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The tandem reaction combining radical and ionic processes: an efficient approach to substituted 3,4-dihydroquinolin-2-ones

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ABSTRACT

3,4-Dihydroquinolin-2-ones are of great importance in the areas of pharmaceuticals. However, the direct intramolecular radical cyclizations of the corresponding amide compounds favor 5-*exo* products **2**. Reports on the radical cyclization reactions producing 3,4-dihydroquinolin-2-one derivatives are limited. Herein, an efficient tandem reaction combining radical and ionic processes was developed, which provides a practical synthetic strategy for the synthesis of substituted 3,4-dihydroquinolin-2-ones from simple and readily available precursors under neutral reaction conditions.

1. Introduction

Tandem reactions have emerged as an attractive synthetic strategy for the synthesis of highly functionalized compounds utilizing one-pot synthesis.[1] However, tandem radical reactions may give undesired polymers, whereas looking for exacting reaction conditions is necessary for tandem reactions that proceed sequentially through ionic species. Recently, tandem reactions that combine radical and ionic processes have attracted a great deal of attention due to their special efficacies during the molecular construction.[2]

3,4-Dihydroquinolin-2-ones are of great importance in the areas of pharmaceuticals due to their ubiquitous structural motifs and powerful biological properties (Fig. 1).[3] Over the past decades, in contrast to lots of significant synthetic approaches for quinolin-2-one derivatives,[4,5] only a few methods have been developed to construct 3,4-dihydroquinolin-2-ones. These approaches include the Friedel–Crafts cyclization and[6] palladium[7] or rhodium[8] catalyzed reactions. Despite their efficiencies, they usually require harsh reaction conditions involving strong acid or base, high pressure, or the use of complicated compounds as substrates. To date, radical reactions have been widely used in organic synthesis, especially in cyclization reactions.[9,10] However, the deeply explored direct intramolecular radical cyclizations of amide compounds **1** favor 5-*exo* products **2** (Scheme 1).[11,12] Reports on the radical cyclization reactions producing 3,4-dihydroquinolin-2-one derivatives **3** are limited.[13] Herein, we describe an efficient intermolecular tandem reactions involving radical and ionic processes leading to 3,4-dihydroquinolin-2-one derivatives from readily available 2-iodoanilines **5** and acrylates **6**, with neutral reaction conditions.

2. Results and discussions

As reported, 3,4-dihydroquinolin-2-ones **3** were difficult to be achieved by the intramolecular radical cyclization of **1**, which favor 5-*exo* products **2**. Therefore, we hypothesized that the expected

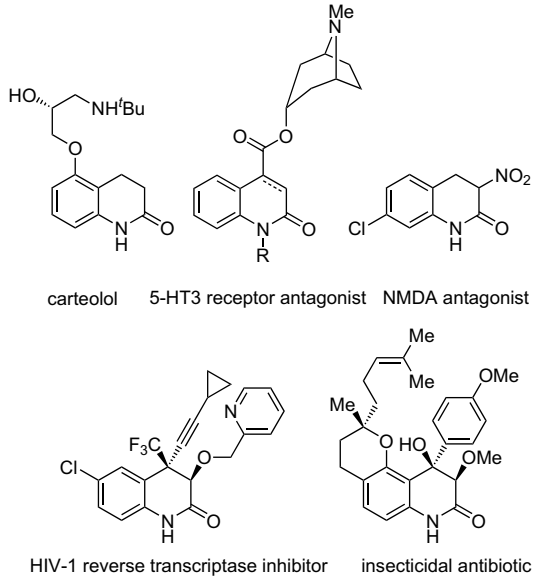

Figure 1. Selected examples of 3,4-dihydroquinolin-2-one frameworks.

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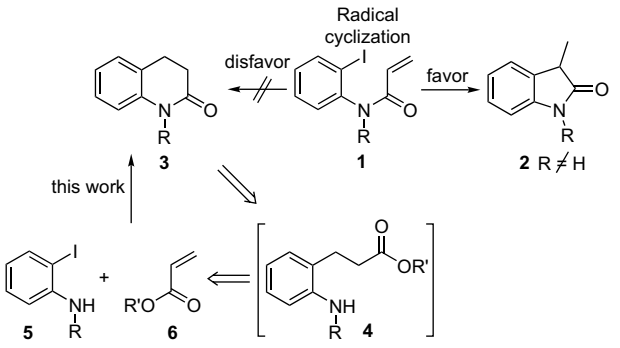
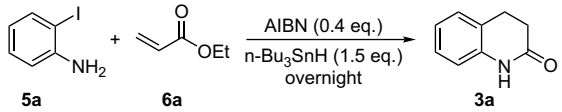


Scheme 1. Intermolecular tandem reaction between **5** and **6**.

