Supporting Information

# Cu-catalyzed atom transfer radical addition reactions of alkenes with *α*-bromoacetonitrile

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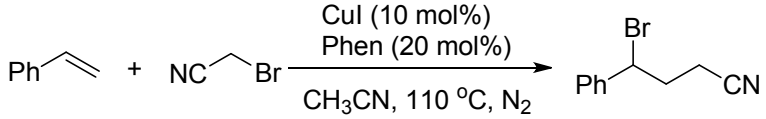
## 1. General Information

Unless otherwise stated, starting materials were purchased from TCI or Energy-Chemical Limited and used as supplied without further purification. Solvents were used directly without further purification. All deuterated solvents were purchased from Cambridge Isotope Laboratories. $^{1}H$ NMR and $^{13}C$ NMR spectra were recorded at 25 ºC on a Brüker Advance 400 spectrometer ($^{1}H$: 400 MHz and $^{13}C$:100 MHz). $^{1}H$ NMR chemical shifts were determined relative to internal $(CH_3)_4Si$ (TMS) at $\delta$ 0.00 ppm or to the signal of the residual protonated solvent: $CDCl_3$ at $\delta$ 7.26 ppm. $^{13}C$ NMR chemical shifts were determined relative to the signal of the solvent: $CDCl_3$ at $\delta$ 77.00 ppm. Data for $^{1}H$, $^{13}C$ NMR were recorded as follows: chemical shift ($\delta$, ppm), multiplicity (s = singlet, d = doublet, t = triplet, m = multiplet, q = quartet, dd = doublet of doublets, dt = doublet of triplets, td = triplet of doublets), coupling constants (Hz) and integration. Melting points were obtained with a micro melting point XT4A Beijing Keyi electrooptic apparatus and are uncorrected. High-resolution mass data were recorded on a Waters LCT PremierxeTM (USA). All reactions were monitored by thin layer chromatography (TLC) with Taizhou GF254 silica gel coated plates. Flash column chromatography was carried out using 200-300 mesh silica gel at increased pressure.

## 2. General procedure for the preparation of 3

**3a as an example**



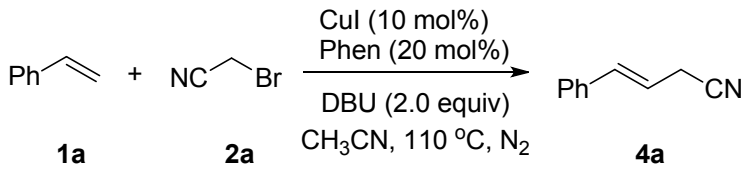

**1a** **2a** **3a**

To a solution of the styrene **1a** (35 μL, 0.3 mmol) in $CH_3CN$ (1.0 ml) was added the $\alpha$-bromoacetonitrile **2a** (38 μL, 0.60 mmol), Phen (10.8 mg, 0.06 mmol), and CuI (5.7 mg, 0.03 mmol) under $N_2$ in a Schlenck tube. The reaction mixture was stirred at 110 °C for 1.0 h. After the reaction finished, the reaction mixture was cooled to room temperature and quenched by water. The mixture was extracted with EtOAc (3.0 mL×3), the combined organic phases were dried over

anhydrous $Na_2SO_4$ and the solvent was evaporated under vacuum. The residue was purified by column chromatography (petroleum ether /ethyl acetate = 40:1) to give the corresponding products **3a** (61.1 mg, 91%).

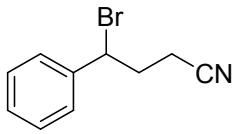
## 3. General procedure for the preparation of 4

**4a as an example**



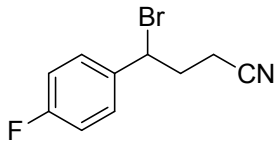

To a solution of the styrene **1a** (35 μL, 0.3 mmol) in $CH_3CN$ (1.0 ml) was added the *α*-bromoacetonitrile **2a** (38 μL, 0.6 mmol), Phen (10.8 mg, 0.06 mmol), CuI (5.7 mg, 0.03 mmol), and DBU (91 μL, 0.60 mmol) under $N_2$ in a Schlenck tube. The reaction mixture was stirred at 110 °C for 1.0 h. After the reaction finished, the reaction mixture was cooled to room temperature and quenched by water. The mixture was extracted with EtOAc (3.0 mL×3), the combined organic phases were dried over anhydrous $Na_2SO_4$ and the solvent was evaporated under vacuum. The residue was purified by column chromatography (petroleum ether /ethyl acetate = 40:1) to give the corresponding products **4a** (38.7 mg, 90%).

## 4. Analytical Data of Compounds 3, 4 and 6



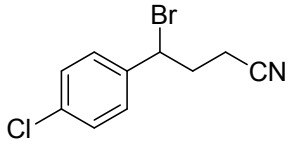

**4-bromo-4-phenylbutanenitrile 3a**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.38-2.62 (m, 4H), 5.04 (dd, $J_1$ = 5.6 Hz, $J_2$ = 8.8 Hz, 1H), 7.32-7.42 (s, 5H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 16.3, 35.2, 52.1, 118.2, 127.1, 128.9, 140.0. HRMS(ESI-TOF) Calcd for $C_{10}H_{11}BrN$, $[M+H]^+$ *m/z* 224.0075, 226.0054; Found 224.0079, 226.0057.



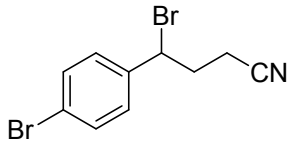

**4-bromo-4-(4-fluorophenyl)butanenitrile 3b**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^{1}$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.36-2.49 (m, 1H), 2.49-2.58 (m, 3H), 5.03 (dd, $J_1$ = 6.0 Hz, $J_2$ = 8.4 Hz, 1H), 7.06 (t, $J$ = 8.4 Hz, 2H), 7.39 (dd, $J_1$ = 5.2 Hz, $J_2$ = 8.4 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 16.4, 35.4, 51.2, 116.0 (d, $J$ = 22.0 Hz), 118.1, 129.0 (d, $J$ = 8 Hz), 136.1 (d, $J$ = 3.0 Hz), 162.6 (d, $J$ = 247.0 Hz). HRMS(ESI-TOF) Calcd for $C_{10}H_{10}BrFN$, $[M+H]^+$ *m/z* 241.9981, 243.9960; Found 241.9985, 243.9963.



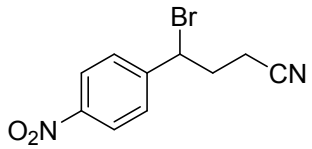

**4-bromo-4-(4-chlorophenyl)butanenitrile 3c**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^{1}$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.35-2.42 (m, 1H), 2.48-2.60 (m, 3H), 5.00 (dd, $J_1$ = 5.6 Hz, $J_2$ = 8.4 Hz, 1H), 7.34 (s, 4H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 16.3, 35.1, 50.9, 118.1, 128.5, 129.2, 134.7, 138.6. HRMS(ESI-TOF) Calcd for $C_{10}H_{10}BrClN$, $[M+H]^+$ *m/z* 257.9685, 259.9665; Found 257.9687, 259.9668.



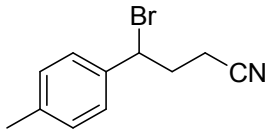

**4-bromo-4-(4-bromophenyl)butanenitrile 3d**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^{1}$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.34-2.39 (m, 1H), 2.48-2.58 (m, 3H), 4.98 (dd, $J_1$ = 5.6 Hz, $J_2$ = 8.4 Hz, 1H), 7.28 (d, $J$ = 8.4 Hz, 2H), 7.50 (d, $J$ = 8.0 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 16.3, 35.1, 50.9, 118.1, 122.9, 128.8, 132.1, 139.2. HRMS(ESI-TOF) Calcd for $C_{10}H_{10}Br_2N$, $[M+H]^+$ *m/z* 303.9160; Found 303.9165.



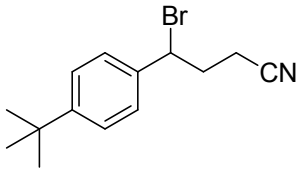

**4-bromo-4-(4-nitrophenyl)butanenitrile 3e**

Yellow solid. mp: 76-78 ºC. Petroleum ether/ethyl acetate = 20/1 as eluent for column chromatography. $^{1}$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.38-2.44 (m, 1H), 2.51-2.69 (m, 3H), 5.08 (dd, $J_1$ = 5.6 Hz, $J_2$ = 9.6 Hz, 1H), 7.60 (d, $J$ = 8.4 Hz, 2H), 8.25 (d, $J$ = 8.8 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 16.4, 34.9, 49.6, 117.8, 124.3, 128.3, 147.0, 148.0. HRMS(ESI-TOF) Calcd for $C_{10}H_{10}BrN_2O_2$, $[M+H]^+$ *m/z* 268.9926, 270.9905; Found 268.9929, 270.9907.



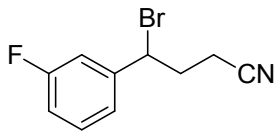

**4-bromo-4-(*p*-tolyl)butanenitrile 3f**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^{1}$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.36 (s, 3H), 2.39-2.58 (m, 4H), 5.02-5.05 (m, 1H), 7.18 (d, $J$ = 7.6 Hz, 2H), 7.29 (d, $J$ = 8.0 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 16.4, 21.1, 35.3, 52.3, 118.3, 127.0, 129.6, 137.1, 139.0. HRMS(ESI-TOF) Calcd for $C_{11}H_{13}BrN$, $[M+H]^+$ *m/z* 238.0231, 240.0211; Found 238.0237, 240.0215.



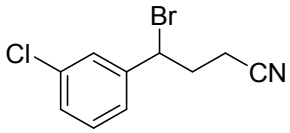

**4-bromo-4-(4-(*tert*-butyl)phenyl)butanenitrile 3g**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^{1}$H NMR (400 MHz; $CDCl_3$): $\delta$ = 1.33 (s, 9H), 2.40-2.59 (m, 4H), 5.04-5.08 (m, 1H), 7.34 (d, $J$ = 8.4 Hz, 2H), 7.40 (d, $J$ = 8.4 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 16.3, 31.1, 34.6, 35.2, 52.3, 118.3, 125.8, 126.8, 137.0, 152.0. HRMS(ESI-TOF) Calcd for $C_{14}H_{19}BrN$, $[M+H]^+$ *m/z* 280.0701, 282.0680; Found 280.0704, 282.0685.



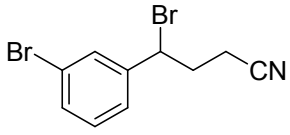

**4-bromo-4-(3-fluorophenyl)butanenitrile 3h**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.37-2.44 (m, 1H), 2.49-2.60 (m, 3H), 4.99-5.02 (m, 1H), 7.03 (t, $J$ = 8.4 Hz, 1H), 7.12 (d, $J$ = 9.6 Hz, 1H), 7.18 (d, $J$ = 8.0 Hz, 1H), 7.35 (dd, $J_1$ = 7.6 Hz, $J_2$ = 14.0 Hz, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 16.3, 35.2, 50.8, 114.3 (d, $J$ = 23.0 Hz), 116.0 (d, $J$ = 21.0 Hz), 118.1, 122.8 (d, $J$ = 3.0 Hz), 130.6 (d, $J$ = 9.0 Hz), 142.5 (d, $J$ = 8.0 Hz), 162.8 (d, $J$ = 246.0 Hz). HRMS(ESI-TOF) Calcd for $C_{10}H_{10}BrFN$, $[M+H]^+$ *m/z* 241.9981, 243.9960; Found 241.9983, 243.9958.



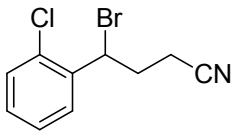

**4-bromo-4-(3-chlorophenyl)butanenitrile 3i**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.35-2.44 (m, 1H), 2.49-2.60 (m, 3H), 4.96-4.99 (m, 1H), 7.28-7.32 (m, 3H), 7.40 (s, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 16.4, 35.2, 50.8, 118.0, 125.4, 127.4, 129.2, 130.3, 134.9, 142.1. HRMS(ESI-TOF) Calcd for $C_{10}H_{10}BrClN$, $[M+H]^+$ *m/z* 257.9685, 259.9665; Found 257.9687, 259.9669.



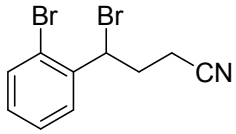

**4-bromo-4-(3-bromophenyl)butanenitrile 3j**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.36-2.40 (m, 1H), 2.48-2.58 (m, 3H), 4.94-4.97 (m, 1H), 7.23 (d, $J$ = 8.0 Hz, 1H), 7.32 (d, $J$ = 8.0 Hz, 1H), 7.46 (dd, $J_1$ = 1.2 Hz, $J_2$ = 8.0 Hz, 1H), 7.55 (d, $J$ = 1.6 Hz, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 16.3, 35.1, 50.6, 118.0, 122.8, 125.8, 130.2, 130.5, 132.0, 142.3. HRMS(ESI-TOF) Calcd for $C_{10}H_{10}Br_2N$, $[M+H]^+$ *m/z* 303.9160; Found 303.9165.



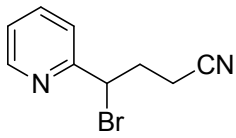

**4-bromo-4-(2-chlorophenyl)butanenitrile 3k**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.42-2.47 (m, 1H), 2.54-2.63 (m, 3H), 5.52 (dd, $J_1$ = 5.2 Hz, $J_2$ = 9.2 Hz, 1H), 7.27-7.33 (m, 2H), 7.39 (dd, $J_1$ = 1.6 Hz, $J_2$ = 8.0 Hz, 1H), 7.57 (dd, $J_1$ = 1.6 Hz, $J_2$ = 8.0 Hz, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 16.3, 34.6, 47.6, 118.1, 127.7, 128.8, 130.0, 132.7, 137.4. HRMS(ESI-TOF) Calcd for $C_{10}H_{10}BrClN$, $[M+H]^+$ *m/z* 257.9685, 259.9665; Found 257.9688, 259.9669.




**4-bromo-4-(2-bromophenyl)butanenitrile 3l**

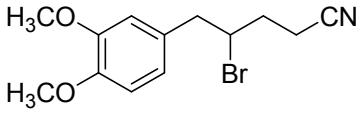
Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.40-2.47 (m, 1H), 2.51-2.62 (m, 3H), 5.50 (dd, $J_1$ = 5.2 Hz, $J_2$ = 8.8 Hz, 1H), 7.16-7.20 (m, 1H), 7.37 (t, $J$ = 7.6 Hz, 1H), 7.56-7.59 (m, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 16.2, 34.7, 50.5, 118.1, 123.0, 128.3, 128.9, 130.2, 133.2, 139.0. HRMS(ESI-TOF) Calcd for $C_{10}H_{10}Br_2N$, $[M+H]^+$ *m/z* 303.9160; Found 303.9165.




**4-(pyridin-2-yl)butanenitrile 3m**

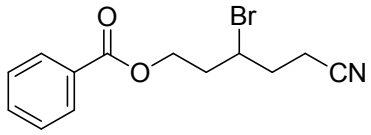
Colorless oil. Petroleum ether/ethyl acetate = 20/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.60-2.72 (m, 4H), 5.16 (dd, $J_1$ = 5.2 Hz, $J_2$ = 8.4 Hz, 1H), 7.28 (dd, $J_1$ = 2.4 Hz, $J_2$ = 4.0 Hz, 1H), 7.45 (d, $J$ = 7.6 Hz, 1H), 7.72-7.76 (m, 1H), 8.63 (d, $J$ = 4.4 Hz, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 16.1, 32.9, 51.6, 118.4, 122.8, 123.6, 137.2, 149.7, 158.1. HRMS(ESI-TOF) Calcd for $C_9H_{10}BrN_2$, $[M+H]^+$ *m/z* 225.0027, 227.0007; Found 225.0024,

227.0005.



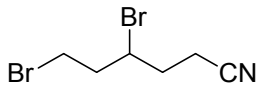

**4-bromo-5-(3,4-dimethoxyphenyl)pentanenitrile 3n**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^{1}$H NMR (400 MHz; $CDCl_3$): $\delta$ = 1.97-2.23 (m, 2H), 2.58-2.61 (m, 2H), 3.05-3.25 (m, 2H), 3.86 (s, 3H), 3.87 (s, 3H), 4.18-4.25 (m, 1H), 6.71-6.82 (m, 3H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 16.1, 33.3, 44.9, 54.2, 55.8, 55.8, 111.1, 112.1, 118.6, 121.2, 129.7, 148.1, 148.9. HRMS(ESI-TOF) Calcd for $C_{13}H_{17}BrNO_2$, $[M+H]^+$ *m/z* 298.0443, 300.0422; Found 298.0446, 300.0425.



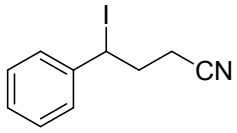

**3-bromo-5-cyanopentyl benzoate 3o**

Colorless oil. Petroleum ether/ethyl acetate = 30/1 as eluent for column chromatography. $^{1}$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.15-2.37 (m, 4H), 2.63-2.68 (m, 2H), 4.22-4.29 (m, 1H), 4.45-4.61 (m, 2H), 7.45 (t, $J$ = 7.6 Hz, 2H), 7.57 (t, $J$ = 7.6 Hz, 1H), 8.02-8.04 (m, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 16.0, 34.6, 37.8, 50.3, 62.3, 118.4, 128.4, 129.6, 129.8, 133.2, 166.3. HRMS(ESI-TOF) Calcd for $C_{13}H_{15}BrNO_2$, $[M+H]^+$ *m/z* 296.0286, 298.0266; Found 296.0291, 298.0273.



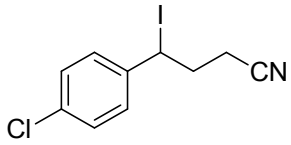

**4,6-dibromohexanenitrile 3p**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^{1}$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.12-2.59 (m, 4H), 2.61-2.70 (m, 2H), 3.57-3.60 (m, 2H), 4.22-4.29 (m, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 15.9, 30.2, 34.3, 41.1, 52.0, 118.4. HRMS(ESI-TOF) Calcd for $C_6H_{10}Br_2N$, $[M+H]^+$ *m/z* 255.9160; Found 255.9165.



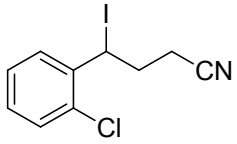

**4-iodo-4-phenylbutanenitrile 3q**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^{1}$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.30-2.68 (m, 4H), 5.15-5.19 (m, 1H), 7.28-7.41 (m, 5H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 18.0, 29.1, 36.8, 118.1, 127.0, 128.6, 129.1, 141.9. HRMS(ESI-TOF) Calcd for $C_{10}H_{11}IN$, $[M+H]^+$ *m/z* 271.9936; Found 271.9939.



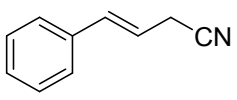

**4-(4-chlorophenyl)-4-iodobutanenitrile 3r**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^{1}$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.25-2.61 (m, 4H), 5.13 (dd, $J_1$ = 6.4 Hz, $J_2$ = 8.8 Hz, 1H), 7.29-7.35 (m, 4H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 17.9, 27.6, 36.4, 117.8, 128.3, 129.1, 134.0, 140.5. HRMS(ESI-TOF) Calcd for $C_{10}H_{10}ClIN$, $[M+H]^+$ *m/z* 305.9546; Found 305.9548.



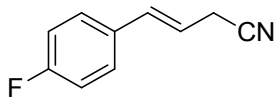

**4-(2-chlorophenyl)-4-iodobutanenitrile 3s**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^{1}$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.33-2.72 (m, 4H), 5.57 (dd, $J_1$ = 6.0 Hz, $J_2$ = 8.8 Hz, 1H), 7.22-7.37 (m, 3H), 7.53-7.55 (m, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 17.8, 24.0, 35.7, 117.9, 127.8, 128.4, 129.6, 130.3, 132.2, 139.1. HRMS(ESI-TOF) Calcd for $C_{10}H_{10}ClIN$, $[M+H]^+$ *m/z* 305.9546; Found 305.9543.



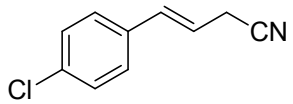

**(*E*)-4-phenylbut-3-enenitrile 4a**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 3.30 (dd, $J_1$ = 1.6 Hz, $J_2$ = 5.6 Hz, 2H), 6.06 (dt, $J_1$ = 15.6, $J_2$ = 5.6 Hz, 1H), 6.75 (d, $J$ = 15.6 Hz, 1H), 7.27-7.39 (m, 5H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 20.8, 116.7, 117.3, 126.5, 128.3, 128.7, 134.7, 135.6. HRMS(ESI-TOF) Calcd for $C_{10}H_{10}N$, $[M+H]^+$ *m/z* 144.0813; Found 144.0811.



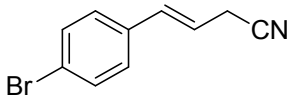

**(*E*)-4-(4-fluorophenyl)but-3-enenitrile 4b**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 3.29 (dd, $J_1$ = 1.2 Hz, $J_2$ = 5.6 Hz, 2H), 5.98 (dt, $J_1$ = 15.6, $J_2$ = 5.6 Hz, 1H), 6.71 (d, $J$ = 15.6 Hz, 1H), 7.03 (t, $J$ = 8.8 Hz, 2H), 7.34 (dd, $J_1$ = 5.6, $J_2$ = 8.4 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 20.7, 115.7 (d, $J$ = 22.0 Hz), 116.5 (d, $J$ = 2.0 Hz), 117.2, 128.1 (d, $J$ = 8.0 Hz), 131.8 (d, $J$ = 3.0 Hz), 133.5, 162.7 (d, $J$ = 246.0 Hz). HRMS(ESI-TOF) Calcd for $C_{10}H_9FN$, $[M+H]^+$ *m/z* 162.0719; Found 162.0725.




**(*E*)-4-(4-chlorophenyl)but-3-enenitrile 4c**

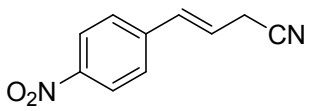
Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 3.29 (dd, $J_1$ = 1.6 Hz, $J_2$ = 5.6 Hz, 2H), 6.04 (dt, $J_1$ = 16.0, $J_2$ = 5.6 Hz, 1H), 6.70 (dt, $J_1$ = 15.6, $J_2$ = 1.6 Hz, 1H), 7.27-7.34 (m, 4H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 20.7, 117.0, 117.4, 127.7, 128.9, 133.4, 134.0, 134.1. HRMS(ESI-TOF) Calcd for $C_{10}H_9ClN$, $[M+H]^+$ *m/z* 178.0424; Found 178.0427.




**(*E*)-4-(4-bromophenyl)but-3-enenitrile 4d**

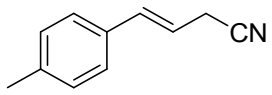
White solid. mp: 62-64 ºC. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 3.29 (dd, $J_1$ = 1.6 Hz, $J_2$ = 5.6 Hz, 2H), 6.05

(dt, $J_1$ = 15.6, $J_2$ = 5.6 Hz, 1H), 6.68 (d, $J$ = 16.0, 1H), 7.23 (d, $J$ = 8.4, 2H), 7.46 (d, $J$ = 8.4, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 20.8, 117.0, 117.5, 122.2, 127.9, 131.8, 133.4, 134.5. HRMS(ESI-TOF) Calcd for $C_{10}H_9BrN$, $[M+H]^+$ *m/z* 221.9918, 223.9898; Found 221.9923, 223.9901.



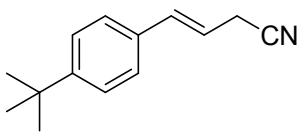

**(*E*)-4-(4-nitrophenyl)but-3-enenitrile 4e**

White solid. mp: 50-51 ºC. Petroleum ether/ethyl acetate = 20/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 3.38 (dd, $J_1$ = 1.6 Hz, $J_2$ = 5.2 Hz, 2H), 6.26 (dt, $J_1$ = 16.0, $J_2$ = 5.6 Hz, 1H), 6.83 (d, $J$ = 16.0, 1H), 7.51 (d, $J$ = 8.4, 2H), 8.20 (d, $J$ = 8.8, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 20.9, 116.5, 121.7, 124.1, 127.1, 132.5, 141.8, 147.3. HRMS(ESI-TOF) Calcd for $C_{10}H_9N_2O_2$, $[M+H]^+$ *m/z* 189.0664; Found 189.0667.




**(*E*)-4-(*p*-tolyl)but-3-enenitrile 4f**

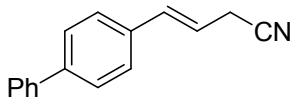
White solid. mp: 50-52 ºC. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.43 (s, 3H), 3.27-3.28 (m, 2H), 5.99 (dt, $J_1$ = 16.0, $J_2$ = 5.6 Hz, 1H), 6.69 (d, $J$ = 15.6, 1H), 7.14 (d, $J$ = 8.0, 2H), 7.26 (d, $J$ = 8.0, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 20.7, 21.2, 115.6, 117.4, 126.3, 129.4, 132.8, 134.5, 138.2. HRMS(ESI-TOF) Calcd for $C_{11}H_{12}N$, $[M+H]^+$ *m/z* 158.0970; Found 158.0965.




**(*E*)-4-(4-(*tert*-butyl)phenyl)but-3-enenitrile 4g**

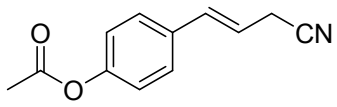
Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 1.33 (s, 9H), 3.29 (dd, $J_1$ = 1.6 Hz, $J_2$ = 5.6 Hz, 2H), 6.02 (dt, $J_1$ = 15.6, $J_2$ = 5.6 Hz, 1H), 6.72 (d, $J$ = 15.6, 1H), 7.32 (d, $J$ = 8.4, 2H), 7.37 (d, $J$ = 8.4, 2H); $^{13}$C NMR (100

MHz, $CDCl_3$): $\delta$ = 20.8, 31.2, 34.6, 115.8, 117.4, 125.6, 126.2, 132.9, 134.4, 151.5. HRMS(ESI-TOF) Calcd for $C_{14}H_{18}N$, $[M+H]^+$ *m/z* 200.1439; Found 200.1435.



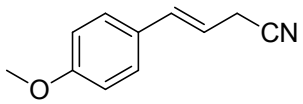

**(*E*)-4-([1,1'-biphenyl]-4-yl)but-3-enenitrile 4h**

White solid. mp: 86-88 ºC. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 3.32 (d, $J$ = 4.2, 2H), 6.10 (dt, $J_1$ = 15.6, $J_2$ = 5.6 Hz, 1H), 6.79 (d, $J$ = 16.0, 1H), 7.37 (t, $J$ = 7.2, 1H), 7.44-7.48 (m, 4H), 7.60 (t, $J$ = 8.0, 4H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 20.8, 116.7, 117.3, 126.9, 126.9, 127.4, 127.5, 128.8, 134.2, 134.6, 140.4, 141.0. HRMS(ESI-TOF) Calcd for $C_{16}H_{14}N$, $[M+H]^+$ *m/z* 220.1126; Found 220.1123.




**(*E*)-4-(3-cyanoprop-1-en-1-yl)phenyl acetate 4i**

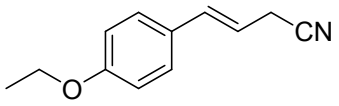
Colorless oil. Petroleum ether/ethyl acetate = 30/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.30 (s, 3H), 3.29 (dd, $J_1$ = 1.2 Hz, $J_2$ = 5.6 Hz, 2H), 6.01 (dt, $J_1$ = 16.0, $J_2$ = 5.6 Hz, 1H), 6.72 (d, $J$ = 15.6 Hz 1H), 7.06 (d, $J$ = 8.8 Hz, 2H), 7.37 (d, $J$ = 8.4 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 20.7, 21.1, 117.0, 117.2, 121.9, 127.4, 133.4, 133.6, 150.5, 169.3. HRMS(ESI-TOF) Calcd for $C_{12}H_{12}NO_2$, $[M+H]^+$ *m/z* 202.0868; Found 202.0868.




**(*E*)-4-(4-methoxyphenyl)but-3-enenitrile 4j**

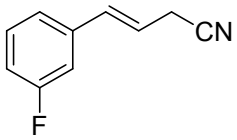
White solid. mp: 78-79 ºC. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 3.26 (dd, $J_1$ = 1.6 Hz, $J_2$ = 5.6 Hz, 2H), 3.81 (s, 3H), 5.90 (dt, $J_1$ = 15.6, $J_2$ = 5.6 Hz, 1H), 6.66 (d, $J$ = 16.0 Hz 1H), 6.87 (d, $J$ = 8.8 Hz, 2H), 7.30 (d, $J$ = 8.8 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 20.7, 55.2, 114.0, 114.3, 117.5, 127.6, 128.4, 134.0, 159.6. HRMS(ESI-TOF) Calcd for $C_{11}H_{12}NO$, $[M+H]^+$ *m/z* 174.0919; Found

174.0922.



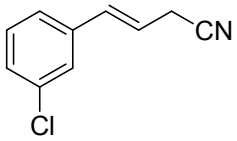

**(*E*)-4-(4-ethoxyphenyl)but-3-enenitrile 4k**

White solid. mp: 81-82 ºC. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 1.42 (t $J$ = 6.8 Hz 3H), 3.26 (d, $J$ = 5.2 Hz, 2H), 4.04 (q, $J$ = 6.8 Hz, 2H), 5.90 (dt, $J_1$ = 15.2, $J_2$ = 5.6 Hz, 1H), 6.66 (d, $J$ = 15.6 Hz, 1H), 6.86 (d, $J$ = 8.4 Hz, 2H), 7.29 (d, $J$ = 8.4 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 14.8, 20.8, 63.5, 114.2, 114.7, 117.5, 127.7, 128.3, 134.2, 159.1. HRMS(ESI-TOF) Calcd for $C_{12}H_{14}NO$, $[M+H]^+$ *m/z* 188.1075; Found 188.1077.




**(*E*)-4-(3-fluorophenyl)but-3-enenitrile 4l**

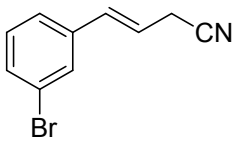
Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 3.31 (dd, $J_1$ = 1.6 Hz, $J_2$ = 5.6 Hz, 2H), 6.07 (dt, $J_1$ = 16.0, $J_2$ = 5.6 Hz, 1H), 6.72 (d, $J$ = 15.6 Hz, 1H), 6.98 (dt, $J_1$ = 8.4 Hz, $J_2$ = 2.0 Hz, 1H), 7.07 (d, $J$ = 9.6 Hz, 1H), 7.13 (d, $J$ = 7.6 Hz, 1H), 7.28-7.33 (m, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 20.7, 112.9 (d, $J$ = 22.0 Hz), 115.1 (d, $J$ = 21.0 Hz), 117.0, 118.2, 122.4 (d, $J$ = 3.0 Hz), 130.2 (d, $J$ = 8.0 Hz), 133.5 (d, $J$ = 2.0 Hz), 137.9 (d, $J$ = 8.0 Hz), 163.0 (d, $J$ = 245.0 Hz). HRMS(ESI-TOF) Calcd for $C_{10}H_9FN$, $[M+H]^+$ *m/z* 162.0719; Found 162.0722.




