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Base-Mediated Selective Synthesis of Diversely Substituted *N*-Heterocyclic Enamines and Enaminones by the Hydroamination of Alkynes

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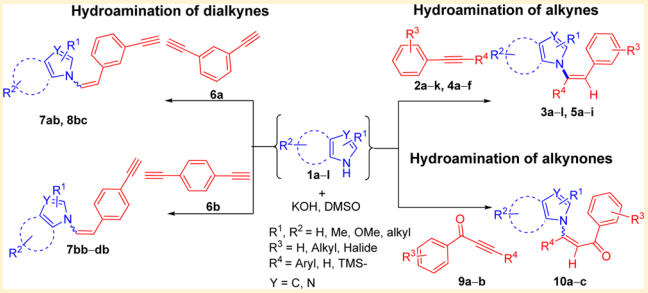
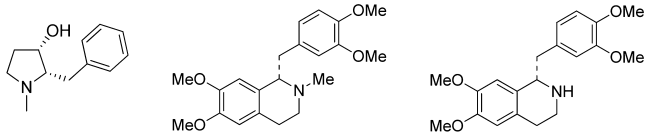
Supporting Information

ABSTRACT: Regio- and stereoselective alkynylation of various *N*-heterocycles **1a−l** using potassium and cesium salts in DMSO is described. Terminal alkynes **2a−k** and internal alkynes **4a−f** provided the kinetically stable *Z*-enamines **3a−l** and **5a−i** in good to excellent yields using KOH at 120 °C. Addition of heterocyclic amines to 1,3- and 1,4-diethynylbenzene **6a−b** provided the mixture of *E*/*Z* isomers with KOH; however, with Cs_2CO_3 selectively *Z*-isomers **7ab−db** were obtained by the hydroamination at one triple bond. This developed methodology also provides an easy and novel access for the synthesis of enaminones **10a−c**. The detailed work also supports the formation of *cis*-isomer by preferential addition of *o*-haloarylalkynes followed by intramolecular C2 arylation in the copper-catalyzed tandem synthesis of indolo and pyrrolo[2,1-*a*]isoquinolines.



INTRODUCTION

The addition of amines onto C−C multiple bonds is rising as a powerful technique for the synthesis of imines, enamines, or other nitrogen-containing molecules used in diverse biological activities.[1] Despite the development of a variety of effective strategies, the hydroamination of alkynes has been reported by both catalytic and noncatalytic methods to overcome the high activation energy required for this process.[2] The products formed not only can be used in a number of synthetically useful transformations but also can be reduced to stable secondary amines.[3] Several natural products are well-known to involve hydroamination of alkynes for their synthesis (Figure 1).[4]



I (+)-preussin **II** (+)-(*S*)-laudanosine **III** (−)-(*S*)-xylopinine

Figure 1. Natural products synthesized via hydroamination.

A significant progress has been made by Knochel[5a,b] and Ackermann[5c−g] for the synthesis of diversely substituted indoles using inter- or intramolecular hydroamination of alkynes (Scheme 1, eq 1). Recent developments in the metal-catalyzed hydroamination of alkynes to synthesize complex biologically important molecules like indolo- or pyrrolo[1,2-*a*]-isoquinolines[6] or isoindoles, isoquinolines, and imidazoles have also attracted much interest.[7]

In our recent report on copper-catalyzed tandem synthesis of indolo- and pyrrolo[2,1-*a*]isoquinolines, the reaction was proposed to undergo via formation of a hydroaminated intermediate **H** (Scheme 1, eq 2).[8] With these successful reports on the synthesis of biologically important molecules via hydroamination and strong demand for the development of general, flexible, and regioselective methodologies motivated us to explore the addition of heterocyclic amines onto alkynes. Among the number of intermolecular hydroamination reactions reported to date, significant progress has been made on addition reactions of primary amines[9] and secondary amines[10] to alkenes and alkynes.

In 1999, the first report on the addition of amines and alcohols onto alkynes was made by Knochel using $CsOH{\cdot}H_2O$ in NMP (Scheme 2, eq 1).[11] Later, in 2004, a phosphazene base *t*-Bu-P4 was used for the addition of pyrrole and other nucleophiles onto phenyl- and diphenylacetylene by Kondo and co-workers (Scheme 2, eq 2).[12] With this limited work on this area and as a part of our ongoing research on alkyne chemistry,[13] very recently, we communicated a direct and more economical synthetic method for the synthesis of an array of styryl and vinyl enamines.[14] Herein, we wish to report the full details of our study on the base-mediated regio- and

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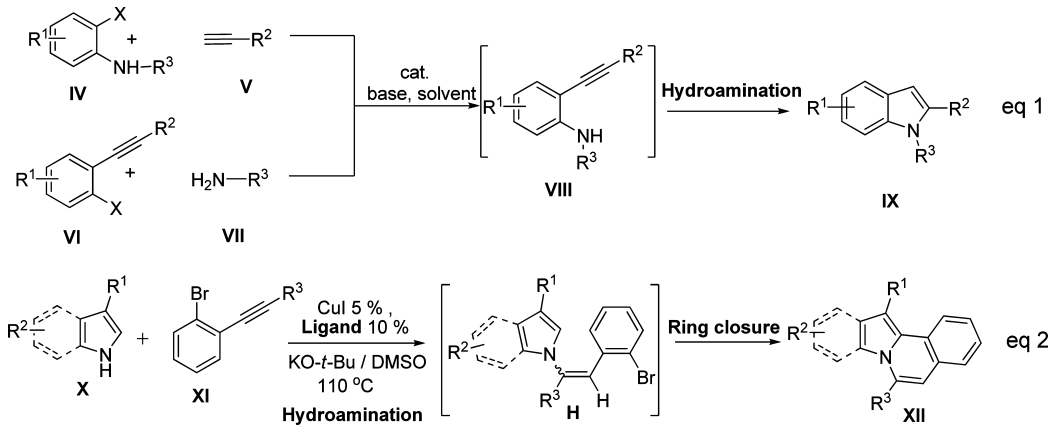
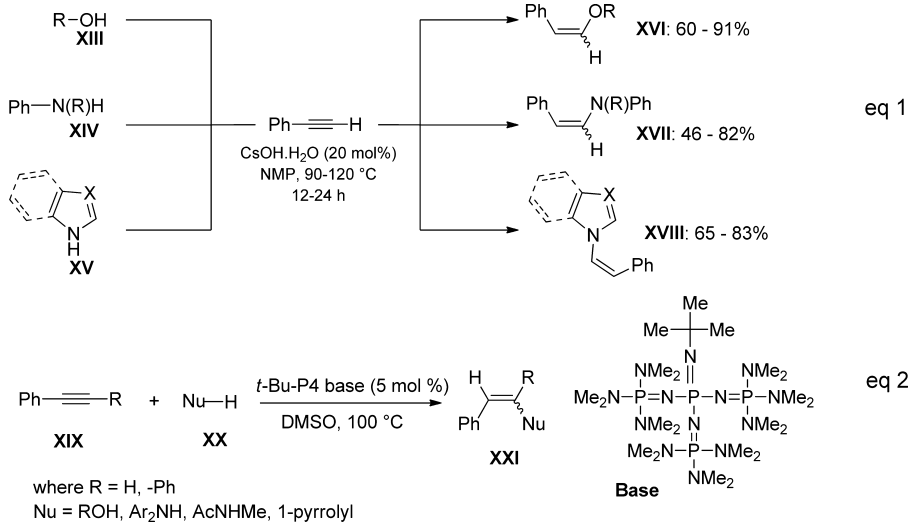
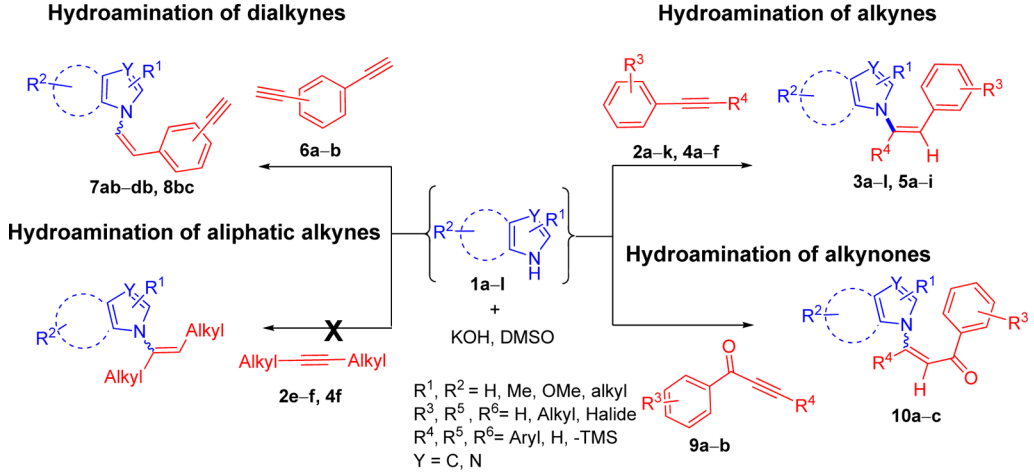
Scheme 1. Applications of Inter- or Intramolecular Hydroamination in the Synthesis of Heterocycles



Scheme 2



Scheme 3. Stereoselective Addition of *N*-Heterocycles onto Alkynes and Alkynones



stereoselective hydroamination of terminal and internal alkynes for the confirmation of the mechanistic pathway of tandem synthesis of [2,1-*a*]isoquinolines (Scheme 3).[8] Present methodology also provides for the first time an effective route for the addition of *N*-heterocycles onto 1,3- and 1,4-diethynylbenzenes and substituted alkynones to yield the corresponding addition products in good yields.

