The Synthesis of Some Pyrano[2,3-*g*]chromene-2,7-diones and Furo[2,3-*g*]chromen-6-ones

D. N. Nicolaides,* K. C. Fylaktakidou, K. E. Litinas and S. G. Adamopoulos

Laboratory of Organic Chemistry, University of Thessaloniki, 54006 Thessaloniki, Greece

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The *o*-hydroxyformylcoumarin **5b**, easily prepared from compound **1**, is further transformed to the title coumarin derivatives **7**, **10**, **19a-c** *via* its initial Wittig olefination with ylides **2b**, **8**, **18a-c** respectively. Coumarins **16a,b** were also formed by treatment of **5b** with compounds **15a,b**. The preparation of the interesting furocoumarin derivatives **11**, **14**, **20b,c** as well as of compound **13** is also described.

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Pyrano[2,3-*g*]chromene-2,7-dione was chosen in the past as compound having the coumarin double bond in an ideal geometrical relationship to span succesive coils of a DNA molecule. This dione was prepared by treatment of 2,5-dihydroxyterephthaldehyde **1** with sodium acetate/acetic acid in a sealed tube at 190° [1]. Recently we reported [2] the synthesis of some alkyl-substituted pyrano[3,2-*g*]-chromene-2,8-diones by treating 4,6-bis(acetyl)resorcinol with alkoxycarbonylalkylidene(triphenyl)phosphorane **2a** and further treatment of the 6-acetyl-7-hydroxycoumarin derivative obtained with ylides **2a-c** under heating.

Our continuous interest in the preparation and study of coumarins [3-8] prompted us to attempt the preparation of the title compounds with possible biological interest. The reactions studied and the products obtained are depicted in Schemes 1-6.

Results and Discussion.

A solution of **1** and phosphorus ylide **2a** (two equivalents) in benzene was heated at reflux for 2 minutes to give compound **3** in 60% yield (Scheme 1). When the same reaction was carried out in dichloromethane for 4 hours at rt, compound **3** was obtained again in 72% yield.

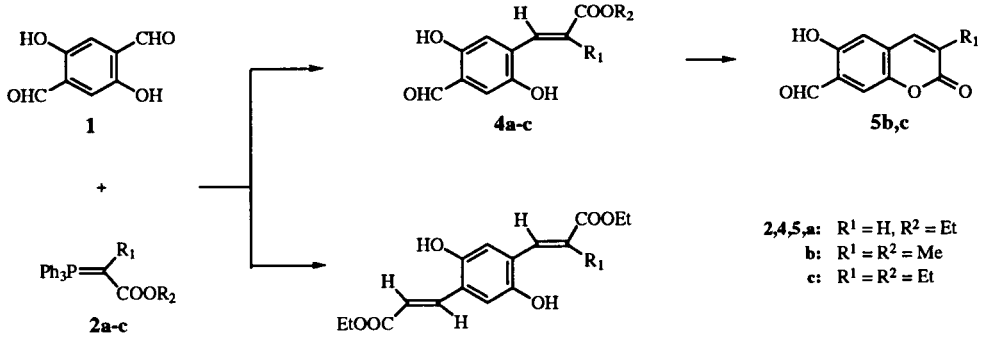
When a solution of **2a** in dichloromethane was added to a stirred solution of **1** (two equivalents) in the same solvent over a 3 hours period at rt, only product **4a** was obtained in 88% yield along with the unreacted starting compound **1**.

By a similar treatment of **1** with ylides **2b** or **2c** compounds **4b** (72%) or **4c** (72%) respectively were obtained as the sole reaction products. By using equimolar amounts of **1** and **2b** under the same conditions compound **4b** was obtained in 53% yield along with 34% of unreacted starting compound **1**.

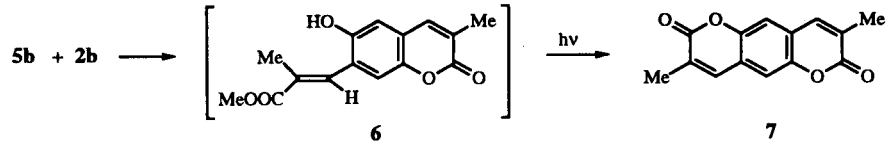
The ^{1}H-nmr spectra of compounds **3** and **4a** exhibit doublets for their olefinic protons with J = 18.4 and 16 Hz respectively, in agreement with the trans configuration suggested for them. All our efforts for lactonization of compounds **3**, **4a** under conditions reported earlier for the lactonization of analogous compounds [9-14] were unsuccessful and the starting materials were recovered. The conditions used were refluxing in toluene, or in *N,N*-dimethylaniline or in diphenyl ether or heating at ~200°, as well as photoirradiation.

Similarly, all efforts for thermal lactonization of compounds **4b** and **4c** failed. In contrast, when benzene solutions of the same compounds were irradiated by a 250-Watt low-pressure Hg lamp for 7 hours and 7.5 hours respectively, the expected coumarin derivatives **5b**, **5c** were formed and precipitated as solids on the walls in 80% and 92% yield respectively. When the same solutions were irradiated by sunlight for 3 and 10 days respectively compounds **5b** (83%) and **5c** (19%) were again obtained. Photo [2+2] cycloaddition products between either the olefinic bond of two pyranono rings [15] of compounds **5** formed or the olefinic double bonds [16] of **4** and **5** were not detected or isolated in the photoreactions studied.

