EurJOC
European Journal of Organic Chemistry

Communications
doi.org/10.1002/ejoc.202100550

Chemistry Europe
European Chemical Societies Publishing

Copper-Phosphine Mediated Oxidative Phosphorylation of Aromatic Amines and $P(OR)_3$ under Aerobic Conditions

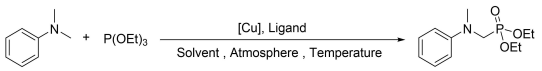
Shihaozhi Wang,[a] Shidi Ma,[a] Jiale Yang,[a] Wenshuang Li,[a] Dianjun Li,*[a] and Jinhui Yang*[a]

A copper-phosphine system ($Cu(OAc)_2$ and t-$Bu_3P{\cdot}HBF_4$) was used to synthesize α-aminophosphonates and phosphoramides from various aromatic amines and trialkyl phosphites under oxygen atmosphere. With this Cu–P system, α-aminophosphonates containing C–P bonds were generated from *N*,*N*-dimethylanilines or *N*-methylanilines and trialkyl phosphites; phosphoramidates containing N–P bonds were produced from *N*-benzylanilines and trialkyl phosphites. This strategy provided a convenient and efficient method for the synthesis of phosphorous compounds. The compounds containing phosphoryl group attracted extensive attention due to their biological activities and wide applications.[1,2] The α-aminophosphonates have been applied in medicine and agriculture such as anticancer drugs, antibiotics, antibacterial agents, and enzyme inhibitors.[1] And phosphoramides could be served as antibiotics, prodrugs, flame retardants, and ligands.[2]

During the past decades, the construction of C–P bond using transition metals has been widely studied.[3] These metals mainly include Cu,[4] Fe,[5] Co,[6] Mn,[7] Ru,[8] Au,[9] Pd,[10] Sb,[11] Ir,[12] Ni,[13] Ag.[14] Among them, the synthesis of α-aminophosphonates by CDC (cross dehydrogenation coupling) reactions[15] involving P(O)-H has been developed.[4–12] For example, Li reported that copper salts catalyzed the synthesis of α-aminophosphonates from *N*-aryltetrahydroisoquinolines and dialkyl phosphites[4a] (Scheme 1A). And the transition metal catalyzed CDC reactions could also be applied for synthesis of phosphoramides[16] containing N–P bonds. Hayes developed the synthesis methodology of phosphoramides catalyzed by Cu[16a] (Scheme 1B). In addition, Lei and coworkers reported a visible light-mediated oxidative phosphorylation that used trialkyl phosphites as phosphorus source to react with tertiary amines (Scheme 1C), and this reaction was catalyzed by two transition metals (Ru and Co).[8b] Because of the importance of compounds containing phosphoryl groups, it is necessary to establish a general protocol to synthesize α-aminophosphonates and phosphoramides. Herein, we developed a copper-phosphine mediated oxidative phosphorylation of aromatic amines and trialkyl phosphites to synthesis α-aminophosphonates/phosphoramides under oxygen atmosphere.

Based on previous reports, some transition metal catalysts could activate $C(sp^3)$-H bonds adjacent to nitrogen in tertiary amines,[4–12,17] and we chose copper salts to produce α-aminophosphonates. *N*,*N*-dimethylaniline and triethyl phosphite were selected as the model substrates. First, several copper salts were tested to catalyze this reaction (Table S1, entries 1–4 in the Supporting Information). To our delight, $CuSO_4$ displayed better catalytic ability in the presence of O_2 (1 atm), and product **3a** was obtained in 36% yield (Table 1, entry 1). Then, a series of ligands were evaluated (Table 1, entry 2; also see Table S1, entries 5–11, in the Supporting Information), wherein t-$Bu_3P{\cdot}HBF_4$ significantly promoted the reaction (Table 1, entry 2). Next, we tested the yields of various copper salts in the presence of ligands (Table 1, entries 2–5; also see Table S1, entries 12–17, in the Supporting Information). $Cu(OAc)_2$ was proved to be the optimal catalyst which increased the yield to 75% (Table 1, entry 3). Obviously, t-$Bu_3P{\cdot}HBF_4$ has better promoting effect on this reaction than its analogues (Table 1, entries 3, 6 and 7). Compared with phosphine salt ligands, the

Table 1. Optimization of reaction conditions.[a]



