

# Palladium-Catalyzed Bicyclization of Alkynyl Aryl Iodide with Allenyl Malonates

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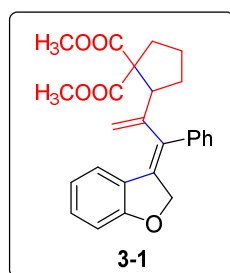
## 1. General remarks

The desired product was purified by flash column chromatography, silica gel (200~300 mesh). <sup>1</sup>H NMR spectra and <sup>13</sup>C NMR spectra were recorded on 400 MHz in CDCl<sub>3</sub> and TMS as internal standard. All products were further characterized by HRMS (high resolution mass spectra). Copies of their <sup>1</sup>H NMR and <sup>13</sup>C NMR spectra are provided. All solvents were dried and distilled according to standard procedures. Commercially available reagents and solvents were used without further purification. Compound **1** was synthesized according to the literature procedure.<sup>1</sup> HRMS analysis of compounds was performed with a time-of-flight mass spectrometer (micrOTOF-Q, Bruker Daltonik, Germany).

## 2. General procedure for the preparation of the products **3**

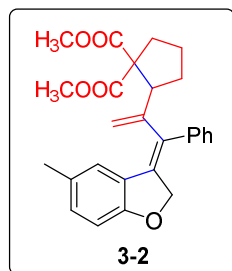
An oven-dried Schlenk tube under a nitrogen atmosphere was charged with aryl iodide-tethered alkene **1** (0.3 mmol, 1.0 equiv) and allenyl malonates **2** (0.6 mmol, 2.0 equiv), Pd(OAc)<sub>2</sub> (10 mol %), P(*p*-OMe-C<sub>6</sub>H<sub>4</sub>)<sub>3</sub> (20 mol%), Cs<sub>2</sub>CO<sub>3</sub> or K<sub>2</sub>CO<sub>3</sub> (0.60 mmol, 2.0 equiv), <sup>n</sup>Bu<sub>4</sub>NBr (If necessary, 0.15 mmol, 0.5 equiv), CH<sub>3</sub>CN (2.0 mL). The mixture was stirred at 35 °C for 30 mins and then stirred at 90 °C for 7 h. The resulting mixture was cooled to room temperature and filtered through Celite eluting with EtOAc. The volatiles were evaporated under reduced pressure and the residue was purified by silica gel flash chromatography to afford the desired products **3**.

## 3. Spectral data of compound **3**

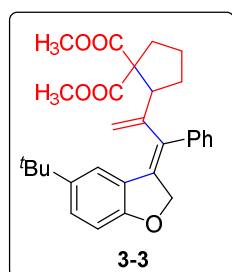


**Dimethyl(Z)-2-(3-(benzofuran-3(2H)-ylidene)-3-phenylprop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow solid; <sup>1</sup>H NMR (400MHz, CDCl<sub>3</sub>) δ: 7.87-7.85(m, 1H), 7.31-7.27(m, 2H), 7.21(d, *J*=7.2Hz, 1H), 7.17-7.16(m, 2H), 7.08-7.04(m, 1H), 6.75-6.72(m, 2H), 5.47(s, 1H), 5.23(s, 1H), 4.91(s, 2H), 3.54(s, 3H), 3.53(s, 3H), 3.08-3.04(m, 1H), 2.45-2.42(m, 1H), 2.10-2.04(m, 1H), 1.86-1.77(m, 3H), 1.53-1.47(m, 1H); <sup>13</sup>C NMR (100MHz, CDCl<sub>3</sub>) δ: 172.5, 171.6, 164.4, 146.1, 140.5, 134.7, 132.8, 129.8, 128.5, 128.0, 127.4, 124.9, 124.7, 119.9, 110.3, 75.2, 63.6, 52.4,

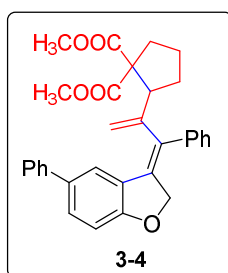
52.1, 49.8, 35.1, 31.6, 21.9; HRMS(ESI)  $m/z$  calcd for  $C_{26}H_{26}O_5Na$   $[M+Na]^+=441.1672$ , found: 441.1669.



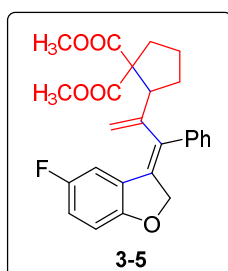
**Dimethyl(Z)-2-(3-(5-methylbenzofuran-3(2H)-ylidene)-3-phenylprop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow oil;  $^1H$  NMR (400MHz,  $CDCl_3$ )  $\delta$ : 7.70(s, 1H), 7.31-7.27(m, 2H), 7.22-7.15(m, 3H), 6.88(dd,  $J=8.4$ , 1.2Hz, 1H), 6.63(d,  $J=8.4$ Hz, 1H), 5.46(s, 1H), 5.23(s, 1H), 4.89(dd,  $J=22.4$ , 14.8Hz, 2H), 3.54(s, 3H), 3.53(s, 3H), 3.08-3.03(m, 1H), 2.47-2.43(m, 1H), 2.22(s, 3H), 2.11-2.05(m, 1H), 1.87-1.77(m, 3H), 1.55-1.49(m, 1H);  $^{13}C$  NMR (100MHz,  $CDCl_3$ )  $\delta$ : 172.5, 171.7, 162.5, 146.1, 140.6, 134.3, 133.1, 130.5, 129.0, 128.5, 128.0, 127.4, 125.2, 124.7, 109.8, 75.4, 63.5, 52.4, 52.1, 50.0, 35.2, 31.6, 21.9, 20.9; HRMS(ESI)  $m/z$  calcd for  $C_{27}H_{28}O_5Na$   $[M+Na]^+=455.1829$ , found: 455.1826.



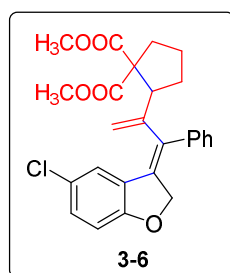
**Dimethyl(Z)-2-(3-(5-(tert-butyl)benzofuran-3(2H)-ylidene)-3-phenylprop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; white solid;  $^1H$  NMR (400MHz,  $CDCl_3$ )  $\delta$ : 7.95(d,  $J=2.0$ Hz, 1H), 7.31-7.27(m, 2H), 7.22-7.18(m, 1H), 7.14-7.10(m, 3H), 6.66(d,  $J=8.4$ Hz, 1H), 5.50(s, 1H), 5.25(s, 1H), 4.85(d,  $J=27.2$ Hz, 2H), 3.52(s, 3H), 3.44(s, 3H), 3.15-3.12(m, 1H), 2.50(d,  $J=7.6$ Hz, 1H), 2.11-2.05(m, 1H), 1.91-1.85(m, 3H), 1.58-1.51(m, 1H), 1.23(s, 9H);  $^{13}C$  NMR (100MHz,  $CDCl_3$ )  $\delta$ : 172.4, 171.2, 162.5, 146.6, 142.9, 140.8, 134.0, 133.5, 128.5, 128.1, 127.3, 126.9, 124.0, 122.1, 109.4, 75.5, 63.7, 52.4, 52.1, 49.7, 34.6, 34.5, 31.7, 31.4, 22.0; HRMS(ESI)  $m/z$  calcd for  $C_{30}H_{34}O_5Na$   $[M+Na]^+=497.2298$ , found: 497.2295.



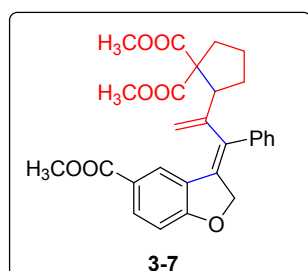
**Dimethyl(Z)-2-(3-phenyl-3-(5-phenylbenzofuran-3(2H)-ylidene)prop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow solid;  $^1\text{H}$  NMR (400MHz,  $\text{CDCl}_3$ )  $\delta$ : 8.22(d,  $J=2.0\text{Hz}$ , 1H), 7.58(d,  $J=7.6\text{Hz}$ , 2H), 7.44-7.36(m, 5H), 7.31-7.24(m, 4H), 6.87(d,  $J=8.4\text{Hz}$ , 1H), 5.62(s, 1H), 5.34(s, 1H), 5.02(s, 2H), 3.60(s, 3H), 3.44(s, 3H), 3.13(t,  $J=7.6\text{Hz}$ , 1H), 2.53-2.48(m, 1H), 2.18-2.10(m, 1H), 1.98-1.85(m, 3H), 1.64-1.53(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.4, 171.5, 164.2, 146.1, 141.3, 140.5, 135.2, 133.5, 132.6, 129.1, 128.6, 128.5, 128.0, 127.5, 127.0, 126.5, 125.2, 123.6, 110.4, 75.8, 63.5, 52.4, 52.0, 50.0, 35.1, 31.6, 21.9; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{32}\text{H}_{30}\text{O}_5\text{Na}$   $[\text{M}+\text{Na}]^+=517.1985$ , found: 517.1979.



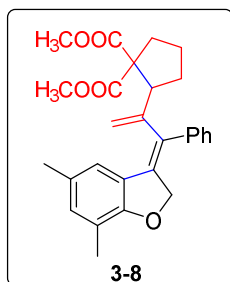
**Dimethyl(Z)-2-(3-(5-fluorobenzofuran-3(2H)-ylidene)-3-phenylprop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400MHz,  $\text{CDCl}_3$ )  $\delta$ : 7.69(dd,  $J=9.6, 2.8\text{Hz}$ , 1H), 7.39-7.36(m, 2H), 7.31-7.28(m, 1H), 7.26-7.24(m, 2H), 6.83(td,  $J=8.8, 2.8\text{Hz}$ , 1H), 6.72-6.69(m, 1H), 5.56(s, 1H), 5.33(s, 1H), 5.04(dd,  $J=31.6, 14.8\text{Hz}$ , 2H), 3.71(s, 3H), 3.63(s, 3H), 3.02-2.98(m, 1H), 2.52-2.45(m, 1H), 2.15-2.07(m, 1H), 1.92-1.80(m, 3H), 1.58-1.51(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.4, 171.9, 160.4, 157.9, 155.5, 145.6, 140.0, 136.2, 128.6, 127.9, 127.7, 125.9(d,  $J=10.0\text{Hz}$ ), 117.1, 116.2(d,  $J=25.0\text{Hz}$ ), 111.3(d,  $J=27.0\text{Hz}$ ), 110.3(d,  $J=9.0\text{Hz}$ ), 76.0, 63.5, 52.4, 52.2, 50.0, 35.5, 32.0, 21.8; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{26}\text{H}_{25}\text{FO}_5\text{Na}$   $[\text{M}+\text{Na}]^+=459.1578$ , found: 459.1576.



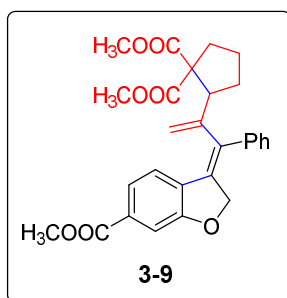
**Dimethyl(Z)-2-(3-(5-chlorobenzofuran-3(2H)-ylidene)-3-phenylprop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400MHz,  $\text{CDCl}_3$ )  $\delta$ : 7.86(d,  $J=2.0\text{Hz}$ , 1H), 7.31-7.28(m, 2H), 7.22(d,  $J=2.0\text{Hz}$ , 1H), 7.18-7.15(m, 2H), 7.01-6.98(m, 1H), 6.64(d,  $J=8.4\text{Hz}$ , 1H), 5.49(s, 1H), 5.26(s, 1H), 4.98-4.88(m, 2H), 3.65(s, 3H), 3.55(s, 3H), 2.94-2.90(m, 1H), 2.43-2.37(m, 1H), 2.06-1.99(m, 1H), 1.85-1.71(m, 3H), 1.51-1.45(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.4, 171.9, 163.0, 145.6, 140.0, 136.4, 131.5, 129.4, 128.6, 127.9, 127.7, 126.6, 124.8, 124.6, 117.2, 111.2, 75.9, 63.4, 52.4, 52.3, 50.0, 35.4, 31.9, 21.8; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{26}\text{H}_{25}\text{ClO}_5\text{Na}$   $[\text{M}+\text{Na}]^+=475.1283$ , found: 475.1278.



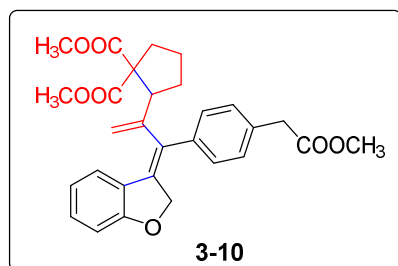
**Dimethyl(Z)-2-(3-(5-(methoxycarbonyl)benzofuran-3(2H)-ylidene)-3-phenylprop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400MHz,  $\text{CDCl}_3$ )  $\delta$ : 8.51(d,  $J=1.6\text{Hz}$ , 1H), 7.82-7.79(m, 1H), 7.31-7.28(m, 2H), 7.23-7.19(m, 1H), 7.17-7.15(m, 2H), 6.73(d,  $J=8.8\text{Hz}$ , 1H), 5.45(s, 1H), 5.26(s, 1H), 5.03-4.89(m, 2H), 3.81(s, 3H), 3.53(s, 3H), 3.49(s, 3H), 3.12(t,  $J=6.4\text{Hz}$ , 1H), 2.57-2.52(m, 1H), 2.10-2.04(m, 1H), 1.94(d,  $J=19.2\text{Hz}$ , 3H), 1.60(d,  $J=16.4\text{Hz}$ , 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.4, 171.2, 168.0, 166.8, 146.1, 140.1, 136.3, 132.2, 131.3, 128.5, 127.9, 127.6, 126.6, 125.1, 122.3, 110.1, 76.3, 63.8, 52.4, 52.1, 51.8, 49.6, 34.6, 31.5, 21.9; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{28}\text{H}_{28}\text{O}_7\text{Na}$   $[\text{M}+\text{Na}]^+=499.1727$ , found: 499.1720.



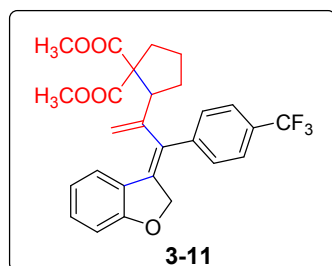
**Dimethyl(Z)-2-(3-(5,7-dimethylbenzofuran-3(2H)-ylidene)-3-phenylprop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; white solid;  $^1\text{H}$  NMR (400MHz,  $\text{CDCl}_3$ )  $\delta$ : 7.52(s, 1H), 7.29-7.25(m, 2H), 7.20-7.14m, 3H), 6.71(s, 1H), 5.43(s, 1H), 5.21(s, 1H), 4.88(dd,  $J=26.0, 14.8\text{Hz}$ , 2H), 3.53(s, 3H), 3.52(s, 3H), 3.08-3.04(m, 1H), 2.46-2.41(m, 1H), 2.18(s, 3H), 2.07(s, 3H), 2.05-2.02(m, 1H), 1.85-1.78(m, 3H), 1.53-1.48(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.5, 171.6, 161.0, 146.1, 140.7, 133.9, 133.7, 131.7, 128.8, 128.4, 128.0, 127.2, 123.9, 122.6, 119.7, 75.2, 63.6, 52.4, 52.0, 49.9, 35.1, 31.5, 21.9, 20.9, 14.8; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{28}\text{H}_{30}\text{O}_5\text{Na}$   $[\text{M}+\text{Na}]^+=469.1985$ , found: 469.1973.



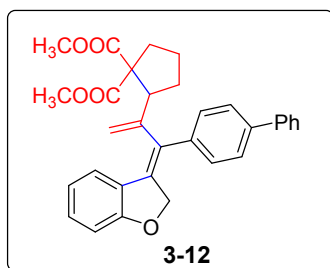
**Dimethyl(Z)-2-(3-(6-(methoxycarbonyl)benzofuran-3(2H)-ylidene)-3-phenylprop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow solid;  $^1\text{H}$  NMR (400MHz,  $\text{CDCl}_3$ )  $\delta$ : 8.01(d,  $J=8.4\text{Hz}$ , 1H), 7.52(d,  $J=8.4\text{Hz}$ , 1H), 7.43-7.37(m, 3H), 7.32-7.24(m, 3H), 5.56(s, 1H), 5.35(s, 1H), 5.09-5.00(m, 2H), 3.89(s, 3H), 3.66(s, 3H), 3.62(s, 3H), 3.09-3.05(m, 1H), 2.53-2.46(m, 1H), 2.15-2.09(m, 1H), 1.91-1.84(m, 3H), 1.59-1.50(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.4, 171.7, 166.6, 164.3, 145.7, 140.0, 137.9, 131.8, 131.1, 129.7, 128.6, 127.8, 124.5, 121.6, 111.1, 75.7, 63.5, 52.4, 52.2, 52.1, 49.9, 35.3, 31.7, 21.8; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{28}\text{H}_{28}\text{O}_7\text{Na}$   $[\text{M}+\text{Na}]^+=499.1727$ , found: 499.1724.



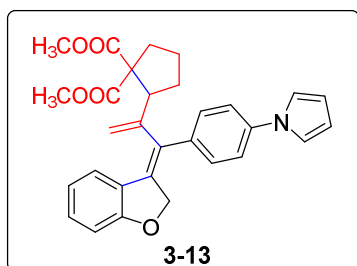
**Dimethyl(Z)-2-(3-(benzofuran-3(2H)-ylidene)-3-(4-(2-methoxy-2-oxoethyl)phenyl)prop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; white solid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.84(d,  $J=7.2\text{Hz}$ , 1H), 7.22-7.19(m, 2H), 7.13(d,  $J=8\text{Hz}$ , 2H), 7.07-7.04(m, 1H), 6.74-6.71(m, 2H), 5.45(s, 1H), 5.24(s, 1H), 4.91(s, 2H), 3.64(s, 3H), 3.57(s, 2H), 3.54(s, 3H), 3.53(s, 3H), 3.06-3.02(m, 1H), 2.46-2.39(m, 1H), 2.10-2.03(m, 1H), 1.87-1.77(m, 3H), 1.53-1.46(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.4, 171.9, 171.6, 164.4, 145.9, 139.2, 134.2, 133.0, 132.9, 129.8, 129.4, 128.2, 124.9, 124.8, 119.8, 110.3, 75.2, 63.5, 52.4, 52.1, 52.0, 49.9, 40.8, 35.2, 31.5, 21.9; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{29}\text{H}_{30}\text{O}_7\text{Na}$   $[\text{M}+\text{Na}]^+=513.1884$ , found: 513.1895.



**Dimethyl(Z)-2-(3-(benzofuran-3(2H)-ylidene)-3-(4-(trifluoromethyl)phenyl)prop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.93(d,  $J=7.2\text{Hz}$ , 1H), 7.63(d,  $J=8.4\text{Hz}$ , 2H), 7.39(d,  $J=8.4\text{Hz}$ , 2H), 7.19-7.15(m, 1H), 6.85-6.81(m, 2H), 5.58(s, 1H), 5.37(s, 1H), 4.96(s, 2H), 3.62(s, 3H), 3.60(s, 3H), 3.12-3.08(m, 1H), 2.57-2.49(m, 1H), 2.18-2.11(m, 1H), 1.94-1.86(m, 3H), 1.62-1.55(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.4, 171.5, 164.6, 145.6, 144.3, 134.2, 133.0, 130.4, 129.5, 129.2, 128.5, 125.6-124.3(m), 125.0, 124.3, 120.0, 117.5, 110.5, 75.0, 63.6, 52.5, 52.1, 49.9, 35.2, 31.7, 22.0; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{27}\text{H}_{25}\text{F}_3\text{O}_5\text{Na}$   $[\text{M}+\text{Na}]^+=509.1546$ , found: 509.1555.

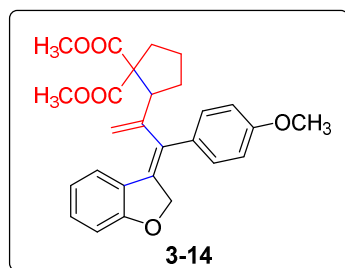


**Dimethyl(Z)-2-(3-([1,1'-biphenyl]-4-yl)-3-(benzofuran-3(2H)-ylidene)prop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; white solid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.88(d,  $J=8\text{Hz}$ , 1H), 7.56-7.51(m, 4H), 7.37(t,  $J=7.6\text{Hz}$ , 2H), 7.28-7.23(m, 3H), 7.08-7.04(m, 1H), 6.76-6.72(m, 2H), 5.49(s, 1H), 5.27(s, 1H), 4.98(s, 2H), 3.56(s, 3H), 3.55(s, 3H), 3.11-3.07(m, 1H), 2.46-2.40(m, 1H), 2.11-2.03(m, 1H), 1.89-1.78(m, 3H), 1.54-1.49 (m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.5, 171.7, 164.5, 145.9, 140.5, 140.0, 139.4, 134.3, 133.0, 129.9, 128.8, 128.4, 127.4, 127.1, 126.9, 125.0, 124.8, 119.9, 110.4, 75.3, 63.6, 52.4, 52.1, 50.0, 35.2, 31.6, 21.9; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{32}\text{H}_{30}\text{O}_5\text{Na}$   $[\text{M}+\text{Na}]^+=517.1985$ , found:517.1977.

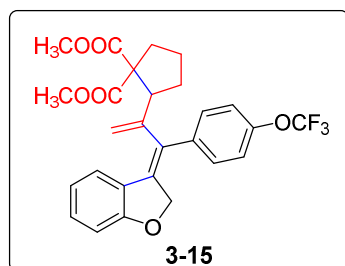


**Dimethyl(Z)-2-(3-(4-(1H-pyrrol-1-yl)phenyl)-3-(benzofuran-3(2H)-ylidene)prop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.94(dd,  $J=8.0, 0.8\text{Hz}$ , 1H), 7.39(d,  $J=8.8\text{Hz}$ , 2H), 7.30(d,  $J=8.8\text{Hz}$ , 2H), 7.17-7.12(m, 3H), 6.84-6.80(m, 2H), 6.36-6.35(m, 2H), 5.56(s, 1H), 5.34(s, 1H), 5.03(s, 2H), 3.63(s, 3H), 3.63(s, 3H), 3.17-3.14(m, 1H), 2.55-2.49(m, 1H), 2.19-2.12(m, 1H), 1.95-1.88(m, 3H), 1.62-1.55(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.5, 171.6, 164.4, 145.8, 139.6, 137.6, 133.6, 133.2, 129.9, 129.3, 124.9, 124.6, 120.2, 119.9, 119.0, 110.6, 110.4, 75.2, 63.5, 52.5, 52.1, 49.9, 35.2, 31.6, 21.9; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{30}\text{H}_{29}\text{NO}_5\text{Na}$   $[\text{M}+\text{Na}]^+=506.1938$ , found:506.1944.

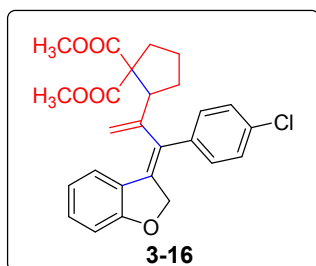




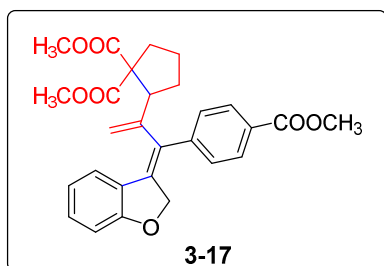
**Dimethyl(Z)-2-(3-(benzofuran-3(2H)-ylidene)-3-(4-methoxyphenyl)prop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow solid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$ : 7.85(d,  $J=7.6\text{Hz}$ , 1H), 7.10-7.07(m, 2H), 7.04(d,  $J=7.6\text{Hz}$ , 1H), 6.82(d,  $J=8.8\text{Hz}$ , 2H), 6.74-6.71(m, 2H), 5.44(s, 1H), 5.21(s, 1H), 4.93(s, 2H), 3.76(s, 3H), 3.57(s, 3H), 3.55(s, 3H), 3.07-3.03(m, 1H), 2.45-2.40(m, 1H), 2.11-2.04(m, 1H), 1.86-1.78(m, 3H), 1.54-1.48(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.5, 171.7, 164.3, 158.8, 146.1, 134.5, 132.7, 132.3, 129.6, 129.2, 125.0, 124.8, 119.8, 113.8, 110.3, 75.4, 63.6, 55.2, 52.4, 52.1, 49.9, 35.2, 31.5, 21.9; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{27}\text{H}_{28}\text{O}_6\text{Na}$   $[\text{M}+\text{Na}]^+=471.1778$ , found:471.1777.



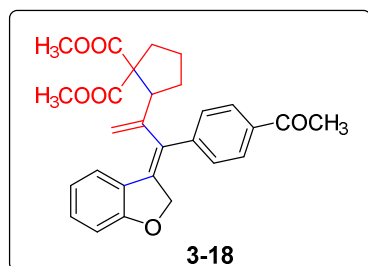
**Dimethyl(Z)-2-(3-(benzofuran-3(2H)-ylidene)-3-(4-(trifluoromethoxy)phenyl)prop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; white solid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$ : 7.91(d,  $J=8.0\text{Hz}$ , 1H), 7.29(d,  $J=8.8\text{Hz}$ , 2H), 7.22(d,  $J=8.4\text{Hz}$ , 2H), 7.16(t,  $J=7.6\text{Hz}$ , 1H), 6.84-6.80(m, 2H), 5.55(s, 1H), 5.33(s, 1H), 4.96(s, 2H), 3.62(s, 3H), 3.59(s, 3H), 3.15-3.11(m, 1H), 2.57-2.49(m, 1H), 2.17-2.13(m, 1H), 1.94-1.86(m, 3H), 1.61-1.55(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.4, 171.5, 164.5, 148.2, 145.9, 139.1, 133.7, 133.0, 130.2, 129.6, 124.9, 124.4, 120.9, 120.0, 110.5, 75.1, 63.6, 52.4, 52.1, 49.8, 35.2, 31.7, 22.0; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{27}\text{H}_{25}\text{F}_3\text{O}_6\text{Na}$   $[\text{M}+\text{Na}]^+=525.1495$ , found:525.1491.



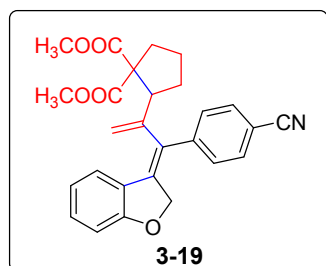
**Dimethyl(Z)-2-(3-(benzofuran-3(2H)-ylidene)-3-(4-chlorophenyl)prop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.85-7.83(m, 1H), 7.26(d,  $J=8.4\text{Hz}$ , 2H), 7.12-7.09(m, 2H), 7.07-7.05(m, 1H), 6.75-6.72(m, 2H), 5.46(s, 1H), 5.24(s, 1H), 4.88(s, 2H), 3.55(s, 3H), 3.54(s, 3H), 3.05-3.01(m, 1H), 2.48-2.41(m, 1H), 2.10-2.03(m, 1H), 1.85-1.79(m, 3H), 1.52-1.49(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.4, 171.5, 164.5, 145.8, 138.9, 133.5, 133.3, 133.1, 130.1, 129.5, 128.8, 124.9, 124.5, 119.9, 110.4, 75.1, 63.6, 52.5, 52.1, 49.8, 35.1, 31.6, 21.9; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{26}\text{H}_{25}\text{ClO}_5\text{Na}$   $[\text{M}+\text{Na}]^+=475.1283$ , found:475.1294.



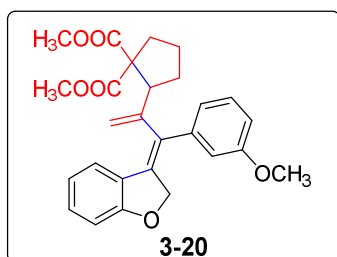
**Dimethyl(Z)-2-(3-(benzofuran-3(2H)-ylidene)-3-(4-(methoxycarbonyl)phenyl)prop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow solid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 8.05(d,  $J=8.4\text{Hz}$ , 2H), 7.93(d,  $J=7.6\text{Hz}$ , 1H), 7.34(d,  $J=8.4\text{Hz}$ , 2H), 7.18-7.14(m, 1H), 6.85-6.81(m, 2H), 5.57(s, 1H), 5.36(s, 1H), 4.98(s, 2H), 3.93(s, 3H), 3.62(s, 3H), 3.61(s, 3H), 3.12-3.09(m, 1H), 2.56-2.49(m, 1H), 2.17-2.10(m, 1H), 1.93-1.84(m, 3H), 1.61-1.54(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.4, 171.5, 166.7, 164.6, 145.6, 145.4, 133.9, 133.4, 130.3, 129.8, 129.0, 128.1, 125.0, 124.4, 120.0, 110.4, 75.0, 63.6, 52.4, 52.1, 49.9, 35.1, 31.6, 21.9; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{28}\text{H}_{28}\text{O}_7\text{Na}$   $[\text{M}+\text{Na}]^+=499.1727$ , found:499.1726.



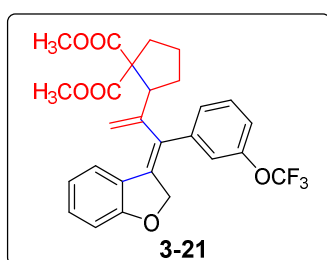
**Dimethyl(Z)-2-(3-(4-acetylphenyl)-3-(benzofuran-3(2H)-ylidene)prop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow solid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.99-7.93(m, 3H), 7.37(d,  $J=8.0\text{Hz}$ , 2H), 7.19-7.15(m, 1H), 6.85-6.81(m, 2H), 5.58(s, 1H), 5.37(s, 1H), 4.99(s, 2H), 3.63(s, 3H), 3.62(s, 3H), 3.11-3.07(m, 1H), 2.63(s, 3H), 2.56-2.48(m, 1H), 2.17-2.11(m, 1H), 1.93-1.84(m, 3H), 1.61-1.54(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 197.6, 172.4, 171.5, 164.6, 145.6, 145.5, 136.0, 134.1, 133.4, 130.3, 128.6, 128.3, 125.1, 124.4, 120.0, 110.5, 75.0, 63.5, 52.5, 52.1, 50.0, 35.1, 31.6, 26.6, 21.9; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{28}\text{H}_{28}\text{O}_6\text{Na}$   $[\text{M}+\text{Na}]^+=483.1778$ , found:483.1780.



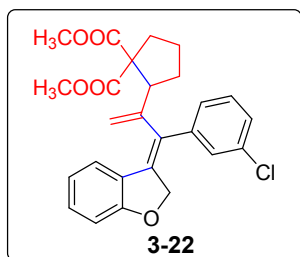
**Dimethyl(Z)-2-(3-(benzofuran-3(2H)-ylidene)-3-(4-cyanophenyl)prop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow solid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.92(dd,  $J=8.0, 0.8\text{Hz}$ , 1H), 7.68(d,  $J=8.4\text{Hz}$ , 2H), 7.39(d,  $J=8.4\text{Hz}$ , 2H), 7.21-7.17(m, 1H), 6.86-8.82(m, 2H), 5.57(s, 1H), 5.39(s, 1H), 4.96(s, 2H), 3.63(s, 3H), 3.61(s, 3H), 3.09-3.06(m, 1H), 2.56-2.49(m, 1H), 2.17-2.10(m, 1H), 1.92-1.84(m, 3H), 1.63-1.55(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.3, 171.4, 164.6, 145.5, 145.3, 134.8, 132.4, 132.3, 130.6, 128.9, 125.1, 124.1, 120.1, 118.7, 118.0, 111.0, 110.6, 74.8, 63.5, 52.5, 52.1, 50.0, 35.2, 31.6, 21.9; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{27}\text{H}_{25}\text{NO}_5\text{Na}$   $[\text{M}+\text{Na}]^+=466.1625$ , found:466.1620.



