Supporting Information

An Efficient Synthesis of Polysubstituted Pyrroles via Copper-Catalyzed Coupling of Oxime Acetates with Dialkyl Acetylenedicarboxylates under Aerobic Conditions

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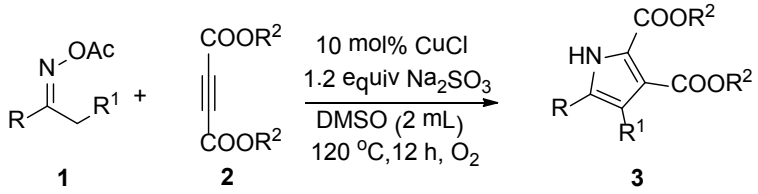
General Information

^{1}H and ^{13}C NMR spectra were recorded on BRUKER DRX-400 spectrometer using $CDCl_3$ as solvent and TMS as an internal standard. Gas chromatograph mass spectra were obtained with a SHIMADZU model GCMS-QP5000 spectrometer. High-resolution mass spectra (ESI) were obtained with a LCMS-IT-TOF mass spectrometer. Unless otherwise stated, all reagents and solvents were purchased from commercial suppliers and used without further purification. Oxime acetates were synthesized according to the literature procedure.

Typical Procedure for the Preparation of Oxime Acetates[1]

The mixture of ketoxime (3.0 mmol), acetic anhydride (6.0 mmol), was stirred at 100 ^{o}C for 3 h. The reaction mixture was cooled to room temperature, diluted with EtOAc (25 mL) and washed with H_2O (20 mL) and brine (10 mL). The organic layers were dried over anhydrous Na_2SO_4 and evaporated in vacuum. The residue was purified by column chromatography on silica gel to afford the oxime acetates **1** with hexane/ethyl acetate as the eluent.

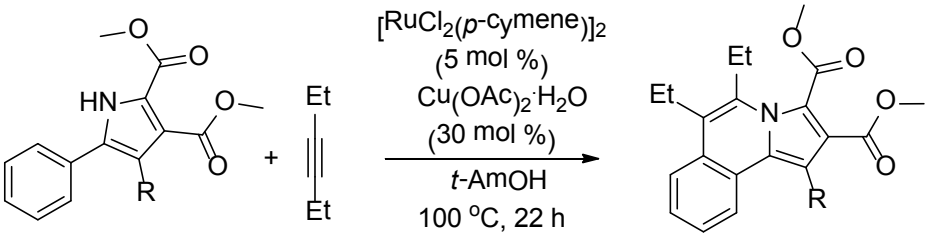
General Procedure for the Synthesis of Pyrroles



1 **2** **3**

The oxime acetates **1** (0.5 mmol), dialkyl acetylenedicarboxylates **2** (0.6 mmol), CuCl (10 mol %) and Na_2SO_3 (0.6 mmol) was stirred in DMSO (2.0 mL) at 120 ^{o}C, in a 20 mL tube with a balloon O_2 for 12 h. When the reaction was completed (detected by TLC), the mixture was cooled to room temperature. The reaction was quenched with H_2O (10 mL) and extracted with EtOAc (3 × 10 mL) or CH_2Cl_2 (3 × 10 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and then evaporated in vacuum. The residue was purified by column chromatography on silica gel to afford the corresponding pyrroles **3** with hexane/ethyl acetate as the eluent.

General Procedure for 4a, 4l



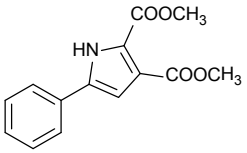
3a, R = H
3l, R = CH_3

4a, R = H, 88%
4l, R = CH_3, 90%

The mixture of **3a** (0.50 mmol), 3-hexyne (1 mmol), $[RuCl_2(p\text{-cymene})]_2$ (5 mol %) and $Cu(OAc)_2 \cdot H_2O$ (30 mol %) in *t*-AmOH (2 mL) was stirred at 100 °C under air for 22 h. At ambient temperature, the reaction mixture was diluted with H_2O (75 mL) and extracted with EtOAc (3 × 75 mL). The combined organic phase was washed with brine (50 mL) and dried over anhydrous Na_2SO_4. After filtration and evaporation of the solvents under reduced pressure, the

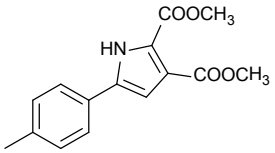
crude product was purified by column chromatography on silica gel to afford **4a**.

Analysis Data for Compounds 3a-3w, 4a, 4l



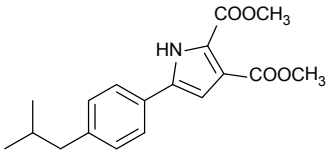
Dimethyl 5-Phenyl-1H-pyrrole-2,3-dicarboxylate (3a)[2]

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.63 (br, 1H), 7.56 (d, *J* = 7.2 Hz, 2H), 7.43 (t, *J* = 7.6 Hz, 2H), 7.34 (t, *J* = 7.4 Hz, 1H), 6.93 (d, *J* = 3.1 Hz, 1H), 3.93 (s, 3H), 3.90 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.3, 160.7, 134.8, 130.3, 129.2, 128.4, 124.9, 122.7, 121.5, 110.7, 52.3, 51.9. IR (KBr) ν (cm^{-1}) 3302, 2953, 1734, 1451, 1267, 1071, 827, 766. MS (EI, 70 eV) m/z (%): 259 (M+), 227, 196, 169, 140, 113, 102, 77.



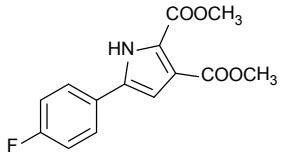
Dimethyl 5-(p-tolyl)-1H-pyrrole-2,3-dicarboxylate (3b)

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.65 (br, 1H), 7.46 (d, *J* = 8.1 Hz, 2H), 7.22 (d, *J* = 8.0 Hz, 2H), 6.89 (d, *J* = 3.0 Hz, 1H), 3.92 (s, 3H), 3.89 (s, 3H), 2.37 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.4, 160.7, 138.4, 135.1, 129.8, 127.5, 124.8, 122.3, 121.5, 110.3, 52.2, 51.9, 21.3. IR (KBr) ν (cm^{-1}) 3303, 2951, 1734, 1450, 1262, 1070, 816, 767. MS (EI, 70 eV) m/z (%): 273(M+), 241, 207, 183, 154, 127, 115, 77. HRMS-ESI (m/z): calcd for $C_{15}H_{15}NO_4$, $[M+Na]^+$: 296.0893; found, 296.0898.



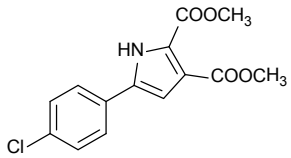
Dimethyl 5-(4-isobutylphenyl)-1H-pyrrole-2,3-dicarboxylate (3c)

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.58 (br, 1H), 7.47 (d, *J* = 8.1 Hz, 2H), 7.20 (d, *J* = 8.1 Hz, 2H), 6.89 (d, *J* = 3.1 Hz, 1H), 3.92 (s, 3H), 3.89 (s, 3H), 2.50 (d, *J* = 7.2 Hz, 2H), 1.89 (td, *J* = 13.3, 6.5 Hz, 1H), 0.92 (s, 3H), 0.91 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.3, 160.7, 142.3, 135.1, 129.9, 127.8, 124.7, 122.3, 121.5, 110.3, 52.2, 51.9, 45.1, 30.2, 22.3. IR (KBr) ν (cm^{-1}) 3304, 2954, 1736, 1451, 1267, 1071, 827, 768. MS (EI, 70 eV) m/z (%): 315 (M+), 283, 240, 207, 191, 133, 115, 96. HRMS-ESI (m/z): calcd for $C_{18}H_{21}NO_4$, $[M+Na]^+$: 338.1363; found, 338.1361.



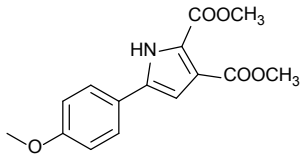
Dimethyl 5-(4-fluorophenyl)-1H-pyrrole-2,3-dicarboxylate (3d)[2]

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.62 (br, 1H), 7.58 - 7.51 (m, 2H), 7.17- 7.08 (m, 2H), 6.87 (d, *J* = 3.1 Hz, 1H), 3.93 (s, 3H), 3.89 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.2, 160. 7, 134.0, 126.8, 126.7, 122.7, 121.5, 116.4, 116.2, 110.6, 52.3, 52.0. IR (KBr) ν (cm^{-1}) 3296, 2954, 1735, 1452, 1264, 1072, 832, 767. MS (EI, 70 eV) m/z (%): 277 (M+), 245, 212, 187, 158, 133, 120, 107, 79.



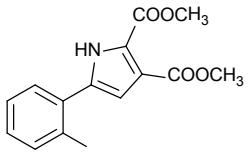
Dimethyl 5-(4-chlorophenyl)-1H-pyrrole-2,3-dicarboxylate (3e)[3]

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.68 (br, 1H), 7.50 (d, *J* = 8.6 Hz, 2H), 7.40 (d, *J* = 8.5 Hz, 2H), 6.91 (d, *J* = 3.1 Hz, 1H), 3.93 (s, 3H), 3.89 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.1, 160.6, 134.3, 133.7, 129.4, 128.8, 126.1, 123.0, 121.6, 111.0, 52.4, 52.0. IR (KBr) ν (cm^{-1}) 3302, 2952, 1736, 1451, 1281, 1072, 824, 766. MS (EI, 70 eV) m/z (%): 293 (M+), 261, 203, 174, 139, 115, 87, 75.



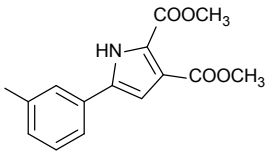
Dimethyl 5-(4-methoxyphenyl)-1H-pyrrole-2,3-dicarboxylate (3f)[4]

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.51 (br, 1H), 7.49 (d, *J* = 8.8 Hz, 2H), 6.95 (d, *J* = 8.8 Hz, 2H), 6.82 (d, *J* = 3.1 Hz, 1H), 3.92 (s, 3H), 3.89 (s, 3H), 3.84 (s, 2H) ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.4, 160.7, 159.8, 135.0, 126.3, 123.1, 122.1, 121.6, 114.6, 109.8, 55.4, 52.2, 51.9. IR (KBr) ν (cm^{-1}) 3302, 2950, 1733, 1449, 1264, 1069, 826, 765. MS (EI, 70 eV) m/z (%): 289(M+), 257, 242, 214, 170, 135, 113, 85, 77.



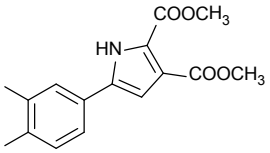
Dimethyl 5-(o-tolyl)-1H-pyrrole-2,3-dicarboxylate (3g)

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.43 (br, 1H), 7.36 (d, *J* = 6.6 Hz, 1H), 7.31- 7.24 (m, 3H), 6.74 (d, *J* = 3.1 Hz, 1H), 3.91 (s, 3H), 3.89 (s, 3H), 2.44 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.4, 160.6, 135.9, 134.4, 131.2, 130.4, 128.7, 128.6, 126.3, 122.1, 120.8, 113.5, 52.2, 51.9, 20. 9. IR (KBr) ν (cm^{-1}) 3294, 2953, 1736, 1446, 1257, 1070, 829, 763. MS (EI, 70 eV) m/z (%): 273 (M+), 241, 210, 183, 155, 127, 115, 91. HRMS-ESI (m/z): calcd for $C_{15}H_{15}NO_4$, $[M+Na]^+$: 296.0893; found, 296.0893.



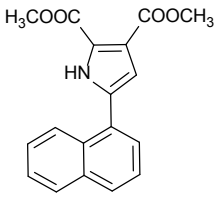
Dimethyl 5-(m-tolyl)-1H-pyrrole-2,3-dicarboxylate (3h)

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.61 (br, 1H), 7.40 - 7.29 (m, 3H), 7.16 (d, *J* = 7.5 Hz, 1H), 6.92 (d, *J* = 3.1 Hz, 1H), 3.93 (s, 3H), 3.89 (s, 3H), 2.40 (s, 3H); ^{13}C NMR (100MHz, $CDCl_3$) δ 164.3, 160. 7, 138.9, 135.00, 130.2, 129.2, 129.1, 125. 6, 122.5, 122.0, 121.5, 110.6, 52.3, 51.9, 21. 5. IR (KBr) ν (cm^{-1}) 3300, 2951, 1731, 1448, 1281, 1070, 834, 782. MS (EI, 70 eV) m/z (%): 273 (M+), 241, 207, 183, 154, 127, 115, 77. HRMS-ESI (m/z): calcd for $C_{15}H_{15}NO_4$, $[M+Na]^+$: 296.0893; found, 296.0898.



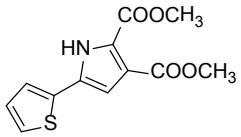
Dimethyl 5-(3,4-dimethylphenyl)-1H-pyrrole-2,3-dicarboxylate (3i)

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.54 (br, 1H), 7.33 (s, 1H), 7.29 (d, *J* = 7.8 Hz, 1H), 7.18 (d, *J* = 7.8 Hz, 1H), 6.88 (d, *J* = 3.1 Hz, 1H), 3.93 (s, 3H), 3.89 (s, 3H), 2.31 (s, 3H), 2.29 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.4, 160.7, 137.5, 137.2, 135.2, 130.4, 127.8, 126.1, 122.4, 122.3, 121.5, 110.2, 52.2, 51.9, 19.9, 19.6. IR (KBr) ν (cm^{-1}) 3301, 2949, 1733, 1450, 1264, 1070, 818, 766. MS (EI, 70 eV) m/z (%): 287 (M+), 255, 212, 182, 168, 128, 115, 105. HRMS-ESI (m/z): calcd for $C_{16}H_{17}NO_4$, $[M+Na]^+$: 310.1050; found, 310.1055.



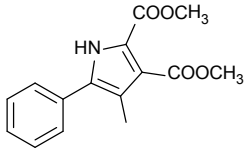
Dimethyl 5-(naphthalen-1-yl)-1H-pyrrole-2,3-dicarboxylate (3j)[2]

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.77 (br, 1H), 8.14 -8.11 (m, 1H), 7.93 - 7.86 (m, 2H), 7.59 -7.49 (m, 4H), 6.91 (d, *J* = 3.0 Hz, 1H), 3.91 (s, 3H), 3.84 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.4, 160.7, 133.9, 133.7, 131.2, 129.3, 128.9, 128.6, 127.1, 127.1, 126.4, 125.3, 125.0, 122.6, 121.0, 114.2, 52.2, 52.0. IR (KBr) ν (cm^{-1}) 3281, 2951, 1736, 1450, 1278, 1072, 833, 774. MS (EI, 70 eV) m/z (%): 309 (M^+), 277, 207, 190, 163, 127, 95.



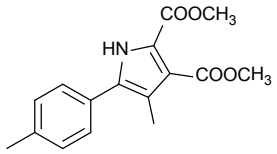
Dimethyl 5-(thiophen-2-yl)-1H-pyrrole-2,3-dicarboxylate (3k)[2]

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.49 (br, 1H), 7.29 (dd, *J* = 5.1, 1.0 Hz, 1H), 7.23 (dd, *J* = 3.6, 1.0 Hz, 1H), 7.07 (dd, *J* = 5.0, 3.7 Hz, 1H), 6.81 (d, *J* = 3.1 Hz, 1H), 3.93 (s, 3H), 3.89 (s, 3H). ^{13}C NMR (100MHz, $CDCl_3$) δ 164.0, 160.5, 133.1, 129.5, 128.0, 125.4, 123.9, 122.3, 121.5, 111.1, 52.3, 51.9. IR (KBr) ν (cm^{-1}) 3284, 2940, 1730, 1448, 1269, 1071. MS (EI, 70 eV) m/z (%): 265 (M^+), 233, 175, 146, 111, 87.



Dimethyl 4-methyl-5-phenyl-1H-pyrrole-2,3-dicarboxylate (3l)[5]

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.26 (br, 1H), 7.45 (d, *J* = 4.3 Hz, 4H), 7.39 - 7.35 (m, 1H), 3.92 (s, 3H), 3.85 (s, 3H), 2.26 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.1, 160.6, 133.1, 131.3, 128.9, 128.1, 127.6, 122.2, 120.4, 118.8, 52.0, 52.0, 10.8. IR (KBr) ν (cm^{-1}) 3285, 2951, 1721, 1442, 1255, 1082, 773. MS (EI, 70 eV) m/z (%): 273 (M^+), 241, 207, 183, 154, 127, 115, 77.



Dimethyl 4-methyl-5-(p-tolyl)-1H-pyrrole-2,3-dicarboxylate (3m)

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.31 (br, 1H), 7.34 (d, *J* = 8.1 Hz, 2H), 7.26 (d, *J* = 2.2 Hz, 2H), 3.91 (s, 3H), 3.84 (s, 3H), 2.39 (s, 3H), 2.24 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.2, 160.7, 138.1, 133.3, 129.6, 128.4, 127.5, 122.3, 120.1, 118.5, 51.9, 21.2, 10.8. IR (KBr) ν (cm^{-1}) 3297, 2951, 1725, 1445, 1253, 1084, 822, 772. MS (EI, 70 eV) m/z (%): 287 (M+), 255, 197, 169, 128, 84, 77. HRMS-ESI (m/z): calcd for $C_{16}H_{17}NO_4$, $[M+Na]^+$: 310.1050; found, 310.1047.

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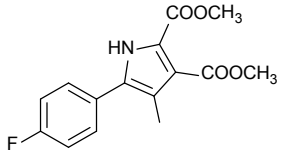
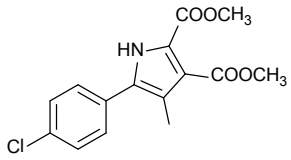


Dimethyl 5-(4-fluorophenyl)-4-methyl-1H-pyrrole-2,3-dicarboxylate (3n)

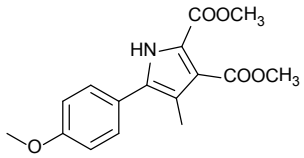
^{1}H NMR (400 MHz, $CDCl_3$) δ 9.22 (br, 1H), 7.47 -7.36 (m, 3H), 7.17-7.12 (m, 2H), 3.91 (s, 3H), 3.86 (s, 3H), 2.22 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.0, 163. 8, 161.3, 160.5, 132.2,

130.9, 129.6, 129.5, 127.4, 122.2, 120.5, 118.8, 116.1, 115.9, 52.0, 52.0, 10.7. IR (KBr) ν (cm^{-1}) 3282, 2959, 1735, 1455, 1295, 1089, 841, 742. MS (EI, 70 eV) m/z (%): 291 (M+), 259, 228, 201, 173, 146, 133, 86. HRMS-ESI (m/z): calcd for $C_{15}H_{14}FNO_4$, $[M+Na]^+$: 314.0799; found, 314.0801.



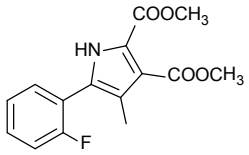
Dimethyl 5-(4-chlorophenyl)-4-methyl-1H-pyrrole-2,3-dicarboxylate (3o)

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.34 (br, 1H), 7.43-7.37 (m, 4H), 3.91 (s, 3H), 3.85 (s, 3H), 2.23 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.9, 160.6, 134.1, 131.9, 129.7, 129.1, 128.9, 122.3, 120.7, 119.1, 52.0, 52.0, 10.8. IR (KBr) ν (cm^{-1}) 3286, 2952, 1729, 1444, 1287, 1088, 833, 743. MS (EI, 70 eV) m/z (%): 307 (M+), 275, 244, 189, 154, 115, 94, 77. HRMS-ESI (m/z): calcd for $C_{15}H_{14}ClNO_4$, $[M+Na]^+$: 330.0504; found, 330.0506.



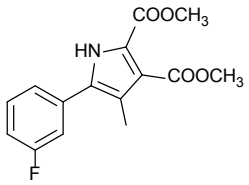
Dimethyl 5-(4-methoxyphenyl)-4-methyl-1H-pyrrole-2,3-dicarboxylate (3p)

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.13 (br, 1H) 7.29 (d, *J* = 8.8 Hz, 2H), 6.90 (d, *J* = 8.8 Hz, 2H), 3.84 (s, 3H), 3.77 (s, 6H), 2.15 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.2, 160.6, 159.6, 133.2, 129.0, 123.8, 122.2, 119.9, 118.2, 114.4, 55.4, 51.9, 51.9, 10.7. IR (KBr) ν (cm^{-1}) 3297, 2951, 1724, 1444, 1282, 1084, 834, 771. MS (EI, 70 eV) m/z (%): 303 (M+), 271, 185, 170, 135, 115, 92, 77. HRMS-ESI (m/z): calcd for $C_{16}H_{17}NO_5$, $[M+Na]^+$: 326.0999; found, 326.1000.



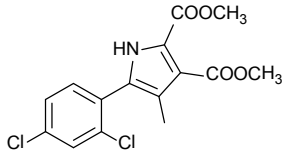
Dimethyl 5-(2-fluorophenyl)-4-methyl-1H-pyrrole-2,3-dicarboxylate (3q)

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.36 (br, 1H), 7.46-7.41 (m, 1H), 7.39-7.33 (m, 1H), 7.25 - 7.16 (m, 3H), 3.92 (s, 3H), 3.86 (s, 3H), 2.22 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.8, 160.9, 159.9, 158.3, 130.5, 130.5, 130.0, 129.9, 126.9, 124.5, 124.4, 121.6, 121.1, 120.7, 116.4, 116.2, 52.0, 51.9, 10.9. IR (KBr) ν (cm^{-1}) 3291, 2952, 1724, 1446, 1211, 1084, 809, 762. MS (EI, 70 eV) m/z (%): 291 (M+), 259, 228, 201, 173, 146, 133, 86, 75. HRMS-ESI (m/z): calcd for $C_{15}H_{14}FNO_4$, $[M+Na]^+$: 314.0799; found, 314.0805.



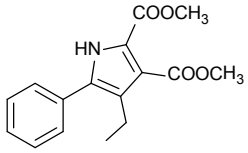
Dimethyl 5-(3-fluorophenyl)-4-methyl-1H-pyrrole-2,3-dicarboxylate (3r)

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.44 (br, 1H), 7.41 (dd, *J* = 14.0, 7.9 Hz, 1H), 7.17 (d, *J* = 9.7 Hz, 1H), 7.06 (t, *J* = 8.4 Hz, 1H), 3.91 (s, 3H), 3.85 (s, 3H), 2.26 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.9, 164.2, 160.6, 131.8, 130.6, 130.5, 123.3, 123.2, 122.3, 120.8, 119.3, 115.1, 114.9, 114.7, 114.4, 52.1, 52.0, 10.7. IR (KBr) ν (cm^{-1}) 3283, 2954, 1720, 1444, 1269, 1084, 806, 769. MS (EI, 70 eV) m/z (%): 291 (M+), 259, 201, 173, 146, 113, 87, 77. HRMS-ESI (m/z): calcd for $C_{15}H_{14}FNO_4$, $[M+Na]^+$: 314.0799; found, 314.0805.



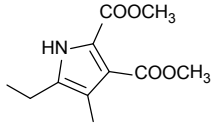
Dimethyl 5-(2,4-dichlorophenyl)-4-methyl-1H-pyrrole-2,3-dicarboxylate (3s)

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.38 (br, 1H), 7.51 (d, *J* = 1.8 Hz, 1H), 7.32 (d, *J* = 6.4 Hz, 1H), 7.26 (s, 1H), 3.91 (s, 3H), 3.84 (s, 3H), 2.09 (s, 3H) ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.7, 160.4, 135.4, 134.6, 132.8, 130.1, 128.9, 128.5, 127.3, 121.3, 121.0, 52.0, 51.9, 10.7. IR (KBr) ν (cm^{-1}) 3287, 2951, 1725, 1446, 1286, 1091, 828, 772. MS (EI, 70 eV) m/z (%): 341 (M+), 309, 277, 251, 223, 188, 139, 111. HRMS-ESI (m/z): calcd for $C_{15}H_{13}Cl_2NO_4$, $[M+Na]^+$: 364.0114; found, 364.0119.



Dimethyl 4-ethyl-5-phenyl-1H-pyrrole-2,3-dicarboxylate (3t)[2]

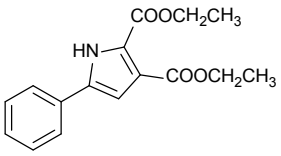
^{1}H NMR (400 MHz, $CDCl_3$) δ 9.19 (br, 1H), 7.48-7.42 (m, 4H), 7.40-7.31 (m, 1H), 3.92 (s, 3H), 3.85 (s, 3H), 2.67 (q, *J* = 7.5 Hz, 2H), 1.16 (t, *J* = 7.5 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.4, 160.5, 132.9, 131.4, 129.0, 128.2, 127.8, 125.3, 121.7, 120.3, 52.1, 52.0, 18.2, 15.9. IR (KBr) ν (cm^{-1}) 3294, 2955, 1726, 1448, 1280, 1093, 771. MS (EI, 70 eV) m/z (%): 287 (M+), 255, 240, 223, 195, 169, 115, 77.



Dimethyl 5-ethyl-4-methyl-1H-pyrrole-2,3-dicarboxylate (3u)[2]

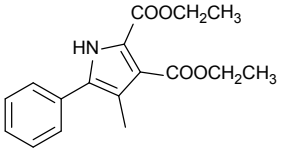
^{1}H NMR (400 MHz, $CDCl_3$) δ 8.99 (br, 1H), 3.81 (s, 3H), 3.77 (s, 3H), 2.52 (q, *J* = 7.6 Hz, 2H), 2.00 (s, 3H), 1.14 (t, *J* = 7.6 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.3, 160.7, 135.4, 121.2,

118.6, 117.6, 51.8, 51.8, 19.0, 13.3, 9.5. IR (KBr) ν (cm^{-1}) 3306, 2954, 1726, 1444, 1279, 1084, 771. MS (EI, 70 eV) m/z (%): 225 (M+), 193, 178, 135, 107, 77.



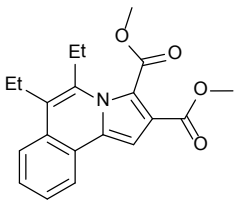
Diethyl 5-phenyl-1H-pyrrole-2,3-dicarboxylate (3v)

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.65 (br, 1H), 7.57 (d, *J* = 7.3 Hz, 2H), 7.42 (dd, *J* = 7.6 Hz, 2H), 7.33 (dd, *J* = 7.4 Hz, 1H), 6.91 (d, *J* = 3.0 Hz, 1H), 4.37 (q, *J* = 7.1 Hz, 4H), 1.39 (t, *J* = 7.1 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.1, 160.4, 134.7, 130.4, 129.1, 128.3, 124.9, 122.8, 122.0, 110.5, 61.2, 60.7, 14.3. IR (KBr) ν (cm^{-1}) 3302, 2982, 1731, 1474, 1267, 1065, 827, 765. MS (EI, 70 eV) m/z (%): 287 (M+), 241, 169, 140, 115, 102, 77. HRMS-ESI (m/z): calcd for $C_{17}H_{19}NO_4$, $[M+Na]^+$: 324.1206; found, 324.1212.



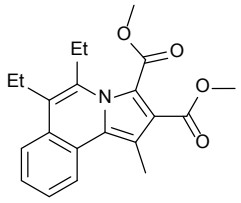
Diethyl 4-methyl-5-phenyl-1H-pyrrole-2,3-dicarboxylate (3w)[6]

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.38 (br, 1H), 7.47-7.43 (m, 4H), 7.37-7.34 (m, 1H), 4.38 (q, *J* = 7.1 Hz, 2H), 4.29 (q, *J* = 7.1 Hz, 2H), 2.25 (s,3H), 1.39 (t, *J* = 7.1 Hz, 3H), 1.32 (t, *J* = 7.1 Hz, 3H) ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.8, 160.4, 133.1, 131.5, 128.8, 128.0, 127.7, 122.6, 120.4, 118.4, 60.9, 14.3, 10. 7. IR (KBr) ν (cm^{-1}) 3290, 2980, 1722, 1434, 1250, 1032, 768. MS (EI, 70 eV) m/z (%): 301 (M+), 255, 183, 155, 116, 104, 77.



