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FACILE SYNTHESIS OF CHIRAL BENZIMIDAZOLIUM SALTS AND THE APPLICATION IN ASYMMETRIC CATALYTIC BORYLATION

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Abstract – A synthetic method towards chiral benzimidazolium salts is developed. The stereocenter is introduced by direct aromatic substitution of 2-fluoronitrobenzene with optically pure amines. After nitro group reduction, selective arylation of the primary amine is achieved via copper catalyzed Chan-Lam coupling reaction. Finally, cyclization of the diamine with $HC(OMe)_3$ afforded the desired chiral benzimidazolium salts. In situ generated benzimidazole carbenes show potential application for asymmetric catalytic borylation of α,β-unsaturated esters, providing up to 85% ee value with a catalyst loading of only 0.5 mol%.

Chiral N-heterocyclic carbene (NHC) catalysts were one of the most rapidly developing catalysts in recent years.[1] Those have been widely used in the benzoin condensation reaction,[2] Stetter reaction,[3] Diels-Alder reaction,[4] olefin metathesis reaction[5] and hydrogenations.[6] The skeleton of N-heterocyclic carbene precursors are mostly imidazoles, benzimidazoles, triazoles and thiazoles (Figure 1).[7]

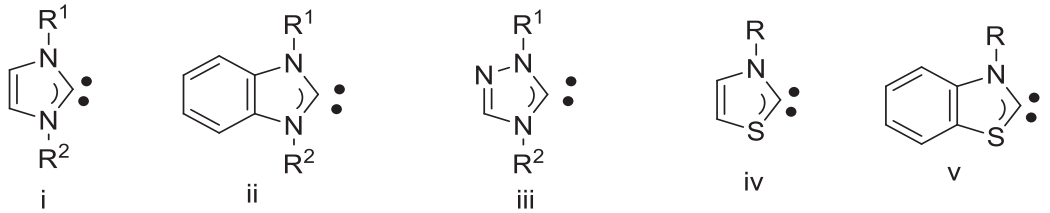


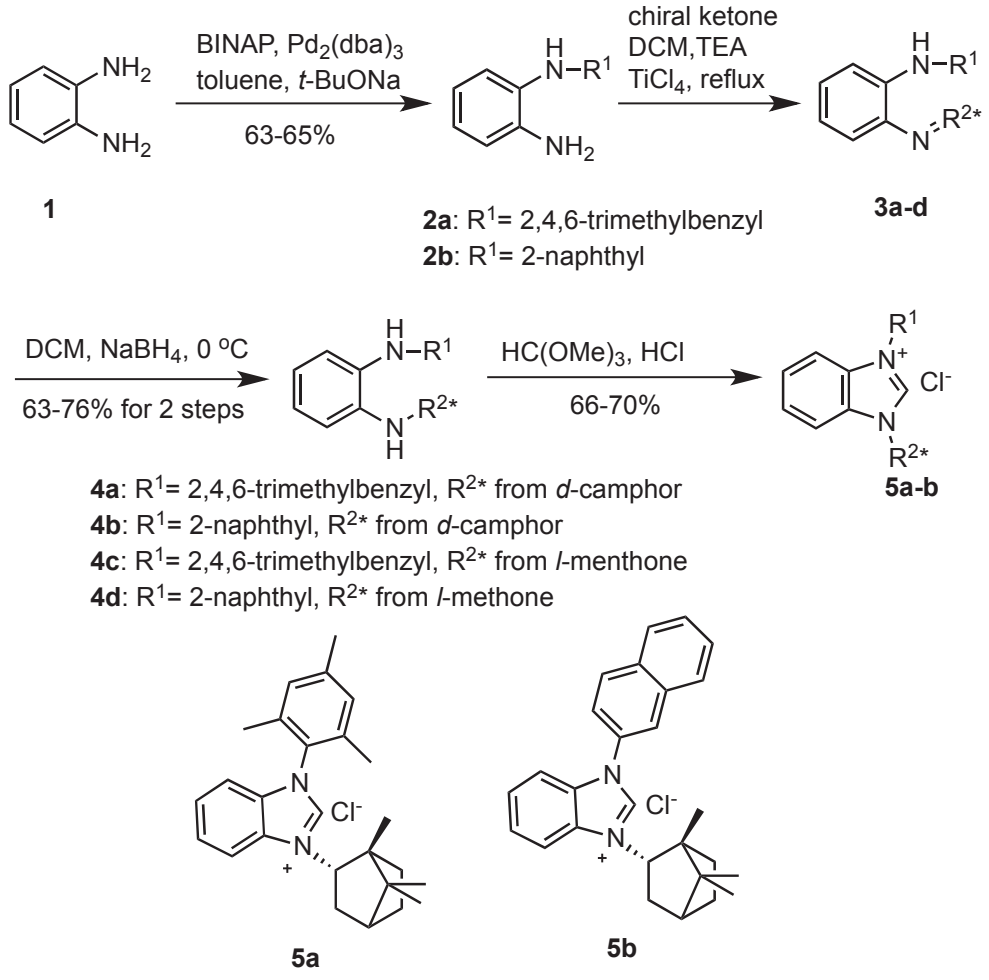
Figure 1. Core structures of classic NHCs

