Advanced Synthesis & Catalysis

Accepted Article

Title: Cobalt(II)-Catalyzed [5+2] C-H Annulation of o-Arylanilines with Alkynes: An Expedient Route to Dibenzo-[b,d]azepines

Authors: Fei Ling, Zhen Xie, Jiachen Chen, Chongren Ai, Haiwei Shen, Ze Wang, Xiao Yi, and Weihui Zhong

To be cited as: *Adv. Synth. Catal.* 10.1002/adsc.201900261

Link to VoR: http://dx.doi.org/10.1002/adsc.201900261

COMMUNICATION

DOI: 10.1002/adsc.201((will be filled in by the editorial staff))

Cobalt(II)-Catalyzed [5+2] C-H Annulation of *o*-Arylanilines with Alkynes: An Expedient Route to Dibenzo-[*b*,*d*]azepines

Fei Ling, Zhen Xie, Jiachen Chen, Chongren Ai, Haiwei Shen, Ze Wang, Xiao Yi, Weihui Zhong*

Key Laboratory for Green Pharmaceutical Technologies and Related Equipment of Ministry of Education, College of Pharmaceutical Sciences, Zhejiang University of Technology, Hangzhou 310014, P.R. China.
Tel.&Fax:+86(571)88320117 E-mail: weihuizhong@zjut.edu.cn

Received: ((will be filled in by the editorial staff))

Supporting information for this article is available on the WWW under http://dx.doi.org/10.1002/adsc.201######.((Please delete if not appropriate))

Abstract. The first example of $CoCl_2$-catalyzed formal [5+2] oxidative annulation of *o*-arylanilines with alkynes was developed, giving access to various important imine-containing dibenzo-[*b*,*d*]azepine scaffolds through sequential C-C/C-N bond formation. The reaction employs catalytic amount of manganese and oxygen as cooxidants, and features a broad substrate scope. Preliminary mechanistic studies suggested that C–H activation is involved in the rate-determining step. Moreover, both internal and terminal alkynes are well tolerated in this transformation. Besides, a regioselective migratory insertion was observed when using terminal alkynes as substrates.

Keywords: C-H activation; cobalt; [5+2] annulation; dibenzo-[*b*,*d*]azepine; picolinamide

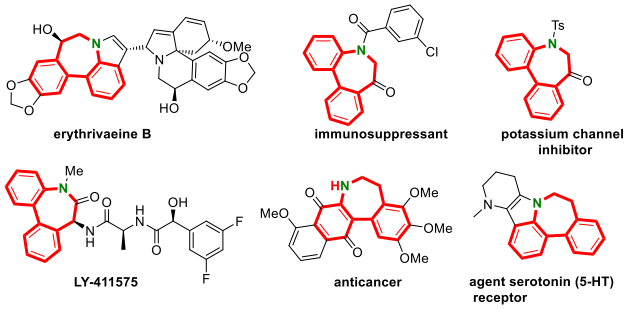
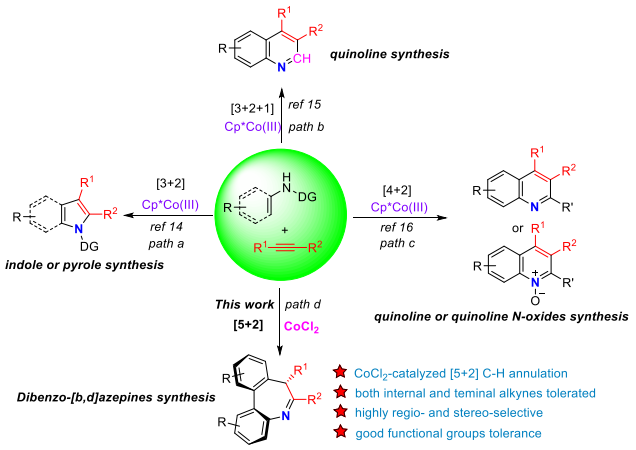


Figure 1. Bioactive compounds bearing an dibenzo[*b*,*d*]azepine core.

Dibenzo[*b*,*d*]azepines are a valuable class of medium-sized *N*-heterocycles, widely found in the core structures of many natural products and bioactive compounds. For example (Figure 1), erythrivaeine B, one of dimeric Erythrina alkaloids, was isolated from the cultivated plant, E. *variegata*.[1] LY-411575 has proved to be an effective g-secretase inhibitor for the treatment of melanoma and Alzheimer's disease.[2] Moreover, other functionalized dibenzo[*b*,*d*]azepines also showed multi biological activity, regarding as immunosuppressant, potassium channel inhibitor,[3] anticancer agent[4] and a serotonin (5-HT) receptor.[5] Because of their great importance, various approaches have been developed for the access of these scaffolds.[6] However, majority of them required highly functionalized substrates, which were prepared through multistep reactions. Thus, the search for novel practical and efficient synthetic approaches starting from less expensive and more readily available reagents is of foremost interest.

