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Graphical Abstract

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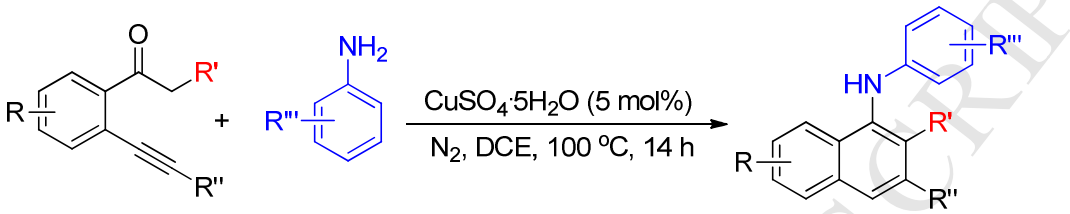

$CuSO_4 \cdot 5H_2O$-catalyzed aminobenzannulation of *ortho*-alkynylaromatic ketones with anilines approach towards 1-aminonaphthalenes

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Abstract:

An efficient catalyst system for the aminobenzannulation of *ortho*-alkynylaromatic ketones with amines affording substituted 1-aminonaphthalene derivatives with high atom-efficiency in the presence of $CuSO_4 \cdot 5H_2O$ was developed.

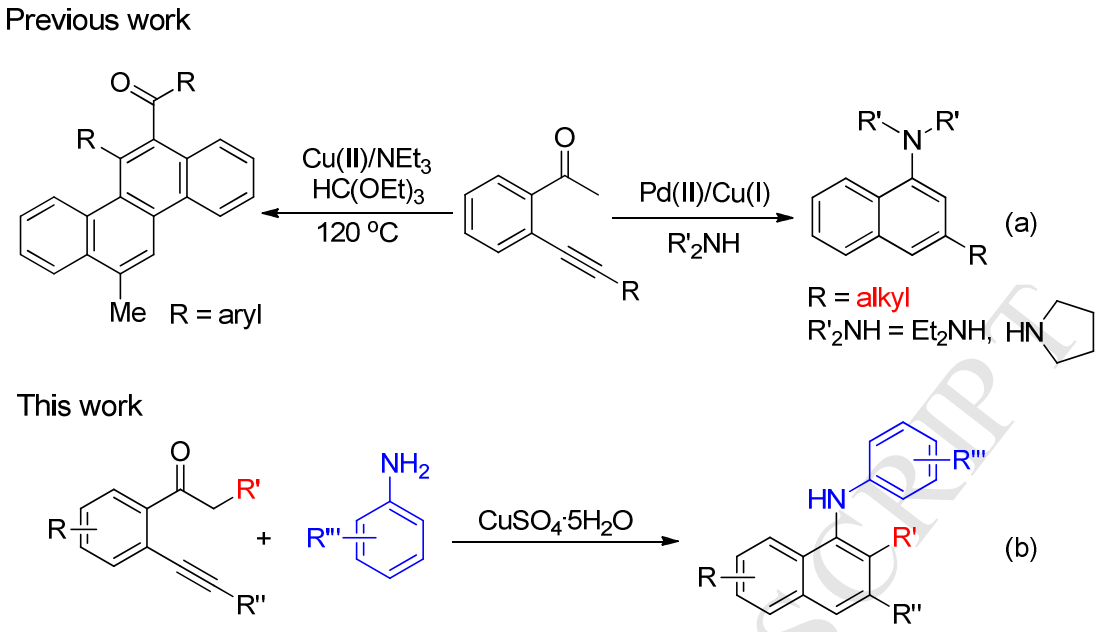
Key Words: o-Alkynylaromatic ketones; Aminobenzannulation; 1-Aminonaphthalene; Amines; Cupric sulfate pentahydrate

1. Introduction

As the simplest class of polycyclic aromatic hydrocarbons (PAHs), naphthalenes are particularly appealing due to their unique biological activities,[1] outstanding optoelectronic properties[2] and versatile roles in synthetic chemistry and material science.[3] In view of these significant applications, the development of efficient reactions for the construction of naphthalene ring from simple and readily available starting compounds is very important. Up to now numerous benzannulation pathways have been developed to access naphthalenes.[4-10] Among them, Asao and Yamamoto did remarkable pioneering work in the [4+2] benzannulation of *o*-alkynylaromatic ketones/aldehydes with alkynes or carbonyl compounds via isochromenylium intermediates to provide multi-substituted naphthyl ketones, which is usually called Asao-Yamamoto benzannulation.[5] Meanwhile, the aminobenzannulation

reactions were also established for the synthesis of 1-aminonaphthalenes. For example, Herndon and co-workers developed a $PdCl_2$/CuI-catalyzed one-pot Sonogashira-aminobenzannulation sequence to produce 1-aminonaphthalenes in amine solvents, and the reactions were limited to *o*-bromoacetophenone and terminal aliphatic alkynes (Scheme 1a).[6] Lu and Wang further studied Herndon's reaction by using terminal aromatic alkynes and $Pd(PPh_3)_4$ to replace $PdCl_2$.[7] Fujii and Ohno developed a gold-catalyzed aminobenzannulation via cascade intermolecular addition/intramolecular carbocyclization reaction of dialkynylbenzenes with amine to give 1-aminonaphthalenes.[8] In addition, amino-substituted acridines,[9] amino-substituted quinolines, dibenzofurans and carbazoles[10] could be also prepared by aminobenzannulation. However, the reported aminobenzannulation procedures are mostly limited to secondary alkyl amines, and the primary amines and anilines were hardly involved. It may attribute to the less nucleophilicity of aniline with respect to alkyl amines, and the favorable forming of the corresponding imines rather than enamines when primary amines were used.

Recent years, we have developed the efficiently synthetic routes for the construction of naphthalene ring by the cycloaddition of 1,3-butadiynes,[11] and the synthesis of *N*-heterocyclic[12] and carbocyclic[13] compounds by using *o*-alkynylaromatic ketones/aldehydes as starting materials or intermediates. In the case of the formation of chrysene derivatives via copper-catalyzed homo-dimerization of *o*-alkynylacetophenones,[13a] isochromenylium is proposed to be one of the key intermediates (Scheme 1a). With further interest in exploring the aminobenzannulation of *o*-alkynylaromatic ketones with anilines via the similar intermediates (*vide infra*), in this paper we wish to report an efficient $CuSO_4{\cdot}5H_2O$-catalyzed synthesis of 1-aminonaphthalene derivatives (Scheme 1b).[14]



Scheme 1. Aminobenzannulation of *o*-alkynyl aromatic ketones

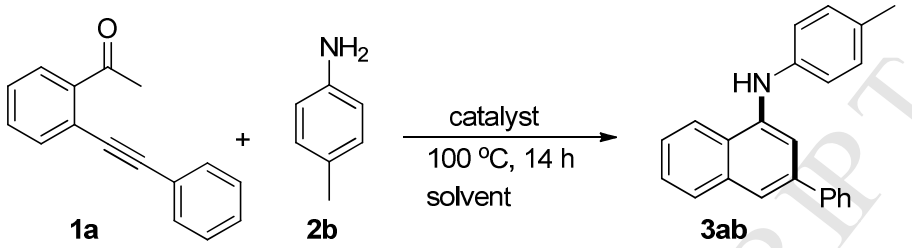
2. Results and discussion

Our initial investigation was carried out by treating 2-(phenylethynyl)acetophenone (**1a**) with 1.4 equiv of 4-methylaniline (**2b**) using $CuSO_4 \cdot 5H_2O$ (5 mol %) as catalyst in toluene under N_2 atmosphere at 100 ^oC for 14 h. To our delight, the desired aminobenzannulation product of 1-aminonaphthalene **3ab** could be isolated in 48% yield (Table 1, entry 1).[15] Repeating the same reaction in dioxane or THF resulted in the considerable increase of yields (Table 1, entries 2-3), but when DMF and EtOH were used, the yields of **3ab** were decreased greatly (Table 1, entries 4-5), and **3ab** could be obtained in 83% yield with the use of DCE (1,2-dichloroethane) as solvent (Table 1, entry 6). Noted that $CuSO_4 \cdot 5H_2O$ showed the best choice of the copper catalyst, since the use of other copper salts as catalysts such as $Cu(OAc)_2 \cdot H_2O$, $Cu(OTf)_2$, $CuCl_2 \cdot H_2O$, CuCl, CuBr and CuI led to low yield or trace amount of 3ab (Table 1, entries 7-12). Decrease of the reaction temperature to 80 ^oC resulted in the decrease of yield (Table 1, entry 13), but the reaction at 120 ^oC afforded **3ab** in a similar yield

as obtained at 100 °C (Table 1, entry 14). In addition, when an equivalent of **2b** (0.5 mmol) was used, the yield of **3ab** was declined to 62% (Table 1, entry 15).

