EurJOC
European Journal of Organic Chemistry

A Journal of
ChemPubSoc Europe

Accepted Article

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To be cited as: *Eur. J. Org. Chem.* 10.1002/ejoc.201700654

Link to VoR: http://dx.doi.org/10.1002/ejoc.201700654

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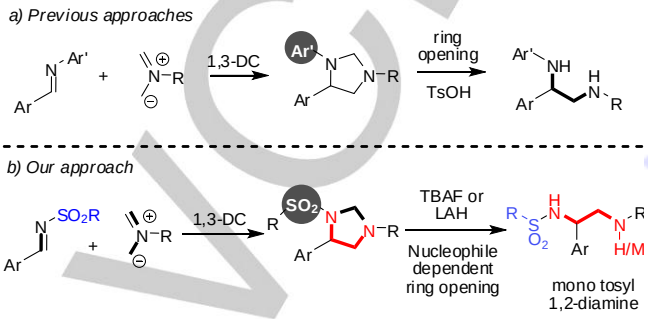
Synthesis of Mono *N*-sulfonyl Imidazolidines by 1,3-Dipolar Cycloaddition Strategy, an Alternative to Selective *N*-Sulfonylation, and their Ring Cleavages to 1,2-Diamines

Joydev K. Laha,* Krupal P. Jethava, K. S. Satyanarayana Tummalapalli, and Sheetal Sharma

Abstract: A 1,3-dipolar cycloaddition reaction of non-stabilized azomethine ylides with N-sulfonyl imines has been developed providing a workable access to mono N-sulfonyl imidazolidines. The improved reactivity of N-sulfonyl imines as dipolarophiles towards azomethine ylides largely eliminated possible Michael addition and favored 1,3-dipolar cycloaddition. Our approach could complement the commonly practiced protection strategy of imidazolidines. Furthermore, nucleophile dependent ring cleavage of N-sulfonyl imidazolidines produced synthetically useful mono N-sulfonyl 1,2-diamines that are otherwise difficult to obtain. While ring cleavage accompanied by CH_2 extrusion occurred by treatment with TBAF yielding mono N-sulfonyl 1,2-diamines, a methyl derivative of N-sulfonyl 1,2-diamines is produced by reaction with LAH.



Scheme 1. Imidazolidine synthesis by **1**,3-dipolar cycloadditions of azomethine ylides and various imines.

Introduction

Imidazolidines represent a structural motif that has profound applications in many areas of chemistry and biology, for example, serving as common integral parts of many biologically relevant agents, catalysts and ligands in organic synthesis.[1] They are also attractive synthetic intermediates in organic synthesis, often employed in the preparation of synthetically useful 1,2-diamines via ring cleavage under acidic conditions.[2] The installation of a sulfonyl functionality to nitrogen of a heterocycle not only serves the purpose of protection, but also could improve the pharmacological profiles if retained as a desired functionality.[3] However, selective installation of a sulfonyl group in the heterocycle containing more than one nitrogen atom could present a significant challenge.[4] Toward this horizon, *N*-sulfonyl imidazolidines is especially attractive as the chemistry of mono *N*-sulfonyl imidazolidines including their preparation and reactions is least investigated.[5]

N-Sulfonyl imidazolidines could be prepared by selective mono-protection of a nitrogen.[6] However, the formation of N,N′-disulfonyl imidazolidine could complicate isolation of the mono *N*-sulfonyl imidazolidine that could result in reduced yield of the product. A few other methods reported for the synthesis of mono *N*-sulfonyl imidazolidines include aziridine ring opening,[5c] and intramolecular oxidative coupling.[5d] Nevertheless, synthesis of selective mono *N*-sulfonyl imidazolidines is a subject of further investigation.

A 1,3-dipolar cycloaddition (1,3-DC) reaction[7] of azomethine ylides with imines has emerged as the one of most convenient accesses to imidazolidines.[8a-d,1c,1f] Generally, N-aryl imines have been employed as dipolarophiles in these reactions, which could make difficult for further functionalization at nitrogen of imidazolidines (Scheme 1a). Because of inadequate reactivity of imines towards azomethine ylides, only a limited progress has been made in the 1,3-DC of azomethine ylides employing imines as the dipolarophiles. Introducing an electro-deficient sulfonyl group into imines may not only improve its reactivity towards dipoles,[1c] but also could serve the purpose for direct synthesis of mono N-sulfonyl imidazolidines (Scheme 1b). Therefore, development of an 1,3-DC of azomethine ylides and N-sulfonyl imines could be a beneficial approach to the direct synthesis of N-sulfonyl imidazolidines. An important question that remains to implement this cycloaddition is whether a non-stabilized azomethine ylide could undergo 1,3-DC with *N*-sulfonyl imines, as they could possibly undergo Michael addition by virtue of extensive resonance of the negative charge on nitrogen in the sulfonyl group.[8] However, the anticipated features that could be associated with, but not limited to: (a) expedient access to *N*-sulfonyl imidazolidines, (b) exploration of ring cleavage in *N*-sulfonyl imidazolidines, and (c) a new pathway to mono N-sulfonyl 1,2-diamines.

Previously, we demonstrated that cycloaddition of cyclic azomethine ylides and electron-deficient alkenes could offer an expedient access to bridged azabicyclic compounds.[9] Very recently, we have developed a synthesis of imidazolidine fused sulfamidates, sulfamides, and benzosultams bearing a quaternary center via 1,3-DC of non-stabilized azomethine ylides.[10] Based on own experiences with transimination of *N*-arylsulfonyl imines via Michael addition,[11] palladium-catalyzed direct arylation in the synthesis of *N*-sulfonyl nitrogen heterocycles,[12] and on-going interest to understand the reactivity of *N*-sulfonyl imines towards azomethine ylides, we envisioned a

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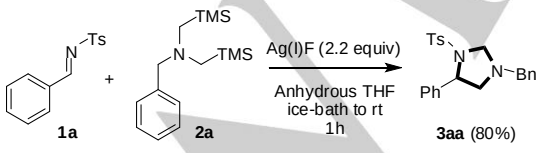
1,3-DC reaction to the synthesis of *N*-sulfonyl imidazolidines, which would be markedly more challenging than our recent contribution. Herein, we describe 1,3-DC of non-stabilized azomethine ylides and *N*-sulfonyl imines providing a workable access to *N*-sulfonyl imidazolidines, which could complement the commonly used protection strategy. Furthermore, nucleophile dependent ring cleavage of *N*-sulfonyl imidazolidines produced synthetically useful mono *N*-sulfonyl 1,2-diamines. The key features that are clearly distinct from our previous work and others include (a) 1,3-DC reactions of non-stabilized azomethine ylides and *N*-sulfonyl aldimines or ketimines affording *N*-sulfonyl imidazolidines, (b) susceptibility of *N*-sulfonyl imidazolidines under various conditions, and (c) synthesis of selective mono *N*-sulfonyl 1,2-diamines that are difficult to prepare by other methods

Results and Discussion

Although we demonstrated previously that cyclic azomethine ylides could undergo cycloaddition with electron-deficient alkenes, our initial focus was to establish a reaction between azomethine ylides and N-sulfonyl imines and find an optimum condition that could deliver best yield of N-sulfonyl imidazolidines. From our previous experiences in double desilytaion using Ag(I)F,[9] it is apparent that Ag(I) is required as one-electron oxidant for transfer of electron from nitrogen to Ag(I), and Fluoride ion is required for efficient deprotection of TMS group. The azomethine ylides were generated from their corresponding suitable precursors by reaction with Ag(I)F in MeCN at room temperature. As the reaction of azomethine ylides and *N*-sulfonyl imines have not been explored previously, our initial investigation was largely focused on 1,3-DC of azomethine ylides with an *N*-sulfonyl imine **1a**. Reaction of **1a** and **2a** in the presence of 2.2 equiv Ag(I)F in anhydrous THF at room temperature gave cycloadduct **3aa** in 80% yield (entry 1). However, among the other solvents DCM and CH_3CN were useful but did not improve the yield, while optimization in dioxane or DMF was futile (entry 4-5). Thus, an optimized condition entailed reaction of **1a** (1 equiv) and **2a** (1.1 equiv) in the presence of Ag(I)F (2.2 equiv) in anhydrous THF at ice-bath to room temperature for 1 h affording imidazolidine **3aa** in 80% isolated yield (Table 1).