Transition metal catalyzed C-H functionalization has emerged as an ideal way for rendering shorter synthetic routes to these frameworks through nitrogen-group-assisted annulations of less pre-functionalized precursors with different coupling partners.[7] In 2012, Zhang's group reported the first Pd-catalyzed free-amine-directed alkenylation/cycloamination sequence of biphenyl-2-amines with α-branched styrenes to furnish dibenzo[*b*,*d*]azepines bearing a quaternary center.[7a] Inspiringly, the group of Luan described a stereoselective Pd(II)-catalyzed [5+2] oxidative annulation of biphenyl-2-amines with internal alkynes, leading to a various imine-type dibenzo[*b*,*d*]azepines, despite its unsuccess when using terminal alkynes.[7b] Later on, Huang and coworkers showed a Rh(III)-catalyzed C–H functionalization/amidation cascade reaction of aminobiaryls with diazomalonates for the synthesis of these compounds.[7c] More recently, Luan's group demonstrated the catalytic activity of Pd(II)/Cu(II) in the preparation of these scaffolds from *o*- arylanilines with dienes.[7d] Despite these major advances, the use of noble metal catalyst limited its further application from a practical and commercial point of view. Therefore, the pursuit of systems based upon more readily available first row transition metal species has become a significant goal.

10.1002/adsc.201900261

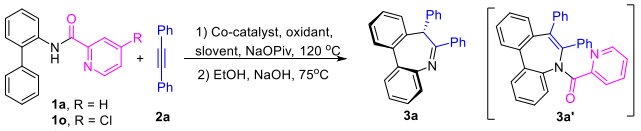


Scheme 1. Cobalt-Catalyzed C-H Annulation of Aniline Derivatives with Alkynes.

Pioneered by Glorius,[8] Nakamura,[9] Ackermann,[10] Kanai,[11] Yoshikai,[12] Daugulis,[13] and others,[14] inexpensive metal cobalt has been identified as viable catalyst for C−H activation reactions.[15] In particular, the cobalt catalyzed C−H annulation of aniline derivatives with alkynes as two-carbon synthons offers a powerful method for the construction of diverse five- or six-membered heterocycles. For example, various indole and pyrrole derivatives could be easily prepared through Cp*Co(III)-catalyzed [3+2] cyclization reactions (Scheme 1, path a).[16] Moreover, a series of quinolines were synthesized via a Cp*Co(III)-catalyzed [3+2+1] C-H annulation of anilines with alkynes involving DMSO as the C1 building block (Scheme 1, path b).[17] Besides, several groups also achieved the construction of quinoline moieties and quinoline *N*-oxides through the formal [4+2] cyclization reactions (Scheme 1, path c).[16b,18] However, all cases employed high-valent Cp*Co(III) as catalyst, which is much more expensive than low-valent cobalt(II). Besides, the assembly of larger heterocyclic rings by means of cobalt-catalyzed C–H annulation was rarely explored.[19] Recently, our group have developed efficient routes for *iso*-indolinones and phenanthridinones via Co(II)-catalyzed formal [3+2] and [4+2] cycloadditions of benzylamines and *o*-arylanilines.[20] Inspired by our previous work, we disclosed herein a $CoCl_2$-catalyzed [5+2] C-H annulation of *o*-arylanilines with alkynes, leading to various seven-membered dibenzo[*b*,*d*]azepines in high regio- and stereo-selectivities (Scheme 1, path d).

The initial assay was carried out with *N*-([1,1'-biphenyl]-2-yl)picolinamide (**1a**) and 1,2-diphenylethyne (**2a**) in the presence of 20 mol % of $Co(OAc)_2.4H_2O$, Ag_2CO_3 (2.0 equiv) and NaOPiv (2.0 equiv) in DMF at 120 °C for 12 h (Table 1, entry 1). Unfortunately, it was difficult to separate the pure enamine-formed product **3a'**, due to its instablity. Therefore, a one-pot procerdure by treatment of the reaction mixture with EtOH and NaOH was performed, giving the imine-type product **3a** with high

Table 1. Optimization of Reaction Conditions.[a]



