Silica-Bonded *S*-Sulfonic Acid as Recyclable Catalyst for the Synthesis of 1,8-Dioxo-decahydroacridines and 1,8-Dioxo-octahydroxanthenes

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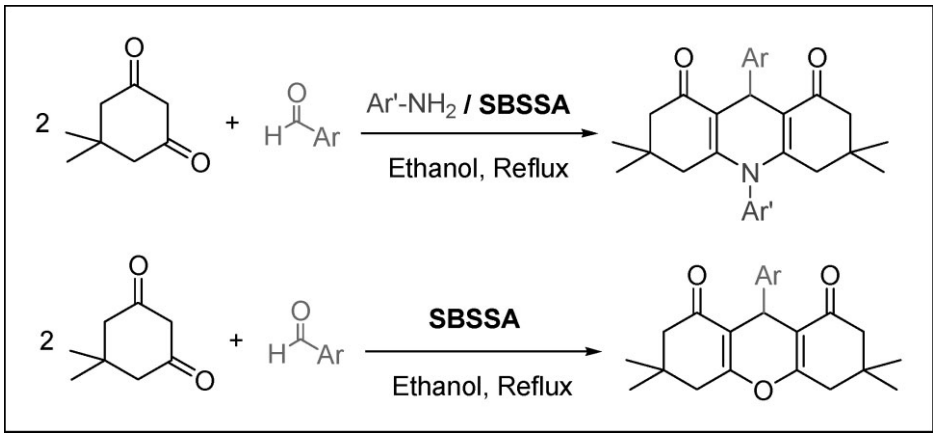

Silica-bonded *S*-sulfonic acid (SBSSA) has been found to be an efficient catalyst for the synthesis of 1,8-dioxo-decahydroacridines and 1,8-dioxo-octahydroxanthenes in excellent yields. The former have been synthesized from aromatic aldehydes, amines, and 5,5-dimethyl-1,3-cyclohexanedione, whereas the latter from this mixture without amines. The method is an easy access to functionalized acridine and xanthene derivatives. The catalyst can be reused.

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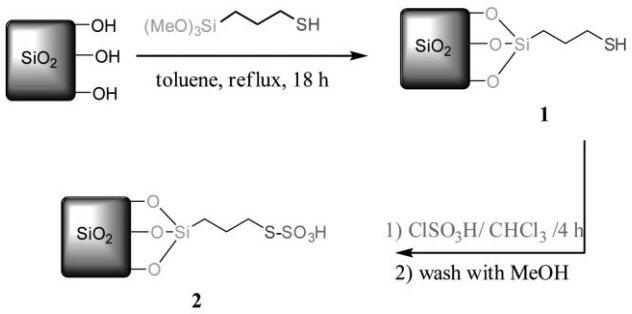
INTRODUCTION

The development of heterogeneous catalysts for fine chemical synthesis has become a major area of research. The potential advantages of these materials over homogeneous systems (simplified recovery and reusability, the potential for incorporation in continuous reactors and micro reactors) can lead to novel and environmentally benign chemical procedures for academia and industry [1]. From this viewpoint, catalytic reactions lead to valuable processes, because the use of stoichiometric reagents that are often toxic poses inherent limitations from both an economical and an environmental viewpoint and in specific relation to product purification and waste management [2]. It is clear that green chemistry not only requires the use of environmentally benign reagents and solvents but also it is very crucial to recover and reuse the catalyst. One way to overcome the problem of recyclability of the traditional acid catalyst is to chemically anchor their reactive center onto a large surface area inorganic solid carrier to create new organic–inorganic hybrid catalyst [3]. In these types of solids, the reactive centers are highly mobile similar to homogeneous catalysts and at the same time these species have the advantage of being recyclable in the same fashion as heterogeneous catalysts. In view of this, several types of solid sulfonic acid functionalized silica (both amorphous and ordered) have been synthesized and applied as an alternative to traditional sulfonic acid resins and homogeneous acids in catalyzing chemical transformations [4,5]. Application of solid acids in organic transformation has an important role, because these species have many advantages, such as, simplicity in handling, decreased reactor and plant corrosion problems, and more environmentally safe disposal [4–10].

1,8-Dioxo-9-aryl-10-aryl-decahydroacridines and their derivatives are polyfunctionalized 1,4-dihydropyridine derivatives. In recent years, 1,4-dihydropyridines and their derivatives have attracted strong interest for the treatment of cardiovascular diseases, such as, angina pectoris [11] and hypertension [12]. Acridine derivatives have been used to synthesize labeled conjugates with medicinals, peptides, proteins, and nucleic acids [13–15] that exhibit antitumor and DNA-binding properties. Multicomponent reactions (MCRs) constitute, an

Scheme 1. Preparation of silica bonded *S*-sulfonic acid.



especially attractive synthetic strategy, for rapid and efficient library generation because the products are formed in a single step and diversity can be achieved simply by varying the reaction components [16]. Thus, new routes utilizing a MCR protocol for the synthesis of these molecules can attract considerable attention in the search for rapid-entry methods to these heterocycles.

Reportedly, the conventional synthesis of acridines and their derivatives has been performed in an organic acid, such as, HOAc [17]. Recently, few methodologies have been reported in the literature for the synthesis of decahydroacridines [18]. Each of these methods has limitations, such as, poor yields, cumbersome work up procedure, and generation of polluting effluents [17].

