JOC The Journal of Organic Chemistry

Article

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An Approach to the Synthesis of 1-Propenylnaphthols and 3-Arylnaphtho[2,1-*b*]furans

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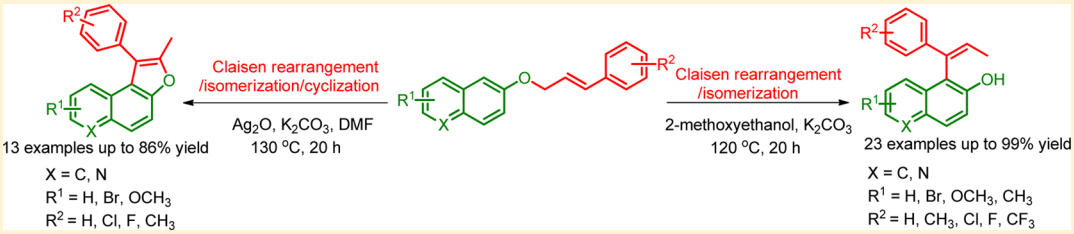
Supporting Information



ABSTRACT: A simple and efficient strategy for the synthesis of 1-propenylnaphthols from readily accessible 3-arylallylnaphthyl ethers has been developed. By using K_2CO_3 as base and 2-methoxyethanol as solvent, direct access to a wide range of 1-propenylnaphthols can be achieved in generally good yield (up to 99%) with high stereoselectivity toward the *Z* isomer. The control experiments indicate that the reaction proceeds through a sequential Claisen rearrangement/isomerization process. Furthermore, starting from the same material, the highly valuable 3-arylnaphtho[2,1-*b*]furans can be obtained in *N*,*N*-dimethylformamide and in the presence of Ag_2O as the oxidant via a one-pot sequential Claisen rearrangement/isomerization/cyclization reaction. Mechanistic studies confirm that 1-propenylnaphthols are the key intermediates to form the 3-arylnaphtho[2,1-*b*]furans. In addition, these two operationally simple and practical protocols could be scaled up to a gram level.

INTRODUCTION

The alkenylnaphthols are important structural units existing in many biologically active compounds, showing anti-inflammatory or antiviral activity (Figure 1).[1] Moreover, such compounds are very useful intermediates in organic synthesis because they can readily participate in a wide spectrum of reactions by acting on the hydroxyl group and carbon−carbon double bonds.[2] Particularly, they can serve as an important precursor for the preparation of naphtho[*b*]furans (Figure 1).[3]

The most convenient method for the preparation of alkenylnaphthols is by a Claisen rearrangement/isomerization of allyl naphthyl ethers.[4] However, the major drawback of the reported procedure is that it often requires high temperature (ranging from 180 to 240 °C) and expensive isomerization catalysts, such as Rh,[4b] Ru,[4b,e] and Ir.[4a] Moreover, the products are usually obtained as a mixture of *E* and *Z* isomers (Scheme 1, eq 1). Recently, a hydroarylation reaction of alkynes with the naphthol protocol has been developed independently by Kumar,[5] Yadav,[6a] and Fedushkin,[6b] by employing an expensive indium salt or gallium complex (Scheme 1, eq 2). In addition, an example of alkenylation of naphthol with the use of magnesium alkylidene carbenoids at −78 °C has also been reported (Scheme 1, eq 3).[7] However, the forcing reaction conditions, poor selectivity, and expensive catalysts limit the synthetic utility of these methods. Consequently, the development of an efficient and practical method for the synthesis of alkenylnaphthols is highly desirable.

On the other hand, naphtho[2,1-*b*]furan derivatives are found in a large number of natural products and synthetic pharmaceuticals.[8] A wide variety of synthetic methods have been established in the literature for their synthesis.[2f,9] The commonly used method is by cyclization of a prefunctionalized naphthol such as 2-alkenylnaphthol, usually promoted by employing either a transition-metal catalyst[9a,b,i] or toxic reagents such as I_2[9c] and hypervalent iodine (Scheme 1, eq 4).[9f] In recent years, significant progress has been made in the development of more straightforward methods by transition-metal-catalyzed coupling reactions of simple naphthol and alkynes.[2f] Very recently, Dong, Zhou, and co-workers have developed an elegant metal-free approach whereby a direct oxidative coupling of free naphthols with terminal alkynes could be achieved in the presence of $BF_3{\cdot}Et_2O$ (Scheme 1, eq 5).[9h] The majority of these methods yielded 2-arylnaphtho[2,1-*b*]furan as products. In contrast, the Claisen rearrangement of an allyl or propargyl naphthyl ether followed by intramolecular

Received: December 4, 2016
Published: February 6, 2017

DOI: 10.1021/acs.joc.6b02902
J. Org. Chem. 2017, 82, 2523−2534

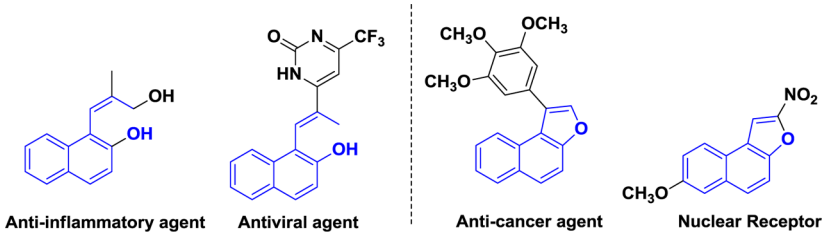
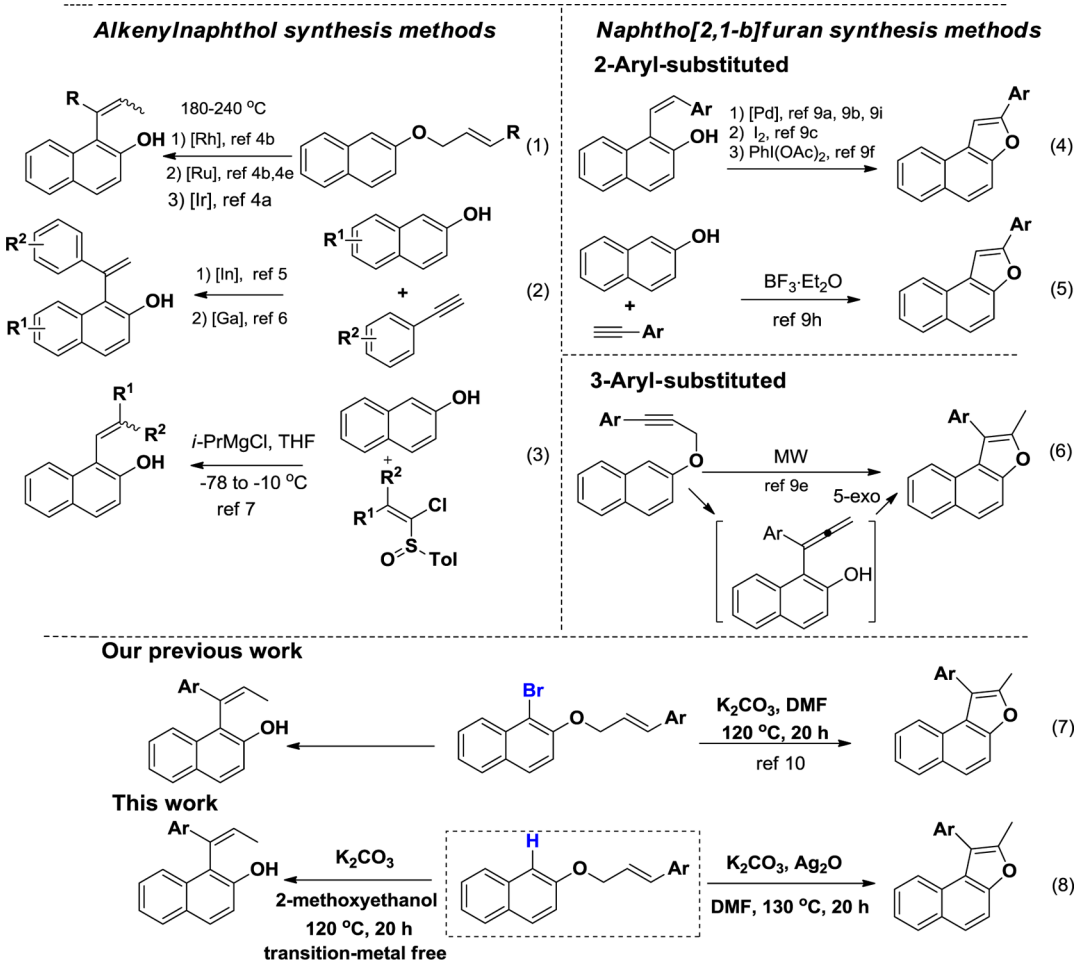


Figure 1. Structure of bioactive alkenylnaphthols and naphtho[*b*]furans.

Scheme 1. Strategies for the Construction of the Alkenylnaphthol and Naphtho[*b*]furan Skeleton



cyclization provides 3-arylnaphtho[2,1-*b*]furan (Scheme 1, eq 6).[9e] We have previously reported a transition-metal-free protocol for the synthesis of 3-arylnaphtho[2,1-*b*]furan starting from 3-arylallyl bromonaphthyl ethers by employing such a strategy.[10] Moreover, we found that the use of a suitable base could lead to formation of alkenylnaphthols as the major products (Scheme 1, eq 7). Nevertheless, the commercial availability of such special 3-arylallyl 2-bromonaphthyl ether substrates is very limited. In addition, undesired halogen-containing wastes are generated, which does not meet the requirements of green and atom-economical chemistry. Herein, we demonstrate our efforts in the development of novel protocols to synthesize both 1-propenylnaphthols and 3-arylnaphtho[2,1-*b*]furans from the simple 3-arylallyl naphthyl ether via a Claisen rearrangement and isomerization or cyclization cascade event (Scheme 1, eq 8).

RESULTS AND DISCUSSION

We initiated the investigations by using [[(2*E*)-3-phenyl-2-propen-1-yl]oxy]naphthalene (**1a**) as the model substrate, employing conditions similar to those reported by our group for the Claisen rearrangement/cyclization of bromonaphthyl 3-phenylallyl ethers.[10] Gratifyingly, the desired transformation proceeded readily under basic conditions. In addition, this reaction performed well in controlling the stereoselectivity, and almost exclusively the *Z* product **2a** was obtained, the structure of which was unambiguously assigned on the basis of single-crystal X-ray diffraction.[10] Screening of bases for the reaction identified that K_2CO_3 was the most effective base when *N*,*N*-dimethylformamide (DMF) was used as solvent (81% yield; Table 1, entry 5). $NaHCO_3$ and Na_2CO_3, were also effective but gave slightly lower yields of the desired product **2a** (62% and 69% yields; Table 1, entries 3 and 4), while weaker bases such as NaOAc and KOAc resulted in further reduced yields

DOI: 10.1021/acs.joc.6b02902
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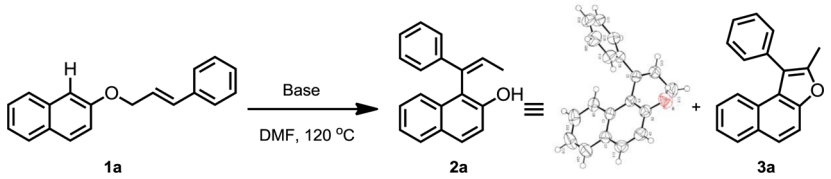
Table 1. Effect of Bases on This Reaction[a]



entry	base	yield (%)[b] 2a	3a
1	NaOAc	30	nd
2	KOAc	53	nd
3	$NaHCO_3$	62	nd
4	Na_2CO_3	69	7
5	K_2CO_3	81	6
6	K_3PO_4	48	nd
7	NaOH	56	nd
8	LiO*t*Bu	73	nd
9	NaO*t*Bu	52	nd
10	KO*t*Bu	55	nd

[a]Reaction conditions: **1a** (0.25 mmol), base (0.5 mmol), DMF (1 mL), under nitrogen, 120 °C, 20 h. [b]Yields were determined by HPLC. nd = not detected.

(30% and 53% yields; Table 1, entries 1 and 2). However, the use of stronger bases, such as K_3PO_4, NaOH, LiO*t*Bu, NaO*t*Bu, and KO*t*Bu, did not improve the yield of **2a** (48−73% yields; Table 1, entries 6−10). Remarkably, when sodium or potassium carbonate was employed as the base, a detectable amount of naphtho[2,1-*b*]furan **3a** was observed (7% and 6% yields; Table 1, entries 4 and 5).