Entry	Catalyst	Oxidant	Solvent	Yield (%)
1	$Co(OAc)_2$ •$4H_2O$	Ag_2CO_3	DMF	14
2	$Co(OAc)_2$ •$4H_2O$	Ag_2CO_3	TFE	35
3	$Co(OAc)_2$ •$4H_2O$	Ag_2CO_3	CH_3CN	trace
4	$Co(OAc)_2$ •$4H_2O$	Ag_2CO_3	HFIP	27
5	$Co(acac)_2$	Ag_2CO_3	TFE	28
6	$CoCl_2$	Ag_2CO_3	TFE	47
7	$Co(ClO_4)_2$ •$6H_2O$	Ag_2CO_3	TFE	20
8	$CoCl_2$	Ag_2CO_3	TFE	45
9[b]	$CoCl_2$	Ag_2CO_3	TFE	31
10[c]	$CoCl_2$	Ag_2CO_3	TFE	N.R.
11	$CoCl_2$	AgOAc	TFE	40
12	$CoCl_2$	$Mn(OAc)_2$	TFE	52
13	$CoCl_2$	$Mn(OAc)_3$	TFE	49
14	$CoCl_2$	$Cu(OAc)_2$	TFE	trace
15	$CoCl_2$	DTBP	TFE	trace
16[e]	$CoCl_2$	$Mn(OAc)_2$	TFE	65
17[e,f]	$CoCl_2$	$Mn(OAc)_2$	TFE	63
18[e,g]	$CoCl_2$	$Mn(OAc)_2$	TFE	40
19[e,h]	$CoCl_2$	$Mn(OAc)_2$	TFE	40
20[e,i]	$CoCl_2$	$Mn(OAc)_2$	TFE	56
21[e,j]	$CoCl_2$	$Mn(OAc)_2$	TFE	47
22[e,k]	$CoCl_2$	$Mn(OAc)_2$	TFE	61

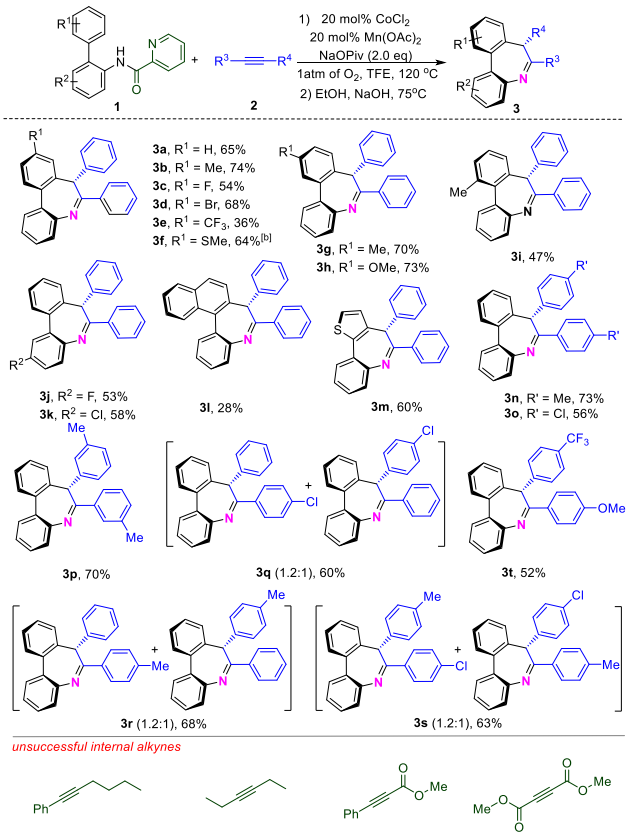
[a] **1a** (0.4 mmol), **2a** (0.8 mmol), Co catalyst (0.08 mmol), oxidant (0.8 mmol), and NaOPiv (0.8 mmol) in solvent (5 mL) for 12 h. Then, removal of the directing group (DG) in a solution of EtOH (6 mL) and NaOH (1.6 mmol) at 75 °C. [b] 130 °C. [c] 100 °C. [d] 80 °C. [e] $Mn(OAc)_2$ (0.01 mmol) and O_2 (1 atm) as cooxidants. [f] KOPiv as additive. [g] PivOH as additive. [h] CH_3CO_2H as additive. [i] 140 °C. [j] **1o** was used. [k] **1p** was used. HFIP = hexafluoroisopropanol; DTBP = di-tert-butyl peroxide.

stereoselectivity, albeit in lower yield. The solvent screening indicated that the fluorine containing solvents showed better results than others, and 2,2-trifluoroethanol (TFE) delivered highest yield of 35% (Table 1, entries 1-4). Next, a set of cobalt salts was examined, $CoCl_2$ turned out to be the best catalyst, affording **3a** in 47% yield (Table 1, entries 5-7). Moreover, changing the reaction temperature did not

10.1002/adsc.201900261

improved the product yield, and the reaction became ineffective when the temperature was below 80 °C

Table 2. Substrate Scope of *o*-Arylanilines with Internal Alkynes.[a]



[a] Reaction conditions: **1** (0.4 mmol), **2** (0.8 mmol), $CoCl_2$ (0.08 mmol), $Mn(OAc)_2$ (0.08 mmol), and NaOPiv (0.8 mmol) in TFE (3 mL) under 1 atm of O_2 for 12 h. Then, removal of the DG in a solution of EtOH (6 mL) and NaOH (1.6 mmol) at 75 °C. [b] a stereoisomer was observed, and the ratio of the major product and minor product was 14.2:1.

