有机化学 DOI: 10.6023/cjoc202311026 研究论文
Chinese Journal of Organic Chemistry ARTICLE

$Na_2S_2O_8$ 介导的咪唑并[1,2-α]吡啶与杂芳胺在无金属条件下的 C—H 胺化反应

孙一平[a] 陈德茂[b] 何 玲*,[c] 王祖利*,[b]
([a]中国科学院兰州化学物理研究所 固体润滑国家重点实验室 兰州 730000)
([b]青岛农业大学化学与药学院 青岛 266109)
([c]重庆大学药学院创新药物研究中心 天然产物合成与药物研究重庆重点实验室 重庆 401331)

摘要 发展了一种高效实用的氨化咪唑[1,2-α]吡啶类化合物的方法. 值得注意的是, 该反应无需任何金属催化剂参与. 在中等至高收率下, 成功得到了带有多样取代基的产物.
关键词 咪唑[1,2-α]吡啶; 过硫酸盐; 杂芳胺; 绿色有机合成

$Na_2S_2O_8$ Mediated C—H Amination of Imidazo[1,2-α]pyridines with Heteroaromatic Amines under Metal-Free Conditions

Sun, Yiping[a] Chen, Demao[b] He, Ling*,[c] Wang, Zuli*,[b]
([a] *State Key Laboratory of Solid Lubrication, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, Lanzhou 730000*)
([b] *College of Chemistry and Pharmaceutical Sciences, Qingdao Agricultural University, Qingdao 266109*)
([c] *Chongqing Key Laboratory of Natural Product Synthesis and Drug Research, Innovative Drug Research Center, School of Pharmaceutical Sciences, Chongqing University, Chongqing 401331*)

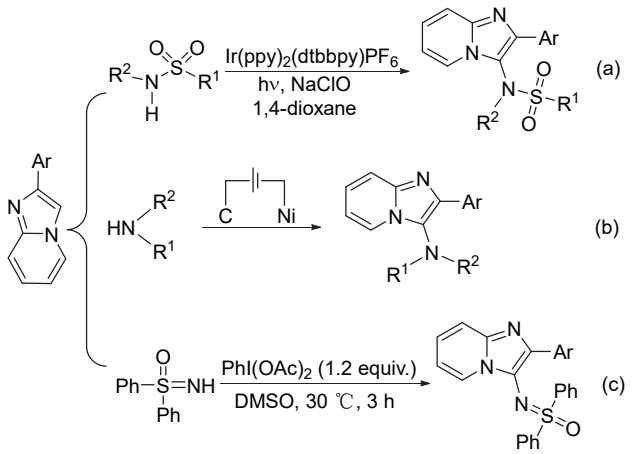
Abstract A highly efficient and practical amination protocol for imidazo[1,2-α]pyridines using heteroaromatic amines was developed. Notably, the transformation proceeds without the need for any metal catalyst. Isolation of products bearing diverse substituents was achieved in moderate to high yields.
Keywords imidazo[1,2-α]pyridines; persulfates; heteroaromatic amines; green organic synthesis

1 Introduction

Imidazo[1,2-α]pyridines as the core structural skeletal framework of many natural products and pharmaceuticals,[1] have attracted considerable interest due to their important biologically active properties. Therefore, developing efficient and facile method for the synthesis of diverse imidazo[1,2-α]pyridine derivatives has become an attractive research topic. At present, the construction of C—C,[2] C—N,[3] C—O,[4] C—F,[5] C—X[6] and C—S[7] bonds at the C-3 position of the imidazopyridine ring has been realized. In 2017, the visible light-induced regioselective sulfonamidation of imidazo[1,2-*a*]pyridines was developed by Sun's group (Scheme 1a).[8] In 2020, Lei's group[3a] realized an electrochemical intermolecular oxidative C—H/N—H cross-coupling of imidazo[1,2-α]pyridines with *N*-nucleophiles (Scheme 1b). The $PhI(OAc)_2$-mediated oxidative C—H sulfoximination of imidazopyridines under mild conditions was presented by Wu's group (Scheme 1c).[9] In these reactions, metal catalyst was sometimes needed to promote animation, which was not eco-friendly. As a consequence, developing an alternative synthetic method for construction of C-3 aminated imidazo[1,2-α]pyridines is still desirable.

Because of its readily available, environmental friendliness and easy operation, persulfates have been widely used in the field of organic synthesis.[10] Persulfate is relatively stable, but it can be easily decomposed into a more active sulfate radical negative ion by mean of light, heating or transition metal reduction. At present, free radical cycliza-

* Corresponding authors. E-mail: wangzulichem@163.com, heling2015@cqu.edu.cn
Received November 24, 2023; revised January 2, 2024; published online January 11, 2024.
Project supported by the National Natural Science Foundation of China (No. 21772107), and the Youth Innovation Team Project for Talent Introduction and Cultivation in Universities of Shandong Province (2021).
国家自然科学基金(No. 21772107)和山东省高等学校青创人才引育计划(2021)资助项目.



Scheme 1 Amination of imidazo[1,2-*a*]pyridines

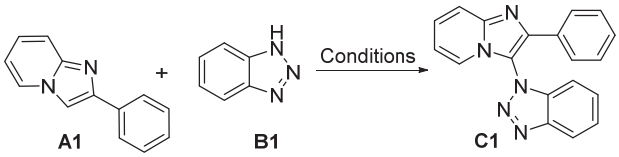
tion,[11] C—H bond functionalization,[12] and other reactions[13] have been presented in the presence of persulfates. However, compared with other types of free radical reactions,[14] reactions promoted by persulfate have fewer reaction types and lower reaction efficiency. With our continuous efforts in radical reaction and C—H bond functionalization[15] and radical chemistry,[16] herein, we demonstrated the $Na_2S_2O_8$ promoted amination reaction of imidazo[1,2-*α*]pyridines with triazoles.

2 Results and discussion

At the outset of our investigation, a model reaction of 2-phenylimidazo[1,2-*a*]pyridine and 1*H*-benzo[*d*][1,2,3]-triazole was chosen to examine the reaction conditions. Solvent screening showed that dichloromethane (DCM)/H_2O was superior to other solvents, delivering the corresponding product in 91% yield (Table 1, Entry 7). Products with moderate yields of 42%～76% were isolated when other solvents such as MeCN/H_2O, $CHCl_3$/H_2O, 1,2-dichloroethane (DCE)/H_2O, acetone/H_2O and *o*-DCB/H_2O were used (Table 1, Entries 1～6). We then turn our attention to investigate the effect of oxidant on this reaction. Slight lower yields of the product were obtained when $K_2S_2O_8$ and $(NH_4)_2S_2O_8$ were used (Table 1, Entries 8～9). When dibenzoyl peroxide (BPO) was used as oxidant, only 42% yield of the product was isolated (Table 1, Entry 16). Other oxidants were not suitable for this reaction (Table 1, Entries 10～15). The reaction was no significant change on the yield when the reaction temperature was elevated to 120 ℃ (Table 1, Entry 19). But lowering the temperature to 80 ℃ resulted in a slightly lower yield than 85% (Table 1, Entry 18).

