SUPPORTING INFORMATION

Visible Light-Induced Synthesis of 1,3-Disubstituted Bicyclo-[1.1.1]pentane Ketones via Cooperative Photoredox and *N*-Heterocyclic Carbene Catalysis

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Contents

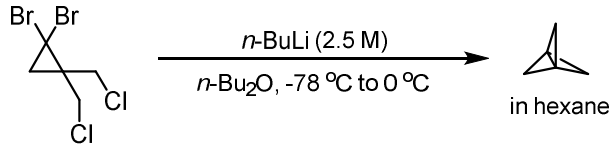
1. General information

General remarks. Reactions were performed under an Ar atmosphere using pre-dried glassware. Thin-layer chromatography (TLC) was conducted on plates (GF254) supplied by Yantai Chemicals (China). Column chromatography was performed on silica gel (300-400 mesh).

Materials. Compounds **1s**,[1] **1ab-1ac**,[2] (**3b-3l**, **3o-3q**),[3] **3m**,[4] **3n**,[5] (NHC **A**, **F**, and **G**),[6] and (NHC **B** and **C**)[7] were prepared using reported procedures. Other compounds were purchased from Energy Chemical or Bidepharm and used without further purification.

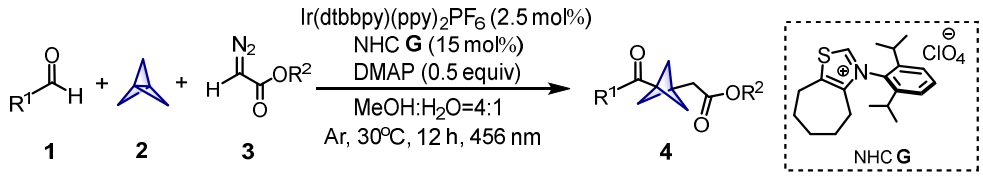
Instrumentation. NMR spectra were recorded using Bruker Avance III 400 MHz or Bruker Avance III 600 MHz spectrometers. Chemical shifts (δ) were reported in ppm relative to the residual solvent signal ($CDCl_3$ δ = 7.26 for ^1H NMR and δ = 77.0 for ^{13}C NMR). Multiplicities are given as s (singlet), d (doublet), t (triplet), dd (doublet of doublets), td (triplet of doublets), or m (multiplet). Melting points were determined using a Büchi B-540 capillary melting point apparatus. HRMS spectra were recorded on an electrospray ionization quadrupole time-of-flight (ESI-Q-TOF) mass spectrometer. Electron spin resonance (ESR) spectra were recorded with a JEOL JES FA200 (X-band). The UV-Vis absorption spectra were measured on a SHIMADZU UV-2550 spectrometer. Emission intensities results were monitored by an F-7000 FL spectrophotometer.

2. Preparation of the solution of [1.1.1]propellane



A solution of *n*-BuLi (48 mL, 120 mmol, 2.0 equiv., 2.5 M in hexane) was added dropwise to a suspension of 1,1-dibromo-2,2-bis(chloromethyl)cyclopropane (60 mmol) in anhydrous dibutyl ether (60 mL) under argon at –78 °C. After the addition was complete, the mixture was allowed to warm to 0 °C and stirred for 2 h before distillation under vacuum. The concentration can be measured by ^1H-NMR with 1,3,5-trimethoxybenzene as an internal standard (typically concentrations are 0.4-0.7 M).

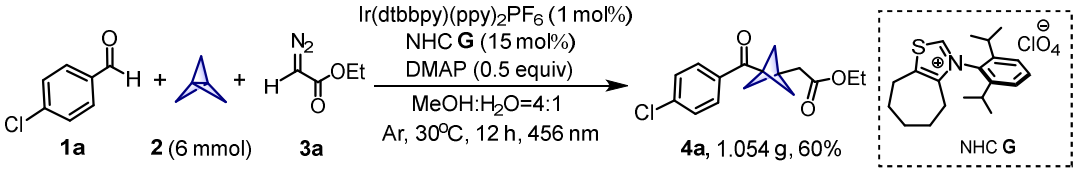
3. General procedure



To a 10 mL seal tube equipped with a magnetic stir bar was added NHC **G** (12 mg, 0.03 mmol, 0.15 equiv.), DMAP (12 mg, 0.1 mmol, 0.5 equiv.), $Ir(dtbbpy)(ppy)_2PF_6$ (5 mg, 0.005 mmol, 2.5

mol %), **1** (if solid) (0.28 mmol, 1.4 equiv.), and **3** (if solid) (0.4 mmol, 2.0 equiv.). The tube was sealed, evacuated, and backfilled with argon three times, then MeOH-H_2O = 4:1 (2.0 mL), **1** (if liquid) (0.28 mmol, 1.4 equiv.), **3** (if liquid) (0.4 mmol, 2.0 equiv.), and **2** (0.2 mmol, 1.0 equiv.) were sequentially added. The resulting solution was irradiated by a 40 W Kessil lamp (456 nm, blue light, third gear) with stirring at a distance of 5 cm (with cooling by a fan) at 30 °C for about 12 h. The mixture was diluted with EtOAc (15 mL), then washed with water (10 mL) and brine (10 mL). The organic phase was dried over Na_2SO_4, filtered, and then concentrated under reduced pressure, purified by column chromatography on silica gel (petroleum ether/EtOAc) to afford the desired product **4**.

4. Gram-scale experiment



To a 100 mL three-necked flask equipped with a magnetic stir bar was added NHC **G** (373 mg, 0.9 mmol, 0.15 equiv.), DMAP (367 mg, 3 mmol, 0.5 equiv.), Ir(dtbbpy)$(ppy)_2PF_6$ (55 mg, 0.06 mmol, 1 mol %), **1a** (8.4 mmol, 1.4 equiv.) sequentially under argon atmosphere, then MeOH-H_2O = 4:1 (50.0 mL), **3a** (12 mmol, 2.0 equiv.), and **2** (6 mmol, 1.0 equiv.) were sequentially added. The resulting solution was irradiated by two 40 W Kessil lamps (456 nm, blue light, third gear) with stirring at a distance of 5 cm (with cooling by a fan) at 30 °C for about 12 h. The mixture was diluted with EtOAc (30 mL), then washed with water (30 mL) and brine (30 mL). The organic phase was dried over Na_2SO_4, filtered, and then concentrated under reduced pressure, purified by column chromatography on silica gel (petroleum ether/EtOAc) to afford the desired product **4a**.

5. Mechanistic studies

5.1 ESR experiments

Electron spin resonance (ESR) spectra were recorded with a JEOL JES FA200 (X-band). The sample was bubbled with Ar for over 5 min, then a small amount of the sample was transferred to a capillary under Ar, and ESR spectra were recorded under different conditions. ESR conditions: frequency (9.228 GHz), power (1 mW), modulation width (0.1 mT), center field (329 mT), amplitude (2 mT), sweep width (5 mT), sweep time (2 min), time constant (0.03 s).

A mixture (20 uL) of **1a** (140 mM), **2** (100 mM), **3a** (200 mM), PC-**I** (2.5 mol%), NHC **G** (15 mol%), 5,5-dimethyl-1-pyrroline *N*-oxide (DMPO; 100 mM), and DMAP (50 mM) in MeOH: H_2O = 4:1 was transferred to a capillary tube, then the capillary tube was transferred to a quartz tube, the quartz tube was then placed in the ESR test cavity. After the mixture was irradiated with visible light (>420 nm) for 2 min, a composite spectrum was recorded with two sextet signals, one was a Breslow

intermediate **II** radical with g = 2.0054, A_N = 1.508 mT, A_H = 1.948 mT, the other carbon-centered radical with g = 2.0051, A_N = 1.526 mT, A_H = 2.227 mT was supposed to be an intermediate of the carbon-centered radical **V** (Figure **S1**).

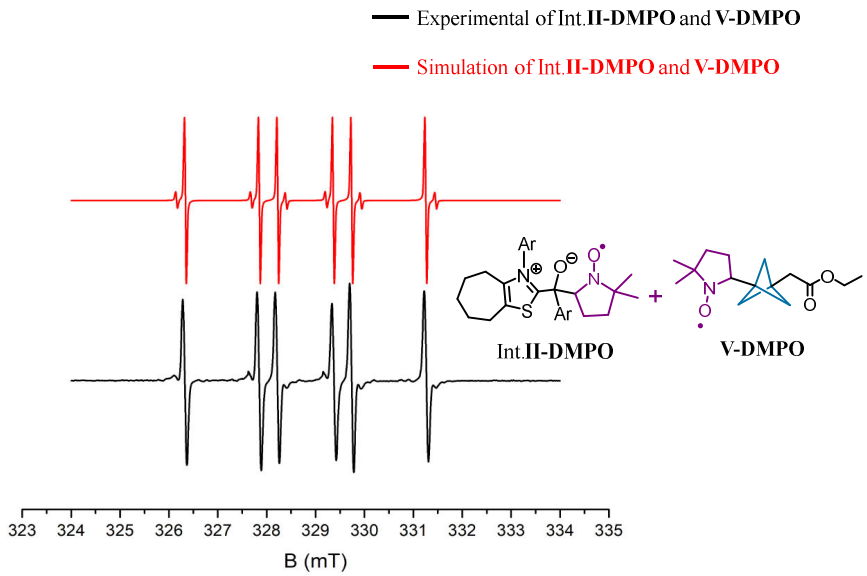


Figure S1**.** (Black line) ESR spectra for a mixture of **1a** (140 mM), **2** (100 mM), **3a** (200 mM), PC-**I** (2.5 mol%), NHC **G** (15 mol%), 5,5-dimethyl-1-pyrroline *N*-oxide (DMPO; 100 mM), and DMAP (50 mM) in MeOH: H_2O = 4:1. (Red line) Stimulated spectra.

A mixture (20 uL) of **1a** (140 mM), **3a** (200 mM), PC-**I** (2.5 mol%), NHC **G** (15 mol%), 5,5-dimethyl-1-pyrroline *N*-oxide (DMPO; 100 mM), and DMAP (50 mM) in MeOH: H_2O = 4:1 was transferred to a capillary tube, then the capillary tube was transferred to a quartz tube, the quartz tube was then placed in the ESR test cavity. After the mixture was irradiated with visible light (>420 nm) for 2 min, a sextet signal was recorded, with a g = 2.0051, A_N = 1.529 mT, A_H = 2.239 mT, which referred to be a carbon-centered radical **IV** (Figure S2).

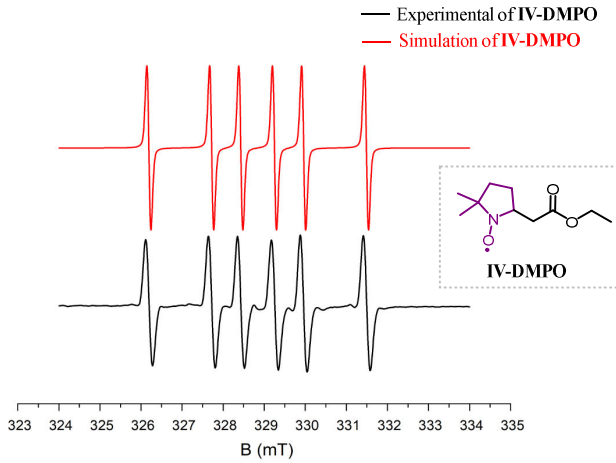


Figure S2**.** (Black line) ESR spectra for a mixture of **1a** (140 mM), **3a** (200 mM), PC-**I** (2.5 mol%), NHC **G** (15 mol%), 5,5-dimethyl-1-pyrroline *N*-oxide (DMPO; 100 mM), and DMAP (50 mM) in MeOH: H_2O = 4:1. (Red line) Stimulated spectra.

A mixture (20 uL) of **1a** (140 mM), **2** (100 mM), PC-**I** (2.5 mol%), NHC **G** (15 mol%), 5,5-

dimethyl-1-pyrroline *N*-oxide (DMPO; 100 mM), and DMAP (50 mM) in MeOH : H_2O = 4:1 was transferred to a capillary tube, then the capillary tube was transferred to a quartz tube, the quartz tube was then placed in the ESR test cavity. After the mixture was irradiated with visible light (>420 nm) for 2 min, a very weak sextet signal was recorded, with a g = 2.0054, A_N = 1.508 mT, A_H = 1.968 mT, which was coincident with a Breslow intermediate **II** radical (Figure S3).

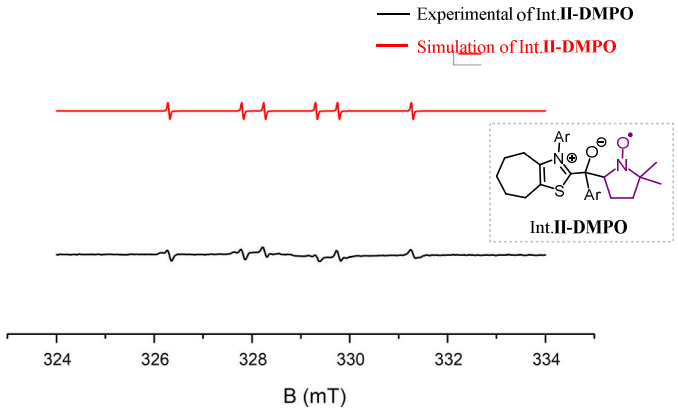


Figure S3**.** (Black line) ESR spectra for a mixture of **1a** (140 mM), **2** (100 mM), PC-**I** (2.5 mol%), NHC **G** (15 mol%), 5,5-dimethyl-1-pyrroline *N*-oxide (DMPO; 100 mM), and DMAP (50 mM) in MeOH:H_2O = 4:1. (Red line) Stimulated spectra.

5.2 UV-Vis absorption and emission spectra

The UV-Vis absorption spectra of Breslow Intermediate **I** (Int. **I**) and $Ir(ppy)_2(dtbbpy)PF_6$ (PC-**I**) were measured on a SHIMADZU UV-2550 spectrometer under reaction concentration in DMSO. The emission spectra of PC-**I** (2.5×10^{-4} M in DMSO) upon excitation at 550 nm were recorded (Figure S4, orange dashed line). In addition, the mixture of Int. **I** (0.14 M) and diazo ester **3a** (0.2 M) did not exhibit a significant bathochromic shift in the absorption, excluding the possibility of the formation of EDA complex (Figure S5).

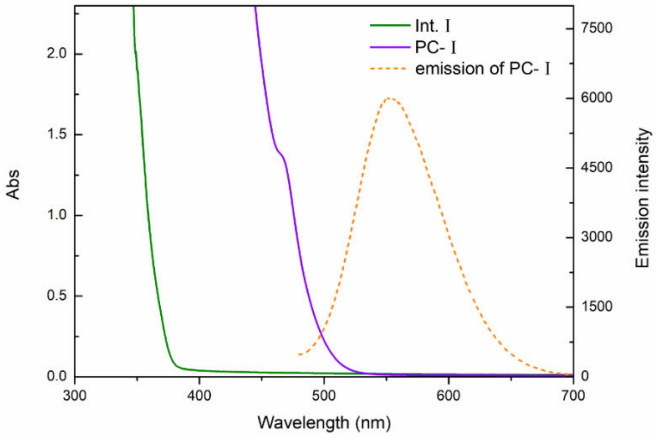


Figure S4**.** UV-Vis absorption and emission spectra (UV-Vis absorption spectra of Int. **I** and PC-**I**. Emission spectrum of PC-**I**).

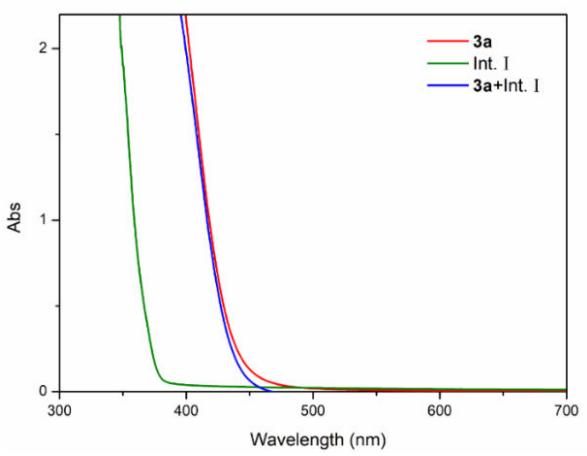


Figure S5. UV-Vis absorption spectra (UV-Vis absorption spectra of Int. **I, 3a**, and the mixture of Int. **I** and **3a**).

5.3 Stern-Volmer quenching experiments

Emission intensities results were monitored by an F-7000 FL spectrophotometer. All $Ir(ppy)_2(dtbbpy)PF_6$ solutions were excited at 410 nm and the emission intensity was collected at 500-700 nm (Figure S6). In general, $Ir(ppy)_2(dtbbpy)PF_6$ (3×10^{-5} M in DMSO) was added to the relative quencher in a 4.5 cm quartz cuvette. The results showed that the Breslow Intermediate **I** could quench the photoexcited $Ir(ppy)_2(dtbbpy)PF_6$, while diazo ester **3a** was less effective. And the fluorescence intensity of PC-**I** exhibited linear attenuation with increases in the concentration of Int. **I**.

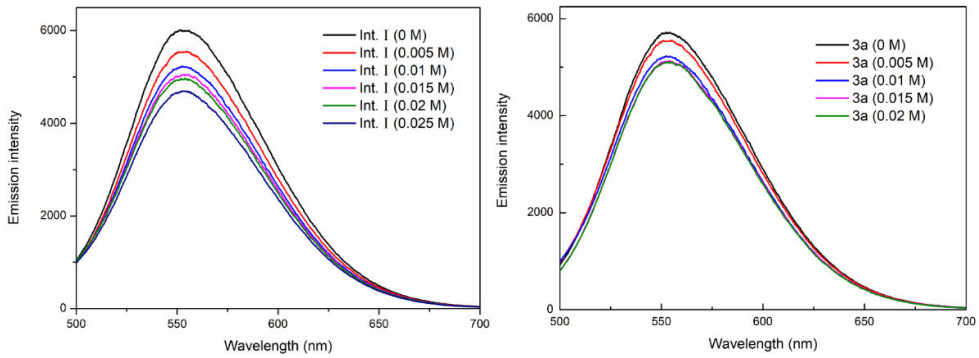
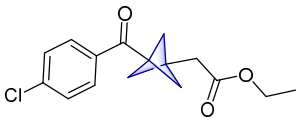


Figure S6. Stern-Volmer quenching experiments of Int. **I** and **3a** as the quencher.

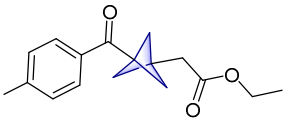
6. Characterization of products

Ethyl 2-(3-(4-chlorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4a)



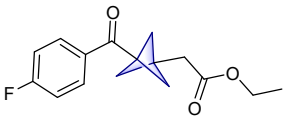
Product **4a** was isolated as a yellow oil (38.4 mg, 66%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.94–7.88 (m, 2H), 7.43–7.36 (m, 2H), 4.15 (q, *J* = 7.0 Hz, 2H), 2.57 (s, 2H), 2.27 (s, 6H), 1.27 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.79, 170.85, 139.30, 134.79, 130.24, 128.75, 60.40, 54.20, 44.57, 37.05, 36.73, 14.29. HRMS (ESI) m/z: calcd for $C_{16}H_{18}ClO_3$ $[M+H]^+$ 293.0939, found: 293.0948.

Ethyl 2-(3-(4-methylbenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4b)



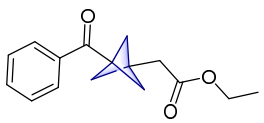
Product **4b** was isolated as a yellow oil (30.3 mg, 56%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.88 (d, *J* = 8.0 Hz, 2H), 7.23 (d, *J* = 8.0 Hz, 2H), 4.15 (q, *J* = 7.0 Hz, 2H), 2.57 (s, 2H), 2.39 (s, 3H), 2.27 (s, 6H), 1.27 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 196.65, 170.98, 143.61, 134.03, 129.08, 128.99, 60.35, 54.20, 44.63, 37.18, 36.58, 21.59, 14.29. HRMS (ESI) m/z: calcd for $C_{17}H_{21}O_3$ $[M+H]^+$ 273.1485, found: 273.1494.

Ethyl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4c)



Product **4c** was isolated as a yellow oil (41.8 mg, 76%). ^{1}H NMR (400 MHz, Chloroform-d) δ 8.08–7.94 (m, 2H), 7.14–7.02 (m, 2H), 4.15 (q, *J* = 7.0 Hz, 2H), 2.57 (s, 2H), 2.27 (s, 6H), 1.26 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.37, 170.87, 165.51 (d, *J* = 254.8 Hz), 132.90 (d, *J* = 3.0 Hz), 131.48 (d, *J* = 9.2 Hz), 115.52 (d, *J* = 21.8 Hz), 60.37, 54.19, 44.53, 37.05, 36.68, 14.27. ^{19}F NMR (376 MHz, Chloroform-*d*) δ -105.20. HRMS (ESI) m/z: calcd for $C_{16}H_{18}FO_3$ $[M+H]^+$ 277.1234, found: 277.1245.

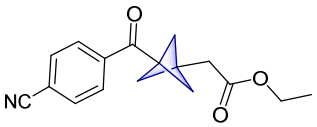
Ethyl 2-(3-benzoylbicyclo[1.1.1]pentan-1-yl)acetate (4d)



Product **4d** was isolated as a yellow oil (30.8 mg, 60%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.02–7.94 (m, 2H), 7.56–.50 (m, 1H), 7.46–7.40 (m, 2H), 4.15 (q, *J* = 7.0 Hz, 2H), 2.57 (s, 2H), 2.29 (s,

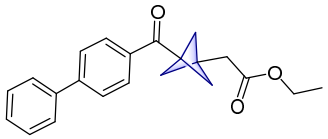
6H), 1.27 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 197.06, 170.93, 136.52, 132.80, 128.83, 128.39, 60.37, 54.20, 44.66, 37.15, 36.65, 14.30. HRMS (ESI) m/z: calcd for $C_{16}H_{19}O_3$ $[M+H]^+$ 259.1329, found: 259.1332.

Ethyl 2-(3-(4-cyanobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4e)



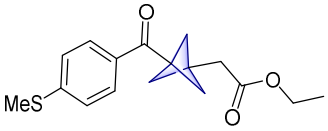
Product **4e** was isolated as a white solid (31.5 mg, 56%). M.p.: 43-45 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.03 (d, *J* = 8.4 Hz, 2H), 7.73 (d, *J* = 8.4 Hz, 2H), 4.15 (q, *J* = 7.0 Hz, 2H), 2.58 (s, 2H), 2.29 (s, 6H), 1.27 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.80, 170.74, 139.52, 132.29, 129.13, 117.86, 116.10, 60.45, 54.17, 44.61, 36.93, 36.90, 14.28. HRMS (ESI) m/z: calcd for $C_{17}H_{18}NO_3$ $[M+H]^+$ 284.1281, found: 284.1260.

Ethyl 2-(3-([1,1'-biphenyl]-4-carbonyl)bicyclo[1.1.1]pentan-1-yl)acetate (4f)



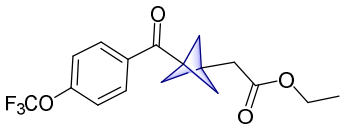
Product **4f** was isolated as a yellow oil (39.9 mg, 60%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.07 (d, *J* = 7.8 Hz, 2H), 7.66 (d, *J* = 8.0 Hz, 2H), 7.62 (d, *J* = 7.6 Hz, 2H), 7.50–7.35 (m, 3H), 4.17 (q, *J* = 7.2 Hz, 2H), 2.60 (s, 2H), 2.32 (s, 6H), 1.29 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 196.58, 170.94, 145.52, 139.88, 135.21, 129.44, 128.90, 128.16, 127.20, 127.05, 60.37, 54.23, 44.71, 37.15, 36.67, 14.30. HRMS (ESI) m/z: calcd for $C_{22}H_{23}O_3$ $[M+H]^+$ 335.1642, found: 335.1650.

Ethyl 2-(3-(4-(methylthio)benzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4g)



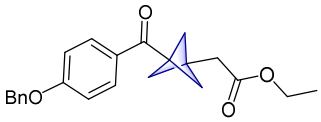
Product **4g** was isolated as a yellow oil (32.6 mg, 54%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.93–7.87 (m, 2H), 7.26–7.21 (m, 2H), 4.16 (q, *J* = 7.0 Hz, 2H), 2.57 (s, 2H), 2.51 (s, 3H), 2.27 (s, 6H), 1.27 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.94, 170.95, 145.70, 132.85, 129.29, 124.94, 60.38, 54.24, 44.58, 37.18, 36.65, 14.77, 14.32. HRMS (ESI) m/z: calcd for $C_{17}H_{21}O_3S$ $[M+H]^+$ 305.1206, found: 305.1212.

Ethyl 2-(3-(4-(trifluoromethoxy)benzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4h)



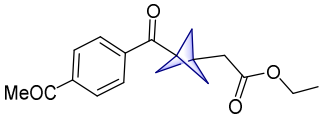
Product **4h** was isolated as a yellow oil (42.2 mg, 62%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.06–8.00 (m, 2H), 7.28–7.23 (m, 2H), 4.15 (q, *J* = 7.0 Hz, 2H), 2.58 (s, 2H), 2.28 (s, 6H), 1.27 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.47, 170.85, 152.41 (d, *J* = 1.8 Hz), 134.76, 130.86, 120.30 (q, *J* = 257.0 Hz), 120.26, 60.42, 54.22, 44.58, 37.06, 36.79, 14.29. ^{19}F NMR (376 MHz, Chloroform-*d*) δ -57.65. HRMS (ESI) m/z: calcd for $C_{17}H_{18}FO_4$ $[M+H]^+$ 343.1152, found: 343.1162.

Ethyl 2-(3-(4-(benzyloxy)benzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4i)



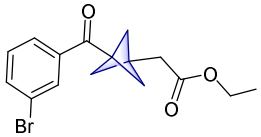
Product **4i** was isolated as a yellow oil (37.7 mg, 52%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.02–7.95 (m, 2H), 7.45–7.30 (m, 5H), 7.02–6.95 (m, 2H), 5.12 (s, 2H), 4.16 (q, *J* = 7.0 Hz, 2H), 2.57 (s, 2H), 2.27 (s, 6H), 1.28 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.40, 170.97, 162.45, 136.18, 131.19, 129.77, 128.64, 128.17, 127.38, 114.48, 70.09, 60.33, 54.22, 44.51, 37.17, 36.56, 14.28. HRMS (ESI) m/z: calcd for $C_{23}H_{25}O_4$ $[M+H]^+$ 365.1747, found: 365.1753.

Ethyl 2-(3-(4-acetylbenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4j)



Product **4j** was isolated as a white solid (25.6 mg, 43%). M.p.: 68-70 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.10–7.93 (m, 4H), 4.15 (q, *J* = 7.0 Hz, 2H), 2.63 (s, 3H), 2.58 (s, 2H), 2.29 (s, 6H), 1.27 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 197.43, 196.71, 170.88, 139.80, 139.70, 128.93, 128.28, 60.43, 54.13, 44.72, 37.00, 36.78, 26.83, 14.28. HRMS (ESI) m/z: calcd for $C_{18}H_{21}O_4$ $[M+H]^+$ 301.1434, found: 301.1422.

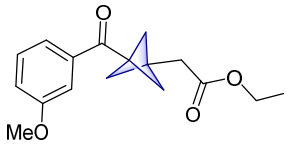
Ethyl 2-(3-(3-bromobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4k)



Product **4k** was isolated as a yellow oil (40.2 mg, 60%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.09–8.05 (m, 1H), 7.92–7.85 (m, 1H), 7.68–7.63 (m, 1H), 7.31 (t, *J* = 8.0 Hz, 1H), 4.15 (q, *J* = 7.2 Hz, 2H), 2.57 (s, 2H), 2.28 (s, 6H), 1.27 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ

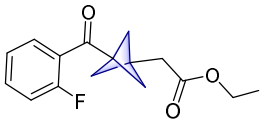
195.72, 170.86, 138.22, 135.67, 131.77, 130.01, 127.35, 122.73, 60.43, 54.22, 44.56, 37.04, 36.77, 14.30. HRMS (ESI) m/z: calcd for $C_{16}H_{18}BrO_3$ $[M+H]^+$ 337.0434, found: 337.0442.

Ethyl 2-(3-(3-methoxybenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4l)



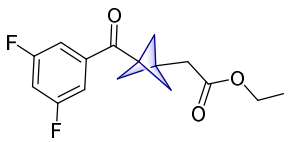
Product **4l** was isolated as a yellow oil (30.0 mg, 52%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.58 (d, *J* = 7.6 Hz, 1H), 7.50–7.44 (m, 1H), 7.33 (t, *J* = 7.6 Hz, 1H), 7.08 (dd, *J* = 8.2, 2.6 Hz, 1H), 4.15 (q, *J* = 7.0 Hz, 2H), 3.83 (s, 3H), 2.57 (s, 2H), 2.28 (s, 6H), 1.27 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 196.83, 170.91, 159.65, 137.80, 129.36, 121.56, 119.28, 113.11, 60.37, 55.36, 54.25, 44.69, 37.15, 36.59, 14.30. HRMS (ESI) m/z: calcd for $C_{17}H_{21}O_4$ $[M+H]^+$ 289.1434, found: 289.1439.

Ethyl 2-(3-(2-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4m)



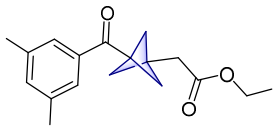
Product **4m** was isolated as a yellow oil (35.8 mg, 65%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.63–7.56 (m, 1H), 7.51–7.41 (m, 1H), 7.21–7.15 (m, 1H), 7.13–7.06 (m, 1H), 4.13 (q, *J* = 7.0 Hz, 2H), 2.54 (s, 2H), 2.17 (s, 6H), 1.25 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 197.46 (d, *J*=2.0 Hz), 170.90, 160.29 (d, *J* = 253.8 Hz), 133.55 (d, *J* = 8.8 Hz), 130.24 (d, *J* = 3.4 Hz), 126.22 (d, *J* = 15.8 Hz), 124.19 (d, *J* = 3.6 Hz), 116.34 (d, *J* = 22.4 Hz)，60.33, 52.87 (d, *J* = 3.2 Hz), 45.41, 37.21, 35.89 (d, *J* = 2.8 Hz), 14.28. ^{19}F NMR (376 MHz, Chloroform-*d*) δ -109.53. HRMS (ESI) m/z: calcd for $C_{16}H_{18}FO_3$ $[M+H]^+$ 277.1234, found: 277.1244.

Ethyl 2-(3-(3,5-difluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4n)



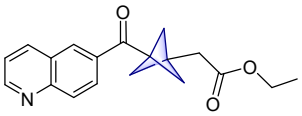
Product **4n** was isolated as a yellow oil (37.5 mg, 64%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.50–7.41 (m, 2H), 7.02–6.95 (m, 1H), 4.15 (q, *J* = 7.0 Hz, 2H), 2.58 (s, 2H), 2.28 (s, 6H), 1.27 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 194.47 (t, *J* = 2.2 Hz), 170.76, 162.82 (dd, *J* = 250.8, 11.8 Hz), 139.15 (t, *J* = 7.6 Hz), 111.72 (dd, *J* = 25.0, 7.0 Hz), 108.14 (t, *J* = 25.4 Hz), 60.46, 54.23, 44.52, 36.95, 36.80, 14.29. ^{19}F NMR (376 MHz, Chloroform-*d*) δ -107.97. HRMS (ESI) m/z: calcd for $C_{16}H_{17}F_2O_3$ $[M+H]^+$ 295.1140, found: 295.1144.

Ethyl 2-(3-(3,5-dimethylbenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4o)



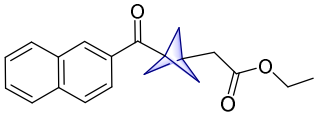
Product **4o** was isolated as a yellow oil (23.2 mg, 41%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.59–7.53 (m, 2H), 7.21–7.13 (m, 1H), 4.16 (q, *J* = 7.0 Hz, 2H), 2.57 (s, 2H), 2.35 (s, 6H), 2.27 (s, 6H), 1.28 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 197.55, 171.01, 138.02, 136.74, 134.45, 126.56, 60.36, 54.24, 44.72, 37.19, 36.56, 21.23, 14.29. HRMS (ESI) m/z: calcd for $C_{18}H_{23}O_3$ $[M+H]^+$ 287.1642, found: 287.1643.

Ethyl 2-(3-(quinoline-6-carbonyl)bicyclo[1.1.1]pentan-1-yl)acetate (4p)



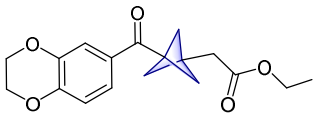
Product **4p** was isolated as a yellow oil (30.2 mg, 49%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 9.05–8.94 (m, 1H), 8.54–8.43 (m, 1H), 8.31–8.20 (m, 2H), 8.13 (d, *J* = 8.8 Hz, 1H), 7.51–7.43 (m, 1H), 4.17 (q, *J* = 7.2 Hz, 2H), 2.61 (s, 2H), 2.37 (s, 6H), 1.28 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 196.48, 170.93, 152.54, 149.88, 137.55, 134.41, 130.28, 129.92, 128.29, 127.39, 121.89, 60.43, 54.36, 44.79, 37.08, 36.82, 14.31. HRMS (ESI) m/z: calcd for $C_{19}H_{20}NO_3$ $[M+H]^+$ 310.1438, found: 310.1449.

Ethyl 2-(3-(2-naphthoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4q)



Product **4q** was isolated as a yellow oil (27.0 mg, 44%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.53 (s, 1H), 8.02 (dd, *J* = 8.6, 1.6 Hz, 1H), 7.95 (d, *J* = 8.0 Hz, 1H), 7.90-7.83 (m, 2H), 7.62–7.51 (m, 2H), 4.18 (q, *J* = 7.2 Hz, 2H), 2.62 (s, 2H), 2.37 (s, 6H), 1.29 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 197.00, 170.98, 135.39, 133.94, 132.40, 130.65, 129.56, 128.41, 128.29, 127.75, 126.69, 124.48, 60.39, 54.39, 44.80, 37.19, 36.72, 14.31. HRMS (ESI) m/z: calcd for $C_{20}H_{21}O_3$$[M+H]^+$ 309.1485, found: 309.1492.

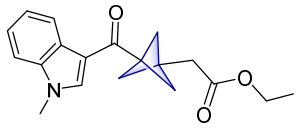
Ethyl 2-(3-(2,3-dihydrobenzo[b][1,4]dioxine-6-carbonyl)bicyclo[1.1.1]pentan-1-yl)acetate (4r)



Product **4r** was isolated as a yellow oil (28.9 mg, 46%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.58–7.49 (m, 2H), 6.88 (d, *J* = 9.0 Hz, 1H), 4.33–4.23 (m, 4H), 4.15 (q, *J* = 7.0 Hz, 2H), 2.56 (s, 2H), 2.25 (s, 6H), 1.27 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.32, 170.98, 147.89,

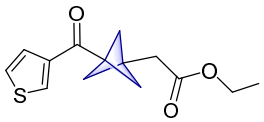
143.16, 130.32, 123.13, 118.43, 117.10, 64.69, 64.10, 60.36, 54.28, 44.53, 37.22, 36.55, 14.31. HRMS (ESI) m/z: calcd for $C_{18}H_{21}O_5[M+H]^+$ 317.1384, found: 317.1385.

Ethyl 2-(3-(1-methyl-1H-indole-3-carbonyl)bicyclo[1.1.1]pentan-1-yl)acetate (4s)



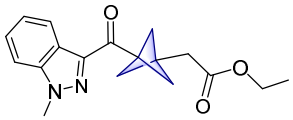
Product **4s** was isolated as a yellow solid (24.7 mg, 40%). M.p.: 92–94 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 10.29 (s, 1H), 8.50–8.27 (m, 1H), 7.32–7.24 (m, 3H), 4.18 (q, *J* = 7.0 Hz, 2H), 3.81 (s, 3H), 2.64 (s, 2H), 2.50 (s, 6H), 1.30 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 185.55, 170.83, 147.02, 137.15, 125.27, 123.71, 123.05, 122.35, 116.73, 108.88, 60.53, 55.34, 39.14, 36.96, 36.70, 31.10, 14.30. HRMS (ESI) m/z: calcd for $C_{19}H_{22}NO_3$ $[M+H]^+$ 312.1594, found: 312.1595.

Ethyl 2-(3-(thiophene-3-carbonyl)bicyclo[1.1.1]pentan-1-yl)acetate (4t)



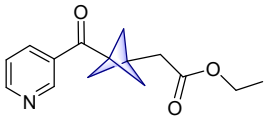
Product **4t** was isolated as a yellow oil (25.3 mg, 48%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.12 (dd, *J* = 2.8, 1.2 Hz, 1H), 7.57 (dd, *J* = 5.0, 1.2 Hz, 1H), 7.29 (dd, *J* = 5.0, 2.8 Hz, 1H), 4.15 (q, *J* = 7.0 Hz, 2H), 2.57 (s, 2H), 2.24 (s, 6H), 1.27 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 191.16, 170.89, 140.89, 132.74, 127.55, 125.84, 60.37, 53.75, 44.53, 37.13, 36.28, 14.29. HRMS (ESI) m/z: calcd for $C_{14}H_{17}O_3S$ $[M+H]^+$ 265.0893, found: 265.0906.

Ethyl 2-(3-(1-methyl-3a,7a-dihydro-1H-indazole-3-carbonyl)bicyclo[1.1.1]pentan-1-yl)acetate (4u)



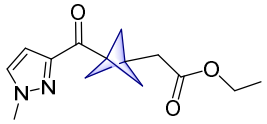
Product **4u** was isolated as a yellow oil (31.2 mg, 50%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.34 (d, *J* = 8.0 Hz, 1H), 7.45–7.38 (m, 2H), 7.34–7.27 (m, 1H), 4.21–4.10 (m, 5H), 2.60 (s, 2H), 2.34 (s, 6H), 1.29 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 193.12, 171.28, 141.34, 140.46, 126.74, 123.51, 123.48, 122.90, 109.05, 60.30, 53.74, 44.22, 37.53, 36.49, 36.42, 14.33. HRMS (ESI) m/z: calcd for $C_{18}H_{21}N_2O_3[M+H]^+$ 313.1547, found: 313.1551.

Ethyl 2-(3-nicotinoylbicyclo[1.1.1]pentan-1-yl)acetate (4v)



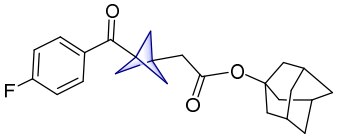
Product **4v** was isolated as a yellow oil (26.8 mg, 52%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 9.22–9.17 (m, 1H), 8.76–8.71 (m, 1H), 8.20 (dt, *J* = 8.0, 1.8 Hz, 1H), 7.38 (dd, *J* = 8.0, 4.8 Hz, 1H), 4.14 (q, *J* = 7.0 Hz, 2H), 2.57 (s, 2H), 2.29 (s, 6H), 1.26 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.88, 170.71, 153.13, 150.13, 135.95, 132.00, 123.55, 60.41, 54.03, 44.54, 37.02, 36.91, 14.27. HRMS (ESI) m/z: calcd for $C_{15}H_{18}NO_3$ $[M+H]^+$ 260.1281, found: 260.1294.