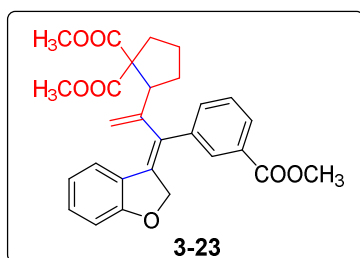
**Dimethyl(Z)-2-(3-(benzofuran-3(2H)-ylidene)-3-(3-methoxyphenyl)prop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.93(d,  $J=8.0\text{Hz}$ , 1H), 7.31-7.26(m, 1H), 7.14(t,  $J=7.6\text{Hz}$ , 1H), 6.84-6.79(m, 5H), 5.54(s, 1H), 5.31(s, 1H), 5.01(s, 2H), 3.82(s, 3H), 3.63(s, 6H), 3.16-3.12(m, 1H), 2.55-2.48(m, 1H), 2.19-2.11(m, 1H), 1.95-1.85(m, 3H), 1.61-1.55(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.5, 171.7, 164.5, 159.6, 146.0, 141.9, 134.5, 132.8, 129.8, 129.5, 125.0, 124.7, 120.5, 119.9, 113.8, 112.7, 110.3, 75.3, 63.6, 55.2, 52.4, 52.1, 49.8, 35.1, 31.7, 21.9; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{27}\text{H}_{28}\text{O}_6\text{Na}$   $[\text{M}+\text{Na}]^+=471.1778$ , found:471.1775.



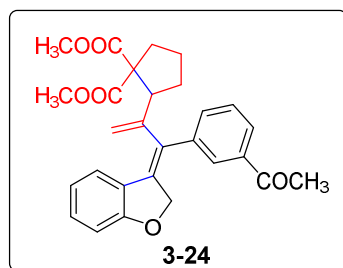
**Dimethyl(Z)-2-(3-(benzofuran-3(2H)-ylidene)-3-(3-(trifluoromethoxy)phenyl)prop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.91(d,  $J=7.2\text{Hz}$ , 1H), 7.43-7.39(m, 1H), 7.21(d,  $J=8.0\text{Hz}$ , 1H), 7.19-7.14(m, 2H), 7.11(s, 1H), 6.84-6.81(m, 2H), 5.56(s, 1H), 5.35(s, 1H), 4.98(s, 2H), 3.63(s, 3H), 3.60(s, 3H), 3.15-3.11(m, 1H), 2.57-2.49(m, 1H), 2.18-2.11(m, 1H), 1.93-1.85(m, 3H), 1.60-1.55(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.5, 171.6, 164.7, 149.4, 145.8, 142.7, 134.1, 132.9, 130.4, 130.0, 126.6, 125.1, 124.4, 120.7, 120.1, 119.9, 110.6, 75.1, 63.7, 52.5, 52.1, 49.9, 35.3, 31.8, 22.1; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{27}\text{H}_{25}\text{F}_3\text{O}_6\text{Na}$   $[\text{M}+\text{Na}]^+=525.1495$ , found:525.1487.



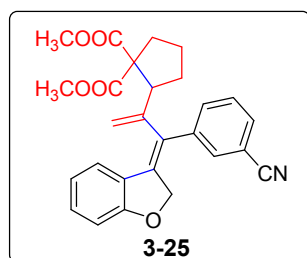
**Dimethyl(Z)-2-(3-(benzofuran-3(2H)-ylidene)-3-(3-chlorophenyl)prop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.91-7.89(m, 1H), 7.31-7.25(m, 2H), 7.22(s, 1H), 7.17-7.14(m, 2H), 6.84-6.80(m, 2H), 5.53(s, 1H), 5.32(s, 1H), 4.98(dd,  $J=26.8, 15.2\text{Hz}$ , 2H), 3.63(s, 3H), 3.62(s, 3H), 3.14(t,  $J=7.6\text{Hz}$ , 1H), 2.59-2.51(m, 1H), 2.18-2.13(m, 1H), 1.95-1.89(m, 3H), 1.68-1.56(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.4, 171.5, 164.6, 145.8, 142.3, 134.3, 133.9, 133.0, 130.2, 129.8, 128.0, 127.6, 126.4, 124.9, 124.4, 120.0, 110.5, 75.0, 63.7, 52.5, 52.2, 49.8, 35.1, 31.7, 22.1; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{26}\text{H}_{25}\text{ClO}_5\text{Na}$   $[\text{M}+\text{Na}]^+=475.1283$ , found:475.1285.



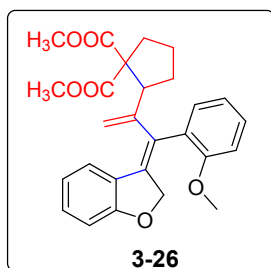
**Dimethyl(Z)-2-(3-(benzofuran-3(2H)-ylidene)-3-(3-(methoxycarbonyl)phenyl)prop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.99-7.96(m, 1H), 7.94-7.92(m, 2H), 7.48-7.46(m, 2H), 7.18-7.14(m, 1H), 6.84-6.81(m, 2H), 5.58(s, 1H), 5.34(s, 1H), 5.02-4.92(m, 2H), 3.93(s, 3H), 3.62(s, 3H), 3.60(s, 3H), 3.14-3.10(m, 1H), 2.58-2.50(m, 1H), 2.17-2.10(m, 1H), 1.94-1.85(m, 3H), 1.61-1.54(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.4, 171.5, 166.8, 164.6, 145.8, 140.9, 133.8, 133.4, 132.7, 130.5, 130.1, 129.1, 128.7, 128.6, 124.9, 124.4, 120.0, 110.4, 75.0, 63.7, 52.5, 52.2, 52.1, 49.7, 35.0, 31.7, 22.0; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{28}\text{H}_{28}\text{O}_7\text{Na}$   $[\text{M}+\text{Na}]^+=499.1727$ , found:499.1729.



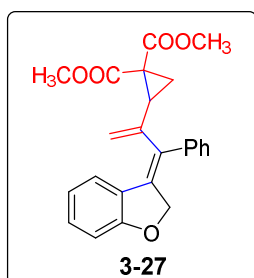
**Dimethyl(Z)-2-(3-(3-acetylphenyl)-3-(benzofuran-3(2H)-ylidene)prop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.93(d,  $J=7.6\text{Hz}$ , 1H), 7.90-7.88(m, 2H), 7.49(d,  $J=4.8\text{Hz}$ , 2H), 7.18-7.14(m, 1H), 6.85-6.81(m, 2H), 5.59(s, 1H), 5.36(s, 1H), 5.02-4.93(m, 2H), 3.62(s, 3H), 3.60(s, 3H), 3.15-3.11(m, 1H), 2.63(s, 3H), 2.56-2.49(m, 1H), 2.17-2.10(m, 1H), 1.94-1.84(m, 3H), 1.60-1.54(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 197.9, 172.4, 171.5, 164.5, 145.8, 141.0, 137.4, 133.8, 133.4, 132.8, 130.2, 128.8, 127.9, 127.4, 124.9, 124.4, 120.0, 117.3, 110.4, 75.0, 63.6, 52.5, 52.1, 49.7, 35.1, 31.7, 26.7, 22.0; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{28}\text{H}_{28}\text{O}_6\text{Na}$   $[\text{M}+\text{Na}]^+=483.1778$ , found:483.1780.



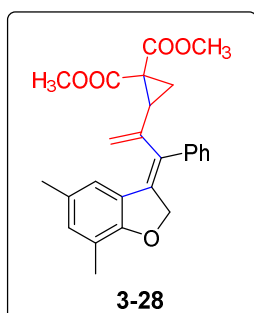
**Dimethyl(Z)-2-(3-(benzofuran-3(2H)-ylidene)-3-(3-cyanophenyl)prop-1-en-2-yl)cyclopentane-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.90(d,  $J=7.6\text{Hz}$ , 1H), 7.60-7.58(m, 1H), 7.55-7.50(m, 3H), 7.20-7.17(m, 1H), 6.86-6.82(m, 2H), 5.57(s, 1H), 5.37(s, 1H), 5.00-4.90(m, 2H), 3.63(s, 3H), 3.61(s, 3H), 3.10(t,  $J=7.6\text{Hz}$ , 1H), 2.59-2.52(m, 1H), 2.17-2.10(m, 1H), 1.93-1.87(m, 3H), 1.63-1.59(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.3, 171.4, 164.6, 145.5, 141.8, 134.8, 132.7, 131.8, 131.7, 131.0, 130.6, 129.5, 124.9, 124.0, 120.1, 118.6, 117.8, 112.7, 110.6, 74.8, 63.7, 52.6, 52.2, 49.8, 35.1, 31.8, 22.1; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{27}\text{H}_{25}\text{NO}_5\text{Na}$   $[\text{M}+\text{Na}]^+=466.1625$ , found:466.1624.



**Dimethyl(Z)-2-(3-(benzofuran-3(2H)-ylidene)-3-(2-methoxyphenyl)prop-1-en-2-yl)cyclopentane-1,1-dicarboxylate;** HRMS(ESI)  $m/z$  calcd for  $C_{27}H_{28}O_6Na$   $[M+Na]^+=471.1778$ , found:471.1775.

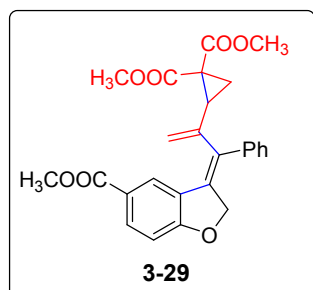


**Dimethyl(Z)-2-(3-(benzofuran-3(2H)-ylidene)-3-phenylprop-1-en-2-yl)cyclopropane-1,1-dicarboxylate;** yellow oil;  $^1H$  NMR (400 MHz,  $CDCl_3$ ) $\delta$ : 7.81(d,  $J=8.0$ Hz, 1H), 7.39-7.35(m, 2H), 7.29(d,  $J=7.2$ Hz, 1H), 7.26-7.23(m, 2H), 7.18-7.14(m, 1H), 6.85-6.81(m, 2H), 5.54(s, 1H), 5.34(s, 1H), 4.93(s, 2H), 3.66(s, 3H), 3.38(s, 3H), 2.61(t,  $J=8.8$ Hz, 1H), 1.92-1.88(m, 1H), 1.46-1.43(m, 1H);  $^{13}C$  NMR (100MHz,  $CDCl_3$ )  $\delta$ : 169.9, 167.3, 164.6, 140.8, 140.4, 133.8, 132.3, 130.2, 128.8, 127.8, 127.5, 124.9, 124.2, 120.1, 118.0, 110.5, 75.1, 52.7, 52.6, 36.5, 32.7, 19.4; HRMS(ESI)  $m/z$  calcd for  $C_{24}H_{22}O_5Na$   $[M+Na]^+=413.1359$ , found:413.1365.

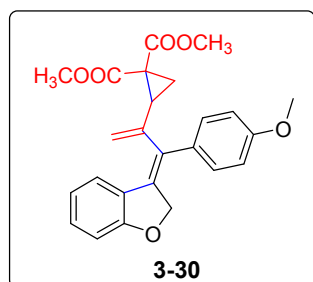


**Dimethyl(Z)-2-(3-(5,7-dimethylbenzofuran-3(2H)-ylidene)-3-phenylprop-1-en-2-yl)cyclopropane-1,1-dicarboxylate;** yellow oil;  $^1H$  NMR (400 MHz,  $CDCl_3$ ) $\delta$ : 7.43(s, 1H), 7.37-7.34(m, 2H), 7.29-7.22(m, 3H), 6.81(s, 1H), 5.50(s, 1H), 5.30(s, 1H), 4.91(s, 2H), 3.66(s, 3H), 3.39(s, 3H), 2.61(t,  $J=8.8$ Hz, 1H), 2.60(s, 3H), 2.15(s, 3H),

1.90(dd,  $J=8.4, 4.8\text{Hz}$ , 1H), 1.44(dd,  $J=9.2, 4.8\text{Hz}$ , 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 170.0, 167.2, 161.2, 140.9, 140.8, 134.6, 132.1, 131.6, 129.0, 128.7, 127.9, 127.3, 123.3, 122.5, 119.9, 117.7, 75.1, 52.6, 52.5, 36.6, 32.6, 20.9, 19.4, 14.9; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{26}\text{H}_{26}\text{O}_5\text{Na}$   $[\text{M}+\text{Na}]^+=441.1672$ , found:441.1660.



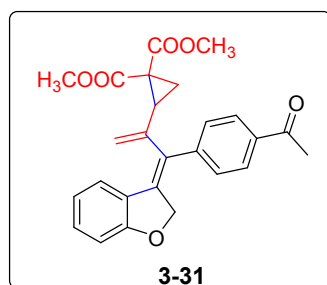
**Dimethyl(Z)-2-(3-(5-(methoxycarbonyl)benzofuran-3(2H)-ylidene)-3-phenylprop-1-en-2-yl)cyclopropane-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$ : 8.47(d,  $J=1.6\text{Hz}$ , 1H), 7.92-7.89(m, 1H), 7.39-7.36(m, 2H), 7.31-7.27(m, 1H), 7.25-7.23(m, 2H), 6.83(d,  $J=8.4\text{Hz}$ , 1H), 5.52(s, 1H), 5.38(s, 1H), 5.03(s, 2H), 3.90(s, 3H), 3.67(s, 3H), 3.41(s, 3H), 2.62(t,  $J=8.8\text{Hz}$ , 1H), 1.96(dd,  $J=8.4, 5.2\text{Hz}$ , 1H), 1.52-1.94(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 169.8, 168.2, 166.9, 166.8, 140.8, 140.1, 134.2, 132.4, 132.1, 128.7, 127.7, 127.6, 126.8, 124.6, 122.4, 117.8, 110.2, 76.2, 52.7, 52.5, 51.9, 36.8, 32.3, 19.4; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{26}\text{H}_{24}\text{O}_7\text{Na}$   $[\text{M}+\text{Na}]^+=471.1414$ , found:471.1404.



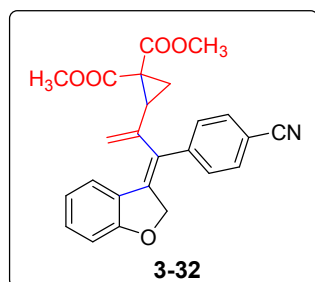
**Dimethyl(Z)-2-(3-(benzofuran-3(2H)-ylidene)-3-(4-methoxyphenyl)prop-1-en-2-yl)cyclopropane-1,1-dicarboxylate**; yellow solid;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$ : 7.77(d,  $J=7.6\text{Hz}$ , 1H), 7.17-7.12(m, 3H), 6.90(d,  $J=8.8\text{Hz}$ , 2H), 6.81(d,  $J=7.6\text{Hz}$ , 2H), 5.51(s, 1H), 5.33(s, 1H), 4.96(s, 2H), 3.82(s, 3H), 3.67(s, 3H), 3.41(s, 3H), 2.64-2.60(m, 1H), 1.88(dd,  $J=8.4, 4.8\text{Hz}$ , 1H), 1.44(dd,  $J=9.6, 4.8\text{Hz}$ , 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 169.9, 167.3, 164.5, 158.8, 141.0, 133.4, 132.6, 131.9, 129.9, 129.0, 124.9, 124.3, 120.0, 117.8, 114.0, 110.3, 75.2, 55.2, 52.6, 52.5, 36.4, 32.7, 19.5;



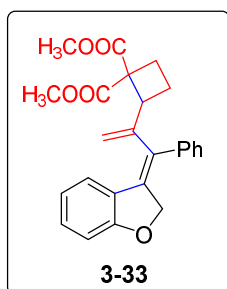
HRMS(ESI)  $m/z$  calcd for  $C_{25}H_{24}O_6Na$   $[M+Na]^+=443.1465$ , found:443.1456.



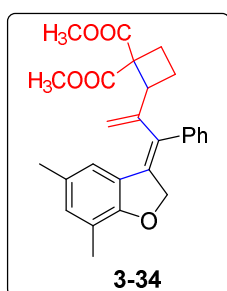
**Dimethyl(Z)-2-(3-(4-acetylphenyl)-3-(benzofuran-3(2H)-ylidene)prop-1-en-2-yl)cyclopropane-1,1-dicarboxylate**; yellow oil;  $^1H$  NMR (400 MHz,  $CDCl_3$ ) $\delta$ : 7.98(d,  $J=8.4$ Hz, 2H), 7.80(d,  $J=7.6$ Hz, 1H), 7.36(d,  $J=8.4$ Hz, 2H), 7.20-7.17(m, 1H), 6.87-6.82(m, 2H), 5.55(s, 1H), 5.39(s, 1H), 4.94(s, 2H), 3.67(s, 3H), 3.38(s, 3H), 2.62(s, 3H), 2.59(d,  $J=9.6$ Hz, 1H), 1.91-1.87(m, 1H), 1.48-1.44(m, 1H);  $^{13}C$  NMR (100MHz,  $CDCl_3$ )  $\delta$ : 197.5, 169.7, 167.0, 164.7, 145.3, 140.3, 136.0, 134.9, 130.9, 130.6, 128.8, 128.0, 125.0, 123.8, 120.2, 118.6, 110.5, 74.8, 52.7, 52.5, 36.5, 32.4, 26.5, 19.3; HRMS(ESI)  $m/z$  calcd for  $C_{26}H_{24}O_6Na$   $[M+Na]^+=455.1465$ , found:455.1468.



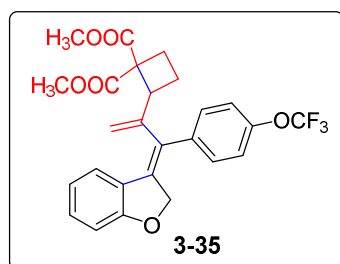
**Dimethyl(Z)-2-(3-(benzofuran-3(2H)-ylidene)-3-(4-cyanophenyl)prop-1-en-2-yl)cyclopropane-1,1-dicarboxylate**; yellow oil;  $^1H$  NMR (400 MHz,  $CDCl_3$ ) $\delta$ : 7.78(d,  $J=7.6$ Hz, 1H), 7.68(d,  $J=8.4$ Hz, 2H), 7.38(d,  $J=8.0$ Hz, 2H), 7.23-7.19(m, 1H), 6.86(t,  $J=8.0$ Hz, 2H), 5.55(s, 1H), 5.39(s, 1H), 4.91(s, 2H), 3.68(s, 3H), 3.39(s, 3H), 2.57(t,  $J=8.8$ Hz, 1H), 1.90-1.87(m, 1H), 1.49-1.46(m, 1H);  $^{13}C$  NMR (100MHz,  $CDCl_3$ )  $\delta$ : 169.6, 167.0, 164.8, 145.2, 140.1, 135.6, 132.6, 131.0, 130.0, 128.8, 125.1, 123.5, 120.4, 119.0, 118.6, 111.2, 110.7, 74.7, 52.8, 52.6, 36.6, 32.3, 19.3; HRMS(ESI)  $m/z$  calcd for  $C_{25}H_{21}NO_5Na$   $[M+Na]^+=438.1312$ , found:438.1315.



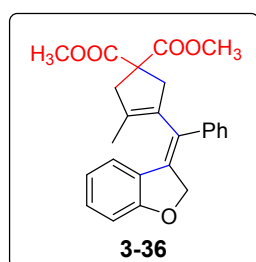
**Dimethyl(Z)-2-(3-(benzofuran-3(2H)-ylidene)-3-phenylprop-1-en-2-yl)cyclobutane-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.76(d,  $J=7.2\text{Hz}$ , 1H), 7.37-7.33(m, 2H), 7.28-7.26(m, 3H), 7.17-7.13(m, 1H), 6.86-6.82(m, 2H), 5.47(s, 1H), 5.38(s, 1H), 5.04(s, 2H), 3.76-3.71(m, 1H), 3.68(s, 3H), 3.52(s, 3H), 2.48-2.43(m, 1H), 2.40-2.30(m, 1H), 2.14-2.07(m, 1H), 1.88-1.81(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 171.9, 170.8, 164.4, 146.0, 140.6, 133.4, 132.6, 129.9, 128.4, 127.9, 127.3, 124.9, 124.9, 120.1, 116.4, 110.4, 75.2, 58.4, 52.4, 52.3, 44.9, 26.5, 22.3; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{25}\text{H}_{24}\text{O}_5\text{Na}$   $[\text{M}+\text{Na}]^+=427.1516$ , found:427.1519.



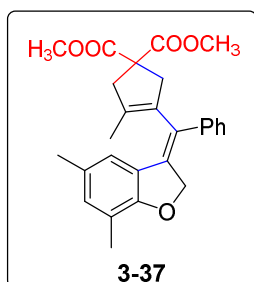
**Dimethyl(Z)-2-(3-(5,7-dimethylbenzofuran-3(2H)-ylidene)-3-phenylprop-1-en-2-yl)cyclobutane-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.40(s, 1H), 7.36-7.32(m, 2H), 7.26(d,  $J=7.2\text{Hz}$ , 3H), 6.81(s, 1H), 5.42(s, 1H), 5.36(s, 1H), 5.07-4.99(m, 2H), 3.77-3.72(m, 1H), 3.69(s, 3H), 3.51(s, 3H), 2.48-2.34(m, 2H), 2.28(s, 3H), 2.16(s, 3H), 2.14-2.05(m, 1H), 1.87-1.80(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.0, 170.8, 160.9, 140.9, 134.2, 131.9, 131.8, 129.1, 128.3, 127.9, 127.1, 124.1, 122.6, 119.8, 116.2, 75.2, 58.4, 52.3, 52.2, 45.0, 29.7, 26.5, 22.4, 20.9; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{27}\text{H}_{28}\text{O}_5\text{Na}$   $[\text{M}+\text{Na}]^+=455.1829$ , found:455.1827.



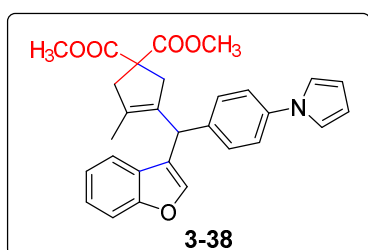
**Dimethyl(Z)-2-(3-(benzofuran-3(2H)-ylidene)-3-(4-(trifluoromethoxy)phenyl)prop-1-en-2-yl)cyclobutane-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.69(s, 1H), 7.33-7.30(m, 2H), 7.21-7.15(m, 3H), 6.85(t,  $J=7.6\text{Hz}$ , 2H), 5.46(s, 1H), 5.41(s, 1H), 5.04-4.99(m, 2H), 3.76-3.71(m, 1H), 3.67(s, 3H), 3.47(s, 3H), 2.50-2.45(m, 1H), 2.43-2.33(m, 1H), 2.16-2.08(m, 1H), 1.91-1.84(m, 1H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 171.8, 170.6, 164.5, 148.2, 139.3, 134.2, 131.1, 130.2, 129.5, 124.9, 124.6, 121.7, 120.8, 120.2, 119.2, 117.0, 110.5, 75.0, 58.5, 52.3, 52.2, 44.8, 26.4, 22.2; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{26}\text{H}_{23}\text{F}_3\text{O}_6\text{Na}$   $[\text{M}+\text{Na}]^+=511.1339$ , found:511.1331.



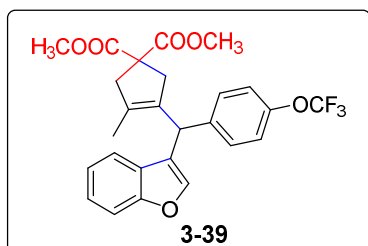
**Dimethyl(E)-3-(benzofuran-3(2H)-ylidene(phenyl)methyl)-4-methylcyclopent-3-ene-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.38-7.34(m, 3H), 7.29-7.25(m, 1H), 7.19-7.14(m, 3H), 6.89-6.83(m, 2H), 5.16(s, 2H), 3.73(s, 6H), 3.14(s, 2H), 3.07(s, 2H), 1.58(s, 3H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.6, 164.0, 139.9, 134.3, 134.0, 132.1, 129.8, 128.6, 127.4, 127.0, 125.6, 123.9, 120.8, 110.3, 75.1, 57.5, 52.8, 45.5, 43.4, 14.7; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{25}\text{H}_{24}\text{O}_5\text{Na}$   $[\text{M}+\text{Na}]^+=427.1516$ , found:427.1501.



**Dimethyl(E)-3-((5,7-dimethylbenzofuran-3(2H)-ylidene)(phenyl)methyl)-4-methylcyclopent-3-ene-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.37-7.33(m, 2H), 7.26(d,  $J=7.2\text{Hz}$ , 1H), 7.18(d,  $J=7.6\text{Hz}$ , 2H), 7.00(s, 1H), 6.82(s, 1H), 5.14(s, 2H), 3.73(s, 6H), 3.14(s, 2H), 3.08(s, 2H), 2.27(s, 3H), 2.18(s, 3H), 1.57(s, 3H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.6, 160.6, 140.0, 135.2, 133.9, 132.2, 131.8, 129.8, 128.6, 127.4, 127.2, 126.2, 124.7, 121.6, 119.7, 75.1, 57.5, 52.8, 45.6, 43.4, 20.9, 14.9, 14.6; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{27}\text{H}_{28}\text{O}_5\text{Na}$   $[\text{M}+\text{Na}]^+=455.1829$ , found:455.1826.



**Dimethyl3-((4-(1H-pyrrol-1-yl)phenyl)(benzofuran-3-yl)methyl)-4-methylcyclopent-3-ene-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.47(d,  $J=8.4\text{Hz}$ , 2H), 7.33-7.31(m, 2H), 7.28-7.23(m, 3H), 7.11-7.08(m, 4H), 6.34-6.33(m, 2H), 5.20(s, 1H), 3.68(s, 3H), 3.67(s, 3H), 3.13-3.01(m, 3H), 2.74(dd,  $J=16.4, 2.0\text{Hz}$ , 1H), 1.78(s, 3H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.8, 172.4, 155.6, 143.2, 139.3, 138.0, 132.0, 131.7, 129.4, 127.4, 124.2, 122.3, 121.0, 120.5, 119.2, 111.5, 110.3, 57.1, 52.8, 52.7, 45.8, 41.8, 39.8, 13.6; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{29}\text{H}_{27}\text{NO}_5\text{Na}$   $[\text{M}+\text{Na}]^+=492.1781$ , found:492.1787.

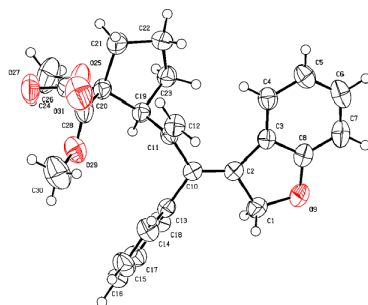
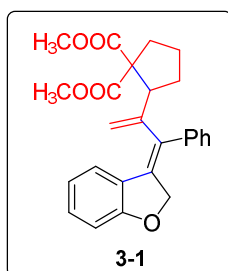


**Dimethyl3-(benzofuran-3-yl(4-(trifluoromethoxy)phenyl)methyl)-4-methylcyclopent-3-ene-1,1-dicarboxylate**; yellow oil;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $\delta$ : 7.48-7.46(m, 2H), 7.28-7.23(m, 3H), 7.15-7.04(m, 4H), 5.19(s, 1H), 3.68(s, 6H), 3.12-2.97(m, 3H), 2.70(d,  $J=16.8\text{Hz}$ , 1H), 1.76(s, 3H);  $^{13}\text{C}$  NMR (100MHz,  $\text{CDCl}_3$ )  $\delta$ : 172.7, 172.4, 155.6, 147.9, 143.2, 139.3, 132.0, 131.7, 129.6, 127.3, 124.3, 122.4, 120.9, 120.8, 120.3, 111.5, 57.1, 52.8, 52.7, 45.7, 41.7, 39.8, 13.7; HRMS(ESI)  $m/z$  calcd for  $\text{C}_{26}\text{H}_{23}\text{F}_3\text{O}_6\text{Na}$   $[\text{M}+\text{Na}]^+=511.1339$ , found:511.1344.

#### 4. References

1. Z. Liu, Y. Xia, S. Zhou, L. Wang, Y. Zhang and J. Wang, Pd-Catalyzed Cyclization and Carbene Migratory Insertion: New Approach to 3-Vinylindoles and 3-Vinylbenzofurans, *Org. Lett.*, 2013, **15**, 5032.

#### 5. The crystal structure of product 3-1



Bond precision: C-C = 0.0027 A

Wavelength=1.54184

Cell: a=9.6625(4)  
alpha=91.327(3)

b=10.0559(4)  
beta=94.413(4)

c=11.1592(5)  
gamma=96.328(3)

Temperature: 293 K

	Calculated	Reported
Volume	1073.94(8)	1073.94(8)
Space group	P -1	P -1
Hall group	-P 1	-P 1
Moiety formula	C26 H26 O5	C26 H26 O5
Sum formula	C26 H26 O5	C26 H26 O5
Mr	418.47	418.47
Dx, g cm-3	1.294	1.294
Z	2	2
Mu (mm-1)	0.722	0.722
F000	444.0	444.0
F000'	445.38	
h, k, lmax	11, 12, 13	11, 12, 13
Nref	4159	4064
Tmin, Tmax	0.871, 0.897	0.391, 1.000
Tmin'	0.853	

Correction method= # Reported T Limits: Tmin=0.391 Tmax=1.000  
AbsCorr = MULTI-SCAN

Data completeness= 0.977

Theta(max)= 71.185

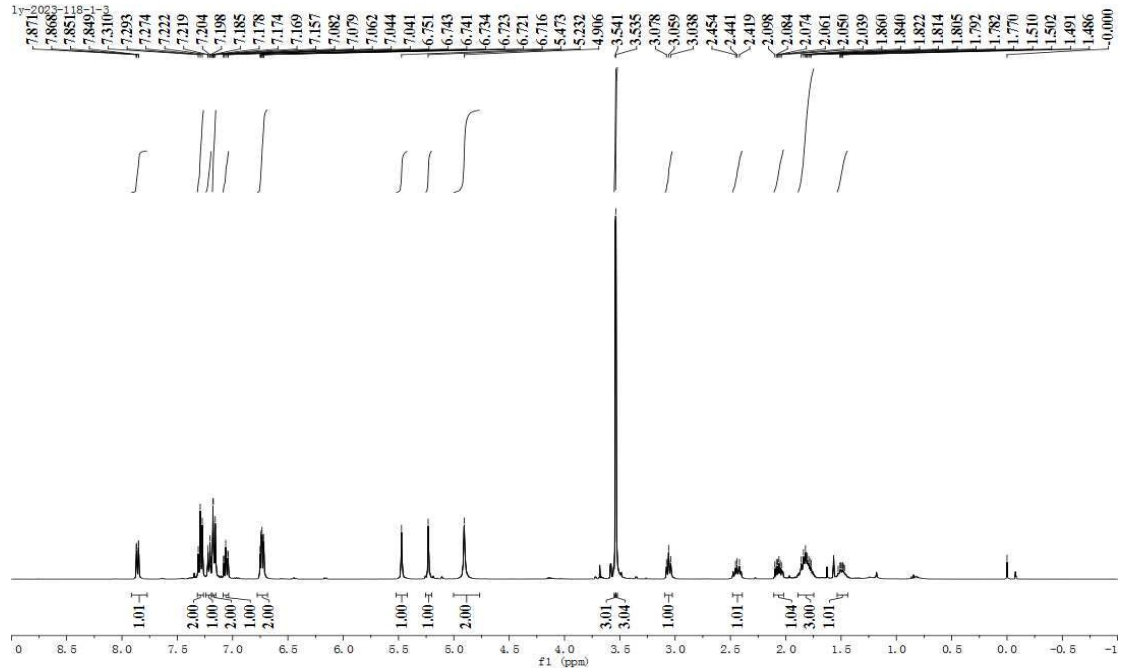
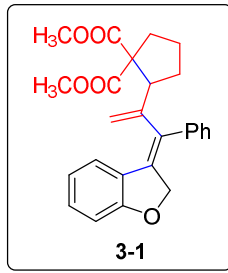
R(reflections)= 0.0499( 3311)

wR2(reflections)=  
0.1355( 4064)

S = 1.082

Npar= 290

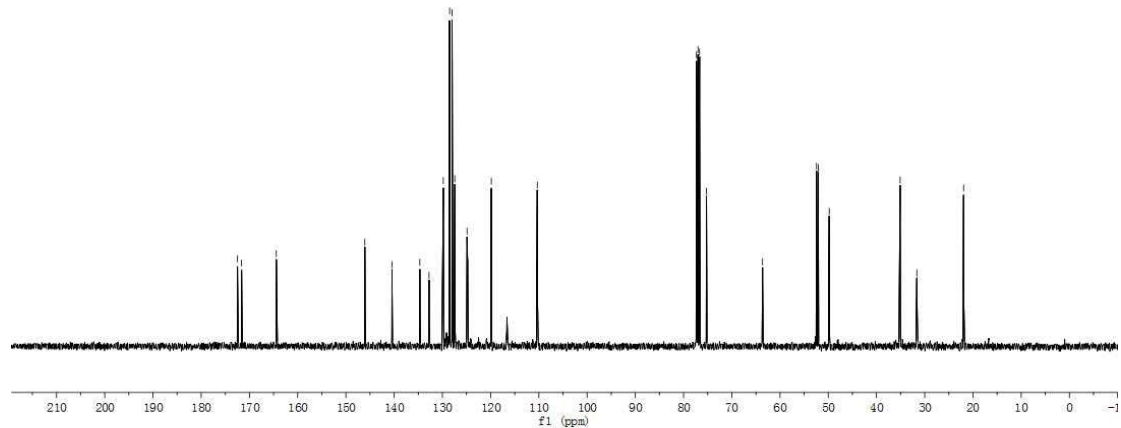
## 6. $^1\text{H}$ , $^{13}\text{C}$ spectra for compound 3

