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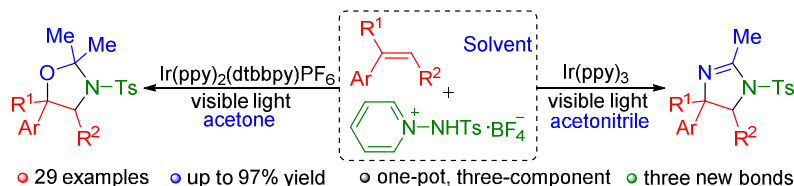
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Photoredox-Induced Functionalization of Alkenes for the Synthesis of Substituted Imidazolines and Oxazolidines

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ABSTRACT

A one-pot, three-component cascade reaction combining photoredox catalyzed radical addition and formal [3+2] annulation was developed. With this approach, highly concise syntheses of imidazoline and oxazolidine derivatives have been achieved. The advantages of this transformation are good to excellent yields, mild reaction conditions, operational simplicity and easy accessibility of raw materials.

KEYWORDS

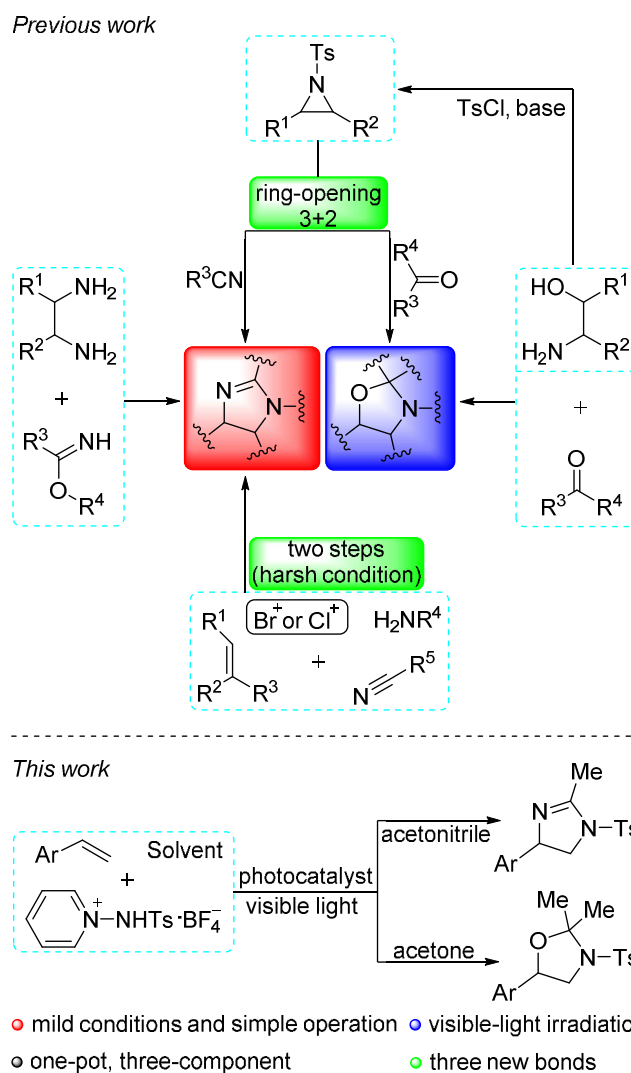
photochemistry, cycloaddition, cascade reaction, imidazolines, oxazolidines

INTRODUCTION

Nitrogenous heterocyclic compounds are widely found in nature.¹ Some examples include imidazolines and oxazolidines, which have been commonly used as biologically active molecules,² organic synthetic intermediates,³ and organocatalysts.⁴ Especially, imidazolines have long been used as auxiliary groups⁵ and metal complexation ligands⁶ for asymmetric synthesis. Therefore, as shown in Scheme 1, it is not surprising that the syntheses of imidazoline and oxazolidine derivatives have been extensively investigated. In general, 1,2-diamine and 1,2-amino alcohol, which are not easily available, can be smoothly transformed into the corresponding imidazoline and oxazolidine under harsh conditions,⁷ respectively. Besides that, Lewis acid mediated [3+2] cycloaddition of *N*-tosylaziridines with nitriles or carbonyls, as an alternative approach, was applied to the syntheses of imidazolines or oxazolidines.⁸ However, *N*-tosylaziridines had to be synthesized from 1,2-amino alcohol.⁹ Recently, Yeung et al. developed the cationic Br or Cl initiated imidazoline synthesis from olefin by a two-step transformation.¹⁰ Therefore, the development of novel methods to transform the unactivated alkenes directly into imidazolines and oxazolidines under mild reaction conditions will be highly desired.

More recently, owing to its ability to implement the incredible conversion reactions under benign conditions, visible-light photocatalysis has attracted a great deal of attention from the chemistry community.¹¹ Recent studies have shown that the *N*-centered radical, generated from the unactivated substrates by photoredox catalysis, could be employed in the cyclization and cross-coupling reactions.¹² We envisioned that the construction of imidazolines or oxazolidines from alkenes might also be realized through visible-light photoredox catalysis under mild conditions.

Scheme 1. The Synthesis of Imidazoline and Oxazolidine Derivatives



RESULTS AND DISCUSSION

To accomplish this goal, we first examined the reaction of styrene and *N*-Ts-protected 1-aminopyridinium¹³ at 20 °C in the presence of acetonitrile, a 25 W blue LED strip, and 1 mol % of Ru(bpy)₃(PF₆)₂. The functionalization of alkenes for the synthesis of substituted imidazolines occurred under these conditions. The choice of photocatalysts was a significant factor to promote this reaction. When Ir(ppy)₃ was used in place of Ru(bpy)₃(PF₆)₂, **3a** was obtained in 59% yield (entry 3 in Table 1),

while no reaction occurred with other organic photocatalysts such as Methylene blue and Eosin Y. To further improve the yield of the desired product, 2-methyl-4-phenyl-1-tosyl-4,5-dihydro-1H-imidazole (**3a**), the equivalent ratio of *N*-centered radical source to styrene was increased, and the yield was dramatically improved (to 95%, entry 8 in Table 1). Finally, control experiments revealed that both the photocatalyst and the light source were necessary for the synthesis of imidazoline derivatives.

