JOC The Journal of Organic Chemistry

Subscriber access provided by UNIV PRINCE EDWARD ISLAND

Article

TRANSITION-METAL-FREE AND VISIBLE LIGHT MEDIATED DESULFONYLATION AND DEHALOGENATION REACTIONS: HANTZSCH ESTER ANION AS ELECTRON AND HYDROGEN ATOM DONOR

Micaela D. Heredia, Walter Damian Guerra, Silvia Maricel Barolo, Santiago José Fornasier, Roberto Arturo Rossi, and María E. BUDEN

J. Org. Chem., **Just Accepted Manuscript** • DOI: 10.1021/acs.joc.0c01523 • Publication Date (Web): 06 Sep 2020

Downloaded from pubs.acs.org on September 7, 2020

Just Accepted

"Just Accepted" manuscripts have been peer-reviewed and accepted for publication. They are posted online prior to technical editing, formatting for publication and author proofing. The American Chemical Society provides "Just Accepted" as a service to the research community to expedite the dissemination of scientific material as soon as possible after acceptance. "Just Accepted" manuscripts appear in full in PDF format accompanied by an HTML abstract. "Just Accepted" manuscripts have been fully peer reviewed, but should not be considered the official version of record. They are citable by the Digital Object Identifier (DOI®). "Just Accepted" is an optional service offered to authors. Therefore, the "Just Accepted" Web site may not include all articles that will be published in the journal. After a manuscript is technically edited and formatted, it will be removed from the "Just Accepted" Web site and published as an ASAP article. Note that technical editing may introduce minor changes to the manuscript text and/or graphics which could affect content, and all legal disclaimers and ethical guidelines that apply to the journal pertain. ACS cannot be held responsible for errors or consequences arising from the use of information contained in these "Just Accepted" manuscripts.

is published by the American Chemical Society. 1155 Sixteenth Street N.W., Washington, DC 20036

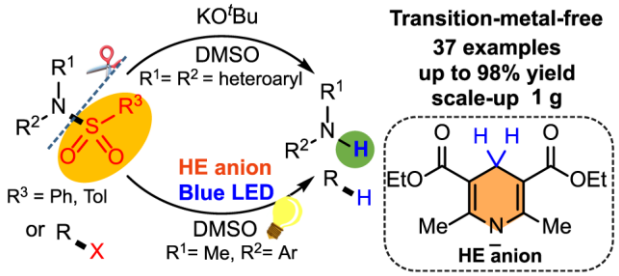
Published by American Chemical Society. Copyright © American Chemical Society. However, no copyright claim is made to original U.S. Government works, or works produced by employees of any Commonwealth realm Crown government in the course of their duties.

TRANSITION-METAL-FREE AND VISIBLE LIGHT MEDIATED DESULFONYLATION AND DEHALOGENATION REACTIONS: HANTZSCH ESTER ANION AS ELECTRON AND HYDROGEN ATOM DONOR

Micaela D. Heredia,[a] Walter D. Guerra,[a] Silvia M. Barolo,[a] Santiago J. Fornasier,[a] Roberto A. Rossi[a] and María E. Budén[a]*

[a]INFIQC, Facultad de Ciencias Químicas, Universidad Nacional de Córdoba, X5000HUA Córdoba, Argentina

TOC



Abstract

Novel approaches for *N* and *O*-desulfonylation under room temperature (rt) and transition-metal-free conditions have been developed. The first methodology involves the transformation of a variety of *N*-sulfonyl heterocycles and phenyl benzenesulfonates to the corresponding desulfonylated products in good to excellent yields using only KO^{t}Bu in DMSO at rt. Alternately, a visible light method has been used for deprotection of *N*-methyl-*N*-arylsulfonamides with Hantzsch ester (HE) anion serving as visible light absorbing reagent and electron and hydrogen atom donor to promote the desulfonylation reaction. HE anion can be easily prepared *in situ* by reaction of the corresponding HE with KO^{t}Bu in DMSO at rt. Both protocols were further explored in terms of synthetic scope as well as mechanistic aspects in order to rationalize key features of desulfonylation processes. Furthermore, HE anion induces reductive dehalogenation reaction of aryl halides under visible light irradiation.

Keywords: Desulfonylation, Dehalogenation, Visible Light, Hantzsch ester (HE)

Introduction

Many protecting groups were developed for amine functionality and provide desired stability towards acid, basic, reducing or oxidizing conditions.[1,2] In particular, sulfonamides as

nitrogen protecting groups play an important role in amine chemistry.[3] For instance, benzene sulfonyl or *p*-toluenesulfonyl (tosyl, Ts) groups are easy to introduce offering extreme robustness and high crystallinity helping in the compound purification.[1] However, drastic conditions are required to remove sulfonyl groups and, consequently, several methodologies to promote desulfonylation reactions have been described. Deprotection methods can be classified into three large families: acidic reductive conditions, reductions in strongly basic media or electron transfer (ET) cleavage.

The cleavage of N-S bond can be acid-mediated by HBr,[4–6] HCl,[7] H_2SO_4,[7,8] CF_3COOH,[9] CF_3SO_3H,[10] HF-pyridine with anisole[11] or $CH_3COOH/HClO_4$[12] mostly in very harsh conditions or at high temperatures. Moreover, *N*-deprotection method using HBr requires a bromine scavenger such as phenol[4] to avoid monobromination and/or dibromination of the aromatic ring of aniline.

Likewise, many methods using strong bases or nucleophiles are well known, such as NaOH or KOH in MeOH,[13,14] KOH in THF/H_2O mixture,[15] NaO^tBu in dioxane,[16] thioglycolate in DMF,[17] Cs_2CO_3 in THF/MeOH,[18] $PhMe_2SiLi$ in THF,[19] sodium bis(2-methoxyethoxy)aluminum hydride in benzene or toluene as solvents[20] and *n*-Bu_4NF[21] in dry THF. Despite the large number of *N*-desulfonylation methodologies in basic media, only a few are useful in industries due to long time reactions and high temperatures are required to obtain the corresponding desulfonylated products. In some cases, a phase transfer catalyst such as cetyltrimethylammonium bromide is needed due to the low solubility of the amines in the media. The use of MeOH is discouraged by its toxicity and production of toxic methyl *p*-toluenesulfonate as byproduct, as consequence of esterification of *p*-toluensulfonic acid liberated during the reaction. Moreover, Cs_2CO_3 in MeOH produces an *N*-methylated impurity that is difficult to remove during purification processes[18] and also, NaOH at reflux in EtOH led to degradation products.[22]

Desulfonylation induced by ET is also widely described. The most common approaches of this type of reductions are promoted by SmI_2,[23–28] Mg/MeOH,[29–33] alkali metals,[34–39] low-valent titanium,[40,41] organic electron donors[42–44] and electrochemistry.[45–48] In particular, photoinduced ET (PET) has also been applied for desulfonylation reactions.[49] PET process under UV irradiation using 2-phenyl-*N,N´*-dimethylbenzimidazoline as electron and hydrogen donor has been used in tosyl amides deprotection.[50] *N*-sulfonyl indoles can be deprotected by a PET reaction with NEt_3 serving as both an electron and proton donor and *n*-Bu_3SnH as a hydrogen atom donor.[51] In 2013, Xiao *et al.* reported *N*-detosylation of tosyl amides using visible light and iridium as photocatalysts with Hantzsch ester (HE, diethyl 2,6-dimethyl-1,4-dihydropyridine-3,5-dicarboxylate) as electron donor.[52] Moreover, in 2018, Hasegawa and co-

workers demonstrated that benzimidazolium naphthoxide betaine and 1,3-dimethyl-2-hydroxynaphthylbenzimidazoline (HONap-BIH) can serve as light absorbing, electron and hydrogen atom donor for desulfonylation of *N*-sulfonyl-amides and amines.[53,54] Another study of Hasegawa has reported a new visible-light-promoted system for desulfonylation process consisting of benzimidazolium aryloxide betaines (BI^{+}– ArO^{-}) and stoichiometric hydride reducing reagents.[55] More recently, a visible light protocol using Cu complex/HE has just been developed in order to deprotect *N*-heterocycles.[56] Finally, an acridine radical as a single-electron reductant has been also used for desulfonylation reactions.[57] However, all these recent visible light protocols use expensive photocatalysts or even catalysts that are not commercially available.

Over the past few years Hantzsch esters (HEs) were extensively used in hydrogen transfer reactions.[58] Additionally, with the continuous advances in visible light photocatalysis field,[59–61] HEs have also been used as electron donor and proton source in a large number of photoredox processes.[62] In this sense, a wide range of organic transformations involve the use of transition-metal photocatalysts in combination with HEs as reductants.[63–68] Other recent reports demonstrated the formation of an electron donor-acceptor (EDA) complex between HE and *N*-alkoxyl derivatives, *N*-acyloxyphthalimides, *N*-alkyl-pyridinium salts or heteroaryl *N*-oxides to undergo PET in absence of a photocatalyst under visible light irradiation.[69–72] Furthermore, HE in the presence of base was recently used as visible light catalyst to obtain alkenes and diaryl sulfinates.[73,74]

In this context, the development of a convenient, practical and more economical method to cleavage N-S bonds avoiding the use of high temperatures, harmful solvents and expensive transition-metal catalysts is highly desired. Herein, we describe two efficient transition-metal-free protocols whose application is related to the nature of the sulfonamide moiety. KO^{t}Bu in DMSO at rt provides a clean approach for deprotection of *N*-sulfonyl heterocycles and phenyl benzenesulfonates.[53] However, for *N*-methyl-*N*-arylsulfonamides a stronger reductive method for an effective desulfonylation is needed. Thus, the use of the anion of HE to promote the deprotection of *N*-methyl-*N*-arylsulfonamides under visible light irradiation was explored. In this work HE anion is easily prepared *in situ* by reaction of the commercial HE with KO^{t}Bu in DMSO. Additionally, HE anion absorbs light in visible region; hence this protocol does not require a transition metal photocatalyst or an absorbing light complex.

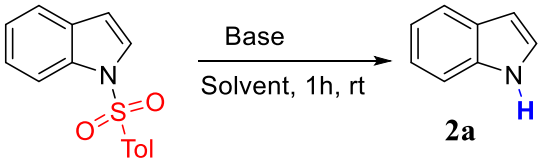
Finally, mechanistic insights were explored in order to understand the difference in reactivity and the mechanisms involved. The scope of these two methods of *N*-S (or O-S) cleavage were successfully examined using a large variety of *N*-sulfonyl heterocycles, *N*-sulfonylamines and even phenyl benzenesulfonates. Furthermore, the use of HE anion as visible

light absorbing reagent was studied in the reduction of several aryl and heteroaryl halides (RX) including iodide, bromide and chloride derivatives.

Results

N-tosylated indole **1a** was selected as model substrate to optimize our *N*-desulfonylation reaction conditions. As summarized in Table 1, **2a** was obtained in 49% yield when the reaction was carried out in DMF for 1 h, using three equivalents of KO^{t}Bu at rt (Table 1, entry 1). Notably, yield was increased to 96% when DMSO was employed as solvent (entry 2). A variety of solvents revealed that the reaction media had a significant impact on the reaction efficiency. THF and ethanol did not work well for this desulfonylation process, and **2a** was obtained in 26% yield and traces, respectively after 1 h (entries 3 and 4). Incomplete conversion was observed when the amount of KO^{t}Bu was lowered (entry 5). Base effect was also examined (entries 6-11) founding that the reaction did not work using K_2CO_3, Cs_2CO_3 or KOH at rt and only 12% yield of **2a** was obtained when the reaction was carried out with KOH at 65 ºC.[13] Moreover, 21% and 84% yields of **2a** were obtained when other bases such as NaH and NaO^{t}Bu were employed. This environmentally friendly methodology avoided the use of transition-metal[56] or phase transfer catalysts,[15] toxic solvents and high temperature conditions.[13]

Table 1. *N*-Desulfonylation reaction of *N*-indole 1a[a]



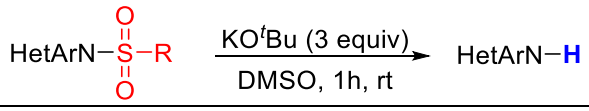
1a **2a**

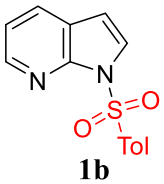
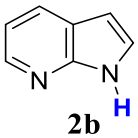
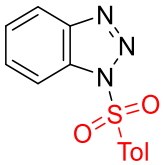
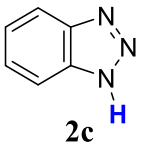
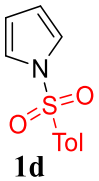
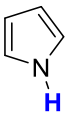
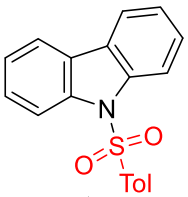
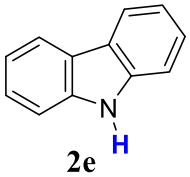
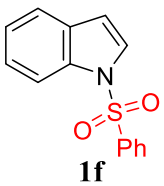
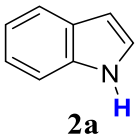
Entry	Conditions[a]	Yields 2a[b]
1	3 equiv. KO^{t}Bu, DMF	49
2	3 equiv. KO^{t}Bu, DMSO	96 (91[c])
3	3 equiv. KO^{t}Bu, THF	26
4	3 equiv. KO^{t}Bu, EtOH	< 5
5	1.1 equiv. KO^{t}Bu, DMSO	48
6	3 equiv. K_2CO_3, DMSO	--
7	3 equiv. Cs_2CO_3, DMSO	--
8	3 equiv. KOH, DMSO	--
9	3 equiv. KOH, 65 °C, DMSO	12
10	3 equiv. NaH, DMSO	21
11	3 equiv. NaO^{t}Bu, DMSO	84

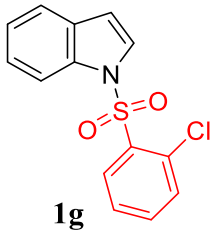
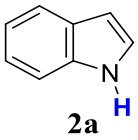
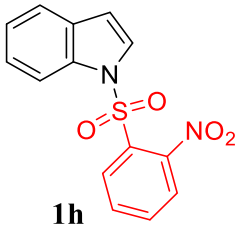
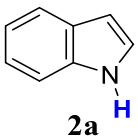
[a]The reaction was carried out under N_2 atmosphere using **1a** (1 equiv, 0.1 mmol) and base in 1 mL of solvent and the mixture was protected from light with aluminum foil. [b]Yields were quantified by GC using internal standard method. [c]Isolated yield.

