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Microwave-Assisted Cascade Strategy for the Synthesis of Indolo[2,3-*b*]quinolines from 2-(Phenylethynyl)anilines and Aryl Isothiocynates

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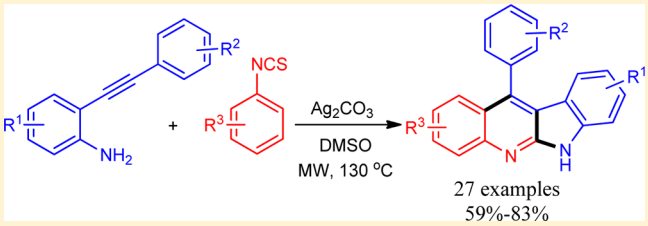
Supporting Information

ABSTRACT: The in situ generated *o*-alkynylthioureas obtain by reacting 2-(phenylethynyl)anilines and aryl isothiocynates undergo efficient cascade cyclization in the presence of Ag_2CO_3 to form indoloquinolines under microwave heating. The present tandem process allows the generation of a variety of indolo[2,3-*b*]quinolines derivatives in good to moderate yields with a wide functional group tolerance.



INTRODUCTION

There has been continuous interest in the synthesis of natural product like compounds with privileged scaffolds that are likely to have potential biological activities. Among these privileged scaffolds, indoloquinoline alkaloids represent one of the important classes of heterocycles due to their immense biological activity[1] (Figure 1) including the ability to interact

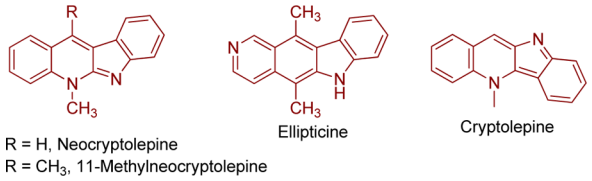
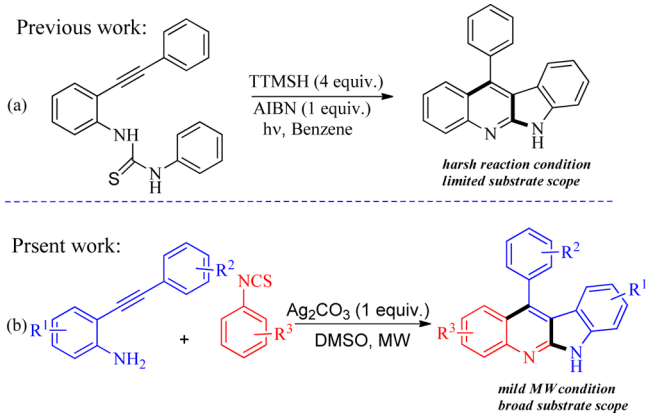


Figure 1. Selected indoloquinolines possessing biological activity.

with DNA as an intercalator to inhibit topoisomerase II activity.[2] Recent results reveal that some new indolo[2,3-*b*]quinoline (norcryptotackieine) types of natural products isolated from the leaves of *Justicia betonica*[3] exhibit exceptional pharmacological properties such as potent antiplasmodial, antiproliferative, and antitumor activity.[4] For example, 2-halosubstituted norcryptotackieines are more active against *Plasmodium falciparum* than neocryptolepine and are less cytotoxic. In addition, indoloquinoline alkaloids are an integral part of the design, development, and synthesis of various modern commercial drugs.[5] For these reasons, over the past several years, tremendous effort has been devoted to the synthesis of such tetracyclic-fused quinoline alkaloids both by organic and medicinal chemists with the aim of enhancing the potency of indolo[2,3-*b*]quinoline, and a variety of approaches have been successfully developed.[6] Most of the available synthetic strategies rely on the use of indole and its derivative as one of the coupling partners.[6d,7] The indoloquinoline system has also been assembled through a thermal cyclization of an enyne−carbodiimide.[8] In 2003, Curran et al. reported the synthesis of indolo[2,3-*b*]quinoline via a cascade radical annulation of *o*-alkynylthiourea that involves irradiation of UV light (with medium pressure Hg lamp) in a Pyrex glass tube requiring a large excess of tris(trimethylsilyl)silane (TTMSS) (4 equiv) and AIBN (1 equiv) in anhydrous benzene (Scheme 1a).[9] Although this method provides fruitful access to indoloquinolines, the use of certain carcinogens (benzene) and expensive and excess amounts of reagents and the requirement of a specialized setup to give moderate yields and lower substrate scope limits their applications. Therefore, developing a strategy for the synthesis of indolo-fused

Scheme 1. Strategy for the Synthesis of Indolo[2,3-*b*]quinolines



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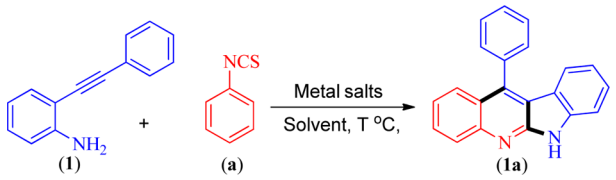
quinolines that are more efficient, cost-effective, atom-economical, and practical are sought-after (Scheme 1b).

Currently, cascade reactions are one of the most promising approaches in organic synthesis due to their high atom economy, better efficiency, and ease of handling during the assembly of complex molecular structures.[10] Such reactions have been adopted, and they have emerged as powerful synthetic tools for the conversion of internal alkynes into biologically active polycyclic heterocycles.[11] Furthermore, microwave-assisted organic syntheses have the advantage of greater reactivity, mild reaction conditions, high selectivity, and shorter reaction times.[12] Therefore, cascade reactions carried out under microwave conditions are further advantageous to conventional heating.

RESULTS AND DISCUSSION

Our group has reported the synthesis of various heterocyclic scaffolds through C−H bond functionalization and cascade/tandem reactions.[13] Owing to the promising applications of indolo[2,3-*b*]quinolines as biologically active molecules, we plan to develop an alternative and straightforward method for the synthesis of various functionalized indolo[2,3-*b*]quinolines from 2-(phenylethynyl)anilines and aryl isothiocynates. We envisaged that the *o*-alkynylthiourea formed from 2-(phenylethynyl)aniline (**1**) and phenyl isothiocynate (**a**) may undergo desulfurization in the presence of thiophilic reagents to produce a carbodiimide intermediate.[14] The enyne−carbodiimide intermediate so generated may undergo a thermal cyclization to produce the expected product indoloquinolines via a subsequent cyclization step. We first treated 2-(phenylethynyl)anilines (**1**) (1 equiv) with phenyl isothiocynate (**a**) (2 equiv) in the presence of $Cu(OAc)_2$ (0.2 equiv) as the catalyst in DMSO at 110 °C for 24 h, but no desired product could be observed (Table 1, entry 1). However, the 2-(phenylethynyl)aniline (**1**) reacted with phenyl isothiocynate (**a**) to form the corresponding thiourea, which did not undergo any further change. This result prompted us to investigate other thiophilic metals such as silver so as to facilitate simultaneous desulfurization as well as activation of the internal alkyne for effective cyclization. The superior alkynophilicity of silver is due to π-coordination with a carbon−carbon multiple bond, making it an ideal catalyst for alkyne-based organic reactions. Based on these facts, we carried out the same reaction under identical conditions but using Ag_2CO_3 (20 mol %) in lieu of $Cu(OAc)_2$. Gratifyingly, formation of a new product was observed in 21% yield (Table 1, entry 2). Characterization of the newly formed product through spectroscopic analysis (^{1}HNMR, ^{13}CNMR, and HRMS) reveals the formation of our expected product 11-phenyl-6*H*-indolo[2,3-*b*]quinoline (**1a**). Further optimizations were carried out to enhance the product yield using various silver salts [Ag_2SO_4 (12%), AgOAc (09%), $AgNO_3$ (13%), $Ag(SO_3CF_3)$ (10%)] (Table 1, entries 3−6), but none was found to be superior to Ag_2CO_3. Replacement of silver salt with another metal salt like $Mn(OAc)_2$ (Table 1, entry 7) did not serve the purpose, and the product was obtained in a mere yield of 8%. The yield of the product was enhanced up to 36% (Table 1, entry 8) when the loading of Ag_2CO_3 was increased to 1 equiv. Further increase in the Ag_2CO_3 (1.5 equiv) loading had no substantial improvement in the product yield (38%) (Table 1, entry 9). Subsequently, we explored the possibility of using nonmetallic thiophilic reagents such as DIB (Diaetoxy iodobenzene) (19%) and molecular iodine (21%) (Table 1, entries 10 and 11) in combination with Ag_2CO_3 (20 mol %).