Table 1

Reaction Optimization for the Synthesis of **3ab**[a]



Entry	Catalyst (mol %)	Solvent	Temp (°C)	Yield (%)[b]
1	$CuSO_4 \cdot 5H_2O$ (5)	toluene	100	48
2	$CuSO_4 \cdot 5H_2O$ (5)	dioxane	100	76
3	$CuSO_4 \cdot 5H_2O$ (5)	THF	100	71
4	$CuSO_4 \cdot 5H_2O$ (5)	DMF	100	52
5	$CuSO_4 \cdot 5H_2O$ (5)	EtOH	100	20
6	$CuSO_4 \cdot 5H_2O$ (5)	DCE	100	83
7	$Cu(OAc)_2 \cdot H_2O$ (5)	DCE	100	46
8	$Cu(OTf)_2$ (5)	DCE	100	23
9	$CuCl_2 \cdot H_2O$ (5)	DCE	100	35
10	CuCl (5)	DCE	100	trace
11	CuBr (5)	DCE	100	trace
12	CuI (5)	DCE	100	trace
13	$CuSO_4 \cdot 5H_2O$ (5)	DCE	80	55
14	$CuSO_4 \cdot 5H_2O$ (5)	DCE	120	84
15[c]	$CuSO_4 \cdot 5H_2O$ (5)	DCE	100	62

[a] Reaction conditions: **1a** (0.5 mmol), **2b** (0.7 mmol), solvent (2.0 mL), under N_2 atmosphere, 14 hours in a screw-capped pyrex tube.

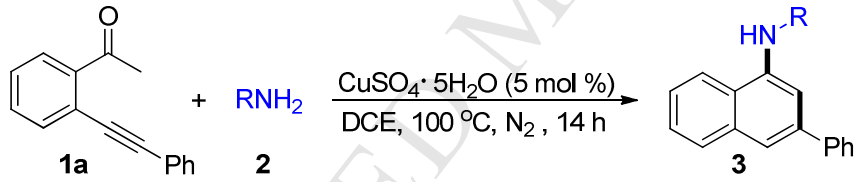
[b] Isolated yield. [c] **2b** (0.5 mmol).

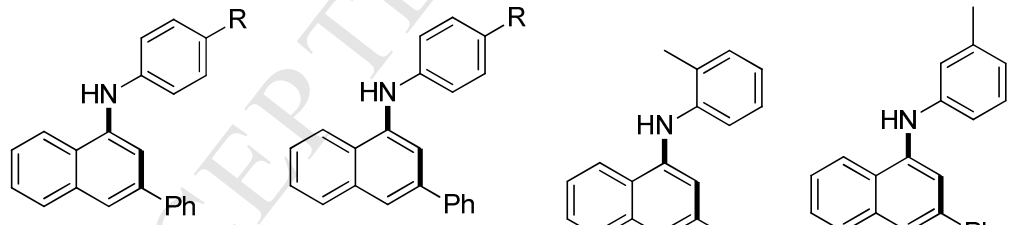
With the optimized conditions (Table 1, entry 6), we then studied the scope of the substrates (Table 2). We first investigated the substitution effect of anilines. The anilines bearing electron-donating groups such as Me, OMe and ^{t}Bu at *para*-position could proceed in

good yield. However, electron-withdrawing groups on the aromatic ring decreased the reaction reactivity to some extent. Especially, the aniline bearing ester group at *para*-position could just give the corresponding annulation product **3ah** in 52% yield even with the use of 2.0 equiv. of **3h** at 120 °C with a prolonged reaction time (30 h). The dramatical substitution effect could be demonstrated easily by the nucleophilicity of aniline. *ortho*-Substituted (**3ai**, 70%) and *meta*-substituted (**3aj**, 77%) anilines could also react with **1a** smoothly, affording corresponding products in modest to excellent yields. Notably, polysubstituents (**3ak**, 81%; **3al**, 54%) were compatible in the catalytic system as well. When using 1-aminonaphthalene as amine, dinaphthylamine **3am** was obtained in 72% yield. For aliphatic amines, both primary and secondary aliphatic amines could afford the desired aminobenzannulation products in good yields (**3an**, 83%; **3ao**, 82%).

Table 2

Scope of amines for 1-aminonaphthalenes synthesis[a]



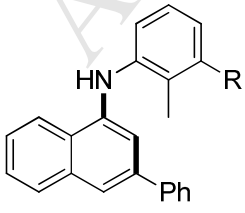


3aa, R = H, 81%
3ab, R = Me, 83%
3ac, R = OMe, 86%
3ad, R = ^{t}Bu, 85%

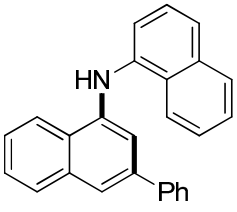
3ae, R = F, 71%
3af, R = Cl, 76%
3ag, R = Br, 67%
3ah, R = COOMe, 52% [b]

3ai, 70%

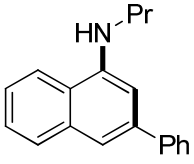
3aj, 77%



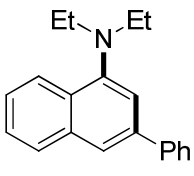
3ak, R = OMe, 81%
3al, R = F, 54%



3am, 72%



3an, 83%



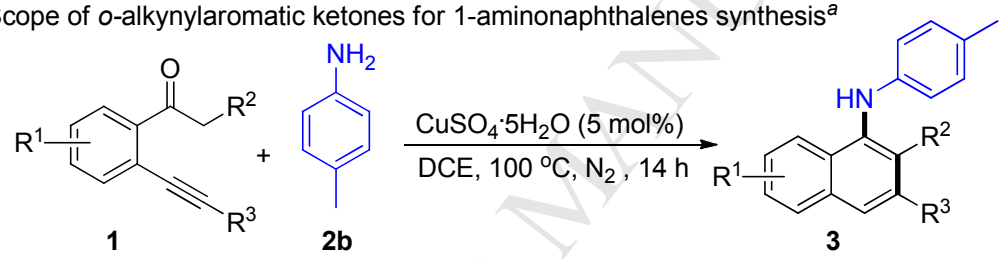
3ao, 82%

[a] Reaction conditions: **1a** (0.5 mmol), 2 (0.7 mmol), DCE (2.0 mL), N_2, 14 h, isolated yield.
[b] 1.0 mmol **2h**, 120 °C, 30 h.

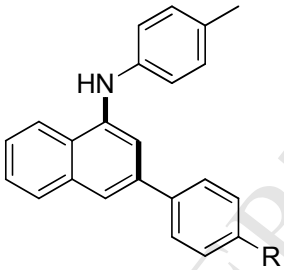
Subsequently, the scope of *o*-alkynylaromatic ketones **1** was investigated (Table 3). It was apparently observed that aromatic alkyne with electron-withdrawing group of COMe on the benzene ring showed relatively low reactivity to give **3eb** in mild yield. *o*-Alkynylaromatic ketones having aliphatic alkynyl groups (Table 3, R^3 = *n*-hexyl **1f**, *t*-butyl **1g** and isopropenyl **1h**) could also react with **2b** affording the desired products in relatively low yields. In addition, the reactions of fluoro-substituted *o*-alkynylaromatic ketones (**1i-k**), phenylacetyl (**1l**) and hexanoyl (**1m**)-bearing *o*-alkynylaromatic ketones also gave the corresponding 1-aminonaphthalenes in good yields.

