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Copper(II)-Catalyzed Synthesis of Benzo[*f*]pyrido[1,2-*a*]indole-6,11-dione Derivatives via Naphthoquinone Difunctionalization Reaction

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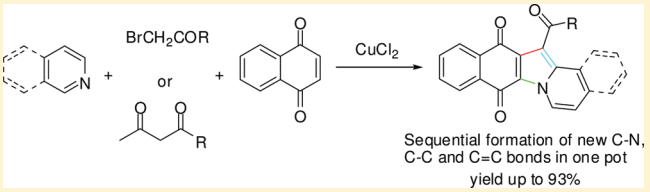
Supporting Information

ABSTRACT: Benzo[*f*]pyrido[1,2-*a*]indole-6,11-diones have been synthesized in high yields by copper(II)-catalyzed three-component reactions of acyl bromide, 1,4-naphthoquinone, and pyridine (or isoquinoline) via sp^2−C−H difunctionalization of naphthoquinone followed by intramolecular cyclization and oxidative aromatization. In an attempt to expand the reaction scope and to help clarify the reaction mechanism, 1,3-dicarbonyl compounds are used in place of acyl bromides to take part in this reaction, and the benzo[*f*]pyrido[1,2-*a*]indole-6,11-diones derivatives are also obtained in excellent yields.



As bridgehead nitrogen heterocycles, indolizines and their annulated derivatives have received much attention in recent years.[1] Annulated indolizines are found in several naturally occurring alkaloids with important biological activity.[2] These natural and synthetic annulated indolizine derivatives have found various pharmaceutical applications.[3,4] As a result, indolizines and their annulated derivatives represent the prime synthetic targets and play an increasingly important role in the development of drugs to treat cancer,[5] cardiovascular diseases,[6] and HIV infections.[7] In addition, polycyclic indolizine derivatives have been found to have interesting optical and electrochemical properties[8] and serve as interesting target compounds for the design and development of optoelectric materials such as new classes of dyes, biological markers,[9] and electroluminescent materials.[10] Thus, there is a growing interest in the synthesis of annulated indolizine derivatives.

Benzo[*f*]pyrido[1,2-*a*]indole-6,11-diones constitute an important class of annulated indolizines derivatives. Until now, three synthetic approaches have been reported. Reaction of 2,3-dichloronaphthoquinone with malonic esters and its analogs in the presence of pyridine gave these compounds.[11] Citterio used iodine oxidation of 2-alkyl-1,4-naphthoquinones in the presence of substituted pyridines to synthesize them.[12] Recently, we reported that by the reaction of dichloro-1,4-naphthoquinone with pyridinium ylides, benzo[*f*]pyrido[1,2-*a*]indole-6,11-diones can also be obtained.[13] Despite the usefulness of these methods, they suffered from a limited reaction scope and unsatisfactory product yields. This fact demands the development of new convenient and versatile synthetic methods for these compounds.

On the other hand, the oxidative functionalization of C−H bonds is one of the most challenging classes of oxidation reactions.[14] Copper(II) is a versatile oxidant, capable of promoting a wide range of oxidative coupling reactions initiated by single-electron transfer (SET) from electron-rich organic molecules.[15] Copper(II) is especially attractive as an oxidant in these reactions because, under appropriate conditions and with suitable substrates, the reactions can be carried out with catalytic Cu using ambient air or O_2 as the stoichiometric oxidant.[15a]

From our continuous research interest in the synthesis of indolizine derivatives,[13,16] we herein report an efficient synthesis of benzo[*f*]pyrido[1,2-*a*]indole-6,11-diones by copper(II)-catalyzed reactions of 1,4-naphthoquinone, acyl bromide or 1,3-dicarbonyl, and pyridine or isoquinoline. By this protocol, naphthoquinone undergoes C(sp^2)−H difunctionalization by a tertiary amine and an active methylene compound, resulting in the successive formation of a C−N and a C−C bond. Subsequent intramolecular nucleophilic cyclization and Cu^{2+} mediated oxidative aromatization furnish the benzo[*f*]pyrido[1,2-*a*]indole-6,11-dione derivatives from easily accessible starting materials in high yields.

Our investigation started with the reactions of the pyridine **1a** (3.0 mmol), acyl bromide **3a** (1.0 mmol), 1,4-naphthoquinone **4** (1.0 mmol), and hydrated copper(II) chloride (0.1 mmol) in acetonitrile (15 mL). To our delight, by heating the reaction mixture at reflux for 12 h and then chromatographic separation of the reaction mixture after evaporation of the solvent gave product **5a** in 83% yield. For the optimization of reaction conditions, different solvents, reaction temperatures, and the types and amounts of catalyst were scanned. Although various solvents such as ethanol, chloroform, toluene, and DMF could be used for the reaction, acetonitrile was found to be the best. We then optimized the reaction temperature with acetonitrile as a solvent. At room temperature, the reaction could not proceed. Increasing the reaction temperature to 60 °C gave the product in 51% yield. When the reaction was carried out at reflux temperature, the

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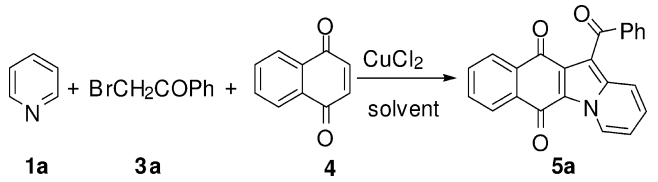
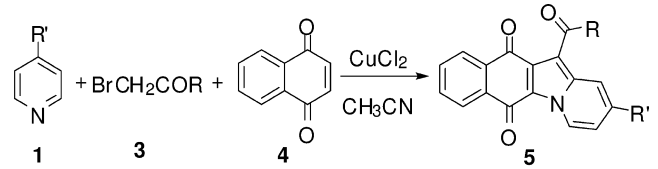
Table 1. Optimization of Reaction Condition[a]



entry	solvent	temp (°C)	catalyst	yield[b] (%)
1	ethanol	reflux	10 mol % $CuCl_2$	73
2	chloroform	reflux	10 mol % $CuCl_2$	55
3	toluene	reflux	10 mol % $CuCl_2$	57
4	DMF	reflux	10 mol % $CuCl_2$	81
5	**acetonitrile**	**reflux**	**10 mol % $CuCl_2$**	**83**
6	acetonitrile	rt	10 mol % $CuCl_2$	0
7	acetonitrile	60	10 mol % $CuCl_2$	51
8	acetonitrile	reflux	10 mol % $CuBr_2$	79
9	acetonitrile	reflux	10 mol % $Cu(OAc)_2$	73
10	acetonitrile	reflux	5 mol % $CuCl_2$	61
11	acetonitrile	reflux	15 mol % $CuCl_2$	83
12	acetonitrile	reflux	0	25
13[c]	acetonitrile	reflux	10 mol % $CuCl_2$	trace

[a]Reagents and conditions: pyridine (3.0 mmol), acyl bromide (1.0 mmol), 1,4-naphthoquinone (1.0 mmol), hydrated copper(II) chloride (0.1 mmol), reflux in solvent for 12 h. [b]Isolated yields. [c]Reaction under nitrogen atmosphere.

