Persulfate promoted carbamoylation of \( N \)-arylacrylamides and \( N \)-arylccinnamamides with 4-carbamoyl-Hantzsch esters

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1. General methods

Unless otherwise noted, all of the reagents were purchased from commercial suppliers and used without purification. $^1$H NMR and $^{13}$C NMR spectra were recorded on a Bruker AVANCE III HD 400 instrument. HRMS (ESI) determinations were carried out on a Bruker Daltonics MicrOTOF II spectrometer. Melting points were determined on a Shanghai Shenguang WRS-3 melting point instrument. The 4-carbamoyl-Hantzsch esters and N-arylacrylamides were prepared according to the published procedures.\textsuperscript{1-6}

2. General procedure for the carbamoylation

4-Carbamoyl Hantzsch ester \textit{1} (0.24 mmol), N-arylacrylamides \textit{2} or N-arylcinnamamides \textit{4} (0.2 mmol), (NH$_4$)$_2$S$_2$O$_8$ (0.4 mmol), and CH$_3$CN-H$_2$O (2 mL, v/v, 1:1) were added to a 10 mL Schlenk tube under N$_2$. The mixture was heated at 50 oC for 12 h and then cooled to room temperature. After the reaction was completed, the mixture was concentrated under reduced pressure, the resulting mixture was dissolved with ethyl acetate (5 mL) and washed with H$_2$O (3 x 5 mL). The organic phase was concentrated under vacuum, the residue was purified by column chromatography on silica gel to give the corresponding products \textit{3} or \textit{5}.

3. Characteristic data of compounds

1,3-dimethyl-3-(2-oxo-2-(piperidin-1-yl)ethyl)indolin-2-one ($3a$)$^7$

Yield (88%), white solid, mp 140.5-141.3 °C, PE/EA = 3/1 to EA as the eluent; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$: 7.25-7.19 (m, 1H), 7.17-7.11 (m, 1H), 7.02-6.96 (m, 1H), 6.84 (d, $J = 8.0$ Hz, 1H), 3.38-3.28 (m, 4H), 3.26 (s, 3H), 2.99 (d, $J = 16.0$ Hz, 1H), 2.94 (d, $J = 16.0$ Hz, 1H), 1.61-1.47 (m, 4H), 1.46-1.35 (m, 2H), 1.34 (s, 3H).

1,3-dimethyl-3-(2-morpholino-2-oxoethyl)indolin-2-one ($3b$)$^7$

Yield (82%), white solid, mp 180.9-181.2 °C, PE/EA = 3/1 to EA as the eluent; $^1$H NMR (400
MHz, CDCl$_3$ δ: 7.27-7.22 (m, 1H), 7.17-7.13 (m, 1H), 7.04-6.98 (m, 1H), 6.86 (d, $J$ = 8.0 Hz, 1H), 3.66-3.48 (m, 4H), 3.48-3.28 (m, 4H), 3.26 (s, 3H), 3.00 (d, $J$ = 16.0 Hz, 1H), 2.92 (d, $J$ = 16.0 Hz, 1H), 1.36 (s, 3H).

1,3-dimethyl-3-(2-oxo-2-(pyrrolidin-1-yl)ethyl)indolin-2-one (3c)

Yield (80%), viscous liquid, PE/EA = 3/1 to EA as the eluent; $^1$H NMR (400 MHz, CDCl$_3$) δ: 7.25-7.19 (m, 1H), 7.18-7.15 (m, 1H), 7.01-6.94 (m, 1H), 6.83 (d, $J$ = 8.0 Hz, 1H), 3.37-3.27 (m, 3H), 3.25 (s, 3H), 3.23-3.17 (m, 1H), 2.91 (d, $J$ = 16.0 Hz, 1H), 2.84 (d, $J$ = 16.0 Hz, 1H), 1.89-1.82 (m, 2H), 1.78-1.70 (m, 2H), 1.36 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) δ: 180.8, 167.4, 143.8, 134.1, 127.6, 121.9, 121.7, 108.0, 46.5, 45.6, 45.4, 41.9, 26.3, 26.0, 24.5, 24.2; HRMS (ESI) m/z: [M+H]$^+$ calcd for C$_{16}$H$_{21}$N$_2$O$_2$ 273.1598; found 273.1598.

2-(1,3-dimethyl-2-oxoindolin-3-yl)-N,N-diethylacetamide (3d)

Yield (75%), colorless liquid, PE/EA = 3/1 to EA as the eluent; $^1$H NMR (400 MHz, CDCl$_3$) δ: 7.25-7.18 (m, 1H), 7.17-7.11 (m, 1H), 6.98 (t, $J$ = 8.0 Hz, 1H), 6.83 (d, $J$ = 8.0 Hz, 1H), 3.30-3.21 (m, 5H), 3.21-3.11 (m, 2H), 2.96 (d, $J$ = 16.0 Hz, 1H), 2.91 (d, $J$ = 16.0 Hz, 1H), 1.36 (s, 3H), 1.14 (t, $J$ = 8.0 Hz, 3H), 0.90 (t, $J$ = 8.0 Hz, 3H).

