Syntheses of 4-Phenylcoumarins Containing a Dimethylpyran Ring

Takanao MATSUI,* Shinji NISHIMURA, Mitsuru NAKAYAMA, Shûichi HAYASHI, and Kenji FUKUI

**Department of Industrial Chemistry, Faculty of Engineering, Miyazaki University, Miyazaki 880*
Department of Chemistry, Faculty of Science, Hiroshima University, Higashisenda-machi, Hiroshima 730

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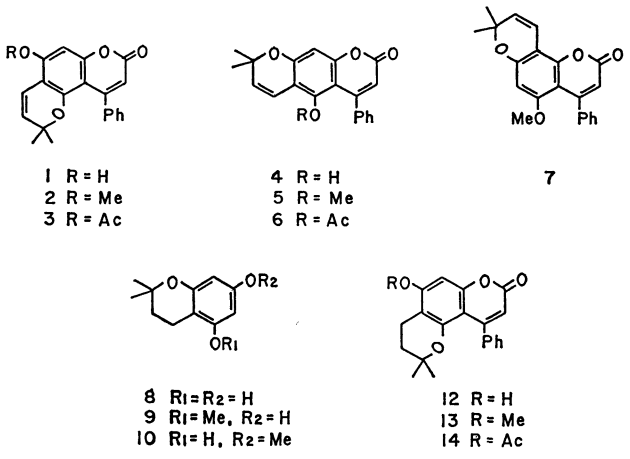
Three isomers of 2*H*,8*H*-benzo[1,2-*b*: 3,4-*b*']dipyran and 2*H*,8*H*-benzo[1,2-*b*: 5,4-*b*']dipyran, were synthesized by dehydrogenation of the dihydrobenzodipyran derivatives using DDQ or NBS and by dehydration of the secondary alcohol prepared by reduction of 4-phenylcoumarin derivatives bearing dihydropyranone ring with sodium borohydride.

A number of coumarins containing a dimethylpyran ring have been found in nature, *e.g.* calophyllolide,[1] inophyllolide,[1,2] ponnalide,[3] tomentolide A[4] as 4-phenylcoumarins. Total syntheses of these compounds and several synthetic routes of a dimethylpyran ring or dimethylchromene ring have been reported.[5-9] In the case of these 4-phenylcoumarins, it is known that the chemical shifts of dimethyl groups in fused dimethylpyran ring at 5,6-position and of the other substituents situated in the proximity of 4-phenyl ring show marked shifts from their normal values in NMR spectra.[4,10]

We have synthesized three isomers of 2*H*,8*H*-benzo[1,2-*b*: 3,4-*b*']dipyran and 2*H*,8*H*-benzo[1,2-*b*: 5,4-*b*']dipyran, (**1**—**7**), by dehydrogenation of the dihydropyran ring using 2,3-dichloro-5,6-dicyano-*p*-benzoquinone (DDQ) or *N*-bromosuccinimide (NBS) and by reduction of the dihydropyranone ring with sodium borohydride, followed by dehydration of the corresponding alcohol. The chemical shifts of methyl protons (*gem*-dimethyl, acetoxyl, and methoxyl groups) of 4-phenylcoumarin derivatives bearing dimethylpyran, dimethyldihydropyran, or dimethyldihydropyranone ring were investigated with respect to a shielding effect of 4-phenyl ring in NMR spectra.



1 R=H, 2 R=Me, 3 R=Ac
4 R=H, 5 R=Me, 6 R=Ac
7
8 R1=R2=H, 9 R1=Me, R2=H, 10 R1=H, R2=Me
12 R=H, 13 R=Me, 14 R=Ac

Scheme 1.

Dimethylchromans (**8**—**10**) and dimethylchromanone (**11**) were used as the starting material for an approach to syntheses of the isomeric 2*H*,8*H*-benzodipyran derivatives (**1**—**7**). The Pechmann reaction of **8** with ethyl benzoylacetate in the presence of sulfuric acid in acetic acid afforded hydroxy-4-phenylcoumarin (**12**), whose structure was proved on the basis of the accompanying evidences. The methyl ether (**13**) of **12** could be synthesized from **9** by a method similar to that for **8**. Bromination of the acetate (**14**) of **12** with NBS in benzene, followed by treatment with zinc dust gave the desired dehydro compound (**1**). The IR spectrum of **1** exhibited absorption due to the hydroxyl group at 3240 cm^{-1} and the double bond at 1647 cm^{-1}. In its NMR spectrum, the signals at δ 0.94 ppm (6H, s) and 5.42, 6.45 ppm (each 1H, d, J=10.0 Hz) showed the presence of a dimethylpyran ring. Therefore, the structure of **1** was established as 5-hydroxy-2,2-dimethyl-10-phenyl-2*H*,8*H*-benzo[1,2-*b*: 3,4-*b*']dipyran-8-one. On the other hand, the dehydrogenation of **13** with DDQ afforded the corresponding dehydro compound (**2**), which was identical with the methyl ether of **1** by a mixed-melting-point determination and by IR and NMR spectral comparison.

