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ARTICLE

Integration of Oxidative Arylation with Sulfonyl Migration: One-Pot Tandem Synthesis of Densely Functionalized (NH)-Pyrroles

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A one-pot synthesis of 2-aryl-3-alkyl/aryl-sulfonyl-(NH)-pyrroles from *N*-sulfonylpyrroles, developed first time, via palladium-catalyzed oxidative C-2 arylation followed by sulfonyl migration is described. The simple, easy access to the highly functionalized free-NH pyrroles secures opportunities for the preparation of compounds with promising biological activities in contemporary organic synthesis. The event of sulfonyl migration from pyrrole-N to C-3 is thermodynamically favored as revealed by density functional methods. The different plausible mechanisms for the migration of the sulfonyl group are also discussed.

Introduction

Many biaryl compounds containing an *ortho*-sulfonyl group have been identified as medicinal agents in therapeutic discovery with a proven track record of druggability, for example BMS-207940 (**1**) and (**2**), while each requiring an *ortho*-sulfonyl functionality for demonstrated pharmacophoric activities (Figure 1).[1,2] Structurally related heterobiaryls are especially interesting as they could encompass the flexibility to accommodate an *ortho*-sulfonyl group on aryl or heteroaryl ring.[3] Despite pyrrole being the common integral part of natural pigments, pharmaceuticals and performance materials,[4a] (NH)-2-arylpyrroles containing a sulfonyl functionality on pyrrole ring (**3**) are less abundant.[4d] More importantly, the understanding of the positional effect of sulfonyl group on pharmacological properties is only superficial.[4d] Therefore, ready availability of (NH)-2-arylpyrroles containing a sulfonyl functionality could provide extended opportunities for understanding the comparative beneficial effect of the sulfonyl group on aryl and pyrrole rings, direct comparison of their biological and pharmacokinetic properties, functionalization of free (NH) group for late-stage

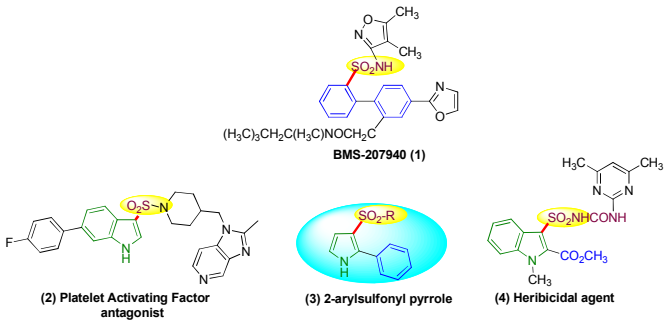

Figure 1. Biaryls and Heterobiaryls with an *ortho*-sulfonyl functionality.

diversification and new opportunities in drug discovery.

While 2-arylpyrroles have been prepared using classical reactions involving multi-steps,[4a,5] widely by direct C-H arylations,[6] and elegantly by oxidative coupling reactions,[7] the synthesis of (NH)-2-arylpyrroles containing a sulfonyl-functionality is limited only to a few reports. Oxidation of a thiol functionality already present on the aryl or pyrrole ring of (NH)-2-arylpyrroles,[4d,e] prepared in steps, and multi-component reactions[4b,c,f] using building blocks are the procedures currently available in literature (Scheme 1).[4b,c,e,f] Nevertheless, the installation of sulfonyl functionality on (NH)-2-arylpyrroles has invariably been resorted to using a classical approach.

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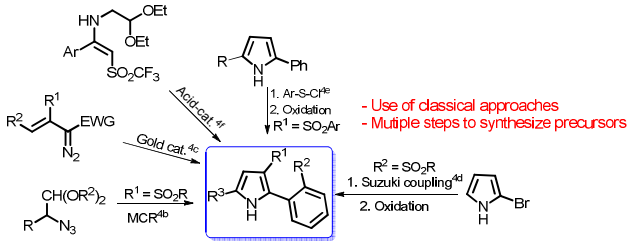
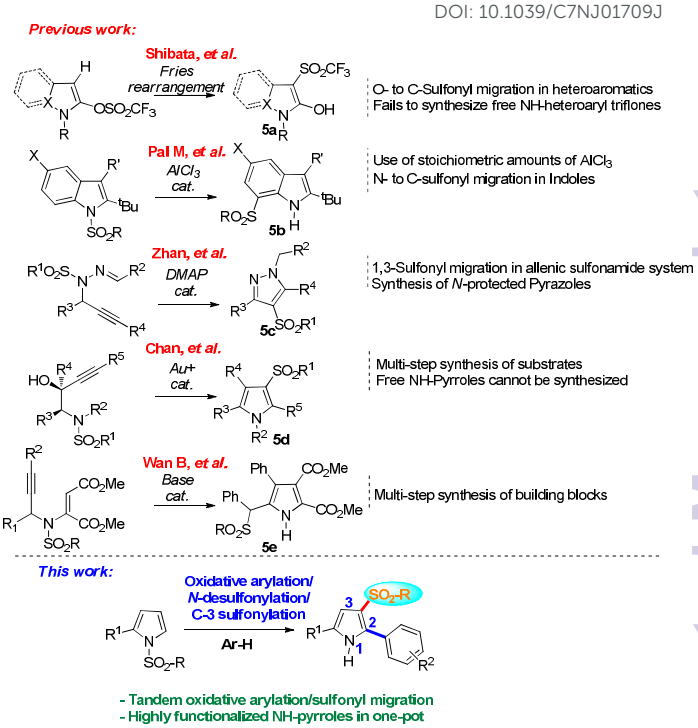


Scheme 1. Approaches for (NH)-2-arylpyrroles with a sulfonyl group.

The practice of protecting a group would be particularly valuable if the protecting group is retained as desired functionality in the product.[8] In this regard, regioselective migration of a sulfonyl group from one position to a different position could be a useful tool, especially when ready installation of the sulfonyl group at the desired position could possess a significant challenge. The arylsulfonyl groups are commonly used as protecting groups in pyrrole chemistry, which are ultimately removed after the desired transformation.[8a,b] The event of sulfonyl migration is reported in the synthesis of 3-sulfonylindole or pyrazoles **5a** (Scheme 2) via an anionic thia-Fries rearrangement in the presence of a strong base,[9] $AlCl_3$ mediated sulfonyl migration in indoles **5b** from N- to C-7 position,[10] Lewis base catalyzed annulations of *N*-propargylic sulfonylhydrazones to 4-sulfonylpyrazoles **5c**,[11] gold(I)-catalyzed cycloisomerization of *N*-substituted *N*-sulfonyl-aminobut-3-yn-2-ols[12] or base catalyzed regioselective migration of sulfonyl group[13] to the synthesis of 3-sulfonyl-(NH)-pyrroles **5d,e**. Many conditions that have been largely used to trigger the *N*- to C-sulfonyl migration require the use of a base, noble metal catalyst, or Lewis acid, which is believed to proceed via an ion-pair mechanism.[10-14] However, a few reports describing thermal induced N- to C-sulfonyl migration use a high temperature (>150 °C), which is known to involve radical generation.[15] While a sulfonyl migration in pyrrole nucleus is scarcely reported, integration of sulfonyl migration with oxidative coupling remains unexplored. Realization of a reaction condition for oxidative arylation in *N*-sulfonylpyrroles followed by sulfonyl migration while elusive could give a direct access to C-sulfonylated (NH)-pyrroles.[16] Leveraging our experiences in oxidative couplings[17] and installation of a sulfonyl functionality on heterobiaryls,[18] we envisaged a tandem approach that could feature event of sulfonyl migration and meet the preparative challenges of highly functionalized (NH)-2-arylpyrroles containing a C-3 sulfonyl functionality on pyrrole ring.

Herein, we describe a novel tandem approach to the synthesis of (NH)-2-arylpyrroles containing a C-sulfonyl functionality on pyrrole via palladium-catalyzed regioselective C-2 arylation of *N*-sulfonylpyrroles followed by intramolecular N(1)- to C(3)-sulfonyl migration. The distinctive features of this work include a) realization, for the first time, of a novel N- to C-3 sulfonyl migration in pyrrole nucleus, b) does not require any base, acid, or metal-catalyst for sulfonyl migration, c) integration of the sulfonyl migration with oxidative coupling, and d) probable mechanism among the different possible mechanisms proposed in this study.



Scheme 2. Selected Examples of Sulfonyl migration observed in Heterocycles.

Results and discussion

Our initial investigations, largely focused on finding a condition that could effect thermal induced sulfonyl migration from N- to C-3 position in pyrroles, ultimately secured a condition for desired sulfonyl migration. The attempts of sulfonyl migration with 2,5-disubstituted-*N*-tosylpyrrole **6a** at room temperature or above (up to 60 °C) did not secure a traceable sulfonyl migration. The event of sulfonyl migration was noticeable only when compound **6a** was heated at or above 80 °C in DMF (Table 1, entry 1). A significantly improved conversion of compound **6a** to $\mathbf{7a_a}$ was observed at 130 °C in DMF in 4 h affording $\mathbf{7a_a}$ in 75% yield (entry 2). Other solvents including *o*-xylene, DCB, quinoline, nitrobenzene, DMSO, ethylene glycol, and pivalic acid were also compatible producing $\mathbf{7a_a}$ in varying yields (entries 3-9). For example, a non-polar solvent, *o*-xylene gave $\mathbf{7a_a}$ in 42% yield (entry 3). Both DMSO (a polar aprotic solvent) and ethylene glycol (a polar protic solvent) gave comparable yields of $\mathbf{7a_a}$ (entries 7-8). However, pivalic acid produced somewhat inferior results (entry 9). Interestingly, pivalic acid is proved comparable at higher concentrations (entry 10). The yield of the reaction is not affected in the presence of a radical quencher TEMPO, suggesting that the reaction does not involve the formation of a free-radical (entry 11). Notably, another sulfonyl migrated product $\mathbf{7a_b}$ was obtained in many of these experiments *albeit* in low quantities.

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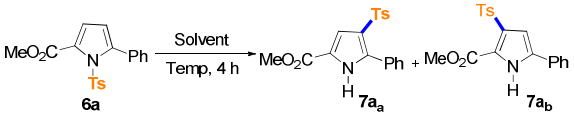
Table 1. Optimization Study for Sulfonyl Migration.[a]



Entry	Solvent	Temp (°C)	% $7a_a$	% $7a_b$
1	DMF	80	15	-
2	DMF	130	75	12
3	*o*-xylene	130	42	5
4	DCB	130	62	8
5	Quinoline	130	40	4
6	Nitrobenzene	130	73	15
7	DMSO	130	87	-
8	Ethylene glycol	130	85	3
9	Pivalic acid	130	60	12
10[b]	Pivalic acid	130	85	5
11[b,c]	Pivalic acid	130	72	5

[a] **6a** (0.1 mmol), solvent (0.25 mL); [b] solvent (1 mL); [c] In the presence of TEMPO (1.2 equiv).

A single crystal X-ray structure was sought for $7a_a$, which is shown in Figure 2.

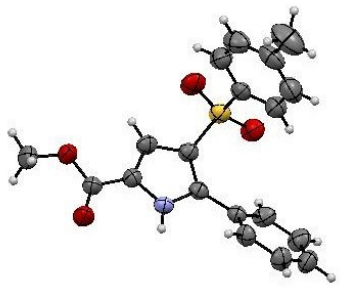
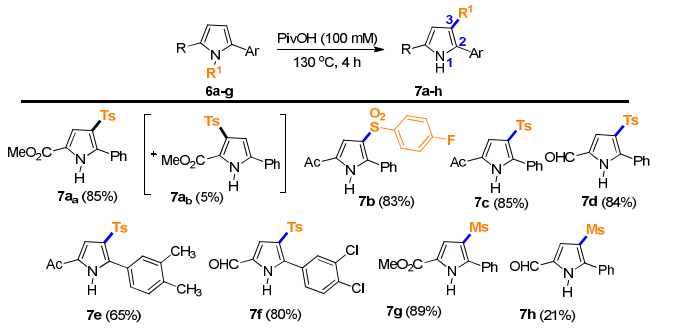


Figure 2. ORTEP diagram of $7a_a$.[19]

Next, we explored briefly the substrate scope that could participate in the reaction (Table 2). Both aryl or alkyl sulfonyl groups are capable of migrating from pyrrole-N to C-3 position affording sulfonylated (NH)-2-arylpyrroles in good to excellent yields. A qualitative comparison of sulfonyl migration involving three different sulfonyl groups, viz. tosyl ($7a_a$), 4-fluorobenzenesulfonyl (**7b**), and mesyl (**7g**) can be made from our investigation. It reveals that migratory aptitude of sulfonyl groups occurring with these groups is comparable, although compound **7h** with a C-3 mesyl group was isolated *albeit* in low yield. Central to this investigation was the key role of temperature that enables regioselective sulfonyl migration in pyrroles in the absence of any base, metal or Lewis acid catalyst.