N-cyclopentyl-2-(1,3-dimethyl-2-oxoindolin-3-yl)acetamide (3e)

Yield (88%), yellow solid, 118. 6-119.2 °C, PE/EA = 3/1 to EA as the eluent; $^1$H NMR (400 MHz, CDCl$_3$) δ: 7.32-7.24 (m, 2H), 7.08 (t, $J$ = 8.0 Hz, 1H), 6.85 (d, $J$ = 8.0 Hz, 1H), 6.33 (s, 1H), 4.11-3.98 (m, 1H), 3.24 (s, 3H), 2.75 (d, $J$ = 16.0 Hz, 1H), 2.62 (d, $J$ = 16.0 Hz, 1H), 1.92-1.74 (m, 2H), 1.68-1.46 (m, 4H), 1.43 (s, 3H), 1.33-1.17 (m, 2H).
N-cycloheptyl-2-(1,3-dimethyl-2-oxoindolin-3-yl)acetamide (3f)

Yield (70%), yellow liquid, PE/EA = 3/1 to EA as the eluent; $^1$H NMR (400 MHz, CDCl$_3$) δ:
7.28-7.22 (m, 2H), 7.05 (t, $J = 8.0$ Hz, 1H), 6.83 (d, $J = 8.0$ Hz, 1H), 6.21 (d, $J = 8.0$ Hz, 1H), 3.83-3.71 (m, 1H), 3.22 (s, 3H), 2.73 (d, $J = 16.0$ Hz, 1H), 2.59 (d, $J = 16.0$ Hz, 1H), 1.78-1.64 (m, 2H), 1.59-1.45 (m, 6H), 1.43-1.38 (m, 4H), 1.33-1.21 (m, 3H).

2-(1,3-dimethyl-2-oxoindolin-3-yl)-N-hexylacetamide (3g)

Yield (85%), yellow liquid, PE/EA = 3/1 to EA as the eluent; $^1$H NMR (400 MHz, CDCl$_3$) δ:
7.30-7.22 (m, 2H), 7.06 (t, $J = 8.0$ Hz, 1H), 6.84 (d, $J = 8.0$ Hz, 1H), 6.32 (s, 1H), 3.23 (s, 3H), 3.13-3.03 (m, 2H), 2.77 (d, $J = 16.0$ Hz, 1H), 2.64 (d, $J = 16.0$ Hz, 1H), 1.41 (s, 3H), 1.38-1.29 (m, 2H), 1.28-1.16 (m, 6H), 0.85 (t, $J = 8.0$ Hz, 3H).

N-benzyl-2-(1,3-dimethyl-2-oxoindolin-3-yl)acetamide (3h)

Yield (70%), yellow liquid, PE/EA = 3/1 to EA as the eluent; $^1$H NMR (400 MHz, CDCl$_3$) δ:
7.31-7.19 (m, 5H), 7.10-6.99 (m, 3H), 6.81 (d, $J = 8.0$ Hz, 1H), 6.60-6.50 (m, 1H), 4.34-4.14 (m, 2H), 3.09 (s, 3H), 2.84 (d, $J = 16.0$ Hz, 1H), 2.68 (d, $J = 16.0$ Hz, 1H), 1.38 (s, 3H).

2-(1,3-dimethyl-2-oxoindolin-3-yl)-N-(1-phenylethyl)acetamide (3i)

Yield (41%), yellow solid, mp 171.7-172.5 °C, PE/EA = 3/1 to EA as the eluent; $^1$H NMR (400 MHz, CDCl$_3$) δ:
7.33-7.23 (m, 5H), 7.21-7.15 (m, 2H), 7.08 (t, $J = 8.0$ Hz, 1H), 6.84 (d, $J = 8.0$ Hz, 1H), 6.54 (d, $J = 8.0$ Hz, 1H), 5.03-4.89 (m, 1H), 3.24 (s, 3H), 2.80 (d, $J = 16.0$ Hz, 1H), 2.65 (d, $J = 16.0$ Hz, 1H), 1.38 (s, 3H), 1.34 (d, $J = 8.0$ Hz, 3H).
2-(1,3-dimethyl-2-oxoindolin-3-yl)-N-(furan-2-ylmethyl)acetamide (3j)

Yield (50%), white solid, mp 100.7-101.1 °C, PE/EA = 3/1 to EA as the eluent; \textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\): 7.32-7.28 (m, 1H), 7.28-7.22 (m, 2H), 7.06 (t, \(J = 8.0\) Hz, 1H), 6.83 (d, \(J = 8.0\) Hz, 1H), 6.65 (s, 1H), 6.29-6.23 (m, 1H), 6.12-6.04 (m, 1H), 4.38-4.20 (m, 2H), 3.18 (s, 3H), 2.80 (d, \(J = 16.0\) Hz, 1H), 2.68 (d, \(J = 16.0\) Hz, 1H), 1.41 (s, 3H); \textsuperscript{13}C NMR (100 MHz, CDCl\textsubscript{3}) \(\delta\): 180.5, 168.7, 151.3, 142.8, 141.9, 133.1, 128.1, 122.3, 110.3, 108.3, 107.1, 46.1, 43.6, 36.3, 26.3, 23.5; HRMS (ESI) m/z: \([M+H]^+\) calcld for C\textsubscript{17}H\textsubscript{19}N\textsubscript{2}O\textsubscript{3} 299.1390; found 299.1387.

