Supplementary Information

Synthesis of Tetrasubstituted Alkenyl Nitriles *via* Cyanocarbene Addition of [1.1.1]Propellane

Xinpeng Jiang,[*a] Zicong Zheng,[b] Yan Gao,[a] Deyou Lan,[a] Wenhao Xu,[a] Wang Zhang[c] and Guofei Chen[c]

[a] *College of Pharmaceutical Sciences, Zhejiang University of Technology, Hangzhou, P.R.*

** Corresponding author. E-mail: xjiang@zjut.edu.cn*

[b] *China Collaborative Innovation Center of Yangtze River Delta Region Green Pharmaceuticals, Zhejiang University of Technology, Hangzhou, P.R. China*

[c] *Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences, Ningbo 315201, People's Republic of China*

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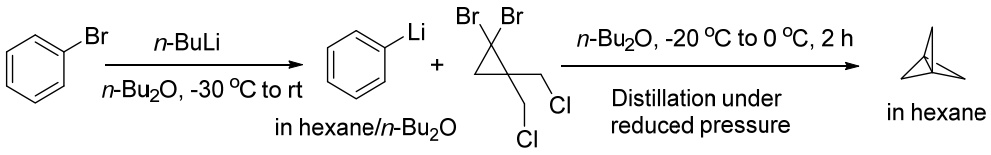
1. General information

Commercially available reagents and solvents were used without any purification. The progress of the reactions was monitored by TLC with silica gel plates, and the visualization was carried out under UV light (254 nm). Melting points were determined using a Büchi B-540 capillary melting point apparatus. NMR spectra were recorded using Varian Mercury Plus 400 MHz or Bruker Avance III 600 MHz spectrometers. Chemical shifts of ^{1}H NMR were reported relative to the solvent signal ($CDCl_3$: δ = 7.26 ppm; DMSO-d_6: δ = 2.50 ppm). Chemical shifts of ^{13}C NMR were reported relative to the solvent signal ($CDCl_3$: δ = 77.00 ppm; DMSO-d_6: δ = 39.50 ppm). HRMS spectra were recorded on an electrospray ionization quadrupole time-of-flight (ESI-Q-TOF) mass spectrometer. Column chromatography was performed on silica gel (300-400 mesh).

2. Synthesis of substrates 2

The substrates (**2a**-**2h**, **2j**-**2q**, and **10**) were synthesized following the procedural reported in previous publications[1], and the NMR data of all these compounds were compared with the corresponding reported data. Substrate **2i** was prepared from trimethyl((4'-methyl-[1,1'-biphenyl]-4-yl)ethynyl)silane following the literature procedure[2].

3. Preparation of the solution of [1.1.1]propellane in hexane



a) Preparation of phenyl lithium in hexane/*n*-Bu_2O

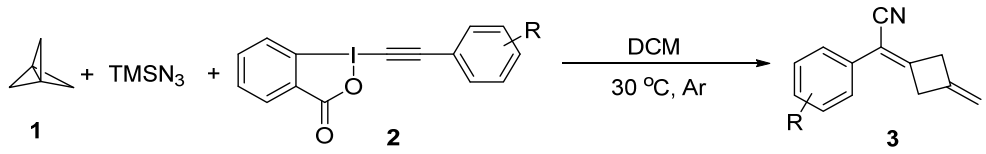
A 100 ml three-neck round bottom flask equipped with a magnetic stirring bar was charged with bromobenzene (100mmol, 1.0 equiv.). After the flask was evacuated and backfilled with argon three times, anhydrous dibutyl ether (20 mL) was added. Then the flask was cooled down to -30 °C and *n*-

BuLi (100 mmol, 1.0 equiv., 2.5 M in hexane) was added dropwise via addition funnel. After the addition was complete, the mixture was allowed to warm to room temperature, and stirred at room temperature for 1 h. The mixture was used in the next step.

b) Preparation of the solution of [1.1.1]propellane in hexane

A solution of the above prepared phenyl lithium in hexane/*n*-Bu_2O (65 mL) was added dropwise to a suspension of 1,1-dibromo-2,2-bis(chloromethyl)cyclopropane (45.0 mmol) in anhydrous dibutyl ether (20 mL) via addition funnel under argon at –20 °C. After the addition was complete, the mixture was allowed to warm to 0 °C and stirred for 2 h, then the addition funnel was swapped out for a distillation head with attached 100 mL round bottom flask in a –78 °C bath (dry ice/acetone). A vacuum was slowly applied to the system and the distillate collected, while maintaining the reaction/distillation flask below 0 °C. Approximately 35 mL of distillate was collected. The concentration can be checked by NMR by taking a 200 uL aliquot of the stock solution and determining the ratio of [1.1.1]propellane to an added dibromomethane as standard (typically concentrations are 0.5-0.7 M with this protocol).

4. General method



1 2 3

Method 1:

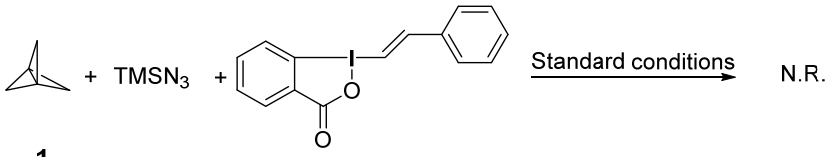
An over-dried 10 mL reaction tube equipped with a magnetic stir bar was charged with **1** (0.6 mmol, 1.5 equiv.), $TMSN_3$ (0.8 mmol, 2.0 equiv.), anhydrous DCM (2.0 mL) and **2** (0.40 mmol, 1.0 equiv.) under argon. The reaction mixture was placed in a preheated metal block and stirred at 30 °C until consumption of starting material (nitrogen gas stopped being generated, monitored by TLC). After the reaction was complete, it was quenched with saturated $NaHCO_3$ solution (5 mL) at room temperature, and then extracted with ethyl acetate (10 mL × 3). The organic layers were combined, washed with brine, dried over Na_2SO_4 filtered, and then concentrated in vacuum. The residue was purified by flash chromatography on silica gel with petroleum ether to afford the desired product **3**.

Method 2:

An over-dried 10 mL reaction tube equipped with a magnetic stir bar was charged with **1** (0.3 mmol, 1.0 equiv.), $TMSN_3$ (0.6 mmol, 2.0 equiv.), anhydrous DCM (2.0 mL) and **2** (0.45 mmol, 1.5 equiv.) under argon. The reaction mixture was placed in a preheated metal block and stirred at 30 °C until consumption of starting material (nitrogen gas stopped being generated, monitored by TLC). After the reaction was complete, it was quenched with saturated $NaHCO_3$ solution (5 mL) at room temperature, and then extracted with ethyl acetate (10 mL × 3). The organic layers were combined, washed with brine, dried over Na_2SO_4 filtered, and then concentrated in vacuum. The residue was purified by flash chromatography on silica gel with petroleum ether to afford the desired product **3**.

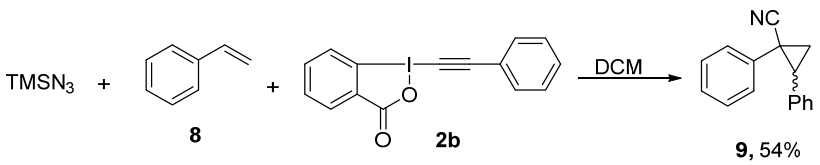
5. Control experiments

a) (*E*)-1-styryl-1λ^3-benzo[*d*][1,2]iodaoxol-3(1*H*)-one 10 as substrate



An oven-dried 10 mL Schlenk tube was charged with **10** (0.4 mmol, 140 mg), **1** (0.6 mmol, 1.0 mL), and $TMSN_3$ (0.8 mmol, 92 mg) in anhydrous DCM (2 mL) under argon atmosphere. The reaction mixture was placed in a preheated metal block and stirred at 30 °C for 1 h. No desired product was detected.

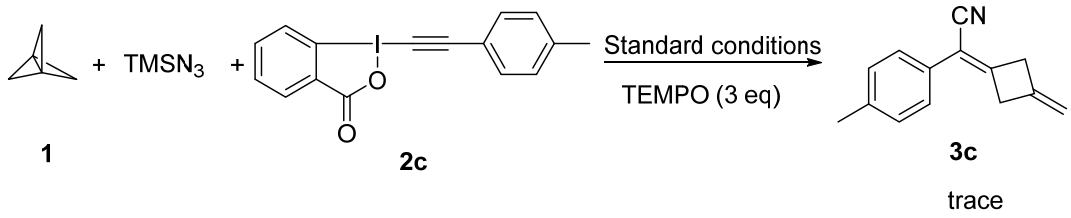
b) Carbene capturing experiment



An oven-dried 10 mL Schlenk tube was charged with **2b** (0.3 mmol, 105 mg), **8** (0.6 mmol, 62 mg), and $TMSN_3$ (0.45 mmol, 52 mg) in anhydrous DCM (1.0 mL) under argon atmosphere. The reaction mixture

was placed in a preheated metal block and stirred at 30 °C for 10 min. Subsequently the solvent was then removed under vacuum. Chromatography on silica gel with petroleum ether/ethyl acetate (100:1 to 50:1) to give **9** (35.0 mg, 54%, 1:1 diastereomers) as a yellow oil; Phenyl groups *cis*: ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.44 – 7.39 (m, 6H), 7.37 – 7.33 (m, 4H), 2.81 (t, *J* = 8.4 Hz, 1H), 2.22 (dd, *J* = 7.8, 6.1 Hz, 1H), 2.02 (dd, *J* = 9.0, 6.2 Hz, 1H). Phenyl groups *trans*: ^{1}H NMR (400 MHz, Chloroform-*d*) δ7.20 – 7.15 (m, 3H), 7.14 – 7.08 (m, 5H), 6.94 – 6.88 (m, 2H), 3.23 – 3.14 (m, 1H), 2.16 – 2.07 (m, 2H). The spectra data matched those previously reported.[3]

c) Radical inhibiting experiment



An oven-dried 10 mL Schlenk tube was charged with **2c** (109 mg, 0.3 mmol), TEMPO (140 mg, 0.9 mmol), **1** (1.0 mL, 0.60M, 0.60 mmol), and $TMSN_3$ (69 mg, 0.60 mmol) in anhydrous DCM (2.0 mL) under argon atmosphere. The reaction mixture was placed in a preheated metal block and stirred at 30 °C for 10 min. Only trace amount of product was detected.

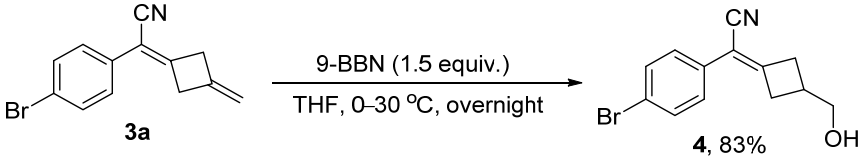
6. Gram-scale synthesis and derivatization of products 3a

a) Gram-scale synthesis of compound 3a

An oven-dried 100 mL three-necked flask equipped with a magnetic stir bar was charged with **2a** (2.570 g, 6.0 mmol) in anhydrous DCM (20 mL) and [1.1.1]propellane **1** (11.2 mL, 0.45M, 5.0 mmol) under argon atmosphere sequentially. Then $TMSN_3$ (1.021 g, 9 mmol) was added slowly with stirring. The reaction mixture was stirred at 30 °C until nitrogen gas stopped being generated. After the reaction was completed as monitored by TLC, it was quenched with saturated $NaHCO_3$ solution (15 mL) at room temperature, and then extracted with ethyl acetate (30 mL × 3). The organic layers were combined, washed with brine, dried over Na_2SO_4 filtered, and then concentrated in vacuum. The residue was

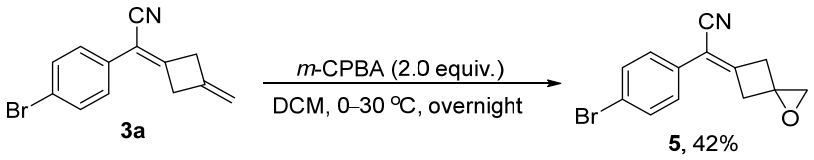
purified by flash chromatography on silica gel with petroleum ether/ethyl acetate to afford the desired product **3a** as a yellow solid (0.792 g, 61%).

b) Synthesis of *tert*-butyl(3-(4-methyl-3-oxo-3,4-dihydroquinoxalin-2yl) bicyclo-[1.1.1]pentan-1-yl) carbamate 4[4]



To a 10 mL Schlenk tube equipped with a stir bar were added **3a** (26 mg, 0.1 mmol). After the tube was evacuated and backfilled with argon three times, dry THF was added. Then cool this to 0 °C, a solution of 9-BBN (150uL, 1.0M in THF, 0.15mmol) was added drop by drop. The mixture was warmed up to 30 °C and stirred for overnight, after which time the reaction mixture was cooled to 0 °C and H_2O (12 uL), 3 N NaOH (40 uL) and 30% H_2O_2 (40 uL) were added successively. The mixture was extracted with EtOAc and the separated organic phase was dried over Na_2SO_4. The residue was purified by flash column chromatography on silica gel, eluting with petroleum ether/ethyl acetate 2:1 (v/v) to give **4** as a white soild (23 mg, 83%); M.p.: 93-95 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.53 – 7.46 (m, 2H), 7.28 – 7.22 (m, 2H), 3.79 – 3.66 (m, 2H), 3.23 – 3.07 (m, 2H), 3.00 – 2.85 (m, 2H), 2.80 – 2.68 (m, 1H), 1.85 (br, 1H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 161.46, 131.95, 131.32, 127.89, 122.17, 116.18, 108.18, 65.29, 35.87, 35.55, 32.45. HRMS (ESI) m/z: calcd for $C_{13}H_{13}BrNO$ $[M+H]^+$ 278.0175, found: 278.0183.

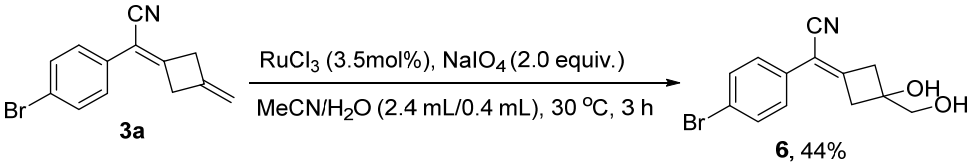
c) Synthesis of 2-(4-bromophenyl)-2-(1-oxaspiro[2.3]hexan-5-ylidene)acetonitrile 5[5]



A 10 mL seal tube equipped with a magnetic stirring bar was charged with **3a** (26 mg, 0.1 mmol), *m*-CPBA (34 mg, 0.2 mmol), and DCM (1.0 mL). The mixture was stirred at 30 °C overnight. Then the solvent was removed under reduced pressure. The residue was purified by flash column chromatography on silica gel, eluting with petroleum ether/ethyl acetate 20:1 (v/v) to give **5** as a white solid (12 mg, 42%); M.p.: 122-124 °C; ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.56 – 7.51 (m, 2H), 7.32 – 7.27 (m, 2H), 3.62

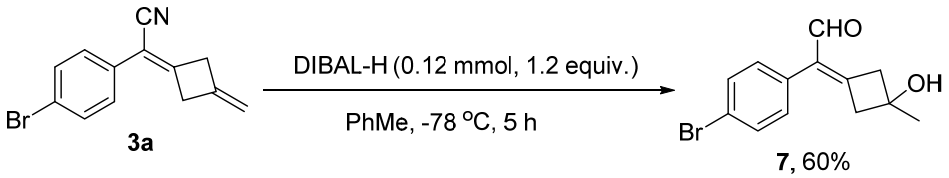
– 3.53 (m, 2H), 3.53 – 3.47 (m, 1H), 3.45 – 3.38 (m, 1H), 2.95 – 2.88 (m, 2H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 152.64, 132.14, 131.09, 127.95, 122.81, 115.97, 109.25, 56.92, 51.15, 42.20, 41.51. HRMS (ESI) m/z: calcd for $C_{13}H_{11}BrNO$ $[M+H]^+$ 276.0019, found: 276.0034.

d) Synthesis of 2-(4-bromophenyl)-2-(3-hydroxy-3-(hydroxymethyl)cyclobutylidene)acetonitrile 6[6]



$NaIO_4$ (43 mg, 0.2 mmol) was added to a solution of the compound **3a** (26 mg, 0.1 mmol) and $RuCl_3$(1 mg, 0.0035 mmol) in 2.8 mL of a 6:1 mixture of MeCN:H_2O. The solution was stirred at room temperature for 3h. The reaction mixture was quenched with 10% aq. $Na_2S_2O_3$ and washed with EtOAc (3 x 5 mL). The organic layers were collected and washed with H_2O, saturated aq.NaCl and dried over $MgSO_4$ and filtered. The crude was purified by column chromatography (silica-gel, petroleum ether/EtOAc 1:2 (v/v) to give **6** as a white solid (13 mg, 44%); M.p.: 139-141 °C; ^{1}H NMR (400 MHz, DMSO-d_6) δ 7.70 – 7.59 (m, 2H), 7.39 – 7.31 (m, 2H), 5.60 (br, 1H), 4.91 (t, J = 5.7 Hz, 1H), 3.35 (d, J = 6.2 Hz, 2H), 3.22 – 3.10 (m, 2H), δ 3.07 – 2.98 (m, 1H), 2.97 – 2.87 (m, 1H). ^{13}C NMR (100 MHz, DMSO-d_6) δ 159.91, 132.03, 131.57, 128.11, 121.35, 116.52, 106.48, 71.56, 66.27, 44.40, 44.33. HRMS (ESI) m/z: calcd for $C_{13}H_{13}BrNO_2$ $[M+H]^+$ 294.1024, found: 294.1036.

e) Synthesis of 2-(4-bromophenyl)-2-(3-hydroxy-3-methylcyclobutylidene)acetaldehyde 7[5]

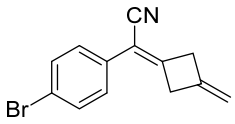


To a solution of acrylotrile **3a** (26 mg, 0.1 mmol) in toluene (1 mL) were added DIBAL-H (120 uL, 1.0M in hexane, 0.12 mmol) at -78 °C. The mixture was stirred for 5 h at -78 °C and then quenched with 5% H_2SO_4 aqueous solution at 0 °C. The aqueous phase was extracted with ethyl acetate. Then the combined organic layers were dried (Na_2SO_4) and purified by flash column chromatography on silica gel, eluting with petroleum ether/ethyl acetate 2:1 (v/v) to give **7** as a white solid (17 mg, 60%); M.p.: 120-122 °C; ^{1}H NMR (400 MHz, DMSO-d_6) δ 9.78 (s, 1H), 7.59 – 7.51 (m, 2H), 7.20 – 7.13 (m, 2H), 5.52 (br, 1H),

3.42 – 3.36 (m, 1H), 3.24 – 3.05 (m, 2H), 2.88 – 2.78 (m, 1H), 1.30 (s, 3H). ^{13}C NMR (100 MHz, DMSO-d_6) δ 189.17, 164.19, 133.48, 132.28, 131.05, 130.98, 120.56, 68.73, 48.79, 46.15, 27.26. HRMS (ESI) m/z: calcd for $C_{13}H_{12}BrO_2$ $[M-H]^-$ 279.0026, found: 279.0029.

