Res Chem Intermed (2015) 41:9951–9966
DOI 10.1007/s11164-015-2001-x

# *p*-Sulfonic acid calix[4]arene as an efficient and reusable catalyst for the synthesis of acridinediones and xanthenes

**Seyed Meysam Baghbanian[1] · Gonja Khanzad[1] · Seyed Mohammad Vahdat[1] · Hamed Tashakkorian[2]**

Received: 2 December 2014 / Accepted: 5 March 2015 / Published online: 26 May 2015


**Abstract** *p*-Sulfonic acid calix[4]arene has been found to be an efficient catalyst for the synthesis of acridinediones and xanthenes under mild conditions in excellent yields. The present approach offers the advantages of simple methodology, short reaction time, and high yield.

**Keywords** *p*-Sulfonic acid calix[4]arene · Organocatalyst · Xanthenes · Acridinediones

## Introduction

Multi-component reactions play an important role in combinatorial chemistry because of their ability to synthesize small drug-like molecules with several degrees of structural diversity. These one-pot reactions introduce the most efficient method to the molecular diversity [1].

Acridine derivatives possess a wide range of pharmaceutical activities, including antibacterial [2], antitumor [3], anticancer [4], fungicidal [5], and DNA-binding properties [6].

Xanthene derivatives are very important heterocyclic compounds because of their wide range of biological and pharmaceutical properties such as anti-inflammatory [7], antibacterial [8], antiviral [9], photodynamic therapy [10], and antiviral [11].

**Electronic supplementary material** The online version of this article (doi:10.1007/s11164-015-2001-x) contains supplementary material, which is available to authorized users.

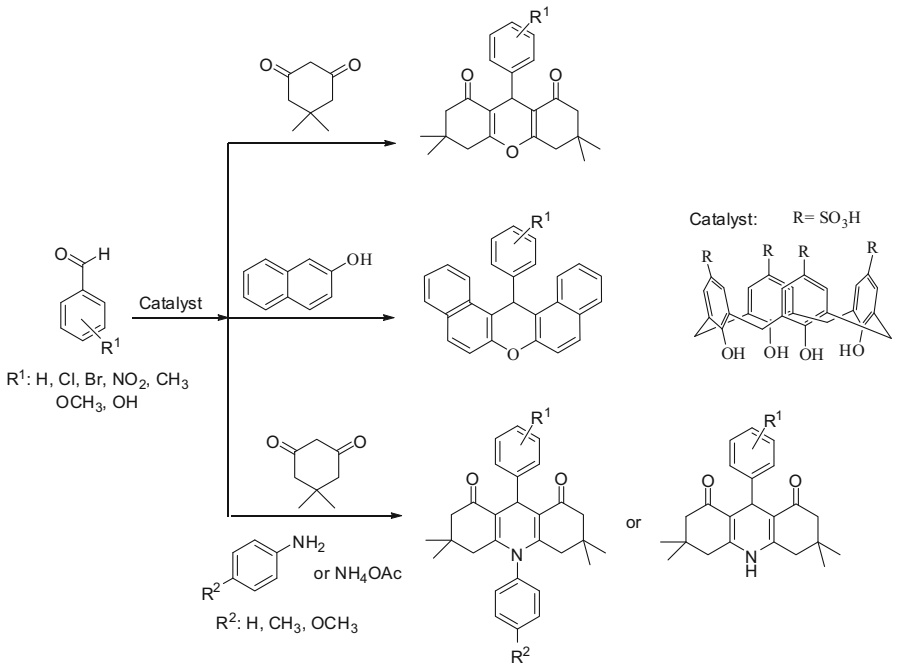
✉ Seyed Meysam Baghbanian
s.m.baghbanian@iauamol.ac.ir; s.baghbanian@gmail.com

[1] Department of Chemistry, Ayatollah Amoli Branch, Islamic Azad University, 698, Amol, Iran

[2] Cellular and Molecular Biology Research Center (CMBRC), Babol University of Medical Sciences, Babol, Iran

Furthermore, these compounds can be used as fluorescent dyes [12], pH-sensitive fluorescent materials for visualization of biomolecular assemblies [13], and also utilized in laser technologies [14]. Well-known dyes having a xanthene nucleus are rhodamine B and rhodamine 6G. Therefore, the synthesis of xanthenes is of great importance. Consequently, several methods have been developed for the synthesis of xanthene derivatives, which in general can be obtained by the condensation of aryloxymagnesium halides with triethyl orthoformate [15], the cyclization of polycyclic aryl triflate esters [16], and the reaction of dimedone or $\beta$-naphthol with aldehydes [17–25]. However, many of these existing methodologies suffer from one or more disadvantages, such as toxic metal ions and solvent, high cost, high catalyst loading, corrosive reagents, large amounts of solid supports, and cumbersome work-up procedures.

In continuation of our studies on the development of new catalysts and offering novel methodology in organic synthesis [26–33], herein we studied its efficiency to catalyze two types of organic transformations, including the preparation of xanthene and acridinedione derivatives under relatively mild conditions. Interestingly, *p*-sulfonic acid calix[4]arene efficiently catalyzed the above reactions under the mentioned conditions to give the desired products in high to excellent yields and in relatively short reaction times (Scheme 1).




**Scheme 1** The synthesis of xanthene and acridinedione derivatives in the presence of *p*-sulfonic acid calix[4]arene as catalyst

## Experimental

All reagents were prepared from analytical reagent-grade chemicals unless specified otherwise and purchased from Merck. Melting points were measured with an Electrothermal 9100 apparatus. Samples were analyzed using FT-IR spectroscopy (using a Perkin-Elmer 65 in KBr matrix in the range of 4000–400 $cm^{-1}$). $^{1}H$, $^{13}C$ NMR spectra were recorded on a BRUKER DRX-400 AVANCE spectrometer using tetramethylsilane as an internal standard.