Dimethyl 5,6-diethylpyrrolo[2,1-a]isoquinoline-2,3-dicarboxylate (4a)

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 - 7.96 (m, 1H), 7.70 - 7.64 (m, 1H), 7.40-7.37 (m, 2H), 7.31 (s, 1H), 3.95 (s, 3H), 3.82 (s, 3H), 2.92 (q, *J* = 7.5 Hz, 2H), 2.84 (q, *J* = 7.5 Hz, 2H), 1.22-1.17 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.7, 164.6, 135.0, 131.5, 127.1, 127.0, 126.8, 125.3, 123.7, 123.1, 122.8, 122.1, 118.4, 101.3, 53.4, 51.8, 22.0, 20.9, 14.6, 12.8. IR (KBr) ν (cm^{-1}) 2929, 1722, 1449, 1382, 1218, 753. MS (EI, 70 eV) m/z (%): 339(M+), 307, 280, 249, 220, 204, 165, 102, 95. HRMS-ESI (m/z): calcd for $C_{20}H_{21}NO_4$, $[M+Na]^+$: 362.1363; found, 362.1356.



Dimethyl 5,6-diethyl-1-methylpyrrolo[2,1-a]isoquinoline-2,3-dicarboxylate (4l)

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.33 (d, *J* = 7.5 Hz, 1H), 7.78 (d, *J* = 7.7 Hz, 1H), 7.52 - 7.41 (m, 2H), 3.96 (s, 3H), 3.89 (s, 3H), 3.02 (q, *J* = 7.5 Hz, 2H), 2.91 (q, *J* = 7.5 Hz, 2H), 2.82 (s, 3H), 1.27 (t, *J* = 7.5 Hz, 3H), 1.20 (t, *J* = 7.5 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.8, 165.5, 135.2, 128.3, 127.7, 127.0, 126.6, 126.1, 123.6, 123.5, 122.9, 120.7, 119.5, 113.9, 53.0, 51.8, 22.1, 21.2, 14.5, 13.5, 12.6. IR (KBr) ν (cm^{-1}) 2952, 1719, 1451, 1220, 1058, 758. MS (EI, 70 eV) m/z (%): 353 (M+), 322, 290, 261, 234, 220, 108, 95. HRMS-ESI (m/z): calcd for $C_{21}H_{23}NO_4$, $[M+Na]^+$: 376.1519; found, 376.1511.

References

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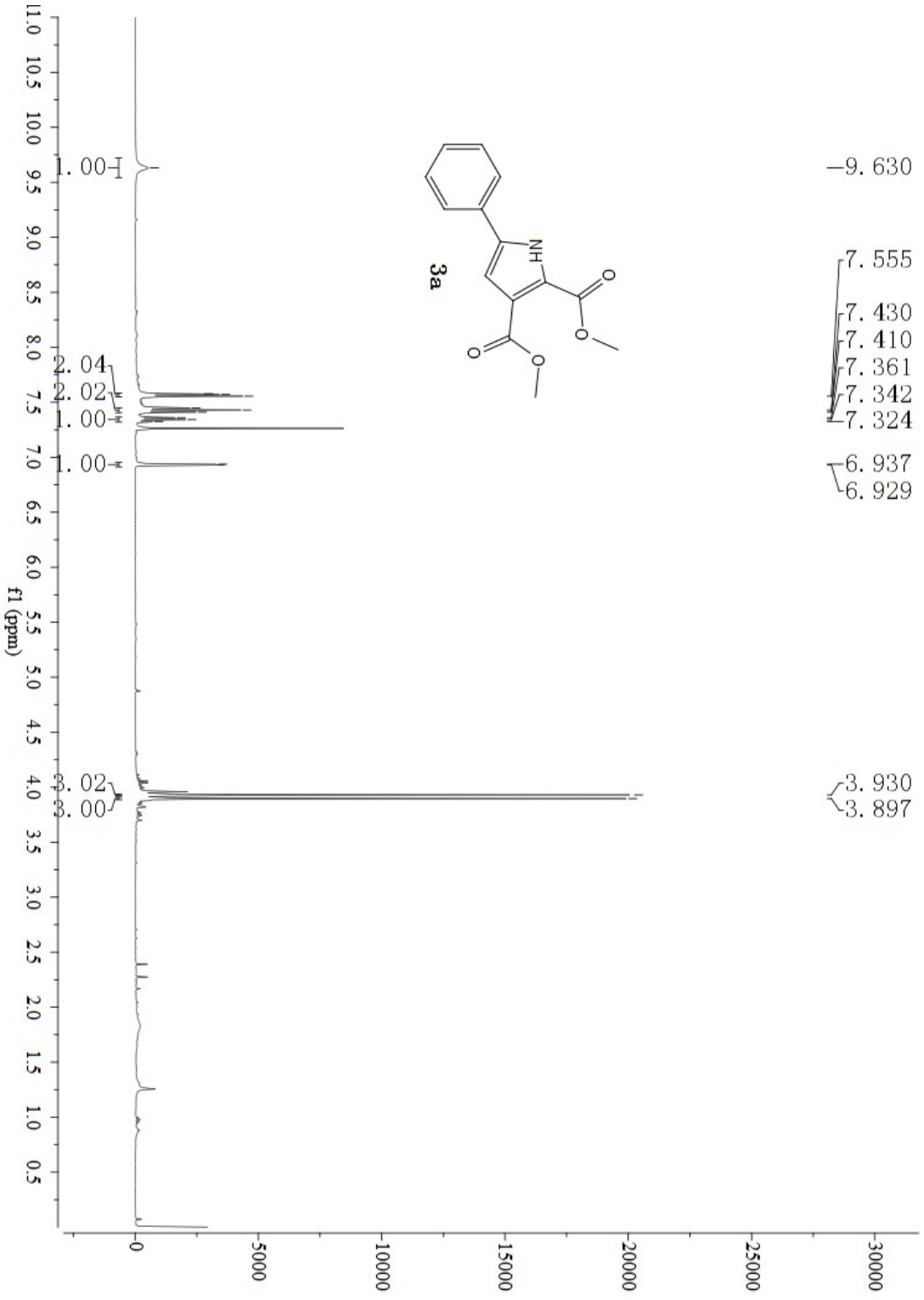
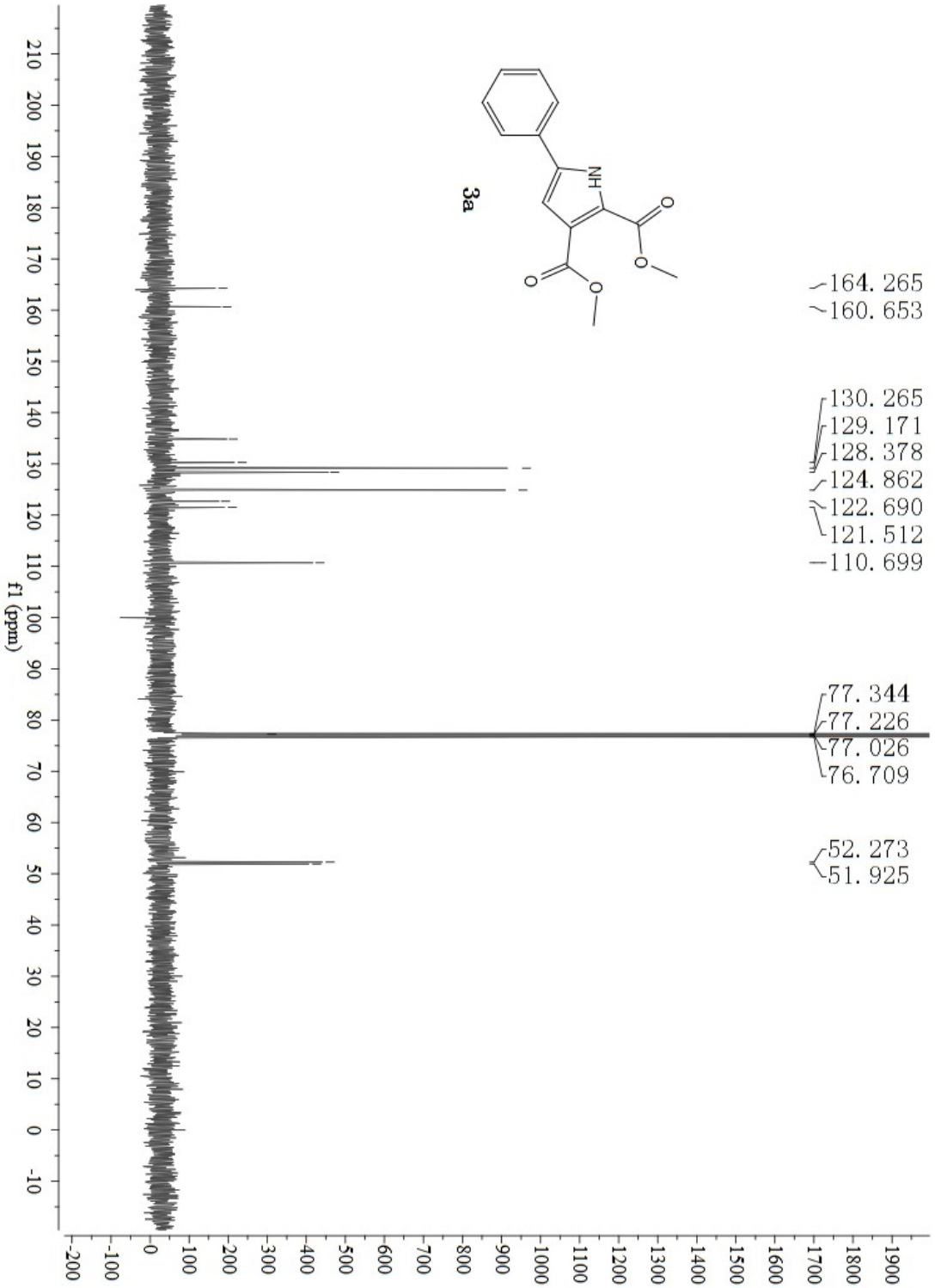
NMR Spectra for the Compounds 3a-3w, 4a, 4l