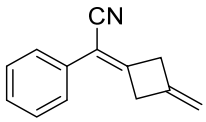
7. Characterization of products

3-(3-azidobicyclo[1.1.1]pentan-1-yl)-1-benzylquinoxalin-2(1*H*)-one (**3a**)



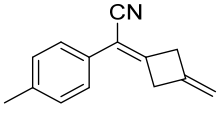
Eluent in chromatography: petroleum ether, **3a** was isolated as a pale yellow solid (60 mg, 58%); M.p.: 105-106 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.59 – 7.46 (m, 2H), 7.36 – 7.27 (m, 2H), 5.16 – 5.03 (m, 2H), 3.84 – 3.65 (m, 4H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 158.07, 139.25, 132.04, 131.32, 127.85, 122.41, 116.08, 109.16, 108.28, 43.00, 42.36. HRMS (ESI) m/z: calcd for $C_{13}H_{11}BrN$ $[M+H]^+$ 260.0069, found: 260.0079.

2-(3-methylenecyclobutylidene)-2-phenylacetonitrile (**3b**)



Eluent in chromatography: petroleum ether, **3b** was isolated as a pale yellow solid (37 mg, 51%); M.p.: 120-121 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.46 – 7.37 (m, 4H), 7.35 – 7.29 (m, 1H), 5.10 – 5.07 (m, 2H), 3.81-3.73 (m, 4H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 157.16, 139.76, 132.34, 128.84, 128.25, 126.32, 116.52, 109.07, 108.89, 42.87, 42.37. HRMS (ESI) m/z: calcd for $C_{13}H_{12}N$ $[M+H]^+$ 182.0964, found: 182.0973.

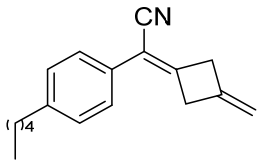
2-(3-methylenecyclobutylidene)-2-(p-tolyl)acetonitrile (3c)



Eluent in chromatography: petroleum ether, **3c** was isolated as a pale yellow solid (44 mg, 56%); M.p.: 69-70 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.35 – 7.29 (m, 2H), 7.23 – 7.17 (m, 2H), 5.12 – 5.04 (m, 2H), 3.81 – 3.72 (m, 4H), 2.36 (s, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 155.88, 139.98, 138.29,

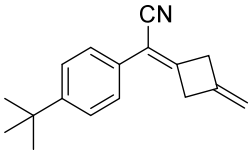
129.58, 129.51, 126.22, 116.66, 108.96, 108.77, 42.79, 42.29, 21.18. HRMS (ESI) m/z: calcd for $C_{14}H_{14}N$ $[M+H]^+$ 196.1121, found: 196.1115.

4-(3-(3-azidobicyclo[1.1.1]pentan-1-yl)-2-oxoquinoxalin-1(2*H*)-yl)benzonitrile (3d)



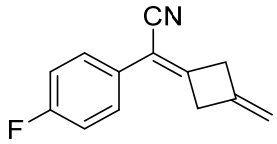
Eluent in chromatography: petroleum ether, **3d** was isolated as a yellow oil (44 mg, 44%); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.34 (d, *J* = 8.3 Hz, 2H), 7.21 (d, *J* = 8.1 Hz, 2H), 5.17 – 4.99 (m, 2H), 3.90 – 3.63 (m, 4H), 2.61 (t, *J* = 7.7 Hz, 2H), 1.65 – 1.58 (m, 2H), 1.37 – 1.28 (m, 4H), 0.89 (t, *J* = 6.8 Hz, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 155.82, 143.35, 140.02, 129.80, 128.87, 126.25, 116.65, 109.03, 108.74, 42.81, 42.32, 35.56, 31.41, 30.94, 22.48, 13.98. HRMS (ESI) m/z: calcd for $C_{18}H_{22}N$ $[M+H]^+$ 252.1747, found: 252.1744.

3-(3-azidobicyclo[1.1.1]pentan-1-yl)-1-phenylquinoxalin-2(1*H*)-one (3e)



Eluent in chromatography: petroleum ether, **3e** was isolated as a pale yellow solid (32 mg, 34%); M.p.: 102-103 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.42 (d, *J* = 8.7 Hz, 1H), 7.37 (d, *J* = 8.7 Hz, 1H), 5.11 – 5.05 (m, 2H), 3.80 – 3.74 (m, 4H), 1.33 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.06, 151.45, 140.00, 129.56, 126.07, 125.78, 116.65, 108.85, 108.79, 42.81, 42.32, 34.65, 31.15. HRMS (ESI) m/z: calcd for $C_{17}H_{20}N$ $[M+H]^+$ 238.1590, found: 238.1595.

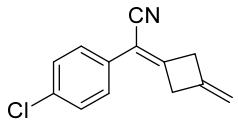
1-allyl-3-(3-azidobicyclo[1.1.1]pentan-1-yl)quinoxalin-2(1*H*)-one (3f)



Eluent in chromatography: petroleum ether, **3f** was isolated as a yellow soild (51 mg, 64%); M.p.: 58-59 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.45 – 7.35 (m, 2H), 7.13 – 7.03 (m, 2H), 5.13 – 5.03 (m, 2H), 3.80 – 3.68 (m, 4H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 162.36 (d, *J* = 249.4 Hz), 156.86 (d, *J* = 1.9 Hz), 139.48, 128.57 (d, *J* = 3.4 Hz), 128.23 (d, *J* = 8.2 Hz), 116.43, 115.99 (d, *J* = 21.8 Hz), 109.10, 108.19, 42.88, 42.23. ^{19}F NMR (376 MHz, Chloroform-*d*) δ -112.38. HRMS (ESI) m/z: calcd for

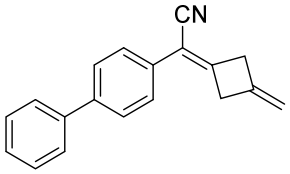
$C_{13}H_{11}NF$ $[M+H]^+$ 200.0870, found: 200.0853.

2-(4-chlorophenyl)-2-(3-methylenecyclobutylidene)acetonitrile (3g)



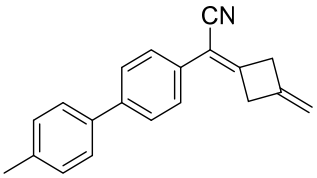
Eluent in chromatography: petroleum ether, **3g** was isolated as a pale yellow solid (38 mg, 59%); M.p.: 93-94 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.44 – 7.32 (m, 4H), 5.15 – 5.05 (m, 2H), 3.85 – 3.70 (m, 4H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 157.90, 139.28, 134.21, 130.85, 129.07, 127.58, 116.15, 109.15, 108.18, 42.95, 42.33. HRMS (ESI) m/z: calcd for $C_{13}H_{11}ClN$ $[M+H]^+$ 216.0575, found: 216.0565.

2-([1,1'-biphenyl]-4-yl)-2-(3-methylenecyclobutylidene)acetonitrile (3h)



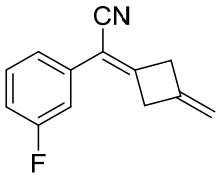
Eluent in chromatography: petroleum ether, **3h** was isolated as a white solid (42 mg, 55%); M.p.: 117-118°C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.68 – 7.56 (m, 4H), 7.56 – 7.42 (m, 4H), 7.42 – 7.34 (m, 1H), 5.16 – 5.03 (m, 2H), 3.89 – 3.72 (m, 4H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 157.05, 141.01, 140.00, 139.76, 131.35, 128.88, 127.72, 127.46, 126.99, 126.75, 116.49, 108.93, 108.82, 42.97, 42.45. HRMS (ESI) m/z: calcd for $C_{19}H_{16}N$ $[M+H]^+$ 258.1277, found: 258.1289.

3-(3-azidobicyclo[1.1.1]pentan-1-yl)-6-fluoro-1-methylquinoxalin-2(1*H*)-one (3i)



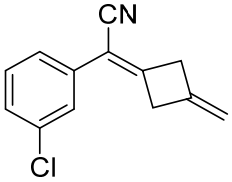
Eluent in chromatography: petroleum ether, **3i** was isolated as a yellow solid (33 mg, 41%); M.p.: 135-136 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.63 – 7.58 (m, 2H), 7.50 – 7.45 (m, 4H), 7.25 – 7.22 (m, 2H), 5.11 – 5.05 (m, 2H), 3.83 – 3.75 (m,4H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 156.91, 140.99, 139.87, 137.68, 137.15, 131.09, 129.66, 127.29, 126.87, 126.77, 116.60, 108.98, 108.89, 43.01, 42.51, 21.18. HRMS (ESI) m/z: calcd for $C_{20}H_{18}N$ $[M+H]^+$ 272.1434, found: 272.1448.

3-(3-azidobicyclo[1.1.1]pentan-1-yl)-1-(prop-2-yn-1-yl)quinoxalin-2(1*H*)-one (3j)



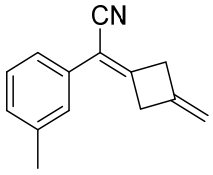
Eluent in chromatography: petroleum ether, **3j** was isolated as a pale yellow solid (39 mg, 50%); M.p.: 61-62 °C; ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.40 – 7.35 (m, 1H), 7.25 – 7.21 (m, 1H), 7.14 – 7.09 (m, 1H), 7.05 – 7.00 (m, 1H), 5.13 – 5.07 (m, 2H), 3.82 – 3.74 (m, 4H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 162.91 (d, *J* = 247.0 Hz), 158.82, 139.28, 134.48 (d, *J* = 8.0 Hz), 130.53 (d, *J* = 8.3 Hz), 122.20 (d, *J* = 2.8 Hz), 116.08, 115.32 (d, *J* = 21.4 Hz), 113.34 (d, *J* = 23.4 Hz), 109.21, 108.34 (d, *J* = 3.1 Hz), 43.03, 42.46. ^{19}F NMR (565 MHz, Chloroform-*d*) δ -111.68. HRMS (ESI) m/z: calcd for $C_{13}H_{11}NF$ $[M+H]^+$ 200.0870, found: 200.0865.

3-(3-azidobicyclo[1.1.1]pentan-1-yl)-1-(2-oxo-2-phenylethyl)quinoxalin-2(1*H*)-one (3k)



Eluent in chromatography: petroleum ether, **3k** was isolated as a pale yellow solid (57 mg, 66%); M.p.: 58-59 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.48 – 7.28 (m, 4H), 5.18 – 5.06 (m, 2H), 3.88 – 3.72 (m, 4H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 158.98, 139.18, 134.93, 134.08, 130.13, 128.39, 126.35, 124.54, 116.00, 109.19, 108.09, 43.02, 42.41. HRMS (ESI) m/z: calcd for $C_{13}H_{11}ClN$ $[M+H]^+$ 216.0575, found: 216.0576.

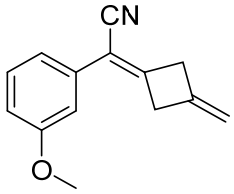
3-(3-azidobicyclo[1.1.1]pentan-1-yl)-6-bromo-1-methylquinoxalin-2(1*H*)-one (3l)



Eluent in chromatography: petroleum ether, **3l** was isolated as a pale yellow solid (52 mg, 67%); M.p.: 37-38 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.32 – 7.25 (m, 2H), 7.21 (d, *J* = 7.8 Hz, 1H), 7.14 (d, *J* = 7.8 Hz, 1H), 5.11 – 5.05 (m, 2H), 3.80 – 3.74 (m, 4H), 2.38 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-

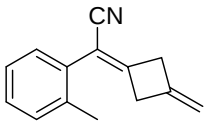
d) δ 156.81, 139.91, 138.65, 132.33, 129.05, 128.71, 127.10, 123.41, 116.63, 109.18, 108.79, 42.87, 42.39, 21.45. HRMS (ESI) m/z: calcd for $C_{14}H_{14}N$ $[M+H]^+$ 196.1121, found: 196.1123.

Ethyl 2-(3-(3-azidobicyclo[1.1.1]pentan-1-yl)-2-oxoquinoxalin-1(2*H*)-yl)acetate (3m)



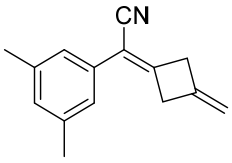
Eluent in chromatography: petroleum ether, **3m** was isolated as a yellow solid (29 mg, 47%); M.p.: 47-48 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.34 – 7.28 (m, 1H), 7.01 (d, *J* = 7.7 Hz, 1H), 6.97 – 6.93 (m, 1H), 6.87 (dd, *J* = 8.3, 2.5 Hz, 1H), 5.12 – 5.04 (m, 2H), 3.82 (s, 3H), 3.80 – 3.73 (m, 4H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.78, 157.54, 139.71, 133.61, 129.87, 118.76, 116.46, 113.74, 111.99, 108.98, 108.89, 55.26, 42.85, 42.41. HRMS (ESI) m/z: calcd for $C_{14}H_{14}NO$ $[M+H]^+$ 212.1070, found: 212.1068.

3-(3-azidobicyclo[1.1.1]pentan-1-yl)-1-methyl-2-oxo-1,2-dihydroquinoxaline-6-carbonitrile (3n)



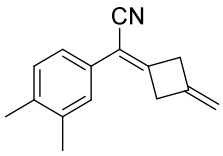
Eluent in chromatography: petroleum ether, **3n** was isolated as a yellow oil (33 mg, 57%); ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.30 – 7.12 (m, 4H), 5.11 – 5.00 (m, 2H), 3.79 – 3.70 (m, 2H), 3.42 – 3.33 (m, 2H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.85, 139.17, 136.37, 131.35, 130.74, 129.00, 128.87, 126.15, 116.51, 108.85, 108.31, 41.64, 40.89, 19.76. HRMS (ESI) m/z: calcd for $C_{14}H_{14}N$ $[M+H]^+$ 196.1121, found: 196.1122.

3-(3-azidobicyclo[1.1.1]pentan-1-yl)-6-chloro-1-methylquinoxalin-2(1*H*)-one (3o)



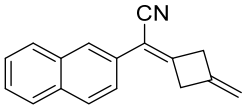
Eluent in chromatography: petroleum ether, **3o** was isolated as a yellow solid (34 mg, 54%); M.p.: 79-80 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.04 (s, 2H), 6.96 (s, 1H), 5.10 – 5.04 (m, 2H), 3.80 – 3.73 (m, 4H), 2.33 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.61, 140.01, 138.46, 132.22, 129.96, 124.14, 116.78, 109.13, 108.73, 42.83, 42.42, 21.34. HRMS (ESI) m/z: calcd for $C_{15}H_{16}N$ $[M+H]^+$ 210.1277, found: 210.1285.

3-(3-azidobicyclo[1.1.1]pentan-1-yl)-1-(4-methoxyphenyl)quinoxalin-2(1*H*)-one (3p)



Eluent in chromatography: petroleum ether, **3p** was isolated as a pale yellow solid (33 mg, 53%); M.p.: 49-50 °C; ^{1}H NMR (600 MHz, Chloroform-*d*) δ 7.21 (s, 1H), 7.17 – 7.12 (m, 2H), 5.11 – 5.04 (m, 2H), 3.80 – 3.72 (m, 4H), 2.28 (s, 3H), 2.27 (s, 3H). ^{13}C NMR (150 MHz, Chloroform-*d*) δ 155.63, 140.11, 137.18, 137.02, 130.03, 129.99, 127.57, 123.72, 116.74, 109.03, 108.68, 42.79, 42.31, 19.84, 19.51. HRMS (ESI) m/z: calcd for $C_{15}H_{16}N$ $[M+H]^+$ 210.1277, found: 210.1277.

Methyl 3-(3-azidobicyclo[1.1.1]pentan-1-yl)-1-methyl-2-oxo-1,2-dihydroquinoxaline-6-carboxylate (3q)



Eluent in chromatography: petroleum ether, **3q** was isolated as a pale yellow solid (38 mg, 41%); M.p.: 56-58 °C; ^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.93 (s, 1H), 7.89 – 7.80 (m, 3H), 7.56 – 7.47 (m, 3H), 5.15 – 5.08 (m, 2H), 3.90 – 3.80 (m, 4H). ^{13}C NMR (100 MHz, Chloroform-*d*) δ 157.32, 139.76, 133.12, 132.67, 129.84, 128.62, 128.25, 127.63, 126.82, 126.80, 126.08, 123.37, 116.64, 109.28, 108.95, 43.06, 42.51. HRMS (ESI) m/z: calcd for $C_{17}H_{14}N$ $[M+H]^+$ 232.1121, found: 232.1117.