During the past few years, one of our main research interests had been focused on the synthesis and

application of achiral benzimidazolium salts in organic reactions.[7a,8] Based on our recent results that chiral 6-membered ring N-heterocyclic carbenes performed excellent asymmetric catalytic activity in borylation of α,β-unsaturated esters,[7a] we were curious to figure out if it could also be applicable to structurally more simplified chiral benzimidazole carbenes. However, the development and diversification of chiral benzimidazolium salts has lagged largely behind that of their imidazolium salts counterparts.[9] Benzimidazolium salts bearing remote stereocenters could be easily accessed by conjugation of benzimidazolium salts with readily available chiral fragments. Sakaguchi et al.[10] had utilized such kinds of chiral carbene precursors in a series of asymmetric catalytic reactions, including asymmetric conjugate addition reaction, asymmetric hydrosilylation of ketones and asymmetric intermolecular boron Heck-type reactions. To the best of our knowledge, currently there are only limited reports available for the synthesis of benzimidazolium salts equipped with chirality alpha to the nitrogen atom.[11] One synthetic approach to such motif was published from Diver's group, highlighting on the palladium catalyzed sequential amination of *o*-dibromobenzene with chiral amine and another amine or imine.[12] Alternatively, chiral benzimidazoles were approached by sequential substitution of 2-halo-nitrobenzene with chiral amine, reduction of nitro group and cyclization with orthoformate. Consequently, chiral benzimidazolium salts were merged via intermolecular or intramolecular N-alkylation with halides.[13a,13b] In a reversed manner, Mauduit's group functionalized the amino group by reductive amination prior to the ring closure, to generate similar molecular scaffold.[13c] Although with available procedures to access benzimidazolium salts with alpha chirality, application of these classes of carbene precursors in asymmetric catalytic reaction was scarce as well and usually provided inferior enantioselectivity or diastereoselectivity.[12c,13] A novel species of axial chiral benzimidazolium salts combining the structure of biphenyl or binaphthyl group with benzimidazolium scaffold is an exception. Developed by Shi's group, they found much more prevalent applications in various asymmetric reactions and offered excellent enantioselectivity.[14] However, it leads to dispute that the induction effect may derive from the axial chirality from naphthyl group, while not that of C1-symmetric stereocenter from benzimidazolium salts. Concerning the rareness of chiral benzimidazole carbenes, especially their limited application in asymmetric catalysis, in this article, we report an alternative method for the generation of chiral benzimidazolium salts with a wide variety of substitution diversity, and exploring their behavior in enantioselective borylation.

