Supporting Information

Phosphine-Mediated Domino Reactions of Phthalimidomalonates with Allenoates or But-2-ynoate: Facile Entry into Highly Functionalized Pyrroloisoindolinone Derivatives

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Context

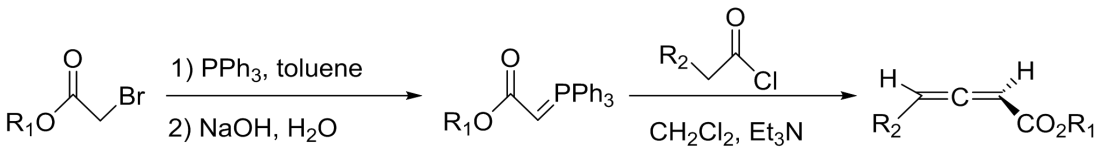
1. General Information

All reactions were performed in dry solvents under an N_2 atmosphere and anhydrous conditions. DCM, THF, DMSO, and MeCN etc were freshly distilled over CaH_2 prior to use. All other reagents were used as received from commercial sources. Reactions were monitored through thin layer chromatography (TLC) on 0.25-mm SiliCycle silica gel plates and visualized under UV light. NMR spectra of the new product were recorded using Bruker Avance-300 and Bruker Avance-500 instruments, calibrated to $CD(H)Cl_3$ as the internal reference (7.26 and 77.0 ppm for ^{1}H-NMR and ^{13}C -NMR spectra, respectively), calibrated to DMSO-d_6 as the internal reference (2.50 and 39.5 ppm for ^{1}H-NMR and ^{13}C-NMR spectra, respectively). ^{1}H-NMR spectral data are reported in terms of chemical shift (δ, ppm), multiplicity, coupling constant (Hz), and integration. ^{13}C-NMR spectral data are reported in terms of chemical shift (δ, ppm) and multiplicity. The following abbreviations indicate the multiplicities: s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet. High resolution mass spectrometry (HRMS) was obtained on a Q-TOF micro spectrometer. IR spectra were recorded on a Bruker Optics Tensor 37 spectrometer by the KBr pellet method.

2. Substrate Preparation

2.1 Allenoate Preparation

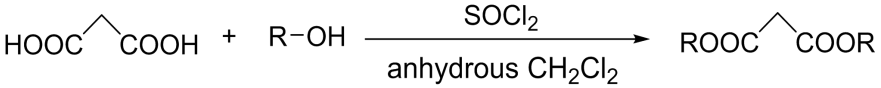
Except for the ethyl 2,3-butadienoate was purchased from TCI Co., other regents: methyl 2,3-butadienoate, benzyl 2,3-butadienoate, were prepared using reported methods.[1]



2.2 Phthalimidomalonates Preparation

2.2.1 Preparationof malonates

Except for the di-tert-butyl malonate and tert-butyl ethyl malonate were purchased from TCI Co. and Aladdin Co., respectively. other dialkyl malonates were prepared by this way below.[2]

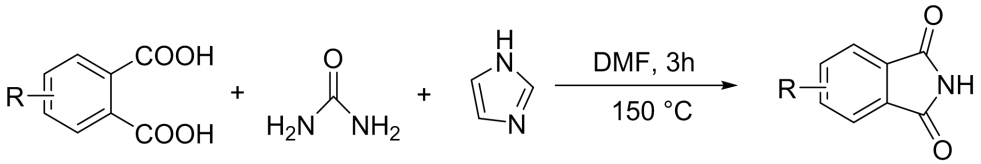


Procedure: malonamic acid (1.041 g, 10 mmol) and R-OH (5 mL) were added to the dried 50mL round-bottom flask, then $SOCl_2$ (2.19 mL, 30 mmol) in 10 mL anhydrous CH_2Cl_2 was added droplet by funnel. Then saturated Na_2CO_3 solvent was added to treat the surplus acid after overnight. The mixture was washed with 3×20 mL CH_2Cl_2, the combined organic layer was over dried by anhydrous Na_2SO_4. The crude product was obtained by evaporating the solvent after

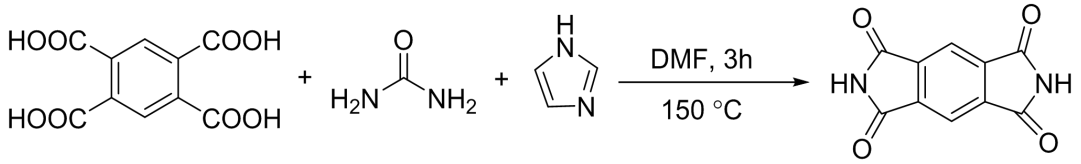
filtration. It was used directly in the next step without further purifying.(Suitable for: R = Me; Et; n-Pr; i-Pr; n-Bu; Bn.)

2.2.2 Substituted PhthaliMide Preparation

Except for the 3-nitrophthalimide, 4-nitrophthalimide and 3,4,5,6-tertachlorophthalimide were purchased from Energy Co., other substituted phthalimide were prepared by this way below.[3] (Suitable for : R = 4,5-dichloro and R = 4-Me.)



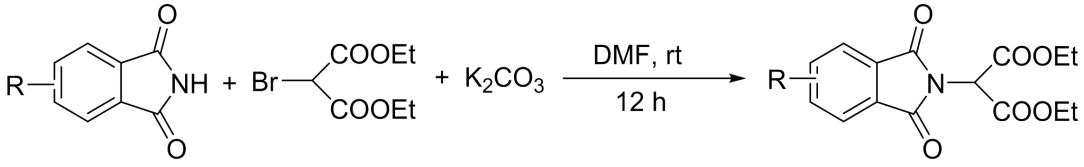
General Procedure: Typical experimental procedure for synthesis of substituted phthalimide. A mixture of substituted phithalic acid (2 mmol), imidazole (0.264g, 3 mmol) and the suitable urea (4 mmol) were well triturated and placed in a 25 mL bottom-flask followed by the addition of 6 drops of DMF. The mixture was heated at 150 °C in an oil bath for 3h. The crude material was cooled down, triturated and stirred in a 10% v/v aqueous HCl solution for 10 min. The resulting solid residue was filtered-off purified by recrystallization from ethanol or column chromatography with gradient ethyl acetate : n-hexane (1:4) to generate the desired pure products.



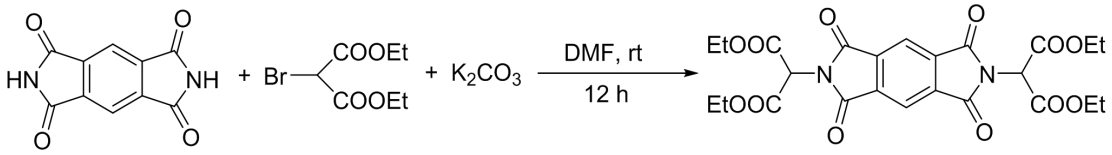
General Procedure: Typical experimental procedure for synthesis of phthalimide. A mixture of 1,2,4,5-benzenetetracarboxylic acid (2 mmol), imidazole (0.528g, 6 mmol) and the suitable urea (8 mmol) were well triturated and placed in a 50 mL bottom-flask followed by the addition of 12 drops of DMF. The mixture was heated at 150 °C in an oil bath for 3h. The crude material was cooled down, triturated and stirred in a 10% v/v aqueous HCl solution for 10 min. The resulting solid residue was filtered-off purified by recrystallization from ethanol or column chromatography with gradient ethyl acetate : n-hexane (1:4) to generate the desired pure products.

2.2.3 Substituted Phthalimidomalonates Preparation

General procedure A

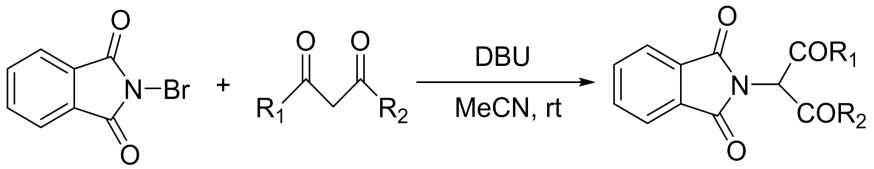


General Procedure: General experimental procedure for synthesis of substituted phthalimidomalonates. A mixture of phthalimide (2 mmol,), potassium carbonate (6 mmol) and the diethyl bromomalonate (2 mmol) placed in a 50 mL bottom-flask followed by the addition of 20 mL DMF. The mixture was stirred at room temperature for 12 h. The reactant solution was dumped into 100 mL of NaCl saturated solution and extracted with 30 mL ethyl acetate, the organic layer was washed by saturated brines (3 x 100 mL), gathered the organic layer, dried with anhydrous Mg_2SO_4, filtered and distilled under reduced pressure to give the crude material, purified by column chromatography with gradient ethyl acetate : petroleum ether (1:10) to give substituted phthalimidomalonates (>80% yield).[4] (Suitable for : R = 3-NO_2, R = 4-NO_2, R = 3,4,5,6-tetrachloro, R = 4,5-dichloro and R = 4-Me.)



General Procedure: A mixture of pyrrolo[3,4-f]isoindole-1,3,5,7(2H,6H)-tetraone(2 mmol), potassium carbonate (12 mmol) and the diethyl bromomalonate (4 mmol) placed in a 50 mL bottom-flask followed by the addition of 20 mL DMF. The mixture was stirred at room temperature for 12 h. The reactant solution was dumped into 100 mL of NaCl saturated solution and extracted with 30 mL ethyl acetate, the organic layer was washed by saturated brines (3 x 100 mL), gathered the organic layer, dried with anhydrous Mg_2SO_4, filtered and distilled under reduced pressure to give the crude material, purified by column chromatography with gradient ethyl acetate : petroleum ether (1:10) to give substituted phthalimidomalonates (90% yield).

General procedure B



General procedure for the preparation of phthalimidomalonates: To a solution of malonates (1.0 mmol) in MeCN (2.0 mL) was added NBP (339.0 mg, 1.5 mmol) and DBU (0.261 mL, 1.8 mmol). The mixture was stirred at room temperature for 20 min. The reaction mixture was poured into water and then extracted with CH_2Cl_2 (3 × 10 mL). The combined organic phase was washed with water (3 × 10 mL), filtered and concentrated under reduced pressure. The crude product was purified by flash chromatography (silica gel, petroleum ether: ethyl acetate = 20: 1 as eluent) to give phthalimidomalonates (>90% yield) as colorless solid.[5] (Suitable for : $R_1 = R_2$ = MeO; $R_1 = R_2$ =EtO; $R_1 = R_2 = {}^{n}$PrO; $R_1 = R_2 = {}^{i}$PrO; $R_1 = R_2 = {}^{n}$BuO; $R_1 = R_2 = {}^{t}$BuO; $R_1 = R_2$ = BnO; $R_1 = {}^{t}$BuO, R_2 = EtO; $R_1 = R_2$ = Me and R_1 = Me, R_2 = EtO).

3. References

[1] L. Rout, A. M. Harned, *Chemistry*. **2009**, *15*, 12926-12928.

[2] Y. Kuang, X. Liu, L. Chang, M. Wang, L. Lin, X. Feng, *Org. Lett*. **2011**, *42*, 3814-3817.

[3] A. W. N. F. Ricardo, A. T. P.-F. Mieder, N. D. O. Ronaldo, *Syn. Commun.* **2013**, *43*, 1571-1571.

[4] Y. Yin, X. Wu, *Faming Zhuanli Shenqing.* **2010**, *15*, 101830842.

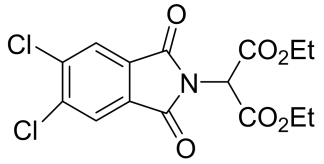
[5] H. Tan, M. Li, F. Liang, *RSC Adv*. **2014**, *4*, 33765-33768.

4. Synthetic procedures and characterization data

4.1 General procedure for synthesis of 3

To a mixture of phthalimidomalonate derivative **1** (0.2 mmol) and allenate **2** (0.44 mmol) in anhydrous Et_2O (2.0 mL), Ph_2EtP (0.22mol, 47mg) was added. The resulting solution was stirred at room temperature for 12h. After removal of solvent, the product was purified through silica gel to give the desired products **3**.

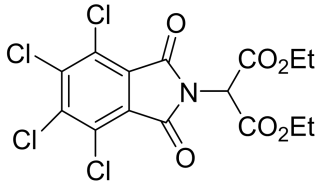
4.2 Characterization data for substituted phthalimidomalonates



1i

Diethyl 2-(5,6-dichloro-1,3-dioxoisoindolin-2-yl)malonate (1i)

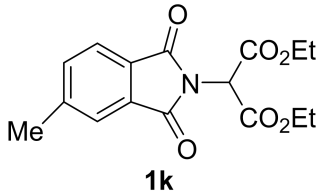
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.98 (d, J = 0.7 Hz, 2H), 5.45 (s, 1H), 4.35– 4.27 (m, 4H), 1.30 (t, J = 7.1 Hz, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) *δ* 164.52 (2C), 163.87 (2C), 139.52 (2C), 130.80 (2C), 125.89 (2C), 62.93 (2C), 54.68, 13.94 (2C). HRMS (ESI-TOF) calcd for $C_{15}H_{13}Cl_2NO_6$ ($M+Na^+$) = 396.0120, found 396.0122.



1j

Diethyl 2-(4,5,6,7-tetrachloro-1,3-dioxoisoindolin-2-yl)malonate (1j)

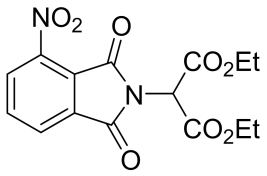
^{1}H NMR (300 MHz, $CDCl_3$) δ 5.47 (s, 1H), 4.36 – 4.27 (m, 4H), 1.32 (t, *J* = 7.1 Hz, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 163.59 (2C), 161.84 (2C), 140.67 (2C), 130.25 (2C), 63.07 (2C), 54.82, 13.95 (2C). HRMS (ESI-TOF) calcd for $C_{15}H_{11}Cl_4NO_6$ ($M+Na^+$) = 465.9312, found 465.9315.



1k

Diethyl 2-(5-methyl-1,3-dioxoisoindolin-2-yl)malonate (1k)

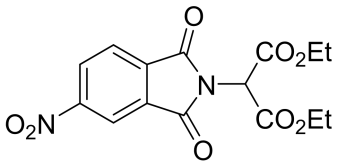
^{1}H NMR (300 MHz, $CDCl_3$) δ 7.76 (d, *J* = 7.7 Hz, 1H), 7.68 (s, 1H), 7.54 (d, *J* = 7.7 Hz, 1H), 5.45 (s, 1H), 4.35 – 4.24 (m, 4H), 2.51 (s, 3H), 1.30 (t, *J* = 7.1 Hz, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 166.65, 166.52, 164.39 (2C), 145.80, 134.94, 132.14, 129.16, 124.30, 123.71, 62.68 (2C), 54.43, 22.00, 13.94 (2C). HRMS (ESI-TOF) calcd for $C_{16}H_{17}NO_6$ ($M+Na^+$) = 342.1078, found 342.1074.



1l

Diethyl 2-(4-nitro-1,3-dioxoisoindolin-2-yl)malonate (1l)

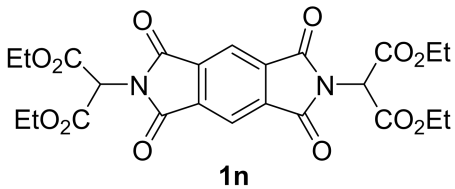
^{1}H NMR (300 MHz, $CDCl_3$) δ 8.17 (ddd, *J* = 7.7, 3.5, 1.0 Hz, 2H), 7.97 (t, *J* = 7.8 Hz, 1H), 5.50 (s, 1H), 4.37 – 4.27 (m, 4H), 1.31 (t, *J* = 7.1 Hz, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 164.01, 163.70 (2C), 161.16, 135.83, 133.74, 129.07, 127.59, 123.55, 114.58, 63.05 (2C), 54.85, 13.94 (2C). HRMS (ESI-TOF) calcd for $C_{15}H_{14}N_2O_8$ ($M+Na^+$) = 373.0754, found 373.0758.



1m

Diethyl 2-(5-nitro-1,3-dioxoisoindolin-2-yl)malonate (1m)

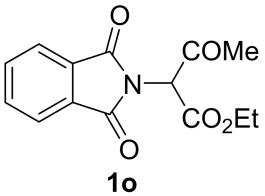
^{1}H NMR (300 MHz, $CDCl_3$) δ 8.70 (dd, *J* = 2.0, 0.6 Hz, 1H), 8.64 (dd, *J* = 8.1, 2.0 Hz, 1H), 8.10 (dd, *J* = 8.1, 0.7 Hz, 1H), 5.50 (s, 1H), 4.38 – 4.27 (m, 4H), 1.31 (t, *J* = 7.1 Hz, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 164.39, 164.12, 163.70 (2C), 151.99, 136.04, 133.11, 129.61, 125.11, 119.23, 63.07 (2C), 54.83, 13.93 (2C). HRMS (ESI-TOF) calcd for $C_{15}H_{14}N_2O_8$ ($M+Na^+$) = 373.0754, found 373.0759.



1n

Tetraethyl 2,2'-(1,3,5,7-tetraoxo-5,7-dihydropyrrolo[3,4-f]isoindole-2,6(1H,3H)-diyl) dimalonate (1n)

^{1}H NMR (300 MHz, $CDCl_3$) δ 8.39 (s, 2H), 5.53 (s, 2H), 4.41 – 4.25 (m, 8H), 1.32 (t, *J* = 7.2 Hz, 12H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 164.22 (4C), 163.63 (4C), 137.11 (3C), 119.42 (3C), 63.03 (4C), 54.84 (2C), 13.94 (4C). HRMS (ESI-TOF) calcd for $C_{24}H_{24}N_2O_{12}$ ($M+Na^+$) = 555.1329, found 555.1336.

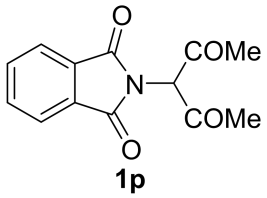


1o

Ethyl 2-(1,3-dioxoisoindolin-2-yl)-3-oxobutanoate (1o)

^{1}H NMR (300 MHz, $CDCl_3$) δ 12.74 (s, 1H), 7.92 (dd, *J* = 5.5, 3.1 Hz, 2H), 7.79 (dd, *J* = 5.6, 3.1 Hz, 2H), 4.17 (t, *J* = 7.1 Hz, 2H), 1.96 (s, 3H), 1.17 (d, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz,

$CDCl_3$) δ 176.92 (2C), 167.35 (2C), 134.39, 134.34, 131.91, 123.81, 123.74, 114.58, 96.33, 61.38, 18.08, 14.04. HRMS (ESI-TOF) calcd for $C_{14}H_{13}NO_5$ ($M+Na^+$) = 298.0794, found 298.0797.

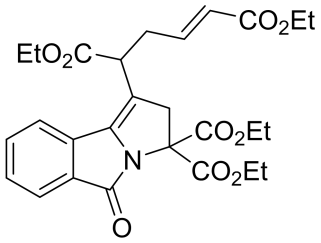


1p

2-(2,4-dioxopentan-3-yl)isoindoline-1,3-dione (1p)

^1H NMR (300 MHz, $CDCl_3$) δ 16.19 (s, 1H), 7.95 (dd, *J* = 5.5, 3.1 Hz, 2H), 7.82 (dd, *J* = 5.5, 3.1 Hz, 2H), 1.98 (s, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 191.06 (2C), 167.38 (2C), 134.71, 134.34, 134.26, 131.58, 123.98, 123.55, 106.47, 21.84 (2C). HRMS (ESI-TOF) calcd for $C_{13}H_{11}NO_4$ ($M+Na^+$) = 268.0691, found 268.0687.

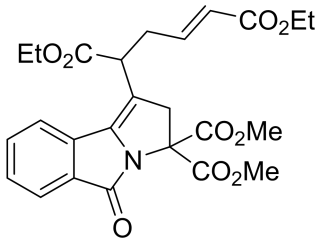
4.3 Characterization data for products



3a, 99%, *E*/*Z*>99/1

Diethyl (*E*)-1-(1,6-diethoxy-1,6-dioxohex-4-en-2-yl)-5-oxo-2,5-dihydro-3H-pyrrolo-[2,1-a]isoindole-3,3-dicarboxylate (3a)

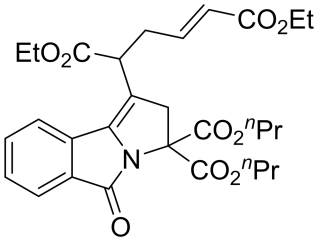
White solid; mp 100-101 °C. Yield (101.5 mg, 99%). ^1H-NMR (300 MHz, DMSO-d_6) δ 8.10 (d, *J* = 7.7 Hz, 1H), 7.82 – 7.69 (m, 2H), 7.63 (t, *J* = 7.5 Hz, 1H), 6.80 (ddd, *J* = 15.0, 7.9, 6.4 Hz, 1H), 5.94 (d, *J* = 15.6 Hz, 1H), 4.38 (dd, *J* = 9.1, 6.2, 1H), 4.25 – 3.98 (m, 8H), 3.71 (d, *J* = 18.4 Hz, 1H), 3.60 (d, *J* = 18.0 Hz, 1H), 2.88 – 2.79 (m, 1H), 2.74 – 2.63 (m, 1H), 1.22 – 1.07 (m, 12H); ^{13}C-NMR (75 MHz, DMSO-d_6) *δ* 171.31, 167.64, 167.52, 166.00, 161.62, 145.85, 137.13, 135.63, 133.07, 130.91, 130.07, 124.27, 124.12, 123.97, 115.18, 68.31, 63.26, 63.22, 61.85, 60.56, 46.60, 42.55, 33.02, 14.84, 14.80, 14.64, 14.57. HRMS (ESI-TOF) calcd for $C_{27}H_{31}NO_9$ ($M+Na^+$) = 536.1891, found 536.1892. IR (KBr) ν (cm^{-1}): 3010, 2988, 2879, 2852, 1738, 1736, 1729, 1711, 1672, 1655, 1560, 1508, 1473, 1369, 1342, 1299, 1272, 1244, 1225, 1201, 1178, 1158, 1095, 1043, 1013, 969, 862, 771, 689.



3b, 93%, *E*/*Z*>99/1

Dimethyl(*E*)-1-(1,6-diethoxy-1,6-dioxohex-4-en-2-yl)-5-oxo-2,5-dihydro-3H-pyrrolo-[2,1-a]isoindole-3,3-dicarboxylate (3b)

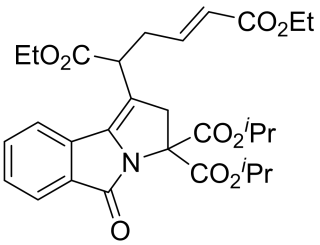
White solid; mp 120-121 °C. Yield (90.2 mg, 93%). ^{1}H-NMR (300 MHz, DMSO-d_6) δ 8.10 (d, J = 7.7 Hz, 1H), 7.81 – 7.71 (m, 2H), 7.63 (t, J = 7.5 Hz, 1H), 6.80 (ddd, J = 15.0, 7.2, 6.2 Hz, 1H), 5.94 (d, J = 15.6 Hz, 1H), 4.37 (dd, J = 8.8, 6.4 Hz, 1H), 4.16 – 4.09 (m, 2H), 4.04 (d, J = 6.7 Hz, 1H), 3.99 (d, J = 7.1 Hz, 1H), 3.82 – 3.58 (m, 8H), 2.86 – 2.79 (m, 1H), 2.73 – 2.62 (m, 1H), 1.16 – 1.07 (m, 6H); ^{13}C-NMR (75 MHz, DMSO-d_6) δ 171.50, 167.21, 167.15, 166.10, 161.28, 145.64, 136.85, 135.26, 132.73, 130.56, 129.68, 123.92, 123.55, 123.40, 114.70, 67.98, 62.87, 62.83, 52.84, 51.64, 46.20, 42.00, 32.69, 14.24, 14.15. HRMS (ESI-TOF) calcd for $C_{25}H_{27}NO_9$ (M+Na$^+$) = 508.1578, found 508.1580. IR (KBr) ν (cm^{-1}): 3013, 2998, 2955, 1762, 1736, 1727, 1705, 1668, 1655, 1562, 1511, 1474, 1436, 1385, 1343, 1286, 1256, 1226, 1195, 1168, 1140, 1098, 1058, 1041, 997, 961, 933, 864, 767, 689.



3c, 88%, *E*/*Z*>99/1

Dipropyl (*E*)-1-(1,6-diethoxy-1,6-dioxohex-4-en-2-yl)-5-oxo-2,5-dihydro-3H-pyrrolo-[2,1-a]isoindole-3,3-dicarboxylate (3c)

White solid; mp 85-86 °C. Yield (95.2 mg, 88%). ^{1}H-NMR (300 MHz, DMSO-d_6) δ 8.10 (d, J = 7.7 Hz, 1H), 7.86 – 7.68 (m, 2H), 7.63 (t, J = 7.4 Hz, 1H), 6.81 (ddd, J = 15.0, 7.9, 6.5 Hz, 1H), 5.91 (d, J = 15.4 Hz, 1H), 4.38 (dd, J = 9.1, 6.1 Hz, 1H), 4.22 – 3.93 (m, 8H), 3.72 (d, J = 18.0 Hz, 1H), 3.61 (d, J = 17.9 Hz, 1H), 2.90 – 2.76 (m, 1H), 2.74 – 2.63 (m, 1H),1.58 (hd, J = 7.2, 3.6 Hz, 4H), 1.11 (q, J = 7.3 Hz, 6H), 0.84 (td, J = 7.4, 5.5 Hz, 6H); ^{13}C-NMR (75 MHz, DMSO-d_6) δ 171.33, 167.81, 167.69, 166.00, 161.66, 145.85, 137.19, 135.66, 133.06, 130.92, 130.08, 124.25, 124.11, 123.97, 115.11, 68.61, 68.58, 68.37, 61.85, 60.56, 46.73, 42.56, 33.03, 22.22, 22.16, 14.83, 14.78, 10.88, 10.85. HRMS (ESI-TOF) calcd for $C_{29}H_{35}NO_9$ (M+Na$^+$) = 564.2204, found 564.2207. IR (KBr) ν (cm^{-1}): 3085, 2983, 2966, 2943, 2922, 2901, 1745, 1738, 1730, 1715, 1671, 1657, 1625, 1584, 1471, 1452, 1370, 1341, 1292, 1267, 1230, 1200, 1175, 1157, 1144, 1112, 1063, 1045, 1014, 989, 974, 942, 928, 892, 866, 766, 692.

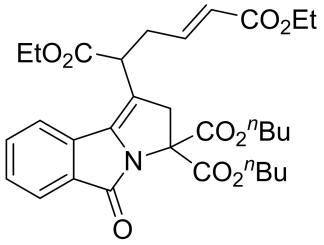


3d, 93%, *E*/*Z*>99/1

Diisopropyl (*E*)-1-(1,6-diethoxy-1,6-dioxohex-4-en-2-yl)-5-oxo-2,5-dihydro-3H-pyrrolo-[2,1-a]isoindole-3,3-dicarboxylate (3d)

White solid; mp 85-86 °C. Yield (100.6 mg, 93%). ^{1}H-NMR (300 MHz, DMSO-d_6) δ 8.09 (d, J = 7.7 Hz, 1H), 7.82 – 7.67 (m, 2H), 7.63 (t, J = 7.9 Hz,1H), 6.80 (ddd, J = 15.1, 7.9, 6.4 Hz, 1H), 5.94 (d, J = 15.6 Hz, 1H), 5.01 (h, J = 6.3 Hz, 2H), 4.38 (dd, J = 9.2, 6.0 Hz, 1H), 4.15 – 4.10 (m, 2H), 4.00 (q, J = 7.1 Hz, 2H), 3.66 (d, J = 18.0 Hz, 1H), 3.56 (d, J = 18.0 Hz, 1H), 2.90 – 2.75 (m, 1H), 2.76 – 2.63 (m, 1H), 1.25 – 1.14 (m, 12H), 1.18 – 1.06 (m, 6H); ^{13}C-NMR (75 MHz,

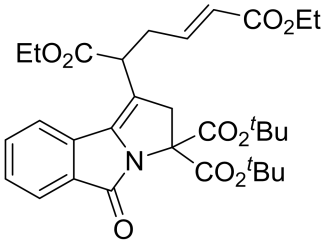
DMSO-d_6) δ 171.32, 167.10, 166.97, 165.96, 161.59, 145.83, 137.21, 135.74, 132.96, 130.84, 130.08, 124.22, 124.10, 123.91, 114.96, 71.10 (2C), 68.58, 61.82, 60.52, 46.39, 42.58, 32.99, 21.99 (2C), 21.92 (2C), 14.80, 14.78. HRMS (ESI-TOF) calcd for $C_{29}H_{35}NO_9$ ($M+Na^+$) = 564.2204, found 564.2207. IR (KBr) ν (cm^{-1}): 3042, 2985, 2940, 2901, 2867, 1739, 1735,1724, 1713, 1668, 1655, 1576, 1506, 1473, 1452, 1374, 1346, 1281, 1236, 1206, 1180, 1159, 1145, 1101, 1046, 992, 939, 922, 890, 862, 832, 773, 691.



3e, 85%, *E*/*Z*>99/1

Dibutyl (*E*)-1-(1,6-diethoxy-1,6-dioxohex-4-en-2-yl)-5-oxo-2,5-dihydro-3H-pyrrolo-[2,1-a]isoindole-3,3-dicarboxylate (3e)

White solid; mp 80-81 °C. Yield (96.7 mg, 85%). ^{1}H-NMR (300 MHz, DMSO-d_6) δ 8.10 (d, J = 7.6 Hz, 1H), 7.81 – 7.71 (m, 2H), 7.63 (t, J = 7.5 Hz, 1H), 6.80 (ddd, J = 15.0, 7.9, 6.5 Hz, 1H), 5.93 (d, J = 15.8 Hz, 1H), 4.38 (dd, J = 9.1, 6.2 Hz, 1H), 4.20 – 3.96 (m, 8H), 3.71 (d, J = 18.0 Hz, 1H), 3.59 (d, J = 18.0 Hz, 1H), 2.90 – 2.77 (m, 1H), 2.75 – 2.62(m, 1H), 1.54 (dtt, J = 8.7, 6.3, 3.5 Hz, 4H), 1.28 (ddt, J = 14.4, 7.1, 3.7 Hz, 4H), 1.11 (q, J = 7.2 Hz, 6H), 0.83 (td, J = 7.4, 2.0 Hz, 6H); ^{13}C-NMR (126 MHz, DMSO-d_6) δ 170.92, 167.37, 167.26, 165.59, 161.28, 145.41, 136.81, 135.30, 132.64, 130.49, 129.69, 123.83, 123.72, 123.55, 114.67, 68.02, 66.43, 66.42, 61.44, 60.15, 46.32, 42.21, 32.65, 30.39 (2C), 30.31 (2C), 18.81, 14.43, 14.38, 13.79. HRMS (ESI-TOF) calcd for $C_{31}H_{39}NO_9$ ($M+Na^+$) = 592.2517, found 592.2519. IR (KBr) ν (cm^{-1}): 3056, 2963, 2934, 2874, 2847, 1746, 1739, 1727, 1716, 1677, 1656, 1578, 1527, 1471, 1453, 1369, 1343, 1311, 1228, 1198, 1158, 1100, 1062, 1039, 994, 932, 858, 775, 690.