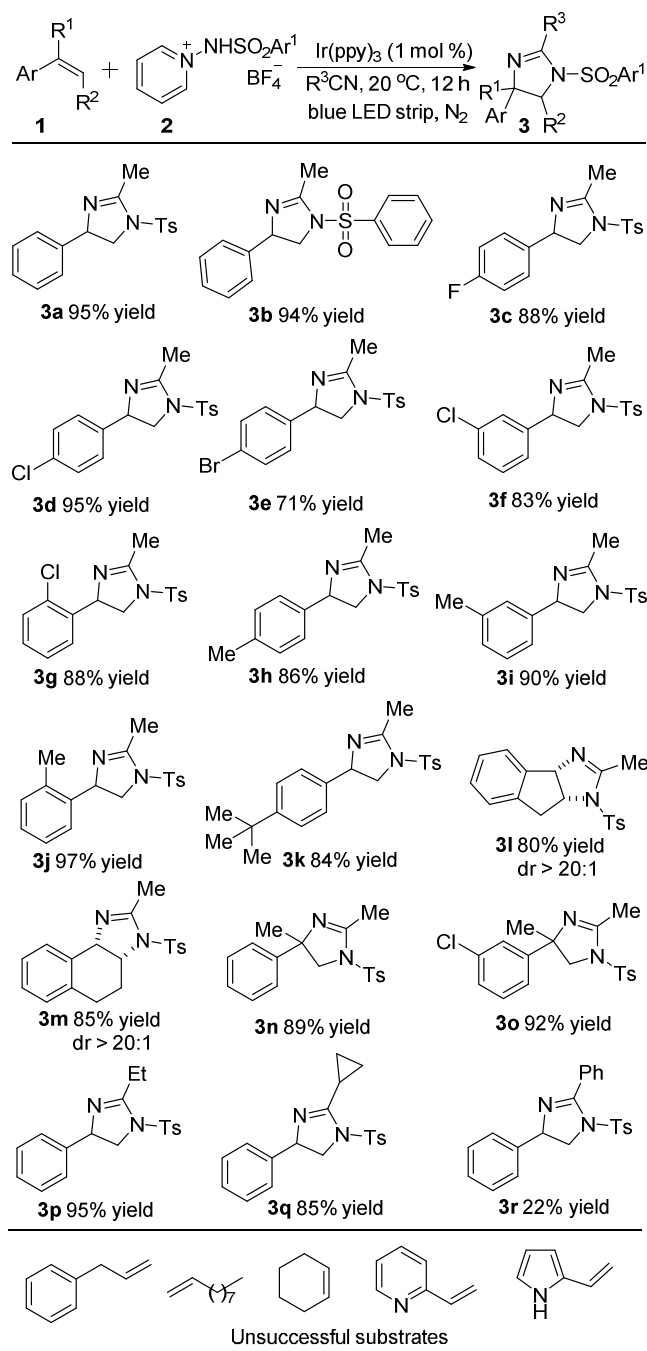
Table 1. Screening of the Reaction Conditions for the Synthesis of Imidazoline^a

entry	photocatalyst	1a:2a	yield (%) ^b
1	Ru(bpy) ₃ (PF ₆) ₂	1:1.5	52
2	Ir(ppy) ₂ (dtbbpy)PF ₆	1:1.5	58
3	Ir(ppy) ₃	1:1.5	59
4	Methylene blue	1:1.5	0
5 ^c	Eosin Y	1:1.5	0
6	Ir(ppy) ₃	1:2	68
7	Ir(ppy) ₃	1:3	78
8	Ir(ppy) ₃	1:4	95
9	-	1:4	0
10 ^d	Ir(ppy) ₃	1:4	0

^aUnless otherwise noted, reaction conditions are as follows: **1a** (0.2 mmol), **2a** (1.5 - 4 equiv), photocatalyst (0.002 mmol), CH₃CN (4 mL), 25 W blue LED strip, 20 °C, under N₂ atmosphere.

^bIsolated yield. ^c25 W white LED strip was used. ^dIn the absence of a light source.

Having successfully identified the optimal reaction conditions, we next turned our attention to examining the scope of the substrates. As shown in Table 2, a variety of substituted alkenes were readily converted to the corresponding imidazolines using Ir(ppy)₃ as the photocatalyst. Interestingly, when *N*-benzenesulfonyl protected 1-aminopyridinium salt was used instead of *N*-Ts-protected reactant, the yield of the product was only slightly diminished (**3a** vs **3b**). Substrates with electron-withdrawing (**3c–3g**) and electron-donating (**3h–3k**) groups in the aromatic ring, including a halogen atom and a methyl group, could proceed smoothly to give the corresponding substituted imidazolines in good to excellent yields. Notably, the substrate with a bulky *tert*-butyl group was also converted into the corresponding target compound **3k** in 84% yield. Furthermore, the transformations of the indene and 1,2-dihydronaphthalene were observed as well in high yields without any undesired diastereomers (**3l–3m**). In addition, α -methylstyrenes were also readily transformed into the imidazolines bearing a tetrasubstituted carbon quaternary stereocenter moiety in high yield (**3n–3o**). Except for acetonitrile, other nitriles, such as propionitrile, cyclopropane-carbonitrile and benzonitrile, could also achieve this kind of transformation under the photoredox catalysis conditions (**3p–3r**). However, the transformation of some heterocyclic aromatic and non-conjugated alkenes was not success.

Table 2. Scope of the Substrates for the Synthesis of Imidazoline Derivatives^{a,b}

^aReaction conditions: substrate **1** (0.2 mmol), substrate **2** (0.8 mmol), Ir(ppy)_3 (0.002 mmol) in R^3CN (anhydrous, 4 mL) at 20 °C under irradiation by 25 W blue LED strip for 12 h. ^bIsolated yields.

Encouraged by the results described above, we expected that the substituted oxazolidines might also be generated under similar reaction conditions. The transformation was smoothly realized (entry 1 in Table 3) under the similar reaction conditions when Ir(ppy)_3 was used as photocatalyst, and the examination of the photocatalysts indicated that $\text{Ir(ppy)}_2(\text{dtbbpy})\text{PF}_6$ produced the highest yield and

took the shortest time to complete the reaction. Interestingly, the optimal equivalent ratio of *N*-centered radical source to styrene was 1:1.5 in this case, either increasing or decreasing the equivalent ratio would reduce the yield of substituted oxazolidine (entries 3–5 in Table 3).

Table 3. Screening of the Reaction Conditions for the Synthesis of Oxazolidine^a

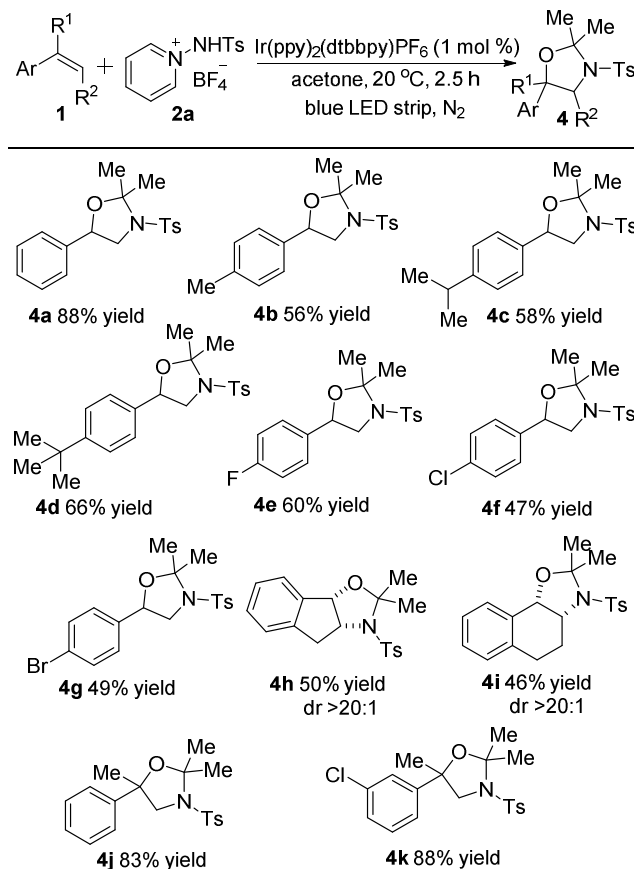
entry	photocatalyst	time (h)	1a:2a	yield (%) ^b
1	Ir(ppy) ₃	12	1:1.5	80
2	Ru(bpy) ₃ (PF ₆) ₂	3	1:1.5	77
3	Ir(ppy) ₂ (dtbbpy)PF ₆	2.5	1:1.5	88
4	Ir(ppy) ₂ (dtbbpy)PF ₆	2.5	1:2	55
5	Ir(ppy) ₂ (dtbbpy)PF ₆	2.5	1:1	75

^aUnless otherwise noted, reaction conditions are as follows: substrate **1a** (0.2 mmol), **2a** (1-2 equiv), photocatalyst (0.002mmol), acetone (anhydrous, 4 mL), 25 W blue LED strip, 20 °C, under N₂ atmosphere. ^bIsolated yield.