2-(1,3-dimethyl-2-oxoindolin-3-yl)-N-phenethylacetamide (3k)

Yield (83%), colorless liquid, PE/EA = 3/1 to EA as the eluent; \textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\): 7.30-7.24 (m, 4H), 7.21-7.16 (m, 1H), 7.14-7.09 (m, 2H), 7.09-7.03 (m, 1H), 6.84 (d, \(J = 8.0\) Hz, 1H), 6.26 (s, 1H), 3.44-3.27 (m, 2H), 3.21 (s, 3H), 2.76 (d, \(J = 16.0\) Hz, 1H), 2.67 (t, \(J = 8.0\) Hz, 2H), 2.61 (d, \(J = 16.0\) Hz, 1H), 1.38 (s, 3H).

2-(1,3-dimethyl-2-oxoindolin-3-yl)-N-phenylacetamide (3l)

Yield (75%), white solid, mp 98.2-99.1°C, PE/EA = 3/1 to EA as the eluent; \textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\): 8.87 (s, 1H), 7.48 (d, \(J = 8.0\) Hz, 2H), 7.34-7.27 (m, 4H), 7.15-7.03 (m, 2H), 6.87 (d, \(J = 8.0\) Hz, 1H), 3.26 (s, 3H), 2.91 (d, \(J = 16.0\) Hz, 1H), 2.84 (d, \(J = 16.0\) Hz, 1H), 1.51 (s, 3H).

2-(1,3-dimethyl-2-oxoindolin-3-yl)-N-(p-tolyl)acetamide (3m)

Yield (76%), yellow solid, mp 111.8-112.5 °C, PE/EA = 3/1 to EA as the eluent; \textsuperscript{1}H NMR (400 MHz, CDCl\textsubscript{3}) \(\delta\): 8.87 (s, 1H), 7.48 (d, \(J = 8.0\) Hz, 2H), 7.34-7.27 (m, 4H), 7.15-7.03 (m, 2H), 6.87 (d, \(J = 8.0\) Hz, 1H), 3.26 (s, 3H), 2.91 (d, \(J = 16.0\) Hz, 1H), 2.84 (d, \(J = 16.0\) Hz, 1H), 1.51 (s, 3H).
MHz, CDCl$_3$ $\delta$: 8.73 (s, 1H), 7.37-7.27 (m, 4H), 7.13-7.05 (m, 3H), 6.86 (d, $J = 8.0$ Hz, 1H), 3.25 (s, 3H), 2.90 (d, $J = 16.0$ Hz, 1H), 2.82 (d, $J = 16.0$ Hz, 1H), 2.29 (s, 3H), 1.50 (s, 3H).

2-(1,3-dimethyl-2-oxoindolin-3-yl)-N-(4-(trifluoromethyl)phenyl)acetamide (3n)$^8$

![Chemical structure of 3n](image)

Yield (51%), white solid, mp 72.1-72.9 °C, PE/EA = 3/1 to EA as the eluent; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$: 9.52 (s, 1H), 7.62 (d, $J = 8.0$ Hz, 2H), 7.50 (d, $J = 8.0$ Hz, 2H), 7.34-7.26 (m, 2H), 7.12 (t, $J = 8.0$ Hz, 1H), 6.89 (d, $J = 8.0$ Hz, 1H), 3.27 (s, 3H), 2.95 (d, $J = 16.0$ Hz, 1H), 2.89 (d, $J = 16.0$ Hz, 1H), 1.50 (s, 3H).

3-(cyclopentylmethyl)-1,3-dimethylindolin-2-one (3o)$^9$

![Chemical structure of 3o](image)

Yield (81%), colorless liquid, PE/EA = 3/1 to EA as the eluent; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$: 7.29-7.22 (m, 1H), 7.18-7.14 (m, 1H), 7.08-7.02 (m, 1H), 6.83 (d, $J = 8.0$ Hz, 1H), 3.21 (s, 3H), 2.11-2.00 (m, 1H), 1.92-1.82 (m, 1H), 1.51-1.18 (m, 10H), 1.06-0.94 (m, 1H), 0.89-0.75 (m, 1H).