Table 3

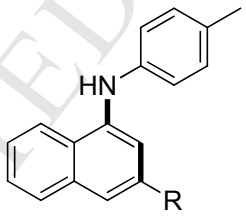
Scope of *o*-alkynylaromatic ketones for 1-aminonaphthalenes synthesis[a]



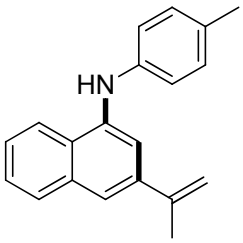
1 **2b** **3**



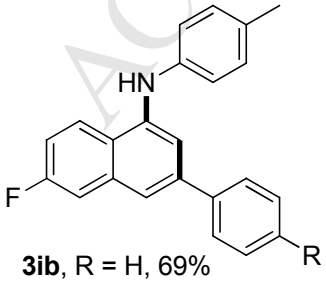
3bb, R = Me, 81%
3cb, R = OMe, 90%
3db, R = Br, 82%
3eb, R = COMe, 65%



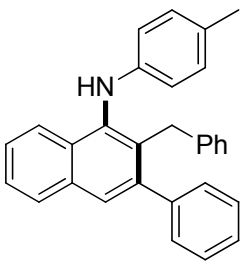
3fb, R = Hexyl, 55%
3gb, R = ^{t}Bu, 54%



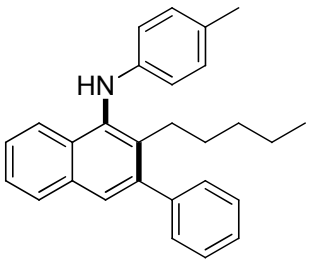
3hb, 52%



3ib, R = H, 69%
3jb, R = Cl, 65%
3kb, R = OMe, 79%



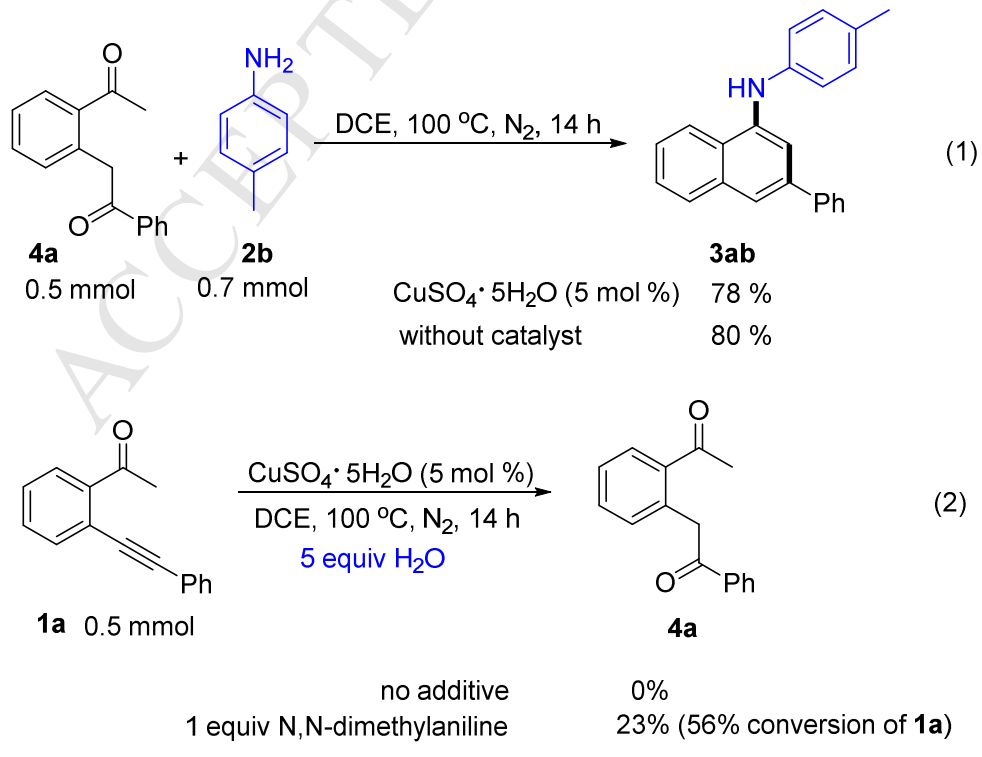
3lb, 61%

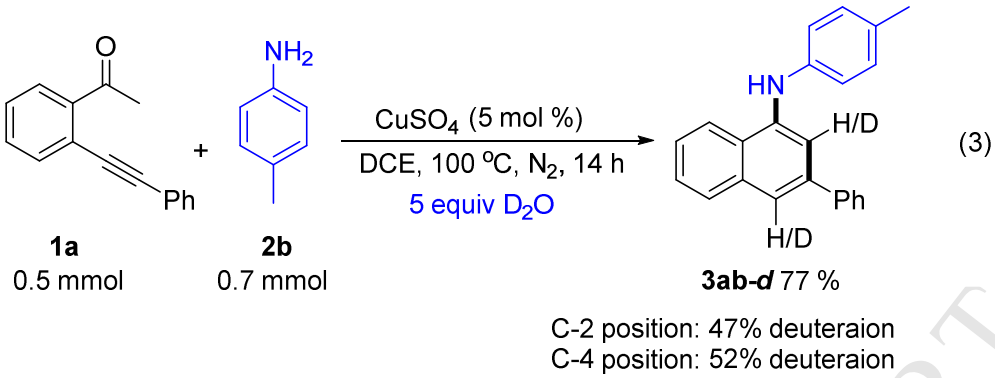


3mb, 54%

[a] Reaction conditions: **1a** (0.5 mmol), **2** (0.7 mmol), DCE (2 mL), N_2, 14 h, isolated yield.

In order to figure out the mechanism of the present reaction, a series of condition-controlled experiments were done. By taking into consideration that the aminobenzannulation might occur via a hydrolysis/dehydration mechanism with diketone **4a** as intermediate, the reactions of **4a** with **2b** in the standard conditions with or without catalyst were conducted, and the reactions afforded **3ab** in 78% and 80% yields, respectively (eq 1). The results strongly indicated that the reaction of **4a** with **2b** was very easy even in the absence of catalyst. Although the formation of **4a** could not be observed in the absence of **2b** in the reaction of **1a** with water (5.0 equiv) under the standard conditions, in the presence of *N*, *N*-dimethylaniline (1.0 equiv), **4a** formed in 23% yield, indicating that **4a** might be an intermediate for the formation of **3** (eq 2). In addition, it was found that under the standard conditions, with the use of 5.0 equiv of D_2O as shown in eq 3, the reaction afforded **3ab-*d*** in 77% yield with 47% deuteration at C-2 and 52% deuteration at C-4 position (see Supplementary data), and Wen and co-workers also reported the similar control experiments to support the similar mechanism hypothesis.[14]