With the reaction conditions optimized, we next sought to examine the scope of olefins that can be applied to this cyclization reaction. As shown in Table 4, this protocol permitted the direct three-component cyclization of *N*-centered radical and acetone with a wide range of unactivated olefins. Furthermore, both electron-withdrawing and electron-donating substituents in the aromatic ring were well accommodated in this conversion under the photoredox catalysis. A variety of substituted oxazolidines were synthesized by this simple method in good to high yields (**4a-4i**). Likewise, α -methylstyrenes could also be easily transformed into the oxazolidines bearing an all-carbon quaternary stereocenter moiety in high yields (**4j-4k**). In a word, the reaction described herein makes an important complementation to the transformation which mentioned above.

The configuration of compound **4i** was determined by X-ray crystal structure analysis. The data of X-ray crystal structures can be found in the Supporting Information.¹⁴

Table 4. Scope of the Substrate for the Preparation of Oxazolidine Derivatives^{a,b}

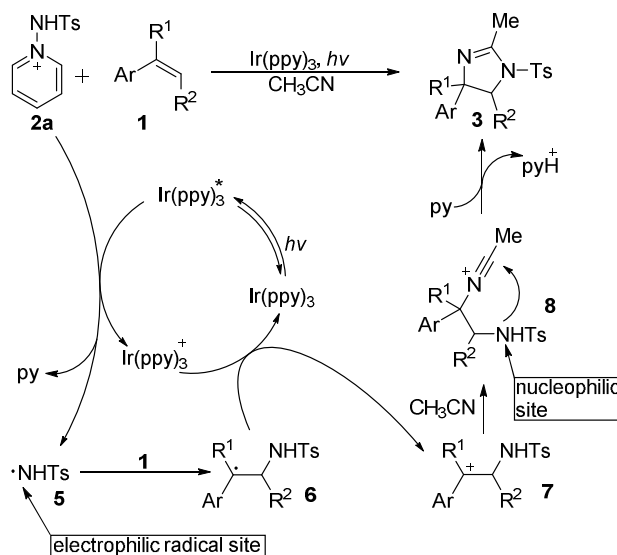


^aReaction conditions: substrate **1** (0.2 mmol), substrate **2a** (0.3 mmol), Ir(ppy)₂(dtbbpy)PF₆ (0.002 mmol) in acetone (anhydrous, 4 mL) at 20 °C under irradiation by 25 W blue LED strip for 2.5 h.

^bIsolated yields.

Control experiments have shown that both the photocatalyst and visible light were involved in the synthesis of substituted imidazolines. On the basis of our previous work as well as other reports,¹⁵ a plausible reaction mechanism is illustrated in Scheme 2. Irradiation of the photoredox catalyst Ir(ppy)₃ with a blue LED strip will generate the photoexcited species ^{*}Ir(ppy)₃, which is a strong electron donor to reduce the substrate **2a**.¹⁶ The *N*-Ts-protected 1-aminopyridinium **2a** accepts a single electron from ^{*}Ir(ppy)₃ and then provides the highly activated *N*-centered radical (**5**) and the oxidized Ir(ppy)₃⁺. The species **5** will react with alkene (**1**) and then afford the stabilized carbon radical (**6**). Ir(ppy)₃⁺ is a powerful oxidant which will be reduced by species **6** and then converted to the ground state photocatalyst. The generated carbocationic intermediate (**7**) is attacked by nitrile to form the highly reactive intermediate (**8**). Finally, the cyclization of intermediate **8** leads to the formation of the imidazoline product. Likewise, the reaction for synthesis of oxazolidine follows the similar mechanism as we proposed. We also confirmed that this nitrogen radical had multiple reaction sites.

Scheme 2. Proposed Mechanism



CONCLUSION

In conclusion, we have developed a direct and concise approach to achieve the visible light photoredox-induced functionalization of alkenes for the synthesis of imidazoline and oxazolidine derivatives. This method achieved a one-pot, three-component cascade reaction through the combination of photoredox catalyzed radical addition and formal [3+2] annulation. In contrast to traditional methods, the advantages of this transformation are good to excellent yields, mild reaction conditions, operational simplicity and easy accessibility of raw materials.

EXPERIMENTAL SECTION

General Information. All glassware was thoroughly oven-dried. Chemicals and solvents were either purchased from commercial suppliers or purified by standard techniques. Thin-layer chromatography plates were visualized by exposure to ultraviolet light and/or staining with phosphomolybdic acid followed by heating on a hot plate. Flash chromatography was carried out using silica gel (200–300 mesh). ^1H NMR and ^{13}C NMR spectra were recorded on a 400 MHz spectrometer. The spectra were recorded in deuteriochloroform (CDCl_3) as solvent at room temperature, ^1H and ^{13}C NMR chemical shifts are reported in ppm relative to the residual solvent peak. The residual solvent signals were used as references and the chemical shifts were converted to the TMS scale (CDCl_3 : $\delta_{\text{H}} = 7.26$ ppm, $\delta_{\text{C}} = 77.0$ ppm). Data for ^1H NMR are reported as follows: chemical shift (δ ppm), multiplicity (s = singlet, d = doublet, t = triplet, m = multiplet, dd = doublet, br = broad), integration, coupling constant (Hz) and assignment. Data for ^{13}C NMR are reported as chemical shift. IR spectra were recorded on a FT-IR instrument and are reported in wave numbers (cm^{-1}). HRMS spectra using ESI were recorded on an ESI-FTMS mass spectrometer.

General Procedure for the Synthesis of Imidazoline Derivatives. Substrate **1** (0.2 mmol) and *N*-Ts-protected 1-aminopyridinium **2** (0.8 mmol) were added to a solution of photocatalyst Ir(ppy)₃ (1 mol%) in nitrile (4 mL) at room temperature. The heterogenous mixture was degassed by three cycles of freeze-pump-thaw and then placed in the irradiation apparatus equipped with a 25 W blue light-emitting diode (LED) strip. The resulting mixture was stirred at 20 °C until the starting material was completely consumed after 12 h. Upon completion of the reaction, the reaction mixture was evaporated under reduced pressure, and the resulting crude mixture was purified on silica gel flash column chromatography using ethyl acetate/hexanes (1/2) eluent to give the corresponding imidazoline derivatives.

General procedure for the synthesis of oxazolidine derivatives. Substrate **1** (0.2 mmol) and *N*-Ts-protected 1-aminopyridinium **2** (0.3 mmol) were added to a solution of photocatalyst Ir(ppy)₂(dtbbpy)PF₆ (1 mol%) in acetone (4 mL) at room temperature. The heterogenous mixture was degassed by three cycles of freeze-pump-thaw and then placed in the irradiation apparatus equipped with a 25 W blue light-emitting diode (LED) strip. The resulting mixture was stirred at 20 °C until the starting material was completely consumed after 2.5 h. Upon completion of the reaction, the reaction mixture was evaporated under reduced pressure, and the resulting crude mixture was purified on silica gel flash column chromatography using ethyl acetate/hexanes (1/4) eluent to give the corresponding oxazolidine derivatives.

