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RESEARCH ARTICLE

Silica-Bonded *N*-Propyl Sulfamic Acid Catalyzed One-Pot Synthesis of Aryl-14-*H*-dibenzo[a,i]xanthenes

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Abstract: Aryl-14-*H*-dibenzo[a,i]xanthenes were synthesized efficiently by one-pot reaction of *β*-naphthol, aldehydes and 2-hydroxy-1,4-naphthoquinone in the presence of silica-bonded *N*-propyl sulfamic acid (SBNPSA) at 120 ^{o}C without solvent. All products were characterized by ^{1}H NMR, ^{13}C NMR, MS techniques and elemental analysis.

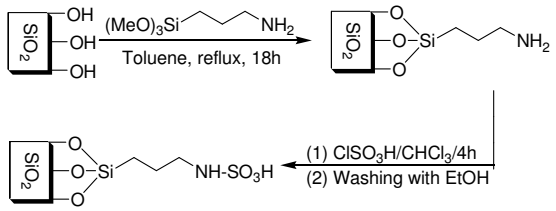
Keywords: Dibenzo[a,i]xanthenes, *β*-Naphthol, 2-Hydroxy-1,4-naphthoquinone, Silica-bonded *N*-propyl sulfamic acid (SBNPSA), Solvent-free

Introduction

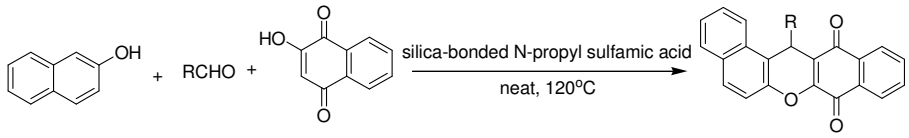
The synthesis of xanthene derivatives, particularly of benzo-fused xanthenes, has attracted considerable attention by chemists because of their biological and pharmaceutical properties, these compounds possess anti-inflammatory[1], antiviral[2] and antibacterial[3] activities and antagonists for the paralyzing acting of zoxazolamine[4]. Furthermore, these compounds can be used as dyes[3], pH-sensitive fluorescent materials for visualization of biomolecules[5] and utilized in laser technologies[6]. Thus, the synthesis of xanthenes derivatives currently is of much importance. Various methods[7] have been reported for the synthesis of these compounds. Considering the above reports, the development of new and simple synthetic methods for the efficient preparation of new dibenzo[a,i]xanthenes is therefore an interesting challenge.

In recent years, the search for environmentally benign chemical processes or methodologies has received much attention[8]. Heterogenization of homogeneous catalysts has been an interesting area of research from an industrial point of view; this combines the advantages of homogeneous catalysts (high activity, selectivity, *etc*.) with the engineering advantages of heterogeneous catalysts (easy catalyst separation, long catalytic life, easy catalyst regeneration, thermal stability and recyclability)[9].

The catalyst shows high thermal stability (up to 300 °C). We now report a simple and efficient route to synthesis of aryl-14-*H*-dibenzo[a,i]xanthenes using SBNPSA as a an efficient catalyst under solvent-free conditions (Scheme 2).



Scheme 1



Scheme 2

Experimental

NMR spectra were determined on Bruker AV-400 instrument at room temperature using TMS as internal standard, coupling constants (*J*) were measured in Hz; IR spectra were determined on FTS-40 infrared spectrometer; Elemental analysis were performed by a Vario-III elemental analyzer; Mass spectra were taken on a Macro mass spectrometer (Waters) by electro-spray method (ESIMS); Melting points were determined on a XT-4 binocular microscope and were uncorrected; SBNPSA was prepared according to literature[10]; Commercially available reagents were used throughout without further purification unless otherwise stated.

Preparation of SBNPSA catalyst

SBNPSA was prepared by the reaction of 3-aminopropylsilica and chlorosulfonic acid in chloroform. To a stirred mixture of 3-aminopropylsilica in dry chloroform, chlorosulfonic acid was added drop wise at 0 °C. HCl gas evolved from the reaction vessel immediately. Afterwards, the resulting mixture was stirred until HCl gas evolution was stopped. After completion of the reaction, the reaction mixture was filtered and then washed with ethanol to remove the unattached substrates. The thus obtained precipitate was dried overnight under reduced pressure at 40 °C to afford SBNPSA[10] (Scheme 1).

