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Ionic liquid-mediated benzoyl transfer-coupling in the Suzuki and Sonogashira reactions and aryl transfer-coupling by decarbonylative Heck reaction, using *N*-Benzoyl-saccharin (NBSac) as reagent



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ABSTRACT

The efficacy of *N*-benzoyl-saccharin (NBSac) as reagent for selective benzoyl transfer-coupling in the Suzuki reaction in BMIM-IL/[PAIM][NTf₂] as solvent/base, and in the Sonogashira reaction employing guanidinium-IL (GIL) as solvent, are demonstrated. Decarbonylative aryl transfer-coupling occurs in the Heck reaction employing GIL as solvent. The reactions are catalyzed by $Pd(OAc)_2$ or $NiCl_2(dppp)$, are performed under mild conditions in good yields, and have the potential for recycling/reuse of the IL solvent. Collectively, these methods provide facile access to diverse libraries of diarylketones, keto-ethynes and diaryl-ethenes.

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Whereas *N*-halo-saccharins have been known as halogen transfer reagents for over two decades [1], more recent discoveries of *N*-functionalized saccharins bearing trifluoromethylthio (SCF₃) [2], formyl (CHO) [3,4], and acyl (RCO) [5,6] as functional group transfer reagents have opened up new dimensions for their deployment in metal-mediated chemistry.

Focusing on *N*-benzoyl-saccharins as transfer benzoylation reagents, two notable previous studies, namely the Suzuki coupling via Pd-catalyzed *N*-acyl bond cleavage [5], and Heck arylation via decarbonylation/arylation have been reported [6]. The Suzuki coupling employed Pd along with PCy₃HBF₄, K₂CO₃ and H₃BO₃ for optimal performance with THF as solvent [5], while optimal yields for the Heck coupling were reported with PdCl₂ in NMP as solvent at 160 °C.

In continuation of our studies on synthetic and catalytic chemistry in ILs [7], and with our more recent emphasis on metal-mediated cross-coupling reactions in imidazolium-ILs [7d]; [7f–7i], we report here on the utility of *N*-benzoyl-saccharin (NBSac) for benzoyl-transfer coupling in both the Suzuki and Sonogashira reactions, and in the Heck reaction by decarbonylative arylcoupling. The Suzuki reaction employed [PAIM][NTf₂] as the basic-IL, [7f,7g] and [BMIM][PF₆] or [BMIM][BF₄] as solvent (Fig. 1), whereas the Sonogashira reactions were performed in ethylguanidinium ethylsulfate (GIL), [8] without the need for base or any additive (Fig. 2).

Similarly, the Heck decarbonylative arylations were conveniently carried out in GIL as solvent (Fig. 3) without the need for external base, CuX, or other additives.

All three types of transfer cross-coupling reactions were catalyzed by either Pd or Ni in comparable yields, thus expanding the catalytic scope of these transformations. The mild reaction conditions employed, and recycling and reuse of the IL solvents provided additional benefits.

Table 1 summarizes the scope of the Suzuki coupling with NBSac in IL employing various aromatic and alicyclic boronic acids, [PAIM][NTf₂] as basic-IL and [BMIM][X] as solvent, employing Pd $(OAc)_2$ or NiCl₂(dppp) as catalyst, with isolated yields ranging from 88% to 82%, when using fresh IL, but with lower isolated yields (81–63%) with the use of recycled ILs.

The scope of benzoyl-transfer coupling in the Sonogashira reaction was examined by employing a diverse set of alkynes and the results are summarized in Table 2. The reactions were performed



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Fig. 1. Trans-benzoylation Suzuki cross-coupling using NBSac.



Fig. 2. Trans-benzoylation Sonogashira cross-coupling in GIL using NBSac.



Fig. 3. Decarbonylative Heck coupling in GIL using NBSac.

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enzoyl-transfer Suzuki coupling with NBSac employing $Pd(OAc)_2$ or $NiCl_2(dppp)$ as catalyst.

Entry	Boronic acid	Product ^a	IL	Time ^b (h)	Yield ^f (%)
1	B(OH) ₂	O	[BMIM][BF ₄]	4	86 ^{c,y}
2	B(OH) ₂	O	[BMIM][BF ₄]	5	88 ^{c,y}
3	MeO		[BMIM][BF ₄]	4	74 ^{d,x}
4	©_−B(OH)₂	O O O O O O O O O O O O O O O O O O O	[BMIM][PF ₆]	5.5	70 ^{d,y}
5	S−B(OH) ₂	O S	[BMIM][PF ₆]	5.5	84 ^{c,y}
6	O ₂ N		[BMIM][BF ₄]	4.5	74 ^{c.x}
7	O OCH ₃ B(OH) ₂		[BMIM][BF4]	4	81 ^{d,x}
8	B(OH) ₂	ÓCH ₃	[BMIM][BF4]	4	63 ^{e,y}

Table 1 (continued)

