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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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Abstract: The *in situ* generated *o*-alkynyl thioureas obtain by reacting 2-(phenylethynyl)anilines and aryl isothiocynates undergo efficient cascade cyclization in the presence of Ag_2CO_3 forming 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 have been continuous interests to synthesized natural product like compounds with privileged scaffolds which are likely to have potential biological activities. Among these privilege scaffolds, indoloquinoline alkaloids represent one of the important class of heterocycle due to their immense biological activity[1] (Figure 1) including the ability to interact with DNA as an intercalator to inhibit topoisomerase II activity.[2] Recent results reveals that some new indolo[2,3-b]quinoline (norcryptotackieine) type of natural product isolated from the leaves of *Justicia betonica*[3] exhibits exceptional pharmacological properties such as potent antiplasmodial, antiproliferative, and antitumor.[4] For example 2-halosubstituted norcryptotackieine are more

active against plasmodium falciparum than neocryptolepine and are less cytotoxic. Besides, 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 efforts have been devoted for the synthesis of such tetracyclic-fused quinoline alkaloids both by organic and medicinal chemists with an aim to enhance 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 partner.[6d,7] The indoloquinoline system have 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*-alkynyl thiourea 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.), AIBN (1 equiv.) in anhydrous benzene (Scheme 1a).[9] Although, this method provides fruitful access to indoloquinolines, but the use of certain carcinogen (benzene), expensive and excess amount of reagents and requirements of specialized setup giving moderate yields and lesser substrate scope limits their applications. Therefore, developing strategy for the synthesis of indolo-fused quinolines that are more efficient, cost effective, atom economical and practical are well sought (Scheme 1b).

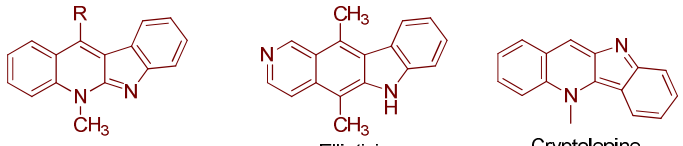
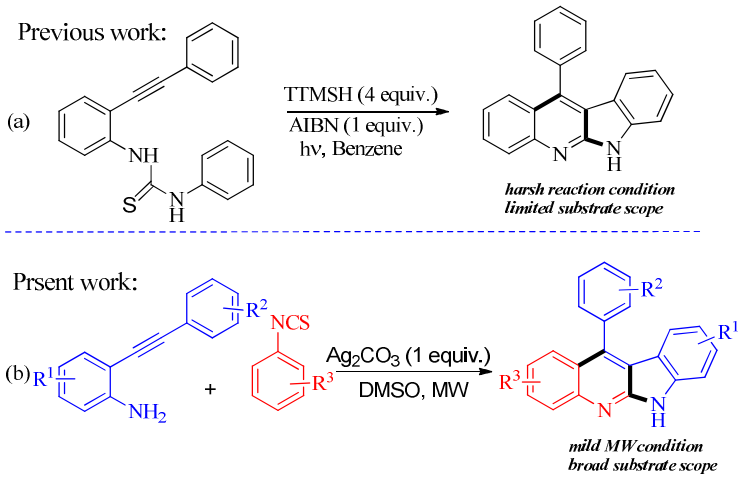


Figure 1. Selected Indoloquinoline Possessing Biological Activity

Currently, cascade reactions are one of the most promising approaches in organic synthesis due to their high atom economy, better efficiency and easy handling during the

assembly of complex molecular structures.[10] Such reactions have been adopted and emerged as powerful synthetic tools for the conversion of internal alkynes into biologically active polycyclic heterocycles.[11] Furthermore, microwave assisted organic synthesis have the advantage of greater reactivity, mild reaction conditions, high selectivity and shorter reaction times.[12] Therefore cascade reaction carried out under a microwave conditions are further advantageous to conventional heating.

