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Synthesis of Dibenzo[*b*,*d*]pyran-6-ones Based on [3 + 3] Cyclizations of 1,3-Bis(silyl enol ethers) with 3-Silyloxy-2-en-1-ones

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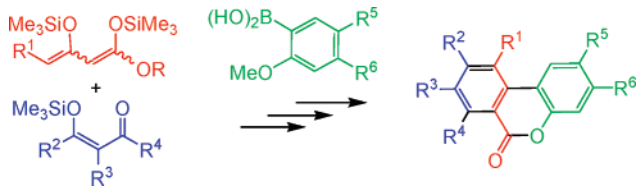

Functionalized dibenzo[*b*,*d*]pyran-6-ones were prepared by formal [3 + 3] cyclization of 1,3-bis(silyl enol ethers) with 3-silyloxy-2-en-1-ones or 1,1-diacetylcyclopropane to give functionalized salicylates, Suzuki cross-coupling reactions of the corresponding triflates, and subsequent BBr_3-mediated lactonization. A second approach to dibenzo[*b*,*d*]pyran-6-ones relies on the [3 + 3] cyclization of 1,3-bis(silyl enol ethers) with 1-(2-methoxyphenyl)-1-(trimethylsilyloxy)alk-1-en-3-ones and subsequent BBr_3-mediated lactonization.

Functionalized dibenzo[*b*,*d*]pyran-6-ones and related lactones are of pharmacological relevance and occur in a number of natural products, such as alternariol,[1] autumnariol, autumnariniol[2] and altenuisol,[3] ellagic or coruleoellagic acid,[4] defucogilvocarcin V, gilvocarcins, chrysomycins, and ravidomycins. Known syntheses of dibenzo[*b*,*d*]pyran-6-ones rely on the cyclization of *o*-bromobenzoic acid with phenols,[5] intramolecular Pd(II)-catalyzed coupling reactions,[6] and directed ortho-metalations (DOM) with subsequent Suzuki cross-coupling reactions.[7] Some years ago, Chan et al. reported an elegant approach to salicylates based on formal [3 + 3] cyclizations of 1,3-bis(silyl enol ethers) with 3-silyloxy-2-en-1-ones (Scheme 1).[8] Recently, we reported[9] the synthesis of dibenzo[*b*,*d*]pyran-6-ones based on [3 + 3] cyclizations[10] of 1,3-bis(silyl enol ethers)[11] with 3-silyloxyalk-2-en-1-ones to give salicylates, Suzuki coupling of their triflates with *o*-methoxyboronic acids, and subsequent BBr_3-mediated lactonization. Herein, we report full details of this work. In addition to our preliminary communication,[9] we also report a related approach to dibenzo[*b*,*d*]pyran-6-ones based on what are, to the best of our knowledge, the first [3 + 3] cyclizations of 1,3-bis(silyl enol ethers) with 1-(2-methoxyphenyl)-1-(trimethylsilyloxy)alk-1-en-3-ones. The chemistry reported complements known methods for the synthesis of dibenzo[*b*,*d*]pyran-6-ones.

1,3-Bis(silyl enol ethers) **1a**−**c** were prepared, as previously reported, from methyl acetoacetate, ethyl acetoacetate, and methyl 4-methoxyacetoacetate, respectively.[8] 4-(Silyloxy)pent-3-en-2-ones **2a**−**g** were prepared from acetylacetone, 3-methylacetylacetone, 3-ethylacetylacetone, benzoylacetone, 2-formylcyclohexanone, 2-acetylcyclohexanone, and 2-acetyltetralone, respectively. The $TiCl_4$-mediated [3 + 3] cyclization of **1a**−**c** with **2a**−**g** afforded the salicylates **3a**−**h** which were transformed into their triflates **4a**−**h** (Scheme 2 and Table 1). The Suzuki reaction[12] of **4a**−**h** with (2-methoxyphenyl)boronic acids **5a**−**c** afforded biaryls **6a**−**k** which were transformed into dibenzo[*b*,*d*]pyran-6-ones **7a**−**k** (Scheme 3 and Table 2) by BBr_3-mediated lactonization.[13] The [3 + 3] cyclizations proceeded in moderate to good yields. The following steps (triflate formation, Suzuki reaction, and lactonization) proceeded, in most cases, in good to excellent yield.

