

A green procedure for synthesis of xanthene derivatives: Micellar solution of sodium dodecylphosphonate catalyzes condensation reaction of aldehydes and β -naphthol in aqueous media

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ABSTRACT

A green and convenient methode for the synthesis of a variety of xanthene derivatives by condensation reaction between aldehydes and β -naphthol or dimedone in an micellar solution of sodium dodecylphosphonate is described. This method offers several advantages, such as using of a cheap and environmentally benign reaction media, low loadings of sodium dodecylphosphonate as catalyst and easy work-up.

Keywords: β -Naphthol, Dimedone, Adehydyes, Micellar media, Sodium dodecylphosphonate, Xanthenes.

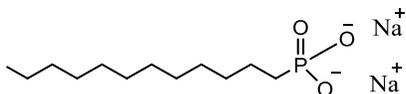
1. Introduction

Since that heterocyclic compounds are widely used in various fields of sciences and technology, the preparation of these compounds, especially xanthene's derivatives is an important part of synthetic organic chemistry. These compounds can be used as dyes [1], in laser technologies [2], fluorescent spectroscopy [3] and peptide synthesis [4]. In addition, xanthenes are reported as important antibacterial [5], antiviral [6] and anti-inflammatory agents [7]. Many synthetic methods exist for the synthesis of 14-aryl-14H-dibenzoxanthenes, including the cyclocondensation reaction of 2-hydroxyaromatic aldehydes and 2-tetralone [8], the reaction of benzaldehyde and acetophenone [9], and the condensation of β -naphthol with alkyl or aryl aldehydes. The xanthene synthesis by the later method is promoted by many acidic catalysts such as; H_2SO_4/Ac_2O [10], *p*-toluenesulfonic acid [11], sulfamic acid [12], Montmorillonite K10 [13], Amberlyst-15 [14], $K_5CoW_{12}O_{40} \cdot 3H_2O$ [15], cellulose [MIMPS]HSO₄ [16], iodine [17], cyanuric chloride [18], LiBr [19], $HClO_4 \cdot SiO_2$ [20], $KAl(SO_4)_2 \cdot 12H_2O$ [21], silica sulfuric acid [22], dodecyl phosphonic acid [23], $Yb(OTf)_3$ [24], PEG-OSO₃H [25], $H_5PW_{10}V_2O_{40}$ [26] and saccharin sulfonic acid [27].

Despite the widely applications of acidic catalysts in synthesis of xanthene's derivatives, alkaline catalysts have not been considered. Only one alkaline catalyst has been reported which is sodium lauryl sulphate [28].

The best procedure for the synthesis of 1,8-dioxo-octahydroxanthenes is the condensation of dimedone with aldehydes. This reaction is catalyzed by silica chloride [29], ferric hydroger sulfate [30], Vanadatesulfuric acid nanorod particles [31], PPA-SiO₂ [32], DABCO [33], TMSCl [34], silica-supported $H_{14}[NaP_5W_{30}O_{110}]$ nanoparticles [35], $SbCl_3/SiO_2$ [36] and $ZrO(OTf)_2$ [37]. However, reported procedures have considerable drawbacks for example low yields, long reaction times, difficulties in work-up, use of an excess of reagents/ catalysts, harsh reaction conditions, and use of toxic organic solvents. Therefore, development of more efficient route for the synthesis of xanthenes is still needed. Recently, the use of water as reaction media has recieved much attention in organic synthesis. Because water is the cheapest, most plentiful and non-toxic chemical in environment. On the other hand, surfactants among the most important materials used in almost every chemical industry, including detergents, paints, dyestuffs, cosmetics, pharmaceuticals, agrochemicals, fibers and plastics [38]. These compounds have bifunctional chemical structure. Therefore, they can cause the organic

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Scheme 1. The structure of Sodium dodecylphosphonate.

reactions to be performed in aqueous media at the critical micelle concentrations point (CMC). Sodium dodecylphosphonate (Na_2DP) is a solid alkaline surfactant (Scheme 1). Here in, we have used it as a efficient micellar and basic catalyst for the synthesis of xanthene derivatives from aldehydes and β -naphthol or dimedone in aqueous media.

