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Palladium-Catalyzed Approach for the General Synthesis of (*E*)-2-Arylmethylidene-*N*-tosylindolines and (*E*)-2-Arylmethylidene-*N*-tosyl/nosyltetrahydroquinolines: Access to 2-Substituted Indoles and Quinolines

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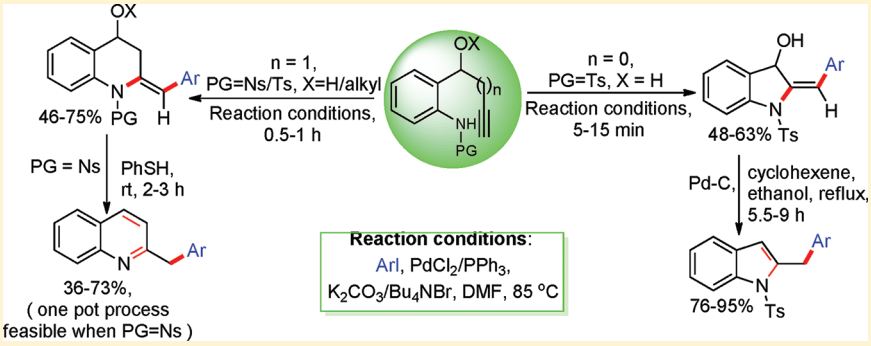
Supporting Information



ABSTRACT: A facile and efficient method for the synthesis of (*E*)-2-arylmethylidene-*N*-tosylindolines and (*E*)-2-arylmethylidene-*N*-tosyl/nosyltetrahydroquinoline variants has been developed through palladium-catalyzed cyclocondensation of aryl iodides with readily available 1-(2-tosylaminophenyl)prop-2-yn-1-ols and their higher homologues, respectively. The proposed reaction mechanism invokes the operation of *trans*-aminopalladation during cyclization (5/6-*exo*-*dig*), which ensures exclusive (*E*)-stereochemistry in the products. The method is fast, operationally simple, totally regio- and stereoselective, and versatile enough to access a variety of 2-substituted indoles and quinolines. The reactions proceeded efficiently with a wide variety of substrates and afforded the corresponding products in moderate to excellent yields.

INTRODUCTION

As privileged fragments, quinolines, indoles, and their saturated analogues (tetrahydroquinolines, indolines) are prevalent in a variety of pharmaceuticals and bioactive natural products, especially alkaloids, and are also known to serve as building blocks in many important synthetic transformations of commercial interest (e.g., dyes, organic materials etc). In particular, 2-substituted quinolines are known to display a wide range of biological activities such as anticancer,[1a] anti-HIV,[1b] antimalarial,[1c] antibacterial,[1d] antituberculosis,[1e] antileishmanial,[1f] etc. On the other hand, indoles have been studied for more than a century yet continue to attract considerable attention because of their broad range of activities[2] and immense importance in pharmaceutical research as critical building blocks in a number of drugs.[3]

Various attempts have been made to synthesize and functionalize quinolines and indoles since the late 1800s, resulting in several important conventional methods.[4,5] However, most of the classical methods often require elevated reaction temperature and/or prolonged reaction time, stoichiometric or excess amount of various reagents including toxic compounds, and harsh reaction conditions. These become difficult to apply on sensitive substrates and constitute a challenge in targeted syntheses. To overcome the lacunae, several transition-metal-catalyzed heteroannulations of acyclic precursors have been developed as they offer the possibility of accessing the heterocycles with desired substitution pattern easily in one step under mild conditions starting from simple and cheap substrates. In this context, catalytic methodologies including the employment of palladium[6,7] have been reported during the past two decades. Scrutiny of the literature indicates that a majority of the transition-metal-catalyzed syntheses of indoles **4**[8] and quinolines **5**[9] were accomplished by utilizing acyclic precursors **1** and **2** and employing 5- and 6-*endo*-*dig* cyclizations, respectively (Scheme 1). In contrast, 5-*exo*-*dig* cyclizations of substrates **2** leading to the formation of products **6** are rare,[10] while 6-*exo*-*dig* cyclizations of substrates **3** culminating in the synthesis of products **8** and their subsequent conversion to **9** are not known at all. Notably, Chan et al.[10a] reported one specific example of the *Z*-isomer of 2-(benzylidene)-3-phenylindolin-3-ol **6a** (R^2 = R^3 = Ph, R^1 = Ts, X = H) as an undesired side product in the cycloisomerization reaction of substrate **2a**. The same group has

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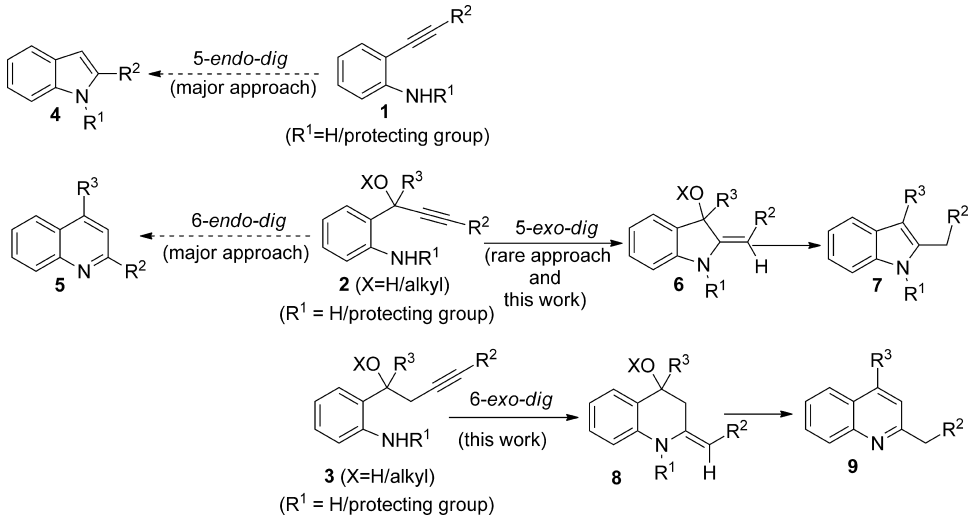
Scheme 1. Synthesis of Indoles and Quinolines from Substrates 1−3



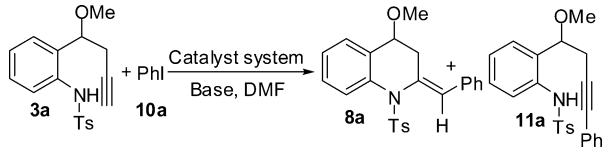
recently reported[10b] gold-catalyzed iodocyclizaton (5-*exo-dig*) of **2** (R^3 = aryl/alkyl, R^2 = X = H, R^1 = Ts) to (*E*)-2-(iodomethylene)indolin-3-ols **6** (R^2 = I), which were subsequently converted in situ to 3-substituted derivatives of indole-2-carbaldehydes **4** (R^2 = CHO, R^1 = Ts). Gevorgyan and co-workers[10c] recently reported a copper-catalyzed 5-*exo-dig* cyclization affording 3-amino-substituted (*Z*)-2-(alkyl/arylmethylidene)indolines **6**, which underwent base induced isomerization to afford indoles **7** (R^3 = piperidinyl, R^2 = aryl/alkyl, R^1 = Ts). With this background, development of a facile route for the general synthesis of products **6** and **8** and their subsequent transformations into indoles **7** and quinolines **9**, respectively, seemed highly desirable.

In continuation of our studies[11] on the synthesis of various heterocyclic structures through palladium-catalyzed reactions, we have recently developed a stereoselective method for the synthesis of (*E*)-3-arylmethylidene-3,4-dihydro-2*H*-1,4-benzoxazines[11c] by palladium-catalyzed reactions between aryl iodides and *N*-tosyl-2-(prop-2′-ynyloxy)aniline. We anticipated that replacing the latter by its carbo analogue **3** (R^3 = R^2 = H, R^1 = Ts) or lower homologue **2** could lead to a stereoselective cyclization resulting in (*E*)-2-(arylmethylidene)-tetrahydroquinoline **8** or (*E*)-2-(arylmethylidene)indolines **6** (R^2 = Ar). However, execution of this strategy posed formidable challenges, including (a) formation of acyclic product of the acetylenic substrate rather than a cyclized product, (b) ensuring stereo- and regio-selectivity, and (c) establishing the optimal catalytic system. Nevertheless, careful screening of the various reaction conditions and catalysts enabled us to achieve the viability of the strategy. In this paper, we disclose a diversified approach for the stereoselective (*E*) synthesis of products **6** and **8** followed by their expedient transformations into indoles **7** and quinolines **9**, respectively, as shown in Scheme 1.

RESULTS AND DISCUSSION

Initially, we chose to test the feasibility of our hypothesis through the synthesis of products **8** and therefore the requisite reactant, i.e., *N*-[2-(1-methoxybut-3-ynyl)phenyl]-4-methylbenzenesulfonamide **3a** was prepared using a sequence of steps (see the Experimental Section for details). We then set out to perform optimization studies, and a series of experiments were carried out with variation of the reaction parameters such as catalyst, solvent, base, temperature, etc. for a model conversion of substrate **3a** into (*E*)-2-benzylidene-*N*-tosyl-tetrahydroquinoline **8a**. Selected results are summarized in Table 1. In the beginning, we tested the reaction conditions [$Pd(OAc)_2/PPh_3$, K_2CO_3, rt] employed in our recent synthesis[11c] of (*E*)-2-arylmethylidene-1,4-benzoxazines, but utilization of that reaction protocol at rt or even at a higher (45 °C) temperature led to the formation of a mixture of products **8a** and **11a** in low yields (Table 1, entry 1 and 2). Replacing K_2CO_3 with a

Table 1. Optimization of the Reaction Conditions for the Synthesis of Product 8a[a]



entry	catalyst system	base[b]	*T* (°C)	time (h)	yield of **8a** (%)	yield of **11a**[c] (%)
1	$Pd(OAc)_2/PPh_3$	K_2CO_3	rt	20	15	13
2	$Pd(OAc)_2/PPh_3$	K_2CO_3	45	3	23	16
3[d]	$Pd(OAc)_2/PPh_3$	Cs_2CO_3	rt	18	3	20
4	$Pd(OAc)_2/PPh_3$	K_2CO_3	85	1.25	43	0
5[d]	$Pd(PPh_3)_4$	K_2CO_3	rt	20	12	3
6	$Pd(PPh_3)_4$	K_2CO_3	85	9	16	0
7	Pd/C, PPh_3	K_2CO_3	85	10	62	0
8[d]	$PdCl_2/PPh_3$	K_2CO_3	rt	24	NR	NR
9	**$PdCl_2/PPh_3$**	**K_2CO_3**	**85**	**1.0**	**69**	**0**
10	$PdCl_2/PPh_3$	Cs_2CO_3	85	1.2	58	20
11	$PdCl_2$	K_2CO_3	85	18	7	0
12[d]	PPh_3	K_2CO_3	85	10	NR	NR
13[e]	$PdCl_2/PPh_3$	K_2CO_3	85	1	62	0

[a]Reaction conditions: **3a** (0.60 mmol), **10a** (0.72 mmol), Pd-cat. (5 mol %, except entry 12), PPh_3 (22 mol %, except entries 5, 6 and 11), base (1.50 mmol), Bu_4NBr (10 mol %) in dry DMF (6 mL) under argon. [b]Bu_4NBr was used as phase-transfer catalyst. [c]Yields of the isolated pure products. [d]Starting material **3a** recovered for entries 3, 5, 8, and 12 was 24%, 37%, 60%, and 70%, respectively. [e]Reaction was performed without Bu_4NBr. Ts = *p*-toluenesulfonyl group.

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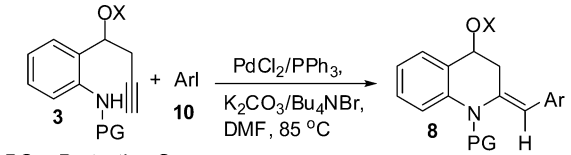
stronger base (Cs_2CO_3) further lowered the yield for **8a** (Table 1, entry 3). Thus, we continued using K_2CO_3 as base and heated the reaction at 85 °C when product **8a** was formed exclusively albeit in moderate yield (Table 1, entry 4). Changing the palladium catalyst to $Pd(PPh_3)_4$ and carrying out the reaction either at room or elevated temperature was also not encouraging (Table 1, entries 5 and 6). Interestingly, a significant improvement in the yield (62%) of **8a** was realized when the reaction was heated at 85 °C for 10 h using Pd/C and PPh_3 as catalytic system (Table 1, entry 7). In order to find a better catalytic system, we replaced Pd/C by $PdCl_2$ and ran the reaction at rt and 85 °C, consecutively. Though no product formation took place at rt even after 20 h, heating (85 °C) the reaction for 1 h changed the situation dramatically, affording the product **8a** with 69% yield (Table 1, entry 8 vs 9). Further change of the reaction conditions; i.e., use of a stronger base (Cs_2CO_3) dropped the yield to 58% (Table 1, entry 10). Additionally, neither $PdCl_2$ nor PPh_3 alone could promote the reaction effectively, indicating the importance of their cooperative assistance in this reaction (Table 1, entries 11 and 12). Employment of phase transfer catalyst (Bu_4NBr) had a beneficial impact on the product yield[12] (see Table 1, entry 9 vs 13). Use of tosyl (or nosyl) as *N*-protecting group was necessary, as free amines or amines protected with other groups (e.g., $COCF_3$, $COCH_3$, CH_2Ph etc.) did not respond to this reaction. Substitution (alkyl/aryl) of the acetylenic hydrogen of substrate **3a** prevented product formation. DMF was found to the best among the various solvents screened.