1a 2a 3a

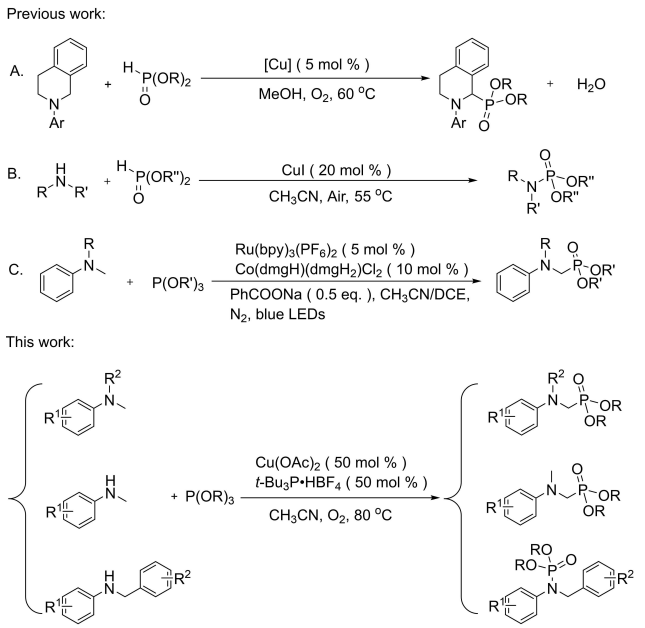
Entry	[Cu] [mol%]	Atmosphere	Ligand [mol%]	Yield[b] [%]
1	$CuSO_4$ (30)	O_2	–	36
2	$CuSO_4$ (30)	O_2	t-$Bu_3P{\cdot}HBF_4$ (30)	57
3	$Cu(OAc)_2$ (30)	O_2	t-$Bu_3P{\cdot}HBF_4$ (30)	75
4	CuCl (30)	O_2	t-$Bu_3P{\cdot}HBF_4$ (30)	53
5	$CuBr_2$ (30)	O_2	t-$Bu_3P{\cdot}HBF_4$ (30)	50
6	$Cu(OAc)_2$ (30)	O_2	$Cy_3P{\cdot}HBF_4$ (30)	65
7	$Cu(OAc)_2$ (30)	O_2	n-$Bu_3P{\cdot}HBF_4$ (30)	55
8	$Cu(OAc)_2$ (30)	O_2	Cy_3P (30)	19
9	$Cu(OAc)_2$ (30)	O_2	t-Bu_3P (30)	22
10[c]	$Cu(OAc)_2$ (30)	O_2	t-$Bu_3P{\cdot}HBF_4$ (30)	56
11[d]	$Cu(OAc)_2$ (30)	O_2	t-$Bu_3P{\cdot}HBF_4$ (30)	42
12	$Cu(OAc)_2$ (30)	Ar	t-$Bu_3P{\cdot}HBF_4$ (30)	16
13	$Cu(OAc)_2$ (30)	Air	t-$Bu_3P{\cdot}HBF_4$ (30)	33
14[e]	$Cu(OAc)_2$ (30)	O_2	t-$Bu_3P{\cdot}HBF_4$ (30)	67
15[f]	$Cu(OAc)_2$ (30)	O_2	t-$Bu_3P{\cdot}HBF_4$ (30)	37
16	*$Cu(OAc)_2$ (50)*	*O_2*	*t-$Bu_3P{\cdot}HBF_4$ (50)*	*80*
17	$Cu(OAc)_2$ (50)	O_2	t-$Bu_3P{\cdot}HBF_4$ (100)	76
18[g]	$Cu(OAc)_2$ (50)	O_2	–	16
19[h]	-	O_2	–	Trace

[a] Reaction conditions: **1a** (2 mmol), **2a** (1 mmol), [Cu], Atmosphere (1 atm), ligand, CH_3CN (2 mL), 80 °C for 18 h; [b] Isolated yield; [c] In DCE (2 mL); [d] In THF (2 mL); [e] At 50 °C; [f] At 100 °C; [g] No ligand; [h] No Cu $(OAc)_2$ and ligand.

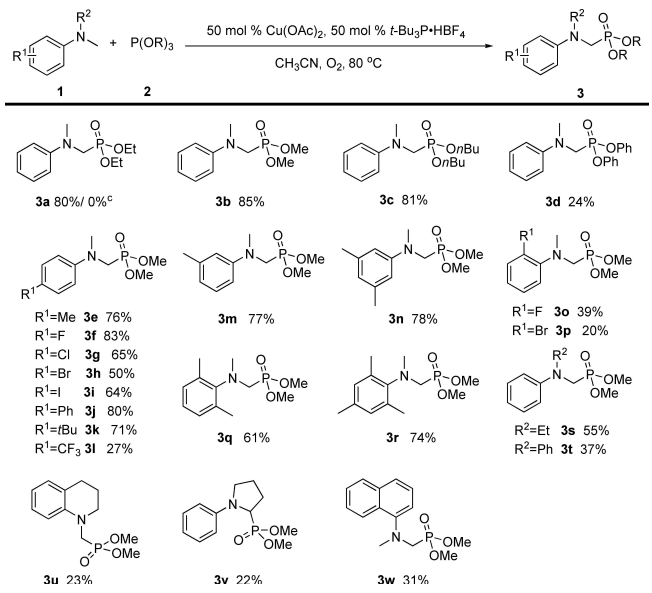
[a] *S. Wang, S. Ma, J. Yang, W. Li, Dr. D. Li, Prof. J. Yang*
State Key Laboratory of High-efficiency Utilization of Coal and Green Chemical Engineering, College of Chemistry and Chemical Engineering, Ningxia University, Yinchuan 750021, China
E-mail: jinhuiyang_nxdx@163.com
nxlidj@126.com