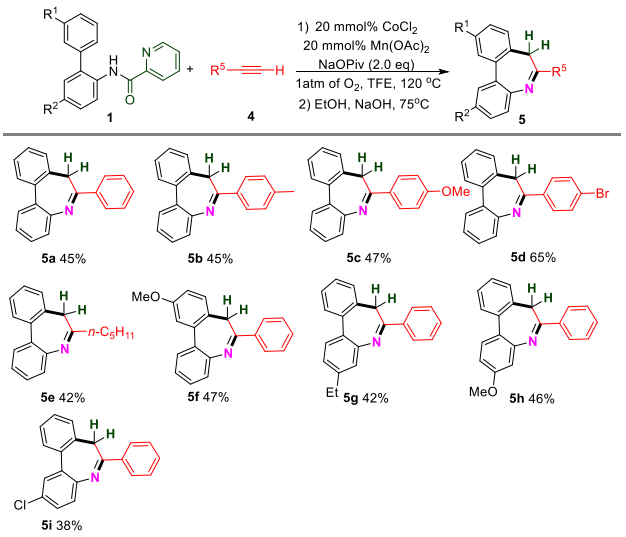
(Table 1, entries 8-10). Notably, the oxidant had a great influence on the reaction outcomes. Ag and Mn salts were found to be the successful oxidants, while Cu salts and other nonmetal oxidants were failed to give the expected product (Table 1, entries 11-15). The best result was achieved by using catalytic ammount of $Mn(OAc)_2$ and O_2 as cooxidant, delivering **3a** in 65% yield (Table 1, entry 16).[21] A decreased yield was obtained when the reaction carried out under conditions of entry 16 but at 140 °C (Table 1, entry 20). Furthermore, the investigation of various additives revealed no benefit to the reaction efficency (Table 1, entries 17-19). Finally, using other substrate (**1o** or **1p**) did not improved the reaction yield (Table 1, entries 21 and 22).

After identifying the optimum reaction conditions, we next set out to determine the versatility of this reaction system in the intermolecular [5+2] oxidative annulation reaction of various *o*-arylanilines with alkynes. The substrate scope of this reaction was initially explored with a range of *o*-arylanilines **1** and 1,2-diphenylethyne (**2a**). Variation of R^1 and R^2 showed that benzene rings with an electron-donating groups (Me, SMe, and OMe) gave better yields than those with an electron-withdrawing groups (F and CF_3). The reaction conditions were compatible with Br and Cl, which are convenient handles for further functionalization (**3d** and **3k**). Moreover, the substitution pattern of the aryl moieties had a significant effect on the reaction efficiency, delivering **3i** and **3l** in 47% and 28% yields, respectively. Delightfully, a heteroaromatic ring (2-thienyl) could be used in this reaction to give **3m** in 60% yield. Next, the scope with respect to the alkynes **2** was studied, and the desired products were achieved in 52-73% yield. Symmetrical diaryl-substituted alkynes with electron-withdrawing groups gave better yields (**3n** and **3p**) than that with an electron-donating group (**3o**). It was noteworthy that the nonsymmetrical diaryl alkynes provided the regioisomers **3q**-**3s** in moderate yields, with nearly 1.2:1 regioselectivities. Pleasingly, captodative diarylethyne having strong electron-biased groups (−OMe and $-CF_3$) at the para positions of the phenyl rings was converted to **3t** with >20:1 regioselectivity in 52% yield. Unfortunately, aliphatic alkynes turned out to be unsuccessful substrates in this reaction as well as ethyl propiolate detivatives.

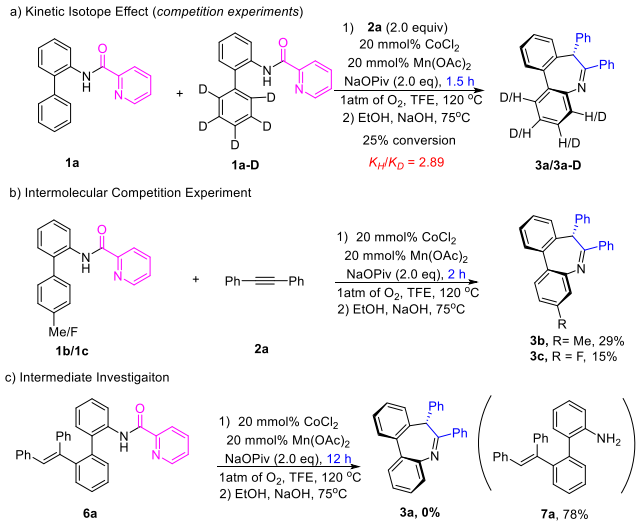
Intriguingly, a variety of terminal alkynes also underwent this [5+2] C-H cyclization reaction smoothly without any modification to the standard conditions for internal alkynes, leading to 6-substitued-7*H*-dibenzo[*b*,*d*]azepines **5a-i** in moderate yields with high regioselectivities. The substituents on the phenyl rings of terminal alkynes had a little influence on the reaction yield, and the alkyne bearing