Table 1. Optimization of Experimental Conditions[a]



entry	metal salt	solvent	temp (°C)	yield[b] (%)
1	$Cu(OAc)_2$ (20%)	DMSO	110	nd
2	Ag_2CO_3 (20%)	DMSO	110	21
3	Ag_2SO_4 (20%)	DMSO	110	12
4	AgOAc (20%)	DMSO	110	9
5	$AgNO_3$ (20%)	DMSO	110	13
6	$Ag(SO_3CF_3)$ (20%)	DMSO	110	10
7	$Mn(OAc)_2$ (20%)	DMSO	110	8
8	Ag_2CO_3 (100%)	DMSO	110	36
9	Ag_2CO_3 (150%)	DMSO	110	38
10	Ag_2CO_3 (20%)	DMSO	110	19[c]
11	Ag_2CO_3 (20%)	DMSO	110	21[d]
12	**Ag_2CO_3 (100%)**	**DMSO**	**130**	**47**
13	Ag_2CO_3 (100%)	DMSO	150	46
14	Ag_2CO_3 (100%)	DMF	130	29
15	Ag_2CO_3 (100%)	mesitylene	130	14
16	Ag_2CO_3 (100%)	chlorobenzene	130	22
17	Ag_2CO_3 (100%)	1,4-dioxane	130	15
18		DMSO	130	trace

[a]Reaction conditions: **1** (0.25 mmol), **a** (0.50 mmol), Ag salts, solvent (3 mL), 24 h. [b]Isolated pure product. [c]1 equiv of DIB. [d]1 equiv of iodine. nd = not detected.

However, the results suggest none of these combinations are suitable for this transformation. To our delight, increasing the reaction temperature to 130 °C from 110 °C improved the yield up to 47% (Table 1, entry 12). Further increasing the reaction temperature to 150 °C had no substantial effect on the product yield (46%) (Table 1, entry 13). The reaction in other solvents such as DMF, mesitylene, chlorobenzene, and 1,4-dioxane tested did not give satisfactory results compared to reaction in DMSO (Table 1, entries 14−17). Formation of a trace amount of the product in the absence of Ag_2CO_3 (Table 1, entry 18) suggests its essential role in this overall transformation.

Recently, microwave-assisted organic synthesis has been widely employed, as reaction under microwave conditions improves the product yields and shortens the reaction time. Thus, we thought of performing the above reaction under microwave conditions. Under microwave conditions [(10 min reaction time at 130 °C (150 W, closed vial)], the desired product was obtained in an improve yield of 58% (Table 2, entry 1) under otherwise identical conditions. Increasing the reaction time from 10 to 30 min enhanced the product yield up to 70% (Table 2, entry 2). However, any further increase in the reaction time (60 min) had a slightly negative effect on the product yield (Table 2, entry 3). An elevated microwave temperature 150 °C did not lead to any improvement (Table 2, entry 4). Here again, reaction in the absence of Ag_2CO_3 gave the desired product in trace amounts, suggesting that it is an essential requirement (Table 2, entry 5). Reduction in the quantity of phenyl isothiocynate (**a**) from 2 to 1.5 equiv had no substantial effect on the overall product yield (Table 2, entry 6) under the present reaction conditions. When the molar ratio of

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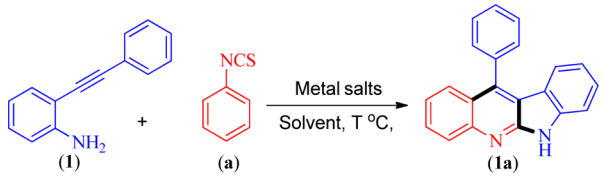
Table 2. Effect of Microwave Heating on Optimization Reaction[a]



entry	metal salt	temp (°C)	yield[b] (%)
1	Ag_2CO_3 (100%)	130	58
2	Ag_2CO_3 (100%)	130	70[c]
3	Ag_2CO_3 (100%)	130	66[d]
4	Ag_2CO_3 (100%)	150	69
5		130	trace
6	**Ag_2CO_3 (100%)**	**130**	**71**[e]
7	Ag_2CO_3 (100%)	130	62[f]

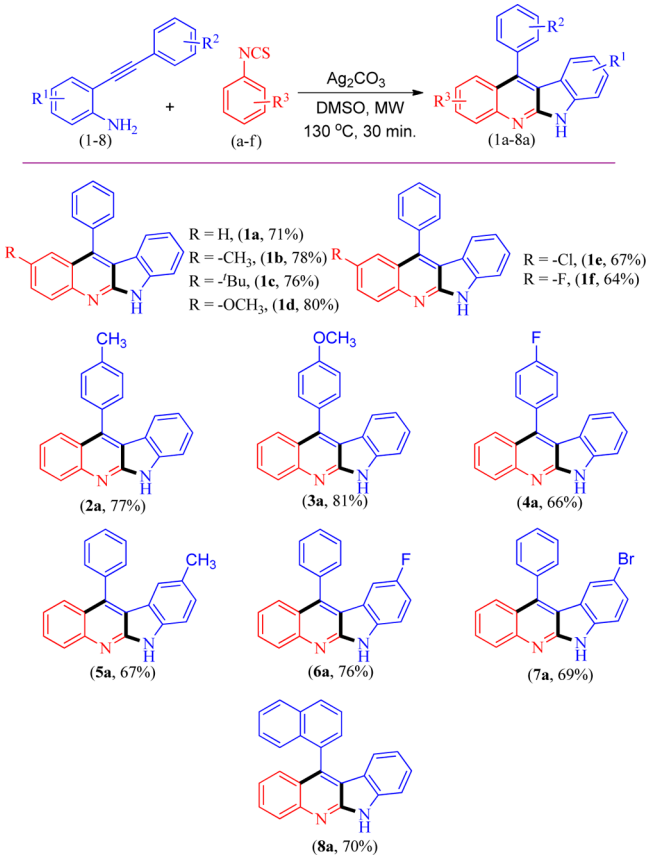
[a]Reaction conditions: **1** (0.25 mmol), **a** (0.5 mmol), Ag_2CO_3 (0.25 mmol), DMSO (3 mL), MW 10 min. [b]Isolated pure product. [c]30 min. [d]1 h. [e]**a** (0.375 mmol). [f]**a** (0.25 mmol).

1 and **a** was 1:1, the yield of the product dropped to 62% (Table 2, entry 7).