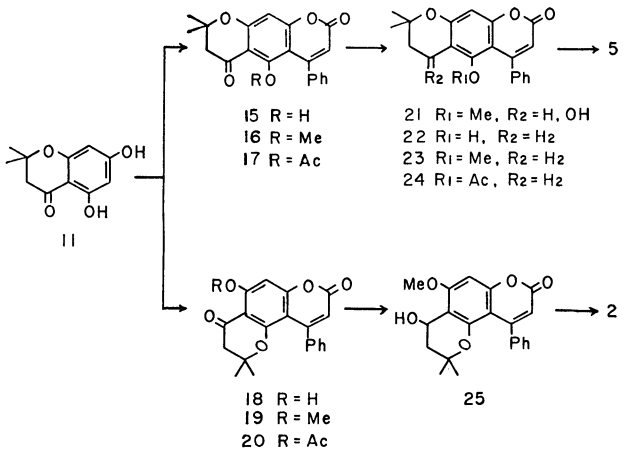
The linear isomers (**4**), (**5**), and (**6**) bearing dimethylpyran ring on 6,7-position of coumarin nucleus were prepared by the following procedure. Treatment of **11** with ethyl benzoylacetate in the presence of polyphosphoric acid (PPA) gave two products, 6,7-dihydro-5-hydroxy-4-phenyl-2*H*,8*H*-benzo[1,2-*b*: 5,4-*b*']dipyran-2,6-dione (**15**) and 3,4-dihydro-5-hydroxy-10-phenyl-2*H*,8*H*-benzo[1,2-*b*: 3,4-*b*']dipyran-4,8-dione (**18**), as expected, both of which could be separated by column chromatography. The IR spectrum of **15** exhibited absorption bands due to the α-pyrone at 1740 and 1623 cm^{-1}. The NMR spectrum indicated the presence of a phenolic proton at δ 13.00 ppm (1H, s) having an intramolecular hydrogen bonding. Reduction of the methyl ether (**16**) of **15** with sodium borohydride, followed by dehydration of the resulting secondary alcohol (**21**) with pyridine–acetic anhydride gave the corresponding dehydro compound (**5**). The NMR spectrum of **5** showed signals at δ 1.46 ppm (6H, s) and 5.63, 6.43 ppm (each 1H, d, J=10.0 Hz) due to *gem*-dimethyl protons and vinyl protons of the dimethylpyran ring. By a similar method, the dehydro compound (**2**) was obtained from the methyl ether (**19**) of **18** *via* secondary alcohol (**25**). However, reaction of the acetate (**17**) or (**20**) with sodium borohydride converted the carbonyl function of the pyranone ring into the methylene function to give **22** or **12** as the main product, respectively. The structures of **12** and **22** were assigned by IR and NMR spectral comparisons. The acetate (**24**) of **22** was treated with NBS. Subsequent dehydrobromination of the resulting brominated product with zinc dust yielded the dehydro compound (**6**). After hydrolysis of **6** with hydrochloric acid in methanol, the

Table 1. NMR spectral data of acetoxy and methoxy compounds of 4-phenylcoumarins

Compound	$(CH_3)_2C$[a]	$C_{3'}$–H and/or $C_{4'}$–H[b]	C_3–H[c]	C_6–H or C_8–H[c]	OAc[d]	OMe[d]
2	0.91(s)	5.30, 6.48(each d, J=10.0 Hz)	5.91(s)	6.39(s)		3.82(s)
3	0.92(s)	5.41, 6.22(each d, J=10.0 Hz)	6.07(s)	6.62(s)	2.30(s)	
5	1.46(s)	5.63, 6.43(each d, J=10.0 Hz)	6.00(s)	6.61(s)		3.00(s)
6	1.46(s)	5.66, 6.11(each d, J=10.0 Hz)	6.00(s)	6.75(s)	1.34(s)	
7	1.48(s)	5.90, 6.90(each d, J=10.0 Hz)	5.98(s)	6.18(s)		3.38(s)
13	0.84(s)	1.58, 2.58(each t, J=6.7 Hz)	5.98(s)	6.50(s)		3.89(s)
14	0.87(s)	1.62, 2.55(each t, J=6.7 Hz)	6.04(s)	6.68(s)	2.37(s)	
16	1.42(s)	2.64(s)	6.01(s)	6.66(s)		3.06(s)
17	1.46(s)	2.66(s)	6.05(s)	6.85(s)	1.46(s)	
19	0.95(s)	2.50(s)	6.00(s)	6.47(s)		3.93(s)
20	0.98(s)	2.50(s)	6.17(s)	6.70(s)	2.39(s)	
23	1.35(s)	1.78, 2.70(each t, J=6.7 Hz)	6.00(s)	6.63(s)		2.97(s)
24	1.33(s)	1.76, 2.43(each t, J=6.7 Hz)	5.95(s)	6.73(s)	1.33(s)	
29	1.38(s)	1.86, 2.88(each t, J=6.7 Hz)	5.97(s)	6.15(s)		3.37(s)
31	1.38(s)	1.87, 2.91(each t, J=6.7 Hz)	5.94(s)	6.29(s)	1.32(s)	