### General procedure

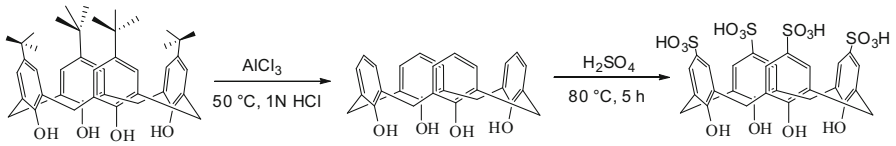
First, *p-tert*-butylcalix[4]arene was prepared by the Gutsche and Iqbal method [34]. Secondly, the *p-tert*-butylcalix[4]arene was dealkylated by treatment with aluminium chloride in the presence of toluene and phenol according to the method described by Ungaro et al. [35]. Preparation of *p*-sulfonic acid calix[4]arene was carried out with the treatment of calix[4]arene with concentrated sulfuric acid (98 wt%) added to the reaction mixture was shaken under nitrogen at 80 °C [36] (Scheme 2).

*General procedure for the synthesis of 25,26,27,28-tetrahydroxycalix[4]arene*

A hot solution of *p-tert*-butylcalix[4]arene (5 g, 6.15 mmol) of toluene (250 ml) was placed in a 500-ml, three-necked, round-bottomed flask fitted with a gas inlet tube and a magnetic stirring bar. The temperature of the solution was reduced to 50 °C and then the anhydrous $AlCl_3$ (5 g, 37 mmol) was added to this mixture slowly under inert atmosphere conditions. After cooling in an ice bath, 125 ml of 1N HCl for 30 min was added, and the organic layer was separated and evaporated to leave a yellow residue. Ether (500 ml) was added to the reaction mixture and the precipitate was recrystallized from $CHC1_3$–$CH_3OH$ to yield white crystals, mp 312–316 °C.

*General procedure for the synthesis of p-sulfonic acid calix[4]arene*

Calix[4]arene (1.0 g, 2.4 mmol) was mixed with concentrated $H_2SO_4$ (10 ml) and the solution was heated at 80 °C for 4 h. An aliquot was withdrawn from the reaction mixture and poured into water. The reaction was completed when no water-insoluble material was detected in the aliquot. After cooling, the precipitate was filtered off through a glass filter. The residue was dissolved in hot water (15 ml) and




**Scheme 2** Sulfonation of calix[4]arne using Shinkai method

the solution was adjusted to pH = 8 by $Na_2CO_3$. After filtration, methanol was added to the filtrate to afford a white precipitate.

## General procedure for the preparation of xanthene derivatives

A mixture of β-naphthol or dimedone (2 mmol), aldehydes (1 mmol), and *p*-sulfonic acid calix[4]arene (1.5 mol%, 0.012 g) were added to 5 ml of ethanol and the mixture was stirred in a round-bottomed flask at 80 °C for an appropriate time. After completion of the reaction confirmed by TLC (thin-layer chromatography) analysis (eluent: hexane/ethyl acetate 2:1), the mixture was cooled to room temperature and the precipitated product was filtered and recrystallized from ethanol. Finally, on filtration, ethanol was evaporated and the organocatalyst dried and reused in successive reactions.

Spectroscopic data for selected examples are listed as follows:

*14-(4-Chlorophenyl)-14H-dibenzo [a,j] xanthene (**3b**)* Yellow solid; M.P. 284–286 °C (lit. 289–290 °C); IR (KBr) υ 3155, 2968, 1648, 1558, 1528, 1496, 1383, 1265, 1247, 1219, 1150 $cm^{-1}$. $^1H$ NMR (400 MHz, $CDCl_3$): δ (ppm) = 6.49 (s, 1H), 7.13 (d, *J* = 8.4 Hz, 2H), 7.43–7.87 (m, 10H), 8.34 (d, *J* = 8.4 Hz, 2H), 8.66 (d, *J* = 7.6 Hz, 2H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): δ (ppm) = 37.4, 116.7, 118.0, 122.4, 124.4, 126.9, 128.6, 128.9, 129.1, 129.5, 131.0, 131.2, 132.1, 143.5, 148.7 ppm.

*9-(4-chlorophenyl)-3,3,6,6-tetramethyl-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8(2H)-dione (**5b**)* White solid; M.P. 228–230 °C (lit. 230–232 °C); IR (KBr) υ 2954, 1664, 1364, 1199 $cm^{-1}$. $^1H$ NMR (400 MHz, $CDCl_3$): δ (ppm) = 1.01 (s, 6H), 1.12 (s, 6H), 2.16–2.28 (dd, *J* = 16.4 Hz, 4H), 2.43–2.53 (m, 4H), 4.73 (s, 1H), 7.20 (d, *J* = 8.4 Hz, 1H), 7.26 (d, *J* = 8.8 Hz, 2H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): δ = 27.3, 29.3, 32.2, 40.8, 50.7, 115.3, 128.2, 129.8, 132.0, 142.7, 162.4, 196.4 ppm.

