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One-Pot Synthesis of Benzoxanthenes in Solvent Free Condition using Chloroaluminate Ionic Liquids as Catalyst

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ABSTRACT

A mild and efficient method has been developed for the preparation of 14-aryl-14H dibenzo[a,j]xanthenes from one-pot condensation of aldehydes with β-naphthol using catalytic amount of Chloroaluminate ionic liquid (imidazolium chloride·3$AlCl_3$ or pyridinium chloride·3$AlCl_3$) under thermal solvent-free conditions. Excellent yields, short reaction times, easy workup and reusability of the catalyst as well as solvent free conditions are advantages of this procedure.

Keywords

Ionic Liquids; Xanthenes; Aldehydes; Naphthol; Solvent free.

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INTRODUCTION

Xanthenes related to specific class of oxygen heterocylic compounds which possess various biological and pharmacological activities such as antibacterial [1-2], anti-proliferative [3], anti-inflammatory [4], and antiviral activities [5]. Xanthenes especially benzoxanthenes are of interest as functional materials in many disciplines due to their useful spectroscopic properties. They are used as dyes [6-7], in laser technologies [8], as pH-sensitive fluorescent materials for visualization of biomolecules [9], as photostable dyes, polymerizable light emitting dyes [10-11], and white organic light emitting dyes [12]. Natural xanthene dyes may also be extracted from soil and plants such as Indigo feralongeracemosa [13]. Recently different methods have been reported for the synthesis of benzoxanthenes, including the reaction of β-naphthol with aldehydes in the presence of a catalyst, such as amberlyst-15 [14], sulfamic acid [15], molecular iodine [16], AcOH-H_2SO_4,in acidic medium [17], heteropoly acids (HPAs) [18], and $HClO_4$-SiO_2 [19]. However, some of these methods suffer from one or more disadvantages such as low yields, long reaction times, special apparatus, excess reagents, and the use of toxic catalyst and solvents. Thus, the development of an improved procedure for the synthesis of benzoxanthene derivatives would be highly desirable. In recent years, ionic liquids have attracted extensive interest as benign reaction media in organic synthesis because of their unique properties of non-volatility, non-flammability, recyclability, and ability to dissolve a wide range of materials [20]. As a result of their green credentials and potential to enhance reaction rates and selectivity, ionic liquids have been found increasing applications to organic synthesis. Previously reactions of xanthenes synthesis have been reported in ionic liquid in presence of catalyst, bronsted acid, and metal salts. Herein, we report one-pot synthesis of 14-aryl-14H-dibenzo[a,j]xanthenes in Lewis acidic ionic liquids such as 1-butylpyridinium chloride and imidazolium chloride·$3AlCl_3$.

EXPERIMENTAL

Instrumentation:

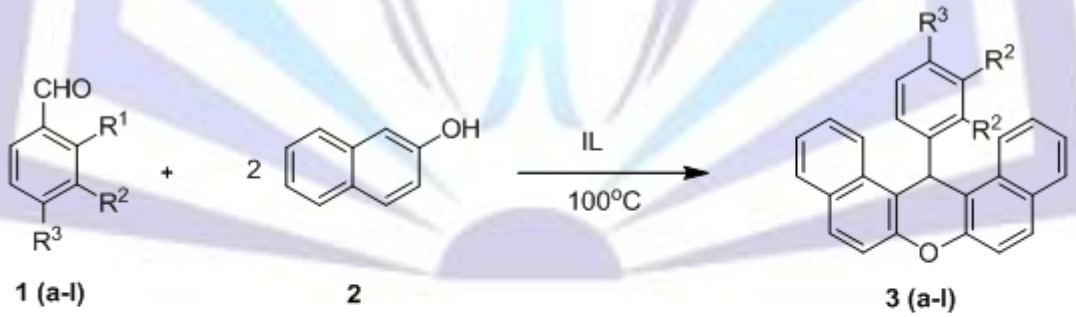
The ^{13}C NMR and ^{1}H NMR spectrum were recorded on JEOL using TMS as internal standard. FT-IR of all synthesized xanthenes was recorded on a spectrometer Perkin Elmer Spectrum BX II from range 4000-400 cm^{-1} by making sample pallets with KBr. The melting points of synthesized compounds were determined on a Thomas Hoover Unimelt capillary melting point apparatus.

