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Catalytic application of *N*,2-dibromo-6-chloro-3,4-dihydro-2*H*-benzo[e][1,2,4]thiadiazine-7-sulfonamide 1,1-dioxide as a new catalyst for the synthesis of 9-aryl-1,8-dioxo-octahydroxanthenes under neutral media

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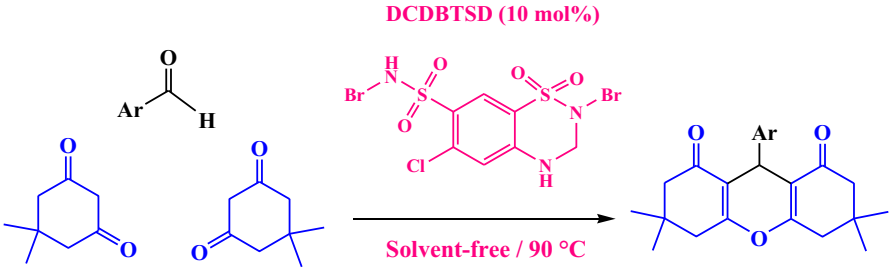
Abstract A new *N*-bromo sulfonamide reagent, namely *N*,2-dibromo-6-chloro-3,4-dihydro-2*H*-benzo[e][1,2,4]thiadiazine-7-sulfonamide 1,1-dioxide, was synthesized and used as a new and highly efficient catalyst for the preparation of 9-aryl-1,8-dioxo-octahydroxanthene derivatives by the condensation reaction of dimedone (5,5-dimethylcyclohexane-1,3-dione) and various arylaldehydes. Mechanistically, it is interesting that in situ generation of the Br^+ ion from the catalyst is successfully catalyzed by this reaction under neutral media.

Graphical Abstract



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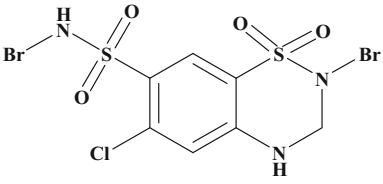
Introduction

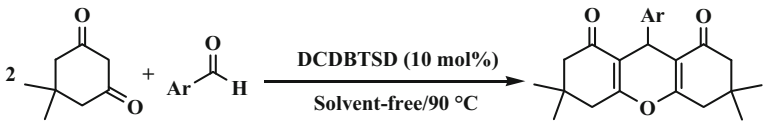
Solvent-free reactions have been demonstrated to be an efficient technique for various organic transformations instead of using harmful organic solvents. Solvent-free conditions often lead to a remarkable decrease in reaction times, increased yields, easier workup, matching with green chemistry protocols, and may enhance the regioselectivity and stereoselectivity of reactions [1–4].

Heterocycles are extensively applied in organic synthesis, pharmaceutical chemistry and industry. For example, xanthene derivatives have various significant biological activities. They are used as antibacterial, anti-inflammatory [5], and antiviral agents [6] and offer potential applications in photodynamic therapy [7]. Moreover, xanthenes are used as a bactericide [8], as dyes in fluorescent materials for visualization of bio-molecules [9], and in laser technology [10]. Some synthetic procedures, wherein suitable active methylene carbonyl compounds are condensed with aldehydes, are available for the synthesis of xanthenes derivatives. Moreover, several synthetic routes have been developed for the preparation of 9-aryl-1,8-dioxo-octahydroxanthenes via the condensation of dimedone (5,5-dimethylcyclohexane-1,3-dione) with aldehydes using various catalysts, such as nano-TiO_2 [11], P_2O_5/SiO_2 [12], $ZrOCl_2{\cdot}8H_2O$ [13], TCCA [14], silica sulfuric acid [15], Fe^{3+}-montmorillonite [16], DBH [17], TMSCl [18], $Fe(HSO_4)_3$ [19], [Msim]Cl [20], $[Et_3N–SO_3H]Cl$ [21], and PEG-SO_3H [22]. Nevertheless, because of the importance of 9-aryl-1,8-dioxo-octahydroxanthenes, introducing a highly efficient and eco-friendly catalyst with high novelty is still needed.

Some specific features of *N*-halo reagents, including the high activity of the *N*–*X* bond and the various modes of splitting of this bond, have led to their wide application in organic synthesis [23]. Due to the considerable characteristics of *N*-halo reagents and the use in applications of these compounds [24–27], a novel and effective *N*-halo reagent, namely *N*,2-dibromo-6-chloro-3,4-dihydro-2*H*-benzo[e][1,2,4] thiadiazine-7-sulfonamide 1,1-dioxide (DCDBTSD), was synthesized [28] (Scheme 1) and tested on the synthesis of 9-aryl-1,8-dioxo-octahydroxanthenes (Scheme 2).