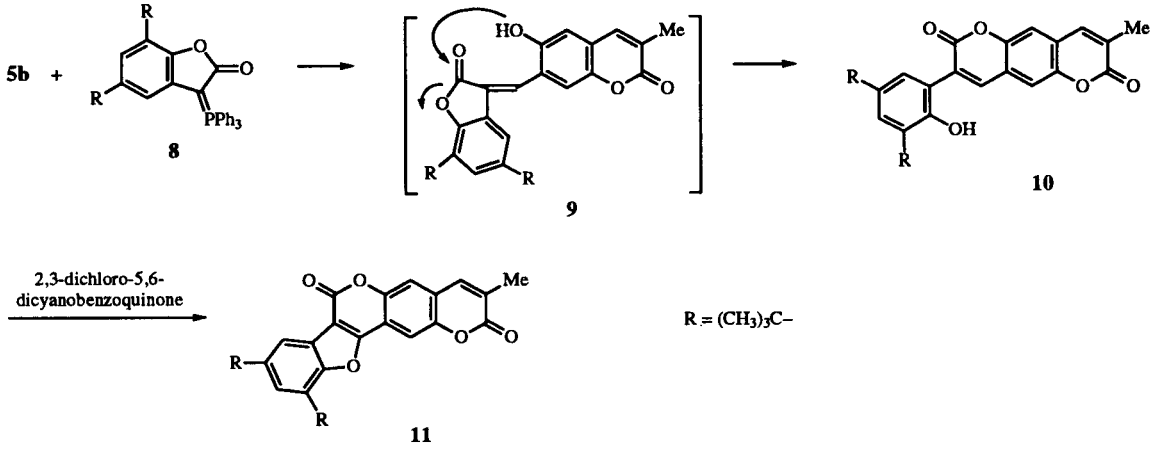
Scheme 1



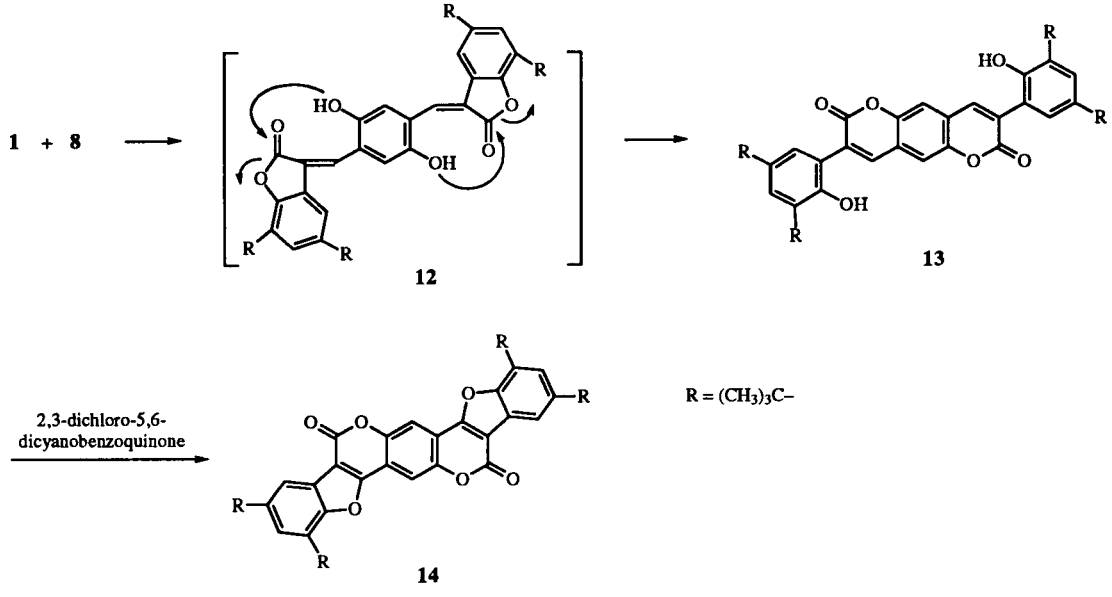
Scheme 2



Scheme 3



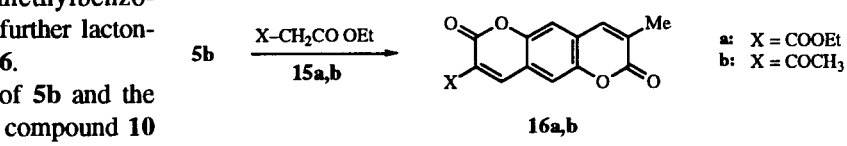
Scheme 4



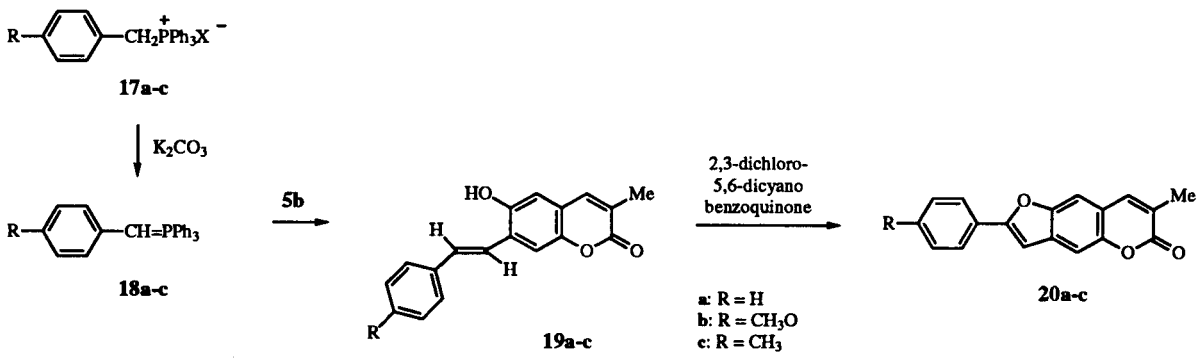
Treatment of 6-hydroxy-3-methylcoumarin-7-carboxaldehyde **5b** with equimolar amount of ylide **2b** in refluxing toluene for 6 hours gave directly the dimethylbenzodipyrandione **7** in 72% yield obviously by further lactonization of the initially formed Wittig product **6**.