**(*E*)-4-(3-chlorophenyl)but-3-enenitrile 4m**

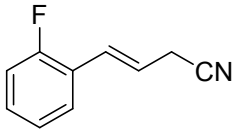
Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 3.30 (dd, $J_1$ = 1.6 Hz, $J_2$ = 5.6 Hz, 2H), 6.07 (dt, $J_1$ = 15.6, $J_2$ = 5.6 Hz,

1H), 6.69 (d, $J$ = 16.0, 1H), 7.23-7.30 (m, 3H), 7.36 (s, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 20.7, 116.9, 118.3, 124.7, 126.3, 128.2, 129.9, 133.3, 134.6, 137.4. HRMS(ESI-TOF) Calcd for $C_{10}H_9ClN$, $[M+H]^+$ *m/z* 178.0424; Found 178.0427.



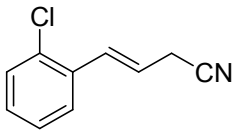

**(*E*)-4-(3-bromophenyl)but-3-enenitrile 4n**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 3.30 (dd, $J_1$ = 1.6 Hz, $J_2$ = 5.6 Hz, 2H), 6.07 (dt, $J_1$ = 16.0, $J_2$ = 5.6 Hz, 1H), 6.68 (d, $J$ = 16.0, 1H), 7.21 (t, $J$ = 8.0, 1H), 7.28 (d, $J$ = 8.0, 1H), 7.41 (d, $J$ = 8.0, 1H), 7.52 (s, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 20.7, 116.9, 118.3, 122.8, 125.2, 129.3, 130.2, 131.2, 133.2, 137.7. HRMS(ESI-TOF) Calcd for $C_{10}H_9BrN$, $[M+H]^+$ *m/z* 221.9918, 223.9898; Found 221.9923, 223.9896.



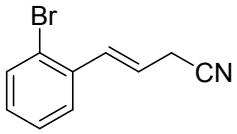

**(*E*)-4-(2-fluorophenyl)but-3-enenitrile 4o**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 3.32 (dd, $J_1$ = 1.6 Hz, $J_2$ = 5.6 Hz, 2H), 6.18 (dt, $J_1$ = 16.0, $J_2$ = 5.6 Hz, 1H), 6.85 (d, $J$ = 16.0 Hz, 1H), 7.04-7.14 (m, 2H), 7.23-7.29 (m, 1H), 7.40 (dt, $J_1$ = 7.6 Hz, $J_2$ = 1.2 Hz, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 21.2, 115.9 (d, $J$ = 22.0 Hz), 117.1, 119.7 (d, $J$ = 6.0 Hz), 123.4 (d, $J$ = 13.0 Hz), 124.2 (d, $J$ = 4.0 Hz), 127.7 (d, $J$ = 3.0 Hz), 127.9 (d, $J$ = 3.0 Hz), 129.6 (d, $J$ = 9.0 Hz), 160.3 (d, $J$ = 249.0 Hz). HRMS(ESI-TOF) Calcd for $C_{10}H_9FN$, $[M+H]^+$ *m/z* 162.0719; Found 162.0715.



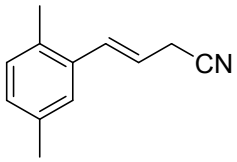

**(*E*)-4-(2-chlorophenyl)but-3-enenitrile 4p**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 3.34 (dd, $J_1$ = 1.6 Hz, $J_2$ = 5.6 Hz, 2H), 6.05 (dt, $J_1$ = 15.6, $J_2$ = 6.0 Hz, 1H), 7.11 (d, $J$ = 15.6, 1H), 7.21-7.25 (m, 2H), 7.36-7.38 (m, 1H), 7.46-7.49 (m, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 21.0, 117.0, 119.7, 127.0, 127.0, 129.3, 129.8, 131.3, 133.1, 133.9. HRMS(ESI-TOF) Calcd for $C_{10}H_9ClN$, $[M+H]^+$ *m/z* 178.0424; Found 178.0421.



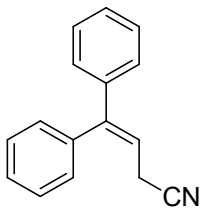

**(*E*)-4-(2-bromophenyl)but-3-enenitrile 4q**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 3.30 (dd, $J_1$ = 1.6 Hz, $J_2$ = 5.6 Hz, 2H), 6.07 (dt, $J_1$ = 15.6, $J_2$ = 5.6 Hz, 1H), 6.69 (d, $J$ = 15.6, 1H), 7.22-7.29 (m, 3H), 7.36 (s, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 20.7, 116.9, 118.3, 124.7, 126.4, 128.2, 129.9, 133.3, 134.7, 137.4. HRMS(ESI-TOF) Calcd for $C_{10}H_9BrN$, $[M+H]^+$ *m/z* 221.9918, 223.9898; Found 221.9913, 223.9895.



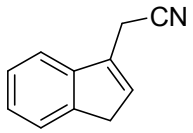

**(*E*)-4-(2,5-dimethylphenyl)but-3-enenitrile 4r**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.32 (s, 6H), 3.31 (dd, $J_1$ = 1.2 Hz, $J_2$ = 5.6 Hz, 2H), 5.93 (dt, $J_1$ = 15.6, $J_2$ = 5.6 Hz, 1H), 6.93 (d, $J$ = 15.6, 1H), 7.02 (d, $J$ = 8.0, 1H), 7.06 (d, $J$ = 7.6, 1H), 7.21 (s, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 19.2, 20.9, 21.0, 117.4, 117.7, 126.4, 128.9, 130.3, 132.5, 132.8, 134.6, 135.6. HRMS(ESI-TOF) Calcd for $C_{12}H_{14}N$, $[M+H]^+$ *m/z* 172.1126; Found 172.1123.



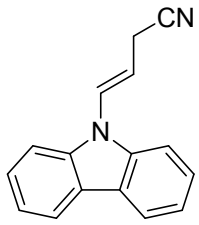
**4,4-diphenylbut-3-enenitrile 4s**

White solid. mp: 76-78 ºC. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 3.16 (d, $J$ = 7.6, 2H), 6.05 (t, $J$ = 7.6, 1H), 7.18-7.46 (m, 10H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 18.3, 115.4, 118.1, 127.4, 128.1, 128.2, 128.3, 128.8, 129.3, 137.9, 140.6, 147.5. HRMS(ESI-TOF) Calcd for $C_{16}H_{14}N$, $[M+H]^+$ *m/z* 220.1126; Found 220.1125.



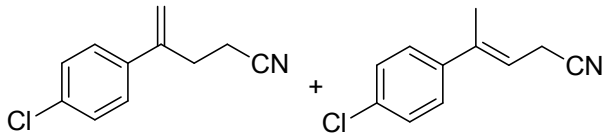

**2-(1*H*-inden-3-yl)acetonitrile 4t**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 3.43 (s, 2H), 3.57 (s, 2H), 6.87 (s, 1H), 7.21 (t, $J$ = 7.2 Hz, 1H), 7.29 (t, $J$ = 7.2 Hz, 1H), 7.36 (d, $J$ = 7.2 Hz, 1H), 7.43 (d, $J$ = 7.2 Hz, 1H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 19.9, 40.7, 117.1, 121.0, 123.6, 125.1, 126.7, 130.9, 136.1, 142.8, 143.7. HRMS(ESI-TOF) Calcd for $C_{11}H_{10}N$, $[M+H]^+$ *m/z* 156.0813; Found 156.0811.



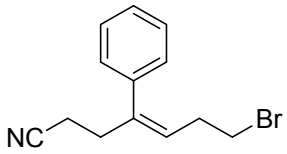

**(*E*)-4-(9*H*-carbazol-9-yl)but-3-enenitrile 4u**

White solid. mp: 88-89 ºC. Petroleum ether/ethyl acetate = 20/1 as eluent for column chromatography. $^1$H NMR (400 MHz; $CDCl_3$): $\delta$ = 3.39 (dd, $J_1$ = 1.6 Hz, $J_2$ = 6.0 Hz, 2H), 5.94 (dt, $J_1$ = 14.0, $J_2$ = 6.0 Hz, 1H), 7.30-7.34 (m, 3H), 7.47-7.51 (m, 2H), 7.58 (t, $J$ = 8.0 Hz, 2H), 8.07 (d, $J$ = 8.0 Hz, 2H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 19.0, 106.0, 110.2, 117.3, 120.3, 121.0, 124.1, 126.4, 127.7, 139.1. HRMS(ESI-TOF) Calcd for $C_{16}H_{13}N_2$, $[M+H]^+$ *m/z* 233.1079; Found 233.1076.




**4-(4-chlorophenyl)pent-4-enenitrile 4v and (E)-4-(4-chlorophenyl)pent-3-enenitrile 4v' (3:2)**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^{1}$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.07 (s, 3H), 2.47 (t, $J$ = 7.2 Hz, 2H), 2.83 (t, $J$ = 7.2 Hz, 2H), 3.25 (d, $J$ = 6.8 Hz, 2H), 5.23 (s, 1H), 5.41 (s, 1H), 5.70 (dt, $J_1$ = 7.2 Hz, $J_2$ = 1.2 Hz, 1H), 7.29-7.35 (m, 8H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 16.3, 16.4, 16.9, 31.1, 115.1, 115.4, 117.8, 118.8, 127.1, 127.4, 128.6, 128.8, 133.7, 134.0, 137.7, 140.3, 143.6. HRMS(ESI-TOF) Calcd for $C_{11}H_{11}ClN$, $[M+H]^+$ *m/z* 192.0580; Found 192.0575.




**7-bromo-4-phenylhept-4-enenitrile 6**

Colorless oil. Petroleum ether/ethyl acetate = 40/1 as eluent for column chromatography. $^{1}$H NMR (400 MHz; $CDCl_3$): $\delta$ = 2.35 (t, $J$ = 7.2 Hz, 2H), 2.83-2.91 (m, 4H), 3.51 (t, $J$ = 6.8 Hz, 2H), 5.78 (t, $J$ = 7.2 Hz, 1H), 7.29-7.40 (m, 5H); $^{13}$C NMR (100 MHz, $CDCl_3$): $\delta$ = 16.2, 25.9, 31.8, 32.2, 119.0, 126.5, 127.7, 128.2, 128.6, 139.0, 140.3. HRMS(ESI-TOF) Calcd for $C_{13}H_{15}BrN$, $[M+H]^+$ *m/z* 264.0388, 266.0367; Found 264.0385, 266.0363.

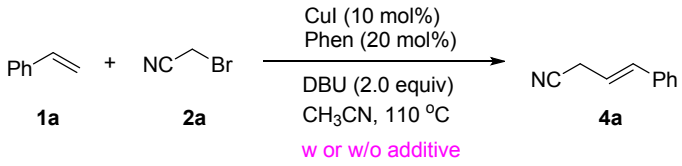
## 5. Mechanistic Study

### 5.1 Radical Inhibition Experiments


**1a** **2a** **3a**

| Additive | **3a**, yield (%) |
|---|---|
| none | 91 |
| BHT (2 equiv) | 10 |
| TEMPO (2 equiv) | 0 |

Reactions were carried out with **1a** (0.3 mmol), **2a** (0.60 mmol), CuI (10 mol %), and Phen (20 mol %) in $CH_3CN$ (1 mL) under $N_2$ atmosphere at 110 °C for 1.0 h. Yield of the isolated product.

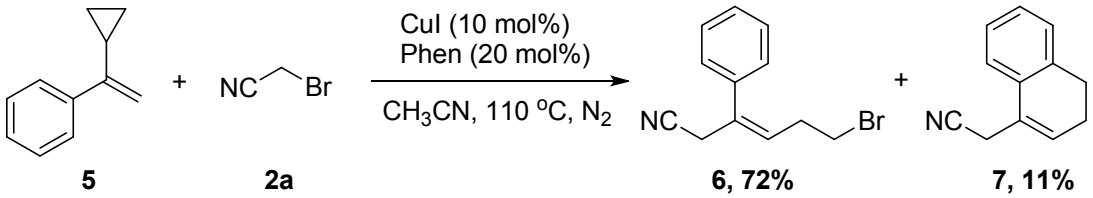



**1a** **2a** **4a**

| Additive | **4a**, yield (%) |
|---|---|
| none | 90 |
| BHT (2 equiv) | 16 |
| TEMPO (2 equiv) | 0 |

Reactions were carried out with **1a** (0.3 mmol), **2a** (0.6 mmol), CuI (10 mol %), Phen (20 mol %) and DBU (2.0 equiv) in $CH_3CN$ (1 mL) under $N_2$ atmosphere at 110 °C for 1.0 h. Yield of the isolated product.

**5.2 Radical Clock Experiment**

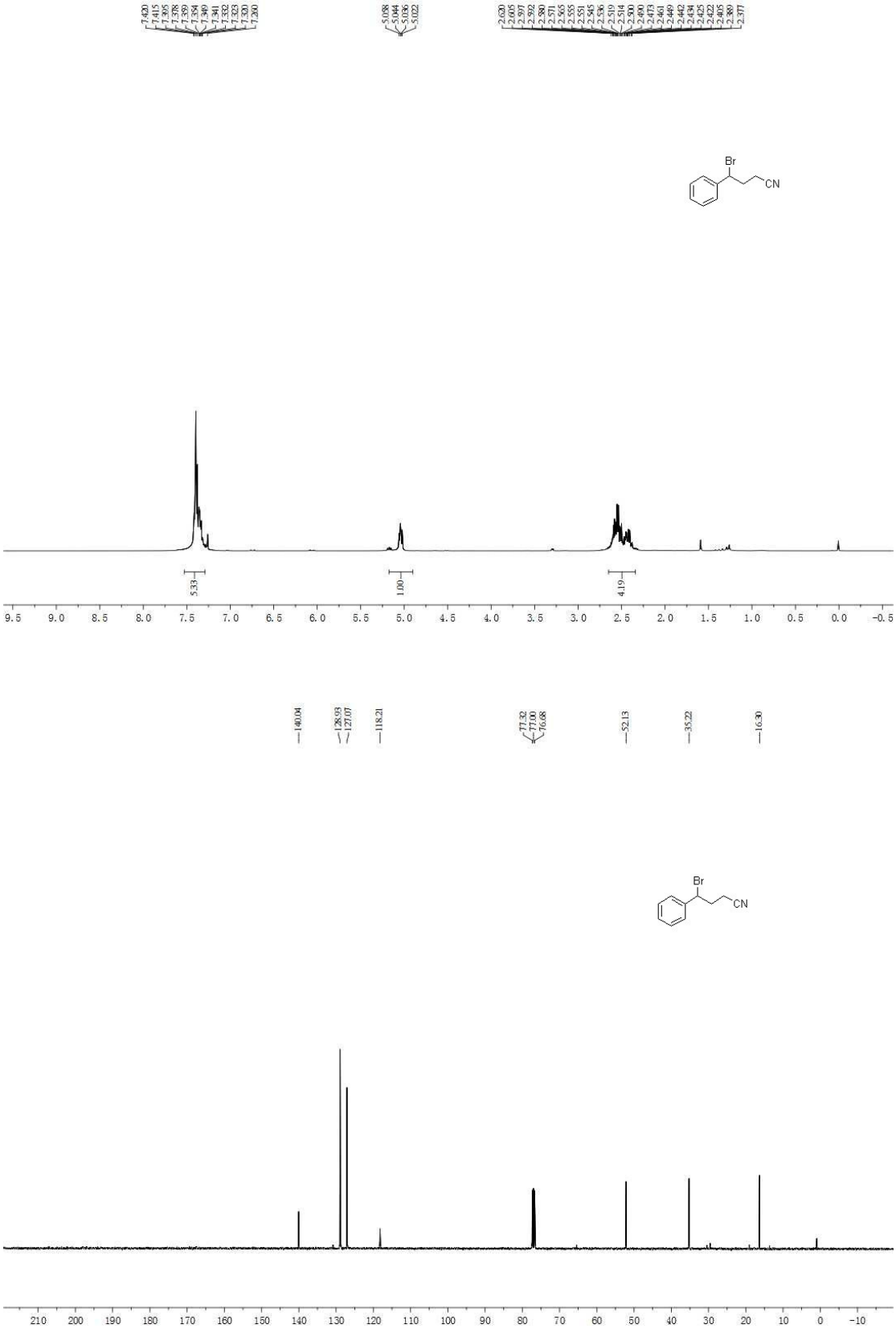



**5** **2a** **6, 72%** **7, 11%**

To a solution of the styrene **5** (43.3 mg, 0.3 mmol) in $CH_3CN$ (1.0 ml) was added the $\alpha$-bromoacetonitrile **2a** (38 μL, 0.60 mmol), Phen (10.8 mg, 0.06 mmol), and CuI (5.7 mg, 0.03 mmol) under $N_2$ in a Schlenck tube. The reaction mixture was stirred at 110 °C for 1.0 h. After the reaction finished, the reaction mixture was cooled to room temperature and quenched by water. The mixture was extracted with EtOAc (3.0 mL×3), the combined organic phases were dried over anhydrous $Na_2SO_4$ and the solvent was evaporated under vacuum. The residue was purified by column chromatography (petroleum ether /ethyl acetate = 40:1) to give the corresponding products **6** and **7** (59.6 mg, total yield 83%).

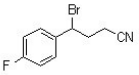
## 6. $^{1}H$ and $^{13}C$ NMR Spectra of Compounds 3, 4 and 6

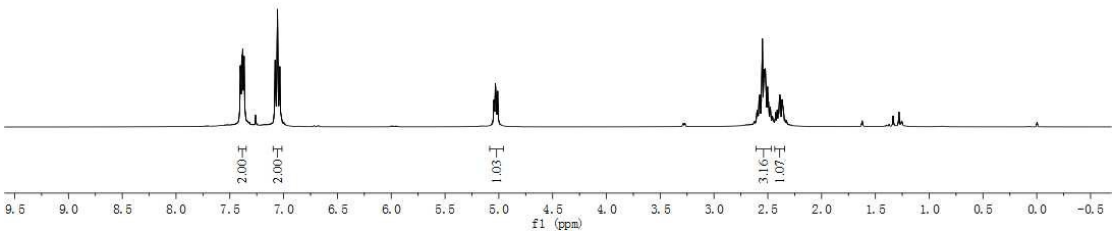
### Product 3a

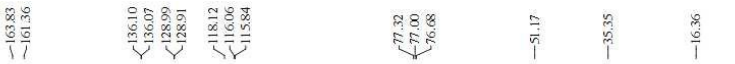


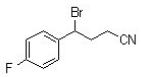
**Product 3b**

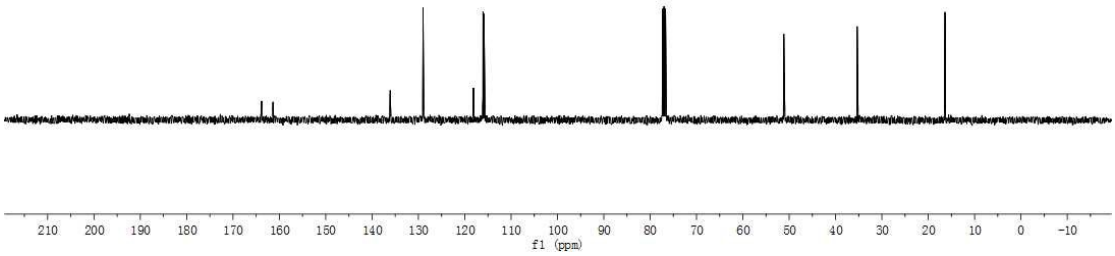

7.402
7.389
7.381
7.368
7.260
7.079
7.057
7.036
5.046
5.031
5.025
5.011
2.580
2.573
2.550
2.535
2.532
2.523
2.502
2.493
2.388
2.384
2.368
2.358


Br
CN
F

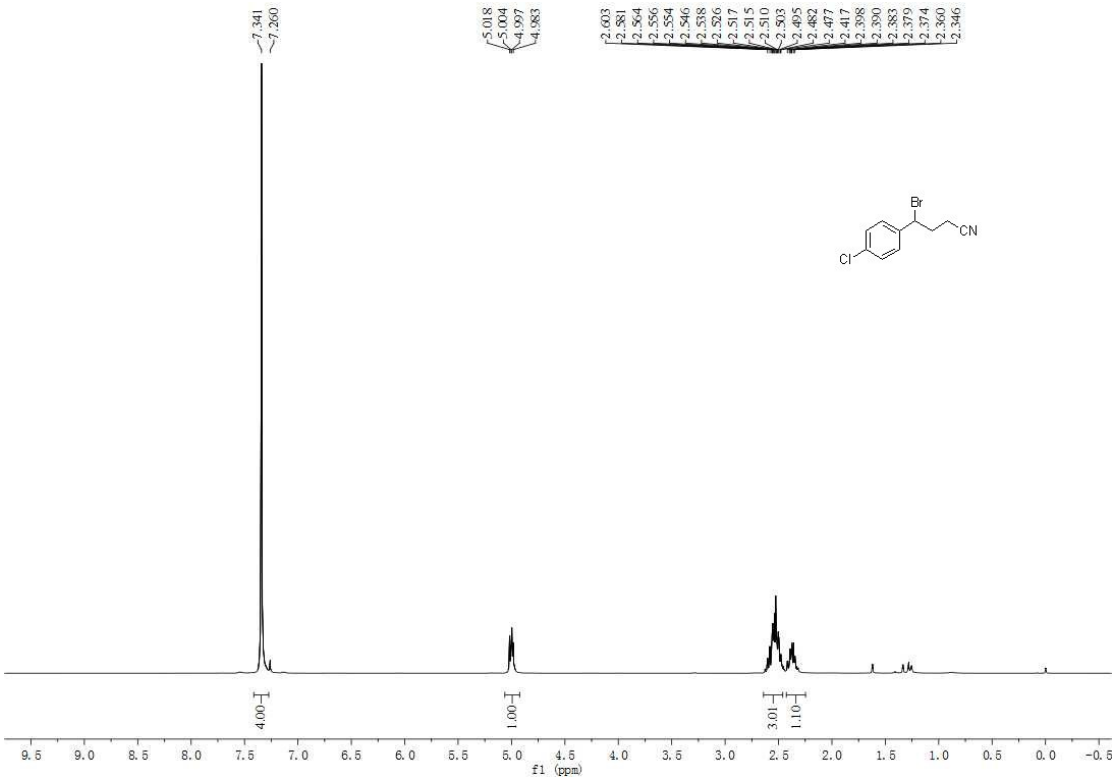

2.00
2.00
1.03
3.16
1.07
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

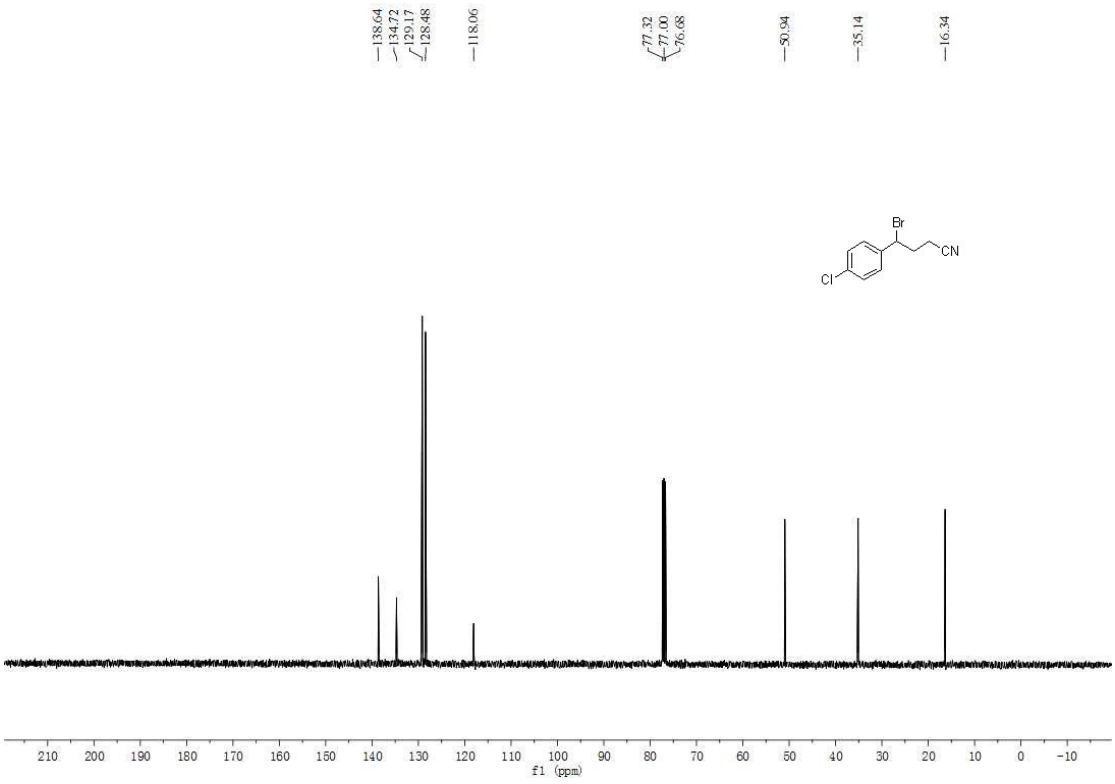

163.83
161.36
136.10
136.07
128.99
128.91
118.12
116.06
115.84
77.32
77.00
76.68
51.17
35.35
16.36


Br
CN
F

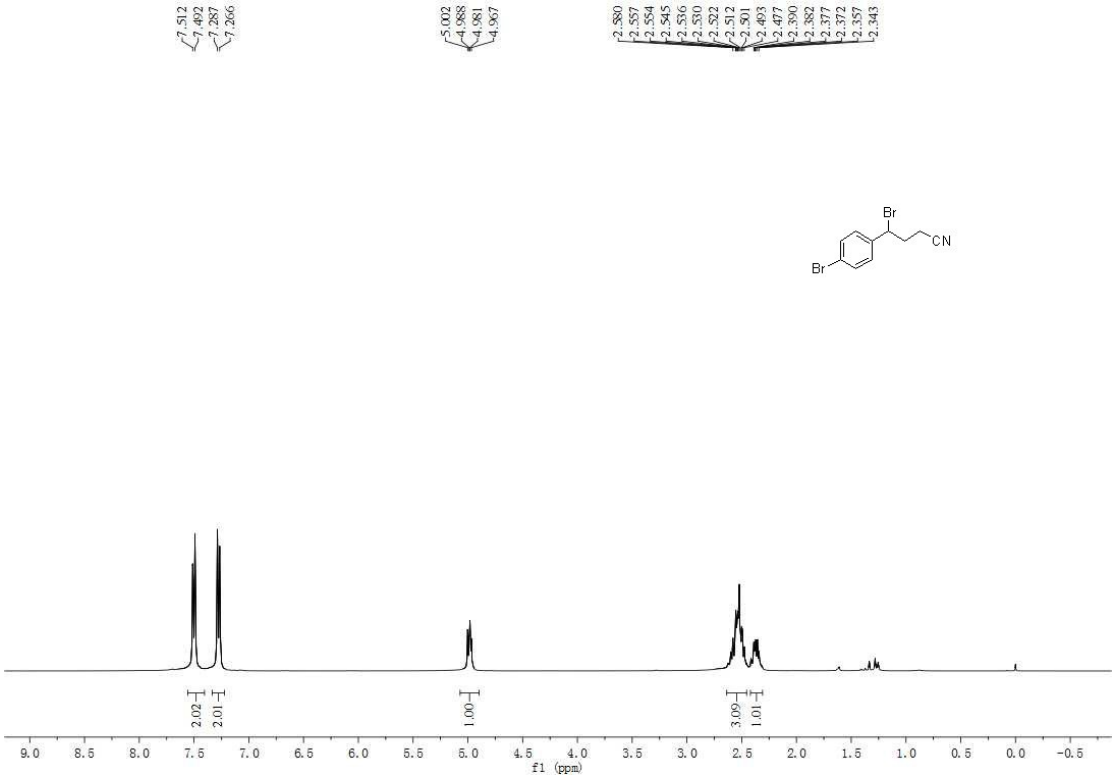

210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

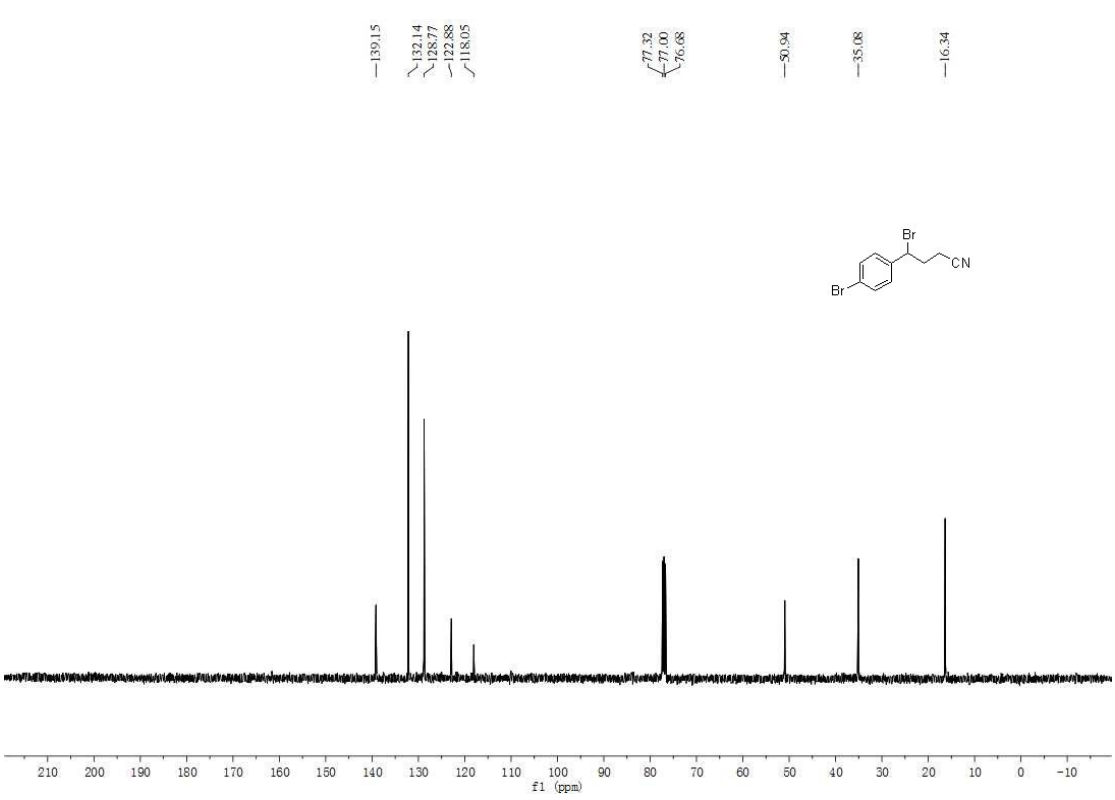
**Product 3c**


7.341
7.260
5.018
5.004
4.997
4.983
2.603
2.581
2.564
2.556
2.554
2.546
2.538
2.526
2.517
2.515
2.510
2.503
2.495
2.482
2.477
2.417
2.398
2.390
2.383
2.379
2.374
2.360
2.346
Br
CN
Cl
4.00
1.00
3.01
1.10
f1 (ppm)