5-methoxy-1,3-dimethyl-3-(2-oxo-2-(piperidin-1-yl)ethyl)indolin-2-one (3p)

![Chemical structure of 3p](image)

Yield (71%), yellow solid, mp 134.5-135.2 °C, PE/EA = 3/1 to EA as the eluent; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$: 6.78-7.76 (m, 1H), 6.74-6.72 (m, 2H), 3.76 (s, 3H), 3.36-3.30 (m, 4H), 3.23 (s, 3H), 2.98 (d, $J = 16.0$ Hz, 1H), 2.90 (d, $J = 16.0$ Hz, 1H), 1.59-1.47 (m, 4H), 1.43-1.33 (m, 2H), 1.32 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$: 180.5, 166.9, 155.5, 137.4, 135.9, 110.9, 109.9, 108.0, 55.6, 46.5, 46.0, 42.5, 40.5, 26.4, 26.2, 25.3, 25.0, 24.3; HRMS (ESI) calcd for C$_{18}$H$_{25}$N$_2$O$_3$+: [M+H]$^+$ 317.1860, found: 317.1860.
1,3,5-trimethyl-3-(2-oxo-2-(piperidin-1-yl)ethyl)indolin-2-one (3q)\(^7\)

Yield (81%), white solid, mp 112.3-112.8 °C, PE/EA = 3/1 to EA as the eluent; \(^1\)H NMR (400 MHz, CDCl\(_3\)) δ: 7.02 (d, \(J = 8.0\) Hz, 1H), 6.95 (s, 1H), 6.72 (d, \(J = 8.0\) Hz, 1H), 3.42-3.26 (m, 4H), 3.23 (s, 3H), 2.97 (d, \(J = 16.0\) Hz, 1H), 2.91 (d, \(J = 16.0\) Hz, 1H), 2.30 (s, 3H), 1.60-1.46 (m, 4H), 1.45-1.34 (m, 2H), 1.33 (s, 3H).

5-fluoro-1,3-dimethyl-3-(2-oxo-2-(piperidin-1-yl)ethyl)indolin-2-one (3r)\(^7\)

Yield (70%), yellow solid, mp 115.4-116.2 °C, PE/EA = 3/1 to EA as the eluent; \(^1\)H NMR (400 MHz, CDCl\(_3\)) δ: 6.95-6.87 (m, 2H), 6.78-6.72 (m, 1H), 3.40-3.28 (m, 4H), 3.25 (s, 3H), 3.02 (d, \(J = 16.0\) Hz, 1H), 2.92 (d, \(J = 16.0\) Hz, 1H), 1.62-1.48 (m, 4H), 1.48-1.34 (m, 2H), 1.33 (s, 3H); \(^19\)F NMR (376 MHz, CDCl\(_3\)) δ: -121.7.

5-chloro-1,3-dimethyl-3-(2-oxo-2-(piperidin-1-yl)ethyl)indolin-2-one (3s)\(^7\)

Yield (86%), white solid, mp 131.5-132.2 °C, PE/EA = 3/1 to EA as the eluent; \(^1\)H NMR (400 MHz, CDCl\(_3\)) δ: 7.22-7.16 (m, 1H), 7.08 (d, \(J = 2.0\) Hz, 1H), 6.76 (d, \(J = 8.4\) Hz, 1H), 3.41-3.28 (m, 4H), 3.24 (s, 3H), 3.03 (d, \(J = 16.0\) Hz, 1H), 2.92 (d, \(J = 16.0\) Hz, 1H), 1.64-1.48 (m, 4H), 1.46-1.34 (m, 2H), 1.32 (s, 3H).

1,3,7-trimethyl-3-(2-oxo-2-(piperidin-1-yl)ethyl)indolin-2-one (3u)\(^7\)
Yield (75%), colorless liquid, PE/EA = 3/1 to EA as the eluent; $^1$H NMR (400 MHz, CDCl$_3$) δ:
6.96-6.91 (m, 2H), 6.89-6.83 (m, 1H), 3.54 (s, 3H), 3.40-3.28 (m, 4H), 3.00 (d, $J = 16.0$ Hz, 1H),
2.93 (d, $J = 16.0$ Hz, 1H), 2.58 (s, 3H), 1.60-1.47 (m, 4H), 1.45-1.32 (m, 2H), 1.30 (s, 3H).
1,3,4-trimethyl-3-(2-oxo-2-(piperidin-1-yl)ethyl)indolin-2-one and 1,3,6-trimethyl-3-(2-oxo-2-
(piperidin-1-yl)ethyl)indolin-2-one ($3v + 3v'$) $^7$

Yield (85%), colorless liquid, PE/EA = 3/1 to EA as the eluent; $^1$H NMR (400 MHz, CDCl$_3$) δ:
7.13 (t, $J = 8.0$ Hz, 0.66H), 7.02 (d, $J = 7.6$ Hz, 0.34H), 6.80 (d, $J = 7.6$ Hz, 0.34H), 6.75 (d, $J =
7.6$ Hz, 0.67H), 6.72-6.65 (m, 1H), 3.42-3.27 (m, 4H), 3.24 (s, 3H), 3.20 (d, $J = 16.8$ Hz, 0.65H),
3.06 (d, $J = 16.8$ Hz, 0.65H), 2.98 (d, $J = 16.4$ Hz, 0.35H), 2.92 (d, $J = 16.4$ Hz, 0.35H), 2.35 (s,
1H), 2.33 (s, 2H), 1.61-1.46 (m, 4H), 1.43-1.30 (m, 5H).
7-chloro-1,3-dimethyl-3-(2-oxo-2-(piperidin-1-yl)ethyl)indolin-2-one ($3w$) $^7$