After completion of the search for the optimized reaction conditions, we set out to examine the scope and limitations of this system. Triazole substituted with methyl group at different positions proceeded smoothly to give the desired products with moderate to high yields (**C1**～**C3**). When pyridine ring of imidazopyridines was substituted with CH_3 or Cl group at different position, the reaction could also react efficiently (**C4**～**C10**). The effect of substituents on the phenyl group moiety of the imidazopyridines was also investigated. It was found that electron-withdrawing or electron-donating groups, such as bromo, fluoro, chloro and methyl, on the phenyl ring at different position were well tolerated in this system (**C11**～**C19**). To our delight, when there are substituents on both pyridine ring and phenyl ring of imidazopyridines, triazole could reacted smoothly with imidazopyridines to afford products with 69%～86% isolated yields (**C20**～**C25**). It is worth noting that polyphenyl-substituted substrates were also proved to be good substrates, which could deliver the corresponding products with moderate yields (**C26**～**C27**).

Table 1 Screening the optimized reaction conditions[a]



Entry	Oxidant	Solvent	Yield[b]/%
1	$Na_2S_2O_8$	DMF/H_2O	42
2	$Na_2S_2O_8$	MeCN/H_2O	76
3	$Na_2S_2O_8$	$CHCl_3$/H_2O	65
4	$Na_2S_2O_8$	DCE/H_2O	61
5	$Na_2S_2O_8$	Acetone/H_2O	49
6	$Na_2S_2O_8$	*o*-DCB/H_2O	59
7	$Na_2S_2O_8$	DCM/H_2O	91
8	$K_2S_2O_8$	DCM/H_2O	83
9	$(NH_4)_2S_2O_8$	DCM/H_2O	78
10	PIDA	DCM/H_2O	N.R.
11	PIFA	DCM/H_2O	N.R.
12	TBHP	DCM/H_2O	Trace
13	DTBP	DCM/H_2O	N.R.
14	DCP	DCM/H_2O	N.R.
15	TBPB	DCM/H_2O	N.R.
16	BPO	DCM/H_2O	42
18[c]	$Na_2S_2O_8$	DCM/H_2O	78
19[d]	$Na_2S_2O_8$	DCM/H_2O	85

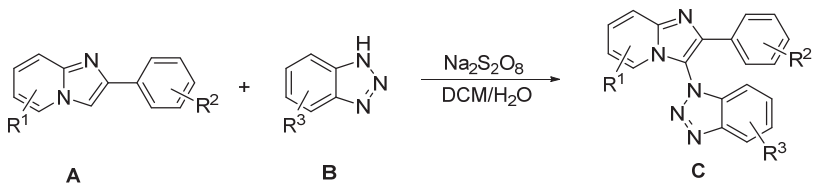
[a] Reaction conditions: **A1** (0.2 mmol), **B1** (0.4 mmol), oxidant (3 equiv.), solvent (V∶V=1∶1, 4 mL) at 100 ℃ for 15 h. [b] Isolated yield. [c] At 80 ℃. [d] At 120 ℃.

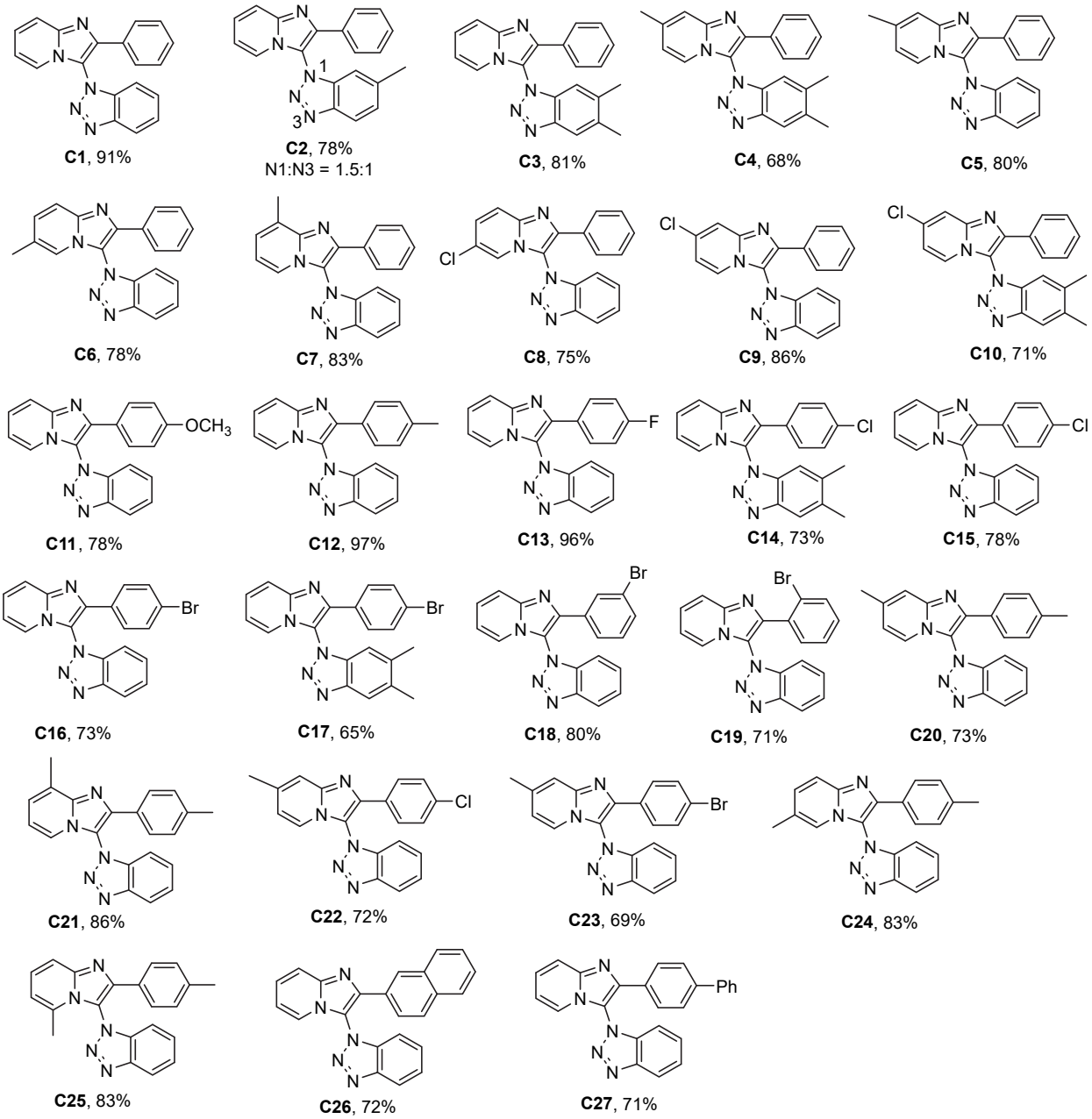
In order to prove the practicability of the reaction, a large-scale synthesis of **C1** was performed. As illustrated in Scheme 2, a reaction of 2-phenylimidazo[1,2-*a*]pyridine and 1*H*-benzo[*d*][1,2,3]triazole was conducted on a 5 mmol scale under the standard conditions, and the corresponding product was isolated in 84% yield (Scheme 2). There was no significant decrease on the yield.