When a solution of equimolar amounts of **5b** and the ylide **8** in toluene was refluxed for 3 days, compound **10**

Scheme 5



Scheme 6



(75%) was directly obtained, obviously [8] *via* the intermediate **9**, which by further treatment with 2,3-dichloro-5,6-dicyanobenzoquinone in refluxing toluene for 16 hours gave the furo derivative **11** in 91% yield (Scheme 3).

A similar treatment of compound **1** with **8** gave directly as a product compound **13** (77%), which was further transformed to the bis-furo derivative **14** (71%) by treatment with 2,3-dichloro-5,6-dicyanobenzoquinone. The easy lactonization of intermediates **9** and **12** to products **10** and **13** respectively can be explained because of the possible *Z*-configuration of these initially formed Wittig products, being favoured by the bulky substituents in their olefinic double bonds and especially due to the presence of the *t*-butyl substituents.

When a mixture of **5b** and excess of diethyl malonate **15a** was heated under reflux for 2 hours, compound **16a** was obtained in 53% yield as an insoluble solid, while treatment of **5b** with ethyl acetoacetate **15b** (equimolar amount) in dichloromethane at rt for 40 hours, in the presence of pyridine, gave precipitated of compound **16b** (63%).

We also studied reactions of **5b** with the arylmethylene-(triphenyl)phosphoranes **18a-c** in order to further transform the expected Wittig products to linear fused furocoumarin derivatives. Treatment of **5b** with ylide **18a** prepared *in situ* from benzyltriphenylphosphonium chloride **17a** and potassium carbonate in dioxane/water solution at 80° afforded compound **19a** in 69% yield.

By similar treatment of **5b** with ylides **18b** or **18c**, prepared also *in situ* from their corresponding phosphonium salts **17b**, **17c**, compounds **19b** (91%) and **19c** (86%) respectively were obtained. Treatment of a benzene solution of **19b** with 2,3-dichloro-5,6-dicyanobenzoquinone afforded the furocoumarin **20b** in 60% yield. The similar transformation of the unsubstituted phenyl derivative **19a** (R=H) into compound **20a** (trace) was less successful, while compound **19c** (R = CH_3) gave again the corresponding furo derivative **20c** in satisfactory yield (32%). Our results are in agreement with the recently reported [17] affection of *p*-substituent R in other analogous aryl furan ring formations being favoured by electron donating substituents.

The structures suggested for all new compounds are in good agreement with their analytical and spectral data.

In conclusion, the reactions studied are offered as an easy way for the transformation of commercially available starting compounds to the title coumarin derivatives in satisfactory yields.

EXPERIMENTAL

Melting points are uncorrected and were determined on a Kofler hot-stage apparatus. The ir spectra were obtained with a Perkin-Elmer 1310 spectrophotometer as Nujol mulls. The ^{1}H-nmr spectra were recorded with deuteriochloroform as solvent, except otherwise stated, on a Bruker AW 80 (80 MHz) or 300 AM (300 MHz) spectrometer with tetramethylsilane as the internal standard. The ^{13}C nmr spectra were obtained at 75.5 MHz on a Bruker 300 AM spectrometer for deuteriochloroform solutions, except otherwise stated, with tetramethylsilane as internal reference. Mass spectra were determined an a VG-250 spectrometer with ionization energy maintained at 70 eV. Earlier reported procedures were used for the preparation of compounds **1** [18] and **8** [4].

Ethyl *E,E* 3-(2,5-Dihydroxy-4-ethoxycarbonylvinylphenyl)-propenoate **3**.

A solution of **1** (0.3 g, 1.8 mmoles) and **2a** (1.32 g, 3.8 mmoles) in dichloromethane (150 ml) was stirred at room temperature for 4 hours. Compound **3** was precipitated as yellow-green crystals (0.34 g, 72%), mp 261-263° (methanol); ir: 3340, 1680, 1610 cm^{-1}; ^{1}H nmr (300 MHz) (deuteriochloroform-hexadeuteriodimethyl sulfoxide): δ 1.32 (t, 6H, J = 7 Hz), 4.22 (q, 4H, J = 7 Hz), 6.46 (d, 2H, J = 18.4 Hz), 6.99 (s, 2H), 7.83 (d, 2H, J = 18.4 Hz), 9.38 (s, 2H, exchangeable with deuterium oxide); ^{13}C nmr (deuteriochloroform-hexadeuteriodimethyl sulfoxide): δ 13.9, 59.6, 114.5, 118.1, 123.7, 139.1, 149.3, 166.5; ms: m/z 306 [M$^+$] (27), 261 (12), 214 (100), 186 (21), 158 (33), 131 (7).

Anal. Calcd. for $C_{16}H_{18}O_6$: C, 62.74; H, 5.92. Found: C, 62.41; H, 5.74.

