JOC The Journal of Organic Chemistry
Cite This: J. Org. Chem. XXXX, XXX, XXX−XXX
Article
pubs.acs.org/joc

Palladium(II)-Catalyzed Cascade Reactions of Ene−Ynes Tethered to Cyano/Aldehyde: Access to Naphtho[1,2-*b*]furans and Benzo[*g*]indoles

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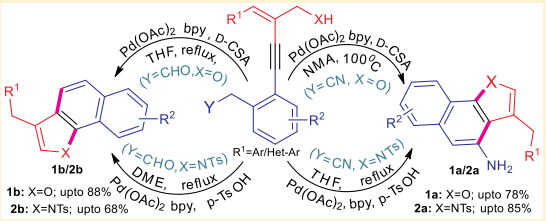
Supporting Information

ABSTRACT: An efficient palladium(II)-catalyzed cascade reaction of ene−yne substrates carrying cyano/aldehyde group is described. It involves successive hetero- and benz-annulations in one pot via *trans*-oxo/aminopalladation onto alkyne, followed by 1,2-addition to cyano/aldehyde, providing a convenient synthesis of both naphtho[1,2-*b*]furans and benzo[*g*]indoles. The reaction constitutes a fast intramolecular assembly through several carbon−carbon and carbon−heteroatom bond formations taking place in one pot. The reactions are operationally simple, compatible with a range of functional groups and atom-economical in nature.



INTRODUCTION

Benzo-fused benzofurans and indoles belong to the group of privileged structures in the area of drug discovery. In particular, naphtho[1,2-*b*]furans[1a−c] (**1**, Figure 1) and benzo[*g*]indoles[1d−f] (**2**, Figure 1) are structural components of a large number of biologically active natural and synthetic compounds.

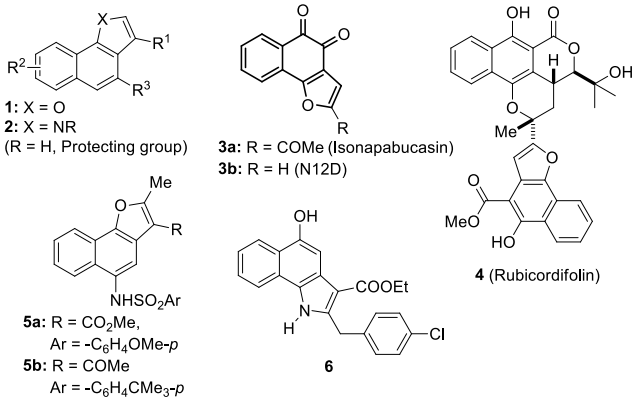


Figure 1. Few biologically active naphtho[1,2-*b*]furans and benzo[*g*]-indoles.

Notable among the former class are isonapabucasin **3a**[2] (Figure 1), which strongly inhibited the growth of human breast cancer cells and naphtho[1,2-*b*]furan-4,5-dione or N12D (**3b**, Figure 1) isolated from mangrove plants, which exhibited significant biological activity against hepatoma, squamous cell carcinoma, breast cancer,[3] and methicillin-resistant *Staphylococcus aureus*.[4] Rubicordifolin (**4**, Figure 1), a constituent of *Rubia cordifolia*, displayed significant efficacy by inhibiting the growth of sarcoma ascites in mice at low concentrations.[5] On the other hand, the arylsulfonamide naphtho[1,2-*b*]furan derivative **5a** is a selective inhibitor of triple-negative breast cancer,[6a] while **5b** displayed significant activity in lung and colon cancer cells.[6b] Finally, naphtho[1,2-*b*]furans have potential applications in functional materials, such as electrically conducting light-emitting diodes,[7a] and photochromic[7b] and organic materials.[7c]

On the other hand, benzo[*g*]indoles (**2**, Figure 1) were reported to be potent anticancer agents[8a] and inhibitors of microsomal prostaglandin E_2 synthase-1,[8b] and expressed significant affinity for dopamine D2-like receptors.[8c] In particular, benzo[*g*]indole **6** (Figure 1) displayed a 10-fold higher 5-lipoxygenase activity than 5-hydroxy indoles.[9] Besides, benzo[*g*]indoles (**2**) have found various applications in material sciences such as yellow-light-emitting activity,[10a] high performance in electrochromic devices,[10b] fluorescence "turn-off" sensing properties of metal ion,[10c] etc.

In view of the immense importance of naphtho[1,2-*b*]furans, various synthetic efforts have been devoted to their constructions. Although there are several examples[11] on their preparation as part of the synthesis of different oxygen heterocycles, there are only few reports on their general synthesis.[12] Representative examples are copper-mediated [3 + 2] cycloaddition of cyclic ketones and olefins or alkynes,[12a] platinum(II)-catalyzed cycloisomerization of allenyl ketones,[12b] base-promoted substitution/elimination reaction between naphthols and nitroallylic acetates,[12c] and use of metal catalysts such as Fe−Pd bimetallic nanoparticles,[12d] indium(III) triflate,[12e] and rhenium oxide[12f] (Re_2O_7) on quinone substrates. However, development of a convenient, scalable, and practical

Received: March 27, 2019

DOI: 10.1021/acs.joc.9b00861
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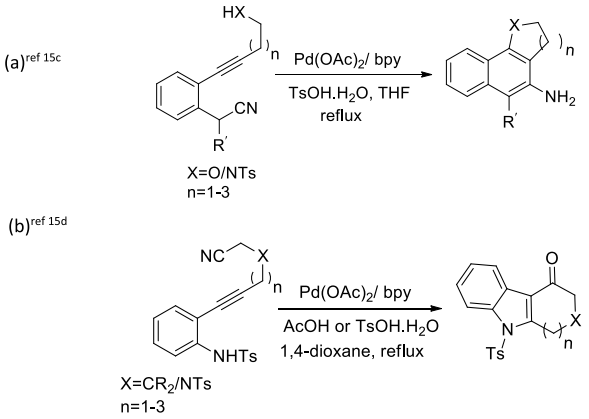
method using readily available and cheap substrates remains a challenge.

Regarding benzo[*g*]indoles, scrutiny of the literature reveals only few methods for the general synthesis[13] involving mostly multicomponent reactions, although several reports exist on the preparation of **2**[14] during the synthesis of other nitrogen heterocycles. Consequently, a straightforward and reliable method for their general synthesis continues to be fascinating.

In recent years, cascade reactions have gained immense interest because of several advantages and many pioneering works in this regard have been well-documented in the literature.[15] Among them, palladium(II)-catalyzed synthesis of 2,3-dihydro derivatives of naphtho[1,2-*b*]furans and benzo[*g*]-indoles (Scheme 1a) and of tosylated derivatives of indoles fused

Scheme 1. Lu's Works: Synthesis of Fused Heterocycles via Pd(II)-Catalyzed Reactions



with carbo- or heterocycles (Scheme 1b) utilizing *ortho*-alkynyl benzenes as substrates, reported by Lu et al. (Scheme 1), deserves particular mention.

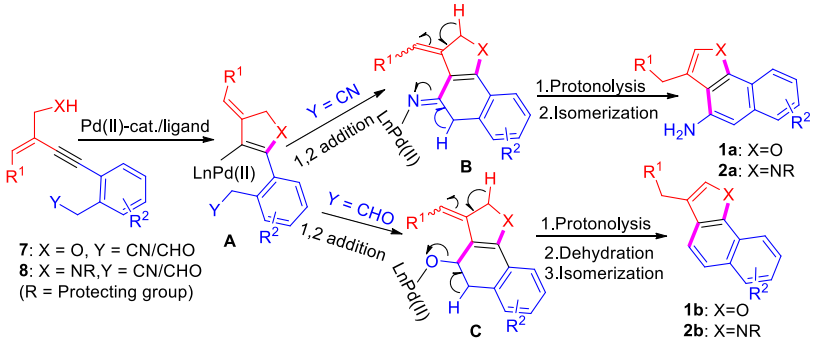
In view of the reported works and in continuation of our work[16] on palladium-catalyzed reactions, we envisioned that compounds **1** and **2** could be built up by exploring the palladium-catalyzed cascade reactions of ene−ynes **7** and **8** containing cyano/aldehyde group, as depicted in Scheme 2. Activation of the triple bond of the substrates by Pd(II) catalyst was expected to trigger a 5-*endo-dig* heteroannulation resulting in an intermediate **A** that might undergo subsequent intramolecular 1,2-addition onto suitably placed carbon−heteroatom multiple bond (e.g., −C═O/−C≡N) resulting in the transient species **B**/**C**. Protonolysis and isomerization of **B** could lead to the formation of **1a**/**2a**, while protonolysis and isomerization followed by dehydration of **C** could easily deliver **1b**/**2b**. Herein, we describe the results obtained so far in this effort.

RESULTS AND DISCUSSION

Synthesis of Naphtho[1,2-*b*]furans 1a and 1b. Initially, we set out with a model study for the synthesis of **1aa** using substrate **7aa** (R^1 = Ph, R^2 = H, X = O, Y = CN) through variation of reaction parameters; selected results are presented in Table 1. Carrying out this reaction in 1,4-dioxane employing $Pd(OAc)_2$/bipyridine (bpy) and using *p*-toluenesulfonic acid (*p*-TsOH) as an additive led to the desired naphtho[1,2-*b*]furan **1aa** with only 30% yield (Table 1, entry 1). Replacing the additive by D-(+)-camphorsulfonic acid (D-CSA) and employing a polar solvent like dimethylacetamide (DMA) or *N*-methylacetamide (NMA) afforded (Table 1, entries 2 and 3) the product **1aa** with 44 and 62% yields, respectively, proving NMA as the better solvent. Gratifyingly, changing the catalyst to $Pd(OAc)_2$bpy enhanced the yield to 72% (Table 1, entry 4). On the contrary, use of the less polar solvent tetrahydrofuran (THF) lowered the yield (Table 1, entry 5). Therefore, we executed few more reactions in NMA using $Pd(OAc)_2$ and different ligands (i.e., 1,10-phenanthroline and 4,4′-dimethoxy-2,2′-bipyridine), but the product **1aa** was obtained in lower yields (Table 1, entries 6 and 7 vs entry 4). Furthermore, replacement of the additive (i.e., D-CSA) by AcOH under the described conditions (i.e., entry 4 of Table 1) proved still less satisfactory (Table 1, entry 8). Thus, reaction conditions of entry 4 emerged to be optimal.

To assess the scope and limitations of this reaction, diversely substituted ene−yne substrates **7a** were then exposed to the optimized reaction conditions; the results are summarized in Scheme 3. When electron-donating methoxy groups are placed at both meta and para positions of the substrate (**7ab**), the desired product **1ab** was formed within 1.5 h with 75% yield. The presence of an electron-withdrawing group (R^2 = CF_3) at the para position of substrate (**7ac**) also led to the formation of product **1ac** within 2 h, albeit with somewhat lower yield (66%). Next, the influence of substituents on the other ring (R^1) of the substrates was studied. Both electron-withdrawing (viz., Cl, CF_3) and electron-donating (viz., OMe) substituents placed at the para position (**7ad**−**af**) delivered products (**1ad**−**af**) smoothly within 1−1.5 h in very good yields (65−76%), showing insignificant effect of such substituents. However, incorporation of electron-donating groups at ortho and meta positions (**7ag**) enhanced the yield of product **1ag** to 78%. Replacement of the aryl group by a heteroaryl one (R^1 = Het-aryl) reduced the yield of products (**1ah**/**ai**) to 25−35% even

Scheme 2. Present Work: Envisaged Pathways for the Formation of Products 1a, 1b, 2a, and 2b



DOI: 10.1021/acs.joc.9b00861
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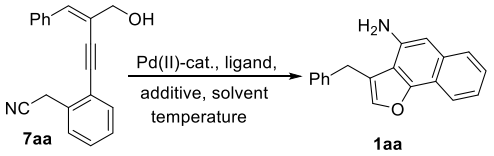
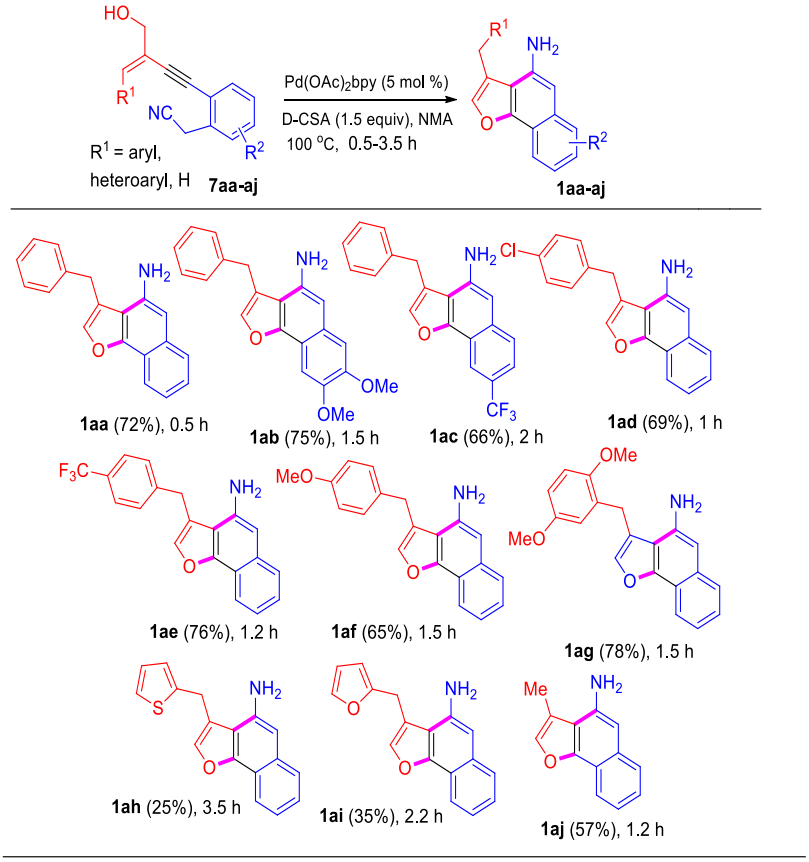
Table 1. Optimization of Reaction Conditions for the Synthesis of Naphtho[1,2-*b*]furan 1aa[a,b]



entry	catalyst	ligand	additives	solvents	time (h)	temp (°C)	yield[b] (%)
1	$Pd(OAc)_2$	bpy[c]	*p*-TsOH	1,4-dioxane	2	100	30
2.	$Pd(OAc)_2$	bpy	D-CSA[d]	DMA	2	100	44
3.	$Pd(OAc)_2$	bpy	D-CSA	NMA	1	100	62
4.	$Pd(OAc)_2$bpy	bpy	D-CSA	NMA	0.5	100	72
5.	$Pd(OAc)_2$bpy		D-CSA	THF	1.5	reflux	65
6.	$Pd(OAc)_2$	Phen[e]	D-CSA	NMA	1.5	100	60
7.	$Pd(OAc)_2$	dmbpy[f]	D-CSA	NMA	2	100	66
8.	$Pd(OAc)_2$bpy		ACOH	NMA	4	100	21

[a]Reaction conditions: **7aa** (0.25 mmol), catalyst (5 mol %), ligand (6 mol %), and additive (1.5 equiv) in solvent (3 mL) at stated temperature under argon atmosphere. [b]Yields of the isolated pure products. [c]bpy: 2,2′-bipyridine. [d]D-CSA: D-(+)-camphorsulfonic acid. [e]Phen: 1,10-phenanthroline. [f]dmbpy: 4,4′-dimethoxy-2,2′-bipyridine.

Scheme 3. Synthesis of 4-Amino Naphtho[1,2-*b*]furan Derivatives 1aa−aj[a]



[a]Reaction conditions: A mixture of **7aa** (0.25 mmol), $Pd(OAc)_2$bpy (5 mol %), and D-CSA (1.5 equiv) in 3 mL of NMA was heated at 100 °C under argon atmosphere.

after slightly longer reaction times (2.2−3.5 h). The moderate yield could be accounted for by the polymerization of the substrates, as a tarry material was observed during the progress of the reaction. But the absence of any substituent (R^1 = H) produced the product **1aj** (57%) within 1.2 h only.

With a view to expanding the scope of this reaction further, we replaced the cyano group of **7aa** by an aldehyde one as in the substrates **7ba−bg** (for preparation, see the Supporting Information). To our dismay, exposure of **7ba** (R^1 = Ph, R^2 = H) to the optimized reaction conditions (entry 4 of Table 1) resulted in the formation of the desired product **1ba** with only moderate yield (42%). Thus, further screening of solvent system and other reaction parameter was needed (Table 2). Changing the solvent from NMA to the less polar 1,4-dioxane increased the yield (80%) and reduced the reaction time (1 h) remarkably (Table 2, entry 2). But the yield of **1ba** dropped to 31% (Table 2,

DOI: 10.1021/acs.joc.9b00861
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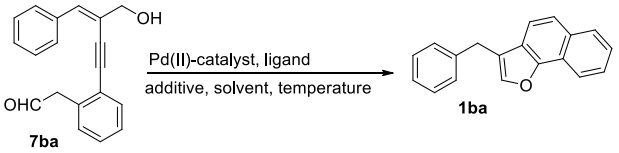
Table 2. Optimization of Reaction Conditions for the Synthesis of Naphtho[1,2-*b*]furan 1ba[a]



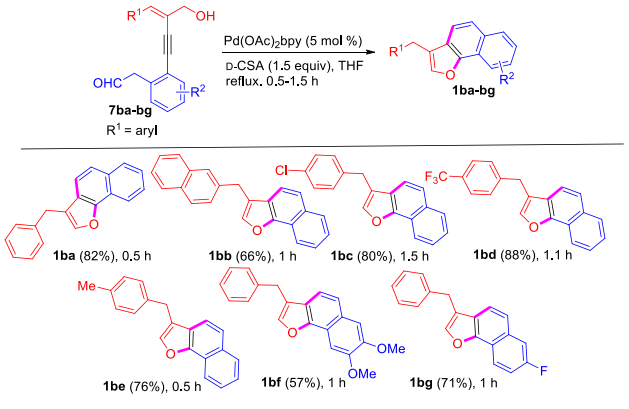
entry	catalyst	ligand	additive	solvent	temp (°C)	time (h)	yield (%)
1	$Pd(OAc)_2bpy$		D-CSA	NMA	100	3	42
2.	$Pd(OAc)_2bpy$		D-CSA	1,4-dioxane	100	1	80
3.	$Pd(OAc)_2$	bpy	D-CSA	1,4-dioxane	100	2	31
4.	$Pd(OAc)_2bpy$		D-CSA	THF	reflux	1	82
5.	$Pd(OAc)_2$	bpy	D-CSA	THF	reflux	4	42
6.	$Pd(OAc)_2bpy$		AcOH	THF	reflux	4	nr

[a]Reaction conditions: **7ba** (0.18 mmol), catalyst (5 mol %), ligand (6 mol %), and additive (1.5 equiv) in 3 mL of solvent heated at specified temperature under argon atmosphere.

entry 3) when $Pd(OAc)_2$ and bpy were separately used instead of $Pd(OAc)_2bpy$ in 1,4-dioxane, underlining the necessity of using $Pd(OAc)_2bpy$ in the reaction. Interestingly, executing the reaction in a less polar solvent like THF successfully increased the yield to 82% (Table 2, entry 4). However, using the catalyst and the ligand separately in THF decreased the yield to 42% (Table 2, entry 5). When the additive was changed to acetic acid instead of D-CSA, product formation did not take place at all proving D-CSA to be a better additive (Table 2, entry 6). Thus, the reaction conditions of entry 4 were found to be optimal. So, we pursued this reaction in THF for further exploration as discussed below.