Ethyl 2-(3-(1-methyl-1H-pyrazole-3-carbonyl)bicyclo[1.1.1]pentan-1-yl)acetate (4w)



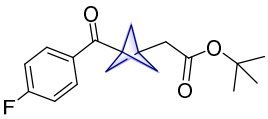
Product **4w** was isolated as a yellow oil (28.7 mg, 55%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.32 (d, *J* = 2.4 Hz, 1H), 6.75 (d, *J* = 2.4 Hz, 1H), 4.14 (q, *J* = 7.0 Hz, 2H), 3.94 (s, 3H), 2.54 (s, 2H), 2.24 (s, 6H), 1.26 (t, *J* = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 191.99, 171.13, 150.43, 130.81, 107.74, 60.25, 53.60, 44.02, 39.53, 37.49, 36.43, 14.30. HRMS (ESI) m/z: calcd for $C_{14}H_{19}N_2O_3$ $[M+H]^+$ 263.1390, found: 263.1397.

Adamantan-1-yl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4x)



Product **4x** was isolated as a yellow oil (54.0 mg, 71%).^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.08–7.95 (m, 2H), 7.10 (t, *J* = 8.0 Hz, 2H), 2.48 (s, 2H), 2.27 (s, 6H), 2.19–2.08 (m, 9H), 1.69–1.63 (m, 6H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.61, 169.99, 165.49 (d, *J* = 254.8 Hz), 132.87 (d, *J* = 3.0 Hz), 131.51 (d, *J* = 9.4 Hz), 115.53 (d, *J* = 21.8 Hz), 80.83, 54.18, 44.57, 41.45, 38.54, 36.92, 36.12, 30.76. ^{19}F NMR (376 MHz, Chloroform-*d*) δ -105.17. HRMS (ESI) m/z: calcd for $C_{24}H_{28}FO_3$ $[M+H]^+$ 383.2017, found: 383.2021.

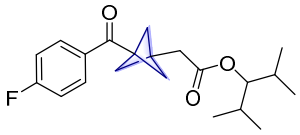
Tert-butyl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4y)



Product **4y** was isolated as a yellow oil (40.6 mg, 67%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.05–7.96 (m, 2H), 7.14–7.04 (m, 2H), 2.48 (s, 2H), 2.26 (s, 6H), 1.46 (s, 9H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.51, 170.19, 165.51 (d, *J* = 254.8 Hz), 132.94 (d, *J* = 3.0 Hz), 131.48 (d, *J* = 9.2 Hz), 115.52 (d, *J* = 21.8 Hz), 80.66, 54.20, 44.56, 38.44, 36.93, 28.17. ^{19}F NMR (376 MHz,

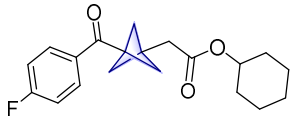
Chloroform-*d*) δ -105.23. HRMS (ESI) m/z: calcd for $C_{18}H_{22}FO_3$ $[M+H]^+$ 305.1547, found: 305.1566.

2,4-dimethylpentan-3-yl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4z)



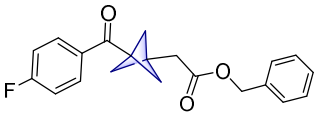
Product **4z** was isolated as a yellow oil (34.5 mg, 50%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.11–7.93 (m, 2H), 7.18–7.01 (m, 2H), 4.62 (t, *J* = 6.2 Hz, 1H), 2.63 (s, 2H), 2.30 (s, 6H), 1.95–1.83 (m, 2H), 0.91–0.82 (m, 12H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.51, 171.06, 165.51 (d, *J* = 254.8 Hz), 132.84 (d, *J* = 3.0 Hz), 131.52 (d, *J* = 9.2 Hz), 115.55 (d, *J* = 21.8 Hz), 82.93, 54.30, 44.75, 37.04, 36.76, 29.26, 19.55, 17.32. ^{19}F NMR (376 MHz, Chloroform-*d*) δ -105.13. HRMS (ESI) m/z: calcd for $C_{21}H_{28}FO_3$ $[M+H]^+$ 347.2017, found: 347.1999.

Cyclohexyl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4aa)



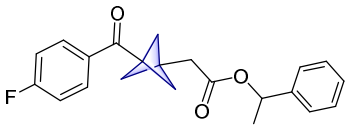
Product **4aa** was isolated as a yellow oil (50.0 mg, 76%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.07–7.95 (m, 2H), 7.16–7.04 (m, 2H), 4.83–4.74 (m, 1H), 2.56 (s, 2H), 2.28 (s, 6H), 1.91–1.82 (m, 2H), 1.76–1.69 (m, 2H), 1.58–1.51 (m, 1H), 1.44–1.23 (m, 5H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.51, 170.40, 165.52 (d, *J* = 254.8 Hz), 132.85 (d, *J* = 3.0 Hz), 131.52 (d, *J* = 9.4 Hz), 115.56 (d, *J* = 22.0 Hz), 72.89, 54.22, 44.56, 37.53, 36.82, 31.75, 25.30, 23.76. ^{19}F NMR (376 MHz, Chloroform-*d*) δ -105.12. HRMS (ESI) m/z: calcd for $C_{20}H_{24}FO_3$ $[M+H]^+$ 331.1704, found: 331.1678.

Benzyl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4ab)



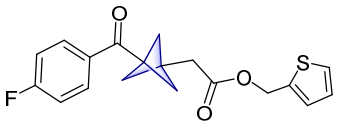
Product **4ab** was isolated as a yellow oil (43.0 mg, 64%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.03–7.94 (m, 2H), 7.40–7.33 (m, 5H), 7.14–7.06 (m, 2H), 5.15 (s, 2H), 2.64 (s, 2H), 2.25 (s, 6H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.32, 170.72, 165.54 (d, *J* = 254.8 Hz), 135.86, 132.85 (d, *J* = 3.0 Hz), 131.51 (d, *J* = 9.2 Hz), 128.58, 128.44, 128.34, 115.53 (d, *J* = 21.8 Hz), 66.35, 54.21, 44.57, 37.07, 36.69. ^{19}F NMR (376 MHz, Chloroform-*d*) δ -105.11. HRMS (ESI) m/z: calcd for $C_{21}H_{20}FO_3$ $[M+H]^+$ 339.1391, found: 339.1395.

1-phenylethyl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4ac)



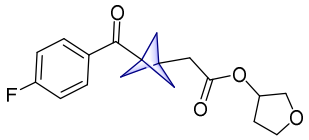
Product **4ac** was isolated as a yellow oil (53.3 mg, 76%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.05–7.91 (m, 2H), 7.41–7.28(m, 5H), 7.15–7.04 (m, 2H), 5.93 (q, *J* = 6.2 Hz, 1H), 2.61 (s, 2H), 2.24 (s, 6H), 1.57 (d, *J* = 6.2 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.32, 170.12, 165.47 (d, *J* = 254.8 Hz), 141.36, 132.76 (d, *J* = 3.0 Hz), 131.48 (d, *J* = 9.2 Hz), 128.47, 127.96, 126.21, 115.50 (d, *J* = 21.8 Hz), 72.50, 54.17, 44.56, 37.31, 36.70, 22.08. ^{19}F NMR (376 MHz, Chloroform-*d*) δ -105.08. HRMS (ESI) m/z: calcd for $C_{22}H_{21}FNaO_3$ $[M+Na]^+$ 375.1367, found: 375.1371.

Thiophen-2-ylmethyl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4ad)



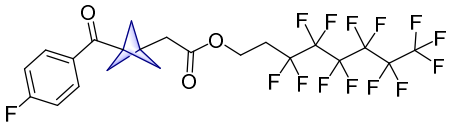
Product **4ad** was isolated as a yellow oil (34.1 mg, 52%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.03–7.94 (m, 2H), 7.37–7.30 (m, 1H), 7.14–7.06 (m, 3H), 7.03–6.95 (m, 1H), 5.30 (s, 2H), 2.61 (s, 2H), 2.24 (s, 6H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.33, 170.57, 165.51 (d, *J* = 254.8 Hz), 137.78, 132.76 (d, *J* = 2.8 Hz), 131.52 (d, *J* = 9.2 Hz), 128.40, 126.93, 126.83, 115.54 (d, *J* = 21.8 Hz), 60.37, 54.19, 44.57, 37.01, 36.63. ^{19}F NMR (376 MHz, Chloroform-*d*) δ -105.09. HRMS (ESI) m/z: calcd for $C_{19}H_{18}FO_3S$ $[M+H]^+$ 345.0955, found: 345.0954.

Tetrahydrofuran-3-yl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4ae)



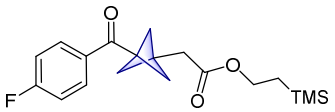
Product **4ae** was isolated as a yellow oil (39.8 mg, 63%).^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.06–7.94 (m, 2H),7.16–7.03 (m, 2H), 5.35–5.24 (m, 1H), 3.95–3.77 (m, 4H), 2.59 (s, 2H), 2.27 (s, 6H), 2.21–2.13 (m, 1H), 2.03–1.96 (m, 1H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.27, 170.68, 165.49 (d, *J* = 254.8 Hz), 132.75 (d, *J* = 2.8 Hz), 131.47 (d, *J* = 9.4 Hz), 115.55 (d, *J* = 21.8 Hz), 74.92, 73.14, 66.94, 54.17, 44.58, 37.00, 36.57, 32.72. ^{19}F NMR (376 MHz, Chloroform-*d*) δ -105.03. HRMS (ESI) m/z: calcd for $C_{18}H_{20}FO_4$ $[M+H]^+$ 319.1340, found: 319.1345.

3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4af)



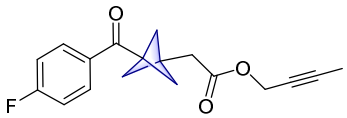
Product **4af** was isolated as a white solid (68.6 mg, 58%). M.p.: 42-44 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.07–7.95 (m, 2H), 7.18–7.03 (m, 2H), 4.41 (td, *J* = 6.6, 2.4 Hz, 2H), 2.63 (s, 2H), 2.56–2.41 (m, 2H), 2.29 (s, 6H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.30, 170.56, 165.58 (d, *J* = 254.8 Hz), 132.78 (d, *J* = 3.0 Hz), 131.52 (d, *J* = 9.2 Hz), 115.58 (d, *J* = 21.8 Hz), 56.34, 54.16, 44.60, 36.72, 36.40, 30.53 (t, *J* = 21.8 Hz). ^{13}C-NMR for $CF_2CF_2CF_2CF_2CF_2CF_3$ could not be assigned. ^{19}F NMR (376 MHz, Chloroform-*d*) δ -80.49 – -80.97 (m, 3F), -105.05 (s, 1F), -112.56 – -114.70 (m, 2F), -121.24 – -122.12 (m, 2F), -122.24 – -123.22 (m, 2F), -123.30 – -124.69 (m, 2F), -125.92 – -126.32 (m, 2F). HRMS (ESI) m/z: calcd for $C_{22}H_{17}F_{14}O_3$ $[M+H]^+$ 595.0949, found: 595.0954.

2-(trimethylsilyl)ethyl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4ag)



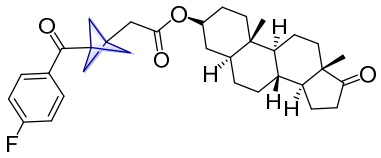
Product **4ag** was isolated as a yellow oil (43.7 mg, 62%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.07–7.94 (m, 2H), 7.15–7.02 (m, 2H), 4.21–4.15 (m, 2H), 2.56 (s, 2H), 2.27 (s, 6H), 1.03–0.96 (m, 2H), 0.04 (s, 9H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.41, 171.08, 165.48 (d, *J* = 254.8 Hz), 132.81 (d, *J* = 3.2 Hz), 131.49 (d, *J* = 9.2 Hz), 115.51 (d, *J* = 21.8 Hz), 62.64, 54.17, 44.57, 37.10, 36.68, 17.45, -1.57. ^{19}F NMR (376 MHz, Chloroform-*d*) δ -105.12. HRMS (ESI) m/z: calcd for $C_{19}H_{26}FO_3Si$ $[M+H]^+$ 349.1630, found: 349.1645.

But-2-yn-1-yl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4ah)



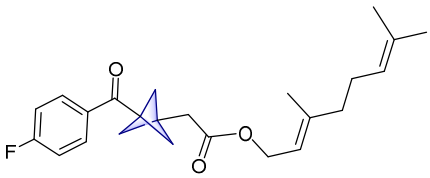
Product **4ah** was isolated as a yellow oil (43.7 mg, 73%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.06–7.94 (m, 2H), 7.16–7.02 (m, 2H), 4.65 (s, 2H), 2.61 (s, 2H), 2.28 (s, 6H), 1.84 (s, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.34, 170.30, 165.50 (d, *J* = 254.8 Hz), 132.79 (d, *J* = 3.0 Hz), 131.50 (d, *J* = 9.2 Hz), 115.54 (d, *J* = 21.8 Hz), 83.25, 73.03, 54.17, 52.72, 44.58, 36.69, 36.53, 3.59. ^{19}F NMR (376 MHz, Chloroform-*d*) δ -105.08. HRMS (ESI) m/z: calcd for $C_{18}H_{18}FO_3$ $[M+H]^+$ 301.1234, found: 301.1253.

(*3R,5S,8R,9S,10S,13S,14S*)-10,13-dimethyl-17-oxohexadecahydro-1H-cyclopenta[a]phenanthren-3-yl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4am)



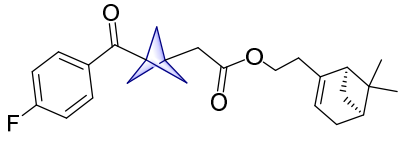
Product **4am** was isolated as a yellow oil (72.4 mg, 70%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.11–7.89 (m, 2H), 7.18–6.98 (m, 2H), 4.79–4.64 (m, 1H), 2.54 (s, 2H), 2.42 (dd, *J* = 19.4, 8.8 Hz, 1H), 2.26 (s, 6H), 2.08–2.01 (m, 1H), 1.96–1.87 (m, 1H), 1.84–1.70 (m, 4H), 1.65–1.44 (m, 5H), 1.39–1.18 (m, 7H), 1.08–0.93 (m, 2H), 0.84 (s, 6H), 0.75–0.65 (m, 1H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 221.14, 195.43, 170.39, 165.48 (d, *J* = 254.8 Hz), 132.80 (d, *J* = 3.0 Hz), 131.48 (d, *J* = 9.2 Hz), 115.53 (d, *J* = 21.8 Hz), 73.64, 54.21, 54.18, 51.27, 47.70, 44.60, 44.50, 37.44, 36.76, 36.61, 35.77, 35.58, 34.94, 34.04, 31.44, 30.72, 28.20, 27.52, 21.70, 20.39, 13.74, 12.16. ^{19}F NMR (376 MHz, Chloroform-*d*) δ -105.04. HRMS (ESI) m/z: calcd for $C_{33}H_{42}FO_4$ $[M+H]^+$ 521.3062, found: 521.3062.

(*E*)-3,7-dimethylocta-2,6-dien-1-yl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4an)



Product **4an** was isolated as a yellow oil (54.3 mg, 71%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.06–7.96 (m, 2H), 7.15–7.03 (m, 2H), 5.34 (t, *J* = 6.8 Hz, 1H), 5.07 (t, *J*=7.2 Hz, 1H), 4.61 (d, *J* = 7.2 Hz, 2H), 2.58 (s, 2H), 2.27 (s, 6H), 2.13–2.01 (m, 4H), 1.70 (s, 3H), 1.66 (s, 3H), 1.57 (s, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.39, 170.92, 165.48 (d, *J* = 254.8 Hz), 142.48, 132.82 (d, *J* = 3.0 Hz), 131.81, 131.48 (d, *J* = 9.2 Hz), 123.60, 118.14, 115.51 (d, *J* = 21.8 Hz), 61.31, 54.19, 44.55, 39.46, 37.03, 36.70, 26.24, 25.61, 17.63, 16.44. ^{19}F NMR (376 MHz, Chloroform-*d*) δ -105.14. HRMS (ESI) m/z: calcd for $C_{24}H_{30}FO_3$ $[M+H]^+$ 385.2173, found: 385.2179.

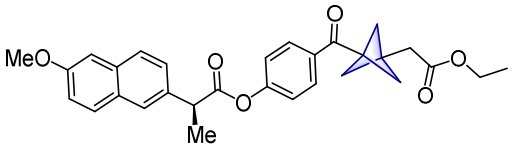
2-((*1R,5S*)-6,6-dimethylbicyclo[3.1.1]hept-2-en-2-yl)ethyl 2-(3-(4-fluorobenzoyl)bicyclo-[1.1.1]pentan-1-yl)acetate (4ao)



Product **4ao** was isolated as a yellow oil (33.0 mg, 42%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.09–7.95 (m, 2H), 7.18–7.03 (m, 2H), 5.34–5.26 (m, 1H), 4.17–4.03 (m, 2H), 2.57 (s, 2H), 2.40–2.33 (m, 1H), 2.32–2.25 (m, 8H), 2.24–2.14 (m, 2H), 2.10–2.02 (m, 2H), 1.26 (s, 3H), 1.14 (d, *J* = 8.6 Hz, 1H), 0.82 (s, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.46, 170.98, 165.52 (d, *J* =

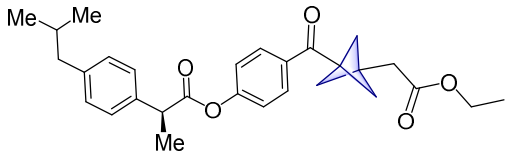
254.8 Hz), 143.92, 132.82 (d, J = 3.2 Hz), 131.52 (d, J = 9.2 Hz), 118.81, 115.55 (d, J = 22.0 Hz), 62.70, 54.20, 45.57, 44.60, 40.64, 37.98, 37.00, 36.63, 35.97, 31.58, 31.30, 26.22, 21.08. ^{19}F NMR (376 MHz, Chloroform-*d*) δ -105.09. HRMS (ESI) m/z: calcd for $C_{25}H_{30}FO_3$ $[M+H]^+$ 397.2173, found: 397.2166.

4-(3-(2-ethoxy-2-oxoethyl)bicyclo[1.1.1]pentane-1-carbonyl)phenyl (*S*)-2-(6-methoxynaphthalen-2-yl)propanoate (4ap)



With DMSO as the solvent, product **4ap** was isolated as a yellow oil (24.2 mg, 25%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.02–7.93 (m, 2H), 7.79–7.71 (m, 3H), 7.51–7.46 (m, 1H), 7.19–7.13 (m, 2H), 7.11–7.01 (m, 2H), 4.19–4.07 (m, 3H), 3.92 (s, 3H), 2.57 (s, 2H), 2.26 (s, 6H), 1.70 (d, J = 7.0 Hz, 3H), 1.27 (t, J = 7.0 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.79, 172.64, 170.96, 157.80, 154.32, 134.70, 133.95, 133.85, 130.44, 129.28, 128.94, 127.46, 126.15, 125.95, 121.49, 119.20, 105.57, 60.42, 55.31, 54.19, 45.58, 44.58, 37.09, 36.66, 18.40, 14.30. HRMS (ESI) m/z: calcd for $C_{30}H_{31}O_6$ $[M+H]^+$ 487.2115, found: 487.2133.

4-(3-(2-ethoxy-2-oxoethyl)bicyclo[1.1.1]pentane-1-carbonyl)phenyl (*S*)-2-(4-isobutylphenyl)propanoate (4aq)



With DMSO as the solvent, product **4aq** was isolated as a yellow oil (38.4 mg, 42%). ^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.02–7.94 (m, 2H), 7.31–7.26 (m, 2H), 7.17–7.12 (m, 2H), 7.09–7.04 (m, 2H), 4.16 (q, J = 7.2 Hz, 2H), 3.95 (q, J = 7.2 Hz, 1H), 2.57 (s, 2H), 2.47 (dd, J = 7.2, 2.4 Hz, 2H), 2.27 (s, 6H), 1.91–1.82 (m, 1H), 1.61 (dd, J = 7.2, 2.6 Hz, 3H), 1.27 (t, J = 5.8 Hz, 3H), 0.91 (dd, J = 6.8, 2.6 Hz, 6H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 195.81, 172.68, 170.96, 154.36, 140.98, 136.81, 133.91, 130.43, 129.56, 127.15, 121.49, 60.42, 54.19, 45.25, 45.00, 44.59, 37.09, 36.66, 30.15, 22.36, 18.40, 14.30. HRMS (ESI) m/z: calcd for $C_{29}H_{35}O_5$ $[M+H]^+$ 463.2479, found: 463.2482.

7. Reference

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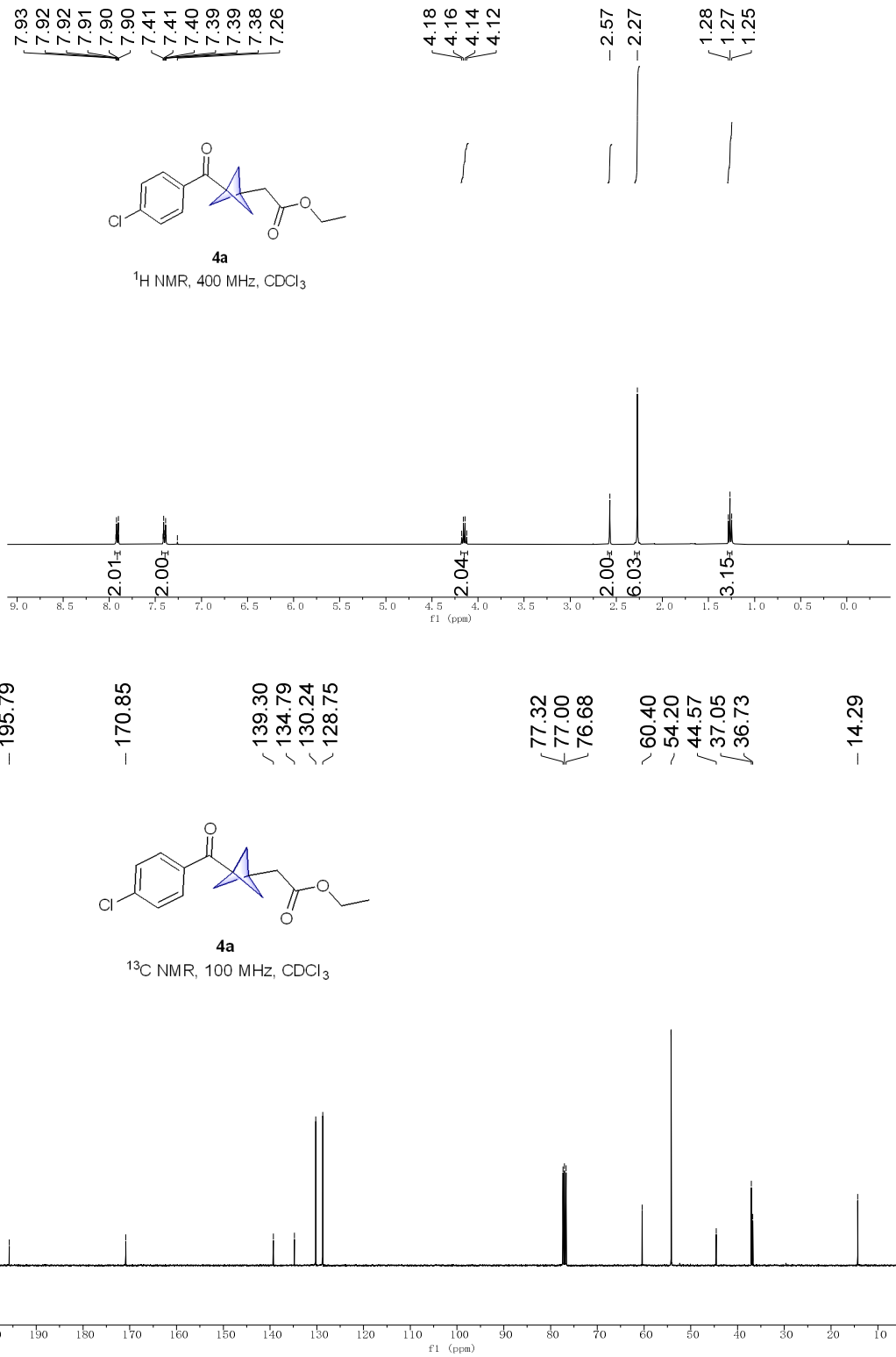
[7] S. C. Gadekar, V. Dhayalan, A. Nandi, I. L. Zak, M. S. Mizrachi, S. Kozuch, A. Milo, *ACS Catal.* **2021**, *11*, 14561-14569.

8. Copies of ^{1}H, ^{19}F, and ^{13}C NMR spectra of all products.

Ethyl 2-(3-(4-chlorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4a)



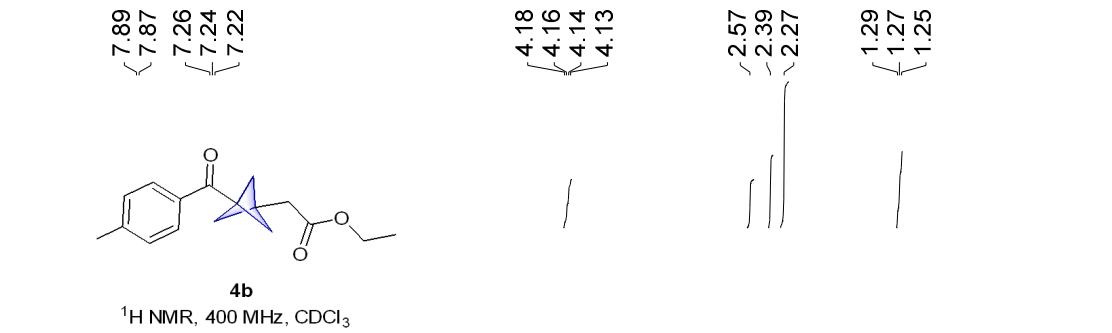
4a

^{1}H NMR, 400 MHz, $CDCl_3$

4a

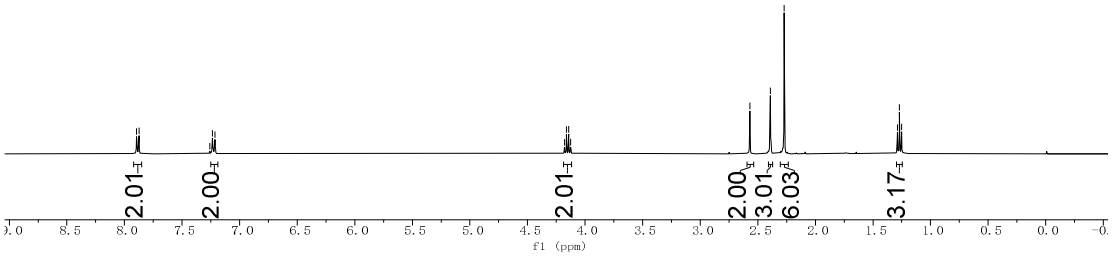
^{13}C NMR, 100 MHz, $CDCl_3$

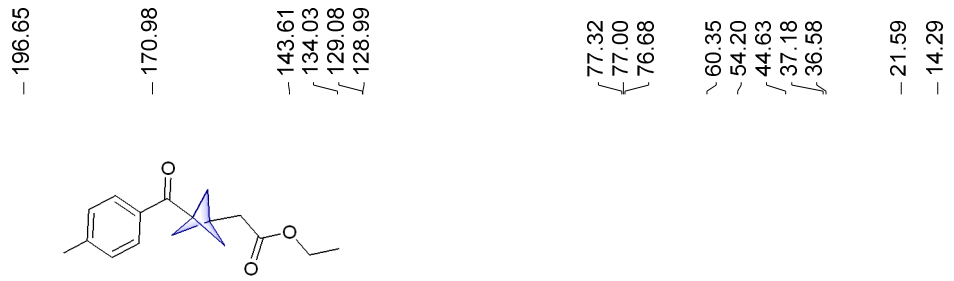
Ethyl 2-(3-(4-methylbenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4b)



4b

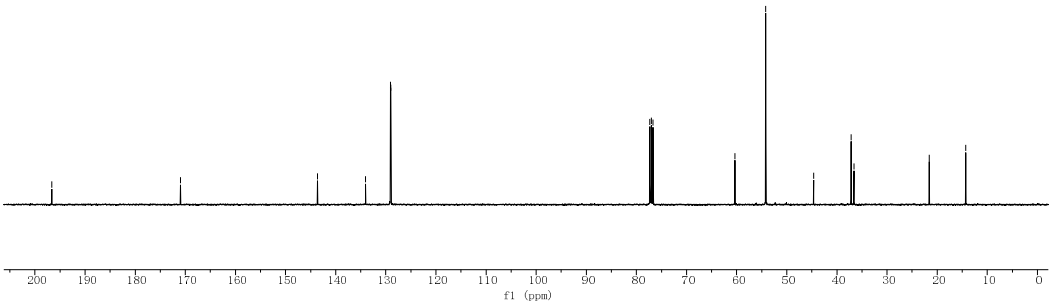
^{1}H NMR, 400 MHz, $CDCl_3$



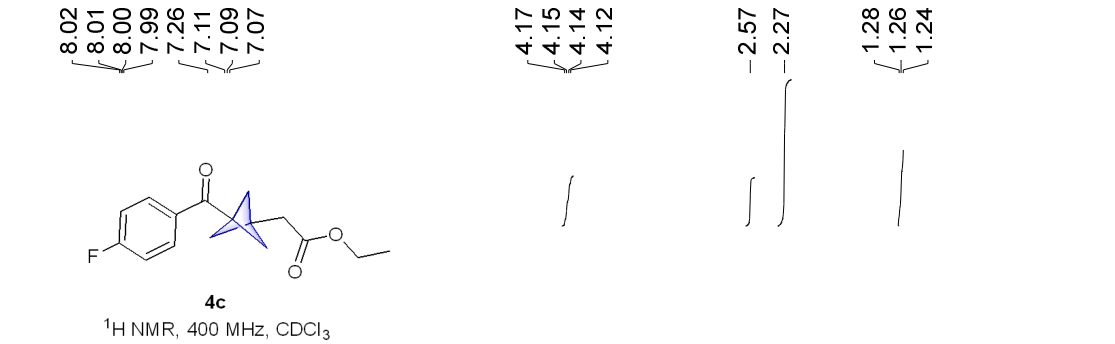


4b

^{13}C NMR, 100 MHz, $CDCl_3$

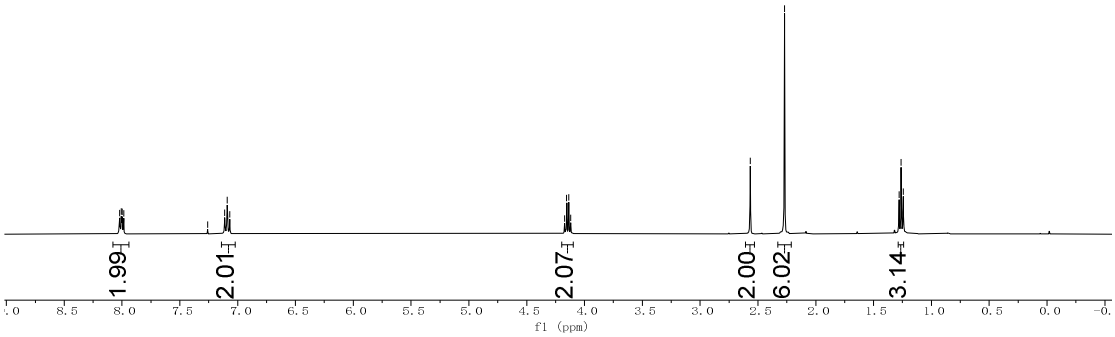


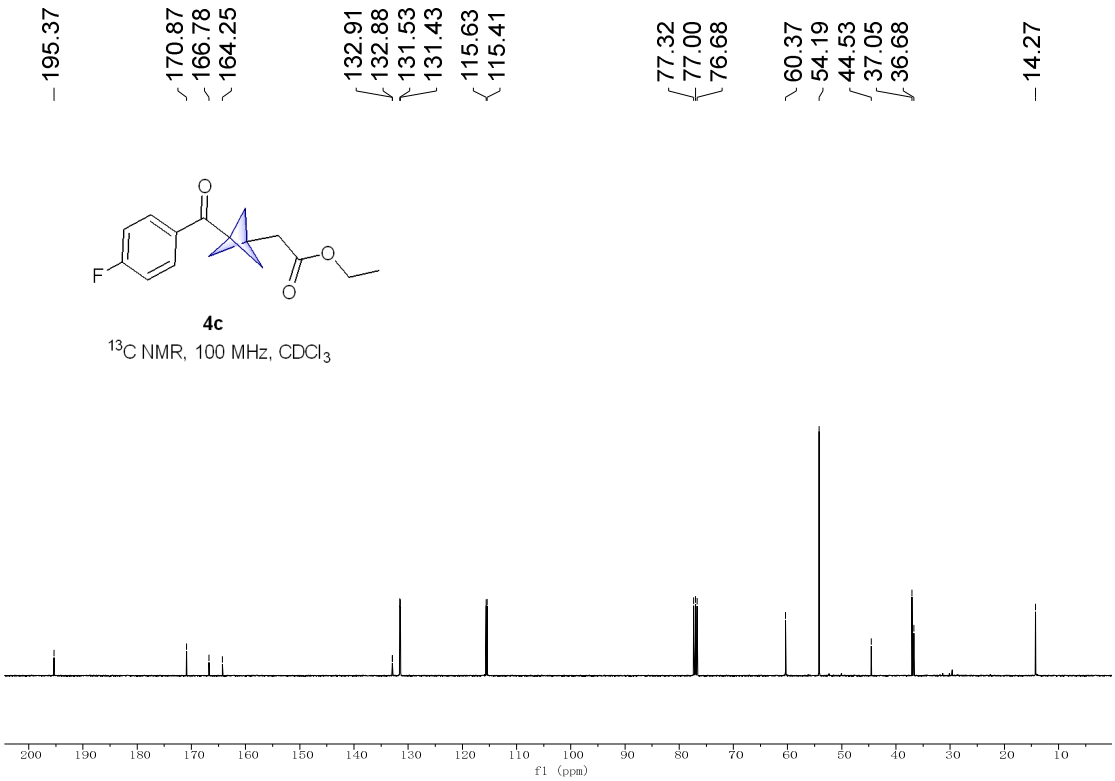
Ethyl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4c)