Xanthenes are an important class of organic compounds that find use as dyes, fluorescent material for visualization of biomolecules, and in laser technologies due to their useful spectroscopic properties [19]. Xanthenes have also received significant attention from many pharmaceutical and organic chemists essentially because of the broad spectrum of their biological and pharmaceutical properties, such as, antiviral [20], antibacterial [21], antinociceptive activities [22] as well as efficiency in photodynamic therapy [23] and anti-inflammatory activities [24]. There are several reports in the literature for the synthesis of 1,8-dioxooctahydroxanthene derivatives using aromatic aldehydes and 5,5-dimethyl-1,3-cyclohexanedione, these include $InCl_3{\cdot}4H_2O$ in ionic liquid [25], solid-state condensation by grinding at room temperature [26], diammonium hydrogen phosphate [27], *p*-dodecylbenzenesulfonic acid in water [28], Fe^{3+}-montmorilonite [29], $NaHSO_4$-SiO_2 or silica chloride [30], amberlyst-15 [18d], silica sulfuric acid [31], tetrabutylammonium hydrogen sulfate [32], trimethylsilylchloride [33], 1-butyl-3-methylimidazolium hydrogen sulfate [34], montmorillonite K-10-supported [35], and covalently anchored sulfonic acid on silica gel [36]. Each of these methods have their own advantages but also some of them often suffer from one or more disadvantages, such as, prolonged reaction time, tedious work-up processes, low yield [37], expensive reagents [18d,25], and hazardous organic solvents [37]. Consequently, there is scope for further innovation of methods with milder reaction conditions, short reaction times, increase in variation of the substituents in the components, and better yields in the synthesis of 1,8-dioxodecahydroacridines and 1,8-dioxo-octahydroxanthenes, which can be possibly achieved by choosing silica-bonded *S*-sulfonic acid (SBSSA) as a catalyst for this MCR.

RESULTS AND DISCUSSION

Recently, we have reported the preparation of SBSSA and its application as catalyst for the synthesis of 1,1-diacetates [5a], quinoxaline [5b], and coumarin derivatives [5c] (Scheme 1).

In our continued interest in the development of a highly expedient methodology for the synthesis of fine chemicals and heterocyclic compounds of biological importance [38], we report here the synthesis of 1,8-dioxo-9-aryl-10-aryl-decahydroacridines and 1,8-dioxo-octahydroxanthenes in the presence of SBSSA as a heterogeneous solid acid (Scheme 2).

To determine the scope of the designed protocol, a number of commercially available aromatic aldehydes have condensed with dimedone and aryl amines under optimized reaction conditions, and the results are summarized in Table 1. We investigated further the electronic effect of different substituents present on the aldehyde component. It was observed that a wide range of aldehydes having both electron-donating and electron-withdrawing groups were equally facile for the reaction, resulting in the formation of decahydroacridine derivatives in very good yields. We also observed that various aniline derivatives reacted smoothly under the reaction conditions.

Scheme 2. Synthesis of 1,8-dioxo-9-aryl-10-aryl-decahydroacridines and 1,8-dioxo-octahydroxanthene using SBSSA as catalyst.

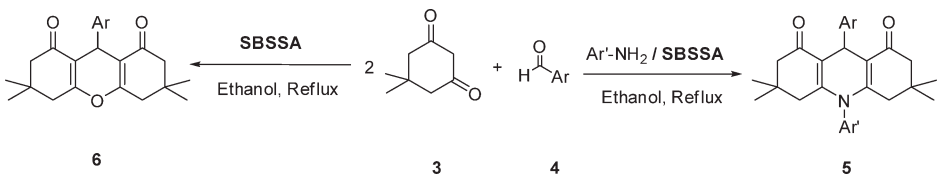
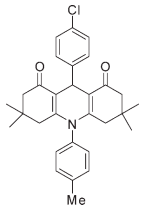
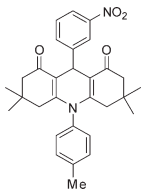
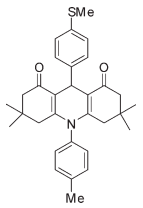
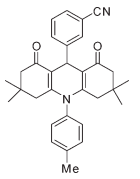
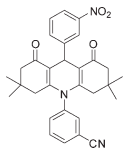
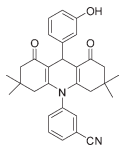
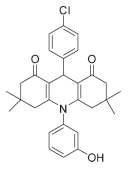
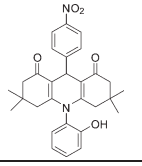


Table 1

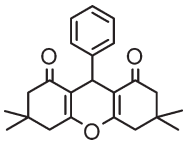
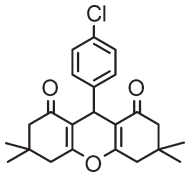
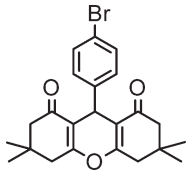
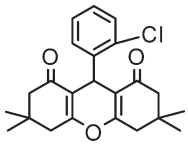
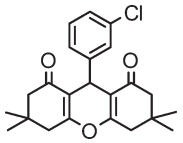
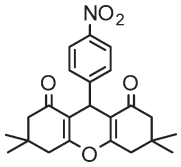
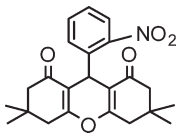
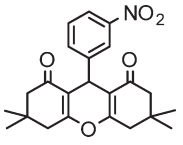
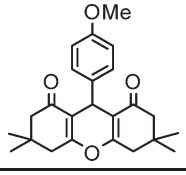
Synthesis of 1,8-dioxo-9-aryl-10-aryl-decahydroacridines derivatives in the presence of SBSSA under reflux conditions.[a]

Entry	Ar	Ar′	Product	Time (h)	Yield[b] (%)
1	4-Cl—C_6H_4	4-Me—C_6H_4	 **5a**	1.0	96
2	3-NO_2—C_6H_4	4-Me—C_6H_4	 **5b**	2.5	85
3	4-MeS—C_6H_4	4-Me—C_6H_4	 **5c**	3.0	93
4	3-CN—C_6H_4	4-Me—C_6H_4	 **5d**	4.5	89
5	3-NO_2—C_6H_4	3-CN—C_6H_4	 **5e**	3.0	84
6	3-HO—C_6H_4	3-CN—C_6H_4	 **5f**	3.0	92
7	4-Cl—C_6H_4	3-HO—C_6H_4	 **5g**	2.5	95
8	4-NO_2—C_6H_4	2-HO—C_6H_4	 **5h**	1.5	96

[a] Reaction conditions: Dimedone (2 mmol), aldehyde (1 mmol), aniline derivative (1 mmol), catalyst (0.03 g) in refluxing ethanol.
[b] Isolated yield.

