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Article

Condensation of 2-naphthol with arylaldehydes using acetic acid functionalized ionic liquids as highly efficient and reusable catalysts

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ABSTRACT

An efficient solvent-free protocol for the synthesis of 14-aryl-14H-dibenzo[a,j]xanthenes from the condensation of 2-naphthol with arylaldehydes, using acetic acid functionalized imidazolium salts (1-carboxymethyl-3-methylimidazolium bromide ([cmmim]Br) and 1-carboxymethyl-3-methylimidazolium tetrafluoroborate ([cmmim]BF₄) as reusable catalysts, has been developed. The turn over frequency on the catalysts is several times higher than the other previously reported catalysts. Also, thermal gravimetric analysis and powder X-ray diffraction pattern of the catalysts have been studied.

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1. Introduction

Ionic liquids (based imidazolium or other organic cations) have received considerable interest as eco-friendly solvents, catalysts, and reagents in organic synthesis because of their unique properties, such as low volatility, non-flammability, high thermal stability, negligible vapor pressure, and the ability to dissolve a wide range of materials [1–9]. Among them, Brønsted acidic ionic liquids, which add the useful characteristics of solid acids and mineral liquid acids, have been designed to replace traditional mineral acids like H₂SO₄ and HCl in chemical procedures [10–25].

The 14-aryl-14H-dibenzo[a,j]xanthene group is a key structural element of many biologically active compounds, such as antibacterials [26], antivirals [27], anti-inflammatory agents [28], and in photodynamic therapy [29]. Xanthene-based com-

pounds have also been investigated for agricultural bactericide activity and some other benzoxanthenes have found applications in industry as dyes for use in lasers [30] and as fluorescent materials for visualization of biomolecules [31]. Xanthene dyes can be extracted from soil and plants, such as *Indigofera Longercacemosa* [32,33]. Some methods for the synthesis of 14-aryl-14H-dibenzo[a,j]xanthenes have been reported by condensing 2-naphthol with aldehydes in the presence of a protic or Lewis acid catalyst [34–45]. However, these catalytic systems suffer from some limitations, such as long reaction time, high catalyst loadings, the use of toxic solvents, or special apparatus. The search for milder and more environmentally benign conditions would therefore be of great benefit in the synthesis of these compounds.

Here, the acetic acid functionalized imidazolium salts 1-carboxymethyl-3-methylimidazolium bromide ([cmmim]Br)

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and 1-carboxymethyl-1-3-methylimidazolium tetrafluoroborate ([cmmim][BF₄]) as highly efficient and reusable catalysts for the preparation of 14-aryl-14H-dibenzo[a,j]xanthene derivatives was reported. Their effectiveness has been tested in the reaction of 2-naphthol with aromatic aldehydes under solvent-free conditions (Scheme 1).

2. Experimental

2.1. General

All chemicals were purchased from Merck or Fluka Chemical Companies. The products were identified by comparison of their melting points (MP) and spectral data in the literature. Acetic acid functionalized ionic liquids were prepared according to literature procedures [44,45]. The progress of each catalyzed reaction was monitored by TLC using silica gel SIL G/UV 254 plates. The ¹H NMR (400 or 300 MHz) and ¹³C NMR (100 or 75 MHz) were run on a Bruker Avance DPX-250 FT-NMR spectrometer (δ in ppm). Melting points were recorded on a Büchi B-545 apparatus in open capillary tubes.

2.2. General procedure for the synthesis of 14-aryl-14H-dibenzo[a,j]xanthenes

A mixture of arylaldehyde (1 mmol), 2-naphthol (2 mmol) and catalyst ([cmmim]Br or [cmmim]BF₄) (0.1 mmol, 10 mol%) was stirred at 115 °C. When the reaction was complete, as judged by TLC, H₂O (1 mL) was added to the reaction mixture, stirred and refluxed for 3 min. Then, the reaction mixture was filtered and all water in the filtrate was removed under reduced pressure to separate the catalyst from the crude product. The solid residue (crude product) was collected by filtration and recrystallized from hot ethanol (95%) to give the pure product. The recovered catalyst was washed with CHCl₃, dried under reduced pressure and reused for the next run.

