



Enhancing nucleophilicity in ionic liquid [bmim]HSO₄: A recyclable media and catalyst for the halogenation of alcohols

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ABSTRACT

Bronsted acidic ionic liquid 1-butyl-3-methylimidazolium hydrogen sulphate [bmim]HSO₄ has been demonstrated as an efficient reusable catalyst and solvent, for halogenation of aromatic and aliphatic alcohols in conjunction with microwave and thermal heating. Use of microwave energy not only accelerates the reaction rate, but also provides enhanced yields. Moreover, anhydrous ionic liquid facilitates nucleophilic attack of halide ions on alcohols, thus indicating the enhancement in their nucleophilic character. Easy work up, good yields and facile regeneration of the ionic liquid further increases the scope of the developed methodology.

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1. Introduction

Sustainable industrial development must employ less polluting neoteric solvents and this quest for new reaction media leads to the exploration of different ionic liquids [1–4]. Interest to explore various inorganic and organic reactions in ionic liquids, particularly, those based on 1,3-dialkylimidazolium cations [4–7] has flourished in recent time. Because of tremendous useful properties of ionic liquids such as vanishingly low vapour pressure, low co-ordinating ability and thermal/chemical stability, these have been used as an attractive alternative to traditional volatile organic solvents in various chemical processes, and in liquid–liquid extractions as documented by recent literature [1–7]. On the other hand, immiscibility of ionic liquid in different organic solvents paves the way for biphasic [8,9] separation of desirable products.

There is a controversy [10,11] whether ionic liquids accelerate or decelerate the nucleophilic substitution reactions. Although many types of reactions have been investigated in ionic liquid, but very few examples of nucleophilic substitution reactions [12–18] are present in the literature. These reactions are traditionally often been carried out using phase transfer catalyst [19,20] and because of the fact that IL are comprised of bulky organic cation, they seem to be an excellent substitute for phase transfer catalysis along with quarternary ammonium salts, crown ether derivatives and phosphonium salts. Alkali metal salts containing different halide anions

viz., chloride, bromide and iodide are economical and can serve as nucleophile [21] in substitution reactions.

Halogenation of alcohols is one of the most important functional group transformation in organic chemistry. Halogen containing compounds are very useful intermediates in organic synthesis [22]. They are useful substrates or intermediates in elimination [23,24], rearrangement [25], lithiation [26,27] and carbon–carbon coupling [28,29] reactions and appropriate for the attack by numerous nucleophiles [17,21,30]. Because of our ongoing efforts to explore acidic ionic liquid [9,31,32] [bmim]HSO₄ in different organic reactions, we report herein, its use in nucleophilic substitution reaction for the first time and utilizing it for the transformation of alcohols into halides, using metal halides.

2. Experimental

Ionic liquid [bmim]HSO₄ was prepared by the reported method [31]. Improved version of the process is also reported using microwave reactor Plazmatronika (RM 2001 PC) (see Section 2.1). Microwave assisted reactions were also carried out in domestic microwave oven [LGMS194A (800 W)]. Ultrasound assisted reaction was carried out using Branson [B-2200 EI (60 W, 47 kHz)] ultrasonic cleaning bath.

2.1. Synthesis of [bmim]HSO₄

In a flame-dried assembly, 1-bromobutane (2 mmol) and 1-methyl imidazole (2 mmol) were stirred together under microwave irradiation at 60–80 °C for 6 min (three cycles each having heating

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period 2 min, cooling period 2 min and power of magnetron 80%). NaHSO₄ (2.5 mmol) was added to the resulting light yellow viscous liquid [(bmim)Br] and irradiated with microwaves for 40 s at 50–70 °C (two cycles each having heating period 20 s, cooling period 30 s and power of magnetron 80%) or exposed to ultrasonic waves for 1 h. Resulting mixture was extracted with dichloromethane (2 × 20 mL) and evaporation of solvent under reduced pressure afforded orange coloured viscous liquid [bmim]HSO₄. Alternatively, in a dry assembly H₂SO₄ (2 mmol) was added dropwise to the light pale yellow liquid [bmim]Br prepared earlier, and stirred at 50 °C for 15 h to ensure complete ion exchange. The resulting orange viscous liquid was extracted with diethylether (2 × 20 mL) to ensure the removal of any organic impurity and the ionic liquid prepared was dried under vacuum for 6 h.