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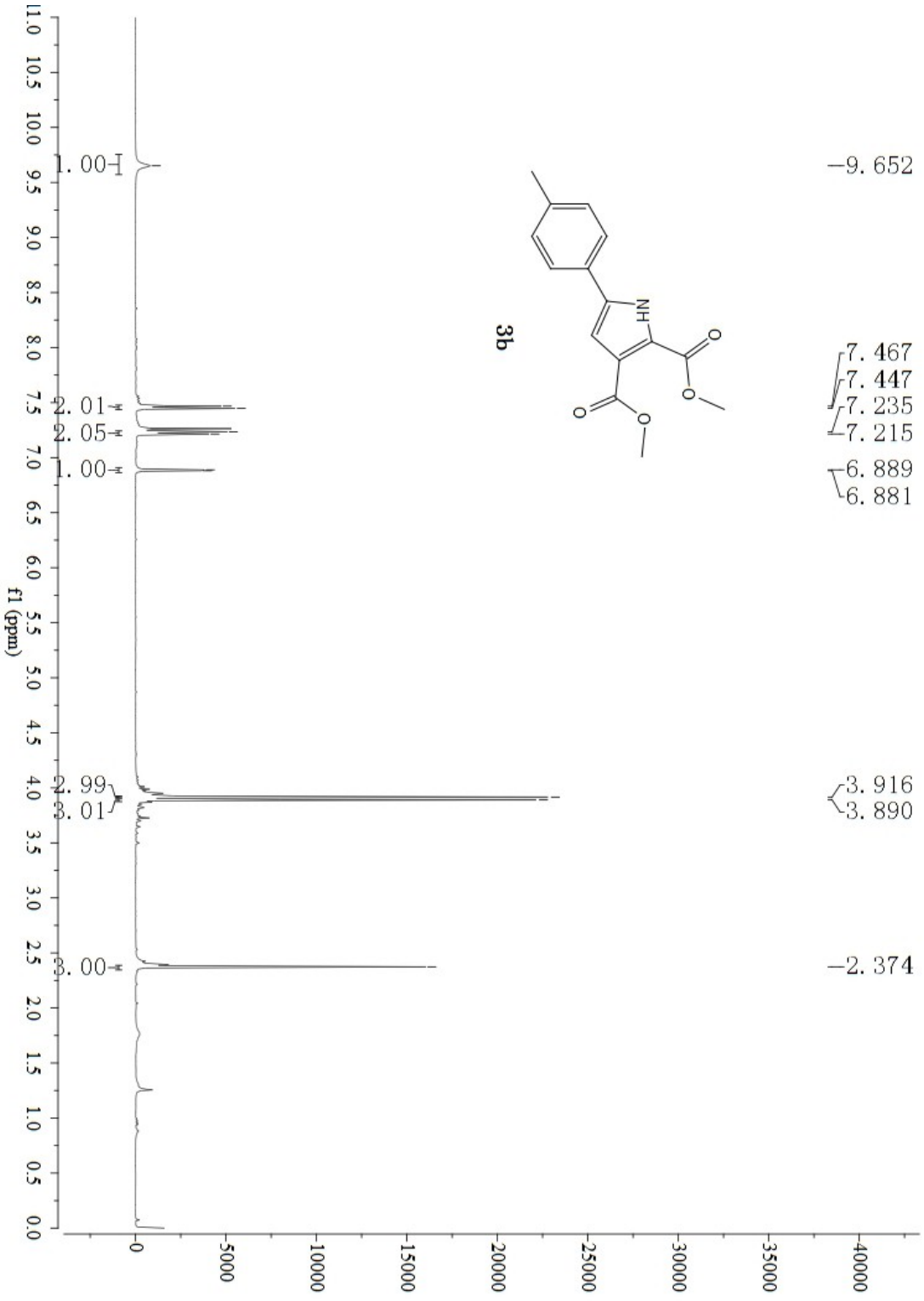
f1 (ppm)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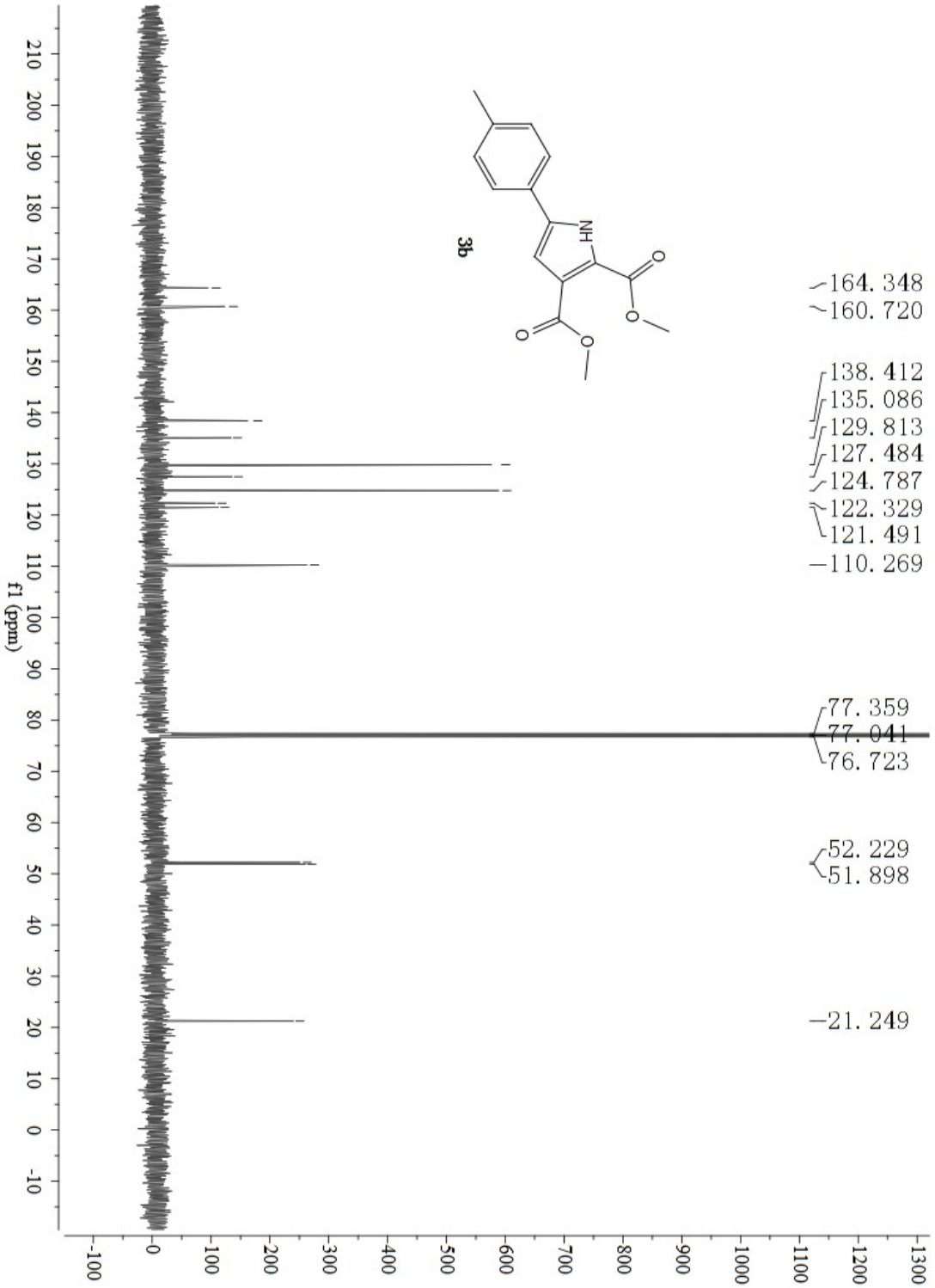
f1 (ppm)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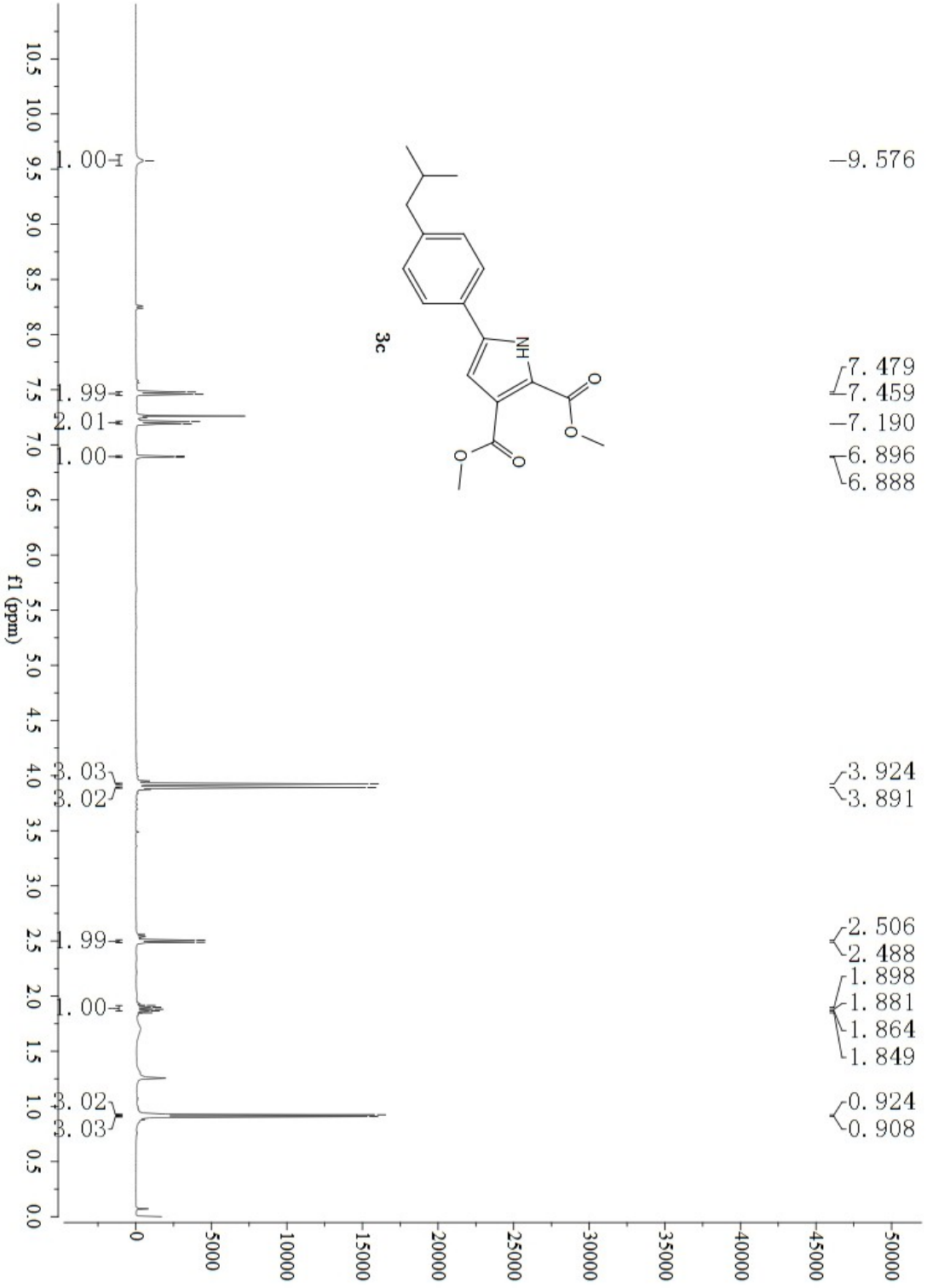
f1 (ppm)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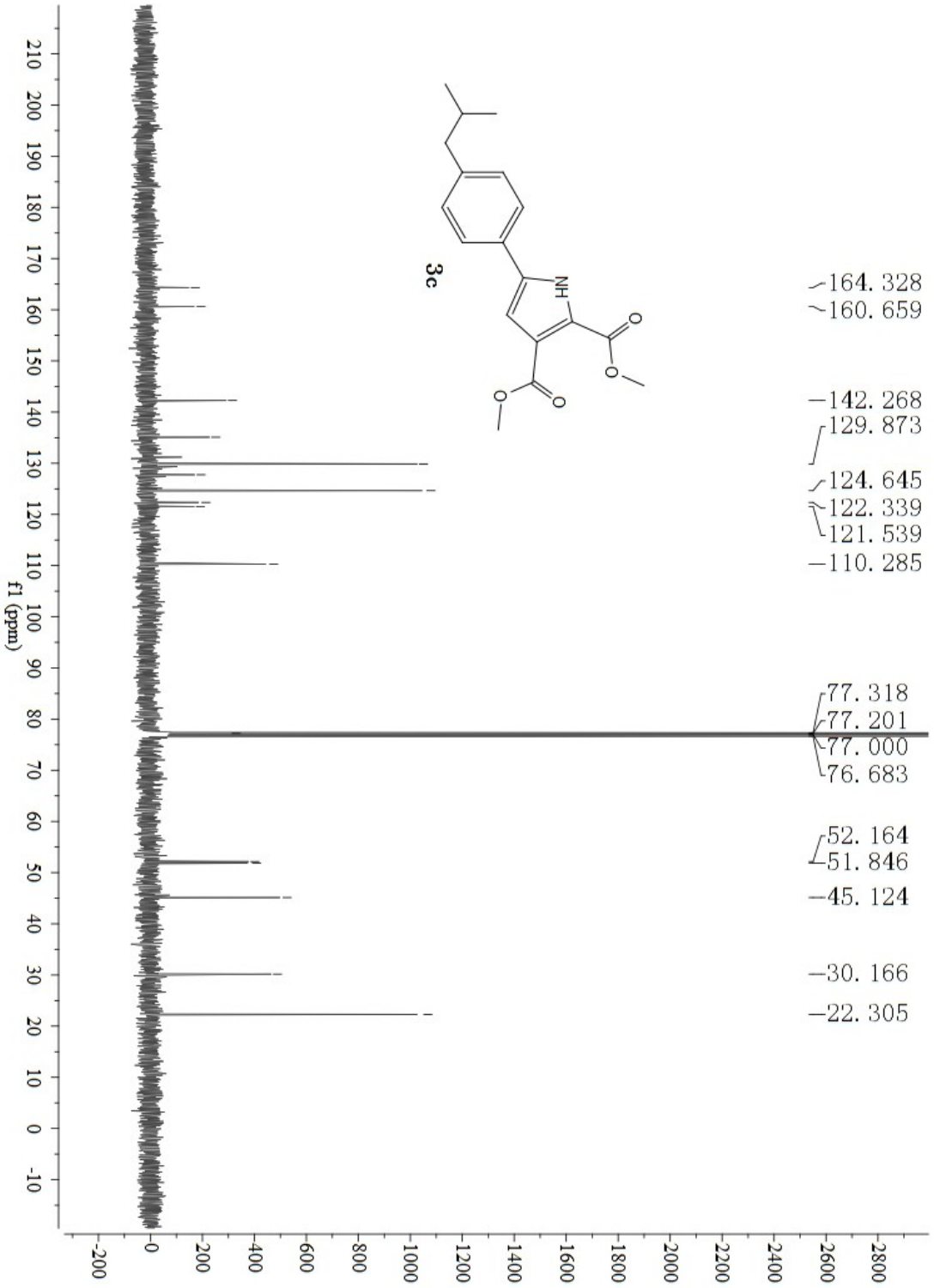
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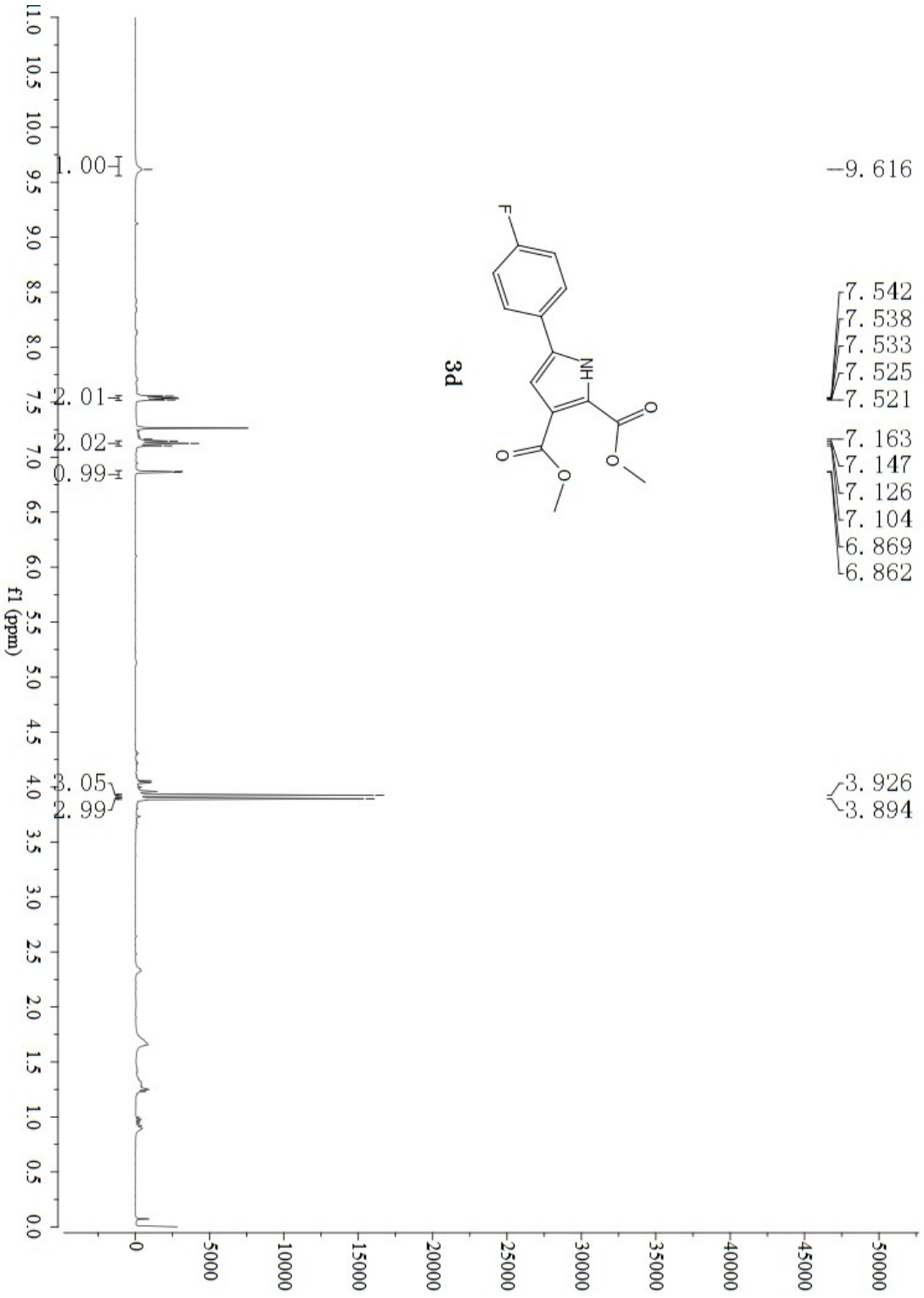
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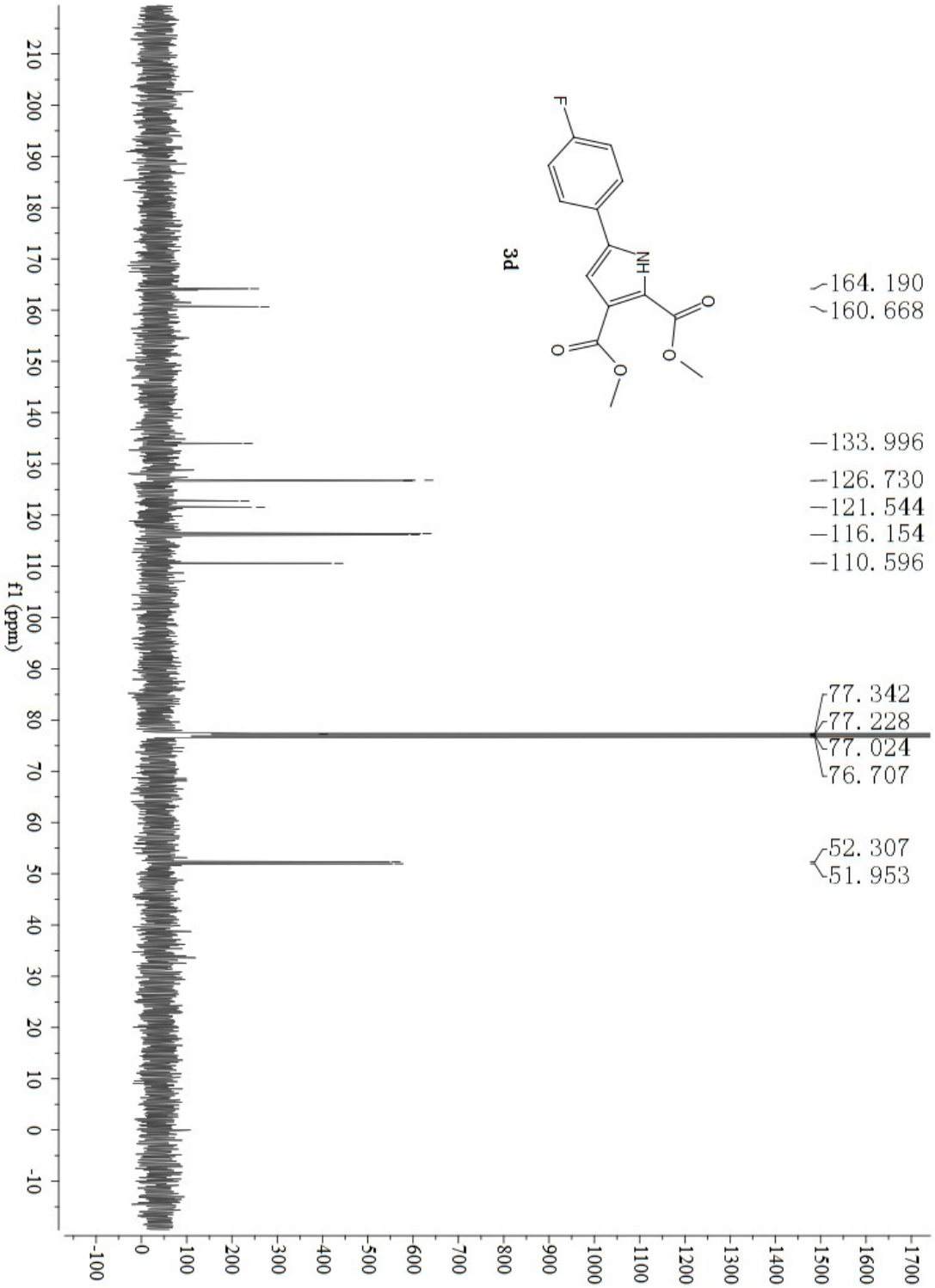
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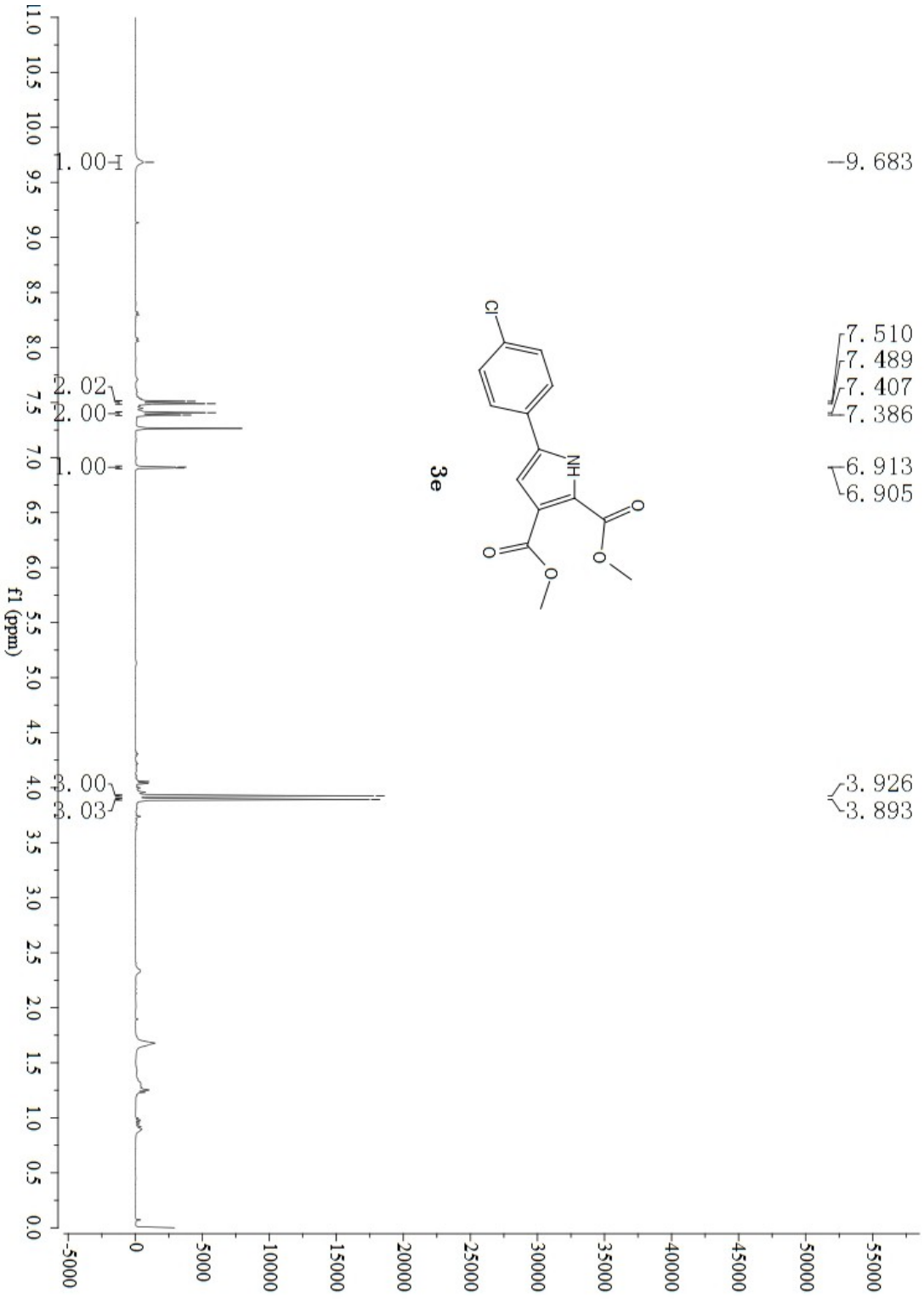
f1 (ppm)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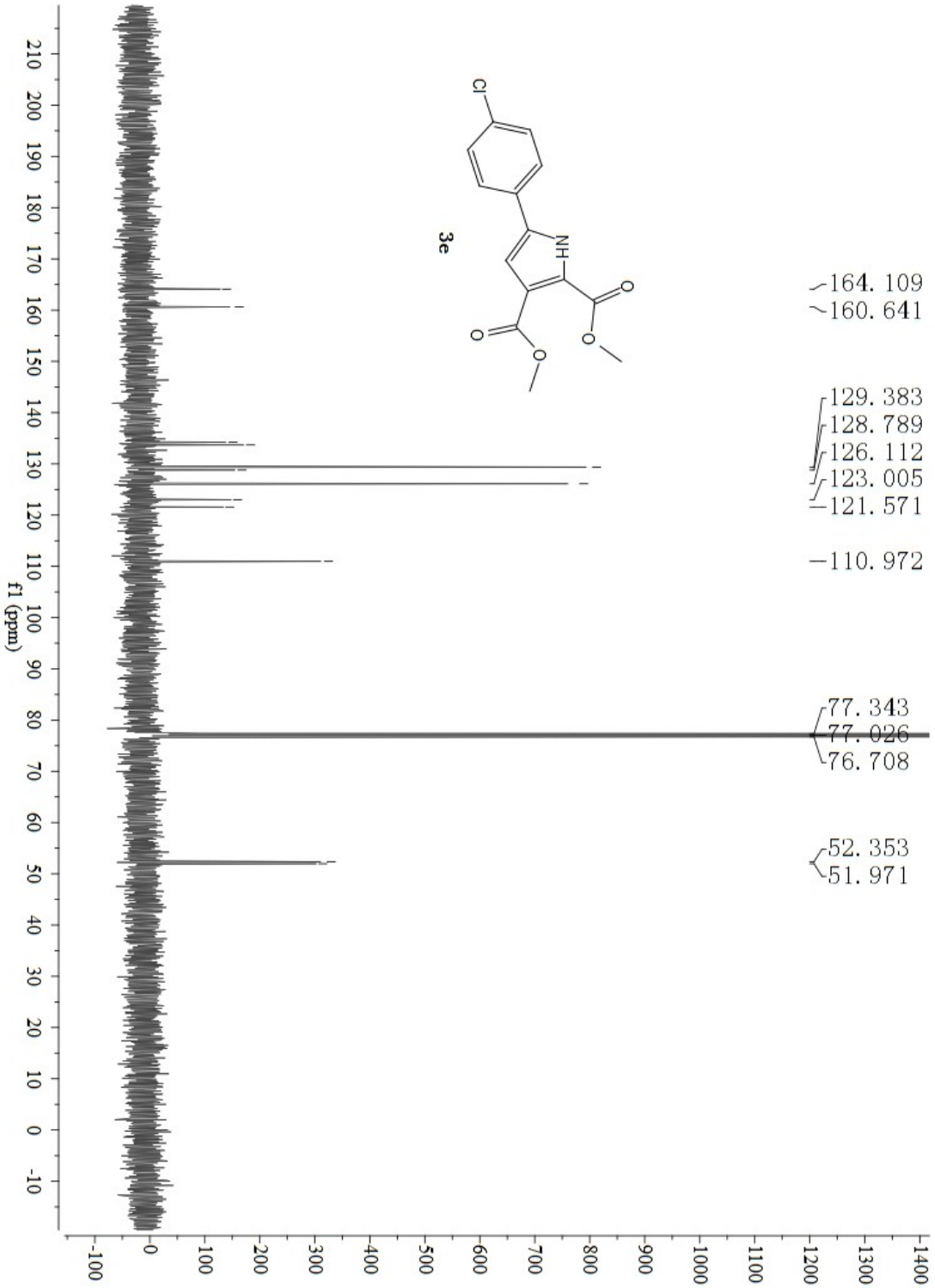
O
f1 (ppm)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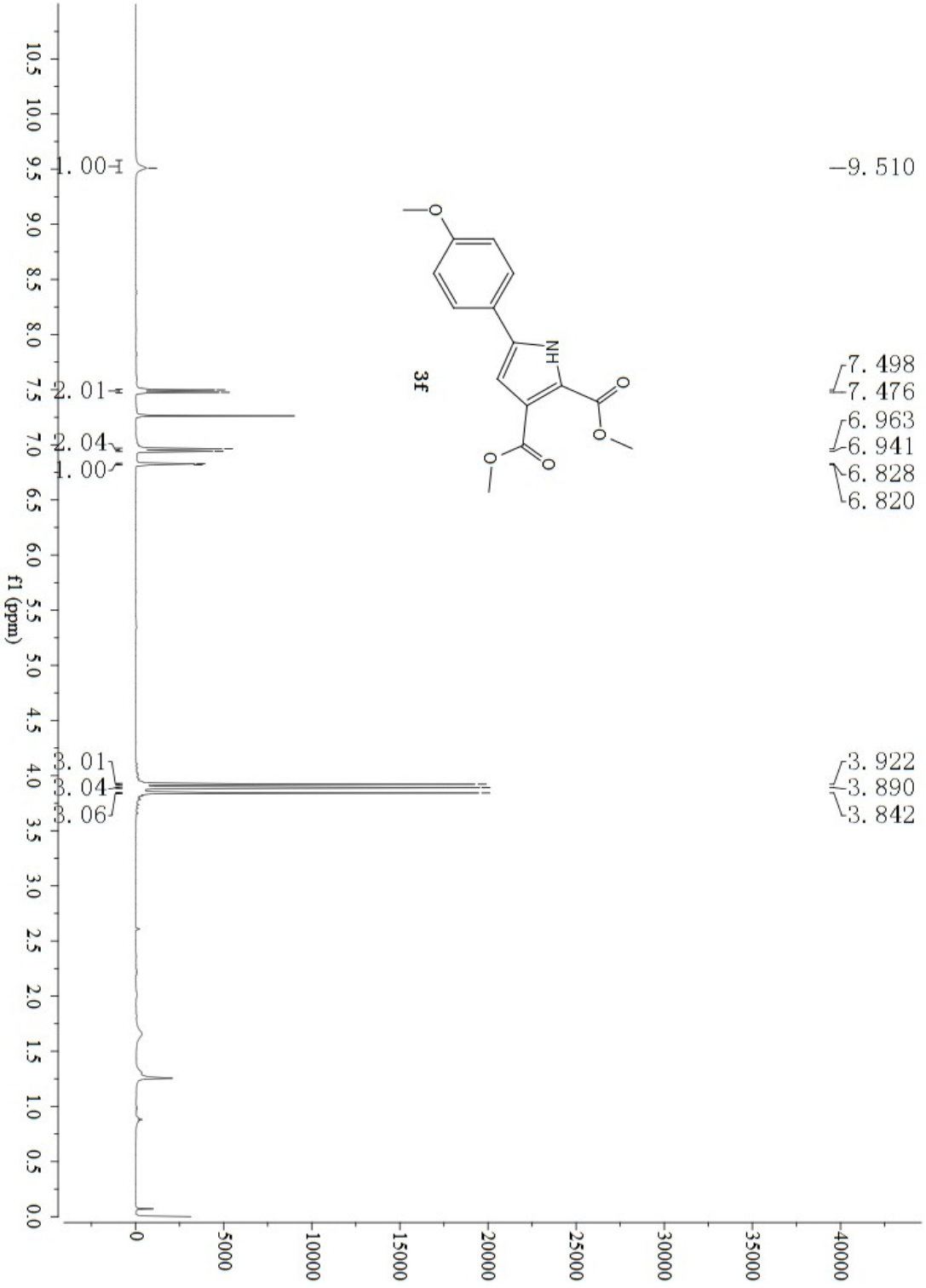
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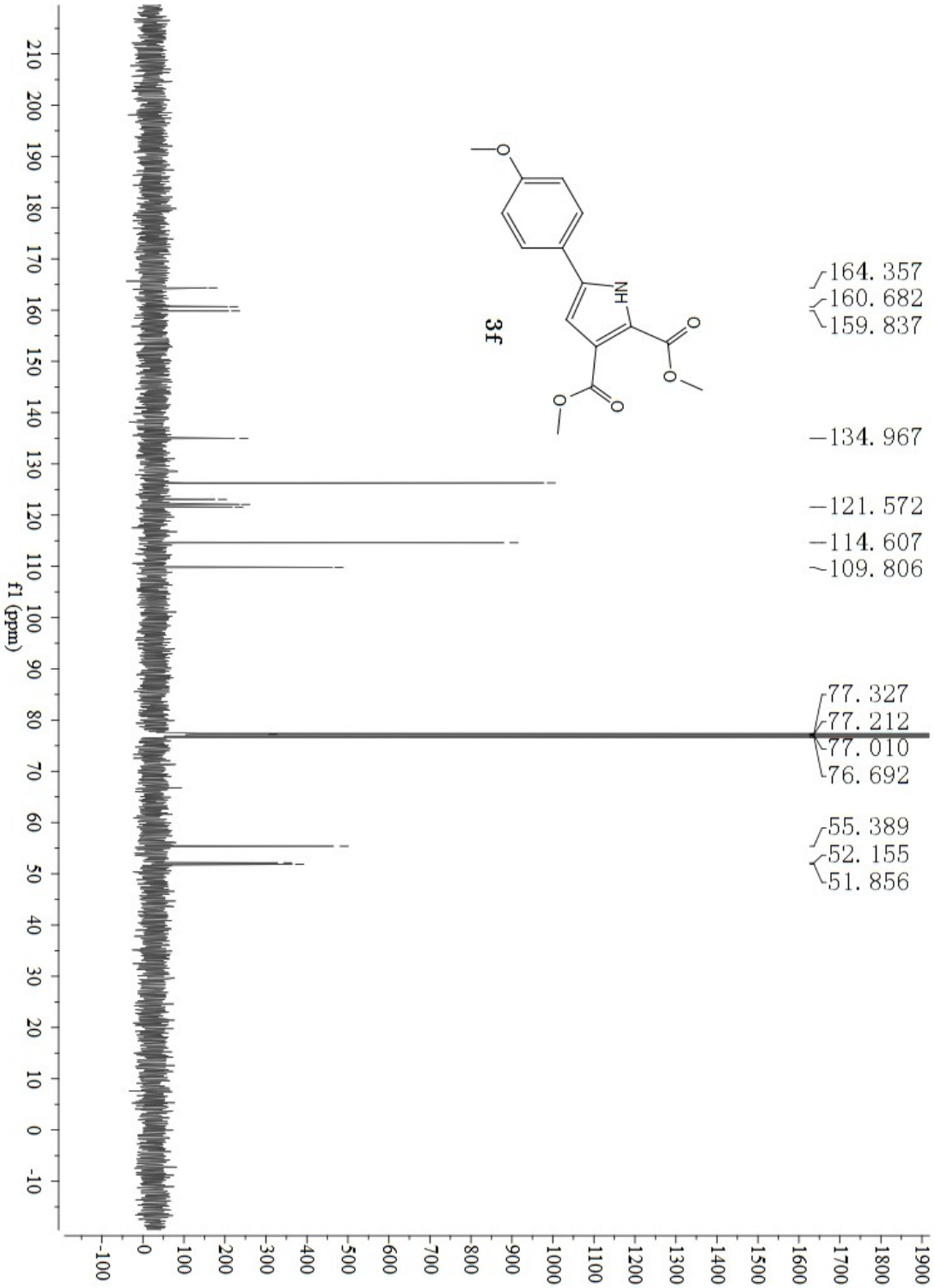
f1 (ppm)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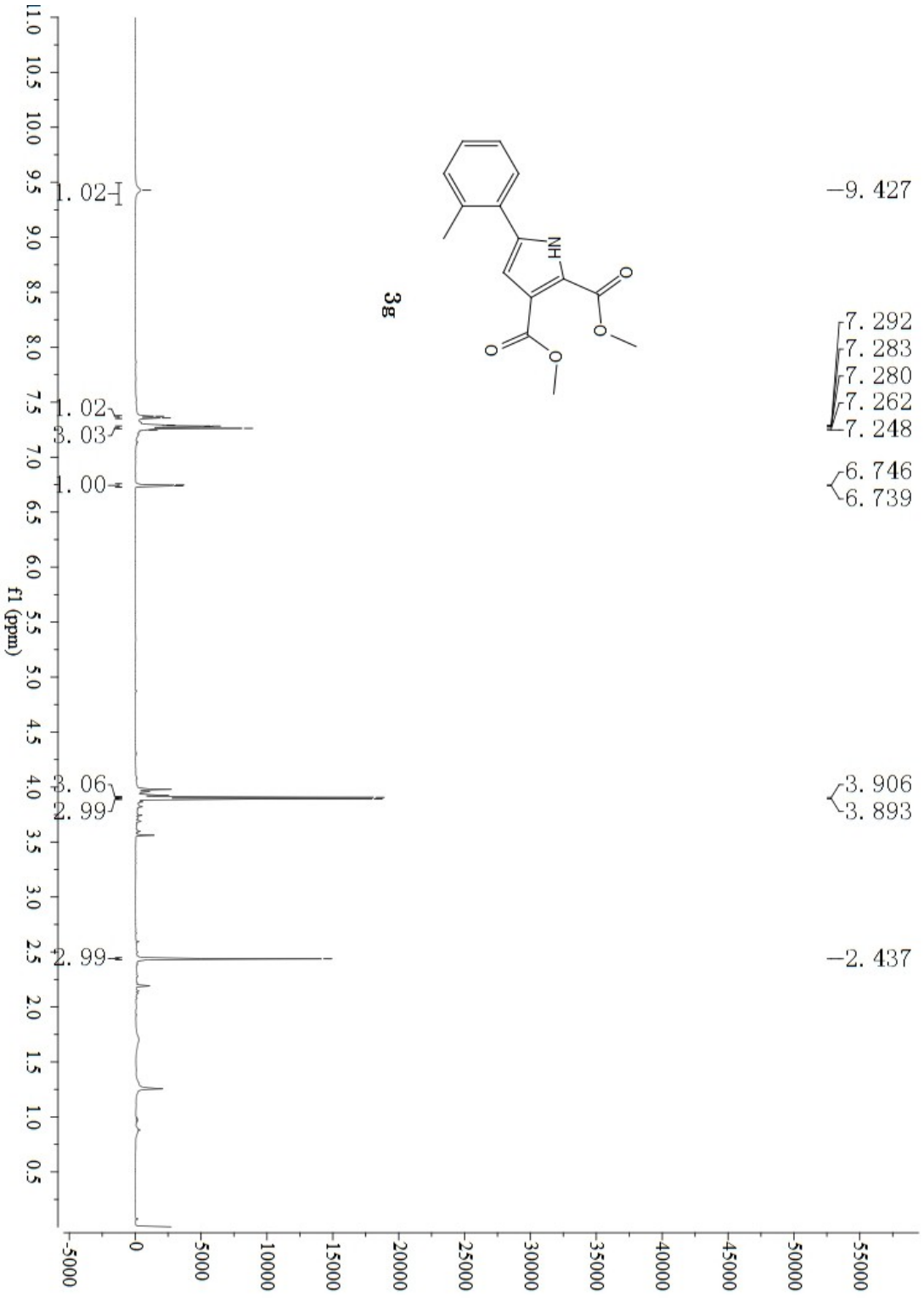
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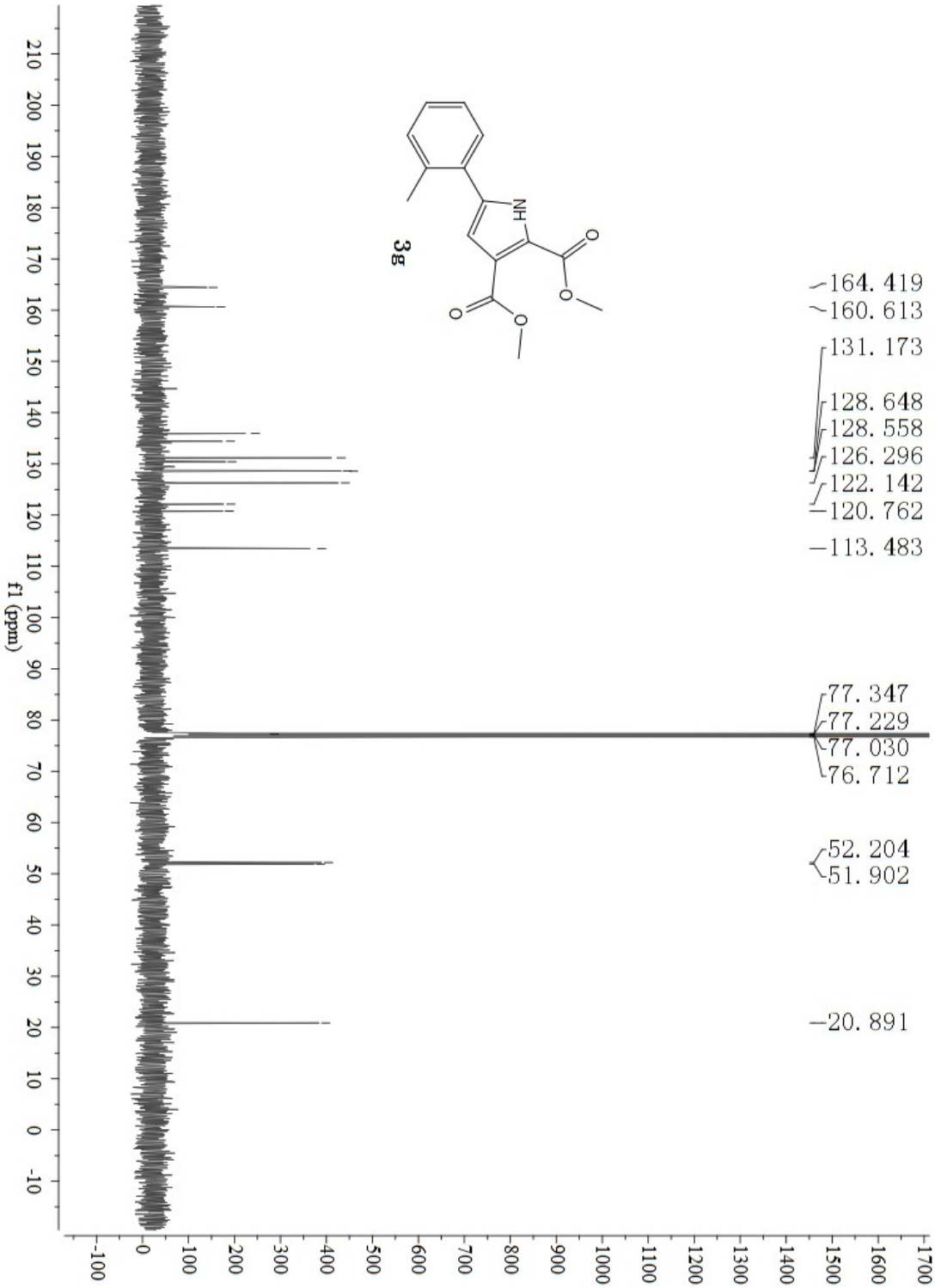
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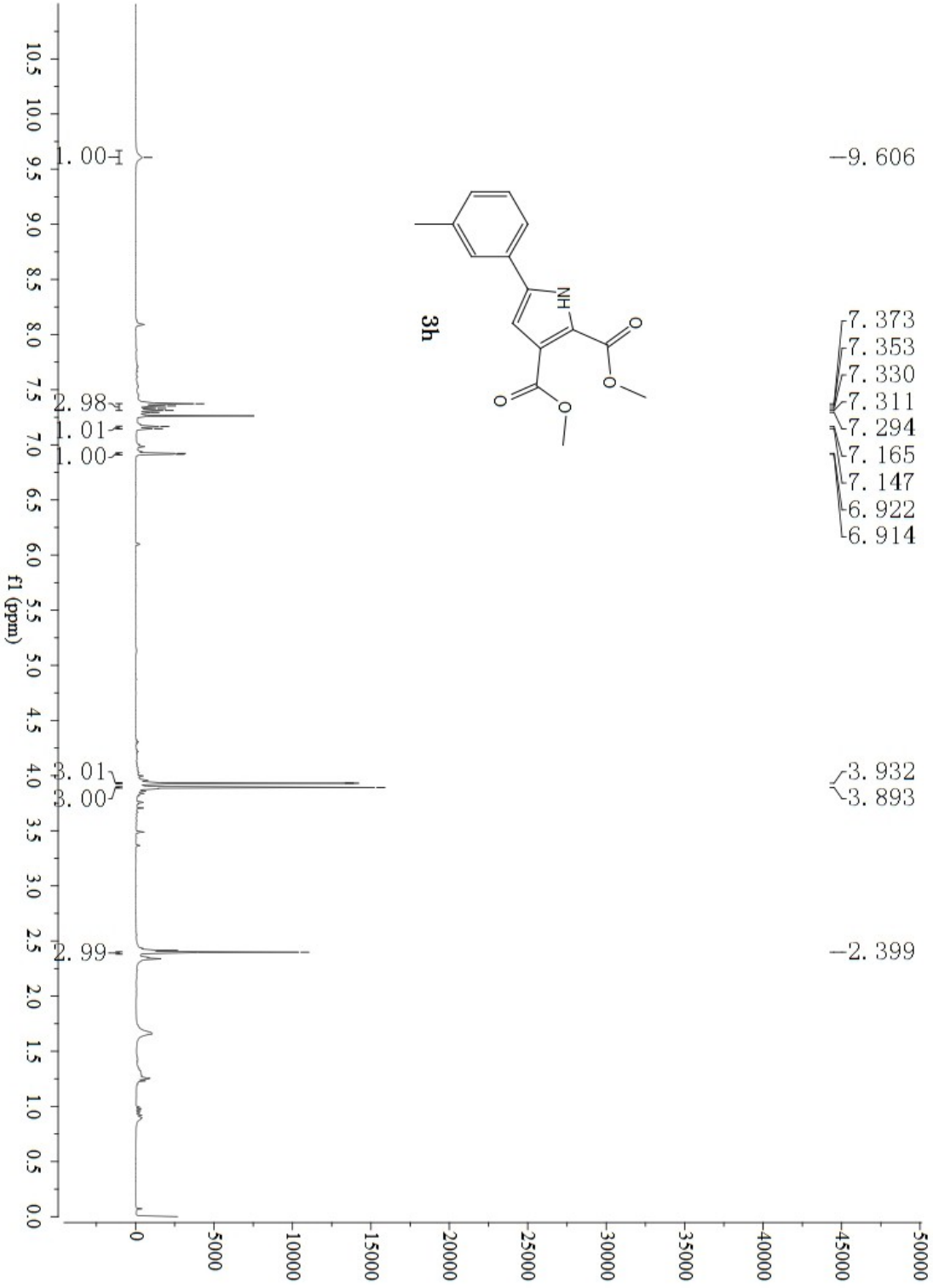
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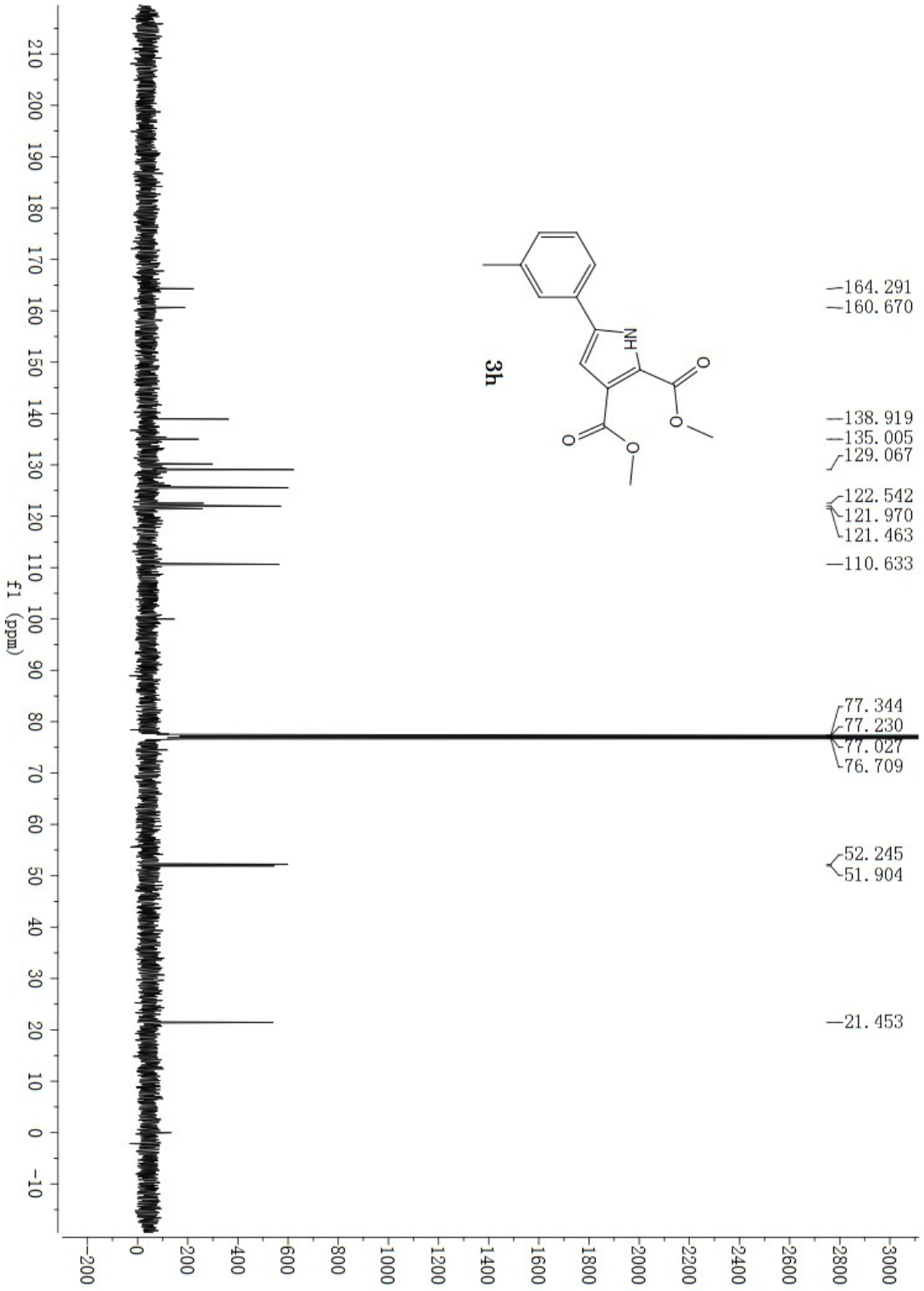
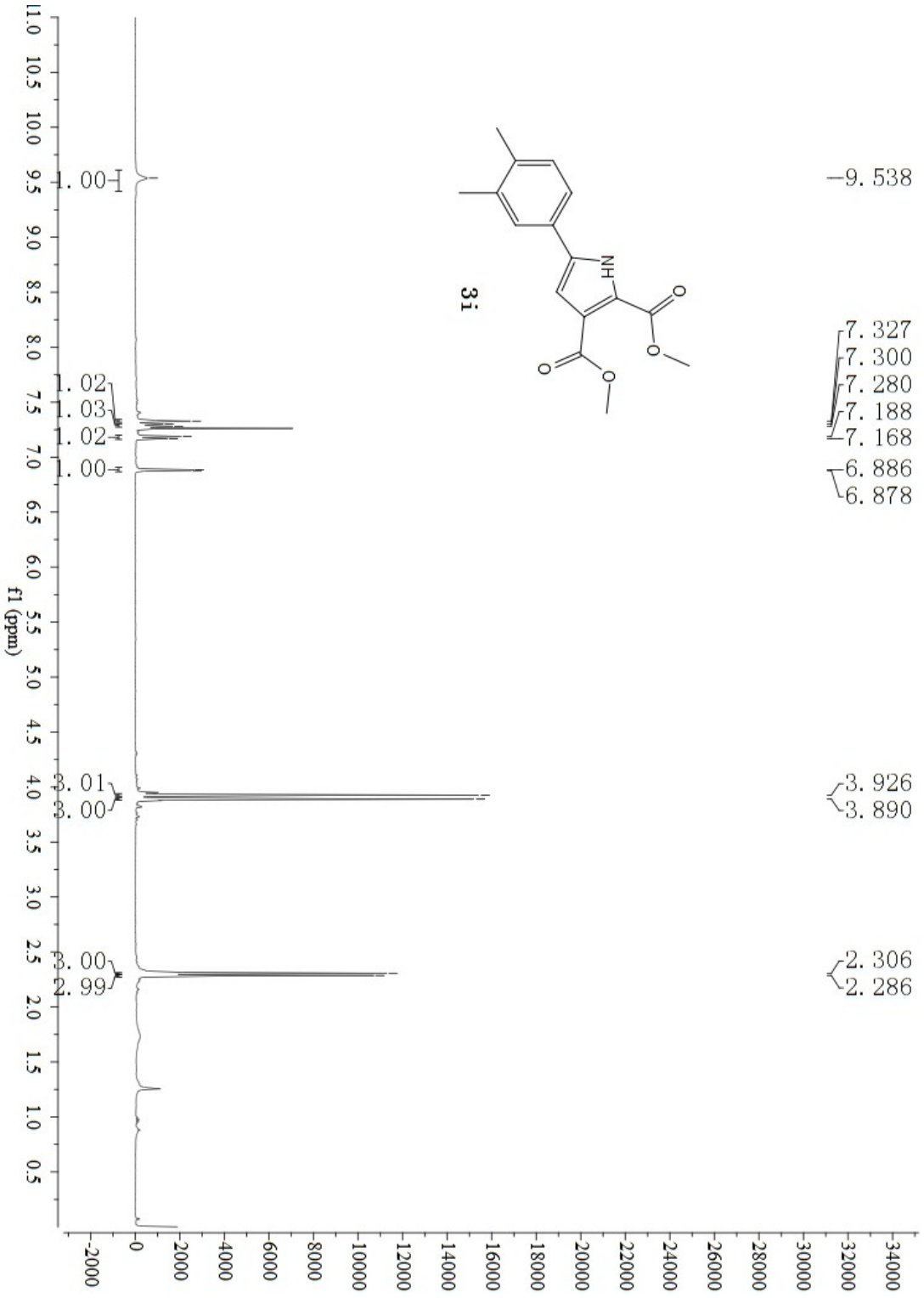
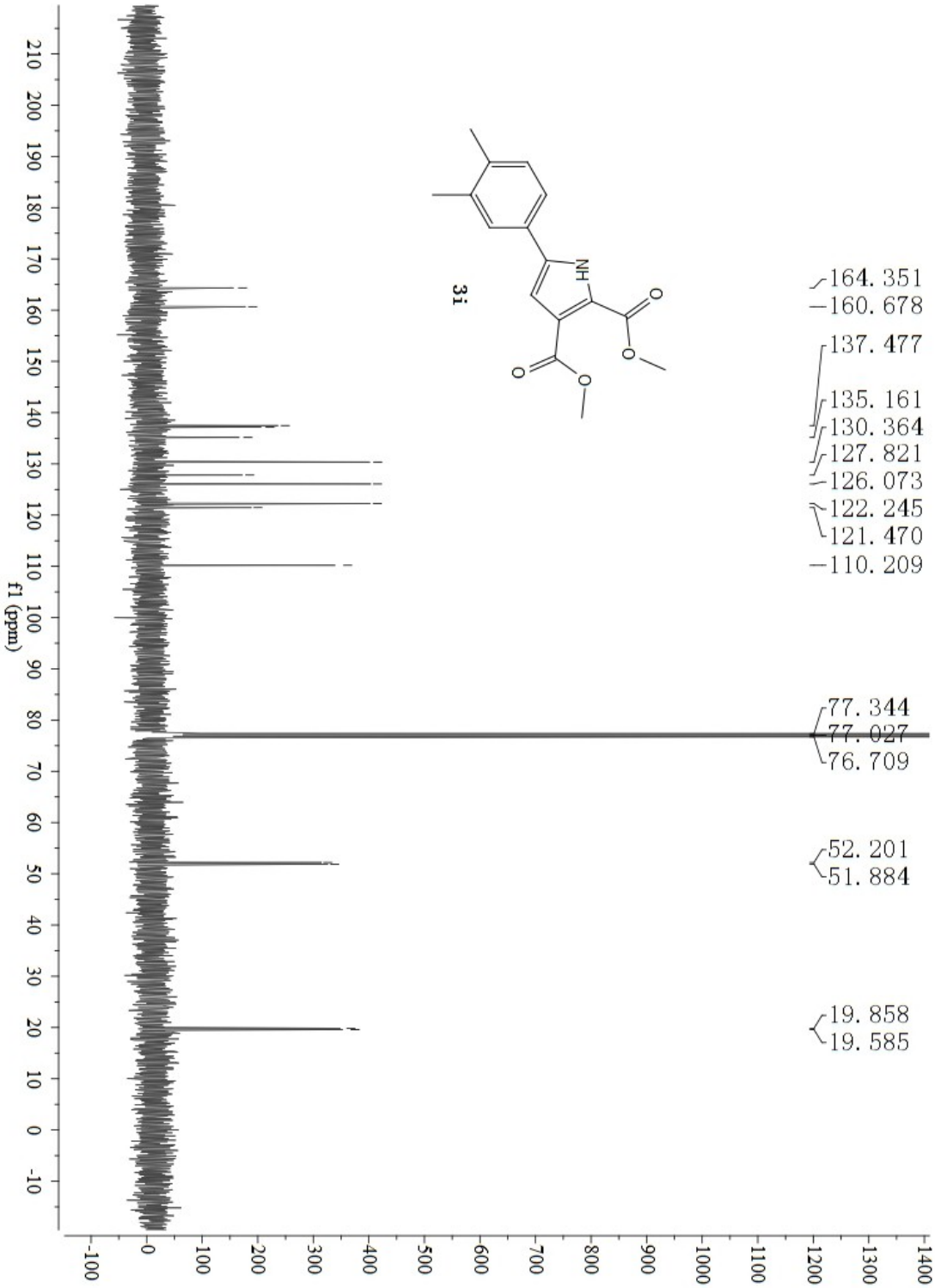
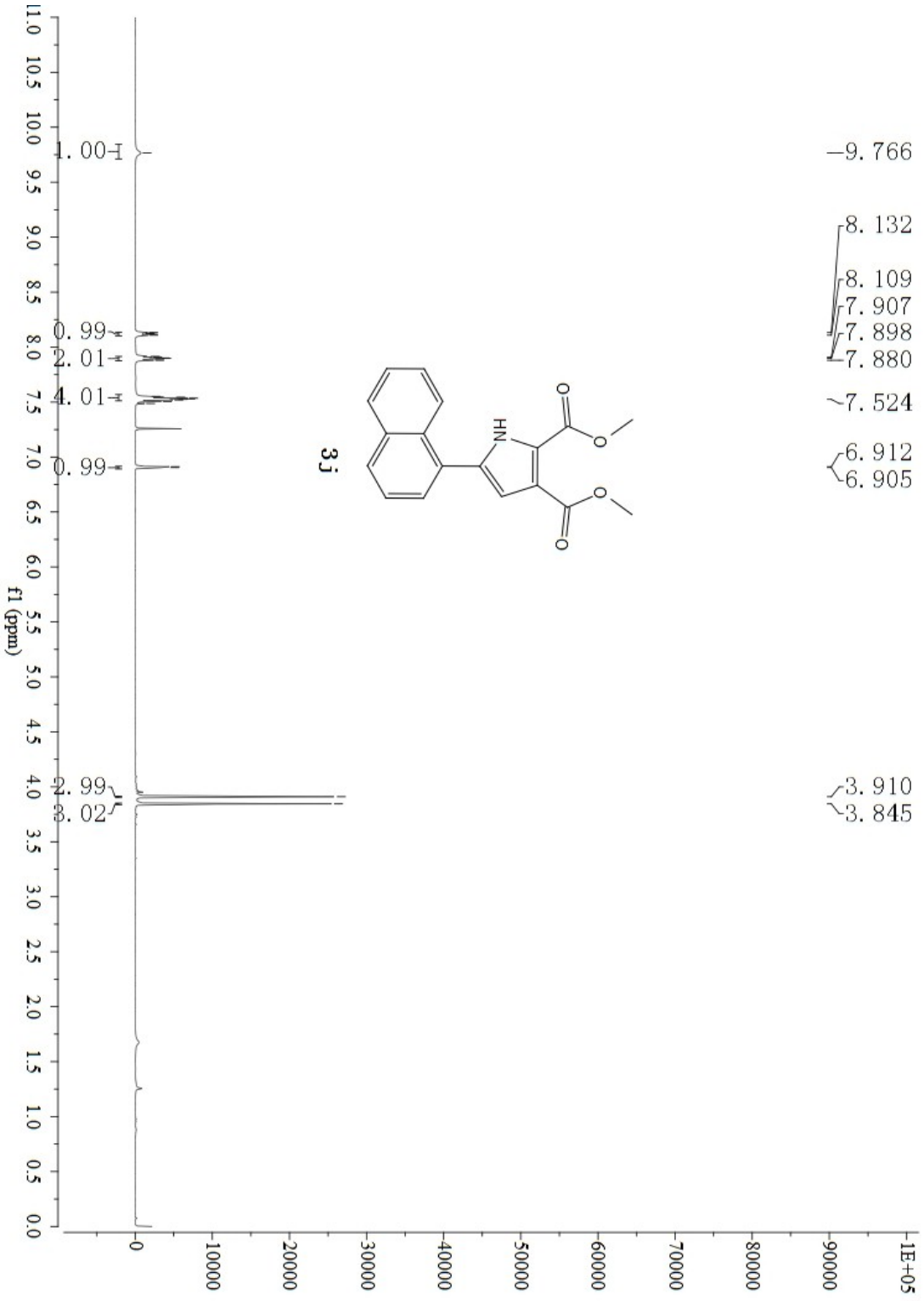
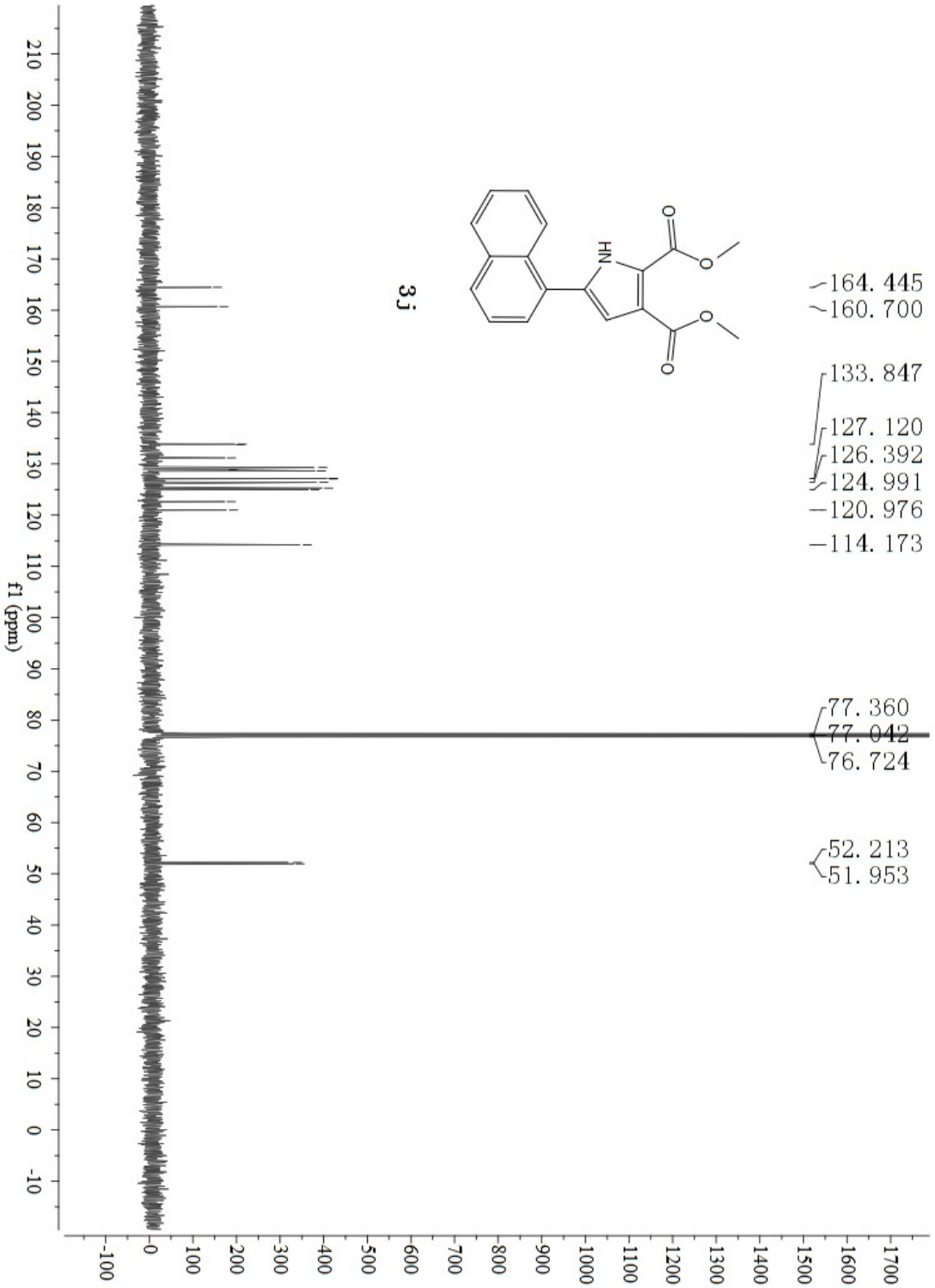
7.147
6.922
6.914
3.932
3.893
2.399
NH
O
O
O
O
3h
f1 (ppm)