2. Experimental

NMR spectra were recorded on a Bruker (^1H NMR 400 MHz and ^{13}C NMR 100 MHz). IR spectra were obtained using a Vertex 70 Bruker FT-IR 8300 spectrophotometer. Melting points were determined in open capillary tubes in a Büchi-545 circulating oil melting point apparatus and for the conductivity measurements of the sodium dodecylphosphonate and determination of CMC, a Metrohm Model 721 conductivity meter was used. Material purchased from Fluka, Aldrich and Merck Chemical Companies.

2.1. Preparation of benzoxanthenes and 1,8-dioxo-octahydroxanthenes in the presence of sodium dodecylphosphonate

A mixture of the aldehyde (1 mmol), β -naphthol (2 mmol) or dimedone (2 mmol) and sodium dodecylphosphonate (3.2 mg) was added to 5 ml of water. The reaction mixture was refluxed at 100°C for the appropriate time (Table 2 and 3). With progress of the reaction, the corresponding product was precipitated in reaction vessel. Completion of the reaction was determined by TLC. Then the mixture was centrifuged and filtrated. The solid product was isolated without any more purification.

Selected spectral data:

1- ((2- hydroxynaphthalen-1-yl) (phenyl) methyl) naphthalen-2-ol (Table 2, Entry 6):

Oil; IR (KBr): $\bar{\nu} = 3214, 3083, 1417, 1111, 760$; ^1H NMR (400 MHz, CDCl_3): $\delta = 5.50$ (s, 1H, CH), 6.61 (s, 2H, OH), 6.99-8.60 (m, 17H, ArH); ^{13}C NMR (100 MHz, CDCl_3): $\delta = 29.7, 117.3, 118.0, 122.7, 124.2, 126.4, 126.8, 128.2, 128.4, 128.8, 128.8, 131.0, 131.4, 145.0, 148.8, 151.1, 151.4$.

4- (bis(2- hydroxynaphthalen-1-yl) methyl) benzonitrile (Table 2, Entry 7):

White solid; m.p.= $225-227^\circ\text{C}$, IR (KBr): $\bar{\nu} = 3206, 2237, 1622, 1602, 1514, 1258, 1210, 1140, 814, 743, 552$; ^1H NMR (400 MHz, CDCl_3): $\delta = 5.31$ (s, 1H, CH),

6.86 (s, 2H, OH), 7.05-7.29 (m, 5H, ArH), 7.35-7.48 (m, 7H, ArH), 7.51-7.92 (m, 4H, ArH); ^{13}C NMR (100 MHz, CDCl_3): $\delta = 29.7, 110.3, 117.3, 118.0, 122.7, 124.2, 126.4, 126.8, 128.2, 128.5, 128.8, 128.8, 131.0, 131.4, 135.0, 148.7, 151.1, 151.4$.

9-(2,4-dichlorophenyl-3,4,6,7-tetrahydro-3,3,6,6-tetramethyl-2H-xanthene-1,8 (5H,9H) -dione (Table 3, Entry 4):

White solid; m.p.= 254°C ; IR (KBr): $\bar{\nu} = 2967, 1706, 1590, 1493, 1376, 1314, 1213, 1048, 761, 699$; ^1H NMR (400 MHz, $\text{DMSO}-d_6$): $\delta = 0.93$ (s, 6H, 2CH₃), 1.08 (s, 6H, 2CH₃), 2.05-2.14 (m, 4H, 2CH₂), 2.15-2.50 (m, 4H, 2CH₂), 4.50 (s, 1H, CH), 7.00-7.46 (m, 3H, ArH); ^{13}C NMR (100 MHz, $\text{DMSO}-d_6$): $\delta = 27.9, 29.6, 32.7, 33.8, 34.3, 43.8, 48.9, 50.2, 110.3, 129.4, 129.8, 132.2, 134.0, 134.5, 141.7, 169.8, 198.3$.