2-methyl-4-phenyl-1-tosyl-4,5-dihydro-1H-imidazole (3a).^{8d} Colorless oil; 59.9 mg, 95% yield; ¹H NMR (400 MHz, CDCl₃) δ (ppm) = 2.39 (s, 3H), 2.44 (s, 3H), 3.62 (t, *J* = 9.5 Hz, 1H), 4.17 (t, *J* = 10.1 Hz, 1H), 4.98 (t, *J* = 9.0 Hz, 1H), 7.04 (dd, *J* = 6.9, 1.6 Hz, 2H), 7.21–7.28 (m, 3H), 7.34 (d, *J* = 8.1 Hz, 2H), 7.74 (d, *J* = 8.2 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ (ppm) = 16.7, 21.5, 55.4, 66.5, 126.3, 127.1, 127.5, 128.6, 130.0, 135.1, 141.5, 144.7, 156.3; IR (KBr, cm⁻¹): 3370, 3282, 3063, 2924, 1646, 1598, 1495, 1359, 1242, 1166, 1115, 1024, 969, 815, 701, 659, 593, 547. HRMS (ESI) for C₁₇H₁₉N₂O₂S [M+H]⁺ calcd. 315.1162, found 315.1172

2-methyl-4-phenyl-1-(phenylsulfonyl)-4,5-dihydro-1H-imidazole (3b). Colorless oil; 56.4 mg, 94% yield; ¹H NMR (400 MHz, CDCl₃) δ (ppm) = 2.41 (s, 3H), 3.64 (dd, *J* = 9.6, 8.1 Hz, 1H), 4.19 (t, *J* = 10.1 Hz, 1H), 5.00 (t, *J* = 8.8 Hz, 1H), 7.04 (dd, *J* = 6.9, 1.4 Hz, 2H), 7.22–7.29 (m, 3H), 7.57 (t, *J* = 7.7 Hz, 2H), 7.66 (t, *J* = 7.4 Hz, 1H), 7.74 (d, *J* = 7.8 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ (ppm) = 16.8, 55.5, 66.6, 126.3, 127.1, 127.7, 128.7, 129.5, 133.7, 138.1, 141.4, 156.2; IR (KBr, cm⁻¹): 3278, 3064, 2927, 1647, 1543, 1448, 1360, 1243, 1169, 1116, 1092, 1024, 970, 757, 730, 690, 600, 570. HRMS (ESI) for C₁₆H₁₇N₂O₂S [M+H]⁺ calcd. 301.1005, found 301.1004.

4-(4-fluorophenyl)-2-methyl-1-tosyl-4,5-dihydro-1H-imidazole (3c).¹⁷ Colorless oil; 58.5 mg, 88% yield; ¹H NMR (400 MHz, CDCl₃) δ (ppm) = 2.39 (d, *J* = 1.4 Hz, 3H), 2.46 (s, 3H), 3.58 (dd, *J* = 9.8, 7.8 Hz, 1H), 4.16 (t, *J* = 10.1 Hz, 1H), 4.97 (t, *J* = 8.7 Hz, 1H), 6.94 (t, *J* = 8.7 Hz, 2H), 7.00–7.03 (m, 2H), 7.35 (d, *J* = 8.1 Hz, 2H), 7.74 (d, *J* = 8.3 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ (ppm) = 16.8, 21.5, 55.5, 65.9, 115.5 (d, *J* = 21.3 Hz), 127.2, 128.0 (d, *J* = 8.1 Hz), 130.1, 137.4 (d, *J* = 3.1 Hz), 144.8, 156.6, 162.1 (d, *J* = 244.5 Hz); IR (KBr, cm⁻¹): 3283, 3060, 2927, 1646, 1599, 1511, 1360, 1225, 1166, 1114, 1092, 1016, 971, 836, 710, 657, 593, 546. HRMS (ESI) for C₁₇H₁₈FN₂O₂S [M+H]⁺

⁺calcd.333.1068, found 333.1076.

4-(4-chlorophenyl)-2-methyl-1-tosyl-4,5-dihydro-1H-imidazole (3d).¹⁷ Colorless oil; 66.0 mg, 95% yield; ¹H NMR (400 MHz, CDCl₃) δ (ppm) = 2.39 (d, *J* = 1.4 Hz, 3H), 2.40 (s, 3H), 3.57 (dd, *J* = 9.8, 7.8 Hz, 1H), 4.17 (t, *J* = 10.1 Hz, 1H), 4.97 (t, *J* = 8.9 Hz, 1H), 6.98 (d, *J* = 8.4 Hz, 2H), 7.23 (d, *J* = 8.4 Hz, 2H), 7.35 (d, *J* = 8.1 Hz, 2H), 7.73 (d, *J* = 8.2 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ (ppm) = 16.8, 21.6, 55.4, 65.8, 127.2, 127.7, 128.8, 130.1, 133.4, 135.0, 140.1, 144.9, 156.9; IR (KBr, cm⁻¹): 3276, 3059, 2926, 1647, 1598, 1493, 1360, 1166, 1115, 1091, 1015, 971, 816, 736, 656, 593, 547. HRMS (ESI) for C₁₇H₁₈ClN₂O₂S [M+H]⁺calcd.349.0772, found 349.0782.

4-(4-bromophenyl)-2-methyl-1-tosyl-4,5-dihydro-1H-imidazole (3e).¹⁷ Colorless oil; 55.7 mg, 71% yield; ¹H NMR (400 MHz, CDCl₃) δ (ppm) = 2.39 (s, 3H), 2.45 (s, 3H), 3.56 (dd, *J* = 9.8, 7.9 Hz, 1H), 4.16 (t, *J* = 10.1 Hz, 1H), 4.95 (t, *J* = 8.7 Hz, 1H), 6.92 (d, *J* = 8.3 Hz, 2H), 7.32–7.38 (m, 4H), 7.72 (d, *J* = 8.2 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ (ppm) = 16.7, 21.5, 55.3, 65.8, 121.4, 127.1, 128.0, 130.1, 131.6, 135.0, 140.6, 144.8, 156.8; IR (KBr, cm⁻¹): 3276, 3055, 2924, 1646, 1597, 1488, 1359, 1242, 1166, 1116, 1091, 1011, 971, 816, 709, 663, 593, 547. HRMS (ESI) for C₁₇H₁₈BrN₂O₂S [M+H]⁺calcd.393.0267, found 393.0279.

4-(3-chlorophenyl)-2-methyl-1-tosyl-4,5-dihydro-1H-imidazole (3f).^{8d} Colorless oil; 58.0 mg, 83% yield; ¹H NMR (400 MHz, CDCl₃) δ (ppm) = 2.40 (d, *J* = 1.3 Hz, 3H), 2.45 (s, 3H), 3.57 (dd, *J* = 9.9, 7.7 Hz, 1H), 4.18 (t, *J* = 10.2 Hz, 1H), 4.96 (t, *J* = 9.0 Hz, 1H), 6.94–6.97 (m, 2H), 7.20 (d, *J* = 5.2 Hz, 2H), 7.34 (d, *J* = 8.2 Hz, 2H), 7.73 (d, *J* = 8.2 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ (ppm) = 16.8, 21.6, 55.2, 66.0, 124.6, 126.4, 127.1, 127.7, 129.9, 130.1, 134.5, 134.9, 143.7, 144.9, 156.9; IR (KBr, cm⁻¹): 3381, 3062, 2927, 1645, 1597, 1360, 1242, 1167, 1116, 1025, 787, 657, 593, 546. HRMS (ESI) for C₁₇H₁₈ClN₂O₂S [M+H]⁺calcd.349.0772, found 349.0771.

