Supporting Information

for

Cu-Catalyzed C-N Bond Cleavage of 3-Aminoindazoles for C-H Arylation of Enamines

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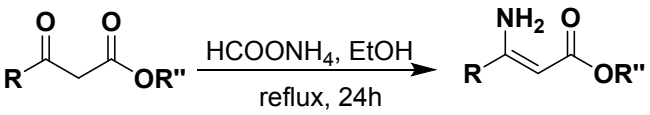
1. General information

All chemicals were purchased from Adamas Reagent, Ltd, Energy chemical company, J&K Scientific Ltd, Alfa Aesa chemical company and so forth. CH_3CN was dried by CaH prior to use. Unless otherwise stated, all experiments were conducted in a seal tube under air atmosphere. Reactions were monitored by TLC or GC-MS analysis. Flash column chromatography was performed over silica gel (200-300 mesh).

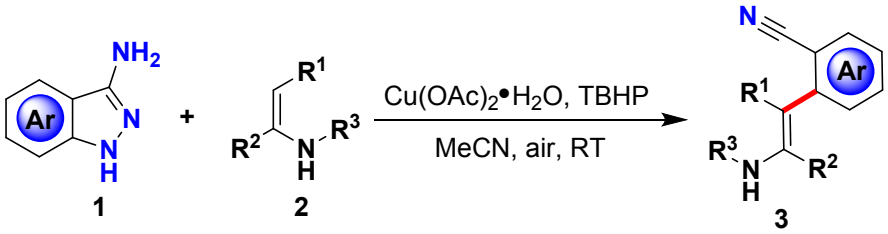
^{1}H-NMR and ^{13}C-NMR spectra were recorded in $CDCl_3$ on a Bruker Avance 500 spectrometer (500 MHz ^{1}H, 125 MHz ^{13}C) at room temperature. Chemical shifts were reported in ppm on the scale relative to $CDCl_3$ (δ = 7.26 for ^{1}H-NMR , δ = 77.00 for ^{13}C-NMR) or DMSO-d_6 (δ = 2.50 for ^{1}H-NMR, δ = 39.60 for ^{13}C-NMR) as an internal reference. High resolution mass spectra were recorded using Q-TOF time-of-flight mass spectrometer. Coupling constants (*J*) were reported in Hertz (Hz).

2. General procedure for starting materials



The mixture of β-keto ester (5 mmol) and $HCOONH_4$ (25 mmol) was stirred in 15 mL EtOH at 80 °C for 24 h. Upon completion of the reaction (detected by TLC), the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatographto using PE/EtOAc as the eluent to give the enamine esters.

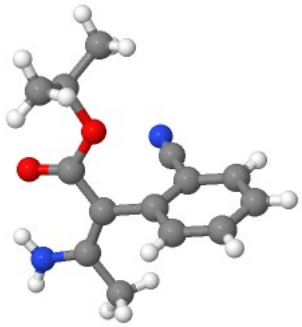
3. General procedure for the synthesis of 3



TBHP (5.0-6.0 M in decane) (0.5 mmol, 2.5 equiv) was added to a mixture of $Cu(OAc)_2•H_2O$ (8 mg, 20 mol%), 3-aminoindazoles **1** (0.4 mmol) and enamines **2** (0.2 mmol, 1 equiv) in CH_3CN (1 mL). Then the sealed tube was stirred at RT for 18 h. Upon completion of the reaction, the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatograph (silica gel, petroleum ether:EtOAc = 10:1, v/v) to give the desired product **3**.

4. Crystal data of 3n

Crystallographic data for compound **3n** (CCDC-1954088) has been deposited with the Cambridge Crystallographic Data Centre, Copies of the data can be obtained, free of charge, on application to CCDC (Email:deposit@ccdc.cam.ac.uk).



Bond precision: C-C = 0.0028 A Wavelength=0.71073

Cell: a=9.5333(7) b=10.8109(10) c=14.0387(13)
alpha=90 beta=104.958(9) gamma=90

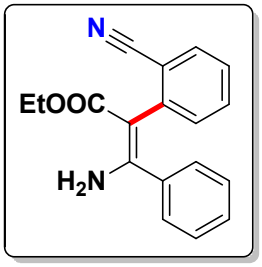
Temperature: 298 K

	Calculated	Reported
Volume	1397.9(2)	1397.9(2)
Space group	P 21/c	P 1 21/c 1
Hall group	-P 2ybc	-P 2ybc
Moiety formula	C14 H16 N2 O2	C14 H16 N2 O2
Sum formula	C14 H16 N2 O2	C14 H16 N2 O2
Mr	244.29	244.30
Dx,g cm-3	1.161	1.161
Z	4	4
Mu (mm-1)	0.079	0.079
F000	520.0	520.2
F000'	520.22	
h,k,lmax	11,12,16	11,12,16
Nref	2461	2450
Tmin,Tmax		0.533,1.000
Tmin'		

Correction method= # Reported T Limits: Tmin=0.533 Tmax=1.000
AbsCorr = MULTI-SCAN
Data completeness= 0.996 Theta(max)= 25.000
R(reflections)= 0.0478(1673) wR2(reflections)= 0.1569(2450)
S = 0.970 Npar= 165

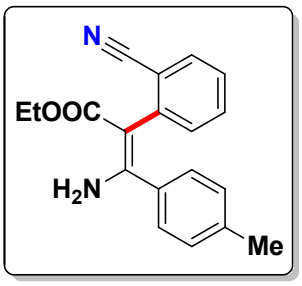
5. Characterization data for products

(Z)-ethyl 3-amino-2-(2-cyanophenyl)-3-phenylacrylate (3a)



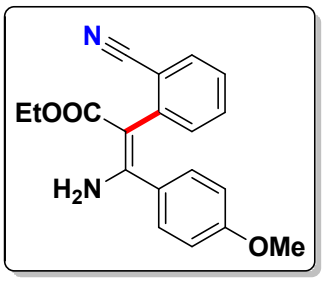
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 10:1, v/v) to give the product as a white solid (51.4 mg, 88%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.97 (brs, 1H), 7.42 (dd, *J* = 7.7, 1.1 Hz, 1H), 7.24 – 7.20 (m, 1H), 7.20 – 7.13 (m, 5H), 7.09 (td, *J* = 7.6, 1.2 Hz, 1H), 7.02 (dd, *J* = 7.8, 0.7 Hz, 1H), 5.15 (brs, 1H), 4.24 – 4.17 (m, 1H), 4.12 – 4.04 (m, 1H), 1.18 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.6, 161.6, 142.2, 137.2, 133.8, 131.8, 131.3, 128.9, 128.1, 127.9, 126.0, 118.8, 115.9, 95.5, 59.5, 14.1. HRMS (ESI, m/z) calcd for $C_{18}H_{17}N_2O_2[M+H]^+$: 293.1285; found: 293.1285.

(Z)-ethyl 3-amino-2-(2-cyanophenyl)-3-(p-tolyl)acrylate (3b)



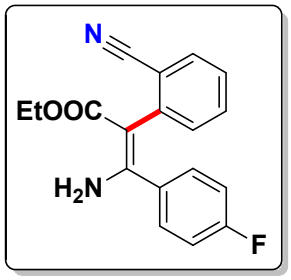
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 10:1, v/v) to give the product as a white solid (55.7 mg, 91%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.02 (brs, 1H), 7.47 (dd, *J* = 7.7, 1.1 Hz, 1H), 7.29 – 7.24 (m, 1H), 7.14 (td, *J* = 7.6, 1.1 Hz, 1H), 7.06 (dd, *J* = 7.3, 5.0 Hz, 3H), 6.98 (d, *J* = 8.0 Hz, 2H), 5.02 (brs, 1H), 4.27 – 4.21 (m, 1H), 4.16 – 4.08 (m, 1H), 2.26 (s, 3H), 1.22 (t, *J* = 7.1 Hz, 3H). 13C NMR (126 MHz, CDCl3) δ 168.8, 161.8, 142.5, 139.1, 134.5, 134.0, 132.0, 131.4, 128.8, 128.2, 126.0, 119.0, 116.1, 95.5, 59.6, 21.2, 14.3. HRMS (ESI, m/z) calcd for $C_{19}H_{19}N_2O_2[M+H]^+$: 307.1441; found: 307.1442.

(Z)-ethyl 3-amino-2-(2-cyanophenyl)-3-(4-methoxyphenyl)acrylate (3c)



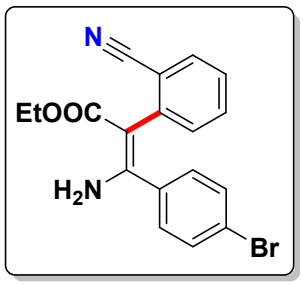
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 10:1, v/v) to give the product as a white solid (47.3 mg, 81%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.03 (brs, 1H), 7.45 (d, *J* = 7.6 Hz, 1H), 7.26 (ddd, *J* = 7.6, 6.8, 1.0 Hz, 1H), 7.16 – 7.03 (m, 4H), 6.66 (d, *J* = 8.7 Hz, 2H), 4.98 (brs, 1H), 4.23 – 4.18 (m, 1H), 4.14 – 4.09 (m, 1H), 3.72 (s, 3H), 1.19 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.9, 161.6, 160.0, 142.7, 134.0, 132.0, 131.5, 129.8, 129.6, 126.0, 119.0, 116.1, 113.4, 95.5, 59.7, 55.1, 14.3. HRMS (ESI, m/z) calcd for $C_{19}H_{19}N_2O_3[M+H]^+$: 323.1390; found: 323.1393.

(Z)-ethyl 3-amino-2-(2-cyanophenyl)-3-(4-fluorophenyl)acrylate (3d)



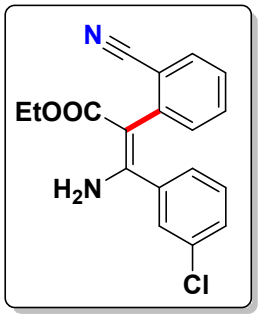
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 10:1, v/v) to give the product as a yellow solid (48.4 mg, 78%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.00 (brs, 1H), 7.51 – 7.44 (m, 1H), 7.32 – 7.27 (m, 1H), 7.21 – 7.14 (m, 3H), 7.06 (dd, J = 7.8, 0.7 Hz, 1H), 6.91 – 6.84 (m, 2H), 5.02 (brs, 1H), 4.27 – 4.19 (m, 1H), 4.16 – 4.09 (m, 1H), 1.21 (t, J = 7.1 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.7, 162.7 (d, J = 250.7 Hz), 160.5, 142.1, 133.9, 133.4, 132.1, 131.6, 130.3 (d, J = 8.5 Hz), 126.3, 118.8, 116.0, 115.2 (d, J = 21.4 Hz), 96.1, 59.8, 14.2. HRMS (ESI, m/z) calcd for $C_{18}H_{16}FN_2O_2$ $[M+H]^+$: 311.1190; found: 311.1191.

(Z)-ethyl 3-amino-3-(4-bromophenyl)-2-(2-cyanophenyl)acrylate (3e)



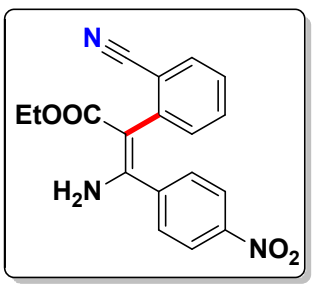
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 10:1, v/v) to give the product as a white solid (51.1 mg, 69%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.96 (brs, 1H), 7.45 (dd, J = 7.7, 1.1 Hz, 1H), 7.32 – 7.26 (m, 3H), 7.15 (td, J = 7.6, 1.2 Hz, 1H), 7.04 (dt, J = 4.1, 2.3 Hz, 3H), 4.98 (brs, 1H), 4.26 – 4.17 (m, 1H), 4.13 – 4.07 (m, 1H), 1.18 (t, J = 7.1 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.6, 160.2, 141.9, 136.2, 133.8, 132.1, 131.7, 131.4, 129.9, 126.4, 123.4, 118.8, 116.0, 96.2, 59.9, 14.2. HRMS (ESI, m/z) calcd for $C_{18}H_{16}BrN_2O_2$ $[M+H]^+$: 371.0390; found: 371.0396.

(Z)-ethyl 3-amino-3-(3-chlorophenyl)-2-(2-cyanophenyl)acrylate (3f)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 10:1, v/v) to give the product as a yellow solid (47.3 mg, 72%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.97 (brs, 1H), 7.48 (dd, J = 7.7, 1.0 Hz, 1H), 7.29 (ddd, J = 7.7, 6.3, 1.4 Hz, 1H), 7.22 – 7.14 (m, 3H), 7.10 (t, J = 7.7 Hz, 1H), 7.07 – 7.02 (m, 2H), 5.06 (brs, 1H), 4.27 – 4.18 (m, 1H), 4.16 – 4.08 (m, 1H), 1.20 (t, J = 7.1 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.6, 159.8, 141.7, 138.9, 134.0, 133.8, 132.0, 131.6, 129.4, 129.2, 128.3, 126.5, 126.4, 118.7, 116.0, 96.3, 59.8, 14.2. HRMS (ESI, m/z) calcd for $C_{18}H_{16}ClN_2O_2$ $[M+H]^+$: 327.0895; found: 327.0897.

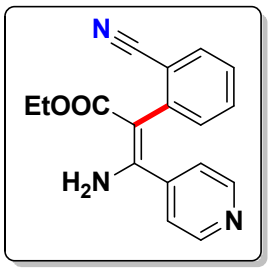
(Z)-ethyl 3-amino-2-(2-cyanophenyl)-3-(4-nitrophenyl)acrylate (3g)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 6:1, v/v) to give the product as a yellow solid (58.6 mg, 87%). ^{1}H NMR (500 MHz, DMSO) δ 8.78 (brs, 1H), 8.09 (d, J = 8.6 Hz, 2H), 7.83 (brs, 1H), 7.60 (d, J = 7.6 Hz, 1H), 7.40 (d, J = 8.6 Hz, 2H), 7.35 (dd, J = 11.1, 4.2 Hz, 1H), 7.22 (t,

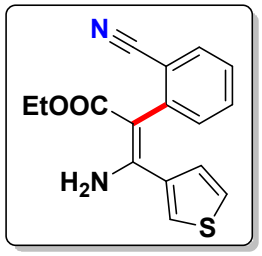
J = 7.5 Hz, 1H), 7.11 (d, *J* = 7.8 Hz, 1H), 4.14 – 4.11 (m, 1H), 4.04 – 4.01 (m, 1H), 1.11 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (126 MHz, DMSO) δ 168.1, 160.7, 147.7, 143.7, 141.9, 134.6, 132.6, 132.5, 130.4, 127.4, 123.5, 119.2, 115.9, 94.5, 59.5, 14.7. HRMS (ESI, m/z) calcd for $C_{18}H_{16}N_3O_4[M+H]^+$: 338.1135; found: 338.1139.

(Z)-ethyl 3-amino-2-(2-cyanophenyl)-3-(pyridin-4-yl)acrylate (3h)



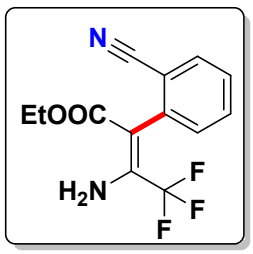
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 2:1, v/v) to give the product as a yellow solid (39.3 mg, 67%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.89 (brs, 1H), 8.37 (s, 2H), 7.44 (dd, *J* = 7.7, 1.1 Hz, 1H), 7.26 (td, *J* = 7.7, 1.4 Hz, 1H), 7.15 (td, *J* = 7.6, 1.2 Hz, 1H), 7.08 – 6.99 (m, 3H), 5.23 (brs, 1H), 4.22 – 4.14 (m, 1H), 4.13 – 4.05 (m, 1H), 1.16 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.4, 158.3, 149.6, 144.9, 141.1, 133.6, 132.1, 131.8, 126.8, 122.7, 118.5, 115.9, 96.5, 60.0, 14.1. HRMS (ESI, m/z) calcd for $C_{17}H_{16}N_3O_2[M+H]^+$: 294.1237; found: 294.1237.

(Z)-ethyl 3-amino-2-(2-cyanophenyl)-3-(thiophen-3-yl)acrylate (3i)



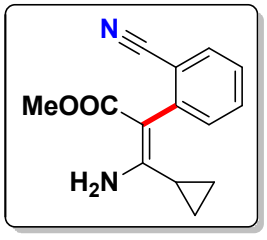
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 10:1, v/v) to give the product as a yellow solid (52.4 mg, 88%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.56 (dd, *J* = 7.7, 1.0 Hz, 1H), 7.38 (td, *J* = 7.7, 1.4 Hz, 1H), 7.30 – 7.23 (m, 2H), 7.19 (dd, *J* = 7.8, 0.7 Hz, 1H), 6.88 (dd, *J* = 3.7, 1.2 Hz, 1H), 6.83 (dd, *J* = 5.0, 3.7 Hz, 1H), 4.23 (dq, *J* = 10.8, 7.1 Hz, 1H), 4.11 (dq, *J* = 10.8, 7.1 Hz, 1H), 1.20 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.6, 153.8, 142.1, 138.2, 133.7, 132.2, 131.8, 129.2, 128.3, 126.8, 126.7, 118.5, 116.2, 96.1, 59.8, 14.2. HRMS (ESI, m/z) calcd for $C_{16}H_{15}N_2O_2S[M+H]^+$: 299.0849; found: 299.0852.

(Z)-ethyl 3-amino-2-(2-cyanophenyl)-4,4,4-trifluorobut-2-enoate (3j)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 10:1, v/v) to give the product as a yellow oil (29.5 mg, 52%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.67 – 7.63 (m, 1H), 7.54 (td, *J* = 7.7, 0.8 Hz, 1H), 7.40 (t, *J* = 7.6 Hz, 1H), 7.29 (d, *J* = 7.7 Hz, 1H), 4.25 – 4.18 (m, 1H), 4.08 – 4.01 (m, 1H), 1.14 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.3, 146.5 (q, *J* = 30.0 Hz), 138.0, 132.8, 132.6, 131.9, 130.6, 127.9, 118.5 (q, *J* = 252.0 Hz), 97.6, 60.7, 39.6, 14.0. HRMS (ESI, m/z) calcd for $C_{13}H_{12}N_2O_2F_3[M+H]^+$: 285.0845; found: 285.0847.

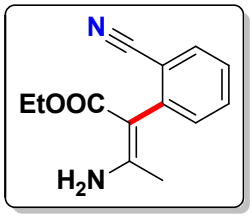
(Z)-methyl 3-amino-2-(2-cyanophenyl)-3-cyclopropylacrylate (3k)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 10:1, v/v) to give the product as a yellow oil (31.9 mg, 66%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.65 (dd, *J* = 7.7, 1.0 Hz, 1H), 7.53 (td, *J* = 7.7, 1.4

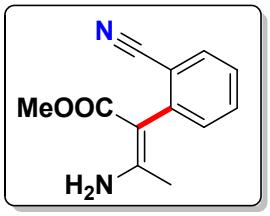
Hz, 1H), 7.38 – 7.31 (m, 2H), 3.59 (s, 3H), 1.32 – 1.26 (m, 1H), 0.85 – 0.77 (m, 1H), 0.77 – 0.67 (m, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.7, 163.1, 142.2, 133.5, 132.4, 132.1, 126.8, 118.6, 116.1, 95.3, 50.8, 14.5, 7.6, 7.5. HRMS (ESI, m/z) calcd for $C_{14}H_{15}N_2O_2$ $[M+H]^+$: 243.1128; found: 243.1130.

(Z)-ethyl 3-amino-2-(2-cyanophenyl)but-2-enoate (3l)



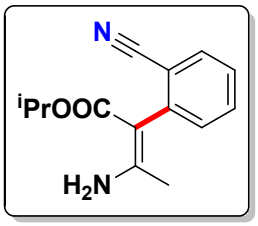
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 5:1, v/v) to give the product as a yellow solid (35.8 mg, 78%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.77 (brs, 1H), 7.63 (dd, *J* = 7.7, 1.2 Hz, 1H), 7.51 (td, *J* = 7.7, 1.4 Hz, 1H), 7.32 (td, *J* = 7.6, 1.1 Hz, 1H), 7.26 (d, *J* = 7.7 Hz, 1H), 4.99 (brs, 1H), 4.12 (dq, *J* = 10.8, 7.1 Hz, 1H), 4.01 (dq, *J* = 10.8, 7.1 Hz, 1H), 1.74 (s, 3H), 1.11 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.5, 159.0, 142.5, 133.1, 132.3, 132.1, 126.8, 118.6, 115.7, 95.0, 59.3, 21.1, 14.3. HRMS (ESI, m/z) calcd for $C_{13}H_{15}N_2O_2$ $[M+H]^+$: 231.1128; found: 231.1129.