8. References

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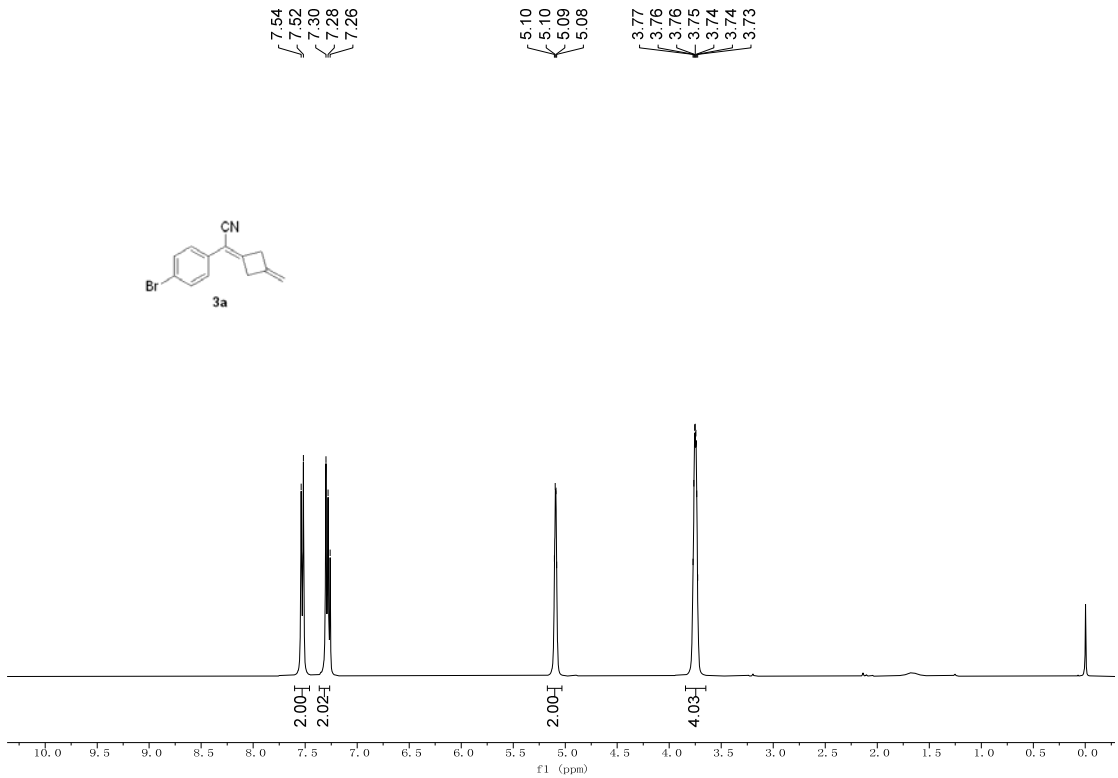
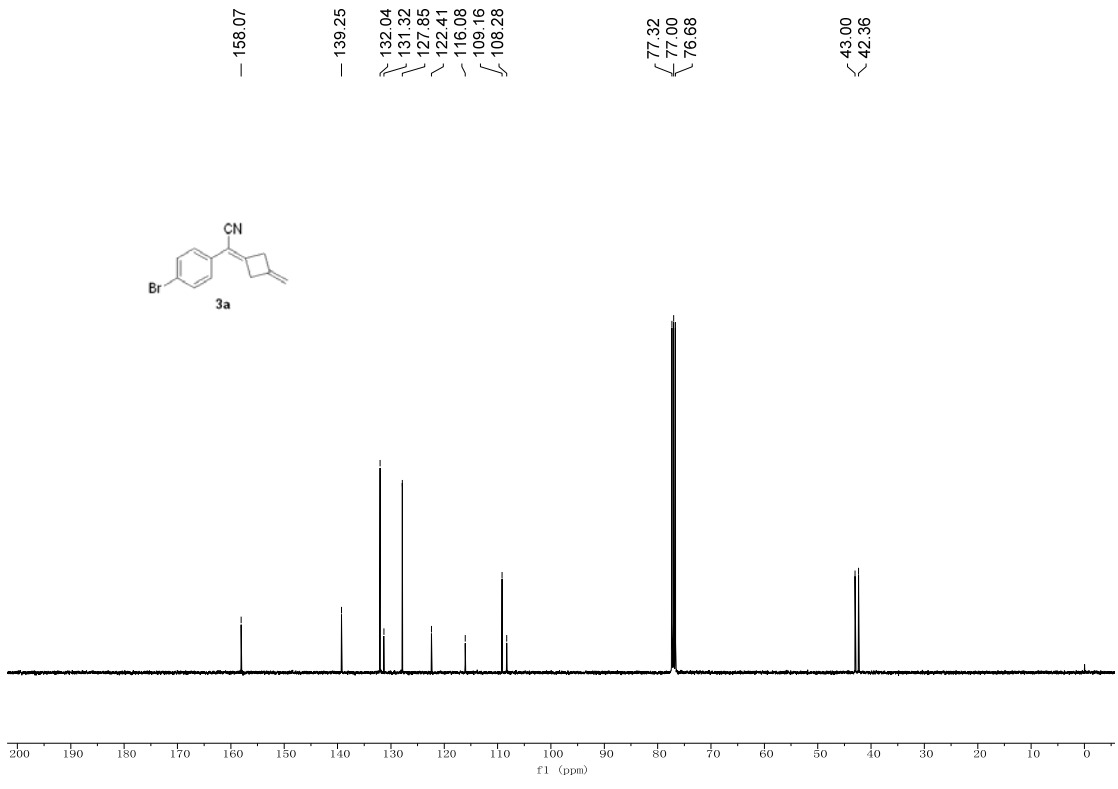
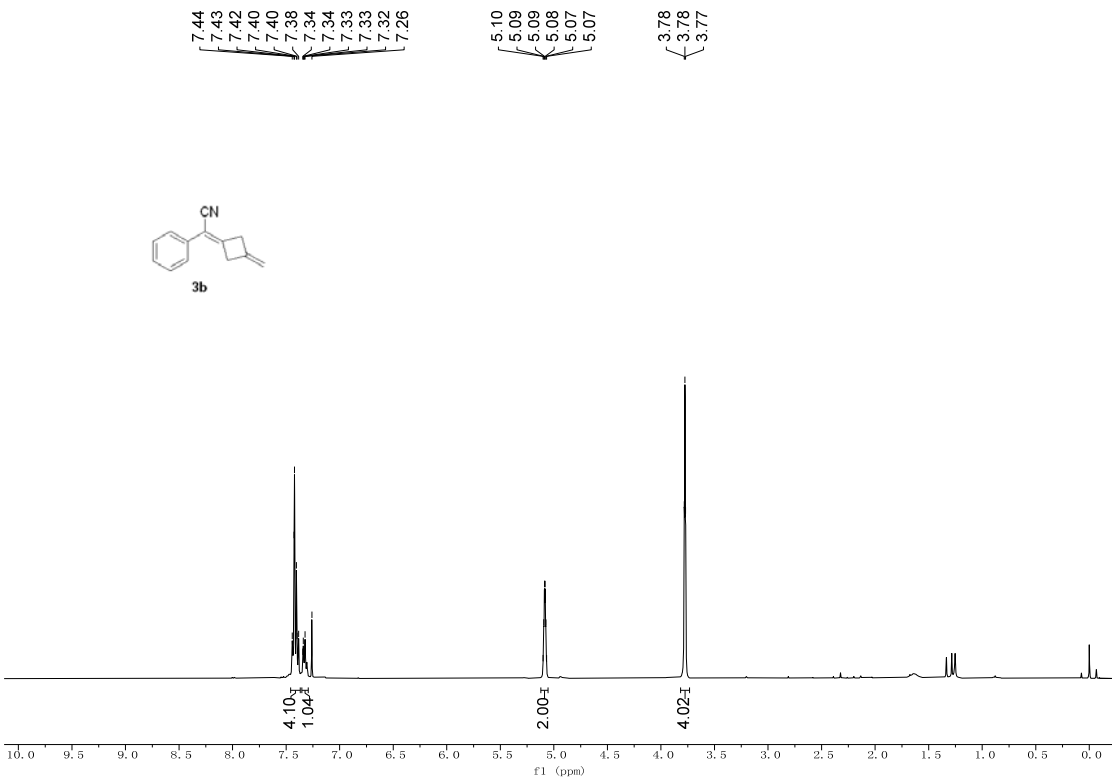
9. Copies of ^{1}H, ^{13}C NMR, and ^{19}F NMR spectra of compounds



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5.09
5.09
5.08
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3b
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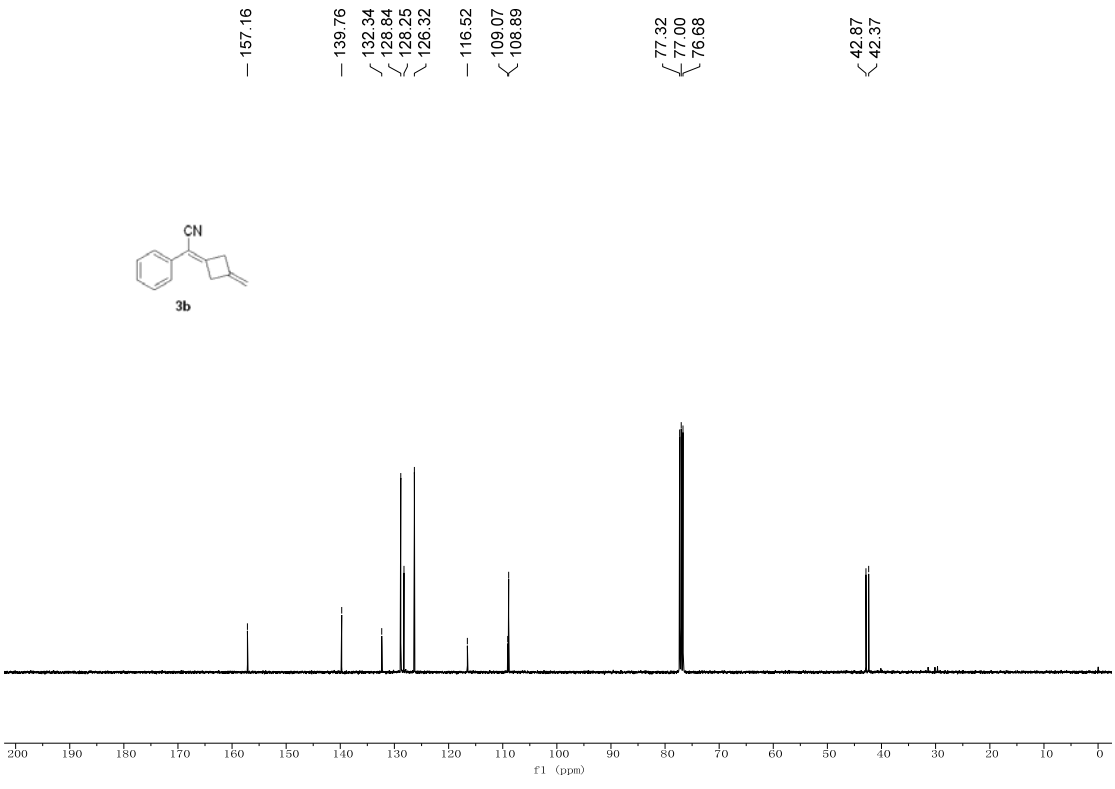
4.02
f1 (ppm)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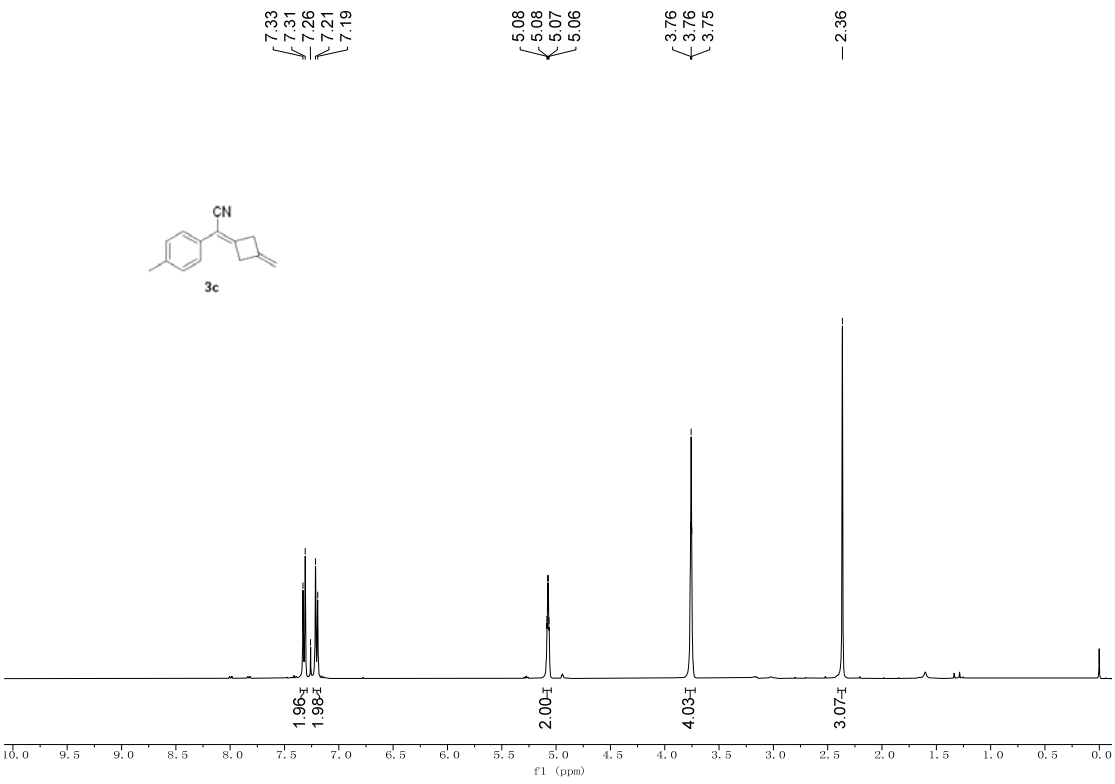
f1 (ppm)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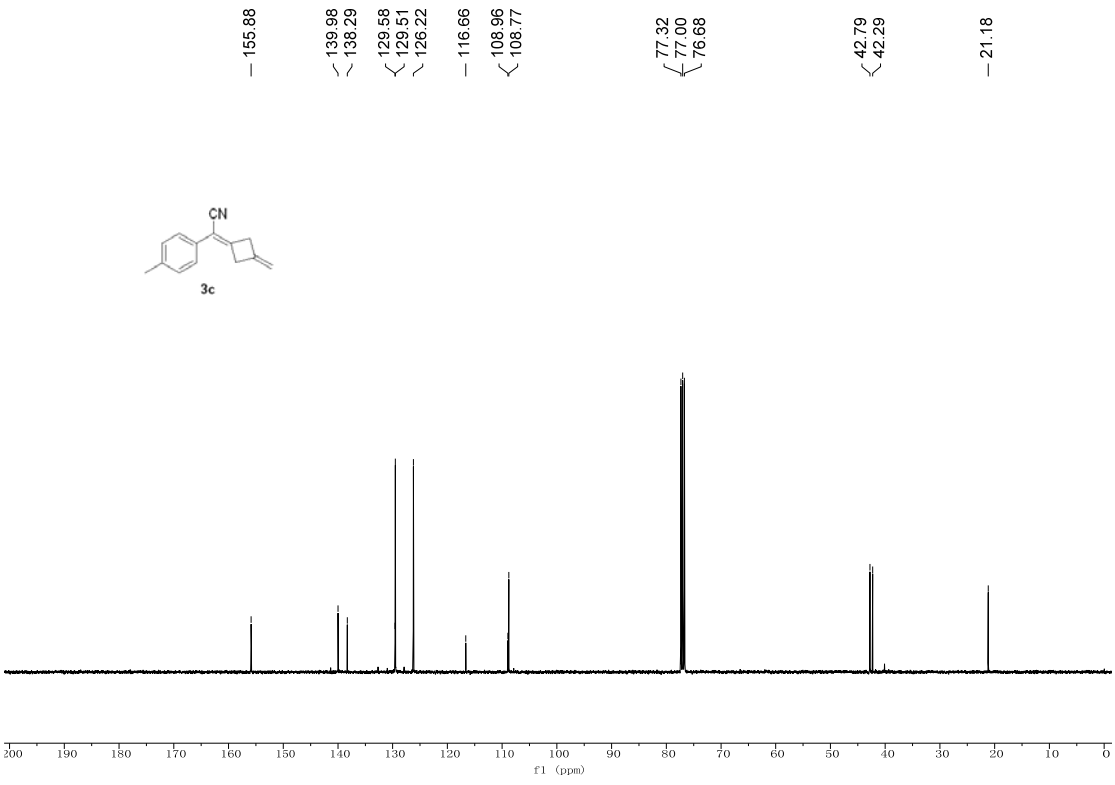
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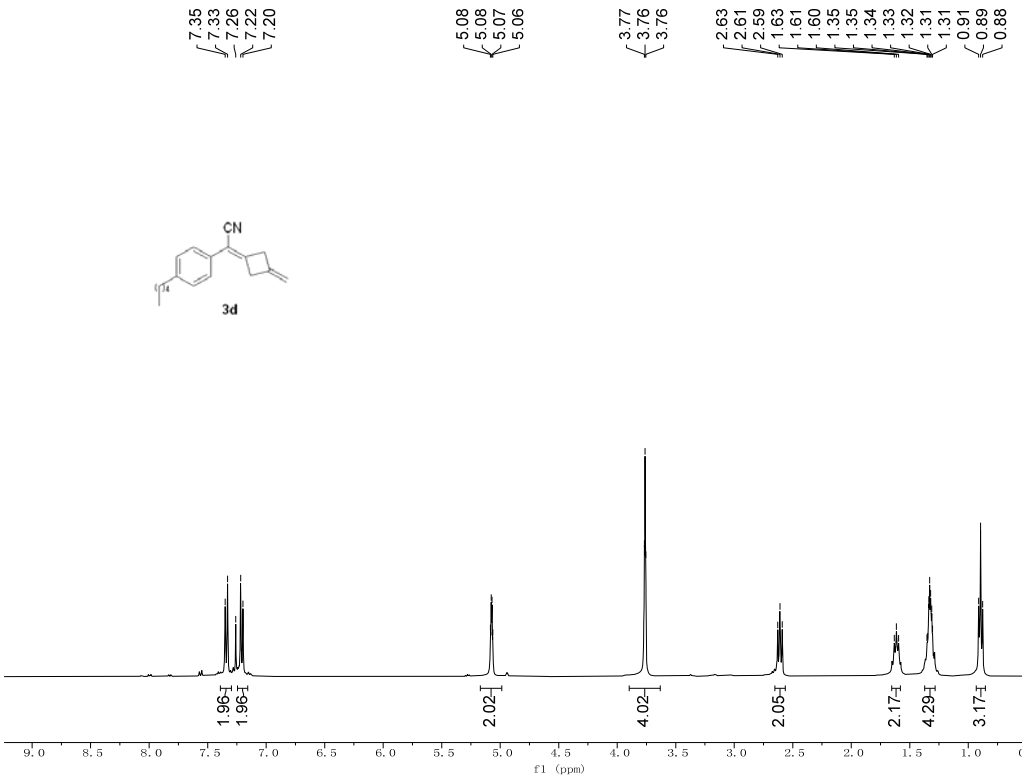
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3d
f1 (ppm)


