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Electronic Supplementary Information for

Phosphine-Catalyzed [4+2] Cycloaddition of Unsaturated Pyrazolones with Allenoates: A Concise Approach toward Spiropyrazolones

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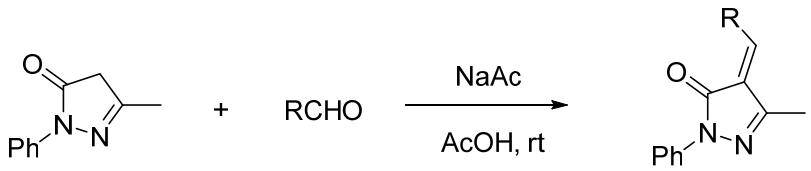
Contents

General Information

All reactions were performed under a Nitrogen atmosphere in oven-dried glassware with magnetic stirring. Unless otherwise stated, all reagents were purchased from commercial suppliers and used without further purification. Dichloromethane employed in the reactions was freshly distilled from CaH_2. Organic solutions were concentrated under reduced pressure using a rotary evaporator or oil pump. Reactions were monitored through thin-layer chromatography (TLC) on silica gel–precoated glass plates. Chromatograms were visualized by fluorescence quenching under UV light at 254 nm. Flash column chromatography was performed using Qingdao Haiyang flash silica gel (200–300 mesh). Infrared spectra were recorded using a Bruker Optics TENSOR 27 instrument. ^{1}H and ^{13}C NMR spectra were recorded in $CDCl_3$, $CDCl_2$ or DMSO-d_6 using a Bruker 300 M spectrometer, as indicated. Chemical shifts (δ, ppm) are relative to tetramethylsilane (TMS) with the resonance of the non-deuterated solvent or TMS as the internal standard. ^{1}H NMR data are reported as follows: chemical shift, multiplicity (s =singlet; d = doublet; t = triplet; q = quartet; p = pentet; m = multiplet; br = broad), coupling constant (Hz), and integral. Data for ^{13}C NMR spectra are reported in terms of chemical shift. HRMS analyses were carried out on a Shimadzu LCMS-IT-TOF apparatus. Data were analyzed using instrument-supplied software. X-ray crystallographic data were collected using a Bruker SMART CCD-based diffractometer equipped with a low-temperature apparatus operated at 100 K.

Preparation of Unsaturated Pyrazolones 1



1

Pyrazolone (5.5 mmol, 1.1 equiv) was slowly added to the mixture of the corresponding aldehyde (5 mmol, 1 equiv) and sodium acetate in glacial acetic acid. The mixture was stirred at room temperature for 15–30 min. After the reaction was completed, ethyl acetate (50 mL) was added. The precipitate was filtered and the filtrate was washed with water (three times). The combined organic layers were dried over Na_2SO_4 and then concentrated in vacuo. The crude product was obtained after quickly purified by flash column chromatography on silica gel (petroleum ether /ethyl acetate 5:1). The corresponding products were obtained as red or yellow solid by recrystallization from ethyl acetate.

General Procedure for the [4+2] Cycloaddition Reaction of Unsaturated Pyrazolones with Allenoates

Under a nitrogen atmosphere, to a stirred solution of unsaturated pyrazolone (0.15 mmol, 1.0 equiv) and catalyst $MePPh_2$ (0.03 mmol, 20 mol %) in toluene (4.5 mL) was added allenoate (0.3 mmol, 2.0 equiv) via a syringe in one portion. Then the reaction solution was vigorously stirred at room temperature and monitored by TLC. After the reaction was complete, the mixture was directly purified by column chromatography on silica gel to furnish the corresponding product (petroleum ether/EtOAc 15:1–7:1).

General Procedure for Asymmetric [4+2] Cycloaddition Reaction of Unsaturated Pyrazolones with Allenoate 1

Under a nitrogen atmosphere, unsaturated pyrazolones (0.15 mmol, 1 equiv) and catalyst **P3** (0.01 mmol, 10 mol%) were dissolved in 4.5 mL toluene, diethyl 2-vinylidenesuccinate **2a** (0.3 mmol, 2 equiv) was added to the mixture at -10 °C. The mixture was stirred at the same temperature until the reaction was completed (monitored by TLC analysis). The product was obtained after purified by flash chromatography on silica gel (petroleum ether/ ethyl acetate 10:1).

General Procedure for the Scale-up Reaction

Under an N_2 atmosphere, to a stirred solution of unsaturated pyrazolone **1a** (1 mmol, 1.0 equiv) and catalyst **P3** (0.2 mmol, 0.2 equiv) in toluene (30 mL) was added diethyl 2-vinylidenesuccinate **2a** (2 mmol, 2 equiv) via a syringe in one portion. Then the reaction solution was vigorously stirred at -10 ^{o}C and monitored by TLC. After the reaction was complete, the mixture was directly purified by column chromatography on silica gel (petroleum ether / ethyl acetate 10 : 1) to obtain the product **3aa** (100.8 mg, 21.9% yield) and **5aa** (232.8 mg, 50.5% yield, 99% ee).

Synthesis of compound 6

5aa (55.2 mg, 0.12 mmol) was dissolved in anhydrous MeOH (15 mL), and Pd/C (22.5 mg, 0.15 mmol) was added. The reaction tube flushed and evacuated with H_2 several times. Then the mixture was stirred at 30 °C for 10 h. The reaction mixture was filtered through Celite and concentrated to give a light yellow oil. Then the product **7a** (35.9 mg, 82% yield) was got by flash column chromatography on silica gel (petroleum ether / ethyl acetate 4:1) as a semisolid.

Characterization Data for all Products

(5R/S,6R/S,10S/R)-Diethyl 1-methyl-4-oxo-3,10-diphenyl-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**3aa**)

White solid (63.6 mg, 92% yield): mp 102 − 103 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.62 (m, 2H), 7.40 – 7.27 (m, 3H), 7.22 – 7.10 (m, 6H), 4.29 – 4.16 (m, 2H), 4.07 – 3.89 (m, 3H), 3.61 – 3.38 (m, 1H), 3.20 (m, 1H), 2.57 – 2.41 (m, 1H), 2.17 (s, 3H), 1.30 (t, *J* = 7.1 Hz, 3H), 1.05 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.0, 168.9, 165.9, 160.2, 141.0, 137.7, 137.5, 128.7, 128.6, 128.2, 127.4, 125.1, 125.1, 119.3, 61.5, 60.9, 58.0, 47.1, 44.9, 28.4, 14.1, 13.9, 13.8; IR(film) ν_{max} 2982, 1732, 1709, 1597, 1501, 1456, 1398, 1367, 1300, 1255, 1178, 1134, 1093, 1032, 757, 704 cm^{-1}; HRMS calcd for $C_{27}H_{28}N_2O_5$ $[M + Na]^+$ 483.1890, found 483.1894.

(5R/S,6R/S,10R/S)-Diethyl 10-(2-fluorophenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**3ba**)

Semisolid (68.0 mg, 95% yield): ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.64 – 7.61 (m, 2H), 7.37 – 7.27 (m, 3H), 7.24 – 7.09 (m, 3H), 7.07 – 6.95 (m, 1H), 6.90 – 6.85 (m, 1H), 4.34 – 4.13 (m, 2H), 4.11 – 3.92 (m, 3H), 3.78 (dd, *J* = 11.9, 4.8 Hz, 1H), 3.54 – 3.38 (m, 1H), 2.50 – 2.40 (m, 1H), 2.20 (s, 3H), 1.30 (t, *J* = 7.1 Hz, 3H), 1.04 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.0, 168.8, 165.8, 160.6, 140.6, 137.3, 129.5, 129.3, 128.6, 127.9, 127.8, 125.2, 125.1, 124.8, 124.6, 124.6, 124.5, 119.2, 115.5, 115.2, 61.4, 60.8, 57.6, 46.9, 27.7, 14.1, 13.7; IR (film) ν_{max} 2983, 1732, 1712, 1661, 1597, 1494, 1455, 1398, 1368, 1300, 1253, 1210, 1178, 1134, 1098, 1030, 954, 904, 853, 816, 760, 735, 715, 692, 653, 572, 509 cm^{-1}; HRMS calcd for $C_{27}H_{27}FN_2O_5$ $[M + Na]^+$ 501.1796, found 501.1797.

(5R/S,6R/S,10S/R)-Diethyl 10-(3-fluorophenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**3ca**)

White solid (45.9 mg, 64% yield): mp 115 – 116 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.66 – 7.57 (m, 2H), 7.37 – 7.27 (m, 3H), 7.21 – 7.07 (m, 2H), 6.97 – 6.81 (m, 3H), 4.29 – 4.15 (m, 2H), 4.07 – 3.90 (m, 3H), 3.53 – 3.41 (m, 1H), 3.21 – 3.15 (m, 1H), 2.57 – 2.42 (m, 1H), 2.17 (s, 3H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.04 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.8, 168.8, 165.8, 164.2, 161.0, 160.0, 140.5, 140.3, 140.2, 137.3, 130.3, 130.2, 128.6, 125.3, 125.1, 123.0, 122.9, 119.3, 115.2, 115.0, 114.8, 114.5, 61.5, 60.9, 57.8, 46.9, 44.4, 28.1, 14.1, 13.9, 13.8; IR (film) ν_{max} 2982, 1709, 1661, 1595, 1500, 1455, 1366, 1241, 1094, 1031, 800, 758, 704, 653 cm^{-1}; HRMS calcd for $C_{27}H_{27}FN_2O_5$ $[M + Na]^+$ 501.1796, found 501.1792.

(5R/S,6R/S,10S/R)-Diethyl 10-(4-fluorophenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**3da**)

White solid (35.0 mg, 49% yield): mp 152 – 153 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.66 – 7.57 (m, 2H), 7.39 – 7.28 (m, 3H), 7.20 – 7.08 (m, 3H), 6.92 – 6.81 (m, 2H), 4.34 – 4.19 (m, 2H), 4.09 – 3.92 (m, 3H), 3.53 – 3.41 (m, 1H), 3.22 – 3.16 (m, 1H), 2.55 – 2.41 (m, 1H), 2.17 (s, 3H), 1.30 (t, *J* = 7.1 Hz, 3H), 1.04 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.9, 168.8, 165.8, 160.1, 140.6, 137.3, 133.5, 133.4, 129.1, 129.0, 128.6, 125.2, 125.1, 119.2, 115.7, 115.5, 61.5, 60.9, 58.0, 58.0, 46.9, 44.0, 28.3, 14.1, 13.8, 13.8; IR (film) ν_{max} 2928, 1740, 1712, 1661, 1598, 1513, 1398, 1367, 1300, 1255, 1163, 1134, 1100, 1030, 840, 800, 760, 692, 654, 566, 536 cm^{-1}; HRMS calcd for $C_{27}H_{27}FN_2O_5$ $[M + Na]^+$ 501.1796, found 501.1791.

(5R/S,6R/S,10R/S)-Diethyl 10-(2-bromophenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**3ea**)

White solid (62.2 mg, 77% yield): mp 151 – 152 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.77 – 7.68 (m, 2H), 7.59 – 7.51 (m, 1H), 7.41 – 7.29 (m, 3H), 7.22 – 7.12 (m, 2H), 7.10 – 6.98 (m, 2H), 4.29 – 4.16 (m, 2H), 4.09 – 3.94 (m, 4H), 3.35 - 3.23 (m, 1H), 2.57 – 2.43 (m, 1H), 2.18 (s, 3H), 1.30 (t, *J* = 7.1 Hz, 3H), 1.05 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.2, 168.7, 165.8, 160.6, 140.9, 137.6, 137.5, 133.3, 129.4, 128.7, 128.3, 127.4, 125.3, 125.1, 124.1, 119.2, 61.5, 60.9, 57.2, 48.1, 42.8, 28.7, 14.1, 13.9, 13.8; IR (film) ν_{max} 2982, 1733, 1710, 1659, 1596, 1501, 1473, 1398, 1367, 1299, 1257, 1177, 1134, 1095, 1023, 801, 756, 692, 654 cm^{-1}; HRMS calcd for $C_{27}H_{27}BrN_2O_5$ $[M + Na]^+$ 561.0996, found 561.0992.

(5R/S,6R/S,10S/R)-Diethyl 10-(3-bromophenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**3fa**)

White solid (64.3 mg, 80% yield): mp 163 – 164 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.68 – 7.57 (m, 2H), 7.39 – 7.28 (m, 5H), 7.20 – 7.11 (m, 1H), 7.10 – 6.98 (m, 2H), 4.29 – 4.16 (m, 2H), 4.09 – 3.92 (m, 3H), 3.52 – 3.39 (m, 1H), 3.18 – 3.12 (m, 1H), 2.56 – 2.40 (m, 1H), 2.17 (s, 3H), 1.30 (t, *J* = 7.1 Hz, 3H), 1.05 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.7, 168.7, 165.8, 159.9, 140.4, 140.0, 137.2, 131.3, 130.7, 130.3, 128.6, 125.8, 125.3, 125.2, 122.6, 119.4, 61.5, 60.9, 57.8, 46.8, 44.5, 28.1, 14.1, 13.9, 13.8; IR (film) ν_{max} 2983, 1739, 1708, 1660, 1597, 1568, 1500, 1398, 1367, 1299, 1253, 1217, 1179, 1135, 1097, 1030, 758, 694, 653 cm^{-1}; HRMS calcd for $C_{27}H_{27}BrN_2O_5$ $[M + Na]^+$ 561.0996, found 561.0991.

(5R/S,6R/S,10S/R)-Diethyl 10-(4-bromophenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**3ga**)

White solid (68.9 mg, 85% yield): mp 169 – 170 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.64 - 7.61 (m, 2H), 7.40 – 7.28 (m, 5H), 7.16 (t, *J* = 7.4 Hz, 1H), 7.02 (d, *J* = 8.5 Hz, 2H), 4.34 – 4.16 (m, 2H), 4.08 – 3.90 (m, 3H), 3.54 – 3.36 (m, 1H), 3.19 – 3.14 (m, 1H), 2.52 – 2.43 (m, 1H), 2.16 (s, 3H), 1.30 (t, *J* = 7.1 Hz, 3H), 1.04 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.8, 168.7, 165.8, 160.0, 140.5, 137.2, 136.7, 131.8, 129.1, 128.7, 125.3, 125.1, 122.1, 119.2, 61.5, 60.9, 57.7, 46.9, 44.2, 28.2, 14.1, 13.8, 13.8. IR (film) ν_{max} 2982, 1739, 1709, 1660, 1596, 1492, 1398, 1367, 1299, 1253, 1180, 1134, 1078, 1029, 1011, 827, 759, 693, 653 cm^{-1}; HRMS calcd for $C_{27}H_{27}BrN_2O_5$ $[M + Na]^+$ 561.0996, found 561.0994.

(5R/S,6R/S,10S/R)-Diethyl 10-(4-chlorophenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**3ha**)

White solid (55.5 mg, 75% yield): mp 198 – 199 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.67 – 7.58 (m, 2H), 7.39 – 7.28 (m, 3H), 7.20 – 7.12 (m, 3H), 7.11 – 7.03 (m, 2H), 4.29 – 4.16 (m, 2H), 4.07 – 3.94 (m, 3H), 3.52 – 3.40 (m, 1H), 3.21 – 3.15 (m, 1H), 2.55 – 2.40 (m, 1H), 2.16 (s, 3H), 1.30 (t, *J* = 7.1 Hz, 3H), 1.04 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.8, 168.8, 165.8, 160.0, 140.5, 137.3, 136.3, 134.0, 128.9, 128.8, 128.7, 125.3, 125.2, 119.2, 61.5, 60.9, 57.9, 47.0, 44.2, 28.3, 14.1, 13.8, 13.8; IR (film) ν_{max} 2982, 1739, 1708, 1596, 1497, 1398, 1367, 1299, 1252, 1179, 1134, 1094, 1029, 831, 758, 692 cm^{-1}; HRMS calcd for $C_{27}H_{27}ClN_2O_5$ $[M + Na]^+$ 517.1501, found 517.1503.

(5R/S,6R/S,10S/R)-Diethyl 1-methyl-4-oxo-3-phenyl-10-(4-(trifluoromethyl)phenyl)-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**3ia**)

White solid (58.5 mg, 74% yield): mp 148 – 149 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.62 – 7.55 (m, 2H), 7.46 – 7.43 (m, 2H), 7.38 – 7.24 (m, 5H), 7.20 – 7.12 (m, 1H), 4.30 – 4.17 (m, 2H), 4.09 – 3.95 (m, 3H), 3.57 – 3.45 (m, 1H), 3.30 – 3.25 (m, 1H), 2.58 – 2.42 (m, 1H), 2.18 (s, 3H), 1.30 (t, *J* = 7.1 Hz, 3H), 1.05 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.7, 168.7, 165.8, 159.8, 141.8, 140.2, 137.2, 128.7, 127.9, 125.7, 125.7, 125.4, 125.2, 119.2, 61.6, 61.0, 57.7, 46.9, 44.6, 28.1, 26.9, 14.1, 13.9, 13.8; IR (film) ν_{max} 2986, 1738, 1709, 1659, 1618, 1596, 1493, 1427, 1400, 1367, 1325, 1251, 1165, 1124, 1071, 1017, 843, 767, 713, 694, 654, 602, 576 cm^{-1}; HRMS calcd for $C_{28}H_{27}F_3N_2O_5$ $[M + Na]^+$ 551.1764, found 551.1764.

(5R/S,6R/S,10S/R)-Diethyl 10-(3,4-dibromophenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**3ja**)

White solid (68.1 mg, 74% yield): mp 166 – 167 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.68 – 7.59 (m, 2H), 7.44 – 7.28 (m, 5H), 7.21 – 7.11 (m, 1H), 6.97 – 6.93 (m, 1H), 4.29 – 4.15 (m, 2H), 4.07 – 3.93 (m, 3H), 3.51 – 3.33 (m, 1H), 3.16 – 3.11 (m, 1H), 2.56 – 2.40 (m, 1H), 2.17 (s, 3H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.05 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.6, 168.6, 165.7, 159.8, 140.0, 138.8, 137.1, 133.9, 132.8, 128.7, 127.3, 125.4, 125.2, 125.1, 124.5, 119.3, 61.6, 60.9, 57.6, 46.8, 43.9, 28.0, 26.9, 14.1, 13.9, 13.8; IR (film) ν_{max} 2982, 1739, 1708, 1597, 1500, 1462, 1398, 1367, 1300, 1253, 1180, 1134, 1094, 1030, 758, 692, 653 cm^{-1}; HRMS calcd for $C_{27}H_{26}Br_2N_2O_5$ $[M + Na]^+$ 641.0082, found 641.0079.

(5R/S,6R/S,10S/R)-Diethyl 10-(2-methoxyphenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**3ka**)

White solid (73.1 mg, 99% yield): mp 151 – 152 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.70 – 7.59 (m, 2H), 7.40 – 7.27 (m, 3H), 7.19 – 7.05 (m, 3H), 6.82 (d, *J* = 7.8 Hz, 1H), 6.72 – 6.62 (m, 1H), 4.28 – 4.16 (m, 2H), 4.07 – 3.94 (m, 4H), 3.80 (s, 3H), 3.48 – 3.32 (m, 1H), 2.46 – 2.30 (m, 1H), 2.15 (s, 3H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.04 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.5, 169.0, 166.0, 161.1, 156.0, 141.6, 137.6, 128.7, 128.5, 127.3, 126.2, 125.0, 124.9, 120.9, 119.2, 110.4, 61.3, 60.7, 57.9, 55.2, 47.4, 28.2, 14.1, 13.8, 13.3; IR (film) ν_{max} 2982, 1732, 1710, 1660, 1598, 1495, 1464, 1398, 1366, 1299, 1250, 1211, 1175, 1133, 1100, 1029, 756, 692, 653 cm^{-1}; HRMS calcd for $C_{28}H_{32}N_2O_6$ $[M + Na]^+$ 513.1996, found 513.1993.

(5R/S,6R/S,10S/R)-Diethyl 10-(3-methoxyphenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**3la**)

White solid (63.4 mg, 86% yield): mp 146 – 147 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.71 – 7.61 (m, 2H), 7.39 – 7.24 (m, 3H), 7.17 – 7.03 (m, 2H), 6.77 – 6.68 (m, 2H), 6.68 – 6.62 (m, 1H), 4.29 – 4.15 (m, 2H), 4.07 – 3.92 (m, 3H), 3.56 – 3.40 (m, 4H), 3.19 – 3.14 (m, 1H), 2.56 – 2.41 (m, 1H), 2.17 (s, 3H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.04 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.0, 168.9, 165.9, 160.2, 159.7, 140.9, 139.2, 137.5, 129.6, 128.6, 125.0, 125.0, 119.8, 119.1, 114.1, 112.3, 61.4, 60.8, 57.9, 54.9, 47.1, 45,0, 28.4, 14.1, 13.9, 13.8; IR (film) ν_{max} 2982, 1739, 1707, 1660, 1598, 1500, 1464, 1398, 1367, 1300, 1254, 1208, 1176, 1134, 1095, 1032, 866, 760, 701, 654 cm^{-1}; HRMS calcd for $C_{28}H_{30}N_2O_6$ $[M + Na]^+$ 513.1996, found 513.1997.

(5R/S,6R/S,10S/R)-Diethyl 10-(4-methoxyphenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**3ma**)

White solid (61.7 mg, 84% yield): mp 114 – 115 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.66 - 7.61 (m, 2H), 7.38 – 7.27 (m, 3H), 7.18 – 7.09 (m, 1H), 7.09 – 7.01 (m, 2H), 6.73 – 6.64 (m, 2H), 4.33 – 4.12 (m, 2H), 4.10 – 3.85 (m, 3H), 3.70 (s, 3H), 3.53 – 3.40(m, 1H), 3.18 – 3.13 (m, 1H), 2.61 – 2.36 (m, 1H), 2.17 (s, 3H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.04 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.1, 168.9, 165.9, 160.3, 159.2, 141.1, 137.5, 129.6, 128.6, 128.4, 125.1, 125.0, 119.2, 114.0, 61.4, 60.8, 58.1, 55.1, 47.1, 44.1, 28.6, 14.1, 13.8, 13.8; IR (film) ν_{max} 2982, 1740, 1709, 1661, 1613, 1597, 1515, 1501, 1398, 1367, 1300, 1253, 1180, 1134, 1095, 1032, 834, 761, 692 cm^{-1}; HRMS calcd for $C_{28}H_{30}N_2O_6$ $[M + Na]^+$ 513.1996, found 513.1992.

(5R/S,6R/S,10S/R)-Diethyl 1-methyl-4-oxo-3-phenyl-10-(m-tolyl)-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**3na**)

White solid (71.3 mg, >99% yield): mp 105 – 106 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.64 – 7.60 (m, 2H), 7.38 – 7.27 (m, 3H), 7.18 – 6.96 (m, 3H), 6.93 – 6.91 (m, 2H), 4.29 – 4.15 (m, 2H), 4.09 – 3.93 (m, 3H), 3.56 – 3.39 (m, 1H), 3.17 – 3.12 (dd, *J* = 11.8, 4.7 Hz, 1H), 2.55 – 2.40 (m, 1H), 2.15 (s, 3H), 2.10 (s, 3H), 1.30 (t, *J* = 7.1 Hz, 3H), 1.05 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.0, 168.9, 165.9, 160.3, 141.1, 138.4, 137.5, 137.4, 128.8, 128.5, 128.4, 127.8, 125.0, 125.0, 124.6, 119.2, 61.4, 60.8, 57.9, 46.9, 44.9, 28.3, 21.1, 14.1, 13.9, 13.8; IR (film) ν_{max} 2982, 1740, 1708, 1597, 1500, 1398, 1367, 1300, 1251, 1177, 1134, 1097, 1030, 760, 692, 653 cm^{-1}; HRMS calcd for $C_{28}H_{30}N_2O_5$ $[M + Na]^+$ 497.2047, found 497.2042.

(5R/S,6R/S,10S/R)-Diethyl 1-methyl-4-oxo-3-phenyl-10-(p-tolyl)-2,3-diazaspiro[4.5] deca-1,7-diene-6,7-dicarboxylate (**3oa**)

White solid (57.9 mg, 81% yield): mp 140 – 141 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.68 – 7.61 (m, 2H), 7.39 – 7.27 (m, 3H), 7.16 – 7.11 (m, 1H), 7.04 – 6.96 (m, 4H), 4.29 – 4.16 (m, 2H), 4.07 – 3.91 (m, 3H), 3.55 – 3.42 (m, 1H), 3.19 – 3.13 (m, 1H), 2.54 – 2.39 (m, 1H), 2.24 (s, 3H), 2.16 (s, 3H), 1.29 (t, *J* = 7.1 Hz, 3H),, 1.04 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.0, 168.9, 165.9, 160.3, 141.1, 137.8, 137.5, 134.6, 129.3, 128.5, 127.2, 125.0, 125.0, 119.2, 61.4, 60.8, 58.0, 47.11, 44.5, 28.5, 20.9, 14.1, 13.8, 13.8; IR (film) ν_{max} 2982, 1740, 1711, 1661, 1597, 1516, 1501, 1398, 1367, 1300, 1253, 1177, 1134, 1096, 1030, 821, 760, 692, 654, 567 cm^{-1}; HRMS calcd for $C_{28}H_{30}N_2O_5$ $[M + Na]^+$ 497.2047, found 497.2049.

(5R/S,6R/S,10S/R)-Diethyl 10-(2,4-dimethylphenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**3pa**)

White solid (60.0 mg, 82% yield): mp 118 – 119 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.83 – 7.68 (m, 2H), 7.42 – 7.29 (m, 3H), 7.20 – 7.14 (ddd, *J* = 8.6, 2.3, 1.1 Hz, 1H), 6.95 – 6.93 (m, 2H), 6.74 (d, *J* = 8.2 Hz, 1H), 4.28 – 4.16 (m, 2H), 4.07 – 3.94 (m, 3H), 3.53 – 3.48 (m, 1H), 3.43 – 3.15 (m, 1H), 2.48 – 2.30 (m, 4H), 2.20 (s, 3H), 2.03 (s, 3H), 1.30 (t, *J*= 7.1 Hz, 3H), 1.05 (t, *J*= 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.6, 168.8, 165.9, 160.3, 141.8, 137.6, 137.1, 134.3, 133.8, 131.7, 128.7, 127.7, 125.3, 125.1, 125.0, 119.3, 61.4, 60.8, 57.2, 48.7, 39.5, 29.5, 20.8, 19.7, 14.1, 13.8, 13.5; IR (film) ν_{max} 2982, 1732, 1712, 1658, 1597, 1502, 1398, 1366, 1299, 1257, 1177, 1133, 1096, 1030, 802, 758, 692, 655 cm^{-1}; HRMS calcd for $C_{29}H_{32}N_2O_5$ $[M + Na]^+$ 511.2203, found 511.2206.

(5R/S,6R/S,10S/R)-Diethyl 10-(2,5-dimethoxyphenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**3qa**)

White solid (54.1 mg, 69% yield): mp 144 – 145 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.77 – 7.67 (m, 2H), 7.38 – 7.27 (m, 3H), 7.17 – 7.05 (m, 1H), 6.79 – 6.73 (m, 1H), 6.70 - 6.66 (m, 2H), 4.28 – 4.16 (m, 2H), 4.07 – 3.93 (m, 4H), 3.76 (s, 3H), 3.43 - 3.32 (m, 1H), 3.24 (s, 3H), 2.49 – 2.29 (m, 1H), 2.15 (s, 3H), 1.29 (t, *J*= 7.1 Hz, 3H), 1.04 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.5, 169.0, 166.0, 161.2, 153.8, 150.1, 141.4, 137.7, 128.5, 126.9, 125.1, 124.9, 118.9, 115.0, 111.8, 61.3, 60.8, 57.9, 55.8, 55.3, 47.4, 28.3, 14.1, 13.8, 13.3; IR (film) ν_{max} 2982, 2837, 1732, 1709, 1660, 1596, 1503, 1465, 1398, 1366, 1299, 1251, 1222, 1178, 1133, 1045, 804, 758, 693 cm^{-1}; HRMS calcd for $C_{29}H_{32}N_2O_7$ $[M + Na]^+$ 543.2102, found 543.2105.

(5R/S,6R/S,10S/R)-Diethyl 10-(3,4-dimethylphenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**3ra**)

White solid (61.5 mg, 84% yield): mp 94 – 95 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.66 – 7.62 (m, 2H), 7.39 – 7.27 (m, 3H), 7.18 – 7.08 (m, 1H), 6.94 – 6.83 (m, 3H), 4.29 – 4.16 (m, 2H), 4.10 – 3.90 (m, 3H), 3.52 – 3.40 (m, 1H), 3.14 – 3.09 (m, 1H), 2.52 – 2.39 (m, 1H), 2.15 – 2.14 (m, 6H), 2.02 (s, 3H), 1.30 (t, *J* = 7.1 Hz, 3H), 1.04 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.1, 169.0, 166.0, 160.4, 141.2, 137.5, 136.9, 136.4, 135.0, 129.8, 128.5, 128.4, 125.0, 125.0, 124.8, 119.2, 61.4, 60.8, 58.0, 47.0, 44.7, 28.6, 19.5, 19.3, 14.1, 13.9, 13.8; IR (film) ν_{max} 2981, 1740, 1709, 1658, 1597, 1501, 1366, 1300, 1251, 1177, 1133, 1095, 1030, 759, 692 cm^{-1}; HRMS calcd for $C_{29}H_{32}N_2O_5$ $[M + Na]^+$ 511.2203, found 511.2204.

(5R/S,6R/S,10S/R)-Diethyl 1-methyl-10-(naphthalen-2-yl)-4-oxo-3-phenyl-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**3sa**)

White solid (58.5 mg, 76% yield): mp 179 – 180 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.80 – 7.68 (m, 1H), 7.68 – 7.55 (m, 5H), 7.48 – 7.35 (m, 3H), 7.35 – 7.18 (m, 3H), 7.20 – 7.06 (m, 1H), 4.34 – 4.16 (m, 2H), 4.14 – 3.95 (m, 3H), 3.68 – 3.54 (m, 1H), 3.39 – 3.33 (m, 1H), 2.65 – 2.46 (m, 1H), 2.17 (s, 3H), 1.31 (t, *J* = 7.1 Hz, 3H), 1.05 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, CDCl3) δ 171.1, 168.9, 165.9, 160.2, 141.0, 137.4, 135.3, 133.2, 133.0, 128.6, 127.7, 127.5, 126.7, 126.3, 126.1, 125.1, 125.1, 124.8, 119.4, 61.5, 60.9, 57.9, 47.3, 45.2, 28.7, 14.1, 13.9, 13.8; IR (film) ν_{max} 2982, 2927, 1739, 1707, 1660, 1597, 1501, 1398, 1367, 1300, 1252, 1178, 1134, 1095, 1030, 860, 822, 758, 692, 651, 481 cm^{-1}; HRMS calcd for $C_{31}H_{30}N_2O_5$ $[M + Na]^+$ 533.2047, found 533.2049.

(5R/S,6R/S,10R/S)-Diethyl 1-methyl-4-oxo-3-phenyl-10-(thiophen-3-yl)-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**3ta**)

White solid (57.0 mg, 82% yield): mp 107 – 108 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.70 – 7.64 (m, 2H), 7.37 – 7.27 (m, 3H), 7.18 – 7.04 (m, 2H), 6.86 – 6.81 (m, 2H), 4.28 – 4.15 (m, 2H), 4.06 – 3.95 (m, 2H), 3.94 – 3.92 (m, 1H), 3.59 – 3.43 (m, 2H), 2.72 – 2.52 (m, 1H), 2.23 (s, 3H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.03 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.5, 168.8, 165.7, 159.9, 140.3, 139.8, 137.5, 128.6, 126.9, 125.2, 125.0, 124.4, 119.1, 61.5, 60.9, 58.1, 46.8, 39.3, 29.8, 14.1, 13.80, 13.75; IR (film) ν_{max} 2982, 2926, 1739, 1709, 1661, 1597, 1501, 1398, 1366, 1300, 1253, 1178, 1134, 1095, 1029, 799, 761, 693, 653 cm^{-1}; HRMS calcd for $C_{25}H_{26}N_2O_5S$ $[M + Na]^+$ 489.1455, found 489.1460.

(5R/S,6S/R,10S/R)-Ethyl 1-methyl-4-oxo-3,6,10-triphenyl-2,3-diazaspiro[4.5] deca-1,7-diene-7-carboxylate (**4ab**)

White solid (36.2 mg, 51% yield): mp 161 – 162 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.87 – 7.79 (m, 2H), 7.52 – 7.50 (dd, *J* = 4.8, 2.0 Hz, 1H), 7.46 – 7.28 (m, 6H), 7.26 – 7.06 (m, 7H), 4.22 (s, 1H), 4.14 – 3.90 (m, 2H), 3.46 (dd, *J* = 11.5, 5.6 Hz, 1H), 3.34 – 3.18 (m, 1H), 2.75 (dt, *J* = 19.7, 5.4 Hz, 1H), 1.09 (t, *J* = 7.1 Hz, 3H), 0.93 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.2, 165.8, 161.6, 139.9, 139.7, 139.3, 137.9, 128.8, 128.8, 128.1, 127.9, 127.7, 127.3, 125.1, 119.2, 60.5, 59.7, 47.3, 38.9, 30.8, 15.6, 13.9; IR (film) ν_{max} 3030, 1706, 1660, 1597, 1499, 1454, 1365, 1291, 1272, 1239, 1192, 1124, 1092, 1031, 758, 704, 653, 573 cm^{-1}; HRMS calcd for $C_{30}H_{28}N_2O_3$ $[M + H]^+$ 465.2191, found 465.2178.

(5R/S,6S/R,10S/R)-Ethyl 6-(2-fluorophenyl)-1-methyl-4-oxo-3,10-diphenyl-2,3-diazaspiro[4.5]deca-1,7-diene-7-carboxylate (**4ac**)

White solid (40.7 mg, 55% yield): mp 75 – 76 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.83 – 7.77 (m, 2H), 7.57 – 7.56 (m, 1H), 7.44 – 7.28 (m, 4H), 7.24 – 7.03 (m, 8H), 4.70 (s, 1H), 4.15 – 3.88 (m, 2H), 3.46 – 3.20 (m, 2H), 2.75 (dt, *J* = 18.9, 5.0 Hz, 1H), 1.11 (s, 3H), 1.07 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.8, 165.4, 160.5, 140.8, 139.3, 137.9, 130.0, 123.0, 129.6, 129.5, 128.8, 128.7, 127.8, 127.6, 127.5, 125.1, 124.3, 124.2, 119.3, 115.7, 115.4, 60.6, 58.9, 39.2, 37.6, 37.5, 30.6, 15.0, 13.8; IR (film) ν_{max} 2930, 1705, 1662, 1597, 1489, 1456, 1367, 1290, 1241, 1098, 1031, 910, 759, 734, 703, 653 cm^{-1}; HRMS calcd for $C_{30}H_{27}FN_2O_3$ $[M + Na]^+$ 505.1898, found 505.1894.

(5R/S,6S/R,10S/R)-Ethyl 6-(4-fluorophenyl)-1-methyl-4-oxo-3,10-diphenyl-2,3-diazaspiro[4.5]deca-1,7-diene-7-carboxylate (**4ad**)

White solid (37.8 mg, 51% yield): mp 168 – 169 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.88 – 7.76 (m, 2H), 7.56 – 7.48 (m, 1H), 7.43 – 7.35 (m, 2H), 7.31 (s, 1H), 7.25 – 6.98 (m, 9H), 4.21 (s, 1H), 4.16 – 3.94 (m, 2H), 3.41 (dd, *J* = 11.5, 5.3 Hz, 1H), 3.34 – 3.18 (m, 1H), 2.75 (dt, *J* = 19.4, 5.2 Hz, 1H), 1.11 (t, *J* = 7.1 Hz, 3H), 0.99 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.0, 165.6, 161.2, 140.0, 139.4, 137.8, 135.2, 135.2, 128.8, 128.8, 128.0, 127.8, 127.6, 125.1, 119.1, 60.6, 59.6, 46.4, 38.8, 30.7, 15.7, 13.9; IR (film) ν_{max} 2918, 1706, 1660, 1598, 1506, 1455, 1416, 1391, 1365, 1290, 1272, 1239, 1160, 1095, 1031, 838, 758, 738, 703, 652 cm^{-1}; HRMS calcd for $C_{30}H_{27}FN_2O_3$ $[M + Na]^+$ 505.1898, found 505.1894.

(5R/S,6S/R,10S/R)-Ethyl 6-(3-chlorophenyl)-1-methyl-4-oxo-3,10-diphenyl-2,3-diazaspiro[4.5]deca-1,7-diene-7-carboxylate (**4ae**)

White solid (38.9 mg, 51% yield): mp 149 – 150 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.86 – 7.77 (m, 2H), 7.54 – 7.47 (m, 1H), 7.43 – 7.35 (m, 2H), 7.31 – 7.29 (m, 1H), 7.24 – 6.99 (m, 9H), 4.21 (s, 1H), 4.12 – 3.94 (m, 2H), 3.40 (dd, *J* = 11.5, 5.3 Hz, 1H), 3.34 – 3.18 (m, 1H), 2.75 (dt, *J* = 19.4, 5.2 Hz, 1H), 1.11 (t, *J* = 7.1 Hz, 3H), 0.99 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.0, 165.6, 161.2, 140.0, 139.4, 137.8, 135.2, 135.2, 128.8, 128.8, 128.0, 127.8, 127.6, 125.1, 119.2, 60.6, 59.6, 46.4, 38.8, 30.7, 15.7, 13.9; IR (film) ν_{max} 2982, 2928, 1706, 1660, 1597, 1501, 1455, 1416, 1391, 1365, 1290, 1272, 1240, 1194, 1160, 1124, 1095, 1031, 909, 838, 758, 736, 692, 652 cm^{-1}. HRMS calcd for $C_{30}H_{27}ClN_2O_3$ $[M + Na]^+$ 521.1602, found 521.1602.

(5R/S,6S/R,10S/R)-Ethyl 6-(4-chlorophenyl)-1-methyl-4-oxo-3,10-diphenyl-2,3-diazaspiro[4.5]deca-1,7-diene-7-carboxylate (**4af**)

White solid (43.5 mg, 57% yield): mp 190 – 191 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.87 – 7.75 (m, 2H), 7.57 – 7.49 (m, 1H), 7.43 – 7.25 (m, 5H), 7.24 – 7.06 (m, 7H), 4.19 (s, 1H), 4.15 – 3.90 (m, 2H), 3.45 – 3.17 (m, 2H), 2.75 (dt, *J* = 19.5, 5.2 Hz, 1H), 1.12 (t, *J* = 7.1 Hz, 3H), 1.01 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.9, 165.5, 161.0, 140.3, 139.3, 138.0, 137.8, 133.9, 129.2, 128.8, 128.8, 127.8, 127.7, 127.6, 125.2, 119.1, 60.6, 59.5, 46.5, 38.9, 30.7, 15.9, 13.9; IR (film) ν_{max} 2927, 1707, 1660, 1597, 1493, 1455, 1413, 1365, 1272, 1240, 1092, 1015, 818, 759, 739, 704, 692, 660, 575 cm^{-1}; HRMS calcd for $C_{30}H_{27}ClN_2O_3$ $[M + Na]^+$ 521.1602, found 521.1600.

(5R/S,6S/R,10S/R)-Ethyl 1-methyl-4-oxo-3,10-diphenyl-6-(4-(trifluoromethyl)phenyl)-2,3-diazaspiro[4.5]deca-1,7-diene-7-carboxylate (**4ag**)

White solid (58.6 mg, 72% yield): mp 192 – 193 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.86 – 7.78 (m, 2H), 7.74 – 7.54 (m, 3H), 7.53 – 7.32 (m, 4H), 7.23 – 7.03 (m, 6H), 4.28 (s, 1H), 4.14 – 3.91 (m, 2H), 3.41 (dd, *J* = 11.5, 5.0 Hz, 1H), 3.37 – 3.22 (m, 1H), 2.79 (dt, *J* = 19.3, 5.1 Hz, 1H), 1.11 (t, *J* = 7.1 Hz, 3H), 0.95 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.8, 165.4, 160.7, 143.6, 143.6, 140.8, 139.1, 137.7, 128.9, 128.8, 127.9, 127.5, 127.4, 125.2, 119.1, 60.7, 59.4, 46.9, 38.9, 30.7, 15.8, 13.9; IR (film) ν_{max} 2983, 1706, 1661, 1597, 1500, 1456, 1419, 1366, 1326, 1274, 1242, 1168, 1126, 1069, 1019, 909, 841, 821, 758, 704, 655, 574 cm^{-1}; HRMS calcd for $C_{31}H_{27}F_3N_2O_3$ $[M + Na]^+$ 555.1866, found 555.1864.

(5R/S,6S/R,10S/R)-Ethyl 6-(3-bromophenyl)-1-methyl-4-oxo-3,10-diphenyl-2,3-diazaspiro[4.5]deca-1,7-diene-7-carboxylate (**4ah**)

White solid (54.6 mg, 66% yield): mp 89 – 90 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.86 – 7.76 (m, 2H), 7.54 (s, 1H), 7.48 – 7.36 (m, 4H), 7.29 – 7.28 (m, 1H), 7.21 – 7.10 (dt, *J* = 17.7, 10.9 Hz, 7H), 4.23 – 3.90 (m, 3H), 3.46 – 3.17 (m, 2H), 2.86 – 2.66 (m, 1H), 1.12 (t, *J* = 6.9 Hz, 3H), 1.01 (d, *J* = 3.0 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.8, 165.4, 160.9, 141.9, 140.4, 139.2, 137.7, 134.1, 131.1, 130.8, 130.5, 130.1, 128.8, 128.7, 127.8, 127.6, 125.2, 119.1, 60.6, 59.5, 46.7, 38.9, 30.6, 15.8, 13.9; IR (film) ν_{max} 2927, 1706, 1660, 1596, 1568, 1500, 1455, 1365, 1271, 1241, 1191, 1093, 1031, 759, 738, 705, 653 cm^{-1}; HRMS calcd for $C_{30}H_{27}BrN_2O_3$ $[M + Na]^+$ 565.1097, found 565.1097.

(5R/S,6S/R,10S/R)-Ethyl 6-(4-bromophenyl)-1-methyl-4-oxo-3,10-diphenyl-2,3-diazaspiro[4.5]deca-1,7-diene-7-carboxylate (**4ai**)

White solid (44.7 mg, 54% yield): mp 198 – 199 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.88 – 7.75 (m, 2H), 7.60 – 7.43 (m, 3H), 7.42 – 7.31 (m, 2H), 7.28 – 7.01 (m, 8H), 4.18 (s, 1H), 4.14 – 3.92 (m, 2H), 3.42 – 3.20 (m, 2H), 2.75 (dt, *J* = 19.4, 5.2 Hz, 1H), 1.12 (t, *J* = 7.1 Hz, 3H), 1.01 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.8, 165.5, 161.0, 140.3, 139.2, 138.5, 137.7, 133.0, 132.0, 131.7, 129.5, 128.8, 128.7, 127.8, 127.6, 127.5, 125.1, 122.0, 119.1, 60.6, 59.4, 46.6, 38.8, 30.6, 15.9, 13.9; IR (film) ν_{max} 2904, 1706, 1659, 1597, 1500, 1455, 1365, 1272, 1240, 1074, 1011, 758, 704, 656, 573 cm^{-1}; HRMS calcd for $C_{30}H_{27}BrN_2O_3$ $[M + Na]^+$ 565.1097, found 565.1097.

(5R/S,6S/R,10S/R)-Ethyl 1-methyl-4-oxo-3,10-diphenyl-6-(o-tolyl)-2,3-diazaspiro [4.5]deca-1,7-diene-7-carboxylate (**4aj**)

White solid (31.4 mg, 43% yield): mp 154 – 155 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.85 – 7.76 (m, 2H), 7.51 – 7.50 (m, 1H), 7.43 – 7.34 (m, 2H), 7.29 – 7.07 (m, 10H), 4.57 (s, 1H), 4.12 – 3.88 (m, 2H), 3.50 (dd, *J* = 11.5, 5.6 Hz, 1H), 3.32 – 3.20 (m, 1H), 2.75 (dt, *J* = 19.7, 5.4 Hz, 1H), 2.32 (s, 3H), 1.08 (t, *J* = 7.1 Hz, 3H), 0.98 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.3, 165.8, 161.7, 139.6, 139.4, 137.8, 137.6, 137.4, 130.8, 128.7, 128.7, 128.5, 127.7, 127.6, 126.2, 125.1, 119.3, 60.5, 59.1, 41.3, 38.9, 30.5, 19.9, 15.0, 13.8; IR (film) ν_{max} 2906, 1705, 1661, 1597, 1500, 1455, 1365, 1272, 1239, 758, 738, 703, 653 cm^{-1}; HRMS calcd for $C_{31}H_{30}N_2O_3$ $[M + Na]^+$ 501.2149, found 501.2145.

(5R/S,6S/R,10S/R)-Ethyl 1-methyl-4-oxo-3,10-diphenyl-6-(m-tolyl)-2,3-diazaspiro [4.5]deca-1,7-diene-7-carboxylate (**4ak**)

White solid (37.0 mg, 50% yield): mp 75 – 76 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.89 – 7.79 (m, 2H), 7.56 – 7.34 (m, 3H), 7.33 – 7.24 (m, 1H), 7.22 – 6.99 (m, 9H), 4.25 – 3.91 (m, 3H), 3.49 – 3.43 (m, 1H), 3.35 – 3.16 (m, 1H), 2.86 – 2.64 (m, 1H), 2.41 – 2.32 (d, *J* = 27.1 Hz, 3H), 1.17 – 1.03 (m, 3H), 0.95 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.3, 165.8, 161.7, 139.7, 139.1, 138.7, 137.9, 128.8, 128.7, 128.7, 128.1, 127.7, 127.6, 125.0, 119.2, 60.5, 59.7, 47.2, 38.9, 30.8, 21.2, 15.6, 13.9; IR (film) ν_{max} 2925, 1707, 1660, 1597, 1500, 1455, 1365, 1290, 1272, 1241, 1093, 1031, 909, 758, 734, 704, 653 cm^{-1}; HRMS calcd for $C_{31}H_{30}N_2O_3$ $[M + Na]^+$ 501.2149, found 501.2152.

(5S/R,6S/R,10R/S)-Ethyl 1-methyl-4-oxo-3,6,10-triphenyl-2,3-diazaspiro[4.5]deca-1,7-diene-7-carboxylate (**3ab**)

White solid (26.8 mg, 38% yield): mp 136 – 137 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.38 – 7.30 (m, 1H), 7.24 – 7.13 (m, 15H), 4.38 – 4.21 (m, 1H), 4.12 – 3.87 (m, 3H), 3.74 – 3.55 (m, 1H), 3.36 (dd, *J* = 11.9, 4.7 Hz, 1H), 2.54 (ddd, *J* = 10.9, 9.3, 4.7 Hz, 1H), 2.25 (s, 3H), 0.97 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.2, 166.6, 159.5, 139.8, 138.9, 136.9, 136.9, 129.8, 128.6, 128.3, 128.2, 127.8, 127.7, 127.4, 127.1, 125.2, 120.1, 61.8, 60.1, 46.6, 45.0, 28.5, 14.2, 13.6. IR (film) ν_{max} 2929, 1713, 1597, 1500, 1455, 1398, 1369, 1298, 1247, 1078, 1031, 759, 738, 703, 574 cm^{-1}; HRMS calcd for $C_{30}H_{28}N_2O_3$ $[M + Na]^+$ 487.1992, found 487.1988.