Having established the optimized reaction conditions (Table 1, entry 9), we next sought to extend the scope of the procedure to a variety of acetylenic ethers/alcohols **3a−e** and aryl iodides **10a−f** (Table 2). In practice, a range of diversely

Table 2. Synthesis of (*E*)-2-Arylmethylidene-*N*-tosyl/nosyltetrahdroquinolines 8[a]



PG = Protecting Group

entry	acetylene **3**; X/PG[b]	iodide **10**; Ar =	time (min)	product **8** (% yield)[c]
1	**3a**; Me/Ts	**10a**; C_6H_5	60	**8a** (69)
2	**3a**	**10b**; C_6H_4Me-*p*	45	**8b** (56)
3	**3a**	**10c**; C_6H_4OMe-*p*	60	**8c** (60)
4	**3a**	**10d**; $C_6H_4CF_3$-*p*	45	**8d** (75)
5	**3a**	**10e**; $C_6H_4CO_2Me$-*p*	45	**8e** (68)
6[d]	**3a**	**10f**; C_6H_4 I-*p*	60	**8f** (56)
7	**3b**; Me/Ns	**10a**; C_6H_5	30	**8g** (68)
8	**3b**	**10d**; $G_6H_5CF_3$-*p*	35	**8h** (72)
9	**3c**; Bn/Ts	**10a**; C_6H_5	30	**8i** (59)
10	**3c**	**10b**; C_6H_5Me-*p*	60	**8j** (46)
11	**3d**; H/Ts	**10a**; C_6H_5	60	**8k** (48)
12	**3e**; H/Ns	**10a**; C_6H_5	45	**8l** (56)

[a]Reaction conditions: **3** (0.60 mmol), **10** (0.72 mmol), $PdCl_2$ (5 mol %), PPh_3 (22 mol %), K_2CO_3 (1.50 mmol), Bu_4NBr (10 mol %), in dry DMF (6 mL) under argon at 85 °C. [b]Ts and Ns represent *p*-toluenesulfonyl and *p*-nitrobenzenesulfonyl group, respectively. [c]Yields of the isolated pure products. [d]2-fold excess of acetylene **3a** and catalyst were used; a stereoselective (*E*) bis-heteroannulatd product **8f** was only formed.

functionalized (*E*)-2-arylmethylidene-*N*-tosyl/nosyltetrahydroquinolines **8** could easily be synthesized within 30−60 min only. The reaction was found to be equally effective with both tosyl and nosyl as *N*-protecting group, but acetylenic ethers (**3a−c**) usually afforded higher yields (Table 2, entry 1 vs 11 and entry 7 vs 12) than the alcohols (**3d,e**). Similarly, various functional groups present in the iodides **10** were found to be tolerated under the reaction conditions. However, the presence of electron withdrawing groups (EWGs) in iodides **10** ensured better yields compared to electron donating groups (Table 2, entries 4, 5, 8 vs 2, 3, 10). When 1,4-diiodobenzene (**10f**) was employed as a coupling agent, a totally regio- and stereoselective bis-heteroannulation took place, furnishing the product **8f** (Table 2, entry 6). No (*Z*)-isomer of product **8** or 7-*endo-dig* cyclization product was formed in any case (confirmed from the crude NMR, TLC, and purification of the products as well).

We then attempted denosylation of the product **8g** using thiophenol (1.3 equiv) in DMF at rt. To our surprise, 2-benzylquinoline (**9a**) was obtained in near-quantitative yield (96%) rather than a simple denosylated product as expected. This result provided the impetus to check the viability of denosylation in one pot in domino fashion in another reaction (Table 2, entry 7). Accordingly, after formation (TLC) of the product **8g**, we added thiophenol (1.3 equiv) in the reaction mixture and continued to stir the reaction at rt for a few hours until completion (TLC). Pleasingly, product **9a** was isolated with 64% yield. We then decided to explore the finding noted in the general synthesis of 2-arylmethyl-substituted quinolines **9** (R^3 = H, R^2 = aryl) envisioned earlier in Scheme 1. In the literature, there are few reports[13] about the synthesis of **9**. For example, Zhou and co-workers[13a] adopted a reported synthetic protocol[14] of 2-benzylpyridine in the synthesis of **9** through two steps comprising (i) the transformation of 2-methylquinoline to 2-(2-quinolyl)ethanol derivatives followed by (ii) coupling with aryl bromides in presence of a palladium catalyst [$Pd(OCOCF_3)_2/PPh_3$]. Additionally, some 4-methyl derivatives of **9** were synthesized[13b] in low yields (10−34%) by photolysis. Besides, 3-aryl substituted derivatives of **9** (R^3 = H, R^2 = Ar) have been prepared in the recent past utilizing rhodium[13c] $[Rh(cod)_2]BF_4$ and ruthenium[13d] $[Cp^*Ru(NCMe)_3]BF_4$ catalyzed reactions, while others[13e−h] reported few specific examples of **9**. This underlines the urgency of developing a facile method for the general synthesis of **9** from readily available and low cost substrates. Indeed, a variety of 2-arylmethyl quinolines **9** (R^3 = H, R^2 = Ar) were synthesized (Table 3) readily using our method. The electronic properties of the functional group attached with the aryl iodides **10** influenced the outcome of the reaction, consistent with our previous observations.

The formation of quinolines **9** via denosylation could be attributed to a mechanistic pathway delineated in Scheme 2. Treatment of the newly formed nosylated product **8** with thiophenol in the presence of base could lead to complex **A**,[15] which is then converted to an anionic species **B** through the extrusion of sulfur dioxide. Species **B** tautomerizes readily to species **C**, which presumably promotes the formation of quinolines with subsequent elimination of water/alcohol (XOH).

Our product **9d** (Table 3, entry 4), prepared earlier[16] by a multistep process starting from **12**, was reported to be converted into α,α′-bis(2-quinolyl)-*p*-xylylene dimethiodide (**13**), a known biologically active peripheral blocking agent,

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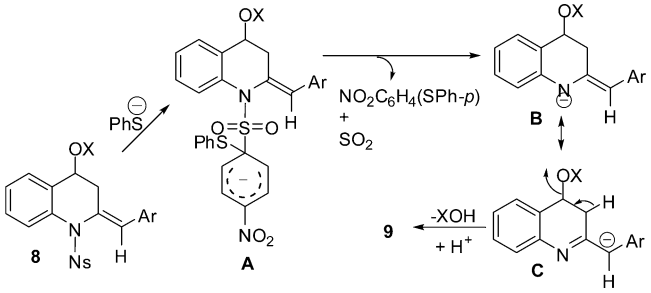
Table 3. Synthesis of 2-Substituted Quinolines 9 in One Pot[a]

Ns = $SO_2C_6H_4NO_2$-*p*

entry	alkyne 3; X =	iodide 10; Ar =	time/h (heating + rt)	product 9 (% yield)[b]
1	**3b**; Me	**10a**; C_6H_5	0.5 + 2.7	**9a** (64)
2	**3b**	**10b**; C_6H_4Me-*p*	0.75 + 2.5	**9b** (56)
3	**3b**	**10c**; C_6H_4OMe-*p*	0.5 + 2.0	**9c** (36)
4	**3b**	**10f**; C_6H_4I-*p*	0.75 + 3.0	**9d**[c] (58)
5	**3b**	**10g**; C_6H_3(Me-*o*)NO_2-*p*	1.7 + 3.0	**9e** (55)
6	**3b**	**10h**; $C_6H_4NO_2$-*p*	0.5 + 3.0	**9f** (70)
7	**3b**	**10i**; C_6H_4Br-*p*	0.5 + 3.0	**9g** (62)
8	**3e**; H	**10a**; C_6H_5	0.66 + 2.7	**9a** (52)
9	**3f**; Bn	**10j**; 2-thienyl	0.75 + 3.0	**9h** (68)
10	**3f**	**10k**; 2-naphthyl	1.2 + 2.5	**9i** (73)

[a]Reaction conditions: **3** (0.41 mmol), **10** (0.49 mmol), $PdCl_2$ (5 mol %), PPh_3 (22 mol %), Bu_4NBr (10 mol %), K_2CO_3 (1.02 mmol) in dry DMF (6 mL) under argon at 85 °C for 0.5−1.7 h; then thiophenol (0.53 mmol) was added and stirred at rt for 2−3 h. [b]Yields of the isolated pure products. [c]A bis-heteroannulated product **9d** (Ar = 2-benzylquinoline-4′-yl) was isolated (for structure of **9d**, see Scheme 3 in text).

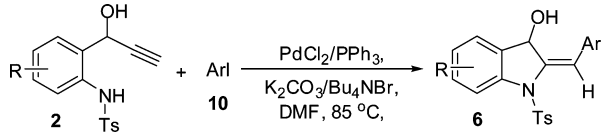
Scheme 2. Plausible Mechanism of Denosylation Leading to Products 9

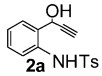
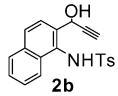


by treatment with methyl iodide (Scheme 3). Additionally, few of the products (**9a**, **9i**) are known[13a] to be easily transformed into their respective (*R*)-1,2,3,4-tetrahydroquinoline derivatives, with high enantioselectivity (94−95%) and yield (93−95%), upon iridium-catalyzed asymmetric hydrogenation. Thus, products **9** may also be used as substrates to access enantiopure 2-substituted tetrahydroqunolines, which are building blocks of many pharmaceuticals, agrochemicals, and bioactive natural products.[17]

In order to test the feasibility of the synthesis of products **6** as envisioned in Scheme 1, 1-(2-tosylaminophenyl)prop-2-yn-1-ol (**2a**) was prepared following the literature procedure[18] and allowed to react with phenyl iodide (**10a**) under our optimized reaction conditions. Gratifyingly, the reaction was found to be complete within only 10 min, affording (*E*)-2-(benzylidene)-indolin-3-ol **6a** in 63% yield (Table 4, entry 1). To demonstrate

Table 4. Synthesis of (*E*)-2-(Arylmethylidene)indolin-3-ols 6[a]

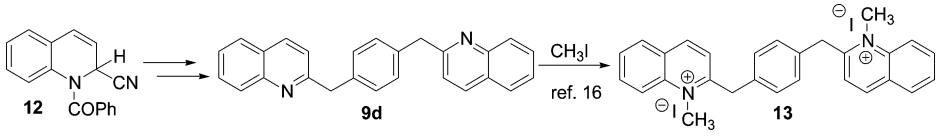


entry	alkyne 2	aryl iodide 10; Ar =	time (min)	product 6 (% yield)[b]
1.	 2a	**10a**; C_6H_5	10	**6a (63)**
2.	**2a**	**10b**; C_6H_4Me-*p*	10	**6b (55)**
3.	**2a**	**10d**; $C_6H_4CF_3$-p	5	**6c (60)**
4.	**2a**	**10i**; C_6H_4Br-*p*	10	**6d (52)**
5.	**2a**	**10j**; 2-thienyl	10	**6e (53)**
6.	**2a**	**10l**; 3-pyridyl	10	**6f (56)**
7.	**2a**	**10m**; 2,4-dimethoxy-5-pyrimidinyl	15	**6g (60)**
8.	**2a**	**10n**; C_6H_4OMe-*m*	10	**6h (52)**
9.	**2a**	**10o**; C_6H_4F-*p*	10	**6i (62)**
10.	 2b	**10a**; C_6H_5	15	**6j (48)**
11.	**2b**	**10d**; $C_6H_4CF_3$-*p*	10	**6k (54)**
12.	**2b**	**10g**; C_6H_3(Me-*o*)NO_2-*p*	10	**6l (52)**
13.	**2b**	**10n**; C_6H_4OMe-*m*	15	**6m (53)**
14.	**2b**	**10o**; C_6H_4F-*p*	7	**6n (56)**

[a]Reaction conditions: **2** (0.49 mmol), **10** (0.58 mmol), $PdCl_2$ (5 mol %), PPh_3 (22 mol %), K_2CO_3 (1.22 mmol), nBu_4NBr (10 mol %) in dry DMF (6 mL) under argon at 85 °C. [b]Yields of the isolated pure products.

the generality of this technique, a series of substituted aryl/heteroaryl iodides **10** were then employed in this reaction to produce (*E*)-2-(arylmethylidene)indolin-3-ols **6** (Table 4, entries 2−9). Employment of a starting alcohol with an embedded naphthalene ring moiety as in **2b** furnished the corresponding naphthyl analogues **6j−n** (Table 4, entries 10−14). All of the reactions proved to be very fast, being completed within a few minutes (5−15 min). Consistent with our previous results (Table 2), aryl iodides **10** bearing electron-withdrawing

Scheme 3. Synthesis of α,α′-Bis(2-quinolyl)-*p*-xylylene Dimethiodide 13[16]



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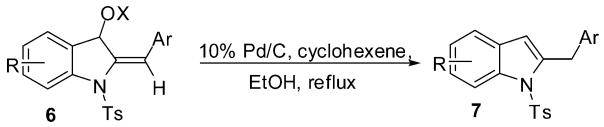
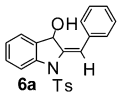
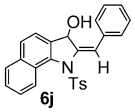
substituents apparently favored the reactions affording higher yields compared to those having electron-donating groups (Table 4, entries 3, 9, 11, 14 vs 2, 8, 13).