4-(2-chlorophenyl)-2-methyl-1-tosyl-4,5-dihydro-1H-imidazole (3g).^{8d} Colorless oil; 61.1 mg, 88% yield; ¹H NMR (400 MHz, CDCl₃) δ (ppm) = 2.43 (s, 6H), 3.53 (dd, *J* = 9.9, 7.7 Hz, 1H), 4.30 (t, *J* = 10.2 Hz, 1H), 5.31 (t, *J* = 8.6 Hz, 1H), 7.08–7.10 (m, 1H), 7.13–7.21 (m, 2H), 7.30–7.34 (m, 3H), 7.72 (d, *J* = 8.3 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ (ppm) = 16.9, 21.5, 54.7, 63.7, 127.0, 127.1, 127.4, 128.6, 129.3, 130.0, 132.2, 135.2, 139.5, 144.7, 157.4; IR (KBr, cm⁻¹): 3379, 3064, 2924, 1648, 1473, 1437, 1360, 1244, 1186, 1118, 1092, 1030, 970, 815, 756, 731, 657, 593, 546. HRMS (ESI) for C₁₇H₁₈ClN₂O₂S [M+H]⁺calcd.349.0772, found 349.0770.

2-methyl-4-(p-tolyl)-1-tosyl-4,5-dihydro-1H-imidazole (3h).^{8b, 8d} Colorless oil; 56.7 mg, 86% yield; ¹H NMR (400 MHz, CDCl₃) δ (ppm) = 2.94 (s, 3H), 2.37 (d, *J* = 1.5 Hz, 3H), 2.45 (s, 3H), 3.60 (dd, *J* = 9.8, 8.0 Hz, 1H), 4.14 (t, *J* = 10.0 Hz, 1H), 4.94 (t, *J* = 8.6 Hz, 1H), 6.92 (d, *J* = 8.0 Hz, 2H), 7.06 (d, *J* = 7.9 Hz, 2H), 7.34 (d, *J* = 8.1 Hz, 2H), 7.73 (d, *J* = 8.3 Hz, 2H); ¹³C NMR (100 MHz, CDCl₃) δ (ppm) = 16.7, 21.0, 21.5, 55.5, 66.3, 126.2, 127.1, 129.2, 130.0, 135.1, 137.2, 138.5, 144.6, 156.1; IR (KBr, cm⁻¹): 3279, 3027, 2923, 1647, 1597, 1515, 1432, 1358, 1241, 1166, 1116, 1091, 1020, 969, 816, 711, 657, 594, 546. HRMS (ESI) for C₁₈H₂₁N₂O₂S [M+H]⁺calcd.329.1318, found 329.1315.

2-methyl-4-(m-tolyl)-1-tosyl-4,5-dihydro-1H-imidazole (3i).^{8d} Colorless oil; 58.9 mg, 90% yield; ¹H NMR (400 MHz, CDCl₃) δ (ppm) = 2.56 (s, 3H), 2.39 (s, 3H), 2.45 (s, 3H), 3.62 (dd, *J* = 9.6, 8.1 Hz, 1H), 4.16 (t, *J* = 10.1 Hz, 1H), 4.95 (t, *J* = 9.0 Hz, 1H), 6.80 (s, 1H), 6.84 (d, *J* = 7.6 Hz, 1H), 7.04 (d, *J*

= 7.5 Hz, 1H), 7.14 (t, J = 7.5 Hz, 1H), 7.34 (d, J = 8.1 Hz, 2H), 7.75 (d, J = 8.2 Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ (ppm) = 16.8, 21.1, 21.5, 55.4, 66.5, 123.4, 126.9, 127.2, 128.3, 128.5, 130.0, 135.1, 138.3, 141.4, 144.6, 156.2; IR (KBr, cm^{-1}): 3281, 2923, 1646, 1597, 1431, 1359, 1167, 1114, 1092, 1024, 815, 788, 710, 659, 594, 546. HRMS (ESI) for $\text{C}_{18}\text{H}_{21}\text{N}_2\text{O}_2\text{S}$ $[\text{M}+\text{H}]^+$ calcd. 329.1318, found 329.1326.

2-methyl-4-(o-tolyl)-1-tosyl-4,5-dihydro-1H-imidazole (3j).^{8d} Colorless oil; 64.0 mg, 97% yield; ^1H NMR (400 MHz, CDCl_3) δ (ppm) = 2.27 (s, 3H), 2.42 (d, J = 1.4 Hz, 3H), 2.45 (s, 3H), 3.49 (dd, J = 9.4, 8.2 Hz, 1H), 4.22 (t, J = 10.0 Hz, 1H), 5.18 (t, J = 9.2 Hz, 1H), 6.92 (d, J = 7.5 Hz, 1H), 7.06–7.10 (m, 1H), 7.11–7.14 (m, 2H), 7.33 (d, J = 8.0 Hz, 2H), 7.33 (d, J = 8.3 Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ (ppm) = 16.9, 19.4, 21.6, 54.9, 63.5, 125.7, 126.4, 127.2, 127.3, 130.1, 130.3, 134.5, 135.3, 140.0, 144.7, 156.5; IR (KBr, cm^{-1}): 3278, 3060, 2928, 1649, 1597, 1510, 1461, 1359, 1271, 1167, 1117, 1091, 968, 815, 758, 711, 658, 594, 545. HRMS (ESI) for $\text{C}_{18}\text{H}_{21}\text{N}_2\text{O}_2\text{S}$ $[\text{M}+\text{H}]^+$ calcd. 329.1318, found 329.1315.

4-(4-(tert-butyl)phenyl)-2-methyl-1-tosyl-4,5-dihydro-1H-imidazole (3k). Colorless oil; 62.2 mg, 84% yield; ^1H NMR (400 MHz, CDCl_3) δ (ppm) = 2.28 (s, 9H), 2.37 (d, J = 1.4 Hz, 3H), 2.45 (s, 3H), 3.65 (dd, J = 9.7, 8.0 Hz, 1H), 4.14 (t, J = 10.0 Hz, 1H), 4.95 (t, J = 8.7 Hz, 1H), 6.97 (d, J = 8.3 Hz, 2H), 7.27 (d, J = 8.3 Hz, 2H), 7.35 (d, J = 8.2 Hz, 2H), 7.75 (d, J = 8.3 Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ (ppm) = 16.7, 21.5, 31.2, 34.4, 55.3, 66.2, 125.5, 126.0, 127.2, 130.0, 135.2, 138.4, 144.6, 150.5, 156.0; IR (KBr, cm^{-1}): 3055, 2962, 1647, 1598, 1510, 1474, 1360, 1242, 1167, 1112, 1019, 971, 815, 656, 594, 546. HRMS (ESI) for $\text{C}_{21}\text{H}_{27}\text{N}_2\text{O}_2\text{S}$ $[\text{M}+\text{H}]^+$ calcd. 371.1788, found 371.1786.

2-methyl-1-tosyl-1,3a,8,8a-tetrahydroindeno[1,2-d]imidazole (3l). White solid; 52.1 mg, 80% yield; ^1H NMR (400 MHz, CDCl_3) δ (ppm) = 2.25 (s, 3H), 2.46 (s, 3H), 3.43–3.57 (m, 2H), 4.83 (t, J = 6.7 Hz, 1H), 5.42 (d, J = 8.7 Hz, 1H), 7.24–7.27 (m, 3H), 7.37 (d, J = 8.0 Hz, 2H), 7.46 (d, J = 7.2 Hz, 1H), 7.78 (d, J = 8.2 Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ (ppm) = 16.8, 21.6, 41.2, 63.7, 74.7, 125.1, 125.3, 127.2, 127.4, 128.6, 130.1, 135.9, 139.8, 140.7, 144.8, 156.3; IR (KBr, cm^{-1}): 3028, 2927, 1716, 1646, 1598, 1434, 1358, 1235, 1165, 1092, 1014, 966, 913, 814, 754, 691, 595, 545. HRMS (ESI) for $\text{C}_{18}\text{H}_{19}\text{N}_2\text{O}_2\text{S}$ $[\text{M}+\text{H}]^+$ calcd. 327.1162, found 327.1164.

