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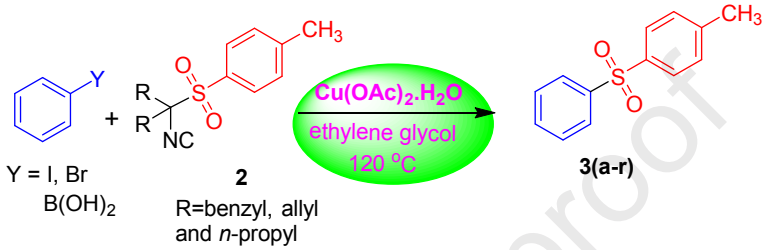

- Cross-coupling
- C-S bond formation
- Neutral conditions
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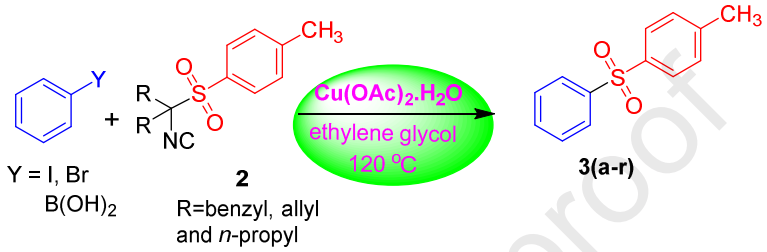

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ABSTRACT

An efficient copper(II) catalyzed sulfonyation of aryl halides has been achieved using TosMIC (*p*-toluenesulfonylmethyl isocyanide) as a sulfonylating agent. This newly developed sulfonylation approach provides an easy access for the synthesis of diaryl sulfones from aryl bromides, iodides and boronic acids with TosMIC under neutral conditions. This method is useful for the sulfonylation of aryl boronic acids under similar conditions. This is the first report on the sulfonylation of aryl bromides, iodides and boronic acids using TosMIC.

1. Introduction

The sulfones are important functional molecules possessing a broad spectrum of biological and pharmacological properties.[1] They are useful building blocks in organic synthesis[2] and also frequently found in many biologically active molecules.[3] Among them, diaryl sulfones are recognized as privileged functional scaffolds, which are being used in agrochemicals,[4] pharmaceuticals[5] and material science.[6] They are often present in various biologically active molecules such as antifungal,[7] antibacterial,[8] and antitumor agents.[9] They act as prostaglandin D2 antagonists, proton pump inhibitors, antidepressants and HIV-1 reverse transcriptase inhibitors.[10] The prominent drugs that contain diaryl sulfone moiety are CX157 (antidepressant),[11] dihydrofolate reductase inhibitor (DHFR)[12] and dapsone (for the treatment of leprosy).[13] The drug intepiridine is used for the treatment of Alzheimer's disease (Figure 1).[14]

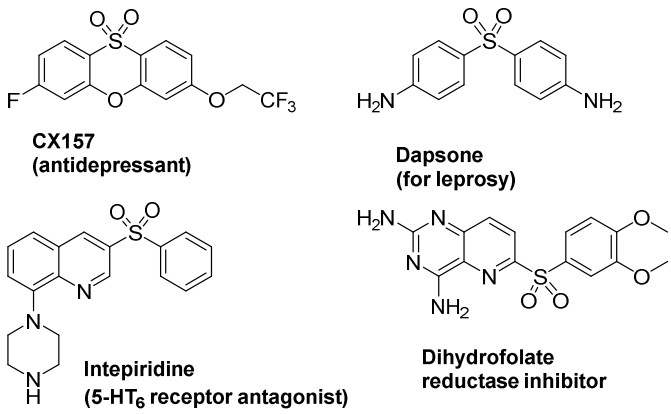


Figure 1. Examples of aryl sulfone drugs

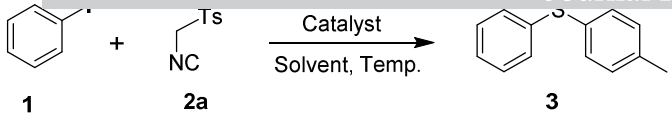
prime importance in medicinal chemistry. As a result, several methods such as the oxidation of sulfides/sulfoxides, the reaction of sodium sulfinate with alkyl/aryl halides, the sulfonylation of arenes and the addition of sulfinate salts to alkynes and alkenes have been developed for the preparation of aryl sulfones.[15] Subsequently, the coupling of aryl halides or arylboronic acids with sodium salt of aryl sulfinic acids or aryl sulfonyl chlorides have been reported using either Pd or Cu catalysts.[16] Recently, a copper catalyzed synthesis of diaryl sulfones has been reported by the cross coupling of arylboronic acids and aryl iodides with DABSO to generate unsymmetrical diaryl sulfones.[17] However, many of these sulfonylating agents are highly sensitive to air and moisture. In addition, inorganic or organic bases are often required to facilitate the reaction, which limit their use in base sensitive substrates. Therefore, the development of novel methods that work under neutral conditions for the synthesis of diaryl sulfones is still desirable.