General procedure for the preparation of 4

A mixture of *β*-naphthol (1 mmol), aldehyde (1 mmol), 2-hydroxy-1,4-naphthoquinone (1 mmol) and SBNPSA (200 mg) was heated at 120 °C for an appropriate time and monitored by thin-layer chromatography (TLC) until the final conversion. After cooling, the reaction mixture was washed with $CHCl_3$ and filtered to recover the catalyst. The solvent was evaporated and the crude product purified by silica gel column chromatography using $CHCl_3$ as eluent to afford the pure product.

14-Phenyl-14H-dibenzo[a,i]xanthene-8,13-dione (**4a**)

Yellow powder, m.p. 319-320 °C; IR (KBr) *v*: 3082, 1663, 1635, 1590, 1575, 1370, 1286, 1237, 1213 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) *δ*: 8.17 (d, 1H, *J* = 7.6 Hz), 8.12 (d, 1H, *J* = 7.6 Hz), 7.99 (d, 1H, *J* = 8.4 Hz), 7.91-7.77 (m, 3H), 7.61-7.41 (m, 6H), 7.20 (t, 2H, *J* = 15.2

Hz), 7.12-7.09 (m, 1H), 5.95 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 178.33, 178.29, 157.19, 147.30, 143.12, 135.11, 131.89, 131.22, 131.01, 130.89, 130.03, 129.51, 129.39, 128.58, 128.55, 127.45, 126.84, 125.53, 124.53, 123.78, 116.88, 116.77, 116.57, 35.16; Anal. Calcd for $C_{27}H_{16}O_3$: C 83.49, H 4.15; found: C 83.25, H 4.12.

14-(4-Chlorophenyl)-14H-dibenzo[a,i] anthenes-8,13-dione (**4b**)

Yellow powder, m.p. 305-306 °C; IR (KBr) *v*: 3046, 1667, 1637, 1591, 1577, 1488, 1367, 1286, 1235, 1213 cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 8.16 (d, 1H, *J* = 7.6 Hz), 8.13 (d, 1H, *J* = 7.6 Hz), 7.92-7.77 (m, 4H), 7.62-7.44 (m, 4H), 7.34 (d, 2H, *J* = 8.4 Hz), 7.15 (d, 2H, *J* = 8.4 Hz), 5.90 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 178.24, 178.18, 157.30, 147.23, 141.59, 135.17, 132.65, 131.90, 131.39, 130.81, 130.68, 130.00, 129.96, 129.79, 129.47, 128.70, 128.65, 127.58, 125.67, 124.60, 123.57, 116.79, 116.26, 116.00, 34.62; Anal. Calcd for $C_{27}H_{15}ClO_3$: C 76.69, H 3.58; found: C 76.48, H 3.62.

14-(4-Methoxylphenyl)-14H-dibenzo[a,i] anthenes-8,13-dione (**4c**)

Yellow powder, m.p. 279-280 °C; IR (KBr) *v*: 2919, 1664, 1635, 1591, 1575, 1367, 1286, 1249, 1235, 1212 cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 8.16 (d, 1H, *J* = 8.0 Hz), 8.12 (d, 1H, *J* = 7.6 Hz), 7.98 (d, 1H, *J* = 8.4 Hz), 7.89-7.76 (m, 4H), 7.60-7.43 (m, 5H), 7.31 (d, 2H, *J* = 8.4 Hz), 5.90 (s, 1H), 3.69 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 178.41, 178.37, 158.26, 157.02, 147.23, 135.47, 135.10, 131.88, 131.17, 131.00, 130.95, 130.00, 129.58, 129.41, 129.38, 128.53, 127.41, 125.50, 124.50, 123.81, 117.06, 116.78, 113.90, 55.13, 34.28; Anal. Calcd for $C_{28}H_{18}O_4$: C 80.37, H 4.34; found: C 80.50, H 4.27.