4c

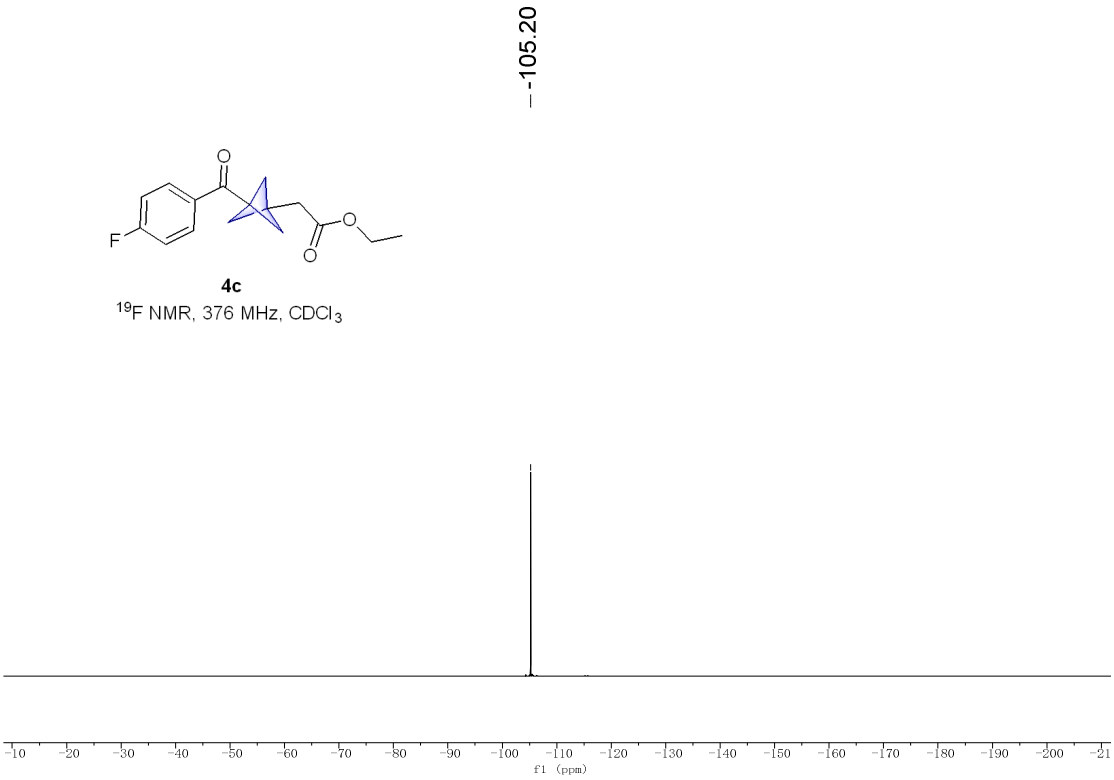
^{1}H NMR, 400 MHz, $CDCl_3$



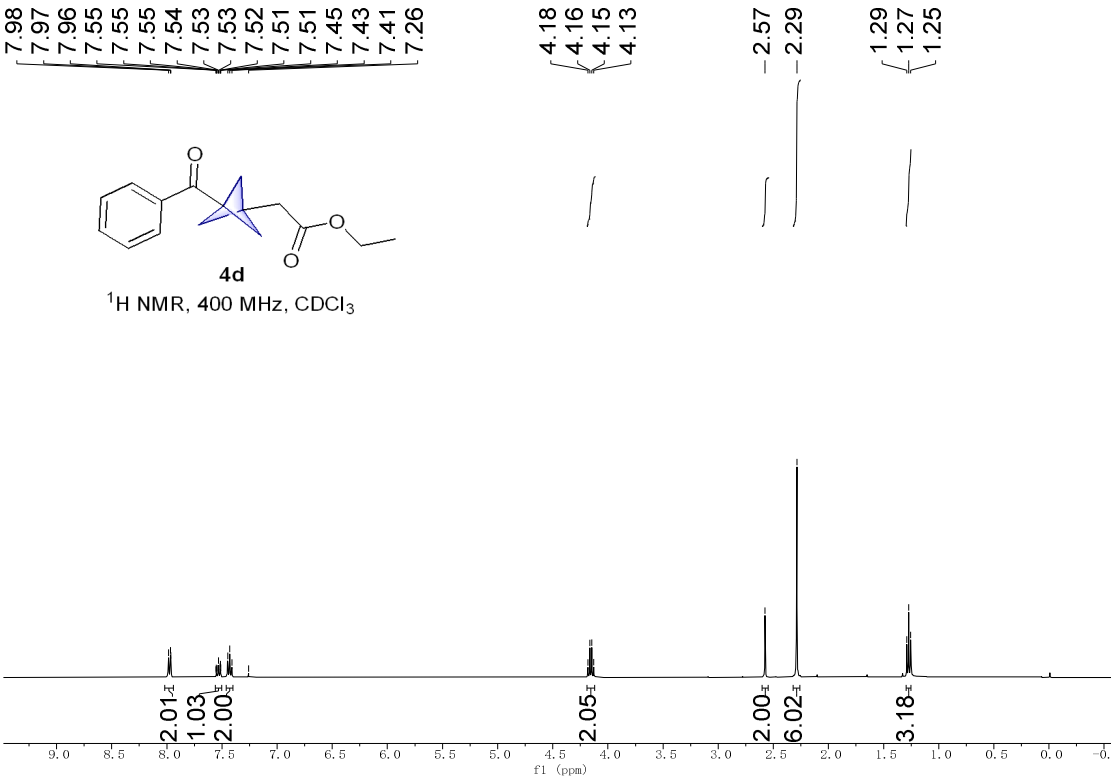


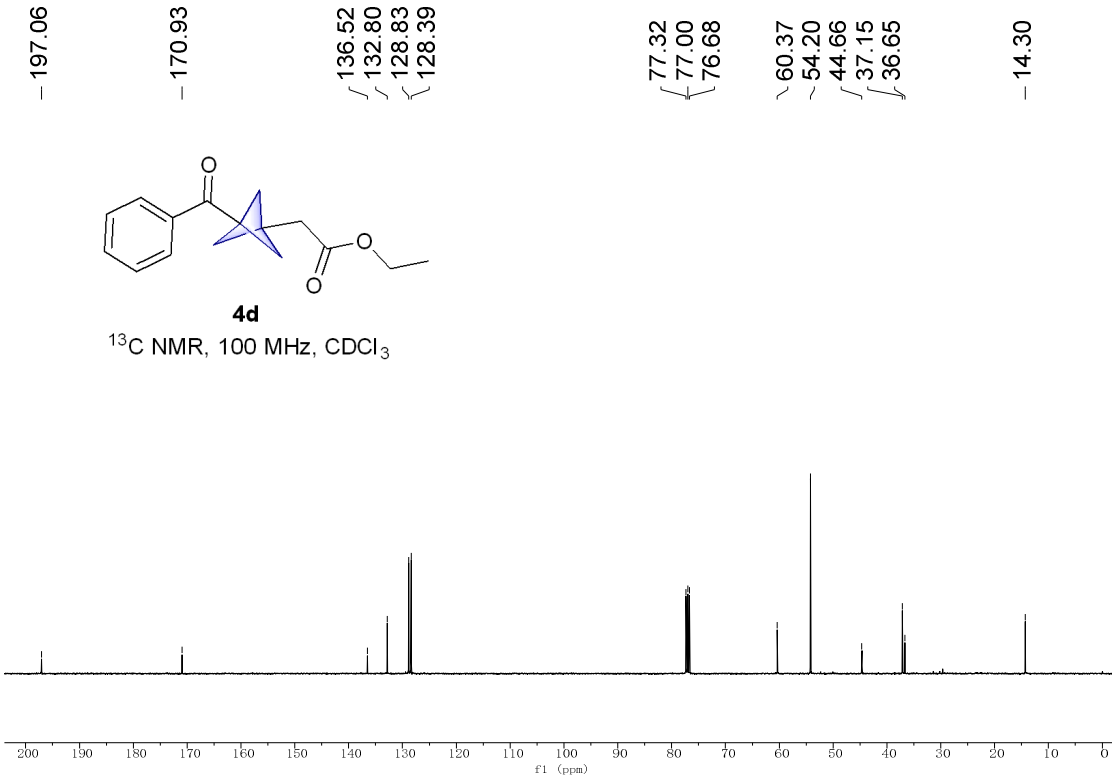
4c

^{13}C NMR, 100 MHz, $CDCl_3$

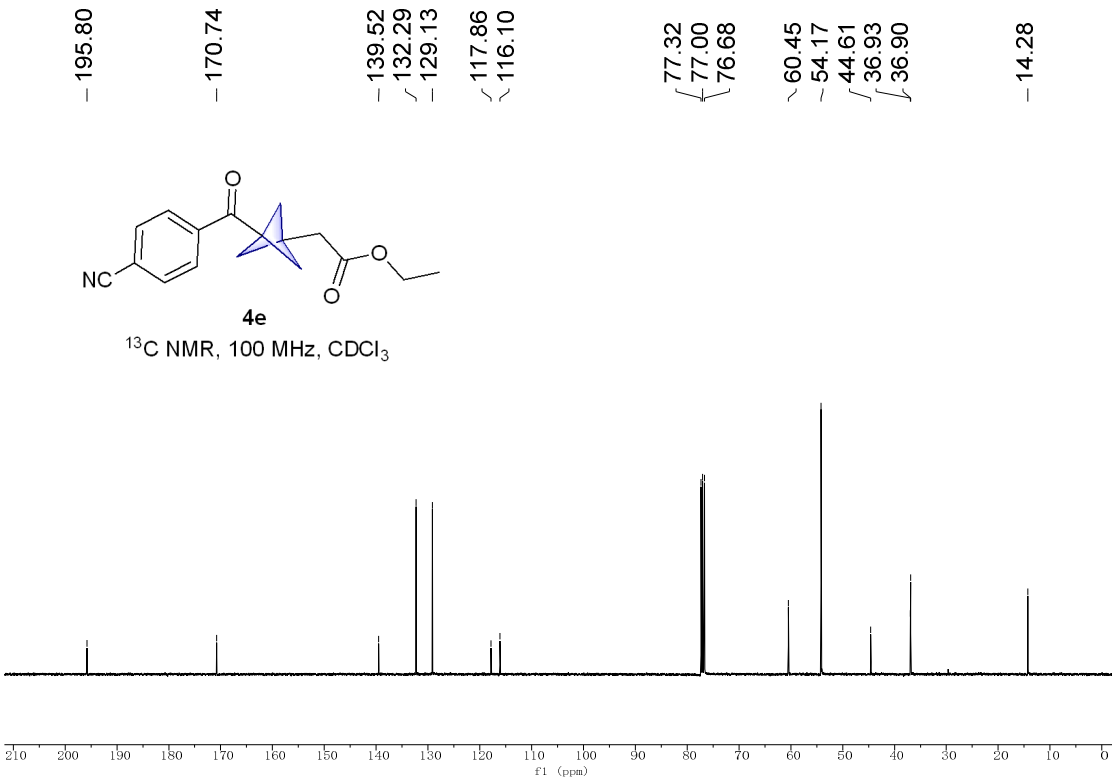


Ethyl 2-(3-benzoylbicyclo[1.1.1]pentan-1-yl)acetate (4d)

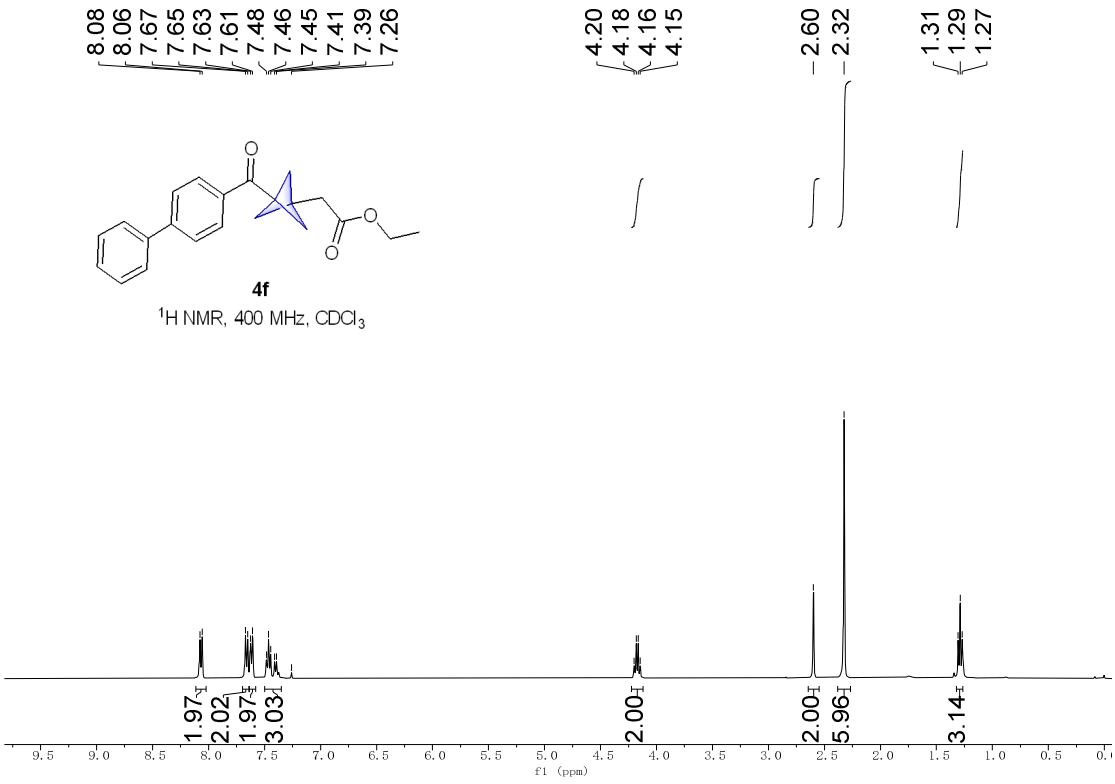


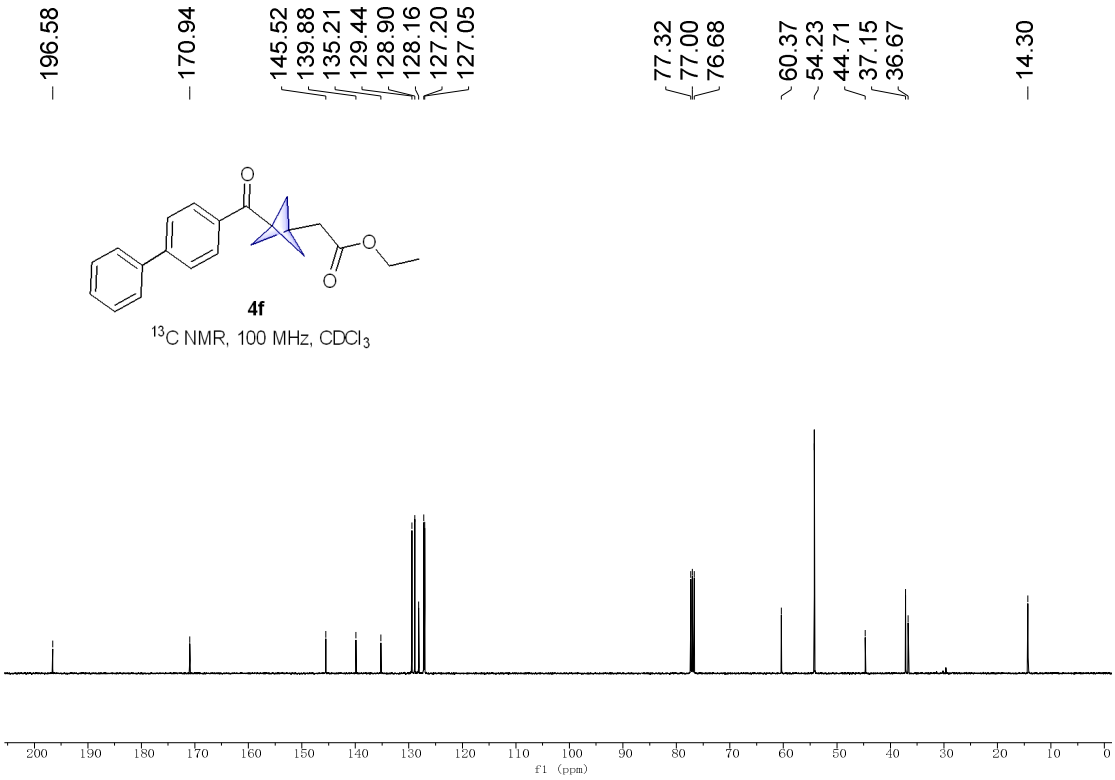


Ethyl 2-(3-(4-cyanobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4e)

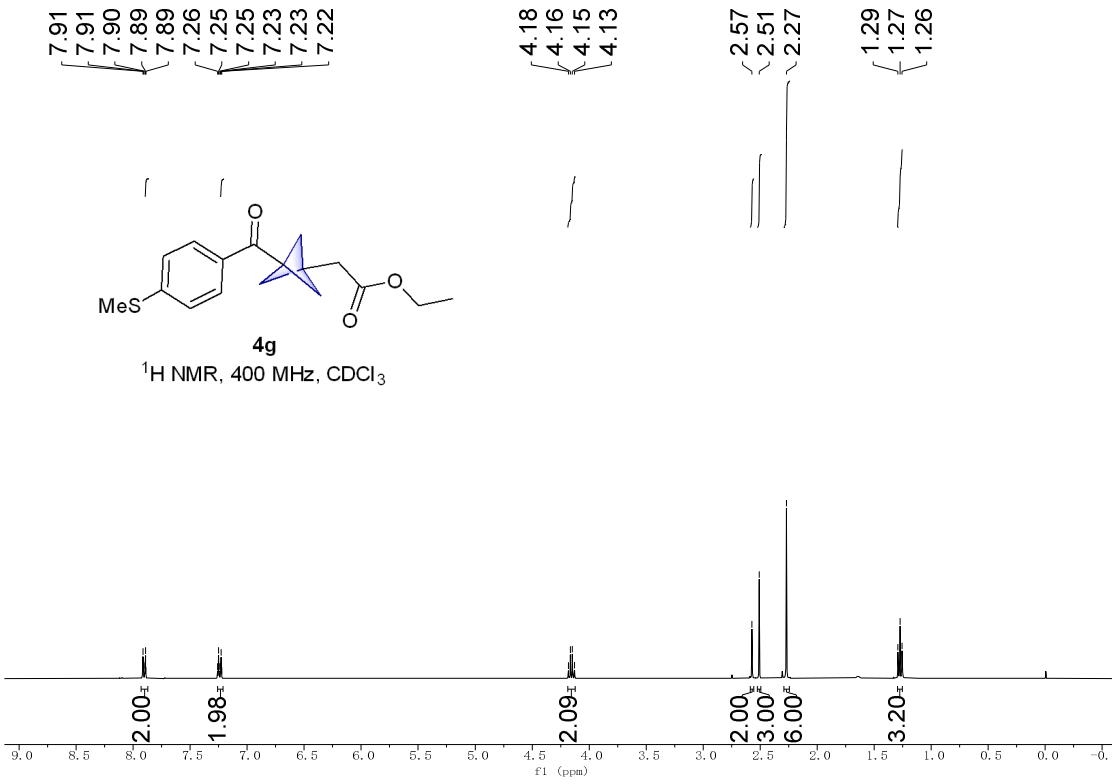


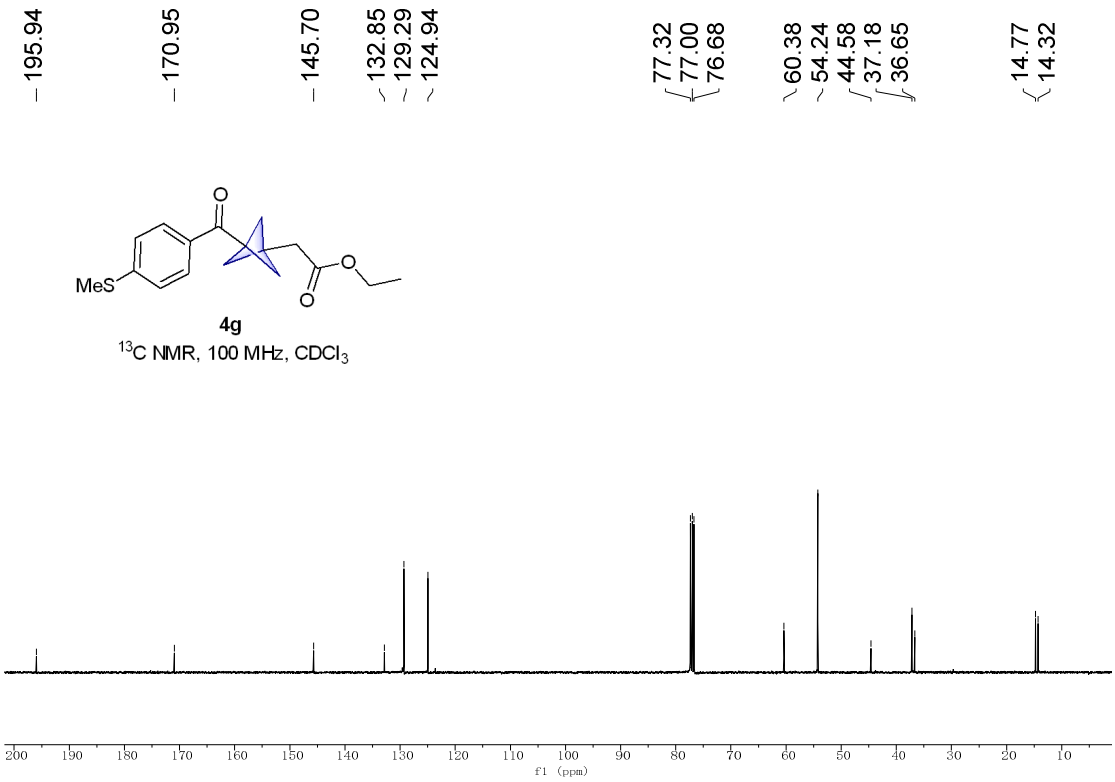
Ethyl 2-(3-([1,1'-biphenyl]-4-carbonyl)bicyclo[1.1.1]pentan-1-yl)acetate (4f)



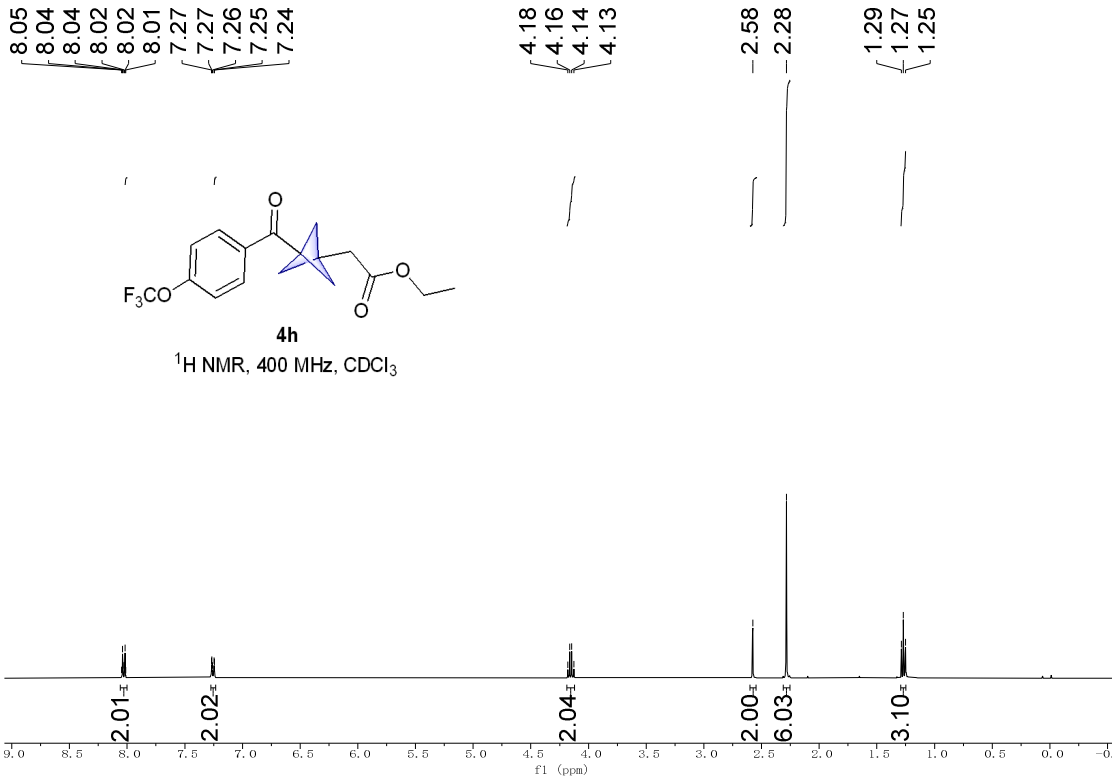


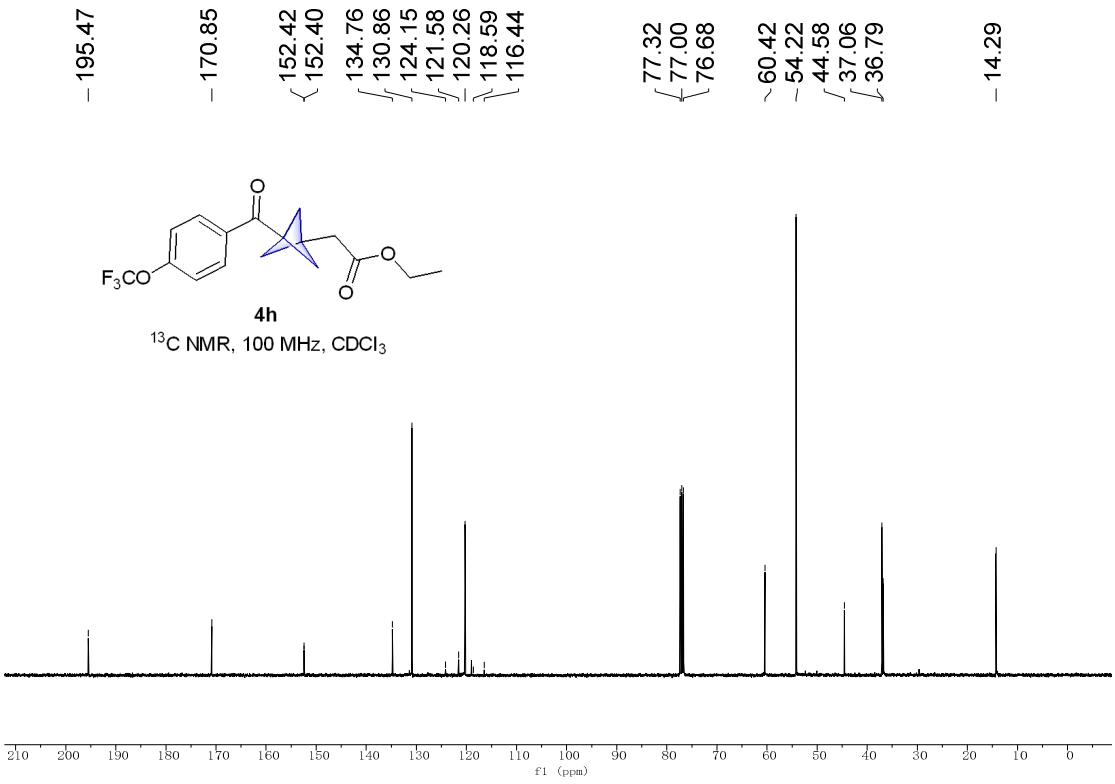
Ethyl 2-(3-(4-(methylthio)benzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4g)





Ethyl 2-(3-(4-(trifluoromethoxy)benzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4h)

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116.44
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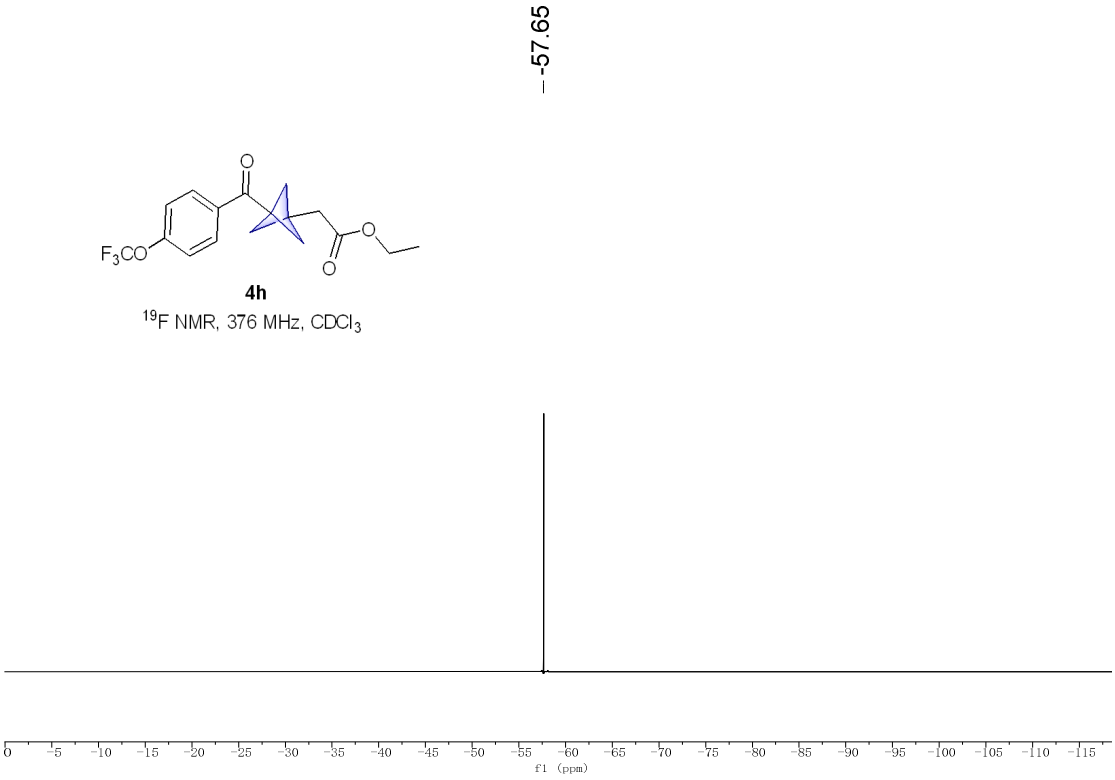
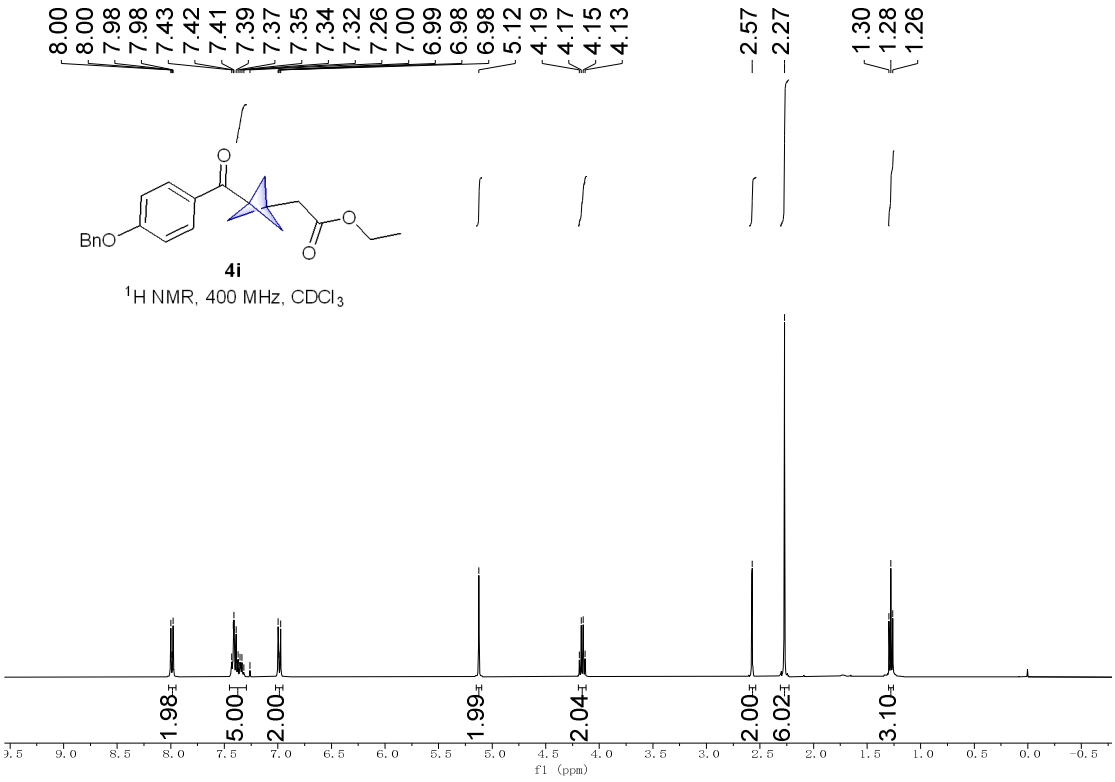
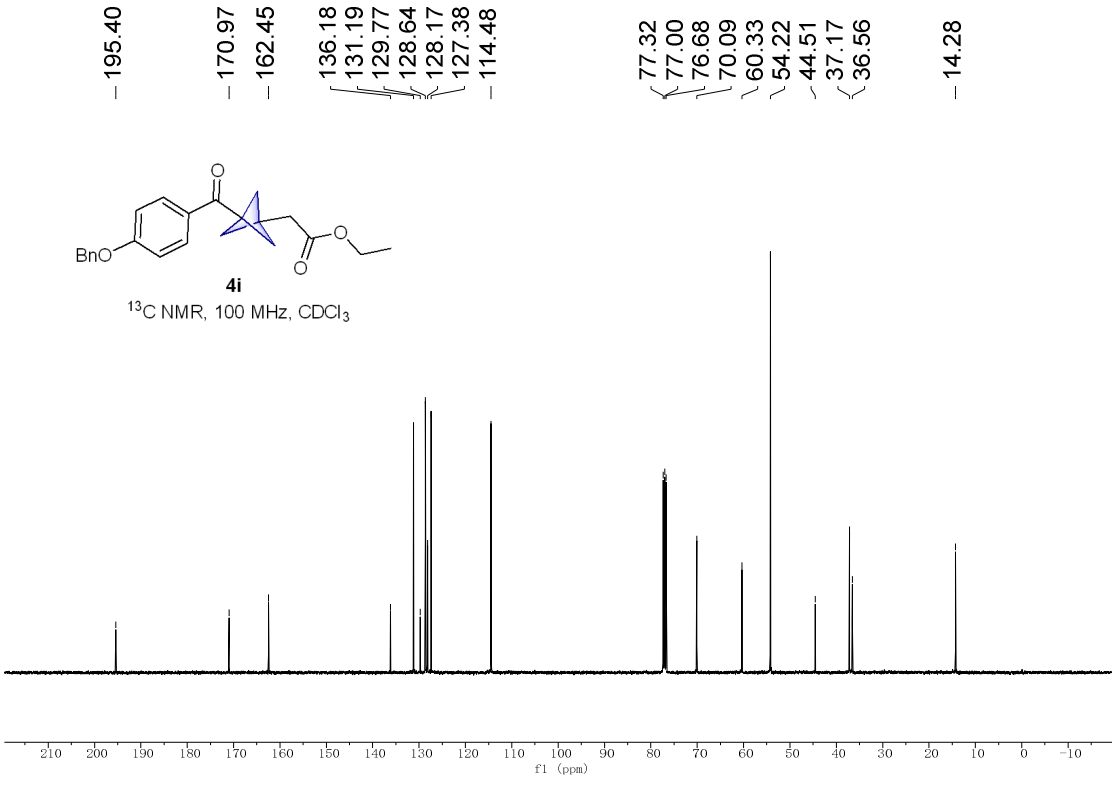
77.00
76.68
60.42
54.22
44.58
37.06
36.79
14.29
O
F3CO
O
O
4h
13C NMR, 100 MHz, CDCl3
f1 (ppm)

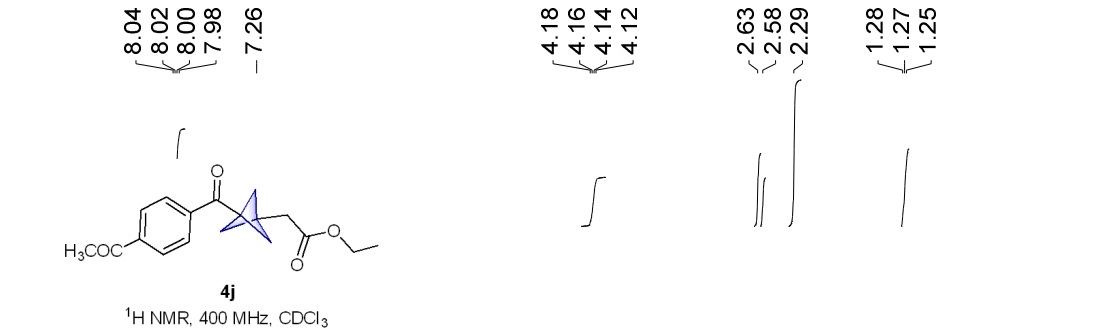

-57.65
O
F3CO
O
O
4h
19F NMR, 376 MHz, CDCl3
f1 (ppm)

Ethyl 2-(3-(4-(benzyloxy)benzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4i)



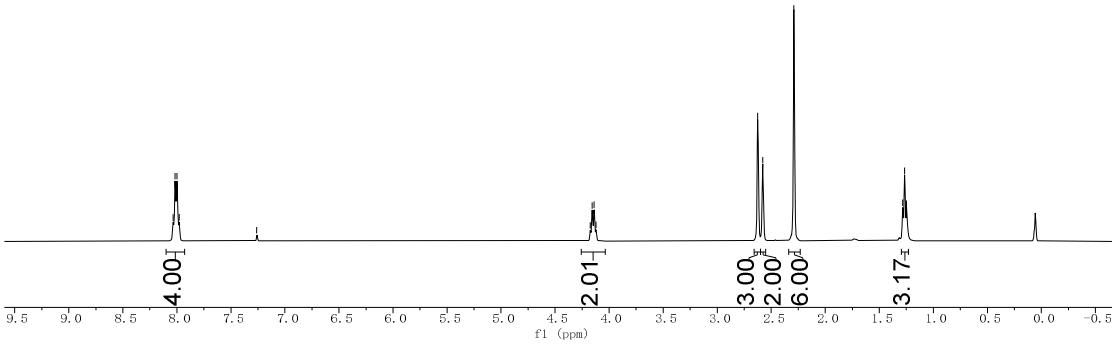


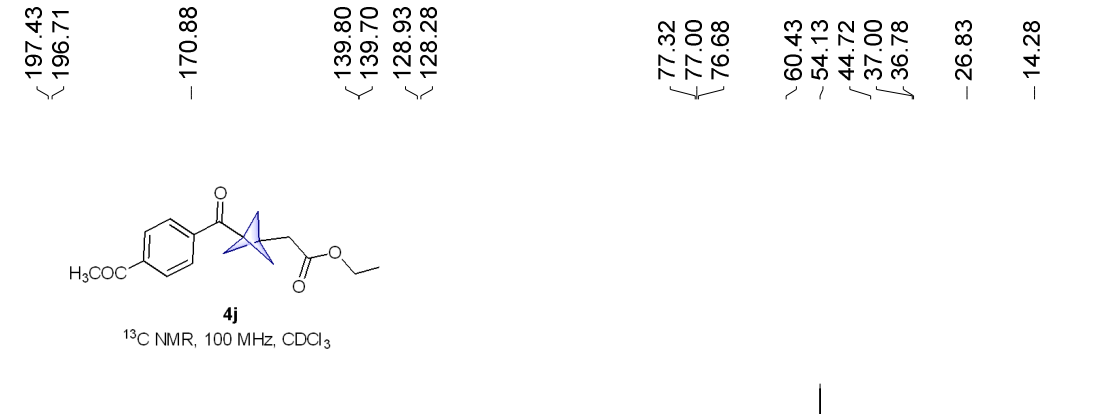
Ethyl 2-(3-(4-acetylbenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4j)