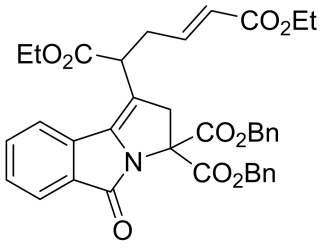


3f, 81%, *E*/*Z*>99/1

Di-tert-butyl (*E*)-1-(1,6-diethoxy-1,6-dioxohex-4-en-2-yl)-5-oxo-2,5-dihydro-3H-pyrrolo-[2,1-a]isoindole-3,3-dicarboxylate (3f)

Brown oil. Yield (92.2 mg, 81%). ^{1}H-NMR (300 MHz, DMSO-d_6) δ 8.08 (d, J = 7.7 Hz, 1H), 7.79 – 7.70 (m, 2H), 7.62 (t, J = 7.5 Hz, 1H), 6.81 (ddd, J = 15.0, 7.2, 6.0 Hz, 1H), 5.95 (d, J = 15.6 Hz, 1H), 4.37 (dd, J = 9.2, 6.0 Hz, 1H), 4.19 – 4.08 (m, 2H), 4.00 (q, J = 7.1 Hz, 2H), 3.60 (d, J = 17.9 Hz, 1H), 3.51 (d, J = 18.0 Hz, 1H), 2.86 – 2.79 (m, 1H), 2.75 – 2.64 (m, 1H), 1.42 (s, 18H), 1.15 – 1.07 (m, 6H); ^{13}C-NMR (126 MHz, DMSO-d_6) δ 171.00, 166.26, 166.15, 165.61, 161.19, 145.48, 136.89, 135.54, 132.50, 130.39, 129.66, 123.76, 123.72, 123.45, 114.53, 83.37, 83.36, 69.50, 61.42, 60.13, 45.84, 42.22, 32.58, 27.80 (2C), 27.76 (2C), 27.76 (2C), 14.43, 14.35. HRMS

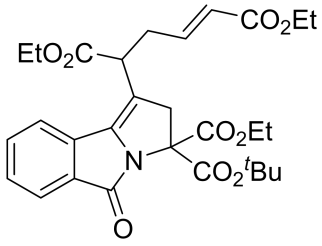
(ESI-TOF) calcd for $C_{31}H_{39}NO_9$ ($M+Na^+$) = 592.2517, found 592.2519. IR (KBr) ν (cm^{-1}): 3048, 2987, 2956, 2879, 2832, 1743, 1731, 1720, 1709, 1670, 1655, 1577, 1529, 1474, 1453, 1370, 1334, 1290, 1228, 1198, 1148, 1114, 1042, 1022, 932, 858, 762, 688.



3g, 82%, *E*/*Z*>99/1

Dibenzyl (*E*)-1-(1,6-diethoxy-1,6-dioxohex-4-en-2-yl)-5-oxo-2,5-dihydro-3H-pyrrolo-[2,1-a]isoindole-3,3-dicarboxylate (3g)

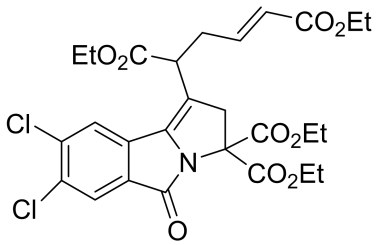
Brown oil. Yield (104.6 mg, 82%). ^{1}H-NMR (300 MHz, DMSO-d_6) δ 8.10 (d, J = 7.6 Hz, 1H), 7.82 – 7.72 (m, 2H), 7.64 (t, J = 7.6 Hz, 1H), 7.33 – 7.29 (m, 10H), 6.81 (ddd, J = 15.7, 7.7, 6.5 Hz, 1H), 5.93 (d, J = 15.5 Hz, 1H), 5.26 – 5.22 (m, 4H), 4.37 (dd, J = 8.6, 6.6 Hz, 1H), 4.09 – 4.05 (m, 2H), 3.99 (q, J = 6.9 Hz, 2H), 3.78 (d, J = 18.0 Hz, 1H), 3.66 (d, J = 18.0 Hz, 1H), 2.87 – 2.78 (m, 1H), 2.70 – 2.58 (m, 1H), 1.11 – 1.05 (m, 6H); ^{13}C-NMR (126 MHz, DMSO-d_6) δ 170.87, 167.06, 167.00, 165.63, 161.45, 145.41, 136.76, 135.52, 135.23, 132.76, 130.58, 129.71, 128.82 (5C), 128.62, 128.58, 128.08, 128.05, 128.02, 127.96, 123.93, 123.75, 123.63, 114.87, 68.21, 68.18, 68.04, 61.46, 60.18, 46.45, 42.25, 32.70, 14.44, 14.37. HRMS (ESI-TOF) calcd for $C_{37}H_{35}NO_9$ ($M+Na^+$) = 660.2205, found 660.2211. IR (KBr) ν (cm^{-1}): 3039, 2994, 2976, 2889, 2842, 1739, 1737, 1730, 1708, 1673, 1655, 1579, 1531, 1473, 1456, 1371, 1297, 1274, 1212, 1198, 1172, 1101, 1042, 1017, 982, 871, 762, 689.



3h, 78%, *E*/*Z*>99/1

3-(tert-butyl) 3-ethyl (*E*)-1-(1,6-diethoxy-1,6-dioxohex-4-en-2-yl)-5-oxo-2,5-dihydro-3H-pyrrolo[2,1-a]isoindole-3,3-dicarboxylate (3h)

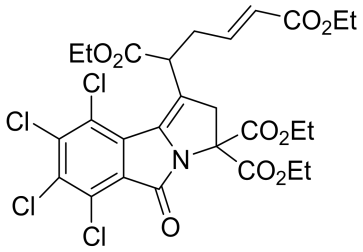
Brown oil. Yield (84.5 mg, 78%). ^{1}H-NMR (300 MHz, DMSO-d_6) δ 8.09 (d, J = 7.7 Hz, 1H), 7.78 (d, J = 7.7 Hz, 1H), 7.72 (dd, J = 7.6, 1.3 Hz, 1H), 7.62 (t, J = 7.5 Hz, 1H), 6.81 (ddd, J = 15.6, 7.5, 6.6 Hz, 1H), 5.95 (dd, J = 15.7, 4.3 Hz, 1H), 4.37 (ddd, J = 8.9, 6.1, 2.6 Hz, 1H), 4.26 – 3.96 (m, 6H), 3.64 (d, J = 18.0 Hz, 1H), 3.59 (d, J = 17.9 Hz, 1H), 2.87 – 2.79 (m, 1H), 2.73 – 2.68 (m,1H), 1.41 (s, 9H), 1.23 – 1.10 (m, 9H); ^{13}C-NMR (75 MHz, DMSO-d_6) δ 171.35, 167.92, 166.33, 165.99, 161.63, 145.88, 137.21, 136.66, 135.76, 132.97, 130.84, 130.05, 124.20, 123.90, 115.06, 84.05, 69.08, 63.02, 61.78, 60.53, 46.42, 42.57, 33.00, 28.16 (3C), 14.82, 14.68, 14.62. HRMS (ESI-TOF) calcd for $C_{29}H_{35}NO_9$ ($M+Na^+$) = 564.2204, found 564.2200. IR (KBr) ν (cm^{-1}): 3045, 3002, 2981, 2889, 2840, 1738, 1735, 1726, 1710, 1675, 1655, 1580, 1536, 1477, 1459, 1370, 1284, 1269, 1214, 1188, 1154, 1101, 1053, 1019, 986, 875, 763, 687.



3i, 93%, *E*/*Z*>99/1

Diethyl(*E*)-7,8-dichloro-1-(1,6-diethoxy-1,6-dioxohex-4-en-2-yl)-5-oxo-2,5-dihydro-3H-pyrrolo[2,1-a]isoindole-3,3-dicarboxylate (3i)

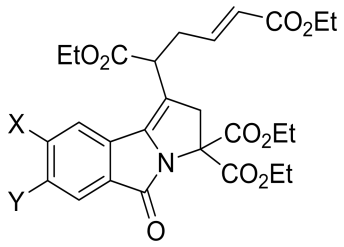
Brown oil. Yield (107.6 mg, 93%). ^{1}H-NMR (500 MHz, DMSO-d_6) δ 8.53 (s, 1H), 8.03 (s, 1H), 6.84 (ddd, J = 15.0, 8.0, 6.5 Hz, 1H), 5.95 (d, J = 15.6 Hz, 1H), 4.55 (dd, J = 9.6, 5.2 Hz, 1H), 4.27 – 4.22 (m, 4H), 4.17 – 4.11 (m, 2H), 4.03 (q, J = 7.1 Hz, 2H), 3.76 (d, J = 18.4 Hz, 1H), 3.66 (d, J = 18.3 Hz, 1H), 2.88 – 2.83 (m, 1H), 2.73 – 2.67 (m, 1H), 1.23 – 1.15 (m, 12H); ^{13}C-NMR (126 MHz, DMSO-d_6) δ 170.71, 166.90, 166.77, 165.58, 159.29, 145.35, 135.90, 135.04, 135.00, 133.51, 129.12, 125.71, 125.69, 123.84, 117.74, 68.10, 63.01, 62.97, 61.53, 60.14, 46.20, 41.91, 32.63, 14.37, 14.19, 14.12, 13.96. HRMS (ESI-TOF) calcd for $C_{27}H_{29}Cl_2NO_9$ ($M+H^+$) = 582.1292, found 582.1300. IR (KBr) ν (cm^{-1}): 3032, 3014, 2987, 2878, 2843, 1742, 1739, 1727, 1717, 1673, 1655, 1579, 1545, 1480, 1447, 1369, 1286, 1270, 1234, 1181, 1156, 1097, 1053, 1027, 970, 879, 763, 687.



3j, 88%, *E*/*Z*>99/1

Diethyl(*E*)-6,7,8,9-tetrachloro-1-(1,6-diethoxy-1,6-dioxohex-4-en-2-yl)-5-oxo-2,5-dihydro-3H-pyrrolo[2,1-a]isoindole-3,3-dicarboxylate (3j)

Brown oil. Yield (114.6 mg, 88%). ^{1}H-NMR (300 MHz, $CDCl_3$) δ 6.90 (ddd, J = 14.9, 7.2, 6.0 Hz, 1H), 5.95 (d, J = 15.6 Hz, 1H), 5.04 (t, J = 7.5 Hz, 1H), 4.38 (q, J = 7.1 Hz, 4H), 4.29 – 4.18 (m, 4H), 3.79 (s, 2H), 3.04 – 2.91 (m, 1H), 2.71 – 2.61(m, 1H), 1.40 – 1.31 (m, 12H); ^{13}C-NMR (75 MHz, $CDCl_3$) δ 170.87, 167.16, 167.10, 166.06, 157.88, 143.61, 137.68, 136.25, 134.80, 132.57, 130.88, 129.82, 126.54, 124.68, 120.30, 67.58, 63.56, 63.48, 62.16, 60.81, 46.89, 44.27, 34.07, 14.53, 14.48, 14.32 (2C). HRMS (ESI-TOF) calcd for $C_{27}H_{27}Cl_4NO_9$ ($M+H^+$) = 652.0489, found 652.0494. IR (KBr) ν (cm^{-1}): 3025, 3007, 2983, 2894, 2852, 1740, 1737, 1724, 1714, 1671, 1655, 1577, 1554, 1487, 1446, 1390, 1368, 1342, 1272, 1234, 1185, 1096, 1044, 1023, 945, 858, 783, 730, 655, 625.

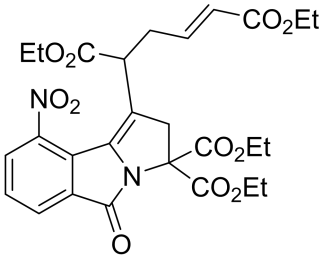


3k(X = H, Y = Me)/**3k'**(X = Me, Y = H),
91%, *E*/*Z*>99/1

Diethyl(*E*)-1-(1,6-diethoxy-1,6-dioxohex-4-en-2-yl)-7-methyl-5-oxo-2,5-dihydro-3H-pyr-rolo[2,1-a]isoindole-3,3-dicarboxylate (3k) and
Diethyl(*E*)-1-(1,6-diethoxy-1,6-dioxohex-4-en-2-yl)-8-methyl-5-oxo-2,5-dihydro-3H-pyr-rolo[2,1-a]isoindole-3,3-dicarboxylate (3k')

Selected data:

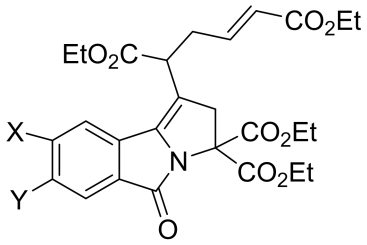
Brown oil. Yield (96.0 mg, 91%). ^{1}H-NMR (300 MHz, DMSO-d_6) δ 7.99 – 7.93 (m, 1H), 7.65 (d, J = 7.8 Hz, 1H), 7.43 (d, J = 7.9 Hz, 1H), 6.80 (ddd, J = 15.0, 7.2, 6.3 Hz, 1H), 5.94 (dd, J = 15.6, 4.4 Hz, 1H), 4.41 – 4.31 (m, 1H), 4.22 (q, J = 7.1 Hz, 6H), 4.01 (q, J = 6.4 Hz, 2H), 3.67 (d, J = 17.9 Hz, 1H), 3.59 (d, J = 17.9 Hz, 1H), 2.89 – 2.79 (m, 1H), 2.73 – 2.63 (m, 1H), 1.21 – 1.12 (m, 15H); ^{13}C-NMR (75 MHz, DMSO-d_6) δ 171.34, 167.72, 167.60, 166.00, 161.75, 145.85, 143.49, 141.14,137.19, 135.93, 133.81, 133.23, 131.69, 130.44, 127.61, 68.29, 63.19, 63.15, 61.80, 60.55, 46.54, 42.53, 33.10, 22.23, 14.79, 14.77, 14.60, 14.54. HRMS (ESI-TOF) calcd for $C_{28}H_{33}NO_9$ (M+Na$^+$) = 550.2048, found 550.2051. IR (KBr) ν (cm^{-1}): 3025, 3011, 2988, 2874, 2831, 1739, 1736, 1726, 1712, 1669, 1655, 1583, 1549, 1487, 1448, 1369, 1297, 1272, 1249, 1183, 1142, 1084, 1054, 1028, 970, 824, 762, 711.



3l, 90%, *E*/*Z*>99/1

Diethyl (*E*)-1-(1,6-diethoxy-1,6-dioxohex-4-en-2-yl)-6-nitro-5-oxo-2,5-dihydro-3H-pyrrolo-[2,1-a]isoindole-3,3-dicarboxylate (3l)

Brown oil. Yield (100.5 mg, 90%). ^{1}H-NMR (500 MHz, DMSO-d_6) δ 8.46 (d, J = 7.8 Hz, 1H), 8.09 (d, J = 7.9 Hz, 1H), 7.98 (d, J = 7.9 Hz, 1H), 6.82 (ddd, J = 15.0, 8.0, 6.5 Hz, 1H), 5.96 (d, J = 15.6 Hz, 1H), 4.51 (dd, J = 9.1, 6.2 Hz, 1H), 4.30– 4.22 (m, 4H), 4.18 – 4.12 (m, 2H), 4.03 (q, J = 7.1 Hz, 2H), 3.80 (d, J = 18.4 Hz, 1H), 3.70 (d, J = 18.4 Hz, 1H), 2.91 – 2.85 (m, 1H), 2.77 – 2.70 (m, 1H), 1.22 (t, J = 6.6 Hz, 6H), 1.16 (t, J = 5.5 Hz, 3H), 1.12 (t, J = 5.5 Hz, 3H); ^{13}C-NMR (126 MHz, DMSO-d_6) δ 170.57, 166.75, 166.60, 165.58, 156.71, 145.97, 145.20, 134.87, 134.23, 131.23, 127.36, 125.07, 124.35, 123.92, 118.90, 68.20, 63.11, 63.07, 61.64, 60.19, 46.38, 42.19, 32.58, 14.42, 14.38, 14.19, 14.13. HRMS (ESI-TOF) calcd for $C_{27}H_{30}N_2O_{11}$ (M+Na$^+$) = 581.1742, found 581.1747. IR (KBr) ν (cm^{-1}): 3030, 3019, 2980, 2940, 2869, 1763, 1742, 1734, 1713, 1677, 1655, 1620, 1578, 1543, 1473, 1369, 1349, 1288, 1237, 1182, 1159, 1098, 1034, 1011, 970, 860, 815, 792, 777, 754, 720, 701.



3m(X = H, Y = NO_2)/**3m'**(X = NO_2, Y = H),

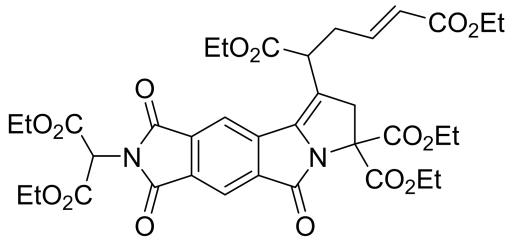
95%, *E*/*Z*>99/1

Diethyl (*E*)-1-(1,6-diethoxy-1,6-dioxohex-4-en-2-yl)-7-nitro-5-oxo-2,5-dihydro-3H-pyrrolo-[2,1-a]isoindole-3,3-dicarboxylate (3m) and

Diethyl (*E*)-1-(1,6-diethoxy-1,6-dioxohex-4-en-2-yl)-8-nitro-5-oxo-2,5-dihydro-3H-pyrrolo-[2,1-a]isoindole-3,3-dicarboxylate (3m')

Selected data:

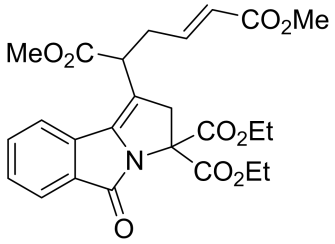
Brown oil. Yield (105.8 mg, 95%). ^{1}H-NMR (500 MHz, DMSO-d_6) δ 8.51 – 8.42 (m, 2H), 8.09 (d, J = 8.6 Hz, 1H), 6.84 (ddd, J = 15.0, 10.8, 6.9 Hz, 1H), 5.97 (d, J = 15.6 Hz, 1H), 4.58 (dd, J = 9.1, 6.3 Hz, 1H), 4.32 – 4.00 (m, 8H), 3.83 – 3.71 (m, 2H), 2.92 – 2.84 (m, 1H), 2.78 – 2.69 (m, 1H), 1.33 – 1.23 (m, 6H), 1.17 (t, J = 7.3 Hz, 3H), 1.12 (dt, J = 6.9, 3.5 Hz, 3H). ^{13}C-NMR (126 MHz, DMSO-d_6) δ 170.72, 170.51, 166.67, 165.60, 159.42, 150.72, 148.74, 145.44, 139.56, 136.04, 135.34, 134.08, 130.05, 123.87, 118.87, 68.22, 63.15, 61.60, 60.55, 60.16, 46.49, 42.04, 32.61, 14.40, 14.36, 14.21, 14.14. HRMS (ESI-TOF) calcd for $C_{27}H_{30}N_2O_{11}$ (M+Na^+) = 581.1742, found 581.1746. IR (KBr) ν (cm^{-1}): 3025, 3013, 2989, 2938, 2865, 1742, 1736, 1723, 1716, 1670, 1655, 1619, 1577, 1533, 1472, 1369, 1349, 1273, 1237, 1184, 1161, 1097, 1037, 1019, 970, 858, 817, 705.



3n, 87%, *E*/*Z*>99/1

Diethyl (*E*)-2-(1,3-diethoxy-1,3-dioxopropan-2-yl)-9-(1,7-diethoxy-1,7-dioxohept-5-en-3-yl)-1,3,5-trioxo-2,3,5,8-tetrahydrodipyrrolo[2,1-a:3',4'-f]isoindole-7,7(1H)-dicarboxylate (3n)

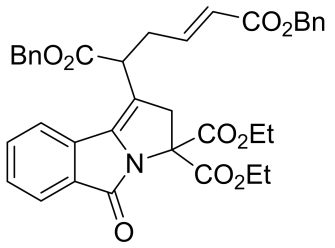
Brown oil. Yield (128.8 mg, 87%). ^{1}H-NMR (300 MHz, DMSO-d_6) δ 8.79 (s, 1H), 8.24 (s, 1H), 6.83 (ddd, J = 15.1, 8.0, 6.4 Hz, 1H), 5.97 – 5.87 (m, 2H), 4.75 (dd, J = 9.0, 6.1 Hz, 1H), 4.29 – 4.19 (m, 8H), 4.16 – 4.10 (m, 2H), 3.97 (q, J = 7.7 Hz, 2H), 3.79 (d, J = 18.0 Hz, 1H), 3.75 (d, J = 18.2 Hz,1H), 2.93 – 2.82 (m, 1H), 2.78 – 2.65 (m, 1H), 1.25 – 1.16 (m, 12H), 1.16 – 1.11 (m, 3H), 1.09 – 1.04 (m, 3H). ^{13}C-NMR (75 MHz, DMSO-d_6) δ 170.97, 167.12, 166.99, 166.05, 165.95, 165.74, 164.78 (2C), 159.73, 145.79, 140.78, 136.14, 135.15, 134.79, 132.27, 124.27, 121.66, 120.31, 119.97, 68.67, 63.53, 63.49, 63.19 (2C), 62.01, 60.53, 55.37, 46.81, 42.43, 33.06, 14.78, 14.76, 14.65 (2C), 14.60, 14.53. HRMS (ESI-TOF) calcd for $C_{36}H_{40}N_2O_{15}$ (M+Na^+) = 763.2324, found 763.2320. IR (KBr) ν (cm^{-1}): 3026, 3011, 2989, 2878, 2857, 1785, 1748, 1728, 1715, 1677, 1655,1601, 1578, 1532, 1508, 1423, 1372, 1341, 1274, 1245, 1218, 1201, 1187, 1160, 1093, 1043, 1013, 975, 862, 762, 692.



3q, 89%, *E*/*Z*>99/1

Diethyl (*E*)-1-(1,6-dimethoxy-1,6-dioxohex-4-en-2-yl)-5-oxo-2,5-dihydro-3H-pyrrolo[2,1-a]-isoindole-3,3-dicarboxylate (3q)

White solid; mp 118-119 °C. Yield (86.4 mg, 89%). ^{1}H-NMR (500 MHz, DMSO-d_6) δ 8.11 (d, J = 7.7 Hz, 1H), 7.81 (d, J = 7.7 Hz, 1H), 7.77 (td, J = 7.6, 1.2 Hz, 1H), 7.66 (t, J = 7.6 Hz, 1H), 6.84 (ddd, J = 14.9, 8.0, 6.4 Hz, 1H), 5.98 (d, J = 15.6 Hz, 1H), 4.43 (dd, J = 9.2, 6.1 Hz, 1H), 4.27 – 4.20 (m, 4H), 3.75 – 3.63 (m, 6H), 3.58 (s, 2H), 2.90 – 2.82 (m, 1H), 2.76 – 2.82 (m, 1H), 1.25 – 1.18 (m, 6H); ^{13}C-NMR (126 MHz, DMSO-d_6) δ 171.50, 167.21, 167.15, 166.10, 161.28, 145.64, 136.85, 135.26, 132.73, 130.56, 129.68, 123.92, 123.55, 123.40, 114.70, 67.98, 62.87, 62.83, 52.84, 51.64, 46.20, 42.00, 32.69, 14.24, 14.15. HRMS (ESI-TOF) calcd for $C_{25}H_{27}NO_9$ (M+H$^+$) = 486.1758, found 486.1755. IR (KBr) ν (cm^{-1}): 3012, 2988, 2957, 1754, 1741, 1729, 1709, 1659, 1655, 1563, 1517, 1475, 1437, 1382, 1339, 1275, 1258, 1227, 1201, 1169, 1151, 1101, 1063, 1039, 998, 962, 931, 863, 760, 687.



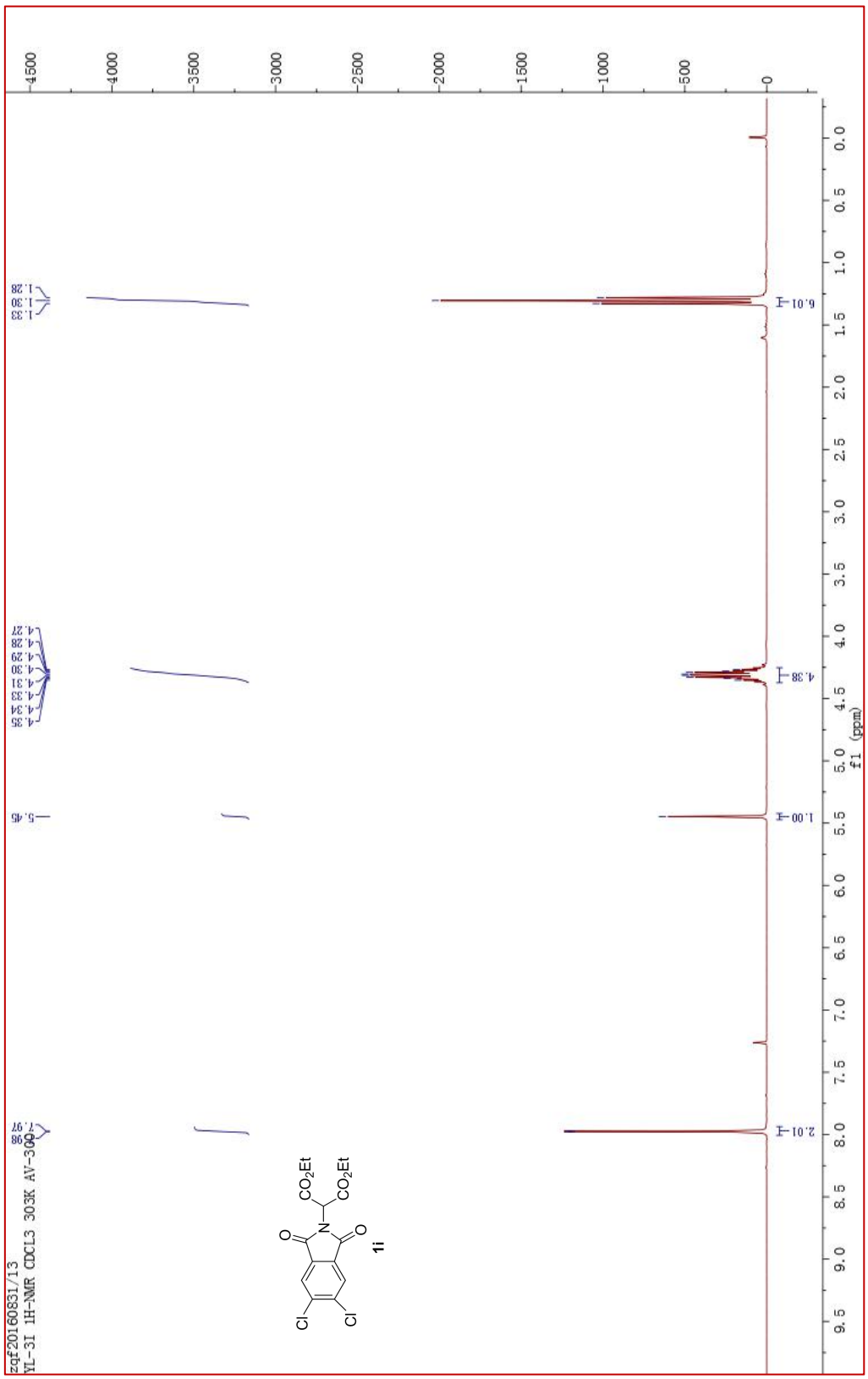
3r, 79%, *E*/*Z*>99/1

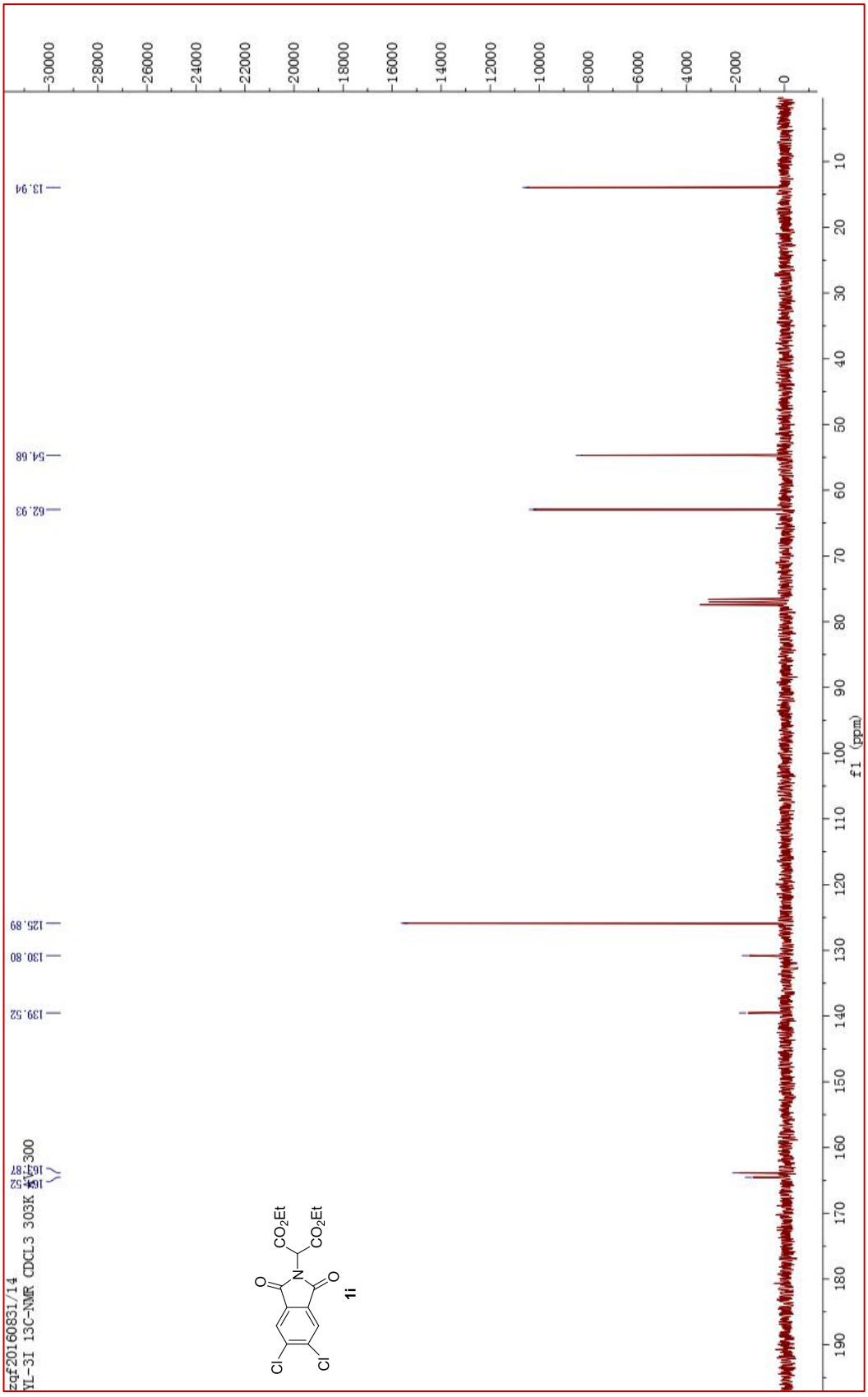
Diethyl (*E*)-1-(1,6-bis(benzyloxy)-1,6-dioxohex-4-en-2-yl)-5-oxo-2,5-dihydro-3H-pyrrolo-[2,1-a]isoindole-3,3-dicarboxylate (3r)

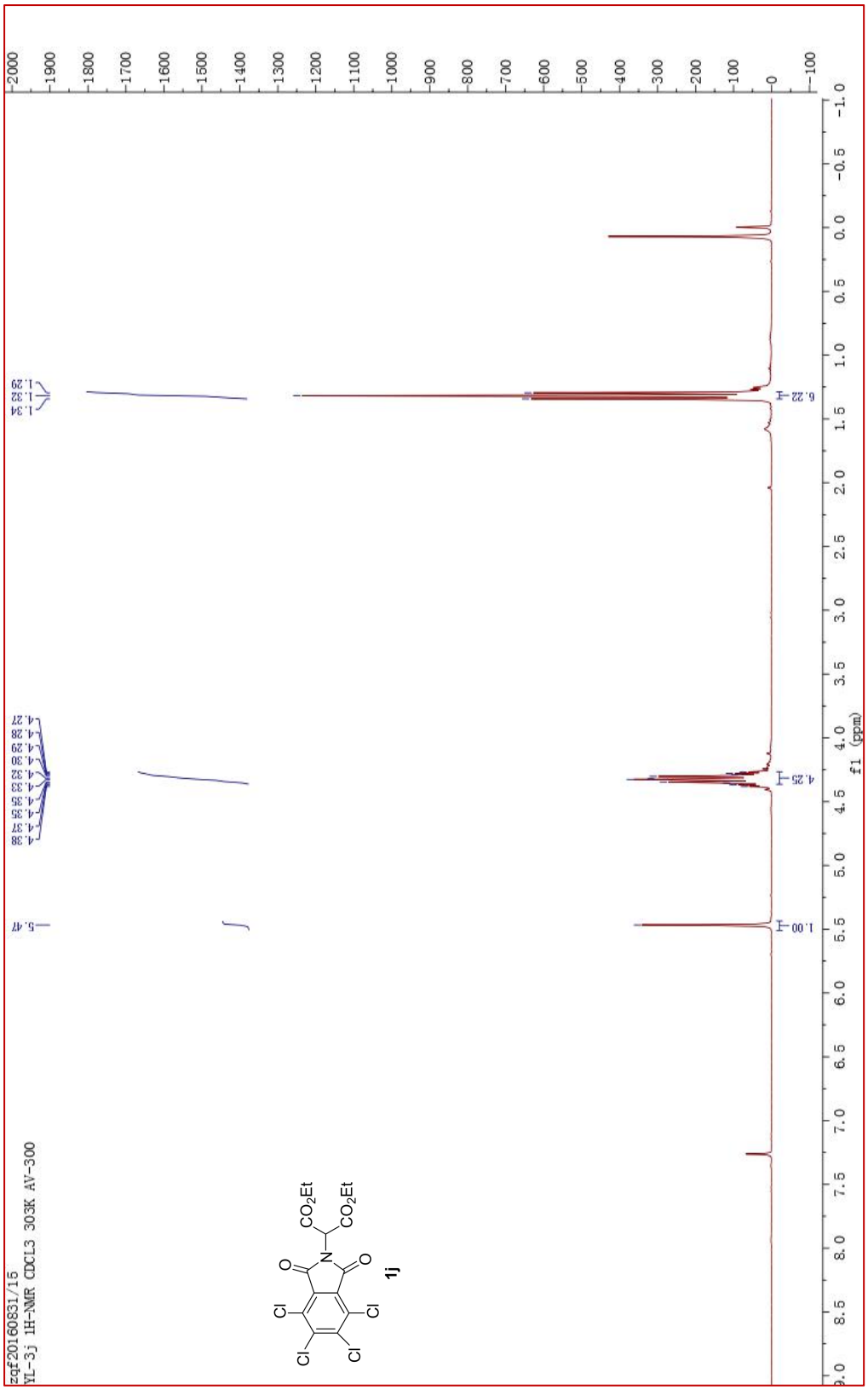
Brown oil. Yield (100.5 mg, 79%). ^{1}H-NMR (300 MHz, DMSO-d_6) δ 8.10 (d, J = 7.6 Hz, 1H), 7.78 (d, J = 7.5 Hz, 1H), 7.68 (t, J = 7.5, 1H), 7.61 (t, J = 7.4 Hz, 1H), 7.31 – 7.22 (m, 10H), 6.89 (ddd, J = 14.8, 7.1, 6.0 Hz, 1H), 6.01 (d, J = 15.6 Hz, 1H), 5.16 (d, J = 4.5 Hz, 2H), 5.06 (d, J = 6.8 Hz, 2H), 4.51 (dd, J = 9.1, 6.1 Hz, 1H), 4.23 – 4.11 (m, 4H), 3.73 (d, J = 18.2 Hz, 1H), 3.59 (d, J = 17.7 Hz, 1H), 2.94 – 2.83 (m, 1H), 2.80 – 2.69 (m, 1H), 1.18 – 1.07 (m, 6H); ^{13}C-NMR (75 MHz, DMSO-d_6) δ 171.23, 167.56, 167.52, 165.81, 161.73, 146.37, 137.40, 136.88, 136.51, 135.65, 133.01, 130.89, 129.99, 129.44, 129.26, 129.20, 129.19, 128.91, 128.77, 128.68, 128.57 (2C), 128.43, 124.26, 123.97, 123.91, 114.88, 68.30, 67.32, 66.14, 63.23, 63.19, 46.58, 42.50, 33.10, 14.60, 14.51. HRMS (ESI-TOF) calcd for $C_{37}H_{35}NO_9$ (M+Na$^+$) = 660.2204, found 660.2199. IR (KBr) ν (cm^{-1}): 3027, 3007, 2962, 2873, 2840, 1742, 1738, 1727, 1718, 1671, 1655, 1580, 1532, 1469, 1456, 1378, 1297, 1262, 1216, 1202, 1179, 1101, 1042, 1017, 987, 876, 764, 698.

