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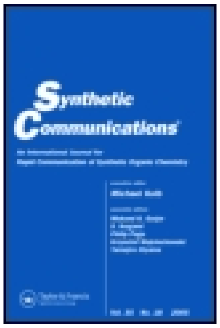

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Ionic Liquid Iodinating Reagent for Mild and Efficient Iodination of Aromatic and Heteroaromatic Amines and Terminal Alkynes

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Ionic liquid iodinating reagent for mild and efficient iodination of aromatic and heteroaromatic amines and terminal alkynes

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Abstract

Hexamethylene bis(*N*-methylimidazolium) bis(dichloroiodate) (HMBMIBDCI), an ionic liquid iodinating reagent, have been prepared and characterized. Its ability to perform iodination reactions with a variety of substrates has been explored. In general, iodination reactions of aromatic and heteroaromatic amines proceed with good yields in the absence of solvent. Reactions of terminal alkynes in the presence of DBU and THF have been investigated as well.

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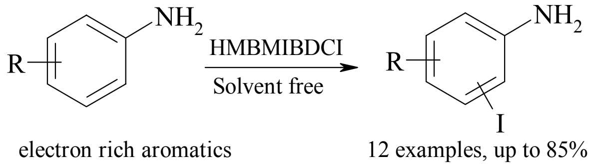

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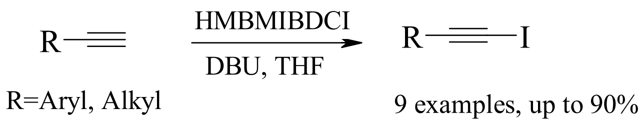

KEYWORDS: Iodination; ionic liquid; aromatic and heteroaromatic amines; terminal alkynes; hexamethylene bis(*N*-methylimidazolium) bis(dichloroiodate)

INTRODUCTION

Iodo-substituted aromatic compounds are the most reactive intermediates in organic chemistry.[1,2] They are utilized as building blocks for the synthesis of various biologically active molecules such as calicheamicine and *L*-thyroxine.[3]

The most aryl iodides were synthesized by Sandmeyer reaction, which is a multistep reaction up to 1950. However, investigations through many years have directed to discovery of new procedures. Direct iodination using I_2 is a simple method, but such reaction is not straightforward and needs the oxidation of iodine to the more reactive species with a pronounced I^+ nature. Some of the reported procedures such as nitric acid/sulfuric acid,[4] iodic or periodic acid,[5] NaI or KI/oleum,[6a] I_2/HgX_2,[6b] I_2/Ag_2SO_4[6c] and $ICl/Hg(OTf)_2$[7] include highly strong oxidizing agents, powerfully corrosive acidic media and toxic heavy metals and reagents. A little less challenging solution is to use sodium hypochlorite as an oxidant on sodium iodide or iodine in the presence of hydrochloric acid to form benzyltriethylammonium ICl_2^- salt that is an efficient electrophilic iodination reagent.[8] Several ammonium ICl_2^- salts have been reported for the iodination of aromatic compounds, including: benzyltrimethylammonium dichloroiodate,[9] tetramethyl and tetraethylammonium dichloroiodate,[10] poly[*N*-(2-aminoethyl)-acrylamido]triethylammonium dichloroiodate.[11]

Similarly iodoalkynes are also important intermediates in organic synthesis.[12] They were found to possess anti-HIV,[13a] antimicrobial[13b] and fungicidal activities.[13c] A variety of method have been introduced for preparation of iodoalkynes, for example: iodination of phenylacetylenes using I_2/NH_3,[14] I_2/DMAP,[15] KI/TBHP,[16] CuI/TBAB/Et_3N,[17] KI/CuI/$Et_3N/PhI(OAc)_2$,[18] metallic lithium/I_2/ultrasonic,[19] *n*-BuLi/ZnI_2/BTMSPO,[20] $I(Py)_2BF_4/CH_3ONa$,[21] BTMSPO/CuI or ZnI_2,[22] $(collidine)_2I^+PF_6^-$[23]; iodination of trimethylsilylacetylenes by $AgNO_3$/NIS,[24] iodination of organotrifluoroborates utilizing NaI/chloramines-T,[25] iodination of 1-bromoalkynes using CuI [26] and halodecarboxylation of propiolic acids by NIS/TBATFA.[27] Although some of these reported procedures are effective, some of them have certain drawbacks, such as formation of diyne byproduct,[26] use of transition metal catalyst,[17-18] use of moisture sensitive bases and intermediates[19-20] and long reaction time.[15-17]

Ionic liquids are interesting media for greener reaction protocols.[28] Their green feature depend on their non-volatility, their unique physico-chemical properties such as large electrochemical window, high thermal and chemical stability, broad range of liquid-state temperature and desired solvation behavior. Ionic liquids have many applications in synthetic transformations,[29] electrochemistry,[30] extraction and separation processes[31] as well as catalysts.[32] In addition, they have important role as non-volatile and reusable solvents in different reactions, for example they have successfully been used as solvent in iodination reactions.[33] Apart from being applied as solvent, they have been shown to serve as reagent in some reactions[34] but, there is only a few examples that ionic liquid was used as iodinating reagent for organic compounds.[35]

Recently, we have introduced an ionic liquid oxidant, hexamethylene bis(*N*-methylimidazolium) dichlorochromate (HMBMIDCC), for oxidation of benzylic alcohols under solvent free condition.[34a] To extend our studies, with replacing of ICl_2^- to $ClCrO_3^-$, we prepared new ionic liquid reagent and it was applied for iodination of aromatic, heteroaromatic amines and terminal alkynes (Scheme 1).

RESULTS AND DISCUSSION

As part of our continuing studies of using bis imidazolium salts,[34a,36] we report here an ionic liquid, hexamethylene bis(*N*-methylimidazolium) bis(dichloroiodate) (HMBMIBDCI), that functions as an iodinating reagent for aromatic and heteroaromatic amines in solvent free condition (Scheme 2).