Scheme 1 The structure of *N*,2-dibromo-6-chloro-3,4-dihydro-2*H*-benzo[e][1,2,4] thiadiazine-7-sulfonamide 1,1-dioxide (DCDBTSD)





Scheme 2 The synthesis of 9-aryl-1,8-dioxo-octahydroxanthenes

Experimental

General

Chemicals were purchased from Merck and Aldrich and used without further purification. All yields refer to isolated products after purification. The reactions were monitored by thin-layer chromatography (TLC) carried out on silica plates. The products were characterized by comparison of their physical data with those of known samples or by their spectral data. Infrared (IR) spectra were recorded on a Shimadzu IR 470 spectrophotometer. The ^{1}H NMR (500, 400 or 90 MHz) and ^{13}C NMR (100 MHz) were run on a Bruker-NMR spectrometer (δ in ppm) using TMS as an internal standard in chloroform ($CDCl_3$) and dimthylsulfoxide (DMSO) as the solvents. Mass spectra were recorded on an Agilent technologies (HP) 5973 network mass selective detector (MSD) operating at an ionization potential of 70 eV. Melting points were determined in open capillaries with a Stuart Scientific melting point apparatus. TLC was performed on silica–gel polygram SILG/UV 254 plates. Thermal gravimetry (TG) and differential thermal gravimetric (DTG) were analyzed by a Perkin Elmer Pyris 1. TG/DTG analysis was at 30–618 °C,with a temperature increase rate of 10 °C min^{-1}, and in nitrogen atmosphere. Melting points were recorded on a Stuart Scientific melting point apparatus in open capillary tubes. The crystal structure of the synthesized materials was determined using an X-ray diffractometer (XRD; Ital structure ADP 2000) at ambient temperature.

General procedure for the synthesis of DCDBTSD (Scheme 1)

A solution of sodium hydroxide (6 mol L^{-1}, 1 mL) was added dropwise to a stirring round-bottomed flask (50 mL) containing hydrochlorothiazide (0.60 g, 2 mmol) in distilled water (2 mL) during 10 min at room temperature. After the addition was completed, the reaction mixture was stirred for 20 min. Then, bromine (0.16 mL, 3 mmol) was slowly added to the stirring solution of hydrochlorothiazide during 15 min at 0 °C. The insoluble brominated catalyst was removed by filtration and washed with H_2O (10 mL) to giveDCDBTSD in 90 % yield (0.82 g) [25].

Spectral data of DCDBTSD

White solid; Yield: 90 %; mp 255 °C (mp 255 °C [25]); IR (KBr): 3377, 3232, 1579, 1495, 1362, 1308, 1244, 1147, 1058, 1025 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ (ppm) 4.70 (*s*, 2H), 6.85 (*s*, 1H), 7.20 (*s*, 1H), 7.88 (*s*, 1H), 8.07 (*s*,

1H);^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) 55.08, 107.26, 110.65, 122.57, 127.55, 136.34, 142.14; MS *m/z* observed: 455 (M^+), 438, 424.

General procedure for the synthesis of 9-aryl-1,8-dioxo-octahydroxanthene using DCDBTSD (Scheme 2) (compound 1–21)

A mixture of dimedone (2 mmol), aromatic aldehyde (1 mmol) and DCDBTSD (0.0455 g, 10 mol %) in a 10-mL round-bottomed flask connected to a reflux condenser was stirred in an oil bath (90 °C) for the appropriate time (Table 2). After completion of the reaction, as monitored by TLC, the reaction mixture was cooled to room temperature and recrystallized from ethanol (95 %). The pure products (compounds 1–21) were identified by IR, ^{1}H, ^{13}CNMR and MS spectra.

Spectral data of the products

*3,3,6,6-tetramethyl-9-phenyl-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8(2H)-dione (**1**)*

White solid; Yield: 85 %; mp 203–205 °C (lit. [14] mp 203–205 °C); IR (KBr) *v*/cm^{-1} 3062, 3032, 2957, 2915, 2871, 1678, 1662, 1625, 1467, 1454, 1362, 1199, 1140, 1002, 699, 555; ^{1}H NMR (500 MHz, DMSO-d_6) δ 0.90 (*s*, 6H), 1.04 (*s*, 6H), 2.09 (*d*, $J = 16.1$ Hz, 2H), 2.27 (*d*, $J = 16.2$ Hz, 2H), 2.53 (*d*, $J = 17.1$ Hz, 2H), 2.58 (*d*, $J = 17.7$ Hz, 2H), 4.53 (*s*, 1H), 7.10 (*t*, $J = 7.0$ Hz, 1H), 7.18 (*d*, $J = 7.0$ Hz, 2H), 7.21 (*t*, $J = 7.20$ Hz, 2H).

*3,3,6,6-tetramethyl-9-(2-nitrophenyl)-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8(2H)-dione (**2**)*

White solid; Yield: 82 %; mp 256–257 °C (lit. [14] mp 203–205 °C); IR (KBr) *v*/cm^{-1} 3099, 3062, 2960, 2932, 2872, 1680, 1666, 1625, 1607, 1527, 1205, 796, 576; ^{1}H NMR (90 MHz, $CDCl_3$) δ 0.99 (s, 6H, CH_3), 1.08 (*s*, 6H, CH_3), 2.18 (*s*, 4H), 2.47 (*s*, 4H), 5.52 (*s*, 1H), 7.35–7.70 (*b*, 4H).