Under the optimized conditions (Table 2, entry 6), various 2-(phenylethynyl)anilines and aryl isothiocynates were subjected to the reaction conditions to explore the scope of this cascade protocol. First, the electronic effect of substituents R^3 on the aryl isothiocynate was evaluated (Scheme 2, **1a**–**f**), and the results are summarized in Scheme 2. The structure of the product (**1a**) has been unequivocally established by single-crystal X-ray crystallography (Figure S1, see the Supporting Information). Phenyl isothiocynates possessing electron-donating (EDG) substituents (**b**–**d**) at the *para* position afforded the corresponding products in better yields compared to unsubstituted (**a**) and electron-withdrawing (EWG) substituents (**e**, **f**). Phenyl isothiocynates having substituents such as −Me (**b**), −^{t}Bu (**c**), and −OMe (**d**) at their *para* position provided the corresponding products **1b** (78%), **1c** (76%), and **1d** (80%) (Scheme 2), respectively. Comparatively lower yields of the indolo[2,3-*b*]quinolines **1e**,**f** (Scheme 2) were obtained when moderately electron-withdrawing groups [−Cl (**e**, 67%) and −F (**f**, 64%)] were present on the phenyl isothiocynate. We also examined the effect of substituents R^2 present on the other phenyl ring of 2-(phenylethynyl)aniline on the product yield and found an effect similar to that of R^3 substituents on the phenyl isothiocynate; i.e., substrates bearing electron-releasing groups such as −Me (**2**) and −OMe (**3**) furnished better yields (**2a**, 77%; **3a**, 81%) of their product compared to electron-withdrawing substituents −F (**4**) giving product (**4a**, 66%) when reacted with phenyl isothiocynate (**a**) (Scheme 2).

Next, the effect of R^1 substituents present on the amine-bearing ring of 2-(phenylethynyl)anilines **5**–**7** on the reaction shows a trend on the product yields opposite to that of substituents R^2 and R^3. When substituent R^1 is an electron-donating group such as −Me (**5**), the product (**5a**) was obtained in 67% yield, whereas the presence of electron-withdrawing substituents such as −F (**6**) and −Br (**7**) leads to their corresponding products **6a** and **7a** in 76% and 69% yield, respectively. 2-(Naphthalen-1-ylethynyl)aniline (**8**) also reacted efficiently with phenyl isothiocynate (**a**) to provide the indoloquinoline (**8a**) in 70% yield (Scheme 2). To demonstrate the scalability of the present methodology, a reaction was carried out with 2-(phenylethynyl)anilines (**1**) (4.15 mmol, 800 mg) with phenyl isothiocynate (**a**) (6.23 mmol, 841 mg) under the optimized reaction conditions to give 51% yield of the product.

Scheme 2. Substrate Scope for the Synthesis of Indolo[2,3-*b*]quinolines[a,b]



[a]Reaction conditions: **1**–**8** (0.25 mmol), **a**–**f** (0.375 mmol), Ag_2CO_3 (0.25 mmol), MW, 130 °C, time 20–30 min. [b]Yields of the pure product reported.

The present strategy was equally successful for any type of substituents (R^1, R^2, and R^3) present anywhere on the aryl ring of the substrates (Scheme 3). When both substituents R^2 and R^3 were electron-donating such as *p*-Me (**2**)/*p*-Me (**b**) and *p*-OMe (**3**)/*p*-Me (**b**), good yields (81% and 83%) of their respective products **2b** and **3b** were obtained. On the other hand, when R^2 was electron-donating and R^3 was electron-withdrawing such as *p*-Me (**2**)/*p*-F (**f**) and *p*-OMe (**3**)/*p*-F (**f**), the yields of the isolated products were slightly lower (**2f**, 74%; **3f**, 76%). When the substituent positions were reversed, i.e., R^2 was substituted with an electron-withdrawing group 4-F (**4**) and R^3 with an electron-donating group 4-Me (**b**), the cascade product (**4b**) was obtained in 73% yield. Substitution of R^2 and R^3 with an electron-withdrawing group 4-F (**4**) led to a further drop in the product yield (**4f**, 62%). Next, when substituents R^1 and R^3 were EDG and EWG or R^1 with an EDG and R^3 with an EWG group or vice versa, moderate yields ranges between 59 and 74% of their corresponding products **5b**–**6f** were obtained. Further, when both R^1 and R^2 were either electron-donating 4-Me (**9**) or electron-withdrawing 4-F (**10**) groups, products **9a** and **10a** were obtained in 67% and 70% yields, respectively. When all of the substituent R^1, R^2, and R^3 were either 4-Me or 4-F, the products (**9b** and **10f**) were isolated in 72% and 63% yields, respectively. In this multistep process it is difficult to

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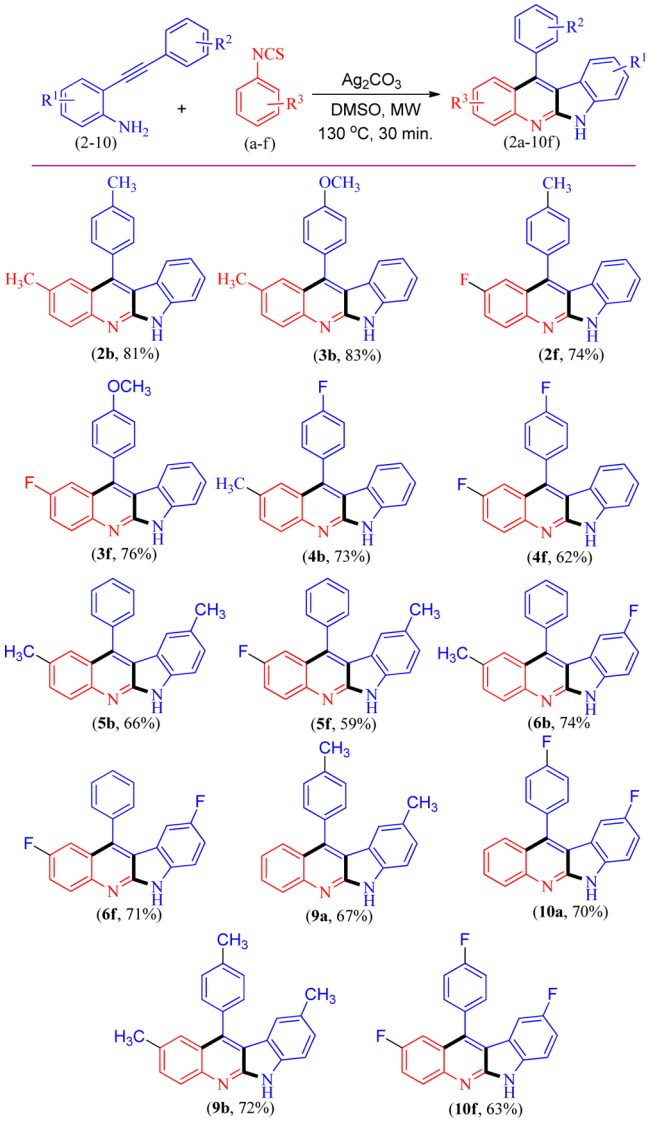
Scheme 3. Reaction of Substituted 2-(Phenylethynyl)anilines and Phenyl Isothiocynates[a,b]

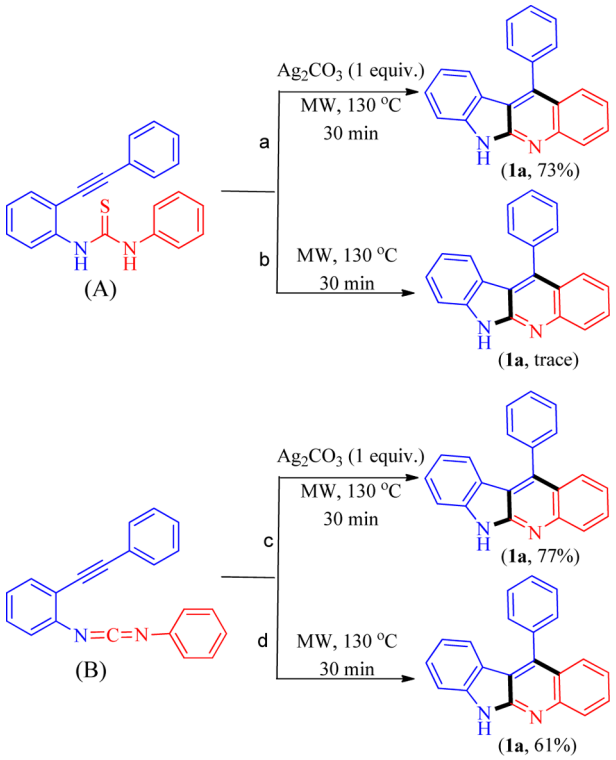


[a]Reaction conditions: **2**–**10** (0.25 mmol), **a**–**f** (0.0375 mmol), Ag_2CO_3 (0.25 mmol), MW, 130 °C, time 20–30 min. [b]Yields of the pure product reported.