To synthesize HMBMIBDCI (**4a**), *N*-methyl imidazole (**1a**) was initially treated with 1,6-dichlorohexane (**2a**) to form hexamethylene bis(*N*-methylimidazolium) dichloride (HMBMIDC) (**3a**) as a white and hygroscopic solid. Then treatment of an aqueous solution of $NaICl_2$ or iodinemonochloride (ICl) with dichloride **3a** resulted in formation of corresponding dichloroiodate **4a** as a yellow-orange solid (Scheme 3).

The structure of compound **4a** was identified by ^{1}H and ^{13}C NMR spectroscopy as well as elemental analysis. Iodometric titration was also carried out to confirm the identity of compound **4a**.[37]

To optimize the reaction conditions, aniline as an activated aromatic compound was chosen as a model substrate. The preliminary reaction conditions applied was based on the reported results for iodination of anilines using dichloroiodate reagents,[8c,e,9] in a mixture of CH_2Cl_2:CH_3OH (3:1) solvent. As a result, the initial experiment using aniline (1mmol), HMBMIBDCI (0.5 mmol) in the presence of calcium carbonate in CH_2Cl_2:CH_3OH (3:1) at room temperature after 45 min resulted in the formation of 2-iodo, 4-iodo and 2,4-diiodoaniline without satisfactory regioselectivity. In the next step, the reaction was performed under solvent free condition at ambient temperature. The progress of the reaction was monitored by GC that demonstrated the formation of 4-iodoaniline in 82% yield with high regioselectivity. Therefore, these reaction conditions were applied for iodination of a wide variety of aromatic and heteroaromatic amines. The results are summarized in Table 1.

It was observed that anilines with open *ortho* and *para* positions were iodinated with high selectivity on the *para* position to generate 4-iodo products (Table 1, entries 1-2 and 5-6). Where the *para* position is substituted, *ortho* products were obtained in good yields (Table 1, entries 3 and 4). In similar reaction conditions, 2-aminopyridine and 2-aminothiazole resulted in the corresponding monoiodinated products with high selectivity (Table 1, entries 7 and 8). It is noteworthy to mention that the same optimized reaction conditions were successfully applied for iodination of heteroaromatic compounds in moderate yields (Table 1, entries 9-12). For example, 5-iodo-1-methyl imidazole which is an important reactant in the synthesis of *Xestospon gia*, was obtained in 20% yield (Table 1, entry 11). This compound was previously prepared by Panosyan and et al. in four consecutive steps.[38d] In addition to imidazole derivatives, 3-methylindole was examined to give selectively 2-iodo-3-methylindole (Table 1, entry 12).

Iodination of terminal alkynes were also studied to prepare iodoalkynes using HMBMIBDCI as an iodinating reagent (Scheme 4).

To optimize the reaction conditions, the reaction of phenyl acetylene and HMBMIBDCI was used as a model reaction in a number of bases and solvents. The optimization results are shown in Table 2.

According to the results, only 19% yield was obtained from the reaction of phenylacetylene with HMBMIBDCI in the absence of a base. The best result was achieved when the reaction was conducted in the presence of DBU and NEt_3 (Table 2, entries 2 and 6). However, DBU was chosen as the base of the reaction because in the presence of NEt_3 a dimeric byproduct (diyne) was formed. Among several solvents which are tested (THF, CH_3OH, H_2O, CH_2Cl_2, CH_3CN and $PhCH_3$) THF was found to be the solvent of the choice for iodination of the terminal alkynes. In spite of good yield in solvents of methanol, water and toluene, these solvents were eliminated due to low solubility of some acetylenic compounds that provide low yields of desired products (see

Table 3, entries 6-8). It should be pointed out that aforementioned solvents can be utilized for soluble acetylenic compounds. The solvent-free condition is not applicable for this reaction in case of solid terminal acetylenes since the viscosity of the reaction mixture is too high which hinders the homogenization of the reaction mixture and reduces the yield of the reaction. Therefore, a wide variety of terminal alkynes using HMBMIBDCI in the presence of DBU in THF was examined and the results are shown in Table **3**.

As it is shown in Table 3, the yields of desired products are excellent (80-90%) for aromatic alkynes containing either electron-releasing or electron-withdrawing groups in *meta*, *para* or *ortho* positions (Table 3, entries 2-5). In addition naphthyl, ferrocenyl and phenylethynyl derivatives of the aromatic alkynes provide corresponding 1-iodoproducts in good yields (Table 3, entries 6-8). Treatment of aliphatic acetylenes such as 1-hexyne also afforded 1-iodohex-1-yne in good yields (Table 3, entry 9) but conversion of propargylic alcohol to the corresponding 1-iodoproduct did not occur. It is interesting to point out that under these reaction conditions and without using strong bases such as *n*-BuLi or Grignard's reagents which are moisture sensitive, 1-iodoalkynes were obtained in shorter reaction time with good yields. Moreover, under this reaction conditions and employing of DBU, a dimeric byproduct was not observed.

Another advantage of this protocol is reusability of the ionic liquid iodinating reagent (HMBMIBDCI) which can be reproduced from the reaction residue and be reused. In this regard, after completion of the reaction, the dark reaction mixture was quenched by water, and was extracted with Et_2O. The aqueous layer was then filtered to separate solid

$CaCO_3$. The resultant residue, which contains imidazolium salt, was treated with an aqueous solution of $NaICl_2$ to afford HMBMIBDCI. The resulting reagent was reused for iodination of aniline under solvent free condition at three successive runs without appreciable loss in its activity (Table 4).