2-methyl-3-tosyl-3a,4,5,9b-tetrahydro-3H-naphtho[1,2-d]imidazole (3m).^{8b} Colorless oil; 57.8 mg, 85% yield; ^1H NMR (400 MHz, CDCl_3) δ (ppm) = 2.00–2.15 (m, 2H), 2.29 (d, J = 1.8 Hz, 3H), 2.45 (s, 3H), 2.55–2.62 (m, 1H), 2.70–2.76 (m, 1H), 4.43–4.48 (m, 1H), 4.85 (d, J = 9.5 Hz, 1H), 7.08 (d, J = 7.3 Hz, 1H), 7.14–7.23 (m, 2H), 7.36 (d, J = 8.0 Hz, 2H), 7.43 (d, J = 7.4 Hz, 1H), 7.78 (d, J = 8.3 Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ (ppm) = 17.1, 21.5, 25.8, 28.5, 60.6, 65.6, 126.8, 126.9, 127.2, 128.1, 129.6, 130.1, 133.8, 136.6, 137.7, 144.5, 155.5; IR (KBr, cm^{-1}): 3278, 3062, 2929, 1647, 1598, 1494, 1454, 1356, 1244, 1164, 1096, 1021, 911, 814, 734, 664, 602, 546. HRMS (ESI) for $\text{C}_{19}\text{H}_{21}\text{N}_2\text{O}_2\text{S}$ $[\text{M}+\text{H}]^+$ calcd. 341.1318, found 341.1322.

2,4-dimethyl-4-phenyl-1-tosyl-4,5-dihydro-1H-imidazole (3n). Colorless oil; 58.3 mg, 89% yield; ^1H NMR (400 MHz, CDCl_3) δ (ppm) = 1.46 (s, 3H), 2.37 (s, 3H), 2.41 (s, 3H), 3.79 (d, J = 9.6 Hz, 1H), 3.91 (d, J = 9.6 Hz, 1H), 7.20–7.30 (m, 7H), 7.70 (d, J = 8.2 Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ (ppm) = 16.8, 21.5, 29.5, 61.0, 69.5, 124.9, 126.8, 127.0, 128.4, 130.0, 135.3, 144.5, 146.3, 154.1; IR

(KBr, cm^{-1}): 3282, 2969, 2926, 1647, 1447, 1358, 1167, 1090, 1041, 924, 815, 765, 717, 664, 593, 545. HRMS (ESI) for $\text{C}_{18}\text{H}_{21}\text{N}_2\text{O}_2\text{S}$ $[\text{M}+\text{H}]^+$ calcd. 329.1318, found 329.1322.

4-(3-chlorophenyl)-2,4-dimethyl-1-tosyl-4,5-dihydro-1H-imidazole (3o). Colorless oil; 66.6 mg, 92% yield; ^1H NMR (400 MHz, CDCl_3) δ (ppm) = 1.45 (s, 3H), 2.38 (s, 3H), 2.42 (s, 3H), 3.74 (d, J = 9.8 Hz, 1H), 3.89 (d, J = 9.8 Hz, 1H), 7.09–7.11 (m, 1H), 7.16–7.22 (m, 3H), 7.30 (d, J = 8.1 Hz, 2H), 7.69 (d, J = 8.2 Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ (ppm) = 16.9, 21.5, 29.4, 60.9, 69.3, 123.2, 125.5, 127.0, 129.7, 130.0, 134.3, 135.1, 144.7, 148.5, 154.7; IR (KBr, cm^{-1}): 3367, 2973, 2926, 1736, 1648, 1597, 1475, 1359, 1283, 1168, 1118, 1041, 1010, 925, 814, 743, 696, 660, 594, 546. HRMS (ESI) for $\text{C}_{18}\text{H}_{20}\text{ClN}_2\text{O}_2\text{S}$ $[\text{M}+\text{H}]^+$ calcd. 363.0929, found 363.0926.

2-ethyl-4-phenyl-1-tosyl-4,5-dihydro-1H-imidazole (3p).¹⁸ Colorless oil; 62.2 mg, 95% yield; ^1H NMR (400 MHz, CDCl_3) δ (ppm) = 1.29 (t, J = 7.4 Hz, 3H), 2.44 (s, 3H), 2.77 (m, 2H), 3.61 (dd, J = 9.8, 7.8 Hz, 1H), 4.17 (t, J = 10.1 Hz, 1H), 4.99 (dd, J = 9.9, 8.0 Hz, 1H), 7.02–7.04 (m, 2H), 7.22–7.27 (m, 3H), 7.33 (d, J = 8.0 Hz, 2H), 7.73 (d, J = 8.2 Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ (ppm) = 11.0, 21.5, 23.3, 55.8, 66.6, 126.3, 127.2, 127.5, 128.6, 130.0, 135.3, 141.8, 144.6, 160.8; IR (KBr, cm^{-1}): 3296, 3030, 2925, 1736, 1637, 1598, 1494, 1471, 1401, 1359, 1244, 1162, 1097, 994, 815, 701, 660, 587, 567. HRMS (ESI) for $\text{C}_{18}\text{H}_{21}\text{N}_2\text{O}_2\text{S}$ $[\text{M}+\text{H}]^+$ calcd. 329.1318, found 329.1315.

2-cyclopropyl-4-phenyl-1-tosyl-4,5-dihydro-1H-imidazole (3q). Colorless oil; 58.0 mg, 85% yield; ^1H NMR (400 MHz, CDCl_3) δ (ppm) = 0.97–1.12 (m, 4H), 2.42–2.50 (m, 4H), 3.60 (dd, J = 10.1, 7.4 Hz, 1H), 4.19 (t, J = 10.2 Hz, 1H), 4.89 (dd, J = 10.2, 7.5 Hz, 1H), 6.89–6.91 (m, 2H), 7.19–7.21 (m, 3H), 7.29 (d, J = 8.1 Hz, 2H), 7.79 (d, J = 8.2 Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ (ppm) = 8.6, 9.7, 10.4, 21.5, 56.4, 65.9, 126.2, 127.3, 127.4, 128.5, 129.9, 135.0, 142.1, 144.5, 161.7; IR (KBr, cm^{-1}): 3290, 2980, 2931, 1736, 1647, 1535, 1454, 1331, 1243, 1161, 1094, 913, 815, 701, 663, 590, 549. HRMS (ESI) for $\text{C}_{19}\text{H}_{21}\text{N}_2\text{O}_2\text{S}$ $[\text{M}+\text{H}]^+$ calcd. 341.1318, found 341.1315.

2,4-diphenyl-1-tosyl-4,5-dihydro-1H-imidazole (3r).^{8b, 8d} Colorless oil; 16.4 mg, 22% yield; ^1H NMR (400 MHz, CDCl_3) δ (ppm) = 2.42 (s, 3H), 3.86 (dd, J = 11.4, 8.1 Hz, 1H), 4.43 (dd, J = 11.3, 10.2 Hz, 1H), 4.99 (dd, J = 9.8, 8.3 Hz, 1H), 6.96–6.98 (m, 2H), 7.18–7.22 (m, 5H), 7.39–7.45 (m, 4H), 7.52 (t, J = 7.4 Hz, 1H), 7.77 (d, J = 7.2 Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ (ppm) = 21.6, 56.9, 67.9, 126.3, 127.4, 127.6, 127.7, 128.6, 129.7, 129.8, 130.2, 131.1, 134.5, 141.5, 144.6, 159.8; IR (KBr, cm^{-1}): 3062, 2924, 1628, 1598, 1509, 1449, 1365, 1169, 1089, 1023, 911, 815, 732, 698, 663, 605, 546. HRMS (ESI) for $\text{C}_{22}\text{H}_{21}\text{N}_2\text{O}_2\text{S}$ $[\text{M}+\text{H}]^+$ calcd. 377.1318, found 377.1316.