To explore further the preparative value of the regioselective sulfonyl migration in pyrroles, we next investigated the possibility of integrating the two steps, viz. oxidative C-2 arylation and sulfonyl migration, into a one-pot domino approach to the synthesis of C-3 sulfonylated 2-arylpyrroles.

Table 2. Approaches for (NH)-2-Arylpyrroles with a Sulfonyl Group.



A challenge was to find a reaction condition for one-pot oxidative regioselective C-2 arylation that could be compatible with the reaction conditions of sulfonyl migration. Reaction of **8a** and benzene (10 mL/mmol) in the presence of $Pd(OAc)_2$ (10 mol%), CsOPiv (20 mol%), and AgOAc (3 equiv) in pivalic acid (10 mL/mmol) at 130 °C for 16 h gave **7c** in 52% yield (Table 3, entry 1). A reduced volume of benzene further improved the yield affording **7c** in 70% yield (entry 2). Further reduced volume (4 mL/mmol) of benzene together with a slightly reduced volume of pivalic acid (8 mL/mmol) resulted the best yield of the product (entry 3). However, use of nearly a stoichiometric amount of benzene reduced the yield significantly (entry 4). DMSO, a solvent that appeared excellent for sulfonyl migration, was not found compatible in combination with pivalic acid (entries 5-6). A different palladium-catalyst, strong oxidant, or exclusion of CsOPiv did not improve the yield further (entries 7-9). Reaction of ethyl (NH)-pyrrole-2-carboxylate and benzene under the standard conditions did not give the corresponding 5-arylated pyrrole. This experiment suggests that the tosyl group at nitrogen not only serves the purpose of protection in pyrroles, but also facilitates the arylation at the 2-position. Interestingly, reaction of pyrrole **8b** in the absence of benzene gave pyrrole-aryl fused sultam **9** in 65% yield via a palladium-catalyzed intramolecular oxidative coupling.

Using the optimized conditions, we prepared various C-3 sulfonyl (NH)-2-arylpyrroles that are otherwise difficult to prepare by literature procedure (Table 4). The readily accessible *N*-Ts-pyrroles containing a C-2 substituent reacted with benzene under the optimized conditions affording good to excellent yields of the products (**$7a_a$, 7c, 7d and 7i**). Reaction of **8d** and a mono-substituted arene, such as nitrobenzene gave an easily separable mixture of 3-arylsulfonyl-2-arylpyrroles $7j_a$ and $7j_b$ in a 7:3 ratio. Disubstituted arenes were also viable substrates affording various substituted 3-arylsulfonyl-2-arylpyrroles **7e**, **7f** and **7k-7n**.

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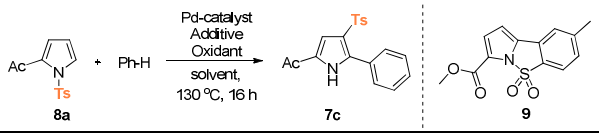
Table 3. Optimization Study for One-pot Synthesis.[a]



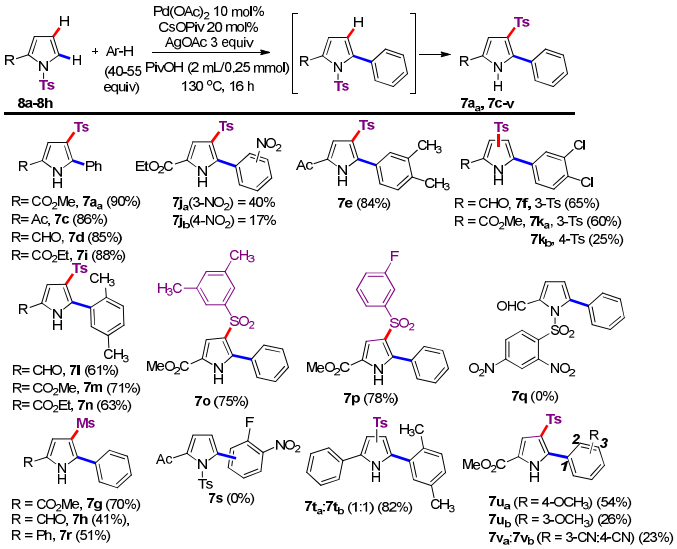
Entry	Pd-catalyst	Oxidant	Additive	Solvent	PhH	**7c** (%)
1	$Pd(OAc)_2$	AgOAc	CsOPiv	PivOH	2.5 mL	52
2	$Pd(OAc)_2$	AgOAc	CsOPiv	PivOH	1.5 mL	70
3[b]	$Pd(OAc)_2$	AgOAc	CsOPiv	PivOH	1 mL	85
4	$Pd(OAc)_2$	AgOAc	CsOPiv	PivOH	1.5 equiv	25
5[c]	$Pd(OAc)_2$	AgOAc	CsOPiv	PivOH: DMSO (3:1)	2.5 mL	0
6[c]	$Pd(OAc)_2$	AgOAc	CsOPiv	PivOH: DMSO (1:1)	2.5 mL	0
7	$Pd(TFA)_2$	AgOAc	CsOPiv	PivOH	1 mL	76
8[c]	$Pd(OAc)_2$	$K_2S_2O_8$	CsOPiv	PivOH	1 mL	0
9	$Pd(OAc)_2$	AgOAc	-	PivOH	1 mL	65

[a] **8a** (0.25 mmol), Pd-catalyst (10 mol%), CsOPiv (20 mol%), oxidant (3.0 equiv), solvent (2.5 mL); [b] PivOH (2 mL); [c] only trace amount of C-2 arylated product formed.

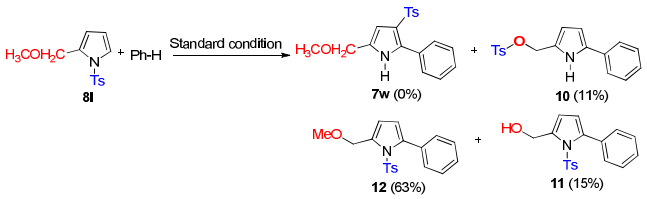
The regioselective migration of sulfonyl group to the C-3 position is particularly notable with an exception to the formation of **7k$_b$**. The migratory aptitude of different aryl or alkyl sulfonyl group was also investigated. While many of them are indeed capable of migration from pyrrole-N to the C-3 position, 2,4-dinitroarylsulfonyl group was not compatible (**7q**). It is noteworthy that strongly electron-deficient arenes failed to undergo the one-pot domino reaction (**7s**). Interestingly, reaction of *N*-Ts-2-phenylpyrrole **8k** and *p*-xylene gave an inseparable regioisomeric mixture of C-3 and C-4 sulfonylated 2,5-diarylpyrroles **7t$_a$** and **7t$_b$**. This suggests that the sulfonyl migration becomes competitive when two different aryl groups are present at 2- and 5-positions. In case of mono substituted arenses such as anisole and benzonitrile as expected, anisole furnished two products (**7u$_a$**) and (**7u$_b$**) in a 2:1 ratio. Likewise, benzonitrile gave an inseparable regioisomeric mixture of C-3 sulfonylated product (**7v**) *albeit* in low yield.

Pyrrole **8l** containing a methoxymethyl group did not give any C-3 sulfonylated pyrrole **7w** under the standard conditions, although 2-arylpyrroles **10**, **11** and **12** were isolated in varying yields (Scheme 3).

Table 4. Substrate Scope for One-Pot Arylation/Migration.



Interestingly, the formation of **10** from **11**, presumably obtained by hydrolysis of **12**, suggests that a competitive sulfonyl migration from N- to O- instead of *N*- to C-3 position has occurred. This experiment suggests that the migration of sulfonyl group from N-1 to the C-3 position could be prohibited in the presence of an electron-donating methoxymethyl group at C-5 position.



Scheme 3. Competitive Sulfonyl Migration from *N*- to -CH_2OH Group.

The mechanism of sulfonyl migration from N-1 position to the C-3 position in pyrrole nucleus would be especially interesting, as a similar migration in pyrroles is unknown. The sulfonyl migration could occur via different pathways as shown in Figure 3. A direct N- to C-3 transfer could occur via intermolecular reaction. The capture of electrophilic SO_2Ar group by another pyrrole could give C-3 sulfonylated product (Pathway A). Heterolytic or homolytic cleavages of pyrrole-N–SO_2Ar bond could give an ion-pair pyrrole-N^- $^+SO_2Ar$,[13] or free radicals,[15] respectively (Pathways B and C). *N*-Desulfonation of pyrrole could occur by arene at C-2 position, which upon subsequent C-desulfonation by pyrrole at C-3 position could give the desired sulfonyl product (Pathway D).

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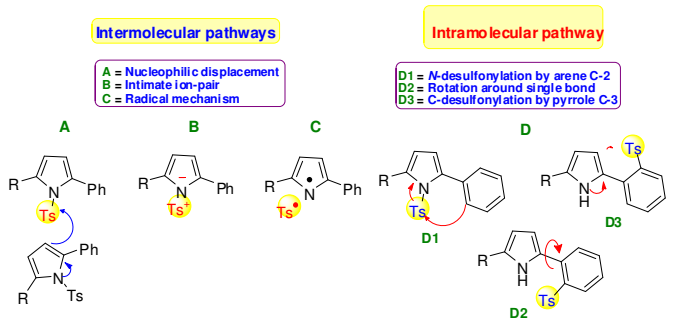
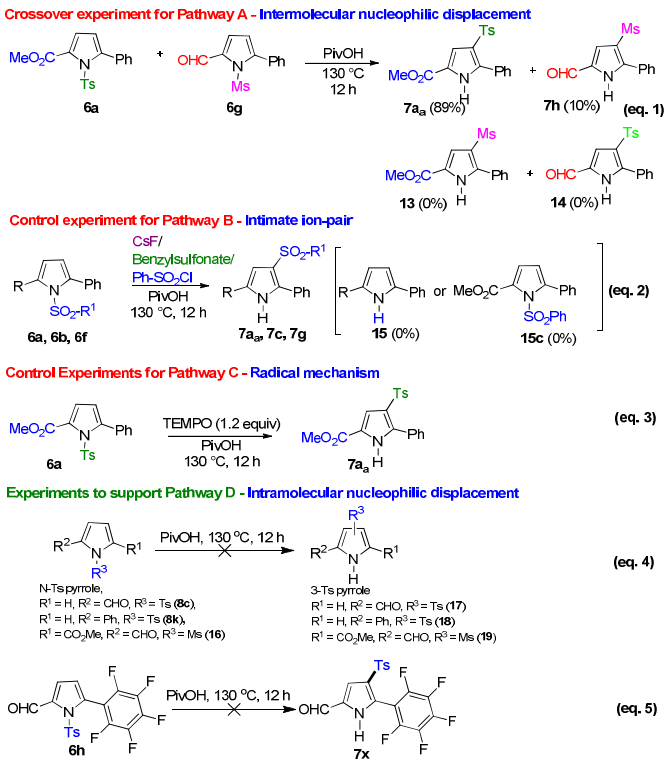


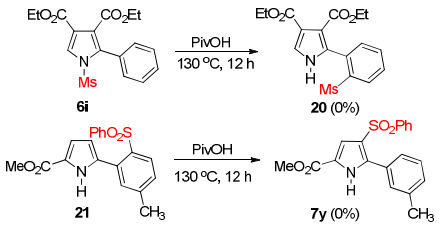
Figure 3. Possible Pathways (A, B, C and D) For Sulfonyl Migration.

