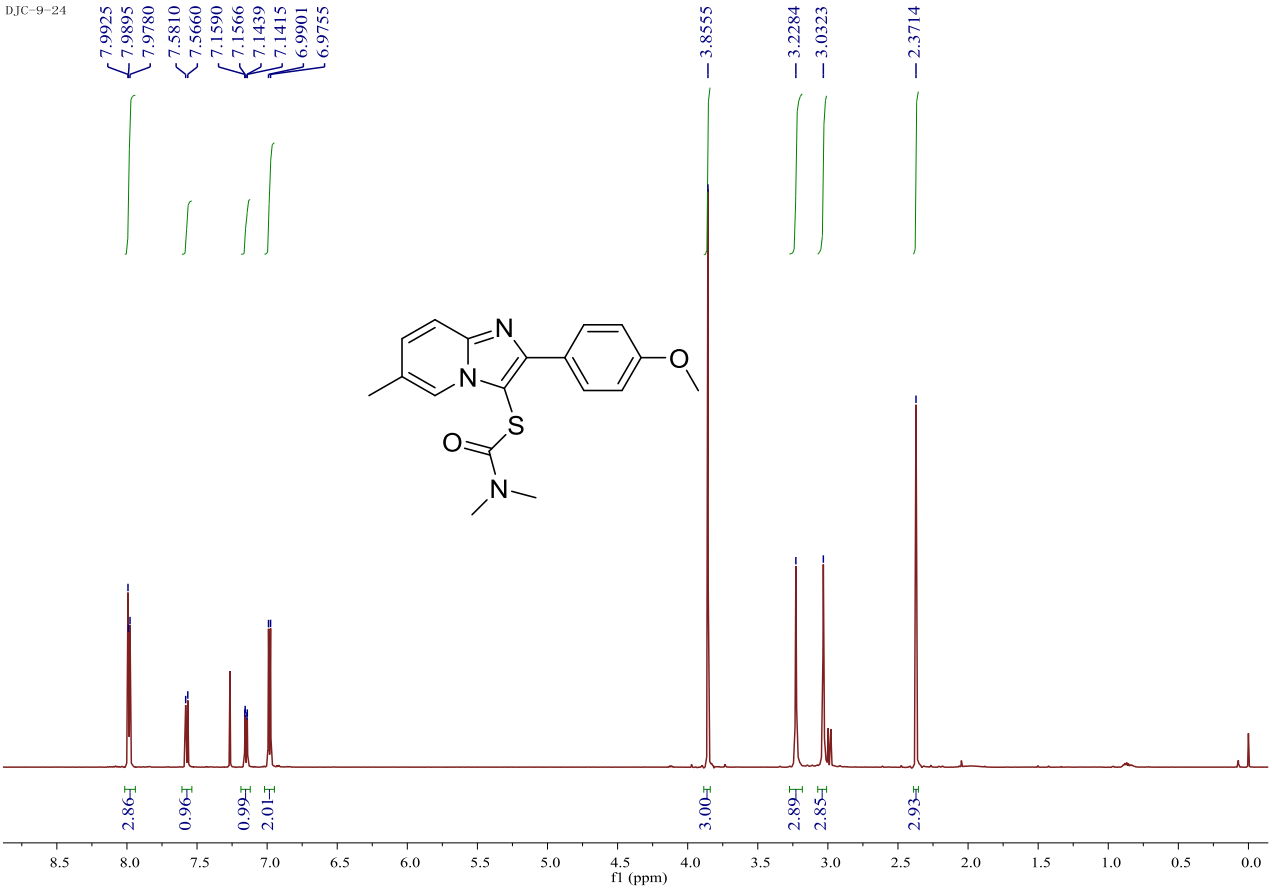


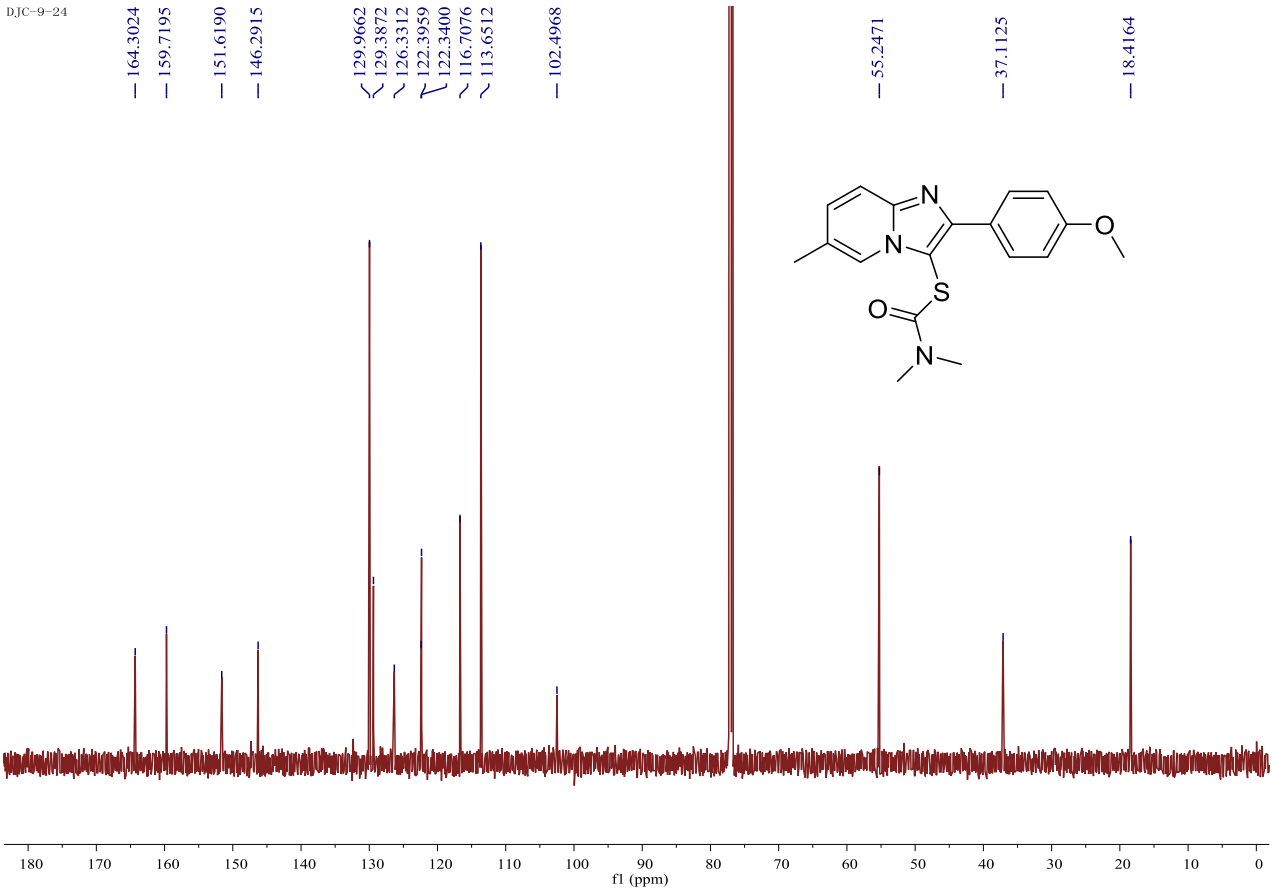
S-(2-(4-methoxyphenyl)-7-methylimidazo[1,2-*a*]pyridin-3-yl) dimethylcarbamothioate (14)



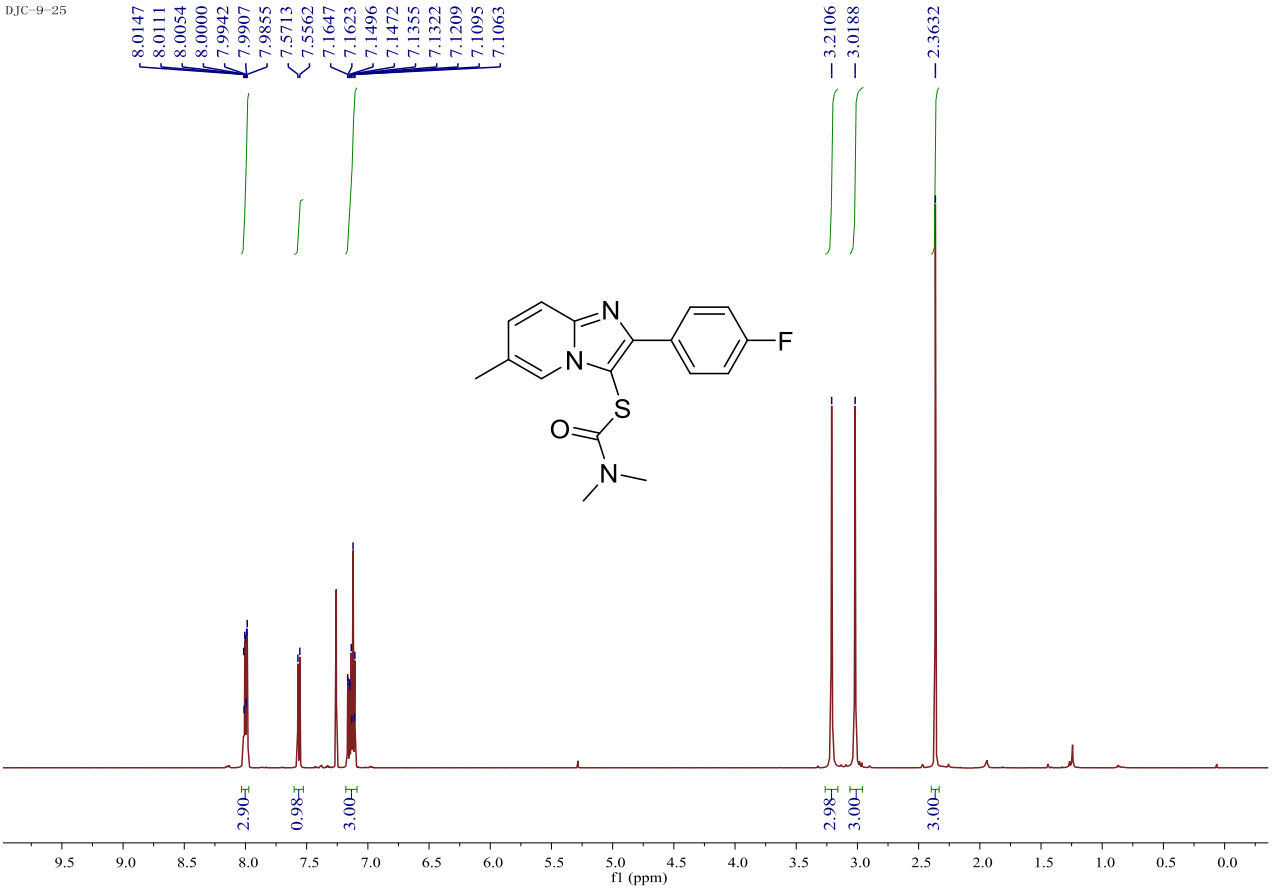


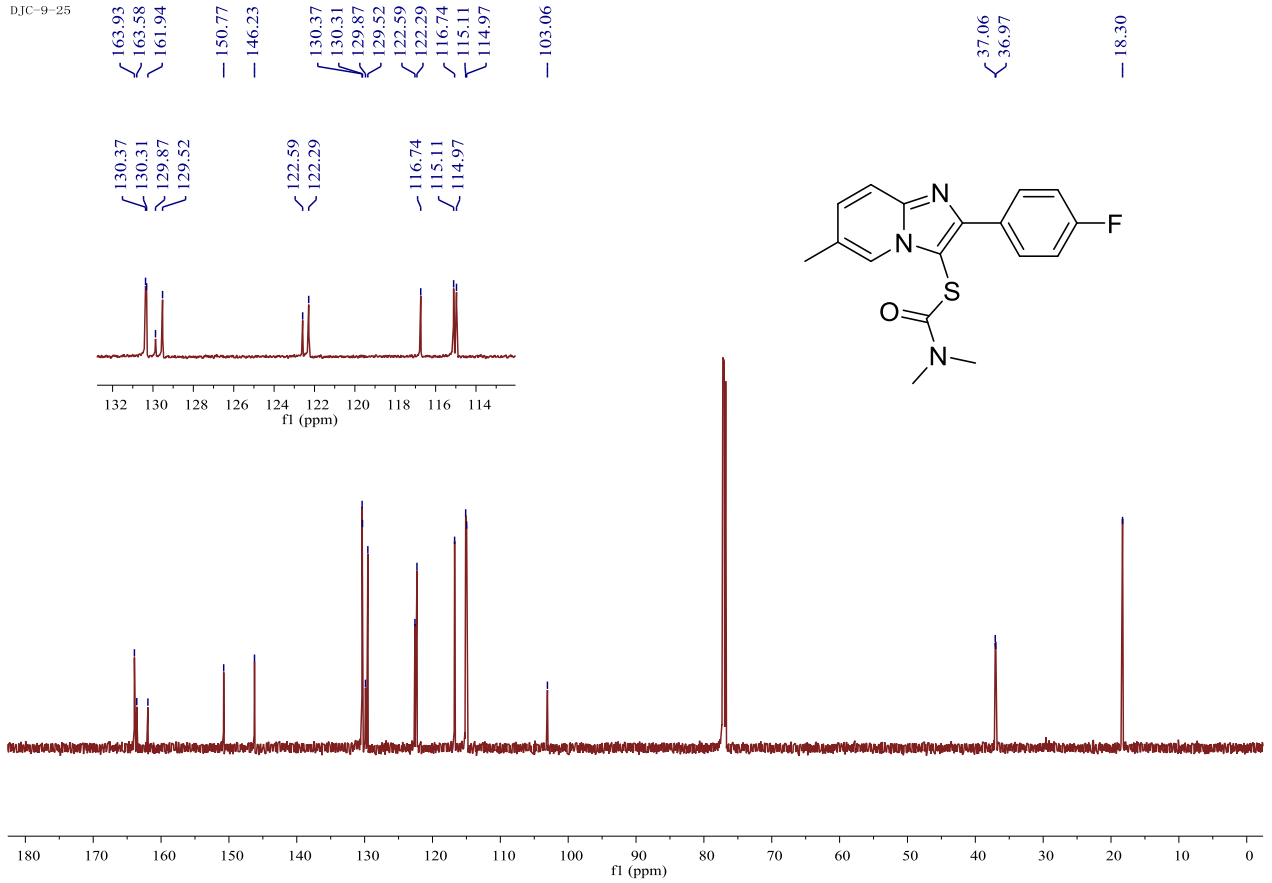
S-(2-(4-methoxyphenyl)-6-methylimidazo[1,2-*a*]pyridin-3-yl) dimethylcarbamothioate (15)