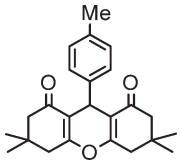
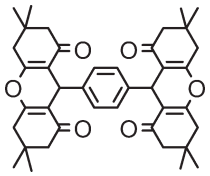
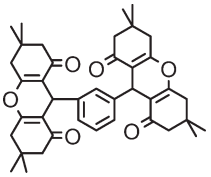
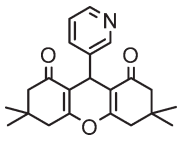
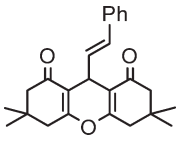
Table 2

Synthesis of 1,8-dioxo-octahydroxanthenes derivatives in the presence of SBSSA in ethanol under reflux conditions.[a]

Entry	Ar	Product	Time (h)	Yield[b] (%)
1	C_6H_5	 **6a**	10.0	98
2	4-Cl—C_6H_4	 **6b**	4.0, 4.0, 4.5, 5.0, 5.0	92, 91, 89, 91, 90
3	4-Br—C_6H_4	 **6c**	3.0	96
4	2-Cl—C_6H_4	 **6d**	5.0	90
5	3-Cl—C_6H_4	 **6e**	5.0	90
6	4-NO_2—C_6H_4	 **6f**	2.0	95
7	2-NO_2—C_6H_4	 **6g**	3.0	87
8	3-NO_2—C_6H_4	 **6h**	3.0	94
9	4-MeO—C_6H_4	 **6i**	6.0	91

(*Continued*)

Table 2
(*Continued*)

Entry	Ar	Product	Time (h)	Yield[b] (%)
10	4-Me—C_6H_4	 **6j**	9.0	91
11	4-OHC—C_6H_4	 **6k**	5.0	64
12	3-OHC—C_6H_4	 **6l**	7.0	65
13	3-Pyridyl	 **6m**	6.0	71
14	C_6H_5—CH=CH—	 **6n**	3.0	94

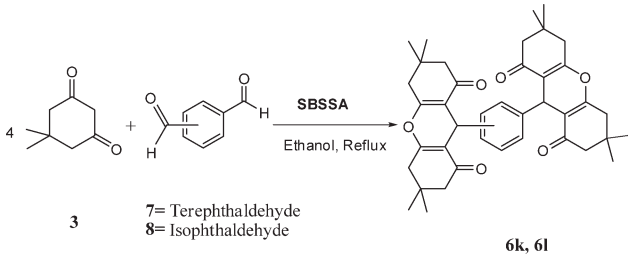
[a] Reaction conditions: Dimedone (2 mmol), aldehyde (1 mmol), catalyst (0.03 g) in refluxing ethanol.
[b] Isolated yield.

Encouraged by these results, we carried out reaction of 5,5-dimethyl-1,3-cyclohexanedione (**3**) and aromatic aldehydes (**4**) in the presence of SBSSA (0.03 g) in refluxing ethanol, which afforded 1,8-dioxo-octahydroxanthene derivatives **6a–n** in excellent yields within a short period of time (Scheme 2, Table 2). Here also the aromatic aldehydes containing both electron-donating and electron-withdrawing groups afforded the products in high yields.

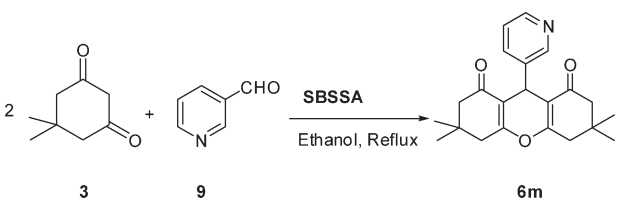
The practical synthetic efficiency of this reaction was highlighted by the reaction of terephthaldehyde (**7**) and isophthaldehyde (**8**) with dimedone (**3**) to give structurally complex xanthenone derivatives (**6k** and **6l**), Scheme 3.

An important feature of this method is that the heterocyclic functionality present in the molecule remains

Scheme 3. Synthesis of bis(1,8-dioxo-octahydroxanthenes).



Scheme 4. Synthesis of 9-(pyridine-3-yl)-1,8-dioxo-octahydroxanthene.



unaffected. This fact was amply demonstrated by the reaction of pyridine-3-caboxaldehyde (**9**) with dimedone (**3**), which gave 9-(pyridine-3-yl)-1,8-dioxo-octahydroxanthene (**6m**) in excellent yield (Scheme 4).

The possibility of recycling the catalyst was examined using the condensation reaction of 5,5-dimethyl-1,3-cyclohexanedione and 4-chlorobenzaldehyde in ethanol under the optimized conditions. When the reaction was complete, the mixture was filtered and the remaining was washed with warm ethanol, and the catalyst reused in the next reaction. The recycled catalyst could be reused four times without any additional treatment. No observation of any appreciable loss in the catalytic activity of SBSSA was observed (Table 2, entry 2).