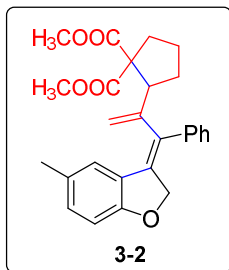


1y-2023-118-1-3

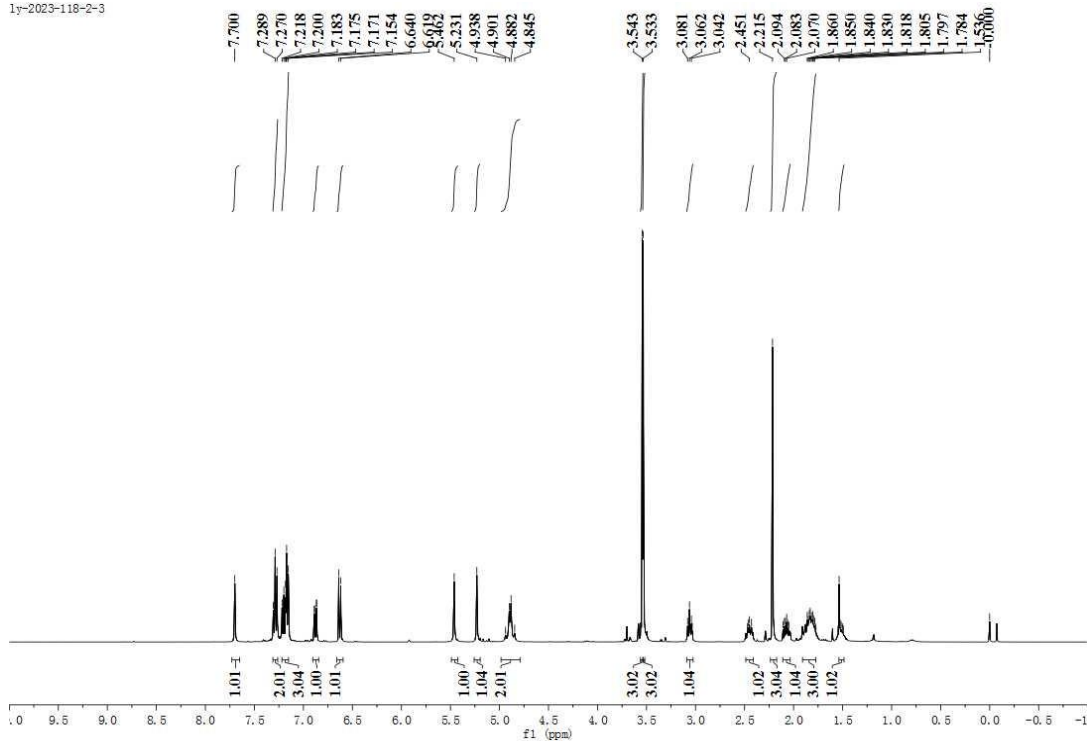
**$^{13}\text{C}$  NMR spectrum (ppm):**

- 172.47, 171.63, 164.44, 146.08, 140.45, 134.68, 132.77, 129.81, 128.50, 127.98, 127.42, 124.89, 124.74, 119.85, 110.32, 77.32, 77.00, 76.68, 75.24, 63.62, 52.42, 52.07, 49.80, 35.10, 31.64, 21.94

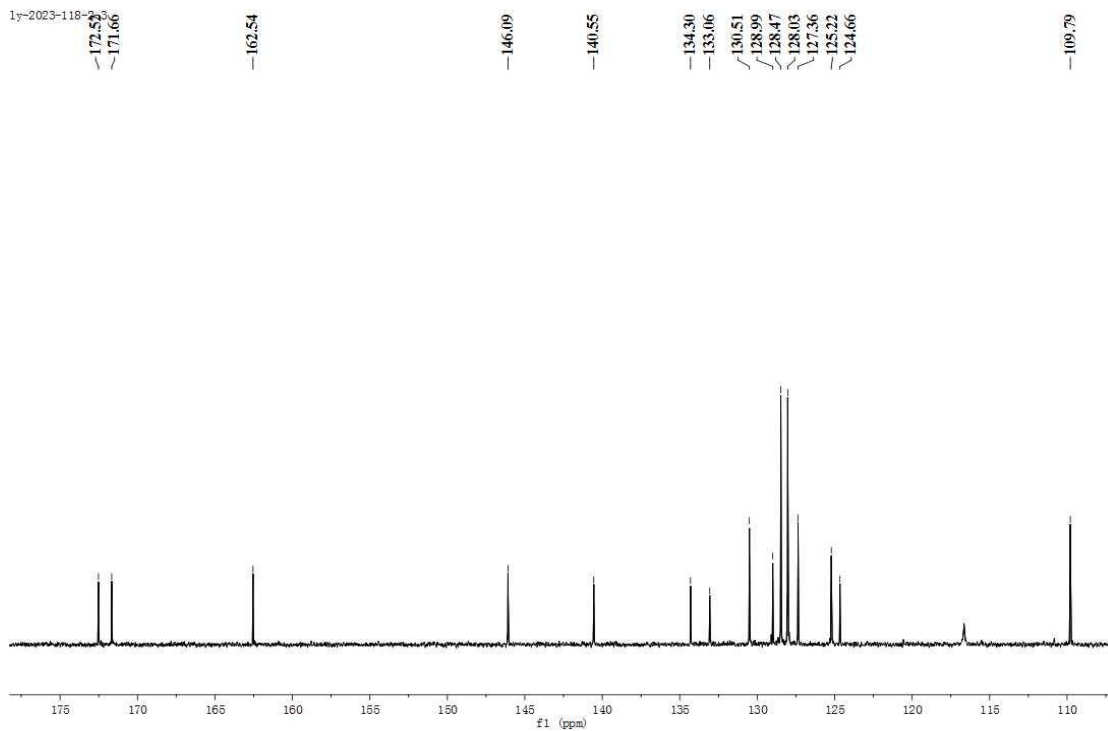




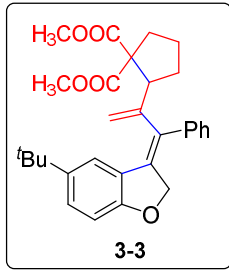
1y-2023-118-2-3



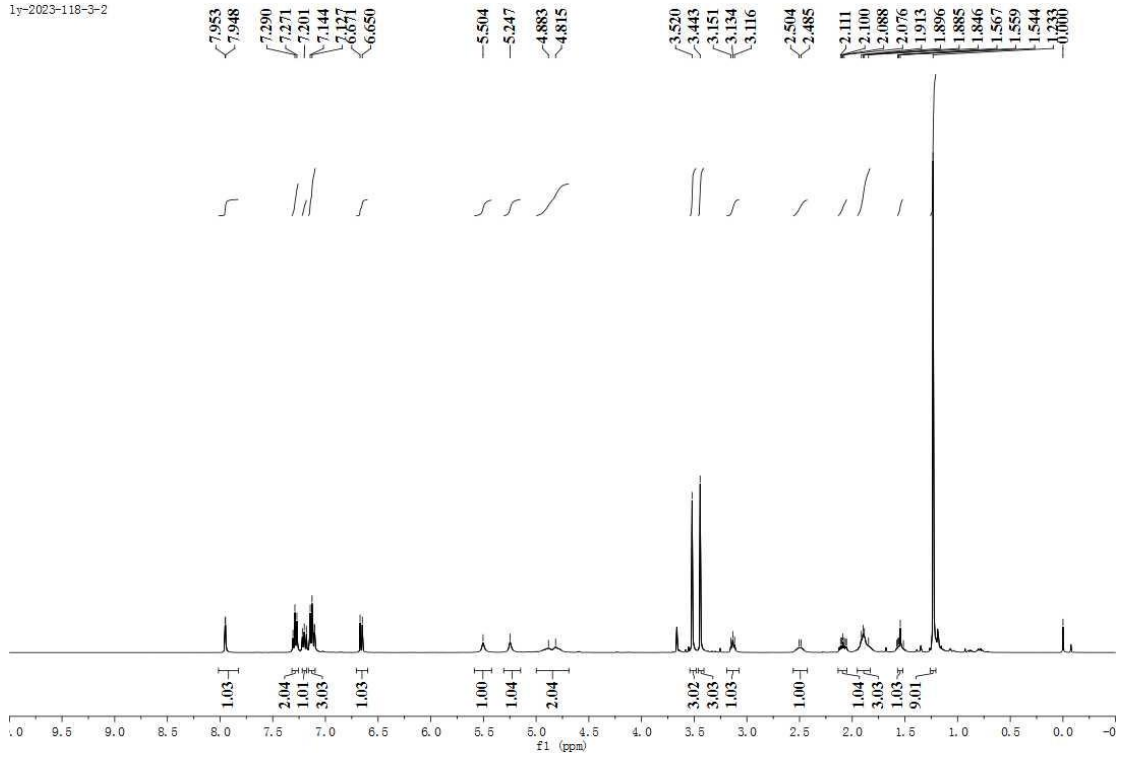
1y-2023-118-



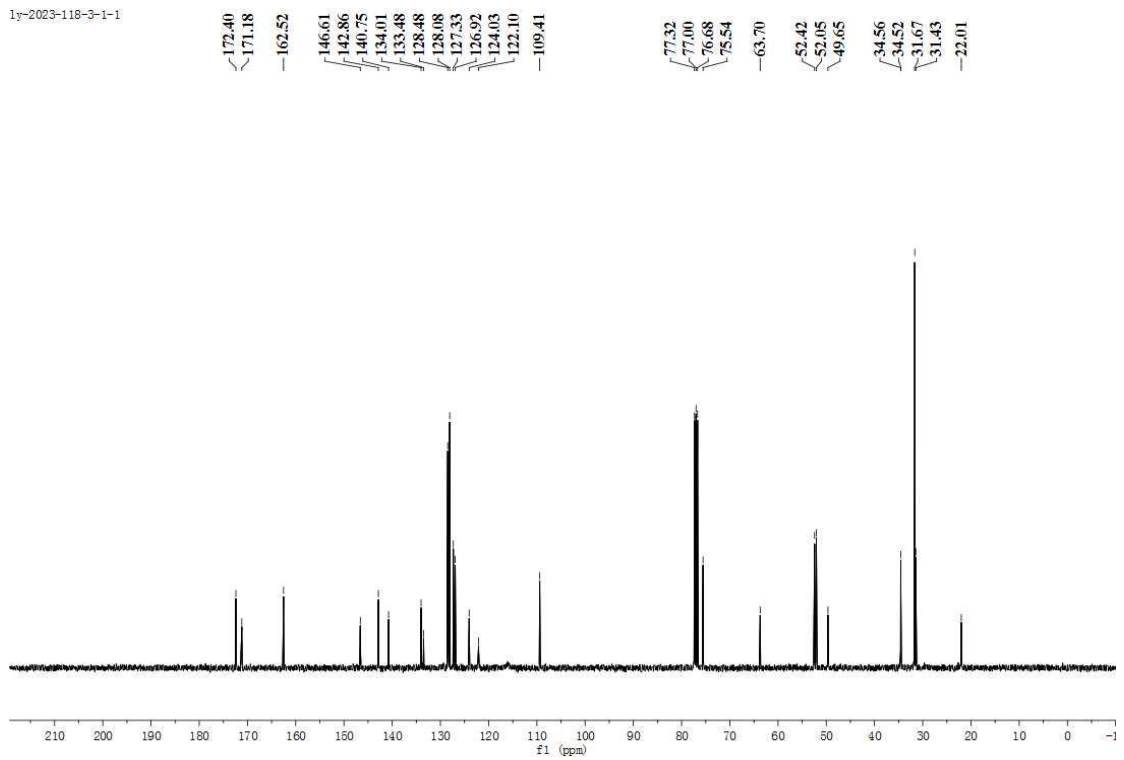


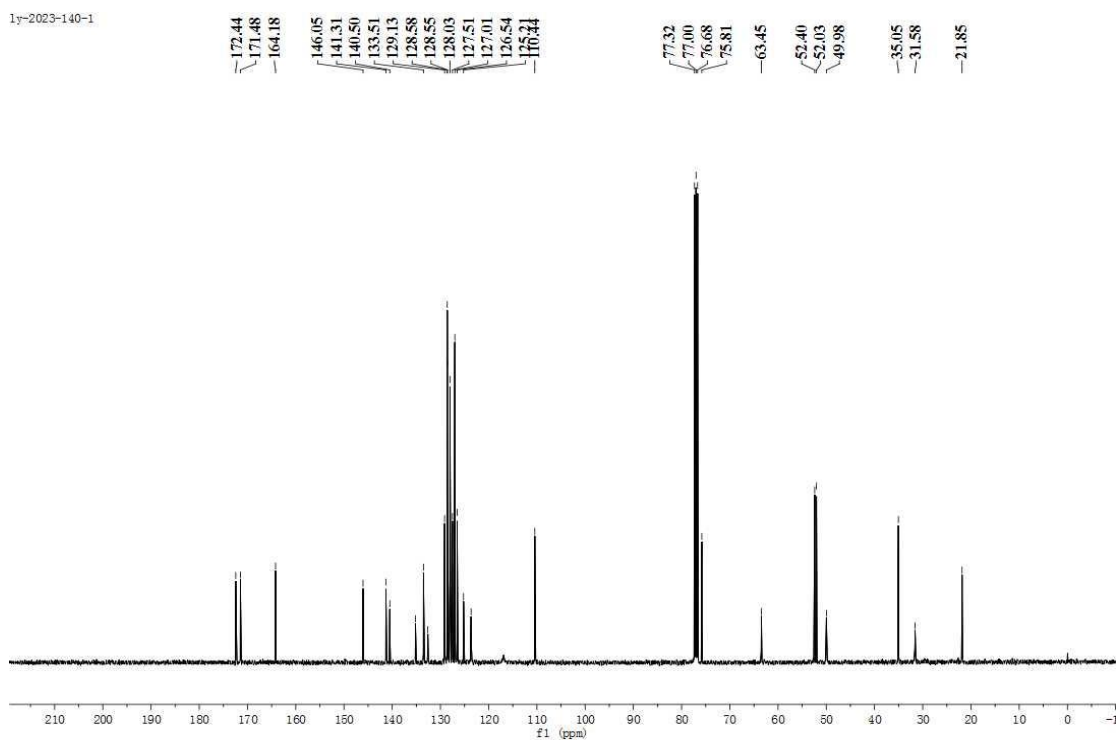
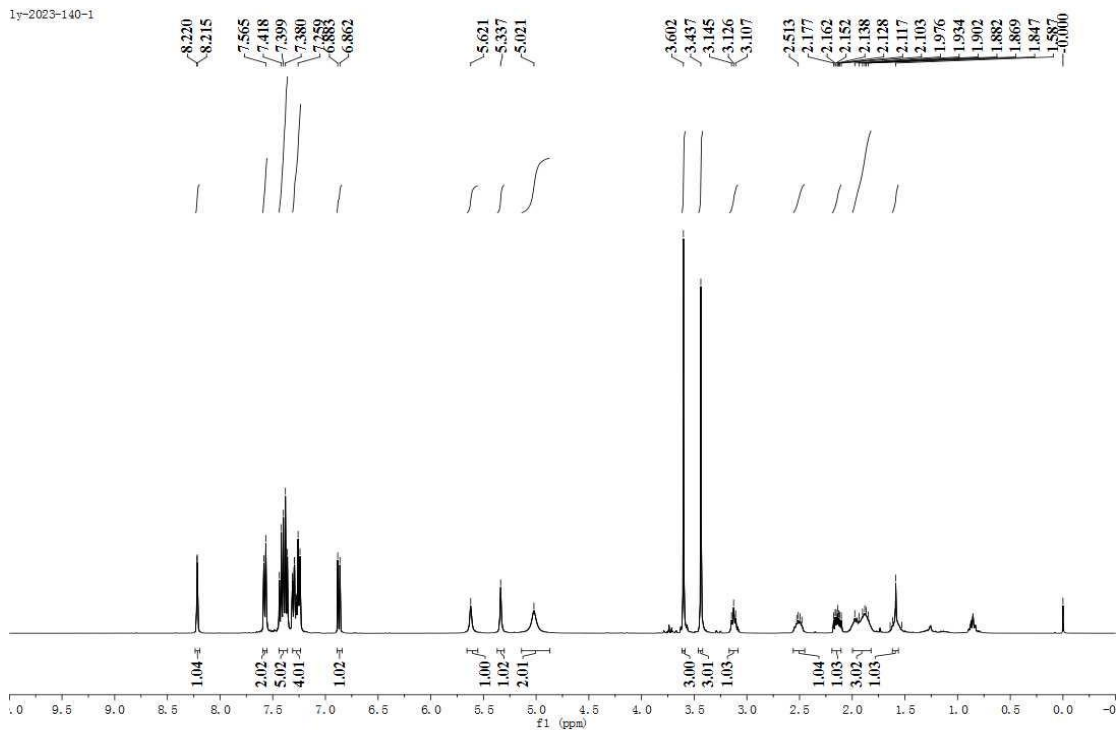
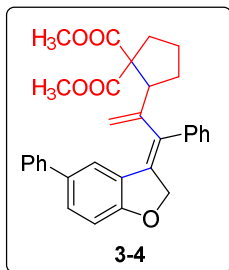


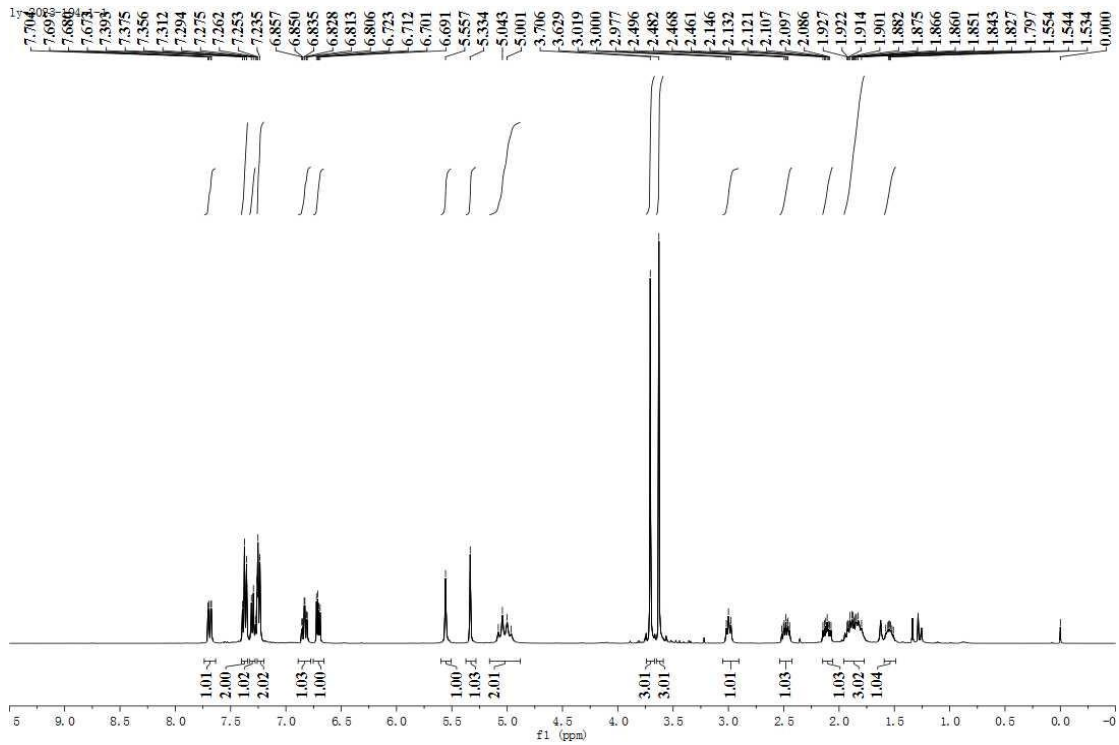
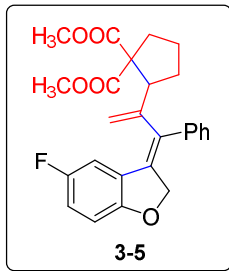
1y-2023-118-3-2



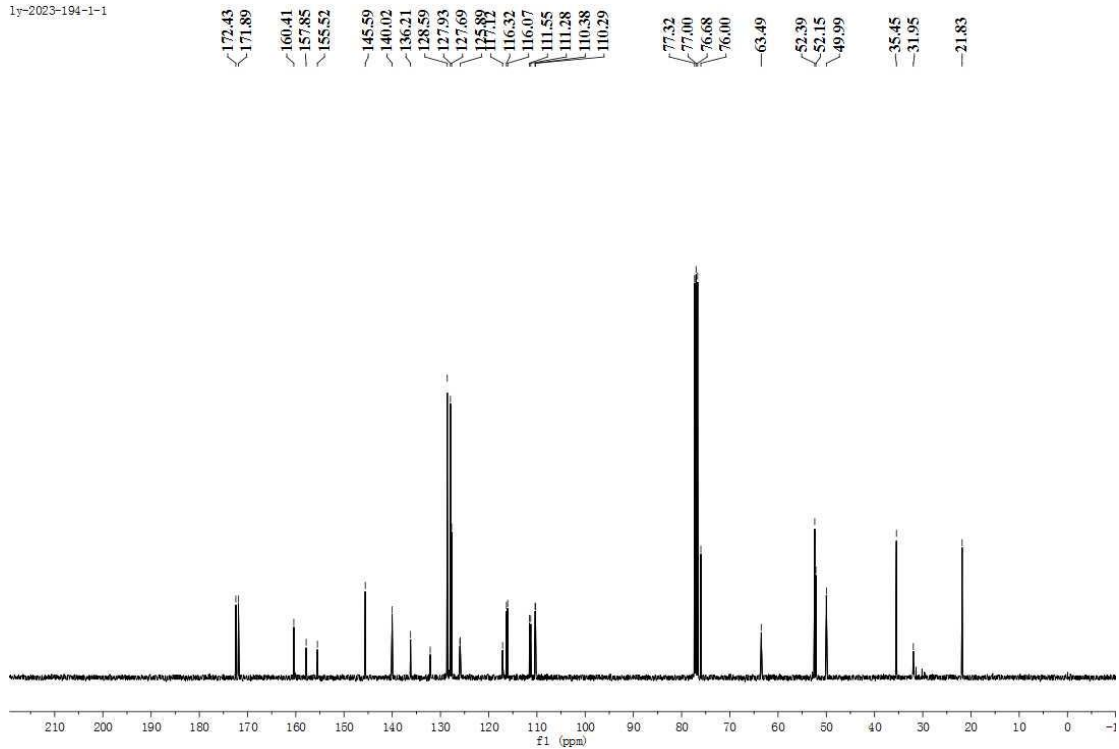
1y-2023-118-3-1-1

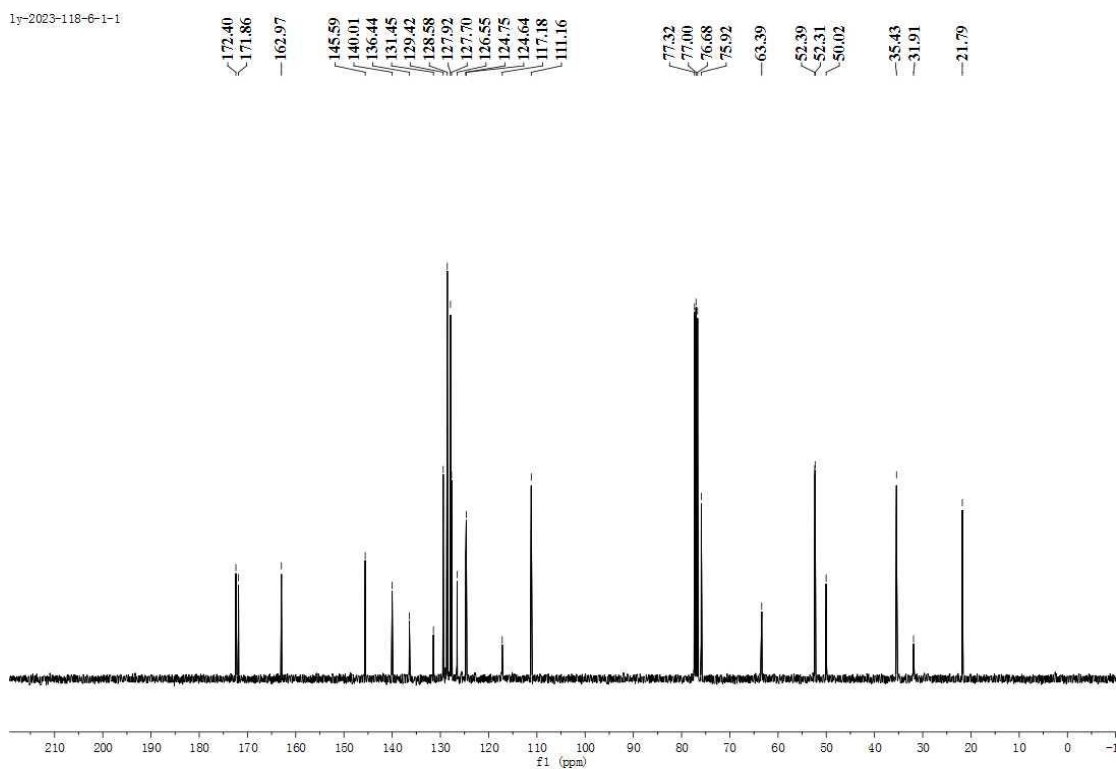
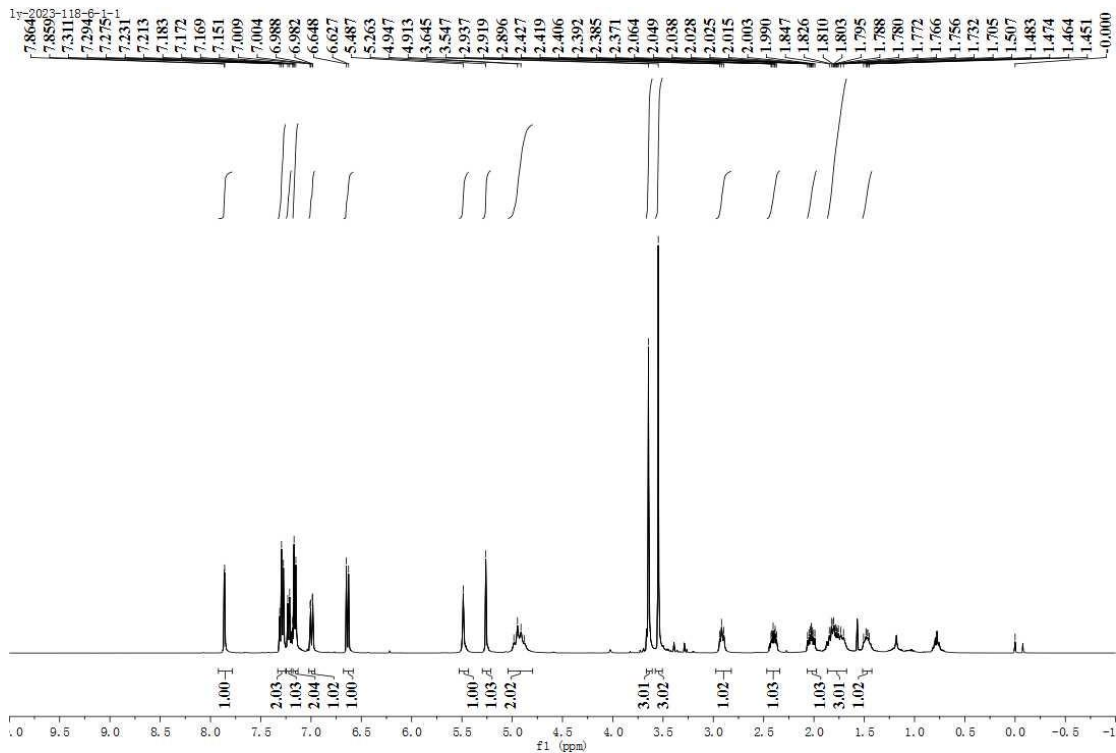
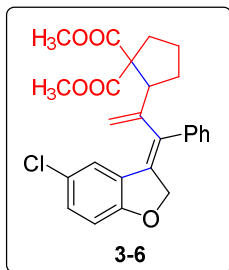