6-*endo* products **3** could be constructed through the relay of intermolecular radical addition and lactamization between **5** and **6** (Scheme 1). With this hypothesis, **4** would be the key intermediates via radical addition reaction.[14] Our initial attempts started by

Table 1
Tandem reaction of 2-iodoaniline **5a** and ethyl acrylate **6a** involving radical and ionic processes[a]



Entry	Solvent	*T* (°C)	Yield[b] of **3a** (%)
1[c]	Toluene	80	18
2	Toluene	80	35
3	Acetonitrile	80	38
4	H_2O	80	42
5	THF	Reflux	21
6	DMF	80	38
7	EtOH	80	42
8	1,4-Dioxane	80	37
9	DME	80	52
10	DMSO	70	61
11	DMSO	120	71 (53)[d]

[a] Compound **5a** (0.5 mmol), **6a** (2.0 mmol), AIBN (0.2 mmol), *n*-Bu_3SnH (0.75 mmol), and solvent (2.0 mL), reacted under air.
[b] Isolated yield. With these yields, there were few oligomers of **6a**, which can be further purified by recrystallization.
[c] Compound **6a** (1.0 mmol) was used.
[d] The yield in parentheses was calculated by ^1H NMR using CH_2Br_2 as the internal standard.

treating 2-iodoaniline, **5a**, and ethyl acrylate, **6a**, with AIBN (40 mol %) in the presence of *n*-Bu_3SnH (150 mol %) in toluene. We were interested to find that the desired 3,4-dihydro-(1*H*)-quinolin-2-one, **3a**, was formed in 18% yield after heating for 10 h at 80 °C

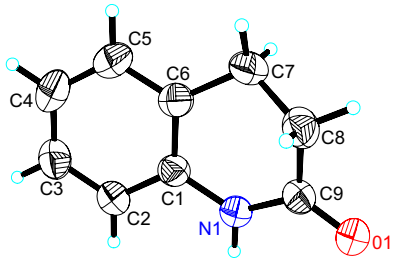


Figure 2. The X-ray diffraction structure of **3a**.

Table 2
Tandem reaction of 2-iodoaniline **5a** and ethyl acrylate **6a** with different radical initiators and reducing reagents[a]

Entry	Initiator	Reducing reagent	Solvent	*T*	*t* (h)	Yield[b] of **3a** (%)
1	Et_3B	*n*-Bu_3SnH	DME	rt	12	NR
2	Et_3B	*n*-Bu_3SnH	DMSO	rt to 120 °C[c]	24	Trace
3	Et_3B	TTMSS	DME	rt	12	41
4	AIBN	*n*-Bu_3SnH	DMSO	rt to 120 °C[c]	24	46
5	AIBN	TTMSS	Toluene	80 °C	12	31

[a] Compound **5a** (0.5 mmol), **6a** (2.0 mmol), AIBN (0.2 mmol) or Et_3B (0.55 mmol), reducing reagent (0.75 mmol), and solvent (2 mL), reacted under air.
[b] Isolated yield. With these yields, there were few oligomers of **6a**, which can be further purified by recrystallization.
[c] The reaction was held at rt for 12 h followed by heating at 120 °C for 12 h.

(entry 1, Table 1). 5-*exo* Product **2a** was not observed in this case. However, the yield was low due to the formation of aniline, which indicated that the radical addition should be the key step for this tandem reaction. Since the ^1H NMR spectrum of **3a** was different in part from the literature,[15] we identified the structure by X-ray diffraction (Fig. 2).

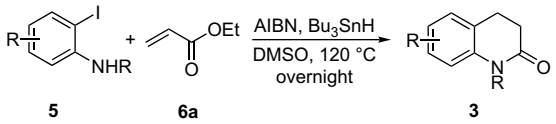
On the basis of this encouraging result, a range of other solvents were screened. To our delight, even using water as the solvent, the tandem reaction proceeded smoothly producing **3a** in 42% yield (entry 4, Table 1). Further investigation indicated that the reaction achieved the highest yield (71%) when the reaction mixture was heated at 120 °C in DMSO (entry 11, Table 1). The yield decreased slightly with lower reaction temperature (cf. entries 10 and 11, Table 1). Some oligomers of **6a** were observed in all of these reactions, which can be completely removed by recrystallization. The radical initiators and reducing reagents show significant effects on the tandem reactions (Table 2). When Et_3B was used as the radical initiator, a trace of **3a** was detected in the presence of *n*-Bu_3SnH (entries 1 and 2, Table 2). Surprisingly, the reaction worked well giving **3a** in 41% yield even at room temperature when TTMSS (tris-(tri-methyl-silyl)-silane) was used instead of *n*-Bu_3SnH as the reducing reagent (cf. entries 1 and 3, Table 2).