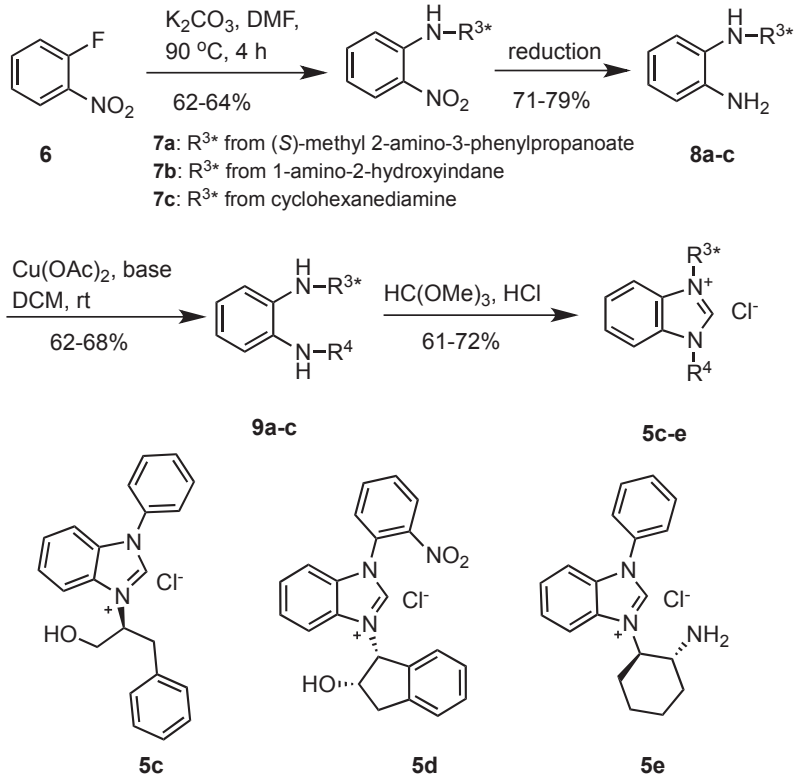
A traditional synthesis of achiral benzimidazolium salts relied on Buchwald-Hartwig coupling of *o*-phenylenediamine with two equivalents of halides, followed by ring closure with orthoester.[8d] The extensive development of Buchwald-Hartwig coupling reaction in recent years has enabled the monoarylation of *o*-phenylenediamine to be easily accessed.[15] We envisioned that the chirality could be introduced to the resultant primary amine, via a serial of operations including condensation with cheap

optically active ketones from chiral pool, and then substrate controlled diastereoselective reduction. Controlled monoarylation of *o*-phenylenediamine was realized by mixing equal molar ratio of amine and aryl halide under general Buchwald-Hartwig coupling condition. With the combination of $Pd_2(dba)_3$ and BINAP (Scheme 1), compounds **2a-b** were obtained in 63-65% yield by applying *t*-BuONa as the base. Compounds **2a-b** were then condensed with *d*-camphor to generate ketimines **3a-b** under the catalysis of $TiCl_4$. **3a-b** were not stable towards silica gel and should be directly transferred to reduction without further purification. The reduction with sodium borohydride went uneventful and provided compounds **4a-b** as single diastereoisomer. Finally, the desired chiral benzimidazole carbene precursors **5a-b** were forged by cyclization of **4a-b** with $HC(OMe)_3$ under acidic condition in 66-70% yield. However, when *l*-menthone was condensed with **2a-b** to generate **3c-d**, the reduction of **3c-d** yielded **4c** as a pair of diastereoisomers with the ratio of nearly 2:1. It could presumably be reasoned by epimerization of the isopropyl group via imine-enamine tautomerization of **3c-d**.[16] While in the case of **3a-b**, tautomerization induced racemization was not possible due to the intrinsic characteristics of quaternary carbon center. **4d** was not stable towards silica gel.