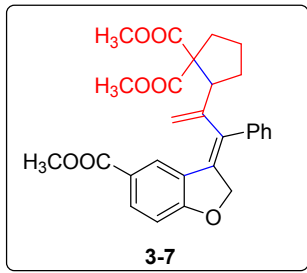




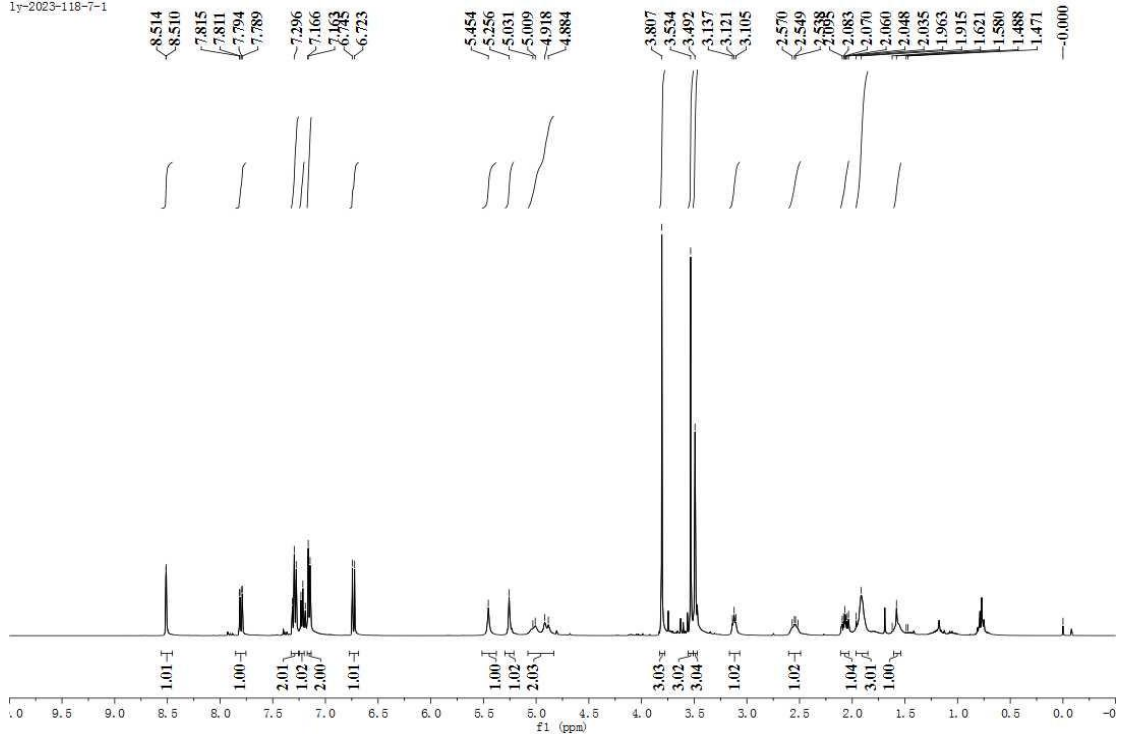
1y-2023-194-1-1



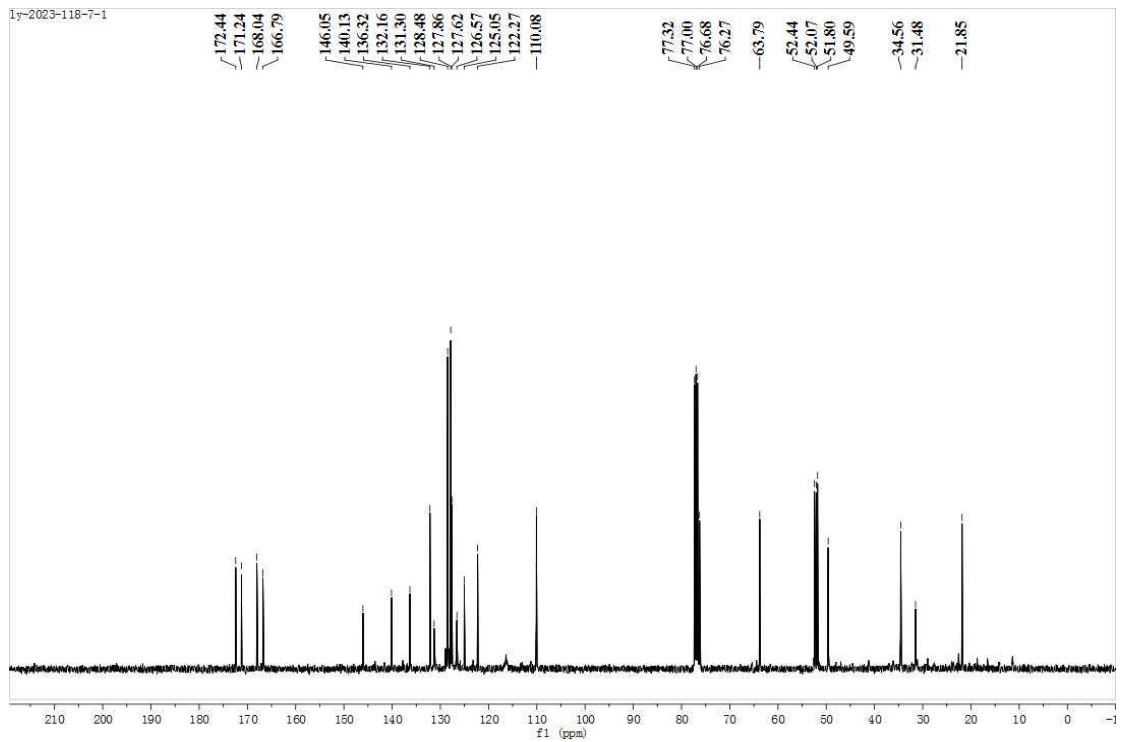


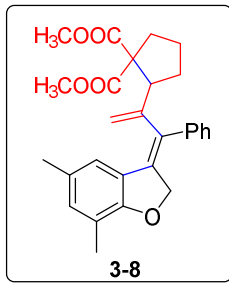


1y-2023-118-7-1

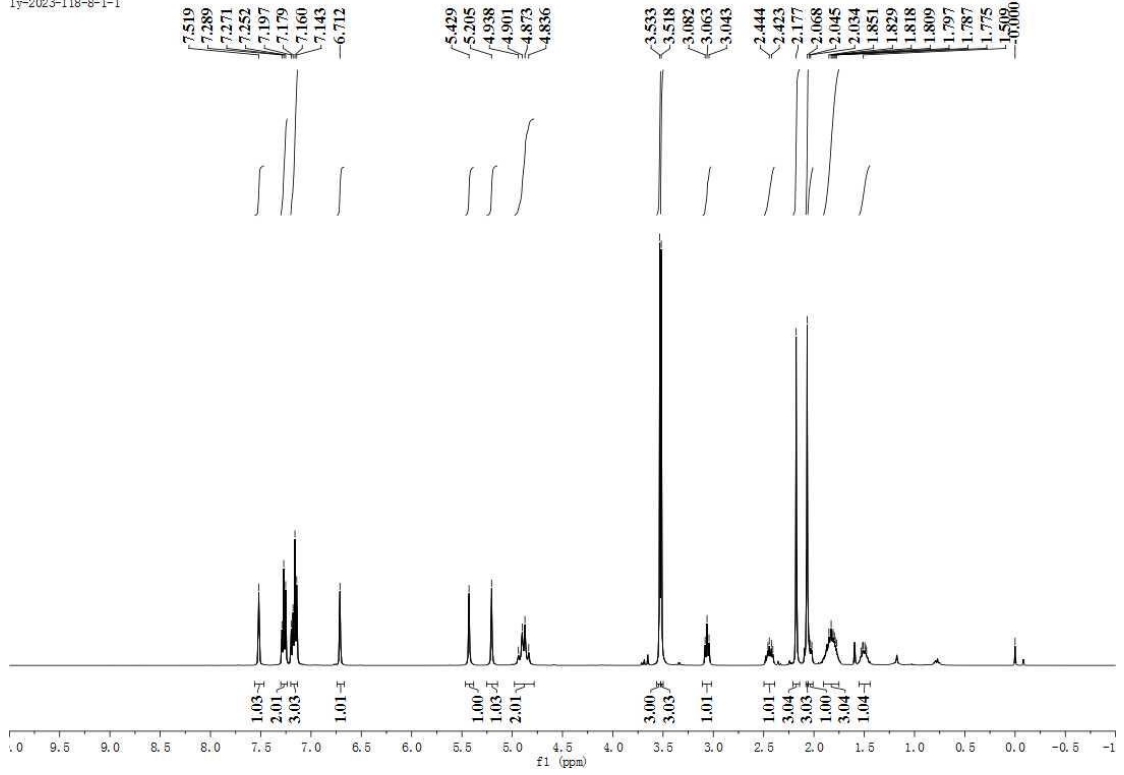


1y-2023-118-7-1

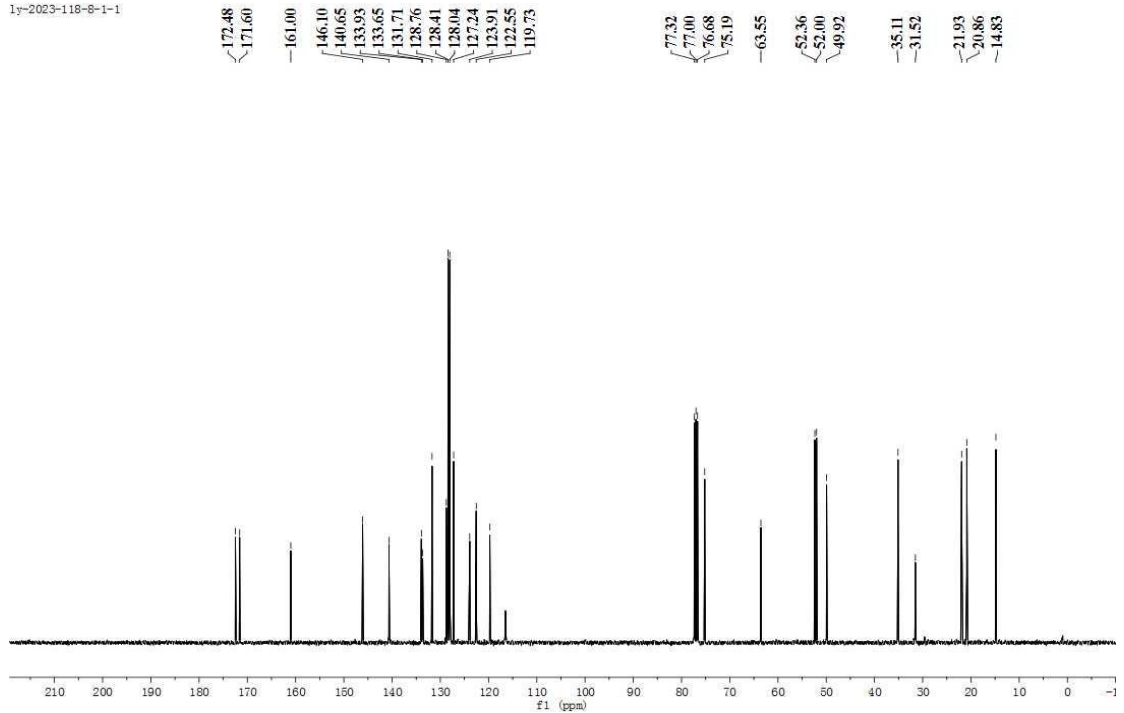


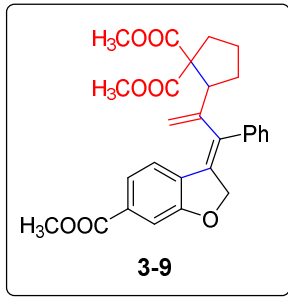


1y-2023-118-8-1-1

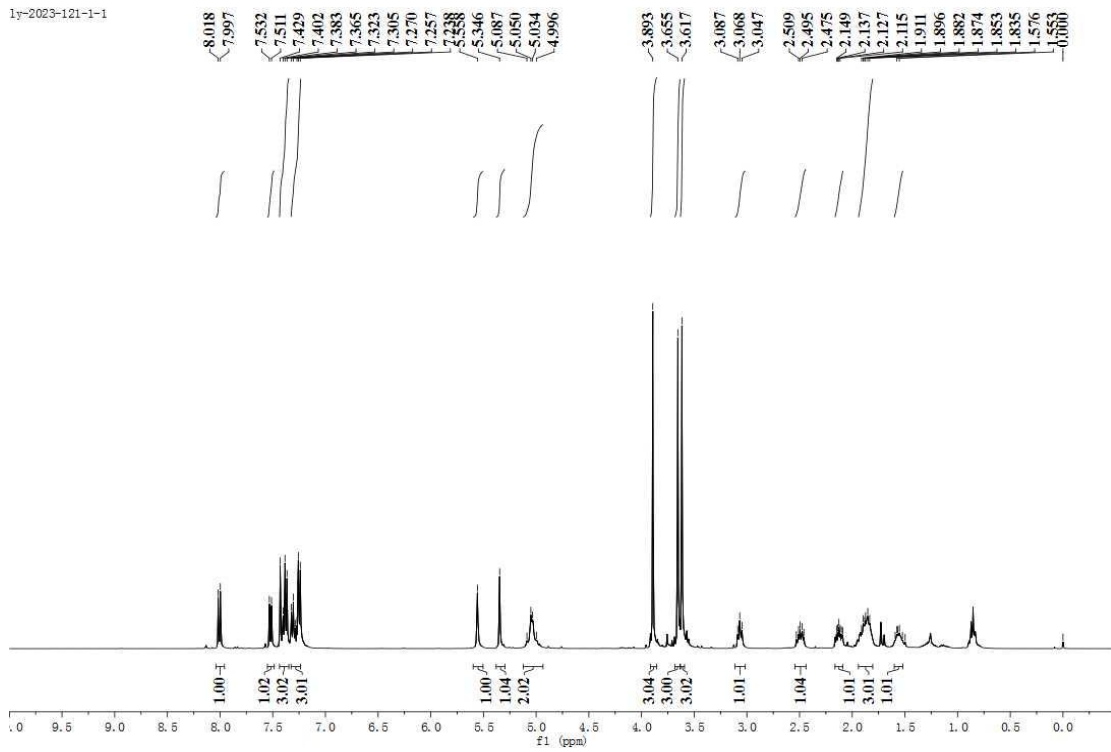


1y-2023-118-8-1-1

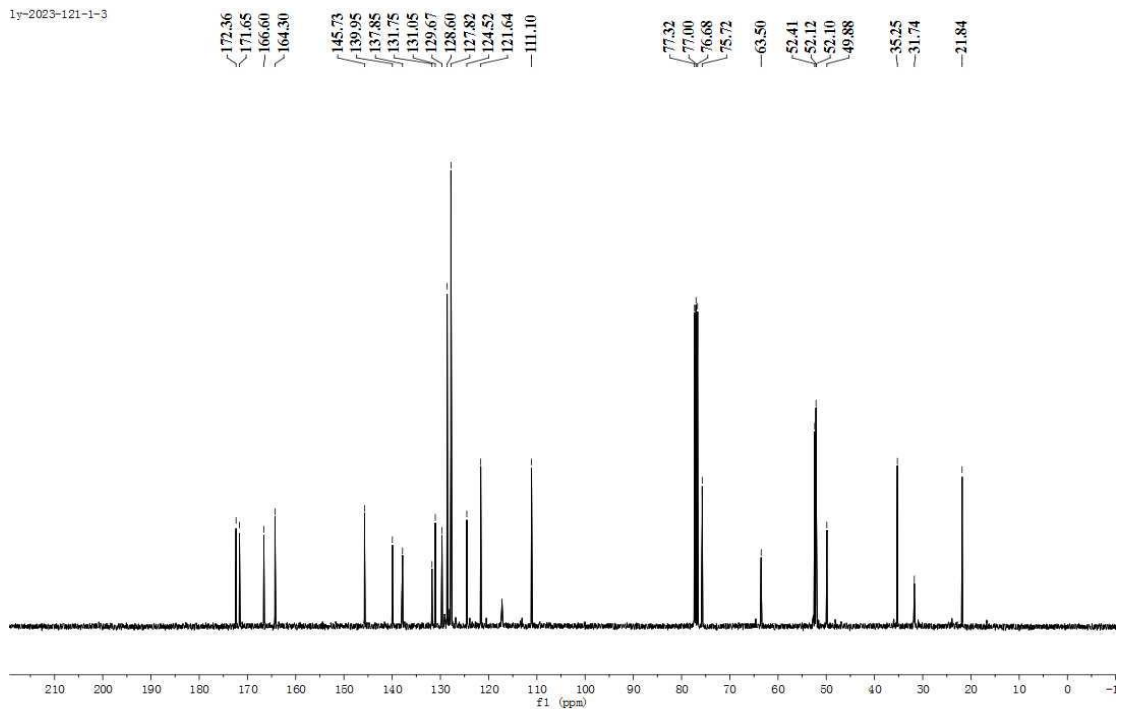


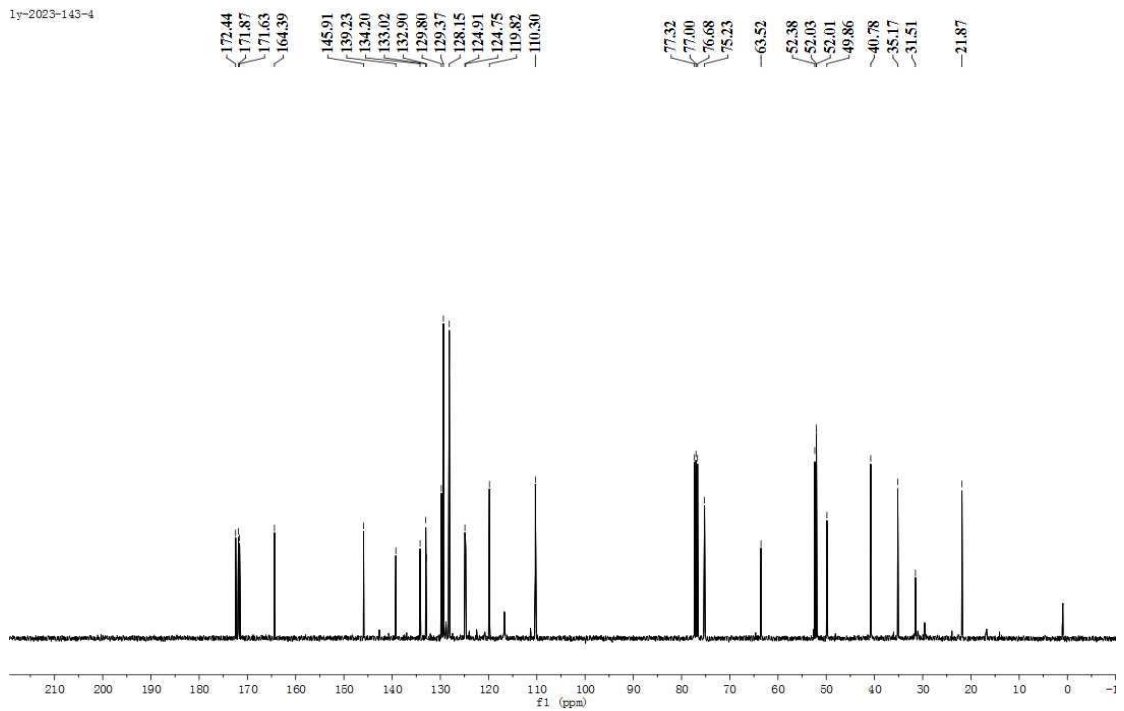
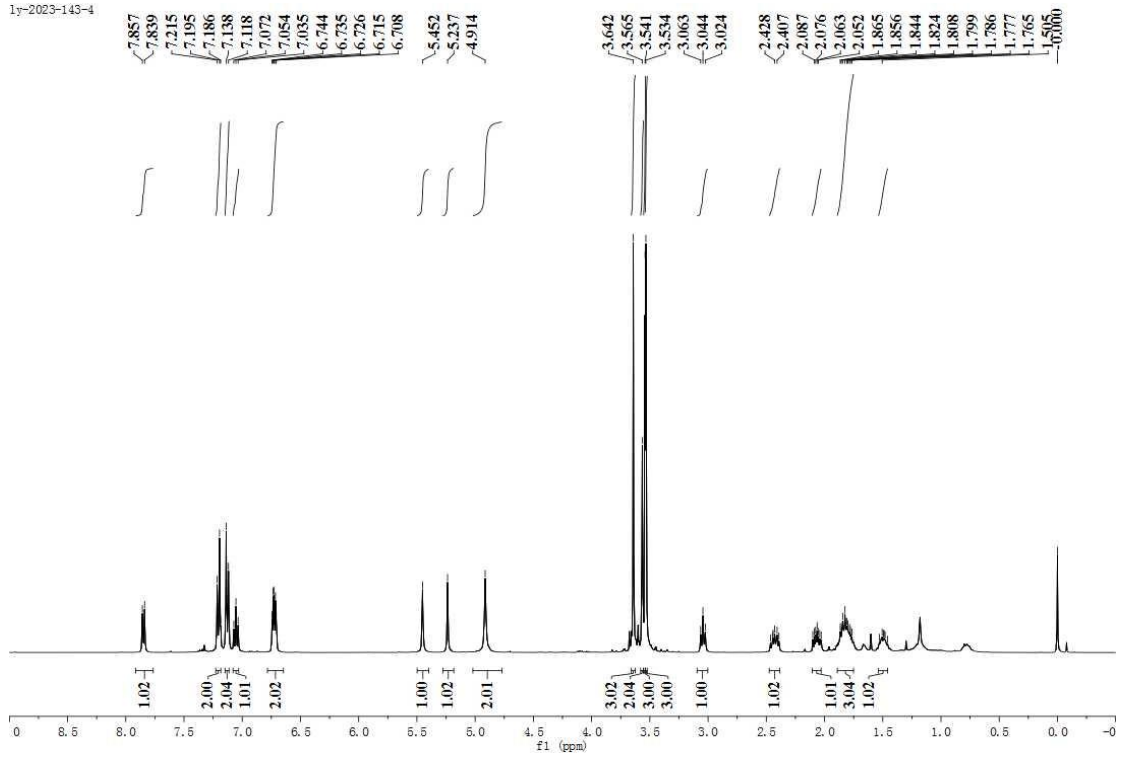
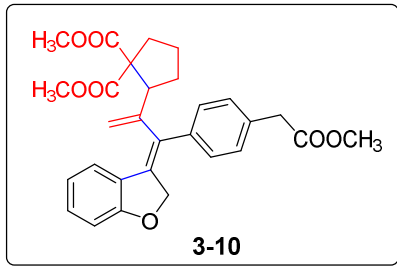


1y-2023-121-1-1

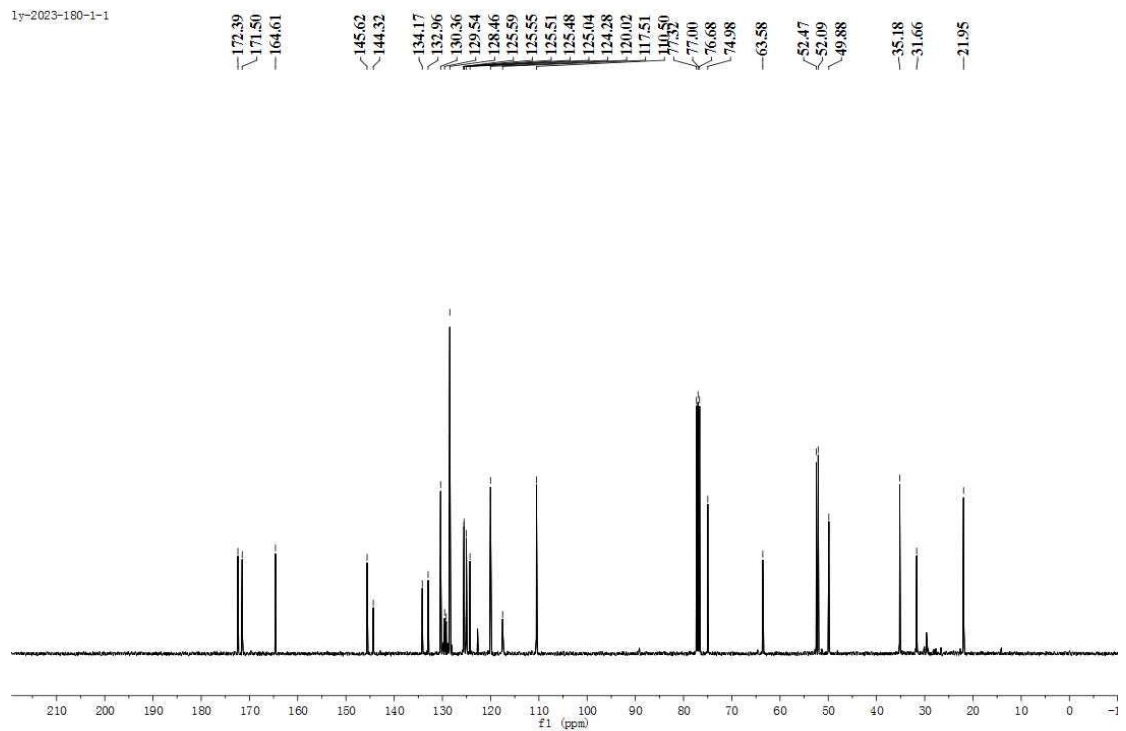
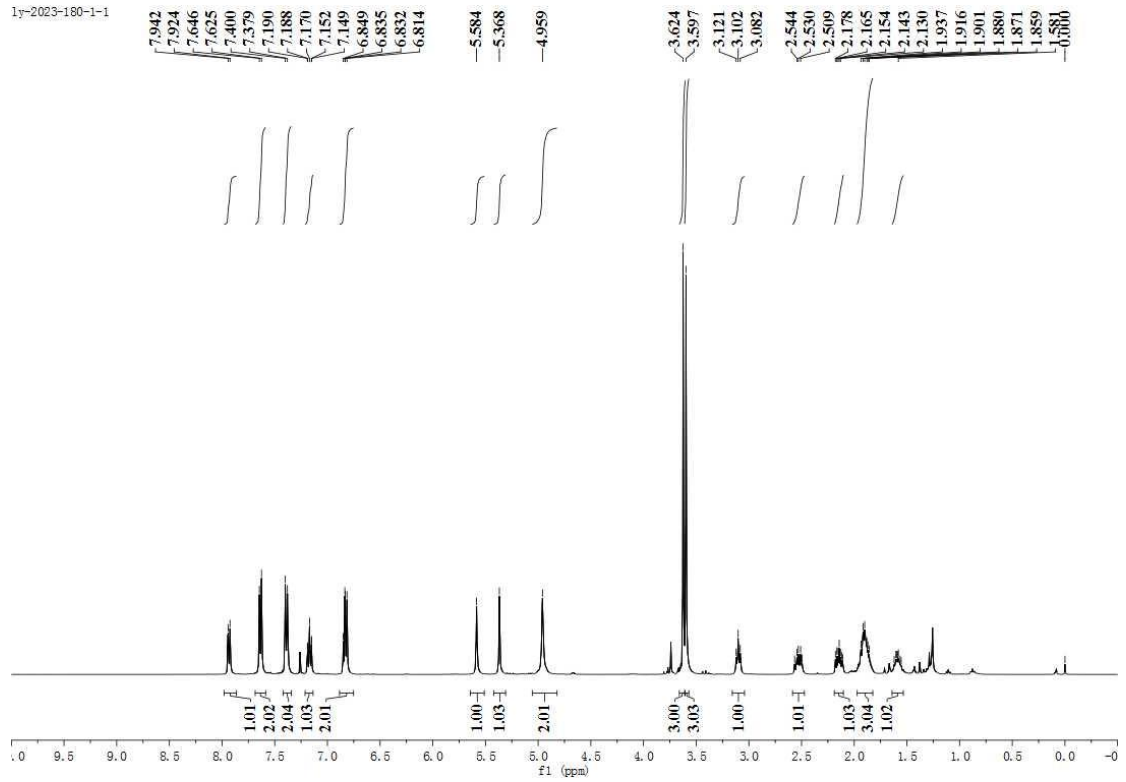
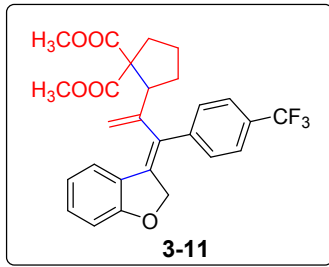


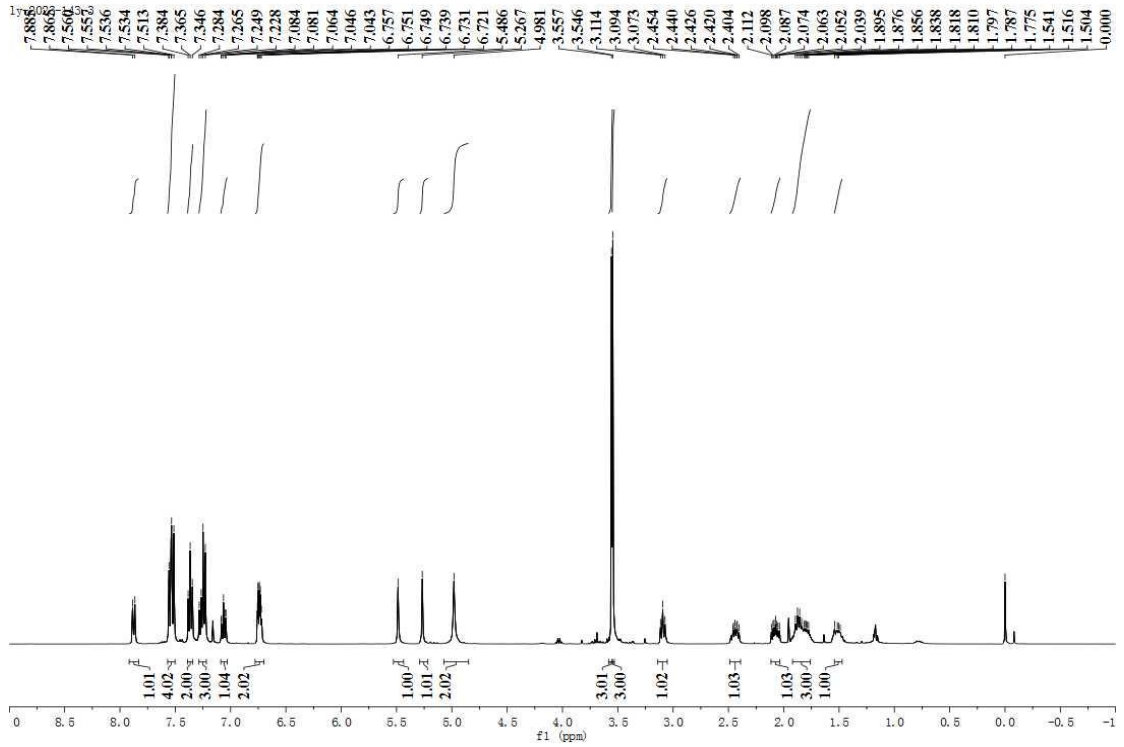
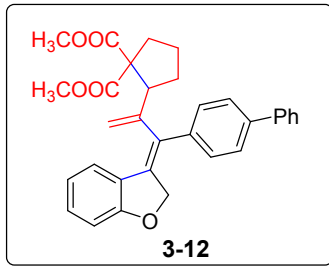
1y-2023-121-1-3