The filtrate was concentrated and the residue was chromatographed on silica gel [hexane/ethyl acetate (4:1)] to give compound **3** (0.59 g, total yield 72%). When a solution of **1** and **2a** (two equivalents) in benzene was heated under reflux for 2 minutes compound **3** was obtained in 60% yield.

Ethyl *E*-3-(4-Formyl-2,5-dihydroxyphenyl)propenoate **4a**.

To a stirred solution of **1** (0.4 g, 2.4 mmoles) in dichloromethane (150 ml) at room temperature a solution of **2a** (0.42 g,

1.2 mmoles) in dichloromethane (80 ml) was added in portions over 3 hours. The solvent was evaporated and the residue was chromatographed on silica gel [hexane/ethyl acetate (4:1)] to give first the unreacted compound **1** (0.19 g) and second compound **4a** (0.25 g, 88%), mp 191-193° (hexane/ethyl acetate); ir: 3280, 1680, 1650, 1620 cm^{-1}; ^1H nmr (80 MHz) (hexadeuteriodimethyl sulfoxide): δ 1.27 (t, 3H, J = 7 Hz), 4.23 (q, 2H, J = 7 Hz), 6.64 (d, 1H, J = 16 Hz), 7.18 (s, 2H), 7.80 (d, 1H, J = 16 Hz), 10.08 (s, 2H), 10.24 (s, 1H, exchangeable with deuterium oxide); ms: m/z 236 [M^+] (44), 190 (100), 162 (24), 161 (23), 134 (6), 107 (15).

Anal. Calcd. for $C_{12}H_{12}O_5$: C, 61.01; H, 5.12. Found: C, 60.89; H, 4.88.

Methyl *E*-3-(4-Formyl-2,5-dihydroxyphenyl)-2-methylpropenoate **4b**.

To a stirred solution of **1** (0.504 g, 3 mmoles) in dichloromethane (100 ml) a solution of **2b** (1.056 g, 3 mmoles) in dichloromethane (80 ml) was added in portions over 3 hours. The solvent was evaporated and the residue was chromatographed on silica gel [hexane/ethyl acetate (4:1)] to give first the unreacted compound **1** (75 mg) and second compound **4b** (0.51 g, 72%), mp 140-142° (hexane/ethyl acetate); ir: 3350, 1710, 1690, 1660, 1610 cm^{-1}; ^1H nmr (80 MHz) (hexadeuteriodimethyl sulfoxide): δ 2.02 (s, 3H), 3.77 (s, 3H), 6.99 (s, 1H), 7.12 (s, 1H), 7.67 (s, 1H), 9.66 (br s, 1H), 10.12 (br s, 1H), 10.23 (s, 1H); ms: m/z 236 [M^+] (100), 204 (83), 175 (51), 147 (6).

Anal. Calcd. for $C_{12}H_{12}O_5$: C, 61.01; H, 5.12. Found: C, 60.80; H, 4.91.

Ethyl *E*-2-Ethyl-3-(4-formyl-2,5-dihydroxyphenyl)propenoate **4c**.

To a stirred solution of **1** (0.4 g, 2.4 mmoles) in dichloromethane (150 ml) a solution of **2c** (0.453 g, 1.2 mmoles) in dichloromethane (70 ml) was added in portions over 3 hours. The solvent was evaporated and the residue was chromatographed on silica gel [hexane/ethyl acetate (4:1)] to give first the unreacted **1** (0.197 g) and second compound **4c** (0.217 g, 72%), mp 242-244° (ethyl acetate); ir 3400, 3290, 1705, 1685, 1660, 1640, 1615 cm^{-1}; ^1H nmr (80 MHz): δ 1.07 (t, 3H, J = 8 Hz), 1.36 (t, 3H, J = 8 Hz), 2.43 (q, 2H, J = 8 Hz), 3.42 (br s, 1H, exchangeable with deuterium oxide), 4.29 (q, 2H, J = 8 Hz), 6.79 (s, 1H), 7.06 (s, 1H), 7.55 (s, 1H), 9.80 (s, 1H), 10.53 (s, 1H, exchangeable with deuterium oxide); ms: m/z 264 [M^+] (40), 218 (85), 190 (8), 189 (21), 175 (100).

Anal. Calcd. for $C_{14}H_{16}O_5$: C, 63.63; H, 6.11. Found: C, 63.38; H, 5.98.

7-Formyl-6-hydroxy-3-methyl-2*H*-[1]benzopyran-2-one **5b**.

a) A solution of **4b** (42 mg, 0.18 mmole) in benzene (20 ml) was irradiated with a 250-Watt low-pressure Hg lamp for 7 hours. The solution was partly concentrated to give crystals of compound **5b** (29 mg, 80%), mp 260-262° (methanol); ir 3500-3100 (br), 1710, 1670, 1625 cm^{-1}; ^1H nmr (80 MHz, hexadeuteriodimethyl sulfoxide): δ 2.15 (s, 3H), 7.21 (s, 1H), 7.56 (s, 1H), 7.90 (s, 1H), 10.37 (s, 1H), 10.78 (s, 1H, deuterium oxide exchangeable); ms: m/z 204 [M^+] (85), 175 (100), 147 (17), 130 (9), 119 (12), 102 (6).

Anal. Calcd. for $C_{11}H_8O_4$: C, 64.71; H, 3.95. Found: C, 64.38; H, 3.92.

b) A solution of **4b** (100 mg, 0.42 mmole) in benzene (100 ml) was irradiated with sun light for 3 days and worked up like above to give compound **5b** (72 mg, 83%).