Accordingly, a number of diversely substituted ene−yne substrates **7b** were investigated (Scheme 4). Different functional

Scheme 4. Synthesis of the Naphtho[1,2-*b*]furan Derivatives 1ba−bg[a]



[a]Reaction conditions: **7ba** (0.18 mmol), $Pd(OAc)_2bpy$ (5 mol %), and D-CSA (1.5 equiv) in refluxing THF (3 mL) under argon atmosphere.

groups (viz., F, Cl, CF_3, Me, OMe, etc.) were found to be compatible for this reaction. Nevertheless, replacing phenyl group attached to the double bond in substrate by a bulky naphthyl group (R^1 = 2-naphthyl) required slightly longer reaction time (1 h) and reduced the yield (of **1bb**) to 66%. In contrast, employment of electron-withdrawing group at the para position of the phenyl ring in substrates (R^1 = *p*-ClC_6H_4−/*p*-$CF_3C_6H_4$−) afforded the products (**1bc**/**bd**) within 1.1−1.5 h with excellent yields (80−88%), while introduction of an electron-donating methyl group at the same position (R^1 = *p*-MeC_6H_4−) furnished the product **1be** within 0.5 h, but with a slightly reduced yield (76%). On the other hand, the electron-donating methoxy group (R^2 = OMe) placed at meta and para positions (substrate **7bf**) produced the expected product **1bf** within 1 h with a moderate yield of 57%, whereas an electron-withdrawing group (i.e., F) at para position enhanced the yield (of **1bg**) to 71%. Furthermore, in contrast to the previous observations (Scheme 3), replacement of the aryl moiety in substrates by a heteroaryl one (R^1 = het-aryl) did not work well since only a trace amount of the desired product was observed in few cases. But employment of the heterocyclic moiety (viz., 2,4-dimethoxy pyrimidine) at the other end of the substrate (i.e., **9**) proved to be effective although NMA had to be used in place of THF and the masked aldehyde was necessary as the free aldehyde could not be generated despite repeated efforts (Scheme 5). The desired product **1bh** was thus produced within 2 h with 85% yield.

In view of the immense importance of the uracil derivatives in cancer chemotherapy[17a,b] and our own interest,[17c] we planned to convert our product **1bh** to the uracil derivative **10**. Pleasingly, treatment of **1bh** with sodium iodide and trimethylsilyl chloride in dry acetonitrile at room temperature (rt) was found to be successful for the formation of **10** albeit in moderate yield (52%). The synthesis of more uracil derivatives and testing the anticancer activity (in vitro) of product **10** in different cancer cell lines are under study.

Synthesis of Benzo[*g*]indoles 2a and 2b. The scope of this reaction was next expanded to nitrogen heterocycles, i.e., benzo[*g*]indoles **2**, utilizing substrate **8** as envisaged in Scheme 2. At the outset, we prepared (see the Supporting Information) the requisite substrate **8aa** (R^1 = Ph, R^2 = H, X = NTs, Y = CN) and treated it under the optimized reaction conditions of Table 1. To our disappointment, the expected product **2aa** was obtained in moderate yield (42%) along with a pyrrole derivative **11a** as side product (Table 3, entry 1), suggesting the necessity of tweaking the reaction parameters. Switching over to other palladium catalysts [viz., $Pd(OAc)_2bpy$, $Pd(OAc)_2Phen$] instead of $Pd(OAc)_2$ was first attempted, but without success (Table 3, entries 2 and 3). After replacing the polar solvent NMA with the relatively less polar 1,4-dioxane, the reaction was complete within 2 h but delivered only modest yield of **2aa** (34%) along with 39% of **11a** (Table 3, entry 4). Experiments with other solvents revealed THF to be the most promising one, although it required somewhat longer reaction times (2.1−10 h). Carrying out this reaction initially in refluxing THF required 6 h to afford the product **2aa** (45%) in addition to **11a** (Table 3,

DOI: 10.1021/acs.joc.9b00861
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Scheme 5. Synthesis of Naphtho[1,2-*b*]furan 1bh and Its Conversion to Uracil Derivative 10

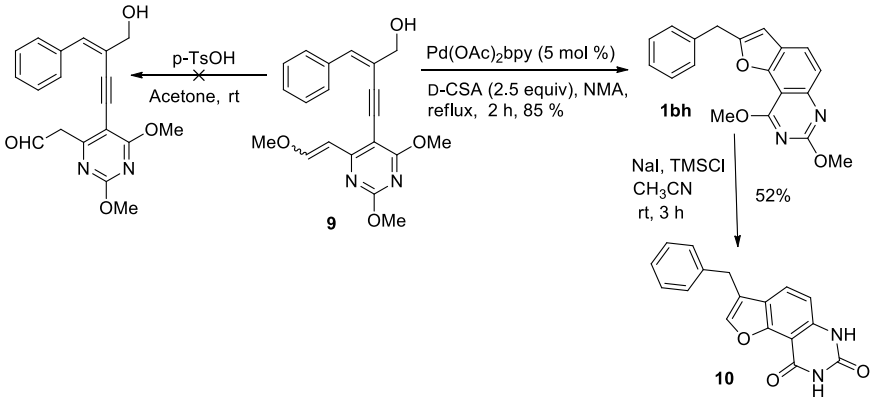
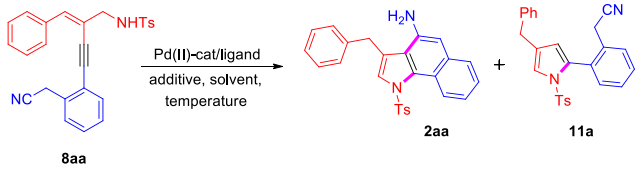


Table 3. Optimization of Reaction Conditions for the Synthesis of 4-Amino Benzo[*g*]indole 2aa[a]



entry	catalyst	ligand	additive	solvent	temp (°C)	time (h)	yield **2aa**	**11a** (%)
1.	$Pd(OAc)_2$	bpy	D-CSA	NMA	100	6	42	32
2.	$Pd(OAc)_2$bpy		D-CSA	NMA	100	6	41	38
3.	$Pd(OAc)_2$phen		D-CSA	NMA	100	5	40	32
4.	$Pd(OAc)_2$	bpy	D-CSA	1,4-dioxane	75	2	34	39
5.	$Pd(OAc)_2$	bpy	D-CSA	THF	reflux	6	45	26
6.	$Pd(OAc)_2$bpy		D-CSA	THF	reflux	2.1	60	25
7.	$PdCl_2(MeCN)_2$	bpy	D-CSA	THF	reflux	9	trace	trace
8.	$Pd(OAc)_2$bpy		$MeSO_3H$	THF	reflux	9	nr	nr
9.	$Pd(OAc)_2$bpy		AcOH−H_2O (1:1)	THF	reflux	10	nr	nr
10.	$Pd(OAc)_2$bpy		*p*-TsOH·H_2O	THF	reflux	3.5	66	25
11.	$Pd(OAc)_2$	bpy	*p*-TsOH·H_2O	THF	reflux	4	74	12
12.	$Pd(OAc)_2$	bpy	TfOH	THF	reflux	7	trace	trace

[a]Reaction conditions: A mixture of **8aa** (0.23 mmol), catalyst (5 mol %), ligand (10 mol %), except entries 2, 3, 6, and 8−10, and additive (2.0 equiv) in solvent (3 mL) was heated at specified temperatures (see table) under argon atmosphere.

entry 5). Interestingly, use of $Pd(OAc)_2$bpy as catalyst instead of $Pd(OAc)_2$/bpy reduced the reaction time (1.2 h) and enhanced the yield of **2aa** to 60% (Table 3, entry 6); the other catalyst tried [i.e., $PdCl_2(MeCN)_2$] proved unsuccessful (Table 3, entry 7). We also checked the role of different additives in this reaction. Although methanesulfonic acid ($MeSO_3H$) and aqueous acetic acid (AcOH/H_2O = 1:1) failed (Table 3, entries 8 and 9), *p*-toluenesulfonic acid (*p*-TsOH·H_2O) could complete the reaction within 3.5 h and furnished **2aa** with 66% yield (Table 3, entry 10) along with **11a** (25%). To our gratification, use of $Pd(OAc)_2$ catalyst and bipyridine individually instead of preformed $Pd(OAc)_2$bpy further improved the yield of **2aa** (74%) and suppressed the yield of the side product **11a** considerably (Table 3, entry 11). But change of the additive to triflic acid proved unsuccessful (Table 3, entry 12). Thus, the reaction conditions of entry 11 appeared to be optimal.

We next sought to explore the scope of the reaction (Scheme 6). Replacing the phenyl ring in **8aa** by naphthyl had little effect as **8ab** (R^1 = 2-naphthyl, R^2 = H) delivered the product **2ab** (78%) with equal ease. Introduction of a heteroaryl moiety also proved to be equally effective affording the respective products **2ac**/**ad** with very good yields (68−76%). Installation of either an electron-withdrawing (viz., Cl) or electron-donating group (viz., Me) at the para position as in **8ae** (R^1 = *p*-ClC_6H_4−) or **8af** (R^1 = *p*-MeC_6H_4−) provided the desired product **2ae** (82%) or **2af** (78%) easily within 4−5 h. In contrast, placement of a strong electron-donating group (OMe) at the same position had detrimental effect, making the reaction sluggish (t = 12 h) and affording the product **2ag** with low yield (24%), though the same substituent located at meta position ensured very good yield (80%) of the corresponding product (**2ah**) in a short reaction time (5 h). Presumably, the low yield of **2ag** may be attributed to the electron-donating effect of the methoxy group to the acetylenic carbon (of **8ag**), thereby reducing the electrophilicity sufficiently and making the *trans*-aminopalladation process [see species **A** (X = NTs) of Scheme 2] somewhat difficult. In contrast, methoxy groups placed at both meta and para positions delivered the desired product **2ai** in 4 h with 65% yield. Even a strongly electron-withdrawing group (CO_2Me) incorporated at the same position also produced the desired product **2aj**, though in moderate yield (55%).

We then turned our attention to synthesize **2b** (R = NTs), as depicted in Scheme 2. Accordingly, the requisite starting material **8ba** (R^1 = Ph, R^2 = H, X = NTs, Y = CHO) was prepared (see the Supporting Information) and allowed to react under the optimum reaction conditions (entry 11 of Table 3).

DOI: 10.1021/acs.joc.9b00861
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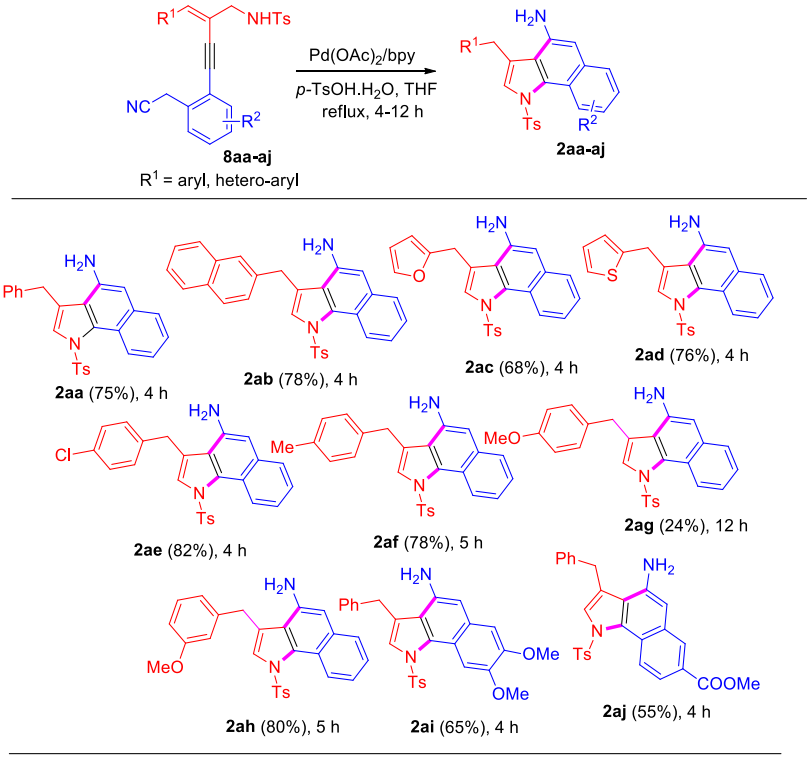
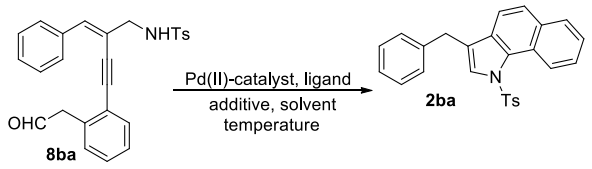
Scheme 6. Synthesis of 4-Amino Benzo[*g*]indole Derivatives 2aa−aj[a,b]



[a]Reaction conditions: **8a** (0.23 mmol), $Pd(OAc)_2$ (5 mol %), bpy (10 mol %), and *p*-TsOH·H_2O (2.0 equiv) in refluxing THF (3 mL) under argon atmosphere. [b]Product **2a** was formed along with a minor amount (8−19%) of the corresponding pyrrole derivative (e.g., **11a** during the use of **8aa**) as side product resulting from monocyclization.

Table 4. Optimization of Reaction Conditions for Benzo[*g*]indole 2ba[a]



entry	catalyst	ligand	additive	solvent	temp (°C)	time (h)	yield **2ba**
1.	$Pd(OAc)_2$	bpy	*p*-TsOH·H_2O	THF	reflux	12	trace
2.	$Pd(OAc)_2$	bpy	*p*-TsOH·H_2O	1,4-dioxane	80	3	25
3.	$Pd(OAc)_2$bpy		*p*-TsOH·H_2O	1,4-dioxane	80	3.5	47
4.	$Pd(OAc)_2$bpy		AcOH−H_2O (1:1)	1,4-dioxane	100	4	nr
5.	$Pd(OAc)_2$bpy		*p*-TsOH·H_2O	DME	85	2	61
6.	$Pd(OAc)_2$	bpy	*p*-TsOH·H_2O	NMA	80	3	nr

[a]Reaction conditions: A mixture of **8ba** (0.14 mmol), catalyst (5 mol %), ligand (10 mol %), and additive (1.5 equiv) was heated at mentioned temperatures under argon atmosphere.

Unlike the case of **2aa**, this reaction showed (entry 1 of Table 4) the formation of the desired product **2ba** only in traces even after heating for 12 h. However, conducting this reaction in 1,4-dioxane using $Pd(OAc)_2$/bpy or $Pd(OAc)_2$bpy did afford **2ba** to the extent of 25−47% (Table 4, entries 2 and 3). When the additive was changed to AcOH−H_2O instead of *p*-TsOH·H_2O, no desired product was formed (Table 4, entry 4), suggesting the necessity of *p*-TsOH in this reaction. Gratifyingly, executing this reaction in 1,2-dimethoxyethane (DME) led to the formation of **2ba** within 2 h with 61% yield (Table 4, entry 5). As changing the solvent to a more polar one such as NMA failed to deliver the desired product **2ba** (Table 4, entry 6), the reaction conditions of entry 5 emerged to be optimal.

We thereafter decided to explore the scope and limitation of this reaction, as shown in Scheme 7. This revealed that the presence of the bulky naphthyl ring in substrate **8bb** produced the desired product **2bb** in moderate yield (44%), presumably due to the steric effect of this ring. Also, contrary to our previous observations, a reactant carrying a heteroaryl ring (R^1 = thienyl/furanyl, etc.) in place of naphthyl turned out to be inert even after prolonged heating (>12 h), although the reason is not very clear at this moment. Furthermore, incorporation of the electron-withdrawing group (viz., Cl/CF_3) at the para position of the benzene ring in substrate **8bc**/**bd** facilitated the reaction, producing the product **2bc**/**bd** in good yield (68/65%). In contrast, the presence of an electron-donating group (viz., CH_3,

DOI: 10.1021/acs.joc.9b00861
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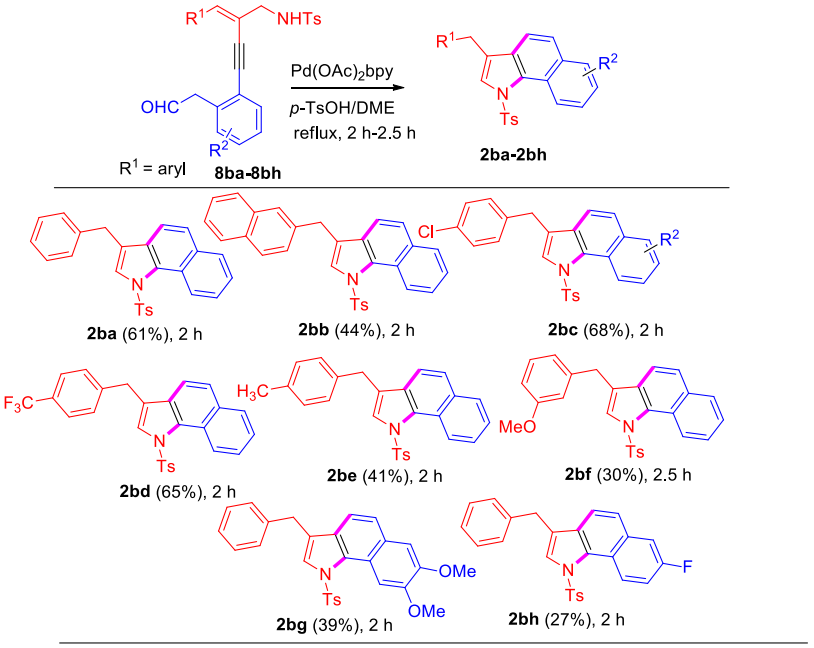
Scheme 7. Synthesis of Benzo[*g*]indole Derivatives 2ba–bh[a]

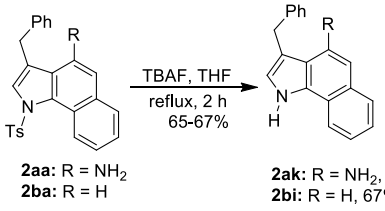


[a]Reaction conditions: **8a** (0.23 mmol), $Pd(OAc)_2bpy$ (5 mol %), and *p*-TsOH·H_2O (1.5 equiv) were refluxed in DME (3 mL) under argon atmosphere.