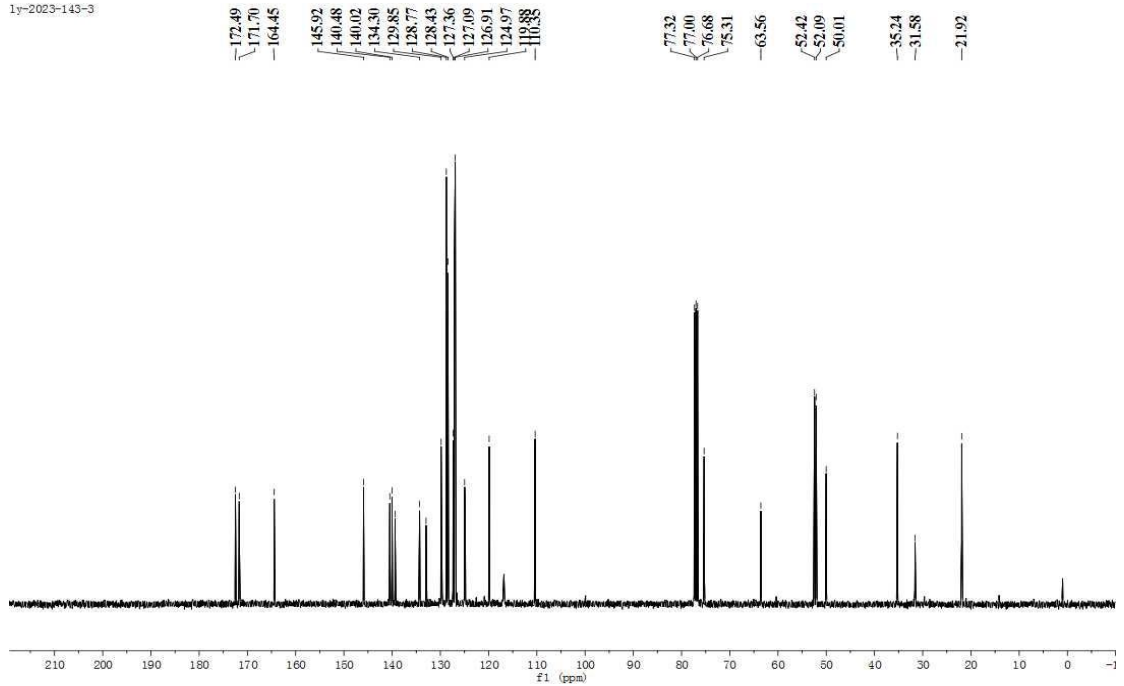


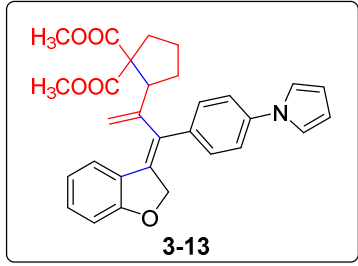




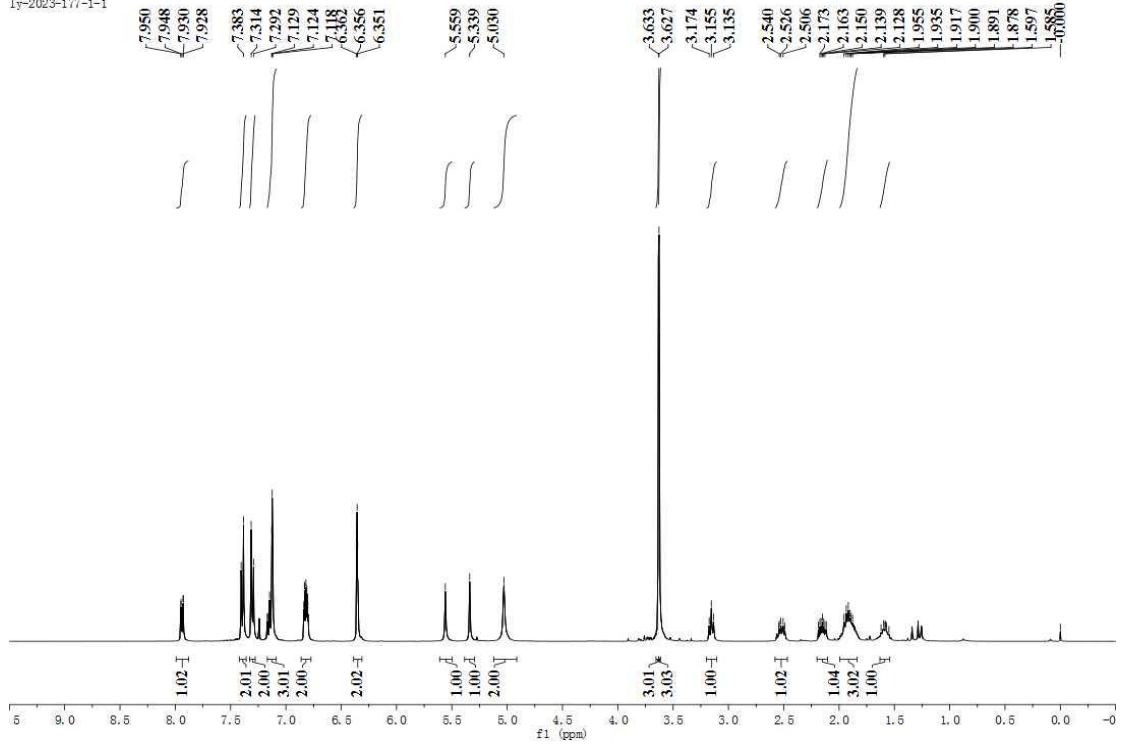


1y-2023-143-3

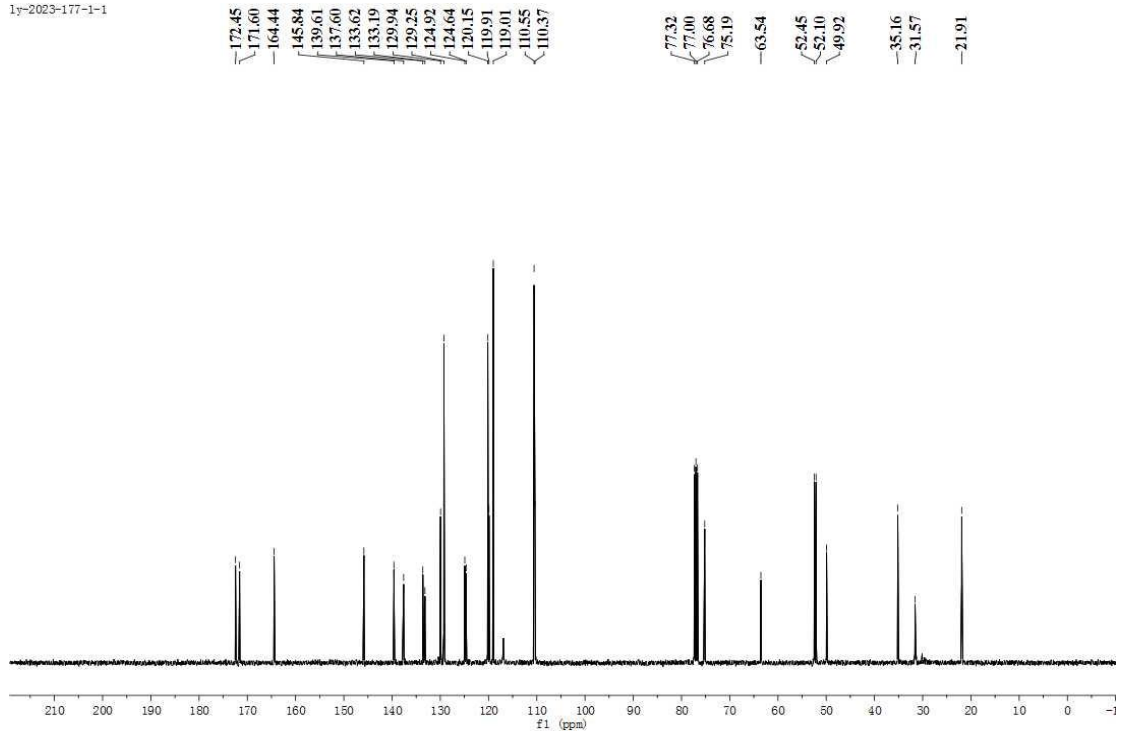


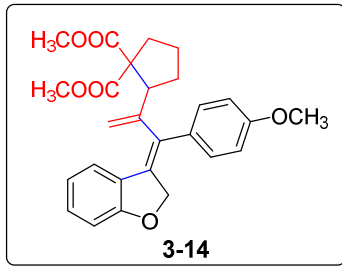


1y-2023-177-1-1

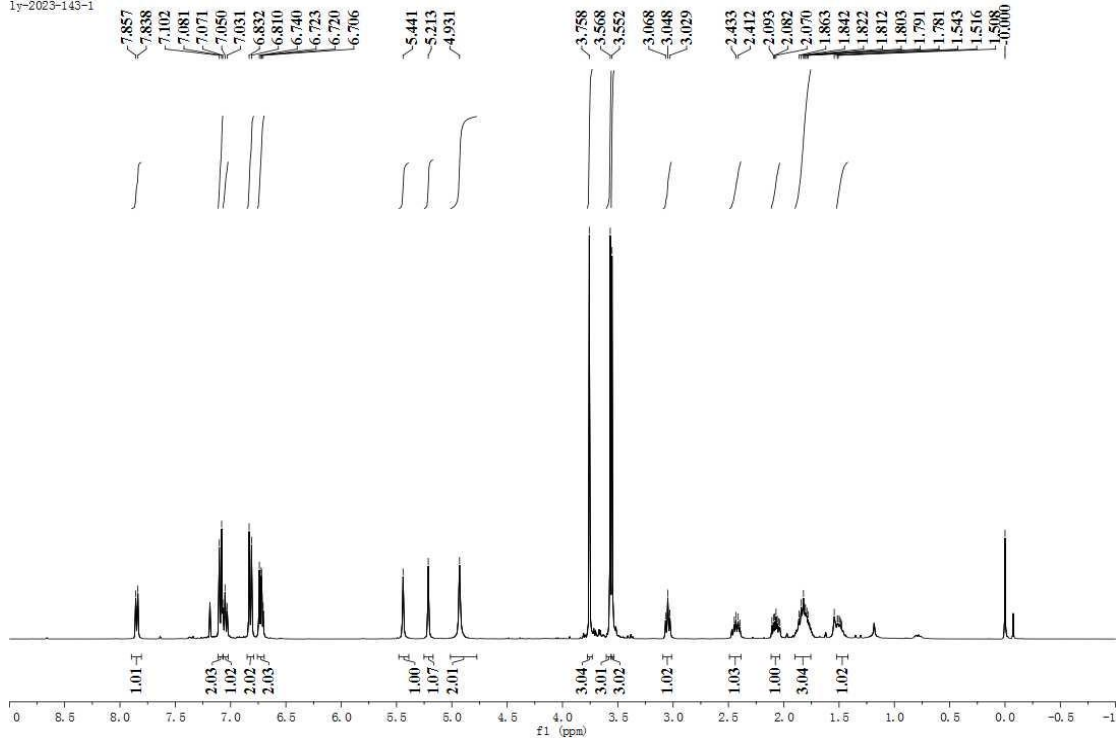


1y-2023-177-1-1

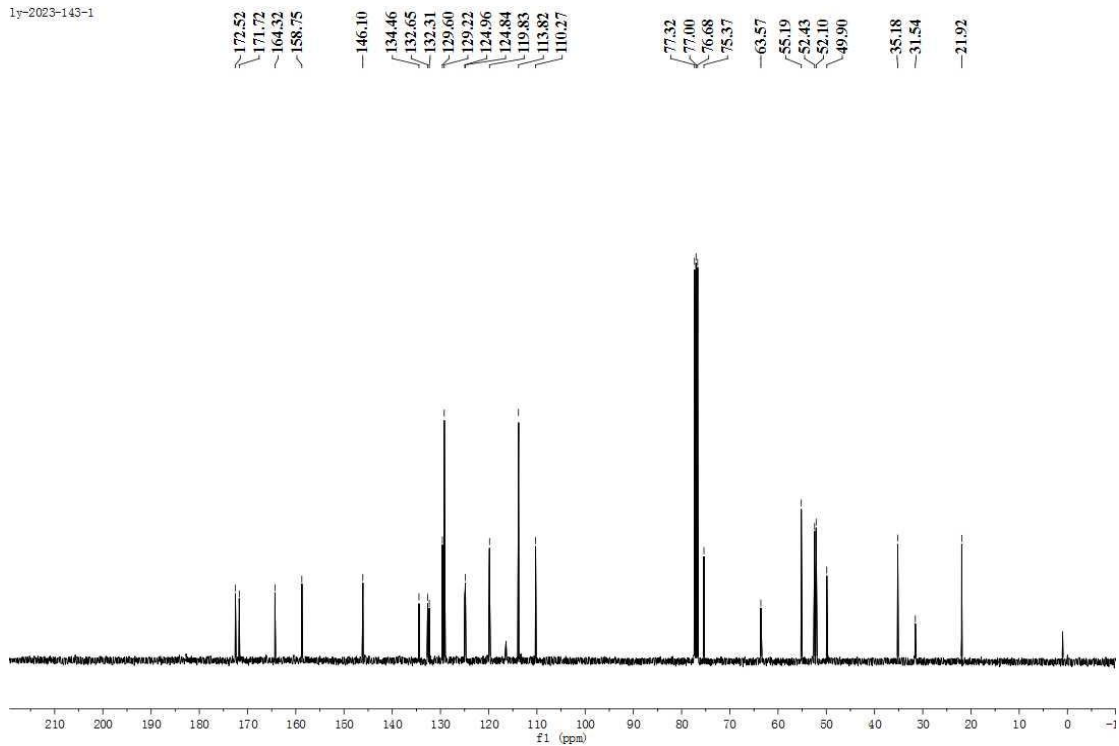


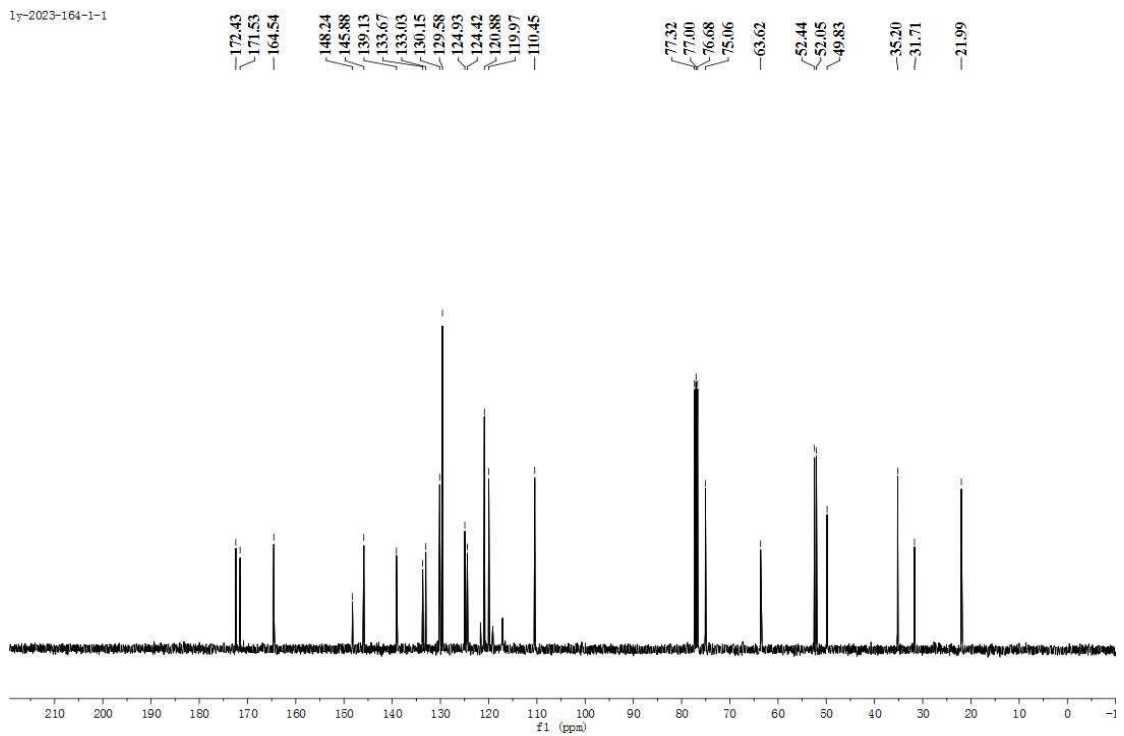
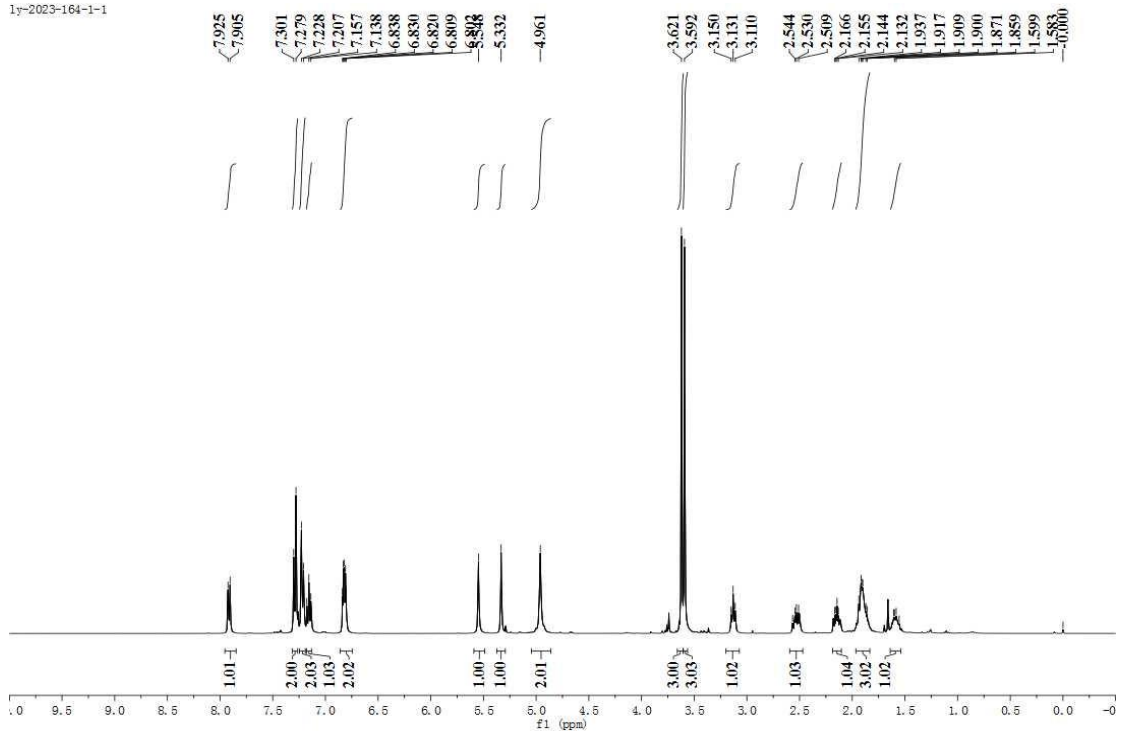
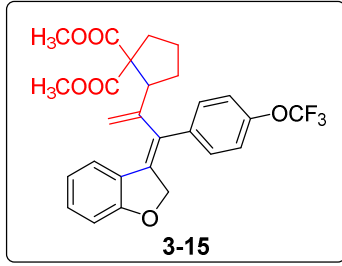


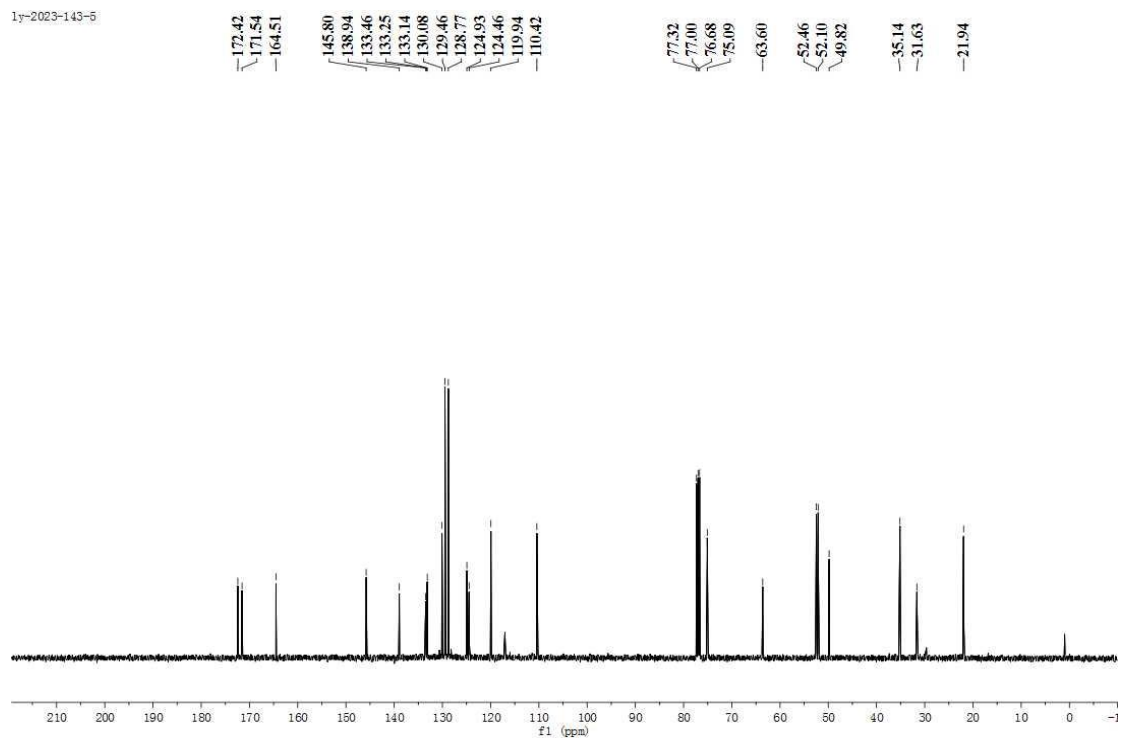
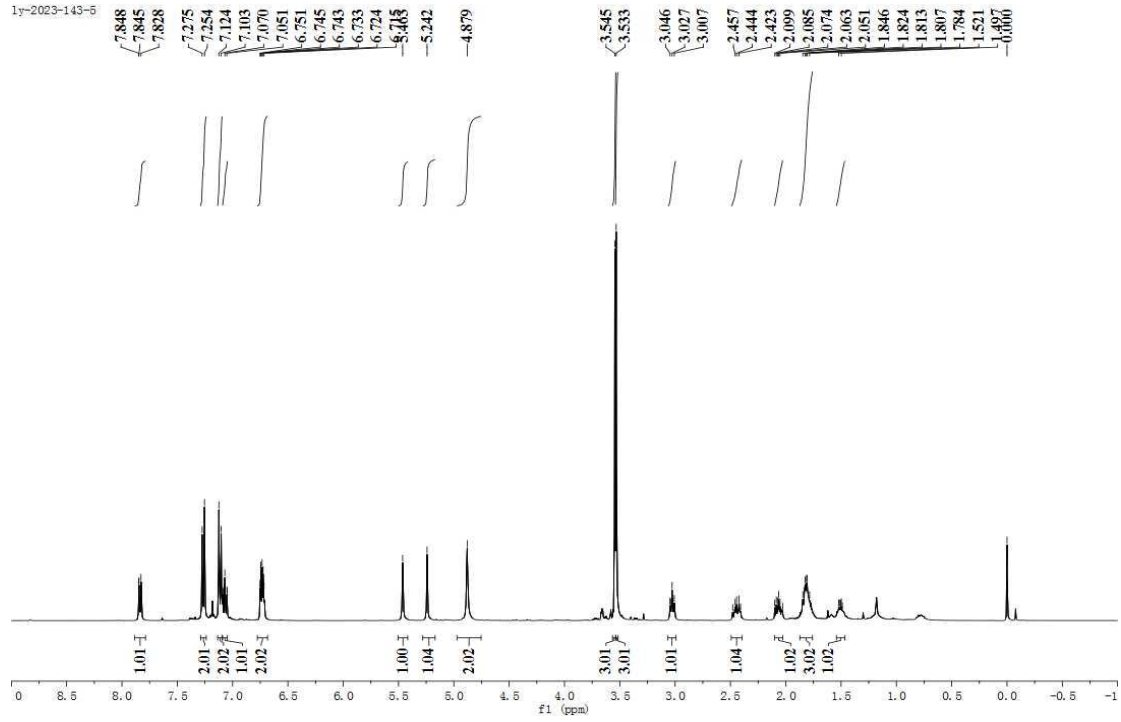
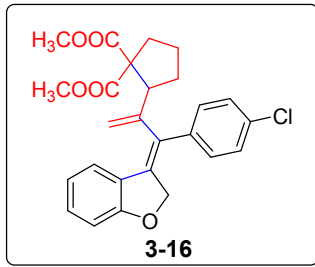
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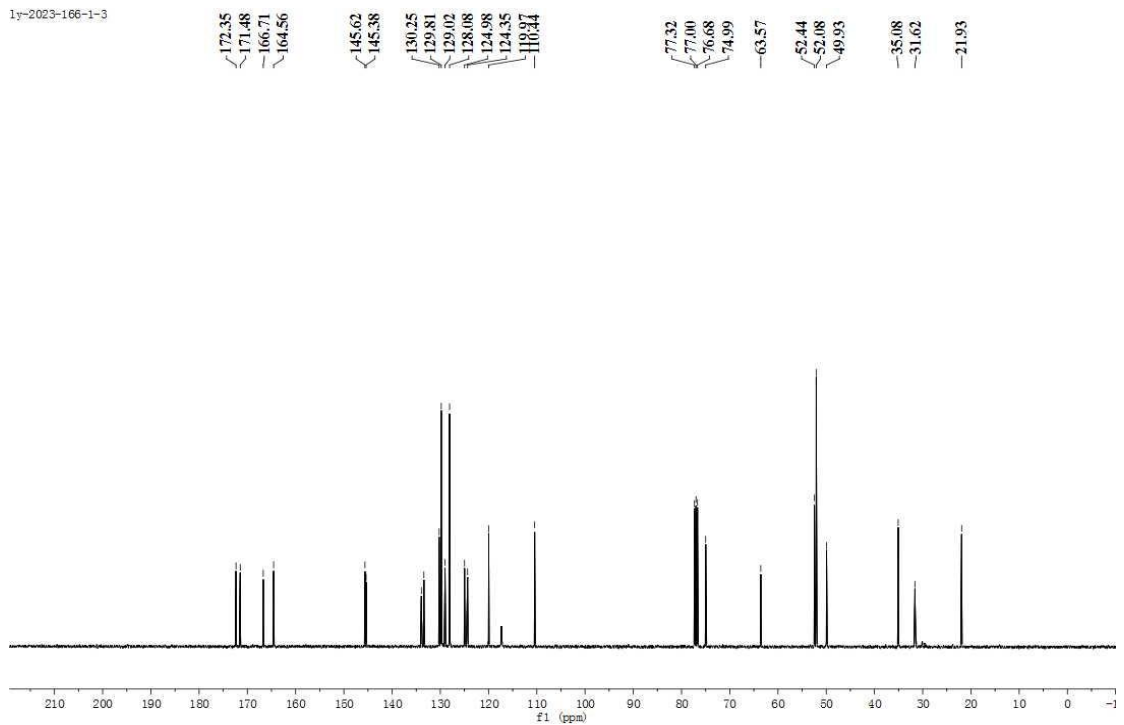
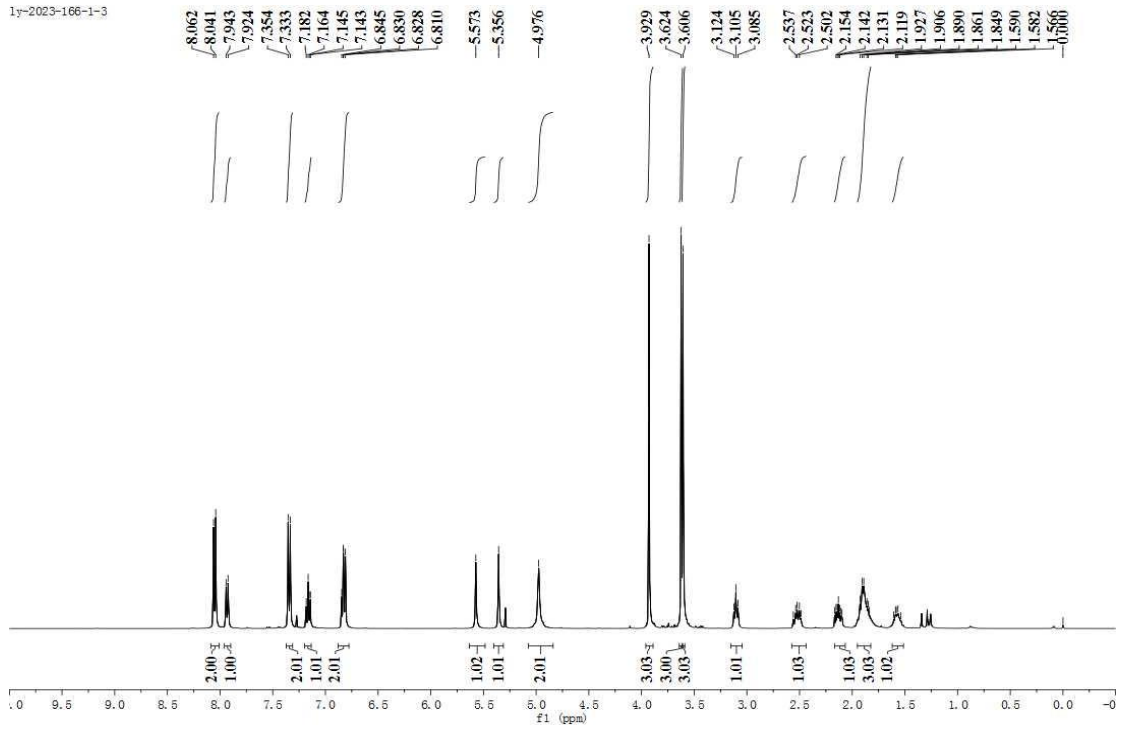
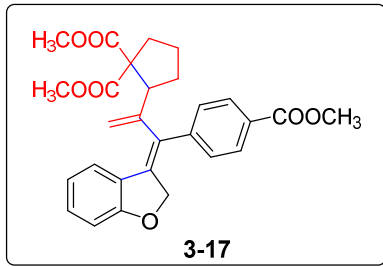


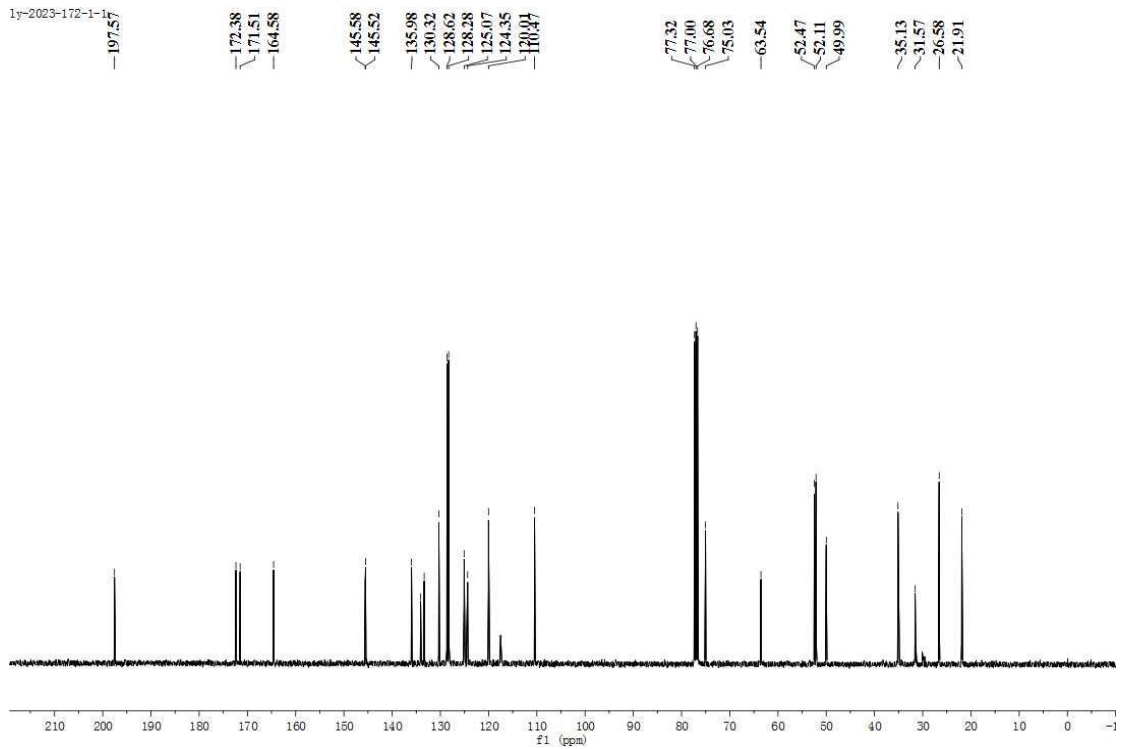
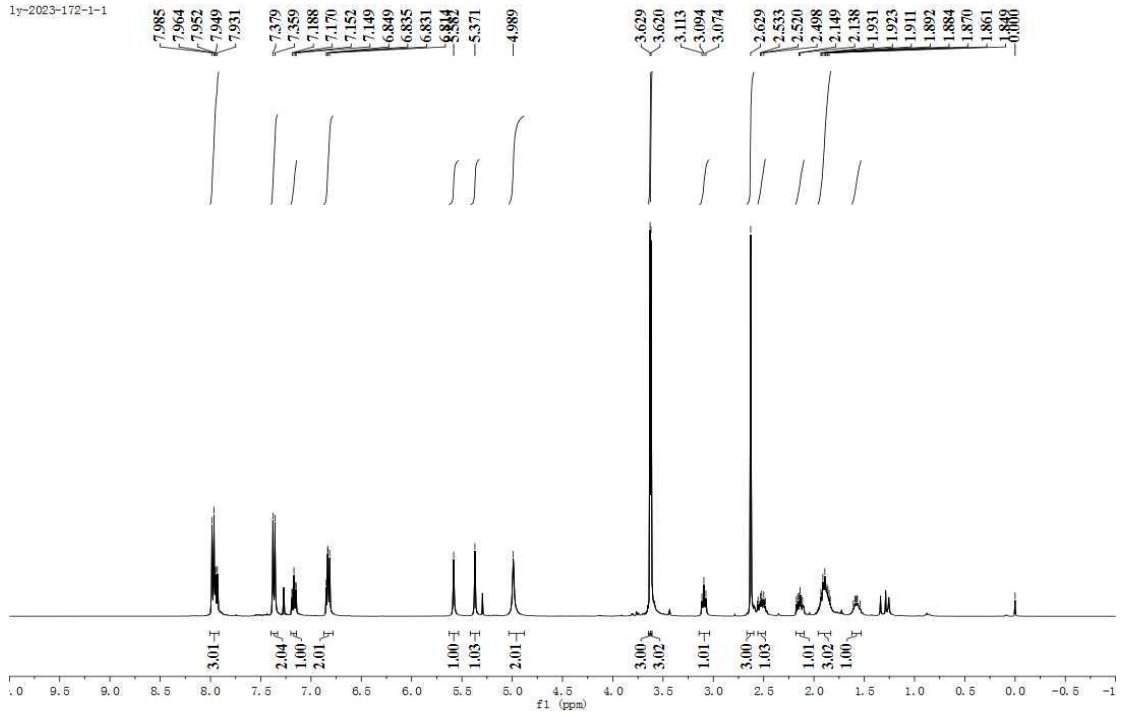
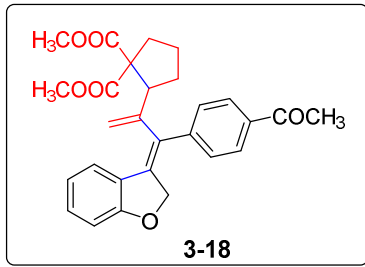
1y-2023-143-1