Recently, we reported the domino [3 + 3] cyclization/homo-Michael reaction of 1,3-bis(silyl enol ethers) with 1,1-diacylcyclopropanes.[14] These reactions proceed by cyclization and subsequent TiX_4 (X = Cl, Br)-mediated cleavage of the cyclopropane moiety to give salicylates with a chlorinated or brominated side chain. The $TiCl_4$-mediated cyclization of 1,3-bis(silyl enol ether) **1b** with 1,1-diacetylcyclopropane (**8**) afforded, as previously reported, chloroethyl-substituted salicylate **3i** which was transformed into triflate **4i**. The Suzuki reaction of **4i** with boronic acid **5a** afforded **6l** which was transformed into chloroethyl-substituted dibenzo[*b*,*d*]pyran-6-one **7l**. The $TiBr_4$-mediated cyclization of **1b** with **8** afforded

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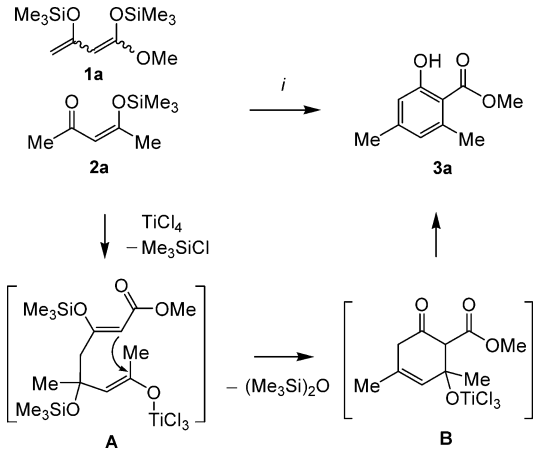
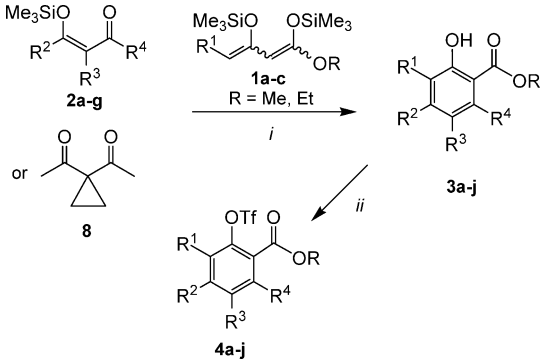
SCHEME 1. Possible Mechanism of the Formal [3 + 3] Cyclization of 1,3-Bis(silyl enol ethers) with 3-Silyloxy-2-en-1-ones[a]



[a] Conditions: (*i*) $TiCl_4$, CH_2Cl_2, −78 → 20 °C.

SCHEME 2. Synthesis of 4a−j[a]



[a] Conditions: (*i*) $TiCl_4$, CH_2Cl_2, −78 → 20 °C; (*ii*) Tf_2O, pyridine, −78 → −10 °C.

TABLE 1. Products and Yields

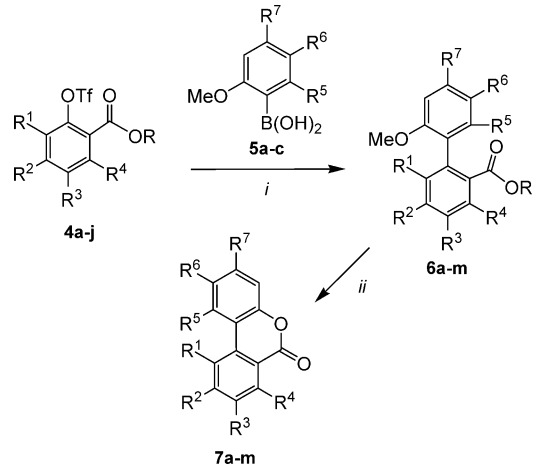
3, 4	R	R^1	R^2	R^3	R^4	% 3[a]	% 4[a]
a	Me	H	Me	H	Me	38	73
b	Me	H	Me	Me	Me	51	74
c	Me	H	Me	Et	Me	45	85
d	Et	H	Me	H	Ph	31	90
e	Me	OMe	Me	H	Me	50	65
f	Me	H	H	$(CH_2)_4$		30	92
g	Me	H	Me	$(CH_2)_4$		32	75
h	Me	H	Me	$(CH_2)_2C_6H_4$		48	61
i	Me	H	Me	$(CH_2)_2Cl$	Me	61[b]	92
j	Me	H	Me	$(CH_2)_2Br$	Me	51[c]	90

[a] Yields of isolated products. [b] From 1,1-diacetylcyclopropane (**8**) and $TiCl_4$. [c] From 1,1-diacetylcyclopropane (**8**) and $TiBr_4$.

bromoethyl-substituted salicylate **3j**. The Suzuki reaction of triflate **4j** with **5a** gave **6m** which was transformed into dibenzo[*b*,*d*]pyran-6-one **7m**. All reactions proceeded in good to excellent yield. The lactonization proceeded in good yield despite the presence of the remote halide function.