Yield (51%), viscous liquid, PE/EA = 3/1 to EA as the eluent; $^1$H NMR (400 MHz, CDCl$_3$) δ:
7.14-7.08 (m, 1H), 6.98-6.94 (m, 1H), 6.87 (t, $J = 8.0$ Hz, 1H), 3.62 (s, 3H), 3.39-3.27 (m, 4H),
3.04 (d, $J = 16.4$ Hz, 1H), 2.93 (d, $J = 16.4$ Hz, 1H), 1.59-1.47 (m, 4H), 1.45-1.31 (m, 2H), 1.29 (s,
3H).
4-chloro-1,3-dimethyl-3-(2-oxo-2-(piperidin-1-yl)ethyl)indolin-2-one and 6-chloro-1,3-dimethyl-
3-(2-oxo-2-(piperidin-1-yl)ethyl)indolin-2-one ($3x+3x'$) $^7$

Yield (70%), colorless liquid, PE/EA = 3/1 to EA as the eluent; $^1$H NMR (400 MHz, CDCl$_3$) δ:
7.15 (t, $J = 7.6$ Hz, 0.81H), 7.03 (d, $J = 8.0$ Hz, 0.19H), 6.96-6.02 (m, 0.19H), 6.91-6.85 (m,
0.80H), 6.82 (d, $J = 2.0$ Hz, 0.19H), 6.76-6.71 (m, 0.81H), 3.62 (d, $J = 16.4$ Hz, 0.83H), 3.48-3.29
(m, 3H), 3.27-3.18 (m, 4H), 3.00 (d, \( J = 16.4 \) Hz, 0.22H), 2.98 (d, \( J = 16.4 \) Hz, 0.83H), 2.93 (d, \( J = 16.4 \) Hz, 0.22H), 1.61-1.48 (m, 4H), 1.46-1.28 (m, 5H).

1,3-dimethyl-3-(2-oxo-2-(piperidin-1-yl)ethyl)-1H-pyrrolo[2,3-b]pyridin-2(3H)-one (3y)

Yield (75%), colorless liquid, PE/EA = 3/1 to EA as the eluent; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \):
8.15-8.11 (m, 1H), 7.42-7.38 (m, 1H), 6.89-6.85 (m, 1H), 3.37-3.30 (m, 7H), 3.00 (d, \( J = 16.4 \) Hz, 1H), 2.94 (d, \( J = 16.4 \) Hz, 1H), 1.60-1.47 (m, 4H), 1.46-1.37 (m, 2H), 1.36 (s, 3H).

1-methyl-1-(2-oxo-2-(piperidin-1-yl)ethyl)-5,6-dihydro-1H-pyrrolo[3,2-1-ij]quinolin-2(4H)-one (3z)

Yield (88%), colorless liquid, PE/EA = 3/1 to EA as the eluent; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \):
7.05-6.94 (m, 2H), 6.91-6.84 (m, 1H), 3.80-3.71 (m, 2H), 3.40-3.30 (m, 4H), 2.94 (s, 2H), 2.87-2.69 (m, 2H), 2.12-1.92 (m, 2H), 1.60-1.50 (m, 4H), 1.49-1.39 (m, 2H), 1.37 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \( \delta \): 179.7, 167.2, 139.5, 132.8, 126.5, 121.4, 119.8, 119.7, 47.0, 46.6, 42.5, 40.2, 38.8, 26.3, 25.4, 24.6, 24.3, 21.2; HRMS (ESI) m/z: [M+H]\(^+\) calcd for C\(_{19}\)H\(_{25}\)N\(_2\)O\(_2\) 313.1911; found 313.1910.

1-ethyl-3-methyl-3-(2-oxo-2-(piperidin-1-yl)ethyl)indolin-2-one (3ab)

Yield (82%), colorless liquid, PE/EA = 3/1 to EA as the eluent; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \( \delta \):
7.24-7.12 (m, 2H), 6.97 (t, \( J = 7.6 \) Hz, 1H), 6.85 (d, \( J = 7.6 \) Hz, 1H), 3.90-3.70 (m, 2H), 3.42-3.23 (m, 4H), 2.95 (s, 2H), 1.59-1.45 (m, 4H), 1.45-1.35 (m, 2H), 1.34 (s, 3H), 1.28 (t, \( J = 7.2 \) Hz, 3H).

3-methyl-3-(2-oxo-2-(piperidin-1-yl)ethyl)-1-phenylindolin-2-one (3ac)
Yield (79%), white solid, mp 88.9-89.5 °C, PE/EA = 3/1 to EA as the eluent; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 7.57-7.45 (m, 4H), 7.42-7.33 (m, 1H), 7.22-7.11 (m, 2H), 7.06-6.98 (m, 1H), 6.81 (d, \(J = 7.6\) Hz, 1H), 3.44-3.31 (m, 4H), 3.12 (d, \(J = 16.4\) Hz, 1H), 3.05 (d, \(J = 16.0\) Hz, 1H), 1.62-1.50 (m, 4H), 1.48-1.36 (m, 5H).