3. Results and Discussion

The current paper describes a green and easy method for the synthesis of xanthene derivatives. At the beginning, to optimize the reaction conditions, the critical micelle concentrations (CMC) of sodium dodecylphosphonate (Na_2DP) in pure water were determined by conductometry method. In Fig. 1 the conductivity vs. concentration of Na_2DP are presented in water at room temperature. In order to estimate the values of CMC, we fit the linear fragments, above and below the breaks and we treat the concentration at which intersection of these lines occurs as the CMC. The CMC was obtained 1.6 mM.

Then, we studied the reaction of 4-nitrobenzaldehyde (1 mmol) and β -naphthol (2 mmol) in different amounts of sodium dodecylphosphonate in water at reflux conditions (Fig. 2). The best result was obtained in 1.4 CMC (3.2 mgr) of Na_2DP (Table 1, Entry 2) and use of higher amount of the catalyst did not show further increase in the conversion or shorter reaction time.

After that, the generality of this method was tested by

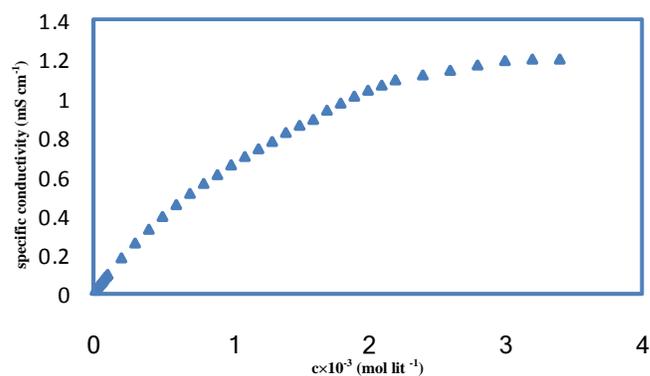


Fig. 1. Conductivity of Na_2DP in water at room temperature.

Table 1. Effect of various amounts of Na₂DP on xanthenes synthesis.

Entry	Na ₂ DP	Time (h)	Isolated Yield (%)
1	1CMC	24	80
2	1.4CMC	6:40	98
3	2CMC	24	50
4	2.5CMC	24	50

various aromatic aldehydes and β -naphthol under the optimized reaction conditions (Table 2).

According to the obtained results, which have been shown in Table 2, aromatic aldehydes bearing electron-withdrawing groups are reacted in high yields. However aldehydes with electron-donating groups (Entries 8 and 9, Table 2) are not reacted in the same conditions. Benzaldehyde and 4-cyanobenzaldehyde (Entries 6 and 7, Table 2) converted to the corresponding diol.

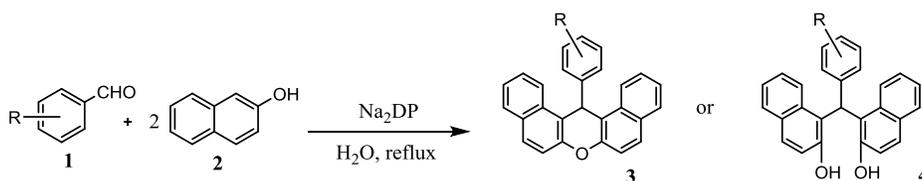
A probable mechanism was reported in Fig. 2.

In line with our studies, we decided to examine reactivity of sodium dodecylphosphonate in the synthesis of 1,8-dioxo-octahydroxanthenes. In optimized conditions for the preparation of benzoxanthenes, we studied the behavior of a range of aldehydes in the reaction with dimedone. The obtained results from this study were shown in Table 3.