To elucidate a plausible mechanism for the sulfonyl migration, the following experiments were carried out. In a crossover experiment, reaction of **6a** and **6g** under the standard conditions gave **7a$_a$** and **7h** (Scheme 4, eq. 1). However, any intermolecular reaction that could lead to crossover products **13** and **14** was not observed. Based on this experiment, the pathway A is least probable. Heating 2-arylpyrrole **6a**, **6b** or **6f** in pivalic acid at 130 °C for 4 h in the presence of CsF, benzyl sulfonate or benzene sulfonylchloride gave only the corresponding C-3 sulfonylated products **7a$_a$**, **7c** and **7g** (eq. 2) respectively. The capture of $^{+}SO_2Ar$ by the nucleophile (F^- and benzyl sulfonyl anion), or pyrrole-N^- by the electrophile (benzenesulfonyl chloride) would be the competitive reactions in Pathway B, which could result in the formation of *N*-desulfonation product **15** or **15c**, respectively. However, no *N*-desulfonation product **15** or **15c** was observed in any of these cases. The sulfonyl migration is not affected in the presence of a radical quencher TEMPO, suggesting that the reaction does not involve the formation of a free-radical (eq. 3). Thus, the two widely accepted pathways (B and C) are seemingly least likely in this case.

When *N*-tosylpyrroles (unsubstituted, 2-substituted, or 2, 5-disubstituted without an aryl substituent) were heated at 130 °C for 12 h, no reaction occurred (eq. 4). Similarly, *N*-Ts-2-pentaflurophenylpyrrole **6h** also did not give any product (eq. 5). These experiments suggest that an arene group is required at the 2-position in pyrroles, and additionally there should be at least one unoccupied *ortho*-position in the arene. Furthermore, wherein a C-3 position is blocked as in compound **6i**, sulfonyl migration was not observed (Scheme 5). Similarly, compound **21** also did not give any C-3 sulfonylpyrrole.

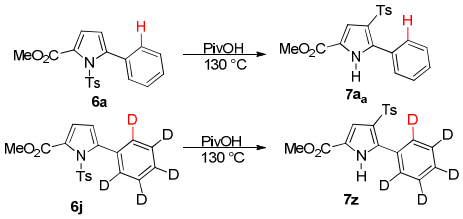


Scheme 4. Control Experiments to Establish Mechanism of Sulfonyl Migration.



Scheme 5. Control Experiments to study Arene-Assited Sulfonyl Migration.

To investigate further the involvement of C-H bond breaking during migration, both the arylated products **6a** and **6j** were heated independently in pivalic acid at 130 °C (Scheme 6). During the experiment, various aliquots were withdrawn from the reaction mixtures at an interval of 5, 10, 15, 20 and 30 min and subjected to HPLC analysis.



Scheme 6. Kinetic Study.

At each time interval, only an insignificant difference in product formation was observed (Figure 4) suggesting that C–H bond breaking is not involved during migration. A similar conclusion can be drawn from the ^{1}H NMR spectrum of **7z** lacking any aromatic phenyl proton. Had there been any C-H bond breaking, the aromatic phenyl proton would have appeared in the ^{1}H NMR spectrum. Overall, our mechanistic study indicates that a C-2 arene is essential for sulfonyl migration, the question was whether this arene group could act as the putative sulfonyl carrier.

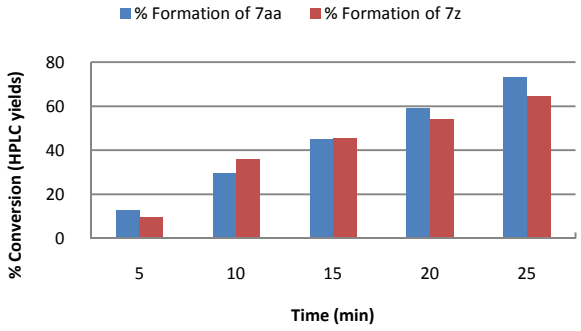
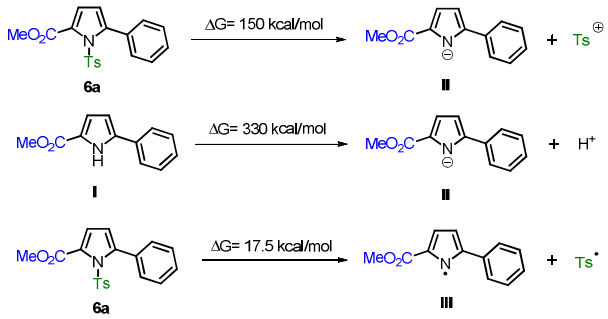
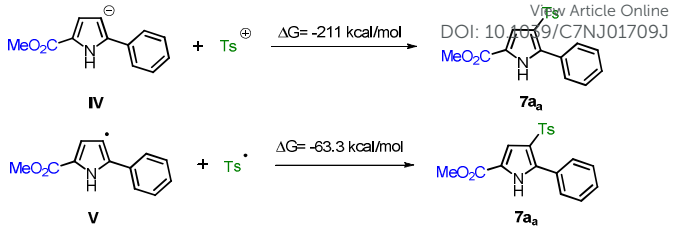


Figure 4. Comparison of HPLC Yields of **7a$_a$** and **7z**.

To understand the mechanism of sulfonyl group migration from pyrrole-N to pyrrole C-3 position computationally, Density Functional Theory (DFT) calculations on reactants, possible intermediates and product, were carried out using parameterized hybrid meta-GGA functional M06/6-311++G(d,p) level of theory. Energy calculation and geometry optimization of reactants and products show that C-3 sulfonylpyrrole **7a$_a$** is relatively more stable than *N*-sulfonylpyrrole **6a** by 9.3 kcal/mol and C-4 sulfonylpyrrole **7a$_b$** is relatively more stable than **6a** by 9.0 kcal/mol. This indicates that sulfonyl group migration from N to C-3 position or C-4 is an energetically favorable process. To prove intermolecular pathway for sulfonyl migration through ion-pair formation,[13] or free radical mechanism,[15] the bond dissociation energies were calculated and attempts were made to obtain the transition states. The bond dissociation energy of N-S bond in **6a** to generate ion-pairs (pyrrole-N- and +SO_2Ar) is ~150 kcal/mol, which is ~180 kcal/mol smaller than the bond dissociation energy of N-H bond in pyrrole (~330 kcal/mol). The homolytic cleavage of N-S bond in **6a** to generate free radicals, requires only 17.5 kcal/mol (Scheme 7). This signifies that N-S bond is very fragile in **6a**. The energy associated with C- +SO_2Ar bond formation is -211 kcal/mol exergonic whereas through radical pathway (C• •SO_2Ar) it is -63.3 kcal/mol exergonic (Scheme 8).



Scheme 7. Thermodynamics of N-S bond cleavage.



Scheme 8. Thermodynamics of C-S bond formation.

Intramolecular C-2 aryl group assisted sulfonyl migration is proposed in Figure 5 and Gibbs free energy changes (ΔG) at each step is indicated. At the first step, *N*-desulfonation of pyrrole by arene at C-2 position is energetically favorable by 5.1 kcal/mol yielding comparatively stable intermediate **VI**. Subsequently, intermediate **VI** undergoes C-C bond rotation around C-2 to C-aryl bond to give intermediate **VII**, which is marginally more stable by 0.4 kcal/mol. Next C-desulfonation by C-3 of pyrrole further stabilizes the product **7a$_a$** by 3.8 kcal/mol. The sum of free energy changes at each step of reaction (Figure 5) is 9.3 kcal/mol, which is the equal to the energy released for stabilizing C-3 sulfonylated product **7a$_a$**. Energetics of reaction pathway indicates that the transformation of **6a** to **7a$_a$** via intermediates **VI** followed by **VII** is continually stabilizing. However, the necessary transition states with their respective energy barrier (Ea) could not be identified on the potential energy surface. Because of limited experiments carried out to understand the mechanism and the complexity of the mechanism, it is hard to depend exclusively on a particular pathway described above.

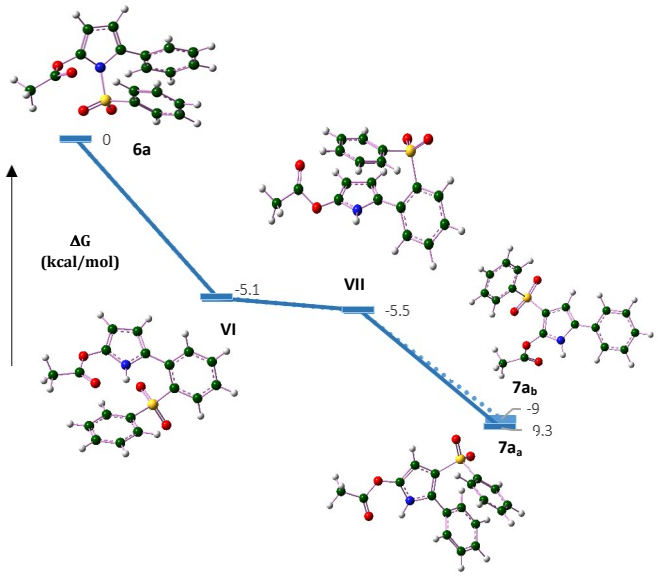


Figure 5. Proposed intermediary steps to establish pathway for C-2 aryl assisted sulfonyl migration quantum chemically.

Conclusions

We have developed an expedient approach to the preparation of (NH)-2-arylpyrroles containing a sulfonyl functionality on pyrrole ring via oxidative coupling followed by migration of sulfonyl group from N-1 to C-3 position. The one-pot tandem approach features an unprecedented C-3 sulfonylation in pyrroles. The high preparative value of our protocol may be justified by considering the ease of preparation of 2-aryl-3-sulfonyl-(NH)-pyrroles that have invariably been prepared in multi-steps. A detailed understanding of the mechanism of sulfonyl migration and biological evaluation of the (NH)-2-arylpyrroles prepared herein are in progress.

Experimental Section

General: Unless noted otherwise, all reagents and solvents were purchased from commercial sources and used as received. All palladium-catalyzed reactions were performed in a screw-cap sealed tube. The ^{1}H and ^{13}C NMR spectra were obtained with Me_4Si as an internal standard. Coupling constants (J values) are reported in Hz. Column chromatography was performed using silica gel (100-200 mesh). High resolution mass spectra (HRMS) were obtained using electron spray ionisation (ESI) technique and as TOF mass analyser. All melting points were taken using a melting point apparatus equipped with a calibrated thermometer and are uncorrected. New compounds were characterized by melting point, IR, ^{1}H NMR, ^{13}C NMR, and HRMS data.

Computational methods

All quantum chemical studies were performed using Gaussian09 suite[20a] of program on acluster computer with Intel octacore processors. The geometry and energy of all structures wereoptimized without any symmetry constraints using M06 level of theory with 6-311++G(d,p)[20b,c] basis set. Vibrational frequencies were calculated for all optimized geometries at the same level to confirm the nature of the stationary points as either minima or transition states. The energy values provided in themanuscript are thermally corrected free energy (ΔG) changes.

1. Typical Procedure for *N*-sulfonylation of pyrroles (8a-8h, 8k, 8n)[21]

Following a literature procedure, to a solution of 2-substituted pyrrole (0.5 mmol) in dichloromethane (2.5 mL) was added KOH (1.5 equiv) and tetrabutylammonium hydrogensulfate (10 mol%) and was allowed to stir for 15 mins followed by addition of solution of sulfonyl chloride (1.2 equiv) in dichloromethane (1.0 mL) and the mixture was stirred at room temperature till the starting material was consumed. Water (20 mL) was added and the aqueous layer was extracted with EtOAc (3 × 20 mL). The combined organic layer was dried (Na_2SO_4) and concentrated, which upon chromatography [silica, EtOAc -hexanes = 1: 19 to 1: 9] gave the *N*-sulfonylated pyrroles.