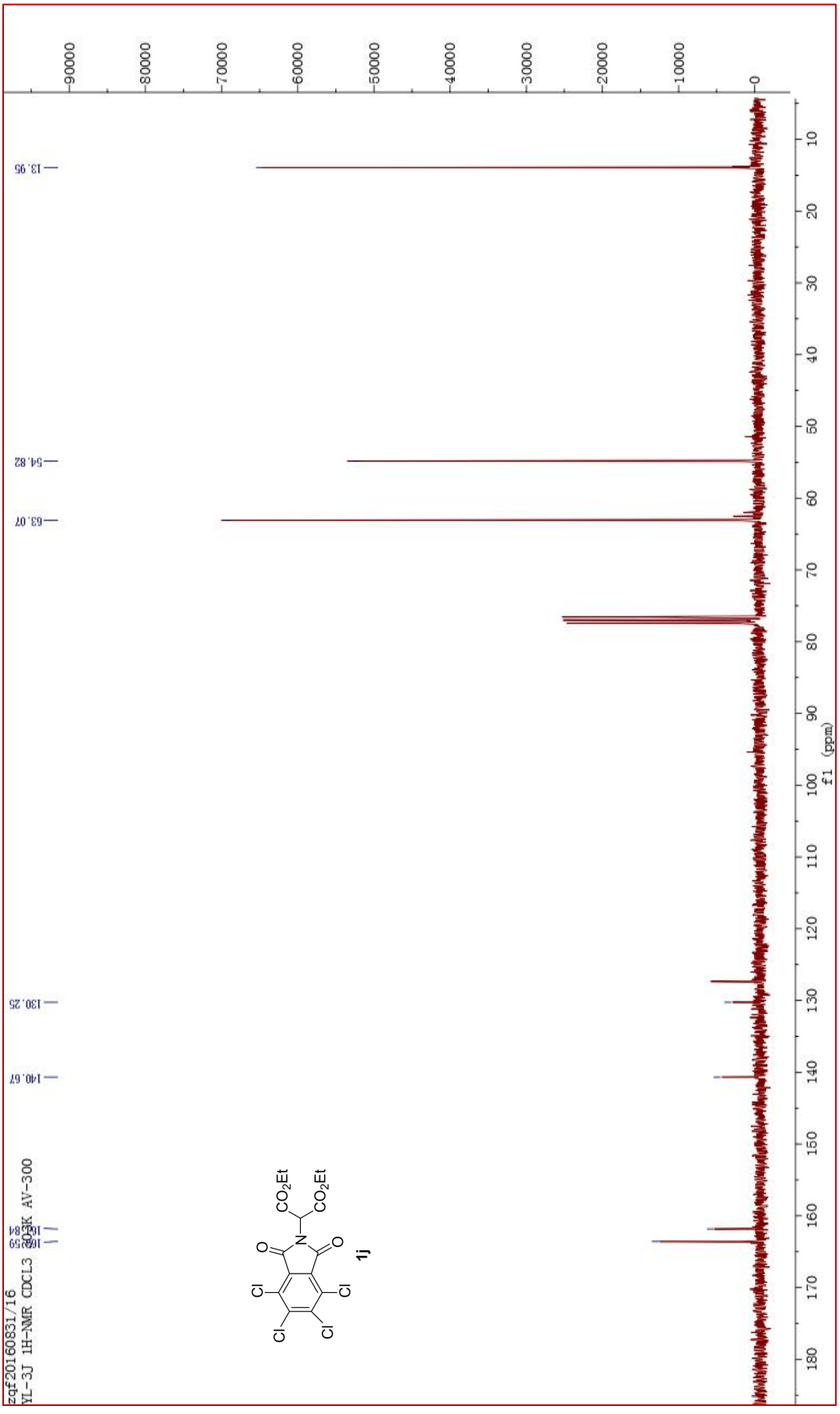
5. Copies of ^{1}H-NMR, ^{13}C-NMR spectra

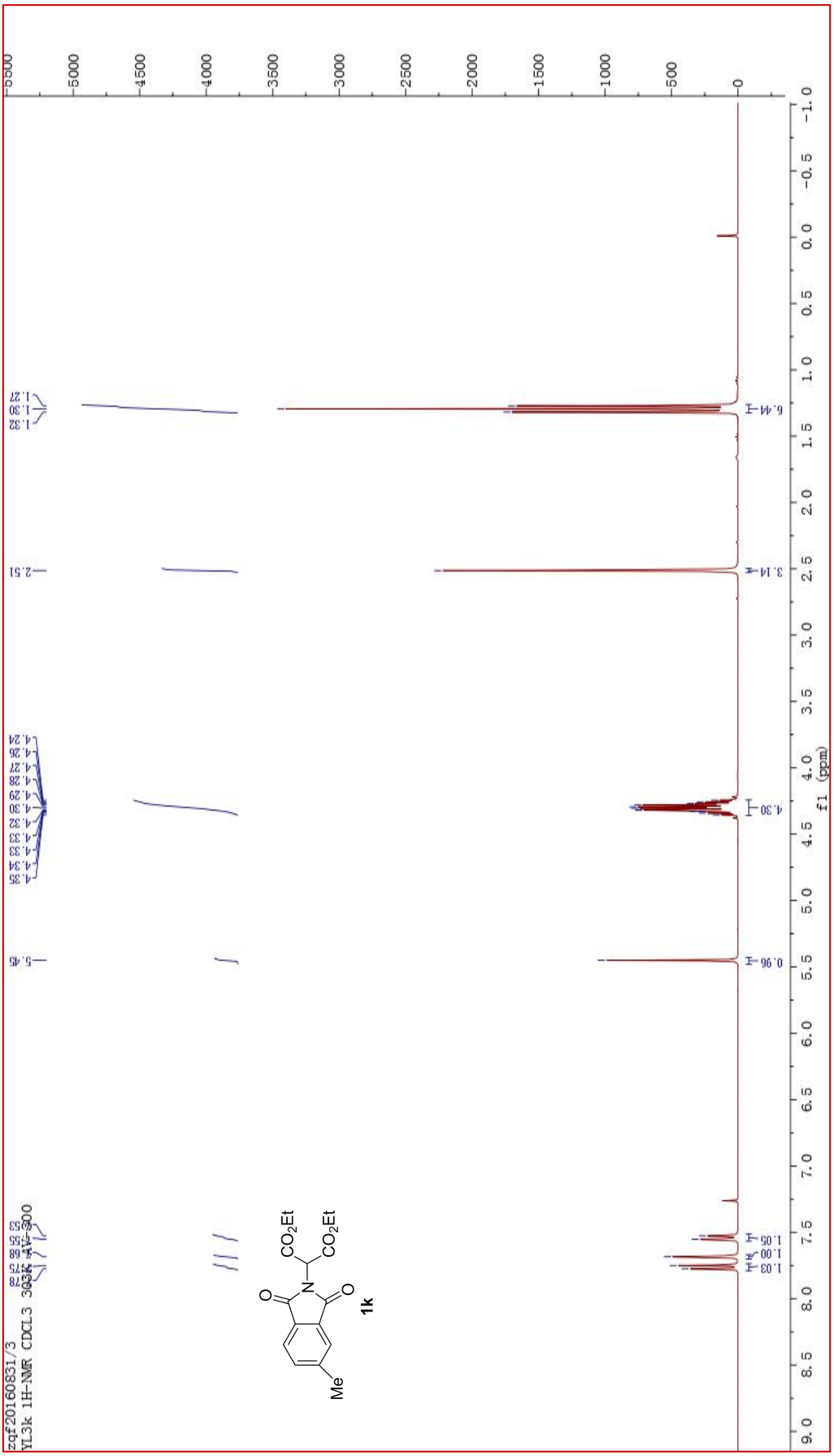
5.1 ^{1}H-NMR, ^{13}C-NMR spectra of Substituted Phthalimidomalonates

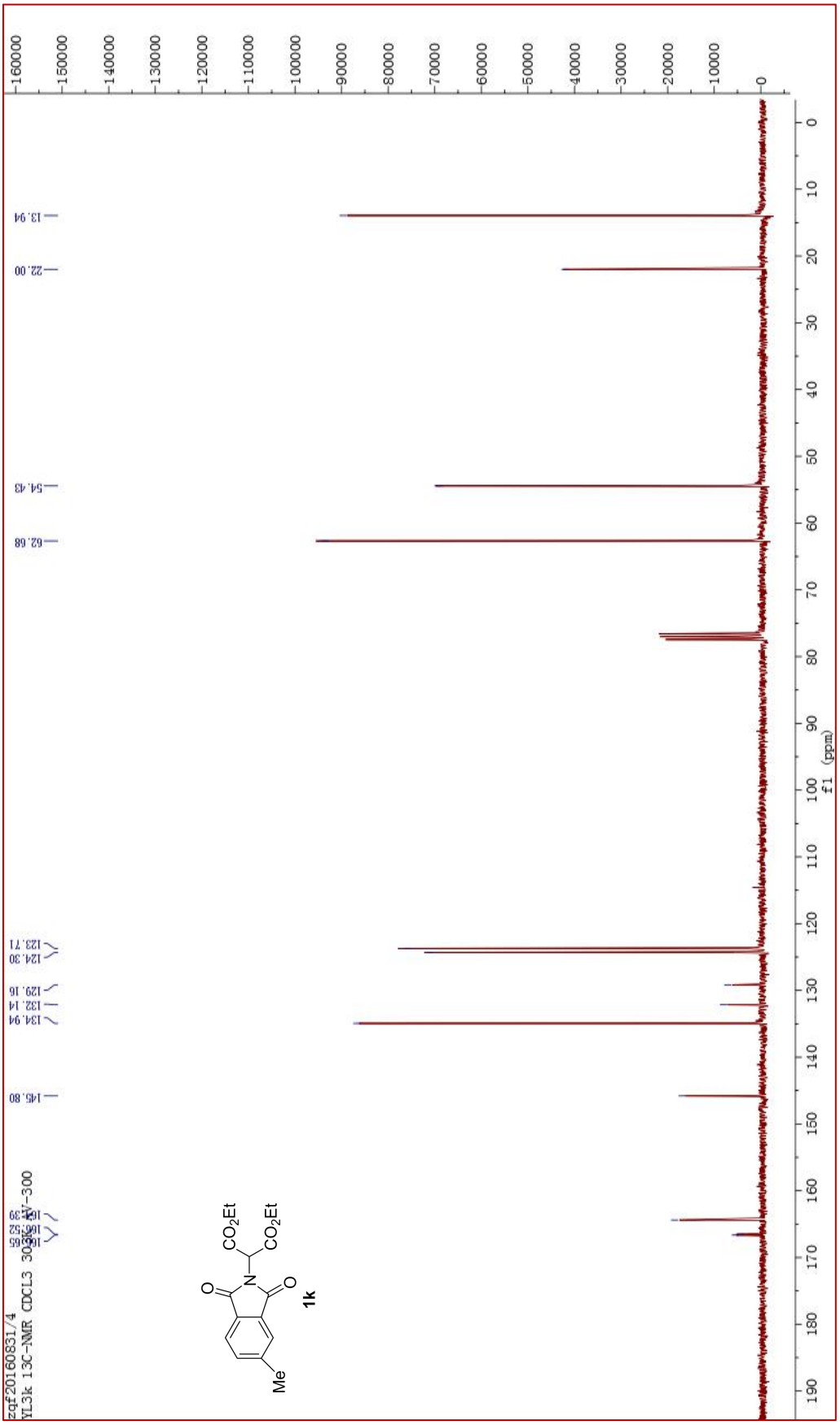


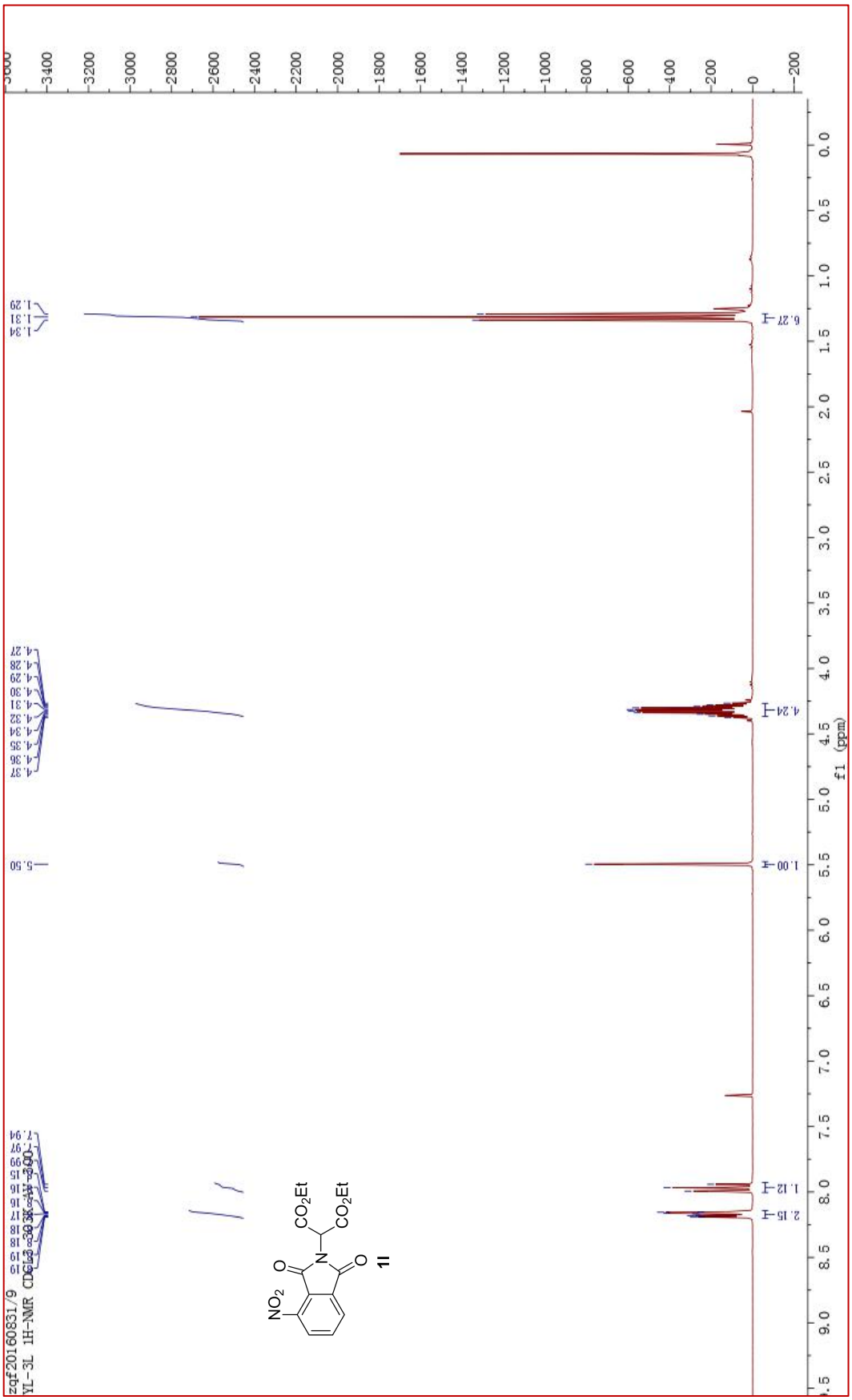

zqf20160831/14
YL-3I 13C-NMR CDCL3 303K 300
13.94
54.68
62.93
125.89
130.80
139.52
163.87
163.52
CO2Et
CO2Et
Cl
Cl
1i
f1 (ppm)

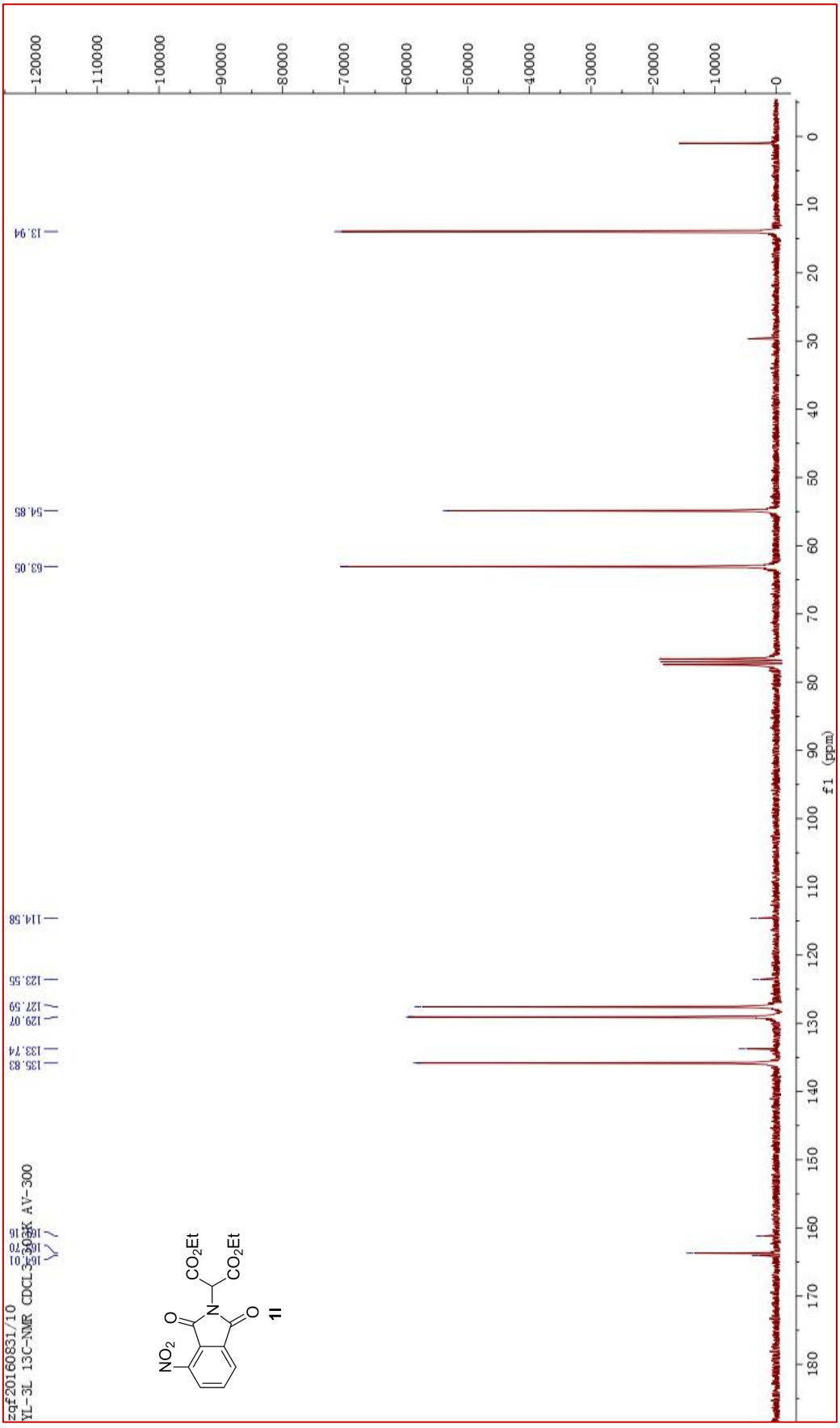

zqf20160831/15
YL-3j 1H-NMR CDCL3 303K AV-300
1j
f1 (ppm)

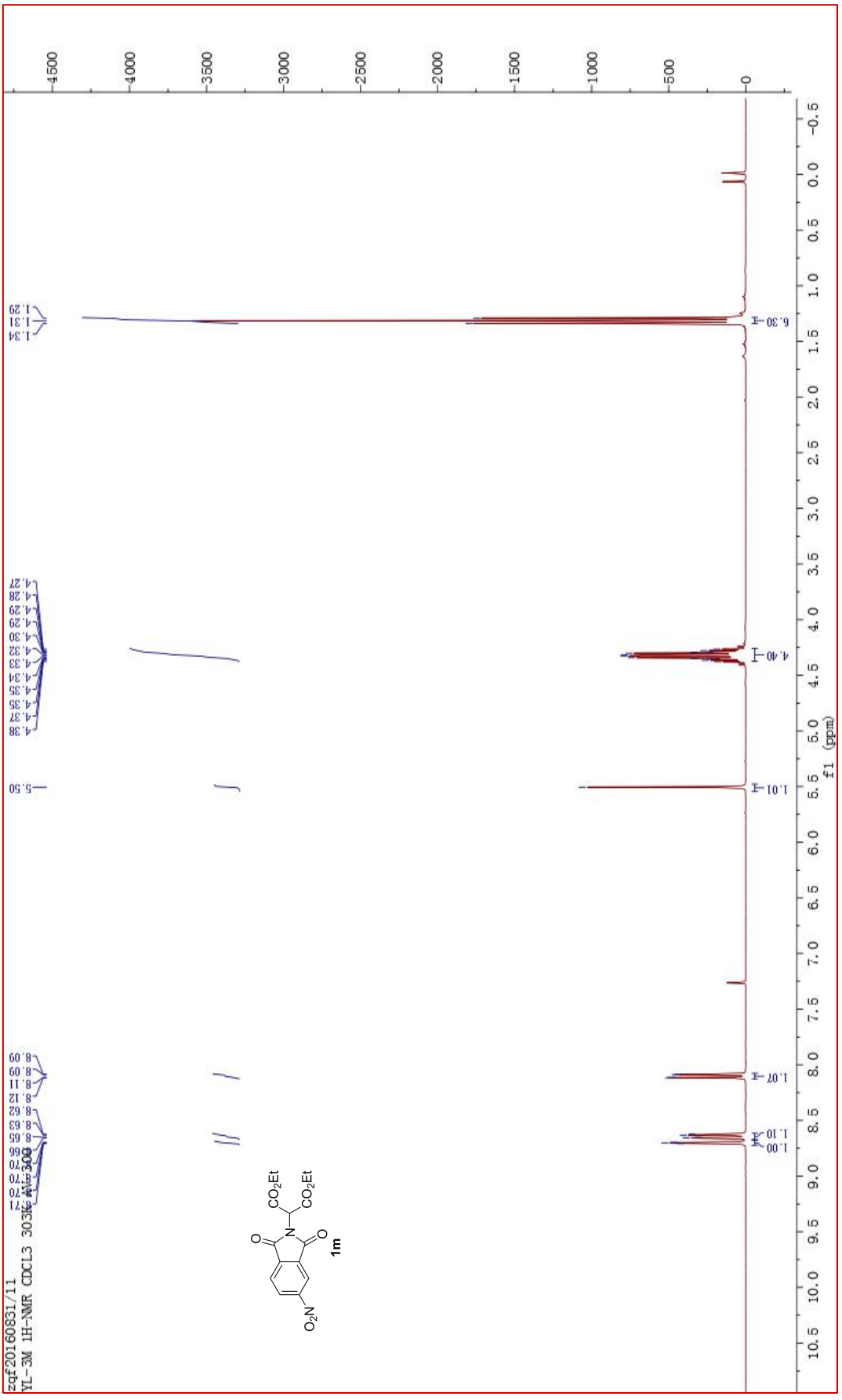

zqf20160831/16
YL-3J 1H-NMR CDCL3 303K AV-300
13.95
54.82
63.07
130.25
140.67
CO2Et
CO2Et
Cl
Cl
Cl
Cl
O
O
N
1j
f1 (ppm)

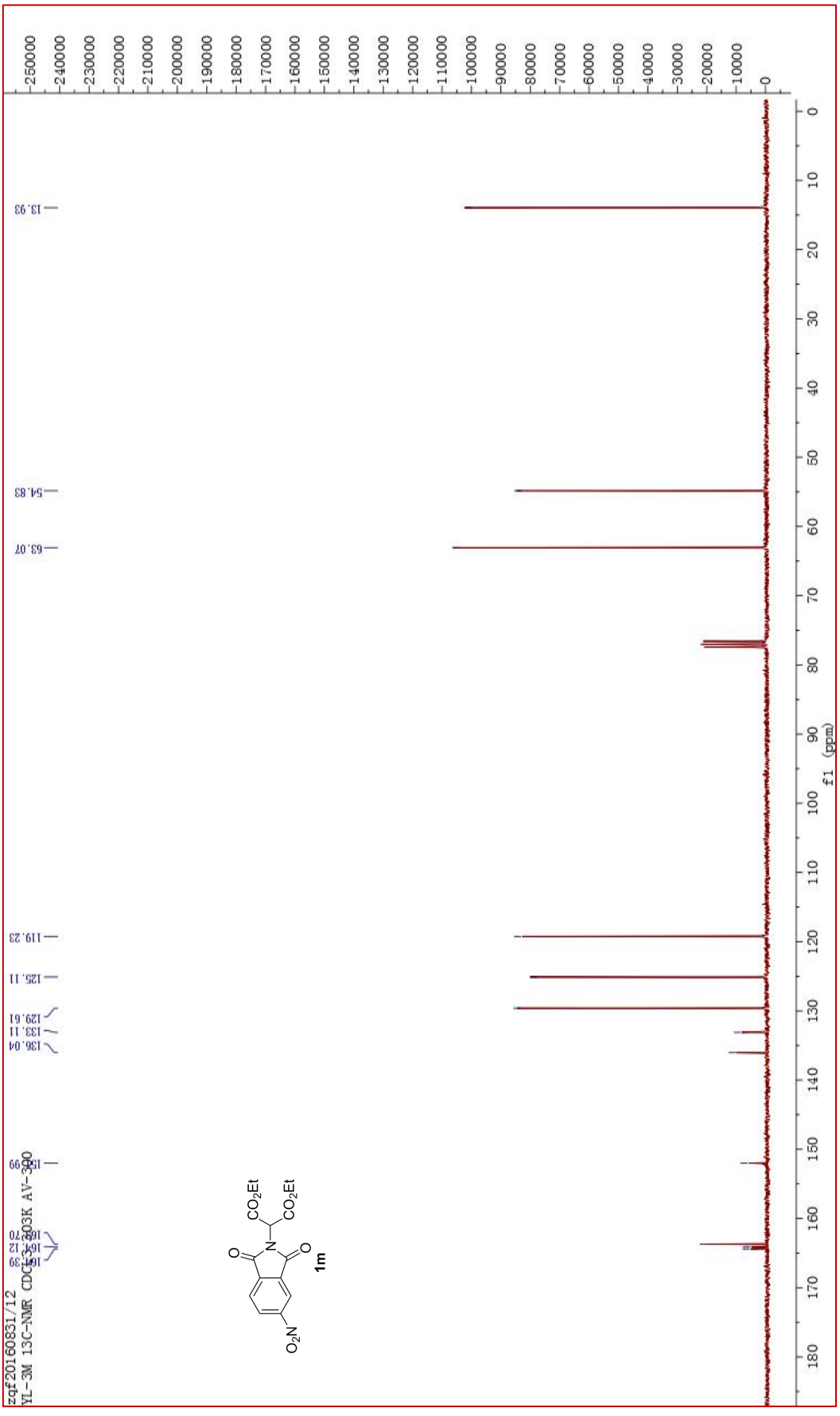

zqf20160831/3
YL3k 1H-NMR CDCL3 300K 400
1.27
1.30
1.32
2.51
4.24
4.26
4.27
4.28
4.29
4.30
4.31
4.32
4.33
4.34
4.35
4.36
4.38
4.39
5.45
7.28
7.35
7.36
7.37
7.38
CO2Et
CO2Et
N
O
O
Me
1k
6.44
3.14
4.30
0.96
1.05
1.00
1.03
f1 (ppm)