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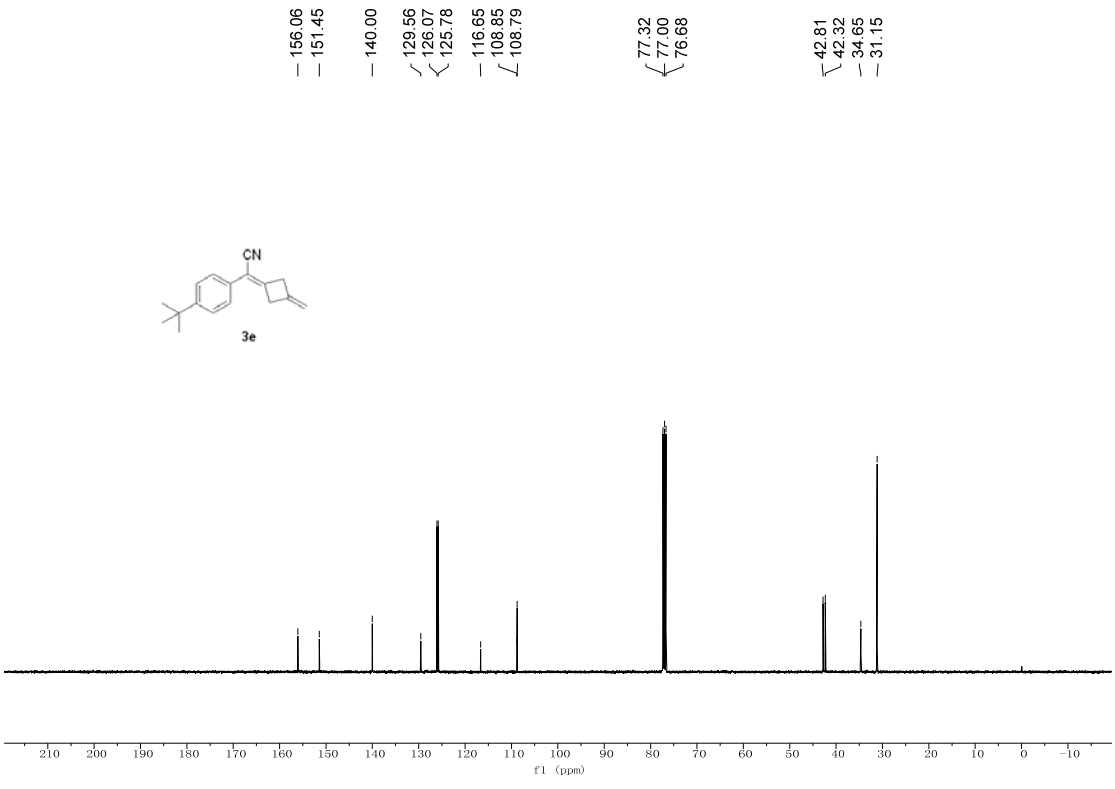
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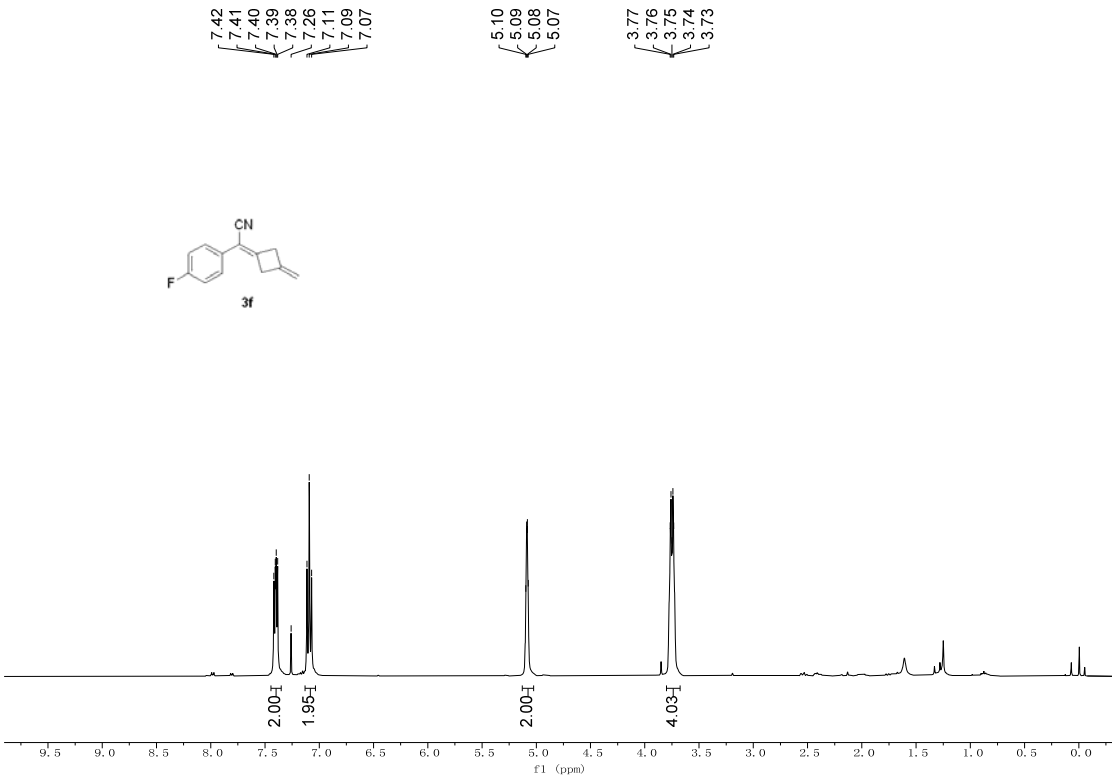
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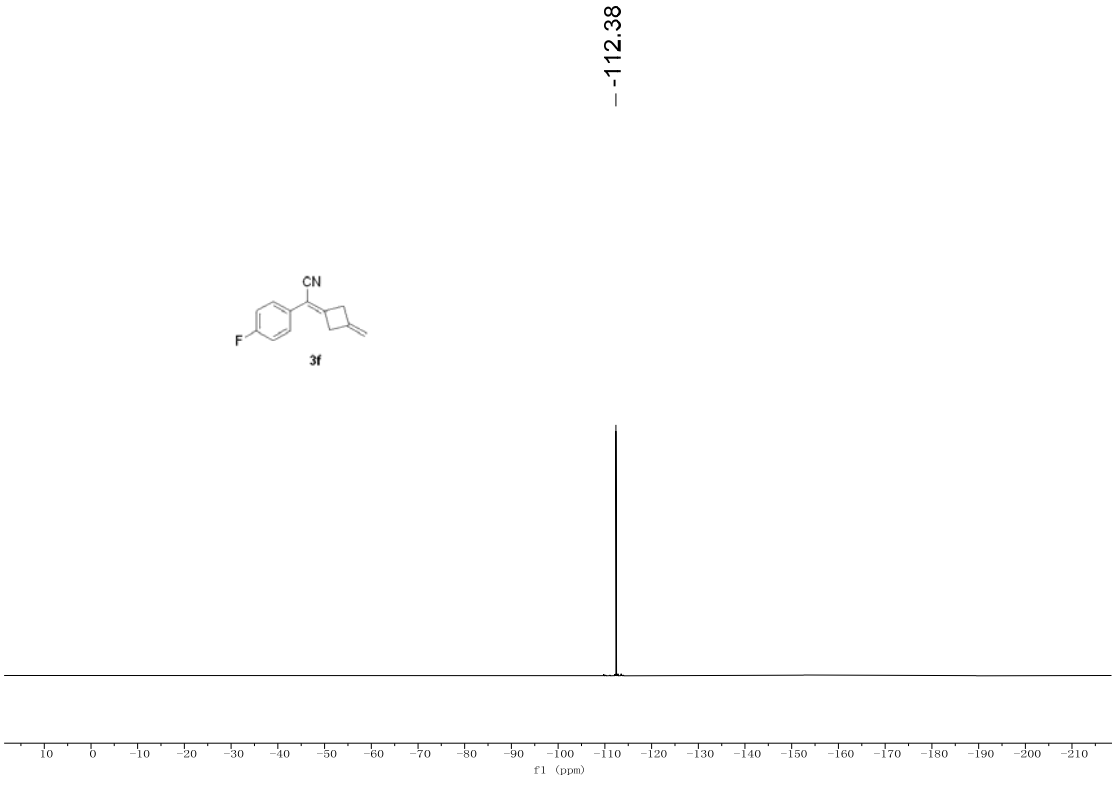
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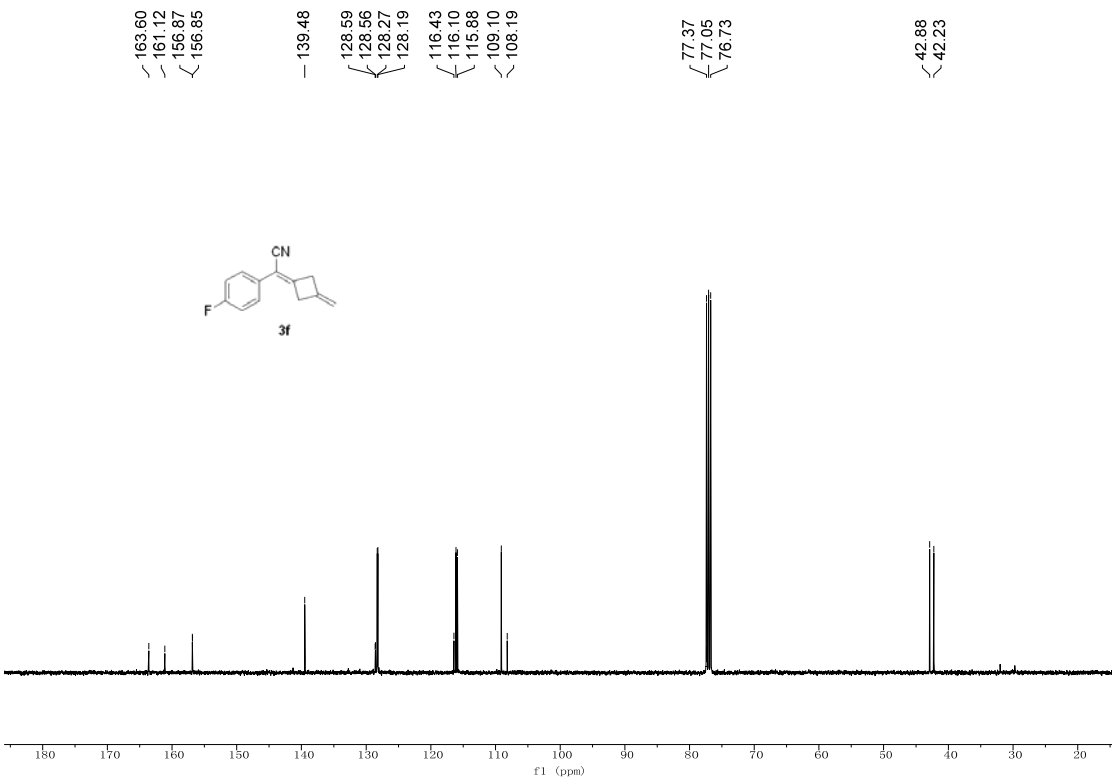
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F
3f
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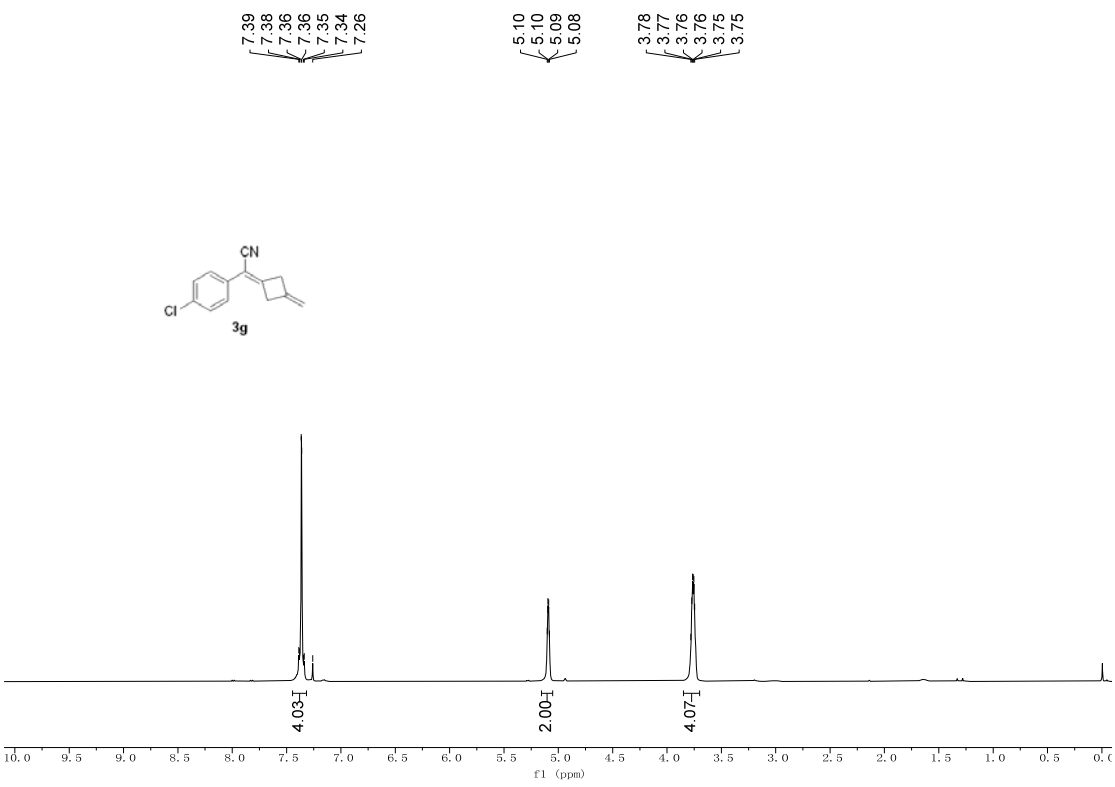
30
20
f1 (ppm)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7.38
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7.34
7.26
5.10
5.10
5.09
5.08
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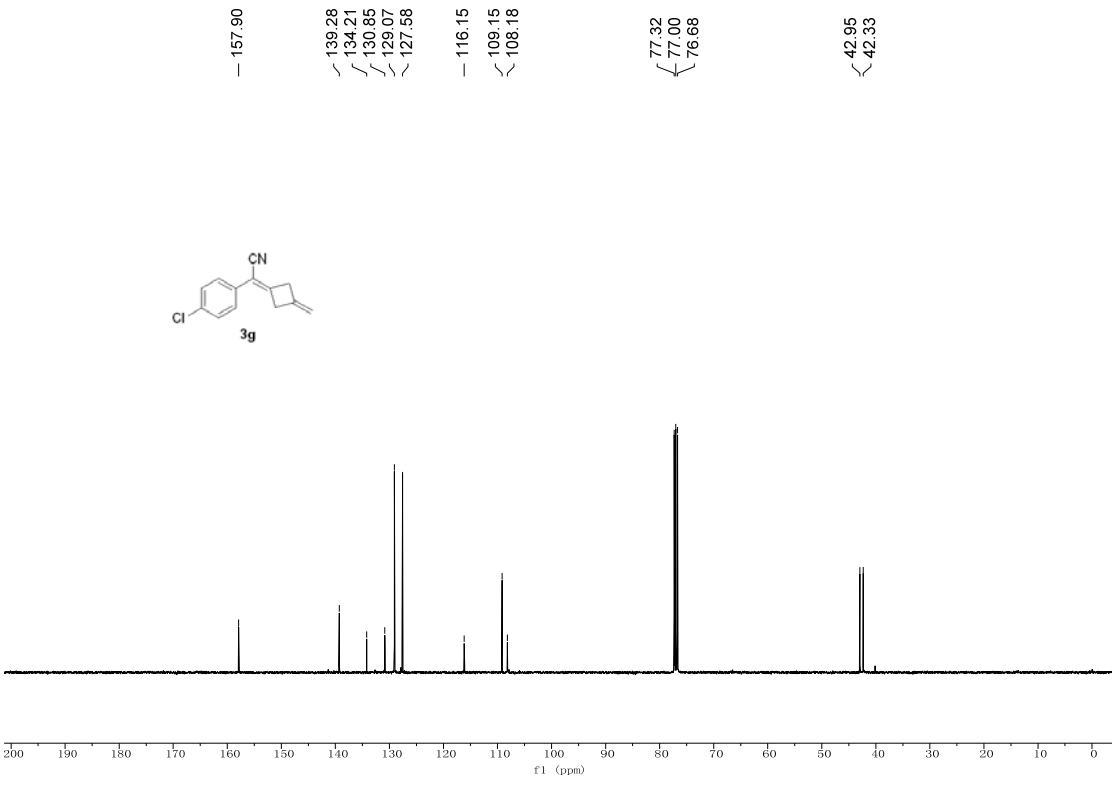
3.76
3.75
3.75
CN
Cl
3g
4.03
2.00
4.07
f1 (ppm)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129.07
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116.15
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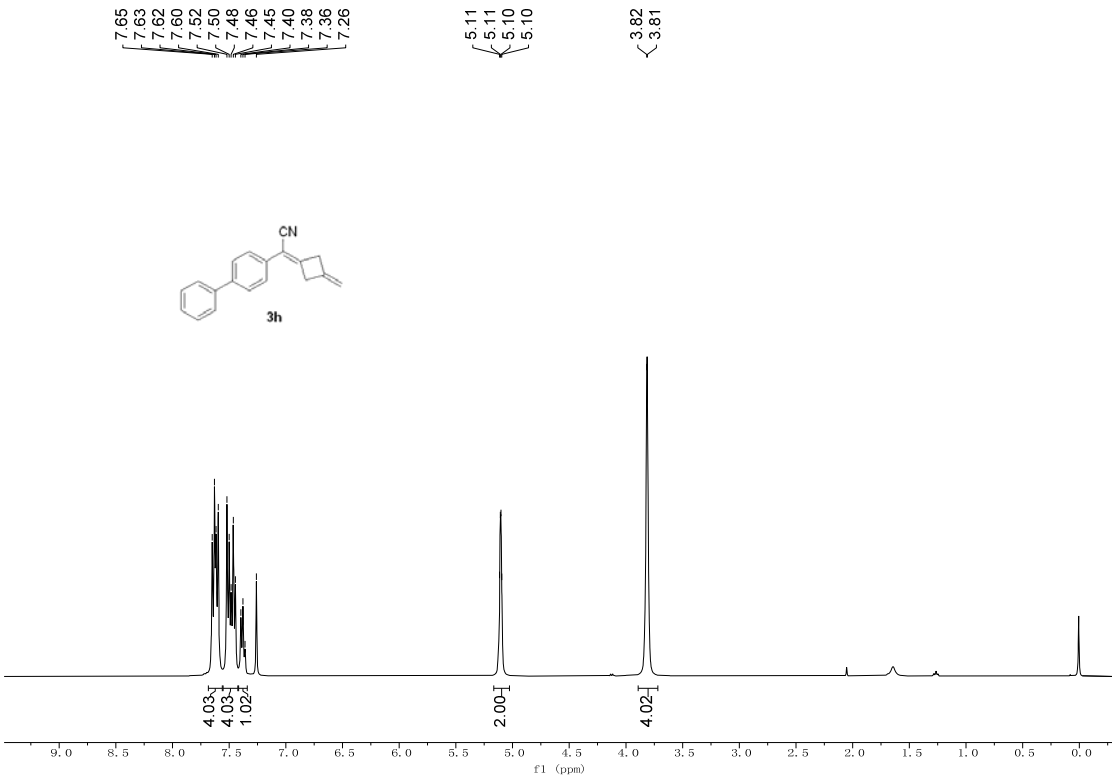
77.00
76.68
42.95
42.33
CN
Cl
3g
f1 (ppm)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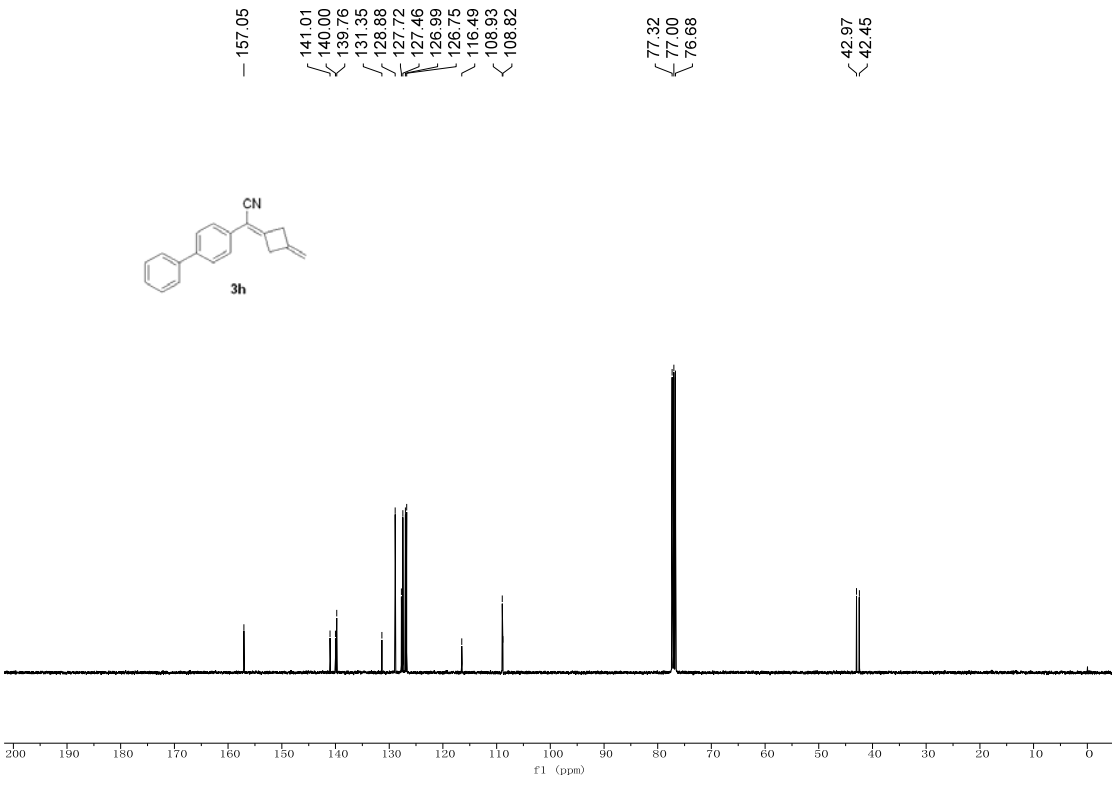
7.40
7.38
7.36
7.26
5.11
5.11
5.10
5.10
3.82
3.81
CN
3h
4.03
4.03
1.02
2.00
4.02
f1 (ppm)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108.82
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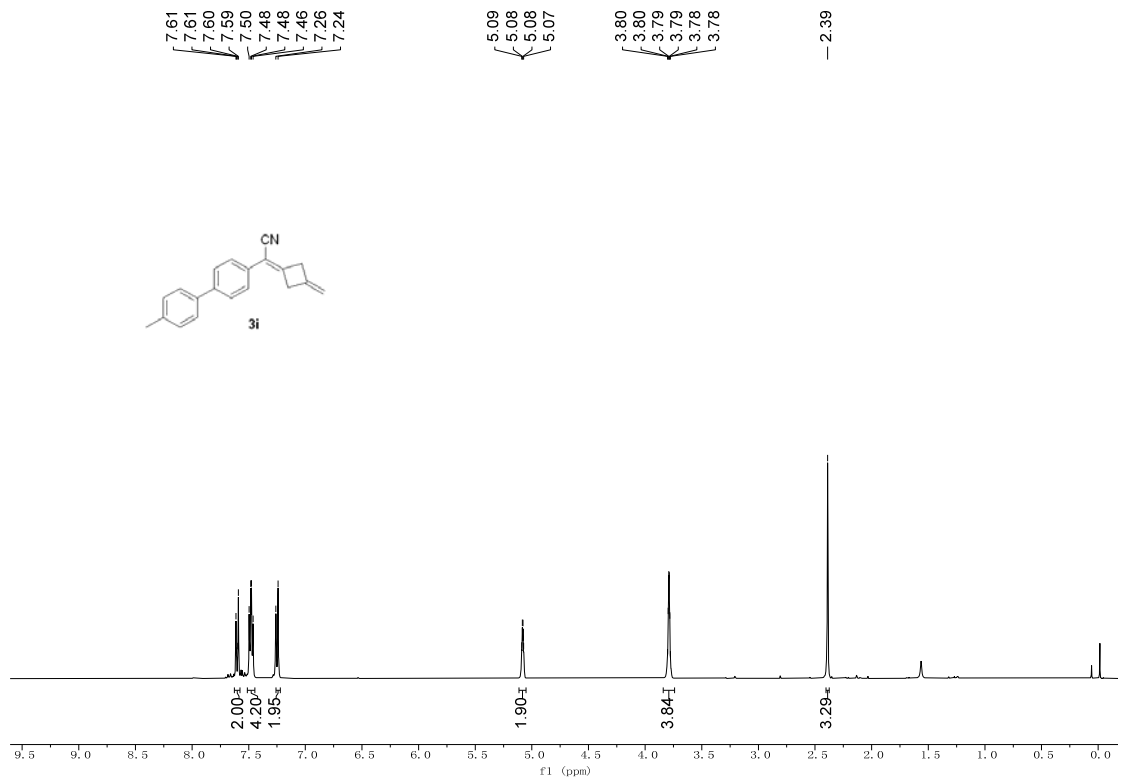
77.00
76.68
42.97
42.45
CN
3h
f1 (ppm)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7.24
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5.08
5.08
5.07
3.80
3.80
3.79
3.79
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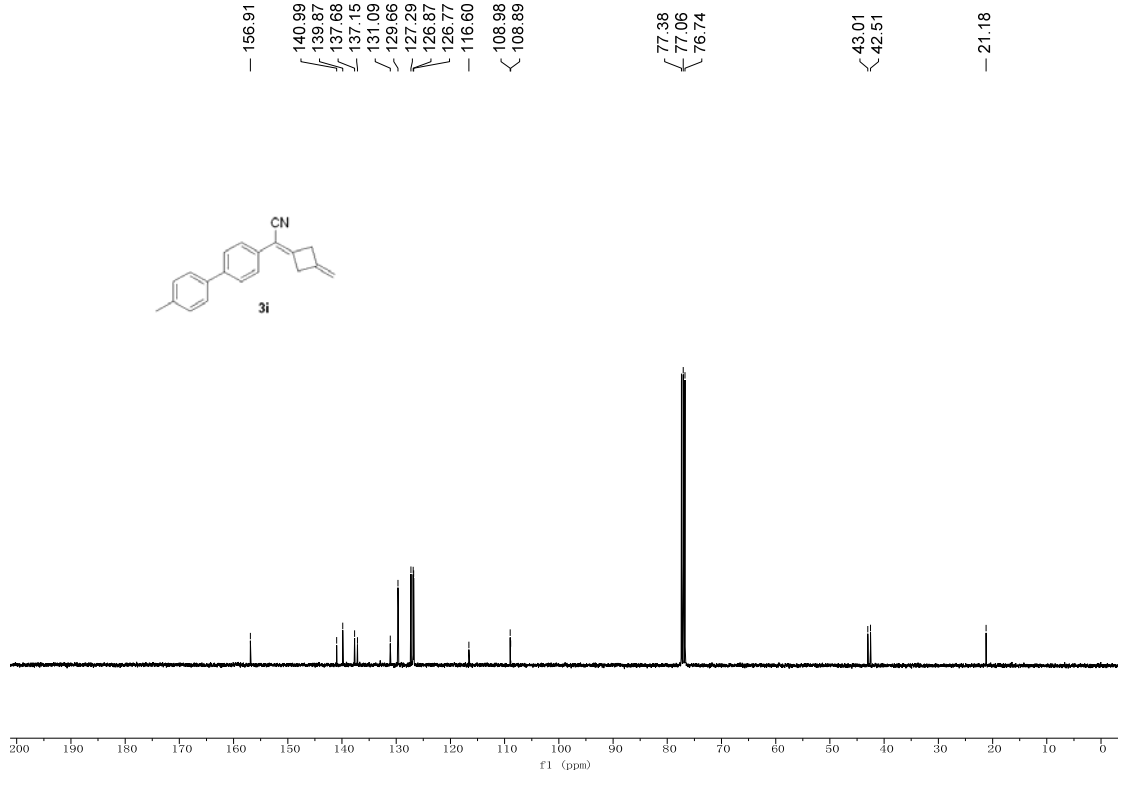
3.78
2.39
CN
3i
2.00
4.20
1.95
1.90
3.84
3.29
f1 (ppm)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126.77
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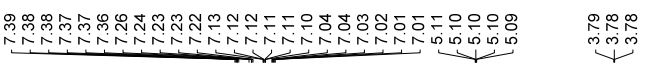
77.38
77.06
76.74
43.01
42.51
21.18
CN
3i
f1 (ppm)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7.11
7.11
7.10
7.04
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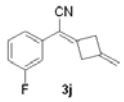
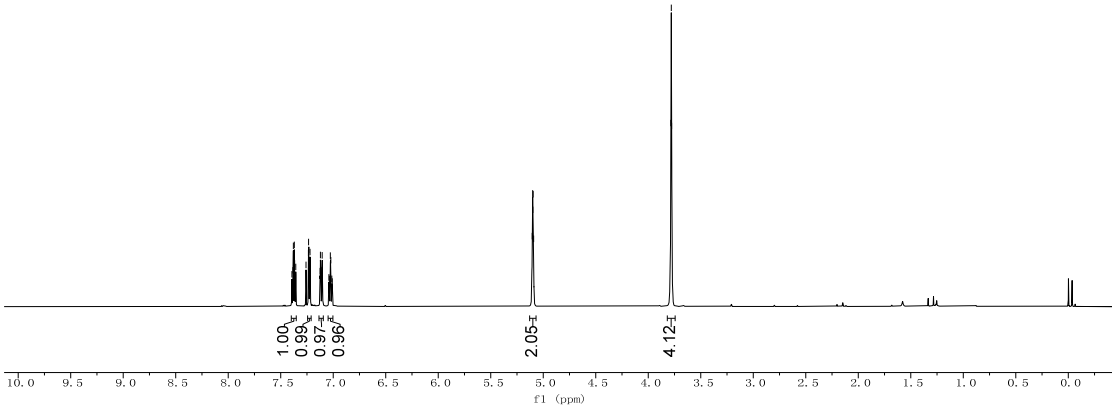
5.10
5.09
3.79
3.78
3.78