The effect of solvent was then examined by using K_2CO_3 as the base. The results are summarized in Table 2. Evidently, the

Table 2. Effect of Solvents on This Reaction[a]

entry	K_2CO_3 (mmol)	solvent	yield (%)[b] 2a	3a
1	0.5	toluene	15	nd
2	0.5	1,4-dioxane	23	nd
3	0.5	NMP	51	nd
4	0.5	DMA	77	nd
5	0.5	DMF	81	6
6	0.5	*n*-butanol	81	nd
7	0.5	cyclohexanol	78	nd
8	0.5	2-methoxyethanol	97	3
9	0.5	1,2-propanediol	9	nd
10	0.5	ethylene glycol	31	nd
11	0.5	DME	28	nd
12[c]	0.5	2-methoxyethanol	87	13
13	0.25	2-methoxyethanol	8	nd
14	0	2-methoxyethanol	nd	nd

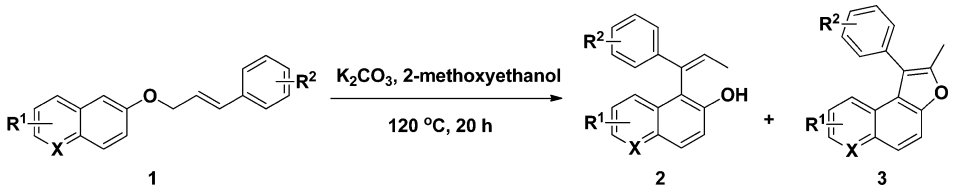
[a]Reaction conditions unless specified otherwise: **1a** (0.25 mmol), under nitrogen, solvent (1 mL), 120 °C, 20 h. [b]Yields were determined by HPLC. nd = not detected. [c]Under an oxygen atmosphere.

reaction conversion among the tested aprotic solvents followed the order toluene < 1,4-dioxane < NMP < DMA < DMF (15−81% yields; Table 2, entries 1−5), which is basically consistent with their solvent polarity trend. The reactivity increased in the polar solvent possibly owing to their relatively higher solubility toward the inorganic base. However, for the protic solvents, there seemed to be no clear correlation between solvent polarity and conversions. For example, *n*-butanol and cyclohexanol gave **2a** in comparable yields with DMF (Table 2, entries 6 and 7), but more polar protic solvents such as 1,2-propanediol and ethylene glycol led to a significant decrease (Table 2, entries 9 and 10). Notably, the optimal solvent was found to be 2-methoxyethanol, affording **2a** in 97% yield (Table 2, entry 8). However, the structurally similar solvent 1,2-dimethoxyethane (DME) only provided a poor yield (Table 2, entry 11), testifying to the positive effect of the −OH group in 2-methoxyethanol. The amount of K_2CO_3 was also briefly assessed. The best yield of **2a** was observed when 2 equiv of K_2CO_3 was employed (Table 2, entry 8 vs entry 13). No desired product **2a** was detected in the absence of base (Table 2, entry 14), showing that the presence of base is crucial for enabling this reaction. Notably, the reaction gave a significant yield of **3a** under an oxygen atmosphere (13%, Table 2, entry 12). On the basis of these optimization studies, subsequent reactions were performed in 2-methoxyethanol at 120 °C in the presence of 2 equiv of K_2CO_3.

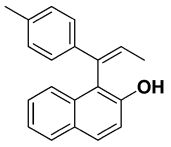
With the optimized conditions in hand, we subsequently tested the scope of this reaction. First, the effect of varying the nature of functional groups on the 3-phenyl moiety was investigated. As shown in Scheme 2, both the electron-donating methyl group (**2b**,**h**) and electron-withdrawing chloro, fluoro, and trifluoromethyl groups (**2c**−**g**,**i**,**j**) were well tolerated. The transformation proceeded quite smoothly and afforded the desired 1-propenylnaphthol derivatives in moderate to good yields (31−90%). Para-substituted phenyl derivatives bearing an electron-donating methyl group afforded the products in higher yield in comparison to those bearing electron-withdrawing groups (Scheme 2, **2b** vs **2c**−**e**). Substituents at either the meta or sterically demanding ortho position led to moderate to excellent yields of products. Interestingly, the more sterically hindered ortho-substituted aryls afforded the corresponding products in yields much higher than those with meta or para substituents (**2h**−**j** vs **2b**−**g**). Unexpectedly, for substrate **1k** bearing a 2-CF_3 group, a double-bond isomerization occurred to give vinyl ether **1k′** in 23% yield, and no

DOI: 10.1021/acs.joc.6b02902
J. Org. Chem. 2017, 82, 2523−2534

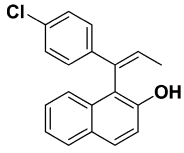
Scheme 2. Scope of the Reaction for the Synthesis of 1-Propenylnaphthols[d]



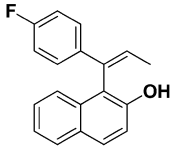
X = C, R1, R2 = H; 2a, 90%; 3a, 3%



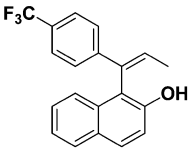
X = C, R1 = H, R2 = 4-CH3; 2b, 68%



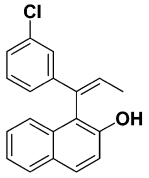
X = C, R1 = H, R2 = 4-Cl; 2c, 31%



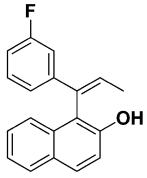
X = C, R1 = H, R2 = 4-F; 2d, 47%; 3d, 14%



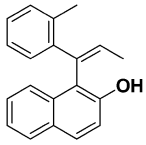
X = C, R1 = H, R2 = 4-CF3; 2e, 41%



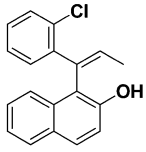
X = C, R1 = H, R2 = 3-Cl; 2f, 69%



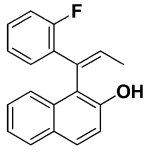
X = C, R1 = H, R2 = 3-F; 2g, 44%; 3g, 12%; 2g, 86%[b]



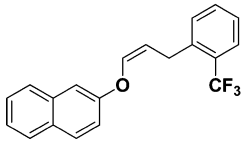
X = C, R1 = H, R2 = 2-CH3; 2h, 88%



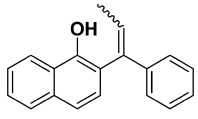
X = C, R1 = H, R2 = 2-Cl; 2i, 70%



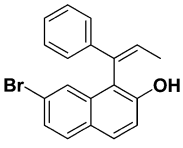
X = C, R1 = H, R2 = 2-F; 2j, 78%



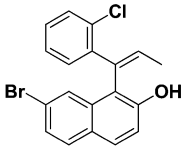
X = C, R1 = H, R2 = 2-CF3; 1k', 23%



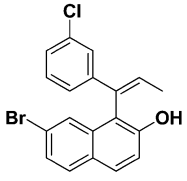
2a', 35%[a]



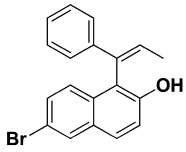
X = C, R1 = 7-Br, R2 = H; 2l, 99%



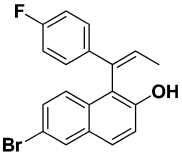
X = C, R1 = 7-Br, R2 = 2-Cl; 2m, 42%; 3m, 33%; 2m, 89%[b]



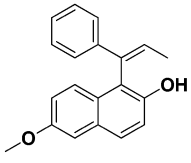
X = C, R1 = 7-Br, R2 = 3-Cl; 2n, 80%; 3n, 7%



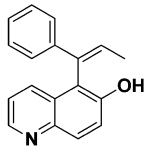
X = C, R1= 6-Br, R2 = H; 2o, 70%; 3o, 8%



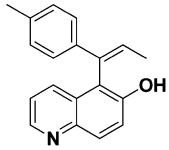
X = C, R1 = 6-Br, R2 = 4-F; 2p, 45%; 3p, 9%; 2p, 89%[b]



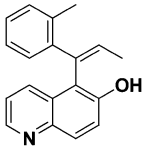
X = C, R1 = 6-OCH3, R2 = H; 2q, 96%



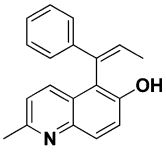
X = N, R1, R2 = H; 2r, 92%



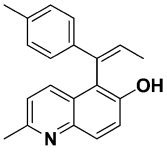
X = N, R1 = H, R2 = 4-CH3; 2s, 35%; 3s, 8%



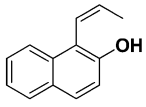
X = N, R1 = H, R2 = 2-CH3; 2t, 99%



X = N, R1 = 6-CH3, R2 = H; 2u, 92%



X = N, R1 = 6-CH3, R2 = 4-CH3; 2v, 78%; 3v, 10%



X = C, R1 = H, 2w n.r.[c]

[a] 1a′ was used.

DOI: 10.1021/acs.joc.6b02902
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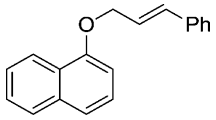
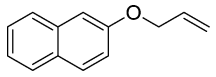
Scheme 2. continued

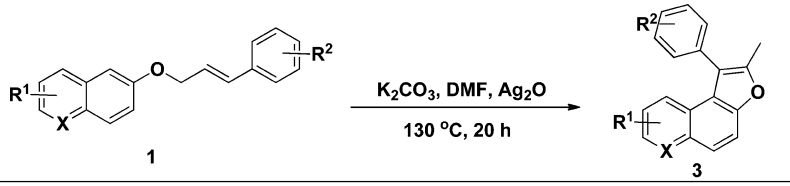


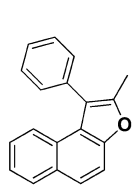
[b]In the glovebox. [c]**1w** was used.



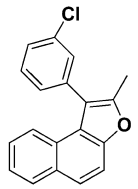
[d]Reaction conditions: **1** (0.25 mmol), K_2CO_3 (0.5 mmol), 2-methoxyethanol (1 mL), under nitrogen, 120 °C, 20 h. Yields of isolated products are given.

Scheme 3. Scope of the Reaction for the Synthesis of 3-Aryl Naphtho[*b*]furans[b]

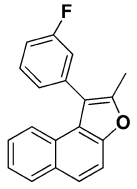




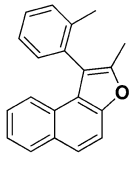
X = C, R^1, R^2 = H;
3a, 85%



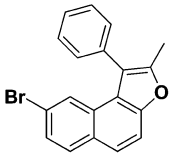
X = C, R^1 = H, R^2 = 3-Cl;
3f, 58%



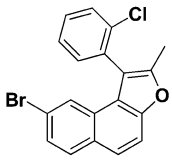
X = C, R^1 = H, R^2 = 3-F;
3g, 80%



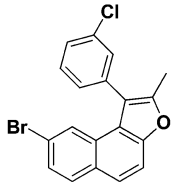
X = C, R^1 = H, R^2 = 2-CH_3;
3h, 81%



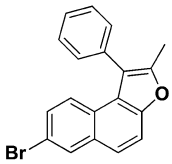
X = C, R^1 = 7-Br, R^2 = H;
3l, 84%



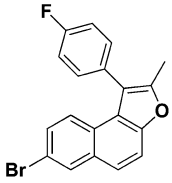
X = C, R^1 = 7-Br, R^2 = 2-Cl;
3m, 64%



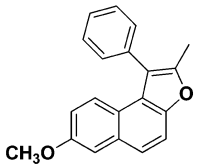
X = C, R^1 = 7-Br, R^2 = 3-Cl;
3n, 66%



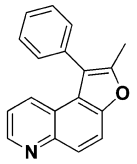
X = C, R^1 = 6-Br, R^2 = H;
3o, 44%



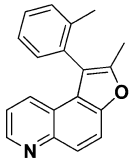
X = C, R^1 = 6-Br, R^2 = 4-F;
3p, 55%



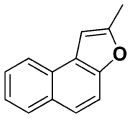
X = C, R^1 = 6-OCH_3, R^2 = H;
3q, 77%



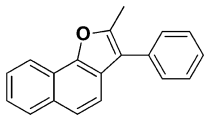
X = N, R^1, R^2 = H;
3r, 47%; 86%[a]



X = N, R^1, R^2 = 2-CH_3;
3t, 75%[a]



3w, n.r.