a) Each 6H. b) Each 1H or 2H. c) Each 1H. d) Each 3H.

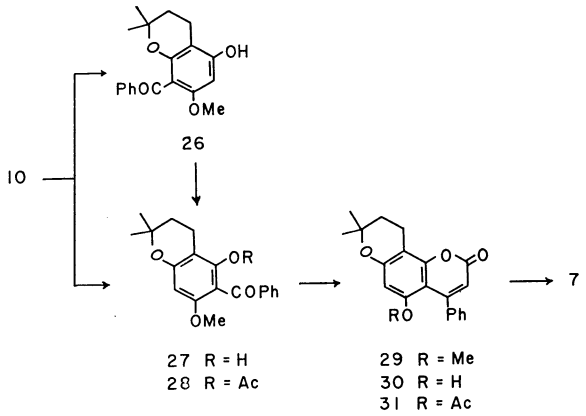
resulting hydroxy derivative (**4**) was methylated with methyl iodide in the presence of anhydrous potassium carbonate to give a methyl ether, which was shown to be identical with **5**.



Scheme 2.

The synthesis of another isomer (**7**) bearing dimethylpyran ring on 7,8-position was carried out as follows. The Hoesch reaction of **10** with benzonitrile using zinc chloride as a catalyst afforded 8-benzoyl-5-hydroxy-7-methoxy-2,2-dimethylchroman (**26**) in higher yield than that of 6-benzoyl isomer (**27**). **26** was readily transformed into **27** in the presence of an acidic catalyst such as sulfuric acid or aluminium chloride.[11] Confirmation of the structures was performed by spectral data and an alcoholic ferric chloride reaction. The acetate (**28**) of **27** was then converted into the coumarin derivative (**29**) by dehydration in the presence of a mixture of acetic anhydride and sodium acetate. **29** was also obtained together with **12** and **30** by the Pechmann reaction of **10** with ethyl benzoylacetate. **29**, **30**, and **31** have been derived from natural mammeisin, and their IR, UV spectra and melting points are compatible with those of authentic samples.[12] Dehydrogenation of **29** with DDQ gave the expected dehydro compound (**7**), which showed signals at δ 1.48 ppm (6H, s) and 5.90, 6.90 ppm (each 1H, d, J=10.0 Hz) due to methyl protons and vinyl protons of the dimethylpyran ring in the NMR spectrum.

It is significant to compare the NMR spectral data of some synthetic samples. The chemical shifts of dimethyl protons of **2**, **3**, **13**, **14**, **19**, and **20** (δ 0.84—0.98 ppm) containing dimethylpyran, dimethyldihydropyran, or dimethyldihydropyranone ring at 5,6-position, appeared in a higher magnetic field than those of **5**, **6**, **7**, **16**, **17**, **23**, **24**, **29**, and **31** (δ 1.33—1.48 ppm) containing a pyran ring at 6,7- or 7,8-position in coumarin nucleus (Table 1). The methyl protons of acetoxyl or methoxyl group substituted at 5-position showed chemical shifts in a higher magnetic field than those at 7-position. These characteristic shifts are though to be due to the anisotropic shielding effect of the phenyl ring at 4-position,[13] as has been found to be the case[2,4,10] in calophyllolide and inophyllolide. Thus, NMR spectral analysis might be useful for the structural confirmation of 4-phenylcoumarin derivatives.



Scheme 3.