Supporting information for this article is available on the WWW under https://doi.org/10.1002/ejoc.202100550

corresponding phosphine ligands (Cy_3P and t-Bu_3P) exhibited much weaker catalytic ability (Table 1, entries 3, 6 and 8, 9). Solvent screening was then performed. When acetonitrile was replaced with DCE or THF, the yield decreased to 56% and 42%, respectively (Table 1, entries 10, 11). Control experiments showed that molecular oxygen is critical to the transformation. The yields in argon (16%) and air (33%) were much lower than that in oxygen (Table 1, entries 12, and 13). Increasing or decreasing the temperature was unfavorable to the reaction, so the appropriate temperature was determined to be 80 °C (Table 1, entries 14, 15). Then, the amounts of catalyst and ligand were examined (Table 1, entries 3, 16, 17), and a yield of 80% was obtained (Table 1, entry 16). In the condition control experiment, when the ligand was removed, the yield was decreased to 16% (Table 1, entry 18). In the absence of catalyst and ligand, no product was obtained (Table 1, entry 19).



Scheme 1. Reaction of phosphite with amine.

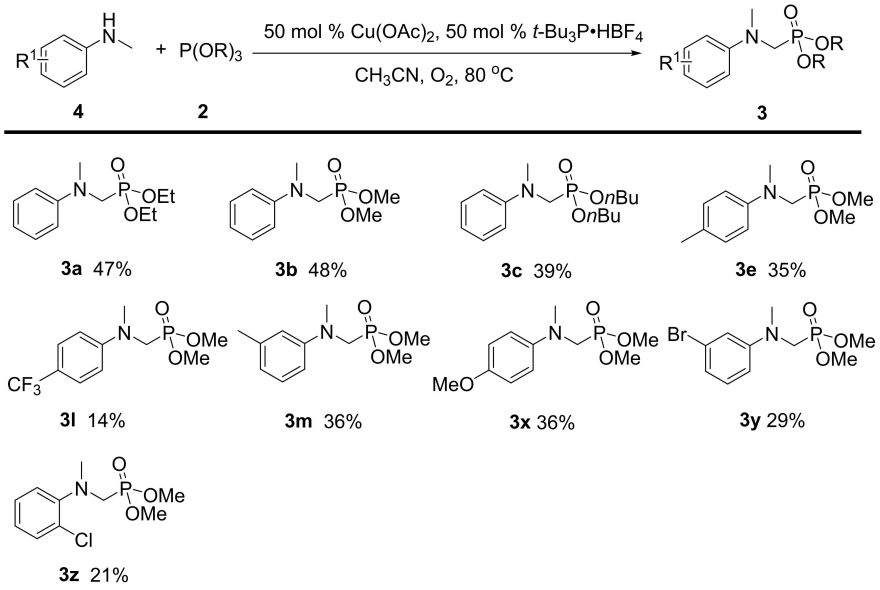


Scheme 2. Investigation of tertiary amine and phosphite.[a,b] [a] Reaction conditions: **1** (2 mmol), **2** (1 mmol), $Cu(OAc)_2$ (50 mol%), t-Bu_3P·HBF_4 (50 mol%), O_2 (1 atm), CH_3CN (2 mL), 80 °C for 18 h; [b] Isolated yield; [c] From $HP(O)(OEt)_2$.