CONCLUSION

In summary, an efficient and solventless protocol has been developed for iodination of aromatic and heteroaromatic amines using an ionic liquid iodinating reagent. The significant advantage of dichloroiodate ionic liquid with respect of reported protocols are simplicity, considerably fast reaction (0.75-4 h), solvent free condition, ragioselectivity, high isolated yields of products and reusability of the ionic liquid reagent. In addition, iodination of terminal alkynes to their corresponding 1-iodoproducts were also achieved using HMBMIBDCI and DBU in solvent of THF. To the best of our knowledge, we are not aware of any such use of dichloroiodate ionic liquid reagent for iodination of acetylenic compounds. Short reaction time, avoiding of a sensitive and strong base, lack of production of diyne byproduct during the iodination of terminal alkynes, good yields of products, regeneration of HMBMIBDCI and devoid in application of any special handling techniques are some other advantages of this protocol, which makes it as a good alternative to the existing methods.

EXPERIMENTAL

General Information

Materials were purchased from Fluka and Merck Chemical Companies. ^{1}H and ^{13}C NMR spectra were obtained on a Bruker Avance instrument at 400 and 100 MHz, respectively using $CDCl_3$, D_2O and DMSO as solvents. Melting points were determined on an Electro Thermal 9100. All the products were characterized by ^{1}H NMR data, and some of the products were characterized by GC analyses. GC analyses were performed on a Perkin Elmer 8500 instrument using a Capillary column 30M with a FID detector under helium as carrier gas. GC parameters were quantified by the authentic product samples prior to the analysis. Elemental analyses were performed on a LECO 600 CHN elemental analyzer. Iodine percentage was determined by iodometric titration. [37]

General Procedure For Preparation Of Hexamethylene Bis(*N*-Methylimidazolium) Bis(Dichloroiodate) (HMBMIBDCI) (4a)

Method 1. A mixture of *N*-methylimidazole (**1a)** (33.00 mmol, 2.71 g) and 1,6-dichlorohexane (**2a**) (15.00 mmol, 2.33 g) was stirred in DMF (10 mL) at 100˚C for 4 h. After cooling the mixture, the hygroscopic white solid was immediately filtered, washed with diethyl ether (40 mL), and dried under vacuum to give hexamethylene bis(*N*-methylimidazolium) dichloride (HMBMIDC) (**3a**) (3.30 g, 69%); mp 159-163˚C; ^{1}H NMR (D_2O) δ: 8.61 (s, 2 H), 7.37 (s, 2 H), 7.33 (s, 2 H), 4.09 (t, $J = 7.0$ Hz, 4 H), 3.79 (s, 6 H), 1.77 (br quin, 4 H), 1.24 (br quin, 4 H); ^{13}C NMR (D_2O) δ: 135.80, 123.48, 122.14, 49.36, 35.66, 29.02, 24.81. Then HMBMIDC (**3a**) (10.30 mmol, 3.30 g) was dissolved in H_2O (20 mL) and was slowly added to an aqueous solution of $NaICl_2$ that was beforehand prepared.[8] The mixture was cooled to 0˚C and the yellow-orange solid formed was collected by filtration, washed first with a small quantity of H_2O (10 mL) and then with Et_2O (30 mL) and dried under vacuum to give HMBMIBDCI (**4a**) (5.0 g, 76%); mp 79-81˚C; ^{1}H NMR (DMSO- d_6) δ: 9.08 (s, 2 H), 7.74 (pseudo t, J = 1.6 Hz, 2 H), 7.70 (pseudo t, J = 1.6 Hz, 2 H), 4.14 (t, J = 7.2 Hz, 4 H), 3.85 (s, 6 H), 1.78 (br quin, 4 H), 1.27 (br quin, 4 H). ^{13}C NMR (DMSO- d_6) δ: 136.9, 124.11, 122.70, 49.16, 36.26, 29.61, 25.40. Anal calcd for $C_{14}H_{24}Cl_4I_2N_4$: C 24.73, H 4.15, N 8.24, I 37.32 found: C 24.63, H 3.90, N 8.13, I 36.69.

Method 2. Following the typical procedure for **3a**, the mixture of ICl (20.60 mmol, 3.34 g) in CH_2Cl_2 (2 mL) was added to an aqueous solution of HMBMIBDCI (**3a**) (10.30 mmol, 3.30 g) in 0˚C. The yellow-orange solid formed was collected by filtration, washed with Et_2O (50 mL) and dried under vacuum to give HMBMIBDCI (**4a**) (4.9 g, 74%).

General Procedure For Iodination Of Aromatic And Heteroaromatic Amines

Aromatic amines (1.00 mmol) was treated with hexamethylene bis(*N*-methyimidazolium) bis(dichloroiodate) (**4a**) (0.70 mmol) in the presence of $CaCO_3$ (2.00 mmol) in a 25-mL round-bottomed flask equipped with a magnetic stirring bar at 30˚C for the time specified in Table **1**. After disappearance of the starting material as monitored by GC, the reaction mixture was quenched with water (20 mL) and was extracted with Et_2O (40 mL) (**Step 1**). The organic layer was washed with aqueous $NaHSO_3$ (5%, 20 mL), dried over Na_2SO_4 and evaporated in vacuum. The crude product was passed through a short column of silica gel and was recrystallized from CH_3OH:H_2O (2:1) to afford corresponding products shown in Table **1**. All products were identified by comparing melting point and ^{1}H NMR with those of authentic samples reported in the literature.

General Procedure For Iodination Of Terminal Alkynes

To a solution of alkyne (0.50 mmol), DBU (0.50 mmol) in THF (2 mL) was added HMBMIBDCI (**4a**) (0.35 mmol) and stirred at room temperature for the time specified in Table **3**. The progress of the reaction was monitored by TLC and the reaction mixture was quenched with aqueous $NaHSO_3$ (5%, 20 mL) and was extracted with Et_2O (40 mL). The organic layer was dried over Na_2SO_4 and the resultant solution was evaporated under reduced pressure. The crude product was purified by preparative thin-layer chromatography. All products were identified by comparing melting point and ^{1}H and ^{13}C NMR with those of authentic samples reported in the literature.

