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One-Pot Access to Benzo[*a*]carbazoles via Palladium(II)-Catalyzed Hetero- and Carboannulations

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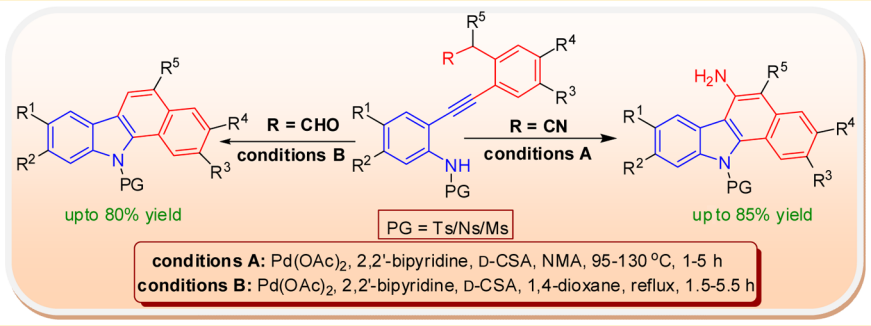
Supporting Information



ABSTRACT: A Pd(II)-catalyzed direct synthesis of benzo[*a*]carbazoles has been achieved through aminopalladation of alkynes, followed by intramolecular nucleophilic addition of the generated carbon−palladium bond to a tethered cyano/aldehyde group. Compared to literature procedures, this synthetic approach is operationally simple, uses simple substrates, and offers a fast intramolecular assembly resulting in the direct synthesis of benzo[*a*]carbazoles in which a wide variation of substituents at different sites is well-tolerated, leaving enough opportunity for diversification.

INTRODUCTION

Carbazoles, prevalent in many naturally occurring alkaloids, have gained considerable attention in recent times due to their diverse biological[1] and unique optical properties.[2] Among the large varieties of carbazoles, aryl/heteroaryl annulated ones are of special interest because of their significant biological and pharmaceutical potential arising out of their special affinity toward DNA.[3] Benzo[*a*]carbazoles display a broad range of activities including anti-inflammatory,[4a] antiestrogenic,[4b] anti-fungal,[4c] and kinase inhibitory[4d] and are also utilized in other fields such as development of light-emitting diodes (LEDs),[4e] dye-sensitized solar cells (DSSC),[4f] and fluorescent reagents.[4g] For example, compound **1** (Figure 1) finds wide application in materials science due to its unique optical properties,[5a] while compound **2** displays significant antitumor (leukemia, renal, colon)[5b] and anti-inflammatory[4a] activity. Compound **3** has been found to display remarkable *in vitro* and *in vivo* anticancer activity comparable to that of *amonafide*, a potent agent developed against advanced breast cancer.[5c] Besides, a series of benzo[*a*]carbazoles and their dihydro analogues such as compound **4** have been shown to bind to estrogen receptors and inhibit the growth of mammary tumors in rats.[4b] In view of the immense importance of the carbazoles and in continuation of our efforts[6] in the development of leads having significant anticancer potency, we became interested in designing novel scaffolds based on benzo[*a*]carbazole and in getting easy access to these compounds for our screening studies.

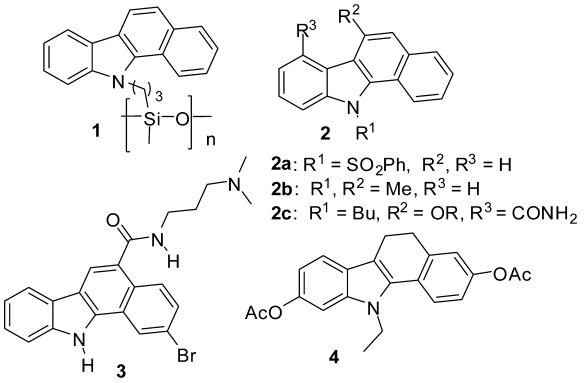


Figure 1. Some important benzo[*a*]carbazoles.

A scrutiny of the literature indicated that a number of synthetic methodologies have been established for benzo[*a*]-carbazoles in the past decades using classical reactions like thermal and photochemical cyclizations,[7a] pericyclic reactions,[5a,7b] and Fischer indole synthesis.[4b,f,7c] In addition, a few reaction strategies using conventional reagents have also been demonstrated.[5b,8] Most of these reactions, however, suffer from the need to synthesize complex starting materials or use harsh reaction conditions, or are multistep ones with low yields. To

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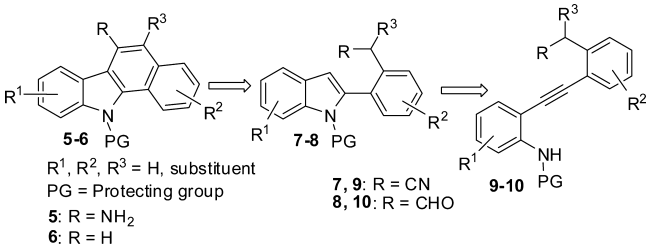
overcome this lacuna, some metal-catalyzed reactions employing prefunctionalized indole derivatives as substrates have recently been demonstrated.[9] Though these are useful, they need to synthesize the precursor indoles and functionalize them prior to use. Surprisingly, more convenient procedures involving in situ formation of indole, followed by benzannulations resulting in carbazoles in one-pot, are rare.[10] Given the great utility of benzo[*a*]carbazoles, exploring efficient, flexible, atom economic, and direct procedures for these heterocycles is thus highly desirable.

With this background, we envisioned that benzo[*a*]-carbazoles **5**−**6** could be accessed through the bond disconnections shown in Scheme 1. The crucial step is an

Scheme 1. Retrosynthesis of Benzo[*a*]carbazoles 5−6

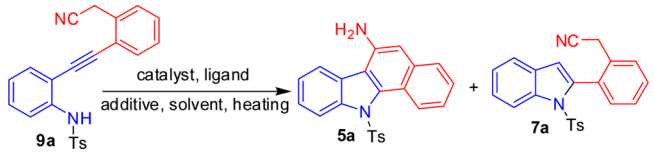


intramolecular transition-metal-catalyzed nucleophilic addition involving C3 of the indole moiety in **7**/**8** onto the pendant nitrile/carbonyl group. Intermediates **7**/**8** in turn are synthesized from alkynes **9**/**10** by metal-catalyzed *N*-heteroannulation reactions. Indeed, these transformations could be carried out in one pot, providing an easy access to the targeted products **5**−**6**. The work was inspired by the pioneering studies of Larock, Lu, and others[11] on the nucleophilic addition of a carbon−palladium bond to carbon−heteroatom multiple bonds, resulting in easy generation of diversified scaffolds. We could thus successfully develop a one-pot palladium-catalyzed cascade reaction strategy for the assembly of benzo[*a*]-carbazoles **5** and **6** using amino-alkyne substrates **9** and **10**, respectively, as a part of our ongoing program[12] on palladium-catalyzed heteroannulations. Herein, we disclose the results obtained so far in this direction.

RESULTS AND DISCUSSION

To test the hypothesis depicted in Scheme 1 and to find out the optimized reaction conditions, we initially chose the substrate **9a** ($R^1 = R^2 = R^3 = H$, R = CN, PG = Ts) for model study. The requisite substrate could easily be obtained in two steps comprising "*Sonogashira coupling*" between *o*-ethynylaniline and (*o*-iodophenyl)acetonitrile, followed by *N*-tosylation of the resulting product (see the Experimental Section and the Supporting Information). Next, we turned our attention toward the optimization study on **9a**; selected results are presented in Table 1. Initial efforts employing the catalytic system $Pd(OAc)_2$/bpy in 1,4-dioxane under neutral or basic conditions (using 2.0 equiv of K_2CO_3) proved disappointing by producing neither **5a** nor **7a**. However, the use of 1,4-dioxane mixed with acetic acid (1,4-dioxane:acetic acid = 4:1) afforded the desired product **5a**, albeit in moderate yield (43%), along with 38% of the side product **7a** (Table 1, entry 1), indicating the necessity of an acid in this reaction. Indeed, switching to DMA and *p*-TsOH as solvent and additive, respectively, afforded the desired product **5a** (62%) within 4.5 h (Table 1, entry 2), suppressing the side product formation completely. However, carrying out this reaction in a less polar solvent like THF failed to afford any product even after refluxing the reaction mixture for 8 h (Table 1, entry 3), underlining the necessity of a polar solvent.

Table 1. Optimization of the Reaction Conditions for the Synthesis of 5a[a]



entry	catalyst	ligand	additive	solvent	temp (°C)	time (h)	yield (%)[b] 5a	7a
1	$Pd(OAc)_2$	bpy	AcOH	1,4-dioxane	reflux	8.0	43	38
2	$Pd(OAc)_2$	bpy	$TsOH·H_2O$	DMA	120	4.5	62	
3	$Pd(OAc)_2$	bpy	$TsOH·H_2O$	THF	reflux	8.0		
4	$Pd(OAc)_2$	bpy	D-CSA	DMA	120	2.5	75	
5	**$Pd(OAc)_2$**	**bpy**	**D-CSA**	**NMA**	**120**	**2.0**	**85**	
6	$Pd(OAc)_2$	bpy		NMA	120	5.0	70	10
7	$Pd(bpy)(OAc)_2$		D-CSA	NMA	120	2.5	46	33
8	$PdCl_2(CH_3CN)_2$	bpy	D-CSA	NMA	120	2.0	60	
9	$Pd(TFA)_2$	bpy	D-CSA	NMA	120	1.5	58	26
10	$PdCl_2$	bpy	D-CSA	NMA	120	1.5	32	25
11	$Pd(OAc)_2$	pyridine	D-CSA	NMA	120	8.5	51	28
12	$Pd(OAc)_2$	6,6′-dimethyl-2,2′-bipyridine	D-CSA	NMA	120	4.0	26	52
13	$Pd(OAc)_2$	4,4′-dimethoxy-2,2′-bipyridine	D-CSA	NMA	120	3.5	65	20
14	$Pd(OAc)_2$	2,2′-biquinoline	D-CSA	NMA	120	2.0	15	45
15	$Pd(OAc)_2$	2,9′-dimethyl-1,10-phenanthroline	D-CSA	NMA	120	12		
16			D-CSA	NMA	120	6	n.r.	

[a]Reaction conditions: **9a** (0.20 mmol), catalyst (5 mol %, except for entry 16), ligand (6 mol % except for entries 7 and 16), and additive (1.5 equiv) in solvent (2 mL) and temperature as mentioned in the table. [b]Isolated pure products. n.r.: no reaction; D-CSA: D-(+)-camphor sulfonic acid; DMA: *N*,*N*-dimethylacetamide; NMA: *N*-methylacetamide.

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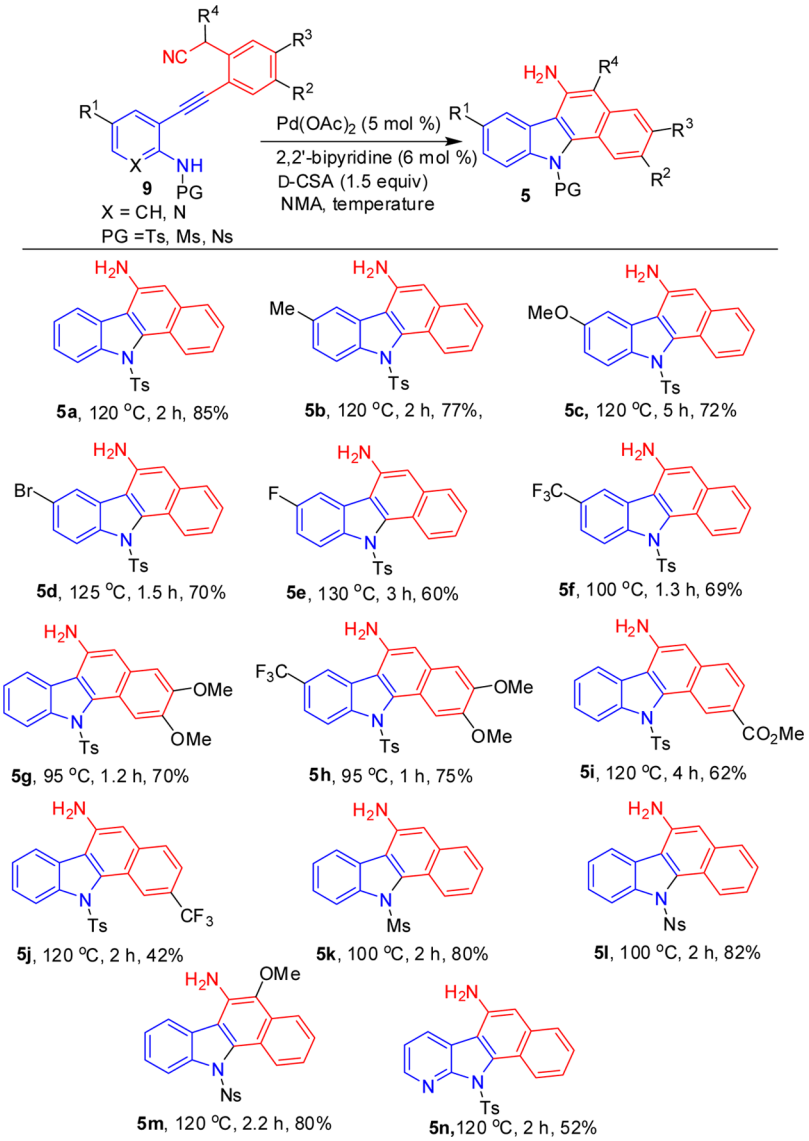
Scheme 2. Synthesis of 6-Amino Benzo[*a*]carbazole Derivatives 5[a,b]



[a]Reaction conditions: **9** (0.20 mmol), $Pd(OAc)_2$ (5 mol %), 2,2′-bipyridine (6 mol %), and D-CSA (1.5 equiv) in NMA (2 mL) under argon. [b]Yield of the isolated pure product.

Interestingly, executing this reaction in a polar solvent like DMA and using D-CSA [D-(+)-camphor sulfonic acid] as an additive reduced the time period and improved the yield (75%) simultaneously (Table 1, entry 4). It may be pointed out that the use of a more polar solvent like NMA completed this reaction within 2 h only and further improved the yield to 85% (Table 1, entry 5). In contrast, conducting this reaction without using the additive (Table 1, entry 6) was not encouraging, providing lower yield with some side product.