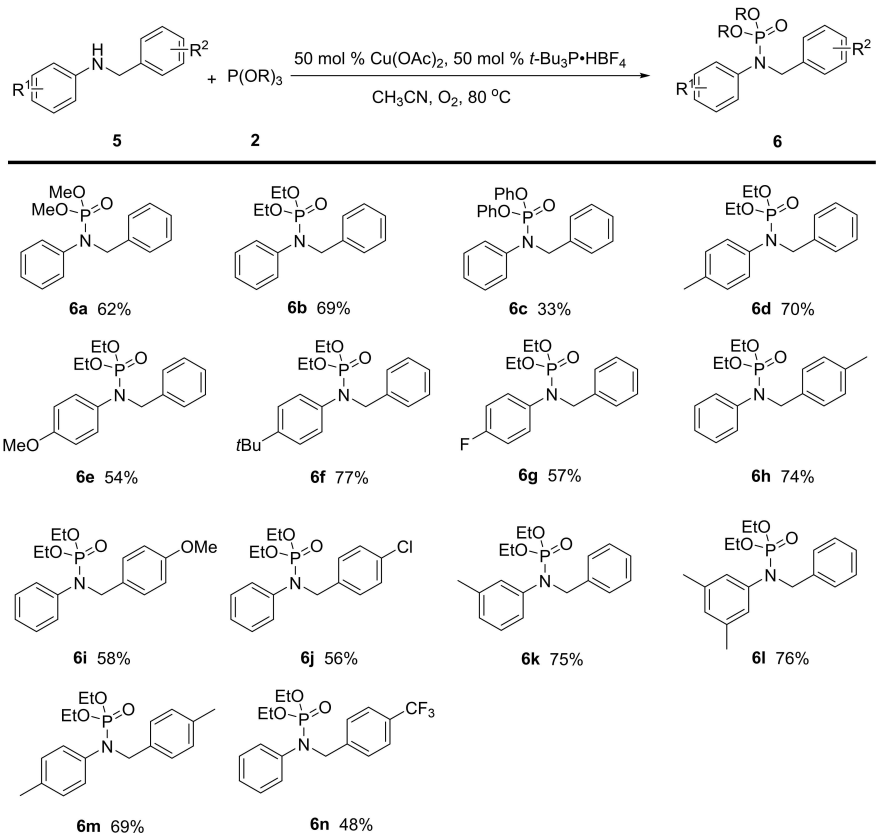
With the optimized conditions in hand, the scope of phosphite was investigated (Scheme 2, **3a**–**3d**). As shown in Scheme 2, the yields of trialkyl phosphites (**3a**–**3d**) were better than dialkyl phosphite (**3a**). For trialkyl phosphite, the yields decreased with increasing alkyl chain length (Scheme 2, **3a**–**3c**). When triphenyl phosphite was used as phosphorus source, the product was obtained in 24% (Scheme 2, **3d**). Consequently, we chose trimethyl phosphite as the phosphorus source in the next steps of the study. Next, we studied different kinds of tertiary amines under the optimized conditions. As shown, various aromatic amines could be smoothly converted into the corresponding α-aminophosphonates. When mono alkyl substituents (Me, *t*-Bu) or a phenyl moiety was present in the *para*-position of *N*-phenyl ring, the expected products were obtained in good yields (Scheme 2, **3e**, **3j** and **3k**). Halogen atoms were all well tolerated, showing their potential application in further chemical transformations (Scheme 2, **3f**-**3i**). The yields of substrates with electron-donating substituents were higher than that with electron-withdrawing substituents (Scheme 2, **3e**, **3l**). This is consistent with the fact that electron rich amines were more facile to be oxidized. Alkyl groups in the *meta*-position also provided the corresponding α-aminophosphonates in a good yield (Scheme 2, **3m** and **3n**). In addition, the yields of *para*- and *meta*- substituted anilines were higher than that of *ortho*-substituted anilines (Scheme 2, **3f** and **3o**, **3h** and **3p**, **3n** and **3q**, **3r**). This difference is probably due to steric hindrance. When methyl and other groups were attached to the nitrogen atom, N-methyl was preferentially reacted and the yields were low to medium (Scheme 2, **3s**, **3t**, **3u**). Moreover, 1-phenylpyrrolidine as substrate, the corresponding product was obtained in 22% yield (Scheme 2, **3v**). Obviously, naphthalene ring was more unfavorable for the reaction (Scheme 2, **3w**).

We also investigated the reaction of *N*-methylaniline and trialkyl phosphite. As shown in Scheme 3, *N*-methylaniline generated the same product **3a** through intermolecular methyl migration and *N*-methyl oxidative phosphorylation in moderate yields might be due to low efficiency of methyl migration. With an increased in the length of the carbon chain on trialkyl phosphites, the yields of the reaction decreased (Scheme 3, **3a**-**3c**). In addition, substituents on the benzene ring were unfavorable to the reaction (Scheme 3, **3e**-**3z**).

We next examined the applicability of this Cu–P system in the reaction of *N*-benzylanilines and trialkyl phosphites (Scheme 4). Interestingly, phosphoramides were formed when *N*-benzylanilines were treated with trialkyl phosphites using the previously mentioned optimal conditions. Various substituted *N*-benzylanilines bearing different substituents were converted smoothly to the corresponding phosphoramides. Obviously, with an increase in the electron-donating ability of the substituents, the yield also increased (Scheme 4, **6d**, **6f**, **6k**–



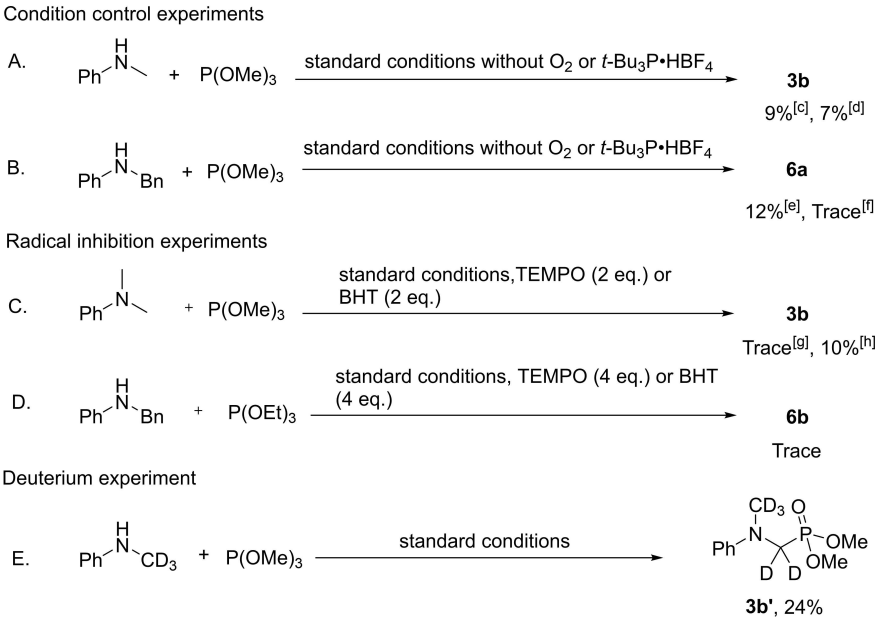
Scheme 3. Substrate scope of *N*-methylaniline and trialkyl phosphite.[a,b] [a] Reaction conditions: **4** (4 mmol), **2** (1 mmol), $Cu(OAc)_2$ (50 mol%), *t*-$Bu_3P{\cdot}HBF_4$ (50 mol%), O_2 (1 atm), CH_3CN (2 mL), 80 °C for 18 h; [b] Isolated yield.