Having established the optimized conditions, we next examined the synthesis of various derivatives. The results are summarized in Table 3. 2-Iodoanilines with electron-withdrawing groups and electron-donating groups proceeded efficiently producing the corresponding 3,4-dihydroquinolin-2-one in moderate yields (entries 1–7, Table 3). It is noteworthy that *N*-methyl-2-iodoaniline, **5i**, also was tolerant giving **3i** in 45% yield (entry 9, Table 3). 3-Amino-4-iodopyridine underwent the tandem reactions but in lower yield (entry 8, Table 3). Under these conditions, 2,5-diiodobenzene-1,4-diamine failed to give the tricyclic product, but 3,4-dihydro-6-iodo-7-amino-(1*H*)-quinolin-2-one, **3j**, was isolated in 36% yield (entry 10, Table 3).

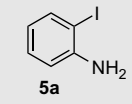
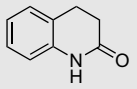
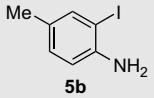
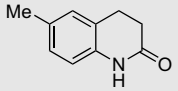
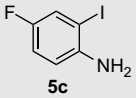
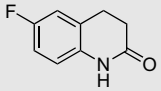
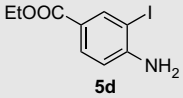
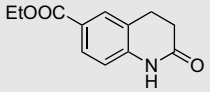
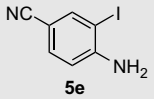
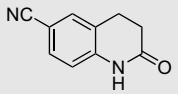
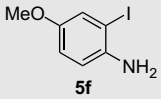
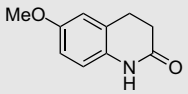
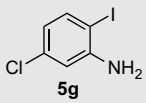
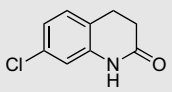
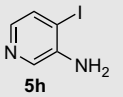
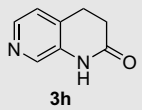
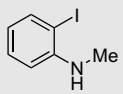
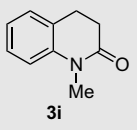
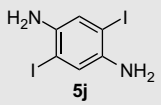
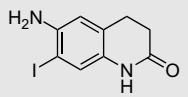
A series of substituted acrylates **6** were investigated as substrates (Table 4). Under the standard reaction conditions, certain α-substituted acrylates underwent the reaction smoothly and delivered moderate yields (entries 3–5, Table 4). It was interesting that dibenzyl itaconate, **6d**, highly selectively produced 3,4-dihydroquinolin-2-one **3k** in 54% yield. The seven-membered benzo-fused lactam was not observed in this reaction (entry 3, Table 4). However, when the terminal position of the acrylate was substituted with a methyl group (**6h**), the tandem reaction was inhibited due to steric hindrance (entry 7, Table 4).

Two separated by-products, **8** and **11**, support our suggestion of the reaction processes (Scheme 2). *n*-$Bu_3Sn^{\bullet}$ attacks the 2-iodoaniline, **5a**, to generate radical **7**, which can be trapped by *n*-Bu_3SnH leading to by-product aniline, **8**. Radical **7** undergoes an addition reaction with acrylate **6a** to produce radical **9** stabilized by an ester group. Radical **9** is trapped with *n*-Bu_3SnH to give intermediate **4a** with the regeneration of an *n*-$Bu_3Sn^{\bullet}$ radical, followed by lactamization to afford the corresponding product **3a**. A trace of by-product **11** was

Table 3
Tandem reaction of different 2-iodoanilines **5** and ethyl acrylate **6a** involving radical and ionic processes[a]



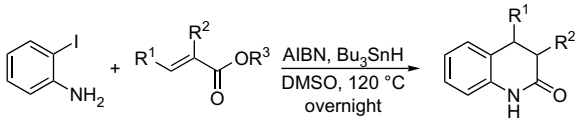
5 6a 3

Entry	Substrate **5**	Product **3**	Yield[b] (%)
1	 **5a**	 **3a**	71
2	 **5b**	 **3b**	63
3	 **5c**	 **3c**	52
4	 **5d**	 **3d**	58
5	 **5e**	 **3e**	49
6	 **5f**	 **3f**	60
7	 **5g**	 **3g**	46
8[c]	 **5h**	 **3h**	17
9[d]	 **5i**	 **3i**	45
10[e]	 **5j**	 **3j**	36

[a] Compound **5** (0.5 mmol), **6a** (2.0 mmol), AIBN (0.2 mmol), *n*-Bu_3SnH (0.75 mmol), and solvent (2 mL), reacted under air.
[b] Isolated yield. With these yields, there were few oligomers of **6a**, which can be further purified by recrystallization.
[c] This reaction mixture was stirred for 24 h.
[d] This reaction mixture was stirred for 36 h.
[e] Compound **6a** (4.0 mmol), AIBN (0.4 mmol), and *n*-Bu_3SnH (1.5 mmol) were used.

observed,[14c] which suggests that radical **9** is one of the intermediates in the tandem reaction. In this tandem reaction, the radical 1,4-addition is faster than acylamidation between **6** and **7**, hence, 5-*exo* product was not formed, even when **5i** (entry 9, Table 3) was used as the substrate.[11,12]