RESULTS AND DISCUSSION

Hydroamination of Terminal Alkynes. Our preliminary investigation revealed that the optimal reaction condition for the synthesis of diversely substituted *Z*-styryl enamines was 20 mol % of KOH in DMSO at 120 °C.[14a] Addition of *N*-heterocycles **1a–l** on terminal alkynes **2a–k** provided the

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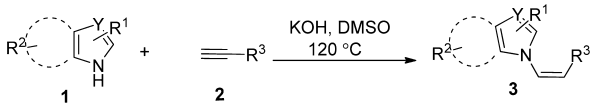
Table 1. Synthesis of *Z*-Styrylenamines[a]



1 2 3

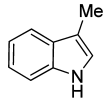
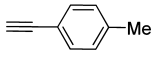
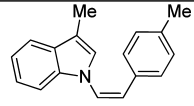
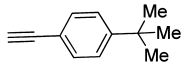
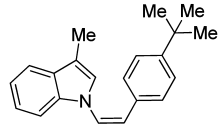
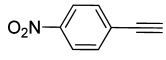
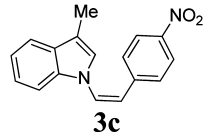
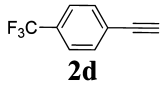
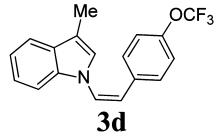
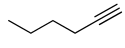
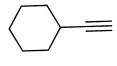
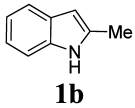
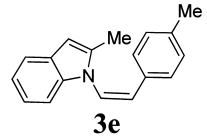
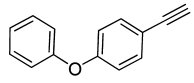
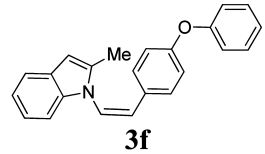
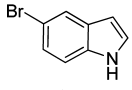
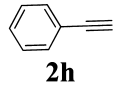
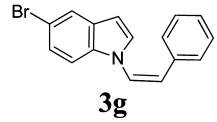
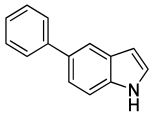
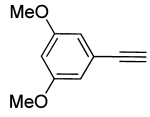
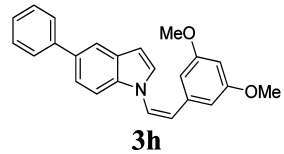
entry	*N*-heterocycle **1**	alkyne **2**	product **3**	yield (%)[b]
1	 **1a**	 **2a**	 **3a**	92
2	**1a**	 **2b**	 **3b**	78
3	**1a**	 **2c**	 **3c**	65
4	**1a**	 **2d**	 **3d**	68
5	**1a**	 **2e**	nr	-
6	**1a**	 **2f**	nr	-
7	 **1b**	**2a**	 **3e**	80
8	**1b**	 **2g**	 **3f**	82
9	 **1c**	 **2h**	 **3g**	86
10	 **1d**	 **2i**	 **3h**	85

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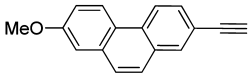
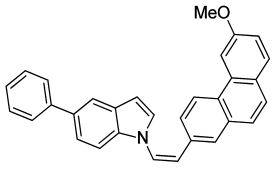
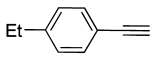
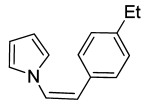
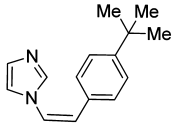
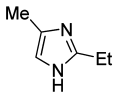
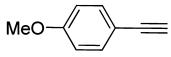
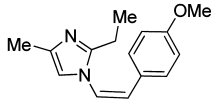
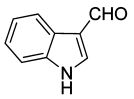
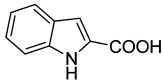
Table 1. continued

entry	*N*-heterocycle **1**	alkyne **2**	product **3**	yield (%)[b]
11	 **1d**	 **2j**	 **3i**	82
12	 **1e**	 **2k**	 **3j**	92[c]
13	 **1f**	**2b**	 **3k**	72[d]
14	 **1g**	 **2l**	 **3l**	82[d]
15	 **1h**	**2a**	nr	-
16	 **1i**	**2a**	nr	-
17	 **1j**	**2a**	nr	-

[a]The reactions were performed using *N*-heterocycle **1** (2.0 equiv), 1.0 mmol of the alkyne **2**, and 0.2 equiv of KOH in 1.5 mL of DMSO at 120 °C for 0.5−1 h unless otherwise noted. [b]Yield of isolated product. [c]Time = 15 min. [d]Time = 2 h.

corresponding *Z*-addition products **3a−l** in good to excellent yields (Table 1, entries 1−17). During the course of reaction, it was noticed that the nature of the heteroarenes and the substituents attached to the aryl group of triple bond were responsible for the success of the process. The reaction tolerates a wide range of substituents (comprising electron-donating and electron-withdrawing groups) both in the *N*-heterocycles and acetylenes, thus demonstrating a general character of the synthesis. Heterocyclic amines with an electron-donating group such as 3-methylindole **1a** and 2-methylindole **1b** afforded the addition products with *Z*-stereoselectivity in good yields (Table 1, entries 1−8). When the scope of various alkynes was checked with **1a**, it was found that electron-donating groups affected the yield of the product formed (Table 1, entries 1 and 2). Electron-withdrawing substituents attached to the alkyne substrate **2c** and **2d** enhanced the rate of reaction and sped up the conversion of desired isomer to more stable *E*-isomer lowering the yield of the product (Table 1, entries 3 and 4). No reaction was observed with aliphatic alkynes **2e** and **2f** with **1a** (Table 1, entries 5 and 6). Heterocycle **1b** also afforded the desired product with alkyne **2g** and **2h** in 80 and 82% yields, respectively (Table 1, entries 7 and 8). 5-Bromoindole **1c** afforded the hydroaminated product **3g** in 86% yield (Table 1, entry 9). Modification in the indole ring by substituting a phenyl ring made no appreciable change in the reactivity of these substrates with the corresponding alkynes (Table 1, entries 10 and 11). Pyrrole **1e** being more nucleophilic afforded the hydroaminated product **3j** in lesser reaction time in 92% yield (Table 1, entry 12).

It is interesting to note that electron-deficient heterocycle **1f** and **1g** reacted well with terminal alkynes **2b** and **2l** and afforded the hydroaminated products **3k** and **3l** in longer time (Table 1, entries 13 and 14). Heterocycles substituted with electron-withdrawing groups −CHO and −COOH in the indole moiety, i.e., 1*H*-indole-3-carbaldehyde **1h** and 1*H*-indole-2-carboxylic acid **1i**, did not react under the given conditions with **2a**, which might be due to decrease in nucleophilicity (Table 1, entries 15 and 16). A cyclic secondary amine, pyrrolidine **1j**, did not react in the presence of KOH with **2a** (Table 1, entry 17).

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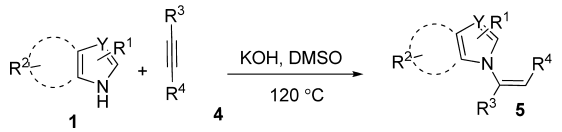
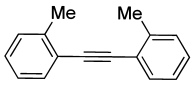
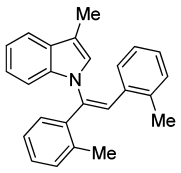
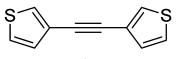
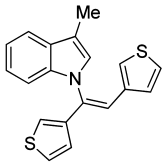
Table 2. Synthesis of *Z*-Styrylenamines[a]



entry	*N*-Heterocycle **1**	alkyne **4**	product **5**	yield (%)[b]
1	**1a**	**4a**	**5a**	70
2	**1b**	**4a**	**5b**	69
3	**1e**	**4a**	**5c**	76[c]
4	**1c**	**4a**	**5d**	74
5	**1f**	**4a**	nr	-
6	**1g**	**4a**	nr	-
7	**1k**	**4b**	**5e**	73
8	**1a**	**4c**	**5f**	76
9	**1e**	**4c**	**5g**	79[c]

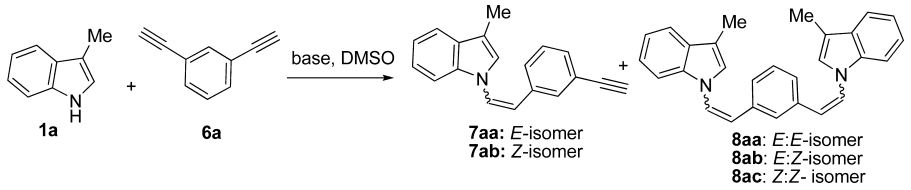
dx.doi.org/10.1021/jo300782n | J. Org. Chem. 2012, 77, 5633−5645

Table 2. continued

entry	*N*-Heterocycle **1**	alkyne **4**	product **5**	yield (%)[b]
10[c]	**1a**	 **4d**	 **5h**	52[d]
11[c]	**1a**	 **4e**	 **5i**	62[d]
12	**1a**	 **4f**	nr	-

[a]The reactions were performed using *N*-heterocycle **1** (2.0 equiv), 1.0 mmol of the alkyne **4**, and 2.5 equiv of KOH in 1.5 mL of DMSO at 120 °C for 24 h unless otherwise noted. [b]Yield of isolated product. [c]Time = 18−20 h. [d]CuI (5 mol %) and ligand/$BtCH_2OH$ (10 mol %).

Table 3. Optimization of Reaction Conditions for the Hydroamination of Dialkynes[a]



				product					
entry	base	*t*/°C	time/min	**7aa**	**7ab**	**8aa**	**8ab**	**8ac**	yield (%)[b]
1	KOH	120	30	45		50	5		62
2	KOH	120	15	75			25		78
3	KOH	80	15	70	20		10		80
4	Cs_2CO_3	80	20	50	50				75
5	Cs_2CO_3	120	10	10	90				68

[a]The reactions were performed using *N*-heterocycle **1a** (3.0 equiv), 1.0 mmol of the alkyne **6a**, and 0.2 equiv of base in 1.5 mL of DMSO. [b]Yield of mixture of isolated product.