3a', 20%

[a]0.5 mmol of Ag_2O. [b]Reaction conditions unless specified otherwise: **1** (0.25 mmol), K_2CO_3 (0.5 mmol), DMF (1 mL), Ag_2O (0.25 mmol), under nitrogen. Yields of isolated products are given.

desired product was observed due to an intramolecular [1,3]-type H-shift.[2c,11] Notably, for the isomer 1-naphthyl ether (**1a′**) this rearrangement/isomerization procedure could also take place, giving the product **2a′** in 35% yield as a mixture of *Z* and *E* isomers (about 6.6:1).

To further evaluate the scope of the reaction, the present protocol was then extended to substrates having a naphthalene with different substitution patterns. All of the tested substrates also worked efficiently and gave moderate to excellent yields of the desired products **2l**–**v** (35–99%). Again, a good functional

DOI: 10.1021/acs.joc.6b02902
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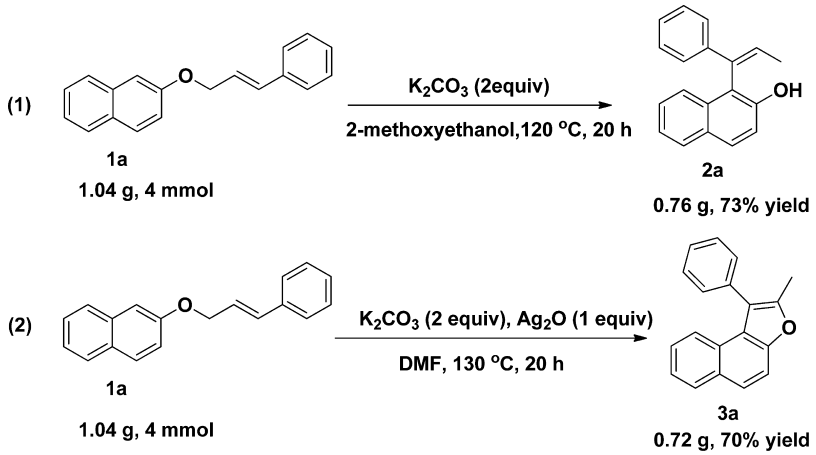
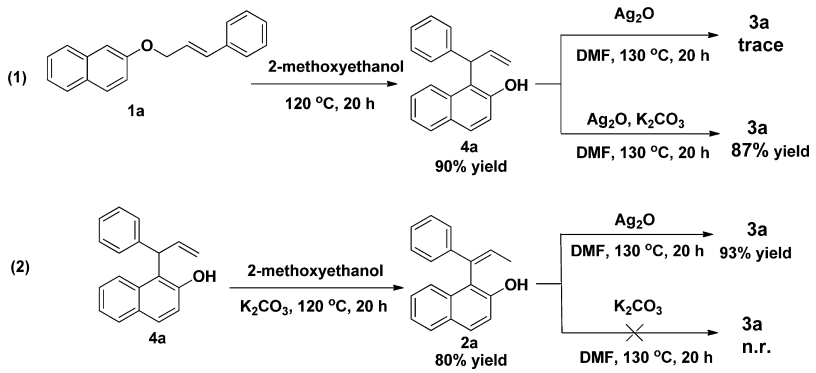
Scheme 4. Scale-up and Synthetic Application



Scheme 5. Mechanistic Investigations



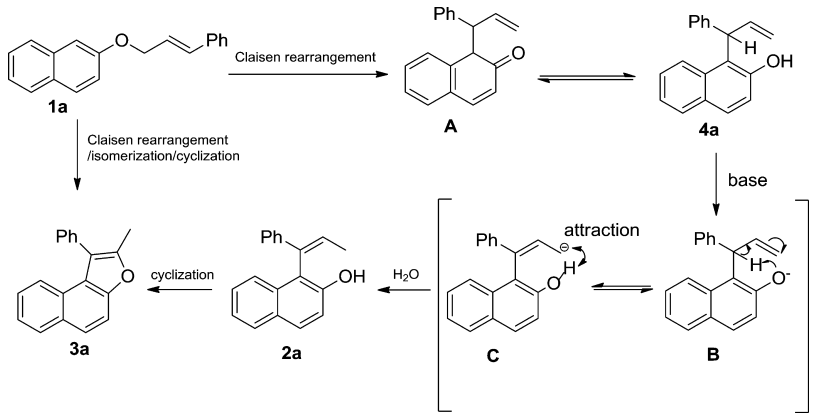
group tolerance was observed. It was noteworthy that for substrate **1l**, containing a 7-Br group at the naphthyl moiety, the corresponding naphthol **2l** was obtained in up to 99% yield. However, when a Br atom was at the C-6 position the yield decreased to 70% (**2o**). The remaining bromide functional group can serve as a versatile handle for further manipulation. However, substitution at the 2-, 3-, or 4-position of the 3-phenyl moiety with electron-withdrawing fluoro or chloro groups remarkably reduced the yields (**2m,n,p**). Importantly, substrates bearing pharmaceutically relevant quinoline rings[12] could also react, resulting in the 6-quinolinols **2r−v** with up to 99% yields. Unfortunately, the rearrangement reaction was completely suppressed when 2-(allyloxy)naphthalene **1w** was employed. It is noteworthy that the highly valuable naphtho-[*b*]furans were generated as coproducts in a number of instances (**3a,d,g,m−p,s,v**) in 7−33% yields; it is possible that the trace amount of oxygen in the solvent might facilitate the formation of **3**. As expected, the corresponding naphthol products were obviously increased for the substrates **1g,m,p** when the reaction was carried out in the glovebox (86−89%).

The observation of the coproduct naphtho[2,1-*b*]furan prompted us to develop an efficient way to prepare naphthofuran derivatives using a one-pot Claisen rearrangement/isomerization/cyclization cascade event. We were pleased to find that **1a** can be easily transformed into the corresponding naphtho[2,1-*b*]furan **3a** at 130 °C in 85% isolated yield in the presence of Ag_2O merely by switching the solvent from 2-methoxyethanol to DMF (for details on the screening conditions, see Table 1 in the Supporting Information). The substrate scope for this transformation was also investigated. As shown in Scheme 3, the reactions of 3-arylallyl naphthyl ethers, bearing various substituents such as halogen, alkyl, and alkoxyl groups, all efficiently provided the corresponding naphthofurans in moderate to good yields. It should be noted that a substrate bearing a Br atom on naphthalene exhibited reactivity similar to that observed in the naphthol system and a substrate containing Br at the C-7 position gave a higher yield in comparison to that at the C-6 position (**3l** vs **3o**). In addition, the quinolinyl allyl ethers **1r,t** could also be smoothly transformed into the quinoline[*b*]furans **3r,t** in high yields by using more Ag_2O to accelerate the reaction. The isomer 1-naphthyl ether (**1a′**) was also compatible with this novel one-pot protocol and formed the naphtho[1,2-*b*]furan **3a′**, albeit in lower yield (20%). The relatively lower reactivity of **1a′** in comparison with **1a** was in good agreement with the literture.[13] However, no desired cyclization product was detected for the substrate **1w**.

Collectively, 3-arylallyl naphthyl ethers were found to be useful substrates capable of being transformed into both alkenylnaphthols and naphtho[2,1-*b*]furans under different conditions. It is worth mentioning that no transition-metal catalyst was employed in the former reaction and the *Z* isomer product was nearly exclusively formed under the established conditions. This was far superior to the previously reported methods, which required noble-metal catalysts and gave products as a mixture of *E* and *Z* isomers.[4] In the latter case, 3-aryl-substituted naphtho[2,1-*b*]furans were effectively formed, which are otherwise difficult to obtain.[9e] We subsequently tested the scalability of these two transformations by using 4 mmol of **1a**. The corresponding products **2a** and

DOI: 10.1021/acs.joc.6b02902
J. Org. Chem. 2017, 82, 2523−2534

Scheme 6. Proposed Mechanism



naphtho[*b*]furan **3a** could be obtained in 73% and 70% isolated yields (Scheme 4, eqs 1 and 2), demonstrating that the reaction was amenable to scale-up, although with slight loss of yield.

To get insight into the origin that underlies the reactions, several experiments to elucidate the mechanism were performed (Scheme 5). It was found that **1a** failed to give any of the desired product **2a** in the absence of a base; instead, the ortho-Claisen rearrangement product **4a** was formed in 90% yield (Scheme 5, eq 1). However, with the addition of K_2CO_3 **1a** can be easily transformed into **2a** in high yield (Scheme 5, eq 2). This implies that base was absolutely essential for the double-bond isomerization process. We then treated **2a** and **4a** with Ag_2O, respectively, to investigate which one is the intermediate for the route to naphtho[2,1-*b*]furans. The desired product **3a** could be formed in 93% yield from **2a** (Scheme 5, eq 2). In contrast, only trace amounts of **3a** were obtained from **4a**. However, upon exposure to Ag_2O and K_2CO_3, **4a** could also be successfully cyclized via a dehydrogenation process to produce naphtho[2,1-*b*]furans in 87% yield (Scheme 5, eq 1). These results clearly indicated that **2a** was an important intermediate for the formation of **3a**. However, the cyclization of **2a** did not occur in the absence of Ag_2O.

On the basis of the above results and literature reports,[14−16] a reasonable mechanism proposed for the above two transformations is summarized in Scheme 6. First, allyl naphthyl ether **1a** readily undergoes a Claisen rearrangement to give the ortho benzodienone **A**, which usually enolizes into naphthol **4a**.[14] Then the **4a** transforms to phenoxide **B** in the presence of base. Subsequently, **B** undergoes a base-promoted synergistic hydrogen transfer to afford **2a**.[15] Almost exclusively the *Z* isomer is obtained due to the electrostatic attraction in **C**.[15] Finally, in the presence of Ag_2O, **2a** is easily dehydrogenated and cyclized into naphtho[2,1-*b*]furan **3a**. In order to explore the cyclization mechanism of **2a**, the introduction of TEMPO as a trapping agent resulted in a decrease in the yield of **3a** from 93% to 75%. When the amount of TEMPO was further increased, the yield of **3a** dropped to 61% (for details see Table 2 in the Supporting Information). Obviously, the reactivity was partially inhibited by TEMPO. According to the reported results,[16] if a radical reaction occurs intramolecularly or the radical reaction rate is fast, the radical trapping agent has difficulty in trapping it. The possibility for the involvement of an intramolecular radical pathway still cannot be ruled out. Therefore, we speculate that the naphthoxide ion of **2a** is oxidized by Ag_2O to form a naphthoxide radical, which subsequently undergoes the oxidative cyclization to give **3a**.

CONCLUSIONS

We have developed simple and efficient methods to construct various 1-propenylnaphthols and 3-arylnaphtho[2,1-*b*]furans from readily accessible 3-arylallylnaphthyl ethers in a practical and atom-economical way. In the former case, the reaction involving a Claisen rearrangement followed by a base-induced double-bond isomerization stereoselectively produces (*Z*)-1-aryl-1-propenylnaphthols. More importantly, such alkenylnaphthols can easily undergo oxidative cyclization to form 3-arylnaphtho[2,1-*b*]furans in the presence of Ag_2O, thus enabling us to develop a one-pot sequential Claisen rearrangement/isomerization/cyclization reaction for the synthesis of naphtho[2,1-*b*]furans. In comparison with the previous approaches, the present novel methodologies comprise the advantages of a simple reaction system, operational ease, high stereoselectivity, and broad applicability and should be an attractive choice for the synthesis of 1-propenylnaphthol and 3-arylnaphtho[2,1-*b*]furan derivatives.

EXPERIMENTAL SECTION

Synthesis of Substrates 1a,a′,l,o,q,r,u,w. The starting naphthol (10 mmol) and K_2CO_3 (30 mmol) were dissolved in acetone (30 mL). Cinnamyl bromide (8 mmol) was added by syringe, and the reaction mixture was heated to 60 °C overnight. After cooling, the mixture was diluted with ethyl acetate and water. The organic layer was washed with brine, dried with anhydrous $MgSO_4$, and concentrated under vacuum. The residue was purified by silica gel chromatography using petroleum ether/ethyl acetate (10/1) as eluent.