Table 2. Copper(II)-Catalyzed Reaction of Pyridine or 4-Substituted Pyridine 1, Acyl Bromide 3, and 1,4-Naphthoquinone 4[a]



1a R' = H
1b R' = Me
1c R' = Et

3a R = Ph
3b R = *p*-ClPh
3c R = *p*-MeOPh
3d R = 2-Naphthyl
3e R = *p*-PhPh
3f R = OEt
3g R = OMe

entry	1	3	product	yield[b] (%)
1	R′ = H	R = Ph	**5a**	83
2	R′ = H	R = *p*-ClPh	**5b**	86
3	R′ = H	R = *p*-MeOPh	**5c**	90
4	R′ = H	R = 2-naphthyl	**5d**	92
5	R′ = H	R = *p*-PhPh	**5e**	93
6	R′ = H	R = OEt	**5f**	85
7	R′ = H	R = OMe	**5g**	85
8	R′ = Me	R = Ph	**5h**	81
9	R′ = Me	R = *p*-ClPh	**5i**	87
10	R′ = Me	R = *p*-MeOPh	**5j**	91
11	R′ = Me	R = 2-naphthyl	**5k**	92
12	R′ = Me	R = *p*-PhPh	**5l**	91
13	R′ = Me	R = OEt	**5m**	84
14	R′ = Me	R = OMe	**5n**	81
15	R′ = Et	R = Ph	**5o**	78
16	R′ = Et	R = PhCl	**5p**	85
17	R′ = Et	R = *p*-MeOPh	**5q**	87
18	R′ = Et	R = *p*-PhPh	**5r**	92
19	R′ = Et	R = OEt	**5s**	84
20	R′ = Et	R = OMe	**5t**	82

[a]Reagents and conditions: pyridine (3.0 mmol), acyl bromide (1.0 mmol), naphthoquinone (1.0 mmol), and hydrated copper(II) chloride (0.1 mmol), reflux in acetonitrile for 12 h. [b]Isolated yields.

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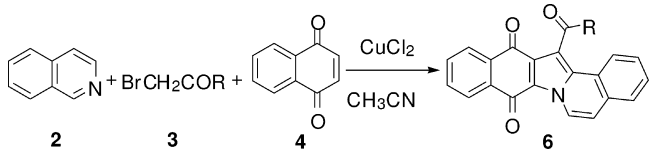
Table 3. Copper(II)-Catalyzed Reaction of Isoquinoline 2, Acyl Bromide 3, and 1,4-Naphthoquinone 4[a]

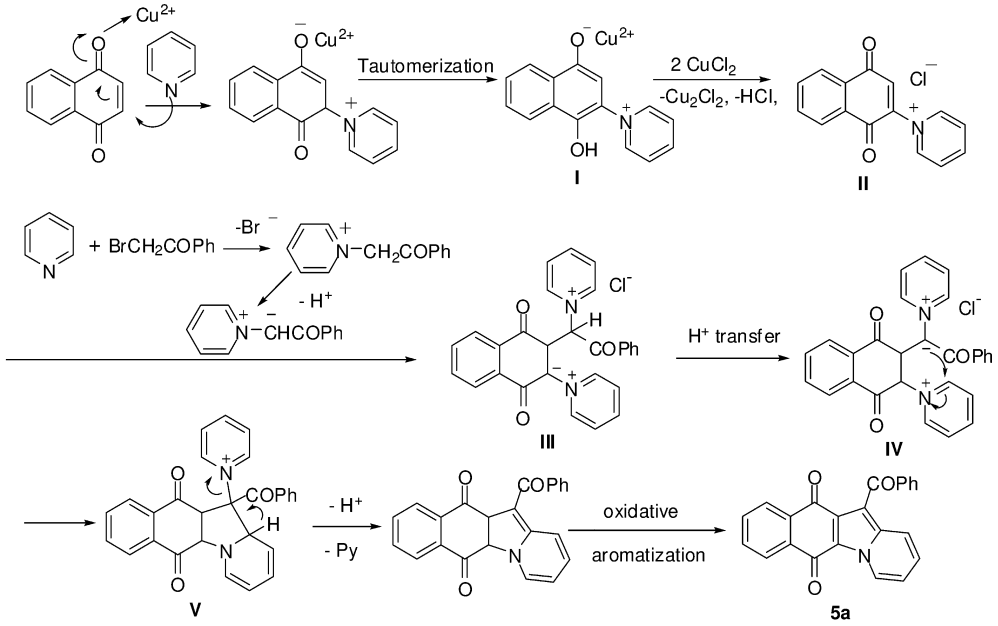


3a R = Ph
3b R = PhCl
3c R = *p*-MeOPh
3d R = OEt
3e R = OMe

entry	3	product	yield[b] (%)
1	R = Ph	**6a**	88
2	R = PhCl	**6b**	92
3	R = *p*-MeOPh	**6c**	93
4	R = OEt	**6d**	86
5	R = OMe	**6e**	85

[a]Reagents and conditions: isoquinoline (3.0 mmol), acyl bromide (1.0 mmol), naphthoquinone (1.0 mmol), and hydrated copper(II) chloride (0.1 mmol), reflux in acetonitrile for 12 h. [b]Isolated yields.

Scheme 1. Proposed Mechanism of the Formation of 5a



yield increased to 83% (Table 1). We then tested different catalysts for this reaction and found that hydrated copper(II) chloride gave better results than other catalysts such as copper(II) bromide and copper(II) acetate (entries 5, 8, and 9 in Table 1). Finally, we tried different catalyst amounts. Using 5 mol % hydrated copper(II) chloride in the reaction led to a decreased yield of 61%, whereas the use of 15 mol % copper(II) salt gave a yield equal to that by using 10 mol % copper(II) salt (entries 5 and 11 in Table 1). Therefore, heating the reactants in acetonitrile at reflux in the presence of 10 mol % copper(II) as the catalyst is chosen as the optimized reaction condition.

In order to test the versatility of this reaction, various pyridines **1** and acyl bromides **3** were subjected to reaction with naphthoquinone **4**. Under the optimized reaction condition, reactions of pyridine **1a** (3.0 mmol) with **4** (1.0 mmol) and **3b–g** (1.0 mmol), respectively, also afforded the corresponding products **5b–g** in satisfactory yields (Table 2, entries 2–7). The result demonstrated that various acyl bromides showed similar reactivity and took part in the reaction effectively to yield the final products. Meanwhile, the reactivity of 4-substituted pyridines in the reaction was also screened. 4-Methylpyridine **1b** and 4-ethylpyridine **1c** under similar conditions reacted equally well to give **5h–t** in high yields (Table 2, entries 8–20). Among these products, **5a**, **5f**, and **5g** are known compounds.[11] All new compounds are fully characterized by analytical and spectral (IR, NMR, and HRMS) data. Moreover, the structure of **5i** was also established by X-ray crystallography (Figure S1 in the Supporting Information).