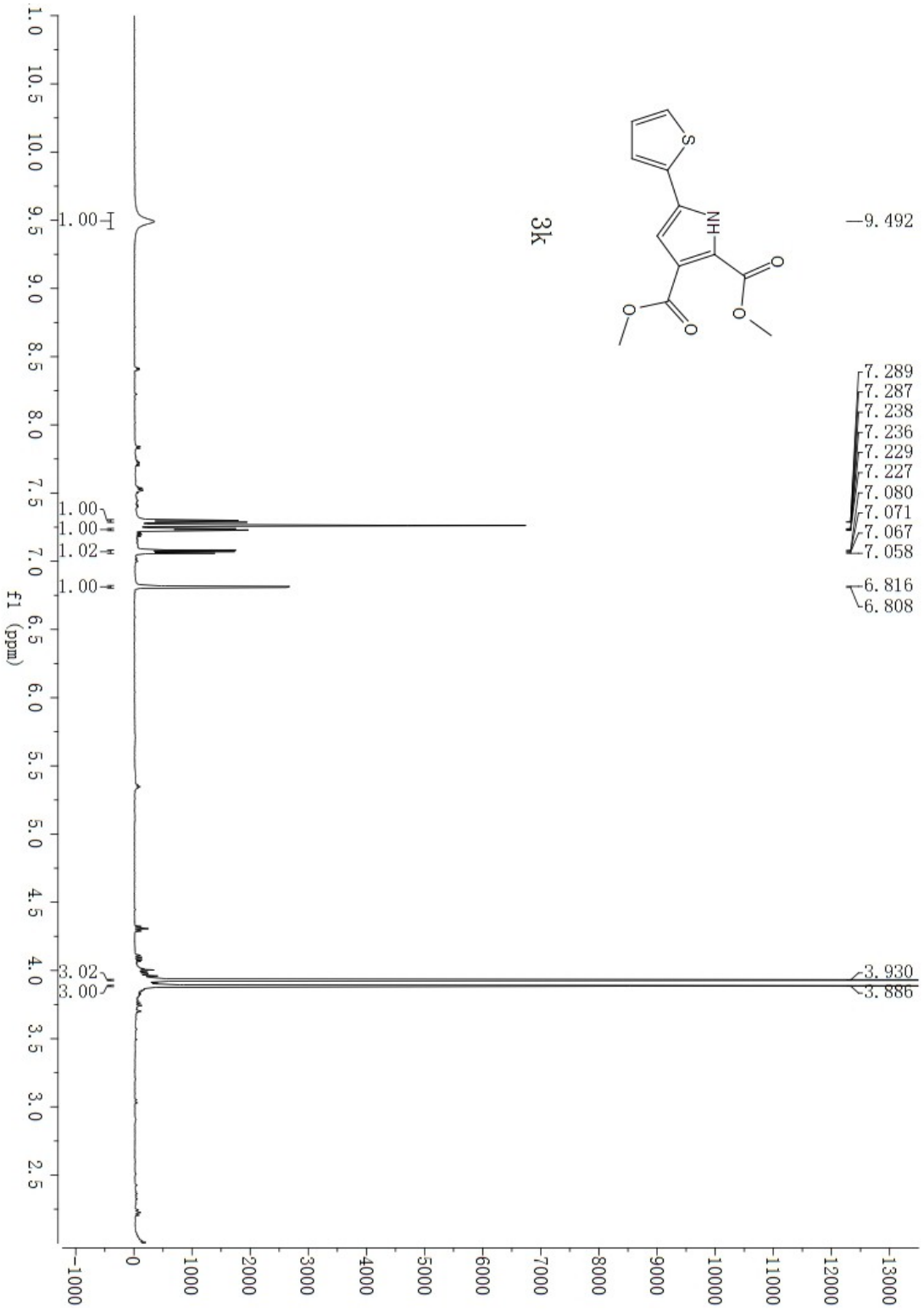

3h
NH
O
O
O
O
164.291
160.670
138.919
135.005
129.067
122.542
121.970
121.463
110.633
77.344
77.230
77.027
76.709
52.245
51.904
21.453
f1 (ppm)

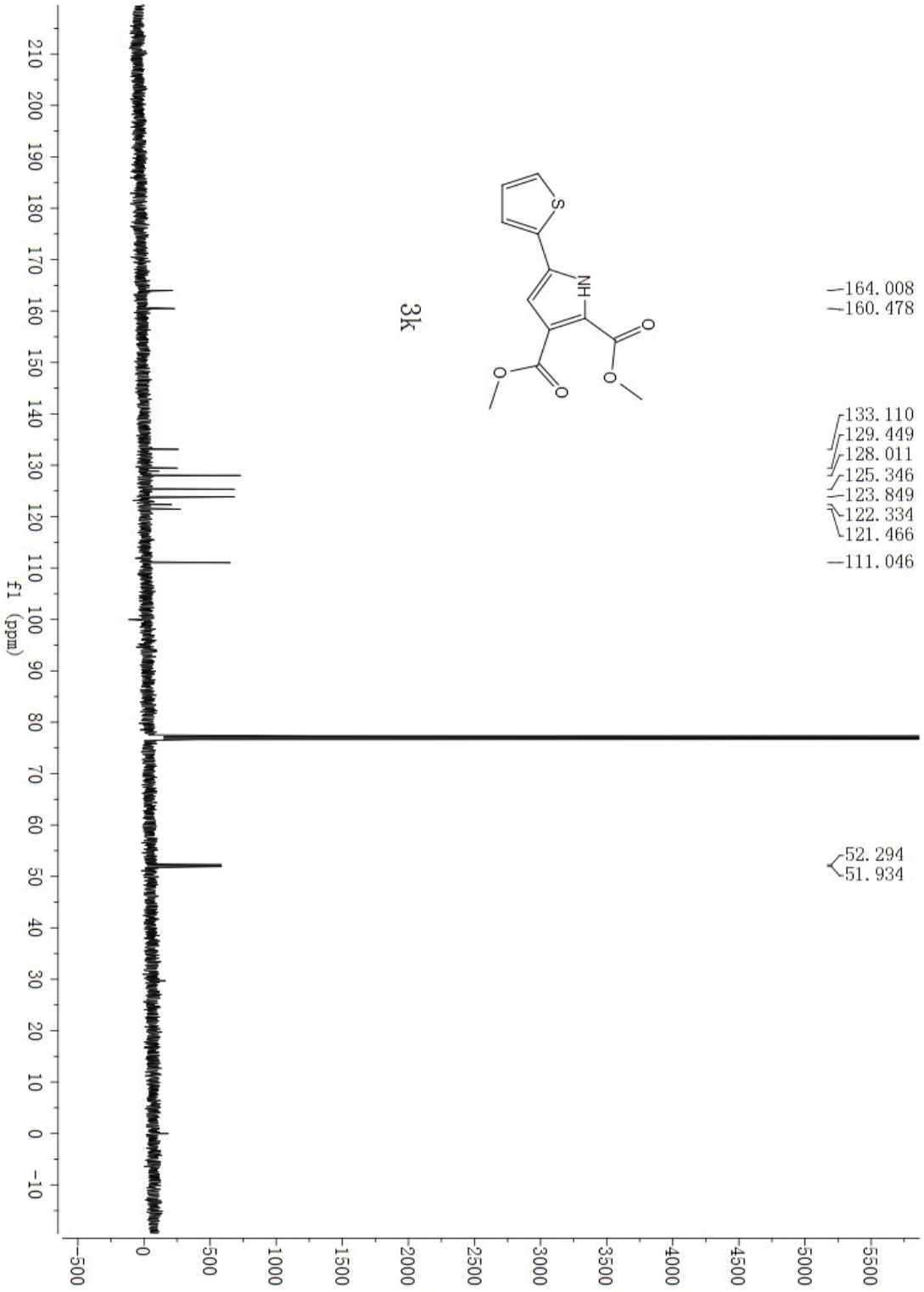

3i
NH
O
O
O
O
9.538
7.327
7.300
7.280
7.188
7.168
6.886
6.878
3.926
3.890
2.306
2.286
1.00
1.02
1.03
1.02
1.00
3.01
3.00
3.00
2.99
f1 (ppm)