2,2-dimethyl-5-phenyl-3-tosyloxazolidine (4a).^{8a, 8b} White solid; 58.3 mg, 88% yield; mp 89–91 °C; ^1H NMR (400 MHz, CDCl_3) δ (ppm) = 1.68 (s, 3H), 1.74 (s, 3H), 2.42 (s, 3H), 3.14 (t, J = 9.1 Hz, 1H), 3.87 (dd, J = 8.7, 5.7 Hz, 1H), 5.10 (dd, J = 9.5, 5.7 Hz, 1H), 7.28–7.35 (m, 7H), 7.75 (d, J = 8.3 Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ (ppm) = 21.5, 27.0, 27.5, 54.0, 76.2, 97.3, 126.2, 127.3, 128.5, 128.5, 129.6, 137.3, 137.4, 143.4; IR (KBr, cm^{-1}): 3033, 2985, 2878, 1737, 1599, 1496, 1370, 1344, 1245, 1218, 1155, 1095, 1060, 1028, 955, 816, 759, 709, 659, 593, 548. HRMS (ESI) for $\text{C}_{18}\text{H}_{22}\text{NO}_3\text{S}$ $[\text{M}+\text{H}]^+$ calcd. 332.1315, found 332.1314.

2,2-dimethyl-5-(p-tolyl)-3-tosyloxazolidine (4b).¹⁹ White solid; 38.6 mg, 56% yield; mp 120–122 °C; ^1H NMR (400 MHz, CDCl_3) δ (ppm) = 1.68 (s, 3H), 1.73 (s, 3H), 2.33 (s, 3H), 2.42 (s, 3H), 3.14 (t, J =

9.1 Hz, 1H), 3.85 (dd, $J = 8.7, 5.7$ Hz, 1H), 5.08 (dd, $J = 9.4, 5.6$ Hz, 1H), 7.14 (d, $J = 8.0$ Hz, 2H), 7.20 (d, $J = 8.1$ Hz, 2H), 7.30 (d, $J = 8.0$ Hz, 2H), 7.76 (d, $J = 8.1$ Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ (ppm) = 21.1, 21.4, 27.1, 27.5, 54.0, 76.1, 97.2, 126.1, 127.3, 129.2, 129.6, 134.3, 137.3, 138.3, 143.3; IR (KBr, cm^{-1}): 3363, 2923, 2852, 1737, 1657, 1598, 1459, 1371, 1343, 1244, 1154, 1094, 954, 813, 687, 653, 592, 547. HRMS (ESI) for $\text{C}_{19}\text{H}_{24}\text{NO}_3\text{S}$ $[\text{M}+\text{H}]^+$ calcd. 346.1471, found 346.1470.

5-(4-isopropylphenyl)-2,2-dimethyl-3-tosyloxazolidine (4c). White solid; 43.4 mg, 58% yield; mp 102–103 °C; ^1H NMR (400 MHz, CDCl_3) δ (ppm) = 1.21 (d, $J = 6.9$ Hz, 6H), 1.67 (s, 3H), 1.72 (s, 3H), 2.42 (s, 3H), 2.83–2.93 (m, 1H), 3.16 (t, $J = 9.1$ Hz, 1H), 3.84 (dd, $J = 8.7, 5.7$ Hz, 1H), 5.07 (dd, $J = 9.5, 5.6$ Hz, 1H), 7.17–7.24 (m, 4H), 7.29 (d, $J = 8.0$ Hz, 2H), 7.75 (d, $J = 8.0$ Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ (ppm) = 21.4, 23.8, 23.9, 27.0, 27.5, 33.8, 76.1, 97.2, 126.3, 126.6, 127.3, 129.6, 134.6, 137.3, 143.3, 149.4; IR (KBr, cm^{-1}): 2961, 2872, 1738, 1599, 1461, 1371, 1345, 1244, 1156, 1094, 956, 828, 687, 654, 593, 549. HRMS (ESI) for $\text{C}_{21}\text{H}_{28}\text{NO}_3\text{S}$ $[\text{M}+\text{H}]^+$ calcd. 374.1784, found 374.1782.

5-(4-(tert-butyl)phenyl)-2,2-dimethyl-3-tosyloxazolidine (4d). White solid; 51.2 mg, 66% yield; mp 99–100 °C; ^1H NMR (400 MHz, CDCl_3) δ (ppm) = 1.29 (s, 9H), 1.67 (s, 3H), 1.73 (s, 3H), 2.42 (s, 3H), 3.16 (t, dd, $J = 9.1$ Hz, 1H), 3.85 (dd, $J = 8.7, 5.6$ Hz, 1H), 5.08 (dd, $J = 9.5, 5.7$ Hz, 1H), 7.24 (d, $J = 8.3$ Hz, 2H), 7.29 (d, $J = 8.2$ Hz, 2H), 7.35 (d, $J = 8.3$ Hz, 2H), 7.75 (d, $J = 8.2$ Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ (ppm) = 21.4, 27.0, 27.5, 31.2, 34.5, 53.8, 76.1, 97.2, 125.5, 126.0, 127.3, 129.6, 134.2, 137.3, 143.3, 151.6; IR (KBr, cm^{-1}): 2961, 1738, 1599, 1461, 1345, 1245, 1222, 1156, 1094, 1015, 956, 826, 711, 684, 653, 593, 549. HRMS (ESI) for $\text{C}_{22}\text{H}_{30}\text{NO}_3\text{S}$ $[\text{M}+\text{H}]^+$ calcd. 388.1941, found 388.1940.

5-(4-fluorophenyl)-2,2-dimethyl-3-tosyloxazolidine (4e). White solid; 42.0 mg, 60% yield; mp 91–93 °C; ^1H NMR (400 MHz, CDCl_3) δ (ppm) = 1.68 (s, 3H), 1.72 (s, 3H), 2.42 (s, 3H), 3.11 (t, $J = 9.1$ Hz, 1H), 3.84 (dd, $J = 8.7, 5.7$ Hz, 1H), 5.07 (dd, $J = 9.4, 5.7$ Hz, 1H), 7.01 (t, $J = 8.6$ Hz, 2H), 7.26–7.31 (m, 4H), 7.75 (d, $J = 8.2$ Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ (ppm) = 21.5, 27.1, 27.4, 54.0, 75.6, 97.3, 115.5 ($J = 21.7$ Hz), 127.3, 128.0 ($J = 8.1$ Hz), 129.6, 133.2 ($J = 3.0$ Hz), 137.2, 143.5, 162.7 ($J = 245.6$ Hz); IR (KBr, cm^{-1}): 2985, 2929, 1606, 1513, 1459, 1370, 1342, 1225, 1153, 1093, 1014, 956, 835, 710, 688, 654, 592. HRMS (ESI) for $\text{C}_{18}\text{H}_{21}\text{FNO}_3\text{S}$ $[\text{M}+\text{H}]^+$ calcd. 350.1221, found 350.1219.