(5S/R,6S/R,10R/S)-Ethyl 6-(2-fluorophenyl)-1-methyl-4-oxo-3,10-diphenyl-2,3-diazaspiro[4.5]deca-1,7-diene-7-carboxylate (**3ac**)

White solid (25.0 mg, 34% yield): mp 156 – 157 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.37 – 7.30 (m, 2H), 7.24 – 7.15 (m, 9H), 7.12 – 7.00 (m, 2H), 6.97 – 6.85 (m, 2H), 4.76 – 4.75 (m, 1H), 4.06 – 3.82 (m, 2H), 3.71 – 3.55 (m, 1H), 3.37 (dd, *J* = 11.9, 4.7 Hz, 1H), 2.58 – 2.47 (m, 1H), 2.17 (d, *J* = 1.7 Hz, 3H), 0.93 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.4, 166.3, 160.8, 140.7, 138.8, 137.1, 129.8, 129.8, 129.5, 128.9, 128.8, 128.4, 127.9, 127.6, 125.3, 123.8, 123.8, 120.1, 114.9, 114.6, 61.4, 60.3, 45.2, 38.5, 38.5, 28.7, 13.7; IR (film) ν_{max} 2982, 1712, 1658, 1597, 1493, 1455, 1398, 1369, 1299, 1248, 1134, 1087, 1032, 907, 827, 757, 741, 704, 691, 574 cm^{-1}; HRMS calcd for $C_{30}H_{27}FN_2O_3$ $[M + Na]^+$ 505.1898, found 505.1893.

(5S/R,6S/R,10R/S)-Ethyl 6-(4-fluorophenyl)-1-methyl-4-oxo-3,10-diphenyl-2,3-diazaspiro[4.5]deca-1,7-diene-7-carboxylate (**3ad**)

White solid (26.5 mg, 36% yield): mp 156 – 157 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.33 – 7.30 (m, 1H), 7.24 – 7.05 (m, 12H), 6.90 – 6.79 (m, 2H), 4.28 (s, 1H), 4.08 – 3.90 (m, 2H), 3.68 – 3.52 (m, 1H), 3.32 (dd, *J* = 11.9, 4.7 Hz, 1H), 2.56 – 2.47 (m, 1H), 2.22 (s, 3H), 1.00 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.3, 166.6, 159.6, 140.3, 138.8, 136.9, 133.0, 133.0, 129.7, 128.8, 128.5, 127.9, 127.5, 125.5, 120.1, 120.0, 115.0, 114.8, 62.0, 62.0, 60.4, 45.9, 45.1, 28.6, 14.3, 13.8; IR (film) ν_{max} 2981, 1712, 1598, 1510, 1455, 1369, 1300, 1248, 1160, 1133, 1086, 1029, 757, 740, 703, 572 cm^{-1}; HRMS calcd for $C_{30}H_{27}FN_2O_3$ $[M + Na]^+$ 505.1898, found 505.1896.

(5S/R,6S/R,10R/S)-Ethyl 6-(3-chlorophenyl)-1-methyl-4-oxo-3,10-diphenyl-2,3-diazaspiro[4.5]deca-1,7-diene-7-carboxylate (**3ae**)

Semisolid (41.2 mg, 54% yield): ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.40 (m, 1H), 7.35 – 7.26 (m, 9H), 7.25 – 7.24 (m, 1H), 7.21 – 7.14 (m, 2H), 6.99 – 6.89 (m, 2H), 4.40 – 4.31 (m, 1H), 4.16 – 4.00 (m, 2H), 3.77 – 3.60 (m, 1H), 3.41 (m, 1H), 2.67 – 2.53 (m, 1H), 2.30 (s, 3H), 1.08 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.3, 166.6, 159.6, 140.4, 138.8, 136.9, 133.0, 133.0, 129.7, 128.8, 128.5, 128.4, 127.9, 127.5, 125.5, 120.1, 120.0, 115.0, 114.8, 62.0, 62.0, 60.4, 45.9, 45.1, 28.6, 14.3, 13.8; IR (film) ν_{max} 2925, 1711, 1598, 1509, 1455, 1398, 1369, 1299, 1248, 1160, 1086, 1030, 908, 847, 757, 703, 572, 537 cm^{-1}; HRMS calcd for $C_{30}H_{27}ClN_2O_3$ $[M + Na]^+$ 521.1602, found 521.1601.

(5S/R,6S/R,10R/S)-Ethyl 6-(4-chlorophenyl)-1-methyl-4-oxo-3,10-diphenyl-2,3-diazaspiro[4.5]deca-1,7-diene-7-carboxylate (**3af**)

White solid (22.9 mg, 30% yield): mp 66 – 67 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.34 – 7.32 (m, 1H), 7.25 – 6.99 (m, 14H), 4.26 (s, 1H), 4.11 – 3.88 (m, 2H), 3.71 – 3.52 (m, 1H), 3.32 (dd, *J* = 11.9, 4.6 Hz, 1H), 2.52 (dt, *J* = 10.9, 4.7 Hz, 1H), 2.21 (s, 3H), 1.01 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.2, 166.5, 159.5, 140.6, 138.7, 136.9, 135.8, 133.1, 129.4, 128.8, 128.5, 128.2, 127.9, 127.5, 125.5, 120.1, 61.9, 60.4, 46.0, 45.1, 28.5, 14.3, 13.9; IR (film) ν_{max} 2925, 1712, 1653, 1597, 1500, 1455, 1398, 1369, 1299, 1248, 1133, 1091, 1016, 846, 743, 704, 691, 575 cm^{-1}; HRMS calcd for $C_{30}H_{27}ClN_2O_3$ $[M + Na]^+$ 521.1602, found 521.1602.

(5S/R,6S/R,10R/S)-Ethyl 1-methyl-4-oxo-3,10-diphenyl-6-(4-(trifluoromethyl)phenyl)-2,3-diazaspiro[4.5]deca-1,7-diene-7-carboxylate (**3ag**)

White solid (17.2 mg, 21% yield): mp 113 – 114 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.44 – 7.39 (m, 3H), 7.26 – 7.15 (m, 9H), 7.12 – 7.00 (m, 3H), 4.34 (s, 1H), 4.11 – 3.87 (m, 2H), 3.71 – 3.54 (m, 1H), 3.34 (dd, *J* = 11.9, 4.7 Hz, 1H), 2.62 – 2.47 (m, 1H), 2.24 (s, 3H), 0.99 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.1, 166.3, 159.3, 141.5, 141.3, 138.6, 136.7, 129.0, 128.9, 128.5, 128.1, 127.5, 125.8, 125.0, 124.9, 120.3, 61.8, 60.5, 46.4, 45.0, 28.6, 14.4, 13.8; IR (film) ν_{max} 2926, 1713, 1619, 1598, 1501, 1456, 1419, 1370, 1326, 1298, 1249, 1167, 1128, 1070, 1020, 852, 757, 704, 663, 603, 574 cm^{-1}; HRMS calcd for $C_{31}H_{27}F_3N_2O_3$ $[M + Na]^+$ 555.1866, found 555.1868.

(5S/R,6S/R,10R/S)-Ethyl 6-(3-bromophenyl)-1-methyl-4-oxo-3,10-diphenyl-2,3-diazaspiro[4.5]deca-1,7-diene-7-carboxylate (**3ah**)

White solid (28.0 mg, 34% yield): mp 77 – 78 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.37 – 7.26 (m, 2H), 7.25 – 7.14 (m, 10H), 7.13 – 6.98 (m, 3H), 4.23 (s, 1H), 4.12 – 3.91 (m, 2H), 3.69 – 3.53 (m, 1H), 3.32 (dd, *J* = 11.9, 4.7 Hz, 1H), 2.60 – 2.44 (m, 1H), 2.20 (s, 3H), 1.00 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.1, 166.4, 159.4, 140.8, 139.6, 138.7, 136.9, 130.5, 129.5, 129.2, 128.8, 128.5, 128.0, 127.5, 125.5, 120.1, 61.8, 60.4, 46.4, 45.1, 28.7, 26.9, 14.3, 13.8; IR (film) ν_{max} 2926, 1713, 1596, 1568, 1500, 1455, 1398, 1369, 1299, 1247, 1134, 1085, 1030, 909, 741, 703, 575 cm^{-1}; HRMS calcd for $C_{30}H_{27}BrN_2O_3$ $[M + Na]^+$ 565.1097, found 565.1097.

(5S/R,6S/R,10R/S)-Ethyl 6-(4-bromophenyl)-1-methyl-4-oxo-3,10-diphenyl-2,3-diazaspiro[4.5]deca-1,7-diene-7-carboxylate (3ai)

White solid (22.0 mg, 26% yield): mp 73 – 74 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.36 – 7.26 (m, 3H), 7.25 – 7.09 (m, 10H), 7.08 – 6.98 (m, 2H), 4.29 – 4.20 (m, 1H), 4.08 – 3.92 (m, 2H), 3.69 – 3.52 (m, 1H), 3.32 (dd, *J* = 11.9, 4.6 Hz, 1H), 2.60 – 2.43 (m, 1H), 2.21 (s, 3H), 1.02 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.2, 166.45, 159.46, 140.68, 138.68, 136.86, 136.34, 131.13, 129.35, 128.81, 128.53, 128.0, 127.5, 125.6, 121.3, 120.2, 61.8, 60.5, 46.1, 45.1, 28.6, 14.3, 13.9; IR (film) ν_{max} 2905, 1713, 1597, 1501, 1455, 1369, 1299, 1248, 1086, 1012, 908, 806, 739, 703 cm^{-1}; HRMS calcd for $C_{30}H_{27}BrN_2O_3$ $[M + Na]^+$ 565.1097, found 565.1097.

(5S/R,6S/R,10R/S)-Ethyl 1-methyl-4-oxo-3,10-diphenyl-6-(o-tolyl)-2,3-diazaspiro [4.5]deca-1,7-diene-7-carboxylate (**3aj**)

White solid (23.9 mg, 33% yield): mp 131 – 132 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.41 – 7.38 (m, 1H), 7.29 – 7.23 (m, 2H), 7.22 – 7.18 (m, 8H), 7.11 – 7.04 (m, 1H), 7.02 – 6.94 (m, 3H), 4.62 – 4.56 (m, 1H), 3.99 – 3.82 (m, 2H), 3.78 – 3.61 (m, 1H), 3.32 (dt, *J* = 14.1, 7.1 Hz, 1H), 2.54 – 2.41 (m, 1H), 2.39 (s, 3H), 2.17 (s, 3H), 0.92 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.0, 166.7, 160.1, 139.2, 139.0, 137.1, 136.1, 135.6, 131.7, 130.1, 129.1, 128.8, 128.4, 127.8, 127.8, 127.1, 125.6, 125.4, 120.3, 61.1, 60.2, 45.7, 42.3, 29.7, 28.8, 19.9, 15.1, 13.7; IR (film) ν_{max} 2928, 1713, 1598, 1500, 1455, 1367, 1297, 1247, 1085, 1032, 908, 798, 740, 704, 574 cm^{-1}; HRMS calcd for $C_{31}H_{30}N_2O_3$ $[M + Na]^+$ 501.2149, found 501.2154.

(5S/R,6S/R,10R/S)-Ethyl 1-methyl-4-oxo-3,10-diphenyl-6-(m-tolyl)-2,3-diazaspiro [4.5]deca-1,7-diene-7-carboxylate (**3ak**)

White solid (34.4 mg, 47% yield): mp 87 – 88 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.28 (dt, *J* = 6.3, 2.3 Hz, 1H), 7.24 – 7.14 (m, 10H), 7.10 – 7.00 (m, 2H), 6.95 (s, 1H), 6.88 – 6.86 (m, 1H), 4.25 (s, 1H), 4.07 – 3.90 (m, 2H), 3.68 – 3.53 (m, 1H), 3.33 (dd, *J* = 11.9, 4.8 Hz, 1H), 2.57 – 2.44 (m, 1H), 2.20 – 2.19 (m, 6H), 0.96 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.4, 166.8, 159.7, 139.7, 139.1, 137.1, 136.9, 130.1, 128.8, 128.4, 128.4, 128.0, 128.0, 127.8, 127.5, 125.3, 120.3, 120.1, 61.9, 60.2, 46.8, 45.2, 28.8, 21.3, 14.3, 13.8; IR (film) ν_{max} 2924, 1712, 1597, 1500, 1455, 1398, 1368, 1298, 1247, 1133, 1085, 1030, 910, 756, 737, 704, 575 cm^{-1}; HRMS calcd for $C_{31}H_{30}N_2O_3$ $[M + Na]^+$ 501.2149, found 501.2144.

(5R,6S,10S)-Diethyl 1-methyl-4-oxo-3,10-diphenyl-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**5aa**)

White solid (25.3 mg, 55% yield): $[\alpha]^{20}_{D}$ = +80.0 (c 0.50, CH_2Cl_2); mp 133 − 134 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.82 – 7.69 (m, 2H), 7.55 – 7.47 (m, 1H), 7.42 – 7.29 (m, 2H), 7.23 – 7.06 (m, 6H), 4.40 – 4.05 (m, 4H), 3.78 – 3.62 (m, 2H), 3.28 – 3.10 (m, 1H), 2.73 – 2.62 (m, 1H), 1.87 (s, 3H), 1.35 – 1.26 (m, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.5, 170.9, 165.5, 159.1, 142.7, 138.8, 137.4, 128.7, 128.7, 127.8, 127.5, 125.3, 124.2, 119.2, 61.7, 60.8, 56.6, 45.5, 39.7, 30.0, 14.8, 14.0, 13.8; IR (film) ν_{max} 2983, 1732, 1710, 1665, 1597, 1500, 1455, 1392, 1368, 1317, 1290, 1273, 1244, 1182, 1097, 1032, 857, 757, 704, 692, 654, 632, 574, 508 cm^{-1}; HRMS calcd for $C_{27}H_{28}N_2O_5$ $[M + Na]^+$ 483.1890, found 483.1894; HPLC analysis 92% ee (Chiralcel OD-H 10:90 isopropanol/hexane, 1 mL/min, 254 nm, t_{R1}= 6.890 min, t_{R2}= 8.867 min).

(5R,6S,10R)-Diethyl 10-(2-fluorophenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro [4.5]deca-1,7-diene-6,7-dicarboxylate (**5ba**)

Semisolid (34.3 mg, 48% yield): $[\alpha]^{20}_{D}$ = +65.7 (c 0.42, CH_2Cl_2); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.76 – 7.62 (m, 2H), 7.52 – 7.50 (m, 1H), 7.40 – 7.34 (m, 2H), 7.22 – 7.14 (m, 2H), 7.10 – 6.98 (m, 2H), 6.96 – 6.89 (m, 1H), 4.39 – 4.07 (m, 5H), 3.74 (s, 1H), 3.20 – 3.08 (m, 1H), 2.72 – 2.62 (m, 1H), 1.90 (s, 3H), 1.36 – 1.26 (m, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.5, 170.6, 165.5, 159.4, 142.4, 137.5, 129.4, 129.3, 128.8, 127.8, 126.2, 126.0, 125.4, 124.8, 124.7, 124.4, 119.3, 115.8, 115.5, 61.8, 60.9, 56.4, 45.7, 29.3, 14.2, 14.1, 13.9; IR (film) ν_{max} 2983, 1732, 1709, 1665, 1597, 1493, 1454, 1392, 1369, 1320, 1289, 1246, 1182, 1096, 1029, 858, 759, 692， 654, 576 cm^{-1}; HRMS calcd for $C_{27}H_{27}FN_2O_5$ $[M + Na]^+$ 501.1796, found 501.1793; HPLC analysis 91% ee (Chiralcel OD-H 10:90 isopropanol/hexane, 1 mL/min, 254 nm, t_{R1}= 6.225 min, t_{R2}= 9.454 min).

(5R,6S,10S)-Diethyl 10-(3-bromophenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro [4.5]deca-1,7-diene-6,7-dicarboxylate (**5fa**)

Semisolid (34.2 mg, 42% yield): $[\alpha]^{20}_{D}$ = +74.1 (c 0.50, CH_2Cl_2); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.78 – 7.68 (m, 2H), 7.50 – 7.49 (m, 1H), 7.43 – 7.29 (m, 4H), 7.24 – 7.15 (m, 1H), 7.11 – 7.00 (m, 2H), 4.40 – 4.06 (m, 4H), 3.79 – 3.60 (m, 2H), 3.21 – 3.09 (m, 1H), 2.73 – 2.63 (m, 1H), 1.88 (s, 3H), 1.36 – 1.27 (m, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.2, 170.9, 165.5, 158.9, 142.3, 141.3, 137.2, 131.1, 131.0, 130.4, 128.8, 125.9, 125.6, 124.3, 122.7, 119.5, 61.9, 61.0, 56.5, 45.3, 39.4, 29.8, 14.9, 14.1, 13.9; IR (film) ν_{max} 2966, 2932, 1715, 1597, 1501, 1455, 1394, 1368, 1317, 1261, 1146, 1094, 1030, 909, 758, 723, 692, 509 cm^{-1}; HRMS calcd for $C_{27}H_{27}BrN_2O_5$ $[M + Na]^+$ 561.0996, found 561.0995; HPLC analysis 93% ee (Chiralcel OD-H 6:94 isopropanol/hexane, 0.7 mL/min, 254 nm, t_{R1}= 13.244 min, t_{R2}= 16.865 min).

(5R,6S,10S)-Diethyl 10-(4-chlorophenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro [4.5]deca-1,7-diene-6,7-dicarboxylate (**5ha**)

White solid (33.1 mg, 45% yield): $[\alpha]^{20}_{D}$ = +84.2 (c 0.55, CH_2Cl_2); mp 131 – 132 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.79 – 7.69 (m, 2H), 7.51 – 7.48 (m, 1H), 7.43 – 7.33 (m, 2H), 7.23 – 7.13 (m, 3H), 7.11 – 7.02 (m, 2H), 4.39 – 4.03 (m, 4H), 3.72 – 3.66 (dd, *J* = 12.2, 6.6 Hz, 2H), 3.20 – 3.08 (m, 1H), 2.71 – 2.61 (m, 1H), 1.87 (s, 3H), 1.36 – 1.27 (m, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.3, 171.0, 165.5, 159.0, 142.4, 137.5, 137.4, 133.8, 129.0, 128.9, 128.8, 125.5, 124.3, 119.2, 61.9, 61.0, 56.6, 45.4, 39.1, 30.0, 14.8, 14.1, 13.9; IR (film) ν_{max} 2982, 1731, 1709, 1665, 1597, 1500, 1367, 1320, 1289, 1268, 1242, 1182, 1095, 1028, 835, 758, 692, 655 cm^{-1}; HRMS calcd for $C_{27}H_{27}ClN_2O_5$ $[M + Na]^+$ 517.1501, found 517.1502; HPLC analysis 94% ee (Chiralcel OD-H 6:94 isopropanol/hexane, 0.6 mL/min, 254 nm, t_{R1}= 15.699 min, t_{R2}= 18.310 min).

(5R,6S,10S)-Diethyl 10-(2-methoxyphenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro [4.5]deca-1,7-diene-6,7-dicarboxylate (**5ka**)

Semisolid (37.9 mg, 52% yield): $[\alpha]^{20}_{D}$ = +71.9 (c 0.70, CH_2Cl_2); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.78 (d, *J* = 7.9 Hz, 2H), 7.52 – 7.51 (m, 1H), 7.42 – 7.32 (m, 2H), 7.23 – 7.11 (m, 2H), 7.02 (d, *J* = 7.5 Hz, 1H), 6.88 – 6.66 (m, 2H), 4.56 – 4.04 (m, 5H), 3.80 – 3.72 (m, 4H), 3.04 – 3.01 (m, 1H), 2.65 – 2.58 (m, 1H), 1.84 (s, 3H), 1.34 – 1.26 (m, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.1, 170.8, 165.7, 143.2, 137.7, 128.7, 128.6, 127.5, 125.1, 124.4, 121.0, 119.2, 110.6, 61.6, 60.8, 56.7, 55.3, 46.0, 29.6, 14.3, 14.1, 13.9; IR (film) ν_{max} 2982, 1733, 1709, 1598, 1495, 1463, 1368, 1320, 1245, 1182, 1097, 1030, 757, 692 cm^{-1}; HRMS calcd for $C_{28}H_{30}N_2O_6$ $[M + Na]^+$ 513.1996, found 513.1991; HPLC analysis 89% ee (Chiralcel OD-H 6:94 isopropanol/hexane, 0.8 mL/min, 254 nm, t_{R1}= 12.566 min, t_{R2}= 16.239 min).

(5R,6S,10S)-Diethyl 10-(3-methoxyphenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro [4.5]deca-1,7-diene-6,7-dicarboxylate (**5la**)

White solid (37.1 mg, 50% yield): $[\alpha]^{20}_{D}$ = +62.8 (c 0.64, CH_2Cl_2); mp 101 – 102 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.81 – 7.71 (m, 2H), 7.52 – 7.50 (m, 1H), 7.41 – 7.32 (m, 2H), 7.22 – 7.14 (m, 1H), 7.13 – 7.06 (m, 1H), 6.77 – 6.68 (m, 2H), 6.66 – 6.62 (m, 1H), 4.38 - 4.27 (m, 1H), 4.26 – 4.06 (m, 3H), 3.72 (s, 1H), 3.66 (dd, *J* = 11.2, 5.5 Hz, 1H), 3.53 (s, 3H), 3.24 – 3.12 (m, 1H), 2.73 – 2.63 (m, 1H), 1.88 (s, 3H), 1.36 – 1.26 (m, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.6, 171.0, 165.6, 159.8, 159.3, 142.7, 140.5, 137.5, 129.8, 128.7, 125.3, 124.2, 119.9, 119.1, 114.0, 112.3, 61.8, 60.9, 56.6, 54.9, 45.5, 39.8, 30.1, 14.9, 14.1, 13.9; IR (film) ν_{max} 2925, 1732, 1707, 1597, 1491, 1367, 1318, 1243, 1181, 1040, 758, 692 cm^{-1}; HRMS calcd for $C_{28}H_{30}N_2O_6$ $[M + Na]^+$ 513.1996, found 513.1992; HPLC analysis 95% ee (Chiralcel OD-H 10:90 isopropanol/hexane, 1 mL/min, 254 nm, t_{R1}= 7.796 min, t_{R2}= 10.498 min).

(5R,6S,10S)-Diethyl 1-methyl-4-oxo-3-phenyl-10-(m-tolyl)-2,3-diazaspiro[4.5] deca-1,7-diene-6,7-dicarboxylate (**5na**)

Semisolid (40.5 mg, 57% yield): $[\alpha]^{20}_{D}$ = +65.2 (c 0.64, CH_2Cl_2); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.74 – 7.70 (m, 2H), 7.52 – 7.50 (m, 1H), 7.42 – 7.32 (m, 2H), 7.21 – 7.16 (m, 1H), 7.12 – 6.96 (m, 2H), 6.92 – 6.90 (m, 2H), 4.43 – 4.05 (m, 4H), 3.72 (s, 1H), 3.64 (dd, *J* = 11.2, 5.4 Hz, 1H), 3.23 – 3.11 (m, 1H), 2.72 – 2.61 (m, 1H), 2.14 (s, 3H), 1.86 (s, 3H), 1.36 – 1.27 (m, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.6, 171.0, 165.6, 159.3, 142.8, 138.8, 138.5, 137.5, 128.7, 128.6, 128.1, 125.3, 124.7, 124.2, 119.3, 61.7, 60.9, 56.7, 45.4, 39.8, 30.0, 21.2, 14.9, 14.1, 13.9; IR (film) ν_{max} 2928, 1732, 1708, 1665, 1597, 1501, 1392, 1367, 1317, 1290, 1242, 1181, 1029, 792, 758, 707, 692, 654, 508 cm^{-1}; HRMS calcd for $C_{28}H_{30}N_2O_5$ $[M + Na]^+$ 497.2047, found 497.2045; HPLC analysis 92% ee (Chiralcel OD-H 6:94 isopropanol/hexane, 0.7 mL/min, 254 nm, t_{R1}= 10.445 min, t_{R2}= 13.373 min).

(5R,6S,10S)-Diethyl 10-(2,5-dimethoxyphenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**5qa**)

Semisolid (28.1 mg, 36% yield): $[\alpha]^{20}_{D}$ = +66.7 (c 0.42, CH_2Cl_2); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.82 (d, *J* = 7.9 Hz, 2H), 7.52 – 7.51 (m, 1H), 7.44 – 7.31 (m, 2H), 7.21 – 7.09 (m, 1H), 6.81 – 6.65 (m, 2H), 6.59 (s, 1H), 4.53 – 4.03 (m, 5H), 3.75 – 3.72 (m, 4H), 3.32 (s, 3H), 3.10 – 3.05 (m, 1H), 2.65 – 2.59 (m, 1H), 1.86 (s, 3H), 1.34 – 1.26 (m, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.1, 170.7, 165.7, 153.8, 143.1, 137.8, 128.7, 128.3, 125.1, 124.4, 118.9, 114.6, 112.0, 77.4, 77.0, 76.6, 61.6, 60.8, 56.0, 55.3, 46.0, 29.7, 14.3, 14.1, 13.9; IR (film) ν_{max} 2934, 1733, 1707, 1663, 1596, 1502, 1465, 1392, 1367, 1318, 1288, 1243, 1224, 1181, 1097, 1047, 856, 808, 757, 692, 655 cm^{-1}; HRMS calcd for $C_{29}H_{32}N_2O_7$ $[M + Na]^+$ 543.2102, found 543.2103; HPLC analysis 90% ee (Chiralcel OD-H 6:94 isopropanol/hexane, 0.8 mL/min, 254 nm, t_{R1}= 12.154 min, t_{R2}= 17.138 min).

(5R,6S,10S)-Diethyl 10-(3,4-dimethylphenyl)-1-methyl-4-oxo-3-phenyl-2,3-diazaspiro[4.5]deca-1,7-diene-6,7-dicarboxylate (**5ra**)

White solid (33.5 mg, 46% yield): $[\alpha]^{20}_{D}$ = +81.8 (c 0.34, CH_2Cl_2); mp 110 – 111 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.81 – 7.69 (m, 2H), 7.51 – 7.50 (m, 1H), 7.44 – 7.31 (m, 2H), 7.24 – 7.12 (m, 1H), 6.99 – 6.80 (m, 3H), 4.39 – 4.06 (m, 4H), 3.71 (s, 1H), 3.60 (dd, *J* = 11.2, 5.4 Hz, 1H), 3.22 – 3.10 (m, 1H), 2.70 – 2.60 (m, 1H), 2.14 (s, 3H), 2.05 (s, 3H), 1.86 (s, 3H), 1.36 – 1.26 (m, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.7, 171.1, 165.7, 159.4, 143.0, 137.5, 137.0, 136.2, 136.2, 130.0, 128.7, 128.6, 125.3, 124.9, 124.2, 119.3, 61.7, 60.9, 56.8, 45.5, 39.4, 30.2, 19.6, 19.3, 14.9, 14.1, 13.9; IR (film) ν_{max} 2928, 1732, 1708, 1665, 1597, 1501, 1456, 1366, 1317, 1289, 1271, 1245, 1181, 1028, 823, 758, 692, 654, 507 cm^{-1}; HRMS calcd for $C_{29}H_{32}N_2O_5$ $[M + Na]^+$ 511.2203, found 511.2203; HPLC analysis 91% ee (Chiralcel OD-H 6:94 isopropanol/hexane, 0.8 mL/min, 254 nm, t_{R1}= 7.458 min, t_{R2}= 8.892 min).

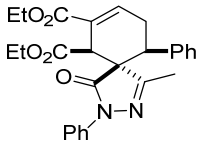
(5R,6S,10S)-Diethyl 1-methyl-10-(naphthalen-2-yl)-4-oxo-3-phenyl-2,3-diazaspiro [4.5]deca-1,7-diene-6,7-dicarboxylate (**5sa**)

Semisolid (47.4 mg, 62% yield): $[\alpha]^{20}_{D}$ = +121.6 (c 0.58, CH_2Cl_2); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.75 – 7.58 (m, 6H), 7.56 – 7.55 (m, 1H), 7.45 – 7.32 (m, 4H), 7.26 – 7.14 (m, 2H), 4.40 – 4.29 (m, 1H), 4.27 – 4.11 (m, 3H), 3.88 (dd, *J* = 11.2, 5.5 Hz, 1H), 3.77 (s, 1H), 3.36 – 3.24 (m, 1H), 2.78 – 2.68 (m, 1H), 1.87 (s, 3H), 1.37 – 1.27 (m, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.6, 171.1, 165.6, 159.3, 142.8, 137.5, 136.4, 133.3, 132.8, 128.8, 128.7, 127.7, 127.5, 126.9, 126.3, 126.1, 125.4, 124.9, 124.3, 119.4, 61.8, 60.9, 56.7, 45.6, 40.0, 30.2, 26.9, 14.9, 14.1, 13.9; IR (film) ν_{max} 2982, 1731, 1707, 1664, 1597, 1501, 1367, 1316, 1289, 1244, 1182, 1097, 1028, 859, 822, 756, 692, 651, 480 cm^{-1}; HRMS calcd for $C_{31}H_{30}N_2O_5$ $[M + Na]^+$ 533.2047, found 533.2043; HPLC analysis 94% ee (Chiralcel OD-H 6:94 isopropanol/hexane, 0.7 mL/min, 254 nm, t_{R1}= 13.692 min, t_{R2}= 17.259 min).

Diethyl 4-hydroxy-1-methyl-3,10-diphenyl-2,3-diazaspiro[4.5]dec-1-ene-6,7-dicarboxylate (**6**)

$[\alpha]^{20}_{D}$ = –14.2 (c 0.66, CH_2Cl_2); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.70 (d, *J* = 7.8 Hz, 2H), 7.37 (t, *J* = 7.9 Hz, 2H), 7.25 – 7.06 (m, 6H), 4.23 – 4.10 (m, 4H), 3.72 (d, *J* = 10.8 Hz, 1H), 3.16 – 2.98 (m, 1H), 2.66 – 2.42 (m, 2H), 2.16 (s, 3H), 1.71 – 1.48 (m, 4H), 1.28 – 1.23 (m, 6H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.2, 147.7, 141.7, 138.2, 128.8, 128.3, 125.8, 121.1, 62.1, 60.8, 43.3, 35.4, 29.3, 28.5, 14.2, 13.9, 12.5; IR (film) ν_{max} 3440, 2929, 1732, 1629, 1501, 1455, 1370, 1261, 1179, 1097, 1028, 802, 756, 700 cm^{-1}; HRMS calcd for $C_{27}H_{32}N_2O_5$ $[M + Na]^+$ 487.2203, found 487.2208. HPLC analysis 97% ee (Chiralcel OD-H 10:90 isopropanol/hexane, 1 mL/min, 254 nm, t_{R1}= 8.808 min, t_{R2}= 10.681 min)

^{1}H and ^{13}C NMR spectra of all cycloadducts



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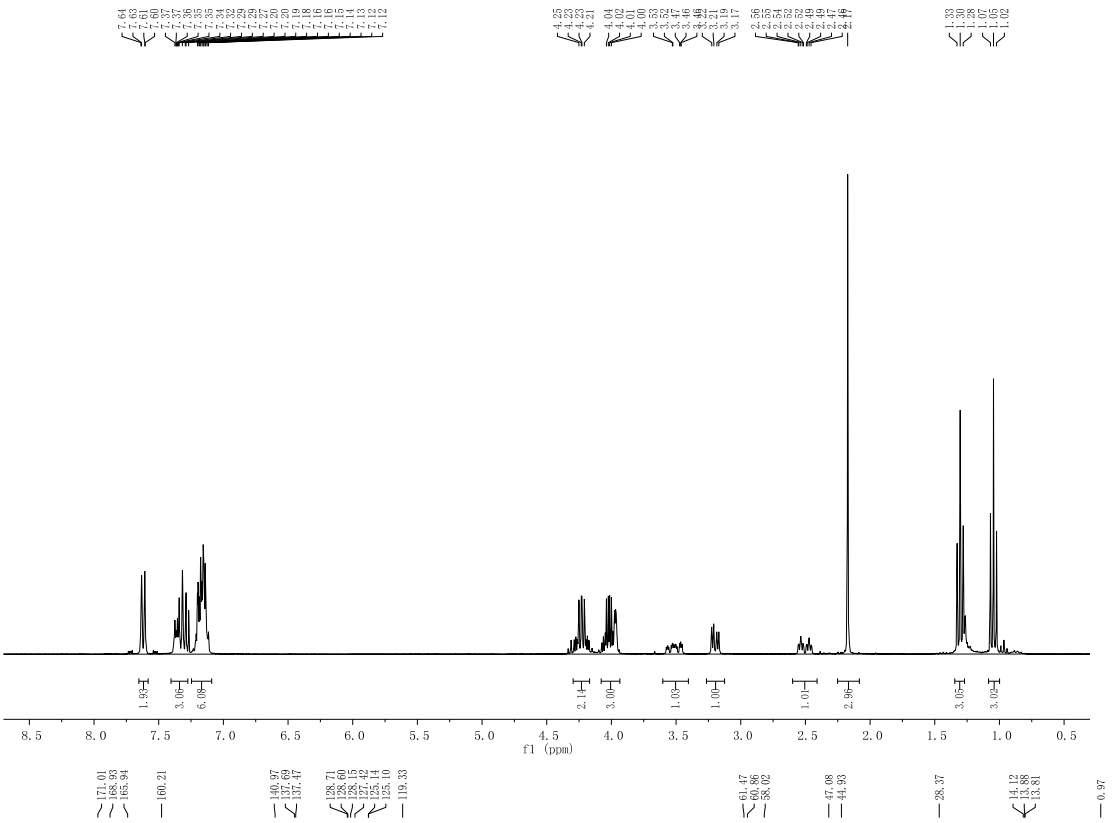

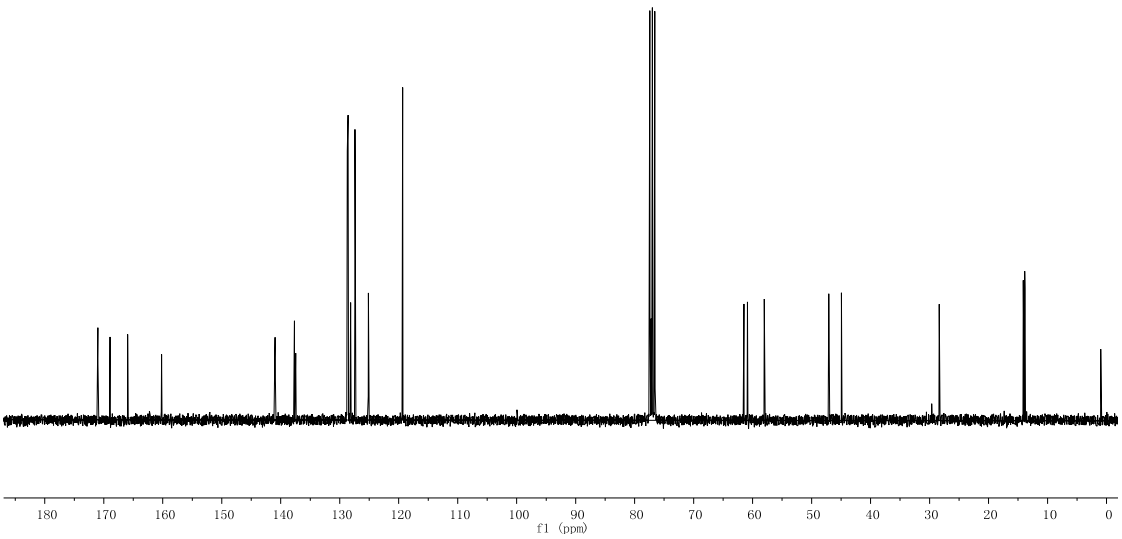

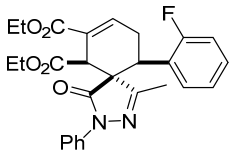

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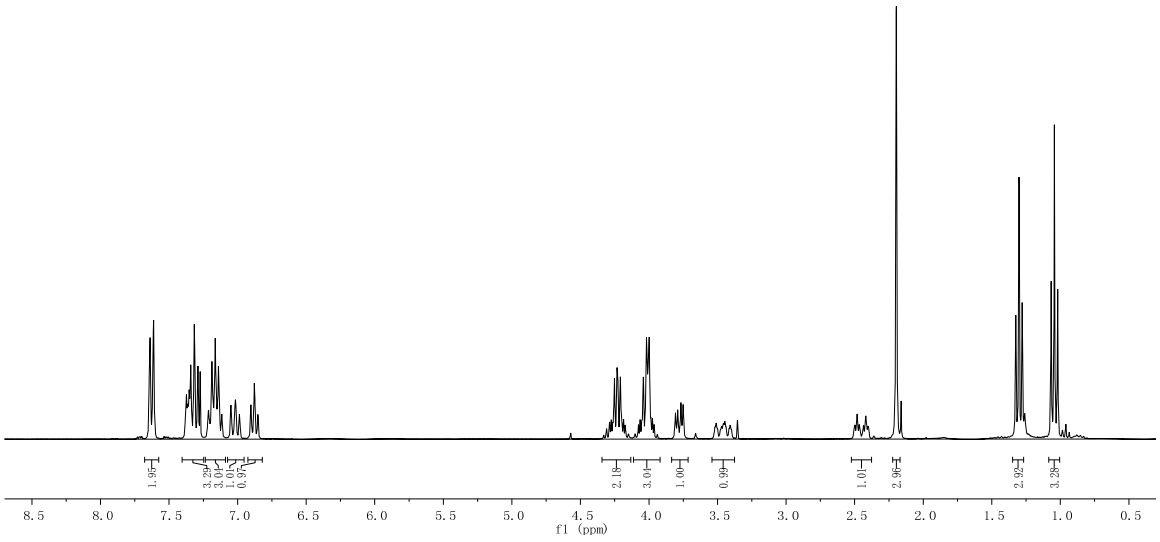

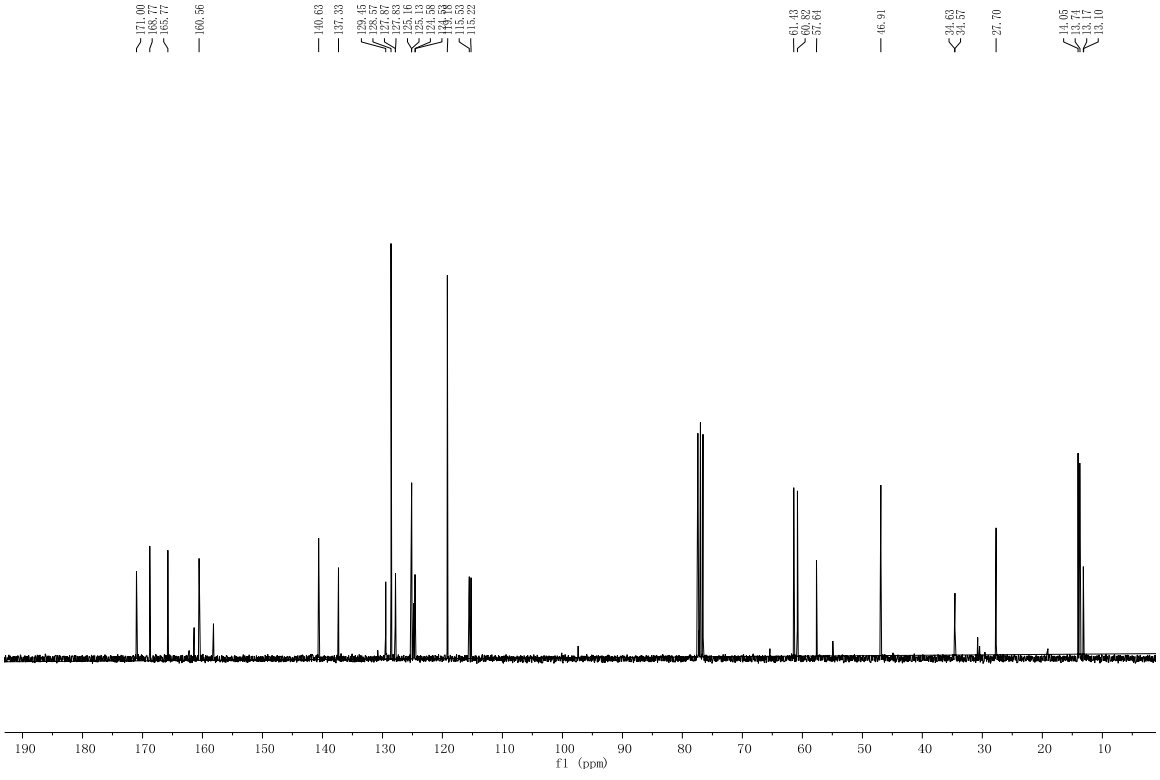

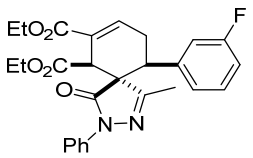

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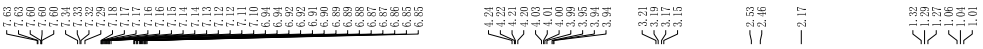

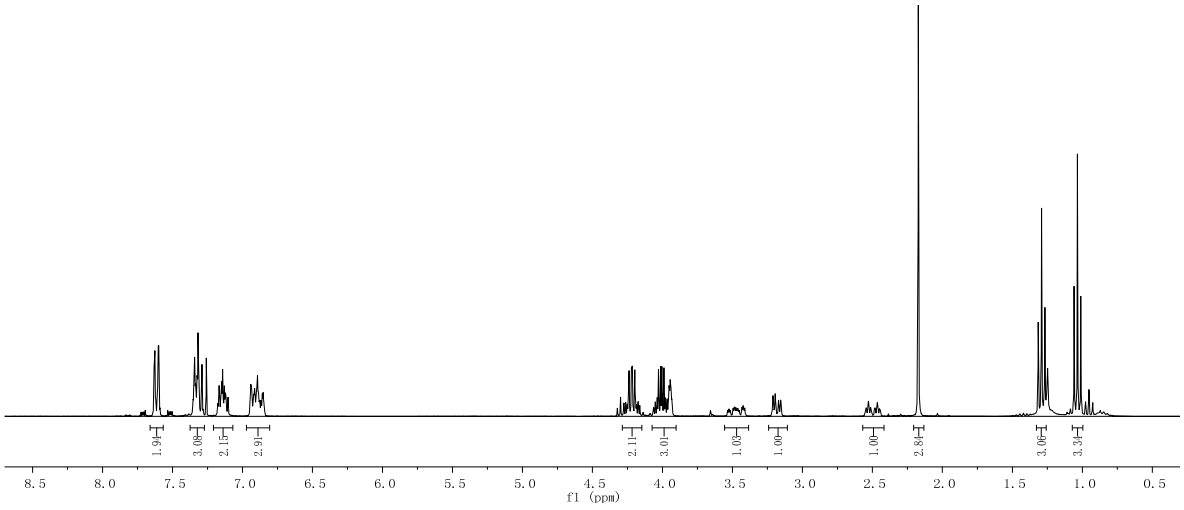

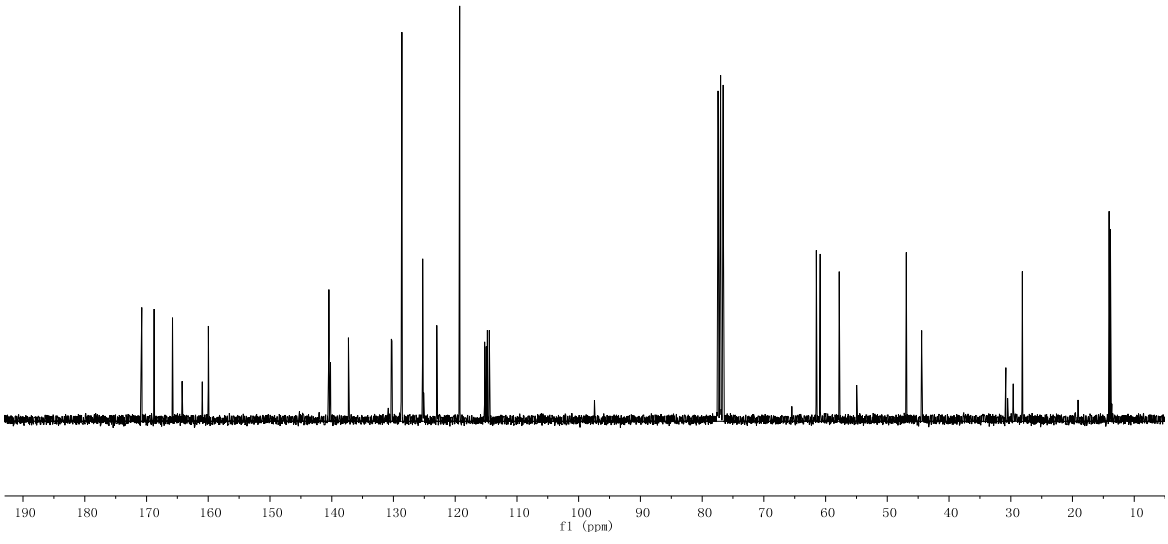

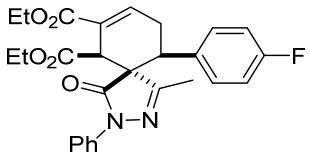
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F

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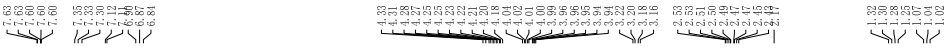

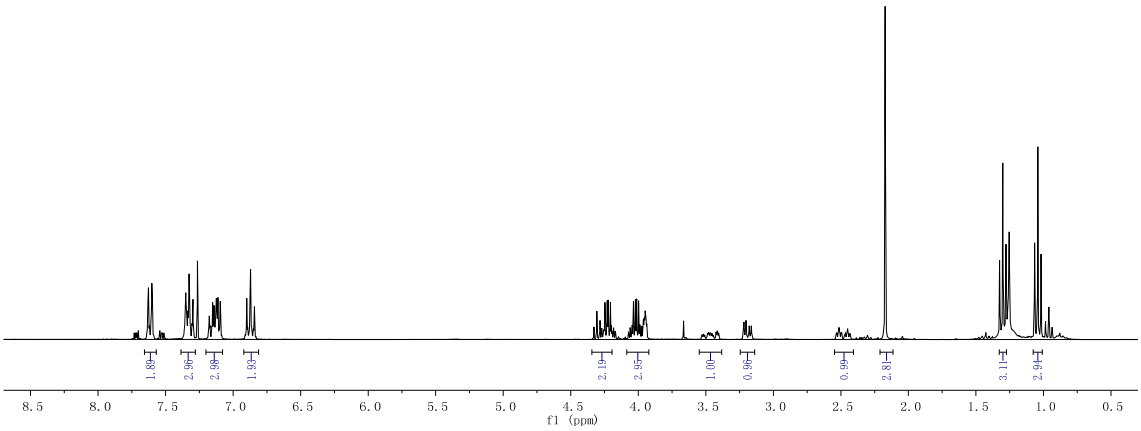
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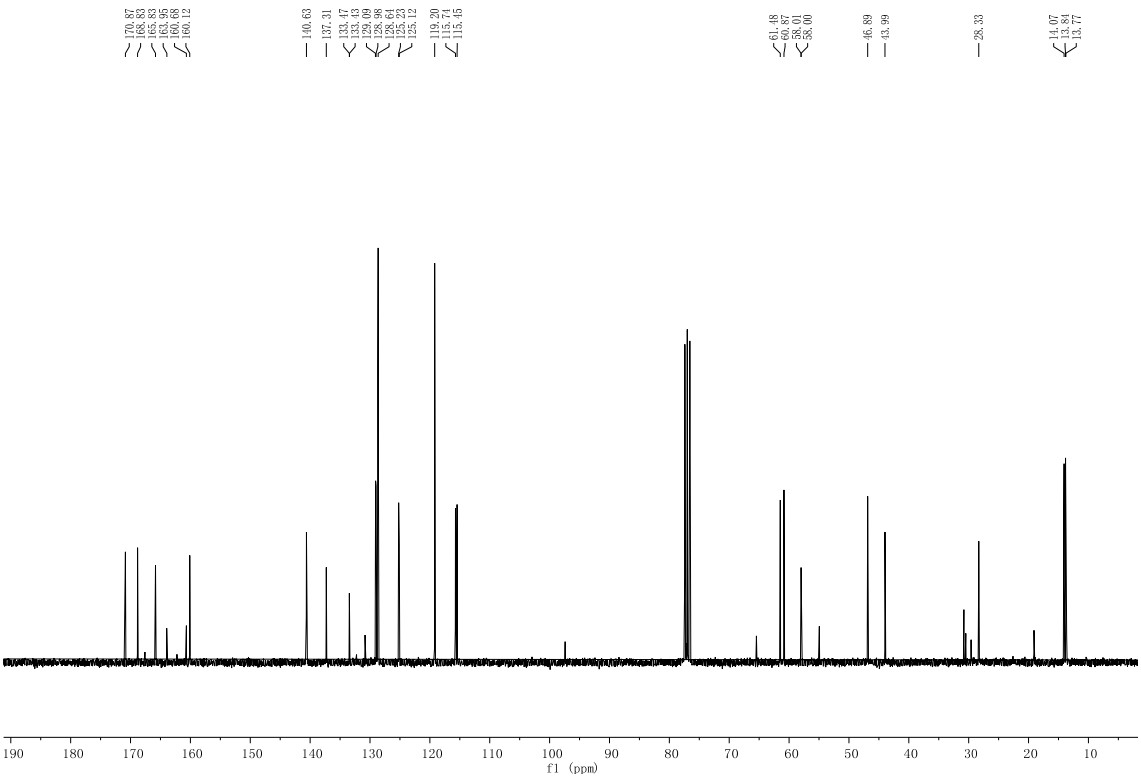
2.94
f1 (ppm)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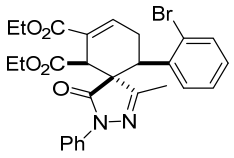