Table 1. Optimization Study[a]

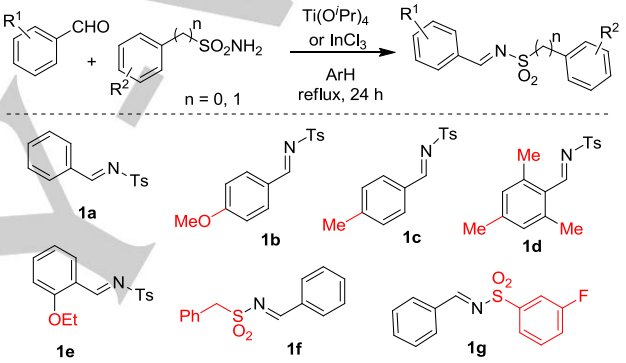


Entry	Fluoride source	Solvent	Yield of **3aa** (%)
1	AgF	Anhy. THF	80
2	AgF	Anhy. DCM	72
3	AgF	Anhy. CH_3CN	53
4	AgF	Anhy. dioxane	0
5	AgF	Anhy. DMF	0

[a]**1a** (0.2 mmol), **2a** (0.22 mmol), AgF (0.44 mmol), temp., 1 h

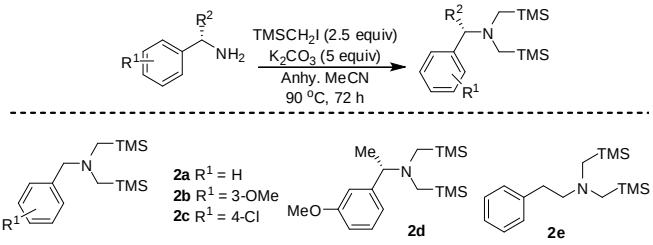
Under the condition, the azomethine ylide, generated in situ from **2a** by reaction with Ag(I)F, undergoes a 1,3-DC with **1a** giving the cycloadduct **3aa**. The study was subsequently extended to establish the scope of 1,3-DC of different azomethine ylides with *N*-sulfonyl imines.

The *N*-sulfonyl imines **1a-g** were synthesized from aldehydes and different sulfonamides as shown in Scheme 2.[13] The reaction of commercially available benzaldehydes and arylsulfonamides in the presence of $Ti(O^iPr)_4$ or $InCl_3$ at reflux gave the desired *N*-sulfonyl imines **1a-g**.



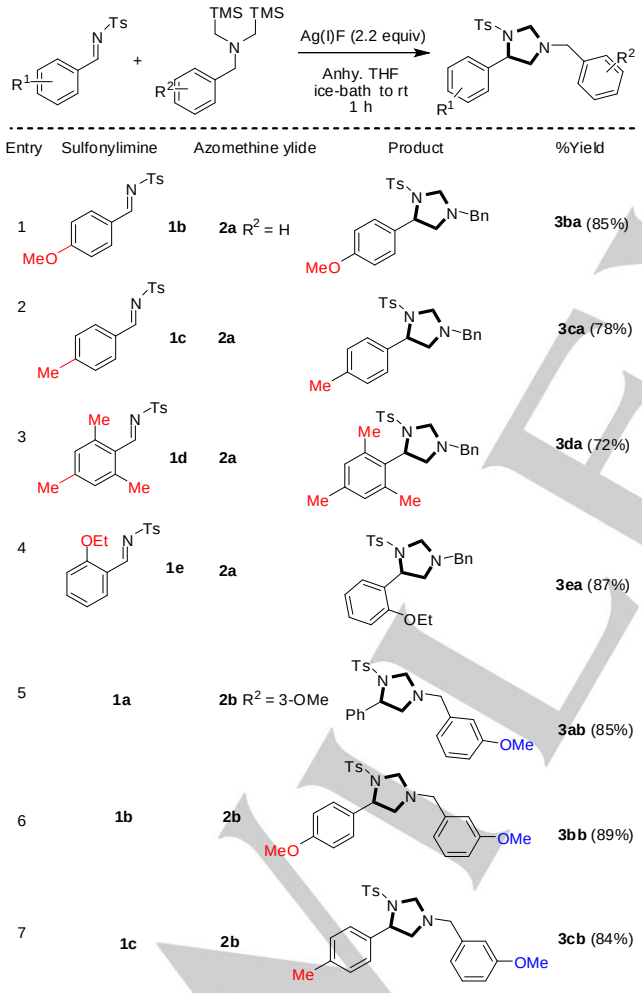
Scheme 2. Preparation of N-sulfonyl imines

The azomethine ylide precursors **2a-e** were prepared according to the literature procedure from commercially available benzylamines and iodomethyltrimethylsilane (Scheme 3).[14] Heating a mixture of benzylamine (1 equiv), iodomethyltrimethylsilane (2.5 equiv), and powdered K_2CO_3 (5 equiv) in anhydrous MeCN at 90 °C for 72 h gave **2a-e**. The desired product was purified by alumina column chromatography with hexane as an eluent.



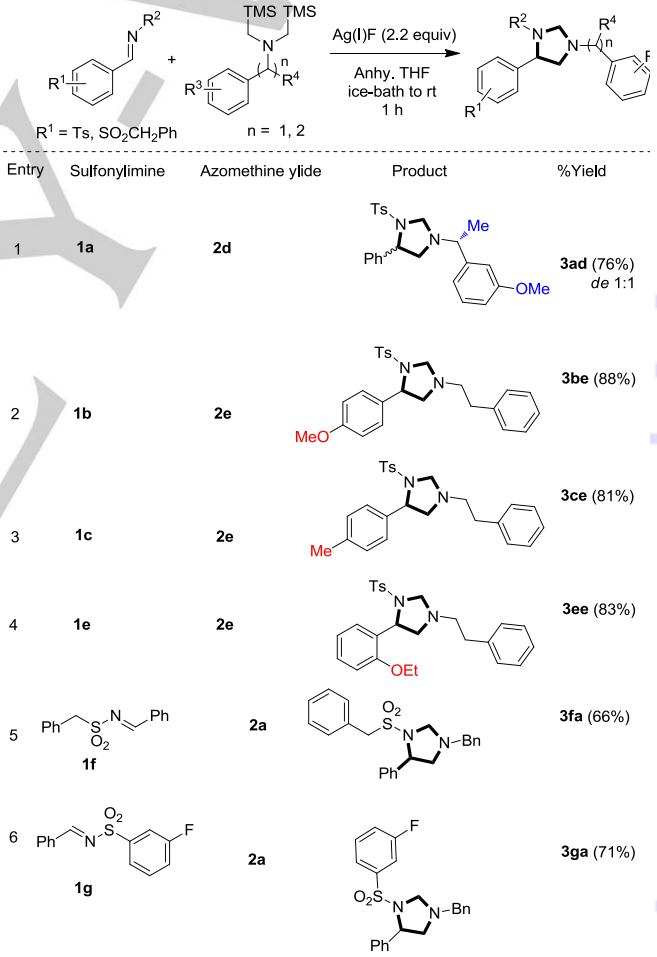
Scheme 3: Preparation of precursors to azomethine ylides

With the optimized condition in hand, we next investigated the substrate scope for the 1,3-DC of substituted N-sulfonyl imines and azomethine ylides (Scheme 4). The reaction of N-sulfonyl imines with electron-donating para substituent OMe (**1b**) and Me (**1c**) produced the corresponding imidazolidines **3ba** and **3ca** in good yields (85% and 78% yields, entries 1-2). The 2,4,6 tri-substituted substrate **1d** was also viable for cycloaddition reaction furnishing product **3da**, however, in a slightly reducedyield (72%, entry 3).The substrate **1e** containing an *ortho* ethoxy substituent on the phenyl ring also reacted efficiently with the azomethine yield **2a** forming the cycloadduct **3ea** in 87% yield (entry 4). Reactions of N-sulfonyl imines **1a-c** with the azomethine ylide generated from **2b** worked eventfully with formation of cycloadducts **3ab, 3bb,** and **3cb** in good yields (entries 5-7). The improved reactivity of N-sulfonyl imines towards dipoles was pivotal to the successive realization of this cycloaddition.