*3,3,6,6-tetramethyl-9-(3-nitrophenyl)-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8(2H)-dione (**3**)*

White solid; Yield: 84 %; mp 173–174 °C (lit. [17] mp 170–171 °C); IR (KBr) *v*/cm^{-1} 3091, 2957, 1677, 1655, 1621, 1524, 1352, 1201, 1166, 1141, 1002, 692; ^{1}H NMR (90 MHz, $CDCl_3$) δ 0.97 (*s*, 6H, CH_3), 1.09 (*s*, 6H, CH_3), 2.18 (*s*, 4H), 2.49 (*s*, 4H), 4.80 (*s*, 1H), 7.28–8.00 (*b*, 4H).

*3,3,6,6-tetramethyl-9-(4-nitrophenyl)-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8(2H)-dione (**4**)*

White solid; Yield: 87 %; mp 237–238 °C (lit. [11] mp 224–226 °C); IR (KBr) *v*/cm^{-1} 2958, 2870, 1663, 1616, 1602, 1514, 1362, 1202, 1166, 868, 564; ^{1}H NMR

(90 MHz, $CDCl_3$) δ 0.99 (*s*, 6H, CH_3), 1.12 (*s*, 6H, CH_3), 2.21 (*s*, 4H), 2.50 (*s*, 4H), 4.82 (*s*, 1H), 7.47 (*d*, $J = 7.2$ Hz, 2H), 8.08 (*d*, $J = 7.47$ Hz, 2H).

*9-(2-chlorophenyl)-3,3,6,6-tetramethyl-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8(2H)-dione (**5**)*

White solid; Yield: 85 %; mp 226–228 °C (lit. [14] mp 225–227 °C); IR (KBr) *v*/cm^{-1} 2963, 1677, 1658, 1622, 1536, 1359, 1199, 1165, 1138, 1051, 1000, 838, 667; ^1H NMR (90 MHz, $CDCl_3$) δ 1.02 (*s*, 6H, CH_3), 1.08 (*s*, 6H, CH_3), 2.17 (*s*, 4H), 2.44 (*s*, 4H), 4.98 (*s*, 1H), 7.09–7.37 (*b*, 4H).

*9-(3-chlorophenyl)-3,3,6,6-tetramethyl-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8(2H)-dione (**6**)*

White solid; Yield: 87 %; mp 192–193 °C (lit. [17] mp 185–187 °C); IR (KBr) *v*/cm^{-1} 3082, 2957, 2879, 1676, 1661, 1626, 1465, 1359, 1200, 1164, 1137, 1000, 876, 806, 695, 456; ^1H NMR (90 MHz, $CDCl_3$) δ 0.98 (*s*, 6H, CH_3), 1.08 (*s*, 6H, CH_3), 2.19 (*s*, 4H), 2.46 (*s*, 4H), 4.70 (*s*, 1H), 7.10–7.20 (*b*, 4H).

*9-(4-chlorophenyl)-3,3,6,6-tetramethyl-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8(2H)-dione (**7**)*

White solid; Yield: 91 %; mp 238–240 °C (lit. [14] mp 233–235 °C); IR (KBr) *v*/cm^{-1} 2952, 2875, 1678, 1661, 1625, 1489, 1469, 1361, 1198, 1165, 1140, 1088, 851, 528; ^1H NMR (90 MHz, DMSO-*d*6) δ 0.89 (*s*, 6H, CH_3), 1.02 (*s*, 6H, CH_3), 2.16 (*s*, 4H), 2.52 (*s*, 4H), 4.49 (*s*, 1H), 7.10–7.25 (*b*, 4H).

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

White solid; Yield: 90 %; mp 226–227 °C; IR (KBr) *v*/cm^{-1} 2956, 2868, 1683, 1670, 1625, 1356, 1196, 1003, 810, 571; ^1H NMR (400 MHz, $CDCl_3$) δ 0.98 (*s*, 6H, CH_3), 1.07 (*s*, 6H, CH_3), 2.18 (*s*, 4H), 2.45 (*s*, 4H), 5.03 (*s*, 1H), 7.09 (1H), 7.24 (1H), 7.26 (1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 28.60, 30.35, 33.19, 33.80, 41.91, 51.82, 77.98, 78.30, 78.61, 114.68, 127.70, 129.82, 132.18, 133.08, 134.58, 143.62, 164.91, 198.18; MS *m/z* observed: 418 (M^+), 383, 273.

*9-(2,4-dichlorophenyl)-3,3,6,6-tetramethyl-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8 (2H)-dione (**9**)*

White solid; Yield: 93 %; mp 251–252 °C (lit. [18] mp 254–255 °C); IR (KBr) *v*/cm^{-1} 3071, 2962, 2932, 2877, 1680, 1660, 1623, 1585, 1473, 1358, 1198, 116, 567, 473; ^1H NMR (90 MHz, $CDCl_3$) δ 1.02 (*s*, 6H, CH_3), 1.07 (*s*, 6H, CH_3), 2.15 (*s*, 4H), 2.44 (*s*, 4H), 5.03 (*s*, 1H), 6.95–7.45 (*b*, 3H).