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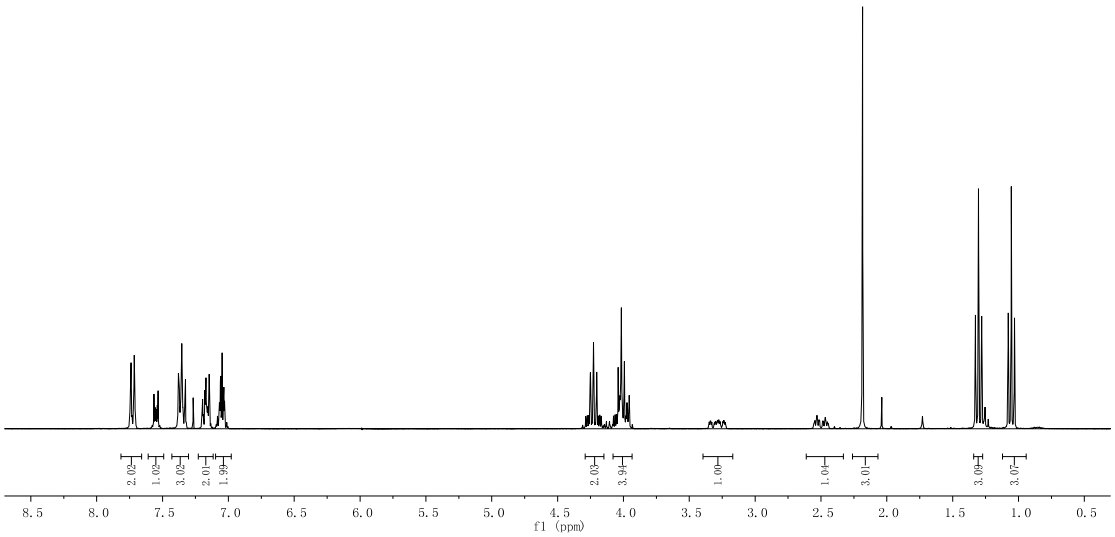

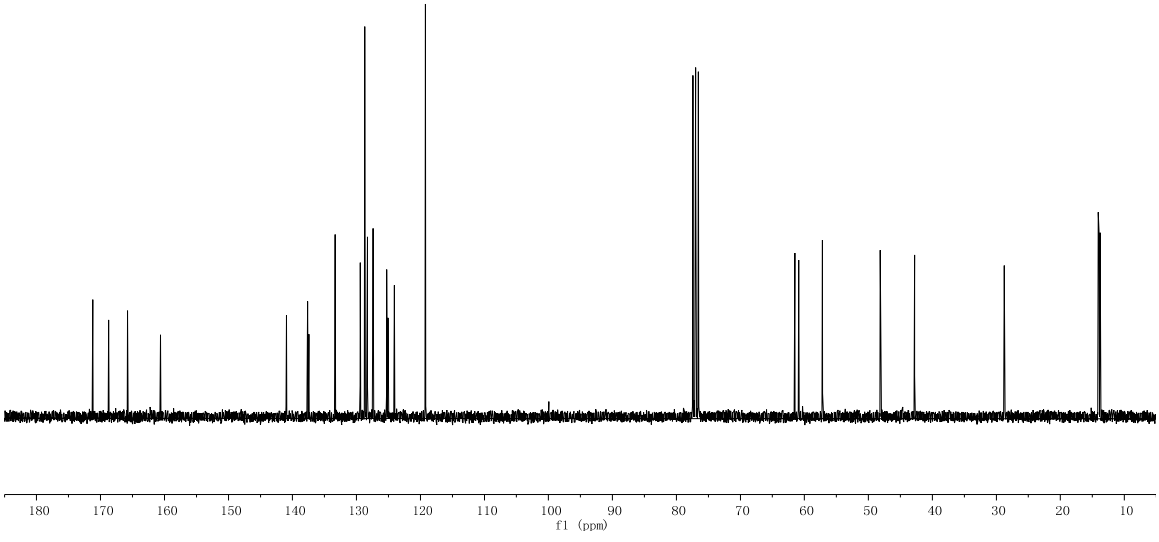

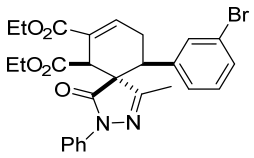

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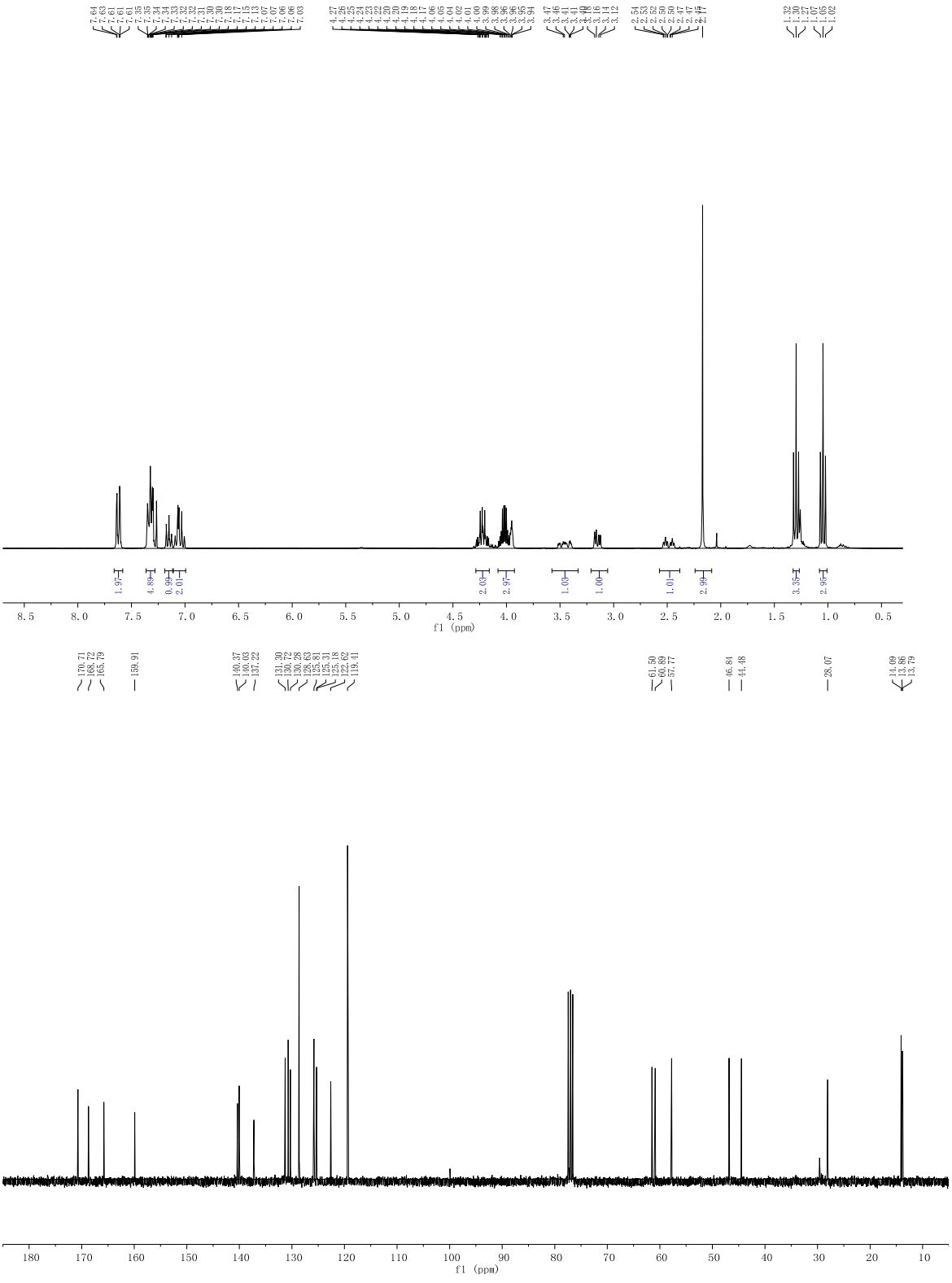

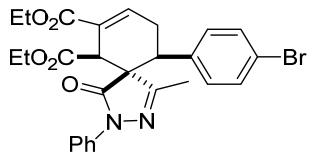

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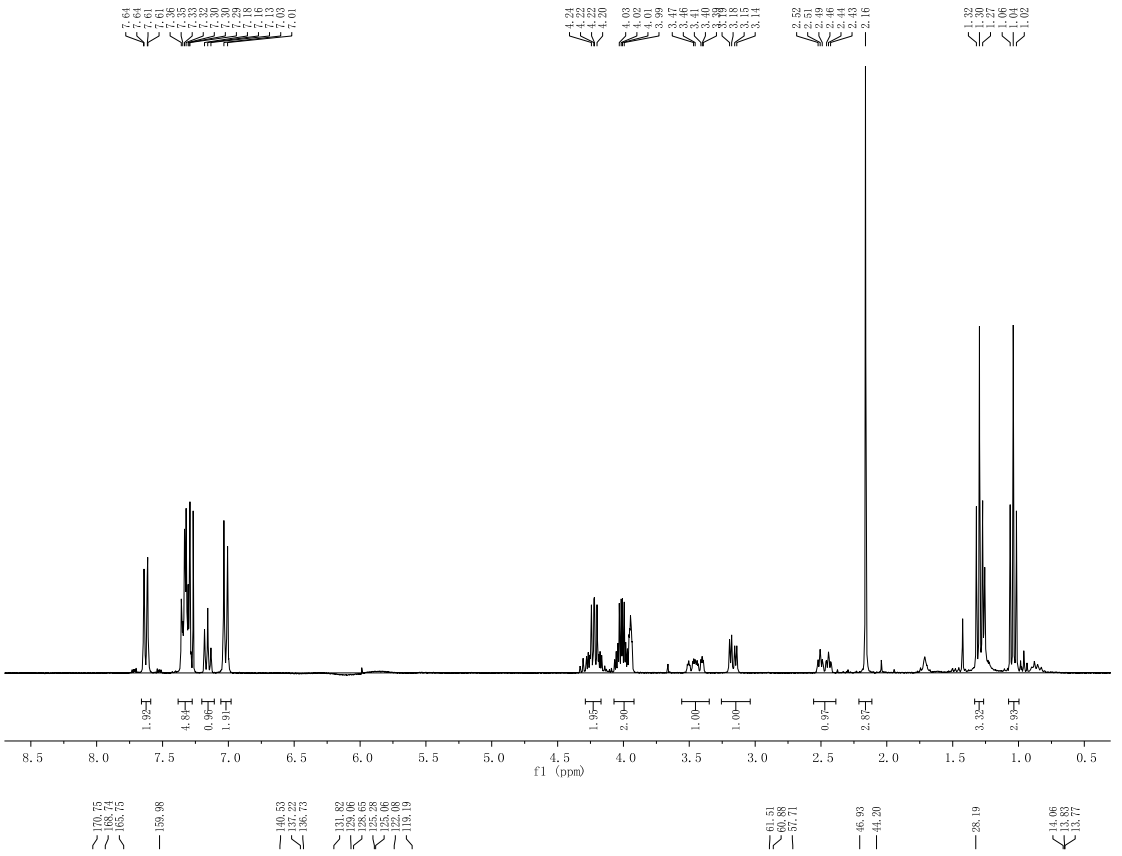
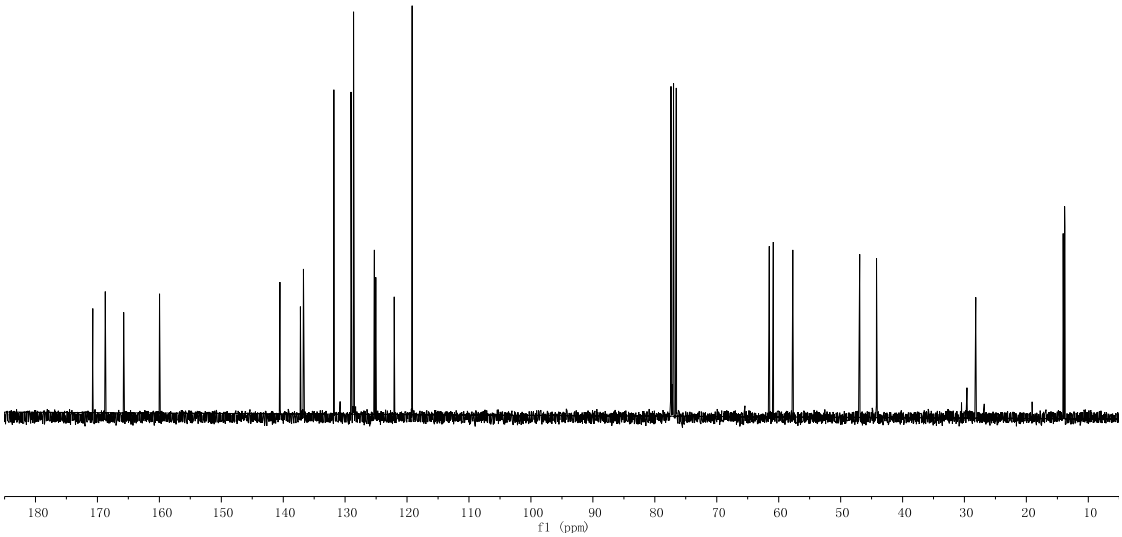
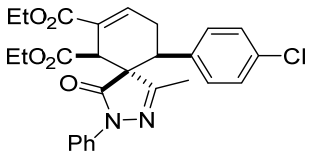
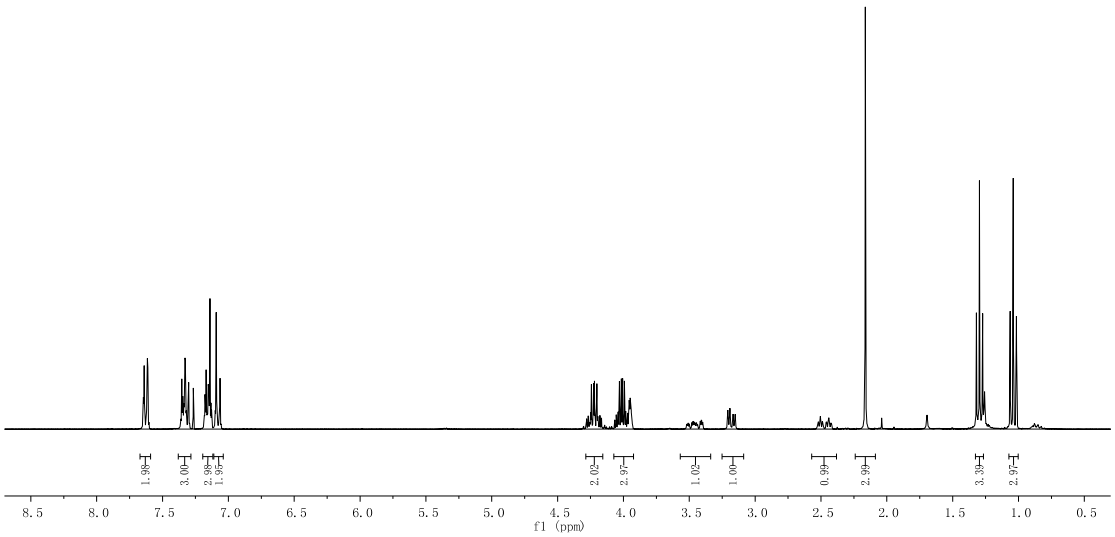





EtO2C
EtO2C
O
N–N
Ph
Cl

3ha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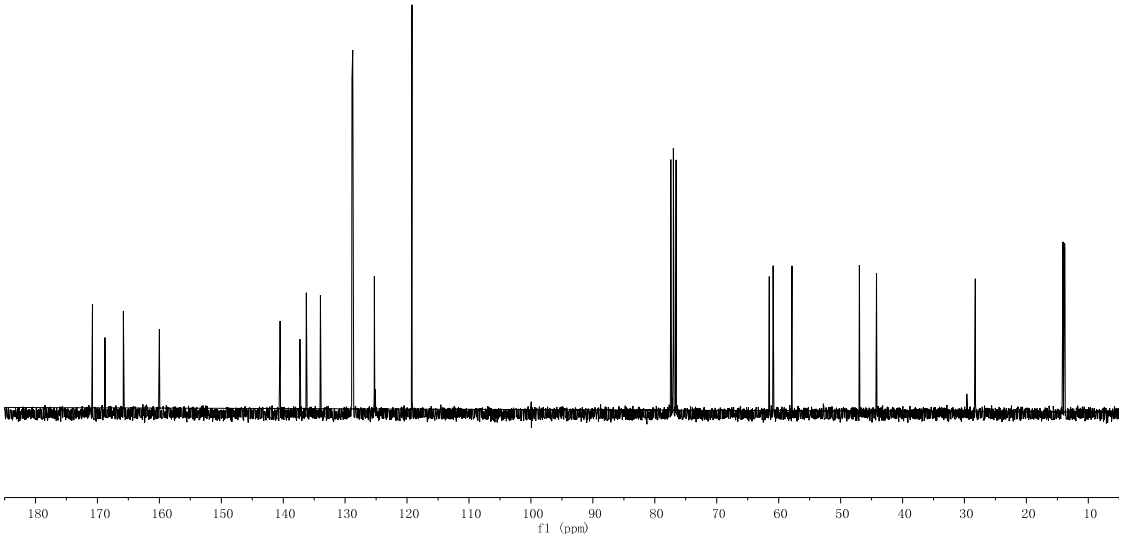
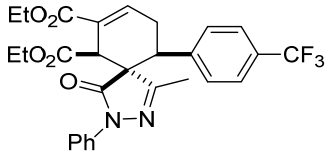
1.02
1.00
0.99
2.99
3.39
2.97
f1 (ppm)


f1 (ppm)



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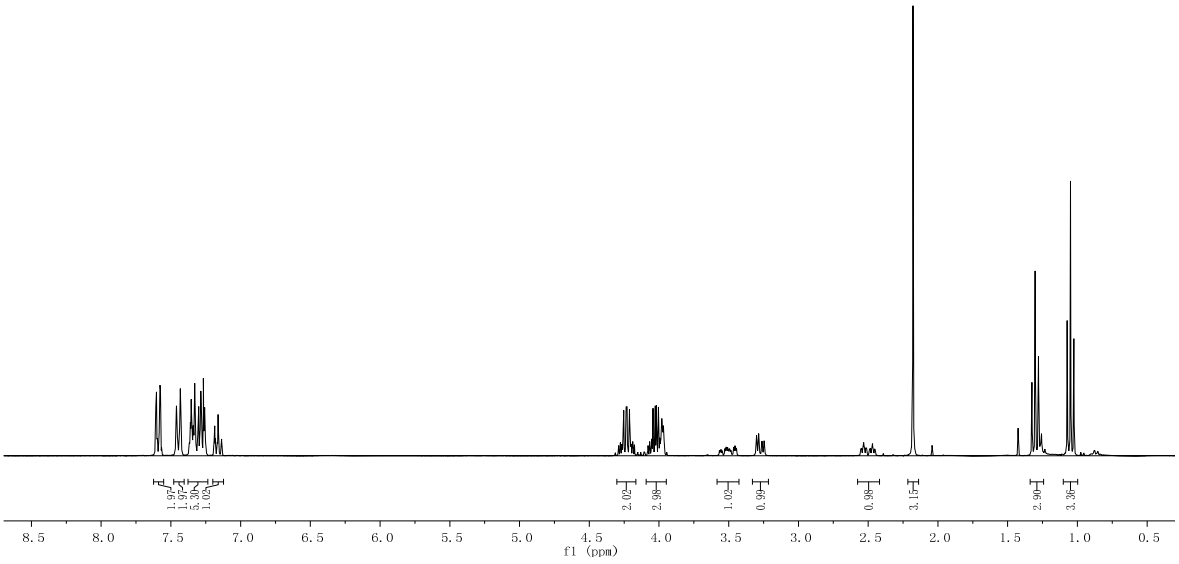
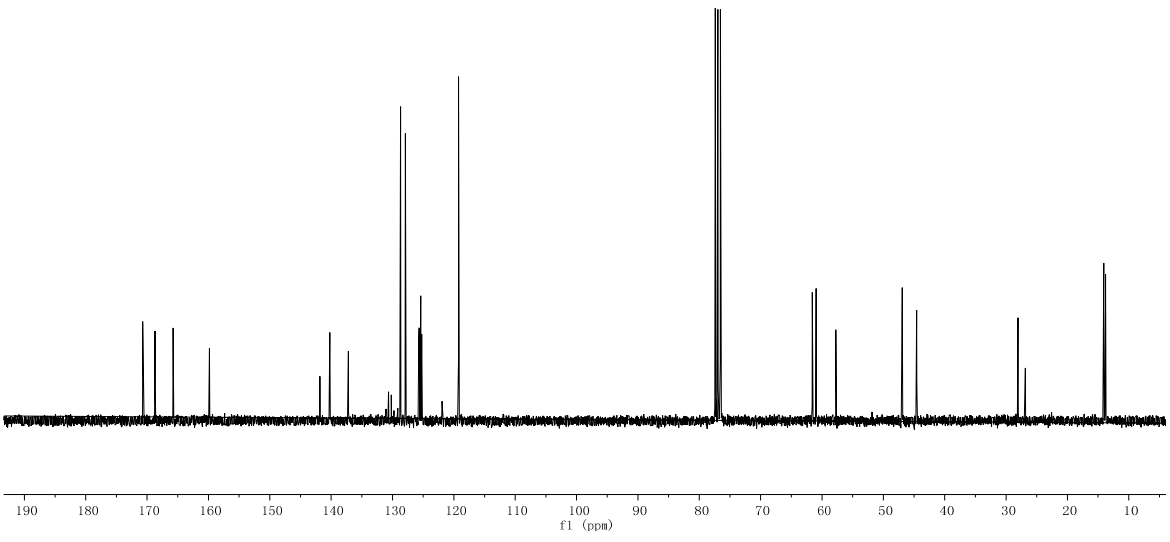
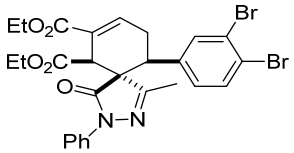
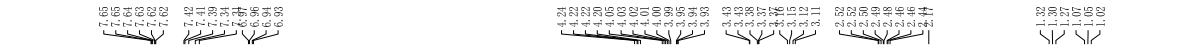
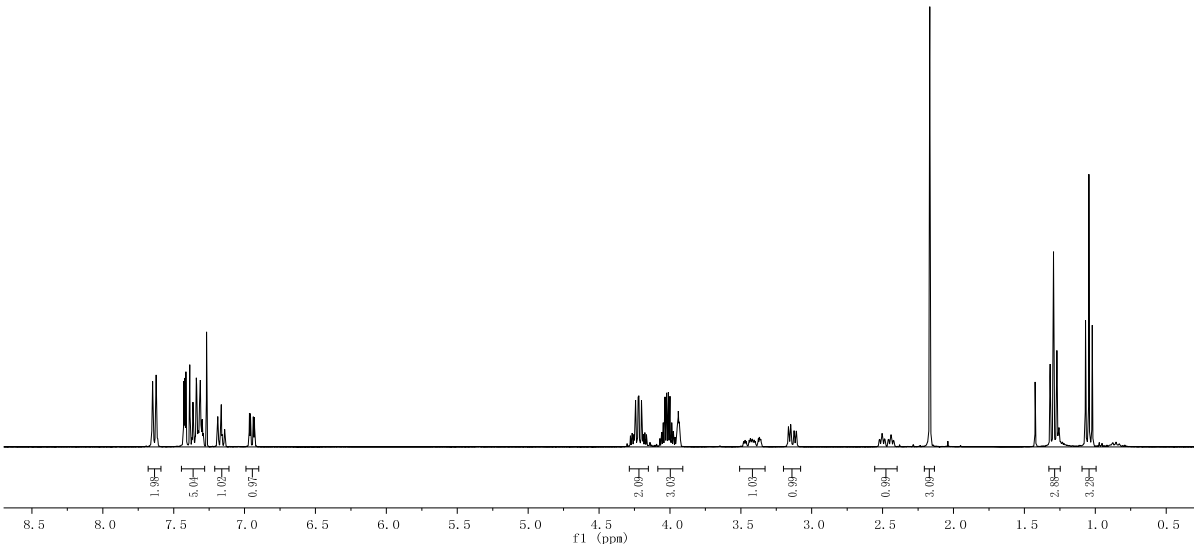





EtO2C
EtO2C
O
N–N
Ph
Br
Br

3ja

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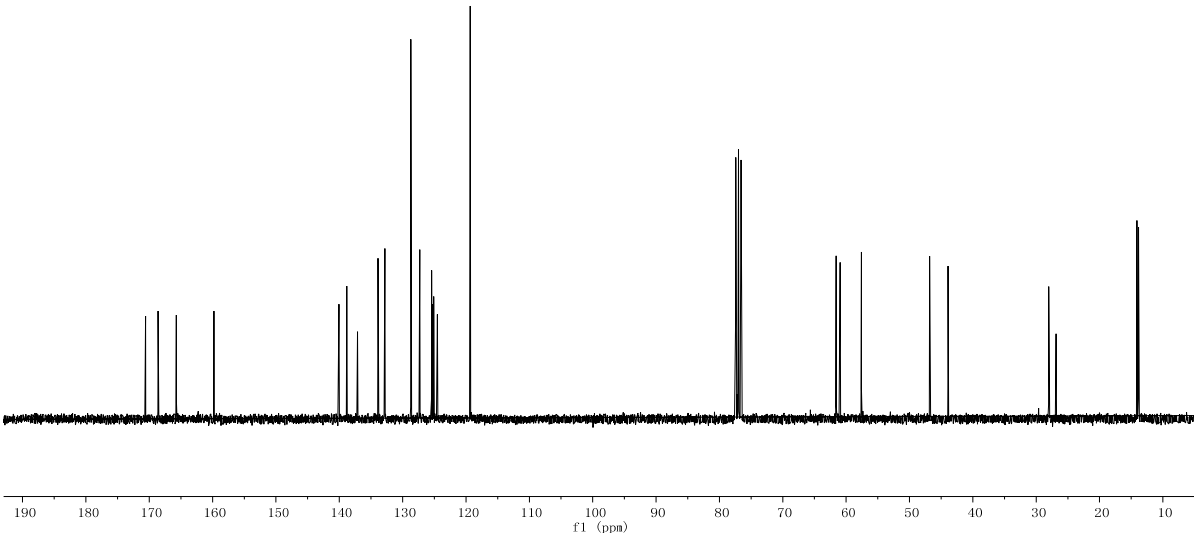
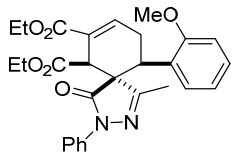
0.97
2.09
3.03
1.03
0.99
0.99
3.09
2.88
3.29
f1 (ppm)


f1 (ppm)



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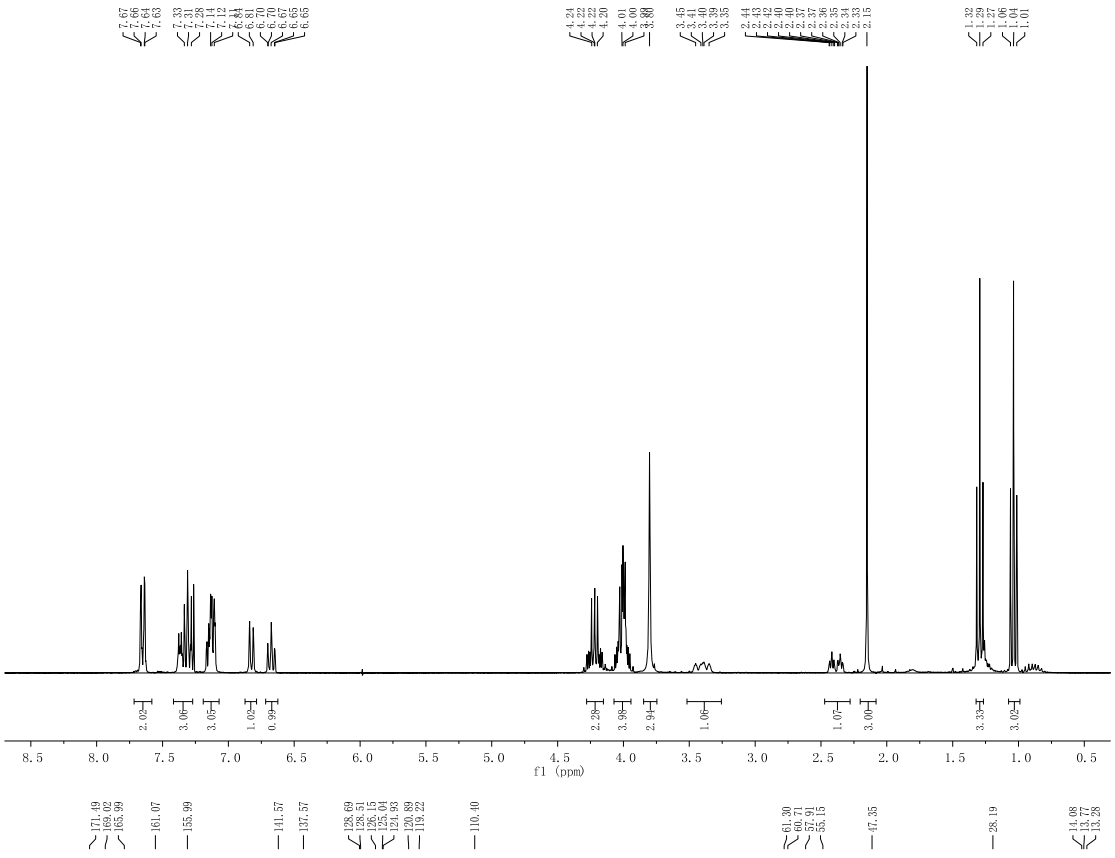
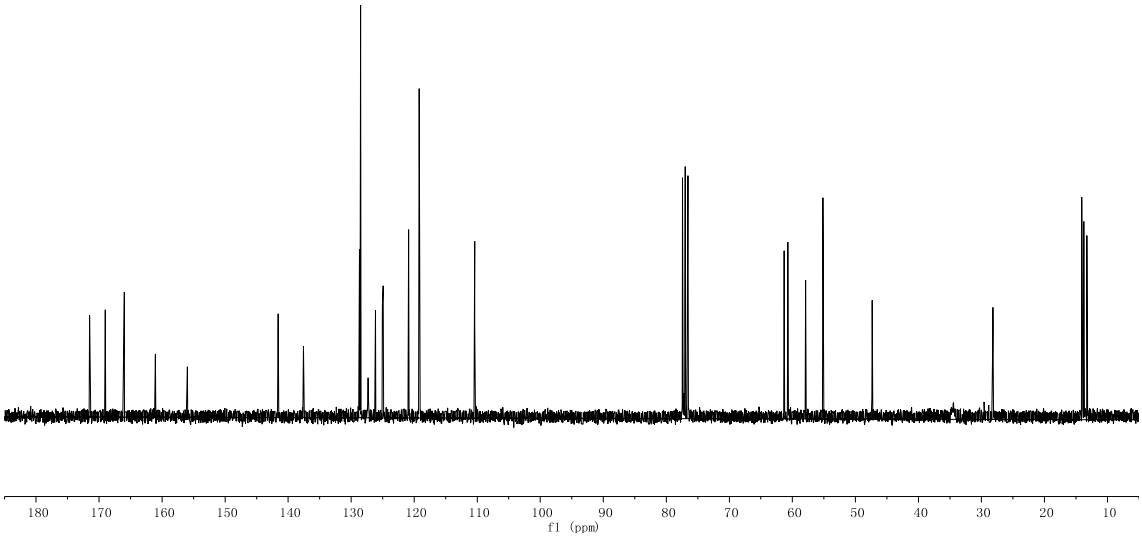
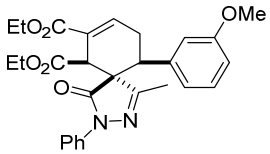
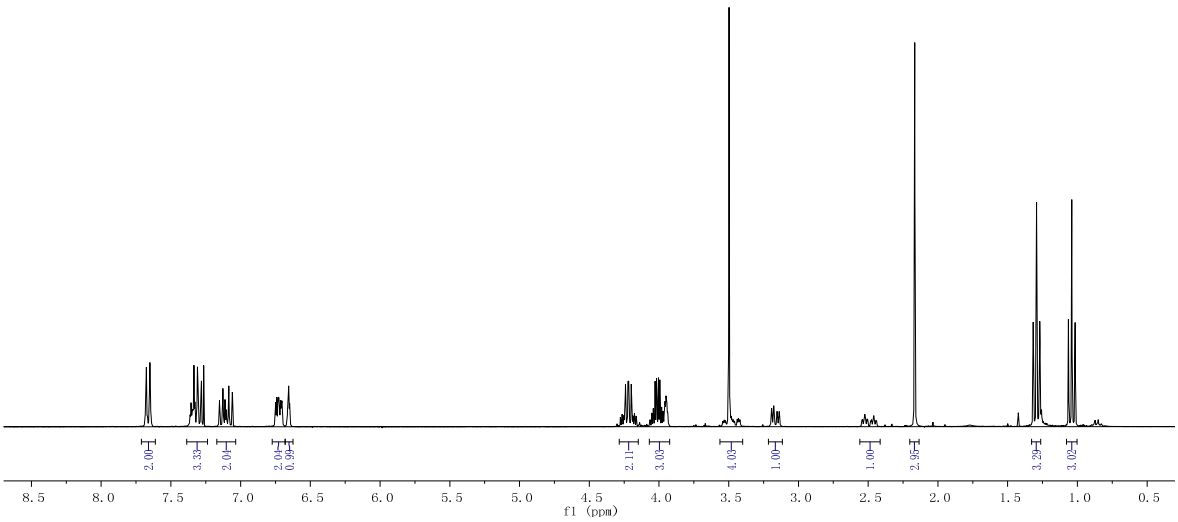
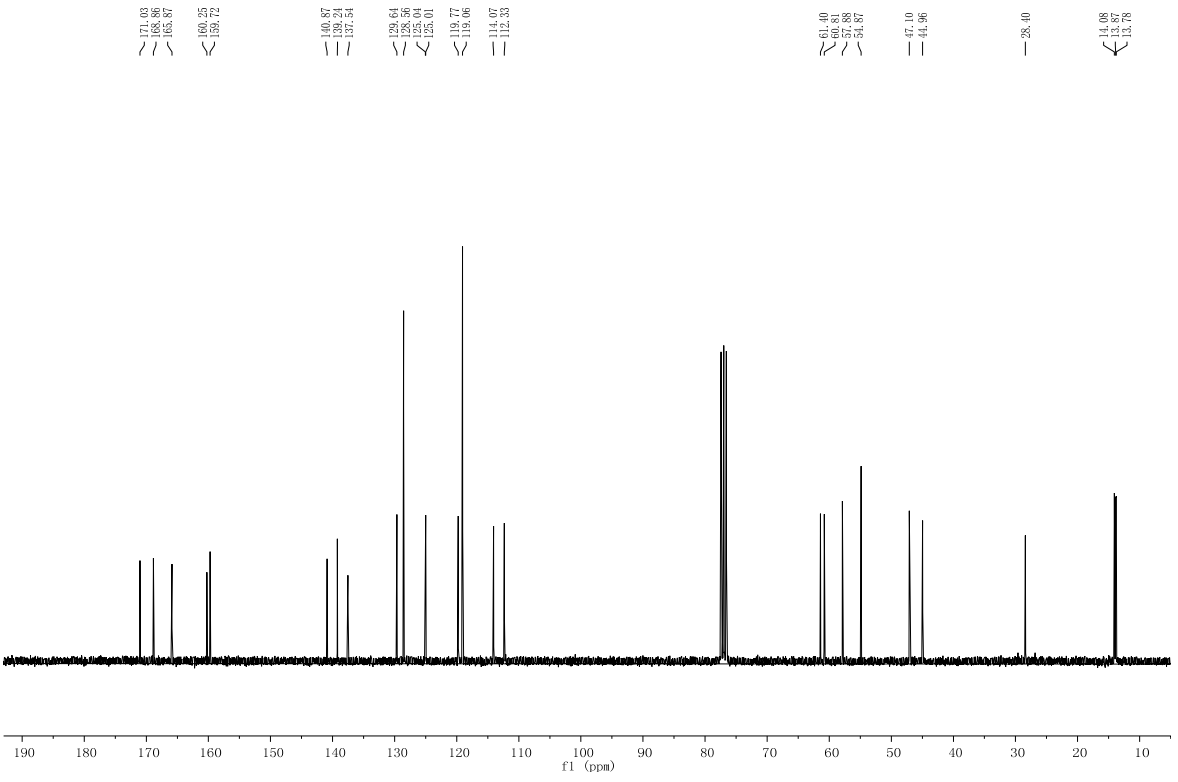





EtO2C
EtO2C
O
N–N
Ph
OMe

3la


2.00
3.33
2.04
2.04
0.99
2.11
3.03
4.03
1.00
1.00
2.95
3.29
3.02
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)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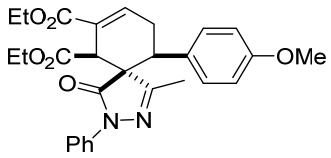
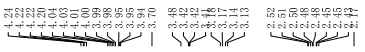
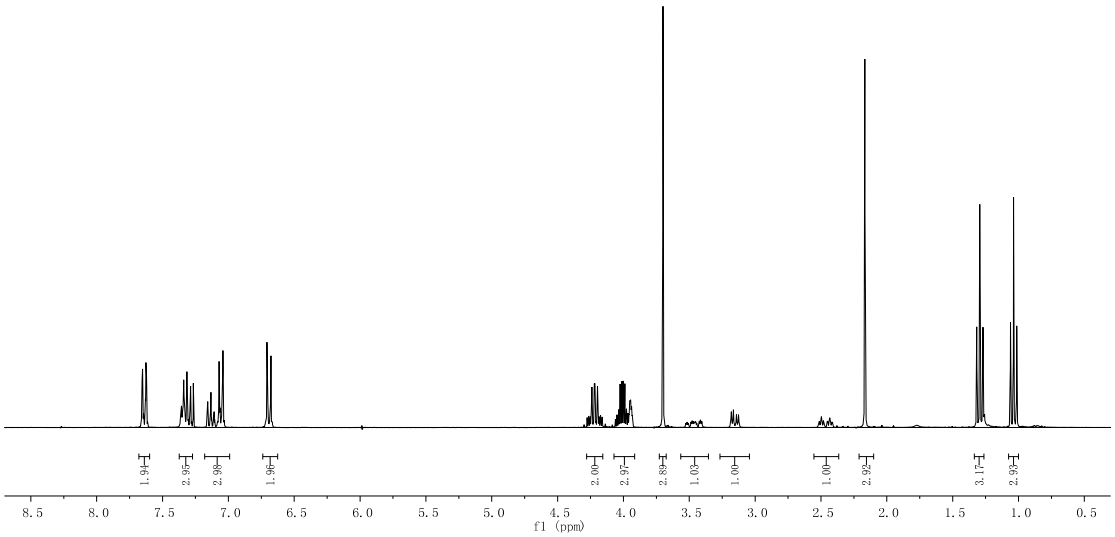
f1 (ppm)


EtO2C
EtO2C
O
N–N
Ph
OMe

3ma




1.94
2.96
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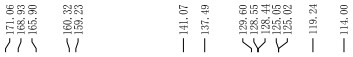
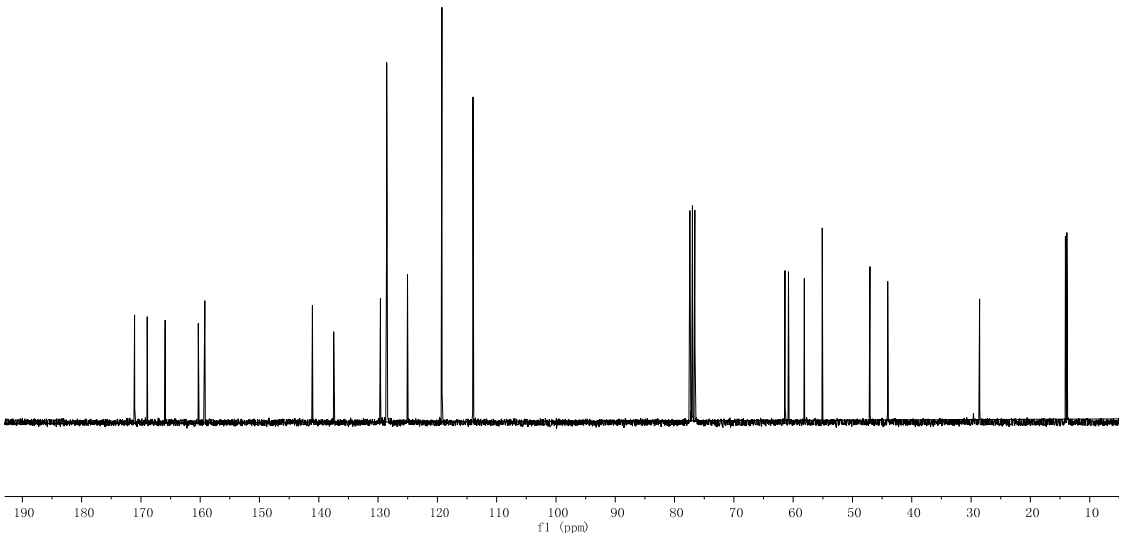
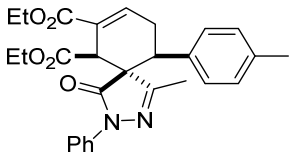
1.96
2.00
2.97
2.89
1.03
1.00
1.00
2.92
3.17
2.93
f1 (ppm)




f1 (ppm)



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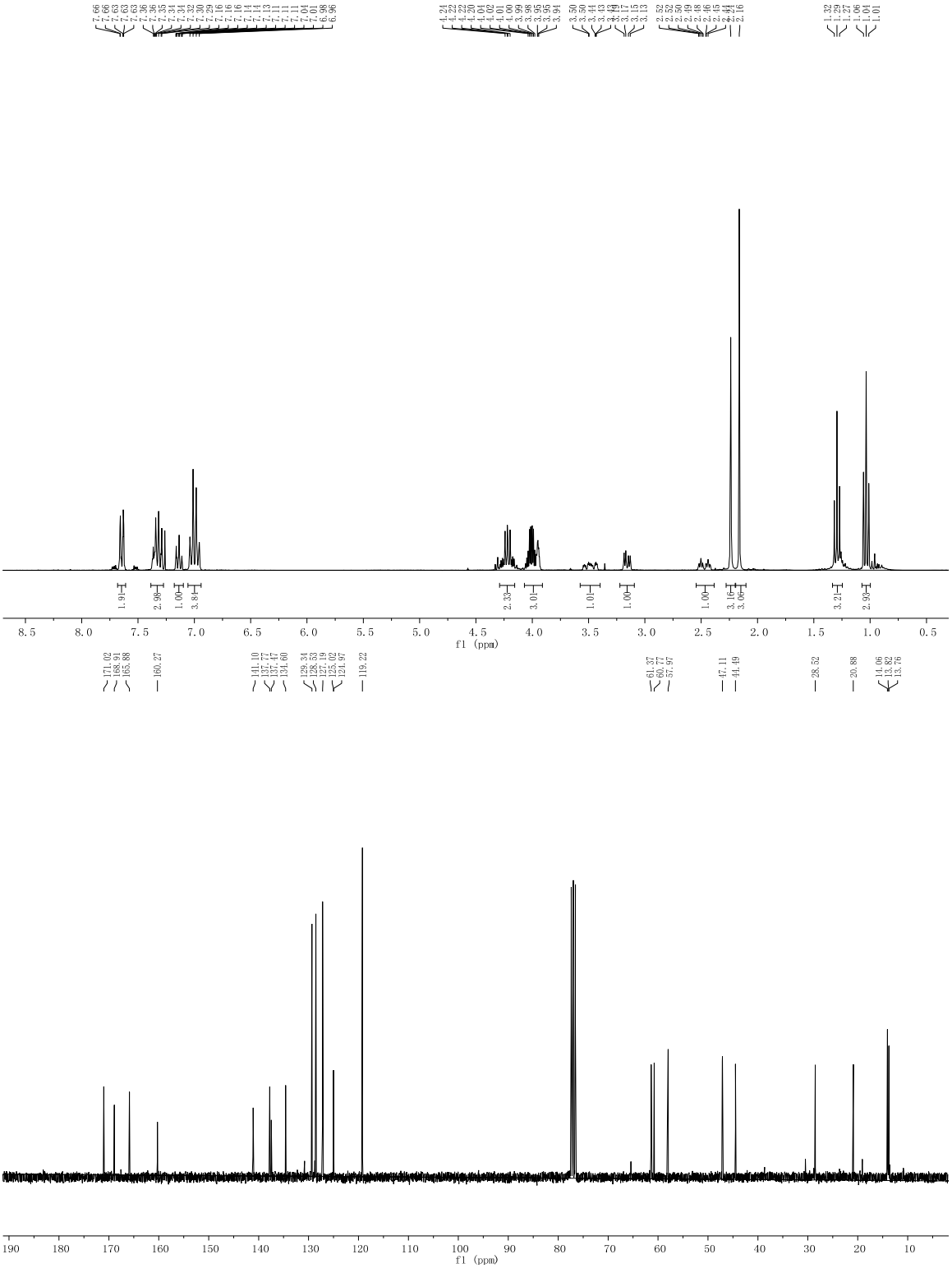
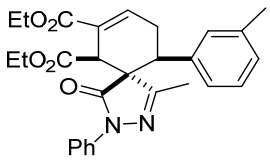
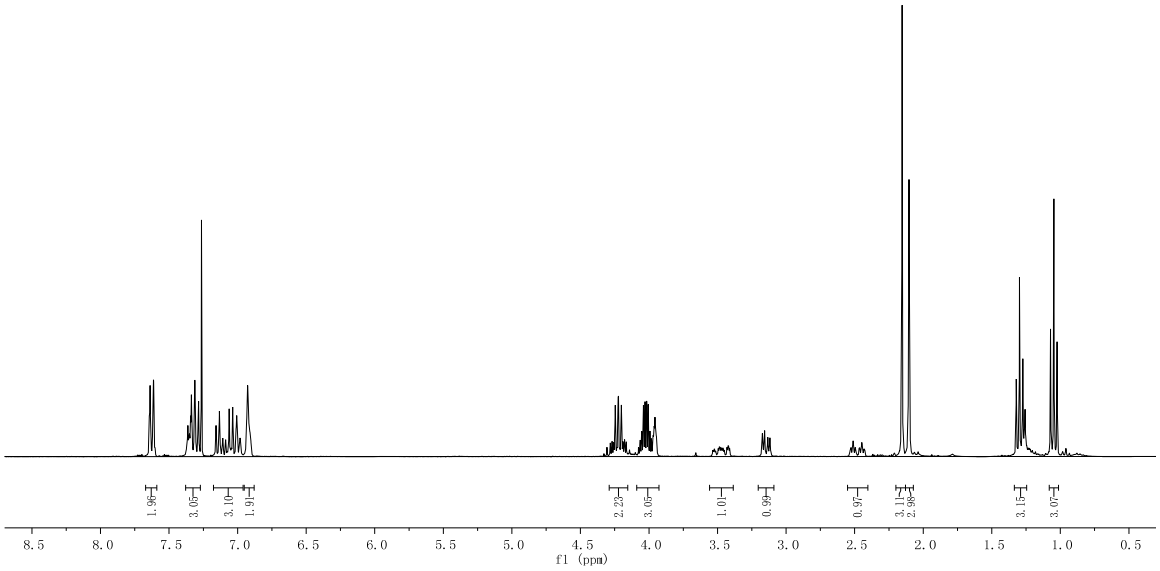