Scheme 4: Synthesis of N-sulfonyl iImidazolidines

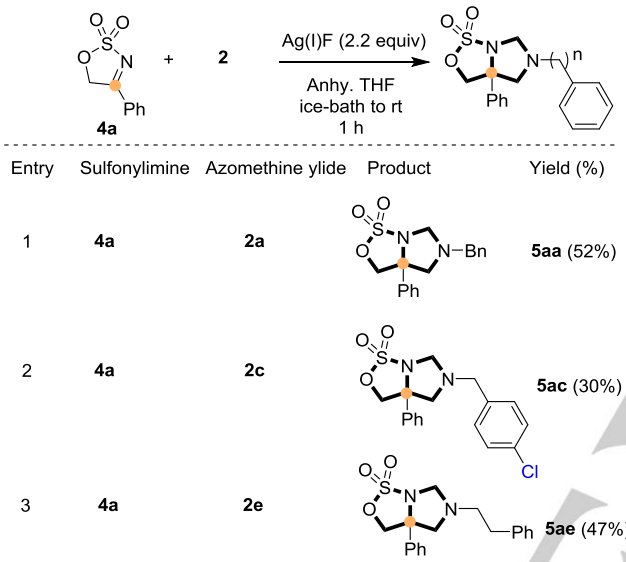
The other azomethine ylide precursors, such as **2d** with a stereocenter at the benzylic position, and **2e** containing an alkyl chain, were also tested for 1,3-dipolar cycloaddition reaction with *N*-sulfonyl imines (Scheme 5). As expected, reaction of **2d** and **1a** furnished a diastereomeric mixture of cycloadduct **3ad** in a combined 76% yield (entry 1). The diastereomeric ratio (1:1 ratio) was determined from the ^{1}H NMR spectra of the mixture. An alkyl azomethine ylide **2e** undergoes fruitful cycloaddition with **1b** or **1c** affording **3be** and **3ce** in 88% and 81% yields, respectively (entry 2-3). Furthermore, alkyl azomethine ylide **2e** undergoes effective cycloaddition with **1e** affording cycloadduct **3ee** in 83% yield (entry 4). Other substituents in *N*-sulfonyl imines were also investigated for cycloaddition with azomethine ylides. While reaction of an N-alkylsulfonyl imine **1f** and **2a** produced a slightly reduced yield (66%) of imidazolidine **3fa**, an electron-withdrawing *meta*-fluoro group restored the yield (71%) in **3ga** (entry 5-6). The 1,3-dipolar cycloaddition reaction of alkyl azomethine yield is very rare in the literature, providing novel access to imidazolidine with an alkyl substituent.



Scheme 5: Synthesis of other imidazolidines

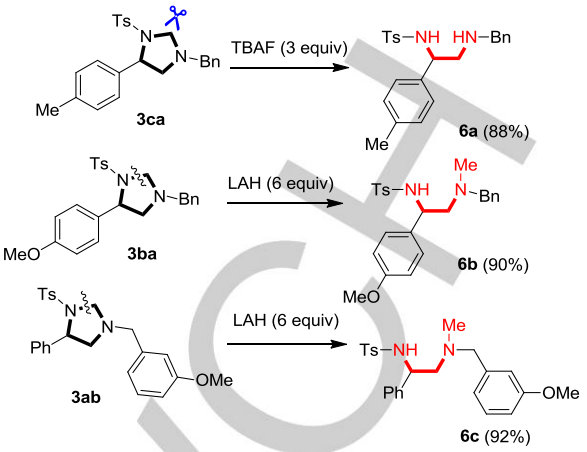
The scope of five-membered *N*-sulfonyl ketimines towards reaction with azomethine ylides was also investigated (Scheme 6). Under the optimized condition, reaction of **2a** and *N*-sulfonyl ketimine **4a** gave sulfamidate fused imidazolidine **5aa** bearing a quaternary center in 52% yield (entry 1). Likewise, fused

imidazolidine **5ac** was also obtained *albeit* in low yield (entry 2). Reaction of azomethine ylide generated from **2e** undergoes reaction with **4a** afforded **5ae** in 47% yield (entry 3). Central to this investigation was the finding that azomethine ylides could undergo 1,3-dipolar cycloaddition with *N*-sulfonyl ketimines to give sulfamidate fused imidazolidines bearing a quaternary center. A qualitative comparison of the reactivity of *N*-sulfonyl aldimines and *N*-sulfonyl ketimines towards azomethine ylides is apparent from our study, which reflects the better reactivity profile of aldimines used in this study.



Scheme 6: Scope of *N*-Sulfonyl Ketimines

Because of the presence of an active methylene (-CH_2) moiety attached to two nitrogen, ring cleavages of imidazolidines, often under strongly acidic conditions, have been utilized in the preparation of 1,2-diamines.[2] The ring cleavage of *N*-sulfonyl imidazolidines while elusive could potentially be used to prepare mono *N*-sulfonyl 1,2-diamines that are attainable using selective protection strategy. Treatment of **3ca** with 3 equiv TBAF in THF at 80 °C gave mono *N*-sulfonyl 1,2-diamine **6a** in 88% yield. The cleavage of imidazolidine ring followed by complete removal of –CH_2 occurred probably via *N*-formyl derivative formed in situ. However, the mechanism for overall -CH_2 extrusion is a subject of further investigation.



Scheme 7: Ring Cleavages of *N*-Sulfonyl Imidazolidines

Treatment of **3ba** or **3ab** with LAH produced *N*-sulfonyl-N′-methyl-1,2-diamines **6b-c** in excellent yields. Distinct from the literature, the selective ring cleavages of *N*-sulfonyl imidazolidines could complement the reported cleavages of imidazolidines performed under strongly acidic conditions. The neutral conditions described herein for ring cleavages may have advantages over acidic conditions. Perhaps most importantly, the sulfonyl group is retained under these conditions.

Conclusions

In conclusion, we have described a new synthesis of *N*-sulfonyl imidazolidines via 1,3-dipolar cycloaddition reaction of non-stabilized azomethine ylides and *N*-sulfonyl aldimine or ketimines. The strategy could complement the preparation of *N*-sulfonyl imidazolidines via selective *N*-sulfonylation. Furthermore novel ring cleavage reactions of *N*-sulfonyl imidazolidines yielded synthetically useful 1,2-diamines that are otherwise difficult to prepare. Taken together, the chemistry reported herein for the preparation of *N*-sulfonyl imidazolidines and their ring cleavages could merit extensive discussion in the contemporary heterocyclic chemistry.

Experimental Section

General Methods. Unless noted otherwise, all reagents and solvents were purchased from commercial sources and used as received. All reactions were performed in a screw-capped vial. The proton (^{1}H) and carbon (^{13}C) NMR spectra were obtained using a 400 MHz using Me_4Si as an internal standard and are reported in δ units. Coupling constants (*J* values) are reported in Hz. Column chromatography was performed on silica gel (100−200#, 230-400#). High resolution mass spectra (HRMS) were obtained using the electron spray ionization (ESI) technique and as TOF mass analyzer. IR spectra are reported in cm^{-1} units. All melting points were taken using a melting point apparatus equipped with a calibrated thermometer and are uncorrected. Following compounds were prepared according to literature procedures. N-sulfonylimines[15]: (*E*)-N-

Benzylidene-4-methylbenzenesulfonamide (**1a**), (*E*)-N-(4-Methoxy benzylidene)-4-methybenzenesulfonamide (**1b**), (*E*)-4-Methyl-N-(4-methylbenzylidene)benzenesulfonamide (**1c**), (*E*)-N-(2-Ethoxybenzylidene)-4-methylbenzenesulfonamide (**1e**); and azomethine ylide precursors[10]:*N*-Benzyl-1-(trimethylsilyl)-N-((trimethylsilyl)methyl) methanamine (**2a**), *N*-(3-Methoxybenzyl)-1-(trimethylsilyl)-N-((trimethylsilyl) methyl) methanamine (**2b**), (*S*)-1-Phenyl-*N,N*-bis((trimethylsilyl)methyl) ethanamine (**2c**), *N*-(4-Chlorobenzyl)-1-(trimethylsilyl)-*N*-((trimethylsilyl)methyl)methanamine (**2d**), (*S*)-1-(3-Methoxyphenyl)-*N,N*-bis((trimethylsilyl)methyl)ethanamine (**2e**).