*9-(4-chloro-3-nitrophenyl)-3,3,6,6-tetramethyl-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8 (2H)-dione (**10**)*

White solid; Yield: 95 %; mp 258–260 °C; IR (KBr) ν/cm^{-1} 2963, 1658, 1622, 1536, 1475, 1360, 1199, 1165, 1138; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.01 (*s*, 6H, CH_3), 1.11 (*s*, 6H, CH_3), 2.20 (*s*, 4H), 2.49 (*s*, 4H), 4.76 (*s*, 1H), 7.40 (1H), 7.66 (2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 28.49, 30.33, 32.92, 33.39, 41.88, 51.71, 77.93, 78.25, 78.57, 115.27, 126.04, 126.18, 132.45, 135.27, 146.00, 148.69, 164.25, 198.18; IR (KBr, cm^{-1}): 2963, 1658, 1622, 1536, 1475, 1360, 1199, 1165, 138, 999, 825, 668, 572; MS *m/z* observed: 429 (M^+), 412, 382, 273.

*9-(2-fluorophenyl)-3,4,6,7-tetrahydro-3,3,6,6-tetramethyl-2H-xanthene-1,8 (5H, 9H)-dione (**11**)*

White solid; Yield: 85 %; mp 210–212 °C; IR (KBr) ν/cm^{-1} 2959, 2871, 1683, 1163, 1624, 1357, 1205, 1007, 792, 757, 573, 483; ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.97 (*s*, 6H, CH_3), 1.07 (*s*, 6H, CH_3), 2.19 (*s*, 4H), 2.44 (*s*, 4H), 4.82 (*s*, 1H), 6.92 (1H), 7.02 (1H), 7.44 (1H), 7.45 (1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 28.12, 29.35, 30.50, 33.26, 41.90, 51.82, 78.01, 78.33, 78.65, 114.69, 116.48, 116.70, 124.82, 129.30, 129.39, 131.15, 131.26, 133.15, 133.19, 161.22, 164.39, 198.01; IR (KBr, cm^{-1}): 2959, 2871, 1683, 1663, 1163, 1624, 1357, 1205, 1007; MS *m/z* observed: 368 (M^+), 311, 273.

*9-(3-fluorophenyl)-3,3,6,6-tetramethyl-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8 (2H)-dione (**12**)*

White solid; Yield: 90 %; mp 231–232 °C; IR (KBr) ν/cm^{-1} 2956, 1682, 1661, 1629, 1508, 1362, 1198, 1165, 851; ^{1}H NMR (90 MHz, $CDCl_3$) δ 0.98 (*s*, 6H, CH_3), 1.09 (*s*, 6H, CH_3), 2.18 (*s*, 4H), 2.45 (*s*, 4H), 4.71 (*s*, 1H), 6.78–7.23 (*b*, 4H).

*9-(4-fluorophenyl)-3,3,6,6-tetramethyl-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8 (2H)-dione (**13**)*

White solid; Yield: 86 %; mp 235–236 °C; IR (KBr) ν/cm^{-1} 2958, 2928, 2875, 1682, 1661, 1627, 1508, 1362, 1199, 1141, 851.^{1}H NMR (90 MHz, $CDCl_3$) δ 0.98 (*s*, 6H, CH_3), 1.01 (*s*, 6H, CH_3), 2.19 (*s*, 4H), 2.46 (*s*, 4H), 4.72 (*s*, 1H), 6.92 (*d*, $J = 7.65$ Hz, 2H), 7.21 (*d*, $J = 6.5$ Hz, 2H).

*9-(2-bromophenyl)-3,3,6,6-tetramethyl-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8 (2H)-dione (**14**)*

White solid; Yield: 80 %; mp 226–228 °C (lit. [12] mp 221–223 °C); IR (KBr) ν/cm^{-1} 3067, 2962, 2941, 2890, 1684, 1667, 1628, 1465, 1355, 1204, 1023, 745; ^{1}H NMR (90 MHz, $CDCl_3$) δ 1.02 (*s*, 6H, CH_3), 1.09 (*s*, 6H, CH_3), 2.17 (*s*, 4H), 2.46 (*s*, 4H), 5.01 (*s*, 1H), 6.93–7.46 (*b*, 4H).

*9-(3-bromophenyl)-3,3,6,6-tetramethyl-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8 (2H)-dione (**15**)*

White solid; Yield: 83 %; mp 196–197 °C; IR (KBr) ν/cm^{-1} 3079, 2956, 2884, 1677, 1661, 1626, 1358, 1199, 999, 806, 695, 565; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.00 (s, 6H, CH_3), 1.10 (*s*, 6H, CH_3), 2.20 (4H), 2.47 (4H), 4.70 (*s*, 1H), 7.09 (1H), 7.22 (1H), 7.28 (1H), 7.35 (1H).

*9-(4-bromophenyl)-3,3,6,6-tetramethyl-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8 (2H)-dione (**16**)*

White solid; Yield: 84 %; mp 243–244 °C (lit. [12] mp 241–243 °C); IR (KBr) ν/cm^{-1} 2951, 2877, 1678, 1661, 1624, 1361, 1198, 1009, 852, 526; ^{1}H NMR (90 MHz, $CDCl_3$) δ 0.99 (*s*, 6H, CH_3), 1.11 (*s*, 6H, CH_3), 2.20 (*s*, 4H), 2.47 (*s*, 4H), 4.70 (*s*, 1H), 7.14–7.29 (*b*, 4H).

