

Supporting Information

Indolizine Synthesis via Cu-catalyzed Cyclization of 2-(2-Enynyl)pyridines with Nucleophiles

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Content

General information.....	S3
Substrate synthesis.....	S3
General datas of substrates 3a-3n.....	S3-S9
Typical procedure for the cyclization reaction.....	S9
General datas of indolizine products 5.....	S10-S20
NMR datas for 3 and 5, 6,7.....	S21-S58
HPLC data for 5ae.....	S59
References.....	S59

EXPERIMENTAL SECTION

Reactions and manipulations involving organometallic or moisture sensitive compounds were carried out under dry nitrogen and glassware heated under oven for two hours prior to use. NMR spectra were recorded on 500 MHz spectrometers for ^1H NMR and 125 or 100 MHz spectrometer for ^{13}C NMR with deuterated chloroform (CDCl_3) as solvent at 298 K. HRMS were obtained with a TOF MS spectrometer. Melting points were uncorrected. Anhydrous THF, toluene, ether were freshly distilled over Na and benzophenone. Anhydrous $\text{CH}_2\text{ClCH}_2\text{Cl}$, CH_2Cl_2 , CH_3CN were freshly distilled over calcium hydride. Commercial reagents were used as received without further purification unless otherwise noticed. Column chromatography was carried out using silica gel (200-300 mesh). The pyridyl-substituted alkynyl ketones **1** was synthesis according to the reference.¹

General Procedure for the Synthesis of 2-(2-Enynyl)pyridine 3. To a solution of the benzyl bromide ylide (1.2 eq.) in dry THF (50) at 0 °C, *n*-butyllithium (1.2 eq.) was added dropwise by syringe over 5 minutes. The white solution gradually turn to orange. After 10 min, pyridyl-substituted alkynyl ketones **1** (1.0 eq.) was added to the solution, after the reaction was over, the mixture was poured into water and extracted with EtOAc (3 x 20 mL). The combines organic phase was dried over MgSO_4 and filtered. The solvent was removed under vacuum and the residue was purified by flash chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:10 (v/v) to afford the 2-(2-enynyl)pyridine **3**.

2-(1,4-Diphenylbut-1-en-3-yn-2-yl)pyridine (3a): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:10 (v/v); 94% yield (60% yield for the major isomer, light yellow solid, m.p. 96-98 °C), ^1H NMR (500 MHz, CDCl_3)

(major isomer): δ 7.23-7.26 (m, 1H), 7.34-7.47 (m, 6H), 7.60-7.63 (m, 2H), 7.78 (td, J = 2.0, 7.5 Hz, 1H), 8.01 (d, J = 7.5 Hz, 1H), 8.15 (d, J = 7.5 Hz, 2H), 8.25 (s, 1H), 8.65-8.67 (m, 1H); ^{13}C NMR (125 MHz, CDCl_3): δ 87.8, 97.5, 119.7, 121.7, 122.5, 123.2, 128.3, 128.5, 128.6, 128.9, 129.8, 131.5, 136.3, 136.8, 137.1, 149.0, 155.2; HRMS m/z (ESI+): Calculated for $\text{C}_{21}\text{H}_{16}\text{N}$ ($[\text{M}+\text{H}]^+$): 282.1277, Found 282.1288.

2-(1-Phenyl-4-p-tolylbut-1-en-3-yn-2-yl)pyridine (3b): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:10 (v/v); 95% yield (62% yield for the major isomer, light yellow solid, m.p. 89-91 °C); ^1H NMR (500 MHz, CDCl_3) (major isomer): δ 2.42 (s, 3H), 7.22-7.25 (m, 3H), 7.36 (tt, J = 1.5, 7.5 Hz, 1H), 7.43-7.46 (m, 2H), 7.51 (d, J = 8.0 Hz, 2H), 7.77 (td, J = 2.0, 8.0 Hz, 1H), 8.01 (d, J = 8.0 Hz, 1H), 8.15 (d, J = 7.5 Hz, 2H), 8.22 (s, 1H), 8.64-8.67 (m, 1H); ^{13}C NMR (125 MHz, CDCl_3): δ 21.5, 87.2, 97.8, 119.9, 120.2, 121.7, 122.4, 128.3, 128.8, 129.3, 129.8, 131.4, 136.4, 136.7, 136.8, 138.8, 148.9, 155.3; HRMS m/z (ESI+): Calculated for $\text{C}_{22}\text{H}_{18}\text{N}$ ($[\text{M}+\text{H}]^+$): 296.1434, Found 296.1441.

2-(4-(4-Chlorophenyl)-1-phenylbut-1-en-3-yn-2-yl)pyridine (3c): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:10 (v/v); 90% yield; (58% yield for the major isomer, light yellow solid, m.p. 68-70 °C); ^1H NMR (500 MHz, CDCl_3) (major isomer): δ 7.25 (dd, J = 5.0, 7.5 Hz, 1H), 7.36-7.40 (m, 3H), 7.45 (t, J = 7.5 Hz, 2H), 7.51-7.55 (m, 2H), 7.78 (td, J = 2.0, 8.0 Hz, 1H), 7.95 (d, J = 8.0 Hz, 1H), 8.10 (d, J = 7.5 Hz, 2H), 8.24 (s, 1H), 8.65-8.67 (m, 1H); ^{13}C NMR (125 MHz, CDCl_3): δ 88.8, 96.2, 119.5, 121.6, 121.7, 122.5, 128.3, 128.85, 128.94, 129.8, 132.7, 134.7, 136.2, 136.8, 137.6, 149.0, 155.0; HRMS m/z (ESI+): Calculated

for $C_{21}H_{15}ClN$ ($[M+H]^+$): 316.0888, Found 316.0895.

2-(4-(4-Methoxyphenyl)-1-phenylbut-1-en-3-yn-2-yl)pyridine (**3d**): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:10 (v/v); 94% yield; (70% yield for the major isomer product, brown solid, m.p. 74-76 °C); 1H NMR (500 MHz, $CDCl_3$) (major isomer): δ 3.87 (s, 3H), 6.93-6.96 (m, 2H), 7.22-7.26 (m, 1H), 7.36 (tt, $J = 1.0, 6.5$ Hz, 1H), 7.43-7.46 (m, 2H), 7.54-7.56 (m, 2H), 7.77 (td, $J = 2.0, 7.5$ Hz, 1H), 8.00 (dt, $J = 0.5, 8.0$ Hz, 1H), 8.15 (d, $J = 7.5$ Hz, 2H), 8.20 (s, 1H), 8.64-8.67 (m, 1H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 55.3, 86.6, 97.7, 114.2, 115.3, 120.0, 121.7, 122.4, 128.2, 128.7, 129.7, 133.0, 136.3, 136.5, 136.7, 148.9, 155.3, 159.9; HRMS m/z (ESI+): Calculated for $C_{22}H_{17}NO$ ($[M+H]^+$): 312.1383, Found 312.1388.

2-(1-Phenyloct-1-en-3-yn-2-yl)pyridine (**3e**): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:10 (v/v); 90% yield; (50% yield for the major isomer product, colorless oil); 1H NMR (500 MHz, $CDCl_3$) (major isomer): δ 1.00 (t, $J = 7.5$ Hz, 3H), 1.56 (qt, $J = 7.5, 15.0$ Hz, 2H), 1.71 (tt, $J = 7.0, 14.5$ Hz, 2H), 2.60 (t, $J = 7.0$ Hz, 2H), 7.19-7.22 (m, 1H), 7.33 (tt, $J = 1.0, 7.0$ Hz, 1H), 7.39-7.42 (m, 2H), 7.73 (td, $J = 2.0, 7.5$ Hz, 1H), 7.91 (d, $J = 8.0$ Hz, 1H), 8.09 (s, 1H), 8.10 (s, 2H), 8.61-8.63 (m, 1H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 13.6, 19.6, 22.1, 30.6, 78.8, 99.3, 120.3, 121.6, 122.2, 128.1, 129.5, 135.7, 136.5, 136.6, 148.8, 155.9; HRMS m/z (ESI+): Calculated for $C_{19}H_{20}N$ ($[M+H]^+$): 262.1590, Found 262.1607.

2-(1-(4-Fluorophenyl)-4-phenylbut-1-en-3-yn-2-yl)pyridine (**3f**): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:10 (v/v); 93%

yield; (60% yield for the major isomer product, light white solid, m.p. 119-121 °C); ¹H NMR (500 MHz, CDCl₃) (major isomer): δ 7.14 (t, *J* = 9.0 Hz, 2H), δ 7.23-7.26 (m, 1H), 7.39-7.45 (m, 3H), 7.58-7.61 (m, 2H), 7.77 (td, *J* = 2.0, 7.5 Hz, 1H), 7.99 (d, *J* = 8.0 Hz, 1H), 8.11-8.16 (m, 2H), 8.20 (s, 1H), 8.64-8.66 (m, 1H); ¹³C NMR (125 MHz, CDCl₃): δ 87.5, 97.6, 115.3 (d, *J*_{C,F} = 21.3 Hz), 119.4 (d, *J*_{C,F} = 1.3 Hz), 121.7, 122.5, 123.0, 128.6 (d, *J*_{C,F} = 20.0 Hz), 131.5 (d, *J*_{C,F} = 11.4 Hz), 131.6, 132.6 (d, *J*_{C,F} = 2.5 Hz), 135.7, 136.8, 149.0, 155.0, 162.8 (d, *J*_{C,F} = 248.8 Hz); HRMS *m/z* (ESI⁺): Calculated for C₂₁H₁₅FN ([M+H]⁺): 300.1183, Found 300.1191.

2-(4-Phenyl-1-p-tolylbut-1-en-3-yn-2-yl)pyridine (3g): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:10 (v/v); 96% yield; (65% yield for the major isomer product, light yellow solid, m.p. 119-121 °C); ¹H NMR (500 MHz, CDCl₃) (major isomer): δ 2.42 (s, 3H), 7.21-7.25 (m, 1H), 7.27 (d, *J* = 8.5 Hz, 2H), 7.40-7.44 (m, 3H), 7.61-7.63 (m, 2H), 7.77 (td, *J* = 1.5, 7.5 Hz, 1H), 8.00 (d, *J* = 8.0, 1H), 8.07 (d, *J* = 8.0 Hz, 2H), 8.22 (s, 1H), 8.64-8.66 (m, 1H); ¹³C NMR (125 MHz, CDCl₃): δ 21.5, 88.0, 97.4, 118.7, 121.6, 122.3, 123.3, 128.47, 128.49, 129.1, 129.8, 131.5, 133.6, 136.8, 137.2, 139.1, 148.9, 155.3; HRMS *m/z* (ESI⁺): Calculated for C₂₂H₁₈N ([M+H]⁺): 296.1434, Found 296.1444.

2-(1-(3-Fluorophenyl)-4-phenylbut-1-en-3-yn-2-yl)pyridine (3h): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:10 (v/v); 93% yield; (57% yield for the major isomer product, gray solid, m.p. 85-87 °C); ¹H NMR (500 MHz, CDCl₃) (major isomer): 7.07 (td, *J* = 2.5, 8.5 Hz, 1H), 7.25-7.28 (m, 1H), 7.37-7.46 (m, 4H), 7.62-7.64 (m, 2H), 7.76 (d, *J* = 8.0 Hz, 1H), 7.79 (td, *J* = 1.5, 7.5

Hz, 1H), 8.01 (d, $J = 7.5$ Hz, 1H), 8.07 (dt, $J = 2.0, 11.0$ Hz, 1H), 8.20 (s, 1H), 8.65-8.67 (m, 1H); ^{13}C NMR (125 MHz, CDCl_3): δ 87.4, 98.5, 115.6 (d, $J_{\text{C,F}} = 22.5$ Hz), 121.0, 121.9, 122.7, 122.9, 126.1 (d, $J_{\text{C,F}} = 3.8$ Hz), 128.6, 128.8, 129.6 (d, $J_{\text{C,F}} = 8.8$ Hz), 131.5, 135.4 (d, $J_{\text{C,F}} = 2.5$ Hz), 136.9, 138.5 (d, $J_{\text{C,F}} = 8.8$ Hz), 149.0, 154.8, 162.7 (d, $J_{\text{C,F}} = 245.0$ Hz); HRMS m/z (ESI⁺): Calculated for $\text{C}_{21}\text{H}_{15}\text{FN}$ ($[\text{M}+\text{H}]^+$): 300.1183, Found 300.1183.

2-(4-Phenyl-1-m-tolylbut-1-en-3-yn-2-yl)pyridine (3i): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:10 (v/v); 93% yield; (65% yield for the major isomer product, white solid, m.p. 82-84 °C); ^1H NMR (500 MHz, CDCl_3) (major isomer) ^1H NMR (500 MHz, CDCl_3) (major isomer): δ 2.43 (s, 3H), 7.20 (d, $J = 7.5$ Hz, 1H), 7.24 (dd, $J = 5.0, 7.5$ Hz), 7.35 (t, $J = 8.0$ Hz, 1H), 7.40-7.44 (m, 3H), 7.60-7.63 (m, 2H), 7.78 (td, $J = 1.5, 8.0$ Hz, 1H), 7.93 (d, $J = 7.5$ Hz, 1H), 8.01 (d, $J = 8.0$ Hz, 1H), 8.03 (s, 1H,), 8.22 (s, 1H), 8.65-8.67 (m, 1H); ^{13}C NMR (125 MHz, CDCl_3): δ 21.5, 88.0, 97.5, 119.5, 121.7, 122.4, 123.3, 127.1, 128.2, 128.5, 128.6, 129.7, 130.4, 131.5, 136.2, 136.8, 137.3, 137.7, 149.0, 155.2; HRMS m/z (ESI⁺): Calculated for $\text{C}_{22}\text{H}_{18}\text{N}$ ($[\text{M}+\text{H}]^+$): 296.1434, Found 296.1448.

2-(1-(2-Bromophenyl)-4-phenylbut-1-en-3-yn-2-yl)pyridine (3j): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:10 (v/v); 90% yield; (60% yield for the major isomer product, white solid, m.p. 103-105 °C); ^1H NMR (500 MHz, CDCl_3) (major isomer): δ 7.22 (td, $J = 2.0, 8.0$ Hz, 1H), 7.25-7.29 (m, 1H), 7.36-7.42 (m, 4H), 7.50-7.54 (m, 2H), 7.67 (dd, $J = 1.5, 8.0$ Hz, 1H), 7.79 (td, $J = 2.0, 8.0$ Hz, 1H), 7.99 (d, $J = 8.0$ Hz, 1H), 8.44 (dd, $J = 1.5, 8.0$ Hz, 1H), 8.46 (s,

1H), 8.68-8.71 (m, 1H); ¹³C NMR (125 MHz, CDCl₃): δ 87.0, 96.8, 121.9, 122.4, 122.8, 123.0, 125.6, 126.8, 128.4, 128.7, 129.8, 130.3, 131.5, 132.8, 136.2, 136.4, 136.8, 149.3, 154.7; Calculated for C₂₁H₁₄BrN ([M+H]⁺): 360.0382, Found 360.0386.

2-(1-Phenylhept-3-en-1-yn-3-yl)pyridine (3k): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:10 (v/v); colorless oil, 90% yield; ¹H NMR (500 MHz, CDCl₃): δ 1.05 (t, *J* = 7.5 Hz, 3H), 1.60-1.69 (m, 2H), 2.62 (q, *J* = 7.5 Hz, 2H), 7.17-7.20 (m, 1H), 7.35-7.41 (m, 4H), 7.56-7.59 (m, 2H), 7.72 (td, *J* = 2.0, 7.5 Hz, 1H), 7.81 (d, *J* = 8.0 Hz, 1H), 8.57-8.60 (m, 1H); ¹³C NMR (125 MHz, CDCl₃): δ 14.0, 22.1, 33.3, 86.0, 95.7, 121.2, 122.1, 122.8, 123.4, 128.2, 128.3, 131.5, 136.7, 142.6, 149.0, 154.7; HRMS *m/z* (ESI⁺): Calculated for C₁₈H₁₈N ([M+H]⁺): 248.1434, Found 248.1442.

Methyl 5-phenyl-3-(pyridin-2-yl)pent-2-en-4-ynoate (3l): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:10 (v/v); (85% yield, white solid, m.p. 88-90 °C); ¹H NMR (500 MHz, CDCl₃): δ 3.87 (s, 3H), 7.32-7.36 (m, 1H), 7.40-7.42 (m, 3H), 7.52 (s, 1H), 7.67-7.69 (m, 2H), 7.81 (td, *J* = 2.0, 7.5 Hz, 1H), 8.06 (d, *J* = 8.0 Hz, 1H), 8.64-8.66 (m, 1H); ¹³C NMR (125 MHz, CDCl₃): δ 51.6, 85.9, 101.9, 122.5, 123.0, 124.4, 124.9, 128.4, 129.3, 132.0, 134.1, 136.9, 149.3, 152.8, 166.0; HRMS *m/z* (ESI⁺): Calculated for C₁₇H₁₄NO₂ ([M+H]⁺): 264.1019, Found 264.1032.

*2-(4-(4-Methoxyphenyl)-1-*p*-tolylbut-1-en-3-yn-2-yl)pyridine (3m)*: Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:10 (v/v); 95% yield; (65% yield for the major isomer product, white solid, m.p. 132-134 °C); ¹H

NMR (500 MHz, CDCl₃) (major isomer): δ 2.42 (s, 3H), 3.87 (s, 3H), 6.93-6.97 (m, 2H), 7.20-7.24 (m, 1H), 7.26 (d, J = 8.5 Hz, 2H), 7.53-7.57 (m, 2H), 7.76 (td, J = 2.0, 7.5 Hz, 1H), 7.99 (dt, J = 1.0, 8.0 Hz, 1H), 8.06 (d, J = 8.0 Hz, 2H), 8.17 (s, 1H), 8.63-8.66 (m, 1H); ¹³C NMR (125 MHz, CDCl₃): δ 21.4, 55.3, 86.8, 97.6, 114.2, 115.5, 119.0, 121.6, 122.3, 129.0, 129.7, 132.9, 133.7, 136.3, 136.7, 138.9, 148.9, 155.5, 159.9; HRMS m/z (ESI⁺): Calculated for C₂₃H₂₀NO ([M+H]⁺): 326.1539, Found 326.1547.

2-(1,4-Diphenylbut-1-en-3-yn-2-yl)quinoline (3n): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:10 (v/v); 83% yield; (50% yield for the major isomer product, light red solid, m.p. 124-126 °C); ¹H NMR (500 MHz, CDCl₃) (major isomer): δ 7.38-7.50 (m, 6H), 7.53-7.57 (m, 1H), 7.63-7.66 (m, 2H), 7.74-7.77 (m, 1H), 7.85 (d, J = 8.5 Hz, 1H), 8.17-8.25 (m, 5H), 8.42 (s, 1H); ¹³C NMR (125 MHz, CDCl₃): δ 88.3, 97.8, 119.9, 120.2, 123.3, 126.3, 127.4, 127.5, 128.3, 128.5, 128.6, 129.0, 129.5, 129.7, 130.0, 131.5, 136.4, 136.6, 138.5, 147.8, 155.3; HRMS m/z (ESI⁺): Calculated for C₂₅H₁₈N ([M+H]⁺): 332.1434, Found 332.1432.

Typical procedure for the cyclization reaction. To a dried Schlenk tube was added 4 Å molecular sieves (100 mg), 2-(2-enynyl)pyridine **3** (0.2 mmol), CuI (1.9 mg, 5 mol%) under N₂, 2.0 mL CH₃CN and Et₃N (1.0 equiv) were then added through syringe, followed by the addition of nucleophiles **4** (1.05 equiv). The mixture was stirred at 80 °C until the reaction was completed (monitored by TLC). The solvent was removed under vacuum and the residue was purified by chromatography on silica

gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v) to afford the product **5**.

Dimethyl 2-(phenyl(3-phenylindolizin-1-yl)methyl)malonate (5aa): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 98% yield, m.p. 86-88 °C; ¹H NMR (500MHz, CDCl₃): δ 3.56 (s, 3H), 3.58 (s, 3H), 4.43 (d, *J* = 12.0 Hz, 1H), 5.13 (d, *J* = 12.0 Hz, 1H), 6.44 (t, *J* = 6.5 Hz, 1H), 6.66 (dd, *J* = 6.5, 9.0 Hz, 1H), 6.89 (s, 1H), 7.18 (t, *J* = 7.5 Hz, 1H), 7.28 (t, *J* = 7.5 Hz, 2H), 7.34 (t, *J* = 7.5 Hz, 1H), 7.41 (d, *J* = 7.5 Hz, 2H), 7.47 (t, *J* = 7.5 Hz, 2H), 7.53 (t, *J* = 8.0 Hz, 3H), 8.19 (d, *J* = 7.0 Hz, 1H); ¹³C NMR (125MHz, CDCl₃): δ 42.6, 52.4, 52.5, 58.3, 110.8, 112.1, 113.3, 116.7, 117.6, 122.0, 124.9, 126.6, 127.0, 127.7, 127.9, 128.4, 128.8, 130.7, 132.2, 141.9, 168.16, 168.24; HRMS *m/z* (ESI⁺): Calculated for C₂₆H₂₄NO₄ ([M+H]⁺): 414.1700, Found 414.1708.

Diethyl 2-(phenyl(3-phenylindolizin-1-yl)methyl)malonate (5ab): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 95% yield, m.p. 56-58 °C; ¹H NMR (500 MHz, CDCl₃) δ 0.98 (t, *J* = 7.1 Hz, 3H), 1.03 (t, *J* = 7.1 Hz, 3H), 3.98-4.05 (m, 4H, 2*CH₂), 4.39 (d, *J* = 11.9 Hz, 1H), 5.10 (d, *J* = 11.9 Hz, 1H), 6.41-6.45 (m, 1H), 6.64-6.68 (m, 1H), 6.90 (s, 1H), 7.17 (t, *J* = 7.4 Hz, 1H), 7.25-7.29 (m, 2H), 7.31-7.35 (m, 1H), 7.42-7.48 (m, 4H), 7.52-7.56 (m, 3H), 8.18 (d, *J* = 7.2Hz, 1H); ¹³C NMR (125MHz, CDCl₃): δ 13.6, 13.7, 42.6, 58.5, 61.22, 61.23, 110.7, 112.3, 113.5, 116.6, 117.6, 121.9, 124.8, 126.5, 126.9, 127.76, 127.79, 128.4, 128.8, 130.7, 132.3, 142.1, 167.78, 167.83; HRMS *m/z* (ESI⁺): Calculated for C₂₈H₂₇NNaO₄ ([M+Na]⁺): 464.1832, Found 464.1838.

Dibenzyl 2-(phenyl(3-phenylindolizin-1-yl)methyl)malonate (5ac): Purified by

chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 99% yield, m.p. 49-51 °C; ¹H NMR (500 MHz, CDCl₃) δ 4.53 (d, *J* = 12.0 Hz, 1H), 4.93-5.01 (m, 4H, 2*CH₂), 5.15 (d, *J* = 12.0 Hz, 1H), 6.44 (t, *J* = 7.0 Hz, 1H), 6.62-6.66 (m, 1H), 6.86 (s, 1H), 7.00 (d, *J* = 7.5 Hz, 2H), 7.06-7.08 (m, 2H), 7.13 (t, *J* = 8.0 Hz, 2H), 7.19 (t, *J* = 7.5 Hz, 2H), 7.24 (t, *J* = 8.0 Hz, 2H), 7.27-7.30 (m, 3H), 7.34 (t, *J* = 5.0 Hz, 1H), 7.39 (d, *J* = 7.5 Hz, 2H), 7.45 (d, *J* = 4.0 Hz, 4H), 7.49 (d, *J* = 9.0 Hz, 1H), 8.18 (d, *J* = 7.5 Hz, 1H); ¹³C NMR (125MHz, CDCl₃): δ 42.8, 58.5, 67.04, 67.05, 110.8, 112.2, 113.3, 116.7, 117.6, 122.0, 124.9, 126.6, 126.9, 127.7, 127.85, 127.93, 128.0, 128.1, 128.2, 128.3, 128.5, 128.8, 130.7, 132.2, 135.11, 135.13, 141.9, 167.5, 167.6; HRMS m/z (ESI+): Calculated for C₃₈H₃₁NNaO₄ ([M+Na]⁺): 588.2145, Found 588.2151.

3-(Phenyl(3-phenylindolizin-1-yl)methyl)pentane-2,4-dione (**5ad**): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 88% yield, m.p. 137-139 °C; ¹H NMR (500MHz, CDCl₃): δ 2.02 (s, 3H), 2.07 (s, 3H), 4.82 (d, *J* = 12.0 Hz, 1H), 5.13 (d, *J* = 12.0 Hz, 1H), 6.43-6.47 (m, 1H), 6.67-6.70 (m, 1H), 6.85 (s, 1H), 7.14-7.18 (m, 1H), 7.25-7.29 (m, 2H), 7.32-7.39 (m, 3H), 7.45-7.48 (m, 2H), 7.51-7.53 (m, 3H), 8.19 (d, *J* = 7.0 Hz, 1H); ¹³C NMR (125MHz, CDCl₃): δ 28.8, 30.4, 42.7, 75.3, 110.9, 112.2, 113.3, 117.0, 117.3, 122.1, 125.2, 126.6, 127.1, 127.6, 127.9, 128.7, 128.9, 130.4, 132.0, 142.1, 203.1, 203.3; HRMS m/z (ESI+): Calculated for C₂₆H₂₃NNaO₂ ([M+Na]⁺): 404.1621, Found 404.1622.

3-(Phenyl(3-phenylindolizin-1-yl)methyl)-1H-indole (**5ae**): Purified by

chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 99% yield, m.p. 149-151 °C; ¹H NMR (500MHz, CDCl₃): δ 5.97 (s, 1H), 6.47 (t, *J* = 7.0 Hz, 1H), 6.57-6.61 (m, 1H), 6.65 (s, 1H), 6.75 (s, 1H), 7.02 (t, *J* = 8.0 Hz, 1H), 7.19 (t, *J* = 7.0 Hz, 1H), 7.23 (t, *J* = 7.0 Hz, 1H), 7.27-7.33 (m, 4H), 7.34-7.45 (m, 7H), 7.54 (d, *J* = 8.0 Hz, 2H), 7.93 (s, 1H, NH), 8.31 (d, *J* = 7.0 Hz, 1H); ¹³C NMR (125MHz, CDCl₃): δ 40.2, 110.5, 111.0, 115.1, 116.0, 116.7, 118.1, 119.2, 119.9, 120.1, 121.8, 122.1, 123.5, 124.2, 126.0, 126.7, 127.0, 127.7, 128.2, 128.6, 128.8, 130.5, 132.5, 136.7, 144.7; HRMS *m/z* (ESI⁺): Calculated for C₂₉H₂₃N₂ ([M+H]⁺): 399.1856, Found 399.1845. The enantiomeric excess is 33% determined by HPLC (AD-H, hexane/isopropanol = 90/10, flow rate 0.8 mL/min): *t_R* = 12.99 min (minor), *t_R* = 15.73 min (major); [α]_D²⁰ = -2.3 (c 0.5, CH₂Cl₂).

7-Methyl-3-(phenyl(3-phenylindolizin-1-yl)methyl)-1H-indole (**5af**): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 99% yield, m.p. 126-128 °C; ¹H NMR (500MHz, CDCl₃): δ 2.50 (s, 3H), 5.96 (s, 1H), 6.44-6.48 (m, 1H), 6.56-6.60 (m, 1H), 6.63 (s, 1H), 6.76 (d, *J* = 1.5 Hz, 1H), 6.94 (t, *J* = 7.5 Hz, 1H), 6.99 (d, *J* = 7.0 Hz, 1H), 7.22 (t, *J* = 7.0 Hz, 2H), 7.27-7.34 (m, 4H), 7.38-7.45 (m, 4H), 7.52-7.55 (m, 2H), 7.88 (s, 1H, NH), 8.30 (d, *J* = 7.0 Hz, 1H); ¹³C NMR (125MHz, CDCl₃): δ 16.5, 40.3, 110.5, 115.1, 115.9, 116.7, 117.7, 118.1, 119.4, 120.1, 120.6, 122.1, 122.4, 123.3, 124.2, 125.9, 126.6, 126.7, 127.7, 128.2, 128.6, 128.8, 130.5, 132.6, 136.3, 144.8; HRMS *m/z* (ESI⁺): Calculated for C₃₀H₂₃N₂ ([M-H]⁺): 411.1861, Found 411.1863.

4-Methyl-N-(phenyl(3-phenylindolizin-1-yl)methyl)benzenesulfonamide (**5ag**):

Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 86% yield, m.p. 153-155 °C; ¹H NMR (500 MHz, CDCl₃) δ 2.31 (s, 3H), 5.15 (d, *J* = 6.5 Hz, 1H), 5.97 (d, *J* = 6.5 Hz, 1H, NH), 6.37 (s, 1H), 6.45-6.49 (m, 1H), 6.62-6.66 (m, 1H), 7.04 (d, *J* = 7.5 Hz, 2H), 7.19-7.27 (m, 4H), 7.30-7.36 (m, 3H), 7.37-7.40 (m, 2H), 7.41-7.45 (m, 2H), 7.50-7.53 (m, 2H), 8.16 (dt, *J* = 1.0, 7.0 Hz, 1H); ¹³C NMR (125MHz, CDCl₃): δ 21.4, 54.5, 110.9, 112.7, 113.4, 117.4, 122.2, 124.9, 127.1, 127.2, 127.8, 128.3, 128.8, 129.0, 130.7, 131.8, 137.5, 140.8, 142.7; HRMS *m/z* (ESI+): Calculated for C₂₈H₂₄N₂NaO₂S ([M+Na]⁺): 475.1451, Found 475.1458.