General Procedure for the Synthesis of N-Sulfonyl Imidazolidine

In an oven-dried aluminium foil coated screw-cap vial with a magnetic bar, sulfonylimine (0.15 mmol, 1 equiv) and Ag(I)F (0.33mmol, 2.2 equiv) were taken. [Note: Ag(I)F was completely dried under vacuum at 55-60 ^{o}C at least for 30 min with aluminium foil coating before use]. The vial was purged three times with nitrogen and kept under ice bath. A solution of the azomethine ylide precursor (0.165 mmol, 1.1 equiv) in anhydrous THF (1 mL) was added dropwise. The ice-bath was removed, and the reaction mixture was stirred at room temperature for 1 h under nitrogen atmosphere. The reaction was monitored by TLC. Then, the reaction mixture was diluted with 5 mL CH_2Cl_2 and passed through a Celite bed. The filtrate was concentrated *in vacuo* and purified by column chromatography (100-200# silica, ethyl acetate:hexane) to give the desired product N-sulfonyl imidazolidine.

General Procedure for the -CH_2Extrusion Reaction (compound 6a)

To a solution of N-sulfonyl imidazolidine (0.1 mmol) in anhydrous THF (1 mL), TBAF▪$3H_2O$ (3 equiv) was added, and the reaction mixture was heated at 80 ^{o}C for 5 h. Silica gel (100-200#) was added to the reaction mixture, and the excess solvent was evaporated. The silica gel mixed with the crude product was loaded on the column, which upon column chromatography (ethyl acetate:hexane = 3:7 − 7:3) afforded the desired product.

General Procedure for the -SO_2Extrusion Reaction (compound 6b-c)

To a suspension of lithium aluminum hydride (0.6 mmol) in anhydrous THF (1 mL), [Note: *LAH should be handled very carefully due to its explosive nature*] solution of N-sulfonyl imidazolidine (0.1 mmol) was added drop wise under ice-cooling. The mixture was refluxed for 6 h and cooled naturally to room temperature, and then to 0 °C with an ice bath. The reaction mixture was quenched by drop wise addition 10% NaOH solution (1 mL) at 0 °C and stirred for 30 min at same temperature. The resulting suspension was passed through Celite bed and filtrate was concentrated *in vacuo*. The crude was purified by short column chromatography (100-200# silica) with ethyl acetate as an eluent to get desire product.

(*E*)-4-Methyl-N-(2,4,6-trimethylbenzylidene)benzene sulfonamide (1d): Off-white solid; mp. 80-82 °C; ^{1}H NMR (400 MHz, $CDCl_3$): *δ* 9.48 (s, 1H), 7.93−7.86 (m, 2H), 7.39−7.33 (m, 2H), 6.94 (s, 2H), 2.55 (s, 6H), 2.46 (s, 3H), 2.34 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 169.1, 143.0, 136.0, 130.7, 129.7, 128.8, 127.8, 126.1, 21.8, 21.6, 20.3; HRMS: calcd for $C_{17}H_{20}NO_2S$ $[M+H]^+$ 302.1215, found 302.1223.

(*E*)-N-Benzylidene-1-phenylmethanesulfonamide (1f): ^{1}H NMR (400 MHz, $CDCl_3$): *δ* 8.75 (s, 1H), 7.92−7.87 (m, 2H), 7.70−7.64 (m, 1H), 7.56−7.50 (m, 2H), 7.43−7.38 (m, 2H), 7.37−7.32 (m, 3H), 4.49 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 173.3, 135.2, 132.1, 131.3, 131.1, 130.1, 129.3, 128.9, 128.7, 128.0, 58.6; HRMS: calcd for $C_{14}H_{14}NO_2S$ $[M+H]^+$ 260.0745, found 260.0756.

(*E*)-N-Benzylidene-3-fluorobenzenesulfonamide (1g): ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.10 (s, 1H), 8.01−7.95 (m, 2H), 7.87−7.82 (m, 1H), 7.77−7.71 (m, 1H), 7.71−7.65 (m, 1H), 7.60−7.47 (m, 3H), 7.36 (ddt, *J* = 8.3, 2.6, 0.9 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 171.4, 135.4, 132.2, 131.6, 131.1, 130.2, 129.3, 123.8, 120.8 (d, *J*=21 Hz), 115.5 (d, *J* = 20 Hz); HRMS: calcd for $C_{13}H_{11}FNO_2S$ $[M+H]^+$ 264.0495, found 264.0499.

(*S*)-1-(3-Methoxyphenyl)-N,N-bis((trimethylsilyl)methyl) ethanamine (2d): ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.24−7.18 (m, 1H), 7.06−7.01 (m, 1H), 7.01−6.96 (m, 1H), 6.80−6.74 (m, 1H), 3.91−3.84 (m, 1H), 3.81 (s, 3H), 1.89 (d, *J* = 9.8 Hz, 4H), 1.25 (d, *J* = 6.8 Hz, 3H), 0.04−0.01 (m, 18H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.3, 145.9, 128.5, 120.3, 113.8, 111.8, 60.7, 55.1, 44.5, 9.2, -1.1; HRMS: calcd for $C_{17}H_{34}NOSi_2$ $[M+H]^+$ 324.2179, found 324.2190.

1-Benzyl-4-phenyl-3-tosylimidazolidine (3aa): Off-white solid; mp. 122-124 °C; Yield 80% (47 mg); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.61 (d, *J* = 8.3 Hz, 2H), 7.35−7.24 (m, 10H), 7.17−7.10 (m, 2H), 4.74 (t, *J* = 7.4 Hz 1H), 4.43 (d, *J* = 8.3 Hz, 1H), 4.08 (d, *J* = 8.0 Hz, 1H), 3.58 (d, *J* = 13.1 Hz, 1H), 3.41 (d, *J* = 13.3 Hz, 1H), 3.33−3.21 (m, 1H), 2.66 (dd, *J* = 10.3, 7.8 Hz, 1H), 2.44 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 143.5, 140.6, 137.6, 135.0, 129.5, 128.5, 128.4, 127.8, 127.5, 126.6, 71.4, 62.4, 61.9, 57.1; HRMS: calcd for $C_{23}H_{25}N_2O_2S$ $[M+H]^+$ 393.1637, found 393.1635; ; IR (Kbr): 2934, 2852, 1362, 1169 cm^{-1}.

1-Benzyl-4-(4-methoxyphenyl)-3-tosylimidazolidine (3ba): Light yellow solid; mp. 100-102 °C; Yield 85% (54 mg); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.65−7.59 (m, 2H), 7.33−7.24 (m, 7H), 7.16 (dd, *J* = 7.7, 1.6 Hz 2H), 6.89−6.80 (m, 2H), 4.71 (t, *J* = 7.3 Hz, 1H), 4.41 (d, *J* = 7.8 Hz, 1H), 4.09 (d, *J* = 8.0 Hz, 1H), 3.81 (s, 3H), 3.60 (d, *J*= 13.1 Hz, 1H), 3.43 (d, *J* = 13.1 Hz, 1H), 3.24 (dd, *J* = 10.0, 7.3 Hz, 1H), 2.67 (dd, *J* = 10.3, 7.8 Hz 1H), 2.47 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.1, 143.5, 137.6, 135.2, 132.7, 129.5, 128.5, 128.4, 127.9, 127.8, 127.5, 113.9, 71.3, 62.4, 61.6, 57.1, 55.3, 21.6; HRMS: calcd for $C_{24}H_{27}N_2O_3S$ $[M+H]^+$ 423.1742, found 423.1746; IR (KBr): 2927, 2855, 1591, 1455, 1348, 1161 cm^{-1}.