We then focused our attention to screen the catalyst by using different Pd(II) sources. Toward this objective, we tested the bpy ligated catalyst [i.e., $Pd(bpy)(OAc)_2$] in lieu of $Pd(OAc)_2$/bpy, but this resulted in the formation of a product mixture (Table 1, entry 7), emphasizing the essentiality of the free ligand in this reaction. However, employment of $Pd(CH_3CN)_2Cl_2$ along with bpy led to the formation of the desired product **5a** exclusively with 60% yield (Table 1, entry 8). Experiments with other palladium(II) catalysts [viz., $PdCl_2$, $Pd(TFA)_2$] were found to be disappointing, as mixtures of **5a** and **7a** were produced with low yields (Table 1, entries 9 and 10). Thus, $Pd(OAc)_2$ was found to be the best among the palladium(II) catalysts screened.

Next, we became interested in the use of other ligands based on pyridine to identify the most effective one. This revealed that even pyridine itself can play the role of requisite ligand to afford the product **5a**, albeit in moderate (51%) yield (Table 1, entry 11). Though employment of 6,6′-dimethyl-2,2′-bipyridine as ligand generated the side product **7a** as the major one (Table 1, entry 12), 4,4′-dimethoxy-2,2′-bipyridine produced the desired **5a** in 65% yield (Table 1, entry 13) with a minor amount of **7a** (20%). Use of 2,2′-biquinoline resulted in a very low yield of **5a** (Table 1, entry 14), while 2,9′-dimethyl-1,10-phenanthroline was found to be completely inactive (Table 1, entry 15). We also carried out the reaction in the absence of palladium catalyst and ligand to check the effect of D-CSA, but no reaction took place (Table 1, entry 16), the starting material **9a** remaining intact (TLC). Thus, reaction conditions of entry 5 of Table 1 were found to be optimal.

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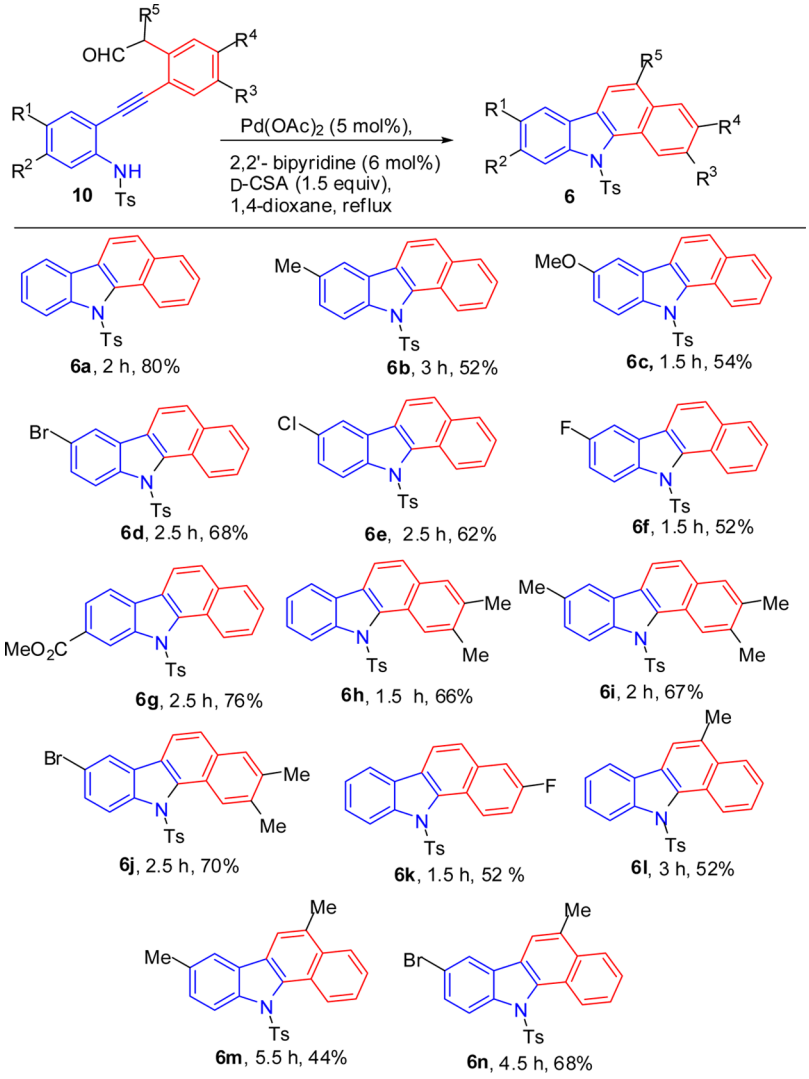
Table 2. Optimization of the Reaction Conditions for the Synthesis of 6a[a]

entry	catalyst	ligand	solvent	temp (°C)	time (h)	yield (%)[b] **6a**
1	$Pd(OAc)_2$	bpy	NMA	120	4.0	45
2	$Pd(OAc)_2$	bpy	NMP	120	2.5	40
3	$Pd(OAc)_2$	bpy	DMF	120	5.5	31
4	$Pd(OAc)_2$	bpy	DMA	120	4.5	15
5	**$Pd(OAc)_2$**	**bpy**	**1,4-dioxane**	**reflux**	**2.0**	**80**
6	$Pd(bpy)(OAc)_2$		1,4-dioxane	reflux	2.0	65
7	$PdCl_2(CH_3CN)_2$	bpy	1,4-dioxane	reflux	4.5	30
8	$PdCl_2$	bpy	1,4-dioxane	reflux	5.0	n.r.
9			1,4-dioxane	reflux	6.0	n.r.

[a]Reaction conditions: **10a** (0.20 mmol), catalyst (5 mol %, except for entry 9), 2,2′-bipyridine (6 mol %, except for entries 6 and 9), and D-CSA (1.5 equiv) in solvent (2 mL) and temperature as mentioned in the table. [b]Isolated pure products. n.r.: no reaction; D-CSA: D-(+)-camphorsulfonic acid; NMA: *N*-methylacetamide; DMA: *N*,*N*-dimethylacetamide; NMP: *N*-methyl-2-pyrrolidone.

Scheme 3. Synthesis of Benzo[*a*]carbazole Derivatives 6[a,b]



[a]Reactions were carried out using **10** (0.20 mmol), $Pd(OAc)_2$ (5 mol %), 2,2′-bipyridine (6 mol %), and D-CSA (1.5 equiv) in refluxing 1,4-dioxane (2 mL) under argon. [b]Yield of the isolated pure product.

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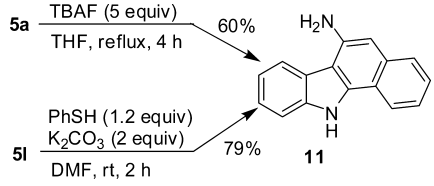
With the optimized reaction conditions in hand, we set out to explore the scope of this domino reaction by employing differently substituted amino-alkynes **9** as shown in Scheme 2. Though other *N*-protecting groups like Ts, Ms, and Ns worked equally well (Scheme 2), neither free nor otherwise protected (e.g., $COCF_3$) amine in substrate **9a** responded. Additionally, an array of useful functional groups (viz., Me, CF_3, OMe, CO_2Me, F, Br) could be used in the rest of the substrate, tweaking the temperature and the duration of reaction in a few cases. For the substituent R^1 (para to the amine group) in the amino aryl moiety of substrate **9**, an electron-donating group (EDG) like methyl or methoxy afforded the corresponding benzo[*a*]carbazoles **5b** and **5c** in 72−77% yield (Scheme 2). However, an electron-withdrawing group (R^1 = Br/F/CF_3) in the same position furnished the corresponding product **5d**/**5e**/**5f** in somewhat lower (60−70%) yields. Of the substituents (R^2, R^3) in the other benzene ring, electron donor groups (R^2 = R^3 = OMe) allowed the reaction to be carried out at lower temperature (95 °C) and in a shorter time (1−1.2 h), but the yields varied (Scheme 2, products **5a** vs **5g** and **5f** vs **5h**). In contrast, when an electron-withdrawing group (e.g., CO_2Me, CF_3) was introduced in the substrate (Scheme 2, products **5i** and **5j**), the yield was distinctly lower (42−62%) and the reaction was required to be carried out at higher temperature (120 °C) for longer time periods (2−4 h). Replacing the tosyl (Ts) group of substrates **9** by either methane sulfonyl (Ms) or *p*-nitro phenyl sulfonyl (Ns) did not change the yields significantly (viz., products **5a** vs **5k** or **5l**). Furthermore, the scope of the reaction could be successfully extended to synthesize product **5m** (80% yield) in which a substituent (R^4 = OMe) was incorporated easily in the third aryl ring. We also checked the reactivity of the substrate in which a pyridine ring is installed in place of the benzene linked with an amine moiety; this new substrate was also found to be capable of producing the desired product (**5n**), albeit in moderate yield (52%).

Encouraged by the above results, we decided to check the viability of the methodology for a domino synthesis of benzo[*a*]carbazoles **6**. The requisite amino-alkyne substrate **10a** was prepared easily in few steps (see the Supporting Information and the Experimental Section) and allowed to react under the optimized reaction conditions. To our dismay, use of reaction conditions, optimized previously, on **10a** furnished the desired product with only 45% yield (Table 2, entry 1). We, therefore, decided to modify the reaction conditions by varying the catalyst, solvent, and temperature to achieve the product **6a** in good yield; pertinent results in this direction are presented in Table 2. Initially, we changed only the solvent system, keeping intact the other parameters. Thus, switching to more polar NMP solvent instead of NMA lowered the yield of **6a** to 40% (Table 2, entry 2), while use of slightly less polar solvents like DMF and DMA made the situation worse, forming the product **6a** within 4.5−5.5 h with yields of 31% and 15%, respectively (Table 2, entries 3 and 4). Surprisingly, conducting this reaction in refluxing 1,4-dioxane, a solvent system comparatively much less polar than NMA, successfully completed the reaction within 2 h and provided a very good yield (80%) of **6a** (Table 2, entry 5). Thereafter, we performed a few reactions in 1,4-dioxane varying the Pd(II) catalyst to find out the most effective one. For example, use of $Pd(bpy)(OAc)_2$ catalyst in place of the $Pd(OAc)_2$/bpy catalytic system kept the time period of the reaction unaltered but lowered the yield of **6a** to some extent (Table 2, entry 5 vs 6). On the other hand, $PdCl_2(CH_3CN)_2$ in combination with a bpy ligand made the reaction somewhat slow and delivered the desired product in merely 30% yield (Table 2, entry 7). $PdCl_2$ proved to be inactive as no reaction took place even after 6 h (Table 2, entry 8). We then checked the effect of D-CSA in the absence of palladium catalyst and ligand, but no reaction took place (Table 2, entry 9). Thus, the reaction conditions of entry 5 of Table 2 appeared to be the best.

With the optimized reaction conditions in hand, we then set out to explore the scope of this reaction using other substrates as shown in Scheme 3. Various functional groups like Me, OMe, Br, Cl, F, or CO_2Me in the aryl ring (or benzylic carbon) of the substrates **10** were well-tolerated, and the products were isolated in moderate to good yields (44−76%). As can be seen from Scheme 3, an electron-donating group (Me/OMe) para to the amine moiety of substrate **10** lowered the yield of the product (**6b**/**6c**), whereas electron-withdrawing groups (Br/Cl/CO_2Me, but not F) in the amino aryl ring of **10** enhanced it (**6d**/**6e**/**6g**). The moderate yield of the fluoro containing product (**6f**) was attributable to side reactions of the corresponding substrate, as few unidentified side products were observed in minor amounts. In contrast, when electron-donating substituents were placed in the other benzene ring of the substrates (e.g., R^3 = R^4 = Me), the reactions were facilitated, leading to the formation of the products (**6h**/**6i**/**6j**) with somewhat better yields (viz., products **6b** vs **6i** and **6d** vs **6j** in Scheme 3). However, employment of an electron-withdrawing group (e.g., R^4 = F) in the same ring reduced the yield of the product (product **6a** vs **6k** in Scheme 3). Furthermore, when one of the benzylic hydrogens of **10** was replaced by a methyl group, the resulting substrate (R^5 = Me) was still found to be reactive, affording the desired product (**6l**/**6m**/**6n**) having methyl substitution in the third ring of the carbazole moiety, though the reaction time of these substrates was found to be slightly higher (3−5.5 h) and yields were somewhat lower (viz., products **6a** vs **6l** and **6b** vs **6m** in Scheme 3). The longer reaction time period and moderate yields appear to be attributable to steric interactions of the benzylic methyl with the palladium complex in the intermediate species (see reaction mechanism in Scheme 5 vide infra). Additionally, reactivity of the substrates **9** and **10** having a similar substitution pattern could be compared (see products **5a**−**d** of Scheme 2 vs products **6a**−**d** of Scheme 3). Compounds **10** mostly reacted at lower temperatures with a comparable reaction time, but had the propensity to polymerize under the reaction conditions, leading to lower yields of the products.