Table 4
Tandem reaction of 2-iodoaniline **5a** and different acrylates **6**[a]



5a 6 3

Entry	R_1	R_2	R_3	**6**	Yield[b] of **3** (%)
1	H	H	Ph	**6b**	38 (**3a**)
2	H	H	Bn	**6c**	64 (**3a**)
3	H	CH_2COOBn	Bn	**6d**	54 (**3k**)
4	H	Me	Me	**6e**	75 (**3l**)
5	H	Bn	Et	**6f**	44 (**3m**)
6	H	Ph	Et	**6g**	26 (**3n**)
7	Me	H	Et	**6h**	Trace

[a] Compound **5a** (0.5 mmol), **6** (2.0 mmol), AIBN (0.2 mmol), *n*-Bu_3SnH (0.75 mmol), and solvent (2 mL), reacted under air.
[b] Isolated yield. With these yields, there were few oligomers of **6**, which can be further purified by recrystallization.

3. Conclusion

We have described an efficient collaboration between radical and ionic processes. This method provides an avenue in which readily available substituted 2-iodoanilines and various acrylates can be used for the easy assembly of substituted 3,4-dihydroquinolin-2-ones under neutral reaction conditions. The magical efficacy of the tandem reaction combining radical and ionic processes would make it a bright prospect in organic synthesis as an attractive synthetic strategy. Further studies on the scope and synthetic applications are ongoing in our laboratory.

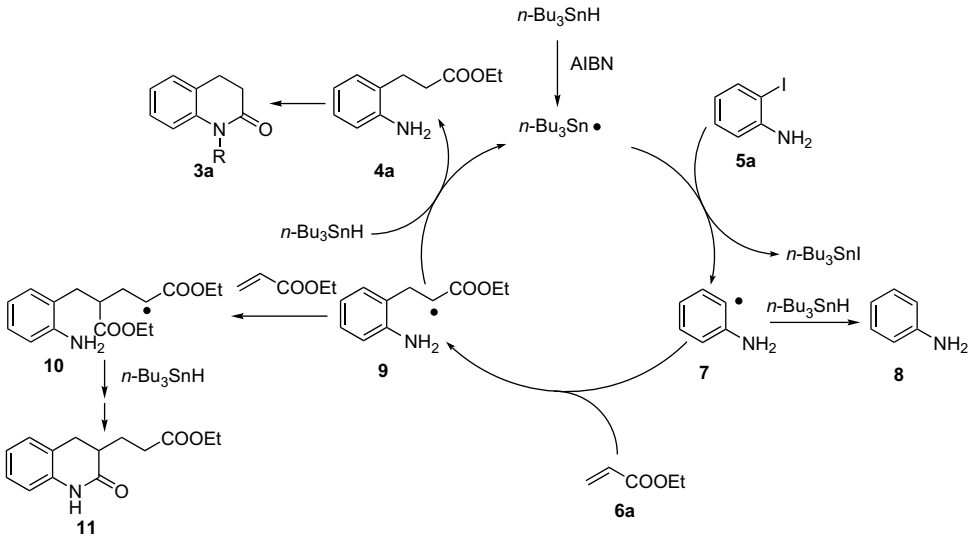
4. Experimental section

4.1. Typical procedure: 3,4-dihydro-1*H*-quinolin-2-one (3a)

To a solution of 2-iodoaniline (**5a**; 109 mg, 0.5 mmol) in DMSO (2 mL), ethyl acrylate (**6a**; 217 μL, 2 mmol), *n*-Bu_3SnH (201 μL, 0.75 mmol), and AIBN (33 mg, 0.2 mmol) were added. The reaction mixture was heated at 120 °C overnight. After cooling, the reaction mixture was diluted with water (10 mL). The aqueous phase was extracted with EtOAc (3×5 mL), the combined organic phases were washed with brine (10 mL), and dried (Na_2SO_4). After evaporation, the residue was purified by flash chromatography on silica gel (EtOAc/petroleum ether, 1:2) to afford 52 mg (71%) of **3a** (there were few oligomers of **6a**, which can be completely removed by further recrystallization) and a trace of by-product **11** (<3%). *Compound **3a***: solid, mp (ethanol): 168–170 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 9.47 (br s, 1H), 7.26–7.05 (m, 2H), 6.98 (t, *J*=7.4 Hz, 1H), 6.87 (d, *J*=7.5 Hz, 1H), 2.97 (t, *J*=7.4 Hz, 2H), 2.65 (t, *J*=7.4 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.4, 137.3, 127.8, 127.5, 123.5, 123.0, 115.6, 30.6, 25.2; IR (neat): 3188, 3087, 2977, 2910, 1681, 1593, 1492, 1434, 1385, 1198, 750, 681 cm^{-1}; MS (70 eV): *m*/*z* (%) 147.1 (M^+, 100); C_9H_9NO: calcd C 73.45, H 6.16, N 9.52; found C 73.15, H 6.10, N 9.38.