Once optimal reaction conditions were determinated, several heterocycles were deprotected using only KO^{t}Bu in DMSO at rt. Results are shown in Table 2. A complete *N*-desulfonylation of *N*-tosyl 7-azaindole (**1b**), benzotriazole (**1c**) and pyrrole (**1d**) was achieved after 1 h (entries 1-3) whereas only 47% yield of carbazole was obtained under identical condition (entry 4). Other sulfonyl protecting groups were tested such as benzenesulfonyl, 2-chlorobenzenesulfonyl and 2-nitrobenzenesulfonyl (*o*-Ns) groups (substrates **1f**-**1h**) and desulfonylated product **2a** was also obtained in very good yields (entries 5-7). Additionally, desulfonylation reaction of compound **1f** was carried out at higher concentrations in order to demonstrate the practical utility of this methodology. Product **2a** was successfully obtained without a decrease in the isolated yield when 0.5 mmol of **1f** in DMSO were employed or even when the reaction was scaled-up to 1 gram (3.9 mmol, entry 5).

Table 2. *N*-Desulfonylation of indoles and related heterocycles[a]



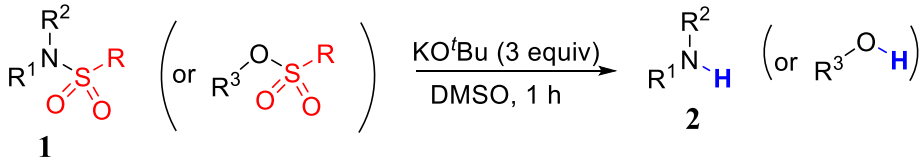
Entry	Substrate	Product	Yield (%)[b]
1	 **1b**	 **2b**	87
2	 **1c**	 **2c**	67
3	 **1d**	 **2d**	99
4	 **1e**	 **2e**	47 (1 h) 48 (3 h)[c]
5	 **1f**	 **2a**	91, 88,[d] 86[e]

6	 **1g**	 **2a**	88
7	 **1h**	 **2a**	93

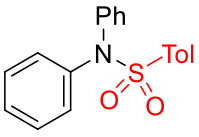
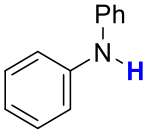
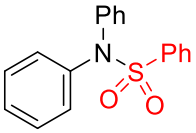
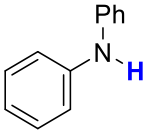
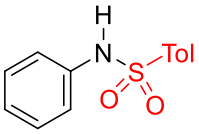
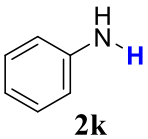
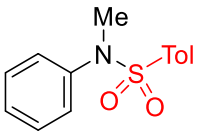
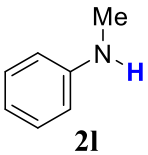
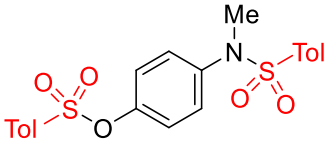
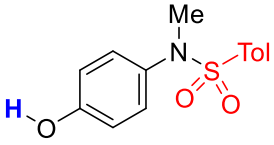
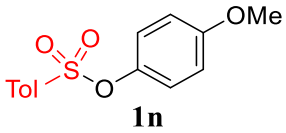
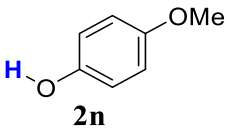
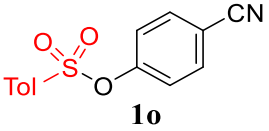
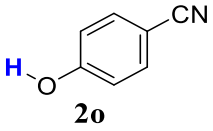
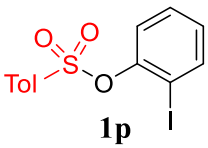
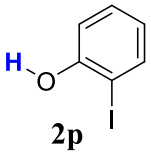
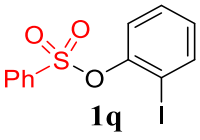
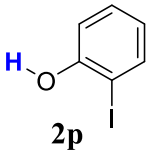
[a]The reaction was carried out under N_2 atmosphere using **1** (1 equiv, 0.1 mmol) and KO^{t}Bu (3 equiv) in DMSO (1 mL) and the mixture was protected from light with aluminum foil. [b]Isolated yields after column chromatography. [c]*N*-tosylcarbazole (**1e**) was recuperated in 50% yield. [d]Reaction carried out 5 times more concentrated (0.5 mmol of **1f** in 1 mL of DMSO). [e]Reaction carried out starting from 1gram of **1f** in 7.8 mL.

Next, our attention was focused on the scope of this desulfonylation process to deprotect different *N*-arylsulfonamides and phenyl benzenesulfonates. For instance, *N*,*N*-diphenyl tosylamine (**1i**) was chosen as representative derivative of aromatic *p*-toluenesulfonamides giving the desufonylted product **2i** in 72% yield (Table 3, entry 1). However, *N*,*N*-diphenyl benzenesulfonamide (**1j**) and unsubstituted or *N*-methylsubstituted aromatic sulfonamides (**1k** and **1l**) did not give the corresponding products **2j**, **2k** or **2l** (Table 3, entries 2-4). These results led us to explore the possibility of carrying out selectively the removal of *p*-toluenesulfonyl group. In this way, the polytosylated substrate **1m** was tested and benzenesulfonate moiety could be selectively deprotected in presence of *p*-toluenesulfonamide moiety, giving **2m** in moderate isolated yield (entry 5). There are few examples of removing sulfonyl groups from sulfonates such as KOH in refluxing MeOH,[75] KOH with ^{t}BuOH in toluene at 100 °C,[76] *n*-PrSLi in HMPA at 180 °C[77] or by using photochemical process via PET.[78,79] Thus, other benzenesulfonate substrates were studied following our protocol such as 4-methoxyphenyl 4-methylbenzenesulfonate (**1n**), 4-cyanophenyl 4-methylbenzenesulfonate (**1o**), 2-iodophenyl 4-methylbenzenesulfonate (**1p**) and 2-iodophenyl benzenesulfonate (**1q**) giving the corresponding phenols **2n-p** in very good yields (74-89%) and using only KO^{t}Bu in DMSO at rt.

Table 3. *N*-Detosylation of amino and sulfonate moiety[a]

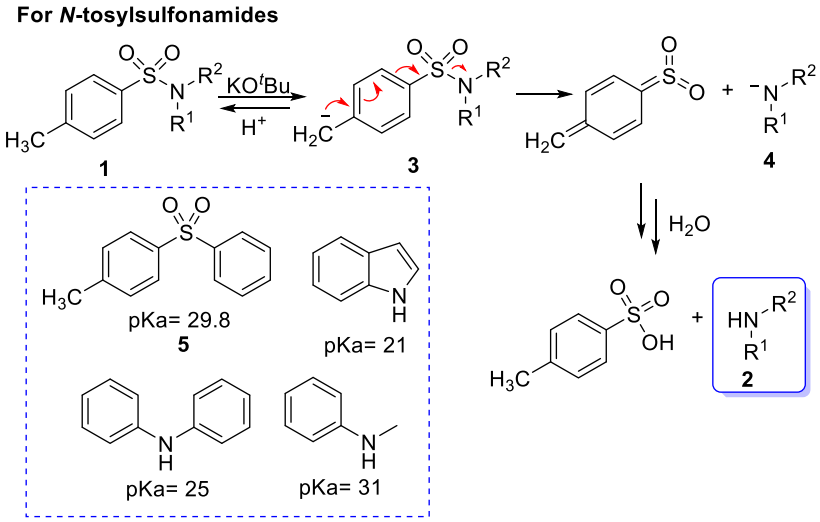


Entry	Substrate	Product	Yield (%)[b]

1	 **1i**	 **2i**	72
2	 **1j**	 **2i**	--
3	 **1k**	 **2k**	--
4	 **1l**	 **2l**	10
5[c]	 **1m**	 **2m**	44[c,d]
6	 **1n**	 **2n**	74 (75)[c]
7	 **1o**	 **2o**	89 (90)[c]
8	 **1p**	 **2p**	88 (93)[c]
9	 **1q**	 **2p**	80

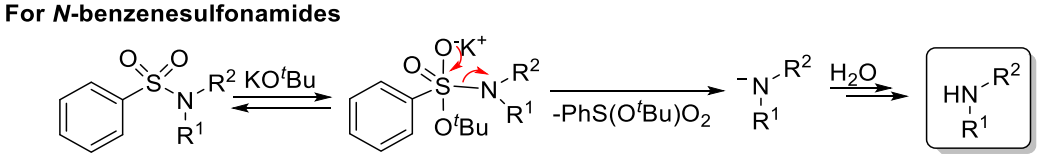
[a]The reaction was carried out under N_2 atmosphere using **1** (1 equiv, 0.1 mmol) and KO^{t}Bu (3 equiv) in DMSO (1 mL) and the mixture was protected from light with aluminium foil. [b]Yields were quantified by GC using internal standard method. [c]Isolated yield. [d]Using 5 equiv. of KO^{t}Bu for 3 h.

A plausible mechanism for the desulfonylation reaction, which is consistent with the observations described above, is shown in Scheme 1. Although the pKa (methyl group) of toluensulfonamide is unknown, it can be approximated to that of 1-methyl-4-(phenylsulfonyl)benzene (**5**), whose pKa is 29.8[80] in DMSO. Therefore, the *N*-tosylsulfonamide forms the corresponding anion **3** in the presence of KO^{t}Bu (^{t}BuOH, pKa=32.2),[81] which was indicated by the observation that the solution turned to blue. The *N*-S bond of anion **3** could fragment to produce amide anion **4**, which after protonation finally gives the deprotected product **2**. This fragmentation is thermodynamically controlled by the acidity (pKa value) of the final deprotected product **2**. Since the conjugate base of compound **5** is more basic than those of indole (pKa= 21.0 in DMSO)[82] and diphenyl amine (pKa= 25.0 in DMSO),[83] this process is favored for *N*-tosyl indole (**1a**) and diphenyl *N*-tosylamine (**1i**). Meanwhile, for *N*-methyl-*N*-phenyltosylamine (**1l**) this fragmentation does not take-place due to the higher pKa value for *N*-methyl-*N*-phenylamine (pKa= 30.6 for aniline in DMSO).[83]



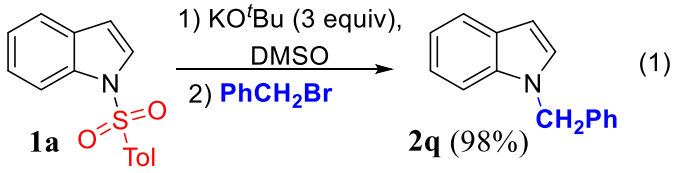
Scheme 1. Possible mechanism of *N*-detosylation reactions in basic medium

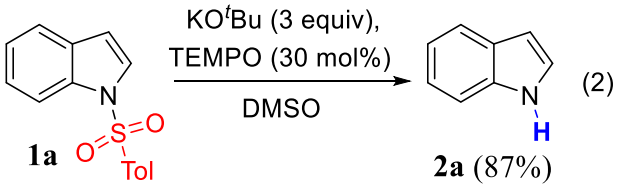
A different mechanism for the deprotection of *N*-benzenesulfonamides is proposed involving a direct attack of the base to the sulfur atom (Scheme 2). This behavior explains the reactivity of **1f-h** with phenyl, 2-chlorophenyl and 2-nitrophenyl as substituents. This mechanism could also explain the lack of reactivity for *N*,*N*-diphenyl benzenesulfonamide (**1j**) due to a high steric hindrance for the nucleophilic attack of the base.



Scheme 2. Possible reaction mechanism for deprotection of *N*-benzenesulfonamides

In order to demonstrate the presence of a polar mechanism, the reaction of **1a** was quenched with benzyl bromide and benzyl indole (**2q**) was obtained in quantitative isolated yield (eq 1). In addition, the reaction of **1a** with KO^{t}Bu was carried out in presence of 2,2,6,6-tetramethyl-1-piperidinyloxy (TEMPO) as a radical trapping and similar yield of **2a** was obtained (87% yield) indicating the absence of radicals as intermediates (eq 2).





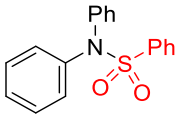
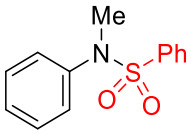
Regarding to the lack of reactivity of **1j** and **1l** substrates under proposed polar mechanism (Table 3, entries 2 and 4), we decided to explore PET for *N*-desulfonylation reactions. As dimsyl anion is able to form aryl and alkyl radicals from RX under visible light irradiation,[84,85] we carried out the reaction for substrate **1j** with KO^{t}Bu in DMSO under irradiation using UV-vis lamps (λ > 350 nm) for 3 h giving the desulfonylation product **2i** in 65% yield (Table 4, entry 1). Moreover, product **2i** was obtained in 88% yield when UV-vis lamps were replaced by using 3W blue light-emitting diodes (LEDs) (entry 2). In order to rule out homolytic fragmentation, photoinduced reaction was performed in absence of base and substrate **1j** was recovered in quantitative yield (entry 3). When same conditions were applied to substrate **1r**, the desulfonylated product **2l** was given in only 20% yield (entry 4). Probably, the reduction potential of the excited dimsyl anion (unknown) could not achieve the ET to initiate the reaction. As some anions of substituted dihydro ethyl benzoates and quinoline previously prepared in liquid ammonia have been used as hydrogen donors in reductive reactions,[86,87] we proposed HE anion as both an electron and hydrogen atom donor to promote desulfonylation reaction of *N*-methyl-*N*-arylsulfonamides as an alternative strategy to [Ir(ppy)$_2$(dtb-bpy)PF$_6$]/HE[52] and Cu complex/HE.[55]

Therefore, the reaction of **1r** with 1 equiv. of HE and 1.1 of KO^{t}Bu for 17 h using blue LED afforded product **2l** in 46% yield (Table 4, entry 5). Furthermore, higher yield was observed when the reaction was carried out employing 2.2 equiv of KO^{t}Bu (73% of **2l**, entry 6). Notably, the yield was increased to 79 and 88% when higher amounts of HE (1.3 and 1.5 equiv) were used (entries 7 and 8). Finally, product **1r** was obtained in 98% yield when 2 equiv of HE were employed (entry 9). No reaction is detected in dark conditions (entry 10) discarding a

spontaneous ET or polar mechanism. Moreover, similar yield of **2l** was given when the reaction was carried out in 1 h, reducing considerably the reaction time (entry 11). No product **2l** was obtained in absence of base (entry 12) or when other bases and reducing reagents such as NEt_3 or *N*-ethyldiisopropylamine (DIPEA) were used as control experiments (entries 13-14). Finally, the desulfonylation was carried out in presence of TEMPO and 1,1-diphenylethylene as radical scavengers and reaction was partially inhibited (entries 15 and 16). We suggest that radical formation could be involved in the key step of this mechanism (Scheme 3).