*3,3,6,6-tetramethyl-9-p-tolyl-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8 (2H)-dione (**17**)*

White solid; Yield: 80 %; mp 210–211 °C (lit. [19] mp 210–213 °C); IR (KBr) ν/cm^{-1} 2959, 2933, 2877, 1678, 1663, 1623, 1466, 1357, 1198, 999, 823, 571, 520; ^{1}H NMR (500 MHz, $CDCl_3$) δ 1.02 (*s*, 6H), 1.10 (*s*, 6H), 2.17–2.27 (*m*, 7H), 2.49 (*s*, 4H), 4.74 (*s*, 1H), 7.04 (*d*, $J = 7.5$ Hz, 2H), 7.20 (*d*, $J = 6.9$ Hz, 2H).

*9-(2-methoxyphenyl)-3,3,6,6-tetramethyl-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8(2H)-dione (**18**)*

White solid; Yield: 82 %; mp 224–225 °C; IR (KBr) ν/cm^{-1} 2957, 2874, 1680, 1661, 1622, 1359, 1198; ^{1}H NMR (400 MHz, $CDCl_3$) δ 0.95 (*s*, 6H, CH_3), 1.08 (*s*, 6H, CH_3), 2.16 (*m*, 4H), 2.41 (*m*, 4H), 3.77 (3H, OCH_3), 4.85 (*s*, 1H), 6.75 (*d*, $J = 7.2$ Hz, 1H), 6.87 (*d*, $J = 6.8$ Hz, 1H), 7.11 (*d*, $J = 8$ Hz, 1H), 7.41 (*d*, $J = 7.5$ Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) 27.85, 30.68, 30.72, 33.25, 42.06, 51.93, 56.27, 78.03, 78.35, 78.67, 111.77, 114.77, 121.44, 128.89, 131.62, 133.25, 158.74, 164.25, 198.21; MS *m/z* observed: 380 (M^+), 349, 273.

*9-(4-methoxyphenyl)-3,3,6,6-tetramethyl-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8 (2H)-dione (**19**)*

White solid; Yield: 94 %; mp 252–255 °C (lit. [19] mp 257–258 °C); IR (KBr) ν/cm^{-1} 3059, 3004, 2927, 2872, 1665, 1626, 1608, 1358, 1193, 1260, 1030, 841, 569, 529; ^{1}H NMR (90 MHz, $CDCl_3$) δ 0.98 (*s*, 6H, CH_3), 1.08 (*s*, 6H, CH_3), 2.18 (*s*, 4H), 2.44 (*s*, 4H), 3.71 (*s*, 3H, CH_3), 4.68 (*s*, 1H), 6.88 (*d*, $J = 7.2$ Hz, 2H), 7.19 (*d*, $J = 7.92$ Hz, 2H).

*3,3,6,6-tetramethyl-9-(3,4,5-trimethoxyphenyl)-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8 (2H)-dione (**20**)*

White solid; Yield: 86 %; mp 212–214 °C; IR (KBr) ν/cm^{-1} 2955, 2932, 1667, 1625, 1592, 1460, 1358, 1128, 840, 571; ^{1}H NMR (500 MHz, DMSO-d_6) δ 0.95 (s, 6H), 1.04 (s, 6H), 2.14 (*d*, J = 16.2 Hz, 2H), 2.29 (*d*, J = 16.2 Hz, 2H), 2.50–2.54 (Distorted AB system, 4H), 3.31 (*s*, 3H), 3.60 (*s*, 3H), 3.69 (*s*, 3H), 4.50 (*s*, 1H), 6.42 (*s*, 2H).

*9-(4-hydroxy-3-methoxyphenyl)-3,3,6,6-tetramethyl-3,4,5,6,7,9-hexahydro-1H-xanthene-1,8 (2H)-dione (**21**)*

White solid; Yield: 83 %; mp 237–239 °C (lit. [19] mp 225–227 °C); IR (KBr) *ν*/cm^{-1} 3206, 2950, 1641, 1582, 1483, 1374, 1312, 1229, 1095, 1007, 757, 580; ^{1}H NMR (90 MHz, DMSO-*d*6) δ 1.02 (*s*, 6H, CH_3), 1.07 (*s*, 6H, CH_3), 2.15 (*s*, 4H), 2.44 (*s*, 4H), 3.88 (*s*, 3H, OCH_3), 4.71 (*s*, 1H), 5.31 (*s*, 1H, OH), 6.73–7.26 (*b*, 3H).

Results and discussion

The structure of DCDBTSD was identified by IR, ^{1}H and^{13}C NMR, XRD and mass spectra. As can be seen in representivr IR spectrum of the catalyst and hydrochlorothiazide in Fig. 1, two sharp peaks of *N*–H groups of hydrochlorothiazide at 3363 and 3169 cm^{-1} were eliminated in DCDBTSD. These differences were proved that the two hydrogens of N–H groups in hydrochlorothiazide were replaced with two N–Br groups in DCDBTSD.

Thermal gravimetric (TG) and derivative thermal gravimetric (DTG) analysis of DCDBTSD was studied at range of 30–618 °C (Fig. 2).