On the other hand, *p*-toluenesulfonylmethyl isocyanide (TosMIC) is a versatile reagent in organic synthesis.[18] It has been widely used as cyanating agent,[19] connecting agent as a source of C1 synthon for the synthesis of natural products,[20] umpolung reagent for the synthesis of ketones[21] and also for the synthesis of heterocycles.[22] Recently, TosMIC has also been used as a sulfonylating agent for the synthesis of sulfinate esters, vinyl, allyl sulfones[23] and sulfonylation of phenacyl halides.[24] Inspired by the wide application of TosMIC, we attempted the sulfonylation of aryl halides and aryl boronic acids with TosMIC using a copper(II) catalyst.

2. Results and discussion

Following our interest on the application of TosMIC,[25] we herein report a novel and efficient protocol for the direct synthesis of diaryl sulfones by means of a copper catalyzed reaction of aryl bromides or iodides or boronic acids with TosMIC. The notable features of present protocol are ready availability of reagents, low cost of the catalyst, and the use of eco-friendly solvent. To optimize the reaction conditions, different catalysts and solvents were screened at various temperatures and the results are summarized in Table 1. Initially, we performed the reaction of iodobenzene 1a (1.2 of $Cu(OTf)_2$ (10 mol%) in ethanol at 120 °C. The desired diaryl sulfone 3a was obtained only in 10% yield (entry 1, Table 1). Other Lewis acids such as $Zn(OTf)_2$, $Sc(OTf)_3$ and $Yb(OTf)_3$ were tested (entries 2-4, Table 1), but none of them gave the desired product. Next, we investigated the efficacy of copper catalysts i.e., $Cu(OAc)_2{\cdot}H_2O$, $Cu(NO_3)_2{\cdot}5H_2O$, $CuSO_4{\cdot}5H_2O$, $CuCl_2{\cdot}2H_2O$, $CuBr_2{\cdot}2H_2O$, and CuO. Among them, the desired product 3a was obtained in 55% yield with $Cu(OAc)_2{\cdot}H_2O$ and low yields were observed with the other copper catalysts (entries 5-9, Table 1). To our surprise, the reaction did not proceed with CuO (entry 10, Table 1). To improve the yield, further reactions were carried out in different solvents such as THF, DCE, $CHCl_3$, EtOAc, ethylene glycol and PEG-400 under similar conditions (entries 11-16, Table 1). To our delight, ethylene glycol gave the desired product **3a** in 82% yield (entry 15, Table 1). However, low yield was observed in PEG-400 (entry 16, Table 1). Furthermore, the reaction was unsuccessful in THF, DCE, $CHCl_3$ and EtOAc. Finally, we examined the effect of temperature ranging from 25-120 °C on the conversion (entries 17-20, Table 1). But yields were dramatically increased with temperature. The optimal temperature is 120 °C to achieve good yields. Next, we investigated the effect of catalyst loading varying from 15 to 25 mol% on the conversion. It is noteworthy that 15 mol% of $Cu(OAc)_2.H_2O$ gave the product 3a in 78% yield over 6h (entry 21, Table1). As evident from Table 1, no further increase in yield was observed even by increasing the amount of catalyst to 25 mol% (entry 22, Table1). However, the reaction was unsuccessful in the absence of catalyst under identical conditions (entry 23, Table1).

Table 1. Optimization of reaction conditions[(a)]



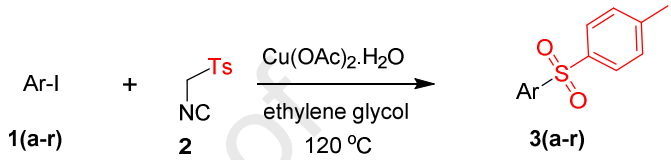
1 2a 3

Entry	Catalyst	Solvent	Temp (°C)	Yield (%)[b]
1.	$Cu(OTf)_2$	EtOH	120	10
2.	$Zn(OTf)_2$	EtOH	120	0
3.	$Sc(OTf)_2$	EtOH	120	0
4.	$Yb(OTf)_3$	EtOH	120	0
5.	$Cu(OAc)_2.H_2O$	EtOH	120	55
6.	$Cu(NO_3)_2 \cdot 5H_2O$	EtOH	120	20
7.	$CuSO_4 \cdot 5H_2O$	EtOH	120	10
8.	$CuCl_2 \cdot 2H_2O$	EtOH	120	15
9.	$CuBr_2 \cdot 2H_2O$	EtOH	120	20
10.	CuO	EtOH	120	0
11.	$Cu(OAc)_2.H_2O$	THF	120	0
12.	$Cu(OAc)_2.H_2O$	DCE	120	0
13.	$Cu(OAc)_2.H_2O$	$CHCl_3$	120	0
14.	$Cu(OAc)_2.H_2O$	EtOAc	120	0
15.	$Cu(OAc)_2.H_2O$	Ethylene glycol	120	82
16.	$Cu(OAc)_2.H_2O$	PEG-400	120	35
17.	$Cu(OAc)_2.H_2O$	Ethylene glycol	rt	20
18.	$Cu(OAc)_2.H_2O$	Ethylene glycol	60	40
19.	$Cu(OAc)_2.H_2O$	Ethylene glycol	90	50
20.	$Cu(OAc)_2.H_2O$	Ethylene glycol	110	66
21.	$Cu(OAc)_2.H_2O$	Ethylene glycol	120	78[c]
22.	$Cu(OAc)_2.H_2O$	Ethylene glycol	120	78[d]
23.	-	Ethylene glycol	120	0