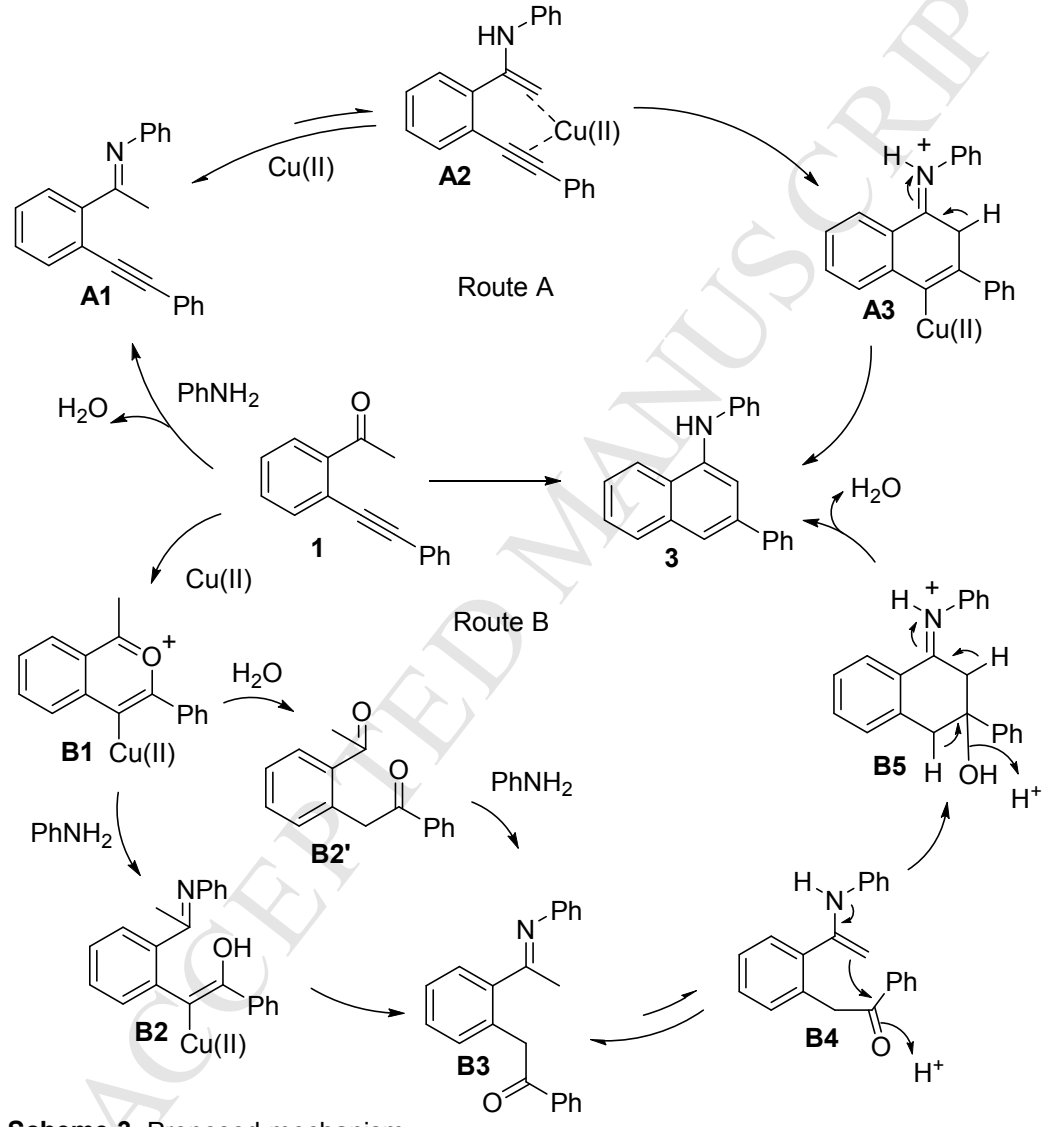
Scheme 2. Condition-controlled experiments

Although the detailed mechanism remained unclear, on the basis of previous studies of *o*-alkynylaromatic ketones and our experimental results, we propose two possible mechanisms for the formation of 1-aminonaphthalenes as depicted in Scheme 3.

In route A, it involves the first formation of imine **A1**, and Cu(II)-promoted tautomerization of imine **A1** with enamine **A2**. **A2** then undergoes a Cu(II)-catalyzed 6-endo-dig annulation affording intermediate **A3**, which takes place the subsequent protonolysis and aromatization producing **3**.

As mentioned above, in the presence of Cu(II), *o*-alkynylaromatic ketones can be transferred to isochromenylium as intermediate in their transformation,[13a] and in the case of using strong Brønsted acid of HOTf to replace Lewis acid of Cu(II), isochromenylium can be isolated.[13b] Therefore, the other route (route B) for the formation of 1-aminonaphthalenes is also proposed. It includes the formation of isochromenylium **B1**, and imine-enol Cu(II) salt **B2** derived from aminolysis of **B1** or diketone **B2'**, derived from the hydrolysis of **B1**. The metal-hydrogen exchange and enol-one tautomerization of **B2** will generate intermediate **B3**, which can also be generated from condensation of **B2'** and aniline, and **B3** is converted to its enamine isomer **B4** and then a cyclic intermediate **B5** by intramolecular nucleophilic attack. The aromatization of **B5** by dehydration produces **3**.

As shown in eq 3, the apparent deuteration at C-2 position undoubtedly supports the procedure of imine-enamine tautomerization, and the deuteration at C-4 position is resulted from the procedure of metal-hydrogen exchange (protonolysis) of intermediate **A3** (in route A) and **B2** (in route B).



Scheme 3. Proposed mechanism

3. Conclusion

We have developed a facile synthetic route for substituted 1-aminonaphthalenes via $CuSO_4 \cdot 5H_2O$-catalyzed aminobenzannulation of *o*-alkynylaromatic ketones with amines. The

scope investigation indicated that both aliphatic amines and anilines could react smoothly under the optimized conditions, providing an alternatively efficient catalyst system for the synthesis of 1-aminonaphthalenes.

4. Experimental section

4.1. General Methods

All commercial reagents are analytically pure and used without further purification. Nuclear magnetic resonance (NMR) spectra were recorded using $CDCl_3$ as solvent at 298 K. ^1H NMR (400 MHz) chemical shifts (δ) were referenced to internal standard TMS (for ^1H, δ = 0.00 ppm). ^{13}C NMR (100 MHz) chemical shifts were referenced to internal solvent $CDCl_3$ (for ^{13}C, δ = 77.16 ppm). High resolution mass spectra (HRMS) were obtained on a TOF-MS instrument with ESI source. *o*-alkynylaromatic ketones were prepared according to literature procedures.[13]

4.2. A typical experimental procedure for the synthesis of 1-aminonaphthalene 3ab

A mixture of 2-(phenylethynyl)acetophenone (**1a**, 110 mg, 0.5 mmol), 4-methyl-aniline (**2b**, 75 mg, 0.7 mmol), $CuSO_4{\cdot}5H_2O$ (7 mg, 0.025 mmol, 5 mol %) and DCE (2.0 mL) was heated at 100 °C (oil bath temperature) with stirring in a 25 mL screw-capped thick-walled Pyrex tube under nitrogen atmosphere. When TLC control showed the completion of the reaction (after 14 h), the reaction mixture was quenched with H_2O. The mixture was extracted with dichloromethane (DCM) three times, and dried over Na_2SO_4. The solvent was evaporated and the crude residue was purified by column chromatography on silica gel to afford **3ab** as a white solid in 83% yield (128 mg).

4.3. Characterization data of products

All the products were characterized by ^1H-NMR, ^{13}C-NMR, and HRMS (ESI). The

copies of NMR charts were reported in Supplementary data.

*4.3.1. N,3-Diphenylnaphthalen-1-amine (**3aa**)*. Light yellow solid (119 mg, 81% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (d, *J* = 8.3 Hz, 1H), 7.85 (d, *J* = 8.2 Hz, 1H), 7.72 (s, 1H), 7.66 – 7.58 (m, 3H), 7.50 – 7.43 (m, 1H), 7.40 (m, 3H), 7.31 (m, 1H), 7.26 – 7.19 (m, 2H), 7.02 – 6.95 (m, 2H), 6.90 (m, 1H), 5.89 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.6, 141.1, 139.3, 138.9, 135.1, 129.5, 129.0, 128.9, 127.5, 127.4, 126.9, 126.7, 125.8, 121.8, 120.9, 120.7, 117.6, 115.2; HRMS (ESI) calcd for $C_{22}H_{18}N$, $[M + H]^+$ 296.1434, found 296.1430.