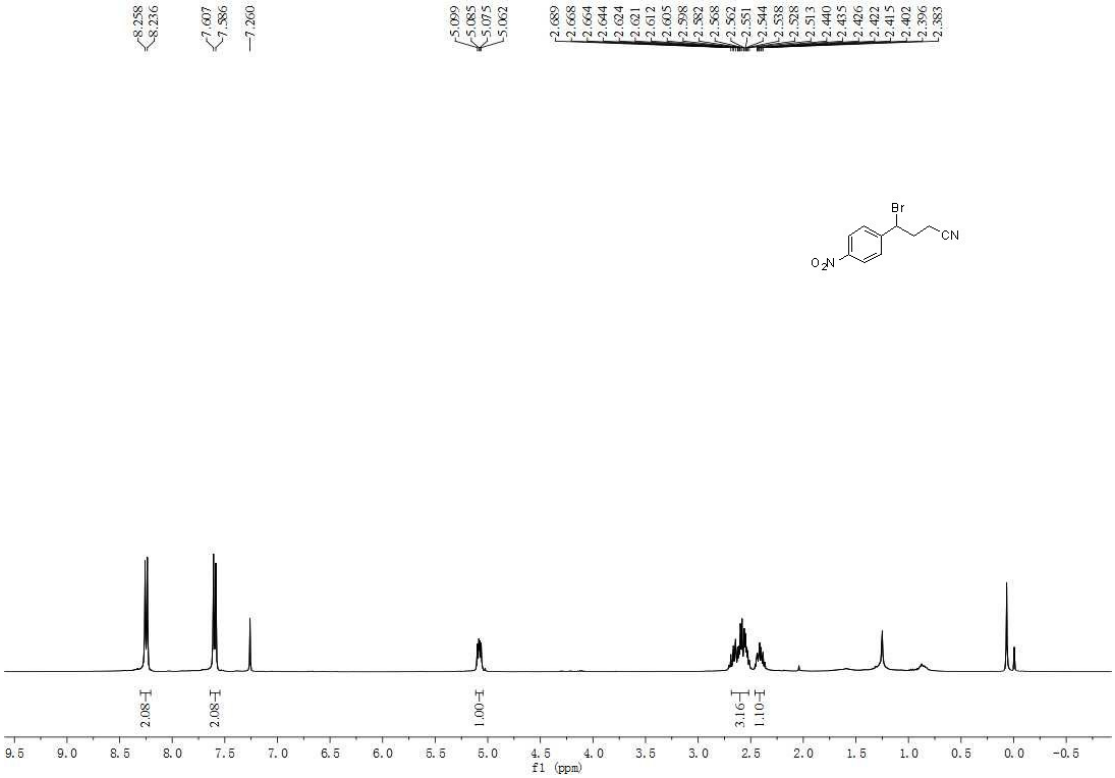

138.64
134.72
129.17
128.48
118.06
77.32
77.00
76.68
50.94
35.14
16.34
Br
CN
Cl
f1 (ppm)

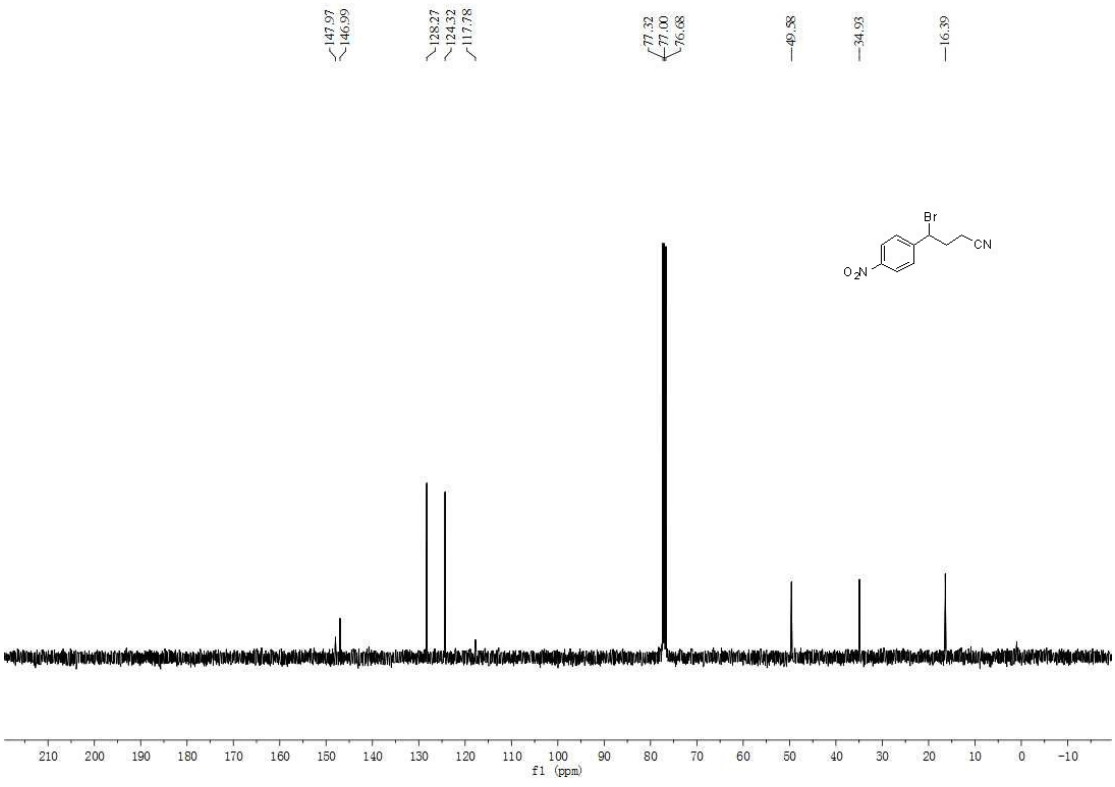
**Product 3d**


7.512
7.402
7.287
7.266
5.002
4.988
4.981
4.967
2.580
2.557
2.554
2.545
2.536
2.530
2.522
2.512
2.501
2.493
2.477
2.390
2.382
2.377
2.372
2.357
2.343
Br
CN
Br
2.02
2.01
1.00
3.09
1.01
f1 (ppm)

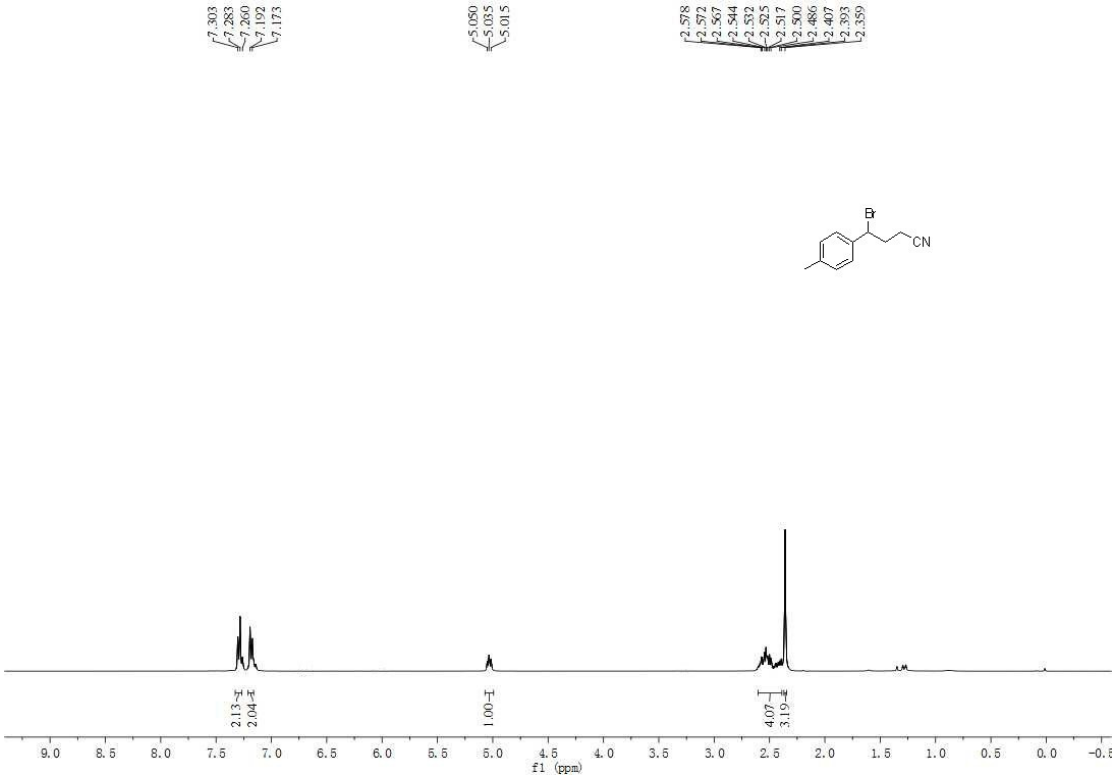

139.15
132.14
128.77
122.88
118.05
77.32
77.00
76.68
50.94
35.08
16.34
Br
CN
Br
f1 (ppm)

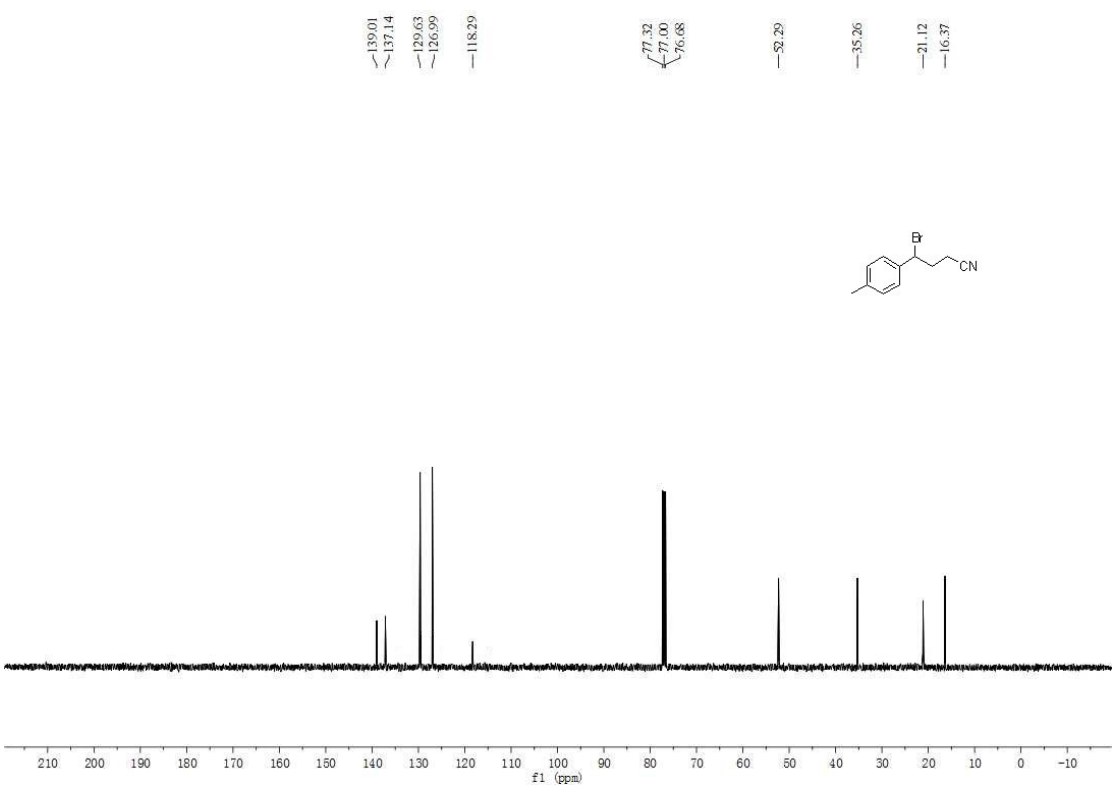
**Product 3e**


8.258
8.236
7.607
7.586
7.260
5.099
5.085
5.075
5.062
2.689
2.668
2.664
2.644
2.624
2.621
2.612
2.605
2.598
2.582
2.568
2.562
2.551
2.544
2.538
2.528
2.513
2.440
2.435
2.426
2.422
2.415
2.402
2.396
2.383
Br
CN
O2N
2.08
2.08
1.00
3.16
1.10
f1 (ppm)

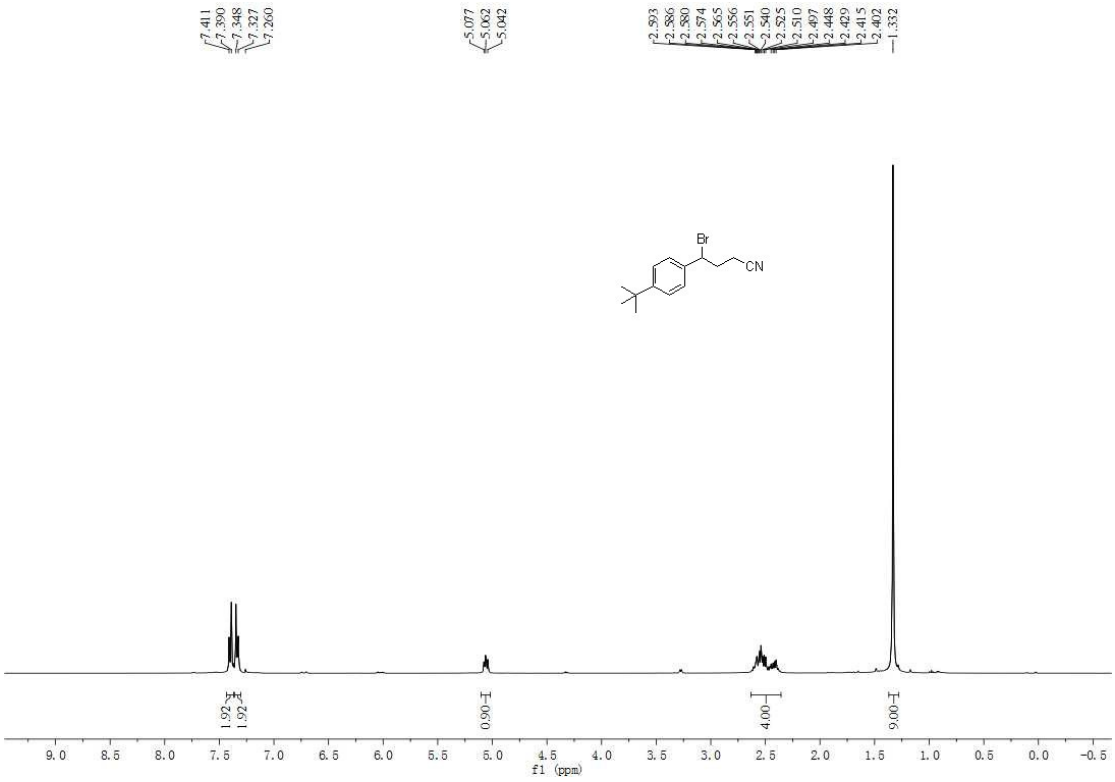

147.97
146.99
128.27
124.32
117.78
77.32
77.00
76.68
49.58
34.93
16.39
Br
CN
O2N
f1 (ppm)

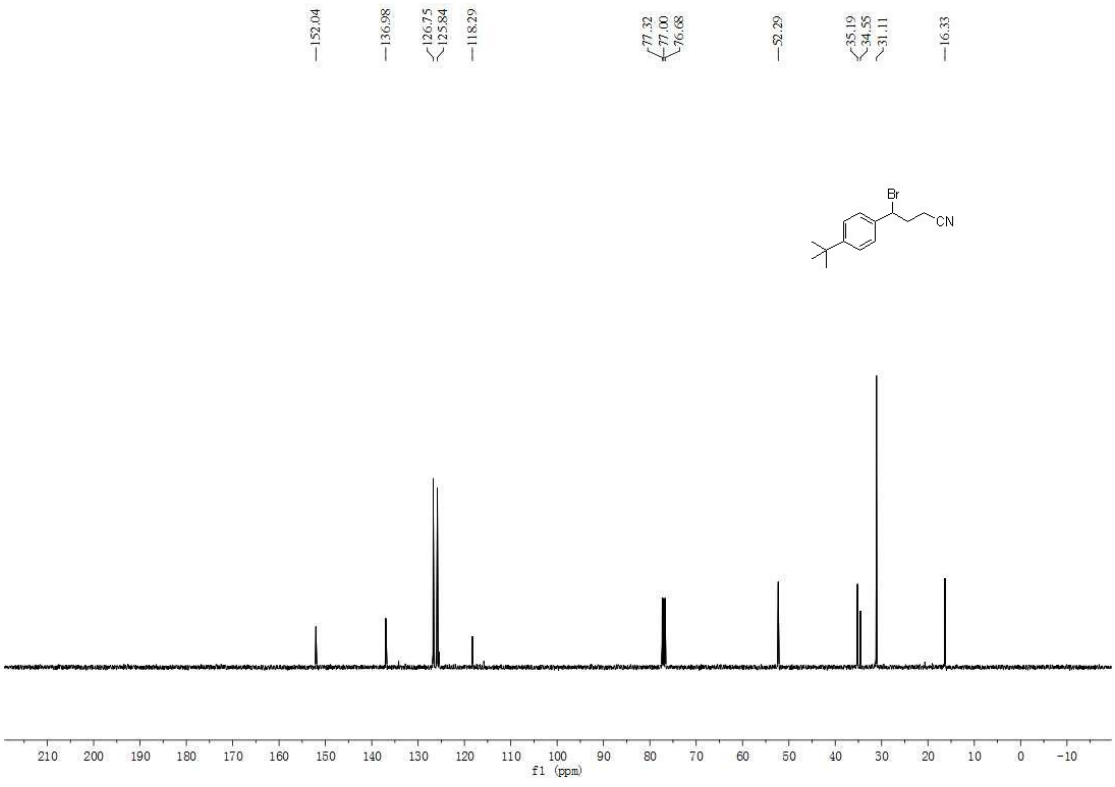
**Product 3f**


7.303
7.283
7.260
7.192
7.173
5.050
5.035
5.015
2.578
2.572
2.567
2.544
2.532
2.525
2.517
2.500
2.486
2.407
2.393
2.359
Br
CN
2.13
2.04
1.00
4.07
3.19
f1 (ppm)

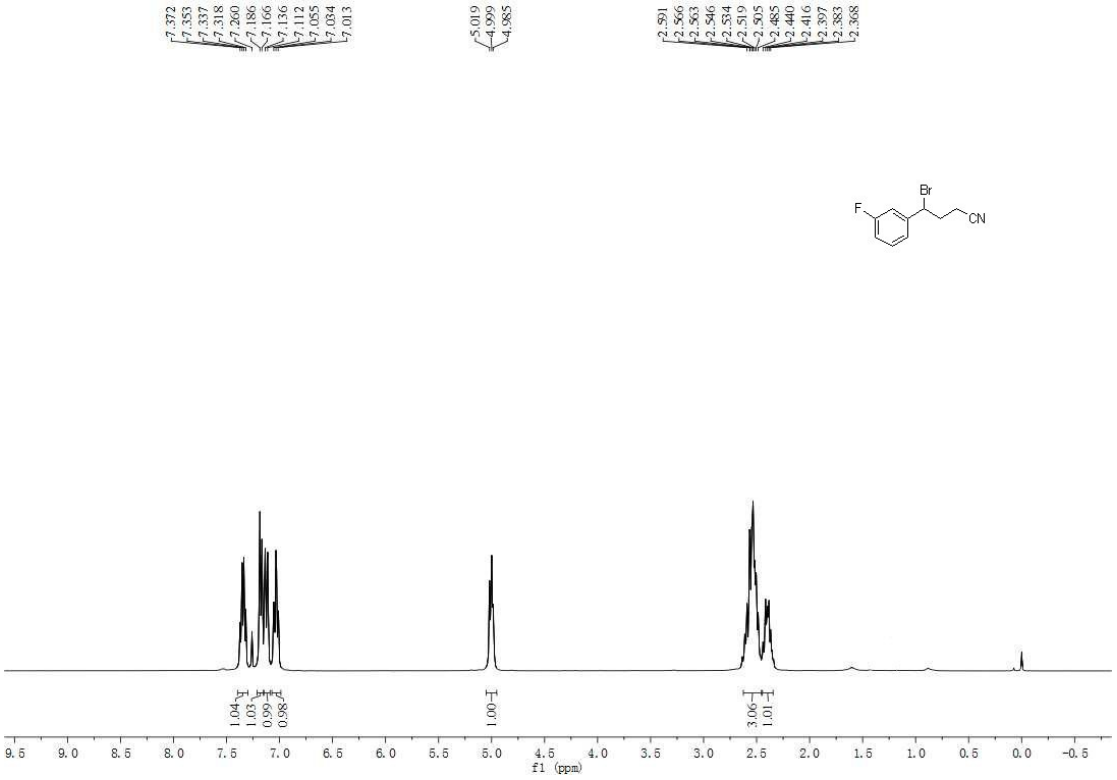

139.01
137.14
129.63
126.99
118.29
77.32
77.00
76.68
52.29
35.26
21.12
16.37
Br
CN
f1 (ppm)

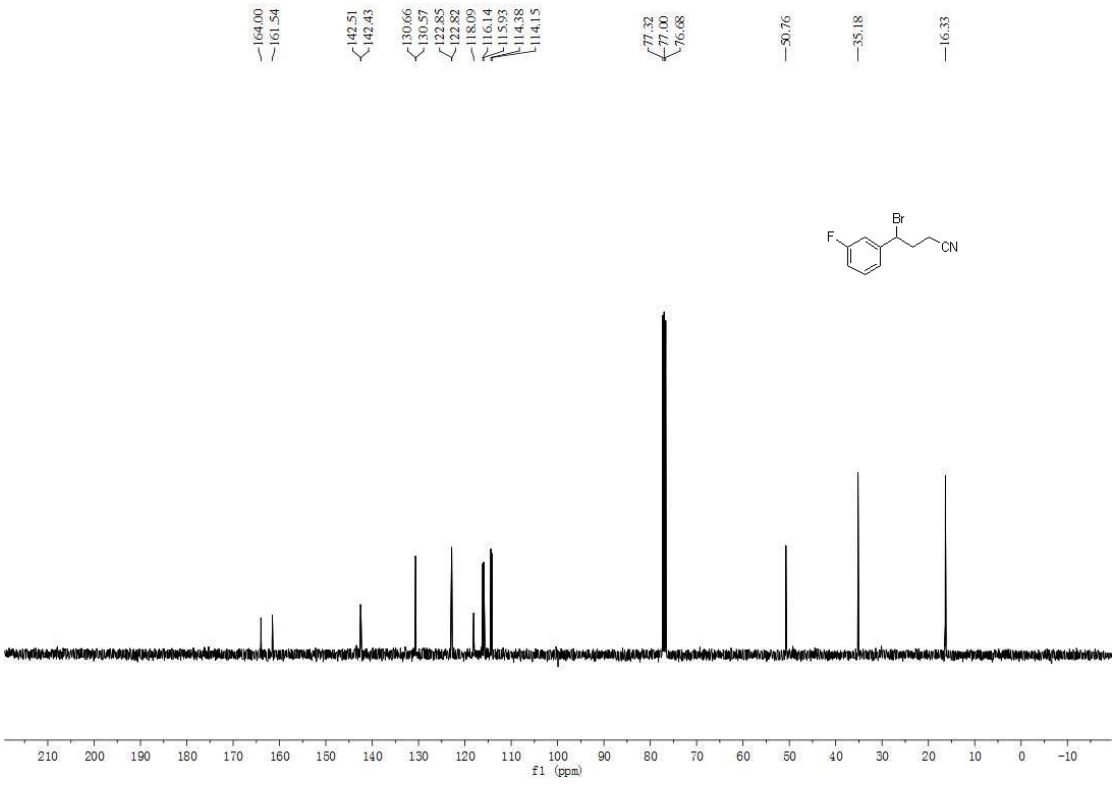
**Product 3g**


7.411
7.390
7.348
7.327
7.260
5.077
5.062
5.042
2.593
2.586
2.580
2.574
2.565
2.556
2.551
2.540
2.525
2.510
2.497
2.448
2.429
2.415
2.402
1.332
Br
CN
1.92
1.92
0.90
4.00
9.00
f1 (ppm)

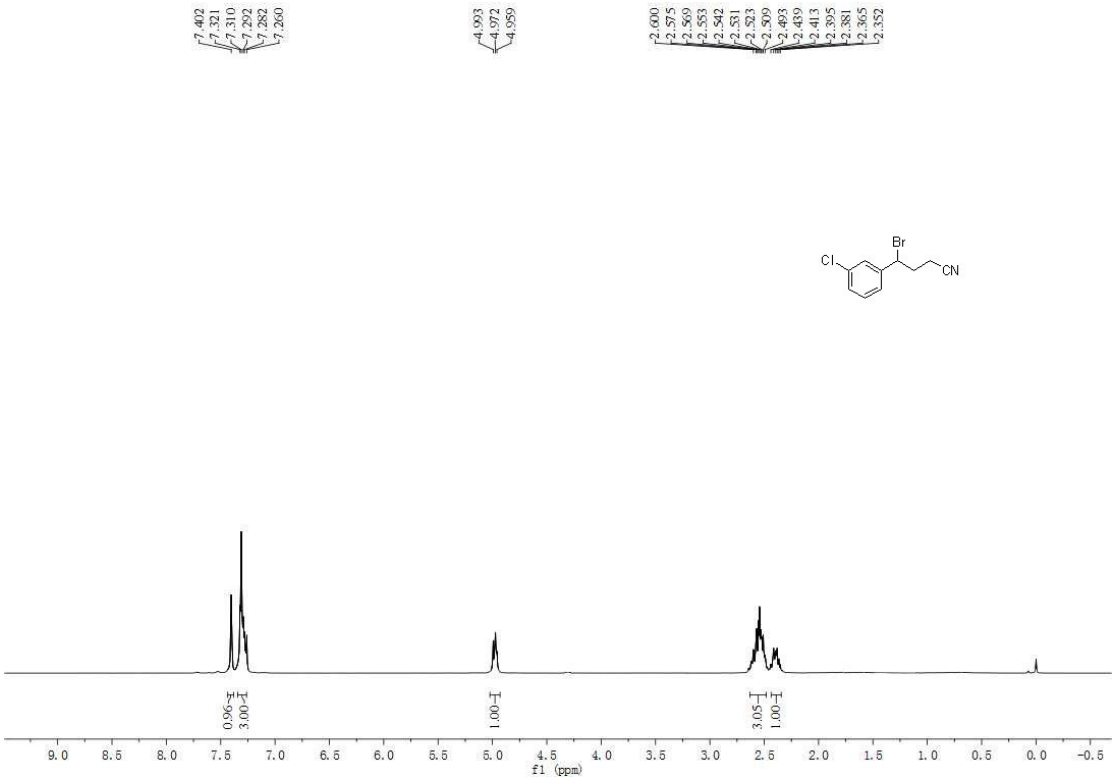

152.04
136.98
126.75
125.84
118.29
77.32
77.00
76.68
52.29
35.19
34.55
31.11
16.33
Br
CN
f1 (ppm)

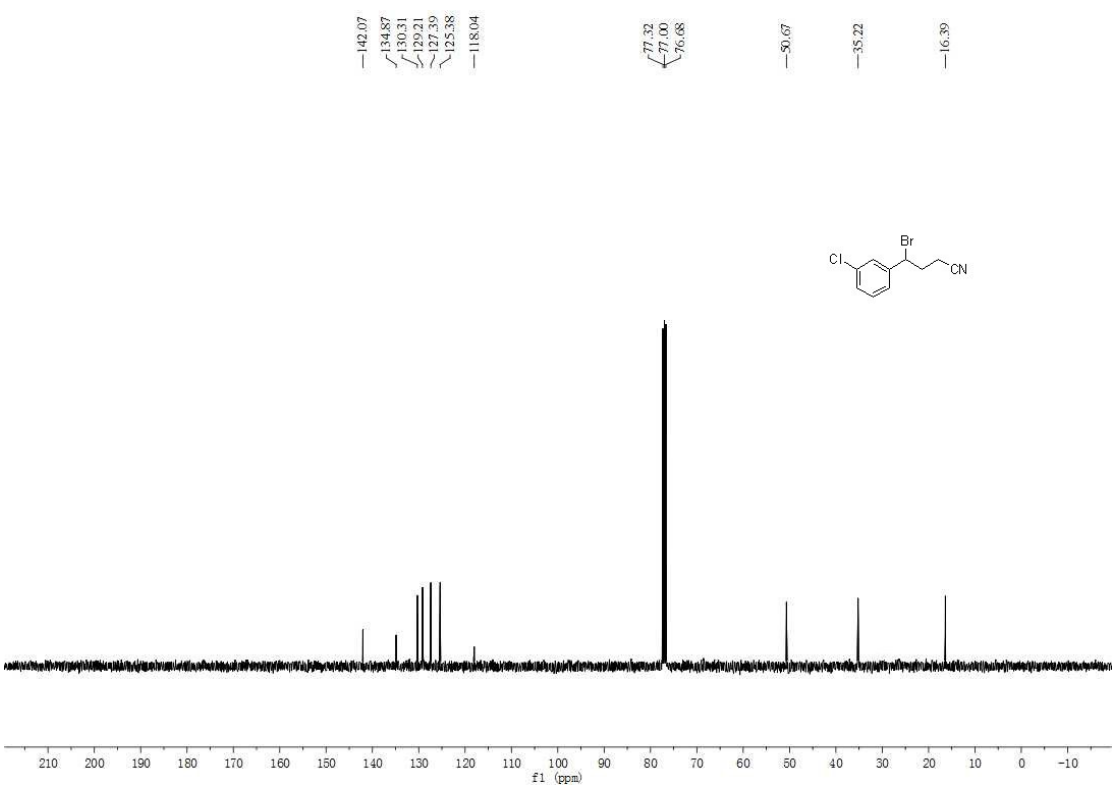
**Product 3h**


7.372
7.353
7.337
7.318
7.260
7.186
7.166
7.136
7.112
7.055
7.034
7.013
5.019
4.999
4.985
2.591
2.566
2.563
2.546
2.534
2.519
2.505
2.485
2.440
2.416
2.397
2.383
2.368
Br
F
CN
1.04
1.03
0.99
0.98
1.00
3.06
1.01
f1 (ppm)

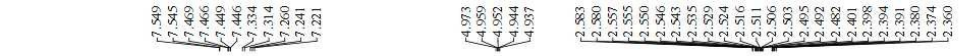

164.00
161.54
142.51
142.43
130.66
130.57
122.85
122.82
118.09
116.14
115.93
114.38
114.15
77.32
77.00
76.68
50.76
35.18
16.33
Br
F
CN
f1 (ppm)

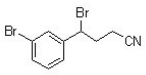
**Product 3i**

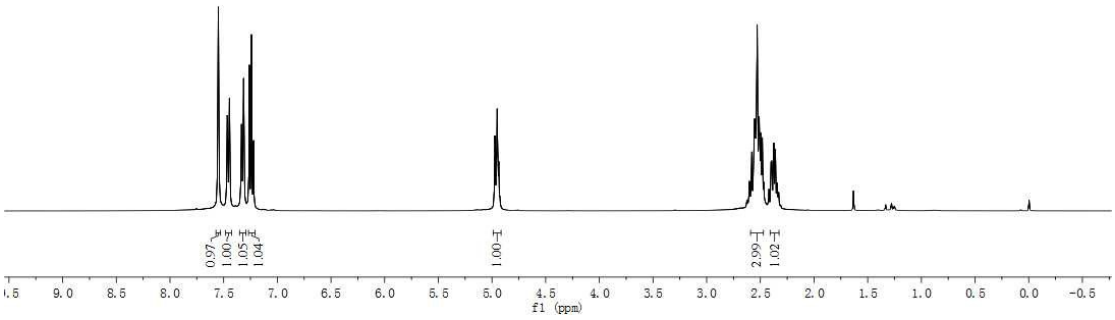

7.402
7.321
7.310
7.292
7.282
7.260
4.993
4.972
4.959
2.600
2.575
2.569
2.553
2.542
2.531
2.523
2.509
2.493
2.439
2.413
2.395
2.381
2.365
2.352
Br
Cl
CN
0.96
3.00
1.00
3.05
1.00
f1 (ppm)