## General procedure for the preparation of acridine derivatives

A mixture of dimedone (2 mmol), aldehydes (1 mmol), aromatic amine or ammonium acetate (1.2 mmol), and *p*-sulfonic acid calix[4]arene (1.5 mol%, 0.012 g) were added to 5 ml of ethanol and the mixture was stirred in a round-bottomed flask at 80 °C for an appropriate time. After completion of the reaction confirmed by TLC (eluent: hexane/ethyl acetate 2:1), the mixture was cooled to room temperature and the precipitated product was filtered and recrystallized from ethanol. Finally, on filtration, ethanol was evaporated and the organocatalyst dried and reused in successive reactions.

*9-(4-Chlorophenyl)-10-(4-methoxyphenyl)-3,3,6,6-tetramethyl-3,4,6,7,9,10-hexahydroacridine-1,8(2H,5H)-dione (**7h**)* White solid; mp 270–272 °C (lit. 270–271 °C); IR (KBr) υ 2956, 1592, 1490, 1373, 1259 $cm^{-1}$. $^1H$ NMR (400 MHz, $CDCl_3$): δ = 1.01 and 1.12 (2s, 12H), 2.16–2.28 (m, 4H), 2.48 (s, 4H), 3.86 (s, 3H), 4.73 (s, 1H), 6.95 (d, *J* = 8.5 Hz, 2H), 7.25 (d, *J* = 8.4 Hz, 2H), 7.45 (t, *J* = 7.4 Hz, 4H), 7.84 (t, *J* = 7.4 Hz, 4H) ppm; $^{13}C$ NMR (100 MHz,

$CDCl_3$): $\delta$ = 27.5, 29.4, 31.2, 32.3, 40.9, 50.9, 55.2, 113.5, 115.8, 121.3, 123.4, 129.5, 129.8, 136.6, 158.4, 163.1, 168.6, 196.6 ppm.

*9-(4-methoxyphenyl)-3,3,6,6-tetramethyl-3,4,6,7,9,10-hexahydroacridine-1,8(2H,5H)-dione (**7m**)* White solid; mp 271–274 °C (lit. 270–272 °C); IR (KBr) υ 3214, 2978, 1658, 1642, 1496, 1265 $cm^{-1}$; $^1H$ NMR (400 MHz, $CDCl_3$): $\delta$ = 1.05 and 1.09 (2S, 12H), 2.16–2.38 (m, 8H), 3.72 (S, 3H), 5.22 (S, 1H), 6.78 (d, $J$ = 8.8 Hz, 2H), 7.39 (d, $J$ = 8.8 Hz, 2H), 8.18 (S, 1H) ppm; $^{13}C$ NMR (100 MHz, $CDCl_3$): $\delta$ = 27.2, 30.1, 31.3, 40.3, 51.4, 55.6, 112.9, 114.3, 129.8, 136.7, 149.7, 157.4, 195.4 ppm.

## Results and discussion

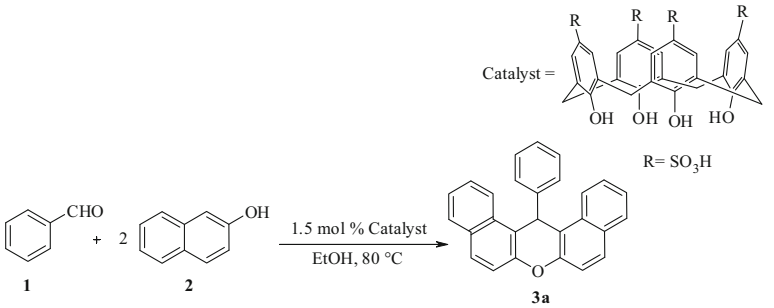
The calixarenes are a class of cyclooligomers formed via a *p*-substituted phenols and formaldehyde condensation. *p*-Sulfonic acid calix[4]arene has shown some interesting capabilities in preparation of conducting polymer, polyaniline, as a doping agent [37], encapsulating to topotecan for improving solubility in chemotherapy [38], and has bee proven to be suitable for bio-pharmaceutical applications [39].

The *p*-sulfonic acid calixarenes have been reported as catalysts in Mannich-type reactions [40], allylic alkylation reactions [41], and esterification reactions [42]. This catalyst offers several advantages including shorter reaction times, mild reaction conditions, cleaner reactions, lower catalyst loading, and simple experimental procedures with high yields.

### Study of the efficacy of *p*-sulfonic acid calix[4]arene in the synthesis of 14-aryl-14*H*-dibenzo[*a,j*]xanthenes and 1,8-dioxo-octahydroxanthenes

To find the optimized condition for the synthesis of this class of compounds, the reaction of benzaldehyde (1 mmol) with $\beta$-naphthol (2 mmol) as a model reaction in the presence of different amounts of *p*-sulfonic acid calix[4]arene, was examined (Scheme 3) and variables affecting on the reaction yields were studied. The optimum amount of *p*-sulfonic acid calix[4]arene was 1.5 mol% as shown in Table 1, entry 8. The influence of solvent was studied when the model reaction was performed using *p*-sulfonic acid calix[4]arene under various solvents and solvent-free conditions (Table 1). As can be seen in Table 1, ethanol was found to be a suitable solvent in the presence of 1.5 mol% of the catalyst (Table 1, entry 8).