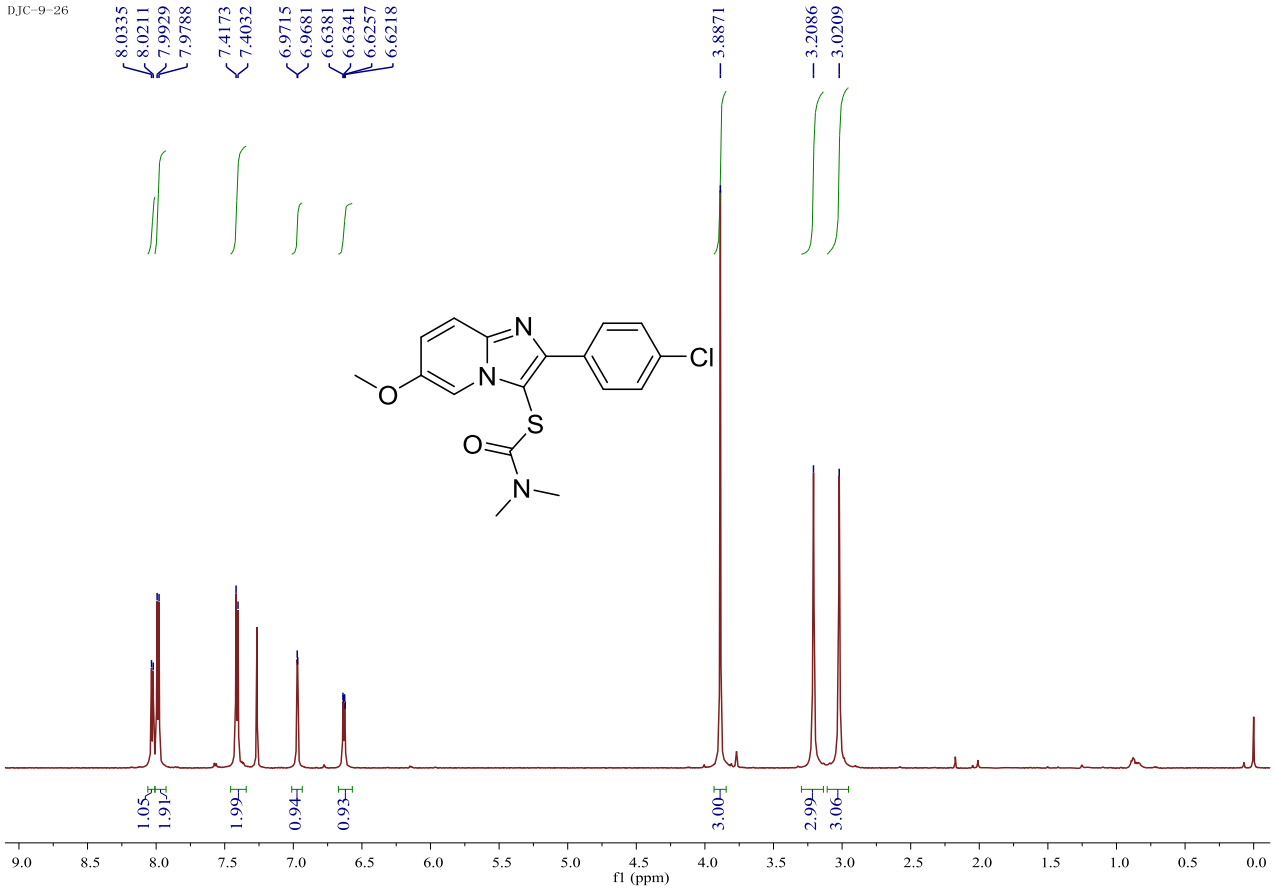


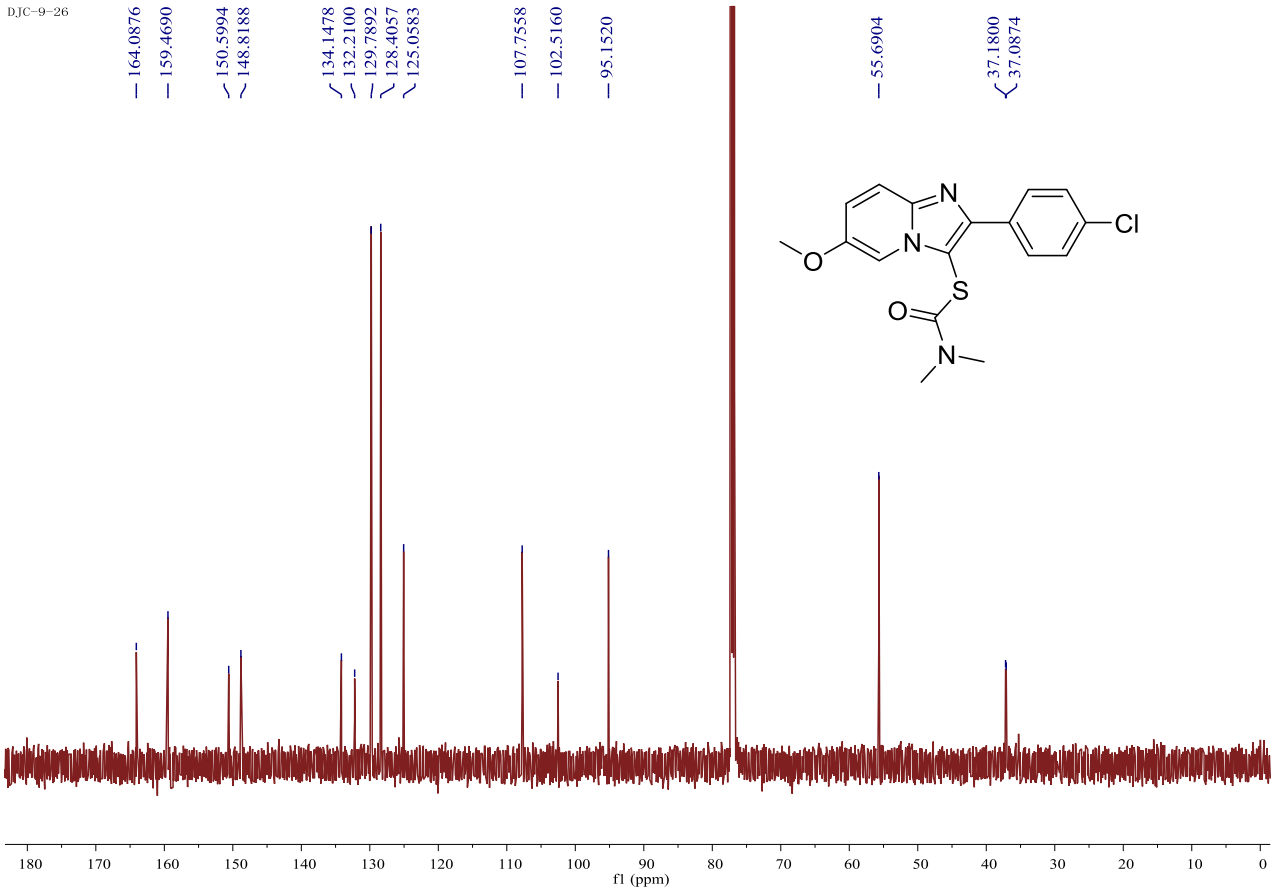
S-(2-(4-fluorophenyl)-6-methylimidazo[1,2-*a*]pyridin-3-yl) dimethylcarbamothioate (16)