4j

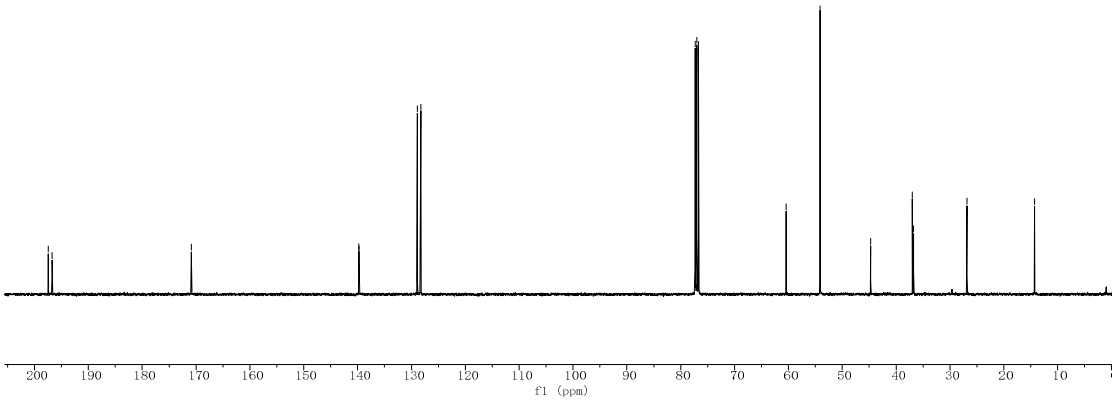
^{1}H NMR, 400 MHz, $CDCl_3$



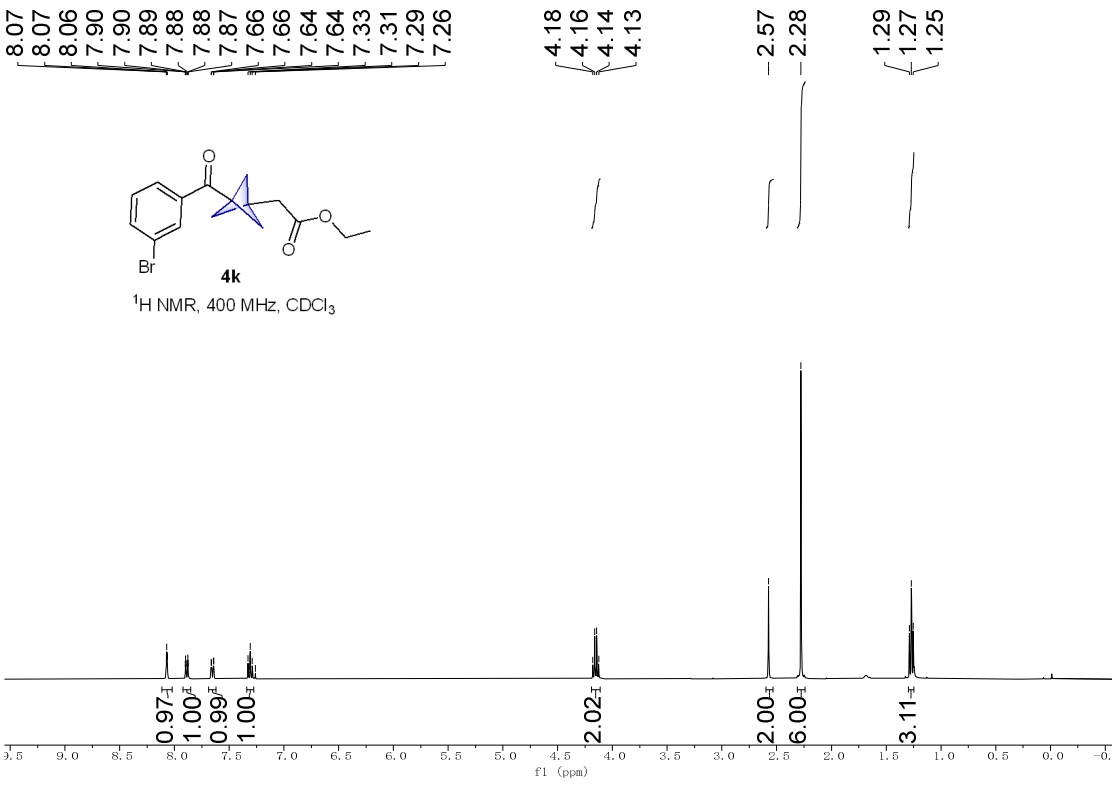


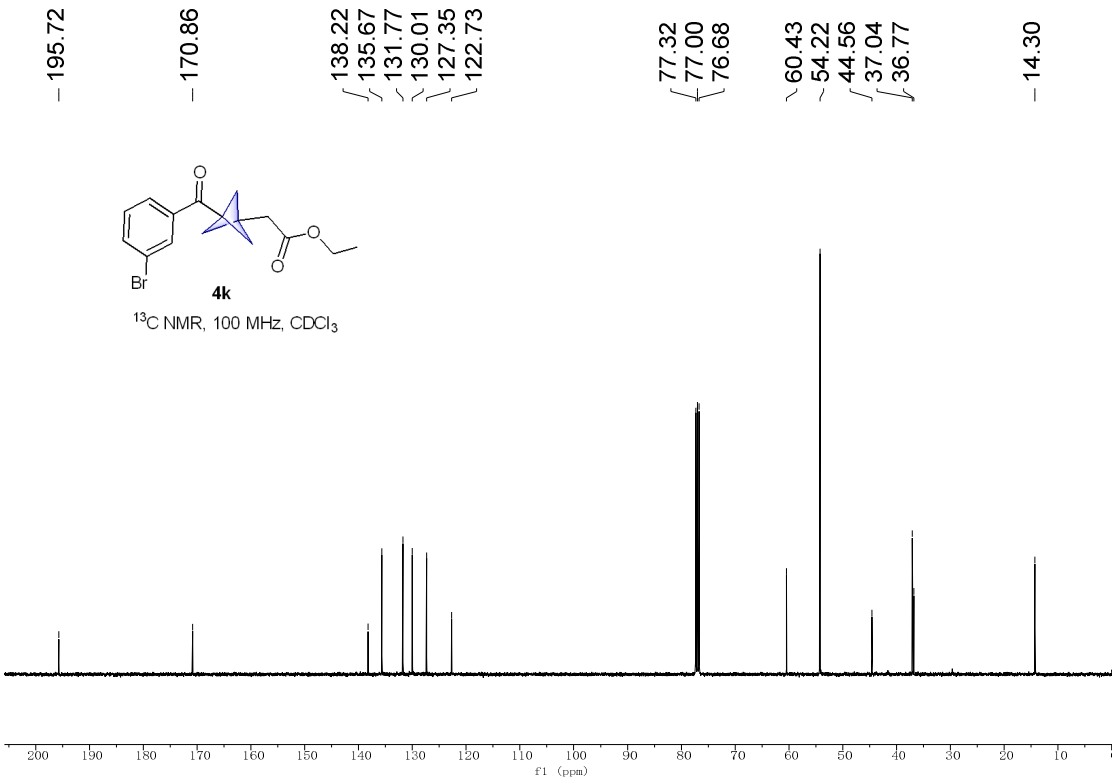
4j

^{13}C NMR, 100 MHz, $CDCl_3$

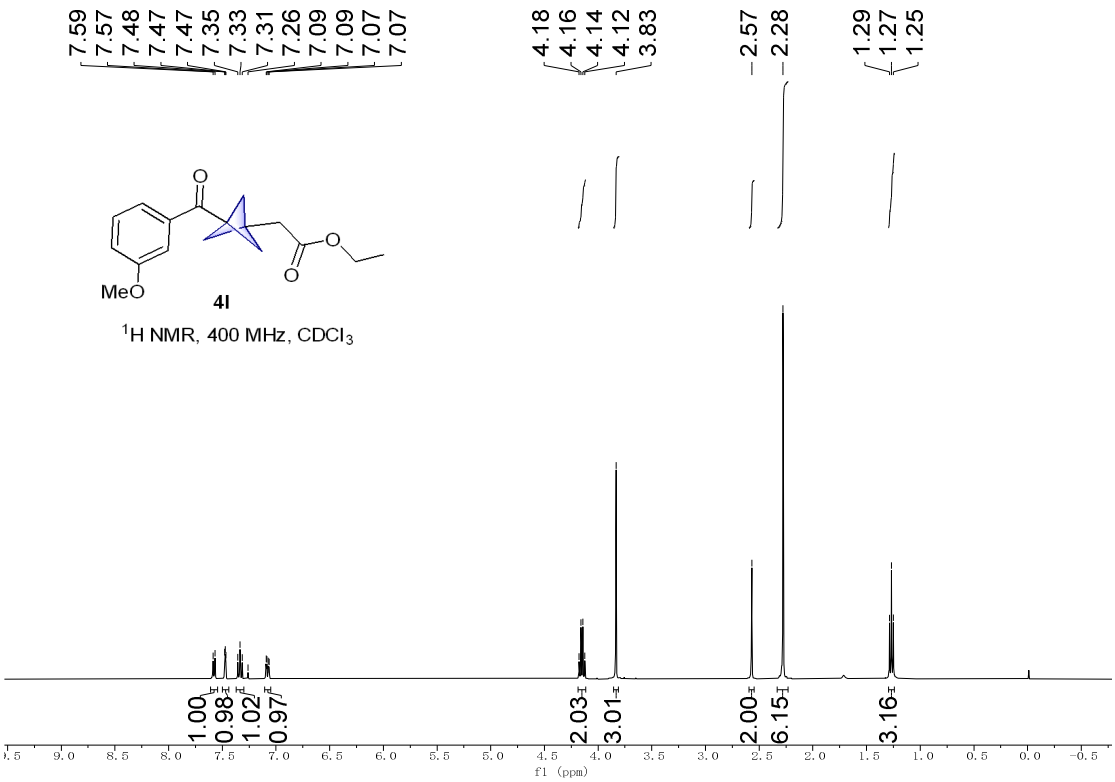


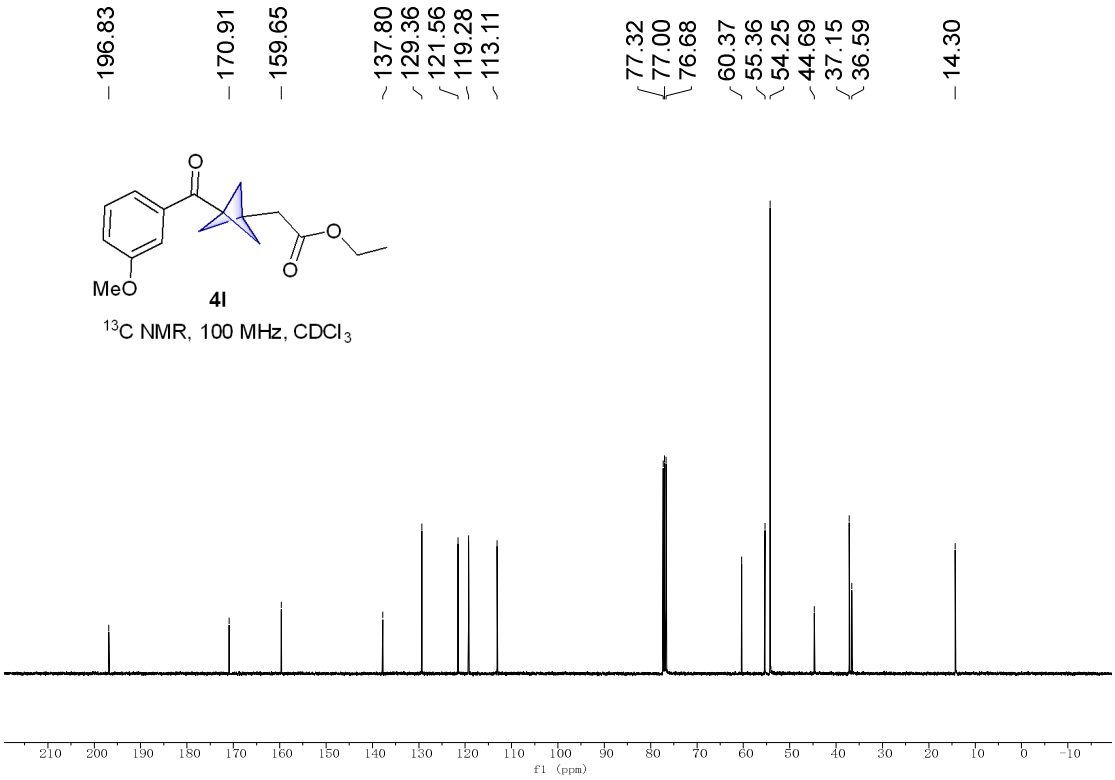
Ethyl 2-(3-(3-bromobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4k)



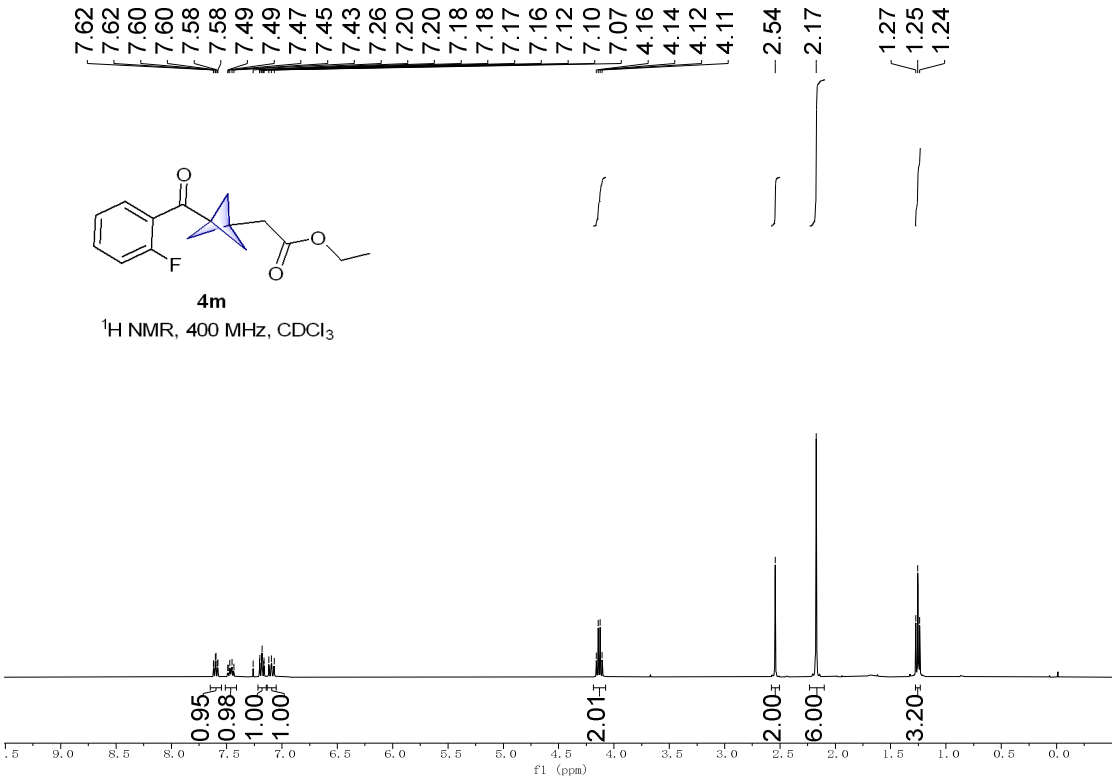


Ethyl 2-(3-(3-methoxybenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4l)



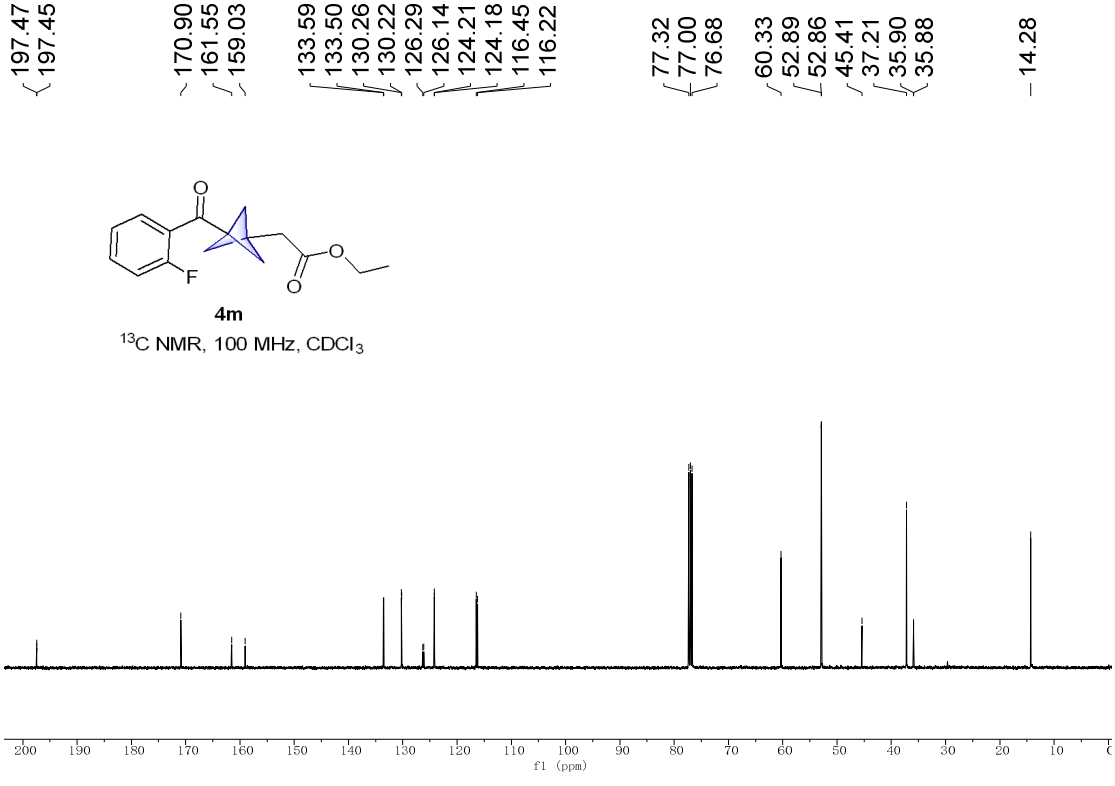


Ethyl 2-(3-(2-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4m)



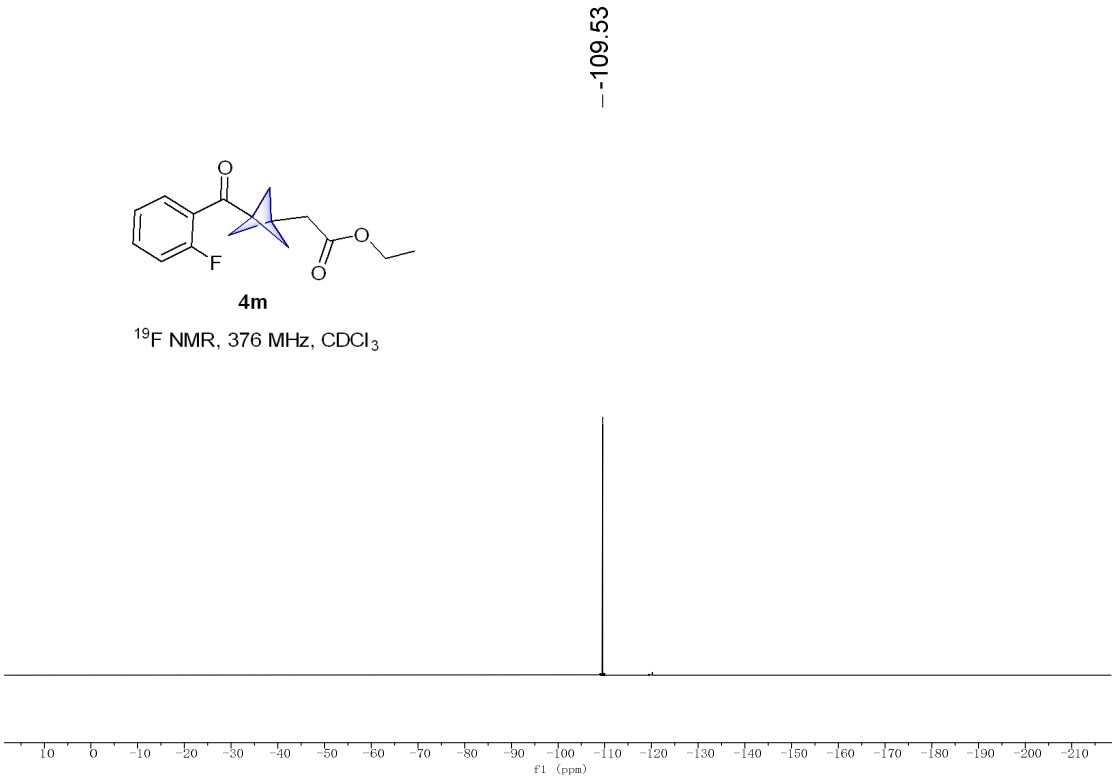
4m

^{1}H NMR, 400 MHz, $CDCl_3$

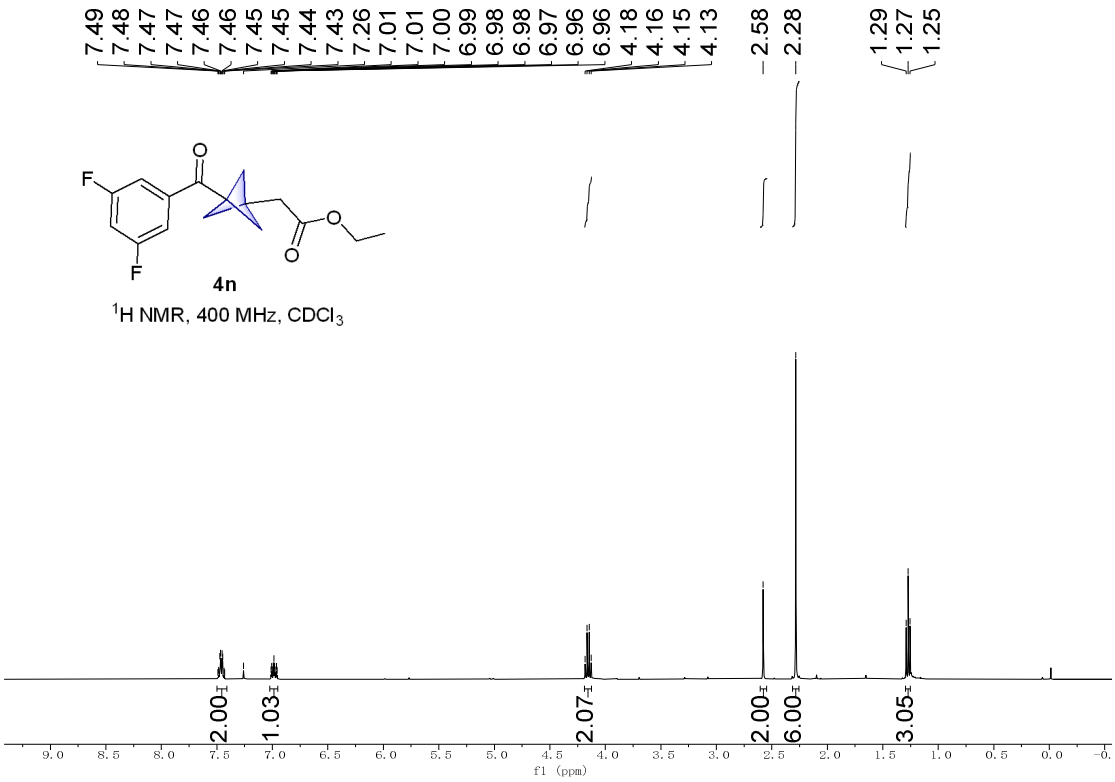


4m

^{13}C NMR, 100 MHz, $CDCl_3$



Ethyl 2-(3-(3,5-difluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4n)



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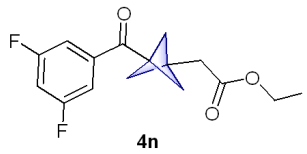
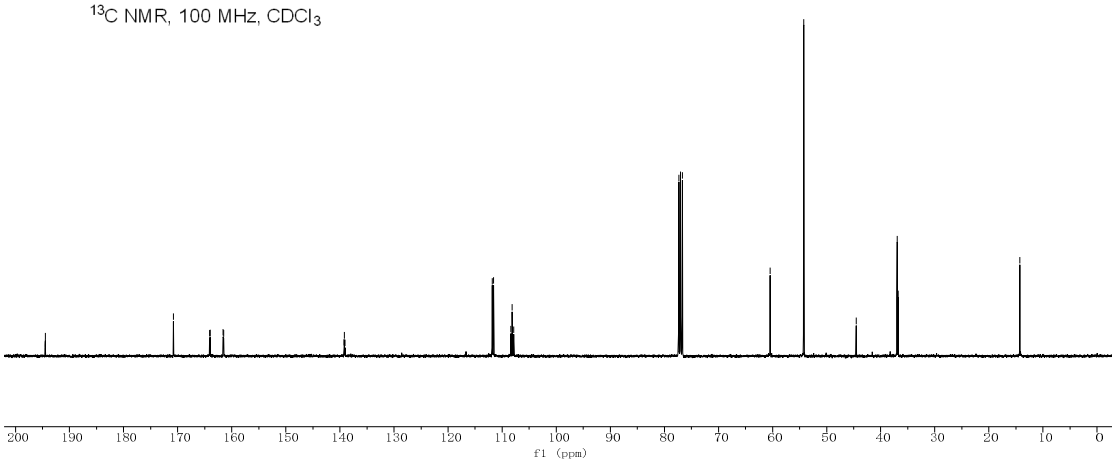


4n

^{13}C NMR, 100 MHz, $CDCl_3$



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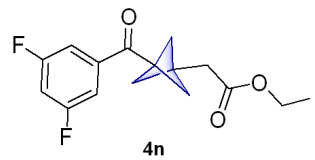
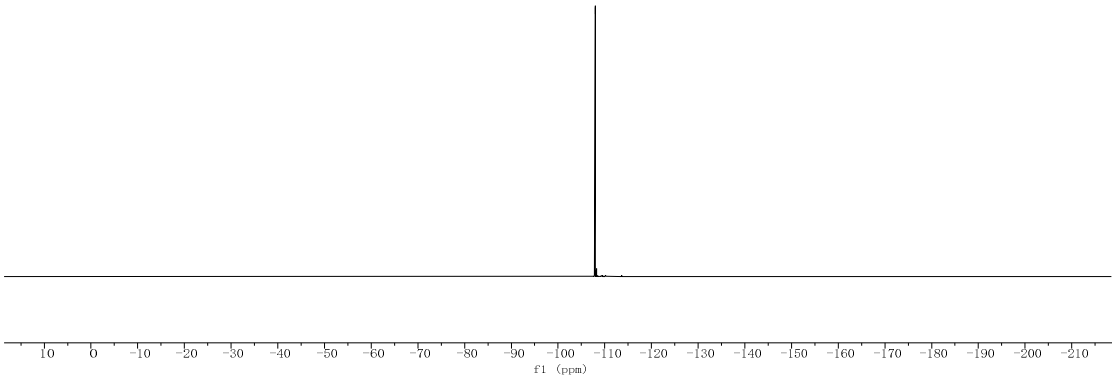
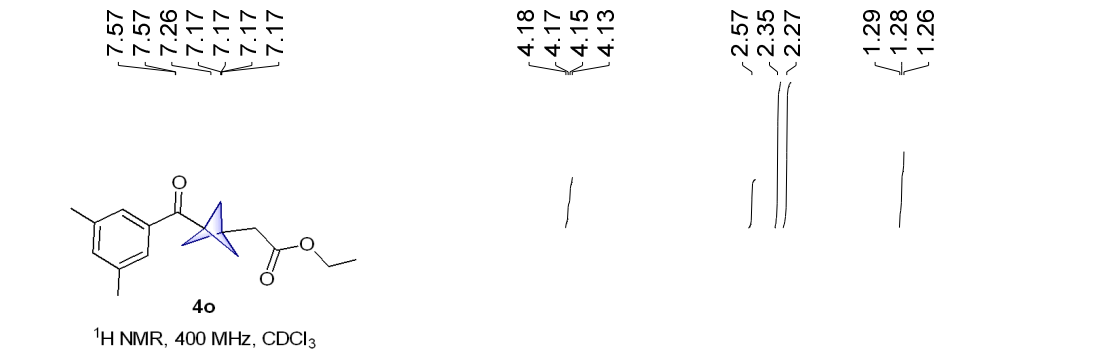


4n

^{19}F NMR, 376 MHz, $CDCl_3$

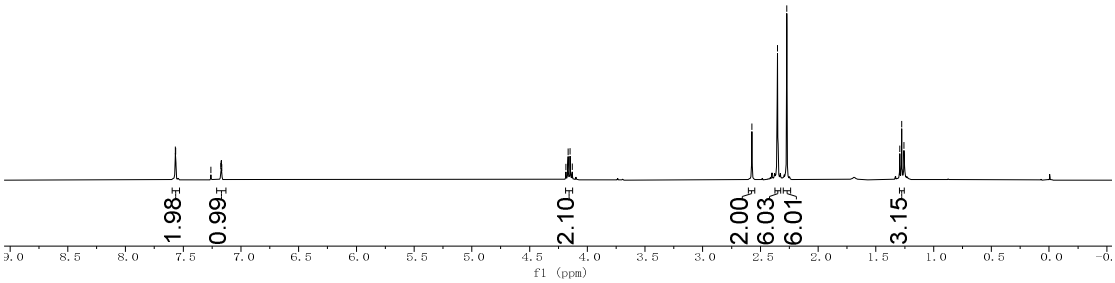


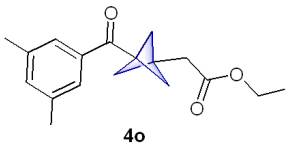
Ethyl 2-(3-(3,5-dimethylbenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4o)



4o

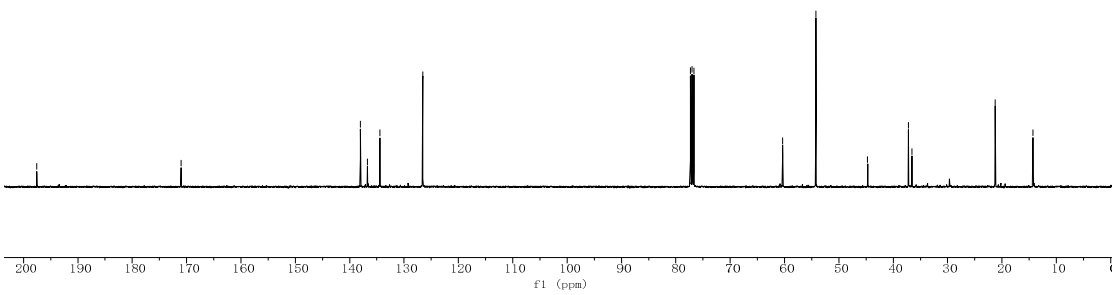
^{1}H NMR, 400 MHz, $CDCl_3$



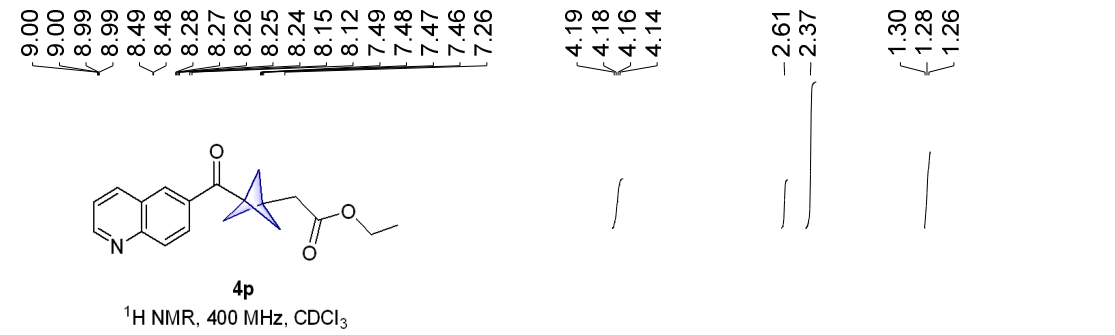


4o

^{13}C NMR, 100 MHz, $CDCl_3$

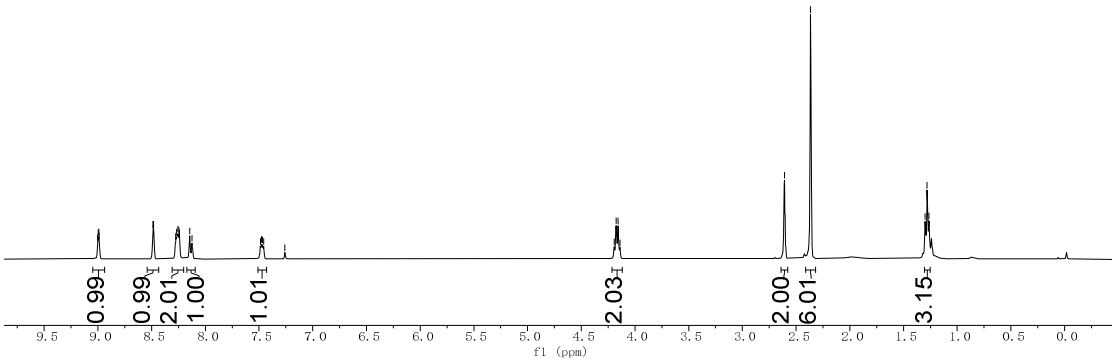


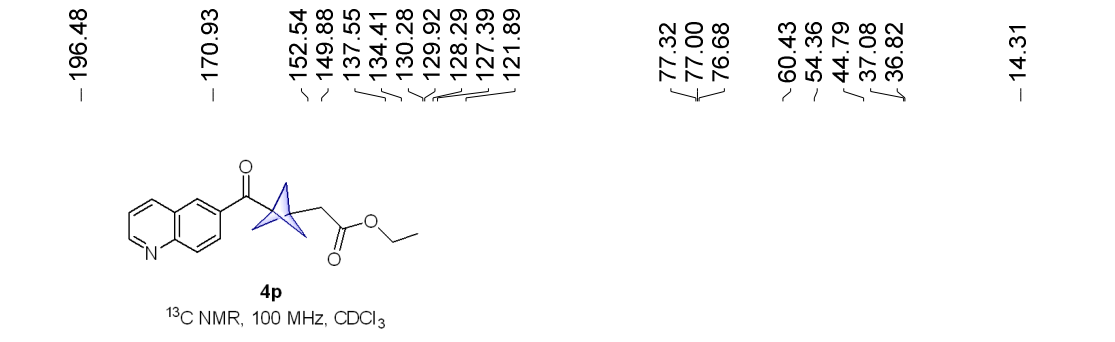
Ethyl 2-(3-(quinoline-6-carbonyl)bicyclo[1.1.1]pentan-1-yl)acetate (4p)



4p

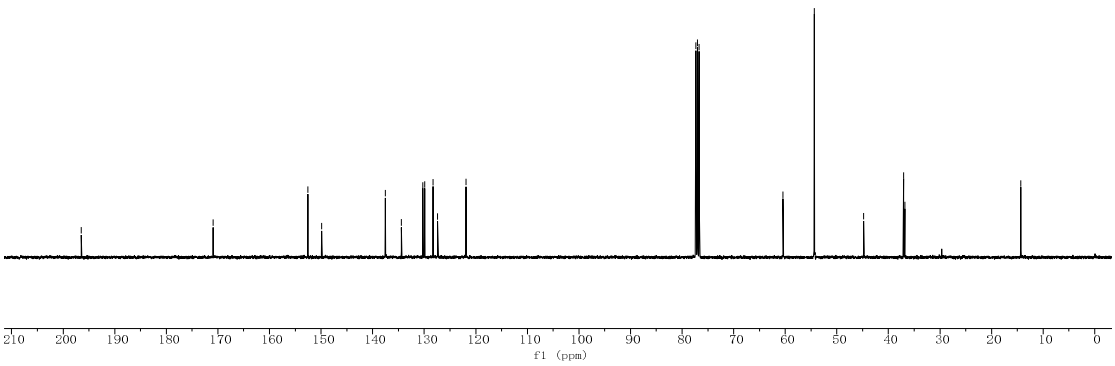
^{1}H NMR, 400 MHz, $CDCl_3$



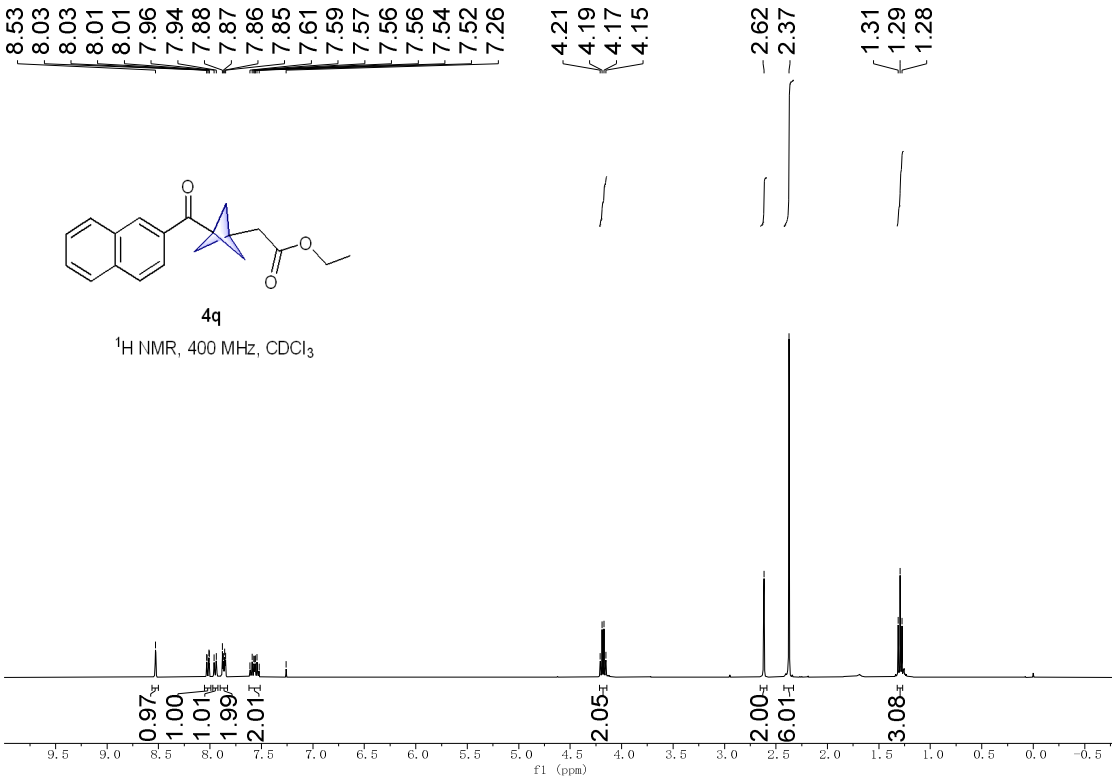


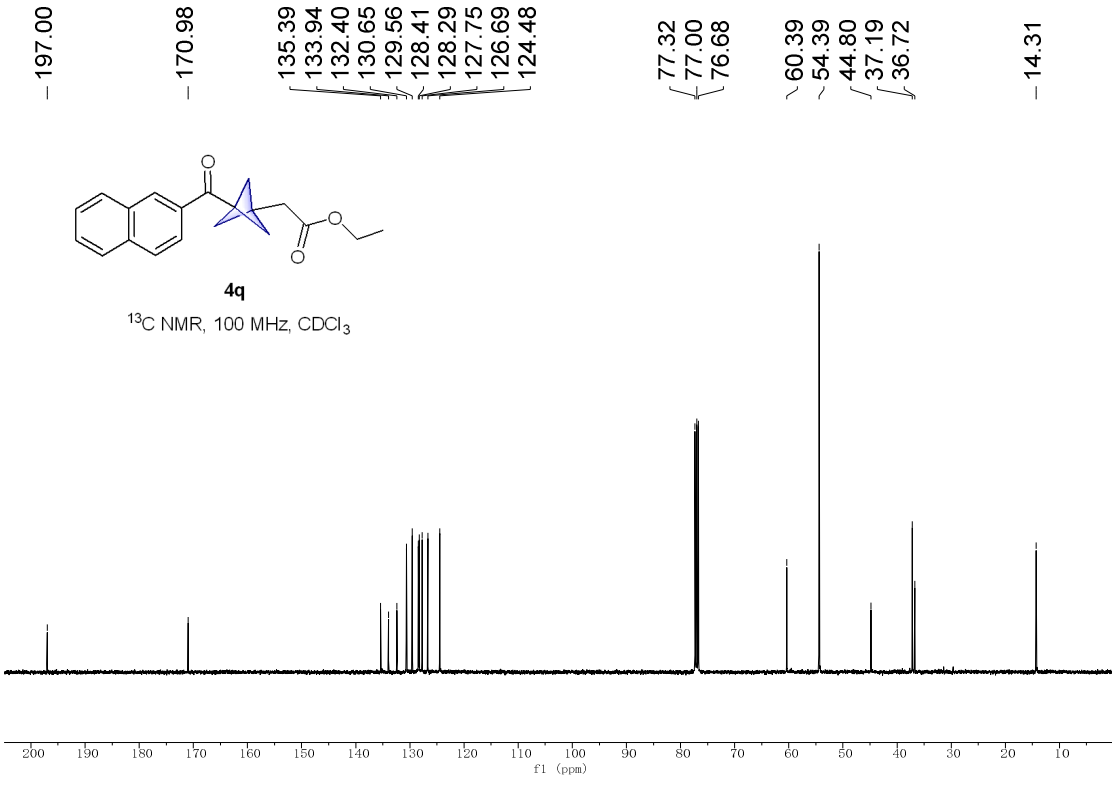
4p

^{13}C NMR, 100 MHz, $CDCl_3$

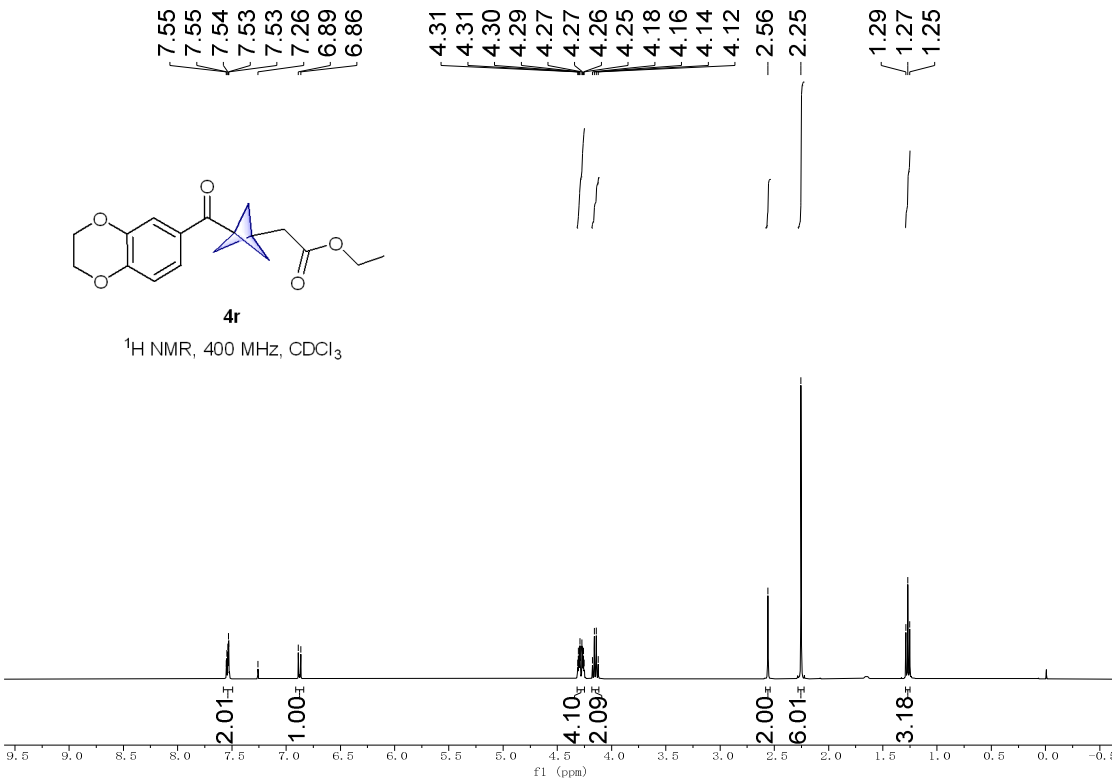


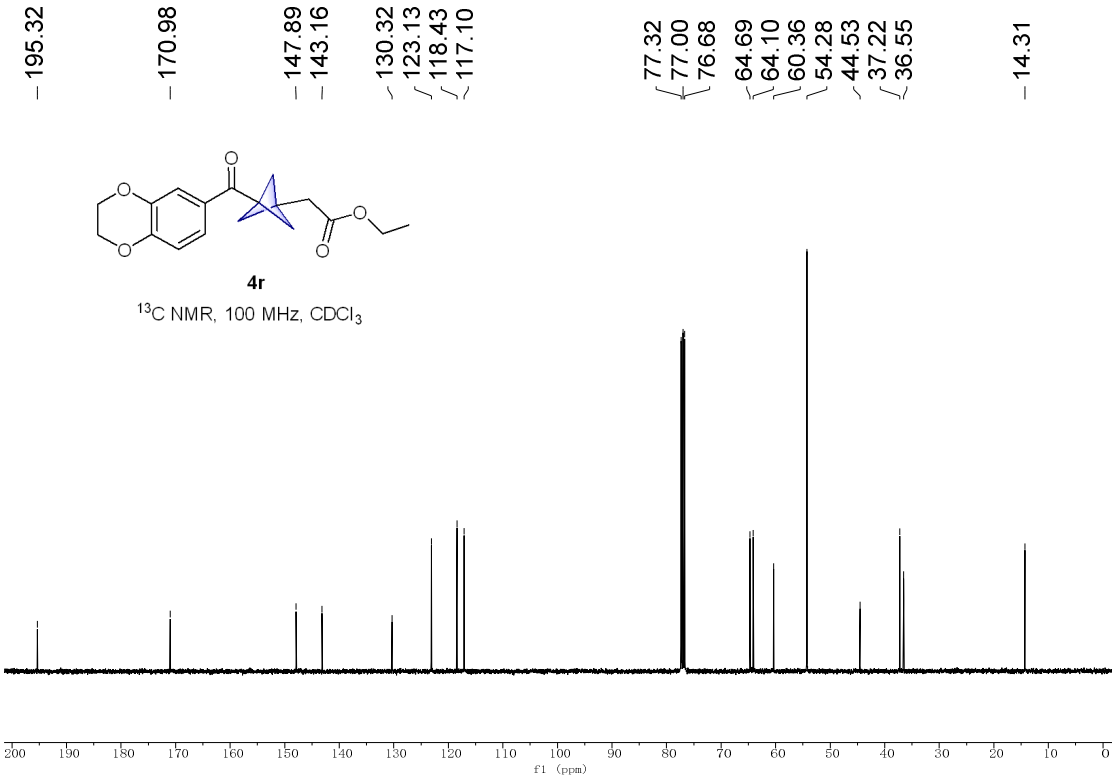
Ethyl 2-(3-(2-naphthoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4q)