OMe) in the same phenyl ring of substrate (**8be**/**bf**) somewhat hindered the reaction, leading to the formation of the respective products **2be** and **2bf** in moderate yields (30–41%), while an electron-withdrawing (viz., F) or electron-donating group (viz., OMe) in the other benzene ring furnished product **2bg** or **2bh** within 2 h though in modest yields (27–39%).

Owing to the presence of benzo[*g*]indoles with free NH group in a large number of bioactive compounds,[8b,c,9] we attempted to deprotect the tosyl group of the products **2aa** and **2ba**, as shown in Scheme 8. The detosylation was carried out successfully within 2 h using tetrabutylammonium fluoride (TBAF) in refluxing THF to furnish the products **2ak–bi** with 65–67% yield.

Scheme 8. Detosylation of Benzo[*g*]indoles 2aa/ba



In conclusion, we have developed a Pd(II)-catalyzed cascade reaction for a facile and general synthesis of naphtho[1,2-*b*]furans **1** and benzo[*g*]indoles **2** using simple and readily available substrates. The newly developed method constitutes a fast intramolecular assembly involving *trans*-oxo/aminopalladation of alkyne, followed by nucleophilic 1,2-addition to cyano/aldehyde group. The reactions are operationally simple, compatible with a range of functional groups, and atom-economical. The method is applicable to both oxygen and nitrogen heterocycles. Because of the structural similarity of 4-amino naphtho[1,2-*b*]furans **1a** to potent anticancer agents **5**,[6a] the anticancer activities of the products **1a** (Scheme 3) and their various sulfonamide derivatives (along with compound **10**) are currently under investigation. We believe that this novel method will find significant applications in organic, medicinal, and material chemistry as well.

EXPERIMENTAL SECTION

General. All solvents were distilled prior to use. Petroleum ether refers to fraction boiling in the range 60–80 °C. Dichloromethane (DCM) was dried over phosphorous pentoxide, distilled, and stored over 3 Å molecular sieves in a sealed container. 1,4-Dioxane was distilled over sodium and benzophenone. Commercial grade dry dimethylformamide (DMF), dimethylacetamide (DMA), *N*-methylacetamide (NMA), and 1,2-dimethoxyethane (DME) were used as solvents. All reactions were carried out under argon atmosphere and anhydrous conditions unless otherwise noted. Analytical thin-layer chromatography (TLC) was performed on silica gel 60 F_{254} aluminum TLC sheets. Visualization of the developed chromatogram was performed by UV absorbance or iodine exposure. For purification, column chromatography was performed using 100–200 mesh silica gel. ^1H and ^{13}C NMR spectra were recorded on a 300, 400, or 600 MHz spectrometer using tetramethylsilane (TMS) as internal standard. Chemical shifts (δ) are given from TMS ($\delta = 0.00$) in parts per million (ppm) with reference to the residual nuclei of the deuterated solvent used [$CDCl_3$: ^1H NMR $\delta = 7.26$ ppm (s); ^{13}C NMR $\delta = 77.0$ ppm]. Coupling constants (J) are expressed in hertz (Hz), and spin multiplicities are given as singlet (s), doublet (d), double doublet (dd), triplet (t), triple doublet (td), quartet (q), multiplet (m), and broad (br), apparent (app). All ^{13}C NMR spectra were obtained with complete proton decoupling. Mass spectra were performed using electrospray ionization (ESI) time-of-flight or electron ionization (EI) mode.

Procedure for the Preparation of Starting Materials 7a. 2-(2-Ethynylphenyl)acetonitrile derivatives **S1** (see Scheme S1 in the Supporting Information) were prepared in two steps comprising "Sonogashira reaction" of 2-iodophenylacetonitrile derivatives with trimethylsilylacetylene followed by deprotection of the silyl group of the resulting product using potassium carbonate[18] (Scheme S1a in the Supporting Information). Thereafter, the desired starting material **7a** was prepared in three steps starting from benzaldehyde derivatives, as

DOI: 10.1021/acs.joc.9b00861
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shown in Scheme S1b (in the Supporting Information). In the first step, the benzaldehyde derivatives were converted into their corresponding α,β-unsaturated ester **S2** employing a halo-Wittig reaction, and the product reduced to the corresponding α,β-unsaturated alcohol **S3** using diisobutylaliminium hydride (DIBAL-H).[19] Finally, compound **S3** underwent "Sonogashira coupling" with acetylenic compound **S1** synthesized previously leading to the formation of the desired starting material **7a**.

General Synthesis of α,β-Unsaturated Esters S2 via Halo-Wittig Reaction (See Scheme S1b in the Supporting Information). To a well-stirred and cooled (−5 °C) solution of (ethoxycarbonylmethyl)triphenylphosphonium bromide (500 mg, 1.17 mmol) dissolved in dry MeOH (10 mL) were added molecular iodine (572 mg, 2.26 mmol) and freshly activated K_2CO_3 (160 mg, 1.17 mmol) successively. The temperature of the reaction mixture was strictly maintained between −5 and 5 °C over a period of 1.5 h, resulting in the formation of a brown-colored suspension. To this, the aldehyde derivatives (0.98 mmol), tetrabutylammonium bromide (16.1 mg, 0.05 mmol), and K_2CO_3 (22.3 mg, 0.16 mmol) were added successively and stirred for few minutes. The reaction pot was then removed from the low-temperature bath (using ice−salt mixture) and heated at 40 °C for another 2−8 h. During this time period, additional amount of K_2CO_3 (2 × 0.05 mmol) was added in two portions at 2 h intervals. Upon completion of reaction (TLC), MeOH was evaporated under vacuum and the crude residue was treated with 2 M sodium thiosulfate solution to remove the excess iodine. It was then extracted with ethyl acetate (2 × 20 mL); the combined organic extracts were washed with brine (25 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 eluting with 10−40% ethyl acetate−petroleum ether to obtain α,β-unsaturated esters **S2** in 60−75% yield.

General Synthesis of α,β-Unsaturated Alcohols S3 (See Scheme S1b in the Supporting Information). To a well-stirred and cooled (using ice−salt mixture) solution of unsaturated ester **S2** (0.69 mmol, 1.0 equiv) dissolved in dry DCM (5 mL) was added DIBAL hydride (1.2 M in toluene, 1.74 mL, 2.08 mmol, 3 equiv) solution dropwise under argon atmosphere and stirring was continued for another 2−3 h at the same temperature. Upon completion of the reaction (TLC), the reaction mixture was quenched with 15% sodium hydroxide solution (15 mL) and diluted with DCM (20 mL). The resulting thick reaction mixture was filtered through a bed of celite to obtain a clear layer separation. The organic layer was taken out and washed successively with water (8 mL) and brine solution (8 mL). The combined organic extracts were dried over Na_2SO_4, concentrated, and purified by silica gel (100−200 mesh) column chromatography using 15−25% ethyl acetate in pet−ether (v/v) as eluent. The pure α,β-unsaturated alcohols **S3** were obtained in 42−76% yields.

General Procedure for the Preparation of Alkynyl Allyl Alcohols 7a (See Scheme S1b in the Supporting Information). Alcohols **7a** were prepared via Sonogashira reaction, as depicted in Scheme S1. Accordingly, acetylene **S1** (0.42 mmol, 1.1 equiv) and the vinyl iodide derivative **S3** (0.38 mmol, 1 equiv) were dissolved in dry Et_3N (2 mL) under argon atmosphere. To this solution was added $Pd(PPh_3)_2Cl_2$ (8.0 mg, 0.011 mmol, 3 mol %). After stirring the whole reaction mixture for another 10 min, copper(I) iodide (2.2 mg, 0.011 mmol, 3 mol %) was added and it was then heated at 65 °C for 16 h. Upon completion of the reaction (TLC), the solvent was removed under reduced pressure and the crude product was purified through silica gel (100−200 mesh) column chromatography to obtain the desired compounds **7a** in 40−80% yield.

*Spectral Data of Starting Materials **7aa**−**aj**. (E)-2-(2-(3-(Hydroxymethyl)-4-phenylbut-3-en-1-yn-1-yl)phenyl)acetonitrile (**7aa**).* Brown solid (75.8 mg, 75%), R_f = 0.43 (30% ethyl acetate in petroleum ether, v/v), mp 68−70 °C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ_H 7.84 (d, J = 7.2 Hz, 2H), 7.56−7.45 (m, 2H), 7.42−7.32 (m, 5H), 6.91 (s, 1H), 4.43 (s, 2H), 3.88 (s, 2H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 75 MHz) δ_C 135.8, 135.1, 132.5, 131.6, 129.3, 128.7, 128.6, 128.4, 128.2, 122.6, 121.1, 117.6, 93.5, 92.9, 67.1, 22.7; high-resolution mass spectrometry (HRMS) (ESI) m/z calcd for $C_{19}H_{15}NNaO$ $[M + Na]^+$ 296.1051, found 296.1056.

*(E)-2-(2-(3-(Hydroxymethyl)-4-phenylbut-3-en-1-yn-1-yl)-4,5-dimethoxyphenyl)acetonitrile (**7ab**).* White solid (94.9 mg, 77%), R_f = 0.19 (30% ethyl acetate in petroleum ether, v/v), mp 158−160 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 7.82 (d, J = 7.2 Hz, 2H), 7.40−7.37 (m, 2H), 7.33−7.30 (m, 1H), 6.97 (s, 1H), 6.91 (s, 1H), 6.88 (s, 1H), 4.41 (s, 2H), 3.93 (s, 3H), 3.89 (s, 3H), 3.83 (s, 2H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 150.0, 148.5, 135.9, 134.5, 128.6, 128.5, 128.3, 124.8, 121.3, 117.8, 115.2, 114.6, 111.1, 93.3, 91.9, 67.2, 56.1, 22.3; HRMS (ESI) m/z calcd for $C_{21}H_{20}NO_3$ $[M + H]^+$ 334.1443, found 334.1445.

*(E)-2-(2-(3-(Hydroxymethyl)-4-phenylbut-3-en-1-yn-1-yl)-4-(trifluoromethyl)phenyl)acetonitrile (**7ac**).* Brown solid (50.5 mg, 40%), R_f = 0.74 (30% ethyl acetate in petroleum ether, v/v), mp 120−122 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 7.80−7.77 (m, 3H), 7.62 (s, 2H), 7.41 (t, J = 7.5 Hz, 2H), 7.36 (t, J = 7.2 Hz, 1H), 6.98 (s, 1H), 4.44 (s, 2H), 3.91 (s, 2H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 136.5, 135.6, 135.4, 131.0 (q, J = 33.0 Hz), 129.3 (q, J_{C-F} = 3.5 Hz), 129.0, 128.9, 128.7, 128.5, 125.8 (q, J_{C-F} = 3.6 Hz), 123.6, 123.3 (q, J = 270.9 Hz), 120.7, 116.7, 95.2, 91.2, 67.0, 22.8; HRMS (ESI) m/z calcd for $C_{20}H_{15}F_3NO$ $[M + H]^+$ 342.1106, found 342.1111.

*(E)-2-(2-(4-(4-Chlorophenyl)-3-(hydroxymethyl)but-3-en-1-yn-1-yl)phenyl)acetonitrile (**7ad**).* Pale yellow solid (90.8 mg, 80%), R_f = 0.36 (30% ethyl acetate in petroleum ether, v/v), mp 80−82 °C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ_H 7.78 (d, J = 8.4 Hz, 2H), 7.54−7.52 (m, 1H), 7.48−7.42 (m, 1H), 7.40−7.35 (m, 4H), 6.86 (s, 1H), 4.43 (d, J = 5.4 Hz, 2H), 3.88 (s, 2H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 75 MHz) δ_C 134.3, 134.2, 133.6, 132.6, 131.6, 129.9, 129.5, 128.6, 128.4, 122.5, 121.6, 117.5, 93.6, 93.2, 67.0, 22.9; HRMS (ESI) m/z calcd for $C_{19}H_{14}ClNNaO$ $[M + Na]^+$ 330.0662, found 330.0657.

*(E)-2-(2-(3-(Hydroxymethyl)-4-(4-(trifluoromethyl)phenyl)but-3-en-1-yn-1-yl)phenyl)acetonitrile (**7ae**).* Pale brown solid (78.2 mg, 62%), R_f = 0.69 (30% ethyl acetate in petroleum ether, v/v), mp 126−128 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 7.94 (d, J = 7.8 Hz, 2H), 7.64 (d, J = 7.8 Hz, 2H), 7.53 (d, J = 6.6 Hz, 1H), 7.46 (d, J = 7.8 Hz, 1H), 7.41 (t, J = 7.2 Hz, 1H), 7.37 (t, J = 7.5 Hz, 1H), 6.94 (s, 1H), 4.46 (s, 2H), 3.87 (s, 2H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 139.2, 133.1, 132.7, 131.7, 130.1 (q, J_{C-F} = 32.6 Hz), 129.7, 128.8, 128.7, 128.5, 125.4 (q, J_{C-F} = 3.6 Hz), 124.0 (q, J_{C-F} = 270 Hz), 123.7, 122.3, 117.5, 94.0, 92.8, 66.9, 22.9; HRMS (ESI) m/z calcd for $C_{20}H_{14}F_3NNaO$ $[M + Na]^+$ 364.0925, found 364.0933.

*(E)-2-(2-(3-(Hydroxymethyl)-4-(4-methoxyphenyl)but-3-en-1-yn-1-yl)phenyl)acetonitrile (**7af**).* Pale yellow solid (86.3 mg, 77%), R_f = 0.66 (30% ethyl acetate in petroleum ether, v/v), mp 60−62 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 7.82 (d, J = 8.4 Hz, 2H), 7.56−7.54 (m, 1H), 7.48 (d, J = 7.2 Hz, 1H), 7.39 (td, J = 7.4, 1.2 Hz, 1H), 7.37−7.34 (m, 1H), 6.93−6.92 (m, 2H), 6.83 (s, 1H), 4.40 (s, 2H), 3.91 (s, 2H), 3.87 (s, 3H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 159.9, 135.2, 132.5, 131.6, 130.2, 129.2, 128.6, 128.4, 128.3, 122.9, 118.5, 117.7, 113.8, 113.8, 94.0, 92.8, 67.6, 55.4, 22.9; HRMS (ESI) m/z calcd for $C_{20}H_{18}NO_2$ $[M + H]^+$ 304.1338, found 304.1328.

*(Z)-2-(2-(4-(2,5-Dimethoxyphenyl)-3-(hydroxymethyl)but-3-en-1-yn-1-yl)phenyl)acetonitrile (**7ag**).* Brown solid (83.8 mg, 68%), R_f = 0.71 (30% ethyl acetate in petroleum ether, v/v), mp 78−180 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 7.86 (d, J = 3.0 Hz, 1H), 7.50 (t, J = 7.8 Hz, 2H), 7.38−7.35 (m, 1H), 7.32−7.29 (m, 1H), 7.23 (s, 1H), 6.86−8.82 (m, 2H), 4.43 (s, 2H), 3.91 (s, 2H), 3.82 (s, 3H), 3.78 (s, 3H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 152.9, 151.5, 132.4, 131.8, 129.9, 129.2, 127.9, 125.5, 122.5, 121.4, 117.6, 115.0, 113.9, 111.4, 93.6, 92.9, 67.3, 56.0, 55.7, 22.8; HRMS (ESI) m/z calcd for $C_{21}H_{20}NO_3$ $[M + H]^+$ 334.1443, found 334.1434.

*(Z)-2-(2-(3-(Hydroxymethyl)-4-(thiophen-2-yl)but-3-en-1-yn-1-yl)phenyl)acetonitrile (**7ah**).* Dark brown gummy liquid (57.8 mg, 56%), R_f = 0.43 (30% ethyl acetate in petroleum ether, v/v); ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 7.68−7.56 (m, 1H), 7.50 (d, J = 7.2 Hz, 1H), 7.42−7.37 (m, 2H), 7.36−7.34 (m, 1H), 7.27−7.26 (m, 1H), 7.12 (s, 1H), 7.06−7.04 (m, 1H), 4.42 (s, 2H), 3.99 (s, 2H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 139.8, 132.4, 131.6, 130.1, 129.4, 128.9, 128.4, 128.3, 127.2, 126.7, 122.7, 118.2, 117.6, 96.3, 93.6, 66.5, 22.9; HRMS

DOI: 10.1021/acs.joc.9b00861
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(ESI) m/z calcd for $C_{17}H_{13}NNaOS$ $[M + Na]^+$ 302.0616, found 302.0616.

*(E)-2-(2-(4-(Furan-2-yl)-3-(hydroxymethyl)but-3-en-1-yn-1-yl)-phenyl)acetonitrile (**7ai**).* Dark brown gum (51.6 mg, 53%), R_f = 0.41 (10% ethyl acetate in petroleum ether, v/v); ^{1}H NMR ($CDCl_3$, 300 MHz) δ_H 7.58−7.56 (m, 1H), 7.51−7.47 (m, 2H), 7.42−7.33 (m, 2H), 6.90 (d, J = 3.6 Hz, 1H), 6.79 (s, 1H), 6.49−6.48 (m, 1H), 4.40 (s, 2H), 4.00 (s, 2H), 2.07 (s, 1H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 75 MHz) δ_C 151.9, 142.6, 132.4, 131.6, 129.2, 128.3, 128.2, 122.9, 122.7, 118.1, 117.7, 111.9, 111.4, 94.0, 93.5, 66.2, 22.6; HRMS (ESI) m/z calcd for $C_{17}H_{13}NNaO_2$ $[M + Na]^+$ 286.0844, found 286.0971.

*2-(2-(3-(Hydroxymethyl)but-3-en-1-yn-1-yl)phenyl)acetonitrile (**7aj**).* Brown gum (32.9 mg, 44%), R_f = 0.38 (10% ethyl acetate in petroleum ether, v/v); ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 7.55−7.50 (m, 2H), 7.46−7.41 (m, 1H), 7.39−7.36 (m, 1H), 7.34−7.31 (m, 1H), 5.65 (d, J = 18.6 Hz, 1H), 4.45 (s, 1 H), 4.28 (s, 1H), 3.90 (d, J = 10.8 Hz, 2H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 133.5, 132.4, 130.1, 129.2, 128.3, 128.2, 121.7, 82.5, 78.9, 51.6, 22.8; HRMS (ESI+) m/z calcd for $C_{13}H_{12}NO$ $[M + H]^+$ 198.0919, found 198.0923.

General Procedure for the Synthesis of 1a. A mixture of $Pd(OAc)_2$bpy (4.8 mg, 0.01 mmol, 5 mol %) and D-CSA (87 mg, 0.38 mmol) in dry NMA (1.5 mL) was stirred at 95 °C for 5 min under argon atmosphere. Then, the starting material **7a** (0.25 mmol) dissolved in NMA (1.5 mL) was added to the reaction mixture dropwise at the same temperature and the whole mixture was stirred at 100 °C for few hours (see Scheme 2 in the text) until completion of the reaction (TLC). Thereafter, the reaction mixture was neutralized by adjusting the pH (∼7) with dropwise addition of 20% aqueous sodium bicarbonate solution and 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 using 5−15% ethyl acetate−petroleum ether (v/v) as eluent to afford the desired product **1aa**−**aj** in 25−78% yield.