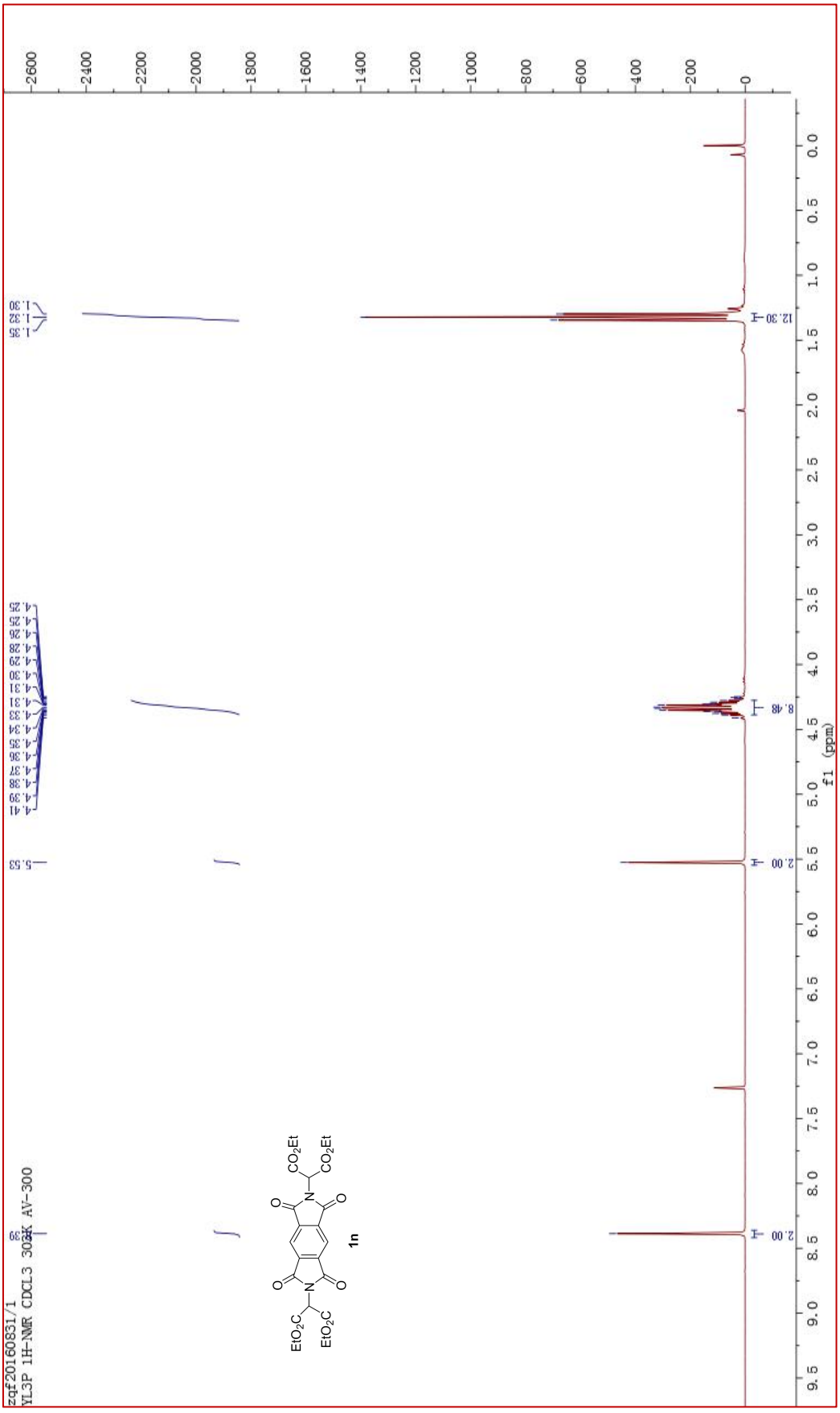

zqf20160831/4
YL3k 13C-NMR CDCL3 300M AV-300
13.94
22.00
54.43
62.68
123.71
124.30
129.16
132.14
134.94
145.80
CO2Et
CO2Et
Me
1k
f1 (ppm)


zqf20160831/9
YL-3L 1H-NMR CDCl3
CO2Et
CO2Et
NO2
O
O
N
O
11
f1 (ppm)


zqf20160831/10
YL-3L 13C-NMR CDCL3 298K AV-300
13.94
54.85
63.05
114.58
123.55
127.59
129.07
133.74
135.83
f1 (ppm)
11


zqf20160831/11
YL-3M 1H-NMR CDCL3
1m


zqf20160831/12
YL-3M 13C-NMR CDCl3 303K AV-300
13.93
54.83
63.07
119.23
125.11
129.61
133.11
136.04
165.39
166.12
CO2Et
CO2Et
O2N
1m
f1 (ppm)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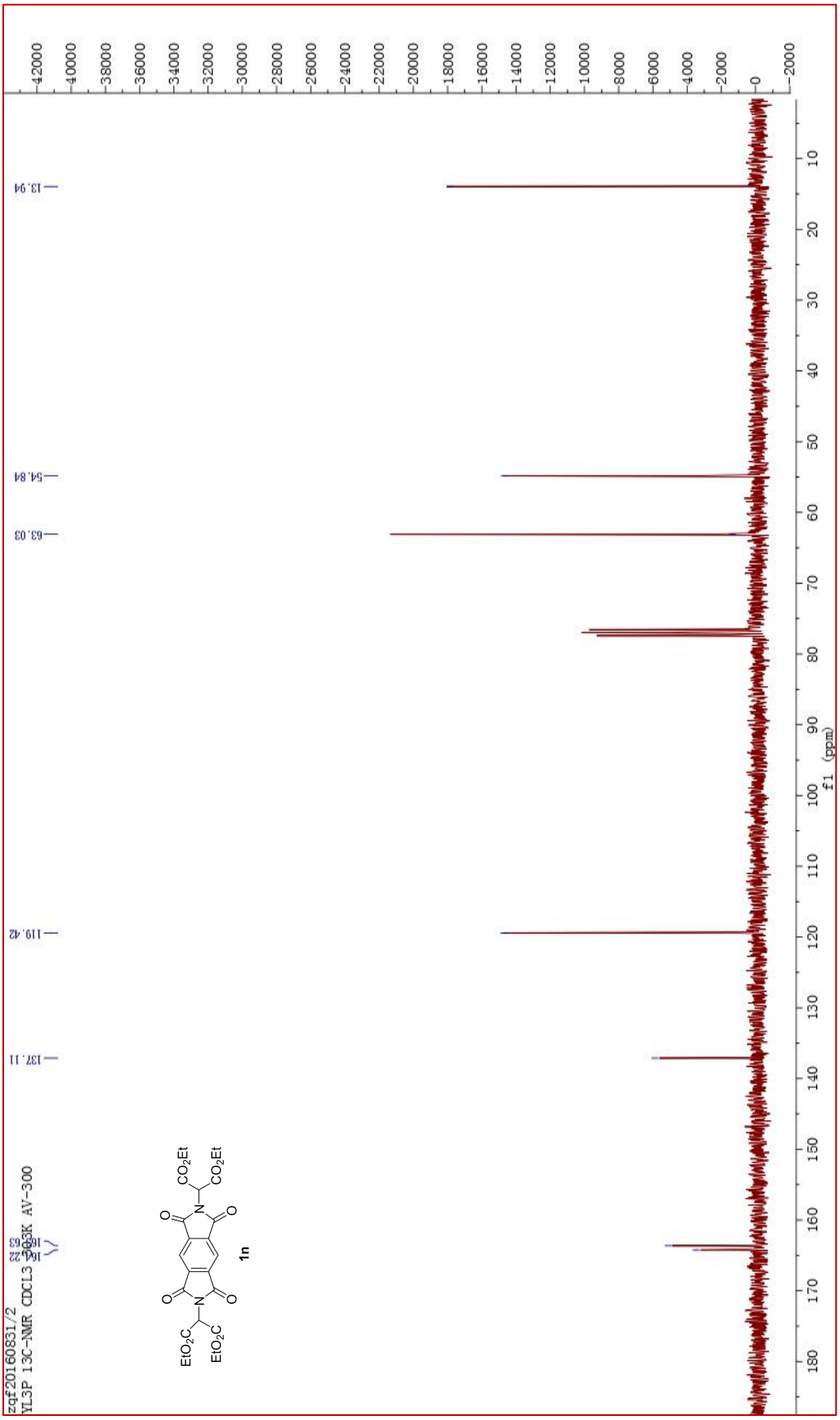
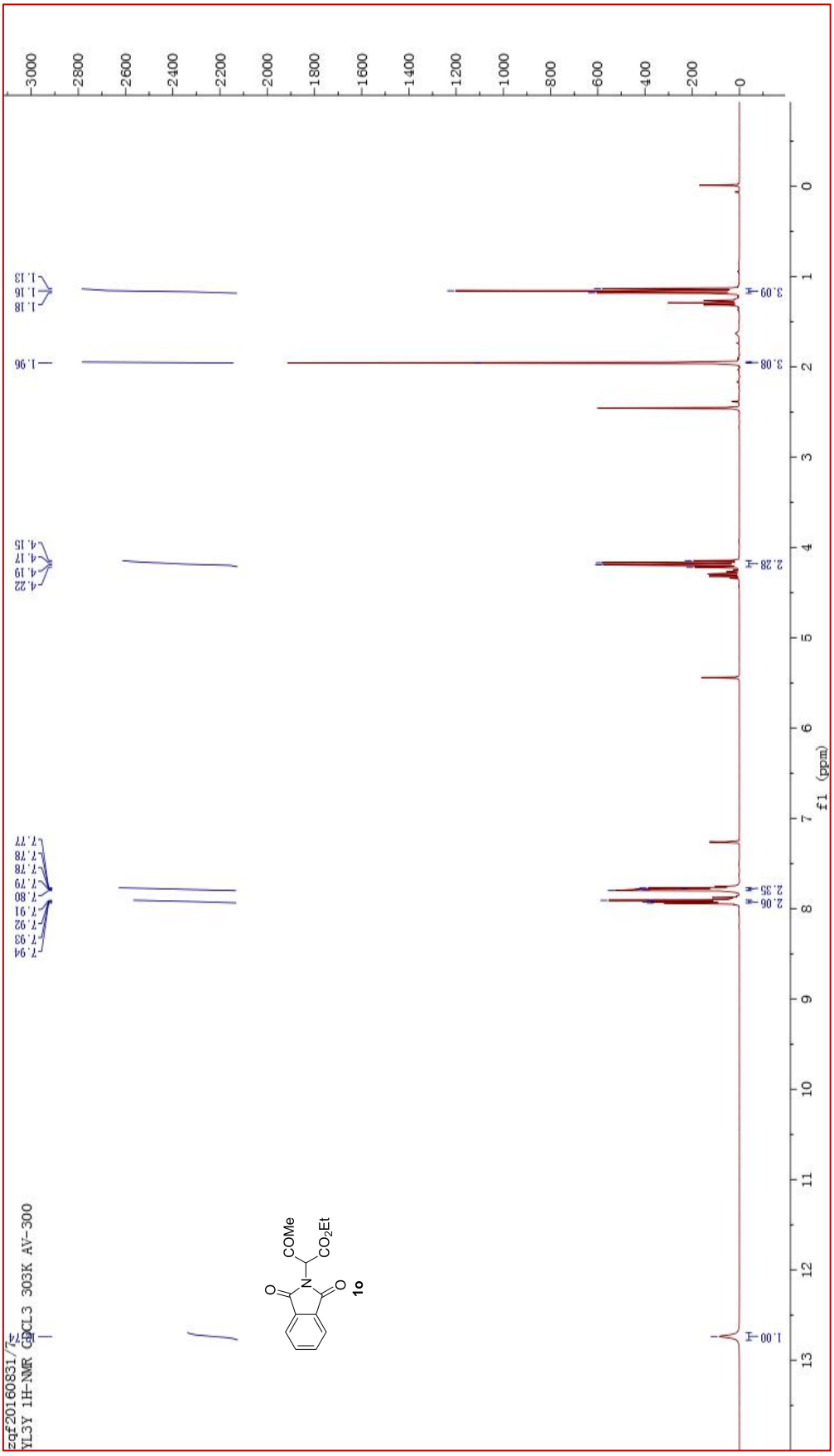
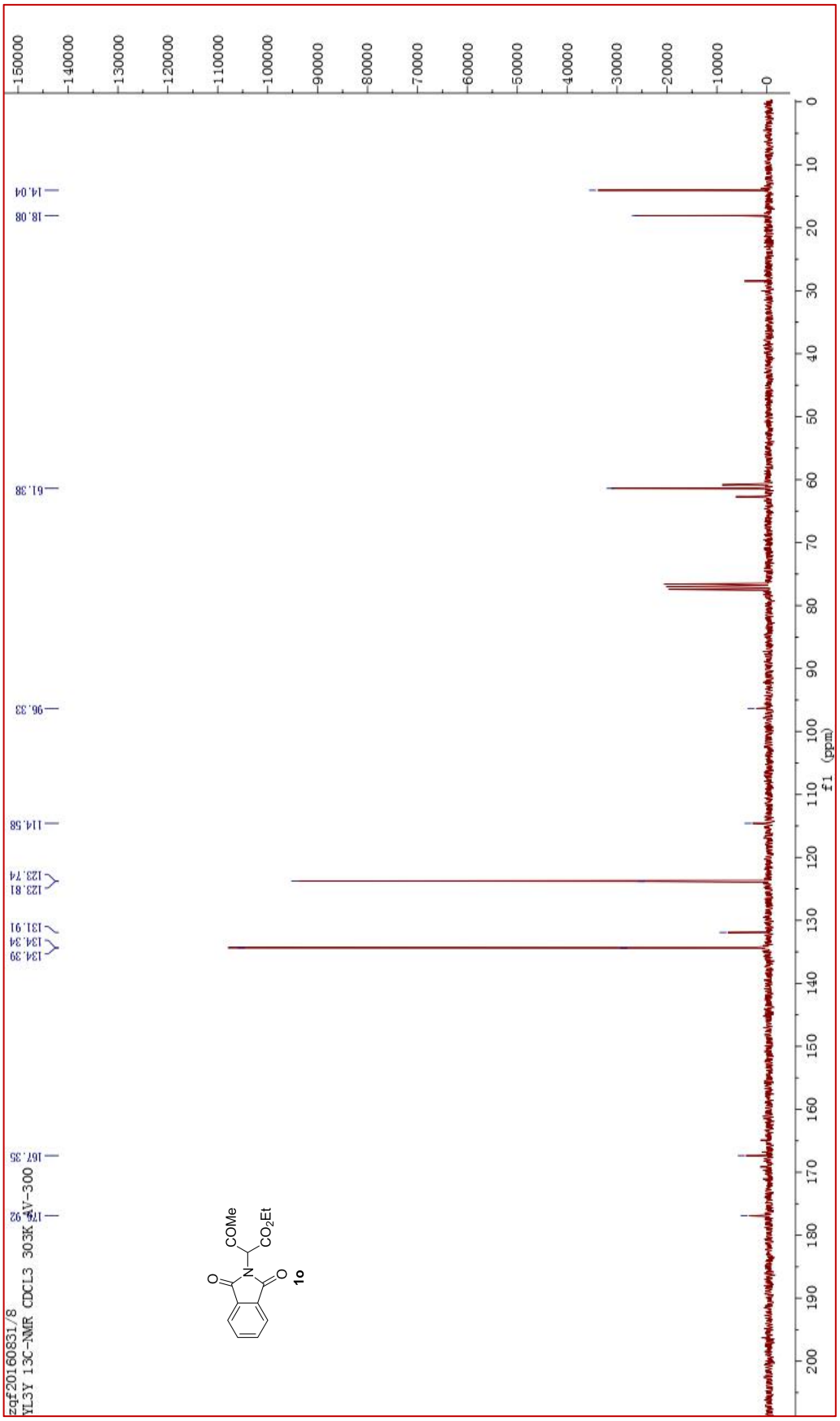
YL3P 1H-NMR CDCL3 303K AV-300
1n
f1 (ppm)


zqf201160831/2
YL3P 13C-NMR CDCL3 298K AV-300
13.94
54.84
63.03
119.42
137.11
EtO2C
EtO2C
CO2Et
CO2Et
1n
f1 (ppm)


zqf20160831/7
YL3Y 1H-NMR CDCL3 303K AV-300
COMe
CO2Et
1o
f1 (ppm)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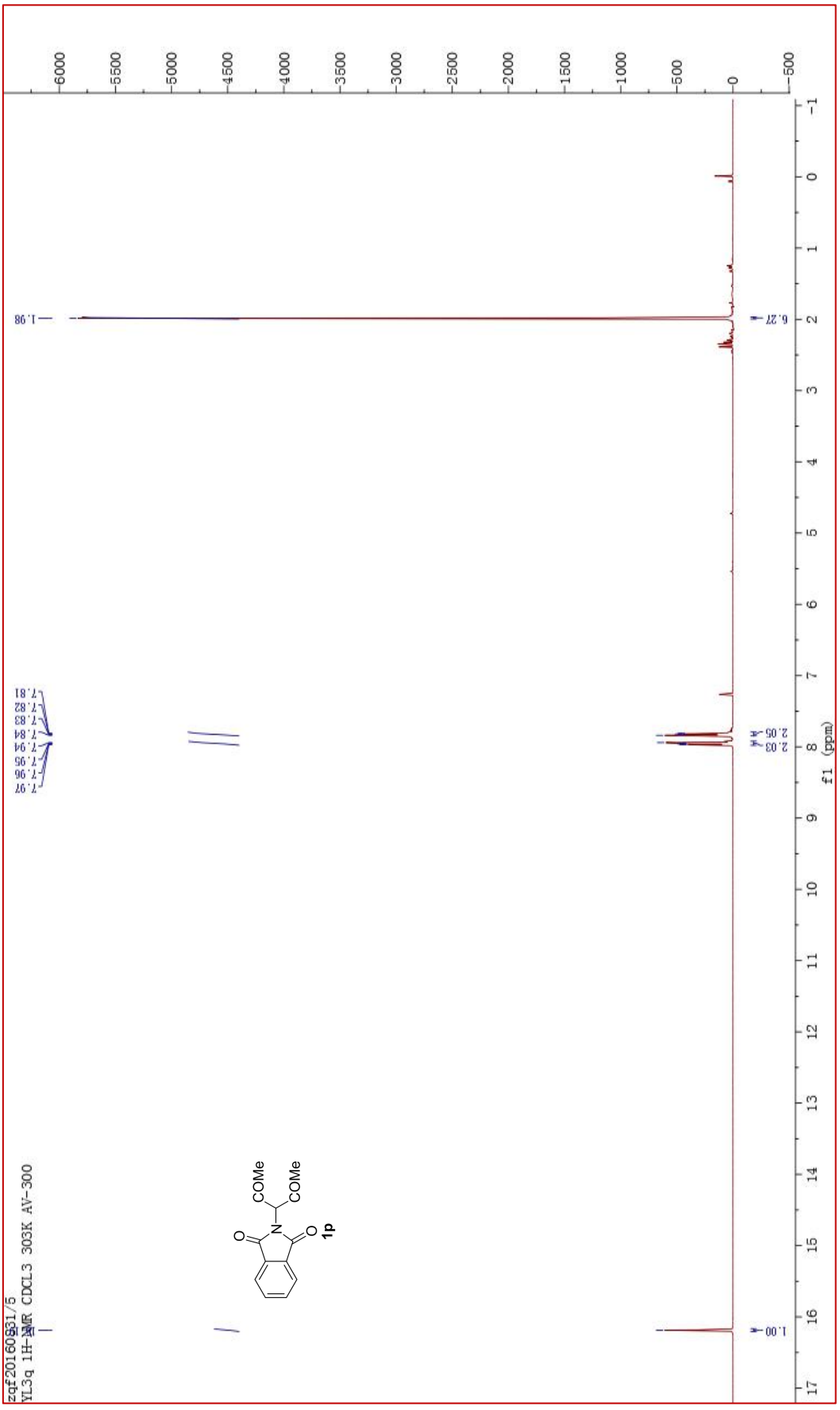
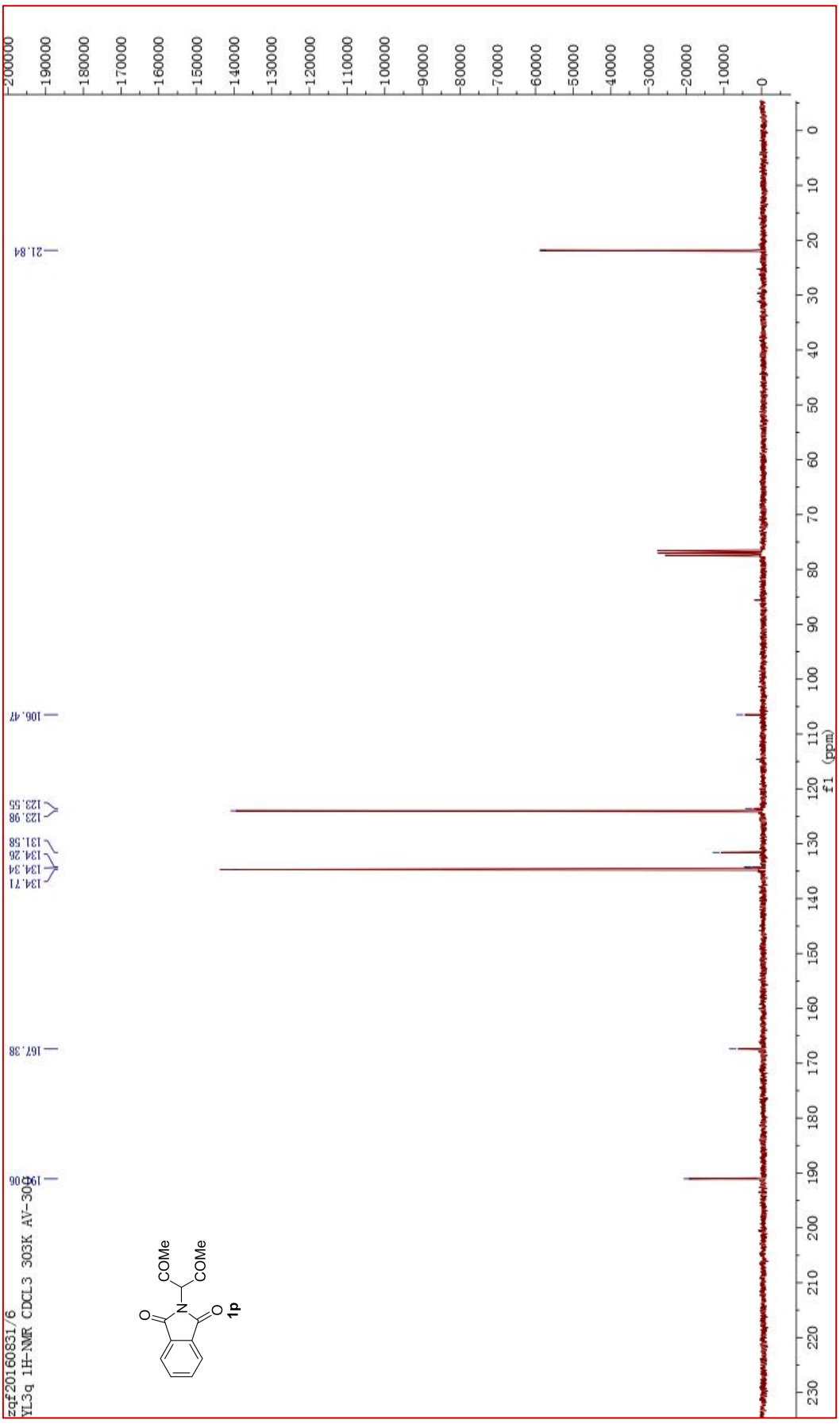
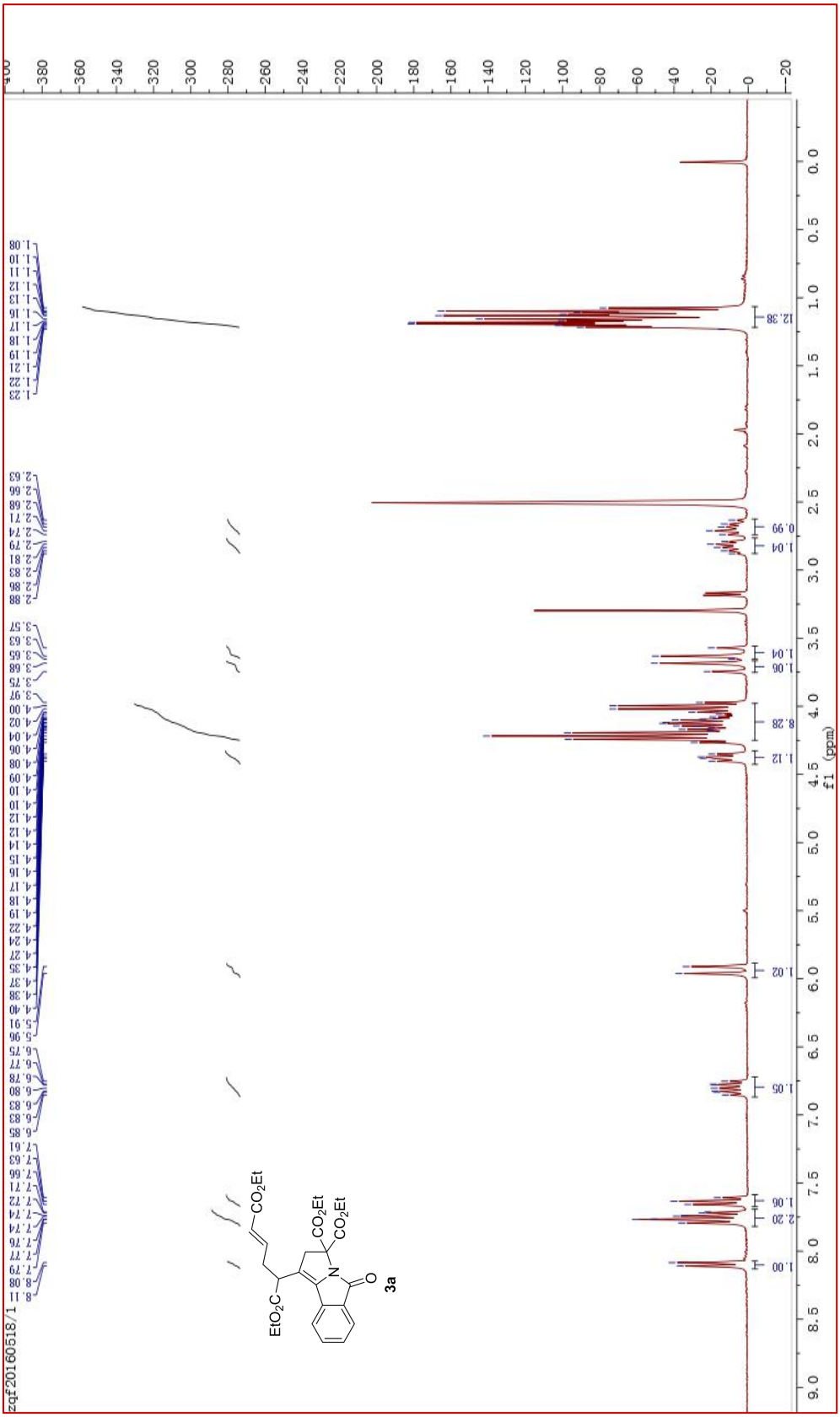
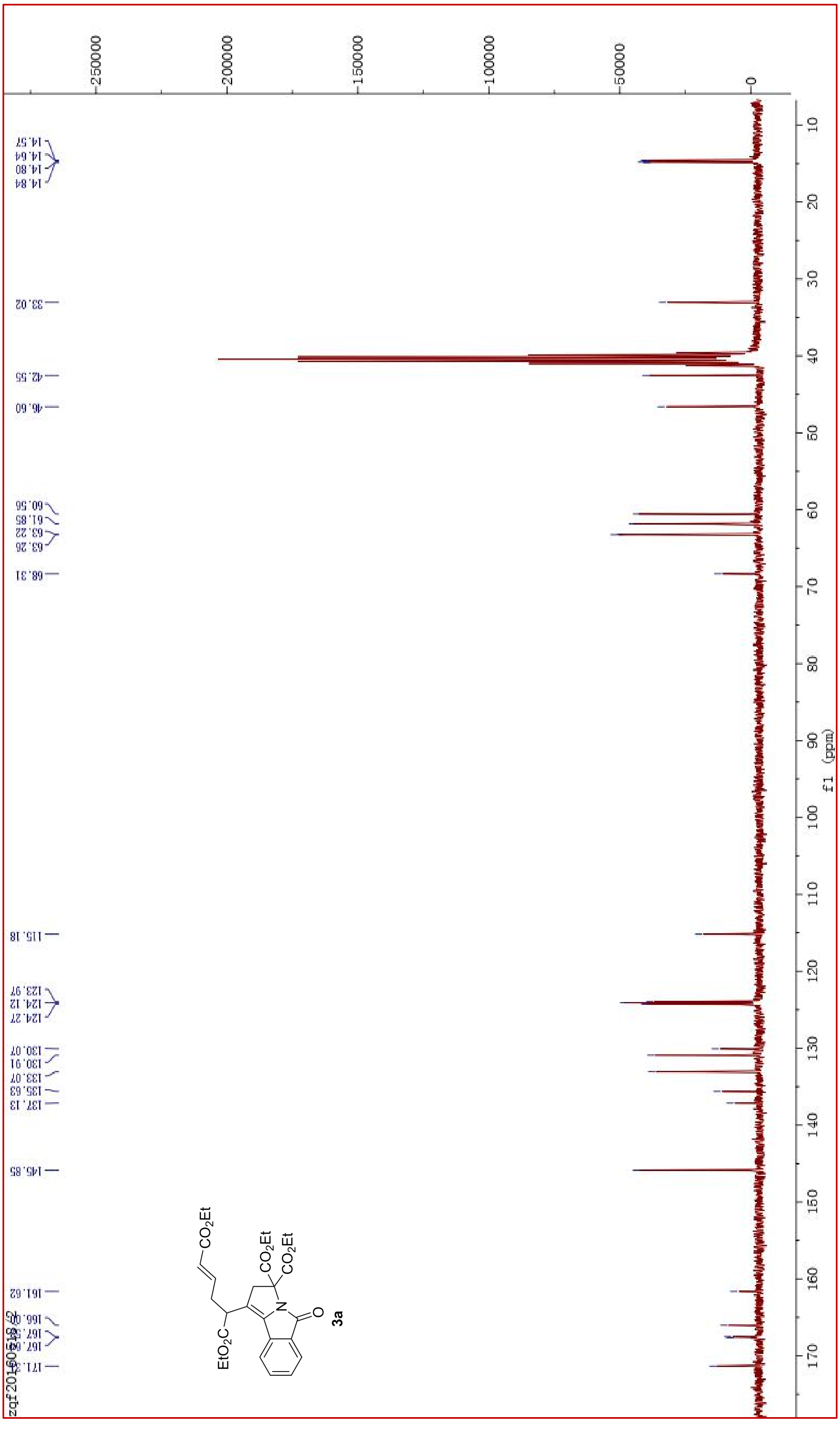
YL3Y 13C-NMR CDCL3 303K AV-300
14.04
18.08
61.38
96.33
114.58
123.74
123.81
131.91
134.34
134.39
167.35
f1 (ppm)
COMe
CO2Et
O
N
O
1o


zqf20160831/5
YL3q 1H-NMR CDCL3 303K AV-300
1.98
6.27
2.03
2.05
1.00
7.97
7.96
7.95
7.94
7.84
7.83
7.82
7.81
COMe
COMe
O
N
O
1p
f1 (ppm)


zqf20160831/6
YL3q 1H-NMR CDCL3 303K AV-300
21.84
106.47
123.98
123.55
131.58
134.26
134.34
134.71
167.38
190.06
COMe
COMe
O
N
O
1p
f1 (ppm)