(2-Methoxybenzoyl)acetone (**10a**) and (2-methoxybenzoyl)-butan-2-one (**10b**) were prepared by LDA-mediated reaction of acetone and butan-2-one with 2-methoxybenzoyl chloride (**9**), respectively. The [3 + 3] cyclization of 1-(2-methoxyphenyl)-1-(trimethylsilyloxy)alk-1-en-3-ones **11a,b**, prepared from **10a,b**, with 1,3-bis(silyl enol ethers) **1a** and **1c−h**,[15] afforded the

SCHEME 3. Synthesis of 7a−m[a]



[a] Conditions: (*i*) $Pd(PPh_3)_4$ (3 mol %), K_3PO_4 (1.5 equiv), dioxane, reflux, 4 h; (*ii*) (1) BBr_3 (4 equiv), CH_2Cl_2, 0 → 20 °C, 18 h, (2) KO*t*Bu, H_2O, 15 min, 20 °C.

TABLE 2. Products and Yields

6, 7	R	R^1	R^2	R^3	R^4	R^5	R^6	R^7	% 6[a]	% 7[a]
a	Me	H	Me	H	Me	H	H	H	75	92
b	Me	H	Me	Me	Me	H	H	H	73	71
c	Me	H	Me	Et	Me	H	H	H	95	81
d	Et	H	Me	H	Ph	H	H	H	95	73
e	Me	OMe	Me	H	Me	H	H	H	83	
e	Me	OH	Me	H	Me	H	H	H		76
f	Me	H	H	$(CH_2)_4$		H	H	H	79	91
g	Me	H	Me	$(CH_2)_4$		H	H	H	61	67
h	Me	H	Me	$(CH_2)_2C_6H_4$		H	H	H	55	62
i	Me	H	Me	Et	Me	H	OMe	H	65	
i	Me	H	Me	Et	Me	H	OH	H		79
j	Me	H	Me	Et	Me	H	H	OMe	47	
j	Me	H	Me	Et	Me	H	H	OH		96
k	Me	H	Me	H	Me	OMe	H	H	59	
k	Me	H	Me	H	Me	OH	H	H		87
l	Me	H	Me	$(CH_2)_2Cl$	Me	H	H	H	78	98
m	Me	H	Me	$(CH_2)_2Br$	Me	H	H	H	90	76

[a] Yields of isolated products.

biaryls **12a−l** with very good regioselectivity. The regioselectivity can be explained by $TiCl_4$-mediated isomerization of **11a,b** (shift of the trimethylsilyl group from one oxygen atom to the other), attack of the terminal carbon atom of the 1,3-bis(silyl enol ether) onto the carbon atom attached to the silyloxy group, and subsequent cyclization via the central carbon atom. Treatment of biaryls **12a−l** with BBr_3 and subsequent addition of an aqueous solution of KO*t*Bu afforded the dibenzo[*b*,*d*]pyran-6-ones **13a−l** (Scheme 4 and Table 3). The [3 + 3] cyclizations proceeded in moderate yields. A general rule for the influence of a specific substitution pattern of the starting materials on the yield of the reactions could not be observed. In contrast, the quality of the starting materials employed for each individual experiment seems to play an important role. The lactonization again proceeded in good yields.

The structure of all products was established by spectroscopic methods. The structure of **13c** was independently confirmed by X-ray crystal structure analysis (see Supporting Information).[16]

In conclusion, two methods for the synthesis for the synthesis of dibenzo[*b*,*d*]pyran-6-ones based on [3 + 3] cyclizations of

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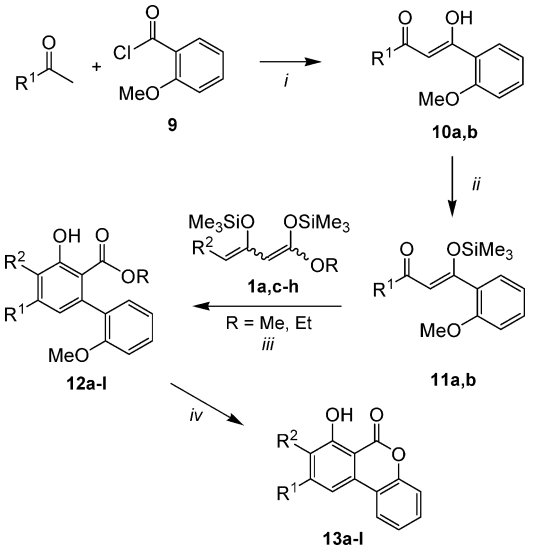
SCHEME 4. Synthesis of 13a−l[a]