Hydroamination of Internal Alkynes. Similarly, hydroamination of internal alkynes **4a−f** to form *Z*-vinyl enamines **5a−i** was selectively done using 2.5 equiv of KOH in 65−79% yields in 18−24 h (Table 2, entries 1−12). Substituents attached in the *N*-heterocycle exerted a similar effect on the progress of the reaction as observed with terminal alkynes. Electron-rich heterocycles afforded the addition products with diphenylacetylene **4a** in good yields in comparison to electron-deficient substrates (Table 2, entries 1−6). Heterocycle **1a** and **1b** provided the *Z*-isomer selectively in 70 and 69% yields, respectively (Table 2, entries 1 and 2). Pyrrole **1e** being more nucleophilic afforded the hydroaminated product **5c** in lesser reaction time in 76% yield (Table 2, entry 3). **1c** afforded the hydroaminated product **5d** in 74% yield (Table 2, entry 4).

No reaction was observed with electron-deficient *N*-heterocycles like imidazole **1f** and **1g** with alkyne **4a** (Table 2, entries 5 and 6). Electron-rich alkynes **4b** and **4c** yielded the corresponding addition products in 76−79% yields, respectively (Table 2, entries 7−9). Sterically hindered and electron-rich alkynes 1, 2-di-*o*-tolylethyne **4d** and 1,2-di(thiophen-3-yl)-ethyne **4e** did not react in the presence of KOH. However, addition of catalytic amount of CuI (5 mol %) and ligand (1*H*-benzo[*d*][1,2,3]triazol-1-yl)methanol ($BtCH_2OH$) (10 mol %) in the reaction yielded the hydroaminated product **5h** and **5i** in 52 and 62% yields, respectively (Table 2, entries 10 and 11). Aliphatic internal alkyne, 3-hexyne **4f**, did not react with **1a** (Table 2, entry 12).

Hydroamination of Dialkynes. Next, we sought to investigate the possibility of the reaction with a dialkyne. More interestingly, when 1,3-diethynylbenzene **6a** was reacted with **1a** using 0.2 equiv of KOH at 120 °C, a complex mixture of three isomers was obtained in 30 min (Table 3, entry 1). Reaction monitoring at continuous interval of time showed that the addition of the amine to the alkyne occurred very fast, leading to the conversion of kinetically stable *Z*-isomer to thermodynamically stable *E*-isomer followed by the attack on another alkyne present in the substrate. Decrease in reaction time and temperature did not show any major change and provided a mixture of addition products **7aa** and **8ab** in 78 and 80% yield, respectively (Table 3, entries 2 and 3). Use of Cs_2CO_3 (0.2 equiv) yielded a mixture of two stereoisomers **7aa** and **7ab** by the addition of **1a** only at one position of the dialkyne (Table 3, entry 4). Increase in temperature provided the product **7ab** in 68% yield (Table 3, entry 5).

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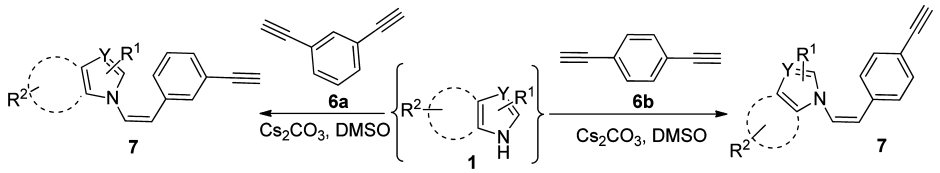
Table 4. Hydroamination of 1,3- and 1,4-Diethynylbenzene[a]



entry	*N*-heterocycle **1**	alkyne **6**	product **7** (*E*:*Z*)	yield (%)[b]
1	**1a**	**6a**	**7ab**	68
2	**1l**	**6a**	**8bc**	42
3	**1a**	**6b**	**7bb** (13:87)	64
4	**1l**	**6b**	**7cb** (30:70)	57
5	**1e**	**6b**	**7db**	54

[a]The reactions were performed using *N*-heterocycle **1** (2.0 equiv), 1.0 mmol of the alkyne **6**, and 0.2 equiv of Cs_2CO_3 in 1.5 mL of DMSO at 120 °C for 10 min. [b]Yield of isolated product.

Under the optimized reaction conditions (Table 3, entry 5), selective hydroamination of dialkynes **6a** and **6b** was done (Table 4, entries 1−5). **6a** provided the 1,3-bis((*Z*)-2-(1*H*-indol-1-yl)vinyl)benzene **8bc** with **1l** in 42% yield (Table 4, entry 2). 1,4-Diethynylbenzene **6b** yielded the mixture of *E*:*Z* isomers with **1a** and **1l** in 64 and 57% yield, respectively (Table 4, entries 3 and 4). **1e** provided *Z*-isomer in 54% yield along with a complex mixture of other isomers (Table 4, entry 5).

Synthesis of Enaminones. For decades, enaminones are known to be prepared by the general reaction of amines and 1,3-diketones and are established substrates in heterocyclic chemistry[15] and possess important biological activities.[16] The current strategy also proved to be efficient for the synthesis of corresponding enaminone derivatives by the reaction of heterocyclic amines and alkynones (Scheme 4).

During the course of reaction of **1a** and **9a**, it was observed that at high temperatures a highly polar unidentified complex was formed. Thus, we carried out the reaction by using 0.2 equiv of KOH at 80 °C. It was motivating to find that reaction of heterocycles **1a** and **1l** with alkynone 1-phenyl-3-(trimethylsilyl)prop-2-yn-1-one **9a** provided *E*-isomers **10a** and **10b** as major products with the in situ hydrolysis of TMS within 10 min in 81 and 76% yields, respectively (Scheme 4). Longer reaction time led to the decomposition of product. Intermolecular addition of heterocycle **1a** and alkynone, 1-phenyl-3-*p*-tolylprop-2-yn-1-one **9b**, yielded **10c** a mixture of *Z*- and *E*-hydroaminated products in 25:75 stereoisomeric ratios in 56% yield (Scheme 4).[20c] The stereochemistry of the products formed by the addition of amines onto alkynes was determined by NMR spectroscopy.[14a]

Hydroamination of Haloarylalkynes. In our ongoing efforts to synthesize heterocyclic compounds via hydroamination and coupling reactions,[17] we extended this work using haloarylalkynes **11a,b** (Table 5). Under the catalytic conditions, it was observed that the addition of *N*-heterocycles **1l** and **1a** onto **11a,b** was preferred over the *N*-arylation, and products **12a−c** were obtained in appreciable yields with *E*-stereochemistry (Table 5, entries 1−3).[14b]

Under the given catalytic conditions, internal alkyne **11c** provided the mixture of hydroaminated products in 68% yield (Table 5, entry 4). Formation of the cyclized product, 6-(4-ethylphenyl)-12-methylindolo[2,1-*a*]isoquinoline **12e**, from 1-bromo-2-((4-ethylphenyl)ethynyl)benzene **11d** supports the formation of addition product with *Z*-stereoselectivity. These results suggest that the copper-catalyzed tandem synthesis of indolo- and pyrrolo[2,1-*a*]isoquinolines undergoes base medi-

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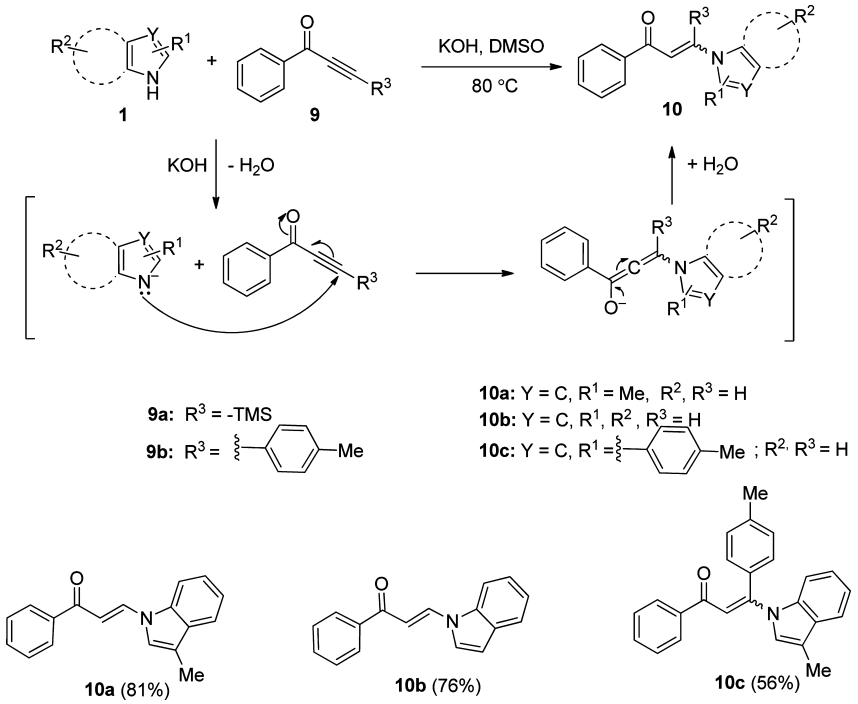
Scheme 4. Hydroamination of Alkynones



ated stereo- and regioselective intermolecular addition of *N*-heterocycle **1a** onto *ortho*-haloarylakyne **11d** and followed by intramolecular C2 cyclization in the presence of metal and ligand (Scheme 5).

We believe that this approach to a variety of enamines and enaminones is quite useful for the synthesis of additional more highly substituted indolo- and pyrroloisoquinolines, particularly when one considers that there are many ways to transform the halide functional group into other substituents. For example, **5d** produced by this strategy can be further functionalized by applying palladium-catalyzed Suzuki,[18] Heck,[19] and Sonogashira[20a] coupling reactions to afford the corresponding products **14**, **16**, and **17** in 85, 81, and 70% yields, respectively (Scheme 6).

■ CONCLUSION

In summary, we have described a versatile and efficient regio- and stereoselective synthetic method to produce a broad range of functionalized vinyl and styryl enamines that are useful and versatile synthetic intermediates for the synthesis of biologically active compounds. This metal- and ligand-free methodology utilizes a simple and economical bases such as KOH and Cs_2CO_3 for the addition of *N*-heterocycles not only onto terminal and internal alkynes but also for 1,3- and 1,4-dialkynes. Addition of heterocyclic nucleophiles onto alkynones has also been reported under mild conditions. Current work also supports and confirms the mechanistic pathway for the copper-catalyzed tandem synthesis of indolo- and pyrrolo[2,1-*a*]isoquinolines via formation of *Z*-stereoisomer by hydroamination of *ortho*-haloarylalkyne followed by oxidative addition in the presence of metal and ligand.