Recovery Of Hexamethylene Bis(*N*-Methylimidazoilum) Bis(Dichloroiodate) (HMBMIBDCI) (4a)

To a separated aqueous layer in **step 1** was added a solution of $NaICl_2$ that was beforehand prepared.[8] The reaction was immediately followed by formation of a yellow precipitate, which was then filtered, washed with Et_2O and dried under vacuum to give HMBMIBDCI (**4a**) (67%). The yellow solid obtained was identical in all aspect with the parent HMBMIBDCI. This procedure was repeated three times for iodination of aniline, and the yield of the product was nearly the same.

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Supporting Information:

Full experimental detail, ^{1}H and ^{13}C NMR spectra. This material can be found via the ‘‘Supplementary Content’’ section of this article’s Web page.

REFERENCES

1. De Meijere, A.; Diederich, F., Eds. *Metal-catalyzed Cross-coupling Reactions*, 2nd ed.; Wiley-VCH; Weinheim, Germany, 2004.

2. (a) Yao, Q.; Kinney, E. P.; Yang, Z. Ligand-free Heck reaction: Pd(OAC)$_2$ as an active catalyst revisited. *J. Org. Chem.* **2003**, *68*, 7528-7531. (b) Seyferth, D. The Grignard reagents. *Organometallics* **2009**, *28*, 1598-1605.

3. (a) Nicolaou, K. C. The battle of calicheamicin γ_{I}^{1}. *Andgew. Chem. Int. Ed. Engl.* **1993**, *32*, 1377-1385. (b) Tedder, J. M.; Nechvatal, A.; Murray, A. W.; Carnduff, J. *Basic Organic Chemistry*; vol. 4; John Wiley & Sons: London, 1971; chapter 3.

4. Merkushev, E. B. Advances in the synthesis of iodoaromatic compounds. *Synthesis* **1988**, *10*, 923-937.

5. (a) Mattern, D. L. Direct aromatic periodination. *J. Org. Chem.* **1984**, *49*, 3051-3053. (b) Lulinski, P.; Skulski, L. Iodination of both deactivated and activated arenes with sodium periodate or sodium iodate as the oxidants. *Bull. Chem. Soc. Jpn.* **2000**, *73*, 951-956. (c) Suzuki, H.; Nakamura, K.; Goto, R. The direct iodination of polyalkylbenzenes bearing bulky groups. *Bull. Chem. Soc. Jpn.* **1966**, *39*, 128-131.

6. (a) Pasha, M. A.; Myint, Y. Y. Acid-catalysed selective monoiodination of electron-rich arenes by alkali metal iodides. *Synth. Commun.* **2004**, *34*, 2829-2833; (b) Abderrazak, B.; Francisco, F.; Miguel, Y. Aromatic iodination with the I_2-HgX_2 combination. *Tetrahedron* **1994**, *50*, 5139-5146; (c) Sy, W.; Lodge, B.; By, A. Aromatic iodination with iodine and silver sulfate. *Synth. Commun.* **1990**, *20*, 877-880.

7. Johnsson, R.; Meijer, A.; Ellervik, U. Mild and efficient direct aromatic iodination. *Tetrahedron* **2005**, *61*, 11657-11663.

8. Kosynkin, D. V.; Tour, J. M. Benzyltriethylammonium dichloroiodate/sodium bicarbonate combination as an inexpensive, environmentally friendly, and mild iodinating reagent for anilines. *Org. Lett.* **2001**, *3*, 991-992.

9. (a) Kajigaeshi, S.; Kakinami, T.; Watanabe, F.; Okamoto, T. Halogenation using quaternary ammonium polyhalides. XVII. Iodination of acetanilide derivatives with benzyltrimethylammonium dichloroiodate and zinc chloride. *Bull. Chem. Soc. Jpn.* **1989**, *62*, 1349-1351; (b) Kajigaeshi, S.; Kakinami, T.; Moriwaki, M.; Watanabe, M.; Fujisaki, S.; Okamoto, T. Iodination of aromatic ethers by use of benzyltrimethylammonium dichloroiodate and zinc chloride. *Chem. Lett.* **1988**, 795-798; (c) Kajigaeshi, S.; Kakinami, T.; Yamasaki, H.; Fujisaki, S.; Okamoto, T. Halogenation using quaternary ammonium polyhalides. VII. Iodination of aromatic amines by use of benzyltrimethylammonium dichloroiodate. *Bull. Chem. Soc. Jpn.* **1988**, *61*, 600-602; (d) Tilve, R. D.; Kanetkar, V. R. Regioselective iodination of activated arenes using phenyl trimethylammonium dichloroiodate in ionic liquid under microwave irradiation. *Synth. Commun.* **2005**, *35*, 1313-1318; (e) Kajigaeshi, S.; Kakinami, T.; Yamasaki, H.; Fujisaki, S.; Kondo, M.; Okamoto, T. Iodination of phenols by use of benzyltrimethylammonium

dichloroiodate. *Chem. Lett.* **1987**, 2109-2112; (f) Okamoto, T.; Kakinami, T.; Fujimoto, H.; Kajigashi, S. Halogenation using quaternary ammonium polyhalides. XXXI Halogenation of thiophene derivatives with benzyltrimethylammonium polyhalides. *Bull. Chem. Soc. Jpn.* **1991**, *64*, 2566-2568; (g) Custelceanu, R.; Vlassa, M.; Silberg, I. A. Reaction of *π*-deficient aromatic heterocycles with ammonium polyhalides III. Halogenation of phenothiazin-5-oxide with benzyltriethylammonium polyhalides. *Monatsh. Chem.* **1997**, *128*, 919-925; (h) Wariishi, K.; Morishima, S. I.; Inagaki, Y. A facile synthesis of 1,4-dialkoxy-2,5-diiodobenzenes: reaction of dialkoxybenzenes with iodine monochloride in alcoholic solvents. *Org. Process Res. Dev.* **2003**, *7*, 98-100.