Several control experiments were conducted to examine the reaction mechanism. When 2,2,6,6-tetramethylpiperidinooxy (TEMPO), 2,6-di-*t*-butyl-*p*-cresol (butylated hydroxytoluene) (BHT) or 1,1-diphenylethylene was added into the reaction system, the current reaction was completely inhibited (Scheme 3). These results indicated that radical pathway was possible for this system.

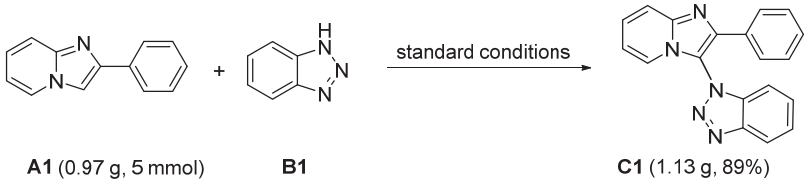
On the basis of the above-mentioned observations and

Table 2 Substrates scope of C—H amination of imidazo[1,2-*α*]pyridines

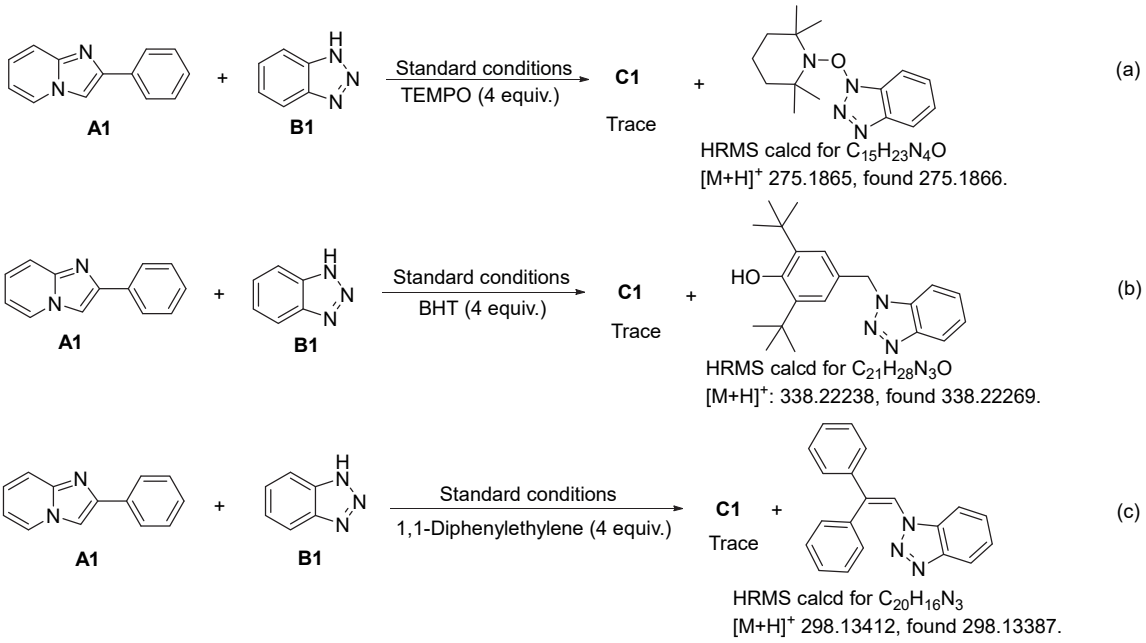




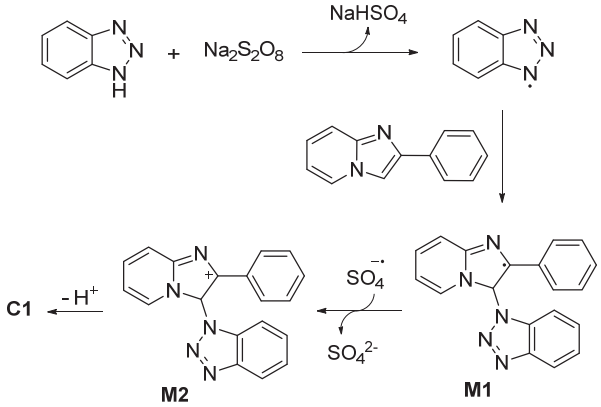
[a] Reaction conditions: **A** (0.2 mmol), **B** (0.4 mmol), $Na_2S_2O_8$ (3 equiv.), DCM/H_2O (V∶V=1∶1, 4 mL) at 100 ℃ for 15 h. [b] Isolated yield.



Scheme 2 Large-scale synthesis of **C1**



Scheme 3 Preliminary mechanistic studies



Scheme 4 Possible mechanism of C—H amination of imidazo[1,2-*α*]pyridines

related references,[10a,10e,17-19] a probable reaction mechanism is outlined in Scheme 4. At the beginning, nitrogen radical was generated from the oxidation reaction of 1*H*-benzo[*d*][1,2,3]triazole with $Na_2S_2O_8$. Then the addition reaction of nitrogen radical to 2-phenylimidazo[1,2-*α*]-pyridine occurred to provide alkyl radical intermediate **M1**, which was converted to **M2** via oxidation. Finally, the desired product was obtained via deportation reaction of **M2**.

3 Conclusions

In conclusion, an efficient and practical amination of imidazo[1,2-*α*]pyridines with heteroaromatic amines was established. No metal was needed for this transformation. Products with various substituents were isolated in moderate to high yields. Further synthetic application and detailed mechanistic studies of this methodology are currently ongoing in our laboratory.

4 Experimental section

4.1 Instruments and reagents

NMR spectra were recorded on a BRUKER AVANCE III HD 500 MHz spectrometers, operating at 500 MHz for ^{1}H NMR and at 126 MHz for ^{13}C NMR acquisitions. High-resolution mass spectrometry (HRMS) measurements were performed on an Orbitrap Fusion Lumos. All major chemicals and solvents were obtained from commercial sources and used without further purification.

4.2 General procedure for the synthesis of **C1**

A sealable reaction tube equipped with a magnetic stirrer bar was charged with 2-phenylimidazo[1,2-*a*]pyridine (0.2 mmol), 1*H*-benzo[*d*][1,2,3]triazole (2 equiv.), $Na_2S_2O_8$ (3 equiv.), DCM/H_2O (V∶V=1∶1, 4 mL). The mixture reacted under air atmosphere at 100 ℃ for 15 h.. After completion, it was diluted with ethyl acetate. After the solvent was removed under reduced pressure, the residue was purified by column chromatography on silica gel to afford the corresponding product.

4.3 Characterization of the compounds

1-(2-Phenylimidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*]-[1,2,3]triazole (**C1**): The pure product was obtained as a yellow solid (33.2 mg, 53%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.26 (d, J=8.5 Hz, 1H), 7.80 (d, J=9.1 Hz, 1H), 7.53～7.43 (m, 5H), 7.41～7.36 (m, 1H), 7.25 (d, J=6.7 Hz, 3H), 7.14 (d, J=7.0 Hz, 1H), 6.86 (t, J=6.7 Hz, 1H); ^{13}C NMR (126 MHz, DMSO) δ: 145.7, 143.9, 140.8, 134.5, 132.0, 130.3, 129.3, 128.0, 126.7, 125.8, 123.9, 120.7, 117.8, 114.7, 112.0, 110.5. HRMS (ESI) calcd for $C_{19}H_{14}N_5$ $[M+H]^+$ 312.1244, found 312.1246.