4-Nitro-N-(phenyl(3-phenylindolizin-1-yl)methyl)benzenesulfonamide (5ah): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 81% yield, m.p. 131-133 °C; ¹H NMR (500 MHz, CDCl₃) δ 5.62 (d, *J* = 7.0 Hz, 1H), 6.10 (d, *J* = 7.5 Hz, 1H, NH), 6.41 (s, 1H), 6.47-6.51 (m, 1H), 6.71-6.74 (m, 1H), 7.22-7.26 (m, 3H), 7.32-7.38 (m, 6H), 7.42-7.46 (m, 2H), 7.62-7.66 (m, 2H), 7.90-7.93 (m, 2H), 8.11 (d, *J* = 7.5 Hz, 1H); ¹³C NMR (125MHz, CDCl₃): δ 54.8, 111.1, 111.8, 113.3, 117.2, 118.0, 122.2, 123.0, 125.2, 127.1, 127.4, 127.56, 127.58, 127.9, 128.4, 129.0, 130.8, 131.3, 139.7, 146.0, 149.0; HRMS *m/z* (ESI+): Calculated for C₂₇H₂₂N₃O₄S ([M+H]⁺): 484.1326, Found 484.1312.

Phenyl(3-phenylindolizin-1-yl)methanol (5ai): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 88% yield, m.p. 86-88 °C; ¹H NMR (500 MHz, CDCl₃) δ 6.28 (s, 1H), 6.50-6.53 (m, 1H), 6.70-6.74 (m, 2H), 7.30 (tt, *J* = 1.0, 7.0 Hz, 1H), 7.34 (tt, *J* = 1.0, 7.0 Hz, 1H), 7.37-7.41 (m,

2H), 7.44-7.48 (m, 2H), 7.52-7.57 (m, 5H), 8.26 (dt, $J = 0.5, 7.0$ Hz, 1H); ^{13}C NMR (125MHz, CDCl_3): δ 70.0, 111.0, 113.4, 116.6, 117.3, 118.0, 122.4, 125.0, 126.2, 127.2, 128.0, 128.3, 128.9, 131.0, 132.2, 144.2.

Dimethyl 2-(phenyl(3-p-tolylindolizin-1-yl)methyl)malonate (5ba): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 99% yield, m.p. 138-140 °C; ^1H NMR (500MHz, CDCl_3): δ 2.42 (s, 3H), 3.55 (s, 3H), 3.57 (s, 3H), 4.41 (d, $J = 12.0$ Hz, 1H), 5.11 (d, $J = 12.0$ Hz, 1H), 6.40-6.43 (m, 1H), 6.61-6.66 (m, 1H), 6.84 (s, 1H), 7.15-7.19 (m, 1H), 7.25-7.29 (m, 4H), 7.39-7.43 (m, 4H), 7.49 (d, $J = 9.0$ Hz, 1H), 8.14 (d, $J = 7.0$ Hz, 1H); ^{13}C NMR (125MHz, CDCl_3): δ 21.2, 42.7, 52.4, 52.5, 58.3, 110.6, 111.7, 113.1, 116.5, 117.5, 122.0, 124.9, 126.6, 127.7, 127.9, 128.4, 129.3, 129.5, 130.5, 136.8, 142.0, 168.19, 167.23; HRMS m/z (ESI+): Calculated for $\text{C}_{27}\text{H}_{25}\text{NNaO}_4$ ($[\text{M}+\text{Na}]^+$): 450.1676, Found 450.1681.

Dimethyl 2-((3-(4-chlorophenyl)indolizin-1-yl)(phenyl)methyl)malonate (5ca): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 98% yield, m.p. 135-137 °C; ^1H NMR (500MHz, CDCl_3): δ 3.55 (s, 3H), 3.57 (s, 3H), 4.40 (d, $J = 11.5$ Hz, 1H), 5.10 (d, $J = 12.0$ Hz, 1H), 6.46 (t, $J = 6.5$ Hz, 1H), 6.65-6.69 (m, 1H), 6.85 (s, 1H), 7.18 (t, $J = 7.0$ Hz, 1H), 7.28 (t, $J = 7.0$ Hz, 2H), 7.38-7.40 (m, 2H), 7.41-7.47 (m, 4H), 7.52 (d, $J = 9.0$ Hz, 1H), 8.11 (d, $J = 7.5$ Hz, 1H); ^{13}C NMR (125MHz, CDCl_3): δ 42.6, 52.4, 52.5, 58.2, 111.1, 112.2, 113.6, 117.0, 117.6, 121.8, 123.6, 126.7, 127.6, 128.5, 128.98, 129.02, 130.6, 131.0, 132.6, 141.8, 168.1, 168.2; HRMS m/z (ESI+): Calculated for $\text{C}_{26}\text{H}_{22}\text{ClNNaO}_4$

([M+Na]⁺): 470.1130, Found 470.1136.

Dimethyl 2-((3-(4-methoxyphenyl)indolizin-1-yl)(phenyl)methyl)malonate (5da):

Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 98% yield, m.p. 75-77 °C; ¹H NMR (500MHz, CDCl₃): δ 3.55 (s, 3H), 3.57 (s, 3H), 3.88 (s, 3H), 4.41 (d, *J* = 11.5 Hz, 1H), 5.11 (d, *J* = 12.0 Hz, 1H), 6.39-6.43 (m, 1H), 6.61-6.65 (m, 1H), 6.80 (s, 1H), 6.99-7.02 (m, 2H), 7.15-7.19 (m, 1H), 7.25-7.29 (m, 3H), 7.38-7.46 (m, 4H), 7.49 (dt, *J* = 1.0, 9.0 Hz, 1H), 8.08 (d, *J* = 7.0 Hz, 1H); ¹³C NMR (125MHz, CDCl₃): δ 42.6, 52.3, 52.4, 55.2, 58.3, 110.5, 111.5, 112.9, 114.3, 116.3, 117.5, 121.9, 124.64, 124.68, 126.5, 127.7, 128.4, 129.4, 130.1, 142.0, 158.7, 168.17, 168.20; HRMS *m/z* (ESI⁺): Calculated for C₂₇H₂₅NNaO₅ ([M+Na]⁺): 466.1625, Found 466.1632.

Dimethyl 2-((4-fluorophenyl)(3-phenylindolizin-1-yl)methyl)malonate (5ea): Purified

by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 99% yield, m.p. 119-121 °C; ¹H NMR (500MHz, CDCl₃): δ 3.57 (s, 3H), 3.58 (s, 3H), 4.36 (d, *J* = 12.0 Hz, 1H), 5.10 (d, *J* = 12 Hz, 1H), 6.44-6.47 (m, 1H), 6.64-6.69 (m, 1H), 6.85 (s, 1H), 6.94-6.98 (m, 2H), 7.33-7.37 (m, 3H), 7.45-7.49 (m, 3H), 7.52-7.54 (m, 2H), 8.19 (d, *J* = 7.5 Hz, 1H); ¹³C NMR (125MHz, CDCl₃): δ 41.9, 52.5, 52.6, 58.4, 110.9, 111.9, 113.0, 115.2 (d, *J*_{C,F} = 21.3 Hz), 116.9, 117.5, 122.1, 125.0, 127.1, 127.9, 128.9, 129.3 (d, *J*_{C,F} = 21.3 Hz), 130.6, 132.1, 137.8 (d, *J*_{C,F} = 2.5 Hz), 161.5 (d, *J*_{C,F} = 243.8 Hz), 168.07, 168.12; HRMS *m/z* (ESI⁺): Calculated for C₂₆H₂₂FNNaO₄ ([M+Na]⁺): 454.1425, Found 454.1437.

Dimethyl 2-((3-butylindolizin-1-yl)(phenyl)methyl)malonate (5fa): Purified by

chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 80% yield, m.p. 100-102 °C; ¹H NMR (500MHz, CDCl₃): δ 0.97 (t, *J* = 7.5 Hz, 3H), 1.38-1.47 (m, 2H), 1.67-1.74 (m, 2H), 2.73-2.76 (m, 2H), 3.52 (s, 3H), 3.54 (s, 3H), 4.38 (d, *J* = 12.0 Hz, 1H), 5.07 (d, *J* = 12.0 Hz, 1H), 6.43-6.46 (m, 1H), 6.56-6.60 (m, 2H), 7.13-7.17 (m, 1H), 7.24-7.28 (m, 2H), 7.35-7.38 (m, 2H), 7.44 (d, *J* = 9.0 Hz, 1H), 7.60 (d, *J* = 7.0 Hz, 1H); ¹³C NMR (125MHz, CDCl₃): δ 13.8, 22.5, 25.6, 29.2, 42.8, 52.30, 52.32, 58.4, 109.7, 109.9, 111.4, 115.0, 117.3, 121.4, 124.0, 126.4, 127.6, 128.4, 129.1, 142.3, 168.25, 168.26; HRMS *m/z* (ESI+): Calculated for C₂₄H₂₇NNaO₄ ([M+Na]⁺): 416.1832, Found 416.1839.

Dimethyl 2-((3-phenylindolizin-1-yl)(p-tolyl)methyl)malonate (5ga): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 98% yield, m.p. 128-130 °C; ¹H NMR (500MHz, CDCl₃): δ 2.28 (s, 3H), 3.569 (s, 3H), 3.574 (s, 3H), 4.41 (d, *J* = 12.0 Hz, 1H), 5.08 (d, *J* = 11.5 Hz, 1H), 6.41-6.45 (m, 1H), 6.63-6.67 (m, 1H), 6.87 (s, 1H), 7.08 (d, *J* = 8.0 Hz, 2H), 7.27-7.35 (m, 3H), 7.44-7.54 (m, 5H), 8.18 (d, *J* = 7.5 Hz, 1H); ¹³C NMR (125MHz, CDCl₃): δ 20.9, 42.2, 52.4, 52.5, 58.3, 110.7, 112.0, 113.6, 116.7, 117.6, 122.0, 124.8, 126.9, 127.5, 127.8, 128.8, 129.1, 130.6, 132.3, 136.1, 139.0, 168.2, 168.3; HRMS *m/z* (EI+): Calculated for C₂₇H₂₅NO₄ ([M]⁺): 427.1784, Found 427.1782.

Dimethyl 2-((3-fluorophenyl)(3-phenylindolizin-1-yl)methyl)malonate (5ha): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 99% yield, m.p. 113-115 °C; ¹H NMR (500MHz, CDCl₃): δ 3.58 (s, 3H), 3.59 (s, 3H), 4.38 (d, *J* = 12.0 Hz, 1H), 5.12 (d, *J* = 12.0 Hz, 1H), 6.44-6.48 (m, 1H),

6.66-6.70 (m, 1H), 6.85-6.90 (m, 2H), 7.09 (dt, $J = 2.0$ Hz, 10.0 Hz, 1H), 7.18-7.21 (m, 1H), 7.22-7.26 (m, 1H), 7.32-7.37 (m, 1H), 7.45-7.50 (m, 3H), 7.52-7.55 (m, 2H), 8.18-8.21 (m, 1H); ^{13}C NMR (125MHz, CDCl_3): δ 42.3, 52.5, 52.6, 58.1, 110.9, 111.9, 112.5, 113.6 (d, $J_{\text{C,F}} = 20.0$ Hz), 114.7 (d, $J_{\text{C,F}} = 21.3$ Hz), 117.0, 117.4, 122.1, 123.4 (d, $J_{\text{C,F}} = 2.5$ Hz), 125.1, 127.1, 128.0, 128.9, 129.9 (d, $J_{\text{C,F}} = 7.5$ Hz), 130.7, 132.1, 144.6 (d, $J_{\text{C,F}} = 6.25$ Hz), 162.7 (d, $J_{\text{C,F}} = 248.8$ Hz), 167.98, 168.02; HRMS m/z (ESI+): Calculated for $\text{C}_{26}\text{H}_{22}\text{FNNaO}_4$ ($[\text{M}+\text{Na}]^+$): 454.1425, Found 454.1435.

*Dimethyl 2-((3-phenylindolizin-1-yl)(*m*-tolyl)methyl)malonate (5ia)*: Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 98% yield, m.p. 130-132 °C; ^1H NMR (500MHz, CDCl_3): δ 2.31 (s, 3H), 3.57 (s, 3H), 4.57 (s, 3H), 4.42 (d, $J = 11.5$ Hz, 1H), 5.08 (d, $J = 12.0$ Hz, 1H), 6.44 (t, $J = 6.5$ Hz, 1H), 6.65-6.69 (m, 1H), 6.87 (s, 1H), 6.99 (d, $J = 7.5$ Hz, 1H), 7.15-7.23 (m, 3H), 7.34 (t, $J = 7.5$ Hz, 1H), 7.47 (t, $J = 7.5$ Hz, 2H), 7.53-7.54 (m, 3H), 8.19 (d, $J = 7.0$ Hz, 1H); ^{13}C NMR (125MHz, CDCl_3): δ 21.5, 42.6, 52.4, 52.5, 58.3, 110.8, 112.1, 113.4, 116.7, 117.7, 122.0, 124.6, 124.9, 127.0, 127.5, 127.9, 128.3, 128.5, 128.9, 130.7, 132.3, 138.0, 141.9, 168.2, 168.3; HRMS m/z (ESI+): Calculated for $\text{C}_{27}\text{H}_{25}\text{NNaO}_4$ ($[\text{M}+\text{Na}]^+$): 450.1676, Found 450.1681.

Dimethyl 2-((2-bromophenyl)(3-phenylindolizin-1-yl)methyl)malonate (5ja): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 98% yield, m.p. 152-154 °C; ^1H NMR (500MHz, CDCl_3): δ 3.55 (s, 3H), 3.59 (s, 3H), 4.44 (d, $J = 12.0$ Hz, 1H), 5.71 (d, $J = 12.0$ Hz, 1H), 6.43-6.47 (m, 1H), 6.69-6.73 (m, 1H), 6.79 (s, 1H), 7.04 (td, $J = 1.5, 8.0$ Hz, 1H), 7.26-7.35 (m, 2H),

7.43-7.47 (m, 2H), 7.50-7.56 (m, 4H), 7.76 (d, $J = 9.0$ Hz, 1H), 8.17 (d, $J = 7.0$ Hz, 1H); ^{13}C NMR (125MHz, CDCl_3): δ 40.8, 52.47, 52.50, 58.3, 110.8, 111.9, 112.3, 117.0, 118.4, 122.0, 124.7, 125.2, 127.0, 127.6, 127.87, 127.91, 128.3, 128.8, 131.1, 132.2, 133.2, 141.2, 167.7, 167.9; HRMS m/z (ESI+): Calculated for $\text{C}_{26}\text{H}_{22}\text{BrNNaO}_4$ ($[\text{M}+\text{Na}]^+$): 514.0624, Found 514.0630.

Dimethyl 2-(1-(3-phenylindolizin-1-yl)butyl)malonate (5ka): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 65% yield, m.p. 60-62 °C; ^1H NMR (500MHz, CDCl_3): δ 0.85 (t, $J = 7.5$ Hz, 3H), 1.16-1.22 (m, 2H), 1.68-1.75 (m, 2H), 3.44 (s, 3H), 3.75 (d, $J = 10.5$ Hz, 1H), 3.79-3.83 (m, 4H), 6.42-6.46 (m, 1H), 6.64-6.68 (m, 1H), 6.72 (s, 1H), 7.33 (t, $J = 7.5$ Hz, 1H), 7.45-7.51 (m, 3H), 7.55-7.57 (m, 2H), 8.22 (d, $J = 7.0$ Hz, 1H); ^{13}C NMR (125MHz, CDCl_3): δ 13.9, 20.4, 36.4, 36.5, 52.1, 52.4, 59.1, 110.5, 112.4, 113.0, 116.3, 117.8, 122.1, 125.0, 126.9, 127.8, 128.9, 131.7, 132.5, 168.6, 169.2; HRMS m/z (ESI+): Calculated for $\text{C}_{23}\text{H}_{25}\text{NNaO}_4$ ($[\text{M}+\text{Na}]^+$): 402.1676, Found 402.1681.

Trimethyl 2-(3-phenylindolizin-1-yl)ethane-1,1,2-tricarboxylate (5la): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 95% yield, m.p. 125-127 °C; ^1H NMR (500MHz, CDCl_3): δ 3.48 (s, 3H), 3.70 (s, 3H), 3.81 (s, 3H), 4.40 (d, $J = 12.0$ Hz, 1H), 4.72 (d, $J = 11.5$ Hz, 1H), 6.48-6.52 (m, 1H), 6.73-6.77 (m, 1H), 6.80 (s, 1H), 7.33-7.36 (m, 1H), 7.45-7.49 (m, 2H), 7.52-7.56 (m, 3H), 8.23 (d, $J = 7.5$ Hz, 1H); ^{13}C NMR (125MHz, CDCl_3): δ 42.2, 52.40, 52.45, 52.8, 55.0, 105.9, 110.9, 113.1, 117.4, 117.6, 122.4, 125.4, 127.2, 128.0, 128.9, 131.4, 131.9, 167.6, 168.5, 172.7; HRMS m/z (ESI+): Calculated for

$C_{22}H_{21}NNaO_6$ ($[M+Na]^+$): 418.1261, Found 418.1269.

Dimethyl 2-((3-(4-methoxyphenyl)indolizin-1-yl)(p-tolyl)methyl)malonate (**5ma**):

Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 95% yield, m.p. 114-116 °C; 1H NMR (500MHz, $CDCl_3$): δ 2.27 (s, 3H), 3.56 (s, 3H), 3.57 (s, 3H), 3.87 (s, 3H), 4.39 (d, $J = 12.0$ Hz, 1H), 5.07 (d, $J = 12.0$ Hz, 1H), 6.38-6.42 (m, 1H), 6.60-6.63 (m, 1H), 6.79 (s, 1H), 6.98-7.02 (m, 2H), 7.07 (d, $J = 8.0$ Hz, 2H), 7.28 (s, 1H), 7.29 (s, 1H), 7.41-7.45 (m, 2H), 7.49 (d, $J = 9.0$ Hz, 1H), 8.07 (d, $J = 7.5$ Hz, 1H); ^{13}C NMR (125MHz, $CDCl_3$): δ 20.9, 42.3, 52.35, 52.43, 55.3, 58.3, 110.5, 111.5, 113.2, 114.3, 116.2, 117.5, 121.9, 124.6, 124.8, 127.5, 129.1, 129.4, 130.1, 136.0, 139.0, 158.7, 168.2, 168.3; HRMS m/z (ESI+): Calculated for $C_{28}H_{27}NNaO_5$ ($[M+Na]^+$): 480.1781, Found 480.1786.

Dimethyl 2-(phenyl(1-phenylpyrrolo[1,2-a]quinolin-3-yl)methyl)malonate (**5na**):

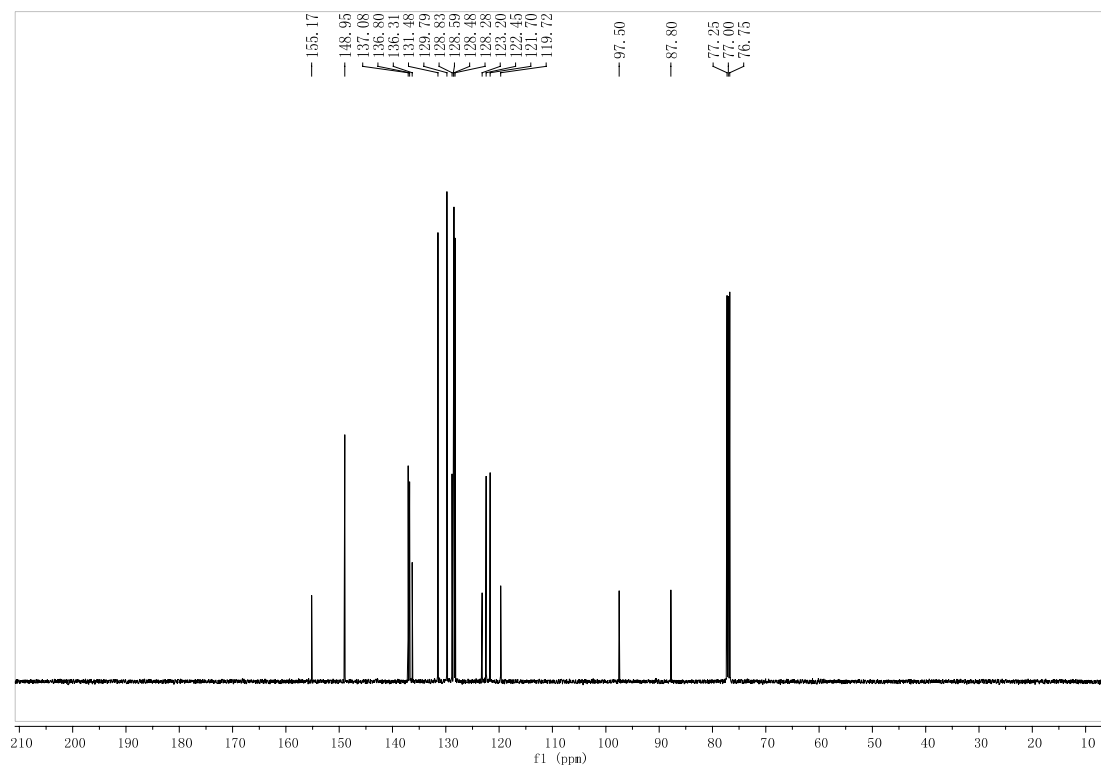
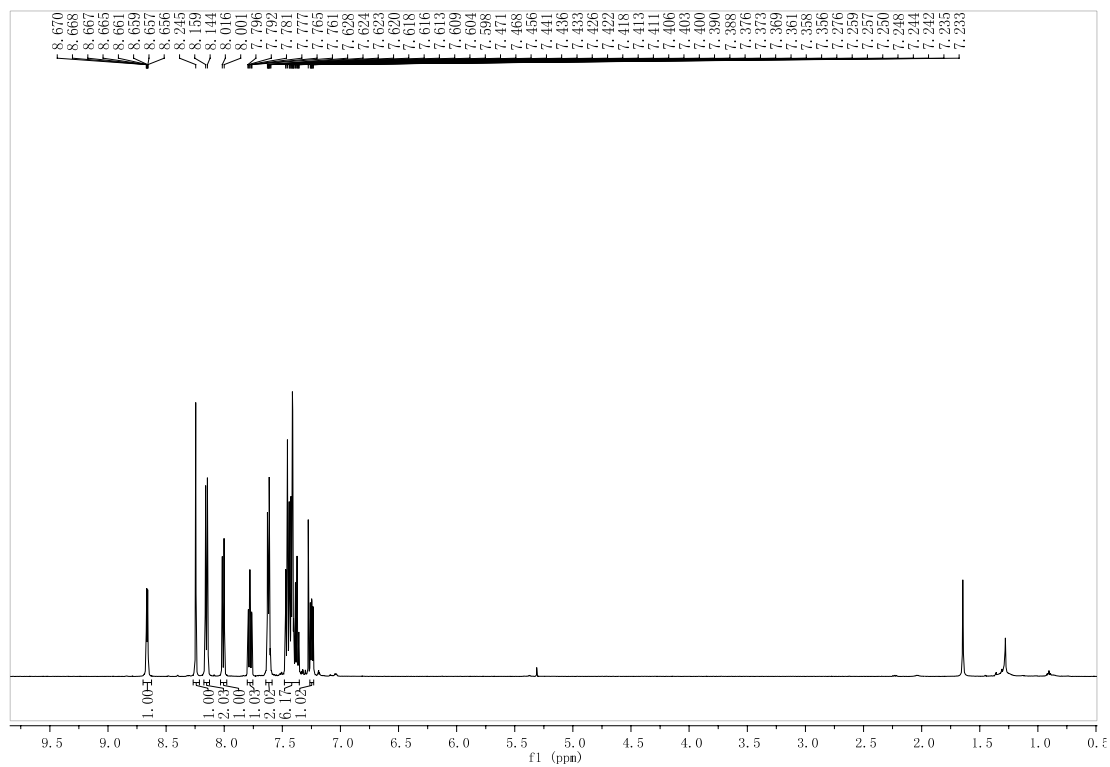
Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); yellow solid, 75% yield, m.p. 180-182 °C; 1H NMR (500MHz, $CDCl_3$): δ 3.56 (s, 3H), 3.58 (s, 3H), 4.41 (d, $J = 11.5$ Hz, 1H), 5.14 (d, $J = 12.0$ Hz, 1H), 6.71 (s, 1H), 7.01 (d, $J = 9.5$ Hz, 1H), 7.05-7.10 (m, 1H), 7.17-7.22 (m, 2H), 7.27-7.32 (m, 2H), 7.40-7.52 (m, 9H), 7.56-7.59 (m, 1H); ^{13}C NMR (125MHz, $CDCl_3$): δ 42.5, 52.4, 52.6, 58.2, 114.4, 116.2, 117.0, 117.5, 119.1, 123.3, 125.4, 126.3, 126.7, 127.6, 127.7, 128.3, 128.4, 128.6, 129.3, 129.6, 129.8, 134.1, 135.4, 141.7, 168.17, 168.18; HRMS m/z (ESI+): Calculated for $C_{30}H_{25}NNaO_4$ ($[M+Na]^+$): 486.1676, Found 486.1685.

Phenyl(3-phenylindolizin-1-yl)methanone (**6**): Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); 1H NMR (500MHz, $CDCl_3$):

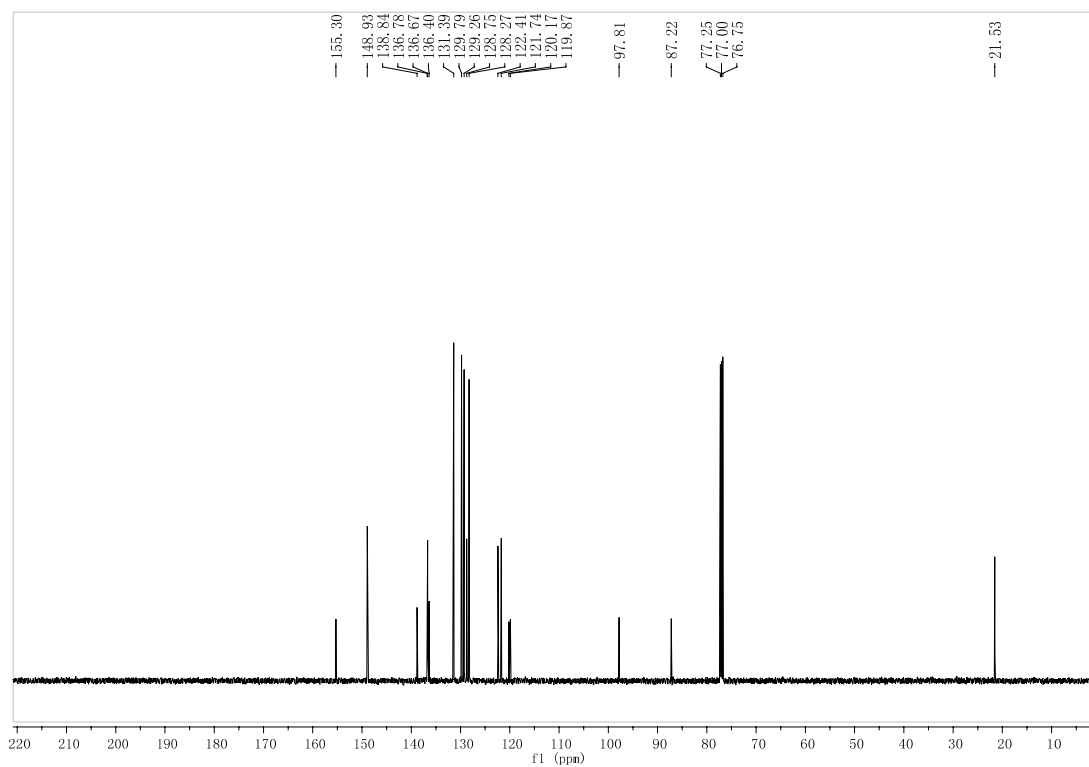
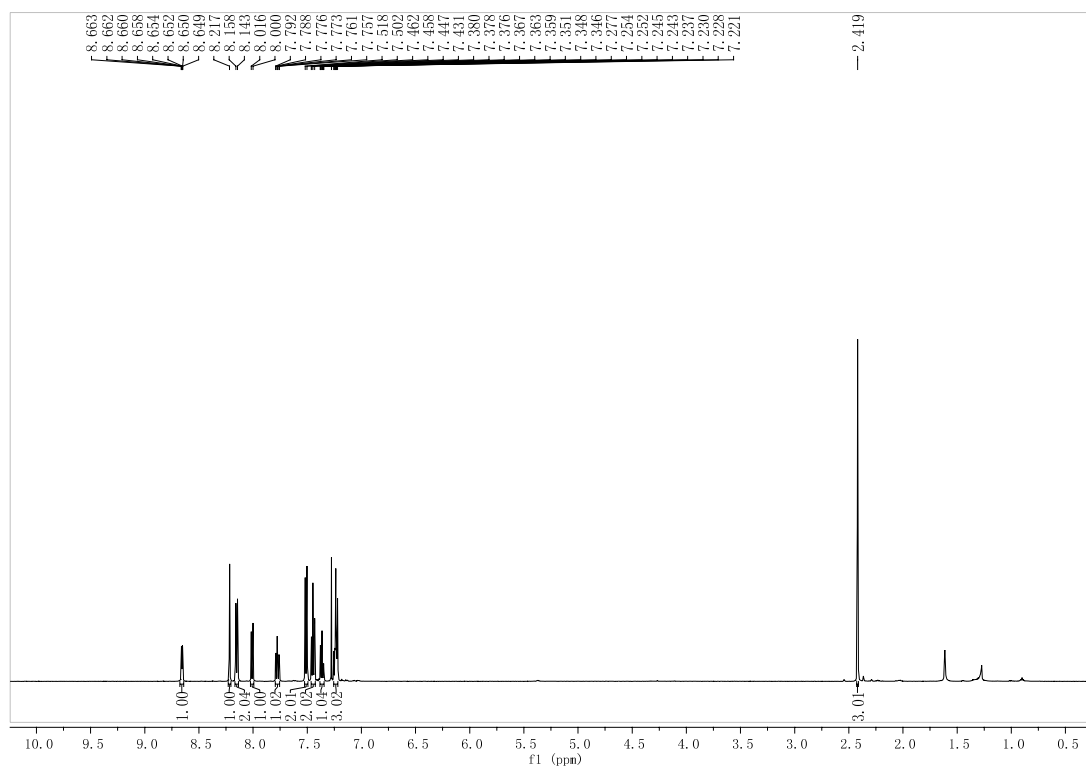
δ 6.86 (td, $J = 1.0, 7.0$ Hz, 1H), 7.15 (s, 1H), 7.22-7.27 (m, 1H), 7.41-7.45 (m, 1H), 7.47-7.58 (m, 7H), 7.87-7.90 (m, 2H), 8.38 (d, $J = 7.0$ Hz, 1H), 8.60 (d, $J = 9.0$ Hz, 1H); ^{13}C NMR (100 MHz, CDCl_3): δ 112.4, 113.9, 118.2, 121.1, 123.3, 124.2, 126.9, 128.1, 128.2, 128.6, 128.9, 129.1, 130.7, 130.9, 137.5, 141.1, 190.2; HRMS m/z (ESI+): Calculated for $\text{C}_{21}\text{H}_{16}\text{NO}$ ($[\text{M}+\text{H}]^+$): 298.1226, Found 298.1234.