Scheme 1. Synthetic route for chiral benzimidazole NHC precursors

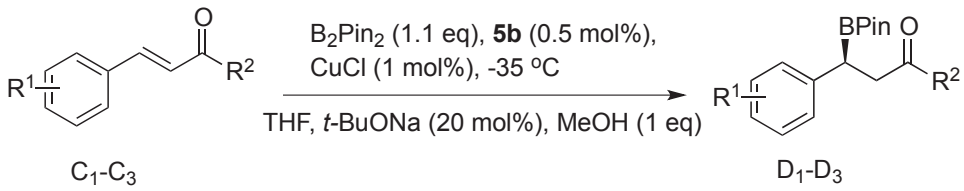
Since the protocol was not applicable to α-monosubstituted ketone, we then resorted to another strategy for assembling the chiral benzimidazolium salts with similar scaffold (Scheme 2). In a reversed manner, we planned to install the chiral amine at the very beginning. Thus, *o*-fluoronitrobenzene was heated with commercial available optically active amines in DMF at 90 ºC.[17] The reaction proceeded smoothly with K_2CO_3 as the base, offering chiral nitrobenzylamines **7a-c** in 62-64% yield. Then the nitro group of **7a-c** was reduced with lithium aluminum hydride, Pd/C-H_2 or iron powder, respectively. Different from Mauduit's protocol,[13c] which functionalized the primary amine by reductive amination with aldehyde, we planned to attach aryl group to the nitrogen atom. Surprisingly, selective arylation of the primary amino group of **8a-c** was not feasible under conventional Buchwald-Hartwig reaction condition, leaving the starting material intact, presumably due to deactivation of palladium catalyst by substrate chelation. To our delight, the same transformation was realized with Chan-Lam coupling condition,[18] using $Cu(OAc)_2$ as the catalyst. It is well known that copper catalyzed Chan-Lam cross coupling reaction is especially suitable for selective amide or aryl amine over alkyl amine or alcohol, thus also circumventing the regioselectivity problem in substrates **8a-c**. With triethylamine serving as the base, **9a** and **9b** were obtained in 62-68% yield. Slightly differently, no reaction occurred with **8c** under the same condition. However, while switching the base from triethylamine to buffer system of K_2CO_3 and benzoic acid,[19] **9c** was assembled in similar yield. The cyclization of **9a-c** with $HC(OMe)_3$ furnished chiral benzimidazolium salts in 61%-72% yield.



Scheme 2. Synthetic route for chiral benzimidazole NHC precursors

In summary, we report a facile synthesis of chiral benzimidazole NHC precursors from 2-fluoronitrobenzene in four steps. Aromatic substitution of 2-fluoronitrobenzene with optically active amine allows smooth introduction of the chiral center. After reduction of the nitro group, selective arylation of primary amine is feasible by Chan-Lam coupling reaction with copper catalyst. Condensation of the diamine with $HC(OMe)_3$ furnished the chiral benzimidazolium salts. NHCs **5b** generated in situ from these precursors shows good asymmetric catalytic properties for borylation of α, β-unsaturated ester with enantioselectivity of up to 85% with a catalyst loading of only 0.5 mol% (Table 1).[7a] The successful application of chiral benzimidazole carbenes in asymmetric catalytic borylation broadens the possibility of their usage in more classes of enantioselective reaction. We are currently screening more chiral benzimidazole carbenes for better asymmetric induction. These results would be reported in due course.

Table 1. Examples of asymmetric borylation



C_1-C_3 D_1-D_3

Entry	R^1	R^2	Product	Isolated yield (%)	ee[a] (%)
1	trifluoromethyl	methoxy	D1	87	85
2	4-methyl	methoxy	D2	89	79
3	4-Cl	methoxy	D3	86	74

[a]Enantiomeric excess: determined by HPLC analysis using a CHIRALPAK® column.