Table 3. Reaction Scope of *o*-Arylanilines with Terminal Alkynes.[a]

10.1002/adsc.201900261



[a] Reaction conditions: **1** (0.4 mmol), **4** (0.8 mmol), $CoCl_2$ (0.08 mmol), $Mn(OAc)_2$ (0.08 mmol), and NaOPiv (0.8 mmol) in TFE (3 mL) under 1 atm of O_2 for 12 h. Then, removal of the DG in a solution of EtOH (6 mL) and NaOH (1.6 mmol) at 75 °C.

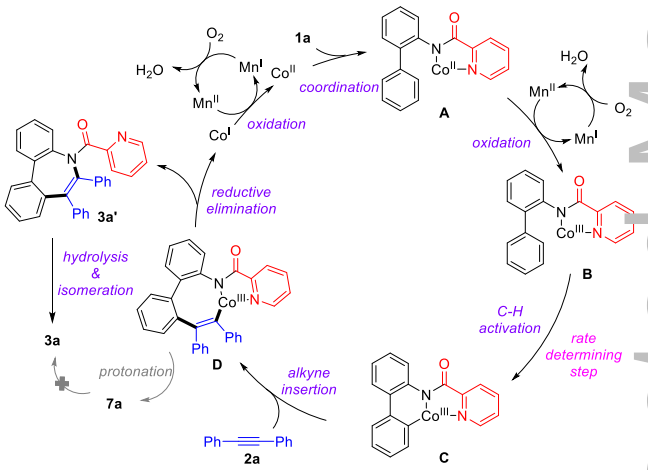


Scheme 2. Mechanism Studies.

an electron-withdrawing group (**5d**) offered higher yield than those with electron-donating groups (**5b** and **5c**). Notably, alkyl alkyne was also tolerated in this transformation, providing the corresponding product **5e** in 42% yield. Furthermore, a set of substituted *o*-arylanilines were examined, all of them could reacted with ethynylbenzene efficiently, affording the expected products **5f-i** in 38-47% yield.

To gain insights into the reaction mechanism, several experiments were conducted (Scheme 2). Initially, an intermolecular kinetic isotope effect study was carried out, and a primary KIE value of 2.89 was observed, which indicated that the C-H bond cleavage probably occurred in the rate-determining step (Scheme 2a). In addition, an intermolecular competition experiment using differently substituted *o*-arylanilines **1b** and **1c** revealed that electron-rich *o*-phenylaniline reacted with **2a** preferentially (Scheme 2b). The preferential formation of **3b**, having an electron-rich substituent, implies that a base (acetate)-assisted intramolecular electrophilic substitution-type mechanism was operative within the C−H cobaltation.[22] Finally, subjecting (*E*)-*N*-(2'-(1,2-diphenylvinyl)-[1,1'-biphenyl]-2-yl)picolinamide (**6a**) under standard conditions failed to give the expected product **3a**, but offered the deprotected aniline **7a** in 78% yield (Scheme 2c). This observation strongly suggested that the protonation of the cobalt might not be involved in current process, while the reductive elimination of Co(III) happened to produce the enamine-formed product **3a'**, along with the release of Co(I) species.

Based on the control experiments and previous cobalt(II) chemistry on annulation reactions,[15e,15f,23] a plausible reaction mechanism for the cobalt catalyzed [5+2] C−H annulation is depicted in Scheme 3 with **1a** and **2a** as the model substrates. The reaction is believed to be initiated by the coordination of Co(II) with *N*-([1,1'-biphenyl]-2-yl)picolinamide (**1a**) to give a substrate coordinate Co(II) complex **A**, which is then



Scheme 3. Mechanistic Hypothesis.

oxidized to a Co(III) species **B** using O_2 as the terminal oxidant. Subsequently, C(Sp^2)-H bond activation of the *ortho*-phenyl group takes place to generate a cyclic Co(III) complex **C**. Thereafter, 1,2-diphenylethyne (**2a**) coordination and migratory insertion generate eight-membered cobaltacycle species **D**, which upon reductive elimination provides the enamine-formed product **3a'** and Co(I). The released Co(I) species is oxidized to active Co(II) species by magnesium and oxygen to complete the catalytic cycle. Finally, hydrolysis and concomitantly tautomerization of **3a'** lead to the formation of the thermodynamically more stable **3a** as the sole product.