10. Filimonov, V. D.; Semenischeva, N. S.; Krasnokutskaya, E. A.; Hwang, H. Y.; Chi, K. W. Tetraalkylammonium dichloroiodates as iodinating agents: absence of activity in solid phases and superelectrophilic activity in sulfuric acid. *Synthesis* **2008**, 401-404.

11. Mitra, S. S.; Sreekumar, K. Polyhalide derivatives of poly[*N*-(2-aminoethyl)-acrylamido]triethylammonium resins as iodinating reagents. *Macromol. Chem. Phys.* **1997**, *198*, 1611-1621.

12. (a) Burli, R.; Vasella, A. Oligosaccharide analogues of polysaccharides. Part 14:. Carbocyclic cyclodextrin analogues. Synthesis of all trimeric and tetrameric isomers by homo- and heterocoupling of 1,4-cis-diethynylated 1,5-anhydroglucitols. *Helv. Chim. Acta* **1997**, *80*, 2215-2237; (b) Nantz, M. H.; Moss, D. K.; Spence, J. D.; Olmstead, M. M. Actuating cycloaromatization of a bicyclo[7.3.1]enediyne by annelation: an example of inverse dependence on bridge atom hybridization. *Angew. Chem., Int. Ed. Engl.* **1998**, *37*, 470-473; (c) Luithle, J. E. A.; Pietruszka, J. Synthesis of enantiomerically pure cis-cyclopropylboronic esters. *Eur. J. Org. Chem.* **2000**, 2557-2562; (d) Kunishima, M.;

Nakata, D.; Tanaka, S.; Hioki, K.; Tani, S. Generation and reactions of alkynylsamariums. *Tetrahedron* **2000**, *56*, 9927-9935; (e) Damle, S. V.; Seomoon, D.; Lee, P. H. Palladium-catalyzed homocoupling reaction of 1-iodoalkynes: a simple and efficient synthesis of symmetrical 1,3-diynes. *J. Org. Chem.* **2003**, *68*, 7085-7087.

13. (a) Joubert, N.; Amblard, F.; Rapp, K. L.; Schinazi, R. F.; Agrofoglio, L. A. Synthesis and anti-HIV activity of 5-haloethynyl and 5-(1,2-dihalo)vinyl analogues of AZT and FLT. *Tetrahedron* **2008**, *64*, 4444-4452; (b) Kabalka, G. W.; Shoup, T. M.; Goodman, M. M. Synthesis and evaluation of a new series of 17α-[123I]iodovinyl estradiols. *Nucl. Med. Biol.* **2000**, *27*, 279-287; (c) Jeffery, T. Copper(I)- and phase-transfer-catalysed iodination of terminal alkynes. *J. Chem. Soc., Chem. Commun*. **1988**, 909-910.

14. Vaughn, T. H.; Nieuwland, J. A. Iodination in liquid ammonia. *J. Am. Chem. Soc.* **1932**, *54*, 787-791.

15. Meng, L. G.; Cai, P. J.; Guo, Q. X.; Xue, S. Direct iodination of monosubstituted aryl acetylenes and acetylenic ketones. *Synth. Commun.* **2008**, *38*, 225-231.

16. Reddy, K. R.; Venkateshwar, M.; Maheswari, C. U.; Kumar, P. S. Mild and efficient oxy-iodination of alkynes and phenols with potassium iodide and tert-butyl hydroperoxide. *Tetrahedron Lett.* **2010**, *51*, 2170-2173.

17. Chen, S. N.; Hung, T. T.; Lin, T. C.; Tsai, F. Y. Reusable and efficient CuI/TBAB-catalyzed iodination of terminal alkynes in water under air. *J. Chin. Chem. Soc*. **2009**, *56*, 1078-1081.

18. Yan, J.; Li, J.; Cheng, D. Novel and efficient synthesis of 1-iodoalkynes. *Synlett* **2007**, 2442-2444.

19. Stefani, H. A.; Cella, R.; Dorr, F. A.; Pereira, C. M. P.; Gomes, F. P.; Zeni, G. Ultrasound-assisted synthesis of functionalized arylacetylenes. *Tetrahedron Lett.* **2005**, *46*, 2001-2003.

20. Ricci, A.; Taddei, M.; Dembech, P.; Guerrini, A.; Seconi, G. Reactions of terminal alkynes with bis(trimethylsilyl) peroxide and zinc(II) iodide: a convenient method for the preparation of 1-iodo-1-alkynes. *Synthesis* **1989**, 461-463.

21. Barluenga, J.; Gonzalez, J. M.; Rodriguez, M. A.; Campos, P. J.; Asensio, G. An improved method for the synthesis of 1-iodoalkynes. *Synthesis* **1987**, 661-662.

22. Casarini, A.; Dembech, P.; Reginato, G.; Ricci, A.; Seconi, G. Terminal 1-halo- 1 and 1-pseudohalo-1-alkynes via bis(trimethylsilyl)peroxide (BTMSPO) promoted umpolung transfer of halides and pseudohalides. *Tetrahedron Lett.* **1991**, *32*, 2169-2170.

23. Brunel, Y.; Rousseau, G. An easy preparation of iodoacetylenes. *Tetrahedron Lett.* **1995**, *36*, 2619-2622.

24. Nishikawa, T.; Shibuya, S.; Hosokawa, S.; Isobe, M. One pot synthesis of haloacetylenes from trimethylsilylacetylenes. *Synlett* **1994**, 485-486.

25. Kabalka, G. W.; Mereddy, A. R. Iodination of organotrifluoroborates: synthesis of vinyl and alkynyl iodides. *Tetrahedron Lett.* **2004**, *45*, 1417-1419.

26. Abe, H.; Suzuki, H. Copper-mediated nucleophilic displacement reactions of 1-haloalkynes. Halogen-halogen exchange and sulfonylation. *Bull. Chem. Soc. Jpn.* **1999**, *72*, 787-798.

27. Naskar, D.; Roy, S. 1-Haloalkynes from propiolic acids: a novel catalytic halodecarboxylation protocol. *J. Org. Chem.* **1999**, *64*, 6896-6897.