To further extend the utility of this tandem reaction, we have also investigated the reactions of the isoquinoline **2** with acyl bromide **3** and 1,4-naphthoquinone **4** for the synthesis of further annulated indolizine derivatives. When naphthoquinone **4** (1.0 mmol) was heated with isoquinoline **2** (3.0 mmol), 2-

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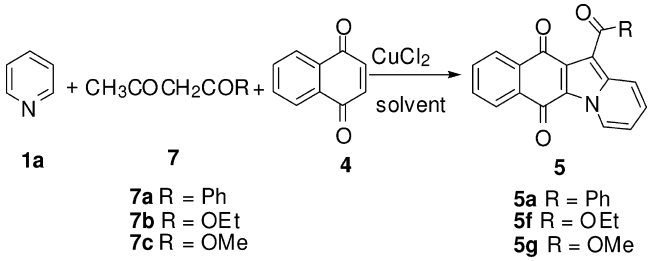
bromoacetophenone **3a** (1.0 mmol), and copper(II) chloride (0.1 mmol) in acetonitrile at reflux for 12 h, the corresponding product **6a** was obtained in 88% yield. Meanwhile, we were very satisfied to see that the reaction of isoquinoline **2** with other acyl bromides **3b−e** and naphthoquinone **4** also led to the one-pot synthesis of the corresponding annulated benzo[*f*]pyrido[1,2-*a*]indole-6,11-dione derivatives **6b−e** as pentacyclic compounds in high yields (Table 3).

The proposed mechanism for this reaction is given in Scheme 1. Nucleophilic attack of pyridine to the Cu^{2+}-complexed naphthoquinone followed by tautomerization leads to the betaine **I**, which on oxidation by Cu^{2+} results in the formation of the 1,4-naphthoquinone-2-pyridinium chloride **II**. Subsequent nucleophilic addition to **II** by the pyridinium ylide generated in situ from pyridine and ω-bromoacetophenone affords **III**, which on intramoleculr cyclization and the ensuing elimination of pyridine and oxidative aromatization furnishes the product **5a**. The copper(II) chloride catalyst is regenerated and recycled by air oxidation of the cuprous chloride. Since the process leading from **I** to **II**[17] and from **V** to **5a** can be affected by air, the reaction can be carried out in air-saturated solution without copper chloride, albeit only in low yield (Entry 12, Table 1). However, the use of $CuCl_2$ substantially improves the product yield. Although we prefer the mechanism shown in Scheme 1 by taking into consideration of the literature precedent of the formation of the naphthoquinonepyridinium salt,[17,18] a mechanistic alternative consisting of initial nucleophilic addition of pyridinium ylide to naphthoquinone and subsequent addition of pyridine can not be ruled out at this stage. To examine the proposed reaction mechanism experimentally, we prepared the 1,4-naphthoquinone-2-pyridinium intermediate **II** according to literature procrdures[17] and subjected it to reaction with phenacyl bromide (1 equiv) and pyridine (2 equiv), and this also gave product **5a** in excellent yield (88%). This fact gives support to the proposed mechanism. Meanwhile, when we carried out the reaction of naphthoquinone, phenacyl bromide, and pyridine in the absence of oxygen under a N_2 atmosphere in the presence of 10 mol % hydrated copper(II) chloride, only a trace amount of the desired product was obtained (entry 13, Table 1).

In order to shed new light to the reaction mechanism and to extend the synthetic utility of this reaction, we used 1,3-dicarbonyl compounds **7** in place of acyl bromides to participate in this reaction. As expected, by adding pyridine **1a** (3.0 mmol), benzoyl acetone **7a** (1.0 mmol), 1,4-naphthoquinone **4** (1.0 mmol), and hydrated copper(II) chloride (0.1 mmol) in acetonitrile (15 mL) and heating the reaction mixture at reflux for 12 h, we also obtained product **5a** in 82% yield (Scheme 2). By using **7b** or **7c** in this reaction, products **5f** and **5g** were obtained in 83 and 85% yields, respectively. In these reactions, an acetaldehyde was eliminated (Scheme 3).[19]

Scheme 2. Copper(II)-Catalyzed Reaction of 1,3-Dicarbonyl Compounds with Pyridine and Naphthoquinone



In conclusion, we have reported a new and efficient protocol for the synthesis of benzo[*f*]pyrido[1,2-*a*]indole-6,11-dione derivatives via copper(II)-catalyzed naphthoquinone sp^2−C−H difunctionalization reaction of naphthoquinone followed by nucleophilic cyclization and oxidative aromatization. The hydrated copper(II) chloride catalyst serves as an oxidant in the reaction sequence, leading to the efficient formation of the pyridinium intermediate **II** and the dehydrogenative aromatization, guaranteeing a clean and high-yielding synthesis of the target products.

EXPERIMENTAL SECTION

General Methods. Melting points are uncorrected. ^{1}H NMR spectra were measured on 400 MHz with $CDCl_3$ as solvent. The chemical shifts (δ) are reported in parts per million relative to the residual deuterated solvent signal, and coupling constants (J) are given in Hertz. ^{13}C NMR spectra were measured on 100 MHz with $CDCl_3$ as solvent. IR spectra were recorded using KBr pellets. HRMS (ESI) data were obtained in the electron impact (EI) (70 eV) mode.

General Procedure for the Preparation of Benzo[*f*]pyrido-[1,2-*a*]indole-6,11-diones 5. Pyridine **1** (3.0 mmol), acyl bromide **3** (1.0 mmol), 1,4-naphthaquionone **4** (1.0 mmol), and hydrated copper chloride (0.1 mmol) were mixed in 15 mL of CH_3CN and heated to reflux for 12 h. After completion of the reaction, the reaction mixture was separated by silica gel column chromatography to afford the compound **5**.

12-Benzoylbenzo[f]pyrido[1,2-a]indole-6,11-dione (***5a***). Red solid: mp 256−257 °C (lit.[11] 256−257.5 °C); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.13 (t, J = 6.8 Hz, 1H), 7.33 (t, J = 8.0 Hz, 1H), 7.38 (t, J = 7.6 Hz, 2H), 7.50−7.59 (m, 2H), 7.66 (t, J = 7.6 Hz, 1H), 7.82 (d, J = 7.6 Hz, 2H), 7.88 (d, J = 8.8 Hz, 1H), 7.94 (d, J = 7.6 Hz, 1H), 8.18 (d, J = 7.6 Hz, 1H), 9.74 (d, J = 6.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.7, 180.9, 175.0, 139.2, 139.0, 134.4, 133.8, 133.6, 133.1, 133.0, 129.3, 128.4, 128.3, 128.2, 1227.7, 127.2, 126.3, 121.3, 120.4, 117.7, 113.7; IR (KBr) 3112, 1671, 1627, 1591, 1497, 1450, 1398, 1368, 1314, 1278, 1231, 1163, 907, 812, 760 cm^{-1}. HRMS (ESI) m/z [M + Na]$^+$ calcd for $C_{23}H_{13}NO_3Na$: 374.0793. Found: 374.0825.