EXPERIMENTAL

^1H NMR and ^{13}C NMR spectra were recorded in $CDCl_3$ operating at 400 MHz and 100 MHz. Proton chemical shifts are reported relative to the residual proton signals of the deuterated solvent $CDCl_3$ (7.26 ppm) or DMSO-d_6 (2.50 and 3.33 ppm) or TMS. Carbon chemical shifts were internally referenced to the deuterated solvent signals in $CDCl_3$ (77.00 ppm) or DMSO-d_6 (40.0 ppm). Data are represented as follows: chemical shift, multiplicity (br = broad singlet, s = singlet, d = doublet, t = triplet, m = multiplet), coupling constant in Hertz (Hz), and integration. Products were identified by comparison to spectral data reported in the literature. Mass spectra (both at low resolution and at high resolution) were recorded on a time-of-flight mass spectrometer with an ESI source. High performance liquid chromatography (HPLC) was performed using a chromatograph equipped with a Chiral pak column (250 mm × 4.6 mm) with hexane/i-PrOH as the eluent.

Typical procedure for synthesis of 8a-c:

(*S*)-2-((2-Aminophenyl)amino)-3-phenylpropan-1-ol (8a): The crude product **7a** (2 g, 6.7 mmol) was dissolved in anhydrous THF (100 mL) in a 250 mL round-bottomed flask and cooled to -20 ºC. Then, lithium aluminum hydride (8.0 mL, 8.0 mmol) was added in batches. Then, the reaction mixture was stirred at rt for about 2 h. After completion of the reaction (checked by TLC), the reaction mixture was quenched with saturated NaCl solution, extracted with DCM and dried with Na_2SO_4. The crude product was purified by silica gel chromatography (hexane: EtOAc =15: 1 to 10:1) to give 1.1 g **8a**; brown oil, yield 71%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.30-7.38 (m, 2H), 7.23-7.25 (m, 3H), 6.78-6.90 (m, 2H), 6.75 (d, *J* = 3.5 Hz, 2H), 3.70-3.78 (m, 2H), 3.53-3.57 (m, 1H), 2.97-3.08 (m, 2H).

(1*R*, 2*S*)-1-((2-Aminophenyl)amino)-2,3-dihydro-1*H*-inden-2-ol (8b): The crude product **7b** (2 g, 7.4 mmol) was dissolved in anhydrous MeOH (50 mL) in a sealed tube and Pd/C was added. Then, the reaction mixture was stirred at rt for about 2 h under H_2. After completion of the reaction (checked by TLC), the resulting suspension was filtered through a plug of Celite (diatomaceous earth), and the filter cake was washed with MeOH. MeOH was removed under vacuum. The crude product was purified by silica gel chromatography (hexane: EtOAc =15: 1 to 10:1) to give 1.1 g **8b**; brown oil, yield 64%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.40 (d, *J* = 7.0 Hz, 1H), 7.22-7.37 (m, 3H), 6.87-7.03 (m, 2H), 6.74-6.86 (m, 2H), 4.90 (d, *J* = 4.6 Hz, 1H), 4.73 (t, *J* = 4.1 Hz, 1H), 3.21 (dd, *J* = 16.6, 5.0 Hz, 2H), 3.09 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.8, 140.6, 137.0, 134.3, 128.3, 127.1, 125.5, 124.2, 121.2, 119.9, 117.7, 113.6, 72.3, 63.0, 39.6. MS (ESI-TOF) *m/z*: 241.1 $[M+H]^+$.

***tert*-Butyl ((1*R*,2*R*)-2-((2-aminophenyl)amino)cyclohexyl)carbamate (8c):** The crude product **7c** (2 g, 6.0 mmol) was dissolved in EtOH: H_2O (1:1, 50 mL) in a 100 mL round-bottomed flask and iron powder (1.7 g, 29.81 mmol). Then, the reaction mixture was heated to reflux. After completion of the reaction (checked by TLC), the resulting suspension was filtered through a plug of Celite (diatomaceous earth), and washed with EtOH. Then, EtOH was removed under vacuum and the water layer was extracted with DCM. The crude product was used for the next step directly without further purification.