1-benzyl-3-methyl-3-(2-oxo-2-(piperidin-1-yl)ethyl)indolin-2-one (3ad)

Yield (72%), white solid, mp 133.1-133.8 °C, PE/EA = 3/1 to EA as the eluent; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 7.39-7.34 (m, 2H), 7.33-7.28 (m, 2H), 7.25-7.20 (m, 1H), 7.19-7.16 (m, 1H), 7.13-7.08 (m, 1H), 7.00-6.94 (m, 1H), 6.69 (d, \(J = 8.0\) Hz, 1H), 5.12 (d, \(J = 16.0\) Hz, 1H), 4.85 (d, \(J = 16.0\) Hz, 1H), 3.41-3.34 (m, 4H), 3.09 (d, \(J = 16.0\) Hz, 1H), 3.02 (d, \(J = 16.0\) Hz, 1H), 1.62-1.53 (m, 2H), 1.51-1.44 (m, 4H), 1.43 (s, 3H).

1-methyl-4-phenyl-3-(piperidine-1-carbonyl)-3,4-dihydroquinolin-2(1\(H\))-one (5a)

Yield (56%), white solid, mp 196.9-197.3 °C, PE/EA = 3/1 to EA as the eluent; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 7.36-7.29 (m, 2H), 7.29-7.20 (m, 4H), 7.03 (d, \(J = 8.0\) Hz, 1H), 6.95 (t, \(J = 7.6\) Hz, 1H) 6.79 (d, \(J = 7.6\) Hz, 1H), 4.74 (d, \(J = 10.8\) Hz, 1H), 4.20 (d, \(J = 10.8\) Hz, 1H), 3.69-3.57 (m, 1H), 3.48-3.31 (m, 5H), 3.30-3.21 (m, 1H), 1.64-1.44 (m, 4H), 1.22-1.08 (m, 2H); \(^1\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 166.7, 166.3, 140.2, 139.4, 128.7, 128.6, 128.2, 127.7, 127.2, 123.1, 114.5, 50.7, 47.3, 45.1, 43.2, 29.9, 26.3, 25.4, 24.4; HRMS (ESI) m/z: [M+H]\(^+\) calcd for C\(_{22}\)H\(_{25}\)N\(_2\)O\(_2\) 349.1911; found 313.1911.
1-methyl-3-(piperidine-1-carbonyl)-4-(p-tolyl)-3,4-dihydroquinolin-2(1H)-one (5b)

Yield (48%), yellow solid, mp 163.8-164.9 °C, PE/EA = 3/1 to EA as the eluent; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$: 7.28-7.24 (m, 1H), 7.16-7.08 (m, 4H), 7.03 (d, $J = 8.0$ Hz, 1H), 6.95 (t, $J = 7.6$ Hz, 1H) 6.81 (d, $J = 7.6$ Hz, 1H), 4.69 (d, $J = 8.0$ Hz, 1H), 4.18 (d, $J = 8.0$ Hz, 1H), 3.69-3.57 (m, 1H), 3.48-3.38 (m, 5H), 3.35-3.27 (m, 1H), 2.33 (s, 3H), 1.60-1.52 (m, 4H), 1.28-1.21 (m, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$: 166.8, 166.4, 139.4, 137.1, 136.8, 129.4, 128.5, 128.4, 128.3, 127.6, 123.1, 114.4, 50.7, 47.3, 44.6, 43.2, 29.9, 26.2, 25.4, 24.4, 21.0; HRMS (ESI) m/z: [M+H]$^+$ calcd for C$_{23}$H$_{27}$N$_2$O$_2$ 363.2067; found 363.2069.

4-(4-bromophenyl)-1-methyl-3-(piperidine-1-carbonyl)-3,4-dihydroquinolin-2(1H)-one (5c)

Yield (48%), yellow solid, mp 185.6-186.4 °C, PE/EA = 3/1 to EA as the eluent; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$: 7.48-7.46 (m, 2H), 7.30-7.26 (m, 1H), 7.12 (d, $J = 8.0$ Hz, 2H), 7.04 (d, $J = 8.0$ Hz, 1H), 6.96 (t, $J = 8.0$ Hz, 1H) 6.73 (d, $J = 8.0$ Hz, 1H), 4.74 (d, $J = 10.2$ Hz, 1H), 4.15 (d, $J = 10.2$ Hz, 1H), 3.62-3.54 (m, 1H), 3.48-3.31 (m, 5H), 3.30-3.21 (m, 1H), 1.64-1.50 (m, 4H), 1.26-1.20 (m, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$: 166.4, 166.0, 139.4, 139.3, 131.8, 130.5, 128.0, 127.9, 127.8, 123.2, 121.1, 114.6, 50.5, 47.3, 44.4, 43.3, 30.0, 26.3, 25.5, 24.4; HRMS (ESI) m/z: [M+H]$^+$ calcd for C$_{22}$H$_{24}$BrN$_2$O$_2$ 427.1016; found 427.1011.
6-fluoro-1-methyl-4-phenyl-3-(piperidine-1-carbonyl)-3,4-dihydroquinolin-2(1H)-one (5d)