Dimethyl 2-(1,4-diphenyl-2-(pyridin-2-yl)buta-2,3-dien-1-yl)malonate (7) Purified by chromatography on silica gel, eluting with ethyl acetate/petroleum ether 1:5 (v/v); dr = 1.5:1, for the major product: ^1H NMR (500MHz, CDCl_3): δ 3.37 (s, 3H), 3.40 (s, 3H), 4.15 (d, $J = 12.5$ Hz, 1H), 5.43 (d, $J = 12.5$ Hz, 1H), 6.91 (s, 1H), 7.02-7.06 (m, 1H), 7.17 (t, $J = 7.5$ Hz, 1H), 7.25 (t, $J = 7.0$ Hz, 3H), 7.29-7.36 (m, 4H), 7.45-7.52 (m, 4H), 8.60 (d, $J = 5.0$ Hz, 1H); ^{13}C NMR (125MHz, CDCl_3): δ 43.9, 52.16, 52.21, 57.3, 102.0, 114.1, 121.7, 122.4, 127.1, 127.4, 127.8, 128.1, 128.7, 128.8, 132.9, 136.0, 139.7, 149.2, 153.5, 168.1, 168.2, 207.1; HRMS m/z (ESI+): Calculated for $\text{C}_{26}\text{H}_{24}\text{NO}_4$ ($[\text{M}+\text{H}]^+$): 414.1705, Found 414.1701.

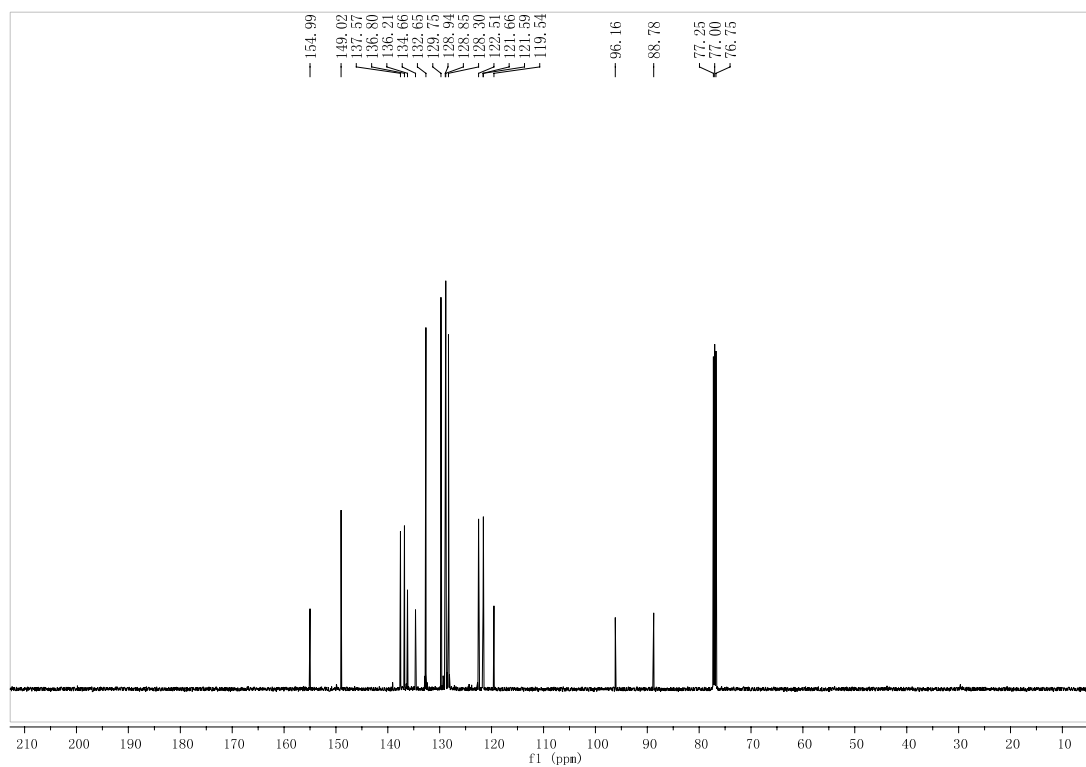
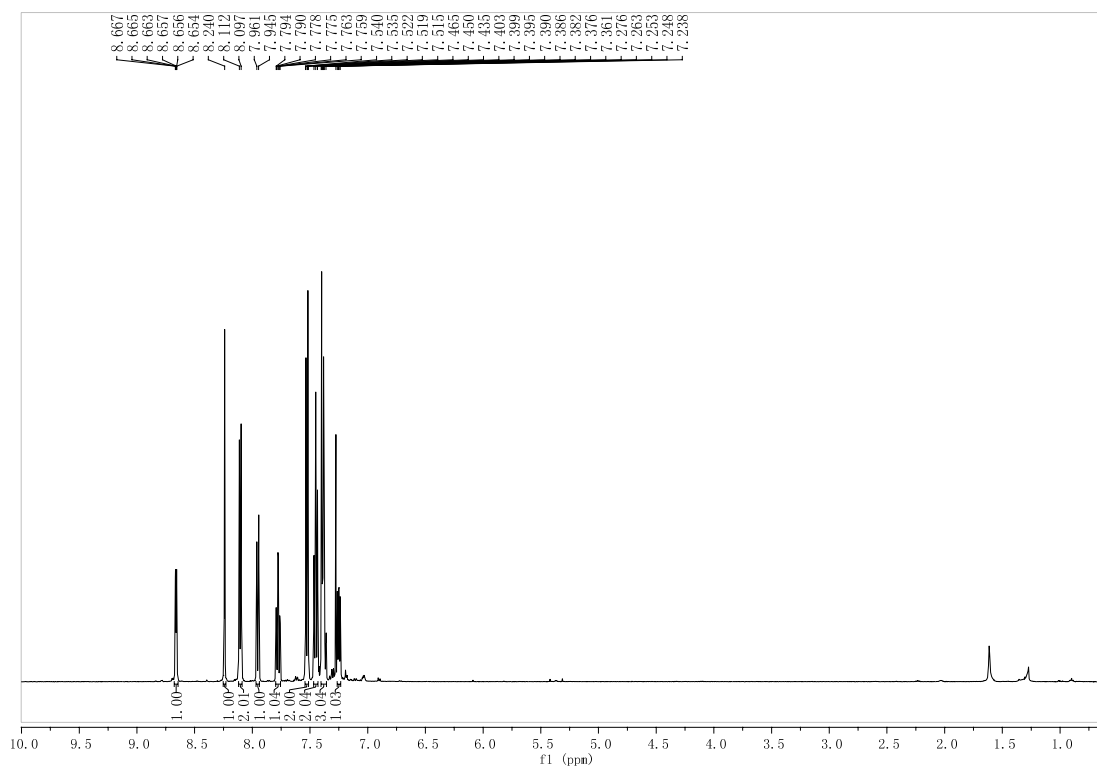
2-(1,4-Diphenylbut-1-en-3-yn-2-yl)pyridine (**3a**):



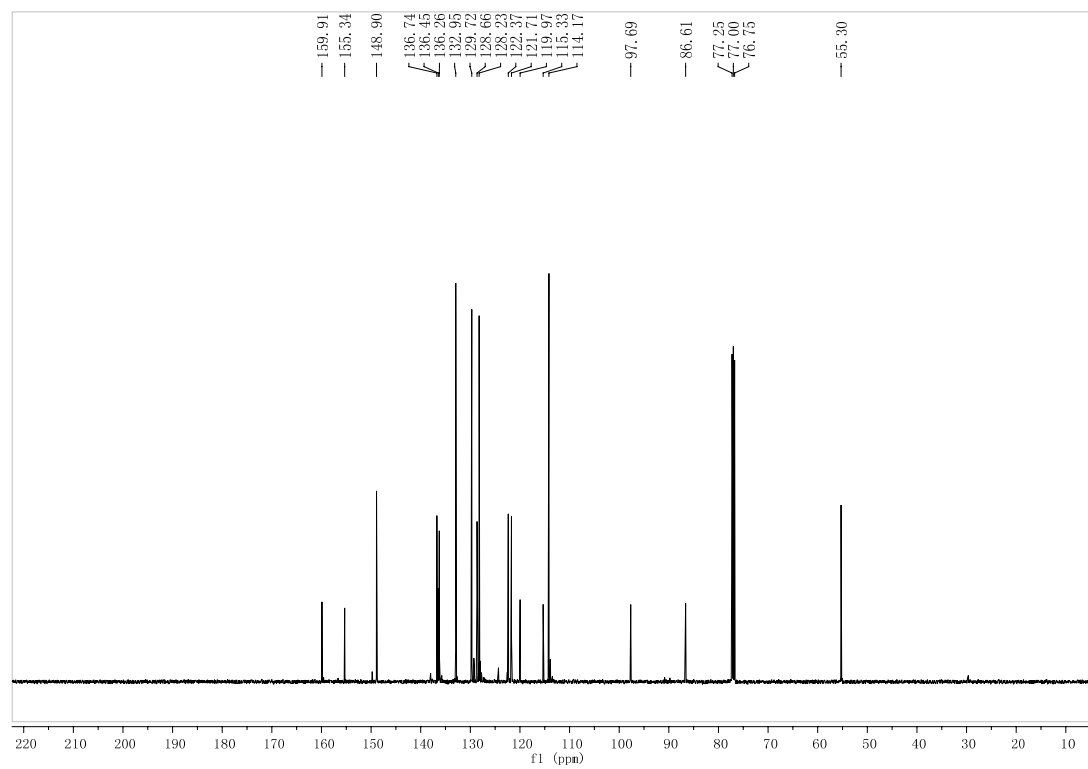
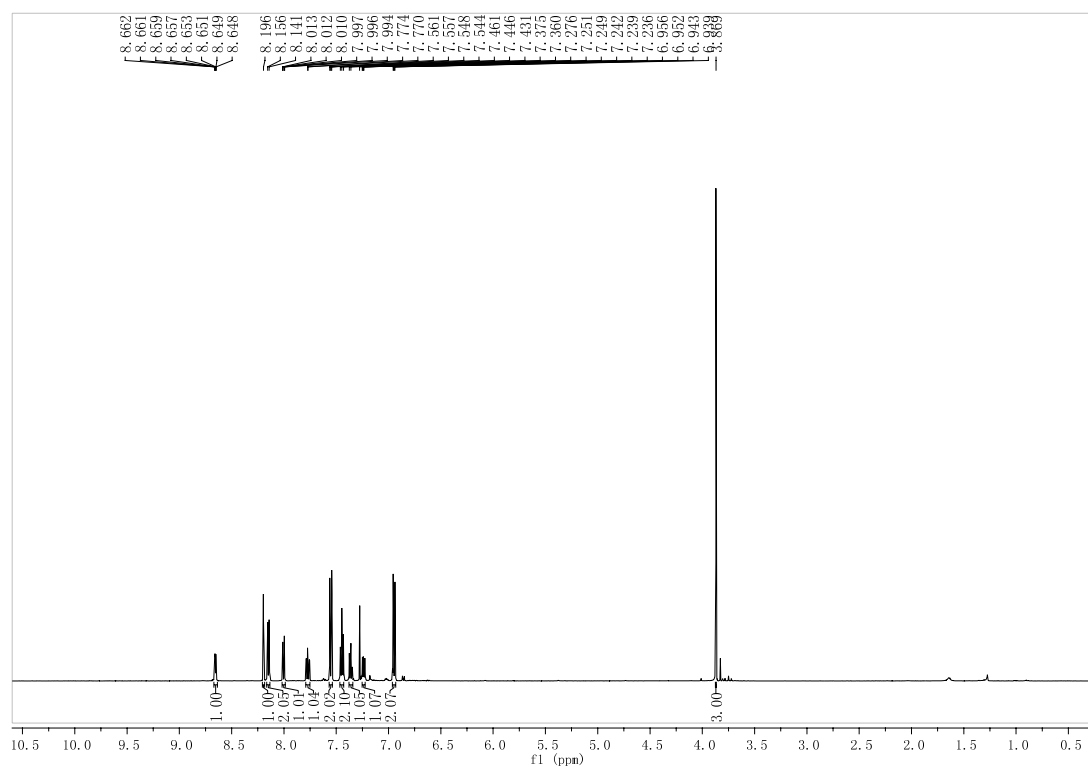
2-(1-Phenyl-4-p-tolylbut-1-en-3-yn-2-yl)pyridine (**3b**):



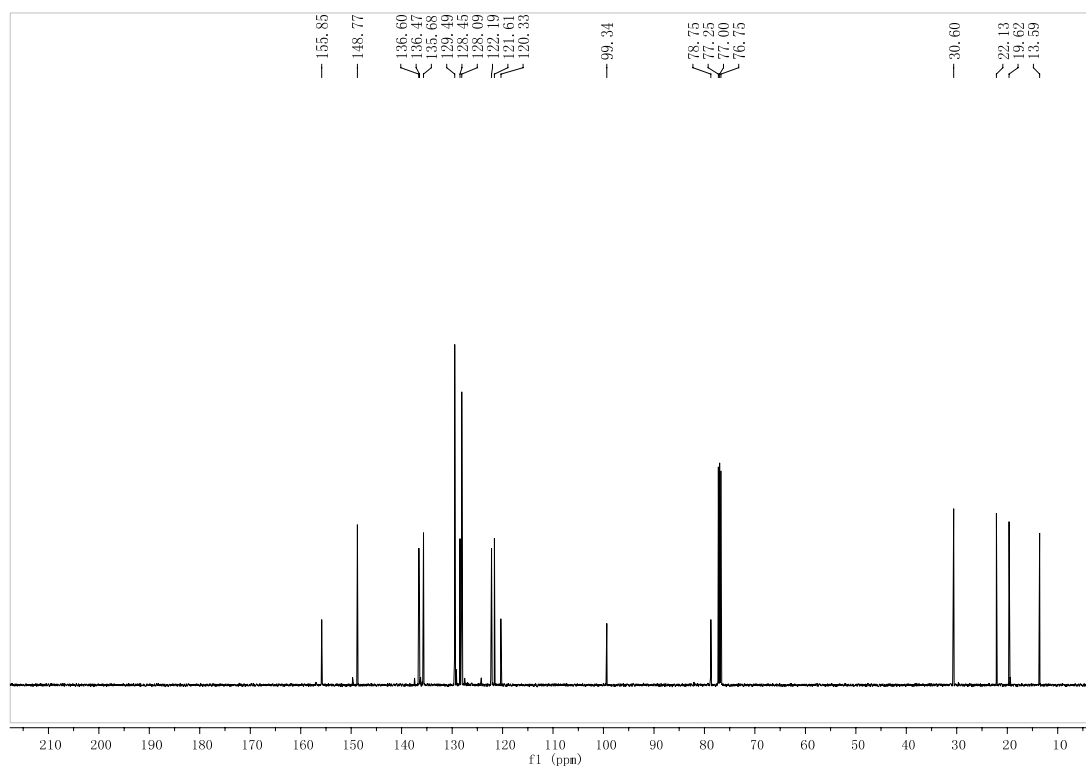
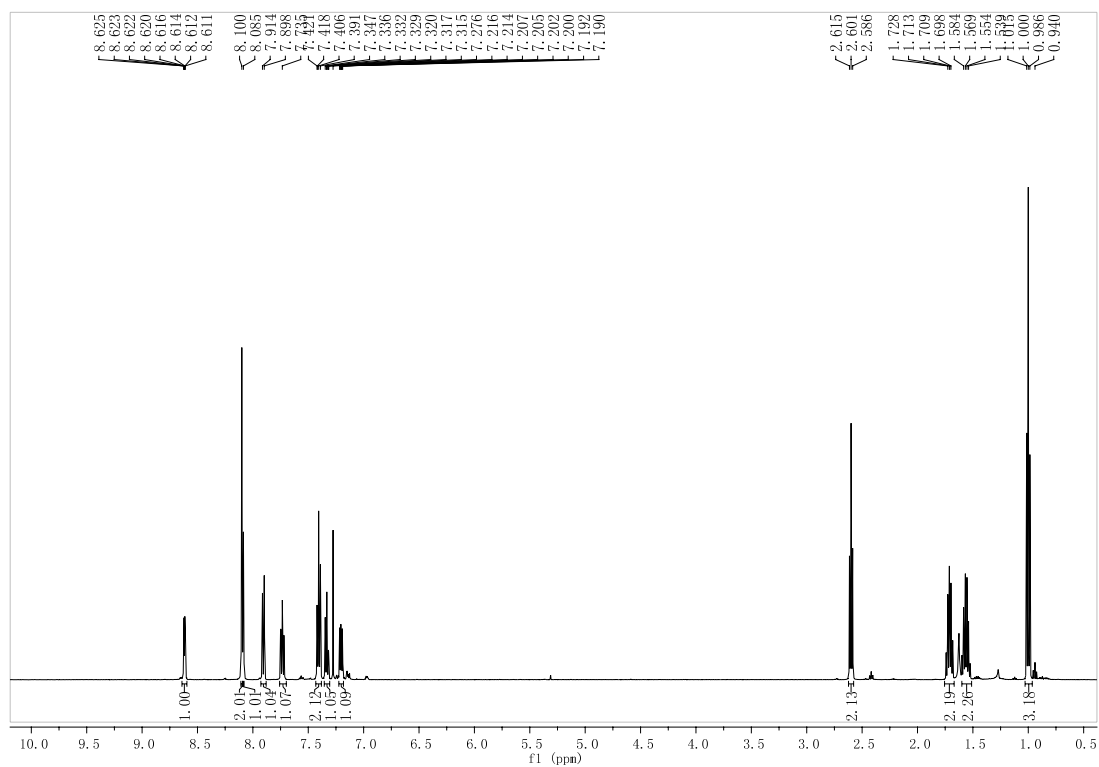
2-(4-(4-Chlorophenyl)-1-phenylbut-1-en-3-yn-2-yl)pyridine (**3c**):



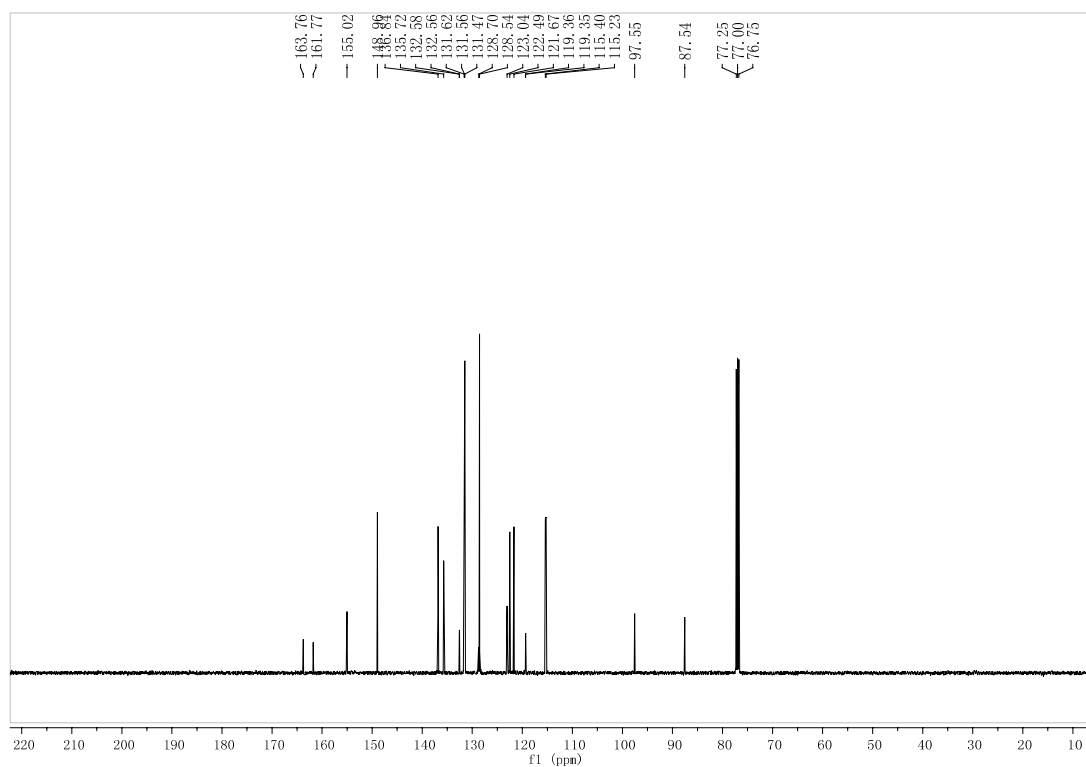
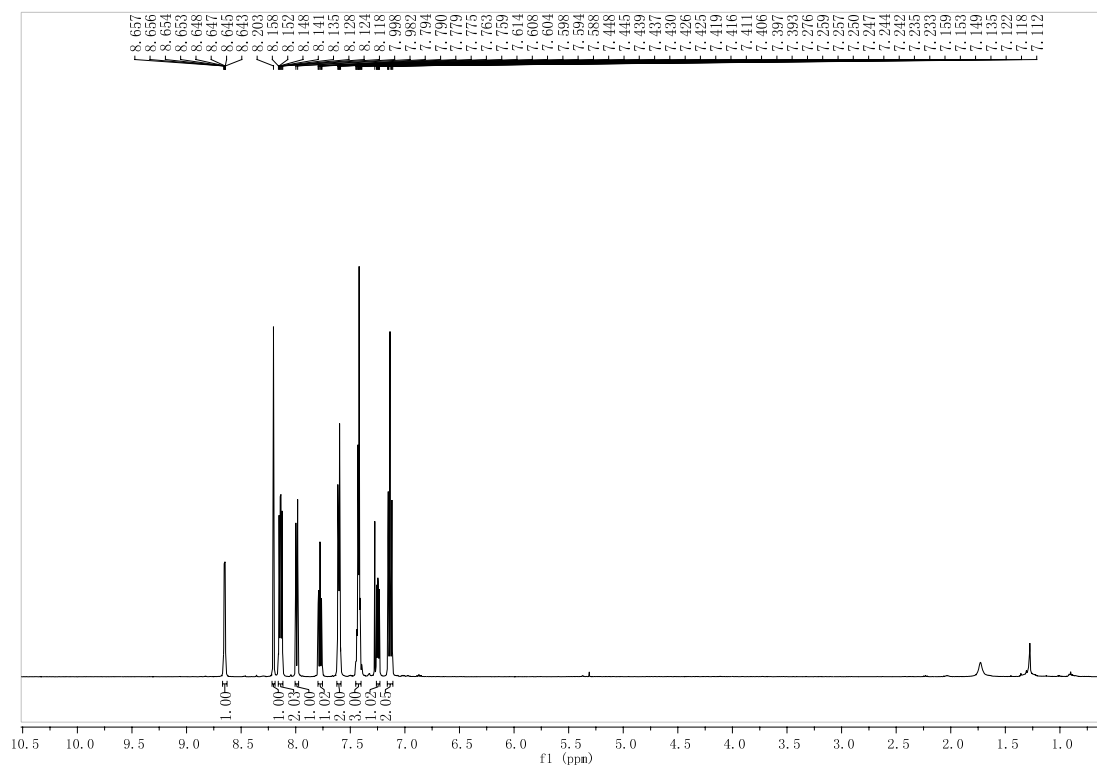
2-(4-(4-Methoxyphenyl)-1-phenylbut-1-en-3-yn-2-yl)pyridine (**3d**):



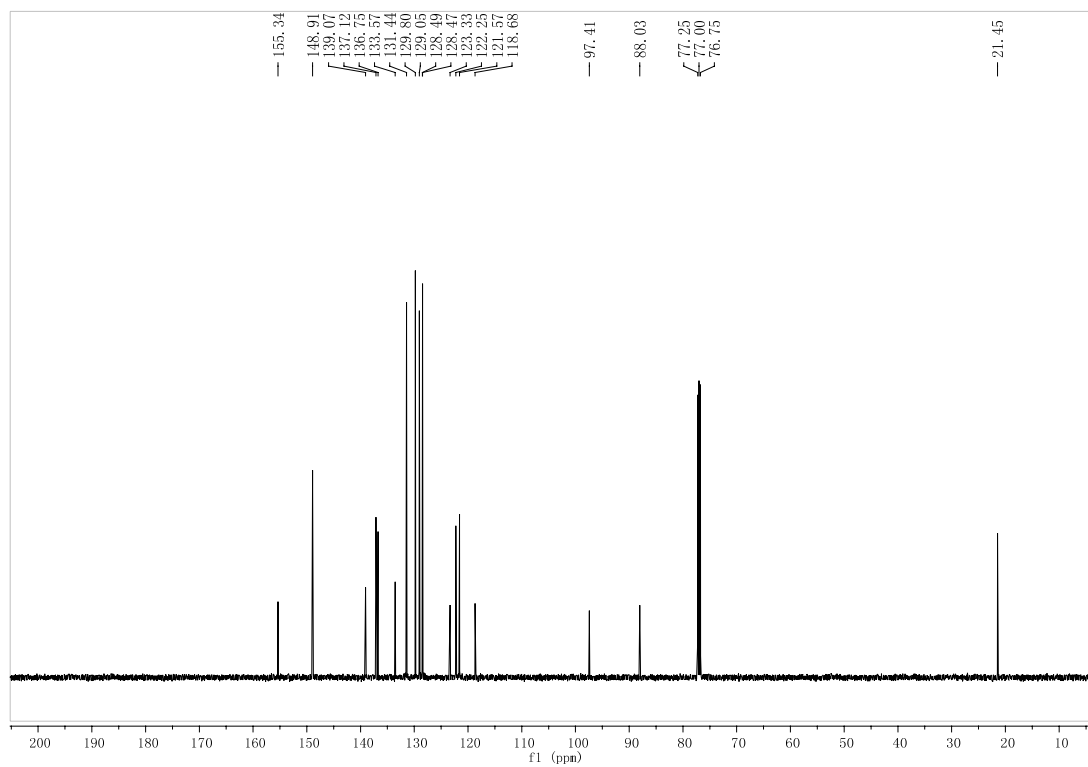
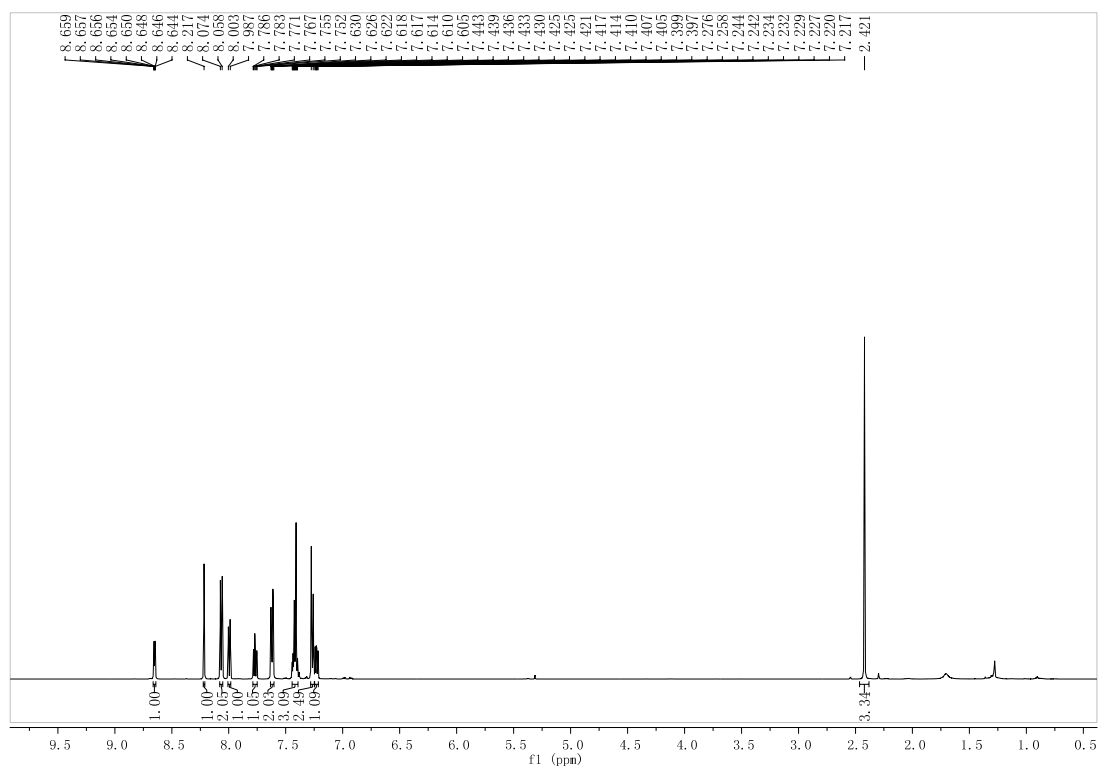
2-(1-Phenyl-1-en-3-yn-2-yl)pyridine (**3e**):