Synthesis of Substrates 1b−k,m,n,p,s,t,v. For the synthesis of **1b**, 4-methylcinnamic acid **S-1b** (2.5 g) and *p*-toluenesulfonic acid (1.0 g) were dissolved in EtOH (20 mL). The resulting mixture was refluxed for 3 h and then treated with petroleum ether (50 mL). The organic layer was washed with water (20 mL) and 10% Na_2CO_3 solution (20 mL), dried with anhydrous $MgSO_4$, and evaporated under reduced pressure to give compound **S-2b** (2.0 g) as a colorless liquid.

DIBAL-H (1.0 M, 25 mL) was slowly added to a stirred solution of ester **S-2b** (1.9 g, 10 mmol) in THF (35 mL) at −78 °C. The reaction mixture was stirred for 1 h at −78 °C and for another 1 h at room temperature. After completion of the reaction, the mixture was poured into cold diluted HCl (0.5 N) and extracted with ethyl acetate. The organic layer was dried over anhydrous $MgSO_4$ and evaporated under reduced pressure to give compound **S-3b** (1.5 g) as a colorless liquid.

To a stirred solution of **S-3b** (5 mmol), 2-naphthol (6 mmol), and triphenylphosphane (1.7 g, 6.5 mmol) in THF (30 mL) under a nitrogen atmosphere was added diethyl azodicarboxylate (DEAD; 1.2

DOI: 10.1021/acs.joc.6b02902
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mL) dropwise at 0 °C. The mixture was further stirred at room temperature for 20 h. The solvent was evaporated under reduced pressure on a rotary evaporator to give a viscous residue. The residue was purified by silica gel column chromatography to give **1b** (0.6 g) as a white solid.

Typical Procedure for the Synthesis of 2a. A mixture of **1a** (0.25 mmol) and K_2CO_3 (0.5 mmol) in 2-methoxyethanol (1 mL) was stirred in a dried Schlenk tube for 20 h at 120 °C under nitrogen. At the end of the reaction, water (3 mL) was added to the mixture and subsequently the mixture was extracted with ethyl acetate (3 × 5 mL). The combined organic extracts were washed with brine (3 × 5 mL), dried with anhydrous $MgSO_4$, and concentrated under vacuum. The residue was purified by silica gel chromatography using petroleum ether/ethyl acetate (20/1) as eluent to give the pure product **2a** (58 mg, 90%).

Typical Procedure for the Synthesis of 3a. A mixture of **1a** (0.25 mmol), K_2CO_3 (0.5 mmol), and Ag_2O (0.25 mmol) in DMF (1 mL) was stirred in a dried Schlenk tube for 20 h at 130 °C. At the end of the reaction, water (3 mL) was added to the mixture and subsequently the mixture was extracted with ethyl acetate (3 × 5 mL). The combined organic extracts were washed with brine (3 × 5 mL), dried with anhydrous $MgSO_4$, and concentrated under vacuum. The residue was purified by silica gel chromatography using petroleum ether as eluent to give the pure product **3a** (55 mg, 85%).

*2-[[(2E)-3-Phenyl-2-propen-1-yl]oxy]naphthalene (**1a**).* Yield: 78% (1.6 g) as a white solid. Mp: 110−111 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.81−7.71 (m, 3H), 7.48−7.41 (m, 3H), 7.38−7.31 (m, 3H), 7.29−7.25 (m, 1H), 7.24−7.19 (m, 2H), 6.80 (d, *J* = 16.0 Hz, 1H), 6.49 (dtd, *J* = 16.0, 5.8, 2.3 Hz, 1H), 4.82 (dd, *J* = 5.8, 1.3 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 155.5, 135.4, 133.5, 132.1, 128.4, 128.0, 127.6, 126.9, 126.6, 125.8, 125.6, 125.3, 123.3, 122.7, 118.0, 106.0, 67.6. HRMS (ESI): calcd for $C_{19}H_{15}O$ [M − H]$^-$ 259.1123, found 259.1104. Spectral data obtained were in agreement with those reported in the literature.[14b]

*2-[[(2E)-3-(4-Methylphenyl)-2-propen-1-yl]oxy]naphthalene (**1b**).* Yield: 85% (1.2 g) as a white solid. Mp: 133−134 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.79−7.70 (m, 3H), 7.46−7.41 (m, 1H), 7.36−7.30 (m, 3H), 7.23−7.18 (m, 2H), 7.14 (d, *J* = 7.9 Hz, 2H), 6.76 (d, *J* = 16.0 Hz, 1H), 6.44 (dt, *J* = 16.0, 5.9 Hz, 1H), 4.80 (dd, *J* = 5.9, 1.4 Hz, 2H), 2.34 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 156.6, 137.8, 134.5, 133.7, 133.2, 129.5, 129.3, 129.0, 127.7, 126.8, 126.5, 126.4, 123.7, 123.2, 119.0, 107.1, 68.8, 21.2. HRMS (ESI): calcd for $C_{20}H_{17}O$ [M − H]$^-$ 273.1279, found 273.1274.

*2-[[(2E)-3-(4-Chlorophenyl)-2-propen-1-yl]oxy]naphthalene (**1c**).* Yield: 80% (1.2 g) as a white solid. Mp: 132−134 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.81−7.72 (m, 3H), 7.47−7.42 (m, 1H), 7.39−7.28 (m, 5H), 7.23−7.18 (m, 2H), 6.75 (d, *J* = 16.0 Hz, 1H), 6.47 (dt, *J* = 16.0, 5.7 Hz, 1H), 4.81 (dd, *J* = 5.7, 1.2 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 156.5, 135.0, 134.5, 133.6, 131.8, 129.5, 129.1, 128.8, 127.8, 127.7, 126.8, 126.4, 125.0, 123.8, 118.9, 107.0, 68.4. HRMS (ESI): calcd for $C_{19}H_{14}ClO$ [M − H]$^-$ 293.0733, found 293.0719.

*2-[[(2E)-3-(4-Fluorophenyl)-2-propen-1-yl]oxy]naphthalene (**1d**).* Yield: 78% (1.1 g) as a white solid. Mp: 124−125 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.82−7.71 (m, 3H), 7.47−7.31 (m, 4H), 7.24−7.18 (m, 2H), 7.02 (t, *J* = 8.5 Hz, 2H), 6.75 (d, *J* = 16.0 Hz, 1H), 6.40 (dt, *J* = 16.0, 5.8 Hz, 1H), 4.80 (dd, *J* = 5.8, 1.3 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 162.7, 160.3, 155.5, 133.5, 131.6, 131.0, 128.5, 128.1, 127.2, 127.1, 126.7, 125.8, 125.4, 123.1, 122.7, 117.9, 114.6, 114.4, 106.1, 67.5. HRMS (ESI): calcd for $C_{19}H_{14}FO$ [M − H]$^-$ 277.1029, found 277.1013.

*2-[[(2E)-3-(4-Trifluoromethylphenyl)-2-propen-1-yl]oxy]-naphthalene (**1e**).* Yield: 83% (1.4 g) as a white solid. Mp: 170−172 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80−7.72 (m, 3H), 7.59 (d, *J* = 8.3 Hz, 2H), 7.52 (d, *J* = 8.2 Hz, 2H), 7.47−7.42 (m, 1H), 7.38−7.32 (m, 1H), 7.24−7.18 (m, 2H), 6.83 (d, *J* = 16.0 Hz, 1H), 6.58 (dt, *J* = 16.0, 5.5 Hz, 1H), 4.85 (dd, *J* = 5.4, 1.2 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 156.4, 139.9, 134.5, 131.3, 130.7, 129.9, 129.6, 129.1, 127.7, 127.1, 126.8, 126.7, 126.5, 125.7, 125.6 (2C), 125.5, 123.8, 118.9, 107.1, 68.2. HRMS (ESI): calcd for $C_{20}H_{14}F_3O$ [M − H]$^-$ 327.0997, found 327.0983.

*2-[[(2E)-3-(3-Chlorophenyl)-2-propen-1-yl]oxy]naphthalene (**1f**).* Yield: 75% (1.1 g) as a white solid. Mp: 104−106 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.81−7.70 (m, 3H), 7.48−7.40 (m, 2H), 7.38−7.32 (m, 1H), 7.31−7.27 (m, 2H), 7.24−7.18 (m, 3H), 6.74 (d, *J* = 16.0 Hz, 1H), 6.49 (dt, *J* = 16.0, 5.6 Hz, 1H), 4.82 (d, *J* = 5.5 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 156.4, 138.3, 134.6, 134.5, 131.5, 129.9, 129.6, 129.1, 127.9, 127.7, 126.8, 126.5 (2C), 125.9, 124.8, 123.8, 118.9, 107.0, 68.3. HRMS (ESI): calcd for $C_{19}H_{14}ClO$ [M − H]$^-$ 293.0733, found 293.0715.

*2-[[(2E)-3-(3-Fluorophenyl)-2-propen-1-yl]oxy]naphthalene (**1g**).* Yield: 76% (1.1 g) as a white solid. Mp: 78−80 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.81−7.71 (m, 3H), 7.48−7.41 (m, 1H), 7.38−7.31 (m, 1H), 7.31−7.26 (m, 1H), 7.23−7.17 (m, 3H), 7.13 (d, *J* = 10.0 Hz, 1H), 6.96 (td, *J* = 8.4, 1.3 Hz, 1H), 6.76 (d, *J* = 16.0 Hz, 1H), 6.49 (dt, *J* = 16.0, 5.6 Hz, 1H), 4.82 (d, *J* = 5.6 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 163.2, 160.8, 155.4, 137.7, 133.4, 130.7 (2C), 129.0, 128.9, 128.4, 128.0, 126.6, 125.7, 125.3, 124.7, 122.7, 121.4 (2C), 117.8, 113.7, 113.5, 112.0, 111.8, 105.9, 67.2. HRMS (ESI): calcd for $C_{19}H_{14}FO$ [M − H]$^-$ 277.1029, found 277.1010.

*2-[[(2E)-3-(2-Methylphenyl)-2-propen-1-yl]oxy]naphthalene (**1h**).* Yield: 62% (0.8 g) as a white solid. Mp: 94 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.81−7.71 (m, 3H), 7.52−7.48 (m, 1H), 7.47−7.42 (m, 1H), 7.37−7.32 (m, 1H), 7.23−7.20 (m, 2H), 7.19−7.14 (m, 3H), 7.02 (d, *J* = 15.8 Hz, 1H), 6.37 (dt, *J* = 15.8, 5.8 Hz, 1H), 4.84 (dd, *J* = 5.8, 1.4 Hz, 2H), 2.36 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 155.5, 134.6 (2C), 133.5, 130.1, 129.3, 128.4, 128.0, 126.8, 126.6, 125.7, 125.3, 125.1, 124.8, 124.6, 122.6, 118.0, 106.1, 67.9, 18.8. HRMS (ESI): calcd for $C_{20}H_{17}O$ [M − H]$^-$ 273.1279, found 273.1273.

*2-[[(2E)-3-(2-Chlorophenyl)-2-propen-1-yl]oxy]naphthalene (**1i**).* Yield: 64% (0.9 g) as a white solid. Mp: 84−85 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80−7.73 (m, 3H), 7.59 (dd, *J* = 7.5, 1.9 Hz, 1H), 7.47−7.42 (m, 1H), 7.39−7.31 (m, 2H), 7.25−7.17 (m, 5H), 6.47 (dt, *J* = 16.0, 5.8 Hz, 1H), 4.86 (dd, *J* = 5.8, 1.5 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 155.4, 133.6, 133.5, 132.2, 128.7, 128.5, 128.4, 128.0, 127.9, 126.6, 126.3, 126.0, 125.9, 125.8, 125.4, 122.7, 118.0, 106.0, 67.6. HRMS (ESI): calcd for $C_{19}H_{14}ClO$ [M − H]$^-$ 293.0733, found 293.0723.

*2-[[(2E)-3-(2-Fluorophenyl)-2-propen-1-yl]oxy]naphthalene (**1j**).* Yield: 70% (1.0 g) as a white solid. Mp: 97−98 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.80−7.72 (m, 3H), 7.47 (dtd, *J* = 15.1, 8.1, 1.2 Hz, 2H), 7.37−7.31 (m, 1H), 7.24−7.19 (m, 3H), 7.11 (td, *J* = 7.6, 0.9 Hz, 1H), 7.05 (ddd, *J* = 10.7, 8.2, 1.0 Hz, 1H), 6.96 (d, *J* = 16.2 Hz, 1H), 6.58 (dt, *J* = 16.2, 5.7 Hz, 1H), 4.84 (dd, *J* = 5.7, 1.4 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 161.6, 159.1, 156.5, 134.5, 129.5, 129.3, 129.2, 129.1, 127.7, 127.1, 127.0, 126.8, 126.4, 125.6 (2C), 124.3, 124.2 (2C), 124.1, 123.7, 119.0, 115.9, 115.7, 107.1, 68.7. HRMS (ESI): calcd for $C_{19}H_{14}FO$ [M − H]$^-$ 277.1029, found 277.1015.