*4.3.2. 3-Phenyl-N-(p-tolyl)naphthalen-1-amine **(3ab)***. White solid (128 mg, 83% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 (d, *J* = 8.3 Hz, 1H), 7.86 (d, *J* = 7.9 Hz, 1H), 7.68 (s, 1H), 7.65 – 7.61 (m, 2H), 7.55 (m, 1H), 7.47 (m, 1H), 7.42 (m, 3H), 7.31 (t, *J* = 7.3 Hz, 1H), 7.07 (d, *J* = 8.2 Hz, 2H), 6.97 (d, *J* = 8.3 Hz, 2H), 5.90 (s, 1H), 2.29 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.6, 141.3, 140.2, 139.0, 135.1, 130.7, 130.1, 129.0, 128.9, 127.5, 126.6, 126.2, 125.6, 121.5, 120.0, 118.8, 113.4, 20.8; HRMS (ESI) calcd for $C_{23}H_{20}N$, $[M + H]^+$ 1310.1590, found 310.1596.

*4.3.3. N-(4-Methoxyphenyl)-3-phenylnaphthalen-1-amine **(3ac)***. Light yellow oil (140 mg, 86% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.76 (d, *J* = 8.3 Hz, 1H), 7.69 (d, *J* = 7.9 Hz, 1H), 7.50 – 7.42 (m, 3H), 7.34 – 7.11 (m, 6H), 6.89 (d, *J* = 8.8 Hz, 1H), 6.69 (d, *J* = 8.8 Hz, 1H), 5.72 (s, 1H), 3.60 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.2, 141.4, 141.4, 139.0, 136.7, 134.97, 129.0, 128.8, 127.4, 126.5, 125.4, 125.1, 122.1, 121.0, 118.8, 114.9, 111.0, 55.6; HRMS (ESI) calcd for $C_{23}H_{20}NO$, $[M + H]^+$ 326.1539, found 326.1537.

*4.3.4. N-(4-(t-Butyl)phenyl)-3-phenylnaphthalen-1-amine **(3ad)***. White solid (149 mg, 85% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.89 (d, *J* = 8.3 Hz, 1H), 7.80 (d, *J* = 8.0 Hz, 1H), 7.65

(s, 1H), 7.60 (m, 3H), 7.45 – 7.31 (m, 4H), 7.30 – 7.21 (m, 3H), 6.99 – 6.92 (m, 2H), 5.83 (s, 1H), 1.28 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.8, 141.7, 141.3, 139.8, 139.0, 135.0, 129.0, 128.9, 127.5, 127.4, 126.6, 126.4, 126.3, 125.6, 121.5, 120.2, 117.8, 113.9, 34.2, 31.6; HRMS (ESI) calcd for $C_{26}H_{26}N$, $[M + H]^+$ 352.2060, found 352.2064.

4.3.5. N-(4-Fluorophenyl)-3-phenylnaphthalen-1-amine ***(3ae)***. Light yellow solid (111 mg, 71% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (d, *J* = 8.3 Hz, 1H), 7.87 (d, *J* = 8.1 Hz, 1H), 7.70 (s, 1H), 7.62 (d, *J* = 7.4 Hz, 2H), 7.52 – 7.38 (m, 5H), 7.33 (t, *J* = 7.3 Hz, 1H), 6.97 (m, 4H), 5.88 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ158.0 (d, *J* = 239.7 Hz), 141.5, 140.3 (d, *J* = 1.6 Hz), 140.2, 139.0, 135.1, 129.1, 128.9, 127.6, 127.4, 126.7, 126.1, 125.8, 121.4, 120.4, 120.3 (d, *J* = 7.7 Hz), 116.2 (d, *J* = 22.3 Hz), 113.6; HRMS (ESI) calcd for $C_{22}H_{17}FN$, $[M + H]^+$ 314.1340, found 314.1338.

4.3.6. N-(4-Chlorophenyl)-3-phenylnaphthalen-1-amine ***(3af)***. White solid (125 mg, 76% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92 (d, *J* = 8.3 Hz, 1H), 7.88 (d, *J* = 8.0 Hz, 1H), 7.76 (s, 1H), 7.66 – 7.61 (m, 2H), 7.56 (s, 1H), 7.54 – 7.46 (m, 1H), 7.43(m, 3H), 7.34 (t, *J* = 7.3 Hz, 1H), 7.17 (d, *J* = 8.7 Hz, 2H), 6.88 (d, *J* = 8.7 Hz, 2H), 5.88 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.5, 140.9, 138.9, 138.9, 135.1, 129.4, 129.0, 129.0, 127.6, 127.4, 127.0, 126.8, 126.0, 125.2, 121.8, 121.5, 118.5, 116.0; HRMS (ESI) calcd for $C_{22}H_{17}ClN$, $[M + H]^+$ 330.1044, found 330.1047.

4.3.7. N-(4-Bromophenyl)-3-phenylnaphthalen-1-amine ***(3ag)***. Light yellow solid (125 mg, 67% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 (d, *J* = 8.3 Hz, 1H), 7.90 (d, *J* = 8.0 Hz, 1H), 7.79 (s, 1H), 7.69 – 7.63 (m, 2H), 7.60 (d, *J* = 1.4 Hz, 1H), 7.51 (m, 1H), 7.45 (m, 3H), 7.39 – 7.30 (m, 3H), 6.86 (d, *J* = 8.7 Hz, 2H), 5.93 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.1,

140.9, 139.0, 138.7, 135.1, 132.4, 129.1, 129.0, 127.7, 127.4, 127.2, 126.8, 126.1, 121.8, 121.7, 118.8, 116.4, 112.4; HRMS (ESI) calcd for $C_{22}H_{17}BrN$, $[M + H]^+$ 374.0539, found 374.0537.

4.3.8. Methyl 4-((3-phenylnaphthalen-1-yl)amino)benzoate ***(2ah)***. White solid (92 mg, 52% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 – 7.94 (m, 1H), 7.93 – 7.89 (m, 3H), 7.74 (m, 1H), 7.69 (m, 2H), 7.57 – 7.44 (m,4H), 7.40-7.36 (m, 1H), 6.92 – 6.87 (m, 2H), 6.25 (s, 1H), 3.86 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.2, 150.0, 140.6, 138.9, 137.1, 135.1, 131.7, 129.0, 128.2, 127.7, 127.4, 126.9, 126.3, 123.1, 122.2, 120.8, 119.7, 114.5, 51.8; HRMS (ESI) calcd for $C_{24}H_{20}NO_2$, $[M + H]^+$ 354.1489, found 354.1495.

4.3.9. 3-Phenyl-N-(o-tolyl)naphthalen-1-amine ***(3ai)***. Light yellow solid (108 mg, 70% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 (d, *J* = 8.2 Hz, 1H), 7.89 (d, *J* = 8.0 Hz, 1H), 7.70 (s, 1H), 7.65 – 7.60 (m, 2H), 7.52 – 7.38 (m, 4H), 7.23 (d, *J* = 7.4 Hz, 1H), 7.09 (d, *J* = 7.4 Hz, 1H), 7.02 (d, *J* = 7.9 Hz, 1H), 6.94 (d, *J* = 7.3 Hz, 1H), 5.79 (s, 1H), 2.33 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.5, 141.3, 140.1, 139.1, 135.1, 131.1, 129.0, 128.9, 127.8, 127.5, 127.1, 126.6, 126.3, 125.7, 121.9, 121.6, 120.2, 119.0, 114.3, 18.1; HRMS (ESI) calcd for $C_{23}H_{20}N$, $[M + H]^+$ 310.1590, found 310.1592.