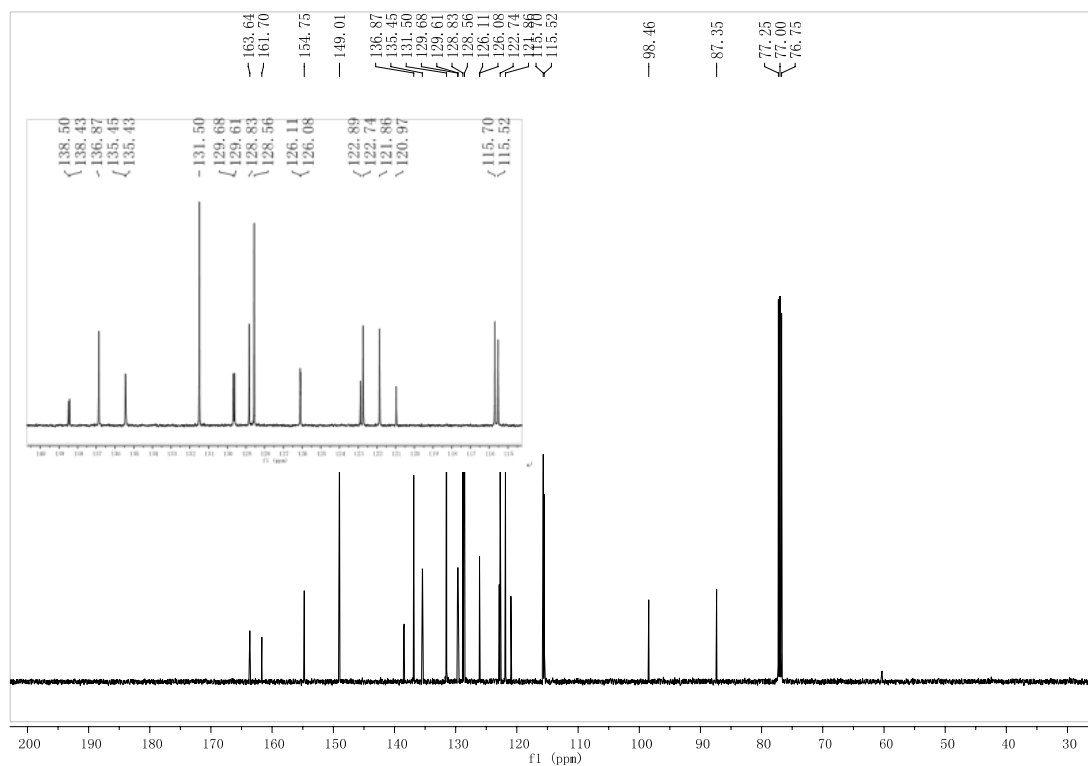
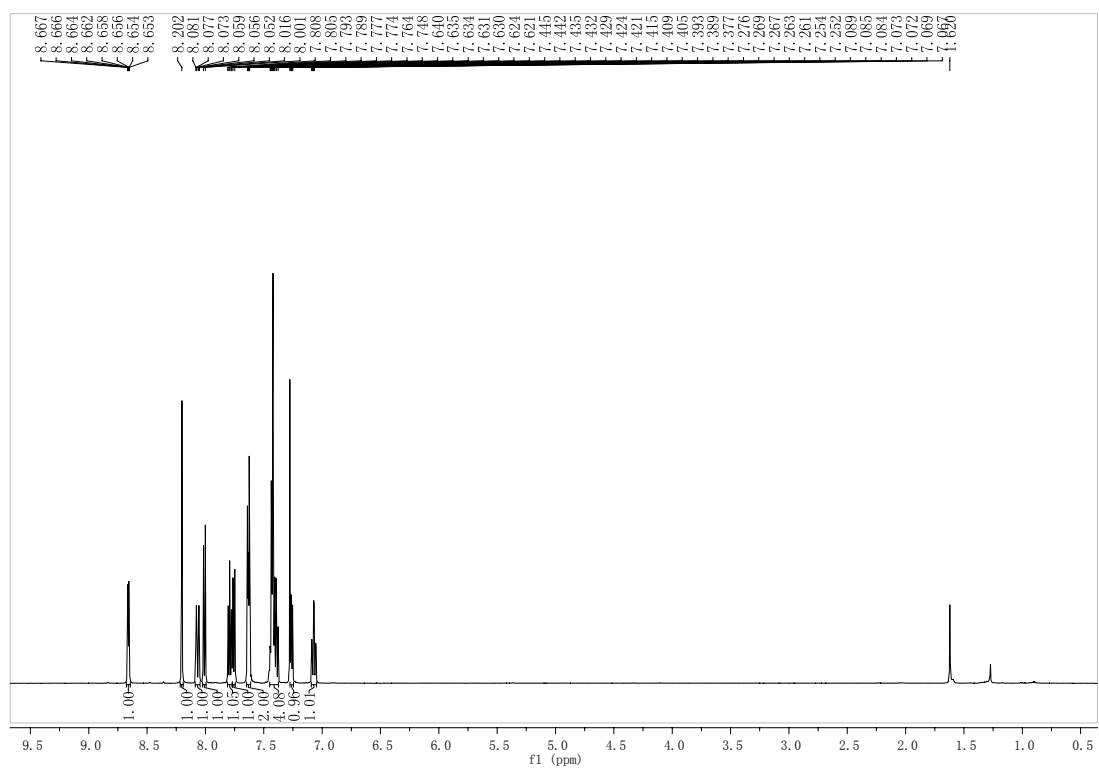
2-(1-(4-Fluorophenyl)-4-phenylbut-1-en-3-yn-2-yl)pyridine (**3f**):



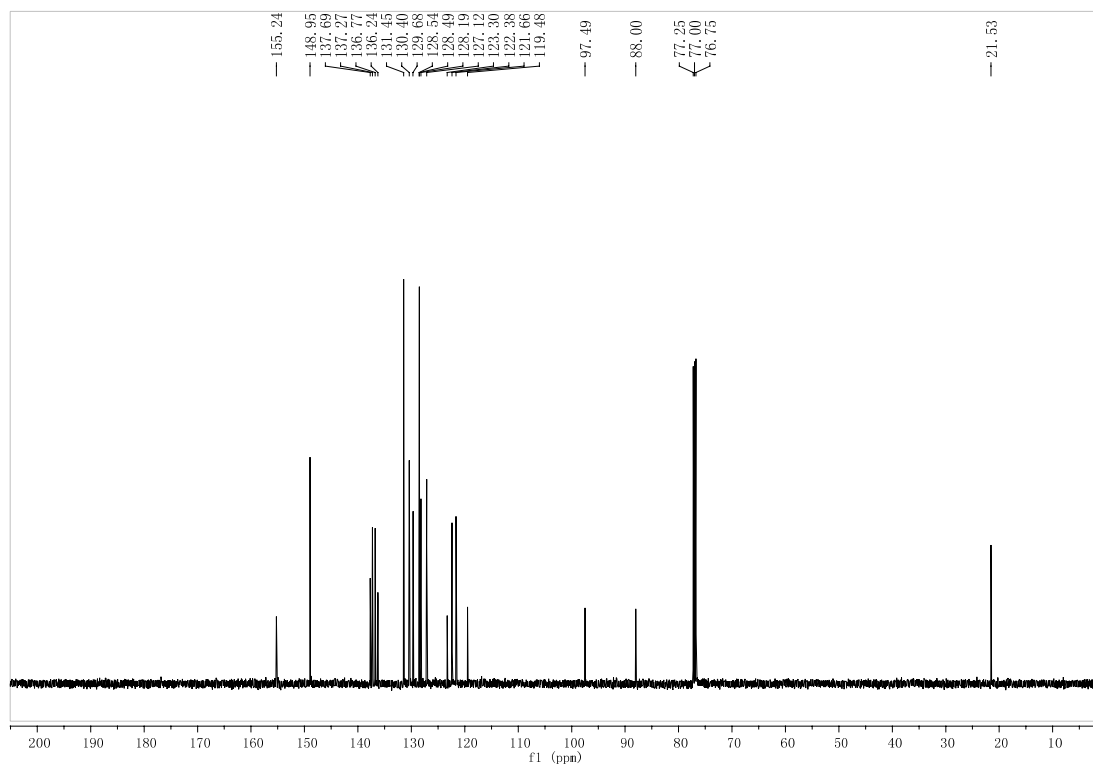
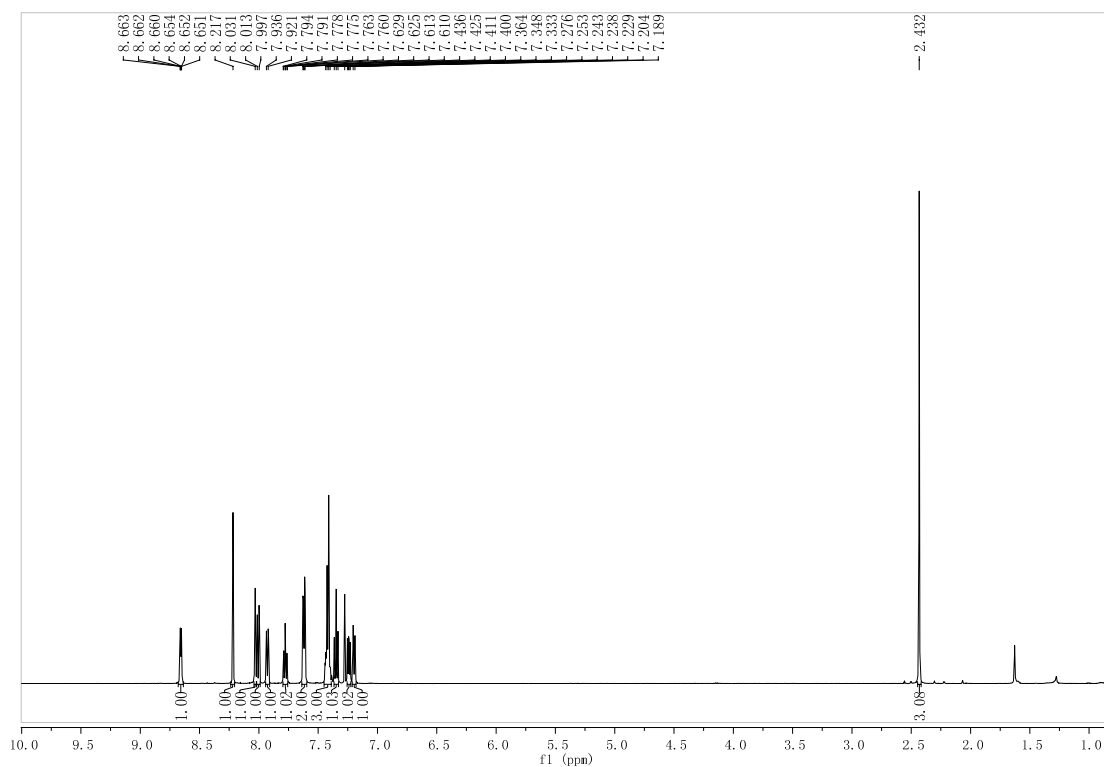
2-(4-Phenyl-1-p-tolylbut-1-en-3-yn-2-yl)pyridine (**3g**):



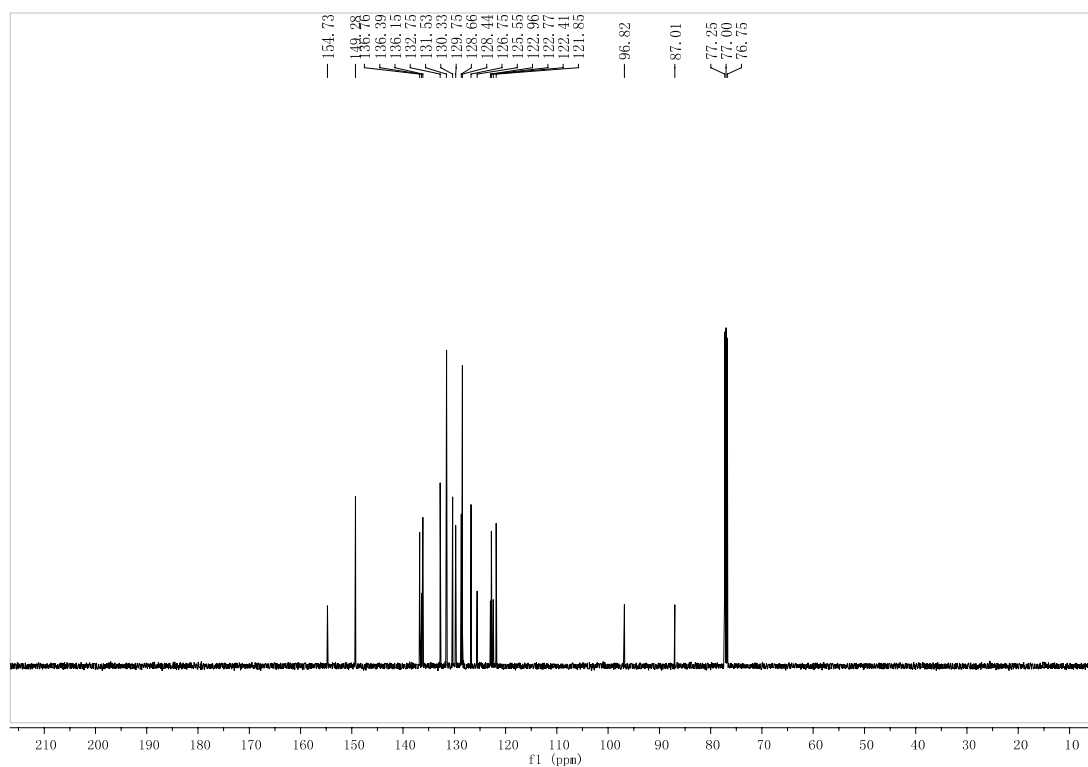
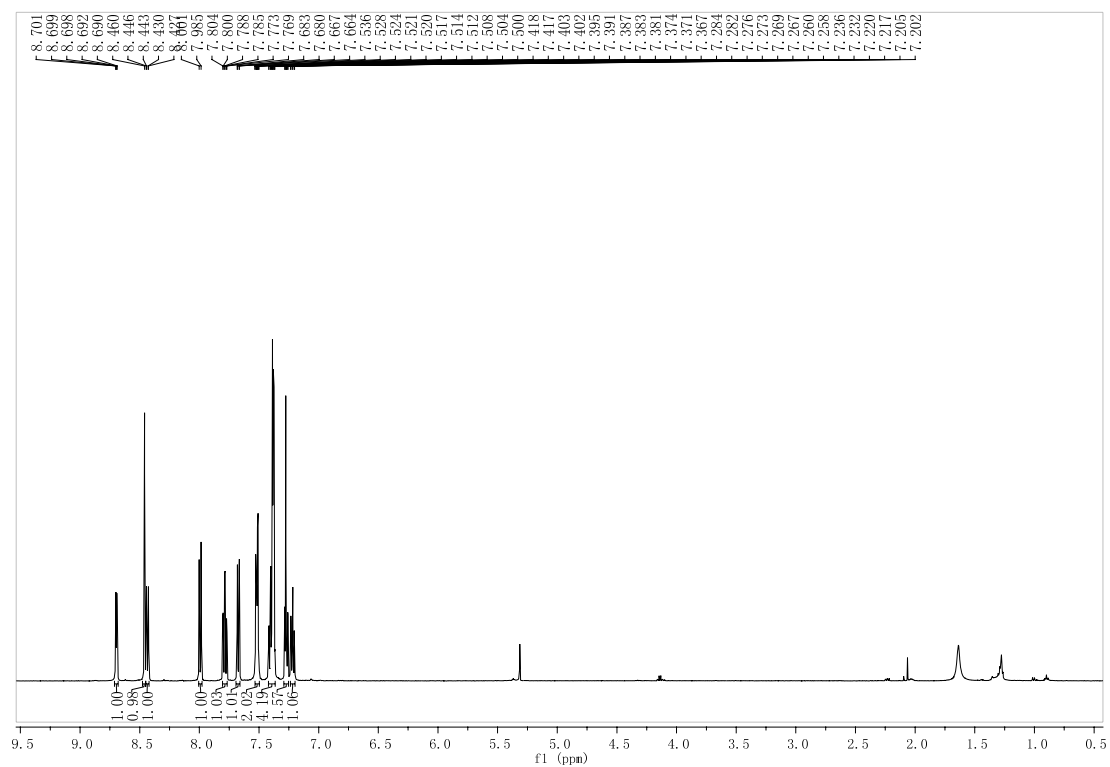
2-(1-(3-Fluorophenyl)-4-phenylbut-1-en-3-yn-2-yl)pyridine (**3h**):



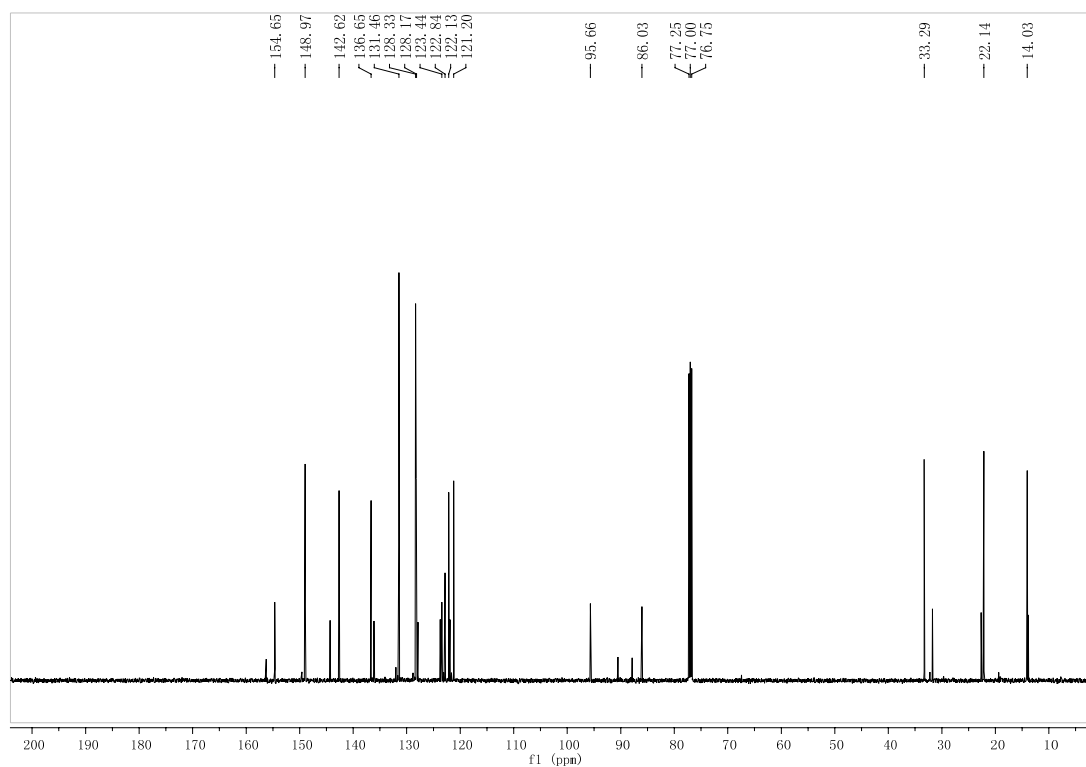
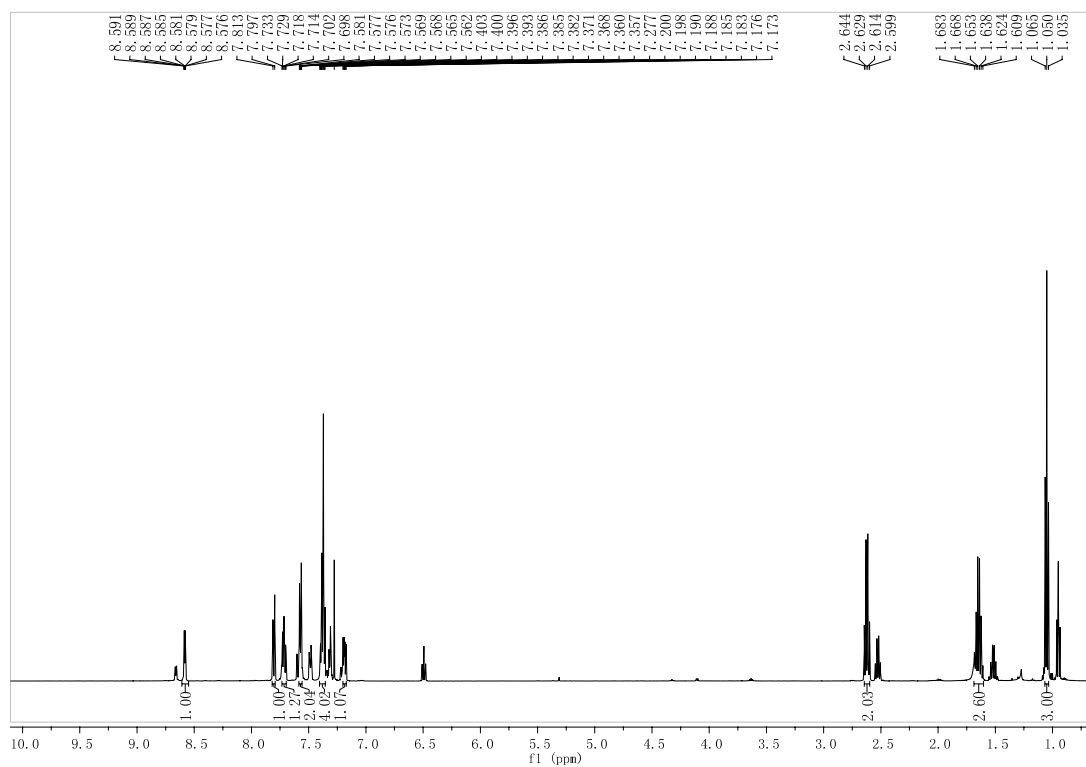
2-(4-Phenyl-1-m-tolylbut-1-en-3-yn-2-yl)pyridine (**3i**):



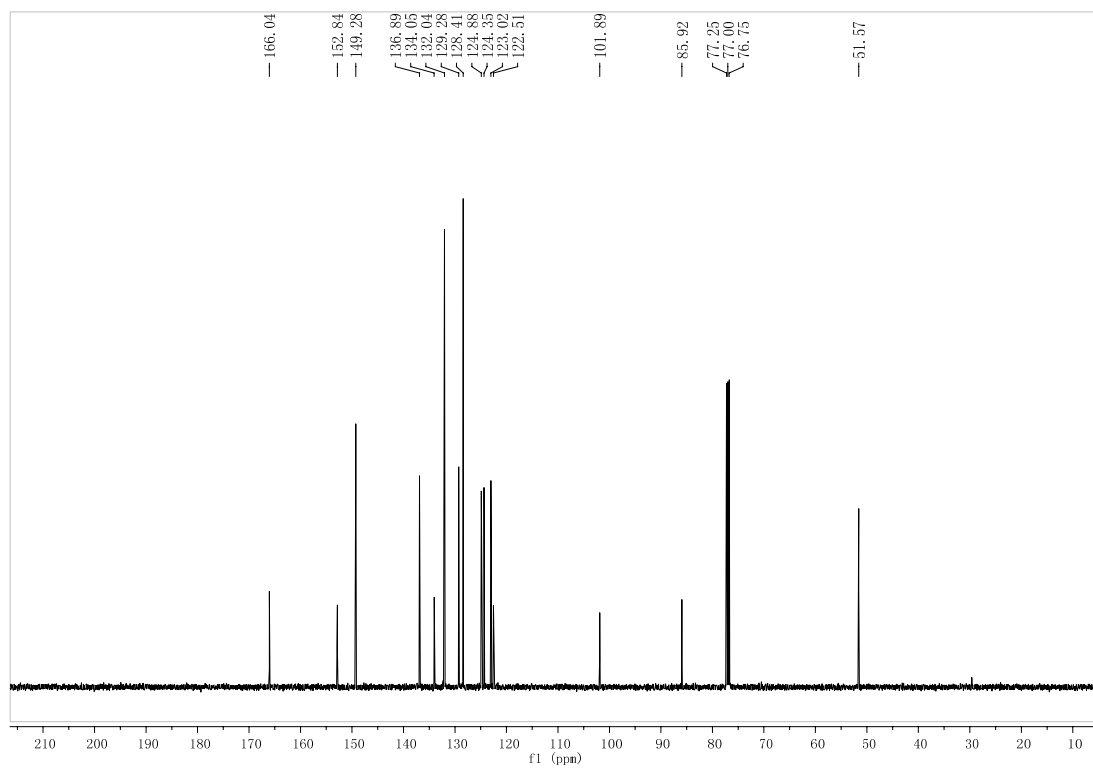
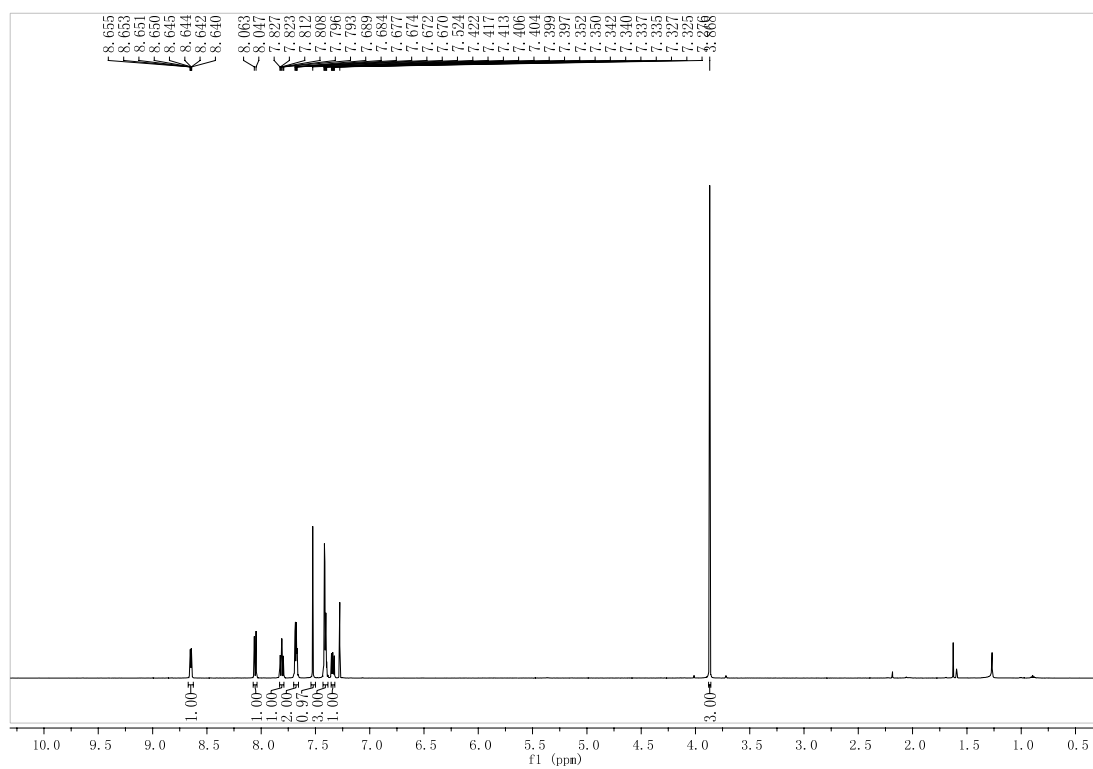
2-(1-(2-Bromophenyl)-4-phenylbut-1-en-3-yn-2-yl)pyridine (**3j**):