14-(4-Methylphenyl)-14H-dibenzo[a,i]xanthene-8,13-dione (**4d**)

Yellow powder, m.p. 255-256 °C; IR (KBr) *v*: 2920, 1665, 1637, 1591, 1577, 1364, 1286, 1237, 1213 cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 8.16 (d, 1H, *J* = 8.0 Hz), 8.11 (d, 1H, *J* = 7.6 Hz), 7.99 (d, 1H, *J* = 8.0 Hz), 7.89-7.76 (m, 3H), 7.60-7.42 (m, 4H), 7.29 (d, 2H, *J* = 8.0 Hz), 7.00 (d, 2H, *J* = 7.6 Hz), 5.90 (s, 1H), 2.21 (s, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 178.34, 178.20, 157.08, 147.24, 140.27, 136.48, 135.08, 131.87, 131.16, 131.01, 130.92, 129.99, 129.41, 129.34, 129.24, 128.52, 128.42, 127.43, 125.50, 124.49, 123.78, 117.02, 116.78, 116.70, 34.70, 20.95; Anal. Calcd for $C_{28}H_{18}O_3$: C 83.57, H 4.51; found: C 83.49, H 4.63.

14-(4- Nitrophenyl)-14H-dibenzo[a,i]xanthene-8,13-dione (**4e**)

Yellow powder, m.p. 332-333 °C; IR (KBr) *v*: 3076, 1664, 1636, 1590, 1576, 1519, 1349, 1285, 1236, 1213 cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 8.20 (d, 1H, *J* = 7.6 Hz), 8.15 (d, 1H, *J* = 7.6 Hz), 8.06 (d, 2H, *J* = 8.8 Hz), 7.97-7.81 (m, 4H), 7.66-7.49 (m, 6H), 6.06 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 178.15, 177.98, 157.84, 150.06, 147.29, 146.68, 135.30, 131.99, 131.73, 130.65, 130.40, 130.32, 130.06, 129.63, 129.57, 128.83, 127.87, 125.91, 124.77, 123.88, 123.26, 116.83, 115.35, 115.03, 35.25; Anal. Calcd for $C_{27}H_{15}NO_5$: C 74.82, H 3.49, N 3.23; found: C74.91, H 3.38, N 3.29.

14-(3- Nitrophenyl)-14H-dibenzo[a,i] anthenes-8,13-dione (**4f**)

Yellow powder, m.p. 304-305 °C; IR (KBr) *v*: 3072, 1652, 1635, 1588, 1576, 1528, 1345, 1289, 1239, 1216 cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ: 8.22 (d, 1H, *J* = 8.0 Hz), 8.15 (d, 1H, *J* = 8.0 Hz), 8.12 (s, 1H), 8.00-7.82 (m, 6H), 7.66-7.61 (m, 2H), 7.52-7.41 (m, 3H), 6.06 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ: 178.14, 178.02, 157.73, 148.56, 147.33, 145.09, 135.31, 135.08, 132.03, 131.68, 130.60, 130.42, 130.35, 130.09, 129.59, 129.38, 128.87, 127.82, 125.85, 124.88, 123.32, 123.26, 122.14, 116.97, 115.27, 115.19, 35.20; Anal. Calcd for $C_{27}H_{15}NO_5$: C 74.82, H 3.49, N 3.23; found: C74.76, H 3.56, N 3.25.

14-(2,4-Dichlorophenyl)-14H-dibenzo[a,i]xanthene-8,13-dione (**4g**)

Yellow powder, m.p. 301-302 °C; IR (KBr) *v*: 3056, 1662, 1637, 1591, 1577, 1466, 1362, 1288, 1238, 1213 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) *δ*: 8.20 (d, 1H, *J* = 8.4 Hz), 8.16-8.11 (m, 2H), 7.89-7.80 (m, 3H), 7.65-7.45 (m, 4H), 7.31-7.27 (m, 2H), 7.07-7.05 (m, 1H), 6.14 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) *δ*: 178.10, 178.05, 157.55, 147.11, 139.20, 135.19, 134.02, 133.09, 132.61, 131.79, 131.52, 131.13, 130.60, 130.13, 130.01, 129.84, 129.47, 128.70, 127.69, 127.49, 125.69, 124.72, 123.71, 116.82, 33.24; Anal. calcd for $C_{27}H_{14}Cl_2O_3$: C 70.91, H 3.09; found: C 70.82, H 3.11.