In conclusion, we have established an expedient and convenient strategy for the construction of

various imine-containing dibenzo-[*b*,*d*]azepines through Co(II)-catalyzed regio- and stereo-selective [5+2] C(Sp^2)-H annulation of *o*-arylanilines with alkynes via sequential C-C/C-N bond formation. The reaction features a broad substrate scope and good functional group tolerances, and both internal alkynes and terminal alkynes were well tolerated. Preliminary mechanistic studies suggested that C–H activation is involved in the rate-determining step.

Experimental Section

Typical Procedure for the $CoCl_2$-Catalyzed [5+2] C−H Annulation of *o*-Arylanilines with Alkynes

A mixture of **1a** (109.7 mg, 0.4 mmol), **2a** (142.6 mg, 0.8 mmol), $CoCl_2$ (10.4 mg, 0.08 mmol, 20 mol%), $Mn(OAc)_2$ (13.9 mg, 0.08 mmol, 20 mol%), NaOPiv (113.7 mg, 0.8 mmol, 2.0 eq.) in TFE (3.0 ml) was heated at 120 °C under O_2 (1 atm) for 12 hours. The reaction mixture was cooled to room temperature, and then the solvent was removed under vacuum. To the residue, 6 mL of EtOH and NaOH (64 mg, 1.6 mmol) were added. The mixture was stirred at 75 °C for 6 h, then cooled to room temperature. The solvent was removed under vacuum and the crude product was purified by column chromatography on silica gel (n-hexane/EtOAc = 200:1 to 100:1) to yield **3a** (70.6 mg, 65%) as a white solid.

Acknowledgements

We thank the National Natural Science Foundation of China (Nos. 21676253 and 21706234), the Natural Science Foundation of Zhejiang Province of China (No. LY19B060011) for financial support.

References

[1] B. Zhang, M. Bao, C. Zeng, X. Zhong, L. Ni, Y. Zeng, X. Cai, *Org. Lett.* **2014**, *16*, 6400-6403.

[2] a) J. S. Nair, T. Sheikh, A. L. Ho, G. K. Schwartz, *Anticancer Res.* **2013**, *33*, 1307-1316; b) G. T. Wong, D. Manfra, F. M. Poulet, Q. Zhang, H. Josien, T. Bara, L. Engstrom, M. Pinzon-Ortiz, J. S. Fine, H. J. Lee, L. Zhang, G. A. Higgins, E. M. Parker, *J. Biol. Chem.* **2004**, *279*, 12876-12882.

[3] S. Pegoraro, M. Lang, T. Dreker, J. Kraus, S. Hamm, C. Meere, J. Feurle, S. Tasler, S. Prüting, Z. Kura, V. Visan, S. Grissmer, *Bioorg. Med. Chem. Lett.* **2009**, *19*, 2299-2304.

[4] W. Phutdhawong, G. Eksinitkun, W. Ruensumran, T. Taechowisan, W. S. Phutdhawong, *Arch. Pharmacal Res.* **2012**, *35*, 769-777.

[5] R. Rajagopalan, A. Bandyopadhyaya, D. R. Rajagopalan, P. Rajagopalan, *Bioorg. Med. Chem. Lett.* **2014**, *24*, 576-579.

[6] a) F. Hoffmann-Emery, R. Jakob-Roetne, A. Flohr, F. Bliss, R. Reentsz, *Tetrahedron Lett.* **2009**, *50*, 6380-6382; b) H. Tabata, H. Suzuki, K. Akiba, H. Takahashi, H. Natsugari, *J. Org. Chem.* **2010**, *75*, 5984-5993; c) X. Pan, C. S. Wilcox, *J. Org. Chem.* **2010**, *75*, 6445-6451; d) B. S. Bhakuni, A. Kumar, S. J. Balkrishna, J. A. Sheikh, S. Konar, S. Kumar, *Org. Lett.* **2012**, *14*, 2838-2841; e) T. W. Liwosz, S. R. Chemler, *Chem. Eur. J.* **2013**, *19*, 12771-12777; f) T. Saget, N. Cramer, *Angew. Chem., Int. Ed.* **2013**, *52*, 7865-7868; *Angew. Chem.* **2013**, *125*, 8019-8022.

[7] a) Z. Liang, L. Ju, Y. Xie, L. Huang, Y. Zhang, *Chem. Eur. J.* **2012**, *18*, 15816-15821; b) Z. Zuo, J. Liu, J. Nan, L. Fan, W. Sun, Y. Wang, X. Luan, *Angew. Chem., Int. Ed.* **2015**, *54*, 15385-15389; *Angew. Chem.* **2015**, *127*, 15605-15609; c) P. Bai, X.-F. Huang, G.-D. Xu, Z.-Z. Huang, *Org. Lett.* **2016**, *18*, 3058-3061; d) L. Bai, Y. Wang, Y. Ge, J. Liu, X. Luan, *Org. Lett.* **2017**, *19*, 1734-1737.