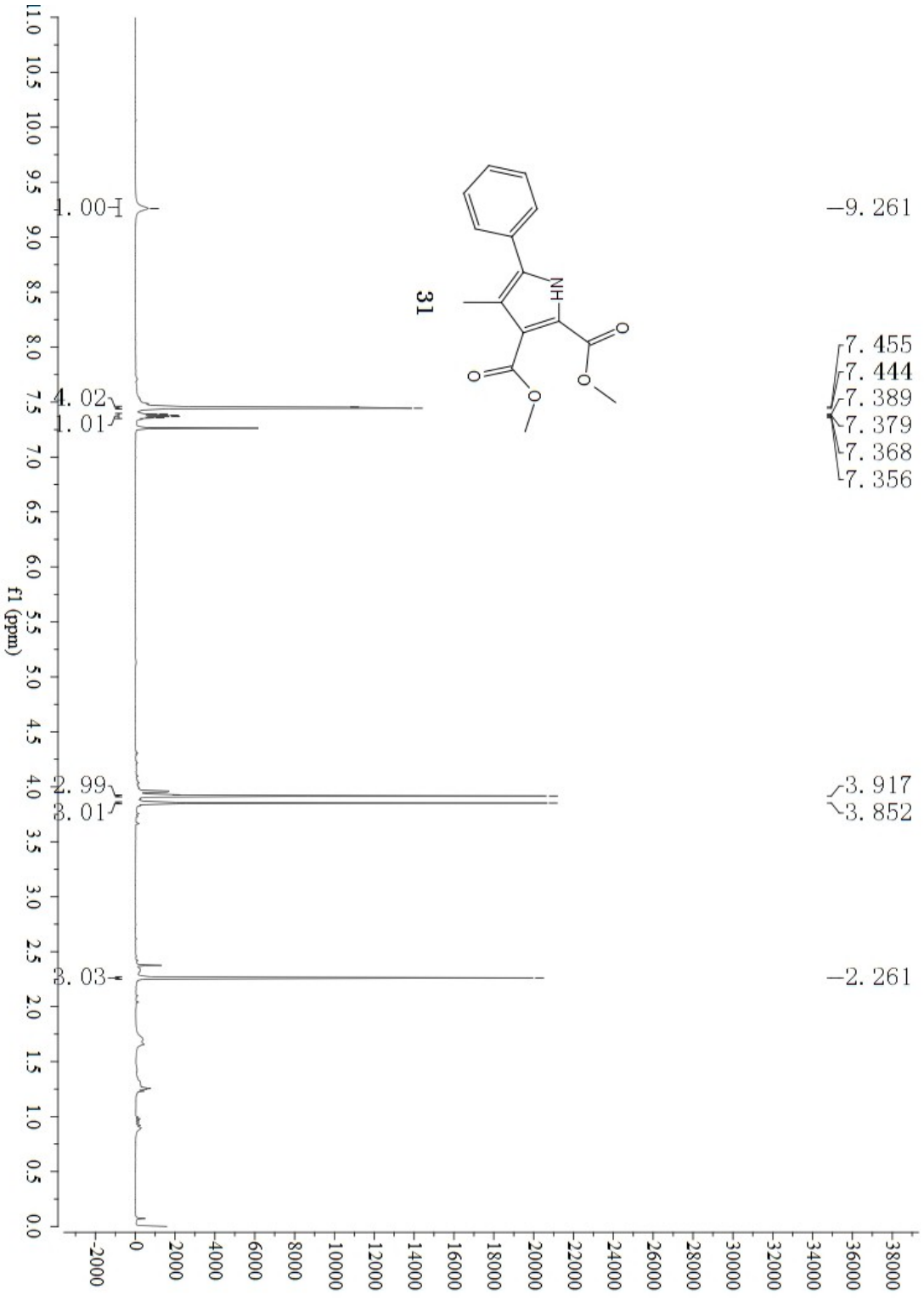

3i
NH
O
O
O
O
164.351
160.678
137.477
135.161
130.364
127.821
126.073
122.245
121.470
110.209
77.344
77.027
76.709
52.201
51.884
19.858
19.585
f1 (ppm)

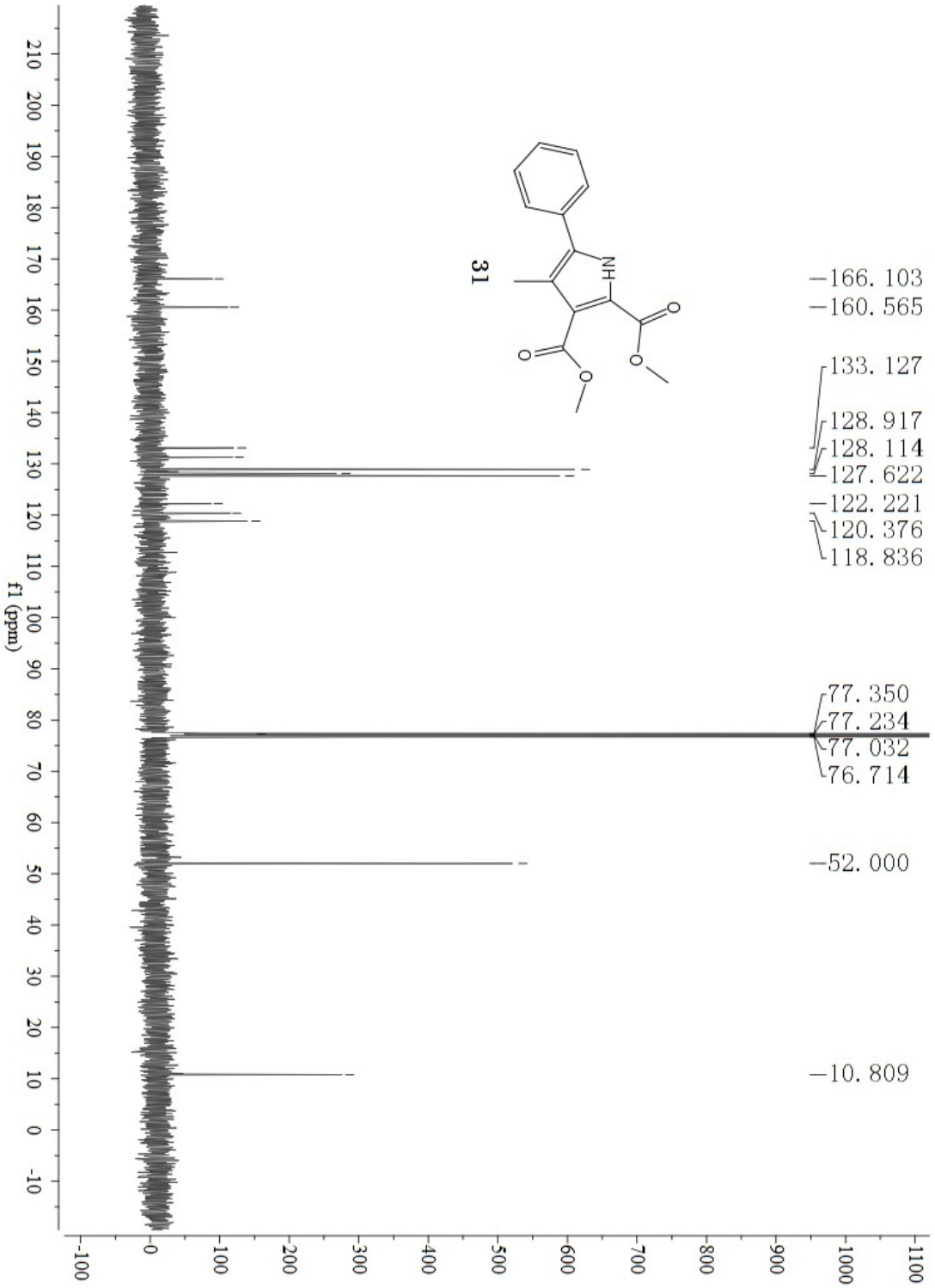

1.00
0.99
2.01
4.01
0.99
2.99
3.02
9.766
8.132
8.109
7.907
7.898
7.880
7.524
6.912
6.905
3.910
3.845
3j
HN
O
O
O
O
f1 (ppm)

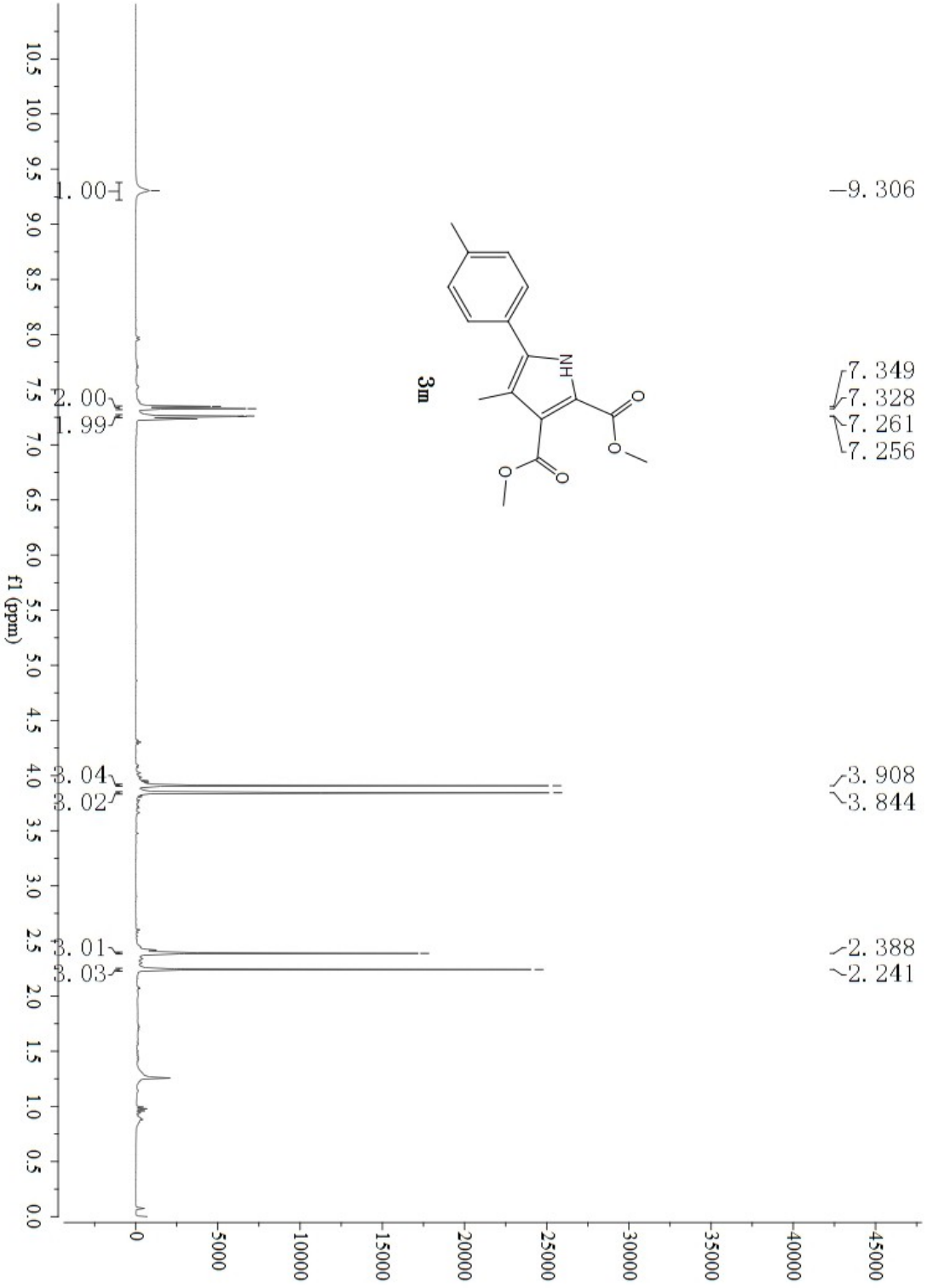

3j
HN
O
O
O
O
164.445
160.700
133.847
127.120
126.392
124.991
120.976
114.173
77.360
77.042
76.724
52.213
51.953
f1 (ppm)

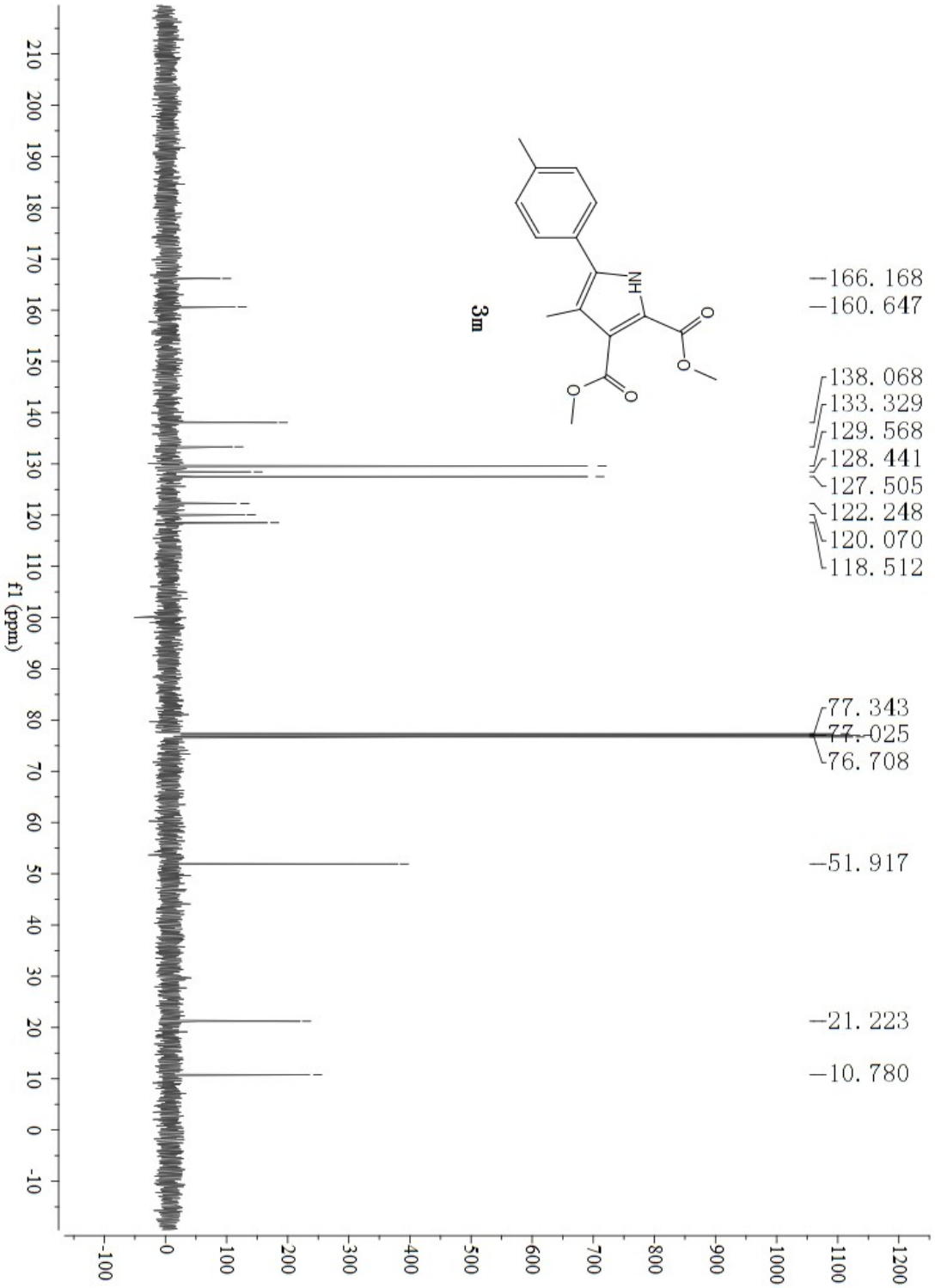

3k
9.492
7.289
7.287
7.238
7.236
7.229
7.227
7.080
7.071
7.067
7.058
6.816
6.808
3.930
3.886
1.00
1.00
1.00
1.02
1.00
3.02
3.00
f1 (ppm)

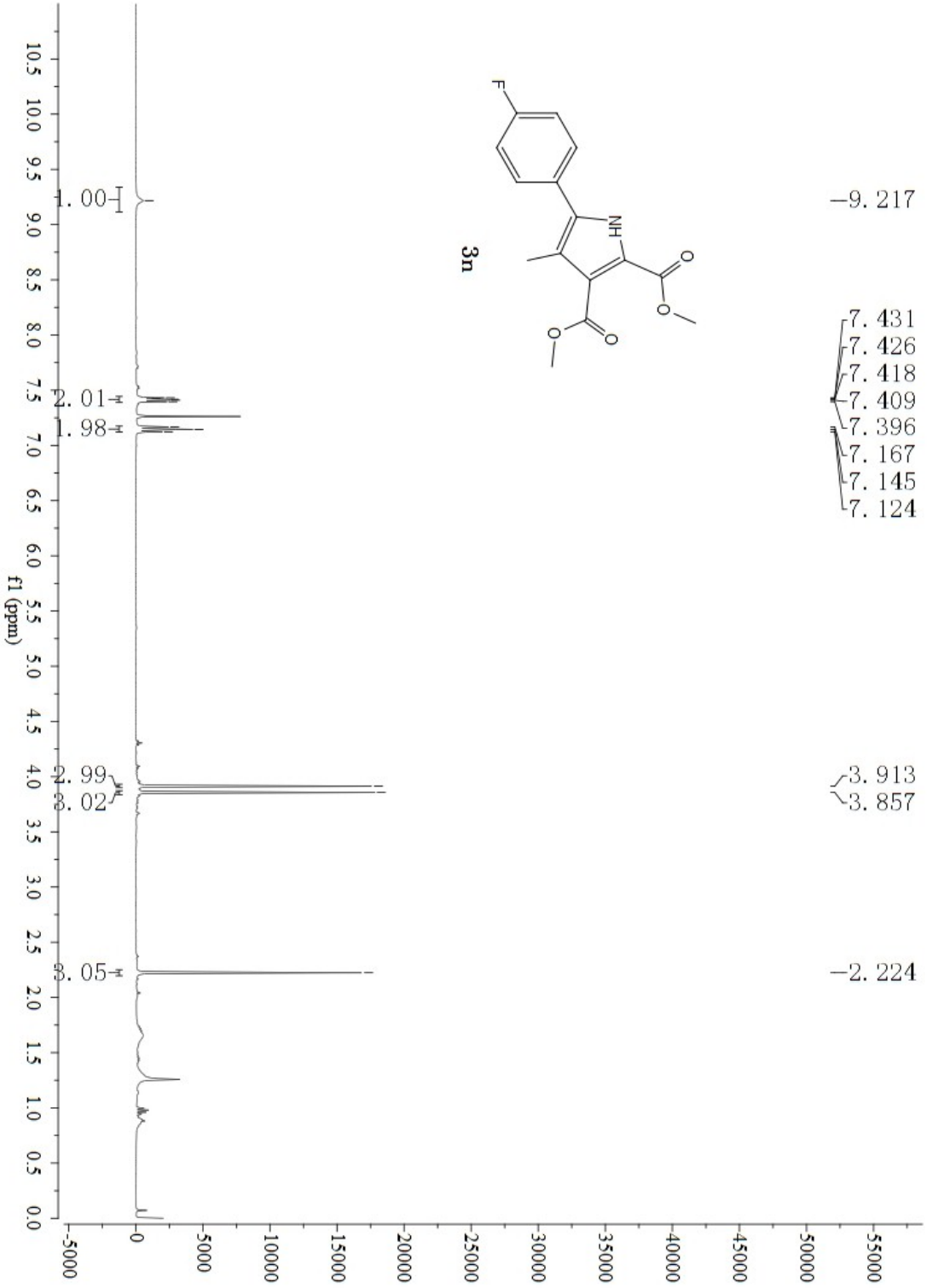

3k
NH
S
O
O
O
O
164.008
160.478
133.110
129.449
128.011
125.346
123.849
122.334
121.466
111.046
52.294
51.934
f1 (ppm)

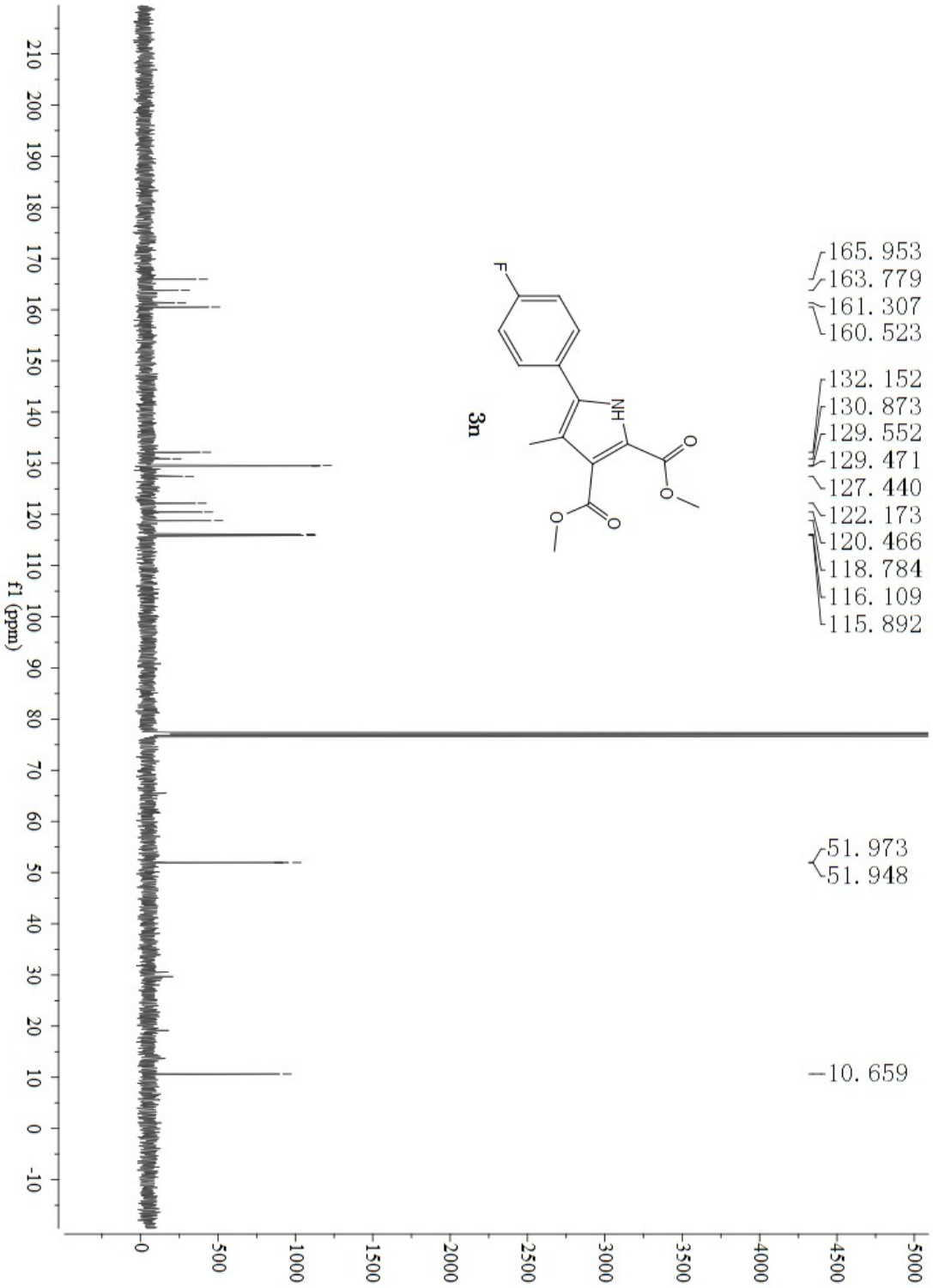

31
NH
O
O
O
O
1.00
4.02
1.01
2.99
3.01
3.03
9.261
7.455
7.444
7.389
7.379
7.368
7.356
3.917
3.852
2.261
f1 (ppm)

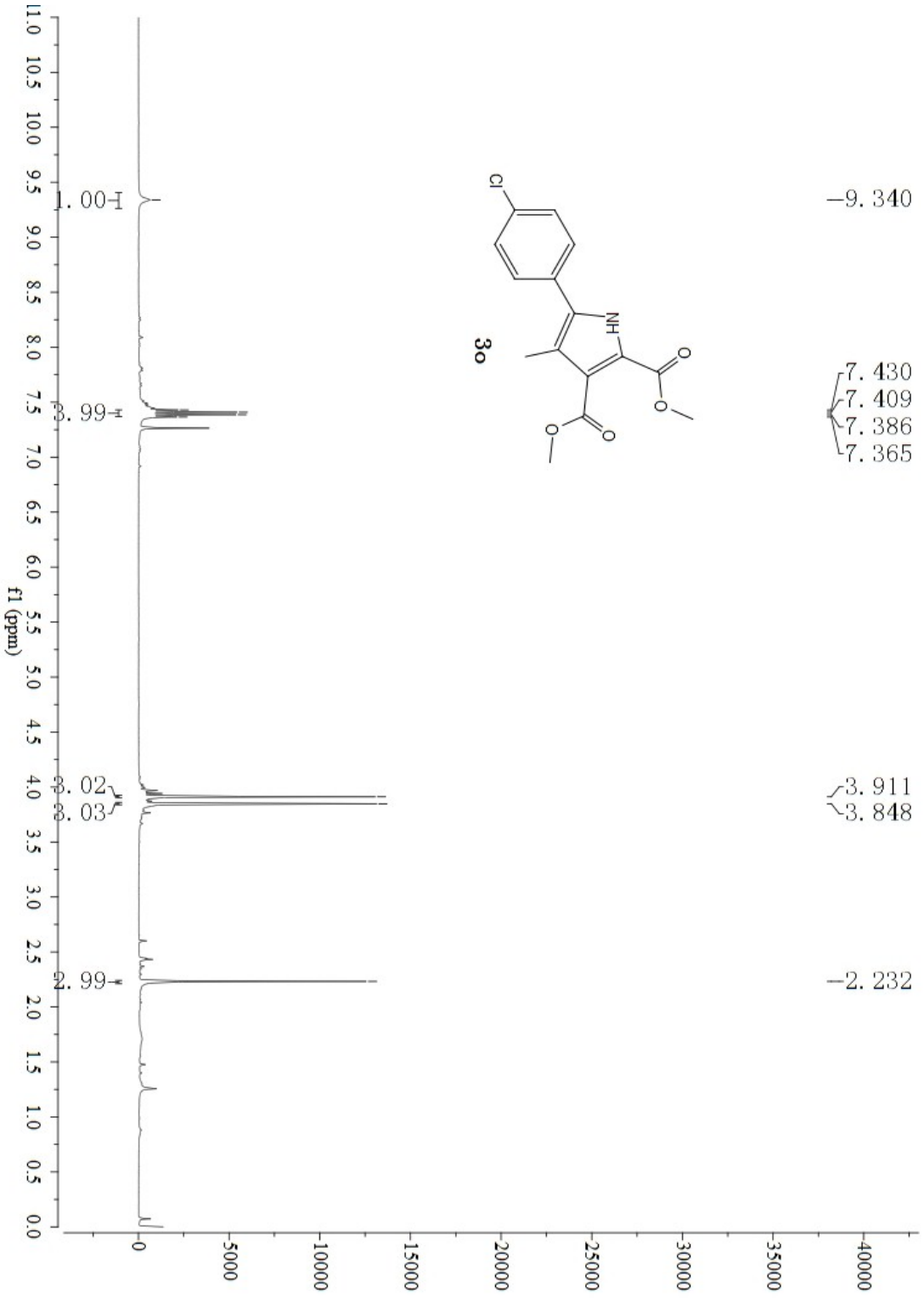

31
NH
O
O
O
O
166.103
160.565
133.127
128.917
128.114
127.622
122.221
120.376
118.836
77.350
77.234
77.032
76.714
52.000
10.809
f1 (ppm)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
-100 0 100 200 300 400 500 600 700 800 900 1000 1100