Experimental

All the melting points are uncorrected. Unless otherwise stated, the NMR spectra were taken in deuteriochloroform using tetramethylsilane as an internal standard on a Hitachi

Model R-20 NMR spectrometer (60 MHz) or a JEOL JNM-MH-100 spectrometer (100 MHz). The chemical shifts are expressed in δ values; s: singlet; br: broad; d: doublet; t: triplet. The data of the UV spectra are described in terms of λ_{max}^{EtOH} nm (log ε). The column chromatography was carried out using Merck silica gel (0.063 or 0.08 mm). PPA was prepared by stirring a mixture of phosphoric acid and phosphorus pentoxide (wt ratio of 1: 1) at 85—90 °C for 3 h.

2,2-Dimethyl-5-methoxy-7-hydroxychroman (9). 2,2-Dimethyl-5-methoxy-7-hydroxychromanone (1 g), which had been prepared by hydrolysis of 2,2-dimethyl-5-methoxy-7-(*p*-tolylsulfonyloxy)chromanone[14] with 7% aq potassium carbonate, was refluxed with zinc amalgam (prepared from zinc dust (12.7 g), mercuric chloride (0.68 g), concentrated hydrochloric acid (0.7 ml), and water (18 ml)), in 10% aq ethanol (100 ml) for 15 h, 1 ml of hydrochloric acid being added at 1 h intervals. After removal of an inorganic material, the solution was concentrated under reduced pressure. The concentrated solution was extracted with ether and the ether layer was washed with water, dried and evaporated. The residue was recrystallized from ethanol to give **9** as colorless needles; mp 107—108°C; yield, 0.4 g, IR (KBr) cm^{-1}: 3330, 1605; Found: C, 69.32; H, 8.01%. Calcd for $C_{12}H_{16}O_3$: C, 69.21; H, 7.74%.

The Pechmann Reaction of 8. 75% sulfuric acid (4 ml) was added to a mixture of **8**[15] (0.8 g) and ethyl benzoylacetate (0.8 g) in acetic acid (6 ml) at room temp and the mixture was allowed to stand for 2 day. After the mixture had been poured into ice–water, the resulting solid was collected, washed, dried and then recrystallized from ethanol to give **12** as colorless prisms, mp 320 °C (lit,[16] 315—320 °C); yield, 0.7 g; IR (Nujol) cm^{-1}: 3245, 1680, 1640, 1590, 1565; UV: sh 253 (3.98), 260 (3.99), 338 (4.16); Found: C, 74.48; H, 5.59%. Calcd for $C_{20}H_{18}O_4$: C, 74.52; H, 5.63%.

Acetate (14): Acetic anhydride–pyridine method; mp 144—145 °C (from methanol) (lit,[16] 140—141 °C), colorless needles; IR (Nujol) cm^{-1}: 1775, 1725, 1605, 1560; UV: 255 (3.95), 310 (4.11); Found: C, 72.45; 5.55%. Calcd for $C_{22}H_{20}O_5$: C, 72.51; H, 5.53%.

Methyl Ether (13): Methyl iodide–potassium carbonate method; mp 202—203 °C (from ethanol) (lit,[16] 200—202 °C), colorless prisms; IR (Nujol) cm^{-1}: 1720, 1605, 1570, 1550; UV: 259 (3.90), 331.5 (4.00); Found: C, 74.80; 6.05%. Calcd for $C_{21}H_{20}O_4$: C, 74.98; H, 5.99%.

The mother liquor of the recrystallization was concentrated to give a small amount of the isomer (**30**) as colorless plates; mp 292—294 °C (lit,[12] 273—276 °C); IR (KBr) cm^{-1}: 3256, 1678, 1628, 1600, 1560; UV: 266 (4.20), 338 (4.10); Found: C, 74.46; H, 5.64%. Calcd for $C_{20}H_{18}O_4$: C, 74.52; H, 5.63%.

Acetate (31): Acetic anhydride–pyridine method; mp 155—156 °C (from aq ethanol) (lit,[12] 161—163 °C), colorless prisms; IR (Nujol) cm^{-1}: 1773, 1730, 1618, 1588; UV: 251 (4.03), 260 (4.00), 334 (4.12); Found: C, 72.60; H, 5.60%. Calcd for $C_{22}H_{20}O_5$: C, 72.51; H, 5.53%.

Methyl Ether (29): Methyl iodide–potassium carbonate method; mp 133—134 °C (from aq ethanol) (lit,[12] 130—132 °C), colorless needles; IR (Nujol) cm^{-1}: 1715, 1615, 1590; UV: 263 (4.16), 286 (3.72), 337 (4.10); Found: C, 74.68; H, 6.01%. Calcd for $C_{21}H_{20}O_4$: C, 74.98; H, 5.99%.