3-Ethyl-7-formyl-6-hydroxy-2*H*-[1]benzopyran-2-one **5c**.

a) A solution of **4c** (1.04 g, 0.4 mmole) in benzene (50 ml) was irradiated with a 250-Watt low-pressure Hg lamp for 7.5 hours. Concentration of the solution gave crystals of compound **5c** (79 mg, 92%), mp 248-250° (methanol/tetrahydrofuran); ir: 3200 (br), 1705, 1670, 1625 cm^{-1}; ^1H nmr (80 MHz, hexadeuteriodimethyl sulfoxide): δ 1.26 (t, 3H, J = 8 Hz), 2.6 (hidden by hexadeuteriodimethyl sulfoxide), 7.26 (s, 1H), 7.60 (s, 1H), 7.88 (s, 1H), 10.39 (s. 1H), 10.78 (s, 1H, deuterium oxide exchangeable); ^1H nmr (80 MHz) (deuteriochloroform-trifluoroacetic acid): δ 1.30 (t, 3H, J = 8 Hz), 2.69 (q, 2H, J = 8 Hz), 7.20 (s, 1H), 7.65 (s, 1H), 7.70 (s, 1H), 9.94 (s, 1H); ms: m/z 218 [M^+] (62), 203 (43), 189 (46), 175 (100), 147 (47), 115 (15), 105 (20).

Anal. Calcd. for $C_{12}H_{10}O_4$: C, 66.05; H, 4.62. Found: C, 65.88; H, 4.60.

b) A solution of **4c** (90 mg, 0.34 mmole) in benzene (100 ml) was irradiated with sun light for 10 days and then worked up like above to give **5c** (14 mg, 19%).

3,8-Dimethyl-2*H*,7*H*-benzo[1,2-b:4,5-*b*']dipyran-2,7-dione **7**.

A solution of **5b** (35 mg, 0.17 mmole) and ylide **2b** (60 mg, 0.17 mmole) in toluene (5 ml) was refluxed for 6 hours. The solvent was evaporated and the residue was triturated with dichloromethane to give crystals of compound **7** (30 mg, 72%), mp >310° (methanol); ir 1710, 1630 cm^{-1}; ^1H nmr (80 MHz) (deuteriochloroform-trifluoroacetic acid): δ 2.29 (s, 3H), 7.52 (s, 1H), 7.77 (s, 1H); ms: m/z 242 [M^+] (100), 214 (24), 185 (61), 171 (7), 157 (13), 128 (23), 115 (22).

Anal. Calcd. for $C_{14}H_{10}O_4$: C, 69.42; H, 4.16. Found: C, 69.38; H, 4.18.

3-(3,5-Di-*tert*-butyl-2-hydroxyphenyl)-8-methyl-2*H*,7*H*-benzo[1,2-b:4,5-*b*']dipyran-2,7-dione **10**.

A solution of compound **5b** (1.43 g, 0.7 mmole) and ylide **8** (0.354 g, 0.7 mmole) in toluene (15 ml) was heated under reflux for 3 days. After cooling to room temperature, yellow crystals of compound **10** were precipitated and collected (0.226 g, 75%), mp >300° (dichloromethane); ir: 3390, 3050, 1725, 1675, 1605 cm^{-1}; ^1H nmr (300 MHz): δ 1.35 (s, 9H), 1.47 (s, 9H), 2.30 (s, 3H), 7.10 (d, 1H, J = 2.5 Hz), 7.13 (brs, 1H), 7.47 (d, 1H, J = 2.5 Hz), 7.48 (s, 1H), 7.53 (s, 1H), 7.61 (s, 1H), 7.89 (s, 1H); ^{13}C nmr: δ 17.5, 29.9, 30.2, 31.6, 31.8, 107.3, 108.2, 113.6, 114.5, 119.3, 122.2, 122.5, 125.5, 126.2, 136.9, 137.8, 138.0, 142.4, 144.3, 149.6, 151.3, 159.8, 161.9; ms: m/z 433 (26), 432 [M^+] (88), 418 (27), 417 (100), 416 (10), 402 (2), 362 (10), 361 (42), 204 (39), 203 (11), 189 (12), 175 (24), 57 (57).

Anal. Calcd. for $C_{27}H_{28}O_5$: C, 74.98; H, 6.53. Found: C, 75.11; H, 6.68.

2,4-Di-*tert*-butyl-10-methyl-6*H*,11*H*-benzo[*b*]furo[3,2-*c*]-pyrano[2,3-*g*][1]benzopyran-6,11-dione **11**.

A mixture of compound **10** (66 mg, 0.15 mmole) and 2,3-dichloro-5,6-dicyanobenzoquinone (45 mg, 0.2 mmole) in toluene (10 ml) was heated under reflux for 16 hours. The hot reaction mixture was then filtered and the filtrate on cooling gave light yellow crystals of compound **11** (60 mg, 91%), mp >300° (dichloromethane); ir: 1705, 1595 cm^{-1}; ^1H nmr (300 MHz): δ 1.43 (s, 9H), 1.60 (s, 9H), 2.28 (s, 3H), 7.49 (d, 1H, J = 1.6 Hz), 7.51 (s, 1H), 7.60 (s, 1H), 7.89 (s, 1H), 7.99 (d, 1H, J = 1.6 Hz); ^{13}C nmr: δ 17.5, 30.1, 31.8, 34.8, 35.3, 107.3, 108.4, 114.1, 114.5, 116.1, 122.0, 122.5, 123.4, 128.7, 134.8, 138.0, 149.0,

149.2, 149.4, 152.6, 157.7, 157.8, 161.0; ms: m/z 430 [M+] (42), 415 (12), 390 (2), 348 (35), 278 (9), 277 (9), 228 (30), 210 (6), 205 (11), 204 (100), 175 (12), 108 (7), 91 (18).