1-Benzyl-4-(*p*-tolyl)-3-tosylimidazolidine (3ca): Off-white solid; mp. 129-131 °C; Yield 78% (47 mg); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.67 (d, *J* = 8.3 Hz, 2H), 7.37−7.24 (m, 7H), 7.20−7.11 (m, 4H), 4.75 (t, *J* = 7.4 Hz, 1H), 4.45 (d, *J* = 7.8 Hz, 1H), 4.12 (d, *J* = 8.0 Hz, 1H), 3.61 (d, *J* = 13.3 Hz, 1H), 3.43 (d, *J* = 13.3 Hz, 1H), 3.28 (dd, *J* = 10.2, 7.2 Hz, 1H), 2.69 (dd, *J* = 10.3, 7.8 Hz, 1H), 2.48 (s, 3H), 2.37 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.5, 137.7, 137.2, 135.1, 129.5, 129.2, 128.5, 128.4, 127.9, 127.5, 126.6, 71.4, 62.5, 61.9, 57.1, 21.6, 21.2; HRMS: calcd for $C_{24}H_{27}N_2O_2S$ $[M+H]^+$ 407.1793, found 407.1787; IR (KBr): 2924, 2854, 1454, 1351, 1161 cm^{-1}.

1-Benzyl-4-mesityl-3-tosylimidazolidine (3da): Pale yellow oil; Yield 82% (48 mg); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.64−7.54 (m, 2H), 7.38−7.29 (m, 3H), 7.27−7.19 (m, 4H), 6.78 (s, 2H), 5.19 (dd, *J* = 10.2, 7.2 Hz, 1H), 4.59 (d, *J* = 9.0 Hz, 1H), 4.12 (d, *J* = 8.5 Hz, 1H), 3.71 (d, *J* = 12.8 Hz, 1H), 3.44 (d, *J* = 13.1 Hz, 1H), 3.23 (dd, *J* = 10.8, 8.0 Hz, 1H), 2.83 (t, *J* = 10.4 Hz, 1H), 2.45 (s, 3H), 2.38 (s, 6H), 2.25 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 167.8, 135.2, 132.4, 131.1, 130.9, 129.3, 128.8, 128.6, 128.4, 127.6, 70.4, 58.1, 58.0, 57.3, 55.7, 21.7, 20.3; HRMS: calcd for $C_{26}H_{31}N_2O_2S$ $[M+H]^+$ 435.2106, found 435.2111; IR (Neat): 2959, 2928, 2859, 1728, 1462, 1275 cm^{-1}.

1-Benzyl-4-(2-ethoxyphenyl)-3-tosylimidazolidine (3ea): Off-white solid; mp. 113-115 °C; Yield 87% (57 mg); ^{1}H NMR (400 MHz, $CDCl_3$): δ

7.69 (d, *J* = 8.3 Hz, 2H), 7.53 (dd, *J* = 7.5, 1.5 Hz, 1H), 7.35−7.27 (m, 5H), 7.22 (dt, *J* = 7.8, 1.8 Hz, 1H), 7.18−7.12 (m, 2H), 6.99−6.91 (m, 1H), 6.80 (d, *J* = 8.3 Hz, 1H), 5.13 (t, *J* = 7.5 Hz, 1H), 4.44 (d, *J* = 8.3 Hz, 1H), 4.09−3.93 (m, 3H), 3.62 (d, *J* = 13.1 Hz, 1H), 3.40 (dd, *J* = 9.9, 7.7Hz, 1H), 3.35 (d, *J* = 13.1 Hz, 1H), 2.62 (dd, *J* = 10.4, 7.9Hz, 1H), 2.48 (s, 3H), 1.41 (t, *J* = 6.9 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 155.7, 143.3, 137.9, 135.2, 129.4, 128.8, 128.6, 128.4, 128.3, 127.9, 127.7, 127.4, 120.5, 111.0, 71.0, 63.4, 60.7, 57.5, 57.2, 21.6, 15.0; HRMS: calcd for $C_{25}H_{29}N_2O_3S$ $[M+H]^+$ 437.1899, found 437.1893; IR (KBr): 2953, 2858, 1456, 1162 cm^{-1}.

1-(3-Methoxybenzyl)-4-phenyl-3-tosylimidazolidine (3ab): Off-white solid; mp. 85-87 °C; Yield 85% (54 mg); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.65 (d, *J* = 8.0 Hz, 2H), 7.19−7.41 (m, 8H), 6.81−6.86 (m, 1H), 6.74−6.79 (m, 2H), 4.77 (t, *J* = 7.4 Hz, 1H), 4.47 (d, *J* = 8.0 Hz, 1H), 4.14 (d, *J* = 8.0 Hz, 1H), 3.81 (s, 3H), 3.58 (d, *J* = 13.3 Hz, 1H), 3.42 (d, *J* = 13.1 Hz, 1H), 3.28 (dd, *J* = 10.2, 7.2 Hz, 1H), 2.69 (dd, *J* = 10.4, 7.7 Hz, 1H), 2.42−2.48 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.8, 143.6, 140.7, 139.2, 135.1, 129.6, 129.4, 128.5, 128.5, 127.8, 127.5, 126.6, 120.7, 114.1, 112.8, 71.4, 62.4, 61.9, 57.0, 55.2, 21.5; HRMS: calcd for $C_{24}H_{27}N_2O_3S$ $[M+H]^+$ 423.1742, found 423.1749; IR (KBr): 2924, 2853, 1599, 1455, 1350, 1161 cm^{-1}.

1-(3-Methoxybenzyl)-4-(4-methoxyphenyl)-3-tosyl imidazolidine (3bb): Light yellow solid; mp. 92-94 °C; Yield 89% (60 mg); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.67 (d, *J* = 8.0 Hz, 2H), 7.37−7.27 (m, 3H), 7.19 (d, *J* = 7.5 Hz, 2H), 7.23 (d, *J* = 8.3 Hz, 2H), 6.92−6.82 (m, 2H), 6.80−6.73 (m, 1H), 4.74 (t, *J* = 7.3 Hz, 1H), 4.46 (d, *J* = 7.8 Hz, 1H), 4.14 (d, *J* = 7.8 Hz, 1H), 3.82 (s, 6H), 3.59 (d, *J* = 13.1 Hz, 1H), 3.42 (d, *J* = 13.1 Hz, 1H), 3.25 (dd, *J* = 10.0, 7.0Hz, 1H), 2.69 (dd, *J* = 10.2, 7.9 Hz, 1H), 2.47 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 158.7, 158.0, 142.4, 138.2, 134.0, 131.6, 128.5, 128.3, 127.1, 126.8, 126.7, 125.3, 119.7, 113.0, 112.8, 70.2, 61.3, 60.5, 55.9, 54.2, 54.1, 20.5; HRMS: calcd for $C_{25}H_{29}N_2O_4S$ $[M+H]^+$ 453.1848, found 453.1852; IR (KBr): 2957, 2926, 2854, 1599, 1455, 1348, 1160 cm^{-1}.

1-(3-Methoxybenzyl)-4-(p-tolyl)-3-tosylimidazolidine (3cb): Off-white solid; mp. 75-77 °C; Yield 84% (55 mg); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.69−7.61 (m, 2H), 7.33−7.28 (m, 2H), 7.24 (dd, *J* = 8.0, 6.5 Hz, 3H), 7.13 (d, *J* = 7.8 Hz, 2H), 6.82 (ddd, *J* = 8.3, 2.4, 1.0 Hz, 1H), 6.77−6.71 (m, 2H), 4.71 (t, *J* = 7.4 Hz, 1H), 4.45 (d, *J* = 8.0 Hz, 1H), 4.11 (d, *J* = 8.0 Hz, 1H), 3.81 (s, 3H), 3.56 (d, *J* = 13.1 Hz, 1H), 3.39 (d, *J* = 13.1 Hz, 1H), 3.26 (dd, *J* = 7.4, 9.9 Hz, 1H), 2.67 (dd, *J* = 10.4, 7.9Hz, 1H), 2.47 (s, 3H), 2.35 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.7, 143.5, 139.2, 137.6, 137.2, 135.0, 129.5, 129.4, 129.2, 127.8, 126.5, 120.7, 114.1, 112.8, 71.4, 62.4, 61.8, 57.0, 55.2, 21.6, 21.1; HRMS: calcd for $C_{25}H_{29}N_2O_3S$ $[M+H]^+$ 437.1899, found 437.1898; IR (Kbr): 2957, 2924, 2854, 1598, 1455, 1350, 1161 cm^{-1}.