As it is shown in Table 3, aromatic aldehydes including electron-withdrawing and electron-donating groups created the corresponding 1,8-dioxo-octahydroxanthenes in high yields. This can be probably related partially to the more acidity strength of α -hydrogen in dimedone vs 2-naphthol. While the cyano- and nitro- derivatives of aldehydes were converted to corresponding diols.

A comparison among this catalyst (Na₂DP) and sodium lauryl sulphate for the synthesis of benzoxanthenes shows clearly that Na₂DP promote the reaction more efficiently than sodium lauryl sulphate [28].

Table 2. Synthesis of Xanthene Derivatives in the Presence of Na₂DP in water.



Entry	R-	Time (h)	Product	Isolated Yield (%)	m.p. (°C)		
					Found	Reported	Ref.
1	4-Cl	2:40	3a	95	291	289-291	[27]
2	4-Br	6	3b	95	297	298-300	[27]
3	4-F	7	3c	93	238	236-238	[16]
4	4-NO ₂	6:40	3d	96	315	310-311	[27]
5	2,4-di-Cl	48	3e	96	255	253-255	[40]
6	H-	24	4a	92	Oil	-	-
7	4-CN	46	4b	95	225-227	-	-
8	4-Me	48	-	-	-	-	-
9	4-MeO	48	-	-	-	-	-

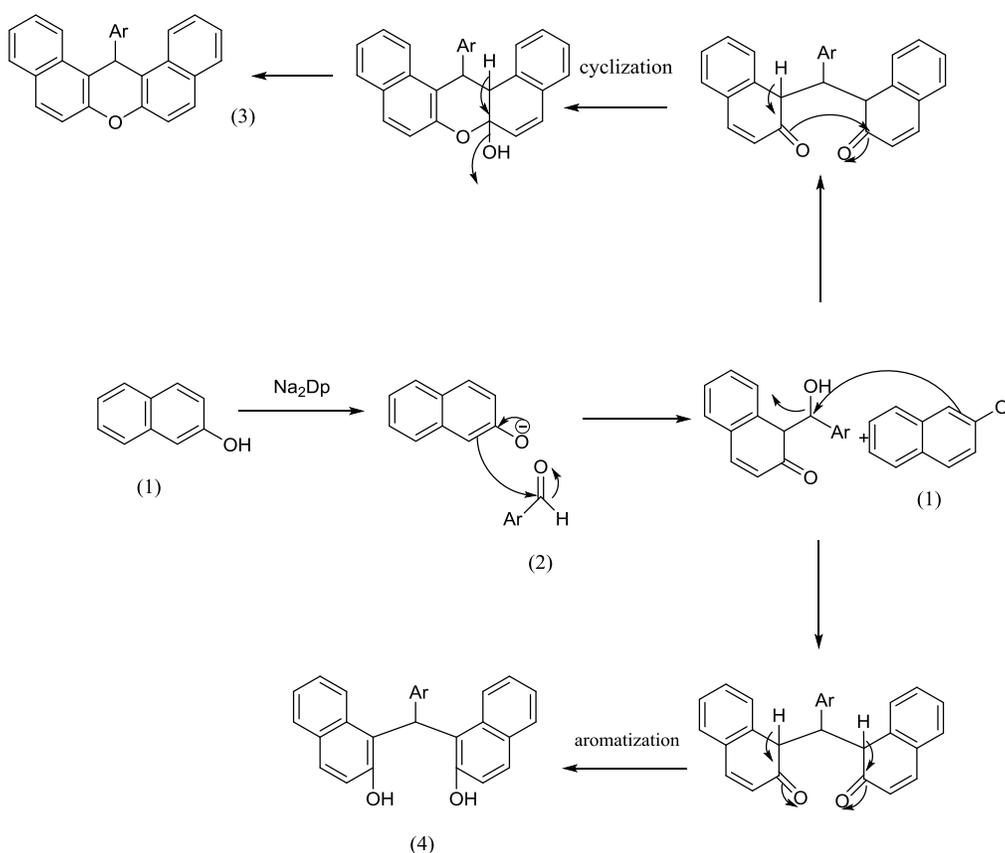
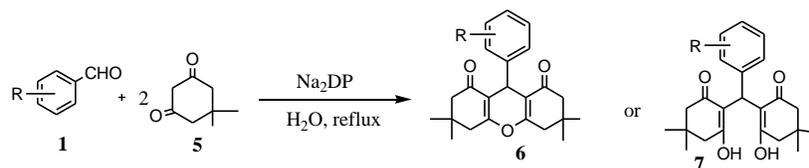


Fig. 2. Proposed mechanism for the reaction.