Because of the prevalence of benzo[*a*]carbazoles with a free NH group in the core structures of a large number of alkaloids and privileged heterocyclic compounds possessing significant biological activities,[3b,5c,13] we checked the *N*-deprotection reactions on a few representative compounds (**5a**, **5l**) as shown in Scheme 4. Transformation of **5a** to **11** can easily be

Scheme 4. *N*-Deprotection Reactions of 5a and 5l



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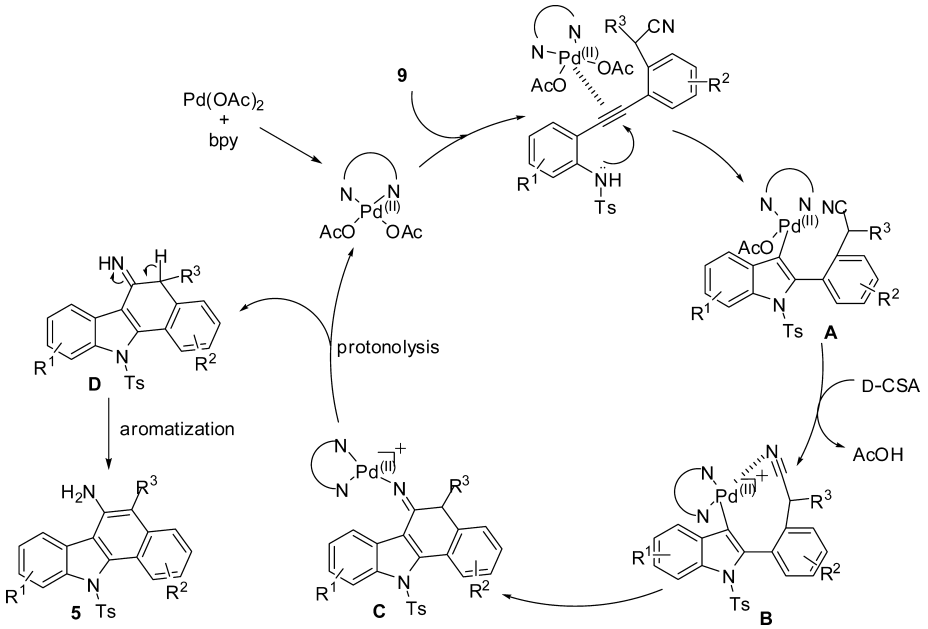
Scheme 5. Plausible Reaction Mechanism for the Formation of Products 5



accomplished using TBAF in refluxing THF. On the other hand, the same product could also be derived from **5l** through denosylation at rt employing thiophenol along with K_2CO_3.

The structures of the products **5**–**6** were fully characterized by NMR spectroscopy and HRMS data. Single-crystal X-ray analysis (see the Supporting Information) of a few products (**5b**, **5g**, and **6f**)[14] also confirmed the formation of benzo[*a*]-carbazoles.

On the basis of the experimental results and known palladium chemistry, a reaction mechanism outlined in Scheme 5 is proposed. Initially, upon activation of the triple bond of the substrate **9** by Pd(II) catalyst acting like a Lewis acid, a palladated species **A** is generated through a *trans*-amino-palladation pathway as observed in our previous studies.[12c,d] In the next step, the active cationic palladated species **B** generated under acidic conditions[11c,15] becomes stabilized through coordination of the tethered nucleophile (i.e., nitrogen atom of the cyano group) and undergoes intramolecular nucleophilic addition to the tethered cyanide bond, resulting in palladated species **C**.[16] The ready addition of the C–Pd bond to nitrile is attributed to the increased polarity caused by the electron-donating effect of the nitrogen atom in the indole ring (of **B**).[17] However, species **C**, upon subsequent protonolysis, generates intermediate imine species **D**, which, upon aromatization, would produce 6-amine-substituted benzo[*a*]carbazole **5**;[18] Pd(II) produced during the protonolysis step keeps the catalytic cycle active. Products **6** can also be generated using the same pathway, except the last step, where dehydration takes places instead of hydrogen migration.

In order to probe the possibility of a two-step process [viz., formation of indole, followed by palladium-catalyzed nucleophilic addition or Friedel–Crafts type of reaction] carried out in one pot and involving the intermediacy of indole **7a** isolated previously (Table 1), compound (**7a**) was subjected to the optimized reaction conditions [$Pd(OAc)_2$/bpy, D-CSA, NMA, 120 °C]; interestingly, no reaction took place even after heating for 12 h, thus ruling out this possibility. This provides indirect support in favor of a cascade reaction.[19]

CONCLUSION

We have described herein a direct and straightforward method for the synthesis of benzo[*a*]carbazoles **5**/**6** through a palladium-catalyzed intramolecular cascade reaction involving *trans*-aminopalladation of alkyne, followed by nucleophilic addition to cyano or aldehyde. This method constitutes a fast intramolecular assembly resulting in the synthesis of benzo[*a*]-carbazoles in which a wide variation of the substituents at different sites is well-tolerated, leaving enough opportunity for diversification. The reaction is operationally simple, compatible with various functional groups, and uses simple substrates. In view of the immense importance of benzo[*a*]carbazoles as pharmacophores and optical materials, we believe that the method will find applications in organic and medicinal chemistry, and materials science 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 was dried over CaH_2, distilled, and stored over 3 Å molecular sieves in a sealed container. 1,4-Dioxane was distilled over sodium and benzophenone. Commercial grade dry DMF, DMA, and NMA were used as a solvent. All the reactions were carried out under an 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 60–120 or 100–200 mesh silica gel. ^{1}H and ^{13}C NMR spectra were recorded on a 300 or 600 MHz spectrometer using tetramethylsilane (TMS) as internal standard. Chemical shifts (δ) are given from TMS (δ = 0.00) in parts per million (ppm) with reference to the residual nuclei of the deuterated solvent used [$CDCl_3$: ^{1}H NMR δ = 7.26 ppm (s); ^{13}C NMR δ = 77.0 ppm]. Coupling constants (J) are expressed in hertz (Hz), and spin multiplicities are given as s (singlet), d (doublet), dd (double doublet), t (triplet), td (triple doublet), q (quartet), m (multiplet), and br (broad). All ^{13}C NMR spectra were obtained with complete proton decoupling. Mass spectra were performed using ESI-TOF, EI, or FAB ionization mode. Infrared spectra were obtained on an FT/IR spectrometer as a neat sample or as a KBr pellet.

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General Procedure for the Preparation of the Starting Substrates 9 (See Scheme S2 in the Supporting Information). The *ortho*-ethynylaniline derivatives **S1** were prepared in three steps starting from aniline derivatives (see Scheme S1 in the Supporting Information) using known methods.[20,21] Initially, iodination of the aniline derivatives using I_2 and sodium bicarbonate in toluene−water (3:7) afforded 2-iodoaniline derivatives;[20] coupling of this product with TMS-acetylene under "*Sonogashira reaction*" conditions, followed by desilylation of the resulting product, led to the desired *ortho*-ethynylaniline derivatives **S1** reported previously.[21] Product **S1** underwent coupling with commercially available *ortho*-iodophenylacetonitrile derivatives in a subsequent step employing "*Sonogashira reaction*" conditions to afford amino-alkyne **S2** tethered with a nitrile group (see Scheme S2 in the Supporting Information). Finally, preparations of requisite sulfonamide substrates **9** were done by treating amino compounds **S2** with *p*-toluenesulfonyl chloride/methylsulfonyl chloride/*p*-nitrosulfonyl chloride in dry dichloromethane in the presence of pyridine as base.

*Synthesis of the Precursor Amine Derivatives (**S2**; See Scheme S2 in the Supporting Information) of the Substrates **9**.* To a well-stirred solution of the substituted 2-iodophenylacetonitrile (0.82 mmol) in Et_3N (5 mL) were added $Pd(PPh_3)_2Cl_2$ (17.2 mg, 0.024 mmol, 3 mol %), *ortho*-ethynylaniline derivative **S1** (0.90 mmol), and CuI (9.3 mg, 0.049 mmol, 6 mol %) successively. The reaction mixture was then stirred at room temperature under an argon atmosphere. After completion of the reaction (TLC), solvent was removed under reduced pressure. 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 residue was purified through silica gel (100−200 mesh) column chromatography and eluted with 10−40% ethyl acetate−petroleum ether to afford the desired amine **S2** (82−98%).

*Preparation of the Substrates **9** (See Scheme S2 in the Supporting Information).* To a well-stirred solution of the aforesaid amino-alkyne **S2** (0.81 mmol) in dry dichloromethane (5 mL) were added pyridine (78 μL, 0.972 mmol, 1.2 equiv) and *p*-toluenesulfonyl (or *p*-nitrobenzenesulfonyl or methanesulfonyl) chloride (0.83 mmol, 1.03 equiv) consecutively at 0 °C, and the reaction mixture was allowed to stir at room temperature for 1.5−3 h (overnight in a few cases). After completion of the reaction, it was extracted with dichloromethane (2 × 25 mL), washed with brine (10 mL), dried over anhydrous Na_2SO_4, and concentrated under reduced pressure. The resulting residue was purified through silica gel (100−200 mesh) column chromatography (eluted with 10−40% ethyl acetate in petroleum ether) to afford the requisite starting substrate **9**.

For compound **9n**, the aforesaid *N*-tosylation reaction was carried out using pyridine instead of dichloromethane under refluxing conditions for 8 h.

*N-(2-((2-(Cyanomethyl)phenyl)ethynyl)phenyl)-4-methylbenzenesulfonamide (**9a**).* Pale yellow solid (262.9 mg, 84% yield); mp 132−134 °C; R_f = 0.58 (50% ethyl acetate in petroleum ether); IR (KBr) 3312, 2916, 2248, 1594, 1491, 1451, 1400, 1337, 1277, 1162 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.69 (d, J = 8.1 Hz, 2H), 7.61 (d, J = 8.4 Hz, 1H), 7.54−7.47 (m, 2H), 7.45−7.42 (m, 2H), 7.40−7.31 (m, 2H), 7.22−7.20 (m, 3H), 7.11 (t, J = 7.5 Hz, 1H), 3.83 (s, 2H), 2.37 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 144.3, 137.7, 136.4, 132.8, 132.6, 131.8, 130.3, 129.9, 129.8, 128.6, 128.5, 127.3, 124.9, 121.9, 120.8, 117.4, 114.3, 92.4, 90.2, 23.0, 21.7; HRMS (EI+) m/z calculated for $C_{23}H_{18}N_2O_2S$ $[M]^+$ 386.1089, found 386.1096.

*N-(2-((2-(Cyanomethyl)phenyl)ethynyl)-4-methylphenyl)-4-methylbenzenesulfonamide (**9b**).* White solid (278.9 mg, 86% yield); mp 128−130 °C; R_f = 0.52 (50% ethyl acetate in petroleum ether); IR (KBr) 3273, 2920, 2854, 2248, 2216, 1597, 1497, 1452, 1396, 1330, 1158 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.66 (d, J = 8.1 Hz, 2H), 7.51−7.48 (m, 2H), 7.47−7.36 (m, 3H), 7.24−7.14 (m, 4H), 7.04 (s, 1H), 3.80 (s, 2H), 2.36 (s, 3H), 2.30 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 144.0, 136.5, 135.1, 134.9, 132.7, 131.7, 131.2, 129.8, 129.7, 128.5, 128.4, 127.3, 121.9, 121.5, 117.3, 114.5, 91.8, 90.5, 22.9, 21.6, 20.7; HRMS (EI+) m/z calculated for $C_{24}H_{20}N_2O_2S$ $[M]^+$ 400.1245, found 400.1235.

*N-(2-((2-(Cyanomethyl)phenyl)ethynyl)-4-methoxyphenyl)-4-methylbenzenesulfonamide (**9c**).* Pale yellow solid (286.7 mg, 85% yield); mp 136−138 °C; R_f = 0.32 (40% ethyl acetate in petroleum ether); IR (KBr) 3287, 2925, 2247, 2223, 1600, 1495, 1446, 1381, 1324, 1279, 1157 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.60 (d, J = 8.1 Hz, 2H), 7.53−7.38 (m, 5H), 7.16 (d, J = 8.1 Hz, 2H), 6.93−7.90 (m, 2H), 6.86 (s, 1H), 3.79 (s, 3H), 3.78 (s, 2H), 2.36 (s, 3H); 13C NMR ($CDCl_3$, 75 MHz) δ_C 157.1, 143.8, 136.4, 132.6, 131.7, 130.4, 129.8, 129.5, 128.4, 128.3, 127.2, 124.9, 121.7, 117.3, 117.1, 116.6, 91.4, 90.4, 55.6, 22.9, 21.5; HRMS (EI+) m/z calculated for $C_{24}H_{20}N_2O_3S$ $[M]^+$ 416.1195, found 416.1200.

*N-(4-Bromo-2-((2-(cyanomethyl)phenyl)ethynyl)phenyl)-4-methylbenzenesulfonamide(**9d**).* White solid (361.8 mg, 96% yield); mp 136−138 °C; R_f = 0.61 (50% ethyl acetate in petroleum ether); IR (KBr) 3230, 2922, 2252, 2222, 1592, 1484, 1389, 1159 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.65 (d, J = 8.4 Hz, 2H), 7.62−7.57 (m, 1H), 7.53−7.48 (m, 3H), 7.46−7.40 (m, 1H), 7.21 (d, J = 8.1 Hz, 2H), 7.17−7.08 (m, 2H), 7.06 (s, 1H), 3.81 (s, 2H), 2.39 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 144.4, 136.8, 136.1, 134.7, 133.2, 132.9, 131.8, 130.2, 129.8, 128.7, 128.5, 127.2, 122.2, 121.3, 117.5, 117.2, 116.0, 93.4, 88.7, 23.0, 21.6; HRMS (EI+) m/z calculated for $C_{23}H_{17}BrN_2O_2S$ $[M]^+$ 464.0194, found 464.0201.

*N-(2-((2-(Cyanomethyl)phenyl)ethynyl)-4-fluorophenyl)-4-methylbenzenesulfonamide (**9e**).* White solid (307.9 mg, 94% yield); mp 122−124 °C; R_f = 0.52 (50% ethyl acetate in petroleum ether); IR (KBr) 3318, 3072, 2919, 2251, 2203,1597, 1492, 1399, 1339, 1269, 1163 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.68 (d, J = 8.4 Hz, 2H), 7.55 (d, J = 2.1 Hz, 1H), 7.53−7.48 (m, 3H), 7.47−7.38 (m, 3H), 7.23 (d, J = 8.1 Hz, 2H), 7.16 (s, 1H), 3.81 (s, 2H), 2.38 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz): δ_C 159.5 (d, J = 244.8 Hz), 144.2, 136.2, 133.7 (d, J = 3.1 Hz), 132.8, 131.8, 130.1, 129.7, 128.6, 128.4, 127.2, 124.2 (d, J = 8.7 Hz), 121.4, 118.8 (d, J = 24.1 Hz), 117.5 (d, J = 22.0 Hz), 116.9 (d, J = 9.9 Hz), 92.7, 89.2, 22.9, 21.6; HRMS (EI+) m/z calculated for $C_{23}H_{17}FN_2O_2S$ $[M]^+$ 404.0995, found 404.0983.