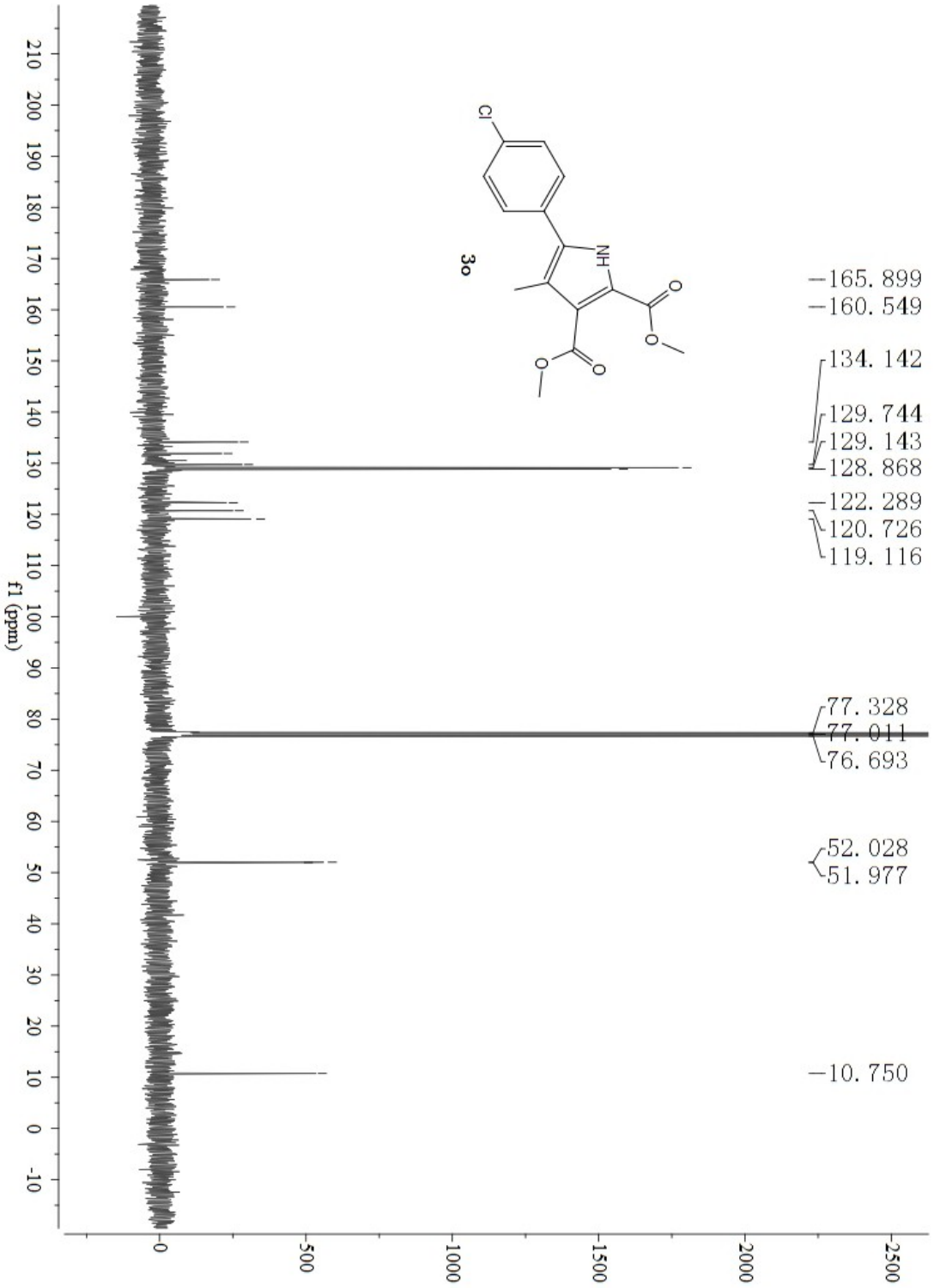

1.00
2.00
1.99
3.04
3.02
3.01
3.03
9.306
7.349
7.328
7.261
7.256
3.908
3.844
2.388
2.241
3m
NH
f1 (ppm)

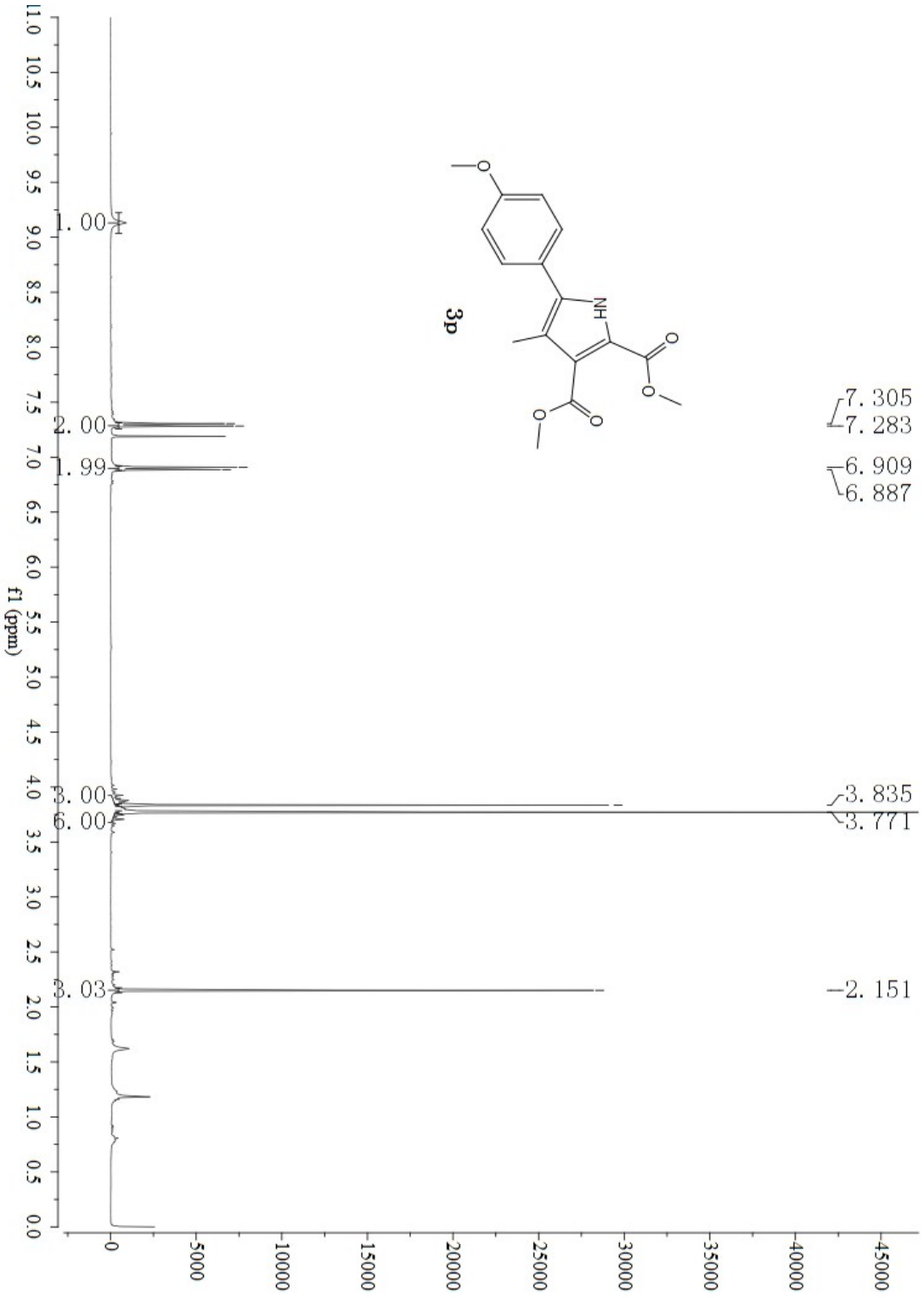

3m
NH
O
O
O
O
166.168
160.647
138.068
133.329
129.568
128.441
127.505
122.248
120.070
118.512
77.343
77.025
76.708
51.917
21.223
10.780
f1 (ppm)

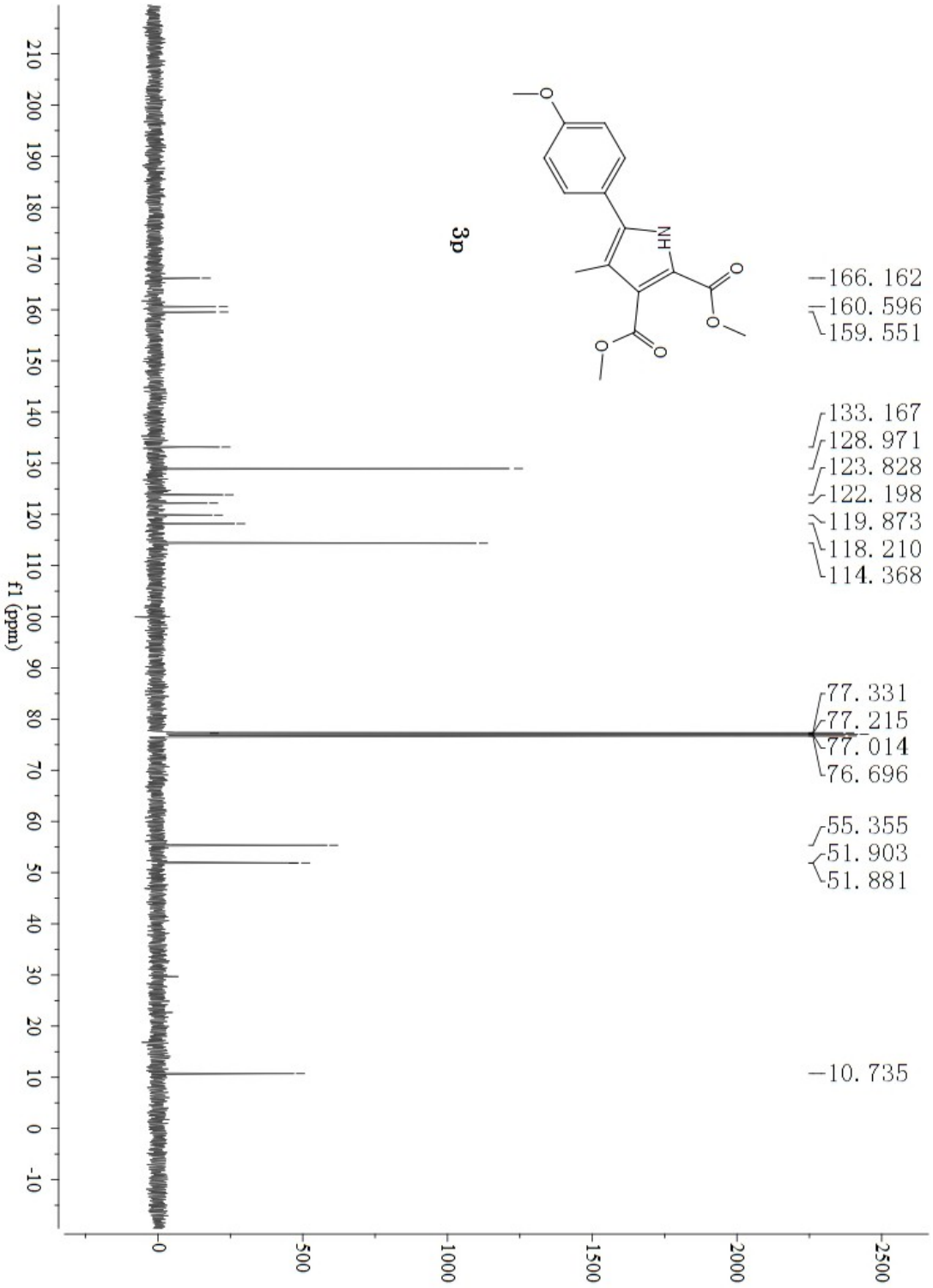

3n
F
NH
O
O
O
O
1.00
2.01
1.98
2.99
3.02
3.05
9.217
7.431
7.426
7.418
7.409
7.396
7.167
7.145
7.124
3.913
3.857
2.224
f1 (ppm)

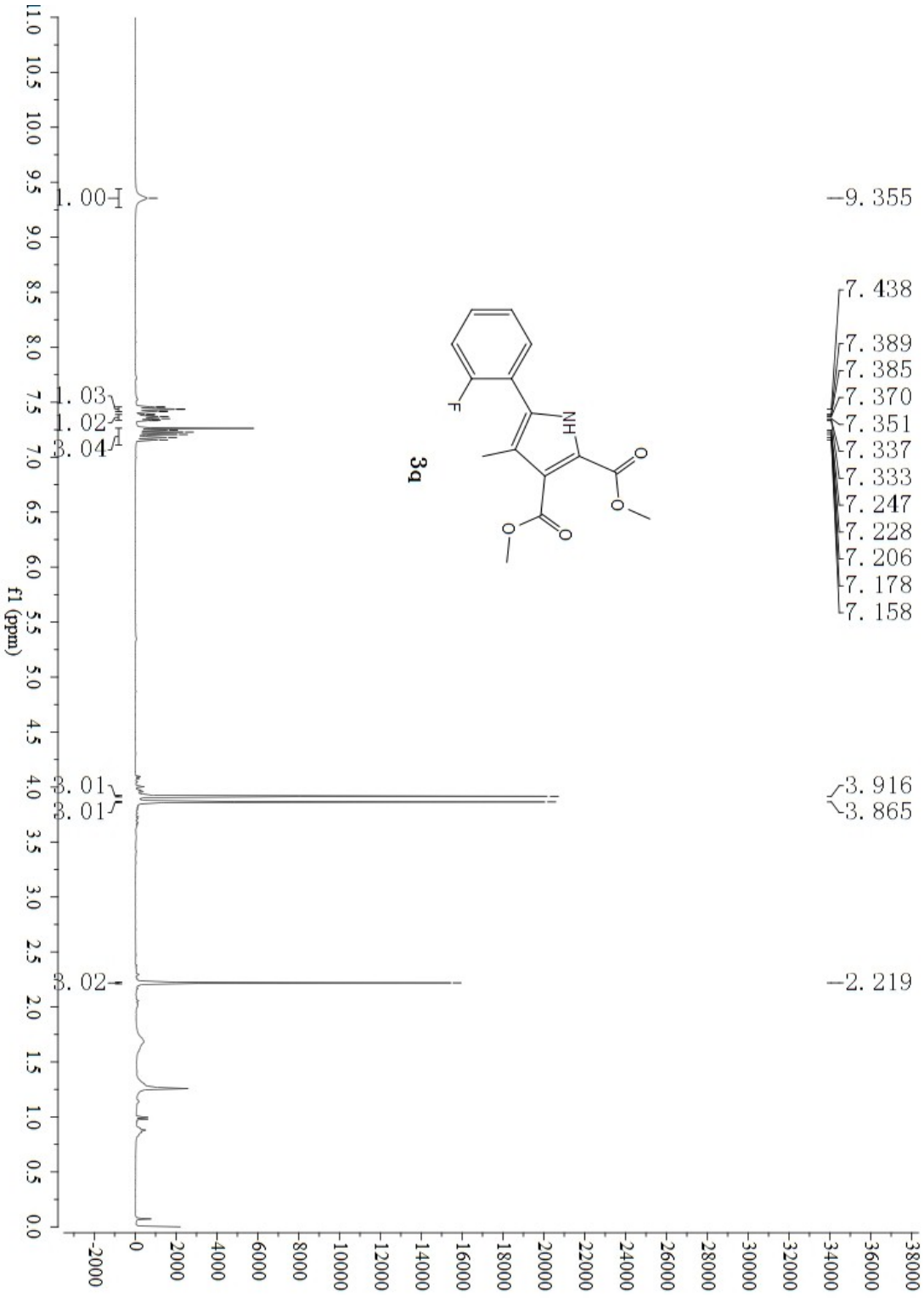

165.953
163.779
161.307
160.523
132.152
130.873
129.552
129.471
127.440
122.173
120.466
118.784
116.109
115.892
51.973
51.948
10.659
3n
F
NH
O
O
O
O
f1 (ppm)

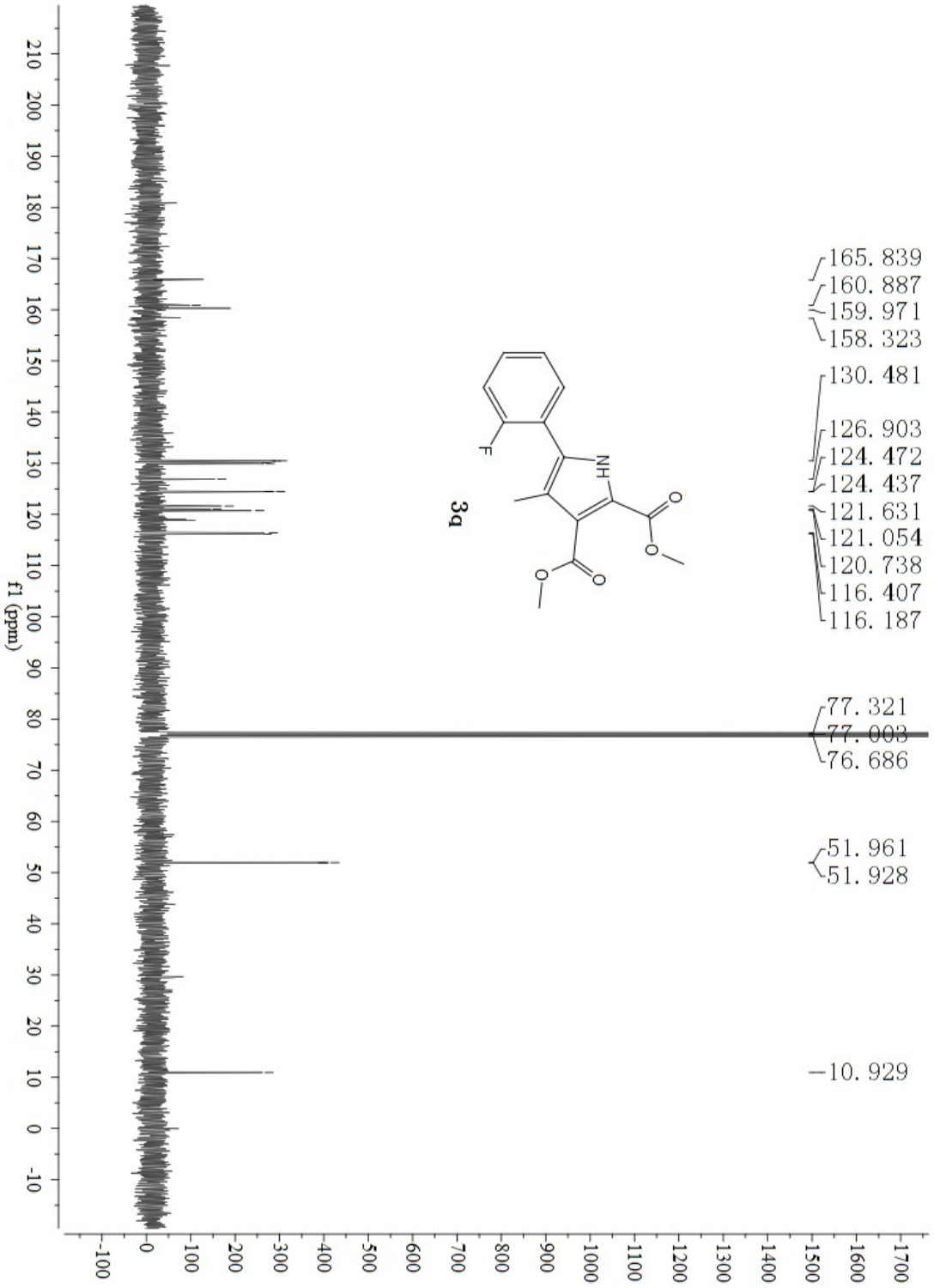

1.00
3.99
3.02
3.03
2.99
9.340
7.430
7.409
7.386
7.365
3.911
3.848
2.232
3o
Cl
NH
O
f1 (ppm)

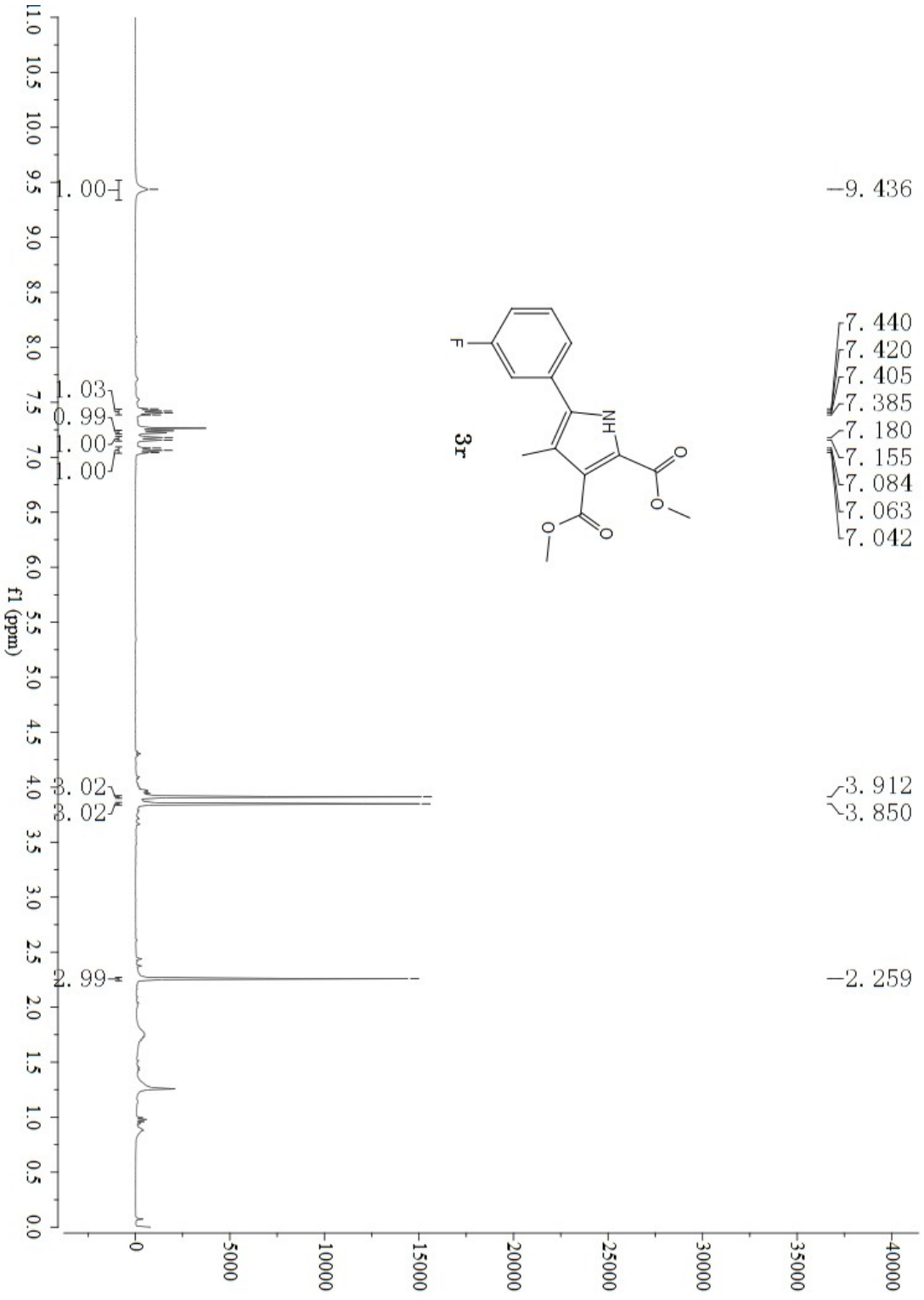

Cl
NH
O
O
O
O
3o
165.899
160.549
134.142
129.744
129.143
128.868
122.289
120.726
119.116
77.328
77.011
76.693
52.028
51.977
10.750
f1 (ppm)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
0 500 1000 1500 2000 2500

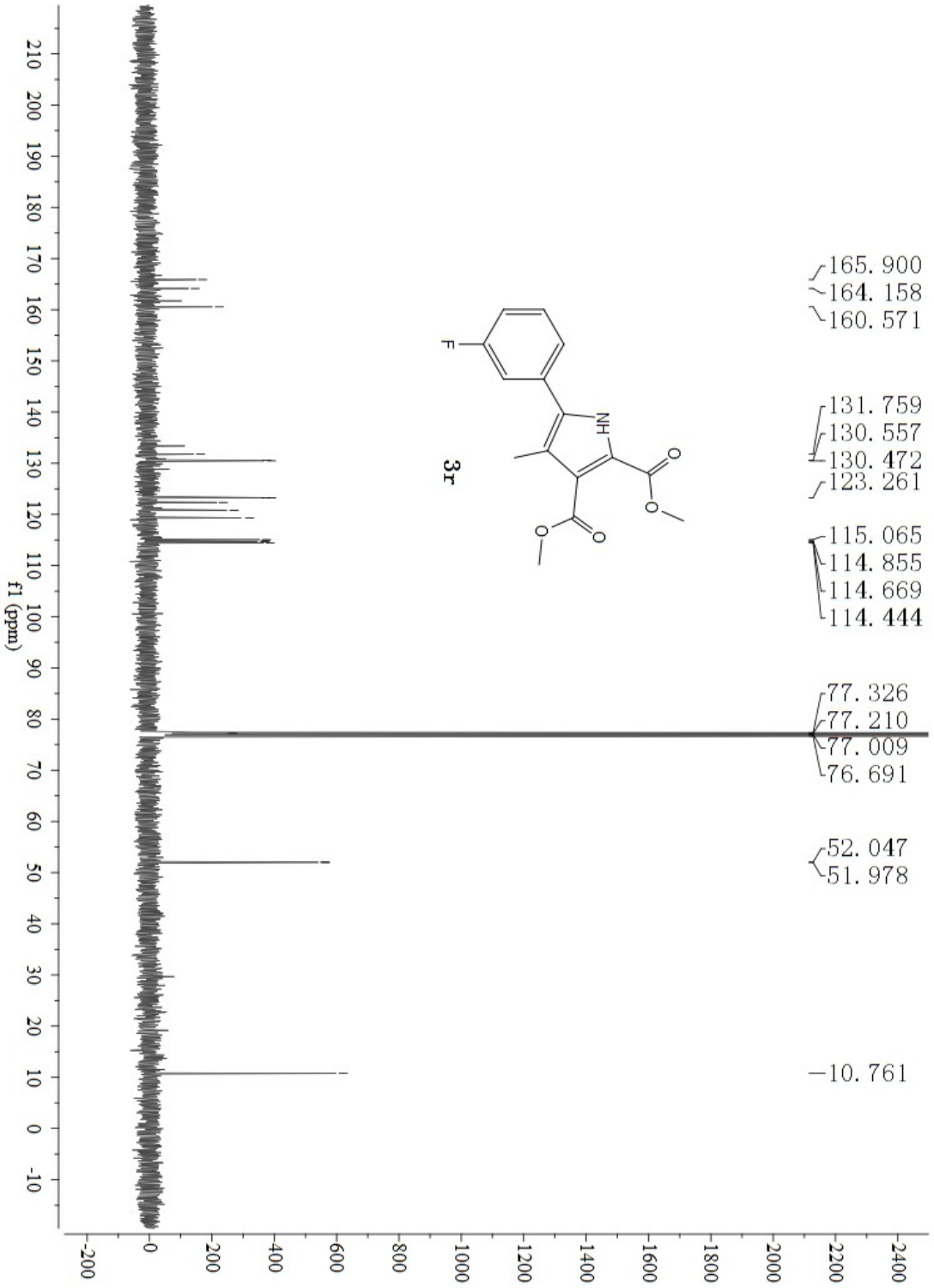

3p
NH
O
O
O
O
O
1.00
2.00
1.99
3.00
6.00
3.03
7.305
7.283
6.909
6.887
3.835
3.771
2.151
f1 (ppm)