5.2 ^{1}H-NMR, ^{13}C-NMR spectra of products




14.57
14.64
14.80
14.84
33.02
42.55
46.60
60.56
61.85
63.22
63.26
68.31
115.18
123.97
124.12
124.27
130.07
130.91
133.07
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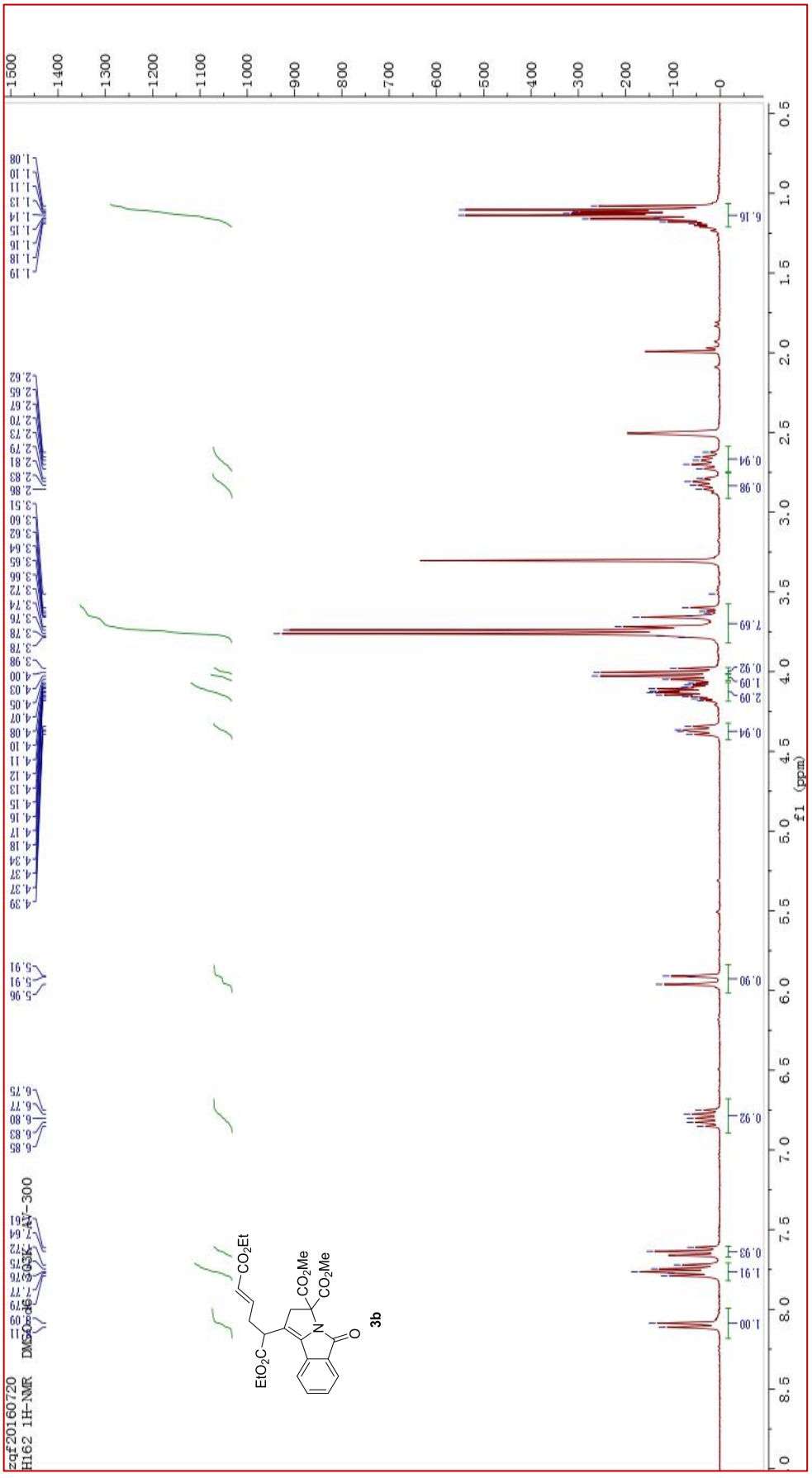
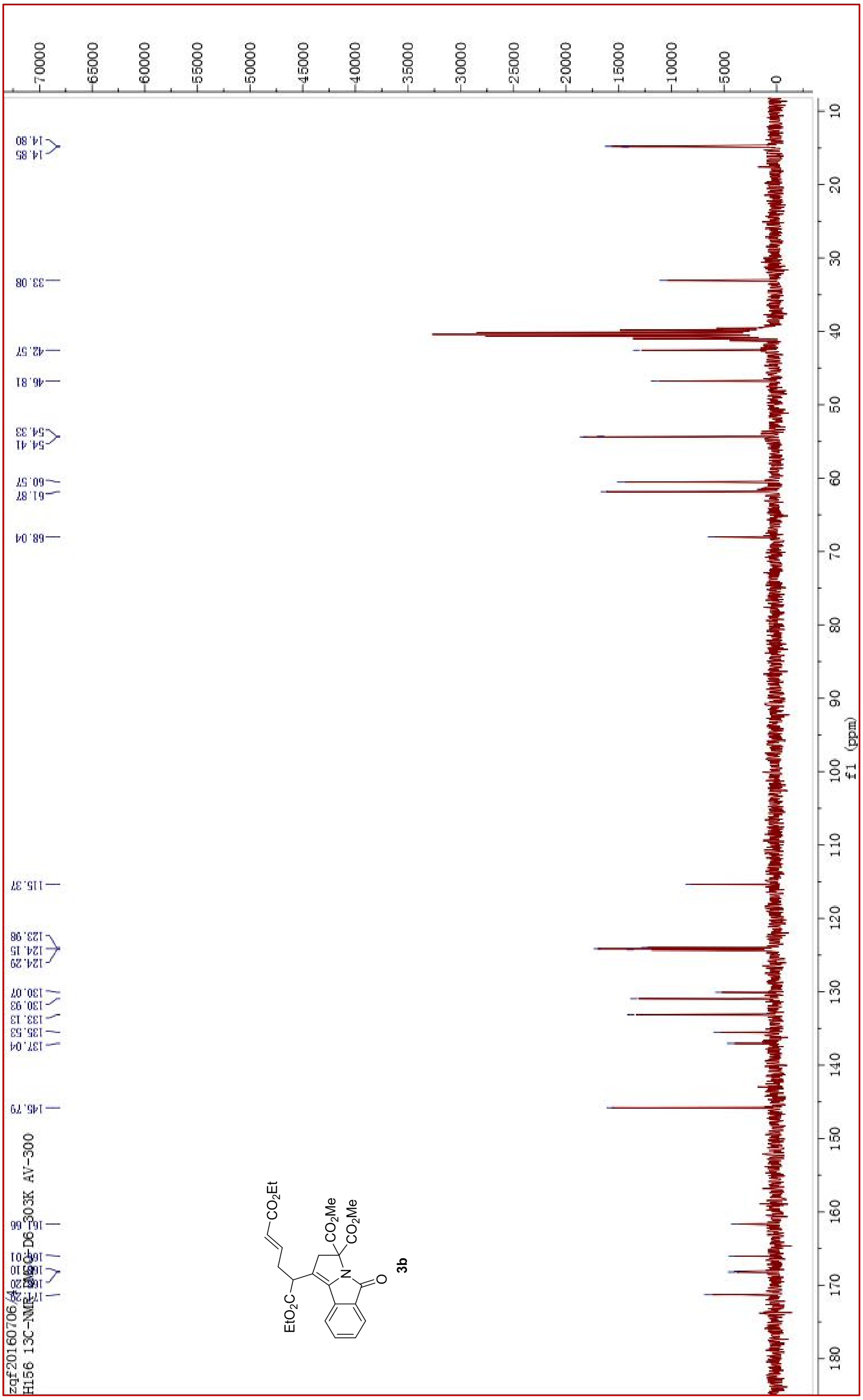
145.85
161.62
f1 (ppm)
EtO2C
CO2Et
CO2Et
CO2Et
N
O
3a


zqf20160720
H162 1H-NMR DMSO-d6
3b
CO2Et
CO2Me
CO2Me
EtO2C
O
N
f1 (ppm)


zqf20160706/4
H156 13C-NMR DMSO-D6 303K AV-300
14.80
14.85
33.08
42.57
46.81
54.33
54.41
60.57
61.87
68.04
115.37
123.98
124.15
124.29
130.07
130.93
133.13
135.53
137.04
145.79
161.66
f1 (ppm)
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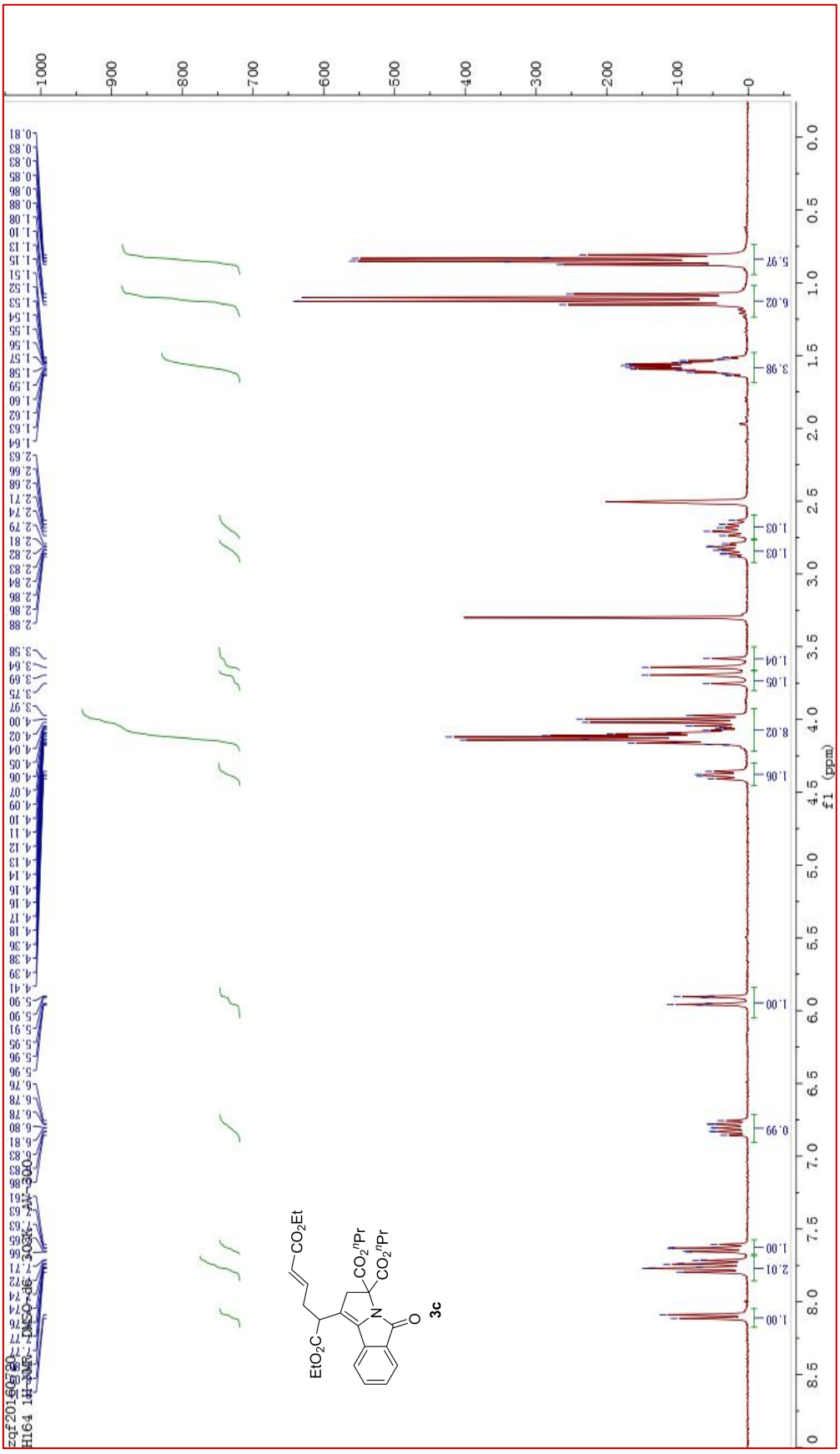
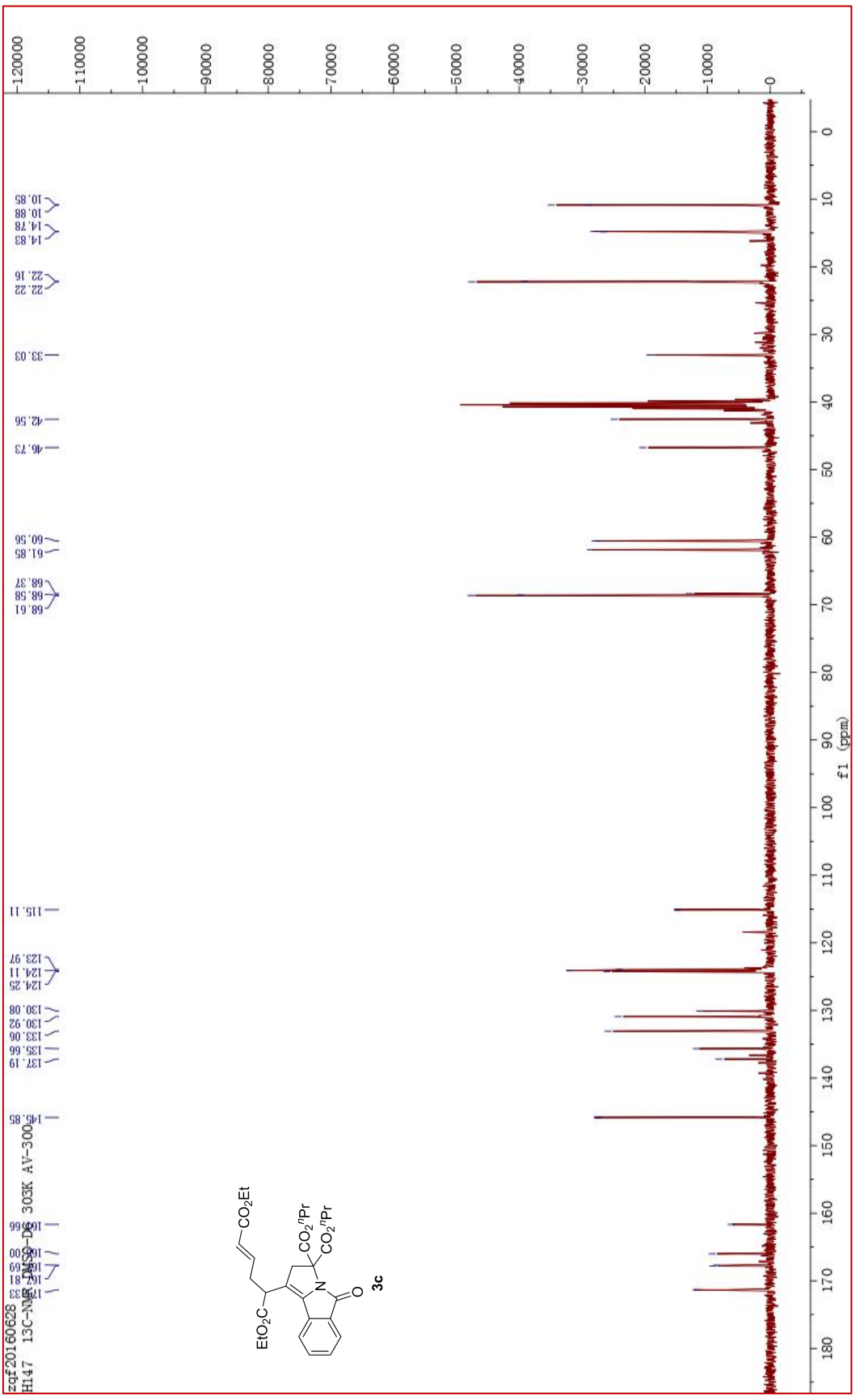
CO2Et
CO2Me
CO2Me
N
O
3b


3c
f1 (ppm)


zqf20160628
H147 13C-NMR-DMSO-DS 303K AV-300
10.85
10.88
14.78
14.83
22.16
22.22
33.03
42.56
46.73
60.56
61.85
68.37
68.58
68.61
115.11
123.97
124.11
124.25
130.08
130.92
133.06
135.66
137.19
145.85
166.66
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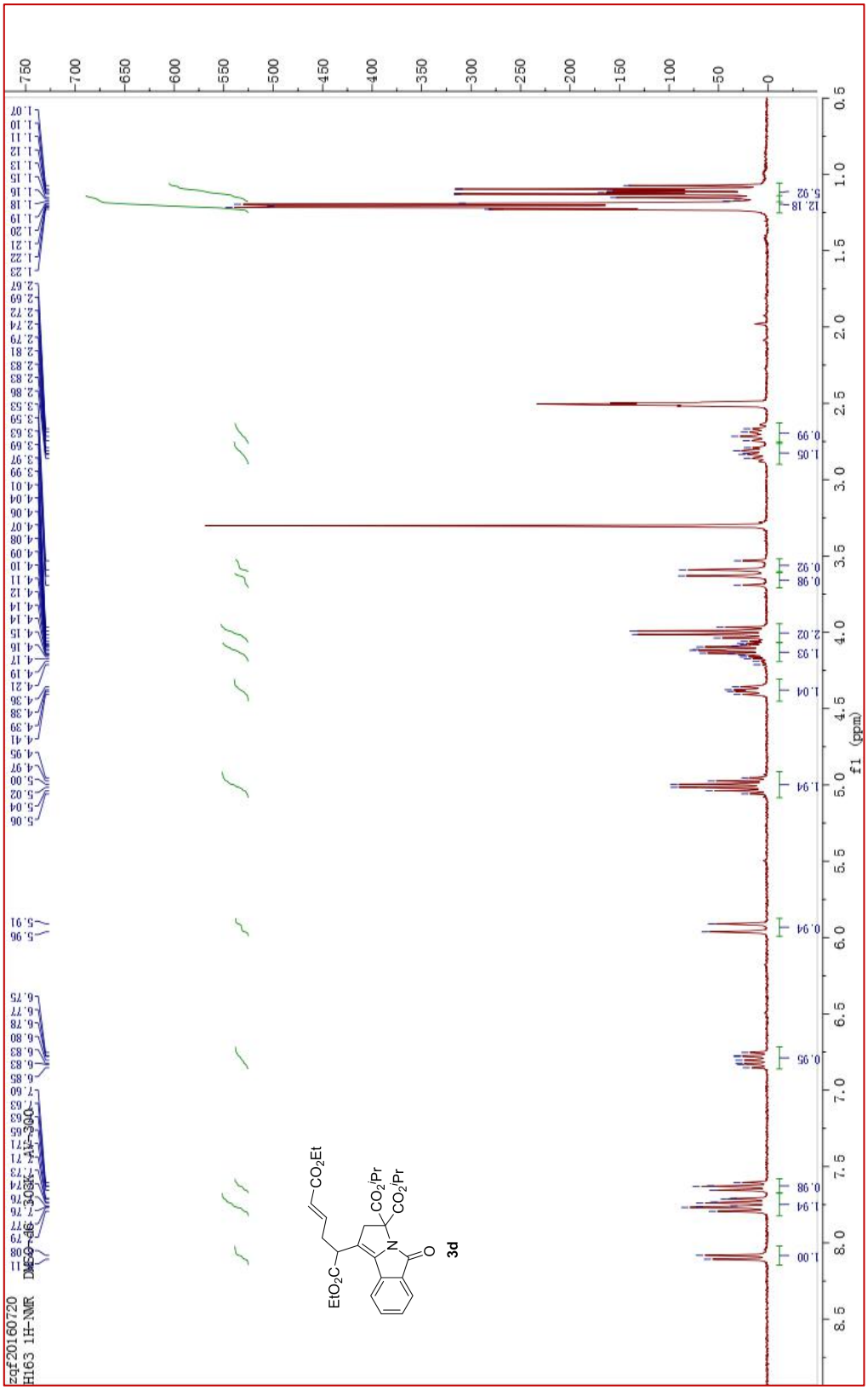
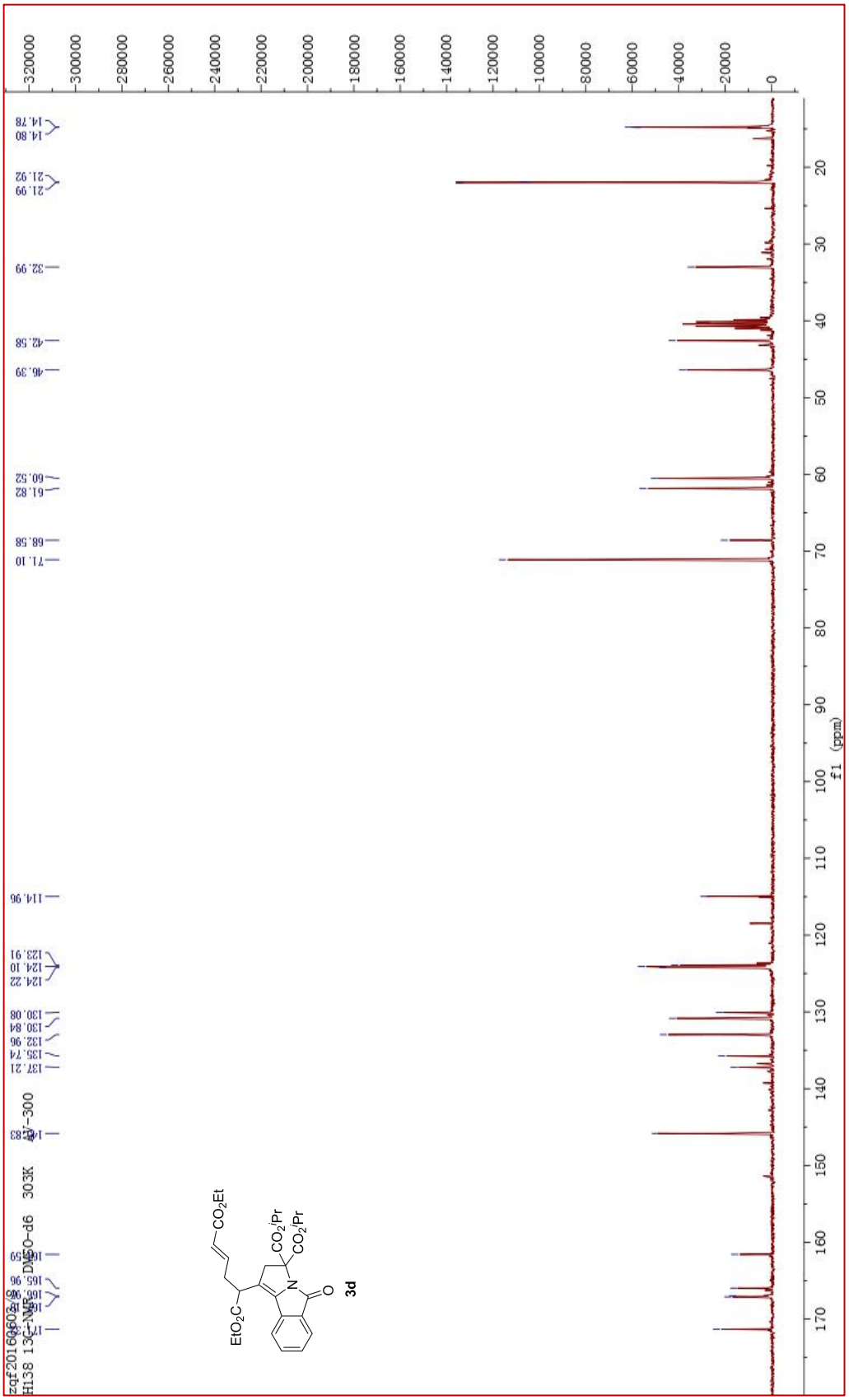
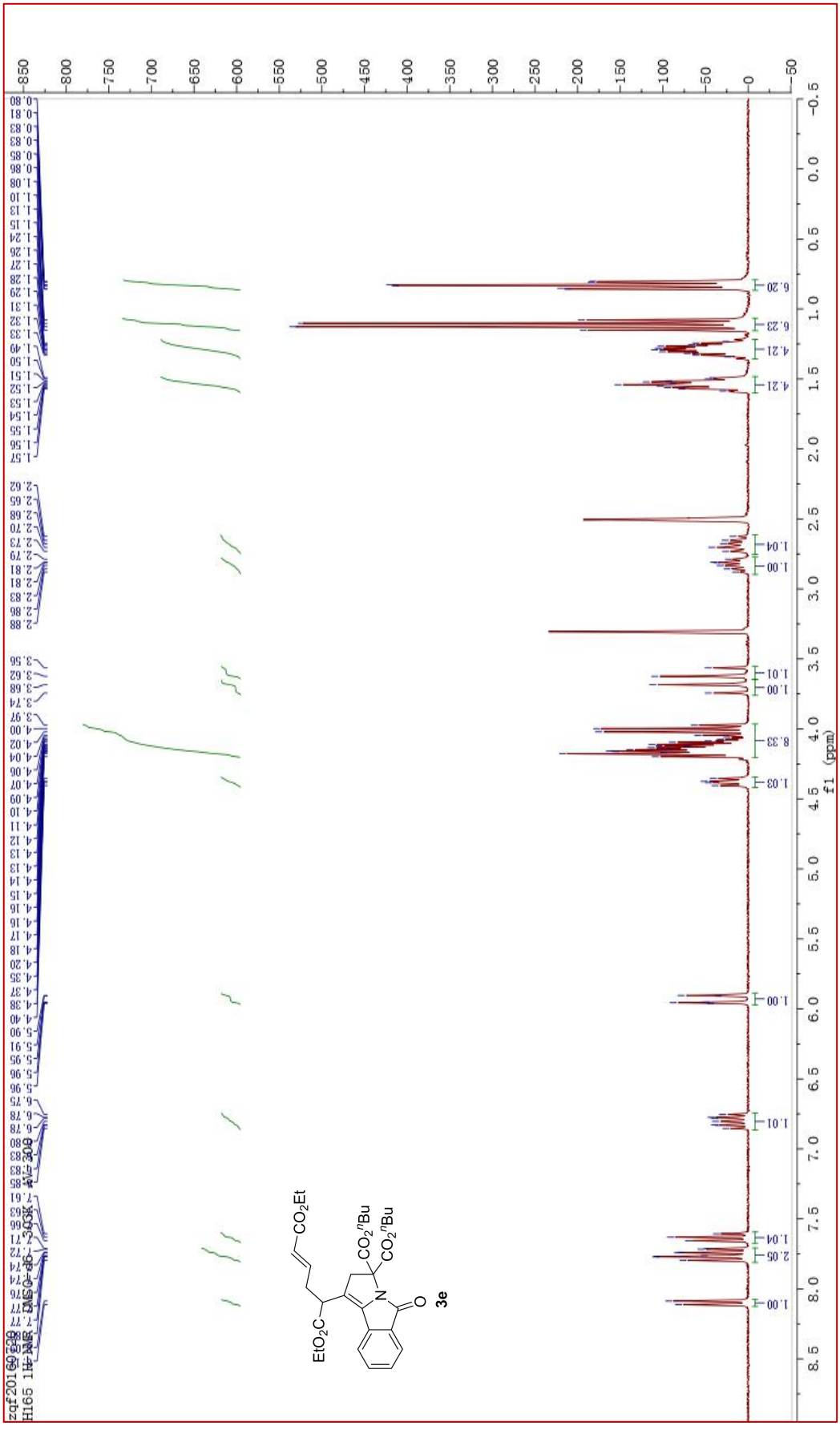
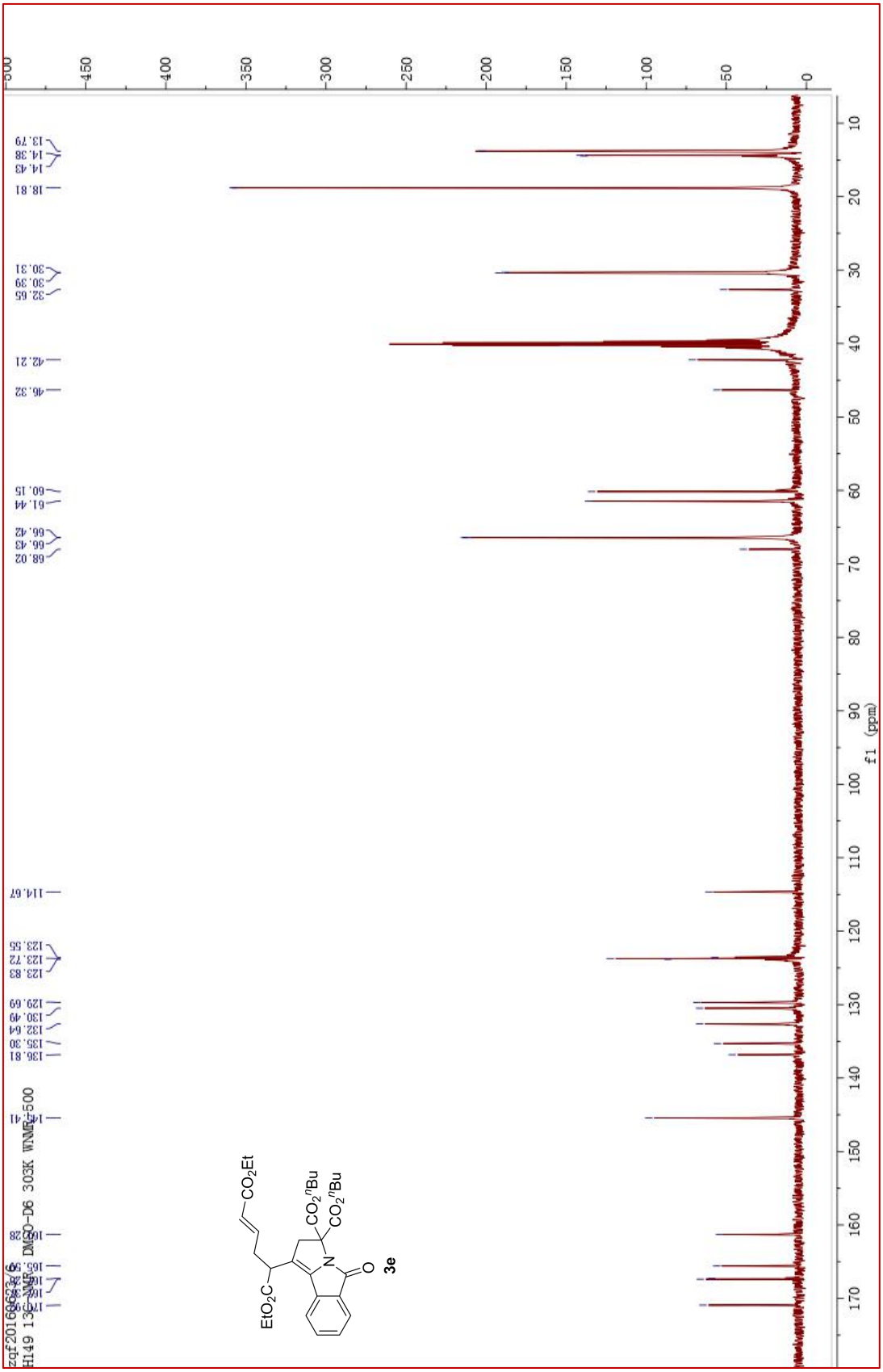
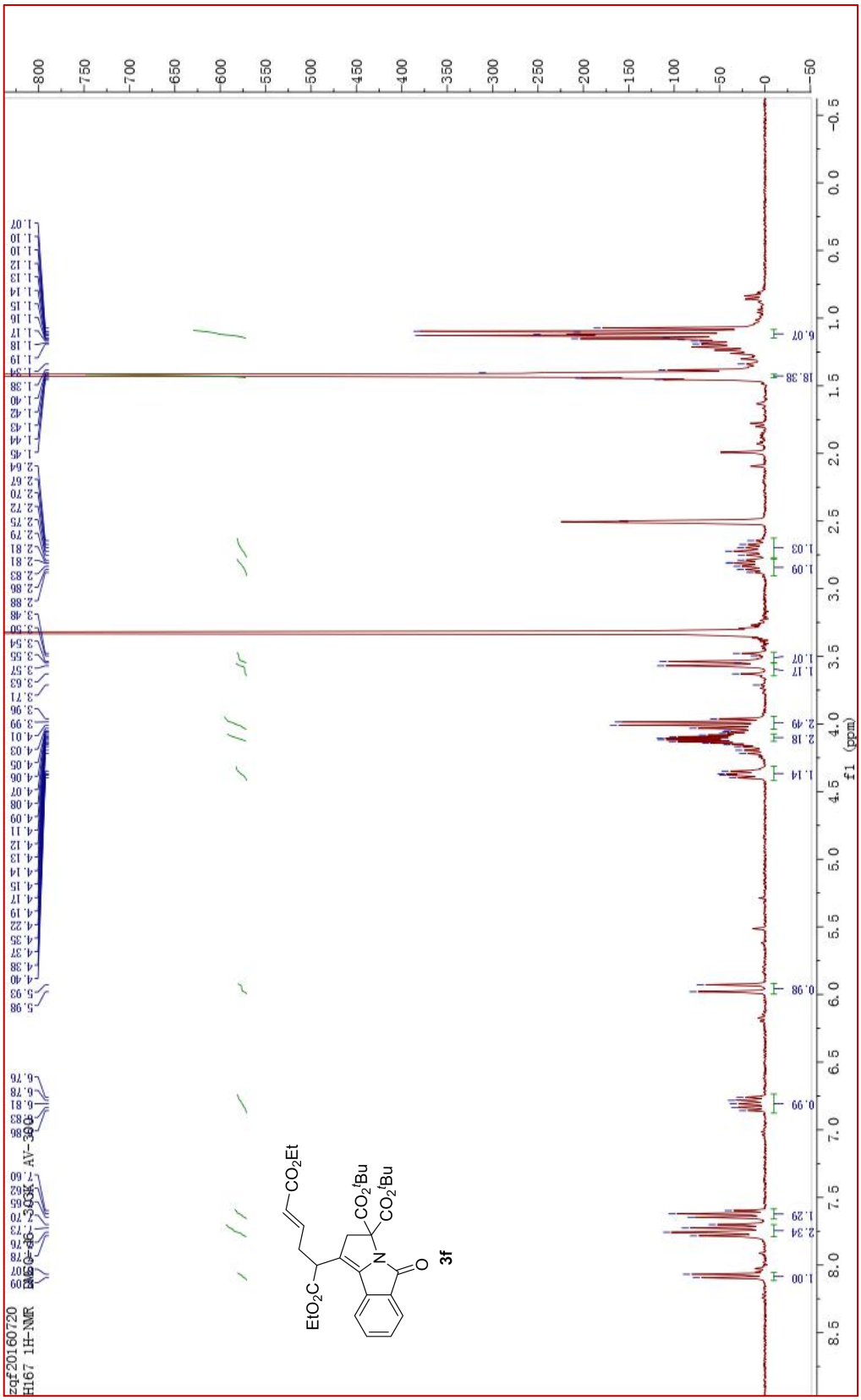
CO2Et
CO2nPr
CO2nPr
EtO2C
N
O
3c
f1 (ppm)