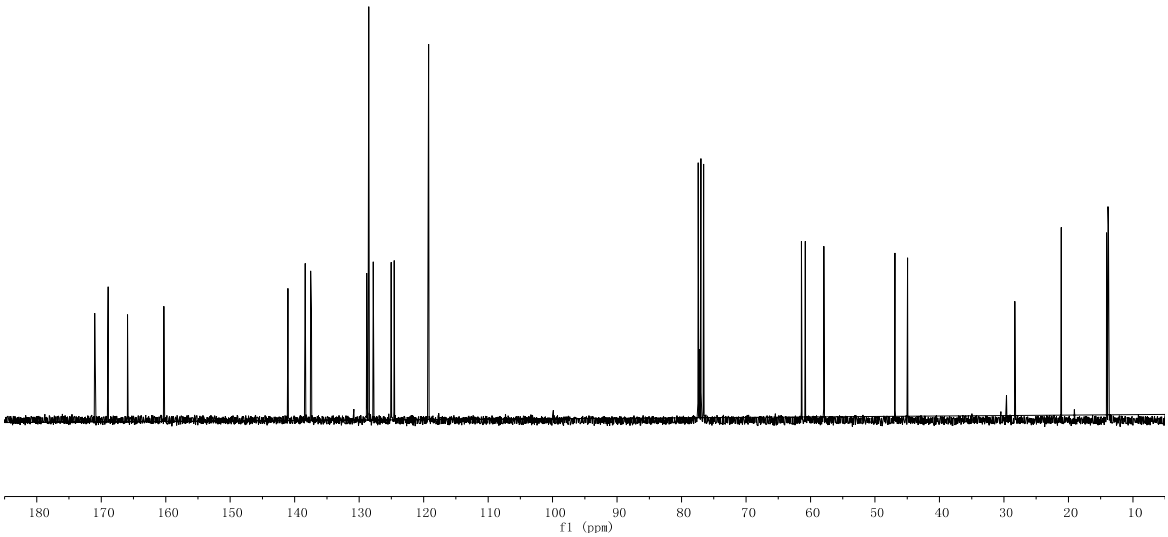

EtO2C
EtO2C
O
N–N
Ph

3oa


7.64 7.61 7.61 7.61 7.37 7.36 7.35 7.34 7.34 7.33 7.31 7.29 7.28 7.16 7.13 7.06 7.04 7.01 6.93 6.91 6.91
4.25 4.22 4.22 4.20 4.05 4.04 4.03 4.02 4.01 3.99 3.97 3.96 3.96 3.95
3.17 3.16 3.13 3.12
2.53 2.53 2.51 2.50 2.49 2.47 2.46 2.45 2.15 2.10
1.32 1.30 1.27 1.07 1.05 1.02


1.96 3.05 3.10 1.91 2.23 3.05 1.01 0.99 0.97 3.14 2.96 3.15 3.07
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


171.03 168.93 165.92 160.29 141.06 138.37 137.51 137.41 128.82 128.52 128.46 127.81 125.04 125.00 124.55 119.22 61.39 60.86 57.94 46.90 44.94 28.31 21.11 14.67 13.55 13.18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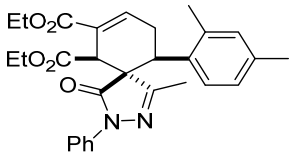
f1 (ppm)



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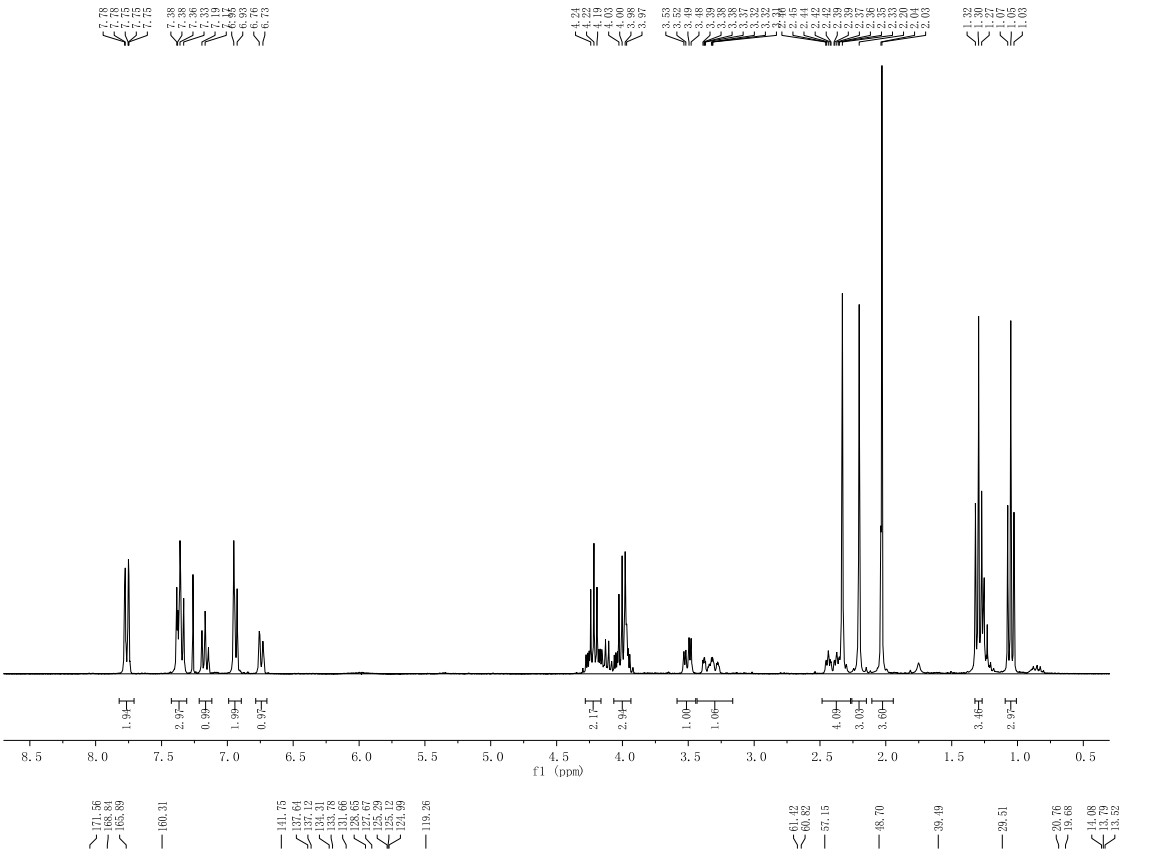

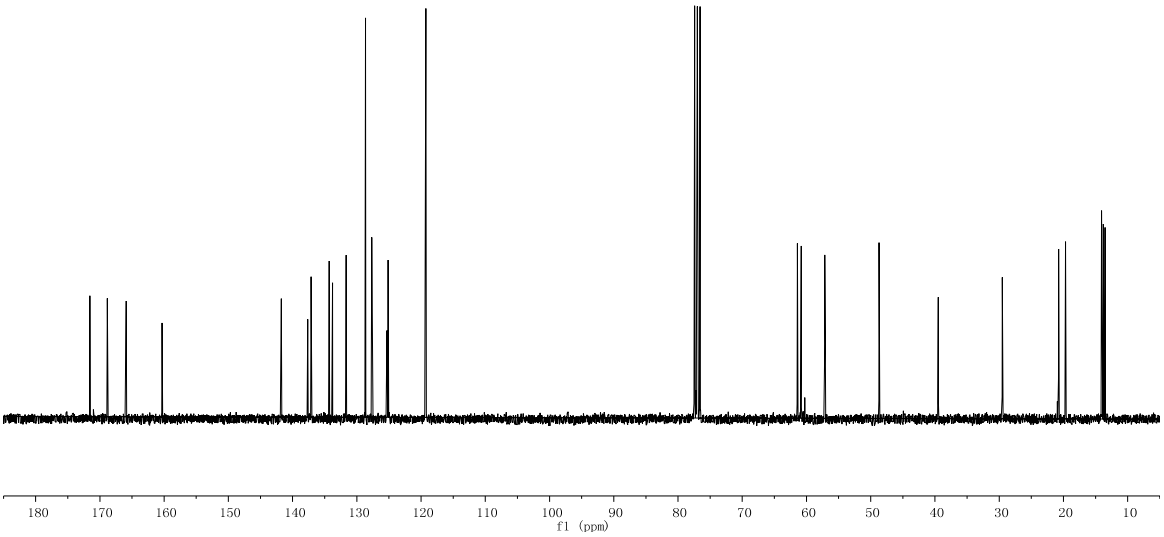

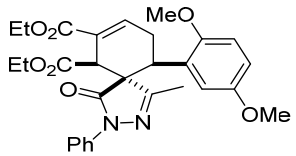

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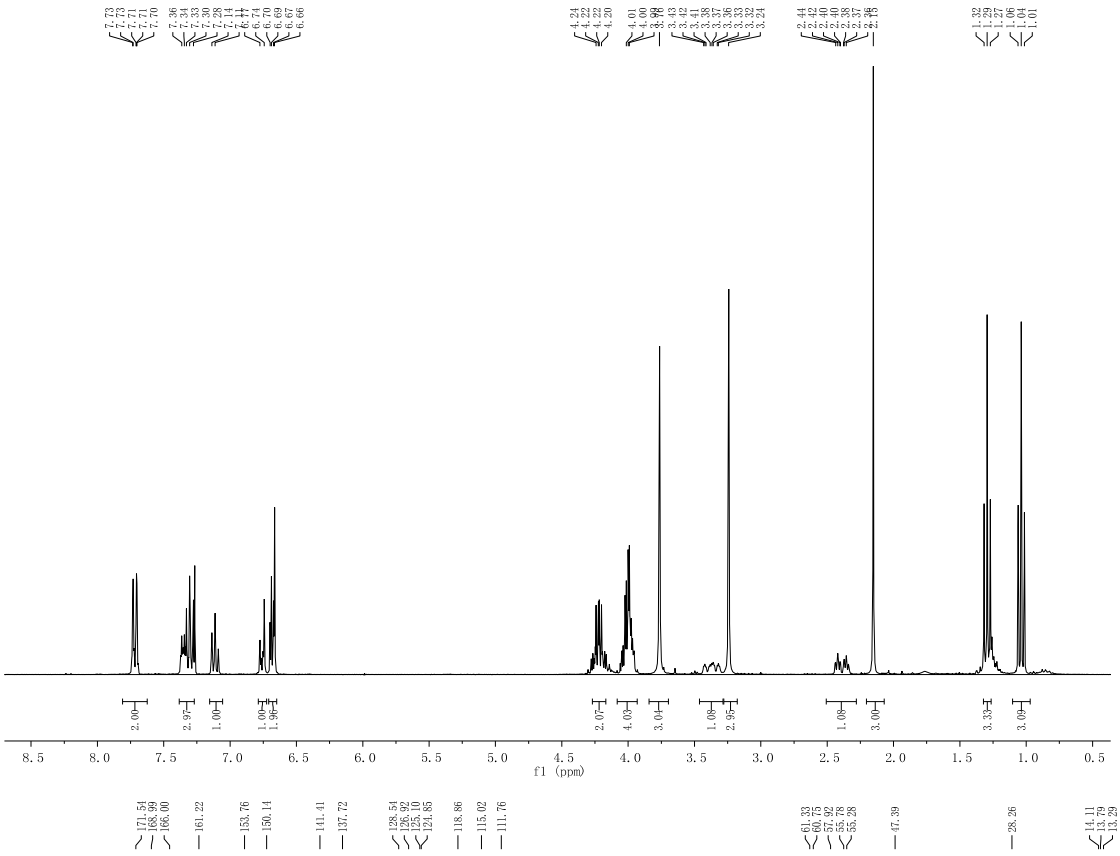

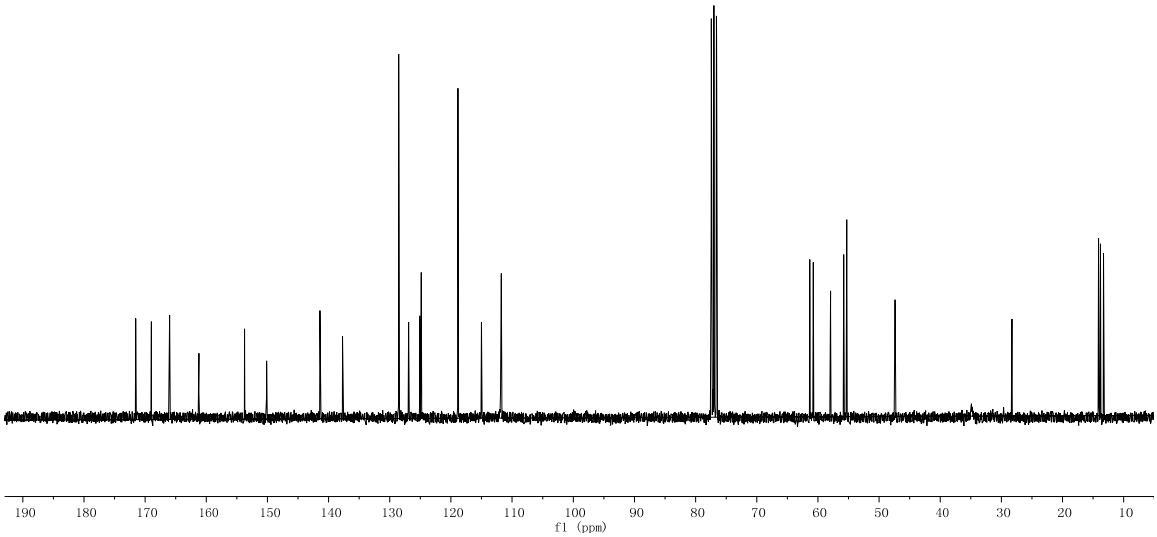

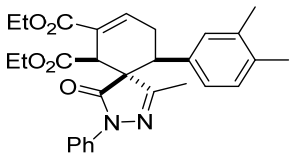

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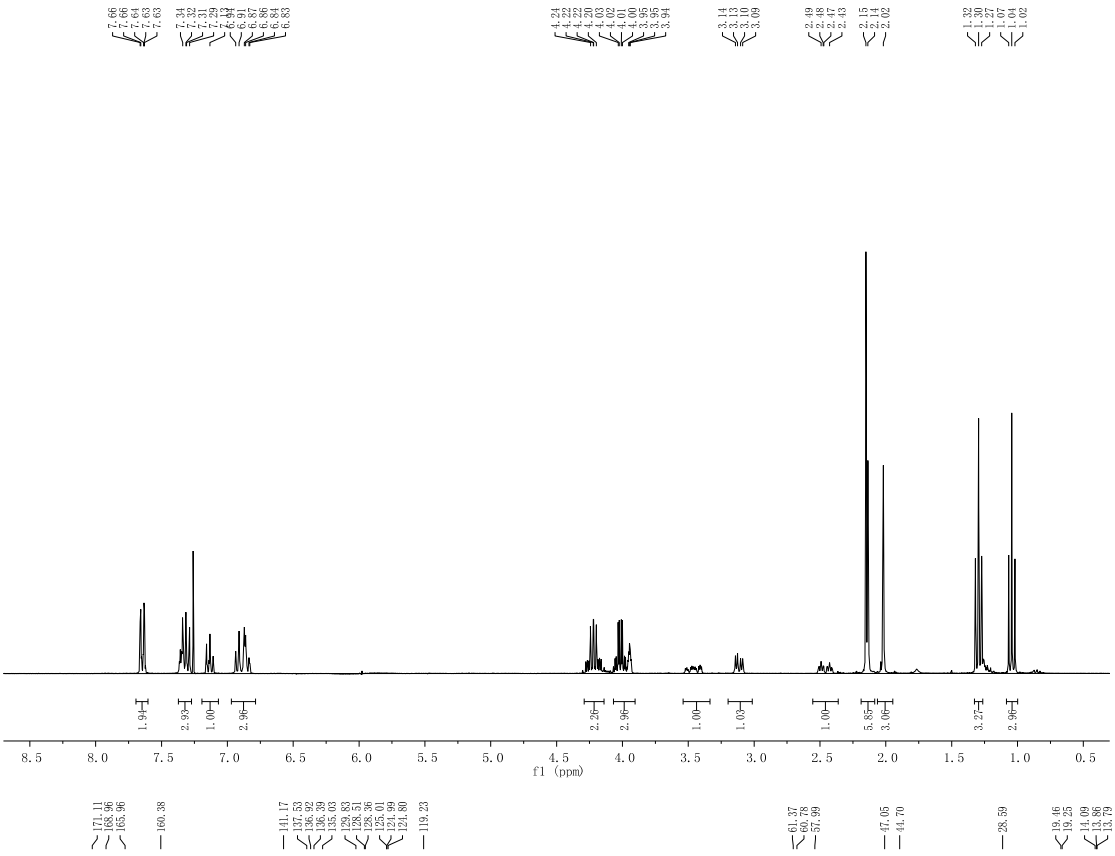

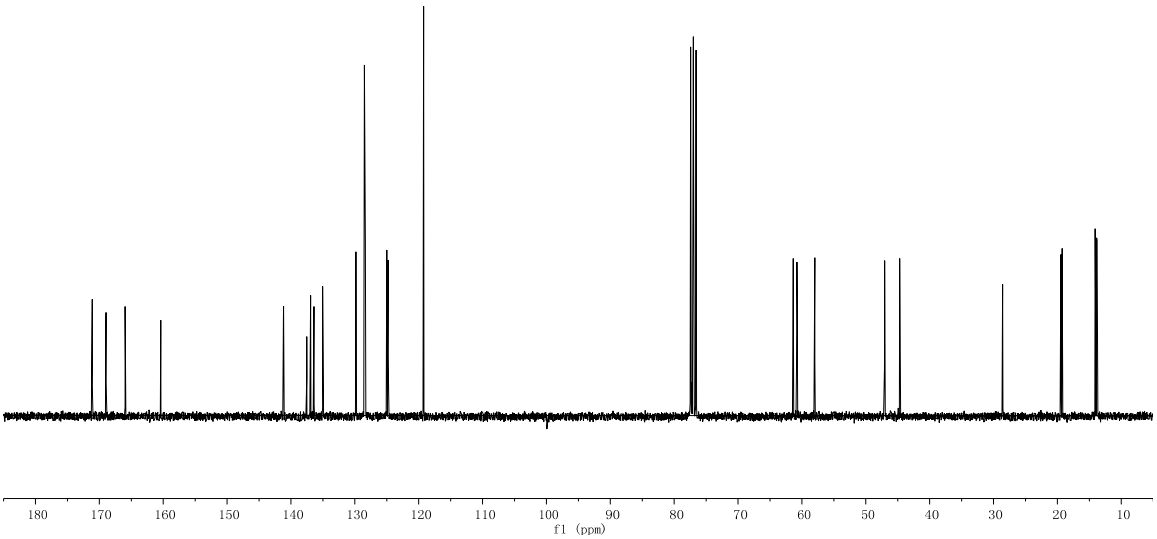

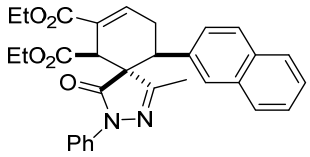

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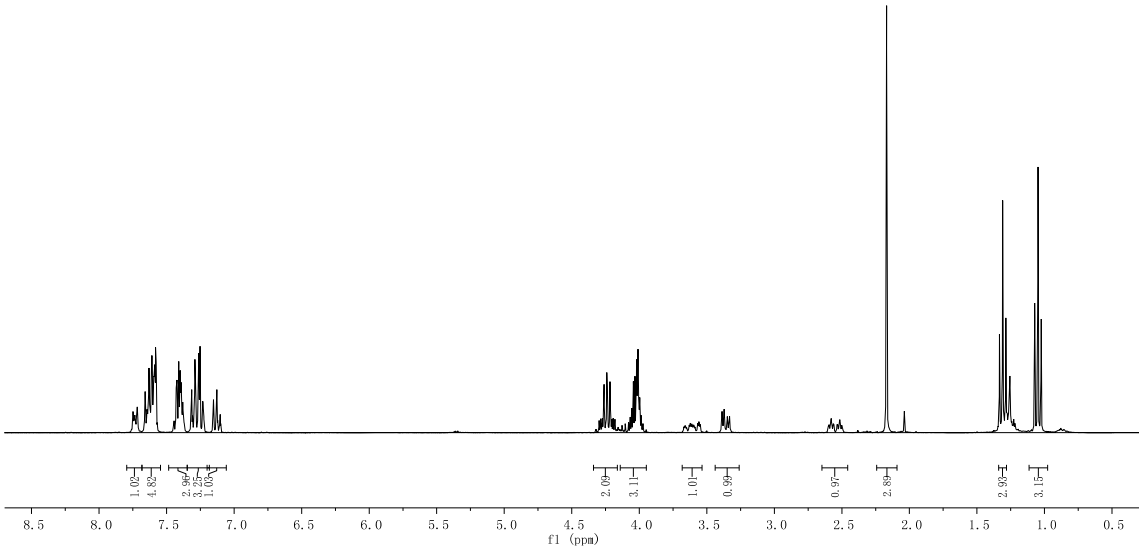

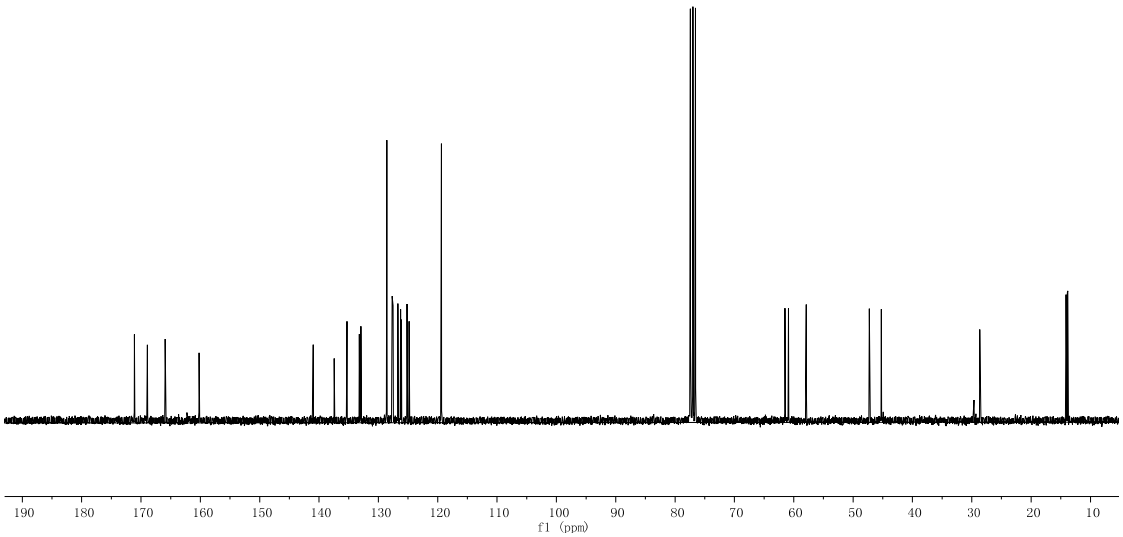

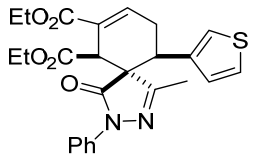

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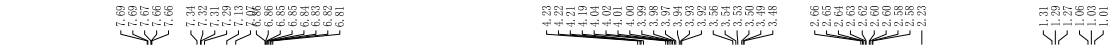
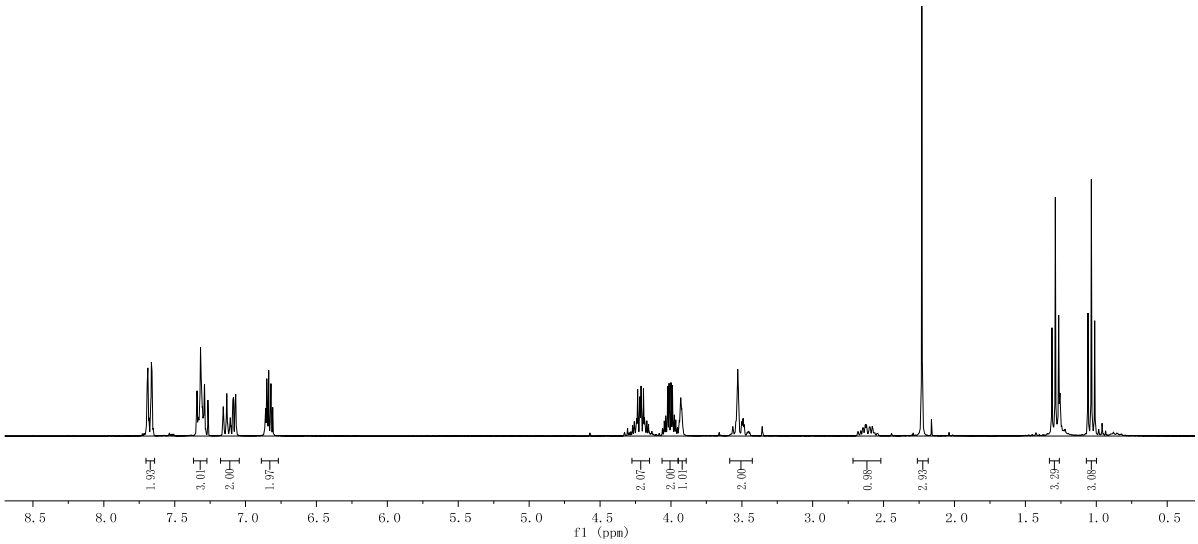
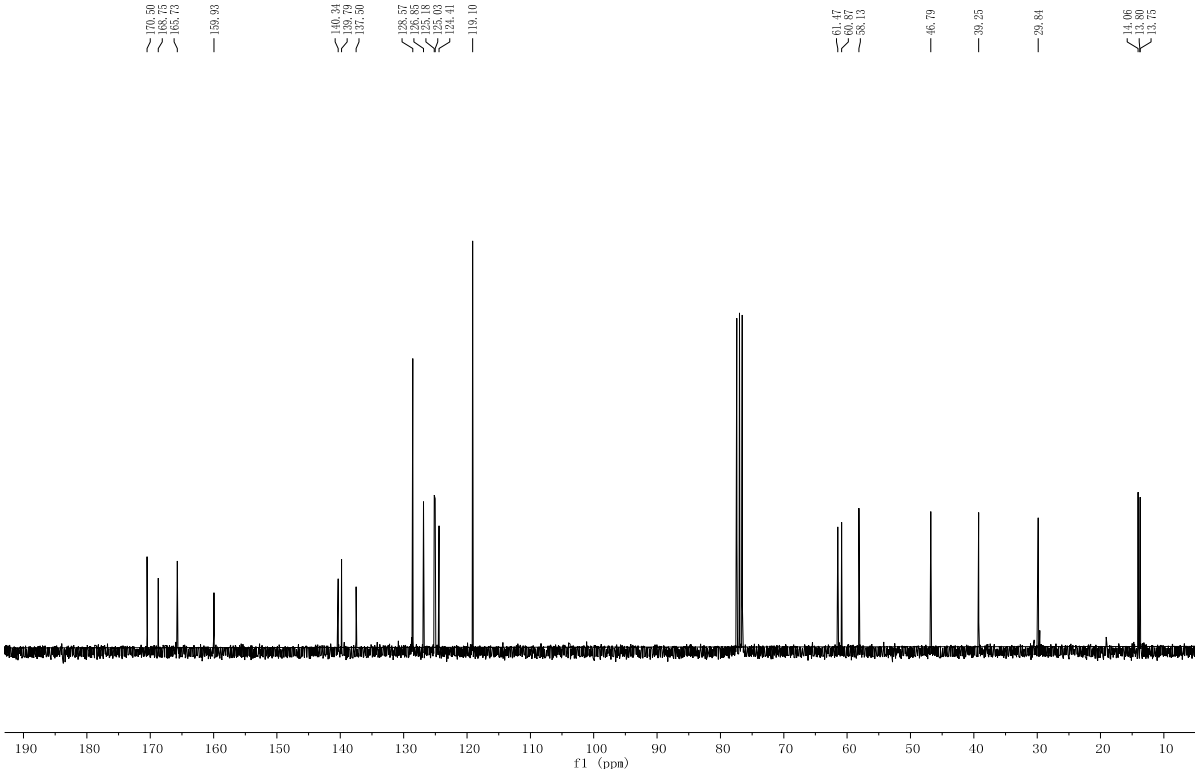
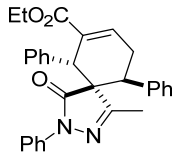
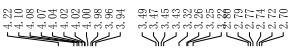


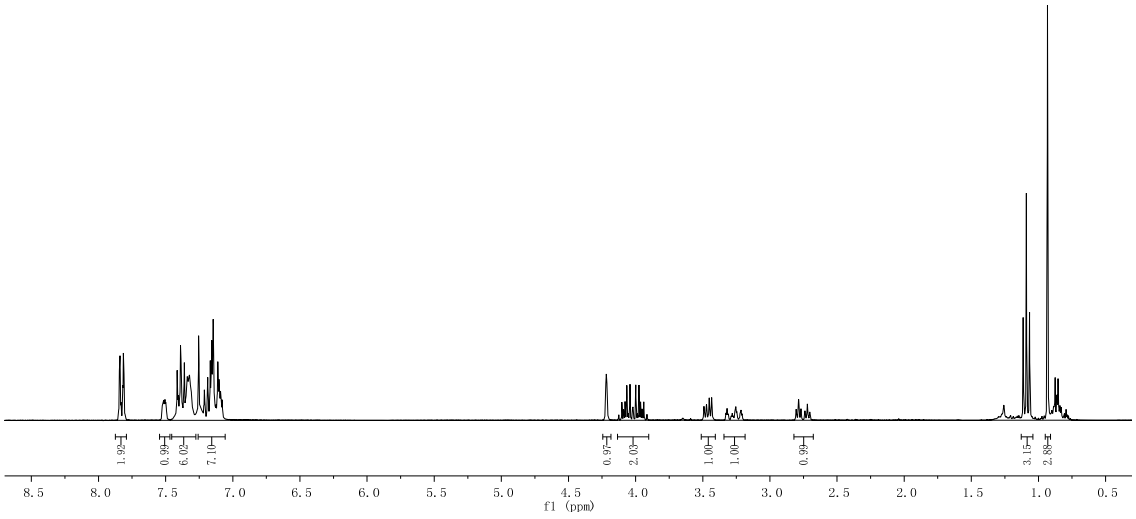


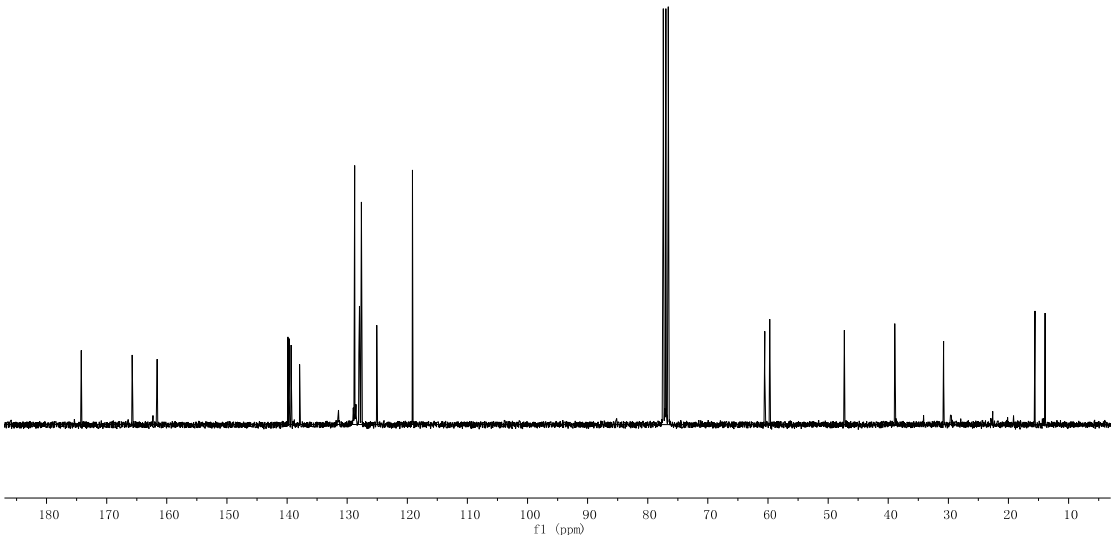


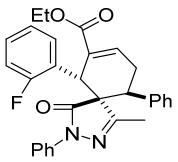

EtO2C
Ph
O
Ph
N
N
Ph

4ab

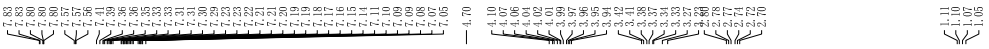


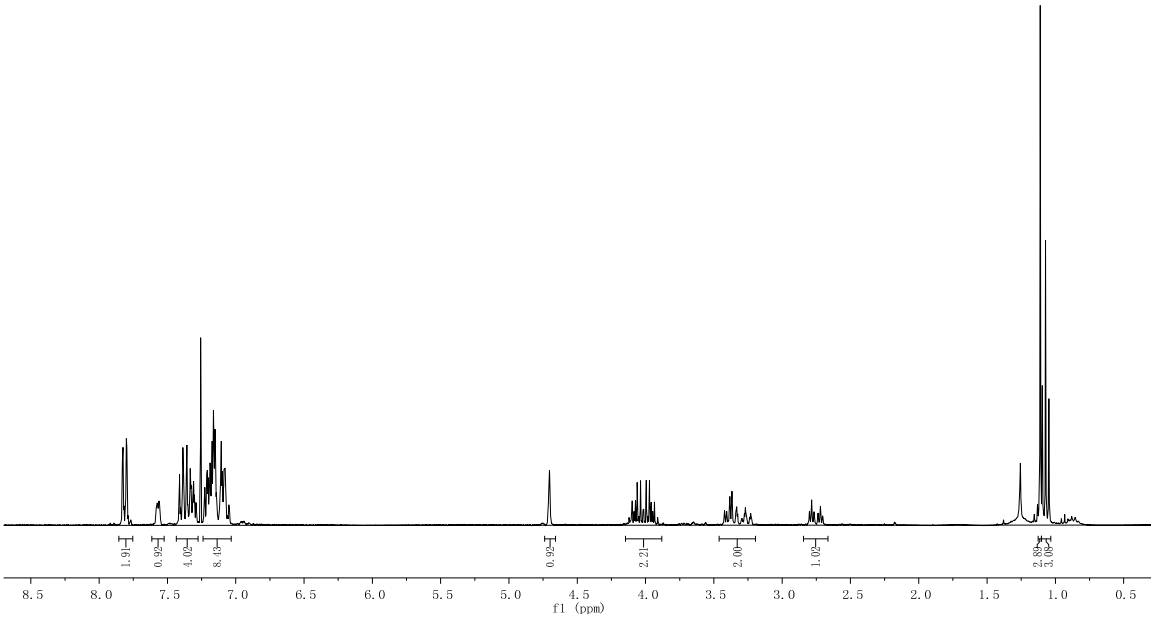

1.99
0.99
6.02
7.10
0.97
2.03
1.00
1.00
0.99
3.15
2.88
f1 (ppm)


f1 (ppm)


EtO
O
F
O
Ph
N
N
Ph

4ac




1.91
0.92
4.02
8.43
0.92
2.21
2.00
1.02
2.89
3.00
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
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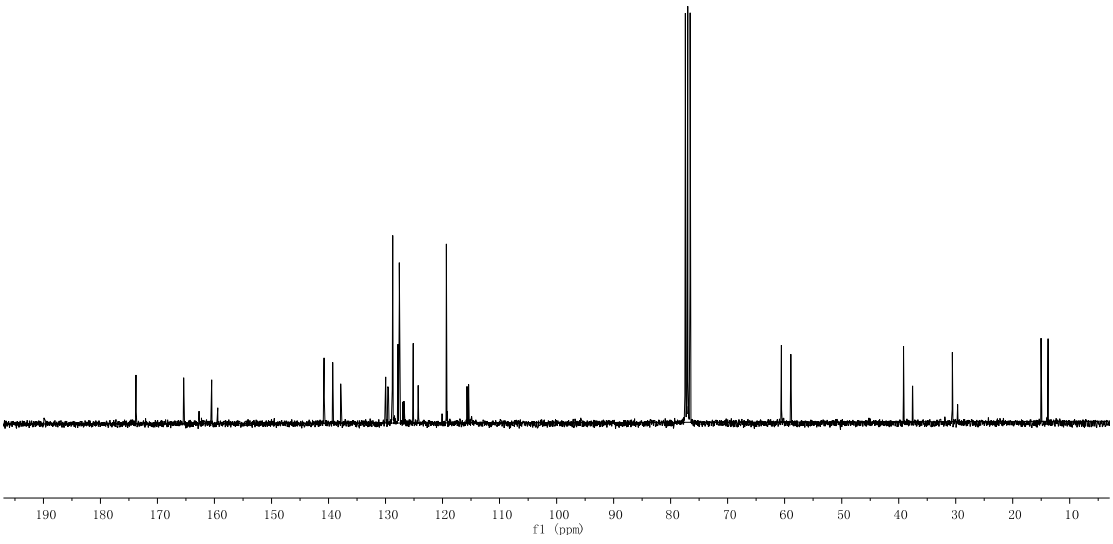
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


190
180
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140
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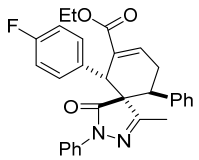
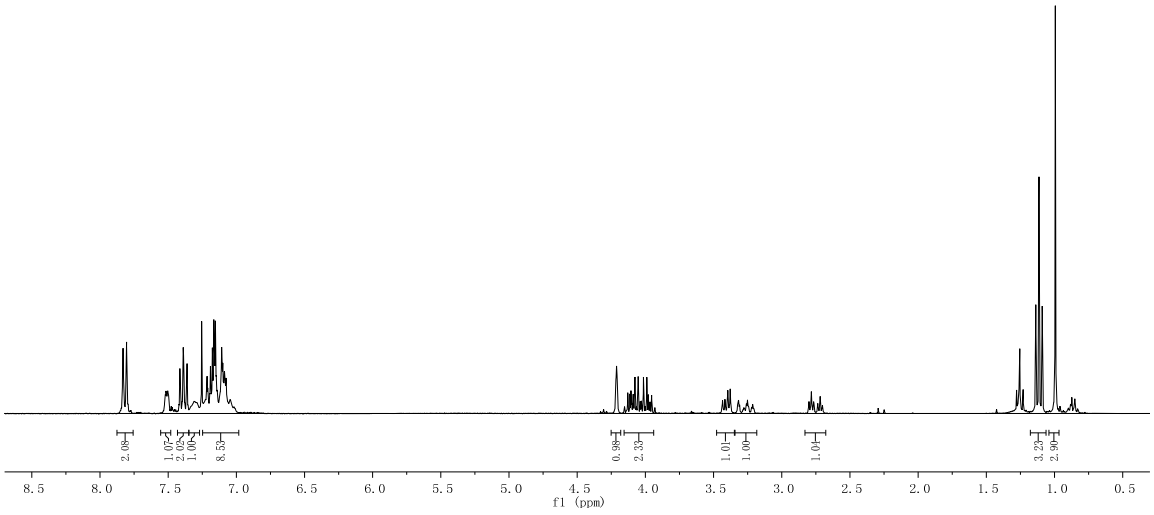
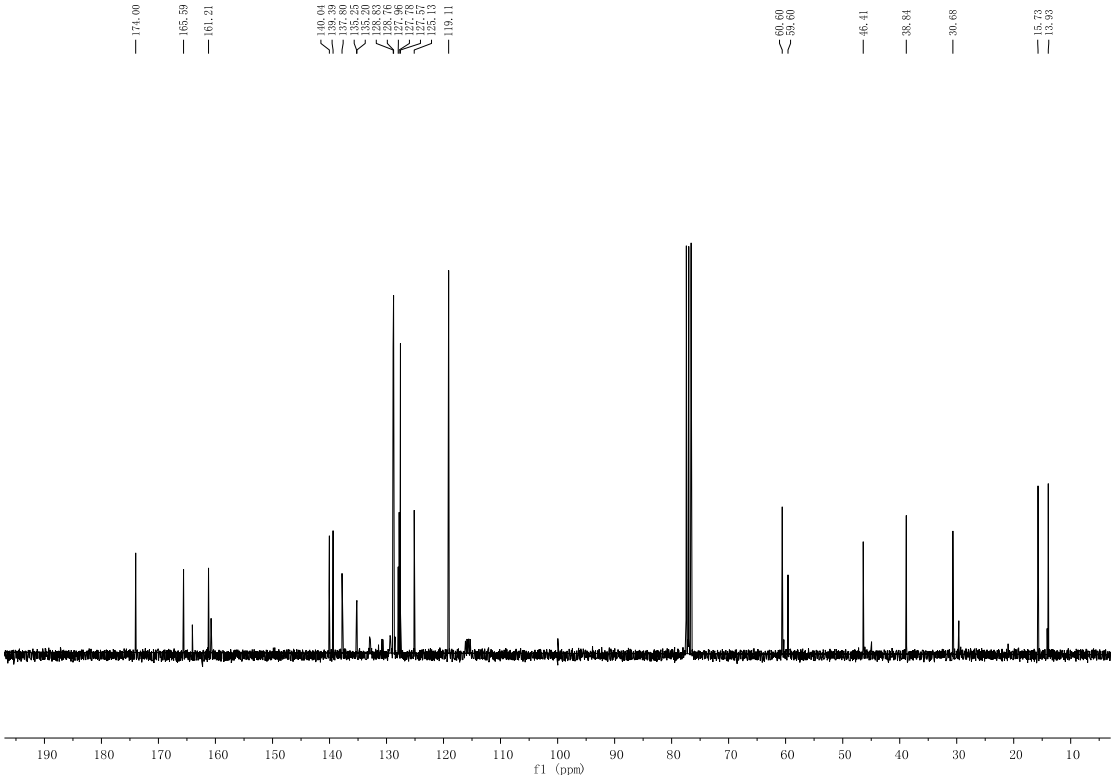
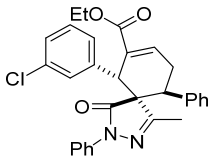
100
90
80
70
60
50
40
30
20
10
f1 (ppm)



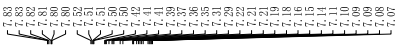
4ad

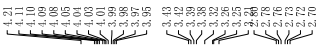


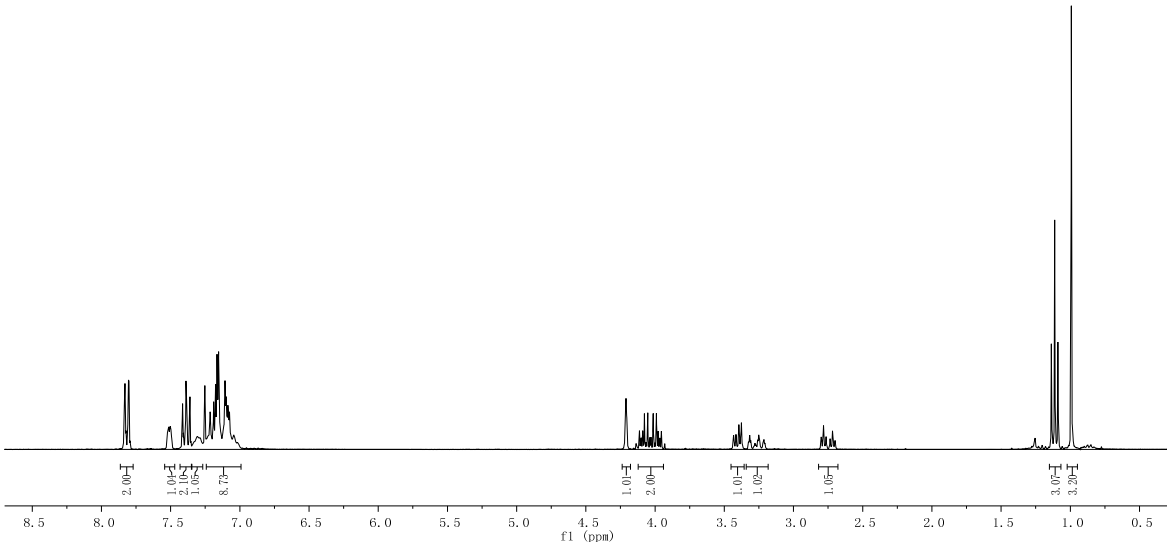


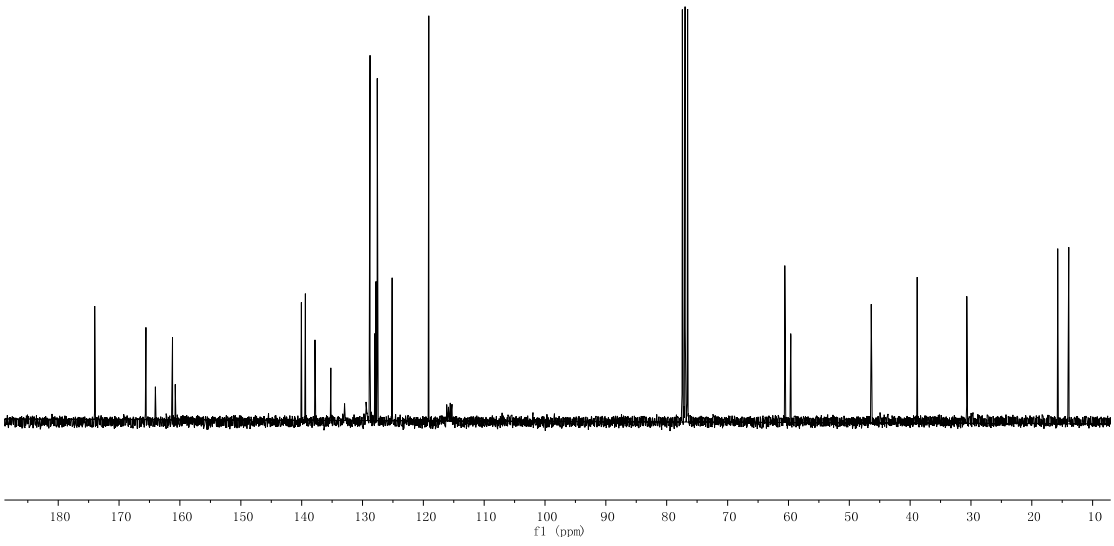

EtO
O
Cl
Ph
O
N
N
Ph

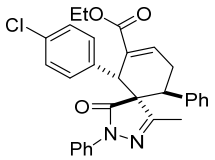
4ae



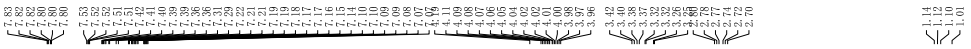


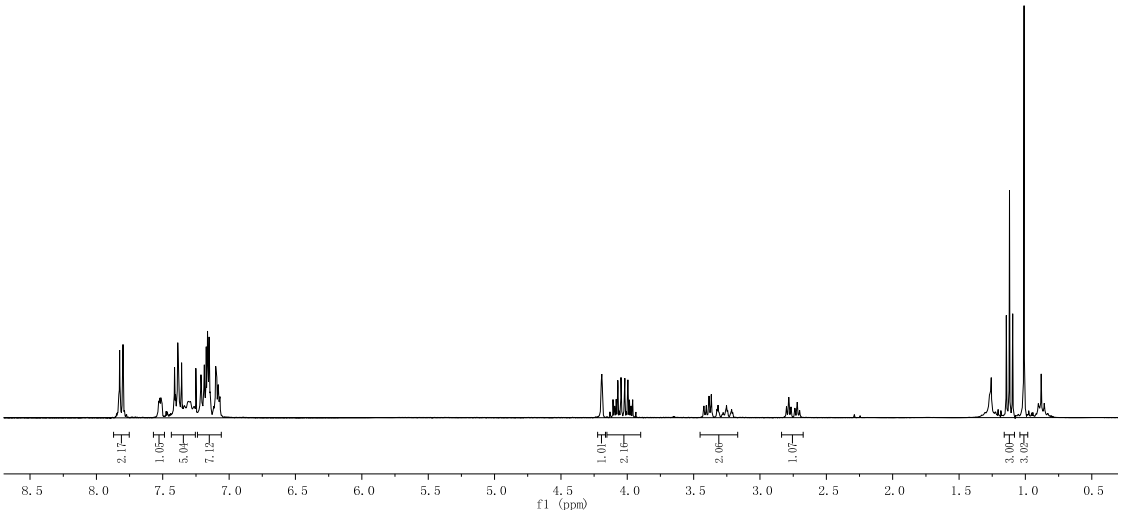

2.00
1.04
2.15
1.05
8.73
1.01
2.00
1.01
1.02
1.05
3.07
3.20
f1 (ppm)