The Pechmann Reaction of 9. A mixture of **9** (0.3 g), ethyl benzoylacetate (0.3 g), and 75% sulfuric acid (4 ml) in acetic acid (7 ml) was allowed to stand at room temp for 2 day. By a treatment to that described above, the crude solid was recrystallized from ethanol to give **13** (0.4 g), which showed superimposable IR and NMR spectra and non-depression of mixed-melting-point with the sample prepared from **12**.

The Pechmann Reaction of 10. A mixture of **10**[17] (2 g), ethyl benzoylacetate (1.8 g), and 75% sulfuric acid (17 ml) in acetic acid (20 ml) was allowed to stand at room temp for 2 day. After the usual work-up, the crude product was purified by a fractional crystallization from aq ethanol to give **12** (1.2 g), **29** (0.2 g), and a small amount of **30**. **12**, **29**, and **30** were identical with the above samples.

5-Hydroxy-2,2-dimethyl-10-phenyl-2H,8H-benzo[1,2-b:3,4-b']-dipyran-8-one (1). A mixture of **14** (0.6 g), NBS (0.3 g), and a trace of benzoyl peroxide in dry carbon tetrachloride (30 ml) was refluxed for 1.5 h. The cooled mixture was filtered and the filtrate was evaporated to dryness under reduced pressure. The residue was dissolved in a mixture of acetic acid (15 ml) and sodium acetate (2 g) and gently refluxed for 1 h. The mixture was poured into ice–water and the resulting material was collected, washed and dried. The crude material was refluxed with fresh zinc dust (0.3 g) in acetic acid (15 ml) for 8 h. The mixture was filtered and the filtrate was poured into water. The resulting solid was collected, washed, dried and recrystallized from methanol to give **1**, as colorless prisms; mp 281—283 °C (lit,[8c] 260—263 °C); yield 0.2 g; IR (Nujol) cm^{-1}: 3240, 1695, 1647, 1585; UV: 233 (4.33), 283 (4.32), 337 (4.12); NMR (DMSO): 0.94 (6H, s, $(CH_3)_2\dot{C}$–), 5.45, 6.45 (each 1H, d, and J=10.0 Hz, –CH=CH–), 5.77 (1H, s, C_3–H), 6.36 (1H, s, C_8–H); Found: C, 74.85; H, 5.21%. Calcd for $C_{20}H_{16}O_4$: C, 74.99; H, 5.03%.

Acetate (3): Acetic anhydride–pyridine method; mp 171—173 °C (from aq methanol), colorless plates; IR (Nujol) cm^{-1}: 1758, 1722, 1635, 1610; UV: 231 (4.29), 261.5 (4.14), 270 (4.17), 295 (4.23); Found: C, 72.68; H, 5.03%. Calcd for $C_{22}H_{18}O_5$: C, 72.92; H, 5.01%.

5-Methoxy-2,2-dimethyl-10-phenyl-2H,8H-benzo[1,2-b:3,4-b']-dipyran-8-one (2). A mixture of **13** (0.17 g) and DDQ (0.5 g) in dry benzene (60 ml) was refluxed under a stream of nitrogen for 25 h until the hydroquinone separated out. While the mixture was hot, it was filtered and the filtrate was evaporated to a solid which was purified by means of column chromatography on silica gel (20 g), using chloroform–petroleum ether (1: 1) as the eluent, to give **2**; mp 183—185 °C, colorless prisms (lit,[19] 184—185 °C; lit,[3b] 192—194 °C); yield, 0.15 g, IR (Nujol) cm^{-1}: 1722, 1640, 1598, 1553; UV: sh 276 (4.28), 283 (4.31), 329 (4.11); Found: C, 75.68; H, 5.39%. Calcd for $C_{21}H_{18}O_4$: C, 75.43; H, 5.43%. **2** was also derived by methylation of **1** with diazomethane.

The Pechmann Reaction of 11. A mixture of **11**[18] (1 g), ethyl benzoylacetate (1 g), and PPA (16 g) was stirred at 75—80 °C for 1 h. After cooling, ice–water was added to the mixture in order to decompose PPA. The resulting solid was collected, washed, dried and then was chromatographed on silica gel (20 g), with chloroform as the eluent. The faster effluent yielded a solid, which was recrystallized from ethanol to give **15** as colorless needles; mp 235—237 °C; yield, 0.15 g. This is shown by the deep violet coloration with ferric chloride in ethanol. IR (Nujol) cm^{-1}: 1740, 1648, 1623, 1603, 1564; UV: 283 (4.49), 328 (4.08); NMR: 1.42 (6H, s, $(CH_3)_2\dot{C}$–), 2.68 (2H, s, $-COCH_2-$), 5.94 (1H, s, C_3–H), 6.33 (1H, s, C_8–H), 7.40 (5H, br, $-C_6H_5$), 13.00 (1H, s, OH); Found: C, 71.30; H, 4.64%. Calcd for $C_{20}H_{16}O_5$: C, 71.42; H, 4.80%.