4.2. Ethyl (2-oxo-3,4-dihydro-(1*H*)-quinolin-3-yl) propionate (11)

Solid; mp (ethanol): 116–118 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.90–8.75 (m, 1H), 7.21–7.14 (m, 2H), 7.01–6.95 (m, 1H), 6.83–6.80 (m, 1H), 4.13 (q, *J*=7.1 Hz, 2H), 3.04 (dd, *J*=7.8, 6.0 Hz, 1H), 2.77 (dd, *J*=15.5, 9.5 Hz, 1H), 2.66–2.56 (m, 1H), 2.56–2.49 (m, 2H), 2.23–2.10 (m, 1H), 1.90–1.77 (m, 1H), 1.25 (t, *J*=7.1 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.4, 173.2, 136.8, 128.1, 127.5, 123.0, 115.1, 60.4, 39.2, 31.9, 31.0, 25.0, 14.2; IR (neat): 3439, 3058, 2921, 2854, 1795, 1686, 1107,



Scheme 2. The proposed processes for the tandem reaction between **5a** and **6a**.

965, 759, 694 cm^{-1}; MS (70 eV): *m*/*z* (%) 247.4 (M^+, 2), 146.2 (100); $C_{14}H_{17}NO_3$: calcd C 68.00, H 6.93, N 5.66; found C 67.86, H 6.93, N 5.66.

4.3. 3,4-Dihydro-6-methyl-(1*H*)-quinolin-2-one (3b)

The reaction of 4-methyl-2-iodoaniline (117 mg, 0.5 mmol), **6a** (217 μL, 2 mmol), *n*-Bu_3SnH (201 μL, 0.75 mmol), and AIBN (33 mg, 0.2 mmol) in DMSO (2 mL) afforded 51 mg (63%) of **3b** as solid; mp (ethanol): 130–132 °C; ^1H NMR (300 MHz, $CDCl_3$) δ 8.95–8.75 (br d, 1H), 6.97 (s, 2H), 6.72 (d, *J*=8.1 Hz, 1H), 2.93 (t, *J*=7.4 Hz, 2H), 2.62 (t, *J*=7.4 Hz, 2H), 2.29 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.0, 134.8, 132.5, 128.5, 127.9, 123.5, 115.3, 30.8, 25.3, 20.7; IR (neat): 3194, 3073, 2935, 1681, 1638, 1506, 1378, 1205, 815 cm^{-1}; MS (70 eV): *m*/*z* (%) 161.1 (M^+, 83), 132.1 (100); $C_{10}H_{11}NO$: calcd C 74.51, H 6.88, N 8.69; found C 74.31, H 6.67, N 8.57.

4.4. 3,4-Dihydro-6-fluoro-(1*H*)-quinolin-2-one (3c)

The reaction of 4-fluoro-2-iodoaniline (119 mg, 0.5 mmol), **6a** (217 μL, 2 mmol), *n*-Bu_3SnH (201 μL, 0.75 mmol), and AIBN (33 mg, 0.2 mmol) in DMSO (2 mL) afforded 43 mg (52%) of **3b** as solid; mp (ethanol): 180–182 °C; ^1H NMR (300 MHz, $CDCl_3$) δ 9.45 (br s, 1H), 6.95–6.78 (m, 3H), 2.96 (t, *J*=7.5 Hz, 2H), 2.63 (t, *J*=7.5 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.0, 158.6 (d, *J*=240.4 Hz), 133.4, 125.4 (d, *J*=8.0 Hz), 116.5 (d, *J*=8.0 Hz), 114.8 (d, *J*=22.8 Hz), 114.0 (d, *J*=22.9 Hz), 30.2, 25.4; IR (neat): 3204, 3061, 2983, 2910, 1675, 1500, 1422, 1383, 1230, 1196, 868 cm^{-1}; MS (70 eV): *m*/*z* (%) 165.1 (M^+, 76), 136.0 (100); C_9H_8FNO: calcd C 65.45, H 4.88, N 8.48; found C 65.70, H 5.00, N 8.47.

4.5. Dihydro-6-ethoxycarbonyl-(1*H*)-quinoline-2-one (3d)

The reaction of 4-ethoxylcarbonyl-2-iodoaniline (146 mg, 0.5 mmol), **6a** (217 μL, 2 mmol), *n*-Bu_3SnH (201 μL, 0.75 mmol), and AIBN (33 mg, 0.2 mmol) in DMSO (2 mL) afforded 64 mg (58%) of **3d** as solid; mp (ethanol): 180–182 °C; ^1H NMR (300 MHz, $CDCl_3$) δ 9.76 (br s, 1H), 7.88 (d, *J*=8.7 Hz, 1H), 7.87 (s, 1H), 6.91 (d, *J*=8.7 Hz, 1H), 4.37 (q, *J*=7.2 Hz, 2H), 3.03 (t, *J*=7.5 Hz, 2H), 2.70 (t, *J*=7.5 Hz, 2H), 1.39 (t, *J*=7.2 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.5, 166.1, 141.2, 129.4, 125.1, 123.2, 115.2, 60.8, 30.4, 25.0, 14.3; IR (neat): 3434, 2974, 2906, 1710, 1680, 1601, 1509, 1369, 1289, 1251, 1187, 767 cm^{-1}; MS (70 eV): *m*/*z* (%) 219.3 (M^+, 68), 174.3 (100); $C_{12}H_{13}NO_3$: calcd C 65.74, H 5.98, N 6.39; found C 65.52, H 6.08, N 6.26.