With the objective of effecting base-induced isomerization of the exocyclic double bond of products **6**, we treated the *O*-methylated product of **6a** with Cs_2CO_3 in THF/MeOH (2:1) at 65 °C, following the literature procedure[10c] applied previously on indoline derivatives of similar type. Unfortunately, no reaction took place in our case even after heating for several hours. However, during our attempts to reduce the exocyclic double bond of product **6a** through hydrogenolysis employing Pd/C and cyclohexene in refluxing ethanol, 2-benzylindole **7a** was formed directly with excellent yield (95%), rather than a simple indoline derivative. We then decided to investigate the scope of this transformation in the general synthesis of indoles **7** using our compounds **6** as potential substrates (Table 5). Apparently, the substituent in the aryl moiety of **6** does not have any significant effect on product formation as most of the products were obtained in very good to excellent yields. Additionally, substrates having an ether/ester moiety (e.g., OMe, OAc) instead of hydroxyl at C3 could also take part in this reaction (Table 5, entries 10 and 11). Even naphthyl analogue **6j** synthesized previously (Table 4) was found to participate in the reaction with equal ease, resulting in the naphthyl variant of product **7j** (Table 5, entry 12). Mechanistically, this reaction is possibly proceeding through reduction of the exocyclic double bond with concurrent elimination of water/alcohol/acid (XOH), as no transient indoline intermediate was found by monitoring the reaction (TLC).

Table 5. Synthesis of 2-Substituted Indoles 7[a]



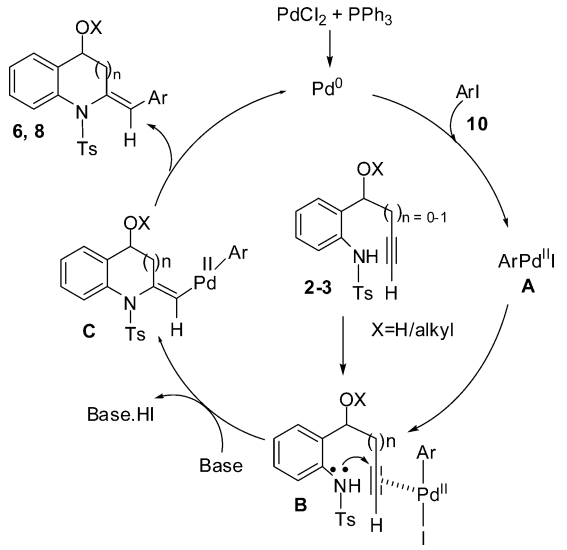
entry	substrate **6**	X/Ar	time (h)	product **7**	yield %[b]
1.	 **6a**	H / Ph	6	**7a**	95
2.	**6b**	H/C_6H_4Me-*p*	5.5	**7b**	84
3.	**6c**	H/$C_6H_4CF_3$-*p*	6	**7c**	91
4.	**6d**	H/C_6H_4Br-*p*	5.5	**7d**	76
5.	**6e**	H/2-thienyl	7	**7e**	85
6.	**6f**	H/3-pyridyl	9	**7f**	77
7.	**6g**	H/2,4-dimethoxy-5-pyrimidinyl	6	**7g**	85
8.	**6h**	H/C_6H_4OMe-*m*	6	**7h**	92
9.	**6i**	H/C_6H_4F-*p*	7	**7i**	81
10.	**6a'**	Me/Ph	6	**7a**	92
11.	**6a"**	Ac/Ph	6	**7a**	90
12.	 **6j**	H / Ph	6	**7j**	92

[a]Reaction conditions: **6** (0.26 mmol), 10% Pd/C (10 mol %), cyclohexene (3 mL) in dry ethanol (10.0 mL) under reflux. [b]Yields of the isolated pure products.

The identities of all new products were established by spectroscopic and analytical data. The (*E*)-stereochemistry of products **6** and **8** was deduced from various NMR measurements, including NOESY experiments. For instance, in ^{1}H NMR, vinylic proton signals of products **6**, **8** appeared in downfield region (δ_H > 7 ppm) due to the deshielding effect of the neighboring tosyl group.[19] With **8d**, the methylenic proton signals did not show any NOE with the peak for the olefinic proton, though individually they showed NOE with the *ortho*-proton signals of *p*-trifluoromethyl benzene ring. Finally, single-crystal X-ray diffraction analysis of products **6a** and **8d** confirmed this geometry (see the Supporting Information).

A plausible reaction mechanism to explain the products (**6**, **8**) formation is outlined in Scheme 3. Oxidative addition of aryl iodide **10** to Pd^0, formed in situ from $PdCl_2$ and PPh_3,[20] generates intermediate $ArPd^{II}I$ (**A**). Species **A**, acting like a Lewis acid, then activates the triple bond which undergoes intramolecular nucleophilic attack[21] by the nitrogen of sulphonamide in proximity (as shown in species **B**) through *trans*-aminopalladation[22] followed by base induced deprotonation, resulting in the formation of (*E*)-vinyl palladium species **C**. Finally, the reductive elimination of Pd^0 furnish the products[23] **6** and **8** ensuring *E*-stereochemistry.

Scheme 4. Plausible Mechanism for the Synthesis of Products 6 and 8



CONCLUSION

In conclusion, we have developed a palladium-catalyzed facile method for the general synthesis of (*E*)-2-arylmethylidene-*N*-tosylindolines and their quinoline variants starting from the readily available 1-(2-tosylaminophenyl)prop-2-yn-1-ol and their higher homologues, respectively. The method is fast,

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operationally simple, totally regio- and stereoselective, and efficient for accessing a variety of 2-substituted indoles and quinolines. The synthesis of 2-substituted quinolines **9** can be either achieved in one pot or halted at the stage of (*E*)-2-arylmethylidene-*N*-tosyl/nosyltetrahydroquinolines **8**. The proposed reaction mechanism invokes the operation of *trans*-aminopalladation during cyclization (5/6-*exo*-*dig*), which ensures exclusive (*E*)-stereochemistry in the products. The synthetic utility of the exocyclic double bond in the products is likely to be explored[10d] further for library generation based on diversity oriented synthesis; the work in this direction and the enzymatic kinetic resolution of 3/4-acetoxy derivatives of products **6**/**8** are currently underway. We believe that this flexible approach has the potential to be equally useful in organic and medicinal chemistry.

EXPERIMENTAL SECTION

Preparation of Starting Substrates 2 and 3 (for Schematic Representation, See the Supporting Information). *Procedure for the Synthesis of Starting Substrate* ***2a****.* To a solution of 2-nitrobenzaldehyde (2.0 g, 13.23 mmol) in dry THF was added 0.5 M ethynylmagnesium bromide solution in THF (39.70 mL) dropwise at 0 °C under nitrogen atmosphere for 45 min.[18] After completion of reaction (TLC), the reaction mixture was quenched with saturated NH_4Cl solution at 0 °C. THF was evaporated under reduced pressure, and the residue was extracted with ethyl acetate (3 × 50 mL). The combined organic extracts were washed with water (30 mL) and brine (30 mL), dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The residue was purified through silica gel (100−200 mesh) column chromatography (ethyl acetate−petroleum ether) to afford the acetylenic carbinol (2.3 g, 98%).

The previous acetylenic carbinol (2.0 g, 11.28 mmol) was dissolved in MeOH (10 mL), and $SnCl_2·H_2O$ (12.7 g, 56.44 mmol) and $NaBH_4$ (1.7 g, 45.15 mmol) were added successively at 0 °C.[18] Upon completion of the reaction (TLC), the mixture was quenched with saturated aqueous ammonia at 0 °C, filtered through Celite, and concentrated under reduced pressure. The resulting residue was purified through silica gel (100−200 mesh) column chromatography (ethyl acetate−petroleum ether) to afford the amine derivative (1.2 g, 72%) as a yellow solid.

To a solution of the preivous amine (1 g, 6.79 mmol) in DCM (20 mL) were added consecutively pyridine (0.82 mL, 10.19 mmol), and *p*-toluenesulfonyl chloride (1.55 g, 8.15 mmol) at 0 °C, and the reaction mixture was allowed to stir at room temperature overnight. After completion of the reaction, the mixture was extracted with DCM (2 × 25 mL), washed with water (10 mL) and brine (10 mL), dried over anhydrous Na_2SO_4, and concentrated under reduced pressure. The resulting residue was purified through silica gel (100−200 mess) column chromatography (ethyl acetate−petroleum ether) to afford the desired tosyl derivative **2a** (1.6 g, 78%).

The same reaction protocol was applied to synthesize the naphthyl analogue **2b**, starting from substrate 1-nitro-2-naphthaldehyde.

*1-(2-(Tosylamino)phenyl)prop-2-yn-1-ol (**2a**):*[10b] colorless solid (1.6 g, 78% yield); mp 106−107 °C; IR (KBr) 3504, 3430, 3330, 3268, 3065, 2884, 2788, 2107, 1593, 1497, 1402, 1322, 1159, 1087, 916, 835 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.75 (brs, 1H), 7.67 (d, *J* = 8.1 Hz, 2H), 7.52 (d, *J* = 7.8 Hz, 1H), 7.38 (dd, *J* = 8.1, 0.6 Hz, 1H), 7.30−7.27 (m, 1H), 7.23 (d, *J* = 8.1 Hz, 2H), 7.14 (t, *J* = 7.5 Hz, 1H), 5.29 (d, *J* = 1.2 Hz, 1H), 2.87 (brs, 1H), 2.67 (d, *J* = 2.1 Hz, 1H), 2.39 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 143.9, 136.3, 135.07, 131.2, 129.6, 129.6, 128.3, 127.1, 125.5, 123.2, 81.4, 76.3, 62.2, 21.4; MS (FAB+) *m*/*z* 301.10 [M^+].

*1-(1-(Tosylamino)naphthyl)prop-2-yn-1-ol (**2b**).* Synthesis of compound **2b** was accomplished according to the procedure of **2a**, starting from commercially available substrate 1-nitro-2-naphthaldehyde. However, during the tosylation step, dichloromethane was replaced by acetonitrile as solvent: colorless solid (1.0 g, 42% yield); mp 126−128 °C; IR (KBr) 3526, 3292, 3247, 3061, 1596, 1503, 1390, 1324, 1233, 1159, 1084, 1025, 817 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.97 (d, *J* = 8.7 Hz, 1H), 7.88 (d, *J* = 8.4 Hz, 1H), 7.78 (d, *J* = 8.1 Hz, 1H), 7.45 (d, *J* = 8.1 Hz, 2H), 7.38 (t, *J* = 7.6, Hz, 1H), 7.32 (d, *J* = 8.7 Hz, 1H), 7.16−7.10 (m, 3H), 6.79 (brs, 1H), 6.04 (brs, 1H), 2.66 (d, *J* = 2.1 Hz, 1H), 2.52 (brs, 1H), 2.35 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 144.1, 137.7, 135.7, 134.0, 130.4, 129.6, 129.2, 127.9, 127.9, 127.2, 126.4, 125.8, 122.9, 83.0, 75.1, 60.6, 21.4; MS (ESI +) *m*/*z* 374.0 [M + Na]$^+$. Anal. Calcd for $C_{20}H_{17}NO_3S$: C, 68.36; H, 4.88; N, 3.99. Found: C, 68.31; H, 4.92; N, 4.04.

Procedure for the Synthesis of Starting Substrates ***3a−f****.* To a well-stirred mixture of activated zinc (7.74 g, 119.10 mmol) in THF (60 mL) was added propargyl bromide (4.3 mL, 49.62 mmol) and the mixture allowed to stir at 0 °C for 1 h. Next, 2-nitrobenzaldehyde (3 g, 19.85 mmol) was added to the reaction mixture and stirred at the same temperature for another 2 h. Saturated aqueous NH_4Cl solution (60 mL) was then added at 0 °C, and the reaction mixture was stirred for another 30 min. After completion of the reaction (TLC), the reaction mixture was filtered, and the filtrate was treated with 10% HCl (20 mL). It was then extracted with ethyl acetate (3 × 50 mL), and the combined organic extracts were dried over Na_2SO_4 and concentrated under reduced pressure. The resulting brown liquid residue was purified through silica gel (100−200 mess) column chromatography (ethyl acetate−petroleum ether) to afford the requisite acetylenic carbinol [i.e., 1-(2-nitrophenyl)but-3-yn-1-ol] (1.4 g, 38%).

To an ice-cooled solution of 1-(2-nitrophenyl)but-3-yn-1-ol (1.5 g, 7.84 mmol) in DMF (50 mL) was added sodium hydride (0.28 g, 11.76 mmol) and the mxiture stirred at 0 °C for 5 min. Then methyl iodide or benzyl bromide (9.4 mmol) was added, and the whole mixture was allowed to stir until completion of the reaction (TLC). It was then quenched with saturated NH_4Cl solution at 0 °C, and the solvent was removed under reduced pressure. The resulting residue was extracted with ethyl acetate (3 × 40 mL) and washed with water (30 mL) and brine (30 mL), successively. The organic layer was dried over anhydrous Na_2SO_4 and concentrated under reduced pressure. The resulting residue was purified through silica gel (100−200 mesh) column chromatography (ethyl acetate−petroleum ether) to afford the methyl/benzyl ether derivative (76−80%) of 1-(2-nitrophenyl)but-3-yn-1-ol.