(Z)-methyl 3-amino-2-(2-cyanophenyl)but-2-enoate (3m)



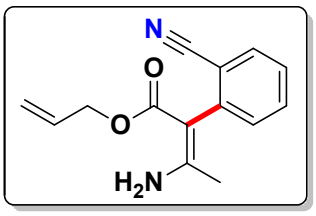
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 4:1, v/v) to give the product as a yellow oil (34.6 mg, 80%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.77 (brs, 1H), 7.65 – 7.62 (m, 1H), 7.52 (td, *J* = 7.7, 1.4 Hz, 1H), 7.33 (td, *J* = 7.6, 1.2 Hz, 1H), 7.27 (dd, *J* = 7.6, 0.9 Hz, 1H), 5.07 (brs, 1H), 3.57 (s, 3H), 1.74 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.8, 159.3, 142.3, 133.1, 132.4, 132.2, 126.9, 118.5, 115.7, 94.5, 50.8, 21.0. HRMS (ESI, m/z) calcd for $C_{12}H_{13}N_2O_2$ $[M+H]^+$: 217.0972; found: 217.0977.

(Z)-isopropyl 3-amino-2-(2-cyanophenyl)but-2-enoate (3n)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 5:1, v/v) to give the product as a white solid (34.6 mg, 71%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.76 (brs, 1H), 7.62 (dd, *J* = 7.7, 1.0 Hz, 1H), 7.50 (td, *J* = 7.7, 1.4 Hz, 1H), 7.30 (td, *J* = 7.6, 1.2 Hz, 1H), 7.24 (dd, *J* = 7.8, 0.6 Hz, 1H), 4.97 (dt, *J* = 12.5, 6.2 Hz, 2H), 1.73 (s, 3H), 1.13 (d, *J* = 6.2 Hz, 3H), 1.05 (d, *J* = 6.3 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.1, 158.7, 142.7, 133.1, 132.2, 132.0, 126.6, 118.7, 115.9, 95.4, 66.4, 21.9, 21.7, 21.1. HRMS (ESI, m/z) calcd for $C_{14}H_{17}N_2O_2$ $[M+H]^+$: 245.1285; found: 245.1289.

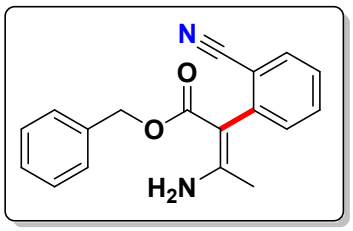
(Z)-allyl 3-amino-2-(2-cyanophenyl)but-2-enoate (3o)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 5:1, v/v) to give the product as a brown solid (30.9 mg, 64%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.77 (brs, 1H), 7.67 – 7.62 (m, 1H), 7.53 (td, *J* = 7.7, 1.4 Hz, 1H), 7.34 (td, *J* = 7.6, 1.2 Hz, 1H), 7.30 (dd, *J* = 7.8, 0.6 Hz, 1H), 5.85 – 5.77 (m, 1H), 5.16 – 4.85 (m, 3H),

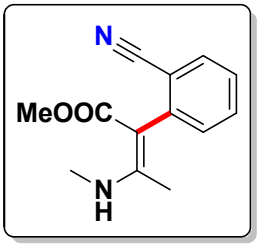
4.53 (dt, J = 5.0, 1.6 Hz, 2H), 1.76 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.0, 159.4, 142.3, 133.2, 132.9, 132.4, 132.2, 126.9, 118.5, 116.2, 115.7, 94.7, 63.8, 21.2. HRMS (ESI, m/z) calcd for $C_{14}H_{15}N_2O_2$ $[M+H]^+$: 243.1128; found: 243.1128.

(Z)-benzyl 3-amino-2-(2-cyanophenyl)but-2-enoate (3p)



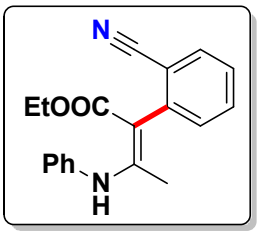
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 4:1, v/v) to give the product as a fulvous solid (33.9 mg, 58%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.78 (brs, 1H), 7.67 – 7.64 (m, 1H), 7.53 (td, J = 7.7, 1.4 Hz, 1H), 7.33 (ddd, J = 9.7, 8.1, 0.9 Hz, 2H), 7.28 – 7.20 (m, 3H), 7.16 – 7.13 (m, 2H), 5.15 (d, J = 13.1 Hz, 1H), 5.06 (d, J = 13.1 Hz, 1H), 4.99 (brs, 1H), 1.77 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.1, 159.5, 142.3, 136.9, 133.2, 132.4, 132.2, 128.2, 127.4, 127.0, 126.9, 118.6, 115.7, 94.7, 64.9, 21.1. HRMS (ESI, m/z) calcd for $C_{18}H_{17}N_2O_2$ $[M+H]^+$: 293.1285; found: 293.1285.

(Z)-methyl 2-(2-cyanophenyl)-3-(methylamino)but-2-enoate (3q)



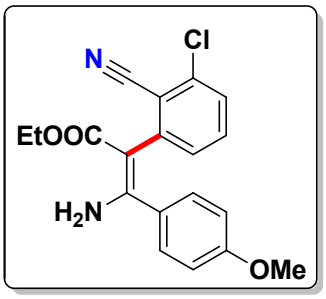
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 4:1, v/v) to give the product as a brown oil (33.1 mg, 72%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.59 (brs, 1H), 7.63 (dd, J = 7.7, 1.1 Hz, 1H), 7.51 (td, J = 7.7, 1.4 Hz, 1H), 7.31 (td, J = 7.6, 1.2 Hz, 1H), 7.24 (dd, J = 7.8, 0.6 Hz, 1H), 3.56 (s, 3H), 2.98 (d, J = 5.2 Hz, 3H), 1.75 (s, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.3, 162.2, 143.0, 133.5, 132.4, 132.1, 126.6, 118.6, 116.1, 92.7, 50.6, 30.0, 16.3. HRMS (ESI, m/z) calcd for $C_{18}H_{17}N_2O_2$ $[M+H]^+$: 231.1128; found: 231.1131.

(Z)-ethyl 2-(2-cyanophenyl)-3-(phenylamino)but-2-enoate (3r)



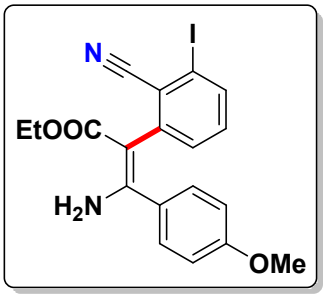
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 6:1, v/v) to give the product as a brown oil (42.2 mg, 69%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 11.37 (brs, 1H), 7.67 (d, J = 7.4 Hz, 1H), 7.54 (td, J = 7.7, 1.4 Hz, 1H), 7.40 – 7.32 (m, 4H), 7.21 – 7.09 (m, 3H), 4.26 – 4.11 (m, 1H), 4.10 – 4.04 (m, 1H), 1.78 (s, 3H), 1.15 (t, J = 7.1 Hz, 3H).^{13}C NMR (126 MHz, $CDCl_3$) δ 168.8, 158.5, 142.5, 138.9, 133.2, 132.4, 132.2, 129.0, 126.8, 125.5, 125.3, 118.6, 115.8, 96.4, 59.5, 18.1, 14.2. HRMS (ESI, m/z) calcd for $C_{19}H_{19}N_2O_2$ $[M+H]^+$: 307.1441; found: 307.1441.

(Z)-ethyl 3-amino-2-(3-chloro-2-cyanophenyl)-3-(4-methoxyphenyl)acrylate (3s)



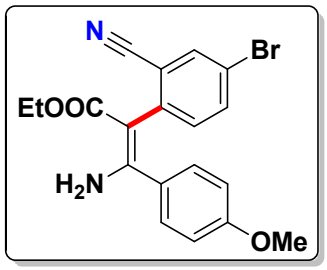
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 10:1, v/v) to give the product as a yellow solid (48.4 mg, 68%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.03 (brs, 1H), 7.21 – 7.15 (m, 2H), 7.12 – 7.06 (m, 2H), 6.92 (dd, *J* = 5.5, 3.4 Hz, 1H), 6.73 – 6.67 (m, 2H), 5.04 (brs, 1H), 4.22 (dq, *J* = 10.9, 7.1 Hz, 1H), 4.10 (dq, *J* = 10.8, 7.1 Hz, 1H), 3.73 (s, 3H), 1.20 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.5, 161.8, 160.2, 145.2, 136.1, 132.2, 131.9, 129.7, 129.3, 126.8, 116.9, 116.0, 113.6, 95.2, 59.8, 55.2, 14.3. HRMS (ESI, m/z) calcd for $C_{19}H_{18}ClN_2O_3[M+H]^+$: 357.1000; found: 357.1004.

ethyl (Z)-3-amino-2-(2-cyano-3-iodophenyl)-3-(4-methoxyphenyl)acrylate (3t)



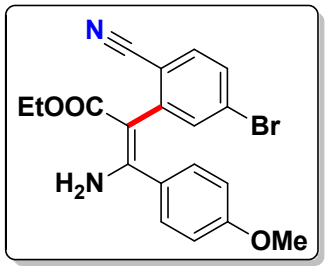
The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 10:1, v/v) to give the product as a brown solid (54.6 mg, 61%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.00 (s, 1H), 7.57 (dd, *J* = 7.8, 1.1 Hz, 1H), 7.10 – 7.04 (m, 2H), 6.98 (dd, *J* = 7.8, 1.1 Hz, 1H), 6.92 (t, *J* = 7.8 Hz, 1H), 6.72 – 6.65 (m, 2H), 5.06 (s, 1H), 4.21 (dq, *J* = 10.8, 7.1 Hz, 1H), 4.12 – 4.06 (m, 1H), 3.72 (s, 3H), 1.19 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.4, 161.7, 160.1, 145.3, 136.5, 133.3, 132.1, 129.7, 129.2, 123.9, 119.4, 113.6, 97.7, 95.7, 59.7, 55.2, 14.3. HRMS (ESI, m/z) calcd for $C_{19}H_{18}IlN_2O_3[M+H]^+$: 449.0357; found: 449.0360.

(Z)-ethyl 3-amino-2-(4-bromo-2-cyanophenyl)-3-(4-methoxyphenyl)acrylate (3u)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 10:1, v/v) to give the product as a yellow solid (51.2 mg, 64%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.03 (brs, 1H), 7.56 (d, *J* = 2.2 Hz, 1H), 7.37 (dd, *J* = 8.4, 2.2 Hz, 1H), 7.10 – 7.04 (m, 2H), 6.91 (d, *J* = 8.4 Hz, 1H), 6.70 (d, *J* = 8.8 Hz, 2H), 5.05 (brs, 1H), 4.22 –4.17 (m, 1H), 4.13 – 4.07 (m, 1H), 3.74 (s, 3H), 1.20 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.4, 161.8, 160.2, 141.8, 135.5, 134.7, 134.4, 129.8, 129.2, 119.2, 117.7, 117.5, 113.7, 94.3, 59.8, 55.2, 14.3. HRMS (ESI, m/z) calcd for $C_{19}H_{18}BrN_2O_3$ $[M+H]^+$: 401.0495; found: 401.0499.

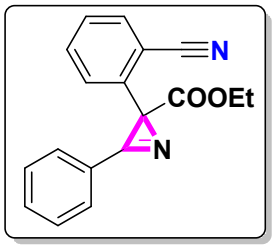
(Z)-ethyl 3-amino-2-(5-bromo-2-cyanophenyl)-3-(4-methoxyphenyl)acrylate (3v)



The reaction was performed following the general procedure. The residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 10:1, v/v) to give the product as a yellow solid (45.6 mg, 57%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.04 (brs, 1H), 7.29 – 7.26 (m, 3H), 7.12 – 7.07 (m, 2H), 6.75 – 6.68 (m, 2H), 5.05

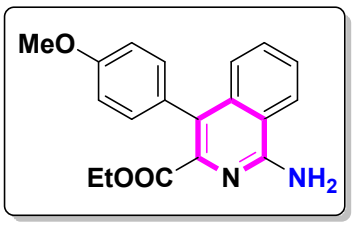
(brs, 1H), 4.23 – 4.18 (m, 1H), 4.17 – 4.09 (m, 1H), 3.75 (s, 3H), 1.21 (t, J = 7.1 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 168.4, 162.1, 160.2, 144.5, 137.1, 133.0, 129.8, 129.3, 129.1, 126.1, 118.3, 114.9, 113.7, 94.4, 59.8 55.2, 14.3. HRMS (ESI, m/z) calcd for $C_{19}H_{18}BrN_2O_3$ $[M+H]^+$: 401.0495; found: 401.0496.

ethyl 2-(2-cyanophenyl)-3-phenyl-2H-azirine-2-carboxylate (4)



To a mixture of **3a** (0.2 mmol), I_2 (0.3 mmol) and DBU (0.5 mmol) was added DCM (1.5 mL). Then, the mixture was stirred at RT for 1.5 h. Upon completion of the reaction, the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 8:1, v/v) to give the desired product as a yellow oil (54.5 mg, 94%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.11 (dd, J = 8.3, 1.3 Hz, 2H), 7.68 (d, J = 7.7 Hz, 1H), 7.64 (ddd, J = 6.5, 3.8, 1.3 Hz, 1H), 7.59 (d, J = 7.7 Hz, 2H), 7.57 – 7.55 (m, 2H), 7.43 – 7.35 (m, 1H), 4.33 – 4.19 (m, 2H), 1.25 (t, J = 7.1 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 170.1, 163.2, 140.3, 134.2, 133.0, 132.5, 130.7, 129.4, 128.2, 128.0, 121.1, 118.3, 113.9, 62.3, 40.6, 14.0. HRMS (ESI, m/z) calcd for $C_{18}H_{15}N_2O_2$ $[M+H]^+$: 291.1128; found: 291.1130.

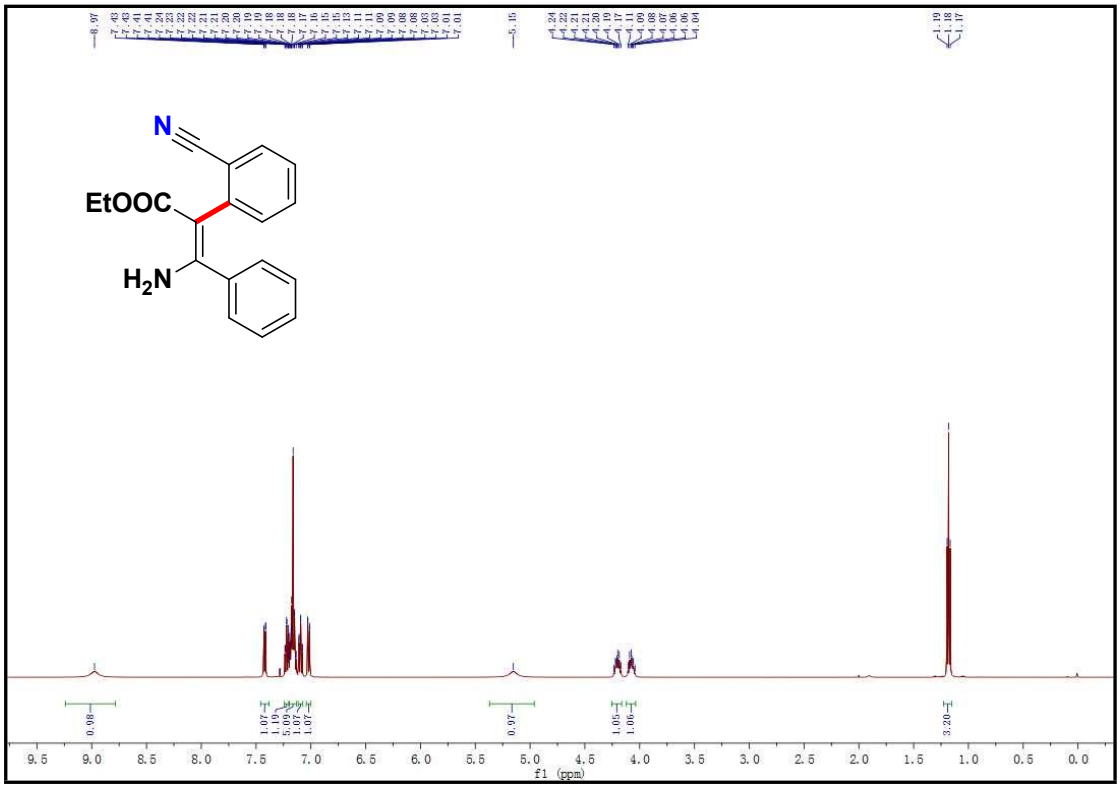
ethyl 1-amino-3-(4-methoxyphenyl)isoquinoline-4-carboxylate (5)

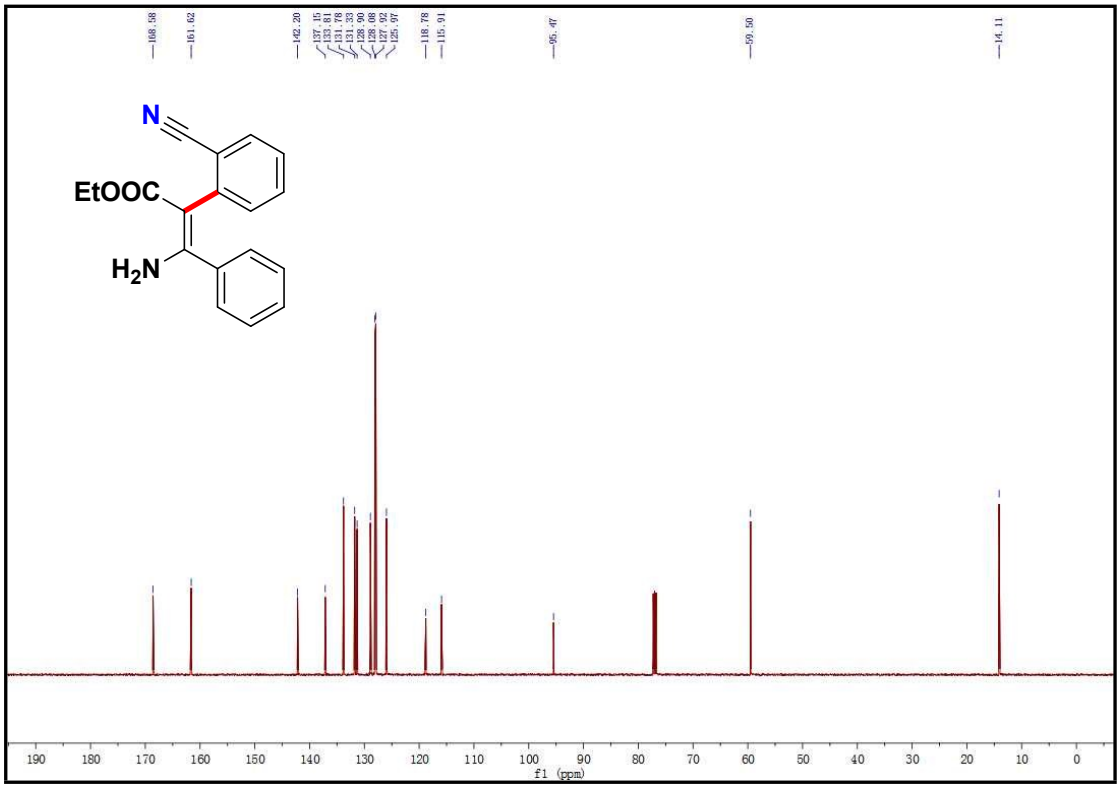


To a mixture of **3c** (0.2 mmol) and ^{t}BuONa (0.5 mmol) was added THF (1 mL). Then, the mixture was stirred at 70 °C for 16 h. Upon completion of the reaction, the solvent was evaporated under reduced pressure and the residue was purified by flash column chromatograph (silica gel, petroleum ether:AcOEt = 4:1, v/v) to give the product as a white solid (59.2 mg, 92%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.03 (d, J = 8.4 Hz, 1H), 7.77 (d, J = 8.3 Hz, 1H), 7.70 – 7.64 (m, 1H), 7.62 – 7.56 (m, 2H), 7.47 (dd, J = 11.2, 4.0 Hz, 1H), 6.96 (d, J = 8.7 Hz, 2H), 5.61 (s, 2H), 4.17 (q, J = 7.1 Hz, 2H), 3.84 (s, 3H), 1.03 (t, J = 7.1 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 169.6, 159.8, 156.4, 151.1, 135.4, 133.5, 131.2, 129.8, 126.1, 124.7, 122.6, 115.5, 114.6, 113.7, 61.2, 55.4, 13.8. HRMS (ESI, m/z) calcd for $C_{19}H_{19}N_2O_3$[M+H]$^+$: 323.1390; found: 323.1395.