(*R*)-1-((*R*)-1-(3-Methoxyphenyl)ethyl)-4-phenyl-3-tosyl imidazolidine (3ad) (1:1 mixture of diastereomers): Transparent oil; Yield 76% (49 mg); ^{1}H NMR (400 MHz, $CDCl_3$): *δ* 7.72 (d, *J* = 8.3 Hz, 2H), 7.64 (d, *J* = 8.3 Hz, 2H), 7.42−7.37 (m, 2 H), 7.37−7.23 (m, 13H), 7.23−7.16 (m, 2H), 6.84−6.75 (m, 2H), 6.74−6.61 (m, 4H), 4.74−4.65 (m, 2H), 4.56 (d, *J* = 7.3 Hz, 1H), 4.30 (d, *J* = 7.5 Hz, 1H), 3.97 (dd, *J* = 7.4, 14.7 Hz, 2H), 3.77 (s, 3H), 3.80 (s, 3H), 3.17 (dd, *J* = 19.8,6.3 Hz, 2H), 3.02 (s, 1H), 2.48 (d, *J* = 3.8 Hz, 6H), 2.46−2.38 (m, 2H), 1.28−1.27 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.8, 159.7, 145.7, 145.6, 143.6, 143.6, 140.8, 140.8, 134.8, 134.6, 129.6, 129.5, 129.5, 129.5, 128.4, 128.4, 128.0, 127.6, 127.5, 126.6, 126.5, 119.1, 112.6, 112.5, 112.4, 70.6, 69.9, 62.8, 62.5, 62.1, 61.9, 60.6, 60.4, 55.2, 55.1, 22.8, 22.8, 21.6, 21.5; HRMS: calcd for $C_{25}H_{29}N_2O_3S$ $[M+H]^+$ 437.1899, found 437.1903; IR (Neat): 2925, 2853, 1597, 1348, 1162 cm^{-1}.

4-(4-Methoxyphenyl)-1-phenethyl-3-tosylimidazolidine (3be): Light yellow solid; mp. 91-93 °C; Yield 88% (57 mg); ^{1}H NMR (400 MHz, $CDCl_3$): *δ* 7.84 (d, *J* = 8.3 Hz, 1H), 7.70−7.64 (m, *J* = 8.0 Hz, 2H), 7.37−7.21 (m, 5H), 7.15 (d, *J* = 7.3 Hz, 3H), 6.91−6.83 (m, *J* = 8.3 Hz, 2H), 4.66 (t, *J* = 7.2 Hz, 1H), 4.51 (d, *J* = 7.5 Hz, 1H), 4.22 (d, *J* = 7.5 Hz, 1H), 3.83 (s, 3H), 3.23 (dd, *J* = 10.2, 6.9 Hz, 1H), 2.74−2.48 (m, 5H), 2.43 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.1, 146.5, 143.6, 139.4, 135.0, 132.6, 129.7, 129.6, 128.6, 128.4, 128.2, 127.9, 127.7, 126.4, 113.9, 71.4, 62.9, 61.3, 55.3, 54.8, 35.1, 21.6; HRMS: calcd for $C_{25}H_{29}N_2O_3S$ $[M+H]^+$ 437.1899, found 437.1907; IR (KBr): 2925, 2854, 1513, 1304, 1160 cm^{-1}.

1-Phenethyl-4-(*p*-tolyl)-3-tosylimidazolidine (3ce): Light yellow solid; mp. 99-101 °C; Yield 81% (51 mg); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.67 (d, *J* = 8.3 Hz, 2H), 7.33−7.22 (m, 7H), 7.17−7.08 (m, 4H), 4.64 (t, *J* = 7.2 Hz 1H), 4.51 (d, *J* = 7.5 Hz, 1H), 4.21 (d, *J* = 7.8 Hz, 1H), 3.24 (dd, *J* = 10.2, 7.4 Hz, 1H), 2.76−2.67 (m, 3H), 2.65−2.47 (m, 2H), 2.42 (s, 3H), 2.36 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.5, 139.4, 137.6, 134.9, 129.6, 129.2, 128.6, 128.4, 127.7, 126.6, 126.3, 71.6, 63.0, 61.5, 54.9, 35.1, 21.6, 21.2; HRMS: calcd for $C_{25}H_{29}N_2O_2S$ $[M+H]^+$ 421.1950, found 421.1955; IR (KBr): 3027, 2924, 2853, 1598, 1454, 1161 cm^{-1}.

4-(2-Ethoxyphenyl)-1-phenethyl-3-tosylimidazolidine (3ee):

Transparent oil; Yield 76% (49 mg); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.71 (d *J* = 8.3 Hz, 2H), 7.51 (dd, *J* = 7.5, 1.5 Hz, 1H), 7.31−7.20 (m, 6H), 7.15−7.09 (m, 2H), 6.94 (dt, *J* = 7.5, 0.9Hz, 1H), 6.80 (d, *J* = 7.5 Hz, 1H), 5.06 (t, *J* = 7.3 Hz, 1H), 4.53 (d, *J* = 7.8 Hz, 1H), 4.17 (d, *J* = 8.0 Hz, 1H), 4.07−3.99 (m, 2H), 3.34 (dd, *J* = 9.9, 7.4, Hz 1H), 2.73−2.55 (m, 4H), 2.54−2.46 (m, 1H), 2.46−2.38 (m, 3H), 1.42 (t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 155.7, 143.4, 139.5, 129.4, 128.6, 128.4, 128.3, 127.8, 126.2, 120.5, 111.0, 71.3, 63.4, 61.3, 57.1, 55.0, 35.2, 21.6, 15.0;HRMS: calcd for $C_{26}H_{30}N_2O_3S$ $[M]^+$ 450.1977, found 450.1987; IR (Neat): 2927, 2854, 1599, 1348, 1160 cm^{-1}.

1-Benzyl-3-(benzylsulfonyl)-4-phenylimidazolidine (3fa): Light brown oil; Yield 66% (38 mg); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.29−7.44 (m, 15H) 4.98 (t, *J*= 7.5 Hz, 1H), 4.38 (dd, *J* = 8.2, 1.4 Hz, 1H), 4.02−4.09 (m, 1H), 3.85−3.96 (m, 2H), 3.69 (d, *J* = 2.0 Hz, 2H), 3.46 (ddd, *J* = 10.9, 7.2, 1.5 Hz, 1H), 2.86−2.93 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 140.5, 137.6, 130.8, 128.9, 128.8, 128.5, 128.0, 127.5, 127.1, 125.6, 71.5, 62.4, 61.3, 59.1, 57.2; HRMS: calcd for $C_{23}H_{25}N_2O_2S$ $[M+H]^+$ 393.1637, found 393.1633; IR (Neat): 2927, 2853, 1598, 1351, 1160cm^{-1}.

