# **P**olystyrene-Supported Aluminum Chloride: An Efficient and Recyclable Green Catalyst for One-Pot Synthesis of 14-Aryl or Alkyl-14*H*-Dibenzo[*a*,*j*]Xanthenes

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ABSTRACT: A new, mild, and efficient method has been developed for the one-pot synthesis of 14aryl or alkyl-14H-dibenzo[a, j]xanthenes by condensation of 2-naphthol and aryl or alkyl aldehydes in the presence of a catalytic amount of cross-linked polystyrene-supported aluminum chloride (PS/AlCl<sub>3</sub>) as an ecofriendly heterogeneous catalyst. This polymeric solid acid catalyst is stable and can be easily recovered and reused without appreciable change in its activity. © 2010 Wiley Periodicals, Inc. Heteroatom Chem 22:51–54, 2011; View this article online at wileyonlinelibrary.com. DOI 10.1002/hc.20655

# INTRODUCTION

The utility of polymer-supported catalysts is now well recognized because of their ease of workup and of separation of products and catalysts, from the economical point of view, and in application to industrial processes, recyclability, easier handling, greater selectivity, enhanced stability, nontoxicity, and noncorrosiveness [1]. In general, catalysts are immobilized on polymers via coordinate or covalent bonds. On the other hand, polymer-supported Lewis acid catalyzed reactions are of great current interest because of the unique reactivities and selectivities that can be achieved as well as for the mild conditions used [2]. The most frequently used polymeric support is polystyrene; Its hydrophobic nature protects water-sensitive Lewis acids from hydrolysis by atmospheric moisture until it is suspended in an appropriate solvent where it can be used in a chemical reaction [3].

Xanthenes, especially benzoxanthenes, are an important and very useful class of intermediates in organic synthesis due to their wide range of biological and pharmaceutical properties such as antibacterial [4], antiviral [5], anti-inflammatory activities [6], and sensitizers in photodynamic therapy for destroying the tumor cells [7], and also these heterocyclic compounds widely used as leucodyes [8], pH-sensitive fluorescent materials for visualization of biomolecules [9], and in laser technology [10]. The reported methods for the synthesis of 14-aryl or alkyl-14*H*-dibenzo[*a*,*j*]xanthenes involve the mixing of 2-naphthol with aldehydes in the presence of an acidic catalyst such as AcOH-H<sub>2</sub>SO<sub>4</sub>[11], *p*TSA [12], sulfamic acid [13], molecular iodine [14], LiBr [15], Amberlyst-15 [16], silica sulfuric acid [17,18a], silica perchloric acid [18b], heteropoly acid [19,20], wet cyanuric chloride [21], BF<sub>3</sub>·SiO<sub>2</sub> [22], Yb(OTf)<sub>3</sub>[23a], In(OTf)<sub>3</sub> [23b], alum [24]. Montmorillonite K-10 [25], P<sub>2</sub>O<sub>5</sub>/Al<sub>2</sub>O<sub>3</sub> [26], and ionic liquids [27,28]. In spite of potential utility of aforementioned routes for the synthesis of benzoxanthene derivatives, some of these methods suffer at least from one or more

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SCHEME 1

disadvantages, such as a long reaction time, relatively expensive reagents, use of toxic solvents and catalysts, requirement of excess of reagents/catalysts, harsh and strong acidic reaction conditions, unsatisfactory yield, and tedious workup procedures. In addition, some of these catalysts are not recyclable and require workup of the reaction mixture. Therefore, to avoid these limitations, the development of simple, mild and environment friendly approaches, especially using heterogeneous catalysts for the preparation of these pharmaceutically important compounds, is still demanding.

In continuation of our interest in synthesis of organic compounds from condensation of phenols with dialdehydes [29], herein, we wish to report an efficient and environmentally benign method for the synthesis of 14-aryl or alkyl-14H-dibenzo[a,j]xanthenes derivatives catalyzed by polystyrene-supported aluminum chloride (PS/AlCl<sub>3</sub>) (Scheme 1).

#### **RESULTS AND DISCUSSION**

Cross-linked polystyrene-supported aluminum chloride (PS/AlCl<sub>3</sub>) was prepared by addition of anhydrous aluminum chloride to polystyrene (8% divinylbenzene) in carbon disulfide under reflux conditions [2b]. The capacity of the polymeric catalyst was 0.48 mmol AlCl<sub>3</sub> per gram catalyst [30]. Although AlCl<sub>3</sub> is a water-sensitive, corrosive, and environmentally harmful compound, PS/AlCl<sub>3</sub> is a stable and watertolerant species. This polymeric catalyst is easy to prepare, stable in air for a long time without any change, easily recyclable, and reusable without appreciable loss of its activity.

Initially, to optimize the reaction conditions, we studied the reaction between 2-naphthol (2 mmol) and 4-chlorobenzaldehyde (1 mmol) as a simple model using catalytic amount of PS/AlCl<sub>3</sub> (20 mol%) under different conditions (Table 1). We found that the best result was obtained when the reaction was carried out in acetonitrile as reaction media (Table 1, entry 6). The use of 20 mol% of PS/AlCl<sub>3</sub> was sufficient to progress the reaction, and an increase in the amount of catalyst did not improve the yield.