CN
F
3j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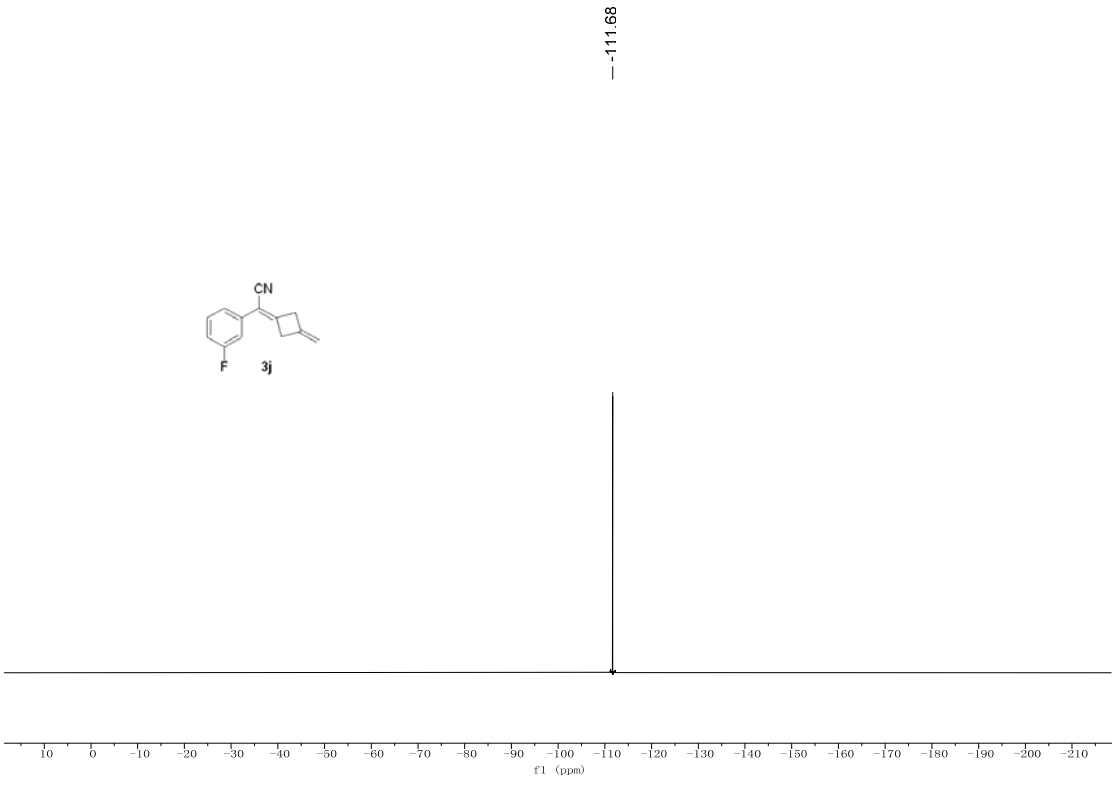
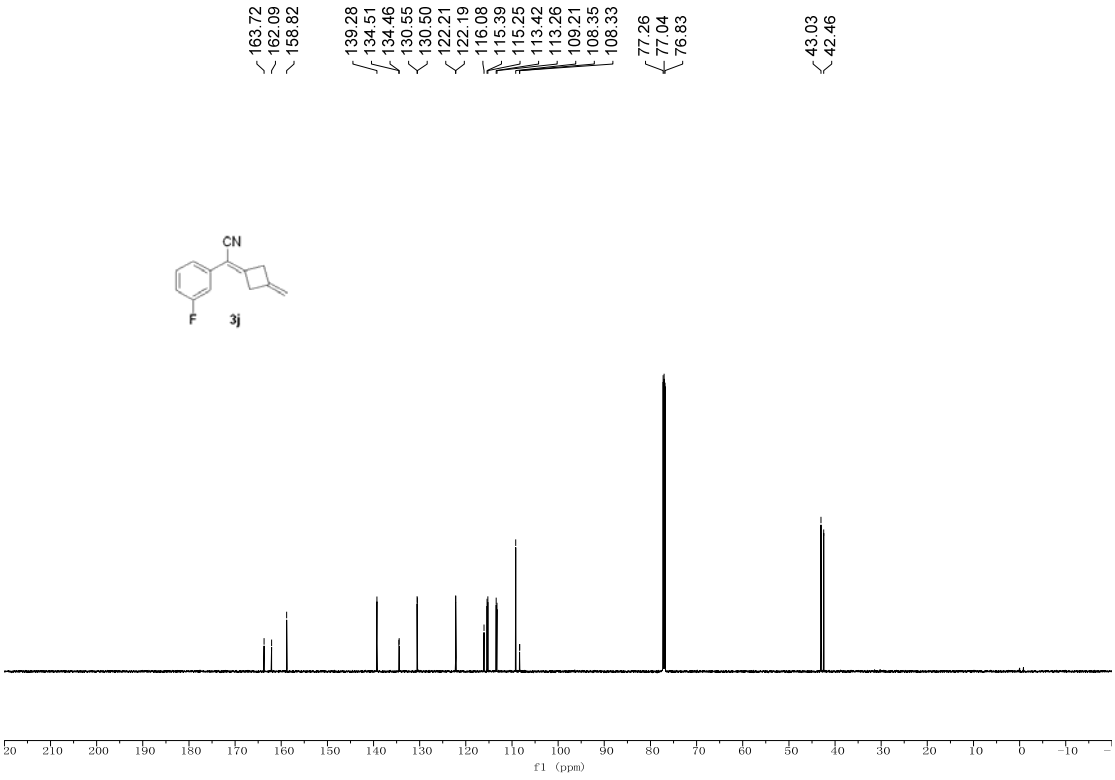
0.99
0.97
0.96
2.05
4.12
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


