Smooth Conversion of 3,4-Diarylcoumarins and 3,4,5-Triaryl-2(5*H*)-furanones to 2*H*-Chromene and 2,5-Dihydrofuran Derivatives with Dimethyl Sulfide-Borane Complex

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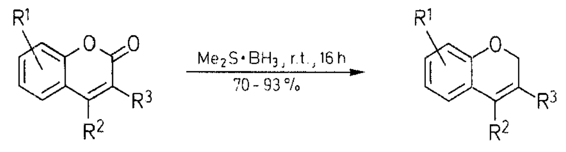
Reaction of 3,4-diarylcoumarins (3,4-diaryl-2-oxo-2*H*-1-benzopyrans) and 3,4,5-triaryl-2(5*H*)-furanones with dimethyl sulfide-borane complex affords the corresponding 2*H*-chromenes (2*H*-1-benzopyrans) and 2,5-dihydrofurans in high yields. 3,4-Diaryl-2(5*H*)-furanones afford the corresponding furans.

Diborane reduction of esters, lactones and isolated double bonds are well documented.[1] Under proper conditions, saturated lactones are known to be converted into cyclic ethers.[2] In unsubstituted or monosubstituted α,β-unsaturated lactones, this reaction is associated with ring opening to form alkenes or hydroxylated saturated cyclic ethers,[3] depending upon the substrate and the reaction conditions.

We report here a convenient synthesis of 2*H*-chromene and furan derivatives from the corresponding coumarins and furanones (α,β-unsaturated lactones) by reaction with dimethyl sulfide-borane complex in high yields. Such compounds are important as fertility regulating agents.[4,5]

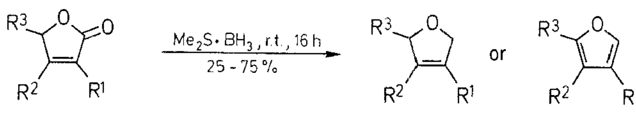
Thus, when 3,4-diarylcoumarins (2-oxo-2*H*-1-benzopyrans) **1**[6-10] were left overnight in borane-methyl sulfide at room temperature and the reaction mixture decomposed with saturated ammonium chloride solution, the corresponding 2*H*-chromenes (2*H*-1-benzopyrans) **2** were obtained as the major product in high yields.



1a-l **2a-l**

1, 2	R^1	R^2	R^3
a	7-CH_3O	C_6H_5	C_6H_5
b	7-CH_3O	4-HOC_6H_4	C_6H_5
c	7-CH_3O	3-HOC_6H_4	C_6H_5
d	7-CH_3O	C_6H_5	4-$AcOC_6H_4$
e	7-CH_3O	C_6H_5	4-$(C_6H_5CH_2O)C_6H_4$
f	7-CH_3O	3-HO-4-$O_2NC_6H_3$	C_6H_5
g	6-CH_3	C_6H_5	C_6H_5
h	5,6-benzo	4-HOC_6H_4	C_6H_5
i	5,6-benzo	4-$CH_3OC_6H_4$	C_6H_5
j	6-CH_3	9,10-phenanthro	
k	7-CH_3O	(3,2-*c*)-benzofuro(6-CH_3O)	
l	7-(2-pyrrolidin-1-ylethoxy)	(2,3-*c*)-benzofuro(6-CH_3O)	

Similarly, 3,4,5-triaryl-2(5*H*)-furanones **3a-c**[11] when subjected to dimethyl sulfide-borane reduction gave 2,5-dihydrofurans **4a-c** in high yields. However, in the case of 3,4-diaryl-2(5*H*)-furanones **3d-f**,[12] the reduction led to a complicated mixture from which the only isolable products characterized were diaryl furans **5d-f**, identical in all respects with samples prepared by reduction of the corresponding 2(5*H*)-furanones[12] with diisobutylaluminum hydride (Table).



3a-g **4a-c** **5d-f**

3-5	R^1	R^2	R^3
a	4-HOC_6H_4	C_6H_5	C_6H_5
b	C_6H_5	4-HOC_6H_4	C_6H_5
c	C_6H_5	C_6H_5	4-HOC_6H_4
d	2-OHC_6H_4	C_6H_5	H
e	4-HOC_6H_4	C_6H_5	H
f	3-HOC_6H_4	C_6H_5	H
g	H	4-HOC_6H_4	C_6H_5

In the absence of a substituent in the 3-position (i.e. α to the carbonyl group) (**1**; R^1=7-HO, R^2=CH_3, R^3=H), the reaction led to a complicated mixture of products (4 spots on TLC) and the mass spectrum of the crude mixture did not show any molecular ion peak at 152 corresponding to the desired compound. Also, the replacement of the substituent in the 4-position (i.e. β to the carbonyl group) by methyl (**1**; R^1=7-CH_3O, R^2=CH_3, R^3=4-$CH_3OC_6H_4$) led to a complicated mixture of products from which the desired compound was isolated in only ca. 20% yield. Similarly in furanones, compound **3g**, which did not carry any substituent at the 3-position, led to a very complicated mixture of products. It therefore appears likely that the smooth conversion of 3,4-diarylcoumarins and triaryl-2(5*H*)-furanones to the corresponding benzopyran and furan derivatives with dimethyl sulfide-borane complex in high yields could be due to the presence of bulky aryl substituents preventing addition across the double bond.