12-(4-Chlorobenzoyl)benzo[f]pyrido[1,2-a]indole-6,11-dione (***5b***). Red solid: mp 273−275 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.22 (t, J = 7.2 Hz, 1H), 7.40−7.44 (m, 3H), 7.66 (t, J = 7.2 Hz, 1H), 7.75 (t, J = 7.6 Hz, 1H), 7.83 (d, J = 8.4 Hz, 2H), 7.98 (d, J = 9.2 Hz, 1H), 8.02 (d, J = 7.6 Hz, 1H), 8.25 (d, J = 7.6 Hz, 1H), 9.82 (d, J = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 190.5, 181.0, 175.0, 139.4, 139.3, 137.5, 134.3, 134.0, 133.6, 133.2, 130.7, 128.8, 128.3, 128.2, 128.0, 127.2, 126.4, 121.5, 120.4, 117.9, 113.1; IR (KBr) 3134, 1663, 1648, 1629, 1590, 1529, 1499, 1466, 1400, 1385, 1319, 1234, 1151, 1089, 968, 940, 908, 756, 710 cm^{-1}. HRMS (ESI) m/z [M + Na]$^+$ calcd for $C_{23}H_{12}ClNO_3Na$: 408.0403. Found: 408.0412.

12-(4-Methoxybenzoyl)benzo[f]pyrido[1,2-a]indole-6,11-dione (***5c***). Red solid: mp 218−220 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.89 (s, 3 H), 6.94 (d, J = 8.4 Hz, 2 H), 7.18 (t, J = 6.8 Hz, 1H), 7.36 (t, J = 8.0 Hz, 1H), 7.65 (t, J = 7.2 Hz, 1H), 7.73 (t, J = 7.2 Hz, 1H), 7.87−7.93 (m, 3 H), 8.05 (d, J = 7.6 Hz, 1H), 8.25 (d, J = 7.6 Hz, 1H), 9.79 (d, J = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 190.1, 181.0, 174.8, 163.6, 138.8, 134.4, 133.8, 133.6, 133.0, 131.8, 131.6, 128.1, 128.0, 127.2, 127.1, 126.3, 121.1, 120.4, 117.6, 114.3, 113.7, 55.4; IR (KBr) 3112, 3072, 2958, 1673, 1620, 1594, 1529, 1501, 1467, 1397, 1386, 1368, 1317, 1263, 1229, 1161, 1065, 1023, 980, 908, 849, 777, 711 cm^{-1}. HRMS (ESI) m/z [M + Na]$^+$ calcd for $C_{24}H_{15}NO_4Na$: 404.0899. Found: 404.0881.

12-(2-Naphthoyl)benzo[f]pyrido[1,2-a]indole-6,11-dione (***5d***). Red solid: mp 285−287 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.24 (t, J = 6.8 Hz, 1H), 7.42 (t, J = 8.0 Hz, 1H), 7.51 (t, J = 7.2 Hz, 1H), 7.59−7.66 (m, 2H), 7.76 (t, J = 7.2 Hz, 1H), 7.86 (d, J = 8.0 Hz, 1H), 7.91−7.99 (m, 4H), 8.08 (d, J = 8.4 Hz, 1 H), 8.29 (d, J = 7.6 Hz, 1 H), 8.36 (s, 1H), 9.87 (d, J = 7.2 Hz, 1 H); ^{13}C NMR (100 MHz,

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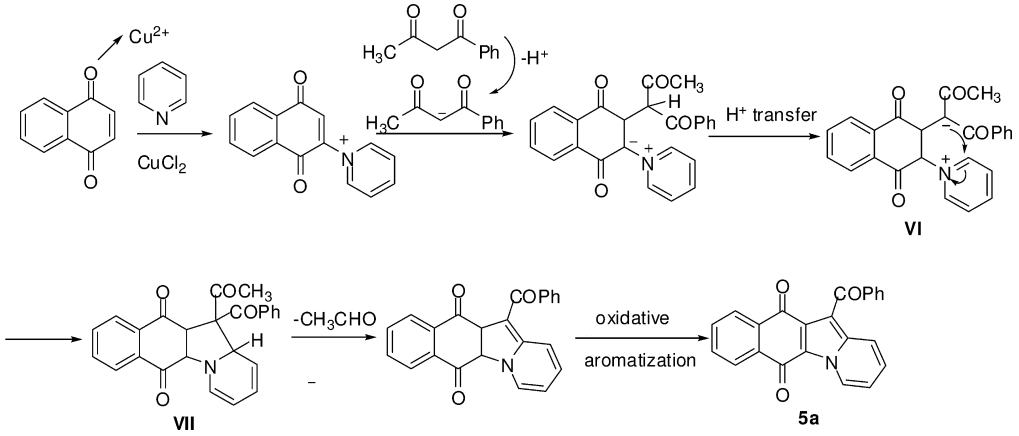
Scheme 3. Proposed Mechanism of the Copper(II)-Catalyzed Reaction of 1,3-Dicarbonyl Compound with Pyridine and Naphthoquinone



$CDCl_3$) δ 191.6, 180.9, 175.0, 139.1, 136.4, 135.7, 134.5, 133.8, 133.6, 133.1, 132.6, 131.2, 129.7, 128.5, 128.4, 128.3, 128.2, 127.9, 127.6, 127.2, 126.5, 126.4, 124.9, 121.4, 120.4, 117.7, 114.0; IR (KBr) 3058, 1665, 1633, 1590, 1572, 1544, 1493, 1472, 1427, 1397, 1285, 1231, 1191, 1161, 1117, 1022, 1003, 908, 827, 809, 754, 712 cm^{-1}. HRMS (ESI) m/z $[M + Na]^+$ calcd for $C_{27}H_{15}NO_3Na$: 424.0950. Found: 424.0930.