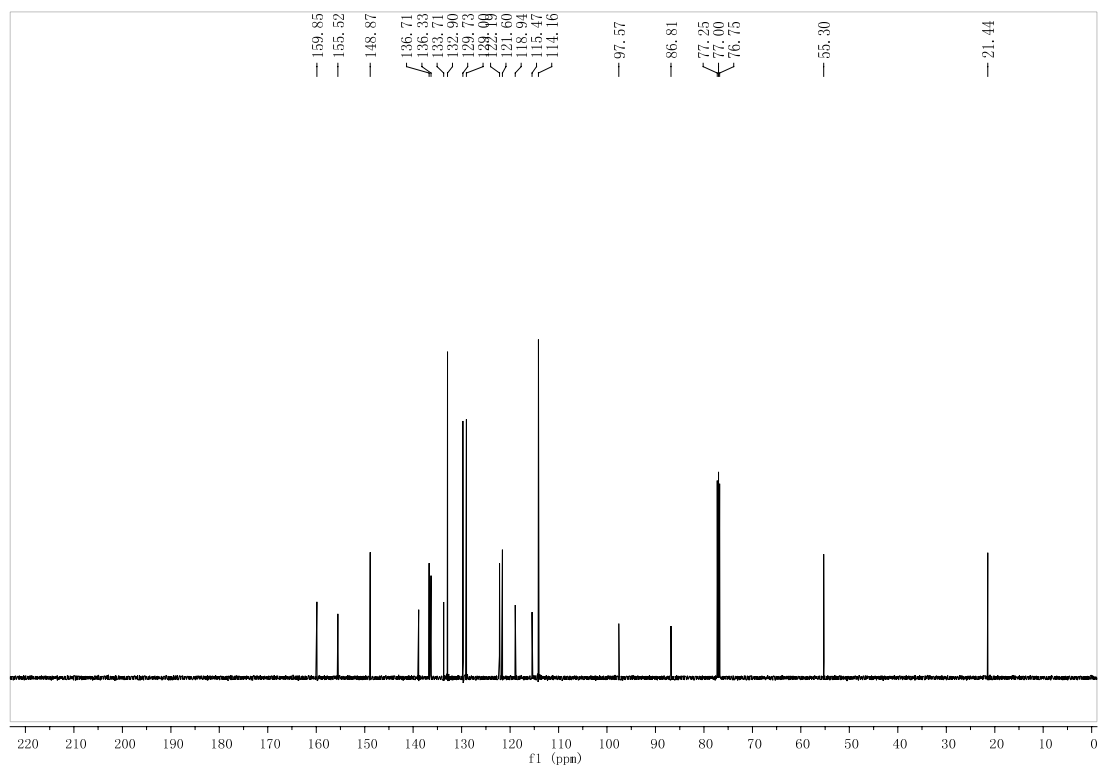
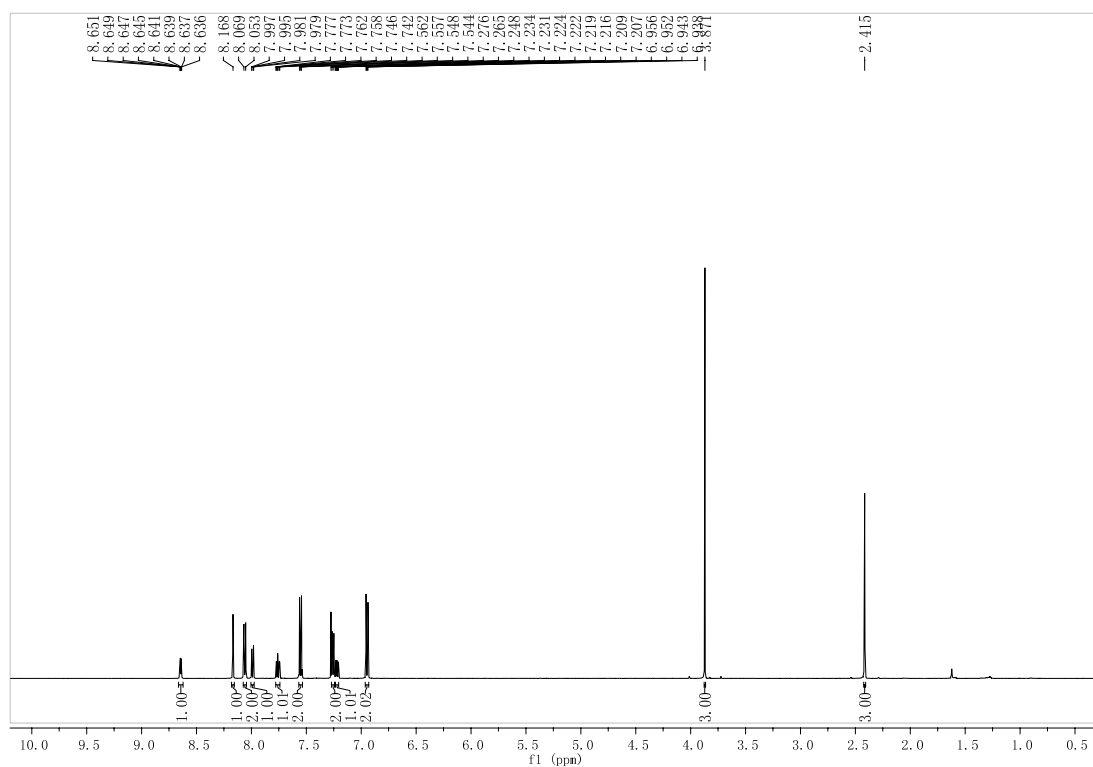
2-(1-Phenylhept-3-en-1-yn-3-yl)pyridine (**3k**):



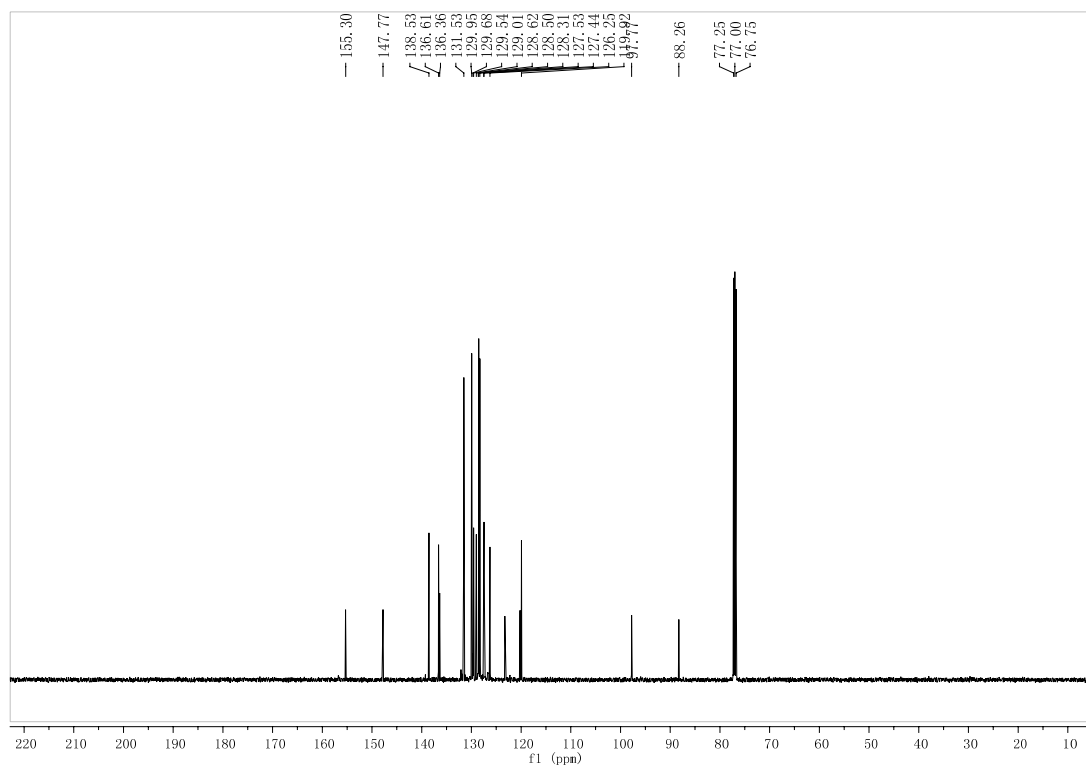
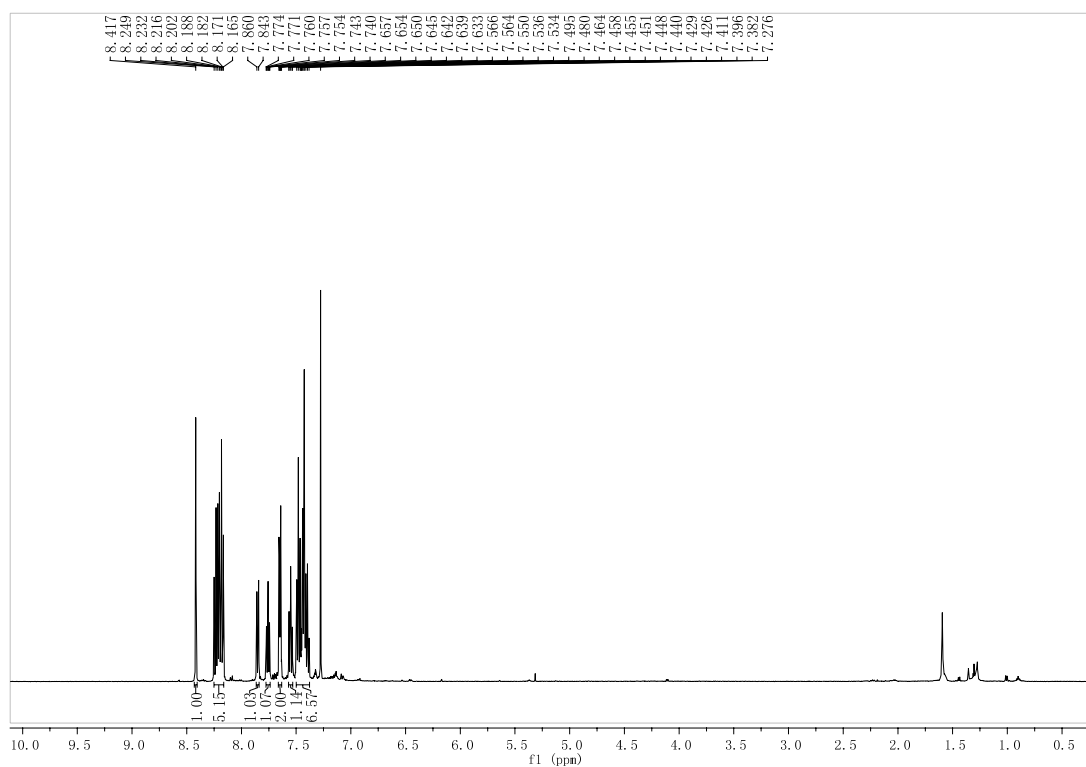
Methyl 5-phenyl-3-(pyridin-2-yl)pent-2-en-4-ynoate (**31**):



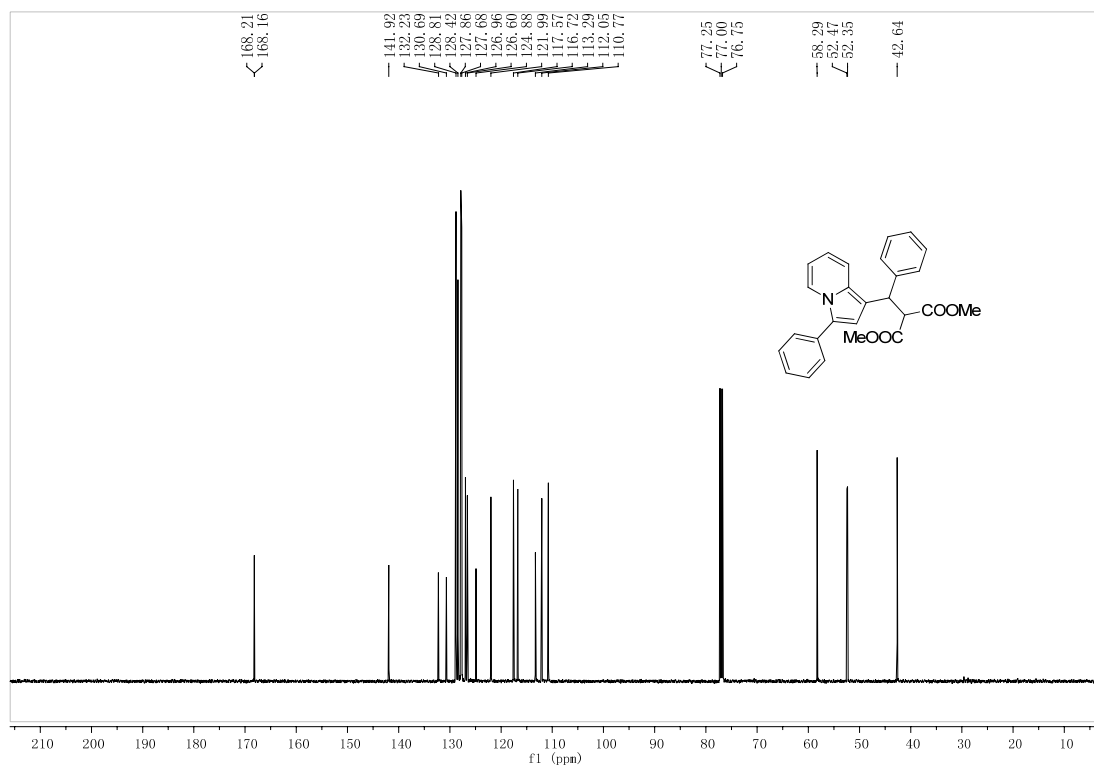
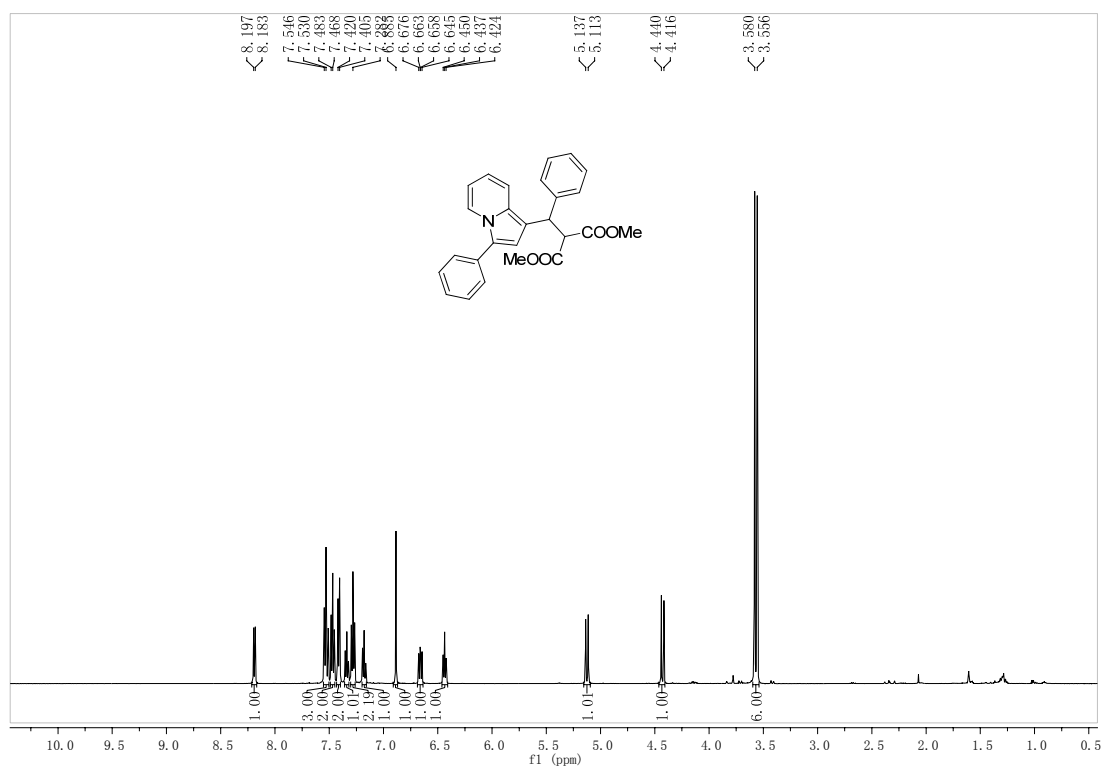
2-(4-(4-Methoxyphenyl)-1-p-tylbut-1-en-3-yn-2-yl)pyridine (**3m**):



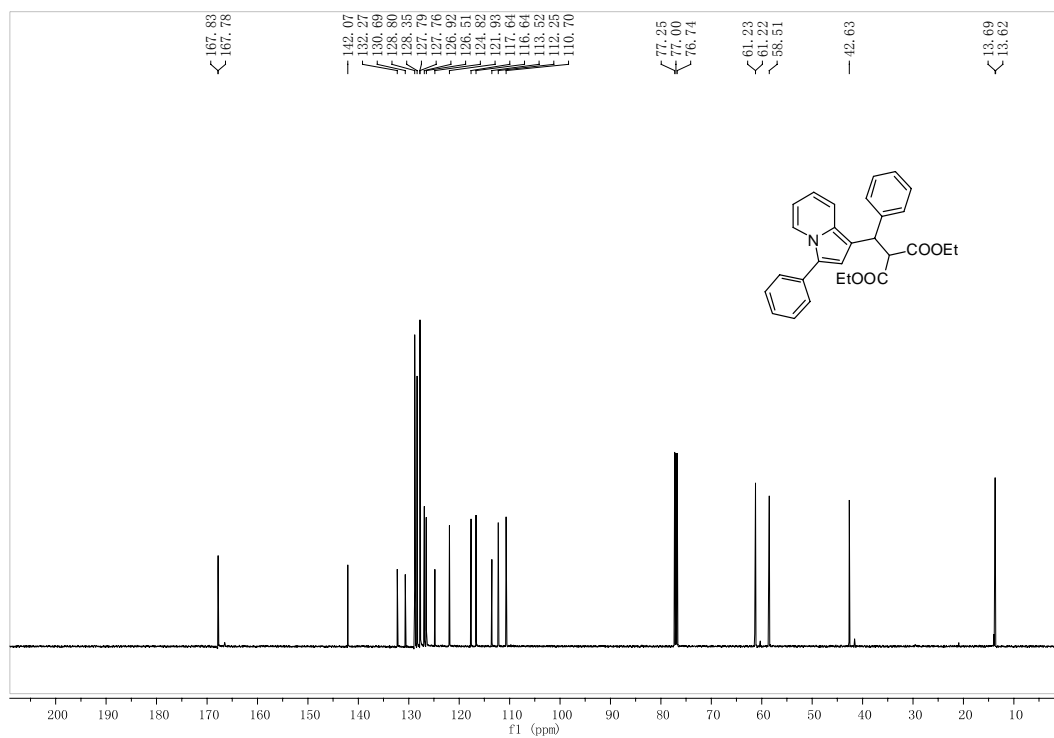
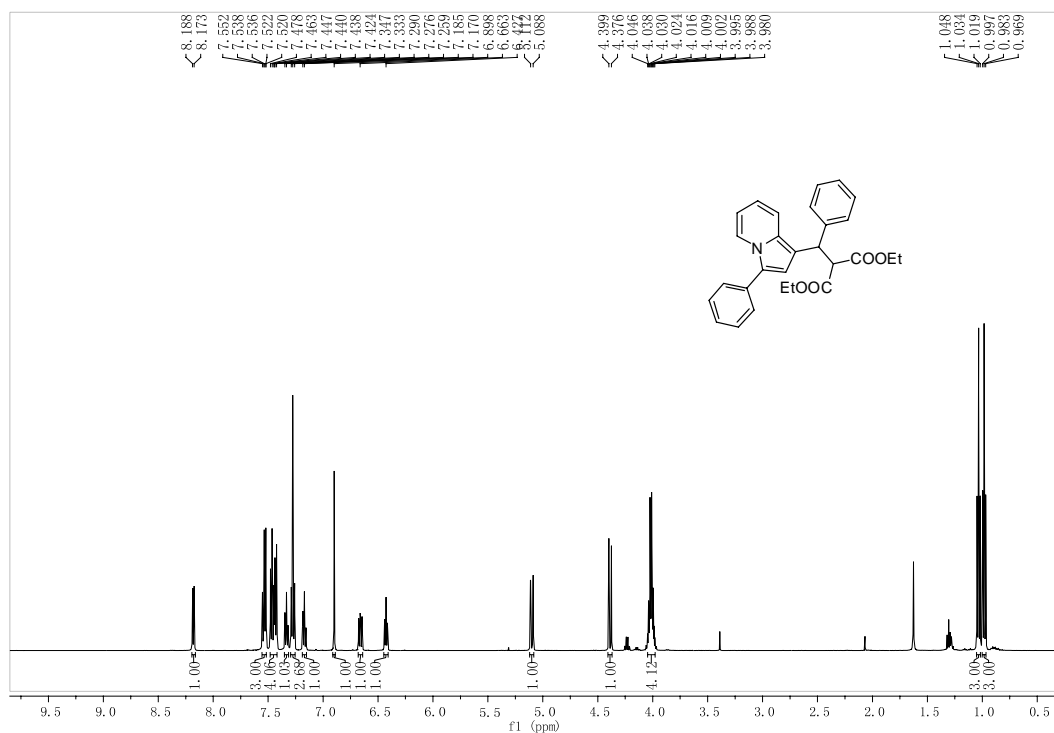
2-(1,4-Diphenylbut-1-en-3-yn-2-yl)quinoline (**3n**):



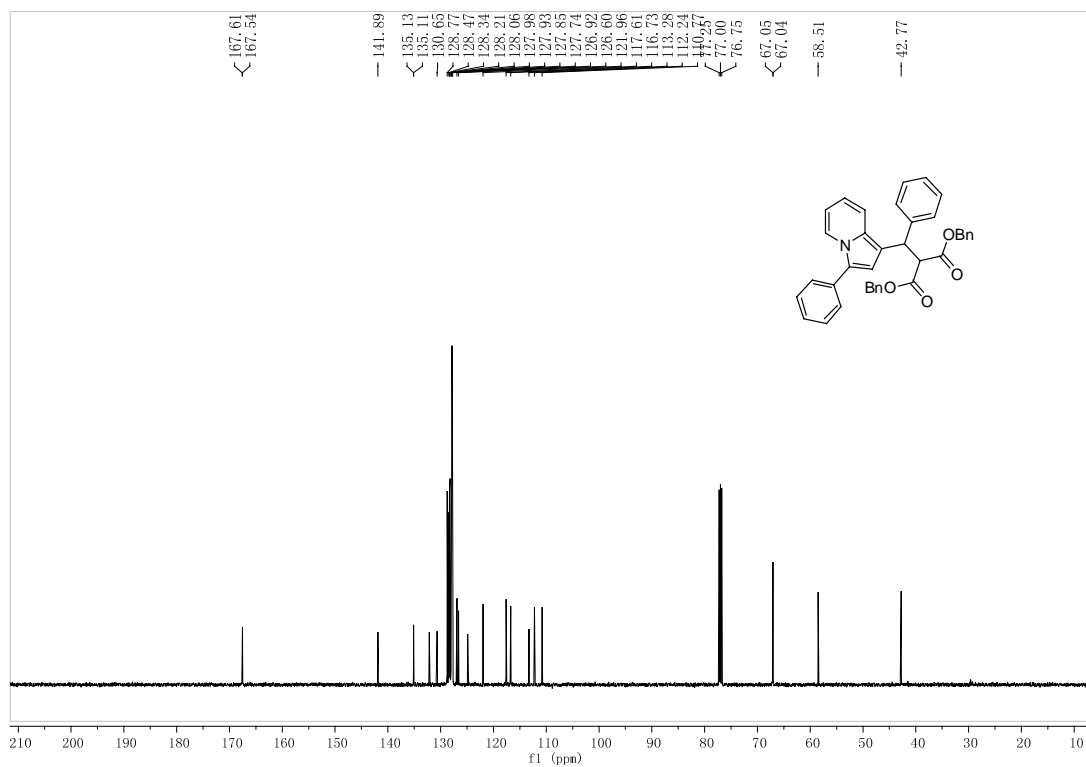
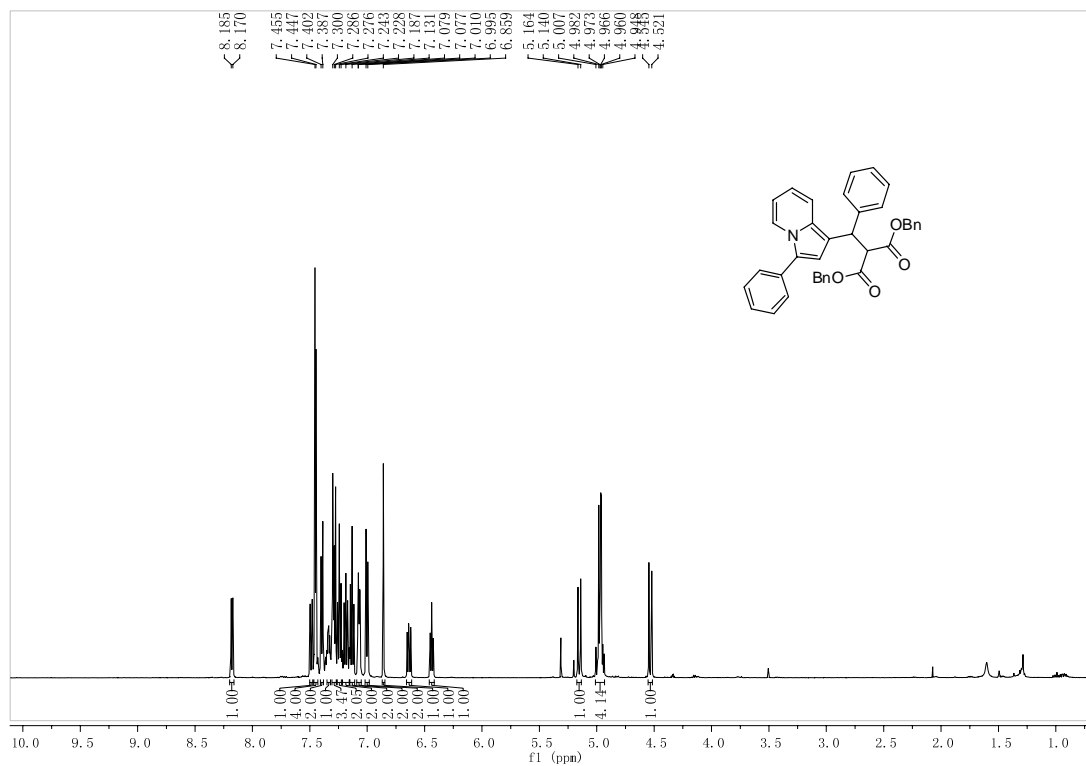
dimethyl 2-(phenyl(3-phenylindolizin-1-yl)methyl)malonate (**5aa**):



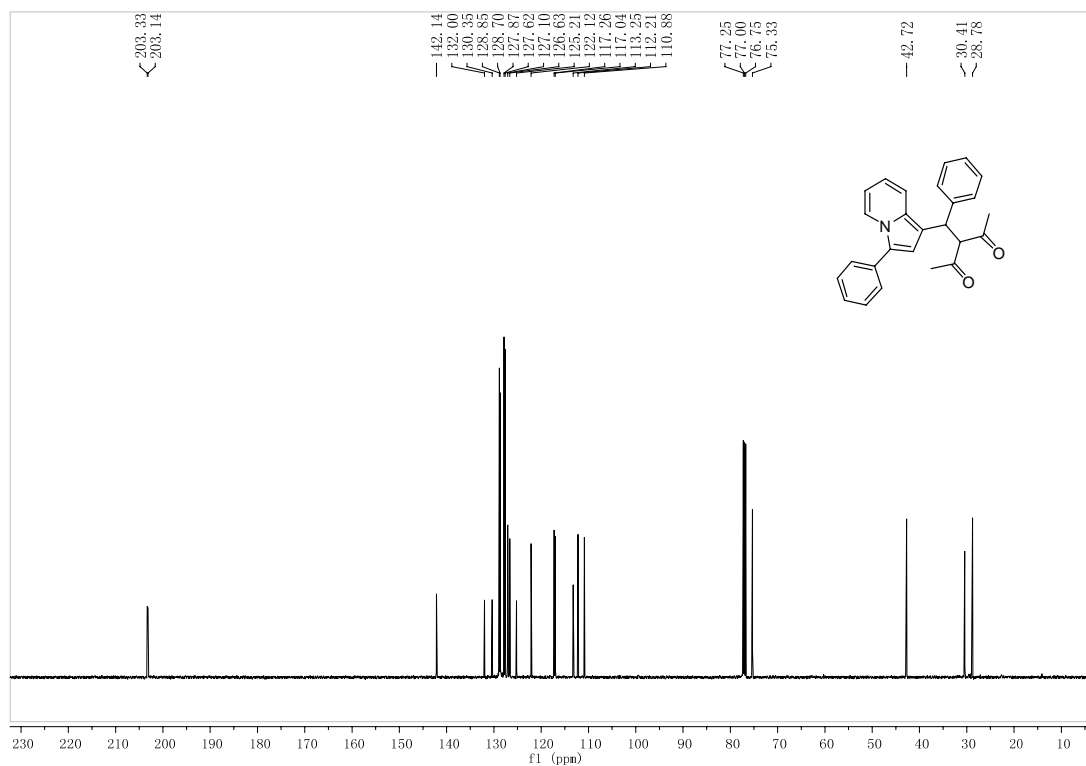
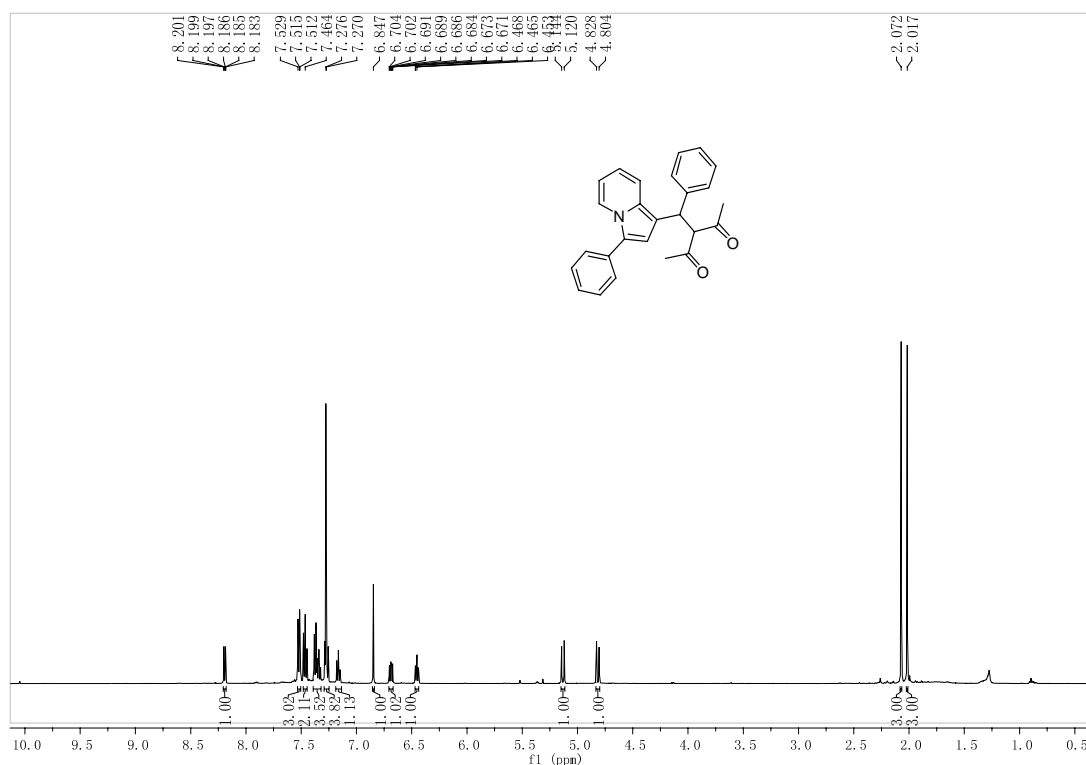
diethyl 2-(phenyl(3-phenylindolizin-1-yl)methyl)malonate (**5ab**):