142.07
134.87
130.31
129.21
127.39
125.38
118.04
77.32
77.00
76.68
50.67
35.22
16.39
Br
Cl
CN
f1 (ppm)

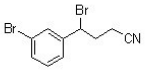
**Product 3j**

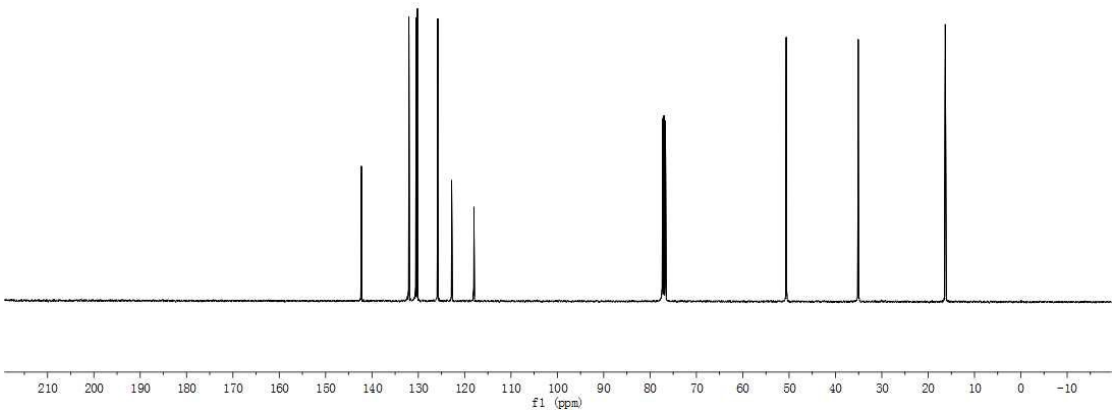

7.549
7.545
7.469
7.466
7.449
7.446
7.334
7.314
7.260
7.241
7.221
4.973
4.959
4.952
4.944
4.937
2.583
2.580
2.557
2.555
2.550
2.546
2.543
2.535
2.529
2.524
2.516
2.511
2.506
2.503
2.495
2.492
2.482
2.401
2.398
2.394
2.391
2.380
2.374
2.360


Br
Br
CN


0.97
1.00
1.05
1.04
1.00
2.99
1.02
f1 (ppm)

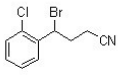

142.25
132.03
130.50
130.19
125.80
122.81
118.00
77.32
77.00
76.68
50.61
35.10
16.30

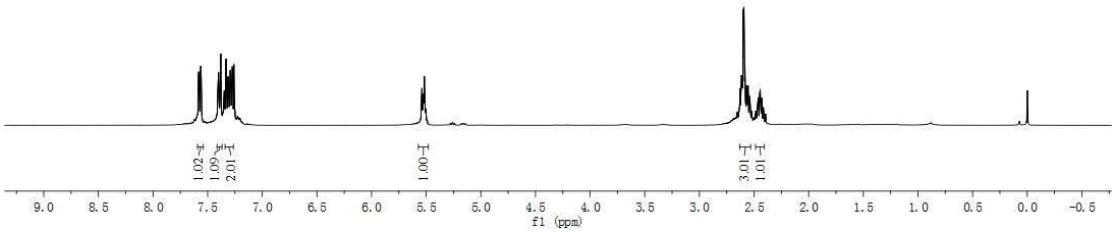

Br
Br
CN


f1 (ppm)

**Product 3k**


7.384
7.380
7.564
7.560
7.403
7.399
7.383
7.380
7.332
7.329
7.313
7.310
7.294
7.290
7.275
7.271
7.260
5.540
5.527
5.517
5.504
2.627
2.615
2.606
2.599
2.592
2.583
2.568
2.560
2.554
2.539
2.466
2.461
2.448
2.443
2.428
2.415

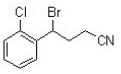

Cl
Br
CN

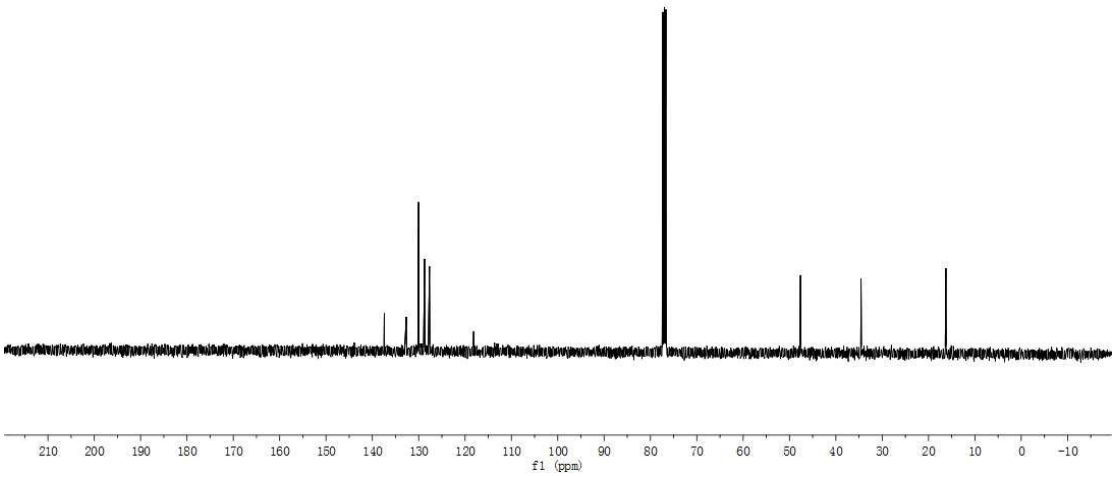

1.02
1.09
2.01
1.00
3.01
1.01
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


137.43
132.69
130.02
128.75
127.69
118.14


77.32
77.00
76.68

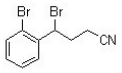

47.62
34.56
16.26

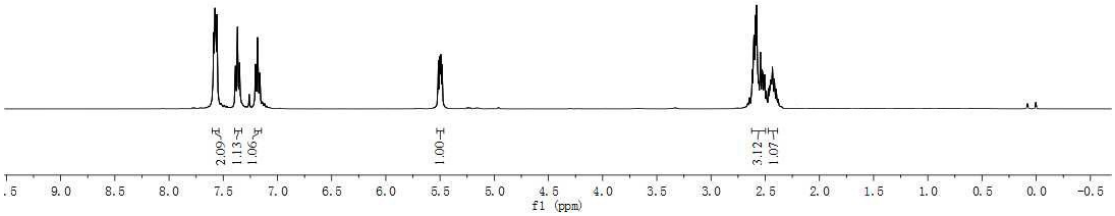

Cl
Br
CN


210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

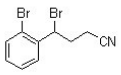
**Product 3l**

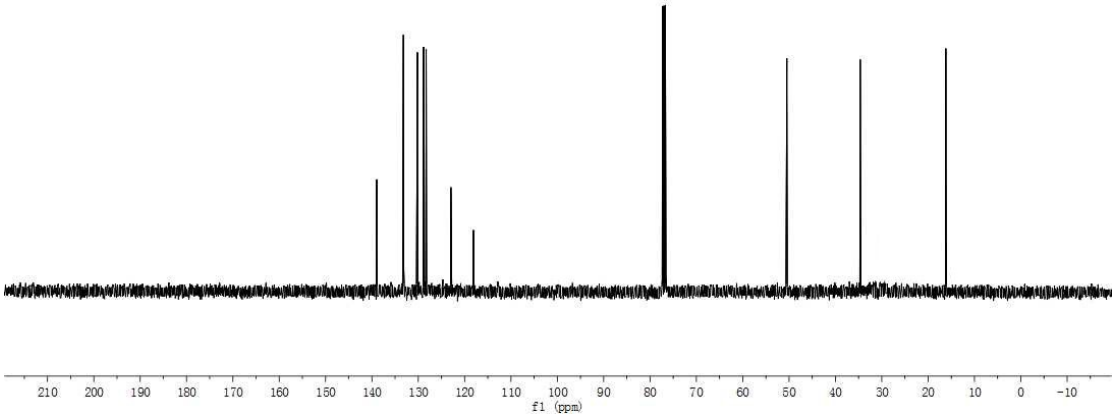

7.587
7.576
7.571
7.568
7.558
7.387
7.368
7.350
7.260
7.203
7.200
7.183
7.165
7.161
5.515
5.502
5.493
5.481
2.619
2.604
2.590
2.580
2.574
2.544
2.528
2.522
2.505
2.467
2.457
2.449
2.445
2.433
2.415
2.398


Br
Br
CN

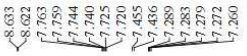

2.09
1.13
1.06
1.00
3.12
1.07
f1 (ppm)


138.97
133.20
130.19
128.86
128.28
122.96
118.11
77.32
77.00
76.68
50.48
34.65
16.18

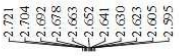

Br
Br
CN

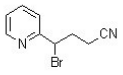

f1 (ppm)

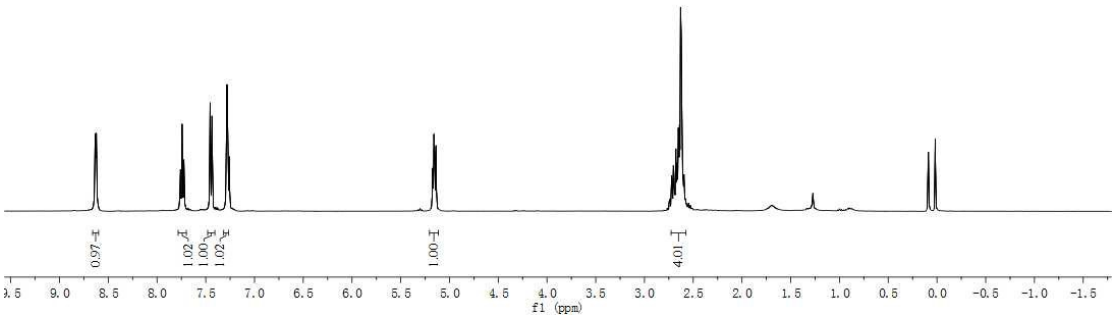
**Product 3m**


8.633
8.622
7.763
7.759
7.744
7.740
7.725
7.720
7.455
7.436
7.289
7.283
7.279
7.272
7.260


5.172
5.159
5.151
5.138

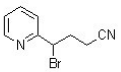

2.721
2.704
2.692
2.678
2.663
2.652
2.641
2.630
2.623
2.605
2.595


CN
N
Br


0.97
1.02
1.00
1.02
1.00
4.01
f1 (ppm)

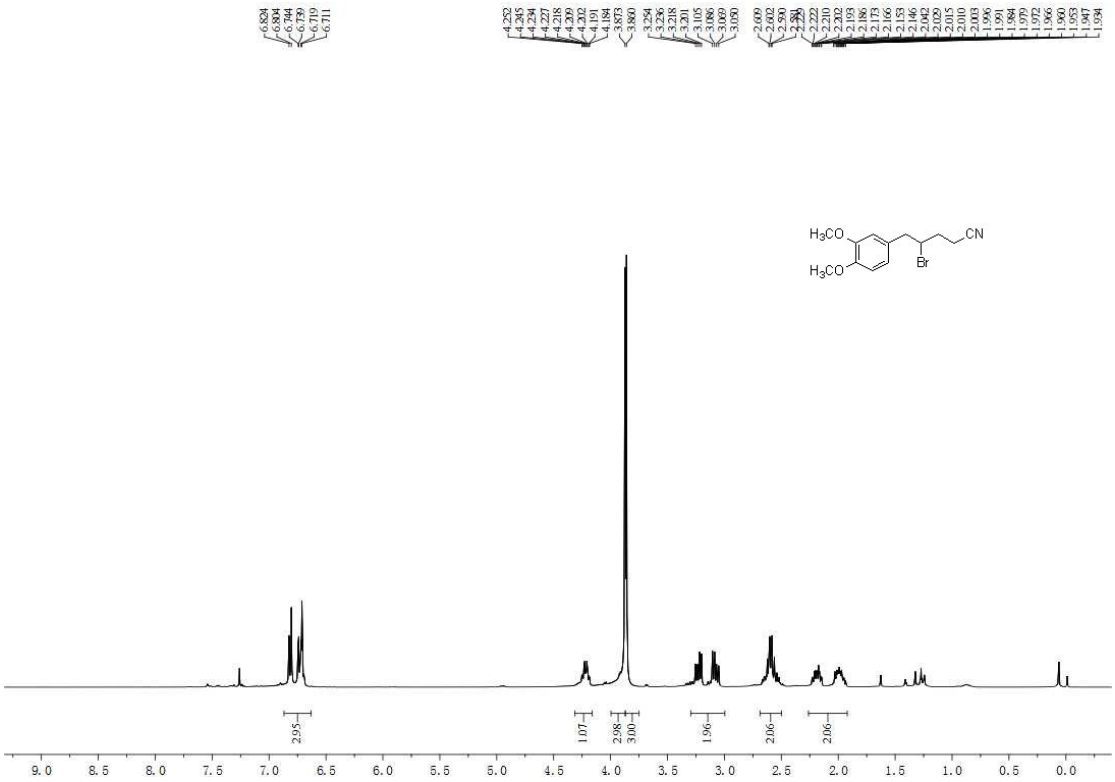

158.06
149.74
137.24
123.56
122.78
118.44

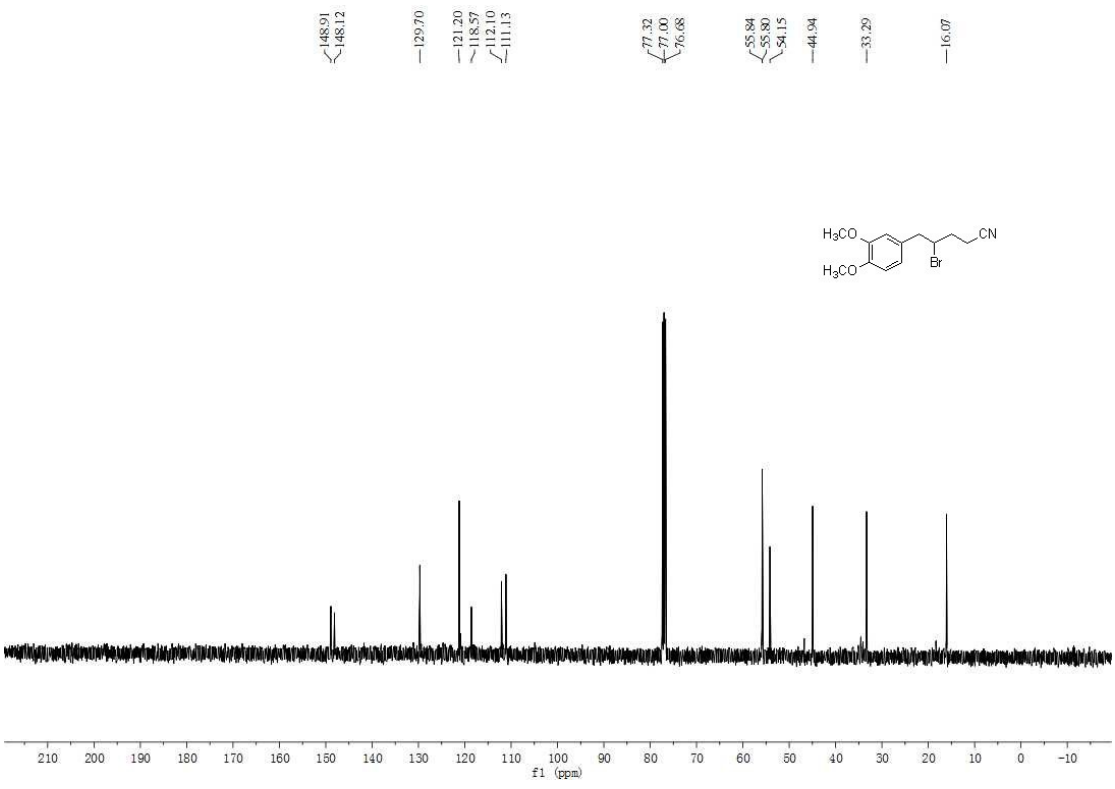

77.32
77.00
76.68
51.63
32.87
16.10


CN
N
Br

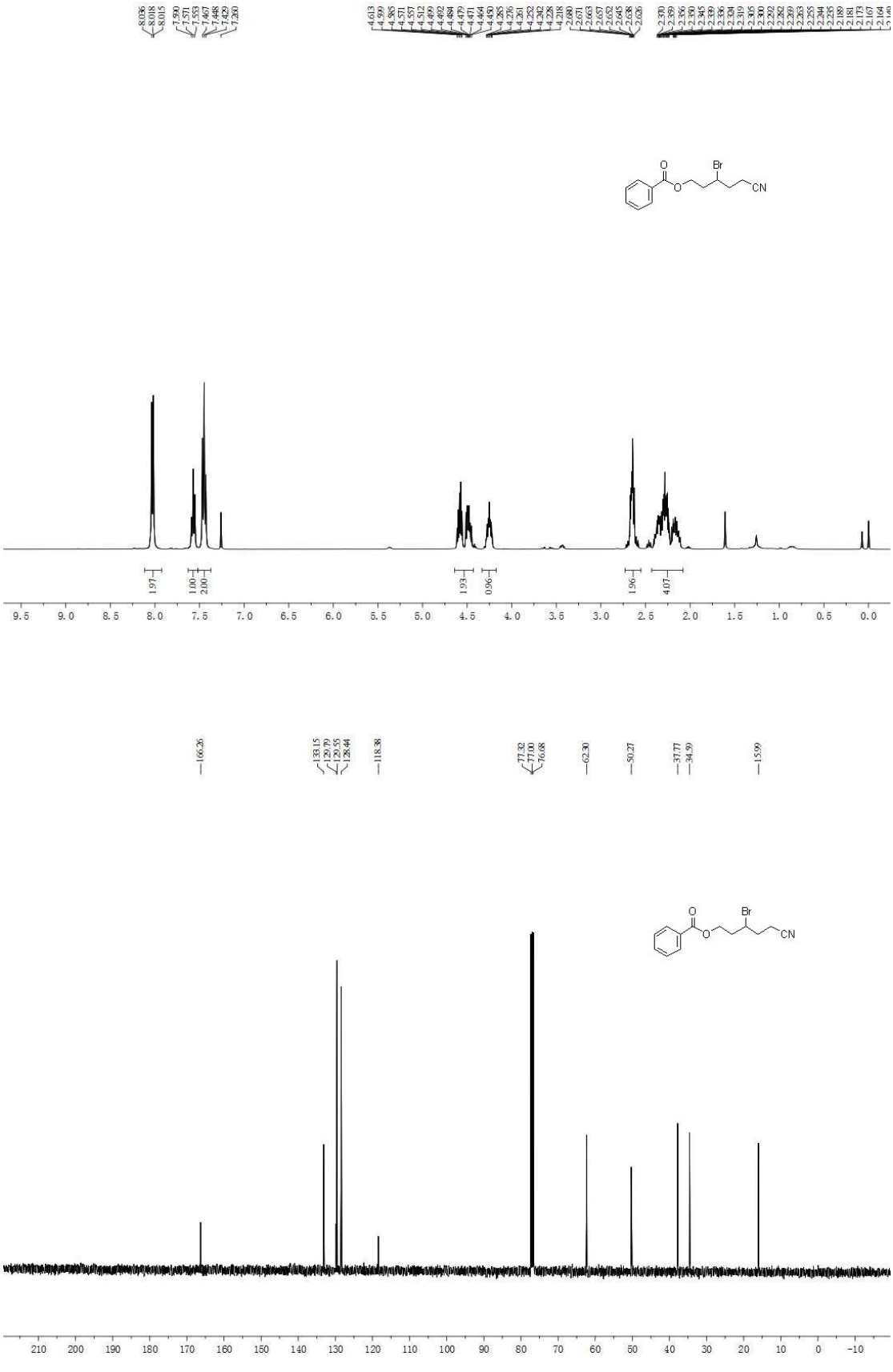

f1 (ppm)

**Product 3n**

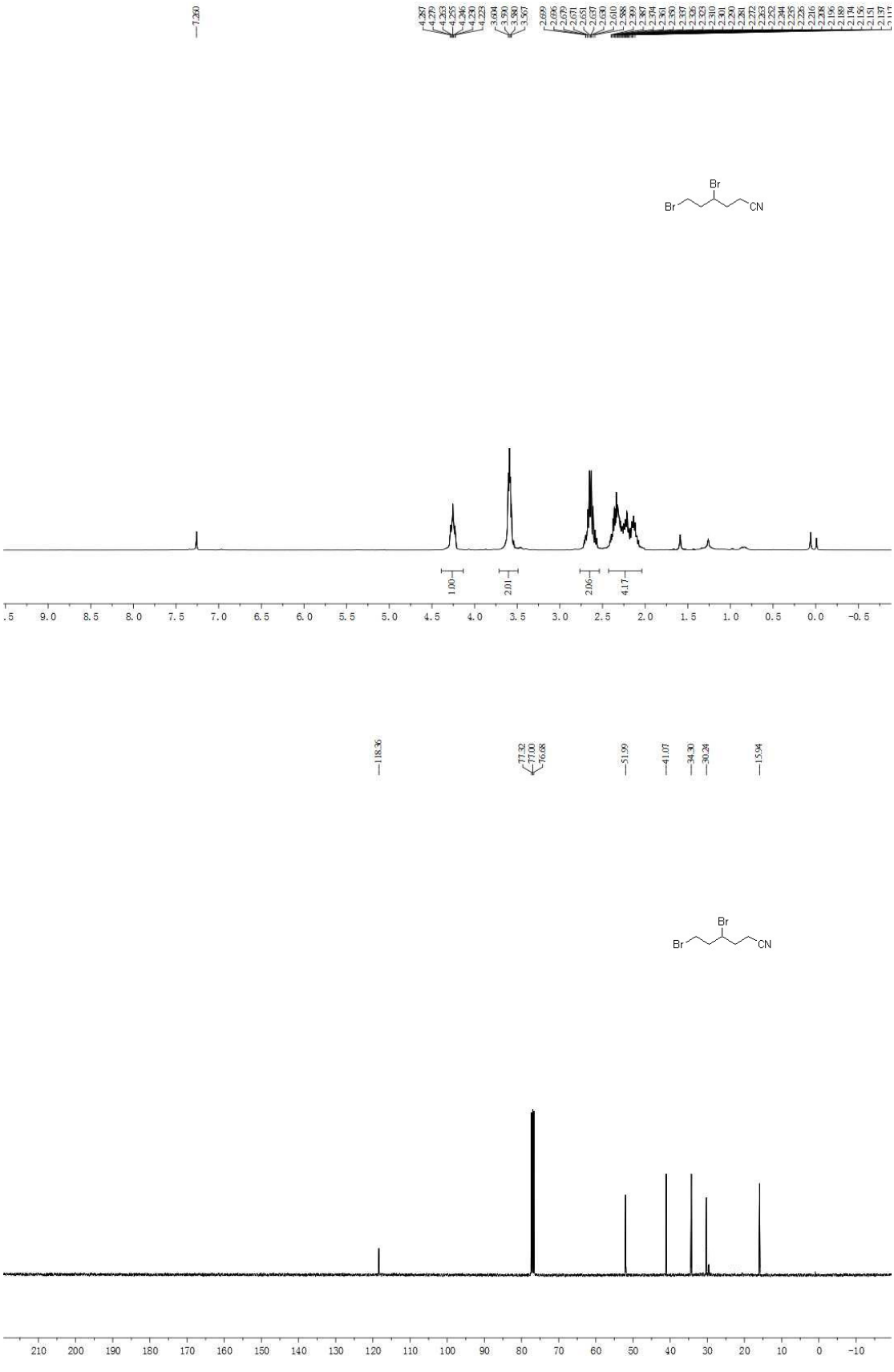

H3CO
H3CO
CN
Br
2.95
1.07
2.98
3.00
1.96
2.06
2.06


148.91
148.12
129.70
121.20
118.57
112.10
111.13
77.32
77.00
76.68
55.84
55.80
54.15
44.94
33.29
16.07
H3CO
H3CO
CN
Br
f1 (ppm)

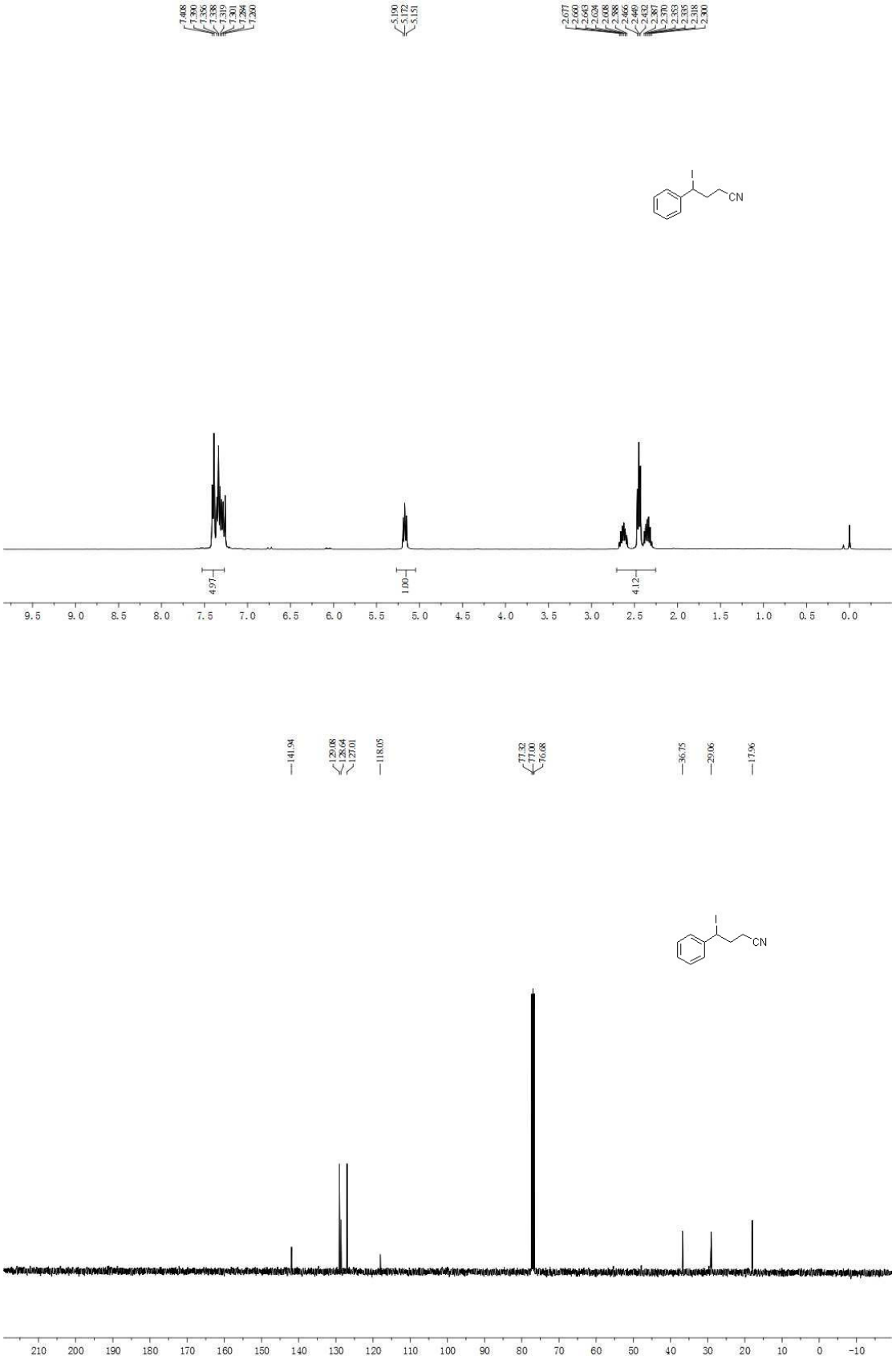
**Product 3o**


8.036
8.018
8.015
7.590
7.571
7.553
7.467
7.448
7.430
7.260
4.613
4.599
4.585
4.571
4.557
4.512
4.499
4.492
4.484
4.470
4.457
4.450
4.285
4.276
4.261
4.252
4.242
4.228
4.218
2.680
2.671
2.663
2.657
2.652
2.645
2.638
2.625
2.330
2.319
2.310
2.305
2.300
2.292
2.282
2.269
2.263
2.255
2.244
2.235
2.189
2.181
2.173
2.167
2.164
Br
O
CN
1.97
1.00
2.00
1.93
0.96
1.96
4.07
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
166.26
133.15
129.79
129.55
128.44
118.38
77.32
77.00
76.68
62.30
50.27
37.77
34.59
15.99
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10

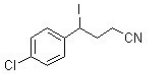
**Product 3p**

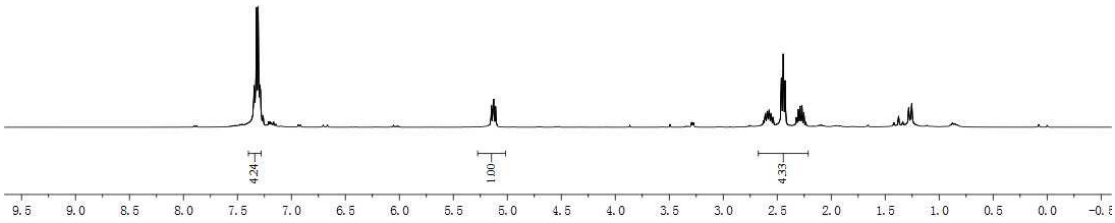


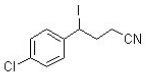
**Product 3q**

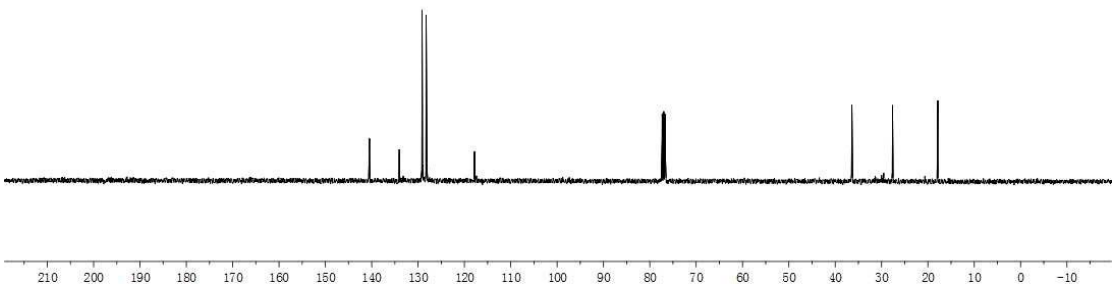

7.408
7.390
7.365
7.338
7.319
7.301
7.284
7.260
5.190
5.172
5.151
2.677
2.660
2.645
2.624
2.608
2.588
2.466
2.449
2.432
2.387
2.370
2.355
2.335
2.318
2.300
I
CN
4.97
1.00
4.12
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
141.94
129.08
128.64
127.01
118.05
77.32
77.00
76.68
36.75
29.06
17.96
I
CN
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