4.6. 3,4-Dihydro-6-cyano-(1*H*)-quinolin-2-one (3e)

The reaction of 4-cyano-2-iodoaniline (122 mg, 0.5 mmol), **6a** (217 μL, 2 mmol), *n*-Bu_3SnH (201 μL, 0.75 mmol), and AIBN (33 mg, 0.2 mmol) in DMSO (2 mL) afforded 42 mg (49%) of **3e** as solid (After evaporation, a mixture of crystals and liquid was obtained. The crystals were collected by filtration and washed twice with EtOAc (2×4 mL). The filtrate was evaporated and purified by flash chromatography on silica gel to afford a solid, combine the filtration residue with this solid; mp (acetone): 276–278 °C; ^1H NMR (300 MHz, DMSO-d_6) δ 10.51 (br s, 1H), 7.64–7.57 (m, 2H), 6.96 (d, *J*=8.1 Hz, 1H), 2.91 (d, *J*=7.5 Hz, 2H), 2.49 (t, *J*=7.5 Hz, 2H); ^{13}C NMR (75 MHz, DMSO-d_6) δ 170.4, 142.7, 131.7, 131.6, 124.8, 119.3, 115.6, 103.7, 29.7, 24.2; IR (neat): 3451, 3193, 3057, 2959, 2227, 1681, 1611, 1596, 1503, 1372, 1204, 829 cm^{-1}; MS (70 eV): *m*/*z* (%) 172.1 (M^+, 89), 143.0 (100); $C_{10}H_8N_2O$: calcd C 69.76, H 4.68, N 16.27; found C 69.52, H 4.67, N 16.01.

4.7. 3,4-Dihydro-6-methoxy-(1*H*)-quinolin-2-one (3f)

The reaction of ethyl 4-methoxy-2-iodoaniline (125 mg, 0.5 mmol), **6a** (217 μL, 2 mmol), *n*-Bu_3SnH (201 μL, 0.75 mmol), and AIBN (33 mg, 0.2 mmol) in DMSO (2 mL) afforded 53 mg (60%) of **3f** as solid; mp (ethanol): 146–148 °C; ^1H NMR (300 MHz, $CDCl_3$) δ 9.31 (br s, 1H), 6.87–6.50 (m, 3H), 3.78 (s, 3H), 2.94 (t, *J*=7.4 Hz, 2H), 2.62 (t, *J*=7.4 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.9, 155.5, 130.8, 124.9, 116.3, 113.7, 112.3, 55.5, 30.6, 25.6; IR (neat): 3439, 3205, 2944, 2908, 1683, 1504, 1428, 1382, 1245, 1149, 1126, 1035, 805 cm^{-1}; MS (70 eV): *m*/*z* (%) 177.2 (M^+, 100); $C_{10}H_{11}NO_2$: calcd C 67.78, H 6.26, N 7.90; found C 67.66, H 6.33, N 7.80.

4.8. 3,4-Dihydro-7-chloro-(1*H*)-quinolin-2-one (3g)

The reaction of 5-chloro-2-iodoaniline (127 mg, 0.5 mmol), **6a** (217 μL, 2 mmol), *n*-Bu_3SnH (201 μL, 0.75 mmol), and AIBN (33 mg, 0.2 mmol) in DMSO (2 mL) afforded 42 mg (46%) of **3g** as solid; mp (ethanol): 194–196 °C; ^1H NMR (300 MHz, $CDCl_3$) δ 9.12 (br s, 1H), 7.08 (d, *J*=8.0 Hz, 1H), 6.96 (dd, *J*=8.0, 2.2 Hz, 1H), 6.85 (d, *J*=2.2 Hz, 1H), 2.94 (t, *J*=7.6 Hz, 2H), 2.65 (t, *J*=7.6 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.0, 138.4, 133.0, 128.9, 122.9, 122.0, 115.5, 30.5, 24.8; IR

(neat): 3197, 3089, 2966, 2903, 1687, 1610, 1590, 1489, 1398, 1373, 1196, 1088, 816 cm^{-1}; MS (70 eV): *m*/*z* (%) 181.1 (M^+, ^{35}Cl, 100), 183.2 (M^+, ^{37}Cl, 30); C_9H_8ClNO: calcd C 59.52, H 4.44, N 7.71; found C 59.50, H 4.69, N 7.54.