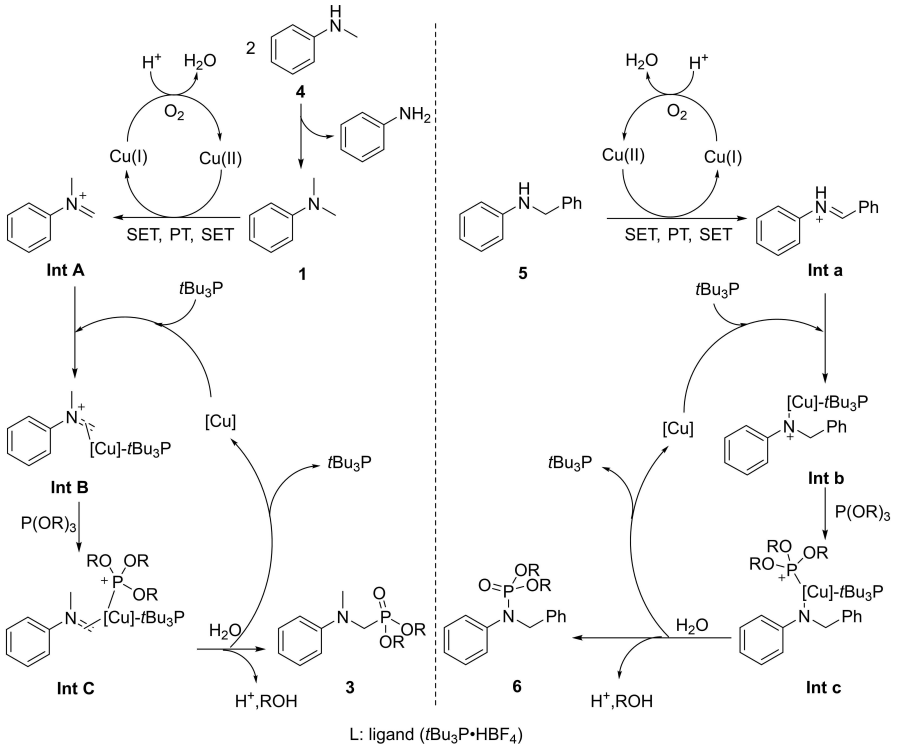
Scheme 4. Substrate scope of *N*-benzylaniline and trialkyl phosphite.[a,b] [a] Reaction conditions: **5** (4 mmol), **2** (1 mmol), $Cu(OAc)_2$ (50 mol%), *t*-$Bu_3P{\cdot}HBF_4$ (50 mol%), O_2 (1 atm), CH_3CN (2 mL), 80 °C for 18 h; [b] Isolated yield.

6n). However, the yields of methoxy-containing substituents were moderate (Scheme 4, **6e** and **6i**). It was likely due to the side reactions.

Several condition control experiments were carried out in order to reveal the mechanism of these transformations (Scheme 5). With the absence of O_2 or *t*-$Bu_3P{\cdot}HBF_4$, the



Scheme 5. Mechanism experiment.[a,b] [a] Standard conditions: tertiary amine (2 mmol) or secondary amine (4 mmol), trialkyl phosphite (1 mmol), $Cu(OAc)_2$ (50 mol%), t-$Bu_3P{\cdot}HBF_4$ (50 mol%), O_2 (1 atm), CH_3CN (2 mL), 80 °C for 18 h; [b] Isolated yield; [c] In Ar; [d] Without t-$Bu_3P{\cdot}HBF_4$; [e] In Ar; [f] Without t-$Bu_3P{\cdot}HBF_4$; [g] Add TEMPO; [h] Add BHT.