determine the exact rate-determining steps; however, from Schemes 2 and 3 it is evident that the electronic effect of substituent R^1 on the product yield is more significant compared to substituents R^2 and R^3. When strongly electron-withdrawing substituents such as $-NO_2$, $-CN$, and $-CF_3$ were present on the R^1 ring (amine-bearing ring), the starting materials remained unreacted (even thiourea intermediate was not formed). Nevertheless, when the same electron-withdrawing substituents were present on the R^3 ring (i.e., aryl isothiocyanate), both reacted to form the intermediate thiourea but failed to undergo any further transformation. However, preformed carbodiimide intermediates were used, similar annulated products were successfully obtained even for substrates bearing strong electron-withdrawing groups as reported.[8b]

To understand the mechanism of this process, a few control experiments were conducted (Scheme 4). When a presynthesized 1-phenyl-3-(2-(phenylethynyl)phenyl)thiourea (**A**) was

Scheme 4. Control Experiments



subjected to the standard reaction conditions, formation of the expected product (**1a**) in 73% yield suggested the possible formation of a thiourea intermediate (**A**) in the present transformation (Scheme 4, path a). However, in the absence of Ag_2CO_3 the reaction was completely unproductive, revealing the essential requirements of Ag_2CO_3 in the overall transformation (Scheme 4, path b). Furthermore, 2-(phenylethynyl)-*N*-((phenylimino)methylene)aniline (**B**) afforded the desired product in the presence of Ag_2CO_3 (77%) (Scheme 4, path c) and in its absence (61%) (Scheme 4, path d). Thus, the major role of the Ag_2CO_3 is the generation of carbodiimide intermediate (**B**) from thiourea (**A**).

Formation of Ag_2S via desulfurization of thiourea has been confirmed by the powder XRD and EDX analysis as shown in Figure 2. The powder X-ray diffraction (PXRD) patterns showed the phase purity and crystal structure of the formed Ag_2S, as shown in Figure 2i. The PXRD pattern of Ag_2S is defined as a monoclinic acanthite phase with (121), (102), (012), (043), (025), (−102), (411), (−103), (−123), (031), (102), (112), (004), (014), (−133), (−215), (041), (−225), (−105), (−116), and (141) crystal planes according to the JCPDS card no. 24-0715. To further confirm the elemental composition and distribution in Ag_2S, selected area elemental mapping was carried out by energy-dispersive X-ray (EDX) spectroscopic technique that is depicted in the Figure 2ii. The EDX pattern in Figure 2ii shows the elemental compositions (At %) contained in the Ag_2S. It shows that Ag_2S contains a weight ratio of silver to sulfur 2.3:1, which is very close to the expected ratio of Ag_2S (2:1).

On the basis of our experimental findings and previous literature,[8] a plausible reaction mechanism has been proposed as depicted in Scheme 5. Reaction of 2-(phenylethynyl)anilines (**1**) and phenyl isothiocynate (**a**) forms intermediate thiourea (**A**), which is desulfurized in the presence of Ag_2CO_3 to a

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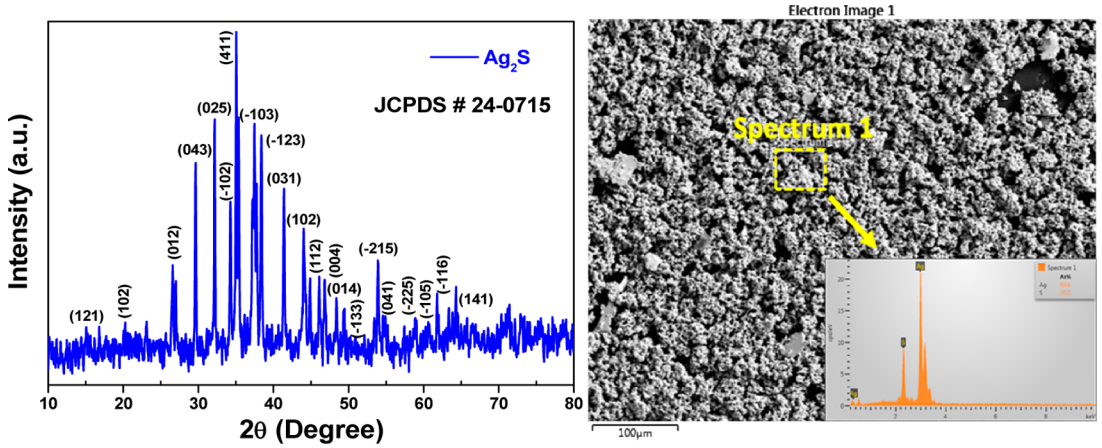
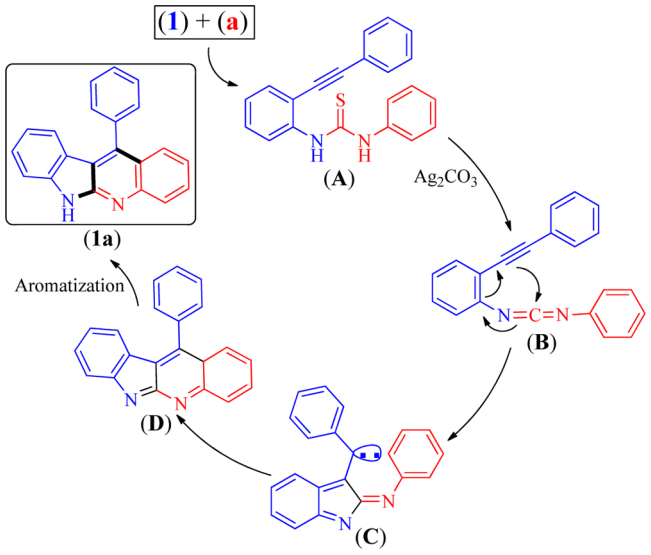


Figure 2. (i) Powder X-ray diffraction (PXRD) and (ii) energy-dispersive X-ray spectroscopy (EDS) pattern of the formed Ag_2S.

Scheme 5. Proposed Mechanistic Pathway



carbodiimide intermediate (**B**).[14] Intramolecular thermal cyclization of (**B**) generated a carbene-type intermediate (**C**). The intermediate (**C**) undergoes further cyclization via carbene C−H insertion to form a nonaromatic cyclize species (**D**), which is aromatized to give the desired product (**1a**) (Scheme 5).

In conclusion, we have developed an elegant cascade approach for the synthesis of indoloquinolines. This protocol allows the practical synthesis of many valuable indolquinoline alkaloids through Ag_2CO_3-mediated cascade annulation of internal alkynes under microwave heating. This methodology has the advantage of good functional group tolerance, mild microwave conditions, and shorter reaction time.

EXPERIMENTAL SECTION

General Information. All of the reagents were commercial grade and used without purification. Organic extracts were dried over anhydrous sodium sulfate. Solvents were removed in a rotary evaporator under reduced pressure. Silica gel (60−120 mesh size) was used for column chromatography. Microwave reactions were carried out on the CEM Discover system (Model No. 908010, manufactured by CEM Co., with a vertically focused infrared (IR) temperature control system. Reactions were monitored by TLC on silica gel 60 F_{254} (0.25 mm). NMR spectra were recorded in DMSO-d_6, $CDCl_3$ with tetramethylsilane as the internal standard for ^{1}H NMR (400 and 600 MHz), DMSO-d_6, or $CDCl_3$ solvent as the internal standard for ^{13}C NMR (100 and 150 MHz). HRMS spectra were recorded using ESI mode (Q-TOF MS analyzer).