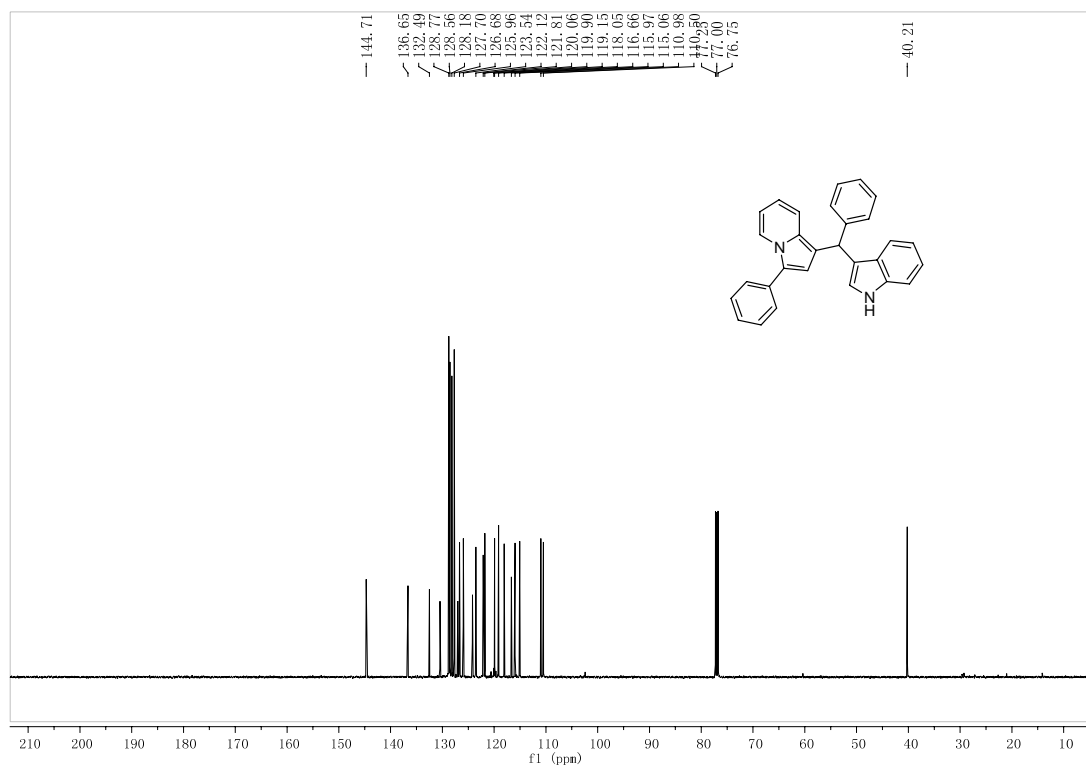
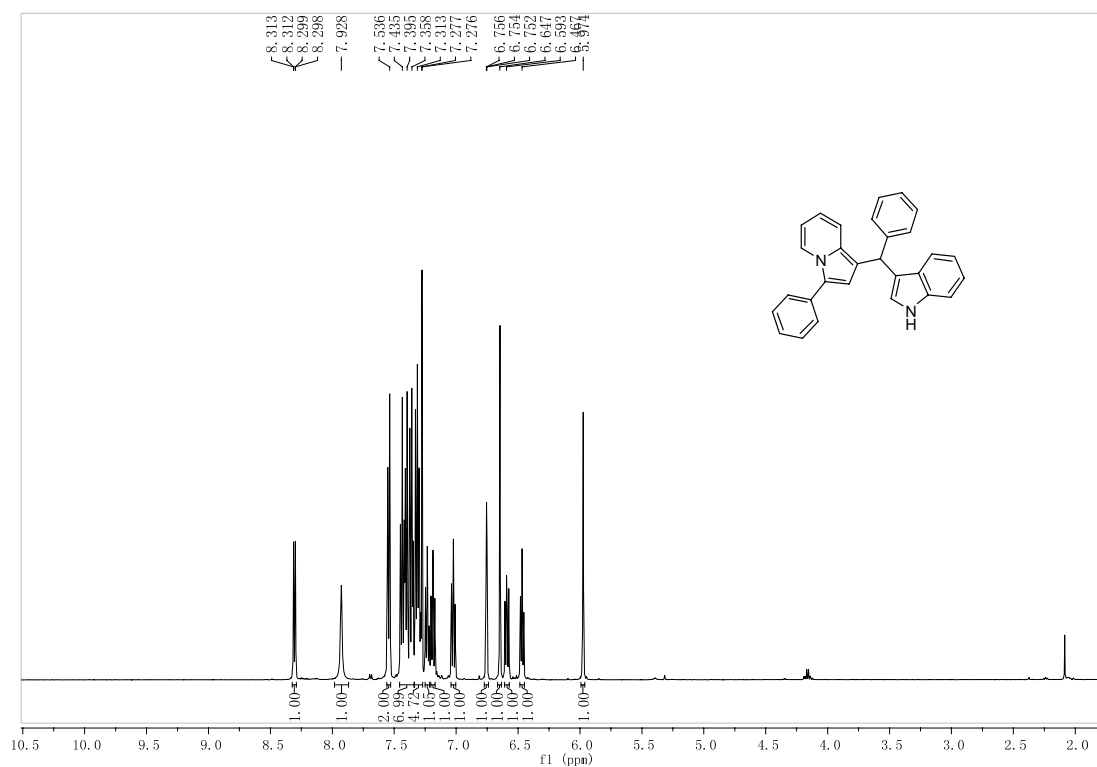
dibenzyl 2-(phenyl(3-phenylindolizin-1-yl)methyl)malonate (**5ac**):



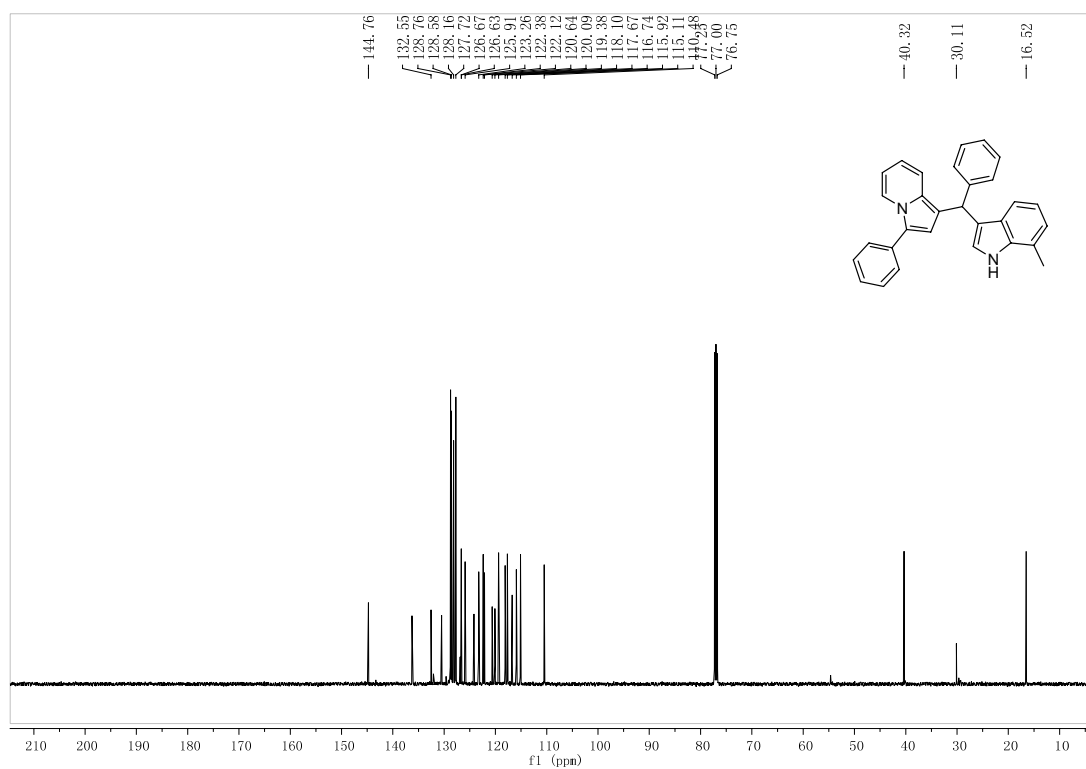
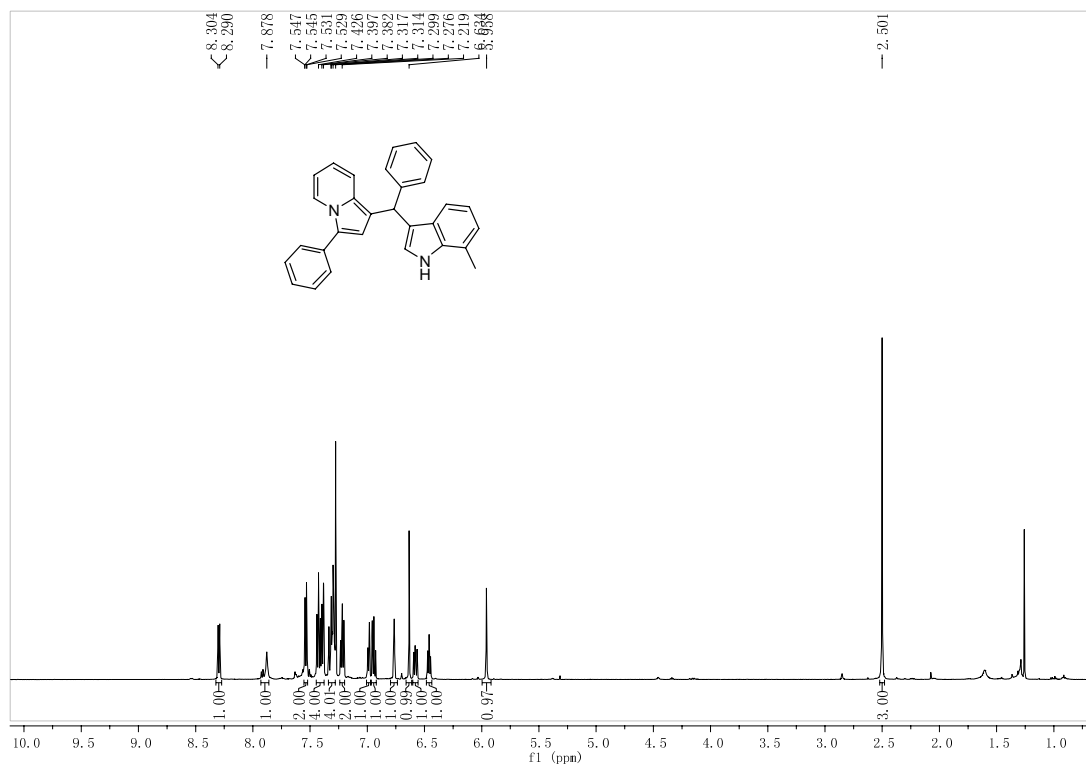
3-(phenyl(3-phenylindolizin-1-yl)methyl)pentane-2,4-dione (**5ad**):



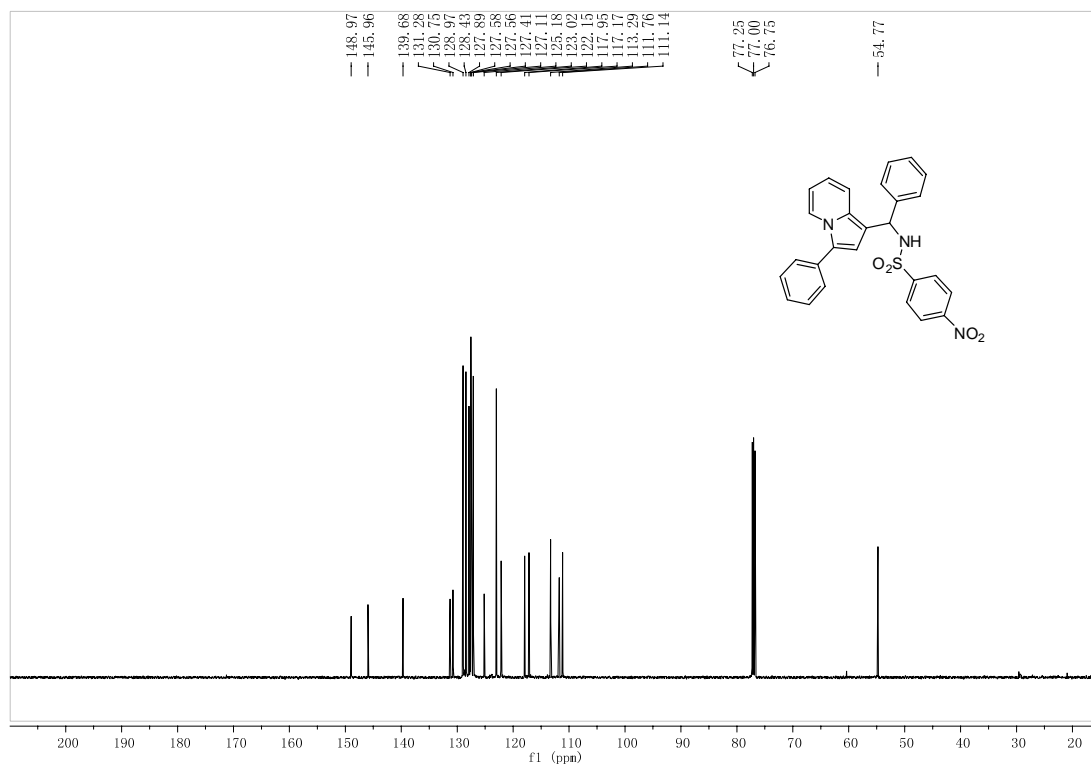
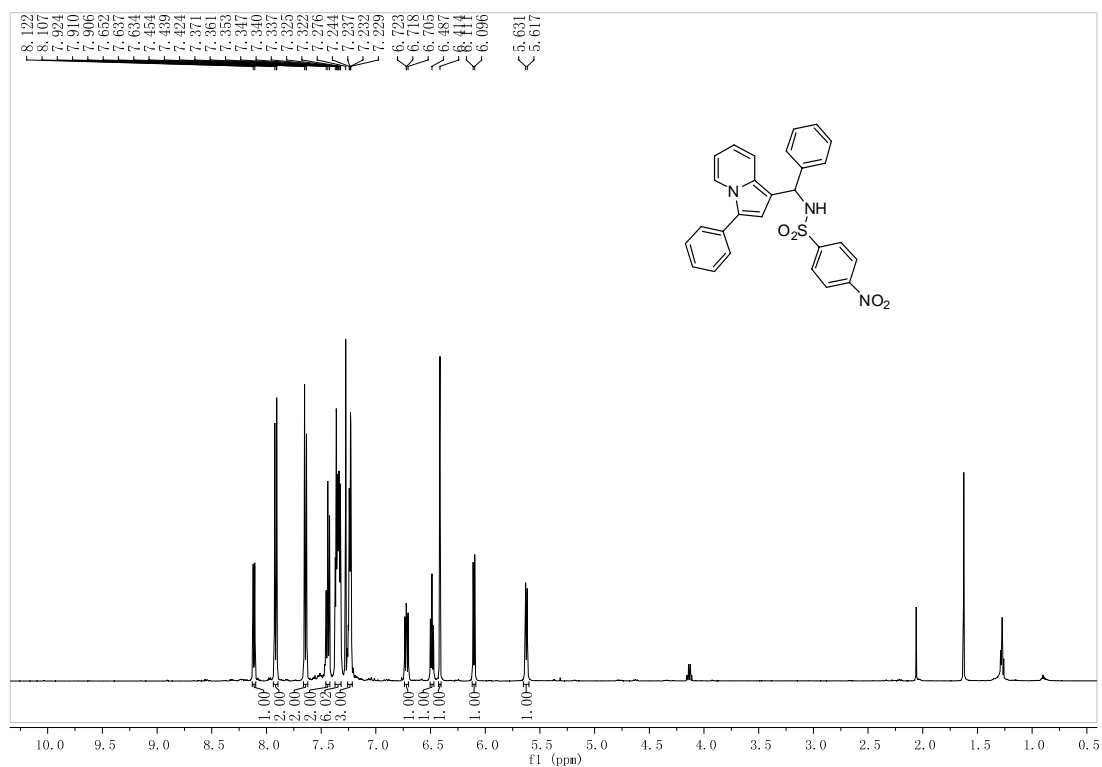
3-(phenyl(3-phenylindolizin-1-yl)methyl)-1H-indole (**5ae**):



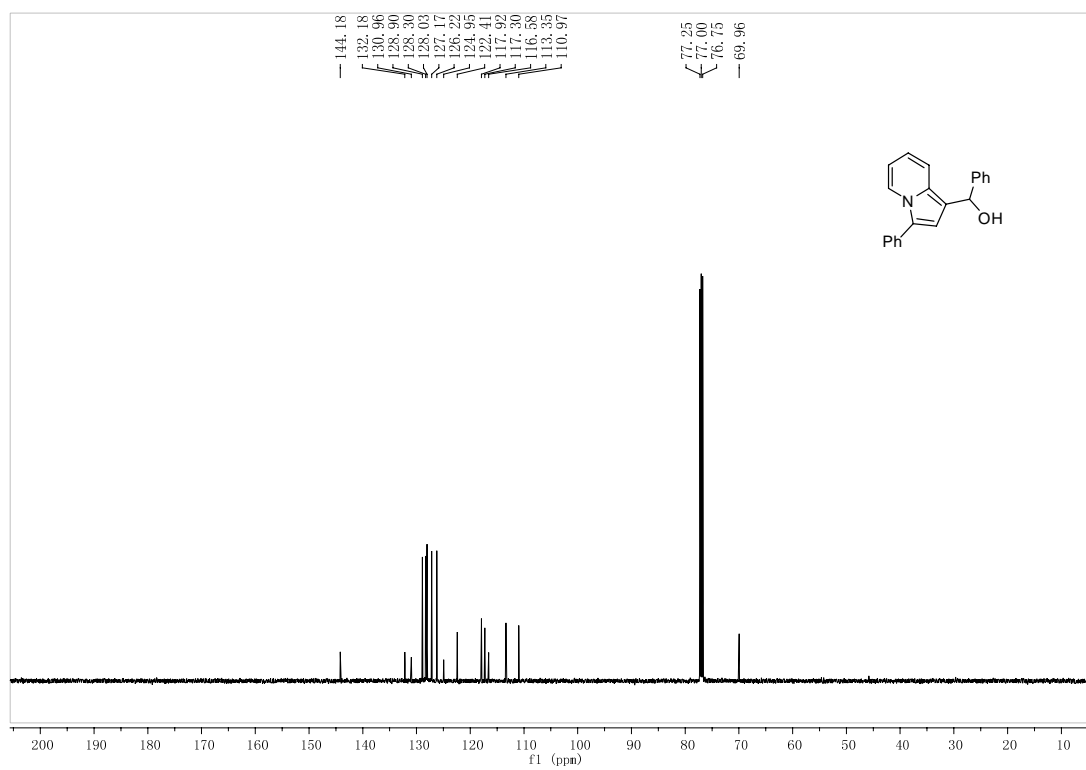
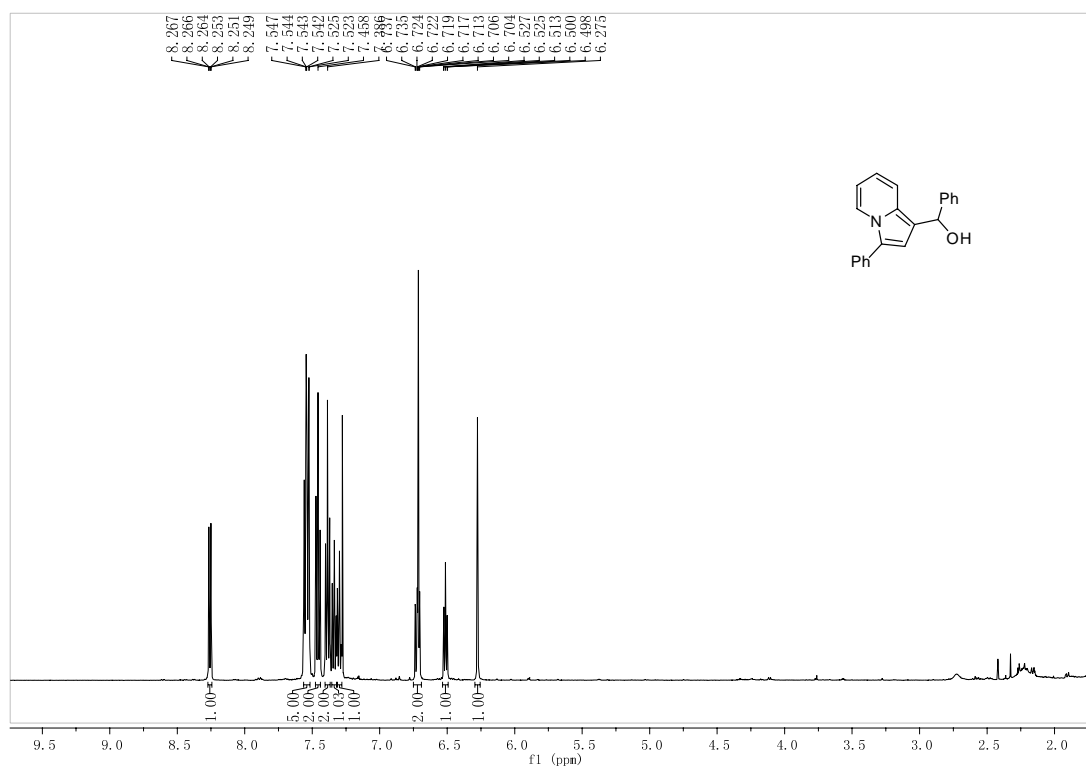
7-methyl-3-(phenyl(3-phenylindolizin-1-yl)methyl)-1H-indole (**5af**):



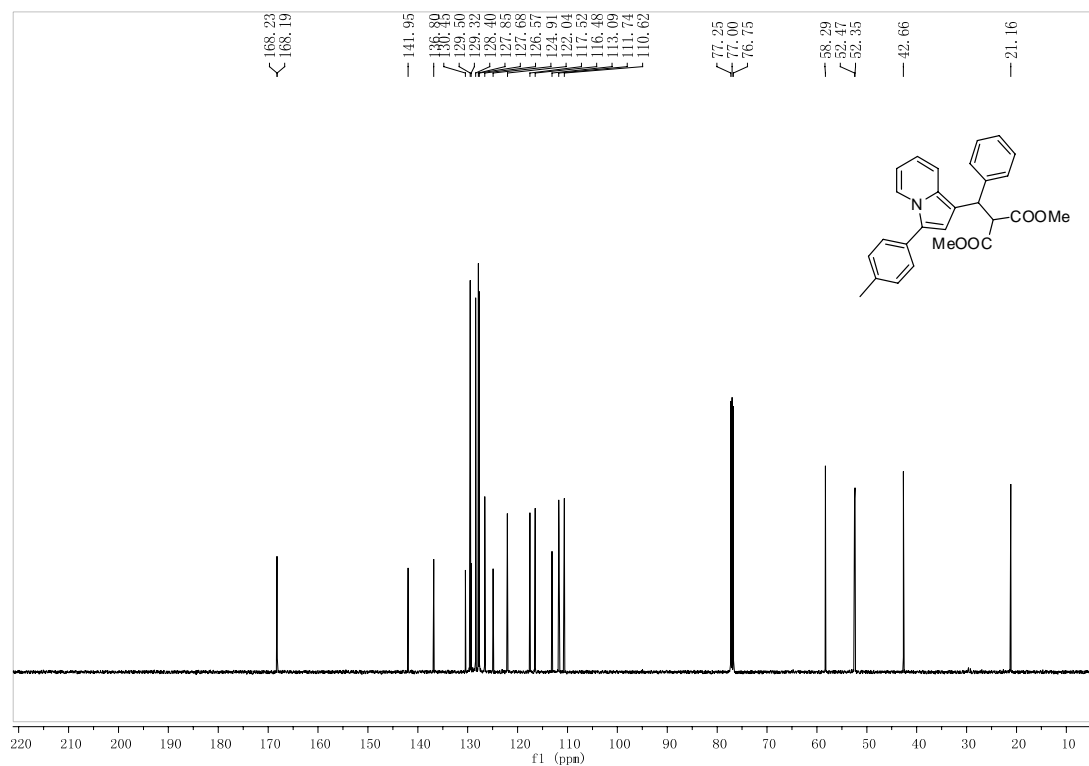
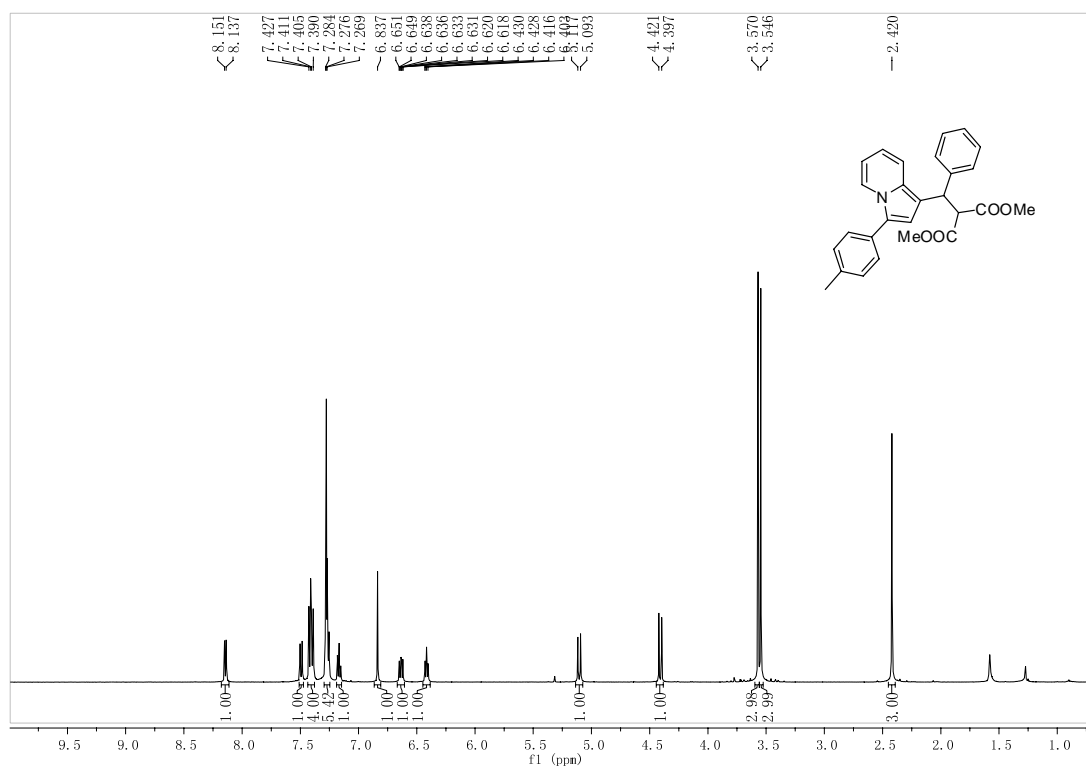
4-nitro-N-(phenyl(3-phenylindolizin-1-yl)methyl)benzenesulfonamide (**5ah**):