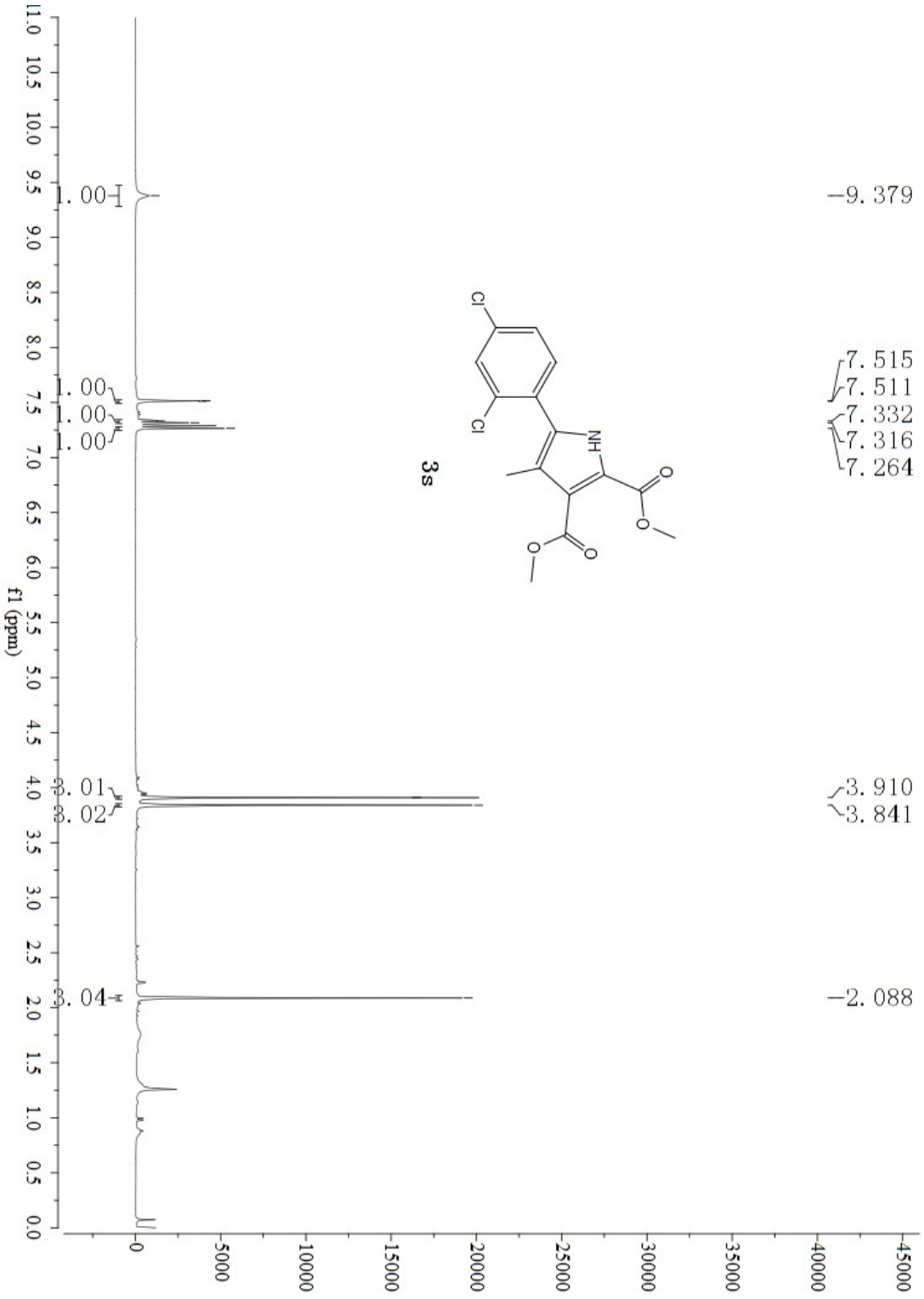

3p
NH
O
O
O
O
O
166.162
160.596
159.551
133.167
128.971
123.828
122.198
119.873
118.210
114.368
77.331
77.215
77.014
76.696
55.355
51.903
51.881
10.735
f1 (ppm)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
0 500 1000 1500 2000 2500

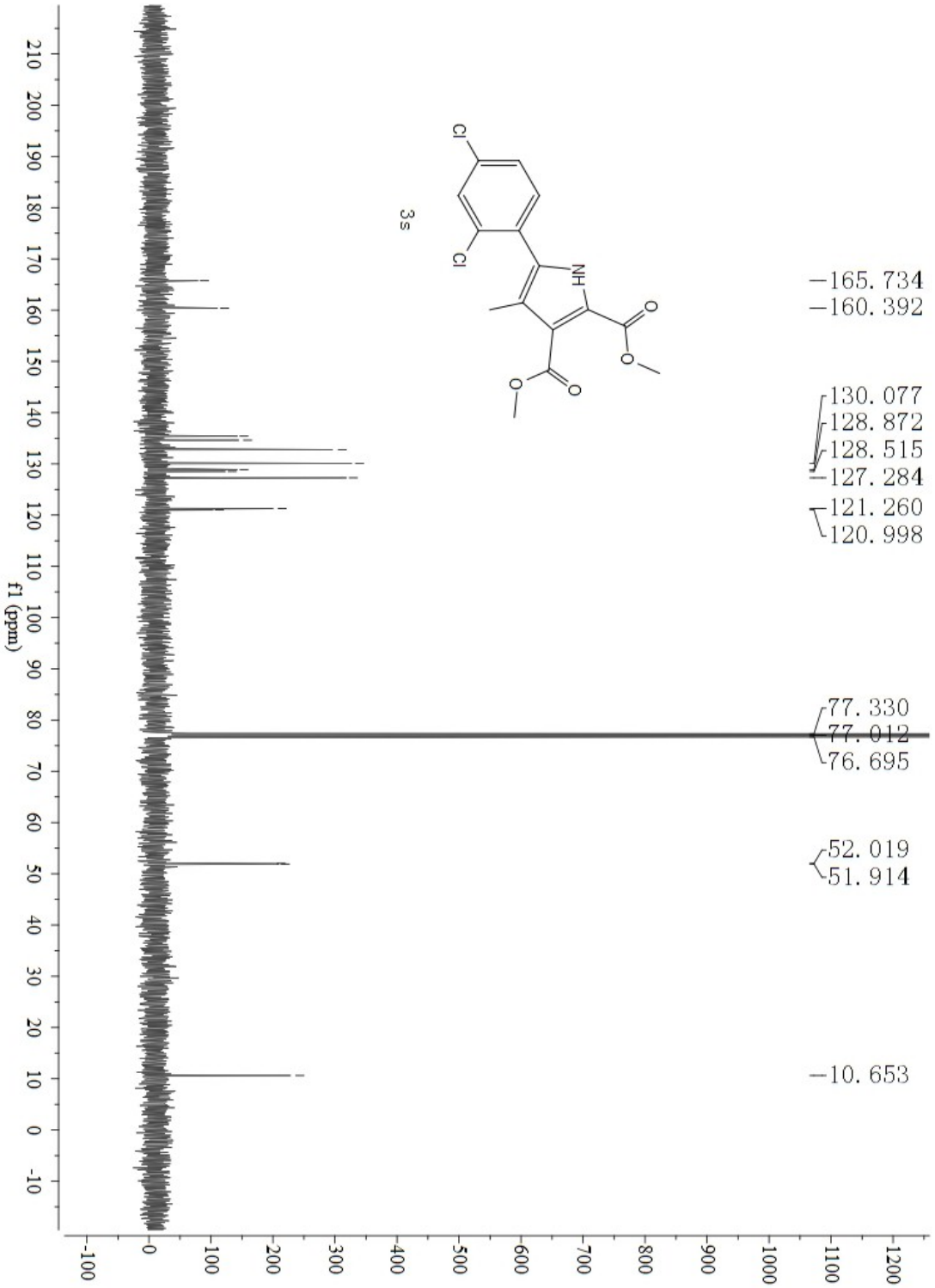

1.00
1.03
1.02
3.04
3.01
3.01
3.02
9.355
7.438
7.389
7.385
7.370
7.351
7.337
7.333
7.247
7.228
7.206
7.178
7.158
3.916
3.865
2.219
3q
f1 (ppm)

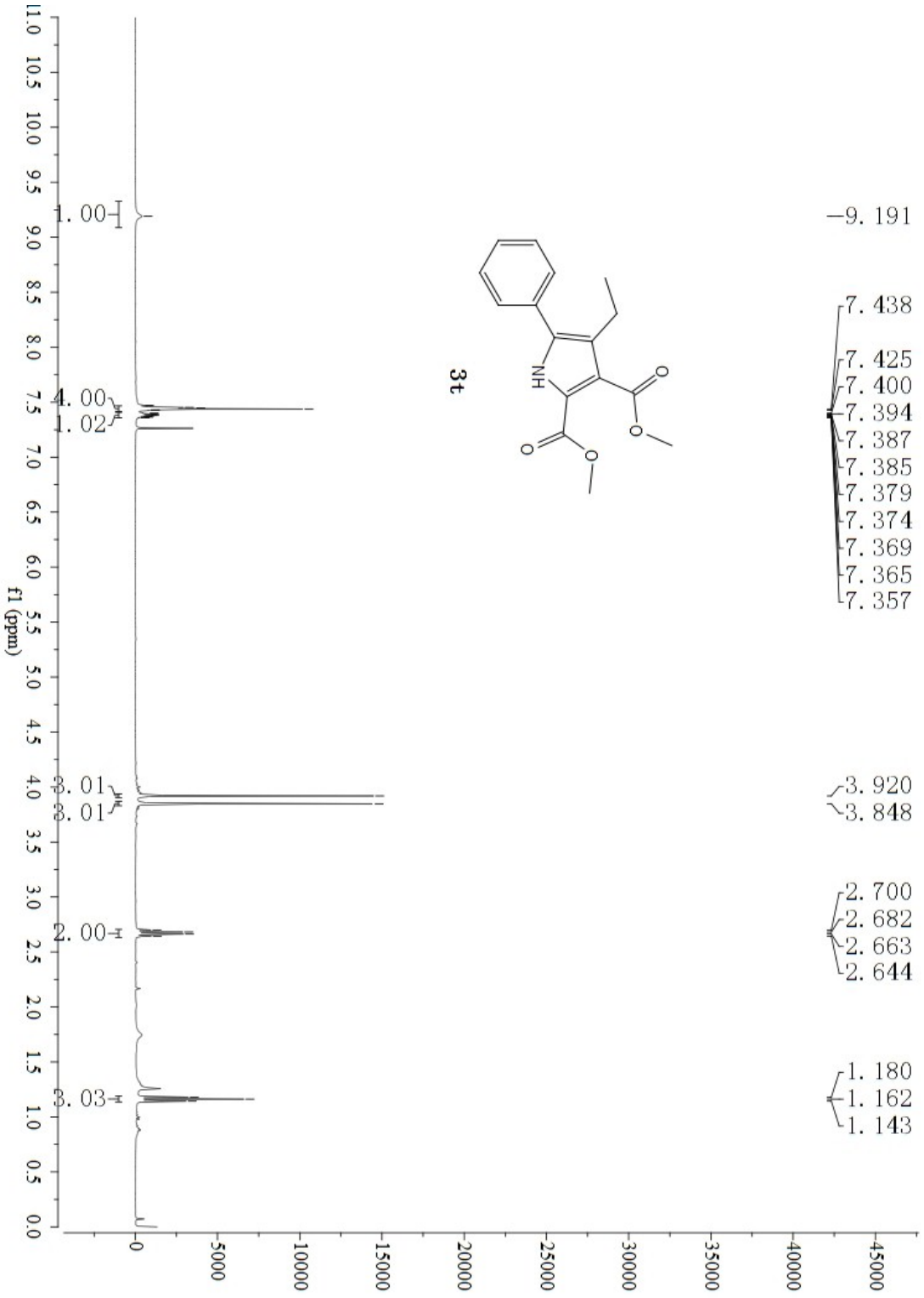

165.839
160.887
159.971
158.323
130.481
126.903
124.472
124.437
121.631
121.054
120.738
116.407
116.187
77.321
77.003
76.686
51.961
51.928
-10.929
3q
F
NH
O
O
O
O
f1 (ppm)

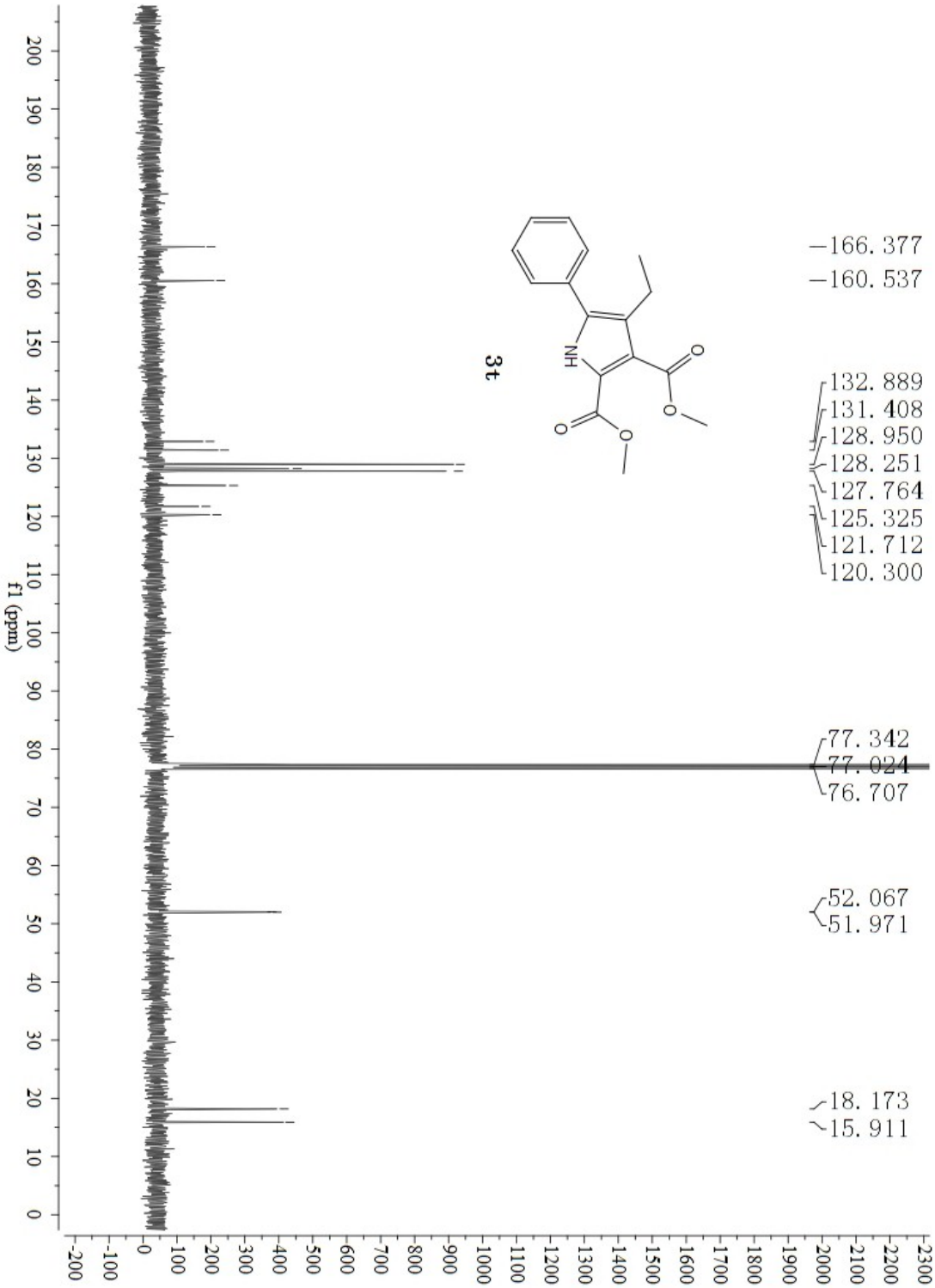

9.436
7.440
7.420
7.405
7.385
7.180
7.155
7.084
7.063
7.042
3.912
3.850
2.259
1.00
1.03
0.99
1.00
1.00
3.02
3.02
2.99
3r
F
NH
O
O
O
O
f1 (ppm)

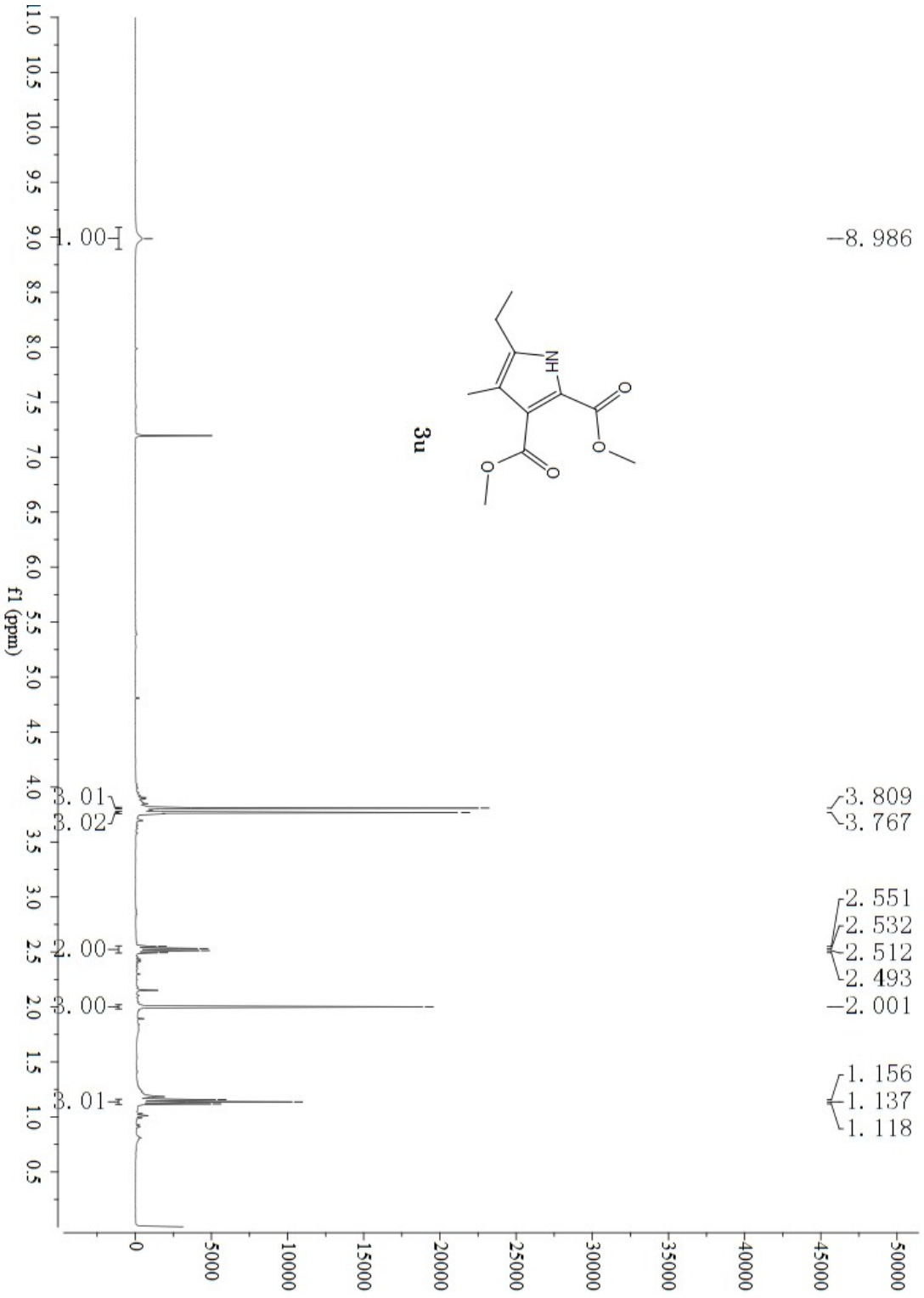

165.900
164.158
160.571
131.759
130.557
130.472
123.261
115.065
114.855
114.669
114.444
77.326
77.210
77.009
76.691
52.047
51.978
10.761
F
NH
O
O
O
O
3r
f1 (ppm)

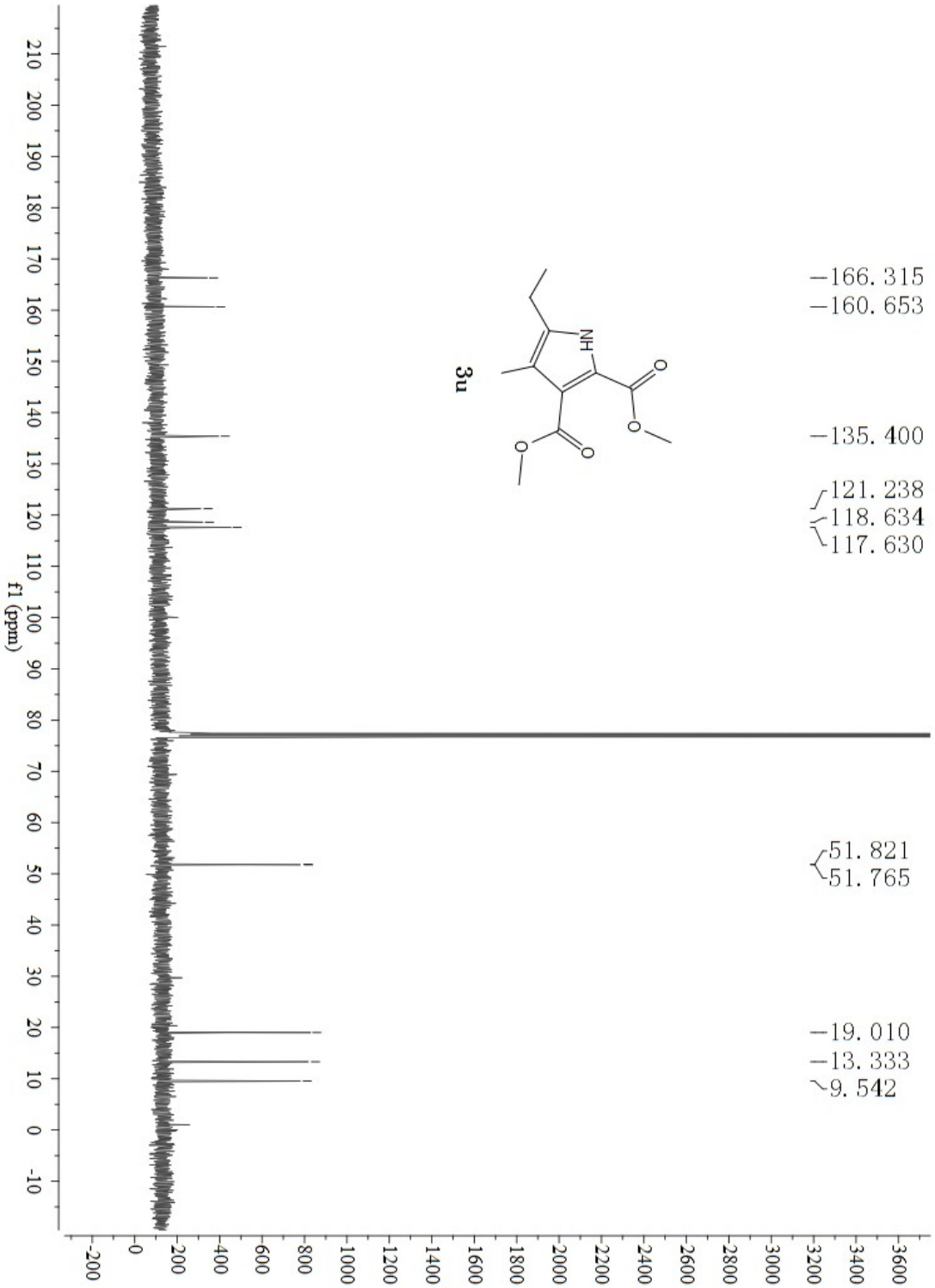

9.379
7.515
7.511
7.332
7.316
7.264
3.910
3.841
2.088
1.00
1.00
1.00
3.01
3.02
3.04
3s
Cl
Cl
NH
O
O
O
O
f1 (ppm)

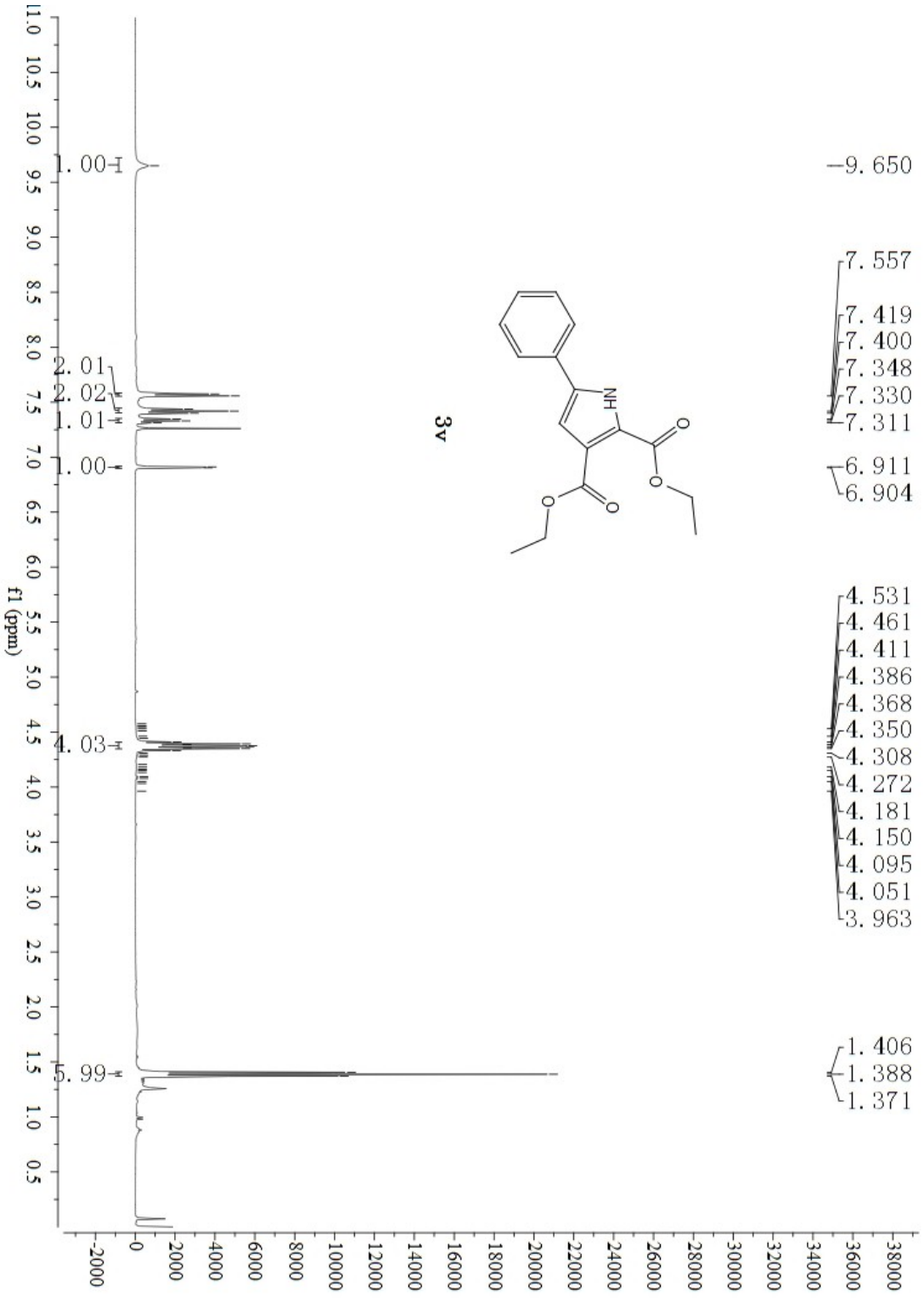

3s
Cl
Cl
NH
O
O
O
O
165.734
160.392
130.077
128.872
128.515
127.284
121.260
120.998
77.330
77.012
76.695
52.019
51.914
10.653
f1 (ppm)