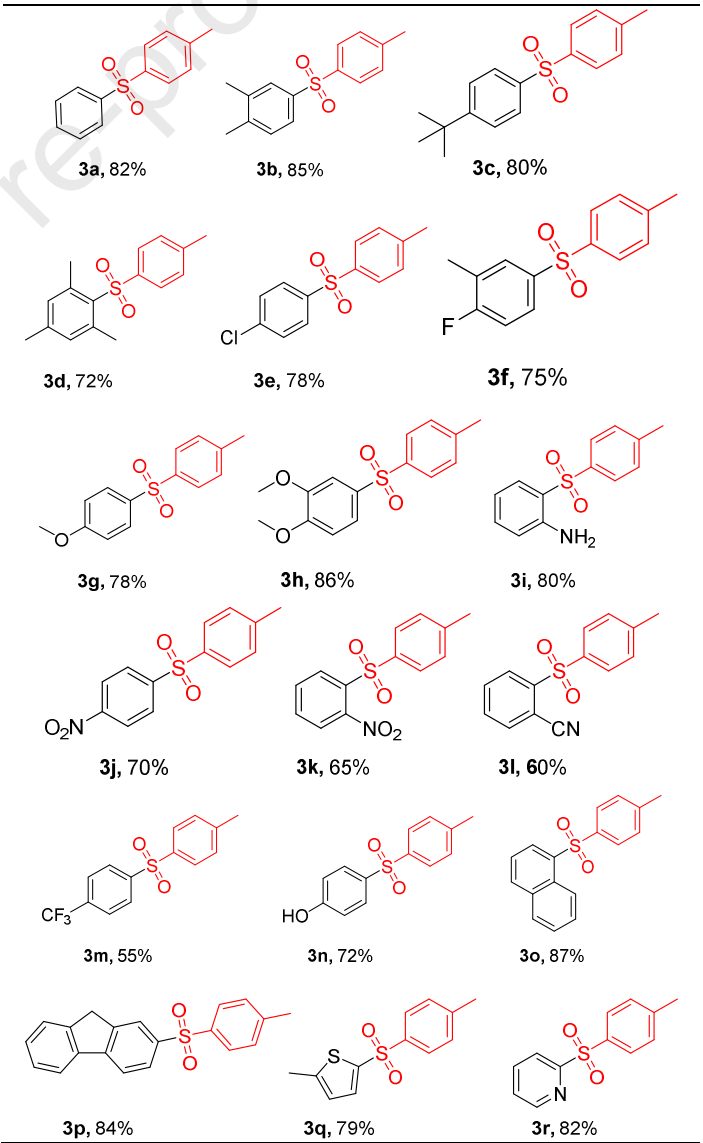
[a]Reaction conditions: TosMIC **1a** (1 mmol), aryl halides **2** (1.2 mmol), Cu catalyst (10 mol%). [b]Isolated yield. [c]Reaction was carried out with 15 mol% of $Cu(OAc)_2.H_2O$. [d]Reaction was carried out with 25 mol% of $Cu(OAc)_2.H_2O$

Inspired by above results, we extended this process to other substrates and the results are summarized in Table 2. Interestingly, a variety of aryl halides participated in this reaction. However, substitution on the aromatic ring had some effect on yield. *para*- and *meta*-Substituted aryl halides afforded the corresponding products in excellent yields, whereas *ortho*-substituted aryl halides gave the products in poor yields probably due to the steric effects. Substituents like dimethyl-, *tert*-butyl-, trimethyl- (**1b-d**) are well tolerated under the reaction conditions and the respective products (**3b-d**) were obtained in good yields. Furthermore, aromatic ring (**1e-f**) are compatible under the reaction conditions due to their poorer leaving ability than bromo and iodo functionalities. The corresponding products (**3e-f**) were obtained in 75% and 78% yields respectively. Electron-donating groups like mono-methoxy-, and dimethoxy- (**1g-h**) are found to be compatible during the reaction and the corresponding products (**3g-h**) were obtained in good yields.

Table 2. Synthesis of diaryl sulfones from aryl iodides



1(a-r) 2 3(a-r)

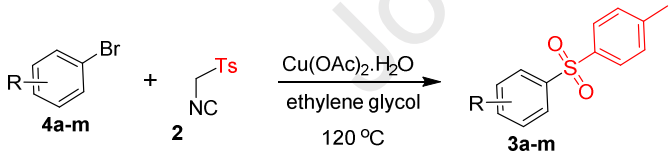


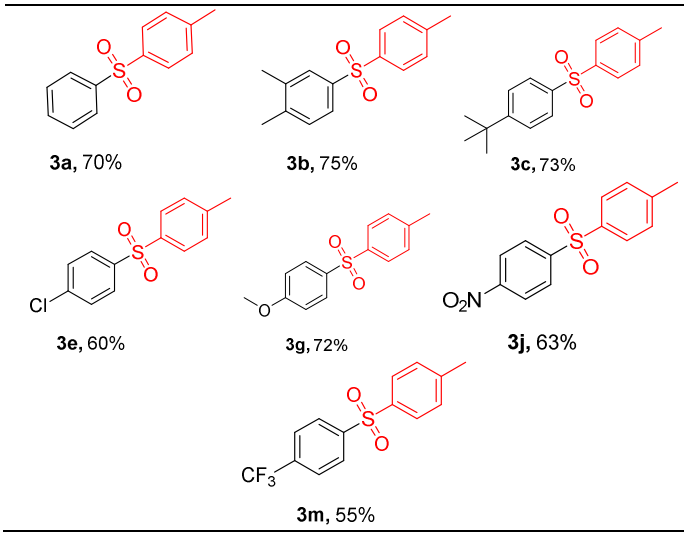
[a]Reaction conditions: Aryl iodide **1a** (1 mmol), TosMIC **2** (1.2 mmol), Cu catalyst (10 mol%) in ethylene glycol (2 mL) at 120 °C. [b]Isolated yield.

