



## Seleniumium ionic liquid as efficient catalyst for the Baylis–Hillman reaction

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### ARTICLE INFO

#### Article history:

Received 5 May 2009

Revised 24 June 2009

Accepted 29 June 2009

Available online 4 July 2009

#### Keywords:

Baylis–Hillman  
Seleniumium salts  
Ionic liquid

### ABSTRACT

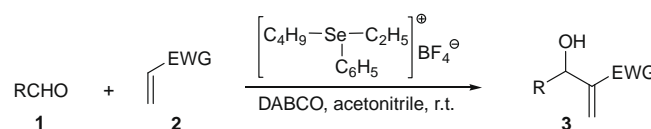
The new acidic ionic liquid phenyl butyl ethyl seleniumium tetrafluoroborate, [pbeSe]BF<sub>4</sub>, was successful used as a co-catalyst in the Baylis–Hillman reaction of aldehydes and electron-deficient alkenes. The Baylis–Hillman adducts were obtained in moderated to good yields and in relatively short reaction times under mild conditions.

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The Baylis–Hillman (BH) and related reactions allows the synthesis of highly functionalized and useful intermediates in a single step, starting from cheap and easily available materials.<sup>1</sup> Despite the high aggregated value to the BH-adducts, the reaction suffers from low reaction rates and limited substrate range.<sup>1,2</sup> A number of methods to overcome these limitations have been described, including the use of new catalysts,<sup>3</sup> novel solvent media,<sup>2,4</sup> non-classical energy sources<sup>5</sup> and high pressure.<sup>6</sup> In the last years the use of ionic liquids to accelerate BH reaction was described,<sup>4</sup> including piridinium<sup>4a,b</sup> and imidazolium ionic liquids<sup>4c–1</sup> derivatives. In view of its high atom efficiency and the high functionality of the BH-adducts, the development of new, general catalysts for the BH reaction continues to attract the attention of synthetic organic chemists.

Our major research goal has been the development of new methods for the preparation and synthetic applications of organochalcogenium compounds,<sup>7</sup> including new selenium and tellurium-containing ionic liquids.<sup>7a,b</sup> Because the effective dual Lewis acid–base activation of the BH reaction, we decide to study the effect of the new acidic seleniumium salts in the rate of the Baylis–Hillman reaction. Thus, we wish to report here the use of phenyl butyl ethyl seleniumium tetrafluoroborate, [pbeSe]BF<sub>4</sub>, firstly described by us,<sup>7a</sup> as a co-catalyst in the BH reaction of aldehydes and electron-poor alkenes (Scheme 1, Table 1).<sup>8</sup>

For to evaluate the effect of [pbeSe]BF<sub>4</sub> in the BH reaction, we started our studies using benzaldehyde **1a** and methyl acrylate



Scheme 1.

Table 1

Optimization of the BH reaction catalyzed by [pbeSe]BF<sub>4</sub> to give **3a**, according to Scheme 1<sup>a</sup>

Entry	Solvent (mol %)	[pbeSe]BF <sub>4</sub> (mol %)	Temp	Time <sup>b</sup> (h)	Yield (%)
1	[bmim]BF <sub>4</sub> (100)	5	rt	2	52
2	[bmim]BF <sub>4</sub> (100)	5	rt	6	65
3	[bmim]BF <sub>4</sub> (100)	5	rt	24	63
4	[bmim]BF <sub>4</sub> (100)	—	rt	24	55
5	[bmim]BF <sub>4</sub> (5)	5	rt	24	64
6	CH <sub>3</sub> CN (100)	—	rt	24	59
7	[bmim]BF <sub>4</sub> (5)/CH <sub>3</sub> CN (100)	5	rt	24	47
8	—	5	rt	24	21
9	CH <sub>3</sub> CN (100)	5	rt	2	62
10	CH <sub>3</sub> CN (100)	5	rt	6	63
11	CH <sub>3</sub> CN (100)	5	rt	24	77
12	CH <sub>3</sub> CN (100)	5	60 °C	24	30
13	CH <sub>2</sub> Cl <sub>2</sub> (100)	5	rt	24	22

<sup>a</sup> Reaction conditions: benzaldehyde (**1a**, 2.5 mmol); methyl acrylate (**2a**, 2.5 mmol); DABCO (1.0 equiv); solvent (100 mol %); [pbeSe]BF<sub>4</sub> (5 mol %).

<sup>b</sup> The reaction was followed by TLC and GC until complete consume of starting aldehyde.

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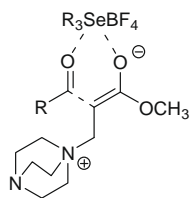


Figure 1. Stabilizing effect of selenonium salt.