28. (a) Earle, M. J.; Seddon, K. R. Ionic liquids. Green solvents for the future. *Pure Appl. Chem.* **2000**, *72*, 1391-1398; (b) Wasserscheid, P.; Keim, W. Ionic liquids—new "solutions" for transition metal catalysis. *Angew. Chem., Int. Ed.* **2000**, *39*, 3772-3789; (c) Olivier-Bourbigou, H.; Magna, L. Ionic liquids: perspectives for organic and catalytic reactions. *J. Mol. Cat. A: Chem.* **2002**, 182-183, 419-437; (d) Davis, J. H., Fox, P. A. From curiosities to commodities: ionic liquids begin the transition. *Chem. Commun.* **2003**, 1209-1212; (e) Sheldon, R. A. Green solvents for sustainable organic synthesis: state of the art. *Green Chem.* **2005**, *7*, 267-278.

29. (a) Welton, T. Room-temperature ionic liquids. Solvents for synthesis and catalysis. *Chem. Rev.* **1999**, *99*, 2071-2083; (b) Zhao, H.; Malhotra, S. V. *Aldrichimica Acta* **2002**, *35*, 75-83; (c) Jain, N.; Kumar, A.; Chauhan, S.; Chauhan, S. M. S. Chemical and biochemical transformations in ionic liquids. *Tetrahedron* **2005**, *61*, 1015-1060; (d) Borodkin, G. I.; Shubin, V. G. Electrophilic reactions of aromatic and heteroaromatic compounds in ionic liquids. *Russ. J. Org. Chem.* **2006**, *42*, 1745-1770; (e) Jorapur, Y. R.; Chi, D. Y. Ionic liquids: an environmentally friendly media for nucleophilic substitution reactions. *Bull. Korean Chem. Soc.* **2006**, *27*, 345-354.

30. (a) Hapiot, P.; Lagrost, C. Electrochemical reactivity in room-temperature ionic liquids. *Chem. Rev.* **2008**, *108*, 2238-2264; (b) Arvai, R.; Toulgoat, F.; Medebielle, M.; Langlois, B.; Alloin, F.; Iojoiu, C.; Sanchez, J. Y. New aryl-containing fluorinated sulfonic acids and their ammonium salts, useful as electrolytes for fuel cells or ionic liquids. *J. Fluor. Chem.* **2008**, *129*, 1029-1035.

31. (a) Blanchard, L. A.; Brennecke, J. F. Recovery of organic products from ionic liquids using supercritical carbon dioxide. *Ind. Eng. Chem. Res.* **2001**, *40*, 287-292; (b)

Hoddleston, J. G.; Willauer, H. D.; Rogers, R. D. Room temperature ionic liquids as novel media for 'clean' liquid–liquid extraction. *Chem. Commun.* **1998**, 1765-1766.

32. (a) Sheldon, R. Catalytic reactions in ionic liquids. *Chem. Commun.* **2001**, 2399-2407; (b) Dupont, J.; De Souza, R. F.; Suarez, P. A. Z. Ionic liquid (molten salt) phase organometallic catalysis. *Chem. Rev.* **2002**, *102*, 3667-3692; (c) Parvulescu, V. I.; Hardacre, C. Catalysis in ionic liquids. *Chem. Rev.* **2007**, *107*, 2615-2665.

33. (a) Chiappe, C.; Pieraccini, D. Regioselective iodination of arenes in ionic liquids mediated by Selectfluor^{TM} reagent F-TEDA-BF4. *Arkivoc* **2002**, *xi*, 249-255; (b) Pavlinac, J.; Laali, K. K.; Zupan, M.; Stavber, S. Iodination of organic compounds with elemental iodine in the presence of hydrogen peroxide in ionic liquid media. *Aust. J. Chem.* **2008**, *61*, 946-955; (c) Bhilare, S. V.; Deorukhkar, A. R.; Darvatkar, N. B.; Salunkhe, M. M. Regioselective iodination of arenes using iodine/$NaBO_3 \cdot 4H_2O$ system in ionic liquid. *Synth. Commun.* **2008**, *38*, 2881-2888; (d) Hubbard, A.; Okazaki, T.; Laali, K. K. Halo- and azidodediazoniation of arenediazonium tetrafluoroborates with trimethylsilyl halides and trimethylsilyl azide and Sandmeyer-type bromodediazoniation with Cu(I)Br in [BMIM][PF_6] ionic liquid. *J. Org. Chem.* **2008**, *73*, 316-319; (e) Tilve, R. D.; Kanetkar, V. R. Regioselective iodination of activated arenes using phenyl trimethylammonium dichloroiodate in ionic liquid under microwave irradiation. *Synth. Commun.* **2005**, *35*, 1313-1318; (f) Meshram, H. M.; Reddy, P. N.; Vishnu, P.; Sadashiv, K.; Yadav, J. S. A green approach for efficient *α*-halogenation of *β*-dicarbonyl compounds and cyclic ketones using *N*-halosuccinimides in ionic liquids. *Tetrahedron Lett.* **2006**, *47*, 991-995; (g) Yadav, J. S.; Reddy, B. V. S.; Reddy, P. S. R.; Basak, A. K.;

Narsaiah, A. V. Efficient halogenation of aromatic systems using *N*-halosuccinimides in ionic liquids. *Adv. Synth. Catal.* **2004**, *346*, 77-82.

34. (a) Hosseinzadeh, R.; Mohadjerani, M.; Tajbakhsh, M.; Nouzarian, M. Ionic liquid oxidant for efficient and selective oxidation of benzylic alcohols. *Synth. Commun.* **2011**, *41*, 1725-1732; (b) Ranu, B. C.; Banerjee, S. Ionic liquid as reagent. A green procedure for the regioselective conversion of epoxides to vicinal-halohydrins using [AcMIm]X under catalyst- and solvent-free conditions. *J. Org. Chem.* **2005**, *70*, 4517-4519; (c) Leadbeater, N. E.; Torenius, H. M.; Tye, H. Ionic liquids as reagents and solvents in conjunction with microwave heating: rapid synthesis of alkyl halides from alcohols and nitriles from aryl halides. *Tetrahedron* **2003**, *59*, 2253–2258.