[a] Conditions: (*i*) LDA (1.5 equiv), THF; (*ii*) NEt_3 (1.6 equiv), Me_3SiCl (1.8 equiv), C_6H_6, 20 °C, 3 d; (*iii*) $TiCl_4$, CH_2Cl_2, −78 → 20 °C; (*iv*) (1) BBr_3 (4 equiv), CH_2Cl_2, 0 → 20 °C, 18 h, (2) KO*t*Bu, H_2O, 15 min, 20 °C.

TABLE 3. Products and Yields

1	12, 13	R^1	R^2	% 12[a]	% 13[a]
a	**a**	Me	H	47	92
c	**b**	Me	Me	27	69
d	**c**	Me	Et	34	62
e	**d**	Me	*n*Hex	26	65
f	**e**	Me	*n*Hept	25	54
g	**f**	Me	*n*Oct	52	60
h	**g**	Me	*n*Undec	47	71
a	**h**	*n*Pr	H	22	77
c	**i**	*n*Pr	Me	21	73
d	**j**	*n*Pr	Et	30	71
e	**k**	*n*Pr	*n*Hex	32	62
h	**l**	*n*Pr	*n*Undec	43	86

[a] Yields of isolated products.

1,3-bis(silyl enol ethers) were reported. Known syntheses of dibenzo[*b*,*d*]pyran-6-ones rely on the transition-metal-catalyzed coupling of two appropriate benzene derivatives and are, thus, limited by the availability of the latter. The synthesis of functionalized and heavily substituted benzene derivatives can be a difficult task. In contrast to known methods, the methodology reported herein involves the assembly of one of the two benzene moieties during the synthesis. Therefore, products can be prepared which are not readily available by other methods. Notably, the two strategies outlined herein, both relying on [3 + 3] cyclizations as the key step, complement each other since different substitution patterns are accessible. The overall yields of the dibenzo[*b*,*d*]pyran-6-ones are mainly limited by the [3 + 3] cyclization step which mostly proceeds only in moderate yield. However, the substitution pattern available by the [3 + 3] cyclization is not readily available by other methods.

Experimental Section

General Comments. All solvents were dried by standard methods, and all reactions were carried out under an inert atmosphere. For ^1H and ^{13}C NMR spectra, the deuterated solvents indicated were used. Mass spectrometric data (MS) were obtained by electron ionization (EI, 70 eV), chemical ionization (CI, H_2O), or electrospray ionization (ESI). For preparative scale chromatography, silica gel (60−200 mesh) was used. Melting points are uncorrected.

General Procedure for the Synthesis of Salicylates 3 and 12: To a CH_2Cl_2 solution of silyl enol ether **2** (1.0 equiv) and 1,3-bis(silyl enol ether) **1** (1.0 equiv) was dropwise added $TiCl_4$ (1.0 equiv) at −78 °C under argon atmosphere. The solution was stirred at −78 °C for 30 min and then allowed to warm to 20 °C during 18 h. To the solution was added a saturated aqueous solution of $NaHCO_3$. The organic layer was separated, and the aqueous layer was repeatedly extracted with CH_2Cl_2. The combined organic extracts were dried (Na_2SO_4) and filtered. The filtrate was concentrated in vacuo, and the residue was purified by chromatography (silica gel, *n*-hexane/EtOAc) to give salicylates **3**. The synthesis of **3a** has been previously reported.[8a]