■ EXPERIMENTAL SECTION

General Method. All the reactions were performed in an oven-dried Schlenk flask under an argon atmosphere. Column chromatography was performed using silica gel (100−200 mesh). Thin layer chromatography (TLC) was performed on silica gel GF254 plates. Visualization of spots on TLC plate was accomplished with UV light (254 nm) and staining over I_2 chamber. ^{1}H and ^{13}C NMR spectra were recorded at 300 and 75 MHz or 400 and 100 MHz, respectively. Thin layer chromatography was performed using commercially prepared 60 F_{254} silica gel plates, and visualization was effected with short wavelength UV light (254 nm). All melting points are uncorrected. High resolution mass spectra were recorded on a double focusing magnetic sector mass spectrometer.

General Procedure for the Synthesis of Internal Alkynes. The 1,2-diarylalkynes and alkynones were prepared by the Sonogashira coupling reaction of corresponding aryl-iodide or benzoyl chloride with terminal alkynes using reported procedures.[20] The structure and purity of known starting materials **4a−d** and **11a−d** were confirmed by comparison of their physical and spectral data (^{1}H NMR, ^{13}C NMR, and HRMS) with those reported in literature.[20b]

1,2-Di(thiophen-3-yl)ethyne (4e).[20a] The product was obtained as a brown solid (158.4 mg, 90% yield): mp 110−115 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.51−7.49 (m, 2H), 7.30−7.28 (m, 2H), 7.17 (dt, J = 1.4, 2.2 Hz, 2H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 129.8, 128.5, 125.4, 122.2, 83.9; HRMS (ESI) $[M]^+$ Calcd for $[C_{10}H_6S_2]$ 189.9911, found 189.9910.

1-Phenyl-3-(trimethylsilyl)prop-2-yn-1-one (9a).[20c] The product was obtained as an orange oil (189.5 mg, 92% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.14−8.12 (m, 2H), 7.60 (td, J = 2.2, 5.1 Hz, 1H), 7.51−7.45 (m, 2H), 6.30 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 177.7, 136.4, 134.2, 129.6, 128.5, 100.8, 100.6, −0.7; HRMS (ESI) $[M]^+$ Calcd for $[C_{12}H_{14}OSi]$ 202.0814, found 202.0814.

1-Phenyl-3-(*p*-tolyl)prop-2-yn-1-one (9b).[20c] The product was obtained as a yellow semisolid (168.8 mg, 89% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.22 (d, J = 7.4 Hz, 2H), 7.65−7.58 (m, 3H), 7.53 (t, J = 7.4 Hz, 2H), 7.25 (t, J = 5.8 Hz, 2H), 2.41 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 178.1, 141.5, 136.9, 133.9, 133.1, 129.5, 129.4, 128.6, 116.9, 93.8, 86.8, 21.8; HRMS (ESI) $[M]^+$ Calcd for $[C_{16}H_{12}O]$ 220.0888, found 220.0887.

General Procedure for the Addition of *N*-Heterocycles with Terminal Alkynes. The compounds were synthesized as per the previously reported procedure.[14a] To a solution of *N*-heterocycle (2.0 equiv) in DMSO and finely crushed KOH (0.2 equiv), 100 mg of alkyne (1.0 mmol) was added. Resulting mixture was heated at 120 °C.

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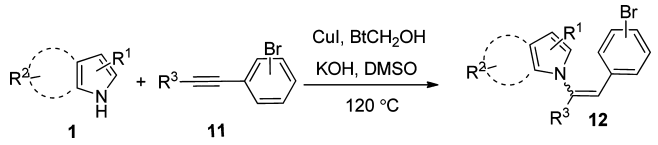
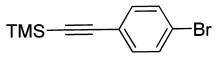
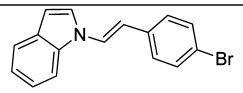
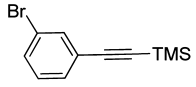
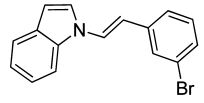
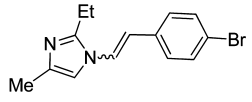
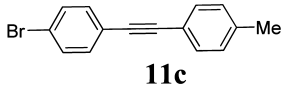
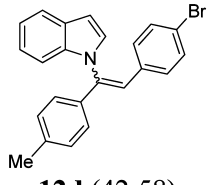
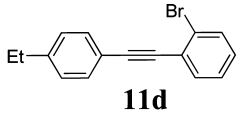
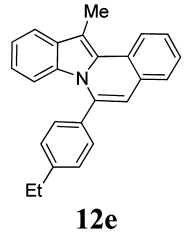
Table 5. Preferential Addition of Haloarylalkynes over *N*-arylation[a]

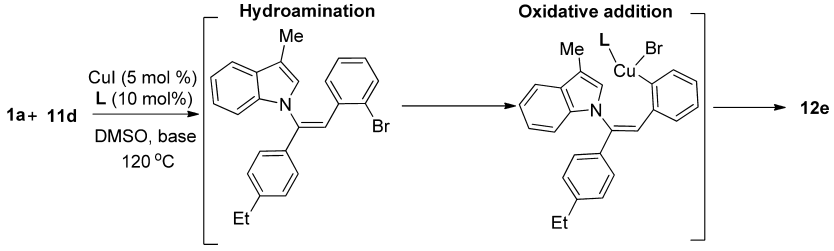


1 11 12

entry	*N*-Heterocycle **1**	alkyne **11**	product **12** (*E*:*Z*)	yield (%)[b]
1	**1l**	 **11a**	 **12a**	72
2	**1l**	 **11b**	 **12b**	76
3	**1g**	**11a**	 **12c** (34:66)	69
4	**1l**	 **11c**	 **12d** (42:58)	68[c]
5	**1a**	 **11d**	 **12e**	70[c]

[a]Reactions were carried out using **1** (2.0 equiv), **11** (1.0 mmol), CuI (10 mol %), $BtCH_2OH$ (20 mol %), and KOH (2.0 equiv) in DMSO (1.5 mL) at 120 °C for 20−30 min. [b]Isolated yield. [c]Time = 10−12 h.

Scheme 5. Tandem Synthesis of Indolo[2,1-*a*]isoquinolines by Addition of *N*-Heterocycle onto *o*-Haloarylalkyne Followed by Intramolecular C2 Arylation



Progress of the reaction was monitored by TLC. After the complete consumption of alkynes, reaction mixture was brought to room temperature. The reaction mixture was extracted with ethylacetate (5 mL × 3) and evaporated under reduced pressure. The crude reaction mixture was purified using silica gel column chromatography.

(*Z*)-3-Methyl-1-(4-methylstyryl)-1*H*-indole (3a). The product was obtained as a white solid (195.8 mg, 92% yield): mp 115−117 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.54 (dd, J = 0.6, 7.2 Hz, 1H), 7.33−7.29 (m, 1H), 7.24−7.22 (m, 1H), 7.19−7.12 (m, 2H), 7.10 (s, 1H), 7.04 (d, J = 8.1 Hz, 2H), 6.85 (m, 2H), 6.13 (d, J = 9.3 Hz, 1H), 2.31 (s, 3H), 2.24 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 137.2, 136.3, 132.3, 129.1, 129.06, 128.6, 124.5, 122.7, 122.4, 120.3, 118.9, 118.1, 113.2, 109.4, 21.3, 9.6; HRMS (ESI) $[M]^+$ Calcd for $[C_{18}H_{17}N]$ 247.1361, found 247.1362.

(*Z*)-1-(4-(*tert*-Butyl)styryl)-3-methyl-1*H*-indole (3b). The product was obtained as orange crystals (142.7 mg, 78% yield): mp 110−115 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56 (d, J = 7.3 Hz, 1H), 7.32 (d, J = 8.0 Hz, 1H), 7.28−7.24 (m, 2H), 7.22 (dd, J = 1.4 Hz, 1H), 7.19−7.15 (m, 3H), 6.88 (d, J = 1.7 Hz, 1H), 6.86 (d, J = 8.8 Hz, 1H), 6.15 (d, J = 9.5 Hz, 1H), 2.25 (s, 3H), 1.30 (s, 9H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 149.7, 135.9, 133.5, 129.6, 129.3, 125.9, 125.7, 125.2, 122.9, 122.7, 121.1, 120.3, 119.2, 114.6, 112.3, 109.4, 34.5, 31.3,

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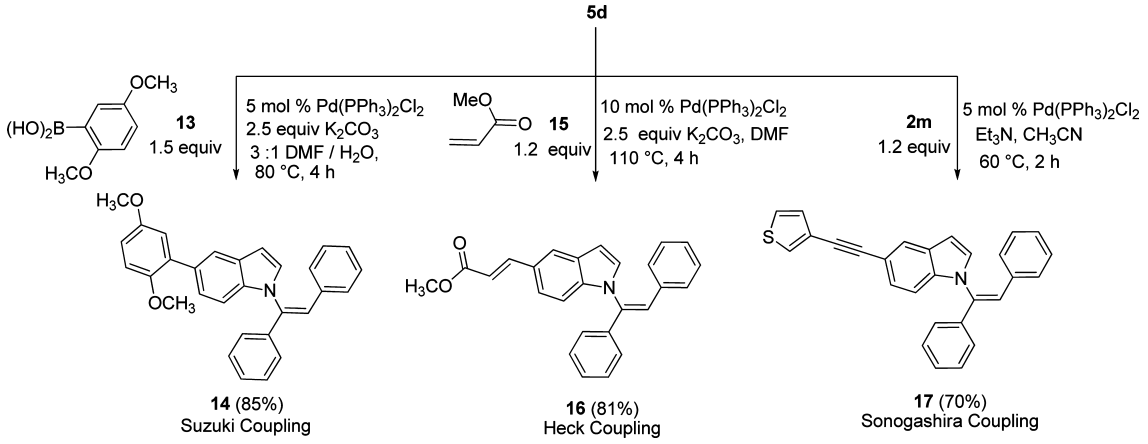
Scheme 6. Palladium-Catalyzed Diversification of 5d



9.7; HRMS (ESI) $[M]^+$ Calcd for $[C_{21}H_{23}N]$ 289.1830, found 289.1831.