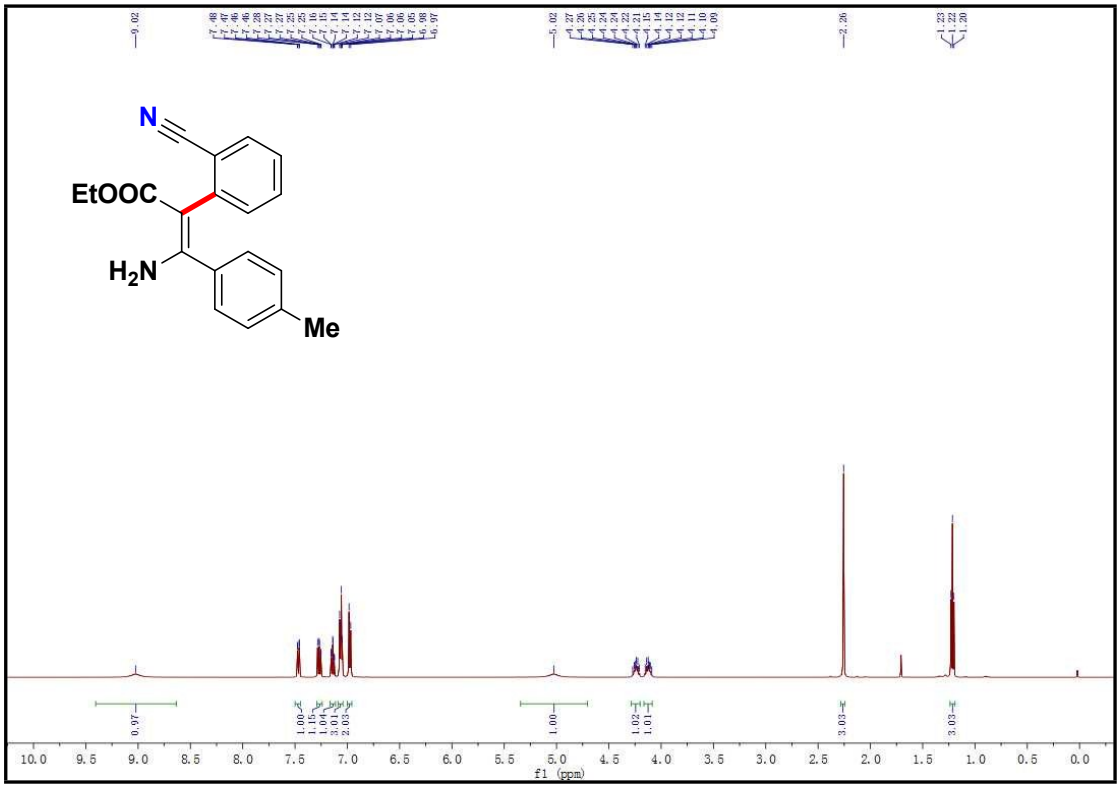
6. NMR spectroscopic data

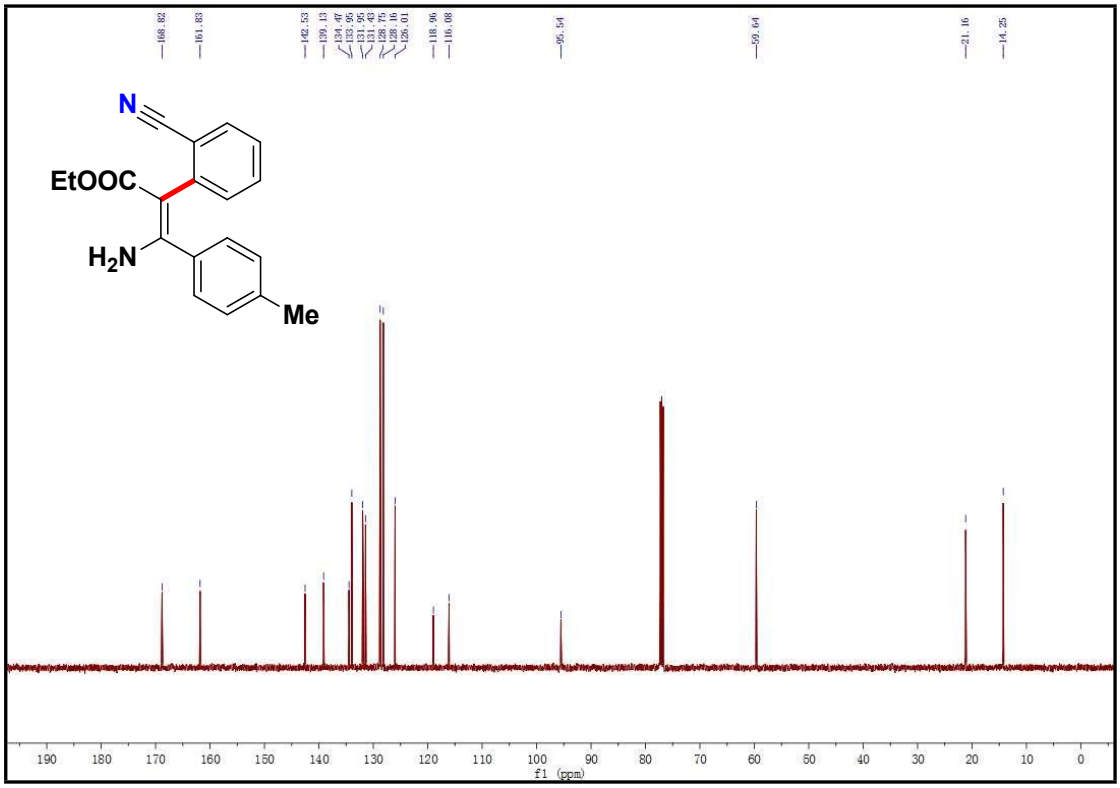
(Z)-ethyl 3-amino-2-(2-cyanophenyl)-3-phenylacrylate (3a)



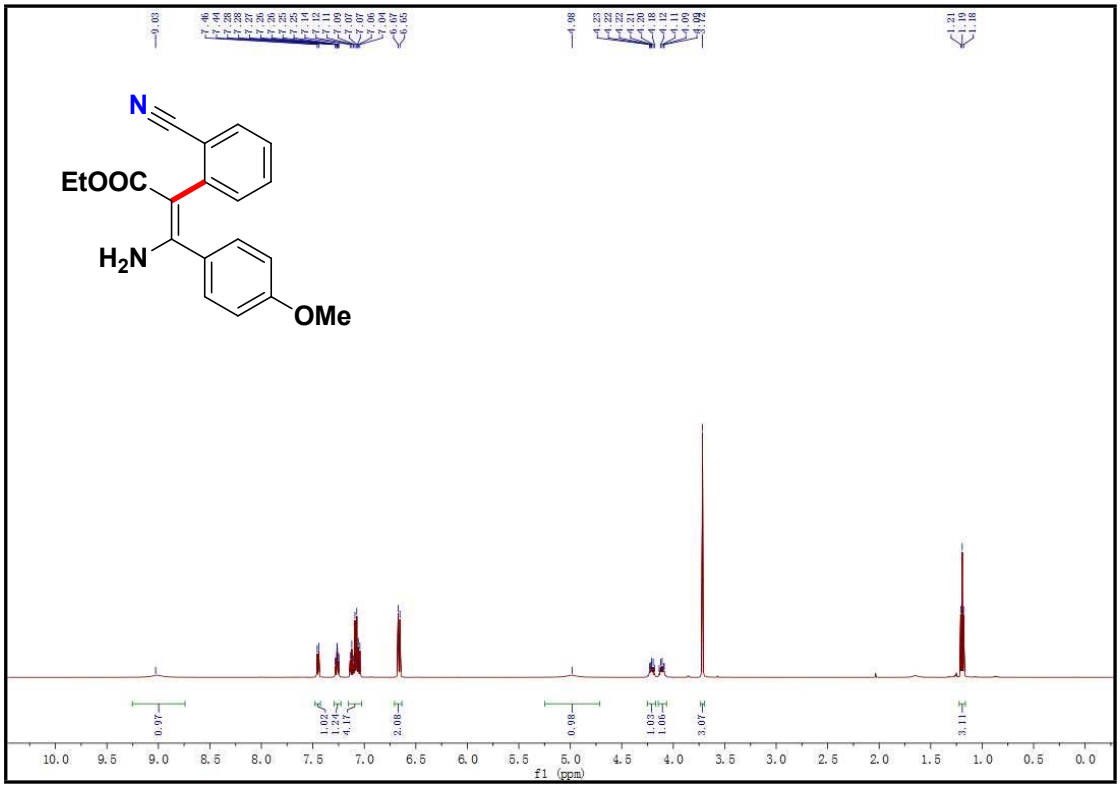


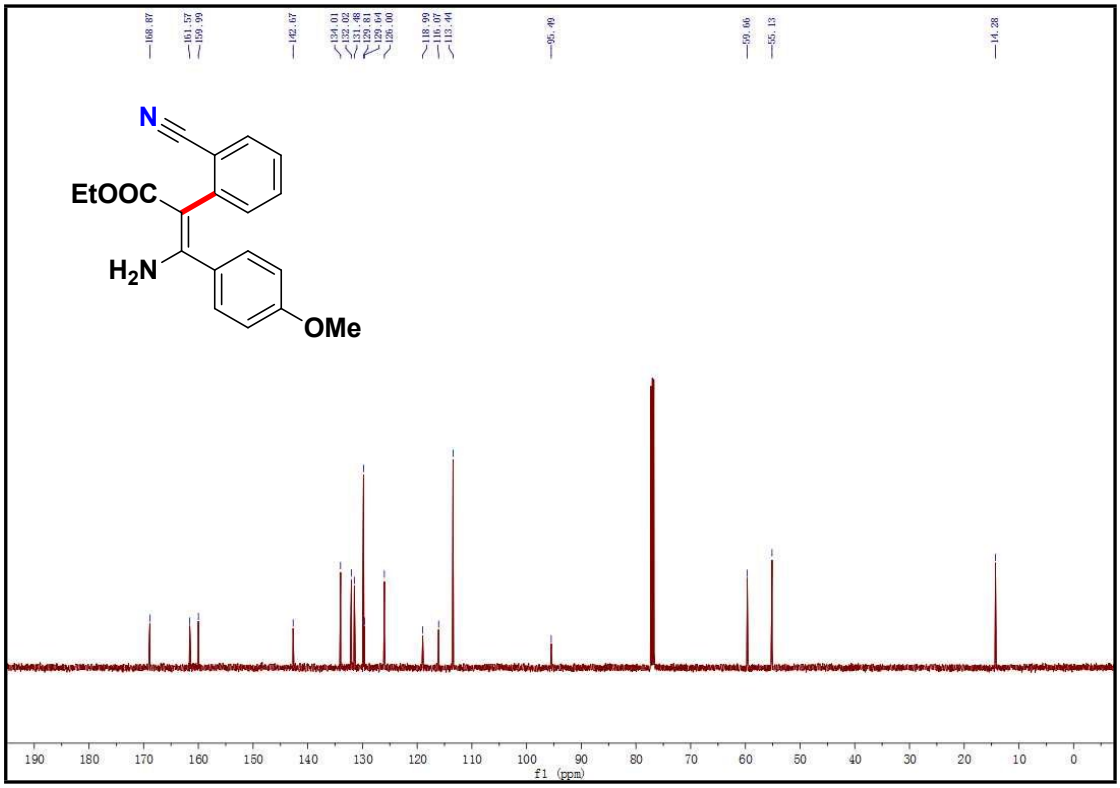
(Z)-ethyl 3-amino-2-(2-cyanophenyl)-3-(p-tolyl)acrylate (3b)



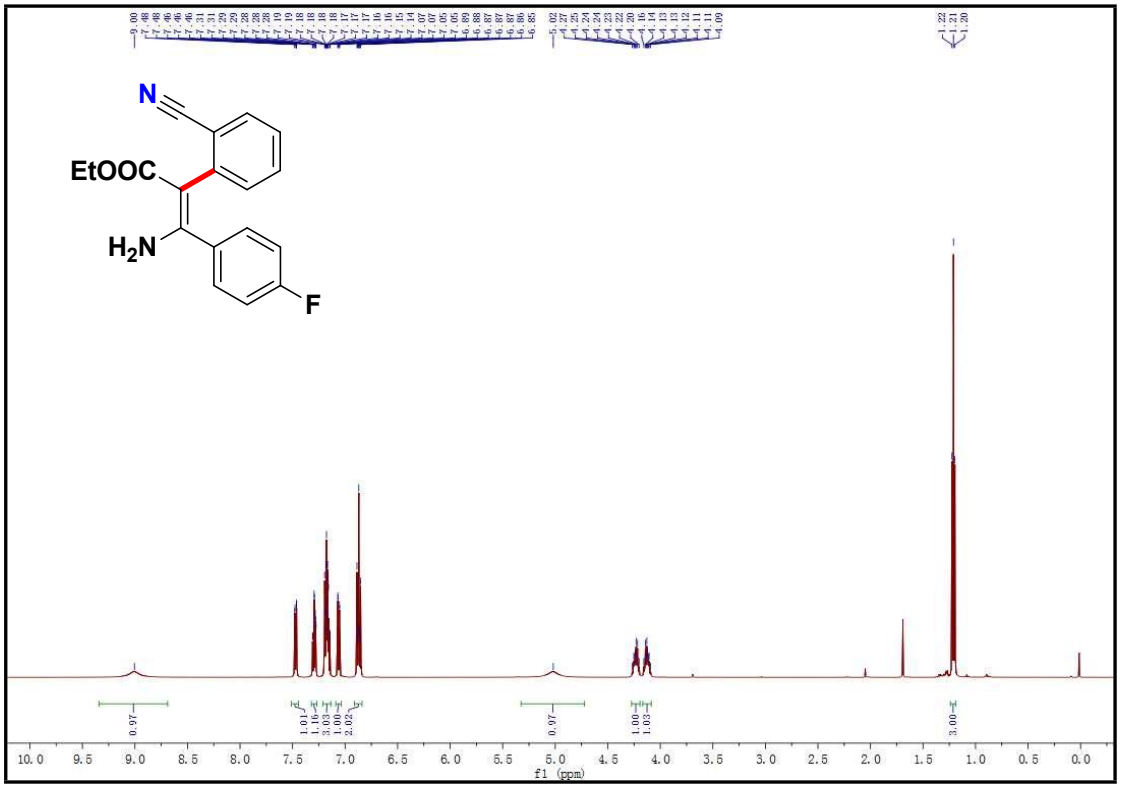


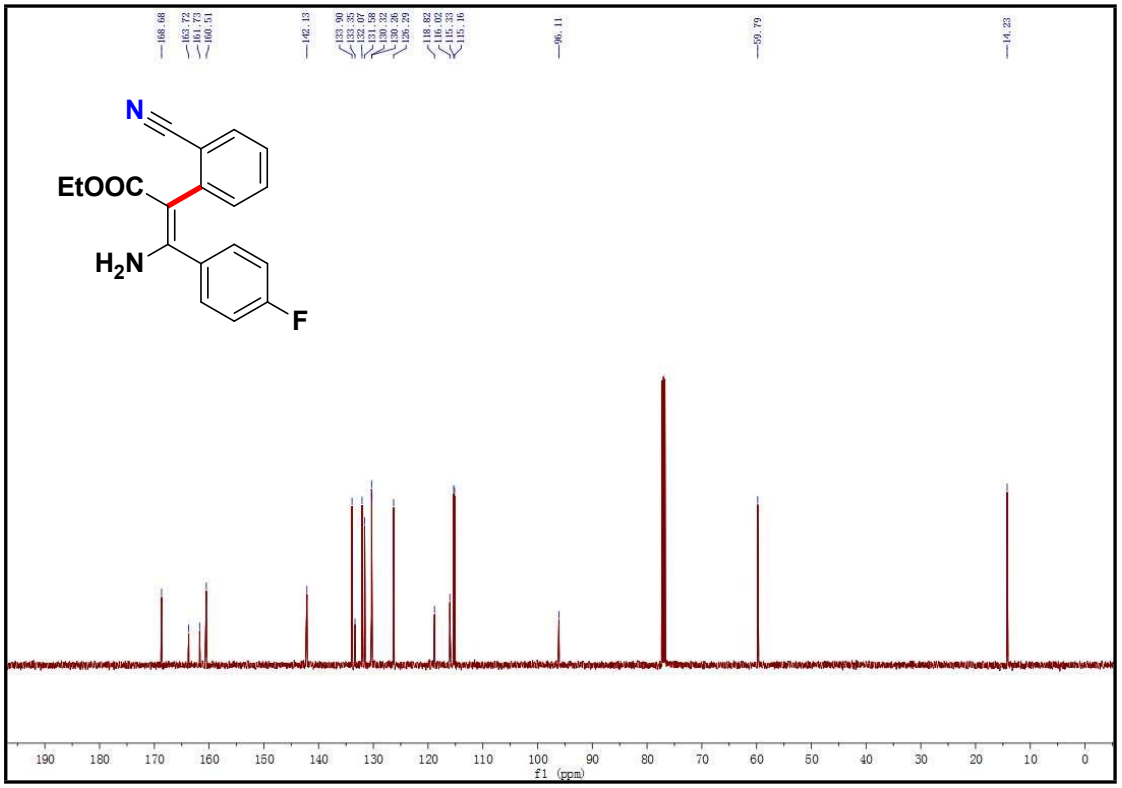
(Z)-ethyl 3-amino-2-(2-cyanophenyl)-3-(4-methoxyphenyl)acrylate (3c)



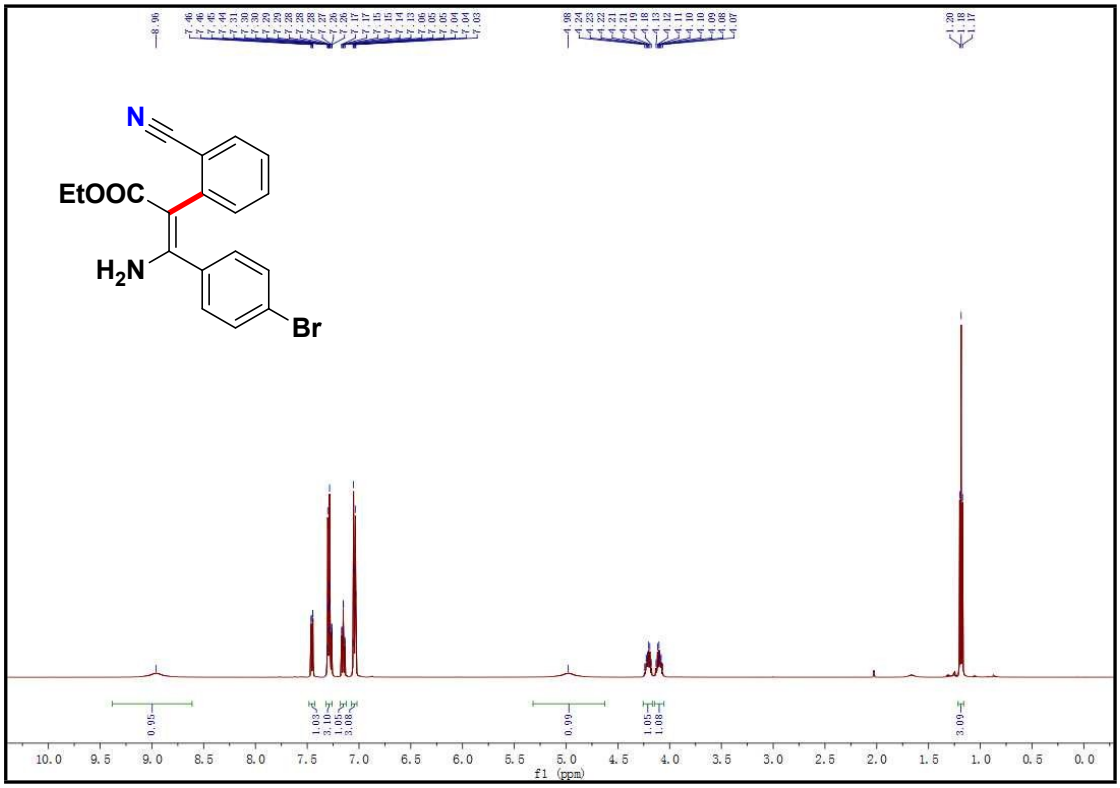


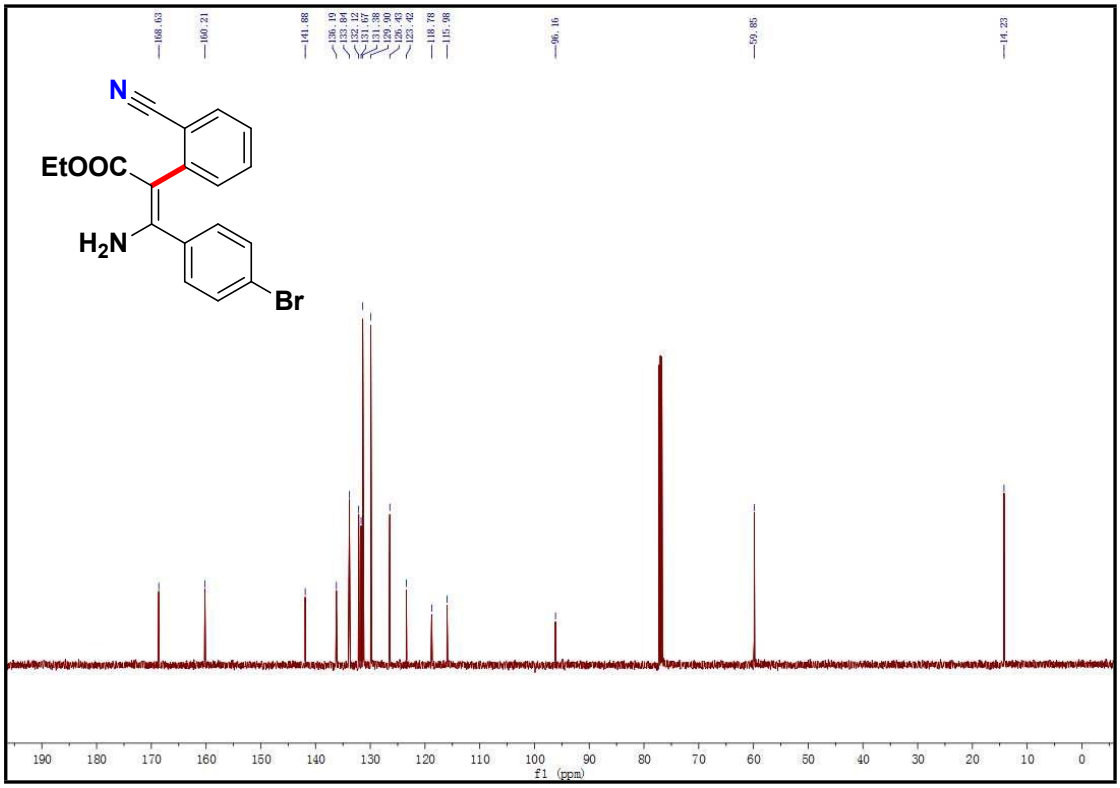
(Z)-ethyl 3-amino-2-(2-cyanophenyl)-3-(4-fluorophenyl)acrylate (3d)