Table 3. Synthesis of 1,8-dioxo-octahydroxanthenes by Na₂DP in water.



Entry	R-	Time (h)	Product	Isolated Yield (%)	m.p. (°C)		
					Found	Reported	Ref.
1	4-Cl	24	6a	98	230	229-231	[31]
2	4-Br	24	6b	90	239-241	240-242	[35]
3	4-F	24	6c	77	232	232-233	[31]
4	2,4-di -Cl	48	6d	91	254	251-253	[32]
5	H-	24	6e	98	204	202-205	[31]
6	4-Me	24	6f	73	210-211	216-218	[31]
7	4-MeO	24	6g	82	202	201-202	[31]
8	4-NO ₂	24	7a	92	183-186	-	-
9	4-CN	48	7b	91	165-166	-	-

4. Conclusions

In this paper, an efficient, green and safe methodology for the preparation of 14-aryl-14*H*-dibenzoxanthenes and 1,8-dioxo-octahydroxanthenes was reported. On the other hand, acyclic intermediates that are produced in current reaction (Table 2, Entries 6 and 7, Table 3, Entries 8 and 9) are important ligands for the synthesis of organometallic compounds [39]. Furthermore, this method offer several additional advantages such as high conversion, employ of green media, clean reaction profiles, simple experimental and work up procedures.