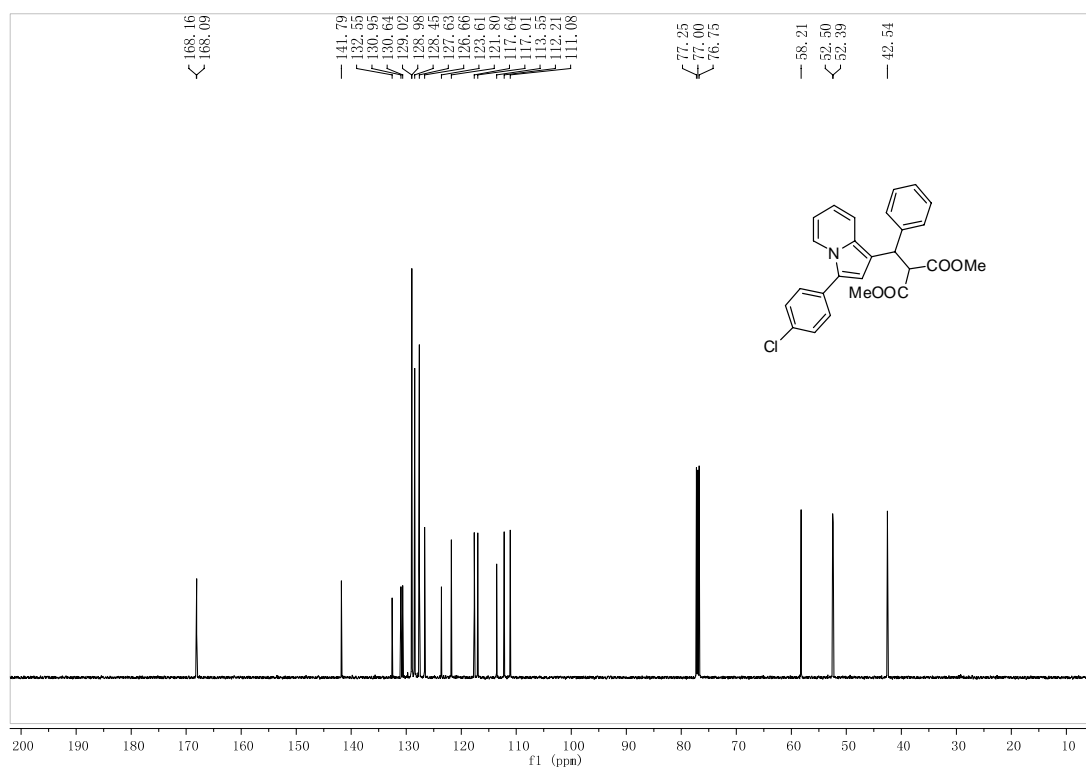
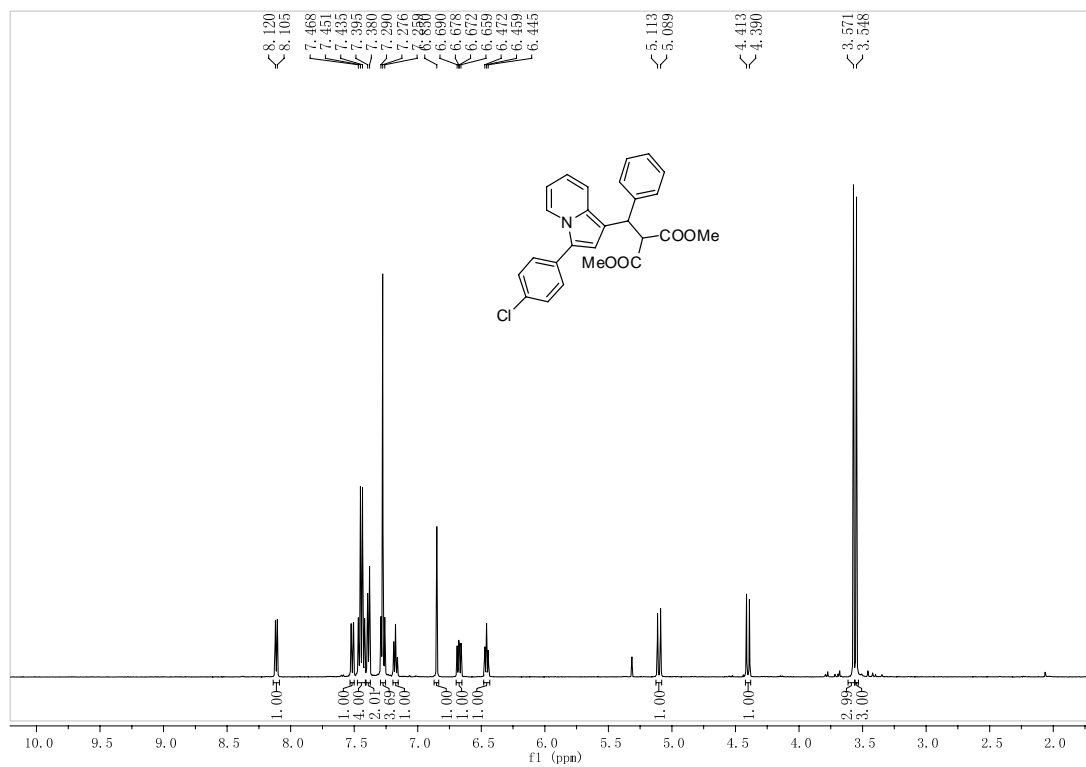
phenyl(3-phenylindolizin-1-yl)methanol (**5ai**):



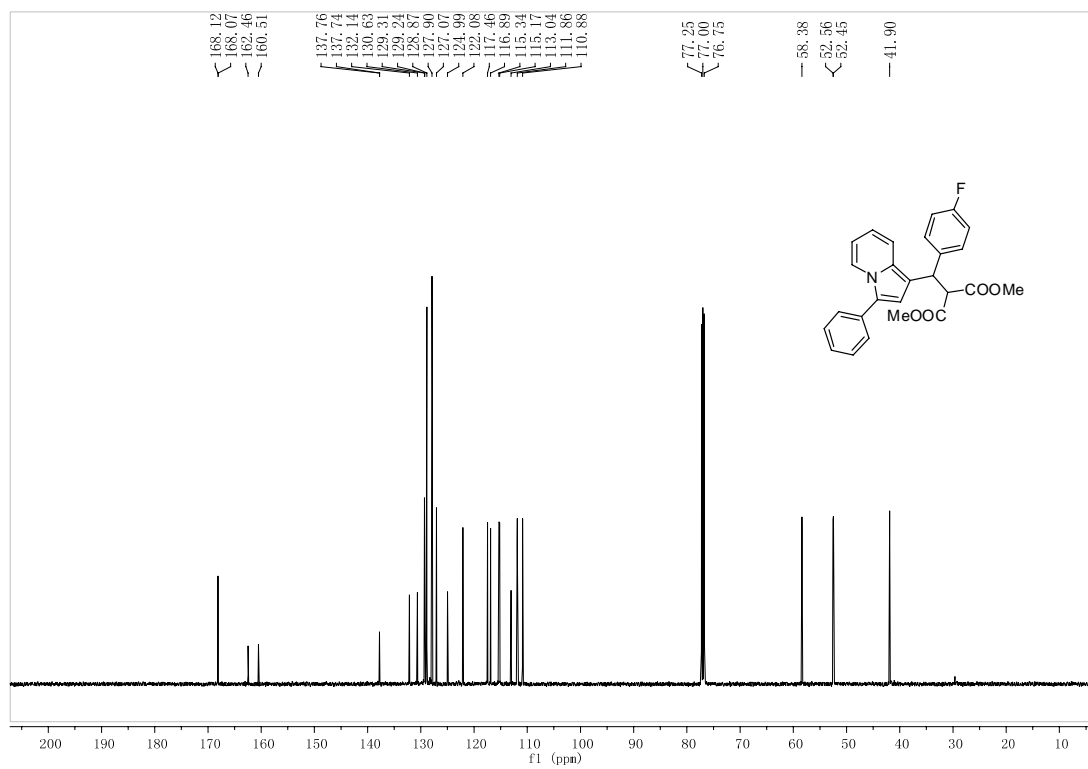
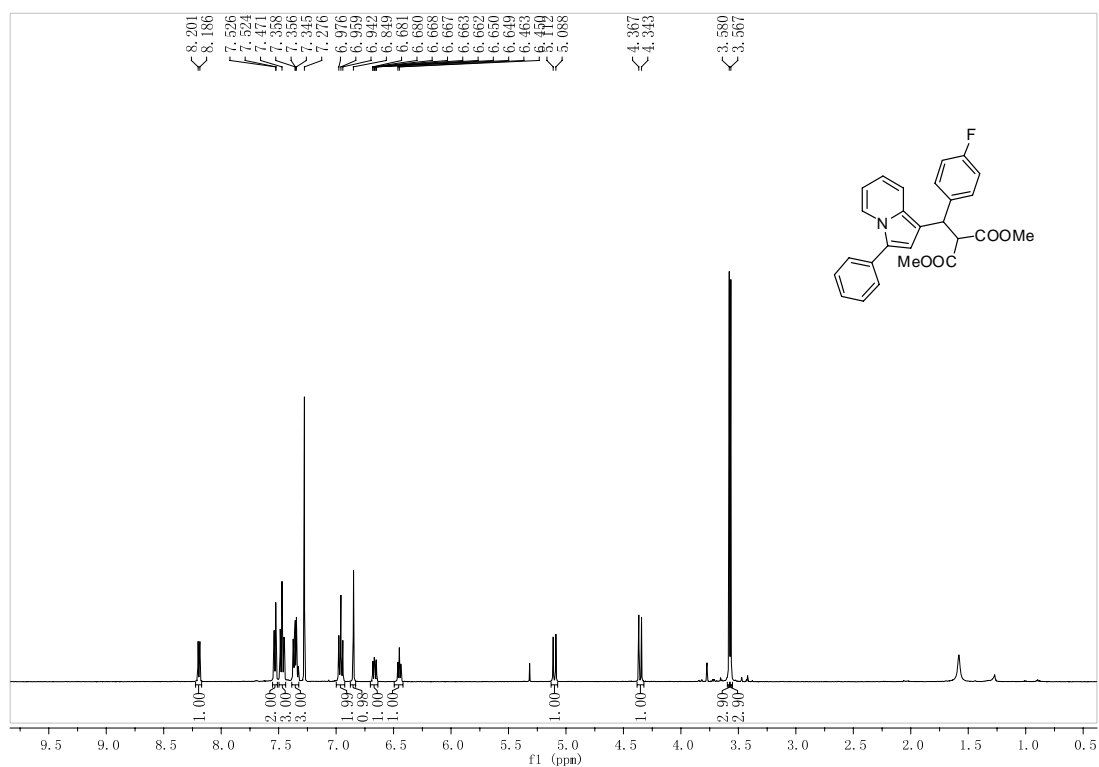
dimethyl 2-(phenyl(3-p-tolylindolizin-1-yl)methyl)malonate (**5ba**):



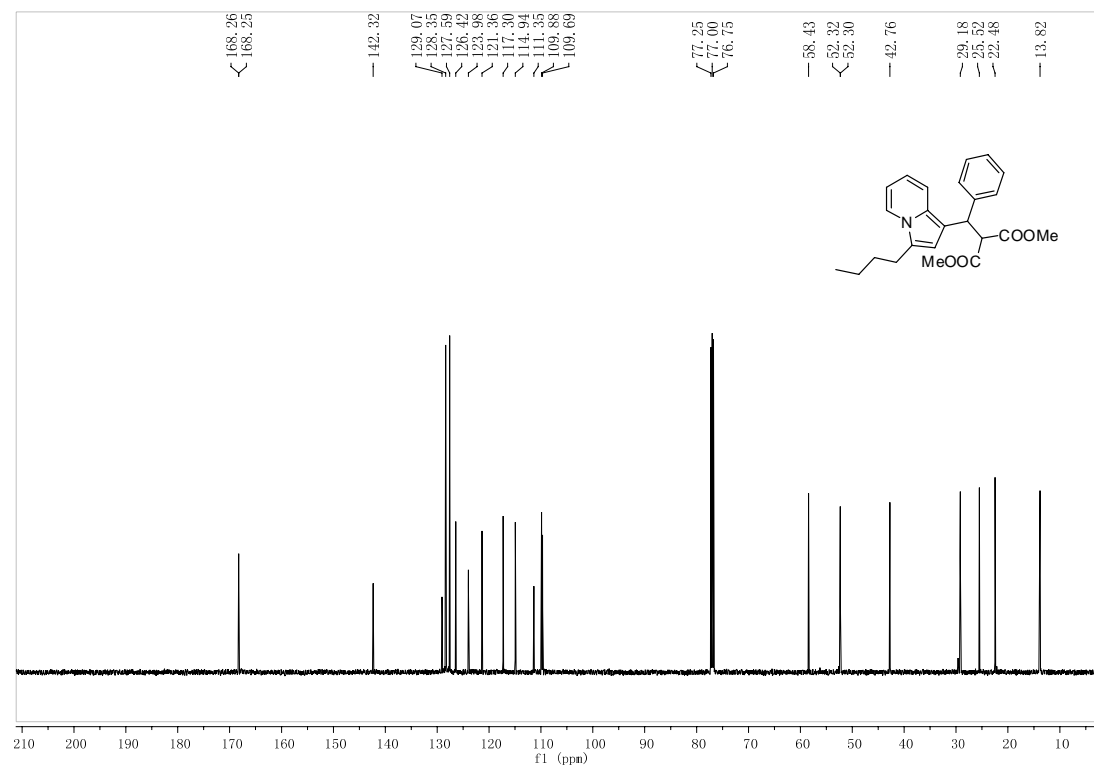
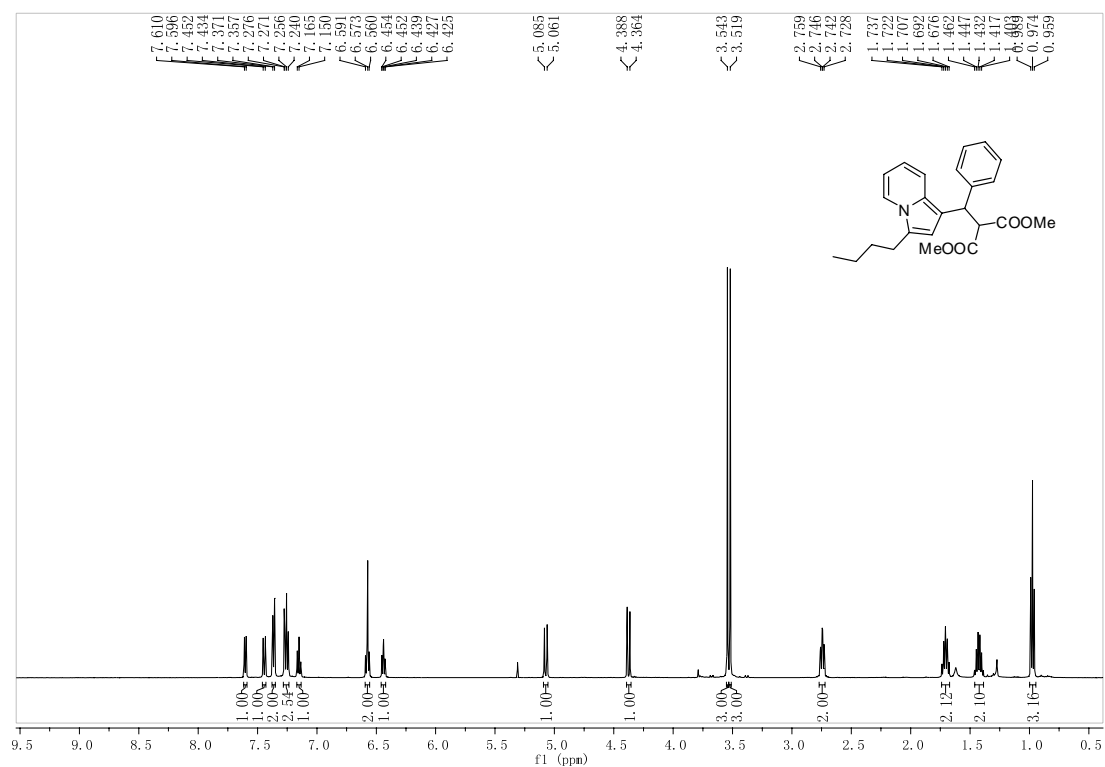
dimethyl 2-((3-(4-chlorophenyl)indolizin-1-yl)(phenyl)methyl)malonate (**5ca**):



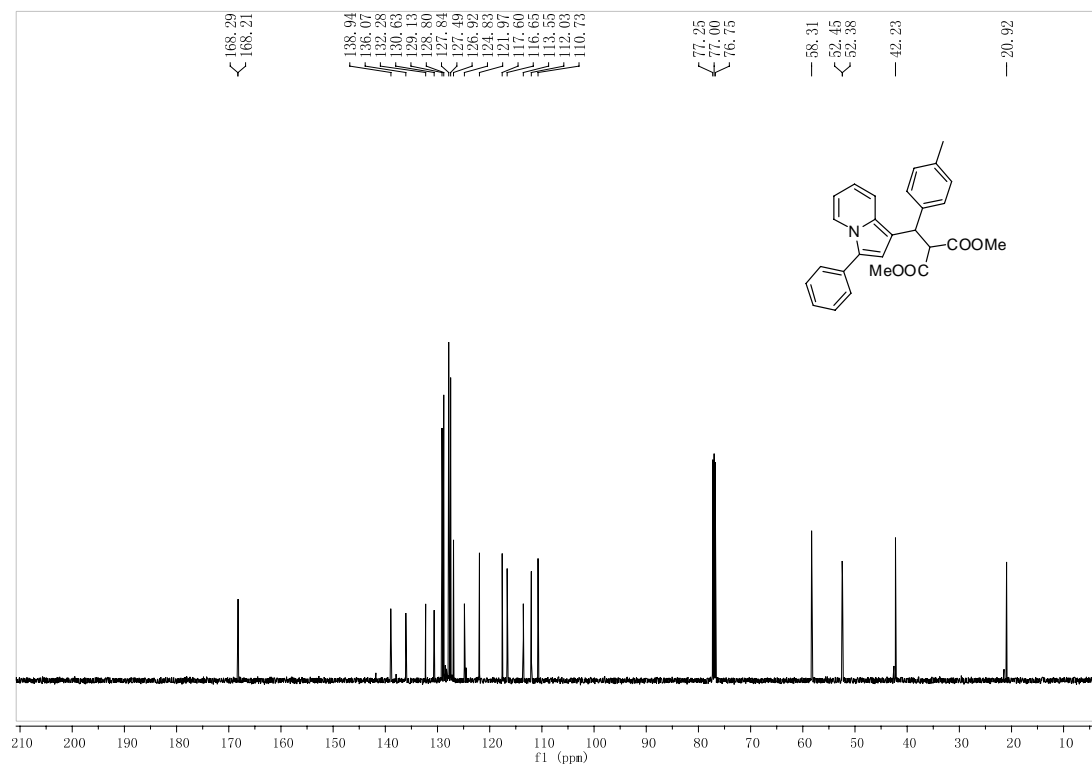
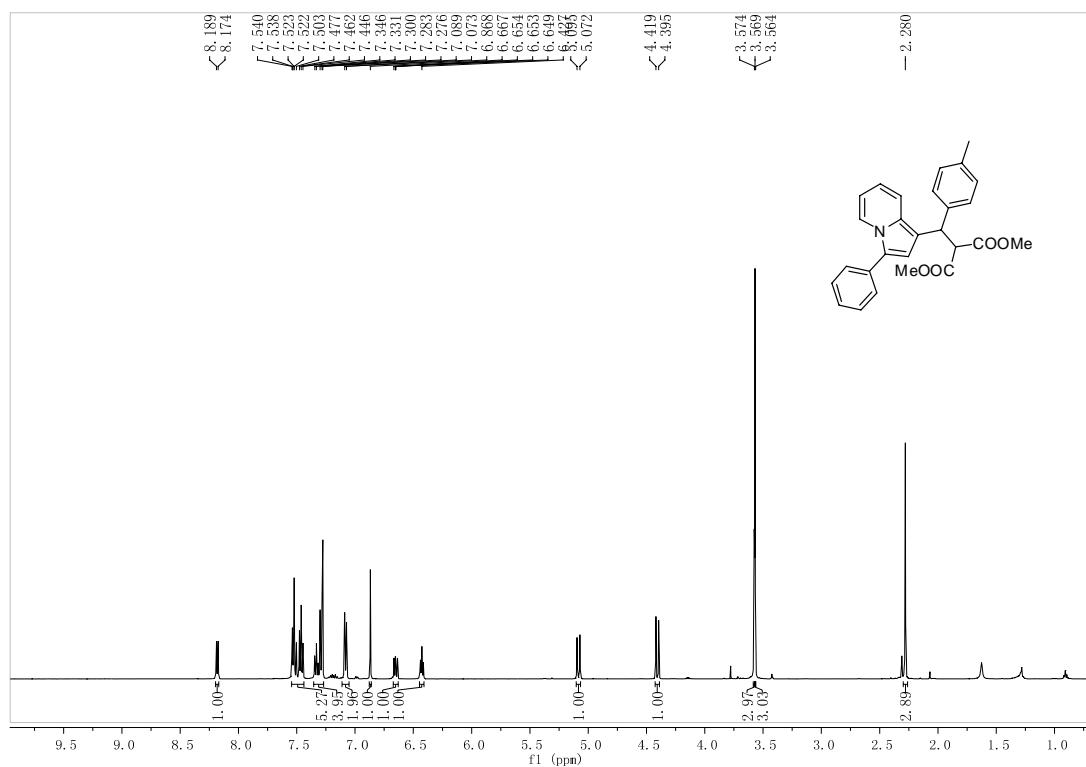
dimethyl 2-((4-fluorophenyl)(3-phenylindolizin-1-yl)methyl)malonate (**5ea**):



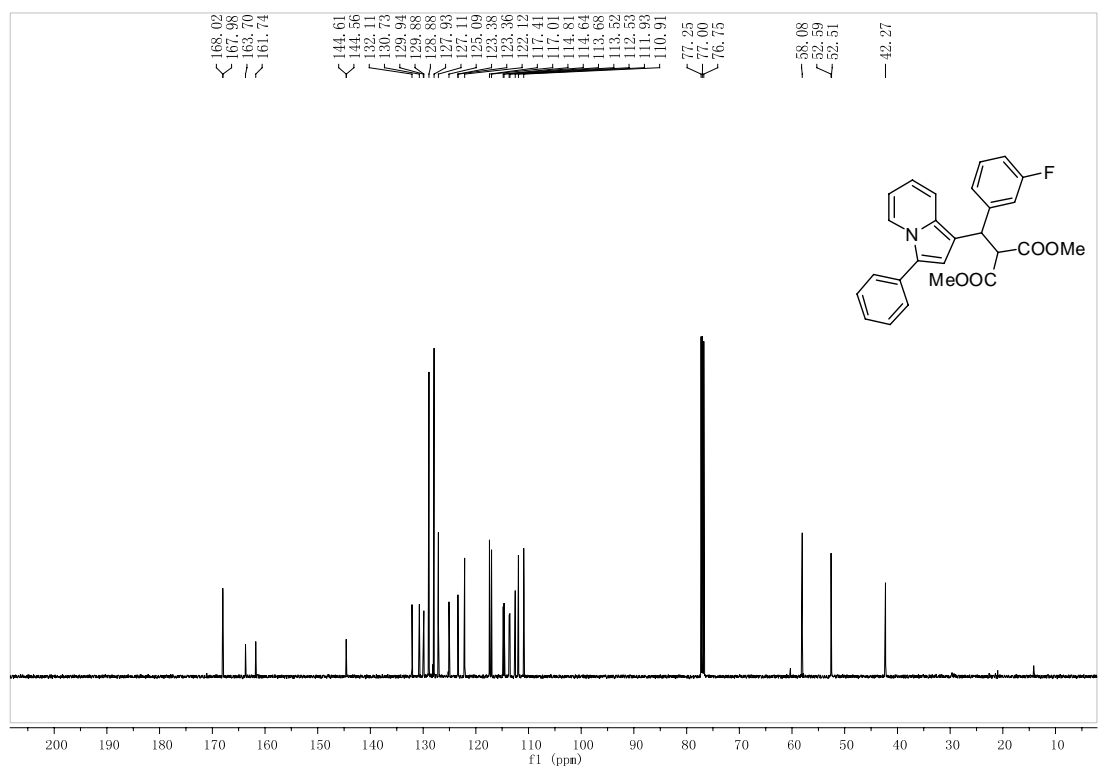
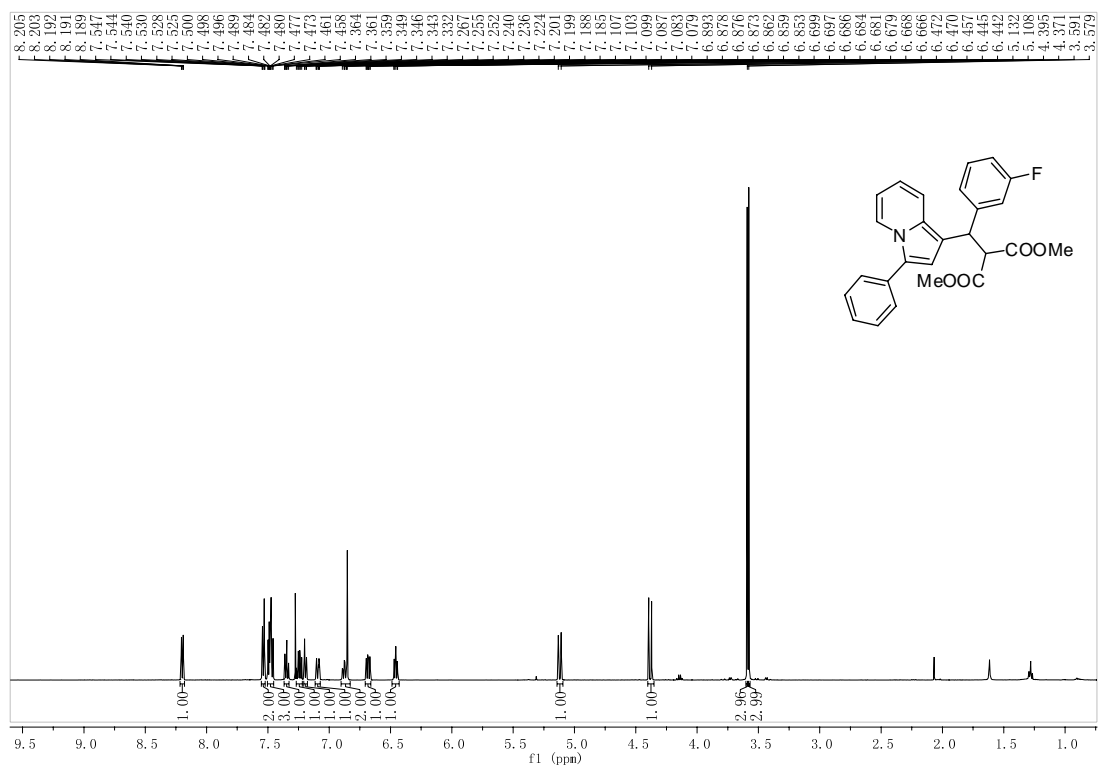
dimethyl 2-((3-butylindolizin-1-yl)(phenyl)methyl)malonate (**5fa**):