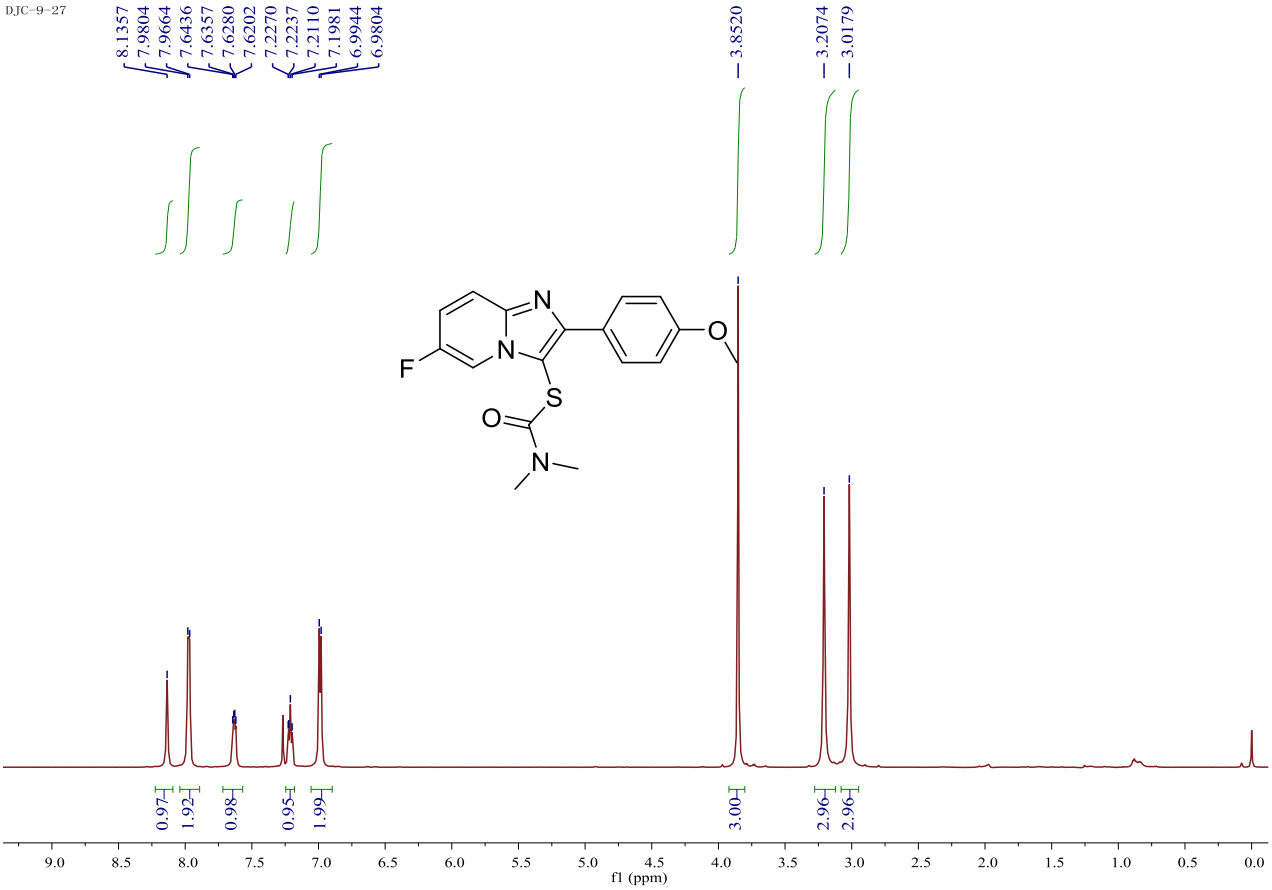


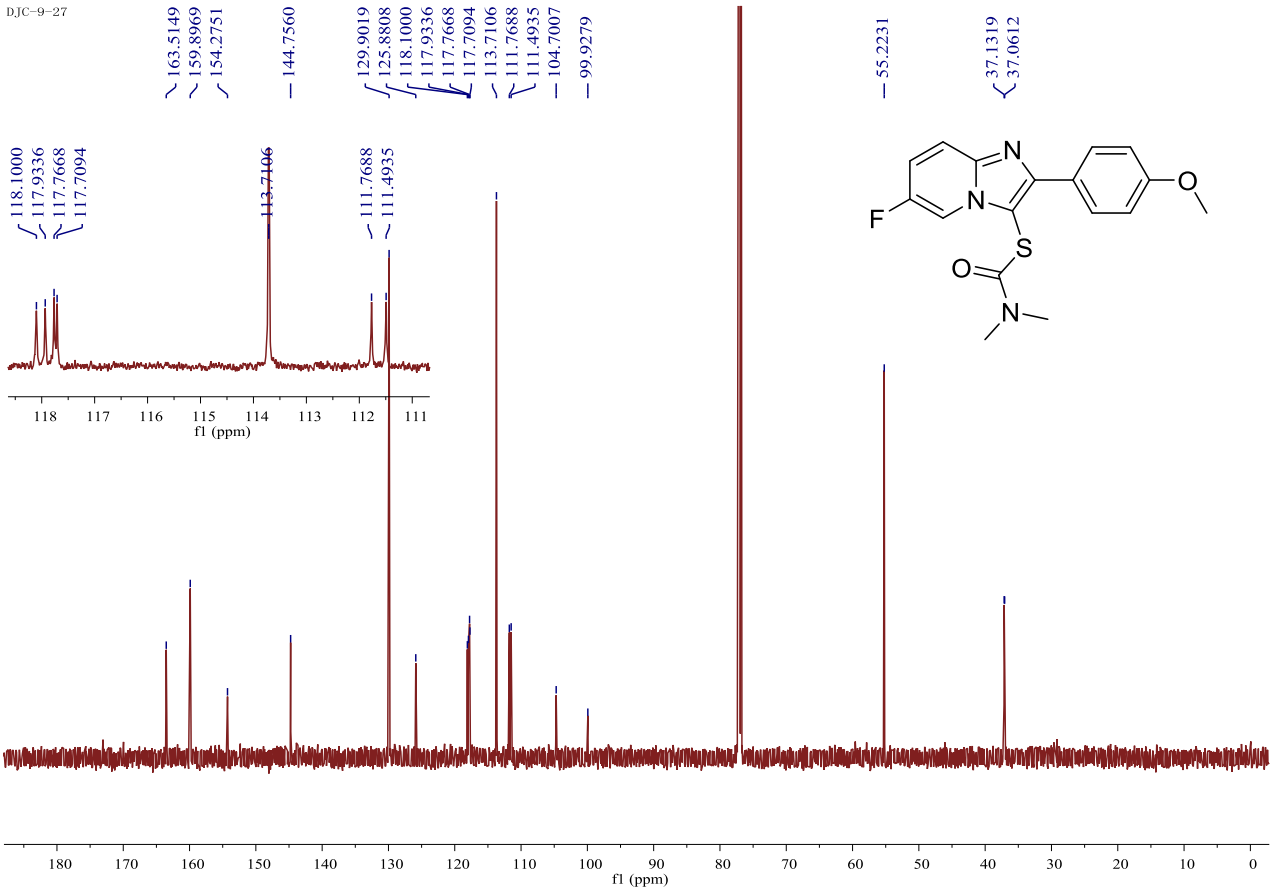
S-(2-(4-chlorophenyl)-6-methoxyimidazo[1,2-*a*]pyridin-3-yl) dimethylcarbamothioate (17)



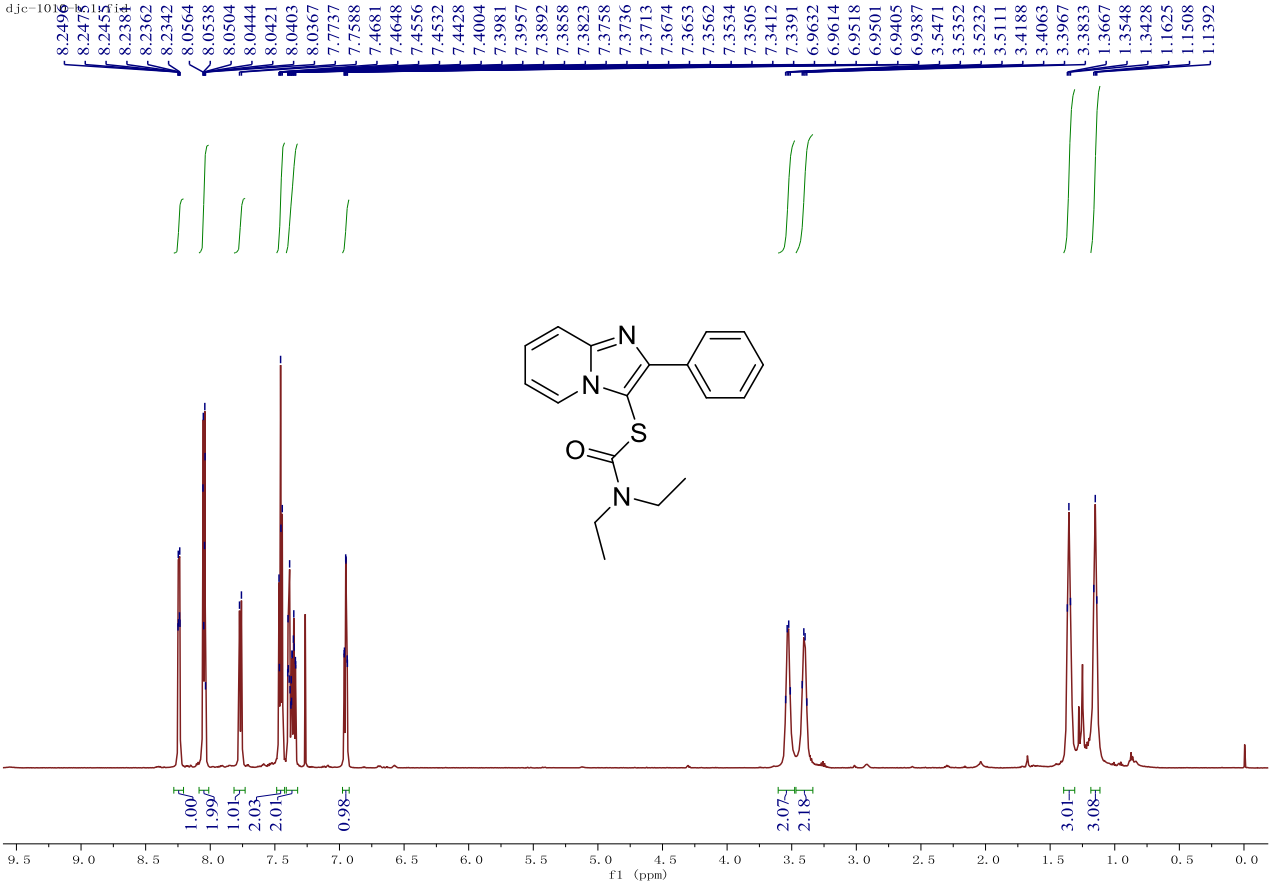


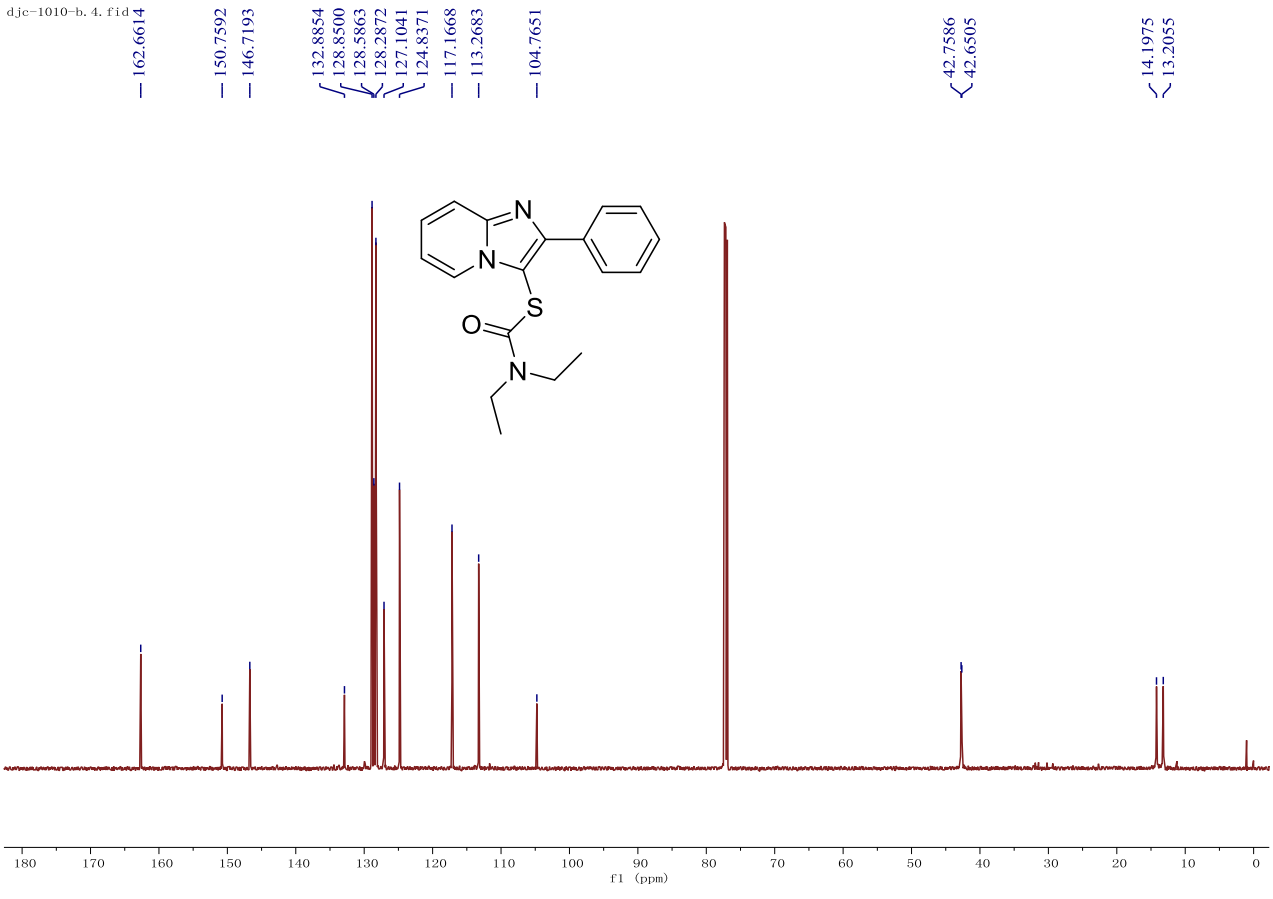
S-(6-fluoro-2-(4-methoxyphenyl)imidazo[1,2-*a*]pyridin-3-yl) dimethylcarbamothioate (18)