6-Methyl-1-(2-phenylimidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C2**)/5-methyl-1-(2-phenylimid-

azo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C2'**): Isomer *n*(**C2'**)∶*n*(**C2'**)=1.4∶1 (based on NMR). The pure product was obtained as a white solid (31.5 mg, 48%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.11 (d, J=8.5 Hz, 1H), 8.00 (s, 1H), 7.79 (d, J=9.1 Hz, 2H), 7.56～7.47 (m, 5H), 7.44 (d, J=6.8 Hz, 1H), 7.40～7.34 (m, 2H), 7.30 (dd, J=8.3, 4.8 Hz, 2H), 7.26～7.22 (m, 5H), 7.02 (d, J=8.4 Hz, 1H), 6.91 (s, 1H), 6.85 (t, J=6.7 Hz, 2H), 2.55 (s, 2H), 2.40 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 146.4, 144.4, 144.0, 141.5, 140.4, 135.3, 134.6, 132.5, 131.7, 131.3, 128.7, 127.3, 127.1, 126.7, 122.4, 120.6, 120.2, 119.8, 118.0, 113.6, 112.3, 109.2, 108.9, 21.9, 21.5. HRMS (ESI) calcd for $C_{20}H_{16}N_5$ $[M+H]^+$ 326.1399, found 326.1400.

5,6-Dimethyl-1-(2-phenylimidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C3**): The pure product was obtained as a white solid (30.6 mg, 45%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.97 (s, 1H), 7.78 (d, J=9.1 Hz, 1H), 7.56～7.49 (m, 2H), 7.42 (d, J=6.8 Hz, 1H), 7.38～7.32 (m, 1H), 7.25 (dd, J=7.3, 5.6 Hz, 3H), 6.91 (s, 1H), 6.82 (t, J=6.8 Hz, 1H), 2.44 (s, 3H), 2.30 (d, J=10.6 Hz, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.0, 144.0, 141.4, 140.0, 134.9, 133.2, 131.7, 128.7, 127.1, 126.5, 122.4, 119.7, 118.0, 113.5, 112.5, 109.1, 20.8, 20.4. HRMS (ESI) calcd for $C_{21}H_{18}N_5$ $[M+H]^+$ 340.1555, found 340.1556.

5,6-Dimethyl-1-(7-methyl-2-phenylimidazo[1,2-*a*]-pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C4**): The pure product was obtained as a white solid (22.6 mg, 32%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.96 (s, 1H), 7.55～7.47 (m, 3H), 7.29 (d, J=6.9 Hz, 1H), 7.25～7.20 (m, 3H), 6.90 (s, 1H), 6.65 (d, J=6.9 Hz, 1H), 2.45 (s, 3H), 2.44 (s, 3H), 2.28 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.0, 144.4, 141.1, 139.9, 137.7, 134.9, 133.2, 131.8, 128.6, 127.0, 121.6, 119.7, 116.4, 116.1, 112.0, 109.1, 21.4, 20.8, 20.4. HRMS (ESI) calcd for $C_{22}H_{20}N_5$ $[M+H]^+$ 354.1711, found 354.1713.

1-(7-Methyl-2-phenylimidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C5**): The pure product was obtained as a white solid (26.1 mg, 40%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.24 (d, J=1.7 Hz, 1H), 7.54 (s, 1H), 7.48 (d, J=2.1 Hz, 4H), 7.37 (d, J=3.3 Hz, 1H), 7.23 (s, 3H), 7.13 (s, 1H), 6.68 (s, 1H), 2.45 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.8, 144.5, 141.1, 138.0, 134.1, 131.7, 129.2, 128.7, 127.0, 125.0, 121.6, 120.6, 116.3, 111.7, 109.8, 21.4. HRMS (ESI) calcd for $C_{20}H_{16}N_5$ $[M+H]^+$ 326.1398, found 326.1400.

1-(6-Methyl-2-phenylimidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C6**): The pure product was obtained as a white solid (24.4 mg, 38%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.25 (d, J=7.0 Hz, 1H), 7.70 (d, J=9.1 Hz, 1H), 7.51～7.42 (m, 4H), 7.28 (s, 1H), 7.22 (d, J=3.0 Hz, 4H), 7.14 (dd, J=6.1, 1.5 Hz, 1H), 2.23 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.8, 143.1, 141.1, 134.1, 131.6, 130.67, 130.2, 129.9, 128.9, 126.9, 125.0, 123.7, 120.6, 120.0, 117.3, 111.8, 109.8, 18.2. HRMS (ESI) calcd for $C_{20}H_{16}N_5$ $[M+H]^+$ 326.1398, found 326.1400.

1-(8-Methyl-2-phenylimidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C7**): The pure product was obtained as a white solid (31.3 mg, 48%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.23 (d, J=6.3 Hz, 1H), 7.53 (s, 2H), 7.49～7.39 (m, 2H), 7.33 (d, J=5.3 Hz, 1H), 7.28～7.19 (m, 3H), 7.17～7.07 (m, 2H), 6.79～6.67 (m, 1H), 2.76 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.8, 144.4, 140.9, 134.1, 131.8, 129.2, 128.7, 128.7, 128.1, 127.2, 125.3, 125.1, 120.6, 120.4, 113.6, 112.5, 109.8, 16.7. HRMS (ESI) calcd for $C_{20}H_{16}N_5$ $[M+H]^+$ 326.1398, found 326.1400.

1-(6-Chloro-2-phenylimidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C8**): The pure product was obtained as a white solid (31.2 mg, 45%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.26 (d, J=7.5 Hz, 1H), 7.73 (d, J=9.6 Hz, 1H), 7.57 (s, 1H), 7.48 (ddd, J=18.9, 12.9, 7.4 Hz, 4H), 7.34 (dd, J=9.5, 0.9 Hz, 1H), 7.24 (dd, J=16.9, 9.4 Hz, 3H), 7.13 (d, J=7.5 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.8, 142.4, 142.1, 133.8, 131.1, 130.2, 129.9, 129.5, 128.9, 128.2, 127.0, 125.2, 122.1, 121.4, 120.9, 120.6, 118.5, 112.6, 109.7. HRMS (ESI) calcd for $C_{19}H_{13}N_5Cl$ $[M+H]^+$ 346.0852, found 346.0854.

1-(7-Chloro-2-phenylimidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C9**): The pure product was obtained as a white solid (31.4 mg, 46%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.24 (d, J=7.3 Hz, 1H), 7.78 (s, 1H), 7.46 (d, J=7.3 Hz, 5H), 7.23 (d, J=7.2 Hz, 3H), 7.12 (d, J=7.5 Hz, 1H), 6.84 (d, J=7.1 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.8, 143.8, 142.0, 133.9, 133.4, 131.1, 130.2, 129.7, 129.5, 128.9, 127.1, 125.2, 122.9, 120.7, 116.9, 115.3, 112.5, 109.7. HRMS (ESI) calcd for $C_{19}H_{13}N_5Cl$ $[M+H]^+$ 346.0851, found 346.0854.