Reagent and Solutions:

All the Aldehydes used were purchased from Merck and β-naphthol from Fisher Scientific Chemicals. All ionic liquids synthesized in lab according to modified procedure.

RESULTS AND DISCUSSION

The 14-aryl-14-H-dibenzo[a,j]xanthenes (**3**) have been prepared in good to high yields by condensing β-naphthol (**2**) with aromatic aldehydes (**1**) in Lewis acid ILs imidazolium (**4a** and **4b**) and pyridinium (**4c** and **4d**) at 100 °C (scheme 1).



1 (a-l) 2 3 (a-l)

3a, R^1 = H, R^2 = H, R^3 = CH_3	**3g**, R^1 = H, R^2 = H, R^3 = Cl
3b, R^1 = H, R^2 = H, R^3 = C_2H_5	**3h**, R^1 = Cl, R^2 = H, R^3 = H
3c, R^1 = H, R^2 = H, R^3 = Br	**3i**, R^1 = H, R^2 = H, R^3 = NO_2
3d, R^1 = H, R^2 = Br, R^3 = H	**3j**, R^1 = NO_2, R^2 = H, R^3 = H
3e, R^1 = H, R^2 = F, R^3 = H	**3k**, R^1 = H, R^2 = NO_2, R^3 = H
3f, R^1 = H, R^2 = H, R^3 = F	**3l**, R^1 = H, R^2 = H, R^3 = H

Scheme 1

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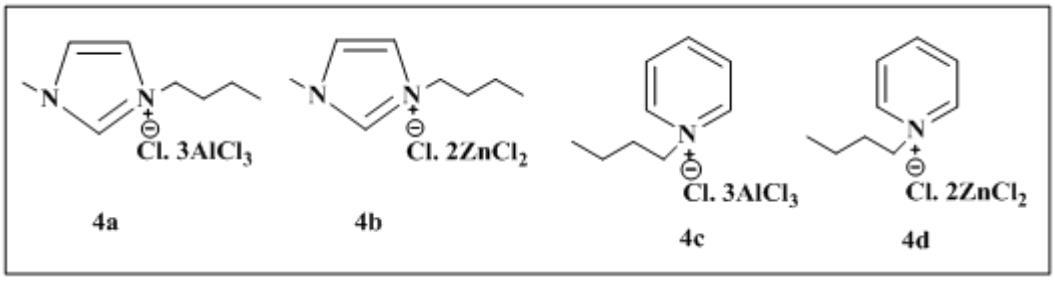

Figure 1: Structure and symbol of ionic liquids

The reaction mixture of β-naphthol (**2**) and 4-methyl benzaldehyde (**1a**) in **4a** IL was heated at 100 °C for 15 minutes to give 14-(4-methylphenyl)-14-H-dibenzo[a,j]xanthene (**3a**) in 92% yield (table 2). The structure of **3a** was characterized by different spectroscopic techniques. The melting point of **3a** (230°C) closely corresponded to the literature value (table 2).The condensation reaction of β-naphthol with 4-methylbenzaldehyde (**1a**) was compared in **4a**, **4b**, **4c** and **4d** Lewis acid ILs at 100 °C, and the best yield of 14-(4-methylphenyl)-14-H-dibenzo[a,j]xanthene (**3a**) was obtained in **4a** IL (table 1).

The poor yield of **3a** in **4b** and **4d** as compared to **4a** IL could be attributed to the lower Lewis acidic nature of $ZnCl_2$, which leads to lower yield of corresponding product. Further, the condensation reaction of (**1a)** in pyridinium ionic liquid **4c** with same counter anion($AlCl_4^-$) found to be less efficient in comparison to imidazolium ionic liquid.