Methyl 4,5,6-Trimethyl-2-hydroxybenzoate (3b). Starting with 1-methoxy-1,3-bis(trimethylsilyloxy)buta-1,3-diene **1a** (1.04 g, 4.0 mmol), **2b** (0.744 g, 4.0 mmol), and $TiCl_4$ (0.760 g, 4.0 mmol) in CH_2Cl_2 (8 mL), **3b** was isolated after chromatography (silica gel, *n*-hexane/EtOAc = 20:1) as a colorless solid (0.395 g, 51%): mp = 66 °C; ^1H NMR ($CDCl_3$, 300 MHz) δ = 2.13 (s, 3H, CH_3), 2.27 (s, 3H, CH_3), 2.44 (s, 3H, CH_3), 3.94 (s, 3H, CH_3), 6.69 (s, 1H, CH), 10.84 (s, 1H, OH); ^{13}C NMR ($CDCl_3$, 75 MHz) δ_C = 15.2, 18.8, 21.5, 51.5 (CH_3), 111.3 (C), 116.2 (CH), 127.2, 138.1, 143.8, 159.0, 171.9 (C); IR (KBr, cm^{-1}) $\tilde{\nu}$ = 3240 (w), 3002 (w), 2956 (s), 1657 (s), 1209 (s), 1236 (s), 1156 (s), 1065 (s), 805 (w); UV−vis (CH_3CN, nm) λ_{max} (log ϵ) = 214 (4.38), 252 (3.88), 314 (3.58); MS (EI, 70 eV) *m*/*z* (%) = 193 (M^+, 35), 162 (100), 134 (34), 28 (16). The exact molecular mass *m*/*z* = 194.0913 ± 2 ppm [M^+] for $C_{11}H_{14}O_3$ was confirmed by HRMS (EI, 70 eV). Anal. Calcd for $C_{11}H_{14}O_3$ (194.227): C, 68.02; H, 7.27. Found: C, 68.13; H, 8.21.

Ethyl 3-Hydroxy-2′-methoxy-5-methyl[1,1′-biphenyl]-2-carboxylate (12a). Starting with bis(silyl enol ether) **1a** (0.659 g, 2.4 mmol), $TiCl_4$ (0.455 g, 2.4 mmol), CH_2Cl_2 (8 mL), and mono(silyl enol ether) **11a** (0.582 g, 2.2 mmol), **12a** was isolated (0.293 g, 47%) by column chromatography (silica gel, *n*-hexane/EtOAc = 30:1 → 20:1) as a colorless solid: mp = 91−93 °C; ^1H NMR (250 MHz, $CDCl_3$) δ = 0.78 (t, *J* = 7.2 Hz, 3H, CH_3), 2.34 (s, 3H, CH_3), 3.70 (s, 3H, OCH_3), 3.97 (q, *J* = 7.3 Hz, 2H, OCH_2CH_3), 6.87−6.58 (m, 1H, Ar), 6.80−6.81 (m, 1H, Ar), 6.85 (dd, *J* = 8.1, 1.2 Hz, 1H, Ar), 6.99 (ddd, *J* = 7.3, 7.6, 1.2 Hz, 1H, Ar), 7.15 (dd, *J* = 7.3, 1.5 Hz, 1H, Ar), 7.32 (ddd, *J* = 8.6, 7.3, 1.8 Hz, 1H, Ar), 10.93 (s, 1H, OH); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 13.5, 22.2 (CH_3), 55.6 (OCH_2CH_3), 60.8 (OCH_3), 109.9, 117.2, 120.5 (CH), 122.8 (C) 124.2, 128.4, 129.5 (CH), 140.8, 145.0, 151.6, 156.4, 161.4, 171.2 (C); IR (KBr, cm^{-1}) $\tilde{\nu}$ = 3432 (m), 2924 (s), 1655 (s), 1616 (m), 1462 (s), 1278 (m), 1217 (m), 1197 (m), 1107 (m), 1026 (m), 871 (w), 759 (m); MS (EI, 70 eV) *m*/*z* (%) = 286 (M^+, 40), 255 (2), 240 (100), 211 (15), 197 (22), 169 (11), 152 (7), 141 (7), 115 (9), 77 (2); HRMS (EI) calcd for $C_{17}H_{18}O4$, 286.11996; found, 286.120041.

General Procedure for the Synthesis of Triflates 4. To a CH_2Cl_2 solution of **4** (1.0 equiv) was added pyridine (2.0 equiv) at −78 °C. After 10 min, triflic anhydride (Tf_2O, 1.2 equiv) was added at −78 °C. The solution was allowed to warm to 0 °C and was stirred for 4 h. The product was isolated by column chromatography (silica gel, CH_2Cl_2) as a colorless viscous oil.

Ethyl 2,4-Dimethyl-6-(trifluoromethylsulfonyloxy)benzoate (4a). Starting with **3a** (0.415 g, 2.14 mmol) in 20 mL of CH_2Cl_2, pyridine (0.339 g, 4.28 mmol), and Tf_2O (0.727 g, 2.57 mmol), **4a** was isolated as a colorless oil (0.505 g, 73%): ^1H NMR (300 MHz, $CDCl_3$) δ = 1.39 (t, *J* = 7.1 Hz, 3H, OCH_2CH_3), 2.37 (s, 3H, CH_3), 2.41 (s, 3H, CH_3), 4.39 (q, *J* = 7.1 Hz, 2H, OCH_2CH_3), 6.95 (s, 1H, Ar), 7.06 (s, 1H, Ar); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 13.9,

(16) CCDC-640386 contains all crystallographic details of this publication and is available free of charge at www.ccdc.cam.ac.uk/conts/retrieving.html or can be ordered from the following address: Cambridge Crystallographic Data Centre, 12 Union Road, GB-Cambridge CB21EZ; Fax: (+44)1223-336-033; or deposit@ccdc.cam.ac.uk.

