

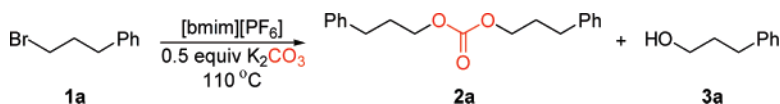
Synthesis of Symmetrical Organic Carbonates via Significantly Enhanced Alkylation of Metal Carbonates with Alkyl Halides/Sulfonates in Ionic Liquid

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We report a new phosgene-free method for the synthesis of symmetrical organic carbonates via alkylation of metal carbonate with various alkyl halides and sulfonates in *n*-1-butyl-3-methylimidazolium hexafluorophosphate, [bmim][PF₆], as an ecofriendly reaction media. Alkylation of metal carbonate in various ionic liquids with 1-bromo-3-phenylpropane (**1a**) as a model reactant has thoroughly been investigated. Potassium and cesium carbonates appeared to be the most suitable metal carbonate due to their high solubility in ionic liquids. Besides good to excellent yields, this simple and convenient methodology is devoid of highly toxic and harmful chemicals such as phosgene and carbon monoxide, which is an additional advantage.

Introduction

Alkyl organic carbonates have played a very important role in the area of synthetic organic chemistry and have become excellent templates for the formation of carbon–carbon and carbon–hetero bonds. They have been used as novel protecting groups,¹ as lubricants and hydraulic fluid,² as herbicides, acaricides, fungicides, and seed disinfectants,³ as octane enhancers for gasoline,⁴ and in cosmetics and pharmaceuticals.⁵ Carbonates have also been used in industry as a solvent for the separation of phenols and cyclohexanones.⁶ Common synthetic methods leading to the carbonate moiety include the use of classical toxic and harmful chemicals such as phosgene, pyridine, and carbon monoxide.⁷ Additionally, carbonates

are synthesized by utilizing alkyl halides and alcohols using the carbonate and bicarbonate salts of alkali metals and silver.⁸ Organic carbonates have been synthesized via oxycarbonylation of alcohols⁹ and also by carbon dioxide insertion into epoxides followed by transesterification of cyclic carbonates with appropriate alcohols.¹⁰ The alternative approach is by the carbonate exchange reaction.¹¹ Recently, Rossi et al.¹² reported synthesis of

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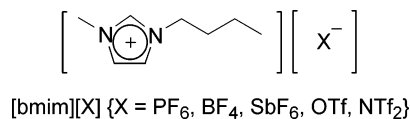


FIGURE 1. Ionic liquids.

organic carbonates from alkyl halides and tetrabutylammonium alkyl carbonates at room temperature. However, it requires initial synthesis of noncommercially available highly hygroscopic reagents. Further, carbonates have been synthesized from primary or secondary alcohols and carbon dioxide via unstable methanesulfonyl carbonates.¹³ Moreover, some of the above methods suffer in practicality since carbonate formation occurs under harsh reaction conditions such as high temperature of 150 °C and above. Furthermore, most of the above processes require external source of carbon dioxide with a need for special experimental assembly. The lack of facile synthetic methodologies for the preparation of symmetrical and unsymmetrical alkyl carbonates motivated us to develop some efficient, convenient, and moreover an environmentally friendly procedures for the synthesis of organic carbonates.

Recently, our research group built a strong and encouraging foundation for state-of-the-art ionic liquid technologies.¹⁴ Ionic liquids composed of an organic cation and an inorganic anion have been found to provide precise tuning of reactions by suitable combinations of cation and anions (Figure 1).¹⁵ Herein, we report the newer synthetic method toward the synthesis of symmetrical alkyl carbonates via alkylation of various metal carbonates with various alkali halides and sulfonates in various ionic liquids. Our initial studies proved how efficiently ionic liquids enhanced the nucleophilicity of K₂CO₃ toward 1-bromo-3-phenylpropane (**1a**) as a model compound.

Results and Discussion

Table 1 illustrates the synthesis of symmetrical alkyl carbonate from **1a** in the presence of K₂CO₃ under various reaction conditions. In [bmim][PF₆], the carbonate synthesis completed within 30 h at 110 °C with an excellent yield of 89% of **2a** (entry 1), whereas the same in a conventional organic solvent such as CH₃CN at 110 °C occurred hardly even after 4 days (yield 2%, entry 3). Entry 2 clearly indicates that the carbonate synthesis proceeds via alkylation of metal carbonate.