**TABLE 1** Reaction between 2-Naphthol (2 mmol) and 4-Chlorobenzaldehyde (1 mmol) Using Catalytic Amount of $PS/AlCl_3$  under Different Conditions<sup>a</sup>

Entry	Solvent	Conditions	Time (h)	Vield (%)	
Linuy	Solven	Conditions	nine (n)		
1	THF	Reflux	6	0	
2	CHCl₃	Reflux	6	Trace	
3	CH <sub>2</sub> Cl <sub>2</sub>	Reflux	6	Trace	
4	CICH <sub>2</sub> CH <sub>2</sub> CI	Reflux	6	Trace	
5	CH <sub>3</sub> CH <sub>2</sub> OH	Reflux	3	66	
6	CH <sub>3</sub> CN	Reflux	1.5	92	
7	Toluene	Reflux	8	Trace	
8	Neat	80°C	6	Trace	
9	Neat	100°C	6	Trace	

<sup>a</sup>The yields refer to the isolated pure products.

It is worthy to note that in the absence of PS/AlCl<sub>3</sub> catalyst, the reaction did not yield any product at reflux temperature even after a long reaction time. To find out whether the reaction takes place in the solid matrix of PS/AlCl<sub>3</sub> or whether released AlCl<sub>3</sub> is responsible for the condensation reaction, PS/AlCl<sub>3</sub> was added to CH<sub>3</sub>CN and the mixture was stirred at reflux temperature for 3 h. Then, the catalyst was filtered off and the filtrate was analyzed for its aluminum content, which showed a negligible release of AlCl<sub>3</sub>. The filtrate was found to be inactive for the condensation reaction indicates that PS/AlCl<sub>3</sub> is stable under the reaction conditions, and there is no leaching of Lewis acid moieties during reactions.

After optimization of the reaction conditions, we studied the generality of this condition to other substrates. Using this method, different kinds of aromatic and aliphatic aldehydes were reacted with 2-naphthol to produce the corresponding 14-aryl or alkyl-14*H*-dibenzo[a,j]xanthenes at the reflux temperature in acetonitrile. The results are summarized in Table 2. Several aromatic aldehydes with different functional groups were subjected to the condensation reaction, and the desired products were synthesized in good to high yields and a short reaction time. The substituted functional groups on the aromatic ring of the aldehyde affected the yield

**TABLE 2** Synthesis of 14-Aryl or Alkyl-14*H*-dibenzo[a,j]-xanthenes Catalyzed by PS/AlCl<sub>3</sub> (20 mol%) Using Different Aldehydes and 2-Naphthol<sup>*a*</sup>

Entry	R <sup>b</sup>	Time (h)	Yield <sup>c</sup> (%)	M.p. (°C) (lit. m.p) [Ref.]
1 2 3 4 5 6 7	$C_6H_5$ $4-MeC_6H_4$ $4-OMeC_6H_4$ $4-CIC_6H_4$ $2-CIC_6H_4$ $4-NO_2C_6H_4$ $2-NO_2C_6H_4$	2.5 2.5 2 1.5 2 1.5 2 5	89 88 92 90 93 91	184-185(185) [19] 228(229) [19] 202-203(204) [19] 289-290(289) [19] 214-215(215) [19] 310-311(310) [19] 213-214(213) [19]
8 9 10 11 12	$\begin{array}{c} 4 \text{-BrC}_{6}\text{H}_{4} \\ 4 \text{-OHC}_{6}\text{H}_{4} \\ \text{CH}_{2}\text{CH}_{3} \\ \text{CH}_{2}\text{CH}_{2}\text{CH}_{3} \\ \text{CH}(\text{CH}_{3})_{2} \end{array}$	2.5 2.5 3 4 4	90 84 85 82 80	297-298(297) [19] 261-262(263) [19] 149-150 (152) [28] 153-154 (155-157) [22] 152-153(153-154) [22]

<sup>&</sup>lt;sup>a</sup>Reaction condition: aldehyde (1 mmol); 2-naphthol (2 mmol), PS/AlCl<sub>3</sub> (20 mol%); reflux in  $CH_3CN$ .

<sup>b</sup>All the products are known and were characterized by comparison of their IR, 1H NMR, and physical data with those reported in the literature. <sup>c</sup>Isolated yields.

and reaction time. In comparison with electronwithdrawing groups on the aryl aldehydes, we found that the presence of electron-donating groups on the aryl aldehydes decreased both the reaction rate and yield of product (Table 2, entries 3,9). The workup procedure is simple and includes filtration of the mixture to separate the catalyst. Although AlCl<sub>3</sub> is a water-sensitive, corrosive, and environmentally harmful compound, PS/AlCl<sub>3</sub> is a very active, stable to air and moisture, nontoxic species, and it can be quantitatively recovered by filtration and reused.

Based on the experimental results and by referring to the literature [32,33], the mechanism of the dibenzoxanthene formation proceeds by the usual pathway proposed using Lewis acids.