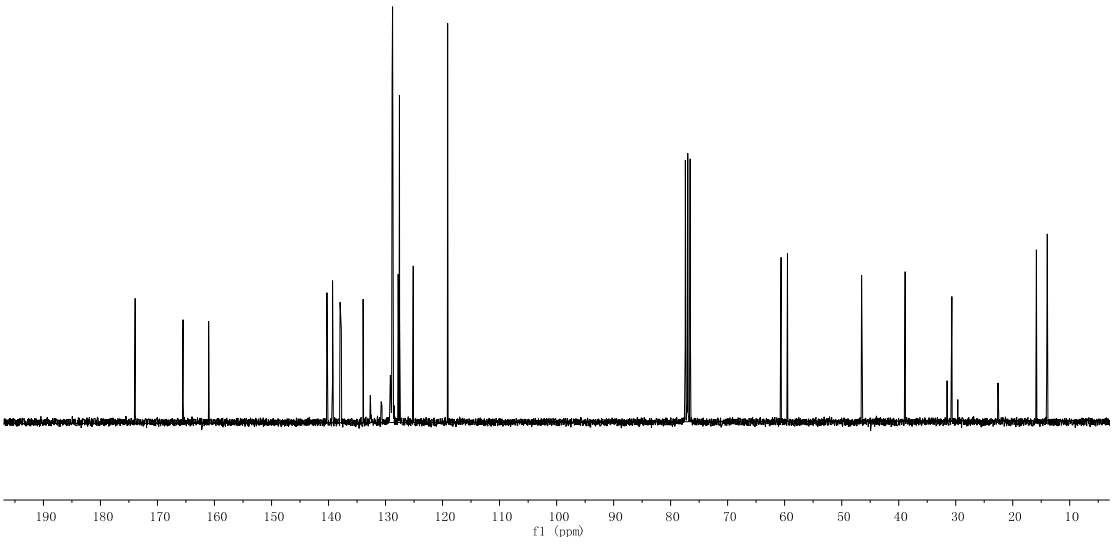

f1 (ppm)

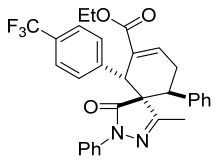

Cl
EtO
O
O
Ph
N
N
Ph

4af

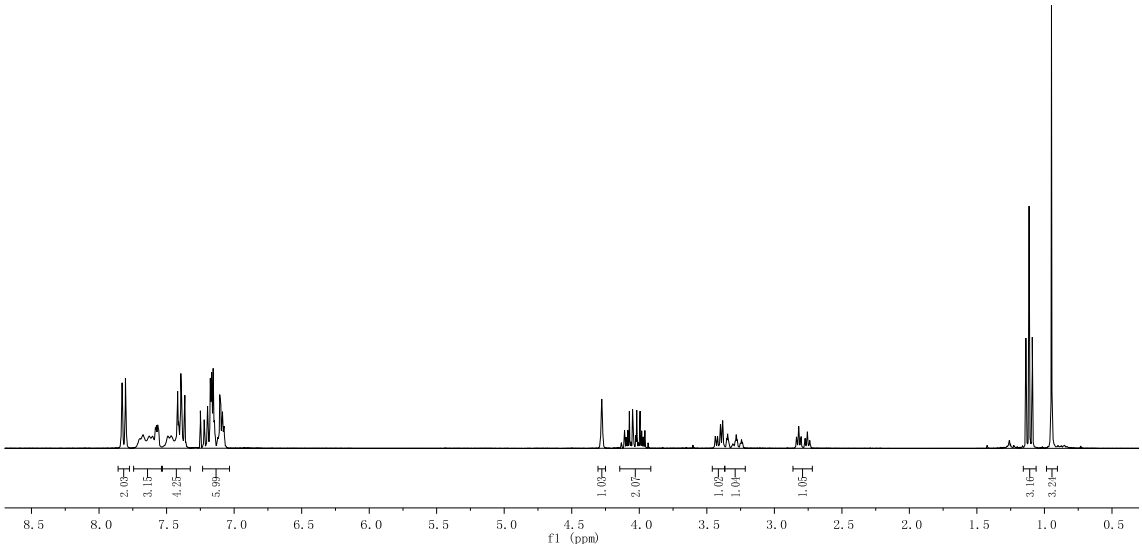


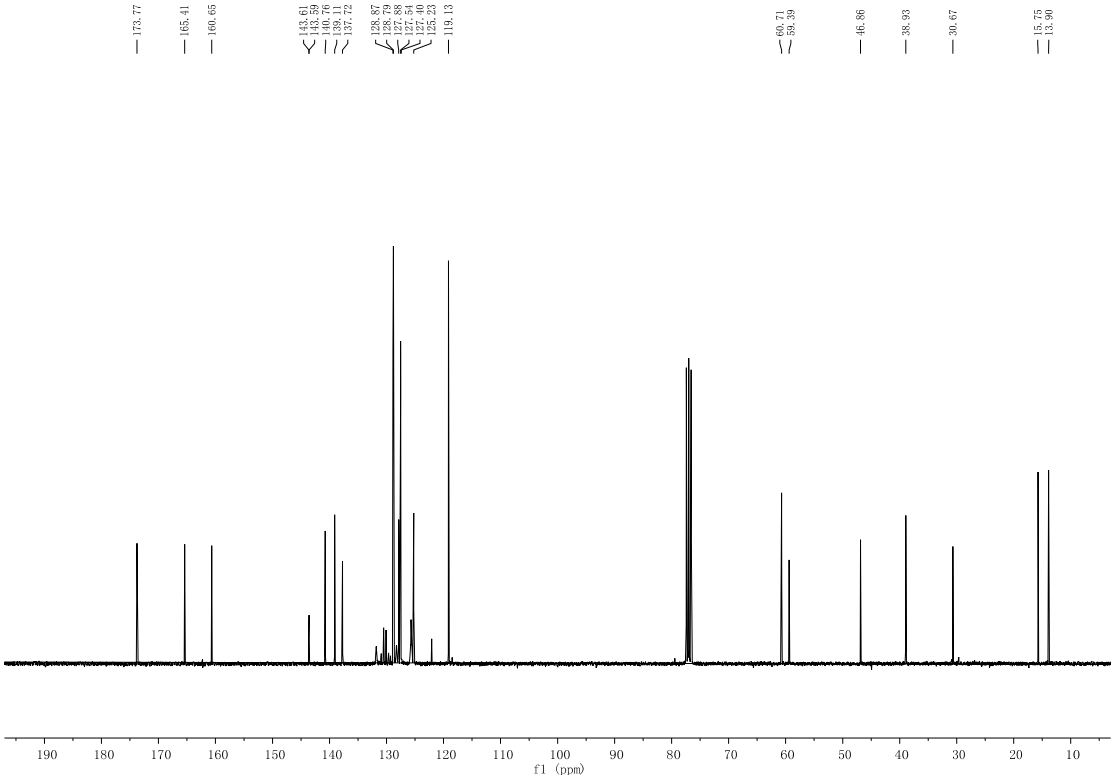

2.17
1.05
5.04
7.12
1.01
2.16
2.00
1.07
3.00
3.02
f1 (ppm)

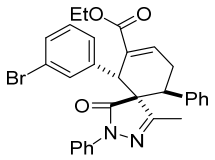

f1 (ppm)


EtO
O
F3C
Ph
O
N
N
Ph

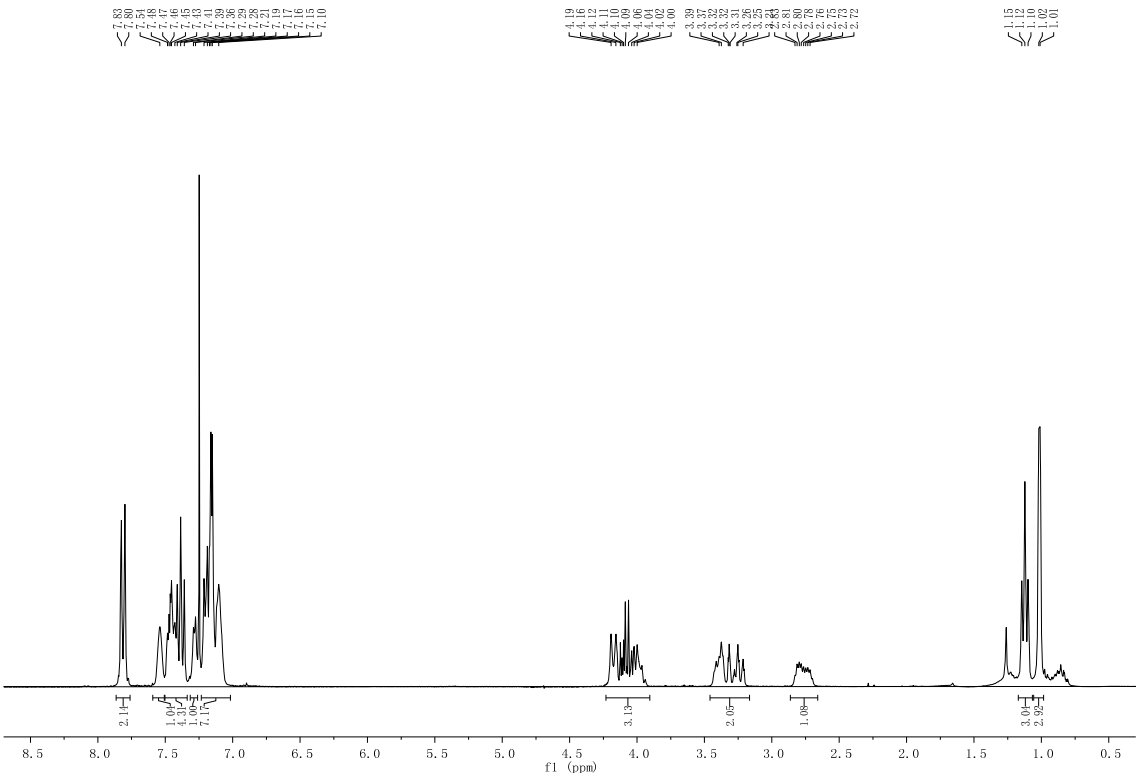
4ag

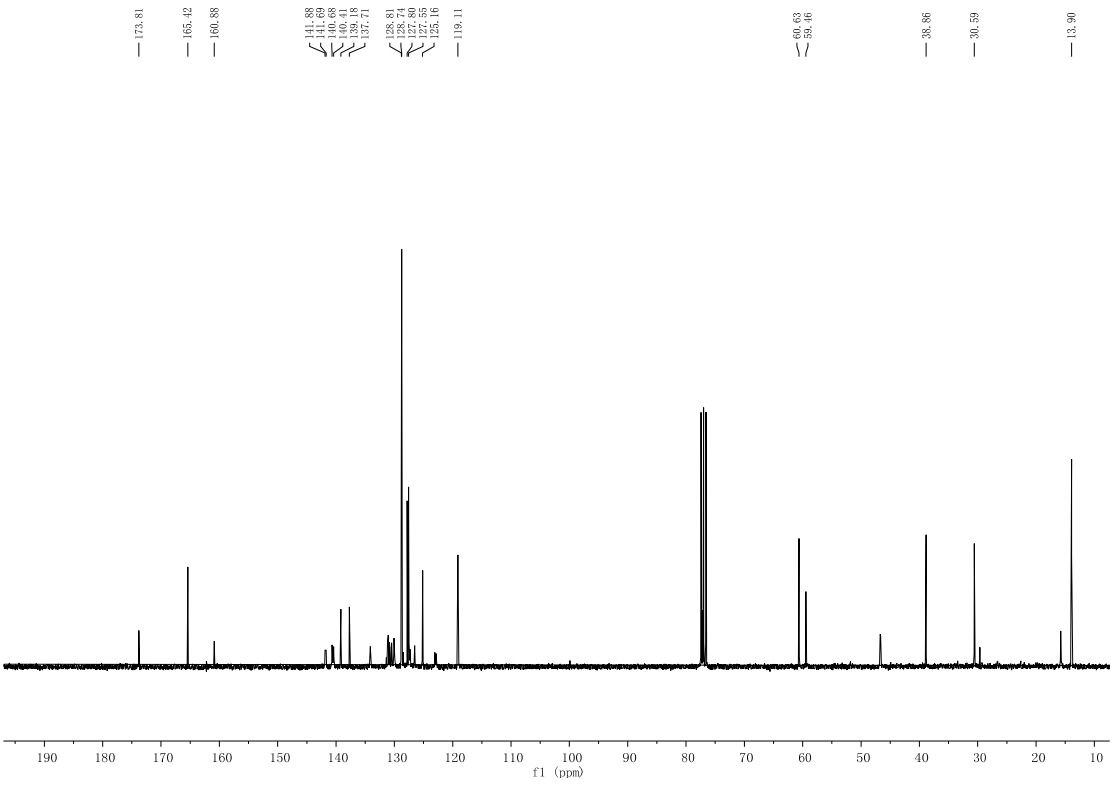

2.03
3.15
4.25
5.99
1.03
2.07
1.02
1.04
1.05
3.10
3.24
f1 (ppm)

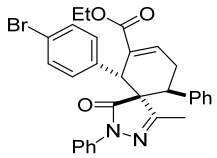

f1 (ppm)



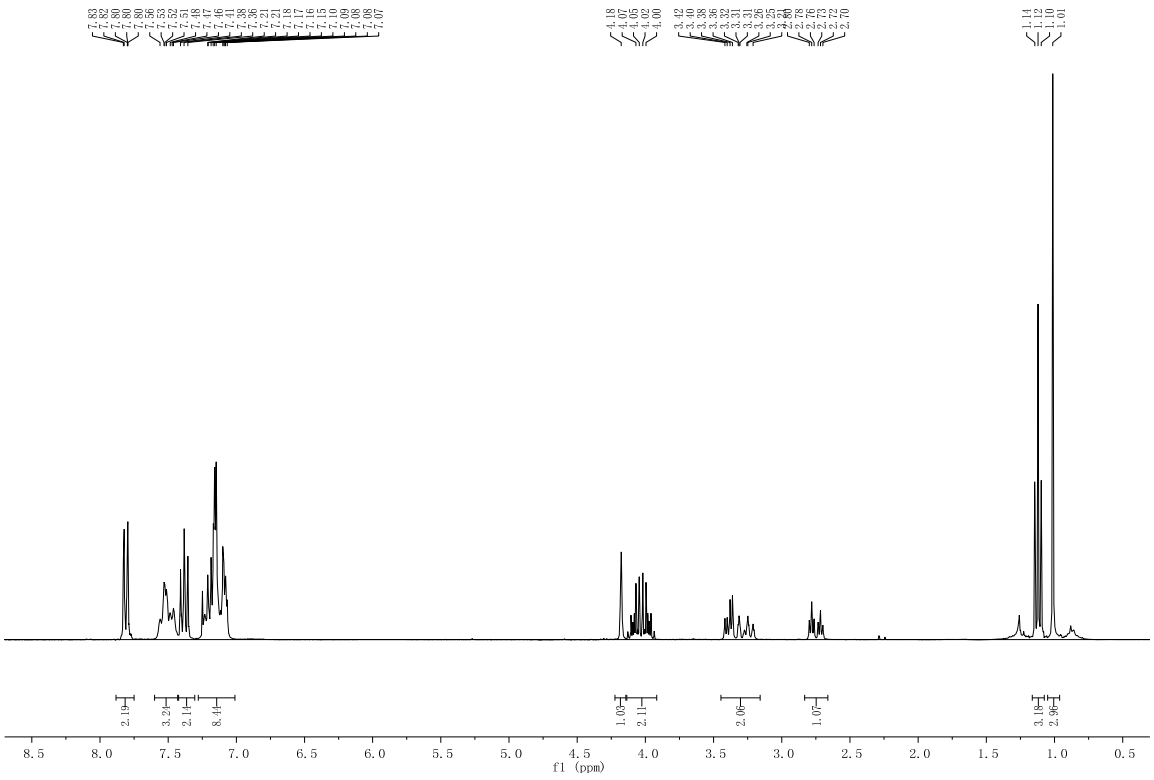
4ah

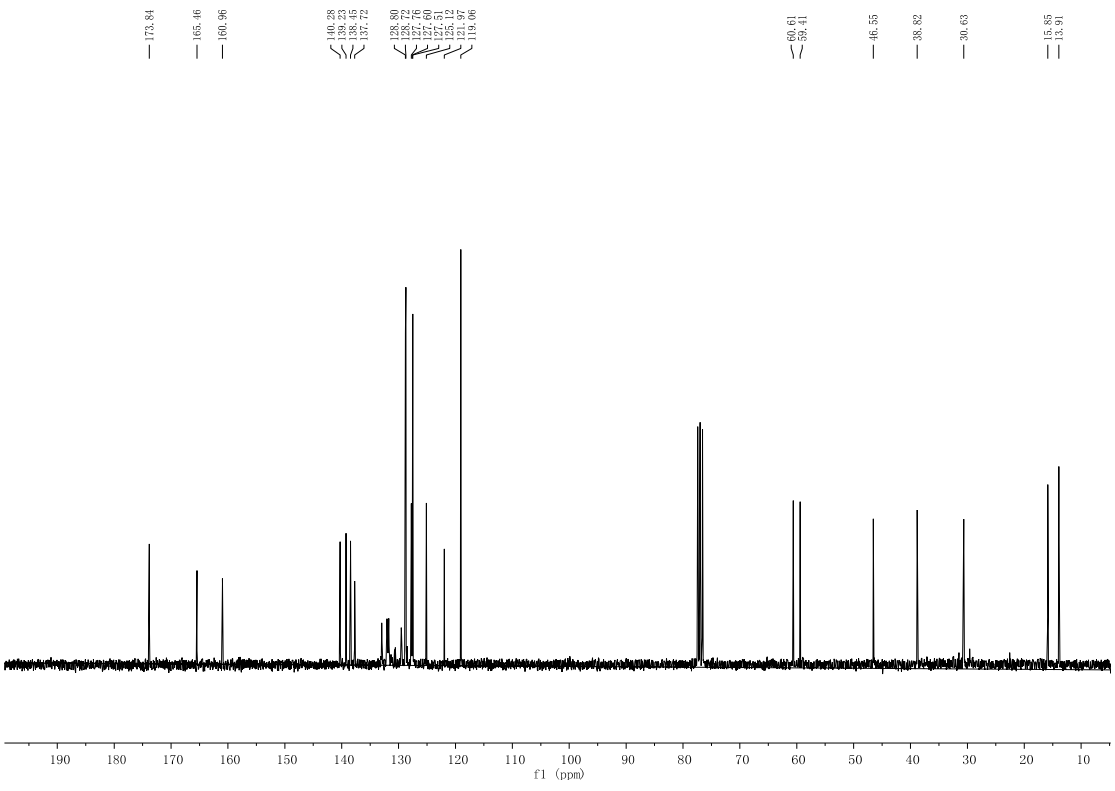


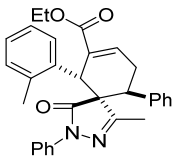




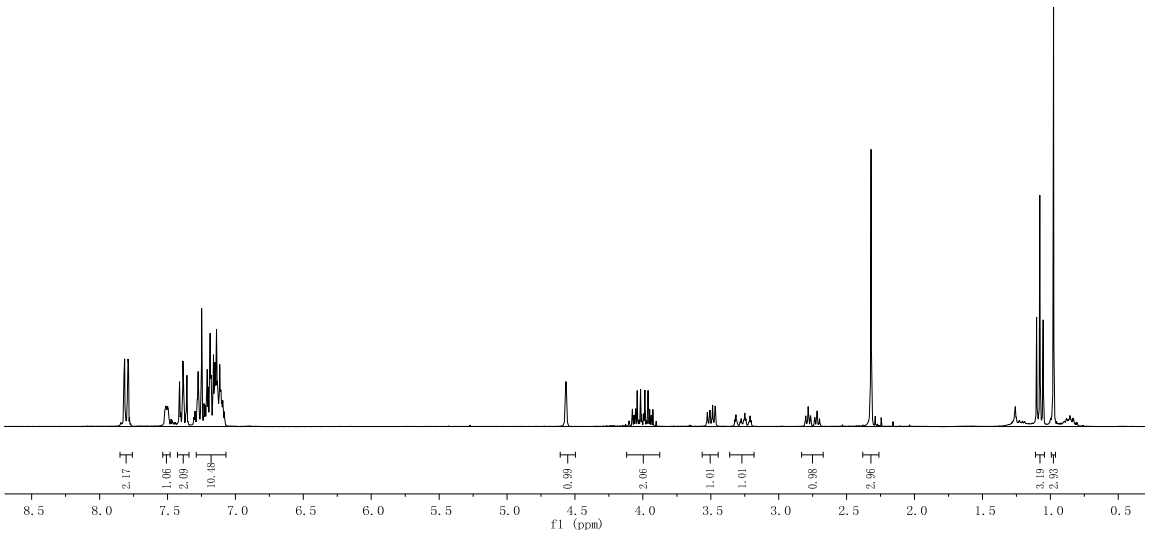
4ai

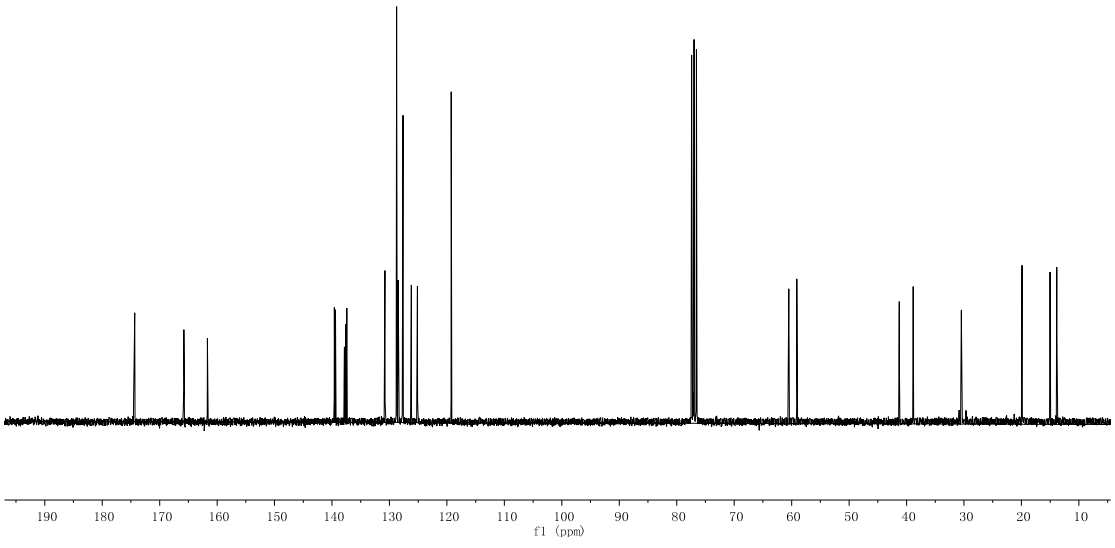


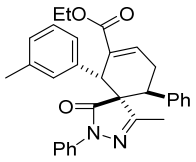



EtO
O
O
Ph
N
N
Ph

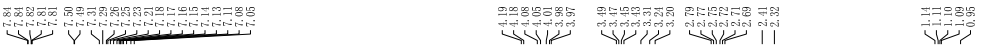
4aj

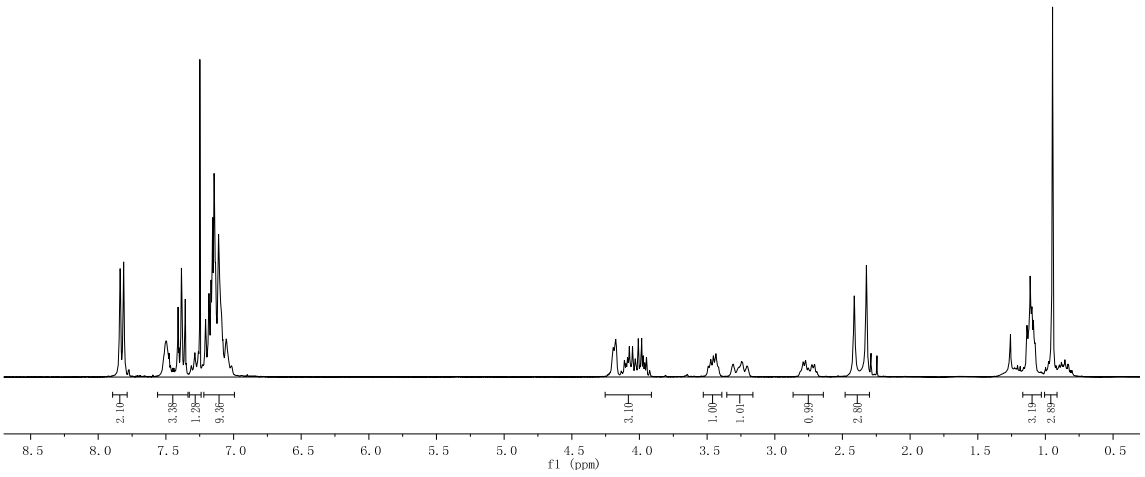

2.17
1.06
2.09
10.48
0.99
2.06
1.01
1.01
0.98
2.96
3.19
2.93
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

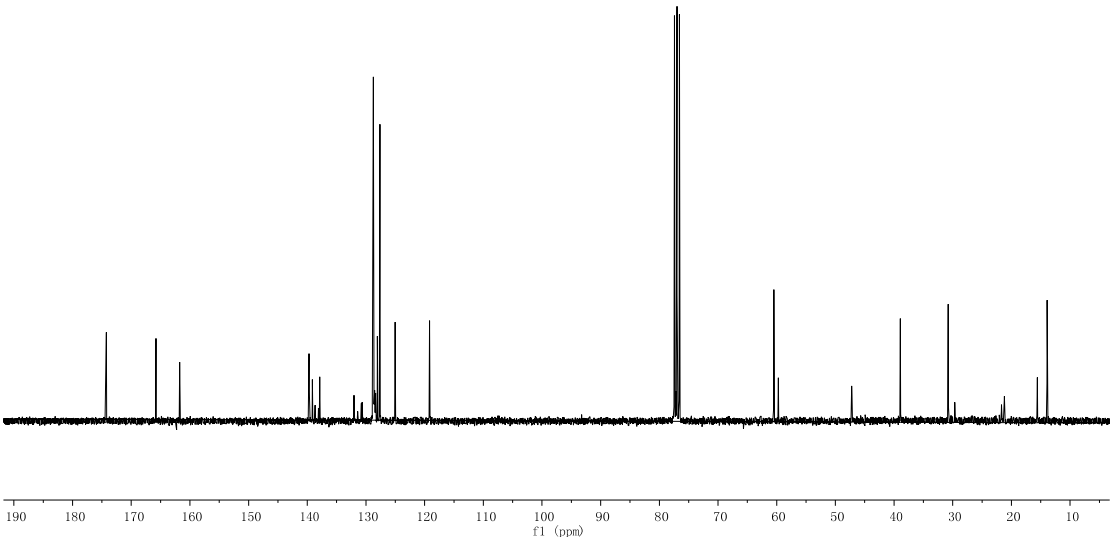

EtO
O
O
Ph
N
N
Ph

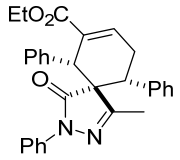
4ak


7.84
7.82
7.81
7.50
7.49
7.31
7.29
7.26
7.25
7.23
7.21
7.18
7.17
7.16
7.15
7.14
7.13
7.11
7.08
7.05
4.19
4.18
4.08
4.05
4.01
3.98
3.97
3.49
3.47
3.45
3.43
3.31
3.24
3.20
2.79
2.77
2.75
2.72
2.71
2.69
2.41
2.32
1.14
1.11
1.10
1.09
0.95

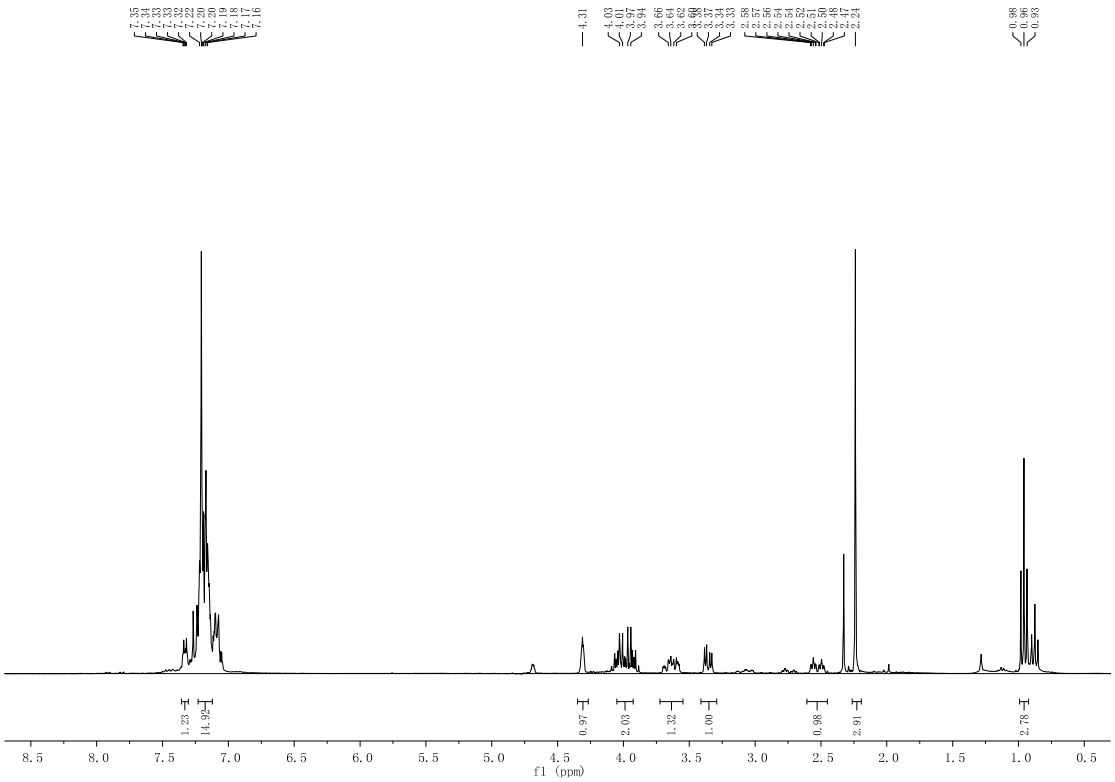

2.10
3.38
1.28
9.36
3.10
1.00
1.01
0.99
2.80
3.19
2.89
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

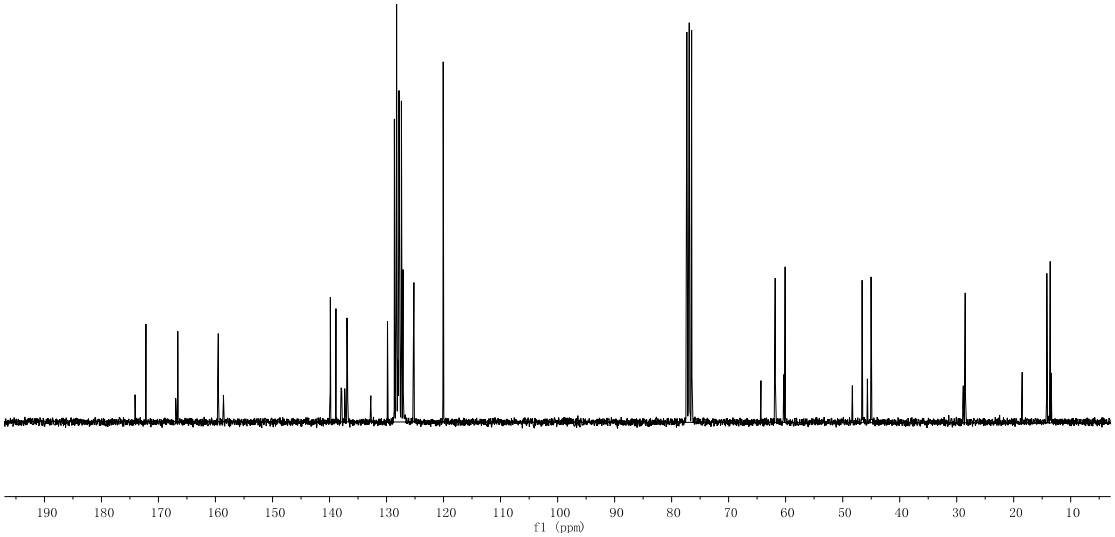

174.25
165.79
161.74
139.71
139.13
137.88
128.77
128.74
128.68
128.05
127.66
127.63
125.04
119.16
60.49
59.71
47.22
38.92
30.76
15.58
13.91

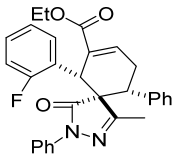

190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)



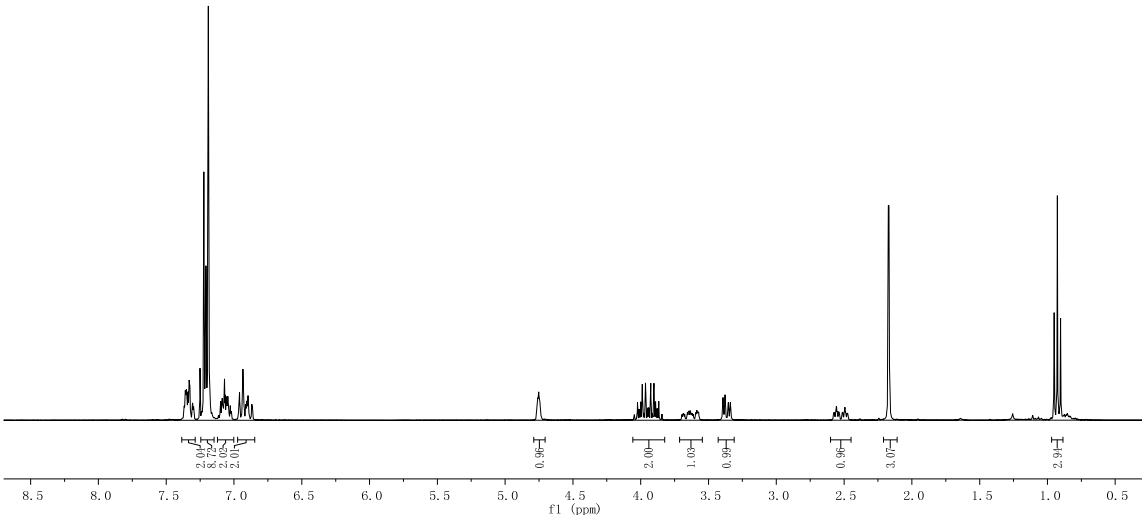
3ab

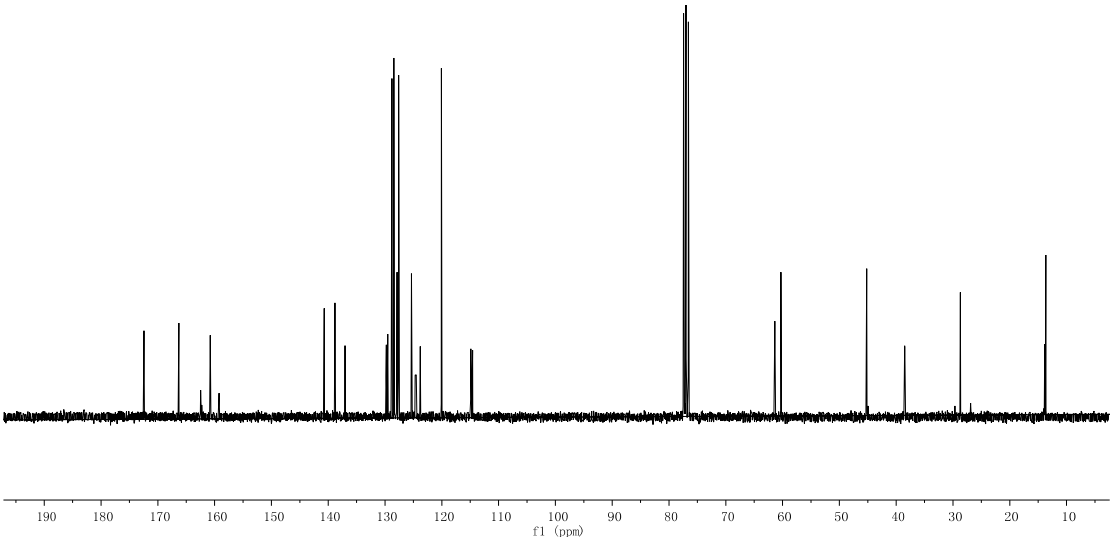


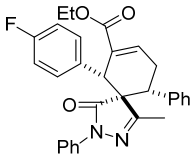



EtO
O
F
O
Ph
N
N
Ph

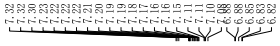
3ac

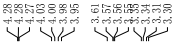

2.01
8.02
2.01
0.96
2.00
1.03
0.99
0.96
3.07
2.94
f1 (ppm)

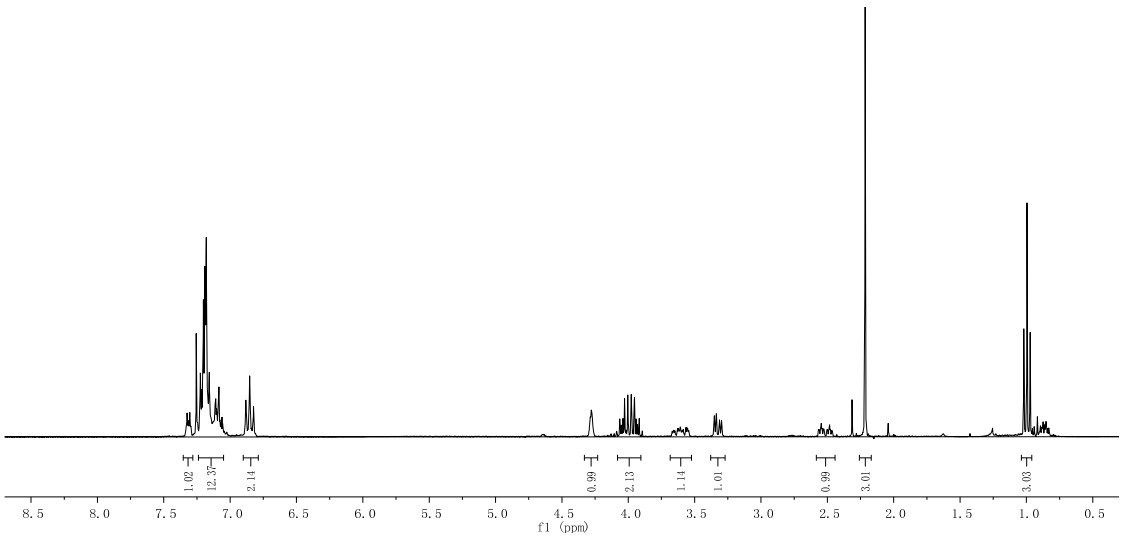

f1 (ppm)

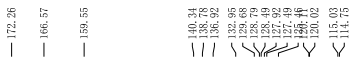

F
EtO
O
O
Ph
N
N
Ph

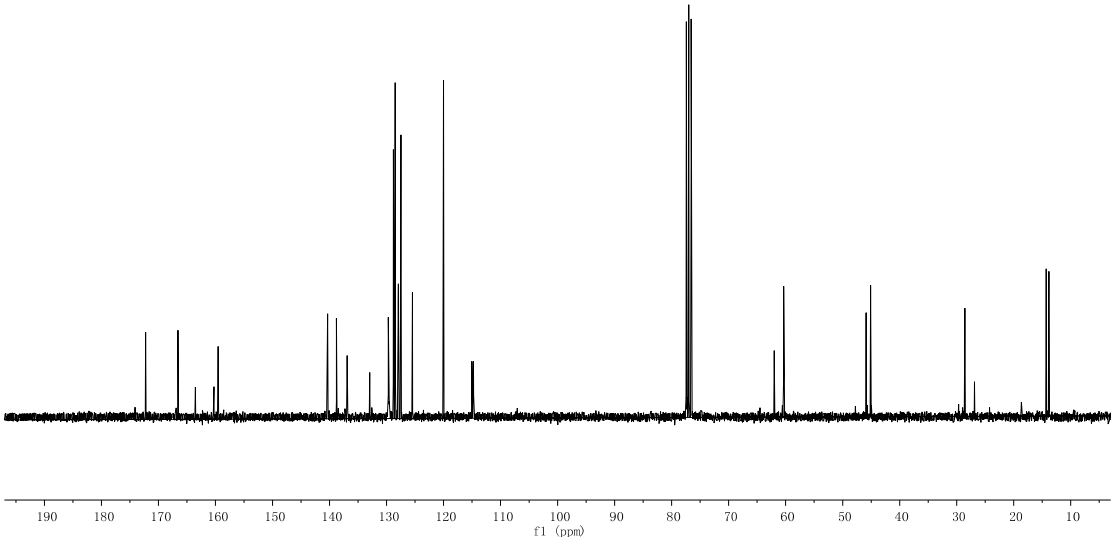
3ad

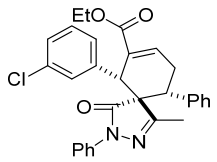




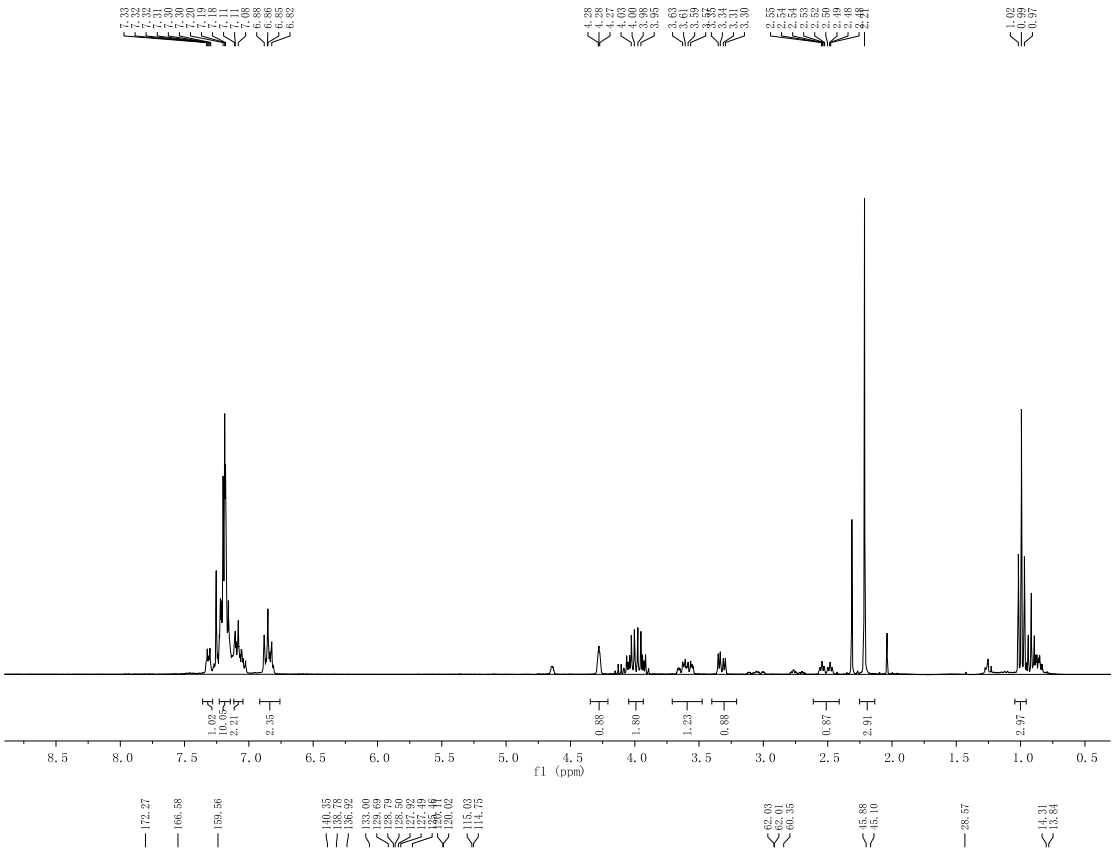

1.02
12.37
2.14
0.99
2.13
1.14
1.01
0.99
3.01
3.03
f1 (ppm)

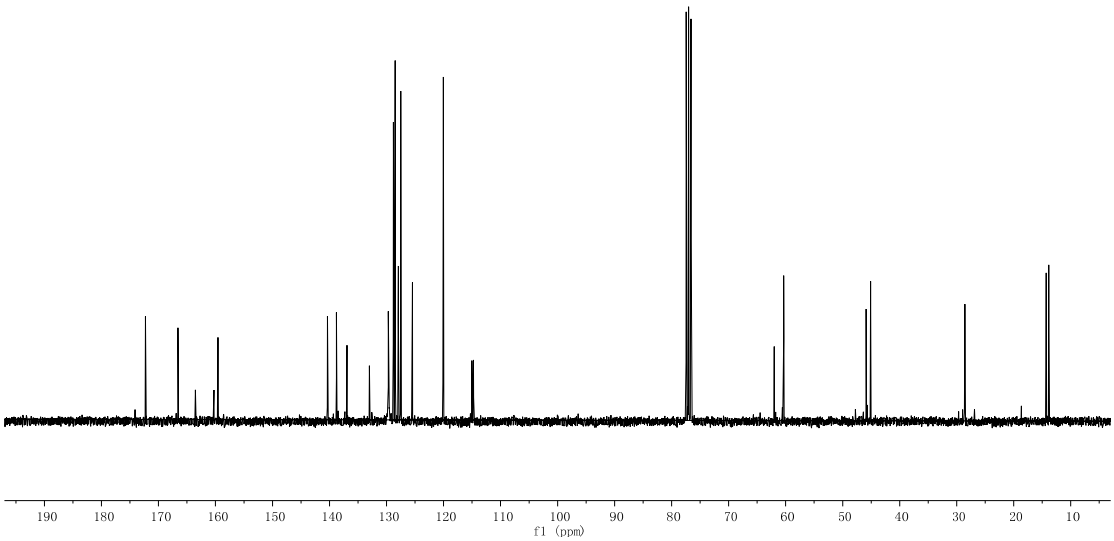


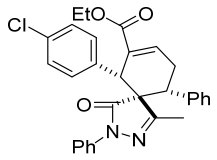

f1 (ppm)