35. (a) Ranu, B. C.; Adak, L.; Banerjee, S. Halogenation of carbonyl compounds by an ionic liquid, [AcMIm]X, and ceric ammonium nitrate (CAN). *Aust. J. Chem.* **2007**, *60*, 358-362; (b) Bortolini, O.; Bottai, M.; Chiappe, C.; Conte, V.; Pieraccini, D. Trihalide-based ionic liquids. Reagent-solvents for stereoselective iodination of alkenes and alkynes. *Green Chem.* **2002**, *4*, 621-627; (c) Cristiano, R.; Ma, K.; Pottanat, G.; Weiss, R. G. Tetraalkylphosphonium trihalides. Room temperature ionic liquids as halogenation reagents. *J. Org. Chem.* **2009**, *74*, 9027-9033.

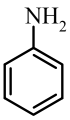
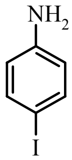
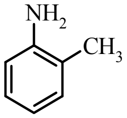
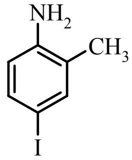
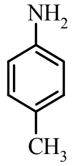
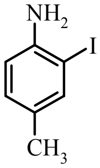
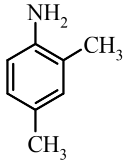
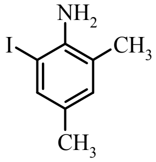
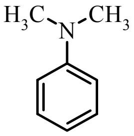
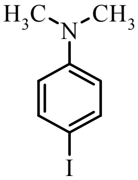
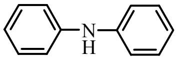
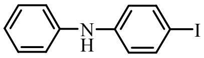
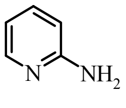
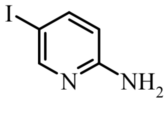
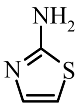
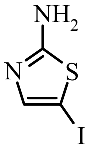
36. (a) Hosseinzadeh, R.; Tajbakhsh, M.; Mohadjerani, M.; Lasemi, Z. Efficient and regioselective bromination of aromatic compounds with ethylenebis(*N*-methylimidazolium) ditribromide (EBMIDTB). *Synth. Commun.* **2010**, *40*, 868-876; (b) Hosseinzadeh, R.; Tajbakhsh, M.; Mohadjerani, M.; Lasemi, Z. Ethylenebis(*N*-methylimidazolium) ditribromide (EBMIDTB): an efficient reagent for the monobromination of 1,3-diketones and *β*-ketoesters. *Monatsh. Chem.* **2009**, *140*, 57-60;

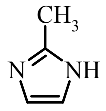
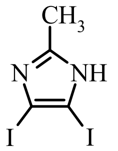
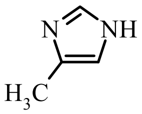
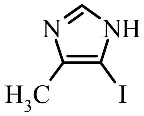
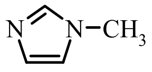
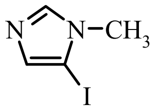
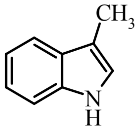
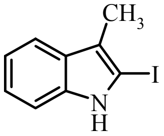
(c) Hosseinzadeh, R.; Tajbakhsh, M.; Khaledi, H. Ethylenebis(*N*-methylimidazolium) chlorochromate (EBMICC): A new selective and mild reagent for oxidation of alcohols, hydroquinones and trimethylsilyl ethers. *J. Chin. Chem. Soc.* **2008**, *55*, 239-243; (d) Hosseinzadeh, R.; Tajbakhsh, M.; Khaledi, H., Ghodrati, K. Ethylenebis(*N*-methylimidazolium) chlorochromate (EBMICC): an efficient and selective reagent for the oxidation of thiols to disulfides. *Monatsh. Chem.* **2007**, *138*, 871-873.

37. Skoog, D. A.; West, D. M.; Holler, F. J. *Fundamentals of Analytical Chemistry,* 5th ed.; Saunders College Publishing, 1988.

38. (a) Srisook, E.; Chi, D. Y. The syntheses of 3-substituted 4-(pyridin-2-ylthio)indoles via Leimgruber-Batcho indole synthesis. *Bull. Korean Chem. Soc.* **2004**, *25*, 895-899; (b) Cliff, M. D.; Pyne, S. G. Synthesis of 4,4′-biimidazoles. *Synthesis* **1994**, 681-682; (c) Naidu, M. S. R.; Bensusan, H. B. Reinvestigation of the orientation of halogen substitution in imidazoles by nuclear magnetic resonance spectroscopy. *J. Org. Chem.* **1968**, *33*, 1307-1309; (d) Panosyan, F. B.; Still, I. W. J. An efficient route to 5-iodo-1-methylimidazole: synthesis of xestomanzamine A. *Can. J. Chem.* **2001**, *79*, 1110-1114; (e) Fiumana, A.; Jones, K. Intermolecular reactions of indol-2-yl radicals: a new route to 2-substituted indoles. *Chem. Commun.* **1999**, 1761-1762.; (f) Russo, M. V.; Lo Sterzo, C.; Franceschini, P.; Biagini, G.; Furlani, A. Synthesis of highly ethynylated mono and dinuclear Pt(II) tethers bearing the 4,4′-bis(ethynyl)biphenyl (debp) unit as central core. *J. Organomet. Chem.* **2001**, *619*, 49-61.