In summary this method has opened up an easy approach to the preparation of substituted chromenes and dihydrofurans from the corresponding coumarins and furanones, which are otherwise difficult to synthesize.

Melting points are uncorrected. The IR spectra were run on Perkin-Elmer 157 and 177 spectrometers. The ^{1}H-NMR spectra were recorded on Perkin-Elmer R-30 (90 MHz) or Varian EM 360 L (60 MHz) spectrometers. The mass spectra were recorded on a Jeol-JMS D300 spectrometer. The purity of the compounds was checked routinely by TLC (silica gel).

4-(*p*-Hydroxyphenyl)-3-phenyl-7-methoxy-2*H*-chromene (2b); Typical Procedure:

A mixture of 3-phenyl-4-(p-hydroxyphenyl)-7-methoxycoumarin (**1b**; 1.5 g, 4.5 mmol) and 10.0 M solution of dimethyl sulfide-borane complex (5 mL, 50 mmol) is kept overnight at room temperature. The reaction mixture is poured onto ice-cold water (250 mL), extracted with EtOAc (2 × 150 mL), washed successively with sat. NH_4Cl solution (100 mL) and water (2 × 100 mL). The organic layer is dried (Na_2SO_4) and concentrated. The residue is dissolved in benzene (10 mL), filtered through a short column of silica gel (15 g) and eluted with benzene. The solid material obtained on concentration is recrystallized from benzene/light petroleum; yield: 1.3 g (93%); mp 148 °C (benzene/light petroleum) (Lit.[13] mp 157 °C).

$C_{22}H_{18}O_3$	calc.	C 79.99	H 5.50
(330.4)	found	79.96	5.54

MS (70 eV): m/z = 330 (M^+).

IR (KBr): ν = 3200, 1605, 1500 cm^{-1}.

^{1}H-NMR ($CDCl_3$ + CCl_4/TMS): δ = 3.7 (s, 3H, OCH_3); 4.95 (s, 2H, OCH_2); 6.1-7.5 (m, 12H_{arom}).