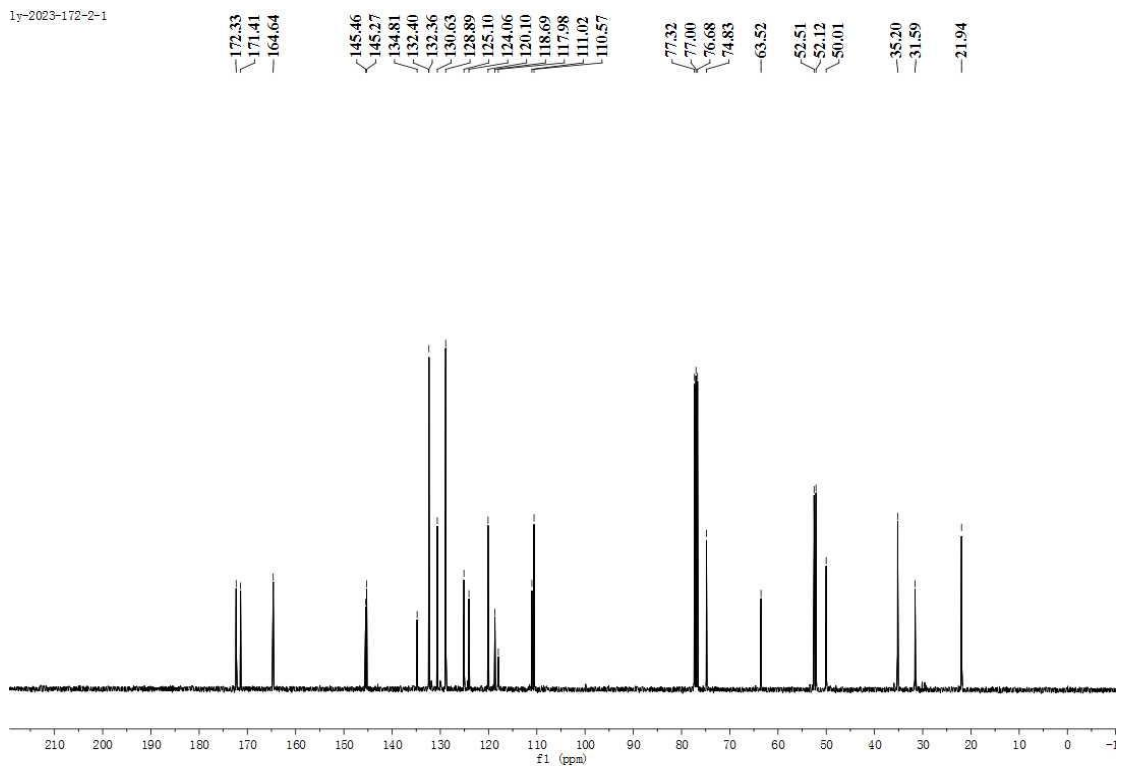
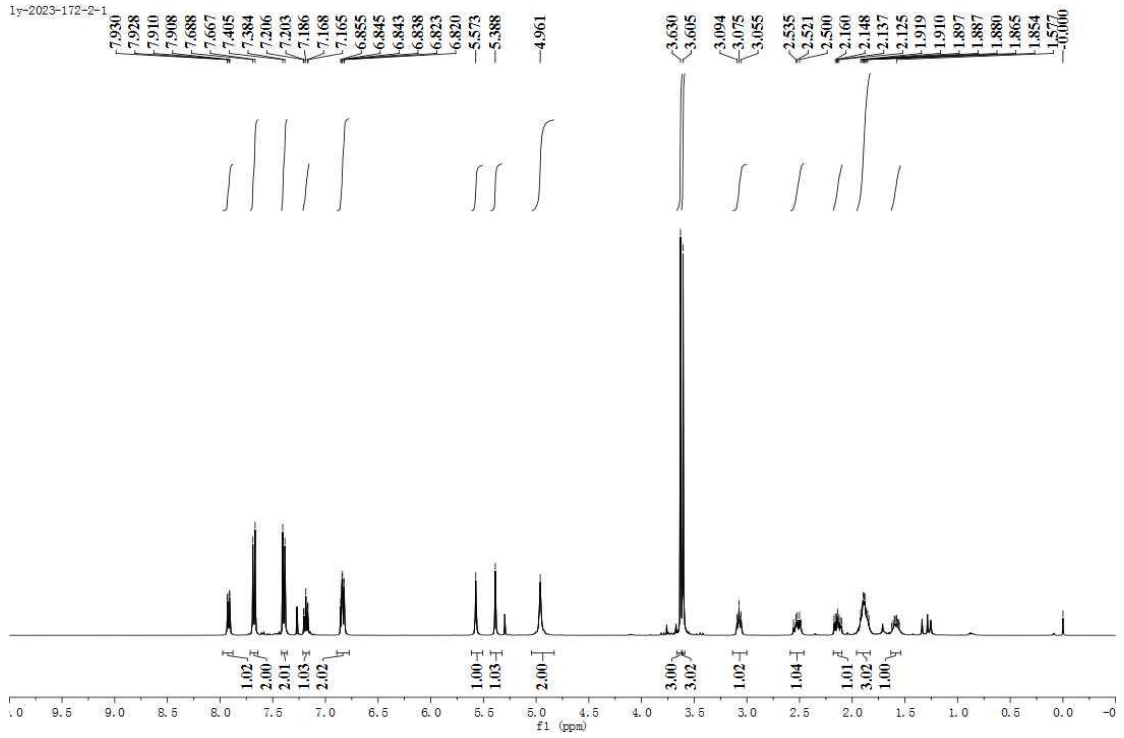
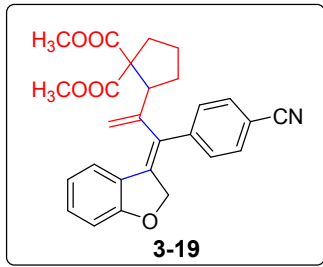


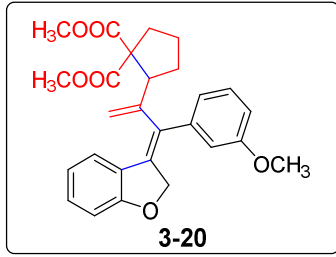




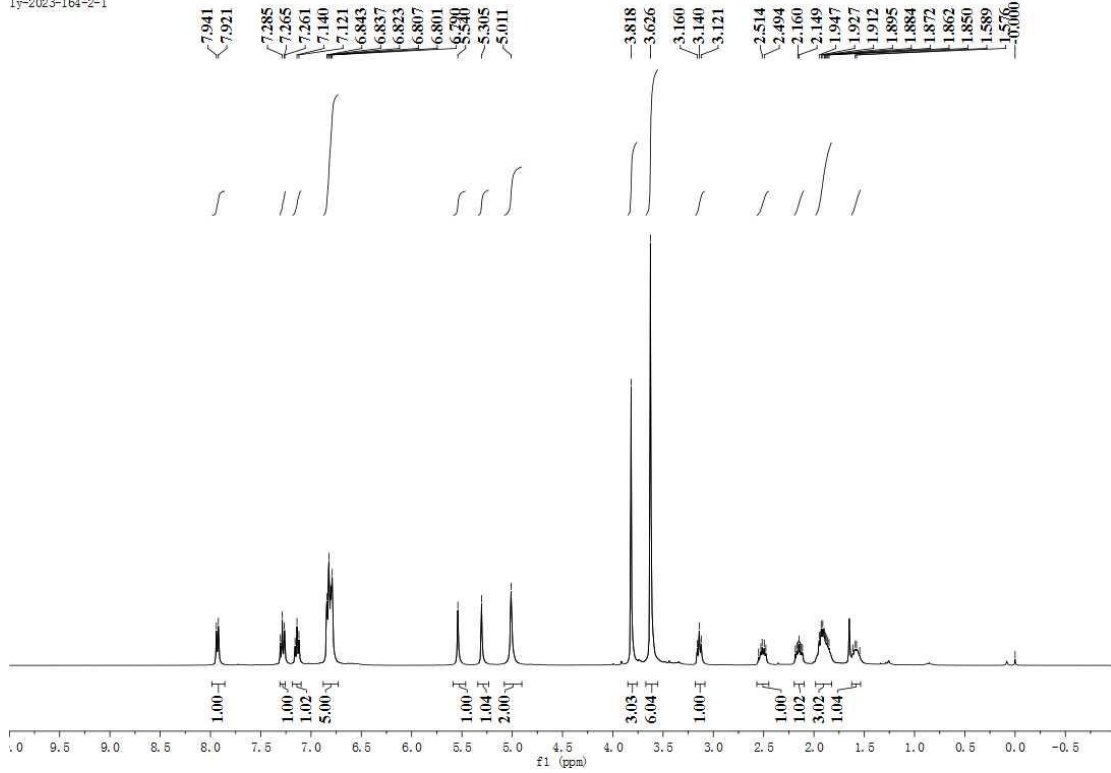




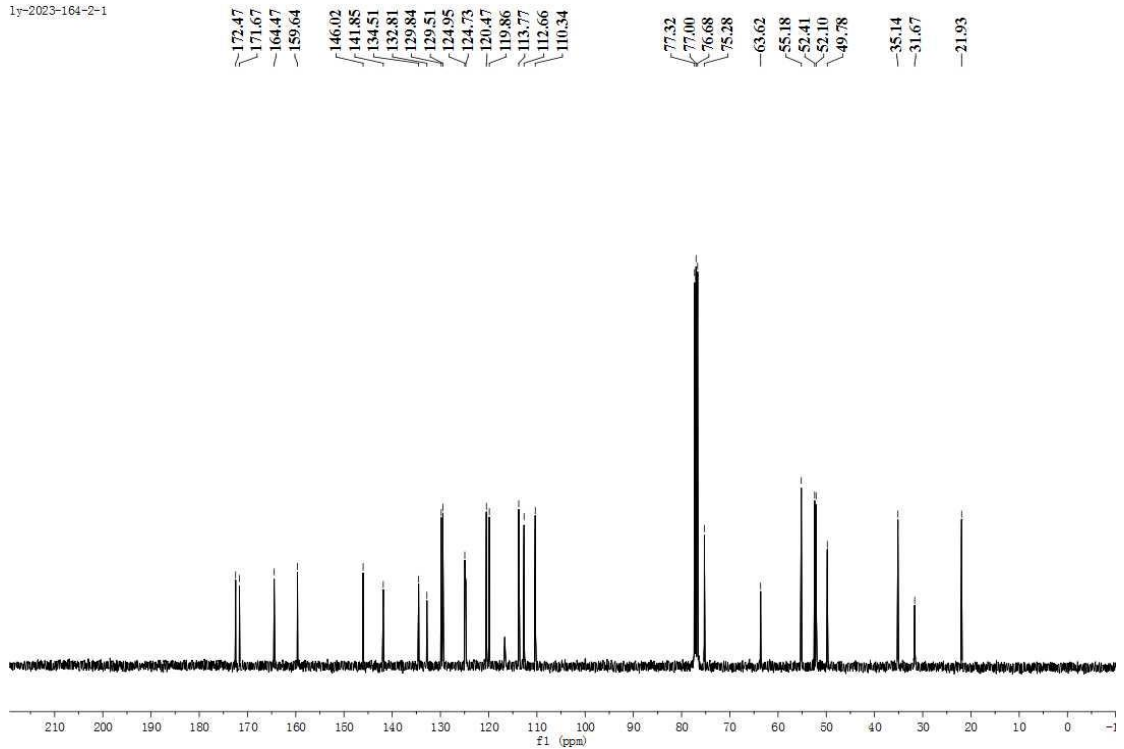


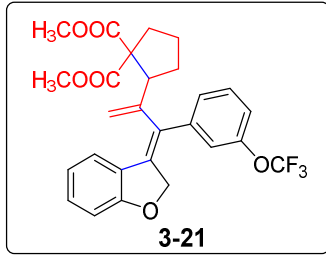


1y-2023-164-2-1

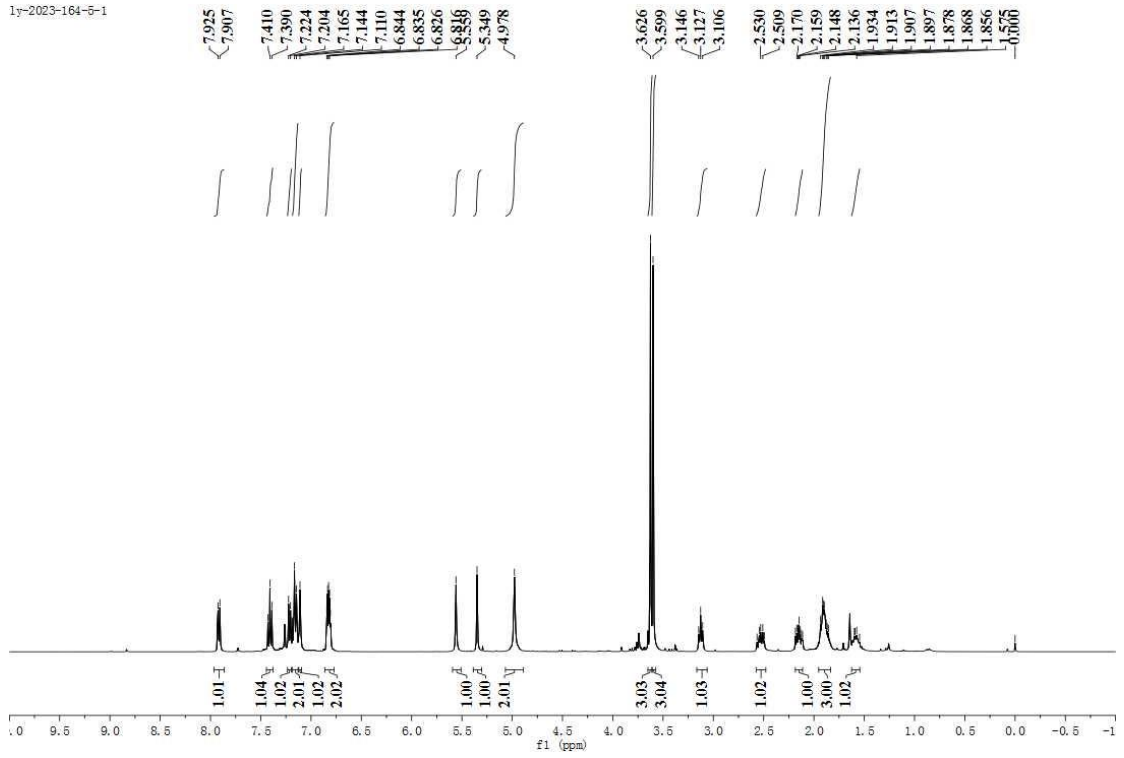


1y-2023-164-2-1

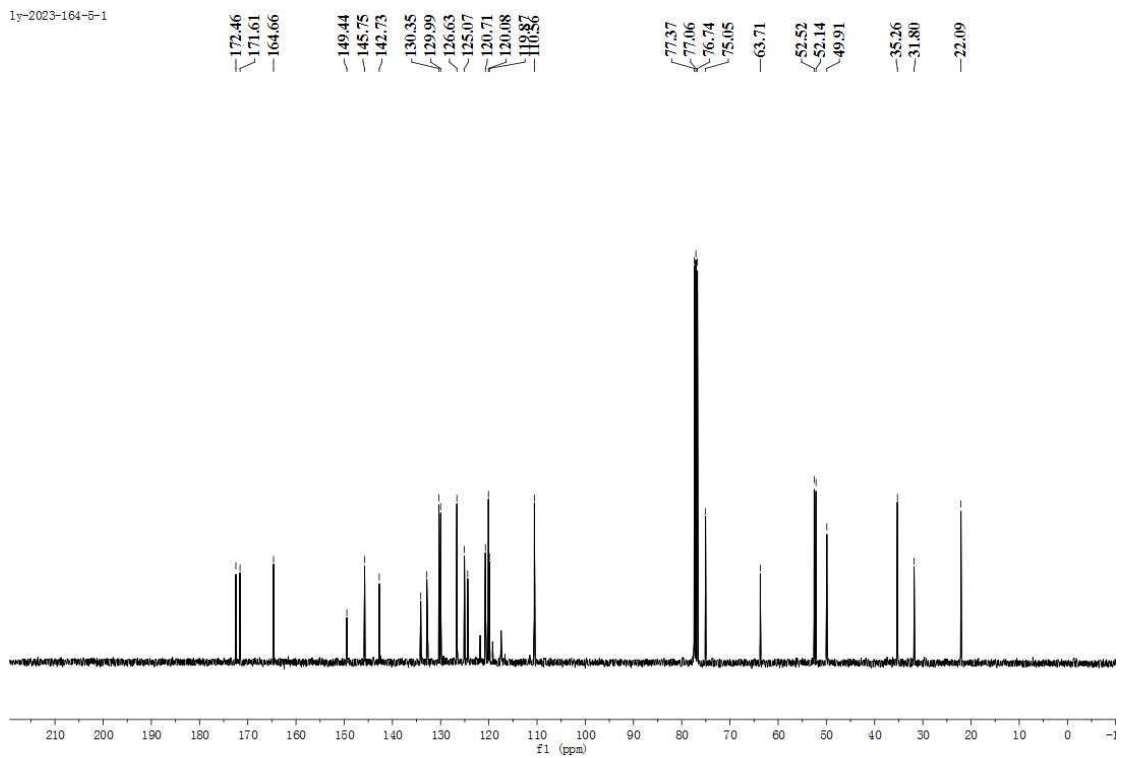


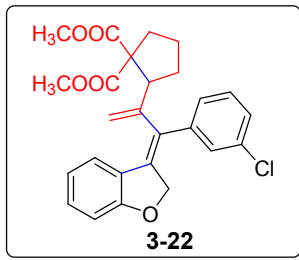


1y-2023-164-5-1

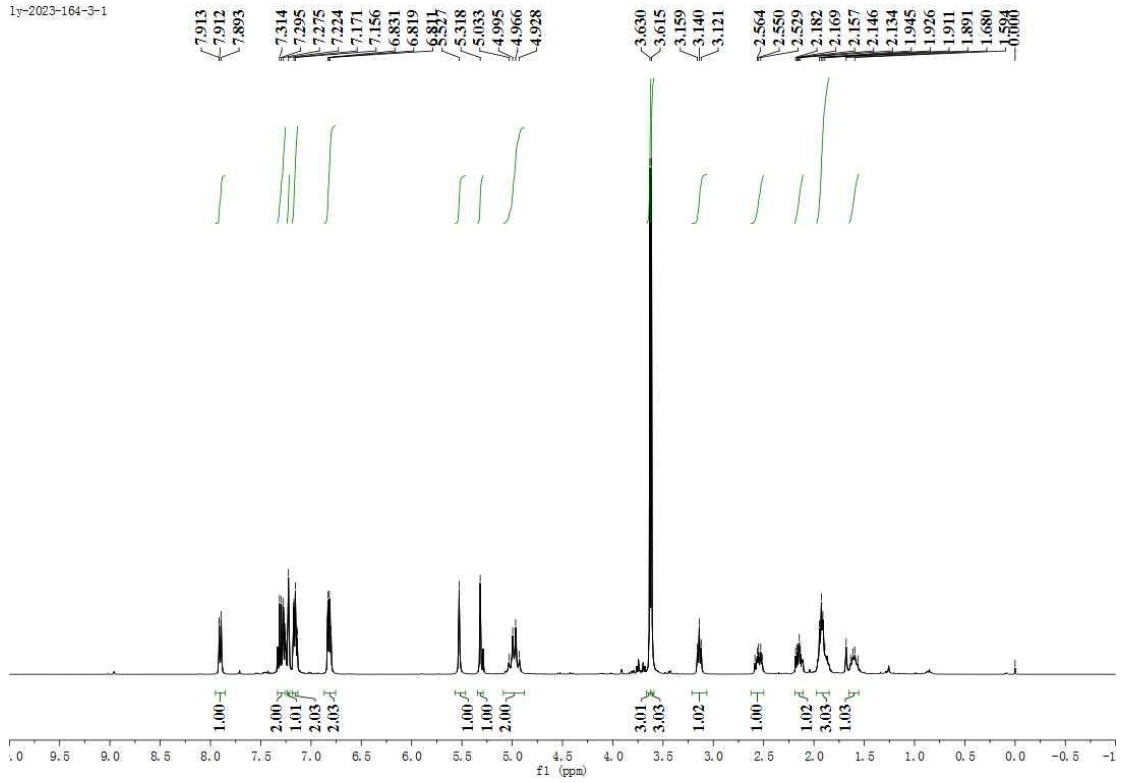


1y-2023-164-5-1

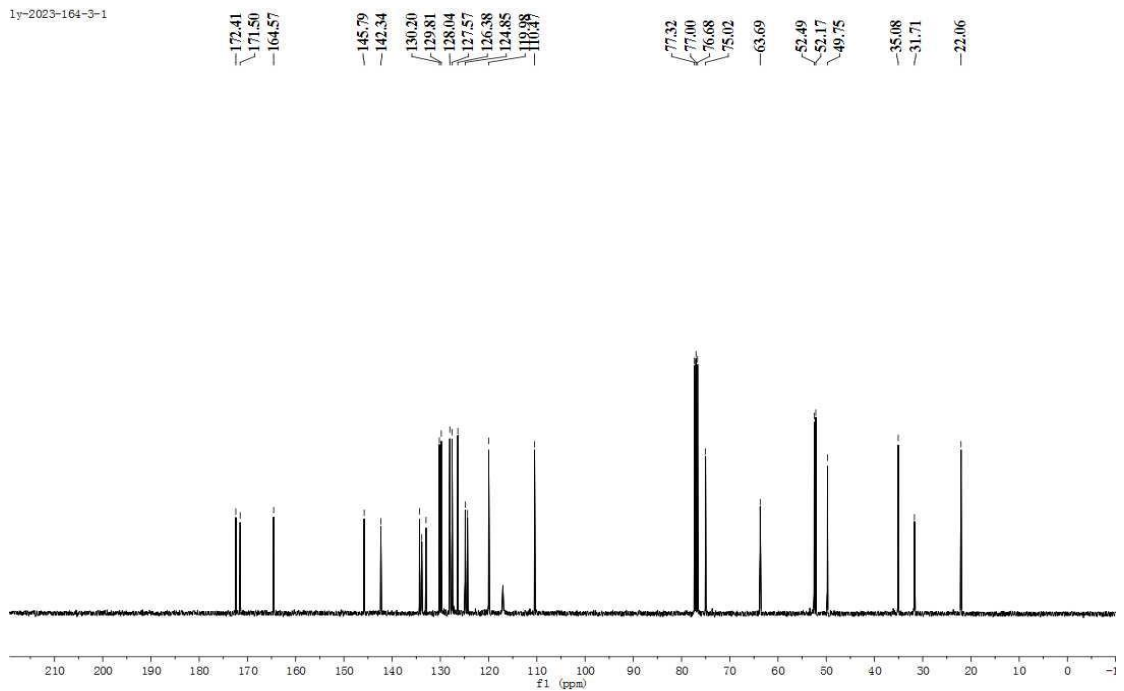


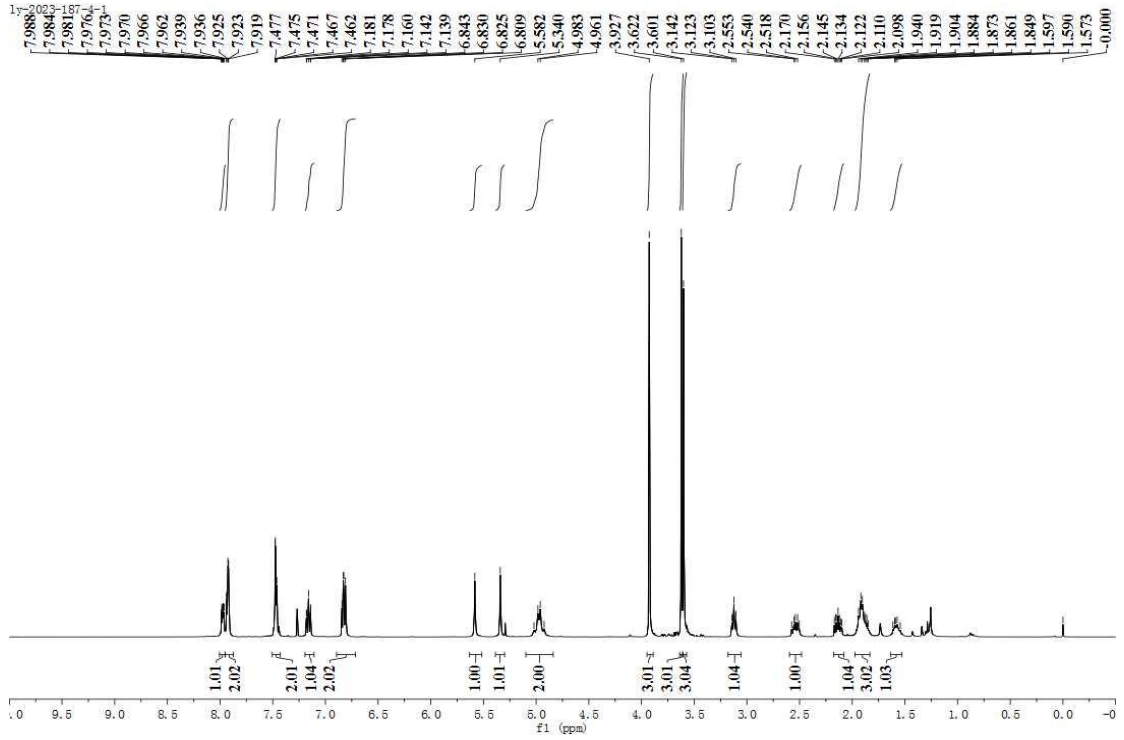
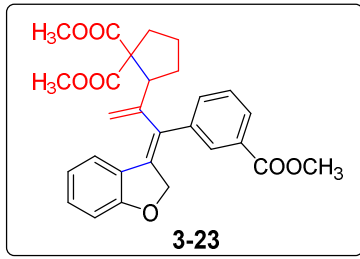


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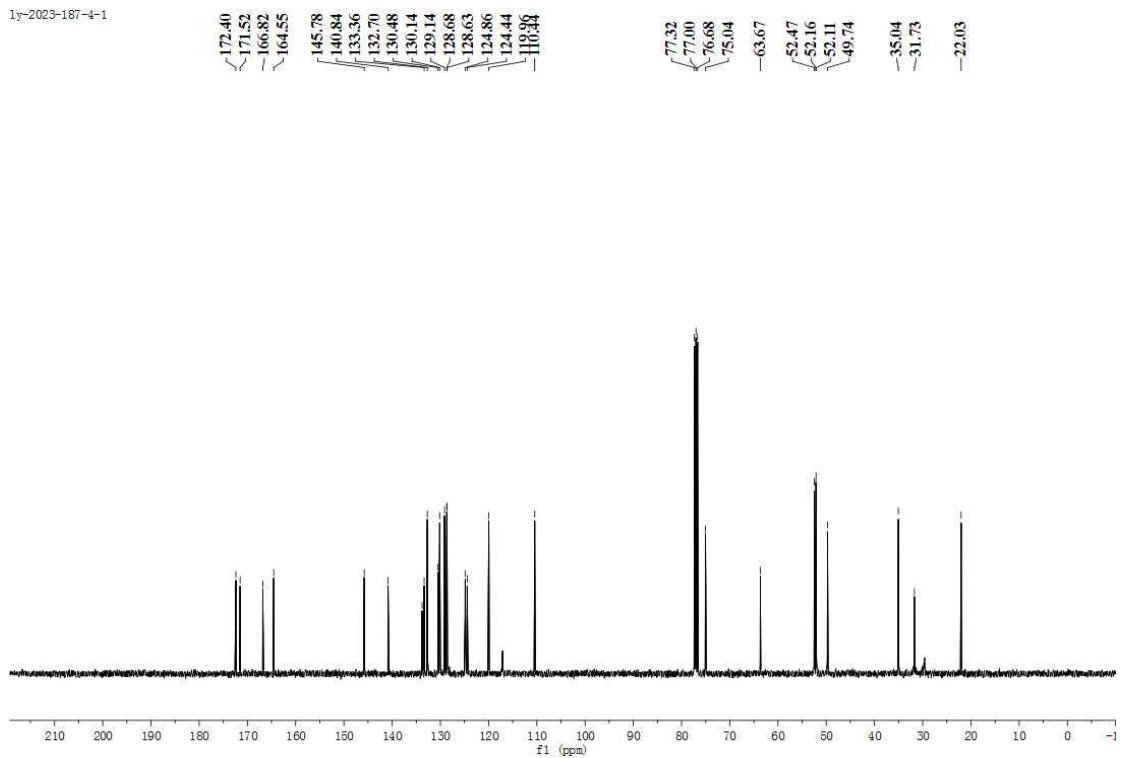