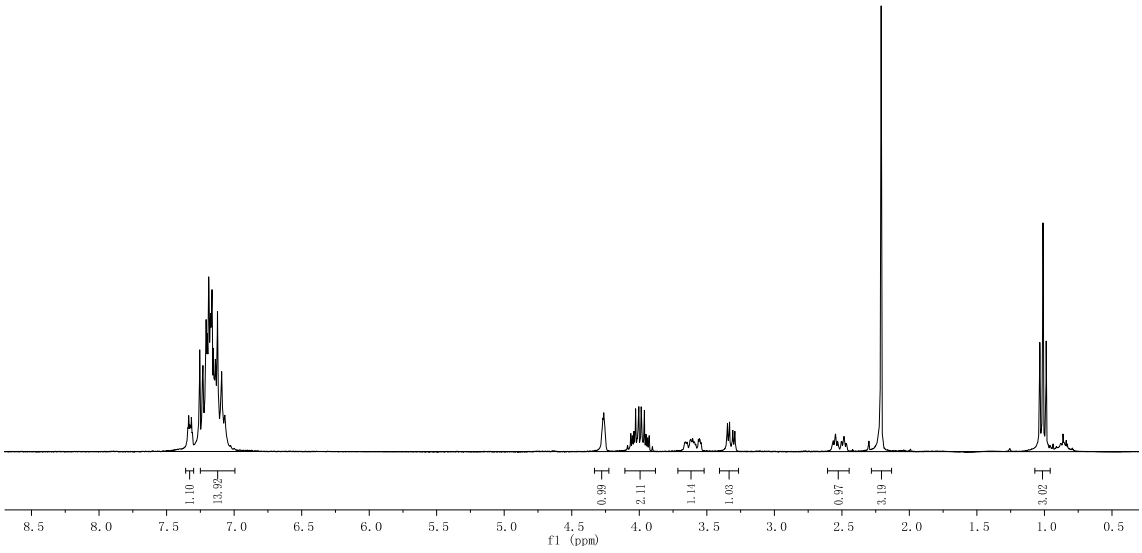
3ae

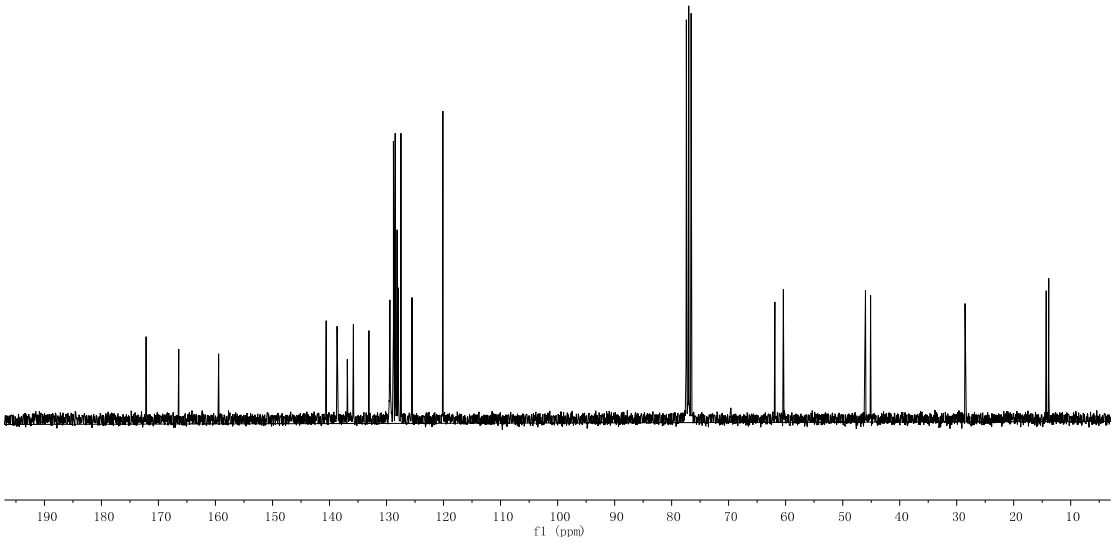


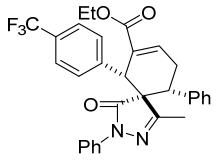



Cl
EtO
O
O
Ph
O
N
N
Ph

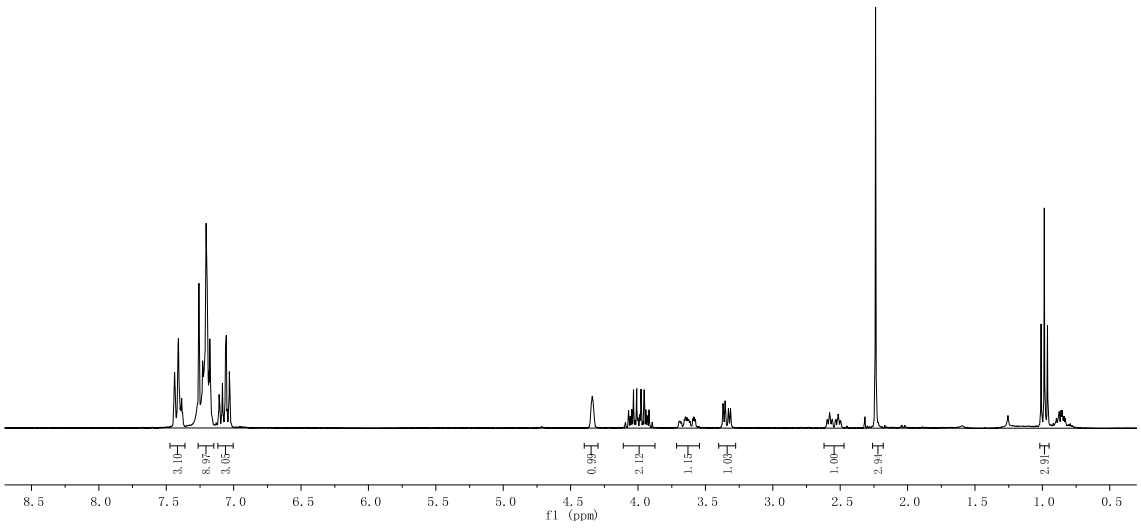
3af

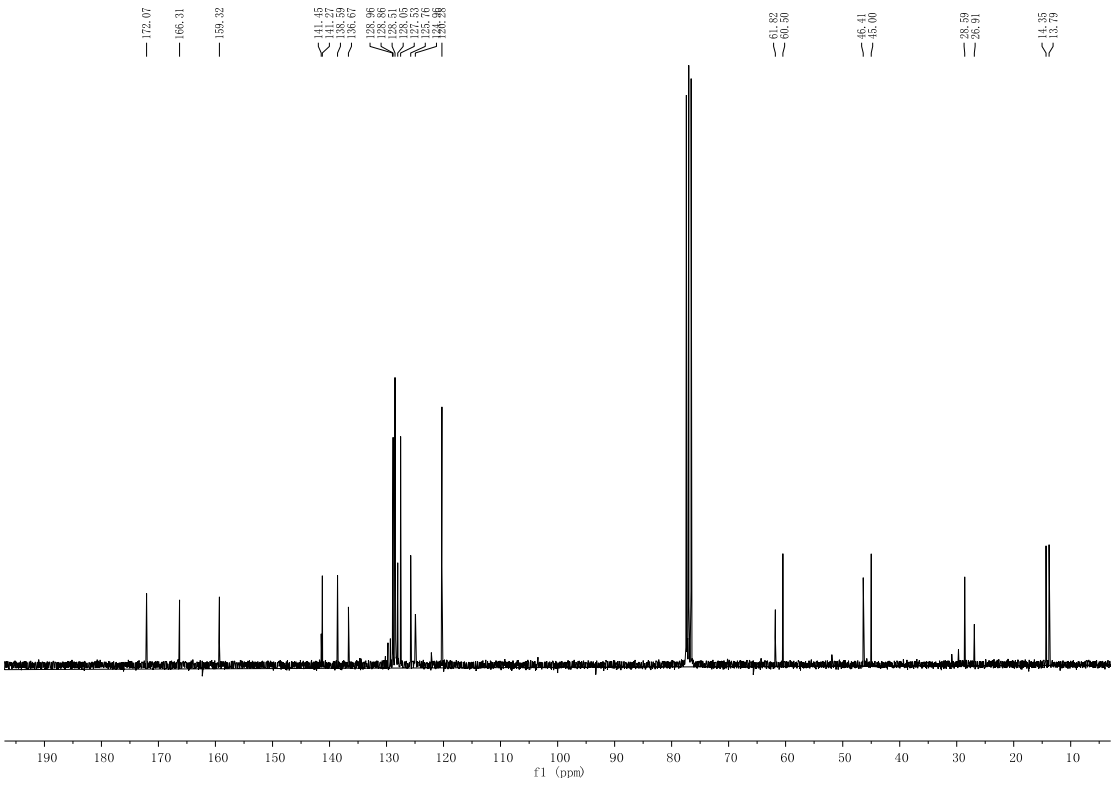

1.10
13.92
0.99
2.11
1.14
1.03
0.97
3.19
3.02
f1 (ppm)

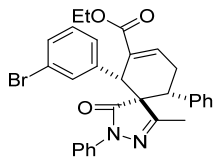

f1 (ppm)



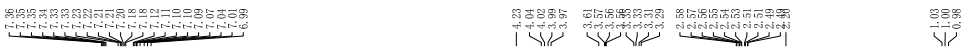
3ag

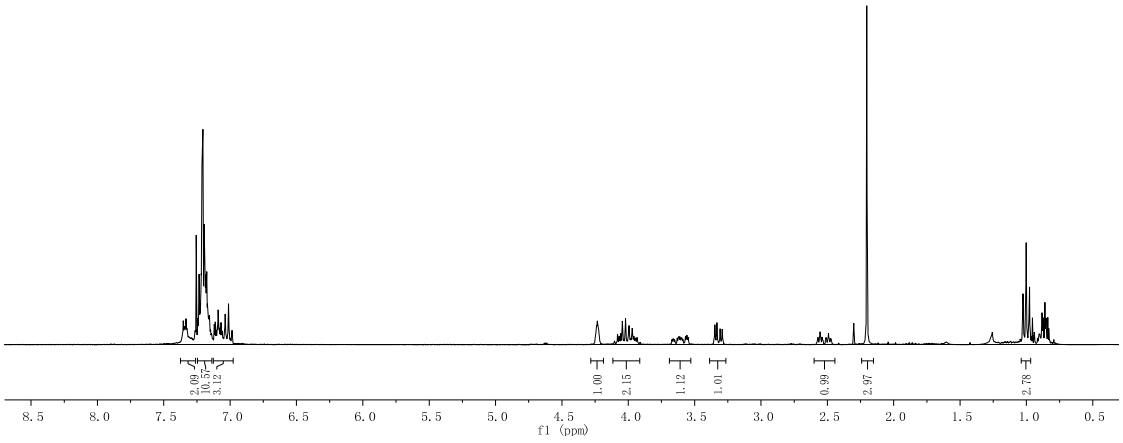


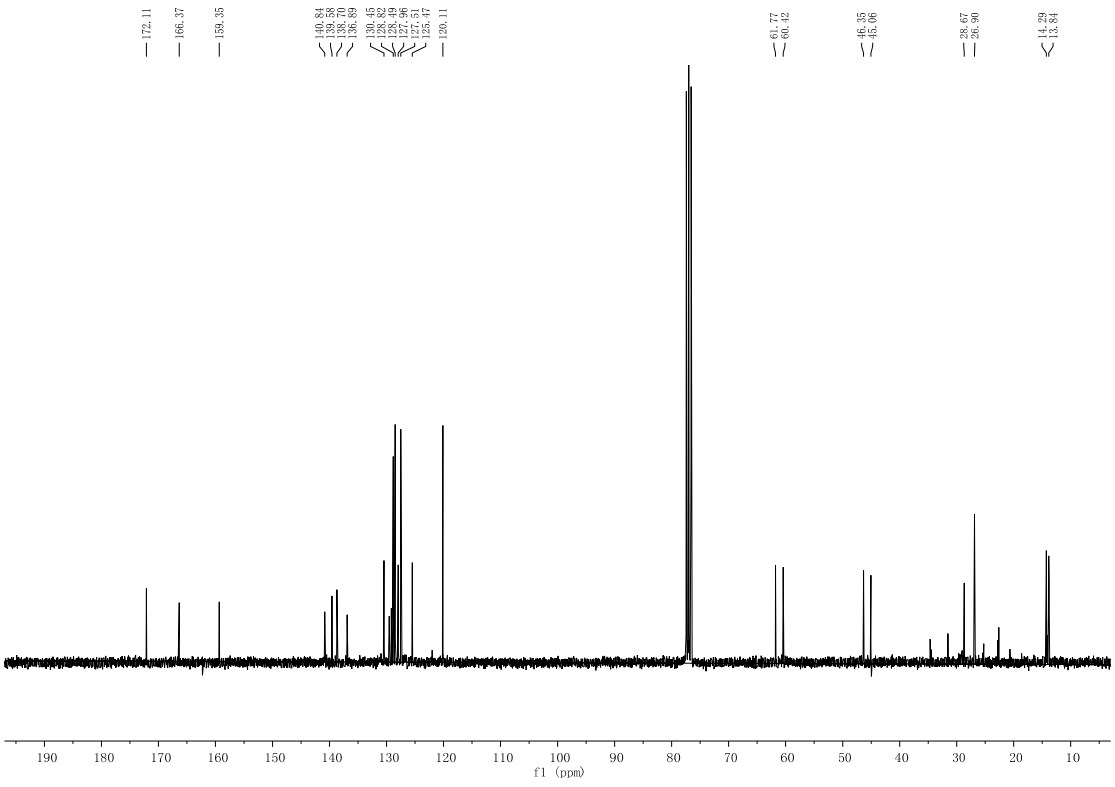



EtO
O
Br
Ph
O
N
N
Ph

3ah




2.09
10.57
3.12
1.00
2.15
1.12
1.01
0.99
2.97
2.78
f1 (ppm)


172.11
166.37
159.35
140.84
139.58
138.70
136.89
130.45
128.82
128.49
127.96
127.51
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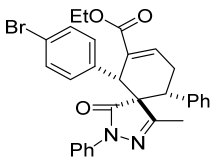
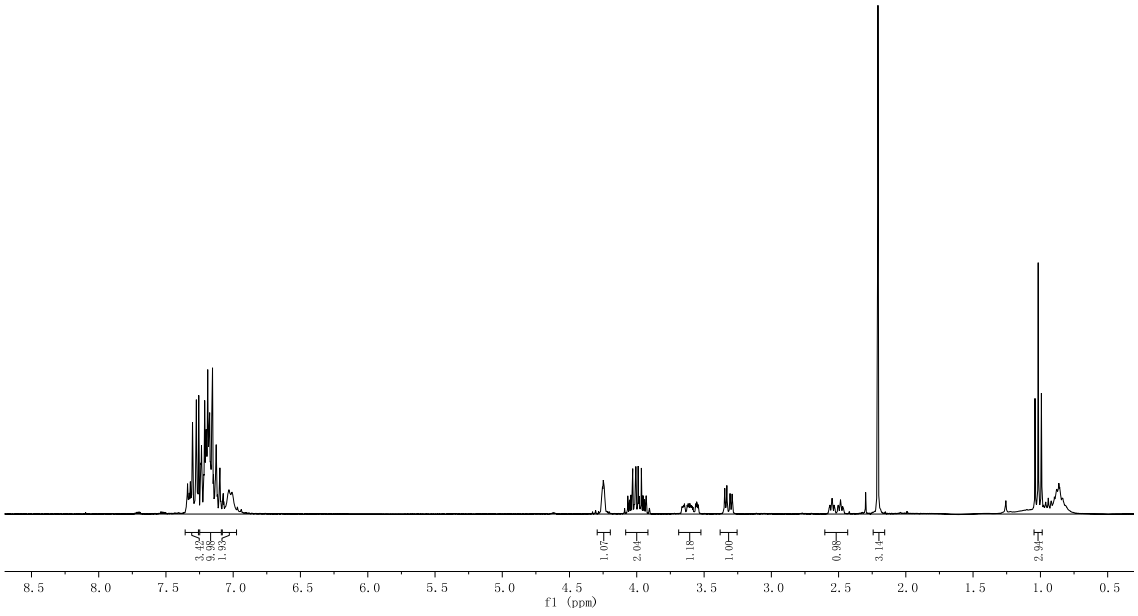
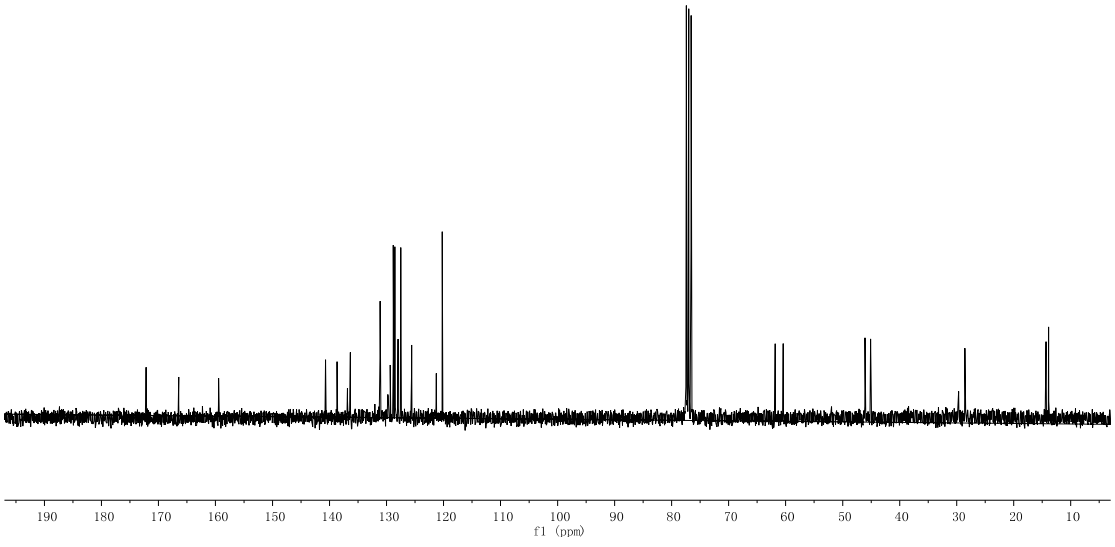
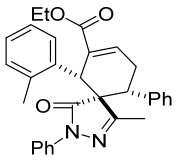
28.67
26.90
14.29
13.84
f1 (ppm)



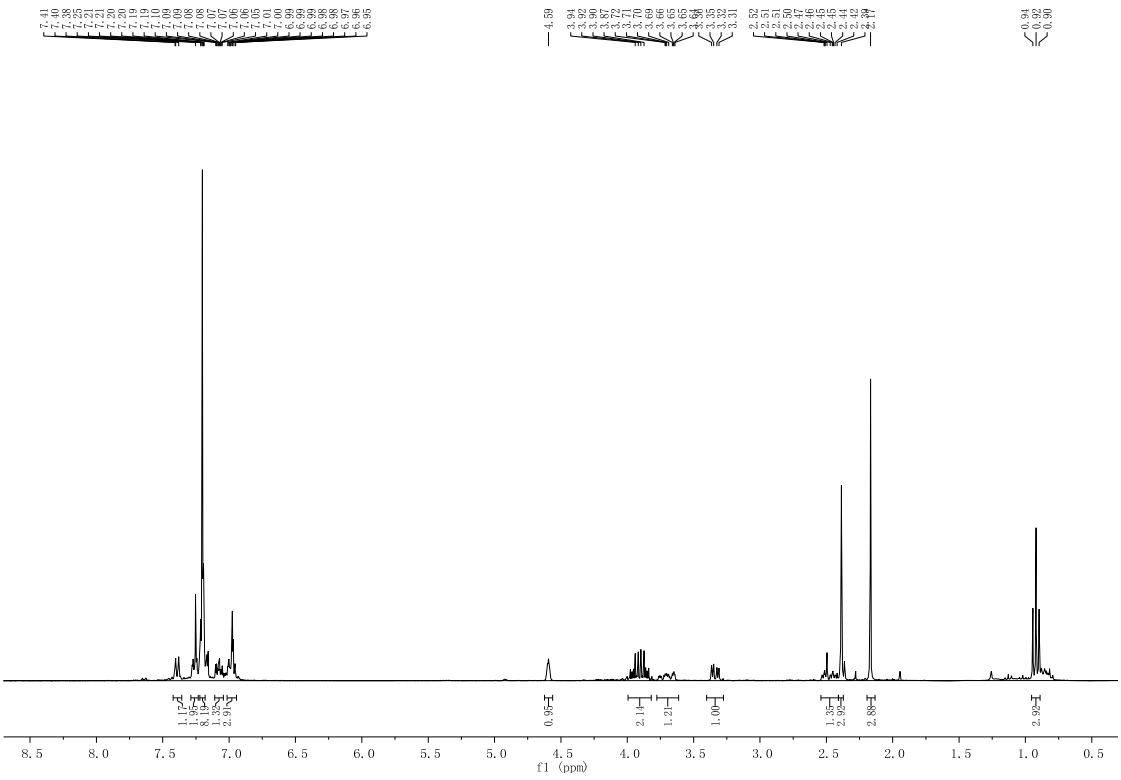
3ai

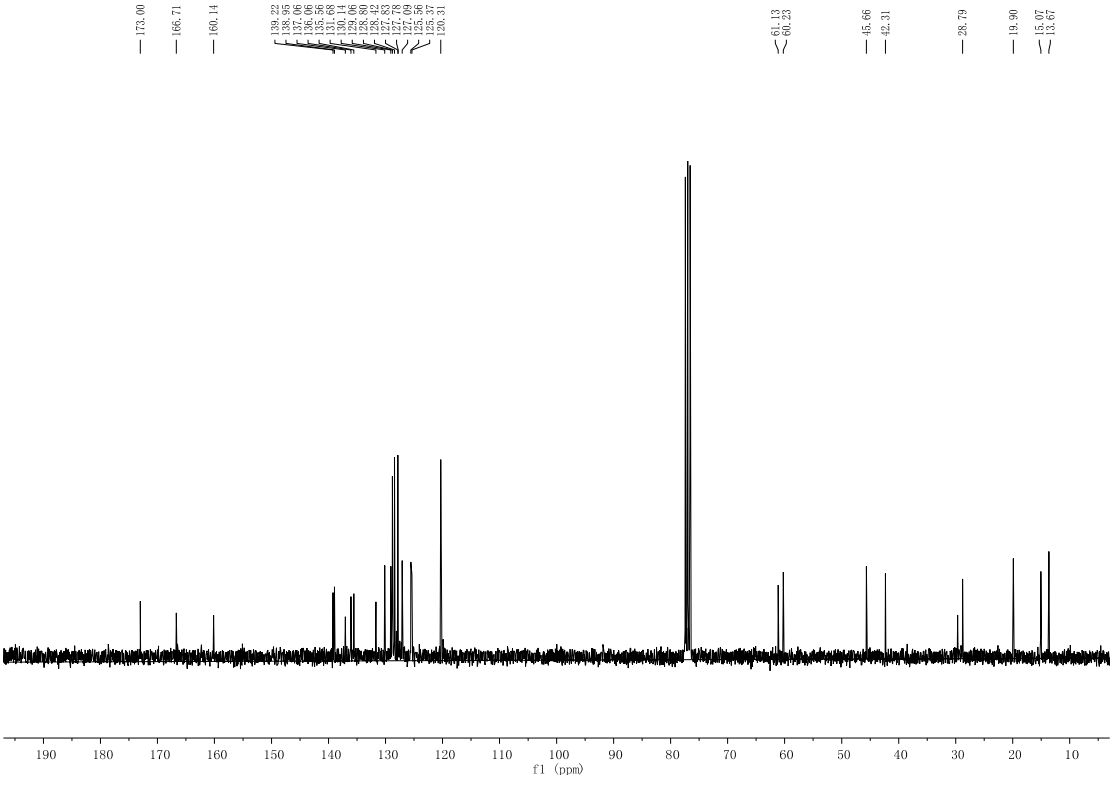


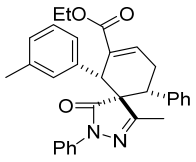




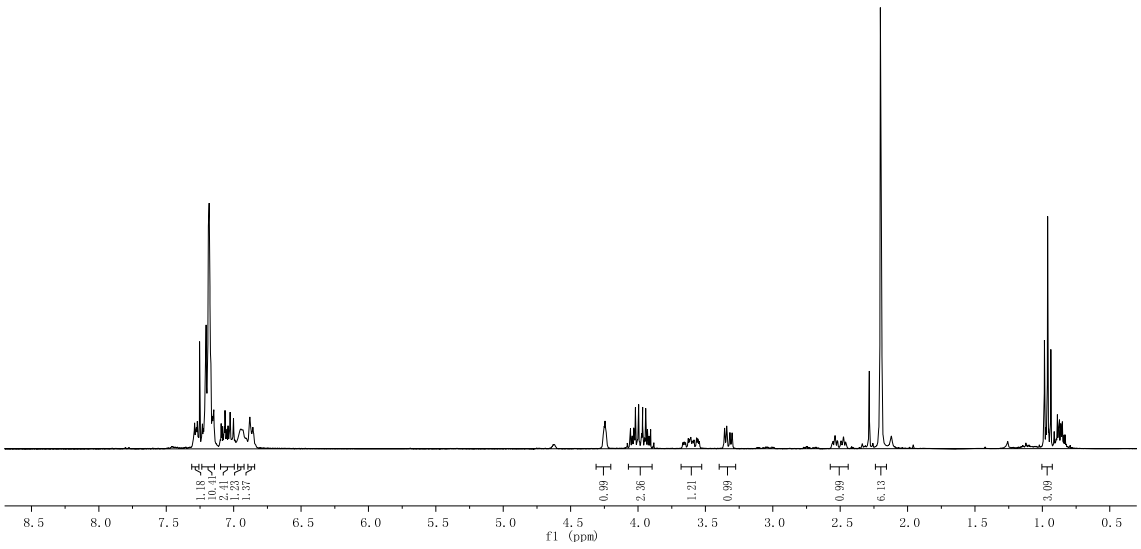
3aj

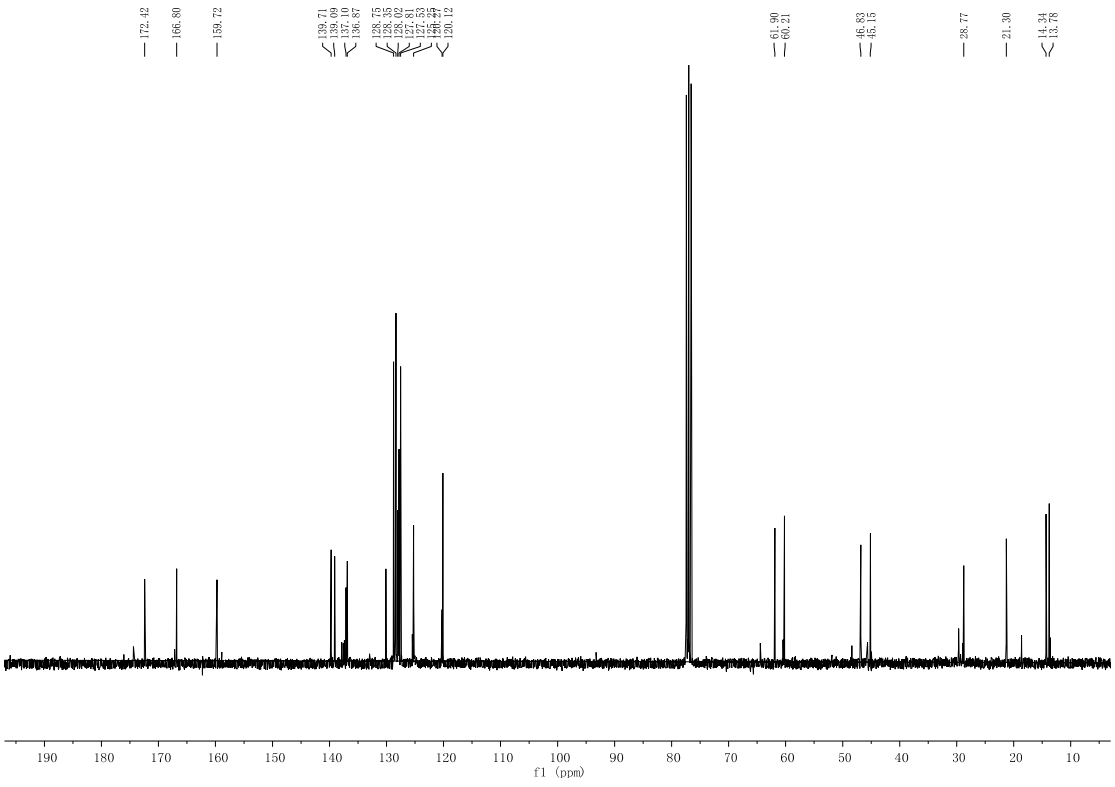


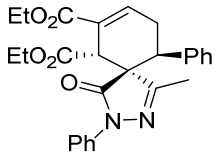



EtO
O
O
Ph
N
N
Ph

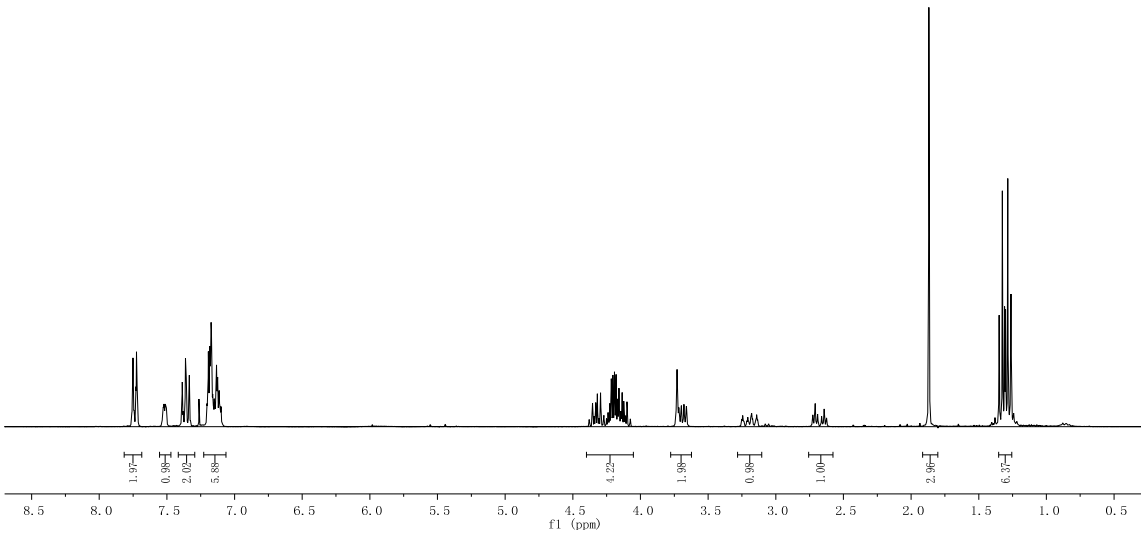
3ak

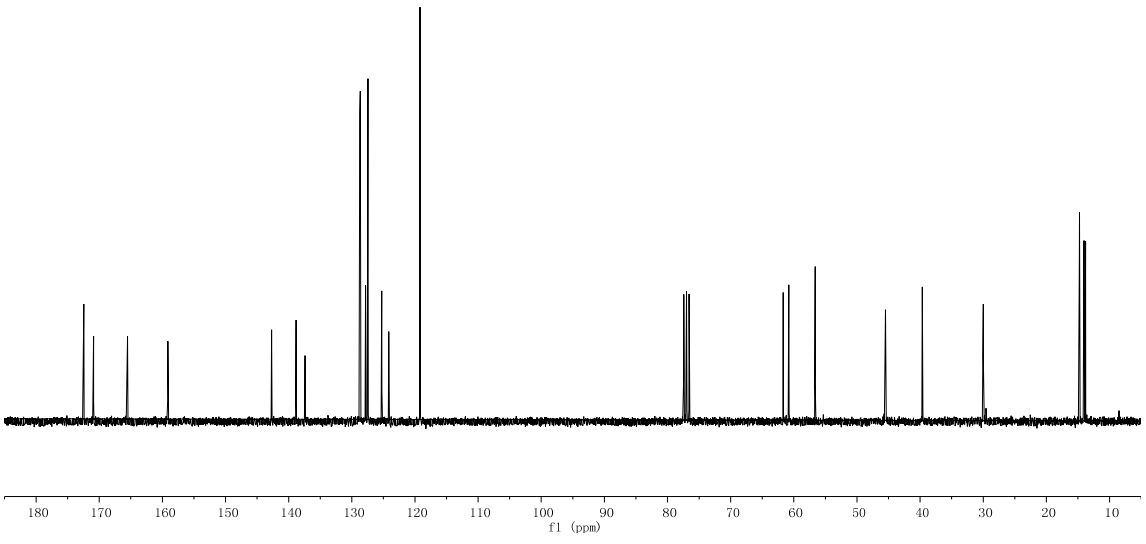

1.18
0.41
2.41
1.23
1.37
0.99
2.36
1.21
0.99
0.99
6.13
3.09
f1 (ppm)

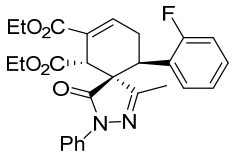

172.42
166.80
159.72
139.71
139.09
137.10
136.87
128.75
128.35
128.02
127.81
127.53
125.45
120.12
61.90
60.21
46.83
45.15
28.77
21.30
14.34
13.78
f1 (ppm)


EtO2C
EtO2C
O
Ph
N–N
Ph

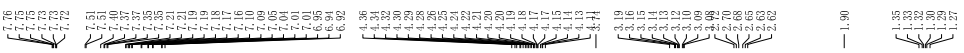
5aa

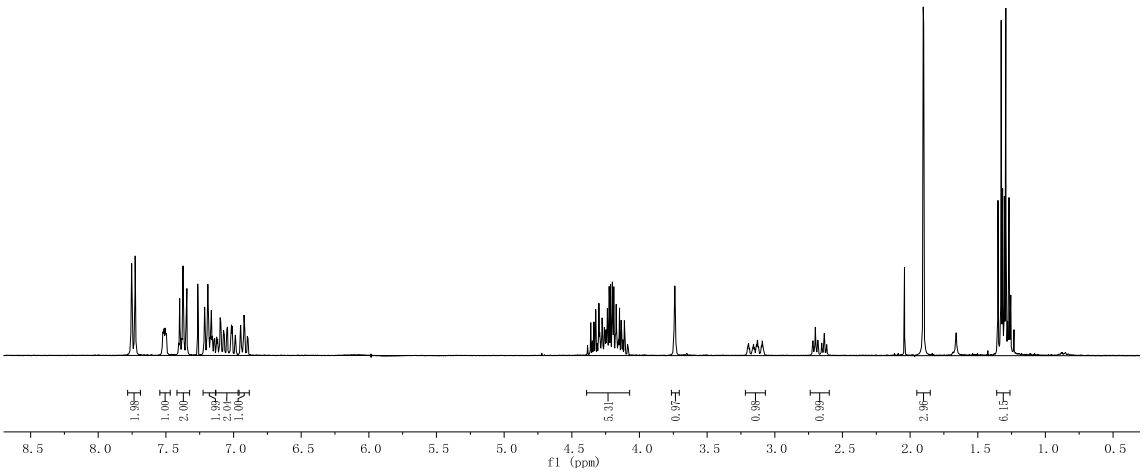

1.97
0.98
2.02
5.88
4.22
1.98
0.98
1.00
2.90
6.37
f1 (ppm)

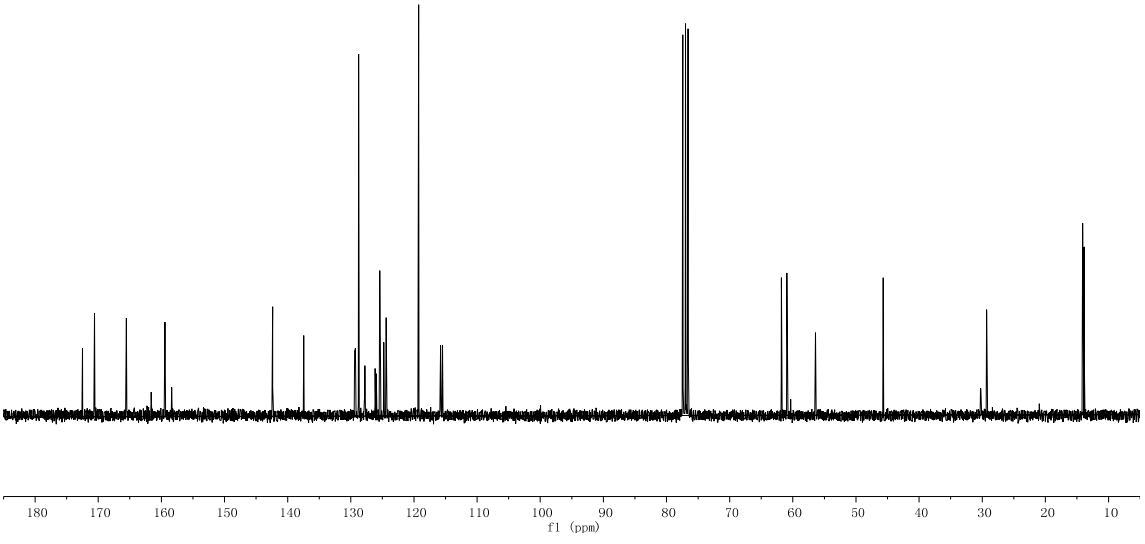

f1 (ppm)

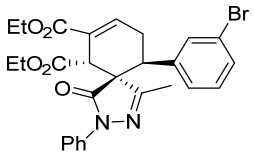

EtO2C
EtO2C
O
N–N
Ph
F

5ba

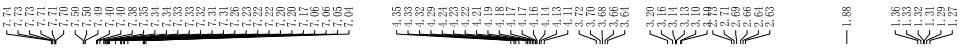


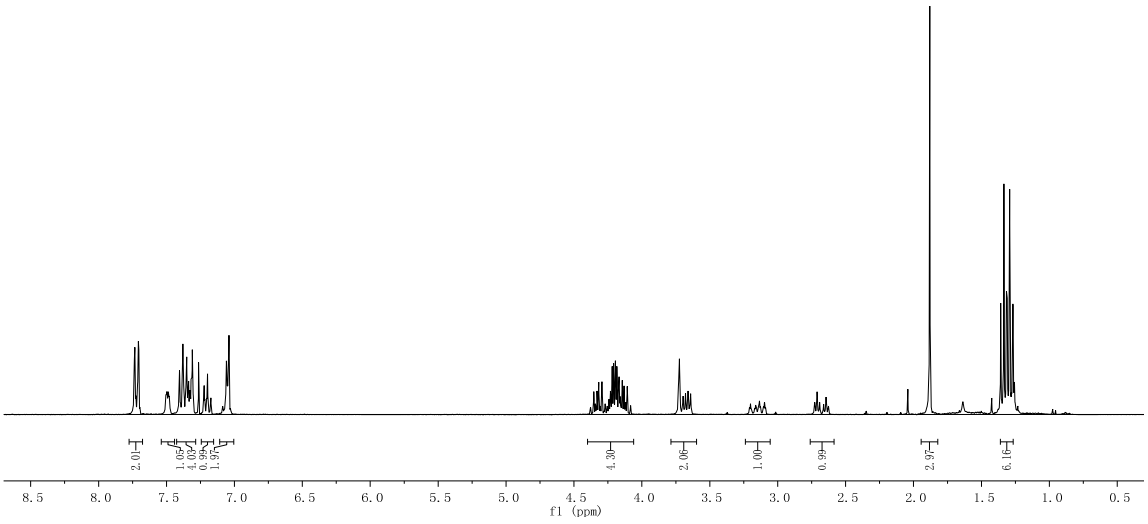

1.00
1.00
2.01
2.01
1.00
5.31
0.97
0.99
0.99
2.96
6.15
f1 (ppm)

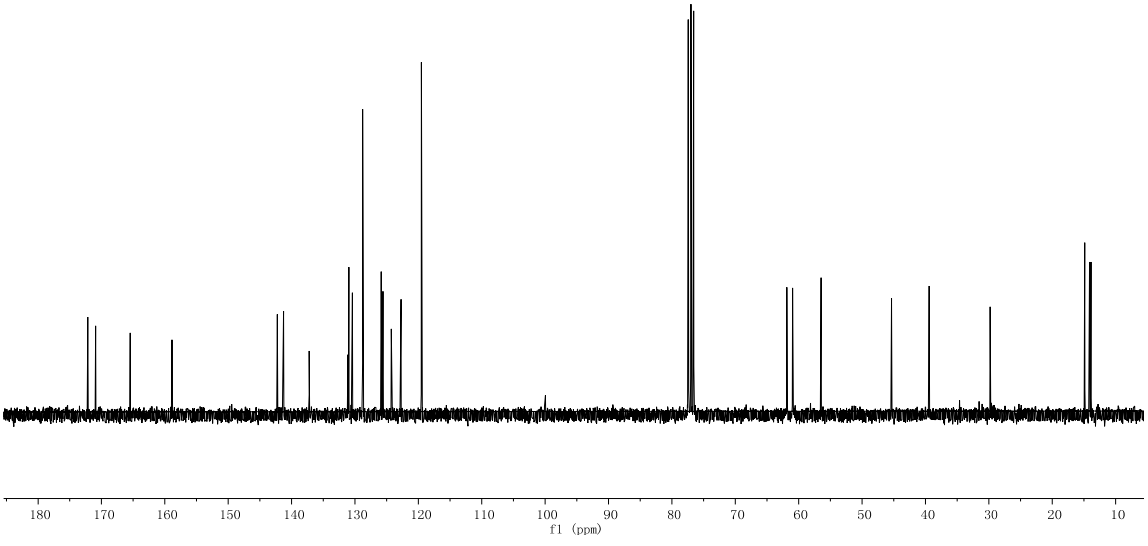

f1 (ppm)

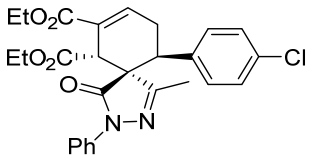


5fa

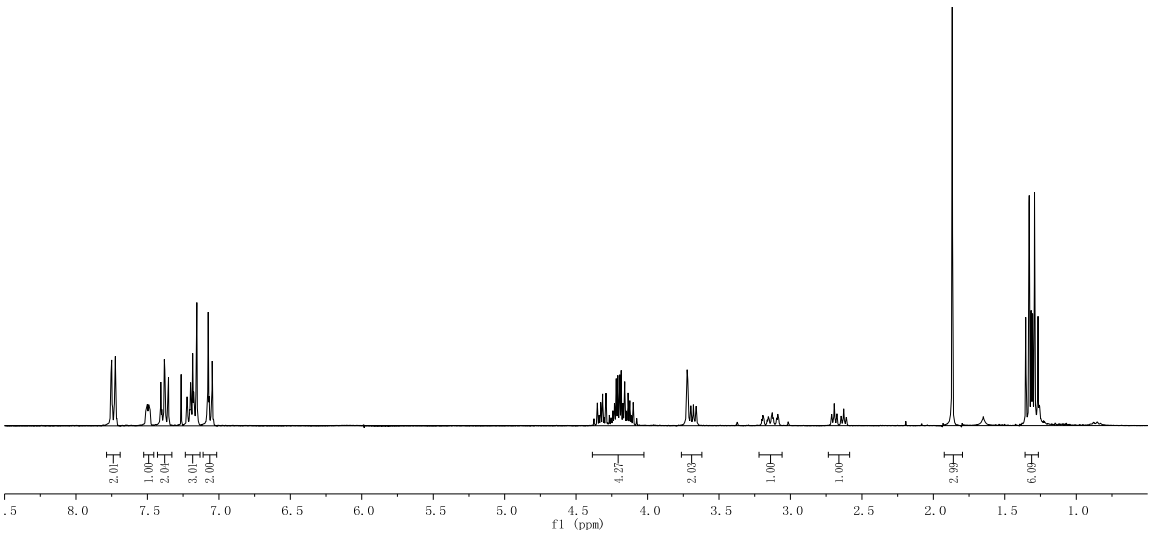


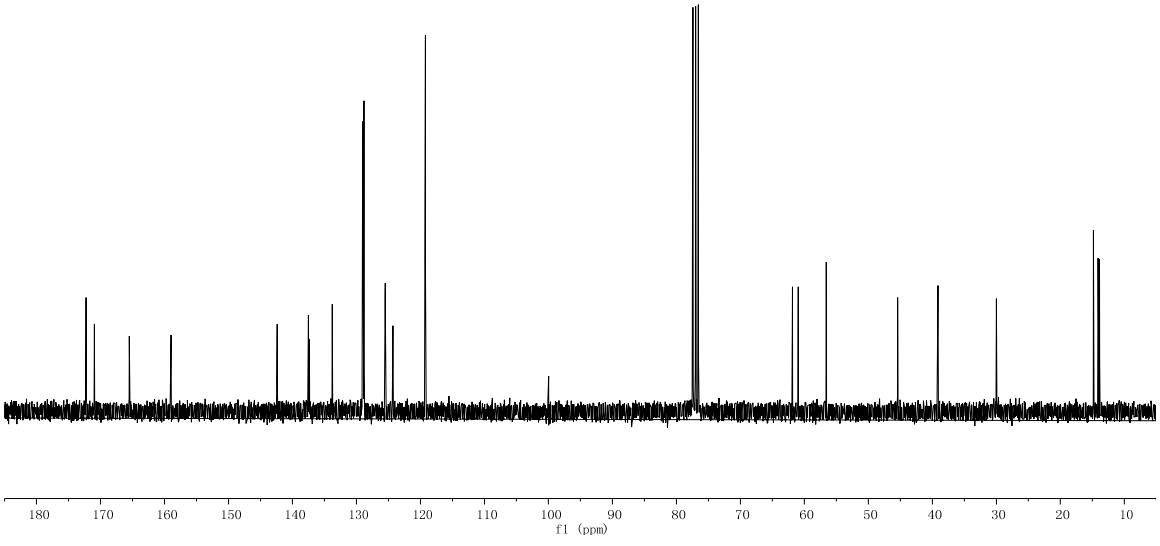


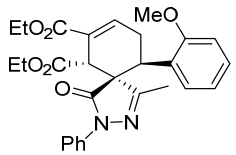



EtO2C
EtO2C
O
N–N
Ph
Cl

5ha

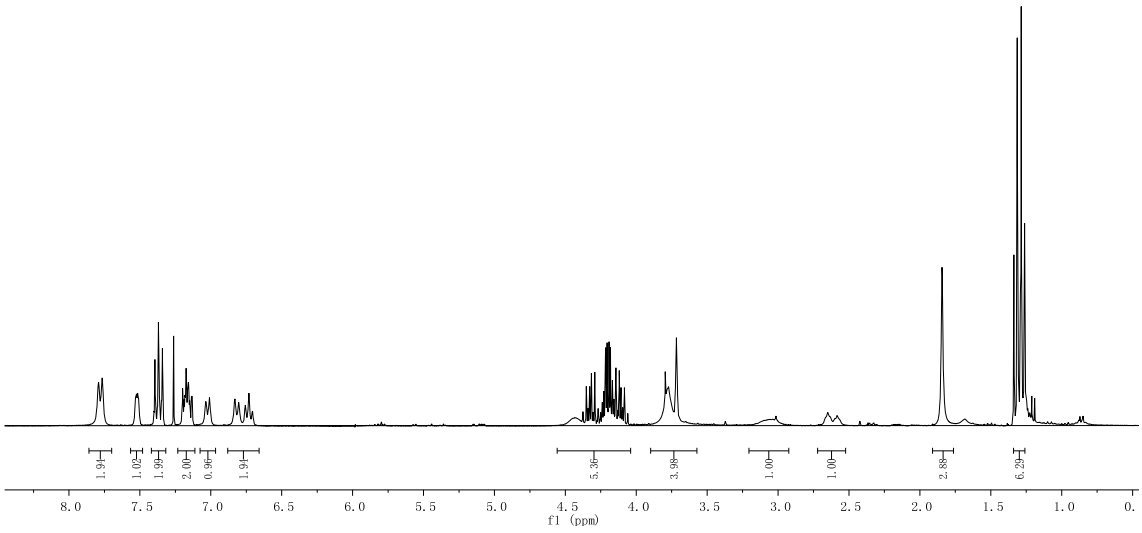

2.01
1.00
2.04
3.01
2.00
4.27
2.03
1.00
1.00
2.99
6.09
f1 (ppm)