Acetate (17): Acetic anhydride–sodium acetate method; mp 196—198 °C (from aq ethanol), colorless prisms; IR (Nujol) cm^{-1}: 1767, 1738, 1693, 1613, 1595; Found: C, 69.54; H, 4.79%. Calcd for $C_{22}H_{18}O_6$: C, 69.83; H, 4.80%.

Methyl Ether (16): Dimethyl sulfate–potassium carbonate method; mp 218.5—219.5 °C (from ethanol), colorless prisms; IR (Nujol) cm^{-1}: 1743, 1708, 1613, 1598; Found: C, 71.99; H, 5.12%. Calcd for $C_{21}H_{18}O_5$: C, 71.99; H, 5.18%.

The slower effluent was recrystallized from ethanol to give

18 (0.3 g) as colorless prisms; mp 246—247 °C; this is shown by the deep violet coloration with ferric chloride in ethanol; IR (Nujol) cm^{-1}: 1733, 1650, 1624, 1586; UV: 282 (4.47), 329 (4.08); NMR: 0.97 (6H, s, $(CH_3)_2\dot{C}$–), 2.56 (2H, s, $-CO-CH_2-$), 5.94 (1H, s, C_3–H), 6.44 (1H, s, C_8–H), 7.38 (5H, br, $-C_6H_5$), 12.27 (1H, s, OH); Found: C, 71.55; H, 4.94%. Calcd for $C_{20}H_{16}O_5$: C, 71.42; H, 4.80%.

*Acetate (**20**)*: Acetic anhydride–sodium acetate method; mp 187—189 °C (from ethanol), colorless flocks; IR (Nujol) cm^{-1}: 1765, 1738, 1688, 1610, 1600, 1587; Found: C, 69.97; H, 4.91%. Calcd for $C_{22}H_{18}O_6$: C, 69.83; H, 4.80%.

*Methyl Ether (**19**)*: Dimethyl sulfate–potassium carbonate method; mp 225—226.5 °C (from ethanol) (lit,[16] 216—218 °C), colorless prisms; IR (Nujol) cm^{-1}: 1746, 1690, 1604, 1598; Found: C, 71.99; H, 5.08%. Calcd for $C_{21}H_{18}O_5$: C, 71.99; H, 5.18%.

*Reduction of **16** and **19**.* *From **16***: A mixture of **16** (150 mg) and sodium borohydride (30 mg) in ethanol (40 ml) was stirred at 20—25 °C for 4 h. The mixture was made slightly acidic with acetic acid–water to decompose an excess sodium borohydride and concentrated to a solid under reduced pressure. The solid was collected, washed, dried and then chromatographed on silica gel, with chloroform as the eluent, to give **21**. This was further recrystallized from benzene; mp 181.5—182.5 °C, colorless prisms; yield, 63 mg; IR ($CHCl_3$) cm^{-1}: 3540, 1720, 1605, 1550; NMR: 1.39, 1.48 (each 3H and s, $(CH_3)_2\dot{C}$–), 2.08 (2H, d, J=6 Hz, $(CH_3)_2\dot{C}CH_2$–), 3.06 (3H, s, OMe), 3.31 (1H, s, OH), 4.95 (1H, t, J=6 Hz, $-\dot{C}HOH$), 6.05 (1H, s, C_3–H), 6.65 (1H, s, C_8–H), 7.40 (5H, s, $-C_6H_5$); Found: C, 71.81; H, 5.71%. Calcd for $C_{21}H_{20}O_5$: C, 71.58; H, 5.72%.

*From **19***: A mixture of **19** (200 mg) and sodium borohydride (42 mg) in ethanol (40 ml) was stirred at 20—23 °C for 4.5 h. The mixture was treated in a similar way to that described above. The crude product was recrystallized from ethanol to give **25** as colorless needles; mp 205—207 °C; yield, 164 mg; IR ($CHCl_3$) cm^{-1}: 3580, 1720, 1605, 1560; NMR: 0.82, 1.04 (each 3H and s, $(CH_3)_2\dot{C}$–), 1.84 (2H, d, J=6 Hz, $(CH_3)_2\dot{C}CH_2$–), 3.04 (1H, s, OH), 3.96 (3H, s, OMe), 4.92 (1H, t, J=6 Hz, $-\dot{C}HOH$), 5.96 (1H, s, C_3–H), 6.49 (1H, s, C_8–H), 7.30 (5H, br, $-C_6H_5$); Found: C, 71.45; H, 5.82%. Calcd for $C_{21}H_{20}O_5$: C, 71.58; H, 5.72%.