*N-(2-((2-(Cyanomethyl)phenyl)ethynyl)-4-(trifluoromethyl)-phenyl)-4-methylbenzenesulfonamide (**9f**).* White solid (228.2 mg, 62% yield); mp 150−152 °C; R_f = 0.32 (40% ethyl acetate in petroleum ether); IR (KBr) 3322, 2922, 2249, 2208, 1609, 1501, 1412, 1342, 1296, 1163 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.77 (d, J = 8.4 Hz, 2H), 7.70−7.67 (m, 2H), 7.59−7.40 (m, 6H), 7.28 (s, 1H), 3.86 (s, 2H), 2.40 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 144.7, 140.6, 135.9, 132.9, 131.8, 130.3, 129.9, 129.6−129.5 (m), 128.7, 128.5, 127.2, 126.9 (m), 121.1, 118.8, 117.2, 113.3, 93.8, 88.5, 23.0, 21.5 (peaks due to C−CF_3 are not distinguished because of low intensity); HRMS (EI+) m/z calculated for $C_{24}H_{17}F_3N_2O_2S$ $[M]^+$ 454.0963, found 454.0958.

*N-(2-((2-(Cyanomethyl)-4,5-dimethoxyphenyl)ethynyl)phenyl)-4-methylbenzenesulfonamide (**9g**).* White solid (274.8 mg, 76% yield); mp 186−188 °C; R_f = 0.13 (40% ethyl acetate in petroleum ether); IR (KBr) 3336, 2928, 2253, 2193, 1600, 1520, 1453, 1395, 1338, 1256, 1158 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.70 (d, J = 8.1 Hz, 2H), 7.58 (d, J = 8.1 Hz, 1H), 7.42 (d, J = 7.5 Hz, 1H), 7.34−7.29 (m, 1H), 7.23−7.21 (m, 3H), 7.09 (t, J = 7.5 Hz, 1H), 6.98 (s, 1H), 6.95 (s, 1H), 3.97 (s, 3H), 3.95 (s, 3H), 3.78 (s, 2H), 2.38 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 150.3, 148.6, 144.1, 137.4, 136.3, 132.4, 129.9, 129.7, 127.2, 124.9, 124.6, 120.2, 117.6, 114.6, 114.2, 113.6, 111.2, 92.7, 88.5, 56.2, 56.1, 22.5, 21.6; HRMS (EI+) m/z calculated for $C_{25}H_{22}N_2O_4S$ $[M]^+$ 446.1300, found 446.1296.

*N-(2-((2-(Cyanomethyl)-4,5-dimethoxyphenyl)ethynyl)-4-(trifluoromethyl)phenyl)-4-methylbenzenesulfonamide (**9h**).* Pale yellow solid (258.3 mg, 62% yield); mp 152−154 °C; R_f = 0.12 (40% ethyl acetate in petroleum ether); IR (KBr) 3297, 2942, 2251, 2206, 1601, 1516, 1456, 1336, 1307, 1278, 1159 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.79 (d, J = 8.1 Hz, 2H), 7.70−7.66 (m, 2H), 7.55−7.51 (m, 2H), 7.31−7.28 (m, 2H), 7.04 (s, 1H), 6.97 (s, 1H), 3.99 (s, 3H), 3.97 (s, 3H), 3.84 (s, 2H), 2.42 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 150.8, 148.7, 144.7, 140.5, 135.9, 129.9, 129.5−129.4 (m), 127.2, 126.6 (m), 125.2, 118.4, 117.5, 114.8, 113.4, 112.9,

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111.4, 94.3, 86.9, 56.2, 56.1, 22.6, 21.6 (Peaks due to C−CF_3 are not distinguished because of low intensity); HRMS (EI+) m/z calculated for $C_{26}H_{21}F_3N_2O_4S$ $[M]^+$ 514.1174, found 514.1169.

*Methyl 4-(Cyanomethyl)-3-((2-(4-methylphenylsulfonamido)-phenyl)ethynyl)benzoate (**9i**).* White solid (306.0 mg, 85% yield); mp 160−162 °C; R_f = 0.17 (40% ethyl acetate in petroleum ether); IR (KBr) 3312, 2923, 2252, 2209, 1715, 1603, 1486, 1419, 1333, 1285, 1160 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.15 (s, 1H), 8.06 (d, J = 8.1 Hz, 1H), 7.70 (d, J = 8.4 Hz, 2H), 7.59 (d, J = 8.4 Hz, 2H), 7.46 (d, J = 7.5 Hz, 1H), 7.37 (t, J = 7.4 Hz, 1H), 7.23−7.10 (m, 4H), 3.97 (s, 3H), 3.87 (s, 2H), 2.37 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz)δ_C 165.6, 144.2, 137.7, 136.3, 132.7, 132.6, 131.9, 130.9, 130.7, 129.7, 129.6, 129.4, 127.2, 126.3, 124.8, 120.8, 116.8, 113.6, 93.0, 91.5, 52.6, 22.9, 21.5; HRMS (EI+) m/z calculated for $C_{25}H_{20}N_2O_4S$ $[M]^+$ 444.1144, found 444.1161.

*N-(2-((2-(Cyanomethyl)-5-(trifluoromethyl)phenyl)ethynyl)-phenyl)-4-methylbenzenesulfonamide (**9j**).* White solid (265.0 mg, 72% yield); mp 130−132 °C; R_f = 0.73 (50% ethyl acetate in petroleum ether); IR (KBr) 3244, 2929, 2253, 2202, 1599, 1496, 1452, 1404, 1335, 1295, 1161 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.72−7.60 (m, 6H), 7.47 (dd, J = 7.5 Hz, 1.2 Hz, 1H), 7.43−7.37 (m, 1H), 7.24 (d, J = 8.1 Hz, 2H), 7.19−7.12 (m, 2H), 3.90 (s, 2H), 2.39 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 144.2, 137.6, 136.4, 135.6, 132.7, 130.6, 129.7, 129.5−129.4 (m), 129.0, 127.1, 126.1−126.0 (m), 125.1, 122.9, 121.7, 116.7, 114.1, 91.8, 90.3, 22.9, 21.4; (Peaks due to C−CF_3 are not distinguished due to low peak intensity); HRMS (EI+) m/z calculated for $C_{24}H_{17}F_3N_2O_2S$ $[M]^+$ 454.0963, found 454.0968.

*N-(2-((2-(Cyanomethyl)phenyl)ethynyl)phenyl)methanesulfonamide (**9k**).* Pale yellow solid (231.2 mg, 92% yield); mp 110−112 °C; R_f = 0.53 (50% ethyl acetate in petroleum ether); IR (KBr) 3235, 2923, 2252, 2204, 1601, 1491, 1452, 1403, 1320, 1152 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 7.67−7.59 (m, 3H), 7.51−7.41 (m, 4H), 7.21 (td, J = 7.5 Hz, 1.1 Hz, 1H), 7.12 (brs, 1H), 3.95 (s, 2H), 3.12 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 137.7, 132.9, 132.8, 131.7, 130.5, 129.9, 128.8, 128.5, 124.8, 121.8, 119.7, 117.4, 113.7, 92.9, 90.1, 40.0, 23.1; HRMS (EI+) m/z calculated for $C_{17}H_{14}N_2O_2S$ $[M]^+$ 310.0776, found 310.0773.

*N-(2-((2-(Cyanomethyl)phenyl)ethynyl)phenyl)-4-nitrobenzenesulfonamide (**9l**).* Pale yellow solid (277.2, 82% yield); mp 140−142 °C; R_f = 0.46 (50% ethyl acetate in petroleum ether); IR (KBr) 3238, 2365, 1605, 1528, 1405, 1348, 1307, 1168 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.22 (d, J = 9.0 Hz, 2H), 7.99 (d, J = 9.0 Hz, 2H), 7.63 (d, J = 8.1 Hz, 1H), 7.51−7.38 (m, 7H), 7.21 (td, J = 7.5 Hz, 0.9 Hz, 1H), 3.83 (s, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 150.2, 145.0, 136.4, 132.8, 132.6, 131.6, 130.4, 130.0, 129.1, 128.5, 125.9, 124.2, 122.4, 121.6, 117.7, 115.5, 92.2, 90.1, 23.1; HRMS (ESI+) m/z calculated for $C_{22}H_{15}N_3NaO_4S$ $[M + Na]^+$ 440.0681, found 440.0688.

*N-(2-((2-(Cyano(methoxy)methyl)phenyl)ethynyl)phenyl)-4-nitrobenzenesulfonamide (**9m**).* Pale yellow solid (289.9 mg, 80% yield); mp 146−148 °C; R_f = 0.28 (40% ethyl acetate in petroleum ether); IR (KBr) 3345, 2925, 2208, 1602, 1527, 1487, 1450, 1405, 1345, 1288, 1161 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.19 (d, J = 9.0 Hz, 2H), 7.93 (d, J = 9.0 Hz, 2H), 7.80 (s, 1H), 7.68−7.65 (m, 2H), 7.54−7.49 (m, 3H), 7.46−7.36 (m, 2H), 7.18−7.14 (m,1H), 5.54 (s, 1H), 3.61 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 150.1, 144.9, 137.3, 133.9, 132.8, 132.3, 130.4, 130.1, 129.5, 128.5, 125.4, 124.1, 121.3, 116.2, 114.4, 91.9, 90.6, 70.7, 56.6; HRMS (ESI+) m/z calculated for $C_{23}H_{17}N_3NaO_5S$ $[M + Na]^+$ 470.0787, found 470.0775.

*N-(3-((2-(Cyanomethyl)phenyl)ethynyl)pyridin-2-yl)-4-methylbenzenesulfonamide (**9n**).* White solid (156.9 mg, 50% yield); mp 156−158 °C; R_f = 0.19 (50% ethyl acetate in petroleum ether); IR (KBr) 3198, 3145, 2921, 2249, 2217, 1588, 1533, 1441, 1387, 1322, 1256, 1128 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.23 (s, 1H), 8.06 (s, 2H), 7.85 (s, 1H), 7.75 (d, J = 7.5 Hz, 1H), 7.62 (s, 1H), 7.52−7.49 (m, 1H), 7.46−7.43 (m, 2H), 7.31 (d, J = 8.1 Hz, 2H), 6.95 (brs, 1H), 3.93 (s, 2H), 2.41 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 143.9, 141.3, 132.8, 132.2, 130.1, 129.4, 128.7, 128.4, 128.0, 121.6, 117.3, 94.2, 88.7, 22.9, 21.4; HRMS (EI+) m/z calculated for $C_{22}H_{17}N_3O_2S$ $[M]^+$ 387.1041, found 387.1038.

General Procedure for the Preparation of the Starting Substrates 10 (See Scheme S3 in the Supporting Information). *ortho*-Ethynylaniline derivative **S1** underwent coupling reaction with1-iodo-2-(2-methoxyvinyl)benzene[22] (or its substituted analogues) to afford the desired amino-alkyne derivative **S3**. Thereafter, *N*-tosylation of the amino group of **S3** using *p*-toluenesulfonyl chloride furnished the intermediate product **S4**. Finally, deprotection of the masked aldehyde **S4** using *p*-toluenesulfonic acid in dry acetone furnished the desired starting subtrate **10**.

*Synthesis of the Amino-alkyne Derivative **S3**.* To a well-stirred solution of 1-iodo-2-(2-methoxyvinyl)benzene or its derivative (2 mmol) in Et_3N (5 mL) were added $Pd(PPh_3)_2Cl_2$ (42.1 mg, 0.06 mmol, 3 mol %), acetylene **S1** (2.2 mmol), and CuI (22.8 mg, 0.12 mmol, 6 mol %) successively. The whole reaction mixture was then allowed to stir at room temperature under an argon atmosphere for 1.5−12 h. After completion of the reaction (TLC), the solvent was removed under reduced pressure and the crude mixture was extracted with ethyl acetate (3 × 30 mL), washed with brine (25 mL), dried over anhydrous Na_2SO_4, filtered, and concentrated *in vacuo*. The resulting residue was purified through silica gel (100−200 mesh) column chromatography using eluent 2−15% ethyl acetate in petroleum ether to give desired compound **S3** (56−92%).

*Tosylation of the Amino-alkyne Substrates **S3** Leading to the Synthesis of Masked Aldehyde **S4**.* To a well-stirred solution of the aforesaid amine **S3** (0.8 mmol) in dry dichloromethane (5 mL) were added pyridine (78 μL, 0.96 mmol, 1.2 equiv) and *p*-toluenesulfonyl chloride (156.5 mg, 0.824 mmol, 1.03 equiv) successively at 0 °C, and the whole reaction mixture was allowed to stir at room temperature for 1.5−3 h (or overnight in a few cases). After completion of the reaction, it was extracted with dichloromethane (2 × 25 mL), washed with brine (10 mL), dried over anhydrous Na_2SO_4, and concentrated under reduced pressure. The resulting residue was purified through silica gel (100−200 mesh) column chromatography using eluent 5−15% ethyl acetate in petroleum ether to afford the desired *N*-tosylated compound **S4** (60−86%).

*Preparation of the Substrates **10** through Deprotection of the Masked Aldehydes **S4**.* To a well-stirred solution of the compound **S4** (0.5 mmol) in dry acetone was added *p*-TsOH (137 mg, 0.8 mmol, 1.6 equiv) at 0 °C, and the whole reaction mixture was then allowed to warm to room temperature with continuous stirring until the completion of the reaction (TLC). The reaction mixture was then neutralized by adding saturated sodium bicarbonate solution dropwise and extracted with diethyl ether (3 × 20 mL). The 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 (eluted with 5−20% ethyl acetate in petroleum ether) to give our desired starting material **10** (47−76%).

*4-Methyl-N-(2-((2-(2-oxoethyl)phenyl)ethynyl)phenyl)benzenesulfonamide (**10a**).* Yellow gum (147.9 mg, 76% yield); R_f = 0.56 (50% ethyl acetate in petroleum ether); IR (KBr) 3258, 3028, 2923, 2838, 2729, 2210, 1720, 1598, 1490, 1448, 1405, 1337, 1283, 1162 cm^{-1}, ^1H NMR ($CDCl_3$, 300 MHz) δ_H 9.71 (t, J = 2.2 Hz, 1H), 7.73 (d, J = 8.1 Hz, 2H), 7.64 (s, 1H), 7.59−7.52 (m, 2H), 7.44−7.30 (m, 5H), 7.20 (d, J = 8.1 Hz, 2H), 7.09−7.04 (m, 1H), 3.90 (d, J = 2.4 Hz, 2H), 2.35 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 198.4, 143.9, 137.7, 136.5, 133.5, 132.6, 132.3, 130.5, 129.9, 129.6, 129.5, 127.8, 127.2, 124.4, 123.0, 120.1, 114.1, 93.6, 88.9, 49.7, 21.5; HRMS (ESI+) m/z calculated for $C_{23}H_{19}NNaO_3S$ $[M + Na]^+$ 412.0983, found 412.0971.