4.3.10. 3-Phenyl-N-(m-tolyl)naphthalen-1-amine ***(3aj)***. Orange red solid (119 mg, 77% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 (d, *J* = 8.3 Hz, 1H), 7.88 (d, *J* = 8.1 Hz, 1H), 7.74 (s, 1H), 7.65 (d, *J* = 8.5 Hz, 3H), 7.49 (dd, *J* = 7.7, 7.0 Hz, 1H), 7.43 (m, 3H), 7.33 (m, 1H), 7.14 (m, 1H), 6.85 (m , 2H), 6.74 (d, *J* = 7.4 Hz, 1H), 5.92 (s, 1H), 2.29 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.7, 141.2, 139.5, 139.0, 135.1, 129.4, 129.0, 128.9, 127.5, 127.5, 126.9, 126.7,

125.8, 121.8, 121.7, 120.8, 118.4, 115.3, 114.8, 21.7; HRMS (ESI) calcd for $C_{23}H_{20}N$, $[M + H]^+$ 310.1590, found 310.1589.

4.3.11. N-(3-Methoxy-2-methylphenyl)-3-phenylnaphthalen-1-amine ***(3ak)***. Light white solid (137 mg, 81% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (d, *J* = 8.2 Hz, 1H), 7.90 (d, *J* = 8.1 Hz, 1H), 7.70 (s, 1H), 7.66 – 7.60 (m, 2H), 7.56 – 7.45 (m, 2H), 7.43 (t, *J* = 7.7 Hz, 2H), 7.37 – 7.30 (m, 2H), 7.07 (t, *J* = 8.2 Hz, 1H), 6.72 (d, *J* = 8.1 Hz, 1H), 6.59 (d, *J* = 8.2 Hz, 1H), 5.86 (s, 1H), 3.87 (s, 3H), 2.23 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 158.6, 143.3, 141.3, 140.4, 139.1, 135.0, 129.0, 128.9, 127.5, 127.4, 126.7, 126.6, 126.2, 125.7, 121.6, 120.0, 116.5, 114.1, 112.5, 104.3, 55.8, 10.1; HRMS (ESI) calcd for $C_{24}H_{22}NO$, $[M + H]^+$ 340.1696' found 340.1695.

*4.3.12. N-(3-Fluoro-2-methylphenyl)-3-phenylnaphthalen-1-amine (****3al****)*. Light white solid (88 mg, 54% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (d, *J* = 8.3 Hz, 1H), 7.88 (d, *J* = 8.3 Hz, 1H), 7.75 (s, 1H), 7.63 (d, *J* = 7.4 Hz, 2H), 7.53 – 7.36 (m, 5H), 7.33 (t, *J* = 7.3 Hz, 1H), 7.02 – 6.94 (m, 1H), 6.74 – 6.63 (m, 2H), 5.78 (s, 1H), 2.24 (d, *J* = 1.5 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ162.0 (d, *J* = 242.3 Hz), 144.7 (d, *J* = 6.8 Hz), 141.0, 139.4, 139.0, 135.1, 129.0, 128.9, 127.6, 127.4, 127.1 (d, *J* = 10.3 Hz), 126.8, 126.7, 125.9, 121.8, 121.1, 116.0, 114.2 (d, *J* = 18.3 Hz), 113.6 (d, *J* = 2.3 Hz), 108.0 (d, *J* = 23.2 Hz), 9.3 (d, *J* = 5.8 Hz); HRMS (ESI) calcd for $C_{23}H_{19}FN$, $[M + H]^+$ 328.1496, found 328.1496.

*4.3.13. N-(Naphthalen-1-yl)-3-phenylnaphthalen-1-amine (****3am****)*. Light yellow oil (124 mg, 72% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10 (d, *J* = 8.2 Hz, 1H), 8.05 (d, *J* = 8.4 Hz, 1H), 7.92 (d, *J* = 8.0 Hz, 1H), 7.90 – 7.86 (m, 1H), 7.74 (s, 1H), 7.60 – 7.42 (m, 7H), 7.40 – 7.26 (m, 5H), 7.09 (d, *J* = 7.4 Hz, 1H), 6.39 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.2, 140.8,

140.2, 139.2, 135.1, 134.8, 129.1, 128.9, 128.8, 127.4, 127.1, 126.7, 126.3, 126.3, 126.2, 125.9, 1822.6, 121.8, 121.8, 120.4, 115.6, 115.0; HRMS (ESI) calcd for $C_{26}H_{20}N$, $[M + H]^+$ 346.1590, found 346.1589.

*4.3.14. 3-Phenyl-N-propylnaphthalen-1-amine (**3an**).* Light yellow solid (108 mg, 83% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.81 (d, *J* = 8.0 Hz, 1H), 7.77 (d, *J* = 8.2 Hz, 1H), 7.73 – 7.69 (m, 2H), 7.53 – 7.29 (m, 6H), 6.82 (s, 1H), 4.35 (s, 1H), 3.28 (t, *J* = 7.1 Hz, 2H), 1.84 – 1.74 (m, 2H), 1.07 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.1, 142.3, 139.6, 134.7, 129.1, 128.8, 127.6, 127.3, 126.2, 124.8, 122.7, 119.8, 115.5, 104.1, 46.2, 22.8, 12.0; HRMS (ESI) calcd for $C_{19}H_{20}N$, $[M + H]^+$ 262.1590, found 262.1592.

*4.3.15. N,N-Diethyl-3-phenylnaphthalen-1-amine (**3ao**).* Light yellow oil (113 mg, 82% yield). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.33 – 8.27 (m, 1H), 7.88 – 7.81 (m, 1H), 7.74 (s, 1H), 7.72 – 7.67 (m, 2H), 7.51 – 7.43 (m, 4H), 7.37 (dd, *J* = 5.8, 1.5 Hz, 2H), 3.25 (q, *J* = 7.1 Hz, 4H), 1.09 (t, *J* = 7.1 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.5, 141.8, 138.4, 135.2, 130.4, 128.9, 128.6, 127.6, 127.4, 126.2, 125.3, 124.3, 121.4, 117.9, 47.8, 12.5; HRMS (ESI) calcd for $C_{20}H_{22}N$, $[M + H]^+$ 276.1747, found 276.1744.

*4.3.16. N,3-di-p-Tolylnaphthalen-1-amine (**3bb**).* Light yellow solid (131 mg, 81% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96 (d, *J* = 8.3 Hz, 1H), 7.86 (d, *J* = 8.1 Hz, 1H), 7.67 (s, 1H), 7.54 (m, 3H), 7.47 (d, *J* = 7.3 Hz, 1H), 7.43 (d, *J* = 7.2 Hz, 1H), 7.23 (d, *J* = 8.0 Hz, 2H), 7.08 (d, *J* = 8.2 Hz, 2H), 6.98 (d, *J* = 8.3 Hz, 2H), 6.08 (s, 1H), 2.37 (s, 3H), 2.30 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.7, 140.1, 138.9, 138.4, 137.3, 135.1, 130.6, 130.1, 129.6, 128.9, 127.3, 126.6, 126.1, 125.5, 121.5, 119.7, 118.7, 113.6, 21.6, 20.8; HRMS (ESI) calcd for $C_{24}H_{22}N$, $[M + H]^+$ 324.1747, found 324.1749.

*4.3.17. 3-(4-Methoxyphenyl)-N-(p-tolyl)naphthalen-1-amine (**3cb**).* Light yellow solid (152 mg, 90% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (d, *J* = 8.3 Hz, 1H), 7.86 (d, *J* = 8.1 Hz, 1H), 7.64 (s, 1H), 7.57 (m, 2H), 7.54 (s, 1H), 7.48 (t, *J* = 7.4 Hz, 1H), 7.45 – 7.39 (m, 1H), 7.09 (d, *J* = 8.2 Hz, 2H), 6.99 (d, *J* = 8.3 Hz, 2H), 6.96 (d, *J* = 8.6 Hz, 2H), 5.95 (s, 1H), 3.83 (s, 3H), 2.31 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.3, 141.8, 140.1, 138.6, 135.2, 133.8, 130.7, 130.1, 128.9, 128.5, 126.6, 126.0, 125.4, 121.5, 119.3, 118.7, 114.3, 113.5, 55.5, 20.8; HRMS (ESI) calcd for $C_{24}H_{22}NO$, $[M + H]^+$ 340.1696, found 340.1700.