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



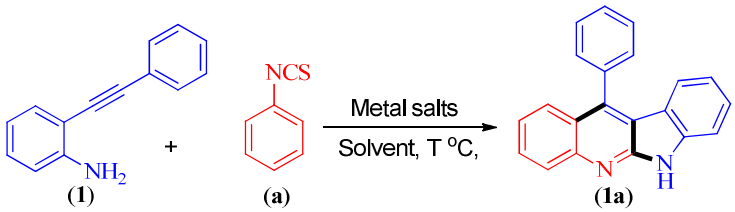
RESULT AND DISCUSSION

Our group has reported the synthesis of various heterocyclic scaffold through C–H bond functionalization and cascade/tandem reactions.[13] Owing to promising applications of indolo[2,3-b]quinolines as biologically active molecules, we plan to develop an alternative and straight forward method for the synthesis of various functionalized indolo[2,3-b]quinolines from 2-(phenylethynyl)anilines and aryl isothiocynates. We envisaged that the *o*-alkynyl thiourea 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 ^oC 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 corresponding thiourea, which did not undergo any further change. This result prompted us to investigate other thiophilic metal such as silver so as to facilitate simultaneous desulfurization as well as activation of the internal alkyne for effective cyclization. Superior alkynophilicity of silver is due to π-coordination with 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 an identical condition 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-6H-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 were found to be superior to Ag_2CO_3. Replacement of silver salt with other 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 08%. 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 equivalent. 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 non metallic thiophilic reagents such as DIB (diacetoxy benzene) (19%) and molecular iodine (21%) (Table 1, entry 10 and 11) in combination with Ag_2CO_3 (20 mol%). 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 any satisfactory result compared to that of DMSO (Table 1, entries 14-17). Formation of a trace of the product in absence of Ag_2CO_3 (Table 1, entry 14) suggests its essential role in this overall transformation.

Table 1. Optimization of Experimental Conditions[a]



(1) (a) (1a)

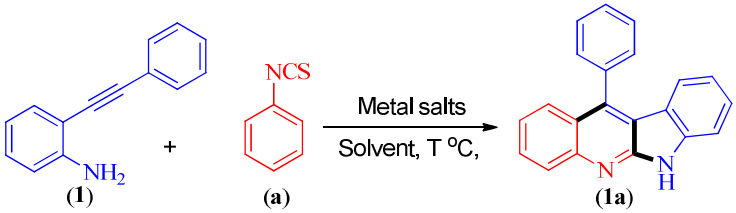
entry	metal salt	solvent	temp. (°C)	yield %[b]
1	$Cu(OAc)_2$ (20%)	DMSO	110	n.d.
2	Ag_2CO_3 (20%)	DMSO	110	21
3	Ag_2SO_4 (20%)	DMSO	110	12
4	AgOAc (20%)	DMSO	110	09
5	$AgNO_3$ (20%)	DMSO	110	13
6	$Ag(SO_3CF_3)$ (20%)	DMSO	110	10
7	$Mn(OAc)_2$ (20%)	DMSO	110	08
8	Ag_2CO_3 (100%)	DMSO	110	36
9	Ag_2CO_3 (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 condition: **1** (0.25 mmol), **a** (0.50 mmol), Ag salts, solvent (3 mL), 24 h. [b]Isolated pure product. [c]1 eq. DIB. [d]1 eq. iodine. n. d. = not detected.

Recently microwave assisted organic synthesis have been widely employed, as reaction under microwave improve the product yields and shorten the reaction time. So, we thought of

performing the above reaction under a microwave condition. Under microwave condition [(10 min. reaction time at 130 ^{o}C (150 W, closed vial)] the desired product was obtain in an improve yield of 58% (Table 2, entry 1) under otherwise identical condition. Increasing the reaction time from 10 min. to 30 min. enhance the product yield up to 70%. (Table 2, entry 2). However, any further increase in the reaction time (60 min.) had slightly negative effect on the product yield (Table 2, entry 3). An elevated temperature 150 ^{o}C of the microwave did not serve the purpose (Table 2, entry 4). Here again reaction in the absence of Ag_2CO_3 gave the desired product in trace, suggesting its essential requirement (Table 2, entry 5). Reduction in the quantity of phenyl isothiocynate (**a**) from 2 to 1.5 equivalent has no substantial effect on the overall product yield (Table 2, entry 6) under the present reaction condition. When the molar ratio of **1** and **a** was 1:1 the yield of product dropped to 62% (Table 2, entry 7).