To a solution of the previous methyl (or benzyl) ether derivative (6.28 mmol) in EtOH (20 mL) were added successively Fe powder (1.75 g, 31.4 mmol) and 20% aqueous acetic acid (20 mL). The mixture was refluxed for 2 h under vigorous stirring. It was cooled and filtered through Celite, and the filtrate was evaporated under reduced pressure. The crude residue was dissolved in ethyl acetate (40 mL), and the pH of the solution was adjusted to 7 by dropwise addition of aqueous $NaHCO_3$ solution. The mixture was then washed with water (30 mL), dried over anhydrous Na_2SO_4, and concentrated under reduced pressure. The crude product was purified by silica gel (100−200 mesh) column chromatography (with ethyl acetate−petroleum ether as eluent) to afford the amine derivative (53−65%).

Thereafter, *N*-tosylation (or *N*-nosylation) of the amine derivative was carried out according to the previous procedure for the preparation of **2a** to afford the requisite substrates **3a−c**,**f**.

*N-[2-(1-Methoxybut-3-ynyl)phenyl]-4-methylbenzenesulfonamide (**3a**).* Tosylated substrate **3a** was synthesized from 2-(1-methoxybut-3-ynyl)aniline (1 g, 5.70 mmol). Amorphous solid (1.42 g, 76% yield): IR (KBr) 3270, 2984, 2935, 2830, 1592, 1491, 1450, 1395, 1322, 1157, 1091 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.26 (brs, 1H), 7.72 (d, *J* = 8.4 Hz, 2H), 7.58 (d, *J* = 8.1 Hz, 1H), 7.28−7.23 (m, 3H), 7.09−7.02 (m, 2H), 4.30 (t, *J* = 7.2 Hz, 1H), 3.22 (s, 3H), 2.52 (ddd, *J* = 16.6, 7.2, 2.7 Hz, 1H), 2.37 (s, 3H), 2.21 (ddd, *J* = 16.6, 7.2, 2.7 Hz, 1H), 1.94 (t, *J* = 2.7 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 143.8, 136.8, 135.4, 129.7, 129.3, 129.0, 128.4, 126.9, 124.2, 120.9, 82.5, 79.9, 70.4, 57.1, 25.6, 21.4; MS (ESI+) *m*/*z* 352.22 [M + Na]$^+$. Anal. Calcd for $C_{18}H_{19}NO_3S$: C, 65.63; H, 5.81; N, 4.25. Found: C, 65.60; H, 5.84; N, 4.29.

*N-[2-(1-Methoxybut-3-ynyl)phenyl]-4-nitrobenzenesulfonamide (**3b**).* Nosylated substrate **3b** was synthesized from 2-(1-methoxybut-3-ynyl)aniline (1 g, 5.70 mmol): colorless solid (1.84 g, 90% yield); mp 102−103 °C; IR (KBr) 3289, 3102, 2935, 1604, 1530, 1406, 1351,

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1168, 1096, 920 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.52 (brs, 1H), 8.31 (d, J = 9 Hz, 2H), 8.02 (d, J = 8.7 Hz, 2H), 7.59 (d, J = 8.1 Hz, 1H), 7.33−7.28 (m, 1H), 7.12−7.10 (m, 2H), 4.31 (t, J = 7.2 Hz, 1H), 3.27 (s, 3H), 2.53 (ddd, J = 16.8, 6.6, 2.4 Hz, 1H), 2.18 (ddd, J = 16.8, 7.6, 2.4 Hz, 1H), 1.91 (t, J = 2.4 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 150.1, 145.4, 134.6, 129.8, 129.3, 128.6, 128.2, 124.9, 124.4, 120.9, 82.6, 79.3, 70.9, 57.3, 25.5; MS (ESI+) m/z 383.11 $[M + Na]^+$. Anal. Calcd for $C_{17}H_{16}N_2O_5S$: C, 56.66; H, 4.47; N, 7.77. Found: C, 56.69; H, 4.49; N, 7.74.

*N-[2-(1-Benzyloxybut-3-ynyl)phenyl]-4-methylbenzenesulfonamide (**3c**).* Tosylated substrate **3c** was synthesized from 2-(1-(benzyloxy)but-3-ynyl)aniline (1 g, 3.97 mmol): colorless solid (1.15 g, 72% yield); mp 95−96 °C; IR (KBr) 3267, 3059, 2921, 1590, 1489, 1395, 1338, 1161, 1099, 1034 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.32 (brs, 1H), 7.65 (d, J = 8.1 Hz, 2H), 7.59 (d, J = 8.4 Hz, 1H), 7.38−7.31 (m, 3H), 7.28−7.23 (m, 3H), 7.20 (d, J = 8.1 Hz, 2H), 7.09−7.03 (m, 2H), 4.50 (t, J = 7.2 Hz, 1H), 4.41 (d, J = 11.7 Hz, 1H), 4.21 (d, J = 11.7 Hz, 1H), 2.62 (ddd, J = 16.8, 6.7, 2.4 Hz, 1H), 2.34−2.25 (m, 4H), 1.93 (t, J = 2.4 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 143.7, 136.8, 136.5, 135.5, 129.6, 129.2, 129.0, 128.6, 128.4, 127.9, 127.6, 126.9, 124.2, 120.9, 79.9, 79.6, 70.9, 70.5, 25.7, 21.3; MS (ESI+) m/z 428.37 $[M + Na]^+$. Anal. Calcd for $C_{24}H_{23}NO_3S$: C, 71.09; H, 5.72; N, 3.45. Found: C, 71.05; H, 5.69; N, 3.41.

*1-(2-(Tosylamino)phenyl)but-3-yn-1-ol (**3d**).* Tosylated substrate **3d** was synthesized from 1-(2-aminophenyl)-but-3-yn-1-ol (1 g, 6.2 mmol): pale yellow solid (1.07 g, 55% yield); mp 68−70 °C; IR (KBr) 3466, 3294, 3123, 2926, 2804, 2306, 2115, 1916, 1593, 1491, 1410, 1315, 1228, 1160, 1095 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.29 (brs, 1H), 7.69 (d, J = 8.1 Hz, 2H), 7.41 (d, J = 8.1 Hz, 1H), 7.25−7.18 (m, 3H), 7.13−7.04 (m, 2H), 4.81 (t, J = 6.7 Hz, 1H), 2.94 (brs, 1H), 2.55−2.38 (m, 5H), 2.08 (brs, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 143.8, 136.5, 135.3, 132.0, 129.6, 128.7, 127.7, 127.0, 124.9, 122.4, 80.0, 71.6, 71.3, 27.1, 21.4; MS (ESI+) m/z 337.99 $[M + Na]^+$. Anal. Calcd for $C_{17}H_{17}NO_3S$: C, 64.74; H, 5.43; N, 4.44. Found: C, 64.71; H, 5.40; N, 4.47.

*1-(2-(Nosylamino)phenyl)but-3-yn-1-ol (**3e**).* Nosylated substrate **3e** was synthesized from 1-(2-aminophenyl)but-3-yn-1-ol (1 g, 6.2 mmol): amorphous solid (1.86 g, 87% yield); IR (neat) 3512, 3289, 3106, 2919, 1947, 1604, 1530, 1403, 1348, 1164 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.67 (brs, 1H), 8.29 (d, J = 9 Hz, 2H), 8.00 (d, J = 9.0 Hz, 2H), 7.44 (d, J = 7.8 Hz, 1H), 7.28−7.21 (m, 1H), 7.14−7.08 (m, 2H), 4.81 (dd, J = 7.8, 5.5 Hz, 1H), 3.07 (brs, 1H), 2.57−2.39 (m, 2H), 2.10 (t, J = 2.7 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 150.1, 145.4, 134.8, 130.8, 129.2, 128.3, 128.0, 125.3, 124.3, 121.8, 79.4, 72.3, 72.2, 27.5; MS (ESI+) m/z 369.27 $[M + Na]^+$. Anal. Calcd for $C_{16}H_{14}N_2O_5S$: C, 55.48; H, 4.07; N, 8.09. Found: C, 55.45; H, 4.10; N, 8.12.

*N-[2-(1-Benzyloxybut-3-ynyl)phenyl]-4-nitrobenzenesulfonamide (**3f**).* Nosylated substrate **3f** was synthesized from 2-(1-(benzyloxy)-but-3-ynyl)aniline (0.5 g, 1.98 mmol): amorphous solid (0.7 g, 81% yield); IR (KBr) 3290, 3104, 3036, 2871, 1603, 1531, 1496, 1406, 1349, 1166, 1087 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.64 (brs, 1H), 8.22 (d, J = 9 Hz, 2H), 7.87 (d, J = 8.7 Hz, 2H), 7.58 (d, J = 8.1 Hz, 1H), 7.42−7.26 (m, 6H), 7.10 (m, 2H), 4.53 (t, J = 7.2 Hz, 1H), 4.46 (d, J = 11.7 Hz, 1H), 4.38 (d, J = 11.7 Hz, 1H), 2.64 (ddd, J = 16.8, 6.6, 2.7 Hz, 1H), 2.30 (ddd, J = 16.8, 7.8, 2.7 Hz, 1H), 1.91 (t, J = 2.5 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 150.0, 145.3, 136.3, 134.8, 129.9, 129.4, 128.6, 128.4, 128.3, 128.2, 127.7, 124.7, 124.3, 120.4, 80.1, 79.3, 71.3, 71.0, 25.6; MS (ESI+) m/z 459.11 $[M + Na]^+$. Anal. Calcd for $C_{23}H_{20}N_2O_5S$: C, 63.29; H, 4.62; N, 6.42. Found: C, 63.33; H, 4.59; N, 6.46.

*General Procedure for the Synthesis of (E)-2-Arylmethylidene-N-tosyl/nosylquinolines **8**.* A mixture of $PdCl_2$ (5.3 mg, 0.03 mmol, 5 mol %) and PPh_3 (39.3 mg, 0.15 mmol, 22 mol %) in dry DMF (6 mL) was stirred at room temperature for 5 min under argon atmosphere. Aryl iodide **10** (0.72 mmol) was added to the reaction mixture with stirring at room temperature for another 5 min. Next, K_2CO_3 (207.3 mg, 1.50 mmol) and tetrabutylammonium bromide (23.2 mg, 0.072 mmol, 10 mol %) and acetylenic carbinol **3** (0.60 mmol) were added successively. The resulting mixture was flushed with argon carefully, and the whole reaction mixture was heated at 85 °C until completion of the reaction (TLC). Upon completion, the solvent was removed in vacuo; the residue was mixed with water (10 mL) and then extracted with ethyl acetate (3 × 20 mL). The combined organic extracts were washed with brine (10 mL), dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The resulting residue was purified through silica gel (100−200 mesh) column chromatography (ethyl acetate−petroleum ether) to afford pure product **8**.

*(E)-2-Benzylidene-4-methoxy-1-(toluene-4-sulfonyl)-1,2,3,4-tetrahydroquinoline (**8a**):* colorless solid (167.8 mg, 69% yield); mp 102−104 °C; IR (KBr) 3058, 2925, 1636, 1597, 1485, 1452, 1357, 1240, 1165, 1091 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.77 (d, J = 8.1 Hz, 1H), 7.50 (d, J = 8.1 Hz, 2H), 7.38−7.33 (m, 3H), 7.30−7.23 (m, 5H), 7.20 (d, J = 8.1 Hz, 2H), 7.15 (s, 1H), 3.48 (t-like, J = 6.4 Hz, 1H), 3.07 (s, 3H), 2.69 (dd, J = 15.5, 5.7 Hz, 1H), 2.52 (dd, J = 15.5, 7.3 Hz, 1H), 2.38 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 144.0, 136.3, 136.2, 135.5, 132.2, 132.1, 129.4, 128.8, 128.3, 128.2, 127.2, 126.6, 126.4, 126.1, 73.8, 56.3, 32.4, 21.5; HRMS (EI+) calcd for $C_{24}H_{23}NO_3S$ $[M]^+$ 405.1398, found 405.1397.

*(E)-2-(4-Methylbenzylidene)-4-methoxy-1-(toluene-4-sulfonyl)-1,2,3,4-tetrahydroquinoline (**8b**):* amorphous solid (140.9 mg, 56% yield); IR (KBr) 2923, 2360, 1597, 1483, 1453, 1357, 1165, 1091 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.76 (d, J = 7.8 Hz, 1H), 7.50 (d, J = 8.1 Hz, 2H), 7.38−7.33 (m, 2H), 7.30−7.23 (m, 2H), 7.21−7.18 (m, 5H), 7.11 (s, 1H), 3.46 (t-like, J = 6.6 Hz, 1H), 3.08 (s, 3H), 2.72 (dd, J = 15.4, 5.4 Hz, 1H), 2.51 (dd, J = 15.4, 7.6 Hz, 1H), 2.39 (s, 3H), 2.35 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 143.9, 137.0, 136.3, 136.2, 132.6, 132.3, 131.3, 129.4, 129.0, 128.7, 128.5, 128.3, 127.7, 126.6, 126.3, 126.1, 73.8, 56.4, 32.5, 21.5, 21.1; HRMS (ESI+) calcd for $C_{25}H_{25}NNaO_3S$ ($[M + Na]^+$) 442.1452, found 442.1489.