Table 4. Photodesulfonylation of 1j and 1r in DMSO[a]

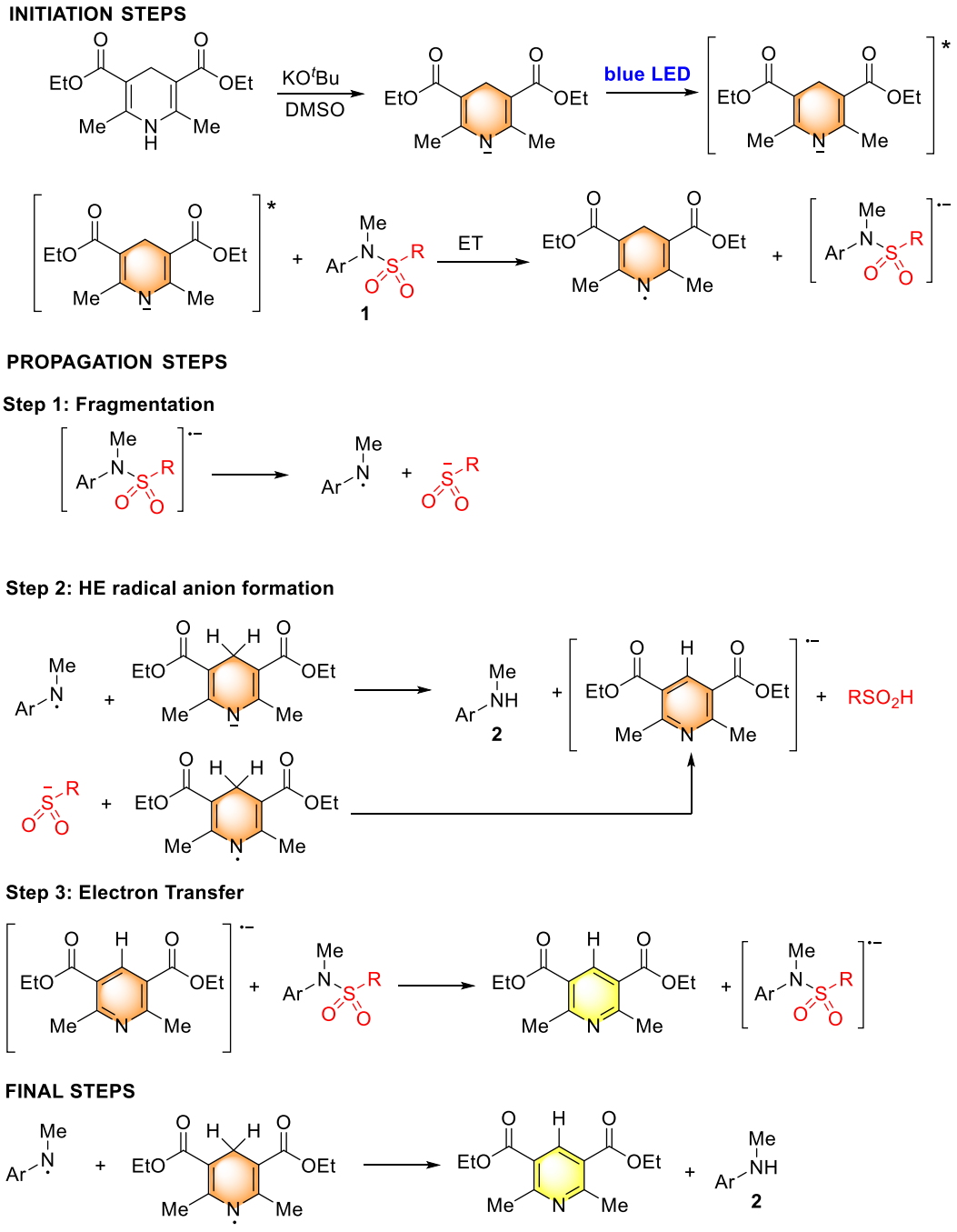
1 **2**

Entry	Substrate	Conditions	Time (h)	Yield[b]
1[c]	 **1j**	hν (λ> 350 nm), KO^{t}Bu (3 equiv)	3	**2i,** 65
2	**1j**	KO^{t}Bu (3 equiv)	3	**2i**, 88
3	**1j**	Without base	3	**2i**, --
4	 **1r**	KO^{t}Bu (3 euiv)	1	**2l,** 20
5	**1r**	HE (1 equiv) , KO^{t}Bu (1.1 equiv)	17	**2l**, 46
6	**1r**	HE (1 equiv) , KO^{t}Bu (2.2 equiv)	17	**2l**, 73
7	**1r**	HE (1.3 equiv) , KO^{t}Bu (2.2 equiv)	17	**2l**, 79
8	**1r**	HE (1.5 equiv) , KO^{t}Bu (2.2 equiv)	17	**2l**, 88
9	**1r**	HE (2 equiv) , KO^{t}Bu (2.2 equiv)	17	**2l**, 98 (95)[d]
10	**1r**	Dark, HE (2 equiv) , KO^{t}Bu (2.2 equiv)	17	**2l**, --
11	**1r**	HE (2 equiv) , KO^{t}Bu (2.2 equiv)	1	**2l**, 98
12	**1r**	HE (2 equiv)	1	**2l**, --
13	**1r**	DIPEA (2 equiv)	1	**2l**, --
14	**1r**	NEt_3 (2 equiv)	1	**2l**, --
15	**1r**	1,1-diphenylethene (0.5 equiv),	1	**2l**, 77

16	**1r**	HE (2 equiv), KO^{t}Bu (2.2 equiv) TEMPO (30 mol%), HE (2 equiv), KO^{t}Bu (2.2 equiv)	1	**2l**, 68

[a]Unless otherwise noted, the photostimulated reaction conditions was carried out under N_2 atmosphere using **1** (1 equiv, 0.1 mmol), base and/or additive in DMSO (1 mL) with blue-LED (3 W) in a sealed tube. [b]Yields were quantified by GC using internal standard method. [c]Irradiation was conducted in a photochemical reactor equipped with two HPIT 400W lamps ($\lambda \geq 350$ nm). [d]Isolated yield.

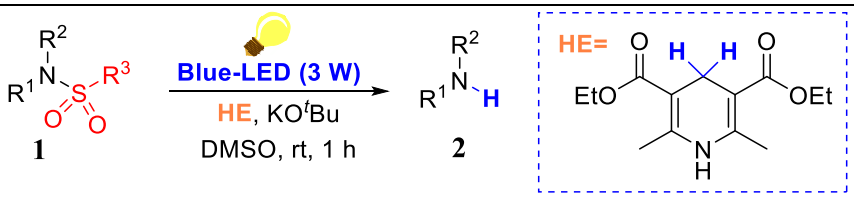
A proposed mechanism for photoinduced *N*-desulfonylation reaction in presence of HE anion is shown in Scheme 3. HE anion is easily prepared *in situ* by reaction of HE with KO^{t}Bu in DMSO as solvent. Anion formation is rapidly detected due to the color of the solution (orange) indicating that HE anion is the visible light absorbing reagent (λ_{max}= 475 nm).[88] After irradiation, ET occurs between the photoexcited HE anion and *N*-methylarylsulfonylamine **1** forming the corresponding radical anion of the substrate (initial step) and HE radical. The *N*-S bond cleavage in these radical anions can generate either *N*-centered anions or -radicals depending on the nature of the *N*-substituent. It is known that *N*-tosyl-*N*,*N*-phenylamine (**1i**) and *N*-benzyl-*N*-phenyl *p*-toluensulfonamide fragments to give aminyl radicals ($Ph_2N\cdot$ and $Ph(Bn)N\cdot$)[53,43] and sulfonate anions ($TolSO_2^-$) (Step 1). A fast hydrogen transfer from HE anion to aminyl radical affords product **2** and HE radical anion. Alternatively, sulfonate anion can deprotonate HE radical to give the corresponding HE radical anion and sulfonic acid. The driving force for this reaction is the rearomatization of HE anion (or HE radical) to give HE radical anion (Step 2). Following, ET from HE radical anion to **1** give a pyridine derivative and *N*-methylarylsulfonylamides radical anion to continue the radical chain process (Step 3). Finally, the intermediate aminyl radical can generate the reductive product **2** removing a hydrogen from HE radical (final step).

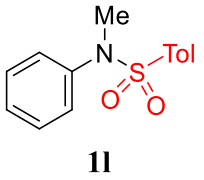
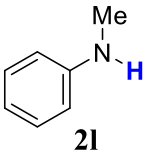
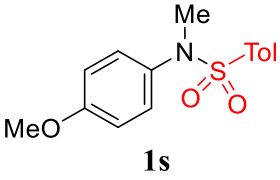
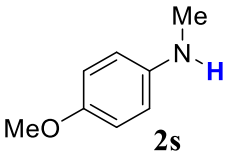
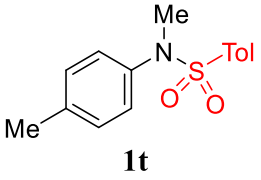
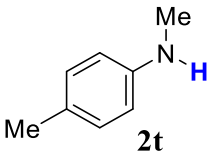
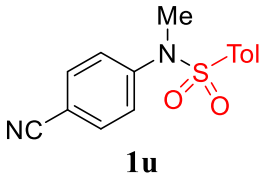
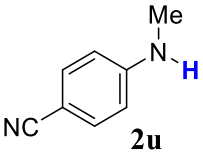
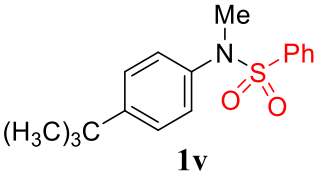
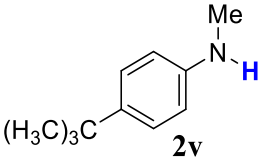
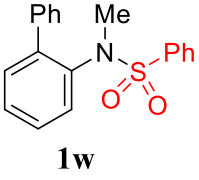
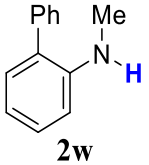
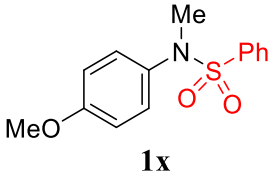
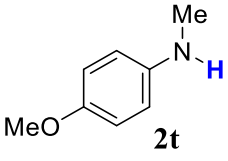


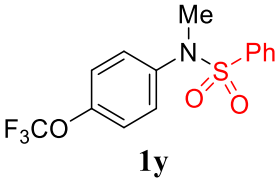
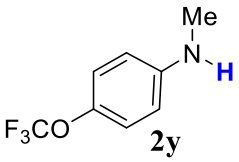
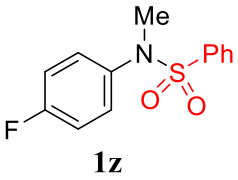
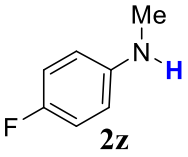
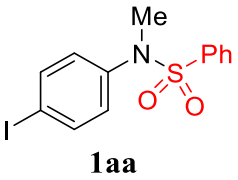
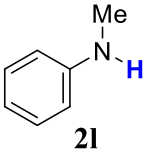
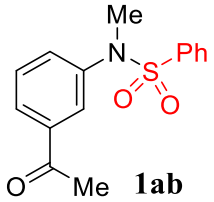
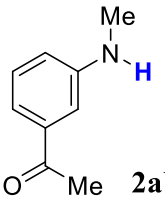
Scheme 3. Proposed photodesulfonylation reaction mechanism using HE anion as visible light absorbing reagent and electron and hydrogen atom donor

Next, several *N*-methyl-*N*-arylsulfonamides (**1l** and **1s-1ab**) were examined under the same photoinduced conditions in presence of HE anion (Table 5). Desulfonylation reaction exhibited high functional group tolerance and yields. For *orto* or *para* substituted sulfonamides with electron-donating and electron-withdrawing groups the reaction gives the desired products in good to excellent yields (51-98 % yields, entries 1-11). Furthermore, similar yields were also obtained if tosyl or benzenesulfonyl protecting groups were used.

Table 5. Substrate scope examination of photodesulfonylation reaction[a]

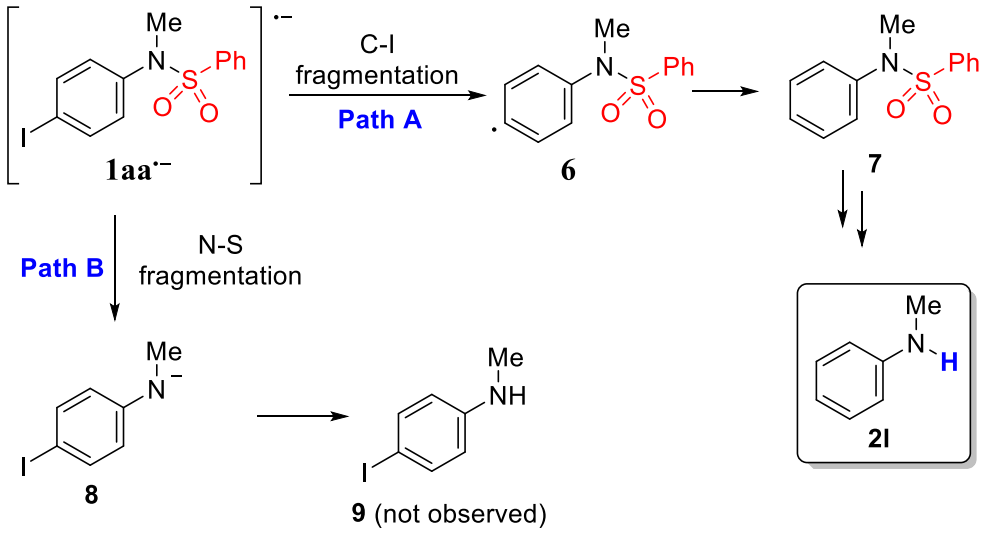


Entry	Substrate	Product	Yield[b]
1	 **1l**	 **2l**	51
2	 **1s**	 **2s**	95(80)[c]
3	 **1t**	 **2t**	98
4	 **1u**	 **2u**	93[c]
5	 **1v**	 **2v**	97 (80)[c]
6	 **1w**	 **2w**	98 (90)[c]
7	 **1x**	 **2t**	64

8	 **1y**	 **2y**	58[c]
9	 **1z**	 **2z**	85
10	 **1aa**	 **2l**	37
11	 **1ab**	 **2ab**	90 (85)[c]

[a]The photostimulated reaction was carried out under N_2 atmosphere using **1** (1 equiv, 0.1 mmol), HE (2 equiv) and KO^{t}Bu (2.2 equiv) in DMSO (1 mL) using 3 W blue LED, at rt in a sealed tube. [b]Yields were quantified by GC using internal standard method. [c]Isolated yields.