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



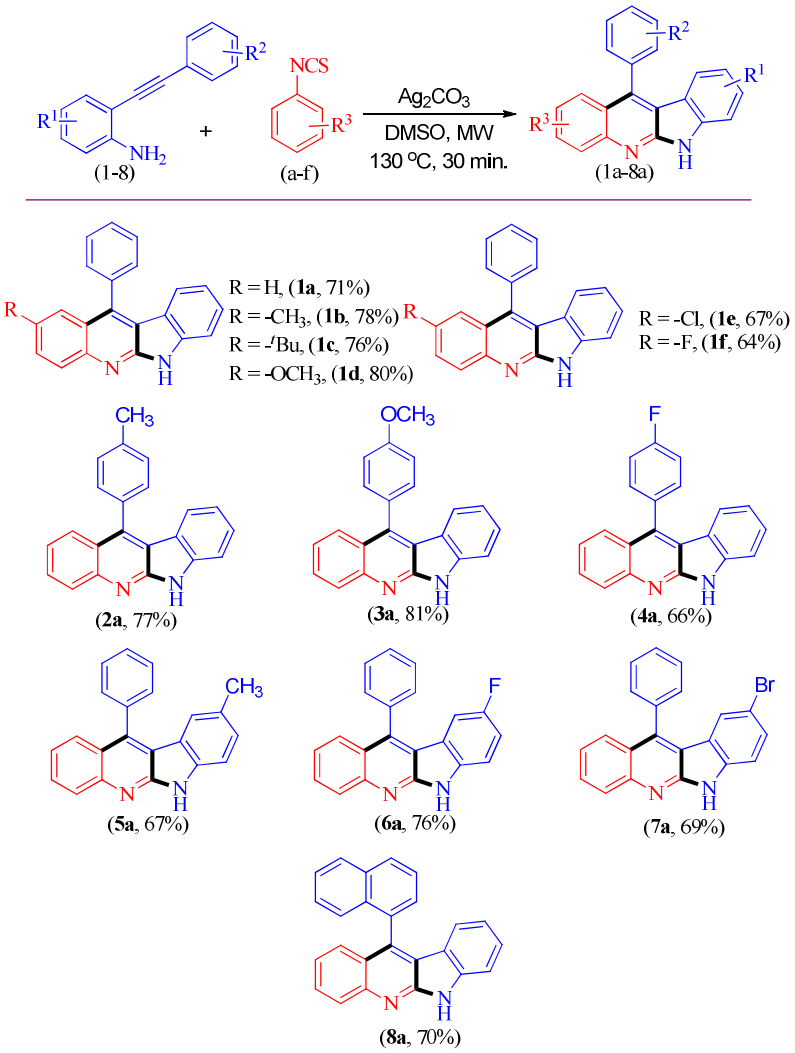
entry	metal salt	temp. (^{o}C)	yield %[b]
1	Ag_2CO_3 (100%)	130	58
2	Ag_2CO_3 (100%)	130	70[c]
3	Ag_2CO_3 (100%)	130	66[d]
4	Ag_2CO_3 (100%)	150	69
5	-	130	trace
6	**Ag_2CO_3 (100%)**	**130**	**71**[e]
7	Ag_2CO_3 (100%)	130	62[f]

[a]Reaction condition: **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).

Under the optimized condition (Table 2, entry 6), various 2-(phenylethynyl)anilines and aryl isothiocynates were subjected to the reaction condition to explore the scope of this cascade protocol. First of all the electronic effect of substituents R^3 on the aryl isothiocynate was

evaluated (Scheme 2, **1a-1f**) 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 Supporting Information). Phenyl isothiocynates possessing electron-donating (EDG) substituents (**b-d**) at *para* position afforded the corresponding products in better yields compared to un-substituted (**a**) and electron-withdrawing (EWG) substituents (**e-f**). Phenyl isothiocynates having substituent such as –Me (**b**), –^{t}Bu (**c**) and –OMe (**d**) at their *para* position provided their corresponding products (**1b**, 78%), (**1c**, 76%) and (**1d**, 80%) (Scheme 2) respectively. Comparatively lower yield of the indolo[2,3-b]quinolines (**1e-1f**, Scheme 2) were obtained when moderately electron-withdrawing groups [–Cl (**e**) (67%) and –F (**f**) (64%)] were present on the phenyl isothiocynate. We also examine the effect of substituents R^2 present on the other phenyl ring of 2-(phenylethynyl)aniline on the product yield and found similar effect 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).