*4.3.18. 3-(4-Bromophenyl)-N-(p-tolyl)naphthalen-1-amine (**3db**).* Light yellow solid (154 mg, 82% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96 (d, *J* = 8.3 Hz, 1H), 7.85 (d, *J* = 8.1 Hz, 1H), 7.61 (s, 1H), 7.56 – 7.41 (m, 7H), 7.09 (d, *J* = 8.3 Hz, 2H), 6.98 (d, *J* = 8.3 Hz, 2H), 5.98 (s, 1H), 2.30 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.3, 140.5, 140.2, 137.8, 135.0, 131.9, 131.1, 130.1, 129.0, 126.8, 126.1, 125.9, 121.7, 121.4, 119.7, 119.0, 112.5, 20.8; HRMS (ESI) calcd for $C_{23}H_{19}BrN$, $[M + H]^+$ 388.0695, found 388.0700.

*4.3.19. 1-(4-(4-(p-Tolylamino)naphthalen-2-yl)phenyl)ethan-1-one (**3eb**).* Light yellow solid (114 mg, 65% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 (d, *J* = 7.0 Hz, 3H), 7.89 (d, *J* = 7.9 Hz, 1H), 7.75 – 7.66 (m, 3H), 7.59 – 7.43 (m, 3H), 7.11 (d, *J* = 8.2 Hz, 2H), 7.02 (d, *J* = 8.2 Hz, 2H), 6.02 (s, 1H), 2.61 (s, 3H), 2.32 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 197.9, 145.9, 141.3, 140.6, 137.6, 135.9, 134.9, 131.2, 130.2, 129.2, 129.0, 127.5, 126.9, 126.4, 126.2, 121.4, 120.2, 119.1, 112.4, 26.8, 20.9; HRMS (ESI) calcd for $C_{25}H_{22}NO$, $[M + H]^+$ 352.1696, found 352.1698.

*4.3.20. 3-n-Hexyl-N-(p-tolyl)naphthalen-1-amine (**3fb**).* Light yellow oil (87 mg, 55% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (d, *J* = 8.3 Hz, 1H), 7.76 (d, *J* = 8.0 Hz, 1H), 7.47 – 7.40

(m, 1H), 7.40 – 7.34 (m, 1H), 7.29 (s, 1H), 7.16 (s, 1H), 7.07 (d, *J* = 8.2 Hz, 2H), 6.92 (d, *J* = 8.3 Hz, 2H), 5.83 (s, 1H), 2.80 – 2.55 (m, 2H), 2.30 (s, 3H), 1.64 (m, 2H), 1.44 – 1.15 (m, 6H), 0.87 (t, *J* = 6.9 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.1, 141.1, 139.1, 135.0, 130.2, 130.0, 128.2, 126.2, 125.8, 124.8, 121.6, 120.9, 118.3, 116.1, 36.4, 31.9, 31.4, 29.2, 22. 8, 20.8, 14.3; HRMS (ESI) calcd for $C_{23}H_{28}N$, $[M + H]^+$ 318.2216, found 318.2211.

*4.3.21. 3-(t-Butyl)-N-(p-tolyl)naphthalen-1-amine (**3gb**).* Light yellow oil (78 mg, 54% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.91 (d, *J* = 8.2 Hz, 1H), 7.81 (d, *J* = 7.8 Hz, 1H), 7.50 – 7.34 (m, 4H), 7.06 (d, *J* = 8.1 Hz, 2H), 6.90 (d, *J* = 8.4 Hz, 2H), 5.85 (s, 1H), 2.30 (s, 3H), 1.36 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 149.1, 142.5, 138.7, 134.7, 130.0, 129.8, 128.7, 126.2, 126.0, 125.1, 121.5, 117.9, 117.5, 114.6, 35.1, 31.3, 20.8; HRMS (ESI) calcd for $C_{21}H_{24}N$, $[M + H]^+$ 290.1903, found 290.1904.

*4.3.22. 3-(Prop-1-en-2-yl)-N-(p-tolyl)naphthalen-1-amine (**3hb**).* Light yellow oil (71 mg, 52% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (d, *J* = 8.2 Hz, 1H), 7.84 (d, *J* = 8.1 Hz, 1H), 7.58 – 7.37 (m, 4H), 7.08 (d, *J* = 8.2 Hz, 2H), 6.94 (d, *J* = 8.2 Hz, 2H), 5.86 (s, 1H), 5.42 (s, 1H), 5.14 (s, 1H), 2.31 (s, 3H), 2.22 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.2, 142.1, 139.3, 138.8, 134.8, 130.3, 130.0, 129.0, 126.9, 126.5, 125.6, 121.6, 119.1, 118.2, 113.1, 112.7, 22.0, 20.8; HRMS (ESI) calcd for $C_{20}H_{20}N$, $[M + H]^+$ 274.1590, found 274.1593.

*4.3.23. 6-Fluoro-3-phenyl-N-(p-tolyl)naphthalen-1-amine (**3ib**).* Light yellow solid (113 mg, 69% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 (m, 1H), 7.60 (m, 3H), 7.50 – 7.38 (m, 4H), 7.34 (d, *J* = 7.3 Hz, 1H), 7.22 – 7.13 (m, 1H), 7.08 (d, *J* = 8.2 Hz, 2H), 6.96 (d, *J* = 8.3 Hz, 2H), 5.86 (s, 1H), 2.30 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 161.3 (d, *J* = 246.4 Hz), 160.1, 141.4, 140.9, 140.5, 140.4, 136.1 (d, *J* = 9.2 Hz), 131.1, 130.1, 128.9, 127.7, 127.5, 124.3 (d,

J = 9.1 Hz), 123.2, 119.3 (d, *J* = 4.7 Hz), 118.9, 115.6 (d, *J* = 25.2 Hz), 113.0, 111.9 (d, *J* = 20.3 Hz), 20.8; HRMS (ESI) calcd for $C_{23}H_{19}FN$, $[M + H]^+$ 328.1496, found 328.1498.

*4.3.24. 3-(4-Chlorophenyl)-6-fluoro-N-(p-tolyl)naphthalen-1-amine (**3jb**).* Light yellow solid (117 mg, 65% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (m, 1H), 7.52 (m, 3H), 7.46 (m, 1H), 7.42 – 7.35 (m, 3H), 7.24 – 7.17 (m, 1H), 7.11 (d, *J* = 8.2 Hz, 2H), 6.98 (d, *J* = 8.3 Hz, 2H), 5.95 (s, 1H), 2.32 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ161.4 (d, *J* = 246.6 Hz), 141.1, 140.8, 139.4, 139.2, 136.1 (d, *J* = 9.4 Hz), 133.8, 131.4, 130.2, 129.1, 128.7, 124.2 (d, *J* = 9.0 Hz), 123.2, 119.1, 119.0 (d, *J* = 5.3 Hz), 115.8 (d, *J* = 25.1 Hz), 112.2, 111.9 (d, *J* = 20.4 Hz), 20.9; HRMS (ESI) calcd for $C_{23}H_{18}ClFN$, $[M + H]^+$ 362.1106, found 362.1112.

*4.3.25. 6-Fluoro-3-(4-methoxyphenyl)-N-(p-tolyl)naphthalen-1-amine (**3kb**).* Light yellow solid (141 mg, 79% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (m, 1H), 7.54 (m, 3H), 7.46 – 7.40 (m, 2H), 7.15 (td, *J* = 9.0, 2.4 Hz, 1H), 7.08 (d, *J* = 8.1 Hz, 2H), 6.94 (d, *J* = 8.5 Hz, 4H), 5.86 (s, 1H), 3.81 (s, 3H), 2.30 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ161.3 (d, *J* = 246.1 Hz), 159.5, 141.5, 140.4, 140.0, 136.2 (d, *J* = 9.2 Hz), 133.4, 130.9, 130.1, 128.5, 124.3 (d, *J* = 9.0 Hz), 123.0, 118.8, 118.6 (d, *J* = 4.9 Hz), 115.3 (d, *J* = 25.1 Hz), 114.4, 112.9, 111.7 (d, *J* = 20.2 Hz), 55.4, 20.8; HRMS (ESI) calcd for $C_{24}H_{21}FNO$, $[M + H]^+$ 358.1602, found 358.1603.