2. Procedure for C-2 arylation of pyrrole ($8k_a$)[22]

Following a literature procedure, in an oven-dried screw cap vial equipped with a magnetic stir bar, pyrrole substrate (0.5 mmol), $Pd(OAc)_2$ (10 mol%), phenyl boronic acid (1.5 equiv) and acetic acid (5 mL) as solvent under O_2 atmoshpere was stirred at room temperature for 8 h. The reaction mixture was quenched by the addtion of saturated solution of $NaHCO_3$ (10 mL). Then, it was extracted with ethyl acetate (2 x 10 mL). The combined organic layer was dried (Na_2SO_4), concentrated under reduced pressure, and purified by column chromatography on silica using (dichloromethane/ hexane:1:4) as an eluent to give the desired product.

3. Procedure for *N-mesylation* of pyrroles (8h-8j, 8m)

To the cooled solution of pyrrole (2 mmol) in THF, NaH (1.2 equiv) was added slowly with vigorous stirring. After 10 mins methane sulfonyl chloride (1.5 equiv) was added dropwise to the reaction mixture. Upon completion of reaction, H_2O (10 mL) was added and extracted with ethyl acetate (2 x 10 mL). Then, combined organic layer was dried over sodium sulphate and concentrated under reduced pressure followed by chromatography [silica, EtOAc-hexanes = 0.5:9.5 ~ 2:8] gave corresponding *N*-mesylated pyrroles (28-30).

4. Procedure for *C-2 arylation* of pyrroles (6a-6j, 6k)[18]

Following a literature procedure, in an oven-dried screw cap vial equipped with a magnetic stir bar, pyrrole substrate (0.5 mmol), $Pd(TFA)_2$ (10 mol%), AgOAc (1.5 mmol), PivOH (5 equiv), 1.5 mL arene as solvent was heated at 80 °C for 12 h. The reaction mixture was allowed to cool to room temperature and neutralized by the addition of saturated solution of Na_2CO_3 (10 mL). Then, it was extracted with ethyl acetate (2 x 10 mL). The combined organic layer was dried (Na_2SO_4), concentrated under reduced pressure, and purified by column chromatography on silica using (ethyl acetate/ hexane) as an eluent to give the desired product.

5. Procedure for reduction of aldehyde by sodium borohydride ($8l_a$)

To a solution of *N*-tosyl pyrrole-2-carboxaldehyde (23) in ethanol was added $NaBH_4$ (1.5 equiv) and stirred at room temperature for 30 mins. Water (20 mL) was added and the aqueous layer was extracted with EtOAc (3 × 20 mL). The combined organic layer was dried (Na_2SO_4) and concentrated, which upon column chromatography [silica, EtOAc -hexanes = 1: 4] gave the desired product.

6. Procedure for alkylation of hydroxyl group (8l)

A dried round bottom flask equipped with a magnetic stirrer bar was charged with (1-Tosyl-1*H*-pyrrol-2-yl)methanol and THF (5 mL) under nitrogen atmosphere. The reaction mixture was cool down to 0 °C and NaH (1.2 equiv) was added and stirred for 15 mins. After which alkyl halide (1.1 equiv) was added and continued the stirring for 1 h. After completion of the reaction, it was quenched with water (10 mL) and was extracted with ethyl acetate (3 x 20 mL). The combined organic

layer was dried over Na_2SO_4 and the solvent was removed under reduced pressure to give 32.

7. Procedure for synthesis of 3,4-disubstituted pyrrole ($8m_a$)[23]
Following a literature procedure, to a solution of sodium *tert*-butoxide (2 equiv) in THF (10 mL), solution of *p*-toluenesulfonylmethylisocyanide (10 mmol) and diethyl fumarate (10 mmol) in THF (10 mL) was added dropwise. As reaction mixture turned brownish upon addition,reaction was allowed to continue overnight. Following which water (10 mL) was added and it was extracted with EtOAc (3 x 10 mL). The combined organic layer was concentrated under reduced pressure and washed with hexane to give 3,4-disubstituted pyrrole as a yellow solid.

8. Procedure for synthesis of pyrrole sultam by intramolecular cyclization (9)[18]
Following a literature procedure, in an oven-dried screw cap vial equipped with a magnetic stir bar, pyrrole substrate (0.5 mmol), $Pd(OAc)_2$ (10 mol%), AgOAc (1.5 mmol), CsOPiv (20 mol%), 3 mL pivalic acid as solvent was heated at 130 ºC for 12 h. The reaction mixture was allowed to cool to room temperature and neutralized by the addition of saturated solution of Na_2CO_3 (10 mL). Then, it was extracted with ethyl acetate (2 x 10 mL). The combined organic layer was dried (Na_2SO_4), concentrated under reduced pressure, and purified by column chromatography on silica using (EtOAc/ hexanes = 2:8) as an eluent to give the desired product.

9. Synthesis of C-3 sulfonylated compounds ($7a_a$-h)
In an oven-dried screw capped vial equipped with magnetic stir bar, 2,5-substituted pyrrole substrate (0.1 mmol) in PivOH (0.5 mL) was heated at 130 °C for 4 h. The reaction mixture was allowed to cool to room temperature and neutralized by the addition of saturated solution of Na_2CO_3 (5 mL). Then, it was extracted with ethyl acetate (2 x 5 mL). The combined organic layer was dried (Na_2SO_4), concentrated under reduced pressure, and purified by column chromatography on silica using (EtOAc/ hexanes = 2:8) as an eluent to give the desired product.

10. Synthesis of C-2 arylated C-3 sulfonylated compounds ($7a_a$, 7c-v)
In an oven-dried screw cap vial equipped with a magnetic stir bar, pyrrole substrate (0.25 mmol), $Pd(OAc)_2$ (10 mol%), AgOAc (0.75 mmol), CsOPiv (20 mol%), 1 mL arene and 2 mL pivalic acid as solvent was heated at 130 ºC for 16 h. The reaction mixture was allowed to cool to room temperature and neutralized by the addition of saturated solution of Na_2CO_3 (10 mL). Then, it was extracted with ethyl acetate (2 x 10 mL). The combined organic layer was dried (Na_2SO_4), concentrated under reduced pressure, and purified by column chromatography on silica using (EtOAc/ hexanes = 2:8) as an eluent to give the desired product.

11. Synthesis of *ortho*-sulfonylated compound 21 by nucleophilic ring opening

In an oven-dried screw cap vial equipped with a magnetic stir bar, a solution of substrate (0.1mmol) in THF (1 mL) was treated with phenylmagnesium chloride (0.5 mL, 1M solution in Me-THF) at room temperature for 5 mins. After completion, saturated solution of ammonium chloride (2 mL) was added and the mixture was diluted with H_2O (5 mL) and extracted with EtOAc (10 mL x 2). The combined organic layer was dried (Na_2SO_4) and concentrated, which upon chromatography [silica, EtOAc -hexanes = 2:8] gave 63.

Methyl 5-phenyl-1-tosyl-1*H*-pyrrole-2-carboxylate (6a).[23] Colorless solid (115 mg, 65%); IR (KBr, cm^{-1}): 2922, 1706, 1478, 1371, 763; ^1H NMR ($CDCl_3$): δ 7.41-7.37(m, 3H), 7.31(dt, J = 8.5, 1.4 Hz, 2H), 7.21(dd, J = 8.0, 1.0 Hz, 2H), 7.14 (d, J = 8.0 Hz, 2H), 6.92 (d, J = 3.5 Hz, 1H), 6.12 (d, J = 3.5 Hz, 1H), 3.96 (s, 3H), 2.40 (s, 3H).

Methyl 5-phenyl-4-tosyl-1*H*-pyrrole-2-carboxylate ($7a_a$). Colorless solid (31 mg, 87%); mp. 189-190 °C; IR (KBr, cm^{-1}): 3244, 2929, 1703, 1312, 1145, 774; ^1H NMR ($CDCl_3$): δ 9.73 (bs, 1H), 7.54-7.51 (m, 2H), 7.49 (d, J = 8.2 Hz, 2H), 7.44-7.40 (m, 3H), 7.37 (d, J = 2.8 Hz, 1H), 7.11 (d, J = 8.0 Hz, 2H), 3.78 (s, 3H), 2.32 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 161.1, 143.5, 139.6, 138.3, 129.7, 129.6, 129.3, 129.1, 128.2, 127.0, 124.3, 121.7, 117.4, 52.0, 21.4; HRMS (ESI) m/z calcd for $C_{19}H_{18}NO_4S$ $[M+H]^+$ 356.0957, found 356.0955.

Methyl 5-phenyl-3-tosyl-1*H*-pyrrole-2-carboxylate ($7a_b$). Colorless semi-solid (2 mg, 5%); IR (KBr, cm^{-1}): 3193, 2920, 1701, 1320, 746; ^1H NMR ($CDCl_3$): δ 9.67 (bs, 1H), 7.83 (d, J = 8.3 Hz, 2H), 7.58 (d, J = 7.4 Hz, 2H), 7.47 (t, J = 7.2, 2H), 7.40 (t, J = 7.2 Hz, 1H), 7.32 (d, J = 8.1 Hz, 2H), 7.22 (s, 1H), 3.85 (s, 3H), 2.44 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 176.4, 143.8, 130.9, 129.3, 129.1, 128.9, 127.9, 124.9, 111.2, 52.1, 21.6; HRMS (ESI) m/z calcd for $C_{19}H_{18}NO_4S$ $[M+H]^+$ 356.0957, found 356.0950.

1-(5-Phenyl-1-tosyl-1*H*-pyrrol-2-yl)ethan-1-one (6b). Colorless solid (123 mg, 73%); mp.132-133 °C; IR (KBr, cm^{-1}): 2922, 1716, 1291, 1121, 770; ^1H NMR ($CDCl_3$): δ 7.41 (d, J = 8.3 Hz, 3H), 7.37-7.29 (m, 2H), 7.22 (d, J = 8.0 Hz, 2H), 7.15 (d, J = 8.0 Hz, 2H), 6.93 (d, J = 3.4 Hz, 1H), 6.13 (d, J = 3.4 Hz, 1H), 2.49 (s, 3H), 2.40 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 161.8, 144.9, 143.8, 135.6, 131.3, 130.6, 130.1, 129.1, 128.8, 127.6, 127.6, 121.8, 114.4, 26.9, 21.6; HRMS (ESI) m/z calcd for $C_{19}H_{18}NO_3S$ $[M+H]^+$ 340.1007, found 340.1006.

5-Phenyl-1-tosyl-1*H*-pyrrole-2-carbaldehyde (6c). Dark brown solid (125 mg, 77%); mp. 163-169 °C; IR (KBr, cm^{-1}): 2912, 1670, 1467, 1369, 760; ^1H NMR ($CDCl_3$): δ 10.37(s, 1H), 7.45 (t, J = 7.2 Hz, 1H), 7.39 (t, J = 8.0 Hz, 2H), 7.32 (d, J = 7.2 Hz, 2H), 7.25-7.21(m, 3H), 7.14 (d, J = 8.2 Hz, 2H), 6.25 (d, J = 3.6 Hz, 1H), 2.38 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 182.2, 145.6, 144.2, 137.8, 134.9, 130.6, 130.6, 129.5, 129.3, 127.6, 126.9, 122.9, 116.6, 21.6; HRMS (ESI) m/z calcd for $C_{18}H_{16}NO_3S$ $[M+H]^+$ 326.0851, found 326.0851.

1-(5-(3,4-Dimethylphenyl)-1-tosyl-1*H*-pyrrol-2-yl)ethanone (6d). Colorless solid (111 mg, 61%); mp. 125-127 °C; IR (KBr, cm^{-1}): 2924, 2851, 1705, 1455, 834; ^1H NMR ($CDCl_3$): δ 7.34 (d,

J = 8.4 Hz, 2H), 7.27 (d, *J* = 3.6 Hz, 1H), 7.22 (d, *J* = 8.1 Hz, 2H), 7.18-7.12 (m, 2H), 6.66 (s, 1H), 6.18 (d, *J* = 3.7 Hz, 1H), 2.48 (s, 3H), 2.37 (s, 3H), 2.32 (s, 3H), 2.28 (s, 3H); ^{13}C NMR ($CDCl_3$): *δ* 181.9, 145.5, 142.3, 136.8, 136.0, 135.4, 134.0, 133.8, 130.2, 130.1, 129.6, 127.4, 122.1, 115.8, 25.3, 21.6, 20.7, 19.7; HRMS: calcd for $C_{21}H_{22}NO_3S$ $[M+H]^+$ 368.1320, found 368.1323.