Table 1: Synthesis of 14-(4-methylphenyl)-14-H-dibenzo[a,j]xanthenes (**3a**) by condensation of β-naphthol with 4-methylbenzaldehyde (**1a**) in the presence of different ionic liquid (**4a-4d**) at 100 $^oC^a$

Entry	Ionic liquids	Time (min)	Yield (%)[b]
4a		15	92
4b		15 60	2 22
4c		15	83
4d		15 60	41 53

[a]2-Naphthol 2 mmol; aldehyde 1 mmol, ionic liquid 0.2 equivalent.

[b]Isolated yields.

The UV-visible spectrum of **3a** showed an intense absorption band at 320 nm and 334 nm, inferring extended conjugation in **3a** heterocycle (figure 2). The appearance of a strong band at 1248 cm^{-1} in the IR spectrum of **3a** was assigned to C-O stretching. In the ^1H NMR spectrum of **3a**, aliphatic CH proton of **3a** appeared as a singlet at 6.43 ppm and aromatic protons resonances were observed in 6.93–8.37 ppm region. The appearance of a peak at m/z 372 corresponding to $[M]^+$ in the electron impact-mass spectroscopy(EI-MS) spectrum further confirmed the formation of **3a** in the reaction.

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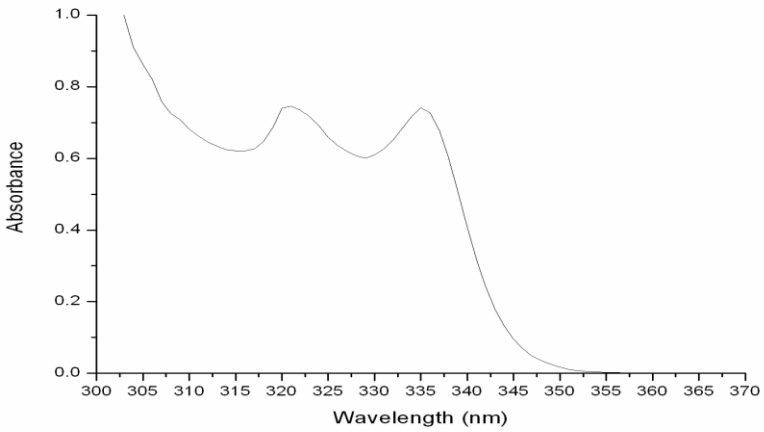

To check the feasibility of the optimized reaction condition, we carried out this reaction using different aromatic aldehydes (table **2**). It has been found that the nature of the functional group on the aromatic ring of the aldehyde affects the reaction time and yield. The presence of electron withdrawing group at *para* position in comparison to the unsubstituted aromatic aldehyde shows increase of the yield while the presence of an electron donating group decreases the yield. Though *meta* and *para*-substituted aromatic aldehydes gave good results, *ortho*-substituted aromatic aldehydes (such as 2-nitro benzaldehyde) gave lower yields because of the steric effects [21]. Based on the results, a possible explanation for the reaction can be proposed.

The IL **4a** was recovered from the reaction mixture by extracting the crude product with dichloromethane and reused for the synthesis of **3a**. In the second run, **3a** was obtained in 81% yield by condensation of β-naphthol with 1a in the presence of recovered **4a** IL. Slight decrease in the yield of **3a** was observed in third run, as **3a** was isolated in 79% yield.

Table 2: Synthesis of 14-alkyl- or aryl-14-H-dibenzo[a,j]xanthenes by condensation of β-naphthol with aldehydes in the presence of ionic liquid (**4a**) at 100 ^{o}C[a]

Aromatic Aldehydes	Time (min)	Yield (%) of 3[b]	M.P. (°C)	Lit. M.P. (°C)
1a	15	92	230	229[22]
1b	15	85	150	152[16]
1c	10	94	298	297[22]
1d	10	92	188	190[22]
1e	10	93	261	259[22]
1f	10	95	238	239[24]
1g	10	93	290	289[22]
1h	10	89	213	215[22]
1i	10	93	312	310[22]
1j	10	87	292	293[23]
1k	10	90	210	211[22]
1l	15	89	186	185[22]

[a]β-Naphthol 2 mmol; aldehyde 1 mmol, ionic liquid 0.2 equivalent.

[b]Isolated yields

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