Scheme 6. Proposed reaction mechanism.

corresponding products were obtained in low yields (Scheme 5, A, B). These results showed that copper-phosphine-oxygen system played crucial role in reaction processes. And the radical inhibition experiments also exhibited that all reactions were greatly inhibited in the presence of TEMPO or BHT, it implied that the reaction might be carried out through a radical process (Scheme 5, C, D). When the reaction was performed using deuterated substrate, the corresponding methyl-deuterated product was obtained (Scheme 5, E). It indicated that the N-methyl group of product was derived from *N*-methylaniline

rather than trimethyl phosphite, and *N*-methylaniline might first generate *N*,*N*-dimethylaniline via intermolecular methyl migration.

Some details of mechanism such were still uncertain up to now. On the basis of our mechanism experiments and previous reports,[4a,18] we proposed a possible mechanism of this reaction as shown in Scheme 6. Initially, *N*-methylaniline **4** generated *N*,*N*-dimethylaniline **1** via intermolecular methyl migration. After that, *N*,*N*-dimethylaniline **1** produced iminium ion intermediate **A** through SET (Single Electron Transfer), PT (Proton Transfer) and SET process, and Cu(II) was reduced to Cu(I) at the same time. Then, Cu(I) was oxidized to Cu(II) by oxygen and formed water. Next, the intermediate **B** was formed by the coordination of intermediate **A**, copper and ligand. Afterwards, $P(OR)_3$ as a nucleophilic reagent combined with intermediate **B** afforded intermediate **C**. Finally, product **3** was produced by hydrolysis of intermediate **C**, and the copper/ligand removed from the substrate. For *N*-benzylaniline **5**, similar to *N*,*N*-dimethylaniline **1**, the iminium ion intermediate **a** was formed through SET, PT and SET process. And Cu(I) was oxidized to Cu(II) by oxygen and produced water. Next, intermediate **b** was generated by the coordination of intermediate **a**, copper and ligand. And then, $P(OR)_3$ combined with intermediate **b** afforded intermediate **c**. At last intermediate **c** hydrolyzed to generate product **6** and the copper/ligand removed.

In summary, we have developed an efficient strategy of various aromatic amines to synthesize compounds containing phosphoryl group by using a copper and phosphine-ligand ($Cu(OAc)_2$ and t-$Bu_3P{\cdot}HBF_4$) system under an aerobic atmosphere. Importantly, this method could be applied not only to synthesis α-aminophosphonates (C–P bonds) but also to produce phosphoramides (N–P bonds). Under this operationally easy protocol, α-aminophosphonates were generated from tertiary amines or secondary amines. In addition, phosphoramides were produced when *N*-benzylanilines were used as substrates. Further studies on enantioselective copper-mediated reactions are currently underway.

Acknowledgements

This work was supported by the National Natural Science Foundation of China (Grant no. 21861031, 21362025), Institute local cooperation project of Chinese Academy of Engineering (2019NXZD1), Key Research and Development project of Ningxia (2019BDE03002), and the National First-rate Discipline Construction Project of Ningxia (Chemical Engineering and Technology) (NXYLXK2017A04).

Conflict of Interest

The authors declare no conflict of interest.

Keywords: α-Aminophosphonate · C–P bond formation · N–P bond formation · Oxidative phosphorylation · Phosphoramide

[1] a) E. D. Naydenova, P. T. Todorov, K. D. Troev, *Amino Acids* **2010**, *38*, 23–30; b) P. Kafarski, B. Lejczak, *Phosphorus, Sulfur, and Silicon and the Relat. Elem.* **1991**, *63*, 193–215; c) J. G. Allen, F. R. Atherton, M. J. Hall, C. H. Hassall, S. W. Holmes, R. W. Lambert, L. J. Nisbet, P. S. Ringrose, *Nature* **1978**, *272*, 56–58; d) F. R. Atherton, C. H. Hassall, R. W. Lambert, *J. Med. Chem.* **1986**, *29*, 29–40; e) P. Kafarski, B. Lejczak, *Curr. Med. Chem. Anti-Cancer Agents* **2001**, *1*, 301–312.

[2] As antibiotics a) R. F. Roush, E. M. Nolan, F. Löhr, C. T. Walsh, *J. Am. Chem. Soc.* **2008**, *130*, 3603–3609; b) D. R. Phillips, M. Uramoto, K. Isono, J. A. McCloskey, *J. Org. Chem.* **1993**, *58*, 854–859; as prodrugs:; c) J. J. Hale, S. G. Mills, M. MacCoss, C. P. Dorn, P. E. Finke, R. J. Budhu, R. A. Reamer, S.-E. W. Huskey, D. Luffer-Atlas, B. J. Dean, E. M. McGowan, W. P. Feeney, S.-H. L. Chiu, M. A. Cascieri, G. G. Chicchi, M. M. Kurtz, S. Sadowski, E. Ber, F. D. Tattersall, N. M. J. Rupniak, A. R. Williams, W. Rycroft, R. Hargreaves, J. M. Metzger, D. E. MacIntyre, *J. Med. Chem.* **2000**, *43*, 1234–1241; d) M. Serpi, R. Bibbo, S. Rat, H. Roberts, C. Hughes, B. Caterson, M. J. Alcaraz, A. T. Gibert, C. R. A. Verson, C. McGuigan, *J. Med. Chem.* **2012**, *55*, 4629–4639; as flame retardants:; e) T.-M. Nguyen, S. Chang, B. Condon, R. Slopek, E. Graves, M. Yoshioka-Tarver, *Ind. Eng. Chem. Res.* **2013**, *52*, 4715–4724; f) T.-M. D. Nguyen, S. Chang, B. Condon, M. Uchimiya, C. Fortier, *Polym. Adv. Technol.* **2012**, *23*, 1555–1563; as ligands:; g) S. E. Denmark, G. L. Beutner, *Angew. Chem. Int. Ed.* **2008**, *47*, 1560–1638; *Angew. Chem.* **2008**, *120*, 1584–1663.