*2-[[(2E)-3-(2-Trifluoromethylphenyl)-2-propen-1-yl]oxy]-naphthalene (**1k**).* Yield: 73% (1.2 g) as a white solid. Mp: 102−103 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.81−7.70 (m, 3H), 7.68−7.60 (m, 2H), 7.53−7.40 (m, 2H), 7.37−7.31 (m, 2H), 7.24−7.14 (m, 3H), 6.44 (dt, *J* = 15.8, 5.7 Hz, 1H), 4.84 (dd, *J* = 5.7, 1.3 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 156.5, 135.7, 134.6, 132.0, 129.6, 129.2, 129.1, 127.8, 127.7 (2C), 127.5, 126.9, 126.5, 126.0, 125.9 (2C), 125.8 (2C), 123.9, 123.1, 119.1, 107.2, 68.6. HRMS (ESI): calcd for $C_{20}H_{14}F_3O$ [M − H]$^-$ 327.0997, found 327.0977.

*1-[[(2E)-3-Phenyl-2-propen-1-yl]oxy]naphthalene (**1a′**).* Yield: 75% (1.5 g) as a white solid. Mp: 80−82 °C. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.36−8.32 (m, 1H), 7.83−7.78 (m, 1H), 7.52−7.46 (m, 2H), 7.46−7.43 (m, 3H), 7.39−7.33 (m, 3H), 7.27 (t, *J* = 7.3 Hz, 1H), 6.88 (d, *J* = 7.6 Hz, 1H), 6.83 (d, *J* = 16.0 Hz, 1H), 6.54 (dt, *J* = 16.0, 5.7 Hz, 1H), 4.89 (d, *J* = 5.6 Hz, 2H). Spectral data obtained were in agreement with those reported in the literature.[14b]

*7-Bromo-2-[[(2E)-3-phenyl-2-propen-1-yl]oxy]naphthalene (**1l**).* Yield: 74% (2 g) as a white solid. Mp: 130 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.89 (d, *J* = 1.7 Hz, 1H), 7.72 (d, *J* = 9.0 Hz, 1H), 7.63 (d, *J* = 8.7 Hz, 1H), 7.45−7.39 (m, 3H), 7.37−7.31 (m, 2H), 7.28 (d, *J* = 7.5 Hz, 1H), 7.21 (dd, *J* = 9.0, 2.4 Hz, 1H), 7.09 (d, *J* = 2.4 Hz, 1H), 6.79 (d, *J* = 16.0 Hz, 1H), 6.47 (dt, *J* = 16.0, 5.8 Hz, 1H), 4.80 (d, *J* = 5.8 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 157.3, 136.3, 135.8,

DOI: 10.1021/acs.joc.6b02902
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133.4, 129.5, 129.3, 128.8, 128.6, 128.0, 127.4, 127.0, 126.6, 124.0, 120.6, 119.4, 106.2, 68.7. HRMS (ESI): calcd for $C_{19}H_{14}BrO$ $[M - H]^-$ 337.0228, found 337.0209.

*7-Bromo-2-[[(2E)-3-(2-chlorophenyl)-2-propen-1-yl]oxy]-naphthalene (**1m**).* Yield: 63% (1.2 g) as a white solid. Mp: 98−99 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.89 (d, J = 1.8 Hz, 1H), 7.72 (d, J = 9.0 Hz, 1H), 7.63 (d, J = 8.7 Hz, 1H), 7.58 (dd, J = 7.4, 2.0 Hz, 1H), 7.39 (ddd, J = 9.3, 8.2, 1.9 Hz, 2H), 7.25−7.17 (m, 4H), 7.10 (d, J = 2.4 Hz, 1H), 6.45 (dt, J = 16.0, 5.8 Hz, 1H), 4.84 (dd, J = 5.8, 1.5 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 156.2, 134.7, 133.5, 132.2, 128.7, 128.6, 128.5, 128.3, 128.0, 127.7, 126.4, 126.0 (2C), 125.9, 125.1, 119.6, 118.4, 105.2, 67.6. HRMS (ESI): calcd for $C_{19}H_{13}BrClO$ $[M - H]^-$ 370.9838, found 370.9815.

*7-Bromo-2-[[(2E)-3-(3-chlorophenyl)-2-propen-1-yl]oxy]-naphthalene (**1n**).* Yield: 67% (1.2 g) as a white solid. Mp: 123 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.89 (d, J = 1.7 Hz, 1H), 7.73 (d, J = 9.0 Hz, 1H), 7.63 (d, J = 8.7 Hz, 1H), 7.46−7.39 (m, 2H), 7.33−7.26 (m, 2H), 7.25−7.19 (m, 2H), 7.08 (d, J = 2.4 Hz, 1H), 6.73 (d, J = 16.0 Hz, 1H), 6.48 (dt, J = 16.0, 5.6 Hz, 1H), 4.81 (dd, J = 5.6, 1.4 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 156.1, 137.1, 134.6, 133.5, 130.6, 128.8, 128.4, 128.2, 127.7, 126.8, 126.3, 126.0, 125.4, 124.5, 123.7, 119.5, 118.2, 105.0, 67.2. HRMS (ESI): calcd for $C_{19}H_{13}BrClO$ $[M - H]^-$ 370.9838, found 370.9823.

*6-Bromo-2-[[(2E)-3-phenyl-2-propen-1-yl]oxy]naphthalene (**1o**).* Yield: 71% (1.9 g) as a white solid. Mp: 148 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.92 (d, J = 1.8 Hz, 1H), 7.66 (d, J = 9.0 Hz, 1H), 7.60 (d, J = 8.8 Hz, 1H), 7.50 (dd, J = 8.7, 2.0 Hz, 1H), 7.45−7.41 (m, 2H), 7.37−7.31 (m, 2H), 7.29−7.26 (m, 1H), 7.22 (dd, J = 9.0, 2.5 Hz, 1H), 7.16 (d, J = 2.4 Hz, 1H), 6.79 (d, J = 16.0 Hz, 1H), 6.47 (dt, J = 16.0, 5.8 Hz, 1H), 4.80 (dd, J = 5.8, 1.4 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 155.8, 135.3, 132.3, 132.0, 129.1, 128.6 (2C), 127.6 (2C), 127.4, 127.0, 125.6, 123.0, 119.0, 116.1, 106.0, 67.7. HRMS (ESI): calcd for $C_{19}H_{14}BrO$ $[M - H]^-$ 337.0228, found 337.0217.

*6-Bromo-2-[[(2E)-3-(4-fluorophenyl)-2-propen-1-yl]oxy]-naphthalene (**1p**).* Yield: 68% (1.2 g) as a white solid. Mp: 134−136 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.92 (d, J = 1.4 Hz, 1H), 7.66 (d, J = 9.0 Hz, 1H), 7.59 (d, J = 8.8 Hz, 1H), 7.50 (dd, J = 8.7, 1.9 Hz, 1H), 7.42−7.36 (m, 2H), 7.26−7.19 (m, 1H), 7.14 (d, J = 2.3 Hz, 1H), 7.02 (t, J = 8.6 Hz, 2H), 6.74 (d, J = 16.0 Hz, 1H), 6.38 (dt, J = 16.0, 5.8 Hz, 1H), 4.78 (d, J = 5.8 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 163.8, 161.3, 156.8, 133.0, 132.5 (2C), 132.2, 130.1, 129.7, 128.6, 128.4, 128.2, 128.1, 123.7 (2C), 120.0, 117.2, 115.7, 115.5, 107.0, 68.6. HRMS (ESI): calcd for $C_{19}H_{13}BrFO$ $[M - H]^-$ 355.0134, found 355.0117.

*6-Methoxy-2-[[(2E)-3-phenyl-2-propen-1-yl]oxy]naphthalene (**1q**).* Yield: 71% (1.6 g) as a white solid. Mp: 156 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.65 (t, J = 8.9 Hz, 2H), 7.45−7.41 (m, 2H), 7.36−7.30 (m, 2H), 7.29−7.26 (m, 1H), 7.21−7.16 (m, 2H), 7.15−7.10 (m, 2H), 6.78 (d, J = 16.0 Hz, 1H), 6.48 (dt, J = 16.0, 5.8 Hz, 1H), 4.79 (dd, J = 5.8, 1.4 Hz, 2H), 3.90 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 156.2, 155.1, 136.5, 133.1, 129.9, 129.7, 128.6, 128.2, 127.9, 126.6, 124.5, 119.2, 119.0, 109.7, 107.5, 106.1, 68.8, 55.3. HRMS (ESI): calcd for $C_{20}H_{17}O_2$ $[M - H]^-$ 289.1229, found 289.1207.

*7-[[(2E)-3-Phenyl-2-propen-1-yl]oxy]quinoline (**1r**).* Yield: 65% (1.4 g) as a white solid. Mp: 80−81 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.77 (dd, J = 4.2, 1.5 Hz, 1H), 8.10−8.01 (m, 2H), 7.47−7.41 (m, 3H), 7.39−7.31 (m, 3H), 7.30−7.24 (m, 1H), 7.14 (d, J = 2.7 Hz, 1H), 6.80 (d, J = 16.0 Hz, 1H), 6.47 (dt, J = 16.0, 5.8 Hz, 1H), 4.83 (d, J = 5.8 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 155.8, 146.9, 143.3, 135.3, 134.1, 132.5, 129.9, 128.3, 127.7, 127.1, 125.7, 122.9, 121.7, 120.4, 105.5, 68.0. HRMS (ESI): calcd for $C_{18}H_{14}NO$ $[M - H]^-$ 260.1075, found 260.1067.

*7-[[(2E)-3-(4-Methylphenyl)phenyl-2-propen-1-yl]oxy]quinoline (**1s**).* Yield: 68% (0.9 g) as a white solid. Mp: 93−95 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.78 (dd, J = 4.2, 1.4 Hz, 1H), 8.09−8.01 (m, 2H), 7.44 (dd, J = 9.2, 2.8 Hz, 1H), 7.39−7.31 (m, 3H), 7.18−7.12 (m, 3H), 6.76 (d, J = 16.0 Hz, 1H), 6.43 (dt, J = 15.9, 5.9 Hz, 1H), 4.81 (dd, J = 5.9, 1.2 Hz, 2H), 2.35 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 155.7, 146.9, 143.3, 137.0, 134.0, 132.5, 132.4, 129.8, 128.3 (2C), 125.5, 121.7, 121.6, 120.3, 105.3, 68.0, 20.2. HRMS (ESI): calcd for $C_{19}H_{16}NO$ $[M - H]^-$ 274.1232, found 274.1226.

*7-[[(2E)-3-(2-Methylphenyl)phenyl-2-propen-1-yl]oxy]quinoline (**1t**).* Yield: 76% (1.0 g) as a white solid. Mp: 83 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.79 (dd, J = 4.3, 1.6 Hz, 1H), 8.12−8.01 (m, 2H), 7.53−7.49 (m, 1H), 7.46 (dd, J = 9.2, 2.7 Hz, 1H), 7.37 (dd, J = 8.3, 4.2 Hz, 1H), 7.22−7.14 (m, 4H), 7.02 (d, J = 15.8 Hz, 1H), 6.37 (dt, J = 15.8, 5.8 Hz, 1H), 4.85 (d, J = 5.8 Hz, 2H), 2.36 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 155.7, 147.0, 143.3, 134.6, 134.4, 133.9, 130.4, 129.9, 129.3, 128.2, 126.9, 125.2, 124.8, 124.1, 121.6, 120.4, 105.4, 68.1, 18.8. HRMS (ESI): calcd for $C_{19}H_{16}NO$ $[M - H]^-$ 274.1232, found 274.1223.