[8] a) A. Lerchen, T. Knecht, C. G. Daniliuc, F. Glorius, *Angew. Chem., Int. Ed.* **2016**, *55*, 15166-15170; *Angew. Chem.* **2016**, *128*, 15391-15395; b) J. H. Kim, S. Gressies, F. Glorius, *Angew. Chem., Int. Ed.* **2016**, *55*, 5577-5581; *Angew. Chem.* **2016**, *128*, 5667-5671.

[9] a) L. Ilies, Q. Chen, X. Zeng, E. Nakamura, *J. Am. Chem. Soc.* **2011**, *133*, 5221-5223; b) R. Shang, L. Ilies, E. Nakamura, *J. Am. Chem. Soc.* **2015**, *137*, 7660-7663.

[10] W. Song, L. Ackermann, *Angew. Chem., Int. Ed.* **2012**, *51*, 8251-8254; *Angew. Chem.* **2012**, *124*, 8376-8379.

[11] T. Yoshino, H. Ikemoto, S. Matsunaga, M. Kanai, *Angew. Chem., Int. Ed.* **2013**, *52*, 2207-2211; *Angew Chem.* **2013**, *125*, 2263-2267.

[12] a) J. Wu, N. Yoshikai, *Angew. Chem., Int. Ed.* **2016**, *55*, 336-340; *Angew. Chem.* **2016**, *128*, 344-348; b) K. Gao, N. Yoshikai, *Acc. Chem. Res.* **2014**, *47*, 1208-1219.

[13] a) T. T. Nguyen, L. Grigorjeva, O. Daugulis, *ACS Catal.* **2016**, *6*, 551-554; b) L. Grigorjeva, O. Daugulis, *Angew. Chem., Int. Ed.* **2014**, *53*, 10209-10212; *Angew. Chem.* **2014**, *126*, 10373-10376.

[14] a) S. Maity, R. Kancherla, U. Dhawa, T. Hoque, S. Pimparkar, D. Maiti, *ACS Catal.* **2016**, *6*, 5493-5499; b) M. Sen, B. Emayavaramban, N. Barsu, J. R. Premkumar, B. Sundararaju, *ACS Catal.* **2016**, *6*, 2792-2796; c) C. Du, P.-X. Li, X. Zhu, J.-F. Suo, J.-L. Niu, M.-P. Song, *Angew. Chem., Int. Ed.* **2016**, *55* 13571-13575; *Angew. Chem.* **2016**, *128*, 13769-13773; d) J. R. Hummel, J. A. Ellman, *J. Am. Chem. Soc.* **2015**, *137*, 490-498; e) P. Patel, S. Chang, *ACS Catal.* **2015**, *5*, 853-858; f) A. B. Pawar, S. Chang, *Org. Lett.* **2015**, *17*, 660-663.

[15] For selected reviews of Co-catalyzed C−H activation, see: a) S. Prakash, R. Kuppusamy, C.-H. Cheng, *ChemCatChem* **2018**, *10*, 683-705; b) N. Sauermann, T. H. Meyer, L. Ackermann, *Chem. Eur. J.* **2018**, *24*, 16209-16217; c) S. M. Ujwaldev, N. A. Harry, M. A. Divakara, G. Anilkumar, *Catal. Sci. Technol.* **2018**, *8*, 5983-6018; d) S. Wang, S.-Y. Chen, X.-Q. Yu, *Chem.*

Commun. **2017**, *53*, 3165-3180; e) Y. Kommagalla, N. Chatani, *Coordin. Chem. Rev.* **2017**, *350*, 117-135; f) M. Moselage, J. Li, L. Ackermann, *ACS Catal.* **2016**, *6*, 498-525.

[16] For selected examples of Co-catalyzed [3+2] annulations of anilines with alkynes, see: a) Z.-Z. Zhang, B. Liu, J.-W. Xu, S.-Y. Yan, B.-F. Shi, *Org. Lett.* **2016**, *18*, 1776-1779; b) Q. Lu, S. Vásquez-Céspedes, T. Gensch, F. Glorius, *ACS Catal.* **2016**, *6*, 2352-2356; c) H. Wang, M. Moselage, M. J. González, L. Ackermann, *ACS Catal.* **2016**, *6*, 2705-2709; d) A. Lerchen, S. Vasquez-Cespedes, F. Glorius, *Angew. Chem., Int. Ed.* **2016**, *55*, 3208-3211; *Angew. Chem.* **2016**, *128*, 3261-3265; e) Y. Liang, N. Jiao, *Angew. Chem., Int. Ed.* **2016**, *55*, 4035-4039; *Angew. Chem.* **2016**, *128*, 4103-4107; f) S. Zhou, J. Wang, L. Wang, K. Chen, C. Song, J. Zhu, *Org. Lett.* **2016**, *18*, 3806-3809; g) W. Yu, W. Zhang, Y. Liu, Y. Zhou, Z. Liu, Y. Zhang, *RSC Adv.* **2016**, *6*, 24768-24772; h) D. M. Lade, A. B. Pawar, *Org. Chem. Front.* **2016**, *3*, 836-840.

