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A task-specific ionic liquid [bmim]SCN for the conversion of alkyl halides to alkyl thiocyanates at room temperature

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Abstract—A new ''task-specific'' ionic liquid (TSIL), 1-*n*-butyl-3-methylimidazolium thiocyanate ([bmim]SCN), has been prepared and used for the first time as the medium as well as reactant for the synthesis of alkyl thiocyanates from the corresponding alkyl halides by thiocyanate-halide exchange at room temperature. The alkyl thiocyanate products can be easily isolated from the reaction mixture by simple extraction and the ionic liquid 1-*n*-butyl-3-methylimidazolium halide may be reused for the synthesis of the ionic liquid [bmim]SCN and recycled for further use.

Room temperature ionic liquids (ILs) are attracting considerable attention as solvents for multiphasic catalysis because they can be tuned for specific applications.[1] ILs based on imidazolium cations have been extensively studied with a variety of structural modifications leading to differences in the physical and chemical properties of the liquid.[2] Moreover, most attention has been focused on modification of the cation, particularly by incorporating hydroxyl, nitrile and carboxylic acid functionalities.[3,4] Not much attention has been directed toward the preparation of ILs with useful anions. A functionalized anion could not only influence the physical and chemical properties of the IL but also may function as a reactant.[5] There are very few examples where ILs have been employed as reaction media and as the nucleophile in an organic transformation.[6] The application of task specific ionic liquids (TSILs) enhances the versatility of classical ionic liquids.[7] Herein, we describe a synthesis of a TSIL containing an imidazolium cation combined with a thiocyanato anion.[8] Furthermore, this TSIL has been applied as the reagent and medium for the nucleophilic substitution reactions of alkyl halides.

Alkyl thiocyanates are important synthetic precursors for the preparation of sulphur-containing organic compounds. This functional group can be used as a masked mercapto group or as a precursor for sulphur-containing heterocyclic compounds. Additionally, α-thiocyanato carbonyl compounds are intermediates for a preferred synthetic route to several types of thiazoles.[9] Thiocyanation is generally carried out via nucleophilic substitution using thiocyanate anions. The low nucleophilicity of the NCS-ion requires rather harsh reaction conditions. Metal thiocyanates and organic halides or sulfonates are generally used to introduce the thiocyanate functionality into an organic molecule.[10] However, the thiocyanate group is not that stable when heated or under acidic conditions. Chromatography on silica gel or prolonged heating over 50 °C can cause intramolecular rearrangement to the thermodynamically favored isothiocyanate isomers.[11] Furthermore, thiocyanates have been obtained from alcohols,[12] silyl ethers[13] or amines[14] using $Ph_3P(SCN)_2$. However, many drawbacks have been observed for these thiocyanation methodologies.[15] This led us to the preparation of the [bmim]SCN ionic liquid **1**.

The ionic liquid, 1-*n*-butyl-3-methyl imidazolium thiocyanate [bmim]SCN **1** was prepared by the anion exchange of 1-*n*-butyl-3-methyl imidazolium chloride[16] with KSCN in acetone for 48 h at room temperature (Scheme 1).[17]

It was characterized by IR and NMR spectroscopy together with FAB mass spectrometry. The IR spectrum of [bmim]SCN **1** exhibited the characteristic absorption of the thiocyanate functionality at 2070 cm^{-1}. Furthermore, the FAB mass spectrum of **1** is different from the corresponding halide salts and exhibits a peak at *m/z* 336 (10%) corresponding to $(C_8H_{15}N_2)_2$ SCN. The

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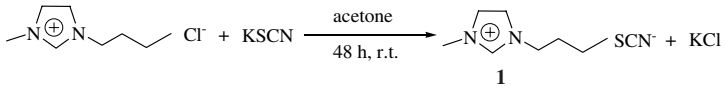


1

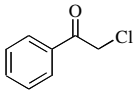
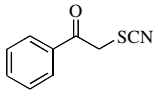
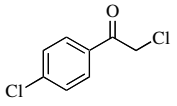
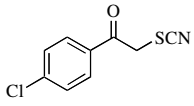
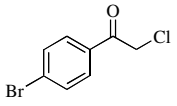
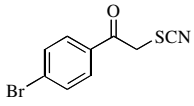
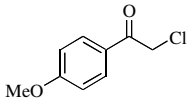
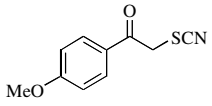
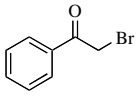
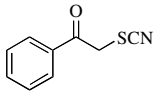
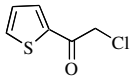
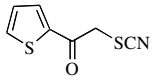
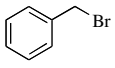
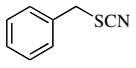
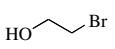
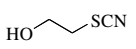
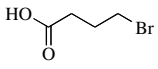
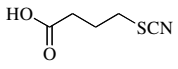
Scheme 1.