Next, we examined the scope of the reaction by using various aromatic aldehydes and the results are summarized in Table 2. In all cases, the corresponding xanthene derivatives were obtained in good to excellent yields. The reaction of $\beta$-naphthol and aldehydes in the presence of *p*-sulfonic acid calix[4]arene (1.5 mol%, 0.012 g) as an organocatalyst under optimized conditions yielded desired 14-aryl-14*H*-dibenzo[*a,j*]xanthenes in excellent yields (Table 2, entries 1–10). The reactions of aromatic aldehydes having electron withdrawing groups were somewhat faster than electron donating groups (Table 2, entries 2–7). Though meta- and para- substituted




**Scheme 3** The model reaction for the synthesis of dibenzo[*a,j*]xanthene **3a**

**Table 1** Optimization of reaction conditions for synthesis of compound **3**

| Entry | Catalyst (mol%) | Solvent | Temp. (°C) | Time (h) | Yield (%)[a] |
|---|---|---|---|---|---|
| 1 | 0.5 | $CH_3CN$ | r.t. | 2 | 50 |
| 2 | 0.5 | $CH_2Cl_2$ | r.t. | 2 | 40 |
| 3 | 0.5 | EtOH | r.t. | 2 | 60 |
| 4 | 0.5 | EtOH | 50 | 2 | 75 |
| 5 | 0.5 | EtOH | 80 | 2 | 85 |
| 6 | 1.5 | EtOH | r.t. | 2 | 75 |
| 7 | 1.5 | EtOH | 50 | 1 | 80 |
| 8 | 1.5 | EtOH | 80 | 45 (min) | 98 |
| 9 | 0.5 | $H_2O$ | r.t. | 2 | 30 |
| 10 | 0.5 | $H_2O$ | 80 | 2 | 70 |
| 11 | 0.5 | Solvent-free | r.t. | 1 | 30 |
| 12 | 0.5 | Solvent-free | 80 | 1 | 45 |
| 13 | 1 | Solvent-free | 80 | 1 | 70 |

Reaction condition: benzaldehyde (1 mmol), *β*-naphthol (2 mmol), *p*-sulfonic acid calix[4]arene

[a] Isolated yield

aromatic aldehydes gave good results, ortho-substituted aromatic aldehydes gave lower yields because of the steric effects (Table 2, entries 3 and 6).

After the successful application of *p*-sulfonic acid calix[4]arene in the synthesis of 14-aryl-14*H*-dibenzo[*a,j*]xanthenes, we examined its efficacy in the preparation of 1,8-dioxo-octahydroxanthenes.

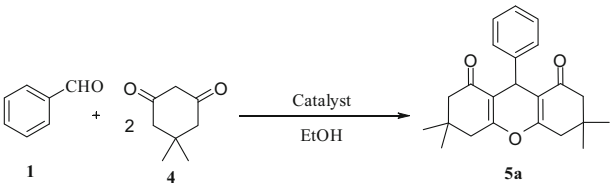
For the initial study, as a model, the condensation of dimedone (2 mmol) and benzaldehyde (1 mmol) was examined (Scheme 4) in the presence of different molar ratios of *p*-sulfonic acid calix[4]arene in ethanol at various temperatures ranging from 25 to 80 °C (Table 2, entries 1–6), which demonstrated 80 °C to be the optimum temperature (Table 2, entry 6). The model reaction was also performed in other solvents such as $CH_3CN$, $H_2O$, and $CH_2Cl_2$ instead of EtOH and solvent-free conditions (Table 2, entries 7–10). Changing the solvent showed no further increase in the yield under optimized conditions. Therefore, the best results were

**Table 2** Optimization of reaction conditions for synthesis of compound **5**

| Entry | Catalyst (mol%) | Solvent | Temp. (°C) | Time (h) | Yield (%)[a] |
|---|---|---|---|---|---|
| 1 | 0.5 | EtOH | r.t. | 2 | 55 |
| 2 | 0.5 | EtOH | 50 | 2 | 70 |
| 3 | 0.5 | EtOH | 80 | 2 | 85 |
| 4 | 1.5 | EtOH | r.t. | 2 | 75 |
| 5 | 1.5 | EtOH | 50 | 1 | 85 |
| 6 | 1.5 | EtOH | 80 | 35 (min) | 97 |
| 7 | 1.5 | $CH_3CN$ | 80 | 1 | 60 |
| 8 | 1.5 | $CH_2Cl_2$ | 80 | 1 | 40 |
| 9 | 1.5 | $H_2O$ | 80 | 1 | 75 |
| 10 | 1.5 | Solvent-free | 80 | 1 | 80 |

Reaction condition: benzaldehyde (1 mmol), dimedone (2 mmol), *p*-sulfonic acid calix[4]arene

[a] Isolated yield




**Scheme 4** The model reaction for the synthesis of 1,8-dioxo-octahydroxanthene **5a**

obtained from the reaction of these components in EtOH in the presence of 1.5 mol % of the catalyst at 80 °C affording the 1,8-dioxo-octahydroxanthene **5a** in 97 % yield within 35 min (Table 2, entry 6).

Under optimized reaction conditions, different aromatic aldehydes (such as aldehydes bearing electron-withdrawing substituents, electron-releasing substituents, and halogens on their aromatic ring) were reacted with dimedone to furnish the corresponding products in high yields and in short reaction times (Table 3, entries 11–20). The aliphatic aldehyde underwent the reaction cleanly in excellent yield (Table 3, entry 20).