Typical procedure for synthesis of 9a-c:

(*S*)-3-Phenyl-2-((2-(phenylamino)phenyl)amino)propan-1-ol (9a): A mixture of diamine **8a** (0.50 g, 2.06 mmol), phenylboronic acid (0.52 g, 4.33 mmol) was dissolved in DCM (20-30 mL) in a 100 mL round-bottomed flask equipped with a stir bar. Then, Et_3N (0.42 g, 4.12 mmol) and $Cu(OAc)_2 \cdot H_2O$ (0.21 g, 1.03 mmol) were added to it respectively at room temperature. They would be stirred overnight under the condition of air atmosphere. After completion of the reaction (checked by TLC), the mixture was filtered through Celite and washed with EtOAc. The crude product was purified by silica gel chromatography (hexane:EtOAc = 40:1, 20:1 or 5:1) to give 0.41 g **9a**; brown oil, yield 62%; ^{1}H NMR

(400 MHz, $CDCl_3$) δ 7.20-7.27 (m, 5H), 7.12-7.17 (m, 4H), 6.86 (dd, *J* = 14.8, 7.5 Hz, 1H), 6.76 (t, *J* = 7.2 Hz, 1H), 6.71 (d, *J* = 7.7 Hz, 1H), 3.78-3.81 (m, 1H), 3.72 (dd, *J* = 11.0, 4.2 Hz, 1H), 3.51 (dd, *J* = 11.0, 5.6 Hz, 1H), 2.80-2.94 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.8, 143.0, 137.9, 129.3, 129.0, 128.9, 128.5, 126.5, 126.3, 125.7, 119.4, 118.1, 115.2, 112.5, 63.4, 56.1, 37.7.MS (ESI-TOF) *m/z*: 319.2 $[M+H]^+$.

(1*R*,2*S*)-1-((2-((2-Nitrophenyl)amino)phenyl)amino)-2,3-dihydro-1*H*-inden-2-ol (9b): brown oil, yield 63%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.11 (s, 1H), 8.23 (d, *J* = 8.8 Hz, 1H), 7.29-7.38 (m, 2H), 7.16-7.30 (m, 4H), 7.12 (dd, *J* = 16.4, 7.8 Hz, 2H), 6.91 (t, *J* = 7.6 Hz, 1H), 6.79 (dd, *J* = 5.0, 3.6 Hz, 2H), 4.95 (d, *J* = 4.2 Hz, 1H), 4.73 (d, *J* = 4.6 Hz, 1H), 3.20 (dd, *J* = 16.7, 4.6 Hz, 1H), 3.04 (d, *J* = 16.7 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.4, 144.2, 141.0, 140.3, 136.0, 133.1, 129.0, 128.6, 128.5, 127.3, 126.7, 125.6, 124.4, 123.9, 118.9, 117.5, 116.0, 112.8, 72.4, 62.8, 39.6. MS (ESI-TOF) *m/z*: 362.1 $[M+H]^+$.

***tert*-Butyl ((1*R*,2*R*)-2-((2-(phenylamino)phenyl)amino)cyclohexyl)carbamate (9c)**: A mixture of diamine **8c** (0.50 g, 1.64 mmol), phenylboronic acid (0.42 g, 3.1 mmol) was dissolved in DCM (20-30 mL) in a 100 mL round-bottomed flask equipped with a stir bar. Then, K_2CO_3 (0.23 g, 1.64 mmol), benzoic acid (0.10 g, 0.82 mmol) and $Cu(OAc)_2 \cdot H_2O$ (0.16 g, 0.33 mmol) were added to it respectively at room temperature. They would be stirred at 80 °C for 4 h under the condition of air atmosphere. After completion of the reaction (checked by TLC), the mixture was filtered through Celite and washed with EtOAc. The crude product was purified by silica gel chromatography (hexane:EtOAc = 40:1, 20:1 or 5:1) to give 0.42 g **9c**. pale yellow oil, yield 68%; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.21 (t, *J* = 7.7 Hz, 3H), 7.04 (t, *J* = 7.7 Hz, 1H), 6.82 (dd, *J* = 14.3, 7.4 Hz, 3H), 6.59-6.77 (m, 2H), 4.53 (br, 1H), 3.47 (br, 1H), 3.12 (br, 1H), 2.25 (d, *J* = 13.3 Hz, 1H), 2.09 (dd, *J* = 11.4, 4.3 Hz, 1H), 1.75 (s, 2H), 1.38 (s, 9H), 1.23-1.34 (m, 4H), 1.04-1.25 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.5, 145.6, 129.1, 125.0, 123.8, 119.1, 115.6, 79.5, 54.4, 32.9, 32.2, 29.7, 28.3, 24.9, 24.5. MS (ESI-TOF) *m/z*: 382.2 $[M+H]^+$.