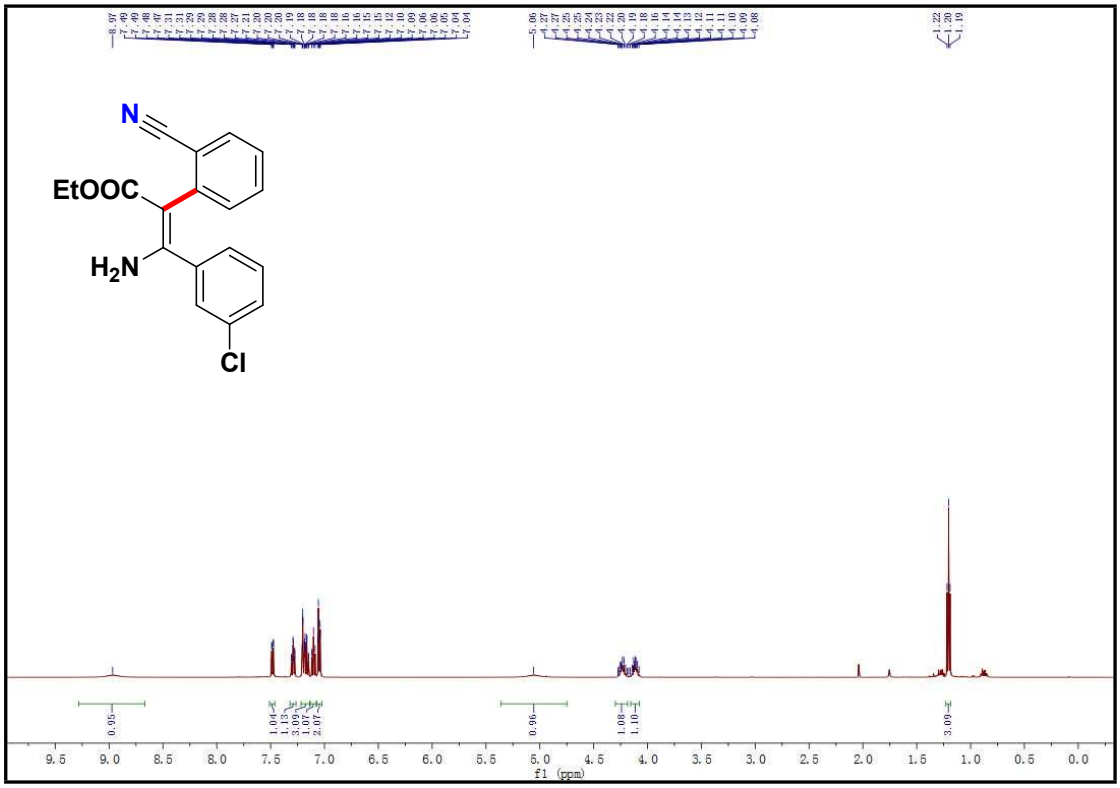


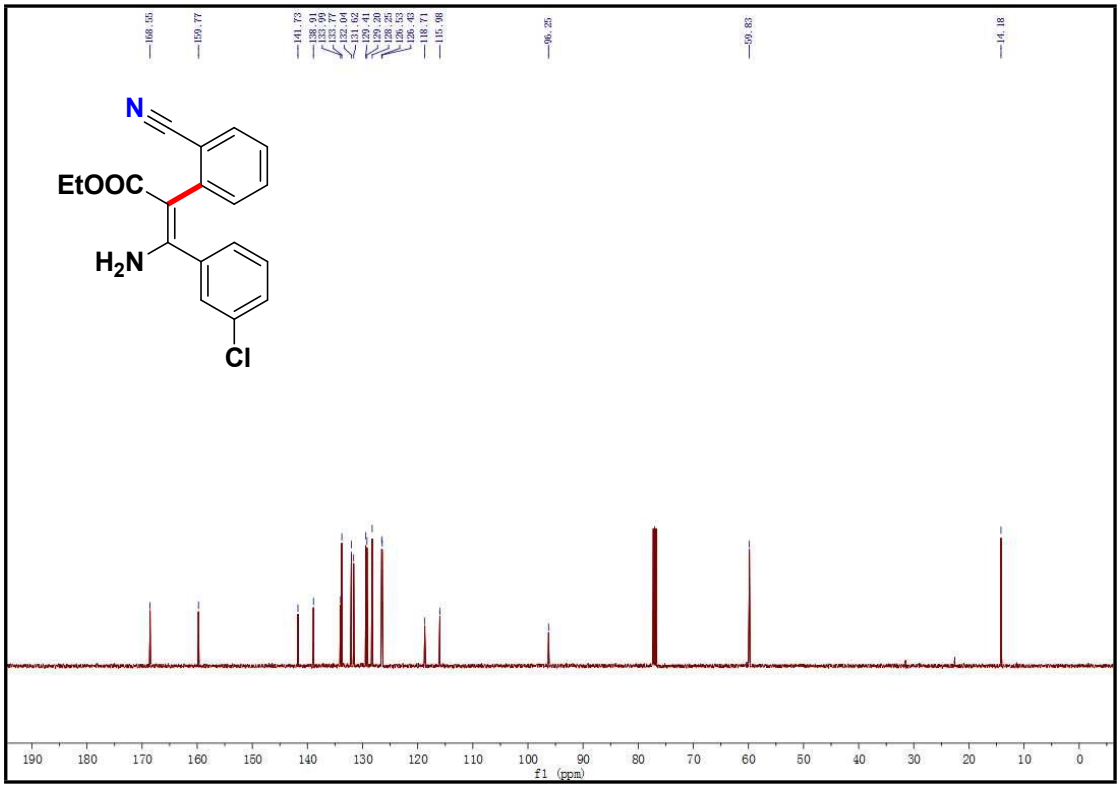
(Z)-ethyl 3-amino-3-(4-bromophenyl)-2-(2-cyanophenyl)acrylate (3e)



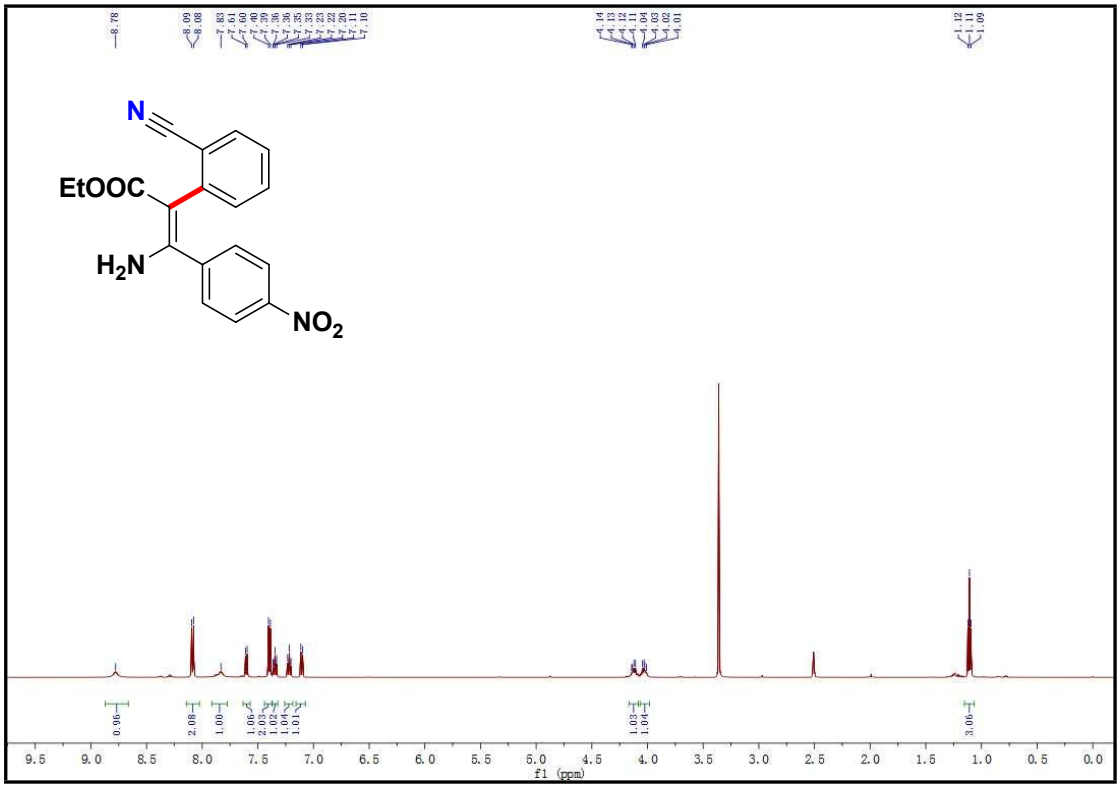


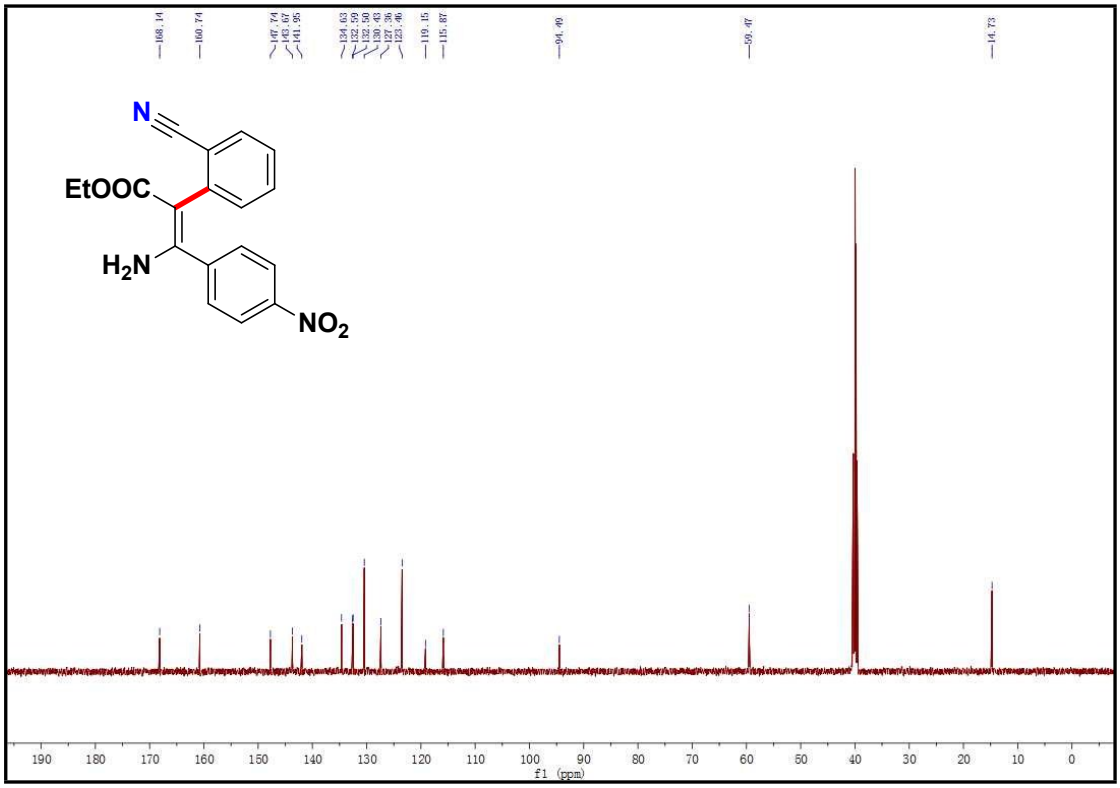
(Z)-ethyl 3-amino-3-(3-chlorophenyl)-2-(2-cyanophenyl)acrylate (3f)



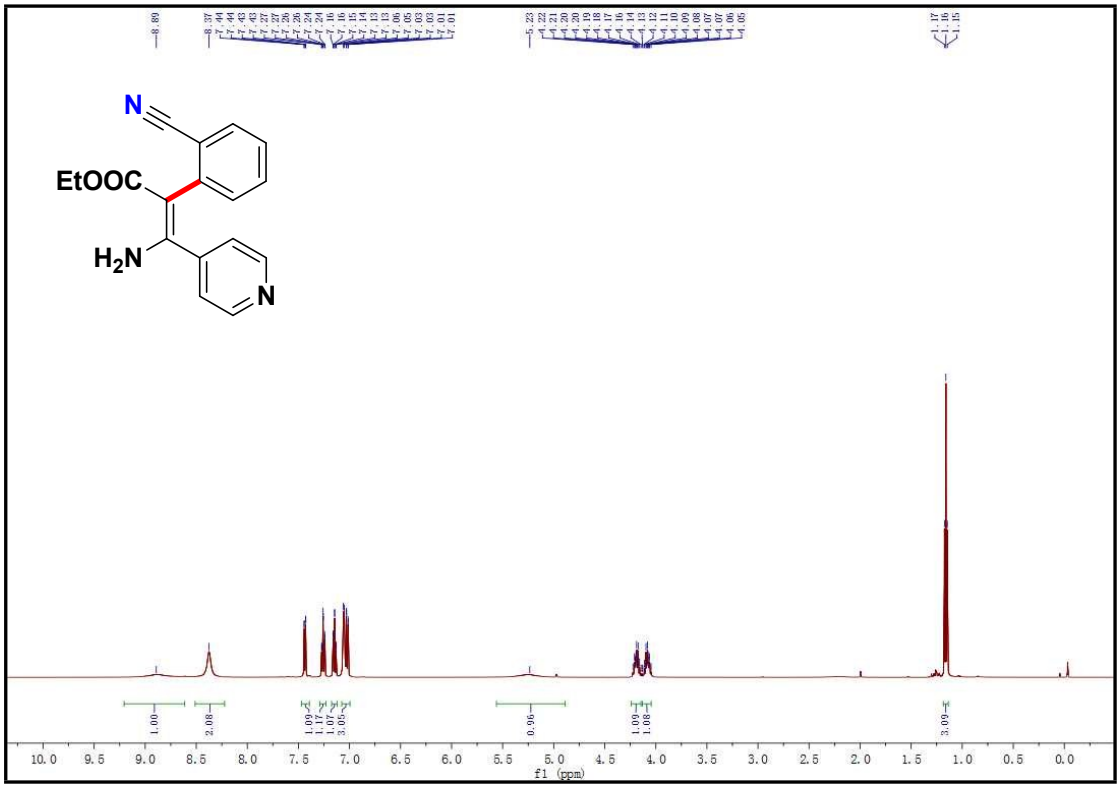


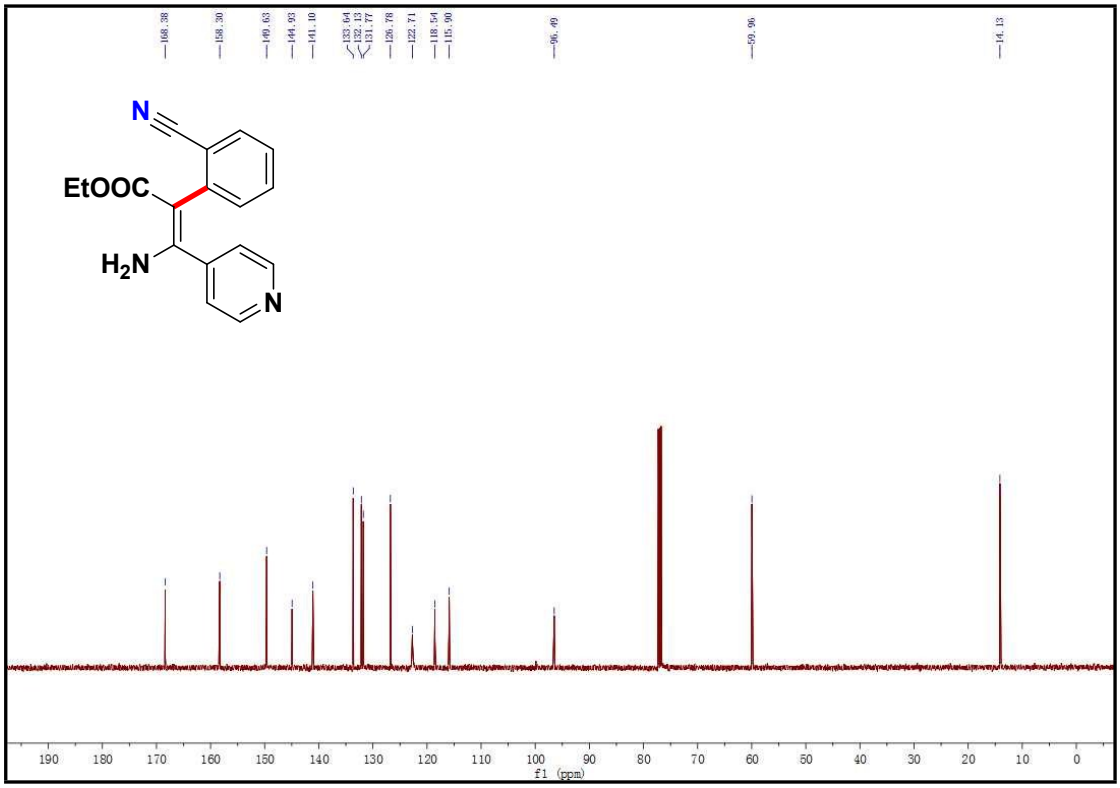
(Z)-ethyl 3-amino-2-(2-cyanophenyl)-3-(4-nitrophenyl)acrylate (3g)