General Procedure for the Synthesis of 11-Phenyl-6*H*-indolo[2,3-*b*]quinolone (1a). 2-(Phenylethynyl)aniline (**1**) (0.25 mmol, 48 mg), phenyl isothiocynate (**a**) (0.375 mmol, 51 mg), and Ag_2CO_3 (0.25 mmol, 69 mg) in DMSO (1 mL) were combined in an oven-dried microwave reaction tube. The reaction vial was then sealed with a cap and stirred at 130 °C (150 W) under microwave irradiation for 0.5 h. The reaction mixture was then cooled to room temperature and admixed with ethyl acetate (25 mL). The organic layer was washed sequentially with a saturated solution of sodium bicarbonate (2 × 5 mL). The organic layer was dried over anhydrous Na_2SO_4 and evaporated under vacuum. The crude product so obtained was then purified by silica gel column chromatography using EtOAc and hexane as eluent to give product **1a** (52 mg, 71%).

*11-Phenyl-6H-indolo[2,3-b]quinoline (**1a**).*[9] Brown solid (52 mg, 71%). Mp: 251−253 °C. ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 6.92−6.93 (m, 2H), 7.34−7.43 (m, 2H), 7.47 (dd, 1H, J = 6.8 Hz), 7.53 (dd, 2H, J = 8.0 Hz), 7.62−7.71 (m, 5H), 8.04 (d, 1H, J = 8.4 Hz), 11.81 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 110.8, 115.4, 119.2, 120.2, 122.3, 122.7, 122.9, 125.7, 127.2, 127.8, 128.4, 128.6, 128.98, 129.02, 136.0, 141.4, 141.6, 146.3, 152.5. HRMS (ESI): calcd for $C_{21}H_{15}N_2$ [M + H$^+$] 295.1230, found 295.1224.

*2-Methyl-11-phenyl-6H-indolo[2,3-b]quinoline (**1b**).*[6e] Yellow solid (60 mg, 78%). Mp: 253−255 °C. ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 2.37 (s, 3H), 6.86 (d, 1H, J = 7.6 Hz), 6.92 (t, 1H, J = 7.6 Hz), 7.38 (s, 1H), 7.41 (t, 1H, J = 6.8 Hz), 7.47 (d, 1H, J = 8.0 Hz), 7.51−7.55 (m, 3H), 7.64−7.72 (m, 3H), 7.95 (d, 1H, J = 8.8 Hz), 11.78 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 21.3, 110.9, 115.4, 119.2, 120.3, 122.5, 122.8, 124.3, 127.2, 127.8, 128.7, 129.1, 129.2, 130.8, 131.8, 136.2, 140.8, 141.6, 144.9, 152.1. HRMS (ESI): calcd for $C_{22}H_{17}N_2$ [M + H$^+$] 309.1386, found 309.1382.

*2-(tert-Butyl)-11-phenyl-6H-indolo[2,3-b]quinoline (**1c**).* Yellow solid (66.5 mg, 76%). Mp: 259−261 °C. ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 1.25 (s, 9H), 6.90−6.96 (m, 2H), 7.40−7.44 (m, 1H), 7.47 (d, 1H, J = 8.0 Hz), 7.56 (d, 3H, J = 6.8 Hz), 7.66−7.74 (m, 3H), 7.84 (dd, 1H, J = 8.8 Hz), 7.99 (d, 1H, J = 8.8 Hz) 11.76 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 30.9, 34.5, 110.9, 115.3, 119.2, 120.2, 120.3, 122.2, 122.3, 127.0, 127.5, 127.8, 128.7, 129.1, 136.1, 141.5, 141.6, 144.8, 144.9, 152.3. HRMS (ESI): calcd for $C_{25}H_{23}N_2$ [M + H$^+$] 351.1856, found 351.1852.

*2-Methoxy-11-phenyl-6H-indolo[2,3-b]quinoline (**1d**).*[6e] Black solid (65 mg, 80%). Mp: 257−259 °C. ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 3.78 (s, 3H), 6.96 (t, 1H, J = 8.4 Hz), 7.03 (d, 1H, J = 7.6 Hz), 7.07 (d, 1H, J = 7.8 Hz), 7.38 (d, 2H, J = 7.6 Hz), 7.48 (d, 1H, J = 8.0 Hz), 7.53−7.55 (m, 2H), 7.63−7.70 (m, 3H), 8.11 (d, 1H, J = 9.2 Hz), 12.18 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 55.7, 105.0, 110.9, 117.0, 119.7, 121.1, 121.2, 123.2, 124.3, 127.9, 128.0, 128.7, 129.3, 129.5, 136.8, 141.6, 141.8, 142.2, 152.3,

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155.4. HRMS (ESI): calcd for $C_{22}H_{17}N_2O$ [M + H$^+$] 325.1335, found 325.1337.

*2-Chloro-11-phenyl-6H-indolo[2,3-b]quinoline (**1e**).* White solid (55 mg, 67%). Mp: 207−209 °C. ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 6.90−6.97 (m, 2H), 7.42−7.46 (m, 1H), 7.49 (d, 1H, J = 8.0 Hz), 7.52−7.55 (m, 3H), 7.66−7.73 (m, 4H), 8.04 (d, 1H, J = 8.8 Hz), 11.94 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 111.0, 116.2, 119.5, 119.9, 122.5, 123.5, 124.0, 127.0, 128.3, 128.8, 128.9, 129.0, 129.2, 129.3, 135.2, 140.5, 141.8, 144.7, 152.6. HRMS (ESI): calcd for $C_{21}H_{14}ClN_2$ [M + H$^+$] 329.0840, found 329.0828.

*2-Fluoro-11-phenyl-6H-indolo[2,3-b]quinoline (**1f**).*[6e] Yellow solid (50 mg, 64%). Mp: 266−268 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 6.91 (t, 1H, J = 8.0 Hz), 6.99 (d, 1H, J = 8.0 Hz), 7.23−7.42 (m, 6H), 7.63−7.65 (m, 3H), 8.04 (dd, 1H, J = 8.8 Hz), 12.55 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 109.6, 109.9, 111.0, 117.3, 118.7, 118.9, 119.9, 120.5, 123.2, 124.0, 124.1, 128.1, 128.2, 128.3, 129.0, 129.3, 129.5, 136.0, 141.9, 142.05, 142.1, 143.0, 152.9, 157.3, 159.7. HRMS (ESI): calcd for $C_{21}H_{14}FN_2$ [M + H$^+$] 313.1136, found 313.1147.

*11-(p-Tolyl)-6H-indolo[2,3-b]quinoline (**2a**).* Yellowish solid (59.5 mg, 77%). Mp: 221−223 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) 2.60 (s, 3H), 7.01 (t, 1H, J = 8.0 Hz), 7.16 (d, 1H, J = 8.0 Hz), 7.38−7.45 (m, 4H), 7.46 (d, 2H, J = 8.0 Hz), 7.53 (t, 1H, J = 8.0 Hz), 7.74 (dd, 1H, J = 6.8 Hz), 7.83 (dd, 1H, J = 8.8 Hz), 8.23 (d, 1H, J = 8.0 Hz), 12.34 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 21.7, 111.0, 117.1, 119.9, 121.4, 123.0, 123.3, 124.1, 125.6, 126.5, 126.9, 128.0, 129.0, 129.5, 129.8, 133.5, 138.5, 141.8, 143.3, 146.3, 153.6. HRMS (ESI): calcd for $C_{22}H_{17}N_2$ [M + H$^+$] 309.1386, found 309.1394.