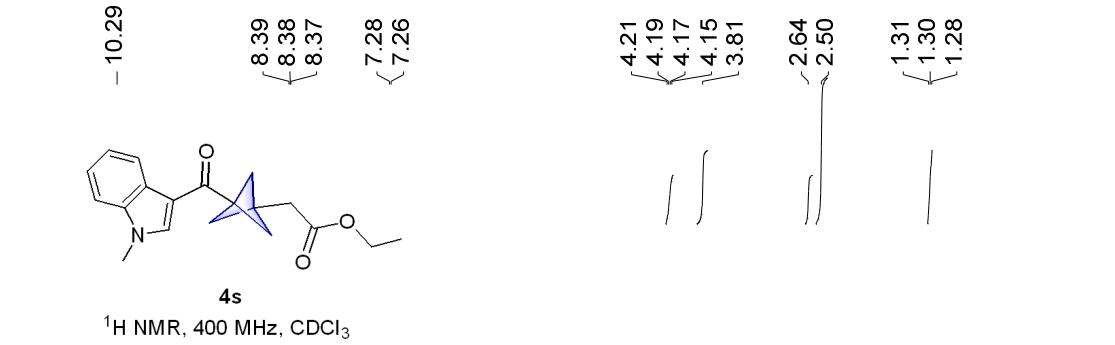


Ethyl 2-(3-(2,3-dihydrobenzo[b][1,4]dioxine-6-carbonyl)bicyclo[1.1.1]pentan-1-yl)acetate (4r)



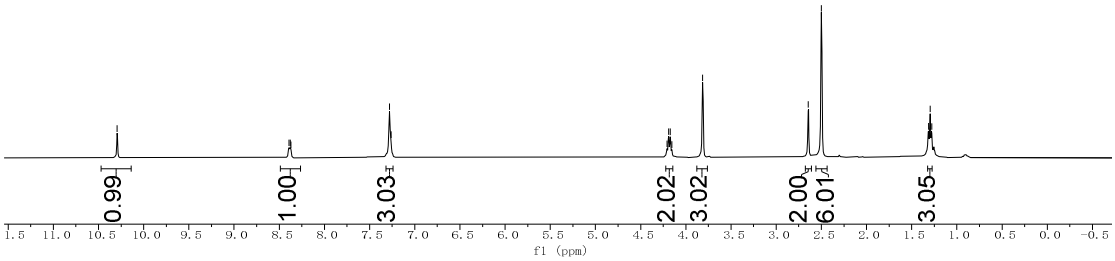


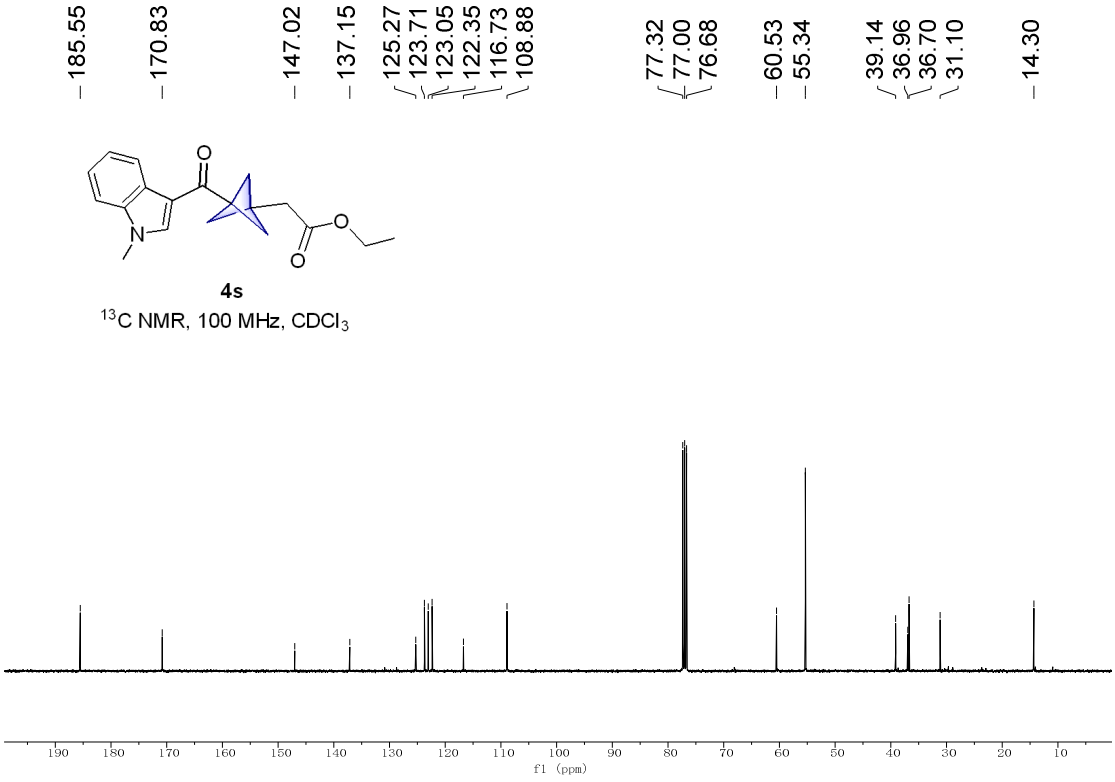
Ethyl 2-(3-(1-methyl-1H-indole-3-carbonyl)bicyclo[1.1.1]pentan-1-yl)acetate (4s):



4s

^{1}H NMR, 400 MHz, $CDCl_3$

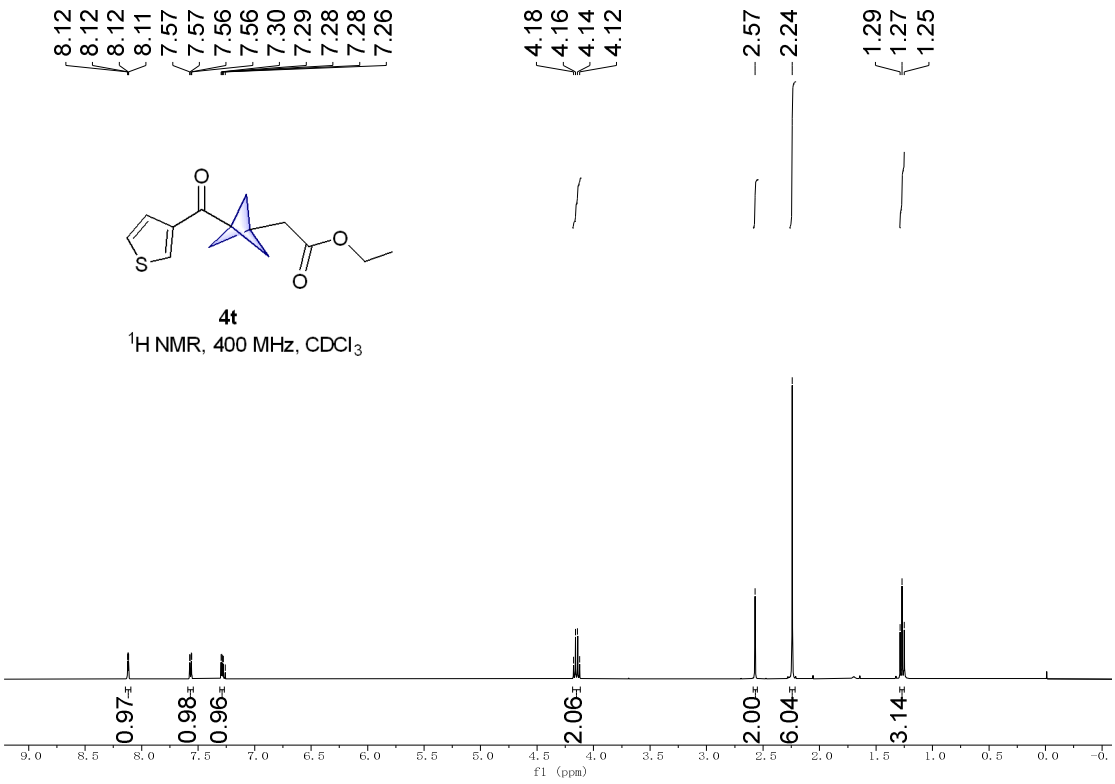




4s

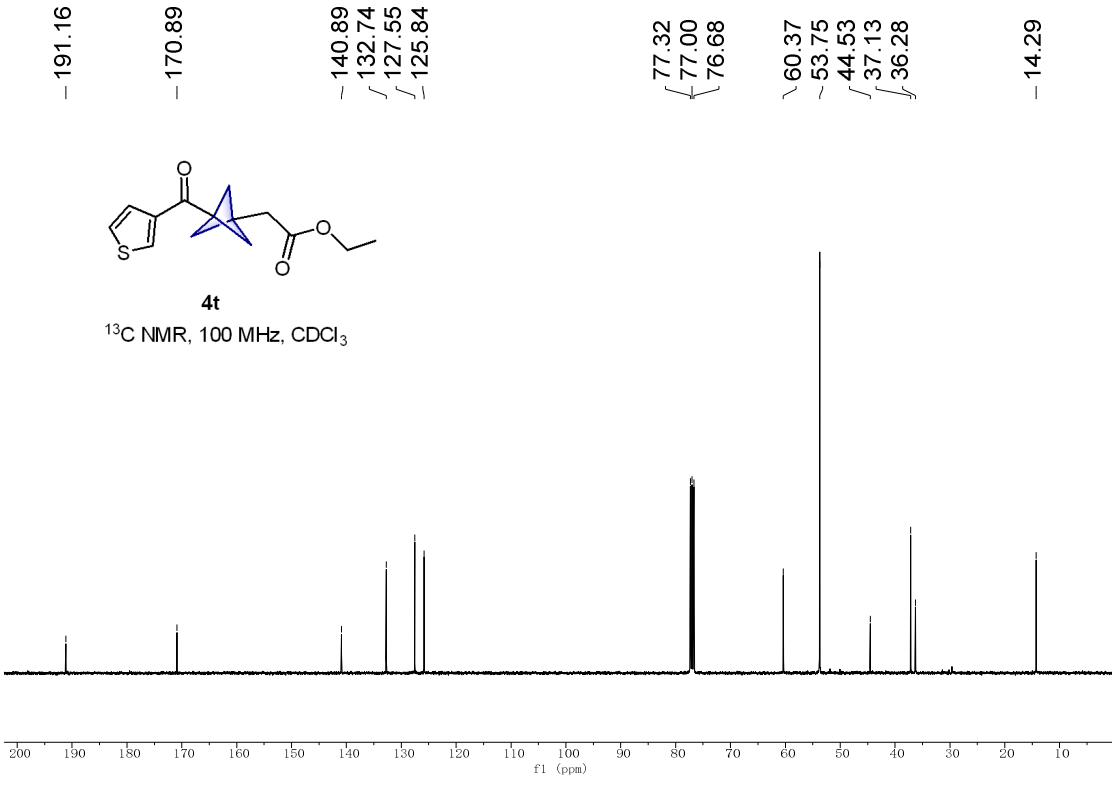
^{13}C NMR, 100 MHz, $CDCl_3$

Ethyl 2-(3-(thiophene-3-carbonyl)bicyclo[1.1.1]pentan-1-yl)acetate (4t)



4t

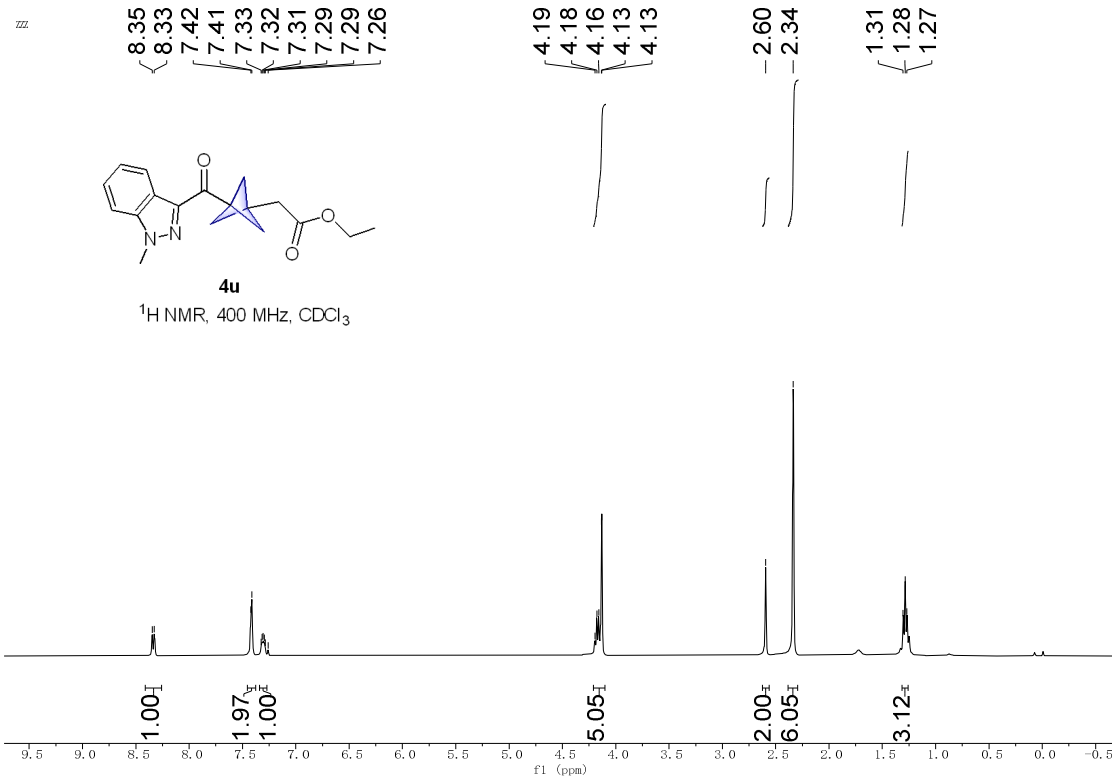
^{1}H NMR, 400 MHz, $CDCl_3$

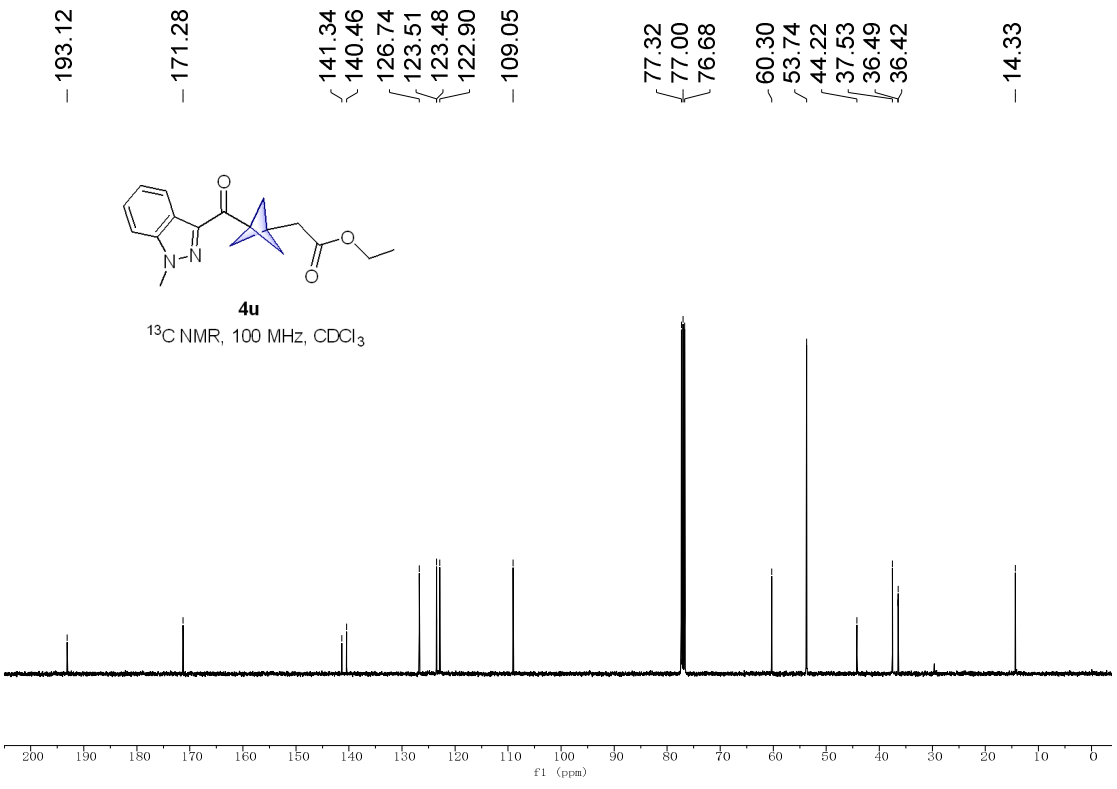


4t

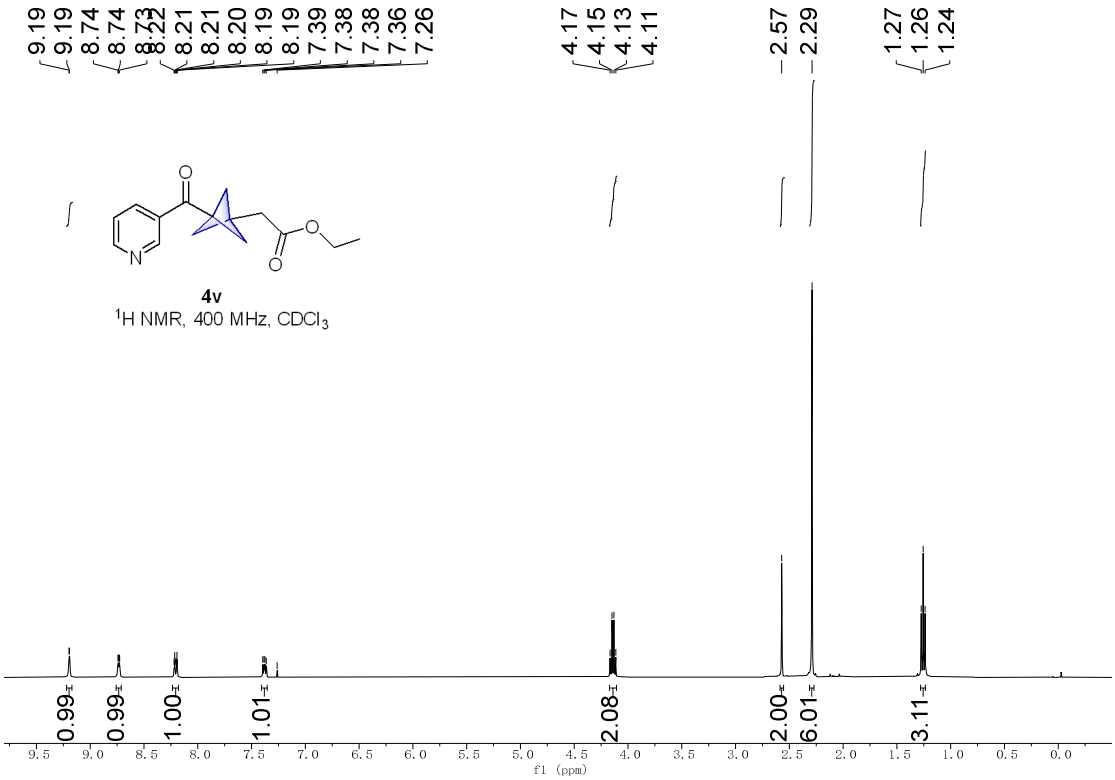
^{13}C NMR, 100 MHz, $CDCl_3$

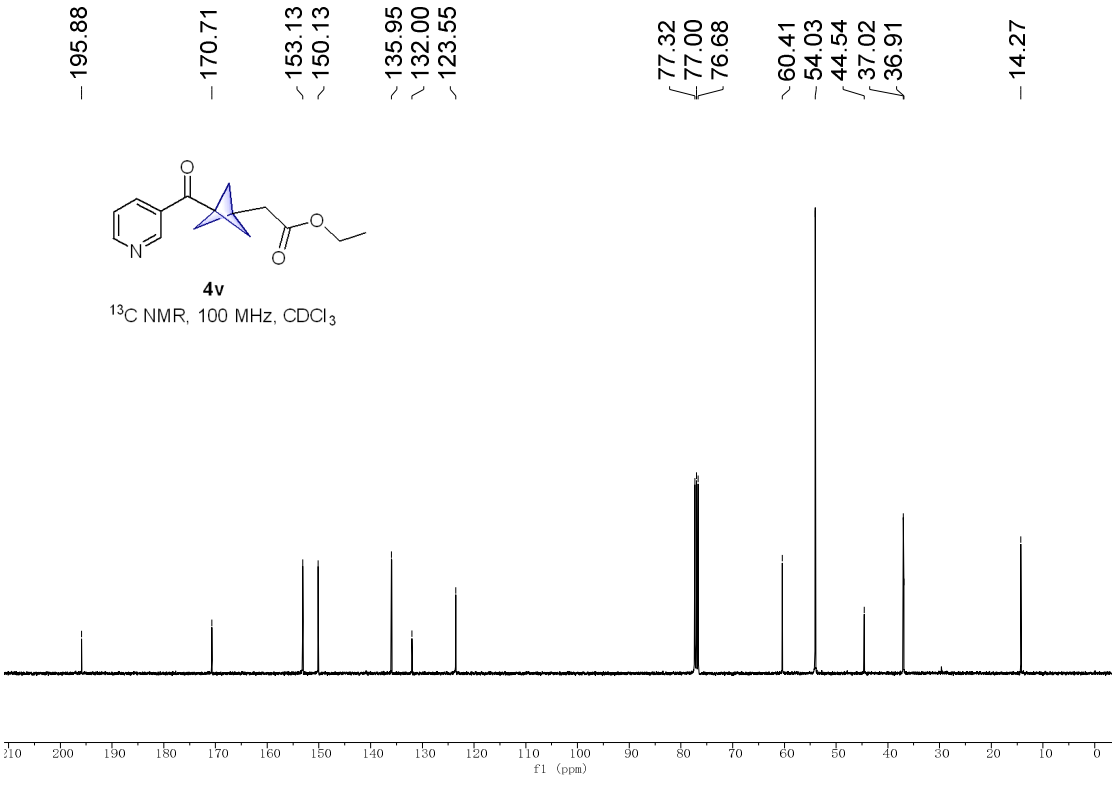
Ethyl 2-(3-(1-methyl-3a,7a-dihydro-1H-indazole-3-carbonyl)bicyclo[1.1.1]pentan-1-yl)acetat-e (4u)



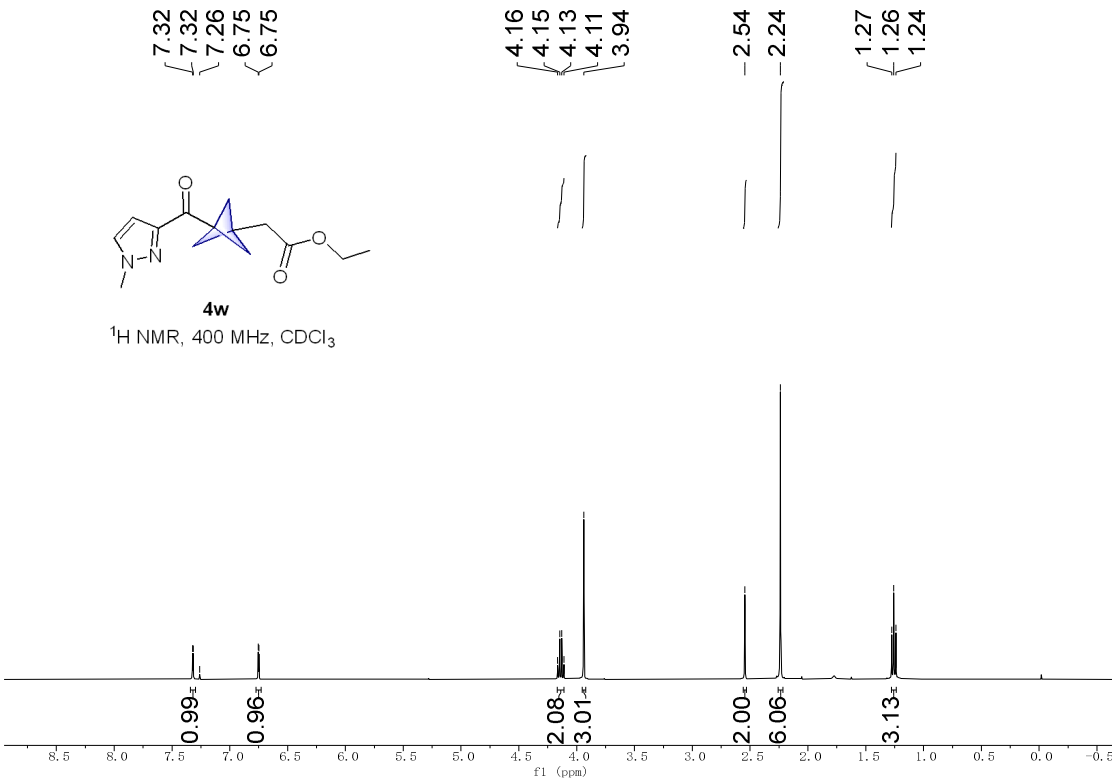


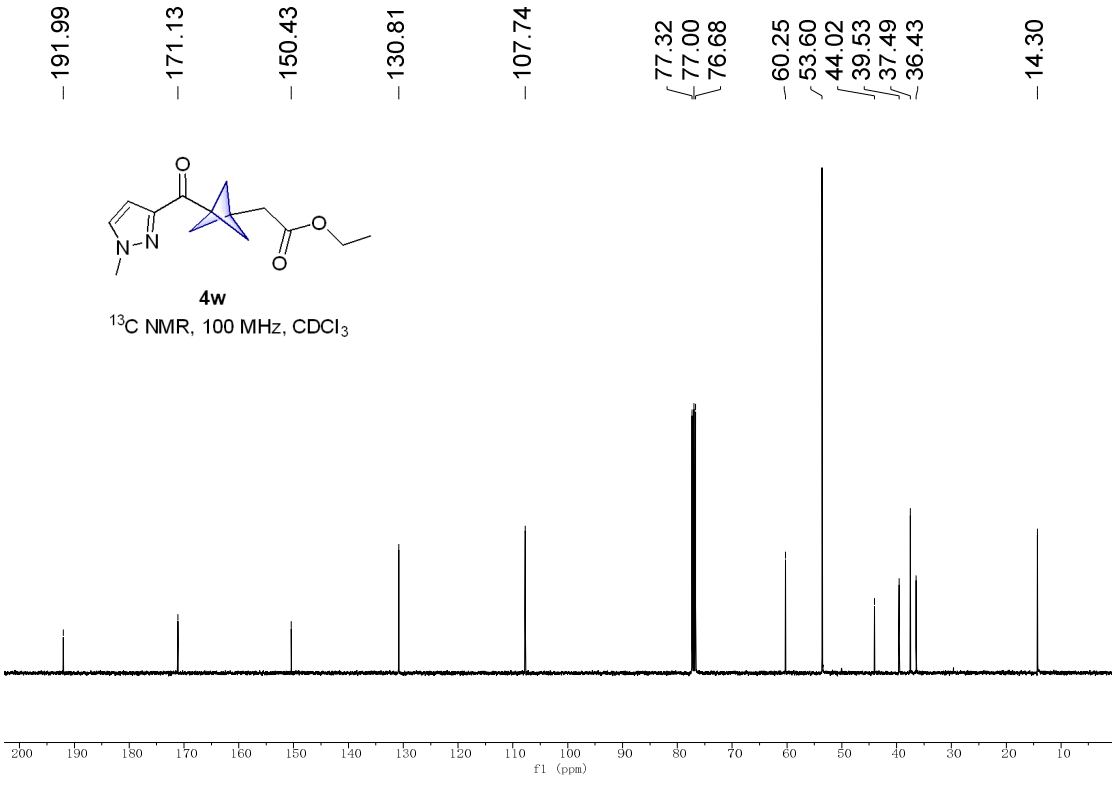
Ethyl 2-(3-nicotinoylbicyclo[1.1.1]pentan-1-yl)acetate (4v)



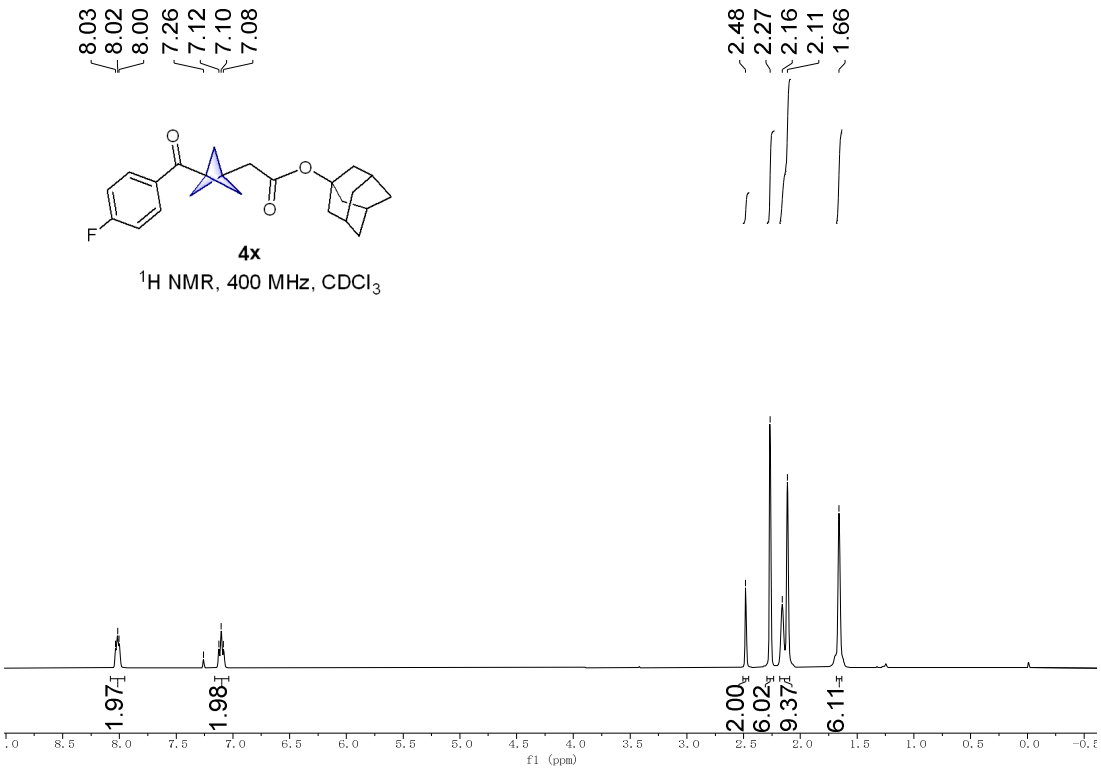


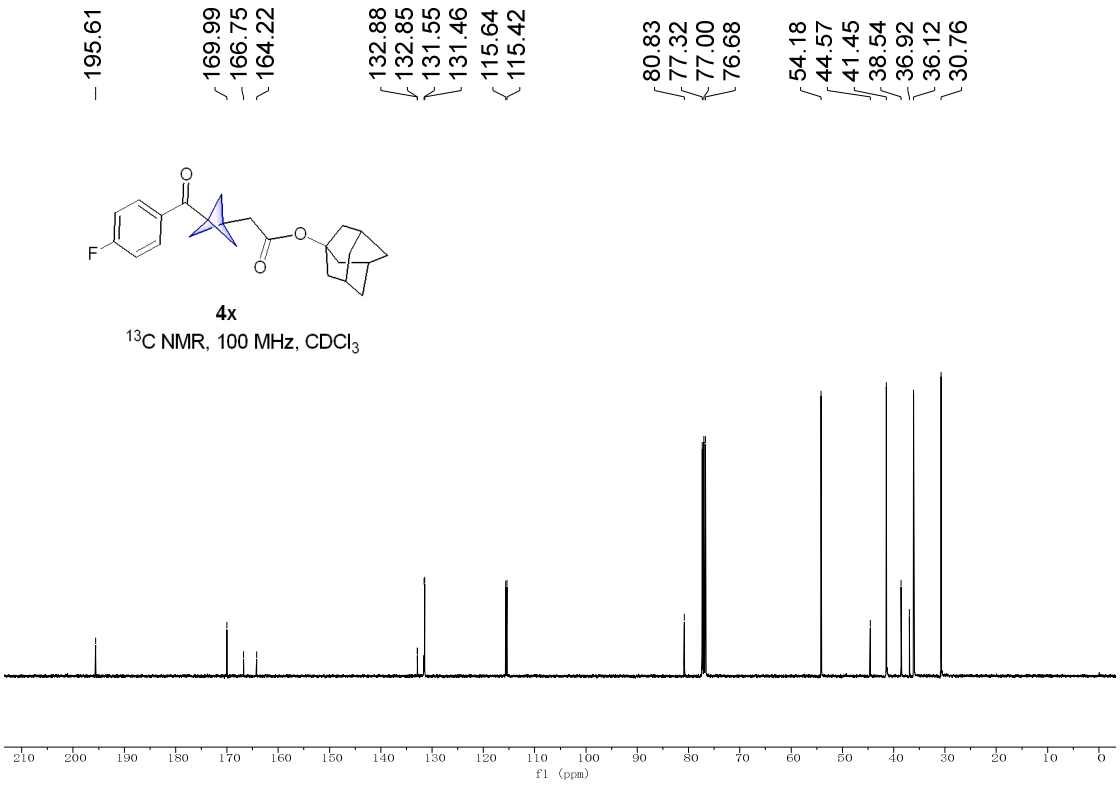
Ethyl 2-(3-(1-methyl-1H-pyrazole-3-carbonyl)bicyclo[1.1.1]pentan-1-yl)acetate (4w)