*(E)-2-(4-Methoxybenzylidene)-4-methoxy-1-(toluene-4-sulfonyl)-1,2,3,4-tetrahydroquinoline (**8c**):* amorphous solid (156.7 mg, 60% yield); IR (neat) 2929, 2831, 1727, 1603, 1509, 1455, 1356, 1296, 1248, 1169, 1091 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.76 (d, J = 8.1 Hz, 1H), 7.50 (d, J = 8.1 Hz, 2H), 7.38−7.19 (m, 7H), 7.08 (brs, 1H), 6.89 (d, J = 8.7 Hz, 2H), 3.82 (s, 3H), 3.46 (t-like, J = 6.6 Hz, 1H), 3.08 (s, 3H), 2.71 (ddd, J = 15.4, 5.8, 1.2 Hz, 1H), 2.53 (ddd, J = 15.4, 7.5, 1.2 Hz, 1H), 2.39 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 158.7, 143.9, 136.4, 136.3, 132.3, 130.4, 130.1,129.4, 128.3, 128.1, 127.9, 127.7, 126.6, 126.3, 126.0, 113.8, 73.8, 56.4, 55.2, 32.5, 21.5; HRMS (ESI+) calcd for $C_{25}H_{25}NNaO_4S$($[M + Na]^+$) 458.1402, found 458.1404.

*(E)-2-(4-Trifluoromethylbenzylidene)-4-methoxy-1-(toluene-4-sulfonyl)-1,2,3,4-tetrahydroquinoline (**8d**):* colorless solid (213 mg, 75% yield); mp 124−126 °C; IR (KBr) 3065, 2926, 1663, 1607, 1483, 1454, 1360, 1324, 1165, 1116 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 7.78 (d, J = 7.8 Hz, 1H), 7.61 (d, J = 8.4 Hz, 2H), 7.49 (d, J = 8.4 Hz, 2H), 7.41−7.37 (m, 3H), 7.29−7.24 (m, 2H), 7.21 (d, J = 7.8 Hz, 2H), 7.18 (brs, 1H), 3.47 (t-like, J = 6.3 Hz, 1H), 3.08 (s, 3H), 2.64 (ddd, J = 15.6, 5.4, 1.8 Hz, 1H), 2.56 (ddd, J = 15.6, 7.2, 1.8 Hz, 1H), 2.39 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 144.2, 139.3, 136.0, 134.0, 132.1, 129.5, 129.1, 128.4, 127.8, 126.7, 126.5, 126.4, 126.3, 125.3 (multiplet), 73.8, 56.5, 32.9, 21.5; HRMS (ESI+) calcd for $C_{25}H_{22}F_3NNaO_3S$ $[M + Na]^+$ 496.1170, found 496.1179.

*(E)-2-(4-Carbomethoxybenzylidene)-4-methoxy-1-(toluene-4-sulfonyl)-1,2,3,4-tetrahydrquinoline (**8e**):* colorless solid (189.1 mg, 68% yield); mp 104−105 °C; IR (KBr) 3429, 2929, 2831, 1721, 1602, 1441, 1359, 1280, 1170, 1106 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.02 (d, J = 8.4 Hz, 2H), 7.77 (d, J = 7.8 Hz, 1H), 7.50 (d, J = 8.1 Hz, 2H), 7.40−7.34 (m, 3H), 7.29−7.24 (m, 2H), 7.21 (d, J = 8.1 Hz, 2H), 7.17 (brs, 1H), 3.92 (s, 3H), 3.49 (t-like, J = 6.3 Hz, 1H), 3.07 (s, 3H), 2.68 (ddd, J = 15.7, 5.6, 1.5 Hz, 1H), 2.58 (ddd, J = 15.7, 7.2, 1.5 Hz, 1H), 2.39 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 166.7, 144.1, 140.3, 137.6, 136.0, 133.9, 132.0, 130.9, 129.6, 129.4, 128.7, 128.6, 128.3, 127.7, 127.0, 126.5, 126.4, 126.2, 73.4, 56.4, 55.0, 21.5; HRMS (EI+) calcd for $C_{26}H_{25}NO_5S$ $[M]^+$ 463.1453, found 463.1451.

*1,4-Bis[(E)-4-methoxy-1-(toluene-4-sulfonyl)-1,2,3,4-tetrahydroquinoline-2-methylideno]benzene (**8f**).* Synthesis of product **8f** was accomplished according to the general procedure of 8 using 1,4-

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diiodobenzene (0.303 mmol) and acetylene **3a** (0.606 mmol): colorless solid (124.3 mg, 56% yield); mp 174−176 °C; IR (KBr) 2925, 1596, 1484, 1454, 1358, 1240, 1166, 1091 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.77 (d, J = 8.1 Hz, 2H), 7.50 (d, J = 8.1 Hz, 4H), 7.39−7.34 (m, 4H), 7.29−7.24 (m, 6H), 7.21 (d, J = 8.1 Hz, 4H), 7.13 (s, 2H), 3.48 (t-like, J = 6.4 Hz, 2H), 3.09 (s, 6H), 2.75 (dd, J = 15.3, 5.4 Hz, 2H), 2.56 (dd, J = 15.3, 6.9 Hz, 2H), 2.39 (s, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 144.0, 136.2, 134.5, 132.3, 129.4, 128.8, 128.2, 127.8, 127.7, 126.6, 126.25, 126.2, 73.8, 56.5, 32.9, 21.5; MS (ESI+) m/z 755.45 $[M + Na]^+$; HRMS (ESI+) calcd for $C_{42}H_{40}N_2NaO_6S_2$ $[M + Na]^+$ 755.2225, found 755.2226.

*(E)-2-Benzylidene-4-methoxy-1-(4-nitrobenzenesulfonyl)-1,2,3,4-tetrahydroquinoline (**8g**):* brown solid (178.0 mg, 68% yield); mp 124−125 °C; IR (KBr) 2929, 1601, 1530, 1484, 1354, 1171, 1088 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.25 (d, J = 8.7 Hz, 2H), 7.84−7.79 (m, 3H), 7.45−7.35 (m, 4H), 7.30−7.26 (m, 4H), 7.19 (s, 1H), 3.73 (t-like, J = 5.4 Hz, 1H), 2.94 (s, 3H), 2.80−2.66 (m, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 150.1 144.7, 135.1, 135.1, 131.6, 131.4, 129.2, 128.8, 127.8, 127.5, 126.6, 126.5, 123.7, 74.0, 56.2, 33.0; HRMS (EI+) calcd for $C_{23}H_{20}N_2O_5S$ $[M]^+$ 436.1092, found 436.1093.

*(E)-2-(4-Trifluoromethylbenzylidene)-4-methoxy-1-(4-nitrobenzenesulfonyl)-1,2,3,4-tetrahydroquinoline (**8h**):* brown amorphous solid (217.9 mg, 72% yield); IR (KBr) 3103, 2930, 1609, 1530, 1482, 1323, 1168, 1119, 1012 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.24 (d, J = 9 Hz, 2H), 7.83−7.79 (m, 3H), 7.68−7.22 (m, 8H), 3.73 (t-like, J = 5.1 Hz, 1H), 2.93 (s, 3H), 2.81 (ddd, J = 16.3, 5.1, 1.5. Hz, 1H), 2.65 (ddd, J = 16.3, 5.2, 1.8, Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 150.1, 144.3, 138.8, 135.8, 133.6, 129.2, 129.0, 128.5, 128.3, 127.9, 126.7, 126.6, 126.5, 125.4 (m), 123.7, 73.9, 56.3, 33.4; HRMS (EI+) calcd for $C_{24}H_{19}F_3N_2O_5S$ $[M]^+$ 504.0966, found 504.0970.

*(E)-2-(Benzylidene)-4-benzyloxy-1-(toluene-4-sulfonyl)-1,2,3,4-tetrahydroquinoline (**8i**):* brown amorphous solid (170.4 mg, 59% yield); IR (neat) 3058, 3030, 2924, 2859, 1641, 1596, 1486, 1451, 1357, 1240, 1165, 1087 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.78 (d, J = 7.8 Hz, 1H), 7.49 (d, J = 8.1 Hz, 2H), 7.36−7.34 (m, 5H), 7.28−7.22 (m, 6H), 7.19−7.12 (m, 5H), 4.29 (d, J = 11.7 Hz, 1H), 4.23 (d, J = 11.7 Hz, 1H), 3.77 (t-like, J = 6.6 Hz, 1H), 2.72 (dd, J = 15.4, 4.8 Hz, 1H), 2.58 (dd, J = 15.4, 6.4 Hz, 1H), 2.33 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 144.0, 137.8, 136.4, 136.2, 135.5, 132.3, 132.1, 129.4, 128.8, 128.5, 128.3, 128.1, 127.7, 127.6, 127.3, 127.2, 126.6, 126.5, 126.4, 126.1, 71.9, 70.6, 32.8, 21.5; HRMS (ESI+) calcd for $C_{30}H_{27}NNaO_3S$ $[M + Na]^+$ 504.1609, found 504.1662.

*(E)-2-(4-Methylbenzylidene)-4-benzyloxy-1-(toluene-4-sulfonyl)-1,2,3,4-tetrahydrquinoline (**8j**):* brown amorphous solid (136.7 mg, 46% yield); IR (KBr) 3030, 2920, 2864, 1597, 1486, 1453, 1356, 1165, 1088 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.77 (d, J = 8.1 Hz, 1H), 7.49 (d, J = 8.1 Hz, 2H), 7.38−7.24 (m, 6H), 7.21−7.10 (m, 9H), 4.29 (d, J = 12 Hz, 1H), 4.23 (d, J = 12 Hz, 1H), 3.75 (t-like, J = 6.7 Hz, 1H), 2.75 (dd, J = 15.4, 5.8 Hz, 1H), 2.56 (dd, J = 15.4, 7.9 Hz, 1H), 2.36 (s, 3H), 2.33 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 143.9, 137.0, 136.4, 136.2, 132.5, 132.4, 131.1, 129.4, 129.0, 128.7, 128.5, 128.3, 128.0, 127.7, 127.6, 127.3, 126.5, 126.3, 126.1, 71.9, 70.6, 32.9, 21.4, 21.1; HRMS (ESI+) calcd for $C_{31}H_{29}NNaO_3S$ $[M + Na]^+$ 518.1765, found 518.1720.

*(E)-2-Benzylidene-1-(toluene-4-sulfonyl)-1,2,3,4-tetrahydroquinolin-4-ol (**8k**):* brown amorphous solid (112.7 mg, 48% yield); IR (KBr) 3512, 3027, 2921, 1643, 1597, 1486, 1452, 1352, 1236, 1162, 1086 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 7.81 (d, J = 7.8 Hz, 1H), 7.49 (d, J = 8.4 Hz, 2H), 7.38−7.34 (m, 4H), 7.31 (d, J = 7.2 Hz, 2H), 7.28−7.22 (m, 2H), 7.19 (d, J = 7.8 Hz, 2H), 7.15 (s, 1H), 4.13 (d, J = 4.2 Hz, 1H), 2.59−2.52 (m, 2H), 2.38 (s, 3H), 1.73 (d, J = 4.8 Hz, 1H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 144.2, 136.2, 136.1, 135.2, 133.2, 131.6, 130.1, 129.6, 128.9, 128.4, 127.7, 127.4, 126.7, 126.3, 126.1, 65.6, 35.1, 21.6; HRMS (EI+) calcd for $C_{23}H_{21}NO_3S$ $[M]^+$ 391.1242, found 391.1242.

*(E)-2-Benzylidene-1-(4-nitrobenzenesulfonyl)-1,2,3,4-tetrahydroquinolin-4-ol (**8l**):* pale yellow solid (141.9 mg, 56% yield); mp 149−150 °C; IR (KBr) 3552, 3106, 2919, 1603, 1530, 1483, 1353, 1234, 1168 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.25 (d, J = 8.7 Hz, 1H), 7.85−7.79 (m, 3H), 7.44−7.28 (m, 8H), 7.20 (s, 1H), 4.17 (t-like, J = 5.8 Hz, 1H), 2.67 (dd, J = 15.1, 6.4 Hz, 1H), 2.56 (dd, J = 15.1, 5.5 Hz, 1H), 1.70 (d, J = 6.6 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 150.2, 144.6, 135.4, 134.6, 133.3, 130.8, 130.7, 128.9, 128.8, 128.5, 127.8, 127.0, 126.9, 125.9, 124.1, 65.4, 35.3; HRMS (EI+) calcd for $C_{22}H_{18}N_2O_5S$ $[M]^+$ 422.0936, found 422.0937.

*General Procedure for the Synthesis of 2-Substituted Quinolines **9**.* A mixture of $PdCl_2$ (3.5 mg, 0.02 mmol, 5 mol %) and PPh_3 (26.2 mg, 0.10 mmol, 22 mol %) in dry DMF (6 mL) was stirred at room temperature for 5 min under argon atmosphere. Aryl iodide **10** (0.49 mmol) was then added to the reaction mixture with stirring at room temperature for another 5 min. Next, K_2CO_3 (140.7 mg, 1.02 mmol) and tetrabutylammonium bromide (12.8 mg, 0.04 mmol, 10 mol %) and acetylenic carbinol **3** (0.41 mmol) were added successively. The resulting mixture was flushed with argon carefully and heated at 85 °C until the completion of the reaction. After disappearance of starting materials (TLC), thiophenol (58.3 mg, 0.53 mmol) was added to the reaction mixture, and the resulting solution was stirred under argon atmosphere at room temperature for another 2−3 h until completion. Upon completion of the reaction (TLC), the solvent was removed in vacuo; the residue was mixed with water (10 mL) and extracted with ethyl acetate (3 × 15 mL). The combined organic extracts were washed with brine (10 mL), dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The resulting residue was then purified through silica gel (100−200 mesh) column chromatography (ethyl acetate−petroleum ether) to afford the pure product **9**.