Anal. Calcd. for $C_{27}H_{26}O_5$: C, 75.33; H, 6.09. Found: C, 75.51; H, 6.02.

3,8-Bis-(3,5-di-*tert*-butyl-2-hydroxyphenyl)-2*H*,7*H*-benzo-[1,2-*b*:4,5-*b'*]dipyran-2,7-dione **13**.

A solution of **1** (83 mg, 0.5 mmole) and ylide **8** (0.506 g, 1 mmole) in hot toluene (15 ml) was heated under reflux for 3 days. After the first 30 minutes of heating a red spot appeared in thin layer chromatography examination of the reaction mixture, which gradually disappeared. After concentration of the reaction mixture and cooling to room temperature yellow crystals of **13** were precipitated and collected (0.24 g, 77%), mp >310° (ethyl acetate); ir: 3320, 1665, 1595 cm^{-1}; ^1H nmr (300 MHz): δ 1.36 (s, 9H), 1.48 (s, 9H), 7.07 (brs, 1H, exchangeable by deuterium oxide), 7.12 (d, 1H, J = 2.0 Hz), 7.48 (d, 1H, J = 2.0 Hz), 7.67 (s, 1H), 7.93 (s, 1H); ^{13}C nmr: δ 29.9, 31.6, 35.6, 114.7, 123.6, 125.5, 126.4, 128.6, 132.2, 139.4, 142.1, 143.7, 149.3, 151.4, 163.1; ms: m/z 623 (38), 622 [M+] (100), 607 (33), 592 (7), 388 (17), 304 (20), 234 (26), 214 (13), 142 (33), 74 (40).

Anal. Calcd. for $C_{40}H_{46}O_6$: C, 77.14; H, 7.44. Found: C, 76.88; H, 7.28.

Compound **14**.

A mixture of compound **13** (62 mg, 0.1 mmole) and 2,3-dichloro-5,6-dicyanobenzoquinone (57 mg, 0.25 mmole) in toluene (10 ml) was heated under reflux for 16 hours and the reaction mixture was filtered still hot. The filtrate after concentration and cooling at room temperature gave orange crystals of compound **14** (35 mg, 71%), mp >315° (dichloromethane/hexane); ir: 1725, 1600 cm^{-1}; ^1H nmr (300 MHz): δ 1.44 (s, 9H), 1.62 (s, 9H), 7.52 (d, 1H, J = 1.9 Hz), 8.04 (d, 1H, J = 1.9 Hz), 8.14 (s, 1H); ms: m/z 618 [M+] (45), 603 (15), 401 (7), 294 (12), 91 (73), 57 (100).

Anal. Calcd. for $C_{40}H_{42}O_6$: C, 77.64; H, 6.84. Found: C, 77.48; H, 6.60.

Ethyl 8-Methyl-2*H*,7*H*-2,7-dioxobenzo[1,2-*b*:4,5-*b'*]dipyran-3-carboxylate **16a**.

A mixture of compound **5b** (25 mg, 0.125 mmole) and diethyl malonate (70 mg, 0.44 mmole) was heated under reflux for 2 hours. After cooling the mixture was filtered and the precipitate was washed with ethanol and ether to give yellow crystals of compound **16a** (19 mg, 53%), mp >300° (ethanol); ir: 3050, 1760, 1706 cm^{-1}; ^1H nmr (300 MHz): δ 1.42 (t, 3H, J = 7.5 Hz), 2.29 (s, 3H), 4.44 (q, 2H, J = 7.5 Hz), 7.34 (s, 1H), 7.52 (s, 1H), 7.58 (s, 1H), 8.51 (s, 1H); ms: m/z 300 [M+] (40), 255 (51), 228 (72), 200 (28), 171 (98), 143 (65), 115 (100), 89 (44).

Anal. Calcd. for $C_{16}H_{12}O_6$: C, 64.0; H, 4.03. Found: C, 64.18; H, 4.16.

3-Acetyl-8-methyl-2*H*,7*H*-benzo[1,2-*b*:4,5-*b'*]dipyran-2,7-dione **16b**.

A mixture of **5b** (0.102 g, 0.5 mmole), ethyl acetoacetate (82 mg, 0.55 mmole) and piperidine (4 drops) in dichloromethane (5 ml) was stirred at room temperature for 42 hours and then filtered. The precipitate was washed with dichloromethane and then with ether, to give a yellow solid of compound **16b** (85 mg, 63%), mp >300° (ethanol); ir: 3060, 1710, 1590 cm^{-1}; ^1H nmr (300 MHz): δ 2.29 (s, 3H), 2.74 (s, 3H), 7.39 (s, 1H), 7.56 (s, 1H), 7.58 (s, 1H), 8.50 (s, 1H); ms: m/z 270 [M+] (66), 255 (100), 227 (12), 200 (10), 171 (34), 115 (35), 89 (8).

Anal. Calcd. for $C_{15}H_{10}O_5$: C, 66.67; H, 3.73. Found: C, 66.92; H, 3.61.

6-Hydroxy-3-methyl-7-(2-phenylvinyl)-2*H*-[1]benzopyran-2-one **19a**.