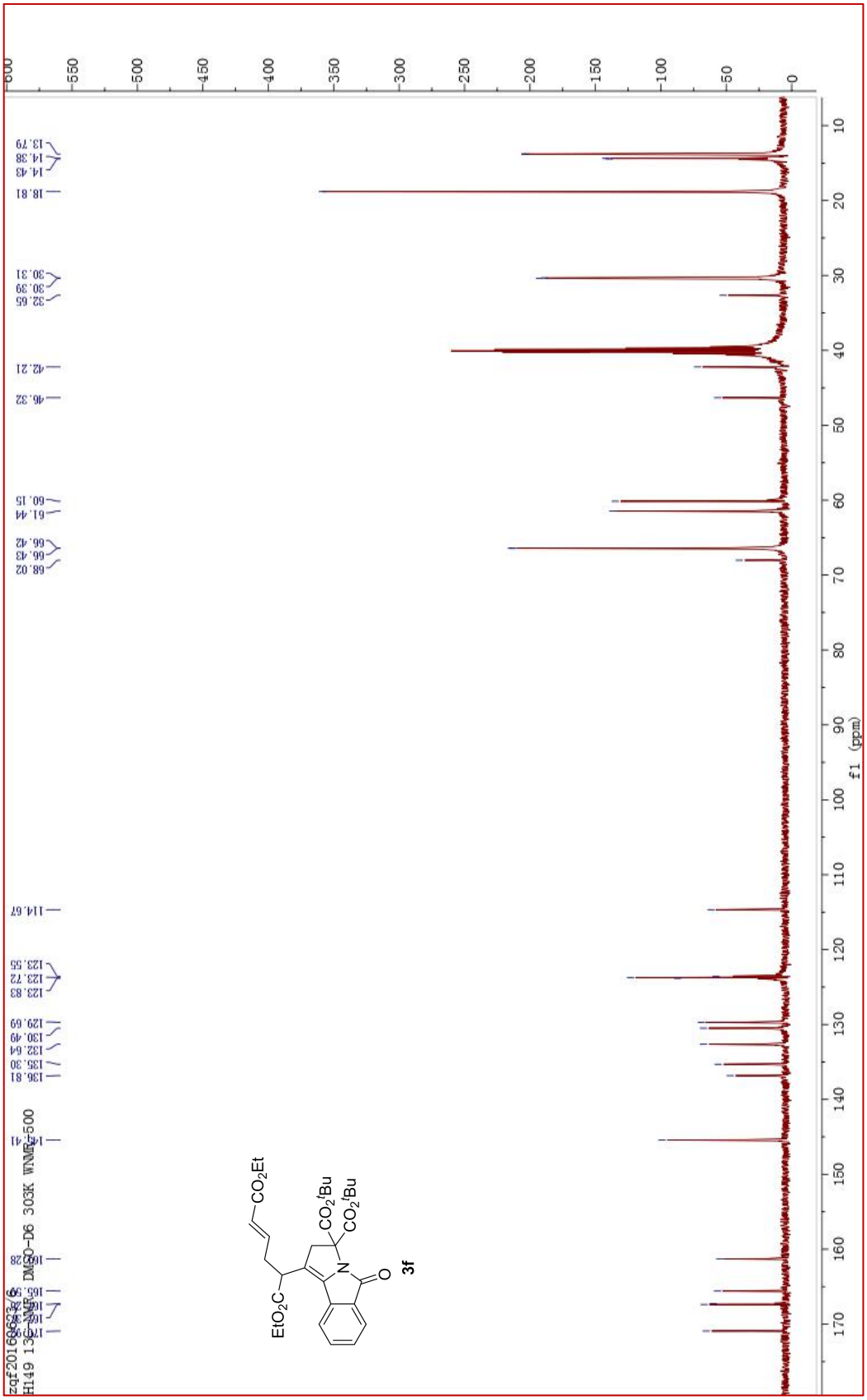

zqf20160720
H163 1H-NMR
DMSO-d6
f1 (ppm)
CO2Et
EtO2C
CO2iPr
CO2iPr
O
N
3d

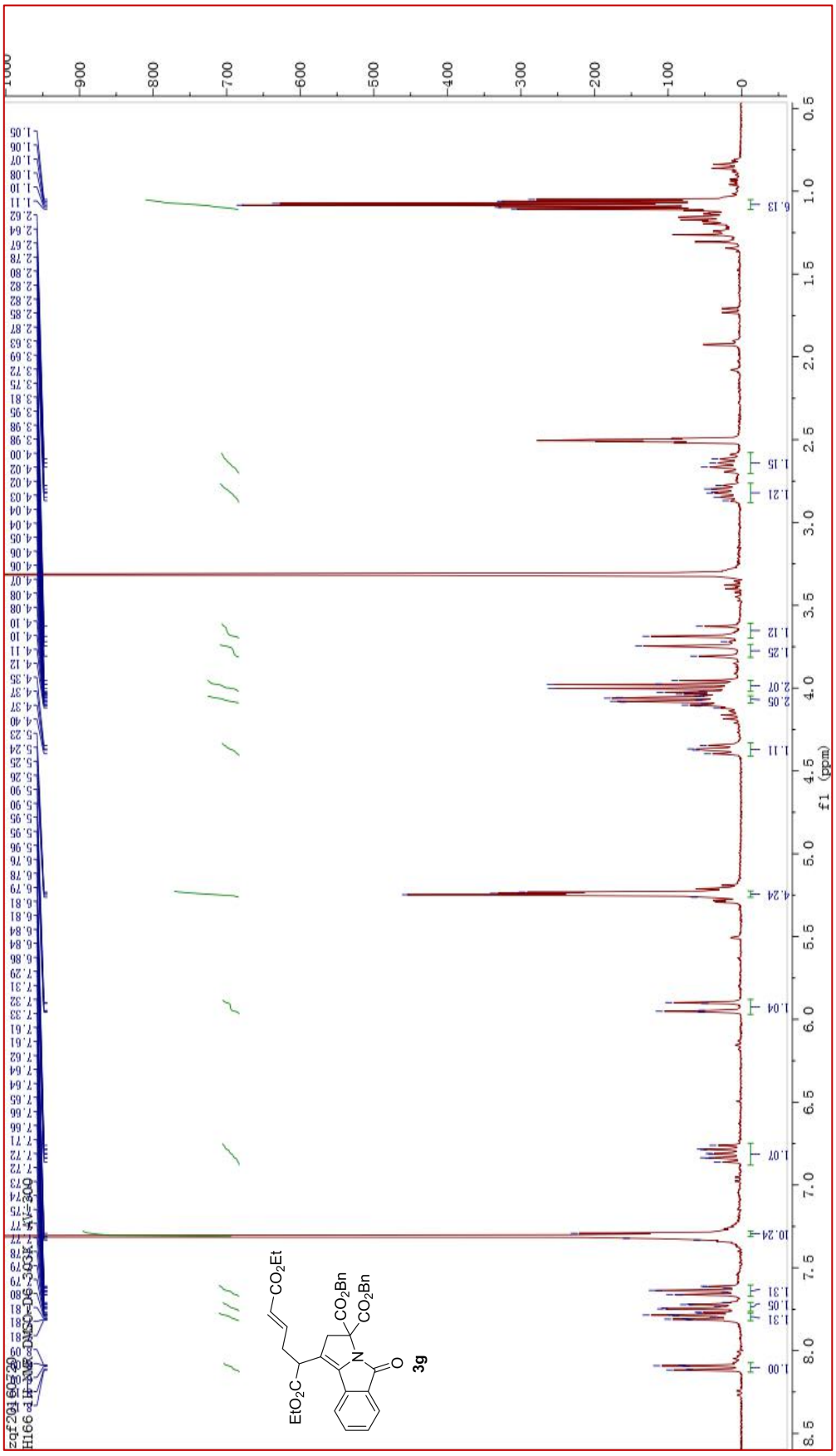

zqf20160603-8
H138 13C-NMR
DMSO-d6
303K
AV-300
14.78
14.80
21.92
21.99
32.99
42.58
46.39
60.52
61.82
68.58
71.10
114.96
123.91
124.10
124.22
130.08
130.84
132.96
135.74
137.21
165.96
f1 (ppm)
EtO2C
CO2Et
CO2iPr
CO2iPr
N
O
3d

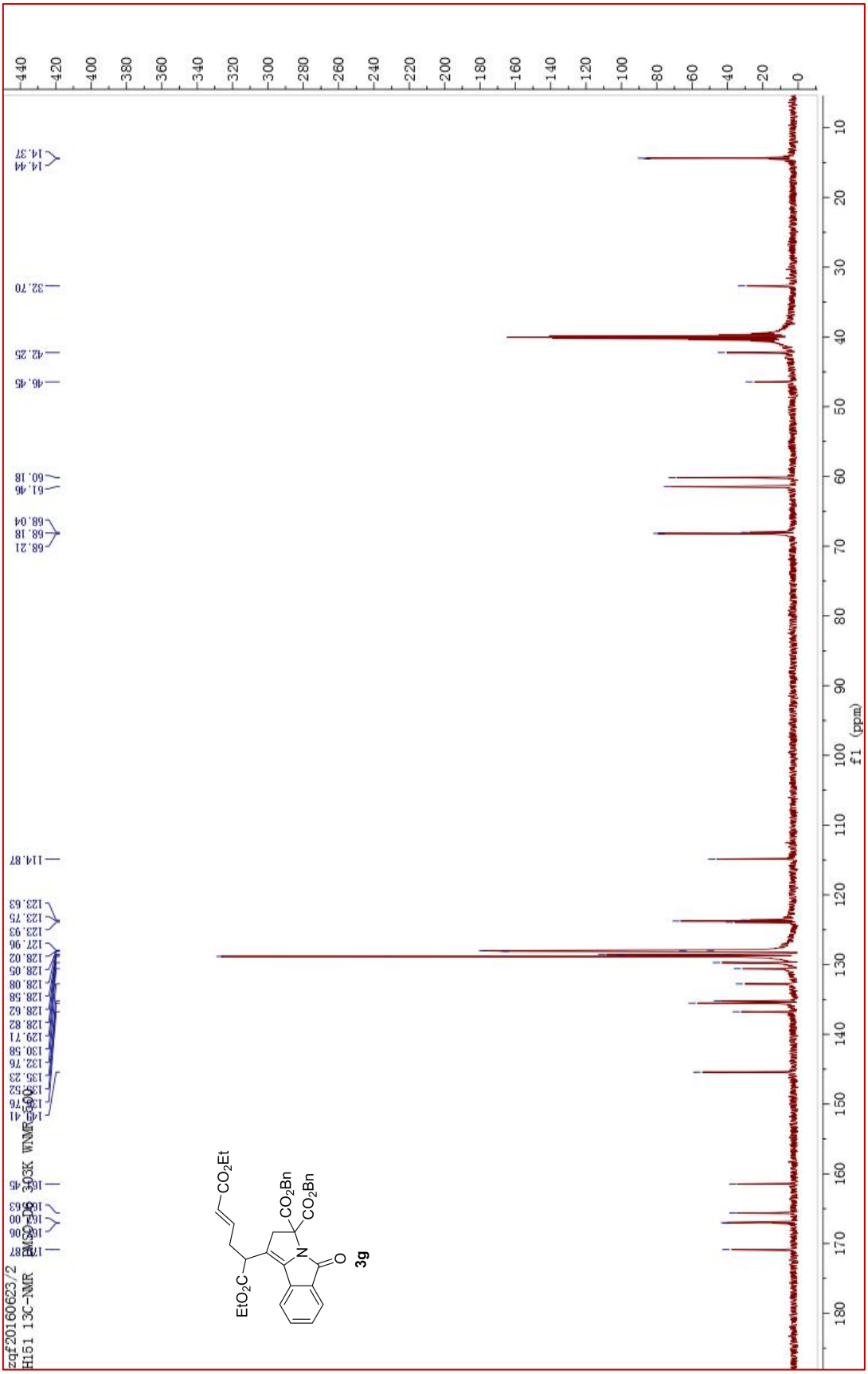

CO2Et
CO2nBu
CO2nBu
EtO2C
O
N
3e
f1 (ppm)

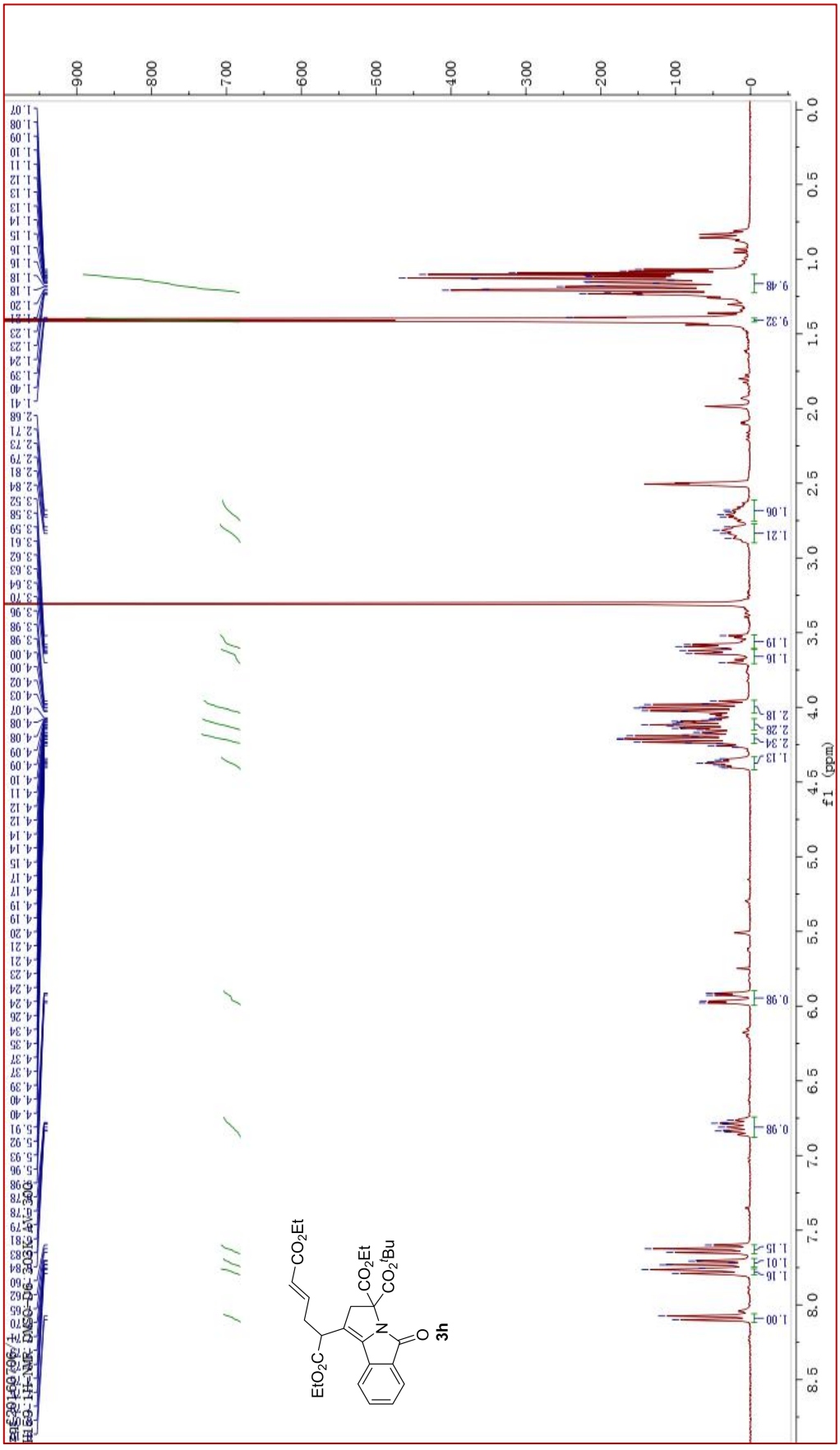

3e
f1 (ppm)

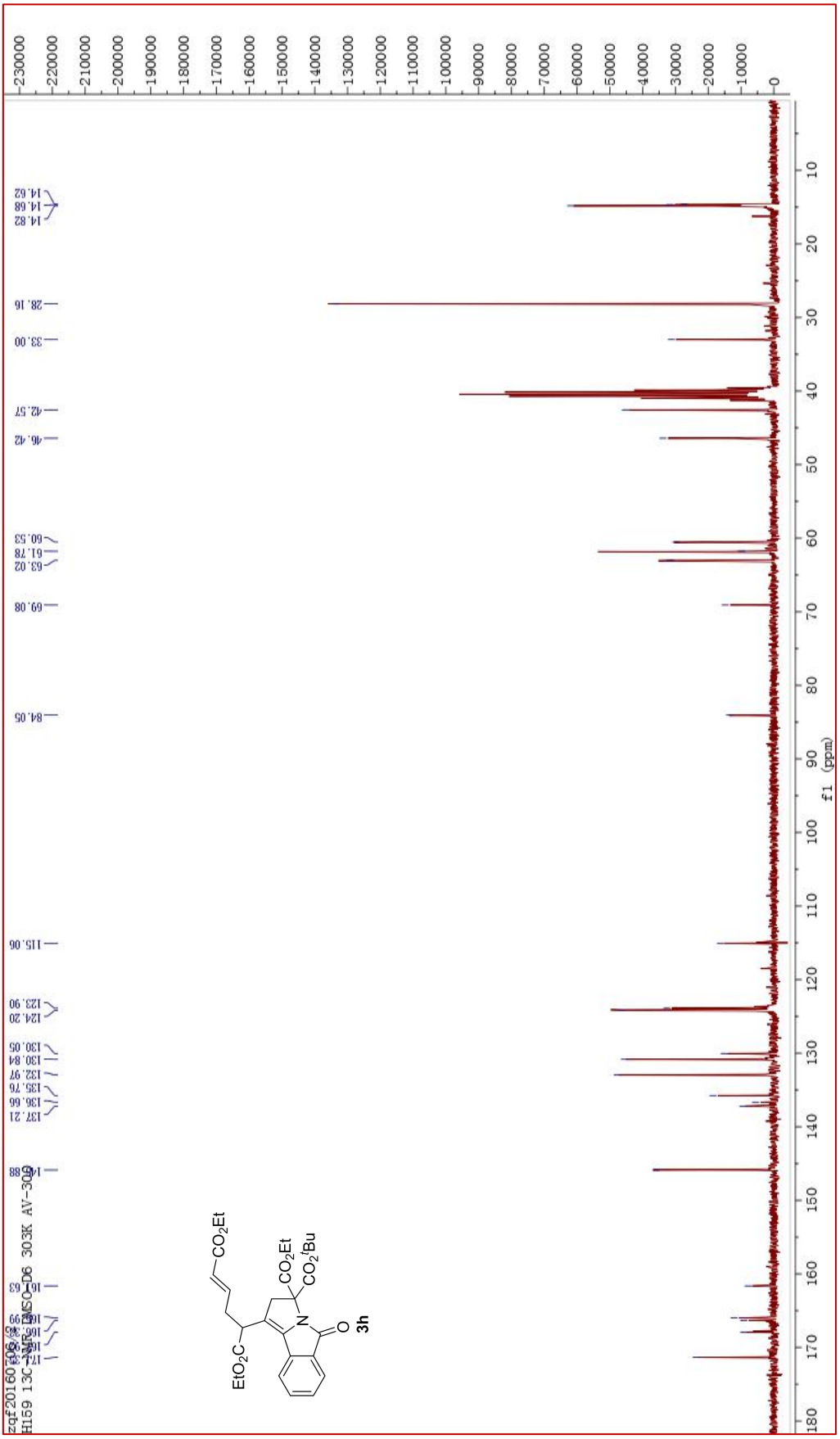

zqf20160720
H167 1H-NMR
DMSO-d6
AV-300
f1 (ppm)
CO2Et
CO2tBu
CO2tBu
EtO2C
N
O
3f

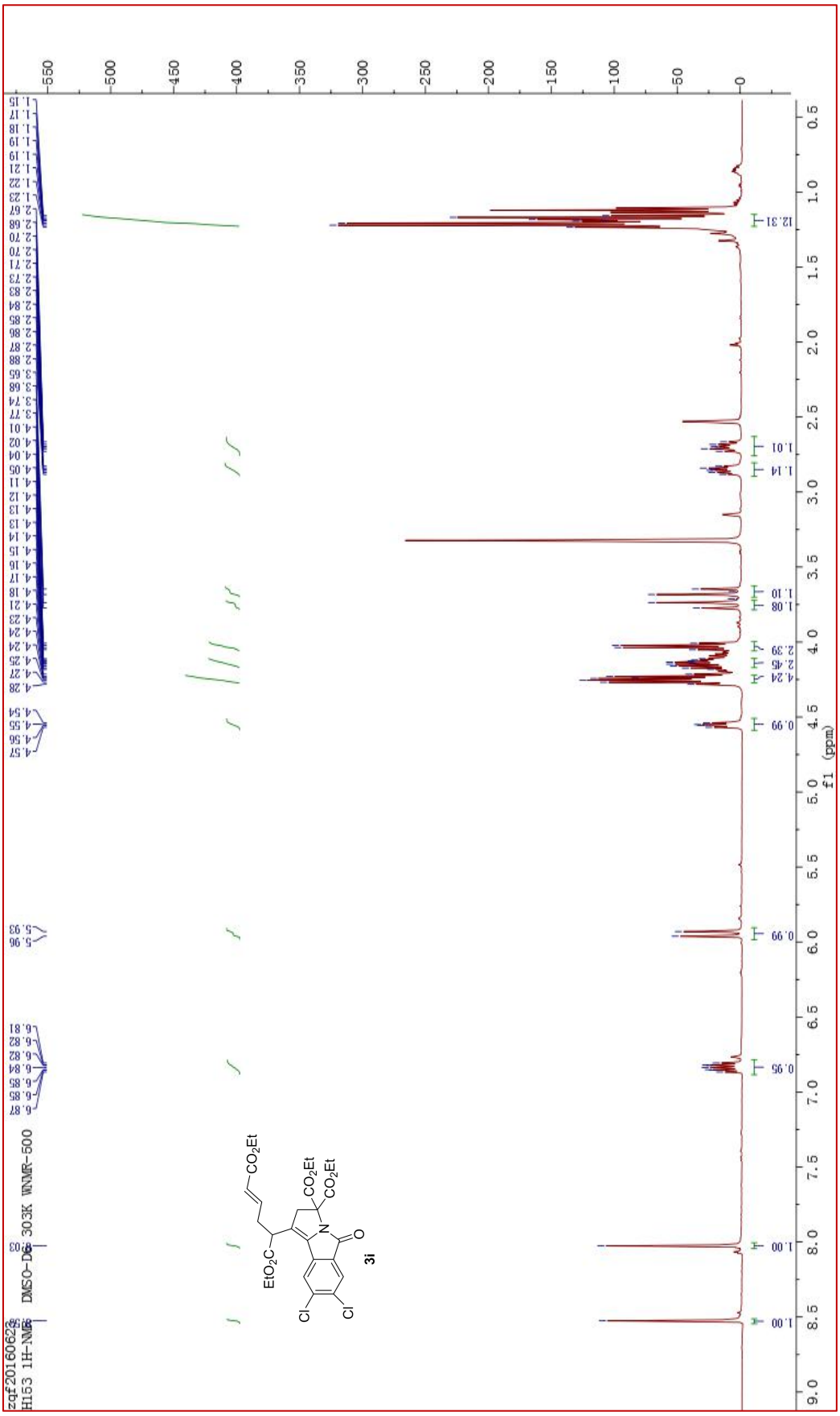

3f
f1 (ppm)

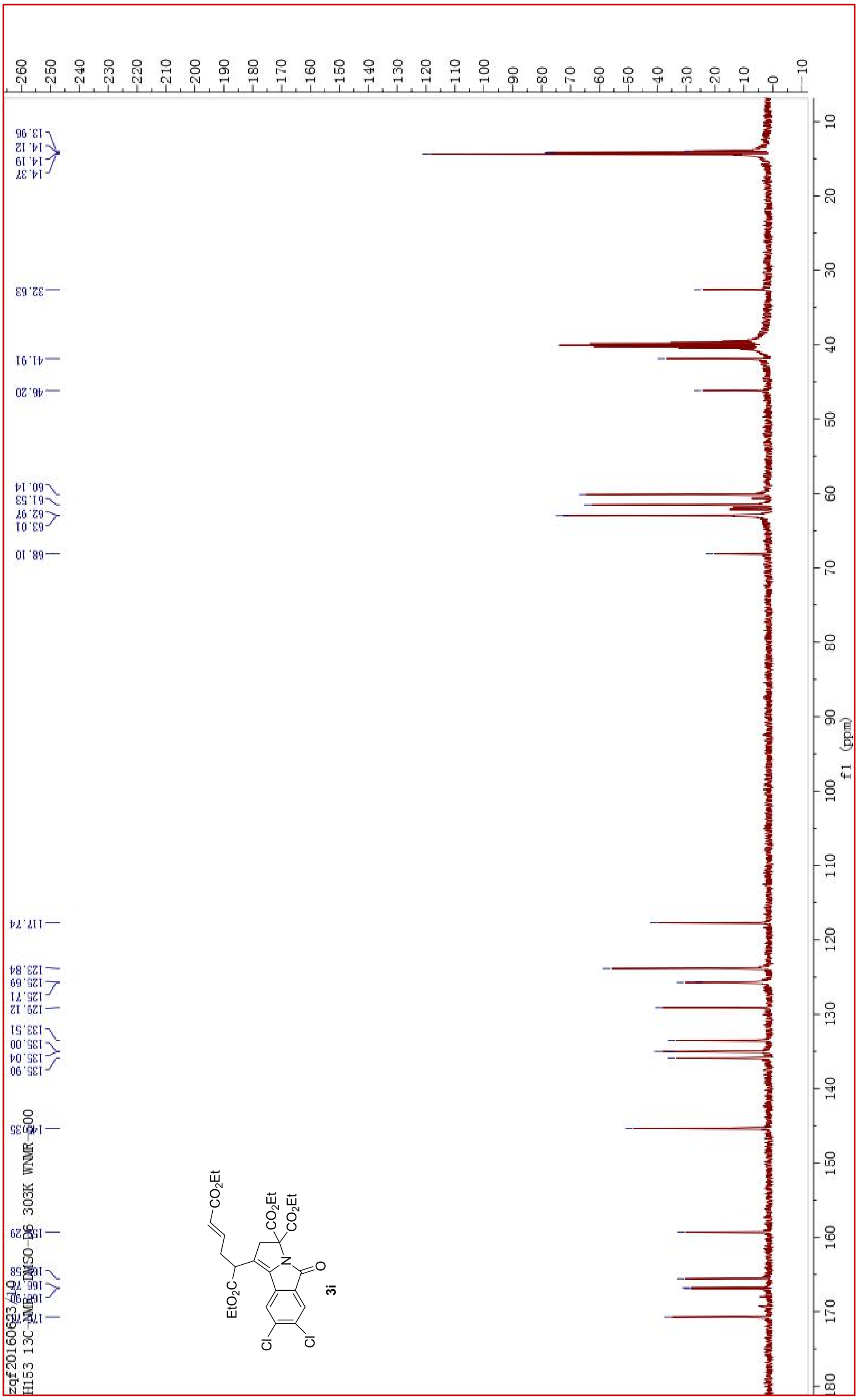

CO2Et
CO2Bn
CO2Bn
EtO2C
O
N
3g
f1 (ppm)

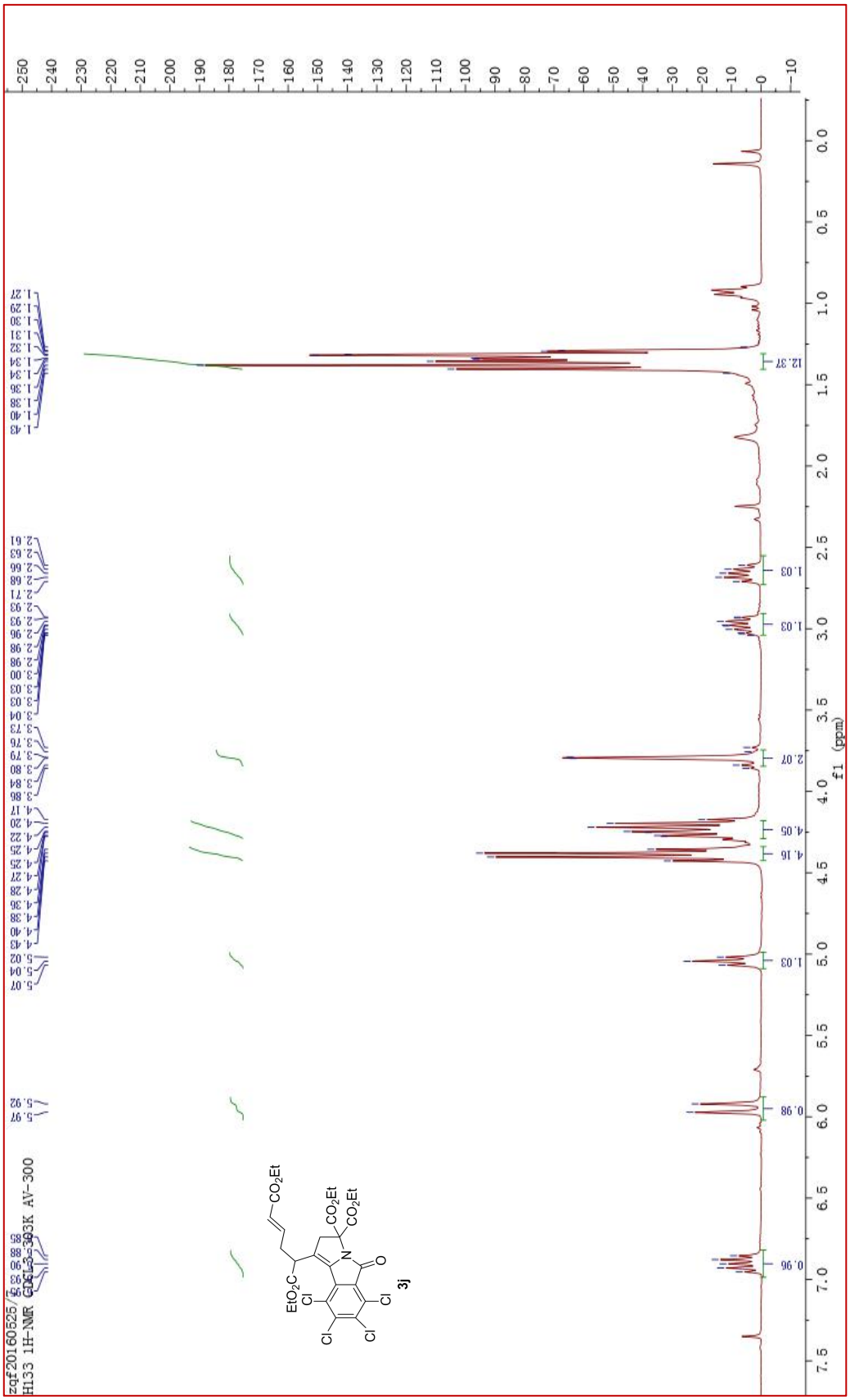

zqf20160623/2
H151 13C-NMR
CO2Et
CO2Bn
CO2Bn
EtO2C
O
N
3g
f1 (ppm)