(*Z*)-3-Methyl-1-(4-nitrostyryl)-1*H*-indole (3c). The product was obtained as yellow needles (122.9 mg, 65% yield): mp 142−145 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 (dt, J = 2.2, 9.5 Hz, 1H), 7.62−7.56 (m, 2H), 7.19−7.14 (m, 2H), 7.12−7.07 (m, 1H), 7.04−6.97 (m, 1H), 6.91−6.86 (m, 2H), 6.73 (t, J = 8.8 Hz, 1H), 6.43 (s, 1H), 2.34 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 145.5, 141.6, 136.2, 134.4, 130.9, 130.2, 127.9, 123.7, 121.3, 119.4, 119.3, 116.4, 115.6, 111.7, 111.6, 108.2, 9.8; HRMS (ESI) $[M]^+$ Calcd for $[C_{17}H_{14}N_2O_2]$ 278.1055, found 278.1051.

(*Z*)-3-Methyl-1-(4-(trifluoromethoxy)styryl)-1*H*-indole (3d). The product was obtained as a yellow oil (126.8 mg, 68% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54 (d, J = 7.4 Hz, 1H), 7.31−7.29 (m, 1H), 7.25−7.21 (m, 3H), 7.19−7.16 (m, 1H), 7.09 (d, J = 8.1 Hz, 2H), 6.94 (d, J = 8.8 Hz, 1H), 6.76 (d, J = 1.1 Hz, 1H), 6.12 (d, J = 8.8 Hz, 1H), 2.24 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 148.1, 136.2, 134.0, 130.0, 129.2, 126.5, 124.0, 123.9, 122.6, 120.7, 120.4, 119.0, 116.0, 113.9, 109.9, 9.6; HRMS (ESI) $[M]^+$ Calcd for $[C_{18}H_{14}F_3NO]$ 317.1027, found 317.1025.

(*Z*)-2-Methyl-1-(4-methylstyryl)-1*H*-indole (3e). The product was obtained as off-white crystals (170.4 mg, 80% yield): mp 120−125 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54 (dd, J = 1.5 Hz, 1H), 7.13 (dd, J = 1.5 Hz, 1H), 7.08 (td, J = 1.4, 5.1 Hz, 2H), 6.94 (d, J = 8.0 Hz, 2H), 6.79 (d, J = 8.8 Hz, 2H), 6.68 (d, J = 8.8 Hz, 1H), 6.59 (d, J = 8.8 Hz, 1H), 6.36 (s, 1H), 2.24 (s, 3H), 2.22 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 138.0, 136.4, 135.8, 131.6, 129.3, 129.2, 128.7, 128.5, 121.8, 120.9, 120.0, 119.4, 110.5, 101.7, 21.2, 13.0; HRMS (ESI) $[M]^+$ Calcd for $[C_{18}H_{17}N]$ 247.1361, found 247.1362.

(*Z*)-2-Methyl-1-(4-phenoxystyryl)-1*H*-indole (3f). The product was obtained as yellow crystals (137.4 mg, 82% yield): mp 130−135 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.51 (dd, J = 2.2, 2.9 Hz, 1H), 7.29 (t, J = 7.7 Hz, 2H), 7.12−7.03 (m, 4H), 6.92 (dd, J = 2.2, 7.3 Hz, 2H), 6.83 (dt, J = 2.6, 8.8 Hz, 2H), 6.73 (dt, J = 2.9, 8.8 Hz, 2H), 6.68 (d, J = 8.8 Hz, 1H), 6.59 (d, J = 8.8 Hz, 1H), 6.35 (s, 1H), 2.25 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 157.1, 156.5, 136.2, 135.6, 130.1, 129.7, 129.4, 128.7, 128.5, 123.6, 121.7, 120.9, 120.1, 119.5, 119.3, 118.3, 110.6, 101.8, 13.0; HRMS (ESI) $[M]^+$ Calcd for $[C_{23}H_{19}NO]$ 325.1467, found 325.1465.

(*Z*)-5-Bromo-1-styryl-1*H*-indole (3g). The product was obtained as white crystals (251.1 mg, 86% yield): mp 130−135 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.73 (d, J = 2.2 Hz, 1H), 7.29 (dd, J = 1.4, 6.6 Hz, 1H), 7.26−7.19 (m, 4H), 7.12 (dd, J = 2.2, 5.1 Hz, 2H), 7.01 (d, J = 2.9 Hz, 1H), 6.89 (d, J = 9.5 Hz, 1H), 6.44 (d, J = 2.9 Hz, 1H), 6.35 (d, J = 8.8 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 134.5, 134.4, 130.2, 128.6, 128.5, 128.3, 127.8, 125.2, 123.4, 122.9, 121.2, 113.9, 111.6, 103.4; HRMS (ESI) $[M]^+$ Calcd for $[C_{16}H_{12}BrN]$ 297.0153, found 297.0150.

(*Z*)-1-(3,5-Dimethoxystyryl)-5-phenyl-1*H*-indole (3h). The product was obtained as brown crystals (186.3 mg, 85% yield): mp 90−95 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.80 (s, 1H), 7.64 (dd, J = 1.5, 8.0 Hz, 2H), 7.51−7.40 (m, 4H), 7.32 (td, J = 1.5, 8.0 Hz, 1H), 7.12 (d, J = 3.6 Hz, 1H), 6.97 (d, J = 8.8 Hz, 1H), 6.55 (d, J = 8.8 Hz, 1H), 6.35 (s, 3H), 6.24 (d, J = 9.5 Hz, 1H), 3.63 (s, 6H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 160.6, 142.2, 136.6, 135.4, 134.2, 129.0, 128.7, 127.9, 127.3, 126.5, 123.5, 122.2, 119.6, 119.4, 110.4, 106.5, 104.3, 100.3, 55.2; HRMS (ESI) $[M]^+$ Calcd for $[C_{24}H_{21}NO_2]$ 355.1572, found 355.1568.

(*Z*)-1-(2-(6-Methoxyphenanthren-2-yl)vinyl)-5-phenyl-1*H*-indole (3i). The product was obtained as light brown crystals (150.3 mg, 82% yield): mp 130−135 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 (s, 1H), 7.68−7.61 (m, 5H), 7.56 (d, J = 8.8 Hz, 1H), 7.52−7.42 (m, 5H), 7.33 (d, J = 7.3 Hz, 1H), 7.20 (dd, J = 2.2, 7.3 Hz, 1H), 7.11−7.07 (m, 3H), 7.02 (d, J = 9.5 Hz, 1H), 6.53 (d, J = 2.9 Hz, 1H), 6.44 (d, J = 9.5 Hz, 1H), 3.91 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 157.9, 142.2, 135.4, 134.2, 133.9, 130.1, 129.5, 129.1, 128.7, 128.6, 127.9, 127.8, 127.3, 126.9, 126.8, 126.4, 122.9, 122.2, 120.1, 119.4, 119.1, 110.4, 105.7, 104.2, 55.3; HRMS (ESI) $[M]^+$ Calcd for $[C_{31}H_{23}NO]$ 425.1780, found 425.1778.

(*Z*)-1-(4-Ethylstyryl)-1*H*-pyrrole (3j). The product was obtained as a white semi-solid (139.4 mg, 92% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.24−7.19 (m, 4H), 6.80−6.78 (m, 3H), 6.26 (t, J = 2.2 Hz, 2H), 6.18 (d, J = 9.5 Hz, 1H), 2.74 (q, J = 7.3 Hz, 2H), 1.34 (t, J = 7.3 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.7, 132.21, 128.7, 127.8, 125.8, 120.8, 118.7, 109.2, 28.6, 15.4; HRMS (ESI) $[M]^+$ Calcd for $[C_{14}H_{15}N]$ 197.1204, found 197.1204.

(*Z*)-1-(4-(*tert*-Butyl)styryl)-1*H*-imidazole (3k). The product was obtained as a colorless oil (103.0 mg, 72% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.51 (s, 1H), 7.30 (d, J = 8.0 Hz, 2H), 7.08 (s, 1H), 7.01 (d, J = 8.8 Hz, 2H), 6.92 (s, 1H), 6.69 (d, J = 9.5 Hz, 1H), 6.35 (d, J = 9.5 Hz, 1H), 1.29 (s, 9H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 151.7, 136.9, 130.4, 129.1, 128.3, 127.9, 125.8, 125.7, 124.3, 121.6, 118.6, 34.8, 31.2; HRMS (ESI) $[M]^+$ Calcd for $[C_{15}H_{18}N_2]$ 226.1470, found 226.1469.

(*Z*)-2-Ethyl-1-(4-methoxystyryl)-4-methyl-1*H*-imidazole (3l). The product was obtained as a off-white semi-solid (150.3 mg, 82% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.83 (d, J = 8.8 Hz, 2H), 6.72 (d, J = 9.5 Hz, 2H), 6.45 (s, 1H), 6.39 (d, J = 3.6 Hz, 2H), 3.73 (s, 3H), 2.61 (q, J = 8.0 Hz, 2H), 2.21 (s, 3H), 1.23−1.18 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.9, 148.3, 139.3, 130.2, 125.1, 119.2, 115.4, 114.2, 55.3, 20.1, 14.1, 12.1; HRMS (ESI) $[M]^+$ Calcd for $[C_{15}H_{18}N_2O]$ 242.1419, found 242.1419.

General Procedure for the Addition of *N*-Heterocycles with Internal Alkynes. To a solution of *N*-heterocycle (2.0 equiv) in DMSO and finely crushed KOH (2.5 equiv), 100 mg of alkyne (1.0 mmol) was added. Resulting mixture was heated at 120 °C. Progress of the reaction was monitored by TLC. After the complete consumption of alkynes, reaction mixture was brought to room temperature. The reaction mixture was extracted with ethylacetate (5 mL × 3) and evaporated under reduced pressure. The crude reaction mixture was purified using silica gel column chromatography. For the synthesis of

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5h and **5i**, CuI (5.0 mol %) and ligand $BtCH_2OH$ (10.0 mol %) were also added.