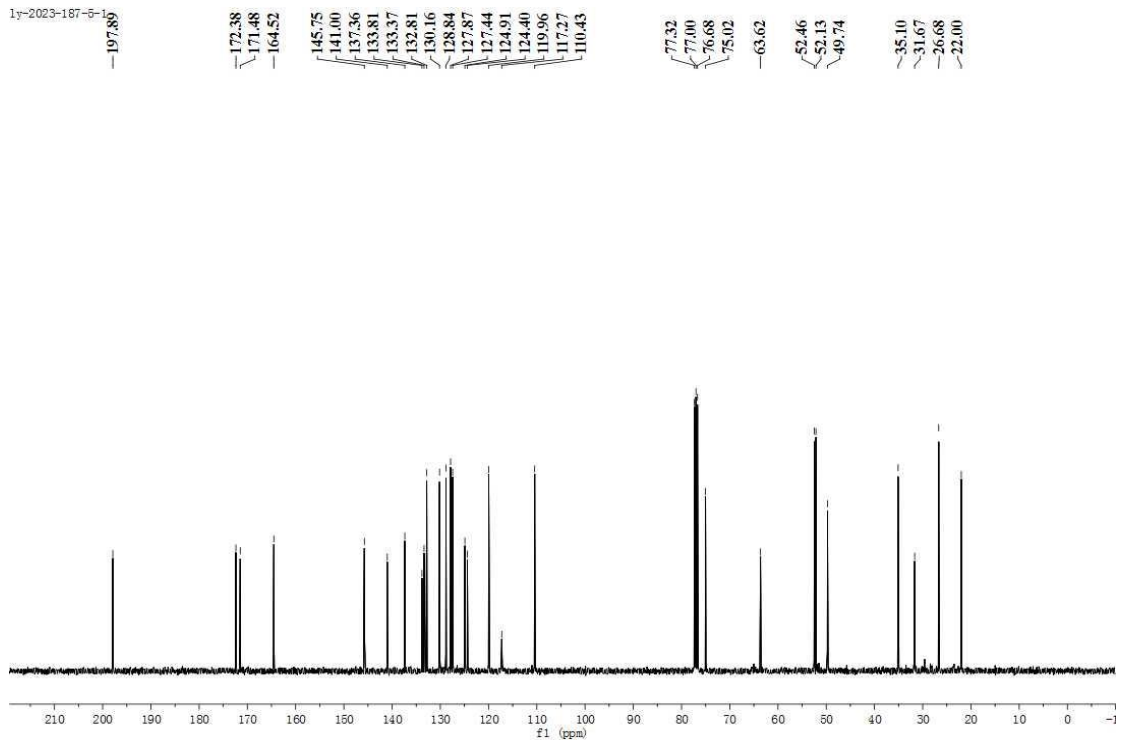
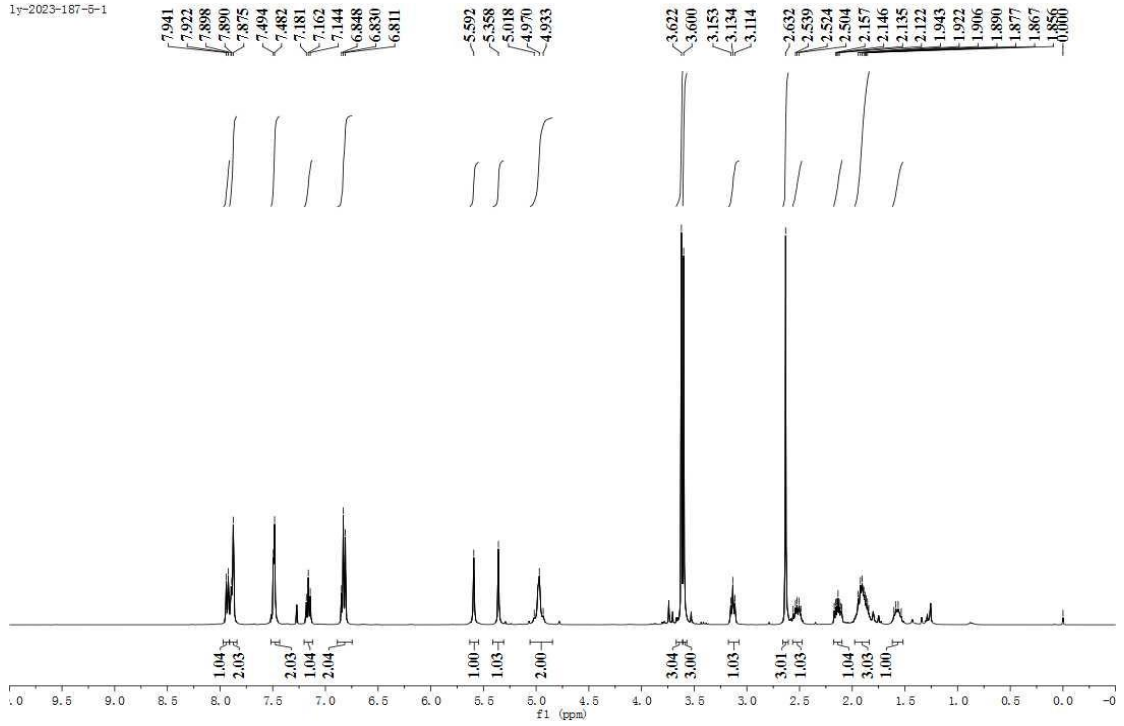
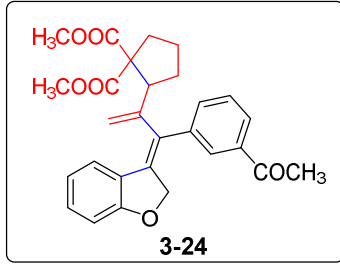
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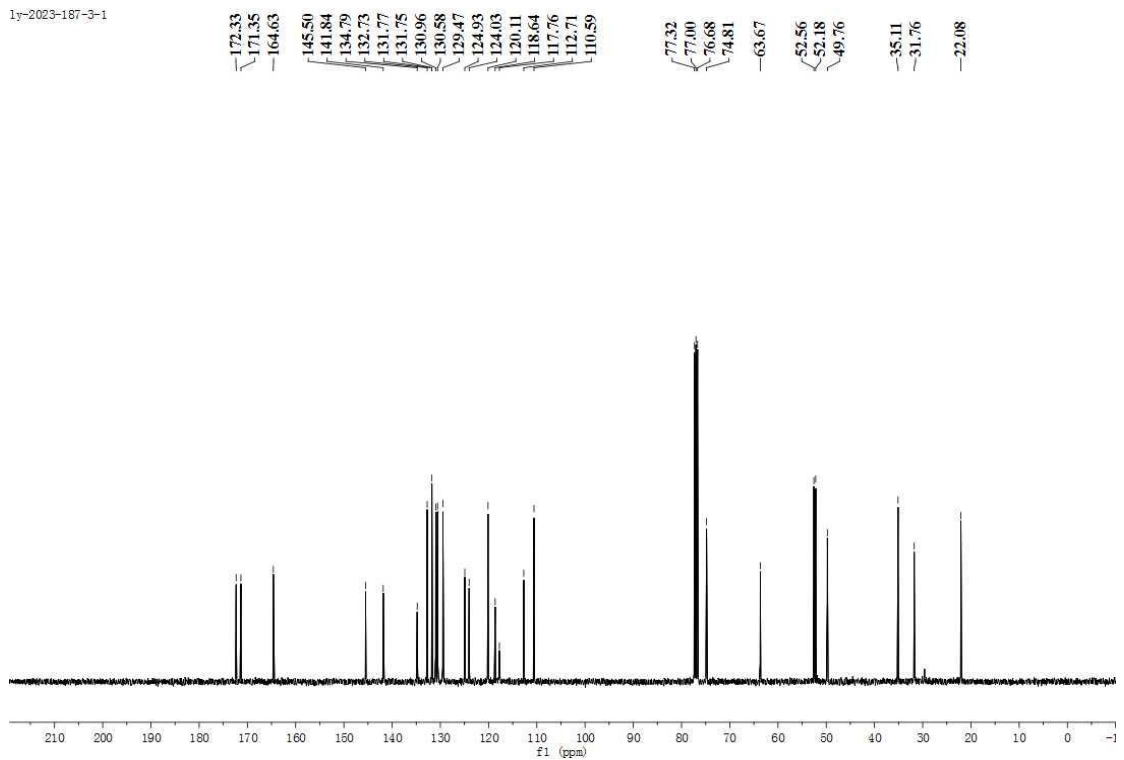
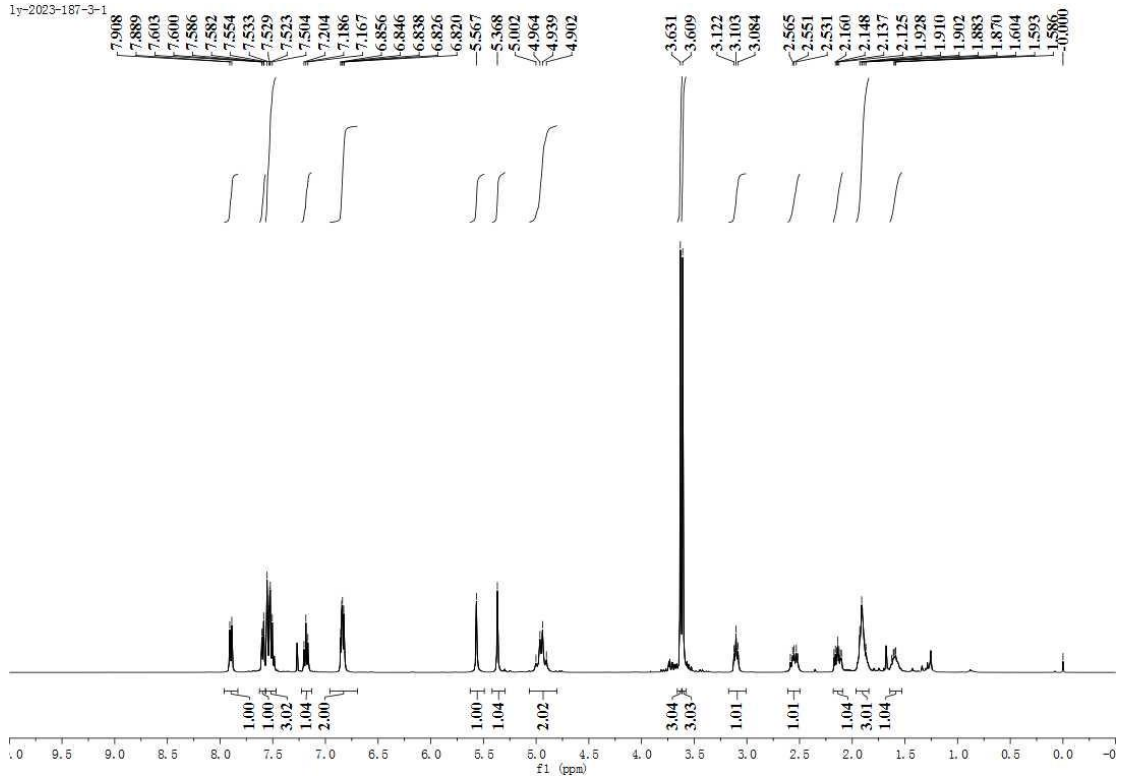
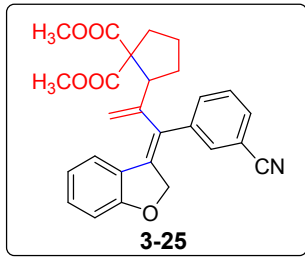


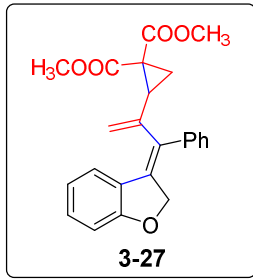


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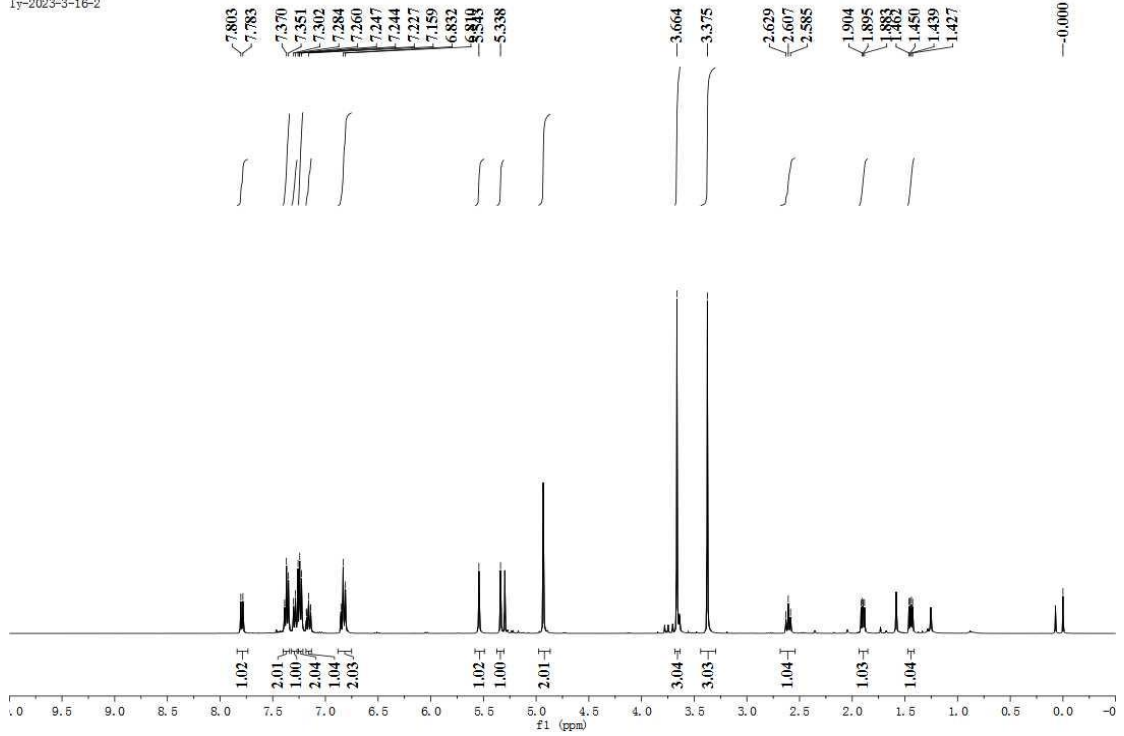




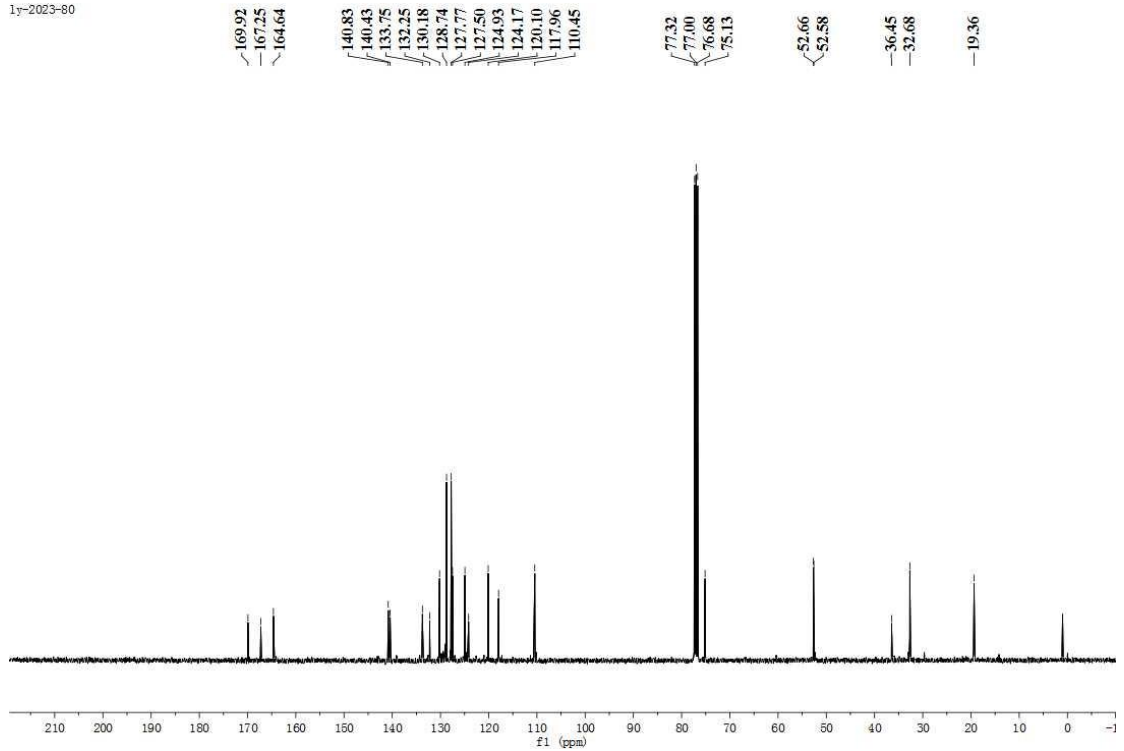




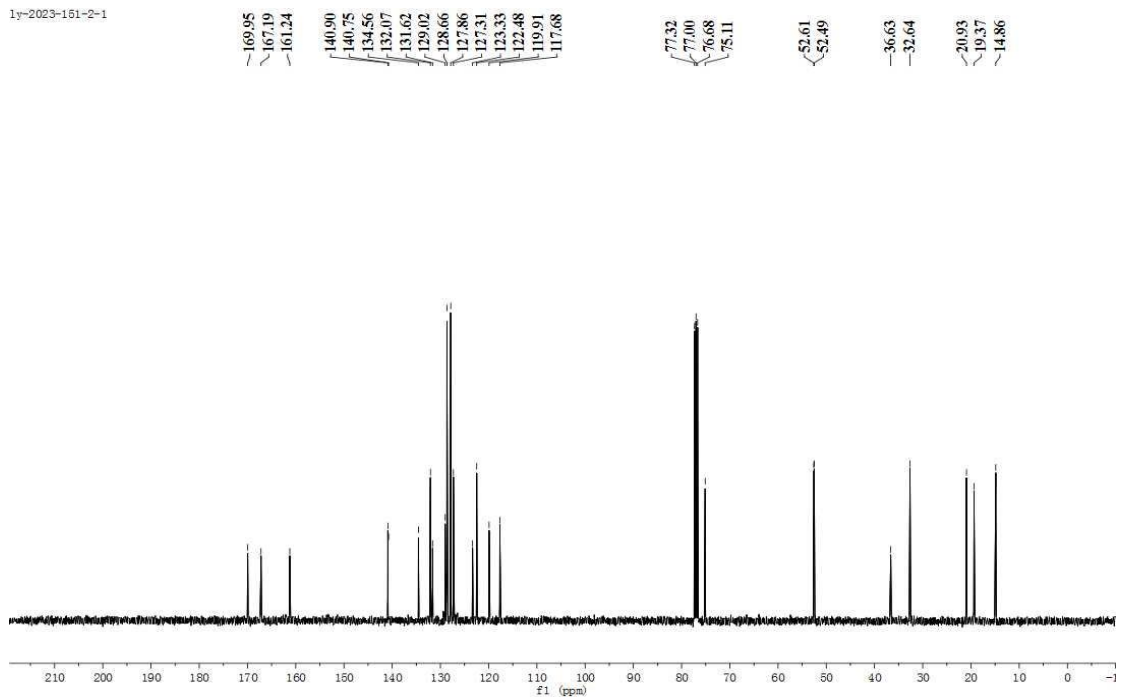
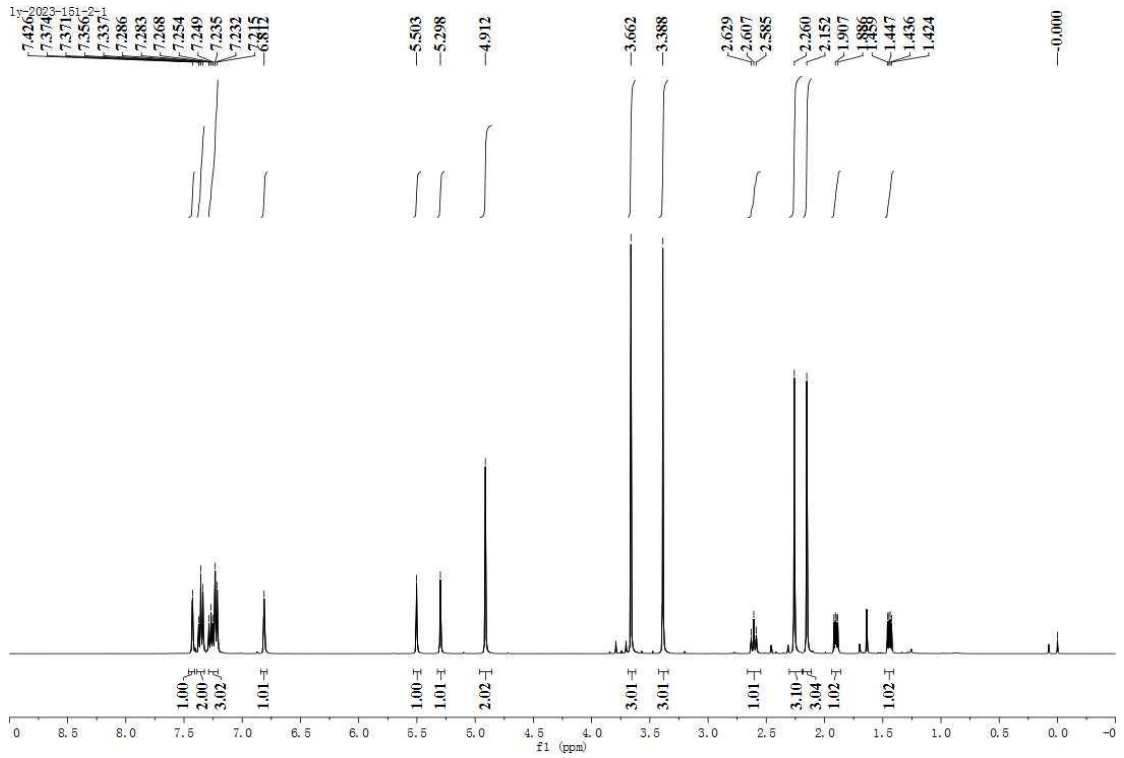
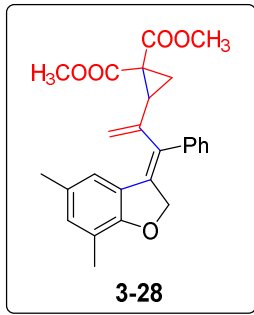
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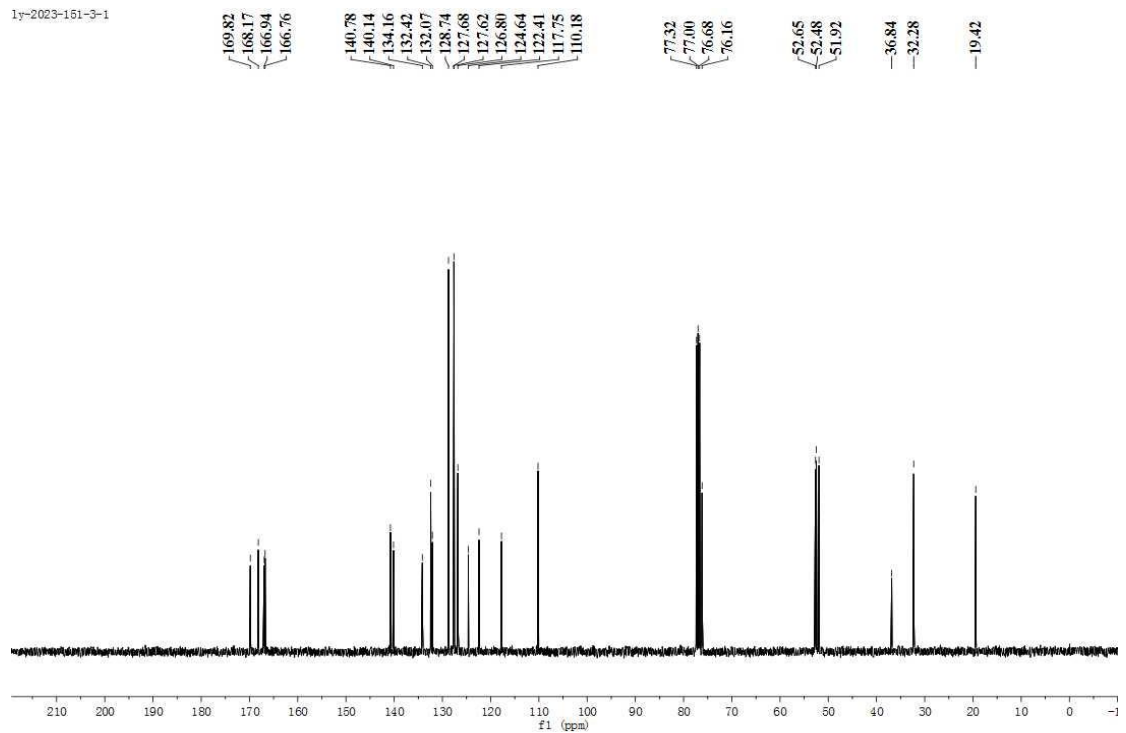
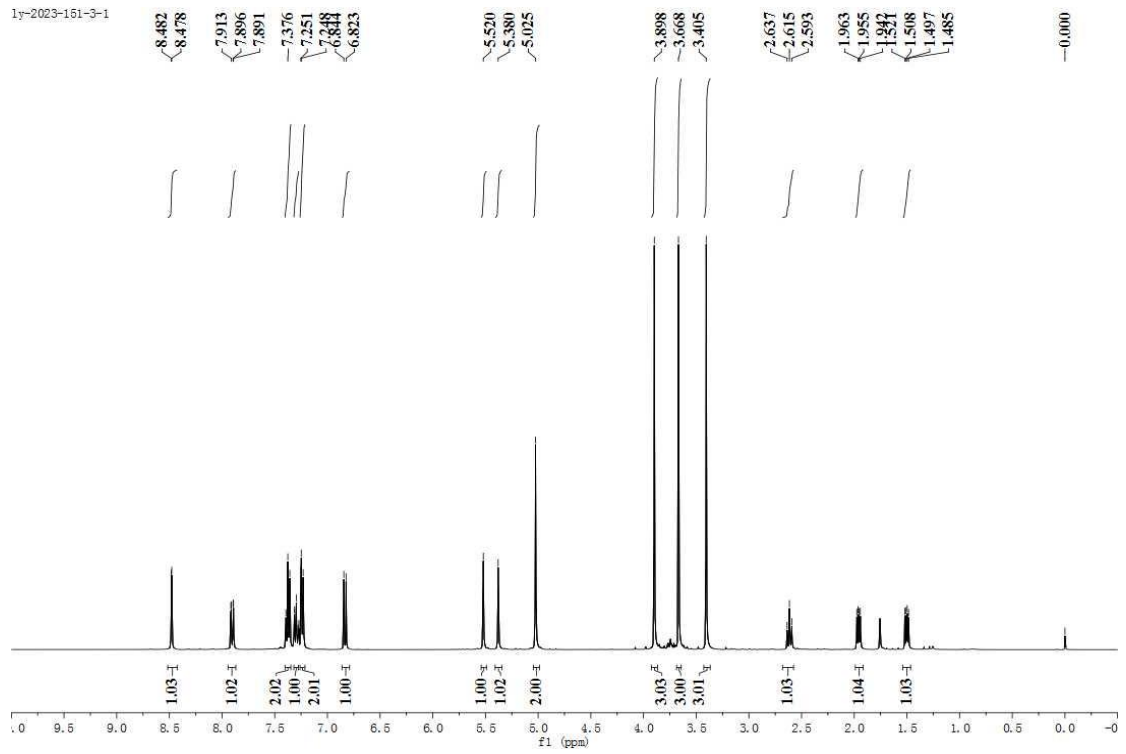
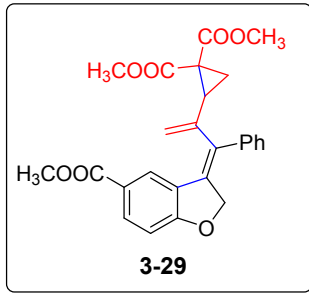


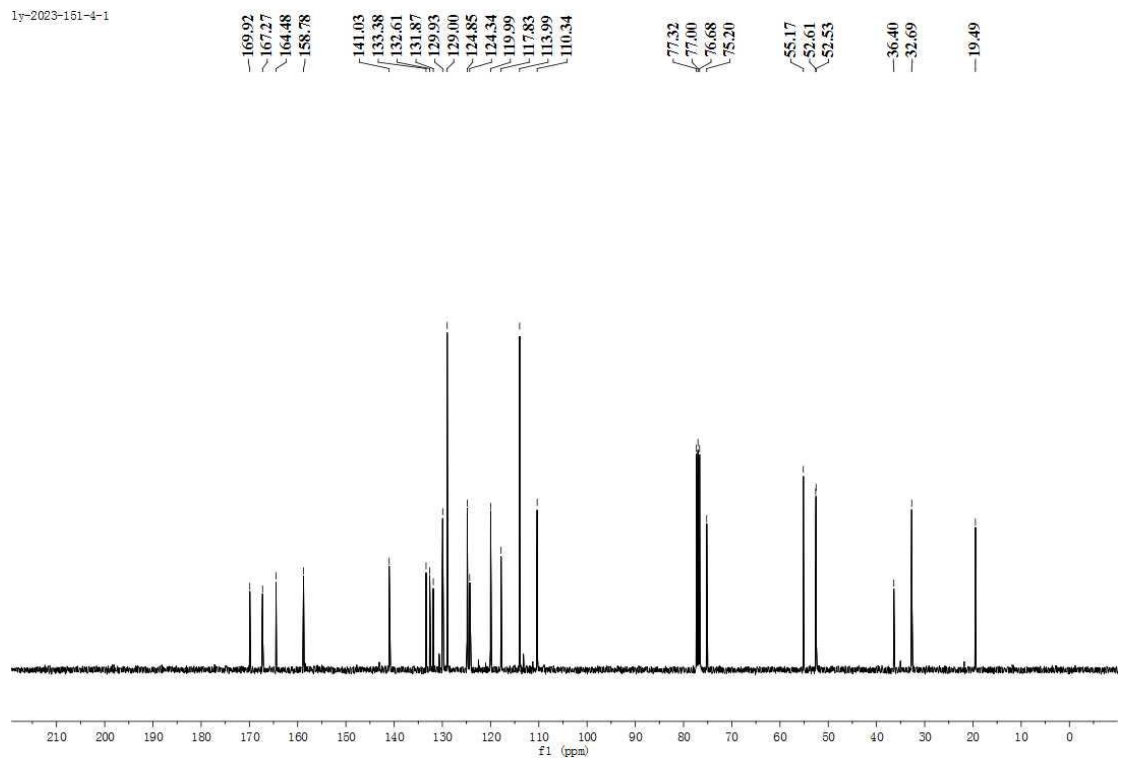
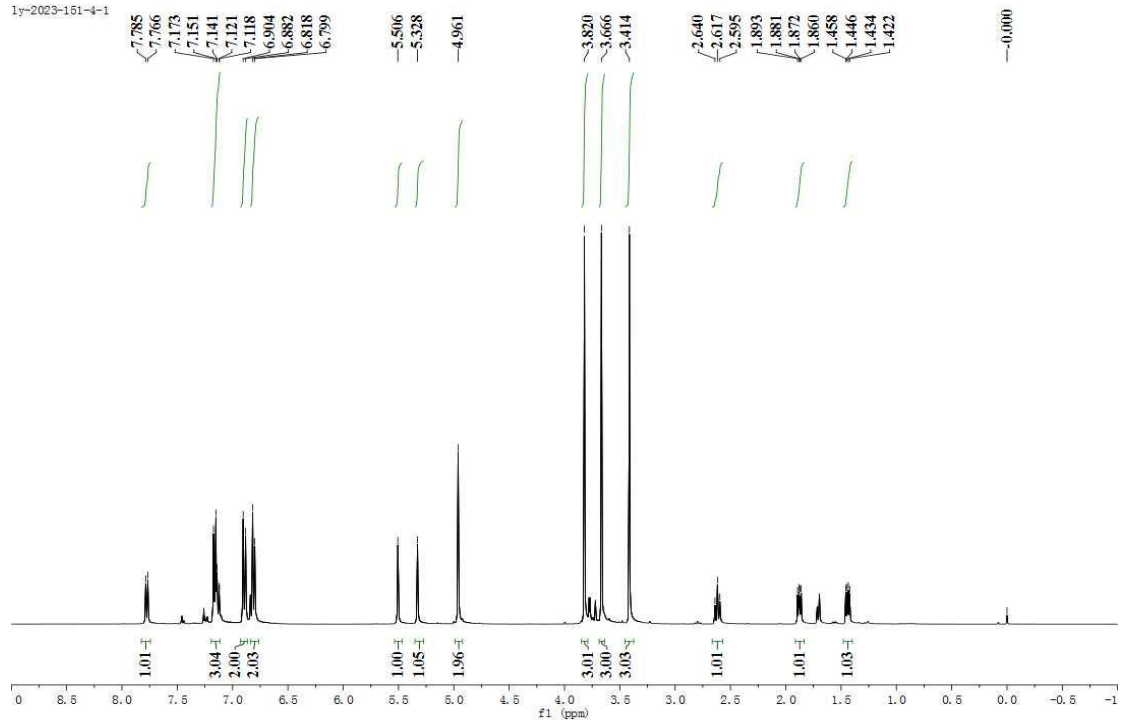
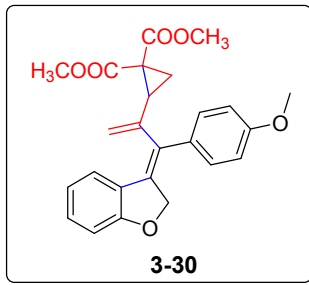
1y-2023-80