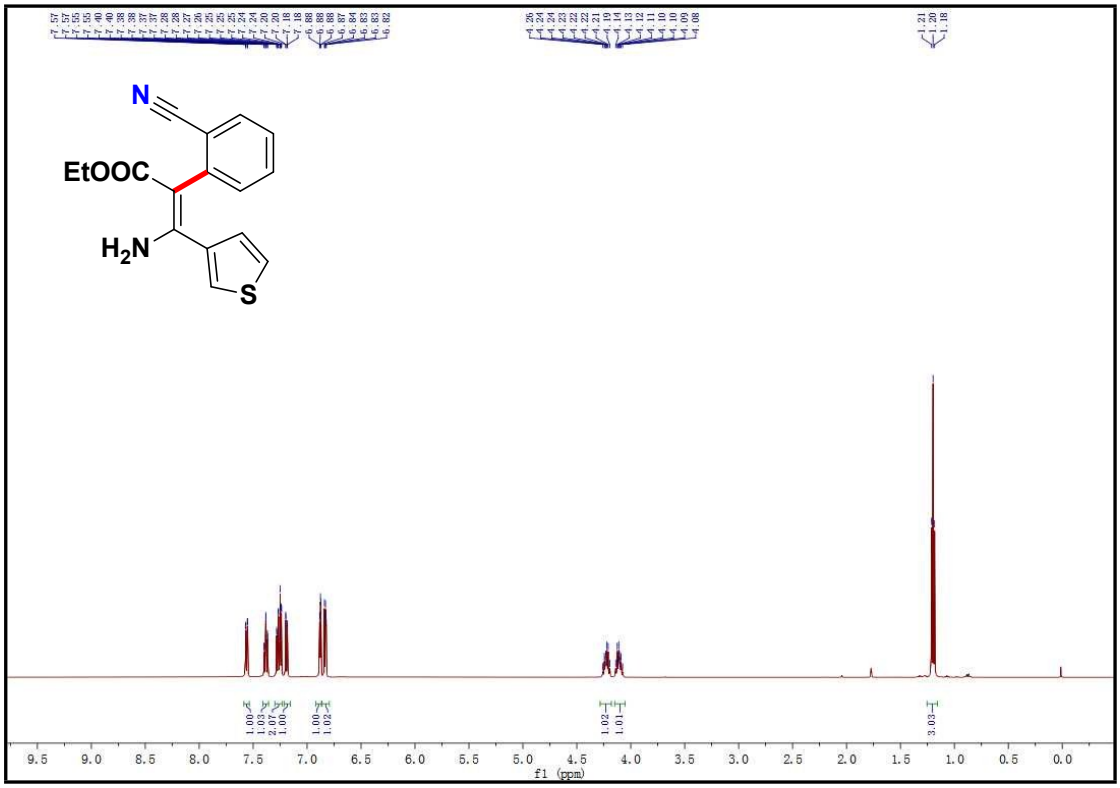


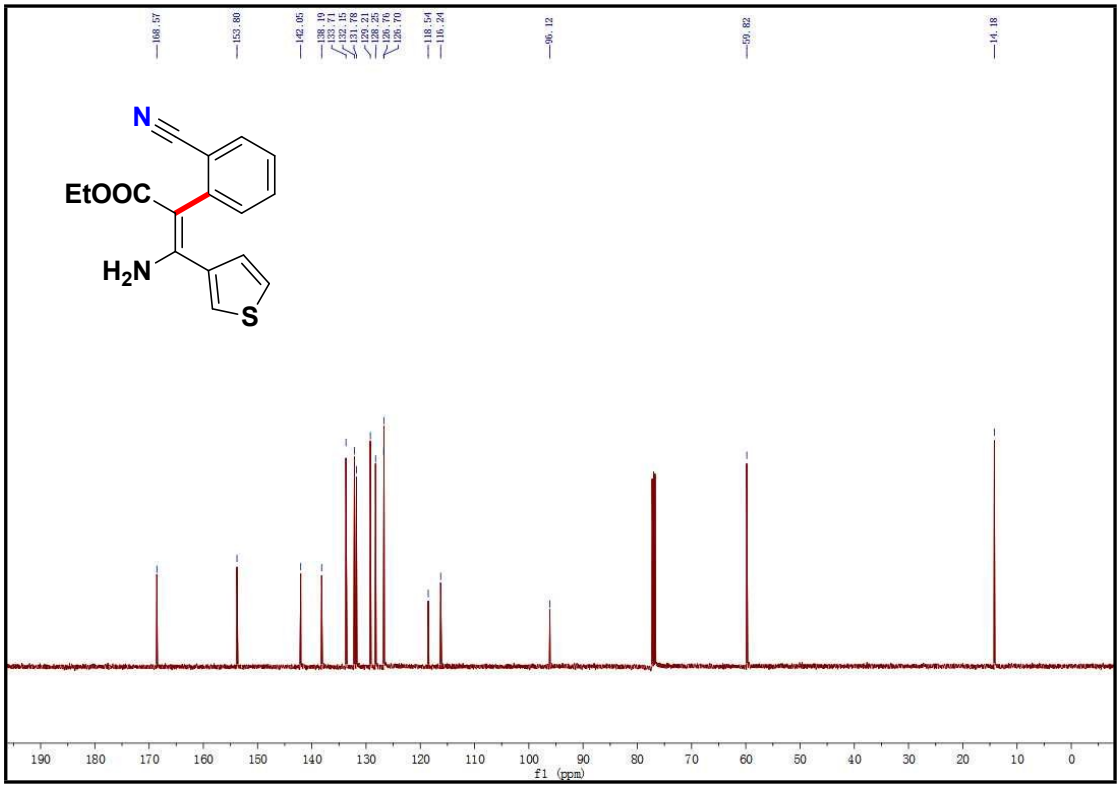
(Z)-ethyl 3-amino-2-(2-cyanophenyl)-3-(pyridin-4-yl)acrylate (3h)



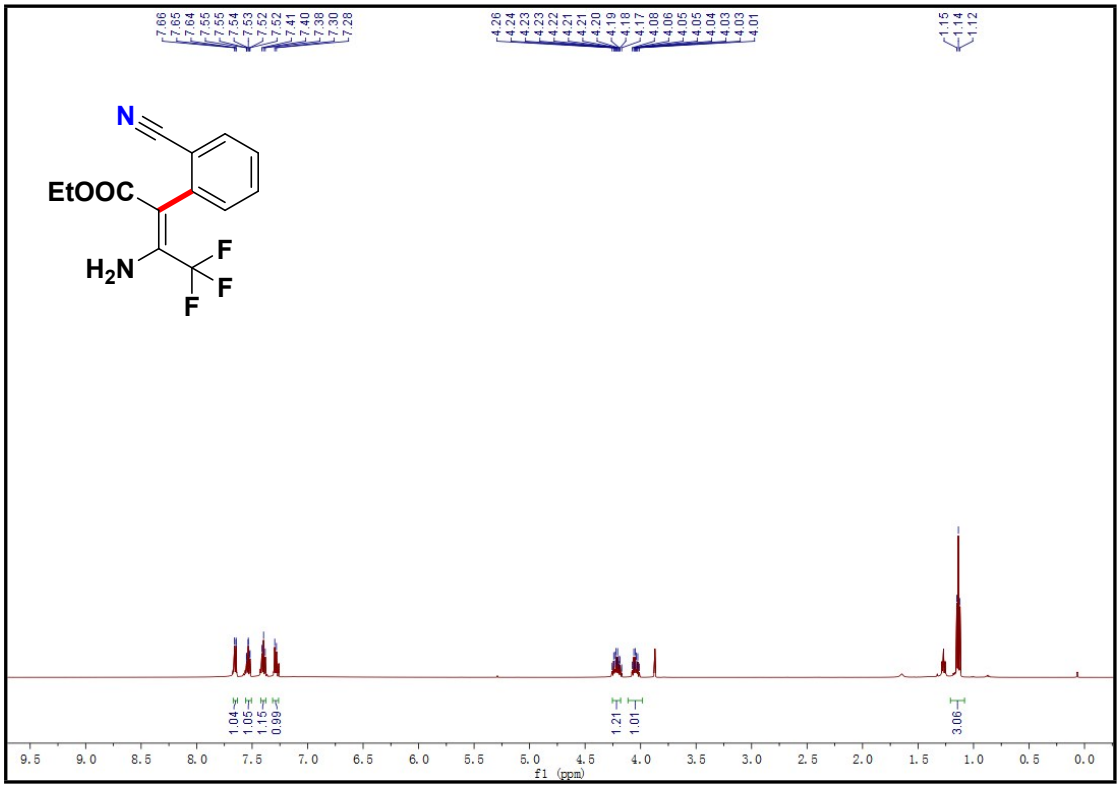


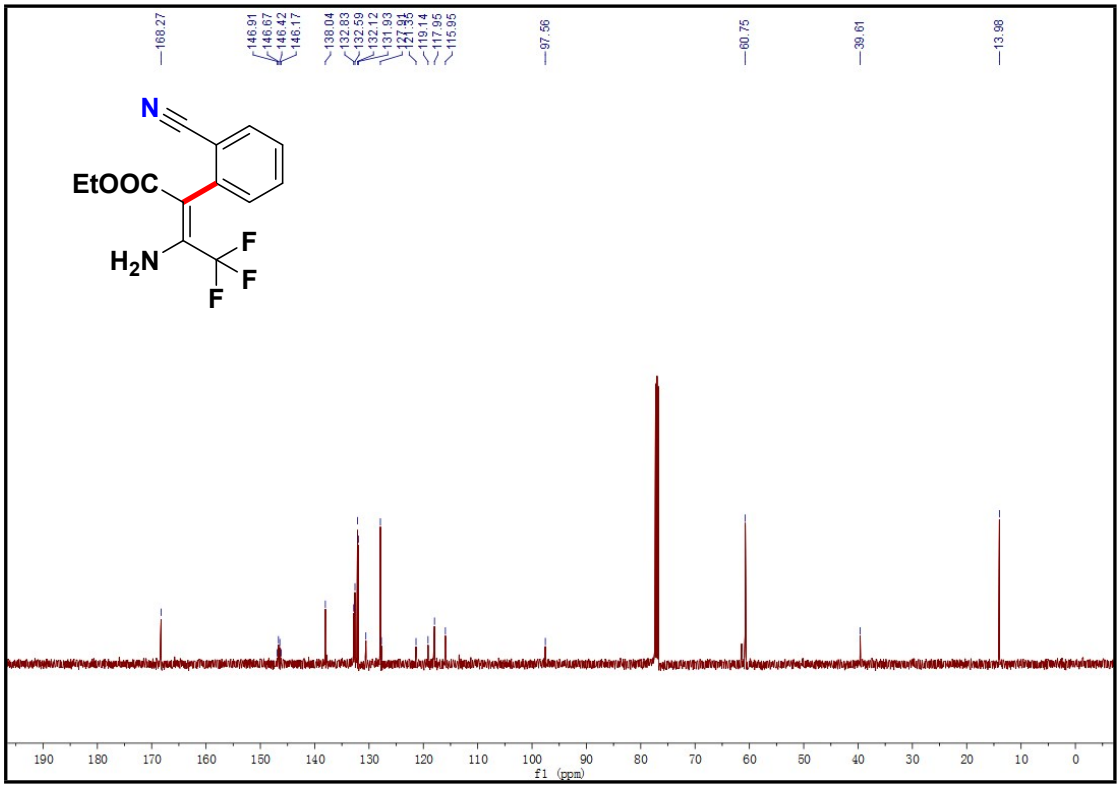
(Z)-ethyl 3-amino-2-(2-cyanophenyl)-3-(thiophen-3-yl)acrylate (3i)



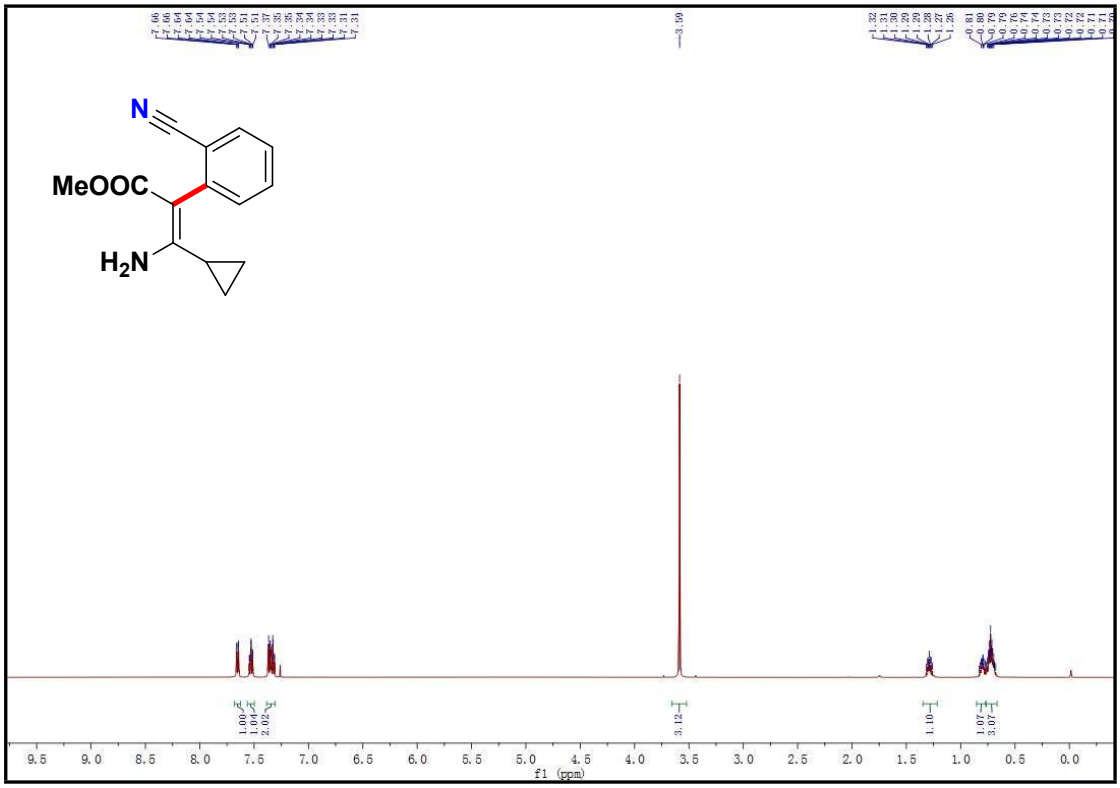


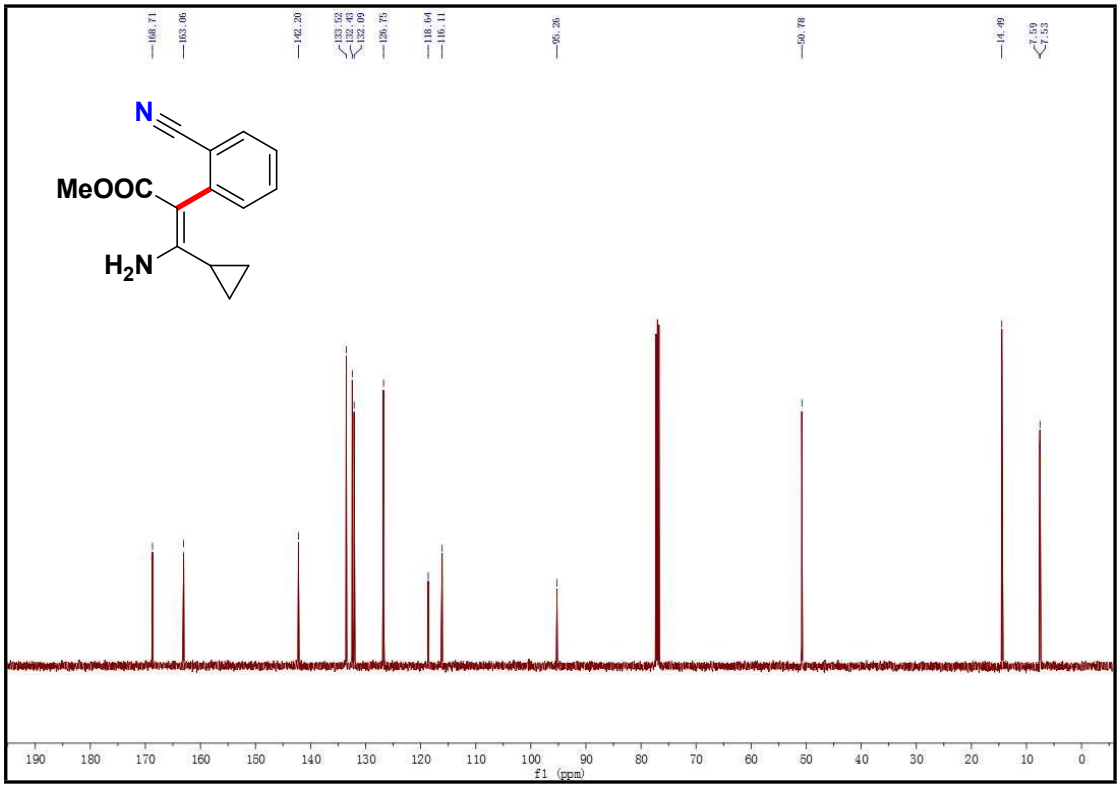
(Z)-ethyl 3-amino-2-(2-cyanophenyl)-4,4,4-trifluorobut-2-enoate (3j)



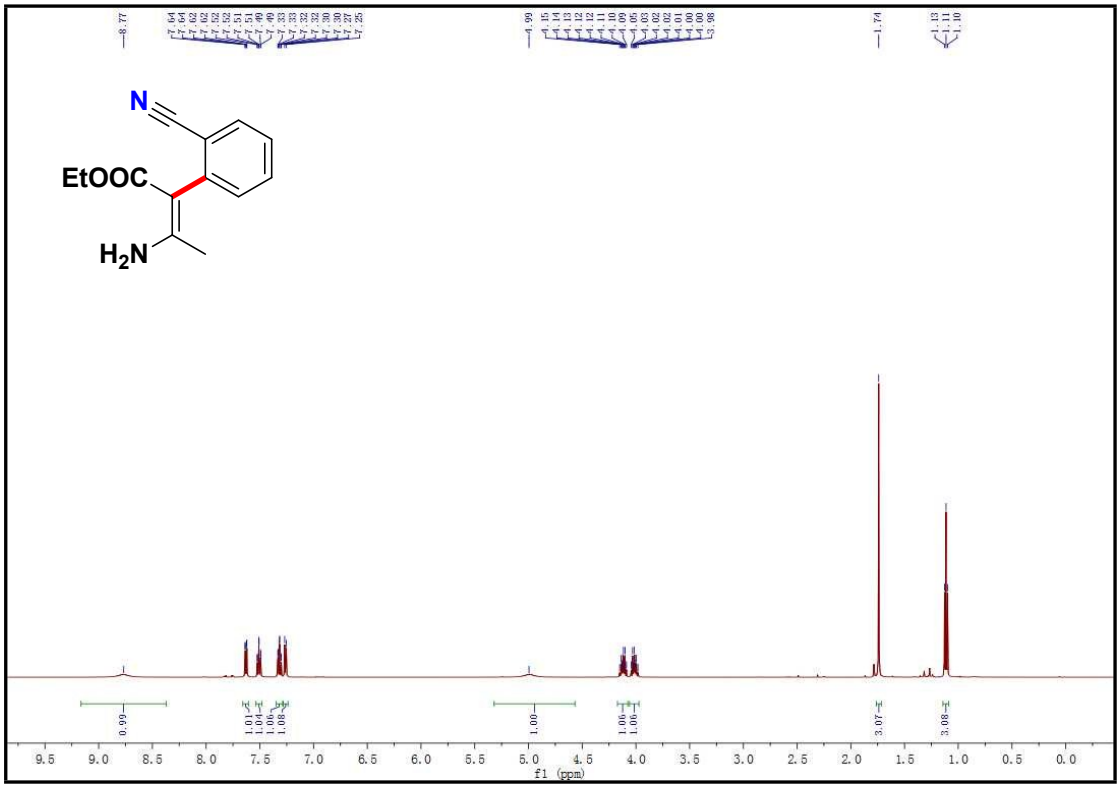


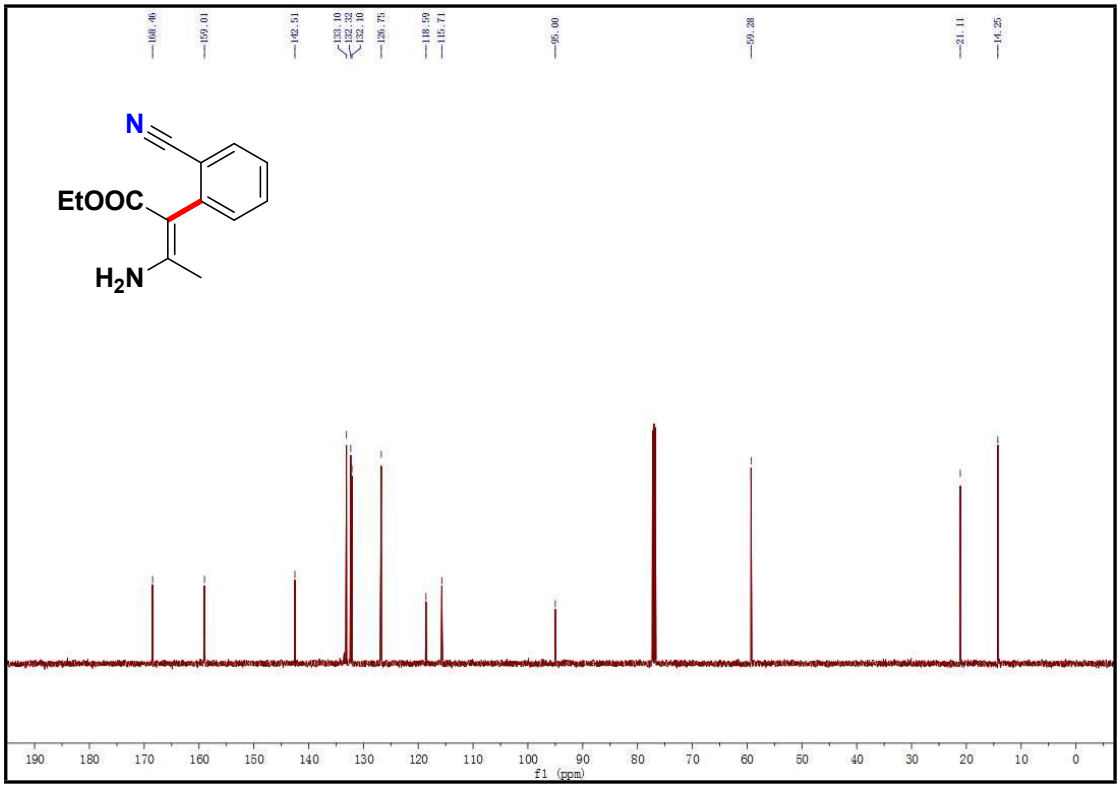
(Z)-methyl 3-amino-2-(2-cyanophenyl)-3-cyclopropylacrylate (3k)