-111.68
CN
F
3j
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)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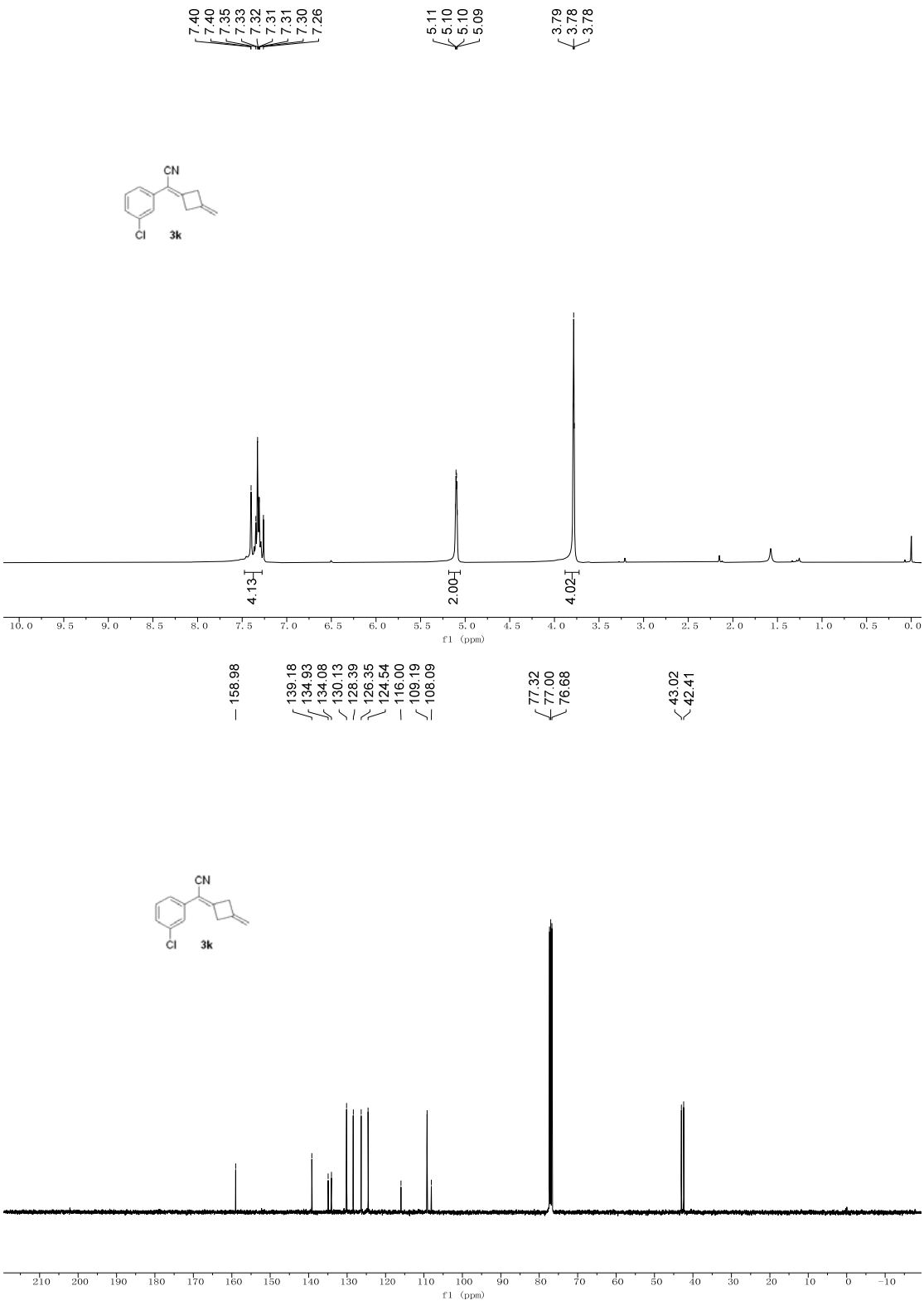
134.46
130.55
130.50
122.21
122.19
116.08
115.39
115.25
113.42
113.26
109.21
108.35
108.33
77.26
77.04
76.83
43.03
42.46
CN
F
3j
f1 (ppm)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7.31
7.31
7.30
7.26
5.11
5.10
5.10
5.09
3.79
3.78
3.78
CN
Cl
3k
4.13
2.00
4.02
f1 (ppm)
158.98
139.18
134.93
134.08
130.13
128.39
126.35
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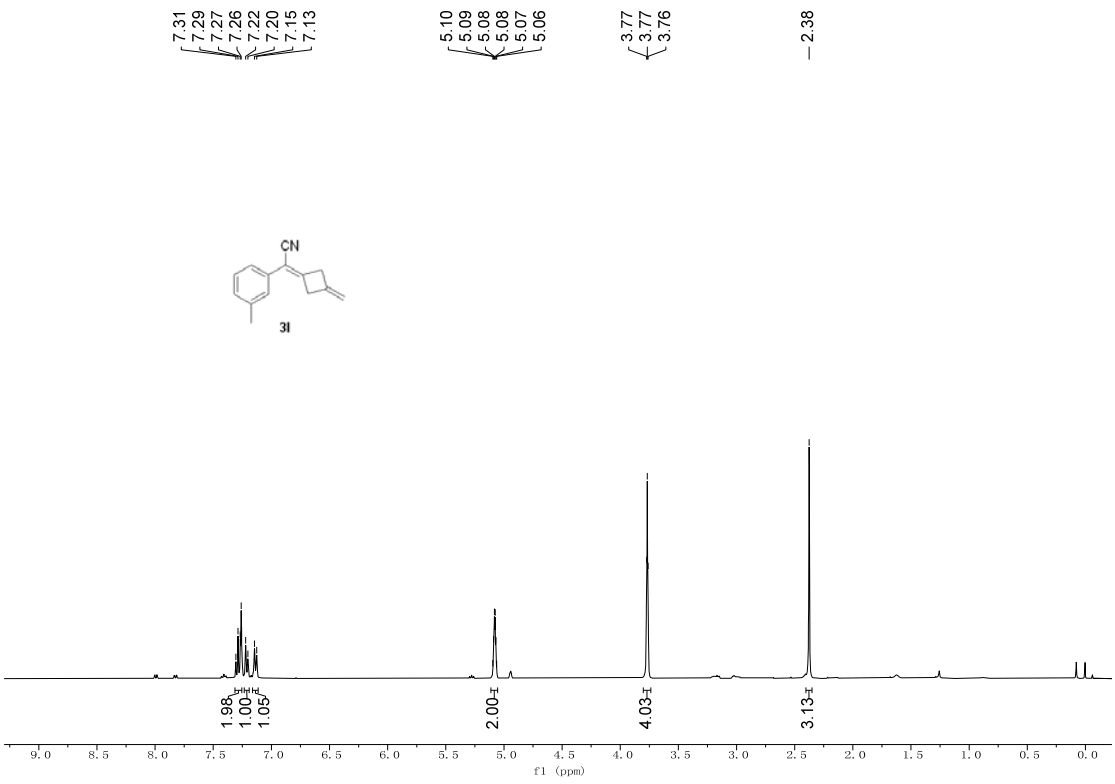
108.09
77.32
77.00
76.68
43.02
42.41
CN
Cl
3k
f1 (ppm)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5.08
5.08
5.07
5.06
3.77
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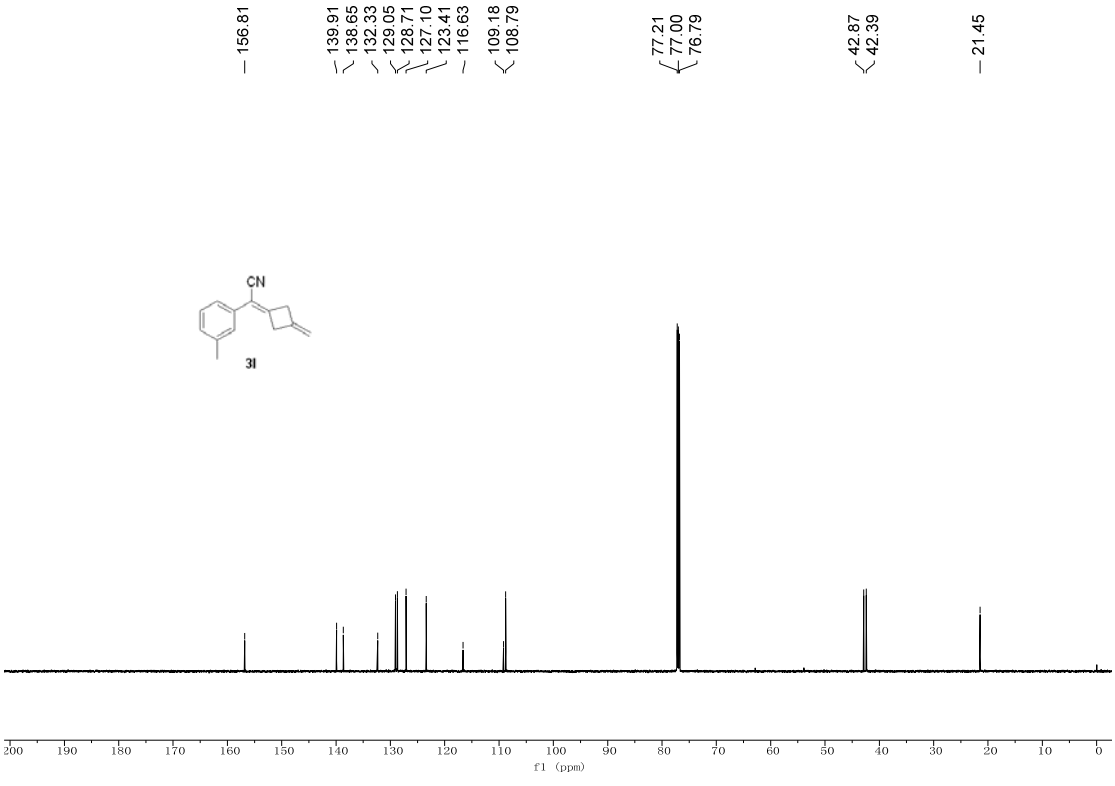
2.38
CN
3l
1.98
1.00
1.05
2.00
4.03
3.13
f1 (ppm)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123.41
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108.79
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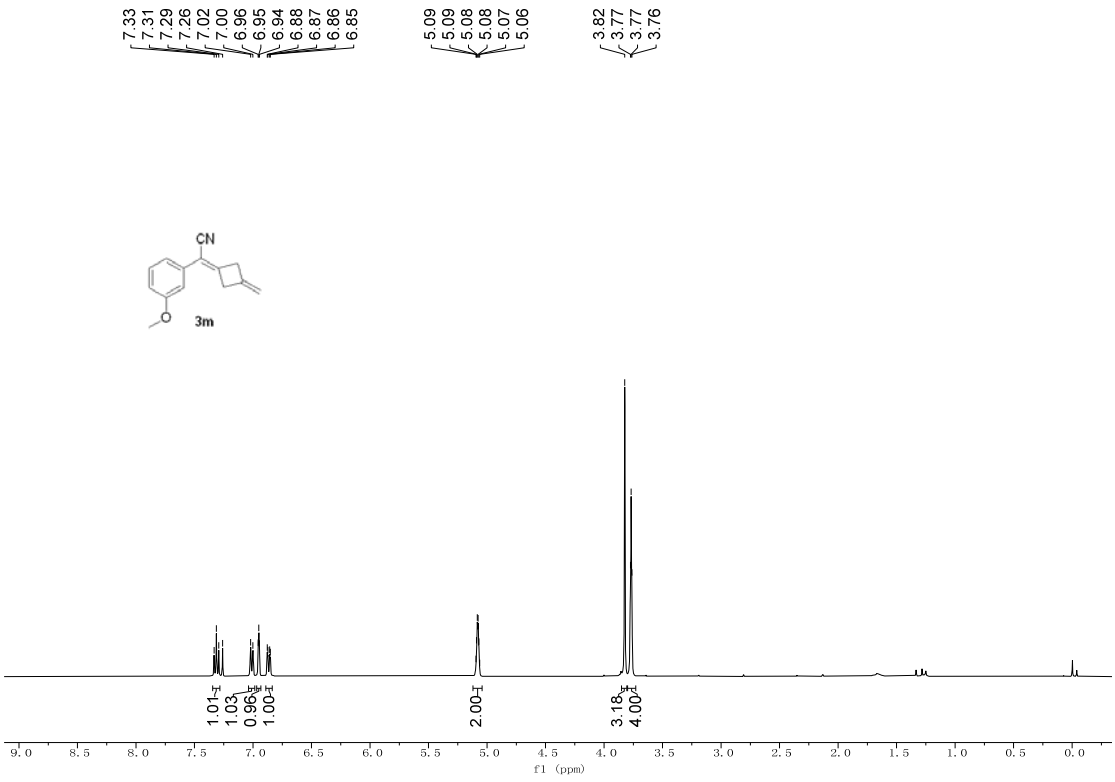
42.39
21.45
CN
3l
f1 (ppm)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6.95
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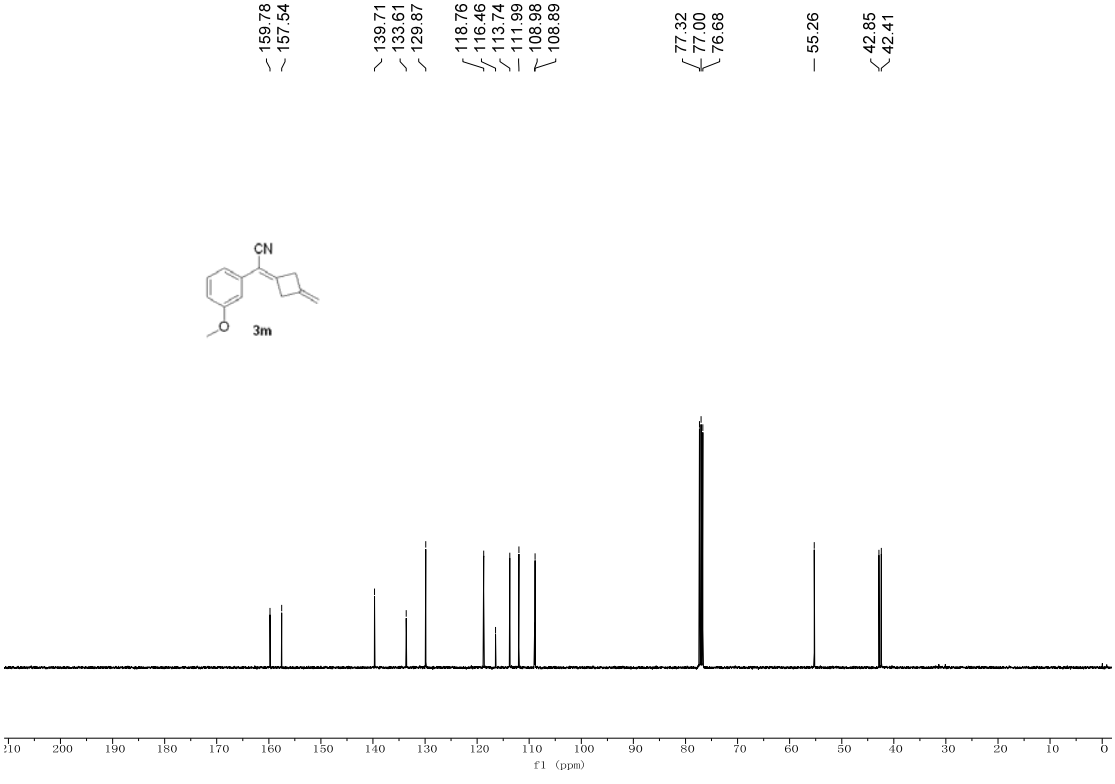
6.88
6.87
6.86
6.85
5.09
5.09
5.08
5.08
5.07
5.06
3.82
3.77
3.77
3.76
CN
O
3m
1.01
1.03
0.96
1.00
2.00
3.18
4.00
f1 (ppm)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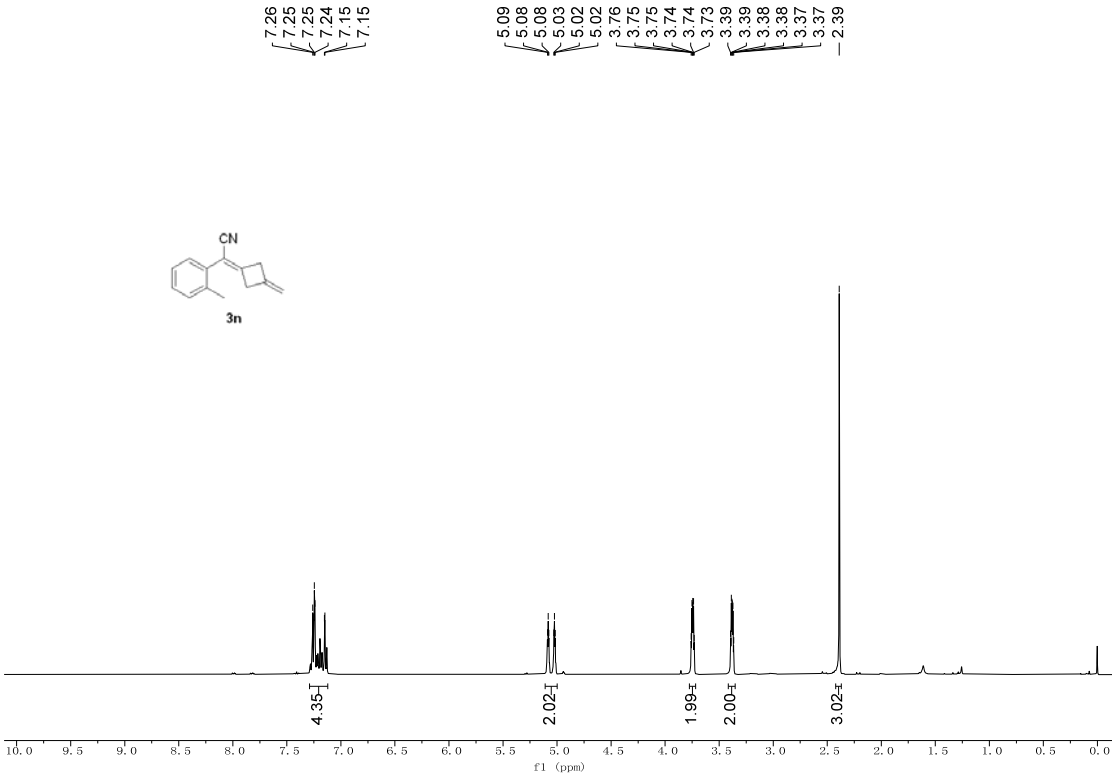
77.32
77.00
76.68
55.26
42.85
42.41
CN
O
3m
f1 (ppm)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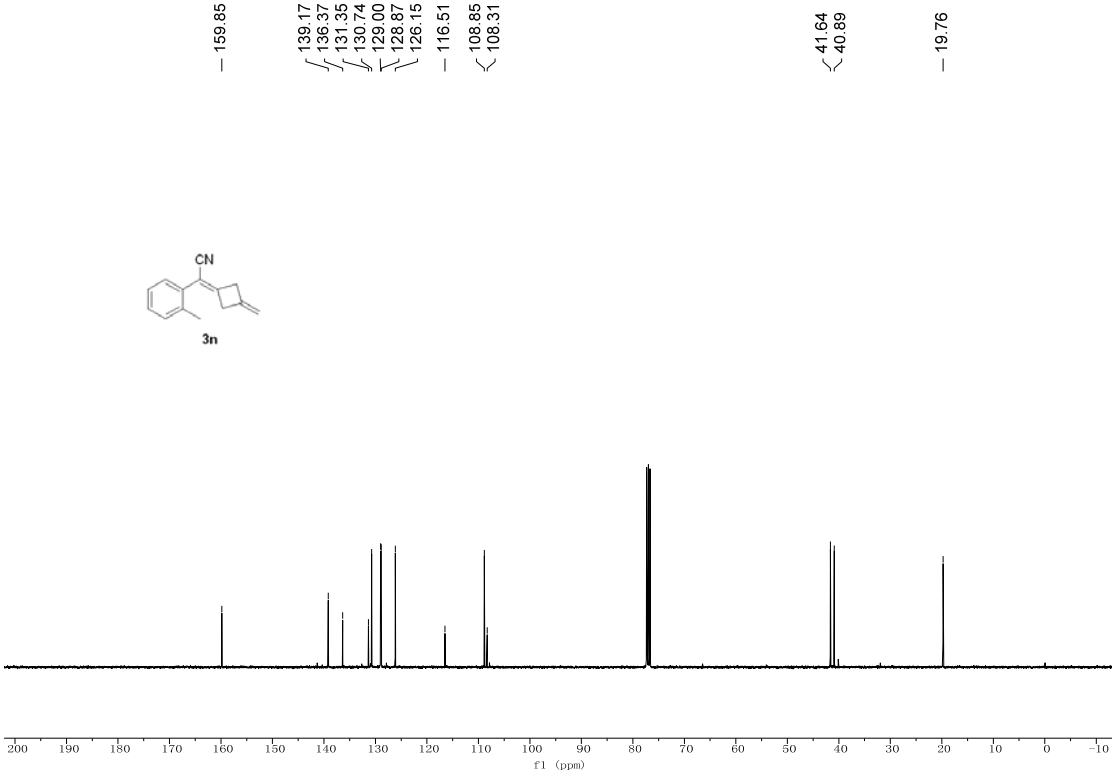
5.03
5.02
5.02
3.76
3.75
3.75
3.74
3.74
3.73
3.39
3.39
3.38
3.38
3.37
3.37
2.39
CN
3n
4.35
2.02
1.99
2.00
3.02
f1 (ppm)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108.31
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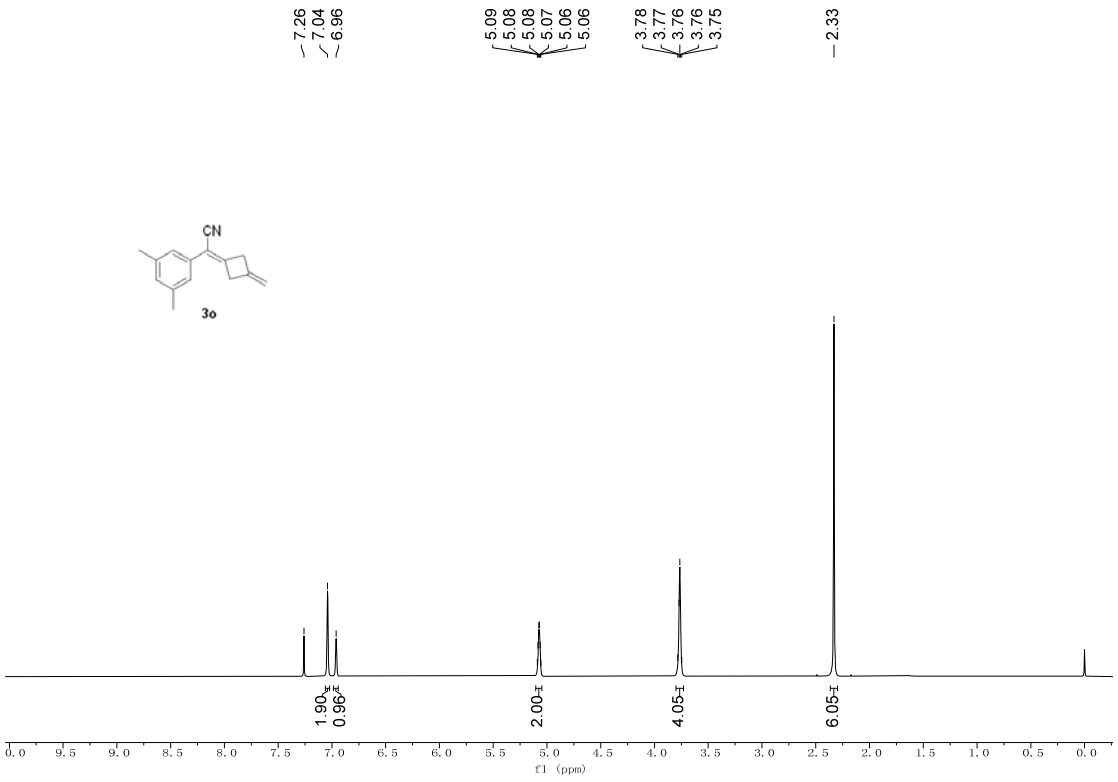