Procedure for the Gram-Scale Synthesis of 1aa. A mixture of $Pd(OAc)_2$bpy (69.6 mg, 0.18 mmol, 5 mol %) and D-CSA (1273.7 mg, 5.49 mmol) in dry NMA (7 mL) was stirred at 95 °C for 5 min under argon atmosphere. Then, **7a** (1.0 g, 3.66 mmol, 1 equiv) dissolved in NMA (6 mL) was added dropwise at the same temperature and the mixture was stirred at 100 °C for 1.5 h. Then, the reaction mixture was neutralized by adjusting the pH (∼7) with dropwise addition of 20% aqueous sodium bicarbonate solution and extracted with ethyl acetate (2 × 30 mL). The combined organic extracts were washed with brine (30 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 using 5% ethyl acetate−petroleum ether (v/v) as eluent to afford the desired product **1aa** in 73% yield (729.4 mg).

*Spectral Data of Products **1aa**−**aj**. 3-Benzylnaphtho[1,2-b]furan-4-amine (**1aa**).* Brown solid (49.1 mg, 72%), R_f = 0.47 (10% ethyl acetate in petroleum ether), mp 118−120 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.16 (d, J = 7.8 Hz, 1H), 7.63 (d, J = 7.8 Hz, 1H), 7.53 (s, 1H), 7.39−7.36 (m, 1H), 7.35−7.32 (m, 3H), 7.30−7.25 (m, 3H), 6.71 (s, 1H), 4.27 (s, 2H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 152.9, 141.7, 139.4, 139.2, 132.9, 129.0, 128.4, 126.9, 125.8, 125.7, 122.8, 120.0, 119.2, 117.1, 115.6, 104.0, 30.7; HRMS (ESI) m/z calcd for $C_{19}H_{16}NO$ $[M + H]^+$ 274.1232, found 274.1238.

*3-Benzyl-7,8-dimethoxynaphtho[1,2-b]furan-4-amine (**1ab**).* Pale yellow solid (62.4 mg, 75%), R_f = 0.10 (10% ethyl acetate in petroleum ether), mp 110−112 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 7.47 (d, J = 8.4 Hz, 2H), 7.34−7.32 (m, 2H), 7.29−7.25 (m, 3H), 6.98 (s, 1H), 6.58 (s, 1H), 4.24 (s, 2H), 4.03 (s, 3H), 3.97 (s, 3H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 152.5, 149.3, 147.3, 140.9, 139.6, 138.2, 128.9, 128.4, 128.3, 126.8, 119.3, 114.2, 111.4, 105.5, 103.4, 99.8, 55.9, 55.8, 30.7; HRMS (ESI) m/z calcd for $C_{21}H_{20}NO_3$ $[M + H]^+$ 334.1443, found 334.1446.

*3-Benzyl-8-(trifluoromethyl)naphtho[1,2-b]furan-4-amine (**1ac**).* Brown solid (56.2 mg, 66%), R_f = 0.36 (10% ethyl acetate in petroleum ether), mp 120−122 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.45 (s, 1H), 7.69 (d, J = 9.0 Hz, 1H), 7.57 (s, 1H), 7.51 (d, J = 9.0 Hz, 1H), 7.35−7.33 (m, 2H), 7.28−7.26 (m, 3H), 6.69 (s, 1H), 4.26 (s, 2H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 153.0, 142.2, 141.8, 139.0, 134.5, 129.1, 128.3, 127.0, 126.3, 124.8 (q, J_{C-F} = 269.9 Hz), 124.2 (q, J_{C-F} = 32.0 Hz), 121.3 (q, J_{C-F} = 3.1 Hz), 119.3, 118.1 (q, J_{C-F} = 4.7 Hz), 116.2, 115.4, 102.9, 30.6; $^{19}F\{^1H\}$ NMR (376 MHz, $CDCl_3$) δ = −161.6 (s, 3F); HRMS (ESI) m/z calcd for $C_{20}H_{15}F_3NO$ $[M + H]^+$ 342.1106, found 342.1108.

*3-(4-Chlorobenzyl)naphtho[1,2-b]furan-4-amine (**1ad**).* White solid (52.9 mg, 69%), R_f = 0.38 (10% ethyl acetate in petroleum ether), mp 80−82 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.16 (d, J = 7.8 Hz, 1H), 7.64 (d, J = 8.4 Hz, 1H), 7.50 (s, 1H), 7.38 (t, J = 6.9 Hz, 1H), 7.34 (t, J = 6.9 Hz, 1H), 7.30 (d, J = 8.4 Hz, 2H), 7.22 (d, J = 8.4 Hz, 2H), 6.70 (s, 1H), 4.22 (s, 2H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 152.9, 141.7, 139.1, 137.9, 133.0, 132.7, 129.7, 129.1, 125.9, 125.8, 122.9, 120.0, 118.8, 117.0, 115.4, 104.1, 30.2; HRMS (EI) m/z calcd for $C_{19}H_{14}ClNO$ $[M]^+$ 307.0764, found 307.0756.

*3-(4-(Trifluoromethyl)benzyl)naphtho[1,2-b]furan-4-amine (**1ae**).* Brown solid (64.8 mg, 76%), R_f = 0.38 (10% ethyl acetate in petroleum ether), mp 94−96 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.17 (d, J = 7.8 Hz, 1H), 7.65 (d, J = 8.4 Hz, 1H), 7.60 (d, J = 7.8 Hz, 2H), 7.51 (s, 1H), 7.41 (d, J = 7.8 Hz, 2H), 7.39 (d, J = 7.2 Hz, 1H), 7.35 (t, J = 7.2 Hz, 1H), 6.70 (s, 1H), 4.31 (s, 2H), 3.77 (bs, 2H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 152.9, 143.6, 141.7, 139.2, 133.0, 129.2 (app q, J_{C-F} = 32.7 Hz), 128.7, 125.8 (q, J_{C-F} = 3.6 Hz), 124.1 (app q, J_{C-F} = 270.5 Hz), 122.9, 119.9, 118.3, 116.9, 115.3, 104.1 30.7; $^{19}F\{^1H\}$ NMR (376 MHz, $CDCl_3$) δ = −162.4 (s, 3F); HRMS (ESI) m/z calcd for $C_{20}H_{15}F_3NO$ $[M + H]^+$ 342.1106, found 342.1146.

*3-(4-Methoxybenzyl)naphtho[1,2-b]furan-4-amine (**1af**).* Pale yellow solid (49.2 mg, 65%), R_f = 0.36 (10% ethyl acetate in petroleum ether), mp 152−154 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.16 (d, J = 7.8 Hz, 1H), 7.63 (d, J = 8.4 Hz, 1H), 7.52 (s, 1H), 7.39−7.36 (m, 1H), 7.33 (t, J = 7.8 Hz, 1H), 7.20 (d, J = 8.4 Hz, 2H), 6.86 (d, J = 8.4 Hz, 2H), 6.70 (s, 1H), 4.20 (s, 2H), 3.79 (s, 3H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 158.5, 152.9, 141.6, 141.5, 133.0, 131.4, 129.3, 125.9, 125.8, 125.7, 122.7, 120.0, 119.6, 114.3, 55.3, 29.8; HRMS (ESI) m/z calcd for $C_{20}H_{18}NO_2$ $[M + H]^+$ 304.1338, found 304.1348.

*2-(2,5-Dimethoxybenzyl)naphtho[1,2-b]furan-4-amine (**1ag**).* Brown solid (56.6 mg, 78%), R_f = 0.27 (10% ethyl acetate in petroleum ether), mp 96−98 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.16 (d, J = 7.8 Hz, 1H), 7.63 (d, J = 7.8 Hz, 1H), 7.51 (s, 1H), 7.37−7.35 (m, 1H), 7.33−7.30 (m, 1H), 6.86 (d, J = 9.0 Hz, 1H), 6.75 (dd, J = 9.0, 3.0 Hz, 1H), 6.69−6.68 (d, 2H), 4.19 (s, 2H), 4.02 (s, 2H), 3.86 (s, 3H), 3.64 (s, 3H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 153.8, 152.6, 151.0, 141.5, 139.8, 132.9, 129.1, 125.7, 125.5, 122.5, 119.9, 118.8, 116.8, 115.9, 115.5, 117.7, 113.3, 103.3, 55.9, 55.6, 24.3; HRMS (ESI) m/z calcd for $C_{21}H_{19}NNaO_3$ $[M + Na]^+$ 356.1263, found 356.1264.

*3-(Thiophen-2-ylmethyl)naphtho[1,2-b]furan-4-amine (**1ah**).* Brown gum (23.0 mg, 25%), R_f = 0.41 (10% ethyl acetate in petroleum ether); ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.16 (d, J = 7.8 Hz, 1H), 7.65−7.63 (m, 2H), 7.38 (t, J = 7.8 Hz, 1H), 7.34 (t, J = 7.5 Hz, 1H), 7.22 (d, J = 4.8 Hz, 1H), 6.97−6.95 (m, 1H), 6.90−6.89 (m, 1H), 6.70 (s, 1H), 4.41 (s, 2H), 3.89 (brs, 2H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 152.8, 143.3, 141.2, 139.5, 133.0, 127.2, 125.8, 125.7, 125.2, 124.8, 122.7 119.9, 119.1, 116.9, 115.3, 103.8, 25.5; HRMS (ESI) m/z calcd for $C_{17}H_{14}NOS$ $[M + H]^+$ 280.0796, found 280.0789.

*3-(Furan-2-ylmethyl)naphtho[1,2-b]furan-4-amine (**1ai**).* Brown solid (23.0 mg, 35% yield), R_f = 0.38 (10% ethyl acetate in petroleum ether), mp 60−62 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.15 (d, J = 7.8 Hz, 1H), 7.65 (d, J = 8.4 Hz, 1H), 7.61 (s, 1H), 7.39−7.37 (m, 2H), 7.36−7.33 (m, 1H), 6.85 (s, 1H), 6.32−6.31 (m, 1H), 6.08−6.07 (m, 1H), 4.25 (s, 2H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 153.6, 152.6, 142.0, 141.5, 132.8, 125.9, 125.7, 123.0, 119.9, 116.9, 115.6, 110.6, 106.6, 24.1; HRMS (ESI) m/z calcd for $C_{17}H_{14}NO_2$ $[M + H]^+$ 264.1025, found 264.1034.

*3-Methylnaphtho[1,2-b]furan-4-amine (**1aj**).* Brown solid (22.5 mg, 57%), R_f = 0.29 (10% ethyl acetate in petroleum ether), mp 122−124 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.13 (d, J = 8.4 Hz, 1H), 7.67 (d, J = 7.8 Hz, 1H), 7.47 (s, 1H), 7.39−7.36 (m, 1H), 7.34−7.32 (m, 1H), 6.83 (s, 1H), 2.52 (s, 3H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 152.4, 140.4, 132.8, 126.0, 125.6, 122.9, 120.0, 117.3, 116.1, 115.7,

DOI: 10.1021/acs.joc.9b00861
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104.1, 10.4; HRMS (EI) m/z calcd for $C_{13}H_{11}NO$ $[M]^+$ 197.0841, found 197.0829.

Preparation of the Starting Materials 7b (See Scheme S2 of the Supporting Information). The acetylenic compound **S5** was prepared from iodo compound **S4** via Sonogashira reaction, as shown in Scheme S2a in the Supporting Information. Next, **S5** underwent the coupling reaction with **S3** via the aforesaid reaction process to furnish the product **S6**. Finally, the exposure of **S6** to acidic conditions led to the formation of the desired substrate **7b** (Scheme S2b in the Supporting Information).

Preparation of Acetylenic Compounds S5 (See Scheme S2a in the Supporting Information). To a well-stirred and ice-cooled solution of **S4**[20] (1.92 mmol, 1 equiv) in Et_3N (5 mL) were added $PdCl_2(PPh_3)_2$ (40.4 mg, 0.057 mmol, 3 mol %), CuI (21.9 mg, 0.115 mmol, 6 mol %), and trimethylsilylacetylene (1.1 equiv) sequentially. The reaction mixture was allowed to reach rt and stirring was continued for 1−1.5 h until completion of the reaction (TLC). Thereafter, the solvent was removed under reduced pressure, diluted with water (10 mL), and extracted with ethyl acetate (3 × 15 mL). The combined organic extracts were dried over anhydrous Na_2SO_4, filtered, and concentrated in vacuo. The crude mass was purified through column chromatography using silica gel (100−200 mesh) to afford pure silylated acetylenic compound (90−95% yield), which was then desilylated. Thus, silylated compound (1.82 mmol, 1 equiv) dissolved in methanol was stirred at rt for 0.5−1 h in the presence of K_2CO_3 (0.1 equiv). Upon completion of reaction, the reaction mixture was diluted with water (10 mL), extracted with ethyl acetate (2 × 15 mL), and concentrated under reduced pressure. The crude product obtained was purified by silica gel (100−200 mesh) column chromatography to obtain the acetylenic compounds **S5** in 56−60% yield.

Preparation of the Intermediates S6 (See Scheme S2b in the Supporting Information). To a well-stirred and ice-cooled solution of **S3** (0.77 mmol, 1 equiv) in Et_3N (2 mL) were added $Pd(PPh_3)_2Cl_2$ (16.2 mg, 0.023 mmol, 3 mol %), acetylenic intermediate **S5** (0.846 mmol, 1.1 equiv), and CuI (8.8 mg, 0.046 mmol, 6 mol %) successively. The reaction mixture was then stirred at rt under argon atmosphere for 1−2 h until the completion of the reaction (TLC). Thereafter, the solvent was removed under reduced pressure and the resulting crude mixture was extracted with ethyl acetate (3 × 30 mL); the combined organic extracts were washed with brine (25 mL), dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The resulting crude residue was purified through silica gel (100−200 mesh) column chromatography eluting with 10−40% ethyl acetate−petroleum ether (v/v) to afford the desired compounds **S6** in 78−90% yield.

Preparation of the Ene−Yne Substrates 7b (See Scheme S2b in the Supporting Information). To a well-stirred and ice-cooled solution of **S6** (0.69 mmol, 1 equiv) in dry acetone, *p*-TsOH (210.9 mg, 1.11 mmol, 1.6 equiv) was added in portions over a period of 20 min and the reaction mixture was stirred at rt for another 3−4 h until completion of reaction (TLC). Next, the reaction mixture was neutralized with dilute sodium bicarbonate solution and extracted with DCM (2 × 10 mL). The combined organic extracts were evaporated under reduced pressure; the resulting crude product was purified by silica gel (100−200 mesh) column chromatography to afford the desired starting materials **7b** in 42−76% yield.

*Spectral Data for Starting Materials **7ba**−**bg**. (Z)-2-(2-(3-(Hydroxymethyl)-4-phenylbut-3-en-1-yn-1-yl)phenyl)acetaldehyde (**7ba**).* Yellow gum (144.7 mg, 76%), R_f = 0.36 (40% ethyl acetate in petroleum ether, v/v); ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 9.69 (t, J = 2.1 Hz, 1H), 7.84 (d, J = 7.8 Hz, 2H), 7.56 (d, J = 7.2 Hz, 1H), 7.37 (d, J = 7.8 Hz, 3H), 7.33−7.31 (m, 3H), 6.85 (s, 1H), 4.39 (s, 2H), 3.89 (d, J = 1.8 Hz, 2H), 3.32 (s, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 75 MHz) δ_C 135.8, 135.2, 132.5, 131.6, 129.3, 128.7, 128.4, 128.2, 122.6, 121.1, 117.6, 93.5, 92.9, 67.1, 22.8; HRMS (ESI) m/z calcd for $C_{19}H_{17}O_2$ $[M + H]^+$ 277.1229, found, 277.1228.

*(Z)-2-(2-(3-(Hydroxymethyl)-4-(naphthalen-2-yl)but-3-en-1-yn-1-yl)phenyl)acetaldehyde (**7bb**).* Yellow gum (150.7 mg, 67%), R_f = 0.31 (40% ethyl acetate in petroleum ether, v/v); ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 9.69 (t, J = 2.1 Hz, 1H), 8.26 (s, 1H), 7.84−7.82 (m, 5H), 7.50−7.48 (m, 5H), 7.01 (s, 1H), 4.45 (s, 2H), 3.91 (d, J = 1.8 Hz, 2H), 2.84 (s, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 75 MHz) δ_C 199.4, 134.8, 133.8, 133.5, 133.2, 132.4, 130.5, 129.2, 128.5, 128.3, 127.9, 127.8, 127.6, 126.5, 126.3, 126.1, 123.8, 121.7, 67.5, 49.6; HRMS (ESI) m/z calcd for $C_{23}H_{19}O_2$ $[M + H]^+$ 327.1385, found 327.1375.

*(Z)-2-(2-(4-(4-Chlorophenyl)-3-(hydroxymethyl)but-3-en-1-yn-1-yl)phenyl)acetaldehyde (**7bc**).* Yellow gum (98.4 mg, 46%), R_f = 0.31 (40% ethyl acetate in petroleum ether, v/v); ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 9.68 (t, J = 2.1 Hz, 1H), 7.76 (d, J = 9 Hz, 2H), 7.34−7.32 (m, 4H), 7.29−7.28 (m, 2H), 6.78 (s, 1H), 4.37 (d, J = 4.2 Hz, 2H), 3.87 (d, J = 1.8 Hz, 2H), 3.32 (s, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 75 MHz) δ_C 199.3, 134.4, 134.0, 133.8, 133.2, 132.5, 130.5, 129.9, 129.3, 128.5, 127.8, 123.6, 122.0, 95.1, 91.9, 67.2, 49.7; HRMS (ESI) m/z calcd for $C_{19}H_{15}ClNaO_2$ $[M + Na]^+$ 333.0658, found 333.0662.

*(Z)-2-(2-(3-(Hydroxymethyl)-4-(4-(trifluoromethyl)phenyl)but-3-en-1-yn-1-yl)phenyl)acetaldehyde (**7bd**).* Yellow liquid (163.8 mg, 69%), R_f = 0.28 (40% ethyl acetate in petroleum ether, v/v); ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 9.69 (t, J = 2.1 Hz, 1H), 7.94 (d, J = 7.8 Hz, 2H), 7.63 (d, J = 7.8 Hz, 2H), 7.55 (d, J = 7.2 Hz, 1H), 7.41 (td, J = 7.5, 1.2 Hz, 1H), 7.35 (td, J = 7.65, 1.4 Hz 1H), 7.31 (d, J = 7.2 Hz, 1H), 6.88 (s, 1H), 4.42 (d, J = 6.6Hz, 2H), 3.88 (d, J = 2.4 Hz, 2H), 2.57 (t, J = 6.9 Hz, 1H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 199.3, 139.3, 133.9, 132.5, 130.3,129.9 (q, J_{C-F} = 32.4 Hz), 129.5, 128.7, 127.8, 125.2 (q, J_{C-F} = 3.7 Hz), 124.1, 124.0 (q, J_{C-F} = 270.3 Hz), 123.4, 95.5, 91.6, 66.9, 49.7; HRMS (ESI) m/z calcd for $C_{20}H_{15}F_3NaO_2$ $[M + Na]^+$ 367.0922, found 367.0922.