20.2, 21.3 (CH_3), 26.0 (CH_2), 116.5 (C), 119.6 (CH), 124.3 (C), 131.3 (CH), 139.4, 142.2, 146.8, 165.1 (C); IR (KBr, cm^{-1}) $\tilde{\nu}$ = 2986 (m), 1733 (s), 1624 (s), 1569 (m), 1426 (s), 1274 (s), 1211 (s), 1142 (s), 1089 (s), 1021 (s), 957 (s), 856 (s), 821 (s), 764 (m), 607 (s); MS (EI, 70 eV) *m*/*z* (%) = 327 ([M + 1]$^+$, 5), 326 (M$^+$, 76), 281 (96), 193 (4), 165 (100), 147 (45), 119 (27), 91 (86), 28 (37). Anal. Calcd for $C_{12}H_{13}O_5SF_3$: C, 44.18; H, 4.01. Found: C, 44.25; H, 3.97.

General Procedure for the Synthesis of Biaryls 6 by Suzuki Cross-Coupling Reactions. A dioxane solution of the boronic acid, potassium phosphate, Pd(PPh_3)$_4$, and triflate **4** was stirred at 110 °C for 4 h. After cooling to 20 °C, a saturated aqueous solution of NH_4Cl was added. The organic and the aqueous layer were separated, and the latter was extracted with CH_2Cl_2. The combined organic layers were dried (Na_2SO_4) and filtered, and the filtrate was concentrated in vacuo. The residue was purified by chromatography (silica gel, *n*-hexane/EtOAc = 20:1).

Ethyl 2,4-Dimethyl-6-(2-methoxyphenyl)benzoate (6a). Starting with 2-methoxyphenylboronic acid (**5a**, 1.3 equiv, 0.306 g, 2.01 mmol), potassium phosphate (1.6 equiv, 0.509 g, 2.40 mmol), Pd(PPh_3)$_4$ (3 mol %, 0.052 g, 0.045 mmol), dioxane (5 mL), and **4a** (1.0 equiv, 0.489 g, 1.5 mmol), **6a** was isolated as a colorless viscous oil (0.320 g, 75%): ^{1}H NMR (300 MHz, $CDCl_3$) δ = 0.89 (t, *J* = 7.1 Hz, 3H, OCH_2CH_3), 2.34 (s, 3H, CH_3), 2.41 (s, 3H, CH_3), 3.74 (s, 3H, CH_3O), 3.98 (q, *J* = 7.2 Hz, 2H, OCH_2CH_3), 6.89−6.91 (d, *J* = 8.3 Hz, 1H, Ar), 6.94−6.96 (dd, *J* = 1.0, 6.5 Hz, 1H, Ar), 6.98 (s, 1H, Ar), 7.02 (s, 1H, Ar), 7.16−7.19 (dd, *J* = 1.7, 5.7 Hz, 1H, Ar), 7.29−7.32 (td, *J* = 1.8, 6.8 Hz, 1H, Ar); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 13.6, 20.2, 21.2, 55.4 (CH_3), 60.3 (CH_2), 110.4 (C), 120.4, 128.6 (CH), 129.0 (2CH), 130.3 (C), 130.5 (CH), 130.6, 135.9, 137.5, 139.3, 156.3, 169.1 (C); IR (KBr, cm^{-1}) $\tilde{\nu}$ = 2978 (s), 2931 (s), 1724 (s), 1605 (s), 1580 (m), 1497 (s), 1459 (s), 1434 (s), 1384 (m), 1265 (s), 1180 (s), 1107 (s), 1081 (s), 1027 (s), 861 (s), 754 (s); UV−vis (CH_3CN, nm) λ_{max} (log ϵ) = 210.3 (4.56), 281.7 (3.59); MS (EI, 70 eV) *m*/*z* (%) = 285 ([M + 1]$^+$, 7), 284 (M$^+$, 100), 253 (64), 239 (58), 225 (61), 195 (32), 181 (28), 165 (27), 151 (15), 115 (5), 29 (12); HRMS (ESI) calcd for $C_{18}H_{20}O_3$ [M + 1]$^+$, 285.14907; found, 285.14842. Anal. Calcd for $C_{18}H_{20}O_3$: C, 76.02; H, 7.09. Found: C, 75.82; H, 6.61.