40.89
19.76
CN
3n
f1 (ppm)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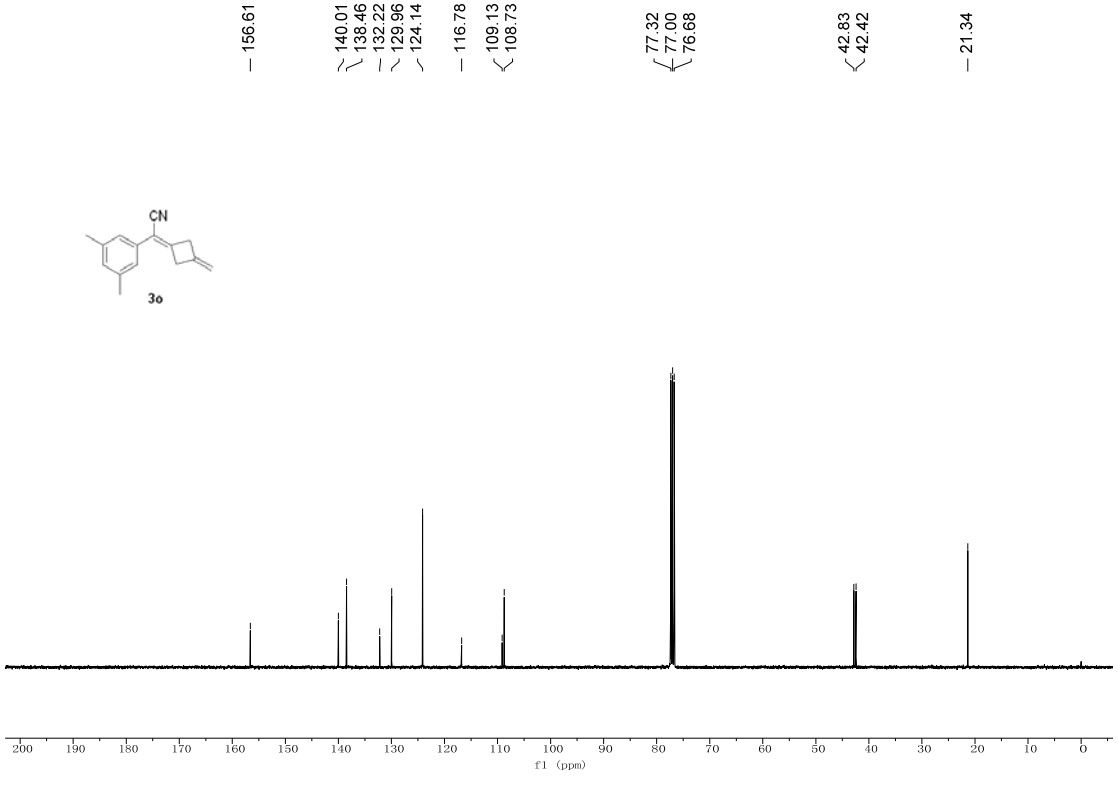
5.08
5.07
5.06
5.06
3.78
3.77
3.76
3.76
3.75
2.33
CN
3o
1.90
0.96
2.00
4.05
6.05
f1 (ppm)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124.14
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77.32
77.00
76.68
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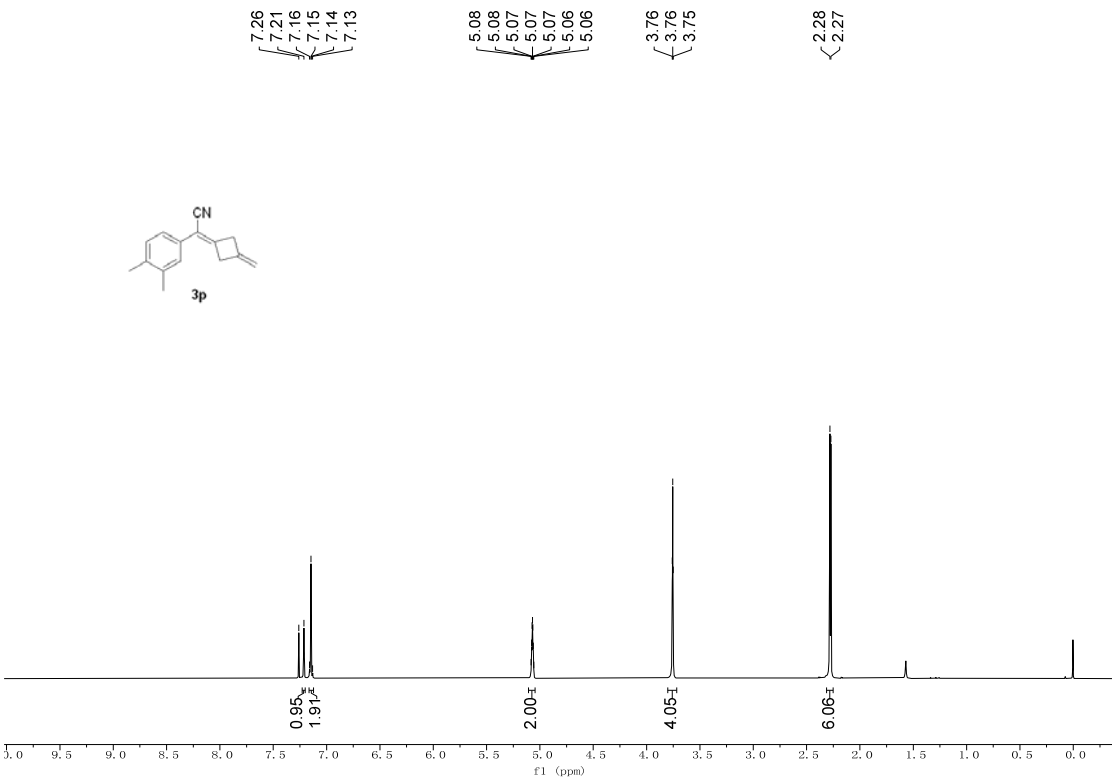
42.42
21.34
CN
3o
f1 (ppm)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5.08
5.07
5.07
5.07
5.06
5.06
3.76
3.76
3.75
2.28
2.27
CN
3p
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2.00
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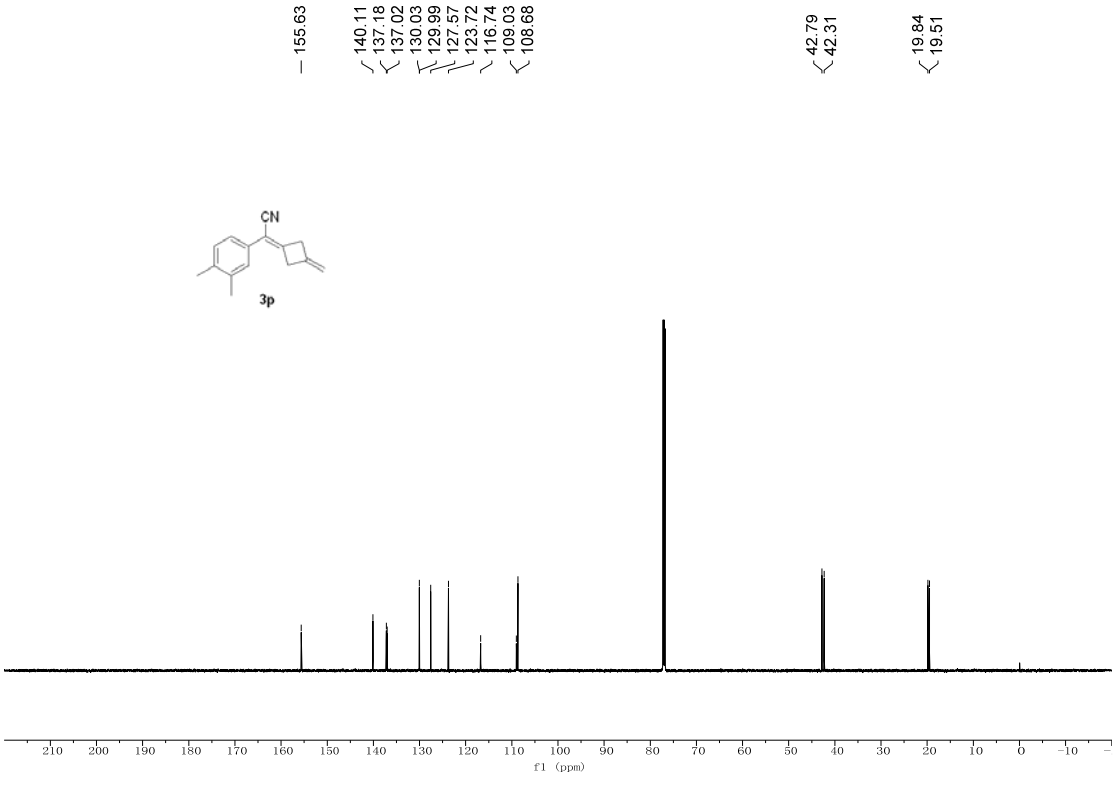
6.06
f1 (ppm)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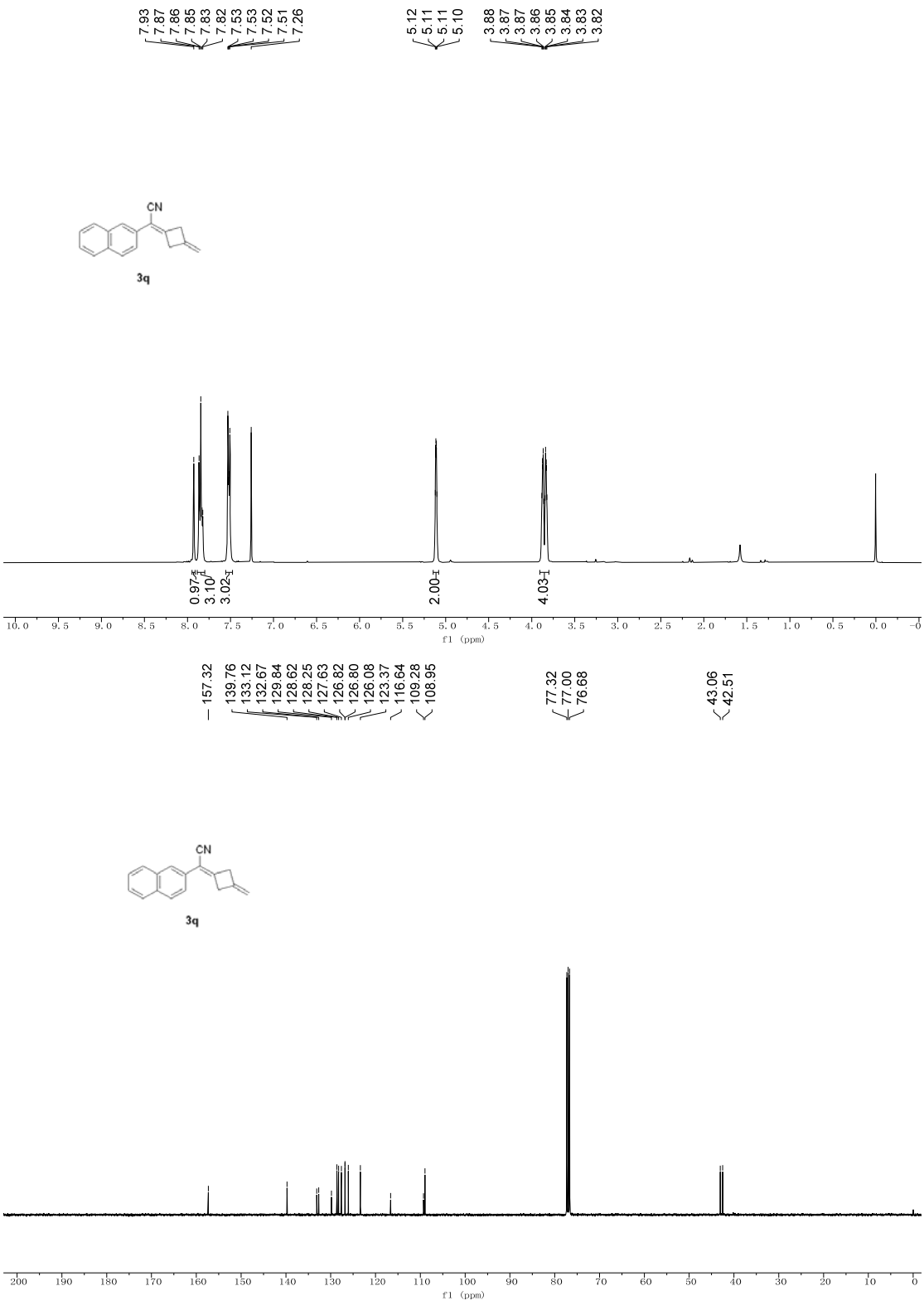
19.84
19.51
CN
3p
f1 (ppm)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5.11
5.11
5.10
3.88
3.87
3.87
3.86
3.85
3.84
3.83
3.82
CN
3q
0.97
3.10
3.02
2.00
4.03
f1 (ppm)
157.32
139.76
133.12
132.67
129.84
128.62
128.25
127.63
126.82
126.80
126.08
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43.06
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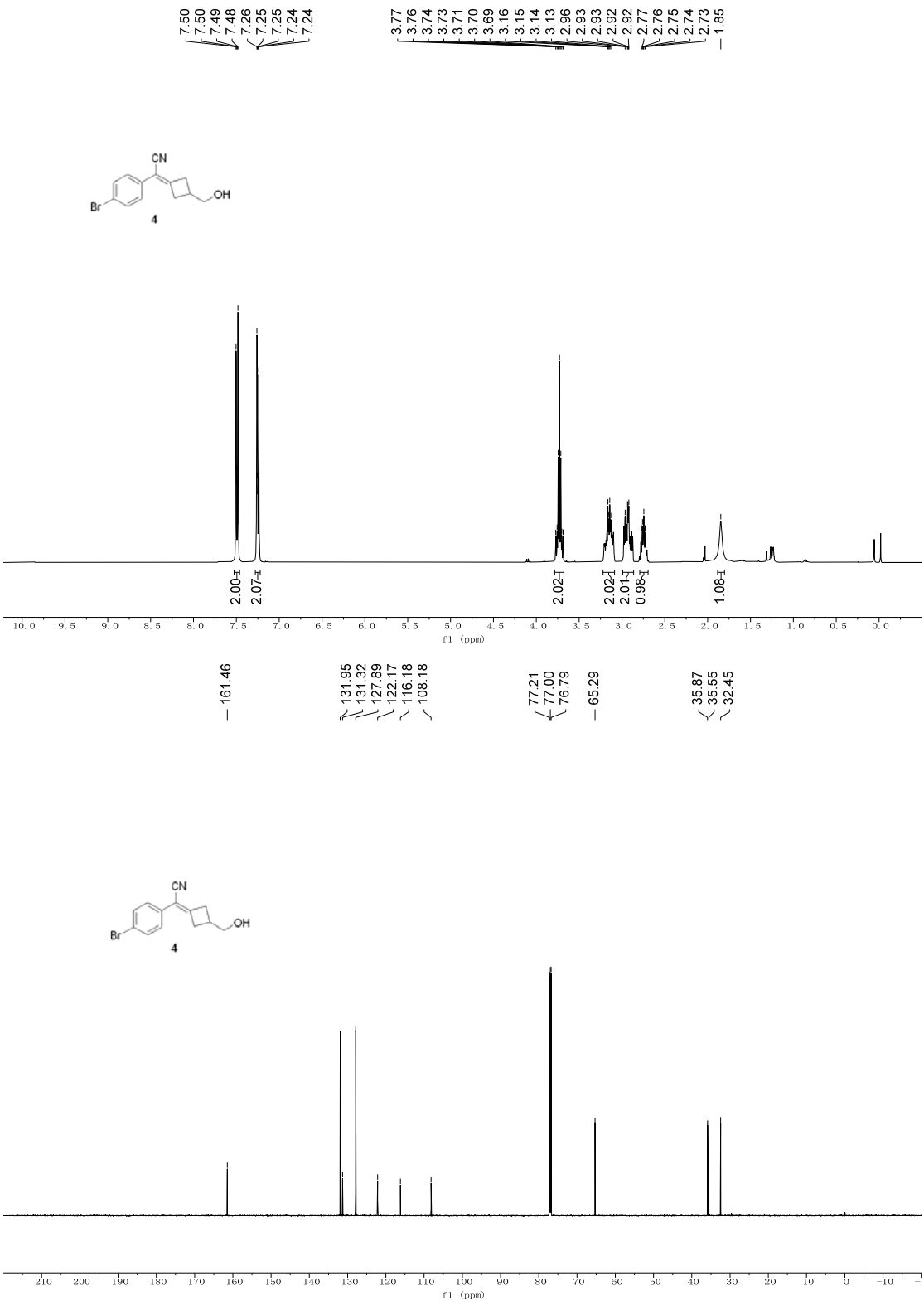
3q
f1 (ppm)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7.24
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3.71
3.70
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3.16
3.15
3.14
3.13
2.96
2.93
2.93
2.92
2.92
2.77
2.76
2.75
2.74
2.73
1.85
CN
OH
Br
4
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2.07
2.02
2.02
2.01
0.98
1.08
f1 (ppm)
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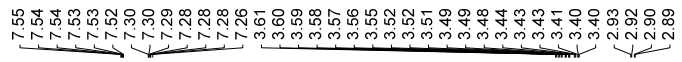
32.45
CN
OH
Br
4
f1 (ppm)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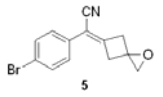
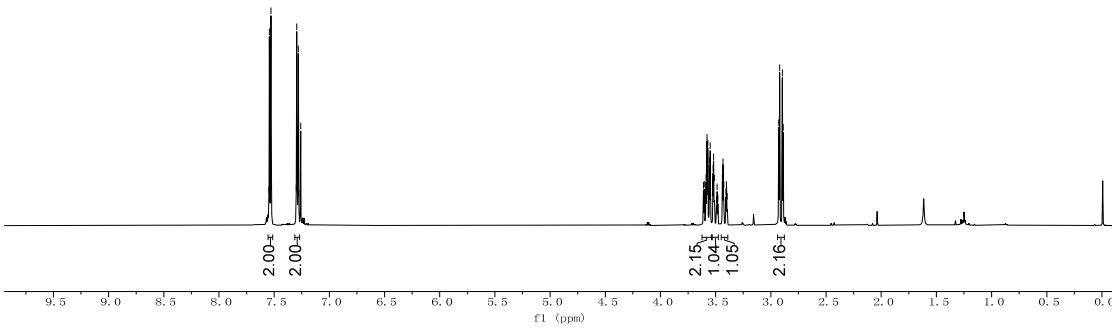