*2-Benzylquinoline (**9a**):*[13a] brownish oil (57.5 mg, 64% yield); IR (neat) 3056, 2924, 2392, 1972, 1599, 1497, 1448, 1363, 1308, 1169. cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.09 (d, J = 8.4 Hz, 1H), 8.03 (d, J = 8.4 Hz, 1H), 7.76 (d, J = 7.8 Hz, 1H), 7.73−7.68 (m, 1H), 7.53−7.47 (m, 1H), 7.31−7.30 (m, 4H), 7.25−7.21 (m, 2H), 4.35 (s, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 161.2, 147.7, 139.1, 136.5, 129.5, 129.2, 128.8, 128.6, 127.5, 126.7, 126.5, 126.0, 121.5, 45.4; MS (ESI+) m/z 220.11 $[M + H]^+$, 242.09 $[M + Na]^+$.

*2-(4-Methylbenzyl)quinoline (**9b**):* reddish-brown oil (53.5 mg, 56% yield); IR (neat) 3051, 2922, 1910, 1599, 1507, 1478, 1359, 1167, 1093 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.08 (d, J = 8.4 Hz, 1H), 8.02 (d, J = 8.7 Hz, 1H), 7.77−7.67 (m, 2H), 7.52−7.47 (m, 1H), 7.23−7.18 (m, 3H), 7.11 (d, J = 8.1 Hz, 2H), 4.30 (s, 2H), 2.31 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 161.5, 147.8, 136.4, 136.1, 136.0, 129.4, 129.3, 129.1, 128.9, 127.4, 126.7, 125.9, 121.4, 45.1, 21.0; HRMS (EI+) calcd for $C_{17}H_{15}N$ $[M]^+$ 233.1204, found 233.1191.

*2-(4-Methoxybenzyl)quinoline (**9c**):* brown oil (36.7 mg, 36% yield); IR (neat) 3051, 3001, 2930, 2834, 1606, 1508, 1459, 1429, 1304, 1246, 1177; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.08 (d, 1H), 8.03 (d, J = 8.4 Hz, 1H) 7.76 (d, J = 8.1 Hz, 1H), 7.73−7.67 (m, 1H), 7.52−7.47 (m, 1H), 7.24−7.20 (m, 3H), 6.84 (d, J = 8.4 Hz, 2H), 4.29 (s, 2H), 3.78 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 161.6, 158.3, 147.7, 136.5, 131.2, 130.1, 129.5, 128.8, 127.5, 126.7, 125.9, 121.4, 114.0, 55.2, 44.6; HRMS (EI+) calcd for $C_{17}H_{15}NO$ $[M]^+$ 249.1153, found 249.1156.

*α,α′-Bis(2-quinolyl)-p-xylylene (**9d**).* Synthesis of product **9d** was accomplished according to the general procedure of **9** using 1,4-diiodobenzene (0.303 mmol) and acetylene **3b** (0.606 mmol): brown solid (63.3 mg, 58% yield); mp 122−124 °C (lit.[16] mp 135−136 °C); IR (KBr) 3046, 2923, 1603, 1501, 1428, 1313, 1138 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.07 (d, J = 8.4 Hz, 2H), 8.01 (d, J = 8.4 Hz, 2H), 7.75 (d, J = 8.4 Hz, 2H), 7.70−7.67 (m, 2H), 7.50−7.47 (m, 2H), 7.25 (m, 4H), 7.21 (d, J = 8.4 Hz, 2H), 4.31 (s, 4H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 161.1, 147.7, 137.4, 136.5, 129.4, 128.9, 127.5, 126.7, 125.9, 121.5, 45.1; MS (ESI+) m/z 361.15 $[M + H]^+$, 383.13 $[M + Na]^+$; HRMS (ESI+) calcd for $C_{26}H_{21}N_2$ $[M + H]^+$ 361.1704, found 361.1727.

*2-(2-Methyl-4-nitrobenzyl)quinoline (**9e**):* brown oil (62.7 mg, 55% yield); IR (neat) 3061, 2937, 1696, 1592, 1515, 1431, 1346; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.09−8.00 (m, 4H), 7.80 (d, J = 8.1 Hz, 1H), 7.75−7.70 (m, 1H), 7.56−7.51 (m, 1H), 7.33 (d, J = 8.4 Hz, 1H), 7.13 (d, J = 8.4 Hz, 1H), 4.42 (s, 2H), 2.42 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 158.9, 147.8, 146.7, 145.1, 138.7, 136.9, 130.6, 129.7, 128.9, 127.5, 126.7, 126.3, 125.0, 121.1, 120.9, 42.9, 20.0; HRMS (EI+) calcd for $C_{17}H_{14}N_2O_2$ $[M]^+$ 278.1055, found 278.1053.

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*2-(4-Nitrobenzyl)quinoline (**9f**):* pale yellow solid (75.8 mg, 70% yield); mp 96−98 °C; IR (KBr) 3053, 1595, 1509, 1425, 1342, 1104 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.15 (d, J = 8.4 Hz, 2H), 8.10−8.06 (m, 2H), 7.79 (d, J = 7.8 Hz, 1H), 7.74−7.71 (m, 1H), 7.54−7.52 (m, 1H), 7.48 (d, J = 8.4 Hz, 2H), 7.23 (d, J = 8.4 Hz, 1H), 4.43 (s, 2H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 159.1, 147.9, 146.8, 146.7, 137.0, 129.9, 129.8, 129.0, 127.6, 126.8, 126.4, 123.8, 121.3, 45.1; HRMS (EI+) calcd for $C_{16}H_{12}N_2O_2$ $[M]^+$ 264.0898, found 264.0887.

*2-(4-Bromobenzyl)quinoline (**9g**):* light pink solid (75.7 mg, 62% yield); mp 88−90 °C; IR (KBr) 3031, 2927, 1594, 1482, 1428, 1360, 1312, 1137, 1066 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.07 (d, J = 8.4 Hz, 1H), 8.04 (d, J = 8.4 Hz, 1H), 7.77 (d, J = 8.4 Hz, 1H), 7.72−7.69 (m, 1H), 7.52−7.49 (m, 1H), 7.41 (d, J = 7.8 Hz, 2H), 7.20−7.17 (m, 3H), 4.28 (s, 2H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 160.4, 147.8, 138.2, 136.7, 131.6, 130.9, 129.6, 128.9, 127.5, 126.7, 126.1, 121.3, 120.4, 44.8; HRMS (EI+) calcd for $C_{16}H_{12}BrN$ $[M]^+$ 297.0153, found 297.0142.

*2-(Thiophene-2-ylmethyl)quinoline (**9h**):* amorphous solid (62.8 mg, 68% yield); IR (KBr) 3034, 3065, 2921, 1637, 1502, 1409, 1359, 1313, 1149, 1043 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.09−8.06 (m, 2H), 7.78 (d, J = 7.8 Hz, 1H), 7.74−7.69 (m, 1H), 7.51 (t, J = 7.5 Hz, 1H), 7.33 (d, J = 8.4 Hz, 1H), 7.18 (dd, J = 4.8, 1.2 Hz, 1H), 6.97−6.94 (m, 2H), 4.53 (s, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 160.1. 147.6, 141.3, 136.8, 128.9, 127.5, 127.0, 126.9, 126.2, 124.5, 121.0, 39.5; HRMS (EI+) calcd for $C_{14}H_{11}NS$ $[M]^+$ 225.0612, found 225.0591.

*2-(Naphthalen-1-ylmethyl)quinoline (**9i**):* pink solid (80.6 mg, 73% yield); mp 88−90 °C; IR (KBr) 3047, 2921, 1693, 1596, 1502, 1425, 1354, 1306, 1167, 1012 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.15−8.09 (m, 2H), 7.93 (d, J = 8.7 Hz, 1H), 7.87−7.78 (m, 2H), 7.75−7.70 (m, 2H), 7.52−7.39 (m, 5H), 7.09 (d, J = 8.7 Hz, 1H), 4.81 (s, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 161.1, 147.7, 136.4, 135.0, 133.9, 132.2, 129.4, 128.8, 128.5, 127.7, 127.6, 127.5, 126.7, 126.1, 125.9, 125.6, 125.5, 124.5, 120.9, 43.1; HRMS (ESI+) calcd for $C_{20}H_{16}N$ $[M + H]^+$ 270.1282, found 270.1303.

*General Procedure for the Synthesis of (E)-2-(Arylmethylidene)-indolin-3-ols **6**.* A mixture of $PdCl_2$ (3.5 mg, 0.02 mmol, 5 mol %) and PPh_3 (31.4 mg, 0.12 mmol, 22 mol %) in dry DMF (6 mL) was stirred at room temperature for 5 min under argon atmosphere. Aryl iodide **10** (0.58 mmol) was added, and the reaction mixture was stirred at room temperature for another 5 min. Next, K_2CO_3 (168.6 mg, 1.22 mmol), tetrabutylammonium bromide (16.1 mg, 0.05 mmol, 10 mol %), and acetylenic carbinol **2** (0.49 mmol) were added successively, and the whole reaction mixture was heated at 85 °C for the requisite time period (as shown in Table 4). Upon completion of the reaction (TLC), the solvent was removed in vacuo; the residue was mixed with water (10 mL) and extracted with ethyl acetate (3 × 15 mL). The combined organic extracts were washed with brine (10 mL), dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The resulting residue was purified through silica gel (100−200 mesh) column chromatography (ethyl acetate−petroleum ether) to afford the pure product **6**.

*(E)-2-Benzylidene-1-(toluene-4-sulfonyl)indolin-3-ol (**6a**):* light yellow solid (116.5 mg, 63% yield); mp 114−116 °C; IR (KBr) 3550, 3059, 1599, 1467, 1359, 1171, 1088, 996, 940, 813 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 7.89 (d, J = 8.4 Hz, 1H), 7.64 (d, J = 7.8 Hz, 2H), 7.51 (d, J = 8.4 Hz, 2H), 7.46 (s, 1H), 7.43−7.39 (m, 3H), 7.34−7.32 (m, 2H), 7.20−7.17 (m, 3H), 5.13 (d, J = 9.6 Hz, 1H), 2.35 (s, 3H), 0.44 (d, J = 10.2 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 144.9, 141.0, 140.1, 134.8, 133.5, 132.4, 130.3, 129.6, 129.3, 128.6, 128.1, 127.5, 125.9, 125.7, 125.4, 118.6, 69.2, 21.6; HRMS (EI+) calcd for $C_{22}H_{19}NO_3S$ $[M]^+$ 377.1085, found 377.1087.

*(E)-2-(4-Methylbenzylidene)-1-(toluene-4-sulfonyl)indolin-3-ol (**6b**):* brown solid (105.5 mg, 55% yield); mp 118−120 °C; IR (KBr) 3562, 3026, 2924, 2860, 1918, 1658, 1602, 1467, 1360, 1170, 1088, 1013 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 7.89 (d, J = 8.4 Hz, 1H), 7.54 (d, J = 7.8 Hz, 2H), 7.49 (d, J = 8.4 Hz, 2H), 7.43 (s, 1H), 7.41−7.39 (m, 1H), 7.32 (d, J = 7.2 Hz, 1H), 7.24−7.19 (m, 2H), 7.18- 7.16 (m, 3H), 5.12 (br, 1H), 2.38 (s, 3H), 2.34 (s, 3H), 0.42 (br, 1H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 144.8, 141.0, 139.2, 138.1, 137.2, 133.4, 132.5, 131.9, 130.2, 129.7, 129.5, 129.4, 129.2, 127.5, 127.2, 125.8, 125.7, 125.3, 118.6, 69.2, 21.6, 21.3; MS (ESI+) m/z 414.23 $[M + Na]^+$, 430.19 $[M + K]^+$. Anal. Calcd for $C_{23}H_{21}NO_3S$: C, 70.56; H, 5.41; N, 3.58. Found: C, 70.53; H, 5.44; N, 3.55.

*(E)-2-(4-(Trifluoromethyl)benzylidene)-1-(toluene-4-sulfonyl)-indolin-3-ol (**6c**):* colorless solid (130.9 mg, 60% yield); mp 147−149 °C; IR (KBr) 1605, 1471, 1363, 1327, 1169, 1120, 1074, 1015 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.90 (d, J = 8.1 Hz, 1H), 7.76 (d, J = 8.1 Hz, 2H), 7.64 (d, J = 7.8 Hz, 2H), 7.53−7.48 (m, 4H), 7.34 (d, J = 7.2 Hz, 1H), 7.23−7.19 (m, 3H), 5.10 (d, J = 10.2 Hz, 1H), 2.36 (s, 3H), 0.50 (d, J = 10.2 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 145.1, 142.2, 140.9, 138.3, 134.8, 134.7, 133.4, 131.8, 130.5, 129.9, 129.8, 129.6, 129.5, 127.9, 127.8, 127.4, 126.0, 125.5, 125.4, 125.4, 123.7, 118.4, 69.1, 21.6; HRMS (EI+) calcd for $C_{23}H_{18}F_3NO_3S$ $[M^+]$ 445.0959, found 445.0957.