In conclusion, we have developed an efficient method for the synthesis of 1,8-dioxo-9-aryl-10-aryl-decahydroacridines and 1,8-dioxo-octahydroxanthenes in high yields using SBSSA as a catalyst. The catalyst was recovered and reused without any noticeable loss of reactivity. The mild reaction conditions and simplicity of the procedure offers improvements over many existing methods.

EXPERIMENTAL

General. Chemicals were purchased from Fluka, Merck, and Aldrich Chemical Companies. All of the products are known, except **5c**–**5h**, and characterized by comparison of their spectral (IR, ^{1}H NMR) and physical data with those reported in literature. SBSSA was prepared according to our previous reported procedure [5].

General procedure for the synthesis of 1,8-dioxo-9-aryl-10-aryl-decahydroacridines derivatives. To a solution of an aromatic aldehyde (1 mmol), 5,5-dimethyl-1,3-cyclohexanedione (2 mmol) and aryl amine (1 mmol) in ethanol (2 mL) in a round-bottom flask, SBSSA (0.03 g) was added. The mixture was heated under reflux conditions and the reaction was monitored by TLC. After completion of the reaction, the mixture was filtered and the remaining was washed with warm ethanol in order to separate catalyst. Then, water (20 mL) was added to the filtrate and was allowed to stand at room temperature for 1 h. During this time, crystals of the pure product were formed, which were collected by filtration and dried. For further purification, if needed, the products were recrystalized from hot ethanol. The spectral data are given below.

9-(4-Chlorophenyl)-3,4,6,7-tetrahydro-3,3,6,6-tetramethyl-10-p-tolylacridine-1,8-(2H,5H,9H,10H)-dione (5a). mp 273–275°C, (ref. 18e, 270–271°C); ^{1}H NMR ($CDCl_3$, 500 MHz), δ: 0.82 (s, 6H), 0.97 (s, 6H), 1.87 (d, 2H, J = 17.4 Hz), 2.08–2.15 (m, 4H), 2.22 (d, 2H, J = 16.2 Hz), 2.51 (s, 3H), 5.26 (s, 1H), 7.12 (d, 2H, J = 8.2 Hz), 7.23 (d, 2H, J = 8.3 Hz), 7.36–7.40 (m, 4H); ^{13}C NMR ($CDCl_3$, 125 MHz), δ: 21.73, 27.15, 30.15, 32.80, 32.87, 42.18, 50.60, 114.56, 128.56, 129.13, 129.74, 130.05, 131.84, 136.60, 140.06, 145.34, 150.64, 196.21.

3,4,6,7-Tetrahydro-3,3,6,6-tetramethyl-9-(3-nitrophenyl)-10-p-tolylacridine-1,8-(2H,5H,9H,10H)-dione (5b). mp 289–291°C, (ref. 18e. 285–287°C); ^{1}H NMR ($CDCl_3$, 500 MHz), δ: 0.81 (s, 6H), 0.99 (s, 6H), 1.92 (dd, 2H, J_1 = 17.5 Hz, J_2 = 0.9 Hz), 2.15 (d, 4H, J = 16.6 Hz), 2.24 (d, 2H, J = 16.2 Hz), 2.52 (s, 3H), 5.38 (s, 1H), 7.14–7.23 (m, 2H), 7.40–7.45 (m, 3H), 7.97–8.01 (m, 2H), 8.25 (t, 1H, J = 1.9 Hz); ^{13}C NMR ($CDCl_3$, 125 MHz), δ: 21.71, 27.05, 30.10, 32.87, 33.31, 42.13, 50.53, 114.21, 121.53, 122.37, 129.22, 129.95, 130.93, 131.79, 135.70, 136.38, 140.22, 148.85, 151.26, 196.11.

3,4,6,7-Tetrahydro-3,3,6,6-tetramethyl-9-(4-(methylthio)-phenyl)-10-p-tolyl-acridine-1,8-(2H,5H,9H,10H)-dione (5c). mp 239°C; IR (KBr): 3080, 2960, 2880, 1639, 1570, 1505, 1360, 1220, 882, 838, 730, 562, 520 (cm^{-1}); ^{1}H NMR ($CDCl_3$, 500 MHz), δ: 0.84 (s, 6H), 0.97 (s, 6H), 1.87 (d, 2H, J = 17.5 Hz), 2.10 (d, 2H, J = 17.5 Hz), 2.15 (d, 2H, J = 16.2 Hz), 2.22 (d, 2H, J = 16.2 Hz), 2.46 (s, 3H), 2.52 (s, 3H), 5.26 (s, 1H), 7.12 (d, 2H, J = 7.7 Hz), 7.19 (d, 2H, J = 8.1 Hz), 7.36–7.40 (m, 4H); ^{13}C NMR ($CDCl_3$, 125 MHz), δ: 16.59, 21.71, 27.23, 30.15, 32.76, 32.80, 42.20, 50.64, 114.85, 127.26, 128.86, 135.52, 136.79, 139.92, 144.06, 150.38, 196.23; Anal. Calc. C, 76.66; H, 7.26; N, 2.88; S, 6.60; Found C, 76.49; H, 7.09; N, 2.67.