**Product 3r**

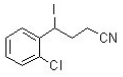

I
CN
Cl

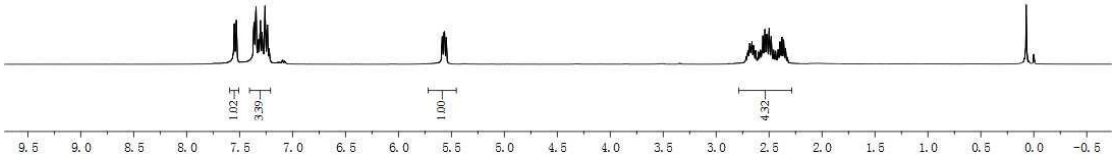

4.24
1.00
4.33
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0

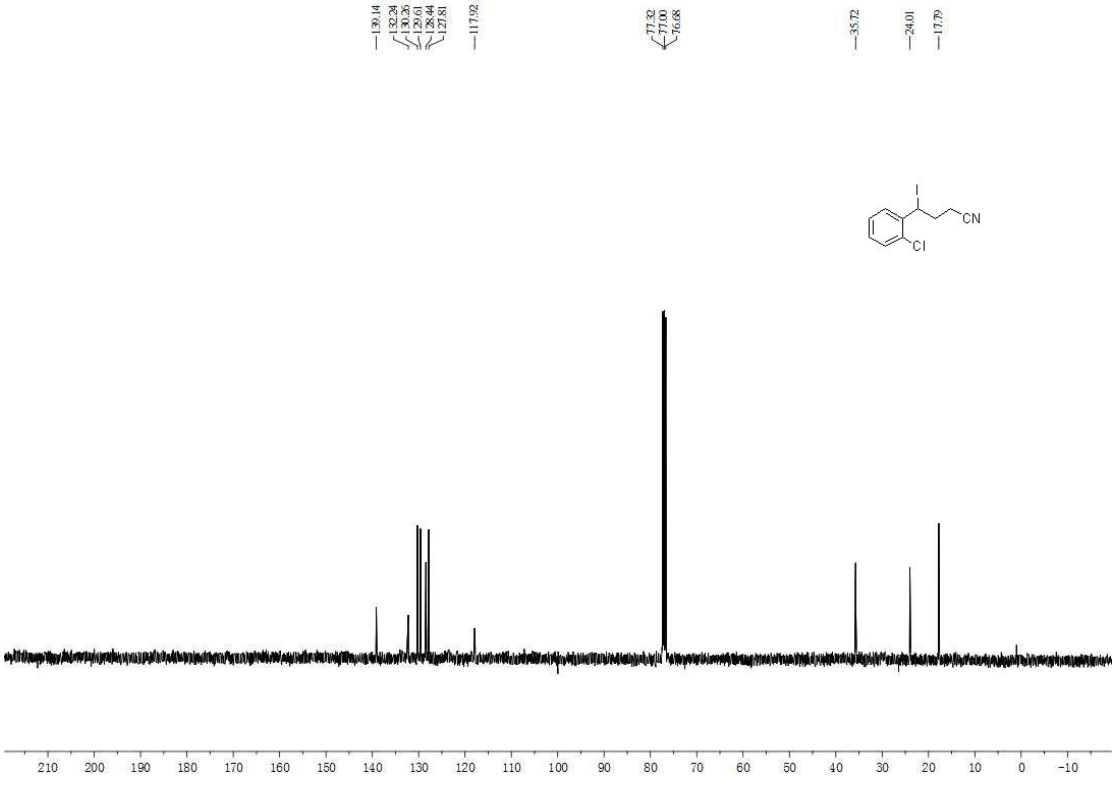

I
CN
Cl


210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

**Product 3s**

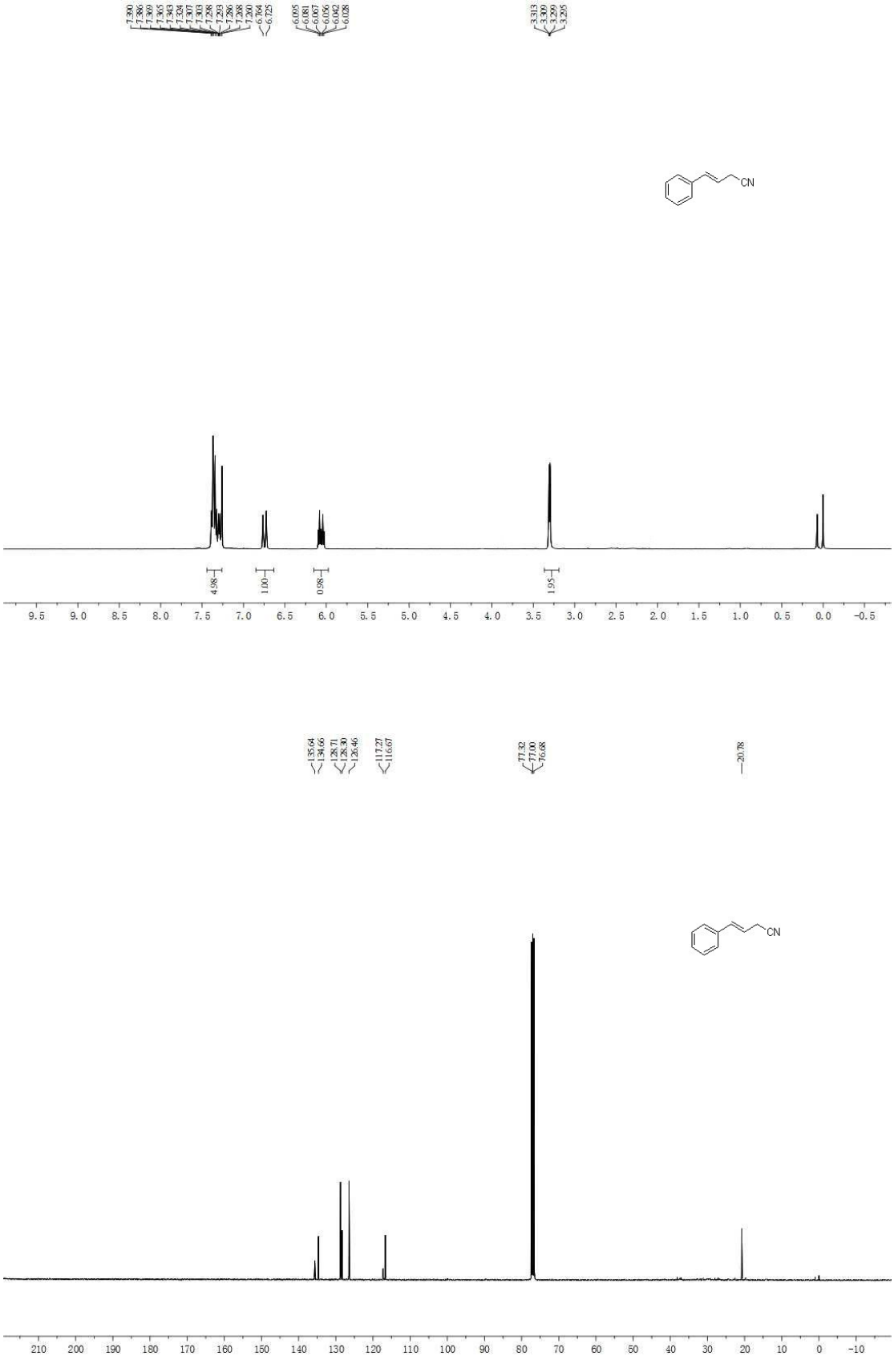

I
CN
Cl


1.02
3.39
1.00
4.32
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 -0.5

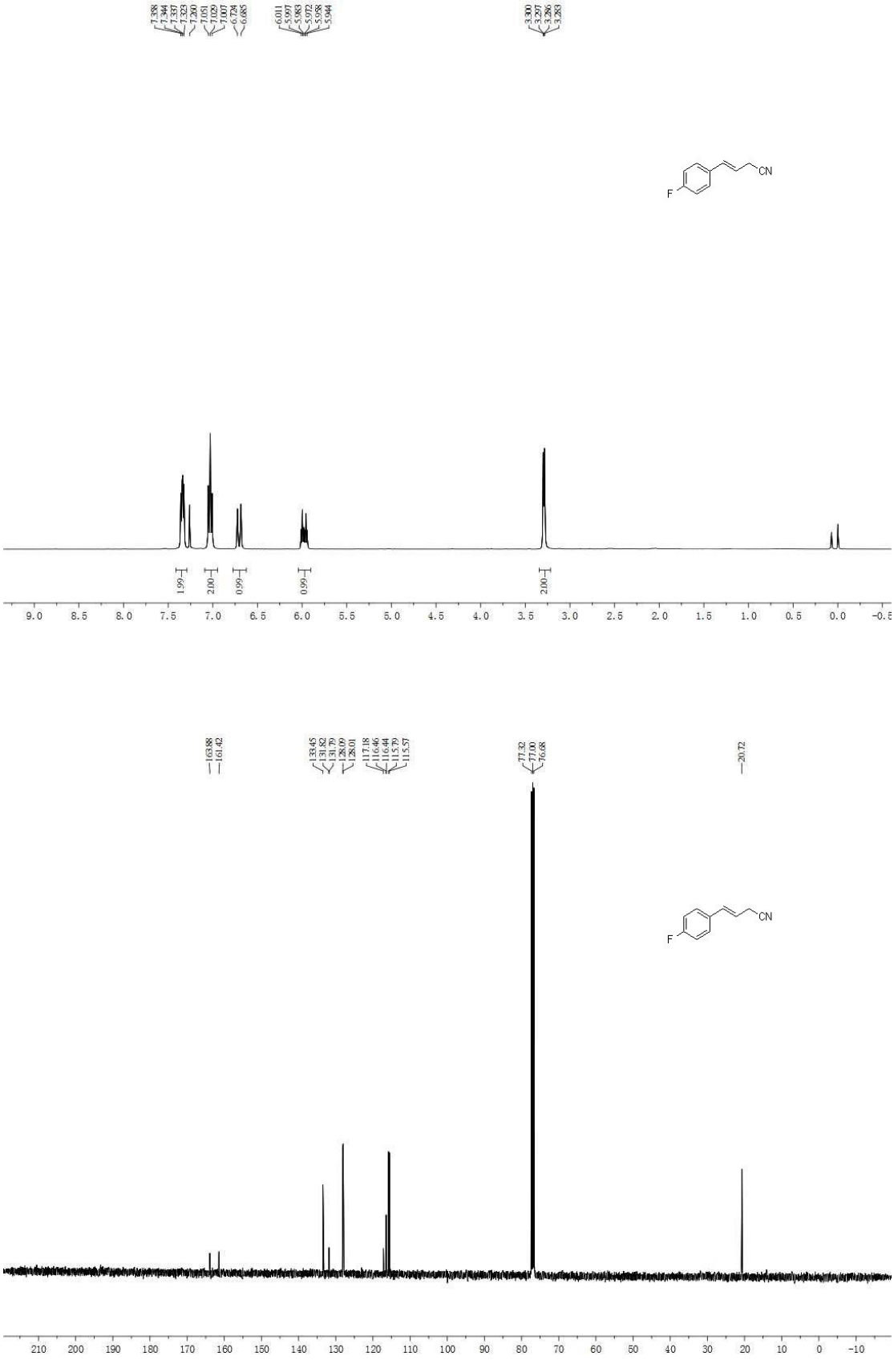

139.14
132.24
130.26
129.61
128.44
127.81
117.92
77.32
77.00
76.68
35.72
24.01
17.79
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10


I
CN
Cl

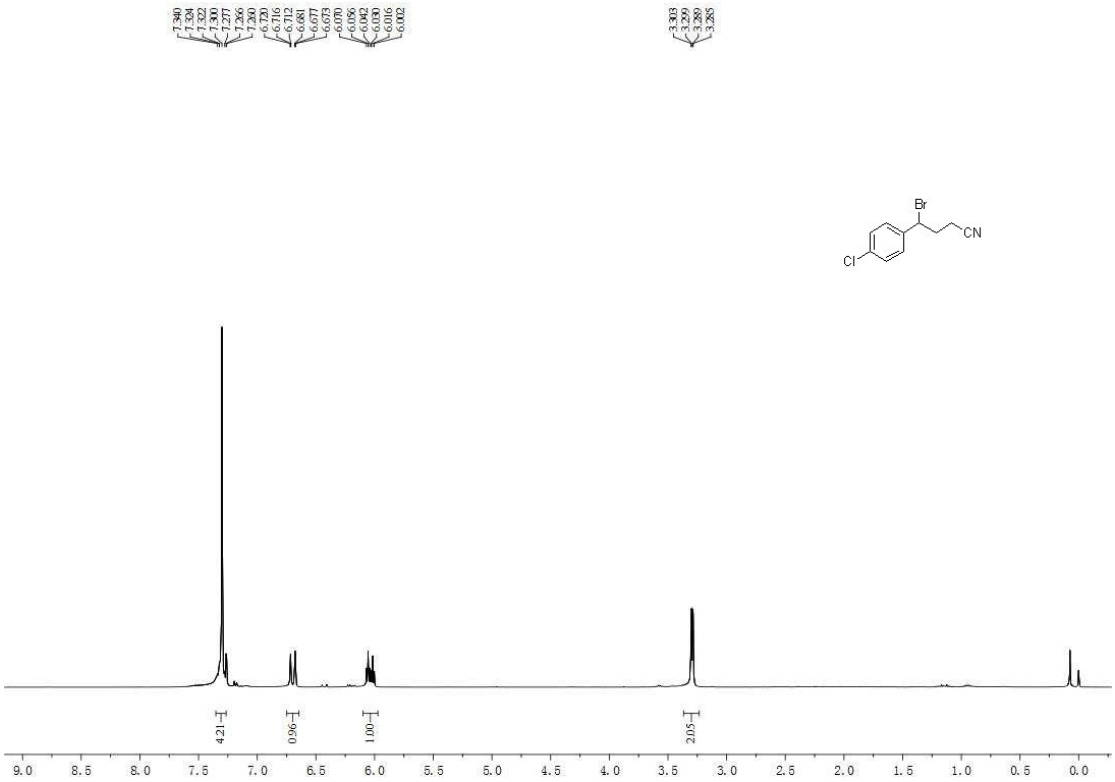
**Product 4a**

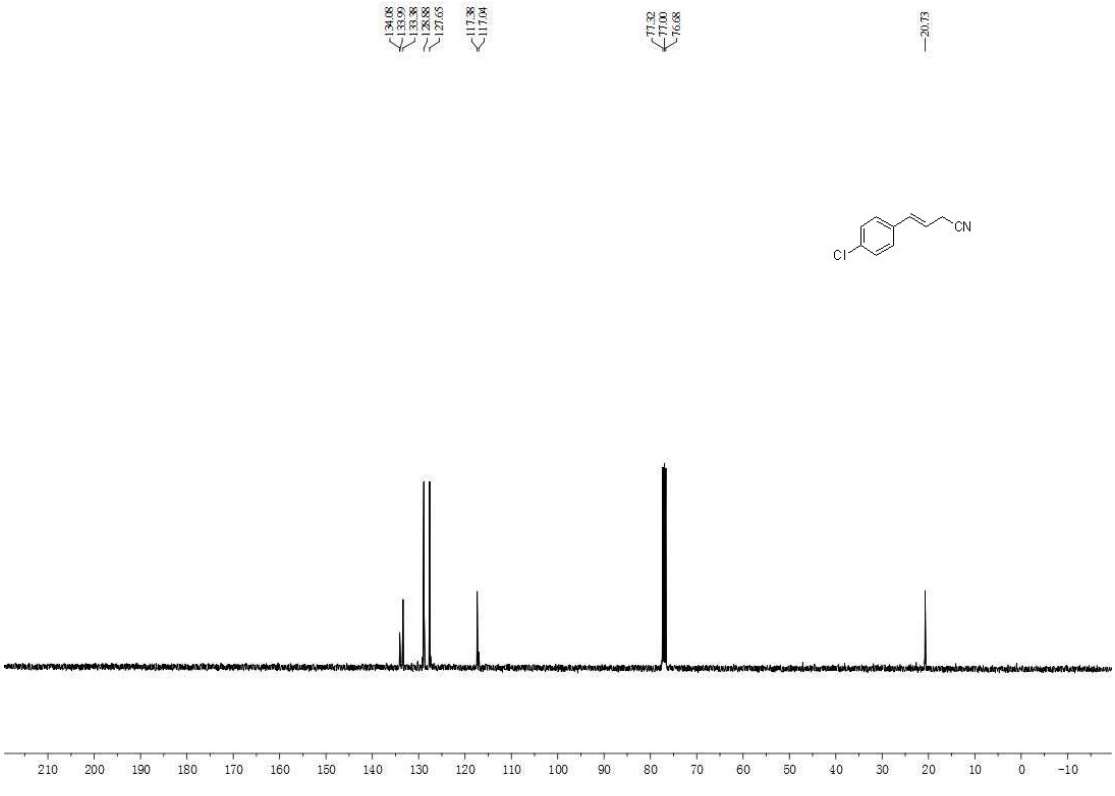

7.390
7.386
7.309
7.305
7.303
7.301
7.228
7.226
7.208
7.200
6.764
6.725
6.095
6.081
6.057
6.056
6.042
6.028
3.313
3.309
3.299
3.295
CN
4.98
1.00
0.98
1.95
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
135.64
134.66
128.71
128.30
126.46
117.27
116.67
77.32
77.00
76.68
20.78
CN
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

**Product 4b**

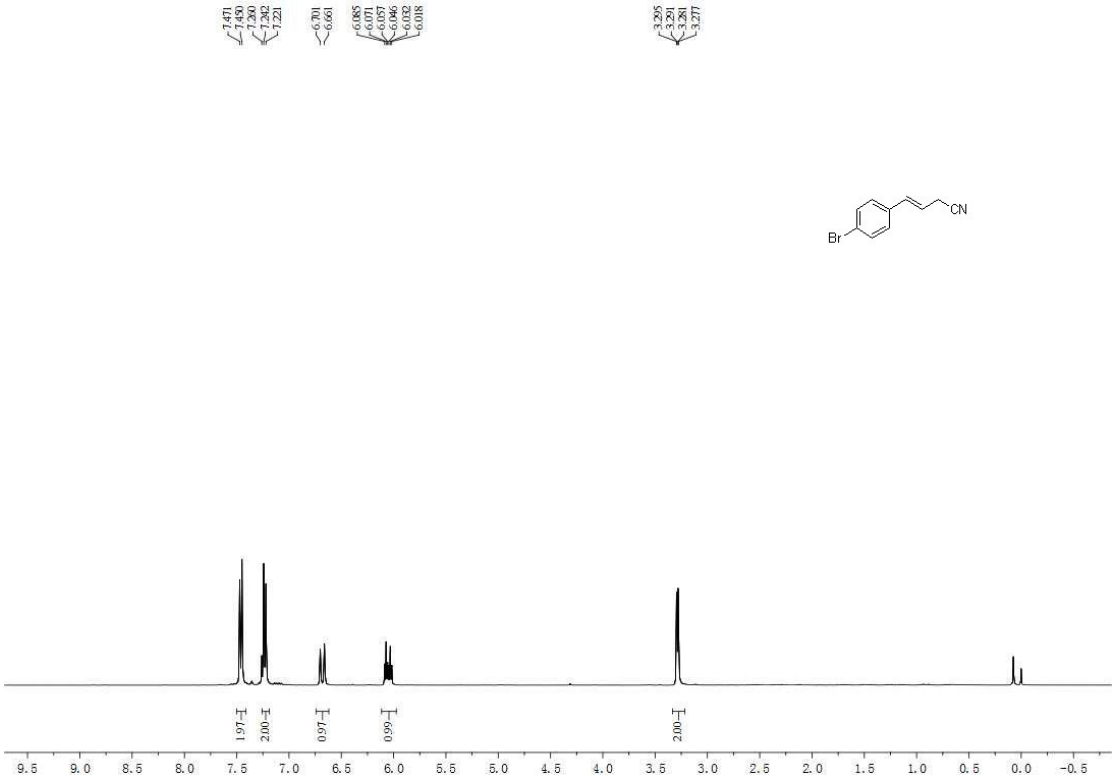

7.358
7.344
7.337
7.323
7.200
7.051
7.030
7.007
6.724
6.685
6.011
5.997
5.983
5.972
5.958
5.944
3.300
3.297
3.286
3.283
CN
F
1.99
2.00
0.99
0.99
2.00
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
163.88
161.42
133.45
131.82
131.79
128.09
128.01
117.18
116.46
116.44
115.79
115.57
77.32
77.00
76.68
20.72
CN
F
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10

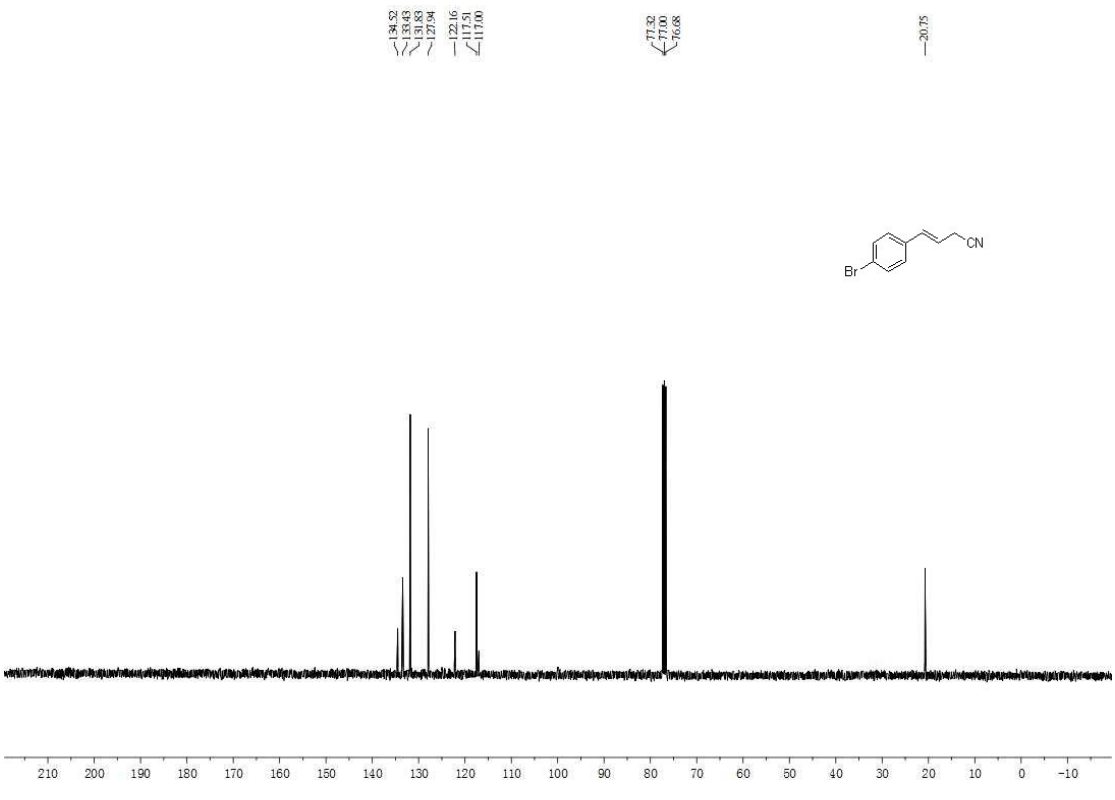
**Product 4c**


7.340
7.324
7.322
7.300
7.277
7.266
7.200
6.720
6.716
6.712
6.681
6.677
6.673
6.670
6.095
6.045
6.030
6.016
6.002
3.303
3.299
3.289
3.285
Br
CN
Cl
4.21
0.96
1.00
2.05
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

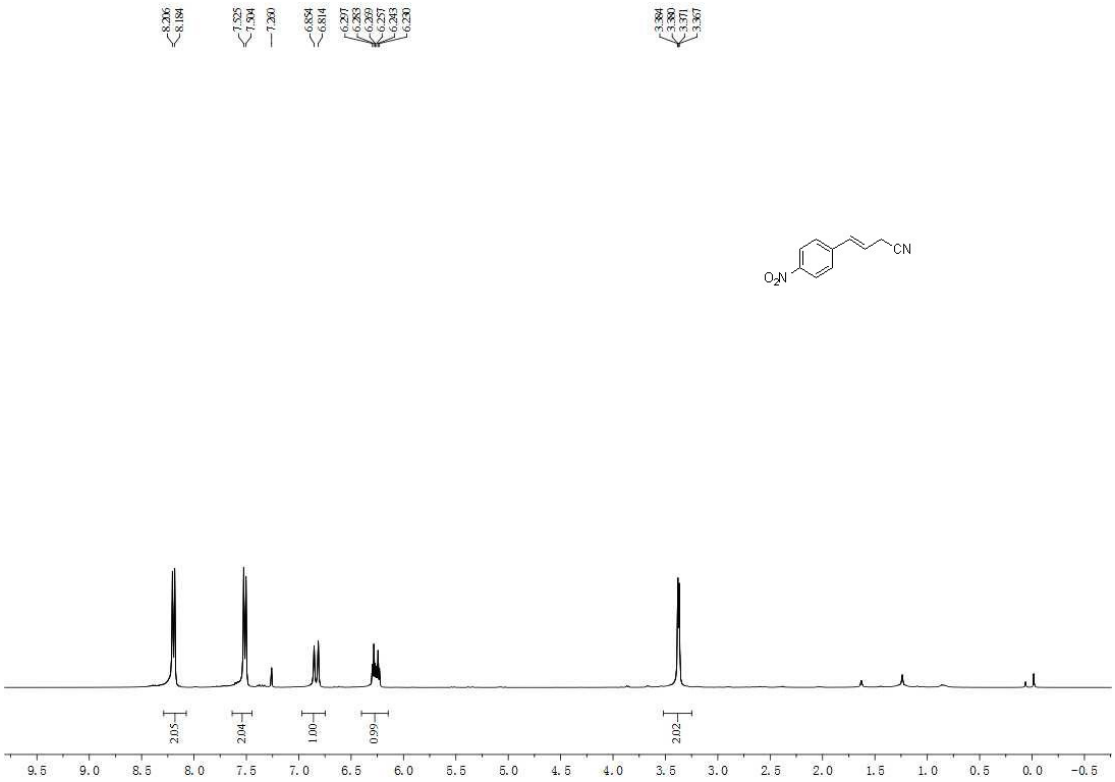

134.08
133.99
133.38
128.88
127.65
117.38
117.04
77.32
77.00
76.68
20.73
CN
Cl
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10

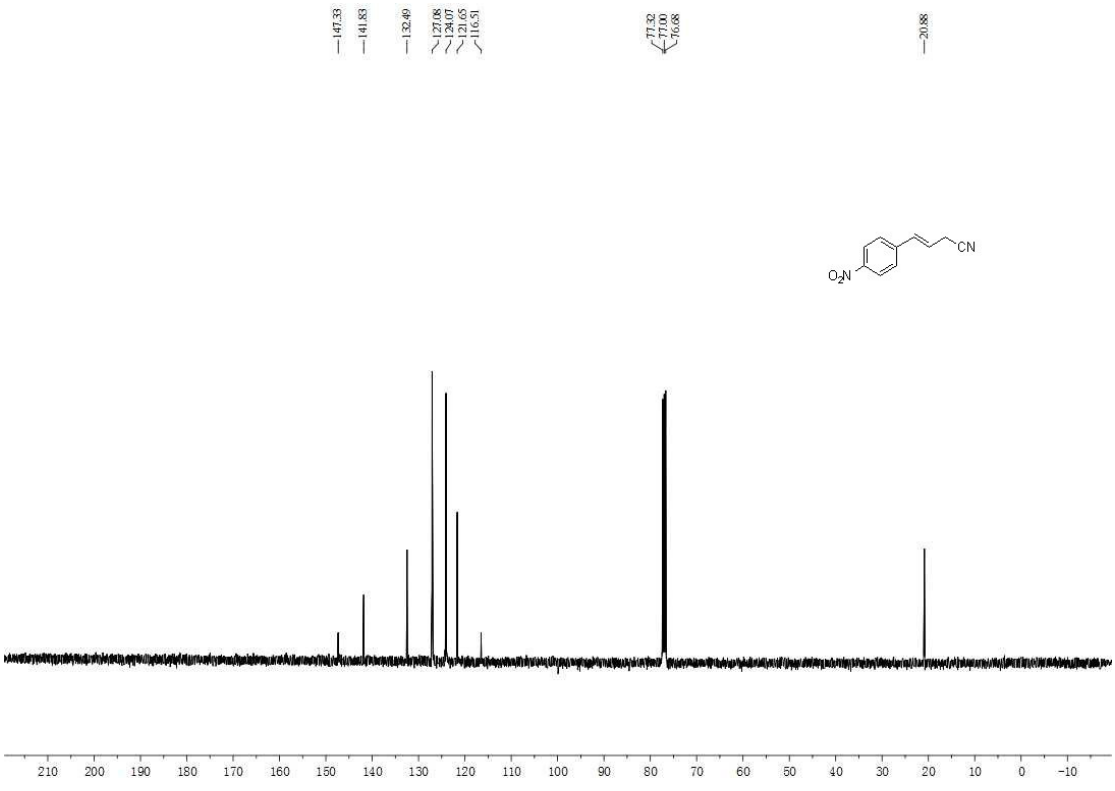
**Product 4d**


7.471
7.450
7.300
7.282
7.221
6.701
6.661
6.085
6.071
6.057
6.045
6.032
6.018
3.295
3.291
3.281
3.277
Br
CN
1.97
2.00
0.97
0.99
2.00
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 -0.5

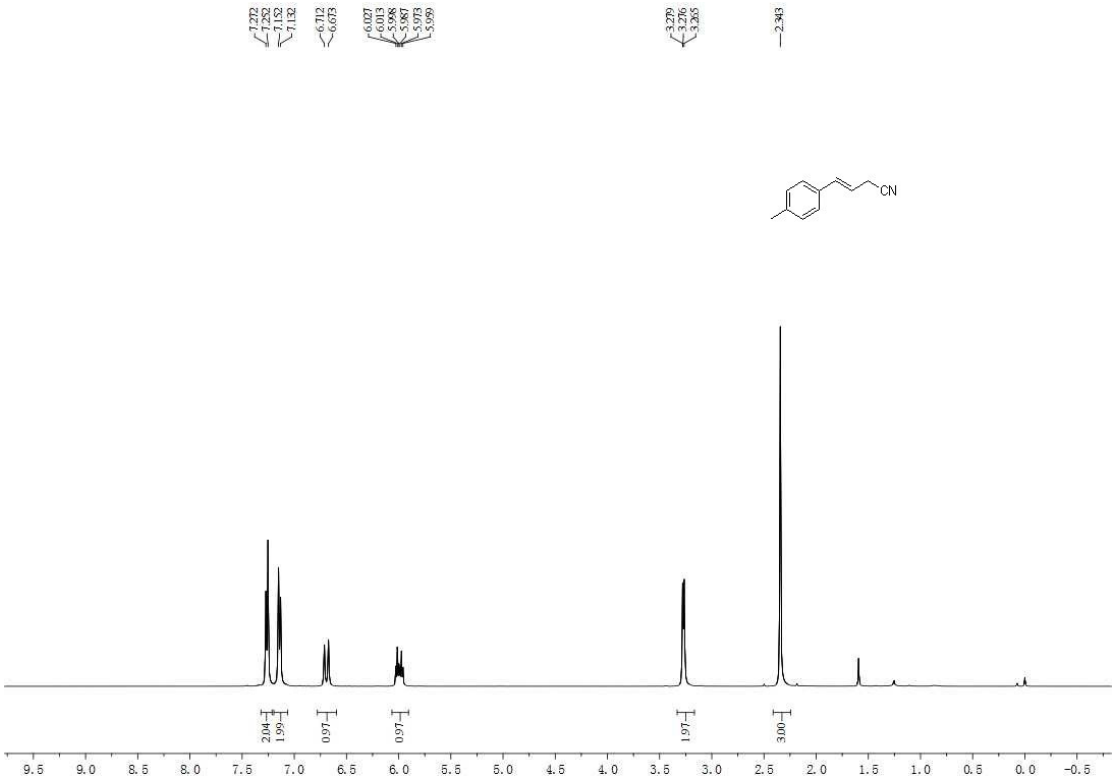

134.52
133.43
131.83
127.94
122.16
117.51
117.00
77.32
77.00
76.68
20.75
Br
CN
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