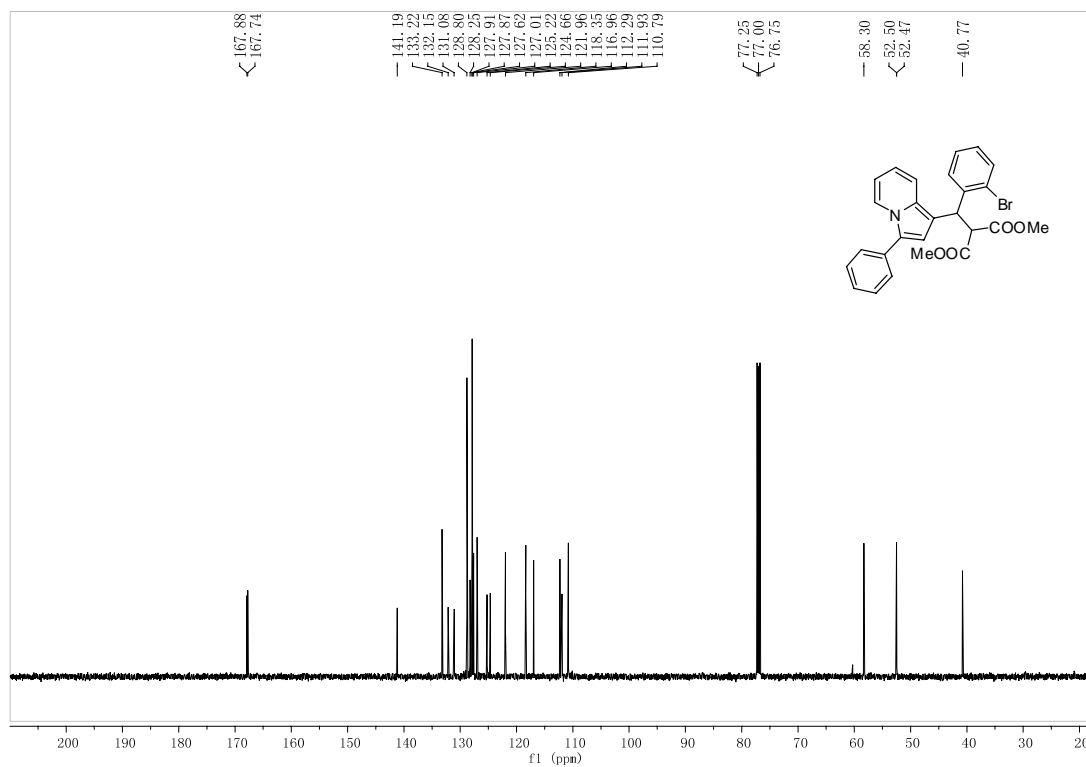
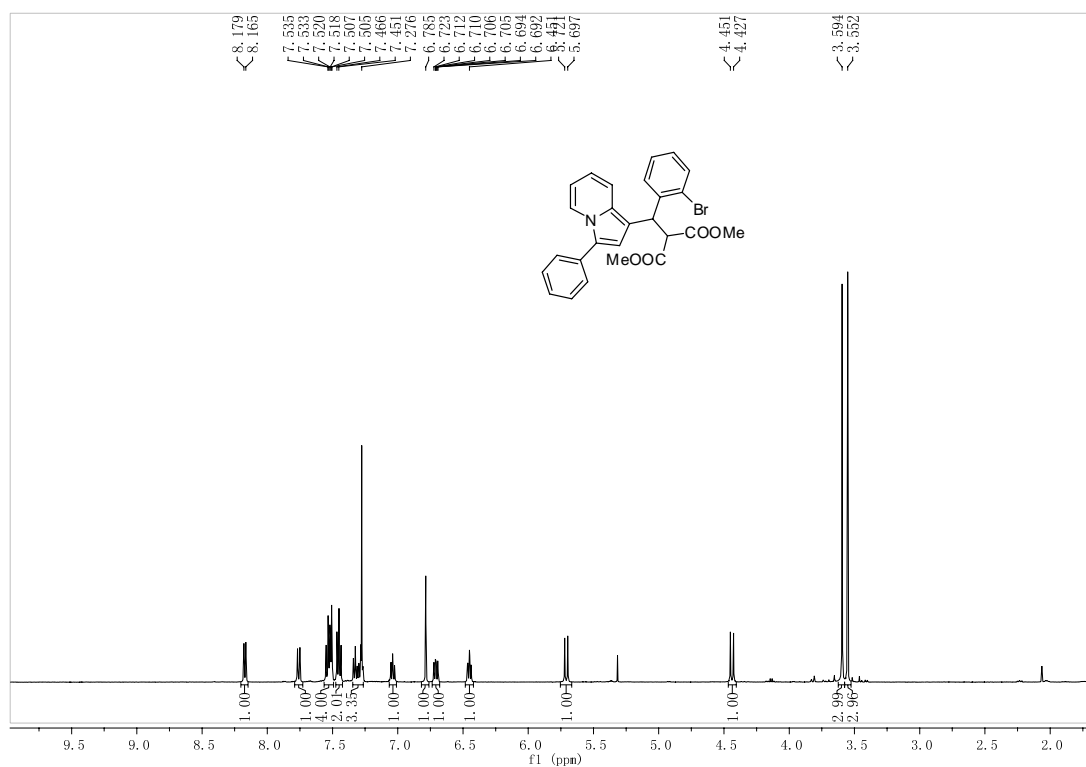
dimethyl 2-((3-phenylindolizin-1-yl)(p-tolyl)methyl)malonate (**5ga**):



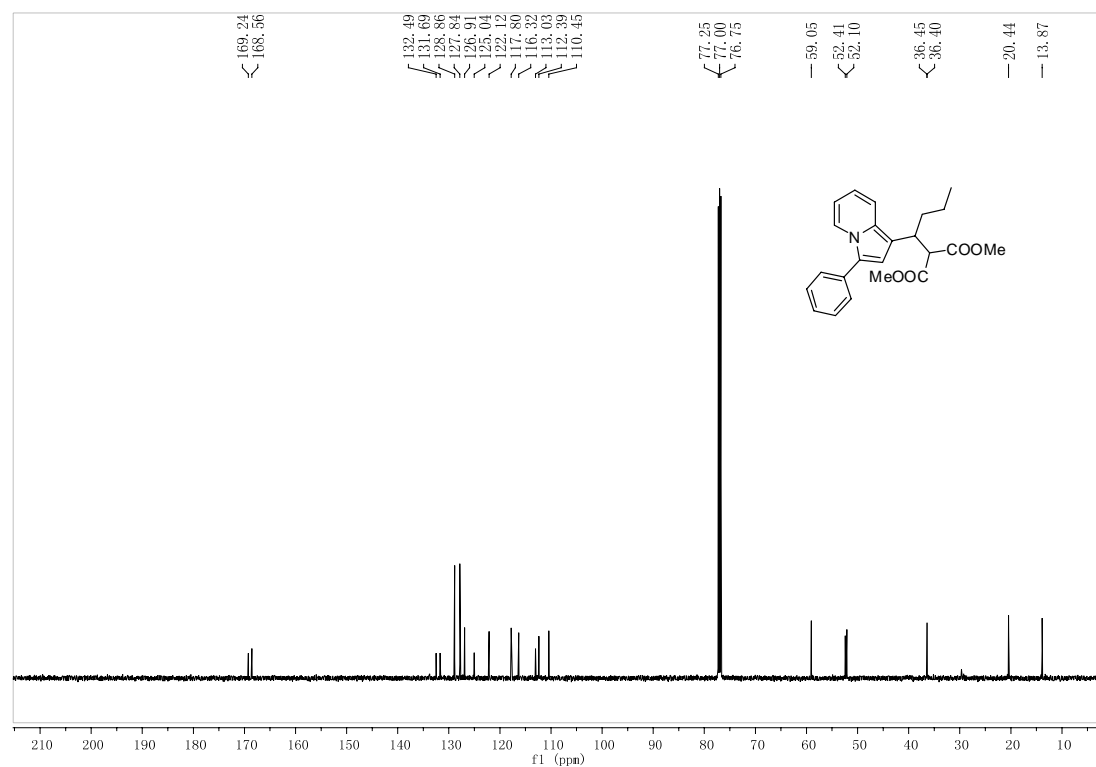
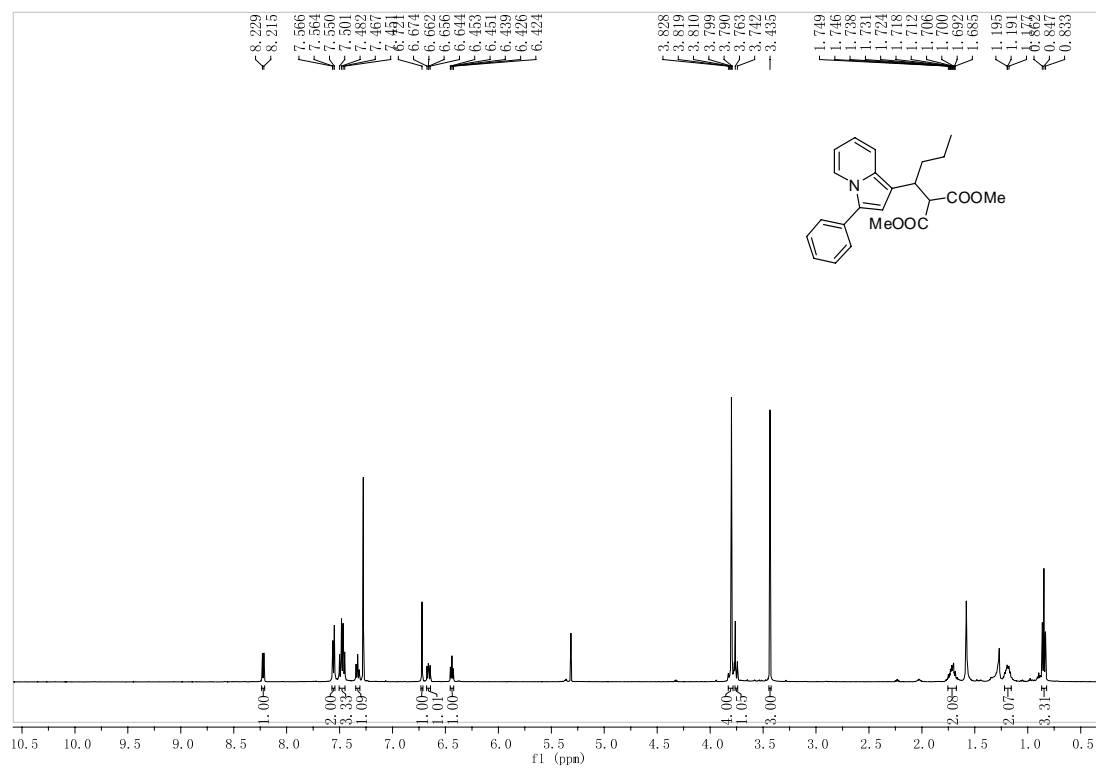
dimethyl 2-((3-fluorophenyl)(3-phenylindolizin-1-yl)methyl)malonate (**5ha**):



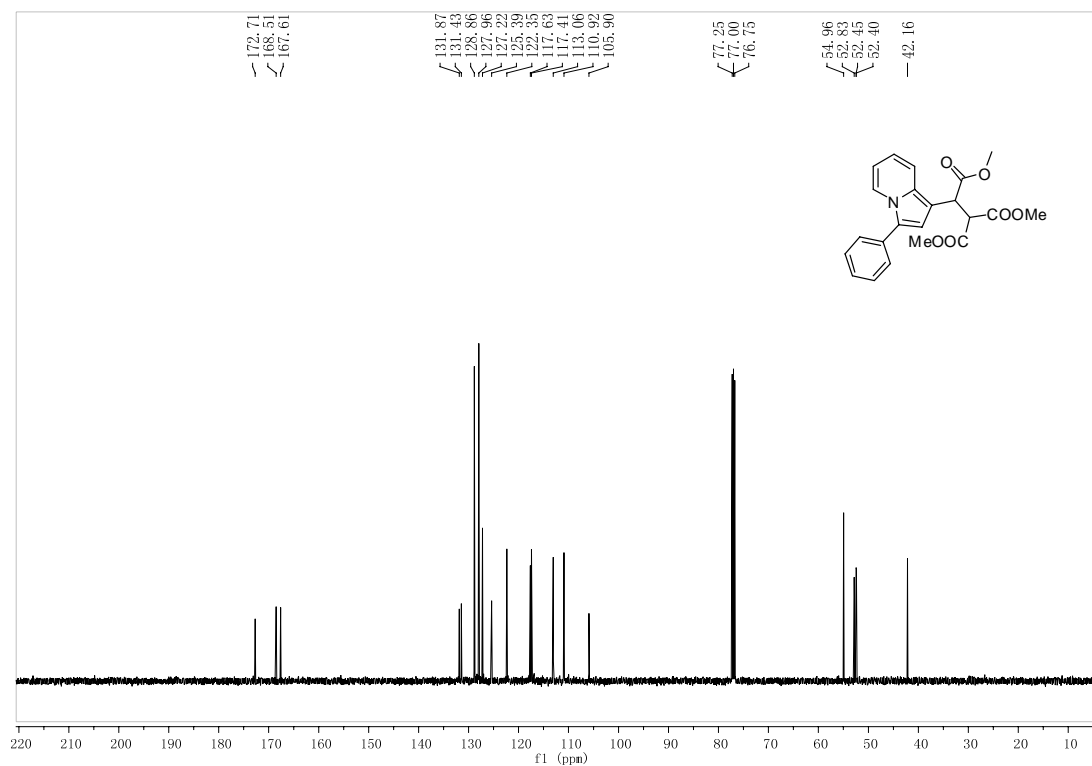
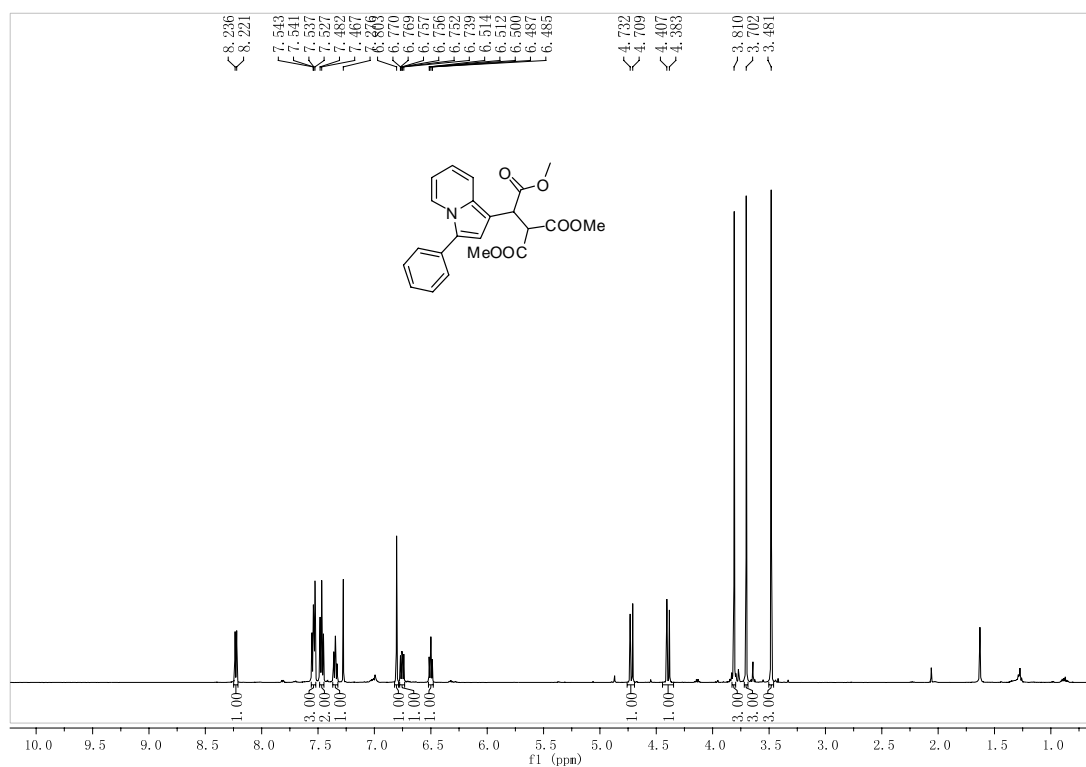
dimethyl 2-((2-bromophenyl)(3-phenylindolizin-1-yl)methyl)malonate (**5ja**):



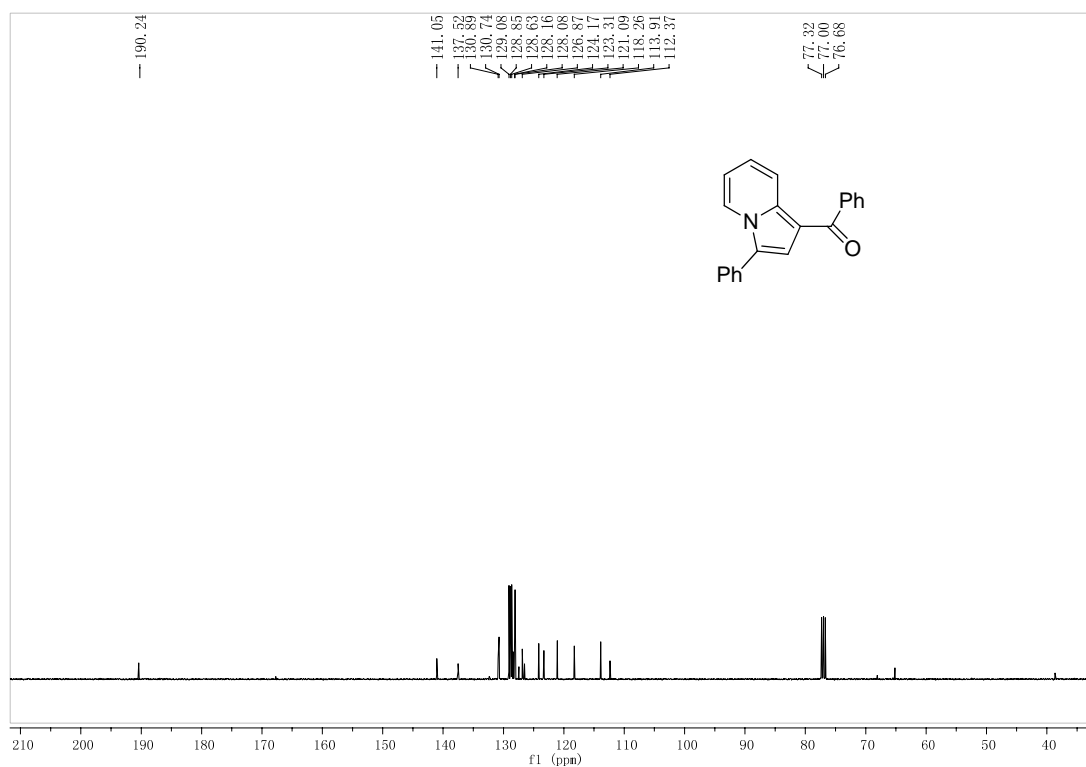
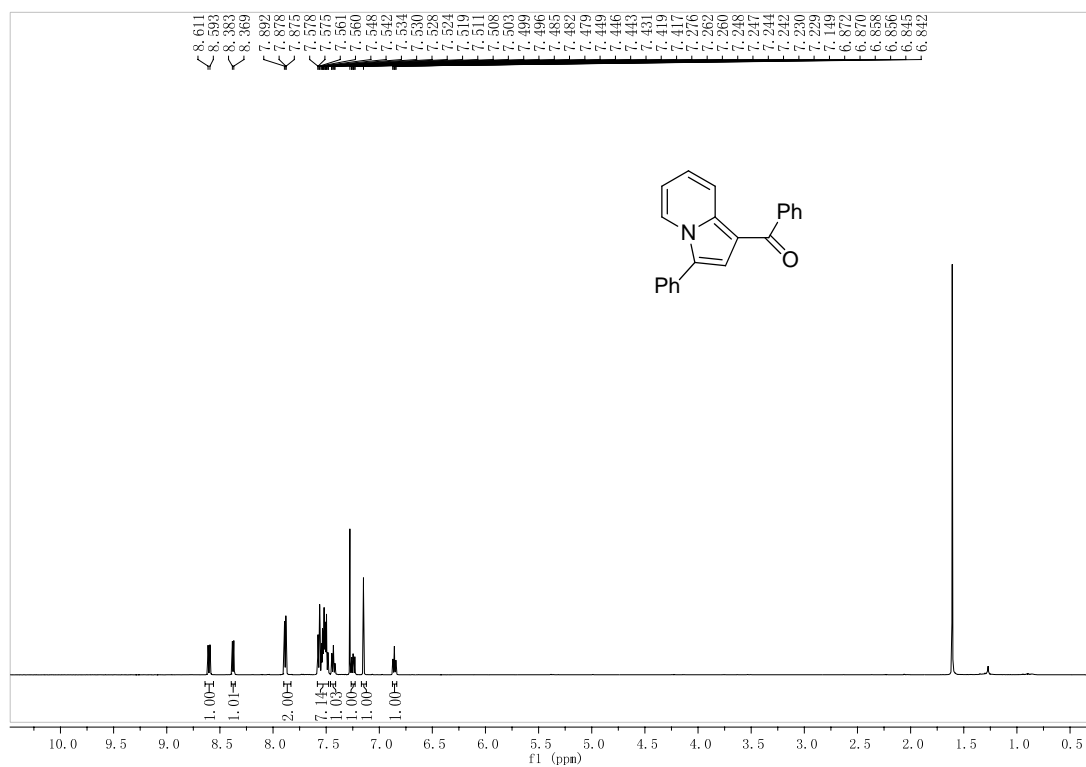
dimethyl 2-(1-(3-phenylindolizin-1-yl)butyl)malonate (**5ka**):



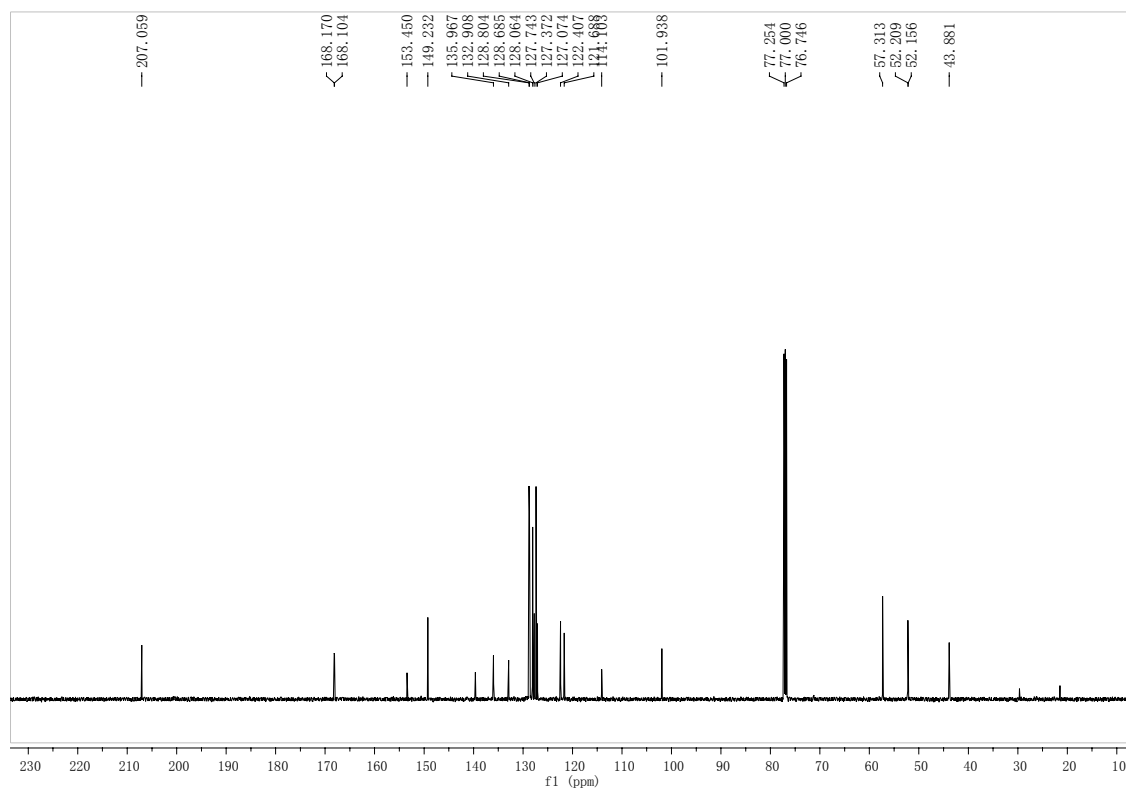
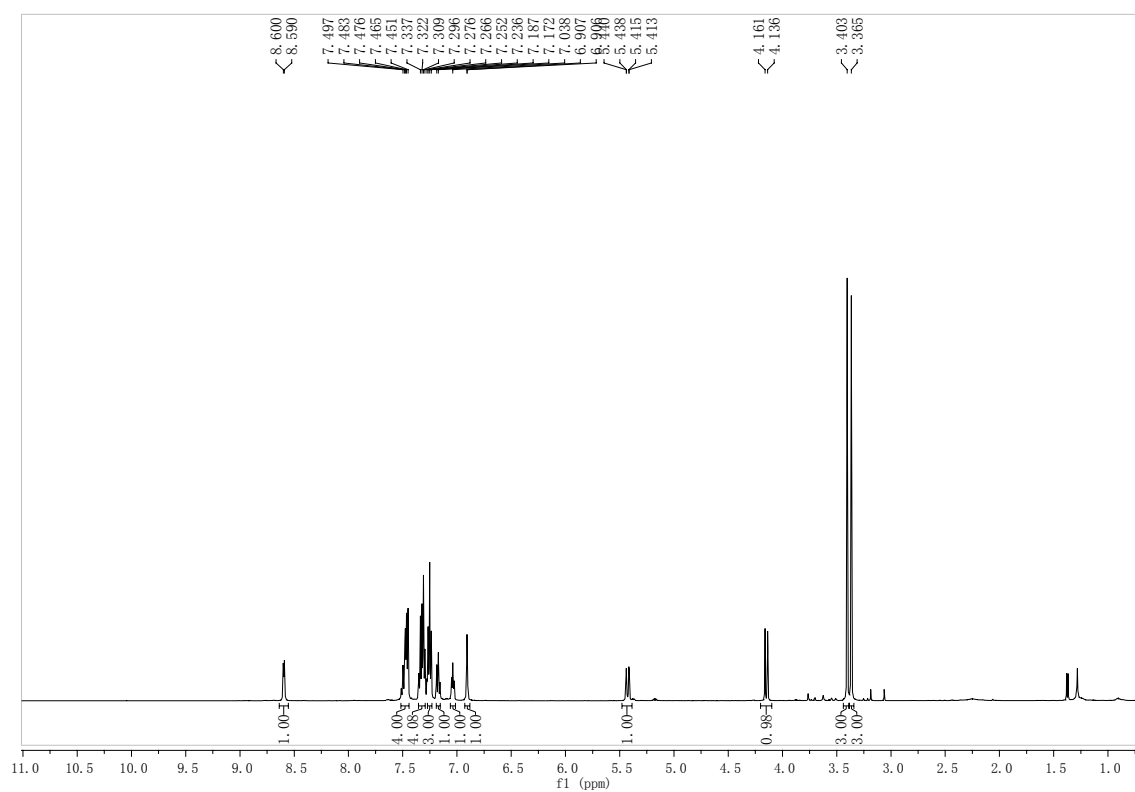
trimethyl 2-(3-phenylindolizin-1-yl)ethane-1,1,2-tricarboxylate (**51a**):

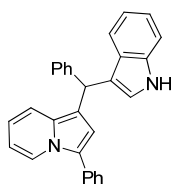


phenyl(3-phenylindolizin-1-yl)methanone (**6**):

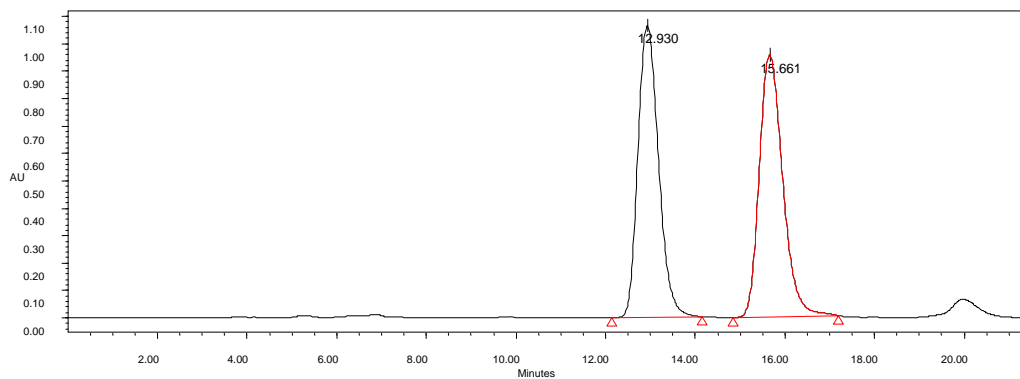


Dimethyl 2-(1,4-diphenyl-2-(pyridin-2-yl)buta-2,3-dien-1-yl)malonate (7)

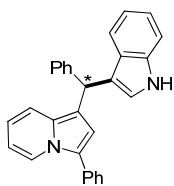




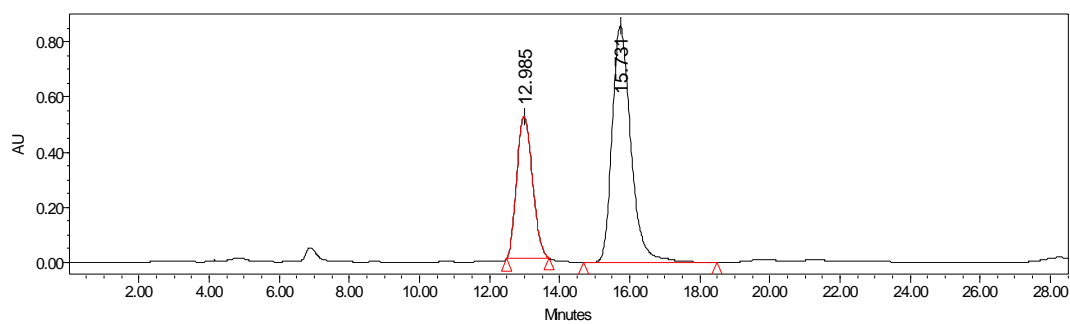
(Race)



	Retention Time	Area	% Area	Height	% Height
1	12.930	34128174	49.70	1063215	52.65
2	15.661	34538228	50.30	956283	47.35



(Opt)



	Retention Time	Area	% Area	Height	% Height
1	12.985	15968971	33.54	515484	37.62
2	15.731	31641950	66.46	854713	62.38

References:

1. D. K. Friel, M. L. Snapper, A. H. Hoveyda, *J. Am. Chem. Soc.* **2008**, *130*, 9942..