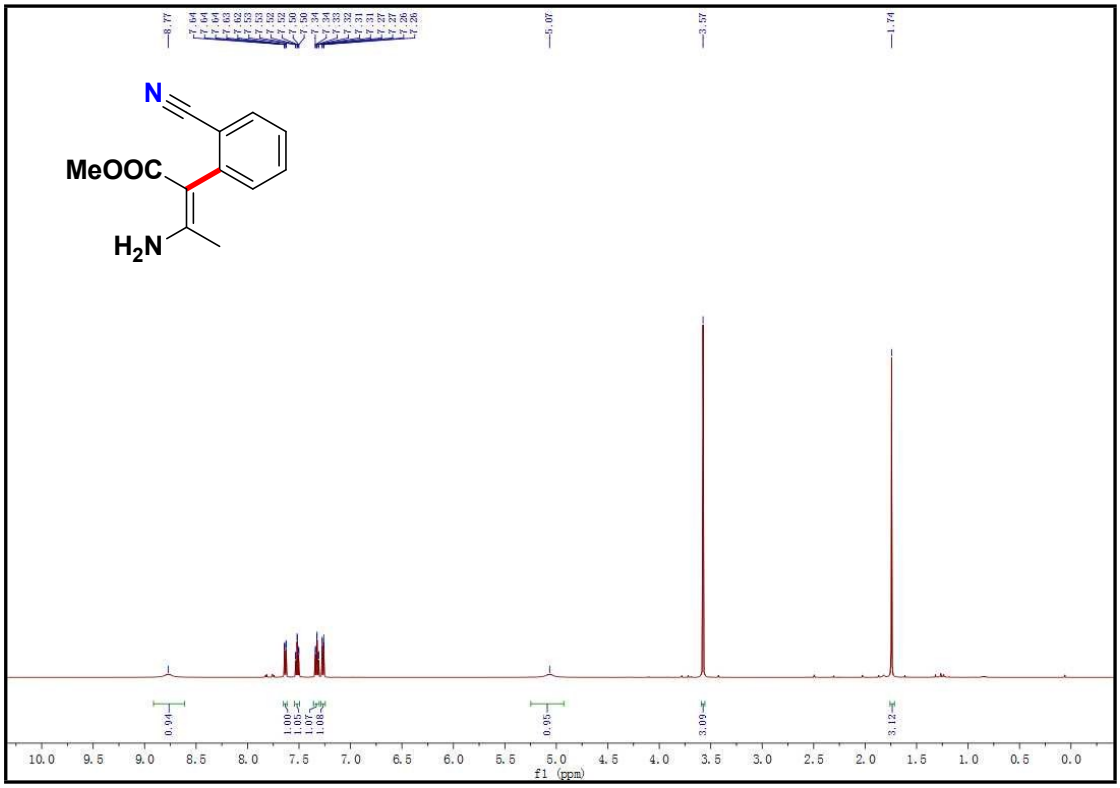


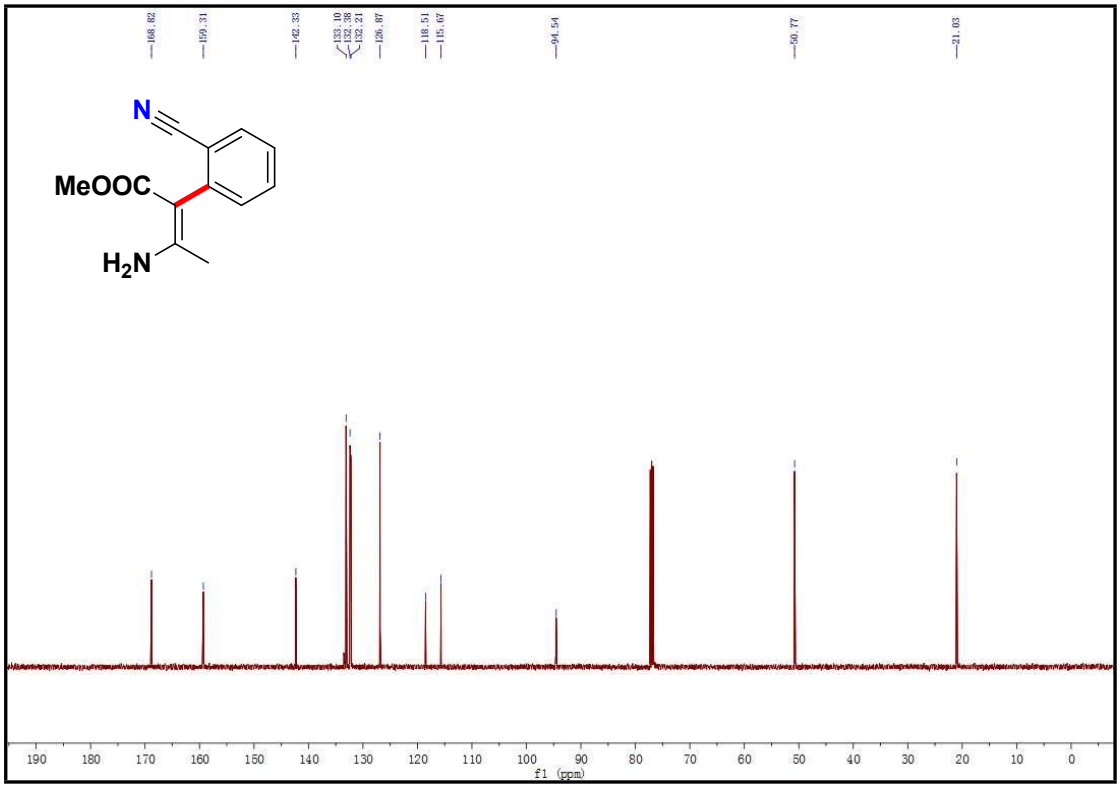
(Z)-ethyl 3-amino-2-(2-cyanophenyl)but-2-enoate (3l)



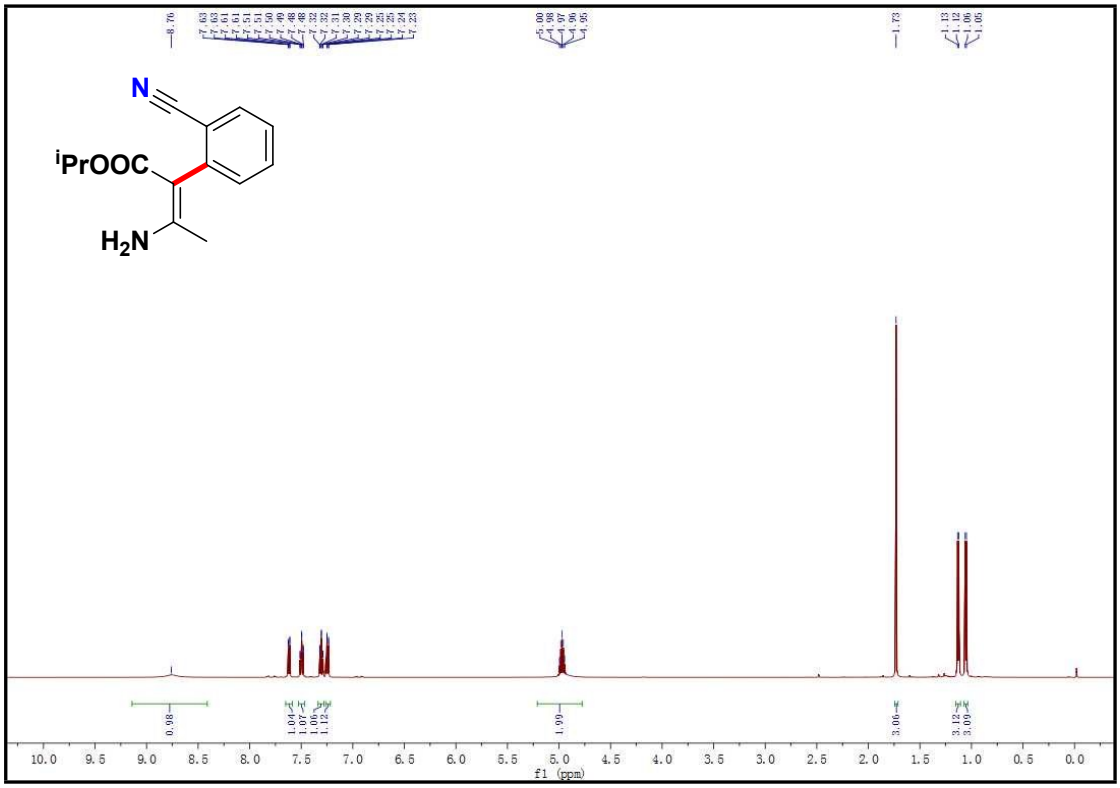


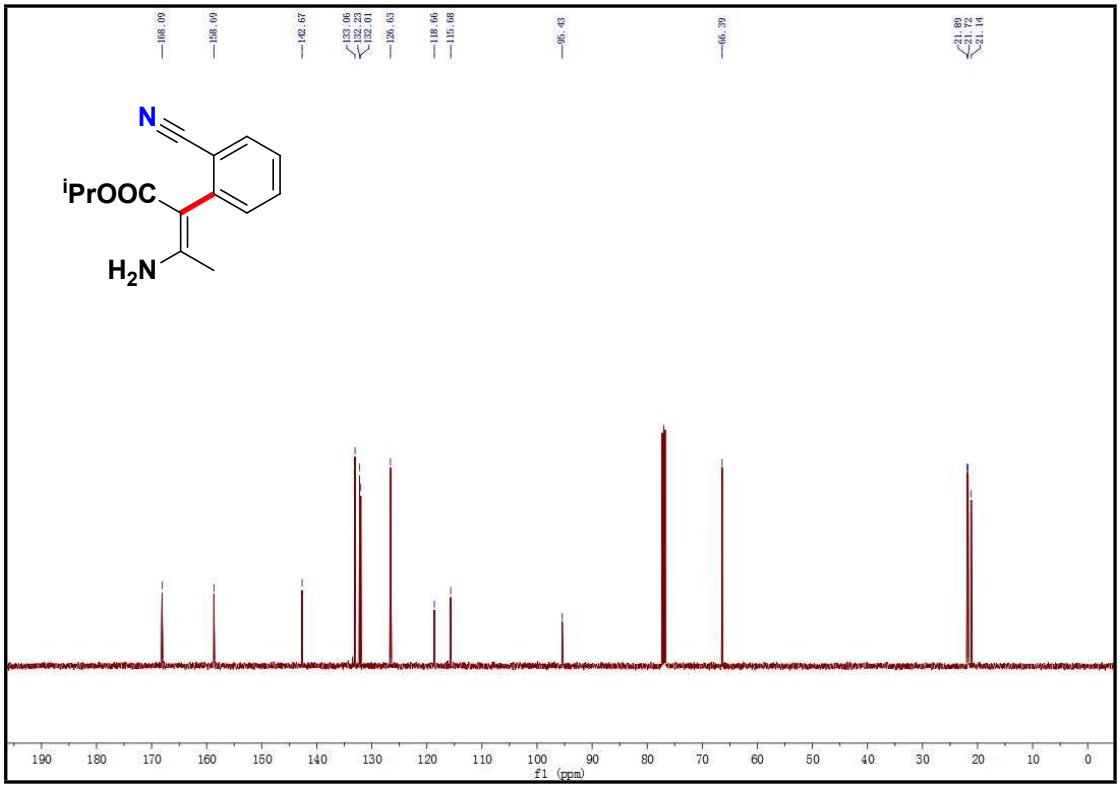
(Z)-methyl 3-amino-2-(2-cyanophenyl)but-2-enoate (3m)



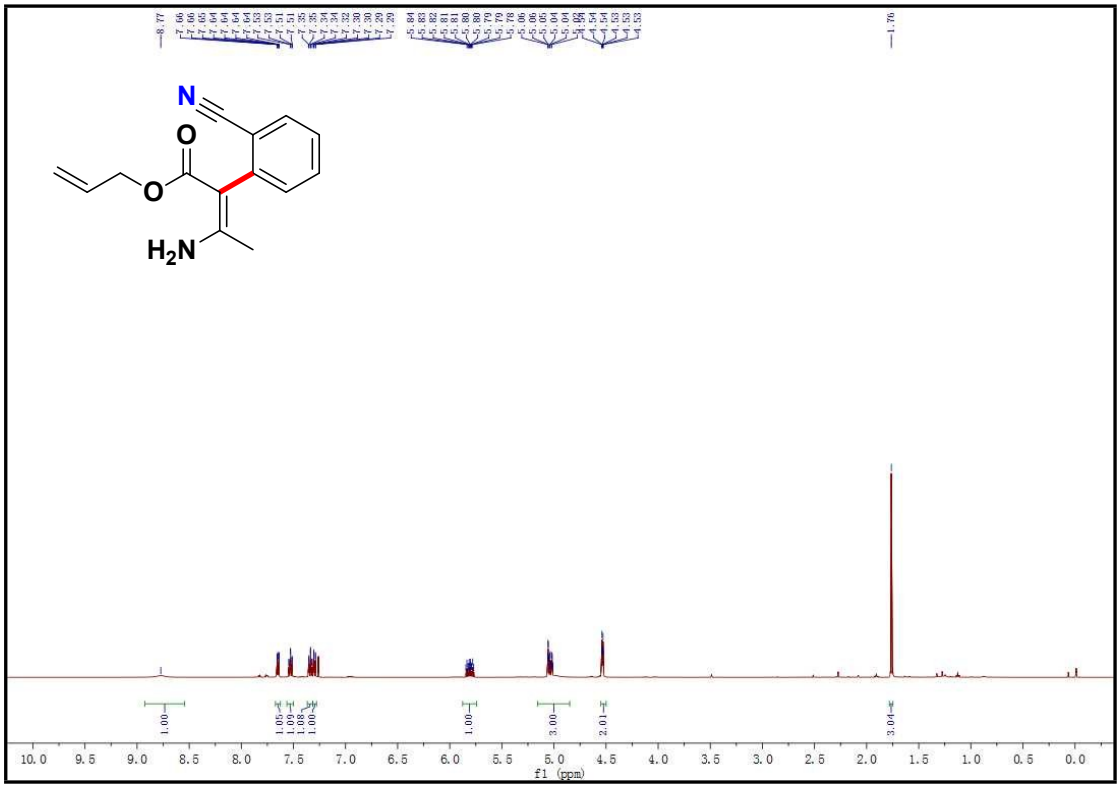


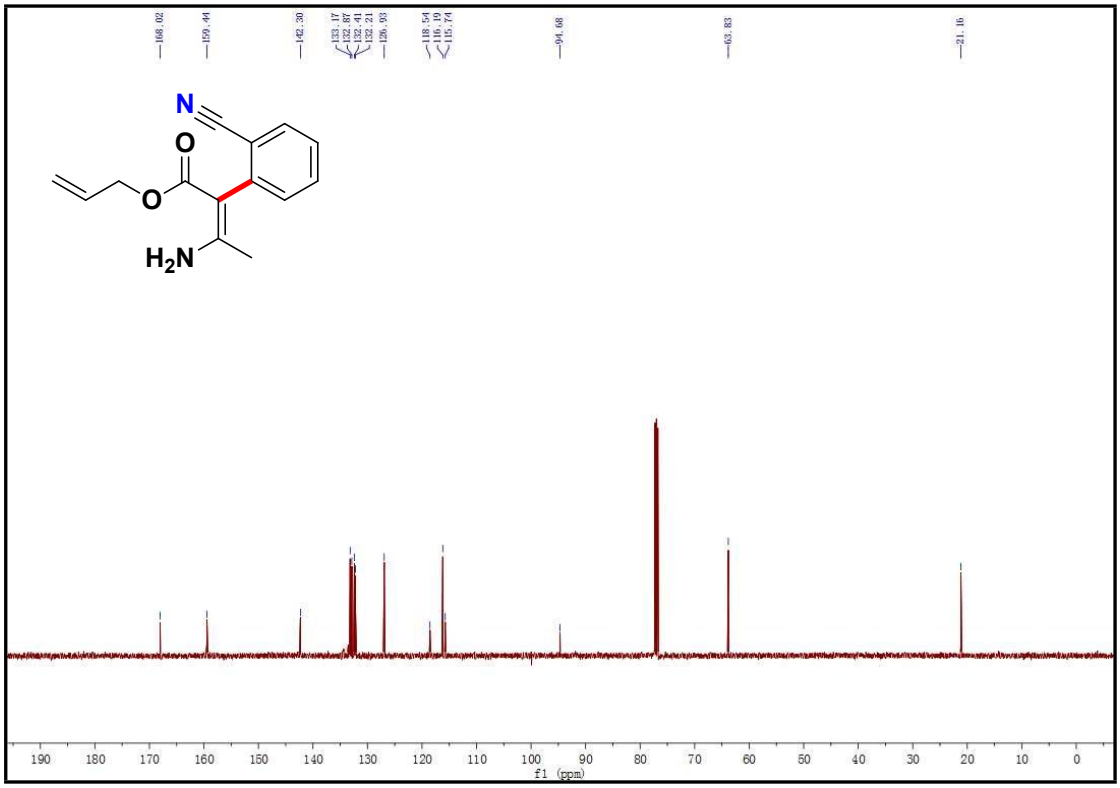
(Z)-isopropyl 3-amino-2-(2-cyanophenyl)but-2-enoate (3n)



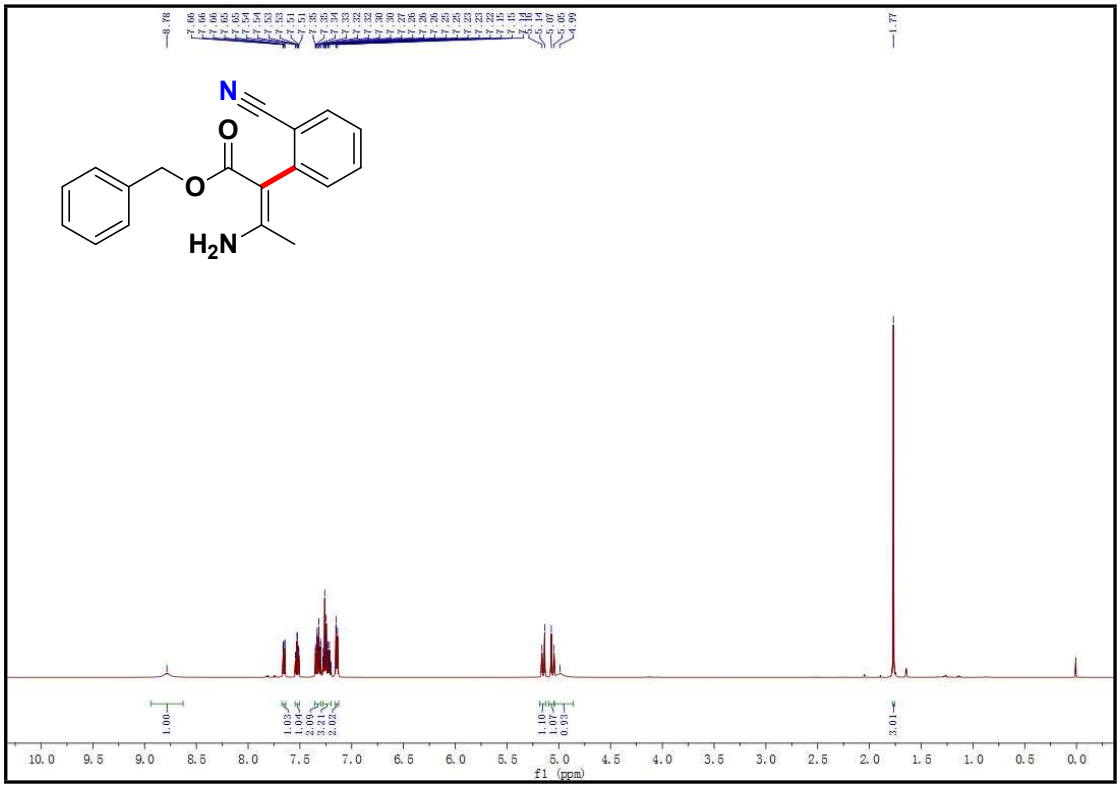


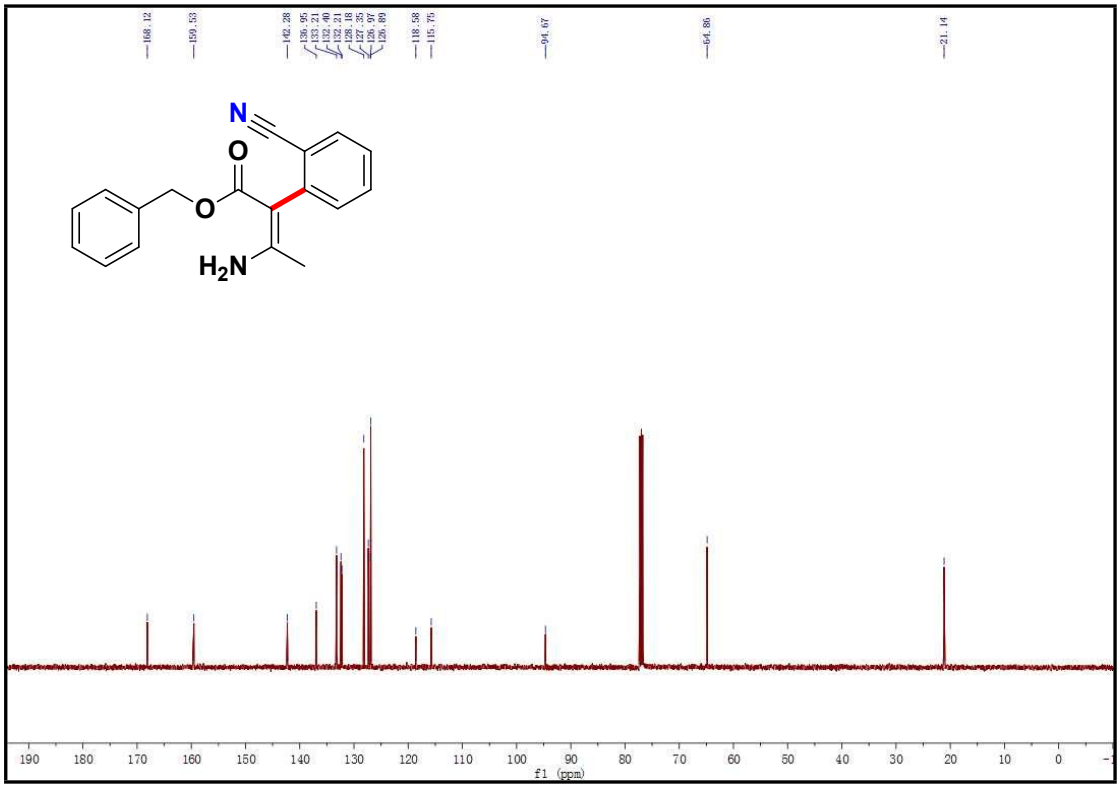
(Z)-allyl 3-amino-2-(2-cyanophenyl)but-2-enoate (3o)