*(E)-2-(4-Bromobenzylidene)-1-(toluene-4-sulfonyl)indolin-3-ol (**6d**):* colorless solid (116.2 mg, 52% yield); mp 143−145 °C; IR (KBr) 3375, 3056, 2920, 1903, 1645, 1600, 1470, 1363, 1169, 1085, 1013 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.89 (d, J = 8.4 Hz, 1H), 7.52 (br, 5H), 7.48 (s, 1H), 7.45−7.43 (m, 1H), 7.40−7.38 (m, 1H), 7.33 (d, J = 7.5 Hz, 1H), 7.22−7.17 (m, 3H), 5.07 (d, J = 10.2 Hz, 1H), 2.35 (s, 3H), 0.44 (d, J = 10.5 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 144.9, 140.9, 140.6, 133.7, 133.4, 132.1, 131.7, 130.8, 130.4, 129.7, 129.6, 127.4, 127.2, 125.9, 125.3, 124.3, 122.2, 118.5, 69.1, 21.5; MS (ESI+) m/z 478.06, 480.05 $[M + Na]^+$. Anal. Calcd for $C_{22}H_{18}BrNO_3S$: C, 57.90; H, 3.98; N, 3.07. Found: C, 57.94; H, 3.96; N, 3.11.

*(E)-2-(Thiophene-2-yl-methylidene)-1-(toluene-4-sulfonyl)-indolin-3-ol (**6e**):* colorless solid (99.5 mg, 53% yield); mp 110−112 °C; IR (KBr) 3379, 3041, 1599, 1467, 1363, 1170, 1088, 1024 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 7.90 (d, J = 8.4 Hz, 1H), 7.61 (s, 1H), 7.48 (d, J = 8.4 Hz, 2H), 7.43 (td, J = 7.8, 1.2 Hz, 1H), 7.39−7.37 (m, 3H), 7.21 (d, J = 7.2, 0.6 Hz, 1H), 7.15 (d, J = 7.8 Hz, 2H), 7.10 (dd, J = 5.1, 3.9 Hz, 1H), 5.37 (d, J = 9.6 Hz, 1H), 2.32 (s, 3H), 0.56 (d, J = 9.6 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 144.9, 141.2, 138.5, 137.2, 133.2, 132.0, 130.3, 129.5, 129.1, 127.8, 127.4, 127.2, 125.9, 125.5, 118.4, 117.2, 69.3, 21.5; HRMS (EI+) calcd for $C_{20}H_{17}NO_3S_2$ $[M]^+$ 383.0649, found 383.0645.

*(E)-2-(Pyridin-3-ylmethylidene)-1-(toluene-4-sulfonyl)indolin-3-ol (**6f**):* brown solid (103.8 mg, 56% yield); mp 177−178 °C; IR (KBr) 3059, 1652, 1601, 1469, 1359, 1169, 1089, 1025 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.79 (m, 1H), 8.52 (d, J = 3.9 Hz, 1H), 8.04 (d, J = 7.8 Hz, 1H), 7.90 (d, J = 8.1 Hz, 1H), 7.52 (d, J = 7.8 Hz, 2H), 7.47−7.44 (m, 1H), 7.41 (s, 1H), 7.36−7.30 (m, 2H), 7.23−7.18 (m, 3H), 5.11 (br, 1H), 2.35 (s, 3H), 0.88 (br, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 150.2, 148.4, 144.9, 142.5, 140.9, 136.0, 133.5, 131.9, 130.4, 129.6, 127.4, 125.9, 125.4, 123.5, 120.5, 118.2, 69.1, 21.6; HRMS (EI+) calcd for $C_{21}H_{18}N_2O_3S$ $[M]^+$ 378.1038, found 378.1033.

*(E)-2-((2,4-Dimethoxypyrimidin-5-yl)methylidene)-1-(toluene-4-sulfonyl)indolin-3-ol (**6g**):* gray solid (129.3 mg, 60% yield); mp 140−141 °C; IR (KBr) 3230, 2952, 1596, 1558, 1469, 1391, 1299, 1170, 1085, 1018 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.69 (s, 1H), 7.88 (d, J = 8.1 Hz, 1H), 7.57−7.48 (m, 3H), 7.45 (s, 1H), 7.42−7.30 (m, 1H), 7.19−7.17 (m, 3H), 4.96 (d, J = 9.0 Hz, 1H), 4.04 (s, 3H), 4.03 (s, 3H), 2.35 (s, 3H), 0.59 (d, J = 9.0 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 168.4, 164.7, 157.7, 144.89, 141.1, 140.7, 133.4, 132.0, 130.3, 129.5, 125.3, 127.4, 125.8, 118.3, 115.1, 110.6, 69.2, 54.9, 54.2, 21.5; MS (FAB+) m/z 440.4 $[M + H]^+$. Anal. Calcd for $C_{22}H_{21}N_3O_5S$: C, 60.12; H, 4.82; N, 9.56; Found: C, 60.07; H, 4.86; N, 9.54.

*(E)-2-(3-Methoxybenzylidene)-1-(toluene-4-sulfonyl)indolin-3-ol (**6h**):* brown amorphous solid (103.8 mg, 52% yield); IR (KBr) 3506, 3064, 2931, 2838, 1694, 1599, 1467, 1359, 1263, 1169, 1087, 1041 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.89 (d, J = 8.4 Hz, 1H), 7.51 (d, J = 8.1 Hz, 2H), 7.44−7.39 (m, 2H), 7.36−7.29 (m, 2H), 7.23−7.17 (m, 5H), 6.89 (dd, J = 1.5, 7.8 Hz, 1H), 5.15 (d, J = 9.9 Hz, 1H), 3.84 (s, 3H), 2.35 (s, 3H), 0.47 (d, J = 10.2 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 159.6, 144.8, 140.9, 140.4, 136.0, 133.4, 132.3, 130.2, 129.5, 127.4, 125.3, 125.8, 125.2, 121.7, 118.4, 114.5, 113.7,

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69.1, 55.2, 21.5; HRMS (ESI+) calcd for $C_{23}H_{21}NNaO_4S$ $[M + Na]^+$ 430.1089, found 430.1125.

(E)-2-(4-Fluorobenzylidene)-1-(toluene-4-sulfonyl)indolin-3-ol ***(6i)****:* colorless solid (120.1 mg, 62% yield); mp 132−134 °C; IR (KBr) 3529, 1599, 1508, 1469, 1355, 1230, 1167, 1087, 1004 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.89 (d, J = 8.1 Hz, 1H), 7.66−7.61 (m, 2H), 7.50 (d, J = 8.4 Hz, 2H), 7.42−7.40 (m, 2H), 7.33 (d, J = 7.5 Hz, 1H), 7.22−7.17 (m, 3H), 7.06 (t, J = 8.7 Hz, 2H), 5.07 (d, J = 10.5 Hz, 1H), 2.35 (s, 3H), 0.39 (d, J = 10.2 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 164.2, 160.9, 141.9, 141.0, 139.7, 133.4, 132.2, 131.2, 131.1, 130.9, 130.9, 130.3, 129.5, 127.4, 125.9, 125.3, 124.6, 118.6, 115.7, 115.4, 69.1, 21.5; HRMS (ESI+) calcd for $C_{22}H_{18}FNNaO_3S$ $[M + Na]^+$ 418.0889, found 418.0834.

(E)-2-Benzylidene-1-(toluene-4-sulfonyl)benz[g]indolin-3-ol ***(6j)****:* colorless solid (100.5 mg, 48% yield); mp 177−179 °C; IR (KBr) 3542, 3059, 1590, 1492, 1443, 1353, 1166, 1082, 1009 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.69 (d, J = 8.4 Hz, 1H), 7.88 (d, J = 7.8 Hz, 1H), 7.77 (d, J = 8.1 Hz, 1H), 7.65−7.54 (m, 4H), 7.43−7.35 (m, 7H), 7.20 (d, J = 7.8 Hz, 2H), 5.06 (d, J = 11.1 Hz, 1H), 2.39 (s, 3H), 0.61 (d, J = 11.1 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 145.2, 141.2, 137.8, 135.3, 134.3, 132.2, 131.9, 129.5, 128.9, 128.7, 128.6, 128.3, 128.3, 127.9, 126.9, 126.8, 126.5, 126.2, 121.6, 69.9, 21.6; HRMS (ESI+) calcd for $C_{26}H_{21}NNaO_3S$ $[M + Na]^+$ 450.1140, found 450.1139.

(E)-2-(4-(Trifluoromethyl)benzylidene)-1-(toluene-4-sulfonyl)-benz[g]indolin-3-ol ***(6k)****:* colorless solid (131.1 mg, 54% yield); mp 166−168 °C; IR (KBr) 3535, 1588, 1362, 1327, 1168, 1124, 1074, 1021 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H, 8.69 (d, J = 8.4 Hz, 1H), 7.89 (d, J = 8.4 Hz, 1H), 7.78 (d, J = 8.4 Hz, 1H), 7.76 (d, J = 7.8 Hz, 2H), 7.66−7.64 (m, 3H), 7.59 (t, J = 7.2, Hz, 1H), 7.42 (d, J = 8.4 Hz, 1H), 7.38 (s, 1H), 7.34 (d, J = 7.8 Hz, 2H), 7.21 (d, J = 8.4 Hz, 2H), 5.02 (d, J = 11.4 Hz, 1H), 2.41 (s, 3H), 0.56 (d, J = 11.4 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 145.5, 143.2, 137.8, 137.7, 135.4, 132.0, 131.3, 129.7, 129.6, 128.8, 128.5, 128.0, 127.2, 127.1, 126.7, 126.4, 125.5, 125.5, 121.5, 69.7, 21.7; HRMS (ESI+) calcd for $C_{27}H_{20}F_3NNaO_3S$ $[M + Na]^+$ 518.1014, found 518.0988.

(E)-2-(2-Methyl-4-nitrobenzylidene)-1-(toluene-4-sulfonyl)benz-[g]indolin-3-ol ***(6l)****:* brown solid (123.9 mg, 52% yield); mp 167−169 °C; IR (KBr) 3583, 2923, 2857, 1591, 1513, 1440, 1341, 1167, 1083 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.70 (d, J = 8.4 Hz, 1H), 8.07 (brd, 2H), 7.89 (t, J = 9 Hz, 2H), 7.78 (d, J = 8.4 Hz, 1H), 7.66 (t, J = 7.8 Hz, 1H), 7.59 (t, J = 6.6 Hz, 1H), 7.43 (brd, 1H), 7.39 (s, 1H), 7.37 (d, J = 8.4 Hz, 2H), 7.24 (d, J = 8.4 Hz, 2H), 4.90 (d, J = 10.8 Hz, 1H), 2.46 (s, 3H), 2.42 (s, 3H), 0.64 (d, J = 11.4 Hz, 1H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 147.3, 145.6, 144.7, 139.9, 138.8, 137.9, 135.4, 132.2, 131.1, 130.2, 129.7, 128.7, 128.6, 128.1, 127.2, 126.6, 126.5, 126.3, 124.9, 124.8, 121.4, 121.2, 69.9, 21.7, 20.4; MS (ESI+) m/z 509.19 $[M + Na]^+$, 525.16 $[M + K]^+$. Anal. Calcd for $C_{27}H_{22}N_2O_5S$: C, 66.65; H, 4.56; N, 5.76; Found: C, 66.68; H, 4.59; N, 5.81.

(E)-2-(3-Methoxybenzylidene)(toluene-4-sulfonyl)benz[g]indolin-3-ol ***(6m)****:* colorless solid (118.8 mg, 53% yield); mp 159−161 °C; IR (KBr) 3545, 3055, 1577, 1487, 1437, 1358, 1271, 1165, 1082, 1015 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.68 (d, J = 9.0 Hz, 1H), 7.88 (d, J = 8.4 Hz, 1H), 7.76 (d, J = 8.4 Hz, 1H), 7.64 (td, J = 8.4, 1.2 Hz, 1H), 7.58 (t, J = 7.8 Hz, 1H), 7.42 (d, J = 8.4 Hz, 1H), 7.36 (d, J = 8.4 Hz, 2H), 7.32 (t, J = 7.8 Hz, 3H), 7.20 (d, J = 7.8 Hz, 3H), 6.90 (dd, J = 7.8, 2.4 Hz, 1H), 5.08 (d, J = 10.8 Hz, 1H), 3.83 (s, 3H), 2.39 (s, 3H), 0.65 (d, J = 10.8 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 159.7, 145.2, 141.4, 137.8, 135.7, 135.3, 132.2, 131.9, 129.6, 129.5, 128.9, 128.7, 128.3, 127.9, 126.9, 126.7, 126.5, 126.2, 122.0, 121.6, 114.6, 114.2, 69.9, 55.3, 21.6; HRMS (ESI+) calcd for $C_{27}H_{23}NNaO_4S$ $[M + Na]^+$ 480.1245, found 480.1235.

(E)-2-(4-Fluorobenzylidene)-1-(toluene-4-sulfonyl)benz[g]indolin-3-ol ***(6n)****:* colorless solid (122.2 mg, 56% yield); mp 181−183 °C; IR (KBr) 3525, 3052, 1597, 1507, 1437, 1352, 1296, 1232, 1164, 1086, 1020 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.69 (d, J = 8.1 Hz, 1H), 7.89 (d, J = 7.8 Hz, 1H), 7.77 (d, J = 8.4 Hz, 1H), 7.66−7.60 (m, 5H), 7.42 (d, J = 8.4 Hz, 2H), 7.36−7.28 (m, 2H), 7.24 (d, J = 8.4 Hz, 2H), 7.09 (t, J = 8.7 Hz, 1H), 5.02 (d, J = 11.4 Hz, 1H), 2.40 (s, 3H), 0.53 (d, J = 11.4 Hz, 1H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 145.3, 140.6, 137.8, 135.3, 134.6, 132.0, 131.7, 131.4, 131.3, 130.4, 129.5, 128.8, 128.6, 128.3, 127.9, 127.7, 127.0, 126.7, 126.4, 126.3, 121.6, 115.8, 115.5, 69.7, 21.6; HRMS (ESI+) calcd for $C_{26}H_{20}FNNaO_3S$ $[M + Na]^+$ 468.1046, found 468.1078.