General Procedure for the Synthesis of Benzo[*c*]chromen-6-ones 7 and 13 by Lactonization with BBr_3. To a CH_2Cl_2 solution of **6** was added BBr_3 at 0 °C. The solution was allowed to warm to 20 °C during 18 h. To the solution was added an aqueous solution of KO*t*Bu (0.1 M), and the solution was stirred for 15 min. The organic and the aqueous layers were separated, and the latter was extracted with CH_2Cl_2. The combined organic layers were dried (Na_2SO_4) and filtered, and the filtrate was concentrated in vacuo. The product was purified by chromatography (silica gel, *n*-hexane/EtOAc = 20:1) as a colorless solid.

7,9-Dimethyl-6*H*-benzo[*c*]chromen-6-one (7a). Starting with **6a** (0.240 g, 0.85 mmol) in CH_2Cl_2 (2.5 mL), BBr_3 (0.423 g, 1.69 mmol), and KO*t*Bu (10 mL, 0.1 M aqueous solution), **7a** was isolated as a colorless solid (0.175 g, 92%): mp = 155.5 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ = 2.51 (s, 3H, CH_3), 2.84 (s, 3H, CH_3), 7.22 (s, 1H, Ar), 7.29 (d, 1H, Ar), 7.35 (m, 1H, Ar), 7.44 (m, 1H, Ar), 7.81 (s, 1H, Ar), 8.05 (d, 1H, Ar); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 21.9, 23.7 (CH_3), 117.3 (CH), 118.3 (C), 120.1, 122.9, 124.1, 130.1, 133.4 (CH), 136.1, 144.3, 144.8, 151.5, 153.2, 160.5 (C); IR (KBr, cm^{-1}) $\tilde{\nu}$ = 3429 (m), 2921 (m), 1721 (s), 1610 (s), 1452 (s), 1422 (m), 1265 (s), 1224 (s), 1169 (s), 1052 (s), 859 (m), 752 (s); UV−vis (CH_3CN, nm) λ_{max} (log ϵ) = 237.9 (4.58), 263.1 (4.05), 272.9 (4.04), 288.2 (3.71), 298.6 (3.87), 317.1 (3.87); MS (EI, 70 eV) *m*/*z* (%) = 225 ([M + 1]$^+$, 16), 224 (M$^+$, 100), 195 (12), 181 (15), 165 (13), 151 (10), 128 (2), 91 (13); HRMS (ESI) calcd for $C_{15}H_{12}O_2$ ([M + 1]$^+$), 225.09155; found, 225.09142. Anal. Calcd for $C_{15}H_{12}O_2$: C, 80.34; H, 5.39. Found: C, 80.02; H, 5.65.

7-Hydroxy-9-methyl-6*H*-benzo[*c*]chromen-6-one (13a). Starting with **12a** (0.278 g, 0.971 mmol) in CH_2Cl_2 (15 mL), BBr_3 (0.973 g, 3.89 mmol), and KO*t*Bu (20 mL, 0.1 M aqueous solution), **13a** was isolated as a colorless solid (0.219 g, 92%): mp = 150−151 °C; ^{1}H NMR (250 MHz, $CDCl_3$) δ = 2.42 (s, 3H, CH_3), 6.77−6.78 (m, 1H, Ar), 7.15 (s, 1H, Ar), 7.21 (dd, *J* = 7.0, 1.5 Hz, 1H, Ar), 7.25−7.27 (m, 1H, Ar), 7.37 (ddd, *J* = 8.3, 7.0, 1.5 Hz, 1H, Ar), 7.90 (dd, *J* = 7.9, 1.2 Hz, 1H, Ar), 11.20 (s, 1H, OH); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 23.0 (CH_3), 104.3 (C), 113.5, 117.4, 118.1 (CH), 118.7 (C) 123.7, 125.4, 130.9 (CH), 135.3, 149.4, 151.1, 162.8, 165.8 (C); IR (KBr, cm^{-1}) $\tilde{\nu}$ = 3438 (m), 3068 (m), 2923 (w), 1680 (s), 1627 (s), 1568 (s), 1512 (w), 1456 (m), 1421 (m), 1276 (s), 1235 (s), 1208 (s), 1148 (m), 1078(s), 842 (m), 750 (s), 511 (m); GC-MS (EI, 70 eV) *m*/*z* (%) = 226 (M$^+$, 100), 197 (20), 169 (8), 141 (8), 115 (11), 77 (3); HRMS (EI) calcd for $C_{14}H_{10}O_3$, 226.06245; found, 226.061951.