In addition, electron-withdrawing groups such as cyano-, nitro-, and trifluoromethyl (**1j-m**) are well tolerated under the reaction conditions and the corresponding products (**3j-m**) were obtained in good yields. It is noteworthy that electron-donating substituents on aryl halide resulted in higher yields compared to electron-deficient substituents . Other functional groups like amine and hydroxyl are compatible under present reaction conditions (**3i** and **3n**). The scope was further extended to polyaromatic compounds like 1-iodonaphthalene and 2-iodofluorene. Remarkably, the corresponding products (**3o-p**) were attained in excellent yields. Subsequently, we examined the reactivity of heteroaromatic halides like 2-iodo-5-methylthiophene (**1q**) and 2-iodopyridine (**1r**). The corresponding sufones were obtained in good yields.

Later on, we tested the reactivity of aryl bromides and chlorides and the results are presented in Table 3. Interestingly, a diverse range of aryl bromides such as bromobenzene (**4a**), 3,4-dimethyl (**4b**), 4-*tert*-butyl (**4c**), 4-chloro (**4e**), 4-methoxy (**4g**), 4-nitro (**4j**), and 4-trifluoromethyl (**4m**) gave the respective sulfones (**3a-m**) in good to moderate yields (Table 3). However, aryl chlorides failed to give the desired product under identical conditions.

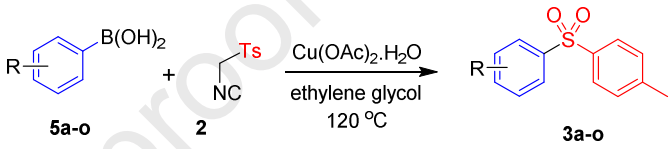
Table 3. Synthesis of diaryl sulfones from aryl bromides[c]

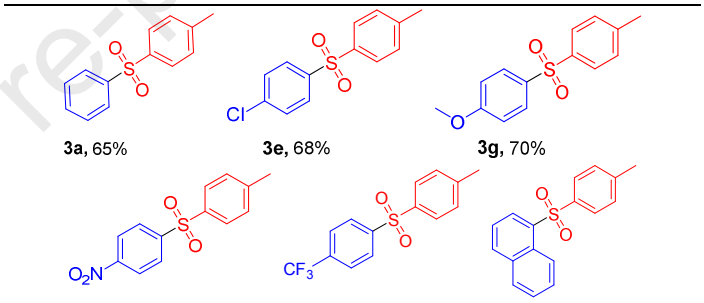




Furthermore, the synthetic utility of this method was exemplified with aryl boronic acids and the results are exampled in Table 4. Interestingly, a diverse range of aryl boronic acids (**5a-o**) bearing Cl, OMe, NO_2, CF_3 groups on aromatic ring reacted smoothly with TosMIC (2a) to generate the corresponding sulfones (**3a-o**) and the results are summarized in Table 4. A sterically hinderd 1-naphthyl boronic acid (**5o**) also gave the sulfone **3o** in 58% yield.

Table 4. Synthesis of diaryl sulfones from aryl boronic acids[c]

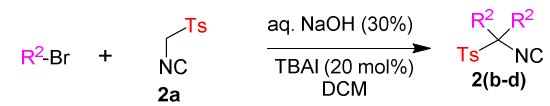




[a]Reaction conditions: Arylboronic acid **5a** (1 mmol), TosMIC **2** (1.2 mmol), Cu catalyst (10 mol%) in ethylene glycol (2 mL) at 120 °C. [b]Isolated yield.

Encouraged by these results, we investigated the scope of this reaction using TosMIC derivatives, which were prepared by a known procedure reported in the literature as shown in Table 5. [27]

Table 5. Preparation of substituted TosMIC



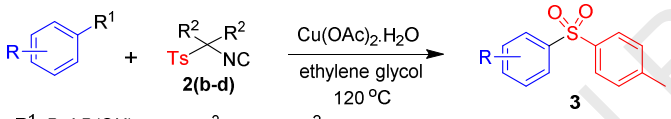
R^2	R^2	Substituted TosMIC[a]	Yield (%)[b]
Benzyl	Benzyl	**2b**	78
Allyl	Allyl	**2c**	54
n-Propyl	H	**2d**	60[c]

[a]Reaction conditions: Alkyl or allyl bromide (21.0 mmol), TosMIC **2a** (10.0 mmol), TBAI (2.0 mmol), aq. NaOH (4 mL) in DCM (6 mL) at 0 to 5°C. [b]Isolated yield. [c]n-propyl bromide (11 mmol)