*Reduction of **17** and **20**.* *From **17***: A mixture of **17** (200 mg) and sodium borohydride (40 mg) in ethanol (50 ml) was stirred at 23—26 °C for 5 h. After the usual work-up, the resulting solid was chromatographed on silica gel, with benzene as the eluent, to give **22**, which was further recrystallized from benzene; mp 233—234 °C, colorless prisms; yield, 110 mg; IR ($CHCl_3$) cm^{-1}: 3510, 1720, 1620, 1560; NMR: 1.32 (6H, s, $(CH_3)_2\dot{C}$–), 1.76, 2.52 (each 2H, t, and J=6.7 Hz, $-CH_2CH_2$–), 5.38 (1H, s, OH), 5.87 (1H, s, C_3–H), 6.44 (1H, s, C_8–H), 7.51 (5H, br, $-C_6H_5$); Found: C, 74.60; H, 5.64%. Calcd for $C_{20}H_{18}O_4$: C, 74.52; H, 5.63%.

*Acetate (**24**)*: Acetic anhydride–pyridine method; mp 195—196 °C (from ethanol), colorless prisms; IR ($CHCl_3$) cm^{-1}: 1765, 1720, 1618, 1552; Found: C, 72.25; H, 5.45%. Calcd for $C_{22}H_{20}O_5$: C, 72.51; H, 5.53%.

*Methyl Ether (**23**)*: Methyl iodide–potassium carbonate method; mp 179—180 °C (from aq ethanol), colorless plates; IR ($CHCl_3$) cm^{-1}: 1710, 1610, 1550; Found: C, 74.95; H, 6.03%. Calcd for $C_{21}H_{20}O_4$: C, 74.98; H, 5.99%.

*From **20***: A mixture of **20** (200 mg) and sodium borohydride (40 mg) in ethanol (70 ml) was stirred at 24—27 °C for 5 h. After the usual work-up, the crude product was recrystallized from ethanol to give **12** (70 mg), which was identical with the sample described above.

*Dehydration of **21** and **25**.* *From **21***: **21** (160 mg) was refluxed in a mixture of acetic anhydride (5 ml) and pyridine (2—3 drops) for 5.5 h. After cooling, the mixture was poured into ice–water and acidified with dilute hydrochloric acid. The resulting solid was collected, washed, dried and then chromatographed on silica gel (5 g), with chloroform as the eluent, to give **5** (60 mg), which was further recrystallized from ethanol; mp 211—212 °C, colorless prisms; IR ($CHCl_3$) cm^{-1}: 1715, 1640, 1605; Found: C, 75.29; H, 5.45%. Calcd for $C_{21}H_{18}O_4$: C, 75.43; H, 5.43%.

*From **25***: **25** (160 mg) was dehydrated to give **2** (110 mg), which was identical with the above mentioned sample.

*5-Acetoxy-8,8-dimethyl-4-phenyl-2H,8H-benzo[1,2-b:5,4'-b]dipyran-2-one (**6**).* A mixture of acetate (**24**: 225 mg), NBS (210 mg), and a trace of benzoyl peroxide in dry carbon tetrachloride (20 ml) was refluxed for 3 h. The resulting succinimide was then filtered off and the solvent was removed. The residue was successively treated according to the usual work-up. The crude product was chromatographed on silica gel (7 g), with benzene as the eluent, to give **6**, which was further recrystallized from methanol; mp 227.5—228.5 °C, colorless prisms; yield, 140 mg, IR ($CHCl_3$) cm^{-1}: 1773, 1720, 1640, 1620; Found: C, 72.87; H, 4.99%. Calcd for $C_{22}H_{18}O_5$: C, 72.92; H, 5.01%.

*5-Hydroxy-8,8-dimetyl-4-phenyl-2H,8H-benzo[1,2-b:5,4-b']dipyran-2-one (**4**).* **6** (95 mg) was hydrolyzed with a mixture of concentrated hydrochloric acid (1 ml) and methanol (24 ml), refluxing for 4 h. After removal of the solvent, the resulting solid was collected, washed and dried. This was recrystallized from benzene to give **4** (24 mg) as colorless needles; mp 197—198 °C; IR ($CHCl_3$), cm^{-1}: 3510, 1720, 1640, 1617; NMR: 1.45 (6H, s, $(CH_3)_2\dot{C}$–), 5.53, 6.46 (each 1H, d, and J=10.0 Hz, –CH=CH–), 5.29 (1H, s, OH), 5.90 (1H, s, C_3–H), 6.44 (1H, s, C_8–H), 7.55 (5H, br, $-C_6H_5$); Found: C, 74.25; H, 5.05%. Calcd for $C_{20}H_{16}O_4$: C, 74.99; H, 5.03%.