General Procedure for the Synthesis of Indoles ***7****.* 2-Arylideneindolin-3-ol **6** (0.26 mmol) and cyclohexene (3 mL) were dissolved in dry EtOH (10 mL), and the resulting mixture was degassed by bubbling nitrogen for about 30 min. Next, 10% Pd/C (21.2 mg, 0.02 mmol, 10 mol %) was added, and the whole reaction mixture was refluxed under nitrogen for 5.5−7 h. After completion (TLC) of the reaction, the catalyst was filtered off and washed with ethyl acetate; the filtrate was evaporated under reduced pressure. The resulting crude product was purified through silica gel (100−200 mesh) column chromatography (ethyl acetate−petroleum ether) to obtain the pure product **7**.

2-Benzyl-1-(toluene-4-sulfony)-1H-indole ***(7a)****:* colorless solid (89.2 mg, 95% yield); mp 127−129 °C; IR (KBr) 3067, 2958, 2913, 1595, 1494, 1448, 1370, 1264, 1174, 1142, 1143, 1091, 1048 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.15 (d, J = 8.4 Hz, 1H), 7.53 (d, J = 8.4 Hz, 2H), 7.35 (d, J = 7.8 Hz, 1H), 7.31- 7.28 (m, 2H), 7.27−7.24 (m, 2H), 7.21 (d, J = 7.2 Hz, 2H), 7.18 (t, J = 7.5 Hz, 1H), 7.13 (d, J = 7.8 Hz, 2H), 6.09 (s, 1H), 4.35 (s, 2H), 2.32 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 144.6, 140.9, 138.0, 137.2, 136.1, 129.7, 129.4, 128.5, 126.6, 126.4, 124.0, 123.4, 120.3, 114.7, 110.8, 35.2, 21.5; HRMS (ESI) calcd for $C_{22}H_{19}NNaO_2S$ $[M + Na]^+$ 384.1034, found 384.1079.

2-(4-Methylbenzyl)-1-(toluene-4-sulfony)-1H-indole ***(7b)****:* colorless solid (82.0 mg, 84% yield); mp 99−101 °C; IR (KBr) 3026, 2913, 1911, 1594, 1515, 1448, 1372, 1300, 1172, 1143, 1092, 1045 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.15 (d, J = 7.8 Hz, 1H), 7.54 (d, J = 8.4 Hz, 2H), 7.34 (d, J = 7.8 Hz, 1H), 7.26−7.23 (m, 1H), 7.19−7.17 (m, 1H), 7.14 (d, J = 8.4 Hz, 2H), 7.11−7.08 (m, 4H), 6.08 (s, 1H), 4.30 (s, 2H), 2.35 (s, 3H), 2.33 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 144.6, 141.3, 137.2, 136.2, 134.9, 129.7, 129.4, 129.3, 129.1, 126.4, 123.9, 123.4, 120.2, 114.7, 110.7, 34.9, 21.5, 21.1; MS (ESI+) m/z 398.26 $[M + Na]^+$. Anal. Calcd for $C_{23}H_{21}NO_2S$: C, 73.57; H, 5.64; N, 3.73. Found: C, 73.60; H, 5.61; N, 3.78.

2-(4-Trifluoromethylbenzyl)-1-(toluene-4-sulfonyl)-1H-indole ***(7c)****:* yellow amorphous solid (101.6 mg, 91% yield); IR (KBr) 2925, 2855, 1918, 1727, 1597, 1449, 1370, 1324, 1259, 1169, 1120 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.17 (d, J = 8.4 Hz, 1H), 7.50 (d, J = 8.4 Hz, 2H), 7.45 (d, J = 8.4 Hz, 2H), 7.41 (d, J = 7.8 Hz, 1H), 7.31−7.29 (m, 1H), 7.29 (d, J = 8.4 Hz, 2H), 7.22 (td, J = 7.5, 1.2 Hz, 1H), 7.09 (d, J = 7.8 Hz, 2H), 6.23 (s, 1H), 4.43 (s, 2H), 2.32 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 144.7, 142.2, 139.2, 137.3, 135.9, 129.7, 129.5, 129.1, 126.2, 125.3, 125.3, 125.3, 125.3, 124,4, 123.6, 120.4, 114.7, 111.3, 34.9, 21.4; HRMS (EI+) calcd for $C_{23}H_{18}F_3NO_2S$ $[M]^+$ 429.1010, found 429.1010.

2-(4-Bromobenzyl)-1-(toluene-4-sulfonyl)-1H-indole ***(7d)****:* colorless solid (87.0 mg, 76% yield); mp 114−115 °C; IR (KBr) 2912, 1594, 1449, 1370, 1175, 1143, 1091, 1049 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.15 (d, J = 8.4 Hz, 1H), 7.53 (d, J = 8.4 Hz, 2H), 7.35 (d, J = 7.8 Hz, 1H), 7.31−7.29 (m, 2H), 7.27- 7.24 (m, 1H), 7.22 (d, J = 7.2 Hz, 2H), 7.18 (t, J = 7.5 Hz, 1H), 7.14 (d, J = 7.8 Hz, 2H), 6.09 (s, 1H), 4.35 (s, 2H), 2.33 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 144.6, 141.0, 138.0, 137.2, 136.1, 129.7, 129.4, 128.5, 126.6, 126.4, 124.0, 123.4, 120.3, 114.7, 110.8, 35.2, 21.5; MS (ESI+) m/z 463.98 $[M + Na]^+$. Anal. Calcd for $C_{22}H_{18}BrNO_2S$: C, 60.01; H, 4.12; N, 3.18. Found: C, 60.05; H, 4.09; N, 3.22.

2-(Thiophene-2-yl-methyl)-1-(toluene-4-sulfonyl)-1H-indole ***(7e)****:* yellow solid (81.2 mg, 85% yield); mp 103−104 °C; IR (KBr) 3067, 2924, 1595, 1446, 1370, 1300, 1210, 1172, 1142, 1090, 1043 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.13 (dd, J = 8.4, 0.6 Hz, 1H), 7.54 (d, J = 8.4 Hz, 2H), 7.39 (d, J = 7.2 Hz, 1H), 7.27−7.26 (m, 1H), 7.21−7.18 (m, 2H), 7.15 (d, J = 8.4 Hz, 2H), 6.95 (dd, J = 4.8, 3.6 Hz, 1H), 6.91−6.90 (m, 1H), 6.33 (d, J = 0.6 Hz, 1H), 4.59 (s, 2H), 2.332 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 144.7, 140.5, 140.2, 137.1, 135.9, 129.8, 129.3, 126.8, 126.5, 126.4, 124.4, 124.2, 123.5, 120.5, 114.7, 110.6, 29.4, 21.5; MS (ESI+) m/z 389.91 $[M + Na]^+$. Anal. Calcd for $C_{20}H_{17}NO_2S_2$: C, 65.37; H, 4.66; N, 3.81. Found: C, 65.41; H, 4.63; N, 3.85.

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*2-(Pyridin-3-ylmethyl)-1-(toluene-4-sulfonyl)-1H-indole (**7f**):* amorphous solid (72.5 mg, 77% yield); IR (KBr) 3056, 2925, 2857, 1713, 1597, 1451, 1367, 1173, 1090, 1047 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.51−8.49 (m, 2H), 8.16 (dd, J = 0.6, 8.4 Hz, 1H), 7.55 (d, J = 8.4 Hz, 2H), 7.53 (brs, 1H), 7.38 (d, J = 7.2 Hz, 1H), 7.29 (td, J = 7.8, 1.2 Hz, 1H), 7.24−7.20 (m, 2H), 7.16 (d, J = 8.4 Hz, 2H), 6.14 (s, 1H), 4.37 (s, 2H), 2.34 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C150.4, 148.0, 144.9, 139.4, 137.3, 136.8, 135.9, 133.7, 129.8, 129.6, 129.2, 127.3, 126.2, 124.4, 123.7, 123.4, 120.4, 114.7, 111.3, 32.5, 21.5; HRMS (EI+) calcd for $C_{21}H_{18}N_2O_2S$ $[M + H]^+$ 362.1089, found 362.1093.

*2-((2,4-Dimethoxypyrimidin-5-yl)methyl)-1-(toluene-4-sulfonyl)-1H-indole (**7g**):* yellow amorphous solid (93.5 mg, 85% yield); IR (KBr) 2926, 2857, 1666, 1600, 1572, 1469, 1376, 1294, 1212, 1175, 1018 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.16 (d, J = 8.4 Hz, 1H), 8.01 (s, 1H), 7.66 (d, J = 8.4 Hz, 2H), 7.35 (d, J = 7.2 Hz, 1H), 7.28−7.25 (m, 1H), 7.21−7.18 (m, 3H), 6.06 (s, 1H), 4.21 (s, 2H), 3.99 (s, 3H), 3.92 (s, 3H), 2.35 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 169.3, 164.7, 158.1, 144.7, 139.0, 137.3, 136.1, 129.8, 129.3, 126.4, 124.2, 120.3, 123.6, 114.7, 111.7, 110.2, 26.2, 54.8, 54.0, 21.6; HRMS (EI+) calcd for $C_{22}H_{21}N_3O_4S$ $[M]^+$ 423.1252, found 423.1251.

*2-(3-Methoxybenzyl)-1-(toluene-4-sulfonyl)-1H-indole (**7h**):* colorless solid (93.6 mg, 92% yield); mp 140−141 °C; IR (KBr) 3049, 3011, 2955, 1596, 1489, 1456, 1362, 1269, 1170, 1085, 1040 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.16 (d, J = 9.0 Hz, 1H), 7.54 (d, J = 8.4 Hz, 2H), 7.36 (d, J = 7.8 Hz, 1H), 7.28−7.25 (m, 1H), 7.23−7.18 (m, 2H), 7.14 (d, J = 7.8 Hz, 2H), 6.82−6.79 (m, 2H), 6.73 (s, 1H), 6.14 (s, 1H), 4.33 (s, 2H), 3.76 (s, 3H), 2.33 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 159.7, 144.6, 140.7, 139.5, 137.2, 136.1, 129.7, 129.4, 129.4, 126.4, 124.0, 123.4, 121.8, 120.3, 115.6, 114.7, 112.0, 110.9, 55.1, 35.2, 21.5; HRMS (ESI+) calcd for $C_{23}H_{21}NNaO_3S$ $[M + Na]^+$ 414.1140, found 414.1176.

*2-(4-Fluorobenzyl)-1-(toluene-4-sulfony)-1H-indole (**7i**):* colorless solid (79.9 mg, 81% yield), mp 91−93 °C; IR (KBr) 3070, 2912, 1903, 1594, 1505, 1447, 1379, 1299, 1220, 1175, 1144, 1090, 1047 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.15 (d, J = 8.4 Hz, 1H), 7.52 (d, J = 8.4 Hz, 2H), 7.37 (d, J = 7.2 Hz, 1H), 7.28−7.27 (m, 1H), 7.21−7.18 (m, 1H), 7.17−7.16 (m, 2H), 7.14 (d, J = 8.4 Hz, 2H), 6.97 (t, J = 8.7 Hz, 2H), 6.12 (s, 1H), 4.37 (s, 2H), 2.33 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 162.5, 160.9, 144.7, 140.7, 137.2, 136.1, 133.7, 133.6, 130.8, 130.7, 129.7, 129.3, 126.3, 124.2, 123.5, 120.3, 115.3, 115.2, 114.7, 110.9, 34.4, 21.5; MS (ESI+) m/z 402.02 $[M + H]^+$. Anal. Calcd for $C_{22}H_{18}FNO_2S$: C, 69.64; H, 4.78; N, 3.69. Found: C, 69.67; H, 4.80; N, 3.65.

*2-Benzyl-1-(toluene-4-sulfony)-1H-benz[g]indole (**7j**):* amorphous solid (98.4 mg, 92% yield); IR (neat) 3360, 3027, 2957, 2927, 2857, 1945, 1725, 1594, 1451, 1370, 1264, 1171, 1084 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.84 (d, J = 8.4 Hz, 1H), 7.86 (d, J = 7.8 Hz, 1H), 7.66 (d, J = 8.4 Hz, 1H), 7.56- 7.53 (m, 1H), 7.46−7.43 (m, 1H), 7.32−7.22 (m, 4H), 7.20 (d, J = 7.2 Hz, 2H), 7.15 (d, J = 8.4 Hz, 2H), 7.00 (d, J = 8.4 Hz, 2H), 6.18 (s, 1H), 4.38 (s, 2H), 2.29 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 144.9, 144.4, 138.5, 135.6, 134.0, 132.3, 130.4, 129.3, 129.0, 128.5, 128.3, 126.9, 126.6, 126.2, 125.9, 125.7, 125.5, 124.7, 118.9, 116.4, 36.8, 21.5; MS (ESI+) m/z 434.20 $[M + Na]^+$, 450.17 $[M + K]^+$. Anal. Calcd for $C_{26}H_{21}NO_2S$: C, 75.88; H, 5.14; N, 3.40. Found: C, 75.91; H, 5.11; N, 3.46.

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

Copies of ^1H and ^{13}C NMR spectrum of compounds **2**, **3**, and **6**−**9** and X-ray crystallographic data of **6a**, **7a**, and **8d**. This material is available free of charge via the Internet at http://pubs.acs.org.

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Notes

The authors declare no competing financial interest.

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