[3] a) D. S. Glueck, *Top. Organomet. Chem.* **2010**, *31*, 65–100; b) C. S. Demmer, N. Krogsgaard-Larsen, L. Bunch, *Chem. Rev.* **2011**, *111*, 7981–8006; c) C. Shao, W. Xu, L. Li, X. Zhang, *Chin. J. Org. Chem.* **2017**, *37*, 335–348; d) K. Sun, H. Liu, Q. Xie, H. Luo, *Chin. J. Org. Chem.* **2020**, *40*, 2275–2289; e) D. S. Glueck, *J. Org. Chem.* **2020**, *85*, 14276–14285.

[4] For synthesis of α-aminophosphonates used Cu: a) O. Baslé, C.-J. Li, *Chem. Commun.* **2009**, 4124–4126; others:; b) D. Gelman, L. Jiang, S. L. Buchwald, *Org. Lett.* **2003**, *5*, 2315–2318; c) S. Thielges, P. Bisseret, J. Eustache, *Org. Lett.* **2005**, *7*, 681–684; d) Y. Gao, G. Wang, L. Chen, P. Xu, Y. Zhao, Y. Zhao, L.-B. Han, *J. Am. Chem. Soc.* **2009**, *131*, 7956–7957; e) R. Zhuang, J. Xu, Z. Cai, G. Tang, M. Fang, Y. Zhao, *Org. Lett.* **2011**, *13*, 2110–2113; f) H. Luo, K. Sun, Q. Xie, X. Li, X. Zhang, X. Luo, *Asian J. Org. Chem.* **2020**, *9*, 2083–2086.

[5] For synthesis of α-aminophosphonates used Fe: a) W. Han, A. R. Ofial, *Chem. Commun.* **2009**, 6023–6025; b) W. Han, P. Mayer, A. R. Ofial, *Adv. Synth. Catal.* **2010**, *352*, 1667–1676.

[6] For synthesis of α-aminophosphonates used Co: a) B. Lin, S. Shi, R. Lin, Y. Cui, M. Fang, G. Tang, Y. Zhao, *J. Org. Chem.* **2018**, *83*, 6754–6761; b) Z.-Q. Zhu, L.-J. Xiao, D. Guo, X. Chen, J.-J. Ji, X. Zhu, Z.-B. Xie, Z.-G. Le, *J. Org. Chem.* **2019**, *84*, 435–442.

[7] Synthesis used Mn: a) O. Tayama, A. Nakano, T. Iwahama, S. Sakaguchi, Y. Ishii, *J. Org. Chem.* **2004**, *69*, 5494–5496; b) X.-J. Mu, J.-P. Zou, Q.-F. Qian, W. Zhang, *Org. Lett.* **2006**, *8*, 5291–5293; c) S. Wang, Q. Xue, Z. Guan, Y. Ye, A. Lei, *ACS Catal.* **2021**, *11*, 4295–4300.

[8] Synthesis of α-aminophosphonates used Ru: a) M. Rueping, S. Zhu, R. M. Koenigs, *Chem. Commun.* **2011**, *47*, 8679–8681; b) L. Niu, S. Wang, J. Liu, H. Yi, X.-A. Liang, T. Liu, A. Lei, *Chem. Commun.* **2018**, *54*, 1659–1662.

[9] Synthesis of α-aminophosphonates used Au: J. Xie, H. Li, Q. Xue, Y. Cheng, C. Zhu, *Adv. Synth. Catal.* **2012**, *354*, 1646–1650.

[10] Synthesis of α-aminophosphonates used Pd: a) W.-P. To, Y. Liu, T.-C. Lau, C.-M. Che, *Chem. Eur. J.* **2013**, *19*, 5654–5664; others:; b) L.-B. Han, M. Tanaka, *J. Am. Chem. Soc.* **1996**, *118*, 1571–1572; c) M. Lera, C. J. Hayes, *Org. Lett.* **2000**, *2*, 3873–3875; d) M. Kalek, A. Ziadi, J. Stawinski, *Org. Lett.* **2008**, *10*, 4637–4640; e) M. Kalek, M. Jezowska, J. Stawinski, *Adv. Synth. Catal.* **2009**, *351*, 3207–3216; f) T. Chen, C.-Q. Zhao, L.-B. Han, *J. Am. Chem. Soc.* **2018**, *140*, 3139–3155; g) C. Chen, W. Sun, Y. Yan, F. Yang, Y. Wang, Y.-P. Zhu, L. Liu, B. Zhu, *Adv. Synth. Catal.* **2020**, *362*, 2970–2975.