*6-Benzoyl-5-hydroxy-7-methoxy-2,2-dimethylchroman (**27**) and 8-Benzoyl Isomer (**26**).* A mixture of **10** (4.7 g), benzonitrile (4.0 g), and anhydrous zinc chloride (3.5 g) in dry ether (80 ml) was saturated with dry hydrogen chloride under ice-cooling and the mixture was allowed to stand at room temp overnight. After removal of the upper ethereal layer by decantation, the residue was heated with 1% hydrochloric acid (100 ml) on a water bath for 3 h. The resulting solid was collected, washed and dried and then recrystallized from ethanol to give **27** as pale yellow needles; this is shown by the violet brown coloration with ferric chloride in ethanol; mp 122—123 °C; yield, 0.9 g; IR (Nujol) cm^{-1}: 1620, 1600, 1585; UV: 253 (3.68), 312 (4.09); Found: C, 73.08; H, 6.60%. Calcd for $C_{19}H_{20}O_4$: C, 73.06; H, 6.45%.

*Acetate (**28**)*: Acetic anhydride–sodium acetate method; mp 126—127 °C (from ethanol), colorless prisms; IR (Nujol) cm^{-1}: 1769, 1669, 1619, 1593, 1580; UV: 251 (4.19), 283 (3.65); NMR: 1.35 (6H, s, $(CH_3)_2\dot{C}$–), 2.02 (3H, s, OAc), 1.78, 2.52 (each 2H, t, and J=6.7 Hz, $-CH_2CH_2$–), 3.60 (3H, s, OMe), 6.35 (1H, s, C_8–H), 7.65 (5H, br, $-C_6H_5$); Found: C, 71.02; H, 6.27%. Calcd for $C_{21}H_{22}O_5$: C, 71.17; H, 6.26%.

The mother liquor of the recrystallization was concentrated to give **26** as pale yellow prisms, which showed a negative ferric chloride reaction in ethanol; mp 213—215 °C; yield, 1.7 g; IR (Nujol) cm^{-1}: 3280, 1645, 1605, 1515; UV: 247 (4.17), 292 (3.41), 308 (3.41); Found: C, 73.23; H, 6.71%. Calcd for $C_{19}H_{20}O_4$: C, 73.06; H, 6.45%.

*Conversion of **26** to **27**.* *a) Aluminium Chloride Method*: A mixture of **26** (1 g) and anhydrous aluminium chloride in dry ether (125 ml) was refluxed for 12 h. After removal of the solvent, ice–water was added to the residue which was then acidified with dilute hydrochloric acid. The resulting

solid was collected, washed, dried and recrystallized from methanol to give **27** (0.7 g); mp 123—124 °C, pale yellow needles. The compound was identical with the sample prepared above.

b) Sulfuric Acid Method: Concentrated sulfuric acid (0.5 ml) was added to a solution of **26** (100 mg) in acetic acid (5 ml) and heated at 65—67 °C for 5 h. After cooling, ice–water was added to the mixture and the resulting solid was collected, washed, dried and recrystallized from methanol to give **27** (50 mg).

Preparation of 29 from 28. A mixture of **28** (200 mg), acetic anhydride (1 ml), and anhydrous sodium acetate (500 mg) was heated at *ca.* 130 °C for 2 min. After cooling, ice–water was added to the mixture and the resulting solid was collected, washed and recrystallized from aq ethanol to give **29** (30 mg); mp 133—134 °C. This was shown to be identical with the above mentioned samples.

*5-Methoxy-8,8-dimethyl-4-phenyl-2*H,*8*H-benzo[*1,2*-b:*3,4*-b']-*dipyran-2-one (7).* A mixture of **29** (150 mg) and DDQ (150 mg) in dry benzene (25 ml) was treated in a similar way to that described above. The crude product was recrystallized from ethanol to give **7** (70 mg) as colorless plates; mp 143—144 °C. IR (Nujol) cm^{-1}: 1718, 1648, 1618, 1587, 1578; UV: 234 (4.56), 284 (4.25), 330 (4.02); Found: C, 75.67; H, 5.52%. Calcd for $C_{21}H_{18}O_4$: C, 75.43; H, 5.43%.

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