**2a** under the classical conditions (DABCO, CH<sub>3</sub>CN) and the results are shown in Table 1. We made a study regarding the solvent media and the best results were observed when **1a** and **2a** were simply mixed with DABCO (1 equiv) and [pbeSe]BF<sub>4</sub> (5 mol %) in the presence of acetonitrile (100 mol %) and were stirred at room temperature (entry 11). In this case, the BH-adduct **3a** was obtained in 77% yield after 24 h. In the absence of selenonium ionic liquid, **3a** was obtained only in 59% yield after 24 h, while using

Table 2  
Selenonium ionic liquid promoted Baylis–Hillman reaction of aldehydes and alkenes

Entry	Aldehyde (1)	Alkene (2)	Product (3)	Time <sup>a</sup> (h)	Yield <sup>b</sup> (%)
1				24	77
2		<b>2a</b>		24	62
3		<b>2a</b>		24	45
4		<b>2a</b>		24	39
5	<b>1a</b>			6	77
6	<b>1b</b>	<b>2b</b>		2	78
7	<b>1c</b>	<b>2b</b>		7	62
8	<b>1d</b>	<b>2b</b>		6	75
9	<b>1a</b>			24	45
10	<b>1b</b>	<b>2c</b>		24	48
11	<b>1a</b>			24	39

<sup>a</sup> The reaction progress was followed by TLC and GC until complete consume of starting alkenes or aldehydes.

<sup>b</sup> Yields of pure products isolated by column chromatography (ethyl acetate/hexanes) and identified by mass spectrometry, <sup>1</sup>H and <sup>13</sup>C NMR.<sup>2–5</sup>

the selenonium ionic liquid a similar yield was obtained just after 2 h (entries 6 and 9, respectively). With the aim to increase the yield of the reaction and to eliminate the use of volatile solvent, we decide to evaluate the use of [bmim]BF<sub>4</sub> instead acetonitrile as solvent. Unfortunately, no increasing in yields or reaction acceleration were observed, even when a smaller amount of [bmim]BF<sub>4</sub> (5 mol %) was used to minimize the competition for the DABCO (Table 1, entries 1–5). Thus, for example, the adduct **3a** was obtained in 63% after 24 h using 0.5 mL (100 mol %) of [bmim]BF<sub>4</sub> as solvent in the presence of DABCO and [pbe]SeBF<sub>4</sub> (entry 3). This result is similar to the observed when [bmim]BF<sub>4</sub> was used alone,<sup>4a</sup> showing that this high polar medium inhibits the selenonium salt action (entry 4). A mixture of [bmim]BF<sub>4</sub> and acetonitrile as solvent was also tested, but **3a** was obtained in modest yields, even after several hours of stirring (entry 7). Because some BH reactions were carried out with good results under solvent-free conditions,<sup>1</sup> we also tested the solvent-free reaction of **1a** and **2a** using our new ionic liquid, [pbeSe]BF<sub>4</sub>, but **3a** was obtained only in 21% yield after 24 h (entry 8). The use of other solvents, such as dichloromethane, was not satisfactory (entry 13).

The chalcogeno-Baylis–Hillman is a variant of the BH reaction using organyl chalcogenides as base and a Lewis acid as catalyst.<sup>9</sup> Thus, we decide to test [pbeSe]BF<sub>4</sub> (5 mol %) as acid catalyst in the presence of 1 equiv of diphenyl selenide or diphenyl diselenide as soft Lewis bases for the reaction of **1a** with **2a**. The reaction mixture was stirred at room temperature for several hours and no adduct **3a** was formed, even heating at 60 °C or using a larger amount of the selenonium salt.

The rate enhancement caused by acidic [pbeSe]BF<sub>4</sub> can be credited to the stabilization of the zwitterionic intermediate formed by the DABCO attack to the electron-poor alkene, similarly to described by Aggarwal<sup>3d</sup> and Kobayashi<sup>3c</sup> for metal salts (Fig. 1).

The scope of our methodology was successfully expanded to others aromatic and aliphatic aldehydes and alkenes, with the best yields obtained when aromatic aldehydes were used (Table 2). The present selenonium-promoted BH-reaction was also applicable to acrylonitrile **2b** (Table 2, entries 5–8), affording the respective adducts **3e–h** in good yields and shorter reaction times, comparing with those obtained with methyl acrylate **2a** (entries 1–4). These results are similar to those described in the literature using DABCO.<sup>1,10</sup> When methyl vinyl ketone **2c** and cyclohexenone **2d** were used, it was also possible to obtain the respective BH-adducts. However, the yields of **3i–k** were only reasonable (Table 2, entries 9–11).

In conclusion, [pbeSe]BF<sub>4</sub> was found to be a new acid catalyst for the BH-reaction of several electron-deficient alkenes with

aromatic and aliphatic aldehydes in good yields. The reaction time was reduced when the selenonium salt was used.

## Acknowledgements

This project is funded by CNPq, FAPERGS and CAPES.

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- General procedure for the Baylis–Hillman reaction*: To a mixture of benzaldehyde (**1a**, 0.265 g; 2.5 mmol) and methyl acrylate (**2a**, 0.215 g; 2.5 mmol) in acetonitrile (128 μL; 2.5 mmol; 100 mol %) were added DABCO (0.28 g; 2.5 mmol) and [pbeSe]BF<sub>4</sub><sup>7a</sup> (0.041 g, 0.125 mmol; 5 mol %) and the solution was stirred at room temperature for 24 h (followed by TLC). The crude product was purified by column chromatography over silica gel (SiO<sub>2</sub>) eluting with ethyl acetate/hexanes (2:8), yielding the product **3a** (0.37 g, 77%) as a colourless oil. <sup>1</sup>H NMR (200 MHz, CDCl<sub>3</sub>) δ (ppm) 3.10 (br s, 1H); 3.68 (s, 3H); 5.53 (s, 1H); 5.84 (s, 1H); 6.31 (s, 1H); 7.28–7.36 (m, 5H).<sup>5b</sup>
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