3-(1,2,3,4,5,6,7,8,9,10-Decahydro-3,3,6,6-tetramethyl-1,8-dioxo-10-p-tolylacridin-9-yl)benzonitrile (5d). mp 256–257°C; IR (KBr): 3080, 2960, 2880, 2320, 1638, 1590, 1558, 1480, 1450, 1360, 1308, 1220, 1140, 998, 930, 842, 830, 720 (cm^{-1}); ^{1}H NMR ($CDCl_3$, 500 MHz), δ: 0.80 (s, 6H), 0.94 (s, 6H), 1.86 (d, 2H, J = 17.5 Hz), 2.09 (d, 2H, J = 14.6 Hz), 2.12 (d, 2H, J = 12.5 Hz), 2.19 (d, 2H, J = 16.2 Hz), 2.47 (s, 3H), 5.24 (s, 1H), 7.05 (d, 1H, J = 7.9 Hz), 7.10 (d, 2H, J = 8.3 Hz), 7.15 (t, 1H, J = 7.8 Hz), 7.33–7.36 (m, 3H), 7.39 (d, 1H, J = 1.7 Hz); ^{13}C NMR ($CDCl_3$, 125 MHz), δ: 21.68, 27.13, 30.09, 32.77, 33.00, 42.13, 50.60, 114.36, 126.46, 126.65, 128.42, 128.98, 129.66, 130.06, 134.13, 136.50, 140.06, 148.68, 150.83, 196.09; Anal. Calc. C, 80.14; H, 6.94; N, 6.03; Found C, 79.97; H, 6.77; N, 5.87.

3-(1,2,3,4,5,6,7,8-Octahydro-3,3,6,6-tetramethyl-9-(3-nitrophenyl)-1,8-dioxo-acridin-10(9H)-yl)benzonitrile (5e). mp 266–268°C; IR (KBr): 3080, 2960, 2880, 2203, 1643, 1635, 1595, 1578, 1440, 1362, 1240, 1220, 1140, 879, 801, 699 (cm^{-1}); ^{1}H NMR ($CDCl_3$, 500 MHz), δ: 0.83 (s, 6H), 1.01 (s, 6H), 1.83 (d, 2H, J = 17.4 Hz), 2.13 (d, 2H, J = 17.5 Hz), 2.17 (d, 2H, J = 16.4 Hz), 2.26 (d, 2H, J = 16.3 Hz), 5.37 (s, 1H), 7.46 (t, 1H, J = 7.9 Hz), 7.63–7.68 (m, 2H), 7.82 (t, 1H, J = 7.8 Hz), 7.91–7.95 (m, 2H), 8.00 (dd, 1H, J_1 = 8.2 Hz, J_2 = 1.4 Hz), 8.21 (s, 1H); ^{13}C NMR ($CDCl_3$, 125 MHz), δ: 27.15, 30.04, 33.03, 33.23, 42.35, 50.39, 114.91, 117.53, 121.77, 122.26, 129.47, 133.82, 135.62, 140.17, 148.26, 148.81, 149.80, 195.90; Anal. Calc. C, 72.71; H, 5.90; N, 8.48; Found C, 72.57; H, 5.76; N, 8.32.

3-(1,2,3,4,5,6,7,8-Octahydro-9-(3-hydroxyphenyl)-3,3,6,6-tetramethyl-1,8-dioxo-acridin-10(9H)-yl)benzonitrile (5f). mp >300°C decomp.; IR (KBr): 3250, 3080, 2960, 2880, 2320, 1610, 1590, 1555, 1500, 1460, 1410, 1340, 1260, 1240, 1142, 1110, 838, 710 (cm^{-1}); ^{1}H NMR [$CDCl_3$-DMSO-d_6 (2%), 500 MHz], δ: 0.72 (s, 6H), 0.85 (s, 6H), 1.63 (d, 2H, J = 17.3 Hz), 1.94 (d, 2H, J = 17.3 Hz), 2.01 (d, 2H, J = 16.2 Hz), 2.08 (d, 2H, J = 16.2 Hz), 5.06 (s, 1H), 6.47 (dd, 1H, J_1 = 7.8 Hz, J_2 = 2.0 Hz), 6.75–6.78 (m, 4H), 6.93 (t, 1H, J = 7.8 Hz), 7.48 (d, 1H, J = 7.3 Hz), 7.62 (t, 2H, 7.8 Hz), 7.76 (d, 1H, J = 7.8 Hz), 8.5 (brs, 1H); ^{13}C NMR [$CDCl_3$-DMSO-d_6 (2%), 125 MHz], δ: 27.05, 29.86, 32.31, 32.64, 41.99, 50.39,

113.56, 114.84, 114.94, 117.68, 119.27, 129.10, 133.47, 135.01, 140.06, 147.30, 149.16, 157.50, 195.72; Anal. Calc. C, 77.23; H, 6.48; N, 6.00; Found C, 77.09; H, 6.33; N, 5.81.

9-(4-Chlorophenyl)-3,4,6,7-tetrahydro-10-(3-hydroxyphenyl)-3,3,6,6-tetramethyl-acridine-1,8-(2H,5H,9H,10H)-dione (5g). mp 267–269°C; IR (KBr): 3390, 3120, 2960, 2880, 1639, 1595, 1560, 1480, 1443, 1360, 1305, 1220, 1140, 998, 935, 840, 720, 560 (cm^{-1}); ^1H NMR [$CDCl_3$-DMSO-d_6 (2%), 500 MHz], δ: 0.68 (s, 6H), 0.83 (s, 6H), 1.82 (d, 2H, J = 17.5 Hz), 1.97–2.09 (m, 6H), 5.07 (s, 1H), 6.54–6.58 (m, 2H), 6.90 (d, 1H, J = 5.0 Hz), 7.07 (d, 2H, J = 8.3 Hz), 7.20–7.24 (m, 3H), 9.52 (brs, 1H); ^{13}C NMR [$CDCl_3$-DMSO-d_6 (2%), 125 MHz], δ: 26.93, 30.03, 32.66, 41.73, 50.52, 114.12, 128.39, 128.62, 131.63, 139.76, 145.27, 150.96, 195.40; Anal. Calc. C, 73.17; H, 6.35; Cl, 7.45; N, 2.94; Found C, 73.01; H, 6.19; N, 2.81.