halide salts [bmim]X (X=Cl, Br) show peaks at *m/z* 357 (4%) and *m/z* 313 (15%), respectively, for $(C_8H_{15}N_2)_2Br$ and $(C_8H_{15}N_2)_2Cl$. Ionic liquid **1** has been investigated for the nucleophilic substitution of a variety of alkyl halides giving alkyl thiocyanates. In a typical experiment, α-chloroacetophenone was reacted with 1.2 equiv of the ionic liquid [bmim]SCN **1** and it was observed (by TLC) that the α-chloroacetophenone was converted quantitatively into the corresponding α-thiocyanato carbonyl compound after about 10 min at room temperature.[18] The product was extracted by ether from the ionic liquid and was pure. It did not require any column chromatography thus avoiding the possibility of rearrangement. Significantly, the ionic liquid [bmim]Cl formed after the reaction, on treatment with KSCN in acetone regenerated this TSIL, [bmim]SCN, thus allowing recycling of the TSIL. A comparison with **1** was carried out by reacting α-chloroacetophenone in [bmim]BF_4 with 1.5 equiv of KSCN. It was interesting to observe that in this case transformation to the corresponding thiocyanate took place with only 20–30% conversion even after 2 h of reaction time. This indicated that the nucleophilicity of the SCN anion is much higher in [bmim]SCN compared to KSCN in [bmim]BF_4.

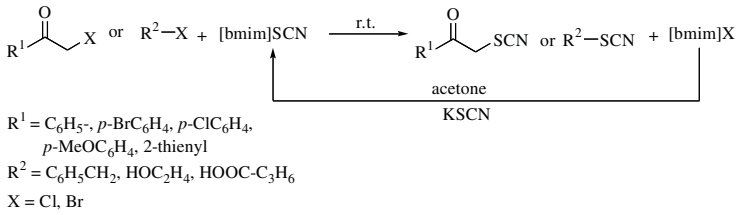
The application of this TSIL for the transformation of different alkyl halides to their alkyl thiocyanates has been examined and the results are summarized in Table 1 (Scheme 2).

In conclusion, we have demonstrated the synthesis of a new task-specific ionic liquid [bmim]SCN and its application as a reaction medium as well as reactant for the conversion of alkyl halides to their alkyl thiocyanates in high yields at room temperature. More importantly there is no formation of any side-products in this process and there is no need for column chromatography for the purification of the products.

Table 1. Thiocyanation of alkyl halides using the ionic liquid [bmim]SCN

Entry	Halide 2	Product 3[a]	Time (min)	Yield (%)[b]
a			10	95
b			9	93
c			10	96
d			15	90
e			8	93
f			15	90
g			60	95
h			24 h	80
i			24 h	75

[a] All products were characterized by ^1H NMR, IR, and mass spectroscopy.[15]
[b] Isolated yields after extraction with ether.



Scheme 2.

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17. The ionic liquid 1-*n*-butyl-3-methylimidazolium chloride [bmim]Cl (3 g) was dissolved in acetone (25 mL) and to this was added KSCN (2 equiv). The mixture was allowed to stir at room temperature for 48 h. The resulting suspension was filtered and the filtrate was subjected to a vacuum to remove volatile material. The residue was dissolved in dichloromethane and again filtered. The filtrate was dried using anhydrous sodium sulfate. Finally, upon concentration under vacuum at 70 °C 1-*n*-butyl-3-methylimidazolium thiocyanate was obtained as a red colored liquid. IR (cm^{-1}): 2070 (-SCN); ^1H NMR (200 MHz, $CDCl_3$): $\delta = 0.98$ (t, 3H, $J = 7.4$ Hz), 1.25–1.40 (m, 2H), 1.80–2.00 (m, 2H), 3.95 (s, 3H), 4.20 (t, 2H, $J = 7.4$ Hz), 7.50 (S, 1H), 7.55 (S, 1H), 8.75 (s, 1H); FABMS (+ve): $m/z = 139$ (M-SCN) (100%), 336 $(C_8H_{15}N_2)_2$ SCN (10%).
18. Typical experimental procedure: A mixture of **1** (1.2 mmol) and α-chloroacetophenone (1 mmol) was placed in a flask and stirred at room temperature. After completion of the reaction as indicated by TLC, ether (3×4 mL) was added to the reaction mixture with vigorous stirring for 5 min. The mixture was allowed to stand for a further 5 min and the clear supernatant liquid was decanted. The combined ether layers were dried over sodium sulphate and concentrated under reduced pressure to give α-thiocyanatoacetophenone as an oil. The remaining ionic liquid was dissolved in acetone and reacted with KSCN (2 equiv) at room temperature for 48 h to afford [bmim]SCN ionic liquid **1** which was used in subsequent runs.