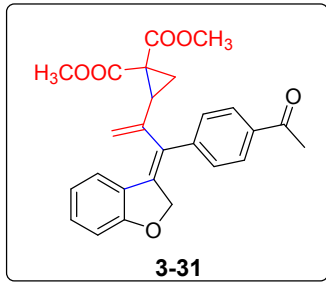




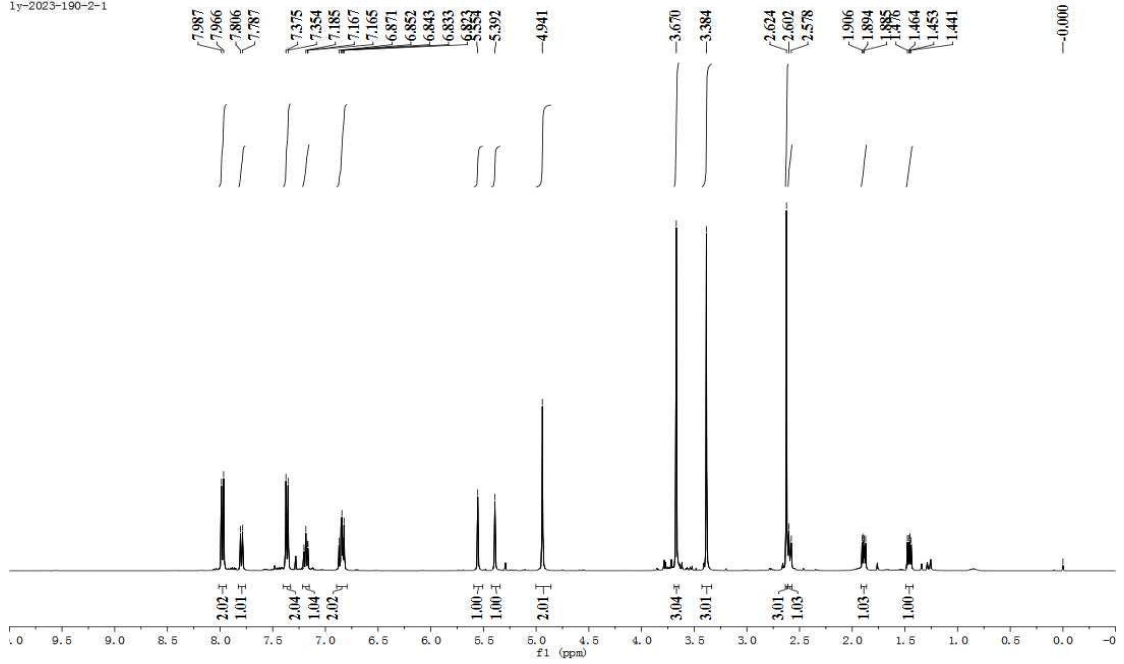




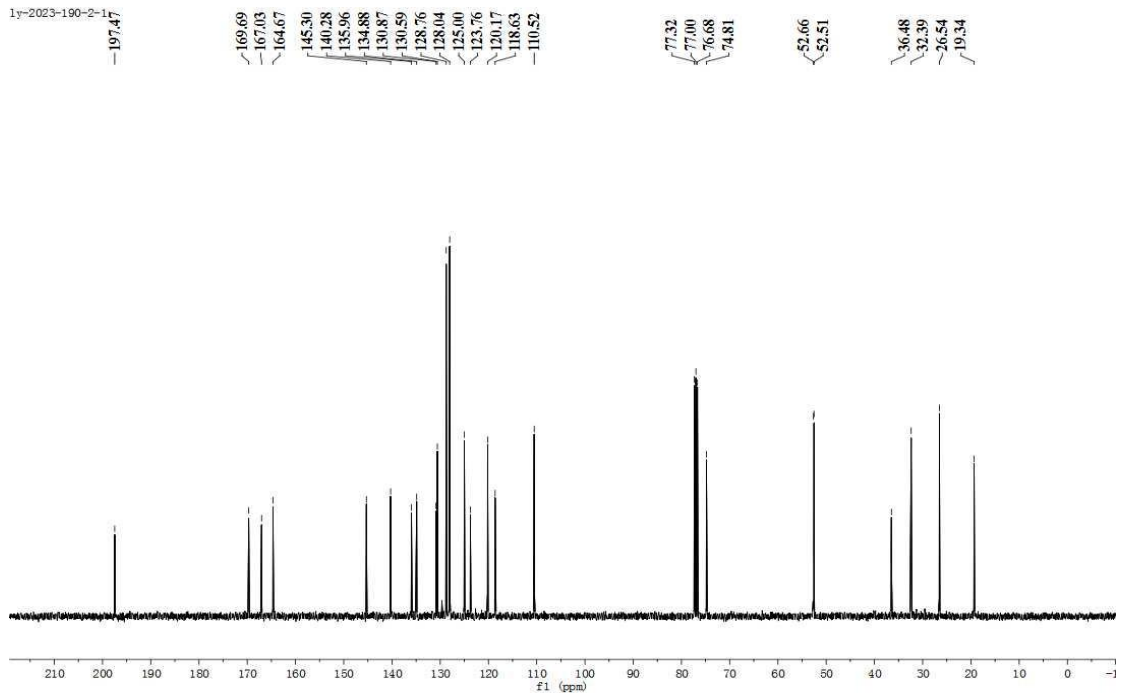


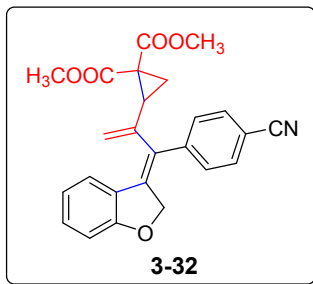


1y-2023-190-2-1

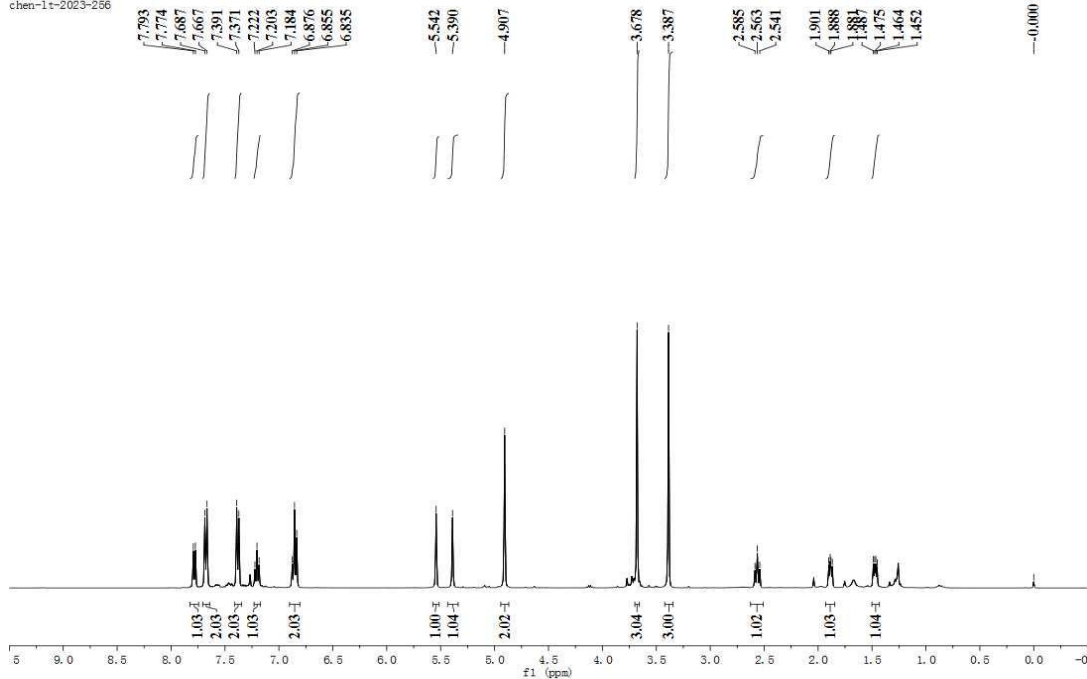


1y-2023-190-2-1

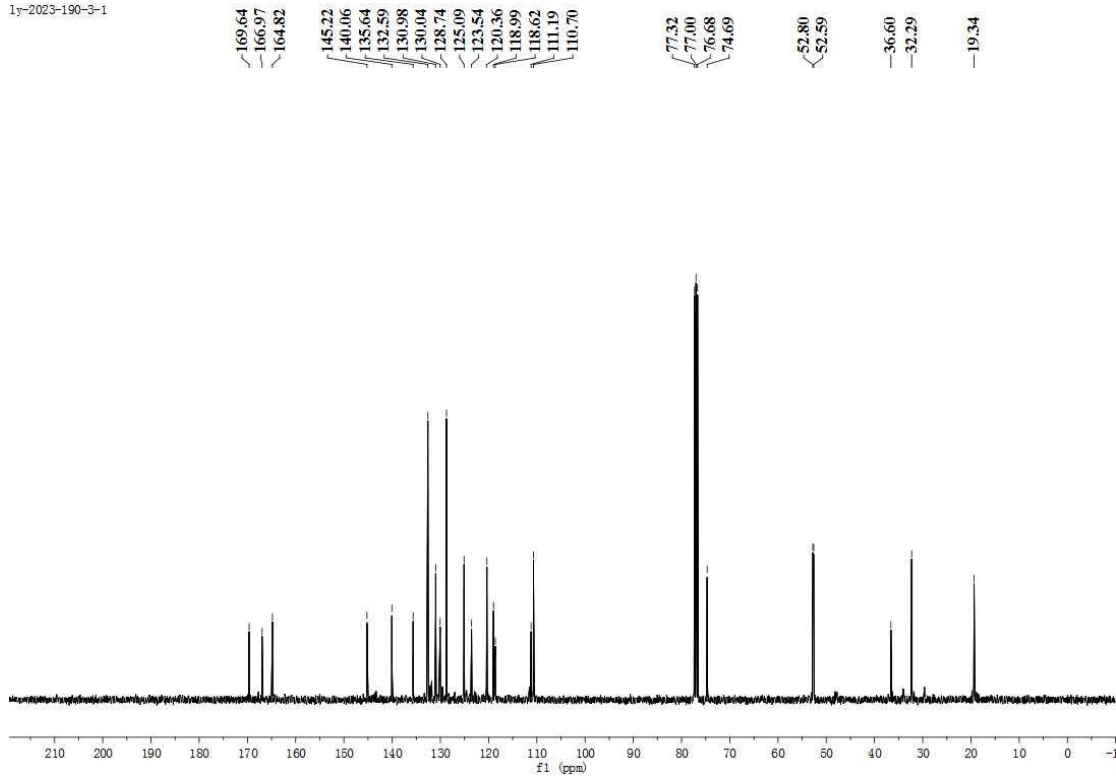


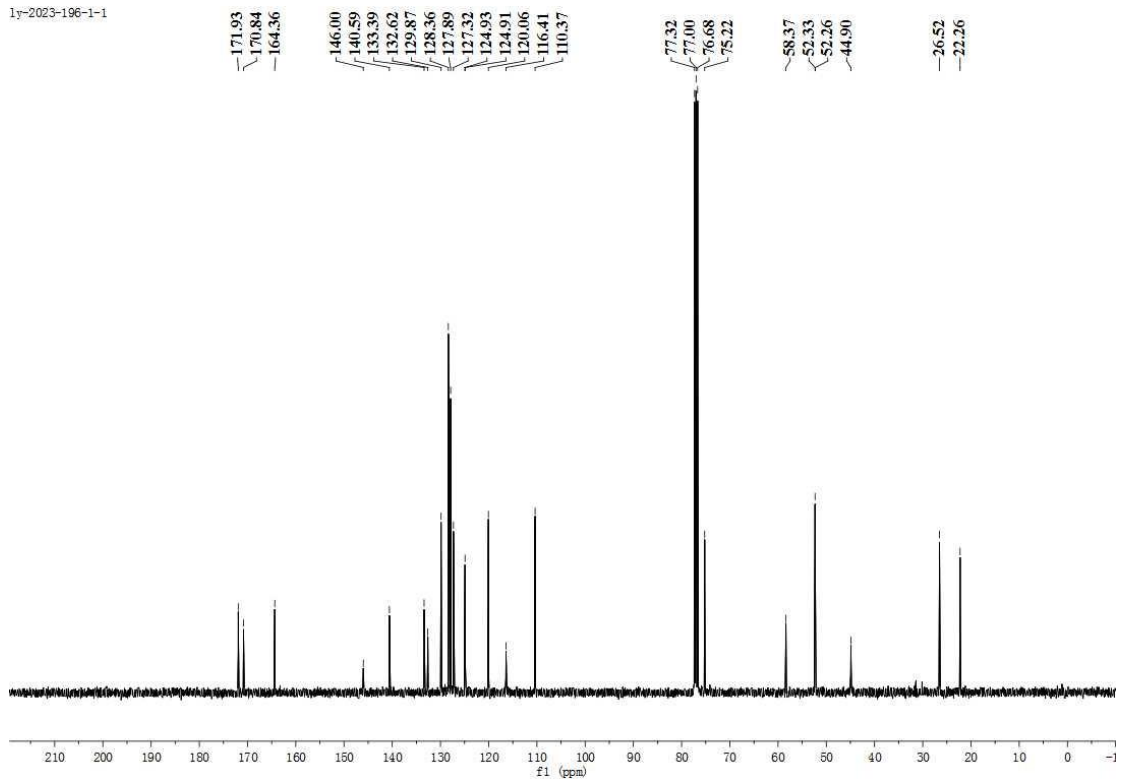
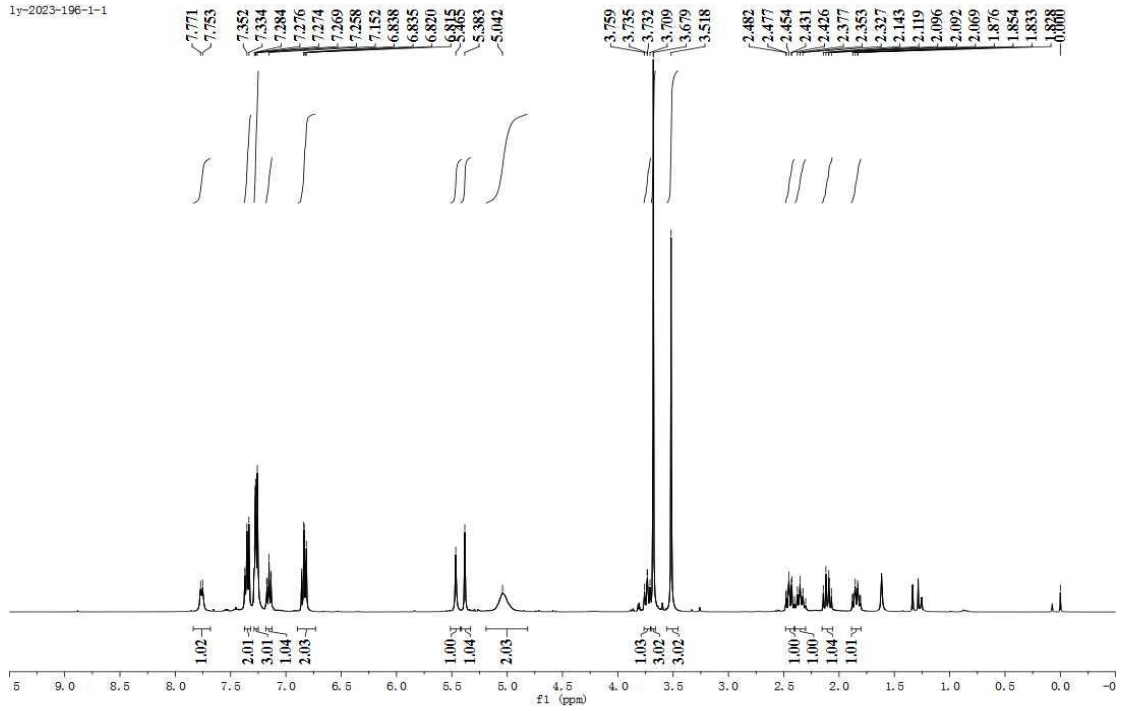
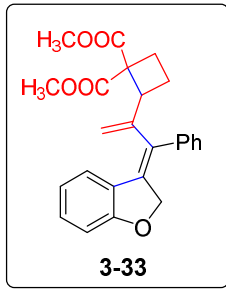


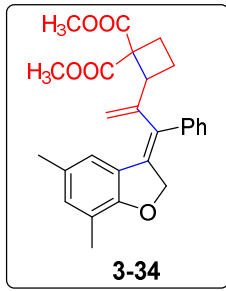
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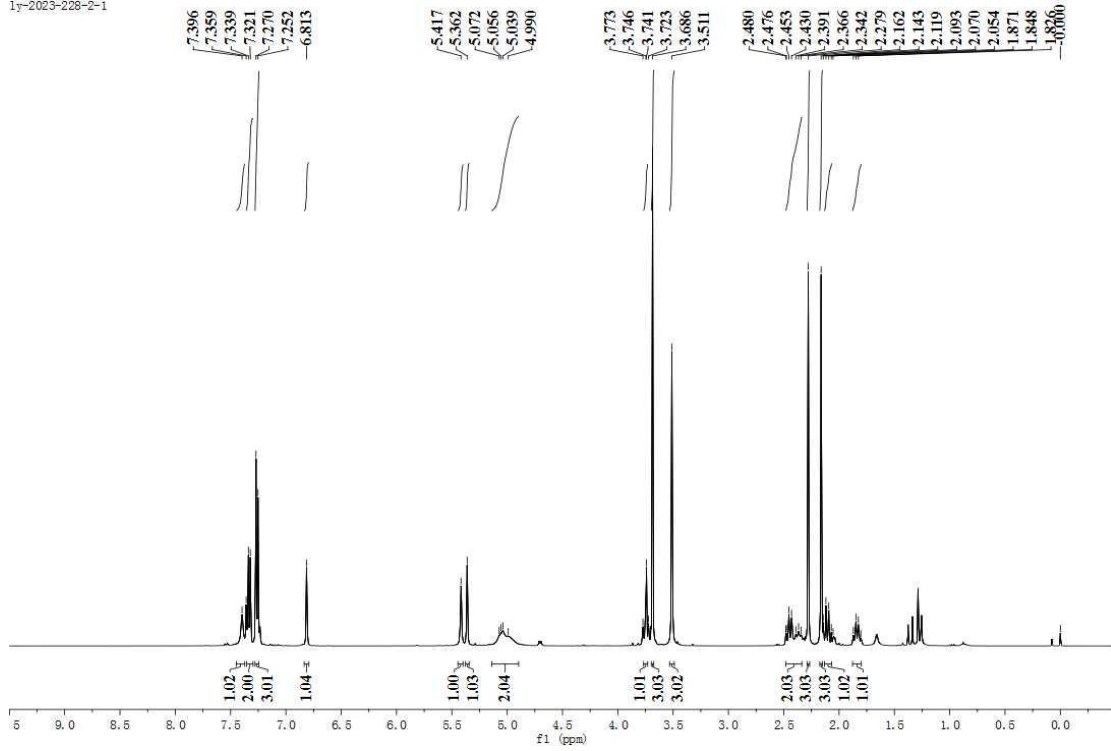
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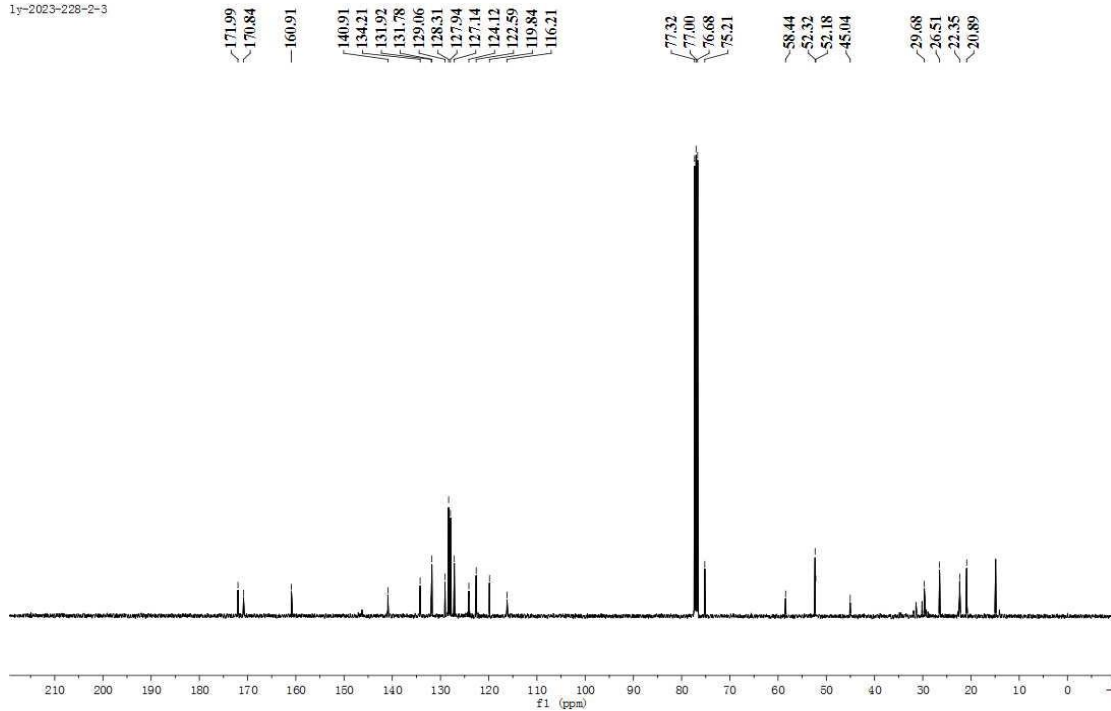


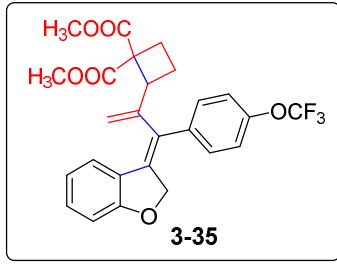


1y-2023-228-2-1

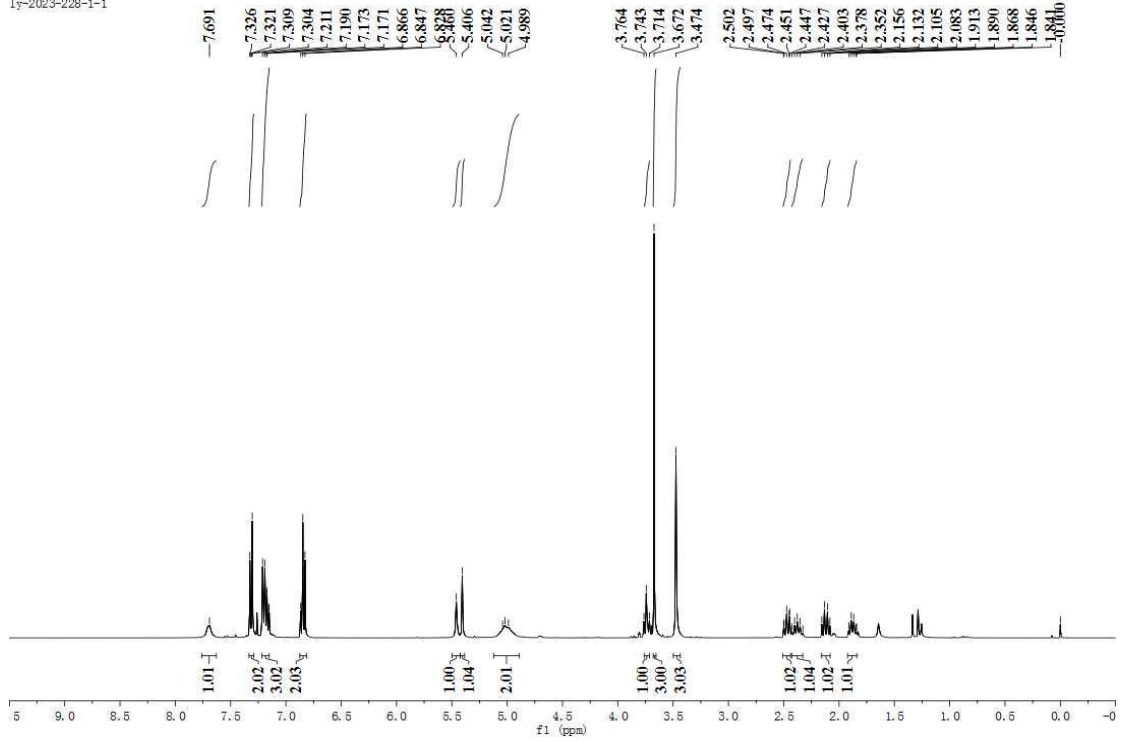


1y-2023-228-2-3

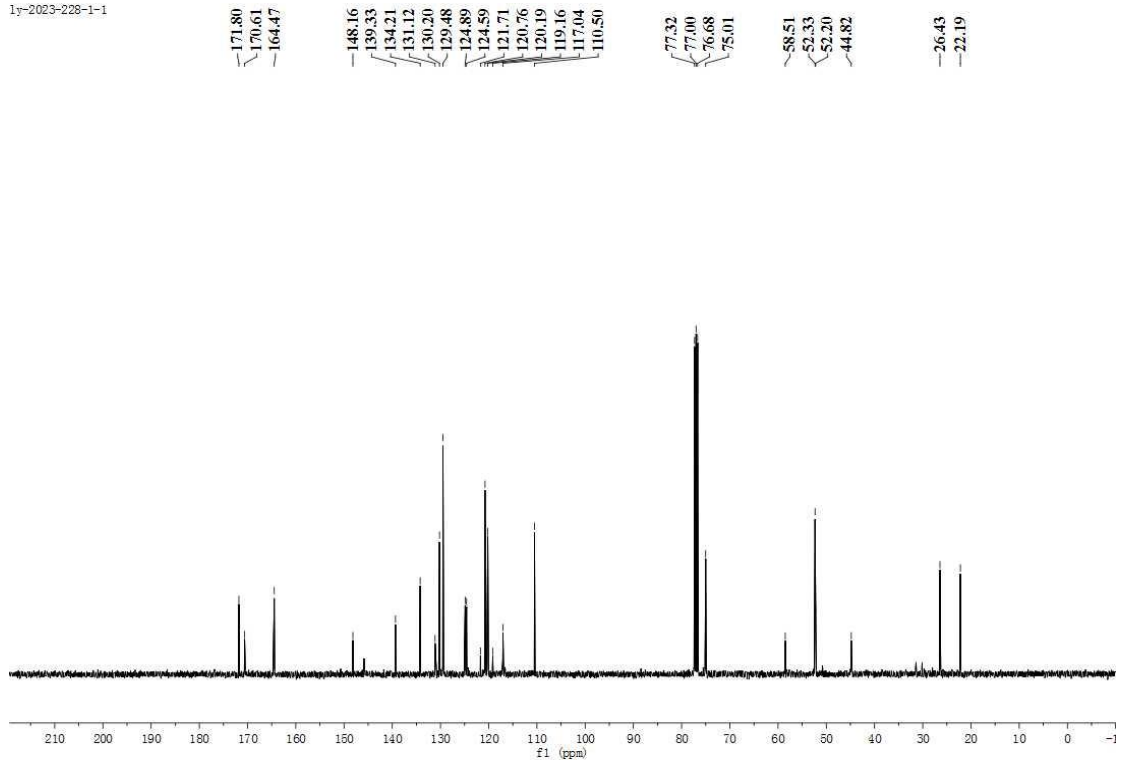




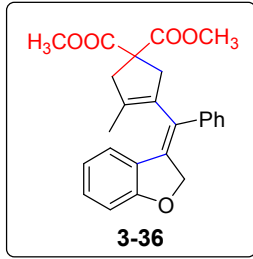
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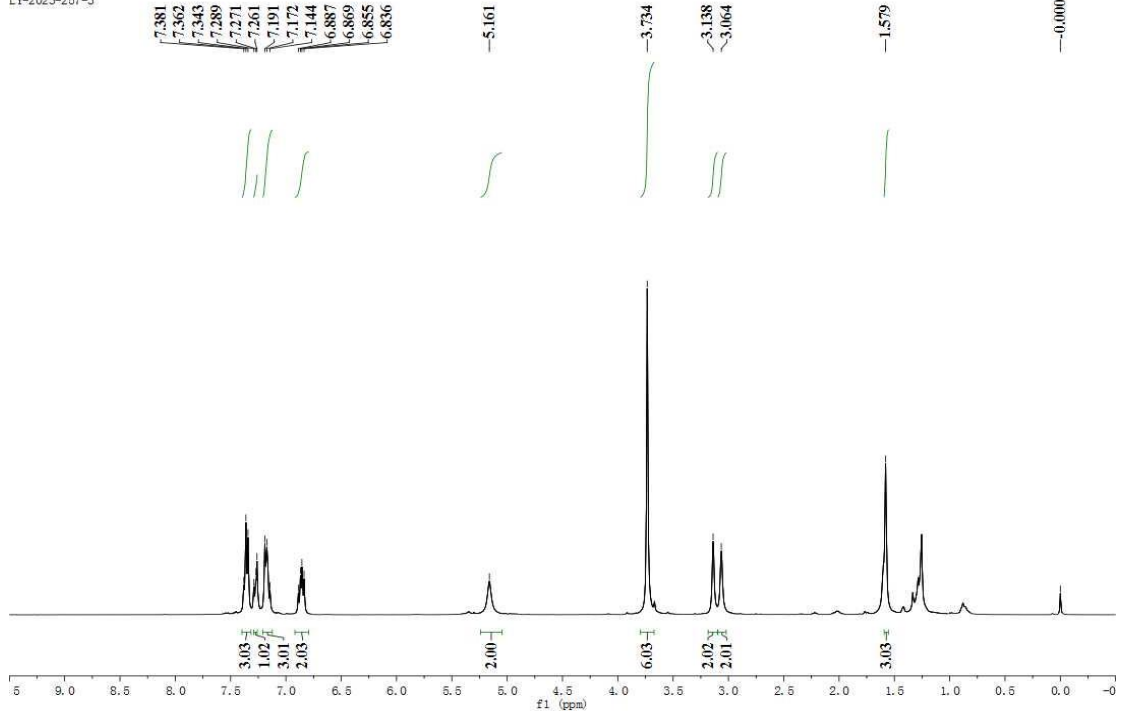
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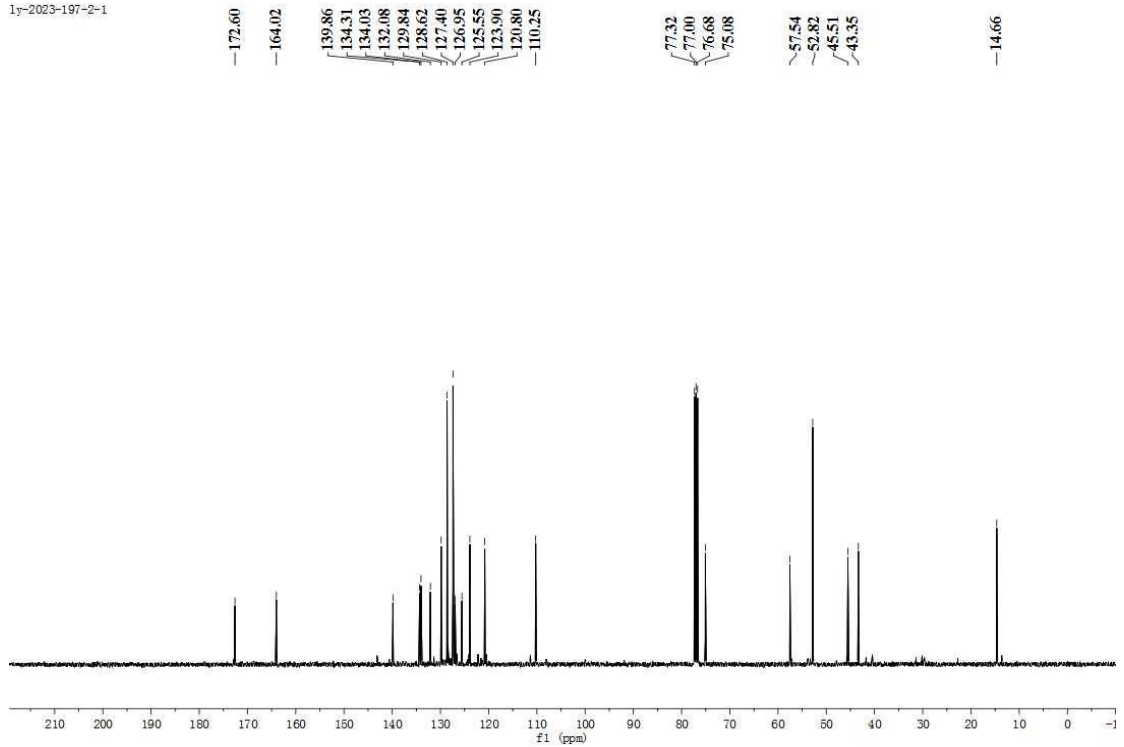


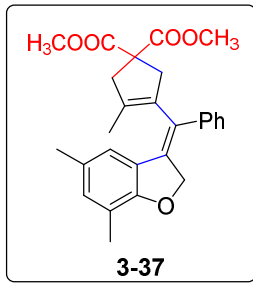


LY-2023-257-3

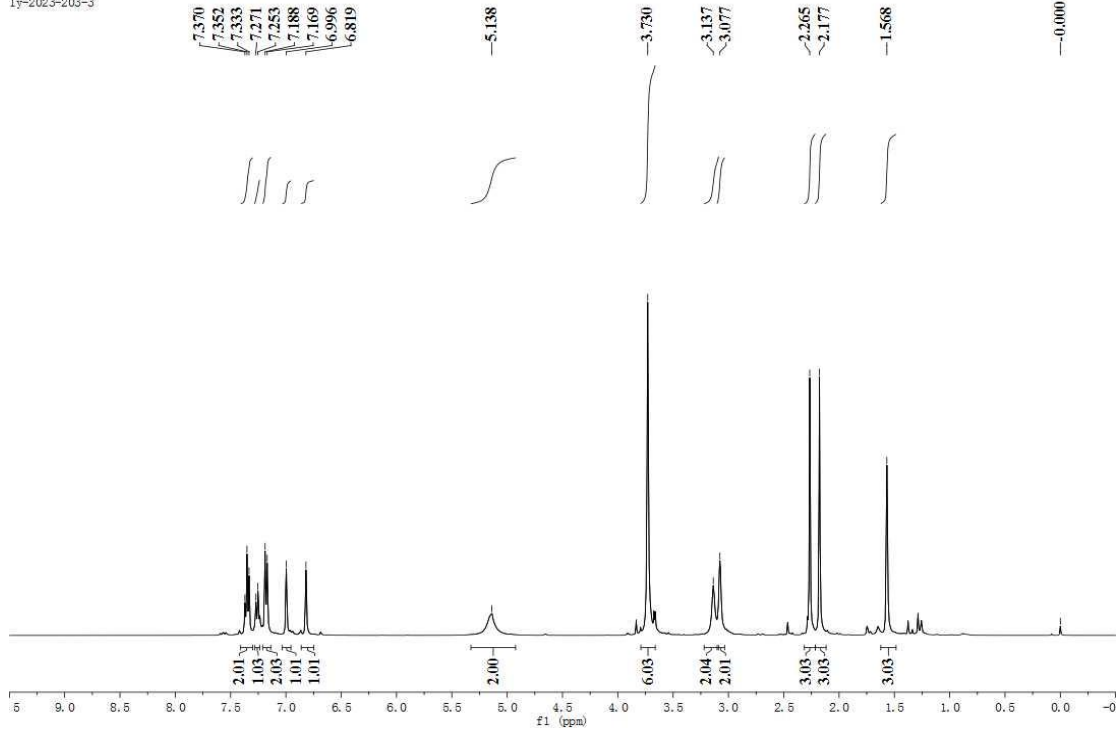


1y-2023-197-2-1





1y-2023-203-3



1y-2023-203-3