3,4,6,7-Tetrahydro-10-(2-hydroxyphenyl)-3,3,6,6-tetramethyl-9-(4-nitrophenyl)-acridine-1,8-(2H,5H,9H,10H)-dione (5h). mp >300°C decomp.; IR (KBr): 3380, 3120, 2960, 2880, 1638, 1595, 1520, 1360, 1340, 1220, 1140, 998, 860, 827 (cm^{-1}); ^1H NMR [$CDCl_3$-DMSO-d_6 (2%), 500 MHz], δ: 0.67 (s, 6H), 0.84 (s, 6H), 1.84 (d, 2H, J = 17.5 Hz), 1.98 (d, 2H, J = 16.3 Hz), 2.04–2.10 (m, 4H), 5.18 (s, 1H), 6.55–6.59 (m, 2H), 6.92 (d, 2H, J = 7.9 Hz), 7.21–7.24 (m, 1H), 7.47 (d, 2H, J = 8.7 Hz), 7.98 (d, 2H, 8.7 Hz), 9.48 (brs, 1H); ^{13}C NMR [$CDCl_3$-DMSO-d_6 (2%), 125 MHz], δ: 26.95, 29.98, 32.68, 41.73, 50.44, 113.44, 123.69, 129.14, 139.58, 146.38, 154.10, 196.09; Anal. Calc. C, 71.59; H, 6.21; N, 5.76; Found C, 71.43; H, 6.09; N, 5.29.

General procedure for the synthesis of 1,8-dioxo-octahydroxanthene derivatives. To a solution of an aromatic aldehyde (1 mmol) and 5,5-dimethyl-1,3-cyclohexanedione (2 mmol) in ethanol (2 mL) in a round-bottom flask, SBSSA (0.03 g) was added. The mixture was heated under reflux conditions and the reaction was monitored by TLC. After completion of the reaction, the mixture was filtered and the remaining was washed with warm ethanol in order to separate catalyst. Then, water (20 mL) was added to the filtrate and was allowed to stand at room temperature for 1 h. During this time, crystals of the pure product were formed, which were collected by filtration and dried. For further purification if needed, the products recrystalized from hot ethanol. The NMR data are given below.

3,4,6,7-Tetrahydro-3,3,6,6-tetramethyl-9-phenyl-2H-xanthene-1,8-(5H,9H)-dione (6a). mp 203–204°C, (ref. 32, 204–206°C); ^1H NMR ($CDCl_3$, 500 MHz), δ: 1.02 (s, 6H), 1.13 (s, 6H), 2.19 (d, 2H, J = 16.2 Hz), 2.26 (d, 2H, J = 16.2 Hz), 2.50 (s, 4H), 4.78 (s, 1H), 7.12 (t, 1H, J = 7.2 Hz), 7.24 (t, 2H, J = 7.5 Hz), 7.32 (d, 2H, J = 7.6 Hz). ^{13}C NMR ($CDCl_3$, 125 MHz), δ: 27.75, 29.69, 32.26, 32.61, 41.29, 51.18, 116.07, 126.76, 128.45, 128.80, 144.54, 162.70, 196.76.

3,4,6,7-Tetrahydro-3,3,6,6-tetramethyl-9-(4-chlorophenyl)-2H-xanthene-1,8-(5H,9H)-dione (6b). mp 230–232°C, (ref. 33, 230–232°C); ^1H NMR ($CDCl_3$, 500 MHz), δ: 1.03 (s, 6H), 1.14 (s, 6H), 2.20 (d, 2H, J = 16.3 Hz), 2.27 (d, 2H, J = 16.3 Hz), 2.50 (s, 4H), 4.75 (s, 1H), 7.22 (d, 2H, J = 8.5 Hz), 7.27 (d, 2H, J = 8.5 Hz). ^{13}C NMR ($CDCl_3$, 125 MHz), δ: 27.72, 29.68, 31.89, 32.61, 41.28, 51.13, 115.69, 128.63, 130.19, 132.45, 143.13, 162.83, 196.71.

3,4,6,7-Tetrahydro-3,3,6,6-tetramethyl-9-(4-bromophenyl)-2H-xanthene-1,8-(5H,9H)-dione (6c). mp 240–241°C, (ref. 33, 240–242°C); ^1H NMR ($CDCl_3$, 500 MHz), δ: 1.03 (s, 6H), 1.14 (s, 6H), 2.20 (d, 2H, J = 16.3 Hz), 2.27 (d, 2H, J = 16.3 Hz), 2.50 (s, 4H), 4.74 (s, 1H), 7.21 (d, 2H, J = 8.4 Hz), 7.37 (d, 2H, J = 8.4 Hz). ^{13}C NMR ($CDCl_3$, 125 MHz), δ: 27.73, 29.69, 31.98, 32.62, 41.28, 51.12, 115.63, 120.66, 130.60, 131.57, 143.64, 162.82, 196.69.