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References

- [1] K. Singh, D. Arora, S. Singh, *Tetrahedron Lett.*, 47 (2006) 4205-4207.
- [2] S. Ko, C.F. Yao, *Tetrahedron Lett.*, 47 (2006) 8827-8829.
- [3] R.J. Sarma, J.B. Baruah, *Dyes Pigments*, 64 (2005) 91-92.
- [4] (a) O. Sirkecioglu, N. Talinli, A. Akar, *J. Chem. Res.(S)*, (1995) 502-506; (b) M. Ahmad, T. A. King, D.O. Ko, B.H. Cha, J. Lee, *J. Phys. D: Appl. Phys.*, 35 (2002) 1473-1476.
- [5] J.P. Bacci, A.M. Kearney, D.L. Van Vranken, *J. Org. Chem.*, 70 (2005) 9051-9053.
- [6] C.G. Knight, *J. Biochem.*, 258 (1989) 683-687.
- [7] K. Chibale, M.R. Visser, D. Van Schalkwyk, P.J. Smith. *Tetrahedron*, 59 (2003) 2289-2296.
- [8] A. Jha, J. Beal, *Tetrahedron Lett.*, 45 (2004) 8999-9001.
- [9] C.W. Kuo, J.M. Fang, *Synth. Commun.*, 31 (2001) 877-892.
- [10] R.J. Sarma, J.B. Baruah, *Dyes Pigments*, 64 (2005) 91-92.
- [11] A.R. Khosropour, M.M. Khodaei, H.A. Moghannian, *Synlett*, (2005) 955-958.
- [12] B. Rajitha, B.S. Kumar, Y.T. Reddy, P. Reddy, N. Sreenivasulu, *Tetrahedron Lett.*, 46 (2005) 8691-8693.
- [13] A. Sharifi, S. Abaee, A. Tavakkoli, M. Mirzaei, A. Zolfaghareh, *Synth. Commun.*, 38 (2008) 2958-2966.
- [14] S. Ko, C.F. Yao, *Tetrahedron Lett.*, 47 (2006) 8827-8829.
- [15] L. Nagarapu, S. Kantevari, V.C. Mahankhali, S. Apuri, *Catal. Commun.*, 8 (2007) 1173-1300.
- [16] L. Khazdooz, A. Zarei, A.R. Hajipour, N. Sheikhan, *Iranian J. Catal.*, 1 (2011) 1-9.
- [17] B. Das, B. Ravikanth, R. Ramu, K. Laxminarayana, B. V. Rao, *J. Mol. Catal. A Chem.*, 255 (2006) 74-82.
- [18] M.A. Bigdeli, M.M. Heravi, G.H. Mahdavinia, *Catal. Commun.*, 8 (2007) 1595-1598.
- [19] A. Saini, S. Kumar, J. S. Sandhu, *Synlett*, (2006) 1928-1932.
- [20] M.A. Bigdeli, M.M. Heravi, G. H. Mahdavinia, *J. Mol. Catal. A Chem.*, 275 (2007) 25-29.
- [21] M. Dabiri, M. Baghbanzadeh, M.S. Nikcheh, E. Arzroomchilar, *Bioorg. Med. Chem. Lett.*, 18 (2008) 436-438.
- [22] M. Seyyedhamzeh, P. Mirzaei, A. Bazgir, *Dyes Pigments*, 76 (2008) 836-839.
- [23] S. Ghassamipour, A.R. Sardarian, *Tetrahedron Lett.*, 50 (2009) 514-519.
- [24] W. Su, K.D. Yang, C. Jin, B. Zhang, *Tetrahedron Lett.*, 49 (2008) 3391-3394.
- [25] M.N. Kalla Reddi, K. Balam Satheesh, A.K. Mungara, A. Palanisamy, L. Shaik. I.K. Ola, *Molecules*, 17 (2012) 7543-7555.
- [26] R. Tayebee, S. Tizabi, *Chin J Catal.*, 33 (2012) 962-969.
- [27] A. Zare, M. Mokhlesi, A.R. Hasaninejad, T. Hekmat-Zadeh, *E. J. Chem*, 9 (2012) 1854-1863.
- [28] G. Kakade, B. Madje, M. Ware, M. Shingare, *Bull. Catal. Soc. India*, 6 (2007) 99-103.
- [29] B. Das, P. Thirupathi, K. Reddy, B. Ravikanth, L. Nagarapu, *Catal. Commun.*, 8 (2007) 535-538.
- [30] H.R. Shaterian, A. Hosseinian, M. Ghaghang, *Tur. J. Chem.*, 33 (2009) 233-240.
- [31] M. Naser-Esfahani, T. Abdizadeh, *J. Chem. Sci. Technol.* 2 (2013) 14-17.
- [32] R. Kantevari, R. Bantu, L. Nagarapu, *J. Mol. Catal. A: Chem.*, 269 (2007) 53-57.
- [33] C. Jiao, S. Jian, Y. Chaoguo, *Chem. Res. Chin. Univ.*, 27 (2011) 49-50.
- [34] S. Kantevari, R. Bantu, L. Nagarapu, *Arkivoc*, xvi (2006) 136-148.
- [35] A. Javid, M.M. Heravi, F.F. Bamoharram, *E. J. Chem.*, 8 (2011) 910-916.
- [36] Z.H. Zhang, Y.H. Liu, *Catal. Commun.*, 9 (2009) 1715-1719.
- [37] M. Moghadam, S. Tangestaninejad, V. Mirkhani, I. Mohammadpoor-Baltork, H.R. Tavakoli, *Chin. Chem. Lett.*, 22 (2011) 9-12.
- [38] M.J. Rosen J.T. Kunjappu, *Surfactants and Interfacial Phenomena*, ed. John Wiley & Sons Press, Hoboken, New Jersey, 2012.
- [39] K. Murtagh, B.A. Sweetman, P.J. Guiry, *Pure Appl. Chem.*, 78 (2006) 311-320.