14-phenyl-14H-dibenzo[a,j]xanthene (**1b**). IR (KBr, cm⁻¹): 3075, 1621, 1592, 1513, 1243, 1152, 803, 765; ¹H NMR (DMSO-d₆, 400 MHz): δ 6.74 (s, 1H), 6.97 (t, J = 7.6 Hz, 1H), 7.14 (t, J = 7.6 Hz, 2H), 7.45 (t, J = 7.2 Hz, 2H), 7.57 (d, J = 8.8 Hz, 2H), 7.62–7.66 (m, 4H), 7.91–7.93 (m, 4H), 8.70 (d, J = 8.8 Hz, 2H); ¹³C NMR (DMSO-d₆, 75 MHz): δ 37.0, 117.9, 118.1, 123.8, 124.9, 126.7, 127.4, 128.4, 128.8, 129.0, 129.4, 131.1, 131.3, 146.0, 148.4.

14-(2-chlorophenyl)-14H-dibenzo[a,j]xanthene (**2b**). IR

(KBr, cm⁻¹): 3057, 1622, 1592, 1515, 1247, 1141, 809, 745; ¹H NMR (DMSO-d₆, 300 MHz): δ 6.64 (s, 1H), 6.91–7.03 (m, 2H), 7.27 (d, J = 7.7 Hz, 2H), 7.38–7.50 (m, 5H), 7.57–7.70 (m, 2H), 7.76–7.90 (m, 4H), 8.54 (d, J = 8.4 Hz, 1H); ¹³C NMR (DMSO-d₆, 75 MHz): δ 34.8, 116.9, 118.2, 123.3, 124.9, 127.4, 128.5, 128.8, 129.2, 129.8, 130.2, 130.3, 130.9, 131.4, 132.0, 143.2, 148.7.

14-(3-chlorophenyl)-14H-dibenzo[a,j]xanthene (**3b**). IR (KBr, cm⁻¹): 3069, 1623, 1591, 1246, 1141, 813, 746; ¹H NMR (DMSO-d₆, 300 MHz): δ 6.74 (s, 1H), 7.01 (d, J = 8.1 Hz, 1H), 7.13 (t, J = 7.8 Hz, 1H), 7.42 (t, J = 7.2 Hz, 2H), 7.52–7.66 (m, 6H), 7.91 (d, J = 8.7 Hz, 4H), 8.67 (d, J = 8.7 Hz, 2H); ¹³C NMR (DMSO-d₆, 75 MHz): δ 36.5, 117.2, 118.1, 123.7, 125.1, 126.8, 127.0, 127.5, 127.9, 129.1, 129.7, 130.7, 131.1, 131.2, 133.5, 148.2, 148.5.

14-(4-chlorophenyl)-14H-dibenzo[a,j]xanthene (**4b**). IR (KBr, cm⁻¹): 3076, 1622, 1593, 1515, 1254, 1153, 804, 745; ¹H NMR (DMSO-d₆, 300 MHz): δ 6.76 (s, 1H), 7.18 (d, J = 6.8 Hz, 2H), 7.46–7.64 (m, 10H), 8.92 (d, J = 7.8 Hz, 2H), 8.66 (d, J = 7.6 Hz, 2H); ¹³C NMR (DMSO-d₆, 75 MHz): δ 36.3, 117.4, 118.1, 123.4, 123.7, 125.0, 127.4, 128.8, 129.1, 129.6, 130.1, 131.1, 131.2, 144.8, 148.4.

14-(2,3-dichlorophenyl)-14H-dibenzo[a,j]xanthene (**5b**). IR (KBr, cm⁻¹): 3058, 1633, 1594, 1255, 1141, 965, 817, 748, 676; ¹H NMR (CDCl₃, 300 MHz): δ 6.86 (s, 1H), 7.11 (t, J = 1.1 Hz, 1H), 7.28 (s, 1H), 7.34 (d, J = 8.0 Hz, 1H), 7.44–7.52 (m, 4H), 7.65 (t, J = 7.9 Hz, 2H), 7.84 (t, J = 8.6 Hz, 4H), 8.69 (d, J = 8.5 Hz, 2H); ¹³C NMR (CDCl₃, 300 MHz): δ 35.6, 117.7, 118.1, 123.3, 124.5, 127.1, 128.1, 128.7, 129.2, 129.9, 130.8, 131.6, 146.4, 148.9, 155.7.