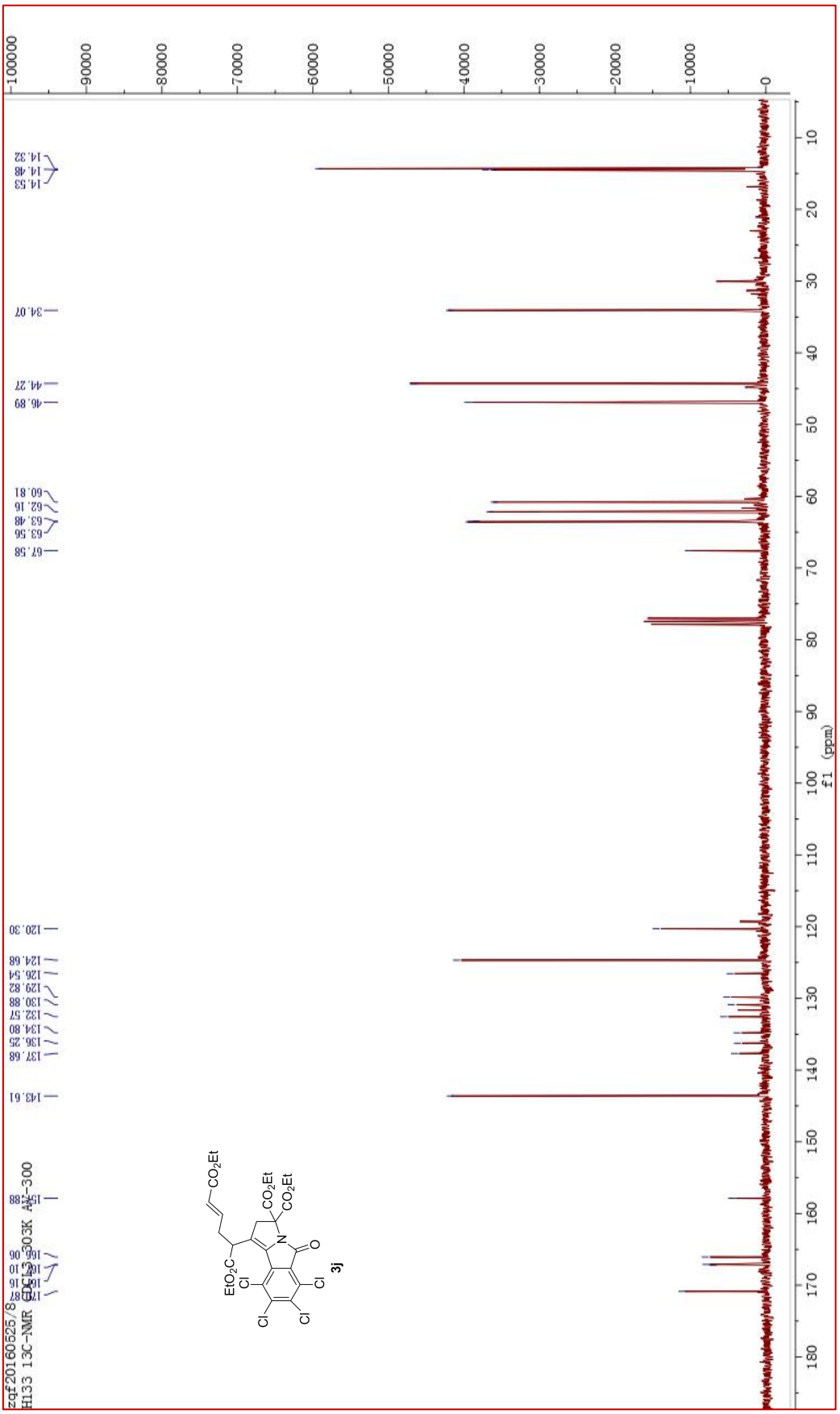

CO2Et
CO2Et
CO2tBu
EtO2C
O
N
3h
f1 (ppm)

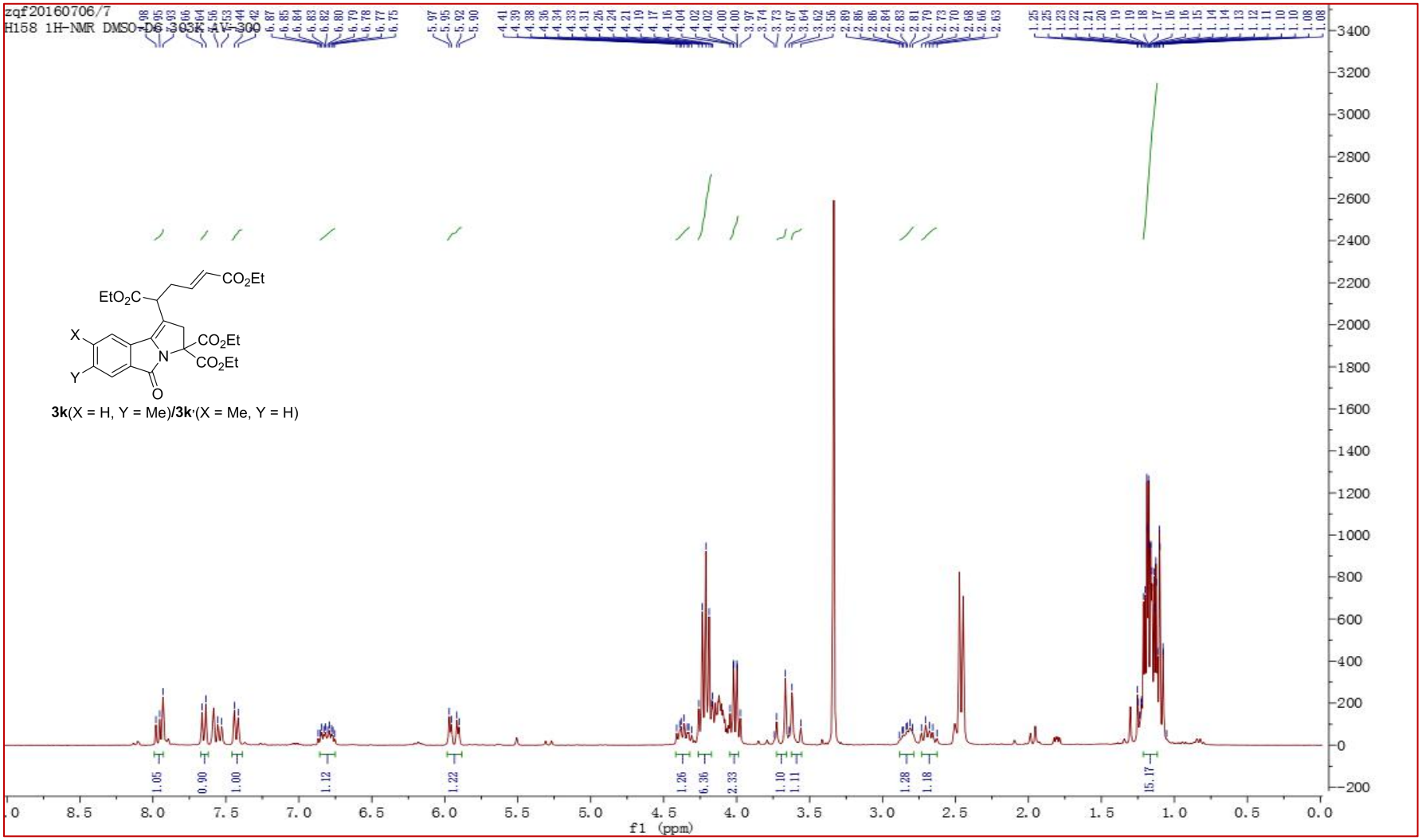

3h
f1 (ppm)

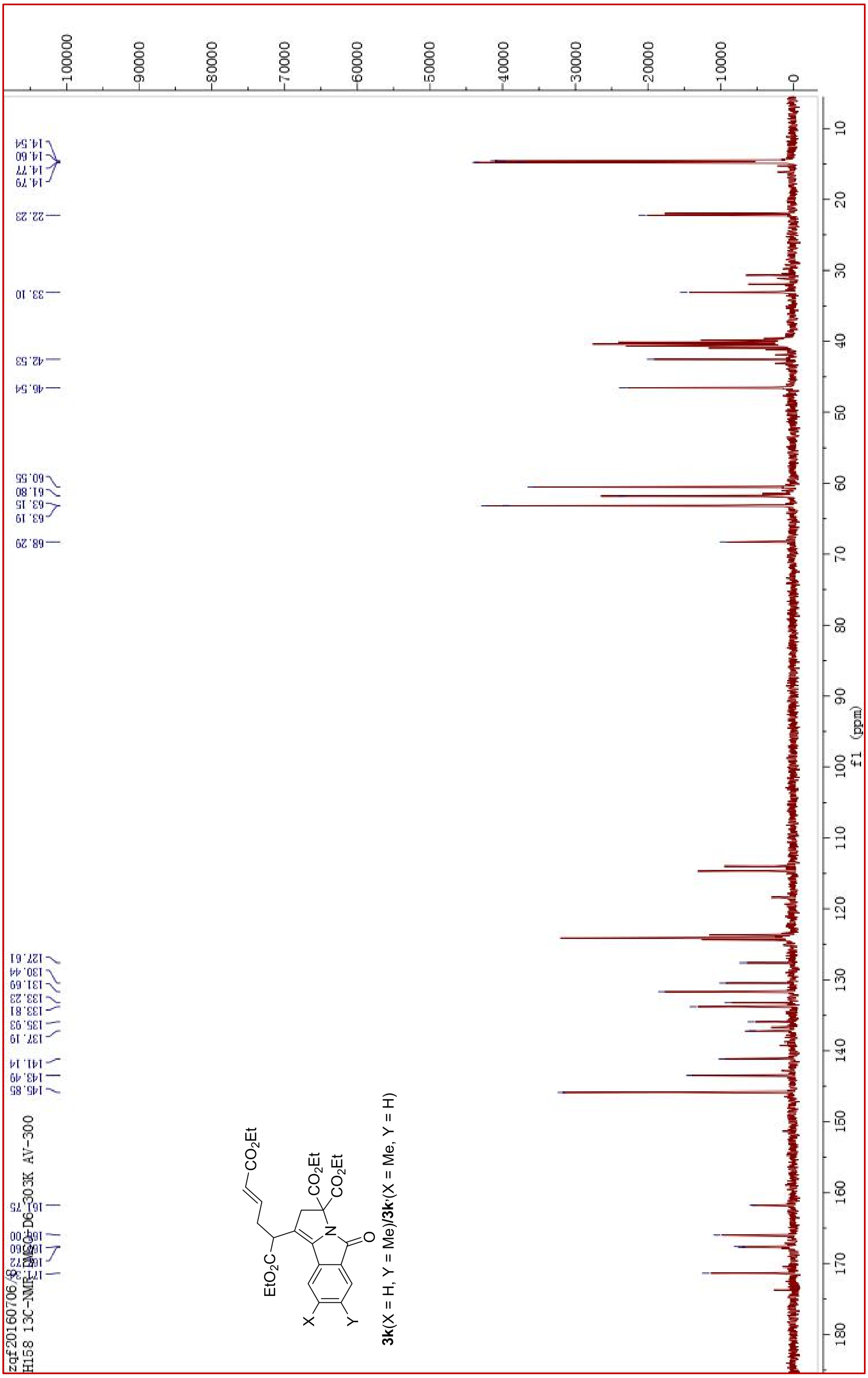

zqf20160623
H153 1H-NMR DMSO-D6 303K VNMR-500
3i
f1 (ppm)


zqf20160623/10
H153 13C-DMSO-D6 303K WNMR-400
3i
f1 (ppm)

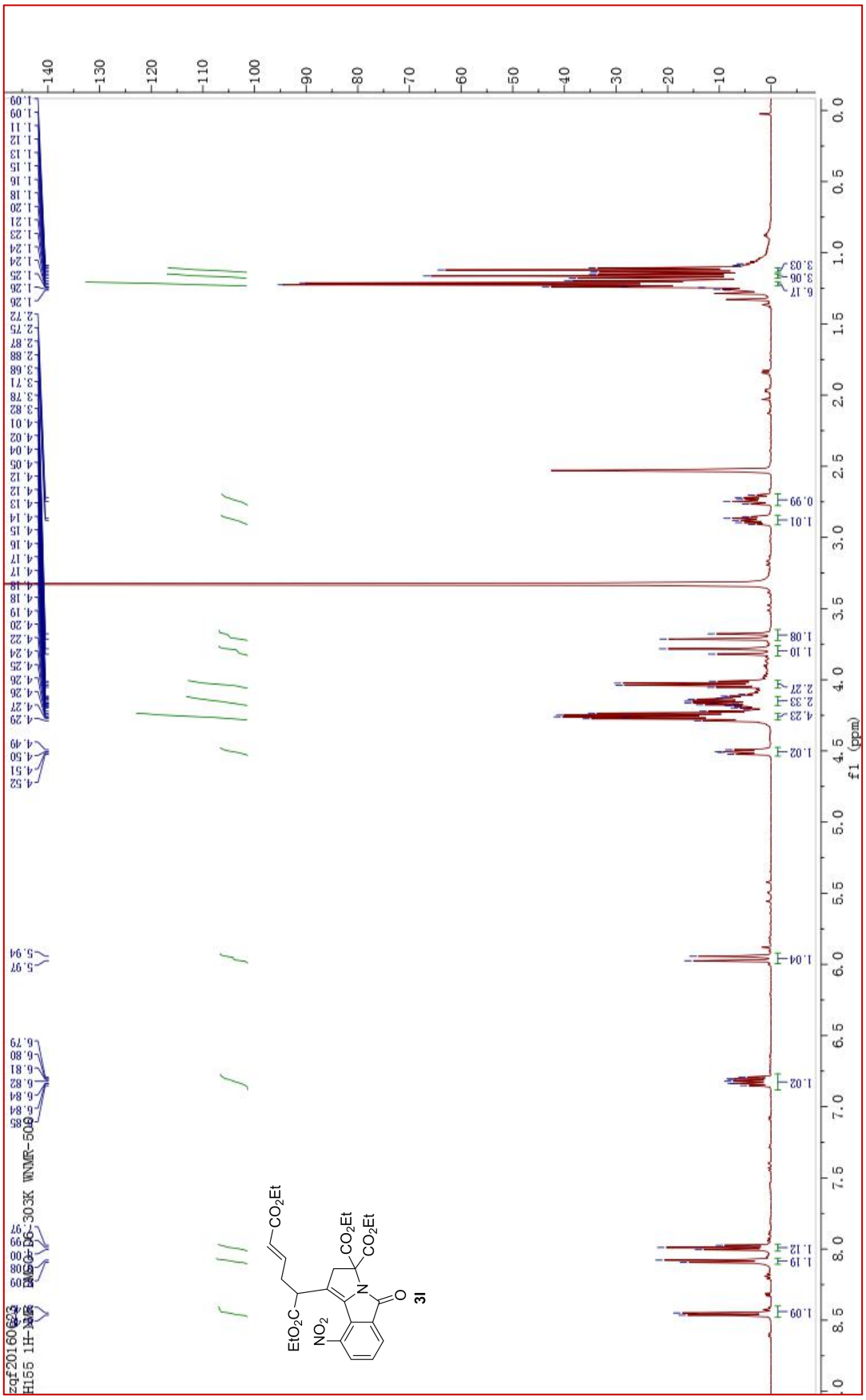

zqf20160525/6
H133 1H-NMR CDCl3 303K AV-300
f1 (ppm)
3j

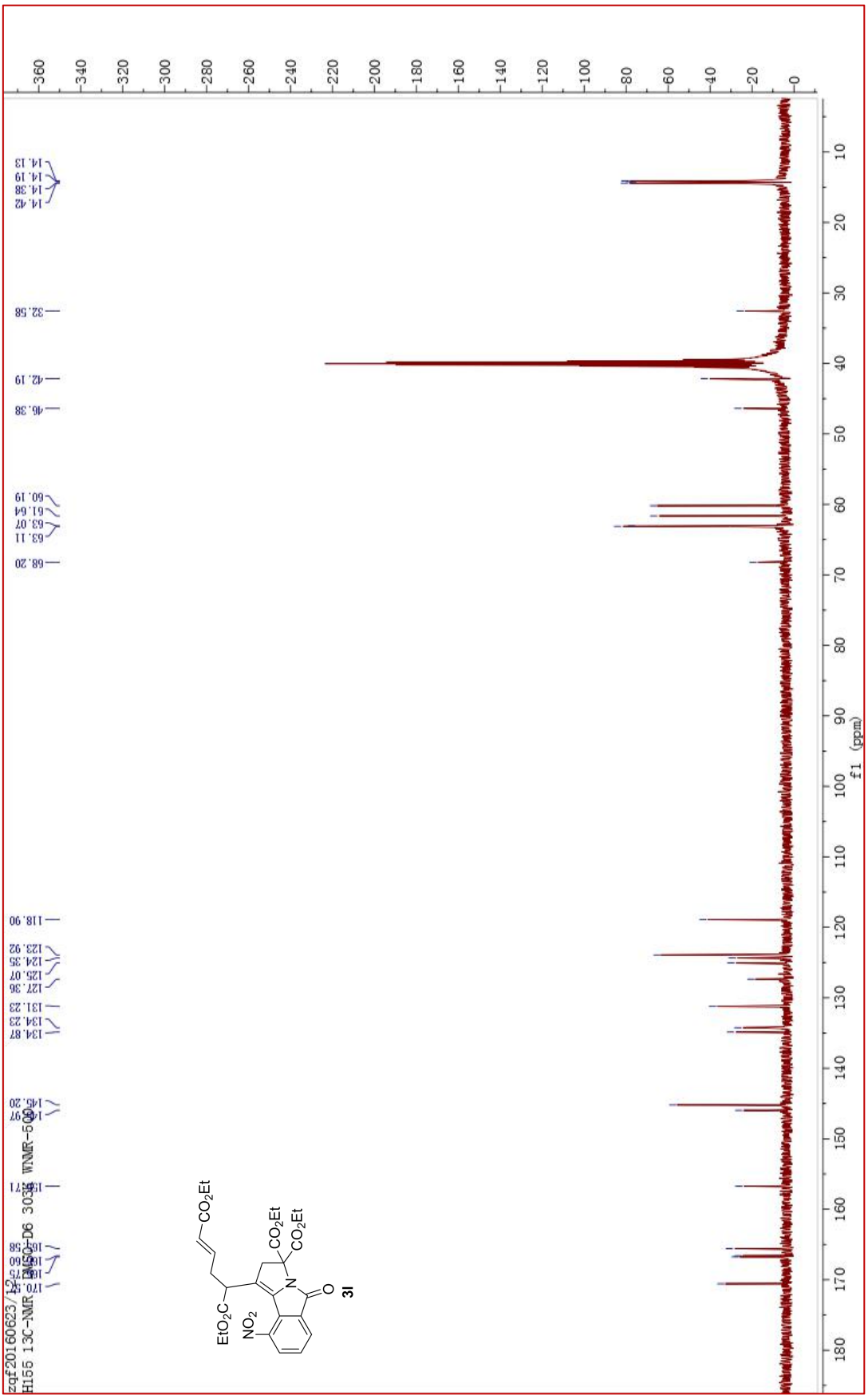

zqf20160625/8
H133 13C-NMR CDCl3 303K AV-300
3j

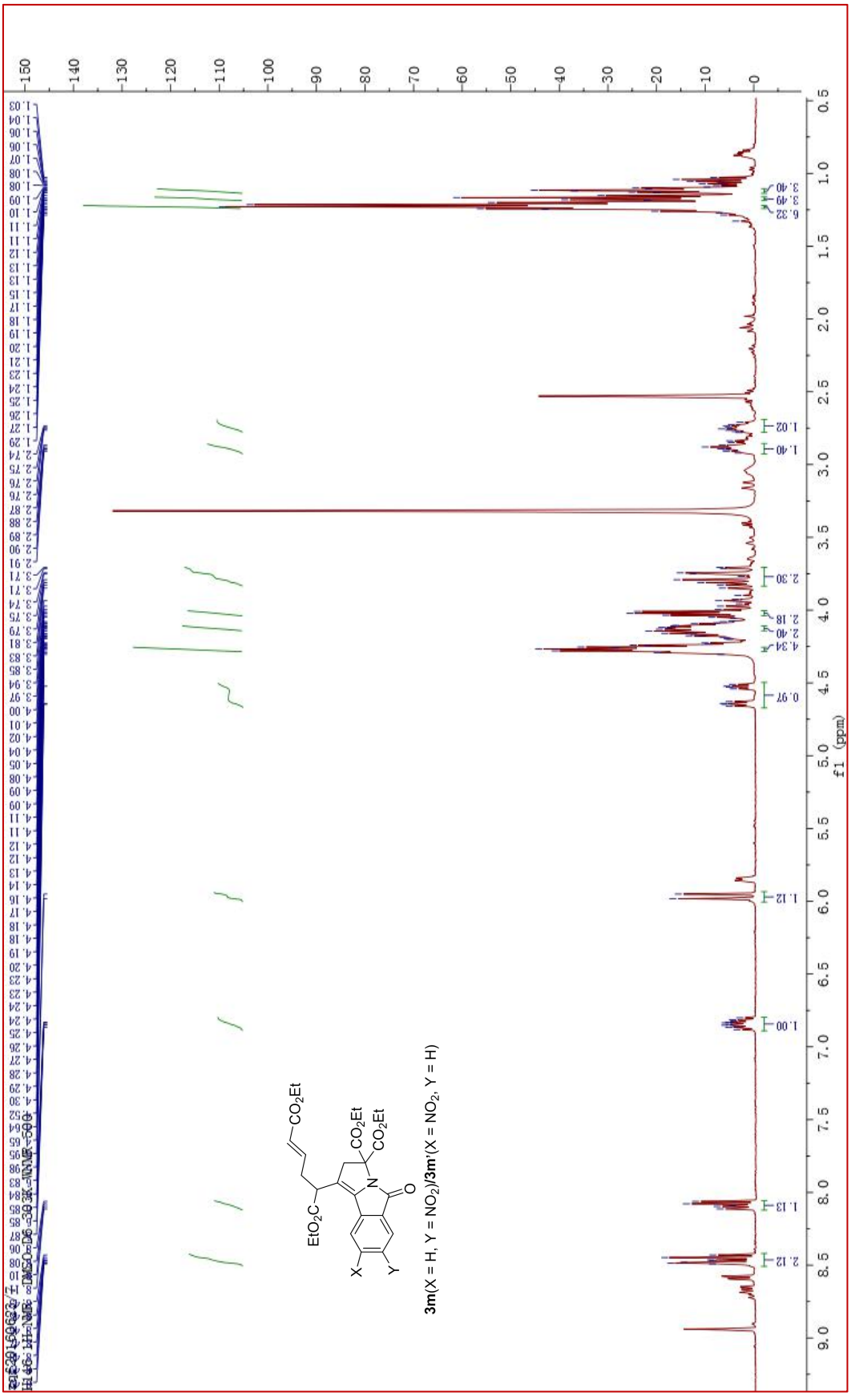

zqf20160706/7
H158 1H-NMR DMSO-D6 303K AV-300
EtO2C
CO2Et
X
Y
N
CO2Et
CO2Et
O
3k(X = H, Y = Me)/3k'(X = Me, Y = H)
f1 (ppm)

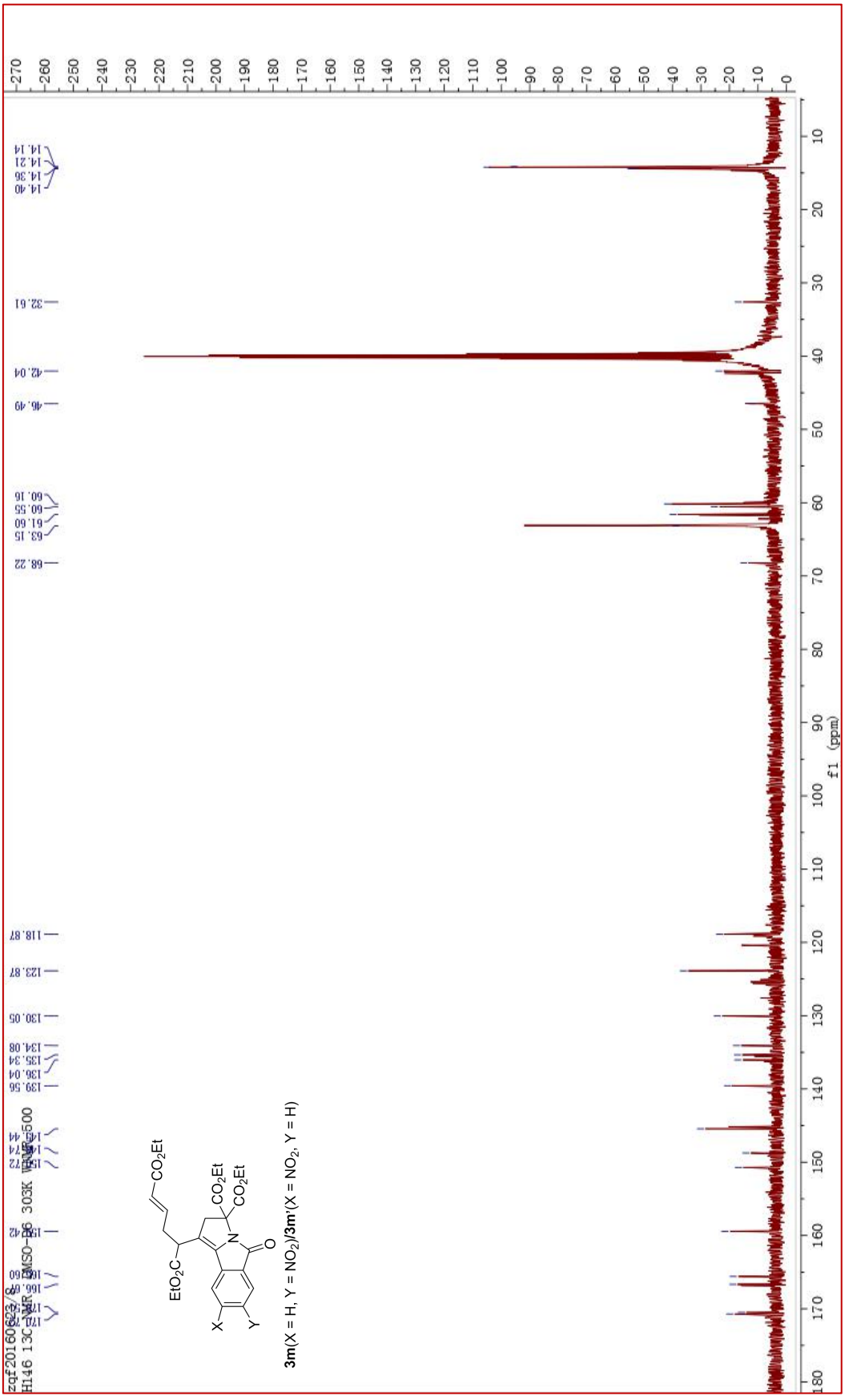


zqf20160706/8
H158 13C-NMR DMSO-D6 303K AV-300
14.54
14.60
14.77
14.79
22.23
33.10
42.53
46.54
60.55
61.80
63.15
63.19
68.29
127.61
130.44
131.69
133.23
133.81
135.93
137.19
141.14
143.49
145.85
161.75
f1 (ppm)
EtO2C
CO2Et
CO2Et
CO2Et
N
O
X
Y
3k(X = H, Y = Me)/3k'(X = Me, Y = H)

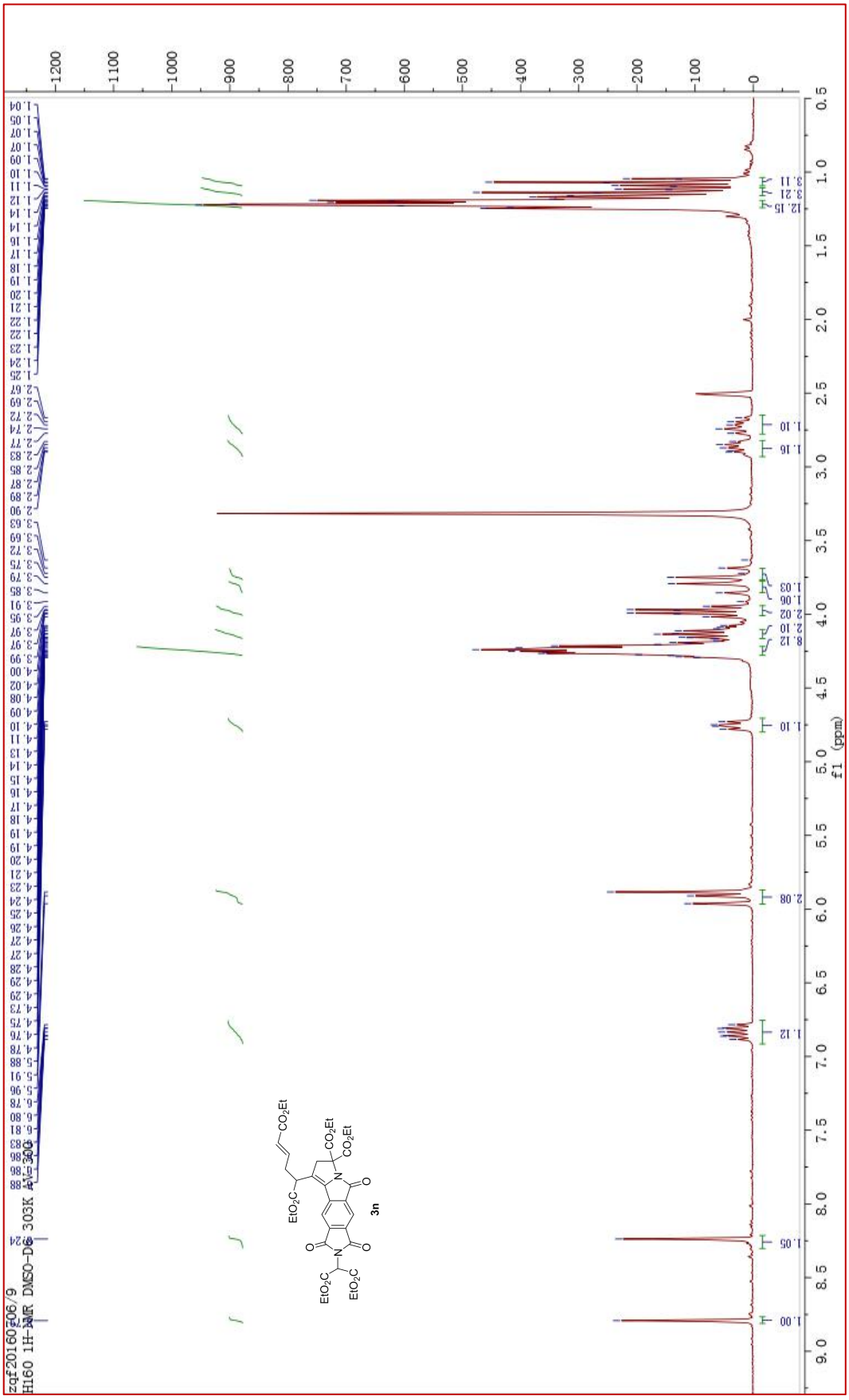

3l
f1 (ppm)