*4.3.26. 2-Benzyl-3-phenyl-N-(p-tolyl)naphthalen-1-amine (**3lb**).* Light yellow solid (122 mg, 61% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96 (d, *J* = 8.4 Hz, 1H), 7.83 (d, *J* = 8.1 Hz, 1H), 7.72 (s, 1H), 7.43 (t, *J* = 7.4 Hz, 1H), 7.39 – 7.26 (m, 6H), 7.19 (t, *J* = 7.2 Hz, 2H), 7.15 – 7.10 (m, 1H), 6.95 (d, *J* = 7.5 Hz, 2H), 6.90 (d, *J* = 8.2 Hz, 2H), 6.36 (d, *J* = 8.2 Hz, 2H), 5.31 (s, 1H), 4.05 (s, 2H), 2.21 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.6, 142.2, 141.9, 140.7,

137.0, 133.2, 133.0, 131.0, 129.8, 129.4, 128.8, 128.2, 128.2, 128.0, 127.8, 127.3, 127.2, 126.3, 126.2, 126.1, 124.5, 114.1, 35.3, 20.6; HRMS (ESI) calcd for $C_{30}H_{26}N$, $[M + H]^+$ 400.2060, found 400.2063.

*4.3.27. 2-n-Pentyl-3-phenyl-N-(p-tolyl)naphthalen-1-amine (**3mb**).* Light yellow liquid (102 mg, 54% yield); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96 (d, *J* = 8.2 Hz, 1H), 7.80 (d, *J* = 7.8 Hz, 1H), 7.62 (s, 1H), 7.51 – 7.33 (m, 7H), 6.95 (d, *J* = 7.8 Hz, 2H), 6.50 (d, *J* = 7.4 Hz, 2H), 5.35(s, 1H), 2.81 – 2.61 (m, 2H), 2.24 (s, 3H), 1.34 (m, 2H), 1.06 (d, *J* = 3.4 Hz, 4H), 0.69 (t, *J* = 6.7 Hz, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 145.5, 142.3, 141.9, 136.4, 135.3, 132.7, 130.9, 129.8, 129.5, 128.2, 128.1, 127.6, 127.3, 127.1, 126.2, 125.8, 124.2, 114.1, 32.0, 30.2, 29.1, 22.2, 20.6, 13.9; HRMS (ESI) calcd for $C_{28}H_{30}N$, $[M + H]^+$ 380.2373, found 380.2370.

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Supplementary data

The copies of ^{1}H-NMR, ^{13}C-NMR charts of all products and the x-ray structural details for **3ai** associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.tet.xxxx.

References and notes:

1. (a) Mewshaw, R. E.; Edsall, R. J.; Yang, C.; Manas, E. S.; Xu, Z. B.; Henderson, R. A.; Keith, J. C.; Harris, H. A. *J. Med. Chem.* **2005**, *48*, 3953–3979. (b) Frotscher, M.; Ziegler, E.; Marchais-Oberwinkler, S.; Kruchten, P.; Neugebauer, A.; Fetzer, L.; Scherer, C.; Müller-Vieira, U.; Messinger, J.; Thole, H.; Hartmann, R. W. *J. Med. Chem.* **2008**, *51*, 2158–2169. (c) Marchais-Oberwinkler, S.; Kruchten, P; Frotscher, M.; Ziegler, E.; Neugebauer, A.; Bhoga, U.; Bey, E.; Müller-Vieira, U.; Messinger, J.; Thole, H.; Hartmann, R. W. *J. Med. Chem.* **2008**, *51*, 4685–4698.
2. (a) Gallivan, J. B. *J. Phys. Chem.* **1969**, *73*, 3070–3075. (b) Zhang, H.; Hanna, J. *J. Phys. Chem. B* **1999**, *103*, 7429–7434. (c) Iino, H.; Hanna, J. *J. Phys. Chem. B* **2005**, *109*, 22120–22125.
3. (a) Leznoff, C. C.; Hayward, R. J. *Can. J. Chem.* **1972**, *50*, 528–533. (b) Nagel, D. L.; Kupper, R.; Antonson, K.; Wallcave, L. *J. Org. Chem.* **1977**, *42*, 3626–3628. (c) Okamoto, H., Yamaji, M., Gohda, S.; Kubozono, Y.; Komura, N.; Sato, K.; Sugino, H.; Satake, K. *Org. Lett.* **2011**, *13*, 2758–2761.
4. (a) Asao, N.; Aikawa, H. *J. Org. Chem.* **2006**, *71*, 5249–5253. (b) Dell'Acqua, M.; Abbiati, G.; Arcadib, A.; Rossi, E. *Org. Biomol. Chem.* **2011**, *9*, 7836–7848. (c) Tatton, M. R.; Simpsonb, I.; Donohoe, T. J. *Chem. Commun.* **2014**, *50*, 11314–11316. (d) Ling, F.; Wan, Y.; Wang, D.; Ma, C. *J. Org. Chem.* **2016**, *81*, 2770–2781.
5. (a) Asao, N.; Takahashi, K.; Lee, S.; Kasahara, T.; Yamamoto, Y.; *J. Am. Chem. Soc.* **2002**, *124*, 12650–12651. (b) Asao, N.; Nogami, T.; Lee, S.; Yamamoto, Y.; *J. Am. Chem. Soc.* **2003**, *125*, 10921–10925. (c) Asao, N.; Aikawa, H.; Yamamoto, Y.; *J. Am. Chem. Soc.* **2004**, *126*, 7458–7459.
6. Herndon, J. W.; Zhang, Y.; Wang, K. *J. Organomet. Chem.* **2001**, *634*, 1–4.
7. Chen, X.; Jin, J.; Wang, N.; Lu, P.; Wang, Y. *Eur. J. Org. Chem.* **2012**, 824–830.

8. Naoe, S.; Suzuki, Y.; Hirano, K.; Inaba, Y.; Oishi, S.; Fujii, N.; Ohno, H. *J. Org. Chem.* **2012**, *77*, 4907−4916.

9. Belmont, P.; Belhadj, T. *Org. Lett.* **2005**, *7*, 1793–1795.

10. Tiano, M.; Belmont, P. *J. Org. Chem.* **2008**, *73*, 4101–4109.

11. (a) Sun, H.; Wu, X.; Hua, R. *Tetrahedron Lett.* **2011**, *52*, 4408–4411. (b) Yang, L.; Hua, R. *Chem. Lett.* **2013**, *42*, 769–771.

12. Ju, J.; Hua, R. *Curr. Org. Synth*. **2013**, *10*, 328−332.

13. (a) Guo, B.; Zheng, L.; Yang, L.; Hua, R. *J. Org. Chem.* **2014**, *79*, 4352−4357. (b) Guo, B.; Zhou, Y.; Zhang, L.; Hua, R. *J. Org. Chem.* **2015**, *80*, 7635−7641.

14. When we finished the experiments, and are preparing manuscript, Wen and co-workers reported a similar $Cu(OAc)_2{\cdot}H_2O$-catalyzed aminobenzannulation of (*ortho*-alkynyl)-arylketones with amines: Zhang, M.; Ruan, W.; Zhang, H.-J.; Li, W.; Wen, T.-B. *J. Org. Chem.* **2016**, *81*, 1696−1703.

15. The structures of all the products were identified by their ^{1}H-NMR, ^{13}C-NMR and HRMS (ESI), **3ai** was further confirmed by x-ray crystallography (see Supplementary data). The supplementary crystallographic data of **3ai**, CCDC 1472396, can be obtained free of charge via www.ccdc.cam.ac.uk.