12-(Biphenylcarbonyl)benzo[f]pyrido[1,2-a]indole-6,11-dione (***5e***). Red solid: mp 246–248 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 7.23 (t, J = 6.8 Hz, 1H), 7.40–7.44 (m, 2H), 7.49 (t, J = 7.6 Hz, 2H), 7.66–7.71 (m, 5H), 7.77 (t, J = 7.6 Hz, 1H), 8.00 (t, J = 8.4 Hz, 3H), 8.06 (d, J = 7.6 Hz, 1H), 8.30 (d, J = 7.6 Hz, 1H), 9.85 (d, J = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.3, 181.0, 174.9, 145.6, 145.1, 140.1, 139.1, 137.6, 134.4, 133.9, 133.6, 133.1, 130.0, 128.9, 128.3, 128.2, 128.1, 127.7, 127.4, 127.2, 127.1, 126.4, 121.3, 120.4, 117.7, 113.9; IR (KBr) 3057, 1672, 1634, 1603, 1499, 1486, 1474, 1429, 1392, 1363, 1322, 1236, 1191, 1164, 1066, 971, 910, 854, 750, 711 cm^{-1}. HRMS (ESI) m/z $[M + Na]^+$ calcd for $C_{29}H_{17}NO_3Na$: 450.1106. Found: 450.1122.

12-Ethoxycarbonylbenzo[f]pyrido[1,2-a]indole-6,11-dione (***5f***). Red solid: mp 156–158 °C (lit.[11] 157–158 °C); ^1H NMR (400 MHz, $CDCl_3$) δ 1.52 (t, J = 7.2 Hz, 3H), 4.54 (q, J = 7.2 Hz, 2H), 7.19 (t, J = 6.8 Hz, 1H), 7.45 (t, J = 8.0 Hz, 1H), 7.72–7.76 (m, 2H), 8.23–8.25 (m, 2H), 8.33 (d, J = 9.2 Hz, 1H), 9.86 (d, J = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 180.2, 175.2, 163.3, 139.6, 134.2, 133.8, 133.4, 133.2, 128.7, 128.2, 127.8, 127.3, 126.0, 122.4, 120.9, 117.3, 106.1, 61.0, 14.4; IR (KBr) 3120, 2976, 2929,1695, 1673, 1638, 1626, 1590, 1510, 1485, 1474, 1229, 1208, 746, 713 cm^{-1}. HRMS (ESI) m/z $[M + Na]^+$ calcd for $C_{19}H_{13}NO_4Na$: 342.0742. Found: 342.0720.

12-Methoxycarbonylbenzo[f]pyrido[1,2-a]indole-6,11-dione (***5g***). Red solid: mp 189–191 °C (lit.[11] 190–191 °C); ^1H NMR (400 MHz, $CDCl_3$) δ 4.00 (s, 3H), 7.10 (t, J = 6.8 Hz, 1H), 7.36 (t, J = 8.0 Hz, 1H), 7.64–7.66 (m, 2H), 8.14–8.09 (m, 2H), 8.22 (d, J = 9.2 Hz, 1H), 9.71 (d, J = 6.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 179.6, 174.5, 163.2, 139.1, 133.6, 133.1, 132.9, 132.7, 127.9, 127.7, 127.4, 126.7, 125.5, 121.9, 120.4, 116.9, 104.8, 51.5; IR (KBr) 2953, 1699, 1683, 1639, 1591, 1507, 1474, 1394, 1313, 1284, 1275, 1230, 1160, 1121, 1062, 1000, 884, 755, 710 cm^{-1}. HRMS (ESI) m/z $[M + Na]^+$ calcd for $C_{18}H_{11}NO_4Na$: 328.0586. Found: 328.0563.

12-Benzoyl-2-methylbenzo[f]pyrido[1,2-a]indole-6,11-dione (***5h***). Red solid: mp 265–267 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 2.38 (s, 3H), 6.96 (dd, J = 7.2, 1.2 Hz, 1H), 7.37 (t, J = 7.6 Hz, 2H), 7.49–7.56 (m, 2H), 7.64 (td, J = 7.6, 1.2 Hz, 1H), 7.71 (s, 1H), 7.82 (dd, J = 7.6, 1.2 Hz, 2H), 7.92 (d, J = 7.6 Hz, 1H), 8.16 (d, J = 7.6 Hz, 1H), 9.61 (d, J = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 190.6, 181.1, 174.7, 139.9, 139.1, 137.6, 134.3, 133.9, 133.5, 133.0, 130.6, 128.7, 128.5, 127.6, 127.1, 126.3, 121.1, 120.5, 118.9, 111.9, 21.7; IR (KBr) 3060, 2919, 1668, 1628, 1589, 1524, 1493, 1447, 1396, 1358, 1286, 1231, 1158, 1068, 1020, 925, 809, 751, 712 cm^{-1}. HRMS (ESI) m/z $[M^+]$ calcd for $C_{24}H_{15}NO_3$: 365.1052. Found: 365.1042.

12-(4-Chlorobenzoyl)-2-methylbenzo[f]pyrido[1,2-a]indole-6,11-dione (***5i***). Red solid: mp 290–292 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 2.39 (s, 3H), 6.97 (dd, J = 6.8, 0.8 Hz, 1H), 7.33 (d, J = 8.4 Hz, 2H), 7.56 (t, J = 7.2 Hz, 1H), 7.65 (t, J = 7.2 Hz, 1H), 7.73–7.76 (m, 3 H), 7.92 (d, J = 7.6 Hz, 1H), 8.16 (d, J = 7.6 Hz, 1H), 9.61 (d, J = 6.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 190.6, 181.1, 174.6, 139.9, 139.1, 137.7, 134.3, 133.8, 133.5, 133.0, 130.6, 128.7, 127.6, 127.1, 126.3, 121.2, 120.4, 118.9, 111.9, 21.7; IR (KBr) 3066, 2918, 1663, 1646, 1627, 1589, 1572, 1523, 1489, 1439, 1396, 1356, 1286, 1234, 1212, 1174, 1088, 1063, 1012, 927, 849, 814, 777, 709 cm^{-1}. HRMS (ESI) m/z $[M + Na]^+$ calcd for $C_{24}H_{14}ClNO_3Na$: 422.0560. Found: 422.0555.

12-(4-Methoxybenzoyl)-2-methylbenzo[f]pyrido[1,2-a]indole-6,11-dione (***5j***). Red solid: mp 272–274 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 2.46 (s, 3H), 3.90 (s, 3H), 6.94 (d, J = 8.4 Hz, 2H), 7.03 (d, J = 7.2 Hz, 1H), 7.65 (t, J = 7.6 Hz, 1H), 7.74 (t, J = 7.6 Hz, 2H), 7.92 (d, J = 8.8 Hz, 2H), 8.05 (d, J = 7.6 Hz, 1H), 8.26 (d, J = 7.6 Hz, 1H), 9.69 (d, J = 6.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 190.3, 181.1, 174.4, 163.6, 139.4, 139.0, 134.6, 133.7, 132.8, 131.8, 131.7, 128.3, 127.5, 127.1, 126.2, 120.9, 120.2, 118.9, 113.7, 113.6, 113.1, 55.4, 21.6; IR (KBr) 3068, 2956, 2919, 1667, 1625, 1600, 1576, 1492, 1441, 1395, 1357, 1256, 1230, 1169, 1063, 1033, 927, 850, 791, 706 cm^{-1}. HRMS (ESI) m/z $[M + Na]^+$ calcd for $C_{25}H_{17}NO_4Na$: 418.1055. Found: 418.1044.