(*Z*)-1-(1,2-Diphenylvinyl)-3-methyl-1*H*-indole (5a). The product was obtained as white crystals (121.6 mg, 70% yield): mp 109−112 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60 (d, J = 7.3 Hz, 1H), 7.33−7.28 (m, 4H), 7.25−7.22 (m, 2H), 7.13−7.09 (m, 4H), 7.03−6.99 (m, 2H), 6.85 (d, J = 8.0 Hz, 1H), 6.84−6.81 (m, 1H), 6.77 (s, 1H), 2.35 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 138.7, 136.2, 135.7, 134.9, 129.4, 128.7, 128.3, 127.6, 126.3, 125.8, 124.2, 122.0, 119.5, 118.7, 113.1, 111.7, 9.7; HRMS (ESI) $[M]^+$ Calcd for $[C_{23}H_{19}N]$ 309.1517, found 309.1514.

(*Z*)-1-(1,2-Diphenylvinyl)-2-methyl-1*H*-indole (5b). The product was obtained as a brown oil (119.8 mg, 69% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58 (d, J = 8.0 Hz, 1H), 7.31−7.29 (m, 4H), 7.20−7.18 (m, 2H), 7.12−7.09 (m, 3H), 7.06 (dd, J = 1.5, 6.6 Hz, 1H), 6.97−6.96 (m, 2H), 6.76−6.74 (m, 2H), 6.46 (s, 1H), 2.08 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 138.4, 136.4, 136.2, 134.7, 134.2, 128.8, 128.6, 128.1, 127.5, 125.4, 121.2, 120.0, 119.5, 110.8, 102.0, 12.7; HRMS (ESI) $[M]^+$ Calcd for $[C_{23}H_{19}N]$ 309.1517, found 309.1517.

(*Z*)-1-(1,2-Diphenylvinyl)-1*H*-pyrrole (5c). The product was obtained as a white semi-solid (104.6 mg, 76% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36−7.33 (m, 3H), 7.29−7.27 (m, 2H), 7.25−7.18 (m, 3H), 6.85−6.82 (m, 3H), 6.58 (t, J = 2.2 Hz, 2H), 6.30 (t, J = 2.2 Hz, 2H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 138.8, 134.8, 130.5, 129.1, 128.8, 128.5, 128.3, 127.7, 126.3, 122.9, 121.4, 120.7, 117.9, 109.7; HRMS (ESI) $[M]^+$ Calcd for $[C_{18}H_{15}N]$ 245.1204, found 245.1203.

(*Z*)-5-Bromo-1-(1,2-diphenylvinyl)-1*H*-indole (5d). The product was obtained as yellow crystals (155.4 mg, 74% yield): mp 130−132 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.78 (d, J = 2.2 Hz, 1H), 7.34−7.29 (m, 3H), 7.23−7.19 (m, 2H), 7.14−7.09 (m, 5H), 6.99 (d, J = 3.6 Hz, 1H), 6.80−6.76 (m, 3H), 6.60 (d, J = 2.2 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 137.9, 135.7, 134.4, 134.1, 130.5, 129.7, 128.9, 128.8, 128.6, 128.5, 128.0, 126.0,125.2, 125.1, 123.3, 113.6, 113.1, 103.4; HRMS (ESI) $[M + 1]^+$ Calcd for $[C_{22}H_{16}BrN]$ 373.0466, found 373.0465.

(*Z*)-1-(1,2-Di-*m*-tolylvinyl)-5-methoxy-1*H*-indole (5e). The product was obtained as an off-white solid (125.1 mg, 73% yield): ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.24−7.08 (m, 4H), 7.02−6.91 (m, 5H), 6.79 (d, J = 9.0 Hz, 1H), 6.69−6.58 (m, 3H), 6.48 (d, J = 6.9 Hz, 1H), 3.83 (s, 3H), 2.31 (s, 3H), 2.14 (s, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 154.4, 138.6, 138.3, 137.8, 136.3, 134.7, 130.7, 129.9, 129.6, 129.3, 129.2, 128.6, 128.5, 128.2, 125.5, 124.6, 123.5, 112.6, 112.2, 103.4, 102.3, 55.7, 21.5, 21.4; HRMS (ESI) $[M]^+$ Calcd for $[C_{25}H_{23}NO]$ 353.1780, found 353.1781.

(*Z*)-1-(1,2-Bis(3-methoxyphenyl)vinyl)-3-methyl-1*H*-indole (5f). The product was obtained as a yellow semi-solid (117.8 mg, 76% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (d, J = 7.3 Hz, 1H), 7.26−7.21 (m, 2H), 7.11−7.00 (m, 3H), 6.91−6.82 (m, 4H), 6.78 (s, 1H), 6.65 (dd, J = 2.2, 5.9 Hz, 1H), 6.57 (d, J = 10.2 Hz, 1H), 6.04 (s, 1H), 3.76 (s, 3H), 3.29 (s, 3H), 2.34 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 159.8, 159.3, 140.1, 136.1, 135.9, 135.7, 129.6, 129.2, 129.0, 125.6, 124.6, 122.1, 122.0, 119.6, 118.9, 118.6, 114.9, 114.1, 113.0, 111.9, 111.6, 55.3, 54.6, 9.7; HRMS (ESI) $[M]^+$ Calcd for $[C_{25}H_{23}NO_2]$ 369.1729, found 369.1728.

(*Z*)-1-(1,2-Bis(3-methoxyphenyl)vinyl)-1*H*-pyrrole (5g). The product was obtained as a dark brown oil (101.3 mg, 79% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28−7.25 (m, 1H), 7.14 (t, J = 7.3 Hz, 1H), 6.92−6.88 (m, 2H), 6.86 (s, 1H), 6.83−6.81 (m, 1H), 6.75 (dd, J = 2.9, 5.1 Hz, 1H), 6.60 (t, J = 2.2 Hz, 3H), 6.30 (t, J = 2.2 Hz, 2H), 6.19 (t, J = 2.2 Hz, 1H), 3.79 (s, 3H), 3.61 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 159.8, 159.4, 140.2, 138.2, 135.9, 129.5, 129.1, 123.3, 122.1, 121.4, 118.7, 114.7, 114.3, 112.2, 111.8, 109.8, 55.3, 54.9; HRMS (ESI) $[M]^+$ Calcd for $[C_{20}H_{19}NO_2]$ 305.1416, found 305.1411.

(*Z*)-1-(1,2-Di-*o*-tolylvinyl)-3-methyl-1*H*-indole (5h). The product was obtained as yellow crystals (85.1 mg, 52% yield): mp 110−115 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.47 (m, 2H), 7.29 (dd, J = 1.5, 5.9 Hz, 1H), 7.15−7.12 (m, 3H), 7.04−6.99 (m, 2H), 6.90 (d, J = 8.0 Hz, 1H), 6.81 (d, J = 8.0 Hz, 1H), 6.65 (t, J = 7.7 Hz, 2H), 6.59 (s, 1H), 6.52 (s, 1H), 2.32 (s, 3H), 2.22 (s, 3H), 1.81 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 138.9, 137.7, 137.4, 136.2, 135.3, 134.8, 130.8, 130.2, 129.9, 129.5, 128.8, 128.1, 127.2, 125.7, 125.6, 121.8, 121.3, 119.8, 119.4, 118.5, 113.1, 111.8, 20.4, 19.7, 9.6; HRMS (ESI) $[M]^+$ Calcd for $[C_{25}H_{23}N]$ 337.1830, found 337.1832.

(*Z*)-1-(1,2-Di(thiophen-3-yl)vinyl)-3-methyl-1*H*-indole (5i). The product was obtained as a dark yellow oil (104.8 mg, 62% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.63 (d, J = 7.3 Hz, 1H), 7.31−7.29 (m, 1H), 7.18 (dd, J = 1.5 Hz, 1H), 7.16 (s, 1H), 7.13 (td, J = 1.5, 6.6 Hz, 1H), 7.07 (t, J = 8.0 Hz, 1H), 7.02−6.99 (m, 2H), 6.85 (s, 1H), 6.79−6.73 (m, 2H), 6.22 (d, J = 5.1 Hz, 1H), 2.39 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 140.9, 135.7, 130.6, 128.9, 127.5, 126.4, 125.3, 125.2, 124.9, 122.4, 122.2, 119.5, 119.0, 118.8, 112.8, 111.1, 9.8; HRMS (ESI) $[M]^+$ Calcd for $[C_{19}H_{15}NS_2]$ 321.0646, found 321.0645.

General Procedure for the Addition of *N*-Heterocycles with Dialkynes. To a solution of *N*-heterocycle (2.0 equiv) in DMSO and finely crushed Cs_2CO_3 (0.2 equiv), 100 mg of alkyne (1.0 mmol) was added. Resulting mixture was heated at 120 °C. Progress of the reaction was monitored by TLC. After the complete consumption of alkynes, reaction mixture was brought to room temperature. The reaction mixture was extracted with ethylacetate (5 mL × 3) and evaporated under reduced pressure.

1-(3-Ethynylstyryl)-3-methyl-1*H*-indole (7ab). The product was obtained as a yellow oil (138.7 mg, 68% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54 (d, J = 8.0 Hz, 1H), 7.41 (s, 1H), 7.35−7.30 (m, 2H), 7.24 (t, J = 9.5 Hz, 1H), 7.19−7.16 (m, 3H), 6.94 (d, J = 9.5 Hz, 1H), 6.77 (s, 1H), 6.08 (d, J = 8.8 Hz, 1H), 3.03 (s, 1H), 2.23 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 Hz) δ 136.7, 135.7, 132.4, 130.9, 129.2, 128.9, 128.4, 124.1, 123.9, 122.6, 122.2, 120.4, 119.0, 115.7, 113.8, 109.9, 83.3, 77.3, 9.6; HRMS (ESI) $[M]^+$ Calcd for $[C_{19}H_{15}N]$ 257.1204, found 257.1201.