Yield (48%), yellow solid, mp 154.2-155.1 °C, PE/EA = 3/1 to EA as the eluent; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 7.38-7.32 (m, 2H), 7.30-7.27 (m, 1H), 7.22-7.18 (m, 2H), 6.97-6.95 (m, 2H) 6.58-6.50 (m, 1H), 4.72 (d, \(J = 8.0\) Hz, 1H), 4.19 (d, \(J = 8.0\) Hz, 1H), 3.69-3.61 (m, 1H), 3.48-3.40 (m, 5H), 3.34-3.26 (m, 1H), 1.56-1.50 (m, 4H), 1.22-1.14 (m, 2H); \(^1^3\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 166.3, 166.1, 158.8 (d, \(J = 242.0\) Hz), 139.6, 135.7 (d, \(J = 2.0\) Hz), 130.6 (d, \(J = 7.0\) Hz), 128.9, 128.6, 127.5, 115.7 (d, \(J = 8.0\) Hz), 115.5 (d, \(J = 20.0\) Hz), 114.0 (d, \(J = 22.0\) Hz), 50.5, 47.4, 45.1, 43.3, 30.2, 26.2, 25.5, 24.4; HRMS (ESI) m/z: [M+H]\(^+\) calcd for C\(_{22}\)H\(_{24}\)FN\(_2\)O\(_2\) 367.1816; found 367.1819.

6-chloro-1-methyl-4-phenyl-3-(piperidine-1-carbonyl)-3,4-dihydroquinolin-2(1H)-one (5e)

Yield (26%), white solid, mp 162.3-162.9 °C, PE/EA = 3/1 to EA as the eluent; \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\): 7.38-7.32 (m, 2H), 7.30-7.28 (m, 1H), 7.25-7.17 (m, 3H), 6.96 (d, \(J = 8.0\) Hz, 1H) 6.82-6.78 (m, 1H), 4.69 (d, \(J = 8.0\) Hz, 1H), 4.17 (d, \(J = 8.0\) Hz, 1H), 3.69-3.57 (m, 1H), 3.48-3.41 (m, 5H), 3.34-3.26 (m, 1H), 1.55-1.47 (m, 4H), 1.22-1.12 (m, 2H); \(^1^3\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\): 166.3, 166.1, 139.6, 138.1, 130.0, 129.0, 128.6, 128.5, 128.3, 127.7, 127.6, 115.8, 50.6, 47.4, 45.1, 43.4, 30.0, 26.2, 25.5, 24.4; HRMS (ESI) m/z: [M+H]\(^+\) calcd for C\(_{22}\)H\(_{24}\)ClN\(_2\)O\(_2\) 383.1521; found 383.1517.
4. Mechanistic Investigations

\[
\begin{align*}
\text{DHP} & \quad \text{standard conditions} \quad \text{TEMPO (2 equiv)} \\
1a + 2a & \quad \rightarrow 3a, 0 \\
\end{align*}
\]

\text{1a (0.24 mmol), 2a (0.2 mmol), (NH}_4\text{)}_2\text{S}_2\text{O}_8 (0.4 mmol), TEMPO (0.4 mmol), and degassed CH}_3\text{CN-H}_2\text{O (2 mL, 1:1, v/v) were added to a 10 mL Schlenk tube under N}_2. The mixture was heated at 50 °C for 12 h and then cooled to room temperature. After the reaction was completed, the reaction mixture was monitored by TLC, and no desired product was observed. Then the mixture was concentrated under reduced pressure, the resulting mixture was dissolved with ethyl acetate (5 mL) and washed with H}_2\text{O (3 x 5 mL). The organic phase was concentrated under vacuum, the residue was measured by HRMS. The HRMS below indicated the formation of carbamoyl-TEMPO adduct.

\[
\begin{align*}
\text{1a (0.24 mmol), 2a (0.2 mmol), (NH}_4\text{)}_2\text{S}_2\text{O}_8 (0.4 mmol), 1,1\text{-diphenylethylene (0.4 mmol), and degassed CH}_3\text{CN-H}_2\text{O (2 mL, 1:1, v/v) were added to a 10 mL Schlenk tube under N}_2. The mixture was heated at 50 °C for 12 h and then cooled to room temperature. After the reaction was completed, the mixture was concentrated under reduced pressure, the resulting mixture was dissolved with ethyl acetate (5 mL) and washed with H}_2\text{O (3 x 5 mL). The organic phase was concentrated under vacuum, the yield was determined by } ^1\text{H NMR with CH}_2\text{Br}_2 \text{ as internal standard.}
\end{align*}
\]
5. References


6. NMR spectra

$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3a

$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3b
$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3c

$^{13}$C NMR (100 MHz, CDCl$_3$) spectra of 3c
$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3d

$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3e
$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3f

$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3g
$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3h

$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3i

$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3l
$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3j