14-(3,4-Dichlorophenyl)-14H-dibenzo[a,i]xanthene-8,13-dione (**4h**)

Yellow powder, m.p. 260-261 °C; IR (KBr) *v*: 3050, 1682, 1594, 1564, 1488, 1384, 1286, 1216 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) *δ*: 8.19 (d, 1H, *J* = 7.6 Hz), 8.16 (d, 1H, *J* = 7.6 Hz), 7.95-7.82 (m, 4H), 7.65-7.43 (m, 5H), 7.31-7.30 (m, 2H), 5.92 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) *δ*: 178.18, 178.02, 157.55, 147.28, 143.19, 135.24, 132.65, 131.96, 131.57, 131.05, 130.70, 130.54, 130.42, 130.10, 129.56, 128.75, 128.15, 127.77, 125.82, 124.73, 123.42, 116.83, 115.58, 115.44, 34.55; Anal. calcd for $C_{27}H_{14}Cl_2O_3$: C 70.91, H 3.09; found: C 70.95, H 3.02.

14-(2-Chlorophenyl)-14H-dibenzo[a,i]xanthene-8,13-dione (**4i**)

Yellow powder, m.p. 281-282 °C; IR (KBr) *v*: 3068, 1666, 1638, 1591, 1577, 1361, 1289, 1237, 1213 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) *δ*: 8.25-8.22 (m, 2H), 8.14 (d, 1H, *J* = 7.2 Hz), 7.89-7.83 (m, 3H), 7.65-7.29 (m, 6H), 7.08-7.04 (m, 2H), 6.22 (s, 1H); ^{13}C NMR ($CDCl_3$, 100 MHz) *δ*: 178.20, 178.13, 157.43, 147.12, 135.15, 133.32, 131.76, 131.36, 131.30, 130.81, 130.19, 130.13, 129.76, 129.40, 128.57, 128.23, 127.56, 127.11, 125.57, 124.67, 123.99, 116.82, 116.70, 115.61, 33.53; Anal. calcd for $C_{27}H_{15}ClO_3$: C 76.69, H 3.58; found: C 76.79, H 3.41.

Results and Discussion

Initially, we conducted the reaction of *β*-naphthol, benzaldehyde and 2-hydroxy-1, 4-naphthoquinone in the presence of SBNPSA at different temperatures under solvent-free conditions. The corresponding aryl-14-*H*-dibenzo[a,i]xanthenes was synthesized, The results were summarized in Table 1 and showed that the reaction using 5 mol % SBNPSA at 120 °C proceeded in highest yield.

Next, to optimize the amount of catalyst and the reaction temperature, the reaction of *β*-naphthol, benzaldehyde and 2-hydroxy-1,4-naphthoquinone was studied under solvent-free conditions in the presence of SBNPSA at different temperatures. The results were summarized in Table 1 and showed that the reaction using 200 mg/mmol SBNPSA at 120 °C proceeded in highest yield.

With this optimized procedure in hand, the scope of application of this three-component reaction was examined using different aldehydes as staring materials. As seen from Table 2, the structures of the products were established from their spectral properties (IR, ^1H NMR, ^{13}C NMR and elemental analysis). In these experiments the catalyst was isolated by filtration and could be recycled up to three times without significant loss of activity. When this reaction was carried out with an aliphatic aldehyde such as butanal or pentanal (Table 2), TLC and ^1H NMR spectra of the reaction mixture showed a combination of starting materials and numerous products, the yield of the expected product was very poor.

Table 1. Synthesis of aryl-14-*H*-dibenzo[a,i]xanthenes under various conditions[a]

Entry	SBNPSA, mg/mmol	Temp., °C	Time, h	Yield, %[b]
1	0	110	5	0
2	50	110	2	59
3	100	110	2	65
4	150	110	1	73
5	150	120	0.5	82
6	200	90	1	68
7	200	100	1	78
8	200	110	0.5	83
9	200	120	0.5	92
10	200	130	0.5	87
11	250	100	0.5	80
12	250	110	0.5	87
13	300	110	0.25	85

[a]*Reaction conditions: β-naphthol (1 mmol); benzaldehyde (1 mmol); 2-hydroxy-1,4-naphthoquinone (1 mmol); neat.* [b]*Isolated yield*