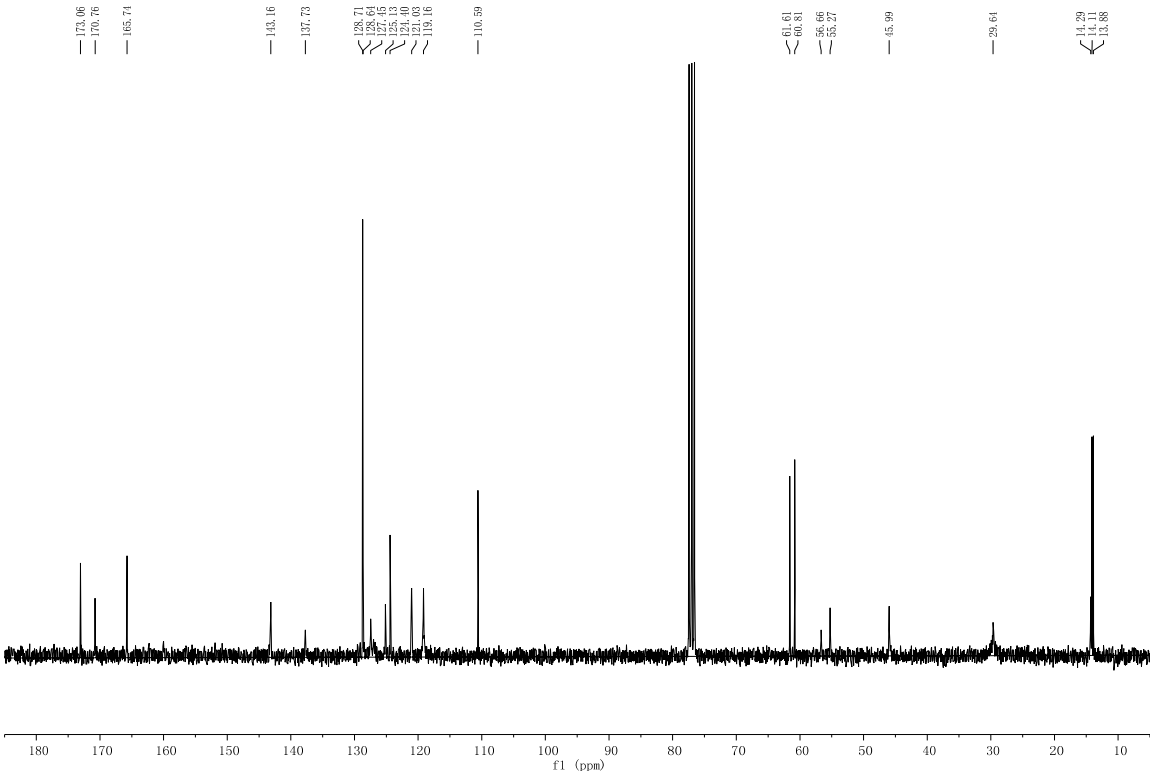

f1 (ppm)

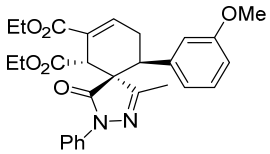

MeO
EtO2C
EtO2C
O
N–N
Ph

5ka

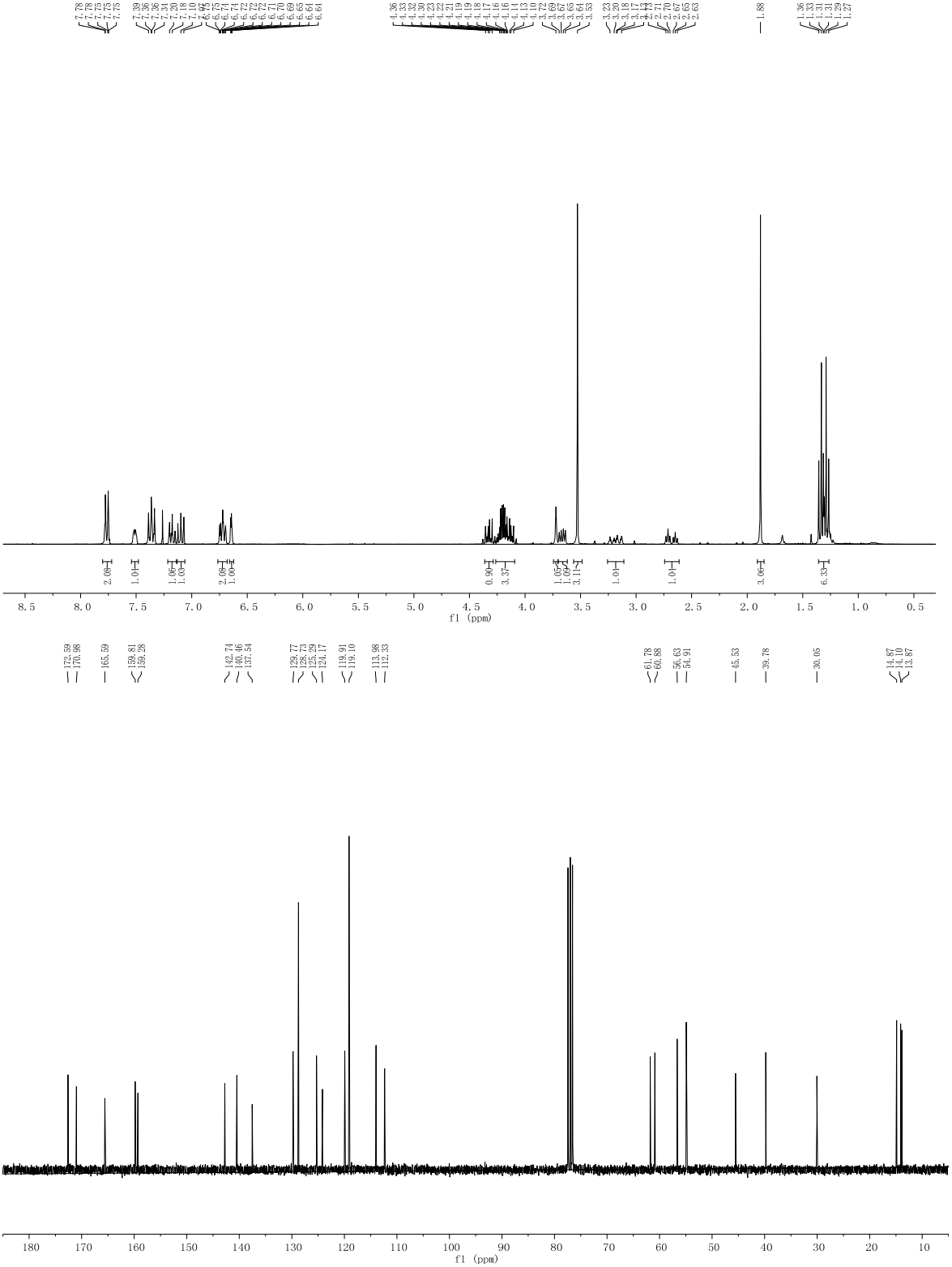

7.79
7.77
7.52
7.32
7.39
7.37
7.34
7.20
7.17
7.15
7.14
6.83
6.80
6.76
6.73
6.71
4.44
4.38
4.35
4.33
4.32
4.29
4.24
4.23
4.22
4.21
4.19
4.18
4.17
4.15
4.14
4.12
4.11
4.08
3.80
3.77
3.72
3.04
3.01
2.65
2.58
1.84
1.34
1.31
1.31
1.29
1.28
1.26

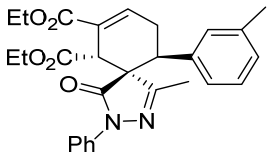

1.94
1.02
1.99
2.00
0.96
1.94
5.36
3.98
1.00
1.00
2.88
6.29
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.
f1 (ppm)


173.06
170.76
165.74
143.16
137.73
128.71
128.64
127.45
125.13
121.40
121.03
119.16
110.59
61.61
60.81
56.66
55.27
45.99
29.64
14.29
14.11
13.88
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

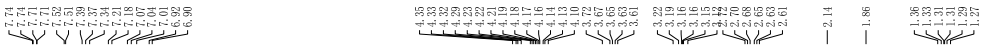


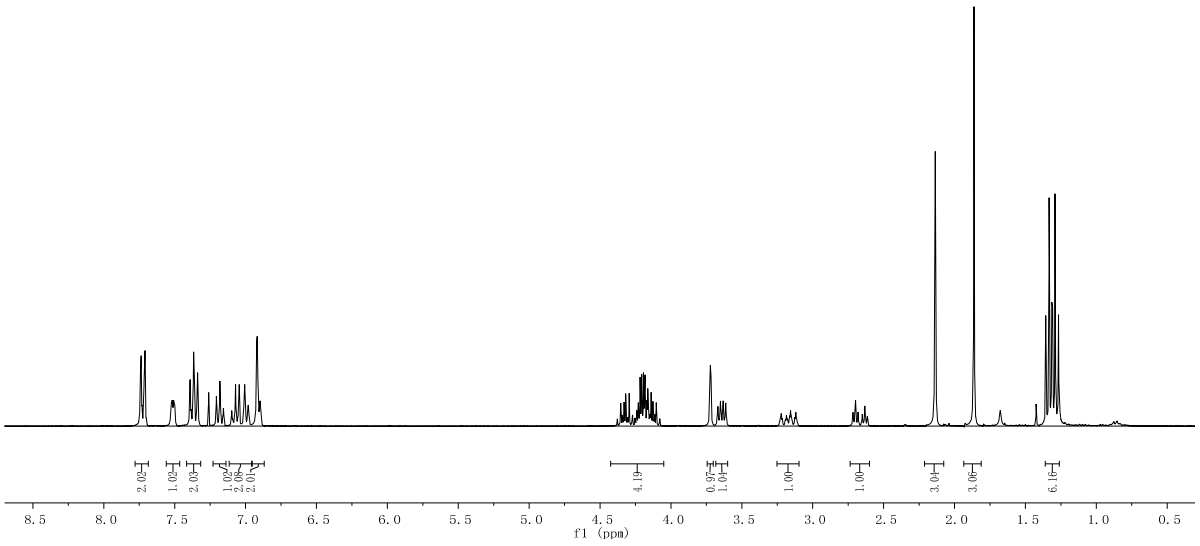
5la



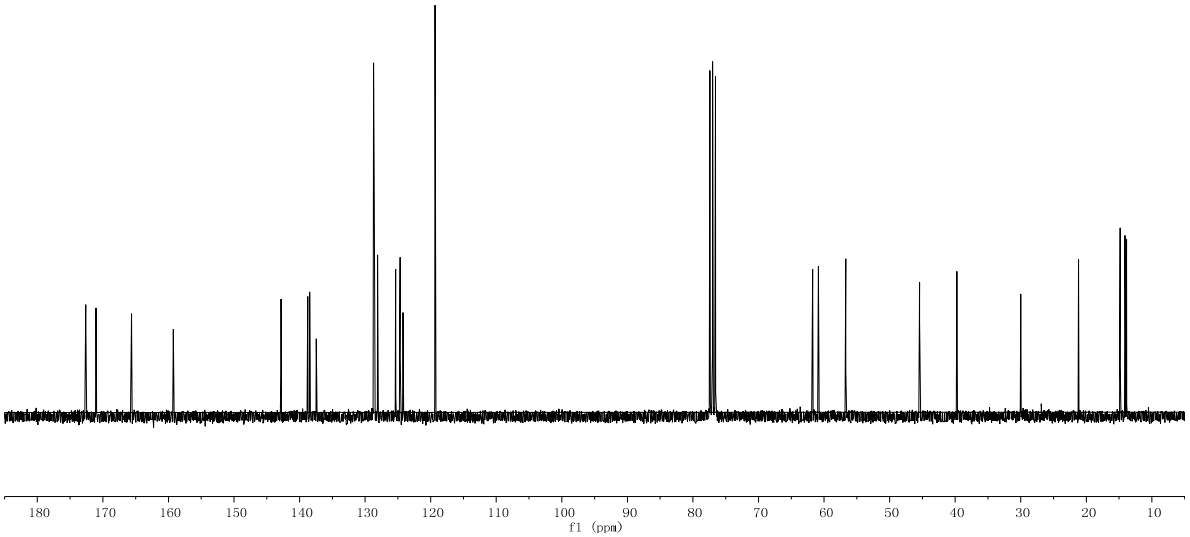

EtO2C
EtO2C
O
N–N
Ph

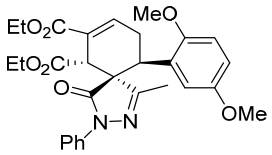
5na


7.74
7.74
7.71
7.71
7.52
7.51
7.39
7.37
7.34
7.21
7.18
7.07
7.04
7.01
6.92
6.90
4.35
4.33
4.32
4.29
4.23
4.22
4.21
4.19
4.18
4.17
4.16
4.14
4.13
4.10
3.72
3.67
3.65
3.63
3.61
3.22
3.19
3.16
3.16
3.15
3.12
2.72
2.70
2.68
2.65
2.63
2.61
2.14
1.86
1.36
1.33
1.31
1.31
1.29
1.27

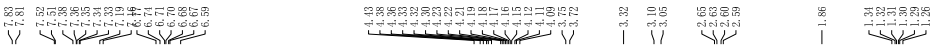

2.02
1.02
2.03
1.08
2.08
2.01
4.19
0.97
1.04
1.00
1.00
3.04
3.00
6.16
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

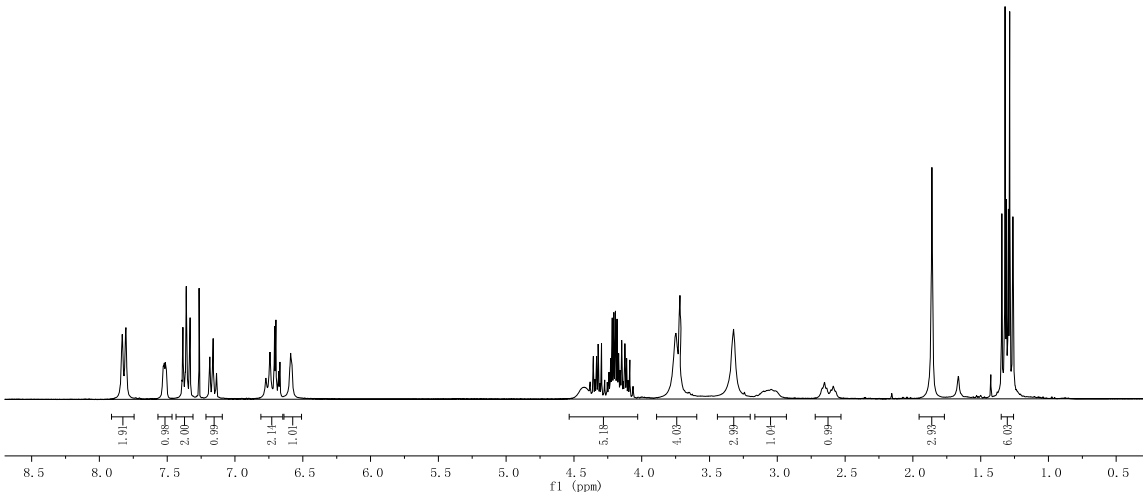

172.62
171.04
165.62
159.26
142.83
138.76
138.45
137.45
128.70
128.62
128.10
125.34
124.67
121.22
119.33
61.74
60.86
56.69
45.44
39.75
30.01
21.20
14.65
14.10
13.87

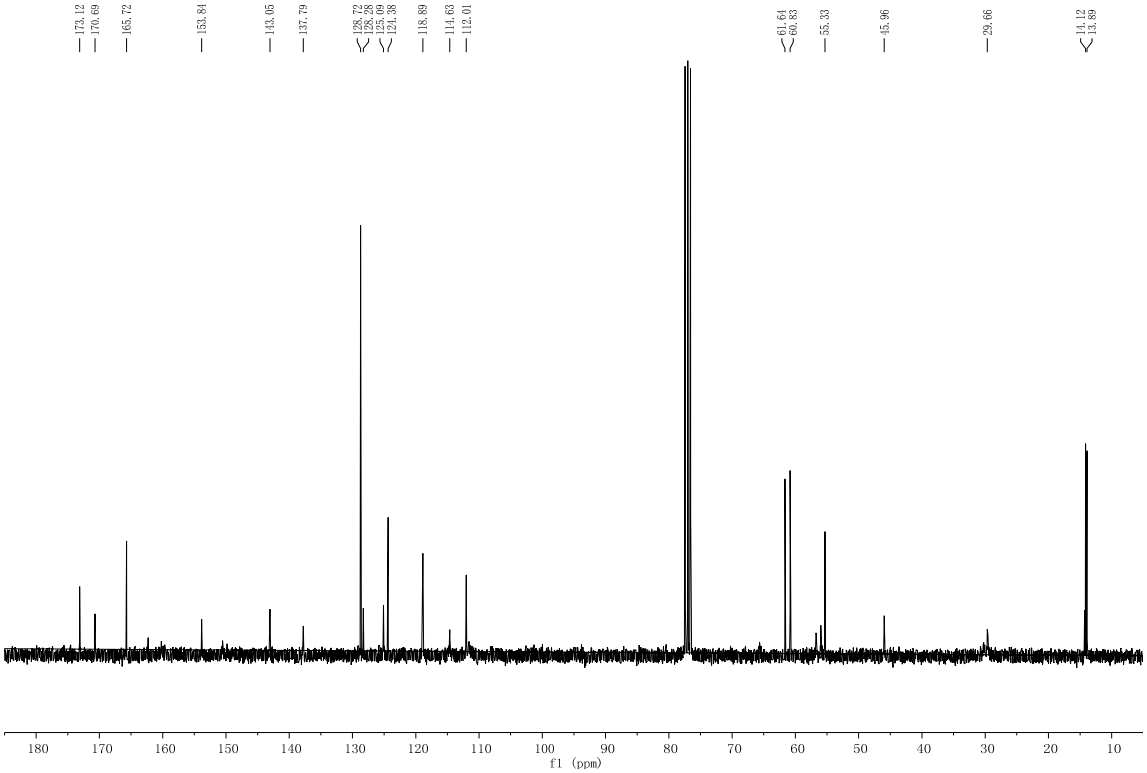

180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

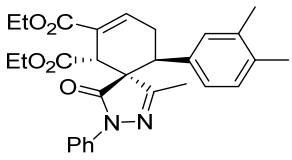


5qa

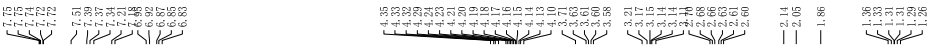


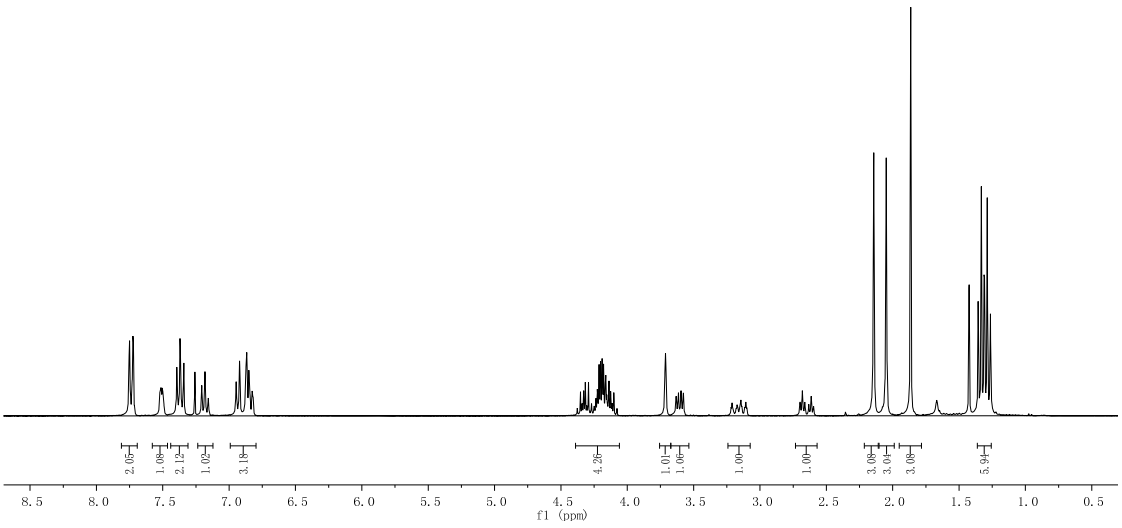


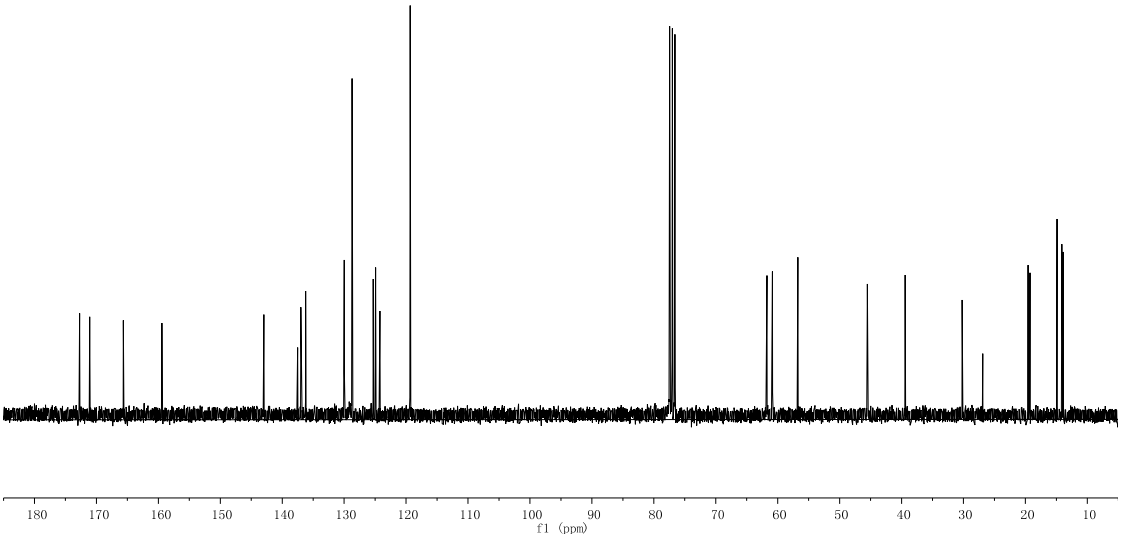


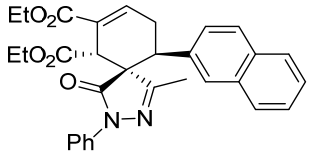

EtO2C
EtO2C
O
N–N
Ph

5ra

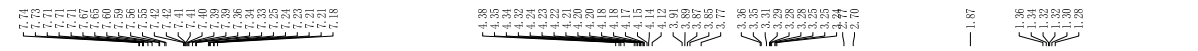


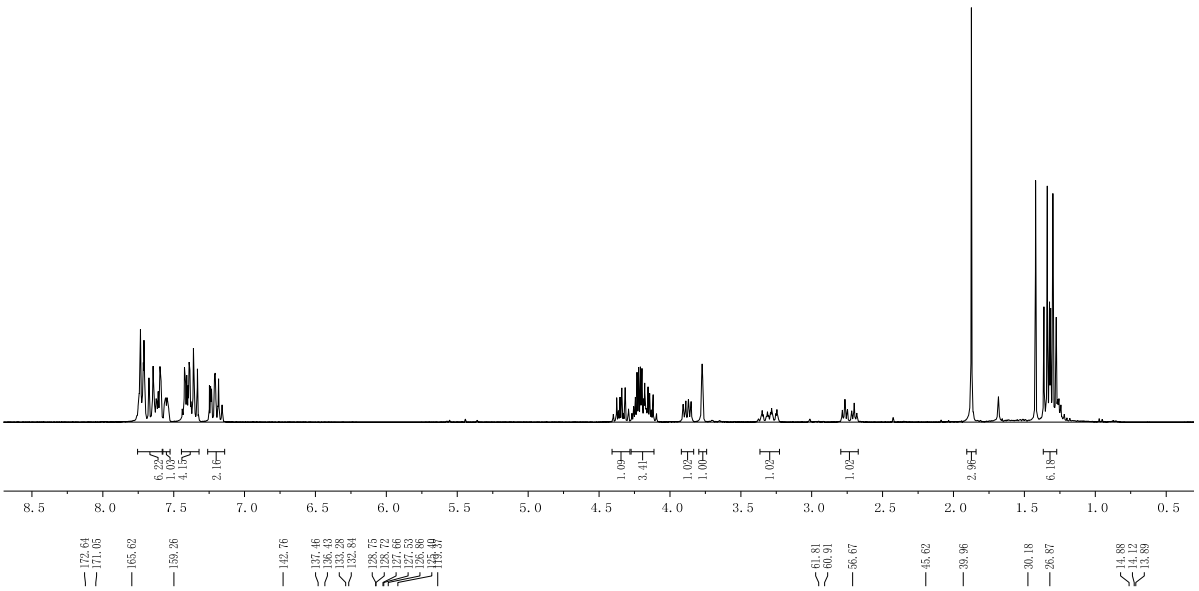

2.05
1.08
2.12
1.02
3.18
4.28
1.01
1.00
1.00
1.00
3.08
3.01
3.08
5.94
f1 (ppm)

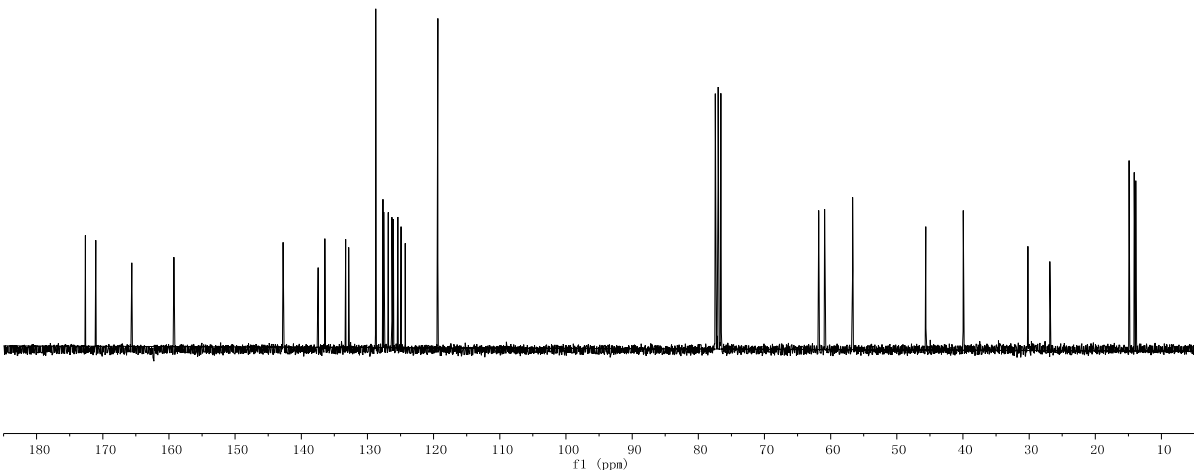

f1 (ppm)

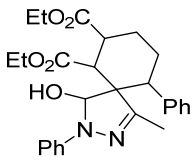


5sa

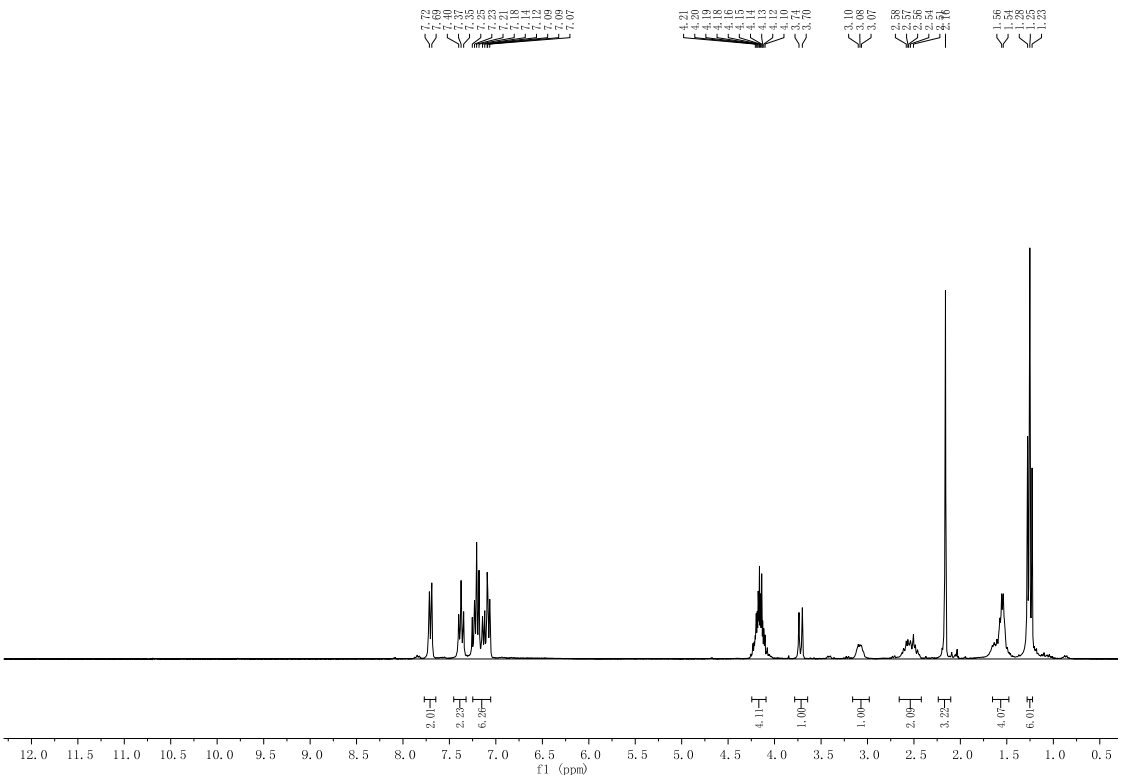


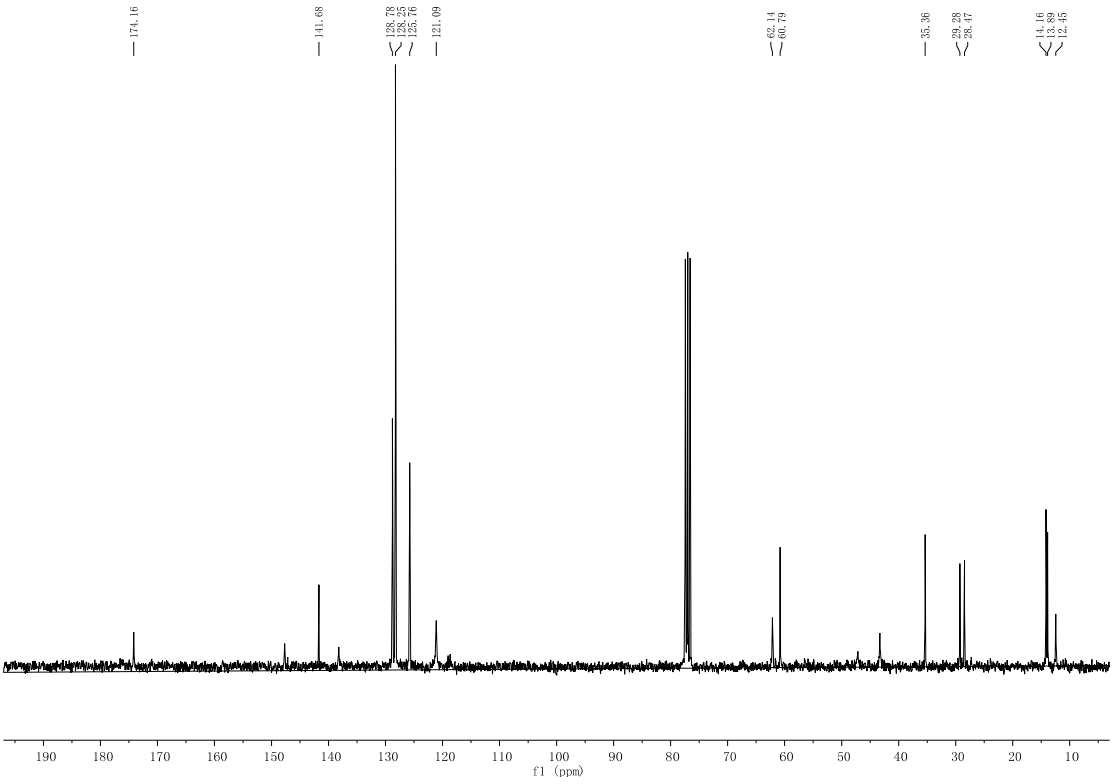




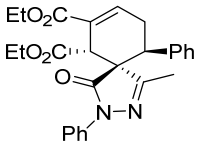


6

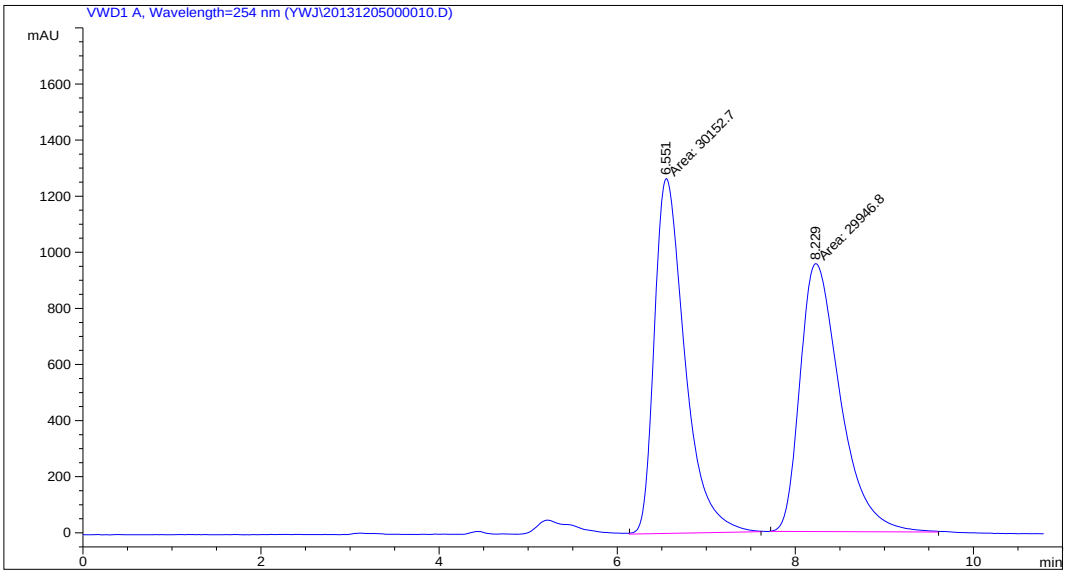




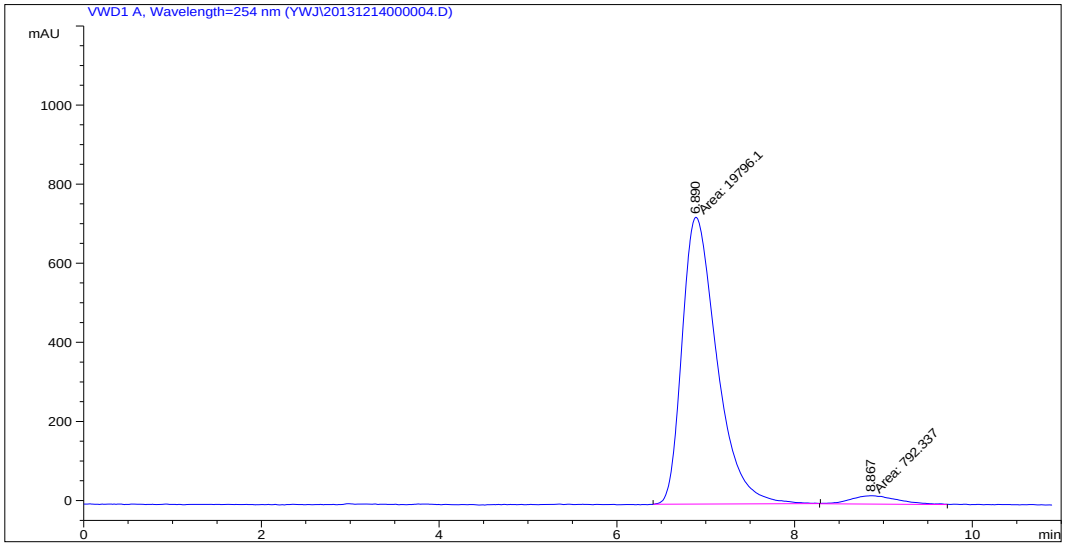
HPLC Chromatograms of Racemic and Chiral Cycloadducts



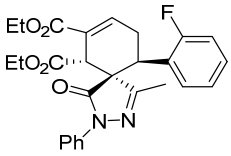
5aa



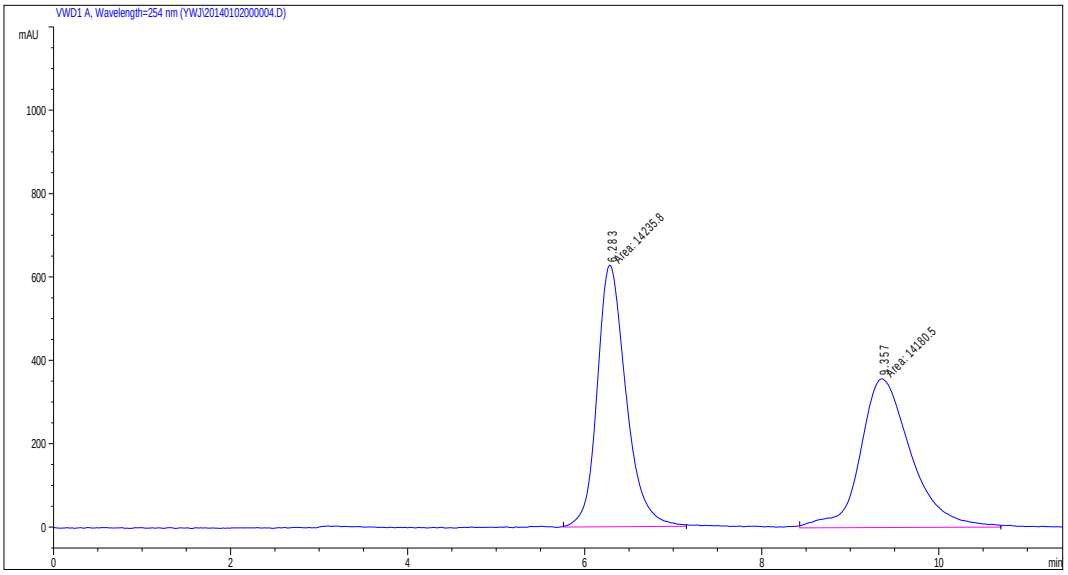
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	6.551	MF	0.3995	3.03017e4	1264.04150	49.5986
2	8.229	FM	0.5332	3.07921e4	962.41260	50.4014



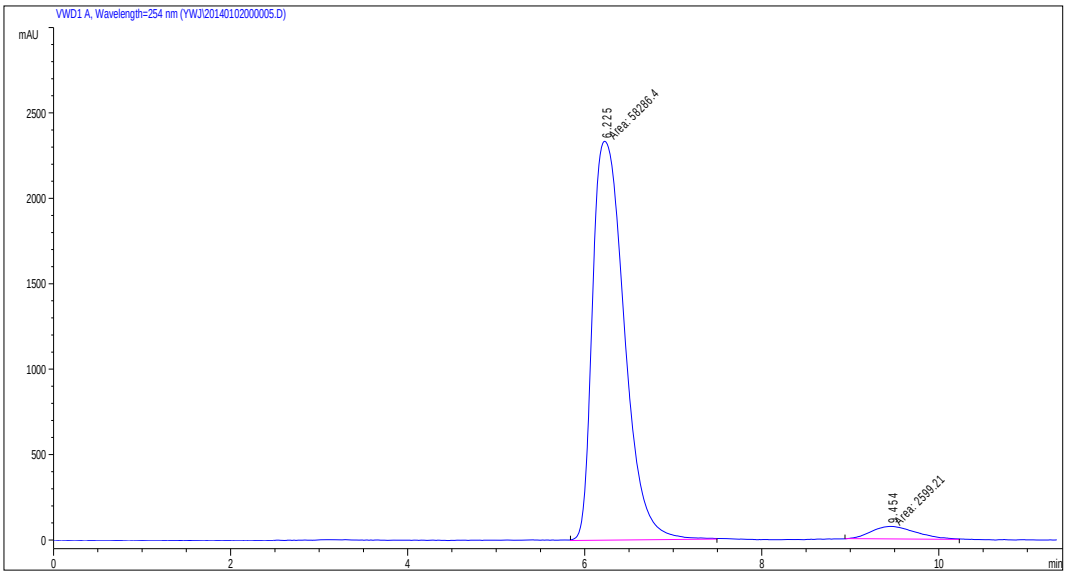
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	6.890	MM	0.4548	1.97961e4	725.45428	96.1516
2	8.867	MM	0.6223	792.33673	21.21998	3.8484



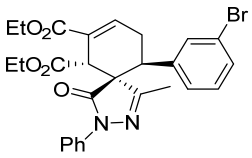
5ba



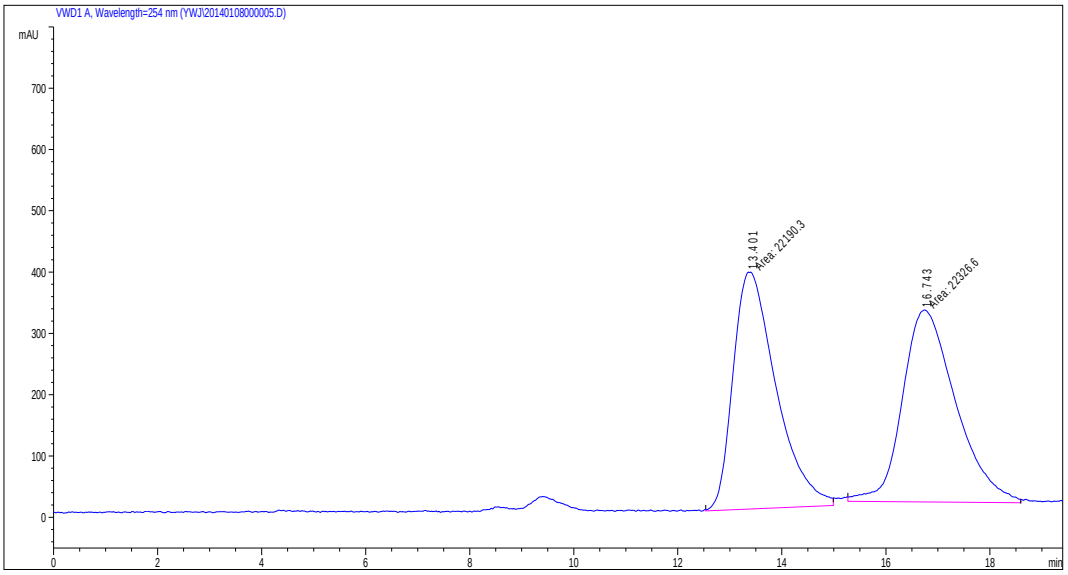
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	6.283	MM	0.3762	1.41555e4	627.09894	50.8363
2	9.357	MM	0.6463	1.36898e4	353.02328	49.1637



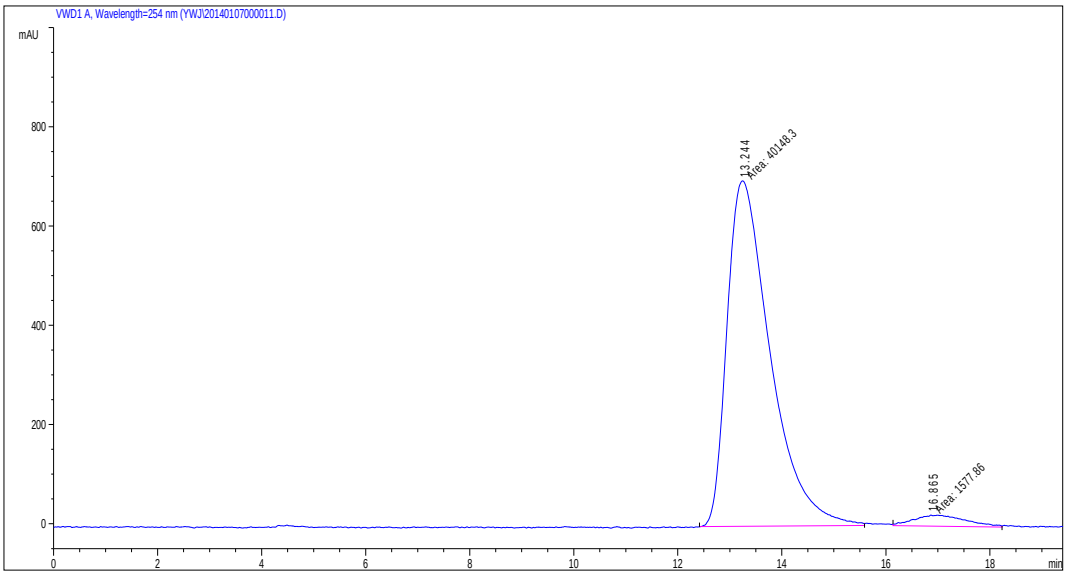
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	6.225	MM	0.4161	5.82864e4	2334.65479	95.7310
2	9.454	MM	0.5921	2599.20728	73.16208	4.2690