Accordingly, the reactions were performed with substituted TosMIC like benzyl, allyl and *n*-propyl and the results are summarized in Table 6. Initially,

we of derivative (**2b**) with aryl iodide, aryl bromide and aryl boronic acids. In all cases, the product **3a** was obtained in good yields. Next, the reaction was performed with diallyl (**2c**) and mono-propyl (**2d**) substituted TosMIC with bromobenzene to give the desired product **3a** in 55% and 50% yields respectively. Furthermore, the reaction of 4-methoxyiodobenzene with **2b** afforded the required product **3g** in 66% yield. However, 2-cyanobromobenzene failed to afford the product **3l**. Indeed, a sterically hindered substrate like 1-bromonaphthalene with **2d** gave the corresponding product **3o** in 65% yield. Subsequently, we examined the reactivity of heteroaromatic halide like 2-iodo-5-methylthiophene with diallyl TosMIC **2c** to give the desired product **3q**. However, the reaction of 2-bromopyridine with **2b** failed to give the product **3r**.

Table 6. Synthesis of diaryl sulfones from substituted TosMIC[a,b]

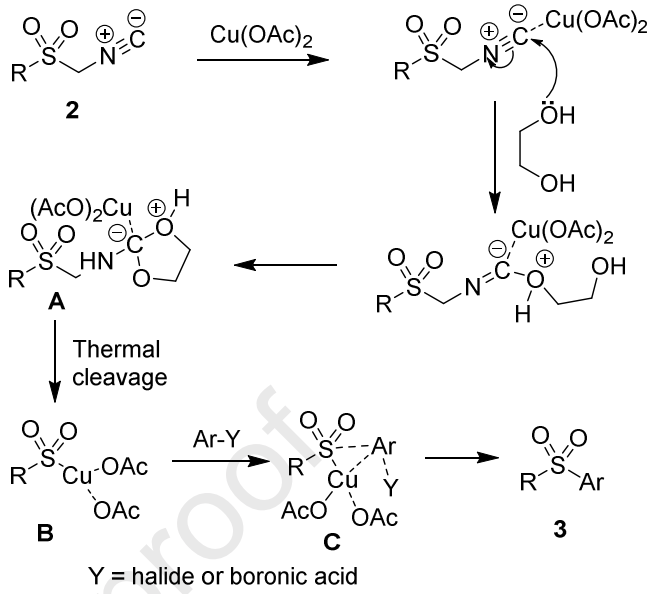


R^1=Br,I,B(OH)$_2$ **2b**: R^2= benzyl, R^2= benzyl
2c: R^2=allyl, R^2=allyl
2d: R^2= *n*-propyl, R^2= H

R	R^1	TosMIC derivative[a]	Product (3)	Yield (%)[b]
H	I	**2b**	**3a**	62
H	Br	**2b**	**3a**	58
H	$B(OH)_2$	**2b**	**3a**	45
H	Br	**2c**	**3a**	55
H	Br	**2d**	**3a**	50
4-MeO-	I	**2b**	**3g**	66
2-Cyano-	Br	**2b**	**3l**	0
1-Naphthyl	Br	**2d**	**3o**	65
5-Methyl-2-thienyl	I	**2c**	**3q**	50
2-Pyridyl	Br	**2b**	**3r**	0

[a]Reaction conditions: Aryl halide and arylboronic acid (1 mmol), **2b-d** (1.2 mmol), Cu catalyst (10 mol%) in ethylene glycol (2 mL) at 120 °C. bIsolated yield.

Based on experimental results and previous reports,[26] a plausible reaction mechanism is proposed in Scheme 1. We assume that TosMIC is activated by $Cu(OAc)_2$ to facilitate the formation of an cyclic acetal **A** from ethylene glycol. A subsequent cleavage of C-S bond in the presence of $Cu(OAc)_2$ under thermal conditions would give the intermediate **B**. Up on addition aryl halide or intermediate **C** would give the desired product **3**.



Scheme 1. A plausible mechanism

Conclusions

In conclusion, we have demonstrated a novel use of TosMIC for an efficient synthesis of diaryl sulfones from aryl halides using a readily available Cu(II) catalyst under neutral conditions. This simple protocol is also extended to arylboronic acids to access diaryl sulfones from TosMIC. This method is very useful for the preparation of diaryl sulfones even from aryl bromides, iodides and boronic acids where the Friedel-Crafts sulfonylation fails to give the product.

3. Experimental Section

General procedure for the preparation of substituted TosMIC.

All the methylene substituted TosMIC derivatives were prepared by the method mentioned in references.[27]

General procedure for the coupling of aryl halides, aryl boronic acids with TosMIC.

A mixture of aryl halide or arylboroic acid (1 mmol), TosMIC (1.2 mmol), cupric acetate (10 mol%), and ethylene glycol (2.0 mL) was heated in a seal tube at 120°C for 6 h. The mixture was quenched with water and extracted with EtOAc (4×10 mL). The combined extracts were washed

filtered, and evaporated, and purified by column chromatography using ethyl acetate/hexane (v/v=1:10) on silica gel to yield the desired product. All the products were characterized by their spectral and analytical data and compared with known compounds.