12-(2-Naphthoyl)-2-methylbenzo[f]pyrido[1,2-a]indole-6,11-dione (***5k***). Red solid: mp 295–297 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 2.48 (s, 3H), 7.08 (d, J = 6.8 Hz, 1H), 7.51 (t, J = 7.6 Hz, 1H), 7.58–7.64 (m, 2H), 7.74 (t, J = 7.6 Hz, 1H), 7.81 (s, 1H), 7.86 (d, J = 8.4 Hz, 1H), 7.91–7.97 (m, 3H), 8.07 (d, J = 8.4 Hz, 1H), 8.28 (d, J = 7.6 Hz, 1H), 8.36 (s, 1H), 9.74 (d, J = 6.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.9, 181.0, 174.6, 139.7, 139.5, 136.5, 135.6, 134.5, 133.7, 133.6, 132.9, 132.6, 131.0, 129.7, 128.7, 128.3, 128.2, 127.9, 127.6, 127.1, 126.5, 126.2, 125.0, 121.1, 120.3, 118.9, 112.8, 21.7; IR (KBr) 3057, 2917, 1666, 1631, 1590, 1487, 1435, 1396, 1287, 1231, 1171, 1153, 1116, 1062, 1018, 923, 786, 709 cm^{-1}. HRMS (ESI) m/z $[M + Na]^+$ calcd for $C_{28}H_{17}NO_3Na$: 438.1106. Found: 438.1118.

12-(Biphenylcarbonyl)-2-methyl-benzo[f]pyrido[1,2-a]indole-6,11-dione (***5l***). Red solid: mp 260–262 °C; ^1H NMR (400 MHz, $CDCl_3$) δ 2.49 (s, 3H), 7.07 (d, J = 7.2 Hz, 1H), 7.41 (t, J = 6.8 Hz, 1H), 7.49 (t, J = 7.2 Hz, 2H), 7.64–7.71 (m, 5H), 7.76 (t, J = 7.2 Hz, 1H), 7.81 (s, 1H), 8.00 (d, J = 8.4 Hz, 2H), 8.04 (d, J = 8.0 Hz, 1H), 8.28 (d, J = 7.6 Hz, 1H), 9.73 (d, J = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.5, 181.1, 174.6, 145.5, 140.1, 139.7, 139.5, 137.7, 134.5, 133.8, 133.6, 132.9, 129.9, 128.9, 128.6, 128.1, 127.6, 127.4, 127.1, 126.3, 121.0, 120.4, 118.9, 112.7, 21.7; IR (KBr) 3070, 2917, 1663, 1630, 1594, 1522, 1485, 1440, 1398, 1359, 1288, 1231, 1179, 1064, 1042, 1005, 927, 850, 760, 705 cm^{-1}. HRMS (ESI) m/z $[M + Na]^+$ calcd for $C_{30}H_{19}NO_3Na$: 464.1263. Found: 464.1270.

12-Ethoxycarbonyl-2-methylbenzo[f]pyrido[1,2-a]indole-6,11-dione (***5m***). Red solid: mp 190–192 °C; ^1H NMR (400 MHz,

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$CDCl_3$) δ 1.52 (t, J = 7.2 Hz, 3H), 2.50 (s, 3H), 4.53 (q, J = 7.2 Hz, 2H), 7.01 (dd, J = 7.2, 1.2 Hz, 1H), 7.70−7.75 (m, 2H), 8.10 (s, 1 H), 8.20−8.23 (m, 2H), 9.72 (d, J = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 180.4, 174.9, 163.7, 140.2, 139.6, 134.2, 133.8, 133.4, 133.0, 128.9, 127.6, 127.3, 125.9, 122.2, 120.0, 119.4, 104.8, 61.0, 21.8, 14.4; IR (KBr) 3057, 2976, 2921, 1698, 1671, 1633, 1591, 1541, 1507, 1488, 1475, 1400, 1387, 1365, 1286, 1228, 1172, 1121, 1019, 789, 712 cm^{-1}. HRMS (ESI) m/z [M + Na]$^+$ calcd for $C_{20}H_{15}NO_4Na$: 356.0899. Found: 356.0908.

12-Methoxycarbonyl-2-methylbenzo[f]pyrido[1,2-a]indole-6,11-dione (**5n**). Red solid: mp 217−218 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.51 (s, 3H), 4.06 (s, 3H), 7.03 (d, J = 6.8 Hz, 1H), 7.72 (s, 2H), 8.13 (s, 1H), 8.22 (d, J = 4.8 Hz, 2H), 9.73 (d, J = 6.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 180.6, 174.9, 164.1, 140.3, 139.8, 134.2, 133.8, 133.5, 133.1, 128.8, 127.6, 127.3, 126.0, 122.3, 120.1, 119.5, 104.2, 52.0, 21.8; IR (KBr) 2953, 1699, 1682, 1634, 1591, 1525, 1502, 1483, 1393, 1357, 1291, 1230, 1162, 1059, 1016, 841, 791, 711 cm^{-1}. HRMS (ESI) m/z [M + Na]$^+$ calcd for $C_{19}H_{13}NO_4Na$: 342.0742. Found: 342.0721.

12-Benzoyl-2-ethylbenzo[f]pyrido[1,2-a]indole-6,11-dione (**5o**). Red solid: mp 205−207 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.32 (td, J = 7.2, 0.4 Hz, 3H), 2.76 (qd, J = 7.2, 0.4 Hz, 2H), 7.09 (dd, J = 7.2, 1.2 Hz, 1H), 7.47 (t, J = 7.6 Hz, 2H), 7.61 (t, J = 7.2 Hz, 1H), 7.65 (dd, J = 7.6, 0.8 Hz, 1H), 7.74 (td, J = 7.6, 0.8 Hz, 1H), 7.81 (s, 1 H), 7.92 (d, J = 7.2 Hz, 2 H), 8.02 (d, J = 7.2 Hz, 1H), 8.26 (d, J = 7.2 Hz, 1H), 9.73 (d, J = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.9, 180.9, 174.5, 145.4, 139.9, 139.2, 134.6, 134.4, 133.7, 132.9, 132.8, 129.2, 128.6, 128.3, 127.8, 127.1, 126.2, 121.0, 119.3, 117.5, 112.7, 28.7, 14.1; IR (KBr) 3058, 2917, 1666, 1632, 1591, 1558, 1506, 1489, 1436, 1396, 1357, 1288, 1231, 1171, 1117, 1062, 1019, 922, 788, 710 cm^{-1}. HRMS (ESI) m/z [M + Na]$^+$ calcd for $C_{25}H_{17}NO_3Na$: 402.1106. Found: 402.1125.