In conclusion, PS/AlCl<sub>3</sub> as a noncorrosive, environmentally benign, and stable heterogeneous polymer-supported Lewis acid has proved to be a very efficient catalyst for the efficient synthesis of dibenzoxanthene derivatives. The notable advantages of this methodology are mild reaction conditions, high yields, short reaction times, operational simplicity, generality, easy workup and low cost, easy preparation, and handling of the catalyst. In addition, the use of water-tolerant PS/AlCl<sub>3</sub> has resulted in a reduction in the unwanted and hazardous waste that is produced during conventional homogeneous processes. Finally, this polymeric solid acid catalyst can be recovered and reused at least five times with negligible loss in its activity.

### EXPERIMENTAL

### Materials and Instruments

All chemical reagents and solvents were obtained from Fluka (Switzerland) and Merck (Germany) and were used without further purification. Cross-linked polystyrene (8% divinylbenzene) was prepared via suspension polymerization. PS/AlCl<sub>3</sub> was prepared using cross-linked polystyrene as reported in the literature [2b]. The capacity of the catalyst was determined by the Mohr titration method. All products were known compounds and were identified by comparison of their physical and spectral data with those of the authentic samples. Melting points were measured on an Electrothermal 535 apparatus and were uncorrected. <sup>1</sup>H NMR spectra were recorded on a Bruker DPX-250 Avance spectrometer at 250.13 MHz. IR spectra were recorded on a Unicam Matteson 1000 spectrophotometer. Reaction monitoring and purity determination of the products were accomplished by TLC on silica-gel polygram SILG/UV<sub>254</sub> plates. All yields refer to isolated products.

# Preparation of PS/AlCl<sub>3</sub>

Anhydrous AlCl<sub>3</sub> (4.5 g) was added to polystyrene (8% divinylbenzene, 3.5 g) in carbon disulfide (25 mL) as the reaction medium. The mixture was stirred using a magnetic stirrer under reflux condition for 50 min, cooled, and then water (40 mL) was cautiously added to hydrolyze the excess AlCl<sub>3</sub>. The mixture was stirred until the deep orange color disappeared, and the polymer became light yellow. The polymer beads were then filtered and washed with water (300 mL) and then with acetone and diethyl ether. The polymer was dried in a vacuum oven for 12 h at room temperature. The capacity of the polymeric catalyst based on its chloride content was 0.47 mmol AlCl<sub>3</sub>/g catalyst [30,31].

#### General Experimental Procedure for the Synthesis of 14-Aryl or Alkyl-14H-dibenzo[a,j]xanthenes

In a round-bottom flask (50 mL) equipped with a condenser and a magnetic stirrer, a solution of the aldehyde (1 mmol) and 2-naphthol (2 mmol) in CH<sub>3</sub>CN (10 mL) was prepared. PS/AlCl<sub>3</sub> (20 mol%) was added to the solution, and the reaction mixture was stirred magnetically under reflux conditions for the specified period of time. The progress of the reaction was monitored by TLC. After completion of the reaction, the catalyst was filtered off and washed with CHCl<sub>3</sub> (2 × 10 mL) to remove any adhering xanthene product and the filtrate concentrated on a

rotary evaporator under reduced pressure to give the crude product. The crude product was recrystallized from ethanol to afford the pure 14-aryl or alkyl-14*H*-dibenzo[a,j]xanthenes derivatives. The spent polymeric catalyst from different experiments was combined, washed with CHCl<sub>3</sub>, and dried overnight in a vacuum oven and reused. Representative examples of spectroscopic and analytical data are given below.

Spectral data for (xanthene product, R = Cl), (Table 2, entry 4): mp 289–290°C;  $\nu_{max}(IR)$  3032, 1618, 1580 cm<sup>-1</sup>;  $\delta_{H}(^{1}H NMR, CDCl_{3})$  6.47 (1H, s, C<u>H</u>), 7–8.35 (16H, m, Ar-<u>H</u>);  $\delta_{c}(^{13}C NMR, CDCl_{3})$ 37.35, 116.70, 118.04, 122. 41, 124.36, 126.93, 128.66, 128.90, 129.10, 129.48, 131.05, 131.24, 132.05, 143.45, 148.65. MS (*m*/*z*): 392 (25), 281 (100), 252 (46), 75 (35)%.

(Xanthene product, R = Br), (Table 2, entry 8): mp 297–298°C;  $\nu_{max}$ (KBr) 3030, 1624, 1586 cm<sup>-1</sup>.  $\delta_{\rm H}(^{1}{\rm H} \,{\rm NMR},{\rm CDCl}_{3})$  6.47 (1H, s, C<u>H</u>), 7.25–8.35 (16H, m, Ar-<u>H</u>);  $\delta_{\rm c}(^{13}{\rm C} \,{\rm NMR},{\rm CDCl}_{3})$  37.46, 116.64, 118.02, 120.21, 122.39, 124.38, 126.93, 128.91, 129.12, 129.88, 131.03, 131.23, 131.56, 143.97, 148.65; MS (*m*/*z*): 437(20), 281(100), 252 (40)%.

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