CN
Br
O

5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2.00
2.15
1.04
1.05
2.16
f1 (ppm)


152.64
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115.97
109.25
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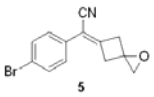
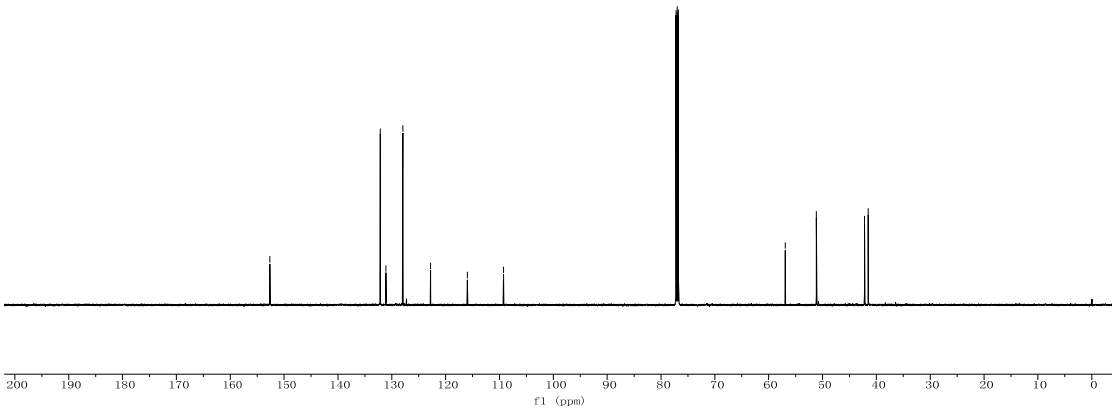
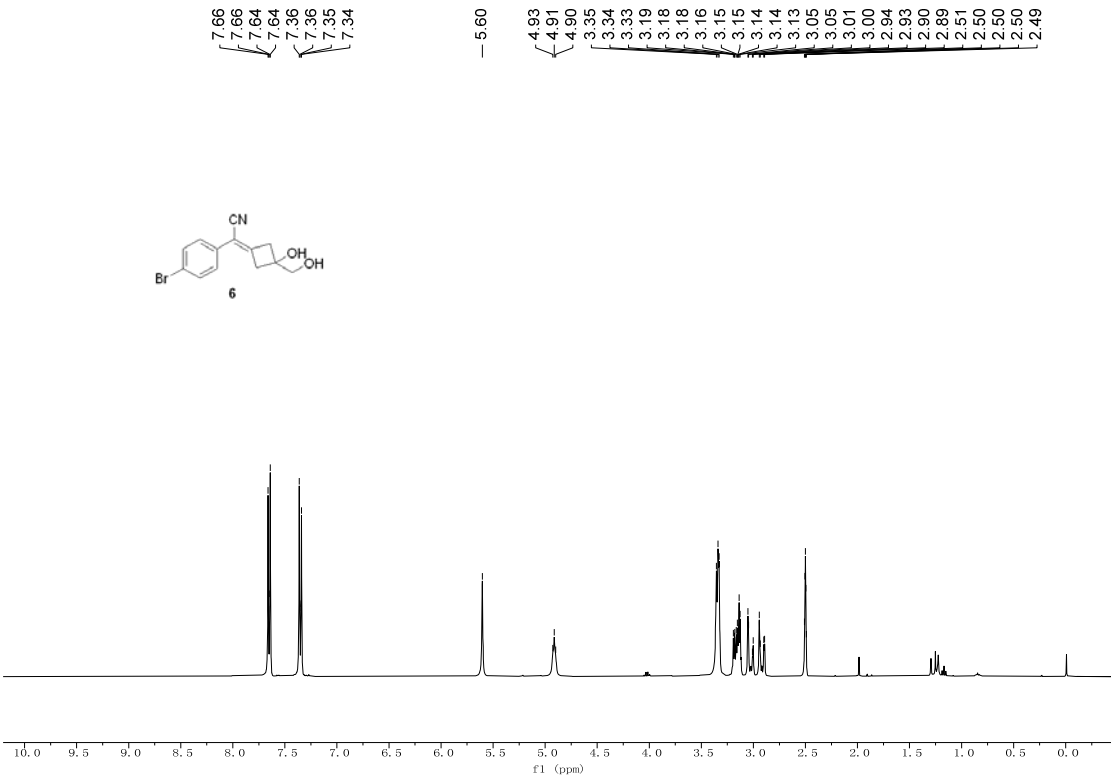
77.00
76.79
56.92
51.15
42.20
41.51


CN
Br
O

5


f1 (ppm)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3.01
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2.93
2.90
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2.51
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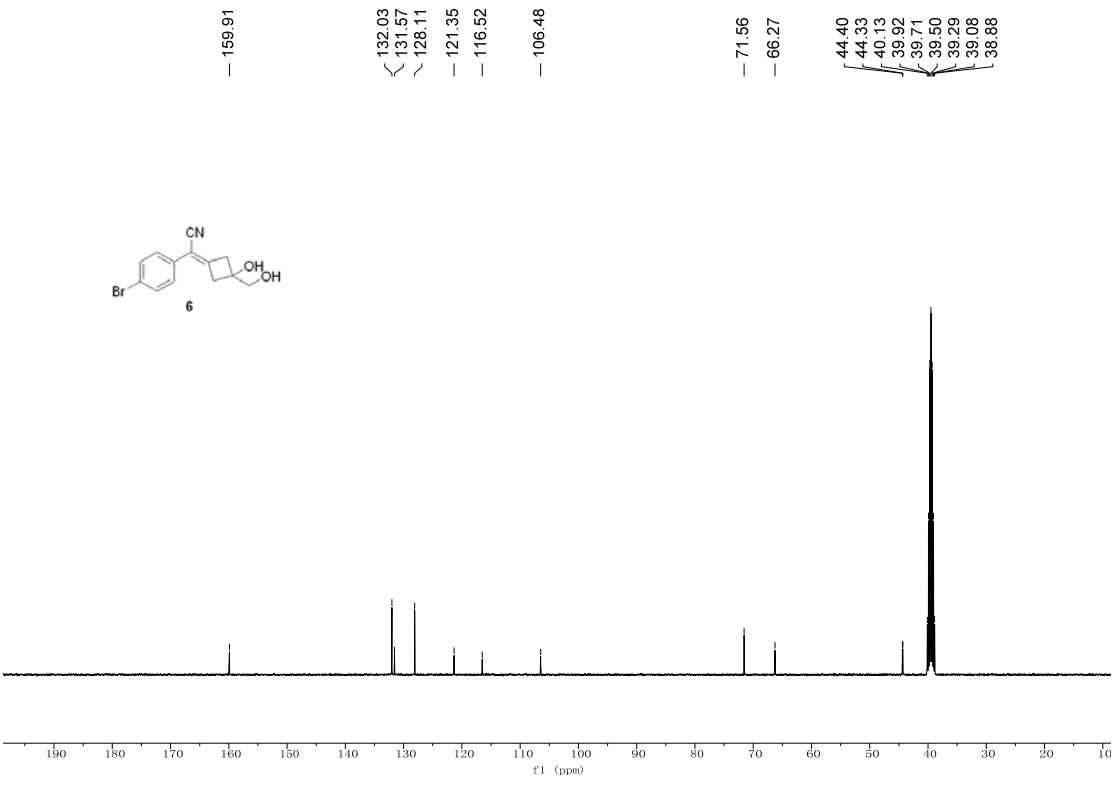
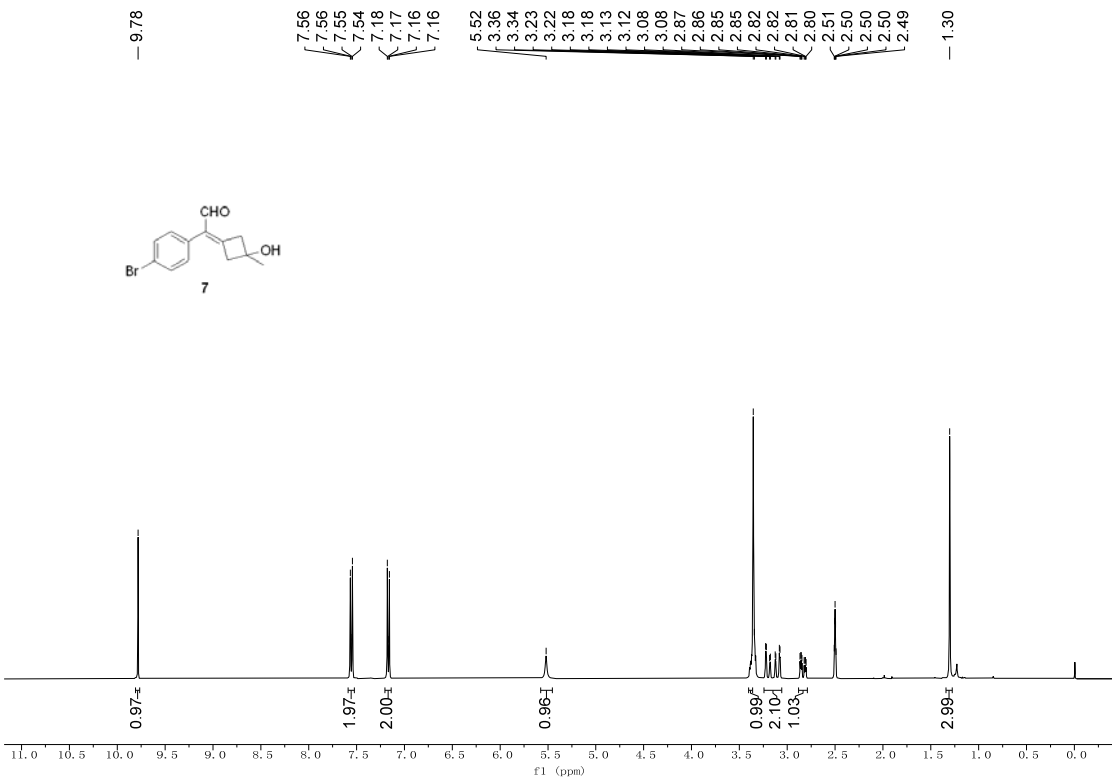
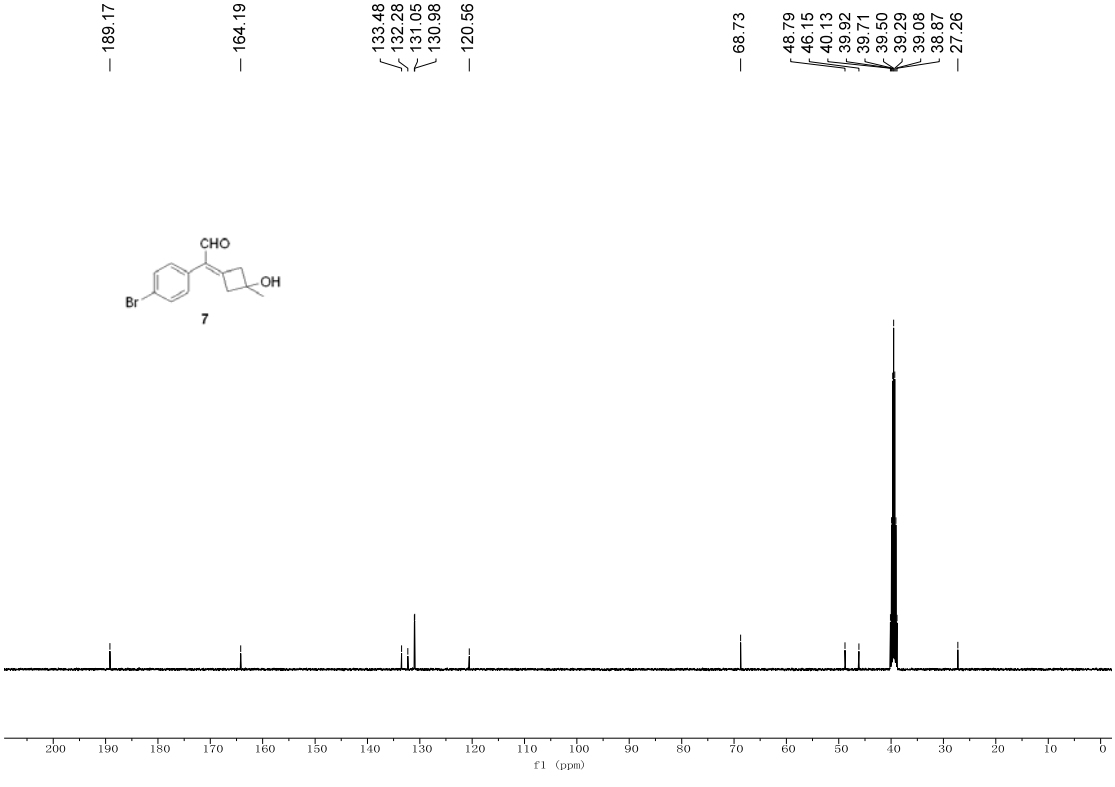
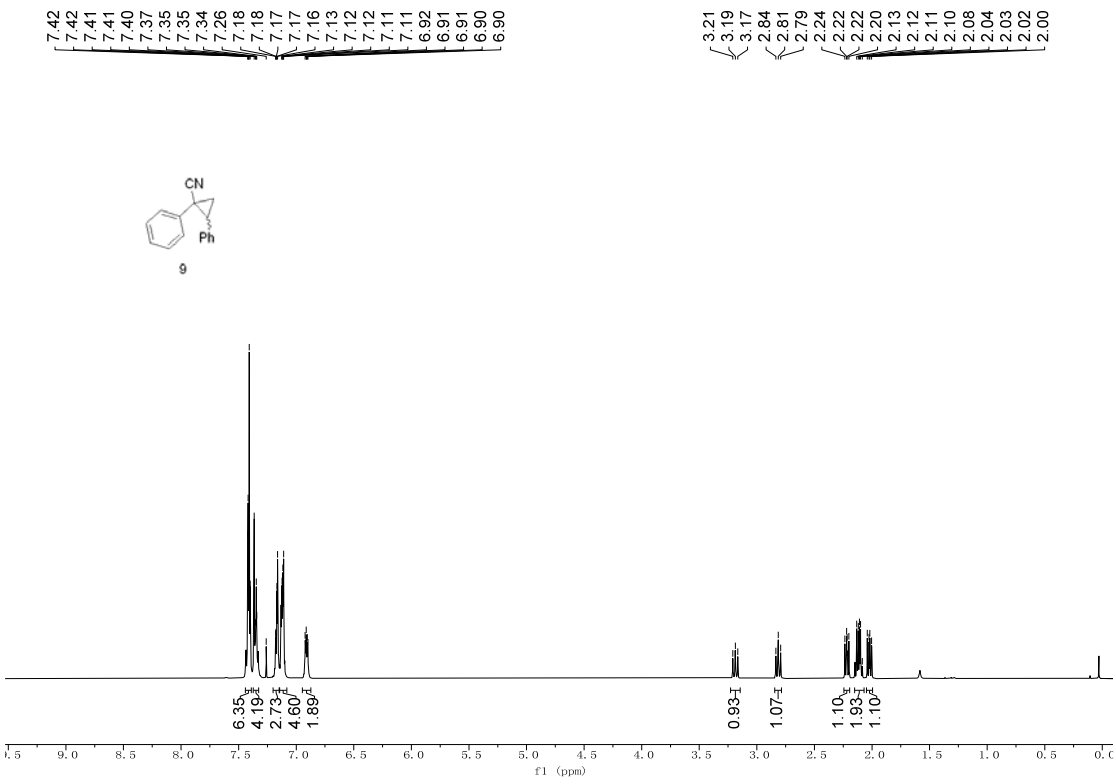
2.50
2.50
2.49
CN
OH
OH
Br
6
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


159.91
132.03
131.57
128.11
121.35
116.52
106.48
71.56
66.27
44.40
44.33
40.13
39.92
39.71
39.50
39.29
39.08
38.88
CN
OH
OH
Br
6
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)


9.78
7.56
7.56
7.55
7.54
7.18
7.17
7.16
7.16
5.52
3.36
3.34
3.23
3.22
3.18
3.18
3.13
3.12
3.08
3.08
2.87
2.86
2.85
2.85
2.82
2.82
2.81
2.80
2.51
2.50
2.50
2.50
2.49
1.30
CHO
OH
Br
7
0.97
1.97
2.00
0.96
0.99
2.10
1.03
2.99
f1 (ppm)


189.17
164.19
133.48
132.28
131.05
130.98
120.56
68.73
48.79
46.15
40.13
39.92
39.71
39.50
39.29
39.08
38.87
27.26
CHO
OH
Br
7
f1 (ppm)


7.42
7.42
7.41
7.41
7.40
7.37
7.35
7.35
7.34
7.26
7.18
7.18
7.17
7.17
7.16
7.13
7.12
7.12
7.11
7.11
6.92
6.91
6.91
6.90
6.90
3.21
3.19
3.17
2.84
2.81
2.79
2.24
2.22
2.22
2.20
2.13
2.12
2.11
2.10
2.08
2.04
2.03
2.02
2.00
CN
Ph
9
6.35
4.19
2.73
4.60
1.89
0.93
1.07
1.10
1.93
1.10
f1 (ppm)