14-(3-bromophenyl)-14H-dibenzo[a,j]xanthene (**6b**). IR (KBr, cm⁻¹): 3065, 1622, 1591, 1398, 1239, 1140, 810, 746; ¹H NMR (DMSO-d₆, 300 MHz): δ 6.63 (s, 1H), 6.90–7.02 (m, 2H), 7.26 (d, J = 7.7 Hz, 2H), 7.37–7.49 (m, 5H), 7.58 (t, J = 7.9 Hz, 2H), 7.85–7.89 (m, 4H), 8.53 (d, J = 8.5 Hz, 1H); ¹³C NMR (DMSO-d₆, 75 MHz): δ 34.8, 116.9, 118.2, 123.3, 124.9, 127.4, 128.5, 128.8, 129.1, 129.8, 130.2, 130.3, 130.9, 131.4, 132.0, 143.2, 148.6.

14-(4-bromophenyl)-14H-dibenzo[a,j]xanthene (**7b**). IR (KBr, cm⁻¹): 3070, 1634, 1591, 1238, 1158, 940, 832, 740, 677; ¹H NMR (CDCl₃, 300 MHz): δ 6.46 (s, 1H), 7.28–7.83 (m, 10H), 8.31 (s, 2H); ¹³C NMR (CDCl₃, 300 MHz): δ 37.4, 116.6, 118.0, 122.4, 124.4, 126.9, 128.9, 129.1, 129.9, 131.2, 131.6, 144.0, 148.6.

14-(4-fluorophenyl)-14H-dibenzo[a,j]xanthene (**8b**). IR (KBr, cm⁻¹): 3034, 1632, 1592, 1502, 1239, 1095, 813, 743; ¹H

Scheme 1. Synthesis of 14-aryl-14H-dibenzo[a,j]xanthenes catalyzed by acetic acid functionalized imidazolium salts.

NMR (CDCl_3 , 300 MHz): δ 6.49 (s, 1H), 6.83–6.89 (m, 2H), 7.43–7.53 (m, 6H), 7.59–7.65 (m, 2H), 7.81–7.88 (m, 4H), 8.36 (d, J = 8.5 Hz, 2H); ^{13}C NMR (CDCl_3 , 300 MHz): δ 37.2, 115.2, 115.5, 117.1, 118.0, 122.5, 124.3, 126.9, 128.9, 129.0, 129.6, 129.7, 131.0, 131.3, 140.8, 148.7, 159.5, 162.8.

14-(3-nitrophenyl)-14H-dibenzo[a,j]xanthene (**9b**). IR (KBr, cm^{-1}): 3081, 1623, 1593, 1530, 1255, 1141, 808, 745; ^1H NMR ($\text{DMSO}-d_6$, 300 MHz): δ 6.91 (s, 1H), 7.11–7.25 (m, 1H), 7.43–7.48 (m, 2H), 7.55–7.71 (m, 4H), 7.88–8.03 (m, 7H), 8.66 (d, J = 8.4 Hz, 2H); ^{13}C NMR ($\text{DMSO}-d_6$, 75 MHz): δ 36.7, 116.6, 118.2, 123.6, 124.2, 125.2, 127.6, 129.1, 129.5, 130.0, 131.10, 131.19, 146.3, 148.4, 153.1.

14-(4-nitrophenyl)-14H-dibenzo[a,j]xanthene (**10b**). IR (KBr, cm^{-1}): 3071, 1622, 1591, 1515, 1239, 1159, 827, 742; ^1H NMR ($\text{DMSO}-d_6$, 300 MHz): δ 6.95 (s, 1H), 7.43 (t, J = 7.2 Hz, 3H), 7.58–7.65 (m, 4H), 7.81 (d, J = 7.5 Hz, 1H), 7.90–7.95 (m, 4H), 8.14 (d, J = 7.8 Hz, 1H), 8.45 (s, 1H), 8.72 (d, J = 8.4 Hz, 2H); ^{13}C NMR ($\text{DMSO}-d_6$, 75 MHz): δ 36.3, 116.9, 118.2, 122.0, 122.5, 123.6, 125.2, 127.7, 129.1, 130.0, 130.4, 131.11, 131.14, 134.7, 147.9, 148.3, 148.6.

14-(4-Methylphenyl)-14H-dibenzo[a,j]xanthene (**11b**). IR (KBr, cm^{-1}): 3074, 1622, 1592, 1512, 1248, 1141, 812, 742; ^1H NMR ($\text{DMSO}-d_6$, 300 MHz): δ 2.01 (s, 3H), 6.63 (s, 1H), 6.90 (d, J = 7.2 Hz, 2H), 7.40–7.61 (m, 8H), 7.88 (t, J = 2.7 Hz, 4H), 8.61 (d, J = 8.7 Hz, 2H); ^{13}C NMR ($\text{DMSO}-d_6$, 75 MHz): δ 20.8, 37.4, 117.9, 118.1, 123.8, 124.9, 127.3, 128.2, 129.0, 129.3, 129.3, 131.1, 131.3, 135.8, 143.0, 148.3.