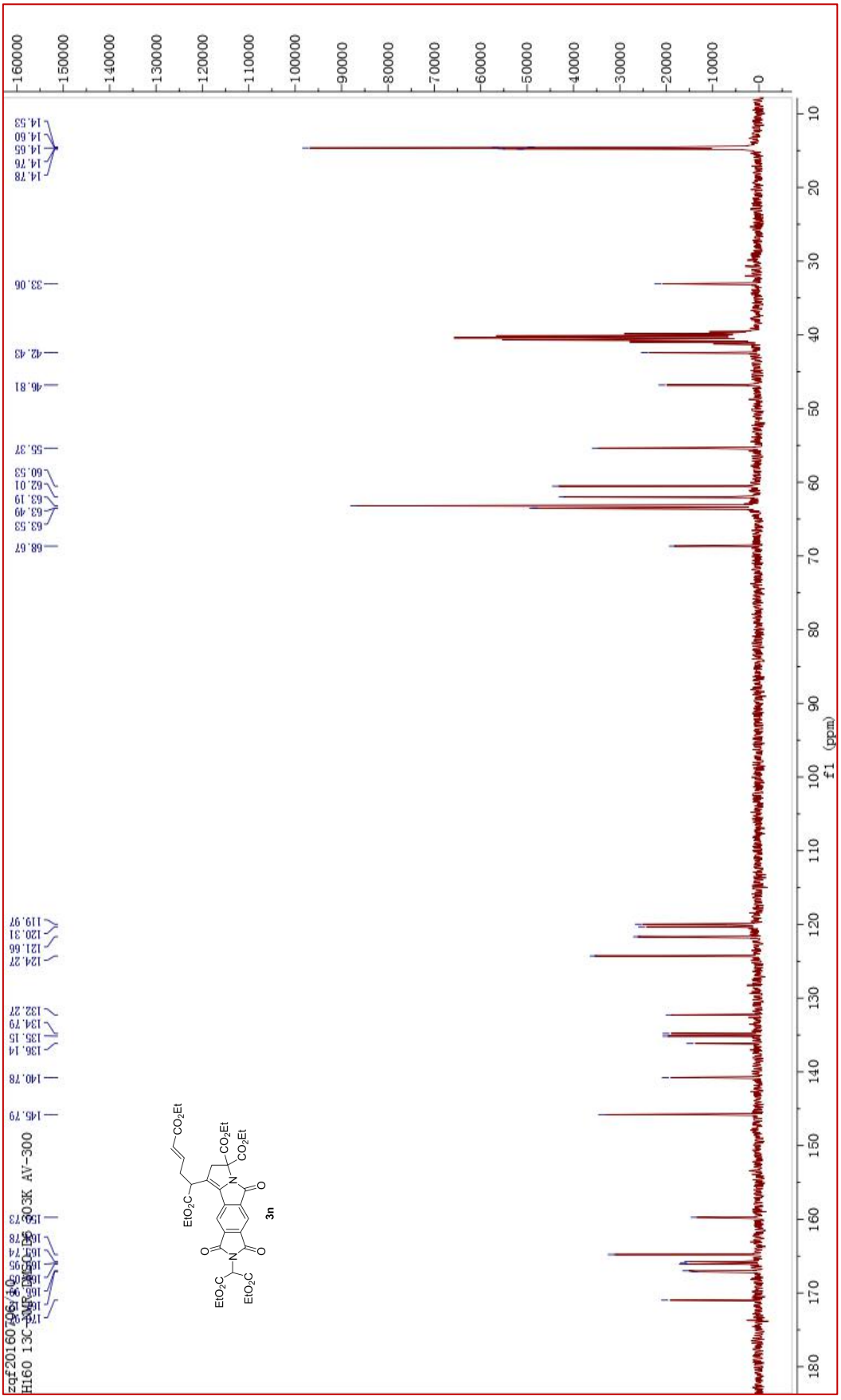

zqf20160623/1
H155 13C-NMR
CDCl3-D6
WNMR-600
f1 (ppm)
3l

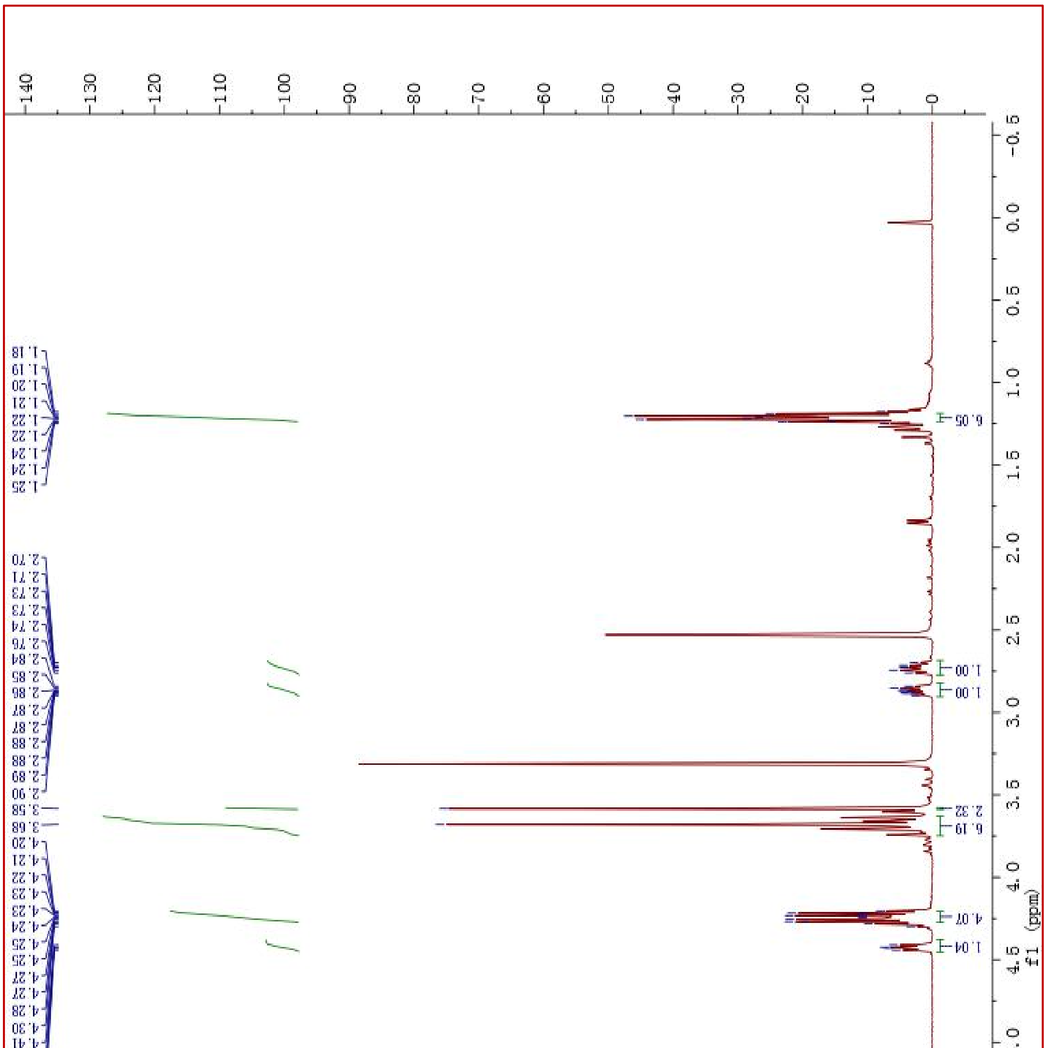

f1 (ppm)
3m(X = H, Y = NO2)/3m'(X = NO2, Y = H)

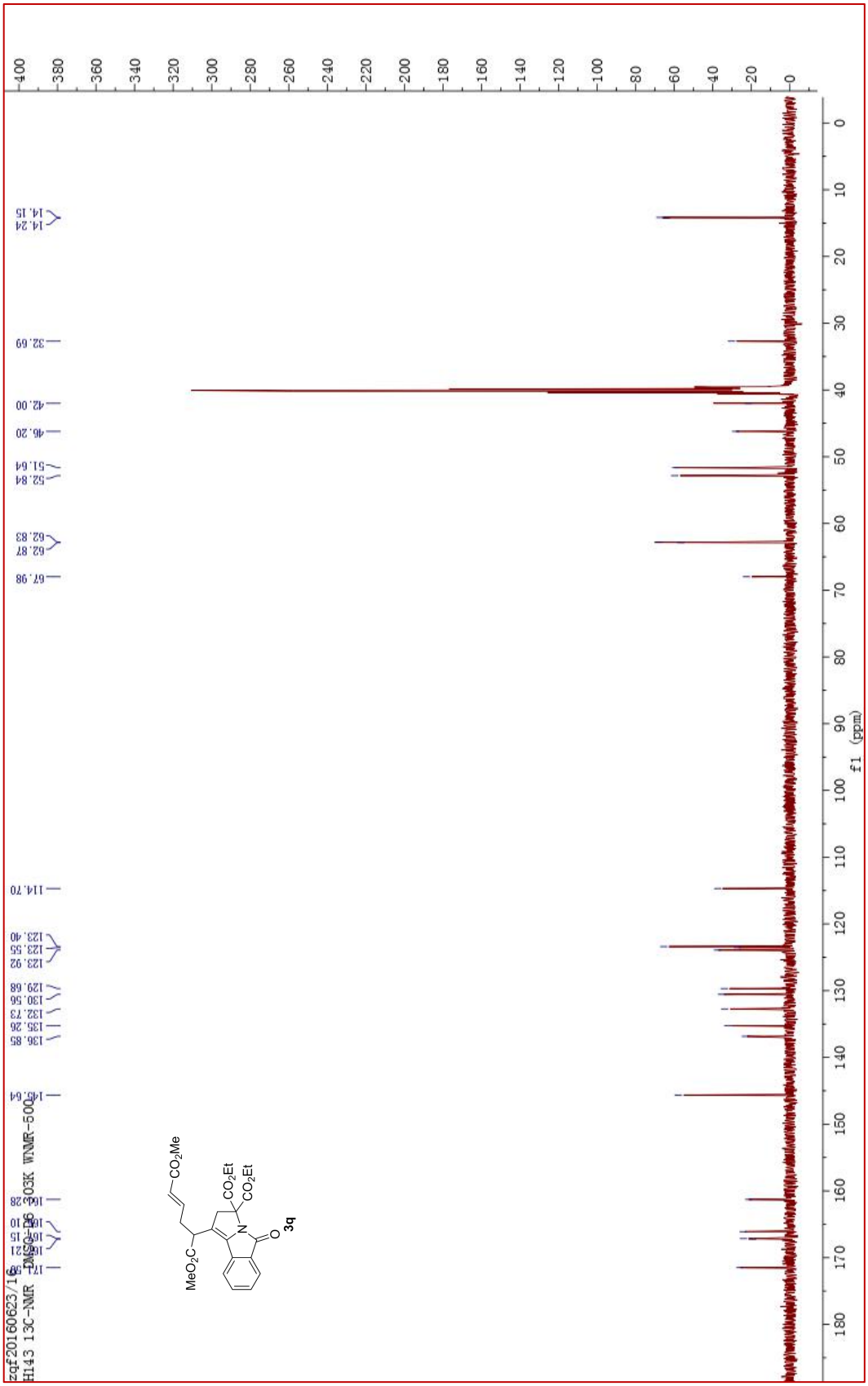


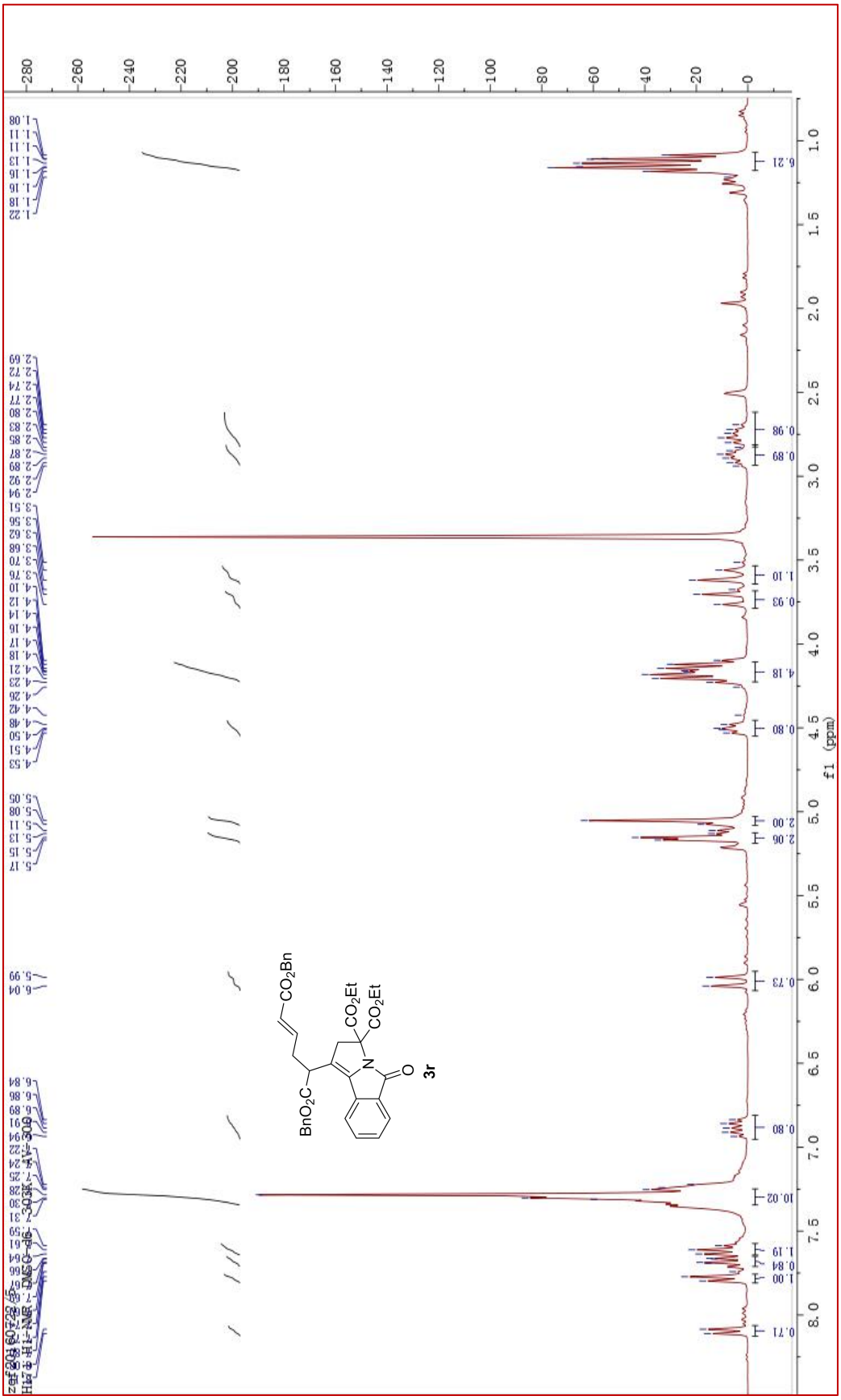
3m(X = H, Y = NO_2)/**3m'**(X = NO_2, Y = H)

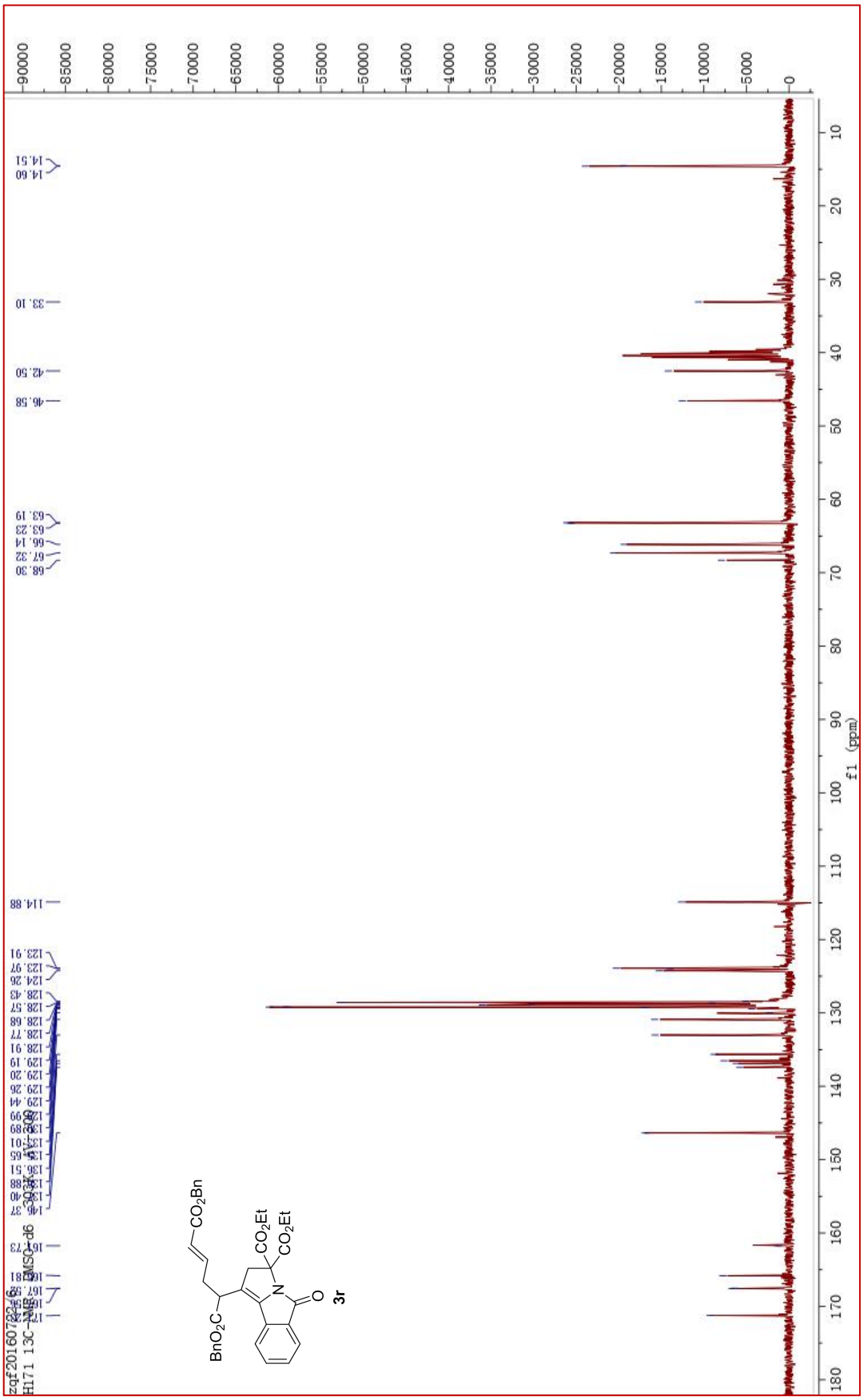

zqf20160706/9
H160 1H-NMR DMSO-D6 303K AV-300
3n
f1 (ppm)


zqf20160706/10
H160 13C-DMF-DMSO 303K AV-300
14.53
14.60
14.65
14.76
14.78
33.06
42.43
46.81
55.37
60.53
62.01
63.19
63.49
63.53
68.67
119.97
120.31
121.66
124.27
132.27
134.79
135.15
136.14
140.78
145.79
3n
f1 (ppm)

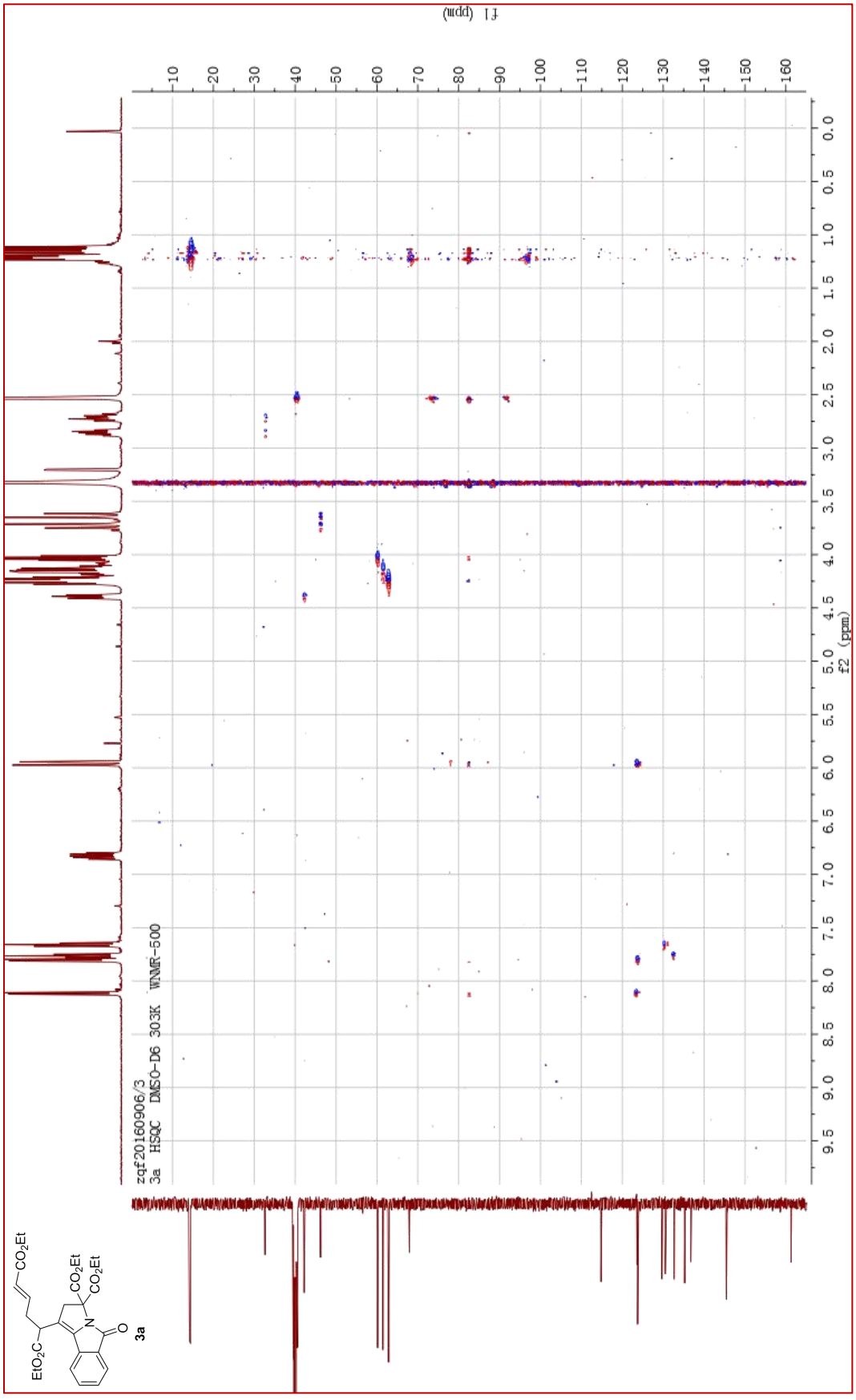


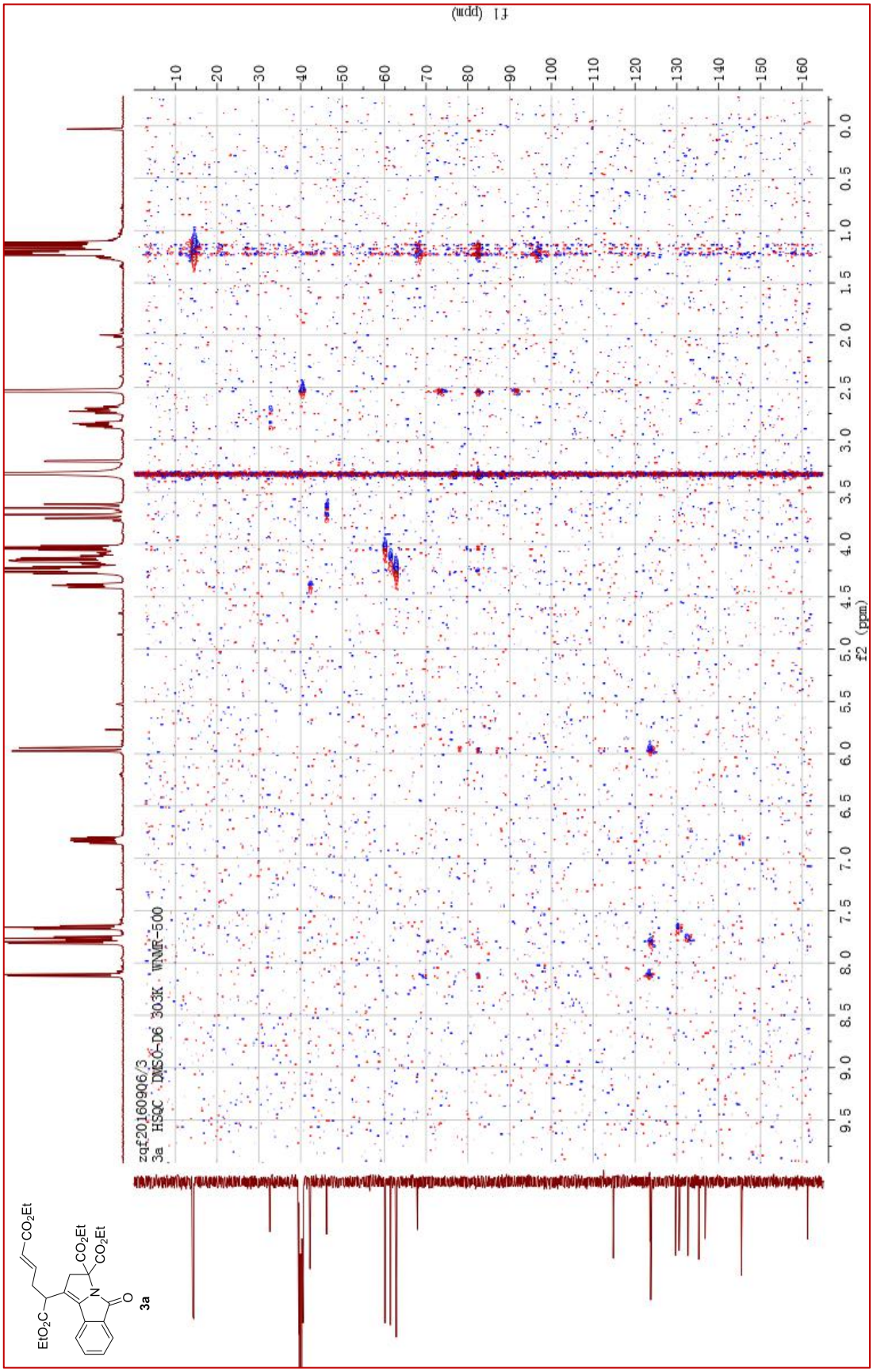

zgf201606231/1
H143 13C-NMR DMSO 303K WNMR-500
14.15
14.24
32.69
42.00
46.20
51.64
52.84
62.83
62.87
67.98
114.70
123.40
123.55
123.92
129.68
130.56
132.73
135.26
136.85
145.64
168.28
168.10
169.15
169.21
171.55
CO2Me
CO2Et
CO2Et
MeO2C
O
N
3q
f1 (ppm)


CO2Bn
CO2Et
CO2Et
BnO2C
O
N
3r
f1 (ppm)

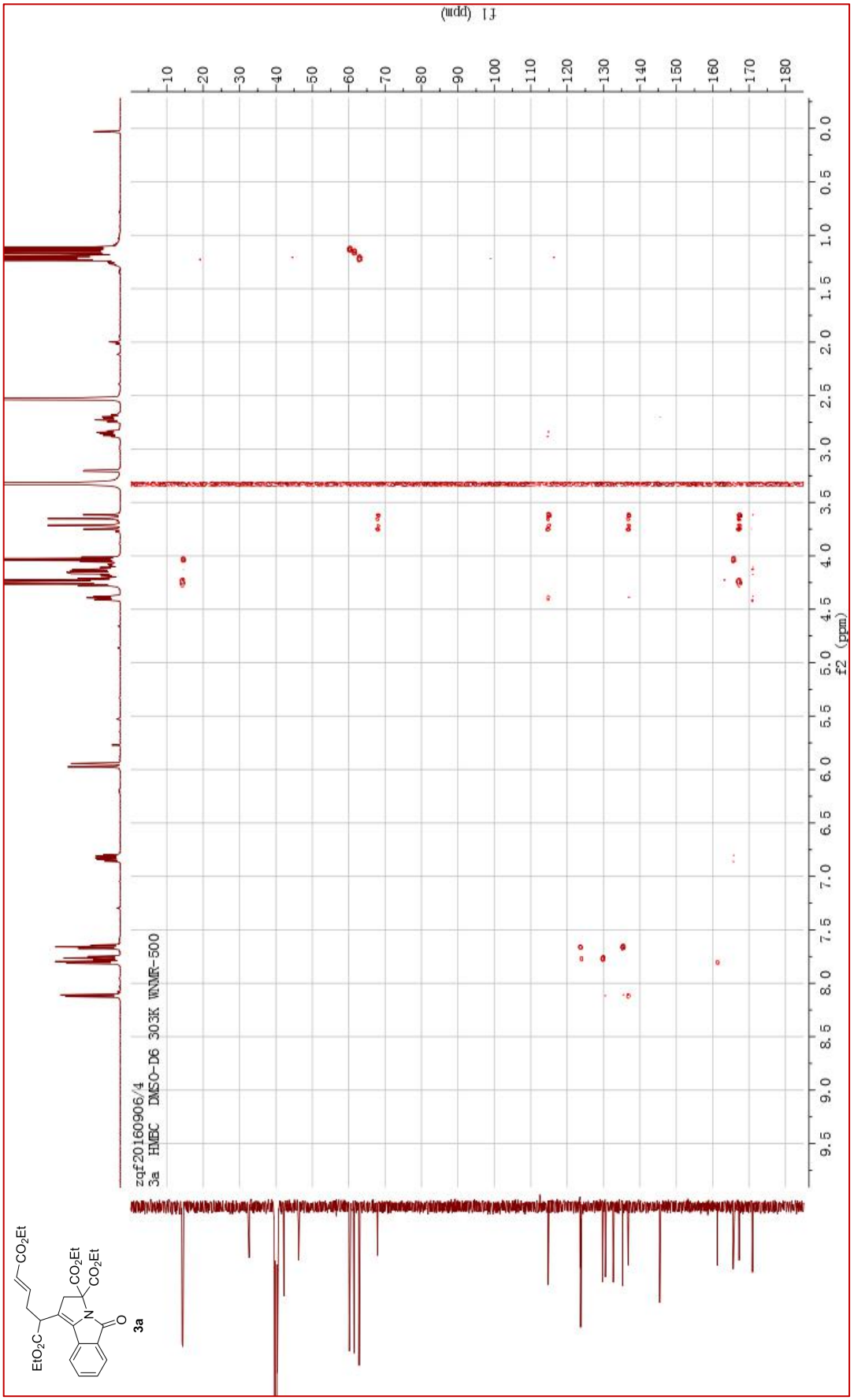

CO2Bn
CO2Et
CO2Et
BnO2C
O
N
3r
f1 (ppm)

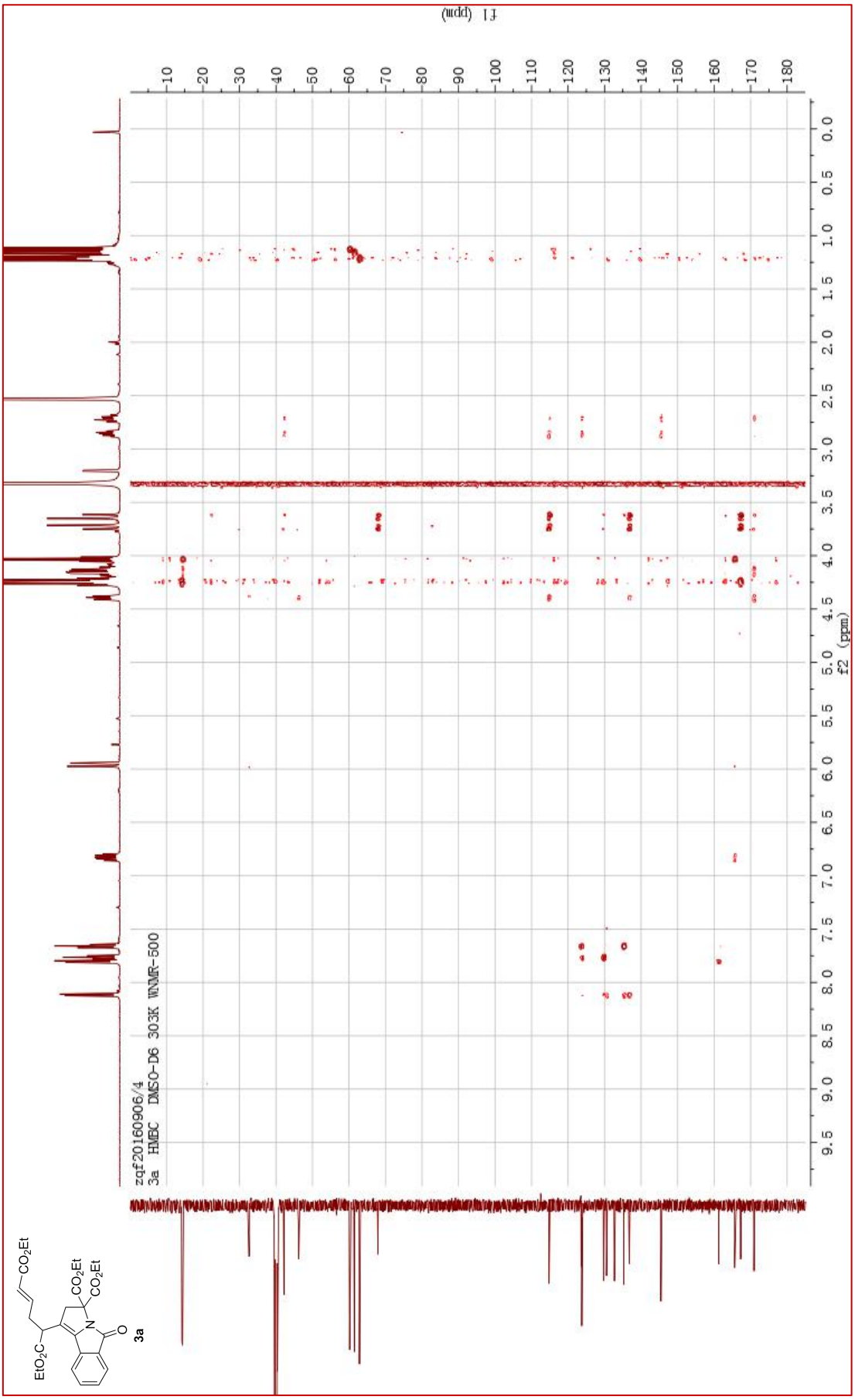
6. Copies of HSQC of Compound 3a




zqf20160906/3
3a HSQC DMSO-D6 303K WNMR-500
f1 (ppm)
f2 (ppm)
3a

7. Copies of HMBC of Compound 3a




zqf20160906/4
3a HMBC DMSO-D6 303K WNMR-500
f1 (ppm)
f2 (ppm)
3a