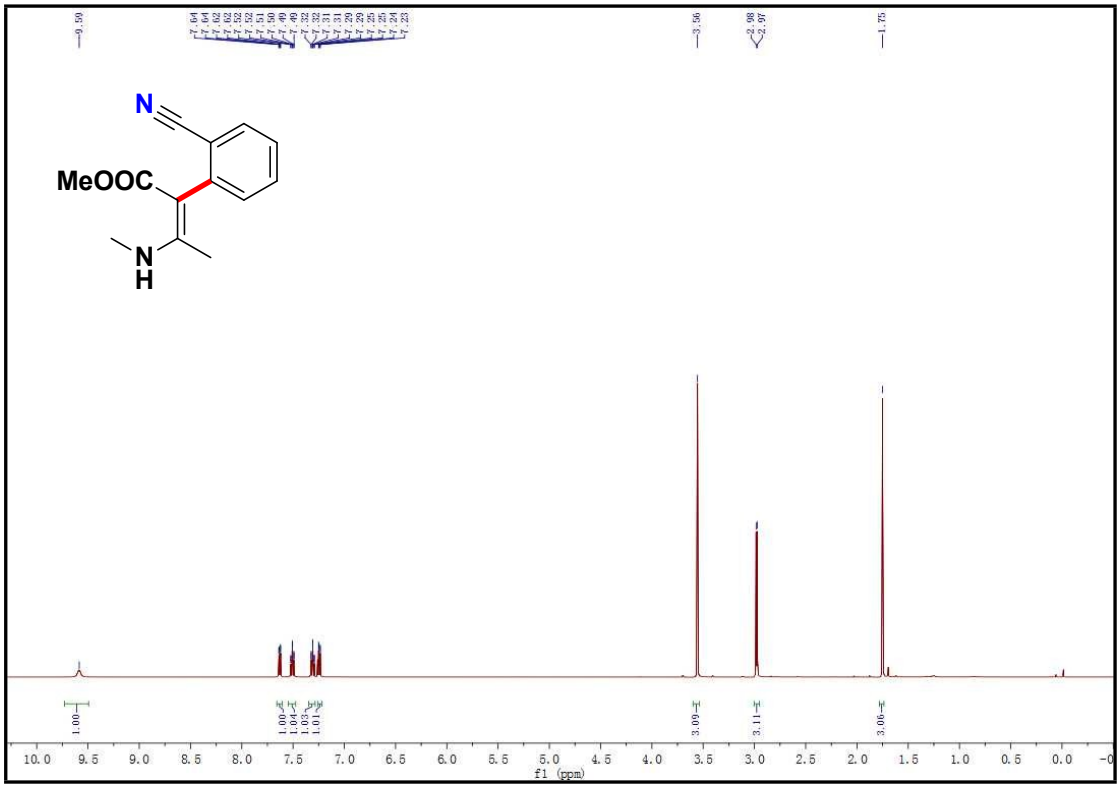


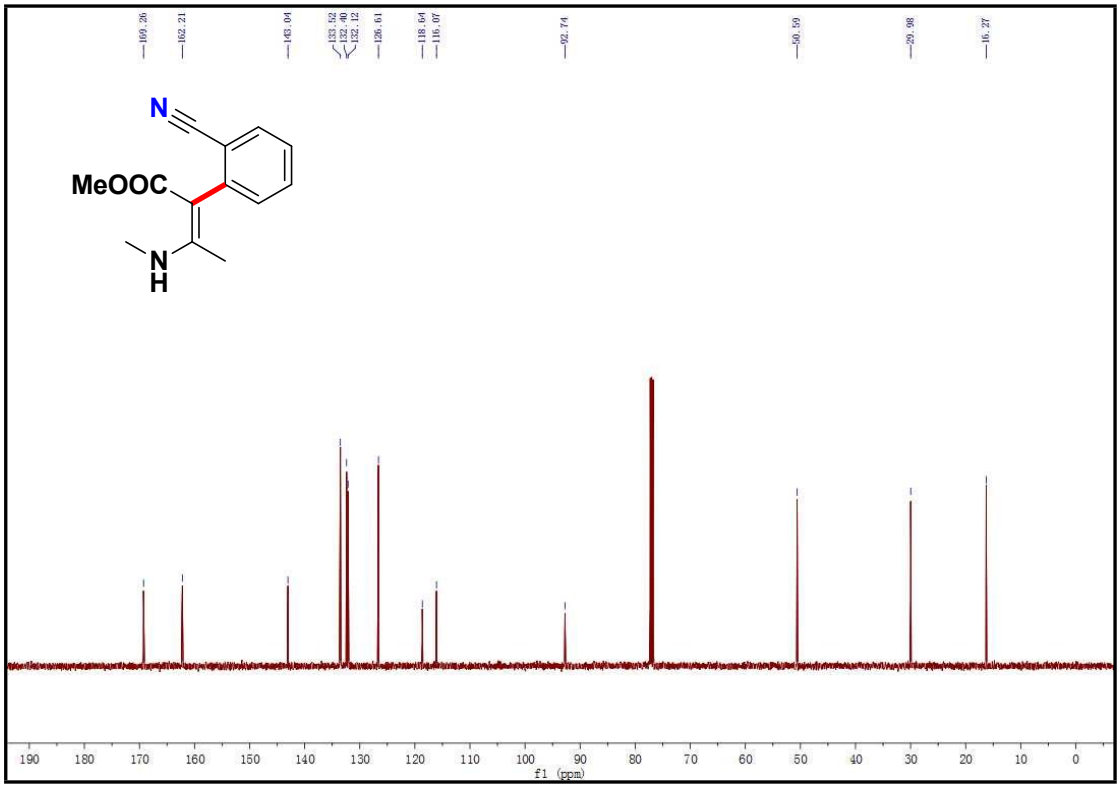
(Z)-benzyl 3-amino-2-(2-cyanophenyl)but-2-enoate (3p)



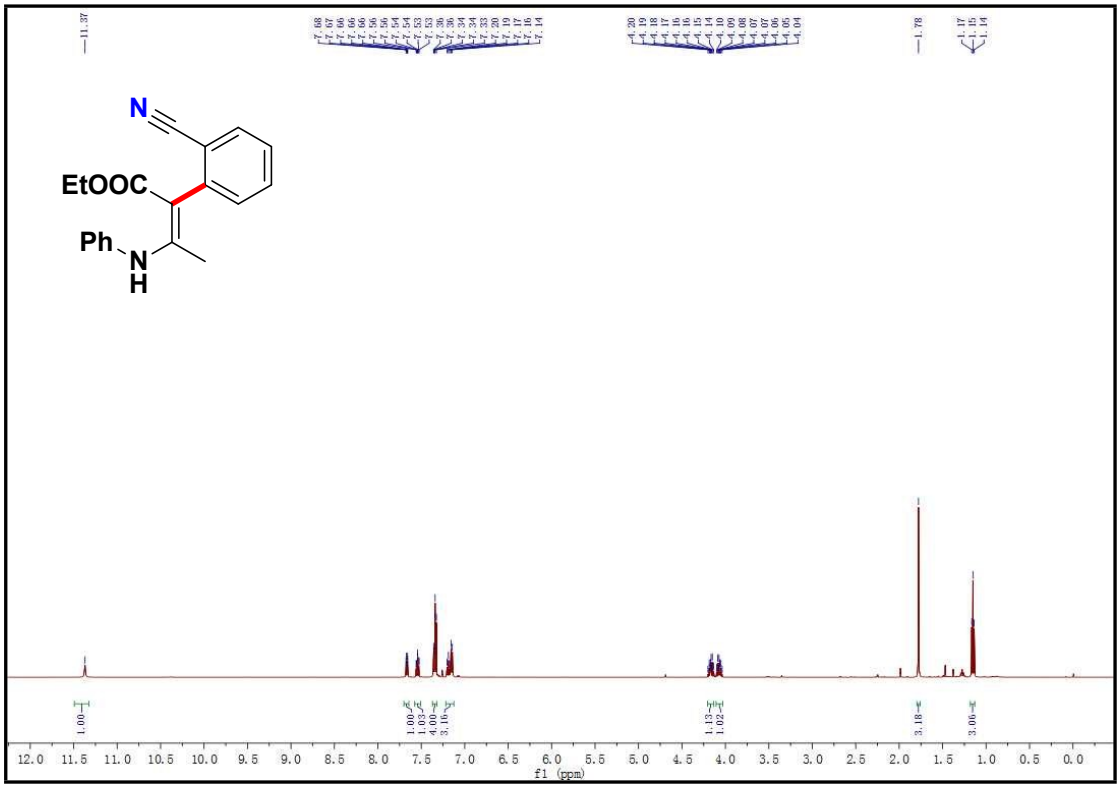


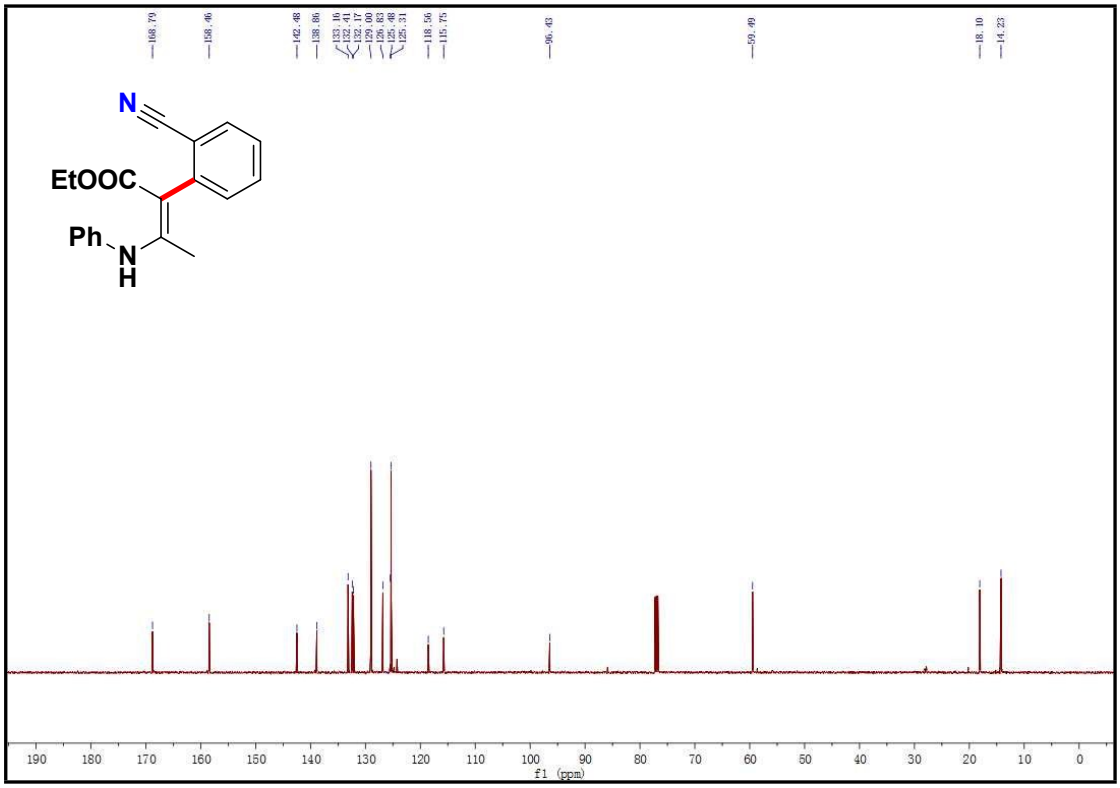
(Z)-methyl 2-(2-cyanophenyl)-3-(methylamino)but-2-enoate (3q)



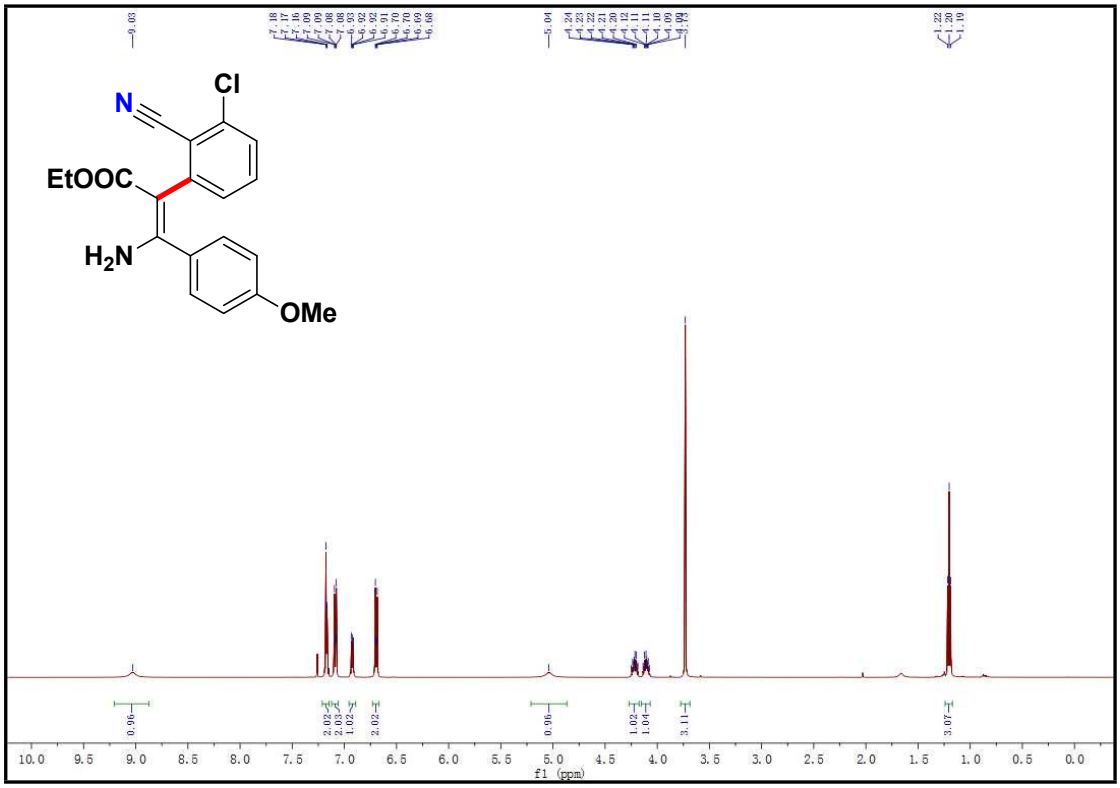


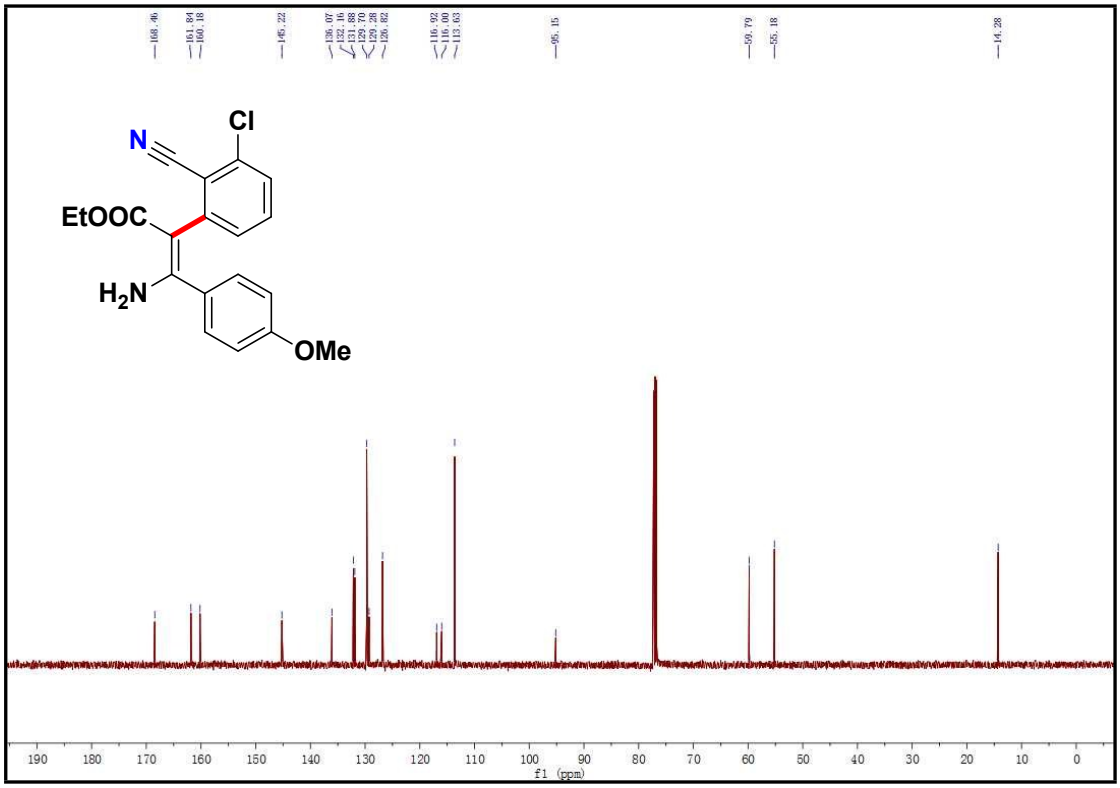
(Z)-ethyl 2-(2-cyanophenyl)-3-(phenylamino)but-2-enoate (3r)