*11-(4-Methoxyphenyl)-6H-indolo[2,3-b]quinoline (**3a**).* Brown solid (65.5 mg, 81%). Mp: 243−245 °C. ^{1}H NMR (600 MHz, DMSO-d_6): δ (ppm) 3.91 (s, 3H), 6.98 (t, 1H, J = 7.8 Hz), 7.06 (d, 1H, J = 7.8 Hz), 7.24 (d, 2H, J = 9.2 Hz), 7.38 (t, 1H, J = 7.8 Hz), 7.43 (dd, 1H, J = 7.8 Hz), 7.44−7.49 (m, 3H), 7.67−7.72 (m, 2H), 8.04 (d, 1H, J = 8.4 Hz) 11.83 (s, 1H). ^{13}C NMR (150 MHz, DMSO-d_6): δ (ppm) 55.3, 110.9, 114.5, 115.7, 119.3, 120.4, 122.4, 122.8, 123.3, 125.9, 127.3, 127.8, 127.9, 128.5, 130.5, 141.5, 141.6, 146.4, 152.5, 159.5. HRMS (ESI): calcd for $C_{22}H_{17}N_2O$ [M + H$^+$] 325.1335, found 325.1334.

*11-(4-Fluorophenyl)-6H-indolo[2,3-b]quinoline (**4a**).* Brown solid (51.5 mg, 66%). Mp: 297−299 °C. ^{1}H NMR (600 MHz, DMSO-d_6): δ (ppm) 6.95 (d, 1H, J = 7.8 Hz), 7.00 (t, 1H, J = 7.2 Hz), 7.40 (t, 1H, J = 7.8 Hz), 7.44−7.47 (m, 1H), 7.50 (d, 1H, J = 7.8 Hz), 7.54 (t, 2H, J = 8.4 Hz), 7.61−7.62 (m, 3H), 7.73 (t, 1H, J = 7.8 Hz), 8.05 (d, 1H, J = 9.0 Hz), 11.88 (s, 1H). ^{13}C NMR (150 MHz, DMSO-d_6): δ (ppm) 111.0, 115.7, 116.2, 116.3, 118.2, 119.5, 120.1, 122.3, 123.0, 125.6, 127.3, 128.1, 128.7, 128.8, 131.35, 131.41, 132.2, 140.5, 141.7, 146.3, 152.4, 161.5, 163.2. HRMS (ESI): calcd for $C_{21}H_{14}FN_2$ [M + H$^+$] 313.1136, found 313.1150.

*9-Methyl-11-phenyl-6H-indolo[2,3-b]quinoline (**5a**).*[8b] Pale yellow solid (51.5 mg, 67%). Mp: 193−195 °C. ^{1}H NMR (600 MHz, DMSO-d_6): δ (ppm) 2.17 (s, 3H), 6.70 (s, 1H), 7.26 (d, 1H, J = 7.6 Hz), 7.37 (dd, 2H, J = 9.6 Hz), 7.47 (d, 1H, J = 7.8 Hz), 7.53 (d, 2H, J = 7.8 Hz), 7.61 (d, 1H, J = 7.8 Hz), 7.68−7.71 (m, 3H), 8.03 (d, 1H, J = 8.4 Hz), 11.73 (s, 1H). ^{13}C NMR (150 MHz, DMSO-d_6): δ (ppm) 21.1, 110.7, 115.4, 118.2, 120.3, 121.8, 122.4, 122.7, 125.7, 127.2, 127.8, 128.5, 128.7, 128.8, 129.1, 136.0, 139.8, 141.4, 146.3, 152.7. HRMS (ESI): calcd for $C_{22}H_{17}N_2$ [M + H$^+$] 309.1386, found 309.1392.

*9-Fluoro-11-phenyl-6H-indolo[2,3-b]quinoline (**6a**).* Light yellow solid (60 mg, 76%). Mp: 276−278 °C. ^{1}H NMR (600 MHz, DMSO-d_6): δ (ppm) 6.51 (dd, 1H, J = 9.6 Hz), 7.30 (td, 1H, J = 9.6 Hz), 7.39 (t, 1H, J = 7.8 Hz), 7.48 (dd, 1H, J = 8.4 Hz), 7.54 (d, 2H, J = 6.0 Hz), 7.63 (d, 1H, J = 7.8 Hz), 7.68−7.44 (m, 4H), 8.05 (d, 1H, J = 8.4 Hz), 11.89 (s, 1H). ^{13}C NMR (150 MHz, DMSO-d_6): δ (ppm) 107.8, 108.0, 111.9, 112.0, 115.1, 115.3, 115.4, 120.6, 120.7, 122.6, 123.0, 125.9, 127.4, 128.9, 128.98, 129.03, 129.2, 135.5, 138.1, 142.3, 146.7, 153.0, 155.4, 157.0. HRMS (ESI): calcd for $C_{21}H_{14}FN_2$ [M + H$^+$] 313.1136, found 313.1150.

*9-Bromo-11-phenyl-6H-indolo[2,3-b]quinoline (**7a**).*[6d] Brown solid (64 mg, 69%). Mp: 229−231 °C. ^{1}H NMR (600 MHz, DMSO-d_6): δ (ppm) 6.93 (s, 1H), 7.27 (t, 2H, J = 7.2 Hz), 7.45 (d, 2H, J = 8.4 Hz), 7.55 (d, 1H, J = 6.0 Hz), 7.63 (d, 1H, J = 8.4 Hz), 7.70−7.76 (m, 4H), 8.06 (d, 1H, J = 8.4 Hz), 12.01 (s, 1H). ^{13}C NMR (150 MHz, DMSO-d_6): δ (ppm) 111.1, 113.0, 114.5, 118.2, 121.8, 123.3, 124.5, 125.9, 127.4, 128.8, 129.0, 129.3, 130.3, 135.5, 139.7, 140.5, 142.4, 146.8, 152.4. HRMS (ESI): calcd for $C_{21}H_{14}BrN_2$ [M + H$^+$] 373.0335, found 373.0350.

*11-(Naphthalen-1-yl)-6H-indolo[2,3-b]quinoline (**8a**).* Brown solid (60 mg, 70%). Mp: 256−259 °C. ^{1}H NMR (600 MHz, DMSO-d_6): δ (ppm) 6.35 (d, 1H, J = 7.8 Hz), 6.73 (t, 1H, J = 7.8 Hz), 7.09 (d, 1H, J = 8.4 Hz), 7.22 (t, 1H, J = 7.8 Hz), 7.26 (t, 1H, J = 7.2 Hz), 7.33−7.38 (m, 2H), 7.48 (d, 1H, J = 8.4 Hz), 7.52 (t, 1H, J = 7.8 Hz), 764 (d, 1H, J = 6.6 Hz), 7.70 (t, 1H, J = 7.8 Hz), 7.79 (t, 1H, J = 7.8 Hz), 8.12 (d, 2H, J = 8.4 Hz), 8.23 (d, 1H, J = 8.4 Hz), 11.93 (s, 1H). ^{13}C NMR (150 MHz, DMSO-d_6): δ (ppm) 110.9, 116.5, 119.3, 120.0, 122.2, 123.0, 123.5, 124.9, 125.8, 126.0, 126.5, 126.9, 127.1, 127.4, 128.0, 128.6, 128.7, 129.0, 131.0, 133.4, 133.5, 139.5, 141.7, 146.4, 152.6. HRMS (ESI): calcd for $C_{25}H_{17}N_2$ [M + H$^+$] 345.1386, found 345.1373.

*2-Methyl-11-(p-tolyl)-6H-indolo[2,3-b]quinoline (**2b**).* Light yellow solid (65 mg, 81%). Mp: 303−305 °C. ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 2.16 (s, 3H), 2.29 (s, 3H), 6.69−6.74 (m, 2H), 7.18 (d, 4H, J = 7.6 Hz), 7.26 (t, 3H, J = 7.6 Hz), 7.31 (dd, 1H, J = 8.8 Hz), 7.72 (d, 1H, J = 8.4 Hz) 11.51 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 21.1, 21.2, 110.7, 115.5, 118.2, 119.1, 120.3, 122.3, 123.0, 124.4, 127.1, 127.7, 128.9, 129.7, 131.5, 133.1, 137.8, 140.9, 141.6, 144.9, 152.1. HRMS (ESI): calcd for $C_{23}H_{19}N_2$ [M + H$^+$] 323.1543, found 323.1552.