## Study of the efficacy of *p*-sulfonic acid calix[4]arene in the synthesis of 1,8-dioxo-decahydroacridines

Considering the high importance of acridine derivatives, in the next step, we examined the efficiency of *p*-sulfonic acid calix[4]arene in the synthesis of 1,8-dioxo-decahydroacridines. To obtain the optimized reaction conditions for the synthesis of this class of compounds, the reaction dimedone (2 mmol), benzaldehyde (1 mmol), and aniline (1.2 mmol) was selected as a model reaction (Scheme 5). The effect of different molar ratios of *p*-sulfonic acid calix[4]arene,

**Table 3** Synthesis of 14-aryl-14*H*-dibenzo[*a,j*]xanthenes and 1,8-dioxo-octahydroxanthenes in the presence of *p*-sulfonic acid calix[4]arenes

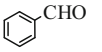
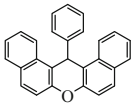
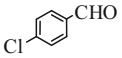
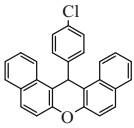
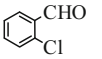
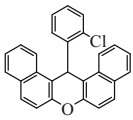
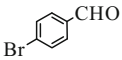
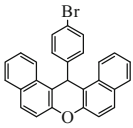
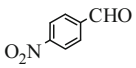
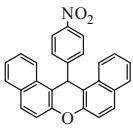
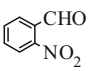
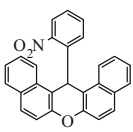
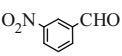
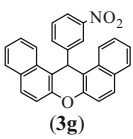
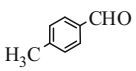
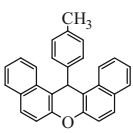
| Entry | Aldehyde | Product[a] | Time (min) | Yield[b] (%) | M.p. °C (Lit.) [Ref.] |
|---|---|---|---|---|---|
| 1 |  |  (**3a**) | 45 | 98 | 186–188 (184–185) [22] |
| 2 |  |  (**3b**) | 35 | 95 | 284-286 (289–290) [23] |
| 3 |  |  (**3c**) | 45 | 92 | 209-211 (214–216) [23] |
| 4 |  |  (**3d**) | 35 | 95 | 294-297 (297–298) [17] |
| 5 |  |  (**3e**) | 30 | 97 | 310-313 (311–312) [17] |
| 6 |  |  (**3f**) | 35 | 95 | 212-215 (214–215) [22] |
| 7 |  |  (**3g**) | 30 | 95 | 212–214 (213) [24] |
| 8 |  |  (**3h**) | 50 | 95 | 224–227 (227-229) [22] |

**Table 3** continued

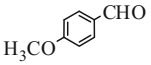
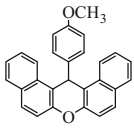
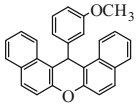
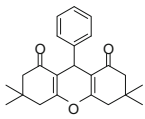
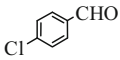
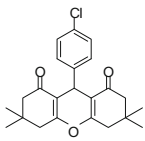
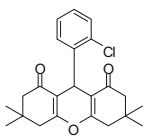
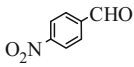
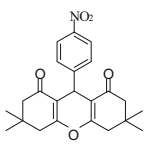
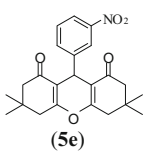
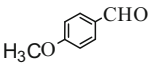
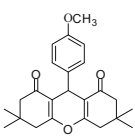
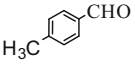
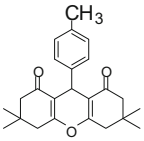
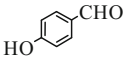
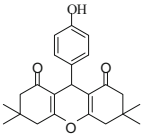
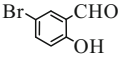
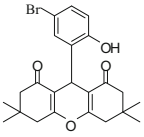
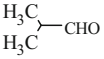
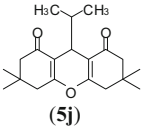
| Entry | Aldehyde | Product[a] | Time (min) | Yield[b] (%) | M.p. °C (Lit.) [Ref.] |
|---|---|---|---|---|---|
| 9 |  |  **(3i)** | 50 | 92 | 202-204 (203–205) [23] |
| 10 |  |  **(3j)** | 45 | 92 | 179-182 (179–180) [17] |
| 11 |  |  **(5a)** | 35 | 97 | 199-201 (201–203) [43] |
| 12 |  |  **(5b)** | 40 | 95 | 228-230 (230-232) [43] |
| 13 |  |  **(5c)** | 45 | 88 | 223-226 (226–227) [18] |
| 14 |  |  **(5d)** | 15 | 98 | 227-229 (228–230) [19] |
| 15 |  |  **(5e)** | 25 | 92 | 165-167 (168–170) [20] |
| 16 |  |  **(5f)** | 42 | 92 | 244-246 (248–250) [19] |

**Table 3** continued

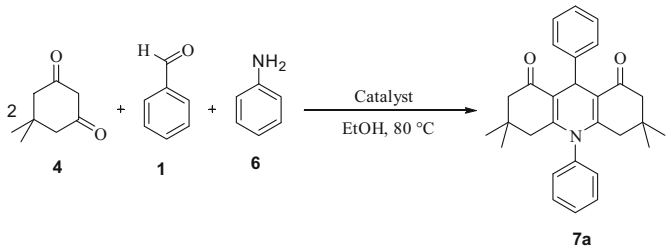
| Entry | Aldehyde | Product[a] | Time (min) | Yield[b] (%) | M.p. °C (Lit.) [Ref.] |
|---|---|---|---|---|---|
| 17 |  |  **(5g)** | 35 | 95 | 218-220 (219–221) [43] |
| 18 |  |  **(5h)** | 40 | 90 | 248-250 (249-251) [21] |
| 19 |  |  **(5i)** | 50 | 85 | 248-252 (250–252) [25] |
| 20 |  |  **(5j)** | 60 | 88 | 142-145 (146-147) [21] |

[a] All compounds are known and their structures were established from their spectral data and melting points as compared with literature values

[b] The yields refer to isolated products

solvent, and temperature on the reaction was studied (Table 4). In order to optimize the reaction conditions, the model reaction was performed in various solvents such as $H_2O$, $CH_3CN$, EtOH, and $CH_2Cl_2$ (Table 4, entries 1–9). It was found that $H_2O$, $CH_3CN$, $CH_2Cl_2$, and the solvent-free system were unfavorable for the formation of the product **7a** (Table 4, entries 7–10). The results indicated that higher yield of the product and shorter reaction time were obtained when the reaction was carried out using 1.5 mol% of the catalyst in ethanol at 80 °C (Table 4, entry 6).