*4-Methyl-N-(4-methyl-2-((2-(2-oxoethyl)phenyl)ethynyl)phenyl)-benzenesulfonamide (**10b**).* Yellow gum (125.0 mg, 62% yield); R_f = 0.56 (50% ethyl acetate in petroleum ether); IR (KBr) 3253, 3028, 2923, 2858, 2733, 2205, 1720, 1598, 1495, 1399, 1336, 1278, 1160 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 9.70 (t, J = 2.1 Hz, 1H), 7.69 (d, J = 8.4 Hz, 2H), 7.52−7.46 (m, 3H), 7.40−7.29 (m, 3H), 7.18−7.16 (m, 3H), 7.11 (d, J = 8.4 Hz, 1H), 3.87 (d, J = 1.8 Hz, 2H), 2.34 (s, 3H), 2.27 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz)δ_C 198.6, 143.8, 136.5, 135.1, 134.4, 133.5, 132.5, 130.7, 130.5, 129.5, 129.4, 127.8, 127.2, 123.0, 120.9, 114.5, 93.0, 89.2, 49.7, 21.5, 20.6; HRMS (ESI+)

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m/z calculated for $C_{24}H_{21}NNaO_3S$ $[M + Na]^+$ 426.1140, found 426.1135.

*N-(4-Methoxy-2-((2-(2-oxoethyl)phenyl)ethynyl)phenyl)-4-methylbenzenesulfonamide (**10c**).* Yellow gum (151.0 mg, 72% yield); R_f = 0.56 (50% ethyl acetate in petroleum ether); IR (KBr) 3261, 3020, 2928, 2845, 2731, 2207, 1720, 1602, 1495, 1399, 1334, 1281, 1159 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 9.67 (s, 1H), 7.61 (d, J = 8.1 Hz, 2H), 7.53−7.46 (m, 2H), 7.41−7.28 (m, 5H), 7.13 (d, J = 8.1 Hz, 2H), 6.87 (s, 1H), 3.84 (d, J = 2.4 Hz, 2H), 3.78 (s, 3H), 2.33 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 198.7, 156.8, 143.6, 136.4, 133.5, 132.5, 130.5, 129.5, 129.4, 127.7, 127.1, 124.4, 122.9, 117.1, 116.4, 116.2, 92.7, 89.1, 55.5, 49.6, 21.4; HRMS (EI+) m/z calculated for $C_{24}H_{21}NO_4S$ $[M]^+$ 419.1191, found 419.1188.

*N-(4-Bromo-2-((2-(2-oxoethyl)phenyl)ethynyl)phenyl)-4-methylbenzenesulfonamide (**10d**).* Yellow gum (142.8 mg, 61% yield); R_f = 0.60 (50% ethyl acetate in petroleum ether); IR (KBr) 3246, 2922, 2850, 2732, 2210, 1718, 1594, 1482, 1389, 1336, 1280, 1159 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 9.69 (s, 1H), 7.74−7.72 (m, 3H), 7.53−7.49 (m, 2H), 7.46−7.32 (m, 5H), 7.22 (d, J = 8.1 Hz, 2H), 3.89 (s, 2H), 2.37 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 198.3, 144.2, 136.9, 136.3, 134.7, 133.4, 132.8, 130.7, 129.9, 129.7, 127.9, 127.2, 122.6, 121.6, 117.0, 116.0, 94.6, 87.6, 49.8, 21.5; MS (EI+) m/z 467 $[M]^+$.

*N-(4-Chloro-2-((2-(2-oxoethyl)phenyl)ethynyl)phenyl)-4-methylbenzenesulfonamide (**10e**).* Yellow gum (110.2 mg, 52% yield); R_f = 0.50 (50% ethyl acetate in petroleum ether); IR (KBr) 3234, 2923, 2855, 2738, 2210, 1718, 1594, 1482, 1392, 1330, 1158 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 9.69 (t, J = 2.2 Hz, 1H), 7.73−7.70 (m, 3H), 7.55−7.51 (m, 2H), 7.46−7.33 (m, 4H), 7.27−7.20 (m, 3H), 3.89 (d, J = 2.1 Hz, 2H), 2.36 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 198.4, 144.2, 136.4, 136.3, 133.4, 132.8, 131.8, 130.7, 129.9, 129.8, 129.7, 127.9, 127.2, 122.6, 121.6, 115.9, 94.5, 87.8, 49.8, 21.6; HRMS (EI+) m/z calculated for $C_{23}H_{18}ClNO_3S$ $[M]^+$ 423.0696, found 423.0693.

*N-(4-Fluoro-2-((2-(2-oxoethyl)phenyl)ethynyl)phenyl)-4-methylbenzenesulfonamide (**10f**).* Yellow gum (116.1 mg, 57% yield) [highly unstable]; R_f = 0.58 (50% ethyl acetate in petroleum ether); IR (KBr) 3251, 3069, 2923, 2852, 2741, 2207, 1718, 1598, 1489, 1397, 1334, 1272, 1156 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 9.68 (t, J = 2.3 Hz, 1H), 7.66 (d, J = 8.4 Hz, 2H), 7.59−7.48 (m, 3H), 7.43−7.32 (m, 3H), 7.18 (d, J = 8.1 Hz, 2H), 7.09−7.02 (m, 2H), 3.87 (d, J = 2.1 Hz, 2H), 2.35 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz): δ_C 198.4, 159.2 (d, J = 244.5 Hz), 143.9, 136.2, 133.8 (d, J = 2.6 Hz), 133.4, 132.6, 130.6, 129.8, 129.6, 127.8, 127.1, 123.5 (d, J = 8.9 Hz), 122.5, 118.5 (d, J = 24.5 Hz), 117.0 (d, J = 22.4 Hz), 93.9, 87.9, 49.7, 21.4.

*Methyl 3-(4-Methylphenylsulfonamido)-4-((2-(2-oxoethyl)-phenyl)ethynyl)benzoate (**10g**).* Pale yellow gum (156.6 mg, 70% yield); R_f = 0.35 (50% ethyl acetate in petroleum ether); IR (KBr) 3206, 2939, 2833, 2729, 1712, 1603, 1565, 1409, 1255, 1160 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 9.70 (t, J = 2.4 Hz, 1H), 8.22 (d, J = 1.2 Hz, 1H), 7.84 (s, 1H), 7.78 (d, J = 8.4 Hz, 2H), 7.73 (dd, J = 8.0 Hz, 1.4 Hz, 1H), 7.57−7.54 (m, 1H), 7.46−7.42 (m, 2H), 7.40−7.34 (m, 2H), 7.22 (d, J = 8.1 Hz, 2H), 3.93−3.92 (m, 5H), 2.36 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 198.4, 165.9, 144.2, 137.9, 136.3, 133.5, 132.9, 132.3, 131.1, 130.8, 130.0, 129.7, 127.9, 127.3, 125.1, 122.6, 120.7, 118.3, 96.0, 88.4, 52.5, 49.9, 21.6; HRMS (EI+) m/z calculated for $C_{25}H_{21}NO_5S$ $[M]^+$ 447.1140, found 447.1134.

*N-(2-((4,5-Dimethyl-2-(2-oxoethyl)phenyl)ethynyl)phenyl)-4-methylbenzenesulfonamide (**10h**).* Pale yellow solid (125.2 mg, 60% yield); mp 120−122 °C; R_f = 0.52 (50% ethyl acetate in petroleum ether); IR (KBr) 3189, 2964, 2921, 2859, 2744, 2204, 1706, 1600, 1490, 1411, 1327, 1285, 1154 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 9.67 (s, 1H), 7.73 (d, J = 8.1 Hz, 2H), 7.64 (s, 1H), 7.58 (d, J = 8.1 Hz, 1H), 7.36 (d, J = 7.5 Hz, 1H), 7.30−7.26 (m, 2H), 7.19 (d, J = 8.1 Hz, 2H), 7.08−7.03 (m, 2H), 3.81 (d, J = 1.8 Hz, 2H), 2.36 (s, 3H), 2.31 (s, 3H), 2.29 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 198.8, 143.9, 138.8, 137.6, 136.5, 136.4, 133.5, 132.2, 131.9, 130.7, 129.6, 127.3, 124.3, 120.1, 119.9, 114.4, 94.1, 87.9, 49.3, 21.5, 19.8, 19.3; HRMS (ESI+) m/z calculated for $C_{25}H_{23}NNaO_3S$ $[M + Na]^+$ 440.1296, found 440.1306.

*N-(2-((4,5-Dimethyl-2-(2-oxoethyl)phenyl)ethynyl)-4-methylphenyl)-4-methylbenzenesulfonamide (**10i**).* Pale yellow solid (105.7 mg, 49% yield); mp 120−122 °C; R_f = 0.69 (50% ethyl acetate in petroleum ether); IR (KBr) 3262, 3031, 2974, 2926, 2824, 2730, 2204, 1720, 1597, 1494, 1452, 1396, 1337, 1278, 1162 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 9.66 (t, J = 2.2 Hz, 1H), 7.68 (d, J = 8.1 Hz, 2H), 7.49−7.46 (m, 2H), 7.27 (s, 1H), 7.18−7.15 (m, 3H), 7.10−7.06 (m, 2H), 3.78 (d, J = 2.1 Hz, 2H), 2.34 (s, 3H), 2.30 (s, 3H), 2.28 (s, 3H), 2.26 (s, 3H); ^{13}CNMR ($CDCl_3$, 75 MHz) δ_C 198.9, 143.7, 138.7, 136.5, 136.3, 135.0, 134.4, 133.5, 132.5, 131.8, 130.7, 130.5, 129.5, 127.2, 120.8, 120.2, 114.7, 93.5, 88.1, 49.2, 21.5, 20.6, 19.8, 19.3; HRMS (ESI+) m/z calculated for $C_{26}H_{25}NNaO_3S$ $[M + Na]^+$ 454.1453, found 454.1450.

*N-(4-Bromo-2-((4,5-dimethyl-2-(2-oxoethyl)phenyl)ethynyl)-phenyl)-4-methylbenzenesulfonamide(**10j**).* Pale yellow solid (163.8 mg, 66% yield); mp 116−118 °C; R_f = 0.58 (50% ethyl acetate in petroleum ether); IR (KBr) 3163, 2981, 2829, 2731, 2201, 1710, 1592, 1486, 1391, 1327, 1289, 1155 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 9.66 (t, J = 2.3 Hz, 1H), 7.74−7.72 (m, 3H), 7.49−7.46 (m, 2H), 7.37 (dd, J = 9.0, 2.1 Hz, 1H), 7.29 (s, 1H), 7.22 (d, J = 8.1 Hz, 2H), 7.10 (s, 1H), 3.81 (d, J = 2.1 Hz, 2H), 2.37 (s, 3H), 2.32 (s, 3H), 2.29 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 198.6, 144.1, 139.2, 136.8, 136.5, 136.3, 134.5, 133.6, 132.5, 131.9, 130.6, 129.7, 127.2, 121.5, 119.7, 116.9, 116.3, 95.1, 86.6, 49.4, 21.5, 19.8, 19.3; HRMS (EI+) m/z calculated for $C_{25}H_{22}BrNO_3S$ $[M]^+$ 495.0504, found 495.0508.

*N-(2-((4-Fluoro-2-(2-oxoethyl)phenyl)ethynyl)phenyl)-4-methylbenzenesulfonamide (**10k**).* Pale yellow gum (97.8 mg, 48% yield); R_f = 0.46 (50% ethyl acetate in petroleum ether); IR (KBr) 3256, 3065, 2924, 2827, 2728, 2210, 1721, 1603, 1495, 1404, 1336, 1281, 1161 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 9.71 (t, J = 1.9 Hz, 1H), 7.73 (d, J = 8.4 Hz, 2H), 7.57−7.49 (m, 3H), 7.37 (dd, J = 7.8, 0.9 Hz, 1H), 7.32−7.30 (m, 1H), 7.21 (d, J = 8.1 Hz, 2H), 7.10−7.04 (m, 3H), 3.89 (d, J = 1.8 Hz, 2H), 2.36 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 197.5, 162.8 (d, J = 250.9 Hz), 144.0, 137.7, 136.5, 136.2 (d, J = 8.2 Hz), 134.4 (d, J = 8.6 Hz), 132.3, 130.0, 129.6, 127.2, 124.4, 120.0, 119.1, 117.8 (d, J = 22.5 Hz), 115.2 (d, J = 21.8 Hz), 113.9, 92.7, 88.6, 49.5, 21.5; HRMS (EI+) m/z calculated for $C_{23}H_{18}FNO_3S$ $[M]^+$ 407.0991, found 407.0990.

*4-Methyl-N-(2-((2-(1-oxopropan-2-yl)phenyl)ethynyl)phenyl)-benzenesulfonamide (**10l**).* Pale yellow gum (127.1 mg, 63% yield); R_f = 0.68 (50% ethyl acetate in petroleum ether); IR (KBr) 3262, 3064, 2929, 2876, 2725, 2210, 1721, 1600, 1490, 1451, 1403, 1338, 1282, 1162 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 9.63 (d, J = 1.5 Hz, 1H), 7.72 (d, J = 8.1 Hz, 2H), 7.63−7.53 (m, 3H), 7.46−7.30 (m, 5H), 7.19 (d, J = 8.1 Hz, 2H), 7.07 (t,J = 7.5 Hz, 1H), 4.11−4.06 (m, 1H), 2.35 (s, 3H), 1.52 (d, J = 7.2 Hz, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 200.6, 143.9, 139.0, 137.8, 136.5, 133.0, 132.3, 129.9, 129.7, 129.6, 127.9, 127.6, 127.2, 124.3, 122.6, 119.9, 114.0, 93.5, 89.0, 51.3, 21.5, 13.8; HRMS (EI+) m/z calculated for $C_{24}H_{21}NO_3S$ $[M]^+$ 403.1242, found 403.1245.