Entry	Boronic acid	Product ^a	IL	Time ^b (h)	Yield ^f (%)
9	B(OH) ₂	O	[BMIM][BF ₄]	5	68 ^{e,x}
10	CI B(OH) ₂	O Cl	[BMIM][PF ₆]	5	71 ^{d,y}
11	NC B(OH) ₂		[BMIM][PF ₆]	4.5	87 ^{c,x}
12	B(OH) ₂		[BMIM][PF ₆]	5.5	82 ^{c.y}

^a Reaction conditions: NBSac (1 mmol), Boronic acid 2 (2 mmol), [PAIM][NTf₂], [BMIM][X] (5-7 mL) and Pd(OAc)₂ or NiCl₂(dppp) (5 mol %).
^b Oil bath temperature 70-80 °C.
^c Yield employing fresh IL.
^d Yield using recycled IL (2nd cycle).
^e Yield using recycled IL (3rd cycle).
^f Isolated yield of pure compound.

^x Using Pd(OAc)₂.
 ^y Using NiCl₂(dppp).

Table 2

Benzoyl-transfer Sonogashira coupling employing Pd(OAc)₂ or NiCl₂(dppp) as catalyst.

Entry	Alkyne	Product ^a	IL	Time ^b (h)	Yield ^f (%)
13		O C	GIL	1.5	91 ^{с.у}
14		O C	GIL	2	61 ^{d,y}
15		O V	GIL	2	66 ^{d,x}
16		0	GIL	2	64 ^{c,x}
17		O C	GIL	2	68 ^{c.y}
18	OMe	OMo	GIL	1.5	80 ^{d.y}
19		O Come	GIL	2	56 ^{e,x}
20	Br	O Br	GIL	2.5	57 ^{e,x}

Table 2 (c	continued)
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^a Reaction conditions: NBSac (1 mmol), Alkyne(1.25 mmol), GIL (3-5 mL) and Pd(OAc)₂or NiCl₂(dppp)(5 mol %).

- ^b Oil bath temperature 55-70 °C.
- с Yield employing fresh IL.
- ^d Yield using recycled IL (2nd cycle).
- e Yield using recycled IL (3rd cycle).
- ^f Isolated yield of pure compound.
- ^x UsingPd(OAc)₂.
- y UsingNiCl₂(dppp).

in GIL as solvent with Pd(OAc)₂ or NiCl₂(dppp) as catalyst, in isolated yields ranging from 91% to 66% by using fresh GIL, and with 80-56% yields when using the recycled IL.

Table 3 summarizes the scope of decarbonylative Heck arylation with NBSac in GIL solvent employing Pd(OAc)₂ or NiCl₂(dppp) as catalyst with isolated yields ranging from 88% to 74% using fresh GIL.

Focusing on the recycling/reuse of the BMIM-IL solvents, reaction 1 in Table 1 was repeated four consecutive times in [BMIM] [PF₆] and in [BMIM][BF₄] solvents. The results presented in graph-

Table 3

Entry	Arylethene	Product ^a	IL	Time ^b (h)	Yield ^f (%)
24			GIL	2.5	85 ^{c,y}
25			GIL	3	72 ^{d,y}
26	OMe	OMe	GIL	3	60 ^{e,x}
27			GIL	2.5	78 ^{c,y}
28	OMe	OMe	GIL	2.5	80 ^{c,x}
29	O Me	O Me O O	GIL	3	73 ^{d,x}
30			GIL	3	72 ^{d.y}

Table 3 (continued)

Entry	Arylethene	Product ^a	IL	Time ^b (h)	Yield ^f (%)
31			GIL	3	63 ^{e,y}
32	NO ₂	NO ₂	GIL	3	70 ^{с,x}
33	Br	Br	GIL	3	61 ^{e,y}

^a Reaction conditions: NBSac (1 mmol), arylethene(1.5 mmol), GIL (3-4 mL), and Pd(OAc)₂ or NiCl₂(dppp)(5 mol %).

- ^d Yield using recycled IL (2nd cycle).
- ^e Yield using recycled IL (3rd cycle).
- ^f Isolated yield of pure compound.
- * UsingPd(OAc)₂.

the second cycle.

y UsingNiCl₂(dppp).

ical format (SI file, chart 1), indicate a fairly consistent trend of decreasing yields after each cycle, in line with our findings from previous studies, [7] with [BMIM][PF₆] exhibiting a slightly better recovery/reuse profile as compared to [BMIM][BF₄]. Recycling and reuse of the GIL solvent was explored by selecting entry 13 in Table 2 and entry 24 in Table 3, and each reaction was repeated four consecutive times. The results presented in graphical format (SI file, charts 2 and 3) show notable drop in conversions after

In summary, we have demonstrated the efficacy of NBSac for transfer-benzoylation coupling in the Suzuki and Sonogashira reactions in BMIM and GIL solvents respectively, with Pd or Ni as catalysts, and for decarbonylation arylation in Heck coupling in GIL solvent.

Collectively, these methods provide facile and efficient access to diverse libraries of diarylketones, keto-ethynes and diaryl-ethenes in IL media using NBSac as reagent.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tetlet.2020.151987.

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^b Oil bath temperature 55–70 °C.

^c Yield employing fresh IL.