Under optimized reaction conditions, dimedone with different aromatic aldehydes and aromatic amines or ammonium acetate were reacted to furnish the corresponding 1,8-dioxo-9-aryl-decahydroacridines in good yields in the presence of 1.5 mol% *p*-sulfonic acid calix[4]arene (Table 5). Aromatic aldehydes containing electron-withdrawing groups (such as nitro, halide groups) or electron-donating groups (alkyl, hydroxyl and alkoxyl groups) were employed and the nature of substituents on the aromatic ring of the aldehydes did not show estimated strong




**Scheme 5** The model reaction for the synthesis of 1,8-dioxo-decahydroacridine **7a**

**Table 4** Optimization of reaction conditions for synthesis of compound **7a**

| Entry | Catalyst (mol%) | Solvent | Temp. (°C) | Time (h) | Yield (%)[a] |
|---|---|---|---|---|---|
| 1 | 0.5 | EtOH | r.t. | 1 | 40 |
| 2 | 0.5 | EtOH | 50 | 1 | 60 |
| 3 | 0.5 | EtOH | 80 | 1 | 75 |
| 4 | 1.5 | EtOH | r.t. | 1 | 85 |
| 5 | 1.5 | EtOH | 50 | 1 | 90 |
| 6 | 1.5 | EtOH | 80 | 30 (min) | 95 |
| 7 | 1.5 | $CH_3CN$ | 80 | 1 | 75 |
| 8 | 1.5 | $CH_2Cl_2$ | 80 | 1 | 55 |
| 9 | 1.5 | $H_2O$ | 80 | 1 | 85 |
| 10 | 1.5 | Solvent-free | 80 | 1 | 75 |

Reaction condition: benzaldehyde (1 mmol), dimedone (2 mmol), and aniline (1.2 mmol), *p*-sulfonic acid calix[4]arene

[a] Isolated yield

effects in terms of yields under these reaction conditions. We also observed that ammonium acetate and various aromatic amines reacted easily under the conditions. The use of anilines as the ammonium source afforded the desired product in lower yield than ammonium acetate as the ammonium source. The reason may be that ammonia released from ammonium acetate is more nucleophilic than aromatic amines like aniline.

The reaction was clean and the products were obtained in high yields without the formation of any by-products. All the xanthene and acridine derivatives prepared were known compounds and their structures were confirmed by their physical properties and $^{1}H$ and $^{13}C$ NMR spectra and comparison with authentic samples. The catalyst was simply recovered from the reaction mixture by treating the precipitate with ethanol to dissolve the catalyst. Finally, on filtration, ethanol was evaporated and the organocatalyst dried and reused in successive reactions. The recycled catalyst was found to be highly efficient even after six times without any significant loss of catalytic activity.

**Table 5** Synthesis of 1,8-dioxo-decahydroacridines catalyzed by *p*-sulfonic acid calix[4]arene

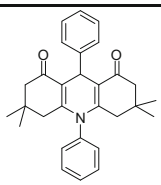
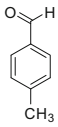
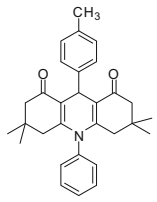
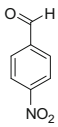
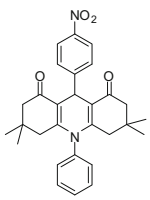
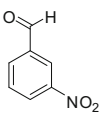
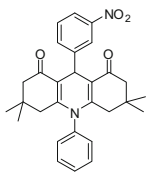
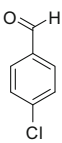
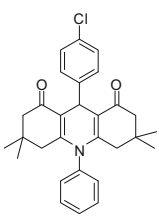
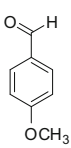
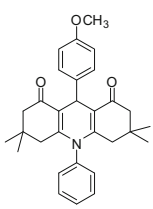
| Entry | Aldehyde | Amine | Product[a] | Time (min) | Yield[b] (%) | M.p. °C (Lit.) [Ref.] |
|---|---|---|---|---|---|---|
| 1 |  |  |  **7a** | 30 | 95 | 255-256 (254-256) [44] |
| 2 |  |  |  **7b** | 40 | 85 | 261-263 (260-263) [45] |
| 3 |  |  |  **7c** | 20 | 92 | 290-292 (289-290) [45] |
| 4 |  |  |  **7d** | 25 | 85 | 297-298 (297-299) [44] |
| 5 |  |  |  **7e** | 20 | 95 | 245-247 (244-246) [44] |
| 6 |  |  |  **7f** | 40 | 85 | 219-222 (220-222) [44] |