1-(7-Chloro-2-phenylimidazo[1,2-*a*]pyridin-3-yl)-5,6-dimethyl-1*H*-benzo[*d*][1,2,3]triazole (**C10**): The pure product was obtained as a yellow solid (23.2 mg, 31%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.97 (s, 1H), 7.78 (d, J=1.1 Hz, 1H), 7.49 (dd, J=7.4, 1.8 Hz, 2H), 7.37 (d, J=7.2 Hz, 1H), 7.26 (d, J=11.4 Hz, 3H), 6.89 (s, 1H), 6.82 (dd, J=7.2, 1.8 Hz, 1H), 2.44 (s, 3H), 2.29 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.0, 143.7, 142.1, 140.2, 135.1, 133.3, 133.0, 131.2, 129.0, 128.7, 127.1, 122.8, 119.8, 116.9, 115.2, 112.8, 109.0, 20.9, 20.4. HRMS (ESI) calcd for $C_{21}H_{17}N_5Cl$ $[M+H]^+$ 374.1165, found 374.1167.

1-(2-(4-Methoxyphenyl)imidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C11**): The pure product was obtained as a white solid (25.8 mg, 38%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.25 (d, J=7.3 Hz, 1H), 7.76 (d, J=9.0 Hz, 1H), 7.60～7.40 (m, 5H), 7.38～7.33 (m, 1H), 7.15 (d, J=5.5 Hz, 1H), 6.89～6.72 (m, 3H), 3.74 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 160.0, 145.8, 144.0, 141.4, 134.0, 129.3, 128.4, 126.5, 125.0, 124.0, 122.3, 120.6, 117.8, 114.2, 113.4, 111.4, 109.8, 55.2. HRMS (ESI) calcd for $C_{20}H_{16}ON_5$ $[M+H]^+$ 342.1347, found 342.1349.

1-(2-(*p*-Tolyl)imidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*]-[1,2,3]triazole (**C12**): The pure product was obtained as a white solid (37.2 mg, 57%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.25 (d, J=7.2 Hz, 1H), 7.79 (d, J=9.0 Hz, 1H), 7.47 (s, 3H), 7.43～7.34 (m, 3H), 7.14 (d, J=7.4 Hz, 1H), 7.04 (d, J=7.5 Hz, 2H), 6.89～6.80 (m, 1H), 2.27 (s, 3H); ^{13}C

NMR (126 MHz, $CDCl_3$) δ: 145.8, 144.0, 141.5, 138.9, 134.0, 130.2, 129.7, 129.4, 128.6, 127.0, 126.8, 125.0, 122.4, 120.6, 117.9, 113.6, 111.8, 109.8, 21.2. HRMS (ESI) calcd for $C_{20}H_{16}N_5$ $[M+H]^+$ 326.1398, found 326.1400.

1-(2-(4-Fluorophenyl)imidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C13**): The pure product was obtained as a white solid (44.9 mg, 56%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.32～8.19 (m, 1H), 7.78 (d, J=9.1 Hz, 1H), 7.57～7.44 (m, 5H), 7.38 (ddd, J=9.1, 6.8, 1.2 Hz, 1H), 7.19～7.09 (m, 1H), 6.99～6.89 (m, 2H), 6.86 (td, J=6.8, 1.0 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 164.0, 162.0, 145.8, 144.0, 140.6, 133.9, 129.4, 128.9, 127.7, 126.8, 125.1, 122.5, 120.7, 118.0, 115.9, 115.7, 113.7, 111.9, 109.6. HRMS (ESI) calcd for $C_{19}H_{13}N_5F$ $[M+H]^+$ 330.1149, found 330.1149.

1-(2-(4-Chlorophenyl)imidazo[1,2-*a*]pyridin-3-yl)-5,6-dimethyl-1*H*-benzo[*d*][1,2,3]triazole (**C14**): The pure product was obtained as a white solid (24.3 mg, 33%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.98 (s, 1H), 7.77 (d, J=9.1 Hz, 1H), 7.48～7.40 (m, 3H), 7.40～7.35 (m, 1H), 7.22 (d, J=8.6 Hz, 2H), 6.89 (s, 1H), 6.84 (t, J=6.8 Hz, 1H), 2.45 (s, 3H), 2.31 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.0, 144.0, 140.3, 135.1, 134.7, 133.0, 130.2, 129.0, 128.3, 126.8, 122.5, 119.8, 118.0, 113.7, 112.5, 108.9, 20.9, 20.4. HRMS (ESI) calcd for $C_{21}H_{17}N_5Cl$ $[M+H]^+$ 374.1164, found 374.1167.

1-(2-(4-Chlorophenyl)imidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C15**): The pure product was obtained as a white solid (26.0 mg, 38%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.26 (d, J=7.5 Hz, 1H), 7.79 (d, J=9.1 Hz, 1H), 7.50 (d, J=7.3 Hz, 3H), 7.46～7.38 (m, 3H), 7.21 (d, J=7.9 Hz, 2H), 7.13 (d, J=5.4 Hz, 1H), 6.90～6.84 (m, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.8, 144.1, 140.3, 134.8, 133.9, 130.6, 130.0, 130.0, 129.2, 128.4, 126.9, 125.2, 122.5, 120.8, 118.1, 113.8, 109.6. HRMS (ESI) calcd for $C_{19}H_{13}N_5Cl$ $[M+H]^+$ 346.0852, found 346.0854.

1-(2-(4-Bromophenyl)imidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C16**): The pure product was obtained as a white solid (25.3 mg, 33%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.26 (d, J=8.3 Hz, 1H), 7.79 (d, J=9.1 Hz, 1H), 7.60～7.47 (m, 4H), 7.43～7.33 (m, 4H), 7.13 (d, J=4.9 Hz, 1H), 6.92～6.83 (m, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.8, 144.1, 137.9, 133.9, 131.9, 129.5, 128.6, 127.0, 125.2, 123.2, 122.5, 120.8, 118.1, 113.8, 109.6. HRMS (ESI) calcd for $C_{19}H_{13}N_5Br$ $[M+H]^+$ 390.0346, found 390.0348.

1-(2-(4-Bromophenyl)imidazo[1,2-*a*]pyridin-3-yl)-5,6-dimethyl-1*H*-benzo[*d*][1,2,3]triazole (**C17**): The pure product was obtained as a white solid (20.6 mg, 25%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 7.98 (s, 1H), 7.77 (d, J=9.1 Hz, 1H), 7.45～7.33 (m, 6H), 6.88 (d, J=11.8 Hz, 1H), 6.84 (t, J=6.8 Hz, 1H), 2.45 (s, 3H), 2.31 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.0, 144.0, 140.3, 137.8, 135.2, 133.0, 131.9, 130.6, 128.6, 126.8, 123.0, 122.5, 119.8, 118.0, 113.7, 112.6, 108.9, 20.9, 20.4. HRMS (ESI) calcd for $C_{21}H_{17}N_5Br$ $[M+H]^+$ 418.0658, found 418.0661.