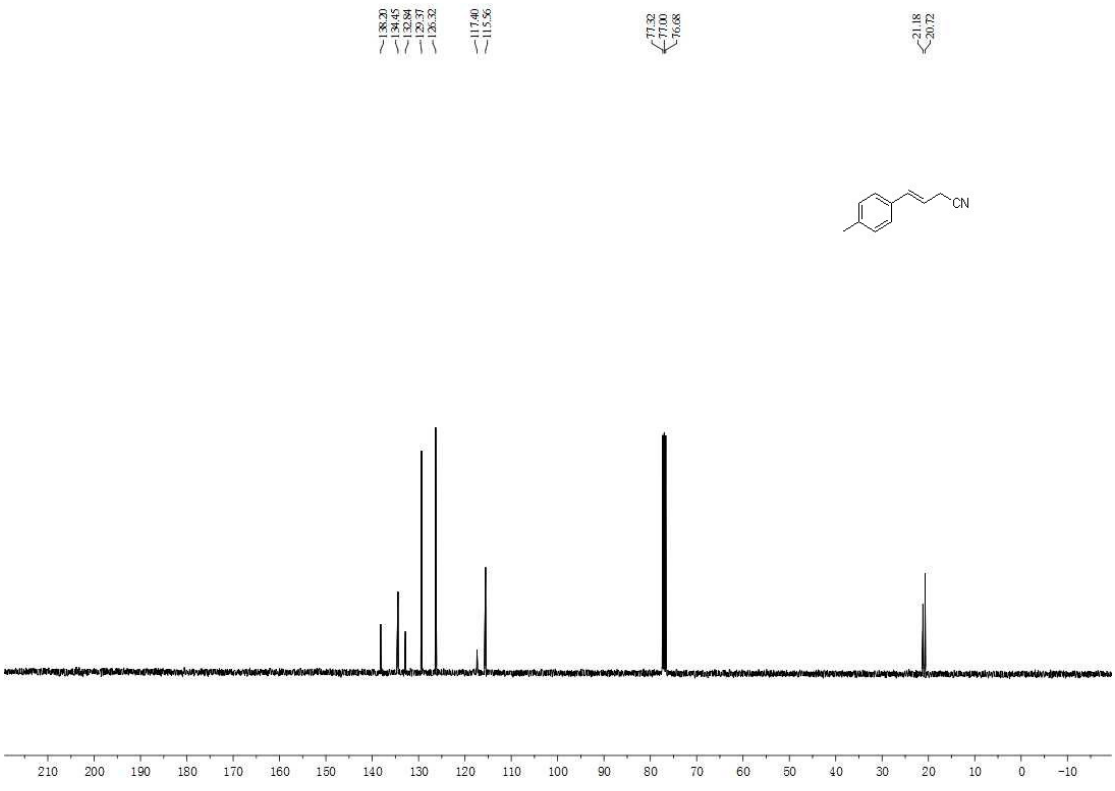
**Product 4e**


8.206
8.184
7.525
7.504
7.200
6.854
6.814
6.297
6.283
6.269
6.257
6.243
6.230
3.384
3.380
3.371
3.367
CN
O2N
2.05
2.04
1.00
0.99
2.02
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 -0.5

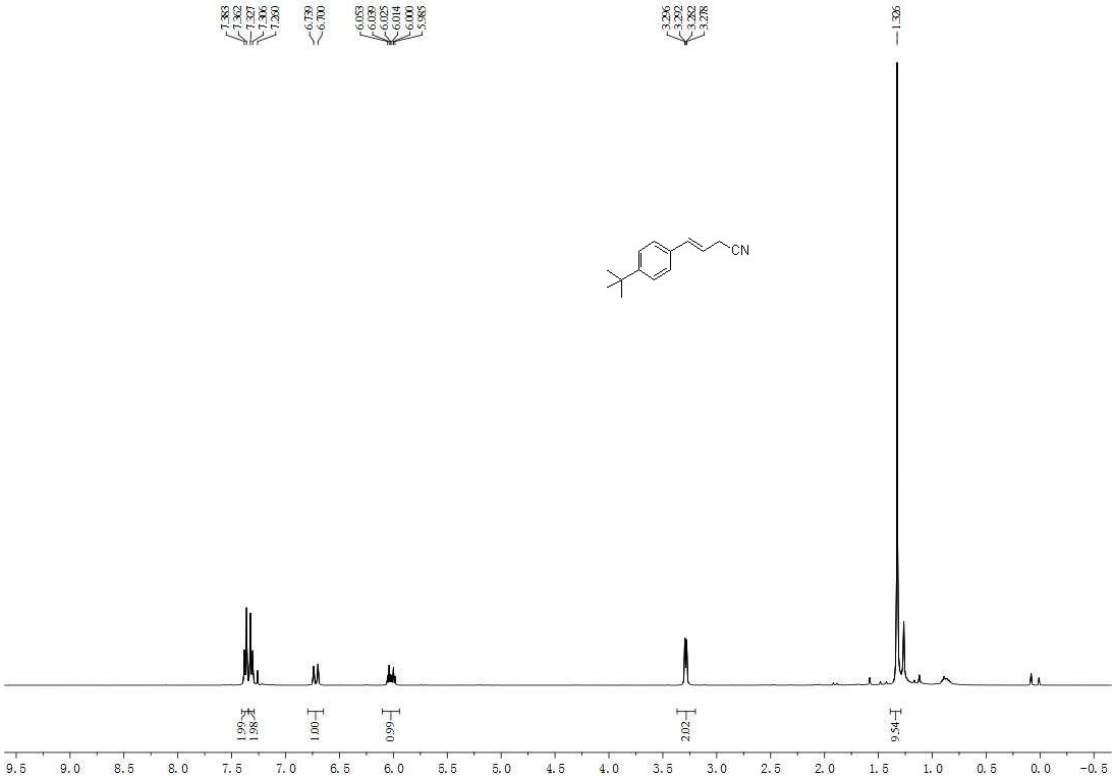

147.33
141.83
132.49
127.08
124.07
121.65
116.51
77.32
77.00
76.68
20.88
CN
O2N
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

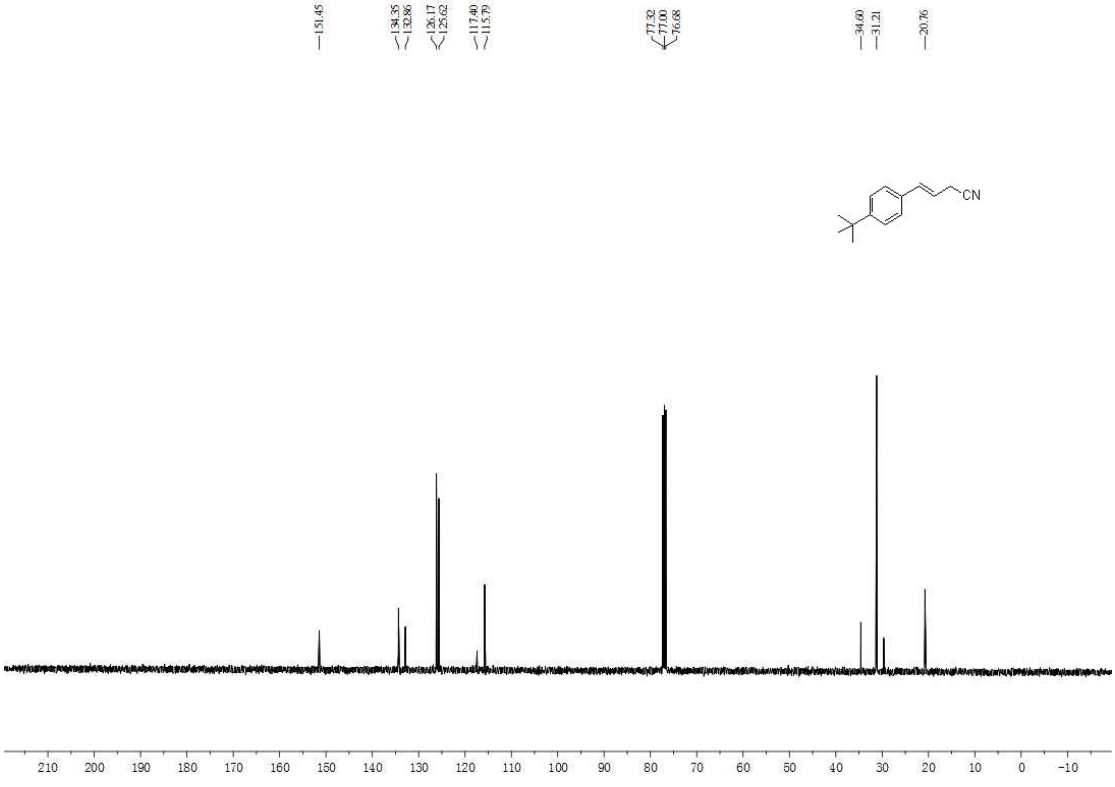
**Product 4f**


7.272
7.252
7.152
7.132
6.712
6.673
6.027
6.013
5.998
5.987
5.973
5.959
3.229
3.226
3.205
2.343
CN
2.04
1.99
0.97
0.97
1.97
3.00
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 -0.5

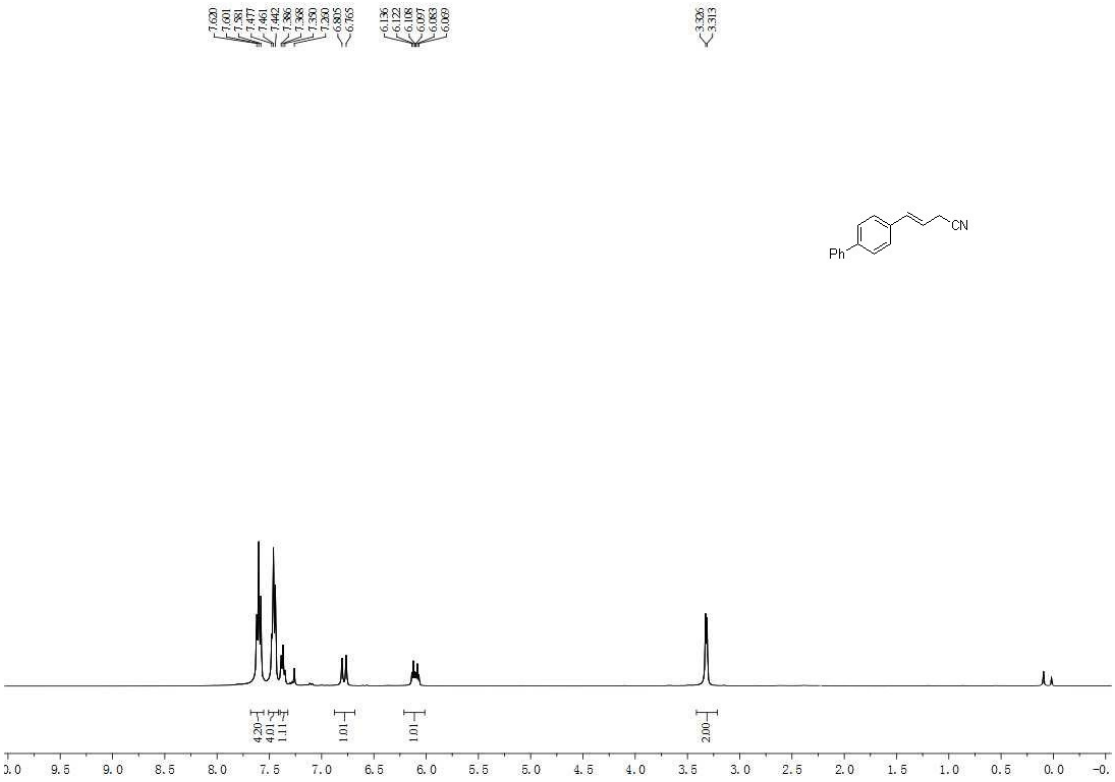

138.20
134.45
131.94
130.97
126.32
117.40
115.56
77.32
77.00
76.68
21.18
20.72
CN
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

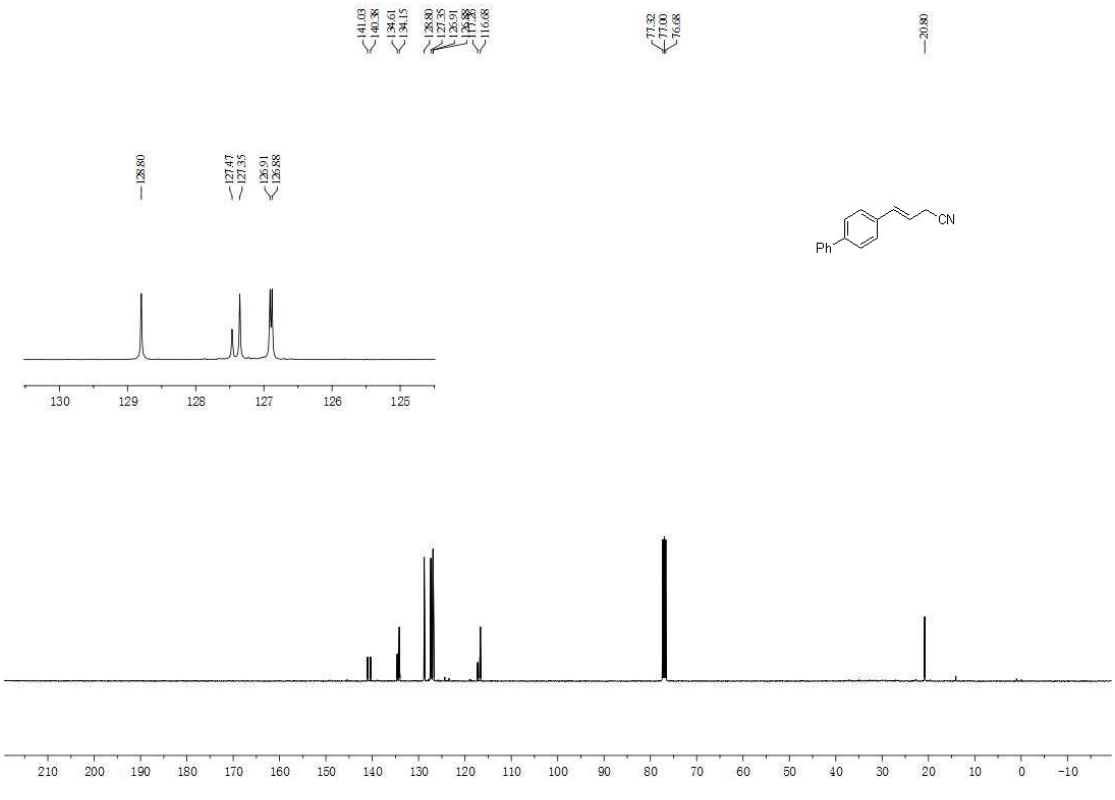
**Product 4g**


7.363
7.362
7.327
7.306
7.290
6.719
6.700
6.053
6.039
6.025
6.014
6.000
5.985
3.296
3.292
3.282
3.278
1.306
CN
1.99
1.98
1.00
0.99
2.02
9.54
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 -0.5

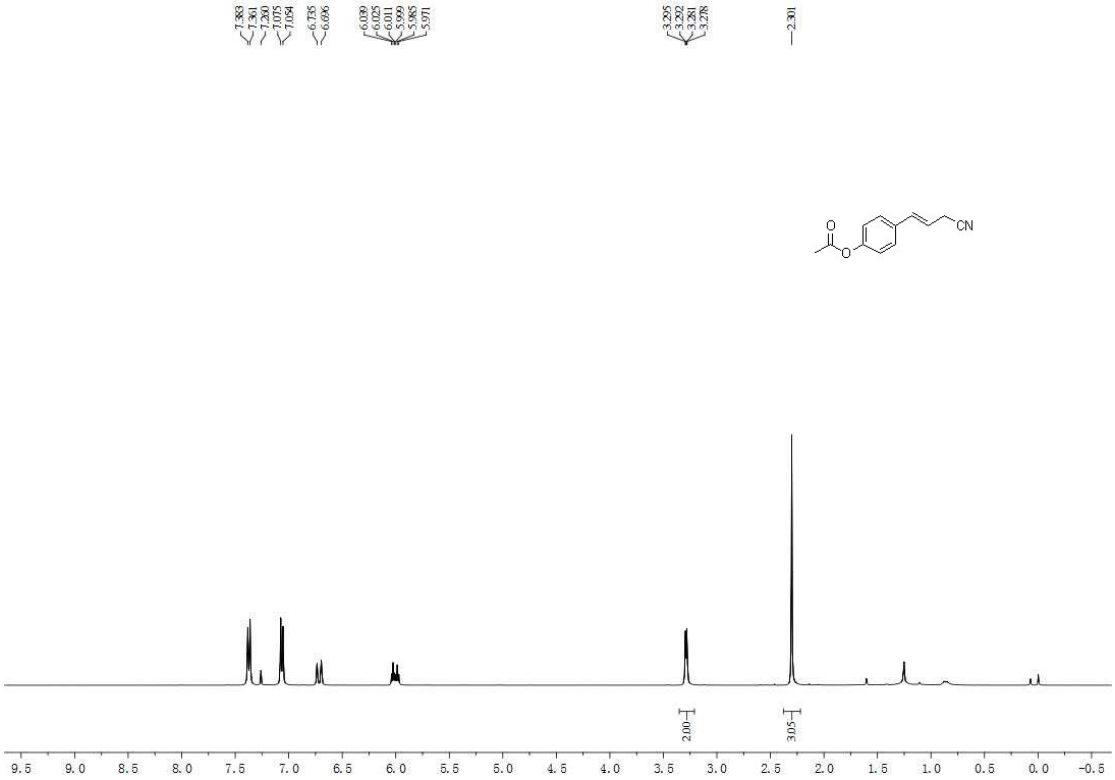

151.45
134.35
132.86
126.17
125.62
117.40
115.79
77.32
77.00
76.68
34.60
31.21
20.76
CN
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

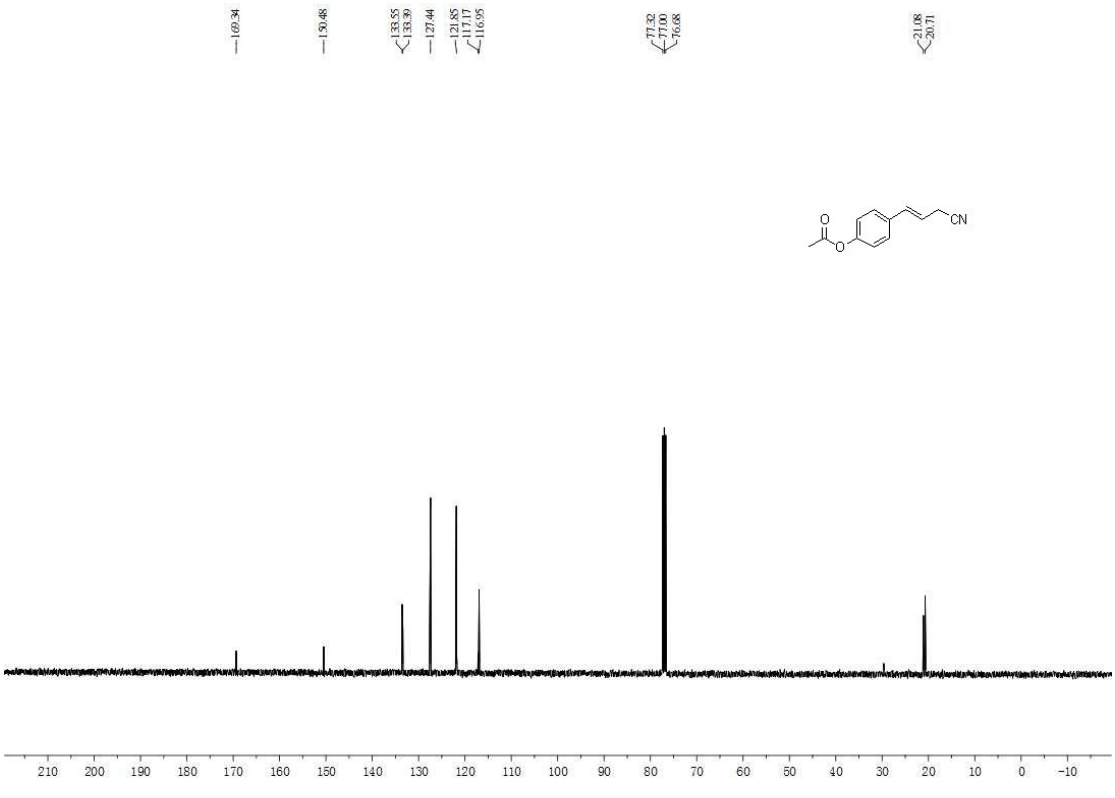
**Product 4h**


7.620
7.601
7.581
7.477
7.461
7.442
7.386
7.308
7.300
7.200
6.895
6.765
6.136
6.122
6.108
6.097
6.083
6.069
3.326
3.313
CN
Ph
4.20
4.01
1.11
1.01
1.01
2.00

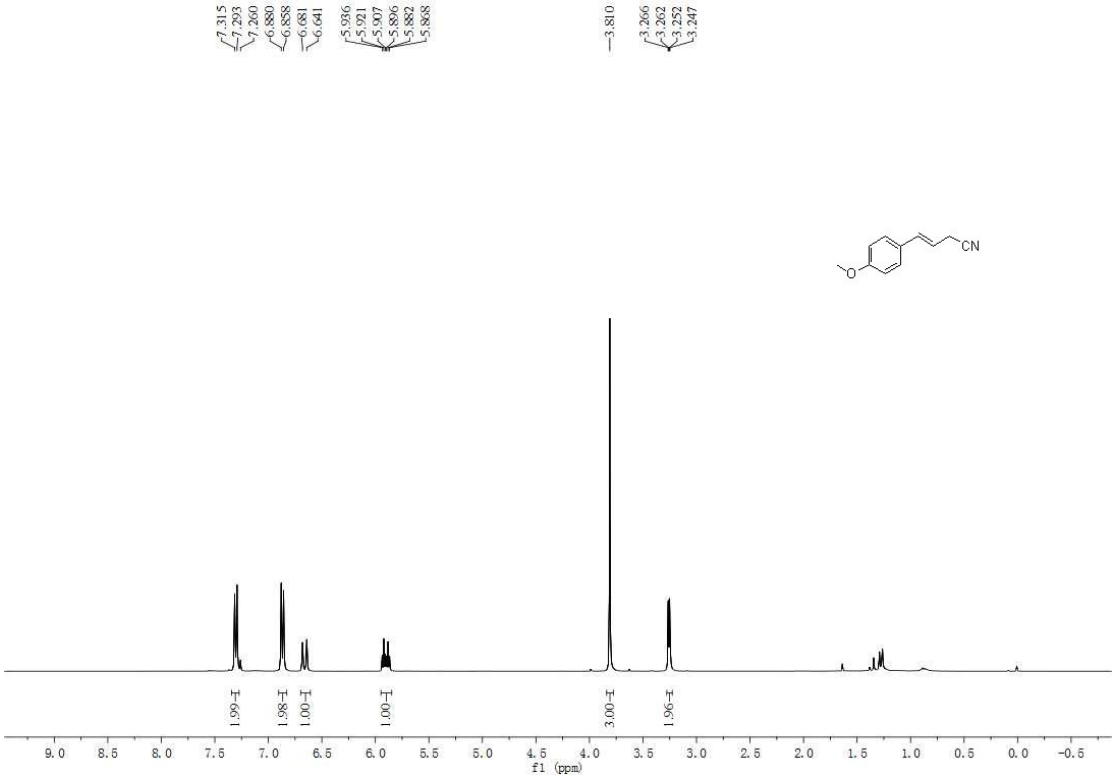

141.03
140.38
134.61
134.15
128.80
127.35
126.91
126.88
116.68
77.32
77.00
76.68
20.80
128.80
127.47
127.35
126.91
126.88
CN
Ph

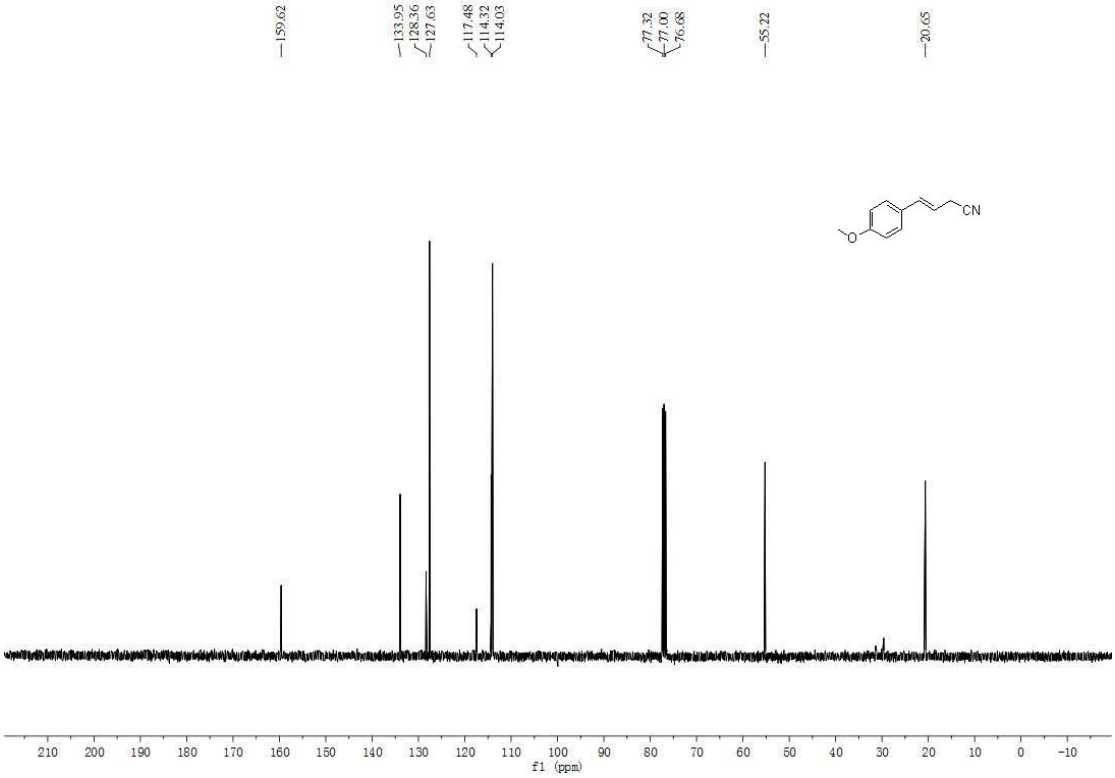
**Product 4i**


7.363
7.361
7.200
7.075
7.054
6.735
6.696
6.039
6.025
6.011
5.999
5.985
5.971
3.295
3.292
3.281
3.278
2.301
CN
2.00
3.05
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 -0.5

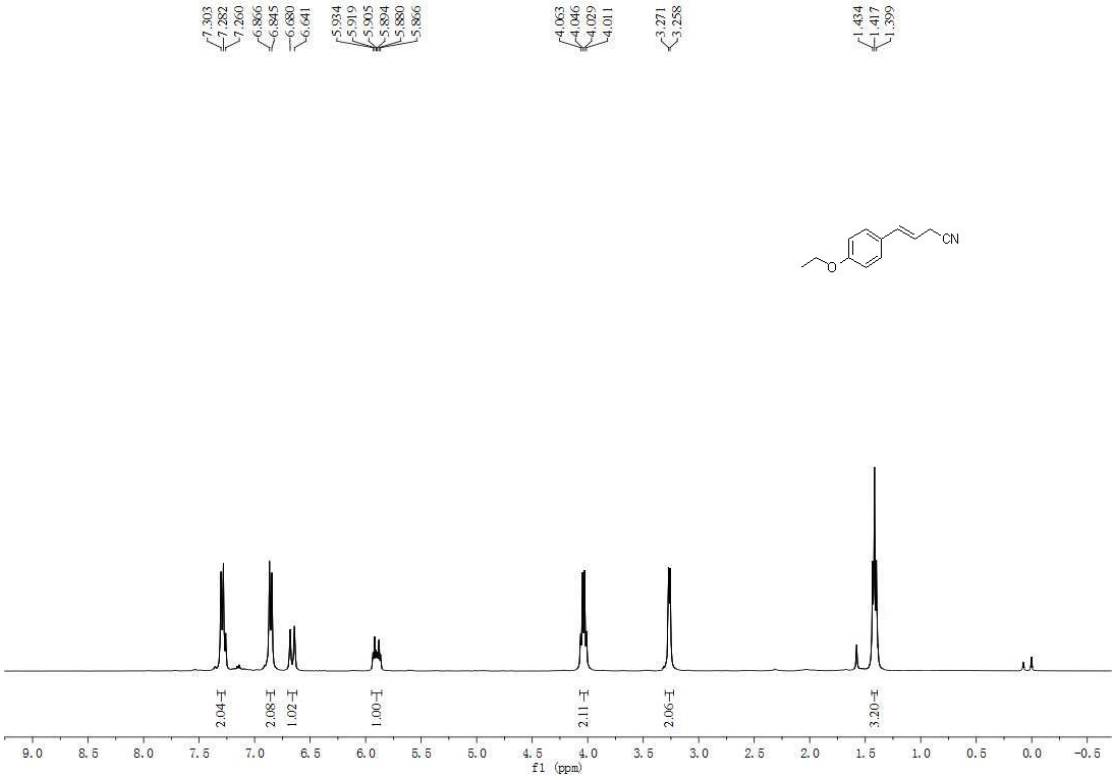

169.34
150.48
133.55
133.39
127.44
121.85
117.17
116.95
77.32
77.00
76.68
21.08
20.71
CN
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

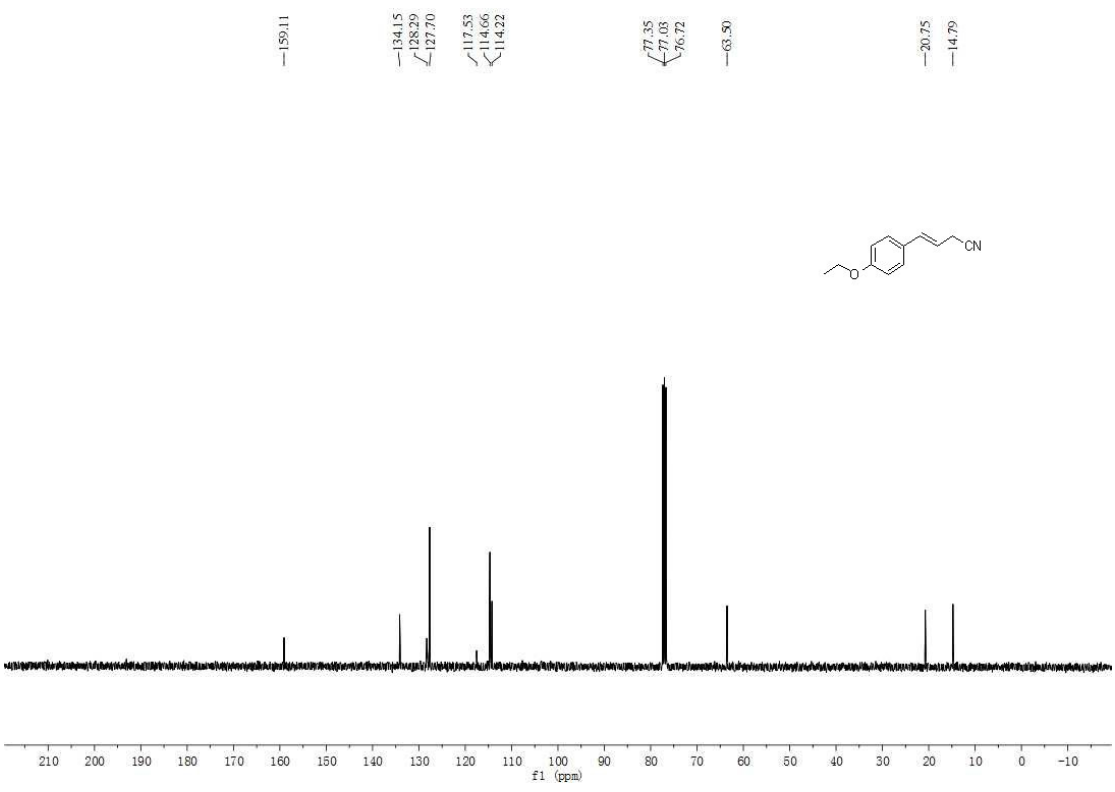
**Product 4j**


7.315
7.293
7.260
6.880
6.858
6.681
6.641
5.936
5.921
5.907
5.896
5.882
5.868
3.810
3.266
3.262
3.252
3.247
CN
O
1.99
1.98
1.00
1.00
3.00
1.96
f1 (ppm)