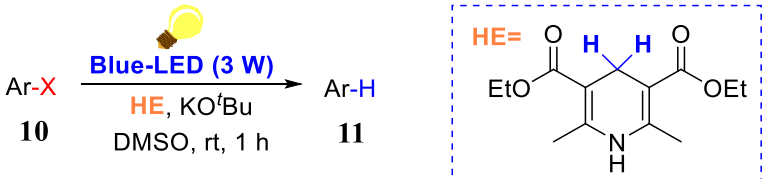
For *N*-(4-iodophenyl)-*N*-methylbenzenesulfonamide (**1aa**, Table 5, entry 10), the dehalogented product **2l** was obtained as main product. Regarding to this result and the mechanism presented in Scheme 4, the formation of radical anion **1aa**$^{\bullet-}$ as intermediate is proposed (Scheme 4). This radical anion has two possible reaction pathways. First, a C-I bond fragmentation may occur to give radical **6** which after reduction affords intermediate **7** (Path A). This intermediate can also react with HE anion under photostimulated conditions to finally yield the product **2l**. The other possibility is a N-S bond fragmentation to give anion **8** which finally provides product **9** with retention of iodine atom (Path B). In this case, path B was discarded because **9** was not detected. This result suggests that C-I fragmentation rate giving radical **6** is faster than *N*-S fragmentation to give **9**. Furthermore, it confirms the presence of radical anions as intermediates in the proposed photoinduced reaction (Scheme 3). Otherwise, C-I fragmentation was not observed for substrates **1p-q** in the first approach (KO^{t}Bu in DMSO at rt, Table 3, entries 8 and 9) showing an important difference between both examined mechanisms.

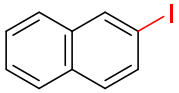
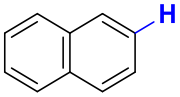


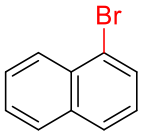
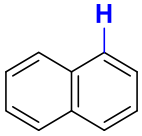
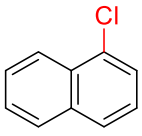
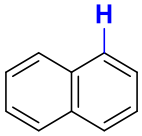
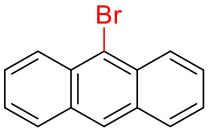
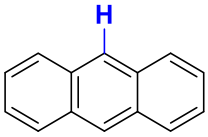
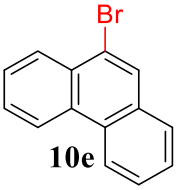
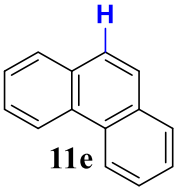
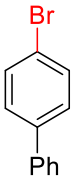
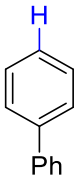
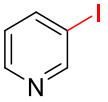
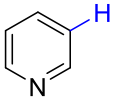
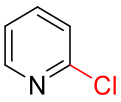
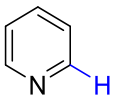
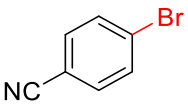
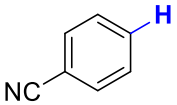
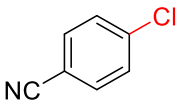
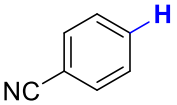
Scheme 4. Possible fragmentations of radical anion 1aa$^{\bullet-}$

PET also provides an alternative route for dehalogenation reactions. In recent years, Pd,[89] Ir,[90] Cu,[91] Pt complex[92] and Ni supported on carbon nitride[89] have been used to undergo reductions of aryl halides under visible light irradiation. Particularly, dehalogenation and aryl radical generation could also be achieved by using many visible light organic photoreductants[93–95] or photocatalyts.[96–102] To further explore our visible-light-promoted method, reduction reaction of aryl or heteroaryl halides in presence of HE anion was studied. As shown in Table 6 aryl chloride, bromide and iodide derivatives are dehalogenated (entries 1-10) in good to excellent yields under visible light irradiation using HE anion as electron and hydrogen atom donor. We finally suggest that oxidation potential of photoexcited HE anion ($E_{ox}^{*}{}_{HE^-/HE^{\bullet}}$ = -2.490 V)[103] is higher than photoexcited dimsyl anion which does not effectively reduce aryl bromides or chlorides.[84,85]

Table 6. Photoinduced reduction of ArX with HE anion[a]



Entry	Substrate	Product	Yield[b]
1	 **10a**	 **11a**	81

2	 **10b**	 **11a**	82
3	 **10c**	 **11a**	90
4	 **10d**	 **11d**	89
5	 **10e**	 **11e**	93
6	 **10f**	 **11f**	76
7	 **10g**	 **11g**	59
8	 **10h**	 **11g**	66
9	 **10i**	 **11i**	45
10	 **10j**	 **11i**	40

[a] The photostimulated reaction (1 h) was carried out under N_2 atmosphere using **10** (1 equiv, 0.1 mmol), HE (2 equiv) and KO^{t}Bu (2.2 equiv) in DMSO (1 mL) using 3 W blue LED, at rt in a sealed tube. [b]Yields were quantified by GC using internal standard method.

Conclusions

In order to summarize, in this work we presented two green synthetic methodologies towards the desulfonylation process under transition-metal-free and rt conditions. First methodology proceeds under mild reaction conditions using only KO^{t}Bu in DMSO at rt where a variety of *N*-sulfonyl heterocycles and phenyl benzenesulfonates were effectively deprotected. This strategy involves a polar mechanism very sensitive to both electronic and steric effects. Second methodology involves a visible-light-promoted method utilizing HE anion as electron and hydrogen atom donor and blue LED as a light source. In this way, several *N*-methyl-*N*-arylsulfonamides have given the corresponding products in good to excellent yields. Furthermore, the reaction was highly tolerant to a variety of functional groups and was successfully scaled-up to 1 gram. Moreover, this methodology was also expanded to aryl halides substrates and it is noteworthy that even the ArCl react giving ArH with good yields. HE anion as visible-light absorbing reagent does not require previous preparation and is a convenient alternative to expensive transition-metal photocatalysts.

Experimental Section

General Methods. Purification of desired compounds was made by column chromatography on silica gel. Gas chromatographic (GC) analysis were performed with a flame-ionization detector, on 30 m capillary column of a 0.32 mm x 0.25 μm film thickness, with a 5% phenylpolysiloxane phase. Gas chromatography-mass spectroscopy (GC-MS) analysis were performed employing an electronic impact (EI) ionization method and a 25 m x 0.2 mm x 0.33 μm column with a 5% phenylpolysiloxane phase. ^{1}H NMR and ^{13}C NMR{1H} spectra were recorded on 400 and 500 MHz in spectrometer $CDCl_3$ or Acetone-d_6 as solvents with TMS as internal standard. Additional ^{19}F NMR spectra was performed for fluorinated compounds and was recorded on 377 MHz in spectrometer $CDCl_3$, Acetone-d_6 (CD_3COCD_3) or DMSO-d_6 ($CD_3S(O)CD_3$) as solvents. Coupling constants are given in Hz and chemical shifts are reported in δ values in ppm. Data are reported as followed: chemical shift, multiplicity (s = singlet, s br = broad singlet, d = doublet, t = triplet, dd = double doublet, dt = double triplet, ddd = double double doublet, m = multiplet), coupling constants (Hz), and integration. All new products were further characterized by 2D NMR techniques (^{1}H/^{1}H COSY, ^{1}H/^{13}C HSQC and ^{1}H/^{13}C HMBC) and high resolution mass spectrometry (HRMS). HRMS analyses were carried out using a time-of-flight mass spectrometry (TOF-MS) instrument with an electrospray ionization (ESI) source. Photoinduced reactions were conducted with blue LED (λ= (465 ± 20) nm) lights performing at 3W of potency and 700 mV of current emission spectra (Figure S1) and HPIT 400W lamps (λ≥ 350 nm, Figure S2). Apparatus and irradiation setup are shown in Figure S3.

Materials. 1*H*-Indole (**2a**), 1*H*-pyrrolo[2,3-*b*]pyridine (**2b**), 1*H*-benzo[*d*][1,2,3]triazole (**2c**), 1*H*-pyrrole (**2d**), 9*H*-carbazole (**2e**), *N*,*N*-diphenylamine (**2i**), 4-methoxyphenol (**2n**), 4-hydroxybenzonitrile (**2o**), 2-iodophenol (**2p**), aniline, benzyl bromide, 4-methoxyaniline, 4-methylaniline, 4-aminobenzonitrile, 4-(*tert*-butil)-aniline, [1,1'-biphenyl]-2-amine, 4-(trifluoromethoxy)aniline, 4-fluoroaniline, 4-iodoaniline, 4-aminophenol, 3-aminoacetophenone, benzenesulfonyl chloride, 2-chlorobenzenesulfonyl chloride, 2-nitrobenzenesulfonyl chloride, 2-iodonaphtalene (**10a**), 1-bromonaphtalene (**10b**), 1-chloronaphtalene (**10c**), 9-bromoanthracene (**10d**), 9-bromophenanthrene (**10e**), 4-bromo-1,1'-biphenyl (**10f**), 3-iodopyridine (**10g**), 2-chloropyridine (**10h**), 4-bromobenzonitrile (**10i**), 4-chlorobenzonitrile (**10j**), naphtalene (**11a**), anthracene (**11d**), phenanthrene (**11e**), biphenyl (**11f**), pyridine (**11g**), cyanobenzene (**11i**), KO^{t}Bu, NaO^{t}Bu, K_2CO_3, Cs_2CO_3, KOH, NaOH, NaH (60% in mineral oil), NH_4NO_3, NH_4Cl, tetrabutylammonium hydrogensulfate, Na_2SO_4, 2,2,6,6-tetramethyl-1-piperidinyloxy (TEMPO), Hantzsch ester, NEt_3, DIPEA, 1,1-diphenyl ethene, pyridine were purchased from commercial suppliers and used without further purification. DMSO, DMF, THF, CH_2Cl_2 and toluene were distilled and dried under molecular sieves (3 Å). All solvents were analytical grade. The silica used in column chromatography corresponds to silica gel 60 (0.063−0.200 mm).

Typical Procedures for Synthesis of Sulfonamides.

Method A. The reaction was carried out in a Schlenk tube equipped with an inert N_2 inlet and magnetic stirred at rt. In the Schlenk tube, DMSO (5 mL) was dried and deoxygenated, KO^{t}Bu (1.0 equiv, 112 mg, 1 mmol) was added and the mixture was protected from light with aluminum foil. Then, the corresponding NH-heterocycle or aniline (1 equiv, 1 mmol) and benzenesulfonyl chloride (1.2 equiv, 1.2 mmol) were added and the reaction mixture was stirred overnight (18 hours). After the reaction was finished, it was quenched with NH_4NO_3 or NH_4Cl and water in excess and the residue was extracted with EtOAc or CH_2Cl_2 (3 x 30 mL), the organic layers extracted were combined, washed with water, dried with anhydrous Na_2SO_4 and concentered under reduced pressure to leave the crude products. The reaction was analyzed with TLC, GC and isolated with column chromatography over silica gel.

For details of Methods B to E see SI.

Characterization Data of Synthetized Sulfonamides.

1-[(2-Chlorophenyl)sulfonyl]-1*H*-indole (**1g**). Titled compound was obtained according to Method B and was purified by column chromatography on silica gel eluting with hexane/EtOAc (90:10 → 80:20). Light yellow solid was isolated in 71% yield (0.71 mmol, 207 mg). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.15 (dd, *J* = 8.2, 1.8 Hz, 1H), 7.74 (d, *J* = 3.7 Hz, 1H), 7.71 - 7.65 (m,

1H), 7.60 - 7.54 (m, 1H), 7.51 - 7.39 (m, 3H), 7.25 - 7.18 (m, 2H), 6.67 (d, *J* = 3.7 Hz, 1H). ^{13}C NMR {1H} (101 MHz, $CDCl_3$) δ 136.4, 134.8, 134.5, 132.9, 132.4, 131.2, 130.6, 127.9, 127.2, 124.3, 123.3, 121.5, 113.0, 107.5. ^{1}H/^{1}H COSY NMR (400 MHz, $CDCl_3$) δ_H/δ_H 8.15/7.51-7.39, 7.74/6.67, 7.71-7.65/7.60-7.54, 7.60-7.54/7.25-7.18, 7.51-7.39/7.51-7.39. ^{1}H/^{13}C HSQC NMR (400 MHz, $CDCl_3$) δ_H/δ_C 8.15/131.4, 7.74/127.9, 7.71-7.65/113.0, 7.60-7.54/121.5, 7.51-7.39/134.8, 7.51-7.39/132.4, 7.51-7.39/127.2, 7.25-7.18/123.3, 7.25-7.18/124.3, 6.67/107.5. ^{1}H/^{13}C HMBC NMR (400 MHz, $CDCl_3$) δ_H/δ_C 8.15/132.9, 8.15/134.8, 7.74/107.5, 7.74/130.6, 7.74/134.5, 7.71-7.65/132.4, 7.71-7.65/130.6, 7.60- 7.54/124.3, 7.60-7.54/134.5, 7.51-7.39/127.2, 7.51-7.39/131.2, 7.51-7.39/132.4, 7.51-7.39/132.9, 7.51-7.39/136.4, 7.25-7.18/113.0, 7.25-7.18/121.5, 7.25-7.18/130.6, 7.25-7.18/134.5, 6.67/127.9, 6.67/130.6, 6.67/134.5. GC/MS EI *m/z* 293 (M^+ +2, 9), 291 (M^+, 22), 117 (10), 116 (100), 111 (27), 90 (11), 89 (61), 75 (35), 63 (37), 51 (10), 50 (17). HRMS (ESI) *m/z*: $[M + H]^+$ Calcd for $C_{14}H_{11}ClNO_2S$ 292.0194; Found 292.0189.