Table 1. Iodination of aromatic and heteroaromatic amines with HMBMIBDCI under solvent free conditions

Entry	Substrate	Product	Time	Yield(%)^a	Mp (^{0}C)^b [Ref]
1			45 min	82	58-60 [8]
2			120 min	77	83-85 [9c]
3			60 min	85	35-37 [9c]
4			90 min	66	65-66.5 [8]
5			60 min	84	75-77 [9c]
6			4 h	25	102-105 [8]
7			180 min	85	1128-130 [38a]
8			90 min	70	95-96

9			180 min	47	193- 195[38b]
10			180 min	50	178-180 [38c]
11			4 h	20	112-115 [38d]
12			90 min	32	103-106 [38e]

[a] Yields refer to isolated products

[b] All products were identified by comparing of melting point and ^{1}H NMR spectra with those of authentic samples reported in the literature

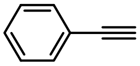
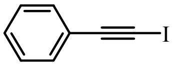
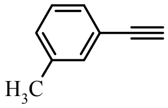
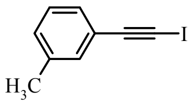
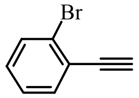
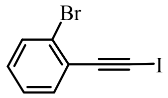
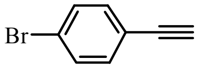
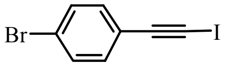
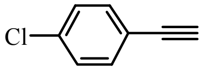
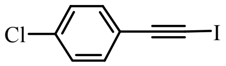
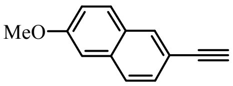
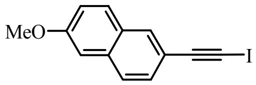
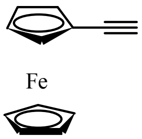
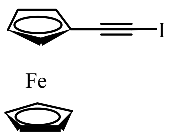
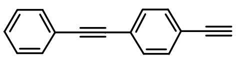
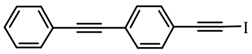
Table 2. Iodination of phenyl acetylene with HMBMIBDCI in different bases and solvents

Entry	Base	Solvent [a]	Time (min)	Yield (%)[b]
1	-	THF	90	19
2	NEt_3	THF	10	80
3	K_2CO_3	THF	10	20
4	KOH	THF	10	22
5	$LiOAC.2H_2O$	THF	10	21
6	DBU	THF	10	90
7	KF/Al_2O_3	THF	10	20
8	DBU	CH_3OH	10	89
9	DBU	CH_2Cl_2	10	76
10	DBU	H_2O	10	90
11	DBU	CH_3CN	10	75
12	DBU	$PhCH_3$	10	90
13	DBU	-	10	90

[a] Reaction conditions: Phenyl acetylene (0.5 mmol), Base (0.5 mmol), HMBMIBDCI (0.25 mmol), Solvent (2 ml), rt.

[b] Yields refer to isolated product, 1-iodoethynylbenzene.

Table 3. Iodination of terminal alkynes with HMBMIBDCI in the presence of DBU

Entry	Substrate	Product	Time (min)	Yield% ^{a}	Mp (^{0}C)^b[Ref]
1			10	90	Oil [18]
2			10	89	Oil [16]
3			30	80	Oil [15]
4			45	85	95-99 [26]
5			45	86	81-84 [26]
6			75	70	115-118
7			45	70	116-117 [38f]
8			60	61	142-145
9	$CH_3CH_2CH_2CH_2C-\equiv$	$CH_3CH_2CH_2CH_2C-\equiv-I$	90	60	Oil [18]

^{a}Yields refer to isolated products

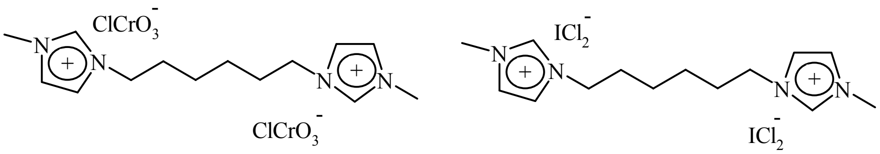
^{b}All products were identified by comparing ^{1}H, ^{13}C NMR and TLC with those of authentic samples reported in literature.

Table 4. Recycling studies of iodination of aniline to 4-iodoaniline with HMBMIBDCI

Entry	Cycle	Time (min)	Yield (%)[a]
1	Fresh	45	82
2	1	45	81
3	2	45	81
4	3	45	81

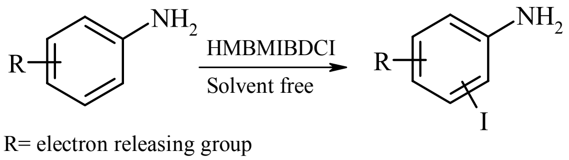
[a] Yields refer to isolated products

Scheme 1. Structures of HMBMIDCC and HMBMIBDCI

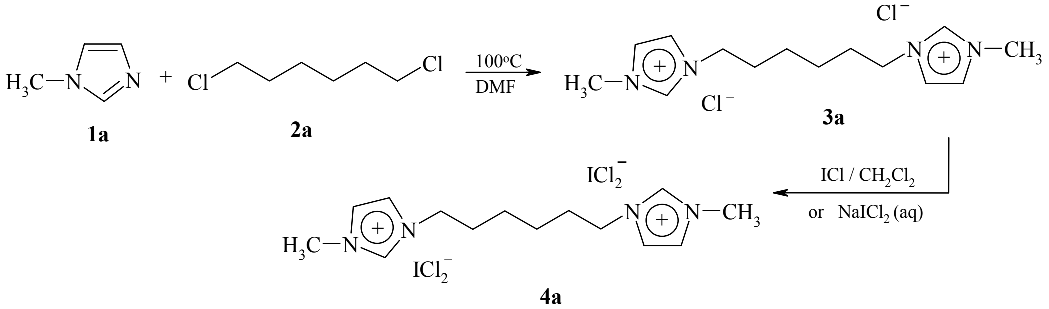


HMBMIDCC **HMBMIBDCI**

Scheme 2. Iodination of aromatic and heteroaromatic amines



Scheme 3. Preparation of HMBMIBDCI



Scheme 4. Iodination of terminal alkynes