12-(4-Chlorobenzoyl)-2-ethylbenzo[f]pyrido[1,2-a]indole-6,11-dione (**5p**). Red solid: mp 278−280 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.24 (t, J = 7.6 Hz, 3H), 2.68 (q, J = 7.6 Hz, 2H), 7.01 (d, J = 7.2 Hz, 1H), 7.34 (d, J = 8.4 Hz, 2H), 7.57 (t, J = 7.6 Hz, 1H), 7.66 (t, J = 7.6 Hz, 1H), 7.74−7.77 (m, 3 H), 7.93 (d, J = 7.6 Hz, 1H), 8.17 (d, J = 7.6 Hz, 1H), 9.64 (d, J = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 190.7, 181.1, 174.7, 145.9, 140.0, 139.1, 137.7, 134.3, 133.9, 133.5, 133.0, 130.6, 128.7, 128.5, 127.8, 127.1, 126.3, 121.1, 119.5, 117.5, 112.1, 28.8, 14.1; IR (KBr) 3067, 2966, 2920, 1667, 1630, 1585, 1527, 1485, 1391, 1356, 1283, 1230, 1170, 1085, 1061, 1033, 1010, 921, 854, 805, 713 cm^{-1}. HRMS (ESI) m/z [M + Na]$^+$ calcd for $C_{25}H_{16}ClNO_3Na$: 436.0716. Found: 436.0728.

12-(4-Methoxybenzoyl)-2-ethylbenzo[f]pyrido[1,2-a]indole-6,11-dione (**5q**). Red solid: mp 236−237 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.32 (t, J = 7.6 Hz, 3H), 2.77 (q, J = 7.6 Hz, 2H), 3.90 (s, 3H), 6.95 (d, J = 8.4 Hz, 2H), 7.07 (d, J = 7.2 Hz, 1H), 7.65 (td, J = 7.2, 1.2 Hz, 1H), 7.73 (s, 1H), 7.76 (d, J = 7.6 Hz, 1H), 7.93 (d, J = 8.4 Hz, 2H), 8.06 (d, J = 7.6 Hz, 1H), 8.27 (d, J = 8.0 Hz, 1H), 9.72 (d, J = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 190.4, 181.1, 177.5, 163.6, 152.5, 145.0, 134.6, 133.7, 132.8, 131.9, 131.7, 128.3, 127.7, 127.1, 126.2, 122.5, 120.9, 119.2, 117.5, 113.7, 113.3, 55.4, 28.7; IR (KBr) 2956, 1667, 1634, 1600, 1575, 1505, 1495, 1395, 1358, 1287, 1256, 1231, 1169, 1063, 1033, 928, 850, 792, 714 cm^{-1}. HRMS (ESI) m/z [M + Na]$^+$ calcd for $C_{26}H_{19}NO_4Na$: 432.1212. Found: 432.1203.

12-(Biphenylcarbonyl)-2-ethylbenzo[f]pyrido[1,2-a]indole-6,11-dione (**5r**). Red solid: mp 240−241 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.32 (t, J = 7.6 Hz, 3H), 2.77 (q, J = 7.6 Hz, 2H), 7.10 (d, J = 7.2 Hz, 1H), 7.41 (d, J = 7.2 Hz, 1H), 7.48 (t, J = 7.6 Hz, 2H), 7.63−7.76 (m, 6H), 7.80 (s, 1H), 8.00 (d, J = 8.0 Hz, 2H), 8.03 (d, J = 8.0 Hz, 1H), 8.27 (d, J = 7.6 Hz, 1H), 9.74 (d, J = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.5, 181.1, 174.6, 145.5, 140.1, 139.8, 137.8, 134.5, 133.8, 133.6, 132.9, 129.9, 128.9, 128.6, 128.1, 127.8, 127.4, 127.1, 127.0, 126.3, 121.2, 121.0, 119.4, 117.5, 112.9, 28.8, 14.1; IR (KBr) 2960, 2924, 1665, 1628, 1601, 1523, 1491, 1395, 1359, 1287, 1232, 1174, 1063, 1006, 922, 852, 811, 757 cm^{-1}. HRMS (ESI) m/z [M + Na]$^+$ calcd for $C_{31}H_{21}NO_3Na$: 478.1419. Found: 478.1423.

12-Ethoxycarbonyl-2-ethylbenzo[f]pyrido[1,2-a]indole-6,11-dione (**5s**). Red solid: mp 142−143 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.37 (t, J = 7.2 Hz, 3H), 1.53 (t, J = 7.2 Hz, 3H), 2.80 (q, J = 7.2 Hz, 2H), 4.53 (q, J = 7.2 Hz, 2H), 7.06 (d, J = 7.2 Hz, 1H), 7.71−7.76 (m. 2H), 8.15 (s, 1H), 8.23 (d, J = 6.4 Hz, 2H), 9.76 (d, J = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 180.5, 174.9, 163.7, 145.5, 140.3, 134.3, 133.8, 133.4, 133.0, 130.7, 129.0, 127.8, 127.3, 126.0, 119.0, 118.0, 105.0, 61.0, 28.8, 14.4, 14.1; IR (KBr) 2964, 2926, 1687, 1676, 1626, 1573, 1524, 1491, 1474, 1438, 1363, 1293, 1228, 1168, 1020, 895, 823, 795, 712 cm^{-1}. HRMS (ESI) m/z [M + Na]$^+$ calcd for $C_{21}H_{17}NO_4Na$: 370.1055. Found: 370.1054.

12-Methoxycarbonyl-2-ethylbenzo[f]pyrido[1,2-a]indole-6,11-dione (**5t**). Red solid: mp 236−237 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.35 (t, J = 7.6 Hz, 3H), 2.78 (q, J = 7.6 Hz, 2H), 4.06 (s, 3H), 7.05 (d, J = 7.2 Hz, 1H), 7.70−7.73 (m, 2H), 8.13 (s, 1H), 8.20−8.22 (m, 2H), 9.74 (d, J = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 180.5, 174.9, 164.2, 145.7, 140.4, 134.2, 133.8, 133.4, 133.1, 128.9, 127.8, 127.3, 126.0, 122.3, 119.0, 118.1, 104.4, 52.0, 28.9, 14.2; IR (KBr) 2966, 1693, 1678, 1632, 1590, 1575, 1525, 1498, 1474, 1395, 1288, 1230, 1164, 1122, 1052, 1011, 891, 821, 791, 709 cm^{-1}. HRMS (ESI) m/z [M + Na]$^+$ calcd for $C_{20}H_{15}NO_4Na$: 356.0899. Found: 356.0883.

General Procedure for the Preparation of Benz[5,6]indolo-[2,1-*a*]isoquinoline-8,13-dione 6. Isoquinoline **2** (3.0 mmol), acyl bromide **3** (1.0 mmol), 1,4-naphthaquionone **4** (1.0 mmol), and hydrated copper chloride (0.1 mmol) were mixed in 15 mL of CH_3CN and heated to reflux for 12 h. After completion of the reaction, the reaction mixture was separated by silica gel column chromatography to afford the compound **6**.