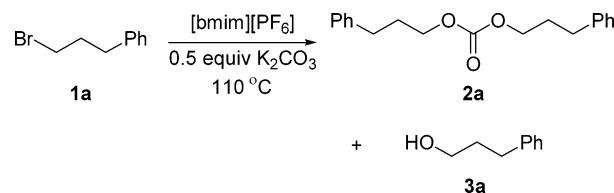
To verify the catalytic activity of [bmim][PF₆], the reaction was performed with 0.25 mL of [bmim][PF₆] (1.2 mmol), which showed sluggish behavior with only 12% of desired product (entry 4). Further, to shed light on various other ionic liquids in comparison to [bmim][PF₆],

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TABLE 1. Symmetrical Organic Carbonate Synthesis from 1-Bromo-3-phenylpropane (**1a**) in the Presence of K₂CO₃ under Various Reaction Conditions^a



entry	[bmim][X] (mL)	CH ₃ CN (mL)	time (h)	yield ^b (%)		
				1a	2a	3a
1	[PF ₆] (1.5)		30		89	trace
2 ^c	[PF ₆] (1.5)		48	92		
3		1.5	96	90	2	2
4	[PF ₆] (0.25)	1.25	48	69	12	trace
5	[SbF ₆] (1.5)		32		83	trace
6	[BF ₄] (1.5)		32		85	2
7	[OTf] (1.5)		36		80	4
8	[NTf ₂] (1.5)		48	58	22	2

^a All reactions were carried out on a 2.0 mmol reaction scale of 1-bromo-3-phenylpropane (**1a**) and 1.0 mmol of K₂CO₃ at 110 °C. ^b Isolated yield. ^c Reaction was carried out in the absence of K₂CO₃.

TABLE 2. Symmetrical Organic Carbonate Synthesis from 1-Bromo-3-phenylpropane (**1a**) in the Presence of Various Metal Carbonates in [bmim][PF₆]^a

entry	M _x CO ₃	time (h)	yield ^b (%)		
			1a	2a	3a
1	BaCO ₃	48	92		
2 ^c	Ag ₂ CO ₃	48	44	20	15
3	Cs ₂ CO ₃	31		86	3
4	CaCO ₃	48	94		
5	Na ₂ CO ₃	48	94	trace	4
6	NaHCO ₃	48	92		

^a All reactions were carried out on a 2.0 mmol reaction scale of alkyl bromide (**1a**) with 1.0 mmol of M_xCO₃ in 1.5 mL of [bmim][PF₆] at 110 °C. ^b Isolated yield. ^c Since silver carbonate is light sensitive, the reaction was carried out in the dark.

we have investigated the synthesis of symmetrical alkyl carbonates using four other ionic liquids. In entries 5–7, [bmim][SbF₆], [bmim][BF₄], and [bmim][OTf] were used as ionic liquids, and we obtained consistent results with desired product in 83, 85, and 80% yields, respectively, whereas [bmim][NTf₂] showed a slow behavior with only 22% of desired product (entry 8). To investigate the recyclability of [bmim][PF₆], we carried out symmetrical carbonate synthesis repeatedly under the conditions of entry 1 in Table 1 by recycling [bmim][PF₆]. The reaction proceeded very well without the degradation of ionic liquid even after three runs.¹⁶

To thoroughly understand the alkylation of metal carbonate in [bmim][PF₆], we carried out the alkylation with various metal carbonates. As shown in Table 2, it is clear that among the group IA alkali metal carbonates Cs₂CO₃ proved to be best, presumably due to less tightness of ion pairs^{17,18} (yield 86%, entry 3). Entries 1 and 4 indicate the poor ability of alkali earth metal with no desired product, whereas transition-metal carbonate

(16) ¹H, ¹³C, and ¹⁹F NMR spectra incorporated in the Supporting Information.

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Ag₂CO₃ generated desired product **2a** in 20% yields (entry 2). The reactions with either Na₂CO₃ or NaHCO₃ did not proceed to symmetrical organic carbonates (entries 5 and 6).¹⁹

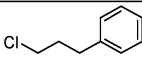
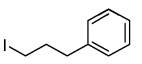
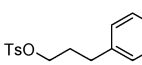
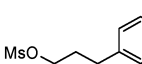
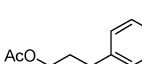
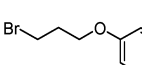
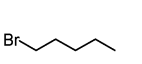
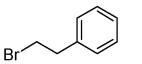
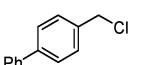
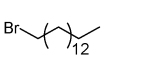
To ascertain the scope of this novel method, we examined several other electrophilic moieties as shown in Table 3. Our methodology proved to be best as it worked for various alkyl halides and sulfonates (entries 1–4). In the case of chloride **1b**, a slower reaction rate was observed compared to those of iodide, tosylate, and mesylate to yield 45% of the desired carbonate. On the other hand, iodide, mesylate, and tosylate reacted within 24, 34, and 42 h to produce carbonate **2a** in 84, 83, and 82% yield, respectively (entries 2–4). Our attempt to synthesize symmetrical carbonates from acetate failed (entry 5). Alkyl halides **1g** and **1h** reacted within 55 and 31 h, respectively, to furnish **4** and **6** with good yields, 78 and 82%, respectively (entries 6 and 7). Alkyl halide **1i** gave a low yield (51%) of desired product **8** together with the unwanted styrene as elimination compound (entry 8). Active alkyl chloride **1j** reacted within 36 h to generate **10** in 80% yield (entry 9), whereas in the case of alkyl halide **1k** the reaction was found to be slow with a yield of **12** of 59%, presumably due to poor solubility in ionic liquid (entry 10).