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

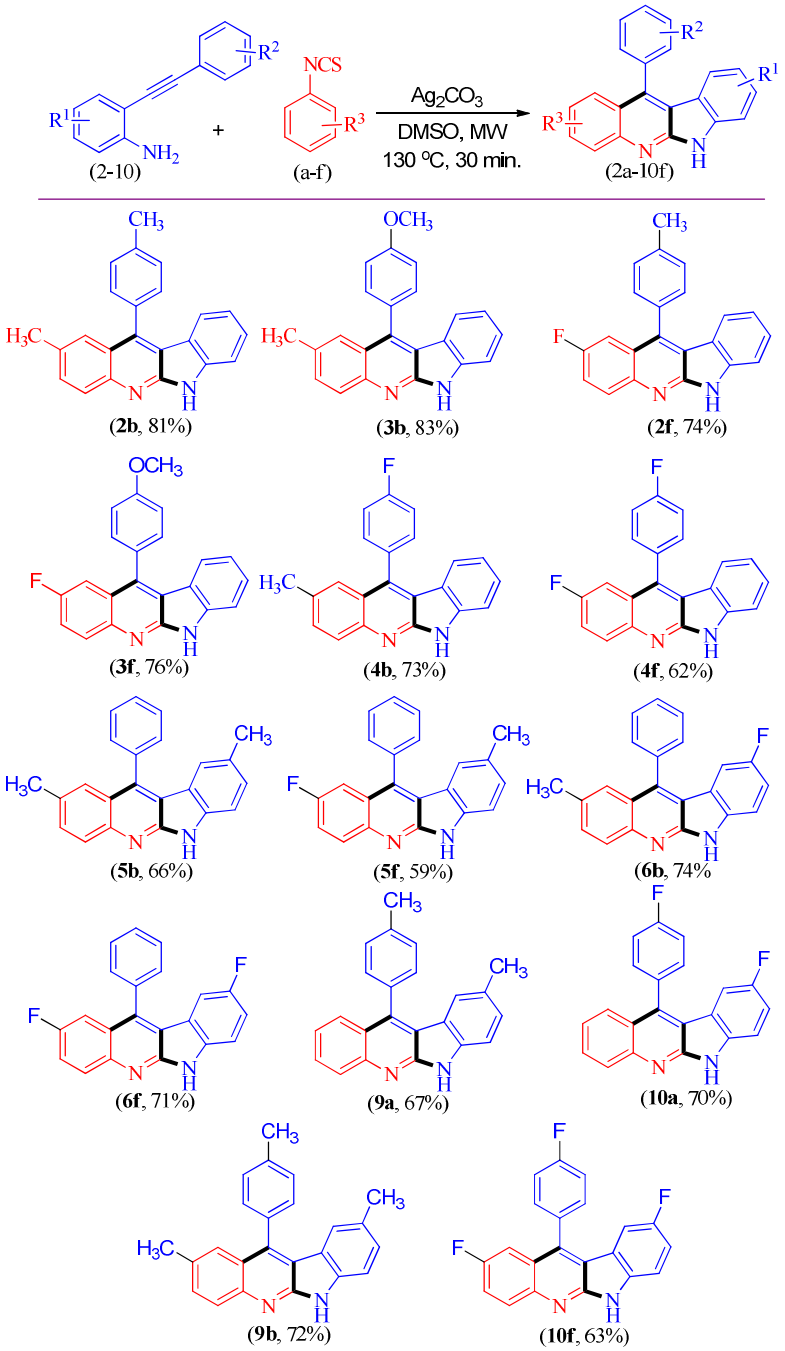


[a]Reaction conditions: **1**–**8** (0.25 mmol), **a**–**f** (0.375 mmol), Ag_2CO_3 (0.25 mmol), MW, 130 °C, time 20–30 min. [b]Yields of the pure product reported.

Next, the effect of R^1 substituents present on the amine bearing ring of 2-(phenylethynyl)anilines (**5**, **6** and **7**) on the reaction shows opposite trend on the product yields 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, presence of electron-withdrawing substituents such as –F (**6**), –Br (**7**) afford 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 giving 51% yield of the product.