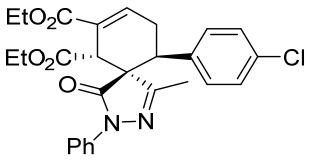
5fa



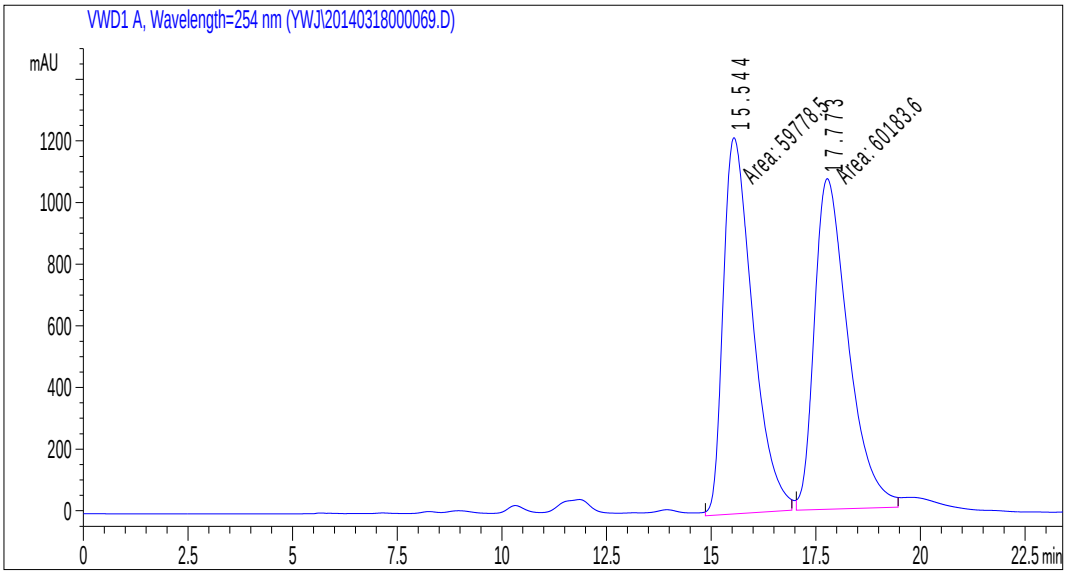
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	13.401	MM	0.9572	2.21903e4	386.36432	49.8469
2	16.743	MM	1.1884	2.23266e4	313.12704	50.1531



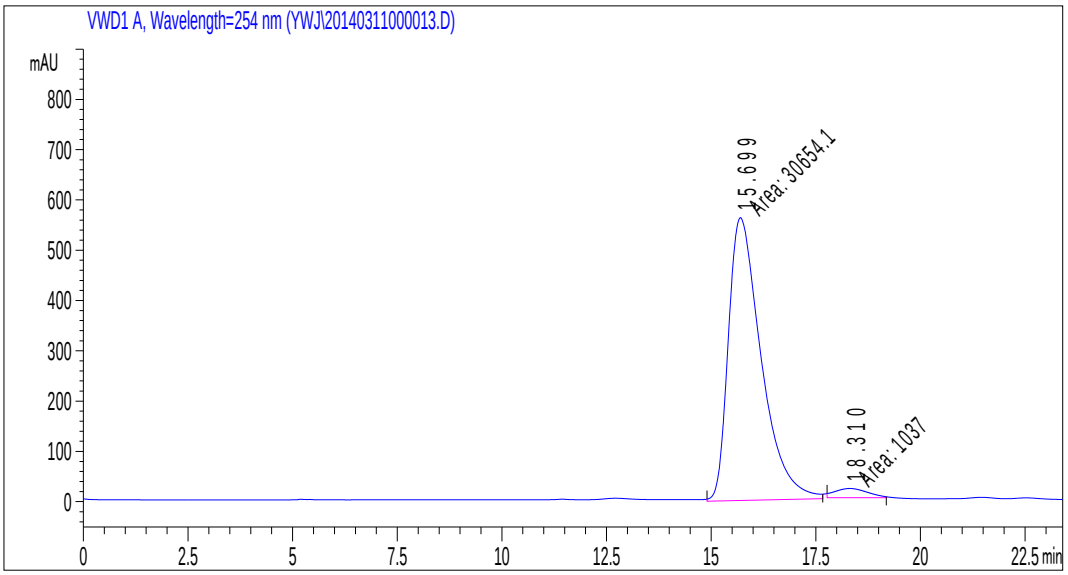
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	13.244	MM	0.9611	4.01483e4	696.20636	96.2185
2	16.865	MM	1.1597	1577.86304	22.67616	3.7815



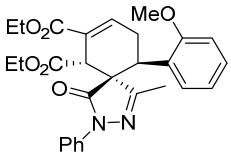
5ha



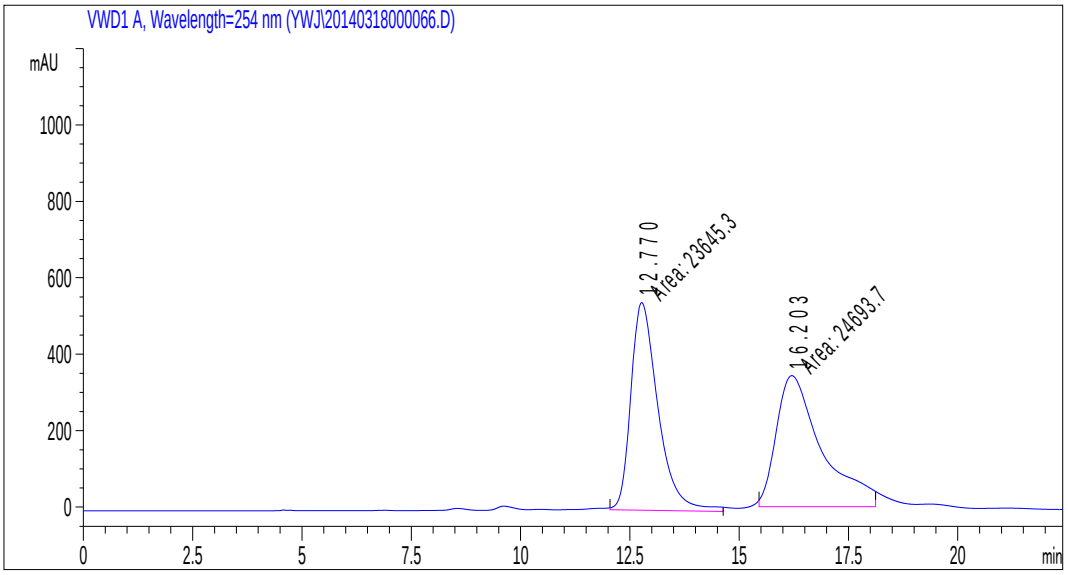
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	15.544	MM	0.8161	5.97785e4	1220.78284	49.8312
2	17.773	MM	0.9348	6.01836e4	1073.04248	50.1688



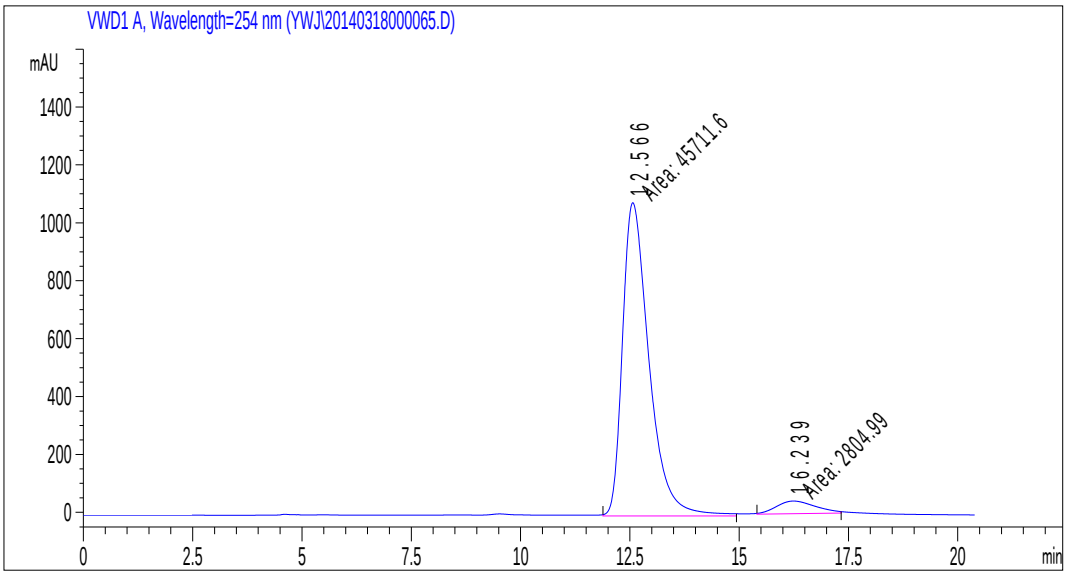
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	15.699	MM	0.9082	3.06541e4	562.53064	96.7278
2	18.310	MM	0.9218	1037.00342	18.75000	3.2722



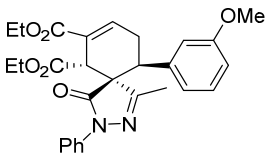
5ka



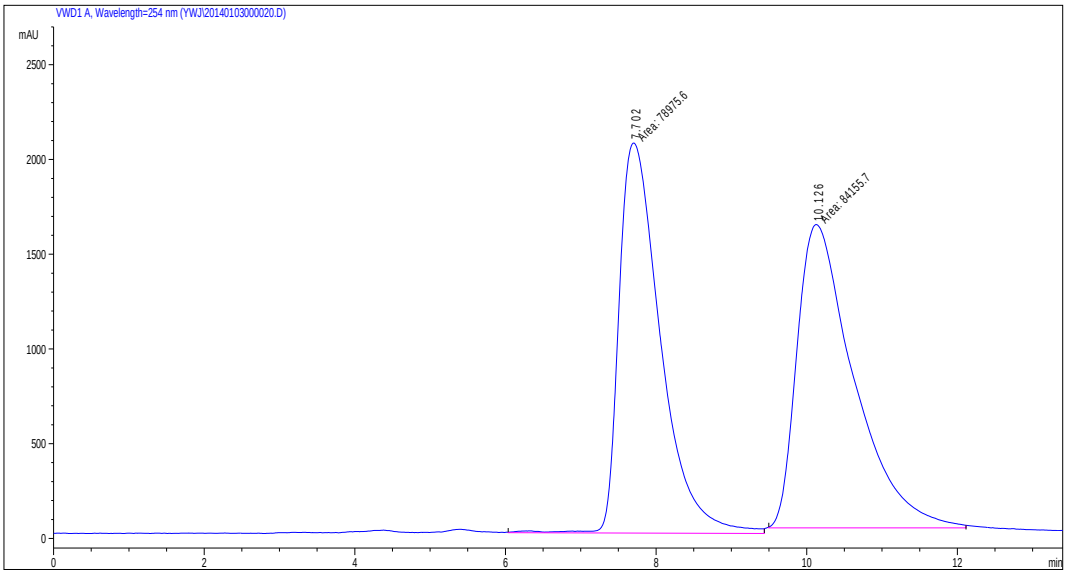
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	12.770	MM	0.7249	2.36453e4	543.67438	48.9156
2	16.203	MM	1.1993	2.46937e4	343.16602	51.0844



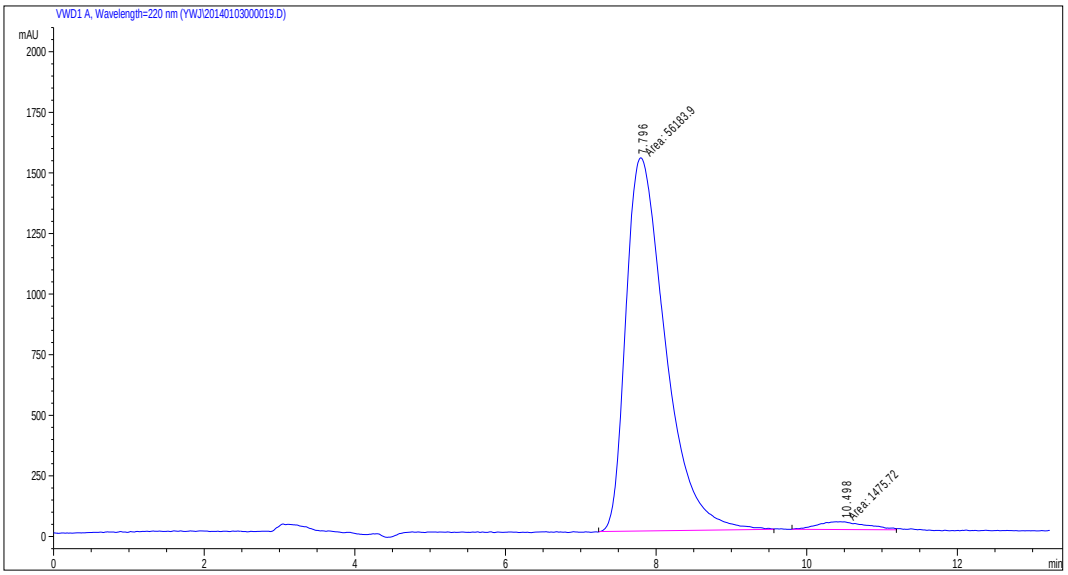
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	12.566	MM	0.7037	4.57116e4	1082.61108	94.2185
2	16.239	MM	1.0530	2804.98926	44.39568	5.7815
Totals :				4.85166e4	1127.00677	



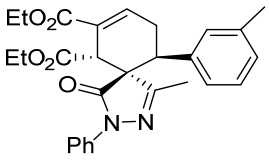
5la



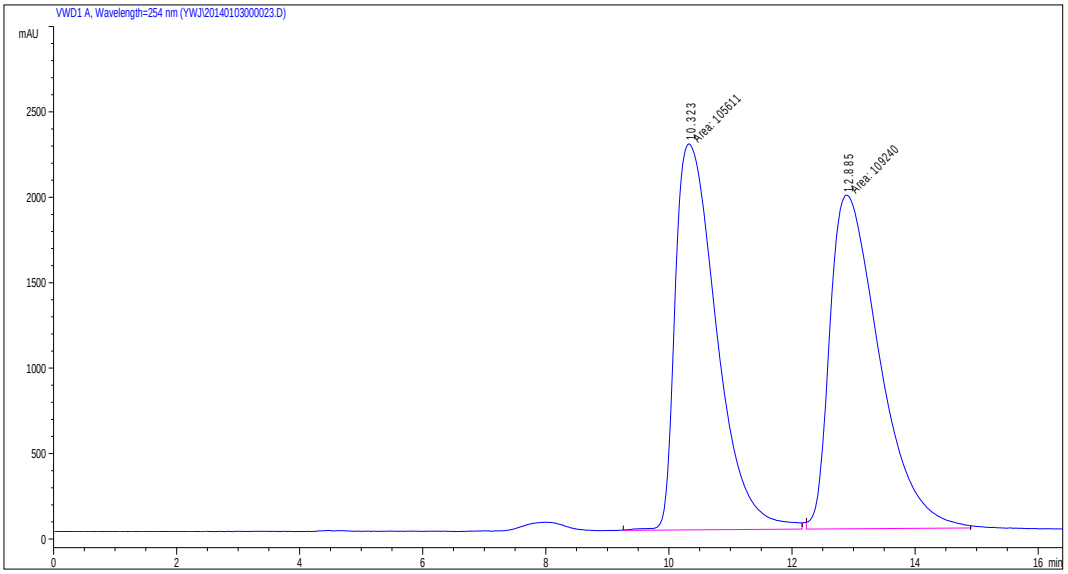
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	7.702	MM	0.6392	7.89756e4	2059.32788	48.4123
2	10.126	MM	0.8760	8.41557e4	1601.21606	51.5877



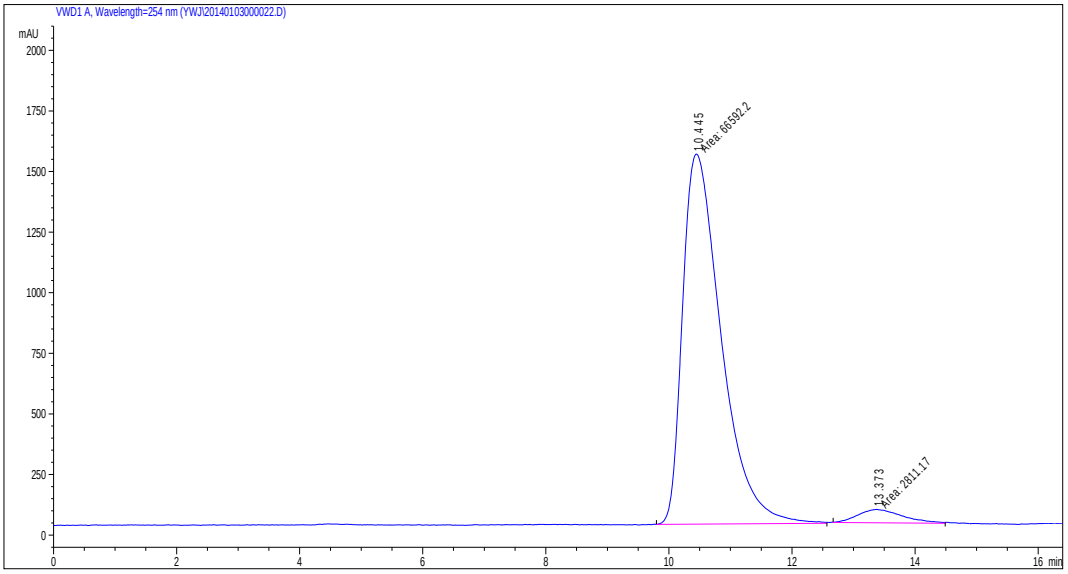
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	7.796	MM	0.6078	5.61839e4	1540.58411	97.4406
2	10.498	MM	0.7712	1475.71899	31.89161	2.5594



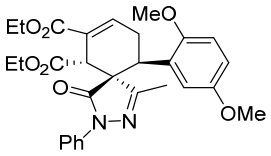
5na



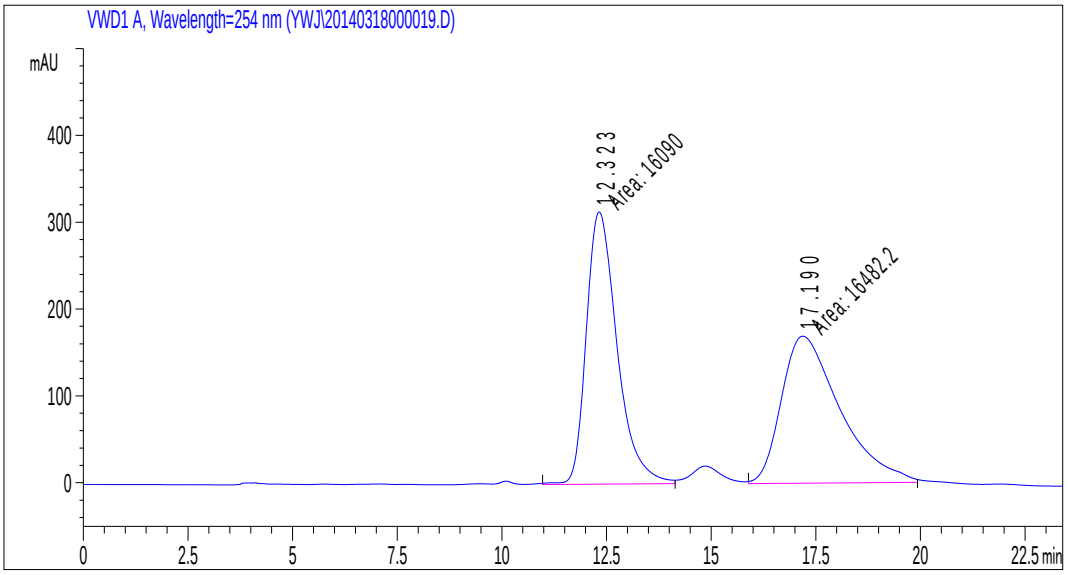
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	10.323	MM	0.7790	1.05611e5	2259.48022	49.1555
2	12.885	MM	0.9321	1.09240e5	1953.29395	50.8445



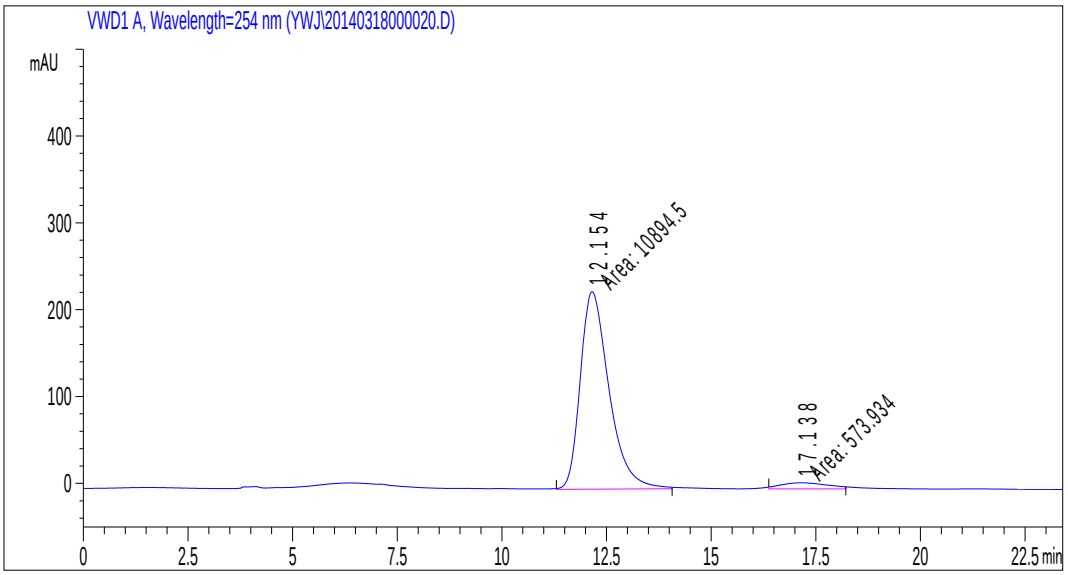
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	10.445	MM	0.7268	6.65922e4	1527.09424	95.9495
2	13.373	MM	0.8419	2811.17041	55.65112	4.0505



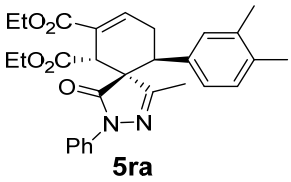
5qa



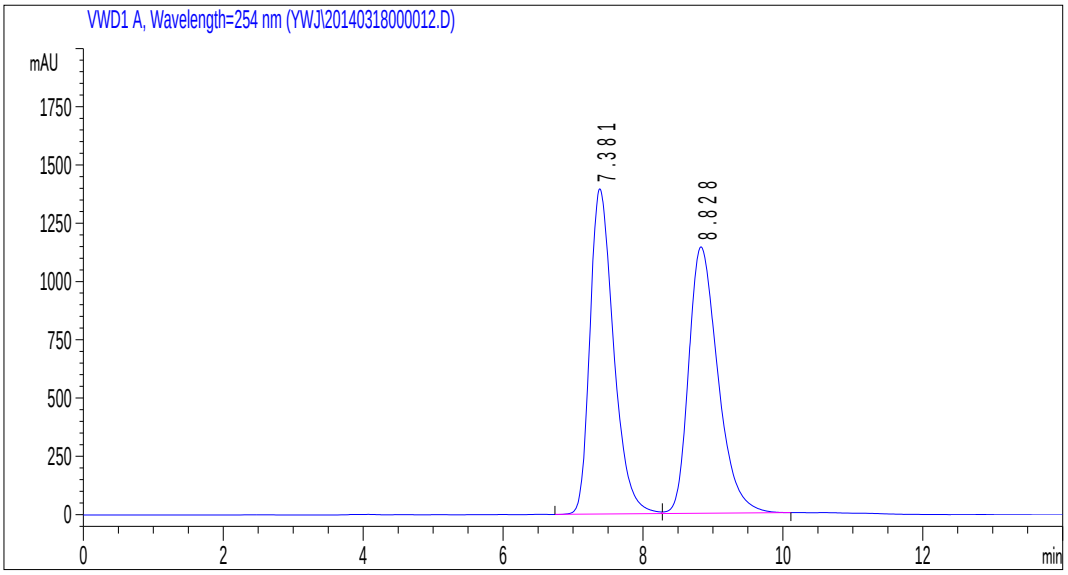
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	12.323	MM	0.8554	1.60900e4	313.51251	49.3979
2	17.190	MM	1.6215	1.64822e4	169.41441	50.6021



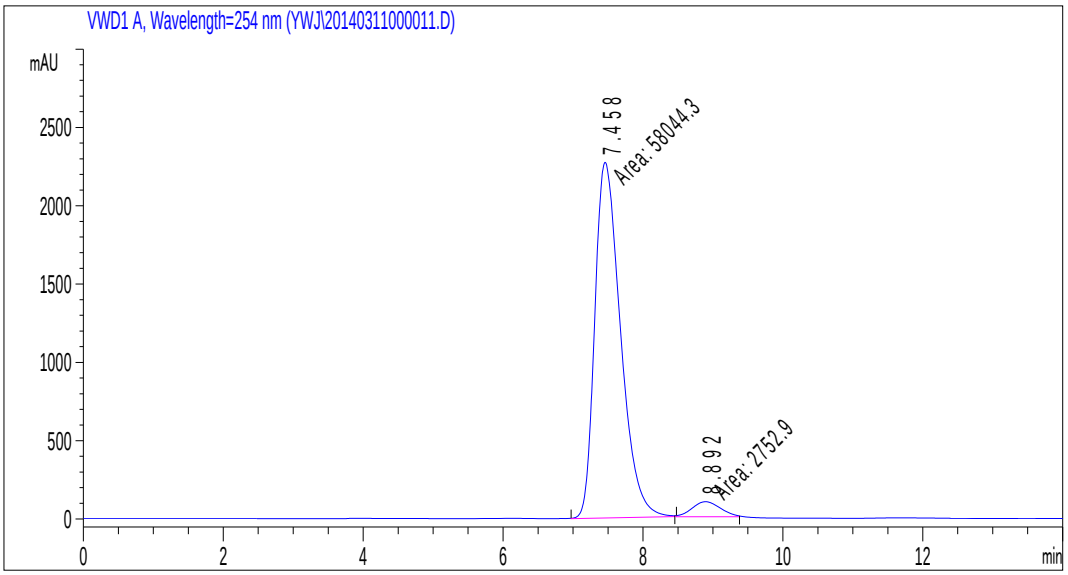
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	12.154	MM	0.7985	1.08945e4	227.40800	94.9955
2	17.138	MM	1.3244	573.93439	7.22282	5.0045



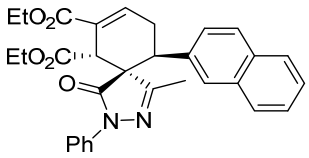
5ra



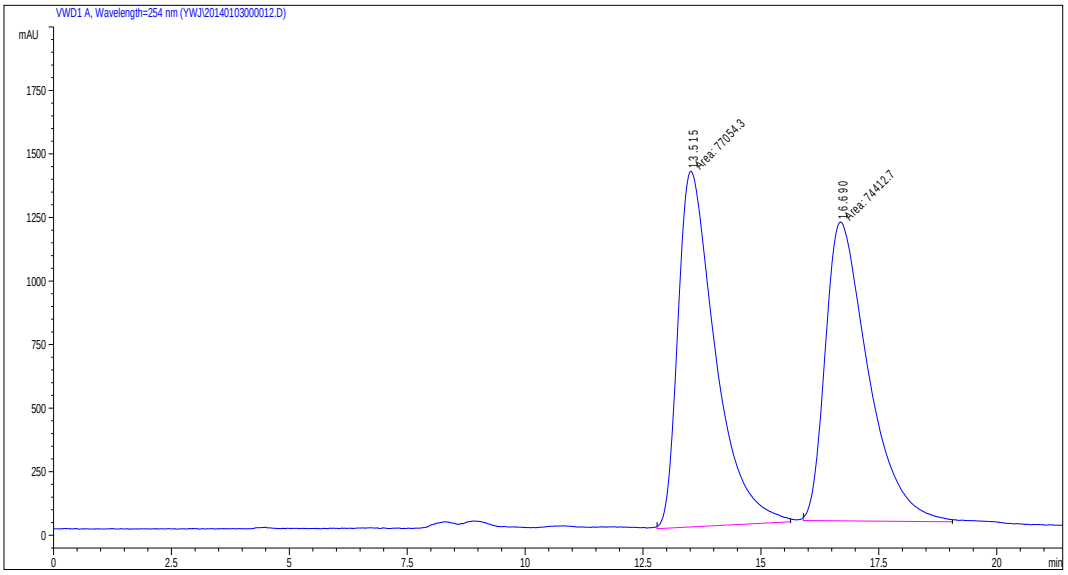
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	7.381	VV	0.3621	3.28722e4	1395.91357	49.7715
2	8.828	VB	0.4462	3.31740e4	1143.68506	50.2285



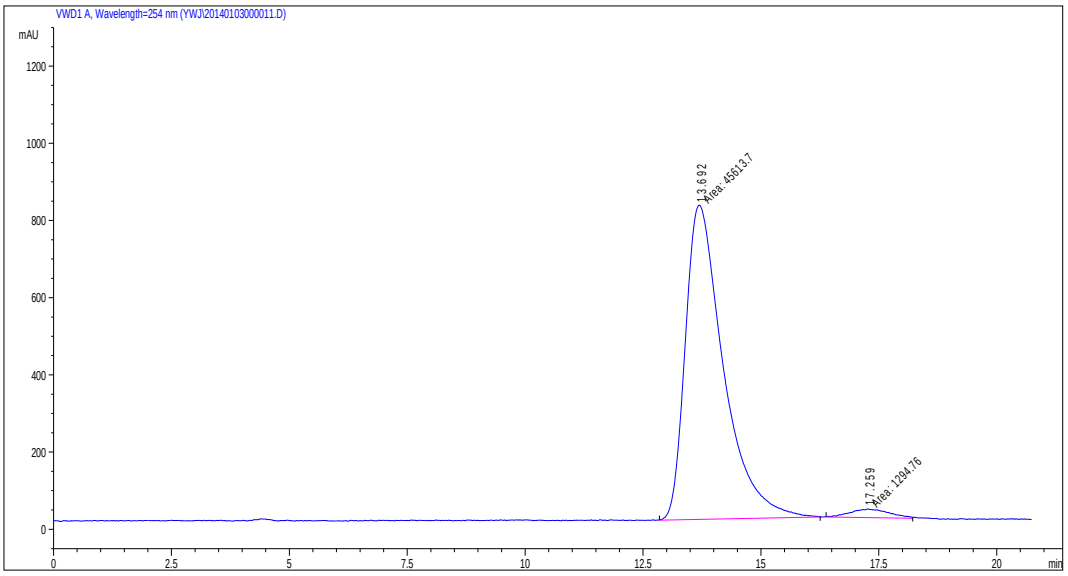
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	7.458	MM	0.4260	5.80443e4	2270.90967	95.4720
2	8.892	MM	0.4727	2752.89722	97.06107	4.5280



5sa

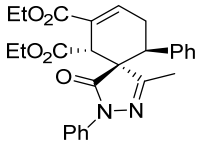


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	13.515	MM	0.9114	7.62869e4	1394.99487	50.2613
2	16.691	MM	1.0702	7.54938e4	1175.67139	49.7387

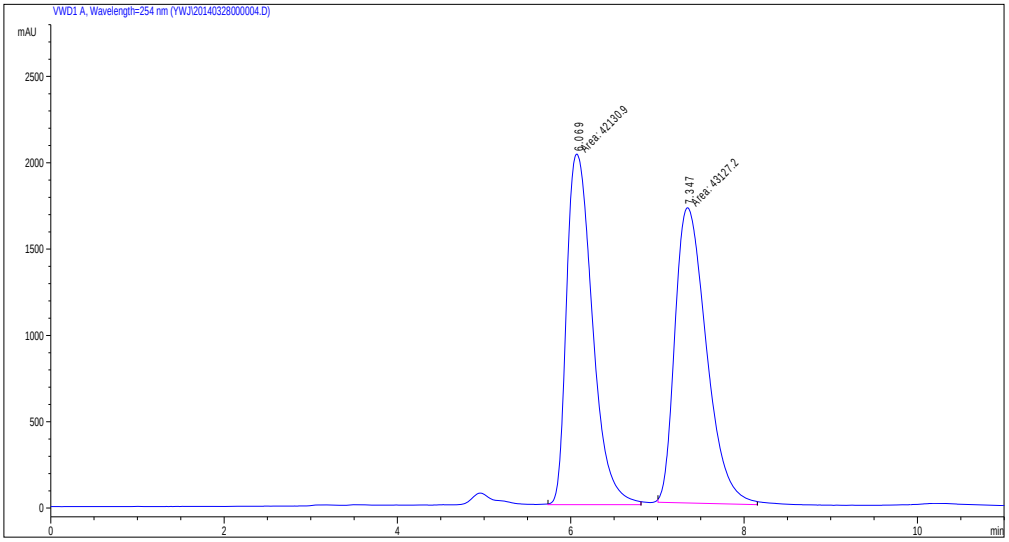


Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	13.692	MM	0.9339	4.56137e4	814.07587	97.2398
2	17.259	MM	0.9627	1294.75793	22.41618	2.7602

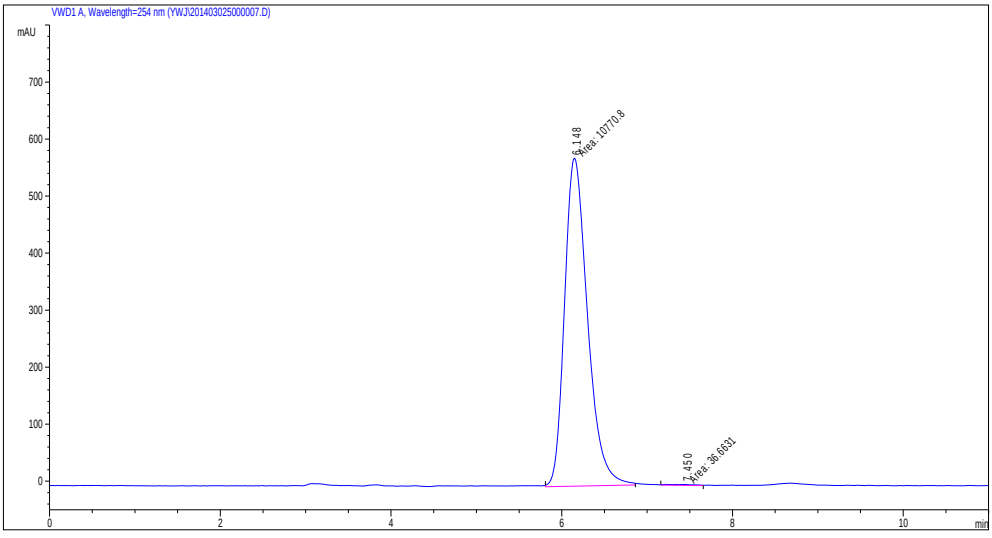
Reaction on 1 mmol of scale



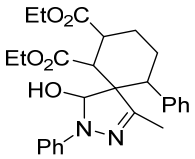
5aa



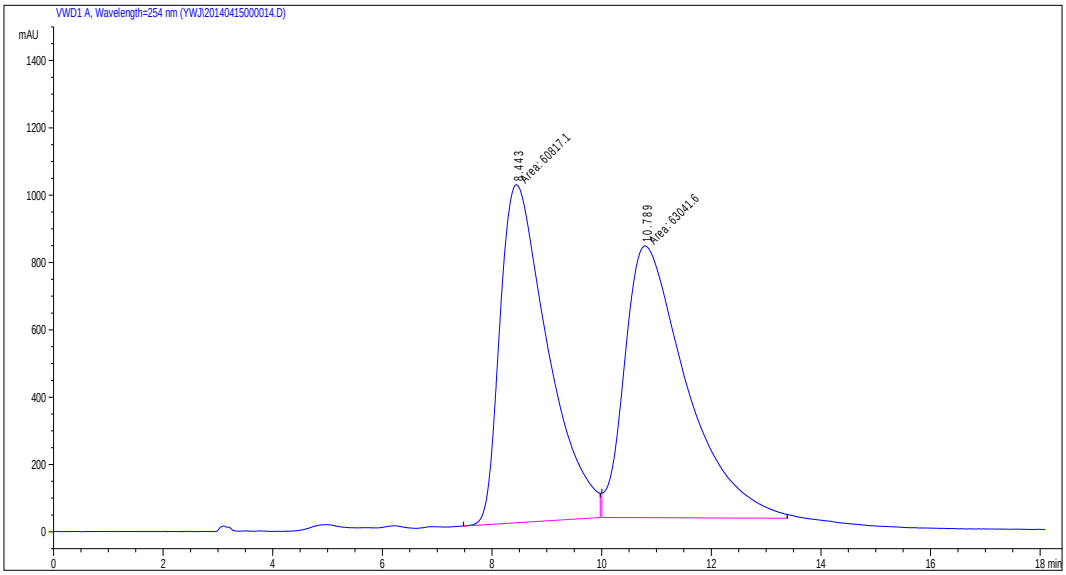
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	6.069	MM	0.3457	4.21309e4	2031.23071	49.4157
2	7.347	MM	0.4202	4.31272e4	1710.76428	50.5843



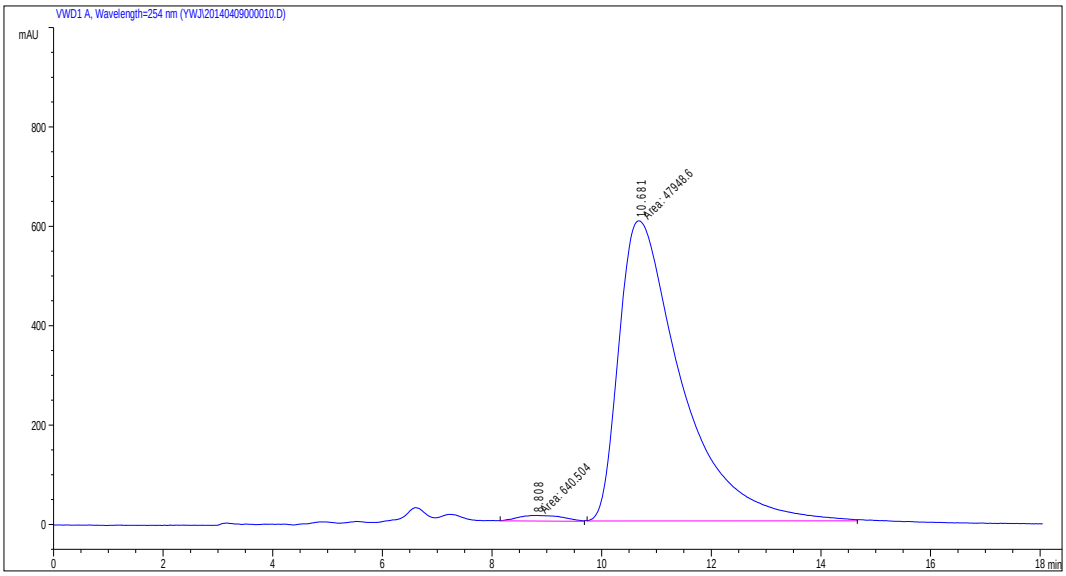
Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	6.148	MM	0.3120	1.07708e4	575.29193	99.6608
2	7.450	MM	0.3948	36.66311	1.54776	0.3392



6



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	8.443	MM	1.0091	6.08171e4	1004.44293	49.1020
2	10.789	MM	1.3018	6.30416e4	807.13000	50.8980



Peak #	RetTime [min]	Type	Width [min]	Area mAU *s	Height [mAU]	Area %
1	8.808	MM	0.9434	640.50427	11.31499	1.3182
2	10.681	MM	1.3230	4.79486e4	604.03577	98.6818

X-ray structure of **3fa**, **3ab**, **4ab** and **5ha**:

Crystallographic data for **3fa**, **3ab**, **4ab** and **5ha** have been deposited with the Cambridge Crystallographic Data Centre as supplementary numbers CCDC 1406999-1407002. These data can be obtained free of charge via www.ccdc.cam.ac.uk/data_request/cif, or by emailing data_request@ccdc.cam.ac.uk, or by contacting The Cambridge Crystallographic Data Centre, 12, Union Road, Cambridge CB2 1EZ, UK; fax: +44 1223 336033.

X-ray structure of **3fa**

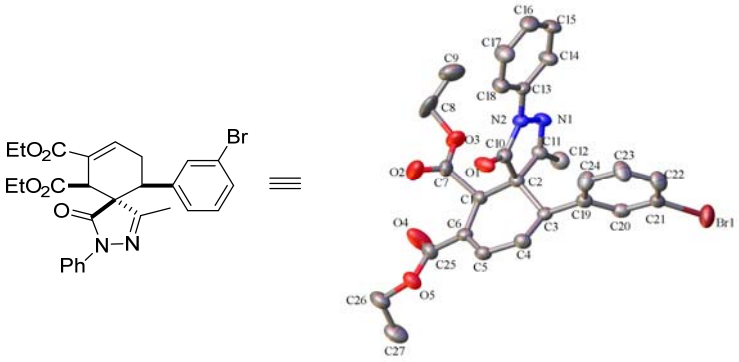


Table 1. Crystal data and structure refinement for **3fa**.

Identification code	**3fa**	
Empirical formula	C_{27} H_{27} Br N_2 O_5	
Formula weight	539.41	
Temperature	223.1500 K	
Wavelength	0.71073 Å	
Crystal system	Monoclinic	
Space group	C 1 c 1	
Unit cell dimensions	a = 16.786(2) Å	α= 90°.
	b = 16.7779(19) Å	β= 92.779(2)°.
	c = 35.405(4) Å	γ = 90°.

Volume	9959(2) $Å^3$
Z	16
Density (calculated)	1.439 Mg/m^3
Absorption coefficient	1.692 mm^{-1}
F(000)	4448
Crystal size	0.28 x 0.23 x 0.1 mm^3
Theta range for data collection	1.717 to 27.505°.
Index ranges	-21<=h<=21, -21<=k<=21, -43<=l<=45
Reflections collected	33600
Independent reflections	20699 [R(int) = 0.0406]
Completeness to theta = 26.000°	99.7 %
Absorption correction	Semi-empirical from equivalents
Max. and min. transmission	1.0000 and 0.7472
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	20699 / 2 / 1273
Goodness-of-fit on F^2	1.095
Final R indices [I>2sigma(I)]	R_1 = 0.0598, wR_2 = 0.1148
R indices (all data)	R_1 = 0.0732, wR_2 = 0.1238
Absolute structure parameter	0.044(7)
Extinction coefficient	n/a
Largest diff. peak and hole	0.503 and -0.436 $e.Å^{-3}$

X-ray structure of **3ab**

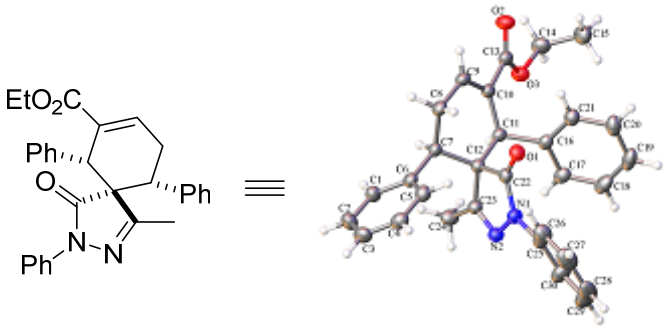


Table 1. Crystal data and structure refinement for **3ab**.

Identification code	**3ab**
Empirical formula	$C_{30}H_{28}N_2O_3$
Formula weight	464.54
Temperature	173(2) K
Wavelength	0.71073 Å
Crystal system	Monoclinic
space group	P21/n
Unit cell dimensions	a = 12.107(2) Å α = 90 °. b = 10.601(2) Å β = 98.78(3) °. c = 18.803(4) Å γ = 90 °.
Volume	2385.0(8) $Å^3$
Z	4
Calculated density	1.294 Mg/m^3
Absorption coefficient	0.084 mm^{-1}
F(000)	984
Crystal size	0.63 x 0.31 x 0.31 mm
Theta range for data collection	2.57 to 27.47 °.
Limiting indices	-15<=h<=15, -13<=k<=13, -24<=l<=23
Reflections collected / unique	16237 / 5434 [R(int) = 0.0351]
Completeness to theta = 27.47	99.5 %
Absorption correction	Semi-empirical from equivalents
Max. and min. transmission	1.0000 and 0.6545
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	5434 / 0 / 318
Goodness-of-fit on F^2	1.147
Final R indices [I>2sigma(I)]	R1 = 0.0526, wR2 = 0.1213
R indices (all data)	R1 = 0.0583, wR2 = 0.1247
Largest diff. peak and hole	0.355 and -0.166 $e.A^{-3}$

X-ray structure of **4ab**

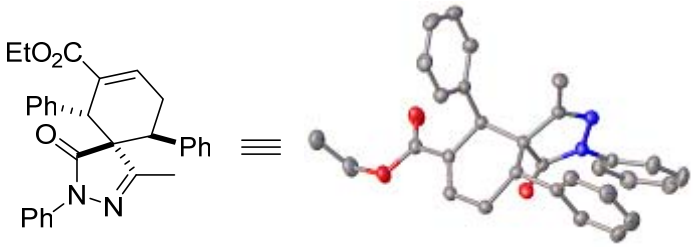


Table 1. Crystal data and structure refinement for **4ab**.

Identification code	**4ab**
Empirical formula	$C_{30}\ H_{28}\ N_2\ O_3$
Formula weight	464.54
Temperature	173(2) K
Wavelength	0.71073 Å
Crystal system	Triclinic
Space group	P-1
Unit cell dimensions	a = 9.994(3) Å α = 107.882(4) ° b = 10.991(6) Å β = 108.124(10) ° c = 12.398(8) Å γ = 95.032(6) °
Volume	1206.2(11) $Å^3$
Z	2
Calculated density	1.279 Mg/m^3
Absorption coefficient	0.083 mm^{-1}
F(000)	492
Crystal size	0.64 x 0.45 x 0.26 mm
Theta range for data collection	2.31 to 27.50 °
Limiting indices	-12<=h<=12, -13<=k<=14, -16<=l<=16
Reflections collected / unique	15521 / 5490 [R(int) = 0.0396]
Completeness to theta = 27.50	99.3 %
Absorption correction	Semi-empirical from equivalents
Max. and min. transmission	1.0000 and 0.6712
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	5490 / 0 / 318
Goodness-of-fit on F^2	1.120
Final R indices [I>2sigma(I)]	R1 = 0.0487, wR2 = 0.1218
R indices (all data)	R1 = 0.0517, wR2 = 0.1240
Largest diff. peak and hole	0.316 and -0.164 e. $Å^{-3}$

X-ray structure of **5ha**

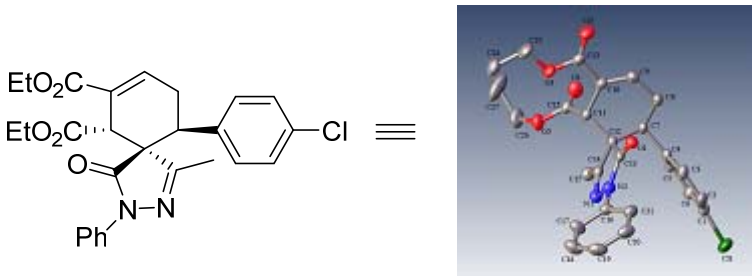


Table 1. Crystal data and structure refinement for **5ha**

Identification code	**5ha**	
Empirical formula	C_{27} H_{27} Cl N_2 O_5	
Formula weight	494.95	
Temperature	173.1500 K	
Wavelength	0.71073 Å	
Crystal system	Orthorhombic	
Space group	P 21 21 21	
Unit cell dimensions	a = 10.513(2) Å	α = 90°
	b = 13.093(3) Å	β = 90°
	c = 17.827(4) Å	γ = 90°
Volume	2453.9(9) $Å^3$	
Z	4	
Density (calculated)	1.340 Mg/m^3	
Absorption coefficient	0.197 mm^{-1}	
F(000)	1040	
Crystal size	0.6 x 0.546 x 0.518 mm^3	
Theta range for data collection	1.930 to 27.480°.	
Index ranges	-13<=h<=13, -16<=k<=17, -22<=l<=23	
Reflections collected	27526	
Independent reflections	5618 [R(int) = 0.0566]	
Completeness to theta = 26.000°	99.9 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	1.0000 and 0.4908	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	5618 / 0 / 319	
Goodness-of-fit on F^2	1.136	
Final R indices [I>2sigma(I)]	R1 = 0.0366, wR2 = 0.1003	
R indices (all data)	R1 = 0.0371, wR2 = 0.1006	
Absolute structure parameter	0.04(3)	
Extinction coefficient	n/a	
Largest diff. peak and hole	0.237 and -0.255 e.$Å^{-3}$	