To a stirred mixture of **5b** (0.118 g, 0.58 mmole), phosponium salt **17a** (0.28 g, 0.72 mmole) and potassium carbonate (0.12 g, 0.87 mmol) in dry dioxane (15 ml) water (0.25 g) was added and the mixture was heated at 94-96° for 5 hours and then it was filtered. The filtrate was concentrated and the residue was chromatographed on silica gel [hexane/ethyl acetate (4:1)] to give compound **19a** (0.112 g, 70%), mp 258-260° (methanol); ir: 3280, 3150, 1660, 1600 cm^{-1}; ^1H nmr (300 MHz) (deuteriochloroform-hexadeuteriodimethyl sulfoxide): δ 2.16 (s, 3H), 6.96 (s, 1H), 7.15-7.70 (m, 8H), 7.73 (s, 1H), 9.76 (brs, 1H); ms: m/z 278 [M+] (100), 263 (7), 249 (8), 219 (28), 178 (9), 131 (17), 115 (6), 100 (6), 77 (6).

Anal. Calcd. for $C_{18}H_{14}O_3$: C, 77.68; H, 5.07. Found: C, 77.48; H, 4.91.

6-Hydroxy-7-[2-(4-methoxyphenyl)vinyl]-3-methyl-2*H*-[1]benzopyran-2-one **19b**.

To a stirred mixture of **5b** (0.1 g, 0.49 mmole), salt **17b** (0.284 g, 0.61 mmole) and potassium carbonate (0.101 g, 0.73 mmole) in dry dioxane (3 ml) water (16 mg) was added and the mixture was heated at 94-96° for 4 hours. After cooling at room temperature the precipitate was collected by filtration and washed with water to give a water-insoluble solid compound **19b** (90 mg), mp 265-267° (methanol); ir: 3250 (br), 1660, 1595 cm^{-1}; ^1H nmr (300 MHz) (deuteriochloroform-hexadeuteriodimethyl sulfoxide): δ 2.15 (s, 3H), 3.83 (s, 3H), 6.90 (s, 1H), 6.93 (d, 2H, J = 9 Hz), 7.20 (d, 1H, J = 16 Hz), 7.32 (d, 1H, J = 16 Hz), 7.43 (s, 1H), 7.51 (d, 2H, J = 9 Hz), 7.53 (s, 1H), 9.77 (brs, 1H); ms: m/z 308 [M+] (100), 293 (32), 279 (11), 264 (18), 219 (17), 178 (18), 165 (9), 115 (62).

Anal. Calcd. for $C_{19}H_{16}O_4$: C, 74.02; H, 5.23. Found: C, 73.88; H, 5.13.

Further concentration of the filtrate gave an additional amount of **19b** (48 mg, total yield 91%).

6-Hydroxy-3-methyl-7-[2-(*p*-tolyl)vinyl]-2*H*-[1]benzopyran-2-one **19c**.

To a stirred mixture of **5b** (0.15 g, 0.74 mmole), phosphonium salt **17c** (0.411 g, 0.92 mmole) and potassium carbonate (0.152 g, 1.1 mmoles) in dry dioxane (5 ml) water (75 mg) was added and it was heated at 94-96° for 4 hours. The reaction mixture was then concentrated and dichloromethane (5 ml) was added. The precipitate was collected by filtration and washed with water for the removement of inorganic materials to give as an insoluble residue compound **19c** (0.12 g). Concentration of the filtrate and column chromatography of the residue on silica [hexane/ethyl acetate (5:1)] gave an additional amount of **19c** (64 mg, total yield 86%), mp 283-285° (methanol/tetrahydrofuran); ir: 3260 (br), 1670, 1620, 1600 cm^{-1}; ^1H nmr: (300 MHz) (deuteriochloroform-hexadeuteriodimethyl sulfoxide): δ 2.16 (s, 3H), 2.35 (s, 3H), 6.95 (s, 1H), 7.16-7.22 (m, 3H), 7.38-7.50 (m, 5H), 7.75 (s, 1H); ^{13}C nmr (deuteriochloroform-hexadeuteriodimethyl sulfoxide): δ 16.6, 20.8, 111.6, 112.1, 115.8, 118.5, 121.3, 124.3, 126.2, 129.0, 130.1, 134.1, 137.2, 138.7, 147.3, 151.2, 161.9; ms: m/z 292 [M+] (4),

290 (8), 265 (46), 159 (11), 132 (100), 117 (16), 106 (22), 91 (92), 77 (35).

Anal. Calcd. for $C_{19}H_{16}O_3$: C, 78.06; H, 5.52. Found: C, 77.88; H, 5.38.

7-Methyl-2-phenylfuro[2,3-*g*][1]benzopyran-6-one **20a**.

A solution of **19a** (0.1 g, 0.36 mmole) and 2,3-dichloro-5,6-dicyanobenzoquinone (0.164 g, 0.72 mmole) in dry benzene (5 ml) was heated under reflux for 8 hours. The solvent was evaporated and the residue was exctracted first with chloroform (50 ml) and then with saturated sodium bicarbonate solution (70 ml). The aqueous layer was exctracted with chloroform (25 ml). The combined chloroform layers was washed over sodium bicarbonate solution (3 x 70 ml), with water (50 ml) and then dried with anhydrous sodium sulfate. After evaporation of the solvent the residue was chromatographed on silica gel [hexane/ethyl acetate (4:1)] to give traces of a compound with ^{1}H nmr (300 MHz): δ 2.15 (s, 3H), 6.60 (s, 1H), 6.88 (s, 1H), 7.22-7.55 (m, 7H) consistent with furo derivative **20a**.

2-(4-Methoxyphenyl)-7-methylfuro[2,3-*g*][1]benzopyran-6-one **20b**.