*2-Methyl-7-[[(2E)-3-phenyl-2-propen-1-yl]oxy]quinoline (**1u**).* Yield: 74% (1.6 g) as a white solid. Mp: 98−99 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.99−7.92 (m, 2H), 7.46−7.38 (m, 3H), 7.37−7.31 (m, 2H), 7.29−7.26 (m, 1H), 7.26−7.22 (m, 1H), 7.11 (d, J = 2.8 Hz, 1H), 6.79 (d, J = 16.0 Hz, 1H), 6.47 (dt, J = 16.0, 5.8 Hz, 1H), 4.81 (dd, J = 5.8, 1.2 Hz, 2H), 2.72 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 155.4, 155.1, 142.7, 135.2, 134.1, 132.2, 128.9, 127.5, 126.9, 126.2, 125.5, 122.9, 121.2, 121.1, 105.5, 67.8, 23.9. HRMS (ESI): calcd for $C_{19}H_{18}NO$ $[M + H]^+$ 276.1388, found 276.1371.

*2-Methyl-7-[[(2E)-3-(4-methylphenyl)phenyl-2-propen-1-yl]oxy]-quinoline (**1v**).* Yield: 76% (1.1 g) as a white solid. Mp: 125−126 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.94 (d, J = 8.8 Hz, 2H), 7.40 (dd, J = 9.1, 2.7 Hz, 1H), 7.33 (d, J = 8.0 Hz, 2H), 7.28−7.22 (m, 1H), 7.17−7.09 (m, 3H), 6.75 (d, J = 16.0 Hz, 1H), 6.42 (dt, J = 15.9, 5.9 Hz, 1H), 4.79 (d, J = 5.8 Hz, 2H), 2.71 (s, 3H), 2.34 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 156.4, 156.2, 143.8, 137.9, 135.2, 133.5, 133.4, 130.0, 129.3, 127.3, 126.5, 122.9, 122.3, 106.5, 69.1, 25.0, 21.3. HRMS (ESI): calcd for $C_{20}H_{20}NO$ $[M + H]^+$ 290.1545, found 290.1529.

*2-(Allyloxy)naphthalene (**1w**).* Yield: 75% (1.1 g) as a colorless liquid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.76−7.65 (m, 3H), 7.44−7.38 (m, 1H), 7.34−7.27 (m, 1H), 7.18−7.13 (m, 1H), 7.10 (d, J = 1.5 Hz, 1H), 6.15−6.03 (m, 1H), 5.48−5.40 (m, 1H), 5.29 (dd, J = 10.5, 1.4 Hz, 1H), 4.60 (dt, J = 5.3, 1.3 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 156.6, 134.6, 133.3, 129.5, 129.1, 127.8, 126.9, 126.5, 123.8, 119.1, 117.9, 107.1, 68.9. Spectral data obtained were in agreement with those reported in the literature.[17]

*1-(1-Phenyl-1-propen-1-yl)-2-naphthol (**2a**).* Yield: 90% (59 mg) as a white solid. Mp: 108−109 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.83−7.77 (m, 2H), 7.52−7.46 (m, 1H), 7.34−7.28 (m, 3H), 7.27−7.18 (m, 5H), 6.80 (q, J = 6.9 Hz, 1H), 5.37 (s, 1H), 1.62 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 150.3, 139.8, 134.4, 132.7, 129.7, 129.6, 129.2, 128.7, 128.2, 127.5, 126.6, 125.9, 124.6, 123.3, 117.6, 117.1, 15.5. MS (ESI): Calcd for $C_{19}H_{15}O$ $[M - H]^-$ 259.1123, found 259.11. Spectral data obtained were in agreement with those reported in the literature.[10]

*1-[1-(4-Methylphenyl)-1-propen-1-yl]-2-naphthol (**2b**).* Yield: 68% (46 mg) as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.84−7.76 (m, 2H), 7.53−7.46 (m, 1H), 7.34−7.31 (m, 1H), 7.30−7.28 (m, 1H), 7.27−7.23 (m, 1H), 7.16 (d, J = 8.2 Hz, 2H), 7.04 (d, J = 8.2 Hz, 2H), 6.76 (q, J = 6.9 Hz, 1H), 5.38 (s, 1H), 2.29 (s, 3H), 1.61 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 150.2, 137.4, 136.9, 134.2, 132.7, 129.5, 129.4, 129.1, 128.6, 128.1, 126.6, 125.8, 124.7, 123.3, 117.8, 117.1, 21.1, 15.4. HRMS (ESI): Calcd for $C_{20}H_{17}O$ $[M - H]^-$ 273.1279, found 273.1278.

*1-[1-(4-Chlorophenyl)-1-propen-1-yl]-2-naphthol (**2c**).* Yield: 31% (23 mg) as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.85−7.77 (m, 2H), 7.46−7.41 (m, 1H), 7.35−7.29 (m, 2H), 7.27 (d, J = 8.9 Hz, 1H), 7.19 (s, 4H), 6.80 (q, J = 6.9 Hz, 1H), 5.31 (s, 1H), 1.63 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 134.7, 122.7, 118.0, 117.8, 117.0, 114.6, 114.3, 113.7, 113.3, 112.7, 111.7, 111.2, 108.9, 107.9, 101.6, 101.5, 14.2. HRMS (ESI): calcd for $C_{19}H_{14}ClO$ $[M - H]^-$ 293.0733, found 293.0728.

*1-[1-(4-Fluorophenyl)-1-propen-1-yl]-2-naphthol (**2d**).* Yield: 47% (33 mg) as a yellow solid. Mp: 89 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.85−7.78 (m, 2H), 7.48−7.43 (m, 1H), 7.35−7.29 (m, 2H), 7.29−7.26 (m, 1H), 7.25−7.21 (m, 2H), 6.96−6.89 (m, 2H), 6.74 (q, J = 6.9 Hz, 1H), 5.35 (s, 1H), 1.62 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 163.5, 161.1, 150.2, 135.9, 135.8, 133.4, 132.5, 129.7, 129.4,

DOI: 10.1021/acs.joc.6b02902
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129.2, 128.2, 127.6, 127.5, 126.7, 124.5, 123.4, 117.3, 117.1, 115.6, 115.4, 15.5. HRMS (ESI): calcd for $C_{19}H_{14}FO$ $[M - H]^-$ 277.1029, found 277.1033.

*1-[1-(4-Trifluoromethylphenyl)-1-propen-1-yl]-2-naphthol (**2e**).* Yield: 41% (33 mg) as a white solid. Mp: 146−148 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.86−7.80 (m, 2H), 7.52−7.47 (m, 2H), 7.45−7.40 (m, 1H), 7.37 (d, J = 8.6 Hz, 2H), 7.34−7.31 (m, 2H), 7.28 (d, J = 8.9 Hz, 1H), 6.92 (q, J = 6.9 Hz, 1H), 1.68 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 150.3, 143.3, 133.7, 132.5, 132.1, 130.0, 129.6, 129.2, 128.3, 126.9, 126.2, 125.7 (2C), 125.6 (2C), 124.3, 123.6, 122.8, 117.2, 116.8, 15.7. HRMS (ESI): calcd for $C_{20}H_{14}F_3O$ $[M - H]^-$ 327.0997, found 327.1018.

*1-[1-(3-Chlorophenyl)-1-propen-1-yl]-2-naphthol (**2f**).* Yield: 69% (51 mg) as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.85−7.79 (m, 2H), 7.48−7.42 (m, 1H), 7.37−7.30 (m, 3H), 7.27 (d, J = 8.9 Hz, 1H), 7.19 (dt, J = 7.9, 1.7 Hz, 1H), 7.17−7.12 (m, 1H), 7.08 (dt, J = 7.4, 1.6 Hz, 1H), 6.83 (q, J = 6.9 Hz, 1H), 5.30 (s, 1H), 1.64 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 150.3, 141.8, 134.7, 133.5, 132.5, 131.1, 129.9 (2C), 129.2, 128.3, 127.6, 126.8, 125.9, 124.4, 124.3, 123.5, 117.2, 116.9, 15.6. HRMS (ESI): calcd for $C_{19}H_{14}ClO$ $[M - H]^-$ 293.0733, found 293.0738.

*1-[1-(3-Fluorophenyl)-1-propen-1-yl]-2-naphthol (**2g**).* Yield: 44% (30 mg) as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.87−7.78 (m, 2H), 7.50−7.42 (m, 1H), 7.36−7.31 (m, 2H), 7.28 (d, J = 9.0 Hz, 1H), 7.20 (td, J = 8.0, 6.1 Hz, 1H), 7.04 (d, J = 7.9 Hz, 1H), 7.01−6.95 (m, 1H), 6.91 (td, J = 8.3, 2.5 Hz, 1H), 6.84 (q, J = 6.9 Hz, 1H), 5.30 (s, 1H), 1.64 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 163.4, 161.0, 149.3, 141.2 (2C), 132.6, 131.5, 129.9, 129.1 (2C), 128.9, 128.2, 127.3, 125.8, 123.4, 122.5, 120.6 (2C), 116.2, 116.0, 113.5, 113.3, 111.9, 111.7, 14.6. HRMS (ESI): calcd for $C_{19}H_{14}FO$ $[M - H]^-$ 277.1029, found 277.1022.

*1-[1-(2-Methylphenyl)-1-propen-1-yl]-2-naphthol (**2h**).* Yield: 88% (60 mg) as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.79−7.74 (m, 2H), 7.54 (dd, J = 8.2, 0.8 Hz, 1H), 7.34−7.26 (m, 2H), 7.23 (d, J = 8.9 Hz, 1H), 7.20−7.12 (m, 3H), 7.11−7.08 (m, 1H), 6.37 (q, J = 6.9 Hz, 1H), 5.58 (s, 1H), 2.31 (s, 3H), 1.70 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 150.3, 141.1, 135.3, 135.0, 133.5, 132.6, 131.4, 129.7, 129.3, 129.2, 128.2, 127.3, 126.5, 126.1, 124.8, 123.2, 118.7, 117.1, 20.9, 15.7. HRMS (ESI): calcd for $C_{20}H_{17}O$ $[M - H]^-$ 273.1279, found 273.1271.

*1-[1-(2-Chlorophenyl)-1-propen-1-yl]-2-naphthol (**2i**).* Yield: 70% (52 mg) as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.70 (d, J = 9.1 Hz, 2H), 7.64 (d, J = 8.4 Hz, 1H), 7.31 (t, J = 7.5 Hz, 2H), 7.26−7.20 (m, 1H), 7.16 (d, J = 8.9 Hz, 1H), 7.10−6.98 (m, 3H), 6.54 (q, J = 6.8 Hz, 1H), 5.61 (s, 1H), 1.62 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 149.6, 138.9, 135.8, 131.5, 130.9, 130.3, 129.5, 129.4, 128.7, 128.1, 127.3, 127.2, 125.8, 125.7, 123.5, 122.2, 117.2, 116.2, 14.6. HRMS (ESI): calcd for $C_{19}H_{14}ClO$ $[M - H]^-$ 293.0733, found 293.0724.

*1-[1-(2-Fluorophenyl)-1-propen-1-yl]-2-naphthol (**2j**).* Yield: 78% (54 mg) as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.82−7.75 (m, 2H), 7.59 (d, J = 8.3 Hz, 1H), 7.37−7.29 (m, 2H), 7.26−7.24 (m, 1H), 7.18−7.12 (m, 1H), 7.07 (dd, J = 11.4, 8.1 Hz, 1H), 7.00−6.89 (m, 2H), 6.83 (q, J = 6.9 Hz, 1H), 5.51 (s, 1H), 1.66 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 160.6, 158.1, 149.3, 134.6, 134.5, 131.5, 129.1 (2C), 128.7, 128.2, 127.9, 127.7, 127.6, 127.4, 127.3, 125.8, 123.4, 123.3, 123.2, 122.4, 116.9, 116.2, 115.4, 115.1, 14.7. HRMS (ESI): calcd for $C_{19}H_{14}FO$ $[M - H]^-$ 277.1029, found 277.1017.

*2-[[(1Z)-3-(2-Trifluoromethylphenyl)-1-propen-1-yl]oxy]-naphthalene (**1k'**).* Yield: 23% (19 mg) as a white solid. Mp: 95−96 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.79−7.72 (m, 3H), 7.66 (dd, J = 12.9, 7.9 Hz, 2H), 7.51 (t, J = 7.6 Hz, 1H), 7.46−7.41 (m, 1H), 7.39−7.32 (m, 2H), 7.23−7.15 (m, 3H), 6.45 (dt, J = 15.8, 5.7 Hz, 1H), 4.86 (dd, J = 5.8, 1.4 Hz, 2H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 155.4, 134.5, 133.4, 130.9, 129.7, 129.0, 128.5, 128.0, 127.9, 127.3, 126.6 (2C), 126.5, 126.0, 125.8, 125.4, 124.8, 124.7, 122.7, 122.3, 117.9, 106.1, 67.4. HRMS (ESI): calcd for $C_{20}H_{14}F_3O$ $[M - H]^-$ 327.0997, found 327.0996.