14-(4-hydroxy-3-methoxyphenyl)-14H-dibenzo[a,j]xanthene (**12b**). IR (KBr, cm^{-1}): 3475, 3063, 1592, 1511, 1242, 1128, 961, 817, 785, 694; ^1H NMR (CDCl_3 , 300 MHz): δ 3.66 (s, 3H), 5.49 (s, 1H), 6.45 (s, 1H), 6.76 (d, J = 8.1 Hz, 1H), 6.87 (s, 1H), 7.19 (d, J = 8.1 Hz, 1H), 7.42–7.52 (m, 4H), 7.61 (t, J = 7.5 Hz, 2H), 7.86 (m, 4H), 8.42 (d, J = 8.4 Hz, 2H); ^{13}C NMR (CDCl_3 , 300 MHz): δ 37.6, 55.67, 110.6, 113.7, 117.5, 117.9, 120.9, 122.7, 124.3, 126.8, 128.8, 131.1, 131.4, 137.1, 144.1, 146.7, 148.7.

14-(4-benzophenyl)-14H-dibenzo[a,j]xanthene (**13b**). IR (KBr, cm^{-1}): 3028, 1620, 1591, 1514, 1401, 1242, 1142, 965, 833, 740, 695; ^1H NMR (CDCl_3 , 300 MHz): δ 6.56 (s, 1H), 7.29–7.66 (m, 15H), 7.85 (t, J = 9.7 Hz, 4H), 8.46 (d, J = 8.4 Hz, 2H); ^{13}C NMR (CDCl_3 , 300 MHz): δ 37.7, 117.2, 118.0, 122.7, 124.3, 126.8, 126.9, 127.0, 127.2, 128.6, 128.8, 131.1, 131.4, 139.2, 140.7, 144.0, 148.8.

14-(phenethyl)-14H-dibenzo[a,j]xanthene (**14b**). IR (KBr, cm^{-1}): 3055, 3022, 1622, 1592, 1516, 1488, 1459, 1158, 957; ^1H NMR (CDCl_3 , 300 MHz): δ 2.39–2.51 (m, 4H), 5.73 (t, J = 4.0 Hz, 1H), 6.87 (d, J = 6.6 Hz, 2H), 7.07–7.16 (m, 3H), 7.48–7.57 (m, 4H), 7.70 (t, J = 7.8 Hz, 2H), 7.87 (d, J = 8.9 Hz, 2H), 7.97 (d, J = 8.0 Hz, 2H), 8.34 (d, J = 8.5 Hz, 2H); ^{13}C NMR (CDCl_3 , 75 MHz): δ 31.1, 37.3, 116.1, 117.7, 122.5, 124.3, 125.6, 126.8, 128.1, 128.2, 128.5, 129.0, 131.2, 131.4, 141.9, 150.1.

14-(4-chloro-3-nitrophenyl)-14H-dibenzo[a,j]xanthene (**15b**). IR (KBr, cm^{-1}): 3050, 1634, 1594, 1532, 1244, 1142, 802, 744; ^1H NMR (CDCl_3 , 300 MHz): δ 6.56 (s, 1H), 7.28 (d, J = 2.3 Hz, 1H), 7.45–7.52 (m, 4H), 7.62–7.67 (m, 3H), 7.86 (t, J = 8.4 Hz, 4H), 8.05 (d, J = 1.7 Hz, 1H), 8.25 (d, J = 8.5 Hz, 2H); ^{13}C NMR (CDCl_3 , 300 MHz): δ 37.1, 115.4, 118.1, 121.8, 124.7, 124.9, 125.2, 127.4, 129.1, 129.7, 130.9, 131.1, 132.0, 132.8, 145.2,

147.5, 148.8.

3. Results and discussion

Thermal gravimetric analysis (TGA) of the acetic acid functionalized imidazolium salts was also conducted from 25 to 600 °C at a rate of 10 °C/min in N_2 atmosphere (Fig. 1). As the TGA and differential thermal gravimetric (DTG) diagrams indicate, [cmmim]Br and [cmmim]BF₄ decomposed in a single process at 230 and 250 °C, respectively. Their TGA curves are similar to a single stage decomposition in which no intermediate is identified.