1-(2-(3-Bromophenyl)imidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C18**): The pure product was obtained as a yellow solid (31.0 mg, 40%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.31～8.20 (m, 1H), 7.93 (s, 1H), 7.79 (d, J=9.1 Hz, 1H), 7.58～7.46 (m, 3H), 7.39 (dd, J=16.6, 8.3 Hz, 2H), 7.13 (d, J=7.2 Hz, 2H), 7.02 (t, J=7.9 Hz, 1H), 6.87 (t, J=6.7 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.8, 144.1, 139.8, 133.9, 133.7, 131.7, 130.2, 129.5, 127.0, 125.2, 123.1, 122.7, 120.8, 118.1, 113.9, 112.5, 109.6. HRMS (ESI) calcd for $C_{19}H_{13}N_5Br$ $[M+H]^+$ 390.0346, found 390.0348.

1-(2-(2-Bromophenyl)imidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C19**): The pure product was obtained as a yellow solid (24.0 mg, 31%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.25 (d, J=6.7 Hz, 1H), 7.80 (d, J=8.4 Hz, 1H), 7.49 (s, 4H), 7.39 (d, J=6.9 Hz, 1H), 7.25 (s, 3H), 7.14 (d, J=6.6 Hz, 1H), 6.86 (s, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.8, 144.1, 141.4, 134.0, 131.5, 129.3, 128.8, 127.1, 126.7, 125.0, 122.4, 120.7, 118.1, 113.6, 112.2, 109.8. HRMS (ESI) calcd for $C_{19}H_{12}N_5Br$ [M] 389.0280, found 389.0270.

1-(7-Methyl-2-(*p*-tolyl)imidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C20**): The pure product was obtained as a white solid (29.1 mg, 43%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.24 (d, J=7.2 Hz, 1H), 7.57～7.44 (m, 3H), 7.36 (d, J=6.8 Hz, 3H), 7.13 (d, J=7.5 Hz, 1H), 7.03 (d, J=7.5 Hz, 2H), 6.66 (d, J=6.7 Hz, 1H), 2.45 (s, 3H), 2.27 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.8, 144.5, 138.6, 137.8, 134.1, 130.0, 129.8, 129.20, 126.9, 125.0, 121.6, 120.6, 117.3, 116.6, 116.2, 109.8, 21.5, 21.2. HRMS (ESI) calcd for $C_{21}H_{18}N_5$ $[M+H]^+$ 340.1555, found 340.1556.

1-(8-Methyl-2-(*p*-tolyl)imidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C21**): The pure product was obtained as a white solid (31.4 mg, 46%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.23 (d, J=7.9 Hz, 1H), 7.50～7.37 (m, 4H), 7.32 (d, J=6.7 Hz, 1H), 7.13 (t, J=7.2 Hz, 2H), 7.03 (d, J=7.8 Hz, 2H), 6.73 (t, J=6.8 Hz, 1H), 2.75 (s, 3H), 2.26 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.8, 144.4, 141.1, 138.5, 134.1, 129.4, 129.2, 128.9, 128.1, 127.0, 125.2, 124.9, 120.6, 120.1, 113.5, 112.1, 109.8, 21.2, 16.7. HRMS (ESI) calcd for $C_{21}H_{18}N_5$ $[M+H]^+$ 340.1554, found 340.1556.

1-(2-(4-Chlorophenyl)-7-methylimidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C22**): The pure product was obtained as a yellow solid (23.1 mg, 32%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.25 (dd, J=5.5, 3.7 Hz, 1H), 7.50 (dd, J=13.0, 9.2 Hz, 3H), 7.39 (dd, J=17.0, 7.8 Hz, 3H), 7.20 (d, J=8.5 Hz, 2H), 7.12 (dd, J=5.1, 3.4 Hz, 1H), 6.69 (d, J=6.9 Hz, 1H), 2.47 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.8, 144.5, 140.0, 138.2, 134.7, 134.0, 130.2, 129.4, 129.0, 128.2, 125.1, 121.6, 120.7, 116.4, 111.8, 109.6, 21.5. HRMS (ESI) calcd for $C_{20}H_{15}N_5Cl$ $[M+H]^+$ 360.1008, found 360.1010.

1-(2-(4-Bromophenyl)-7-methylimidazo[1,2-*a*]pyridin-

3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C23**): The pure product was obtained as a yellow solid (27.3 mg, 29%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.41～8.20 (m, 1H), 7.69～7.46 (m, 4H), 7.46～7.31 (m, 4H), 7.22～7.09 (m, 1H), 6.69 (d, J= 6.1 Hz, 1H), 2.46 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.8, 144.5, 140.0, 138.3, 137.8, 134.0, 131.9, 130.7, 129.4, 128.5, 125.1, 123.0, 121.6, 120.7, 116.4, 111.8, 109.6, 21.5. HRMS (ESI) calcd for $C_{20}H_{15}N_5Br$ $[M+H]^+$ 404.0499, found 404.0505.

1-(6-Methyl-2-(*p*-tolyl)imidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C24**): The pure product was obtained as a white solid (29.0 mg, 43%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.18 (d, J=6.9 Hz, 1H), 7.63 (d, J=9.1 Hz, 1H), 7.49～7.37 (m, 2H), 7.32 (dd, J=13.1, 10.3 Hz, 2H), 7.18 (d, J=6.8 Hz, 1H), 7.14 (d, J=9.2 Hz, 1H), 7.11～7.04 (m, 1H), 6.95 (d, J=7.9 Hz, 2H), 2.18 (d, J= 11.8 Hz, 6H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.8, 143.1, 141.3, 138.7, 134.1, 129.9, 129.4, 128.7, 126.8, 125.0, 123.7, 120.6, 120.0, 117.2, 111.5, 109.9, 21.2, 18.2. HRMS (ESI) calcd for $C_{21}H_{18}N_5$ $[M+H]^+$ 340.1554, found 340.1556.

1-(5-Methyl-2-(*p*-tolyl)imidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C25**): The pure product was obtained as a white solid (29.4 mg, 43%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.21 (d, J=8.1 Hz, 1H), 7.69 (d, J=9.0 Hz, 1H), 7.48 (dt, J=14.9, 7.2 Hz, 2H), 7.28 (d, J=12.6 Hz, 3H), 7.20 (d, J=7.9 Hz, 1H), 6.99 (d, J=7.7 Hz, 2H), 6.57 (d, J=6.8 Hz, 1H), 2.24 (s, 3H), 1.74 (s, 3H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.7, 145.2, 143.5, 138.7, 137.3, 135.4, 129.5, 129.4, 128.8, 126.8, 124.9, 120.6, 116.1, 114.6, 111.8, 110.0, 21.2, 17.1. HRMS (ESI) calcd for $C_{21}H_{18}N_5$ $[M+H]^+$ 340.1554, found 340.1556.