4. Characterization data of TosMIC derivatives

(2-Isocyano-2-tosylpropane-1,3-diyl)dibenzene (2b):

Yield: 78%, White solid. mp.92-94 ^{o}C, ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.81 (d, *J* = 8.3 Hz, 2H), 7.34 (d, *J* = 8.0 Hz, 2H), 7.29 – 7.26 (m, 1H), 7.26 – 7.07 (m, 9H), 3.25 (dd, *J* = 53.5, 14.2 Hz, 4H), 2.45 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 166.84, 146.28, 132.49, 131.28, 130.94, 130.61, 129.82, 128.42, 127.98, 81.82, 39.72, 21.82. HRMS: Exact mass calcd for $C_{23}H_{25}N_2O_2S$ $[M+NH_4]^+$: 393.1914, Found: 393.1901.

1-((4-Isocyanohepta-1,6-dien-4-yl)sulfonyl)-4-methylbenzene (2c):

Yield: 54%, White solid, mp. 78-80 ^{o}C, ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88 (d, *J* = 8.3 Hz, 2H), 7.42 (d, *J* = 8.0 Hz, 2H), 5.83 (ddt, *J* = 17.2, 10.2, 7.2 Hz, 2H), 5.28 (dd, *J* = 10.1, 1.2 Hz, 2H), 5.23 (ddd, *J* = 16.9, 2.8, 1.4 Hz, 2H), 2.75 (qd, *J* = 14.6, 7.2 Hz, 4H), 2.49 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 164.77, 146.61, 131.31, 129.95, 129.01, 121.83, 80.49, 37.63, 21.85. HRMS: Exact mass calcd for $C_{15}H_{18}NO_2S$ $[M+H]^+$: 276.1143, Found: 276.1267.

1-((1-Isocyanobutyl)sulfonyl)-4-methylbenzene (2d):

Yield: 60%, Yellow oil, ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.82 (dd, *J* = 49.0, 8.3 Hz, 2H), 7.39 (dd, *J* = 44.1, 8.0 Hz, 2H), 4.47 (dd, *J* = 10.9, 3.4 Hz, 1H), 2.52 – 2.42 (m, 3H), 1.90 – 1.64 (m, 2H), 1.59 – 1.23 (m, 2H), 1.06 – 0.93 (m, 3H). HRMS: Exact mass calcd for $C_{12}H_{16}NO_2S$ $[M+H]^+$: 238.0926, Found: 238.1732.

5. Characterization data of products

1-Methyl-4-(phenylsulfonyl)benzene (3a):[26c]
Yield: 76%, (70%)[c] White solid. mp. 71-72 ^{o}C. ^{1}H NMR (300 MHz, $CDCl_3$) *δ* 8.02-7.91 (m, 2H), 7.82 (t, *J* = 7.1 Hz, 2H), 7.60-7.37 (m, 3H), 7.34-7.20 (m, 2H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.2, 141.9, 138.6, 133.0, 129.9, 129.2, 127.7, 127.4, 21.59. HRMS: Exact mass calcd for $C_{13}H_{13}O_2S$ $[M+H]^+$: 233.0626. found: 233.0630.

1,2-Dimethyl-4-tosylbenzene (3b):[26c]
Yield: 85%, (75%)[c] Yellow solid. mp. 55-57 ^{o}C. ^{1}H NMR (500 MHz, $CDCl_3$) *δ* 7.81 (d, *J* = 8.3 Hz, 4H), 7.68-7.64 (m, 3H), 7.27 (d, *J* = 8.0 Hz, 4H), 7.23 (d, *J* = 7.9 Hz, 2H), 2.38 (s, 6H), 2.28 (d, *J* = 3.1 Hz, 6H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 143.8, 142.7, 139.1, 138.0, 130.3, 129.8, 128.3, 127.5, 125.1, 21.5, 19.9. HRMS: Exact mass calcd for $C_{15}H_{16}O_2S$ $[M+H]^+$: 261.0944. found: 261.0942.

1-(*tert*-Butyl)-4-tosylbenzene (3c):[26b]
Yield: 80%, (73%)[c] White solid. mp. 142-144 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.83 (d, *J* = 4.8 Hz, 3H), 7.49 (d, *J* = 8.2 Hz, 3H), 7.32-7.24 (m, 2H), 2.39 (s, 3H), 1.30 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.9, 143.9, 139.0, 129.8, 127.6, 127.3, 126.2, 35.1, 31.0, 21.5. HRMS: Exact mass calcd for $C_{17}H_{21}O_2S$ $[M+H]^+$: 289.1184. found: 289.1261.

1,3,5-Trimethyl-2-tosylbenzene (3d):[26e]
Yield: 72%, White solid. mp. 115-117 ^{o}C. ^{1}H NMR (300 MHz, $CDCl_3$) *δ* 7.67 (d, *J* = 8.3 Hz, 2H), 7.31-7.15 (m, 2H), 6.93 (s, 2H), 2.59 (s, 6H), 2.39 (s, 3H), 2.29 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.3, 143.1, 140.6, 139.9, 134.1, 132.1, 129.4, 126.3, 22.8, 21.5, 21.0. HRMS: Exact mass calcd for $C_{16}H_{19}O_2S$ $[M+H]^+$: 275.1014. found: 275.1018.