1,3-Bis((*Z*)-2-(1*H*-indol-1-yl)vinyl)benzene (8bc). The product was obtained as a yellow oil (120.0 mg, 42% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.67 (d, J = 7.3 Hz, 2H), 7.39 (d, J = 8.1 Hz, 2H), 7.30 (td, J = 5.8, 1.5 Hz, 2H), 7.26−7.22 (m, 2H), 7.15−7.13 (m, 2H), 7.08−7.04 (m, 4H), 6.96 (d, J = 8.8 Hz, 2H), 6.50 (d, J = 2.9 Hz, 2H), 6.20 (d, J = 9.5 Hz, 2H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 135.8, 135.2, 129.1, 128.5, 128.4, 127.6, 126.9, 123.6, 122.4, 120.9, 120.7, 118.9, 110.1, 104.0; HRMS (ESI) $[M]^+$ Calcd for $[C_{26}H_{20}N_2]$ 360.1626, found 360.1625.

1-(4-Ethynylstyryl)-3-methyl-1*H*-indole (7bb). The product was obtained as a light yellow semi-solid (130.5 mg, 64% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60 [d, J = 14.6 Hz, 0.17H; (for minor)], 7.47 [d, J = 8.1 Hz, 1.0H; (for major)], 7.43−7.39 [m, 0.5H; (for minor)], 7.30 [d, J = 8.3 Hz, 2.4H; (2.0H for major +0.4H for minor)], 7.24−7.22 [m, 1.2H; (1.0H for major +0.4H for minor)], 7.19−7.17 [m, 3.5H; (3.0H for major +0.5H for minor)], 6.86 [d, J = 8.8 Hz, 1.0H; (for major)], 6.72 [s, 1H; (for major)], 6.46 [d, J = 13.9 Hz, 0.22H; (for minor)], 6.04 [d, J = 8.8 Hz, 1.0H; (for major)], 3.04 [s, 0.17H; (17% for minor regioisomer)], 3.02 [s, 1.0H; (83% for major regioisomer)], 2.29 [s, 0.58H; (for minor)], 2.17 [s, 3H; (for major)]; ^{13}C NMR ($CDCl_3$, 100 MHz) δ 135.9, 132.1, 128.6, 125.2, 124.1, 124.0, 122.6, 120.4, 119.0, 116.4, 113.9, 109.9, 83.6, 77.7, 9.6 (for major regioisomer); 136.2, 132.6, 129.2, 123.0, 120.8, 120.6, 119.4, 111.2, 109.4, 9.8 (for minor regioisomer); HRMS (ESI) $[M]^+$ Calcd for $[C_{19}H_{15}N]$ 257.1204, found 257.1202.

1-(4-Ethynylstyryl)-1*H*-indole (7cb). The product was obtained as a brown oil (109.9 mg, 57% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71 [d, J = 14.6 Hz, 0.5H; (for minor)], 7.61 [d, J = 8.1 Hz, 1.5H; (1.0H for major +0.5H for minor)], 7.55 [d, J = 8.0 Hz, 0.5H; (for minor)], 7.52−7.48 [m, 1.5H; (1.0H for major +0.5H for minor)], 7.40 [d, J = 8.1 Hz, 1H; (for major)], 7.37−7.35 [m, 3H; (2.0H for major +1.0H for minor)], 7.31−7.30 [m, 0.6H; (for minor)], 7.22−7.21 [m, 1H; (for major)], 7.19−7.13 [m, 2H; (for major)], 7.00−6.98 [m, 2H; (for major)], 6.69−6.63 [m, 1H; (for minor)], 6.50 [d, J = 2.9 Hz, 1.0H; (for major)], 6.24 [d, J = 8.8 Hz, 1.0H; (for major)], 3.13 [s, 0.3H; (30% for minor regioisomer)], 3.09 [s, 1H; (70% for major regioisomer)]; ^{13}C NMR ($CDCl_3$, 100 MHz) δ 136.7, 135.7, 132.6, 129.2, 125.4, 124.4, 123.6, 122.9, 121.3, 121.2, 120.2, 112.9, 110.9, 109.6, 105.9, 83.7, 77.7 (for major regioisomer); 128.6, 123.9, 121.9,

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120.7, 119.8, 110.9, 102.6 (for minor regioisomer); HRMS (ESI) $[M]^+$ Calcd for $[C_{18}H_{13}N]$ 243.1048, found 243.1048.

(*Z*)-1-(4-Ethynylstyryl)-1*H*-pyrrole (7db). The product was obtained as white needles (82.7 mg, 54% yield): mp 115−119 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32 (d, J = 8.1 Hz, 2H), 7.06 (d, J = 8.8 Hz, 2H), 6.67 (d, J = 9.5 Hz, 1H), 6.56 (t, d, J = 2.2 Hz, 2H), 6.08 (t, d, J = 2.2 Hz, 2H), 5.98 (d, J = 9.5 Hz, 1H), 3.02 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 136.3, 132.5, 127.8, 125.5, 120.3, 119.1, 113.3, 110.8, 83.6, 77.7; HRMS (ESI) $[M]^+$ Calcd for $[C_{14}H_{11}N]$ 193.0891, found 193.0891.

General Procedure for the Addition of *N*-Heterocycles with Alkynones. To a solution of *N*-heterocycle (2.0 equiv) in DMSO and finely crushed KOH (0.2 equiv), 100 mg of alkyne (1.0 mmol) was added. Resulting mixture was heated at 80 °C. Progress of the reaction was monitored by TLC. After the complete consumption of alkynes, reaction mixture was brought to room temperature. The reaction mixture was extracted with ethylacetate (5 mL × 3) and evaporated under reduced pressure. The crude reaction mixture was purified using silica gel column chromatography.

(*E*)-3-(3-Methyl-1*H*-indol-1-yl)-1-phenylprop-2-en-1-one (10a). The product was obtained as yellow crystals (104.6 mg, 81% yield): mp 110−112 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.39 (d, J = 13.9 Hz, 1H), 7.93 (dd, J = 7.4, 1.4 Hz, 2H), 7.52 (d, J = 8.1 Hz, 1H), 7.51−7.47 (m, 2H), 7.45−7.39 (m, 2H), 7.26 (t, J = 8.1 Hz, 1H), 7.23−7.17 (m, 2H), 6.89 (d, J = 13.2 Hz, 1H), 2.25 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 189.6, 138.7, 137.6, 136.8, 132.5, 132.4, 130.9, 128.5, 128.0, 124.8, 124.2, 122.5, 120.7, 119.6, 119.4, 111.2, 102.3, 9.8; HRMS (ESI) $[M]^+$ Calcd for $[C_{18}H_{15}NO]$ 261.1154, found 261.1153.

(*E*)-3-(1*H*-Indol-1-yl)-1-phenylprop-2-en-1-one (10b). The product was obtained as light brown crystals (92.9 mg, 76% yield): mp 105−108 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.51 (d, J = 13.9 Hz, 1H), 8.02 (d, J = 6.6 Hz, 2H), 7.67 (d, J = 8.8 Hz, 1H), 7.62 (d, J = 8.0 Hz, 1H), 7.58 (dt, J = 7.4, 2.2 Hz, 1H), 7.54−7.50 (m, 3H), 7.37 (t, J = 7.3 Hz, 1H), 7.28−7.24 (m, 1H), 7.09 (d, J = 13.2 Hz, 1H), 6.78 (d, J = 3.6 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 189.9, 138.6, 137.8, 136.4, 132.6, 129.9, 128.6, 128.1, 124.2, 123.6, 122.8, 121.6, 110.4, 109.4, 104.6; HRMS (ESI) $[M]^+$ Calcd for $[C_{17}H_{13}NO]$ 247.0997, found 247.0997.

3-(3-Methyl-1*H*-indol-1-yl)-1-phenyl-3-(*p*-tolyl)prop-2-en-1-one (10c). The product was obtained as a yellow oil (89.4 mg, 56% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 [dd, J = 7.3, 1.5 Hz, 0.7H; (for minor)], 7.70 [dt, J = 7.4, 1.5 Hz, 2.0H; (for major)], 7.40 [d, J = 7.3 Hz, 2.0H; 1.0 H (for major) + 1.0 (for minor)], 7.37−7.32 [m, 2H; 1.0 H (for major) + 1.0 (for minor)], 7.27−7.16 [m, 6H; 5.0 H (for major) + 1.0 (for minor)], 7.06 [t, J = 7.3 Hz, 1H; (for major)], 7.03−6.99 [m, 1H; (for major)], 6.81−6.76 [m, 3H; (for major)], 2.42 [s, 3H; (75% for major regioisomer)], 2.39 [s, 1H; (25% for minor regioisomer)], 2.29 [s, 1H; (25% for minor regioisomer)], 2.18 [s, 3H; (75% for major regioisomer)]; ^{13}C NMR (100 MHz, $CDCl_3$) δ 190.7, 152.0, 148.8, 141.5, 139.1, 138.5, 136.7, 134.1, 132.4, 132.1, 130.1, 129.6, 129.3, 128.6, 128.4, 127.9, 127.8, 125.8, 122.3, 120.4, 118.9, 114.4, 112.9, 21.5, 9.6 (for major regioisomer); and 190.8, 140.6, 138.5, 136.7, 132.2, 131.6, 130.3, 127.0, 123.0, 121.4, 119.4, 115.3, 114.1, 112.5, 21.4, 9.5 (for minor regioisomer); HRMS (ESI) $[M]^+$ Calcd for $[C_{25}H_{21}NO]$ 351.1623, found 351.1622.

General Procedure for the Addition of *N*-Heterocycles with Haloarylalkynes. To a solution of *N*-heterocycle (2.0 equiv) in DMSO, finely crushed KOH (2.0 equiv), CuI (5.0 mol %), ligand $BtCH_2OH$ (10.0 mol %) and 100 mg of alkyne (1.0 mmol) were added. Resulting mixture was heated at 120 °C. Progress of the reaction was monitored by TLC. After the complete consumption of alkynes, reaction mixture was brought to room temperature. The reaction mixture was extracted with ethylacetate (5 mL × 3) and evaporated under reduced pressure. The crude reaction mixture was purified using silica gel column chromatography.