*4-Methyl-N-(4-methyl-2-((2-(1-oxopropan-2-yl)phenyl)ethynyl)-phenyl)benzenesulfonamide (**10m**).* Yellow gum (98.1 mg, 47% yield); R_f = 0.67 (50% ethyl acetate in petroleum ether); IR (KBr) 3303, 3180, 2922, 2851, 2739, 1711, 1598, 1497, 1415, 1325, 1285, 1154 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 9.63(d, J = 1.2 Hz, 1H), 7.68 (d, J = 8.1 Hz, 2H), 7.53−7.48 (m, 3H), 7.43−7.40 (m, 1H), 7.37−7.32 (m, 1H), 7.26−7.24 (m, 1H), 7.19−7.10 (m, 4H), 4.07−4.05 (m, 1H), 2.34 (m, 3H), 2.28 (s, 3H), 1.51 (d, J = 7.2 Hz, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 200.7, 143.8, 139.1, 136.5, 134.4, 133.0, 132.5, 130.8, 129.6, 129.5, 128.0, 127.6, 127.2, 122.7, 120.8, 115.3, 114.4, 93.0, 89.3, 51.3, 21.5, 20.6, 13.8; HRMS (ESI+) m/z calculated for $C_{25}H_{23}NNaO_3S$ $[M + Na]^+$ 440.1296, found 440.1295.

*N-(4-Bromo-2-((2-(1-oxopropan-2-yl)phenyl)ethynyl)phenyl)-4-methylbenzenesulfonamide (**10n**).* Pale yellow solid (180.9 mg, 75% yield); mp 96−98 °C; R_f = 0.73 (50% ethyl acetate in petroleum ether); IR (KBr) 3266, 3071, 2923, 2855, 2712, 2209, 1723, 1591, 1482, 1376, 1333, 1167 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 9.59 (s, 1H), 7.74−7.71 (m, 3H), 7.54−7.50 (m, 2H), 7.47 (m, 1H), 7.43−7.34 (m, 3H), 7.30−7.26 (m, 1H), 7.22 (d, J = 8.1 Hz, 2H), 4.07−4.04 (m, 1H), 2.37 (s, 3H), 1.54 (d, J = 6.9 Hz, 3H); ^{13}C NMR ($CDCl_3$, 75

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MHz) δ_C 200.5, 144.2, 138.9, 137.0, 136.3, 134.7, 133.2, 132.8, 130.1, 129.8, 128.1, 127.8, 127.2, 122.2, 121.5, 116.9, 115.9, 94.6, 87.8, 51.3, 21.6, 13.7; HRMS (EI+) m/z calculated for $C_{24}H_{20}BrNO_3S$ $[M]^+$ 483.0327, found 483.0330.

General Procedure for the Synthesis of 6-Amino-benzo[*a*]-carbazoles 5. A mixture of $Pd(OAc)_2$ (2.2 mg, 0.01 mmol, 5 mol %), 2,2′-bipyridine (1.9 mg, 0.012 mmol, 6 mol %), and D-CSA (69.6 mg, 0.3 mmol, 1.5 equiv) in dry NMA (3 mL) was stirred at 90 °C for 5 min under an argon atmosphere. Then, the starting material **9** (0.20 mmol), dissolved in NMA (1.5 mL) was added to the reaction mixture at the same temperature, and the whole mixture was allowed to stir at heating conditions (95−125 °C) for a few hours (see Scheme 2 in text) until the completion of the reaction (TLC). Thereafter, the acidity of the reaction 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) column chromatography using eluent 10−40% ethyl acetate−petroleum ether to afford desired product **5**.

*6-Amino-11-tosyl-11H-benzo[a]carbazole (**5a**).* Brown solid (65.7 mg, 85% yield); mp 164−166 °C; R_f = 0.45 (40% ethyl acetate in petroleum ether); IR (KBr) 3418, 3350, 3046, 2920, 1626, 1594, 1446, 1362, 1302, 1173 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.84 (d, J = 7.5 Hz, 1H), 8.38 (d, J = 8.1 Hz, 1H), 7.78−7.70 (m, 2H), 7.50−7.44 (m, 3H), 7.38−7.33 (m, 1H), 7.06 (s, 1H), 6.84 (d, J = 8.1 Hz, 2H), 6.76 (d, J = 7.8 Hz, 2H), 4.13 (s, 2H), 2.16 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 144.2, 141.4, 139.4, 138.1, 134.8, 131.4, 129.4, 128.4, 127.2, 126.9, 126.4, 125.8, 125.6, 122.6, 121.1, 120.6, 119.9, 119.4, 109.8, 21.4; HRMS (EI+) m/z calculated for $C_{23}H_{18}N_2O_2S$ $[M]^+$ 386.1089, found 386.1082.

*6-Amino-8-methyl-11-tosyl-11H-benzo[a]carbazole (**5b**).* White solid (61.6 mg, 77% yield); mp 190−192 °C; R_f = 0.41 (40% ethyl acetate in petroleum ether); IR (KBr) 3449, 3371, 2923, 2855, 1628, 1593, 1445, 1357, 1299, 1169 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.84 (d, J = 8.7 Hz, 1H), 8.25 (d, J = 8.4, 1H), 7.70 (d, J = 7.5 Hz, 1H), 7.56 (s, 1H), 7.49−7.41 (m, 2H), 7.27−7.25 (m, 1H), 7.04 (s, 1H), 6.84 (d, J = 8.1 Hz, 2H), 6.77 (d, J = 8.4 Hz, 2H), 4.13 (s, 2H), 2.46 (s, 3H), 2.17 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 144.1, 139.5, 139.4, 138.3, 135.4, 134.7, 131.5, 129.5, 128.5, 127.2, 127.0, 126.3, 125.8, 122.6, 121.2, 120.9, 119.6, 119.5, 109.8, 21.6, 21.5; HRMS (EI+) m/z calculated for $C_{24}H_{20}N_2O_2S$ $[M]^+$ 400.1245, found 400.1230.

*6-Amino-8-methoxy-11-tosyl-11H-benzo[a]carbazole (**5c**).* Brown gum (59.9 mg, 72% yield); R_f = 0.40 (40% ethyl acetate in petroleum ether); IR (KBr) 3368, 2927, 1629, 1476, 1442, 1362, 1299, 1220, 1172 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.83 (d, J = 8.4 Hz, 1H), 8.27 (d, J = 9.0 Hz, 1H), 7.69 (d, J = 8.4 Hz, 1H), 7.47−7.43 (m, 2H), 7.25 (d, J = 2.4 Hz, 1H), 7.02−7.00 (m, 2H), 6.81 (d, J = 8.4 Hz, 2H), 6.77 (d, J = 8.4 Hz, 2H), 4.06 (s, 2H), 3.88 (s, 3H), 2.17 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 159.4, 145.6, 140.9, 140.6, 137.0, 136.4, 132.8, 132.2, 130.0, 128.8, 128.6, 128.0, 127.4, 124.3, 122.9, 122.3, 121.3, 113.8, 111.5, 107.0, 57.3, 23.0. HRMS (EI+) m/z calculated for $C_{24}H_{20}N_2O_3S$ $[M]^+$ 416.1195, found 416.1180.

*6-Amino-8-bromo-11-tosyl-11H-benzo[a]carbazole (**5d**).* Brown gum (65.1 mg, 70% yield); R_f = 0.34 (40% ethyl acetate in petroleum ether); IR (KBr) 3431, 3362, 2922, 2853, 1626, 1595, 1442, 1363, 1296, 1173 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.83 (d, J = 8.4 Hz, 1H), 8.25 (d, J = 9.0 Hz, 1H), 7.94 (s, 1H), 7.71 (d, J = 7.8 Hz, 1H), 7.55 (dd, J = 9.0, 1.5 Hz, 1H), 7.50−7.44 (m, 2H), 7.06 (s, 1H), 6.85 (d, J = 8.4 Hz, 2H), 6.81 (d, J = 7.8 Hz, 2H), 4.06 (s, 2H), 2.19 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 140.2, 139.1, 138.7, 135.1, 131.4, 131.1, 128.7, 128.6, 127.2, 126.9, 126.8, 125.9, 123.5, 122.9, 121.2, 121.0, 119.1, 118.5, 110.3, 21.5; HRMS (ESI+): m/z calculated for $C_{23}H_{17}BrN_2NaO_2S$ $[M + Na]^+$ 487.0092, found 487.0090.

*6-Amino-8-fluoro-11-tosyl-11H-benzo[a]carbazole (**5e**).* Brown gum (48.5 mg, 60% yield); R_f = 0.28 (40% ethyl acetate in petroleum ether); IR (KBr) 3439, 3363, 2920, 2851, 1629, 1602, 1468, 1443, 1364, 1169 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.83 (d, J = 8.4 Hz, 1H), 8.33 (dd, J = 9.0, 4.8 Hz, 1H), 7.71 (d, J = 7.8 Hz, 1H), 7.49−7.48 (m, 1H), 7.47−7.44 (m, 2H), 7.16 (td, J = 9.0 Hz, 2.4 Hz, 1H), 7.06 (s, 1H), 6.82 (d, J = 8.4 Hz, 2H), 6.79 (d, J = 8.4 Hz, 2H), 4.04 (s, 2H), 2.18 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 160.7 (d, J = 241.6 Hz), 144.4, 139.3, 139.1, 137.5, 135.1, 131.2, 130.7 (d, J = 9.6 Hz), 128.5, 127.2, 127.0, 126.8, 125.9, 122.9, 121.2, 121.1 (d, J = 9.0 Hz), 119.2, 113.1 (d, J = 24.5 Hz), 110.2, 107.2 (d, J = 25.2 Hz), 21.4; HRMS (EI+) m/z calculated for $C_{23}H_{17}FN_2O_2S$ $[M]^+$ 404.0995, found 404.0983.

*6-Amino-8-(trifluoromethyl)-11-tosyl-11H-benzo[a]carbazole (**5f**).* Reddish brown solid (62.7 mg, 69% yield); mp 140−142 °C; IR (KBr) 3435, 3385, 1626, 1446, 1370, 1327, 1277, 1175 cm^{-1}; R_f = 0.35 (30% ethyl acetate in petroleum ether); ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.85 (d, J = 8.1 Hz, 1H), 8.49 (d, J = 8.7, 1H), 8.07 (s, 1H), 7.74−7.69 (m, 2H), 7.52−7.43 (m, 2H), 7.10 (s, 1H), 6.88 (d, J = 8.4 Hz, 2H), 6.81 (d, J = 8.4 Hz, 2H), 4.13 (s, 2H), 2.18 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 144.7, 143.4, 139.1, 138.8, 135.2, 131.6, 130.0, 128.8, 127.6(q, J = 32.0 Hz), 127.2, 126.9, 126.8, 124.2 (q, J = 270.6 Hz), 126.0, 123.1, 122.6 (m), 120.9, 119.9, 118.5, 117.8−117.7 (m), 110.5, 21.5; HRMS (EI+) m/z calculated for $C_{24}H_{17}F_3N_2O_2S$ $[M]^+$ 454.0963, found 454.0951.

*6-Amino-2,3-dimethoxy-11-tosyl-11H-benzo[a]carbazole (**5g**).* Brown solid (62.5 mg, 70% yield); mp 208−210 °C; R_f = 0.24 (40% ethyl acetate in petroleum ether); IR (KBr) 3438, 3360, 2956, 2833, 1624, 1493, 1443, 1365, 1249, 1216, 1158 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.39 (d, J = 8.1 Hz, 1H), 8.31 (s, 1H), 7.75 (d, J = 7.2 Hz, 1H), 7.47−7.34 (m, 2H), 7.03 (s,1H), 6.96 (s, 1H), 6.87 (d, J = 8.1 Hz, 2H), 6.79 (d, J = 8.4 Hz, 2H), 4.15 (s, 3H), 4.05 (brs, 5H), 2.18 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 149.9, 147.0, 144.1, 141.4, 138.1, 137.4, 131.4, 130.9, 129.9, 128.4, 126.9, 125.6, 125.4, 120.3, 120.0, 118.0, 116.4, 109.4, 106.9, 104.8, 56.0, 55.7, 21.4; HRMS (EI+) m/z calculated for $C_{25}H_{22}N_2O_4S$ $[M]^+$ 446.1300, found 446.1298.

*6-Amino-8-(trifluoromethyl)-2,3-dimethoxy-11-tosyl-11H-benzo-[a]carbazole (**5h**).* Brown solid (77.1 mg, 75% yield); mp 168−170 °C; R_f = 0.12 (50% ethyl acetate in petroleum ether); IR (KBr) 3382, 2941, 1627, 1495, 1374, 1333, 1285, 1215, 1168 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.47 (d, J = 8.4 Hz, 1H), 8.30 (s, 1H), 8.03 (s, 1H), 7.67 (d, J = 8.4 Hz, 1H), 7.02 (s,1H), 6.98 (s, 1H), 6.88 (d, J = 8.4 Hz, 2H), 6.81 (d, J = 8.4 Hz, 2H), 4.12 (s, 3H), 4.03 (s, 3H), 4.00 (s, 2H), 2.18 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 151.8, 148.8, 146.3, 144.9, 139.5, 139.4, 133.0, 132.9, 131.4, 130.3, 129.2 (q, J = 32.1 Hz), 128.4, 125.9 (q, J = 270.6 Hz), 123.7 (m), 121.5, 119.0 (m), 118.6, 117.7, 111.6, 108.2, 106.2, 57.6, 57.3, 23.0; HRMS (EI+) m/z calculated for $C_{26}H_{21}F_3N_2O_4S$ $[M]^+$ 514.1174, found 514.1171.

*Methyl 6-Amino-11-tosyl-11H-benzo[a]carbazole-2-carboxylate (**5i**).* Brown solid (55.1 mg, 62% yield); mp 170−172 °C; R_f = 0.31 (40% ethyl acetate in petroleum ether); IR (KBr) 3489, 3397, 2923, 1709, 1634, 1457, 1424, 1364, 1271, 1175 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.88 (d, J = 9.0 Hz, 1H), 8.46 (d, J = 1.2 Hz, 1H), 8.40 (d, J = 8.4 Hz, 1H), 7.99 (dd, J = 8.7, 1.5 Hz, 1H), 7.79 (d, J = 7.8 Hz, 1H), 7.50−7.47 (m, 1H), 7.39−7.37 (m, 1H), 7.13 (s, 1H), 6.83 (d, J = 7.8 Hz, 2H), 6.77 (d, J = 7.8 Hz, 2H), 4.22 (s, 2H), 4.00 (s, 3H), 2.16 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 169.0, 145.9, 143.3, 141.7, 139.3, 135.4, 133.0, 130.5, 130.4, 130.1, 129.1, 129.0, 128.5, 128.1, 127.3, 124.5, 123.5, 122.7, 122.4, 121.5, 112.2, 53.8, 22.9; HRMS (EI+) m/z calculated for $C_{25}H_{20}N_2O_4S$ $[M]^+$ 444.1144, found 444.1157.