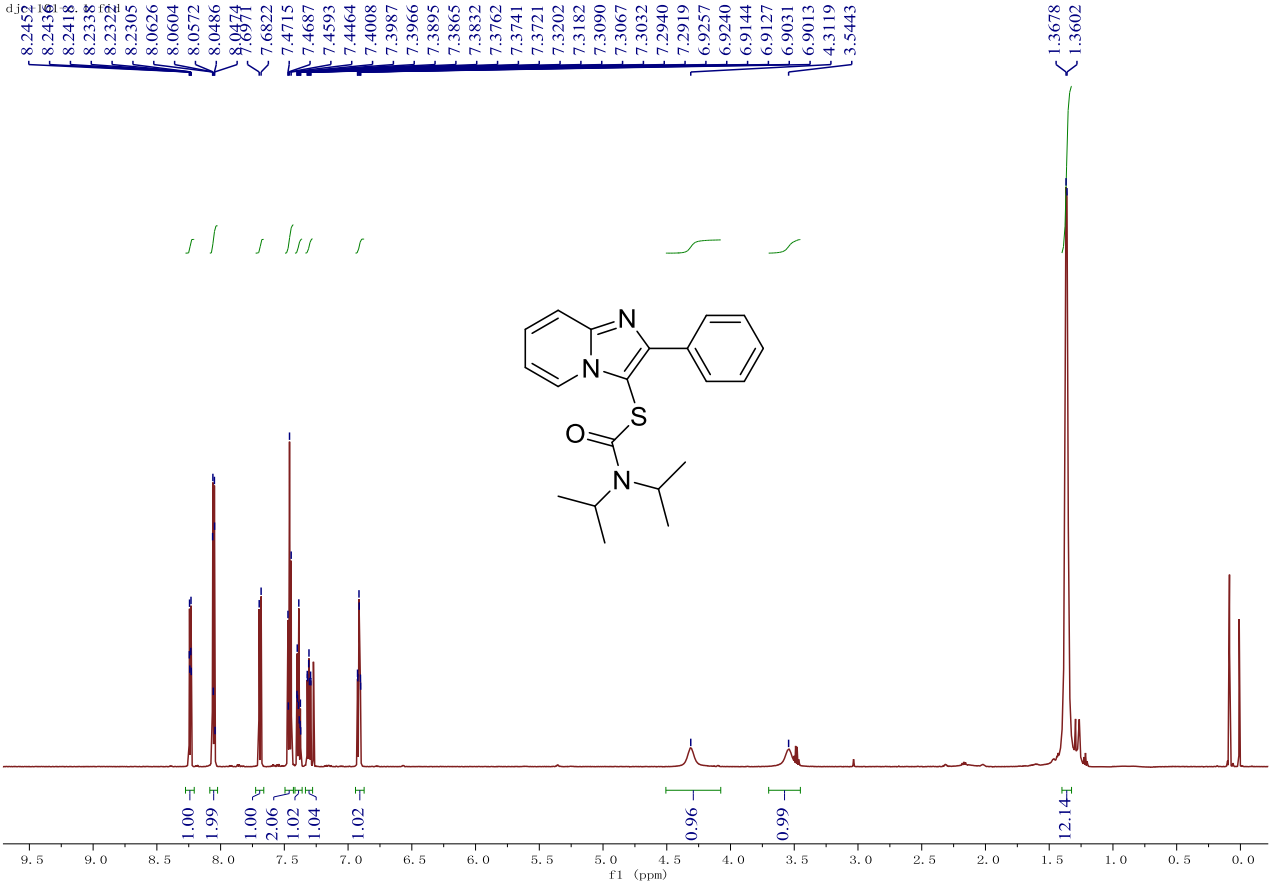


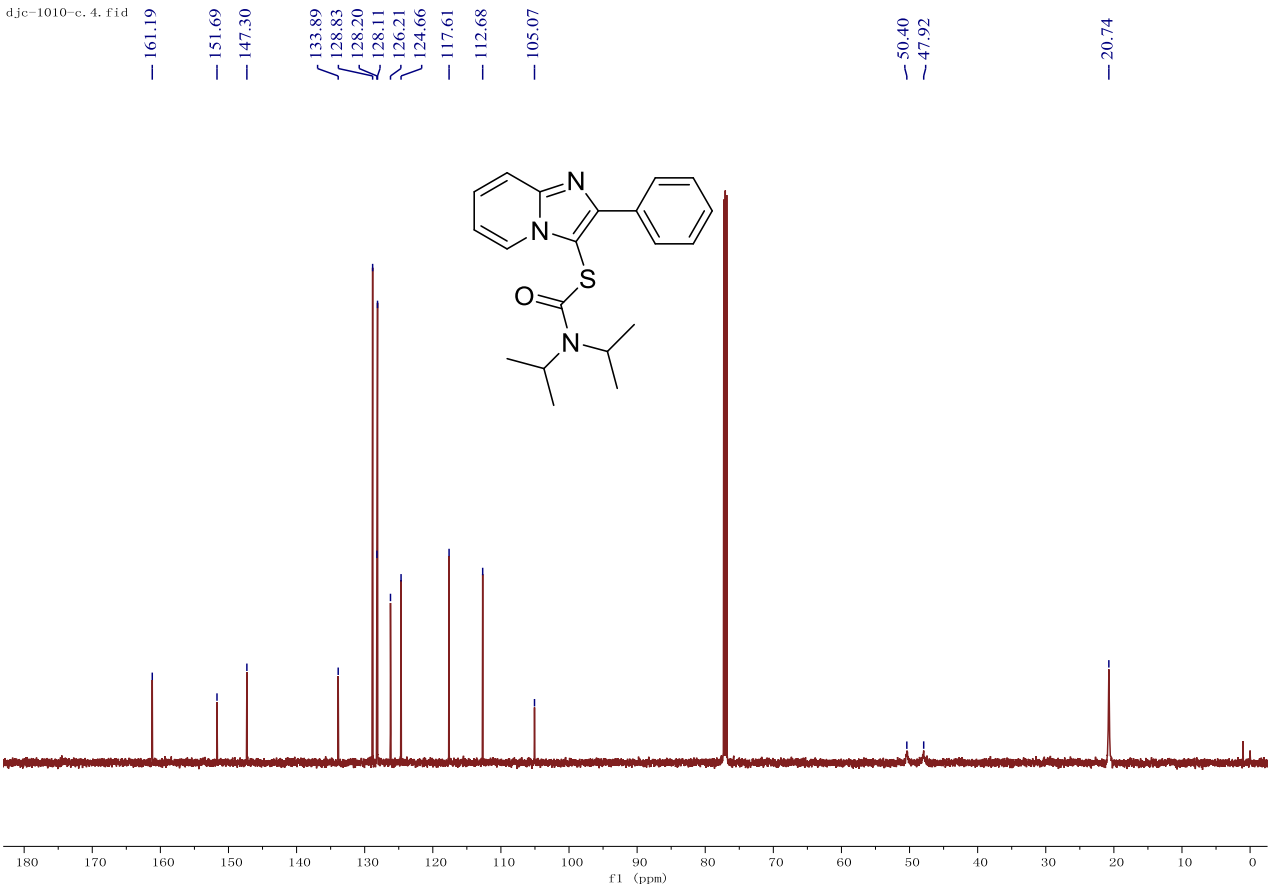
S-(2-phenylimidazo[1,2-*a*]pyridin-3-yl) diethylcarbamothioate (19)



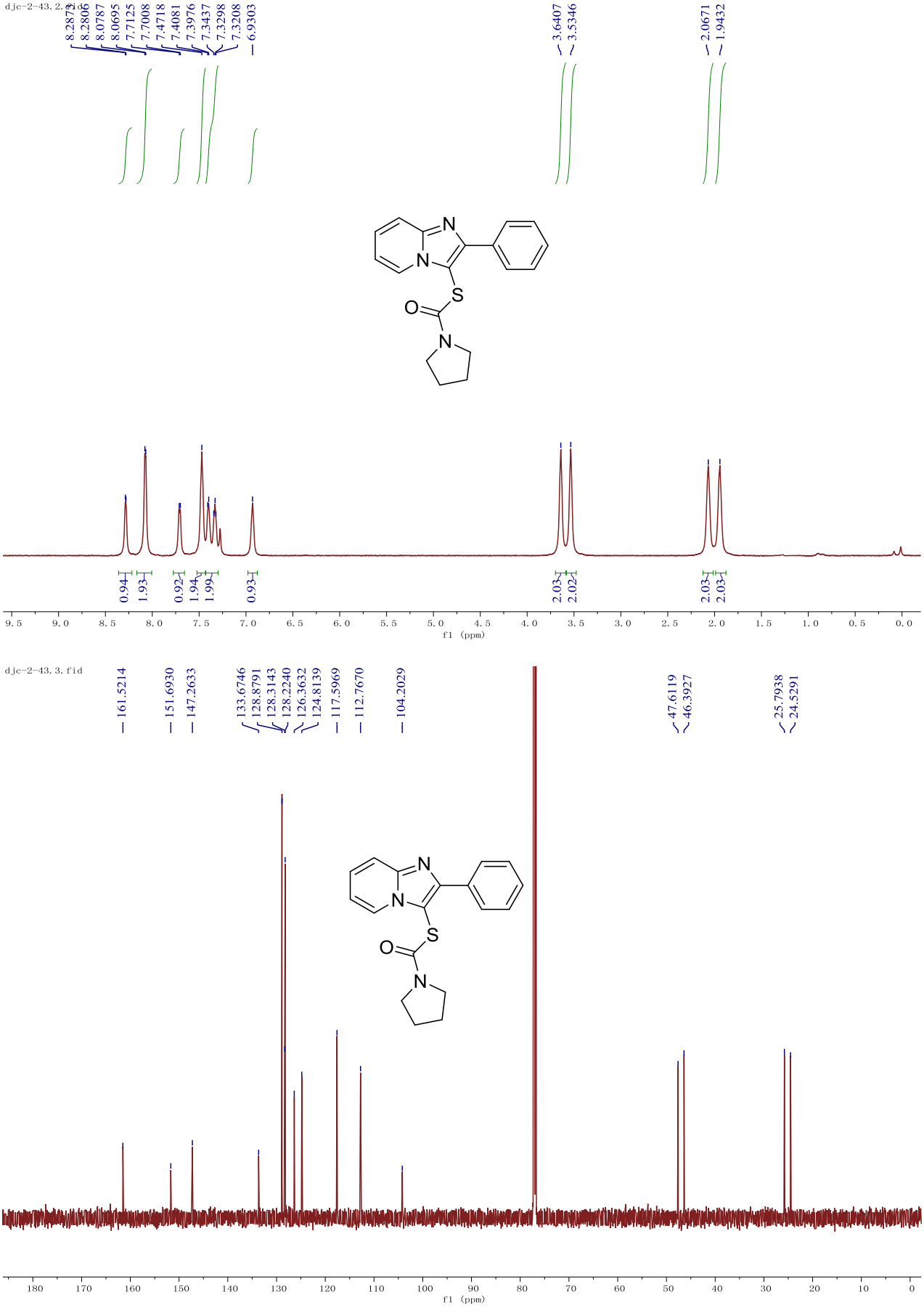


S-(2-phenylimidazo[1,2-*a*]pyridin-3-yl) diisopropylcarbamothioate (20)