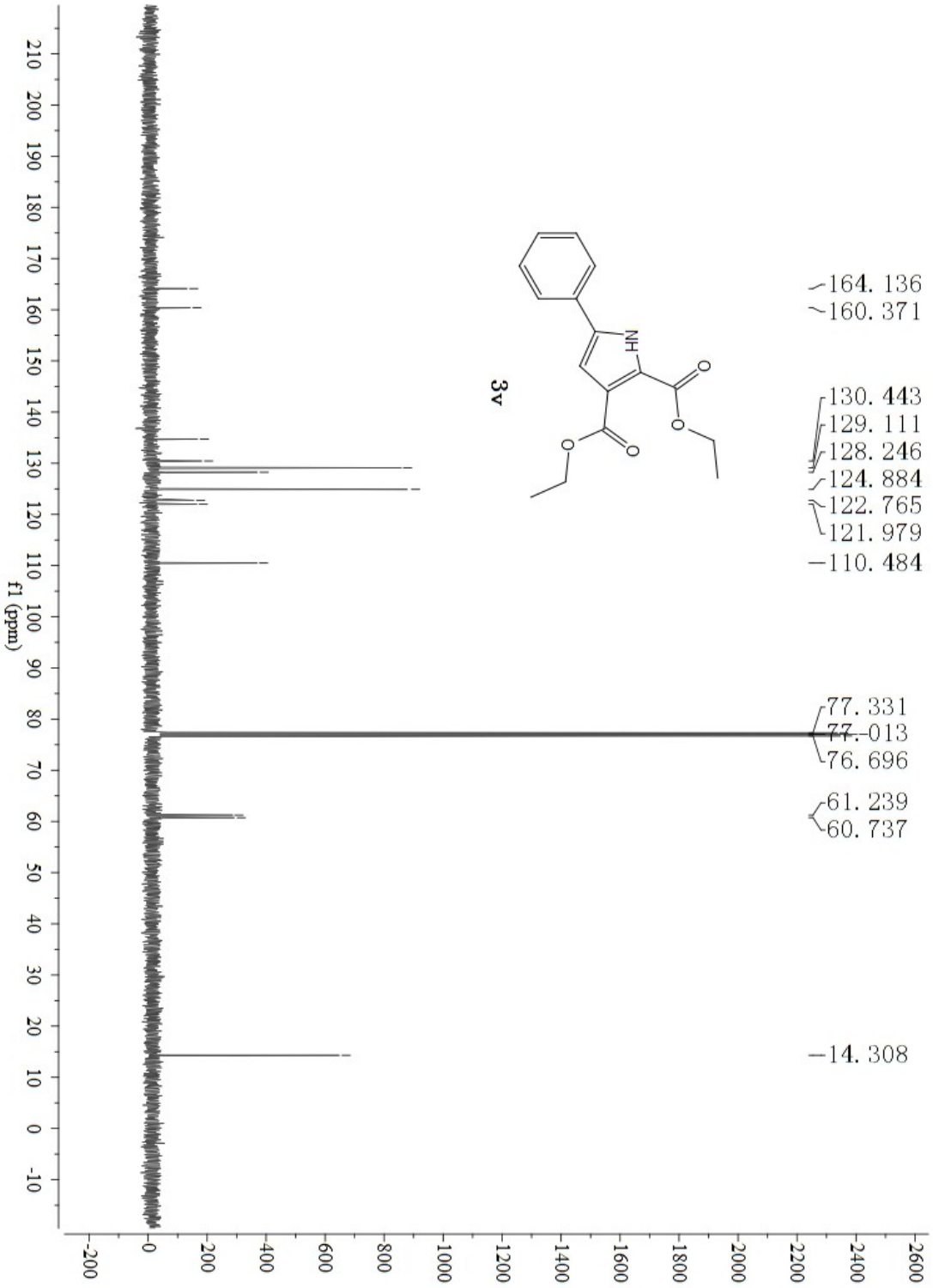

1.00
4.00
1.02
3.01
3.01
2.00
3.03
f1 (ppm)
3t
NH
O
O
O
O
9.191
7.438
7.425
7.400
7.394
7.387
7.385
7.379
7.374
7.369
7.365
7.357
3.920
3.848
2.700
2.682
2.663
2.644
1.180
1.162
1.143

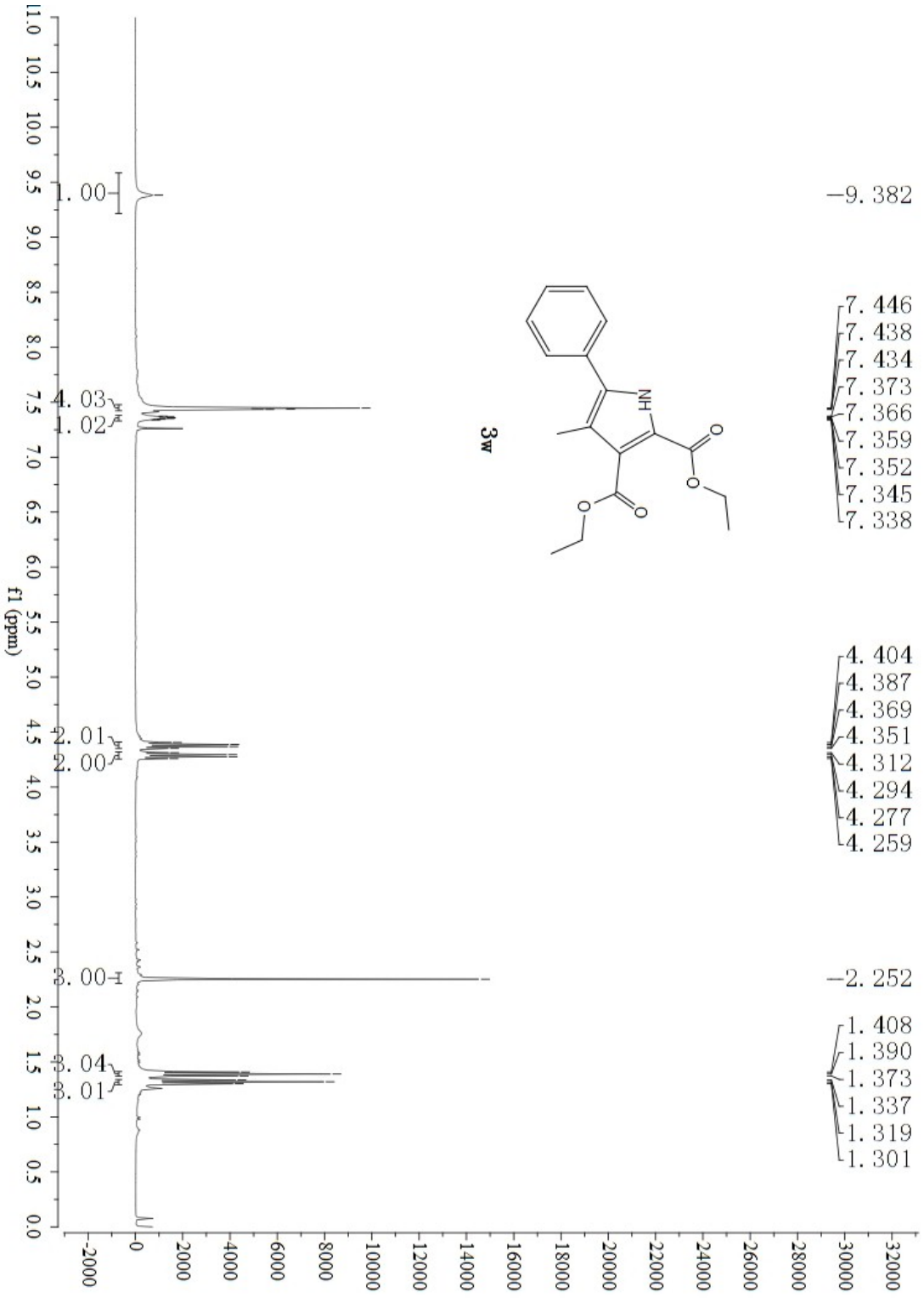

166.377
160.537
132.889
131.408
128.950
128.251
127.764
125.325
121.712
120.300
77.342
77.024
76.707
52.067
51.971
18.173
15.911
3t
NH
f1 (ppm)

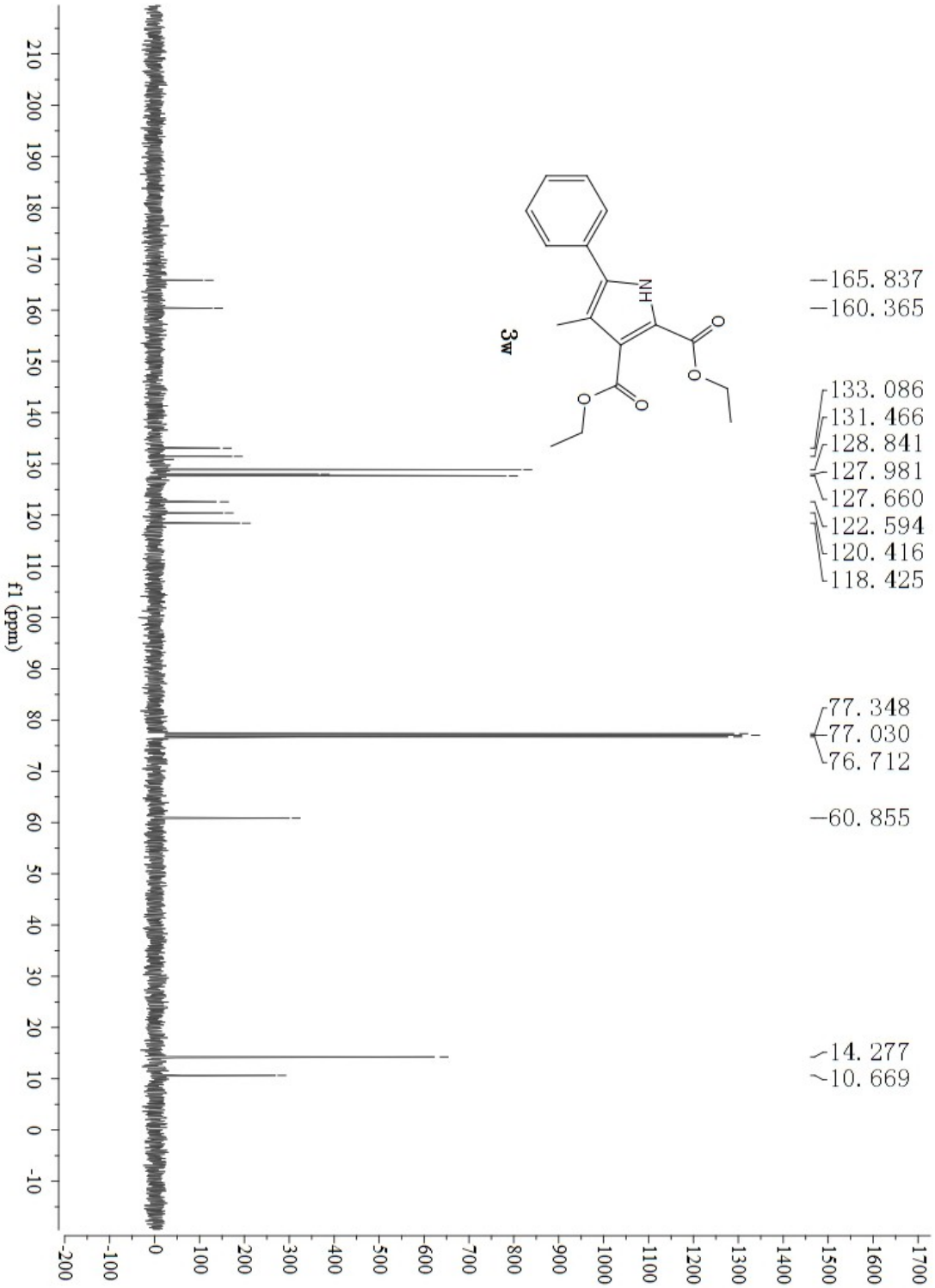

f1 (ppm)
1.00
3.01
3.02
2.00
3.00
3.01
8.986
3.809
3.767
2.551
2.532
2.512
2.493
2.001
1.156
1.137
1.118
NH
O
O
O
O
3u

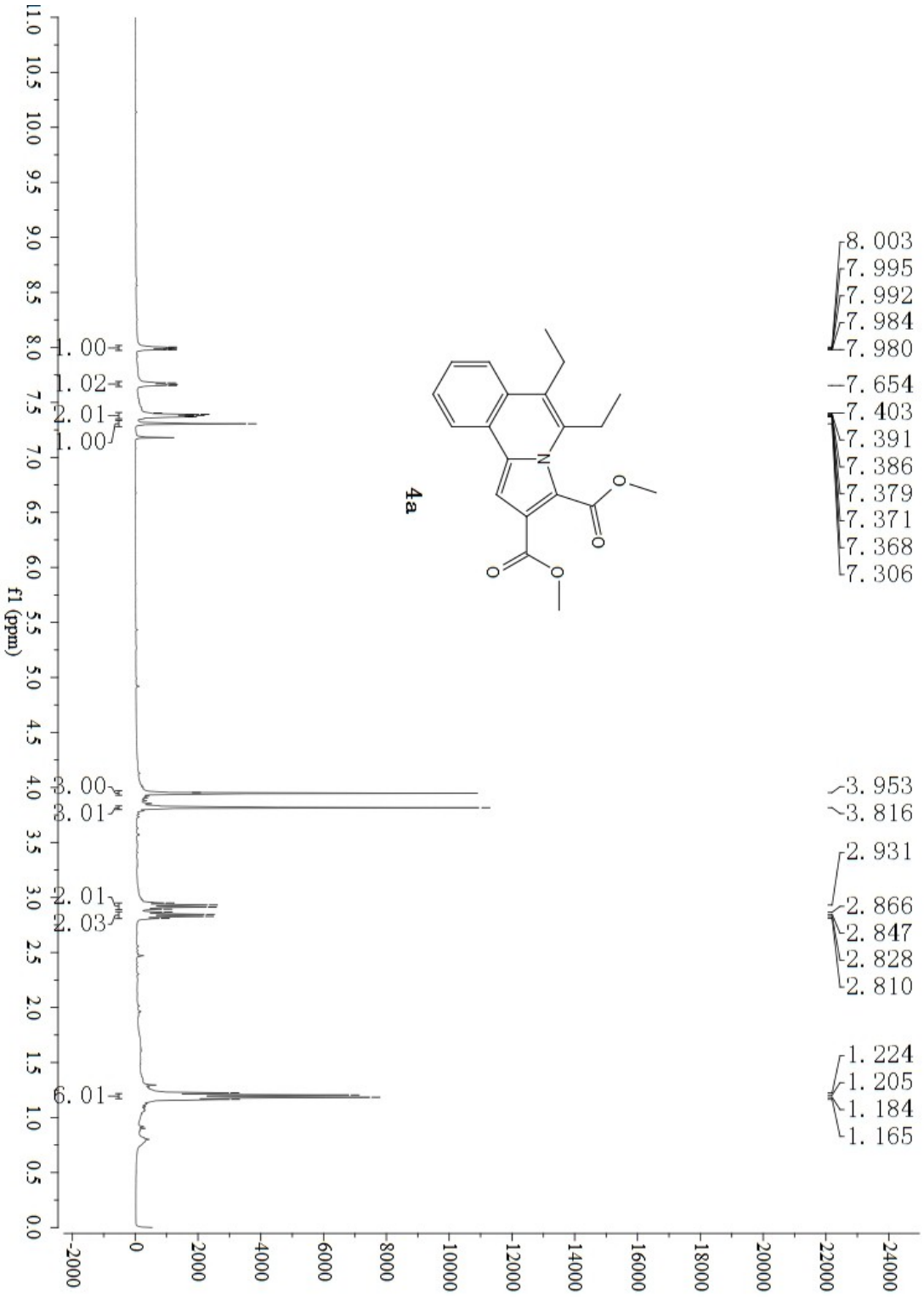

3u
NH
O
O
O
O
166.315
160.653
135.400
121.238
118.634
117.630
51.821
51.765
19.010
13.333
9.542
f1 (ppm)

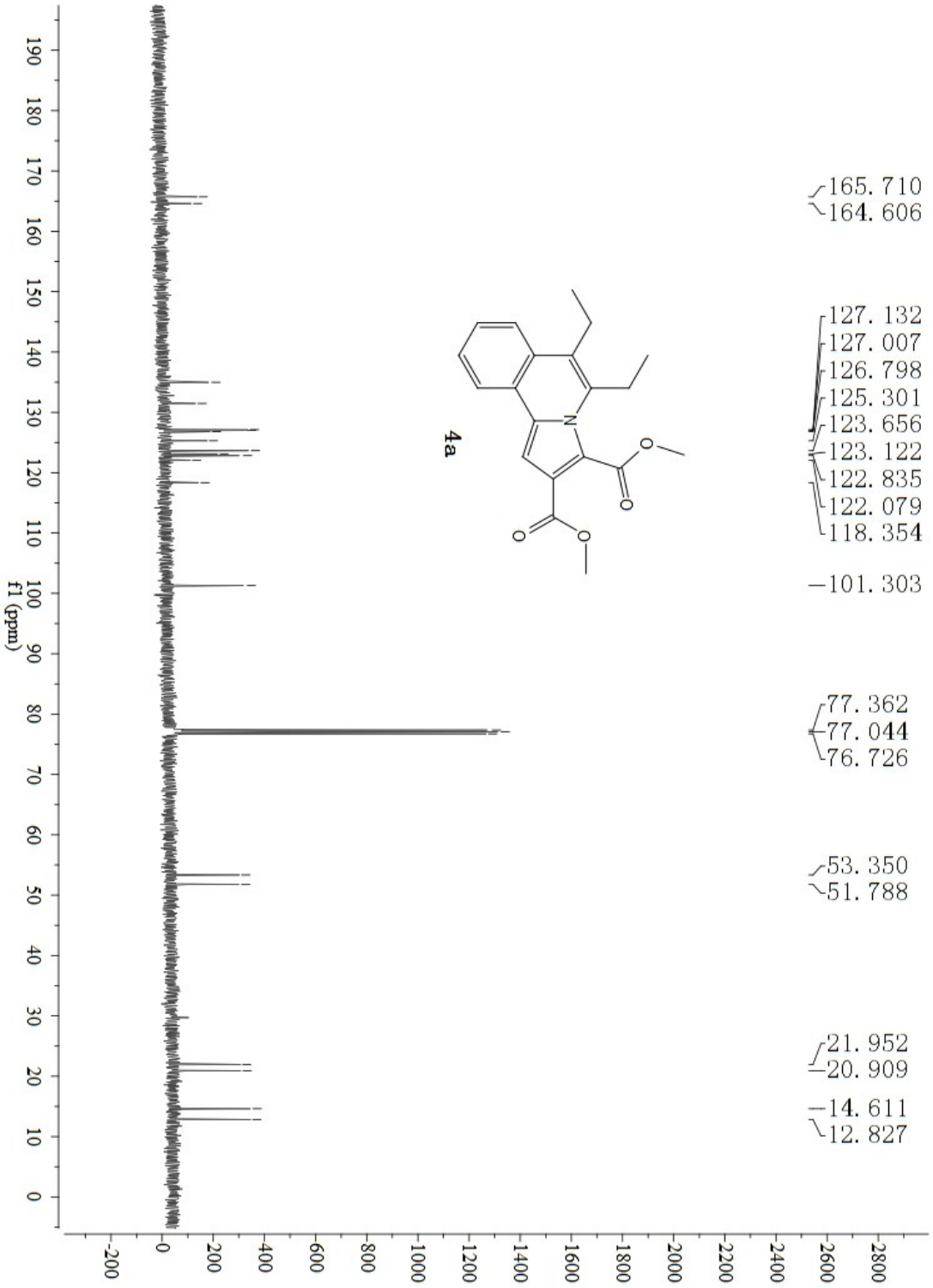

9.650
7.557
7.419
7.400
7.348
7.330
7.311
6.911
6.904
4.531
4.461
4.411
4.386
4.368
4.350
4.308
4.272
4.181
4.150
4.095
4.051
3.963
1.406
1.388
1.371
1.00
2.01
2.02
1.01
1.00
4.03
5.99
3v
NH
f1 (ppm)

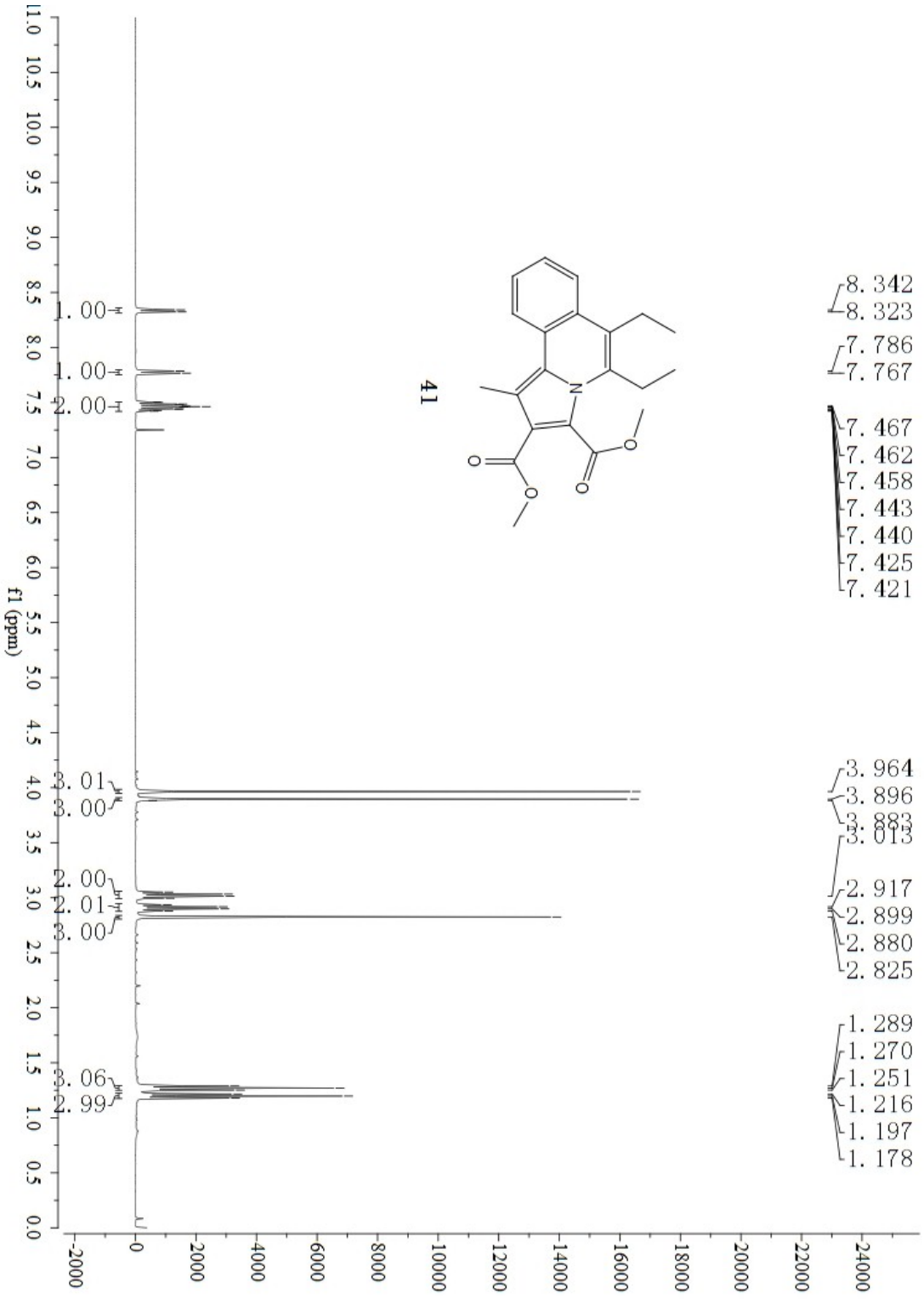

f1 (ppm)
3v
NH
O
O
O
O
164. 136
160. 371
130. 443
129. 111
128. 246
124. 884
122. 765
121. 979
110. 484
77. 331
77. 013
76. 696
61. 239
60. 737
14. 308

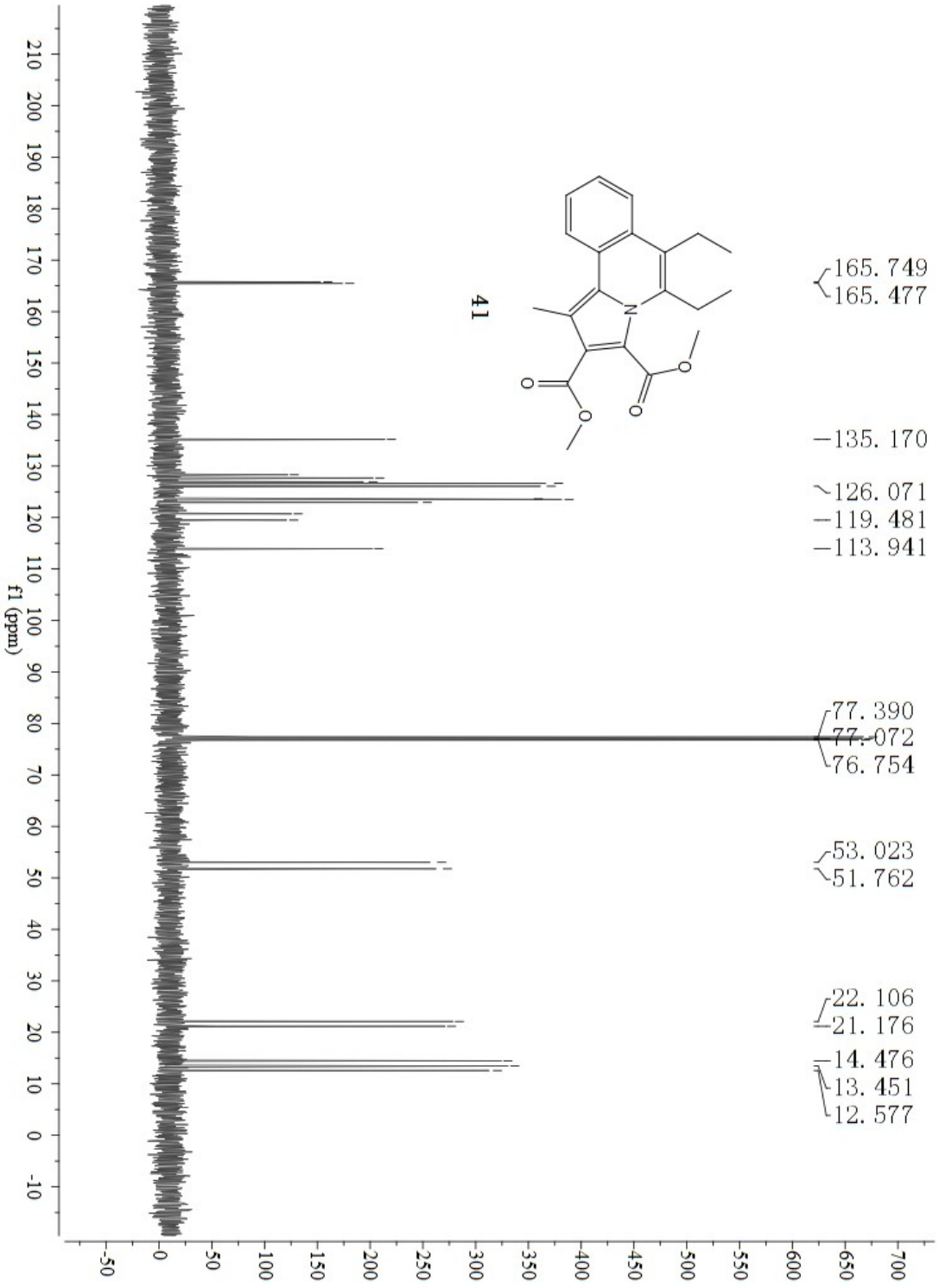

9.382
7.446
7.438
7.434
7.373
7.366
7.359
7.352
7.345
7.338
4.404
4.387
4.369
4.351
4.312
4.294
4.277
4.259
2.252
1.408
1.390
1.373
1.337
1.319
1.301
1.00
4.03
1.02
2.01
2.00
3.00
1.04
1.01
3w
NH
f1 (ppm)


3w
NH
O
O
O
O
165.837
160.365
133.086
131.466
128.841
127.981
127.660
122.594
120.416
118.425
77.348
77.030
76.712
60.855
14.277
10.669
f1 (ppm)


4a
f1 (ppm)
8.003
7.995
7.992
7.984
7.980
7.654
7.403
7.391
7.386
7.379
7.371
7.368
7.306
3.953
3.816
2.931
2.866
2.847
2.828
2.810
1.224
1.205
1.184
1.165
1.00
1.02
2.01
1.00
3.00
3.01
2.01
2.03
6.01


165.710
164.606
127.132
127.007
126.798
125.301
123.656
123.122
122.835
122.079
118.354
101.303
77.362
77.044
76.726
53.350
51.788
21.952
20.909
14.611
12.827
4a
f1 (ppm)


41
f1 (ppm)
8.342
8.323
7.786
7.767
7.467
7.462
7.458
7.443
7.440
7.425
7.421
3.964
3.896
3.883
3.013
2.917
2.899
2.880
2.825
1.289
1.270
1.251
1.216
1.197
1.178
1.00
1.00
2.00
3.01
3.00
2.00
2.01
3.00
3.06
2.99


41
165.749
165.477
135.170
126.071
119.481
113.941
77.390
77.072
76.754
53.023
51.762
22.106
21.176
14.476
13.451
12.577
f1 (ppm)