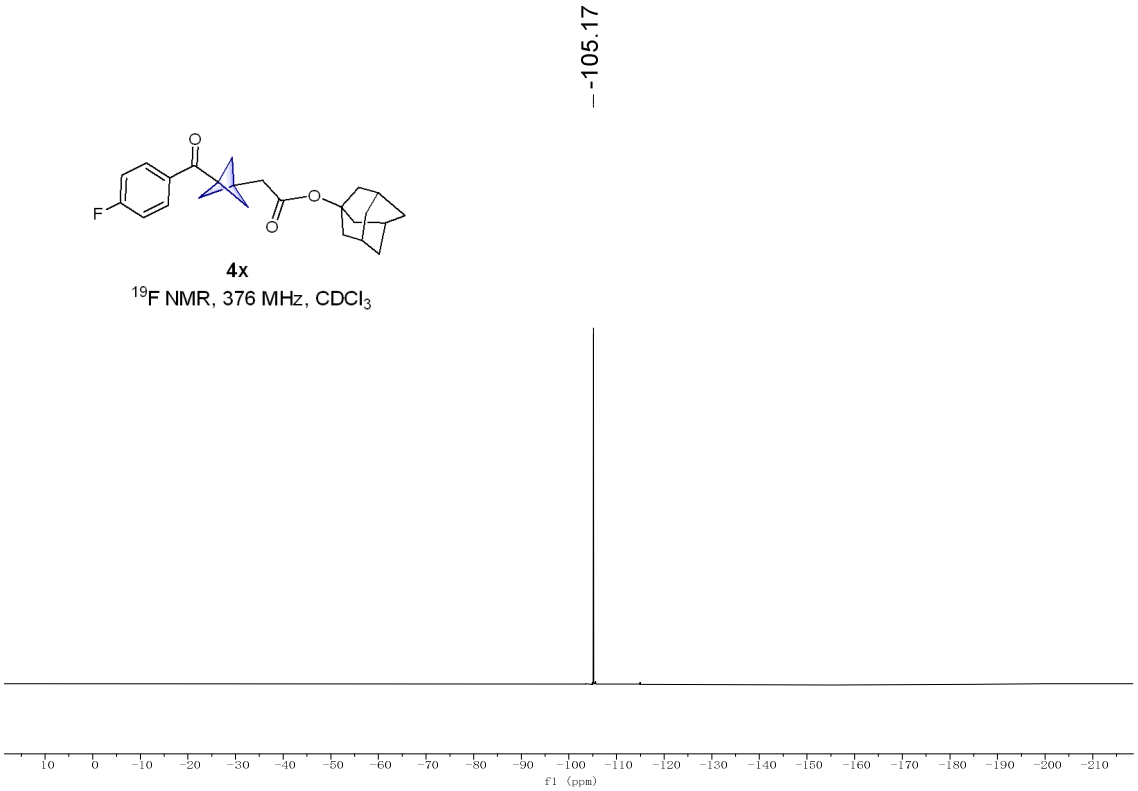




Adamantan-1-yl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4x)



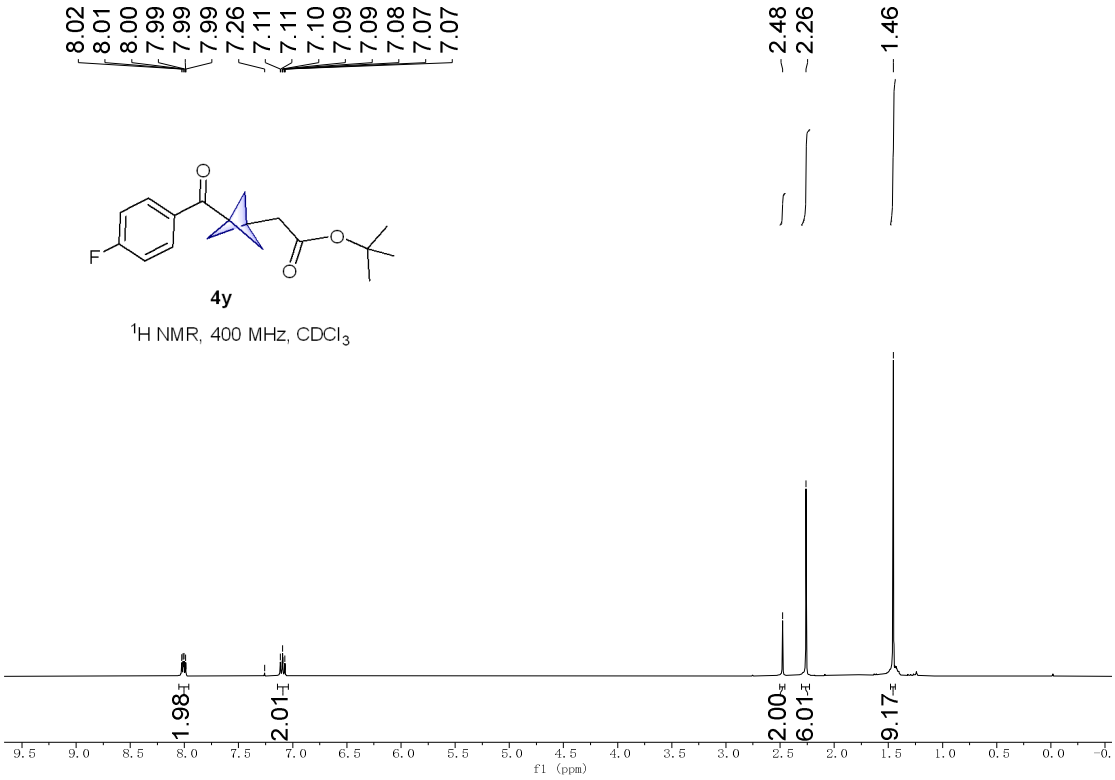




4x

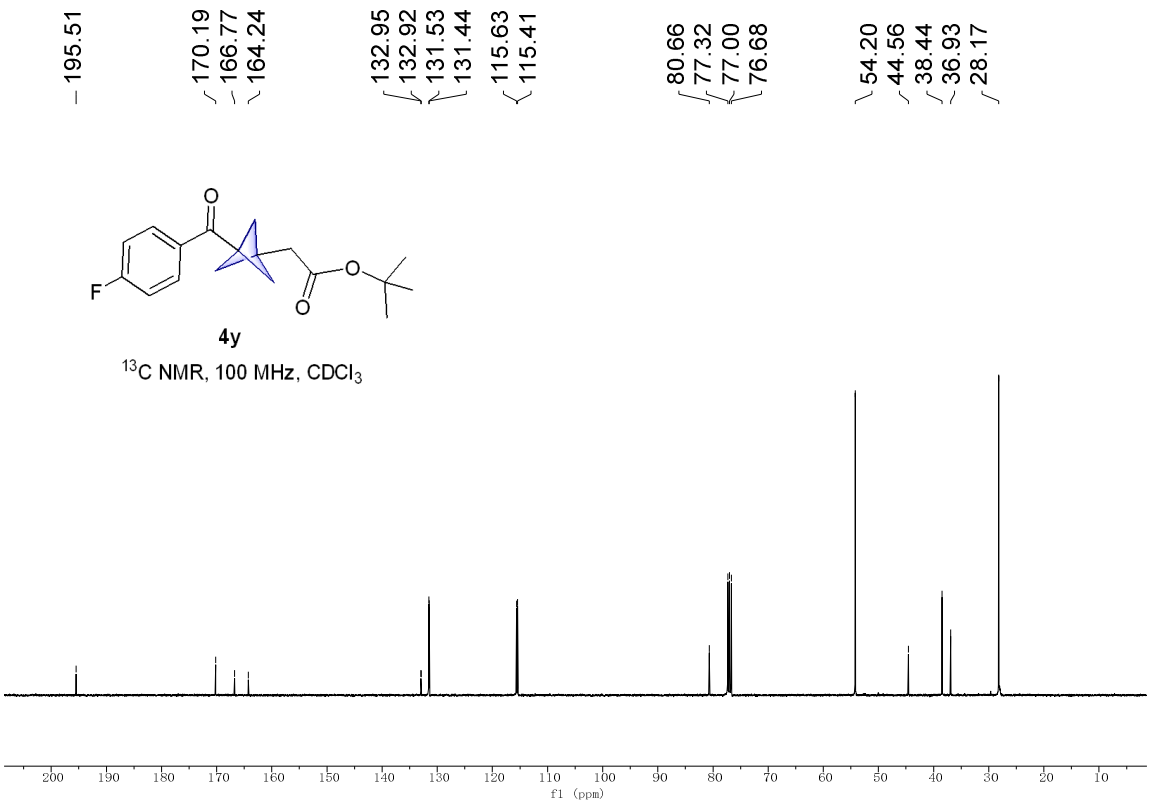
^{19}F NMR, 376 MHz, $CDCl_3$

Tert-butyl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4y)



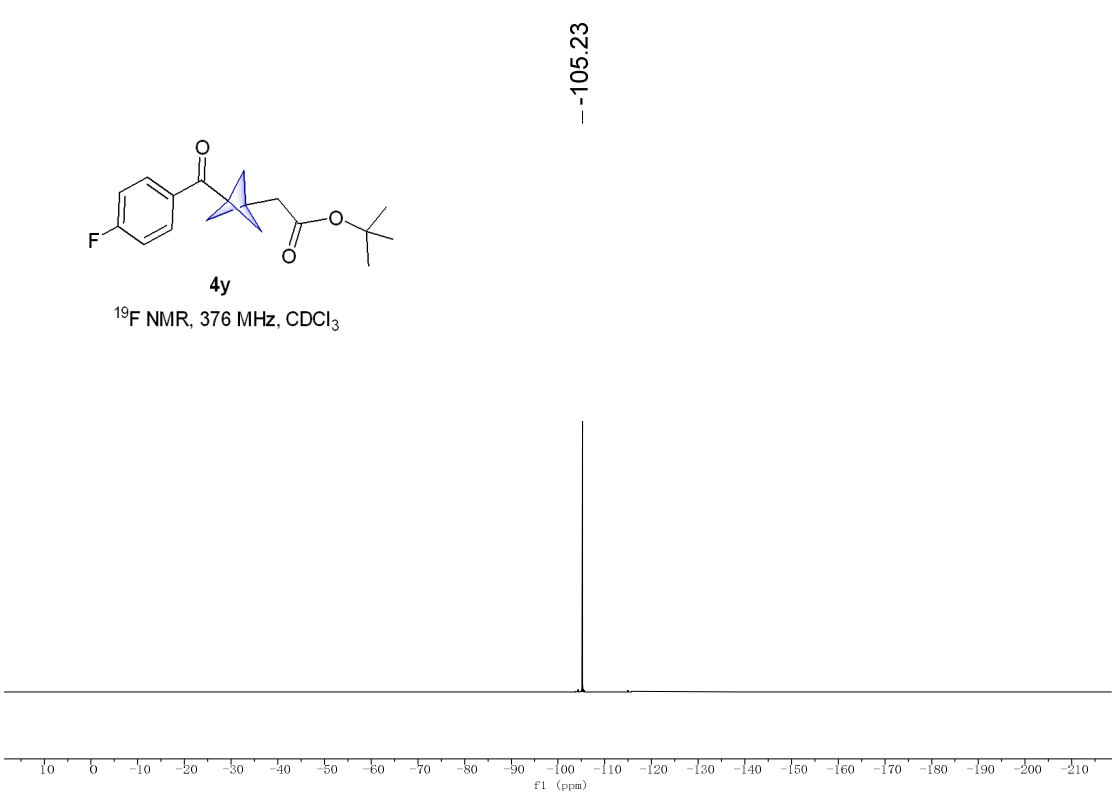
4y

^{1}H NMR, 400 MHz, $CDCl_3$



4y

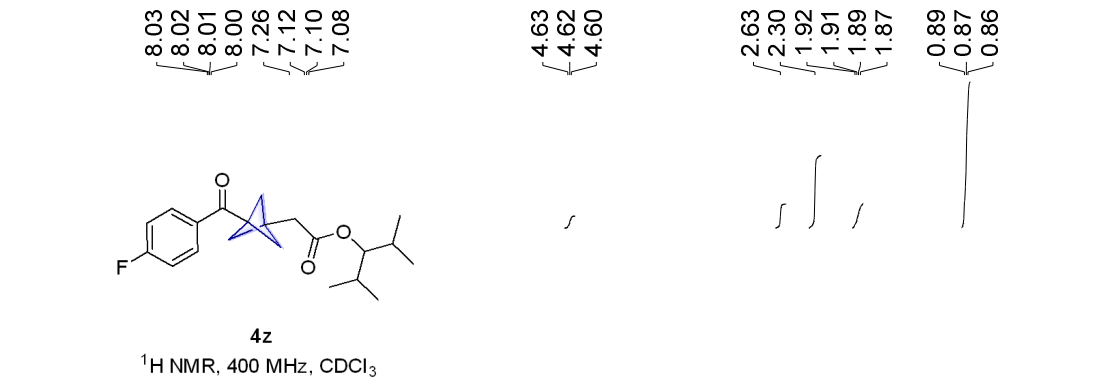
^{13}C NMR, 100 MHz, $CDCl_3$



4y

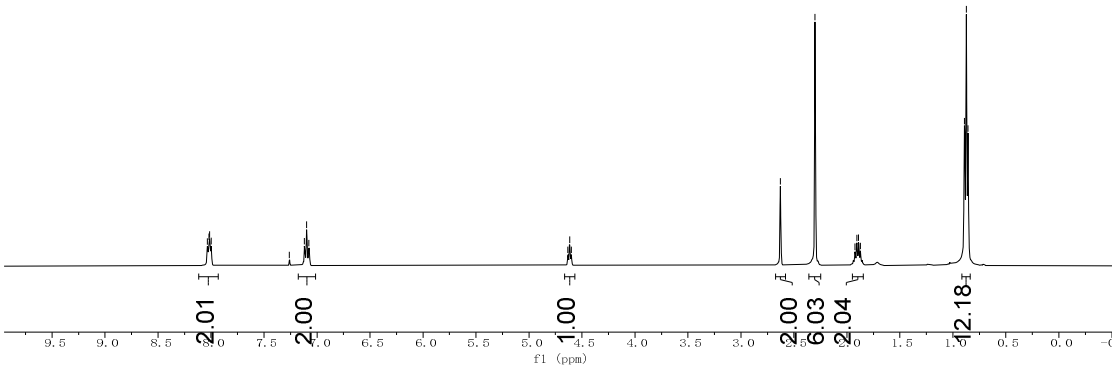
^{19}F NMR, 376 MHz, $CDCl_3$

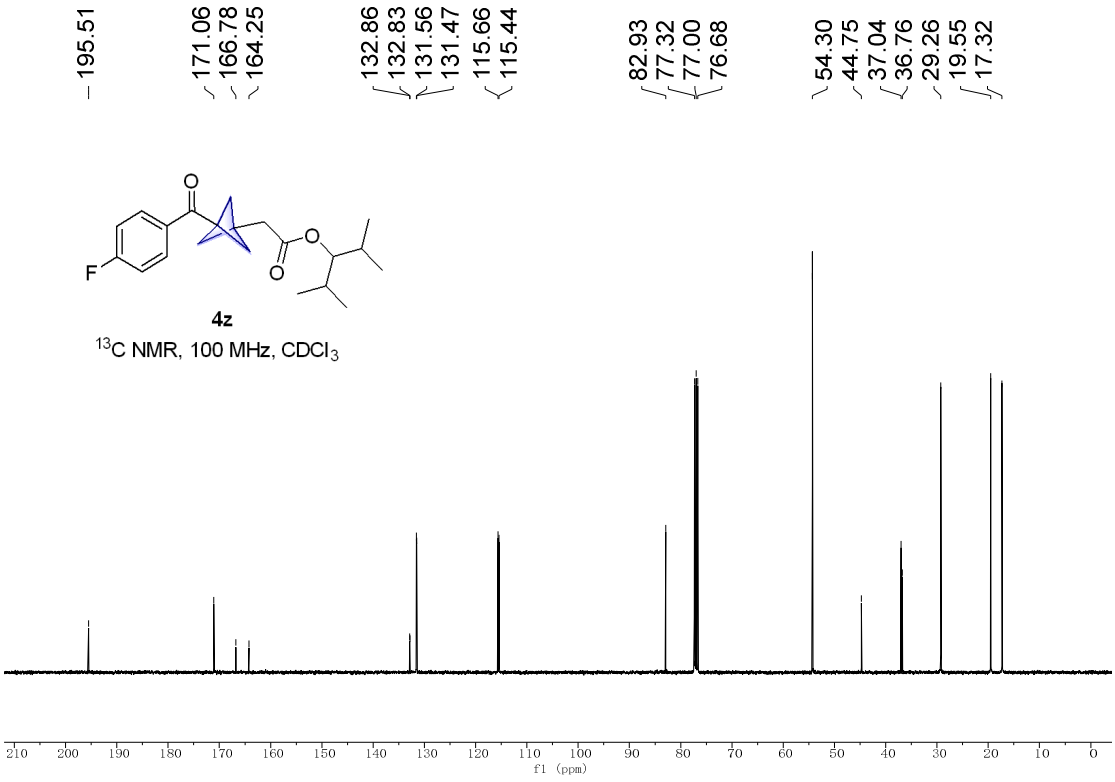
2,4-dimethylpentan-3-yl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4z)



4z

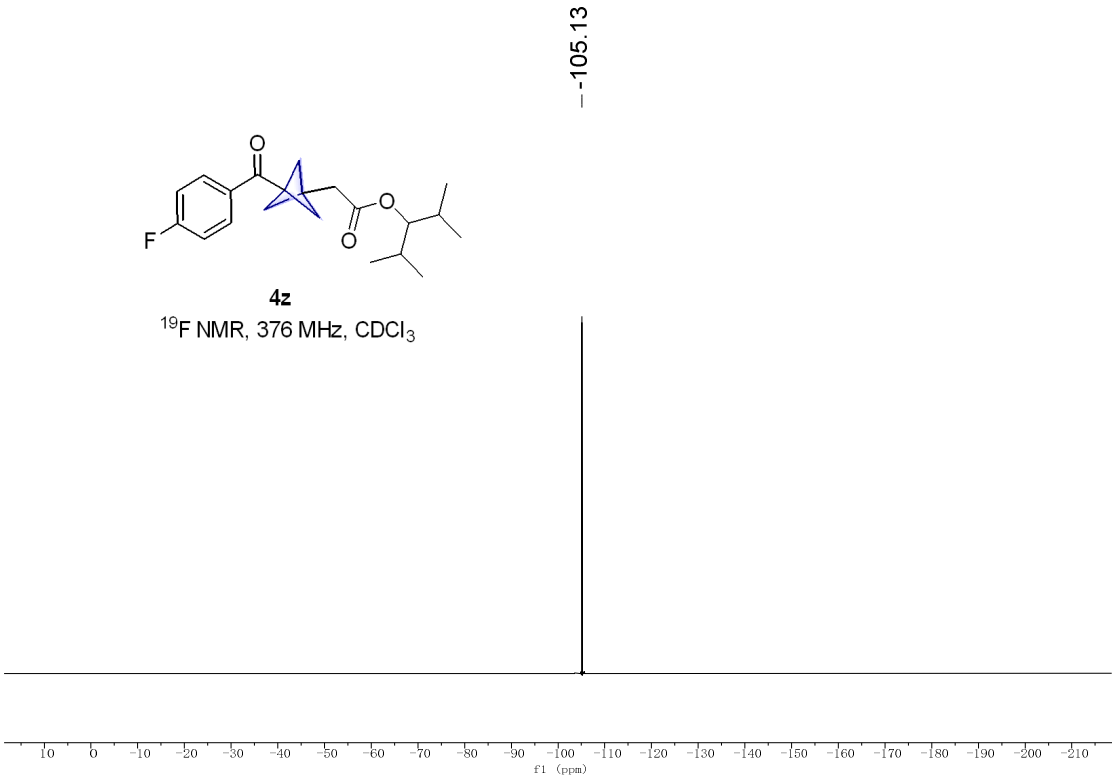
^{1}H NMR, 400 MHz, $CDCl_3$



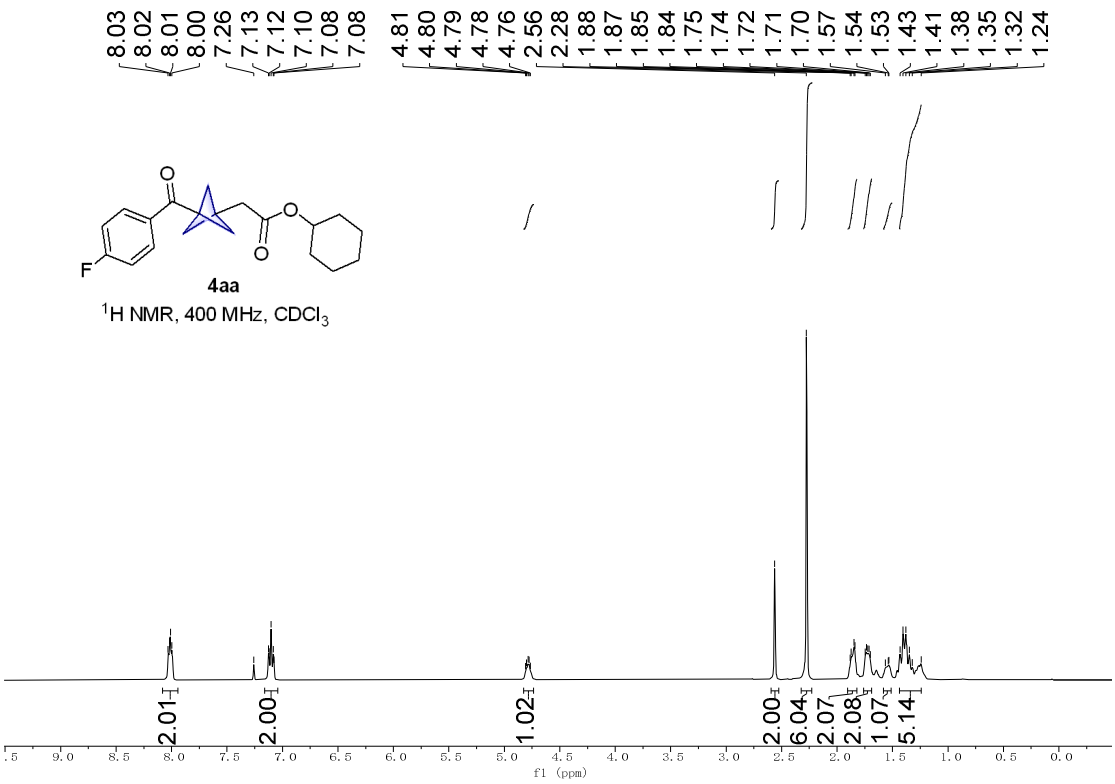


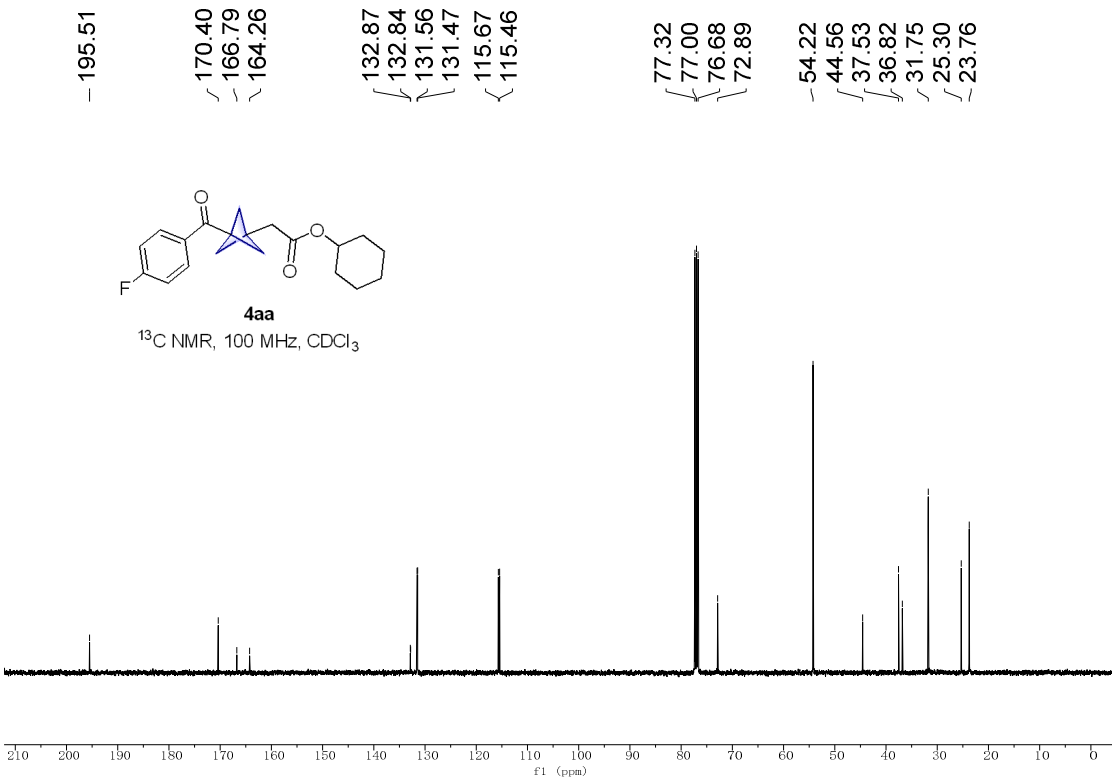
4z

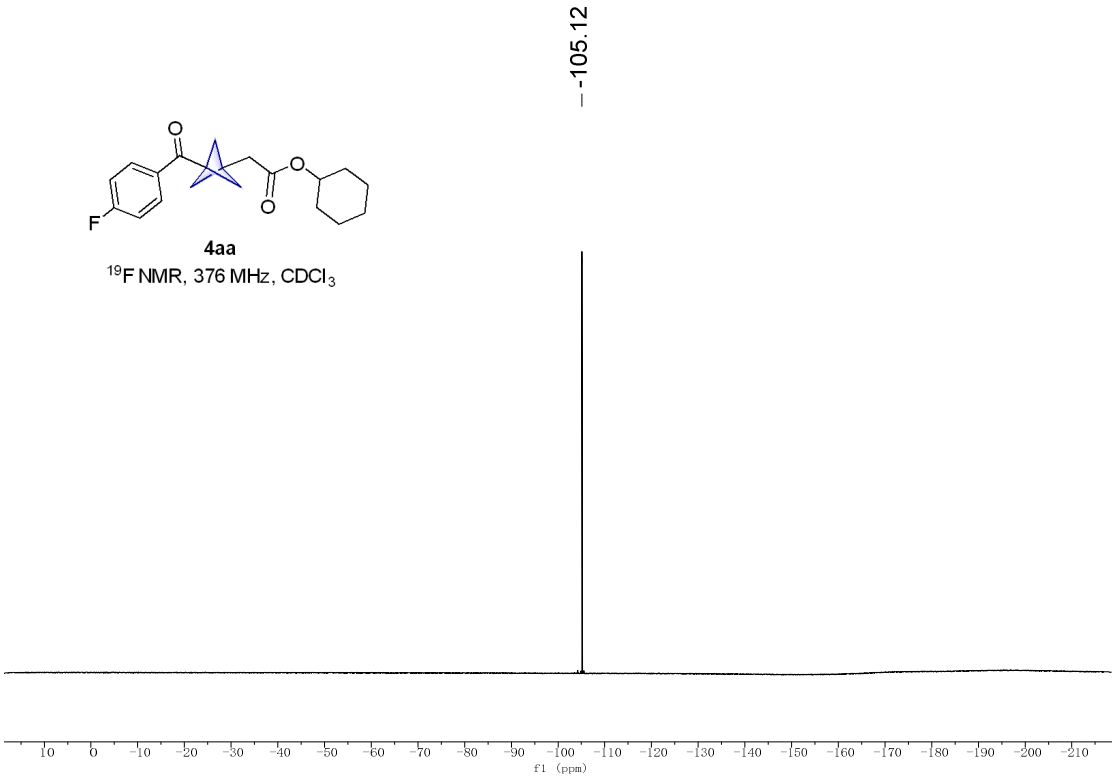
^{13}C NMR, 100 MHz, $CDCl_3$



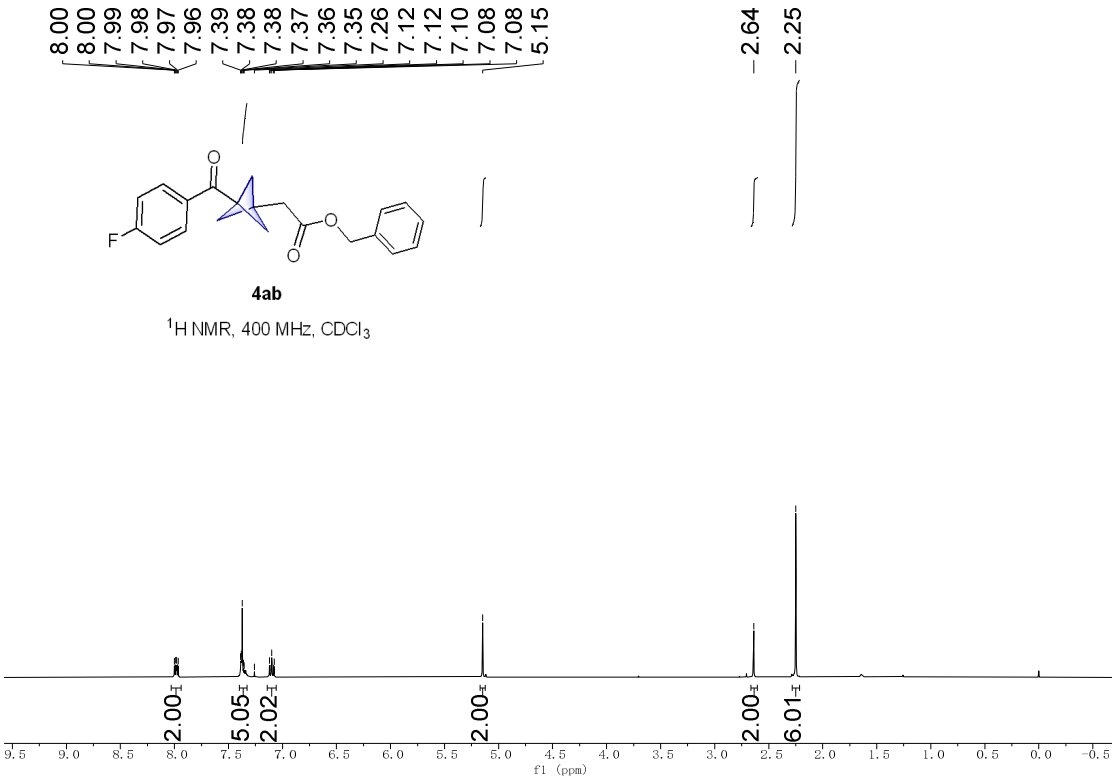
Cyclohexyl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4aa)




195.51
170.40
166.79
164.26
132.87
132.84
131.56
131.47
115.67
115.46
77.32
77.00
76.68
72.89
54.22
44.56
37.53
36.82
31.75
25.30
23.76
F
O
O
O
4aa
13C NMR, 100 MHz, CDCl3
f1 (ppm)

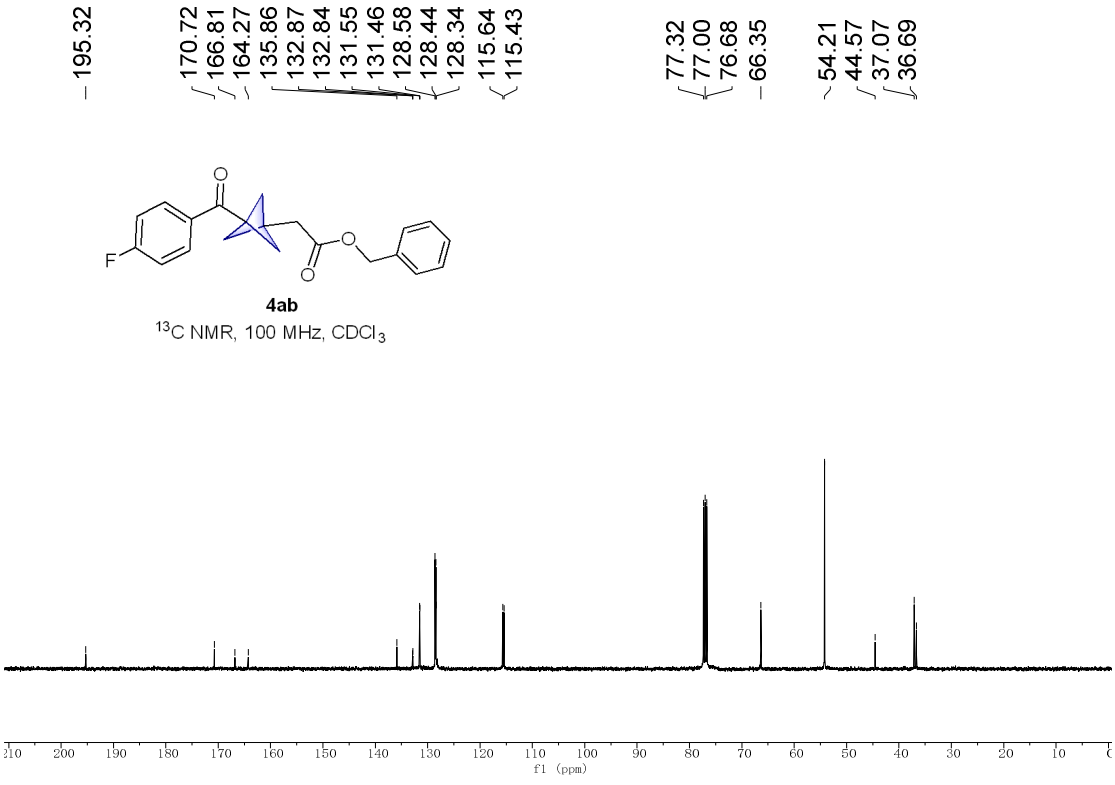

-105.12
F
O
O
O
4aa
19F NMR, 376 MHz, CDCl3
f1 (ppm)

Benzyl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4ab)