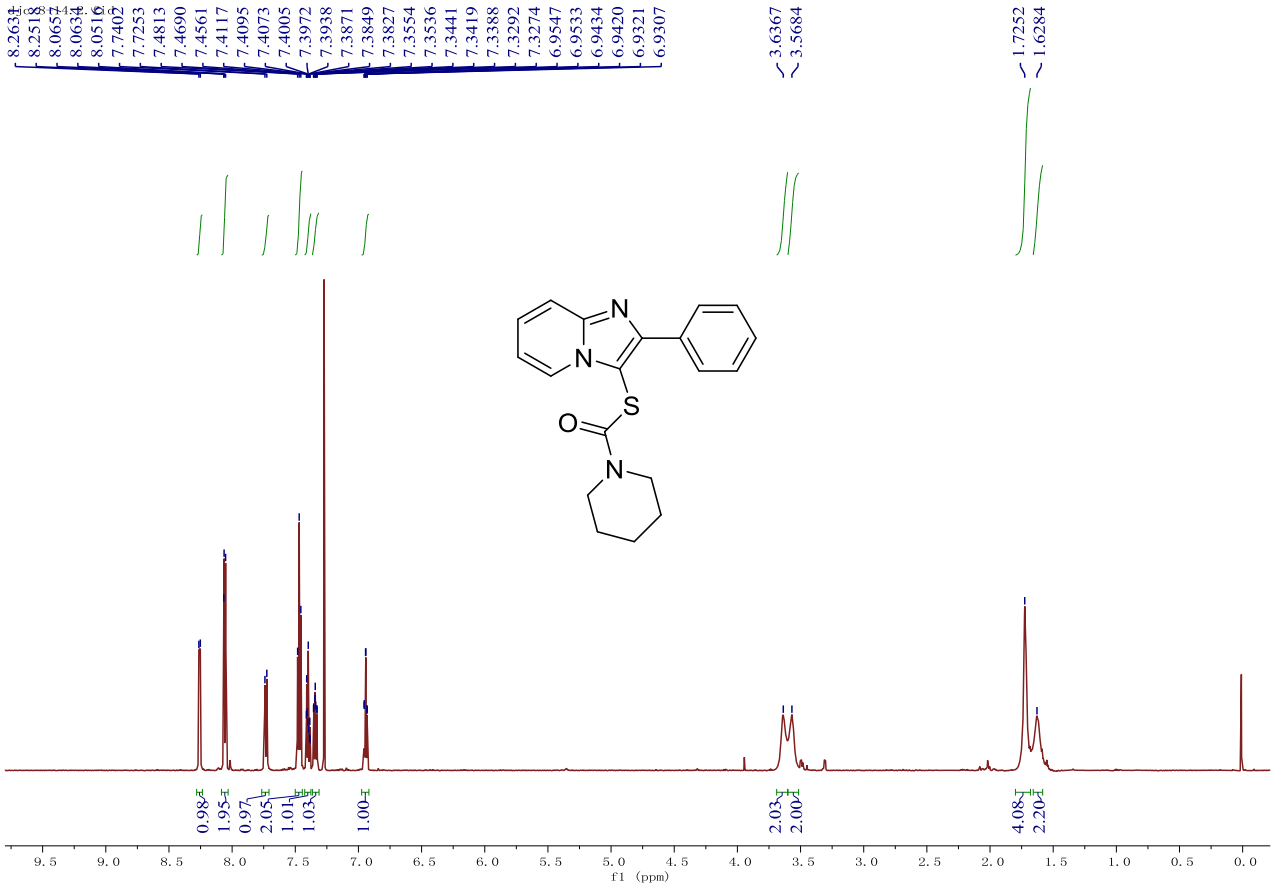


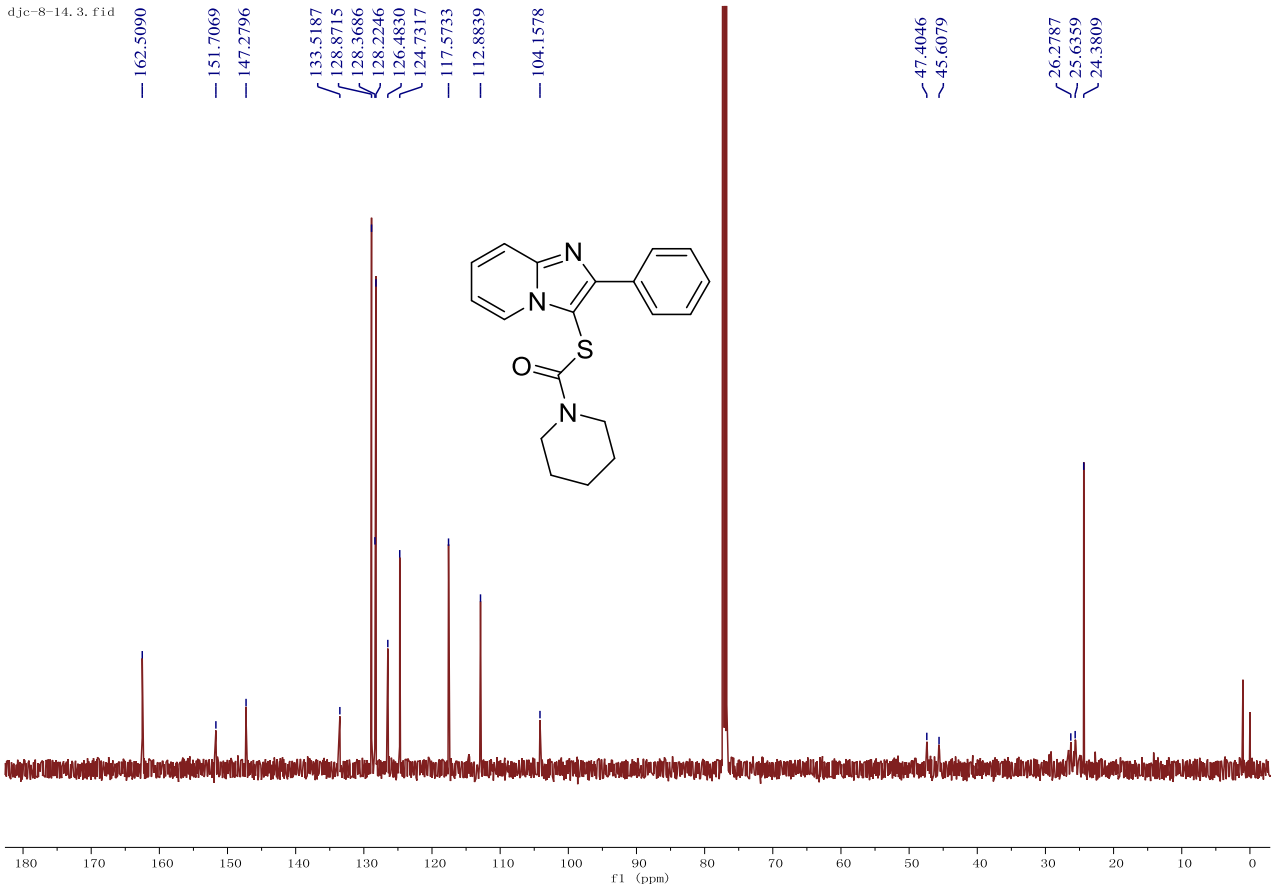


S-(2-phenylimidazo[1,2-*a*]pyridin-3-yl) pyrrolidine-1-carbothioate (21)

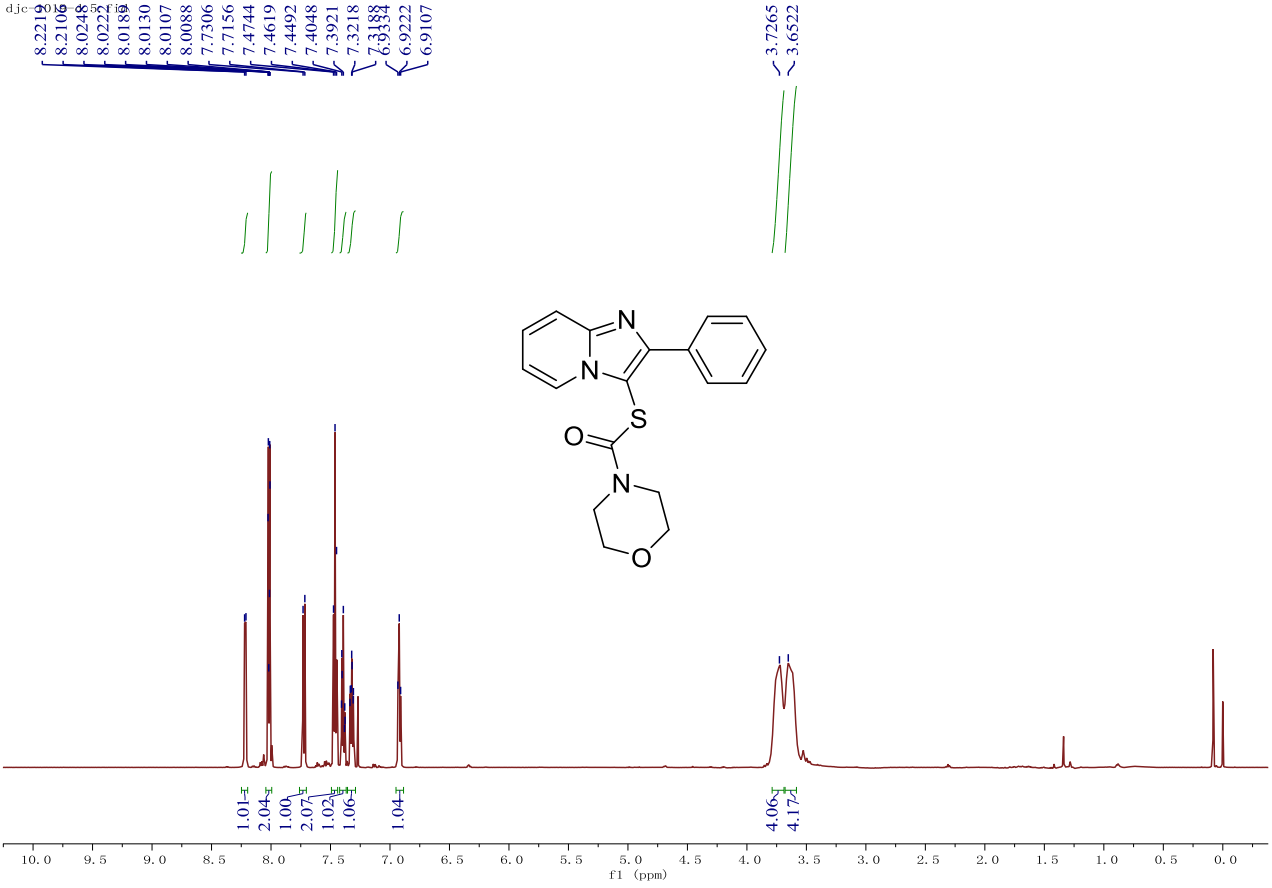


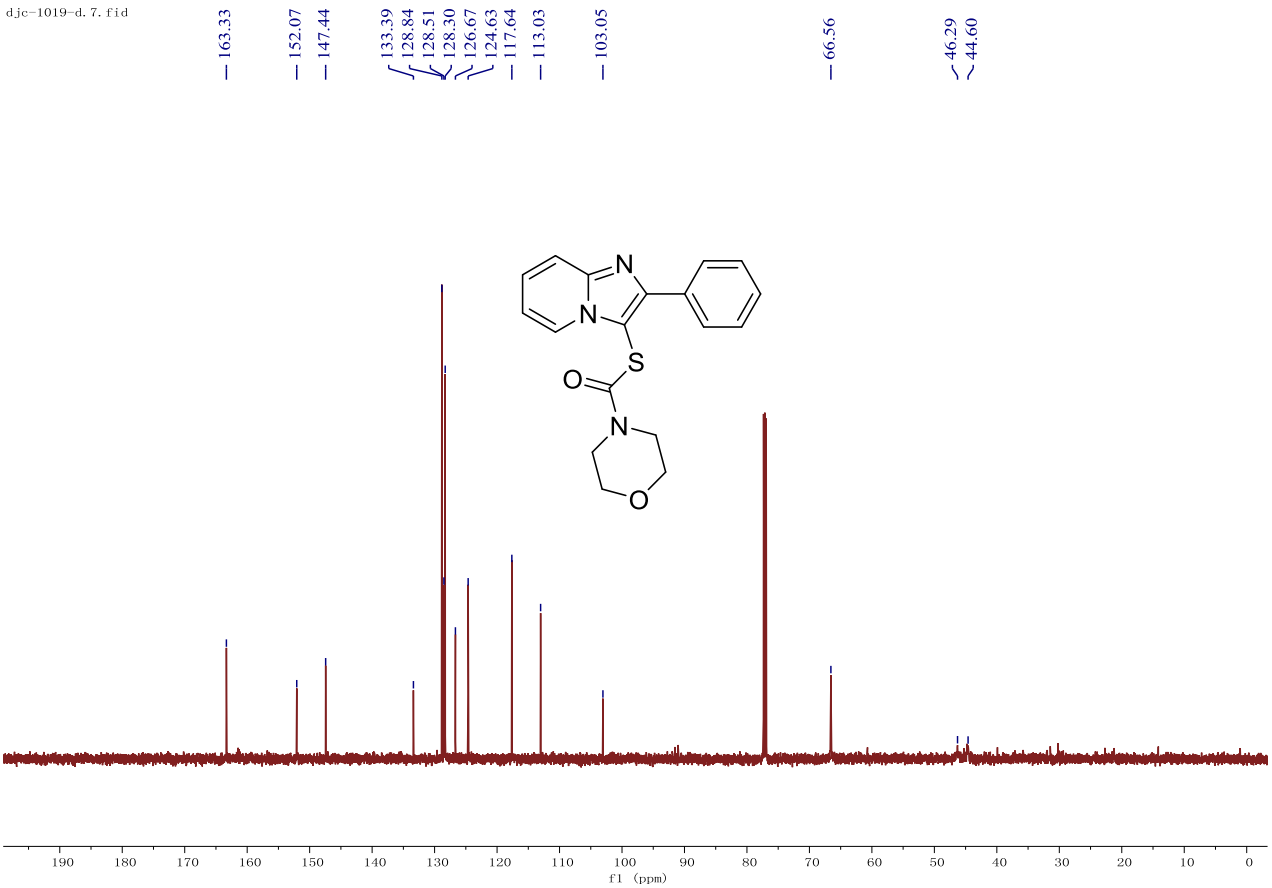
S-(2-phenylimidazo[1,2-*a*]pyridin-3-yl) piperidine-1-carbothioate (22)