14-Benzoylbenz[5,6]indolo[2,1-a]isoquinoline-8,13-dione (**6a**). Yellow solid: mp >300 °C (lit.[11] 307.5−308.5 °C); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 (d, J = 7.6 Hz, 1H), 7.45−7.69 (m, 6H), 7.76 (t, J = 8.4 Hz, 2H), 7.94 (d, J = 8.0 Hz, 1H), 8.08 (d, J = 7.6 Hz, 3H), 8.29 (d, J = 7.6 Hz, 1 H), 9.54 (d, J = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.8, 180.7, 175.3, 137.5, 134.6, 134.0, 133.8, 133.7, 133.3, 133.2, 133.0, 129.5, 129.2, 129.1, 128.9, 127.8, 127.7, 126.9, 126.6, 124.8, 124.5, 122.6, 117.6, 116.9; IR (KBr) 3126, 3055, 1665, 1657, 1645, 1593, 1505, 1393, 1236, 1221, 957, 792, 706 cm^{-1}. HRMS (ESI) m/z [M + Na]$^+$ calcd for $C_{27}H_{15}NO_3Na$: 424.0950. Found: 424.0969.

14-(4-Chlorobenzoyl)benz[5,6]indolo[2,1-a]isoquinoline-8,13-dione (**6b**). Yellow solid: mp >300 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37 (d, J = 7.6 Hz, 1H), 7.48 (t, J = 8.4 Hz, 3H), 7.60 (t, J = 7.6 Hz, 1H), 7.69 (t, J = 7.6 Hz, 1H), 7.75−7.80 (m, 2H), 7.92 (d, J = 8.0 Hz, 1H), 8.01 (d, J = 8.4 Hz, 2H), 8.08 (d, J = 7.2 Hz, 1H), 8.29 (d, J = 7.6 Hz, 1H), 9.54 (d, J = 7.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.7, 181.0, 175.1, 136.5, 135.8, 134.6, 133.9, 133.7, 133.2, 132.7, 131.3, 129.8, 128.5, 128.4, 128.3, 128.0, 127.7, 127.3, 126.7, 126.5, 125.1, 120.5, 117.8, 114.2; IR (KBr) 3057, 1673, 1659, 1643, 1585, 1547, 1530, 1508, 1480, 1456, 1392, 1358, 1285, 1268, 1234, 1220, 1093, 989, 956, 795 cm^{-1}. HRMS (ESI) m/z [M + Na]$^+$ calcd for $C_{27}H_{14}ClNO_3Na$: 458.0560. Found: 458.0551.

14-(4-Methoxybenzoyl)benz[5,6]indolo[2,1-a]isoquinoline-8,13-dione (**6c**). Yellow solid: mp 273−275 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.88 (s, 3H), 6.96 (d, J = 8.4 Hz, 2H), 7.35 (d, J = 7.2 Hz, 1H), 7.46 (t, J = 7.6 Hz, 1H), 7.58 (t, J = 7.2 Hz, 1H), 7.68 (t, J = 7.6 Hz, 1H), 7.76 (t, J = 7.2 Hz, 2H), 7.96 (d, J = 8.4 Hz, 1H), 8.05 (d, J = 8.0 Hz, 2H), 8.09 (d, J = 7.6 Hz, 1H), 8.29 (d, J = 7.2 Hz, 1H), 9.53 (d, J = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.2, 180.8, 175.2, 164.4, 134.6, 133.7, 133.3, 133.2, 132.0, 130.7, 129.5, 129.1, 129.0, 127.6, 126.9, 126.6, 124.9, 124.6, 124.5, 117.5, 117.3, 114.2, 55.5; IR (KBr) 3063, 2919, 1656, 1644, 1598, 1575, 1526, 1504, 1478, 1457, 1409, 1393, 1358, 1307, 1257, 1238, 1219, 1164, 990, 962, 847, 807 cm^{-1}. HRMS (ESI) m/z [M + Na]$^+$ calcd for $C_{28}H_{17}NO_4Na$: 454.1055. Found: 454.1068.

14-Ethoxycarbonylbenz[5,6]indolo[2,1-a]isoquinoline-8,13-dione (**6d**). Yellow solid: mp 238−240 °C (lit.[11] 239−239.5 °C); ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.55 (t, J = 7.2 Hz, 3H), 4.69 (q, J = 7.2 Hz, 2H), 7.27 (d, J = 7.2 Hz, 1H), 7.60 (t, J = 7..6 Hz, 2H), 7.68−7.75 (m, 3H), 8.21 (dd, J = 8.0, 1.6 Hz, 1H), 8.23−8.27 (m, 2H), 9.41 (d, J = 7.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 180.5, 175.1, 166.5, 134.4, 133.6, 133.4, 133.1, 132.5, 129.4, 129.3, 128.9, 127.6, 126.8, 126.7, 126.5, 124.4, 124.3, 124.2, 122.4, 117.3, 110.2, 62.4, 14.1; IR

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(KBr) 3149, 3060, 2985, 2950, 1724, 1661, 1644, 1611, 1592, 1571, 1506, 1390, 1232, 1224, 1199, 952, 798, 704 cm^{-1}. HRMS (ESI) m/z $[M + Na]^+$ calcd for $C_{23}H_{15}NO_4Na$: 392.0899. Found: 392.0913.

*14-Methoxycarbonylbenz[5,6]indolo[2,1-a]isoquinoline-8,13-dione (**6e**).* Yellow solid: mp 245−247 °C (lit.[11] 246.5−247.5 °C); ^1H NMR (400 MHz, $CDCl_3$) δ 4.19 (s, 3H), 7.25 (d, J = 7.6 Hz, 1H), 7.57−7.59 (m, 2H), 7.70−7.72 (m, 3H), 8.17 (d, J = 7.2 Hz, 1H), 8.21 (d, J = 7.6 Hz, 2H), 9.38 (d, J = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 180.6, 175.1, 167.1, 134.3, 133.7, 133.4, 133.2, 132.7, 129.4, 129.3, 129.0, 127.6, 126.8, 126.5, 124.4, 124.3, 124.1, 122.4, 117.4, 109.6, 53.4; IR (KBr) 3068, 2989, 2945, 1735, 1661, 1645, 1593, 1535, 1506, 1486, 1456, 1411, 1391, 1286, 1224, 1164, 1111, 1082, 956, 855, 808, 797, 703 cm^{-1}. HRMS (ESI) m/z $[M + Na]^+$ calcd for $C_{22}H_{13}NO_4Na$: 378.0742. Found: 378.0728.

■ ASSOCIATED CONTENT

Supporting Information

^1H and ^{13}C NMR spectra of all compounds, X-ray crystallographic data (CIF file), and an ORTEP drawing for **5i**. This material is available free of charge via the Internet at http://pubs.acs.org.

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