4.9. 3,4-Dihydro-(1*H*)-1,7-naphthyridin-2-one (3h)

The reaction of 3-amino-4-iodopyridine (110 mg, 0.5 mmol), **6a** (217 μL, 2 mmol), *n*-Bu_3SnH (201 μL, 0.75 mmol), and AIBN (33 mg, 0.2 mmol) in DMSO (2 mL) was heated for 24 h to afford 17 mg (23%) of **3h** as solid; mp (ethyl acetate): 194–196 °C; ^1H NMR (300 MHz, $CDCl_3$) δ 9.48 (br s, 1H), 8.26 (d, *J*=4.6 Hz, 1H), 8.23 (s, 1H), 7.12 (d, *J*=4.6 Hz, 1H), 3.01 (t, *J*=7.6 Hz, 2H), 2.69 (t, *J*=7.6 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.5, 144.5, 136.7, 134.6, 132.0, 122.5, 29.8, 24.7; IR (neat): 3190, 3091, 2963, 2885, 1700, 1645, 1611, 1580, 1491, 1404, 1381, 1338, 1272, 1199, 912, 827 cm^{-1}; MS (70 eV): *m*/*z* (%) 148.3 (M^+, 100); $C_8H_8N_2O$: calcd C64.85, H 5.44, N 18.91; found C 64.74, H 5.31, N 18.70.

4.10. *N*-Methyl-3,4-dihydroquinolin-2-one (3i[16])

The reaction mixture of 2-iodo-*N*-methylaniline (117 mg, 0.5 mmol), **6a** (217 μL, 2 mmol), *n*-Bu_3SnH (201 μL, 0.75 mmol), and AIBN (33 mg, 0.2 mmol) in DMSO (2 mL) was heated for 36 h to afford 36 mg (45%) of **3i** as liquid; ^1H NMR (300 MHz, $CDCl_3$) δ 7.29–7.82 (m, 1H), 7.17 (d, *J*=7.5 Hz, 1H), 7.05–6.96 (m, 2H), 3.36 (s, 3H), 2.91 (t, *J*=7.3 Hz, 2H), 2.65 (t, *J*=7.3 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.5, 140.6, 127.7, 127.4, 126.2, 122.7, 114.6, 31.7, 29.5, 25.4; IR (neat): 2923, 1676, 1602, 1472, 1367, 1131, 756 cm^{-1}; MS (70 eV): *m*/*z* (%) 161.3 (M^+, 57), 118.2 (100).

4.11. 3,4-Dihydro-6-amino-7-iodo-(1*H*)-quinolin-2-one (3j)

The reaction of 2,5-diiodobenzene-1,4-diamine (180 mg, 0.5 mmol), **6a** (434 μL, 4 mmol), *n*-Bu_3SnH (404 μL, 1.5 mmol), and AIBN (66 mg, 0.4 mmol) in DMSO (2 mL) afforded 52 mg (36%) of **3j** as solid; mp (ethanol): 196–198 °C; ^1H NMR (300 MHz, DMSO-d_6) δ 9.74 (br s, 1H), 7.04 (s, 1H), 6.58 (s, 1H), 4.84 (br s, 2H), 2.69 (t, *J*=7.4 Hz, 2H), 2.33 (t, *J*=7.4 Hz, 2H); ^{13}C NMR (75 MHz, DMSO-d_6) δ 169.4, 143.5, 129.9, 125.4, 124.0, 113.6, 80.2, 30.4, 24.9; IR (neat): 3405, 3321, 3179, 3036, 2939, 1655, 1497, 1399, 1261, 1195, 872, 678 cm^{-1}; MS (70 eV): *m*/*z* (%) 288.1 (M^+, 100); $C_9H_9IN_2O$: calcd C 37.52, H 3.15, N 9.72; found C 37.62, H 3.29, N 9.61.

4.12. Benzyl (2-oxo-3,4-dihydro-(1*H*)-quinolin-3-yl) acetate (3k)

The reaction of 2-iodoaniline (109 mg, 0.5 mmol), **6d** (620 mg, 2 mmol), *n*-Bu_3SnH (201 μL, 0.75 mmol), and AIBN (33 mg, 0.2 mmol) in DMSO (2 mL) afforded 79 mg (54%) of **3k** as solid; mp (ethanol): 146–148 °C; ^1H NMR (300 MHz, $CDCl_3$) δ 9.15 (br s, 1H), 7.40–7.20 (m, 5H), 7.20–7.09 (m, 2H), 6.98 (d, *J*=7.5 Hz, 1H), 6.80 (d, *J*=7.8 Hz, 1H), 5.23–5.12 (m, 2H), 3.16–2.78 (m, 4H), 2.54(dd, *J*=18, 9 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.5, 171.8, 137.0, 135.8, 128.5, 128.1, 127.9, 127.6, 123.1, 123.0, 115.3, 66.5, 36.7, 34.4, 31.0; IR (neat): 3198, 3063, 2923, 1726, 1669, 1595, 1492, 1383, 1351, 1278, 1187, 1174, 1158, 742 cm^{-1}; MS (70 eV): *m*/*z* (%) 295.3 (M^+, 2), 146.3 (100); $C_{18}H_{17}NO_3$: calcd C 73.20, H 5.80, N 4.74; found C 73.31, H 5.76, N 4.66.