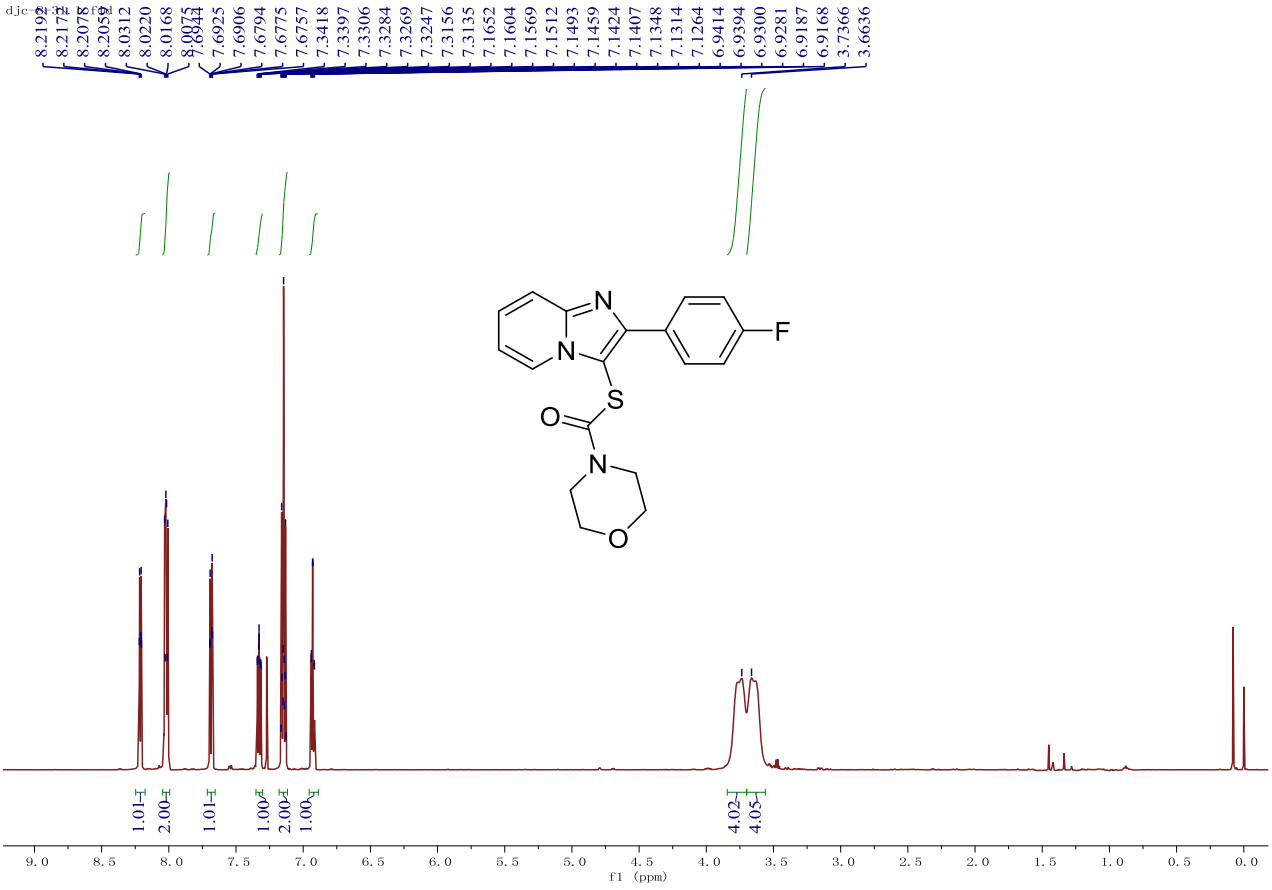


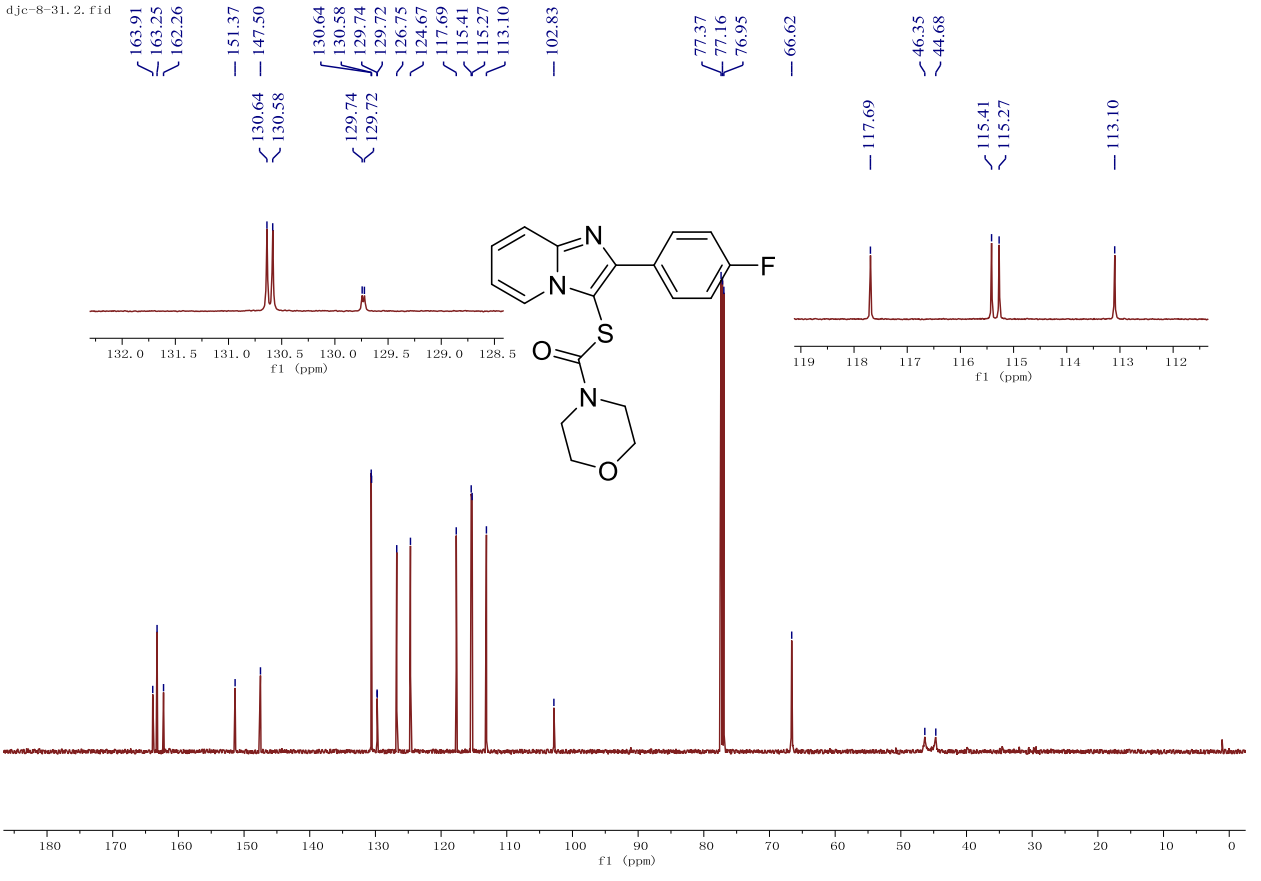
S-(2-phenylimidazo[1,2-*a*]pyridin-3-yl) morpholine-4-carbothioate (23)



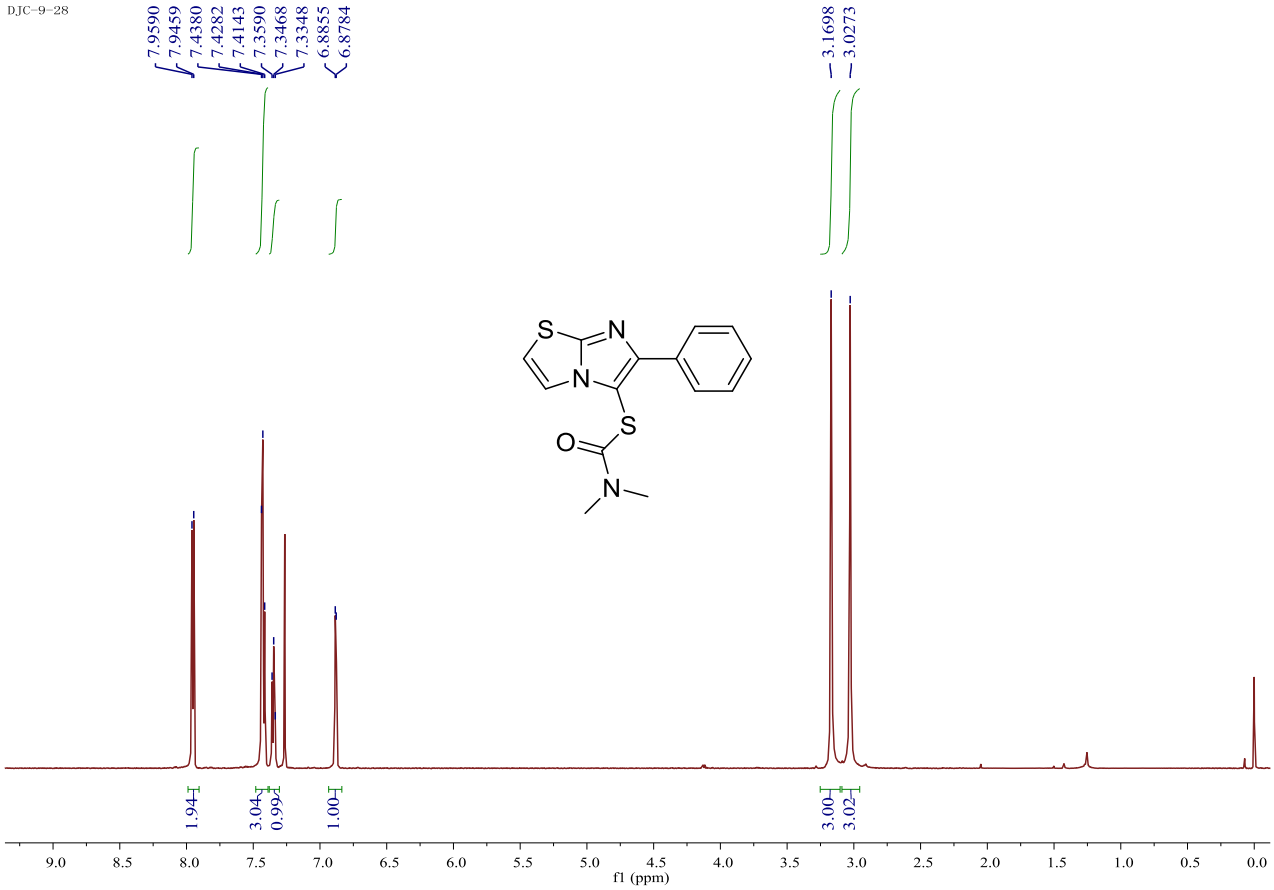


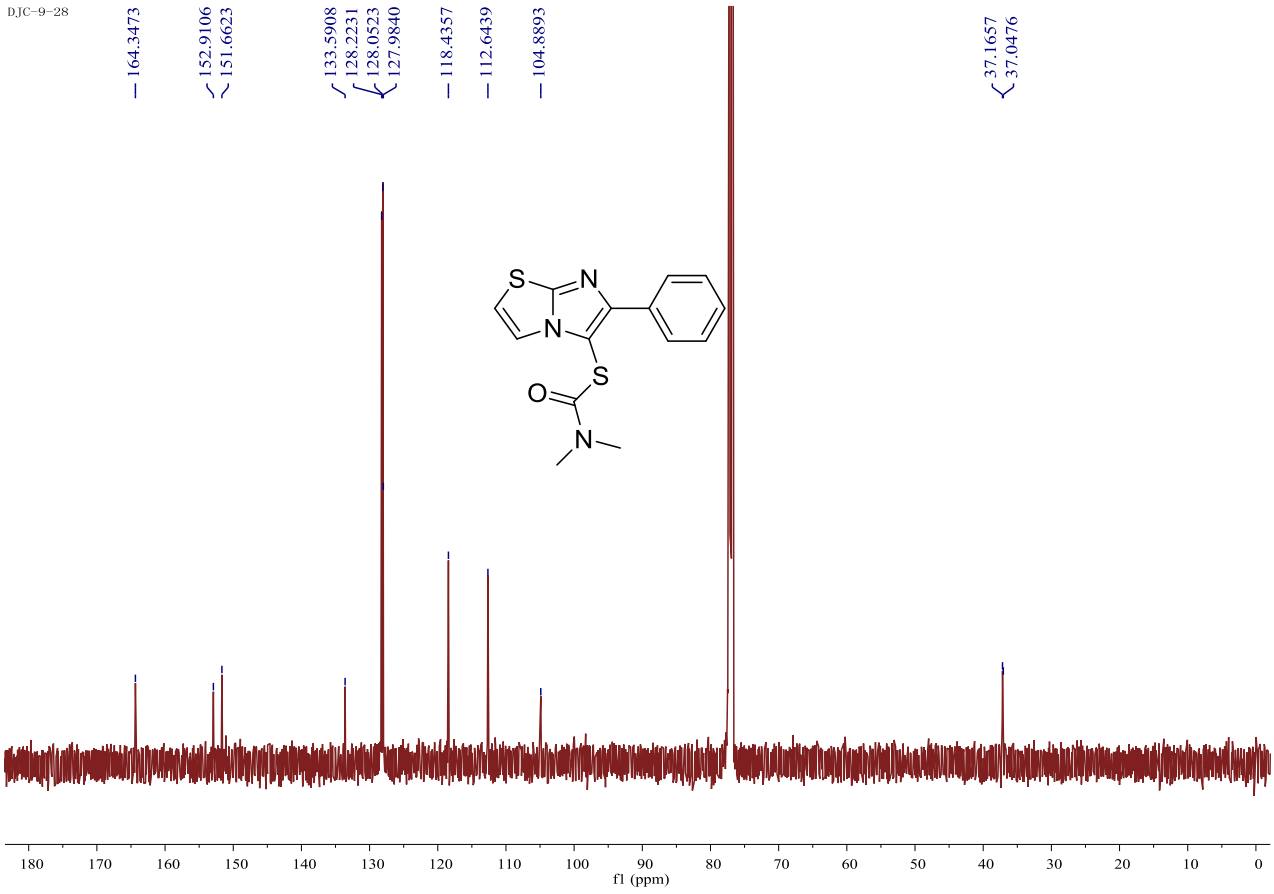
_S_-(2-(4-fluorophenyl)imidazo[1,2-_a_]pyridin-3-yl) morpholine-4-carbothioate (24)