5-(3,4-Dichlorophenyl)-1-tosyl-1*H*-pyrrole-2- carbaldehyde (6e). Colorless solid (110 mg, 56%); mp. 143-145 °C; IR (KBr, cm^{-1}): 2922, 1672, 1169, 812, 592; ^{1}H NMR ($CDCl_3$): *δ* 10.35 (s, 1H), 7.50 (d, *J* = 8.2 Hz, 1H), 7.29-7.19 (m, 7H), 6.28 (d, *J* = 3.6 Hz, 1H), 2.41 (s, 3H); ^{13}C NMR ($CDCl_3$): *δ* 181.9, 146.0, 141.0, 138.1, 134.7, 133.7, 131.9, 131.9, 130.5, 130.0, 129.8, 129.6, 126.9, 122.6, 117.0, 21.6; HRMS (ESI) m/z calcd for $C_{18}H_{14}Cl_2NO_3S$ $[M+H]^+$ 394.0071, found 394.0069.

Methyl 1-(methylsulfonyl)-5-phenyl-1*H*-pyrrole-2-carboxylate (6f).[23] White Solid (96 mg, 69%); IR (KBr, cm^{-1}): 3017, 2938, 1723, 1472, 753; ^{1}H NMR ($CDCl_3$): *δ* 7.44-7.41(m, 5H), 7.04 (d, *J* = 3.6 Hz, 1H), 6.23 (d, *J* = 3.6 Hz, 1H), 3.92 (s, 3H), 3.78 (s, 3H).

1-(Methylsulfonyl)-5-phenyl-1*H*-pyrrole-2-carbaldehyde (6g).[22] Brown Solid (93 mg, 75%); IR (KBr, cm^{-1}): 1663, 1377, 752; ^{1}H NMR ($CDCl_3$): *δ* 9.88 (s, 1H), 7.48-7.45 (m, 5H), 7.25 (d, *J* = 3.7 Hz, 1H), 6.39 (d, *J* = 3.7 Hz, 1H), 3.46 (s, 3H).

1-(4-((4-fluorophenyl)sulfonyl)-5-phenyl-1*H*-pyrrol-2-yl)ethanone (7b). Colorless solid (29 mg, 83%); mp. 158-160 °C; IR (KBr, cm^{-1}): 3246, 1698, 1477, 1320, 1169, 777; ^{1}H NMR ($CDCl_3$): *δ* 9.89 (bs, 1H), 7.61-7.57 (m, 2H), 7.54-7.52 (m, 2H), 7.50-7.41 (m, 4H), 7.00-6.95 (m, 2H), 2.62 (s, 3H); ^{13}C NMR ($CDCl_3$): *δ* 188.2, 166.3 (d, *J* = 253 Hz), 139.4, 138.2 (d, *J* = 3 Hz), 130.4, 130.1, 129.8, 129.7, 129.5, 128.6, 124.0, 118.2, 116.0 (d, *J* = 22 Hz), 25.3; HRMS (ESI) m/z calcd for $C_{18}H_{15}FNO_3S$ $[M+H]^+$ 344.0757, found 344.0759.

1-(5-Phenyl-4-tosyl-1*H*-pyrrol-2-yl)ethanone (7c). Brownish solid (29 mg, 85%); mp. 186-188 °C; IR (KBr, cm^{-1}): 3245, 2924, 2854, 1739, 1651, 1139, 841; ^{1}H NMR($CDCl_3$): *δ* 9.69 (bs, 1H), 7.56-7.54 (m, 2H), 7.51 (d, *J* = 8.3 Hz, 2H), 7.47-7.40 (m, 4H), 7.13 (d, *J* = 8.0 Hz, 2H), 2.47 (s, 3H), 2.34 (s, 3H); ^{13}C NMR ($CDCl_3$): *δ* 188.0, 143.6, 139.4, 139.1, 130.3, 130.0, 129.4, 129.3, 128.8, 128.4, 127.0, 124.5, 118.1, 25.3, 21.4; HRMS (ESI) m/z calcd for $C_{19}H_{18}NO_3S$ $[M+H]^+$ 340.1007, found 340.1009.

5-Phenyl-4-tosyl-1*H*-pyrrole-2-carbaldehyde (7d). Yellowish solid (27 mg, 84%); mp. 191-192 °C; IR (KBr, cm^{-1}): 3244, 2924, 2834, 1651, 707; ^{1}H NMR ($CDCl_3$): *δ* 9.95 (bs, 1H), 9.57 (s, 1H), 7.59 (d, *J* = 6.8 Hz, 2H), 7.57-7.42 (m, 6H), 7.15 (d, *J* = 8.0 Hz, 2H), 2.35 (s, 3H); ^{13}C NMR ($CDCl_3$): *δ* 179.3, 143.8, 140.4, 139.1, 130.7, 130.2, 129.4, 129.4, 128.5, 127.1, 125.5, 122.3, 119.1, 21.4; HRMS (ESI) m/z calcd for $C_{18}H_{16}NO_3S$ $[M+H]^+$ 326.0851, found 326.0852.

1-(5-(3,4-Dimethylphenyl)-4-tosyl-1*H*-pyrrol-2-yl)ethanone (7e). Colorless solid (24 mg, 65%); mp. 191-193 °C; IR (KBr, cm^{-1}): 3257, 2924, 2853, 1666, 1465, 822; ^{1}H NMR ($CDCl_3$): *δ* 9.62 (bs, 1H), 7.58 (d, *J* = 8.2 Hz, 2H), 7.44 (d, *J* = 2.8 Hz, 1H), 7.31 (dd, *J* = 1.6, 7.7 Hz, 1H), 7.25 (s, 1H), 7.18-7.15 (m, 3H), 2.48 (s, 3H), 2.37 (s, 3H), 2.32 (s, 3H), 2.28 (s, 3H); ^{13}C NMR ($CDCl_3$): *δ* 187.9, 143.5, 139.7, 139.6, 138.9, 136.7, 130.2, 130.1, 129.7, 129.3, 127.0, 126.7, 126.2, 123.9, 118.4, 25.2, 21.4, 19.7, 19.6; HRMS (ESI) m/z calcd for $C_{21}H_{22}NO_3S$ $[M+H]^+$ 368.1320, found 368.1323.

5-(3,4-Dichlorophenyl)-4-tosyl-1*H*-pyrrole-2-carbaldehyde (7f). Colorless solid (31 mg, 80%); mp.207-208 °C; IR (KBr, cm^{-1}): 3247, 2924, 2853, 1650, 755; ^{1}H NMR ($CDCl_3$): *δ* 10.02 (bs, 1H), 9.55 (s, 1H), 7.60 (d, *J* = 1.6 Hz, 1H), 7.56 (d, *J* = 8.3 Hz, 2H), 7.50-7.47 (m, 3H), 7.20 (d, *J* = 8.0 Hz, 2H), 2.37 (s, 3H); ^{13}C NMR ($CDCl_3$): *δ* 179.4, 144.3, 138.8, 137.2, 134.8, 132.9, 131.1, 131.0, 130.6, 129.3, 128.7, 128.2, 127.1, 126.2, 122.1, 21.5; HRMS (ESI) m/z calcd for $C_{18}H_{14}Cl_2NO_3S$ $[M+H]^+$ 394.0071, found 394.0069.

Methyl 4-(methylsulfonyl)-5-phenyl-1*H*-pyrrole-2-carboxylate (7g). Colorless solid (19 mg, 70%); mp. 180-185 °C; IR (KBr, cm^{-1}): 3443, 2922, 1716, 1291, 1121, 770; ^{1}H NMR ($CDCl_3$): *δ* 9.72 (bs, 1H), 7.76-7.75 (m, 2H), 7.52-7.51 (m, 3H), 7.42 (d, *J* = 2.8 Hz, 1H), 3.88 (s, 3H), 2.89 (s, 3H); ^{13}C NMR ($CDCl_3$): *δ* 160.9, 137.5, 130.1, 129.2, 128.9, 127.6, 123.4, 121.9, 117.2, 52.2, 44.3; HRMS (ESI) m/z calcd for $C_{13}H_{14}NO_4S$ $[M+H]^+$ 280.0644, found 280.0639.

4-(Methylsulfonyl)-5-phenyl-1*H*-pyrrole-2-carbaldehyde (7h). Yellow solid (5 mg, 21%); mp. 130-135 °C; IR (KBr, cm^{-1}): 3239, 2923, 1668, 1297, 1129, 764; ^{1}H NMR ($CDCl_3$): *δ* 9.93 (bs, 1H), 9.59 (s, 1H), 7.80-7.78 (m, 2H), 7.53-7.49 (m, 4H), 2.88 (s, 3H); ^{13}C NMR ($CDCl_3$): *δ* 179.4, 131.1, 130.8, 130.6, 129.1, 128.4, 125.6, 124.4, 122.2, 44.1; HRMS (ESI) m/z calcd for $C_{12}H_{12}NO_3S$ $[M+H]^+$ 250.0538, found 250.0539.

1-(1-Tosyl-1*H*-pyrrol-2-yl)ethanone (8a). Colorless solid (117 mg, 89%); mp. 93-94 °C; IR (KBr, cm^{-1}): 3050, 1672, 1593, 1442, 1367, 1173, 744; ^{1}H NMR ($CDCl_3$): *δ* 7.92 (d, *J* = 8.4 Hz, 2H), 7.84 (dd, *J* = 3.2, 1.7 Hz, 1H), 7.34 (d, *J* = 8.4 Hz, 2H), 7.07 (dd, *J* = 3.7, 1.7 Hz, 1H), 6.35 (t, *J* = 3.4 Hz, 1H), 2.43 (s, 3H), 2.37 (s, 3H); ^{13}C NMR ($CDCl_3$): *δ* 185.8, 144.7, 135.9, 133.2, 130.3, 129.3, 128.3, 124.3, 110.2, 26.9, 21.6; HRMS (ESI) m/z calcd for $C_{13}H_{14}NO_3S$ $[M+H]^+$ 264.0694, found 264.0693.

Methyl 1-tosyl-1*H*-pyrrole-2-carboxylate (8b). Colorless solid (125 mg, 90%); mp. 104-106 °C; IR (KBr, cm^{-1}): 2923, 1728, 1594, 1358, 1146, 742; ^{1}H NMR ($CDCl_3$): *δ* 7.90 (d, *J* = 8.4 Hz, 2H), 7.74 (dd, *J* = 3.1, 1.8 Hz, 1H), 7.35 (d, *J* = 8.2 Hz, 2H), 7.07 (dd, *J* = 3.5, 1.8 Hz, 1H), 6.32 (t, *J* = 3.5 Hz, 1H), 3.74 (s, 3H), 2.44 (s, 3H); ^{13}C NMR ($CDCl_3$): *δ* 159.1, 144.9, 135.8, 129.4, 129.1, 128.2, 124.8, 123.3, 110.3, 51.7, 21.7; HRMS (ESI) m/z calcd for $C_{13}H_{14}NO_4S$ $[M+H]^+$ 280.0644, found 280.0639.

Methyl 8-methylbenzo[d]pyrrolo[1,2-b]isothiazole-3-carboxylate 5,5-dioxide (9).[18] White-crystalline solid (94 mg, 68%); IR (KBr, cm^{-1}): 3421, 2949, 1632, 1421, 1160, 1033; ^{1}H NMR ($CDCl_3$): *δ* 7.68 (d, *J* = 8.0 Hz, 1H), 7.40 (s, 1H), 7.30 (d, *J* = 8.0 Hz, 1H), 7.05 (d, *J* = 3.7 Hz, 1H), 6.48 (d, *J* = 3.7 Hz, 1H), 3.97 (s, 3H), 2.48 (s, 3H).

1-Tosyl-1*H*-pyrrole-2-carbaldehyde (8c). Bluish solid, (105 mg, 85%); mp. 107-109 °C; IR (KBr, cm^{-1}): 2895, 1666, 1538, 1421, 1363, 1251, 1153, 1086, 1056, 776, 670; ^{1}H NMR ($CDCl_3$): δ 9.98 (s, 1H), 7.82 (d, J = 8.4 Hz, 2H), 7.63 (dd, J = 3.0, 1.8 Hz, 1H), 7.34 (d, J = 8.1 Hz, 2H), 7.17 (dd, J = 3.7, 1.7 Hz, 1H), 6.41 (t, J = 3.3 Hz, 1H), 2.43 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 178.9, 145.9, 135.2, 133.5, 130.1, 129.4, 127.4, 124.4, 112.4, 21.6; HRMS (ESI) m/z calcd for $C_{12}H_{12}NO_3S$ $[M+H]^+$ 250.0538, found 250.0537.