$^{13}$C NMR (100 MHz, CDCl$_3$) spectra of 3j
$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3k

$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3l
$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3m

$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3n

\[
\begin{align*}
\text{H} & \quad \text{N} \\
\text{O} & \\
\text{N} & \quad \text{O} \\
\text{C} & \\
\text{F} & \\
\end{align*}
\]

\[
\begin{align*}
\text{H} & \quad \text{N} \\
\text{O} & \\
\text{N} & \quad \text{O} \\
\text{C} & \\
\text{F} & \\
\end{align*}
\]
$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3o

![NMR spectrum of 3o]

$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3p

![NMR spectrum of 3p]
$^{13}$C NMR (100 MHz, CDCl$_3$) spectra of 3p

$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3q
$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3r

$^{19}$F NMR (376 MHz, CDCl$_3$) spectra of 3r
$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3s

$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3u
$^1$H NMR (400 MHz, CDCl$_3$) spectra of $3v+3v'$

$^1$H NMR (400 MHz, CDCl$_3$) spectra of $3w$
$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3x + 3x'

\[ f_1 (ppm) \]

\[ 5.24 \quad 4.12 \quad 0.22 \quad 1.02 \quad 3.88 \quad 3.34 \quad 0.83 \quad 0.81 \quad 0.19 \quad 0.80 \quad 0.19 \quad 0.19 \quad 0.81 \]

\[ 1.309 \quad 1.346 \quad 1.367 \quad 1.380 \quad 1.418 \quad 1.511 \quad 1.553 \quad 1.589 \quad 2.907 \quad 2.949 \quad 2.964 \quad 2.983 \quad 3.005 \quad 3.024 \quad 3.200 \quad 3.209 \quad 3.219 \quad 3.233 \quad 3.250 \quad 3.327 \quad 3.340 \quad 3.354 \quad 3.364 \quad 3.371 \quad 3.380 \quad 3.397 \quad 3.405 \quad 3.415 \quad 3.422 \quad 3.443 \quad 3.456 \quad 3.466 \quad 3.596 \quad 3.637 \quad 6.730 \quad 6.732 \quad 6.750 \quad 6.751 \quad 6.823 \quad 6.828 \quad 6.872 \quad 6.874 \quad 6.893 \quad 6.895 \quad 6.933 \quad 6.937 \quad 6.952 \quad 6.957 \quad 7.018 \quad 7.038 \quad 7.130 \quad 7.149 \quad 7.170 \quad 7.260 \]

$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3y

\[ f_1 (ppm) \]

\[ 3.16 \quad 2.05 \quad 4.14 \quad 1.04 \quad 1.02 \quad 6.93 \quad 1.00 \quad 0.99 \quad 0.97 \]

\[ 1.361 \quad 1.389 \quad 1.400 \quad 1.411 \quad 1.426 \quad 1.498 \quad 1.511 \quad 1.528 \quad 1.542 \quad 1.554 \quad 1.566 \quad 1.580 \quad 2.916 \quad 2.957 \quad 2.978 \quad 3.019 \quad 3.316 \quad 3.332 \quad 3.342 \quad 3.357 \quad 6.859 \quad 6.873 \quad 6.877 \quad 6.891 \quad 7.260 \quad 7.397 \quad 7.401 \quad 7.415 \quad 7.419 \quad 8.123 \quad 8.127 \quad 8.136 \quad 8.140 \]
\(^{1}\)H NMR (400 MHz, CDCl\(_3\)) spectra of \(3z\)

\[^{13}\)C NMR (100 MHz, CDCl\(_3\)) spectra of \(3z\)
$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3ab

$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3ac
$^1$H NMR (400 MHz, CDCl$_3$) spectra of 3ad

$^1$H NMR (400 MHz, CDCl$_3$) spectra of 5a
$^{13}$C NMR (100 MHz, CDCl$_3$) spectra of 5a

$^1$H NMR (400 MHz, CDCl$_3$) spectra of 5b
$^{13}$C NMR (100 MHz, CDCl$_3$) spectra of 5b

$^1$H NMR (400 MHz, CDCl$_3$) spectra of 5c
$^{13}$C NMR (100 MHz, CDCl$_3$) spectra of 5c

$^1$H NMR (400 MHz, CDCl$_3$) spectra of 5d
$^{13}$C NMR (100 MHz, CDCl$_3$) spectra of 5d

1H NMR (400 MHz, CDCl$_3$) spectra of 5e

Cl

F

N

O

O

N

O

N

Cl

F
\(^{13}\)C NMR (100 MHz, CDCl\(_3\)) spectra of 5e

![Chemical structure](image)

\[\begin{array}{c}
24.43 \\
25.50 \\
26.29 \\
30.09 \\
43.41 \\
45.10 \\
47.47 \\
50.65 \\
76.68 \\
77.00 \\
77.20 \\
77.32 \\
115.81 \\
127.62 \\
127.70 \\
128.36 \\
128.54 \\
128.62 \\
129.05 \\
130.05 \\
138.15 \\
139.60 \\
166.10 \\
166.36 \\
\end{array}\]