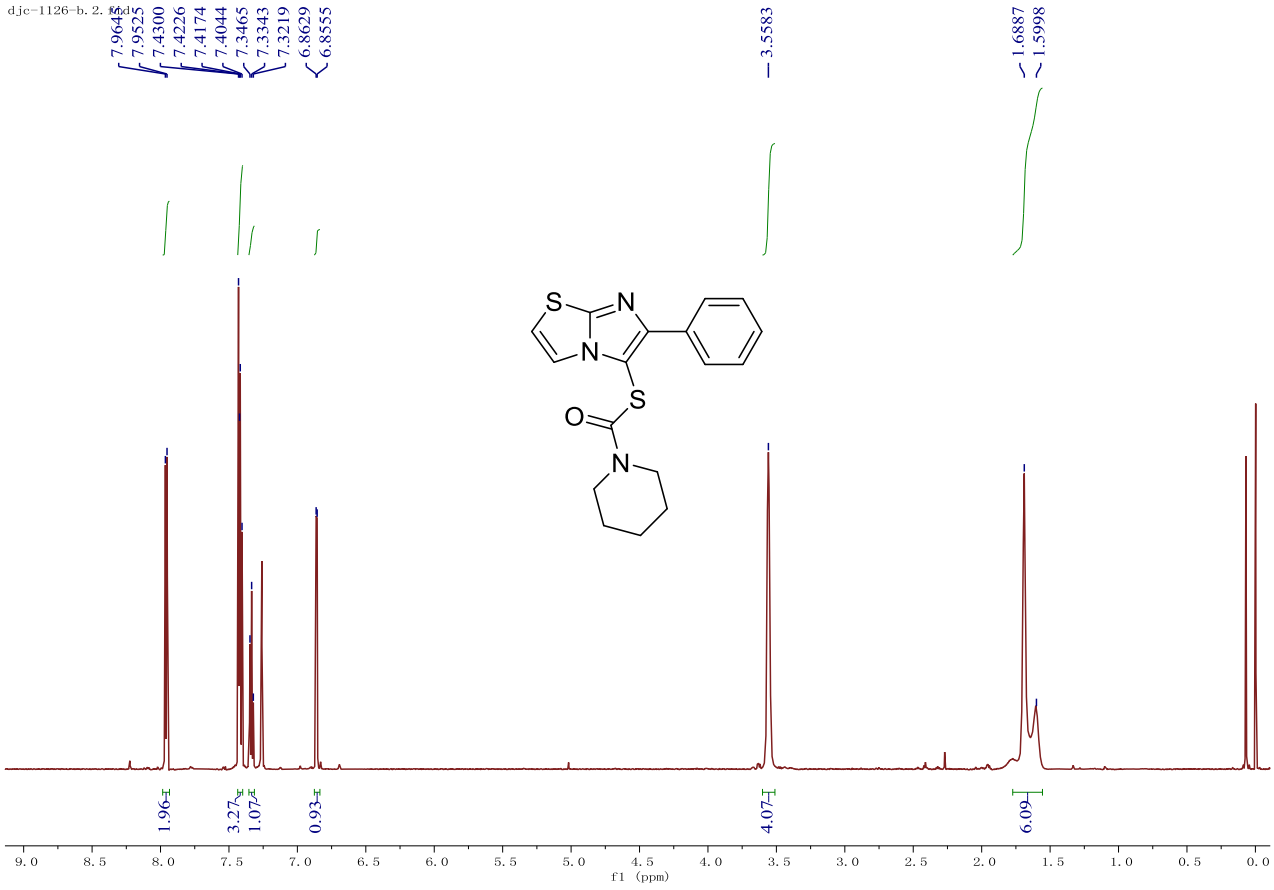


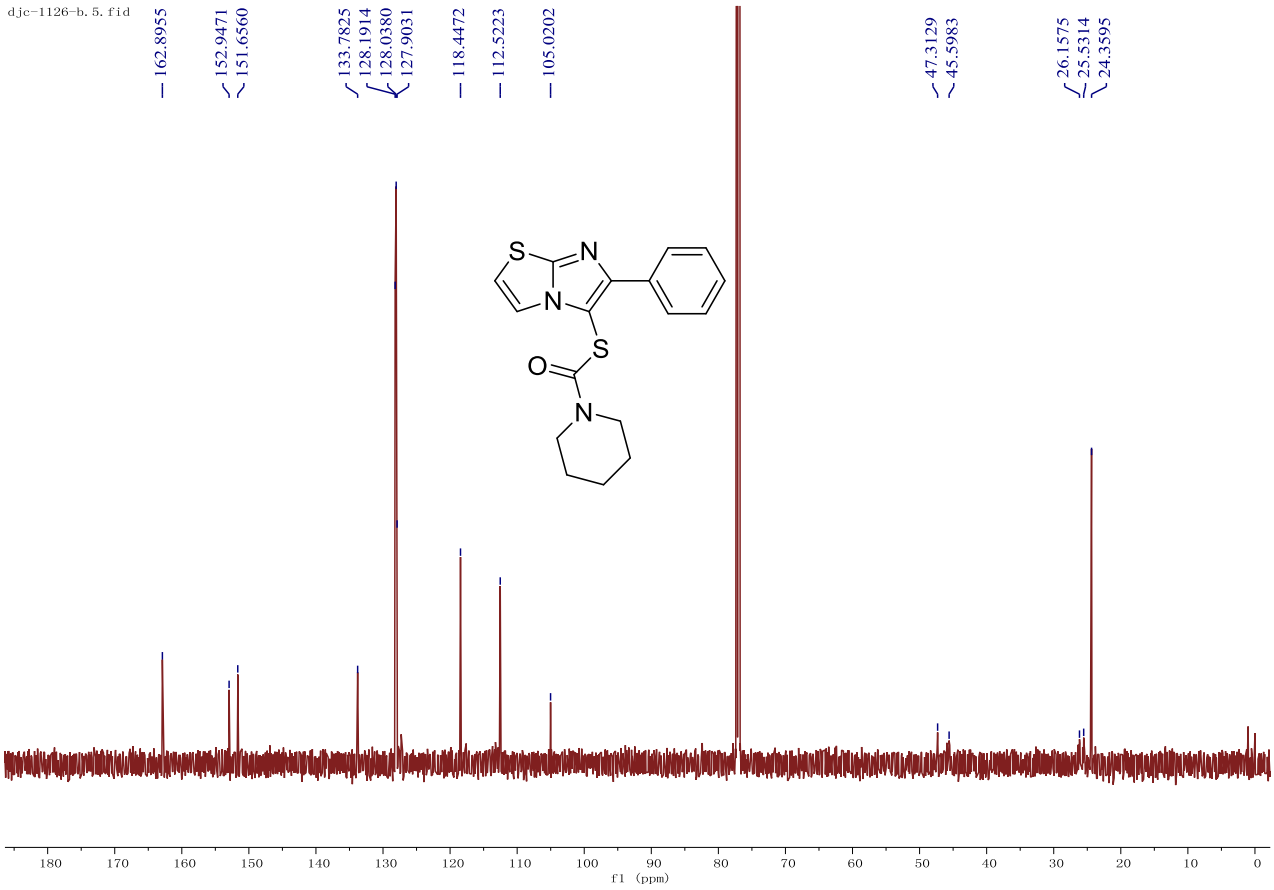
_S_-(6-phenylimidazo[2,1-_b_]thiazol-5-yl) dimethylcarbamothioate (25)



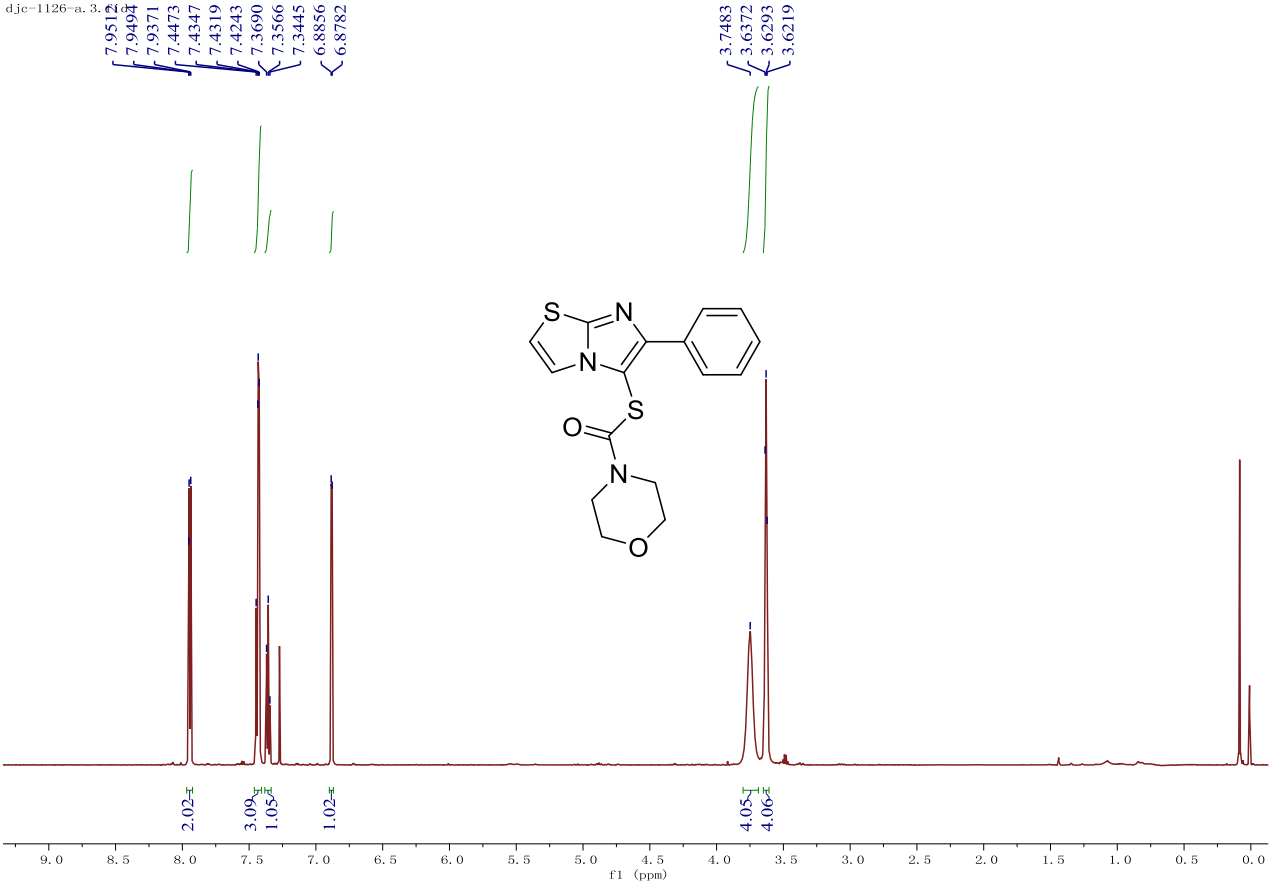


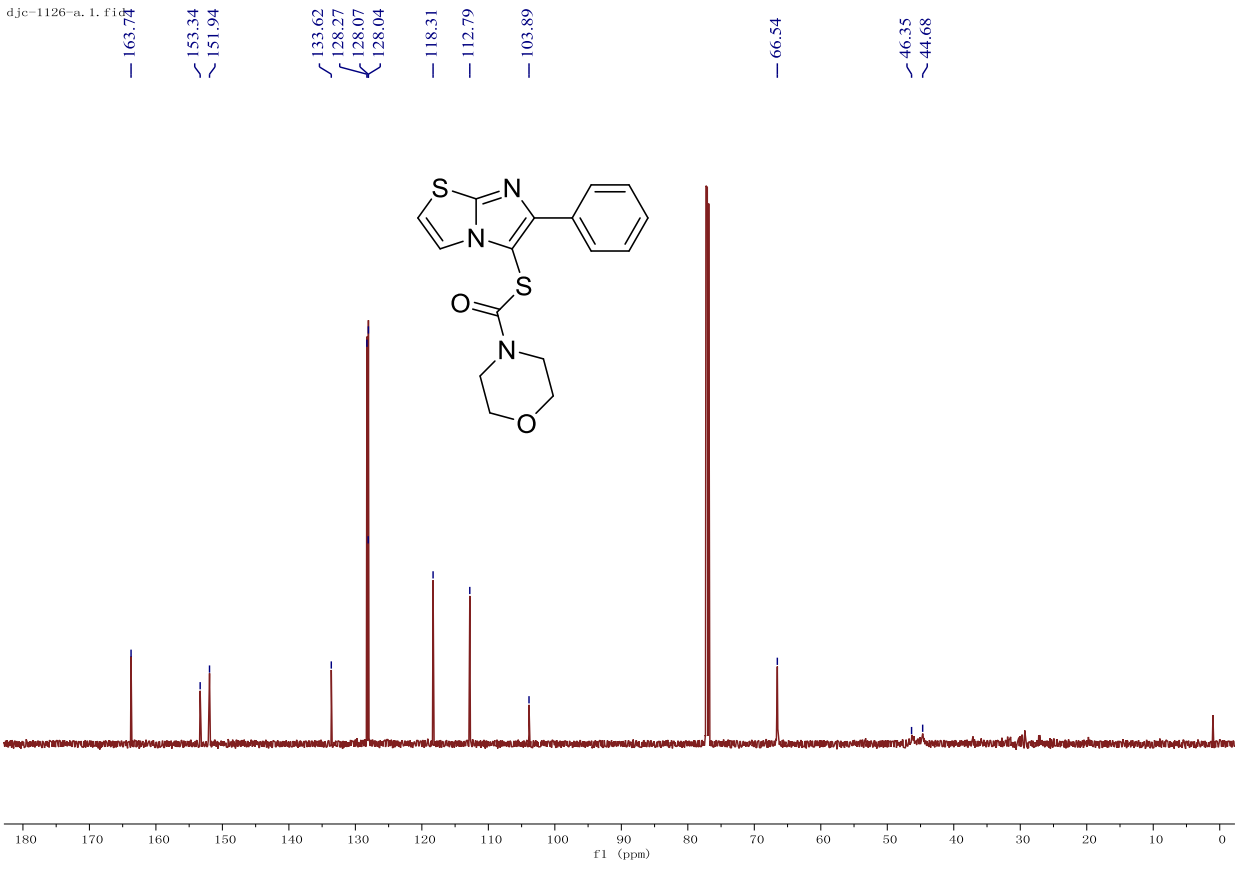
S-(6-phenylimidazo[2,1-*b*]thiazol-5-yl) piperidine-1-carbothioate (26)