*2-(1-Phenyl-1-propen-1-yl)-1-naphthol (**2a'(Z)**).* Yield: 35% (23 mg) as a white solid. Mp: 89−91 °C. ^{1}H NMR (600 MHz, $CDCl_3$): δ 8.32−8.23 (m, 1H), 7.86−7.78 (m, 1H), 7.55−7.49 (m, 2H), 7.44 (d, J = 8.3 Hz, 1H), 7.28 (d, J = 3.7 Hz, 3H), 7.25 (s, 2H), 7.10 (d, J = 8.3 Hz, 1H), 6.56 (q, J = 6.8 Hz, 1H), 5.61 (s, 1H), 1.76 (d, J = 6.9 Hz, 3H). HRMS (ESI): calcd for $C_{19}H_{15}O$ $[M - H]^-$ 259.1123, found 259.1131. Spectral data obtained were in agreement with those reported in the literature.[10]

*7-Bromo-1-(1-phenyl-1-propen-1-yl)-2-naphthol (**2l**).* Yield: 99% (84 mg) as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.77 (d, J = 8.8 Hz, 1H), 7.68−7.63 (m, 2H), 7.38 (dd, J = 8.6, 2.0 Hz, 1H), 7.28 (d, J = 8.9 Hz, 2H), 7.26 (s, 3H), 7.25−7.23 (m, 1H), 6.83 (q, J = 6.9 Hz, 1H), 5.40 (s, 1H), 1.62 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 150.1, 138.2, 133.0, 132.7, 129.3, 128.8, 128.5, 127.8, 126.8, 126.5, 125.8, 125.6, 124.8, 120.2, 116.6, 116.1, 14.5. HRMS (ESI): calcd for $C_{19}H_{14}BrO$ $[M - H]^-$ 337.0228, found 337.0227.

*7-Bromo-1-[1-(2-chlorophenyl)-1-propen-1-yl]-2-naphthol (**2m**).* Yield: 42% (39 mg) as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.89 (d, J = 1.8 Hz, 1H), 7.73 (d, J = 8.9 Hz, 1H), 7.63 (d, J = 8.6 Hz, 1H), 7.43−7.40 (m, 1H), 7.38 (dd, J = 8.6, 1.9 Hz, 1H), 7.23 (d, J = 8.9 Hz, 1H), 7.19−7.10 (m, 3H), 6.61 (q, J = 6.9 Hz, 1H), 5.71 (s, 1H), 1.70 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 150.4, 138.6, 136.4, 132.8, 130.9, 129.8, 129.5 (2C), 128.9, 128.7, 127.5, 126.5, 125.9, 125.7, 125.6, 120.2, 116.7, 116.6, 14.7. HRMS (ESI): calcd for $C_{19}H_{13}BrClO$ $[M - H]^-$ 370.9838, found 370.9831.

*7-Bromo-1-[1-(3-chlorophenyl)-1-propen-1-yl]-2-naphthol (**2n**).* Yield: 80% (75 mg) as a yellow solid. Mp: 121−123 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.77 (d, J = 8.9 Hz, 1H), 7.66 (d, J = 8.6 Hz, 1H), 7.60 (d, J = 1.7 Hz, 1H), 7.38 (dd, J = 8.6, 1.9 Hz, 1H), 7.29−7.24 (m, 2H), 7.22−7.13 (m, 2H), 7.08 (dt, J = 7.5, 1.4 Hz, 1H), 6.82 (q, J = 6.9 Hz, 1H), 5.36 (s, 1H), 1.61 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 150.1, 140.2, 133.8, 132.8, 131.7, 130.6, 129.0, 128.9, 128.8, 126.8, 126.6, 125.9, 125.4, 124.7, 123.1, 120.4, 116.7, 115.3, 14.6. HRMS (ESI): calcd for $C_{19}H_{13}BrClO$ $[M - H]^-$ 370.9838, found 370.9834.

*6-Bromo-1-(1-phenyl-1-propen-1-yl)-2-naphthol (**2o**).* Yield: 70% (59 mg) as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.95 (s, 1H), 7.72 (d, J = 8.9 Hz, 1H), 7.37 (d, J = 1.6 Hz, 2H), 7.31−7.28 (m, 1H), 7.26−7.25 (m, 1H), 7.25−7.22 (m, 4H), 6.82 (q, J = 6.9 Hz, 1H), 5.39 (s, 1H), 1.62 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 150.6, 139.4, 133.9, 131.2, 130.3, 130.1, 130.0, 129.9, 128.8, 128.7, 127.7, 126.5, 125.9, 118.3, 117.9, 117.1, 15.5. HRMS (ESI): calcd for $C_{19}H_{14}BrO$ $[M - H]^-$ 337.0228, found 337.0221.

*6-Bromo-1-[1-(4- fluorophenyl)-1-propen-1-yl]-2-naphthol (**2p**).* Yield: 45% (40 mg) as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.95 (d, J = 1.7 Hz, 1H), 7.71 (d, J = 8.9 Hz, 1H), 7.38 (dd, J = 9.0, 1.9 Hz, 1H), 7.30 (dd, J = 14.9, 8.9 Hz, 2H), 7.22−7.17 (m, 2H), 6.96−6.88 (m, 2H), 6.73 (q, J = 6.9 Hz, 1H), 5.39 (s, 1H), 1.60 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 162.6, 160.1, 149.5, 134.5 (2C), 131.9, 130.0, 129.3, 129.1, 128.9, 128.6 (2C), 127.8, 126.5, 126.4, 125.3, 117.3, 116.6, 116.2, 114.7, 114.5, 14.4. HRMS (ESI): calcd for $C_{19}H_{13}BrFO$ $[M - H]^-$ 335.0134, found 355.0128.

*6-Methoxy-1-(1-phenyl-1-propen-1-yl)-2-naphthol (**2q**).* Yield: 96% (70 mg) as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.70 (d, J = 8.9 Hz, 1H), 7.40 (d, J = 9.2 Hz, 1H), 7.29−7.26 (m, 2H), 7.25−7.18 (m, 4H), 7.13 (d, J = 2.6 Hz, 1H), 7.00 (dd, J = 9.1, 2.6 Hz, 1H), 6.78 (q, J = 6.9 Hz, 1H), 5.21 (s, 1H), 3.87 (s, 3H), 1.62 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 155.9, 148.7, 139.8, 134.6, 130.0, 129.4, 128.7, 128.2, 127.9, 127.5, 126.2, 125.9, 119.1, 118.0, 117.5, 106.6, 55.3, 15.5. HRMS (ESI): calcd for $C_{20}H_{17}O_2$ $[M - H]^-$ 289.1229, found 289.1226.

*7-Hydroxy-6-(1-phenyl-1-propen-1-yl)quinoline(**2r**).* Yield: 92% (60 mg) as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.65 (dd, J = 4.2, 1.5 Hz, 1H), 8.01 (d, J = 9.2 Hz, 1H), 7.87 (d, J = 8.0 Hz, 1H), 7.50 (d, J = 9.1 Hz, 1H), 7.35−7.13 (m, 7H), 6.77 (q, J = 6.9 Hz, 1H), 1.62 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 150.3, 146.0, 142.7, 138.7, 132.8, 132.3, 129.1, 128.4, 127.6, 127.0, 126.5, 124.8, 120.4, 120.3, 116.8, 14.5. HRMS (ESI): calcd for $C_{18}H_{14}NO$ $[M - H]^-$ 260.1075, found 260.1074.

DOI: 10.1021/acs.joc.6b02902
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*7-Hydroxy-6-[1-(4-methylphenyl)-1-propen-1-yl]quinoline(**2s**).* Yield: 35% (24 mg) as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.75 (s, 1H), 8.16 (d, J = 9.1 Hz, 1H), 7.89 (d, J = 8.4 Hz, 1H), 7.54 (d, J = 9.1 Hz, 1H), 7.27 (s, 1H), 7.13 (d, J = 8.3 Hz, 2H), 7.06 (d, J = 8.1 Hz, 2H), 6.80 (q, J = 6.9 Hz, 1H), 5.34 (s, 1H), 2.30 (s, 3H), 1.62 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 149.8, 146.2, 143.0, 136.6, 135.6, 132.3 (2C), 129.4, 128.5, 128.4, 128.0, 126.9, 124.7, 120.4, 120.1, 116.7, 20.0, 14.5. HRMS (ESI): calcd for $C_{19}H_{18}NO$ $[M + H]^+$ 276.1388, found 276.1380.

*7-Hydroxy-6-[1-(2-methylphenyl)-1-propen-1-yl]quinoline (**2t**).* Yield: 99% (68 mg) as a white solid. Mp: 201−202 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.71 (d, J = 2.8 Hz, 1H), 8.02 (d, J = 9.0 Hz, 1H), 7.93 (d, J = 8.4 Hz, 1H), 7.45 (d, J = 9.1 Hz, 1H), 7.26−7.22 (m, 1H), 7.21−7.08 (m, 4H), 6.39 (q, J = 6.9 Hz, 1H), 2.26 (s, 3H), 1.70 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 151.0, 147.2, 144.0, 141.0, 135.4, 134.4, 133.8, 133.3, 131.5, 130.6, 129.4, 127.8, 127.5, 126.2, 121.3, 121.2, 118.7, 20.8, 15.8. HRMS (ESI): calcd for $C_{19}H_{18}NO$ $[M + H]^+$ 276.1388, found 276.1381.

*2-Methyl-7-hydroxy-6-(1-phenyl-1-propen-1-yl)quinoline (**2u**).* Yield: 92% (64 mg) as a white solid. Mp: 220 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.00 (d, J = 9.1 Hz, 1H), 7.73 (d, J = 8.6 Hz, 1H), 7.46 (d, J = 9.1 Hz, 1H), 7.30−7.21 (m, 6H), 7.12 (d, J = 8.6 Hz, 1H), 6.82 (q, J = 6.9 Hz, 1H), 2.68 (s, 3H), 1.63 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 155.0, 149.2, 142.7, 138.6, 132.8, 132.5, 132.4, 128.9, 128.8, 127.8, 126.8, 124.9, 121.5, 119.7, 116.6, 23.8, 14.6. HRMS (ESI): calcd for $C_{19}H_{16}NO$ $[M - H]^-$ 274.1232, found 274.1233.

*2-Methyl-7-hydroxy-6-[1-(4-methylphenyl)-1-propen-1-yl]-quinoline (**2v**).* Yield: 78% (56 mg) as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.90 (dd, J = 9.1, 0.6 Hz, 1H), 7.66 (d, J = 8.6 Hz, 1H), 7.38 (d, J = 9.1 Hz, 1H), 7.08−7.02 (m, 3H), 7.00−6.95 (m, 2H), 6.68 (q, J = 6.9 Hz, 1H), 2.59 (s, 3H), 2.22 (s, 3H), 1.53 (d, J = 6.9 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 155.9, 150.2, 143.6, 137.5, 136.8, 133.6, 133.5, 129.6, 129.4, 128.7, 126.0, 125.8, 122.4, 120.8, 117.8, 24.7, 21.1, 15.5. HRMS (ESI): calcd for $C_{20}H_{20}NO$ $[M + H]^+$ 290.1545, found, 290.1537.