*6-Amino-2-(trifluoromethyl)-11-tosyl-11H-benzo[a]carbazole (**5j**).* Brown solid (38.1 mg, 42% yield); mp 152−154 °C; R_f = 0.13 (50% ethyl acetate in petroleum ether); IR (KBr) 3450, 3376, 2924, 1630, 1453, 1372, 1308, 1258, 1170 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 9.16 (s, 1H), 8.41 (d, J = 8.4 Hz, 1H), 7.76 (d, J = 7.8 Hz, 2H), 7.60 (dd, J = 9.0, 1.2 Hz, 1H), 7.50−7.47 (m, 1H), 7.40−7.37 (m, 1H), 7.04 (s,1H), 6.86 (d, J = 8.4 Hz, 2H), 6.78 (d, J = 8.4 Hz, 2H), 4.30 (s, 2H), 2.16 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 144.5, 141.5. 138.5, 136.0, 131.5, 128.7, 128.6, 126.9, 126.6, 126.4, 125.8, 125.4−125.3 (m), 124.3, 124.1, 121.9−121.8 (m), 120.6, 119.8, 119.4, 108.9, 21.4 (Peaks due to C−CF_3 are not distinguished because

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of low intensity); HRMS (EI+) m/z calculated for $C_{24}H_{17}F_3N_2O_2S$ $[M]^+$ 454.0963, found 454.0971.

*6-Amino-11-(methylsulfonyl)-11H-benzo[a]carbazole (**5k**).* Brown solid (49.6 mg, 80% yield); mp 170−172 °C; R_f = 0.15 (50% ethyl acetate in petroleum ether); IR (KBr) 3461, 3381, 2919, 2850, 1629, 1456, 1349, 1167 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.67 (d, J = 7.2 Hz, 1H), 8.28 (s,1H), 8.07 (s, 1H), 7.71 (d, J = 6.6 Hz, 1H), 7.53−752 (m, 2H), 7.45−7.39 (m, 2H), 7.14 (s, 1H), 4.34 (s, 2H), 2.31 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 141.5, 139.7, 137.7, 135.0, 128.9, 126.9, 126.6, 126.5, 126.0, 122.8, 121.2, 120.6, 119.0, 118.8, 110.1, 35.1; HRMS (EI+) m/z calculated for $C_{17}H_{14}N_2O_2S$ $[M]^+$ 310.0776, found 310.0765.

*6-Amino-11-(4-nitrophenylsulfonyl)-11H-benzo[a]carbazole (**5l**).* Brown solid (68.4 mg, 82% yield); mp 214−216 °C; R_f = 0.45 (40% ethyl acetate in petroleum ether); IR (KBr) 3429, 3382, 2920, 1628, 1601, 1527, 1374, 1347, 1309, 1179 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.79−8.76 (m, 1H), 8.36 (d, J = 7.8 Hz, 1H), 7.80 (d, J = 8.7 Hz, 2H), 7.77−7.71 (m, 2H), 7.53−7.44 (m, 3H), 7.42−7.37 (m, 1H), 7.10−7.07 (m, 3H), 4.13 (s, 2H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 150.1, 140.7, 139.4, 139.0, 137.5, 134.9, 129.5, 128.2, 126.8, 126.5, 126.3, 126.0, 123.1, 122.8, 120.9, 120.8, 120.0, 119.5, 110.4; HRMS (ESI+) m/z calculated for $C_{22}H_{15}N_3NaO_4S$ $[M + Na]^+$ 440.0681, found 440.0683.

*6-Amino-5-methoxy-11-(4-nitrophenylsulfonyl)-11H-benzo[a]-carbazole (**5m**).* Brown solid (71.5 mg, 80% yield); mp 186−188 °C; R_f = 0.28 (40% ethyl acetate in petroleum ether); IR (KBr): 3406, 3100, 2929, 1614, 1527, 1442, 1371, 1173 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.81 (d, J = 8.7 Hz, 1H), 8.35 (d, J = 8.1 Hz, 1H), 8.05 (d, J = 8.1 Hz, 1H), 7.80 (d, J = 9 Hz, 2H), 7.75 (d, J = 7.8 Hz, 1H), 7.61−7.56 (m, 1H), 7.53−7.46 (m, 2H), 7.42−7.37 (m, 1H), 7.08 (d, J = 8.7 Hz, 2H), 4.29 (s, 2H), 3.95 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 150.2, 141.0, 139.4, 139.0, 133.3, 131.2, 129.9, 128.3, 128.2, 127.2, 126.8, 126.5, 126.4, 123.2, 122.8, 120.9, 120.8, 120.4, 120.1, 119.8, 60.6; HRMS (ESI+) m/z calculated for $C_{23}H_{17}N_3NaO_5S$ $[M + Na]^+$ 470.0787, found 470.0810.

*6-Amino-11-tosyl-11H-benzo[g]pyrido[2,3-b]indole (**5n**).* Brown solid (40.2 mg, 52% yield); mp 210−212 °C; R_f = 0.16 (40% ethyl acetate in petroleum ether); IR (KBr) 3442, 3366, 2920, 1630, 1590, 1525, 1401, 1355, 1245, 1172 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.71 (d, J = 8.4 Hz, 1H), 8.50 (dd, J = 4.8, 1.2 Hz, 1H), 8.12 (dd, J = 7.8, 1.2 Hz, 1H), 7.73 (d, J = 7.8 Hz, 1H), 7.50−7.42 (m, 4H), 7.25−7.24 (m,1H), 7.11 (s, 1H), 7.00 (d, J = 8.4 Hz, 2H), 4.16 (s, 2H), 2.26 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 154.0, 145.3, 144.5, 139.4, 137.1, 135.3, 134.3, 128.9, 128.6, 127.6, 127.5, 126.8, 126.1, 122.8, 121.2, 120.6, 120.1, 115.7, 109.6, 21.5; HRMS (EI+) m/z calculated for $C_{22}H_{17}N_3O_2S$ $[M]^+$ 387.1041, found 387.1038.

General Procedure for the Synthesis of Benzo[*a*]carbazoles 6. A mixture of $Pd(OAc)_2$ (2.2 mg, 0.01 mmol, 5 mol %) and 2,2′-bipyridine (1.9 mg, 0.012 mmol, 6 mol %) and D-CSA (69.6 mg, 0.3 mmol, 1.5 equiv) in dry 1,4-dioxane (3 mL) was stirred at 90 °C for 5 min under an argon atmosphere. Then, the starting material (0.20 mmol) dissolved in dry 1,4-dioxane was added to the reaction mixture at the same temperature and allowed to stir under refluxing conditions until the completion of the reaction (TLC). Upon completion, the reaction mixture was mixed with water (10 mL) and extracted with ethyl acetate (3 × 20 mL). The combined organic extracts were washed with brine (10 mL), dried over anhydrous Na_2SO4, filtered, and concentrated under reduced pressure. The resulting residue was purified through silica gel (100−200 mesh) column chromatography using eluent 1−10% ethyl acetate in petroleum ether to afford the desired product **6**.

*11-Tosyl-11H-benzo[a]carbazole (**6a**).*[23] White solid (59.4 mg, 80% yield); mp 148−150 °C; R_f = 0.44 (20% ethyl acetate in petroleum ether); IR (KBr): 2919, 1630, 1598, 1457, 1369, 1172 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 9.02 (d, J = 8.4 Hz, 1H), 8.35 (d, J = 7.8 Hz, 1H), 7.95 (d, J = 7.8 Hz, 1H), 7.84 (d, J = 8.4 Hz, 1H), 7.77 (d, J = 8.4 Hz, 1H), 7.71−7.67 (m, 2H), 7.58−7.56 (m, 1H), 7.47−7.44 (m, 1H), 7.36 (td, J = 7.4, 0.9 Hz, 1H), 6.85−6.83 (m, 2H), 6.75 (d, J = 8.4 Hz, 2H), 2.15 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 144.2, 141.8, 136.7, 133.9, 131.5, 130.1, 128.4, 128.2, 127.8, 127.6, 127.0, 126.9, 126.6, 126.2, 126.1, 125.9, 125.6, 119.8, 119.3, 117.4, 21.4; HRMS (EI+) m/z calculated for $C_{23}H_{17}NO_2S$ $[M]^+$ 371.0980, found 371.0975.

*8-Methyl-11-tosyl-11H-benzo[a]carbazole (**6b**).* White solid (40.1 mg, 52% yield); mp 166−168 °C; R_f = 0.48 (20% ethyl acetate in petroleum ether); IR (KBr): 2920, 1592, 1459, 1365, 1171 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 9.02 (d, J = 9.0 Hz, 1H), 8.21 (d, J = 8.4 Hz, 1H), 7.94 (d, J = 8.4 Hz, 1H), 7.82 (d, J = 8.4 Hz, 1H), 7.73 (d, J = 8.4 Hz, 1H), 7.68−7.66 (m, 1H), 7.56−7.54 (m, 1H), 7.50 (s, 1H), 7.25 (m, 1H), 6.84 (d, J = 8.4 Hz, 2H), 6.75 (d, J = 8.4 Hz, 2H), 2.46 (s, 3H), 2.15 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 144.0, 139.7, 136.9, 135.4, 133.8, 131.5, 130.1, 128.4, 128.2, 127.9, 127.8, 127.5, 127.0, 126.9, 126.3, 126.0, 125.7, 119.5, 119.4, 117.3, 21.4; HRMS (EI+) m/z calculated for $C_{24}H_{19}NO_2S$ $[M]^+$ 385.1136, found 385.1134.

*8-Methoxy-11-tosyl-11H-benzo[a]carbazole (**6c**).* White solid (43.3 mg, 54% yield); mp 148−150 °C; R_f = 0.28 (20% ethyl acetate in petroleum ether); IR (KBr): 2922, 1618, 1592, 1485, 1463, 1361, 1224, 1172 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 9.02 (d, J = 9.0 Hz, 1H), 8.23 (d, J = 9.0 Hz, 1H), 7.94 (d, J = 7.8 Hz, 1H), 7.82 (d, J = 8.4 Hz, 1H), 7.70 (d, J = 8.4 Hz, 1H), 7.69−7.66 (m, 1H), 7.58−7.56 (m, 1H), 7.14 (d, J = 2.4 Hz, 1H), 7.03 (dd, J = 9.0, 2.4 Hz, 1H), 6.81 (d, J = 8.4 Hz, 2H), 6.74 (d, J = 8.4 Hz, 2H), 3.88 (s, 3H), 2.15 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 158.0, 144.1, 137.5, 135.6, 133.9, 131.3, 128.4, 128.2, 128.0, 127.5, 127.0, 126.9, 126.3, 126.1, 125.9, 120.8, 117.3, 114.2, 102.8, 55.7, 21.4; HRMS (EI+) m/z calculated for $C_{24}H_{19}NO_3S$ $[M]^+$ 401.1086, found 401.1077.

*8-Bromo-11-tosyl-11H-benzo[a]carbazole (**6d**).* Pale yellow solid (61.2 mg, 68% yield); mp 140−142 °C; R_f = 0.62 (20% ethyl acetate in petroleum ether); IR (KBr): 2923, 1595, 1455, 1365, 1179 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 9.02 (d, J = 9.0 Hz, 1H), 8.22 (d, J = 9.0 Hz, 1H), 7.96 (d, J = 7.8 Hz, 1H), 7.86−7.84 (m, 2H), 7.71−7.68 (m, 2H), 7.61−7.58 (m, 1H), 7.55 (dd, J = 9.0, 1.8 Hz, 1H), 6.84 (d, J = 8.4 Hz, 2H), 6.79 (d, J = 8.4 Hz, 2H), 2.17 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 144.5, 140.5, 137.3, 134.2, 131.8, 131.4, 129.4, 128.7, 128.3, 127.9, 127.0, 126.8, 126.5, 126.4, 126.3, 126.0, 122.3, 121.2, 119.2, 117.2, 21.4; HRMS (EI+) m/z calculated for $C_{23}H_{16}BrNO_2S$ $[M]^+$ 449.0085, found 449.0082.

*8-Chloro-11-tosyl-11H-benzo[a]carbazole (**6e**).* White solid (50.3 mg, 62% yield); mp 152−154 °C; R_f = 0.52 (20% ethyl acetate in petroleum ether); IR (KBr) 2924, 1595, 1458, 1366, 1179 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 9.02 (d, J = 9.0 Hz, 1H), 8.28 (d, J = 8.4 Hz, 1H), 7.95 (d, J = 7.8 Hz, 1H), 7.84 (d, J = 8.4 Hz, 1H), 7.70−7.66 (m, 3H), 7.60−7.58 (m, 1H), 7.41 (dd, J = 8.7, 2.1 Hz, 1H), 6.84 (d, J = 8.4 Hz, 2H), 6.78 (d, J = 8.4 Hz, 2H), 2.17 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz): δ_C 144.5, 140.0, 137.4, 134.2, 131.42, 131.4, 131.3 128.7, 128.3, 127.8, 127.0, 126.8, 126.7, 126.6, 126.4, 126.3, 126.0, 120.8, 119.3, 117.2, 21.4; HRMS (ESI+) m/z calculated for $C_{23}H_{16}ClNNaO_2S$ $[M + Na]^+$ 428.0488, found 428.0482.