Ethyl 1-tosyl-1*H*-pyrrole-2-carboxylate (8d). Off-white solid (121 mg, 83%); mp. 105-107 °C; IR (KBr, cm^{-1}): 2929, 1728, 1443, 1360, 1144, 754; ^{1}H NMR ($CDCl_3$): δ 7.90 (d, J = 8.3 Hz, 2H), 7.73 (dd, J = 3.2, 1.8 Hz, 1H), 7.34 (d, J = 8.3 Hz, 2H), 7.06 (dd, J = 3.6, 1.8 Hz, 1H), 6.31 (t, J = 3.4 Hz, 1H), 4.22 (q, J = 7.1 Hz, 2H), 2.44 (s, 3H), 1.27 (t, J = 7.1 Hz, 3H); ^{13}C NMR ($CDCl_3$): δ 158.7, 144.8, 135.9, 129.4, 129.0, 128.1, 125.2, 123.0, 110.2, 60.7, 21.6, 14.1; HRMS (ESI) m/z calcd for $C_{14}H_{16}NO_4S$ $[M+H]^+$ 294.0800, found 294.0798.

Methyl 1-((3,5-dimethylphenyl)sulfonyl)-1*H*-pyrrole-2-carboxylate (8e). Yellowish solid (95 mg, 65%); mp. 120-122 °C; IR (KBr, cm^{-1}): 3142, 2923, 1732, 1450, 1147, 757; ^{1}H NMR ($CDCl_3$): δ 7.47 (dd, J = 3.1, 1.8 Hz, 1H), 7.57 (s, 2H), 7.25 (s, 1H), 7.09 (dd, J = 3.6, 1.8 Hz, 1H), 6.35 (t, J = 3.4 Hz, 1H), 3.74 (s, 3H), 2.40 (s, 6H); ^{13}C NMR ($CDCl_3$): δ 159.0, 138.9, 138.6, 135.6, 129.2, 125.3, 124.9, 123.3, 110.3, 51.7, 21.2; HRMS (ESI) m/z calcd for $C_{14}H_{16}NO_4S$ $[M+H]^+$ 294.0800 found 294.0804.

Methyl 1-((3-fluorophenyl)sulfonyl)-1*H*-pyrrole-2-carboxylate (8f). Off-white solid (108 mg, 77%); mp. 128-130 °C; IR (KBr, cm^{-1}): 3077, 2962, 1762, 1597, 1365, 1147, 794; ^{1}H NMR ($CDCl_3$): δ 7.82-7.79 (m, 1H), 7.73-7.69 (m, 2H), 7.57-7.51 (m, 1H), 7.37-7.32 (m, 1H), 7.10 (q, J = 1.8 Hz, 1H), 6.37 (t, J = 3.4 Hz, 1H), 3.75 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 163.2 (d, J = 251 Hz), 159.0, 140.7 (d, J = 29 Hz), 130.6 (d, J = 31 Hz), 129.1, 125.0, 123.8 (d, J = 13 Hz), 123.6, 121.2 (d, J = 21 Hz), 115.6, 115.3, 110.0, 51.8; HRMS (ESI) m/z calcd for $C_{12}H_{11}FNO_4S$ $[M+H]^+$ 284.0393, found 284.0396.

1-((2,4-Dinitrophenyl)sulfonyl)-1*H*-pyrrole-2-carbaldehyde (8g). Yellowish solid (84 mg, 52%); mp. 142-143 °C; IR (KBr, cm^{-1}): 2923, 2852, 1675, 1539, 1349, 745; ^{1}H NMR ($CDCl_3$): δ 9.49 (s, 1H), 8.86 (d, J = 8.0 Hz, 1H), 8.66-8.63 (m, 2H), 7.80-7.78 (m, 1H), 7.27 (dd, J = 3.6, 1.7 Hz, 1H), 6.57 (t, J = 3.5 Hz, 1H); ^{13}C NMR ($CDCl_3$): δ 177.0, 150.6, 148.3, 136.4, 135.9, 133.4, 132.6, 130.6, 126.3, 120.1, 112.3; HRMS(ESI) m/z calcd for $C_{11}H_8N_3O_7S$ $[M+H]^+$ 326.0083, found 326.0080.

Methyl 1-(methylsulfonyl)-1*H*-pyrrole-2-carboxylate (8h).[23] Colorless liquid; (285 mg, 77%); IR (ATR, cm^{-1}): 2924, 2853, 1722, 1150, 757; ^{1}H NMR ($CDCl_3$): δ 7.53-7.52 (m, 1H), 7.12-7.11 (m, 1H), 6.29 (t, J = 3.4 Hz, 1H), 3.89(s, 3H), 3.73(s, 3H).

1-(Methylsulfonyl)-1*H*-pyrrole-2-carbaldehyde (8i).[23] Brown solid; (283 mg, 82%); IR (KBr, cm^{-1}): 3017, 2933, 2843 2793, 1674, 1362, 743; ^{1}H NMR ($CDCl_3$): δ 9.69 (d, J = 0.84 Hz, 1H), 7.62-7.61 (m, 1H), 7.23-7.22 (m, 1H), 6.42(t, J = 3.3 Hz, 1H), 3.64(s, 3H).

1-(Methylsulfonyl)-1*H*-pyrrole (8j).[23] Brown liquid; (128 mg, 44%); IR (ATR, cm^{-1}): 3025, 2933, 1730, 1456, 739; ^{1}H NMR ($CDCl_3$): δ 7.15(t, J = 2.3 Hz, 2H), 6.39(t, J = 2.3 Hz, 2H), 3.16(s, 3H).

2-Phenyl-1-tosyl-1*H*-pyrrole (8k). Brown solid (100 mg, 68%); mp. 112-114 °C; IR (KBr, cm^{-1}): 2923, 1634, 1368, 1169, 761; ^{1}H NMR ($CDCl_3$): δ 7.46 (dd, J = 3.2, 1.8 Hz, 1H), 7.40-7.36 (m, 1H), 7.35-7.30 (m, 2H), 7.25 (d, J = 8.4 Hz, 4H), 7.12 (d, J = 8.1 Hz, 2H), 6.33 (d, J = 3.3 Hz, 1H), 6.18 (dd, J = 1.8, 3.1 Hz, 1H), 2.37 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 144.4, 136.0, 135.6, 131.4, 130.9, 129.4, 128.2, 127.3, 127.1, 124.0, 115.7, 112.0, 21.5; HRMS (ESI) m/z calcd for $C_{17}H_{16}NO_2S$ $[M+H]^+$ 298.0902, found 298.0904.

(1-Tosyl-1*H*-pyrrol-2-yl)methanol ($8l_a$). Colorless solid (114 mg, 91%); mp. 131-132 °C; IR (KBr, cm^{-1}): 3785, 3389, 2924, 1597, 1366, 812; ^{1}H NMR ($CDCl_3$): δ 7.74 (d, J = 8.4 Hz, 2H), 7.33 (d, J = 8.1 Hz, 2H), 7.31 (m, 1H), 6.28-6.24 (m, 2H), 4.62 (d, J = 7.0 Hz, 2H), 2.74 (t, J = 7.1 Hz, 1H), 2.43 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 145.2, 136.1, 134.5, 130.1, 126.6, 123.6, 115.2, 111.8, 56.8, 21.6; HRMS: calcd for $C_{12}H_{14}NO_3S$ $[M+H]^+$ 252.0694, found 252.0698.

2-(Methoxymethyl)-1-tosyl-1*H*-pyrrole (8l). Off-white solid (101 mg, 76%): mp. 102-103 °C; IR (KBr, cm^{-1}): 2925, 1596, 1397, 1366, 1175, 949, 669; ^{1}H NMR ($CDCl_3$): δ 7.79 (d, J = 8.4 Hz, 2H), 7.34 (dd, J = 1.8, 3.2 Hz, 1H), 7.29 (d, J = 8.1 Hz, 2H), 6.28 (dd, J = 1.8, 3.2 Hz, 1H), 6.24 (t, J = 3.2 Hz, 1H), 4.56 (s, 2H), 3.20 (s, 3H), 2.41 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 144.6, 136.4, 131.2, 129.6, 127.1, 123.8, 115.9, 111.1, 65.8, 57.3, 21.6; HRMS (ESI) m/z calcd for $C_{13}H_{16}NO_3S$ $[M+H]^+$ 266.0851, found 266.0850.

Diethyl 1-(methylsulfonyl)-1*H*-pyrrole-3,4-dicarboxylate (8m). Brown solid (421 mg, 73%); mp. 132-134 °C; IR (KBr, cm^{-1}): 2930, 1730, 1175, 1067, 770; ^{1}H NMR ($CDCl_3$): δ 7.65 (s, 2H), 4.33(q, J = 7.1 Hz, 4H), 1.36 (t, J = 7.2 Hz, 6H); ^{13}C NMR ($CDCl_3$): δ 162.1, 125.3, 120.1, 61.0, 43.3, 14.1; HRMS (ESI) m/z calcd for $C_{11}H_{16}NO_6S$ $[M+H]^+$ 290.0698, found 290.0699.

1-(1-((4-Fluorophenyl)sulfonyl)-1*H*-pyrrol-2-yl)ethanone (8n). White solid (85 mg, 62%); mp. 105-107 °C; IR (KBr, cm^{-1}): 3044, 1701, 1442, 1385, 1176, 737; ^{1}H NMR ($CDCl_3$): δ 8.07-8.03 (m, 2H), 7.81 (dd, J = 1.7, 3.1 Hz, 1H); 7.21 (m, 2H), 7.07 (dd, J = 1.7, 3.7 Hz, 1H), 6.36 (t, J = 3.5 Hz, 1H), 2.36 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 185.9, 166.8 (d, J = 256 Hz), 134.7 (d, J = 3 Hz), 133.3, 131.4, 131.3, 130.3, 124.5, 116.1 (d, J = 22 Hz), 110.5, 26.9; HRMS (ESI) m/z calcd for $C_{12}H_{11}FNO_3S$ $[M+H]^+$ 268.0444, found 268.0447.

Ethyl 5-phenyl-4-tosyl-1*H*-pyrrole-2-carboxylate (7i). Off-white solid (81 mg, 88%); mp. 192-194 °C; IR (KBr, cm^{-1}): 3239, 2981, 1698, 1509, 1312, 714; ^{1}H NMR ($CDCl_3$): δ 9.65 (bs, 1H), 7.56-7.53 (m, 2H), 7.52 (d, J = 8.3 Hz, 2H), 7.48-7.40 (m, 4H), 7.14 (d, J = 8.0 Hz, 2H), 4.29 (q, J = 7.6 Hz, 2H), 2.35 (s, 3H), 1.36 (t, J = 7.1 Hz, 3H); ^{13}C NMR ($CDCl_3$): δ 160.5, 143.4, 139.7, 137.9, 129.5, 129.3, 129.1, 128.3, 127.0, 124.3, 122.1, 117.1,

61.2, 21.4, 14.2; HRMS(ESI) m/z calcd for $C_{20}H_{20}NO_4S$ $[M+H]^+$ 370.1113, found 370.1114.

Ethyl 5-(4-nitrophenyl)-4-tosyl-1*H*-pyrrole-2-carboxylate (7j$_a$). Yellowish solid (41 mg, 40%); mp. 122-127 °C; IR (KBr, cm^{-1}): 3220, 1721, 1533, 1105, 715; ^{1}H NMR ($CDCl_3$): δ 10.09 (bs, 1H), 8.31-8.28 (m, 2H), 8.04 (d, *J* = 8.0 Hz, 1H), 7.65 (t, *J* = 8.3 Hz, 1H), 7.58 (d, *J* = 8.2 Hz, 2H), 7.41 (d, *J* = 2.6 Hz, 1H), 7.19 (d, *J* = 8.1 Hz, 2H), 4.27 (q, *J* = 7.1 Hz, 2H), 2.38 (s, 3H), 1.34 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR ($CDCl_3$): δ 160.3, 147.9, 144.1, 139.3, 135.9, 134.6, 130.6, 129.6, 129.5, 127.0, 125.5, 124.2, 124.2, 123.2, 117.3, 61.5, 21.5, 14.2; HRMS (ESI) m/z calcd for $C_{20}H_{19}N_2O_6S$ $[M+H]^+$ 415.0964, found 415.0959.