Methylation of Synthetized Sulfonamides (Method F). The reaction was carried out in a round-bottom flask equipped with a magnetic stirred bar. KO^{t}Bu was added (1.1 equiv) to a solution of sulfonamide (1 equiv) in DMSO (2 mL) then, iodomethane (3 equiv) was slowly added. The resulting mixture was stirred at rt overnight. Water was added, the crude was extracted with EtOAc (3 x 30 mL), and the layers were separated. The organic layers extracted were combined, washed with water, dried with anhydrous Na_2SO_4 and concentered under reduced pressure to leave the crude products. The reaction was analyzed with TLC, GC and isolated with column chromatography over silica gel.

***N*-(4-(*tert*-Butyl)phenyl)-*N*-methylbenzenesulfonamide** (**1v**) was obtained from **1v-s** and was purified by column chromatography on silica gel eluting with hexane/EtOAc (95:5 → 80:20). Colorless oil was isolated in 74% yield (0.73 mmol, 223 mg). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.59-7.57 (m, 3H), 7.46 (t, *J* = 7.6 Hz, 2H), 7.30 (d, *J* = 8.5 Hz, 2H), 7.00 (d, *J* = 8.5 Hz, 2H), 3.16 (s, 3H), 1.30 (s, 9H). ^{13}C NMR{1H} (101 MHz, $CDCl_3$) δ 150.5, 138.8, 136.9, 132.6, 128.7, 127.9, 126.2, 125.8, 38.2, 34.6, 31.3. ^{1}H/^{1}H COSY NMR (400 MHz, $CDCl_3$) δ_H/δ_H 7.59-7.57/7.46, 7.30/7.00, 3.16/3.16, 1.30/1.30. ^{1}H/^{13}C HSQC NMR (400 MHz, $CDCl_3$) δ_H/δ_C 7.59-7.57/127.9, 7.59-7.54/132.6, 7.46/128.7, 7.30/125.5, 7.00/126.2, 3.16/38.2, 1.30/31.3. ^{1}H/^{13}C HMBC NMR (400 MHz, $CDCl_3$) δ_H/δ_C 7.59-7.57/127.9, 7.59-7.57/132.6, 7.46/128.7, 7.46/136.9, 7.30/125.8, 7.30/138.8, 7.00/126.2, 7.00/138.8, 7.00/150.5, 3.16/138.8, 1.30/31.3, 1.30/34.6, 1.30/150.5. GC/MS EI *m/z* 304 (M^+ +1, 2), 303 (M^+, 14), 288 (20), 162 (45), 147 (24), 146 (25), 141 (11), 132 (21), 118 (12), 91 (21), 78 (11), 77 (100), 51 (42). HRMS (ESI-TOF$^+$) *m/z*: $[M + H]^+$ Calcd for $C_{17}H_{22}NO_2S$: 304.1366; Found 304.1383.

***N*-([1,1'-Biphenyl]-2-yl)-*N*-methylbenzenesulfonamide** (**1w**) was obtained from **1w-s** and was purified by column chromatography on silica gel eluting with pentane/EtOAc (90:10 → 70:30).

Brown solid was isolated in 80% yield (1.33 mmol, 431.3 mg). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60-7.53(m, 3H), 7.44-7.34 (m, 9H), 7.28-7.23 (m, 1H), 7.01 (d, *J* = 7.8 Hz, 1H), 2.99 (s, 3H). ^{13}C NMR{1H} (101 MHz, $CDCl_3$) δ 142.4, 139.3, 139.1, 138.8, 132.5, 131.5, 129.1, 128.8, 128.4, 128.1, 128.1, 127.8, 127.7, 127.2, 39.2. ^{1}H/^{1}H COSY NMR (400 MHz, $CDCl_3$) δ_H/δ_H 7.60-7.54/7.46-7.35, 7.46-7.35/7.29-7.25, 7.46-7.35/7.00, 7.29-7.25/7.00, 3.00/3.00. ^{1}H/^{13}C HSQC NMR (400 MHz, $CDCl_3$) δ_H/δ_C 7.60-7.54/127.8, 7.60-7.54/132.5, 7.46-7.35/127.2, 7.46-7.35/128.1, 7.46-7.35/128.4, 7.46-7.35/128.8, 7.46-7.35/129.1, 7.46-7.35/131.5, 7.29-7.25/128.1, 7.00/127.7, 3.00/39.2. ^{1}H/^{13}C HMBC NMR (400 MHz, $CDCl_3$) δ_H/δ_C 7.60-7.54/127.8, 7.60-7.54/132.5, 7.60-7.54/127.8, 7.46-7.35/127.2, 7.45-7.35/127.7, 7.46-7.35/127.8, 7.46-7.35/128.1, 7.46-7.35/128.8, 7.46-7.35/129.1, 7.46-7.35/138.8, 7.46-7.35/139.3, 7.46-7.35/142.4, 7.29-7.25/131.5, 7.29-7.25/139.1, 7.00/128.4, 7.00/142.4, 3.00/139.1. GC/MS EI *m*/*z* 323 (M^+, 1), 182 (66), 181 (26), 180 (28), 167 (85), 166 (14), 152 (15), 115 (11), 77 (100), 51 (54), 50 (11). HRMS (ESI-TOF$^+$) *m/z*: $[M + H]^+$ Calcd for $C_{19}H_{18}NO_2S$ 324.1053; Found 324.1077.

***N*-Methyl-*N*-(4-(trifluoromethoxy)phenyl)benzenesulfonamide** (**1y**) was obtained from **1y-s** and was purified by column chromatography on silica gel eluting with hexane/EtOAc (95:5 → 80:20). Brown oil was isolated in 70% yield (0.7 mmol, 232 mg). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61-7.45 (m, 5H), 7.16-7.10 (m, 4H), 3.16 (s, 3H). ^{13}C NMR{1H} (101 MHz, $CDCl_3$) δ 147.9, 140.0, 136.2, 133.0, 128.9, 128.0, 127.8, 121.3, 38.1. ^{1}H/^{1}H COSY NMR (400 MHz, $CDCl_3$) δ_H/δ_H 7.61-7.45/7.61-7.45, 7.16-7.10/7.16-7.10, 3.16/3.16. ^{1}H/^{13}C HSQC NMR (400 MHz, $CDCl_3$) δ_H/δ_C 7.61-7.45/127.8, 7.61-7.45/128.9, 7.61-7.45/133.0, 7.16-7.10/121.3, 7.16-7.10/128.0, 3.16/38.1. ^{1}H/^{13}C HMBC NMR (400 MHz, $CDCl_3$) δ_H/δ_C 7.61-7.45/127.8, 7.61-7.45/128.9, 7.61-7.45/133.0, 7.61-7.45/136.1, 7.16-7.10/121.3, 7.16-7.10/128.0, 7.16-7.10/139.9, 7.16-7.10/147.9, 3.16/139.9. ^{19}F NMR (377 MHz, $CDCl_3$) δ - 58.0. GC/MS EI *m*/*z* 332 (M^+ +1, 2), 331 (M^+, 15), 190 (81), 162 (11), 95 (20), 92 (11), 78 (11), 77 (100), 69 (16), 66 (12), 65 (11), 51 (61), 50 (16). HRMS (ESI-TOF$^+$) *m/z*: $[M + H]^+$ Calcd for $C_{14}H_{13}F_3NO_3S$ 332.0563; Found 332.0572.

One-pot Synthesis of *N*-methyl-*N*-arylsulfonamides. 1s, **1t**, **1x, 1z** and **1ab** were prepared by a one-pot synthesis starting from the corresponding anilines (2 mmol). First, the sulfonylation reaction was carried out according to Methods A to E and secondly, without purification, methylation reaction proceeded.

***N*-(4-Fluorophenyl)-*N*-methylbenzenesulfonamide** (**1z**) was obtained from 4-fluoroaniline according to Methods E and methylation reaction and was purified by column chromatography on silica gel eluting with hexane/EtOAc (95:5 → 80:20). Brown oil was isolated in 79% global yield (1.57 mmol, 416 mg). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61-7.44 (m, 5H). 7.06-6.95 (m,

4H), 3.16 (s, 3H). ^{13}C NMR{1H} (101 MHz, $CDCl_3$) δ 161.5 (d, *J* = 248 Hz, 1C), 137.4 (d, *J* = 3, 1C), 136.3, 132.8, 128.8, 128.5 (d, *J* = 9 Hz, 2C), 127.8, 115.7 (d, *J* = 23 Hz, 2C), 38.3. ^{1}H/^{1}H COSY NMR (400 MHz, $CDCl_3$) δ_H/δ_H 7.61-7.44/7.61-7.44, 7.06-6.95/7.06-6.95, 3.16/3.16. ^{1}H/^{13}C HSQC NMR (400 MHz, $CDCl_3$) δ_H/δ_C 7.61-7.44/127.8, 7.61-7.44/128.8, 7.61-7.44/132.8, 7.06-6.95/115.7, 7.06-6.95/128.5, 3.16/38.3. ^{1}H/^{13}C HMBC NMR (400 MHz, $CDCl_3$) δ_H/δ_C 7.61-7.44/127.8, 7.61-7.44/128.8, 7.61-7.44/132.8, 7.61-7.44/136.3, 7.06-6.95/115.7, 7.06-6.95/128.5, 7.06-6.95/137.4, 7.06-6.95/161.5, 3.16/137.4. ^{19}F NMR (377 MHz, $CDCl_3$) δ -113.8. GC/MS EI *m/z* 266 (M^+ +1, 2), 265 (M^+, 17), 124 (100), 122 (14), 97 (26), 96 (29), 95 (41), 77 (80), 75 (21), 57 (13), 51 (51), 50 (15). HRMS (ESI-TOF$^+$) *m/z*: $[M + H]^+$ Calcd for $C_{13}H_{13}FNO_2S$ 266.0646; Found 266.0654.

***N*-(3-Acetylphenyl)-*N*-methylbenzenesulfonamide (1ab)** was obtained from 1-(3-amino phenyl)ethan-1-one according to Methods B and methylation reaction and was purified by column chromatography on silica gel eluting with hexane/EtOAc (100:0 → 75:25). Orange oil was isolated in 65% global yield (1.3 mmol, 373.4 mg). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.87-7.85 (m, 1H), 7.62-7.37 (m, 8H), 3.20 (s, 3H), 2.56 (s, 3H). ^{13}C NMR {1H} (101 MHz, $CDCl_3$) δ 197.1, 142.0, 137.7, 136.0, 133.0, 131.4, 129.1, 128.8, 127.7, 127.1, 125.7, 37.9, 26.6. ^{1}H/^{1}H COSY NMR (400 MHz, $CDCl_3$) δ_H/δ_H 7.87-7.85 /7.62-7.37, 3.20/3.20, 2.56/2.56. ^{1}H/^{13}C HSQC NMR (400 MHz, $CDCl_3$) δ_H/δ_C 7.87-7.85 /121.1, 7.62-7.37/125.7, 7.62-7.37/133.0, 7.62-7.37/127.7, 7.62-7.37/129.1, 7.62-7.37/128.8, 7.62-7.37/131.4. ^{1}H/^{13}C HMBC NMR (400 MHz, $CDCl_3$) δ_H/δ_C 7.87-7.85 /125.7, 7.87-7.85 /134.4, 7.87-7.85/197.1, 7.62-7.37/127.1, 7.62-7.37/127.7, 7.62-7.37/128.8, 7.62-7.37/131.4, 7.62-7.37/133.0, 7.62-7.37/136.0, 7.62-7.37/137.7, 7.62-7.37/142.0, 7.62-7.37/197.1, 3.20/142.0, 2.56/197.1. HRMS (ESI-TOF$^+$) *m/z*: $[M + H]^+$ Calcd for $C_{15}H_{16}NO_3S$ 290.0845; Found 290.0860.

Desulfonylation Reactions in Dark Conditions. The desulfonylation reaction was carried out in a Schlenk tube equipped with an inert N_2 inlet and magnetic stirred at rt. In the Schlenk tube, DMSO (1 mL) was dried and deoxygenated, then the corresponding sulfonamide (1 equiv, 0.1 mmol) and KO^{t}Bu (3 equiv, 0.3 mmol) were added and the mixture was protected from light with aluminum foil. After the reaction was finished, it was quenched with NH_4NO_3 or NH_4Cl and water in excess and the residue was extracted with EtOAc (3 x 30 mL), the organic layers extracted were combined, washed with water, dried with anhydrous Na_2SO_4 and concentered under reduced pressure to leave the crude products. Yields were quantified by GC employing internal method using biphenyl as internal standard.

Photodesulfonylation Reactions under Visible Light Irradiation. The photodesulfonylation reactions were carried out in a vial at rt and under N_2 atmosphere and irradiated with blue- LED (3 W) using 1 equiv. (0.1 mmol) of sulfonamide, 2.2 equiv. of KO^{t}Bu (0.22 mmol) and 2 equiv. of Hantzsch ester (0.2 mmol) in DMSO (1 mL previously dried and deoxygenated). After the

reaction was finished, it was quenched with NH_4NO_3 or NH_4Cl and water in excess and the residue was extracted with EtOAc (3 x 30 mL), the organic layers extracted were combined, washed with water, dried with anhydrous Na_2SO_4 and concentered under reduced pressure to leave the crude products. Yields were quantified by GC using internal method employing 9*H*-carbazole as internal standard.