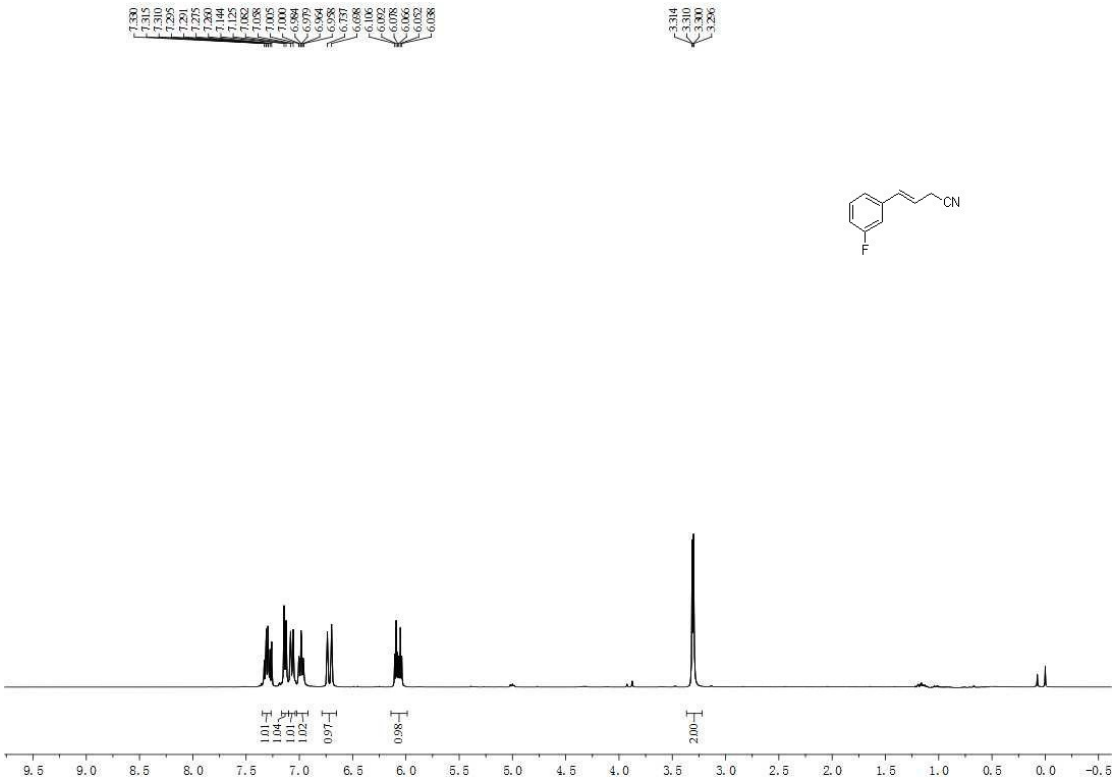

159.62
133.95
128.36
127.63
117.48
114.32
114.03
77.32
77.00
76.68
55.22
20.65
CN
O
f1 (ppm)

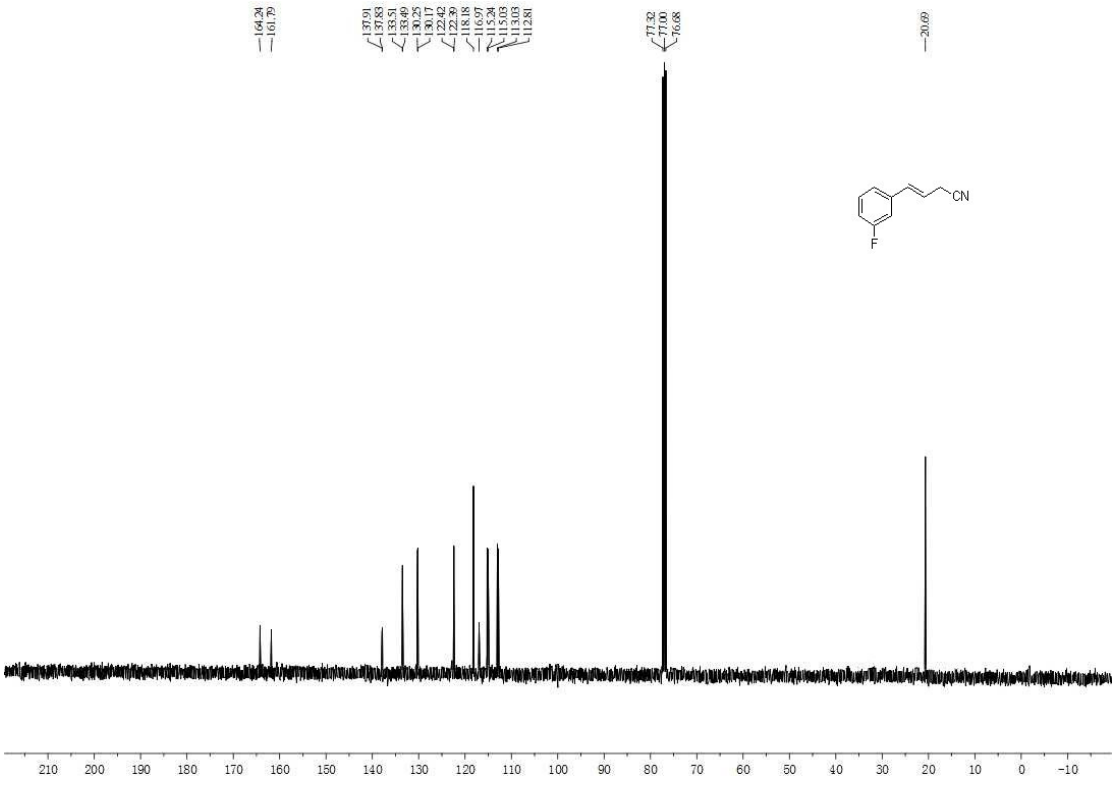
**Product 4k**


7.303
7.282
7.260
6.866
6.845
6.680
6.641
5.934
5.919
5.905
5.894
5.880
5.866
4.063
4.046
4.029
4.011
3.271
3.258
1.434
1.417
1.399
CN
O
2.04
2.08
1.02
1.00
2.11
2.06
3.20
f1 (ppm)

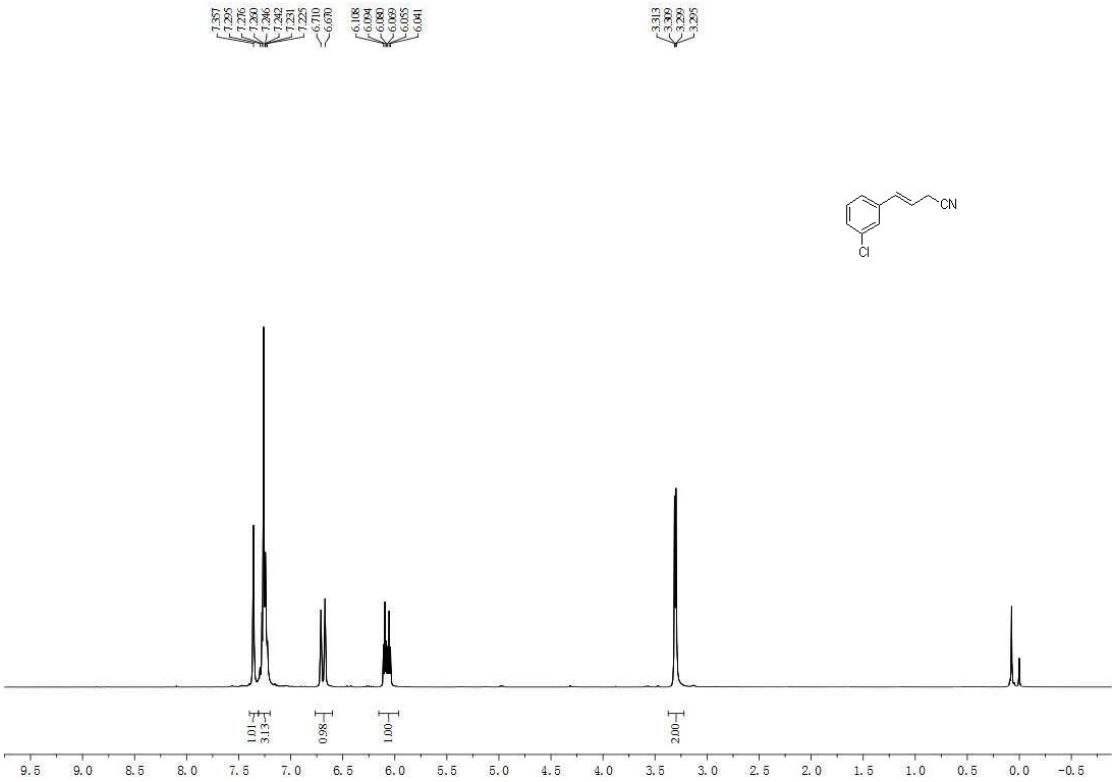

159.11
134.15
128.29
127.70
117.53
114.66
114.22
77.35
77.03
76.72
63.50
20.75
14.79
CN
O
f1 (ppm)

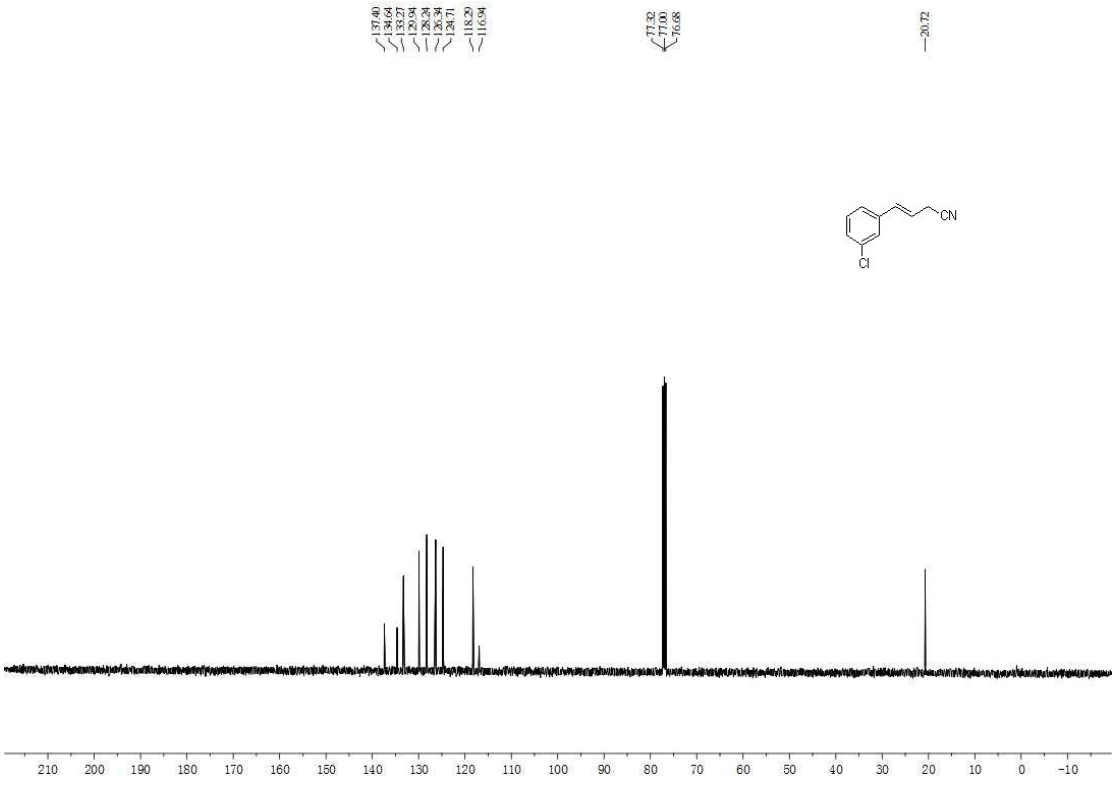
**Product 4l**


7.330
7.315
7.310
7.295
7.291
7.271
7.200
7.144
7.125
7.082
7.058
7.005
7.000
6.984
6.979
6.964
6.958
6.737
6.638
6.106
6.092
6.078
6.066
6.052
6.038
3.314
3.310
3.300
3.296
CN
F
1.01
1.04
1.01
1.02
0.97
0.98
2.00
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 -0.5

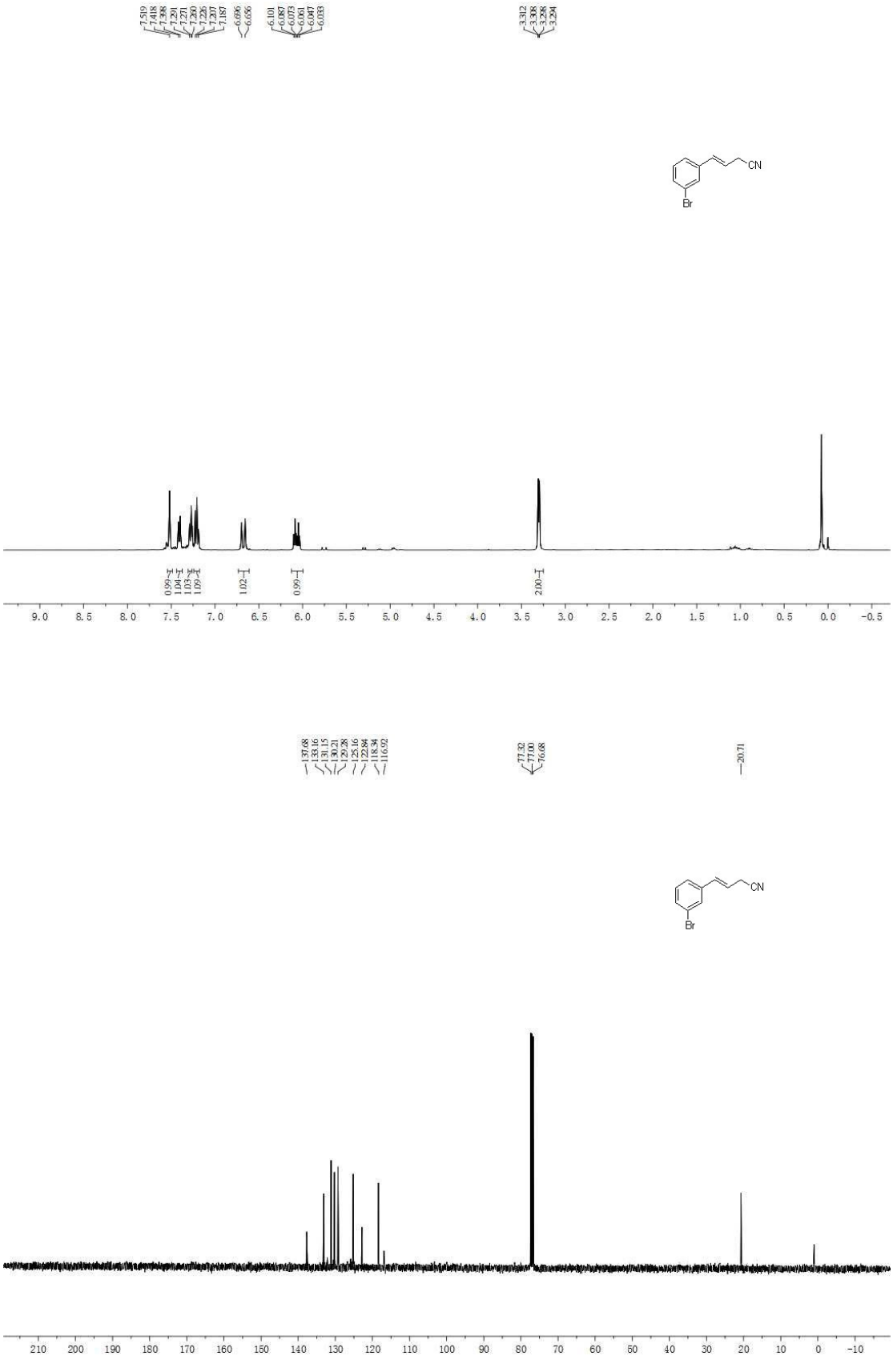

164.24
161.79
137.91
137.83
133.51
133.49
130.25
130.17
122.42
122.39
118.18
116.97
116.74
115.03
113.03
112.81
77.32
77.00
76.68
20.69
CN
F
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

**Product 4m**

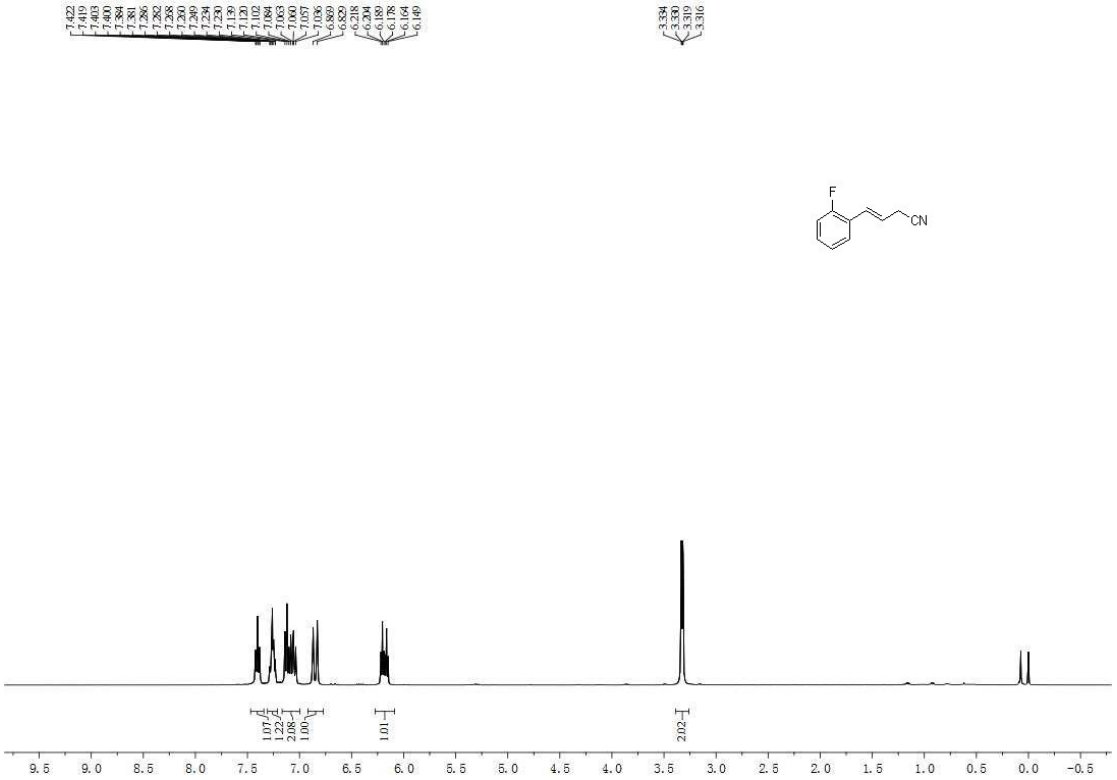

7.357
7.295
7.276
7.260
7.246
7.242
7.231
7.225
6.710
6.670
6.108
6.084
6.069
6.060
6.055
6.041
3.313
3.309
3.299
3.295
CN
Cl
1.01
3.13
0.98
1.00
2.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5

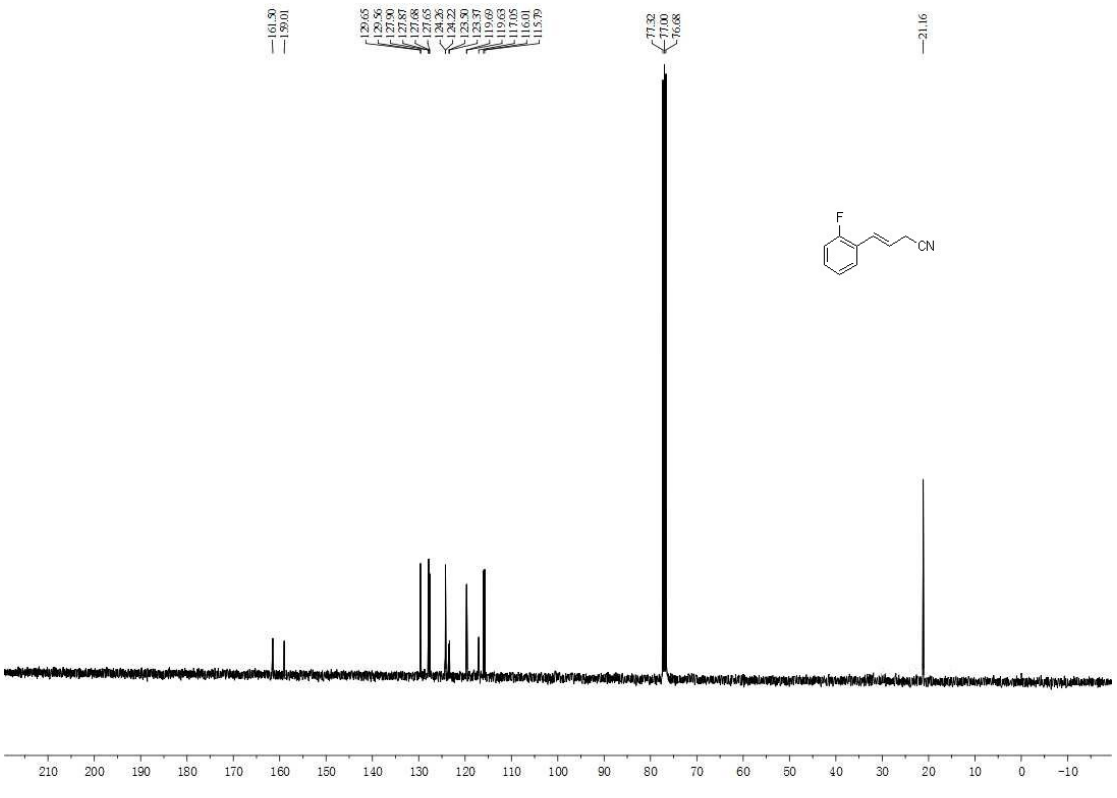

137.40
134.64
133.27
130.94
128.24
125.34
124.71
118.29
116.94
77.32
77.00
76.68
20.72
CN
Cl
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

**Product 4n**


7.519
7.418
7.398
7.291
7.271
7.260
7.225
7.207
7.187
6.696
6.656
6.101
6.087
6.073
6.061
6.047
6.033
3.312
3.308
3.228
3.224
CN
Br
0.99
1.04
1.03
1.09
1.02
0.99
2.00
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
-0.5
137.68
133.16
131.15
130.21
129.28
125.16
122.84
118.34
116.92
77.32
77.00
76.68
20.71
CN
Br
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10

**Product 4o**

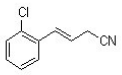

7.422
7.419
7.403
7.400
7.384
7.381
7.296
7.292
7.265
7.260
7.249
7.234
7.230
7.139
7.120
7.102
7.084
7.065
7.060
7.057
7.036
6.889
6.829
6.218
6.204
6.188
6.178
6.164
6.149
3.334
3.330
3.319
3.316
F
CN
1.07
1.22
2.08
1.00
1.01
2.02
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5

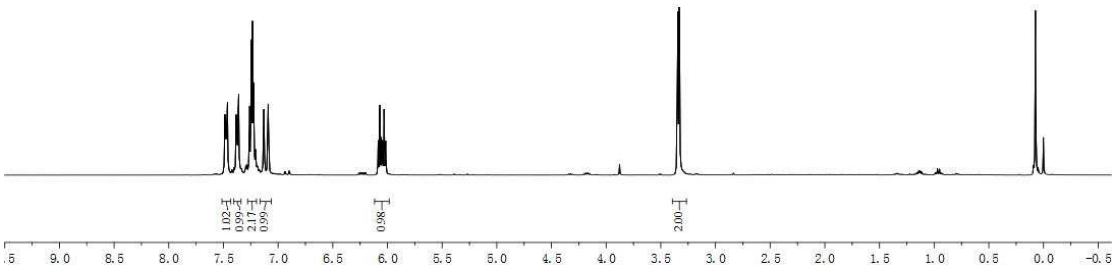

161.50
159.01
130.65
130.56
127.90
127.87
127.68
127.65
124.26
124.22
123.59
123.57
119.69
119.63
117.05
116.01
115.79
77.32
77.00
76.68
21.16
F
CN
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10

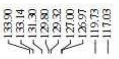
**Product 4p**


7.487
7.480
7.468
7.463
7.384
7.379
7.375
7.367
7.361
7.300
7.296
7.294
7.235
7.226
7.220
7.207
7.130
7.091
6.085
6.070
6.055
6.045
6.031
6.016


3.348
3.343
3.333
3.329

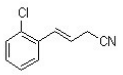

Cl
CN

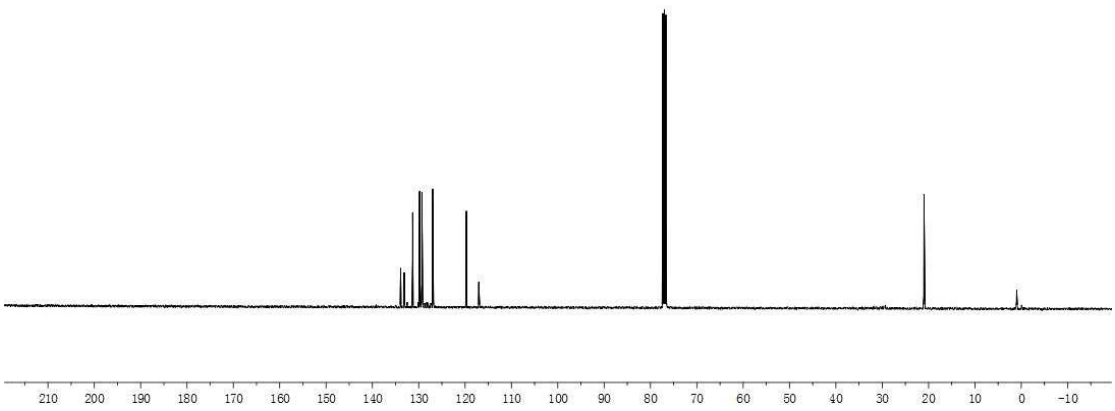

1.02
0.99
2.17
0.99
0.98
2.00
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5