*2-Methyl-1-phenylnaphtho[2,1-b]furan (**3a**).* Yield: 85% (55 mg) as a colorless liquid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.91 (d, J = 8.1 Hz, 1H), 7.77 (d, J = 8.4 Hz, 1H), 7.67 (dd, J = 20.8, 8.9 Hz, 2H), 7.55−7.44 (m, 5H), 7.38 (t, J = 6.9 Hz, 1H), 7.28 (t, J = 7.0 Hz, 1H), 2.43 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 150.2 (2C), 133.1, 129.7, 129.5, 127.8, 127.6, 126.8, 126.5, 124.6, 123.5, 122.9, 122.1, 121.2, 117.9, 111.0, 11.3. Spectral data obtained were in agreement with those reported in the literature.[10]

*1-(1-Phenylallyl)-2-naphthol (**4a**).* Yield: 90% (59 mg) as a yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.92 (d, J = 8.6 Hz, 1H), 7.79 (d, J = 8.0 Hz, 1H), 7.73 (d, J = 8.8 Hz, 1H), 7.45−7.39 (m, 1H), 7.35−7.28 (m, 5H), 7.10 (d, J = 8.8 Hz, 1H), 6.60 (ddd, J = 16.8, 10.2, 6.0 Hz, 1H), 5.70 (d, J = 6.2 Hz, 2H), 5.42 (d, J = 10.2 Hz, 1H), 5.16 (d, J = 17.3 Hz, 1H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 151.6, 139.7, 137.9, 132.0, 128.6, 128.4, 127.9, 127.8, 127.1, 125.9, 125.6, 122.1, 121.8, 118.3, 117.8, 117.6, 45.1. Spectral data obtained were in agreement with those reported in the literature.[14b]

*2-Methyl-1-(4-fluorophenyl)naphtho[2,1-b]furan (**3d**).* Yield: 14% (10 mg) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.91 (d, J = 7.7 Hz, 1H), 7.73−7.67 (m, 2H), 7.63 (d, J = 8.9 Hz, 1H), 7.49−7.43 (m, 2H), 7.39 (t, J = 6.9 Hz, 1H), 7.30 (t, J = 7.0 Hz, 1H), 7.24−7.19 (m, 2H), 2.41 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 163.6, 161.2, 151.4, 151.2, 132.1 (2C), 130.7, 130.1, 130.0, 128.9, 127.8, 125.7, 124.6, 124.0, 122.9, 122.2, 118.0, 115.8, 115.6, 112.1, 12.3. Spectral data obtained were in agreement with those reported in the literature.[10]

*2-Methyl-1-(3-chlorophenyl)naphtho[2,1-b]furan (**3f**).* Yield: 58% (43 mg) as a yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.92 (d, J = 8.1 Hz, 1H), 7.74−7.68 (m, 2H), 7.63 (dd, J = 8.9, 1.7 Hz, 1H), 7.51 (s, 1H), 7.48−7.44 (m, 2H), 7.43−7.37 (m, 2H), 7.35−7.29 (m, 1H), 2.43 (d, J = 1.8 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 151.5, 151.3, 136.2, 134.4, 130.8, 130.5, 129.9, 128.9, 128.8, 127.8, 127.7, 125.8, 124.8, 124.1, 123.0, 121.9, 117.8, 112.0, 12.3. HRMS(APCI): Calcd for $C_{19}H_{14}ClO$ $[M + H]^+$ 293.0733, found 293.0732.

*2-Methyl-1-(3-fluorophenyl)naphtho[2,1-b]furan (**3g**).* Yield: 80% (56 mg) as a colorless liquid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.91 (d, J = 8.1 Hz, 1H), 7.74 (d, J = 8.3 Hz, 1H), 7.69 (d, J = 8.9 Hz, 1H), 7.63 (dd, J = 8.9, 1.3 Hz, 1H), 7.51−7.44 (m, 1H), 7.42−7.36 (m, 1H), 7.34−7.27 (m, 2H), 7.23−7.12 (m, 2H), 2.42 (d, J = 1.3 Hz, 3H). ^{13}C NMR (101 MHz, CDCl3): δ 163.0, 160.6, 150.4, 150.2, 135.5, 135.4, 129.7, 129.1, 129.0, 127.9, 126.6, 125.3 (2C), 124.7, 123.7, 123.1, 122.0, 120.9, 116.9 (2C), 116.5, 116.3, 113.7, 113.4, 111.0, 11.3. Spectral data obtained were in agreement with those reported in the literature.[10]

*2-Methyl-1-(2-methylphenyl)naphtho[2,1-b]furan (**3h**).* Yield: 81% (56 mg) as a colorless liquid. ^{1}H NMR (400 MHz, CDCl3): δ 7.89 (d, J = 8.1 Hz, 1H), 7.66 (q, J = 8.9 Hz, 2H), 7.43 (d, J = 8.4 Hz, 1H), 7.41−7.30 (m, 5H), 7.24 (d, J = 6.0 Hz, 1H), 2.35 (s, 3H), 2.13 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 151.4, 150.8, 138.3, 133.6, 131.0, 130.7, 130.2, 128.7, 128.2, 126.2, 126.0, 124.4, 124.0, 122.6, 118.0, 112.2, 20.0, 12.3. Spectral data obtained were in agreement with those reported in the literature.[10]

*2-Methyl-7-bromo-1-phenylnaphtho[2,1-b]furan (**3l**).* Yield: 84% (71 mg) as a white solid. Mp:78−80 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.91 (s, 1H), 7.74 (d, J = 8.7 Hz, 1H), 7.65−7.59 (m, 2H), 7.57−7.52 (m, 2H), 7.51−7.43 (m, 4H), 2.43 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 150.6 (2C), 132.3, 129.3, 128.1, 127.9, 127.7, 126.9, 126.3, 124.6, 123.2, 120.5, 118.8, 117.8, 111.4, 11.3. HRMS(APCI): Calcd for $C_{19}H_{14}BrO$ $[M + H]^+$ 337.0228, found 337.0202.

*2-Methyl-7-bromo-1-(2-chlorophenyl)naphtho[2,1-b]furan (**3m**).* Yield: 64% (60 mg) as a colorless liquid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.74 (d, J = 8.7 Hz, 1H), 7.67−7.61 (m, 3H), 7.58 (d, J = 1.9 Hz, 1H), 7.49−7.40 (m, 4H), 2.38 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 151.2, 150.7, 134.2, 131.5, 131.3, 129.2, 129.0, 128.8, 128.0, 127.9, 126.4, 126.1, 124.2, 123.3, 120.7, 119.0, 115.0, 111.5, 11.5. HRMS(APCI): Calcd for $C_{19}H_{13}BrClO$ $[M + H]^+$ 370.9838, found 370.9809.

*2-Methyl-7-bromo-1-(3-chlorophenyl)naphtho[2,1-b]furan (**3n**).* Yield: 66% (62 mg) as a yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.88 (d, J = 1.6 Hz, 1H), 7.75 (d, J = 8.7 Hz, 1H), 7.66−7.59 (m, 2H), 7.51−7.44 (m, 4H), 7.41−7.35 (m, 1H), 2.43 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 151.9, 151.7, 135.4, 134.6, 130.4, 130.3, 130.0, 129.2, 128.7, 128.6, 128.1, 127.5, 125.5, 124.6, 121.1, 120.0, 117.6, 112.5, 12.4. HRMS(APCI): Calcd for $C_{19}H_{13}BrClO$ $[M + H]^+$ 370.9838, found 370.9810.

*2-Methyl-6-bromo-1-phenylnaphtho[2,1-b]furan (**3o**).* Yield: 44% (38 mg) as a white solid. Mp: 80−82 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.05 (d, J = 2.0 Hz, 1H), 7.64 (t, J = 9.0 Hz, 2H), 7.57 (d, J = 8.9 Hz, 1H), 7.55−7.44 (m, 5H), 7.34 (dd, J = 8.9, 1.7 Hz, 1H), 2.43 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 151.8, 151.3, 133.8, 132.1, 130.7, 130.4, 128.8, 128.7, 127.8, 126.3, 124.9, 123.5, 122.5, 118.8, 117.7, 113.1, 12.3. Spectral data obtained were in agreement with those reported in the literature.[10]

*2-Methyl-6-bromo-1-(4-fluorophenyl)naphtho[2,1-b]furan (**3p**).* Yield: 55% (49 mg) as a white solid. Mp: 116−118 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.05 (s, 1H), 7.64 (dd, J = 8.9, 1.5 Hz, 1H), 7.60−7.55 (m, 2H), 7.47−7.40 (m, 2H), 7.36 (dd, J = 8.9, 1.7 Hz, 1H), 7.24−7.19 (m, 2H), 2.41 (d, J = 1.5 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 163.7, 161.2, 152.0, 151.2, 132.1, 132.0, 130.8, 129.6 (2C), 128.9, 126.2, 124.6, 123.6, 122.4, 117.8 (2C), 115.9, 115.7, 113.1, 12.3. Spectral data obtained were in agreement with those reported in the literature.[10]

*2-Methyl-6-methoxy-1-phenylnaphtho[2,1-b]furan (**3q**).* Yield: 77% (56 mg) as a white solid. Mp: 68−69 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.67 (d, J = 9.2 Hz, 1H), 7.62−7.58 (m, 2H), 7.54−7.45 (m, 5H), 7.24 (s, 1H), 6.96 (dd, J = 9.1, 2.6 Hz, 1H), 3.89 (s, 3H), 2.41 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 156.1, 151.3, 150.2, 134.2, 131.9, 130.5, 128.6, 127.5, 124.6, 123.3, 122.8, 122.6, 118.7, 117.5, 112.4, 107.6, 55.3, 12.3. HRMS(APCI): Calcd for $C_{20}H_{17}O_2$ $[M + H]^+$ 289.1229, found 289.1225.

*5-Methyl-6-phenylfuro[2,3-h]quinoline (**3r**).* Yield: 86% (56 mg) as a yellow solid. Mp: 100−101 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.86−8.78 (m, 1H), 8.13−8.06 (m, 1H), 7.98 (d, J = 9.1 Hz, 1H), 7.86 (dd, J = 9.1, 1.3 Hz, 1H), 7.57−7.45 (m, 5H), 7.22−7.17 (m, 1H),

DOI: 10.1021/acs.joc.6b02902
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2.45 (d, J = 1.2 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 151.4, 149.8, 147.0, 145.1, 132.4, 130.3, 129.2, 127.8, 126.9, 124.5, 121.9, 121.1, 119.2, 118.1, 114.4, 11.3. MS(ESI): Calcd for $C_{18}H_{14}NO$ $[M + H]^+$ 260.1075, found 260.1046.

*5-Methyl-6-(2-methylphenyl)furo[2,3-h]quinoline (**3t**).* Yield: 75% (52 mg) as a yellow liquid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.81 (d, J = 2.9 Hz, 1H), 7.98 (d, J = 9.1 Hz, 1H), 7.87 (d, J = 9.1 Hz, 1H), 7.74 (d, J = 8.2 Hz, 1H), 7.45−7.38 (m, 2H), 7.37−7.29 (m, 2H), 7.17 (dd, J = 8.4, 4.3 Hz, 1H), 2.37 (s, 3H), 2.12 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 151.0, 149.8, 147.1, 145.0, 136.9, 131.7, 129.8, 129.3, 127.4 (2C), 125.3, 124.4, 122.1, 121.5, 119.5, 117.1, 114.4, 114.3, 18.9, 11.3. HRMS (ESI): calcd for $C_{19}H_{16}NO$ $[M + H]^+$ 274.1232, found 274.1199.

*5-Methyl-6-(4-methylphenyl)-9-methylfuro[2,3-h]quinoline (**3v**).* Yield: 10% (7 mg) as a yellow solid. Mp: 100−101 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.02 (d, J = 8.6 Hz, 1H), 7.88 (d, J = 9.1 Hz, 1H), 7.80 (d, J = 9.1 Hz, 1H), 7.38−7.30 (m, 4H), 7.08 (d, J = 8.6 Hz, 1H), 2.70 (s, 3H), 2.48 (s, 3H), 2.43 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ 156.5, 152.2, 150.5, 145.7, 137.5, 131.5, 130.5, 130.1, 129.5, 124.8, 122.3, 120.9 (2C), 118.9, 115.0, 25.1, 21.4, 12.3. HRMS (ESI): calcd for $C_{20}H_{18}NO$ $[M + H]^+$ 288.1388, found 288.1387.

*2-Methyl-3-phenylnaphtho[1,2-b]furan (**3a′**).* Yield: 20% (13 mg) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.32 (d, J = 8.2 Hz, 1H), 7.93 (d, J = 8.2 Hz, 1H), 7.70−7.64 (m, 2H), 7.61−7.46 (m, 6H), 7.39 (t, J = 7.2 Hz, 1H), 2.66 (s, 3H). Spectral data obtained were in agreement with those reported in the literature.[10]

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.joc.6b02902.

General experimental details and supplementary experimental data and ^{1}H and ^{13}C NMR spectra for compounds **1**−**3** and **4a** (PDF)

Crystallographic data (CIF)

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Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

We gratefully acknowledge the National Natural Science Foundation of China (No. 21572137).

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