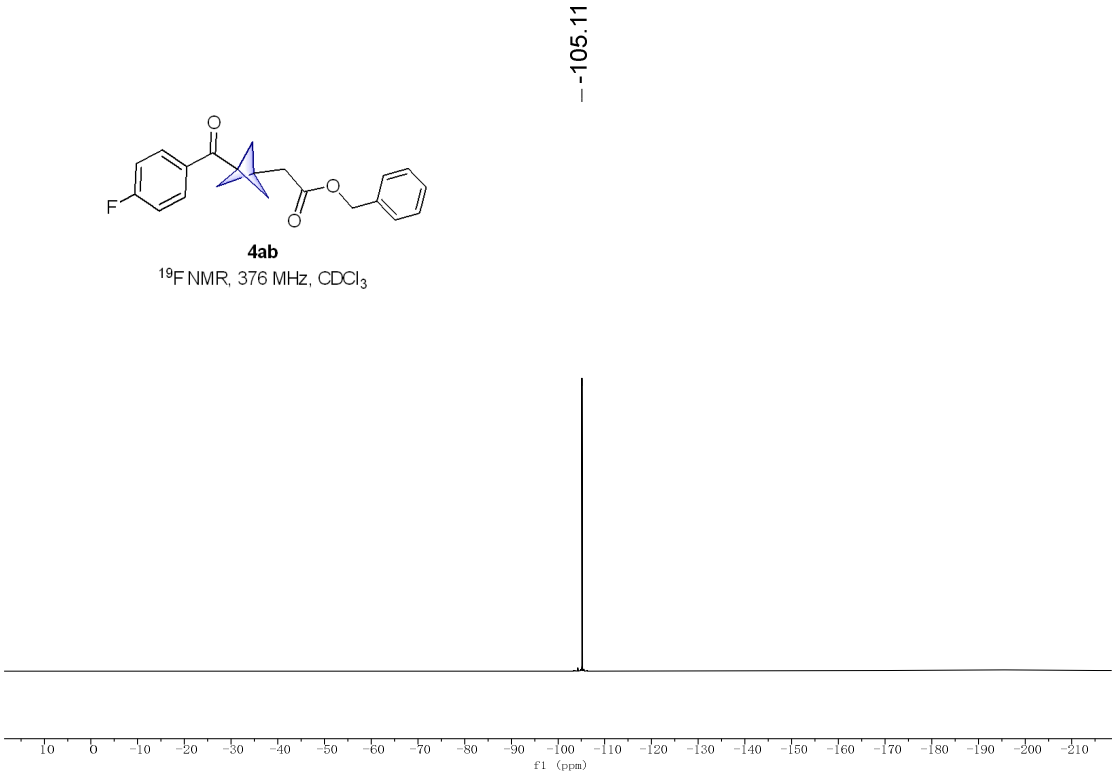
4ab

^{1}H NMR, 400 MHz, $CDCl_3$

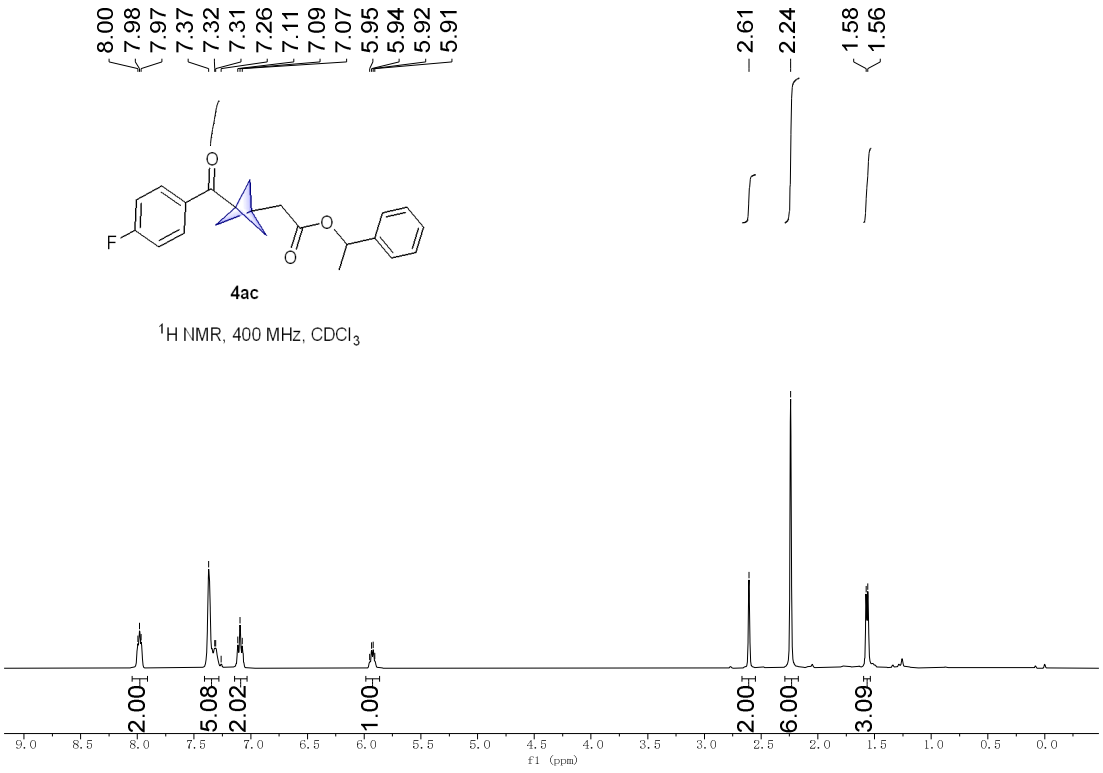


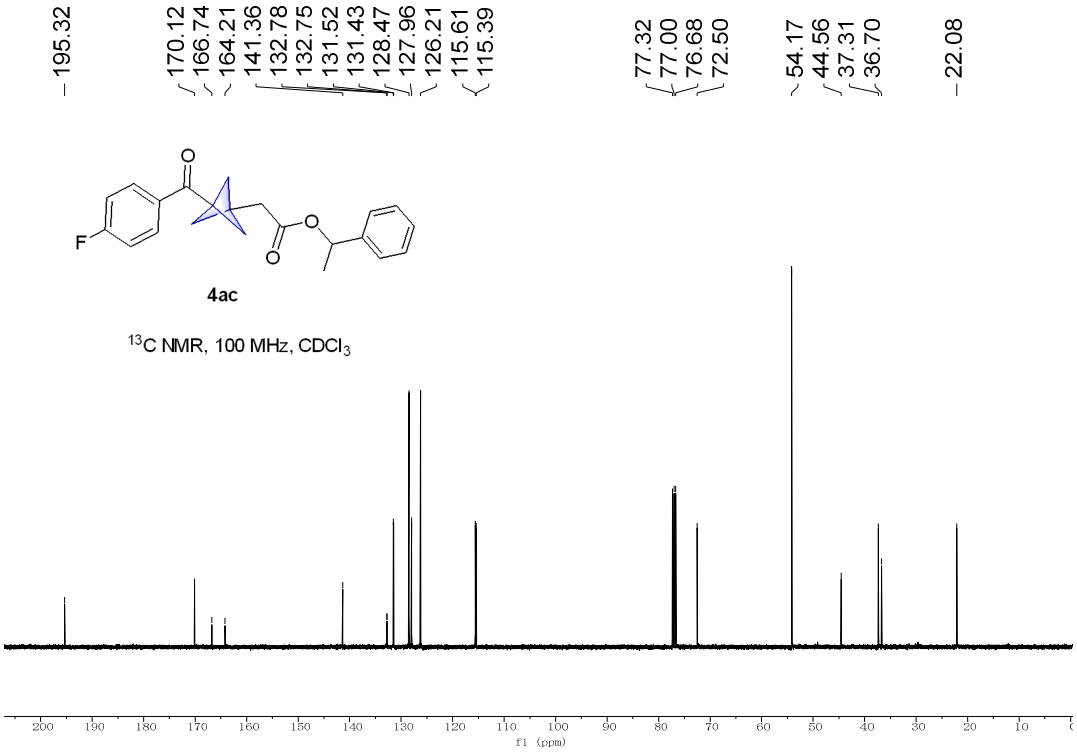
4ab

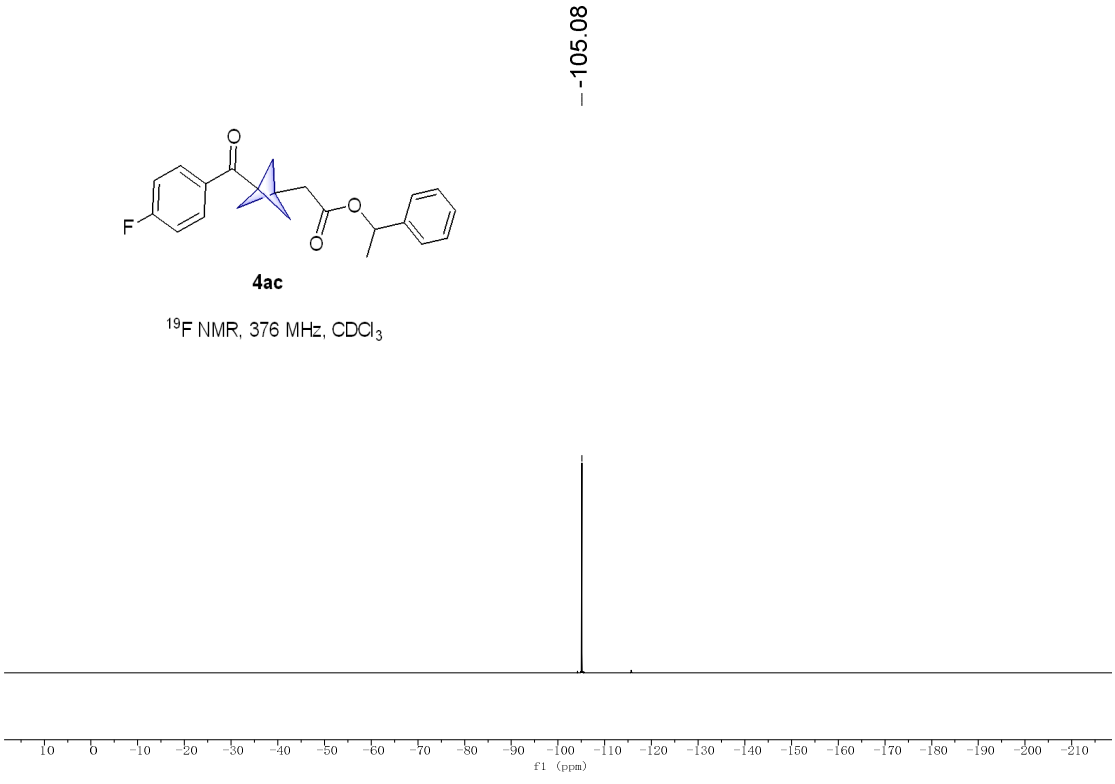
^{13}C NMR, 100 MHz, $CDCl_3$



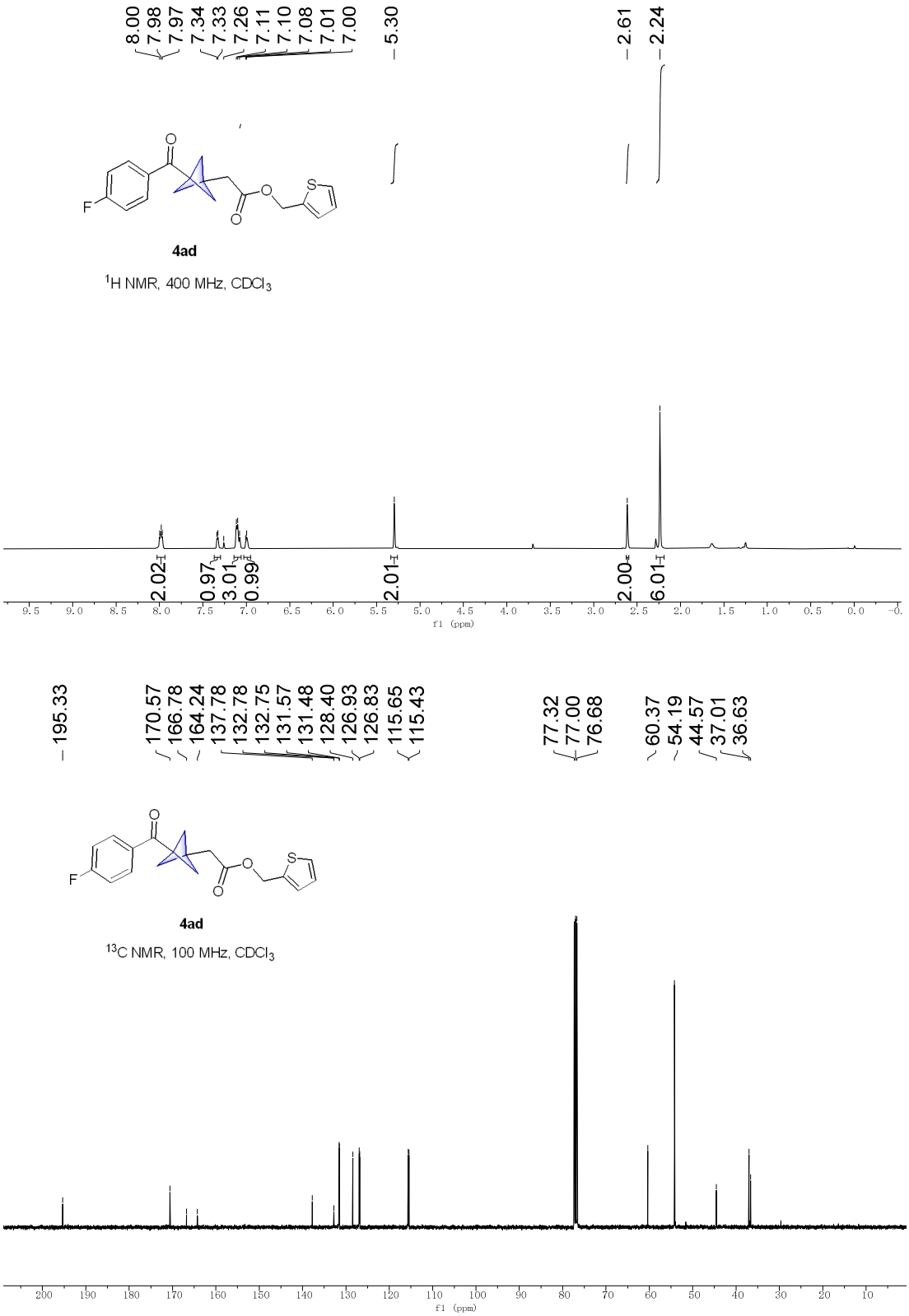
1-phenylethyl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4ac)

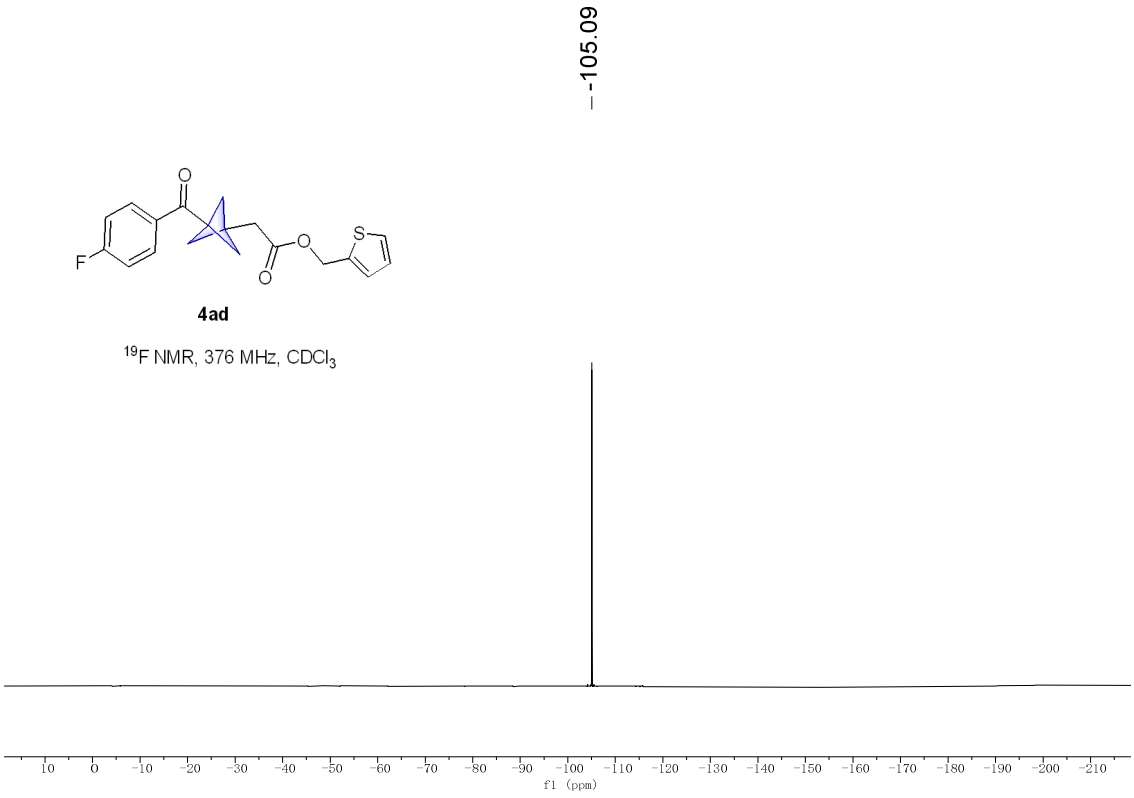



195.32
170.12
166.74
164.21
141.36
132.78
132.75
131.52
131.43
128.47
127.96
126.21
115.61
115.39
77.32
77.00
76.68
72.50
54.17
44.56
37.31
36.70
22.08
O
F
O
O
4ac
13C NMR, 100 MHz, CDCl3
f1 (ppm)

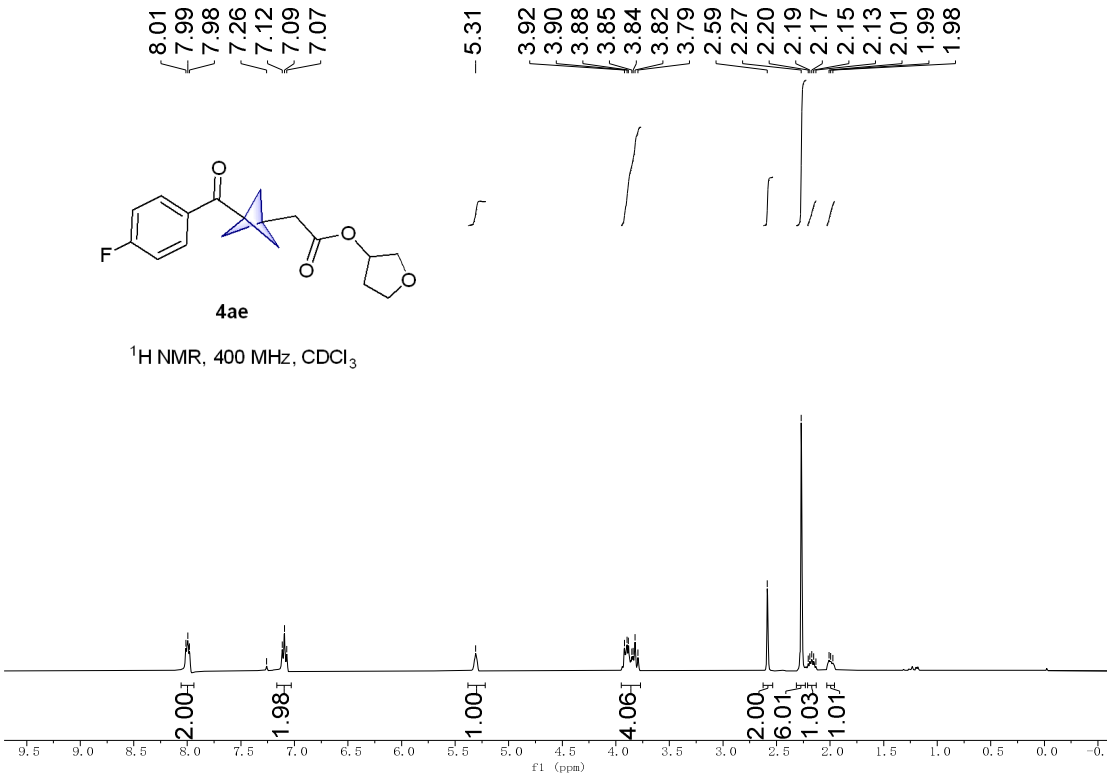

-105.08
O
F
O
O
4ac
19F NMR, 376 MHz, CDCl3
f1 (ppm)

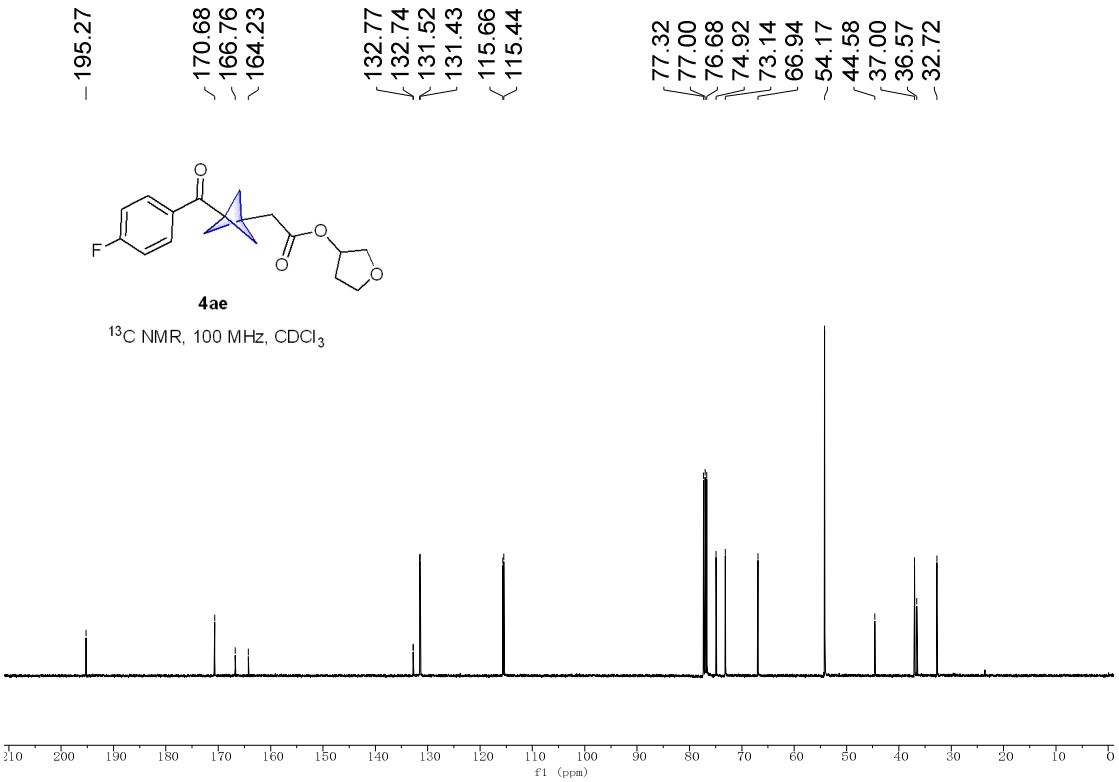
Thiophen-2-ylmethyl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4ad)





Tetrahydrofuran-3-yl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4ae)

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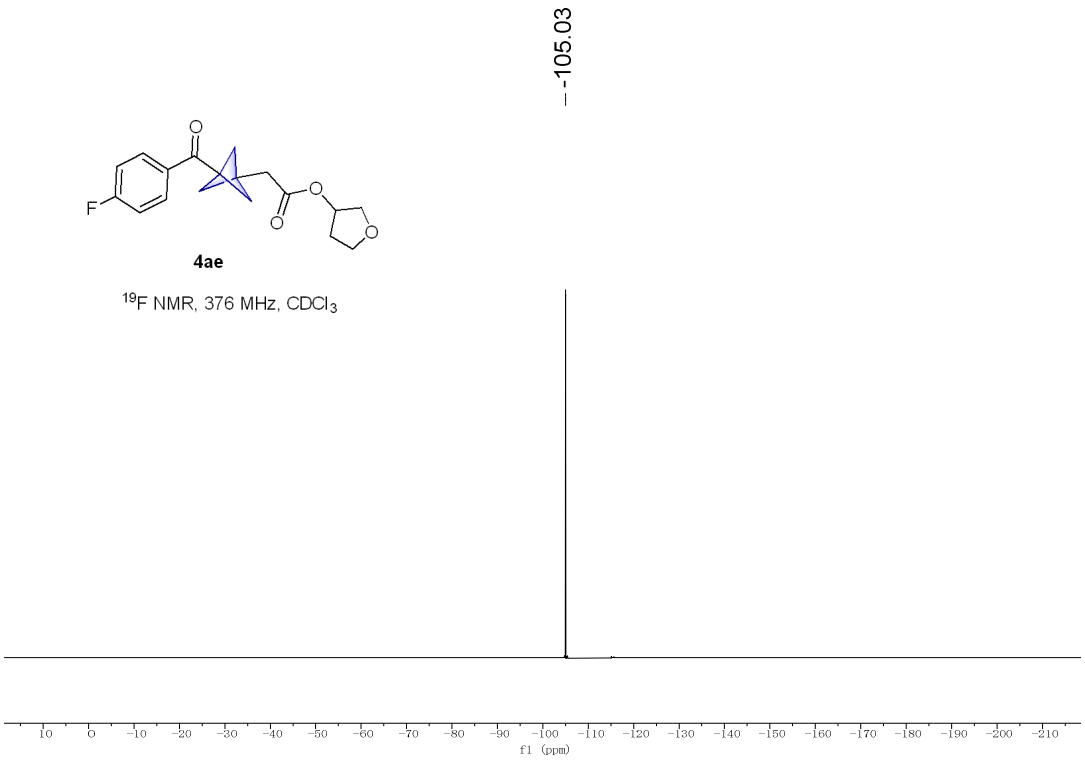
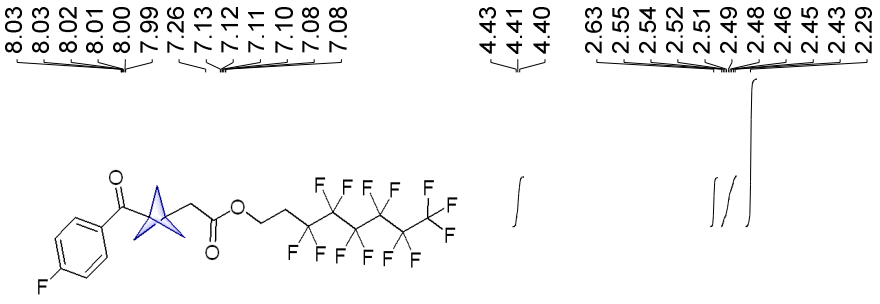
164.23
132.77
132.74
131.52
131.43
115.66
115.44
77.32
77.00
76.68
74.92
73.14
66.94
54.17
44.58
37.00
36.57
32.72
F
O
O
O
O
4ae
13C NMR, 100 MHz, CDCl3
f1 (ppm)

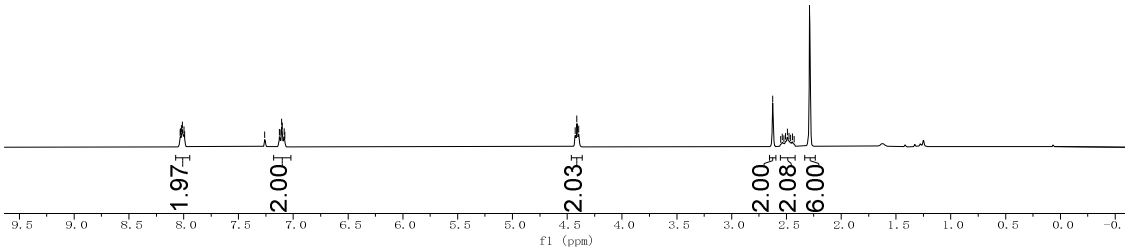

-105.03
F
O
O
O
O
4ae
19F NMR, 376 MHz, CDCl3
f1 (ppm)

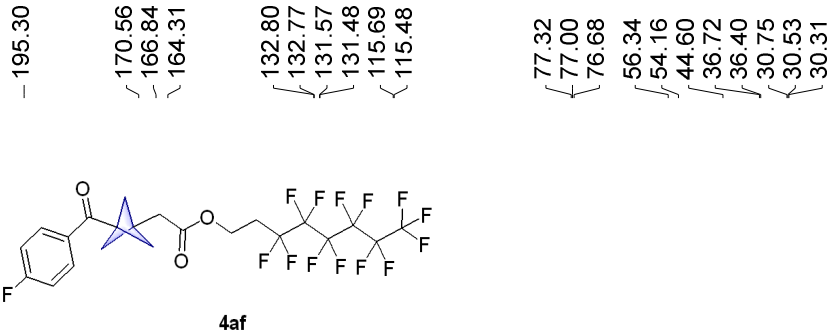
3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4af)



4af

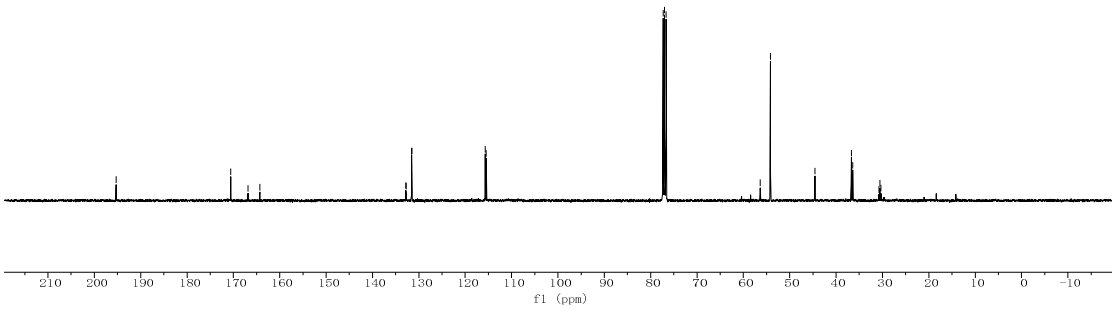
^{1}H NMR, 400 MHz, $CDCl_3$

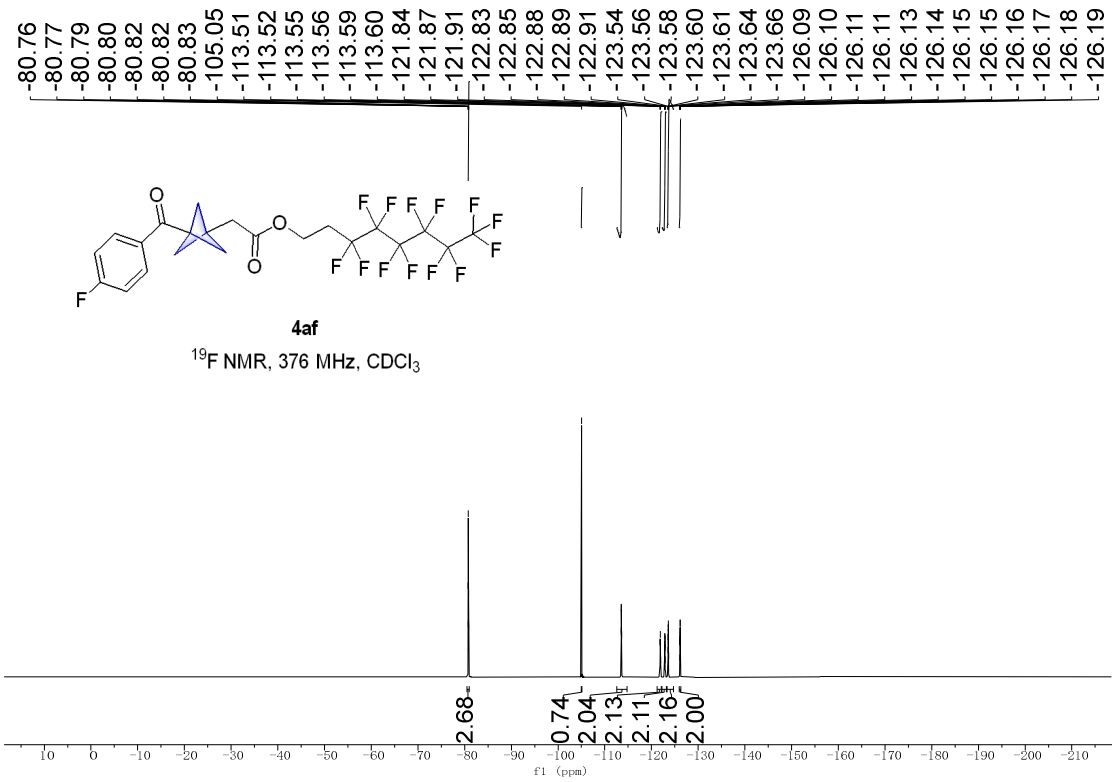




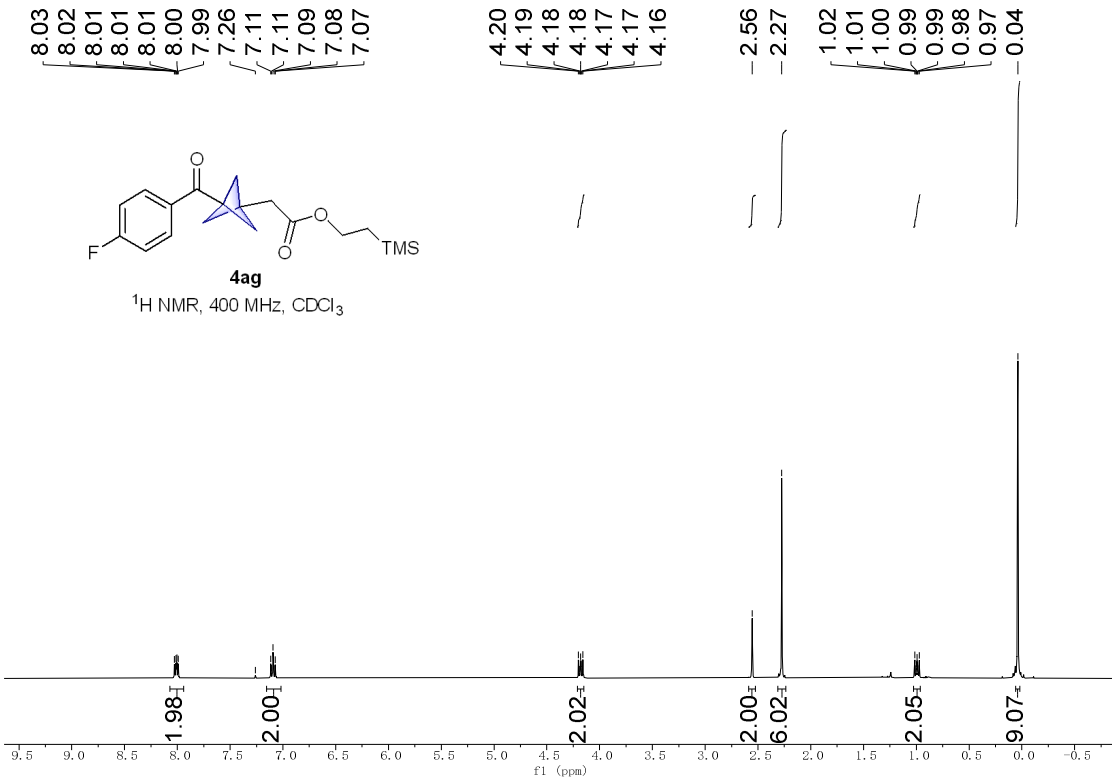
4af

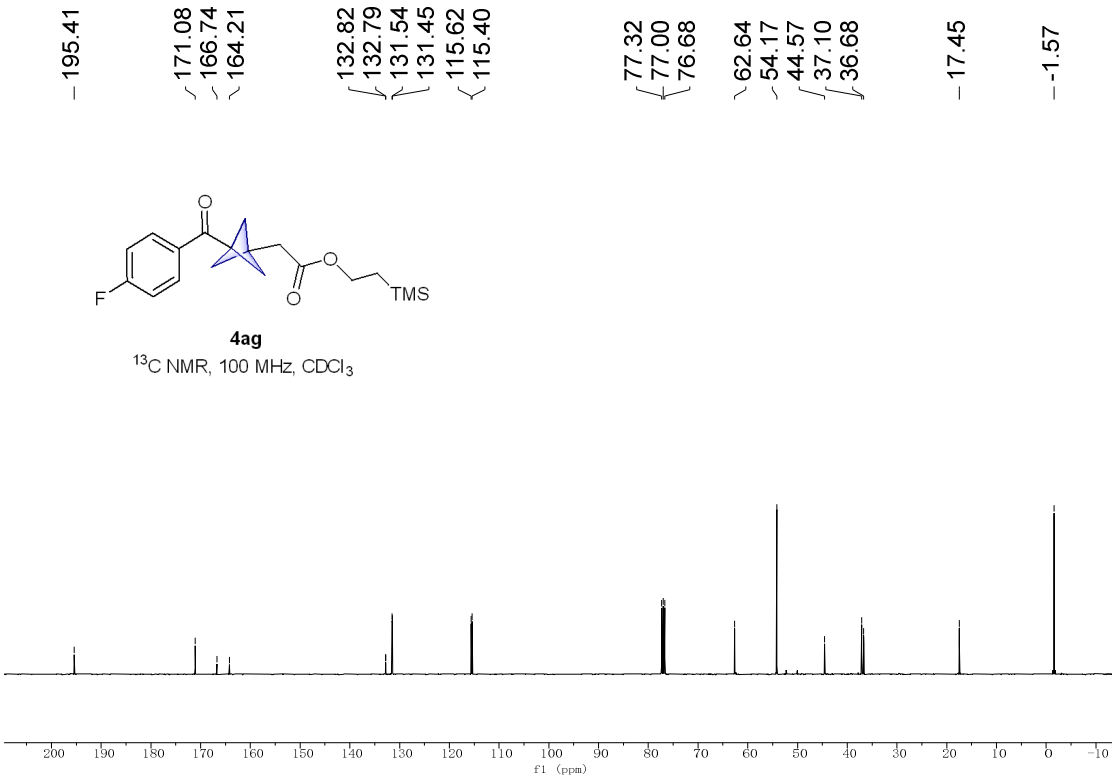
^{13}C NMR, 100 MHz, $CDCl_3$





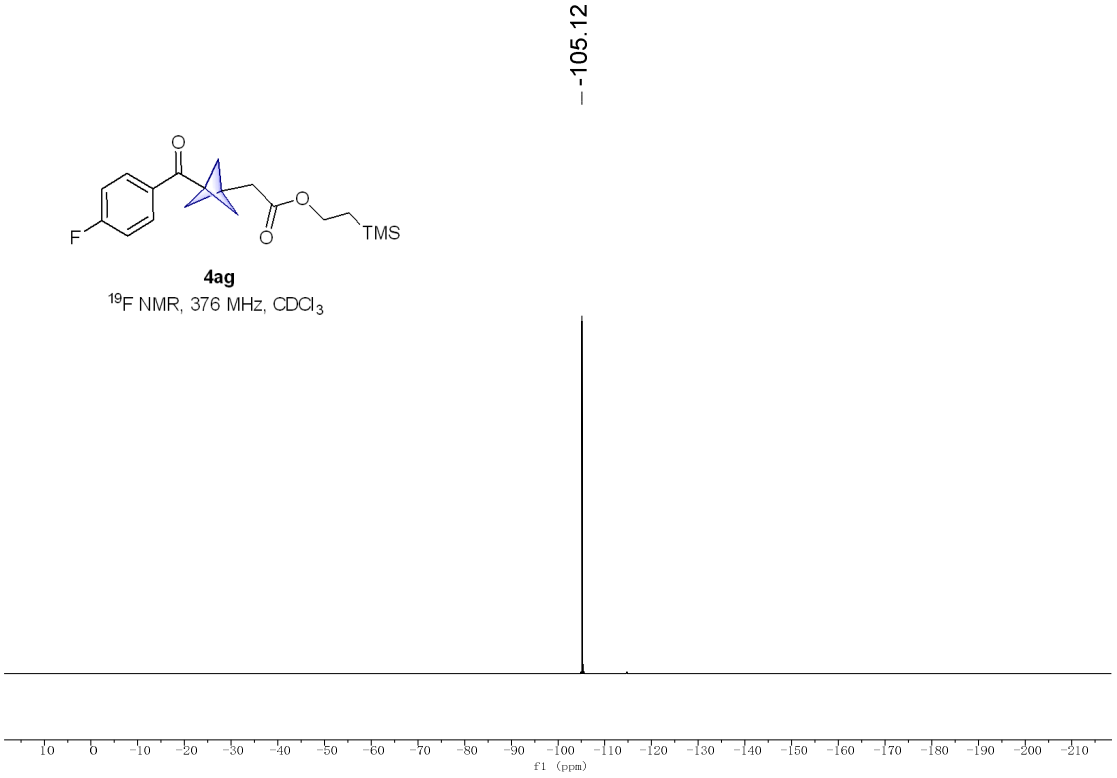
2-(trimethylsilyl)ethyl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4ag)





4ag

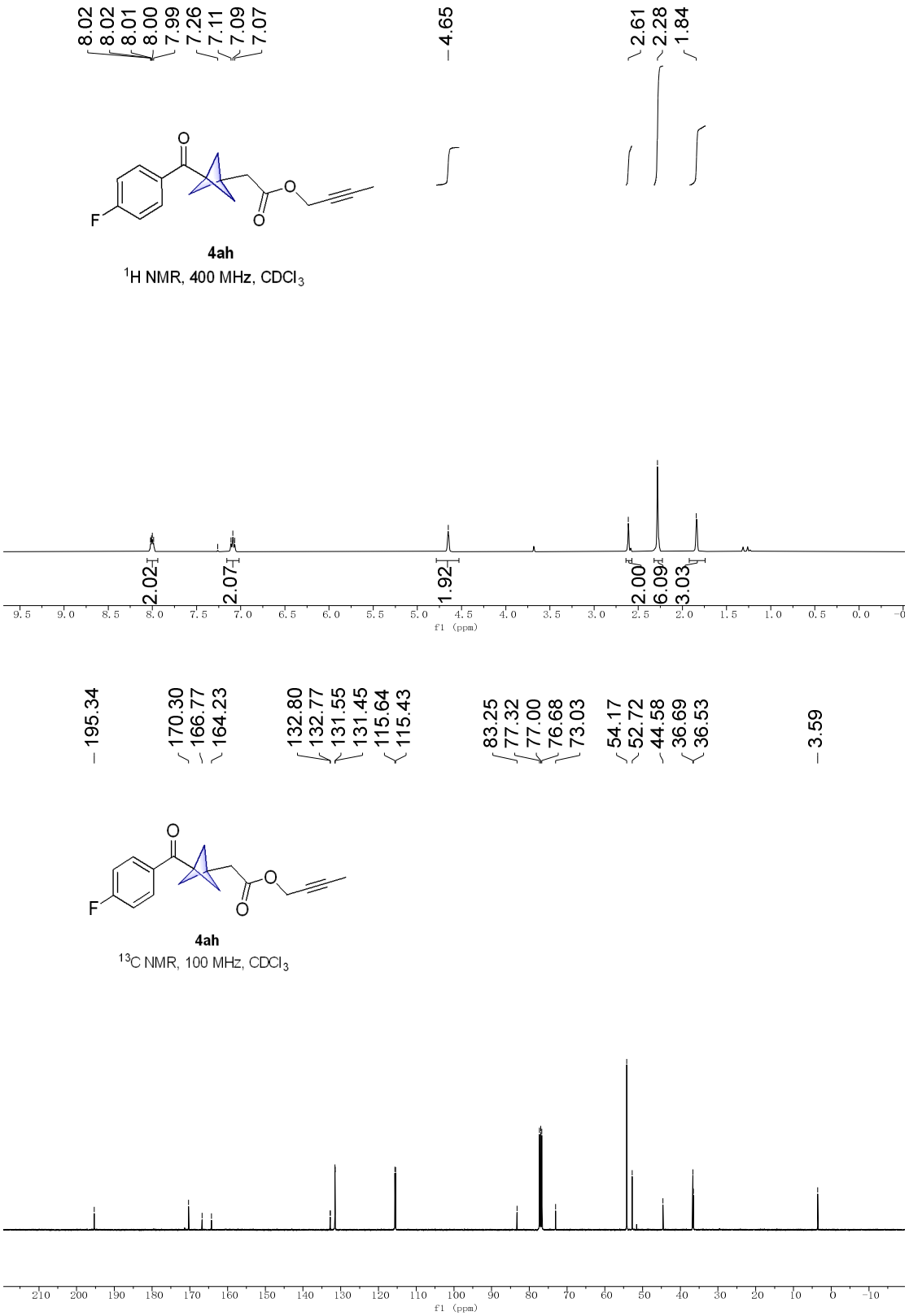
^{13}C NMR, 100 MHz, $CDCl_3$



4ag

^{19}F NMR, 376 MHz, $CDCl_3$

But-2-yn-1-yl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4ah)