Ethyl 5-(4-nitrophenyl)-4-tosyl-1*H*-pyrrole-2-carboxylate (7j$_b$). Yellowish semi-solid (17 mg, 17%); IR (KBr, cm^{-1}): 3239, 1714, 1534, 1350, 1140, 701; ^{1}H NMR ($CDCl_3$): δ 10.05 (bs, 1H), 8.28 (d, *J* = 8.7 Hz, 2H), 7.80 (d, *J* = 8.7 Hz, 2H), 7.55 (d, *J* = 8.3 Hz, 2H), 7.39 (d, *J* = 2.6 Hz, 1H), 7.19 (d, *J* = 8.1 Hz, 2H), 4.25 (q, *J* = 7.1 Hz, 2H), 2.37 (s, 3H), 1.34 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR($CDCl_3$): δ 160.3, 148.2, 144.1, 139.2, 135.2, 134.7, 130.6, 129.6, 127.0, 125.7, 123.5, 117.4, 61.5, 21.5, 14.2; HRMS (ESI) m/z calcd for $C_{20}H_{19}N_2O_6S$ $[M+H]^+$ 415.0964, found 415.0960.

Methyl 5-(3,4-dichlorophenyl)-4-tosyl-1*H*-pyrrole-2-carboxylate (7k$_a$). Colorless solid (63 mg, 60%); mp. 218-219 °C; IR (KBr, cm^{-1}): 3292, 2924, 1733, 1460, 810; ^{1}H NMR ($CDCl_3$): δ 9.93 (bs, 1H), 7.55-7.53 (m, 3H), 7.50 (d, *J* = 8.2 Hz, 1H), 7.46 (dd, *J* = 8.3, 2.1Hz, 1H), 7.35 (d, *J* = 2.8 Hz, 1H), 7.19 (d, *J* = 8.0 Hz, 2H), 3.80 (s, 3H), 2.36 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 160.8, 144.0, 139.2, 134.9, 134.2, 132.7, 131.0, 130.4, 129.5, 129.0, 128.8, 127.1, 125.2, 122.4, 117.3, 52.2, 21.5; HRMS (ESI) m/z calcd for $C_{19}H_{16}Cl_2NO_4S$ $[M+H]^+$ 424.0177, found 424.0176.

Methyl 5-(3,4-dichlorophenyl)-3-tosyl-1*H*-pyrrole-2-carboxylate (7k$_b$). Off-white solid (26 mg, 25%); mp. 238-240 °C; IR (KBr, cm^{-1}): 3214, 1724, 1417, 773; ^{1}H NMR ($CDCl_3$): δ 9.90 (bs, 1H), 7.92 (d, *J* = 8.2 Hz, 2H), 7.68 (d, *J* = 2.0 Hz, 1H), 7.54 (d, *J* = 8.3 Hz, 1H), 7.43 (dd, *J* = 8.3, 2.0 Hz, 1H), 7.33 (d, *J* = 8.1 Hz, 2H), 7.21 (d, *J* = 3.1 Hz, 1H), 3.83 (s, 3H), 2.44 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 158.7, 144.0, 138.8, 133.6, 132.9, 132.1, 131.2, 131.1, 129.5, 129.2, 127.9, 126.8, 124.1, 121.7, 112.0, 52.2, 21.6; HRMS (ESI) m/z calcd for $C_{19}H_{16}Cl_2NO_4S$ $[M+H]^+$ 424.0177, found 424.0180.

5-(2,5-Dimethylphenyl)-4-tosyl-1*H*-pyrrole-2-carbaldehyde (7l). Buff-color solid (53 mg, 61%), mp. 89-91 °C; IR (KBr, cm^{-1}): 3239, 2948, 2853, 1650, 710; ^{1}H NMR ($CDCl_3$): δ 9.79 (bs, 1H), 9.54 (s, 1H), 7.59 (d, *J* = 8.3 Hz, 2H), 7.49 (d, *J* = 2.76 Hz, 1H), 7.35 (dd, *J* = 1.7, 7.7 Hz, 1H), 7.30 (s, 1H), 7.20-7.16 (m, 3H), 2.37 (s, 3H), 2.33 (s, 3H), 2.29 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 179.3, 143.5, 139.5, 138.1, 135.1, 134.6, 131.5, 130.6, 129.8, 129.0, 128.1, 127.3, 125.0, 121.4, 115.7, 21.5, 20.7, 19.0; HRMS (ESI) m/z calcd for $C_{20}H_{20}NO_3S$ $[M+H]^+$ 354.1164, found 354.1168.

Methyl 5-(2,5-dimethylphenyl)-1*H*-pyrrole-2-carboxylate (7m). Buff-color solid (67 mg, 71%); mp. 198-199 °C; IR (KBr, cm^{-1}): 3251, 2955, 1686, 1484, 1315, 816; ^{1}H NMR ($CDCl_3$): δ 9.85 (bs, 1H), 7.42 (d, *J* = 2.4 Hz, 1H), 7.40 (d, *J* = 8.1 Hz, 2H), 7.16-7.06 (m, 4H), 6.82 (s, 1H), 3.70 (s, 3H), 2.37 (s, 3H), 2.27 (s, 3H), 1.85 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 161.1, 143.3, 139.5, 138.0, 135.1, 134.6, 131.5, 130.6, 129.7, 129.1, 128.3, 127.3, 125.0, 121.4, 115.8, 51.9, 21.5, 20.7, 19.0; HRMS (ESI) m/z calcd for $C_{21}H_{22}NO_4S$ $[M+H]^+$ 384.1270, found 384.1271.

Ethyl 5-(2,5-dimethylphenyl)-4-tosyl-1*H*-pyrrole-2-carboxylate (7n). Off-white solid (62 mg, 63%); mp. 212-213 °C; IR (KBr, cm^{-1}): 3240, 2982, 1681, 1484, 1316, 816; ^{1}H NMR ($CDCl_3$): δ 9.41 (bs, 1H), 7.42 (d, *J* = 2.8 Hz, 1H), 7.39 (d, *J* = 8.2 Hz, 2H), 7.16-7.06 (m, 4H), 6.80 (s, 1H), 4.25 (q, *J* = 7.1 Hz, 2H), 2.35 (s, 3H), 2.26 (s, 3H), 1.85 (s, 3H), 1.33 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR ($CDCl_3$): δ 160.5, 143.3, 139.5, 137.8, 135.1, 134.7, 131.5, 130.6, 129.7, 129.1, 128.3, 127.4, 125.0, 121.8, 115.6, 61.1, 21.4, 20.7, 19.1, 14.2; HRMS (ESI) m/z calcd for $C_{22}H_{24}NO_4S$ $[M+H]^+$ 398.1426, found 398.1424.

Methyl 4-((3,5-dimethylphenyl)sulfonyl)-5-phenyl-1*H*-pyrrole-2-carboxylate (7o). Off-white solid (69 mg, 75%); mp. 176-178 °C; IR (KBr, cm^{-1}): 3244, 2928, 1733, 1490, 868; ^{1}H NMR ($CDCl_3$): δ 9.71 (bs, 1H), 7.55-7.52 (m, 2H), 7.47-7.40 (m, 4H), 7.18 (s, 2H), 7.05 (s, 1H), 3.81 (s, 3H), 2.21 (s, 6H); ^{13}C NMR ($CDCl_3$): δ 160.9, 142.0, 138.6, 138.1, 134.3, 129.7, 129.7, 129.1, 128.3, 124.6, 121.6, 117.2, 52.0, 21.0; HRMS (ESI) m/z calcd for $C_{20}H_{20}NO_4S$ $[M+H]^+$ 370.1113, found 370.1110.

Methyl 4-((3-fluorophenyl)sulfonyl)-5-phenyl-1*H*-pyrrole-2-carboxylate (7p). Colorless solid (70 mg, 78%); mp. 161-163 °C; IR (KBr, cm^{-1}): 3248, 1699, 1474, 1318, 1172, 777; ^{1}H NMR ($CDCl_3$): δ 10.06 (bs, 1H), 7.53 (d, *J* = 3.6 Hz, 2H), 7.49-7.37 (m, 4H), 7.32-7.24 (m, 2H), 7.16 (dt, *J* = 1.7, 8.1 Hz, 1H), 3.75 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 163.3 (d, *J* = 250 Hz), 161.0, 144.5 (d, *J* = 26 Hz), 138.8, 130.5 (d, *J* = 29 Hz), 129.9, 129.6, 128.8, 128.3, 123.3, 122.7 (d, *J* = 12 Hz), 122.0, 119.9 (d, *J* = 84 Hz), 117.4, 114.5, 52.1; HRMS (ESI) m/z calcd for $C_{18}H_{15}FNO_4S$ $[M+H]^+$ 360.0706, found 360.0707.

3-(Methylsulfonyl)-2,5-diphenyl-1*H*-pyrrole (7r). Buff-color solid (51%, 38 mg); mp. 120-125 °C; IR (KBr, cm^{-1}): 3257, 1286, 1116, 762; ^{1}H NMR($CDCl_3$): δ 9.02(s, 1H), 7.74 (d, *J* = 7.9 Hz, 2H), 7.54 (d, *J* = 7.6 Hz, 2H), 7.50-7.42 (m, 5H), 7.33 (t, 1H, *J* = 7.4 Hz), 6.98 (d, 1H, *J* = 3 Hz), 2.88 (s, 3H); ^{13}C NMR: δ 134.4, 132.0, 130.6, 129.9, 129.2, 129.1, 129.1, 128.8, 127.7, 124.3, 122.5, 108.1, 44.5; HRMS (ESI) m/z calcd for $C_{17}H_{16}NO_2S$ $[M+H]^+$ 298.0902, found 298.0909.

5-(2,5-dimethylphenyl)-2-phenyl-3-tosyl-1*H*-pyrrole & 2-(2,5-dimethylphenyl)-5-phenyl-3-tosyl-1*H*-pyrrole (1:1 mixture) (7t). Off-white solid (82 mg, 82%): mp. 244-245 °C; IR (KBr, cm^{-1}): 3775, 3302, 2924, 2854, 1735, 1598, 1450, 1156, 1082, 812, 709; ^{1}H NMR ($CDCl_3$): δ 8.54 (bs, 1H), 8.49 (bs, 1H), 7.60-7.58 (m, 4H), 7.49-7.38 (m, 9H), 7.31-7.29 (m, 1H), 7.19-7.12 (m, 8H), 7.09 (d, *J* = 7.6 Hz, 1H), 7.04 (d, *J* = 3.0 Hz, 1H), 6.92 (s, 1H), 6.84 (d, *J* = 3.0 Hz, 1H), 2.44 (s, 3H), 2.38 (s, 3H), 2.36-2.35 (m, 6H), 2.31 (s, 3H), 1.97 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 142.9, 140.5, 140.3, 135.7, 134.6, 134.2, 132.3, 132.0, 131.3, 131.2, 130.9, 130.3, 129.7, 129.4, 129.3, 129.2, 129.1, 129.0, 128.9, 128.7, 128.3, 127.4, 127.2, 126.9, 123.9, 122.6, 111.0, 21.4

20.8, 20.7, 20.6, 19.3; HRMS (ESI) m/z calcd for $C_{25}H_{24}NO_2S$ $[M+H]^+$ 402.1528, found 402.1532.