[11] Synthesis of α-aminophosphonates used Sb: A. Tanoue, W.-J. Yoo, S. Kobayashi, *Adv. Synth. Catal.* **2013**, *355*, 269–273.

[12] Synthesis of α-aminophosphonates used Ir: W.-J. Yoo, S. Kobayashi, *Green Chem.* **2014**, *16*, 2438–2442.

[13] Used Ni: a) L.-B. Han, C. Zhang, H. Yazawa, S. Shimada, *J. Am. Chem. Soc.* **2004**, *126*, 5080–5081; b) G. Hu, W. Chen, T. Fu, Z. Peng, H. Qiao, Y. Gao, Y. Zhao, *Org. Lett.* **2013**, *15*, 5362–5365.

[14] Used Ag: a) C.-B. Xiang, Y.-J. Bian, X.-R. Mao, Z.-Z. Huang, *J. Org. Chem.* **2012**, *77*, 7706–7710; b) X. Mao, X. Ma, S. Zhang, H. Hu, C. Zhu, Y. Cheng, *Eur. J. Org. Chem.* **2013**, 4245–4248.

[15] a) C.-J. Li, Z. Li, *Pure Appl. Chem.* **2006**, *78*, 935–945; b) C.-J. Li, *Acc. Chem. Res.* **2009**, *42*, 335–344; c) C. J. Scheuermann, *Chem. Asian J.* **2010**, *5*, 436–451.

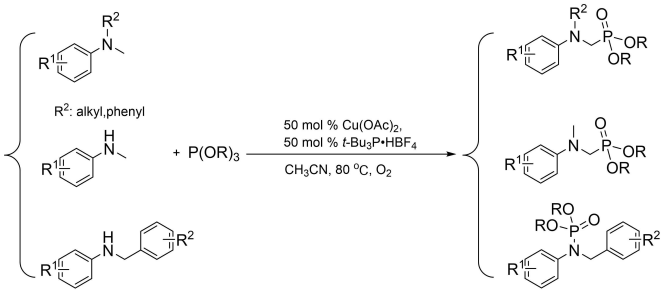
[16] Used Cu: a) J. Fraser, L. J. Wilson, R. K. Blundell, C. J. Hayes, *Chem. Commun.* **2013**, *49*, 8919–8921; b) X. Jin, K. Yamaguchi, N. Mizuno, *Org. Lett.* **2013**, *15*, 418–421; c) G. Wang, Q.-Y. Yu, S.-Y. Chen, X.-Q. Yu, *Tetra. Lett.* **2013**, *54*, 6230–6232; Used Fe:; d) B. Kaboudin, F. Kazemi, F. Habibi, *Tetrahedron Lett.* **2015**, *56*, 6364–6367.

[17] a) K. R. Campos, *Chem. Soc. Rev.* **2007**, *36*, 1069–1084; b) O. Baslé, C.-J. Li, *Green Chem.* **2007**, *9*, 1047–1050; c) O. Baslé, C.-J. Li, *Org. Lett.* **2008**, *10*, 3661–3663; d) W. Han, A. R. Ofial, *Chem. Commun.* **2009**, 5024–5026; e) Y. Shen, M. Li, S. Wang, T. Zhan, Z. Tan, C.-C. Guo, *Chem. Commun.* **2009**, 953–955; f) A. Gogoi, S. Guin, S. K. Rout, B. K. Patel, *Org. Lett.* **2013**, *15*, 1802–1805.

[18] a) Z. Li, D. S. Bohle, C.-J. Li, *Proc. Natl. Acad. Sci. USA* **2006**, *103*, 8928–8933; b) Z. Li, C.-J. Li, *J. Am. Chem. Soc.* **2005**, *127*, 3672–3673; c) Y. Zhang, H. Fu, Y. Jiang, Y. Zhao, *Org. Lett.* **2007**, *9*, 3813–3816; d) M. Niu, Z. Yin, H. Fu, Y. Jiang, Y. Zhao, *J. Org. Chem.* **2008**, *73*, 3961–3963; e) A. Gogoi, A. Modi, S. Guin, S. K. Rout, D. Das, B. K. Patel, *Chem. Commun.* **2014**, *50*, 10445–10447.

Manuscript received: May 3, 2021
Revised manuscript received: May 22, 2021
Accepted manuscript online: May 27, 2021

COMMUNICATIONS



S. Wang, S. Ma, J. Yang, W. Li, Dr. D. Li, Prof. J. Yang**

A copper-phosphine system was developed to promote the formation of α-aminophosphonates and phosphoramides from various aromatic amines and trialkyl phosphites under aerobic conditions. Importantly, this method could be applied not only to the synthesis of α-aminophosphonates (C–P bonds) but also to produce phosphoramides (N–P bonds). This strategy provided a convenient and efficient method for the synthesis of phosphorous compounds.