Table. Dimethyl Sulfide-Borane Reduction Products

Product	Yield (%)	mp (°C) (solvent)	Molecular Formula[a]	IR (KBr) ν(cm^{-1})	^{1}H-NMR (Solvent/TMS) δ, J(Hz)	MS (70 eV) m/z (M$^+$)
2a	84	120 (C_6H_6/PE[b])	$C_{22}H_{18}O_2$ (314.4)	3200, 1610, 1500	$CDCl_3$: 3.7 (s, 3H, OCH_3); 5.0 (s, 2H, OCH_2); 6.3–8 (m, 13 H_{arom})	314
2b	93	157 (C_6H_6/PE[b])	$C_{22}H_{18}O_3$ (330.4)	3200, 1605, 1500	$CDCl_3 + CCl_4$: 3.7 (s, 3H, OCH_3); 4.95 (s, 2H, OCH_2); 6.1–7.5 (m, 12 H_{arom})	330
2c	78	132 (C_6H_6/PE)	$C_{22}H_{18}O_3$ (330.4)	3400, 1610, 1500	$CDCl_3 + CCl_4$: 3.7 (s, 3H, OCH_3); 4.95 (s, 2H, OCH_2); 6.1–7.5 (m, 12 H_{arom})	330
2d	82	152–154 (C_6H_6)	$C_{22}H_{18}O_3$ (330.4)	3200, 1610, 1500	$CDCl_3$: 3.7 (s, 3H, OCH_3); 4.95 (s, 2H, OCH_2); 6.1–7.4 (m, 12 H_{arom})[c]	330
2e	76	108–110 (C_6H_6)	$C_{29}H_{24}O_3$ (420.5)	3200, 1610, 1510	$CDCl_3 + CCl_4$: 3.7 (s, 3H, OCH_3); 4.8–5 (2s, 4H, OCH_2, $OCH_2C_6H_5$); 6.3–7.5 (m, 17 H_{arom})	420
2f	78	228 (C_6H_6)	$C_{22}H_{17}O_5N$ (375.4)	3200, 1610	$CDCl_3$: 3.7 (s, 3H, OCH_3); 5.0 (s, 2H, OCH_2); 6.0–7.8 (m, 11 H_{arom})	375
2g	84	146–148 (C_6H_6/PE)	$C_{22}H_{18}O$ (298.4)	3200, 1480	$CDCl_3$: 1.95 (s, 3H, CH_3); 4.9 (s, 2H, OCH_2); 6.4–7.9 (m, 13 H_{arom})	298
2h	83	188–190 (C_6H_6)	$C_{25}H_{18}O_2$ (350.4)	3200, 1605, 1510	$CDCl_3$ + DMSO: 4.85 (s, 2H, OCH_2); 6.8–9 (m, 15 H_{arom})	350
2i	73	150–152 (C_6H_6/PE)	$C_{26}H_{20}O_2$ (364.4)	3200, 1610, 1500	$CDCl_3 + CCl_4$: 3.5 (s, 3H, OCH_3); 4.9 (s, 2H, OCH_2); 6.3–8 (m, 15 H_{arom})	364
2j	84	146–148 (C_6H_6/PE)	$C_{22}H_{16}O$ (296.4)	3200, 1610, 1500	$CDCl_3 + CCl_4$: 2.1 (s, 3H, CH_3); 5.0 (s, 2H, OCH_2); 6.5–8 (m, 11 H_{arom})	296
2k	79	114–116 (C_6H_6)	$C_{17}H_{14}O_4$ (282.3)	3200, 1616, 1500	$CDCl_3$: 6.3–3.75 (2s, 6H, OCH_3); 5.5 (s, 2H, OCH_2); 6.2–7.7 (m, 6 H_{arom})	282
2l	70	142 (C_6H_6)	$C_{22}H_{28}O_4N$ (365.4)	3210, 1620	$CDCl_3$: 1.5–2.5 (m, 8H, CH_2); 2.7–3.2 (m, 6H, NCH_2); 3.8 (s, 3H, OCH_3); 4.3–4.5 (t, 2H, OCH_2, J = 4.5); 5.4 (s, 2H, OCH_2); 6.5–7.7 (m, 6 H_{arom})	365
4a	53	225 (EtOAc/PE)	$C_{23}H_{18}O_2$ (314.4)	3300	$CDCl_3$ + DMSO-d_6: 5.15 (m, 2H, OCH_2, $J_{gem(5a,5b)} = 12$, $J_{2,5a} = 3.5$, $J_{2,5b} = 5.3$); 6.0 (dd, 1H, OCH, $J_{2,5a} = 3.5$, $J_{2,5b} = 5.3$); 6.6 (d, 2 H_{arom}, *ortho* to OH, $J = 9$); 6.9–7.2 (m, 12 H_{arom})	314
4b	75	183–185 (EtOAc/PE)	$C_{23}H_{18}O_2$ (314.4)	3300	$CDCl_3$ + DMSO-d_6: 5.1 (m, 2H, OCH_2, $J_{gem(5a,5b)} = 12$, $J_{2,5a} = 3.5$, $J_{2,5b} = 5.3$); 5.9 (dd, 1H, OCH, $J_{2,5a} = 3.5$, $J_{2,5b} = 5.3$); 6.6 (d, 2 H_{arom}, *ortho* to OH, $J = 9$); 6.9–7.3 (m, 12 H_{arom})	314
4c	75	180–181 (EtOAc/PE)	$C_{23}H_{18}O_2$ (314.4)	3300, 1620	$CDCl_3$: 5.19 (m, 2H, OCH_2, $J_{gem(5a,5b)} = 12$, $J_{2,5a} = 3.5$, $J_{2,5b} = 5.3$); 5.9 (dd, 1H, OCH, $J_{2,5a} = 3.5$, $J_{2,5b} = 5.3$); 6.5 (d, 2H *ortho* to OH, $J = 9$); 6.75 (d, 2H *meta* to OH, $J = 9$); 7.15 (s, 10 H_{arom})	314
5d	25	75–77 (EtOAc/PE)	$C_{16}H_{12}O_2$ (236.3)	3500	$CDCl_3$: 6.8–7.3 (m, 9 H_{arom}); 7.5–7.6 (d each, 2H, OCH, $J_{2,5} = 2.3$)	236
5e	25	149–150 (EtOAc/PE)	$C_{16}H_{12}O_2$ (236.3)	3500	$CDCl_3$: 6.8 (d, 2H ortho to OH, $J = 9$); 7.05 (d, 1H meta to OH, $J = 9$); 7.41–7.46 (d each, 2H, OCH, $J_{2,5} = 2.3$)	236
5f	40	oil	$C_{16}H_{12}O_2$ (236.3)	3500	($CDCl_3$: 6.3–6.9 (m, 4 H_{arom}); 7.05 (s, 5 H_{arom}); 7.3 (dd, 2H, OCH, $J_{2,5} = 2.3$)	236

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[a] Satisfactory microanalyses obtained: C ±0.10, H ±0.10, N ±0.01.

[b] PE = light petroleum ether.

[c] Data for $R^3 = 4\text{-}HOC_6H_4$.

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