Supporting Information

for

Cu-Catalyzed C-N Bond Cleavage of 3-Aminooindazoles 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$_3$CN 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$_3$ ($\delta = 7.26$ for $^1$H-NMR , $\delta = 77.00$ for $^{13}$C-NMR) or DMSO-$d_6$ ($\delta = 2.50$ for $^1$H-NMR, $\delta = 39.60$ 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

![Chemical structure of β-keto ester and HCOONH₄ reaction](image)

The mixture of β-keto ester (5 mmol) and HCOONH₄ (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 chromatography using PE/EtOAc as the eluent to give the enamine esters.

3. General procedure for the synthesis of 3

![Chemical structures of reaction between 3-aminoindazoles and enamines](image)

TBHP (5.0-6.0 M in decane) (0.5 mmol, 2.5 equiv) was added to a mixture of Cu(OAc)₂•H₂O (8 mg, 20 mol%), 3-aminoindazoles 1 (0.4 mmol) and enamines 2 (0.2 mmol, 1 equiv) in CH₃CN (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 chromatography (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: \( \text{C-C} = 0.0028 \text{ \AA} \)

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

Volume
- Calculated: 1397.9(2)
- Reported: 1397.9(2)

Space group
- Calculated: P 21/c
- Reported: P 1 \( \overline{2} \) 1/c 1

Hall group
- Calculated: -P 2 \( \overline{1} \) cbc
- Reported: -P 2 \( \overline{1} \) cbc

Moiety formula
- Calculated: C14 H16 N2 O2
- Reported: C14 H16 N2 O2

Sum formula
- Calculated: C14 H16 N2 O2
- Reported: C14 H16 N2 O2

Mr
- Calculated: 244.29
- Reported: 244.30

Dx,g cm\(^{-3}\)
- Calculated: 1.161
- Reported: 1.161

Z
- Calculated: 4
- Reported: 4

Mu (mm\(^{-1}\))
- Calculated: 0.079
- Reported: 0.079

F000
- Calculated: 520.0
- Reported: 520.2

F000'
- Calculated: 520.22

h,k,lmax
- Calculated: 11,12,16
- Reported: 11,12,16

Nref
- Calculated: 2461
- Reported: 2450

Tmin,Tmax
- Calculated: 0.533,1.000
- Reported: 0.533,1.000

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$_3$)  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), 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$_2$O$_2$[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$_3$)  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). 

$^{13}$C NMR (126 MHz, CDCl$_3$) 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$_2$O$_2$[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$_3$)  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$_2$O$_3$[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$_2$O$_2$ [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$_2$O$_2$ [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, 1.1 Hz, 1H), 7.29 (dd, $J$ = 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), 4.13 – 4.07 (m, 1H), 1.18 (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, 126.3, 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$_2$O$_2$ [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), 7.40 (d, $J$ = 7.6 Hz, 1H), 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). 13C 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 C18H16N3O4[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%). 1H NMR (500 MHz, CDCl3) 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).

13C NMR (126 MHz, CDCl3) 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 C17H16N3O2[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%). 1H NMR (500 MHz, CDCl3) 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). 13C NMR (126 MHz, CDCl3) 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 C16H15N2O2S[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%). 1H NMR (500 MHz, CDCl3) 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). 13C NMR (126 MHz, CDCl3) 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 C13H12N2F2O3[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%). 1H NMR (500 MHz, CDCl3) 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$_2$O$_2$[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), 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, 159.3, 142.7, 133.1, 132.2, 132.0, 126.6, 118.7, 115.9, 95.4, 66.4, 21.1, 21.0. HRMS (ESI, m/z) calcd for C$_{12}$H$_{13}$N$_2$O$_2$[M+H]$^+$: 231.0972; found: 231.0977.

(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, 3H), 1.74 (s, 3H), 1.11 (t, $J$ = 7.1 Hz, 3H).

$^{13}$C NMR (126 MHz, CDCl$_3$) δ 168.5, 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$_2$O$_2$[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, 1H), 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 168.8, 159.3, 142.3, 133.1, 132.4, 132.2, 126.9, 118.5, 115.7, 94.5, 66.4, 21.9, 21.7, 21.1. HRMS (ESI, m/z) calcd for C$_{14}$H$_{17}$N$_2$O$_2$[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$_3$) $\delta$ 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$_{13}$N$_2$O$_2$ [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$_3$) $\delta$ 8.78 (brs, 1H), 7.67 – 7.64 (m, 1H), 7.53 (td, $J = 7.7, 1.4$ Hz, 1H), 7.33 (dd, $J = 9.7, 8.1, 0.9$ 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$_3$) $\delta$ 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$_2$O$_2$ [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$_3$) $\delta$ 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$_3$) $\delta$ 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$_2$O$_2$ [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$_3$) $\delta$ 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$_3$) $\delta$ 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$_2$O$_2$ [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$_3$) $\delta$ 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$_3$) $\delta$ 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$_2$O$_3$[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$_3$) $\delta$ 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$_3$) $\delta$ 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$_2$O$_3$[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$_3$) $\delta$ 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), 4.13 (s, 3H), 1.20 (t, $J = 7.1$ Hz, 3H).

$^{13}$C NMR (126 MHz, CDCl$_3$) $\delta$ 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$_2$O$_3$[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$_3$) $\delta$ 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$_2$O$_3$ [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$_2$O$_2$ [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 tBuONa (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$_2$O$_3$[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)