Typical procedure for synthesis of 5a-e:

1-Mesityl-3-((1*R*,2*S*)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl)-1*H*-benzo[*d*]imidazol-3-ium chloride (5a): Compound **4a** (0.050 mg, 0.14 mmol) was dissolved in trimethyl orthoformate (5 mL). Then, concentrated hydrochloric acid (0.1 mL) was added. The mixture was reacted at room temperature for 12 h. Then most solvent was evaporated under reduced pressure. The crude product was purified by silica gel chromatography (DCM: MeOH = 10:1) to give 37 mg **5a**; white solid, yield 66%, mp 206.3-206.8 °C; ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.41 (s, 1H), 8.18-8.49 (m, 1H), 7.79 (t, *J* = 7.7 Hz, 1H), 7.70 (t, *J* = 7.7 Hz, 1H), 7.42 (d, *J* = 8.2 Hz, 1H), 7.27 (d, *J* = 7.2 Hz, 2H), 4.85-5.10 (m, 1H), 2.67 (d, *J* = 13.2 Hz, 1H), 2.41 (d, *J* = 4.9 Hz, 3H), 2.24 (dd, *J* = 13.3, 9.4 Hz, 1H), 1.94-2.09 (m, 5H), 1.92 (d, *J* = 13.1 Hz, 3H),

1.66-1.86 (m, 2H), 1.32-1.46 (m, 1H), 1.18 (s, 1H), 0.99 (s, 3H), 0.90 (s, 3H), 0.79 (s, 2H); ^{13}C NMR (100 MHz DMSO-d_6) δ 142.6, 141.4, 135.8, 135.5, 133.1, 130.2, 130.1, 127.5, 116.3, 113.6, 66.1, 51.0, 48.4, 44.8, 36.0, 26.7, 21.4, 21.2, 19.9, 17.5. MS (ESI-TOF) *m/z*: 373.3 $[M+H]^+$. HRMS (ESI-TOF) calcd for $C_{26}H_{33}N_2^+$ $[M]^+$ 373.2638, Found: 373.2641.

1-(Naphthalen-2-yl)-3-((1*R*,2*S*)-1,7,7-trimethylbicyclo[2.2.1]heptan-2-yl)-1*H*-benzo[*d*]imidazol-3-ium chloride (5b): white solid, yield 67%, mp 168.3-170.2 ºC; ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.41 (s, 1H), 8.46 (s, 1H), 8.29 (dd, *J* = 24.0, 8.5 Hz, 2H), 8.16 (d, *J* = 4.9 Hz, 2H), 7.91 (dd, *J* = 14.3, 9.2 Hz, 2H), 7.63-7.85 (m, 4H), 4.94 (t, *J* = 7.8 Hz, 1H), 2.78-2.81 (m, 1H), 2.21 (dd, *J* = 13.1, 9.5 Hz, 1H), 2.03 (s, 1H), 1.66-1.94 (m, 3H), 1.42 (s, 1H), 1.08 (s, 3H), 0.92 (t, *J* = 9.0 Hz, 6H); ^{13}C NMR (100 MHz, DMSO-d_6) 142.1, 133.6, 133.4, 133.1, 132.0, 130.5, 128.9, 128.5, 128.1, 127.3, 125.6, 123.7, 115.9, 114.1, 66.2, 51.1, 48.4, 44.9, 36.5, 36.0, 26.8, 21.5, 20.3, 12.8. MS (ESI-TOF) *m/z*: 381.2 $[M+H]^+$. HRMS (ESI-TOF) calcd for $C_{26}H_{33}N_2^+$ $[M]^+$ 381.2325, Found: 381.2323.