2.2. Synthesis of aryl or alkyl halides using thermal heating


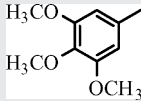
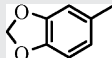
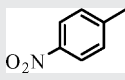
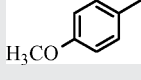
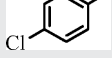
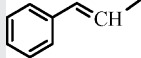
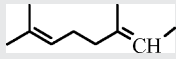
In a flame-dried assembly [bmim]HSO₄ (6 mmol) and NaX [X = Br, I] (7.5 mmol) were stirred at 80 °C for half an hour, followed by addition of alcohol (5 mmol) and stirring continued at the same

temperature for the time specified (Table 1). After the completion of the reaction (monitored by TLC) the product was extracted with diethyl ether (3 × 20 mL). Combined organic layer was washed with brine and dried over anhydrous sodium sulfate. Evaporation of the solvent under reduced pressure afforded the crude product that was purified by column chromatography using ethyl acetate and *n*-hexane (1:9) to obtain product.

2.3. Synthesis of aryl and alkyl halides using microwave energy

Ionic liquid [bmim]HSO₄ (1.2 mmol) and MX (NaI, NaBr, CsCl) (1.5 mmol) were stirred together in a vial (10 mL) under microwave irradiation in microwave reactor [Plazmatronika (RM 2001 PC)] at 60–80 °C for 1 min, followed by cooling period of 1 min. Alcohol (1 mmol) was added to vial, sealed properly and irradiated for 10 min in microwave reactor at 80–90 °C (five cycles each having heating period 2 min, cooling period 1 min and power of magnetron 80%). Alternatively, the reaction mixture can also be irradiated in domestic microwave oven [LGMS194A (800 W)] at 160 W for the time specified (Table 1) with the mechanical shaking after each 30 s

Table 1
Halogenation of different aromatic and aliphatic alcohols using [bmim]HSO₄ and metal salts at 80 °C and under microwave irradiation.

S. no.	R ^a	Alkali metal salt used	Reaction time		Yield (%) ^b	
			MWI (160 W) (min)	Conventional (h)	MWI	Conventional
1.		NaI	7	15	90	75
		NaBr	8	16	88	72
2.		NaI	8	16	87	78
		NaBr	10	18	85	75
3.		NaI	7	15	85	77
		NaBr	9	16	84	74
4.		NaI	7	15	90	74
		NaBr	8	16	89	73
5.		NaI	8	16	82	70
		NaBr	9	17	80	70
6.		NaI	7	15	85	71
		NaBr	8	16	81	71
7.		NaI	7	15	75	64
		NaBr	9	18	74	62
8.		NaI	9	20	68	59
		NaBr	10	20	64	55
9.	H ₃ C–[CH ₂] ₈ –	NaI	8	18	72	62
		NaBr	10	20	70	61
10.	H ₃ C–[CH ₂] ₄ –	NaI	8	18	71	60
		NaBr	10	20	71	59

^a All the compounds were characterised on the basis of ¹H NMR and IR spectral data.

^b Isolated and unoptimised yields.

4. Conclusion

In conclusion, we have found that metal salts behave as good source of nucleophiles in anhydrous ionic liquid [bmim]HSO₄, and can be used to synthesize aryl and alkyl halides from the corresponding alcohols, using microwave and thermal energy. Simple experimental and product isolation procedures, combined with ease of regeneration and reuse of ionic liquid, are expected to contribute towards the development of green methodologies.

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- [33] Cinnamyl bromide: IR (neat)/ ν_{\max} cm⁻¹: 3022, 2922, 1660, 1200, 640. ¹H NMR (CDCl₃, 300 MHz) δ : 7.42–7.34 (m, 5H, ArH), 6.61 (d, 1H, *J*=12.4 Hz, Ar-CH=CH-), 4.58–4.49 (m, 1H, Ar-CH=CH-), 3.42 (d, 2H, *J*=6.3 Hz, -CH₂Br). Cinnamyl iodide: IR (neat)/ ν_{\max} cm⁻¹: 3010, 2928, 1650, 1190, 510. ¹H NMR (CDCl₃, 300 MHz) δ : 7.41–7.30 (m, 5H, ArH), 6.58 (d, 1H, *J*=12.2 Hz, Ar-CH=CH-), 4.50–4.41 (m, 1H, Ar-CH=CH-), 3.34 (d, 2H, *J*=6.1 Hz, -CH₂Br).
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