1-Chloro-4-tosylbenzene (3e):[26e]
Yield: 78%, (60%)[c] White solid. mp. 122-124 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.88-7.84 (m, 2H), 7.83-7.78 (m, 2H), 7.48-7.43 (m, 2H), 7.31 (d, *J* = 8.0 Hz, 2H), 2.40 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.5, 140.5, 139.6, 138.2, 130.0, 129.5, 129.0, 127.7, 21.6. HRMS: Exact mass calcd for $C_{13}H_{12}ClO_2S$ $[M+H]^+$: 267.0210. found: 267.0210.

1-Fluoro-2-methyl-4-tosylbenzene (3f):
Yield: 75%, Pale Yellow solid. mp. 89-91 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 8.01-7.68 (m, 4H), 7.30 (d, *J* = 7.5 Hz, 2H), 7.09 (t, *J* = 8.5 Hz, 1H), 2.40 (s, 3H), 2.30 (s, 3H).^{13}C NMR (100 MHz, $CDCl_3$) δ 165.2 (d, *J* =253.9 Hz), 162.6, 144.2, 138.7, 137.5, 131.2 (d, *J* = 6.6 Hz), 129.9, 127.6, 127.5, 126.7, 126.5, 116.1 (d, *J* = 23.8 Hz), 115.9, 21.6, 14.6. HRMS: Exact mass calcd for $C_{14}H_{13}FO_2SNa$ $[M+Na]^+$: 287.0509. found: 287.0514.

1-Methoxy-4-tosylbenzene (3g):[26e]
Yield: 78%, (72%)[c] Yellow solid. mp. 103-105 ^{o}C. ^{1}H NMR (500 MHz, $CDCl_3$) *δ* 7.89-7.83 (m, 2H),

7.08-6.72 (m, 2H), 3.82 (s, 3H), 2.37 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.2, 143.7, 139.4, 133.5, 129.8, 129.6, 127.3, 114.4, 55.6, 21.5. HRMS: Exact mass calcd for $C_{14}H_{15}O_3S$ $[M+H]^+$: 263.0736. found: 263.0730.

1,2-Dimethoxy-4-tosylbenzene (3h):[26f]
Yield: 86%, White solid. mp. 128-130 °C. ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 8.05 (t, *J* = 6.5 Hz, 1H), 7.82 (d, *J* = 8.3 Hz, 2H), 7.32-7.17 (m, 2H), 6.57 (dd, *J* = 8.8, 2.3 Hz, 1H), 6.38 (d, *J* = 2.2 Hz, 1H), 3.83 (s, 3H), 3.73 (s, 3H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.5, 158.5, 143.4, 139.1, 131.5, 129.1, 128.1, 121.6, 104.6, 99.4, 55.8, 55.7, 21.5. HRMS: Exact mass calcd for $C_{15}H_{16}O_4SNa$ $[M+Na]^+$: 315.0642. found: 315.0656.

2-Tosylaniline (3i):[26e]
Yield: 80%, White solid. mp. 124-126 °C. ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.89-7.77 (m, 3H), 7.33-7.22 (m, 3H), 6.83-6.72 (m, 1H), 6.63 (d, *J* = 8.2 Hz, 1H), 5.11 (s, 2H), 2.38 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 146.0, 144.0, 138.8, 134.8, 129.8, 126.9, 122.3, 117.8, 117.6, 21.5. HRMS: Exact mass calcd for $C_{13}H_{14}NO_2S$ $[M+H]^+$: 248.0740. found: 248.0737.

1-Methyl-4-((4-nitrophenyl)sulfonyl)benzene (3j):[26a]
Yield: 70%, (63%)[c] White solid. mp. 160-162 °C. ^{1}H NMR (500 MHz, $CDCl_3$) *δ* 8.37-8.30 (m, 2H), 8.13-8.07 (m, 2H), 7.87-7.83 (m, 2H), 7.35 (d, *J* = 8.0 Hz, 2H), 2.42 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 150.2, 147.8, 145.4, 137.0, 130.3, 129.8, 128.8, 128.1, 127.5, 124.4, 21.6. HRMS: Exact mass calcd for $C_{13}H_{12}NO_4S$ $[M+H]^+$: 278.0483. found: 278.0501.

1-Nitro-2-tosylbenzene (3k):[26a]
Yield: 65%, White solid. mp. 162-164 °C. ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 8.32 (dt, *J* = 6.6, 3.6 Hz, 1H), 7.86 (d, *J* = 8.4 Hz, 2H), 7.79-7.66 (m, 3H), 7.35 (d, *J* = 8.1 Hz, 2H), 2.43 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.4, 145.0, 137.4, 134.9, 134.4, 132.4, 131.4, 129.8, 128.4, 124.6, 21.7. HRMS: Exact mass calcd for $C_{13}H_{12}NO_4S$ $[M+H]^+$: 278.0480. found: 278.0489.

2-Tosylbenzonitrile (3l):[26d]
Yield: 60%, White solid. mp. 132-134 °C. ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 8.37-8.28 (m, 1H), 7.96 (d, *J* = 8.1 Hz, 1H), 7.35 (d, *J* = 8.1 Hz, 2H), 2.42 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.0, 150.4, 144.8, 138.1, 135.9, 129.8, 128.9, 126.8, 122.0, 21.6. HRMS: Exact mass calcd for $C_{14}H_{12}NO_2S$ $[M+H]^+$: 258.0583. found: 258.0584.