1-(2-(Naphthalen-2-yl)imidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C26**): The pure product was obtained as a yellow solid (25.6 mg, 32%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.27 (d, J=8.2 Hz, 1H), 8.13 (s, 1H), 7.83 (d, J=9.1 Hz, 1H), 7.73 (dd, J=7.6, 5.4 Hz, 1H), 7.71～7.63 (m, 2H), 7.55 (d, J=6.8 Hz, 1H), 7.50～7.37 (m, 6H), 7.14 (d, J=8.1 Hz, 1H), 6.87 (td, J=6.8, 0.8 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.9, 144.2, 141.4, 134.1, 133.3, 129.4, 128.9, 128.5, 127.6, 126.8, 126.6, 126.3, 125.1, 124.2, 122.5, 120.7, 118.1, 113.7, 112.5, 109.8. HRMS (ESI) calcd for $C_{23}H_{16}N_5$ $[M+H]^+$ 362.1399, found 362.1400.

1-(2-([1,1'-Biphenyl]-4-yl)imidazo[1,2-*a*]pyridin-3-yl)-1*H*-benzo[*d*][1,2,3]triazole (**C27**): The pure product was obtained as a yellow solid (24.9 mg, 31%). ^{1}H NMR (500 MHz, $CDCl_3$) δ: 8.31～8.22 (m, 1H), 7.81 (d, J=9.1 Hz, 1H), 7.52 (ddd, J=18.7, 13.9, 8.5 Hz, 9H), 7.39 (t, J=7.5 Hz, 3H), 7.31 (t, J=7.2 Hz, 1H), 7.22～7.15 (m, 1H), 6.86 (t, J=6.8 Hz, 1H); ^{13}C NMR (126 MHz, $CDCl_3$) δ: 145.9, 141.9, 141.4, 141.3, 140.2, 134.0, 130.4, 129.4, 128.7, 128.1, 127.3, 127.3, 127.1, 126.8, 125.1, 122.4, 120.7, 118.1, 113.6, 109.8. HRMS (ESI) calcd for $C_{25}H_{18}N_5$ $[M+H]^+$ 388.1556, found 388.1556.

Supporting Information ^{1}H NMR and ^{13}C NMR spectra of compounds. The Supporting Information is available free of charge via the Internet at http://sioc-journal.cn.

References

[1] (a) Cecile, E.-G.; Alain, G. *Mini-Reviews Med. Chem.* **2007**, *7*, 888.
(b) Stasyuk, A. J.; Banasiewicz, M.; Cyranski, M. K.; Gryko, D. T. *J. Org. Chem.* **2012**, *77*, 5552.
(c) Li, Y.; Shu, K.; Liu, P.; Sun, P. *Org. Lett.* **2020**, *22*, 6304.
(d) Zhang, J.; She, M.; Liu, L.; Liu, M.; Wang, Z.; Liu, H.; Sun, W.; Liu, X.; Liu, P.; Zhang, S.; Li, J. *Chin. Chem. Lett.* **2021**, *32*, 3083.

[2] (a) Shi, T.; Sun, K.; Chen, X. L.; Zhang, Z. X.; Huang, X. Q.; Peng, Y. Y.; Qu, L. B.; Yu, B. *Adv. Synth. Catal.* **2020**, *362*, 2143.
(b) Zhang, J.; Xie, S.; Liu, P.; Sun, P. *Adv. Synth. Catal.* **2020**, *362*, 2173.

[3] (a) Yu, Y.; Yuan, Y.; Liu, H.; He, M.; Yang, M.; Liu, P.; Yu, B.; Dong, X.; Lei, A. *Chem. Commun.* **2019**, *55*, 1809.
(b) Mondal, S.; Samanta, S.; Jana, S.; Hajra, A. *J. Org. Chem.* **2017**, *82*, 4504.

[4] Kibriya, G.; Samanta, S.; Jana, S.; Mondal, S.; Hajra, A. *J. Org. Chem.* **2017**, *82*, 13722.

[5] Liu, P.; Gao, Y.; Gu, W.; Shen, Z.; Sun, P. *J. Org. Chem.* **2015**, *80*, 11559.

[6] Gui, Q.-W.; Jiang, H.; Guo, D.; Zhang, Y.; Shen, Q.-P.; Tang, S.; You, J.; Huo, Y.; Wang, H. *Synthesis* **2020**, *52*, 2713.

[7] (a) Yang, D.; Sun, P.; Wei, W.; Liu, F.; Zhang, H.; Wang, H. *Chem.-Eur. J.* **2018**, *24*, 4423.
(b) Zhang, H.; Wei, Q.; Wei, S.; Qu, J.; Wang, B. *Eur. J. Org. Chem.* **2016**, *2016*, 3373.

[8] Gao, Y.; Chen, S.; Lu, W.; Gu, W.; Liu, P.; Sun, P. *Org. Biomol. Chem.* **2017**, *15*, 8102.

[9] Luan, N. N.; Liu, Z. W.; Han, S. J.; Shen, L. H.; Li, J. Y.; Zou, D. P.; Wu, Y. J.; Wu, Y. S. *Tetrahedron Lett.* **2020**, *61*.

[10] (a) Zhao, J. F.; Duan, X. H.; Guo, L. N. *Chin. J. Org. Chem.* **2017**, *37*, 2498 (in Chinese).
(赵景峰, 段新华, 郭丽娜, 有机化学, **2017**, *37*, 2498.)
(b) Mandal, S.; Bera, T.; Dubey, G.; Saha, J.; Laha, J. K. *ACS Catal.* **2018**, *8*, 5085.
(c) Dong, D.-Q.; Yang, H.; Shi, J.-L.; Si, W.-J.; Wang, Z.-L.; Xu, X.-M. *Org. Chem. Front.* **2020**, *7*, 2538.
(d) Dong, D.; Sun, Y.; Li, G.; Yang, H.; Wang, Z.; Xu, X. *Chin. J. Org. Chem.* **2020**, *40*, 4071.
(e) Xie, L.-Y.; Peng, S.; Liu, F.; Chen, G.-R.; Xia, W.; Yu, X.; Li, W.-F.; Cao, Z.; He, W.-M. *Org. Chem. Front.* **2018**, *5*, 2604.
(f) Ilangovan, A.; Polu, A.; Satish, G. *Org. Chem. Front.* **2015**, *2*, 1616.
(g) Han, Q.-Q.; Li, G.-H.; Sun, Y.-Y.; Chen, D.-M.; Wang, Z.-L.; Yu, X.-Y.; Xu, X.-M. *Tetrahedron Lett.* **2020**, *61*, 151704.

[11] (a) Sun, K.; Si, Y. F.; Chen, X. L.; Lv, Q. Y.; Peng, Y. Y.; Qu, L. B.; Yu, B. *Asian J. Org. Chem.* **2019**, *8*, 2042.
(b) Sun, K.; Li, S. J.; Chen, X. L.; Liu, Y.; Huang, X. Q.; Wei, D. H.; Qu, L. B.; Zhao, Y. F.; Yu, B. *Chem. Commun.* **2019**, *55*, 2861.

[12] (a) Shi, Z.; Glorius, F. *Chem. Sci.* **2013**, *4*, 829.
(b) More, N. Y.; Jeganmohan, M. *Org. Lett.* **2014**, *16*, 804.