*11-(4-Methoxyphenyl)-2-methyl-6H-indolo[2,3-b]quinoline (**3b**).* Yellow solid (70 mg, 83%). Mp: 275−278 °C. ^{1}H NMR (600 MHz, DMSO-d_6): δ (ppm) 2.38 (s, 3H), 3.91 (s, 3H), 6.96 (t, 1H, J = 7.2 Hz), 7.00 (d, 1H, J = 7.8 Hz), 7.24 (d, 2H, J = 8.4 Hz), 7.40−7.45 (m, 5H), 7.53 (d, 1H, J = 9.0 Hz), 7.94 (d, 1H, J = 8.4 Hz), 11.75 (s, 1H); ^{13}C NMR (150 MHz, DMSO-d_6): δ (ppm) 21.2, 55.2, 110.8, 114.5, 115.7, 119.2, 120.4, 122.3, 123.2, 124.5, 127.1, 127.8, 128.0, 130.4, 130.7, 131.7, 140.9, 141.6, 145.0, 152.1, 159.4. HRMS (ESI): calcd for $C_{23}H_{19}N_2O$ [M + H$^+$] 339.1492, found 339.1482.

*2-Fluoro-11-(p-tolyl)-6H-indolo[2,3-b]quinoline (**2f**).* Pale brown solid (60 mg, 74%). Mp: 280−282 °C. ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 2.49 (s, 3H), 6.94−7.01 (m, 2H), 7.22 (dd, 1H, J = 10.6 Hz), 7.40−7.51 (m, 6H), 7.58−7.65 (m, 1H), 8.08 (dd, 1H, J = 9.2 Hz), 11.86 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 21.1, 108.4, 108.7, 111.0, 116.1, 118.2, 118.5, 119.5, 119.8, 122.5, 123.2, 123.3, 128.3, 128.9, 129.7, 129.8, 129.9, 132.4, 138.3, 140.88, 140.93, 141.8, 143.4, 152.3, 156.4, 158.8. HRMS (ESI): calcd for $C_{22}H_{16}FN_2$ [M + H$^+$] 327.1292, found 327.1285.

*2-Fluoro-11-(4-methoxyphenyl)-6H-indolo[2,3-b]quinoline (**3f**).* Black solid (65 mg, 76%). Mp: 238−240 °C. ^{1}H NMR (600 MHz, DMSO-d_6): δ (ppm) 3.92 (s, 3H), 7.00 (t, 1H, J = 7.2 Hz), 7.07 (t, 2H, J = 7.8 Hz), 7.26 (d, 2H, J = 8.4 Hz), 7.45−7.50 (m, 3H), 7.64 (td, 1H, J = 9.6 Hz), 7.81 (d, 1H, J = 9.0 Hz), 8.09 (dd, 1H, J = 9.6 Hz), 11.85 (s, 1H). ^{13}C NMR (150 MHz, DMSO-d_6): δ (ppm) 55.3, 108.5, 108.7, 111.0, 112.4, 112.5, 114.5, 114.7, 116.3, 118.3, 118.5, 119.5, 119.9, 122.6, 123.47, 123.52, 127.3, 128.3, 129.5, 130.5, 141.8, 143.8, 143.4, 152.3, 156.8, 159.57, 159.63. HRMS (ESI): calcd for $C_{22}H_{16}FN_2O$ [M + H$^+$] 343.1241, found 343.1231.

*11-(4-Fluorophenyl)-2-methyl-6H-indolo[2,3-b]quinoline (**4b**).* Pale brown solid (59.5 mg, 73%). Mp: 288−289 °C. ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 2.39 (s, 3H), 6.89 (d, 1H, J = 7.6 Hz), 6.97 (t, 1H, J = 7.6 Hz), 7.36 (s, 1H), 7.41−7.48 (m, 2H), 7.52−7.61 (m, 5H), 7.95 (d, 1H, J = 8.4 Hz), 11.78 (s, 1H). ^{13}C NMR (150 MHz, DMSO-d_6): δ (ppm) 21.4, 111.2, 115.9, 116.4, 116.5, 119.6, 120.3, 122.4, 123.1, 124.4, 127.3, 128.2, 131.2, 131.5, 131.6, 132.3, 132.47, 132.49, 140.1, 141.8, 144.9, 152.1, 161.7, 163.3. HRMS (ESI): calcd for $C_{22}H_{16}FN_2$ [M + H$^+$] 327.1292, found 327.1274.

*2-Fluoro-11-(4-fluorophenyl)-6H-indolo[2,3-b]quinoline (**4f**).* Pale brown solid (51 mg, 62%). Mp: 308−310 °C. ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 6.96 (d, 1H, J = 7.6 Hz), 7.01 (dd, 1H, J = 8.0 Hz), 7.22 (dd, 1H, J = 7.6 Hz), 7.43−7.51 (m, 2H), 7.56 (t, 2H, J = 4.8 Hz), 7.62−7.69 (m, 3H), 8.11 (dd, 1H, J = 9.2 Hz), 11.90 (s, 1H). ^{13}C

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NMR (150 MHz, DMSO-d_6): δ (ppm) 108.7, 108.9, 111.5, 115.5, 115.7, 116.67, 116.72, 116.8, 118.9, 119.1, 119.9, 120.0, 120.5, 120.6, 122.7, 123.4, 123.5, 128.9, 129.86, 129.92, 131.59, 131.64, 140.4, 142.2, 143.3, 152.3, 157.3, 158.9, 161.9, 163.6. HRMS (ESI): calcd for $C_{21}H_{13}F_2N_2$ [M + H$^+$] 331.1041, found 331.1058.

*2,9-Dimethyl-11-phenyl-6H-indolo[2,3-b]quinoline (**5b**).* Brown solid (53 mg, 66%). Mp: 233−236 °C. ^{1}H NMR (600 MHz, DMSO-d_6): δ (ppm) 2.16 (s, 3H), 2.37 (s, 3H), 6.64 (s, 1H), 7.23 (d, 1H, J = 7.8 Hz), 7.36 (d, 2H, J = 7.8 Hz), 7.52 (dd, 3H, J = 9.6 Hz), 7.66−7.71 (m, 3H), 7.93 (d, 1H, J = 9.0 Hz), 11.64 (s, 1H). ^{13}C NMR (150 MHz, DMSO-d_6): δ (ppm) 21.1, 21.2, 110.6, 115.4, 120.4, 122.4, 122.7, 124.3, 127.1, 127.7, 128.6, 128.9, 129.08, 129.13, 130.7, 131.7, 136.2, 139.7, 140.7, 144.9, 152.3. HRMS (ESI): calcd for $C_{23}H_{19}N_2$ [M + H$^+$] 323.1543, found 323.1548.

*2-Fluoro-9-methyl-11-phenyl-6H-indolo[2,3-b]quinoline (**5f**).* Yellow solid (48 mg, 59%). Mp: 211−213 °C. ^{1}H NMR (600 MHz, DMSO-d_6): δ (ppm) 2.17 (s, 3H), 6.70 (s, 1H), 7.19 (dd, 1H, J = 8.4 Hz), 7.28 (d, 1H, J = 7.8 Hz), 7.38 (d, 1H, J = 8.4 Hz), 7.55 (d, 2H, J = 6.6 Hz), 7.63 (td, 1H, J = 9.0 Hz), 7.69−7.74 (m, 3H), 8.08 (dd, 1H, J = 9.6 Hz), 11.76 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 21.1, 108.4, 108.6, 110.8, 116.0, 118.3, 118.5, 119.9, 122.6, 122.97, 123.03, 128.0, 128.98, 129.04, 129.3, 129.5, 129.7, 129.8, 135.5, 140.0, 140.7, 143.3, 152.5, 156.8, 158.4. HRMS (ESI): calcd for $C_{22}H_{16}FN_2$ [M + H$^+$] 327.1292, found 327.1278.