Characterization Data of Desulfonylation Products (2). 1*H*-Indole (**2a**), 1*H*-pyrrolo[2,3-*b*]pyridine (**2b**), 1*H*-benzo[*d*][1,2,3]triazole (**2c**), 1*H*-pyrrole (**2d**), 9*H*-carbazole (**2e**), diphenylamine (**2i**), aniline (**2k**), 4-methoxyphenol (**2n**), 4-hydroxybenzonitrile (**2o**), 2-iodophenol (**2p**) and 1-benzyl-1*H*-indole (**2q**) were identified by comparing with authentic samples (GC/FID and GC–MS).

1*H*-Indole (2a). Titled compound was purified by column chromatography on silica gel eluting with hexane/EtOAc (100:0 → 80:20) in 91% yield (0.091 mmol, 10.6 mg) as white solid. Starting from 0.5 mmol of substrate, 88% isolated yield (0.44 mmol, 51.5 mg) was obtained. For large-scale reaction, 86% isolated yield (3.6 mmol, 423 mg) starting from 1.080 g of substrate.

1*H*-pyrrolo[2,3-*b*]pyridine (**2b**). Titled compound was purified by column chromatography on silica gel eluting with hexane/EtOAc (100:0 → 80:20) in 87% yield (0.087 mmol, 10.2 mg) as white solid.

1*H*-benzo[*d*][1,2,3]triazole (2c). Titled compound was purified by column chromatography on silica gel eluting with hexane/EtOAc (100:0 → 80:20) in 67% yield (0.067 mmol, 8.0 mg) as white solid.

1*H*-pyrrole (2d). Titled compound was purified by column chromatography on silica gel eluting with hexane/EtOAc (100:0 → 80:20) in 99% yield (0.099 mmol, 6.6 mg) as colorless oil.

9*H*-carbazole (2e). Titled compound was purified by column chromatography on silica gel eluting with hexane/EtOAc (100:0 → 80:20) in 47% yield (0.047 mmol, 7.8 mg) as white solid.

Diphenylamine (2i). Titled compound was obtained in 72% yield (0.072 mmol, 12.2 mg) as brown solid.

4-Methoxyphenol (2n). Titled compound was purified by column chromatography on silica gel eluting with hexane/EtOAc (50:50) in 75% yield (0.075 mmol, 9.3 mg) as light-pink solid.

4-Hydroxybenzonitrile (2o). Titled compound was purified by column chromatography on silica gel eluting with hexane/EtOAc (50:50) in 90% yield (0.09 mmol, 10.7 mg) as white solid.

2-Iodophenol (2p). Titled compound was purified by column chromatography on silica gel eluting with hexane/EtOAc (50:50) in 93% yield (0.093 mmol, 20.5 mg) as grey solid.

1-Benzyl-1*H*-indole (2q). Titled compound was purified by column chromatography on silica gel eluting with hexane/EtOAc (80:20) in 98% yield (0.098 mmol, 20.3 mg) as colorless oil.

***N*-Methylaniline** (**2l**).[134] Titled compound was purified by column chromatography on silica gel eluting with hexane/EtOAc (90:10 → 50:50) in 95% yield (0.095 mmol, 10 mg) as brown oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.20-7.16 (m, 2H), 6.70 (t, *J* = 7.3 Hz, 1H), 6.59 (d, *J* = 7.7 Hz, 2H), 3.64 (s br, 1H), 2.80 (s, 3H). ^{13}C NMR{1H} (101 MHz, $CDCl_3$) δ 149.3, 129.1, 117.2, 112.3, 30.6. GC/MS EI *m*/*z* 108 (8, M^+ +1), 107 (81 M^+), 106 (100), 79 (33), 78 (14), 77 (39), 65 (14), 51 (23), 50 (8).

***N*-(4-Hydroxyphenyl)-*N*,4-dimethylbenzenesulfonamide** (**2m**).[135] Titled compound was purified by column chromatography on silica gel eluting with hexane/EtOAc (90:10 → 50:50). Brown oil was isolated in 44 % yield (0.014 mmol, 4 mg). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.45 (d, *J* = 8.0 Hz, 2H), 7.26-7.24 (m, 2H), 6.93 (d, *J* = 8.6 Hz, 2H), 6.73 (d, *J* = 8.6 Hz, 2H), 5.19 (s br, 1H), 3.12 (s, 3H), 2.42 (s, 3H). ^{13}C NMR{1H} (101 MHz, $CDCl_3$) δ 154.9, 143.5, 134.4, 133.6, 129.3, 128.4, 128.0, 115.6, 38.4, 21.5. GC/MS EI *m*/*z* 279 (M^+ +2, 1), 278 (M^+ +1, 2), 277 (M^+, 10), 123 (7), 122 (100), 94 (19), 91 (11), 65 (18).

4-Methoxy-*N*-methylaniline (**2s**).[136] Titled compound was purified by column chromatography on silica gel eluting with hexane/EtOAc (100:0 → 70:30). Light yellow oil was isolated in 80 % yield (0.08 mmol, 9.8 mg). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25 (s, 1H), 6.82-6.78 (m, 2H), 6.61-6.57 (m, 2H), 3.75 (s, 3H), 2.80 (s, 3H). ^{13}C NMR{1H} (101 MHz, $CDCl_3$) δ 152.1, 143.7, 114.9, 113.6, 55.8, 31.6. GC/MS EI *m*/*z* 138 (M^+ +1, 4), 137 (M^+, 61), 122 (100), 94 (60), 77 (13), 67 (13), 66 (12), 65 (35), 63 (23), 53 (18), 52 (26), 51 (15), 50 (8).

4-Methyl-*N*-methylaniline (**2t**).[134] Titled compound was obtained in 98% yield (0.098 mmol, 11.9 mg). ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.99 (d, *J* = 8.5 Hz, 2H), 6.54 (d, *J* = 8.4 Hz, 2H), 3.51 (s br, 1H), 2.80 (s, 3H), 2.24 (s, 3H). ^{13}C NMR{1H} (101 MHz, $CDCl_3$) δ 147.2, 129.7, 126.4, 112.6, 31.1, 20.3. GC/MS EI *m*/*z* 122 (M^+ +1, 7), 121 (M^+, 93), 120 (100), 106 (13), 91 (41), 89 (10), 79 (12), 78 (15), 77 (26), 65 (25), 63 (16), 60 (12), 53 (11), 52 (18), 51 (26), 50 (16).

4-Cyano-*N*-methylaniline (**2u**).[137] Titled compound was purified by column chromatography on silica gel eluting with hexane/EtOAc (80:20 → 50:50) as colorless oil and isolated in 50 % yield (0.05 mmol, 6.6 mg). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 (d, *J* = 8.6 Hz, 2H), 6.55 (d, *J* = 8.6 Hz, 2H), 4.25 (s br, 1H), 2.88 (s, 3H). ^{13}C NMR{1H} (101 MHz, $CDCl_3$) δ 152.2, 133.7, 120.4, 111.8, 30.0. GC/MS EI *m*/*z* 133 (M^+ +1, 7), 132 (M^+, 74), 131 (100), 104 (22), 102 (14), 77 (17), 76 (13), 75 (14), 66 (12), 64 (11), 63 (13), 51 (15), 50 (11).

4-(*tert*-Butyl)-*N*-methylaniline (**2v**).[136] Titled compound was purified by column chromatography on silica gel eluting with hexane/EtOAc (95:5 → 80:20) as colorless oil and isolated in 80 % yield (0.08 mmol, 13.0 mg). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.22 (d, *J* = 8.5 Hz, 2H), 6.59 (d, *J* = 8.5 Hz, 2H), 3.57 (s br, 1H), 2.82 (s, 3H), 1.28 (s, 9H). ^{13}C NMR{1H} (101 MHz, $CDCl_3$) δ 147.0, 140.1, 126.0, 112.2, 33.8, 31.6, 31.0. GC/MS EI *m*/*z* 164 (M^+ +1, 3), 163

(M^+, 28), 149 (11), 148 (100), 133 (16), 120 (21), 108 (12), 107 (13), 91 (13), 77 (16), 65 (12), 50 (3).

***N*-Methyl-[1,1'-biphenyl]-2-amine** (**2w**).[134] Titled compound was purified by column chromatography on silica gel eluting with hexane/EtOAc (100:0 → 90:10) as light yellow oil and isolated in 86 % yield (0.086 mmol, 15.7 mg). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.44-7.40 (m, 4H), 7.35-7.32 (m, 2H), 7.08 (dd, *J* =7.4, 1.2 Hz, 1H), 6.76 (t, *J* = 7.4 Hz, 1H), 6.68 (d, *J* = 8.1 Hz, 1H), 4.09 (s br, 1H), 2.78 (s, 3H).

4-(Trifluoromethoxy)-*N*-methylaniline (**2y**).[137] Titled compound was purified by column chromatography on silica gel eluting with hexane/EtOAc (90:10 → 70:30) as a colorless oil and isolated in 58 % yield (0.058 mmol, 11.1 mg). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.03 (d, *J* = 8.8 Hz, 2H), 6.54-6.52 (m, 2H), 3.72 (s br, 1H), 2.8 (s, 3H). ^{13}C NMR{1H} (101 MHz, $CDCl_3$) δ 148.1, 140.4, 122.3, 120.8 (q, *J* = 255 Hz, 1C), 112.5, 30.7. GC/MS EI *m*/*z* 192 (M^+ +1, 6), 191 (M^+,60), 190 (16), 123 (10), 122 (100), 106 (11), 95 (16), 94 (54), 79 (12), 78 (12), 77 (32), 75 (11), 69 (36), 67 (15), 66 (15), 65 (38), 64 (16), 63 (21), 53 (17), 52 (23), 51 (14).

4-Fluoro-*N*-methylaniline (**2z**).[137] Titled compound was obtained in 85% yield (0.085 mmol, 10.6 mg) as a colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.93-6.86 (m, 2H), 6.55-6.51 (m, 2H), 3.32 (s br, 1H), 2.80 (s, 3H). ^{13}C NMR{1H} (101 MHz, $CDCl_3$) δ 155.8 (d, *J* = 234, 1C), 145.7, 115.6 (d, *J* = 22 Hz, 2C), 113.1 (d, *J* = 7 Hz, 2C), 31.3. GC/MS EI *m*/*z* 126 (M^+ +1, 7), 125 (M^+, 89), 124 (100), 97 (32), 96 (20), 95 (20), 83 (23), 77 (17), 75 (18), 62 (15), 57 (12).

1-(3-(Methylamino)phenyl)ethan-1-one (2ab).[138] Titled coumpound was purified by column chromatography on silica gel eluting with hexane/EtOAc (90:10 → 70:30) as a white solid in 85% yield (0.085 mmol, 12.7 mg) as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28-7.26 (m, 2H), 7.20-7.18 (m, 1H), 6-81-6.78 (m, 1H), 3.90 (s br, 1H), 2.88 (s, 3H), 2.58 (s, 3H).

Photoinduced Reduction of Aryl Halides in presence of HE. The photostimulated reduction was carried out under N_2 atmosphere using 1 equiv. (0.1 mmol) of the corresponding aryl halide, 2 equiv. of HE and KO^{t}Bu (2.2 equiv) in DMSO (1 mL) and irradiating with 3 W blue LED at rt. DMSO was previously dried and deoxygenated. After the reaction was finished, it was quenched with NH_4NO_3 or NH_4Cl and water in excess. The residue was extracted with EtOAc (3 x 30 mL), and the organic layers were combined, washed with water, dried with anhydrous Na_2SO_4 and concentered under reduced pressure to leave the crude products. Yields were quantified by GC using internal method using 9*H*-carbazole as internal standard. Naphtalene (**11a**), anthracene (**11d**), phenanthrene (**11e**), biphenyl (**11f**), pyridine (**11g**) and cyanobenzene (**11i**) were identified by comparing with authentic samples (GC/FID and GC–MS).

Naphtalene (11a). Titled compound was obtained in 81% yield (0.081 mmol, 10.4 mg) as a white solid.

Anthracene (11d). Titled compound was obtained in 89 % yield (0.089 mmol, 15.9 mg) as a white solid.

Phenanthrene (11e). Titled compound was obtained in 93 % yield (0.093 mmol, 16.5 mg) as white solid.

Biphenyl (11f). Titled compound was obtained in 76 % yield (0.076 mmol, 11.6 mg) as a white solid.

Pyridine (11g). Titled compound was obtained in 59 % yield (0.059 mmol, 4.67 mg) as a colorless oil.

Cyanobenzene (11i). Titled compound was obtained in 45 % yield (0.045 mmol, 4.6 mg) as a colorless oil.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website. Extra experimental details, UV−vis spectra, ^{1}H NMR and ^{13}C NMR{1H} spectra for substrates and products, Emission Spectrum for Blue-LEDs and HPIT 400W lamps ($\lambda \geq 350$ nm, Figures S1 and S2), Figures S3-S6, and Tables S1−S3 (PDF).

AUTHOR INFORMATION

Corresponding Author

*E-mail for M. E.B.: eugebuden@unc.edu.ar

ORCID:

Micaela D. Heredia: 0000-0002-5688-4162

Walter D. Guerra: 0000-0003-0712-2740

Silvia M. Barolo: 0000-0003-3730-0018

Santiago J. Formasier: 0000-0001-8675-1160

Roberto A. Rossi: 0000-0001-8659-082X

María E. Budén: 0000-0002-2424-3299

Notes

The authors declare no competing financial interest.

ACKNOWLEDGEMENTS

This work was supported partly by Agencia Córdoba Ciencia, Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Secretaría de Ciencia y Tecnología,

Universidad Nacional de Córdoba (SECyT) and Agencia Nacional de Promoción Científica y Técnica (ANPCyT). M. D. H. gratefully acknowledge receipt of fellowship from CONICET.

REFERENCES AND ENDNOTES

(1) Wuts, P. G. M.; Greene, T. W. Protection for the Amino Group. In *Greene's Protective Groups in Organic Synthesis*; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2006; 696–926.

(2) Thomas, E. J. Protecting Groups. Philip J. Kocienski. Georg Thieme, Stuttgart, New York. *Appl. Organomet. Chem.* **2001**, *15*, 725-726.

(3) Kan, T.; Fukuyama, T. Ns Strategies: A Highly Versatile Synthetic Method for Amines. *Chem. Commun.* **2004**, *4*, 353–359.

(4) Snyder, H. R.; Heckert, R. E. A Method for the Rapid Cleavage of Sulfonamides 1. *J. Am. Chem. Soc.* **1952**, *74*, 2006–2009.