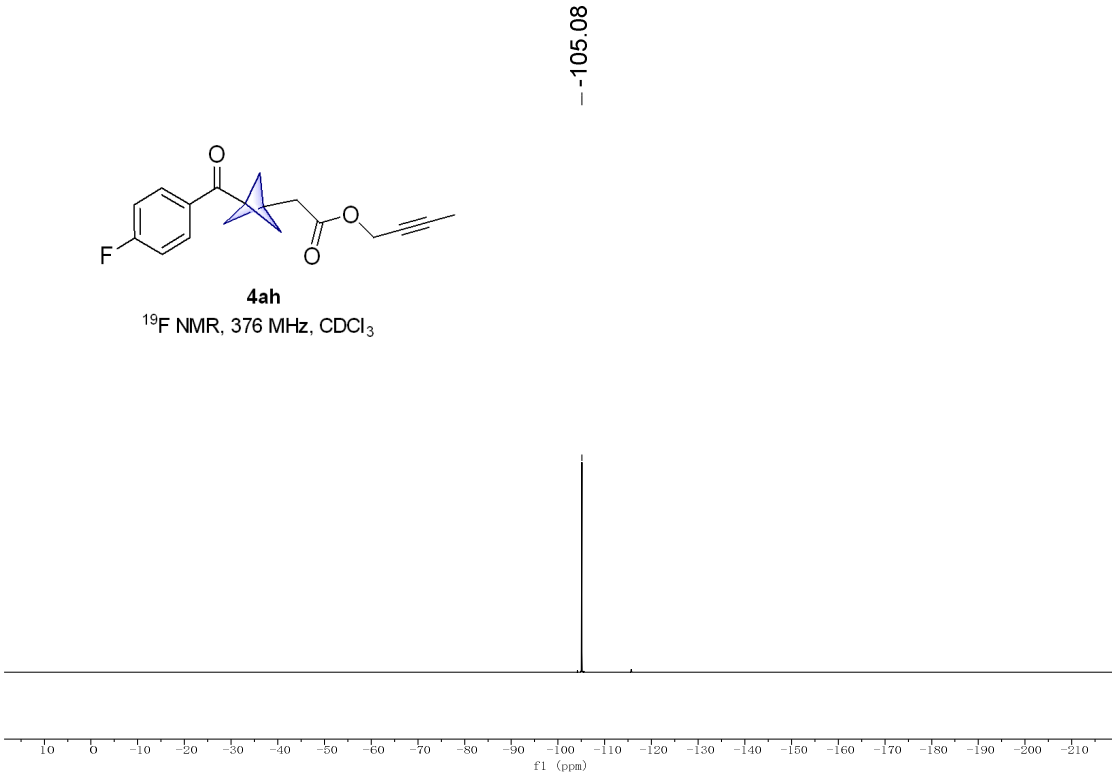


4ah

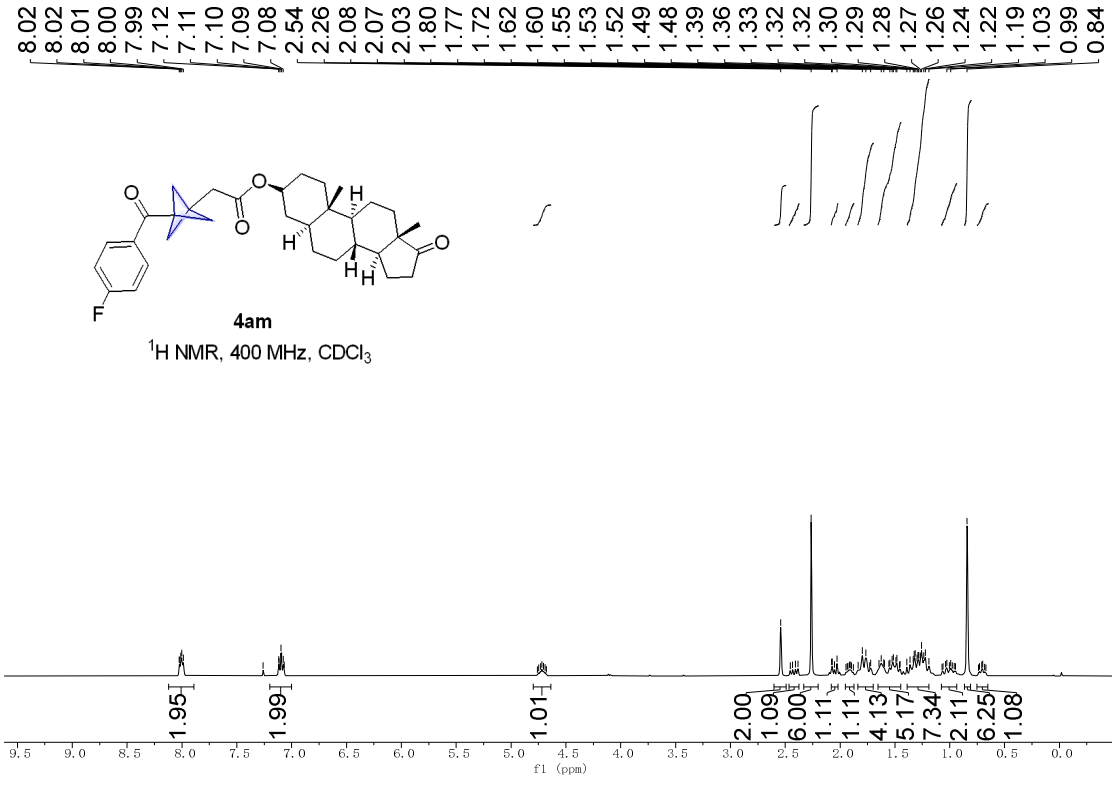
^{1}H NMR, 400 MHz, $CDCl_3$

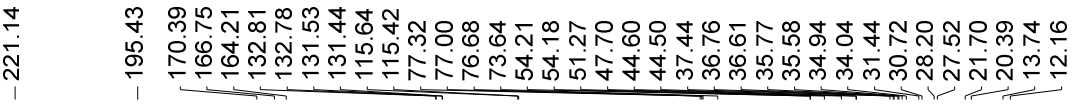
4ah

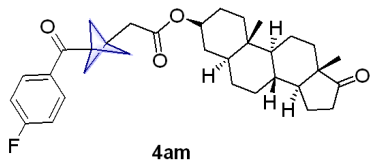
^{13}C NMR, 100 MHz, $CDCl_3$



(*3R,5S,8R,9S,10S,13S,14S*)-10,13-dimethyl-17-oxohexadecahydro-1H-cyclopenta[a]phenanthren-3-yl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4am)

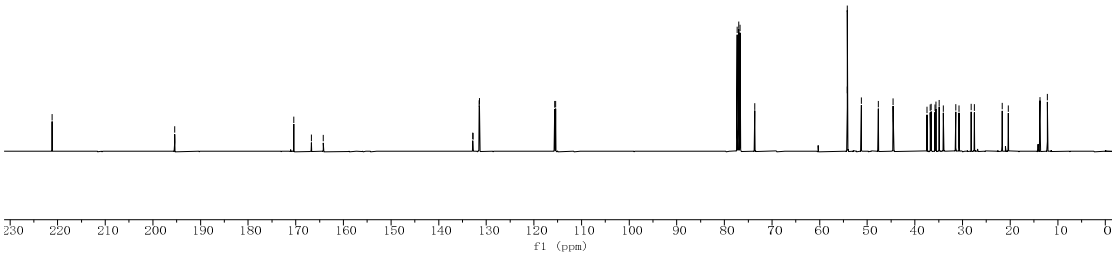


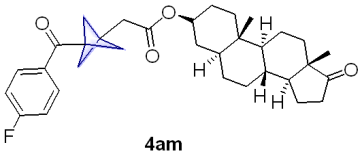




4am

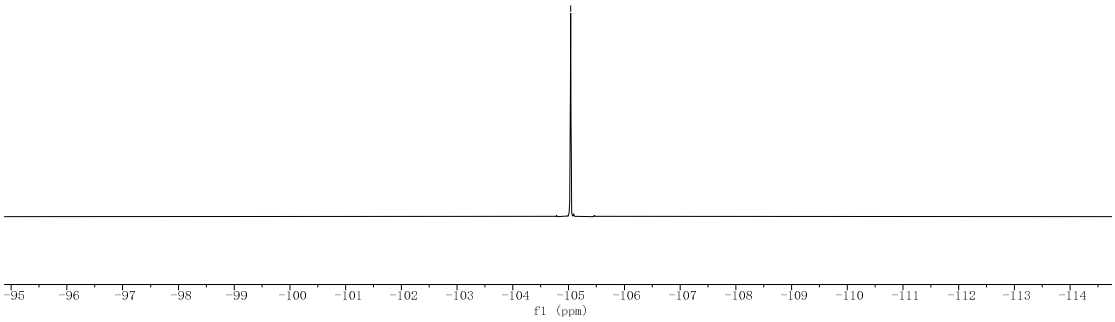
^{13}C NMR, 100 MHz, $CDCl_3$



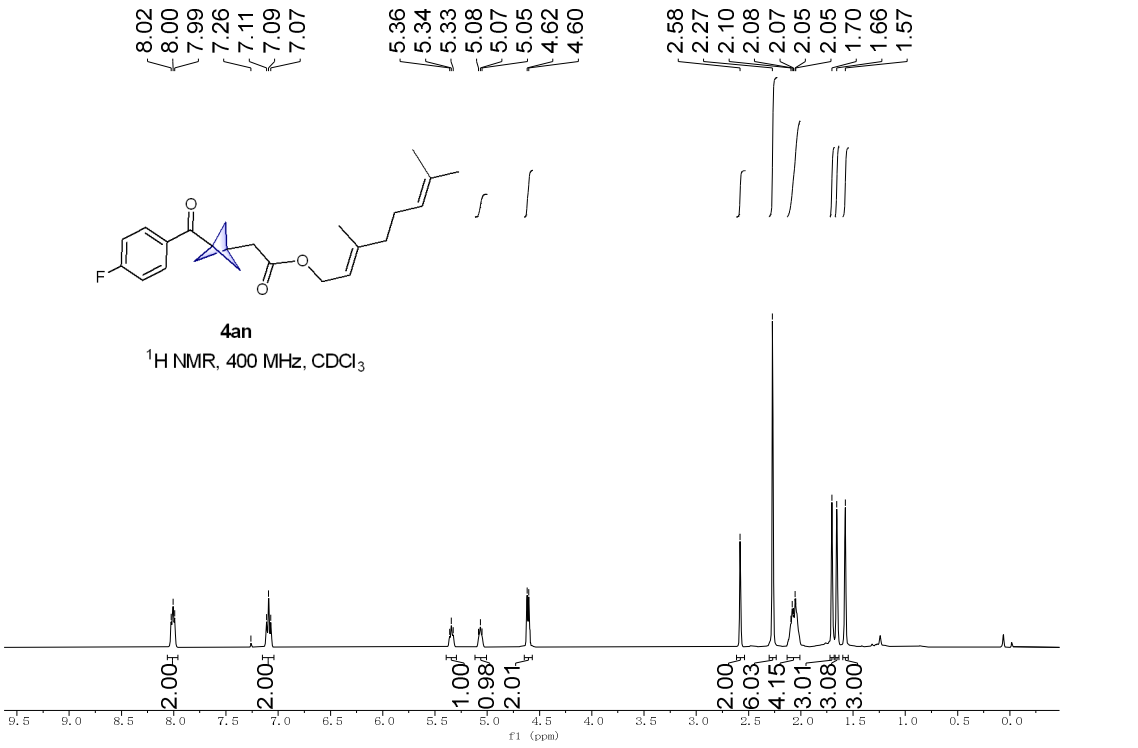


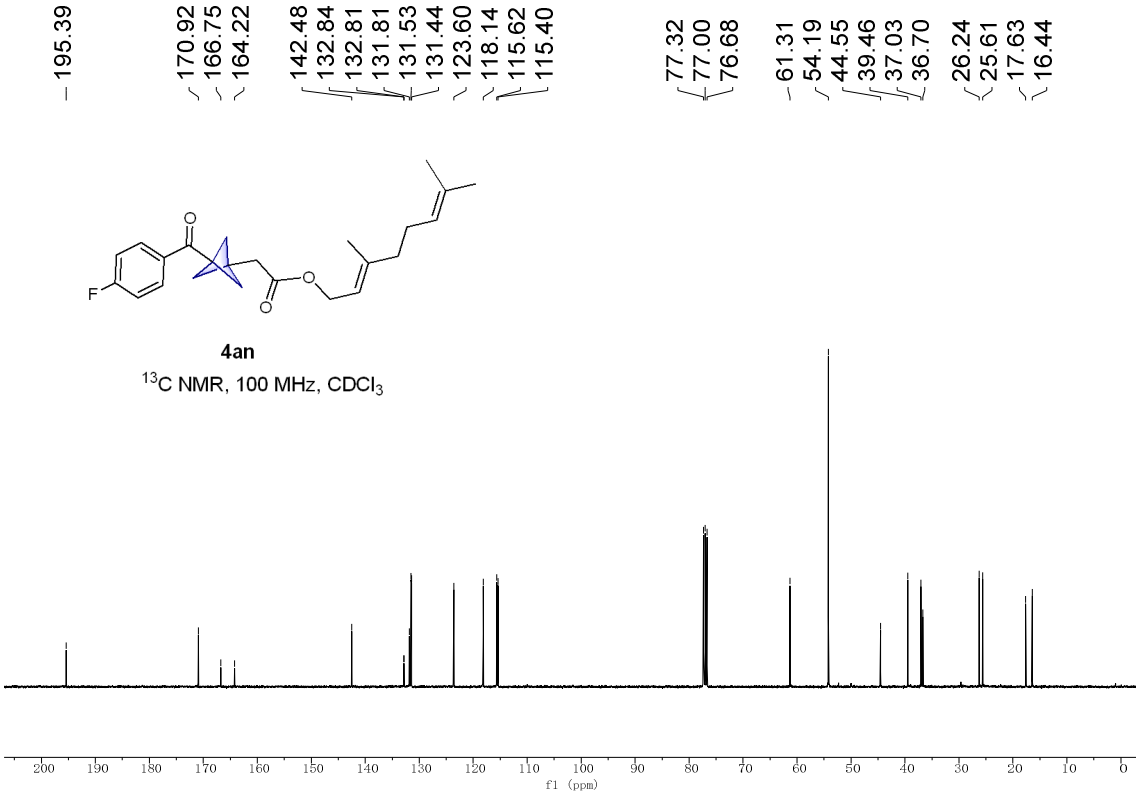
4am

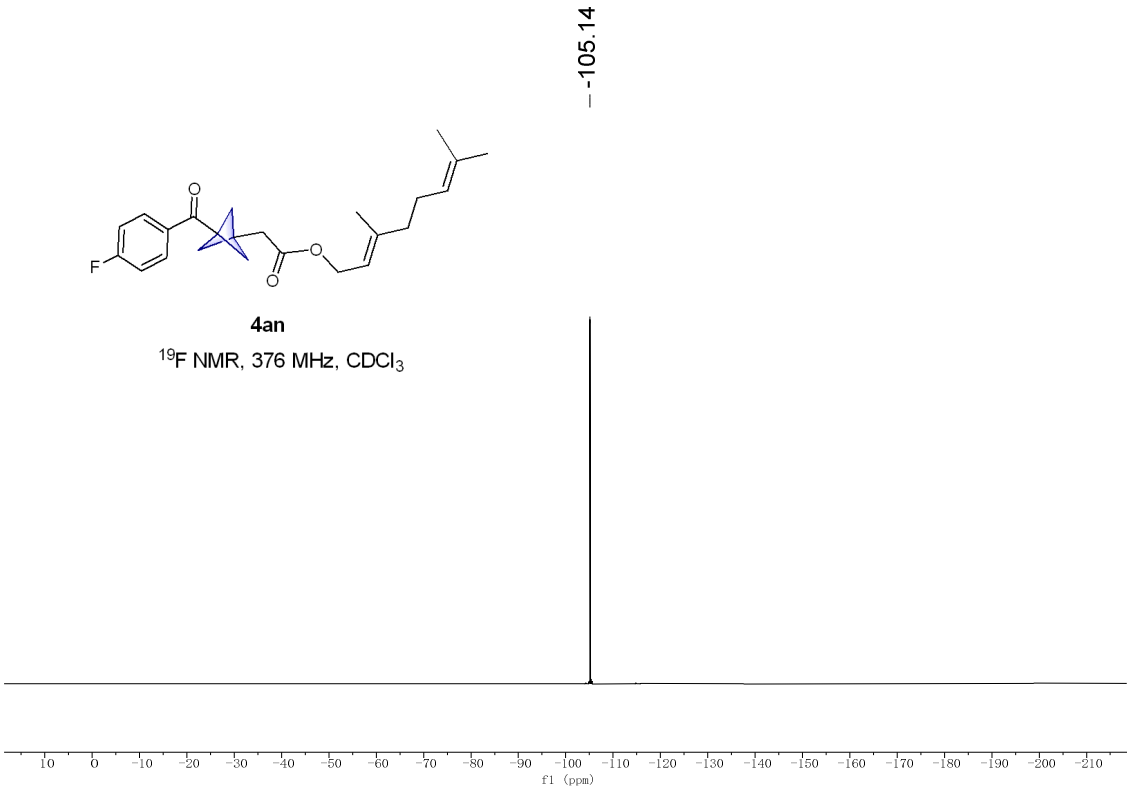
^{19}F NMR, 376 MHz, $CDCl_3$



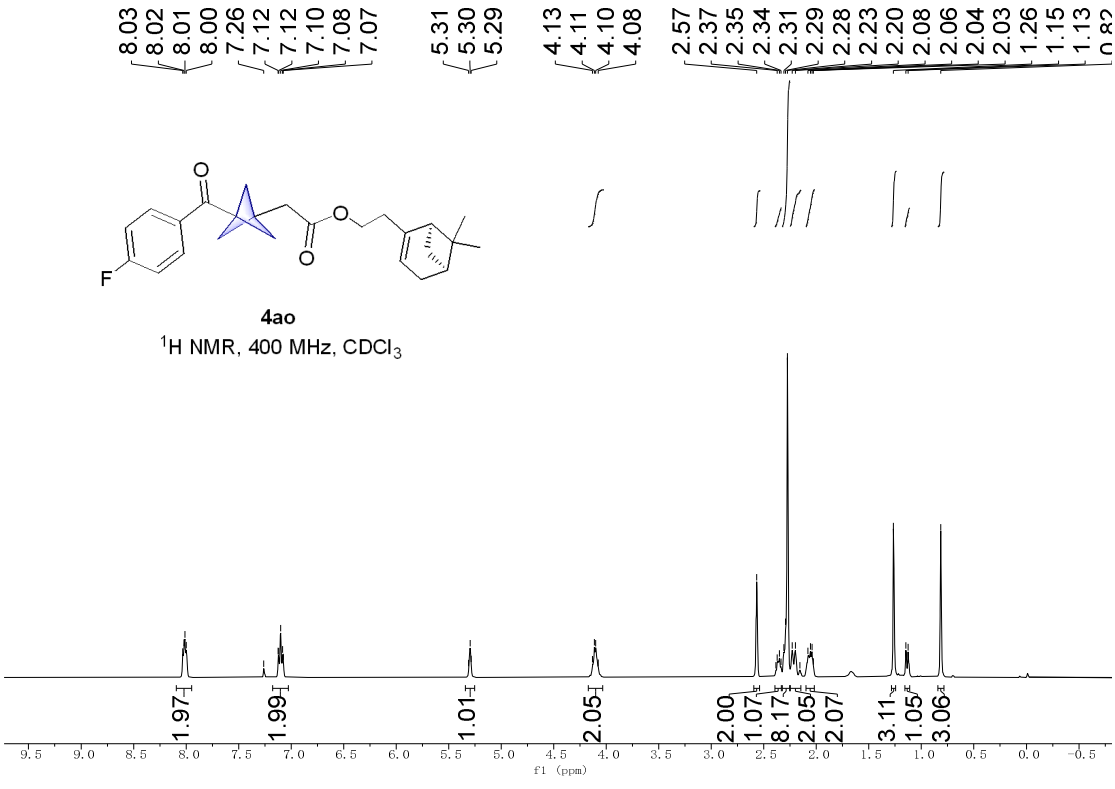
(*E*)-3,7-dimethylocta-2,6-dien-1-yl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4an)

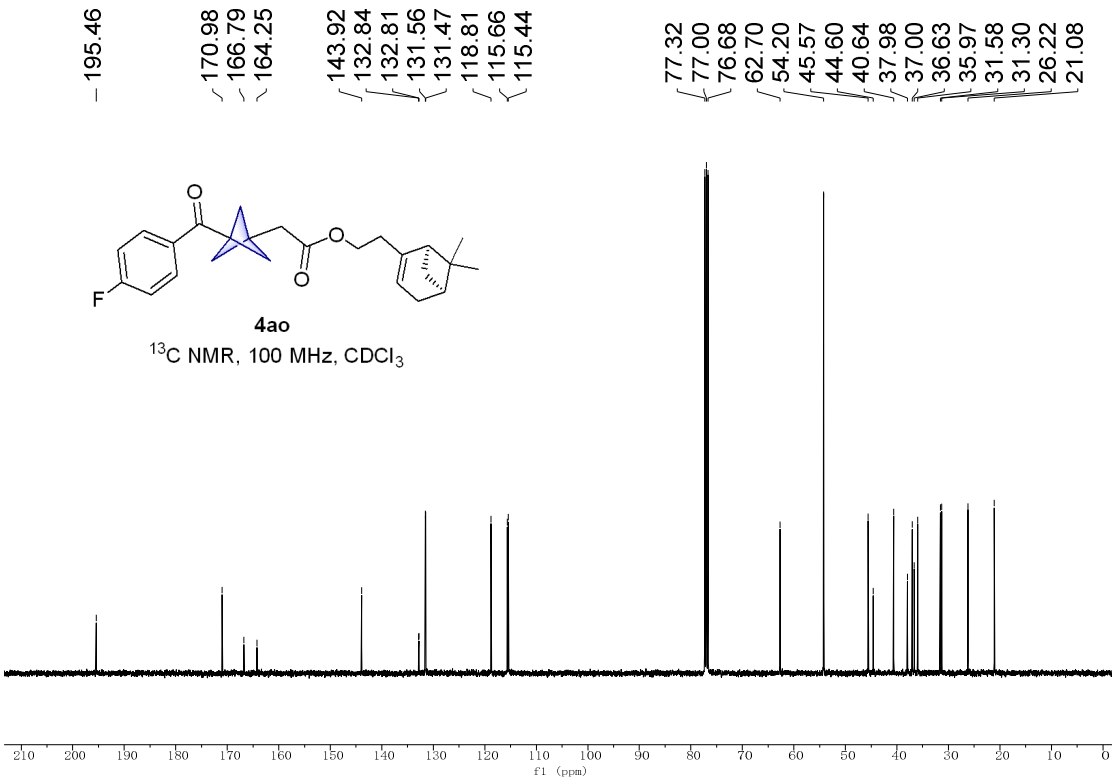


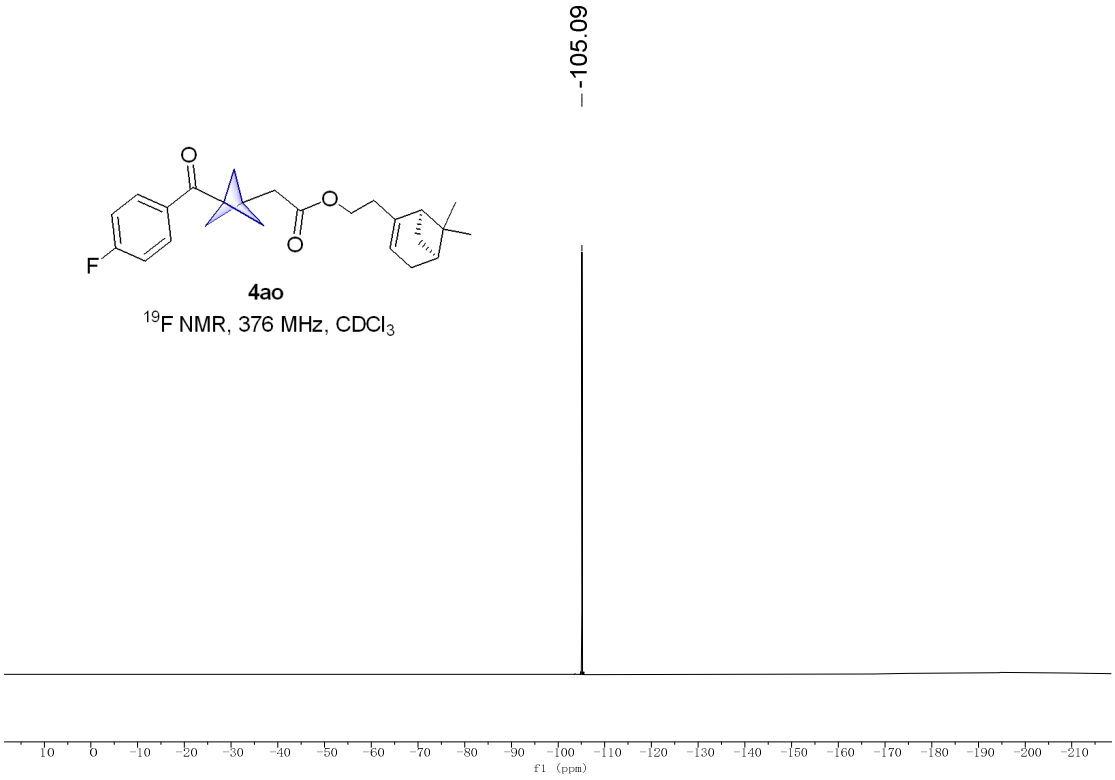




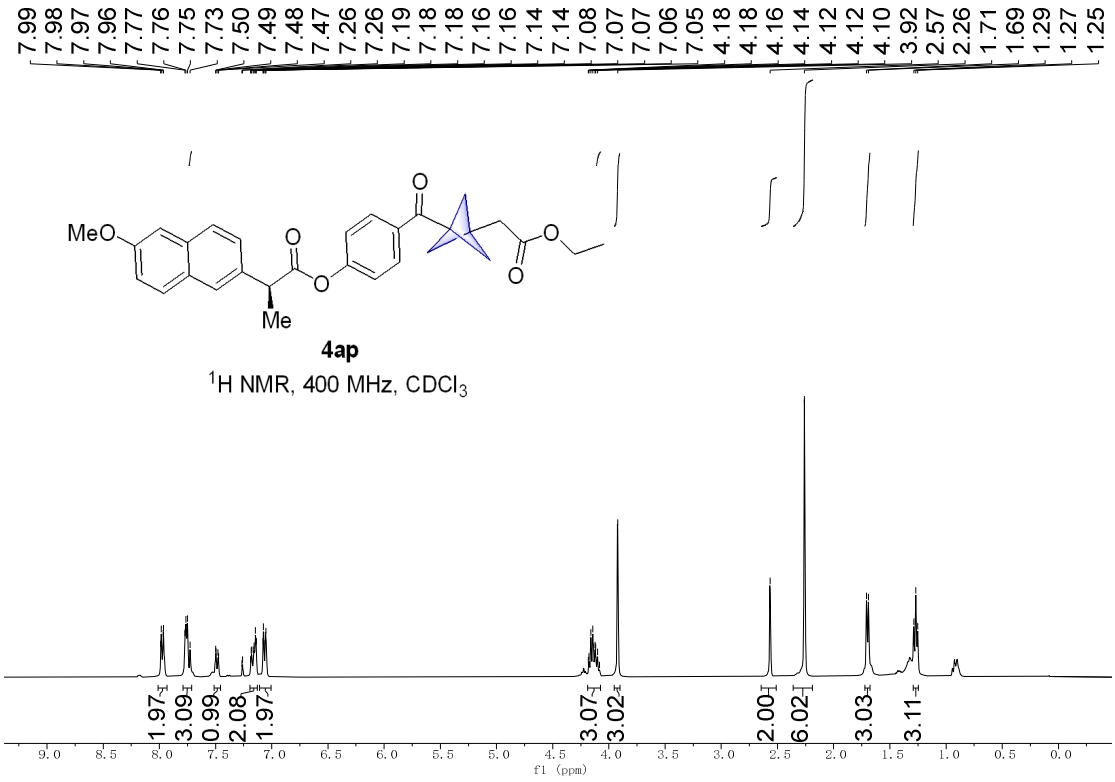
2-((*1R,5S*)-6,6-dimethylbicyclo[3.1.1]hept-2-en-2-yl)ethyl 2-(3-(4-fluorobenzoyl)bicyclo[1.1.1]pentan-1-yl)acetate (4ao)




195.46
170.98
166.79
164.25
143.92
132.84
132.81
131.56
131.47
118.81
115.66
115.44
77.32
77.00
76.68
62.70
54.20
45.57
44.60
40.64
37.98
37.00
36.63
35.97
31.58
31.30
26.22
21.08
O
O
O
F
4ao
13C NMR, 100 MHz, CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

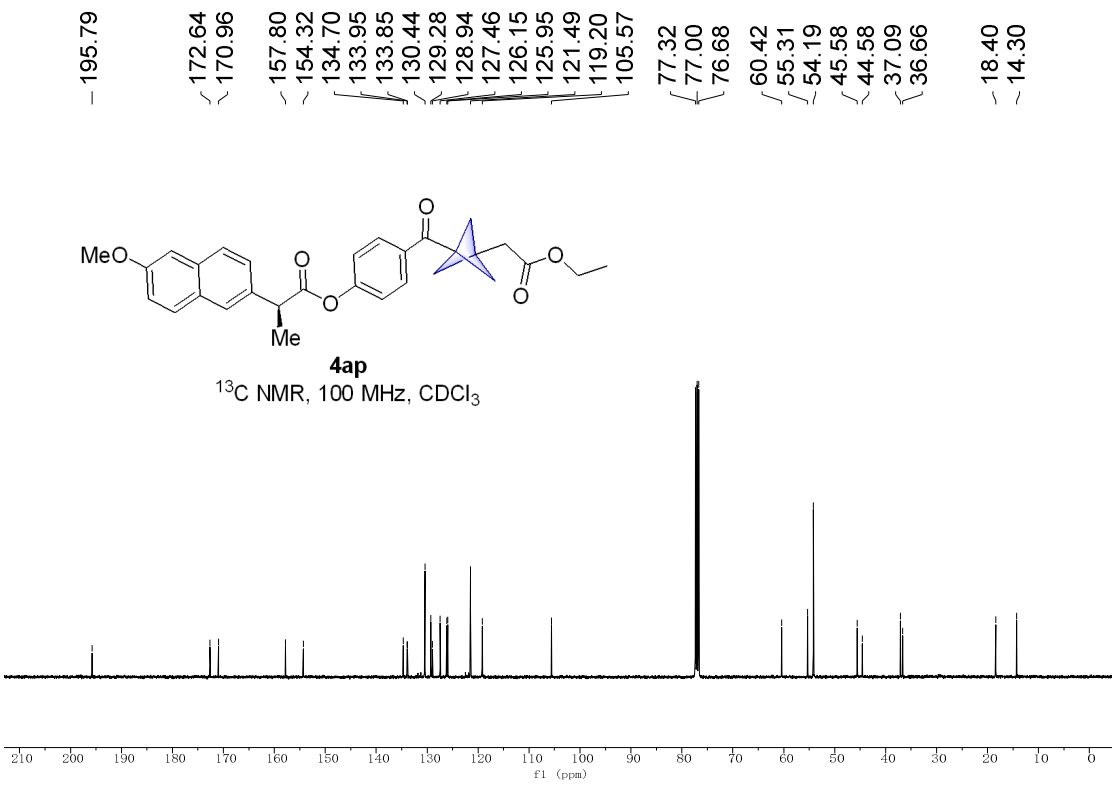

-105.09
O
O
O
F
4ao
19F NMR, 376 MHz, CDCl3
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

4-(3-(2-ethoxy-2-oxoethyl)bicyclo[1.1.1]pentane-1-carbonyl)phenyl (*S*)-2-(6-methoxynaphthalen-2-yl)propanoate (4ap)



4ap

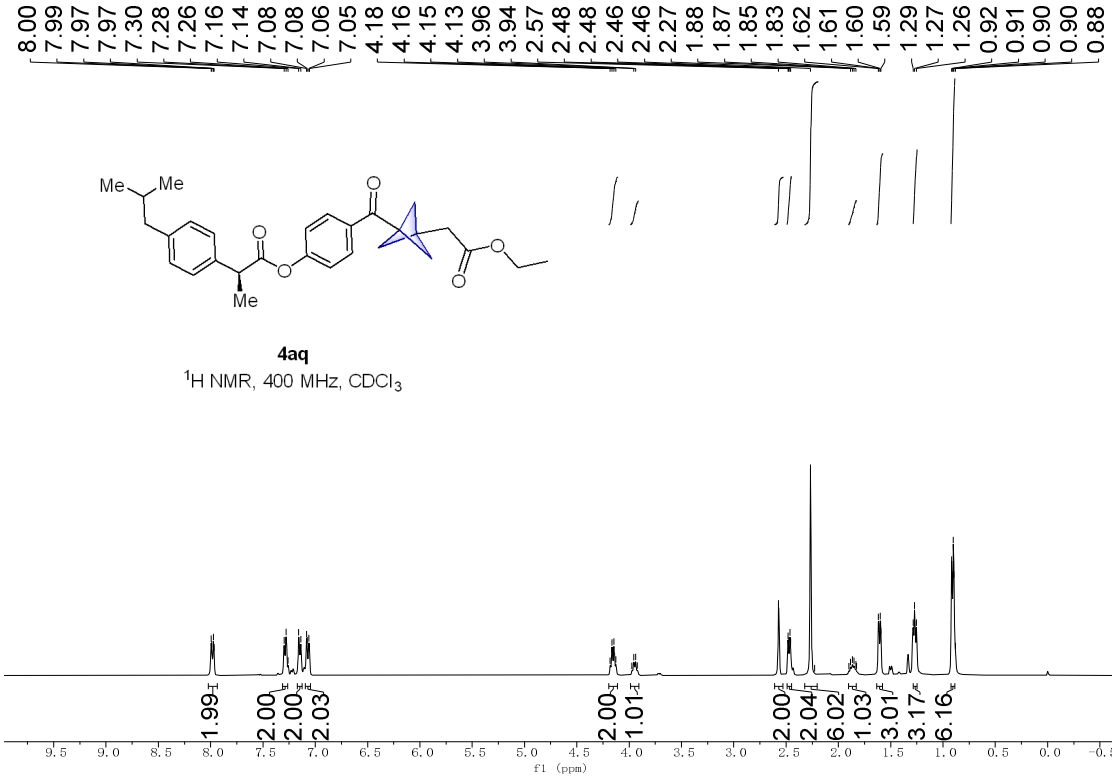
^{1}H NMR, 400 MHz, $CDCl_3$



4ap

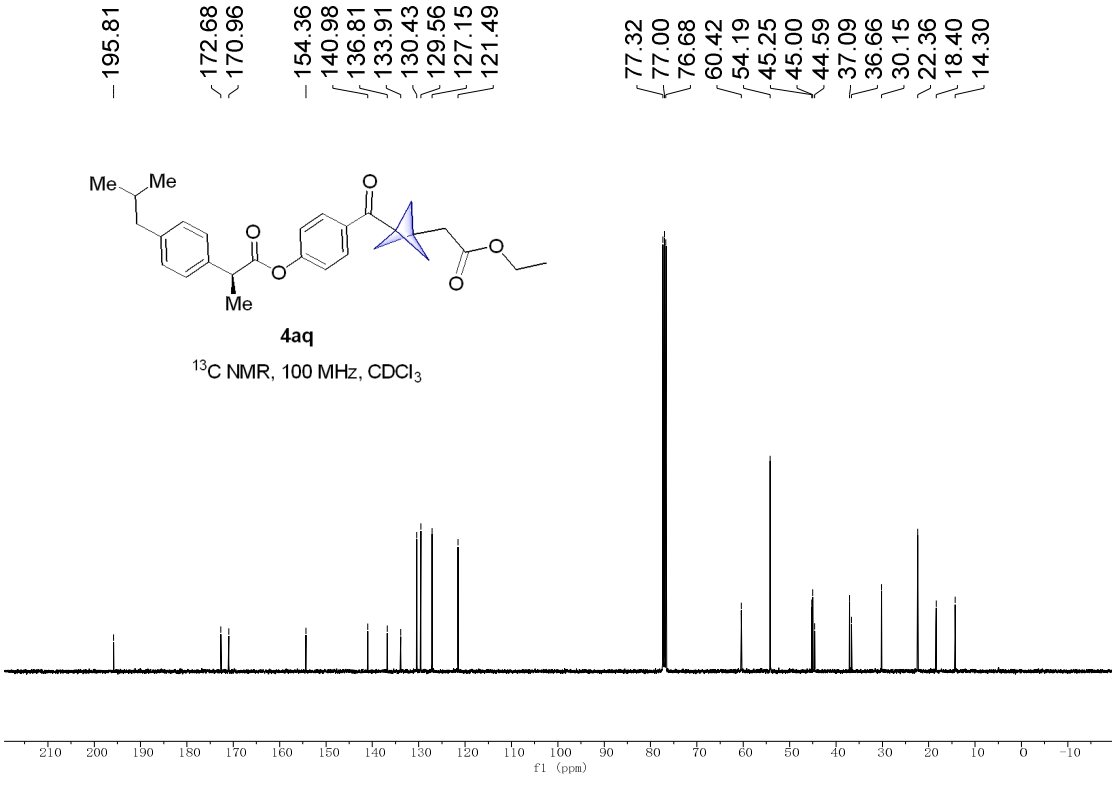
^{13}C NMR, 100 MHz, $CDCl_3$

4-(3-(2-ethoxy-2-oxoethyl)bicyclo[1.1.1]pentane-1-carbonyl)phenyl (*S*)-2-(4-isobutylphenyl)propanoate (4aq)



4aq

^{1}H NMR, 400 MHz, $CDCl_3$



4aq

^{13}C NMR, 100 MHz, $CDCl_3$