Methyl 5-(4-methoxyphenyl)-4-tosyl-1*H*-pyrrole-2-carboxylate ($7u_a$). Yellow semi-solid (53 mg, 54%); IR (KBr, cm^{-1}): 3195, 2927, 1680, 1277; ^1H NMR ($CDCl_3$): δ 9.57 (s, 1H), 7.53-7.50(m, 4H), 7.38 (d,*J* = 2.7 Hz, 1H), 7.15 (d, *J* = 8.0 Hz, 2H), 6.96 (d, *J* = 8.8 Hz, 2H), 3.88 (s, 3H), 3.84 (s, 3H), 2.35 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 160.9, 160.7, 143.4, 139.7, 138.2, 130.9, 129.3, 127.0, 123.7, 121.4, 121.3, 117.4, 113.8, 55.4, 52.1, 21.5; HRMS (ESI) m/z calcd for $C_{20}H_{20}NO_5S$ $[M+H]^+$386.1062, found 386.1060.

Methyl 5-(3-methoxyphenyl)-4-tosyl-1*H*-pyrrole-2-carboxylate ($7u_b$). Yellow semi-solid, (26 mg, 26%); IR (KBr, cm^{-1}): 3255, 2919, 1661, 766; ^1H NMR ($CDCl_3$): δ 10.04 (s, 1H), 7.53(d, *J* = 8.3 Hz, 2H), 7.39 (d,*J* = 2.7 Hz, 1H), 7.30-7.28 (m, 1H), 7.16-7.12(m, 3H),7.09 (d, *J* = 8 Hz, 1H), 6.99 – 6.97 (m, 1H), 3.83 (s, 3H), 3.80 (s, 3H), 2.34 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 161.0, 159.2, 143.5, 139.5, 138.0, 130.2, 129.4, 129.3, 127.0, 124.2, 121.6, 121.6, 117.5, 115.9, 114.8, 55.4, 52.1, 21.5; HRMS (ESI) m/z calcd for $C_{20}H_{20}NO_5S$ $[M+H]^+$386.1062, found 386.1055.

Methyl 5-(cyanophenyl)-4-tosyl-1*H*-pyrrole-2-carboxylate ($7v_a$:$7v_b$). Yellow semi-solid, (26 mg, 23%); IR (KBr, cm^{-1}): 3195, 2230, 2927, 1680, 1277; ^1H NMR($CDCl_3$): δ 10.01 (s, 1H), 7.93(d, *J* = 8.0 Hz, 0.6 H), 7.76-7.74 (m, 2.5 H), 7.61-7.53 (m, 2.6 H), 7.39 (d, *J* = 8.3 Hz, 1H), 7.21-7.18 (m, 2H), 3.89 (s, 3H), 3.50 (s, 1.6H), 2.39 (s, 3.2H); ^{13}C NMR ($CDCl_3$): δ161.6, 160.8, 144.1, 139.3, 139.2, 134.2, 133.0, 132.7, 132.1, 130.4, 130.2, 129.6, 129.6, 129.4, 128.6, 127.3, 127.0, 127.0, 125.4, 122.7, 117.3, 114.0, 112.8, 53.2, 52.3, 22.7, 21.5; HRMS (ESI) m/z calcd for $C_{20}H_{17}N_2O_4S$ $[M+H]^+$381.0909, found 381.0900.

(5-Phenyl-1*H*-pyrrol-2-yl)methyl 4-methylbenzenesulfonate (10). Colorless semi-solid (8 mg, 11%); IR (ATR, cm^{-}): 3434, 2924, 1371, 1189, 763; ^1H NMR ($CDCl_3$): δ 9.12 (bs, 1H), 7.56-7.51 (m, 4H), 7.43-7.40 (m, 4H), 7.15 (d, *J* = 8.0 Hz, 2H), 6.75 (d, *J* = 2.8 Hz, 1H), 5.01 (s, 2H), 2.35 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 144.6, 138.8, 136.2, 132.6, 131.0, 129.3, 128.2, 127.2, 126.7, 115.7, 114.9, 60.4, 21.5; HRMS (ESI) m/z calcd for $C_{18}H_{18}NO_3S$ $[M+H]^+$ 328.1007, found 328.1010.

(5-Phenyl-1-tosyl-1*H*-pyrrol-2-yl)methanol (11). Colorless semi-solid (12 mg, 15%); IR (ATR, cm^{-1}): 3389, 2924, 1597, 1371, 1174, 663, 590; ^1H NMR ($CDCl_3$): δ 7.38 (t, *J* = 7.3 Hz, 1H), 7.31-7.26 (m, 4H), 7.20 (d, *J* = 8.1 Hz, 2H), 7.12 (d, *J* = 8.1 Hz, 2H), 6.37 (d, *J* = 3.3 Hz, 1H), 6.11 (d, *J* = 3.3 Hz, 1H), 5.43 (s, 2H), 2.38 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 144.6, 138.8, 136.2, 132.0, 131.0, 129.3, 128.2, 127.1, 126.7, 115.7, 114.9, 60.4, 60.2, 21.5; HRMS (ESI) m/z calcd for $C_{18}H_{18}NO_3S$ $[M+H]^+$ 328.1007, found 328.1008.

2-(Methoxymethyl)-5-phenyl-1-tosyl-1*H*-pyrrole (12). Yellowish semi-solid (53 mg, 63%); IR (ATR, cm^{-1}): 2924, 1735, 1445, 1371, 1174, 1093, 811, 660, 590; ^1H NMR ($CDCl_3$): δ 7.37-7.29 (m, 5H), 7.26 (d, *J* = 8.1 Hz, 2H), 7.15 (d, *J* = 8.1 Hz, 2H), 6.32 (d, *J* = 3.3 Hz, 1H), 6.18 (d, *J* = 3.3 Hz, 1H), 4.74 (s, 2H), 3.44 (s, 3H), 2.35 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 144.4, 138.6, 136.3, 134.5, 132.4, 131.0, 129.2, 128.1, 127.1, 127.0, 115.3, 114.9, 68.1, 58.0, 21.5; HRMS (ESI) m/z calcd for $C_{19}H_{20}NO_3S$ $[M+H]^+$ 342.1164, found 342.1161.

Methyl 5-formyl-1-(methylsulfonyl)-1*H*-pyrrole-2-carboxylate (16). Colorless liquid (15%); IR (ATR, cm^{-1}): 2950, 2932, 2580, 1710, 1730, 770; ^1H NMR($CDCl_3$): δ 9.94 (s, 1H), 7.08 (d, *J* = 3.8 Hz, 1H), 6.91 (d, *J* = 3.8 Hz, 1H), 3.95 (s, 3H), 3.87 (s, 3H); ^{13}C NMR($CDCl_3$): δ 179.7, 160.3, 139.1, 133.2, 122.1, 119.3, 52.9, 43.7; HRMS (ESI) m/z calcd for $C_8H_{10}NO_5S$ $[M+H]^+$ 232.0280, found 232.0281.

5-(Perfluorophenyl)-1-tosyl-1*H*-pyrrole-2-carbaldehyde (6h). Yellowish liquid (35 mg, 17%); IR (ATR, cm^{-1}): 2978, 2675, 2580, 1704, 1484, 1201, 937, 589, 546;^1H NMR ($CDCl_3$): δ 10.30 (s, 1H), 7.48 (d, 2H, *J*= 8.4 Hz), 7.30 (d, 2H, *J* = 8.2 Hz), 7.27 (d, 1H, *J* = 3.8 Hz), 6.48 (d, 1H, *J* = 3.7 Hz), 2.44 (s, 3H);^{13}C NMR ($CDCl_3$): δ 180.9, 146.4, 137.5, 135.0, 134.6, 133.2, 130.3, 130.2, 127.7 (d, *J* = 236 Hz), 126.6, 122.1, 118.9, 21.7

; HRMS (ESI) m/z calcd for $C_{18}H_{11}F_5NO_3S$ $[M+H]^+$ 416.0380, found 416.0385.

Diethyl 1-(methylsulfonyl)-2-phenyl-1*H*-pyrrole-3,4-dicarboxylate (6i). Brownish liquid (27 mg, 15%); IR (ATR, cm^{-1}): 2980, 2932, 1730, 1175, 1069, 770; ^1H NMR ($CDCl_3$): δ 7.88 (s, 1H), 7.50-7.43 (m, 5H), 4.34 (q, *J* = 7.2 Hz, 2H), 4.12 (q, *J* = 7.2 Hz, 2H), 2.96 (s, 3H), 1.36 (t, *J* = 7.2 Hz, 3H), 1.05 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR ($CDCl_3$): δ 163.6, 162.3, 131.6, 129.9, 128.2, 128.0, 127.9, 126.2, 121.2, 117.0, 61.1, 60.9, 43.2, 14.2, 13.7; HRMS (ESI) m/z calcd for $C_{17}H_{20}NO_6S$ $[M+H]^+$ 366.1011, found 366.1003.

Methyl 5-(4-methyl-2-(phenylsulfonyl)phenyl)-1*H*-pyrrole-2-carboxylate (21). Yellowish liquid (5 mg, 15%); IR (ATR, cm^{-1}): 3420, 1660, 1470, 748; ^1H NMR ($CDCl_3$): δ 10.42 (s, 1H), 8.32 (d, *J* = 8.2 Hz, 1H), 7.54 (s, 1H), 7.43-7.25 (m, 6H), 6.79-6.77 (m, 1H), 6.01-5.99 (m, 1H), 3.95 (s, 3H), 2.45 (s, 3H); HRMS (ESI) m/z calcd for $C_{19}H_{18}NO_4S$ $[M+H]^+$ 356.0957, found 356.0947.

Deuterated Methyl 5-phenyl-1-tosyl-1*H*-pyrrole-2-carboxylate (6j). Colorless solid, (127 mg, 71%); mp.124-126 °C; IR (KBr, cm^{-1}): 2924, 2853, 1716, 1374, 1174, 667, 587; ^1H NMR ($CDCl_3$): δ 7.37 (d, *J* = 8.3 Hz, 2H), 7.12 (d, *J* = 8.1 Hz, 2H), 6.91 (d, *J* = 3.4 Hz, 1H), 6.11 (d, *J* = 3.4 Hz,1H), 3.94 (s, 3H), 2.37 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 161.8, 143.8, 135.5, 131.0, 130.6, 129.6, 129.1, 127.5, 127.4, 121.8, 124.4, 52.5, 21.0; HRMS (ESI) m/z calcd for $C_{19}H_{12}D_5NO_4S$ $[M+H]^+$ 361.1270, found 361.1272.

Deuterated Methyl 5-phenyl-3-tosyl-1*H*-pyrrole-2-carboxylate (7z). Colorless solid, (25 mg, 86%); mp. 184-185 °C; IR (KBr, cm^{-1}): 3431, 2924, 1716, 1375, 1174, 667, 591; ^1H NMR ($CDCl_3$): δ 9.84 (bs, 1H), 7.51 (d, *J* = 8.3 Hz, 2H), 7.39 (d, *J* = 2.8 Hz, 1H), 7.13 (d, *J* = 7.9 Hz, 2H), 3.81 (s, 3H), 2.34 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 161.0, 143.5, 139.5, 138.1, 129.3, 129.1, 128.9, 127.0, 124.3, 121.7, 117.4, 52.1, 21.5; HRMS (ESI) m/z calcd for $C_{19}H_{12}D_5NO_4S$ $[M+H]^+$ 361.1270, found 361.1269.

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1-(1-((4-Fluorophenyl)sulfonyl)-5-phenyl-1*H*-pyrrol-2-yl)ethanone (6k). Semi-solid (82 mg, 48%); IR (DCM, cm^{-1}): 2969, 2681, 2559, 1708, 1484, 1201, 985, 727; ^{1}H NMR ($CDCl_3$): δ 7.63-7.59 (m, 2H), 7.44-7.34 (m, 3H), 7.25-7.23 (m, 2H), 7.07-7.03 (m, 2H), 6.91 (d, J = 3.4 Hz, 1H), 6.18 (d, J = 3.4 Hz, 1H), 2.62 (s, 3H); ^{13}C NMR ($CDCl_3$): δ 190.2, 167.0 (d, J = 255 Hz), 144.8, 139.8, 134.3 (d, J = 3 Hz), 131.2, 130.8, 130.7, 129.9, 129.1, 127.8, 122.4, 115.9 (d, J = 22 Hz), 114.9, 29.3; HRMS (ESI) m/z calcd for $C_{18}H_{15}FNO_3S$ $[M+H]^+$ 344.0757, found 344.0762

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