4.13. 3,4-Dihydro-3-methyl-(1*H*)-quinolin-2-one (3l)

The reaction of 2-iodoaniline (109 mg, 0.5 mmol), **6e** (214 μL, 2 mmol), *n*-Bu_3SnH (201 μL, 0.75 mmol), and AIBN (33 mg, 0.2 mmol) in DMSO (2 mL) afforded 60 mg (75%) of **3l** as solid; mp (ethanol): 134–136 °C; ^1H NMR (300 MHz, $CDCl_3$) δ 9.03 (br s, 1H), 7.20–7.13 (m, 2H), 6.98 (t, *J*=7.2 Hz, H), 6.84 (d, *J*=7.8 Hz, 1H), 3.00 (dd, *J*=14.1, 4.5 Hz, 1H), 2.79–2.62 (m, 2H), 1.29 (d, *J*=6.6 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.8, 137.2, 128.0, 127.4, 123.5, 122.8, 115.2, 34.9, 33.3, 15.3; IR (neat): 3199, 3071, 2987, 2926, 1667, 1593, 1491, 1391, 1285, 761 cm^{-1}; MS (70 eV): *m*/*z* (%) 161.2 (M^+, 100); $C_{10}H_{11}NO$: calcd C 74.51, H 6.88, N 8.69; found C 74.33, H 6.86, N 8.65.

4.14. 3-Benzyl-3,4-dihydro-(1*H*)-quinolin-2-one (3m)

The reaction of 2-iodoaniline (109 mg, 0.5 mmol), **6f** (380 mg, 2 mmol), *n*-Bu_3SnH (201 μL, 0.75 mmol), and AIBN (33 mg, 0.2 mmol) in DMSO (2 mL) was heated for 17 h to afford 52 mg (44%) of **3m** as solid; mp (ethanol): 114–116 °C; ^1H NMR (300 MHz, $CDCl_3$) δ 8.86–8.76 (br d, 1H), 7.35–7.16 (m, 6H), 7.80 (d, *J*=7.2 Hz, 1H), 6.98 (t, *J*=7.4 Hz, 1H), 6.84 (d, *J*=7.8 Hz, 1H), 3.34 (dd, *J*=13.6, 3.7 Hz, 1H), 2.89–2.78 (m, 2H), 2.70–2.58 (m, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.4, 138.9, 136.9, 129.2, 128.5, 128.4, 127.5, 126.4, 123.1, 123.0, 115.1, 41.8, 35.3, 29.4; IR (neat): 3210, 3106, 3063, 3025, 2997, 2941, 1676, 1596, 1494, 1391, 1294, 752, 697 cm^{-1}; MS (70 eV): *m*/*z* (%) 237.3 (M^+, 53), 146.2 (100); $C_{16}H_{15}NO$: calcd C 80.98, H 6.37, N 5.90; found C 80.80, H 6.15, N 5.96.

4.15. 3-Phenyl-3,4-dihydro-(1*H*)-quinolin-2-one (3n)

The reaction of 2-iodoaniline (109 mg, 0.5 mmol), **6g** (352 mg, 2 mmol), *n*-Bu_3SnH (201 μL, 0.75 mmol), and AIBN (33 mg, 0.2 mmol) in DMSO (2 mL) for 17 h afforded 29 mg (26%) of **3n** as solid; mp (ethanol): 174–176 °C; ^1H NMR (300 MHz, $CDCl_3$) δ 9.08 (br s, 1H), 7.32–7.14 (m, 7H), 6.99 (t, *J*=7.4 Hz, 1H), 6.81 (d, *J*=7.8 Hz, 1H), 3.88 (t, *J*=7.8 Hz, 1H), 3.30–3.00 (m, 2H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.3, 138.4, 137.0, 128.7, 128.1, 128.0, 127.6, 127.3, 123.2, 115.4, 46.5, 33.5; IR (neat) 3218, 3065, 3029, 2944, 1680, 1597, 1492, 1379, 1268, 751 cm^{-1}; MS (70 eV): *m*/*z* (%) 223.4 (M^+, 100); $C_{15}H_{13}NO$: calcd C 80.69, H 5.87, N 6.27; found C 80.40, H 5.71, N 6.15.

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Supplementary data

Experimental details and NMR spectra are available as Supplementary data. Supplementary data associated with this article can be found in the online version, at doi:10.1016/j.tet.2009.01.027.

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