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



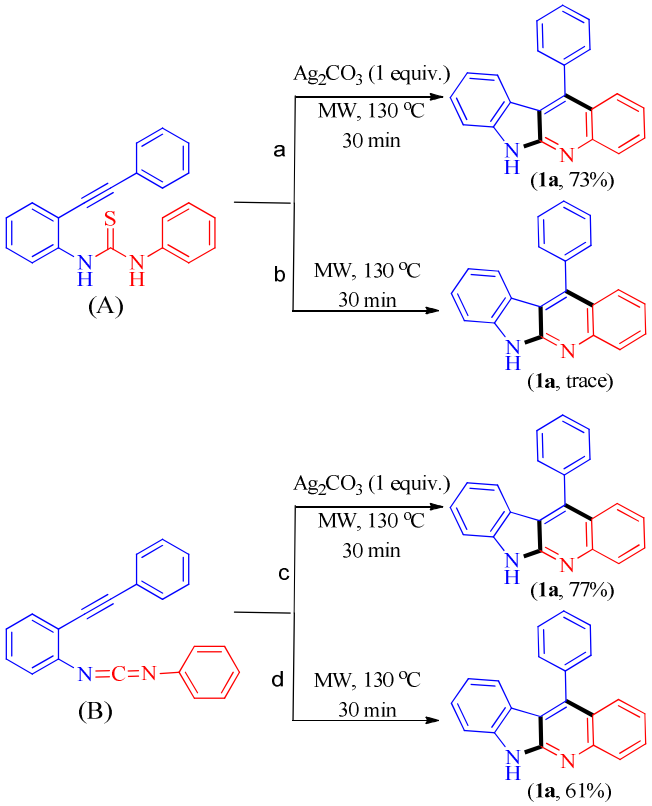
[a]Reaction conditions: **2**–**10** (0.25 mmol), **a**–**f** (0.0375 mmol), Ag_2CO_3 (0.25 mmol), MW, 130 °C, time 20–30 min. [b]Yields of the pure product reported

The present strategy was equally successful to any type of substituents (R^1, R^2 and R^3) present anywhere in the aryl ring of the substrates (Scheme 3). When both the substituents R^2 and R^3 are electron-donating such as *p*-Me (**2**)/*p*-Me (**b**), *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 is electron-donating and R^3 is electron-withdrawing substituents such as *p*-Me (**2**)/*p*-F (**f**), *p*-OMe (**3**)/*p*-F (**f**), the yields of the isolated products were slightly lower [(**2f**, 74%), (**3f**, 76%)]. When the substituents positions are reversed i.e. R^2 is 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**) leads to further drop in the product yield (**4f**, 62%). Next, when substituents R^1 and R^3 are EDG and EWG or R^1 with an EDG and R^3 with EWG group or vice versa moderate yields ranges between 59%–74% of their corresponding products (**5b**-**6f**) were obtained. Further, when both R^1 and R^2 are 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 the substituent R^1, R^2 and R^3 are either 4-Me or 4-F the products (**9b** and **10f**) were isolated in 72% and 63% yields respectively. Although, in this multistep process it is difficult to determine the exact rate determining steps, however from Scheme 2 and Scheme 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 substituent such as $–NO_2$, –CN and $–CF_3$ are 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 are 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, using preformed carbodiimide intermediates, similar annulated products were successfully obtained even for substrates bearing strong electron-withdrawing groups as reported.[8b]

To understand the mechanism of this process, few control experiments were conducted (Scheme 4). When a presynthesized 1-phenyl-3-(2-(phenylethynyl)phenyl)thiourea (**A**) was subjected to the standard reaction condition, formation of the expected product (**1a**) in 73% yield suggests 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**).

Scheme 4. Control Experiments



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 2(i). PXRD pattern of Ag_2S is defined to be 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 which is depicted in the Figure 2(ii). EDX pattern in Figure 2(ii) shows the elemental compositions (At

%) contained in the Ag_2S. It displays that Ag_2S contain a weight ratio of silver to sulphur 2.3:1, which is very close to the expected ratio of Ag_2S (2:1).