*(Z)-2-(2-(3-(Hydroxymethyl)-4-(p-tolyl)but-3-en-1-yn-1-yl)-phenyl)acetaldehyde (**7be**).* Yellow gum (84.0 mg, 42%), R_f = 0.37 (40% ethyl acetate in petroleum ether, v/v); ^{1}H NMR ($CDCl_3$, 300 MHz) δ_H 9.71 (t, J = 2.25 Hz, 1H), 7.75 (d, J = 8.1 Hz, 2H), 7.58−7.55 (m, 1H), 7.37−7.29 (m, 3H), 7.19 (d, J = 7.8 Hz, 2H), 6.81 (s, 1H), 4.38 (s, 2H), 3.90 (d, J = 2.1 Hz, 2H), 2.37 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 75 MHz) δ_C 199.5, 138.6, 134.8, 133.8, 133.2, 132.5, 130.4, 129.0, 128.7, 127.7, 123.9, 120.3, 94.4, 92.7, 67.4, 49.6, 21.4; HRMS (ESI) m/z calcd for $C_{20}H_{18}NaO_2$ $[M + Na]^+$ 313.1204, found 313.1202.

*(Z)-2-(2-(3-(Hydroxymethyl)-4-phenylbut-3-en-1-yn-1-yl)-4,5-dimethoxyphenyl)acetaldehyde (**7bf**).* Yellow gum (115.9 mg, 50%), R_f = 0.21 (10% ethyl acetate in petroleum ether, v/v); ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 9.66 (t, J = 1.8 Hz, 1H), 7.79 (d, J = 6.8 Hz, 2H), 7.32−7.31 (m, 2H), 7.28−7.26 (m, 1H), 6.98 (s, 1H), 6.80 (s, 1H), 6.68 (s, 1H), 4.35 (s, 2H), 3.87 (s, 1H), 3.86 (s, 3H), 3.858 (s, 3H), 3.78 (s, 2H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 199.4, 149.9, 148.1, 136.1, 133.7, 128.6, 128.2, 127.2, 121.7, 115.7, 114.7, 112.9, 94.7, 90.7, 67.1, 56.0, 55.9, 49.0; HRMS (ESI) m/z calcd for $C_{21}H_{21}O_4$ $[M + H]^+$ 337.1440, found 337.1437.

*(Z)-2-(4-Fluoro-2-(3-(hydroxymethyl)-4-phenylbut-3-en-1-yn-1-yl)phenyl)acetaldehyde (**7bg**).* Yellow gum (97.4 mg, 48%), R_f = 0.35 (40% ethyl acetate in petroleum ether, v/v); ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 9.67 (t, J = 1.8 Hz, 1H), 7.80 (d, J = 7.2 Hz, 2H), 7.53−7.51 (m, 1H), 7.37 (t, J = 7.8 Hz, 3H), 7.02 (td, J = 8.4, 2.4 Hz, 1H), 6.99 (dd, J = 9, 2.4 Hz, 1H), 6.85 (s, 1H), 4.37 (s, 2H), 3.87 (d, J = 1.8 Hz, 2H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 198.4, 162.5 (d, J = 249 Hz), 136.5 (d, J = 7.5 Hz), 135.9, 134.8, 134.2 (d, J = 9 Hz), 128.6, 128.5, 128.3, 121.2, 119.8, 117.6 (d, J = 22.5 Hz), 115.1 (d, J = 21.0 Hz), 93.4, 91.9, 67.2, 49.3; HRMS (ESI) m/z calcd for $C_{19}H_{15}FKO_2$ $[M + K]^+$ 333.0693, found 333.0689.

General Procedure for the Synthesis of Products 1b. A mixture of $Pd(OAc)_2$bpy (3.4 mg, 0.009 mmol, 5 mol %) and D-CSA (62.6 mg, 0.27 mmol, 1.5 equiv) in dry THF (2 mL) was stirred at 60 °C under argon atmosphere. Then, **7b** (0.18 mmol) dissolved in dry THF (1.0 mL) was added at the same temperature (i.e., 60 °C) and the mixture was refluxed for 1−2 h until the completion of the reaction (TLC). The mixture was neutralized by adjusting the pH (~7) through dropwise addition of 20% aqueous sodium bicarbonate solution and extracted with ethyl acetate (3 × 20 mL). The combined organic extracts were washed with saturated 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)

DOI: 10.1021/acs.joc.9b00861
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column chromatography using 1−8% ethyl acetate−petroleum ether (v/v) as eluent to afford desired product **1ba**−**bg** in 57−88% yield.

*Spectral Data for Products **1ba**−**bg**. 3-Benzylnaphtho[1,2-b]furan (**1ba**).* Brown solid (38.1 mg, 82%), R_f = 0.71 (5% ethyl acetate in petroleum ether, v/v), mp 80−82 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.31 (d, J = 8.4 Hz, 1H), 7.92 (d, J = 8.4 Hz, 1H), 7.62−7.58 (m, 2H), 7.56 (s, 1H), 7.51−7.47 (m, 2H), 7.33 (s, 2H), 7.32 (d, J = 1.8 Hz, 2H), 7.26−7.23 (m, 1H), 4.13 (s, 2H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 151.1, 141.4, 139.4, 131.4, 128.6, 128.5, 128.3, 126.4, 126.2, 125.1, 123.4, 123.0, 121.5, 120.7, 119.9, 118.4, 30.0; HRMS (ESI) m/z calcd for $C_{19}H_{14}NaO$ $[M + Na]^+$ 281.0942, found 281.0945.

*3-(Naphthalen-2-ylmethyl)naphtho[1,2-b]furan (**1bb**).* White solid (36.6 mg, 66%), R_f = 0.62 (5% ethyl acetate in petroleum ether, v/v), mp 108−110 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.34 (d, J = 7.8 Hz, 1H), 7.92 (d, J = 7.8 Hz, 1H), 7.84 (d, J = 7.2 Hz, 1H), 7.81 (d, J = 8.4 Hz, 1H), 7.79−7.77 (m, 2H), 7.62−7.59 (m, 3H), 7.51−7.45 (m, 5H), 4.29 (s, 2H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 151.2, 141.6, 136.9, 133.6, 132.2, 131.4, 128.3, 128.2, 127.65, 127.57, 127.2, 126.8, 126.3, 126.0, 125.4, 125.1, 123.5, 123.1, 121.5, 120.6, 120.0, 118.5, 30.2; HRMS (ESI) m/z calcd for $C_{23}H_{16}NaO$ $[M + Na]^+$ 331.1099, found 331.1098.

*3-(4-Chlorobenzyl)naphtho[1,2-b]furan (**1bc**).* Yellow gum (42.1 mg, 80%), R_f = 0.71 (5% ethyl acetate in petroleum ether, v/v), ^{1}H NMR ($CDCl_3$, 400 MHz) δ_H 8.29 (d, J = 8.4 Hz, 1H), 7.91 (d, J = 8.4 Hz, 1H), 7.61−7.56 (m, 2H), 7.54 (t, J = 1 Hz, 1H), 7.50−7.46 (m, 1H), 7.41 (d, J = 8.4 Hz, 1H), 7.28−7.21 (m, 4H), 4.07 (s, 2H); ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz) δ_C 151.3, 141.5, 137.9, 132.3, 131.5, 130.0, 128.7, 128.4, 126.5, 125.3, 123.3, 121.6, 120.3, 120.1, 118.3, 29.5; HRMS (ESI) m/z calcd for $C_{19}H_{14}ClO$ $[M + H]^+$ 293.0733, found 293.0733.

*3-(4-(Trifluoromethyl)benzyl)naphtho[1,2-b]furan (**1bd**).* Yellow solid (51.6 mg, 88%), R_f = 0.60 (5% ethyl acetate in petroleum ether, v/v), mp 60−62 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.32 (d, J = 7.8 Hz, 1H), 7.93 (d, J = 7.8 Hz, 1H), 7.63−7.59 (m, 2H), 7.58−7.56 (m, 3H), 7.52−7.50 (m, 1H), 7.43−7.42 (m, 3H), 4.18 (s, 2H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 151.2, 143.5, 141.5, 131.5, 128.8, 128.7, 128.3, 126.4, 125.5 (q, J_{C-F} = 3.8 Hz), 125.3, 124.2 (app q, J_{C-F} = 270.1 Hz), 123.2, 123.1, 121.5, 119.9, 119.7, 118.1, 29.9; ^{19}F{^{1}H} NMR (376 MHz, $CDCl_3$) δ = −162.2 (s, 3F); HRMS (ESI) m/z calcd for $C_{20}H_{14}F_3O$ $[M + H]^+$ 327.0997, found 327.0993.

*3-(4-Methylbenzyl)naphtho[1,2-b]furan (**1be**).* Brown solid (37.2 mg, 76%), R_f = 0.73 (5% ethyl acetate in petroleum ether, v/v); mp 44−46 °C ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.31 (d, J = 7.8 Hz, 1H), 7.92 (d, J = 8.4 Hz, 1H), 7.62−7.57 (m, 2H), 7.55 (s, 1H), 7.50−7.47 (m, 2H), 7.21 (d, J = 7.8 Hz, 2H), 7.13 (d, J = 8.4 Hz, 2H), 4.09 (s, 2H), 2.34 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 151.1, 141.4, 136.3, 135.8, 131.4, 129.2, 128.5, 128.3, 126.2, 125.0, 123.5, 122.9, 121.5, 120.9, 119.9, 118.5, 29.7, 21.0; HRMS (ESI) m/z calcd for $C_{20}H_{16}NaO$ $[M + Na]^+$ 295.1099, found 295.1100.

*3-Benzyl-7,8-dimethoxynaphtho[1,2-b]furan (**1bf**).* White solid (32.6 mg, 57%), R_f = 0.17 (5% ethyl acetate in petroleum ether, v/v), mp 120−122 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 7.59 (s, 1H), 7.49−7.47 (m, 2H), 7.35−7.32 (m, 5H), 7.26−7.23 (m, 2H), 4.10 (s, 2H), 4.08 (s, 3H), 4.01 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 150.8, 149.7, 148.7, 140.7, 139.5, 128.6, 128.5, 126.9, 126.3, 122.4, 121.6, 120.8, 116.6, 116.5, 107.4, 99.3, 56.0, 55.8, 30.1; HRMS (ESI) m/z calcd for $C_{21}H_{18}NaO_3$ $[M + Na]^+$ 341.1154, found 341.1150.

*3-Benzyl-7-fluoronaphtho[1,2-b]furan (**1bg**).* Brown solid (35.3 mg, 71%), R_f = 0.69 (5% ethyl acetate in petroleum ether, v/v), mp 48−50 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.31−8.828 (m, 1H), 7.56−7.53 (m, 3H), 7.51−7.49 (m, 1H), 7.36 (td, J = 8.7, 2.4 Hz, 1H), 7.34−7.33 (m, 4H), 7.27−7.25 (m, 1H), 4.12 (s, 2H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 160.2 (d, J = 243.0 Hz), 151.2, 141.3, 139.3, 132.3 (d, J = 9.0 Hz), 128.6, 128.5, 126.4, 122.9, 122.4 (d, J = 9.0 Hz), 122.3 (d, J = 4.5 Hz), 120.8, 119.8, 118.5, 116.3, 116.1, 111.8, 111.7, 30.1; ^{19}F NMR{^{1}H} (376 MHz, $CDCl_3$) δ = −115.6 (s, 1F); HRMS (ESI) m/z calcd for $C_{19}H_{13}OFK$ $[M + K]^+$ 315.0588, found 315.0585.

*Procedure for the Synthesis of 7-Benzyl-2,4-dimethoxyfuro[3,2-h]quinazoline (**1bh**).* A mixture of $Pd(OAc)_2$bpy (2.7 mg, 0.007 mmol, 5 mol %) and D-CSA (82.4 mg, 0.355 mmol, 1.5 equiv) in dry THF (2 mL) was stirred at 60 °C under argon atmosphere. The substrate **10** (50 mg, 0.14 mmol) dissolved in NMA (1.0 mL) was then added to the reaction mixture, which was heated at 70 °C until the completion of the reaction (TLC). The reaction mixture was neutralized by adjusting the pH (~7) through dropwise addition of 20% aqueous sodium bicarbonate solution and 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 using 10% ethyl acetate−petroleum ether (v/v) as eluent to afford desired product **1bh** in 85% yield.

*7-Benzyl-2,4-dimethoxyfuro[3,2-h]quinazoline (**1bh**).* Brown solid (38.6 mg, 85%), R_f = 0.39 (20% ethyl acetate in petroleum ether, v/v), mp 134−136 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 7.72 (d, J = 8.4 Hz, 1H), 7.61 (s, 1H), 7.54 (d, J = 8.4 Hz, 1H), 7.32−7.27 (m, 4H), 7.25−7.22 (m, 1H), 4.29 (s, 3H), 4.11 (s, 3H), 4.10 (s, 2H); ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz) δ_C 167.8, 161.6, 151.9, 149.8, 142.5, 139.0, 128.7, 128.6, 126.6, 126.2, 123.9, 121.3, 120.5, 101.8, 54.9, 54.8, 29.8; HRMS (ESI) m/z calcd for$C_{19}H_{17}N_2O_3$ $[M + H]^+$ 321.1239, found 321.1244.

Procedure for the Synthesis of Uracil Derivative 10. To a well-stirred solution of **1bh** (30 mg, 0.085 mol, 1 equiv) in dry acetonitirile was added NaI (380 mg, 2.55 mmol, 3.0 equiv); this was followed by dropwise addition of trimethylsilyl chloride (0.3 mL, 2.55 mmol, 3.0 equiv), and the reaction was stirred at rt for 3 h until TLC showed complete conversion. The solvent was removed under vacuum and the crude mass was filtered, washed with ethyl acetate followed by water, and dried to obtain the pure product **10** in 52% yield.

*7-Benzylfuro[3,2-h]quinazoline-2,4(1H,3H)-dione (**10**).* Yellow solid (11.2 mg, 52%), mp > 250 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 11.28 (s, 1H), 11.26 (s, 1H), 7.89 (s, 1H), 7.71 (d, J = 8.4 Hz, 1H), 7.30−7.27 (m, 4H), 7.19−7.17 (m, 1H), 7.03 (d, J = 8.4 Hz, 1H), 4.01 (s, 2H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 161.0, 152.5, 150.6, 143.1, 139.84, 139.83, 128.9, 127.0, 126.7, 123.3, 119.9, 111.2, 101.6, 29.0; HRMS (ESI) m/z calcd for $C_{17}H_{13}N_2O_3$ $[M + H]^+$ 293.0926, found 293.0923.

Synthesis of Ene−Yne Substrates 8a (See Scheme S3 in the Supporting Information). The starting α,β-unsaturated alcohols **S3** utilized in this reaction (Scheme S3) were prepared from commercially available benzaldehyde derivatives, as shown previously under Scheme S1. The α,β-unsaturated alcohols **S3**, however, were converted into azide derivatives **S7** using NaN_3 in DMF. The azide compounds were reduced to the amine derivatives **S8** using 1,3-propanedithiol. In the next step, the amine derivatives were tosylated and the resulting compounds were allowed to undergo Sonogashira reaction with trimethylsilylacetylene. The deprotection of the silyl group using potassium carbonate led to the production of the desired acetylene derivatives **S10**, which underwent Sonogashira coupling with commercially available 2-iodophenylacetonitrile derivatives to afford the requisite ene−yne substrates **8a**.

Procedure for the Synthesis of Azide Derivatives S7 (See Scheme S3 in the Supporting Information). To a well-stirred ice-cooled solution of the α,β-unsaturated alcohols **S3** (3.85 mmol, 1 equiv) in dry DCM (10 mL), Et_3N (643 μL, 4.62 mmol, 1.2 equiv) was added dropwise and the stirring was continued for 10 min at the same temperature. Methanesulfonyl chloride (293 μL, 3.85 mmol, equiv) was then added dropwise at 0 °C, and the temperature of the reaction was increased up to rt with continuation of the stirring. After completion of reaction (TLC), the reaction was quenched with water (20 mL) and extracted with DCM (3 × 20 mL). The combined organic extracts were dried over anhydrous Na_2SO_4, filtered, and concentrated in vacuo to obtain a crude mixture. The crude product (without purification) was dissolved in dry DMF (5 mL) and treated with NaN_3 (1.5 equiv), and the mixture was stirred at rt for 1−2.5 h. After completion of reaction (TLC), the solvent (DMF) was removed in vacuo, diluted with water, and extracted with DCM (3 × 20 mL). The combined organic layers were dried over anhydrous Na_2SO_4 and concentrated in vacuo. The resulting crude mixture was subjected to silica gel (100−200 mesh) column chromatography and eluted with 5−10% ethyl acetate in

DOI: 10.1021/acs.joc.9b00861
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petroleum ether (v/v) to obtain the pure azide derivatives **S7** in 50−93% yields.

Procedure for the Synthesis of Amine Derivatives S8 (See Scheme S3 in the Supporting Information). To a well-stirred solution of azide derivative **S7** (2.81 mmol, 1 equiv) in a mixture of solvents (i.e., MeOH/MeCN = 1:1, 10 mL) was dropwise added *N*,*N*-diisopropylethylamine (1.5 mL, 8.42 mmol, 3 equiv) and the reaction mixture was stirred at rt for 5 min. Thereafter, 1,3-propanedithiol (0.6 mL, 5.61 mmol, 2 equiv) was added dropwise and the whole reaction mixture was stirred at rt for 2−4 h. After completion of reaction (TLC), the reaction was quenched with water (20 mL) and extracted with ethyl acetate (3 × 20 mL); the combined organic extracts were dried over anhydrous Na_2SO_4 and concentrated under reduced pressure; and the crude product was purified by silica gel (100−200 mesh) column chromatography eluting with 3−5% methanol in chloroform (v/v) to obtain the desired pure amine derivatives **S8** in 64−95% yields.

Procedure for the Synthesis of N-Tosylated Derivatives S9 (See Scheme S3 in the Supporting Information). To a well-stirred and cooled solution of amine derivative **S8** (2.32 mmol, 1 equiv) in dry DCM (8 mL) was added pyridine (242 μL, 3.01 mmol, 1.3 equiv) dropwise. Thereafter, *p*-toluenesulfonyl chloride (529 mg, 2.78 mmol, 1.2 equiv) was added portionwise at the same temperature and the reaction mixture was stirred at rt for 1−4 h. Upon completion of the reaction (TLC), it was quenched with water (20 mL) and extracted with ethyl acetate (3 × 30 mL). The combined organic extracts were dried over anhydrous Na_2SO_4 and concentrated in vacuo. Then, the crude product was purified by silica gel (100−200 mesh) column chromatography eluting with 10−26% ethyl acetate in petroleum ether (v/v) to obtain the pure tosylated products **S10** in 72−90% yields.