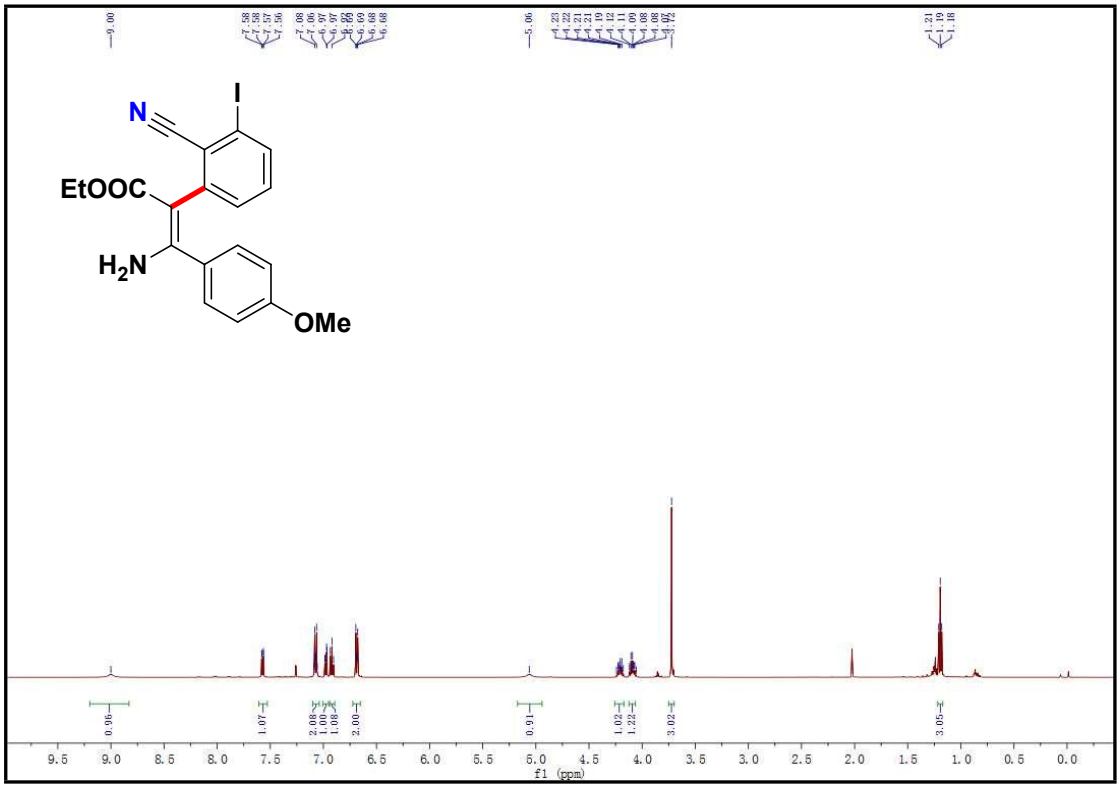


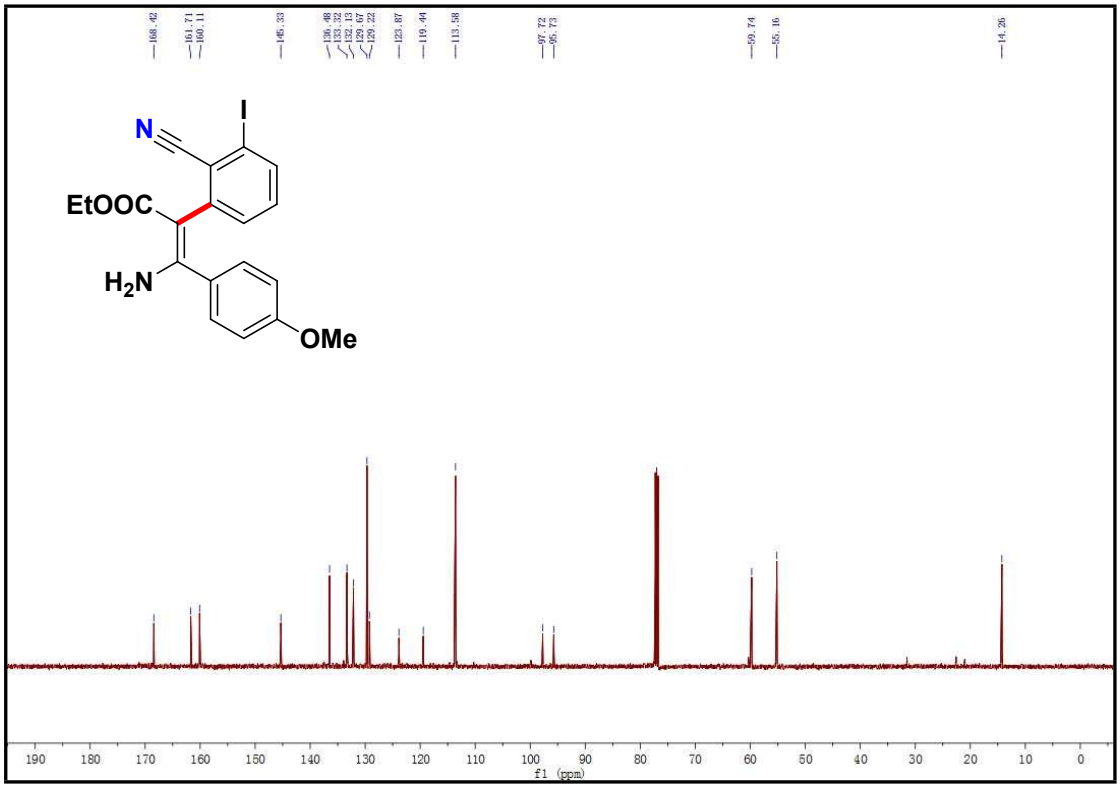
(Z)-ethyl 3-amino-2-(3-chloro-2-cyanophenyl)-3-(4-methoxyphenyl)acrylate (3s)



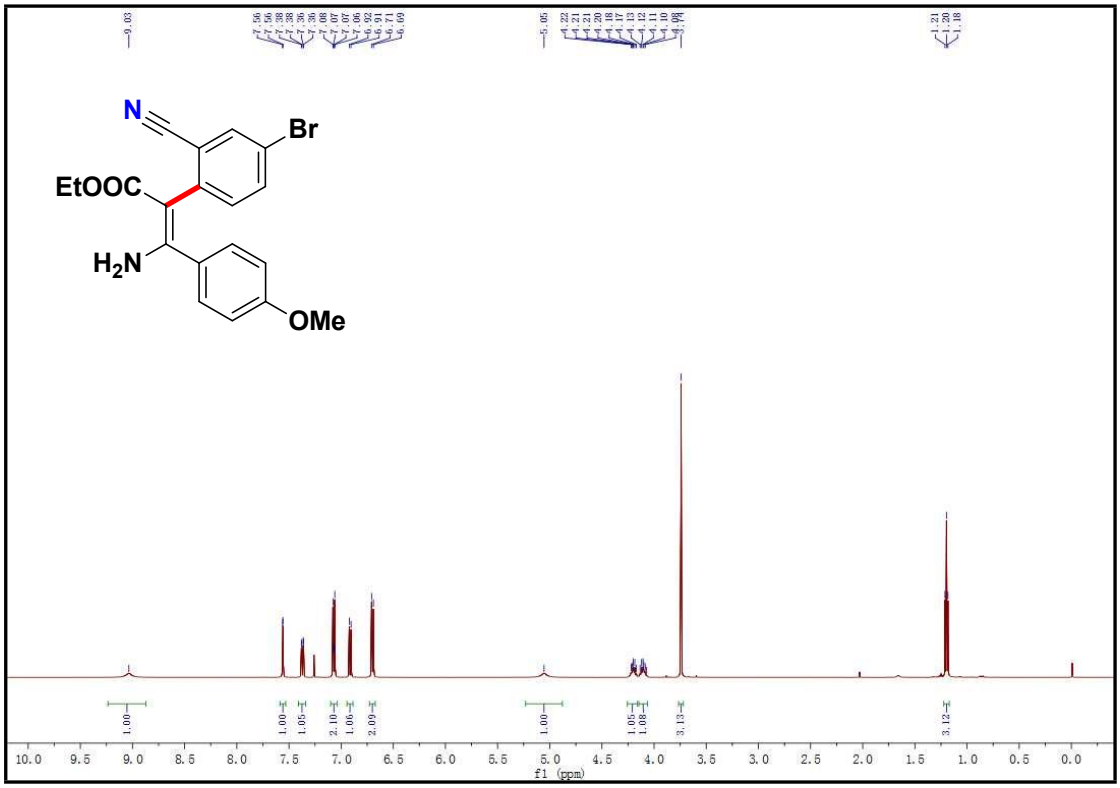


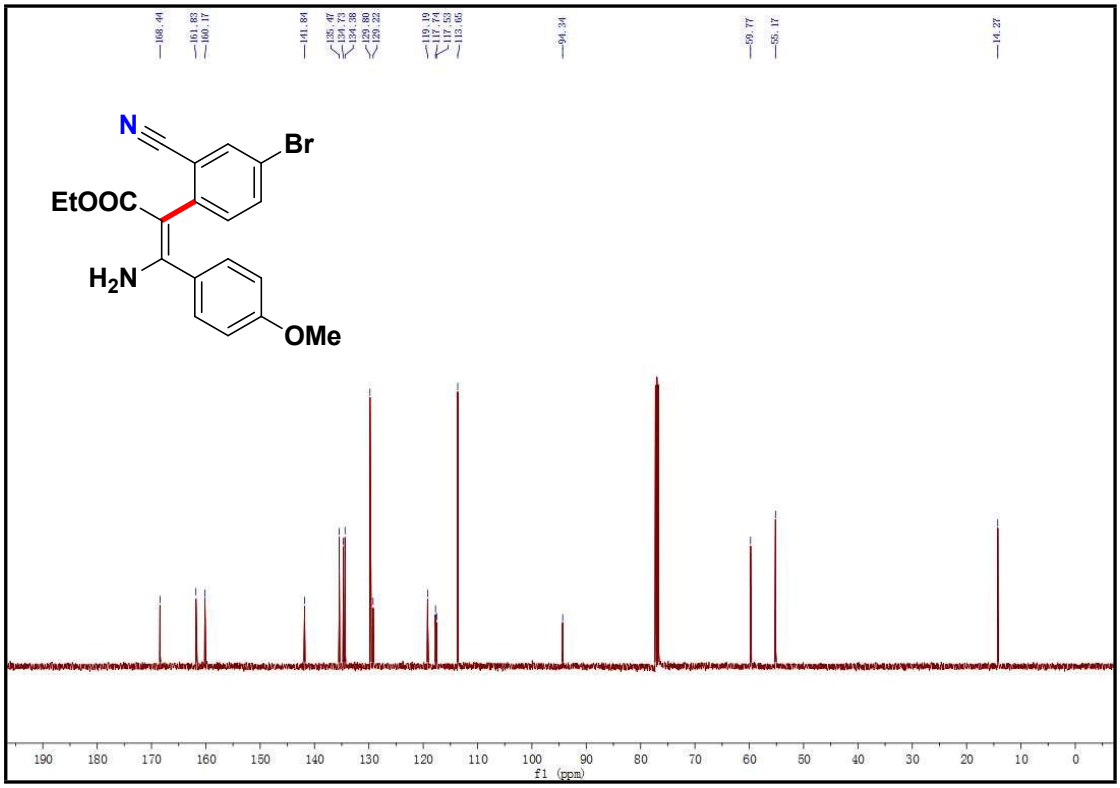
(Z)-ethyl 3-amino-2-(2-cyano-3-iodophenyl)-3-(4-methoxyphenyl)acrylate (3t)



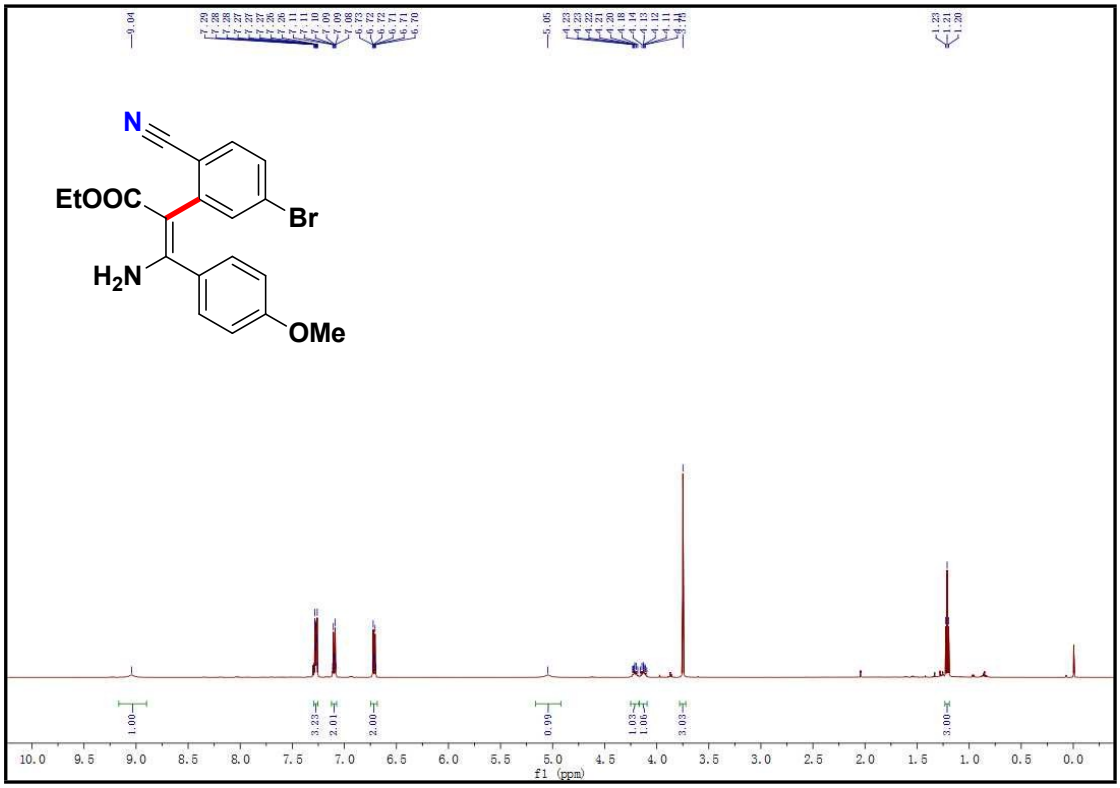


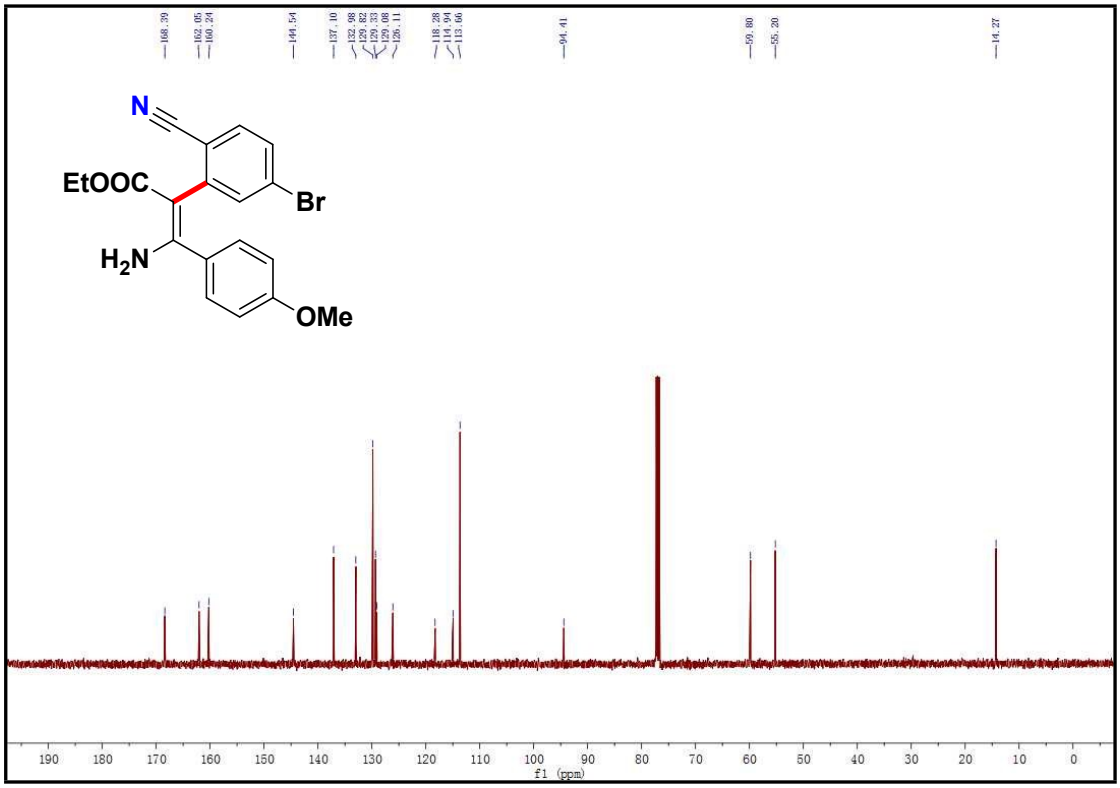
(Z)-ethyl 3-amino-2-(4-bromo-2-cyanophenyl)-3-(4-methoxyphenyl)acrylate (3u)



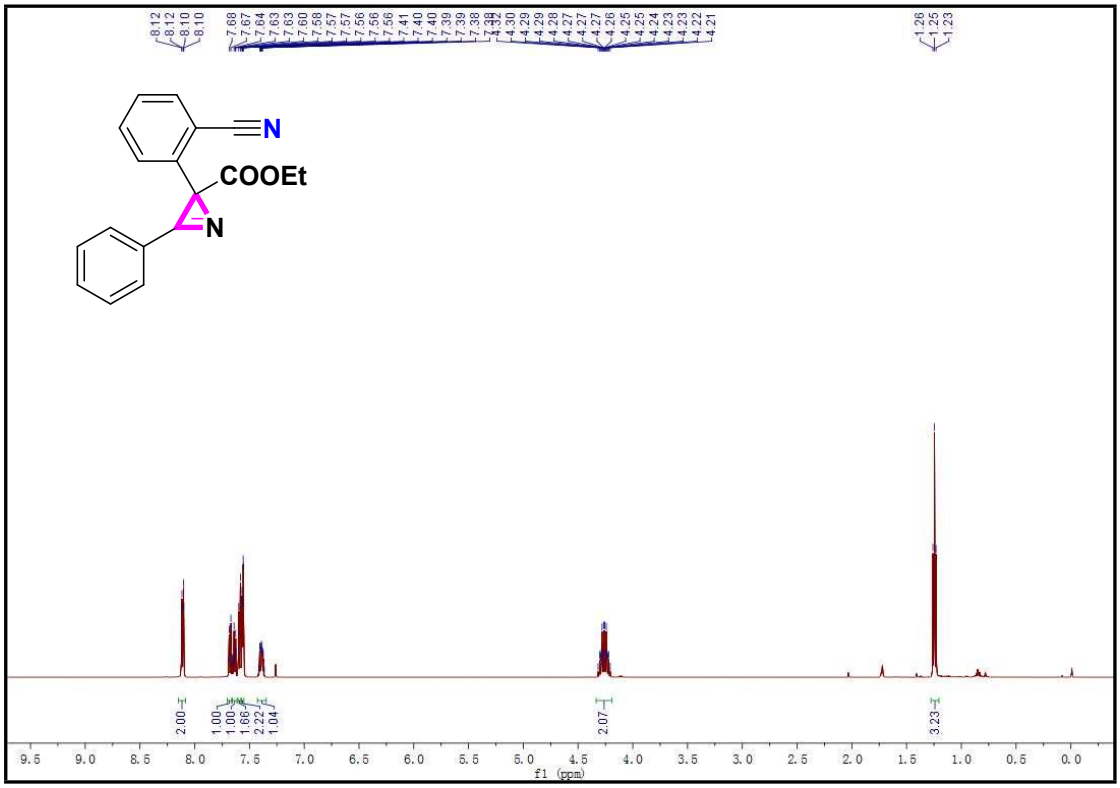


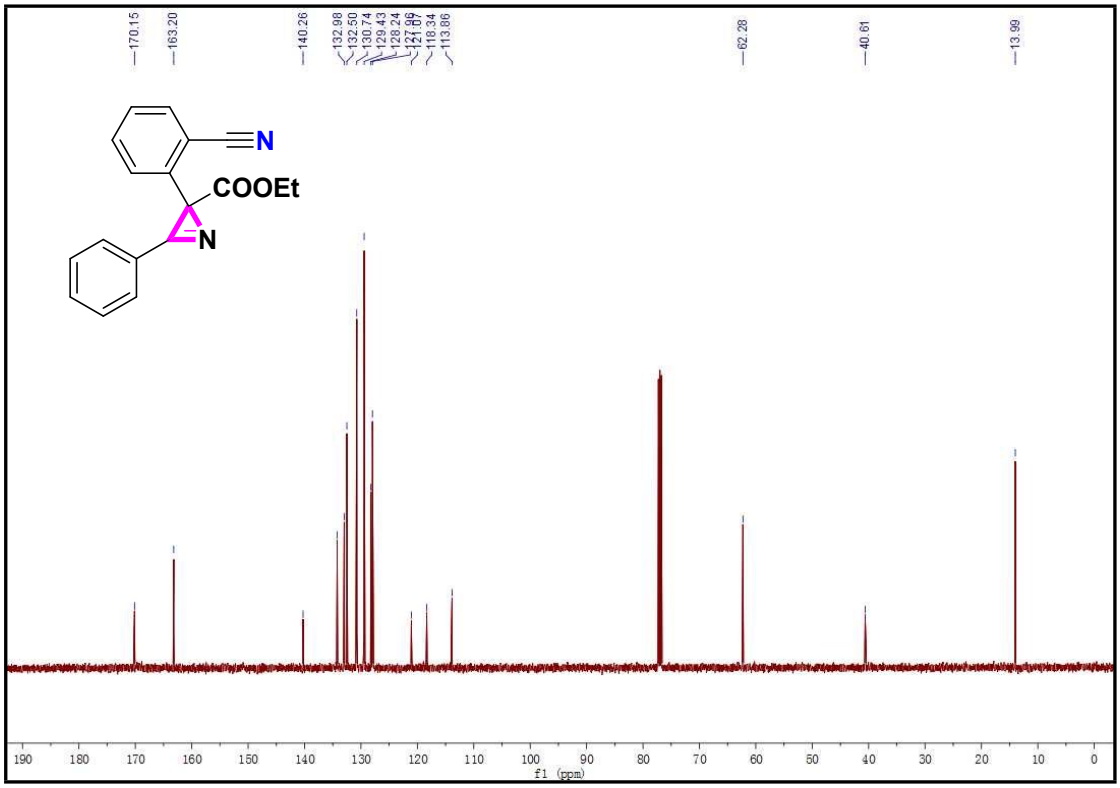
(Z)-ethyl 3-amino-2-(5-bromo-2-cyanophenyl)-3-(4-methoxyphenyl)acrylate (3v)





ethyl 2-(2-cyanophenyl)-3-phenyl-2H-azirine-2-carboxylate (4)





ethyl 1-amino-3-(4-methoxyphenyl)isoquinoline-4-carboxylate (5)