(*S*)-3-(1-Hydroxy-3-phenylpropan-2-yl)-1-phenyl-1*H*-benzo[*d*]imidazol-3-ium chloride (5c): brown solid, yield 72%; mp 147.2-148.7 ºC; ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.45 (s, 1H), 8.21 (d, *J* = 7.8 Hz, 1H), 7.62-7.92 (m, 8H), 7.34 (d, *J* = 7.3 Hz, 2H), 7.27 (t, *J* = 7.5 Hz, 2H), 7.18 (t, *J* = 7.3 Hz, 1H), 5.47 (t, *J* = 6.0 Hz, 1H), 5.36 (br, 1H), 3.77-4.05 (m, 2H), 3.49 (d, *J* = 7.2 Hz, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 142.1, 137.0, 134.5, 133.5, 132.1, 131.3, 131.1, 130.9, 129.5, 129.0, 128.0, 127.4, 127.3, 125.8, 114.8, 113.9. MS (ESI-TOF) *m/z*: 329.2 $[M+H]^+$. HRMS (ESI-TOF) calcd for $C_{22}H_{21}ClN_2O^+$ $[M]^+$ 329.1648, Found: 329.1649.

3-((1*R*,2*S*)-2-Hydroxy-2,3-dihydro-*1H*-inden-1-yl)-1-(2-nitrophenyl)-1*H*-benzo[*d*]imidazol-3-ium chloride (5d): white solid, yield 71%; mp 137.5-139.8 ºC; ^{1}H NMR (400 MHz, DMSO-d_6) δ 9.95 (s, 1H), 8.50 (s, 1H), 8.25 (d, *J* = 33.6 Hz, 1H), 8.03-8.13 (m, 3H), 7.75 (dd, *J* = 23.3, 15.7 Hz, 2H), 7.64 (d, *J* = 8.2 Hz, 1H), 7.39-7.57 (m, 3H), 7.35 (t, *J* = 7.2 Hz, 1H), 6.71 (s, 1H), 5.74-5.98 (m, 1H), 4.86 (s, 1H), 3.31 (d, *J* = 5.1 Hz, 1H), 3.11 (d, *J* = 16.3 Hz, 1H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 144.7, 144.2, 142.4, 139.9, 136.4, 133.3, 132.2, 131.4, 130.0, 128.2, 127.9, 127.4, 127.1, 126.5, 126.2, 126.5, 126.2, 125.0, 115.1, 113.6. MS (ESI-TOF) *m/z*: 372.2 $[M+H]^+$. HRMS (ESI-TOF) calcd for $C_{22}H_{18}N_3O_3^+$ $[M]^+$ 372.1343, Found: 372.1341.

3-((1*R*,2*R*)-2-Aminocyclohexyl)-1-phenyl-1*H*-benzo[*d*]imidazol-3-ium chloride (5e): white solid, yield 61%; mp 108.3-109.6 ºC; ^{1}H NMR (400 MHz, DMSO-d_6) δ 10.44 (s, 1H), 8.38 (d, *J* = 7.8 Hz, 1H), 7.88-7.93 (m, 2H), 7.82-7.87 (m, 1H), 7.69-7.80 (m, 5H), 4.73 (t, *J* = 9.3 Hz, 1H), 1.99-2.29 (m, 3H), 1.71-1.95 (m, 2H), 1.38-1.61 (m, 4H); ^{13}C NMR (100 MHz, DMSO-d_6) δ 142.1, 133.8, 132.2, 131.6, 130.9, 130.7, 127.8, 127.1, 125.8, 115.2, 113.8, 63.7, 53.9, 34.0, 32.2, 25.1, 24.4. MS (ESI-TOF) *m/z*: 292.1 $[M+H]^+$. HRMS (ESI-TOF) calcd for $C_{19}H_{22}N_3^+$ $[M]^+$ 292.1808, Found: 292.1809.

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