Procedure for the Synthesis of Acetylene Derivatives S10 (See Scheme S3 in the Supporting Information). To a well-stirred solution of iodoamine derivative **S9** (1.21 mmol, 1 equiv) in a mixture of solvents (i.e., Et_3N/DMF = 2:1, 3 mL), $PdCl_2(PPh_3)_2$ (25.4 mg, 0.036 mmol, 3 mol %) was added. The reaction mixture was then cooled to 0 °C, and trimethylsilylacetylene (189 μL, 1.33 mmol, 1.1 equiv) and CuI (13.7 mg, 0.072 mmol, 6 mol %) were added subsequently to the reaction mixture. After stirring few minutes at 0 °C, the temperature of the reaction was allowed to rise to rt and stirring was continued for 1.5−4 h. Upon completion of reaction (TLC), solvent was removed under reduced pressure and extracted with ethyl acetate (3 × 20 mL); the combined organic extracts were dried over anhydrous Na_2SO_4 and concentrated in vacuo. The crude product was then purified by silica gel (100−200 mesh) column chromatography eluting with 10−26% ethyl acetate in petroleum ether to obtain a silylated acetylenic intermediate (70−85% yields), which (1.04 mmol, 1 equiv) was later dissolved in dry MeOH (10 mL) and treated with K_2CO_3 (14.4 mg, 0.104 mmol, 0.1 equiv); the reaction mixture was then stirred at room temperature for 0.5−1.75 h until completion (TLC). The reaction was immediately quenched with water (20 mL) and extracted with ethyl acetate (3 × 30 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered, and concentrated in vacuo, and the crude product was purified by silica gel (100−200 mesh) column chromatography eluting with 10−30% ethyl acetate in petroleum ether (v/v) to obtain pure acetylene derivatives **S10** in 85−96% yields.

Procedure for the Synthesis of the Ene−Yne Substrates 8a (See Scheme S3 in the Supporting Information). To a well-stirred solution of commercially available 2-iodophenylacetonitrile (0.41 mmol, 1 equiv) in a mixture of solvents (Et_3N/DMF = 2:1, 2 mL) was added $PdCl_2(PPh_3)_2$ (8.6 mg, 0.012 mmol, 3 mol %). The whole reaction mixture was then cooled to 0 °C and the acetylenic intermediate **S10** (0.45 mmol, 1.1 equiv) dissolved in a mixture of solvents (i.e., Et_3N/DMF = 2:1) was added dropwise followed by CuI (4.6 mg, 0.024 mmol, 6 mol %). The temperature of the reaction was then increased to rt, and the stirring was continued for 1−8 h until completion of the reaction. Upon completion of reaction (TLC), the solvent was removed under reduced pressure and the crude material was diluted with water (10 mL) and extracted with ethyl acetate (3 × 20 mL); the combined organic extracts were dried over anhydrous Na_2SO_4, filtered, and concentrated in vacuo. The crude product was then purified by silica gel (100−200 mesh) column chromatography eluting with 10−30% ethyl acetate in petroleum ether (v/v) to obtain the requisite ene−yne substrates **8a** in 60−96% yields.

*Spectral Data of Starting Materials **8aa**−**aj**. (E)-N-(2-Benzylidene-4-(2-(cyanomethyl)phenyl)but-3-yn-1-yl)-4-methylbenzenesulfonamide (**8aa**).* Pale yellow solid (105 mg, 60%), R_f = 0.35 (25% ethyl acetate in petroleum ether, v/v), mp 106−108 °C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ_H 7.77 (d, *J* = 8.1 Hz, 2H), 7.66 (d, *J* = 6.9 Hz, 2H), 7.46−7.43 (m, 2H), 7.40−7.31 (m, 5H), 7.20 (d, *J* = 8.1 Hz, 2H), 6.69 (s, 1H), 5.29 (t, *J* = 6 Hz, 1H), 3.95 (d, *J* = 6 Hz, 2H), 3.79 (s, 2H), 2.33 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 75 MHz) δ_C 143.4, 137.4, 137.3, 135.3, 132.6, 131.7, 129.6, 129.4, 128.9, 128.6, 128.4, 128.3, 128.2, 127.1, 122.3, 117.6, 116.6, 93.1, 49.9, 22.8, 21.4; HRMS (ESI) *m*/*z* calcd for $C_{26}H_{23}N_2O_2S$ $[M + H]^+$ 427.1480, found 427.1480.

*(E)-N-(4-(2-(Cyanomethyl)phenyl)-2-(naphthalen-2-ylmethylene)but-3-yn-1-yl)-4-methylbenzene-sulfonamide (**8ab**).* Light yellow solid (147 mg, 75%), R_f = 0.26 (25% ethyl acetate in petroleum ether, v/v), mp 150−152 °C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ_H 8.06 (s, 1H), 7.90−7.77 (m, 6H), 7.51−7.34 (m, 6H), 7.22 (d, *J* = 8.1 Hz, 2H), 6.85 (s, 1H), 5.11 (t, *J* = 6.3 Hz, 1H), 4.02 (d, *J* = 6 Hz, 2H), 3.81 (s, 2H), 2.32(s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 75 MHz) δ_C 143.4, 137.5, 137.4, 133.3, 133.0, 132.8, 132.6, 131.7, 129.6, 129.5, 128.7, 128.5, 128.3, 128.2, 127.8, 127.7, 127.2, 126.7, 126.5, 125.7, 116.8, 93.4, 93.3, 50.1, 22.9, 21.4; HRMS (ESI) *m*/*z* calcd for $C_{30}H_{24}N_2NaO_2S$ $[M + Na]^+$ 499.1456, found 499.1469.

*(E)-N-(4-(2-(Cyanomethyl)phenyl)-2-(furan-2-ylmethylene)but-3-yn-1-yl)-4-methylbenzene-sulfonamide (**8ac**).* Brown solid (130 mg, 76%), R_f = 0.31 (25% ethyl acetate in petroleum ether, v/v), mp 102−104 °C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ_H 7.75 (d, *J* = 8.4 Hz, 2H), 7.48−7.31 (m, 5H), 7.21 (d, *J* = 8.1 Hz, 2H), 6.80 (d, *J* = 3.3 Hz, 1H), 6.57 (s, 1H), 6.46−6.44 (m, 1H), 5.29−5.25 (m, 1H), 3.91 (s, 2H), 3.88 (d, *J* = 6.3 Hz, 2H), 2.34 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 75 MHz) δ_C 151.3, 143.4, 142.8, 137.2, 132.5, 131.8, 129.5, 129.4, 128.3, 128.1, 127.1, 124.9, 122.4, 117.8, 113.5, 111.9, 111.8, 94.2, 93.1, 49.0, 22.6, 21.4; HRMS (ESI) *m*/*z* calcd for $C_{24}H_{20}N_2NaO_3S$ $[M + Na]^+$ 439.1092, found 439.1092.

*(E)-N-(4-(2-(Cyanomethyl)phenyl)-2-(thiophen-2-ylmethylene)-but-3-yn-1-yl)-4-methylbenzene-sulfonamide (**8ad**).* Yellow solid (160 mg, 90%), R_f = 0.33 (25% ethyl acetate in petroleum ether, v/v), mp 110−112 °C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ_H 7.74 (d, *J* = 8.4 Hz, 2H), 7.58−7.55 (m, 1H), 7.47−7.36 (m, 3H), 7.32 (d, *J* = 5.1 Hz, 1H), 7.19−7.16 (m, 3H), 7.03−7.00 (m, 1H), 6.91 (s, 1H), 5.34 (t, *J* = 6 Hz, 1H), 3.92 (d, *J* = 6.3 Hz, 2H), 3.89 (s, 2H), 2.32 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 75 MHz) δ_C 143.4, 139.3, 137.4, 132.5, 131.7, 131.0, 130.6, 129.6, 129.5, 128.4, 128.2, 127.5, 127.1, 126.6, 122.4, 117.8, 113.6, 96.4, 93.3, 49.2, 23.0, 21.4; HRMS (ESI) *m*/*z* calcd for $C_{24}H_{20}N_2NaO_2S_2$ $[M + Na]^+$ 455.0864, found 455.0868.

*(E)-N-(2-(4-Chlorobenzylidene)-4-(2-(cyanomethyl)phenyl)but-3-yn-1-yl)-4-methylbenzene-sulfonamide (**8ae**).* Pale yellow solid (165 mg, 87%), R_f = 0.33 (25% ethyl acetate in petroleum ether, v/v), mp 148−150 °C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ_H 7.76 (d, *J* = 8.1 Hz, 2H), 7.63 (d, *J* = 8.4 Hz, 2H), 7.46−7.31 (m, 6H), 7.22 (d, *J* = 7.8 Hz, 2H), 6.66 (s, 1H), 5.14 (t, *J* = 6.3 Hz, 1H), 3.95 (d, *J* = 6.3 Hz, 2H), 3.80 (s, 2H), 2.36 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 75 MHz) δ_C 143.4, 137.5, 135.8, 134.5, 133.7, 132.7, 131.7, 129.8, 129.7, 129.6, 128.6, 128.5, 128.3, 127.1, 122.2, 117.4, 117.3, 93.8, 92.8, 49.9, 22.9, 21.4; HRMS (ESI) *m*/*z* calcd for $C_{26}H_{21}ClN_2NaO_2S$ $[M + Na]^+$ 483.0910, found 483.0910.

*(E)-N-(4-(2-(Cyanomethyl)phenyl)-2-(4-methylbenzylidene)but-3-yn-1-yl)-4-methylbenzene-sulfonamide (**8af**).* White solid (174 mg, 96%), R_f = 0.38 (25% ethyl acetate in petroleum ether, v/v), mp 116−118 °C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ_H 7.76 (d, *J* = 8.1 Hz, 2H), 7.56 (d, *J* = 8.1 Hz, 2H), 7.45−7.43 (m, 2H), 7.39−7.29 (m, 2H), 7.20−7.14 (m, 4H), 6.64 (s, 1H), 5.40 (brs, 1H), 3.92 (d, *J* = 6.3 Hz, 2H), 3.79 (s, 2H), 2.36 (s, 3H), 2.32 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 75 MHz) δ_C 143.3, 139.0, 137.4, 137.3, 132.5, 131.6, 129.5, 129.3, 128.9, 128.5, 128.2, 128.1, 127.1, 122.3, 117.7, 115.4, 93.3, 92.9, 49.9, 22.7, 21.4, 21.3; HRMS (ESI) *m*/*z* calcd for $C_{27}H_{24}N_2NaO_2S$ $[M + Na]^+$ 463.1456, found 463.1458.

*(E)-N-(4-(2-(Cyanomethyl)phenyl)-2-(4-methoxybenzylidene)-but-3-yn-1-yl)-4-methylbenzene-sulfonamide (**8ag**).* Yellow solid (173 mg, 92%), R_f = 0.29 (25% ethyl acetate in petroleum ether, v/

DOI: 10.1021/acs.joc.9b00861
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v), mp 118−120 °C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ_H 7.76 (d, J = 8.1 Hz, 2H), 7.65 (d, J = 8.7 Hz, 2H), 7.46−7.43 (m, 2H), 7.40−7.31 (m, 2H), 7.19 (d, J = 8.1 Hz, 2H), 6.87 (d, J = 8.7 Hz, 2H), 6.62 (s, 1H), 5.25−5.23 (m, 1H), 3.91 (d, J = 6.3 Hz, 2H), 3.82 (s, 3H), 3.80 (s, 2H), 2.33 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 75 MHz) δ_C 160.0, 143.4, 137.5, 137.1, 132.6, 131.6, 130.2, 129.6, 129.3, 128.4, 128.2, 128.1, 127.2, 122.5, 117.7, 113.9, 113.7, 93.6, 92.8, 55.3, 50.1, 22.9, 21.5; HRMS (ESI) m/z calcd for $C_{27}H_{24}N_2NaO_3S$ $[M + Na]^+$ 479.1405, found 479.1409.

*(E)-N-(4-(2-(Cyanomethyl)phenyl)-2-(3-methoxybenzylidene)-but-3-yn-1-yl)-4-methylbenzene-sulfonamide (**8ah**).* Pale yellow solid (163 mg, 87%), R_f = 0.29 (25% ethyl acetate in petroleum ether, v/v), mp 124−126 °C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ_H 7.77 (d, J = 8.1 Hz, 2H), 7.48−7.28 (m, 6H), 7.26−7.15 (m, 3H), 6.87 (dd, J = 8.1, 1.8 Hz, 1H), 6.67 (s, 1H), 5.13 (t, J = 6.4 Hz, 1H), 3.95 (d, J = 6.3 Hz, 2H), 3.83 (s, 2H), 3.80 (s, 3H), 2.35 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 75 MHz) δ_C 159.3, 143.4, 137.4, 137.1, 136.6, 132.6, 131.8, 129.6, 129.5, 129.3, 128.2, 128.1, 127.1, 122.2, 121.4, 117.7, 117.0, 114.2, 113.9, 93.5, 93.0, 55.2, 49.9, 22.9, 21.4; HRMS (ESI) m/z calcd for $C_{27}H_{25}N_2O_3S$ $[M + H]^+$ 457.1586, found 457.1590.

*(E)-N-(2-Benzylidene-4-(2-(cyanomethyl)-4,5-dimethoxyphenyl)-but-3-yn-1-yl)-4-methylbenzene-sulfonamide (**8ai**).* Yellow solid (162 mg, 81%), R_f = 0.13 (25% ethyl acetate in petroleum ether, v/v), mp 140−142 °C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ_H 7.78 (d, J = 8.1 Hz, 2H), 7.67 (d, J = 6.9 Hz, 2H), 7.39−7.31 (m, 3H), 7.26−7.23 (m, 2H), 6.95 (s, 1H), 6.90 (s, 1H), 6.65 (s, 1H), 5.05 (t, J = 6.4 Hz, 1H), 3.95−3.94 (m, 5H), 3.90 (s, 3H), 3.75 (s, 2H), 2.36 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz) δ_C 150.3, 148.6, 143.5, 137.6, 136.6, 135.6, 129.7, 128.8, 128.6, 128.3, 127.2, 125.1, 118.0, 117.1, 114.9, 114.4, 111.2, 93.7, 91.6, 56.3, 56.2, 50.0, 22.4, 21.5; HRMS (ESI) m/z calcd for $C_{28}H_{26}N_2NaO_4S$ $[M + Na]^+$ 509.1511, found 509.1514.

*(E)-Methyl 3-(Cyanomethyl)-4-(3-((4-methylphenylsulfonamido)methyl)-4-phenylbut-3-en-1-yn-1-yl)-benzoate (**8aj**).* Light yellow solid (175 mg, 88%), R_f = 0.22 (25% ethyl acetate in petroleum ether, v/v), mp 128−130 °C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ_H 8.09 (s, 1H), 7.98 (dd, J = 8.1, 1.2 Hz, 1H), 7.76 (d, J = 8.1 Hz, 2H), 7.66−7.63 (m, 2H), 7.50 (d, J = 7.8 Hz, 1H), 7.37−7.32 (m, 3H), 7.21 (d, J = 8.1 Hz, 2H), 6.75 (s, 1H), 5.33 (t, J = 6.4 Hz, 1H), 3.96−3.94 (m, 5H), 3.83 (s, 2H), 2.34 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 75 MHz) δ_C 165.8, 143.5, 138.5, 137.4, 135.1, 132.7, 132.0, 130.5, 129.6, 129.5, 129.3, 129.1, 128.7, 128.4, 127.1, 126.8, 117.2, 116.4, 96.0, 92.2, 52.5, 49.8, 22.8, 21.4; HRMS (ESI) m/z calcd for $C_{28}H_{25}N_2O_4S$ $[M + H]^+$ 485.1535, found 485.1539.

General Procedure for the Synthesis of Products 2a. To a well-stirred solution of $Pd(OAc)_2$ (2.58 mg, 0.011 mmol, 5 mol %) and bpy (3.59 mg, 0.023 mmol, 10 mol %) in dry THF (1.5 mL), *p*-TsOH·H_2O (87.4 mg, 0.46 mmol, 2 equiv) was added and the mixture was heated to reflux under argon atmosphere. Next, **8a** (0.23 mmol, 1 equiv) dissolved in dry THF (1.5 mL) was added dropwise and heating was continued for another 4−12 h. Upon completion of reaction (TLC), the reaction mixture was neutralized by adding 10% aqueous sodium bicarbonate solution (to pH ∼ 7) dropwise. It was then extracted with ethyl acetate (3 × 20 mL) and 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 using 10−18% ethyl acetate in petroleum ether to afford the pure products (**2aa**−**aj**) in 24−82% yields.

*Spectral Data of Products **2aa**−**aj**. 3-Benzyl-1-tosyl-1H-benzo-[g]indol-4-amine (**2aa**).* Brown solid (73.5 mg, 75%), R_f = 0.24 (15% ethyl acetate in petroleum ether, v/v), mp 146−148 °C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ_H 8.93 (d, J = 8.1 Hz, 1H), 7.60−7.54 (m, 2H), 7.50 (d, J = 8.1 Hz, 2H), 7.34−7.26 (m, 5H), 7.12−7.08 (m, 4H), 6.70 (s, 1H), 4.28 (s, 2H), 3.73 (brs, 2H), 2.31 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz) δ_C 144.8, 139.3, 139.0, 135.0, 133.92, 133.90, 129.7, 129.0, 128.5, 128.3, 127.0, 126.9, 126.3, 125.3, 124.4, 122.8, 122.1, 121.2, 119.1, 107.6, 32.8, 21.6; HRMS (ESI) m/z calcd for $C_{26}H_{22}N_2NaO_2S$ $[M + Na]^+$ 449.1300, found 449.1300.

*3-(Naphthalen-2-ylmethyl)-1-tosyl-1H-benzo[g]indol-4-amine (**2ab**).* Brown solid (85.4 mg, 78%), R_f = 0.25 (15% ethyl acetate in petroleum ether, v/v), mp 196−198 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.97 (d, J = 9 Hz, 1H), 7.84−7.82 (m, 1H), 7.80 (d, J = 9 Hz, 1H), 7.69 (s, 1H), 7.66−7.64 (m, 1H), 7.56−7.54 (m, 3H), 7.49−7.46 (m, 3H), 7.34−7.28 (m, 3H), 7.14 (d, J = 8.4 Hz, 2H), 6.68 (s, 1H), 4.45 (s, 2H), 3.76 (brs, 2H), 2.33 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 144.8, 139.0, 137.0, 135.0, 133.8, 133.7, 133.6, 132.4, 129.7, 128.8, 128.5, 127.7, 127.6, 126.9, 126.6, 126.5, 126.4, 126.3, 125.9, 125.3, 124.3, 122.8, 122.1, 120.7, 118.9, 107.6, 32.9, 21.6; HRMS (ESI) m/z calcd for $C_{30}H_{25}N_2O_2S$ $[M + H]^+$ 477.1637, found 477.1639.