1-Benzyl-3-((3-fluorophenyl)sulfonyl)-4-phenylimidazolidine (3ga): Light brown solid; mp. 96-98 °C; Yield 42% (71 mg); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.51-7.49 (m, 1H), 7.46-7.42 (m, 1H), 7.39−7.34 (m, 3H), 7.32−7.26 (m, 8H), 7.21−7.20 (m, 1H), 5.16 (dd, *J* = 6.5, 4.3Hz, 1H), 4.44 (d, *J* = 7.3 Hz, 1H), 4.23 (d, *J* = 7.0 Hz, 1H), 3.77 (s, 2H), 3.53−3.46 (m, 1H), 3.22 (dd, *J* = 11.0, 4.0Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 163.5, 161.0, 140.4, 139.9, 137.4, 130.6, 128.6, 127.7, 126.6, 125.8, 123.4, 119.9, 115.1, 71.4, 62.5, 61.9, 57.1; HRMS: calcd for $C_{22}H_{22}FN_2O_2S$ $[M+H]^+$ 397.1386, found 397.1389; IR (KBr): 2924, 2852, 1591, 1474, 1356, 1156 cm^{-1}.

N-(2-(Benzylamino)-1-(*p*-tolyl)ethyl)-4-methylbenzene sulfonamide (6a): Transparent sticky oil; Yield 88% (35 mg); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.61−7.56 (m, 2H), 7.37−7.25 (m, 3H), 7.25−7.21 (m, 2H), 7.19−7.11 (m, 2H), 7.10−7.00 (m, 4H), 4.29 (dd, *J* = 5.0, 7.3 Hz, 1 H), 3.63 (s, 2 H), 2.82−2.70 (m, 2 H), 2.38 (s, 3 H), 2.31 (s, 3 H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 143.1, 139.6, 137.3, 136.3, 129.4, 129.1, 128.5, 128.1, 127.3, 127.2, 126.7, 56.4, 54.1, 53.0, 21.5, 21.1; HRMS: calcd for

$C_{23}H_{27}N_2O_2S$ $[M+H]^+$ 395.1793, found 395.1799; IR (Neat): 3272, 3027, 2924, 2854, 1325, 1160 cm^{-1}.

N-(2-(Benzyl(methyl)amino)-1-(4-methoxyphenyl)ethyl)-4-methylbenzenesulfonamide (6b): Light brown oil; Yield 90% (38 mg); ^1H NMR (400 MHz, $CDCl_3$): δ 7.58−7.51 (m, *J* = 8.0 Hz, 2H), 7.40−7.34 (m, 2H), 7.32 (d, *J* = 7.0 Hz, 1H), 7.28−7.21 (m, 2H), 7.16−7.06 (m, 4H), 6.78−6.72 (m, *J* = 8.5 Hz, 2H), 4.20 (dd, *J* = 11.0, 4.5 Hz, 1H), 3.78 (s, 3H), 3.56 (d, *J* = 13.1 Hz, 1H), 3.37 (d, *J* = 13.1 Hz, 1H), 2.57 (t, *J* = 11.9 Hz, 1H), 2.37 (s, 3H), 2.35−2.30 (m, 1H), 2.05 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.1, 143.0, 137.7, 136.7, 131.2, 129.2, 128.9, 128.5, 128.4, 127.4, 113.8, 62.8, 61.7, 55.3, 54.7, 41.2, 21.5; HRMS: calcd for $C_{24}H_{29}N_2O_3S$ $[M+H]^+$ 425.1899, found 425.1904; IR (Neat): 3277, 3027, 2927, 2853, 1332, 1157cm^{-1}.

N-(2-((3-Methoxybenzyl)(methyl)amino)-1-phenylethyl)-4-methylbenzenesulfonamide (6c): Light brown oil; Yield 92% (39 mg); ^1H NMR (400 MHz, $CDCl_3$): δ 7.53−7.49 (m, 2H), 7.40 (d, *J* = 7.8 Hz, 1H), 7.19−7.13 (m, 5H), 7.11−7.06 (m, *J* = 8.3 Hz, 2H), 6.89−6.84 (m, 3H), 4.37−4.33 (m, 1H), 3.86 (s, 3H), 3.70 (d, *J* = 13.1 Hz, 1H), 3.44 (d, *J* = 13.3 Hz, 1H), 2.44 (d, *J* = 4.8 Hz, 1H), 2.44−2.40 (m, 1H), 2.35−2.32 (m, 3H), 2.17 (s, 3H); 13c NMR (100 MHz, $CDCl_3$): δ 159.8, 143.1, 139.4, 139.2, 136.0, 129.5, 129.2, 128.3, 127.6, 127.4, 127.2, 121.2, 114.2, 113.1, 62.7, 61.7, 55.3, 50.8, 41.4, 21.5; HRMS: calcd for $C_{24}H_{29}N_2O_3S$ $[M+H]^+$ 425.1899, found 425.1908; IR (Neat): 3277, 3027, 2927, 2852, 1327, 1161cm^{-1}.

5-Benzyl-3*a*-phenyltetrahydro-3*H*-imidazo[1,5-*c*][1,2,3]oxa-thiazole 1,1-dioxide (6aa): Off-white solid; mp. 108-110 °C; Yield 52% (25 mg); ^1H NMR (400 MHz, $CDCl_3$): δ 7.47−7.41 (m, 4H), 7.39−7.30 (m, 6H), 4.81 (d, *J* = 8.0 Hz, 1H), 4.68 (d, *J* = 8.3 Hz, 1H), 4.52 (d, *J* = 8.0 Hz, 1H), 3.79−3.68 (m, 2H), 3.60 (d, *J* = 13.1 Hz, 1H), 3.46 (d, *J* = 10.0 Hz, 1H), 2.71 (d, *J* = 10.3 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 140.8, 137.0, 129.1, 128.7, 128.4, 128.4, 127.7, 124.9, 78.4, 75.8, 72.6, 64.3, 55.9; HRMS: calcd for $C_{17}H_{19}N_2O_3S$ $[M+H]^+$ 331.1116, found 331.1119; IR (KBr): 3029, 2923, 2821, 1361, 1194 cm^{-1}.

5-phenethyl-3*a*-phenyltetrahydro-3*H*-imidazo[1,5-*c*][1,2,3]oxathiazole 1,1-dioxide (6ac): Transparent oil; Yield 47% (24 mg); ^1H NMR (400 MHz, $CDCl_3$): δ 7.46−7.41 (m, 4H), 7.40−7.35 (m, 1H), 7.31 (q, *J* = 7.4 Hz, 2H), 7.27−7.24 (m, 1H), 7.23−7.19 (m, 2H), 4.84 (d, *J* = 7.8 Hz, 1H), 4.66 (d, *J* = 8.3 Hz, 1H), 4.53 (d, *J* = 8.3 Hz, 1H), 3.65 (d, *J* = 8.0 Hz, 1H), 3.53 (d, *J* = 9.8 Hz, 1H), 2.91−2.81 (m, 2H), 2.77−2.70 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 140.8, 139.3, 129.2, 128.7, 128.5, 128.4, 126.5, 124.8, 78.3, 75.5, 72.7, 65.0, 53.5, 35.1; HRMS: calcd for $C_{18}H_{21}N_2O_3S$ $[M+H]^+$ 345.1273, found 345.1279; IR (Neat): 3028, 2925, 2851, 1454, 1361, 1194cm^{-1}.

5-(4-Chlorobenzyl)-3*a*-phenyltetrahydro-3*H*-imidazo[1,5-*c*][1,2,3]oxathiazole 1,1-dioxide (6ae): Off-white solid; mp. 124-126°C; Yield 30% (16 mg); ^1H NMR (400 MHz, $CDCl_3$): δ 7.45−7.39 (m, 4H), 7.39−7.31 (m, 3H), 7.31−7.24 (m, 2H), 4.78 (d, *J* = 8.0 Hz, 1H), 4.67 (d, *J* = 8.3 Hz, 1H), 4.53 (d, *J* = 8.3 Hz, 1H), 3.75−3.68 (m, 2H), 3.62−3.53 (m, 1H), 3.44 (d, *J* = 10.0 Hz, 1H), 2.73 (d, *J* = 10.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 140.7, 135.5, 133.5, 129.7, 129.2, 128.9, 128.4, 124.8, 78.3, 75.7, 72.6, 64.3, 55.2; HRMS: calcd for $C_{17}H_{18}ClN_2O_3S$ $[M+H]^+$ 365.0727, found 365.0735; IR (KBr): 3029, 2924, 2853, 1352, 1187cm^{-1}.