*9-Fluoro-2-methyl-11-phenyl-6H-indolo[2,3-b]quinoline (**6b**).* Yellow solid (60 mg, 74%). Mp: 248−250 °C. ^{1}H NMR (600 MHz, DMSO-d_6): δ (ppm) 2.36 (s, 3H), 6.46 (dd, 1H, J = 9.0 Hz), 7.27 (td, 1H, J = 9.0 Hz), 7.37 (s, 1H), 7.46 (dd, 1H, J = 7.8 Hz), 7.51−7.54 (m, 3H), 7.66−7.71 (m, 3H), 7.93 (d, 1H, J = 8.4 Hz), 11.93 (s, 1H). ^{13}C NMR (150 MHz, DMSO-d_6): δ (ppm) 21.2, 107.7, 107.9, 111.8, 111.9, 115.0, 115.07, 115.09, 115.3, 120.68, 120.74, 122.5, 124.4, 127.2, 128.9, 129.0, 129.2, 131.2, 132.0, 135.7, 138.0, 141.6, 145.3, 152.6, 155.3, 156.9. HRMS (ESI): calcd for $C_{22}H_{16}FN_2$ [M + H$^+$] 327.1292, found 327.1303.

*2,9-Difluoro-11-phenyl-6H-indolo[2,3-b]quinoline (**6f**).* Yellow solid (58.5 mg, 71%). Mp: 296−298 °C. ^{1}H NMR (600 MHz, DMSO-d_6): δ (ppm) 6.52 (dd, 1H, J = 9.0 Hz), 7.20 (dd, 1H, J = 10.2 Hz), 7.31 (td, 1H, J = 9.0 Hz), 7.48 (dd, 1H, J = 9.0 Hz), 7.54 (d, 2H, J = 7.2 Hz), 7.63 (td, 1H, J = 9.6 Hz), 7.00−7.74 (m, 3H), 8.08 (d, 1H, J = 9.0 Hz),11.91 (s, 1H). ^{13}C NMR (150 MHz, DMSO-d_6): δ (ppm) 107.9, 108.1, 108.5, 108.6, 112.0, 112.1, 115.2, 115.3, 115.7, 115.9, 118.9, 119.0, 120.0, 120.07, 120.13, 120.2, 122.75, 122.81, 128.9, 129.2, 129.4, 129.8, 129.9, 135.0, 138.3, 141.5, 141.6, 143.7, 152.7, 155.4, 156.90, 156.94, 158.5. HRMS (ESI): calcd for $C_{21}H_{13}F_2N_2$ [M + H$^+$] 331.1041, found 331.1058.

*9-Methyl-11-(p-tolyl)-6H-indolo[2,3-b]quinoline (**9a**).* Brown solid (54 mg, 67%). Mp: 258−260 °C. ^{1}H NMR (600 MHz, DMSO-d_6): δ (ppm) 2.18 (s, 3H), 250 (s, 3H), 6.81 (s, 1H), 7.25 (d, 1H, J = 7.8 Hz), 7.34−7.38 (m, 2H), 7.41 (d, 2H, J = 7.8 Hz), 7.49 (d, 2H, J = 7.8 Hz), 7.62 (d, 1H, J = 8.4 Hz), 7.69 (t, 1H, J = 7.8 Hz), 8.02 (d, 1H, J = 8.4 Hz), 11.70 (s, 1H). ^{13}C NMR (150 MHz, DMSO-d_6): δ (ppm) 21.1, 21.2, 110.6, 115.4, 118.2, 120.4, 122.5, 122.6, 123.0, 125.8, 127.2, 128.5, 128.8, 129.0, 129.6, 133.0, 138.0, 139.7, 141.5, 146.4, 152.7. HRMS (ESI): calcd for $C_{23}H_{19}N_2$ [M + H$^+$] 323.1543, found 323.1541.

*9-Fluoro-11-(4-fluorophenyl)-6H-indolo[2,3-b]quinoline (**10a**).* Yellow solid (58 mg, 70%). Mp: 314−316 °C. ^{1}H NMR (600 MHz, DMSO-d_6): δ (ppm) 6.56 (dd, 1H, J = 9.0 Hz), 7.32 (t, 1H, J = 9.0 Hz), 7.41 (t, 1H, J = 7.8 Hz), 7.49 (dd, 1H, J = 9.0 Hz), 7.56 (t, 2H, J = 8.4 Hz), 7.62 (d, 3H, J = 7.8 Hz), 7.74 (t, 1H, J = 7.8 Hz), 8.05 (d, 1H, J = 8.4 Hz), 11.90 (s, 1H); ^{13}C NMR (150 MHz, DMSO-d_6): δ (ppm) 107.8, 107.9, 111.97, 112.03, 114.1, 115.3, 115.4, 115.6, 116.2, 116.4, 120.5, 120.6, 122.7, 123.1, 125.7, 127.4, 128.3, 129.1, 131.3, 131.4, 131.7, 138.1, 141.2, 146.7, 152.9, 155.4, 157.0, 161.6, 163.6. HRMS (ESI): calcd for $C_{21}H_{13}F_2N_2$ [M + H$^+$] 331.1041, found 331.1040.

*2,9-Dimethyl-11-(p-tolyl)-6H-indolo[2,3-b]quinoline (**9b**).* Pale brown solid (60.5 mg, 72%). Mp: 308−310 °C. ^{1}H NMR (600 MHz, DMSO-d_6): δ (ppm) 2.18 (s, 3H), 2.38 (s, 3H), 2.52 (s, 3H), 6.74 (s, 1H), 7.24 (d, 1H, J = 7.8 Hz), 7.34−7.40 (m, 4H), 7.51−7.54 (m, 3H), 7.92 (d, 1H, J = 9.0 Hz), 11.58 (s, 1H). ^{13}C NMR (150 MHz, DMSO-d_6): δ (ppm) 21.1, 21.18, 21.23, 110.6, 115.4, 120.5, 122.4, 122.9, 124.4, 127.1, 127.6, 128.9, 129.0, 129.7, 130.7, 131.6, 133.1, 137.9, 139.7, 140.9, 144.9, 152.3. HRMS (ESI): calcd for $C_{24}H_{21}N_2$ [M + H$^+$] 337.1699, found 337.1693.

*2,9-Difluoro-11-(4-fluorophenyl)-6H-indolo[2,3-b]quinoline (**10f**).* Greenish brown solid (55 mg, 63%). Mp: 316−318 °C. ^{1}H NMR (600 MHz, DMSO-d_6): δ (ppm) 6.57 (dd, 1H, J = 9.0 Hz), 7.21 (dd, 1H, J = 10.2 Hz), 7.32 (td, 1H, J = 9.0 Hz), 7.46−7.48 (m, 1H), 7.56 (t, 2H, J = 8.4 Hz), 7.63 (dd, 3H, J = 5.4 Hz), 8.07 (dd, 1H, J = 8.4 Hz), 11.90 (s, 1H). ^{13}C NMR (150 MHz, DMSO-d_6): δ (ppm) 108.5, 108.7, 109.0, 109.2, 112.68, 112.74, 115.8, 116.0, 116.4, 116.6, 117.0, 117.2, 119.5, 119.6, 120.67, 120.71, 123.48, 123.54, 130.46, 130.52, 131.9, 131.95, 132.01, 138.9, 141.08, 141.12, 144.3, 153.3, 156.0, 157.57, 157.59, 159.2, 162.4, 164.0. HRMS (ESI): calcd for $C_{21}H_{12}F_3N_2$ [M + H$^+$] 349.0947, found 349.0939.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.joc.6b02912.

X-ray diffraction data of compound **1a** and pectral data for all compounds (PDF)

X-ray data for compound **1a** (CIF)

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Notes

The authors declare no competing financial interest.

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