*3-(Furan-2-ylmethyl)-1-tosyl-1H-benzo[g]indol-4-amine (**2ac**).* Brown solid (65.1 mg, 68%), R_f = 0.20 (15% ethyl acetate in petroleum ether, v/v), mp 134−136 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.90 (d, J = 8.4 Hz, 1H), 7.70 (s, 1H), 7.57 (d, J = 7.8 Hz, 1H), 7.49 (d, J = 8.4 Hz, 2H), 7.39−7.38 (m, 1H), 7.33−7.30 (m, 1H), 7.27−7.25 (m, 1H), 7.09 (d, J = 8.4 Hz, 2H), 6.76 (s, 1H), 6.30−6.29 (m, 1H), 5.86−5.85 (m, 1H), 4.27 (s, 2H), 3.96 (brs, 2H), 2.28 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 153.7, 144.8, 142.1, 138.9, 134.9, 133.7, 133.3, 129.7, 128.2, 126.9, 126.3, 125.2, 124.1, 122.8, 121.8, 118.9, 118.5, 110.6, 107.9, 106.7, 26.3, 21.6; HRMS (ESI) m/z calcd for $C_{24}H_{21}N_2O_3S$ $[M + H]^+$ 417.1273, found 417.1304.

*3-(Thiophen-2-ylmethyl)-1-tosyl-1H-benzo[g]indol-4-amine (**2ad**).* Brown solid (75.5 mg, 76%), R_f = 0.21 (15% ethyl acetate in petroleum ether, v/v), mp 174−176 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.94 (d, J = 8.4 Hz, 1H), 7.73 (s, 1H), 7.56 (d, J = 8.4 Hz, 1H), 7.52 (d, J = 8.4 Hz, 2H), 7.31 (t, J = 7.5 Hz, 1H), 7.28−7.26 (m, 1H), 7.21 (d, J = 4.8 Hz, 1H), 7.11 (d, J = 8.4 Hz, 2H), 6.93−6.92 (m, 1H), 6.73 (s, 1H), 6.70−6.69 (m, 1H), 4.43 (s, 2H), 3.86 (brs, 2H), 2.29 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 144.9, 143.4, 138.9, 134.9, 133.8, 133.6, 129.8, 128.1, 127.2, 126.9, 126.3, 125.3, 125.2, 125.1, 124.2, 122.8, 121.7, 120.7, 118.9, 107.7, 27.7, 21.6; HRMS (ESI) m/z calcd for $C_{24}H_{21}N_2O_2S_2$ $[M + H]^+$ 433.1044, found 433.1046.

*3-(4-Chlorobenzyl)-1-tosyl-1H-benzo[g]indol-4-amine (**2ae**).* Brown solid (86.7 mg, 82%), R_f = 0.22 (15% ethyl acetate in petroleum ether, v/v), mp 158−160 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.92 (d, J = 8.4 Hz, 1H), 7.58−7.56 (m, 2H), 7.49 (d, J = 8.4 Hz, 2H), 7.32 (t, J = 7.2 Hz, 1H), 7.29−7.25 (m, 3H), 7.11 (d, J = 7.8 Hz, 2H), 7.03 (d, J = 8.4 Hz, 2H), 6.72 (s, 1H), 4.24 (s, 2H), 3.71 (brs, 2H), 2.31 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 144.9, 138.7, 137.7, 134.9, 133.8, 133.7, 132.7, 129.7, 129.6, 129.1, 128.4, 126.9, 126.3, 125.4, 124.3, 122.9, 121.8, 120.5, 118.9, 107.7, 32.2, 21.6; HRMS (ESI) m/z calcd for $C_{26}H_{22}ClN_2O_2S$ $[M + H]^+$ 461.1091, found 461.1097.

*3-(4-Methylbenzyl)-1-tosyl-1H-benzo[g]indol-4-amine (**2af**).* Brown solid (78.9 mg, 78%), R_f = 0.27 (15% ethyl acetate in petroleum ether, v/v), mp 178−180 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.92 (d, J = 9 Hz, 1H), 7.59 (s, 1H), 7.56 (d, J = 7.8 Hz, 1H), 7.49 (d, J = 8.4 Hz, 2H), 7.33−7.30 (m, 1H), 7.28−7.25 (m, 1H), 7.11 (d, J = 8.4 Hz, 2H), 7.08 (d, J = 7.8 Hz, 2H), 6.97 (d, J = 7.8 Hz, 2H), 6.70 (s, 1H), 4.23 (s, 2H), 3.77 (brs, 2H), 2.33 (s, 3H), 2.31 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 144.7, 139.0, 136.5, 136.1, 134.9, 133.8, 129.7, 129.6, 128.4, 128.1, 126.9, 126.2, 125.3, 124.3, 122.7, 122.1, 121.4, 119.0, 107.5, 32.3, 21.6, 21.1; HRMS (ESI) m/z calcd for $C_{27}H_{25}N_2O_2S$ $[M + H]^+$ 441.1637, found 441.1640.

*3-(4-Methoxybenzyl)-1-tosyl-1H-benzo[g]indol-4-amine (**2ag**).* Pale brown solid (25.2 mg, 24%), R_f = 0.18 (15% ethyl acetate in petroleum ether, v/v), mp 190−192 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.92 (d, J = 8.4 Hz, 1H), 7.58 (s, 1H), 7.56 (d, J = 7.8 Hz, 1H), 7.49 (d, J = 8.4 Hz, 2H), 7.31 (td, J = 7.5, 0.8 Hz, 1H), 7.28−7.26 (m, 1H), 7.11 (d, J = 8.4 Hz, 2H), 6.99 (d, J = 8.4 Hz, 2H), 6.81 (d, J = 9 Hz, 2H), 6.70 (s, 1H), 4.21 (s, 2H), 3.79−3.77 (m, 5H), 2.31 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 158.5, 144.6, 138.9, 134.9, 133.81, 133.80, 131.0, 129.6, 129.2, 128.3, 126.9, 126.2, 125.2, 124.3, 122.7, 122.0, 121.6, 118.9, 114.3, 107.4, 55.2, 31.8, 21.5; HRMS (ESI) m/z calcd for $C_{27}H_{25}N_2O_3S$ $[M + H]^+$ 457.1586, found 457.1592.

*3-(3-Methoxybenzyl)-1-tosyl-1H-benzo[g]indol-4-amine (**2ah**).* Pale yellow solid (83.9 mg, 80%), R_f = 0.16 (15% ethyl acetate in petroleum ether, v/v), mp 142−144 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.95 (d, J = 9 Hz, 1H), 7.63 (s, 1H), 7.55 (d, J = 8.4 Hz, 1H), 7.51 (d, J = 8.4 Hz, 2H), 7.31 (t, J = 7.5 Hz, 1H), 7.29−7.27 (m, 1H), 7.20 (t, J = 7.8 Hz, 1H), 7.10 (d, J = 8.4 Hz, 2H), 6.79 (dd, J = 8.1, 2.1 Hz, 1H), 6.72 (s, 1H), 6.69−6.67 (m, 2H), 4.25 (s, 2H), 3.76 (s, 5H), 2.29 (s, 3H);

DOI: 10.1021/acs.joc.9b00861
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$^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 160.1, 144.7, 140.9, 138.9, 134.9, 133.8, 133.7, 129.9, 129.6, 128.4, 126.8, 126.2, 125.2, 124.2, 122.7, 121.9, 120.8, 120.4, 118.9, 114.2, 111.9, 107.5, 55.1, 32.7, 21.5; HRMS (ESI) m/z calcd for $C_{27}H_{25}N_2O_3S$ $[M + H]^+$ 457.1586, found 457.1576.

*3-Benzyl-7,8-dimethoxy-1-tosyl-1H-benzo[g]indol-4-amine (**2ai**).* Brown solid (72.7 mg, 65%), R_f = 0.08 (15% ethyl acetate in petroleum ether, v/v), mp 148−150 °C; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.46 (s, 1H), 7.48 (s, 1H), 7.43 (d, J = 8.4 Hz, 2H), 7.28−7.22 (m, 3H), 7.09 (d, J = 8.4 Hz, 2H), 7.06 (d, J = 6.6 Hz, 2H), 6.89 (s, 1H), 6.62 (s, 1H), 4.24 (s, 2H), 4.01 (s, 3H), 3.94 (s, 3H), 3.62 (brs, 2H), 2.31 (s, 3H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 148.6, 146.7, 144.6, 139.2, 137.4, 134.8, 133.8, 129.6, 129.5, 128.9, 128.2, 127.9, 126.8, 126.6, 121.9, 120.9, 114.1, 107.4, 105.4, 104.9, 56.0, 55.6, 32.7, 21.5; HRMS (ESI) m/z calcd for $C_{28}H_{27}N_2O_4S$ $[M + H]^+$ 487.1692, found 487.1684.

*Methyl 4-Amino-3-benzyl-1-tosyl-1H-benzo[g]indole-7-carboxylate (**2aj**).* Yellow solid (61.2 mg, 55%), R_f = 0.14 (15% ethyl acetate in petroleum ether, v/v), mp 178−180 °C; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.97 (d, J = 9 Hz, 1H), 8.29 (s, 1H), 7.84 (dd, J = 8.7, 1.8 Hz, 1H), 7.68 (s, 1H), 7.50 (d, J = 8.4 Hz, 2H), 7.31−7.29 (m, 2H), 7.27−7.25 (m, 1H), 7.13−7.10 (m, 4H), 6.77 (s, 1H), 4.29 (s, 2H), 3.94 (s, 3H), 3.84 (brs, 2H), 2.31 (s, 3H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 167.5, 145.1, 139.8, 139.0, 134.7, 133.2, 133.0, 129.8, 129.5, 129.1, 129.0, 128.2, 127.1, 126.9, 126.4, 124.4, 123.6, 122.2, 120.9, 120.8, 108.1, 52.2, 32.7, 21.6; HRMS (ESI) m/z calcd for $C_{28}H_{25}N_2O_4S$ $[M + H]^+$ 485.1535, found 485.1538.

Preparation of the Ene−Yne Substrates 8b (See Scheme S4 in the Supporting Information). The requisite starting material **8b** was synthesized as depicted in Scheme S4. The starting compound **S4**[19] was synthesized by executing the Wittig reaction on 2-iodobenzaldehyde derivative, which underwent coupling with **S10** (see Scheme S3 in the Supporting Information) under Sonogashira reaction conditions resulting in the formation of **S11**. Finally, exposure of **S11** under acidic conditions led to **8b**.

Procedure for the Synthesis of Intermediates S11 (See Scheme S4 in the Supporting Information). To a well-stirred solution of **S4** (0.77 mmol, 1 equiv) in dry Et_3N/DMF (3:1, 0.7 mL) was added $Pd(PPh_3)_2Cl_2$ (16.2 mg, 0.023 mmol, 3 mol %). The whole reaction mixture was cooled to 0 °C; thereafter, **S10** (0.85 mmol, 1.1 equiv) dissolved in a mixture of solvents [i.e., Et_3N/DMF (2:1), 0.6 mL] and CuI (8.74 mg, 0.046 mmol, 6 mol %) was added sequentially. The reaction mixture was then stirred at rt for 2−7 h. After completion of the reaction (TLC), solvent was removed in vacuo, diluted with water (15 mL), and extracted with ethyl acetate (3 × 20 mL). The combined organic extracts were dried over anhydrous Na_2SO_4, and the solvent was removed in vacuo. Then, the crude product was subjected to silica gel (100−200 mesh) column chromatography and eluted with 10−15% ethyl acetate in petroleum ether (v/v) to obtain pure **S11** derivatives in 60−85% yields.

Synthesis of the Ene−Yne Substrates 8b (See Scheme S4 in the Supporting Information). To a well-stirred and cooled (0 °C) solution of the masked aldehydes **S11** (0.45 mmol, 1 equiv) in a minimum amount of dry acetone (3 mL) was added p-TsOH·H_2O (0.72 mmol, 1.6 equiv, 136.8 mg) portionwise. The temperature of the reaction mixture was allowed to reach rt and stirring was continued for another 3.5−5 h. After completion of reaction (TLC), the reaction mixture was neutralized with dilute sodium bicarbonate solution and extracted with DCM (3 × 20 mL). The combined organic layers were dried over anhydrous Na_2SO_4, filtered, and concentrated in vacuo, and the crude residue was subjected to silica gel (100−200 mesh) column chromatography eluting with 17−30% ethyl acetate in petroleum ether (v/v) to obtain the desired starting materials **8b** in 47−70% yields.

*Spectral Data of Starting Materials **8ba−bh**. (E)-N-(2-Benzylidene-4-(2-(2-oxoethyl)phenyl)but-3-yn-1-yl)-4-methylbenzene-sulfonamide (**8ba**).* White solid (118 mg, 61%), R_f = 0.22 (20% ethyl acetate in petroleum ether, v/v), mp 94−96 °C; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 9.66 (s, 1H), 7.77 (d, J = 8.4 Hz, 2H), 7.65 (d, J = 7.2 Hz, 2H), 7.46 (d, J = 7.8 Hz, 1H), 7.39−7.28 (m, 6H), 7.19 (d, J = 7.8 Hz, 2H), 6.62 (s, 1H), 5.46 (t, J = 6 Hz, 1H), 3.93 (d, J = 6.6 Hz, 2H), 3.85−3.84 (m, 2H), 2.31 (s, 3H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 199.1, 143.2, 137.6, 136.9, 135.4, 133.7, 132.6, 130.5, 129.5, 129.3, 128.7, 128.6, 128.2, 127.7, 127.2, 123.5, 116.6, 94.4, 91.7, 50.1, 49.6, 21.4; HRMS (ESI) m/z calcd for $C_{26}H_{23}NNaO_3S$ $[M + Na]^+$ 452.1296, found 452.1298.

*(E)-4-Methyl-N-(2-(naphthalen-2-ylmethylene)-4-(2-(2-oxoethyl)phenyl)but-3-yn-1-yl)benzene-sulfonamide (**8bb**).* Pale yellow solid (112 mg, 52%), R_f = 0.19 (20% ethyl acetate in petroleum ether, v/v), mp 108−110 °C; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 9.66 (t, J = 2.4 Hz, 1H), 8.06 (s, 1H), 7.86−7.84 (m, 1H), 7.82−7.78 (m, 5H), 7.51−7.47 (m, 3H), 7.40−7.37 (m, 1H), 7.35−7.33 (m, 1H), 7.30 (d, J = 7.8 Hz, 1H), 7.18 (d, J = 7.8 Hz, 2H), 6.77(s, 1H), 5.56 (t, J = 6.3 Hz, 1H), 3.99 (d, J = 6.6 Hz, 2H), 3.87 (d, J = 2.4 Hz, 2H), 2.27 (s, 3H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 199.1, 143.2, 137.7, 136.9, 133.7, 133.3, 133.1, 133.0, 132.5, 130.5, 129.5, 129.4, 128.6, 128.2, 127.8, 127.7, 127.6, 127.2, 126.6, 126.4, 125.8, 123.5, 117.0, 94.6, 92.1, 50.2, 49.7, 21.4; HRMS (ESI) m/z calcd for $C_{30}H_{25}NNaO_3S$ $[M + Na]^+$ 502.1453, found 502.1456.

*(E)-N-(2-(4-Chlorobenzylidene)-4-(2-(2-oxoethyl)phenyl)but-3-yn-1-yl)-4-methylbenzene-sulfonamide (**8bc**).* White solid (137 mg, 66%), R_f = 0.20 (20% ethyl acetate in petroleum ether, v/v), mp 136−138 °C; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 9.66 (t, J = 2.1 Hz, 1H), 7.76 (d, J = 7.8 Hz, 2H), 7.59 (d, J = 8.4 Hz, 2H), 7.45−7.43 (m, 1H), 7.41−7.38 (m, 1H), 7.35−7.33 (m, 1H), 7.32−7.30 (m, 3H), 7.19 (d, J = 7.8 Hz, 2H), 6.58 (s, 1H), 5.50 (t, J = 6.6 Hz, 1H), 3.92 (d, J = 6.6 Hz, 2H), 3.85 (d, J = 2.4 Hz, 2H), 2.33 (s, 3H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 199.0, 143.3, 137.7, 135.4, 134.3, 133.8, 133.6, 132.6, 130.6, 129.8, 129.6, 129.5, 128.4, 127.8, 127.2, 123.3, 117.4, 95.1, 91.4, 50.0, 49.7, 21.4; HRMS (ESI) m/z calcd for $C_{26}H_{22}ClNNaO_3S$ $[M + Na]^+$ 486.0907, found 486.0908.

*(E)-4-Methyl-N-(4-(2-(2-oxoethyl)phenyl)-2-(4-(trifluoromethyl)-benzylidene)but-3-yn-1-yl)benzene-sulfonamide (**8bd**).* White solid (155 mg, 70%), R_f = 0.30 (25% ethyl acetate in petroleum ether, v/v), mp 154−156 °C; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 9.66 (t, J = 2.1 Hz, 1H), 7.78−7.74 (m, 4H), 7.59 (d, J = 8.4 Hz, 2H), 7.45 (dd, J = 7.8, 0.9 Hz, 1H), 7.41−7.39 (m, 1H), 7.35−7.30 (m, 2H), 7.19 (d, J = 8.4 Hz, 2H), 6.66 (s, 1H), 5.67 (t, J = 6.6 Hz, 1H), 3.94 (d, J = 6.6 Hz, 2H), 3.85 (d, J = 2.4 Hz, 2H), 2.31 (s, 3H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 199.0, 143.3, 138.8, 137.7, 134.8, 133.7, 132.6, 130.6, 130.1 (q, J_{C-F} = 32.3 Hz), 129.7, 129.5, 128.7, 127.8, 127.2, 125.1 (q, J_{C-F} = 3.6 Hz), 123.9 (app q, J = 270.5 Hz), 123.1, 119.5, 95.5, 91.1, 49.9, 49.7, 21.3; HRMS (ESI) m/z calcd for $C_{27}H_{22}F_3NNaO_3S$ $[M + Na]^+$ 520.1170 found, 520.1169.