Acknowledgements

We greatly appreciate the Science & Engineering Research Board (SERB) of DST, New Delhi for financial support. KPJ thanks the NIPER S.A.S. Nagar for a research fellowship.

Keywords: N-sulfonyl imidazolidine • 1,3-Dipolar cycloaddition • 1,2-Diamine • Azomethine ylides • N-Sulfonyl imines

[1] a) Y.-M. Wang, H.-H. Zhang, C. Li, T. Fan, F. Shi, *Chem. Commun.* **2016**, *52*, 1804-1807; b) Q.-H. Li, L., Wei, X. Chen, C.-J, Wang, *Chem. Commun.* **2013**, *49*, 6277-6279; c) I. Karunker, E. Morou, D. Nikou, R. Nauen, R. Sertchook, B. J. Stevenson, M. J. Paine, S. Morin, J. Vontas, *Insect Biochem. Mol. Biol.* **2009**, *39*, 697-706; d) T. Arai, K. Tsuchiya, E. Matsumura, *Org. Lett.* **2015**, *17*, 2416-2419; e) M. N. Hopkinson, C. Richter, M. Schedler, F. Glorius, *Nature* **2014**, *510*, 485-496; f) A. E. Allen, D. W. MacMillan, *J. Am. Chem. Soc.* **2011**, *133*, 4260-4263.

[2] a) C. Izquierdo, F. Esteban, J. L. G. Ruano, A. Fraile, J. Alemán, *Org. Lett.* **2015**, *18*, 92-95; b) J.-F. Rousseau, I. Chekroun, V. Ferey, J. R. Labrosse, *Org. Process Res. Dev.* **2015**, *19*, 506-513; c) A. Viso, R. Fernandez de la Pradilla, M. L. López-Rodríguez, A. García, A. Flores, M. Alonso, *J. Org. Chem.* **2004**, *69*, 1542-1547.

[3] a) L. M. Lima, E. J. Barreiro, *Curr. Med. Chem.* **2005**, *12*, 23-49; b) C. Ballatore, D. M. Huryn, A. B. Smith, *ChemMedChem* **2013**, *8*, 385-395; c) S. K. Singh, P. G. Reddy, K. S. Rao, B. B. Lohray, P. Misra, S. A. Rajjak, Y. K. Rao, A. Venkateswarlu, *Bioorg. Med. Chem. Lett.* **2004**, *14*, 499-504; d) R. H. Peters, W.-R. Chao, B. Sato, K. Shigeno, N. T. Zaveri, M. Tanabe, *Steroids* **2003**, *68*, 97-110.

[4] a) D. Uraguchi, N. Kinoshita, T. Kizu, T. Ooi, *J. Am. Chem. Soc*. **2015**, *137*, 13768-13771; b) C. Röben, J. A. Souto, E. C. Escudero-Adán, K. Muniz, *Org. Lett.*, **2013**, *15*, 1008-1011.

[5] a) S. Gosiewska, R. Soni, G. J. Clarkson, M. Wills, *Tetrahedron Lett.* **2010**, *51*, 4214-4217; b) J. Xuan, Y. Cheng, J. An, L.-Q. Lu, X.-X. Zhang, W.-J. Xiao, *Chem. Commun.* **2011**, *47*, 8337-8339; c) S. Muthusamy, S. G. Kumar, *Org. Biomol. Chem.* **2016**, *14*, 2228-2240; d) V. Satheesh, M. Sengoden, T. Punniyamurthy, *J. Org. Chem.* **2016**, *81*, 9792-9801; e) M. Sengoden, A. Bhowmick, T. Punniyamurthy, *Org. Lett* **2017**, *19*, 158–161.

[6] P. G. M. Wuts, Theodora W. Greene. *Greene's protective groups in organic synthesis*. John Wiley & Sons, **2006**, pp. 696-926.

[7] a) F. Shi, Z. L. Tao, S. W. Luo, S. J. Tu, L. Z. Gong, *Chem. Eur. J.* **2012**, *18*, 6885-6894; b) R. Narayan, M. Potowski, Z.-J. Jia, A. P. Antonchick, H. Waldmann, *Acc. Chem. Res.* **2014**, *47*, 1296; c) J. Adrio J. C. Carretero, *Chem. Commun.* **2014**, *50*, 12434-12446; d) T. Hashimoto, K. Maruoka, *Chem. Rev.* **2015**, *115*, 5366-5412; e) C. S. Wang, R. Y. Zhu, J. Zheng, F. Shi, S. J. Tu, *J. Org. Chem.* **2015**, *80*, 512–520; f) W. Dai, H. Lu, X. Li, F. Shi, S. J. Tu, *Chem. Eur. J.* **2014,** *20*, 11382-11389; g) Q. H. Li, L. Wei, C. J. Wang, *J. Am. Chem. Soc.* **2014**, *136*, 8685–8692.

[8] a) H. Xie, J. Zhu, Z. Chen, S. Li, Y. Wu, *J. Org. Chem.* **2010**, *75*, 7468-7471; b) Y.-H. Sun, Y. Xiong, C.-Q. Peng, W. Li, J.-A. Xiao, H. Yang, *Org. Biomol. Chem.* **2015**, *13*, 7907-7910; c) W.-J. Liu, X.-H. Chen, L.-Z Gong, *Org. Lett.* **2008**, *10*, 5357-5360; d) R.-Y. Zhu, C.-S. Wang, F. Jiang, F. Shi, S.-J. Tu, *Tetrahedron: Asymmetry* **2014**, *25*, 617-624.

[9] a) G. Pandey, J. K. Laha, G. Lakshmaiah, *Tetrahedron* **2002**, *58*, 3525-3534; b) G. Pandey, J. K. Laha, A. Mohanakrishnan, *Tetrahedron Lett.* **1999**, *40*, 6065-6068.

[10] J. K. Laha, K. P. Jethava, *J. Org. Chem.* **2017**, *82*, 3597–3604.

[11] J. K. Laha, K. S. Tummalapalli, K. P. Jethava, *Org. Biomol. Chem.* **2016**, *14*, 2473-2479.

[12] J. K. Laha, N. Dayal, R. Jain, K. Patel, *J. Org. Chem.* **2014**, *79*, 10899-10907.

[13] a) K. Yoshida, N. Akashi, A. Yanagisawa, *Tetrahedron: Asymmetry* **2011**, *22*, 1225-1230; b) G. S. Deng, J. Y. Zou, T. F. Sun, *Chin. Chem. Lett.* **2011**, *22*, 511-514.

[14] G. Pandey, G. Lakshmaiah, G. Kumaraswamy, *J. Chem. Soc., Chem. Commun.* **1992**, 1313-1314.
[15] K. Yoshida, N. Akashi, A. Yanagisawa, *Tetrahedron: Asymmetry* **2011**, *22*, 1225-1230.

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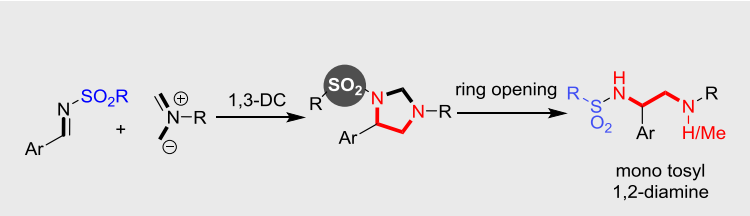

A new synthesis of *N*-sulfonyl imidazolidines via 1,3-dipolar cycloaddition reaction of non-stabilized azomethine ylides and *N*-sulfonyl aldimine or ketimines and their ring cleavage reactions to 1,2-diamines

*N-sulfonyl imidazolidine, 1,3-dipolar cycloaddition

Key Topic*

Joydev K. Laha, Krupal P. Jethava, K. S. Satyanarayana Tummalapalli, and Sheetal Sharma*

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Synthesis of Mono *N*-sulfonyl Imidazolidines by 1,3-Dipolar Cycloaddition Strategy, an Alternative to Selective *N*-Sulfonylation, and their Ring Cleavages to 1,2-Diamines