**Table 5** continued

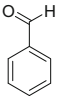
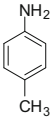
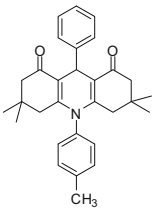
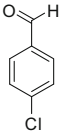
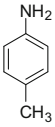
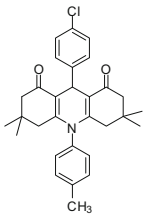
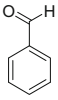
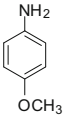
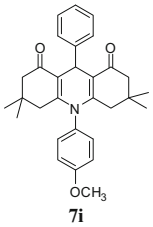
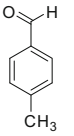
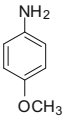
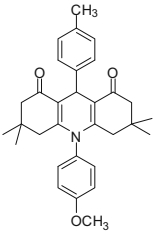
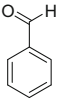
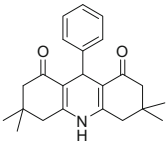
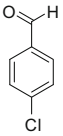
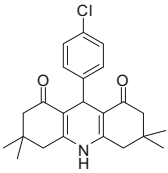
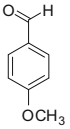
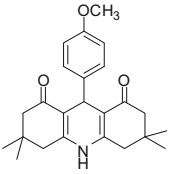
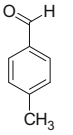
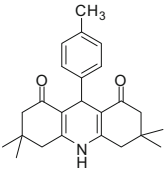
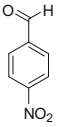
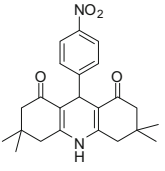
| Entry | Aldehyde | Amine | Product[a] | Time (min) | Yield[b] (%) | M.p. °C (Lit.) [Ref.] |
|---|---|---|---|---|---|---|
| 7 |  |  |  **7g** | 25 | 90 | 261-263 (260-263) [46] |
| 8 |  |  |  **7h** | 17 | 95 | 270-272 (270-271) [46] |
| 9 |  |  |  **7i** | 25 | 90 | 216-217 (215-217) [47] |
| 10 |  |  |  **7j** | 35 | 85 | 240-241 (238-240) [46] |
| 11 |  | $NH_4OAc$ |  **7k** | 20 | 95 | 278-279 (272-273) [48] |
| 12 |  | $NH_4OAc$ |  **7l** | 15 | 95 | 303-304 (300-302) [49] |

**Table 5** continued

| Entry | Aldehyde | Amine | Product[a] | Time (min) | Yield[b] (%) | M.p. °C (Lit.) [Ref.] |
|---|---|---|---|---|---|---|
| 13 |  | $NH_4OAc$ |  **7m** | 20 | 90 | 271-274 (270-272) [50] |
| 14 |  | $NH_4OAc$ |  **7n** | 25 | 85 | 318-320 (298-309) [51] |
| 15 |  | $NH_4OAc$ |  **7o** | 15 | 95 | 322-324 (300) [52] |

[a] All compounds are known and their structures were established from their spectral data and melting points as compared with literature values

[b] The yields refer to isolated products

## Conclusions

In this study, a simple, efficient, and eco-friendly procedure is described for the synthesis of 14-aryl-14*H*-dibenzo[*a,j*]xanthenes, 1,8-dioxo-octahydroxanthene and 1,8-dioxo-decahydroacridine derivatives in ethanol and under mild conditions using *p*-sulfonic acid calix[4]arene as a reusable organocatalyst. The present approach offers the advantages of simple methodology, clean and mild reaction conditions, short reaction time, low loading of catalyst, high yield, and excellent product purity.

**Acknowledgments** This research was supported by the Islamic Azad University, Ayatollah Amoli Branch, I. R. Iran.

## References

1. A. Dömling, B. Beck, E. Herdtweck, W. Antuch, C. Oefner, N.A. Yehia, A. Gracia-Marques, Arkivoc **12**, 99 (2007)
2. Y.M. Shchekotikhin, T.G. Nikolaeva, G.M. Shub, A.P. Kriven'ko, Pharm. Chem. J. **35**, 206 (2001)