*(E)-4-Methyl-N-(2-(4-methylbenzylidene)-4-(2-(2-oxoethyl)-phenyl)but-3-yn-1-yl)benzene-sulfonamide (**8be**).* White solid (119 mg, 60%), R_f = 0.22 (20% ethyl acetate in petroleum ether, v/v), mp 96−98 °C; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 9.67−9.66 (m, 1H), 7.77 (d, J = 7.8 Hz, 2H), 7.56 (d, J = 7.8 Hz, 2H), 7.46 (d, J = 7.8 Hz, 1H), 7.37−7.26 (m, 3H), 7.18 (d, J = 7.8 Hz, 2H), 7.14 (d, J = 7.8 Hz, 2H), 6.59 (s, 1H), 5.53 (t, J = 6.3 Hz, 1H), 3.91 (d, J = 6.6 Hz, 2H), 3.85 (s, 2H), 2.36 (s, 3H), 2.31 (s, 3H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 199.2, 143.2, 138.8, 137.6, 137.0, 133.7, 132.6, 132.5, 130.4, 129.5, 129.2, 128.9, 128.6, 127.6, 127.2, 123.6, 115.5, 94.4, 92.0, 50.1, 49.6, 21.4, 21.3; HRMS (ESI) m/z calcd for $C_{27}H_{25}NNaO_3S$ $[M + Na]^+$ 466.1453 found 466.1455.

*(E)-N-(2-(3-Methoxybenzylidene)-4-(2-(2-oxoethyl)phenyl)but-3-yn-1-yl)-4-methylbenzene-sulfonamide (**8bf**).* Yellow liquid (97 mg, 47%), R_f = 0.15 (20% ethyl acetate in petroleum ether, v/v); ^1H NMR ($CDCl_3$, 600 MHz) δ_H 9.66−9.65 (m, 1H), 7.77 (d, J = 7.8 Hz, 2H), 7.46 (d, J = 7.2 Hz, 1H), 7.37−7.34 (m, 1H), 7.31−7.29 (m, 2H), 7.27−7.23 (m, 2H), 7.19−7.17 (m, 3H), 6.84 (dd, J = 7.8, 2.1 Hz, 1H), 6.60 (s, 1H), 5.62 (t, J = 6.3 Hz, 1H), 3.91 (d, J = 6.6 Hz, 2H), 3.86−3.85 (m, 2H), 3.77 (s, 3H), 2.31 (s, 3H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz) δ_C 199.1, 159.3, 143.2, 137.6, 136.7, 133.8, 132.5, 130.5, 129.5, 129.3, 129.2, 127.6, 127.2, 123.4, 121.4, 117.0, 114.2, 113.9, 94.8, 91.7, 55.2, 50.0, 49.6, 21.4; HRMS (ESI) m/z calcd for $C_{27}H_{25}NNaO_4S$ $[M + Na]^+$ is 482.1402, found 482.1407.

*(E)-N-(2-Benzylidene-4-(4,5-dimethoxy-2-(2-oxoethyl)phenyl)-but-3-yn-1-yl)-4-methylbenzene-sulfonamide (**8bg**).* Yellow gum (125 mg, 57%), R_f = 0.06 (20% ethyl acetate in petroleum ether, v/

DOI: 10.1021/acs.joc.9b00861
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v); ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 9.64 (t, J = 2.4 Hz, 1H), 7.78 (d, J = 8.4 Hz, 2H), 7.64 (d, J = 7.2 Hz, 2H), 7.33−7.31 (m, 2H), 7.29−7.28 (m, 1H), 7.20 (d, J = 7.8 Hz, 2H), 6.95 (s, 1H), 6.72 (s, 1H), 6.58 (s, 1H), 5.43 (t, J = 6.6 Hz, 1H), 3.92−3.91 (m, 5H), 3.89 (s, 3H), 3.78 (d, J = 2.4 Hz, 2H), 2.32 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 199.0, 150.1, 148.2, 143.3, 137.6, 136.0, 135.5, 129.5, 128.6, 128.5, 128.2, 127.2, 127.1, 117.0, 115.4, 114.8, 113.0, 94.9, 90.3, 56.1, 56.0, 50.1, 49.2, 21.4; HRMS (ESI) m/z calcd for $C_{28}H_{27}NNaO_5S$ [M + Na]$^+$ 512.1508, found 512.1503.

*(E)-N-(2-Benzylidene-4-(4-fluoro-2-(2-oxoethyl)phenyl)but-3-yn-1-yl)-4-methylbenzene-sulfonamide (**8bh**).* White solid (110 mg, 55%), R_f = 0.23 (20% ethyl acetate in petroleum ether, v/v), mp 80−82 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 9.67 (t, J = 1.8 Hz, 1H), 7.77 (d, J = 7.8 Hz, 2H), 7.63 (d, J = 7.2 Hz, 2H), 7.45−7.43 (m, 1H), 7.34−7.28 (m, 3H), 7.20 (d, J = 7.8 Hz, 2H), 7.03−6.98 (m, 2H), 6.62 (s, 1H), 5.44 (t, J = 6.3 Hz, 1H), 3.90 (d, J = 6.6 Hz, 2H), 3.86−3.85 (m, 2H), 2.33 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 198.2, 162.6 (d, J = 250.6 Hz), 143.3, 137.5, 136.9, 136.5 (d, J = 7.8 Hz), 135.4, 134.4 (d, J = 8.5 Hz), 129.6, 128.7, 128.6, 128.2, 127.1, 119.6 (d, J = 3.3 Hz), 117.6 (d, J = 22.2 Hz), 116.7, 115.0 (d, J = 21.6 Hz), 93.5, 91.4, 50.0, 49.3, 21.4; HRMS (ESI) m/z calcd for $C_{26}H_{22}FNNaO_3S$ [M + Na]$^+$ 470.1202, found 470.1200.

General Procedure for the Synthesis of Products 2b. To a well-stirred and heated (85 °C) reaction mixture of $Pd(OAc)_2$bpy (4.37 mg, 0.011 mmol, 5 mol %) and p-TsOH·H_2O (65.5 mg, 0.34 mmol, 1.5 equiv) in dry DME (1.5 mL) was dropwise added a solution of **8b** (0.23 mmol, 1 equiv) dissolved in dry DME (1.5 mL). The heating was continued until completion of the reaction (TLC). The solvent was then removed under reduced pressure. The crude material obtained was directly loaded onto silica gel (100−200 mesh) column for purification. The desired products **2ba**−**bh** were eluted with 1−6% ethyl acetate−petroleum (v/v) and isolated in 27−68% yields.

*Spectral Data of Products **2ba**−**bh**. 3-Benzyl-1-tosyl-1H-benzo-[g]indole (**2ba**).* White solid (57.7 mg, 61%), R_f = 0.56 (10% ethyl acetate in petroleum ether, v/v), mp 106−108 °C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ_H 9.09 (d, J = 8.7 Hz, 1H), 7.84 (d, J = 8.1 Hz, 1H), 7.62−7.39 (m, 7H), 7.31−7.16 (m, 5H), 7.08 (d, J = 8.1 Hz, 2H), 4.09 (s, 2H), 2.28 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 144.6, 139.1, 135.0, 132.3, 131.6, 129.9, 129.6, 128.8, 128.52, 128.50, 127.6, 126.7, 126.4, 126.2, 125.8, 124.7, 124.1, 123.6, 122.9, 118.1, 31.2, 21.5; HRMS (ESI) m/z calcd for $C_{26}H_{22}NO_2S$ [M + H]$^+$ 412.1371, found 412.1368.

*3-(Naphthalen-2-ylmethyl)-1-tosyl-1H-benzo[g]indole (**2bb**).* Light brown solid (46.4 mg, 44%), R_f = 0.50 (10% ethyl acetate in petroleum ether, v/v), mp 160−162 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 9.13 (d, J = 9 Hz, 1H), 7.85−7.82 (m, 2H), 7.77 (d, J = 8.4 Hz, 1H), 7.72 (d, J = 8.4 Hz, 1H), 7.67 (s, 1H), 7.62 (s, 1H), 7.59 (d, J = 8.4 Hz, 1H), 7.55 (t, J = 7.5 Hz, 1H), 7.51 (d, J = 8.4 Hz, 2H), 7.48−7.43 (m, 4H), 7.33 (d, J = 8.4 Hz, 1H), 7.07 (d, J = 8.4 Hz, 2H), 4.26 (s, 2H), 2.28 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 144.6, 136.7, 135.0, 133.5, 132.3, 132.2, 131.7, 130.0, 129.6, 128.8, 128.1, 127.7, 127.6, 127.5, 127.1, 126.8, 126.7, 126.3, 126.0, 125.9, 125.5, 124.7, 124.1, 123.6, 122.7, 118.2, 31.4, 21.5; HRMS (ESI) m/z calcd for $C_{30}H_{24}NO_2S$ [M + H]$^+$ 462.1528, found 462.1526.

*3-(4-Chlorobenzyl)-1-tosyl-1H-benzo[g]indole (**2bc**).* White solid (69.6 mg, 68%), R_f = 0.50 (10% ethyl acetate in petroleum ether, v/v), mp 110−112 °C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ_H 9.08 (d, J = 8.7 Hz, 1H), 7.85 (d, J = 8.1 Hz, 1H), 7.62−7.41 (m, 6H), 7.36 (d, J = 8.4 Hz, 1H), 7.25−7.22 (m, 2H), 7.11−7.07 (m, 4H), 4.06 (s, 2H), 2.28 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 75 MHz) δ_C 144.8, 137.7, 135.0, 132.3, 132.2, 131.8, 131.7, 129.9, 129.6, 128.9, 128.6, 127.6, 126.7, 126.4, 125.9, 124.9, 124.1, 123.6, 122.3, 118.0, 30.6, 21.5; HRMS (ESI) m/z calcd for $C_{26}H_{21}ClNO_2S$ [M + H]$^+$ 446.0982, found 446.0984.

*1-Tosyl-3-(4-(trifluoromethyl)benzyl)-1H-benzo[g]indole (**2bd**).* Pale yellow solid (71.6 mg, 65%), R_f = 0.50 (10% ethyl acetate in petroleum ether, v/v), mp 126−128 °C; ^{1}H NMR ($CDCl_3$, 300 MHz) δ_H 9.09 (d, J = 8.7 Hz, 1H), 7.86 (d, J = 8.1 Hz, 1H), 7.64−7.61 (m, 2H), 7.57−7.42 (m, 6H), 7.36 (d, J = 8.4 Hz, 1H), 7.30−7.26 (m, 2H), 7.09 (d, J = 8.1 Hz, 2H), 4.15 (s, 2H), 2.29 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_C 144.8, 143.3, 135.0, 132.3, 131.6, 129.6, 129.5, 128.9, 128.8, 128.7 (q, J_{C-F} = 32.3 Hz), 127.6, 126.7, 126.4, 126.0, 125.4 (q, J_{C-F} = 3.8 Hz), 124.9, 124.2 (q, J_{C-F}= 270.2 Hz), 124.1, 123.5, 121.7, 117.8, 31.0, 21.5; ^{19}F{^{1}H} NMR (376 MHz, $CDCl_3$) δ = −162.3 (s, 3F); HRMS (ESI) m/z calcd for $C_{27}H_{21}F_3NO_2S$ [M + H]$^+$ is 480.1245, found 480.1240.

*3-(4-Methylbenzyl)-1-tosyl-1H-benzo[g]indole (**2be**).* Yellow gum (40.1 mg, 41%), R_f = 0.56 (10% ethyl acetate in petroleum ether, v/v); ^{1}H NMR ($CDCl_3$, 400 MHz) δ_H 9.09 (d, J = 8.8 Hz, 1H), 7.83 (d, J = 8.0 Hz, 1H), 7.60−7.58 (m, 2H), 7.54−7.50 (m, 1H), 7.47 (d, J = 8.4 Hz, 2H), 7.44−7.39 (m, 2H), 7.09−7.05 (m, 6H), 4.04 (s, 2H), 2.32 (s, 3H), 2.26 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz) δ_c 144.7, 136.1, 136.0, 135.2, 132.4, 131.8, 130.1, 129.7, 129.3, 128.9, 128.5, 127.6, 126.8, 126.3, 125.9, 124.8, 124.3, 123.7, 123.5, 118.3, 30.9, 21.6, 21.1; HRMS (ESI) m/z calcd for $C_{27}H_{24}NO_2S$ [M + H]$^+$ 426.1528, found 426.1526.

*3-(3-Methoxybenzyl)-1-tosyl-1H-benzo[g]indole (**2bf**).* Yellow solid (30.4 mg, 30%), R_f = 0.39 (10% ethyl acetate in petroleum ether, v/v), mp 150−152 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 9.10 (d, J = 8.4 Hz, 1H), 7.85 (d, J = 7.8 Hz, 1H), 7.63−7.60 (m, 2H), 7.55−7.52 (m, 1H), 7.49 (d, J = 8.4 Hz, 2H), 7.45−7.42 (m, 2H), 7.20 (t, J = 8.1 Hz, 1H), 7.08 (d, J = 8.4 Hz, 2H), 6.78−6.77 (m, 3H), 4.07 (s, 2H), 3.77 (s, 3H), 2.27 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_c 159.7, 144.6, 140.7, 135.0, 132.3, 131.6, 129.9, 129.6, 129.5, 128.8, 127.6, 126.7, 126.2, 125.8, 124.7, 124.1, 123.6, 122.6, 120.9, 118.1, 114.5, 111.4, 55.1, 31.2, 21.5; HRMS (ESI) m/z calcd for $C_{27}H_{24}NO_3S$ [M + H]$^+$ 442.1477, found 442.1477.

*3-Benzyl-7,8-dimethoxy-1-tosyl-1H-benzo[g]indole (**2bg**).* Light brown solid (42.2 mg, 39%), R_f = 0.15 (10% ethyl acetate in petroleum ether, v/v), mp 158−160 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.60 (s, 1H), 7.49−7.47 (m, 2H), 7.40 (d, J = 8.4 Hz, 2H), 7.28−7.21 (m, 4H), 7.16−7.15 (m, 3H), 7.05 (d, J = 7.8 Hz, 2H), 4.06−4.05 (m, 5H), 3.99 (s, 3H), 2.28 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_c 149.2, 148.1, 144.5, 139.1, 135.0, 131.8, 129.5, 129.2, 128.5, 128.4, 128.1, 127.2, 126.4, 126.3, 124.5, 123.7, 119.2, 116.2, 107.6, 104.5, 56.1, 55.7, 31.2, 21.5; HRMS (ESI) m/z calcd for $C_{28}H_{26}NO_4S$ [M + H]$^+$ 472.1583, found 472.1584.

*3-Benzyl-7-fluoro-1-tosyl-1H-benzo[g]indole (**2bh**).* Yellow solid (26.6 mg, 27%), R_f = 0.54 (10% ethyl acetate in petroleum ether, v/v), mp 86−88 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 9.14−9.12 (m, 1H), 7.58 (s, 1H), 7.53 (d, J = 8.4 Hz, 1H), 7.47−7.42 (m, 4H), 7.32−7.26 (m, 3H), 7.24−7.22 (m, 1H), 7.17 (d, J = 7.2 Hz, 2H), 7.09 (d, J = 7.8 Hz, 2H), 4.08 (s, 2H), 2.29 (s, 3H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_c 159.6 (d, J = 244.5 Hz), 144.8, 139.0, 134.8, 133.5 (d, J = 8.5 Hz), 131.8, 129.6, 129.4, 128.5, 128.4, 127.4, 126.8 (d, J = 8.7 Hz), 126.7, 126.4, 125.0 (d, J = 4.5 Hz), 123.1, 120.6, 119.4, 115.9 (d, J = 24.0 Hz), 112.1 (d, J = 20.5 Hz), 31.2, 21.5; ^{19}F{^{1}H} NMR (376 MHz, $CDCl_3$) δ = −116.5 (s, 1F); HRMS (ESI) m/z calcd for $C_{26}H_{21}FNO_2S$ [M + H]$^+$ 430.1277, found 430.1275.

Procedure for the Preparation of Detosylated Products 2ak and 2bi. To a well-stirred solution of **2aa** or **2ba** (0.12 mmol, 1 equiv) in dry THF was added tetrabutylammonium fluoride (1 M solution in THF, 5 equiv), and the mixture was stirred for 2 h under refluxing conditions. It was then poured into water (10 mL) and extracted with dichloromethane (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 using 5−10% ethyl acetate in petroleum ether as eluent to afford pure detosylated products **2ak** and **2bi** in 65−67% yield.

*4-Amino-3-benzyl-1H-benzo[g]indole (**2ak**).* Light brown solid (21.2 mg, 65%), R_f = 0.32 (20% ethyl acetate in petroleum ether, v/v), mp 160−162 °C; ^{1}H NMR ($CDCl_3$, 600 MHz) δ_H 8.72 (s, 1H), 7.85 (d, J = 7.8 Hz, 1H), 7.63 (d, J = 8.4 Hz, 1H), 7.33−7.26 (m, 6H), 7.24−7.21 (m, 1H), 6.98 (s, 1H), 6.56 (s, 1H), 4.37 (s, 2H), 3.89 (s, 2H); ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz) δ_c 141.2, 140.4, 132.9, 132.3, 128.7, 128.4, 126.4, 126.1, 124.5, 121.8, 121.1, 119.0, 117.3, 115.8, 115.6, 101.0, 32.9; HRMS (ESI) m/z calcd for $C_{19}H_{17}N_2$ [M + H]$^+$ 273.1392, found 273.1380.

*3-Benzyl-1H-benzo[g]indole (**2bi**).* Light brown solid (20.7 mg, 67%), R_f = 0.48 (20% ethyl acetate in petroleum ether, v/v), mp 122−124 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ_H 8.68 (s, 1H), 7.95 (d, J = 8.0

DOI: 10.1021/acs.joc.9b00861
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Hz, 1H), 7.90 (d, J = 8.4 Hz, 1H), 7.59 (d, J = 8.4 Hz, 1H), 7.52−7.46 (m, 2H), 7.43−7.39 (m, 1H), 7.32−7.24 (m, 4H), 7.21−7.17 (m, 1H), 6.97 (s, 1H), 4.19 (s, 2H); $^{13}C\{^1H\}$ NMR ($CDCl_3$, 100 MHz) δ_c 141.4, 131.1, 130.5, 129.0, 128.7, 128.4, 126.0, 125.5, 123.9, 123.3, 121.8, 120.6, 120.3, 119.4, 119.3, 117.6, 31.7; HRMS (ESI) m/z calcd for $C_{19}H_{16}N$ $[M + H]^+$ 258.1283, found 258.1277.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.joc.9b00861.

Oak ridge thermal ellipsoid plots of products **1ba**, **2aa**, **2ah**, and **2bd** along with their some important crystal data; schemes for the preparation of starting materials **7** and **8**; ^1H and ^{13}C NMR spectra for all compounds synthesized; and ^{19}F spectra of all fluorine-containing products (PDF)

Single-crystal data of products **1ba** (CIF)

Single-crystal data of products **2aa** (CIF)

Single-crystal data of products **2ah** (CIF)

Single-crystal data of products **2bd** (CIF)

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Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

M.J. acknowledges UGC, New Delhi, and S.D. and S.P. acknowledge CSIR, New Delhi, for fellowship. C.C. acknowledges CSIR-IICB for financial support.

■ DEDICATION

This paper is dedicated to Dr. Nitya G. Kundu, former Professor and Head, Dept. of Organic Chemistry, IACS, Kolkata, on the occasion of his 83rd birth anniversary.

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