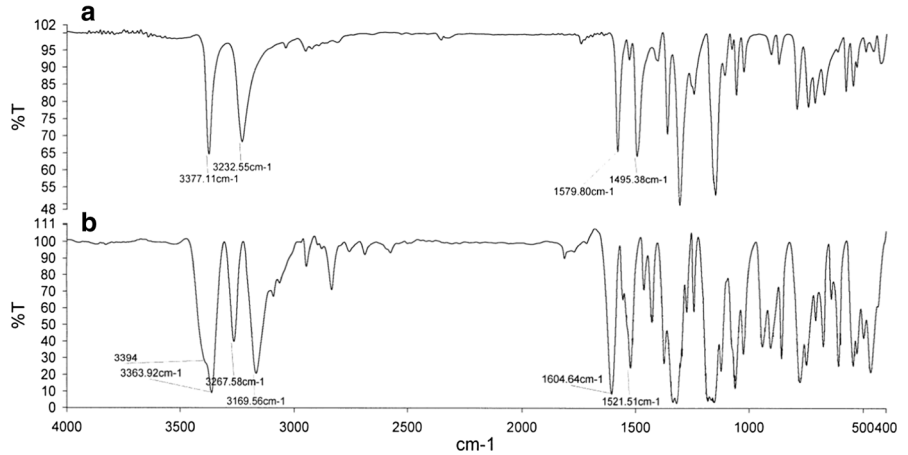


Fig. 1 IR spectra of **a** DCDBTSD and **b** hydrochlorothiazide

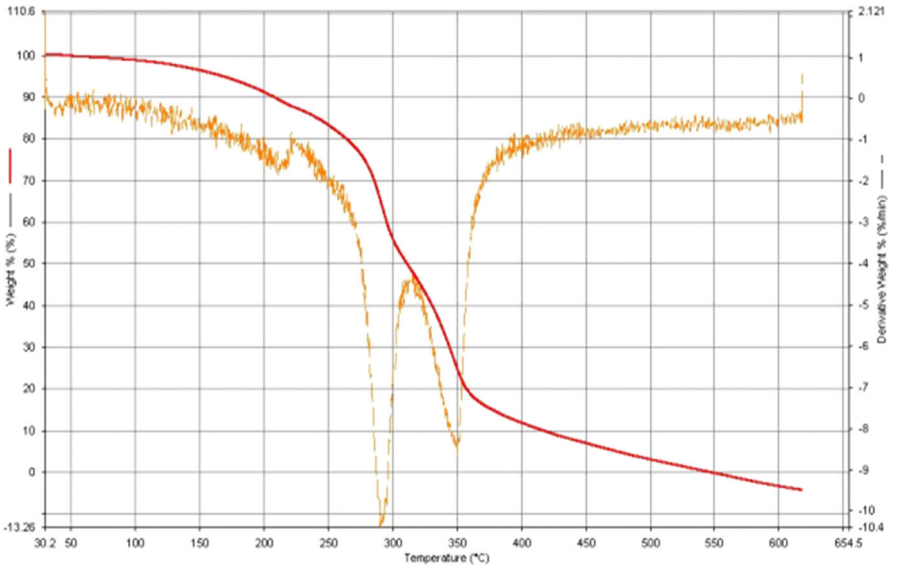


Fig. 2 TG/DTG diagrams of the DCDBTSD

Multi-stage decomposition pattern was observed In TG pattern and therefore DCDBTSD could be applied as a catalyst below 200 °C and decomposed above 255 °C.

XRD pattern of DCDBTSD was studied in a domain of 5–90° (Fig. 3) and diffraction lines of a high crystalline nature at $2\theta \approx 9.20°$, 18.50°, 20.80°, 27.90°, 29.50°, 33.70°, 38.80°, 47.50° and 58.70°, and several small lines in the 25–60° range were obtained.

After full characterization of DCDBTSD, its catalytic activity for the preparation of 9-aryl-1,8-dioxo-octahydroxanthene was evaluated.

First, to optimize the reaction conditions (amount of catalysts and temperature) as a model reaction, the condensation of dimedone (2 mmol) and benzaldehyde (1 mmol) was tested in the presence of different amounts of the DCDBTSD, in the range of 70–100 °C under solvent-free conditions (Table 1).

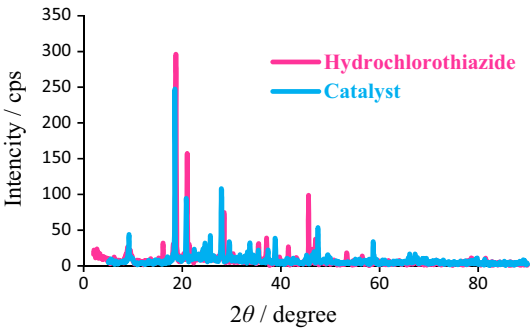


Fig. 3 XRD patterns of DCDBTSD in comparison with hydrochlorothiazide

Table 1 Optimization of the reaction conditions for synthesis of 9-aryl-1,8-dioxo-octahydroxanthene

Entry	Catalyst	Catalyst (mol%)	Temperature (°C)	Time (min)	Yield[a] (%)
1	No catalyst	–	90	180	–
2	Hydrochlorothiazide	10	90	180	–
3	DCDBTSD	5	90	45	77
4	DCDBTSD	10	90	30	85
5	DCDBTSD	15	90	30	85
6	DCDBTSD	10	70	45	70
7	DCDBTSD	10	80	40	74
8	DCDBTSD	10	100	30	80

[a] Isolated yield

Based on Table 1, the higher yield and shorter reaction time were earned using 10 mol% of catalyst at 90 °C under solvent-free conditions. No improvement in the reaction results was seen by increasing the quantities of the catalyst or the temperature. The solvent-free condensation was also tested at 90 °C without catalyst and with hydrochlorothiazide in which the reaction was not progressed even after a long reaction time (3 h).