The ionic liquids acted not only as a solvent but also as an activator for K₂CO₃, which further generates a complex of increased lipophilicity, and “naked” carbonate anion underwent nucleophilic substitution with an alkyl halide or sulfonate. Although there has been a controversy regarding the enhancement of nucleophilicity in ionic liquid,²⁰ symmetrical carbonate could be prepared in high yield by alkylation using potassium carbonate, which is generally considered as a poor nucleophile. Our protocol is supported by the recent studies on remarkable solubility of CO₂ in imidazolium based ionic liquids.²¹

Our attempt to synthesize unsymmetrical organic carbonates via alkylation of K₂CO₃ by two different reactants (1:1) (alkyl halide or sulfonate) in [bmim][PF₆] as expected did not produce consistent results. We observed a low yield of unsymmetrical organic carbonates along with the mixture of two symmetrical organic carbonates generated from two different reactants.

In conclusion, we displayed a new methodology toward the synthesis of symmetrical organic carbonates in ionic liquid under mild conditions. The strategy is based on the alkylation of a cheap, nontoxic, stable, and easy to handle potassium carbonate. This method is devoid from the use of extremely toxic phosgene and carbon monoxide. The experimental and workup procedure is very simple, and convenient with no special equipments. Apart from the alkyl bromides, this method works well for the other alkyl halides or sulfonates, which are found to be an additional practical incentive. Thus, our industrially feasible protocol opens avenues for today's organic chem-

TABLE 3. Symmetrical Organic Carbonates from Various Alkyl Halides/Mesylates and Tosylates in [bmim][PF₆]^a

entry	RX	time (h)	product (yield, ^b %)		
			RX	ROCOOR	ROH
1		72	38	2a (45)	3a (2)
	1b				
2		24		2a (84)	3a (2)
	1c				
3		42		2a (82)	3a (4)
	1d				
4		34		2a (83)	3a (2)
	1e				
5		72	91	-	3a (3)
	1f				
6		55		4 (78)	5 (2)
	1g				
7		31		6 (82)	7 (-)
	1h				
8 ^c		35		8 (51)	9 (4)
	1i				
9		36		10 (80)	11 (2)
	1j				
10		72		12 (59)	13 (4)
	1k				

^a All reactions were carried out on a 2.0 mmol reaction scale of alkyl halides/mesylates and tosylates **1** with 1.0 mmol of K₂CO₃ in 1.5 mL of [bmim][PF₆] at 110 °C. ^b Isolated yield. ^c Styrene was obtained in 32% yield.

(18) For the alkyl carbonates synthesis using cesium carbonate, see: (a) Kim, S.-I.; Chu, F.; Dueno, E. E.; Jung, K. W. *J. Org. Chem.* **1999**, *64*, 4578–4579. (b) Cella, J. A.; Bacon, S. W. *J. Org. Chem.* **1984**, *49*, 1122–1125.

(19) For dialkyl carbonate synthesis using potassium bicarbonate in the presence of phase-transfer catalyst, see ref 18b.

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ist who is concerned with safety and toxic waste minimization. It is expected that reactions using polymer-supported ionic liquid (PSIL)²² instead of ionic liquid might provide excellent yields with low reaction time for the synthesis of organic carbonates. In addition, we are

(22) Kim, D. W.; Chi, D. Y. *Angew. Chem., Int. Ed.* **2004**, *43*, 483–485.

trying to improve our prodigious ionic liquid methodology toward the synthesis of unsymmetrical organic carbonates.

Experimental Section

Typical Procedure for Di(3-phenylpropyl)carbonate (2a). 3-Bromopropylbenzene (**1a**, 398.0 mg, 2.0 mmol) was added to the mixture of K_2CO_3 (138.2 mg, 1.0 mmol) and 1-*n*-butyl-3-methylimidazolium hexafluorophosphate [bmim][PF₆] (1.5 mL). The mixture was stirred over 30 h at 110 °C. The reaction mixture was extracted from the ionic liquid phase with ethyl ether (5 mL × 5). The organic layer was dried over anhydrous sodium sulfate and evaporated under reduced pressure. The residue was purified by flash column chromatography (silica gel) (5% EtOAc/Hx) to obtain 265.2 mg (89%) of di(3-phenylpropyl)carbonate (**2a**) as a colorless liquid: ¹H

NMR (400 MHz, CDCl₃) δ 1.97–2.04 (m, 4H), 2.72 (t, *J* = 7.6 Hz, 4 H), 4.15 (t, *J* = 6.4 Hz, 4H), 7.18–7.30 (m, 10 H); ¹³C NMR (100 MHz, CDCl₃) δ 30.2, 31.9, 67.2, 126.0, 128.3, 128.4, 140.9, 155.3; MS FAB 299.0 (M + H⁺), 199.7 (100). Anal. Calcd: C, 76.48; H, 7.43. Found: C, 76.29; H, 7.49. CAS Registry No.: 102162-49-2.

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Supporting Information Available: Experimental procedures including characterization of all compounds. This material is available free of charge via the Internet at <http://pubs.acs.org>.

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