[13] (a) Wang, S.; Guo, L. N.; Wang, H.; Duan, X. H. *Org. Lett.* **2015**, *17*, 4798.
(b) Sun, K.; Wang, X.; Lv, Y.; Li, G.; Jiao, H.; Dai, C.; Li, Y.; Zhang, C.; Liu, L. *Chem. Commun.* **2016**, *52*, 8471.

[14] (a) Song, H.-Y.; Liu, M.-Y.; Huang, J.; Wang, D.; Jiang, J.; Chen, J.-Y.; Yang, T.-B.; He, W.-M. *J. Org. Chem.* **2023**, *88*, 2288.
(b) Lu, Y.-H.; Zhang, Z.-T.; Wu, H.-Y.; Zhou, M.-H.; Song, H.-Y.; Ji, H.-T.; Jiang, J.; Chen, J.-Y.; He, W.-M. *Chin. Chem. Lett.* **2023**, *34*, 108036.
(c) Ma, C.-H.; Zhao, L.; He, X.; Jiang, Y.-Q.; Yu, B. *Org. Chem. Front.* **2022**, *9*, 1445.
(d) Cui, W.; Li, Y.; Li, X.; Li, J.; Song, X.; Lv, J.; Jiang, Y.-Y.; Yang, D. *Chin. Chem. Lett.* **2023**, *34*, 107477.

(e) Yu, Q.; Liu, Y. Y.; Wan, J. P. *Org. Chem. Front.* **2020**, *7*, 2770.
[15] (a) Han, Q.-Q.; Chen, D.-M.; Wang, Z.-L.; Sun, Y.-Y.; Yang, S.-H.; Song, J.-C.; Dong, D.-Q. *Chin. Chem. Lett.* **2021**, *32*, 2559.
(b) Dong, D.-Q.; Song, J.-C.; Yang, S.-H.; Qin, Q.-X.; Wang, Z.-L.; Zhang, E.-X.; Sun, Y.-Y.; Han, Q.-Q.; Yue, S. *Chin. Chem. Lett.* **2022**, *33*, 1199.
(c) Yang, S.-H.; Song, J.-C.; Yang, H.; Zhou, M.-Y.; Wei, Z.-H.; Gao, J.-H.; Dong, D.-Q.; Wang, Z.-L. *Chin. Chem. Lett.* **2023**, 108131.
[16] (a) Li, G.-H.; Han, Q.-Q.; Sun, Y.-Y.; Chen, D.-M.; Wang, Z.-L.; Xu, X.-M.; Yu, X.-Y. *Chin. Chem. Lett.* **2020**, *31*, 3255.
(b) Sun, Y.; Song, J.; Qin, Q.; Zhang, E.; Han, Q.; Yang, S.; Wang, Z.; Yue, S.; Dong, D. *Chin. J. Org. Chem.* **2021**, *41*, 4651 (in Chinese).
(孙媛媛, 宋敬城, 秦启学, 张恩选, 韩晴晴, 杨少慧, 王祖利, 岳姗, 董道, 有机化学, **2021**, *41*, 4651.)
(c) Han, Q. Q.; Sun, Y. Y.; Yang, S. H.; Song, J. C.; Wang, Z. L. *Chin. Chem. Lett.* **2021**, *32*, 3632.
(d) Yang, W.-C.; Chen, C.-Y.; Li, J.-F.; Wang, Z.-L. *Chin. J. Catal.* **2021**, *42*, 1865.
(e) Yang, S.-H.; Song, J.-C.; Dong, D.-Q.; Yang, H.; Zhou, M.-Y.; Zhang, H.-S.; Wang, Z.-L. *Chin. J. Org. Chem.* **2022**, *42*, 4099 (in Chinese).
(杨少慧, 宋敬城, 董道青, 杨昊, 周梦宇, 张会淑, 王祖利, 有机化学, **2022**, *42*, 4099.)
[17] (a) Wang, Y. N.; Li, Q.; Fang, Y. L.; Gao, L. H.; Song, S. Z.; Dong, Y.; Wei, W. T. *Asian J. Org. Chem.* **2019**, *8*, 832.
(b) Wu, Y.; Chen, J.-Y.; Ning, J.; Jiang, X.; Deng, J.; Deng, Y.; Xu, R.; He, W.-M. *Green Chem.* **2021**, *23*, 3950.
[18] Li, H.; Chen, P.; Wu, Z.; Lu, Y.; Peng, J.; Chen, J.; He, W. *Chin. J. Org. Chem.* **2022**, *42*, 3398 (in Chinese).
(李红霞, 陈棚, 伍智林, 陆雨函, 彭俊梅, 陈锦杨, 何卫民, 有机化学, **2022**, *42*, 3398.)
(b) Mu, S.; Li, H.; Wu, Z.; Peng, J.; Chen, J.; He, W. *Chin. J. Org. Chem.* **2022**, *42*, 4292 (in Chinese).
(穆思宇, 李红霞, 伍智林, 彭俊梅, 陈锦杨, 何卫民, 有机化学, **2022**, *42*, 4292.)
(c) Wang, K.; Huang, J.; Liu, W.; Wu, Z.; Yu, X.; Jiang, J.; He, W. *Chin. J. Org. Chem.* **2022**, *42*, 2527 (in Chinese).
(王苛莉, 黄静, 刘伟, 伍智林, 于贤勇, 蒋俊, 何卫民, 有机化学, **2022**, *42*, 2527.)
(d) Lu, Y.-H.; Wu, C.; Hou, J.-C.; Wu, Z.-L.; Zhou, M.-H.; Huang, X.-J.; He, W.-M. *ACS Catal.* **2023**, *13*, 13071.
(e) Ji, H.-T.; Wang, K.-L.; Ouyang, W.-T.; Luo, Q.-X.; Li, H.-X.; He, W.-M. *Green Chem.* **2023**, *25*, 7983.
(f) Song, H.-Y.; Xiao, F.; Jiang, J.; Wu, C.; Ji, H.-T.; Lu, Y.-H.; Wang, K.-L.; He, W.-M. *Chin. Chem. Lett.* **2023**, *34*, 108509.
[19] (a) Xu, Z.; Wan, J.; Liu, Y. *Chin. J. Org. Chem.* **2023**, *43*, 2425 (in Chinese).
(徐忠荣, 万结平, 刘云云, 有机化学, **2023**, *43*, 2425.)
(b) Shi, L.; Li, T.; Mei, G.-J. *Green Synth. Catal.* **2022**, *3*, 227.
(c) Ashitha, K. T.; Krishna M. S, A.; D, B.; B. Somappa, S. *Org. Chem. Front.* **2022**, *9*, 5306.
(d) Chen, D.; Jiang, J.; Wan, J.-P. *Chin. J. Chem.* **2022**, *40*, 2582.
(e) Chen, X.; Ouyang, W.-T.; Li, X.; He, W.-M. *Chin. J. Org. Chem.* **2023**, *43*, 4213 (in Chinese).
(陈祥, 欧阳文韬, 李潇, 何卫民, 有机化学, **2023**, *43*, 4213.)
(f) Song, H.-Y.; Jiang, J.; Wu, C.; Hou, J.-C.; Lu, Y.-H.; Wang, K.-L.; Yang, T.-B.; He, W.-M. *Green Chem.* **2023**, *25*, 3292.

(Lu, Y.)