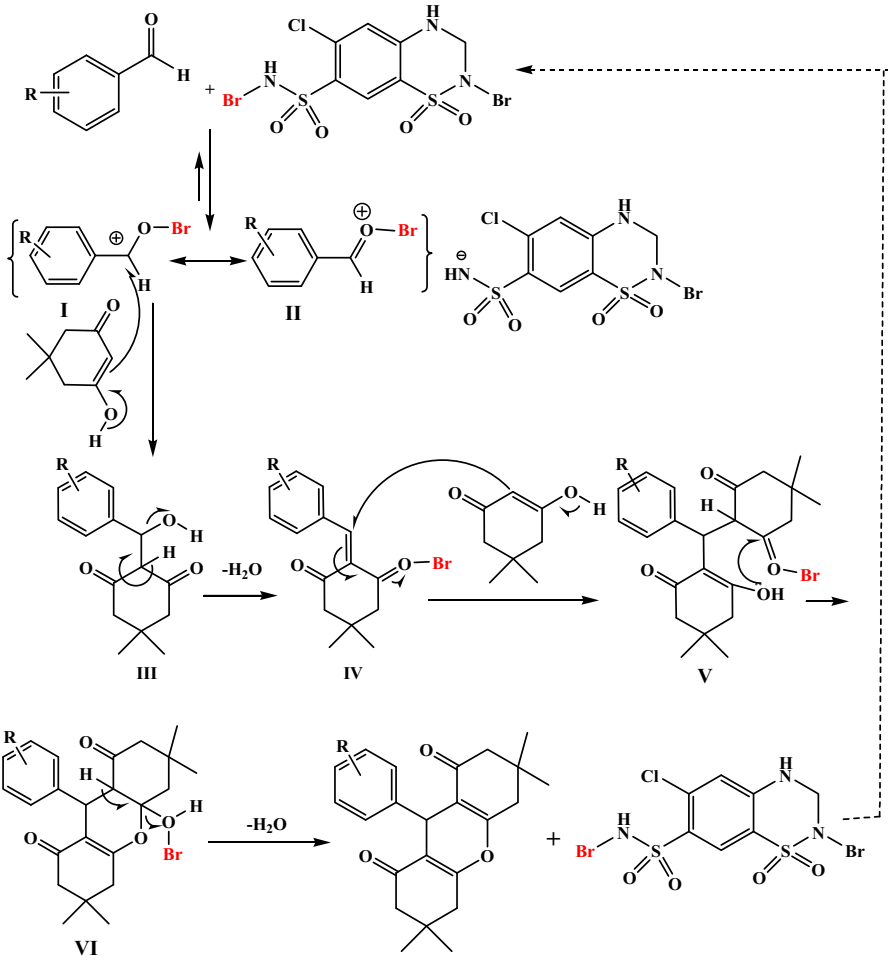
Table 2 The synthesis of 9-aryl-1,8-doxo-octahydro-xanthene derivatives using DCDBTSD at 90 °C

Entry	*R*	Time/yield[a] (min/%)	MP (°C) (References)
1	C_6H_5	30/85	203–205 (203–205) [14]
2	2-$NO_2C_6H_4$	40/82	256–257 (251–253) [14]
3	3-$NO_2C_6H_4$	40/84	173–174 (170–171) [17]
4	4-$NO_2C_6H_4$	30/87	237–238 (224–226) [11]
5	2-ClC_6H_4	25/85	226–228 (225–227) [14]
6	3-ClC_6H_4	20/87	192–193 (185–187) [17]
7	4-ClC_6H_4	20/91	238–240 (233–235) [14]
8	2,3-diClC_6H_3	25/90	226–227
9	2,4-diClC_6H_3	25/93	251–252 (254–255) [18]
10	4-Cl–3-$NO_2C_6H_3$	15/95	258–260
11	2-FC_6H_4	40/85	210–212
12	3-FC_6H_4	35/90	231–232 (–)
13	4-FC_6H_4	30/86	235–236 (–)
14	2-BrC_6H_4	40/80	226–228 (221–223) [12]
15	3-BrC_6H_4	40/83	196–197 (–)
16	4-BrC_6H_4	35/84	243–244 (241–243) [12]
17	4-$CH_3C_6H_4$	20/80	210–211 (210–213) [19]
18	2-$OCH_3C_6H_4$	35/82	224–225
19	4-$OCH_3C_6H_4$	30/94	252–255 (257–258) [19]
20	3,4,5-$OCH_3C_6H_2$	25/86	212–214 (–)
21	4-OH–3-$OCH_3C_6H_3$	35/83	237–239 (225–227) [19]

[a] Isolated yield

To estimate the efficiency of DCDBTSD in the synthesis of 9-aryl-1,8-dioxo-octahydroxanthene, the reaction of dimedone with structurally varied aromatic aldehydes in the presence of DCDBTSD as catalyst was checked in the optimized reaction condition (Table 2), from which it can be seen that several aromatic aldehyde including electron-releasing and electron-withdrawing substituents and halogens on the aromatic ring of aldehydes were successfully reacted with dimedone to prepare corresponding products in good yields and in relatively short reaction times.