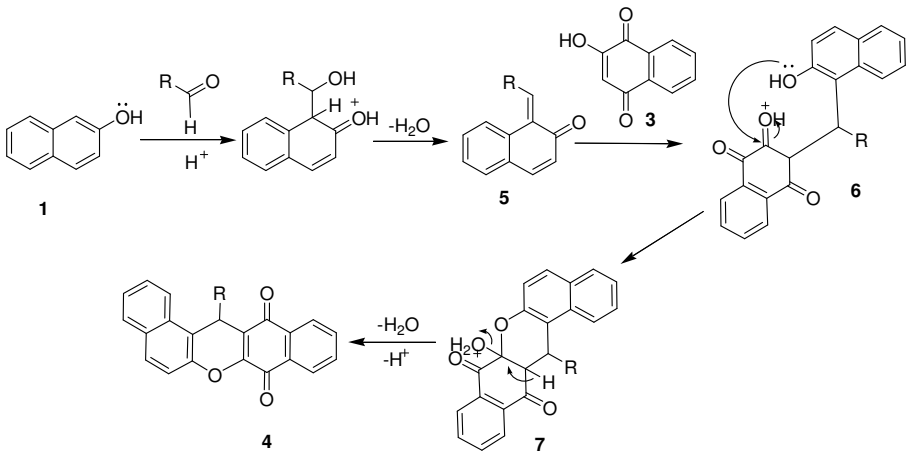
Table 2. Preparation of aryl-14-*H*-dibenzo[a,i]xanthenes[a]

Entry	R	Time /h	Product	Yield /%[b]
1	C_6H_5	0.75	**4a**	87 (80,54, 96)[c]
2	4-Cl-C_6H_4	0.75	**4b**	92
3	4-MeO-C_6H_4	0.5	**4c**	88
4	4-Me-C_6H_4	0.5	**4d**	90
5	4-NO_2-C_6H_4	0.5	**4e**	93
6	3-NO_2-C_6H_4	0.75	**4f**	91
7	2,4-Cl_2-C_6H_3	1	**4g**	86
8	3,4-Cl_2-C_6H_3	0.75	**4h**	87
9	2-Cl-C_6H_4	1	**4i**	89
10	butyl	1	**4j**	0
11	pentyl	1	**4k**	0

[a]*Reaction conditions: β-naphthol (1 mmol); aldehyde (1 mmol); 2-hydroxy-1,4-naphthoquinone (1 mmol); silica-based sulfonic acid (500 mg); 120 °C; neat.* [b]*Isolated yield.* [c]*Yield after the fifth cycle*

SBNPSA works under heterogeneous conditions, but its reaction centers are highly mobile, as in a homogeneous catalyst. It is an inexpensive and nonhazardous solid acid catalyst. It can easily be handled and removed from the reaction mixture by simple filteration. The recovered catalyst was reused consecutively 5 times with a minimum of variation of the yields of the products. This reusability demonstrates the high stability. The simplicity, together with the use of an inexpensive, nontoxic and environmentally benign catalyst under solvent-free conditions, is another remarkable feature of the procedure.

A tentative mechanism for this transformation is proposed in Scheme 3. We proposed that the reaction proceeded via a reaction sequence of condensation, addition, cyclization and dehydration. First, the formation of the intermediate (**5**) was based on the Knoevenagel condensation between β-naphthol (**1**) and aldehyde (**2**), the addition of (**5**) to (**3**) leading to the formation of (**6**), which on intermolecular cyclization gave rise to (**7**). In the last step, the intermediate product (**7**) undergoes dehydration to affords the corresponding products (**4a-4i**).



Scheme 3

Conclusion

We have developed a novel and highly efficient method for the synthesis of aryl-14-*H*-dibenzo[a,i]xanthene-8,13-diones by treatment of aromatic aldehydes, *β*-naphthol with 2-hydroxy-1,4-naphthoquinone in the presence of SBNPSA as catalyst. The significant advantages of this methodology are high yields, a simple work-up procedure, cleaner reaction, and easy preparation and handling of the catalyst. The catalyst can be recovered by filtration and reused.

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