3. S. Tu, X. Zhang, F. Shi, T. Li, Q. Wang, X. Zhu, J. Zhang, J. Xu, J. Heterocycl. Chem. **42**, 1155 (2005)
4. S.A. Gamage, J.A. Spicer, G.J. Atwell, G.J. Finlay, B.C. Baguley, W.A. Denny, J. Med. Chem. **42**, 2383 (1999)
5. M.J. Wainwright, Antimicrob. Chemother. **47**, 1 (2001)
6. K. Venkatesan, S.S. Pujari, K.V. Srinivasan, Synth. Commun. **39**, 228 (2009)
7. J.P. Poupelin, G. Saint-Rut, O. Foussard-Blanpin, G. Narcisse, G. Uchida-Ernouf, R. Lacroix, Eur. J. Med. Chem. **13**, 67 (1978)
8. H. Takeshiba JP 56 005 480 (1981)
9. R.W. Lambert, J.A. Martin, J.H. Merrett, K.E.B. Parkes, G.J. Thomas, Chem. Abstr. **126**, 212377y (1997)
10. R.M. Ion, A. Planner, K. Wiktorowicz, D. Frackowiak, Acta Biochim. Pol. **45**, 833 (1998)
11. J.M. Jamison, K. Krabill, A. Hatwalker, E. Jamison, C. Tsai, Cell. Biol. Intern. **14**, 1075 (1990)
12. B.B. Bhowmik, P. Ganguly, Spectrochim. Acta Part A **61**, 1997 (2005)
13. A.M. El-Brashy, M.E. Metwally, F.A. El-Sepai, Farmaco **59**, 809 (2004)
14. E. Klimtchuk, M.A.J. Rodgers, D.C. Neckers, J. Phys. Chem. **96**, 9817 (1992)
15. G. Casiraghi, G. Casnati, M. Cornia, Tetrahedron Lett. **14**, 679 (1973)
16. J.Q. Wang, R.G. Harvey, Tetrahedron **58**, 5927 (2002)
17. N.G. Khaligh, Ultra. Sonochem. **19**, 736 (2012)
18. Z.H. Zhang, Y.H. Liu, Catal. Commun. **9**, 1715 (2008)
19. M.A. Zolfigol, V. Khakyzadeh, A.R. Moosavi-Zare, A. Zare, S.B. Azimi, Z. Asgari, A. Hasaninejad, C. R. Chim. **15**, 719 (2012)
20. G.H. Mahdavinia, M.A. Bigdeli, Y.S. Hayeniaz, Chin. Chem. Lett. **20**, 539 (2009)
21. G.K. Verma, K. Raghuvanshi, R.K. Verma, P. Dwivedi, M.S. Singh, Tetrahedron **67**, 3698 (2011)
22. B.F. Mirjalili, A. Bamoniri, A. Akbari, N. Taghavinia, J. Iran. Chem. Soc. **8**, 129 (2011)
23. M. Dabiri, M. Baghbanzadeh, M. Shakouri Nikcheh, E. Arzroomchilar, Bioorg. Med. Chem. Lett. **18**, 436 (2008)
24. P.S. Kumar, B.S. Kumar, B. Rajitha, P.N. Reddy, N. Sreenivasulu, Y.T. Reddy, Arkivoc **12**, 46 (2006)
25. A. Zare, A.R. Moosavi-Zare, M. Merajoddin, M.A. Zolfigol, T. Hekmat-Zadeh, A. Hasaninejad, A. Khazaei, M. Mokhlesi, V. Khakyzadeh, F. Derakhshan-Panah, M.H. Beyzavi, E. Rostami, A. Arghoon, R. Roohandeh, J. Mol. Liq. **167**, 69 (2012)
26. S.M. Baghbanian, M. Farhang, J. Mol. Liq. **183**, 45 (2013)
27. S.M. Baghbanian, Y. Babajani, H. Tashakorian, S. Khaksar, M. Farhang, C. R. Chim. **16**, 129 (2013)
28. S.M. Baghbanian, M. Farhang, R. Baharfar, Chin. Chem. Lett. **22**, 555 (2011)
29. S.M. Baghbanian, S. Khaksar, S.M. Vahdat, M. Tajbakhsh, Chin. Chem. Lett. **2**, 563 (2011)
30. S.M. Baghbanian, N. Rezaei, H. Tashakkorian, Green Chem. **15**, 3446 (2013)
31. S.M. Baghbanian, M. Farhang, J. Iran. Chem. Soc. **10**, 1033 (2013)
32. S.M. Baghbanian, M. Farhang, Synth. Commun. **44**, 697 (2013)
33. S.M. Baghbanian, M. Farhang, RSC Adv. **4**, 11624 (2014)
34. C.D. Gutsche, M. Iqbal, Org. Synth. **68**, 234 (1989)
35. A. Casnati, D. Della Ca, F. Sansone, F. Ugozzoli, R. Ungaro, Tetrahedron **60**, 7869 (2004)
36. S. Shinkai, K. Araki, T. Tsubaki, T. Arimura, O. Manabe, J. Chem. Soc. Perkin. Trans. **1**, 2297 (1987)
37. J.M. Davey, C.O. Too, S.F. Ralph, L.A.P. Kane-Maguire, G.G. Wallace, Macromolecules **33**, 7044 (2000)
38. G.S. Wang, H.Y. Zhang, F. Ding, Y.J. Liu, Incl. Phenom. Macrocycl. Chem. **69**, 85 (2011)
39. R.A.P. Castanheiro, A.M.S. Silva, N.A.N. Campos, M.S.J. Nascimento, M.M.M. Pinto, Pharmaceuticals **2**, 33 (2009)
40. S. Shimizu, N. Shimada, Y. Sasaki, Green Chem. **8**, 608 (2006)
41. Y.L. Liu, L. Liu, Y.W. Lin, Y.C. Han, D. Wang, Y.J. Chen, Green Chem. **10**, 635 (2008)
42. S.A. Fernandes, R. Natalino, P.A. Rodrigues, M. Gazolla, M. José da Silva, G.N. Jham, Tetrahedron Lett. **53**, 1630 (2012)
43. S. Kantevari, R. Bantu, L. Nagarapu, Arkivoc **16**, 136 (2006)
44. M. Kidwai, D. Bhatnagar, Tetrahedron Lett. **51**, 2700 (2010)
45. T.S. Jin, J.S. Zhang, T.T. Guo, A.Q. Wang, T.S. Li, Synthesis **12**, 2001 (2004)
46. A. Davoodnia, A. Khojastehnezhad, N. Tavakoli-Hoseini, Bull. Korean Chem. Soc. **32**, 2243 (2011)
47. W. Shen, L.M. Wang, H. Tian, J. Tang, J.J. Yu, J. Fluor. Chem. **130**, 522 (2009)

48. X.S. Wang, M.M. Zhang, H. Jiang, D.Q. Shi, S.J. Tu, X.Y. Wei, Z.M. Zong, Synthesis **24**, 4187 (2006)
49. A.A. Bakibaev, V.D. Fillimonov, E.S. Nevgodova, Zh. Org. Khim. **27**, 1512 (1991)
50. N. Martin, M. Quinteiro, C. Seoane, J.L. Soto, A. Mora, M. Suárez, A. Morales, E. Ochoa, J.D. Bosque, J. Heterocycl. Chem. **32**, 235 (1995)
51. X. Fan, Y. Li, X. Zhang, G. Qu, J. Wang, Heteroat. Chem. **18**, 786 (2007)
52. A.G. Bayer, Patent: DE2003148; Chem. Abstr. 75 98459 (1971)