A solution of **19b** (0.154 g, 0.5 mmole) and 2,3-dichloro-5,6-dicyanobenzoquinone (0.227 g, 1 mmole) in dry benzene (5 ml) was heated under reflux for 7 hours. The solvent was evaporated and the residue was exctracted with chloroform (50 ml) and then with saturated sodium bicarbonate solution (70 ml). The aqueous layer was further exctracted with more chloroform (25 ml) and the combined chloroform exctracts were washed with saturated sodium bicarbonate solution (3 x 70 ml) and then with water (50 ml) and dried over anhydrous sodium sulfate. Evaporation of the solvent and column chromatography separation of the residue on silica gel [hexane/ethyl acetate (4:1)] afforded compound **20b** (97 mg, 60%), mp 285-287° (methanol); ir: 1690, 1605 cm^{-1}; ^{1}H nmr (80 MHz) (deuteriochloroform-trifluoroacetic acid): δ 2.24 (s, 3H), 3.92 (s, 3H), 6.90-7.90 (m, 8H); ms: m/z 306 [M$^+$] (100), 291 (43), 278 (10), 263 (40), 235 (30).

Anal. Calcd. for $C_{19}H_{14}O_4$: C, 74.50; H, 4.61. Found: C, 74.30; H, 4.31.

7-Methyl-2-(*p*-tolyl)furo[2,3-*g*][1]benzopyran-6-one **20c**.

The reaction of **19c** (90 mg, 0.31 mmole) with 2,3-dichloro-5,6-dicyanobenzoquinone (0.14 g, 0.62 mmole) for 8 hours and the separation of the reaction mixture were performed like in the case of **19b** to give compound **20c** (29 mg, 32%), mp >300° (methanol); ir: 1700, 1650 cm^{-1}; ^{1}H nmr (300 MHz) (deuteriochloroform-hexadeuteriodimethyl sulfoxide): δ 2.10 (s, 3H), 2.44 (s, 3H), 6.55 (s, 1H), 6.94 (s, 1H), 7.19 (s, 1H), 7.31 (d, 2H, J = 7.7 Hz), 7.42 (d, 2H, J = 7.7 Hz), 7.53 (s, 1H); ms: m/z 290 [M$^+$] (6), 262 (25), 234 (14), 219 (33), 143 (30), 131 (34), 115 (61), 105 (51), 89 (55), 77 (100).

Anal. Calcd. for $C_{19}H_{14}O_3$: C, 78.61; H, 4.86. Found: C, 78.49; H, 4.71.

REFERENCES AND NOTES

[1] J. N. Marx, P.-S. Song and P. K. Chui, *J. Heterocyclic Chem.*, **12**, 417 (1975).

[2] D. N. Nicolaides, K. C. Fylaktakidou, C. Bezergiannidou-Balouctsi and K. E. Litinas, *J. Heterocyclic Chem.*, **31**, 173 (1994).

[3] K. E. Litinas, D. N. Nicolaides and E. A. Varella, *J. Heterocyclic Chem.*, **27**, 769 (1990).

[4] D. N. Nicolaides, S. G. Adamopoulos, D. A. Lefkaditis, K. E. Litinas and P. V. Tarantili, *J. Chem. Soc., Perkin Trans. 1*, 283 (1992).

[5] D. N. Nicolaides, C. Bezergiannidou-Balouctsi, K. E. Litinas, E. Malamidou-Xenikaki, D. Mentzafos and A. Terzis, *J. Chem. Res.* (*S*), 108 (1993); (*M*), 826 (1993).

[6] D. N. Nicolaides, C. Bezergiannidou-Balouctsi, K. E. Litinas, E. Malamidou-Xenikaki, D. Mentzafos and A. Terzis, *Tetrahedron*, **49**, 9127 (1993).

[7] C. Bezergiannidou-Balouctsi, K. E. Litinas, E. Malamidou-Xenikaki and D. N. Nicolaides, *Liebigs Ann. Chem.*, 1175 (1993).

[8] K. E. Litinas and X. N. Stampelos, *J. Chem. Soc., Perkin Trans. 1*, 2981 (1992).

[9] R. S. Mali and V. J. Yadav, *Synthesis*, 465 (1977).

[10] G. Guillaumet, M. Hretani and G. Loudert, *Tetrahedron Letters*, **29**, 2665 (1988).

[11] H. Ishii, Y. Kaneko, H. Miyaraki and T. Harayama, *Chem. Pharm. Bull.*, **39**, 3100 (1991).

[12] T. Harayama, K. Nakatsuka, K. Katsuno, H. Nishioka, K. Murakami, M. Fujii, N. Hagashida and Y. Takeuchi, *Chem. Express*, **8**, 245 (1993).

[13] E. Zubia, F. R. Luis, G. M. Massanet and I. G. Collado, *Tetrahedron*, **48**, 4239 (1992).

[14] R. S. Mali, S. G. Tilve, S. N. Yeola and A. R. Manekar, *Heterocycles*, **26**, 121 (1987).

[15] V. A. Kumar, N. S. Begum and K. Venkatesan, *J. Chem. Soc., Perkin Trans. 2*, 463 (1993).

[16] K. Kobayashi, M. Suzuki and H. Suginome, *J. Chem. Soc., Perkin Trans. 1*, 2837 (1993).

[17] K. Imafuku and R. Fujita, *Chem. Express*, **6**, 323 (1991).

[18] J. N. Marx, P. S. Song and P. K. Chui, *J. Heterocyclic Chem.*, **28**, 1517 (1991).