3,4,6,7-Tetrahydro-3,3,6,6-tetramethyl-9-(2-chlorophenyl)-2H-xanthene-1,8-(5H,9H)-dione (6d). mp 225–227°C, (ref. 32, 225–227°C); ^1H NMR ($CDCl_3$, 500 MHz), δ: 1.05 (s, 6H), 1.13 (s, 6H), 2.19 (d, 2H, J = 16.2 Hz), 2.26 (d, 2H, J = 16.2 Hz), 2.48 (s, 4H), 5.03 (s, 1H), 7.09 (dt, 1H, J_1 = 7.6 Hz, J_2 = 1.6 Hz), 7.19 (dt, 1H, J_1 = 7.6 Hz, J_2 = 1.1 Hz), 7.26 (dd, 1H, J_1 = 7.9 Hz, J_2 = 1.0 Hz),), 7.46 (d, 1H, J = 7.3 Hz). ^{13}C NMR ($CDCl_3$, 125 MHz), δ: 27.79, 29.69, 32.28, 32.43, 41.25, 51.14, 114.13, 126.74, 128.20, 130.56, 133.34, 133.88, 140.32, 163.37, 196.84.

3,4,6,7-Tetrahydro-3,3,6,6-tetramethyl-9-(3-chlorophenyl)-2H-xanthene-1,8-(5H,9H)-dione (6e). mp 184–186°C, (ref. 32, 182–184°C); ^1H NMR ($CDCl_3$, 500 MHz), δ: 0.99 (s, 6H), 1.09 (s, 6H), 2.17 (d, 2H, J = 16.2 Hz), 2.22 (d, 2H, J = 16.2 Hz), 2.46 (s, 4H), 4.71 (s, 1H), 7.06 (dt, 1H, J_1 = 9.1 Hz, J_2 = 1.5 Hz), 7.13 (t, 1H, J = 7.9 Hz), 7.21 (d, 1H, J = 1.2 Hz),), 7.23 (t, 1H, J = 1.3 Hz). ^{13}C NMR ($CDCl_3$, 125 MHz), δ: 27.79, 29.62, 32.16, 32.63, 41.27, 51.13, 115.51, 127.05, 127.40, 128.75, 129.65, 134.28, 146.54, 162.99, 196.67.

3,4,6,7-Tetrahydro-3,3,6,6-tetramethyl-9-(4-nitrophenyl)-2H-xanthene-1,8-(5H,9H)-dione (6f). mp 222–223°C, (ref. 32, 221–223°C); ^1H NMR ($CDCl_3$, 500 MHz), δ: 1.02 (s, 6H), 1.15 (s, 6H), 2.20 (d, 2H, J = 16.3 Hz), 2.29 (d, 2H, J = 16.3 Hz), 2.53 (s, 4H), 4.86 (s, 1H), 7.51 (dd, 2H, J_1 = 7.0 Hz, J_2 = 1.7 Hz), 8.12 (dd, 2H, J_1 = 7.0 Hz, J_2 = 1.7 Hz). ^{13}C NMR ($CDCl_3$, 125 MHz), δ: 27.70, 29.64, 32.64, 32.79, 41.27, 51.03, 114.96, 123.83, 129.78, 146.92, 151.94, 163.36, 196.63.

3,4,6,7-Tetrahydro-3,3,6,6-tetramethyl-9-(2-nitrophenyl)-2H-xanthene-1,8-(5H,9H)-dione (6g). mp 252–254°C, (ref. 32, 248–249°C); ^1H NMR ($CDCl_3$, 500 MHz), δ: 0.98 (s, 6H), 1.07 (s, 6H), 2.13 (d, 2H, J = 16.2 Hz), 2.21 (d, 2H, J = 16.2 Hz), 2.45 (s, 4H), 5.51 (s, 1H), 7.21 (dt, 1H, J_1 = 7.7 Hz, J_2 = 1.4 Hz), 7.34 (d, 1H, J = 7.5 Hz), 7.41 (dt, 1H, J_1 = 7.5 Hz, J_2 = 1.2 Hz),), 7.73 (d, 1H, J = 8.1 Hz). ^{13}C NMR ($CDCl_3$, 125 MHz), δ: 28.00, 29.16, 29.36, 32.48, 41.26, 51.04, 114.60, 125.03, 127.59, 131.46, 132.40, 138.46, 150.27, 163.44, 196.73.

3,4,6,7-Tetrahydro-3,3,6,6-tetramethyl-9-(3-nitrophenyl)-2H-xanthene-1,8-(5H,9H)-dione (6h). mp 170–172°C, (ref. 32, 170–172°C); ^1H NMR ($CDCl_3$, 500 MHz), δ: 0.98 (s, 6H), 1.10 (s, 6H), 2.15 (d, 2H, J = 16.3 Hz), 2.24 (d, 2H, J = 16.3 Hz), 2.49 (s, 4H), 4.82 (s, 1H), 7.38 (t, 1H, J = 7.9 Hz), 7.79 (d, 1H, J = 7.7 Hz), 7.96 (dd, 1H, J_1 = 8.0 Hz, J_2 = 1.9 Hz),), 8.02 (t, 1H, J = 1.9 Hz). ^{13}C NMR ($CDCl_3$, 125 MHz), δ: 27.72, 29.61, 32.52, 32.66, 41.23, 51.06, 114.96, 122.06, 123.02, 129.21, 136.07, 146.74, 148.73, 163.46, 196.76.

3,4,6,7-Tetrahydro-3,3,6,6-tetramethyl-9-(4-methoxyphenyl)-2H-xanthene-1,8-(5H,9H)-dione (6i). mp 242–244°C, (ref. 32, 240–242°C); ^1H NMR ($CDCl_3$, 500 MHz), δ: 0.98 (s, 6H), 1.08 (s, 6H), 2.15 (d, 2H, J = 16.3 Hz), 2.21 (d, 2H, J = 16.3 Hz), 2.44 (s, 4H), 3.71 (s, 3H), 4.68 (s, 1H), 6.74 (dd, 2H, J_1 = 6.8 Hz, J_2 = 1.9 Hz), 7.19 (dd, 2H, J_1 = 6.8 Hz, J_2 = 1.9 Hz). ^{13}C NMR ($CDCl_3$, 125 MHz), δ: 27.76, 29.69, 31.38, 32.61, 41.29, 51.20, 55.52, 113.89, 116.21, 129.73, 136.98, 158.38, 162.48, 196.86.