*8-Fluoro-11-tosyl-11H-benzo[a]carbazole (**6f**).* Pale yellow solid (40.5 mg, 52% yield); mp 170−172 °C; R_f = 0.40 (20% ethyl acetate in petroleum ether); IR (KBr): 2928, 1594, 1469, 1367, 1168 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 9.01 (d, J = 8.4 Hz, 1H), 8.30 (dd, J = 9.0, 4.2 Hz, 1H), 7.96 (d, J = 7.8 Hz, 1H), 7.84 (d, J = 7.8 Hz, 1H), 7.71−7.68 (m, 2H), 7.61−7.58 (m, 1H), 7.34 (dd, J = 8.1, 2.7 Hz, 1H), 7.17−7.14 (m, 1H), 6.81−6.80 (m, 2H), 6.76 (d, J = 8.4 Hz, 2H), 2.17 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 161.0 (d, J = 242.4 Hz), 144.4, 137.3, 137.8, 134.1, 131.6 (d, J = 9.6 Hz), 131.1, 128.5, 128.2, 127.8, 127.3, 127.1, 126.9, 126.3, 126.2, 121.2 (d, J = 9.3 Hz), 117.3, 114.0 (d, J = 24.2 Hz), 105.7 (d, J = 24.2 Hz), 21.4; HRMS (EI+) m/z calculated for $C_{23}H_{16}FNO_2S$ $[M]^+$ 389.0886, found 389.0882.

*Methyl 11-Tosyl-11H-benzo[a]carbazole-9-carboxylate (**6g**).* White solid (65.3 mg, 76% yield); mp 158−160 °C; R_f = 0.32 (20% ethyl acetate in petroleum ether); IR (KBr) 3046, 2953, 1714, 1596, 1438, 1372, 1287, 1241, 1170 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 9.04 (d, J = 8.4 Hz, 1H), 9.01 (s,1H), 8.07 (d, J = 8.4 Hz, 1H), 7.97 (d, J = 8.4 Hz, 1H), 7.87 (d, J = 8.4 Hz, 1H), 7.79 (d, J = 8.4 Hz, 1H), 7.75 (d, J = 7.8 Hz, 1H), 7.70 (t, J = 7.5 Hz, 1H), 7.61 (t, J = 7.5 Hz, 1H), 6.85 (d, J = 7.8 Hz, 2H), 6.76 (d, J = 7.8 Hz, 2H), 4.03 (s, 3H), 2.15 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 166.9, 144.5, 141.4,

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138.4, 134.4, 133.8, 131.4, 128.7, 128.3, 128.2, 127.9, 127.3, 127.0, 126.8, 126.7, 126.6, 126.4, 126.0, 121.1, 119.1, 117.5, 52.4, 21.4; HRMS (EI+) m/z calculated for $C_{25}H_{19}NO_4S$ $[M]^+$ 429.1035, found 429.1028.

*2,3-Dimethyl-11-tosyl-11H-benzo[a]carbazole (**6h**).* White solid (52.7 mg, 66% yield); mp 182−184 °C; R_f = 0.42 (20% ethyl acetate in petroleum ether); IR (KBr) 2912, 1594, 1452, 1362, 1175 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H 8.76 (s, 1H), 8.31 (d, J = 8.1 Hz, 1H), 7.73−7.63 (m, 4H), 7.43−7.38 (m, 1H), 7.34−7.29 (m, 1H), 6.84 (d, J = 8.1 Hz, 2H), 6.73 (d, J = 8.4 Hz, 2H), 2.56 (s, 3H), 2.48 (s, 3H), 2.13 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 144.1, 135.9, 135.7, 132.9, 131.4, 130.4, 128.4, 127.8, 127.2, 126.9, 126.7, 126.6, 126.3, 125.5, 119.8, 119.2, 116.5, 21.4, 20.6, 20.2; HRMS (EI+) m/z calculated for $C_{25}H_{21}NO_2S$ $[M]^+$ 399.1293, found 399.1300.

*2,3,8-Trimethyl-11-tosyl-11H-benzo[a]carbazole (**6i**).* White solid (55.4 mg, 67% yield); mp 196−198 °C; R_f = 0.42 (20% ethyl acetate in petroleum ether); IR (KBr) 2915, 1598, 1467, 1362, 1175 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.78 (s, 1H), 8.19 (d, J = 8.4 Hz, 1H), 7.70 (d, J = 8.4 Hz, 1H), 7.68 (s, 1H), 7.61 (d, J = 7.8 Hz, 1H), 7.44 (s, 1H), 7.22 (d, J = 8.4 Hz, 1H), 6.86 (d, J = 7.8 Hz, 2H), 6.74 (d, J = 8.4 Hz, 2H), 2.57 (s, 3H), 2.49 (s, 3H), 2.44 (s, 3H) 2.14 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 143.9, 139.5, 136.4, 135.8, 135.6, 135.2, 132.9, 131.6, 130.4, 128.4, 127.8, 127.5, 127.2, 126.9, 126.5, 125.1, 119.4, 119.3, 116.4, 21.4, 20.6, 20.1; HRMS (EI+) m/z calculated for $C_{26}H_{23}NO_2S$ $[M]^+$ 413.14495, found 413.14493.

*8-Bromo-2,3-dimethyl-11-tosyl-11H-benzo[a]carbazole (**6j**).* White solid (67.0 mg, 70% yield); mp 152−154 °C; R_f = 0.46 (20% ethyl acetate in petroleum ether); IR (KBr) 2921, 1593, 1448, 1366, 1170 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 8.76 (s, 1H), 8.20 (d, J = 8.4 Hz, 1H), 7.78 (d, J = 1.8 Hz, 1H), 7.72 (d, J = 8.4 Hz, 1H), 7.69 (s, 1H), 7.58 (d, J = 8.4 Hz, 1H), 7.51 (dd, J = 9, 1.8 Hz, 1H), 6.86 (d, J = 8.4 Hz, 2H), 6.78 (d, J = 8.4 Hz, 2H), 2.57 (s, 3H), 2.49 (s, 3H), 2.17 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 144.4, 140.3, 136.8, 136.2, 136.1, 133.2, 132.1, 131.4, 128.9, 128.6, 127.8, 126.9, 126.8, 126.6, 125.8, 124.7, 122.1, 121.1, 119.1, 116.2, 21.4, 20.6, 20.1; HRMS (EI+) m/z calculated for $C_{25}H_{20}BrNO_2S$ $[M]^+$ 477.0398, found 477.0404.

*3-Fluoro-11-tosyl-11H-benzo[a]carbazole (**6k**).* White solid (40.5 mg, 52% yield); mp 148−150 °C; R_f = 0.40 (20% ethyl acetate in petroleum ether); IR (KBr) 2924, 1625, 1565, 1452, 1369, 1257, 1174 cm^{-1}; ^1H NMR ($CDCl_3$, 300 MHz) δ_H9.04 (dd, J = 9.3, 5.7 Hz, 1H), 8.34 (d, J = 8.1 Hz, 1H), 7.82−7.75 (m, 2H), 7.70 (d, J = 7.8 Hz, 1H), 7.57 (dd, J = 9.8, 2.7 Hz, 1H), 7.49−7.42 (m, 2H), 7.39−7.34 (m, 1H), 6.83 (d, J = 8.4 Hz, 2H), 6.76 (d, J = 8.4 Hz, 2H), 2.16 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C 160.5 (d, J = 245.9 Hz), 144.3, 141.6, 136.8, 135.0 (d, J = 8.9 Hz), 131.3, 129.9, 129.7 (d, J = 9.0 Hz), 128.5, 127.3, 126.8, 126.7, 126.6, 125.7, 123.2, 119.8, 119.3, 118.6, 116.1 (d, J = 24.7 Hz), 111.4 (d, J = 20.7 Hz), 21.4; HRMS (EI+) m/z calculated for $C_{23}H_{16}FNO_2S$ $[M]^+$ 389.0886, found 389.0882.

*5-Methyl-11-tosyl-11H-benzo[a]carbazole (**6l**).* White solid (40.1 mg, 52% yield); mp 162−164 °C; R_f = 0.37 (20% ethyl acetate in petroleum ether); IR (KBr) 2920, 1598, 1450, 1358, 1172 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 9.04 (d, J = 8.4 Hz, 1H), 8.33 (d, J = 8.4 Hz, 1H), 8.09 (d, J = 8.4 Hz, 1H), 7.70−7.66 (m, 2H), 7.63−7.61 (m, 2H), 7.43 (t, J = 7.8 Hz, 1H), 7.33 (t, J = 7.2 Hz, 1H), 6.84 (d, J = 8.4 Hz, 2H), 6.74 (d, J = 7.8 Hz, 2H), 2.79 (s, 3H), 2.15 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 144.0, 141.9, 135.7, 133.7, 132.9, 131.4, 130.2, 128.4, 127.6, 127.4, 126.9, 126.5, 126.3, 125.8, 125.7, 125.5, 124.4, 119.9, 119.2, 118.0, 21.4, 20.2; HRMS (EI+) m/z calculated for $C_{24}H_{19}NO_2S$ $[M]^+$ 385.1136, found 385.1133.

*5,8-Dimethyl-11-tosyl-11H-benzo[a]carbazole (**6m**).* White solid (35.2 mg, 44% yield); mp 200−202 °C; R_f = 0.40 (20% ethyl acetate in petroleum ether); IR (KBr) 2918, 1596, 1445, 1363, 1173 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 9.03 (d, J = 9.0 Hz, 1H), 8.19 (d, J = 8.4 Hz, 1H), 8.08 (d, J = 8.4 Hz, 1H), 7.69−7.67 (m, 1H), 7.61 (d, J = 7.2 Hz, 1H), 7.59 (s, 1H), 7.46 (s,1H), 7.24 (d, J = 7.8 Hz, 1H), 6.84 (d, J = 8.4 Hz, 2H), 6.75 (d, J = 8.4 Hz, 2H), 2.77 (s, 3H), 2.45 (s, 3H), 2.15 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 143.9, 139.8, 135.8, 135.3, 133.5, 132.8, 131.5, 130.3, 128.4, 127.7, 127.5, 127.4, 127.0, 126.3, 125.6, 124.3, 119.5, 119.4, 118.0, 21.4, 20.2; HRMS (EI+) m/z calculated for $C_{25}H_{21}NO_2S$ $[M]^+$ 399.1293, found 399.1299.

*8-Bromo-5-methyl-11-tosyl-11H-benzo[a]carbazole (**6n**).* White solid (63.2 mg, 68% yield); mp 214−216 °C; R_f = 0.40 (20% ethyl acetate in petroleum ether); IR (KBr) 2919, 1595, 1451, 1368, 1175 cm^{-1}; ^1H NMR ($CDCl_3$, 600 MHz) δ_H 9.02 (d, J = 9.0 Hz, 1H), 8.19 (d, J = 8.4 Hz, 1H), 8.08 (d, J = 8.4 Hz, 1H), 7.77 (s, 1H), 7.71−7.68 (m, 1H), 7.65−7.62 (m, 1H), 7.53−7.51 (m, 2H), 6.84 (d, J = 8.4 Hz, 2H), 6.78 (d, J = 8.4 Hz, 2H), 2.76 (s, 3H), 2.16 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz) δ_C 144.4, 140.6, 136.2, 134.0, 133.2, 131.9, 131.3, 129.2, 128.7, 127.6, 126.9, 126.2, 126.1, 126.0, 125.9, 124.4, 122.2, 121.2, 119.1, 117.8, 21.4, 20.6; HRMS (EI+) m/z calculated for $C_{24}H_{18}BrNO_2S$ $[M]^+$ 463.0242, found 463.0242.

Procedure for the Synthesis of 6-Amino-1*H*-benzo[*a*]carbazole (11). *Synthesis of 6-Amino-1H-benzo[a]carbazole (**11**) via Deprotection of the N-Tosyl Group of **5a**.* To a well-stirred solution of **5a** (50 mg, 0.13 mmol) in dry THF was added tetrabutylammonium fluoride (1 M solution in THF, 5 equiv), and the whole mixture was allowed to stir for 4 h under refluxing conditions. The reaction mixture 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 eluent 15% ethyl acetate in petroleum ether to afford pure product **11** (18.1 mg, 60% yield).

*Synthesis of 6-Amino-1H-benzo[a]carbazole (**11**) via Deprotection of the N-Nosyl group of **5l**.* To a well-stirred solution of **5l** (50 mg, 0.12 mmol) in dry DMF were added K_2CO_3 (33 mg, 0.24 mmol, 2 equiv) and thiophenol (14.6 μL, 0.14 mmol, 1.2 equiv) successively under ice cold conditions, and the whole mixture was allowed to stir at room temperature for 2 h. Upon completion of the reaction (TLC), the solvent was removed *in vacuo*; the resulting residue was mixed with water (10 mL) and extracted with ethyl acetate (3 × 15 mL). The combined organic extracts were washed with brine (10 mL), dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The crude product was then purified through silica gel (100−200 mesh) column chromatography with eluent 15% ethyl acetate−petroleum ether) to afford the pure product **11** as a brown solid (22.0 mg, 79% yield): mp > 230 °C; R_f = 0.36 (50% ethyl acetate in petroleum ether); IR (KBr): 3375, 3309, 3180, 2918, 1621, 1563, 1531, 1448, 1382, 1332, 1297, 1186 cm^{-1}; ^1H NMR (DMSO-d_6, 600 MHz) δ_H 12.06 (s, 1H), 8.31 (d, J = 7.8 Hz, 1H), 8.28 (d, J = 8.4 Hz, 1H), 7.62 (d, J = 7.8 Hz, 1H), 7.59 (d, J = 7.8 Hz, 1H), 7.36−7.31 (m, 2H), 7.23−7.17(m, 2H), 6.68 (s, 1H), 5.66 (s, 2H); ^{13}C NMR (DMSO-d_6, 150 MHz) δ_C 145.0, 140.3, 138.5, 135.8, 127.4, 127.3, 125.4, 124.6, 123.6, 123.3, 122.4, 120.8, 117.3, 112.8, 110.8, 100.9; HRMS (EI+) m/z calculated for $C_{16}H_{12}N_2$ $[M]^+$ 232.1000, found 232.1003.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.joc.6b02022.

Schematic representation for the preparation of starting materials, copies of NMR (^1H and ^{13}C), HRMS of representative compounds, and tables of crystal data of compounds **5b**, **5g**, and **6f** (PDF)

X-ray crystallographic data (CIF) for compounds **5b**, **5g**, and **6f** (ZIP)

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Notes

The authors declare no competing financial interest.

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■ DEDICATION

This paper is dedicated to Dr. Pradeep K. Dutta, a former scientist of our Chemistry Division, on the occasion of the 70th anniversary of his birth.

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