5-(4-chlorophenyl)-2,2-dimethyl-3-tosyloxazolidine (4f).¹⁹ White solid; 34.2 mg, 47% yield; mp 112–114 °C; ^1H NMR (400 MHz, CDCl_3) δ (ppm) = 1.67 (s, 3H), 1.72 (s, 3H), 2.42 (s, 3H), 3.09 (t, $J = 9.1$ Hz, 1H), 3.85 (dd, $J = 8.8, 5.8$ Hz, 1H), 5.07 (dd, $J = 9.3, 5.7$ Hz, 1H), 7.22–7.31 (m, 6H), 7.74 (d, $J = 8.3$ Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ (ppm) = 21.5, 27.0, 27.4, 53.5, 75.5, 97.4, 127.3, 127.5, 128.7, 129.6, 134.2, 136.1, 137.2, 143.5; IR (KBr, cm^{-1}): 3376, 2925, 1736, 1598, 1509, 1459, 1342, 1245, 1154, 1092, 1015, 955, 817, 682, 592. HRMS (ESI) for $\text{C}_{18}\text{H}_{21}\text{ClNO}_3\text{S}$ $[\text{M}+\text{H}]^+$ calcd. 366.0925, found 366.0926.

5-(4-bromophenyl)-2,2-dimethyl-3-tosyloxazolidine (4g). White solid; 40.0 mg, 49% yield; mp 100–102 °C; ^1H NMR (400 MHz, CDCl_3) δ (ppm) = 1.67 (s, 3H), 1.72 (s, 3H), 2.42 (s, 3H), 3.09 (t, $J = 9.0$ Hz, 1H), 3.86 (dd, $J = 8.7, 5.8$ Hz, 1H), 5.06 (dd, $J = 9.2, 5.7$ Hz, 1H), 7.17 (d, $J = 8.4$ Hz, 2H), 7.30 (d, $J = 8.0$ Hz, 2H), 7.45 (d, $J = 8.4$ Hz, 2H), 7.74 (d, $J = 8.3$ Hz, 2H); ^{13}C NMR (100 MHz, CDCl_3) δ (ppm) = 21.5, 27.0, 27.4, 53.8, 75.5, 97.4, 122.3, 127.3, 127.8, 129.6, 131.7, 136.6, 137.1, 143.5; IR (KBr, cm^{-1}): 2984, 2931, 1736, 1597, 1489, 1343, 1246, 1217, 1156, 1093, 1012, 817, 676,

592, 551. HRMS (ESI) for $C_{18}H_{21}BrNO_3S$ $[M+H]^+$ calcd. 410.0420, found 410.0418.

2,2-dimethyl-3-tosyl-3,3a,4,8b-tetrahydro-2H-indeno[2,1-d]oxazole (4h). White solid; 34.2 mg, 50% yield; mp 111–112 °C; 1H NMR (400 MHz, $CDCl_3$) δ (ppm) = 1.60 (s, 3H), 1.64 (s, 3H), 2.44 (s, 3H), 3.05–3.20 (m, 2H), 4.58–4.63 (m, 1H), 5.45 (d, J = 6.5 Hz, 1H), 7.15 (d, J = 7.5 Hz, 1H), 7.23 (d, J = 7.1 Hz, 1H), 7.28–7.33 (m, 3H), 7.39 (d, J = 7.4 Hz, 1H), 7.81 (d, J = 8.3 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) = 21.5, 25.8, 29.2, 39.7, 62.2, 83.1, 100.5, 125.2, 125.4, 127.2, 127.6, 129.6, 129.8, 138.2, 138.6, 142.3, 143.5; IR (KBr, cm^{-1}): 3370, 2984, 2927, 1737, 1599, 1462, 1370, 1338, 1245, 1210, 1152, 1093, 1014, 956, 753, 585, 552. HRMS (ESI) for $C_{19}H_{21}NO_3SNa$ $[M+Na]^+$ calcd. 366.1134, found 366.1133.

2,2-dimethyl-3-tosyl-2,3,3a,4,5,9b-hexahydronaphtho[2,1-d]oxazole (4i). White solid; 33.0 mg, 46% yield; mp 121–123 °C; 1H NMR (400 MHz, $CDCl_3$) δ (ppm) = 1.67 (s, 3H), 1.73 (s, 3H), 1.78–1.88 (m, 1H), 2.02–2.09 (m, 1H), 2.43 (s, 3H), 2.58–2.67 (m, 1H), 2.76–2.82 (m, 1H), 3.95–4.00 (m, 1H), 4.83 (d, J = 5.5 Hz, 1H), 7.13 (d, J = 6.9 Hz, 1H), 7.18–7.25 (m, 2H), 7.30 (d, J = 8.2 Hz, 3H), 7.82 (d, J = 8.3 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) = 21.5, 25.5, 27.3, 27.7, 30.1, 58.5, 73.1, 97.0, 126.4, 127.4, 128.4, 128.5, 129.6, 130.2, 131.9, 137.8, 138.7, 143.3; IR (KBr, cm^{-1}): 3372, 2931, 2870, 1737, 1599, 1495, 1458, 1341, 1241, 1224, 1150, 1108, 1027, 984, 751, 664, 551. HRMS (ESI) for $C_{20}H_{23}NO_3SNa$ $[M+Na]^+$ calcd. 380.1291, found 380.1289.

2,2,5-trimethyl-5-phenyl-3-tosyloxazolidine (4j). Colorless oil; 57.3 mg, 83% yield; 1H NMR (400 MHz, $CDCl_3$) δ (ppm) = 1.46 (s, 3H), 1.54 (s, 3H), 1.74 (s, 3H), 2.39 (s, 3H), 3.65–3.71 (m, 2H), 7.22–7.31 (m, 7H), 7.67 (d, J = 8.2 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) = 21.4, 27.4, 28.8, 29.1, 57.6, 81.2, 97.2, 124.6, 127.1, 127.3, 128.2, 129.4, 137.1, 143.4, 145.0; IR (KBr, cm^{-1}): 3379, 2982, 2932, 1737, 1599, 1447, 1346, 1245, 1162, 1090, 1028, 701, 662, 594, 549. HRMS (ESI) for $C_{19}H_{23}NO_3SNa$ $[M+Na]^+$ calcd. 368.1291, found 368.1290.

5-(3-chlorophenyl)-2,2,5-trimethyl-3-tosyloxazolidine (4k). Colorless oil; 66.6 mg, 88% yield; 1H NMR (400 MHz, $CDCl_3$) δ (ppm) = 1.48 (s, 3H), 1.51 (s, 3H), 1.72 (s, 3H), 2.40 (s, 3H), 3.65 (s, 2H), 7.16–7.27 (m, 6H), 7.66 (d, J = 8.1 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ (ppm) = 21.4, 27.3, 28.7, 28.9, 57.3, 80.7, 97.3, 122.9, 124.9, 127.3, 129.5, 129.6, 134.2, 136.9, 143.5, 147.2; IR (KBr, cm^{-1}): 2983, 2932, 1737, 1598, 1473, 1414, 1372, 1347, 1244, 1091, 996, 906, 790, 684, 594, 549. HRMS (ESI) for $C_{19}H_{22}ClNO_3SNa$ $[M+Na]^+$ calcd. 402.0901, found 402.0902.

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Notes

The authors declare no competing financial interest.

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Supporting Information

Devices for the photocatalytic reactions, nOe spectra of **3l**, **4h**, and X-ray crystallographic data of **4i**, ^1H and ^{13}C NMR spectra of the products. This material is available free of charge via the Internet at <http://pubs.acs.org>.

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