Powder X-ray diffraction (XRD) patterns of [cmmim]Br and [cmmim]BF₄ were measured at 2θ = 10°–90° (Fig. 2). As shown in Fig. 2, [cmmim]Br showed high crystallinity by the sharp, intense peaks at 2θ $\approx$ 13.0°, 15.7°, 17.7°, 20.8°, 22.1°, 23.3°, 26.2°, 27.8°, 29.5°, 30.9°, 40.9°, and several small lines from 50° to 60°.

For [cmmim]BF₄, high crystallinity was also observed through the sharp peaks at 2θ $\approx$ 12.8°, 15.6°, 17.3°, 20.7°, 21.9°,

Fig. 1. TGA and DTG curves of [cmmim]Br (a) and [cmmim]BF₄ (b).

Fig. 2. XRD patterns of [cmmim]Br (1) and [cmmim]BF₄ (2).

Table 1

The effect of the amount of the catalysts and temperature on the condensation of β -naphthol (2 mmol) with 3-nitrobenzaldehyde (1 mmol).

Entry	Catalyst amount (mol%)	T (°C)	[cmmim]Br		[cmmim]BF ₄	
			Time (min)	Yield ^a (%)	Time (min)	Yield ^a (%)
1	10	70	70	32	140	21
2	10	80	60	54	120	36
3	10	90	45	74	120	53
4	10	100	40	83	100	57
5	10	115	20	93	90	65
6	10	120	20	93	90	68
7	7.5	115	20	87	90	60
8	5	115	45	81	110	52
9	15	115	20	93	80	75

^a Isolated yield.

23.2°, 25.4°, 25.9°, 27.6°, 29.4°, 30.8°, 31.7°, 32.5°, 34.90°, 36.5°, 38.6°, 40.8°, 43.0°, 43.5°, 44.8° and several small lines from 45° to 70° (Fig. 2).

Next, we studied the efficacy of the catalysts in the synthesis of 14-aryl-14H-dibenzo[a,j]xanthenes. To optimize the reaction conditions, the solvent-free condensation of 2-naphthol with 3-nitrobenzaldehyde was used as a test reaction. Different amounts of [cmmim]Br and [cmmim]BF₄ were used at different temperatures from 70 to 120 °C. The best results were obtained using 10 mol% of [cmmim]Br at 115 °C. Increasing the reaction time did not further improve the results (Table 1). Moreover, the addition of acetic acid, in comparison with the acetic acid functionalized ionic liquid, was also investigated on the model reaction. Due to the low boiling point of acetic acid (118 °C), acetic acid was used as the catalyst in the model reaction at 115 °C. The expected product was produced in just 50% yield after 40 min. This shows the superiority of the acetic acid functionalized ionic liquids over acetic acid.

To explore the scope of the catalyst, [cmmim]Br (10 mol%) was used in the solvent-free with different aromatic aldehydes to prepare a series of 14-aryl-14H-dibenzo[a,j]xanthenes (Table 2). Various aromatic aldehydes containing electron-donating, electron-withdrawing, or halogen substituents on the aromatic ring were utilized successfully in the reaction, and gave the corresponded products in high yields and in short reaction time.

A possible mechanism is also presented here (Scheme 2). First, the aromatic aldehyde is activated by the acidic group of the catalyst to produce **I**. β -naphthol then attacks the carbonyl group of the activated aldehyde, which gives the intermediate **II**. Next, H₂O leaves giving *ortho*-quinone methide (*o*-QM, **III**). Intermediate **III** is again activated by [cmmim]Br to give **IV** which is a Michael acceptor. Michael addition of another β -naphthol to **IV** affords **V**. **V** converts to **VI** by tautomerization. Finally, ring condensation occurs to give 14-aryl-14H-dibenzo[a,j]xanthenes.

This mechanism implies that hydrobromic acid could be generated during the reaction. Accordingly, the catalytic application of hydrobromic acid, in comparison with acetic acids functionalized ionic liquid, was studied on model reaction. Due to its low boiling point (122 °C), hydrobromic acid was used as

Table 2

The solvent-free synthesis of 14-aryl-14H-dibenzo[a,j]xanthenes using [cmmim]Br.