1-Methyl-4-((4(trifluoromethyl)phenyl)sulfonyl) benzene (3m):[26c]
Yield: 64%, Yellow solid. mp. 105-107 °C. ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 8.05 (d, *J* = 7.3 Hz, 1H), 7.84 (d, *J* = 7.4 Hz, 1H), 7.75 (d, *J* = 7.3 Hz, 1H), 7.44-7.20 (m, 1H), 2.41 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 145.6, 144.9, 137.6, 135.1, 134.8, 134.5 (t, *J* = 33.0 Hz), 134.1, 130.2, 128.0 (d, *J* = 8.6 Hz), 127.9, 126.4 (d, J = 3.4 Hz), 126.3, 124.5, 121.8, 21.6. HRMS: Exact mass calcd for $C_{14}H_{11}F_3O_2S$ Na $[M+Na]^+$: 323.0324. found: 323.0316.

4-Tosylphenol (3n):[26c]
Yield: 72%, White solid. mp. 140-142 °C. ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 7.75 (s, 4H), 7.27 (d, *J* = 6.5 Hz, 2H), 6.91 (d, *J* = 7.8 Hz, 2H), 2.38 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 160.7, 144.1, 138.8, 132.3, 129.8, 127.2, 116.2, 21.5. HRMS: Exact mass calcd for $C_{13}H_{13}O_3S$ $[M+H]^+$: 249.0560. found: 249.0582.

1-Tosylnaphthalene (3o):[26c]
Yield: 87%, White solid. mp. 101-103 °C. ^{1}H NMR (500 MHz, $CDCl_3$) *δ* 8.64 (d, *J* = 8.7 Hz, 1H), 8.49 (dd, *J* = 7.4, 1.1 Hz, 1H), 8.07 (d, *J* = 8.2 Hz, 1H), 7.86 (dd, *J* = 16.5, 8.1 Hz, 3H), 7.63-7.44 (m, 3H), 7.26 (t, *J* = 9.4 Hz, 2H), 2.34 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.0, 138.8, 136.2, 135.0, 134.2, 129.8, 129.7, 129.0, 128.4, 128.3, 127.5, 126.8, 124.4, 21.5. HRMS: Exact mass calcd for $C_{17}H_{15}O_2S$ $[M+H]^+$: 283.0775. found: 283.0787.

2-Tosyl-9H-fluorene (3p):
Yield: 84%, White solid. mp. 221-223 °C. ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 8.08 (d, *J* = 0.8 Hz, 1H), 8.00-7.93 (m, 1H), 7.89-7.77 (m, 4H), 7.57 (m, 1H), 7.43-7.35 (m, 2H), 7.30 (d, *J* = 8.0 Hz, 2H), 3.93 (s, 2H), 2.39 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 146.5, 144.2, 143.8, 139.8, 139.6, 139.1, 129.9, 128.4, 127.6, 127.2, 126.7, 125.3, 124.2, 120.9, 120.2, 36.9, 21.5. HRMS: Exact mass calcd for $C_{20}H_{17}O_2S$ $[M+H]^+$: 321.0799. found: 321.0814.

Yield: 79%, Yellow solid. mp. 120-122 ^{o}C. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.86-7.82 (m, 2H), 7.49 (d, J = 3.7 Hz, 1H), 7.29 (d, J = 8.0 Hz, 2H), 6.77-6.67 (m, 1H), 2.48 (d, J = 0.8 Hz, 3H), 2.40 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 149.6, 144.0, 140.1, 139.5, 133.4, 129.8, 127.5, 127.2, 126.2, 21.6, 15.7 HRMS: Exact mass calcd for $C_{12}H_{12}O_2S_2Na$ $[M+Na]^+$: 275.0159. found: 275.0167.

2-Tosylpyridine (3r):[26c]

Yield: 82%, White solid. mp. 102-104 ^{o}C. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.68-8.64 (m, 1H), 8.18 (d, J = 7.9 Hz, 1H), 7.96-7.88 (m, 3H), 7.45 (ddd, J = 7.6, 4.7, 1.0 Hz, 1H), 7.33 (d, J = 8.0 Hz, 2H), 2.41 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.0, 150.4, 144.9, 138.1, 135.9, 129.8, 128.9, 126.8, 122.0, 21.6. HRMS: Exact mass calcd for $C_{12}H_{12}NO_2S$ $[M+H]^+$: 234.0583. found: 234.0577.

Declaration of competing interest

We declare that no competing financial interest or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at.....Copies of ^{1}H & ^{13}C NMR are provided in SI.

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Highlights

- First report on the sulfonylation of aryl bromides & iodides with TosMIC.
- This method is useful for the synthesis of diaryl sulfones.
- It also works with aryl boronic acids.
- This method works with a diverse range of aryl halides and boronic acids.

Declaration of Interest

Title: "**TosMIC as a Versatile Sulfonating Agent for the Synthesis of Unsymmetrical Diaryl Sulfones**" for publication in your esteemed journal -*Tetrahedron***.**

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All authors are declared that no conflict of interest.