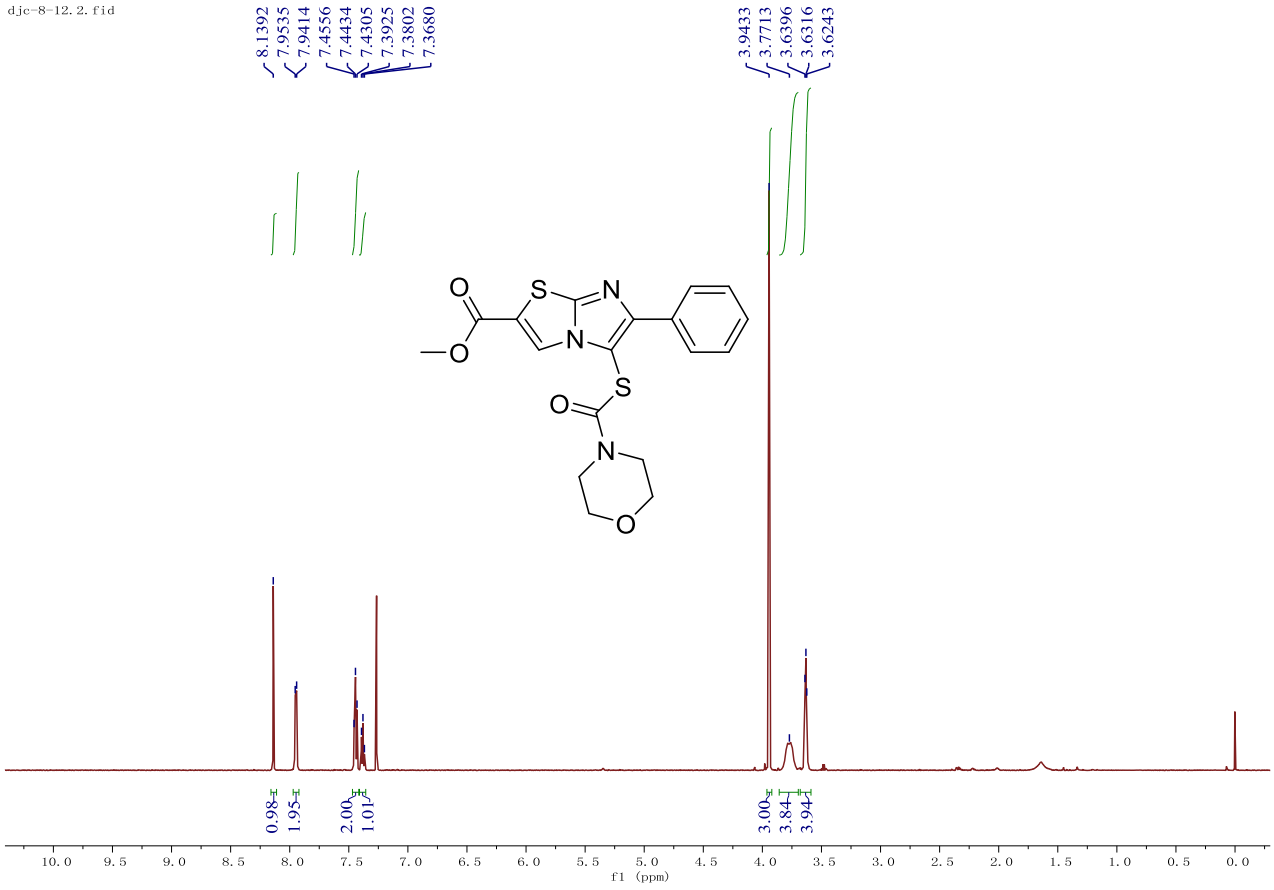


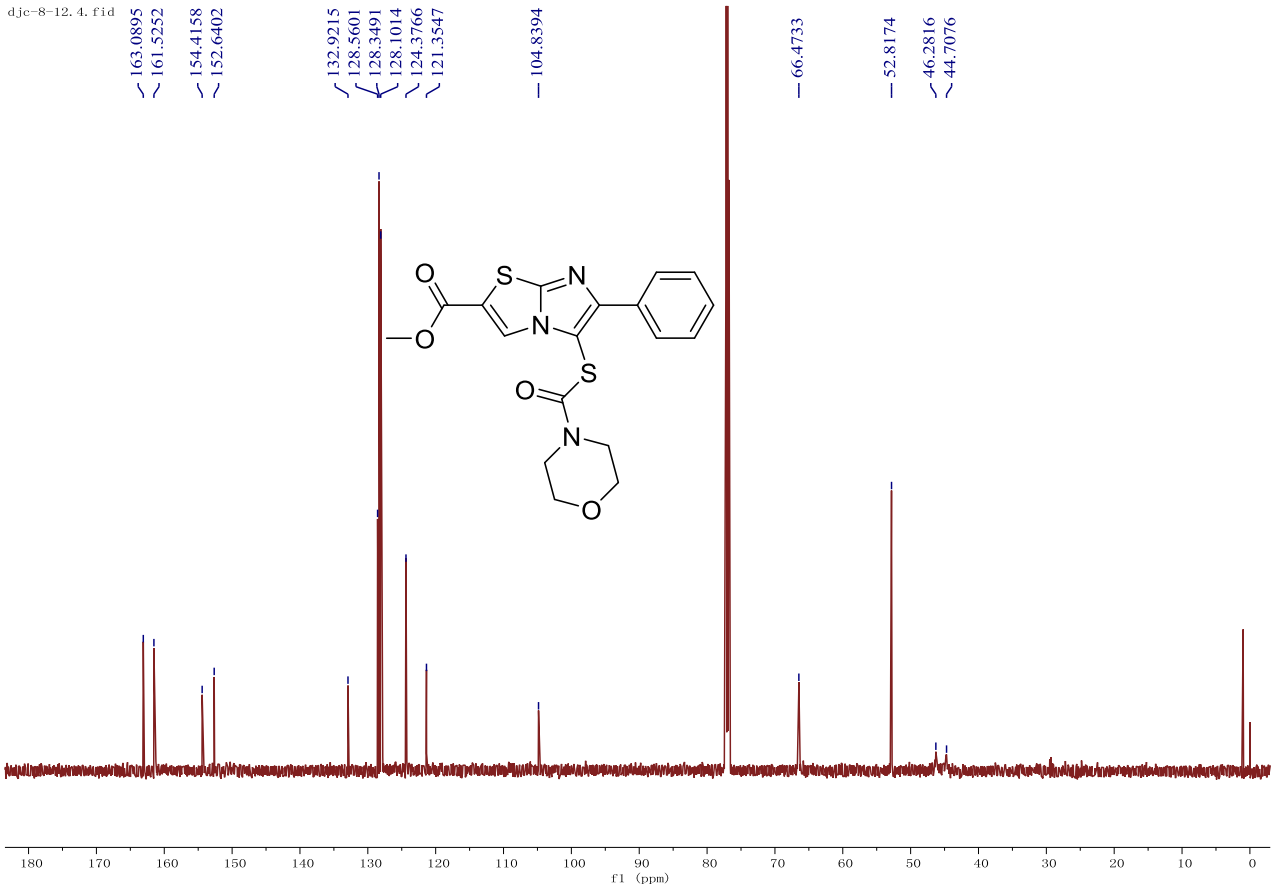
S-(6-phenylimidazo[2,1-*b*]thiazol-5-yl) morpholine-4-carbothioate (27)



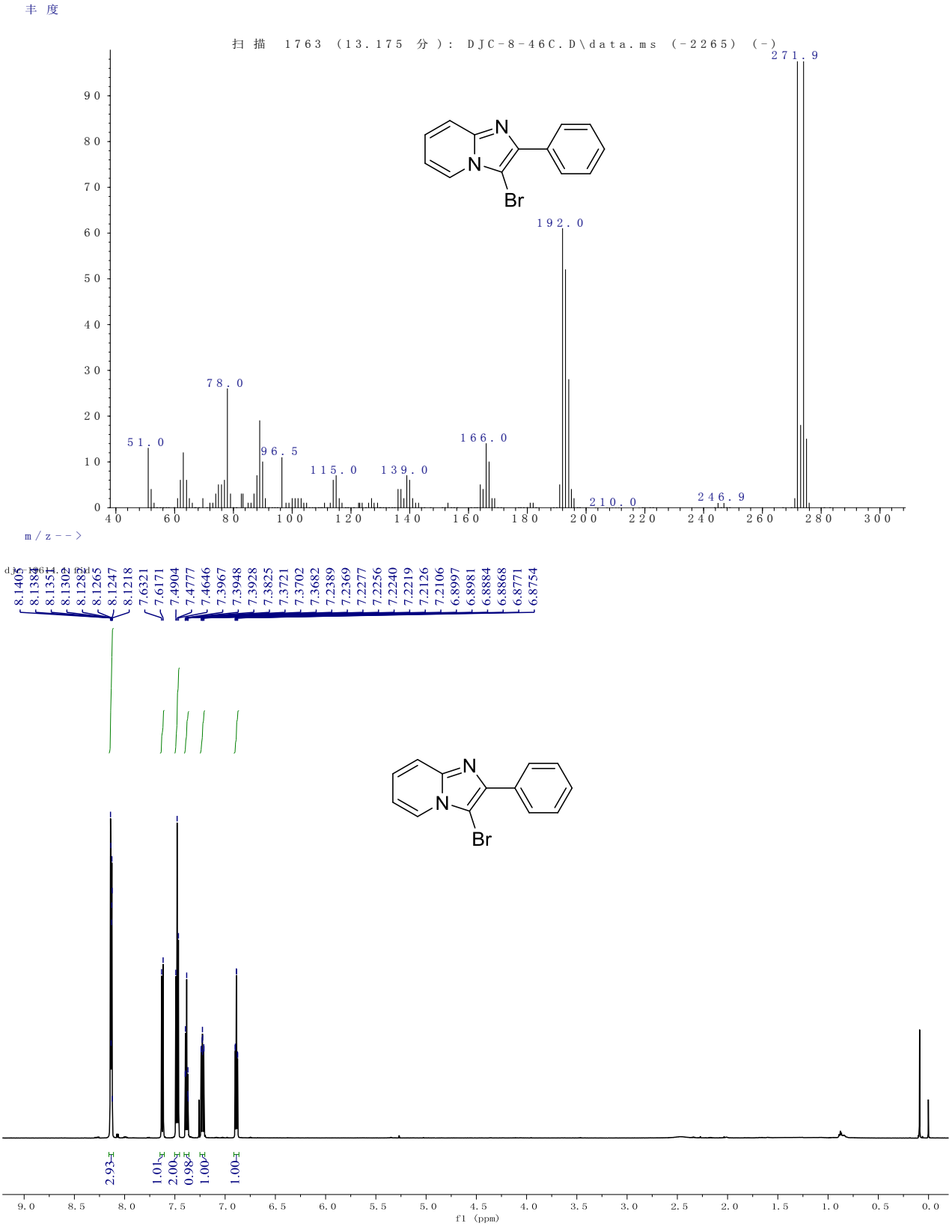


methyl 5-((morpholine-4-carbonyl)thio)-6-phenylimidazo[2,1-*b*]thiazole-2-carboxylate (28)





3-bromo-2-phenylimidazo[1,2-*a*]pyridine (30)



5 References

[1] J.-C. Deng, S.-B. Zhuang, Q.-Z. Liu, Z.-W. lin, Y.-S. Su, J.-H. Chen, and R.-Y. Tang, *RSC Adv.*, 2017, **7**, 54013-54016.

[2] E. S. Hand, and W. W. Paudler, *J. Org. Chem.*, 1978, 43, 658-663.