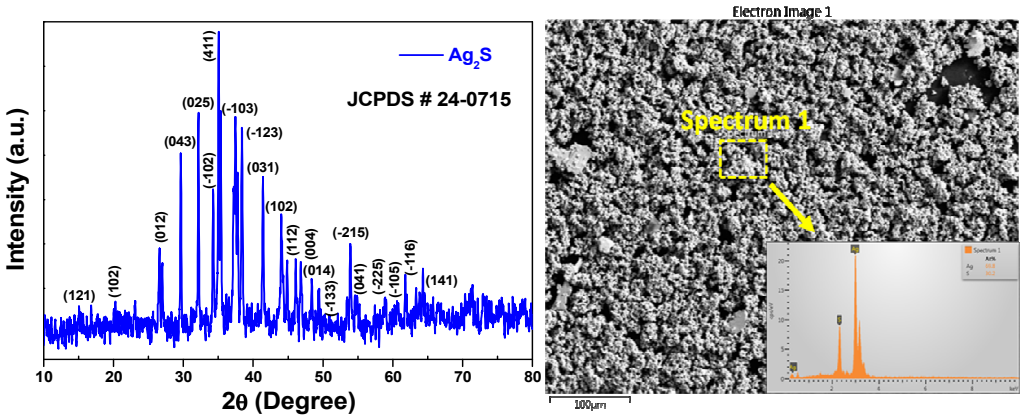
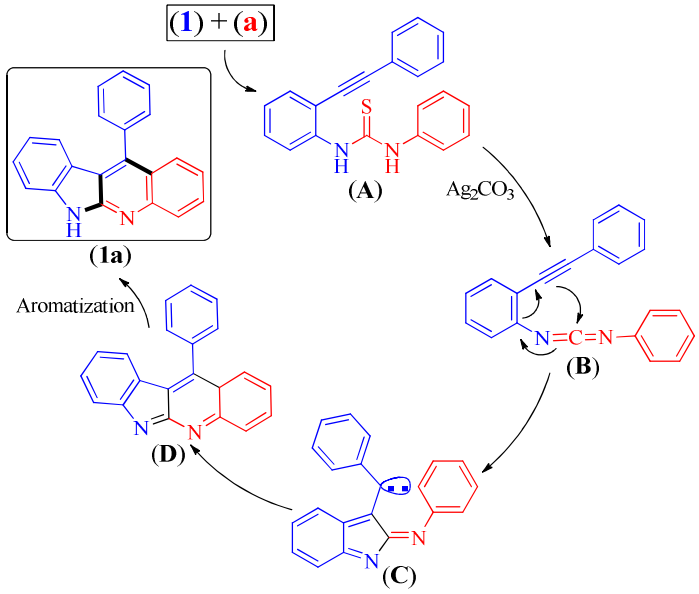


Figure 2. (i) Powder X-ray diffraction (PXRD) and (ii) Energy-dispersive X-ray spectroscopy (EDS) pattern of the formed Ag_2S

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

Scheme 5. Proposed Mechanistic Pathway



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 reaction and shorter reaction time.

EXPERIMENTAL SECTION

General information:

All the reagents were commercial grade and used without purification. Organic extracts were dried over anhydrous sodium sulphate. Solvents were removed in a rotary evaporator under reduced pressure. Silica gel (60-120 mesh size) was used for the column chromatography. The microwave reactions were carried out on the CEM Discover system (Model No. 908010, manufactured by CEM Company in USA, with vertically focused infrared [IR] temperature control system. Reactions were monitored by TLC on silica gel 60 F_{254} (0.25mm). NMR spectra

were recorded in DMSO-d_6, $CDCl_3$ with tetramethylsilane as the internal standard for ^{1}H NMR (400 MHz and 600 MHz), DMSO-d_6 or $CDCl_3$ solvent as the internal standard for ^{13}C NMR (100 MHz and 150 MHz). HRMS spectra were recorded using ESI mode (Q-TOF MS Analyzer).

General Procedure for the Synthesis of 11-Phenyl-6H-indolo[2,3-b]quinolone (1a).

2-(Phenylethynyl)aniline (**1**) (0.25 mmol, 48 mg) and phenyl isothiocynate (**a**) (0.375 mmol, 51 mg), and Ag_2CO_3 (0.25 mmol, 69 mg) in DMSO (1 mL) were taken in an oven dried microwave reaction tube. The reaction vial was then sealed with a cap and stirred at 130 ^{o}C [150 W] under microwave irradiation for 0.5h. 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 x 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%); m.p. 251–253 ^{o}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%); m.p. 253–255 ^{o}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%); m.p. 259–261 ^oC; ^1H 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%); m.p. 257–259 ^oC; ^1H 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, 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%); m.p. 207–209 ^oC; ^1H 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%); m.p. 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%); m.p. 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%); m.p. 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%); m.p. 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%); m.p. 193–195 ^{o}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%); m.p. 276–278 ^{o}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%); m.p. 229–231 ^{o}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 (60mg, 70%); m.p. 256–259 ^{o}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%); m.p. 303–305 ^{o}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%); m.p. 275–278 ^{o}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%); m.p. 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%); m.p. 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%); m.p. 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%); m.p. 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 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%); m.p. 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%); m.p. 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%); m.p. 248–250 ^oC; ^1H 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%); m.p. 296–298 ^oC; ^1H 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%); m.p. 258–260 ^oC; ^1H 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%); m.p. 314–316 ^oC; ^1H 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%); m.p. 308–310 ^oC; ^1H 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%); m.p. 316–318 ^oC; ^1H 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.

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Supporting Information Available

Spectral data for all compounds, X-ray diffraction data (CIF file) of compound **1a**, this material is available free of charge *via* the Internet at http://pubs.acs.org.

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