Based on the literature [14, 26, 28–30] and the suggested mechanism (Scheme 3), the reaction is catalyzed by in situ generation of Br^+ from the DCDBTSD. By the intraction of generated Br^+ ion with aldehyde, intermediates



Scheme 3 The plausible mechanism for the synthesis of 9-aryl-1,8-doxo-octahydro-xanthene using DCDBTSD

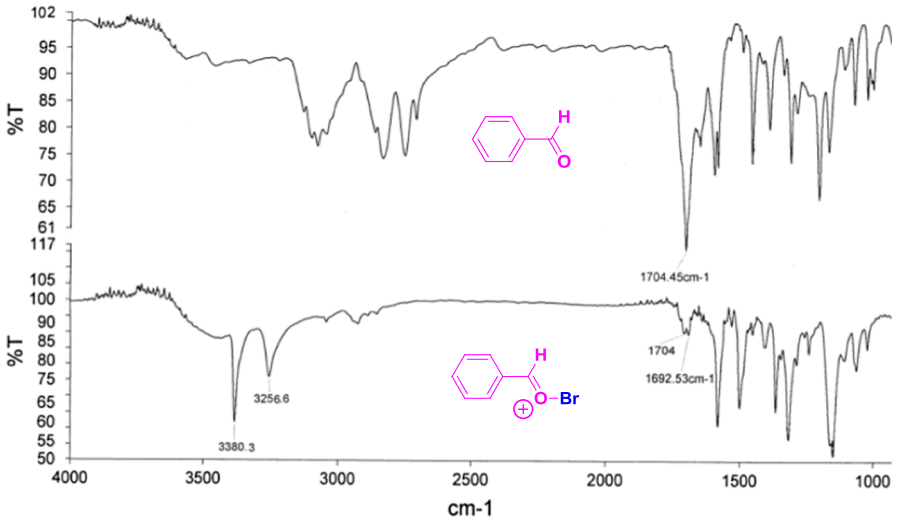


Fig. 4 IR spectra of benzaldehyde and the mixture of it and DCDBTSD

I and **II**, as activated forms of aldehyde, are prepared. These complexes are performed as activated carbonyl compounds and then are reacted with dimedone to obtain intermediate **III**, which is converted to **IV** by the elimination of one molecule H_2O. Hence, **V** reacts with secondary dimedone to produce **V** and then **VI** is formed by ring closing via the reaction between the hydroxyl group and the activated carbonyl. Finally, by the elimination of another molecule of H_2O from **VI**, the expected product is prepared and the catalyst is regenerated for the next catalytic cycles.

To verify the formation of intermediates **I** and **II**, benzaldehyde was reacted with the catalyst at 90 °C, and then IR and UV spectra of the carbonyl functional group in the reaction mixture were compared with benzaldehyde as follows: IR (Nujol): ν (cm^{-1}) of C=O benzaldehyde from 1704 to 1692 decreased in the reaction mixture and is indicative of the decreased nature of the double bond and the formation of activated carbonyl (Fig. 4). Also, in the IR spectrum of this complex, two sharp peaks at 3380 and 3253 cm^{-1} are observed.

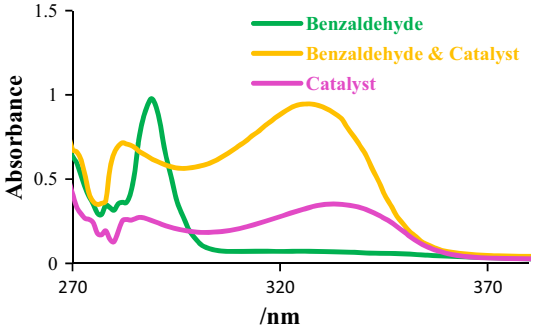


Fig. 5 UV spectra of benzaldehyde, DCDBTSD and complexes of them and Br^+ (**I** and **II**) at 90 °C in tetrahydrofuran

UV spectra were studied to confirm the structure of **I** and **II**. UV studies were performed in tetrahydrofuran as solvent. The maximum of absorption for benzaldehyde and catalyst appeared at 282 and 333 nm, respectively. However, λ_{max} of the complexes of aldehyde with Br^{+}, which were formed by the addition of benzaldehyde, was observed at 282 nm (Fig. 5).

Conclusion

In conclusion, we have reported a clean, efficient and simple procedure for the preparation of 9-aryl-1,8-doxo-octahydro-xanthene via the condensation of dimedone with aromatic aldehydes using DCDBTSD as a new, effective and homogenous organic catalyst at 90 °C under solvent-free and neutral conditions. The efficiency, generality, high yield, cleaner reaction profile, ease of product isolation and simplicity are some of the advantages of this work.

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