(5) Weisblat, D. I.; Magerlein, B. J.; Myers, D. R. The Cleavage of Sulfonamides. *J. Am. Chem. Soc.* **1953**, *75*, 3630–3632.

(6) Wellner, E.; Sandin, H.; Pääkkönen, L. Synthesis of 6,6-Difluorohomopiperazines via Microwave-Assisted Detosylation-. *Synthesis* **2003**, *2*, 0223–0226.

(7) Searles, S.; Nukina, S. Cleavage and Rearrangement of Sulfonamides. *Chem. Rev.* **1959**, *59*, 1077–1103.

(8) Nolan, C.; Gunnlaugsson, T. Improved Synthesis of a C_3-Symmetrical Pyridinophane. *Tetrahedron Lett.* **2008**, *49*, 1993–1996.

(9) Sakamoto, I.; Izumi, N.; Yamada, T.; Tsunoda, T. 2-(1,3-Dioxan-2-il)ethylsulfonyl Group: A New Versatile Protecting and Activating Group for Amine Synthesis. *Org. Lett.* **2006**, *8*, 71–74.

(10) Javorskis, T.; Orentas, E. Chemoselective Deprotection of Sulfonamides Under Acidic Conditions: Scope, Sulfonyl Group Migration, and Synthetic Applications. *J. Org. Chem.* **2017**, *82*, 13423–13439.

(11) Oppolzer, W.; Bienayme, H.; Genevois-Borella, A. Enantioselective Synthesis of (+)-3-Isorauniticine via a Catalytic Tandem Palladium-Ene/carbonylation Reaction. *J. Am. Chem. Soc.* **1991**, *113*, 9660–9661.

(12) Kudav, D. P.; Samant, S. P.; Hosangadi, B. D. Perchloric Acid-Acetic Acid: A Reagent System for Detosylation. *Synth. Commun.* **1987**, *17*, 1185–1187.

(13) Merrill, B. A.; LeGoff, E. A General Synthetic Route to 2,2':5',2''-terpyrrole, 2,5-di(2-Pyrryl)thiophene, and Alkyl-Substituted Analogs. *J. Org. Chem.* **1990**, *55*, 2904–2908.

(14) Garg, N. K.; Sarpong, R.; Stoltz, B. M. The First Total Synthesis of Dragmacidin D. *J. Am. Chem. Soc.* **2002**, *124*, 13179–13184.

(15) Liu, Y.; Shen, L.; Prashad, M.; Tibbatts, J.; Repič, O.; Blacklock, T. J. A Green *N*-

Detosylation of Indoles and Related Heterocycles Using Phase Transfer Catalysis. *Org. Process Res. Dev.* **2008**, *12*, 778–780.

(16) Chaulet, C.; Croix, C.; Basset, J.; Pujol, M.; Viaud-Massuard, M.-C. Desulfonylation of Indoles and 7-Azaindoles Using Sodium *tert*-Butoxide. *Synlett* **2010**, *10*, 1481–1484.

(17) Haskins, C. M.; Knight, D. W. Efficient Indole *N*-Detosylation Using Thioglycolate. *Tetrahedron Lett.* **2004**, *45*, 599–601.

(18) Bajwa, J. S.; Chen, G.; Prasad, K.; Repič, O.; Blacklock, T. J. Deprotection of *N*-Tosylated Indoles and Related Structures Using Cesium Carbonate. *Tetrahedron Lett.* **2006**, *47*, 6425–6427.

(19) Fleming, I.; Frackenpohl, J.; Ila, H. Cleavage of Sulfonamides with Phenyldimethylsilyllithium. *J. Chem. Soc. Perkin Trans. 1* **1998**, *7*, 1229–1236.

(20) Gold, E. H.; Babad, E. Reductive Cleavage of Sulfonamides with Sodium Bis(2-Methoxyethoxy)aluminum Hydride. *J. Org. Chem.* **1972**, *37*, 2208–2210.

(21) Itoh, T.; Yokoya, M.; Miyauchi, K.; Nagata, K.; Ohsawa, A. Proline-Catalyzed Asymmetric Addition Reaction of 9-Tosyl-3,4-Dihydro-β-Carboline with Ketones. *Org. Lett.* **2003**, *5*, 4301–4304.

(22) Mendiola, J.; Baeza, A.; Alvarez-Builla, J.; Vaquero, J. J. Reaction of Bromomethylazoles and Tosylmethyl Isocyanide. A Novel Heterocyclization Method for the Synthesis of the Core of Marine Alkaloids Variolins and Related Azolopyrimidines. *J. Org. Chem.* **2004**, *69*, 4974–4983.

(23) Ankner, T.; Hilmersson, G. Instantaneous Deprotection of Tosylamides and Esters with SmI_2/Amine/Water. *Org. Lett.* **2009**, *11*, 503–506.

(24) Vedejs, E.; Lin, S. Deprotection of Arenesulfonamides with Samarium Iodide. *J. Org. Chem.* **1994**, *59*, 1602–1603.

(25) Knowles, H.; Parsons, A.; Pettifer, R. Desulfonylation of Amides Using Samarium Iodide. *Synlett* **1997**, *1997*, 271–272.

(26) Jensen, K. L.; Franke, P. T.; Nielsen, L. T.; Daasbjerg, K.; Jørgensen, K. A. Anodic Oxidation and Organocatalysis: Direct Regio- and Stereoselective Access to Meta-Substituted Anilines by α-Arylation of Aldehydes. *Angew. Chem. Int. Ed.* **2010**, *49*, 129–133.

(27) Blay, G.; Cardona, L.; Climent, E.; Pedro, J. R. Highly Enantioselective Zinc/binol-Catalyzed Alkynylation of *N*-Sulfonyl Aldimines. *Angew. Chem. Int. Ed.* **2008**, *47*, 5593–5596.

(28) Kuriyama, M.; Soeta, T.; Hao, X.; Chen, Q.; Tomioka, K. *N*-Boc-L-Valine-Connected Amidomonophosphane Rhodium(I) Catalyst for Asymmetric Arylation of *N*-Tosylarylimines with Arylboroxines. *J. Am. Chem. Soc.* **2004**, *126*, 8128–8129.

(29) Nyasse, B.; Grehn, L.; Ragnarsson, U. Mild, Efficient Cleavage of Arenesulfonamides

by Magnesium Reduction. *Chem. Commun.* **1997**, *11*, 1017–1018.

(30) Das, I.; Pathak, T. Desulfonylation with Mg−MeOH−$NiBr_2$: An Expedient Reagent System for the Synthesis of 2-Amino-2,3-Dideoxy Furanosides. *Org. Lett.* **2006**, *8*, 1303–1306.

(31) Deck, J. A.; Martin, S. F. Enantioselective Synthesis of (+)-Isolysergol via Ring-Closing Metathesis. *Org. Lett.* **2010**, *12*, 2610–2613.

(32) Grehn, L.; Ragnarsson, U. Reagent for Synthesis of Secondary Amines by Two Consecutive *N*-Alkylations and Its Application to Orthogonally Protected Spermidine. *J. Org. Chem.* **2002**, *67*, 6557–6559.

(33) Nyasse, B.; Grehn, L.; Maia, H. L. S.; Monteiro, L. S.; Ragnarsson, U. 2-Naphthalenesulfonyl as a Tosyl Substitute for Protection of Amino Functions. Cyclic Voltammetry Studies on Model Sulfonamides and Their Preparative Cleavage by Reduction. *J. Org. Chem.* **1999**, *64*, 7135–7139.

(34) Carraro, M.; Pisano, L.; Azzena, U. Silica Gel Stabilized Na and Na/K Alloys: Highly Effective, Versatile and Environmentally Friendly Reducing Agents. *Synthesis* **2017**, *49*, 1931–1937.

(35) Nandi, P.; Redko, M. Y.; Petersen, K.; Dye, J. L.; Lefenfeld, M.; Vogt, P. F.; Jackson, J. E. Alkali Metals in Silica Gel (M-SG): A New Reagent for Desulfonation of Amines. *Org. Lett.* **2008**, *10*, 5441–5444.

(36) Alonso, E.; Ramón, D. J.; Yus, M. Reductive Deprotection of Allyl, Benzyl and Sulfonyl Substituted Alcohols, Amines and Amides Using a Naphthalene-Catalysed Lithiation. *Tetrahedron* **1997**, *53*, 14355–14368.

(37) Ji, S.; Gortler, L. B.; Waring, A.; Battisti, A. J.; Bank, S.; Closson, W. D.; Wriede, P. A. Cleavage of Sulfonamides with Sodium Naphthalene. *J. Am. Chem. Soc.* **1967**, *89*, 5311–5312.

(38) Birkinshaw, T. N.; Holmes, A. B. Synthesis of (±)-Isoprosopinines A and B. *Tetrahedron Lett.* **1987**, *28*, 813–816.

(39) Roemmele, R. C.; Rapoport, H. Removal of *N*-Arylsulfonyl Groups from Hydroxy-α-Amino Acids. *J. Org. Chem.* **1988**, *53*, 2367–2371.

(40) Shohji, N.; Kawaji, T.; Okamoto, S. Ti(O-*i*-Pr)$_4$/Me_3SiCl/Mg-Mediated Reductive Cleavage of Sulfonamides and Sulfonates to Amines and Alcohols. *Org. Lett.* **2011**, *13*, 2626–2629.

(41) Vellemäe, E.; Lebedev, O.; Mäeorg, U. A Mild Method for Cleavage of *N*-Tos Protected Amines Using Mischmetal and $TiCl_4$. *Tetrahedron Lett.* **2008**, *49*, 1373–1375.

(42) Schoenebeck, F.; Murphy, J. A.; Zhou, S.; Uenoyama, Y.; Miclo, Y.; Tuttle, T. Reductive Cleavage of Sulfones and Sulfonamides by a Neutral Organic Super-Electron-Donor (S.E.D.) Reagent. *J. Am. Chem. Soc.* **2007**, *129*, 13368–13369.

(43) O'Sullivan, S.; Doni, E.; Tuttle, T.; Murphy, J. A. Metal-Free Reductive Cleavage of C-*N* and S-*N* Bonds by Photoactivated Electron Transfer from a Neutral Organic Donor. *Angew. Chem. Int. Ed.* **2014**, *53*, 474–478.

(44) Hanson, S. S.; Doni, E.; Traboulsee, K. T.; Coulthard, G.; Murphy, J. A.; Dyker, C. A. Pushing the Limits of Neutral Organic Electron Donors: A Tetra(iminophosphorano)-Substituted Bispyridinylidene. *Angew. Chem. Int. Ed.* **2015**, *54*, 11236–11239.

(45) Viaud, P.; Coeffard, V.; Thobie-Gautier, C.; Beaudet, I.; Galland, N.; Quintard, J.-P.; Le Grognec, E. Electrochemical Cleavage of Sulfonamides: An Efficient and Tunable Strategy to Prevent β-Fragmentation and Epimerization. *Org. Lett.* **2012**, *14*, 942–945.

(46) Senboku, H.; Nakahara, K.; Fukuhara, T.; Hara, S. Hg Cathode-Free Electrochemical Detosylation of *N*,*N*-Disubstituted *p*-Toluenesulfonamides: Mild, Efficient, and Selective Removal of *N*-Tosyl Group. *Tetrahedron Lett.* **2010**, *51*, 435–438.

(47) Coeffard, V.; Thobie-Gautier, C.; Beaudet, I.; Le Grognec, E.; Quintard, J. Mild Electrochemical Deprotection of *N*-Phenylsulfonyl *N*-Substituted Amines Derived from (*R*)-Phenylglycinol. *Eur. J. Org. Chem.* **2008**, *2008*, 383–391.

(48) Civitello, E. R.; Rapoport, H. The Regioselective Cleavage of Aryl Tosylates by Electrochemical Reduction. *J. Org. Chem.* **1992**, *57*, 834–840.

(49) Hamada, T.; Nishida, A.; Yonemitsu, O. Selective Removal of Electron-Accepting *p*-Toluene- and Naphthalenesulfonyl Protecting Groups for Amino Function via Photoinduced Donor Acceptor Ion Pairs with Electron-Donating Aromatics. *J. Am. Chem. Soc.* **1986**, *108*, 140–145.

(50) Liu, Q.; Liu, Z.; Zhou, Y.-L.; Zhang, W.; Yang, L.; Liu, Z.-L.; Yu, W. Photochemical Desulfonylation of *N*-Tosyl Amides by 2-Phenyl-*N*,*N*′-Dimethylbenzimidazoline (PDMBI). *Synlett* **2005**, *16*, 2510–2512.

(51) Hong, X.; Mejía-Oneto, J. M.; France, S.; Padwa, A. Photodesulfonylation of Indoles Initiated by Electron Transfer from Triethylamine. *Tetrahedron Lett.* **2006**, *47*, 2409–2412.

(52) Xuan, J.; Li, B.; Feng, Z.; Sun, G.; Ma, H.; Yuan, Z.; Chen, J.; Lu, L.; Xiao, W. Desulfonylation of Tosyl Amides through Catalytic Photoredox Cleavage of *N*-S Bond Under Visible-Light Irradiation. *Chem. Asian J.* **2013**, *8*, 1090–1094.

(53) Hasegawa, E.; Nagakura, Y.; Izumiya, N.; Matsumoto, K.; Tanaka, T.; Miura, T.; Ikoma, T.; Iwamoto, H.; Wakamatsu, K. Visible Light and Hydroxynaphthylbenzimidazoline Promoted Transition-Metal-Catalyst-Free Desulfonylation of *N*-Sulfonylamides and *N*-Sulfonylamines. *J. Org. Chem.* **2018**, *83*, 10813–10825.

(54) Hasegawa, E.; Izumiya, N.; Miura, T.; Ikoma, T.; Iwamoto, H.; Takizawa, S.; Murata, S. Benzimidazolium Naphthoxide Betaine Is a Visible Light Promoted Organic Photoredox Catalyst. *J. Org. Chem.* **2018**, *83*, 3921–3927.

(55) Hasegawa, E.; Tanaka, T.; Izumiya, N.; Kiuchi, T.; Ooe, Y.; Iwamoto, H.; Takizawa, S.; Murata, S. Protocol for Visible-Light-Promoted Desulfonylation Reactions Utilizing Catalytic Benzimidazolium Aryloxide Betaines and Stoichiometric Hydride Donor Reagents. *J. Org. Chem.* **2020**, *85*, 4344–4353.