Procedure for the Synthesis of 4-Hydroxy-4-(2-methoxyphenyl)-3-buten-2-one (10a). To a stirred solution of LDA (75 mmol) in THF (62 mL) was added acetone (2.904 g, 50.0 mmol) at −78 °C. After the solution was stirred for 1 h, 2-methoxy anisoyl chloride (10.235 g, 60.0 mmol) was added. The temperature of the solution was allowed to rise to 20 °C during 12 h. A saturated solution of NH_4Cl was added, the layers were separated, and the aqueous layer was extracted with ethylacetate (3 × 150 mL). The combined organic layers were dried (Na_2So_4) and filtered, and the solvent was removed in vacuo. The residue was purified by chromatography (silica gel, *n*-hexane/EtOAc 30:1 → 20:1) to give **10a** as a yellowish oil (3.550 g, 37%): ^{1}H NMR (250 MHz, $CDCl_3$) δ = 1.99 (s, 3H, CH_3), 3.69 (s, 3H, OCH_3), 6.28 (s, 1H, CH), 6.76 (dd, *J* = 8.5, 0.9 Hz, 1H, Ar), 6.84 (ddd, *J* = 7.3, 7.3, 0.9 Hz, 1H, Ar), 7.22 (ddd, *J* = 8.5, 8.2, 1.8 Hz, 1H, Ar), 7.70 (dd, *J* = 7.6, 1.8 Hz, 1H, Ar), 15.3 (br s, 1H, OH); ^{13}C NMR (62 MHz, $CDCl_3$) δ = 26.1 (CH_3), 55.4 (OCH_3), 101.9, 111.6, 120.9, 130.8, 133.1 (CH), 134.8, 158.4, 181.3, 194.6 (C); IR (Nujol, cm^{-1}) $\tilde{\nu}$ = 3076 (w), 3005 (w) 2962 (w), 1721 (m), 1603 (s), 1490 (s), 1250 (s), 1164 (m), 1022 (m), 989 (m), 755 (m), 533 (w); MS (EI, 70 eV) *m*/*z* (%) = 192 ([M]$^+$, 12), 174 (10), 161 (54), 136 (10), 135 (100), 120 (5), 105 (4), 92 (11), 77 (25), 63.1 (5), 51 (5), 43 (11); HRMS (EI) calcd for $C_{11}H_{12}O_3$, 192.07810; found, 192.07797. Anal. Calcd for $C_{11}H_{12}O_3$: C, 68.73; H, 6.29. Found: C, 69.16; H, 6.52.

Procedure for the Synthesis of 4-(2-Methoxyphenyl)-4-[(trimethylsilyl)oxy]-3-buten-2-one (11a). To a stirred benzene solution (37 mL) of **10a** (2.854 g, 14.9 mmol) was added triethylamine (2.406 g, 23.8 mmol). After the solution was stirred for 2 h, trimethylchlorosilane (2.905 g, 26.7 mmol) was added. After the solution was stirred for 72 h, the solvent was removed in vacuo and hexane (75 mL) was added to the residue to give a suspension. The latter was filtered under argon atmosphere. The filtrate was concentrated in vacuo to give **11a** as yellowish oil (2.893 g, 73%): ^{1}H NMR (250 MHz, $CDCl_3$) δ = 0.21 (s, 9H, $3CH_3$), 2.31 (s, 3H, CH_3), 3.78 (s, 3H, OCH_3), 6.16 (s, 1H, CH), 6.84−6.86 (m, 1H, Ar), 6.90 (dd, *J* = 8.7, 1.1 Hz, 1H, Ar), 7.28−7.30 (m, 1H, Ar), 7.51 (dd, *J* = 8.7, 2.1 Hz, 1H, Ar); ^{13}C NMR (75 MHz, $CDCl_3$) δ = 0.16 ($3CH_3$), 21.9 (CH_3), 55.1 (OCH_3), 101.3, 111.0, 119.8, 130.5, 131.5 (CH), 132.7, 157.2, 169.7, 191.3 (C).

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Supporting Information Available: Experimental procedures, compound characterization, copies of NMR spectra, and details of the X-ray crystal structure analysis. This material is available free of charge via the Internet at http://pubs.acs.org.

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