Entry	R	Time (min)	Yield ^a (%)	MP (°C)
1	C ₆ H ₅	30	90	183–184 (184–185) ^b
2	2-ClC ₆ H ₄	25	86	215–216 (209–211)
3	3-ClC ₆ H ₄	25	88	174–175 (207–209)
4	4-ClC ₆ H ₄	20	91	288–289 (284–286)
5	2,3-dichloroC ₆ H ₃	20	94	286–287
6	3-BrC ₆ H ₄	21	89	189–190 (186–188)
7	4-BrC ₆ H ₄	21	90	296–297
8	4-FC ₆ H ₄	20	91	238–239
9	3-O ₂ NC ₆ H ₄	20	93	210–211 (215–217)
10	4-O ₂ NC ₆ H ₄	17	95	310–311 (312–314)
11	4-MeC ₆ H ₄	22	85	228–229 (225–227)
12	4-HO-3-MeOC ₆ H ₄	22	83	211–212
13	4-PhC ₆ H ₄	30	84	281–282
14	PhCH ₂ CH ₂	30	85	176–177
15	4-Cl-3-O ₂ NC ₆ H ₄	15	95	245–246

^a Isolated yield. ^b Data in the brackets are from Ref. [16].

catalyst in this reaction at 115 °C. The desired product was produced in 58% of yield after 45 min. This shows that the acetic acid functionalized ionic liquid is responsible for the catalysis in the reaction over any hydrobromic acid present.

Finally, the recyclability of the catalyst was examined in the condensation of 2-naphthol with 3-nitrobenzaldehyde. When the reaction was complete, H₂O was added to the reaction mixture, stirred and refluxed for 3 min. The reaction mixture was filtered and the water in the filtrate was removed under re-

Scheme 2. The proposed mechanism for the synthesis of 14-aryl-14H-dibenzo[a,j]xanthenes using [cmmim]Br.

Fig. 3. The condensation of 2-naphthol with dimedone and 3-nitrobenzaldehyde in the presence of reused [cmmim]Br (10 mol%) in solvent-free conditions at 115 °C.

duced pressure to separate the catalyst from crude product. The reused catalyst was then used in another reaction. The catalytic activity of the catalyst was restored to within the limits of experimental error for four successive runs (Fig. 3).

To compare the applicability and efficiency of [cmmim]Br with other reported catalysts in the synthesis of 14-aryl-14H-dibenzo[a,j]xanthenes, we have tabulated the TOF of these catalysts in the condensation reaction of β -naphthol with 3-nitrobenzaldehyde (Table 3). [cmmim]Br is superior to the previously reported catalysts, in terms of TOF.

4. Conclusions

In summary, we have used acetic acid functionalized imidazolium salts as the catalyst for the synthesis of 14-aryl-14H-dibenzo[a,j]xanthenes from the condensation of 2-naphthol with arylaldehydes. Recovery of the catalyst, easy purification, high yields, short reaction time and higher TOF over the catalyst than the reported catalyst are some important advantages.

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Table 3

Comparison of the results of the condensation of 2-naphthol with 3-nitrobenzaldehyde using [cmmim]Br with those obtained by the recently reported catalysts.

Reaction conditions	Catalyst loading (mol%)	Time (min)	Yield ^a (%)	TOF ^b (min ⁻¹)	Ref.
[cmmim]Br, solvent-free, 115 °C	10	20	93	0.465	this work
TaCl ₅ , reflux conditions, 1,2-dichloroethane	10	60	93	0.155	[13]
I ₂ , 90 °C, solvent-free	10	180	92	0.051	[16]
HClO ₄ -SiO ₂ , reflux conditions, 1,2-dichloroethane	1	720	88	0.122	[17]
CyCl, 110 °C, solvent-free	20	45	90	0.100	[19]
Al(HSO ₄) ₃ , 125 °C, solvent-free	16	39	91	0.145	[25]
P ₂ O ₅ , 80 °C, solvent-free	20	52	90	0.086	[26]
InCl ₃ , 80 °C, solvent-free	30	60	82	0.045	[26]

^a Isolated yield. ^b Turnover frequency.

Graphical Abstract

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Condensation of 2-naphtol with arylaldehydes using acetic acids functionalized ionic liquid as highly efficient and reusable catalysts

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The catalytic activity of acetic acid functionalized imidazolium salts as reusable catalysts were investigated for the synthesis of 14-aryl-14H-dibenzo[a,j]xanthenes. Thermal gravimetric analysis and powder X-ray diffraction patterns of the catalysts have been studied in this investigation.

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