(56) Hunter, C. J.; Boyd, M. J.; May, G. D.; Fimognari, R. Visible-Light-Mediated *N*-Desulfonylation of *N*-Heterocycles Using a Heteroleptic Copper(I) Complex as a Photocatalyst. *J. Org. Chem.* **2020**, *85*, 8732–8739.

(57) Mackenzie, I. A.; Wang, L.; Onuska, N. P. R.; Williams, O. F.; Begam, K.; Moran, A. M.; Dunietz, B. D.; Nicewicz, D. A. Discovery and Characterization of an Acridine Radical Photoreductant. *Nature* **2020**, *580*, 76-80.

(58) Zheng, C.; You, S.-L. Transfer Hydrogenation with Hantzsch Esters and Related Organic Hydride Donors. *Chem. Soc. Rev.* **2012**, *41*, 2498-2518.

(59) Romero, N. A.; Nicewicz, D. A. Organic Photoredox Catalysis. *Chem. Rev.* **2016**, *116*, 10075–10166.

(60) Chen, J.; Hu, X.; Lu, L.; Xiao, W. Visible Light Photoredox-Controlled Reactions of *N*-Radicals Ions. *Chem. Soc. Rev.* **2016**, *45*, 2044–2056.

(61) Cai, B.; Xuan, J.; Xiao, W. Visible Light-Mediated C-P Bond Formation Reactions. *Sci. Bull.* **2019**, *64*, 337–350.

(62) Wang, P.-Z.; Chen, J.-R.; Xiao, W.-J. Hantzsch Esters: An Emerging Versatile Class of Reagents in Photoredox Catalyzed Organic Synthesis. *Org. Biomol. Chem.* **2019**, *17*, 6936–6951.

(63) Huang, W.; Chen, J.; Hong, D.; Chen, W.; Cheng, X.; Tian, Y.; Li, G. Hydrophosphonodifluoromethylation of Alkenes via Thiyl-Radical/Photoredox Catalysis. *J. Org. Chem.* **2018**, *83*, 578–587.

(64) Wang, C.-M.; Song, D.; Xia, P.-J.; Wang, J.; Xiang, H.-Y.; Yang, H. Visible-Light-Promoted Synthesis of 1,4-Dicarbonyl Compounds via Conjugate Addition of Aroyl Chlorides. *Chem. Asian J.* **2018**, *13*, 271–274.

(65) Park, G.; Yi, S. Y.; Jung, J.; Cho, E. J.; You, Y. Mechanism and Applications of the Photoredox Catalytic Coupling of Benzyl Bromides. *Chem. Eur. J.* **2016**, *22*, 17790–17799.

(66) Bogonda, G.; Patil, Di. V.; Kim, H. Y.; Oh, K. Visible-Light-Promoted Thiyl Radical Generation from Sodium Sulfinates: A Radical–Radical Coupling to Thioesters. *Org. Lett.* **2019**, *21*, 3774–3779.

(67) Qi, L.; Chen, Y. Polarity-Reversed Allylations of Aldehydes, Ketones, and Imines Enabled by Hantzsch Ester in Photoredox Catalysis. *Angew. Chem. Int. Ed.* **2016**, *55*, 13312–13315.

(68) Lee, K. N.; Lei, Z.; Ngai, M.-Y. β-Selective Reductive Coupling of Alkenylpyridines

with Aldehydes and Imines via Synergistic Lewis Acid/Photoredox Catalysis. *J. Am. Chem. Soc.* **2017**, *139*, 5003–5006.

(69) Zhang, J.; Li, Y.; Xu, R.; Chen, Y. Donor-Acceptor Complex Enables Alkoxyl Radical Generation for Metal-Free C(sp^3)-C(sp^3) Cleavage and Allylation/Alkenylation. *Angew. Chem. Int. Ed.* **2017**, *56*, 12619–12623.

(70) Li, Y.; Zhang, J.; Li, D.; Chen, Y. Metal-Free C(sp^3)–H Allylation via Aryl Carboxyl Radicals Enabled by Donor–Acceptor Complex. *Org. Lett.* **2018**, *20*, 3296–3299.

(71) Wu, J.; Grant, P. S.; Li, X.; Noble, A.; Aggarwal, V. K. Catalyst-Free Deaminative Functionalizations of Primary Amines by Photoinduced Single-Electron Transfer. *Angew. Chem. Int. Ed.* **2019**, *58*, 5697–5701.

(72) Konev, M. O.; Cardinale, L.; Jacobi von Wangelin, A. Catalyst-Free *N*-Deoxygenation by Photoexcitation of Hantzsch Ester. *Org. Lett.* **2020**, *22*, 1316–1320.

(73) Wu, Q.; Li, H. Hantzsch Ester as a Visible-Light Photoredox Catalyst for Transition-Metal-Free Coupling of Arylhalides and Arylsulfinates. *Chem. Eur. J.* **2020**, *26*, 3484-3488.

(74) Chen, W.; Tao, H.; Huang, W.; Wang, G.; Li, S. Hantzsch Ester as a Photosensitizer for the Visible-Light-Induced Debromination of Vicinal Dibromo Compounds. *Chem. Eur. J.* **2016**, *22*, 9546–9550.

(75) Chang, J. J.; Chan, B.; Ciufolini, M. A. Synthetic Studies toward Spiroleucettadine. *Tetrahedron Lett.* **2006**, *47*, 3599–3601.

(76) Alam, M. S.; Koo, S. Deprotection of Durable Benzenesulfonyl Protection for Phenols - Efficient Synthesis of Polyphenols. *Synth. Commun.* **2018**, *48*, 247–254.

(77) Cons, B. D.; Bunt, A. J.; Bailey, C. D.; Willis, C. L. Total Synthesis of (−)-Blepharocalyxin D and Analogues. *Org. Lett.* **2013**, *15*, 2046–2049.

(78) Masnovi, J.; Koholic, D. J.; Berki, R. J.; Binkley, R. W. Reductive Cleavage of Sulfonates. Deprotection of Carbohydrate Tosylates by Photoinduced Electron Transfer. *J. Am. Chem. Soc.* **1987**, *109*, 2851–2853.

(79) Nishida, A.; Hamada, T.; Yonemitsu, O. Hydrolysis of Tosyl Esters Initiated by an Electron Transfer from Photoexcited Electron-Rich Aromatic Compounds. *J. Org. Chem.* **1988**, *53*, 3386–3387.

(80) Bordwell, F. G. Equilibrium Acidities in Dimethyl Sulfoxide Solution. *Acc. Chem. Res.* **1988**, *21*, 456–463.

(81) Olmstead, W. N.; Margolin, Z.; Bordwell, F. G. Acidities of Water and Simple Alcohols in Dimethyl Sulfoxide Solution. *J. Org. Chem.* **1980**, *45*, 3295–3299.

(82) Bordwell, F. G.; Drucker, G. E.; Fried, H. E. Acidities of Carbon and Nitrogen Acids: The Aromaticity of the Cyclopentadienyl Anion. *J. Org. Chem.* **1981**, *46*, 632–635.

(83) Bordwell, F. G.; Algrim, D. J. Acidities of Anilines in Dimethyl Sulfoxide Solution. *J.*

Am. Chem. Soc. **1988**, *110*, 2964–2968.

(84) Budén, M. E.; Bardagí, J. I.; Puiatti, M.; Rossi, R. A. Initiation in Photoredox C–H Functionalization Reactions. Is Dimsyl Anion a Key Ingredient? *J. Org. Chem.* **2017**, *82*, 8325–8333.

(85) Budén, M. E.; Guastavino, J. F.; Rossi, R. A. Room-Temperature Photoinduced Direct C-H-Arylation via Base-Promoted Homolytic Aromatic Substitution. *Org. Lett.* **2013**, *15*, 1174–1177.

(86) Bardagí, J. I.; Vaillard, S. E.; Rossi, R. A. Anions from Dihydro Substituted Ethyl Benzoates and Quinoline. New Hydrogen Donors for Tin-Free Radical Chemistry. *Tetrahedron Lett.* **2006**, *47*, 3149–3152.

(87) Vaillard, S. E.; Postigo, A.; Rossi, R. A. Fast Tin-Free Hydrodehalogenation and Reductive Radical Cyclization Reactions: A New Reduction Process. *J. Org. Chem.* **2004**, *7*, 2435–2439.

(88) See *Supporting Information*.

(89) Wei, Y.; Gong, Y.; Zhao, X.; Wang, Y.; Duan, R.; Chen, C.; Song, W.; Zhao, J. Ligand Directed Debromination of Tetrabromodiphenyl Ether Mediated by Nickel under Visible Irradiation. *Environ. Sci. Nano* **2019**, *6*, 1585–1593.

(90) Nguyen, J. D.; D'Amato, E. M.; Narayanam, J. M. R.; Stephenson, C. R. J. Engaging Unactivated Alkyl, Alkenyl and Aryl Iodides in Visible-Light-Mediated Free Radical Reactions. *Nat. Chem.* **2012**, *4*, 854–859.

(91) Michelet, B.; Deldaele, C.; Kajouj, S.; Moucheron, C.; Evano, G. A General Copper Catalyst for Photoredox Transformations of Organic Halides. *Org. Lett.* **2017**, *19*, 3576–3579.

(92) Li, K.; Wan, Q.; Yang, C.; Chang, X.-Y.; Low, K.-H.; Che, C.-M. Air-Stable Blue Phosphorescent Tetradentate Platinum(II) Complexes as Strong Photo-Reductant. *Angew. Chem. Int. Ed.* **2018**, *130*, 14325–14329.

(93) Cahard, E.; Schoenebeck, F.; Garnier, J.; Cutulic, S. P. Y.; Zhou, S.; Murphy, J. A. Electron Transfer to Benzenes by Photoactivated Neutral Organic Electron Donor Molecules. *Angew. Chem. Int. Ed.* **2012**, *51*, 3673–3676.

(94) Xu, Z.; Gao, L.; Wang, L.; Gong, M.; Wang, W.; Yuan, R. Visible Light Photoredox Catalyzed Biaryl Synthesis Using Nitrogen Heterocycles as Promoter. *ACS Catal.* **2015**, *5*, 45–50.

(95) Hasegawa, E.; Izumiya, N.; Fukuda, T.; Nemoto, K. Visible Light-Promoted Reductive Transformations of Various Organic Substances by Using Hydroxyaryl-Substituted Benzimidazolines and Bases. *Tetrahedron* **2016**, *72*, 7805–7812.

(96) Schmalzbauer, M.; Ghosh, I.; König, B. Utilising Excited State Organic Anions for Photoredox Catalysis: Activation of (Hetero)aryl Chlorides by Visible Light-Absorbing

9- Anthrolate Anions. *Faraday Discuss.* **2019**, *215*, 364–378.

(97) Matsubara, R.; Yabuta, T.; Idros, U.; Hayashi, M.; Ema, F.; Kobori, Y.; Sakata, K. UVA- and Visible-Light-Mediated Generation of Carbon Radicals from Organochlorides Using Nonmetal Photocatalyst. *J. Org. Chem.* **2018**, *83*, 9381–9390.

(98) Axel, A.; Wangelin, J. Von; Neumeier, M.; Perez, R.; Majek, M.; Sampedro, D.; Pena, V. De; Shea, O. Dichromatic Photocatalytic Substitutions of Aryl Halides with a Small Organic Dye. *Chem. Eur. J.* **2018**, *24*, 105–108.

(99) Zhang, L.; Jiao, L. Visible-Light-Induced Organocatalytic Borylation of Aryl Chlorides. *J. Am. Chem. Soc.* **2019**, *141*, 9124–9128.

(100) Discekici, E. H.; Treat, N. J.; Poelma, S. O.; Mattson, K. M.; Hudson, Z. M.; Luo, Y.; Hawker, C. J.; de Alaniz, J. R. A Highly Reducing Metal-Free Photoredox Catalyst: Design and Application in Radical Dehalogenations. *Chem. Commun.* **2015**, *51*, 11705–11708.

(101) Ghosh, I.; Ghosh, T.; Bardagi, J. I.; König, B. Reduction of Aryl Halides by Consecutive Visible Light-Induced Electron Transfer Processes. *Science* **2014**, *346*, 725–728.

(102) Gong, H. X.; Cao, Z.; Li, M. H.; Liao, S. H.; Lin, M. J. Photoexcited Perylene Diimide Radical Anions for the Reduction of Aryl Halides: A Bay-Substituent Effect. *Org. Chem. Front.* **2018**, *5*, 2296–2302.

(103) Zhu, D. L.; Wu, Q.; Li, H. Y.; Li, H. X.; Lang, J. P. Hantzsch Ester as a Visible-Light Photoredox Catalyst for Transition-Metal-Free Coupling of Arylhalides and Arylsulfinates. *Chem. Eur. J.* **2020**, *26*, 3484–3488.

(104) Wang, L.; Neumann, H.; Beller, M. Palladium-Catalyzed Methylation of Nitroarenes with Methanol. *Angew. Chem. Int. Ed.* **2019**, *131*, 5471–5475.

(105) Irshad, M.; Abbasi, M. A.; Aziz-Ur-Rehman; Rasool, S.; Siddiqui, S. Z.; Ahmad, I.; Ashraf, M.; Lodhi, M. A.; Jamal, S. B. *O*- and *N*-Substituted Derivatives of Planetol as Valuable Bioactive Compounds. *Asian J. Chem.* **2014**, *26*, 1151–1160.

(106) Huang, M.; Li, Y.; Li, Y.; Liu, J.; Shu, S.; Liu, Y.; Ke, Z. Room Temperature *N*-Heterocyclic Carbene Manganese Catalyzed Selective *N*-Alkylation of Anilines with Alcohols. *Chem. Commun.* **2019**, *55*, 6213–6216.

(107) Chen, J.; Wu, J.; Tu, T. Sustainable and Selective Monomethylation of Anilines by Methanol with Solid Molecular NHC-Ir Catalysts. *ACS Sustain. Chem. Eng.* **2017**, *5*, 11744–11751.

(108) Shang, Y.; Jonnada, K.; Yedage, S. L.; Tu, H.; Zhang, X.; Lou, X.; Huang, S.; Su, W. Rhodium(iii)-Catalyzed Indole Synthesis at Room Temperature Using the Transient Oxidizing Directing Group Strategy. *Chem. Commun.* **2019**, *55*, 9547–9550.