3,4,6,7-Tetrahydro-3,3,6,6-tetramethyl-9-p-tolyl-2H-xanthene-1,8-(5H,9H)-dione (6j). mp 215–217°C, (ref. 32, 217–218°C); ^{1}H NMR ($CDCl_3$, 500 MHz), δ: 0.98 (s, 6H), 1.09 (s, 6H), 2.15 (d, 2H, J = 16.3 Hz), 2.20–2.23 (m, 5H), 2.45 (s, 4H), 4.70 (s, 1H), 7.00 (d, 2H, J = 8.0 Hz), 7.17 (d, 2H, J = 8.0 Hz). ^{13}C NMR ($CDCl_3$, 125 MHz), δ: 21.47, 27.80, 29.69, 31.86, 32.62, 41.30, 51.20, 116.19, 128.66, 129.20, 136.17, 141.63, 162.51, 196.80.

3,4,6,7-Tetrahydro-9-(4-(2,3,4,5,6,7,8,9-octahydro-3,3,6,6-tetramethyl-1,8-dioxo-1H-xanthen-9-yl)phenyl)-3,3,6,6-tetramethyl-2H-xanthene-1,8(5H,9H)-dione (6k). mp >300°C (dec.), (ref. 34, >300°C); ^{1}H NMR ($CDCl_3$, 500 MHz), δ: 0.87 (s, 12H), 0.99 (s, 12H), 2.07 (d, 4H, J = 16.2 Hz), 2.11 (d, 4H, J = 16.2 Hz), 2.33 (d, 4H, J = 17.6 Hz), 2.39 (d, 4H, J = 17.6 Hz), 4.59 (s, 2H), 6.99 (s, 4H); ^{13}C NMR ($CDCl_3$, 125 MHz), δ: 27.80, 29.41, 31.03, 32.57, 41.12, 51.10, 115.91, 128.16, 142.15, 162.93, 196.73.

3,4,6,7-Tetrahydro-9-(3-(2,3,4,5,6,7,8,9-octahydro-3,3,6,6-tetramethyl-1,8-dioxo-1H-xanthen-9-yl)phenyl)-3,3,6,6-tetramethyl-2H-xanthene-1,8(5H,9H)-dione (6l). mp 238–240°C, (ref. 32, 236–238°C); ^{1}H NMR ($CDCl_3$, 500 MHz), δ: 1.03 (s, 12H), 1.11 (s, 12H), 2.16 (d, 4H, J = 16.2 Hz), 2.21 (d, 4H, J = 16.2 Hz), 2.46 (d, 4H, J = 17.4 Hz), 2.56 (d, 4H, J = 17.4 Hz), 4.72 (s, 2H), 7.07–7.09 (m, 3H), 7.15 (s, 1H). ^{13}C NMR ($CDCl_3$, 125 MHz), δ: 28.02, 29.57, 31.76, 32.56, 41.27, 51.27, 116.01, 126.84, 128.18, 128.66, 144.04, 162.72, 196.66.

3,4,6,7-Tetrahydro-3,3,6,6-tetramethyl-9-(pyridin-3-yl)-2H-xanthene-1,8(5H,9H)-dione (6m). mp 184–186°C, (ref. 34, 184–186°C); ^{1}H NMR ($CDCl_3$, 500 MHz), δ: 1.01 (s, 6H), 1.12 (s, 6H), 2.18 (d, 2H, J = 16.3 Hz), 2.26 (d, 2H, J = 16.3 Hz), 2.50 (s, 4H), 4.73 (s, 1H), 7.16–7.18 (m, 1H), 7.72–7.75 (dt, 1H, J_1 = 7.8 Hz, J_2 = 1.9 Hz), 8.36 (dd, 1H, J_1 = 4.7 Hz, J_2 = 1.5 Hz), 8.45 (d, 1H, J = 1.9 Hz); ^{13}C NMR ($CDCl_3$, 125 MHz), δ: 27.79, 29.58, 32.63, 41.20, 51.03, 115.11, 123.44, 136.96, 140.07, 148.04, 149.90, 163.24, 196.73.

3,4,6,7-Tetrahydro-3,3,6,6-tetramethyl-9-styryl-2H-xanthene-1,8-(5H,9H)-dione (6n). mp 174–176°C, (ref. 32, 176–178°C); ^{1}H NMR ($CDCl_3$, 500 MHz), δ: 1.16 (s, 12H), 2.31 (d, 2H, J = 16.3 Hz), 2.35 (d, 2H, J = 16.3 Hz), 2.45 (d, 2H, J = 18.7 Hz), 2.50 (d, 2H, J = 17.8 Hz), 4.44 (d, 1H, J = 6.0 Hz), 6.30 (d, 1H, J = 16.0 Hz), 6.36 (dd, 1H, J_1 = 16.0 Hz, J_2 = 6.0 Hz), 7.17–7.20 (m, 1H), 7.26 (t, 2H, J = 7.5 Hz), 7.31 (dd, 2H, J_1 = 7.1 Hz, J_2 = 1.4 Hz). ^{13}C NMR ($CDCl_3$, 125 MHz), δ: 28.02, 28.32, 29.66, 32.62, 41.38, 51.28, 114.95, 126.77, 127.51, 128.70, 130.84, 131.76, 137.69, 163.44, 196.91.

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