(*E*)-1-(4-Bromostyryl)-1*H*-indole (12a). The product was obtained as a colorless oil (84.8 mg, 72% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69−7.63 (m, 2H), 7.55 (d, J = 8.8 Hz, 1H), 7.51−7.47 (m, 3H), 7.33−7.28 (m, 3H), 7.18 (t, J = 8.8 Hz, 1H), 6.68 (d, J = 2.9 Hz, 1H), 6.61 (d, J = 14.7 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 135.8, 133.9, 131.6, 130.2, 128.6, 126.9, 123.9, 122.6, 121.3, 120.9, 120.8, 118.2, 110.1, 104.3; HRMS (ESI) $[M]^+$ Calcd for $[C_{16}H_{12}BrN]$ 297.0153, found 297.0153.

(*E*)-1-(3-Bromostyryl)-1*H*-indole (12b). The product was obtained as white crystals (89.5 mg, 76% yield): mp 122−125 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.67−7.62 (m, 2H), 7.59 (t, J = 1.5 Hz, 1H), 7.55 (d, J = 8.0 Hz, 1H), 7.48 (d, J = 2.9 Hz, 1H), 7.37−7.34 (m, 2H), 7.30 (td, J = 1.5, 5.9 Hz, 1H), 7.24−7.17 (m, 2H), 6.68 (d, J = 3.7 Hz, 1H), 6.59 (d, J = 13.9 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 138.4, 135.7, 130.3, 129.6, 129.2, 128.3, 124.6, 124.3, 123.5, 122.9, 121.3, 121.2, 112.1, 109.6, 105.9; HRMS (ESI) $[M]^+$ Calcd for $[C_{16}H_{12}BrN]$ 297.0153, found 297.0153.

1-(4-Bromostyryl)-2-ethyl-4-methyl-1*H*-imidazole (12c). The product was obtained as a yellow oil (79.4 mg, 69% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 [d, J = 8.0 Hz, 1H; (for major)], 7.34 [d, J = 8.1 Hz, 2H; 1.0H (for major) and 1.0H (for minor)], 7.26−7.29 [m, 1.5H; 1.0 H (for major), 0.5 H (for minor)], 6.93−6.91 [m, 0.5 H; (for minor)], 6.88 [d, J = 8.8 Hz, 2H; 1.0 H (for major) and 1.0 H (for minor)], 6.61 [d, J = 9.5 Hz, 1H; (for major)], 6.49 [t, J = 13.9 Hz, 0.5 H; (34% for minor regioisomer)], 6.38 [s, 1H; (for major)], 6.27 [d, J = 9.5 Hz, 1 H; (66% for major regioisomer)], 2.78−2.77 [m, 1H; (for minor)], 2.59 [q, J = 7.3 Hz, 2H; (for major)], 2.20 [s, 2H; (for minor)], 2.14 [s, 3H; (for major)], 1.32 [t, J = 6.5 Hz, 1.5H; (for minor)], 1.24−1.21 [m, 3H; (for major)]; ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.5, 136.9, 133.9, 131.9, 131.7, 130.2, 127.4, 124.5, 122.6, 114.5, 20.5, 13.3, 12.2 (for major regioisomer); and 137.4, 132.5, 132.3, 125.7, 122.3, 116.8, 111.7, 20.4, 13.3, 12.3 (for minor regioisomer); HRMS (ESI) $[M + 1]^+$ Calcd for $[C_{14}H_{15}BrN_2]$ 290.0419, found 291.0419.

(*Z*)-1-(2-(4-Bromophenyl)-1-*p*-tolylvinyl)-1*H*-indole (12d). This compound was obtained as a white semi-solid (97.4 mg, 68% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.59 [d, J = 8.0 Hz, 1.5H; 1.0 H (for major) + 0.5 H (for minor)], 7.35 [d, J = 8.0 Hz, 0.5H; 0.5 H (for minor)], 7.13 [d, J = 8.0 Hz, 2.0H; 1.0 H (for major) + 1.0 H (for minor)], 7.05 [s, 5H; 4.0 H (for major) + 1.0 H (for minor)], 7.02−7.00 [m, 0.75H (for minor)], 6.98−6.94 [m, 2H (for major)], 6.88−6.82 [m, 4.5H; 3.0 H (for major) + 1.5 H (for minor)], 6.60−6.58 [m, 2H (for major)], 6.53[d, J = 8.0, 2.5H; 2.0 H (for major) + 0.5 H (for minor)]), 2.28 [s, 5.2H; 3.0 H (58% for major regioisomer) + 2.2 H (42% for minor regioisomer)]; ^{13}C NMR (100 MHz, $CDCl_3$) δ 139.3, 137.0, 135.4, 133.9, 131.9, 131.5, 130.2, 129.5, 128.8, 128.3, 126.2, 122.6, 122.3, 121.6, 120.9, 120.4, 111.9, 104.3, 21.3 (for major regioisomer); 135.3, 129.2, 128.9, 127.6, 125.6, 111.7 (for minor regioisomer); HRMS (ESI) $[M]^+$ Calcd for $[C_{23}H_{18}BrN]$ 387.0623, found 387.0623.

6-(4-Ethylphenyl)-12-methylindolo[2,1-*a*]isoquinoline (12e). The product was obtained as yellow crystals (82.3 mg, 70% yield): mp 130−132 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.42 (d, J = 7.8 Hz, 1H), 7.79 (d, J = 8.1 Hz, 1H), 7.53−7.52 (m, 2H), 7.50−7.41 (m, 3H), 7.38−7.35 (m, 2H), 7.28−7.18 (m, 1H), 6.90 (t, J = 8.4 Hz, 1H), 6.44 (d, J = 7.5 Hz, 2H), 2.89 (s, 3H), 2.81 (q, J = 7.5 Hz, 2H), 1.36 (t, J = 7.5 Hz, 3H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 145.5, 138.5, 134.2, 131.4, 130.9, 130.2, 130.0, 129.1, 128.3, 127.2, 126.6, 126.5, 126.2, 124.4, 121.0, 120.2, 118.0, 114.4, 110.7, 105.4, 28.8, 15.5, 11.8; HRMS (ESI) $[M]^+$ Calcd for $[C_{25}H_{21}N]$ 335.1674, found 335.1674.

(*Z*)-5-(2,5-Dimethoxyphenyl)-1-(1,2-diphenylvinyl)-1*H*-indole (14). The product was obtained as an orange semi-solid (98.0 mg, 85% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 (s, 1H), 7.35−7.33 (m, 3H), 7.29−7.28 (m, 2H), 7.23 (dd, J = 1.4 Hz, 1H), 7.15−7.13 (m, 3H), 7.06 (s, 1H), 6.99 (d, J = 2.9 Hz, 1H), 6.97 (d, J = 2.9 Hz, 1H), 6.93 (d, J = 4.4 Hz, 1H), 6.91 (d, J = 4.4 Hz, 1H), 6.87−6.84 (m, 2H), 6.83−6.80 (m, 1H), 6.69 (d, J = 3.7 Hz, 1H), 3.81 (s, 3H), 3.75 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 153.7, 150.8, 138.3, 136.3, 134.7, 132.6, 130.4, 128.9, 128.8, 128.6, 128.4, 127.8, 126.3, 124.8, 124.1, 121.5, 117.0, 112.6, 112.4, 111.7, 104.3, 56.3, 55.8; HRMS (ESI) $[M]^+$ Calcd for $[C_{30}H_{25}NO_2]$ 431.1885, found 431.1885.

(*E*)-Methyl 3-(1-((*Z*)-1,2-diphenylvinyl)-1*H*-indol-5-yl)acrylate (16). The product was obtained as white crystals (82.2 mg, 81% yield): mp 130−135 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 (dd, J = 1.6, 15.6 Hz, 2H), 7.37−7.33 (m, 3H), 7.28−7.24 (m, 3H), 7.16−7.14 (m,

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4H), 7.05 (d, J = 3.2 Hz, 1H), 6.94 (d, J = 8.4 Hz, 1H), 6.83−6.80 (m, 2H), 6.73 (d, J = 3.2 Hz, 1H), 6.39 (d, J = 14.0 Hz, 1H), 3.82 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 167.9, 146.4, 144.9, 137.9, 136.7, 135.7, 134.4, 130.3, 129.7, 129.1, 129.0, 128.9, 128.8, 128.6, 128.5, 128.0, 126.9, 126.0, 125.3, 122.4, 121.8, 117.8, 114.8, 112.2, 104.7, 51.5; HRMS (ESI) $[M]^+$ Calcd for $[C_{26}H_{21}NO_2]$ 379.1572, found 379.1572.

(*Z*)-1-(1,2-Diphenylvinyl)-5-(thiophen-3-ylethynyl)-1*H*-indole (17). The product was obtained as a brown oil (75.1 mg, 70% yield): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.86 (s, 1H), 7.47 (d, J = 2.2 Hz, 1H), 7.35−7.33 (m, 2H), 7.29−7.22 (m, 5H), 7.19−7.16 (m, 1H), 7.13−7.10 (m, 3H), 7.02 (d, J = 3.7 Hz, 1H), 6.88 (d, J = 8.0 Hz, 1H), 6.79−6.77 (m, 2H), 6.71 (s, 1H), 6.66 (d, J = 2.9 Hz, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 138.1, 135.8, 135.3, 134.6, 129.9, 129.4, 128.9, 128.7, 128.6, 128.4, 127.9, 127.8, 126.1, 125.8, 125.2, 125.1, 124.6, 122.9, 116.2, 114.7, 111.8, 104.1, 90.2, 82.3; HRMS (ESI) $[M]^+$ Calcd for $[C_{28}H_{19}NS]$ 401.1238, found 401.1238.

■ ASSOCIATED CONTENT

Supporting Information

Copies of ^{1}H ^{13}C NMR and HRMS spectra for selected compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

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Notes

The authors declare no competing financial interest.

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