[17] For an example of Co-catalyzed [3+2+1] annulation of anilines with alkynes, see: X. Xu, Y. Yang, X. Zhang, W. Yi, *Org. Lett.* **2018**, *20*, 566-569.

[18] For selected examples of Co-catalyzed [4+2] annulations of anilines with alkynes, see: a) L. Kong, S. Yu, X. Zhou, X. Li, *Org. Lett.* **2016**, *18*, 588-591; b) Q. Yan, Z. Chen, Z. Liu, Y. Zhang, *Org. Chem. Front.* **2016**, *3*, 678-682; (c) Y. Liu, C. Wang, N. Lv, Z. Liu, Y. Zhang, *Adv. Synth. Catal.* **2017**, *359*, 1351-1358.

[19] For a limited example of Co-catalyzed [5+2] annulation, see: a) X.-L. Han, X.-G. Liu, E. Lin, Y. Chen, Z. Chen, H. Wang, Q. Li, *Chem. Commun.* **2018**, *54*, 11562-11565; b) P. G. Chirila, J. Adams, A. Dirjal, A. Hamilton, C. J. Whiteoak, *Chem. Eur. J.* **2018**, *24*, 3584-3589.

[20] a) F. Ling, C. Ai, Y. Lv, W. Zhong, *Adv. Synth. Catal.* **2017**, *359*, 3707-3712; b) F. Ling, C. Zhang, C. Ai, Y. Lv, W. Zhong, *J. Org. Chem.* **2018**, *83*, 5698-5706.

[21] Removal of the DG directly in the TFE resulted in a sharp decrease on yield (approximately 30%) and extended reaction time.

[22] a) C. Tirler, L. Ackermann, *Tetrahedron* **2015**, *71*, 4543-4551; b) W. Ma, R. Mei, G. Tenti, L. Ackermann, *Chem. Eur. J.* **2014**, *20*, 15248-15251.

[23] For recent examples of cobalt(II)-catalyzedreactions, see: a) T. H. Meyer, J. C. A. Oliveira, S. C. Sau, N. W. J. Ang, L. Ackermann, *ACS Catal.* **2018**, *8*, 9140-9147; b) S. Qiu, S. Zhai, H. Wang, C. Tao, H. Zhao, H. Zhai, *Adv. Synth. Catal.* **2018**, *360*, 3271-3276; c) D. Kalsi, S. Dutta, N. Barsu, M. Rueping, B. Sundararaju, *ACS Catal.* **2018**, *8*, 8115-8120; d) S. Zhai, S. Qiu, X. Chen, C. Tao, Y. Li, B. Cheng, H. Wang, H. Zhai, *ACS Catal.* **2018**, *8*, 6645-6649; e) R. Mei, N. Sauermann, J. C. A. Oliveira, L. Ackermann, *J. Am. Chem. Soc.* **2018**, *140*, 7913-7921; f) R. Nallagonda, N. Thrimurtulu, C. M. R. Vollaa, *Adv. Synth. Catal.* **2018**, *360*, 255-260; g) C. Tian, L. Massignan, T. H. Meyer, L. Ackermann, *Angew. Chem., Int. Ed.* **2018**, *57*, 2383-2387; *Angew. Chem.* **2018**, *130*, 2407-2411; h) L. Zeng, H. Li, S. Tang, X. Gao, Y. Deng, G. Zhang, C.-W. Pao, J.-L. Chen, J.-F. Lee, A. Lei, *ACS Catal.* **2018**, *8*, 5448-5453; i) G. Cahiez, A. Moyeux, *Chem. Rev.* **2010**, *110*, 1435-1462; j) O. Planas, P. G. Chirila, C. J. Whiteoak, X. Ribas, *Adv. Organomet. Chem.* **2018**, *69*, 209-282; k) O. Planas, C. J. Whiteoak, V. M. Diaconescu, I. Gamba, J. M. Luis, T. Parella, A. Company, X. Ribas *J. Am. Chem. Soc.* **2016**, *138*, 14388-14397; l) M. Moselage, J. Li, L. Ackermann, *ACS Catal.* **2016**, *6*, 498-525.

10.1002/adsc.201900261

COMMUNICATION

Cobalt(II)-Catalyzed [5+2] C-H Annulation of *o*-Arylanilines with Alkynes: An Expedient Route to Dibenzo-[*b*,*d*]azepines

Adv. Synth. Catal. **2019**, *Volume*, Page – Page

Fei Ling, Zhen Xie, Jiachen Chen, Chongren Ai, Haiwei Shen, Ze Wang, Xiao Yi, Weihui Zhong*