133.90
133.14
131.30
129.80
129.32
127.00
126.97
119.73
117.03

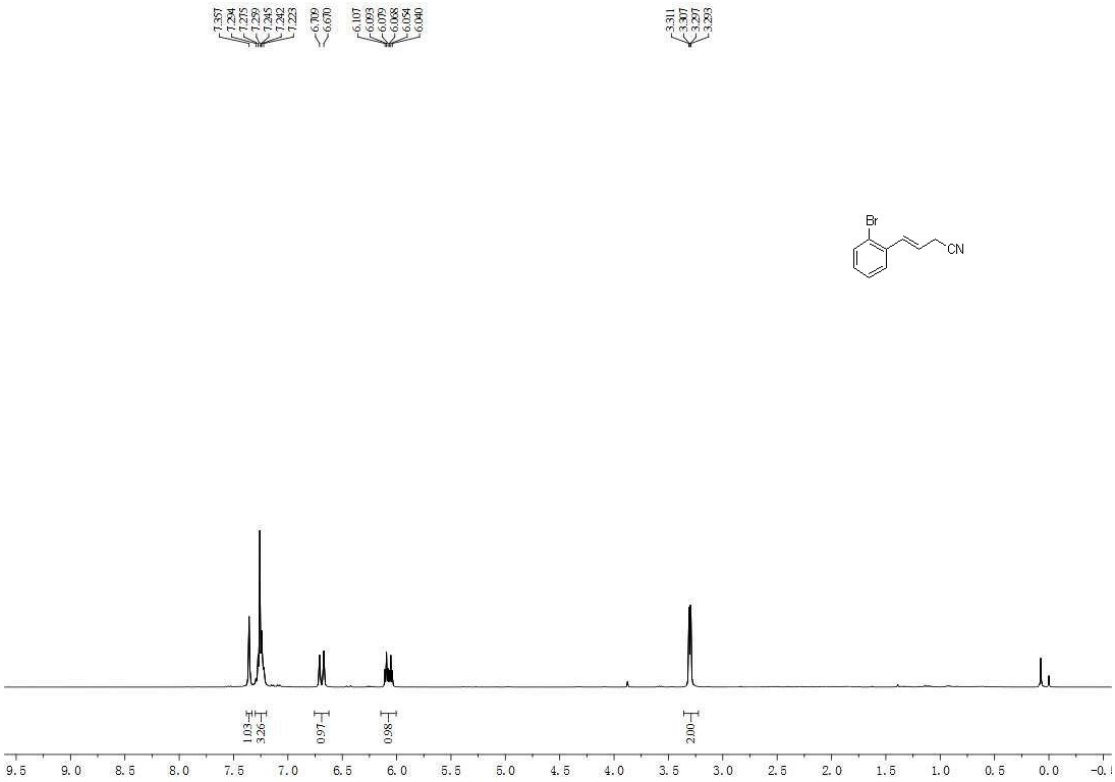

77.32
77.00
76.68

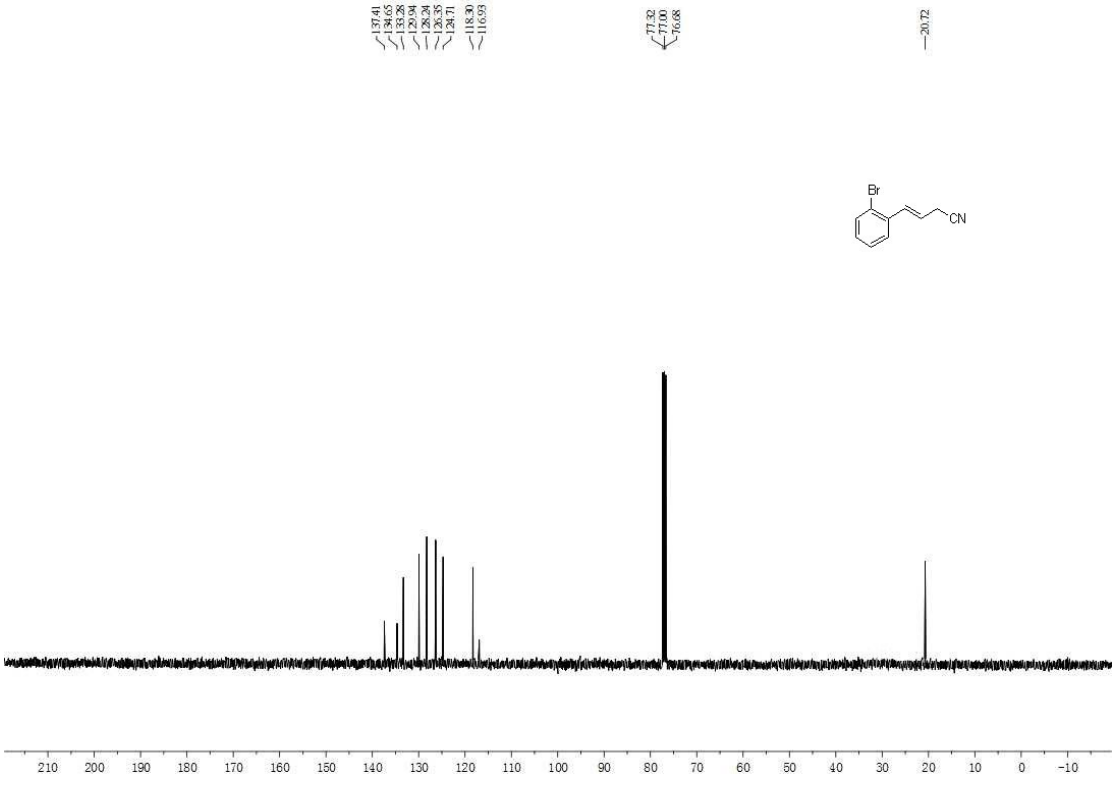

20.99


Cl
CN

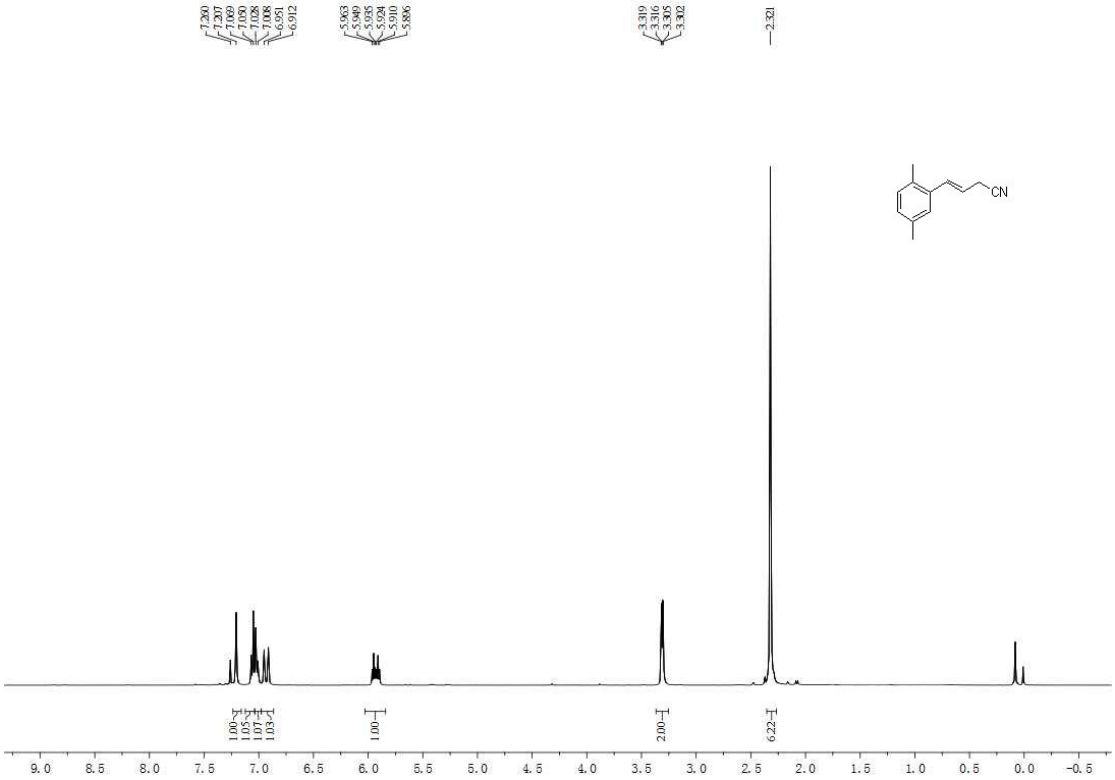

210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10

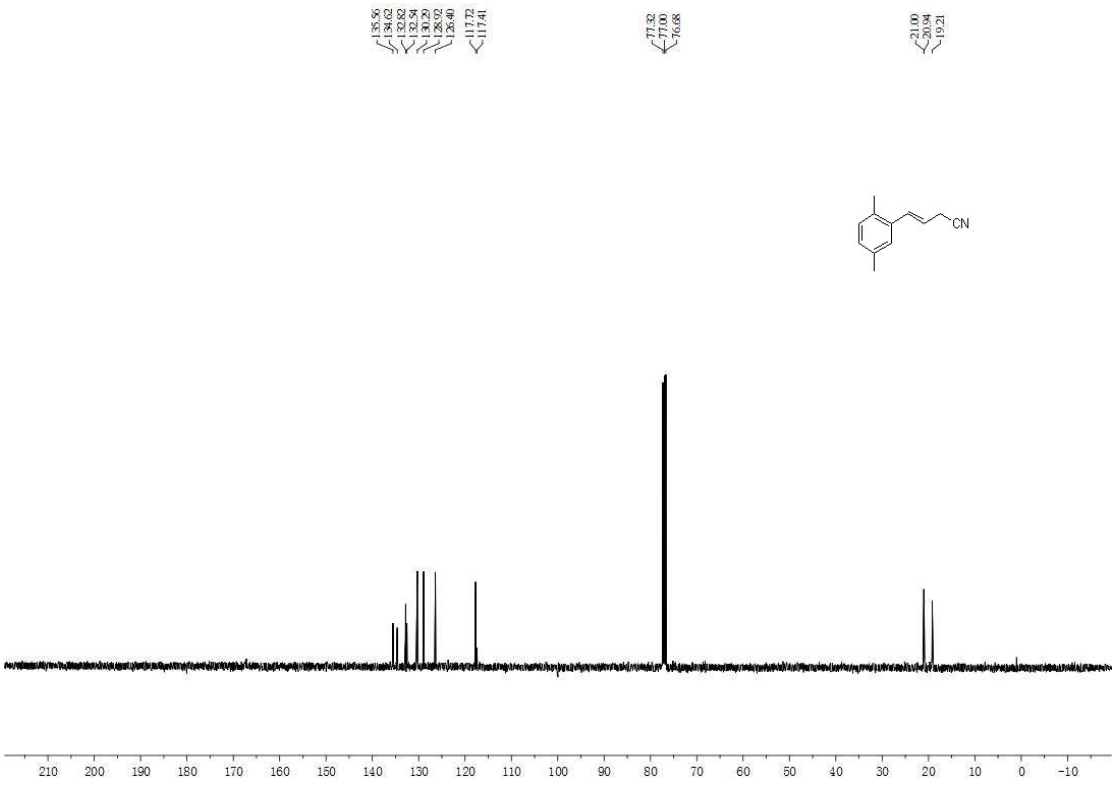
**Product 4q**


7.357
7.294
7.275
7.259
7.245
7.230
7.222
6.709
6.670
6.107
6.093
6.079
6.068
6.054
6.040
3.311
3.307
3.297
3.293
Br
CN
1.03
3.26
0.97
0.98
2.00
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

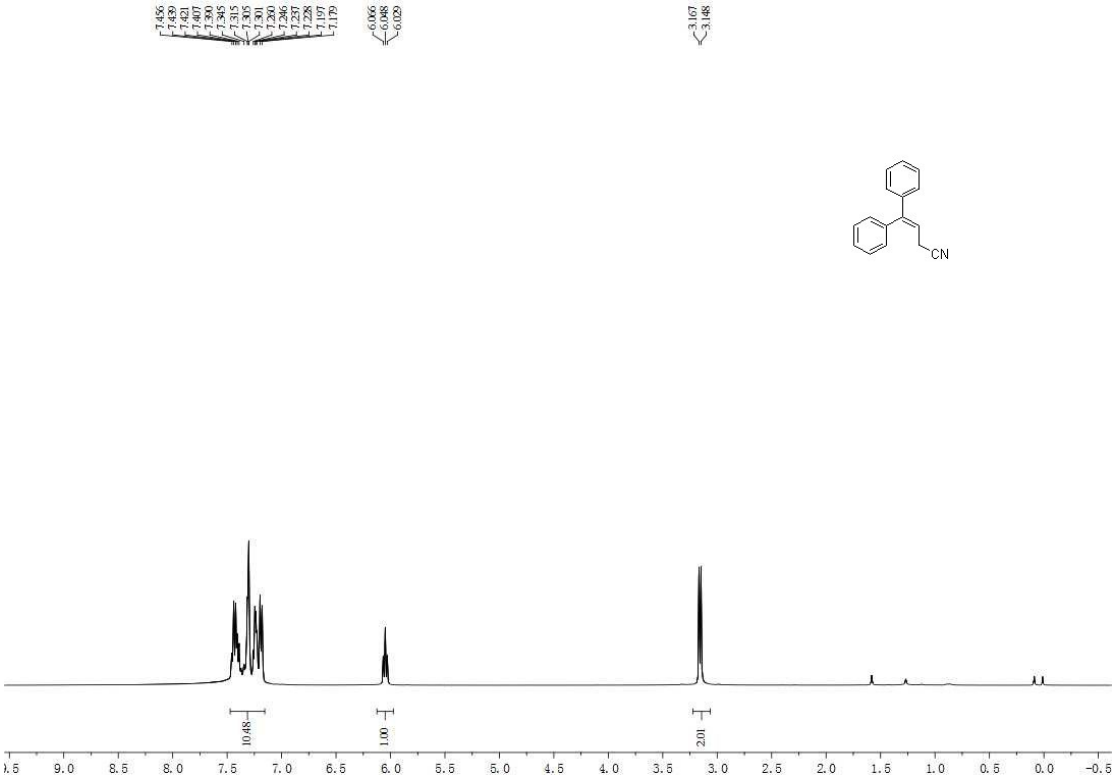

137.41
134.65
133.28
130.94
128.24
126.35
124.71
118.30
116.93
77.32
77.00
76.68
20.72
Br
CN
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10

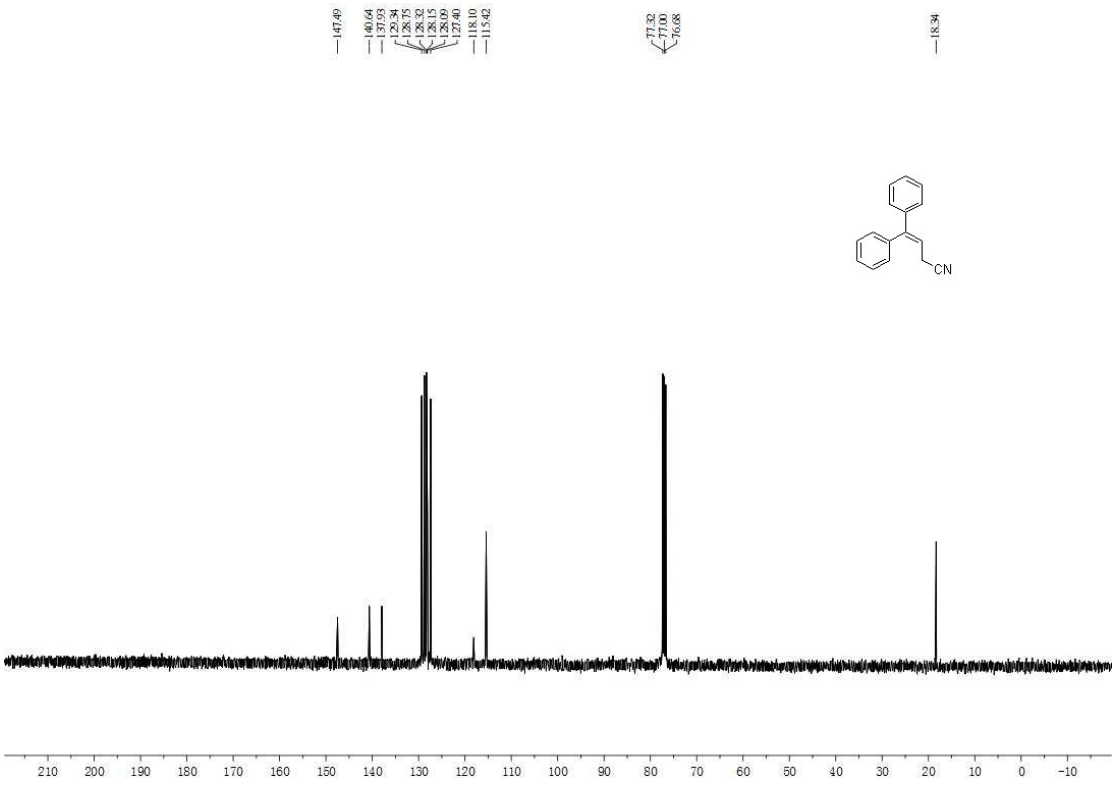
**Product 4r**


7.200
7.207
7.069
7.090
7.078
7.068
6.951
6.912
5.963
5.949
5.935
5.924
5.910
5.896
3.319
3.316
3.305
3.302
2.321
CN
1.00
1.05
1.07
1.03
1.00
2.00
6.22
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
-0.5

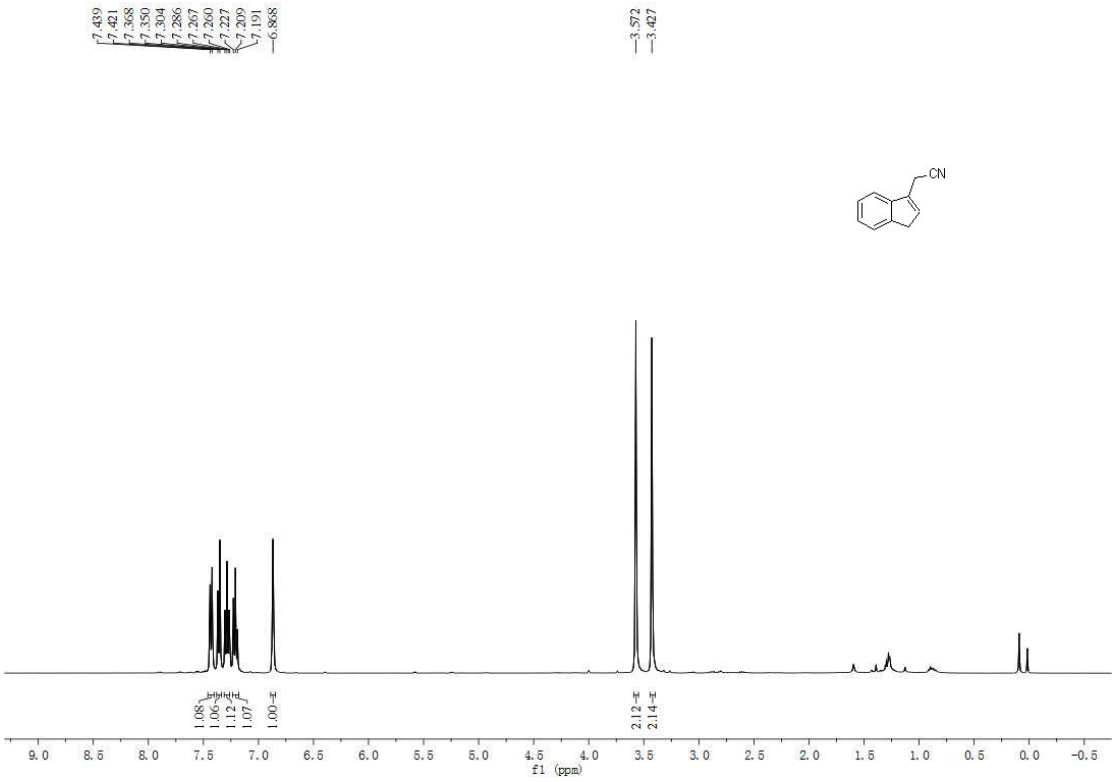

135.56
134.62
132.82
132.54
130.29
128.92
126.40
117.72
117.41
77.32
77.00
76.68
21.00
20.94
19.21
CN
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10

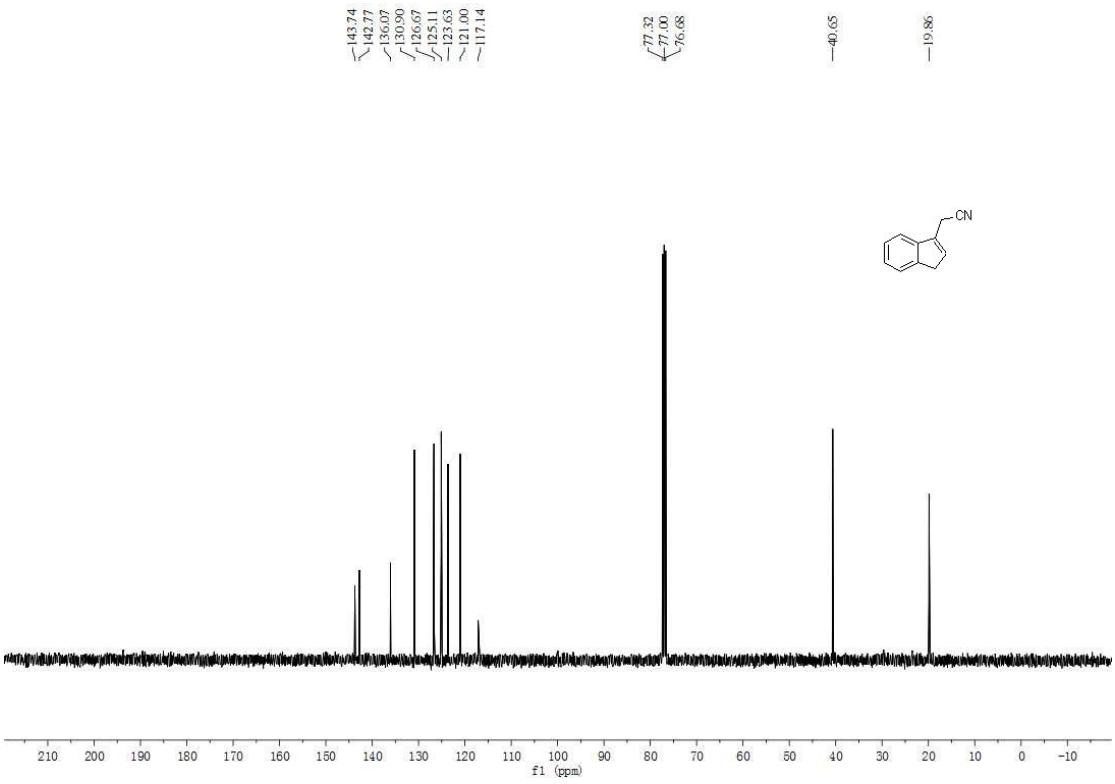
**Product 4s**


7.456
7.439
7.421
7.407
7.390
7.345
7.315
7.305
7.301
7.260
7.246
7.237
7.225
7.197
7.179
6.066
6.048
6.029
3.167
3.148
CN
10.48
1.00
2.01

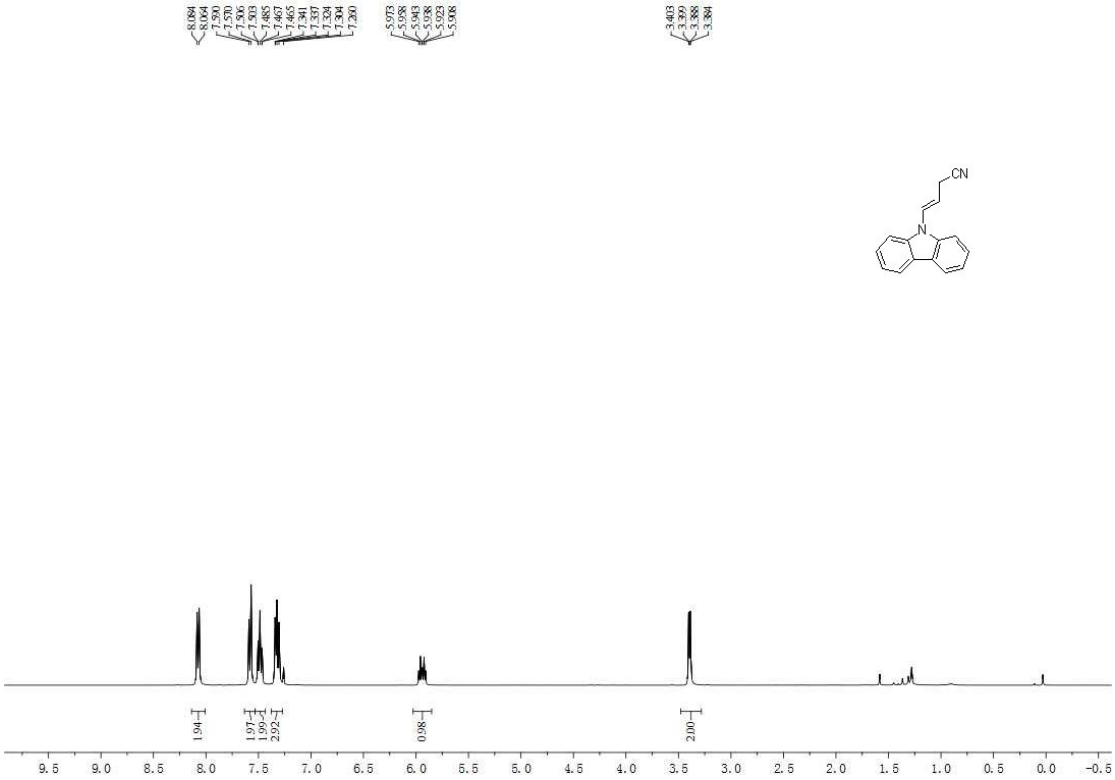

147.49
140.64
137.93
129.34
128.75
128.32
128.15
128.09
127.40
118.10
115.42
77.32
77.00
76.68
18.34
CN

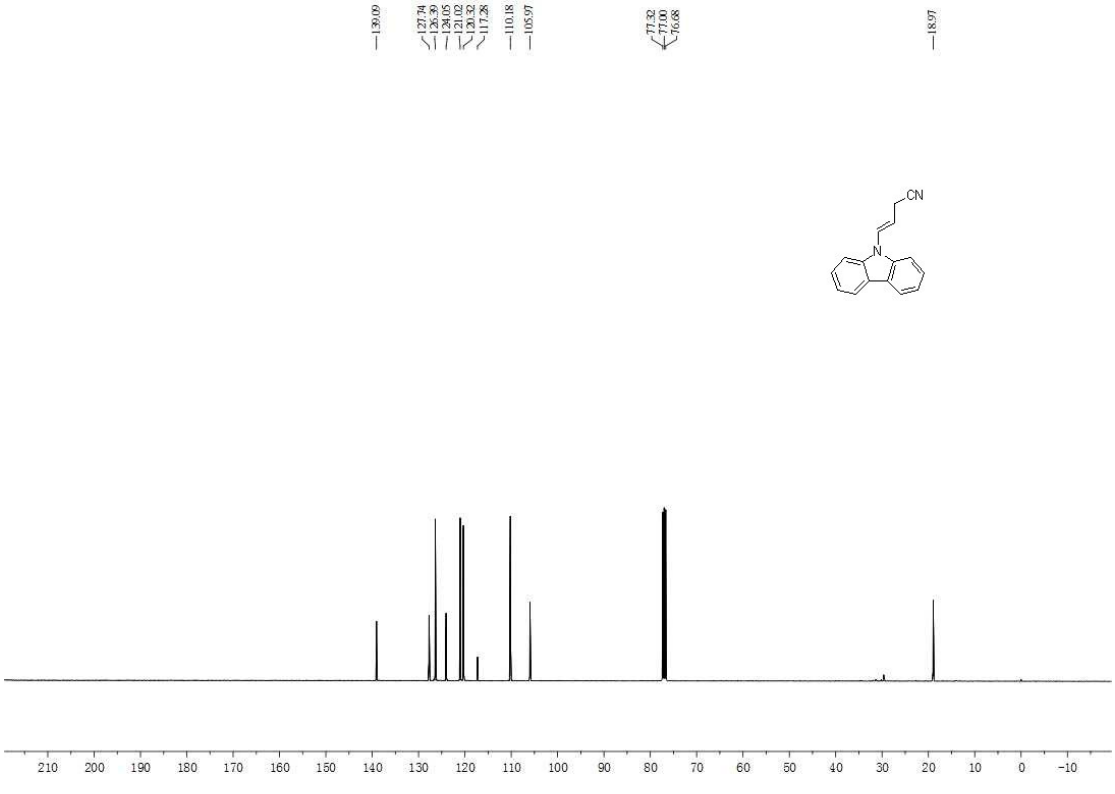
**Product 4t**


7.439
7.421
7.368
7.350
7.304
7.286
7.267
7.260
7.227
7.209
7.191
6.868
3.572
3.427
CN
1.08
1.06
1.12
1.07
1.00
2.12
2.14
f1 (ppm)

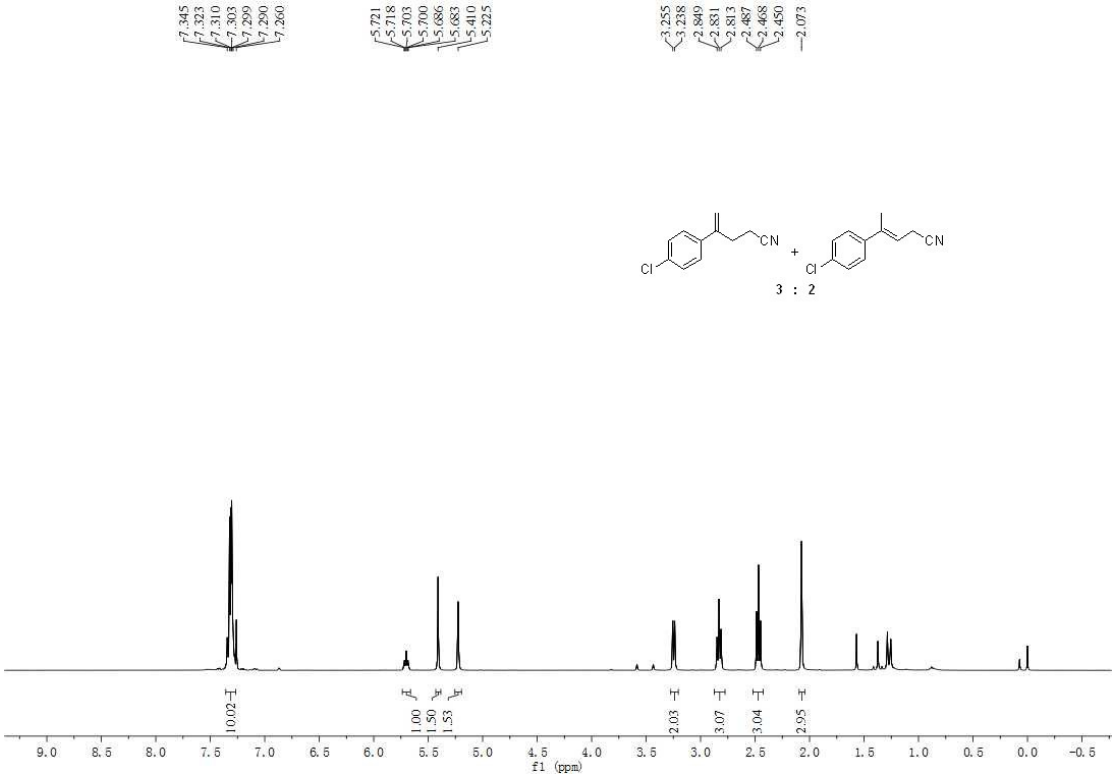

143.74
142.77
136.07
130.90
126.67
125.11
123.63
121.00
117.14
77.32
77.00
76.68
40.65
19.86
CN
f1 (ppm)

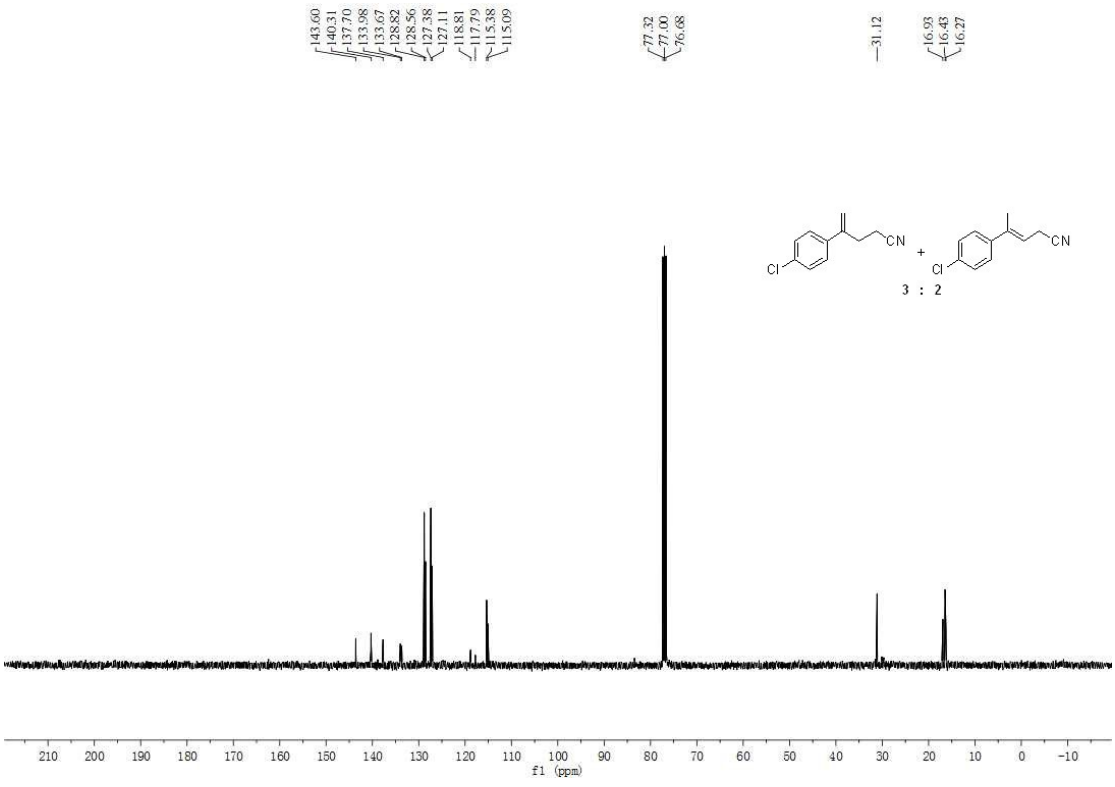
**Product 4u**


8.084
8.064
7.590
7.570
7.506
7.486
7.485
7.467
7.465
7.341
7.337
7.324
7.304
7.200
5.973
5.958
5.943
5.938
5.923
5.908
3.403
3.399
3.388
3.384
CN
N
1.94
1.97
1.99
2.92
0.98
2.00
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
-0.5


139.09
127.74
126.39
124.05
121.02
120.32
117.28
110.18
105.97
77.32
77.00
76.68
18.97
CN
N
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10

**Product 4v and 4v'**



**Product 6**